

## JAHRESBERICHT 2005

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für subatomare Physik**

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## VORWORT

Das Stefan Meyer Institut für subatomare Physik steht in einer langen, erfolgreichen Forschungstradition in Österreich. Es ist das Nachfolgeinstitut des Instituts für Radiumforschung, des ältesten Instituts der Österreichischen Akademie der Wissenschaften.

Wir betreiben methodenorientierte Grundlagenforschung auf dem Gebiet der fundamentalen Wechselwirkungen und Symmetrien.

Wir sind das einzige Forschungsinstitut in Österreich, das auf dem Gebiet der starken Wechselwirkung und ihrer gebundenen Systemen, den Hadronen, experimentell tätig ist.

Wir führen unsere Forschungsprojekte in Zusammenarbeit mit internationalen Gruppen durch. Die Experimente werden an Teilchenbeschleunigeranlagen in Italien, der Schweiz, in Deutschland und in Japan durchgeführt.

Zusammenarbeit und wissenschaftlicher Austausch innerhalb Österreichs findet vor allem mit Instituten der Universität Wien und der TU-Wien statt.

Das Institut und seine Mitarbeiter ersuchen das Kuratorium um Unterstützung in wissenschaftlicher und institutioneller Hinsicht, um auch in Zukunft die hier dargelegten Aufgaben wahrnehmen zu können.



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# 1 WISSENSCHAFTLICHE TÄTIGKEIT

## 1.1 Zusammenfassung des wissenschaftlichen Berichts 2005

Das Forschungsprogramm des Stefan Meyer Instituts umfasst das „Studium fundamentaler Wechselwirkungen und Symmetrien mit exotischen Atomen“. Wissenschaftlich stand das Jahr 2005 im Zeichen von drei gleichzeitig durchgeführten Experimenten:

i) Die abschließende genaue Bestimmung der Breite der  $K_\alpha$ -Linie in pionischem Wasserstoff am Paul Scherrer Institut, die trotz apparativer Probleme erfolgreich mit genügend großer Statistik, abgeschlossen werden konnte. Ziel des Experiments ist es, die Pion-Nukleon Isospin-Streulängen mit einer Genauigkeit  $\leq 1\%$  zu bestimmen. Damit können, mit bisher nicht erreichter Präzision, Vorhersagen der Theorie im Bereich der Niederenergie-QCD überprüft werden. Die Daten werden im Moment ausgewertet.

ii) Die Messung der Energie des 3d-2p Röntgenübergangs in kaonischem Helium mittels Silicon Drift Detektoren zusammen mit der E549/E570-Kollaboration am KEK/Japan. Die Verschiebung des 2p-Niveaus in kaonischem Helium ist sehr empfindlich auf die Details der Kaon-Nukleon Wechselwirkung und somit werden Hinweise darauf erwartet, ob das von Akaishi und Yamazaki vorgeschlagene stark anziehende Potential, das die Grundlage für die Vorhersage der tiefgebunden kaonischen Kern-Clustern liefert, richtig ist. Das Experiment hatte zwei Messperioden im Jahr 2005 und wurde erfolgreich abgeschlossen. Die Daten sind noch in der Auswertung.

iii) Die erste Testmessung zur Suche nach tiefgebundenen kaonischen Kern-Clustern in der p-d Reaktion mit dem FOPI Detektor an der GSI Darmstadt, zu dem wir ein ultraleichtes Flüssigdeuterium-Target entwickelten. Mit dieser Reaktion kann das einfachste System K-pp erzeugt werden. Die Verwendung des  $4\pi$ -Detektors FOPI ermöglicht nicht nur die bei der Erzeugung des Clusters entstehenden Teilchen, sondern auch die beim Zerfall emittierten Teilchen zu detektieren und liefert somit zusätzliche detaillierte Informationen. Das Testexperiment ergab wertvolle Hinweise für das Hauptexperiment, das für das Frühjahr 2007 geplant ist.

Ein wichtiges Ereignis im Rahmen des Forschungsprogramms Kaon-Nukleon Wechselwirkung war der zusammen mit C. Guaraldo und C. Curceanu vom LNF Frascati erarbeitete vorläufige Letter of Intent zum Studium tiefgebundener kaonischer Kern-Cluster mit gestoppten Kaonen an der geplanten Facility DAΦNE2. Dieses Experiment mit Namen AMADEUS kann, sofern es akzeptiert wird, ein europäisches Gegenstück zu an J-PARC mit Kaonen im Flug geplanten Experimenten werden. Für AMADEUS soll der KLOE-Detektor benutzt werden, mit dem erstmals alle beim Zerfall der Cluster entstehenden Teilchen, einschließlich neutraler, mit hoher Effizienz nachgewiesen werden können. Dies ist entscheidend um die Cluster zweifelsfrei nachzuweisen sowie deren Eigenschaften wie Dichte zu bestimmen.

Die Entwicklung von großflächigen Silicon Drift Detektoren in Rahmen des SIDDHARTHA Projektes ging im Berichtsjahr weiter. Die Computersimulationen zum optimalen Aufbau des Experiments wurden abgeschlossen und die Konfiguration vorläufig fixiert. Am CERN fand 2005 wegen Shutdowns des ADs kein Experiment statt. Es wurden vornehmlich Simulati-

onen für die in den nächsten Jahren geplanten Messungen der Hyperfeinstruktur von antiprotonischem Helium und Antiwasserstoff sowie apparative Vorbereitungen durchgeführt. Für alle drei Experimente an FAIR: PANDA, FLAIR, und AIC wurden sogenannte Technical Proposals verfasst und eingereicht. Ein Teststand mit NEG-beschichteten Strahlrohren für das Cluster-Jet-Target von PANDA wurde am SMI aufgebaut, und an dem bestehenden Cluster-Jet-Target an der GSI Darmstadt wurden erste Testmessungen durchgeführt. Für das VIP-Experiment zum Test des Pauli-Prinzips wurde die Apparatur aufgebaut und eine Testmessung am LNF Frascati durchgeführt, die bereits eine Verbesserung des bisherigen Grenzwerts um eine Größenordnung lieferte. Das Experiment wurde im unterirdischen Gran-Sasso-Labor installiert, wo es die nächsten zwei Jahre Daten nehmen wird.

## 1.2 Summary of the scientific report 2005

The research program of the Stefan Meyer Institute comprehends the study of fundamental interactions and symmetries using exotic atoms. The scientific work in 2005 was dominated by three experiments performed in parallel:

i) The final precision determination of the width of the  $K_\alpha$  line in pionic hydrogen in an experiment at the Paul Scherrer Institute which was successfully performed with sufficient high statistics in spite of technical problems. The experiment aims at the determination of the isospin-dependent scattering lengths with an accuracy of  $\leq 1\%$ . Therefore, these precision experimental data provide a test of theoretical predictions in low-energy QCD with unprecedented accuracy. The experimental data are in analysis now.

ii) The measurement of the 3d-2p X-ray transition energy in kaonic helium using silicon drift detectors was performed together with the E549/E570 Collaboration at KEK/Japan. The shift of the 2p state in kaonic helium is very sensitive to the details of the kaon-nucleon interaction. Therefore, indications of the strongly attractive potential proposed by Akaishi and Yamazaki are anticipated which is the basis for the prediction of deeply bound kaonic clusters. The experiment took two measuring periods in 2005 and was successfully finalized. The data analysis is in progress now.

iii) The first test measurement on the search for deeply bound kaonic nuclear clusters in the p-d reaction using the FOPI detector at GSI Darmstadt for which we developed an ultra light liquid deuterium target. With this reaction the simplest system  $K^-pp$  can be produced. The use of the  $4\pi$  detector FOPI at GSI Darmstadt allows not only the detection of the particles emerging in the production of the cluster but also the detection of the emitted particles in the decay, thus providing additional detailed information. The test experiment gave valuable hints for the main experiment which is planned for spring 2007.

An important event in the framework of the research program kaon-nucleon interaction was the pre-Letter-of-Intent prepared together with C. Guaraldo and C. Curceanu from LNF Frascati for the study of deeply bound kaonic nuclear clusters with stopped kaons at the planned facility DAΦNE2. If accepted this experiment named AMADEUS can become a European counterpart to the planned experiments with kaons in-flight at J-PARC. For AMADEUS the KLOE detector is supposed to be used which allows the highly efficient detection of all emitted particles in the decay including neutral particles. This is crucial for the clear proof of the clusters and for the determination of the properties like density.



In the framework of SIDDHARTA the development of large area silicon drift detectors was continued. The computer simulations for an optimized experimental setup were finalized and the preliminary configuration fixed. Due to the shutdown of AD no experiment took place at CERN. Mainly simulations for measurements of the hyperfine structure of antiprotonic helium and antihydrogen planned for the next years and technical preparations were performed. So called Technical Proposals were prepared and submitted for all three experiments at FAIR: PANDA, FLAIR and AIC. A test setup with NEG-coated beam pipes for the cluster-jet target of PANDA was installed at SMI and first test measurements with the cluster-jet target at GSI were conducted. An apparatus for the VIP experiment testing the Pauli Exclusion Principle was set up and a test measurement at LNF Frascati was performed which resulted in an improvement of the previous limit by an order of magnitude. The experiment was installed in the underground Gran-Sasso laboratory where it will take data for the next two years.

### 1.3 Scientific Report 2005

The Stefan Meyer Institute has three scientific programs (two medium term and one long term), each of which contains several research projects. The medium term programs are the Kaon-Nucleon Interaction and Matter-Antimatter Symmetry. Antiprotons at FAIR is a long term program, where FAIR will start operation with antiprotons around 2012 and will run for about 15 years.

#### 1.3.1 Kaon-Nucleon Interaction: Kaonic atoms and kaonic nuclear clusters

One of the outstanding fundamental problems in hadron physics today is the question of the origin of the large hadron masses made up of light quarks. The current mass of the up and down quarks is two orders of magnitude smaller than a typical hadron mass of about 1 GeV. This extraordinary phenomenon is proposed to originate from spontaneous breaking of chiral symmetry of massless quarks in strong interaction physics [1]. It results in a ground state - the vacuum state - with a finite expectation value of quark-antiquark pairs, the chiral quark condensate [2]. The hadrons are considered to be quasi-particle excitations of this chiral condensate. The lowest excitation modes of the condensate, so called Nambu-Goldstone bosons, are identified as mesons containing light quarks. Their s-wave interaction with nucleons is determined by the pion decay constants  $f_\pi$  [3], the square of  $f_\pi$  is also the order parameter of chiral symmetry breaking [4,5] and is directly connected to the magnitude of the quark condensate through the Gell-Mann-Oaks-Renner relation [5].

Since long time it is known that the antikaon-nucleon ( $\bar{K} - N$ ) interaction around threshold is dominated by the  $\Lambda(1405)$  baryon resonance located 27 MeV below the  $K^-p$  threshold, which can be looked at as a  $K^-p$  bound state. The  $\bar{K} - N$  amplitude, calculated by a coupled channel approach in the resonance regime [6,7], shows in the real part of the isospin

$K^-$ cluster	$Mc^2$ [MeV]	$-E_K$ [MeV]	$\Gamma_K$ [MeV]	$\rho(0)$ [fm $^{-3}$ ]	$R_{\text{rms}}$ [fm]
$pK^-$	1407	27	40	0.59	0.45
$ppK^-$	2322	48	61	0.52	0.99
$pppK^-$	3211	97	13	1.56	0.81
$ppnK^-$	3192	118	21	1.50	0.72
$ppppK^-$	4171	75	162	1.68	0.95
$pppnK^-$	4135	113	26	1.29	0.97
$ppnnK^-$	4135	114	34		1.12
$ppK^-K^-$	2747	117	35		
$ppnK^-K^-$	3582	221	37	2.97	0.69
$pppnK^-K^-$	4511	230	61	2.33	0.73

**Tab. 1** Various kaonic nuclear clusters and their predicted properties.

$I=0$ ,  $K^-p$  amplitude a dispersive behaviour, being strongly attractive below the resonance and repulsive above it. The latter is experimentally reflected by the  $\bar{K} - N$  scattering cross section [8], the X-ray results from kaonic hydrogen experiments KpX [9] at KEK and recently DEAR [10] at LNF-INFN, which repulsive shifts. Precision X-ray spectroscopy on kaonic hydrogen

to study the chiral symmetry breaking scenario in the strangeness sector will be continued with SIDDHARTA investigating the  $K^-p$  and, for the first time,  $K^-d$  s-wave interaction at threshold.

Another way to gain information how the hadron mass is generated will be the study how the hadron mass change in a nuclear medium. The mass shift of a meson in a nuclear me-

dium gives an evidence of the partial restoration of spontaneous chiral symmetry breaking in QCD. A new way of in-medium hadron mass spectroscopy has started with a series of experiments at GSI, which observed deeply bound pionic 1s and 2p states in Pb and Sn nuclei [11].

Recently, exotic nuclear systems involving a  $\bar{K}$  ( $K^-$  or  $\bar{K}^0$ ) as a constituent have been investigated theoretically [12,13] based on phenomenological constructed  $\bar{K} - N$  interactions, which reproduce low energy  $\bar{K} - N$  scattering data [8], kaonic hydrogen atom data (KpX [9] and DEAR [10]) and the binding energy and decay width of  $\Lambda(1405)$ . These interactions, which are consistent with the prediction based on a chiral SU(3) effective Lagrangian as well as the recent experimental indication on decreased in-medium  $K^-$ -mass from sub-threshold nuclear reactions, are characterized by a strongly attractive  $I=0$  part, causing drastic shrinkage of  $\bar{K}$ -bound nuclei and increasing the binding energies in proton-rich nuclei. The predicted  $\bar{K}$ -bound states have enormous average nucleon densities, several times the normal nuclear density, with large binding energies.

These clusters would represent indeed the ideal condition to investigate how the spontaneous and explicit symmetry breaking pattern of low-energy QCD changes in a dense nuclear medium.

Very recently, double  $K^-$ -systems  $ppK^-K^-$  and  $ppnK^-K^-$  have also been predicted to be high-density systems [14]. Such compact nuclear systems, which can be called “ $\bar{K}$  clusters”, may be beyond the scope of the present theoretical treatment based on hadronic structure and interactions, as they are likely to be in a new phase of nuclear matter. “Antikaon mediated bound nuclear systems”, with quarks, anti-quarks and gluons as constituents are microscopic building blocks of kaon condensed matter [15] or represent colour superconducting systems with high di-quark content. Of course, information whether kaon condensation can occur in nuclear matter will have direct applications in astrophysics (neutron stars, strange stars).

The SMI will participate in the search for antikaon-mediated bound nuclear systems on different experimental studies:

- The precision studies of kaonic hydrogen and kaonic deuterium with SIDDHARTA will set new constraints in the description of  $\Lambda(1405)$ .
- The KEK experiment PS-E570 will measure the 2p shift and width of kaonic helium, induced by strong interaction, with high precision (in the order of  $\sim$  eV). This will help to clarify the existence of deeply bound kaon nuclear systems.
- With FOPI at GSI a search of deeply bound nuclear clusters, like  $ppK^-$ , will be performed, using proton induced reactions and heavy ion collisions.
- To study the formation of antikaon-mediated bound nuclear systems in full detail the AMADEUS project has been started. An LOI will be submitted to LNF - INFN.

- *The SIDDHARTA project: Silicon drift detectors for hadronic atom research*

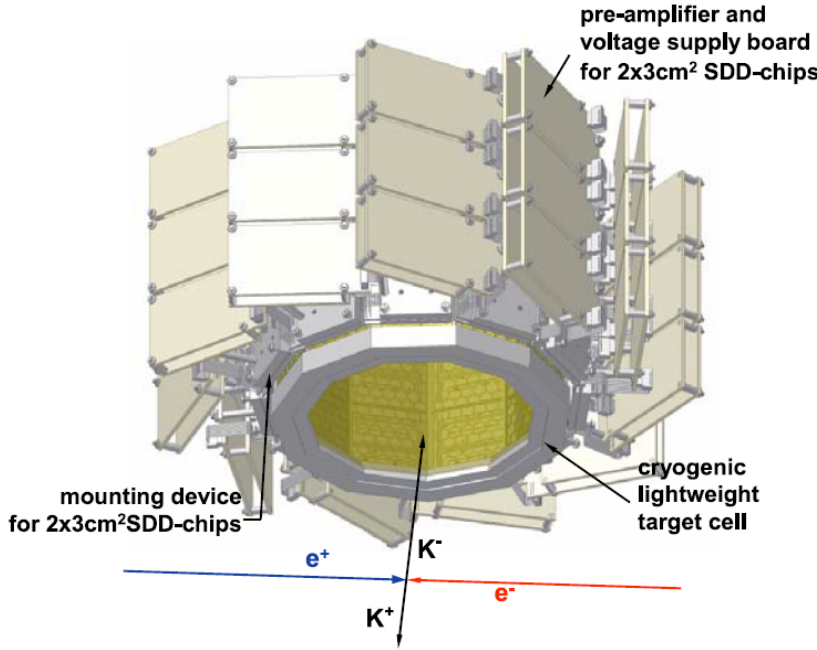


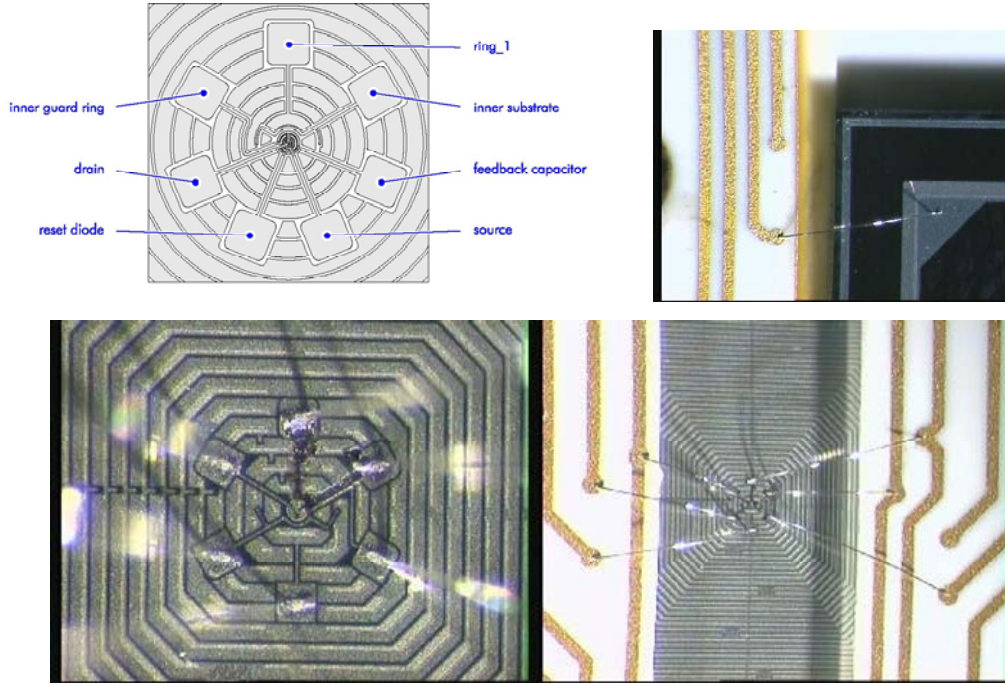
Fig. 1: *The SIDDHARTA target-detector arrangement.*

The final results of the DEAR (DAΦNE Exotic Atom Research) experimental program at Laboratori Nazionali di Frascati to measure the strong interaction induced shift and width of the kaonic hydrogen 1s atomic state was published in 2005 in Phys. Rev. Lett. [16]. The hadronic shift and width of the 1s state are sensitive observables to study quantitatively the low energy antikaon-nucleon interaction. In

the year 2005 the experimental programs of kaonic atom X-ray measurements evolved from the DEAR to the SIDDHARTA project. The SIDDHARTA project aims at a precise determination of the isospin-dependent antikaon-nucleon scattering lengths by measuring the kaonic hydrogen X-ray spectrum with utmost precision and for the first time kaonic deuterium. These precision measurements are a powerful tool to test chiral symmetry breaking in systems with strangeness. Kaonic hydrogen together with precision measurements of kaonic helium X-rays will allow to study the sub-threshold  $\Lambda(1405)$  resonance, which might lead to strongly bound kaonic states in light nuclei.

Therefore, a new detector has to be developed, namely, a Silicon Drift Detector (SDD) with good timing properties and excellent energy resolution. This new SDD system together with a kaon-trigger will suppress the X-ray background by more than two orders of magnitude compared to the DEAR case.

The development of the new detectors and experimental setup made decisive steps forward: the final target – detector layout was fixed (see Fig. 1) and a production run for the SDD-chips was successfully finished at the Halbleiterlabor of the Max-Planck-Institut in Munich. More than half of the necessary chips are characterized there, and fulfil our requirements. A set of three prototypes were produced supervised by SMI, with the gluing and bonding done at the Fraunhofer Institut (IZM) Berlin. The electrical characterization of the glued and bonded SDD chip as well as first spectroscopic test measurements are performed at SMI with good results. The time resolution of the new 1 cm<sup>2</sup> SDDs were studied with radioactive sources in the lab in Vienna. Test measurements under more realistic conditions were done with an electron beam at the ‘beam test facility’ of LNF (Italy) and with a kaon beam at KEK/Japan (see next chapter). The KEK data showed that the time correlation between X-ray events measured with



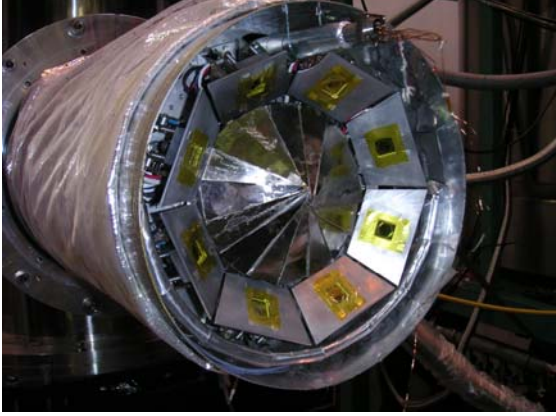
**Fig. 2: Details of the structure of the SIDDHARTA SDDs and photos taken for quality assurance of the bonding process. All chips will finally be inspected and tested in Vienna.**

SDDs and the kaon trigger (indicating that a kaon stopped in the liquid helium target cell) could suppress the background events by a factor 200. The time resolution of the SDDs was determined to be about 1  $\mu$ s. The trigger condition used at the KEK experiment is similar to the planned kaon-trigger in the SIDDHARTA experiment. Therefore, the anticipated large background suppression could be verified.

- ***Kaonic helium X-rays and deeply bound kaonic nuclei  $K^-ppn$  and  $K^-pnn$ : Experiment E549/E570 at KEK***

In 2004, the E471 collaboration found a narrow peak – named “strange tribaryon  $S^0(3115)$ ” – in the proton spectrum in the  $^4\text{He}(\text{stopped } K^-, p)$  reaction at KEK, Japan [17]. The experiment was motivated by the prediction of deeply bound kaonic states by Akaishi and Yamazaki [12,13]. A statistically not significant structure was also found in the neutron spectrum of the  $^4\text{He}(\text{stopped } K^-, n)$  reaction [18]. To verify the  $S^0(3115)$  state and to increase the statistics of the neutron spectrum to a level where the existence of a structure could be proved or excluded, an extension was approved under the name E549 which took data for about one month in May/June 2005. The analysis here is still in progress. Preliminary results indicate that the  $S^0(3115)$  has been reconfirmed.

To study this state and to clarify whether it comes from the deeply bound kaonic nuclei predicted by Akaishi and Yamazaki, the determination of the energy shift in the 2p state of kaonic  $^4\text{He}$  atoms is also quite important. Because the 2p state in kaonic  $^4\text{He}$  atoms has little overlap with the nucleus, the energy shift of the 2p state due to the strong interaction is quite small according to the traditional theories. On the other hand, the recently developed theory of Akaishi and Yamazaki predicts that a large energy shift ( $\sim 10$  eV) in the 2p state will occur in case the deeply bound kaonic nuclei exist. The kaonic  $^4\text{He}$  3d-2p transition was already measured by three experimental groups in the 1970’s and 80’s, and a large shift of about  $-40$  eV and



**Fig. 3:** Arrangement of 8 SDD detectors mounted inside the E549 target.

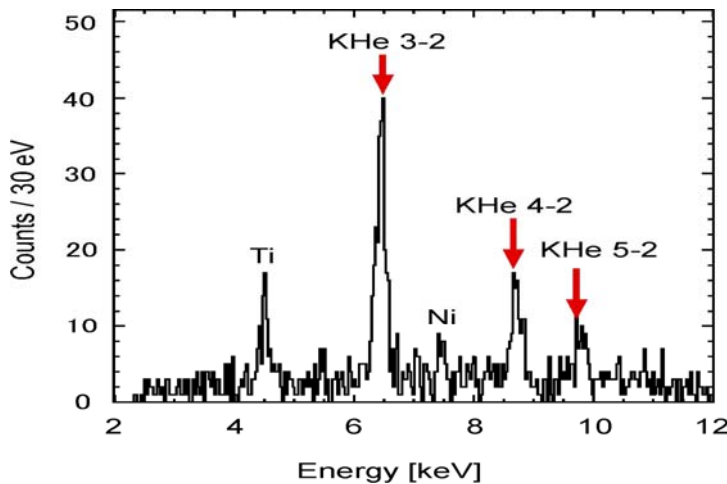
a width of about 60 eV was observed. However, the detector resolution and energy calibration were not sufficient to perform a convincing measurement. Therefore, an accurate determination of the shift is needed with large statistics, high energy resolution, and high accuracy for the energy calibration.

Due to our experience with the development of silicon drift detectors for SIDDHARTA (see above), SMI proposed to add 8 SDDs to the existing E471/549 setup and proposed together with the E549 collaboration a new experiment to KEK to determine the energy shift accurately by observing over

10,000 events of the 3d-2p X-ray line. The goal of the experiment, which was accepted under the name E570, is the determination of the shift in the 2p state with an accuracy of 2 eV. Depending on the shift obtained by this experiment, three scenarios exist:

1. If the shift is about  $-10$  eV, the  $S^0(3115)$  state is supposed to be a deeply bound kaonic nuclei, and this experiment supports the Akaishi-Yamazaki theory.
2. If the shift is consistent with 0 eV, the traditional theories are correct, and the deeply bound nuclei would not exist.
3. If the shift is about  $-40$  eV, the previously performed experiments of the kaonic helium X-ray measurements were correct. In this case, no theory can currently explain this value.

The E570 experiment, the measurement of kaonic helium X-ray lines, was performed in two periods in October and December 2005 at the KEK K5 beam line. The X-ray data were taken with a high energy resolution (about 180 eV FWHM at 6.5 keV), while in the previous experiments the energy resolution was about 350 eV FWHM at 6.5 keV. The production points of kaonic atoms were identified from the vertex information which consists of the tracks of the charged particles. Selecting X-ray events coming from the production points, energy spectra of



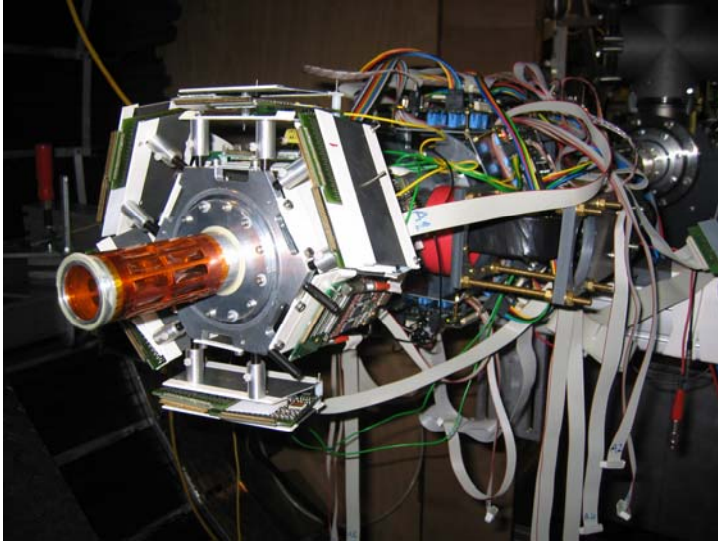
**Fig. 4** Preliminary X-ray spectrum of kaonic  ${}^4\text{He}$  with selection of kaons stopped inside the liquid helium.

the kaonic He X-ray peaks were observed almost background free as seen in Fig. 4.

As a preliminary result of the data analysis, the energy shift in the 2p state of kaonic  ${}^4\text{He}$  atoms is  $-8 \pm 4$  eV. We can conclude that the results of the previous experiments are wrong. The analysis of the data is now in progress. The final results will give us whether the shift is consistent with 0 eV or not. As a next step, measurements of kaonic  ${}^3\text{He}$  X-ray lines are planned at LNF (Italy) and J-PARC (Japan).

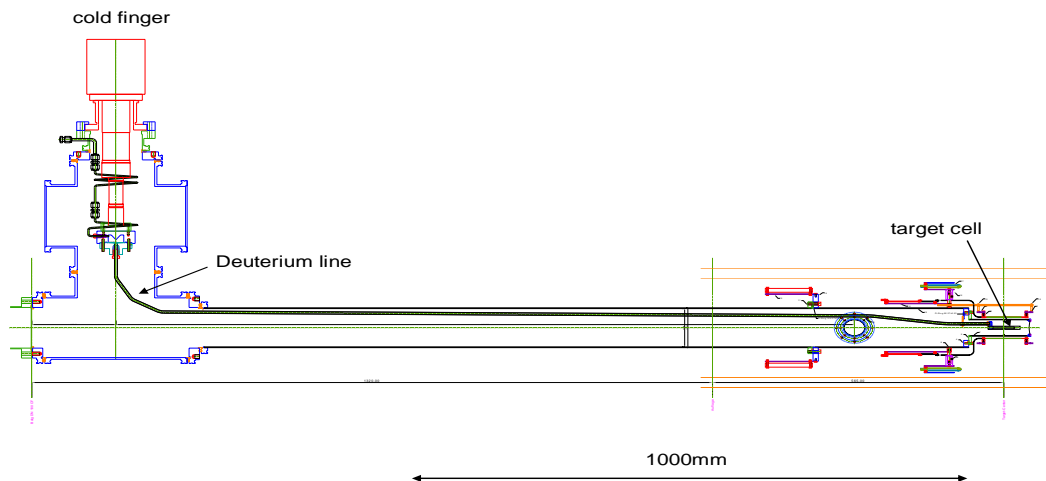


- *Deeply bound kaonic nuclei with FOPI at GSI*



Our proposal to study deeply bound kaonic states in nuclei with the FOPI detector at GSI, was accepted by the 'Experimentierausschuss' at the end of 2004. Two slots of ten days each were allocated for 2005 to study the production of kaonic clusters in Al+Al and p+D<sub>2</sub> collisions. The aim of the experiments is to identify kaonic clusters by the decay products in these nuclear collisions, exploiting the capabilities of FOPI to identify and characterize charged particles in nearly the entire solid angle.

At the beginning of the year the design of the experimental setup was finalized in close contact with our collaborators at the Technische Universität München. The first run measuring Al+Al collisions at 2 GeV/u took place in August. Due to the lighter Al+Al system, compared to previously measured Ni+Ni less combinatorial background, and hence, an enhanced signal-to-noise ratio is expected. The goal of the p+D<sub>2</sub> test - experiment was to proof that the setting is working and a first search for the simplest type of kaonic cluster (ppK<sup>-</sup>) in the reaction  $p+d \rightarrow ppK^- + K^0 + p$  was done. For this experiment we developed and built a liquid deuterium target at SMI. In Fig. 5 the target system is shown schematically.



**Fig. 5:** *The liquid deuterium target for FOPI.*

The target system consists of a 5 mm diameter target cell built of a 12.5  $\mu\text{m}$  thin Kapton-foil, to allow low energy particles to escape. The target was placed inside the FOPI magnet, but

due to technical reasons the cold-finger to cool the D<sub>2</sub> had to be positioned outside. Thus the long feed line to the target cell as shown in Fig. 5 was necessary.

The data taking of the experiment took place in October. It was shown, that the Si – array around the target cell as well as the target was working in the FOPI environment. Due to the problem of focusing the proton beam on the small target cell, we replaced the liquid deuterium cell with a solid scintillator disk (H:C 1.1:1) as well as with a [CD<sub>2</sub>]<sub>n</sub> disc, to get a first hint of proton induced deeply bound kaon nuclear clusters. This still allows to investigate the ppK<sup>-</sup> cluster, with - however - reduced signal-to-noise ratio.

The analysis of the data taken during the two runs is in progress and is expected to be finalized until the end of 2006. The submission of a request for beamtime in 2007 is agreed within the FOPI collaboration with improved beam diagnostic and an improved target.

- *AMADEUS LoI to DAPHNE2*

The objective of the AMADEUS (Antikaon Matter At DAΦNE: an Experiment Using Spectroscopy) Letter of Intent (LOI) is to attract attention to one of the hottest topics of hadron physics, the case of deeply bound antikaonic nuclear clusters. If these systems exist, a new paradigm in strangeness nuclear physics is created. It has many impacts and leads very far-away: because kaonic nuclear clusters represent indeed the ideal conditions for investigating the way in which the spontaneous and explicit chiral symmetry breaking pattern of low-energy QCD changes in the nuclear environment. Cold dense matter is formed, a phase transitions from hadronic matter to a quark-gluon phase could be expected.

The hypothesis of deeply bound kaonic nuclear states was put in a structured form of a phenomenological model by Y. Akaishi and T. Yamazaki [12,13]. A successful example of deeply bound pionic atomic states did already exist, after their observation at GSI in 1996 (Yamazaki, Kienle, et al.) [11]. The deeply bound states in pionic atoms have become an important tool to test partial chiral symmetry restoration in hadronic matter. Some experimental indications of kaonic nuclear clusters have been recently produced mainly at KEK, and also at DAΦNE (FINUDA) and GSI (FOPI) [19].

DAΦNE2, with its special features and a dedicated setup to study kaonic nuclear clusters in nuclei, would be the only facility in the world where the method of K<sup>-</sup> induced reactions at rest can be applied. The future experiments in Japan (J-PARC) [20] will produce kaonic nuclear states only with K<sup>-</sup>-induced reactions in-flight, while an alternative approach, followed at GSI, is represented by nucleus-nucleus and proton-nucleus collisions [21] at beam energies close to the strangeness production threshold.

The salient features of DAΦNE2 are:

- Low-momentum (127 MeV/c), with  $\approx 1200/s$  charged kaons produced at  $L \approx 10^{33} \text{ cm}^{-2}\text{s}^{-1}$ ;
- Low momentum spread ( $<0.1\%$ );
- K<sup>±</sup> pairs produced in a back-to-back topology;
- hadronic background intrinsically low – differently from an extracted beam.



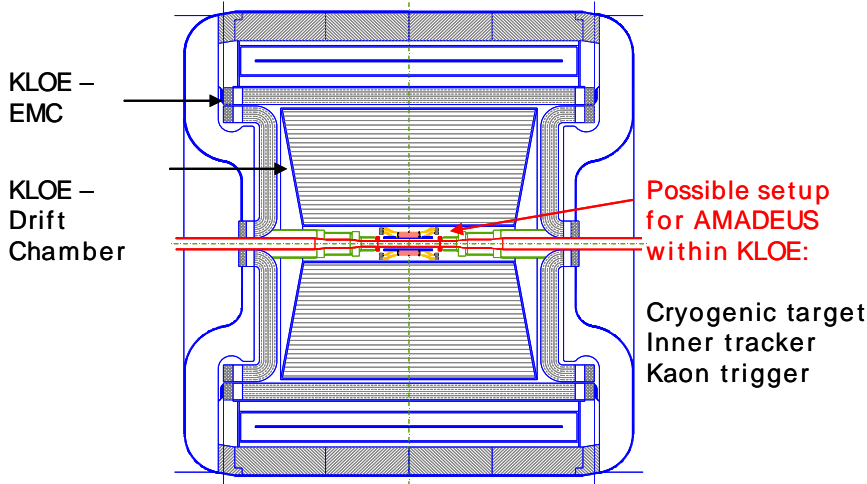


Fig. 6 Drawing of the KLOE detector with possible additions for AMADEUS.

As far as the experimental setup is concerned, it has to be stressed that it must be a dedicated one, to have all the necessary degrees of freedom. The method, described in the AMADEUS LOI, to study the characteristic

features of the kaonic nuclear clusters consists not only in observing the production stage of a kaonic nuclear cluster, but also in detecting the decay products. It is then compelling to use a  $4\pi$  detector capable of detecting all particles (charged: protons and pions and neutrals: neutrons and gammas) created in both the formation and decay of kaonic nuclear clusters.

The KLOE detector, already existing at DAΦNE with the goal to detect direct CP violation in the  $K^0$  decay and to study rare kaon decays, is very well suited for our needs to detect charged particle as well as neutrons and gamma rays. The KLOE detector consists of a huge drift chamber (diameter 4.0 m, length 3.5 m) for tracking charged particles and an electromagnetic calorimeter consisting of a barrel and two end-caps, covering almost  $4\pi$ .

Only some changes around the interaction region are needed for the AMADEUS setup: a cryogenic target system around the beam pipe and an inner-tracker and trigger system for detecting the kaons.

The experimental program consists of precision spectroscopy studies of a number of light kaonic nuclei, as a function of their baryonic number and isospin, followed by measurements on heavier nuclei.

The measurements to be performed are:

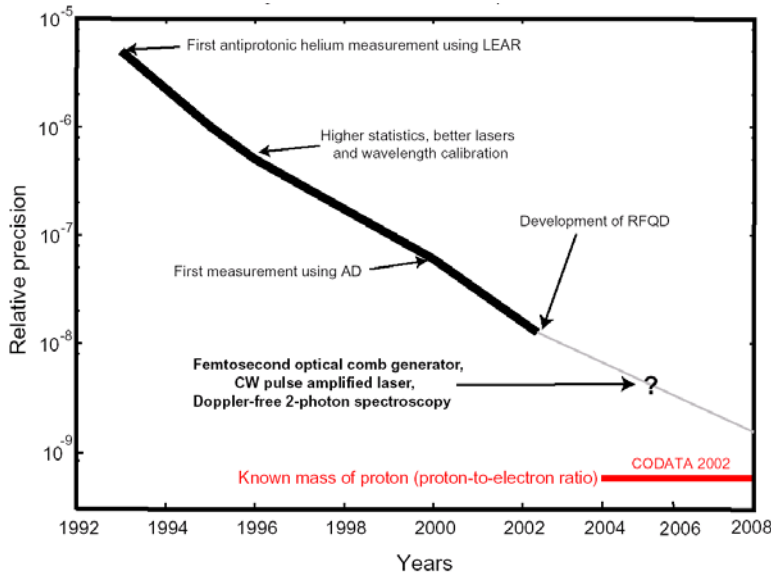
- ${}^3\text{He}(K^-_{\text{stopped}}, p/n)$  reactions to study strange dibaryons  $K^-pp$  and  $K^-pn$ . Their masses, including their total widths, will be determined by neutron and proton spectra. Exclusive measurements of their decays will allow to determine partial decay widths.
- A similar program of measurements is intended for a  ${}^4\text{He}$  target, including three-body decays, to study sizes, densities, and angular momenta.
- We plan to extend these studies systematically to a broad range of nuclear targets starting from Li, B and Be nuclei.

### 1.3.2 Matter - Antimatter Symmetry – ASACUSA at CERN-AD

This is the second main scientific program at SMI. Our institute has become a full member of ASACUSA and a Memorandum of Understanding is being signed between the Academy of Sciences, the other member institutes, and CERN. Within the ASACUSA program, SMI is involved in the precision spectroscopy of antiprotonic helium and the development of a spectrometer beam line for the measurement of the ground-state hyperfine splitting of antihydrogen. These experiments investigate the matter/antimatter symmetry (CPT symmetry) as well as the accuracy of state-of-the-art three-body QED calculations via the precision laser and microwave spectroscopy of atoms containing antiprotons.

- *Analysis of laser spectroscopy data of antiprotonic helium*

In 2005 there was no beam time at CERN because all machines except the PS booster (used for ISOLDE) were shut down as a saving measure for the timely completion of the LHC. During the year, a careful analysis of the data taken in 2004 with a newly developed laser system was performed. The laser system allows measuring the transition frequencies of the antiproton in the exotic three-body system  $\bar{p} - e^- - He^{++}$  or  $\bar{p}He^+$  with significantly higher precision than before. Due to the Doppler broadening, however, the hyperfine levels cannot be resolved and the determination of the line centers therefore requires a very elaborate numerical treatment solving the optical Bloch equations for all possible transitions between the hyperfine quadruplets ( $^4He$ ) and octuplets ( $^3He$ ). The process has been performed mainly by ASACUSA members at CERN and is now completed. The experimental results can be compared with the



**Fig. 7** *Advances of the precision of the relative mass difference between proton and antiproton from the laser spectroscopy of antiprotonic helium.*

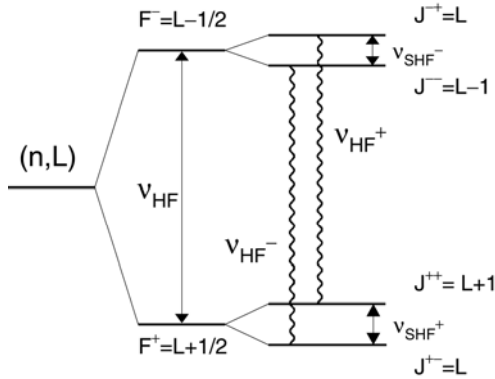
latest three-body QED calculations by V.I. Korobov from Dubna, who stayed twice at SMI during 2005. Because he uses the numerical value of the proton mass in his calculations, a comparison to our experimental data constitutes a test of CPT if there is agreement within the experimental error.

The results are about to be published in Physical Review Letters. While the agreement is excellent for  $\bar{p}^4He^+$ , there is a small but systematic deviation of about  $2\sigma$  in the case of  $\bar{p}^3He^+$ . The reason for that is unclear, and

it calls for an experimental determination of the hyperfine structure in  $\bar{p}^3He^+$  which was never measured before. Including all data points, the maximum relative difference of the masses and

charges of proton and antiproton is limited to 2 ppb ( $2 \times 10^{-9}$ ), a factor 5 better than our previous results [22].

- *Hyperfine structure of antiprotonic helium*

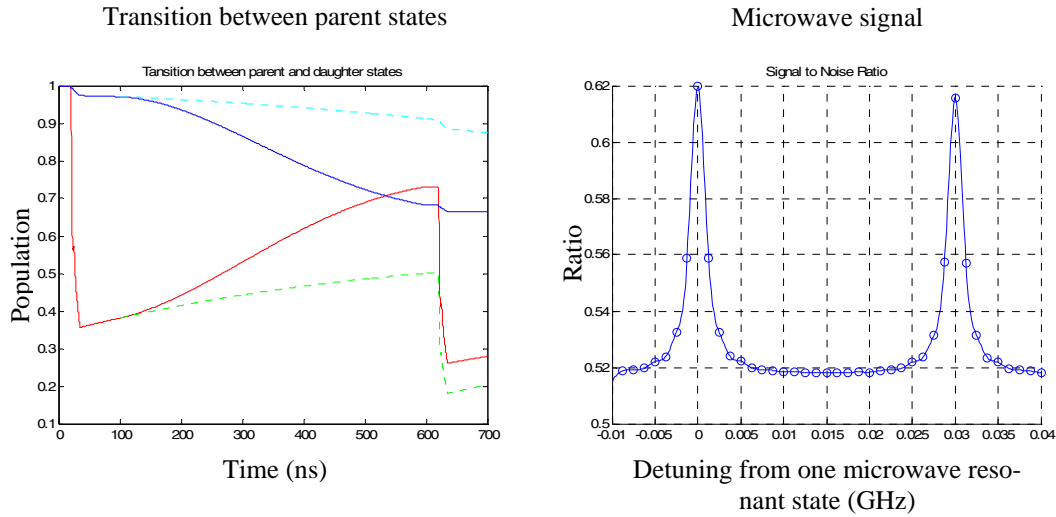


**Fig. 8** Hyperfine splitting of a state of antiprotonic  $^4\text{He}$  and observable microwave transitions (wavy lines).

caused by the magnetic interaction of the antiproton *orbital* angular momentum, while the *superhyperfine* (SHF) splitting originates from the interaction of the antiproton *spin* magnetic moment with the other magnetic moments.  $v_{\text{HF}}^+$  and  $v_{\text{HF}}^-$  have been determined with 30 ppb precision. These transitions are indirectly sensitive to the spin magnetic moment  $\mu_{\bar{p}}$  of the antiproton, which is currently known to only 0.3%. Using sensitivity factors obtained from theory, the current result corresponds to an error of 1.6% on  $\mu_{\bar{p}}$ . The goal is to improve our experimental accuracy by a factor 10 in order to perform a measurement of  $\mu_{\bar{p}}$  better than the current PDG value.

The previous measurement was limited by laser parameters. The new pulse amplified CW laser that was used at CERN in 2004 has a reduced band width, longer pulse length, better shot to shot stability, and makes possible a larger duration between each laser pulse. These capabilities allow a greater depopulation of the parent state. A longer, lower powered, microwave pulse could also be implemented, which would greatly reduce the width of the resonant peaks which is currently limited by the Fourier limit given by the observation time window.

To test the above hypotheses, numerical simulations were solved. These simulations made an estimation of the experimental parameters to discover the approximate magnitude of the improvement which can be expected with the new laser system. In addition they were used to determine the optimal laser and microwave power, and the optimum time period for which to pulse the microwave. The simulations were also used to determine whether there would be any negative effects of the new laser system and showed which parameters were most important for producing a large signal to noise ratio and narrow signal. Examples of some of the simulation results are shown in Fig. 9. The left figure shows the time evolution of the population density for the quadruplet of super hyperfine states. The right figure shows the signal to noise ratio (20%) and FWHM (2 MHz) of the microwave signal. The peaks show the relative positions of the two hyperfine states.



**Fig. 9** Numerical simulations of the time evolution of the populations of the four HF states during a microwave-induced transition (left) and simulated resonance scan (right)



**Fig. 10** Microwave test setup at SMI. In the foreground the waveguide assembly leading to the cavity is seen.

In parallel to the numerical simulations, the microwave apparatus has been reassembled at SMI. A new oscilloscope and pulse generator have been purchased and the LabVIEW programs, which were used previously for the experiment in 2001, have been edited and updated so that computerised control remains possible. This process is being undertaken for confirmation of functionality and operation before the apparatus is sent to CERN for beam time in May 2006.

- **Measurement of the ground-state hyperfine structure of antihydrogen**

Antihydrogen, the simplest atom made of antimatter consisting of an antiproton and a positron, is a very compelling system to study CPT symmetry, because its matter counterpart, hydrogen, has been measured to the highest precision in physics. ASACUSA has proposed a measurement of the ground-state hyperfine splitting of 1.4 GHz which is known in hydrogen to  $\sim 10^{-12}$ . This measurement is complementary to the measurement of the 1S–2S two-photon transition (accuracy for hydrogen  $\sim 10^{-14}$ ) proposed by the other two collaborations at the AD and has the advantage that no trapping of the neutral antihydrogen atoms is needed. We propose to use an atomic beam line as employed in the early experiments with hydrogen.

In July 2005, Dr. Bertalan Juhasz from the Institute of Nuclear Research (ATOMKI) of the Hungarian Academy of Sciences, Debrecen, Hungary, joined the institute to continue his work. He was performing simulations on an atomic beamline which will be used to measure

the ground-state hyperfine splitting of antihydrogen. This beamline will consist of two sextupole magnets, a resonance microwave cavity between them, and an antihydrogen detector (see Fig. 11), and it will be connected to a superconducting radiofrequency trap. The latter will produce the antihydrogen atoms for the measurements.

At such an early stage of the project (see the timeline in Sect. 2.5), the most important thing was to decide what kind of magnet the spectrometer line should use. According to the simulations, the most favourable choice is a superconducting magnet, which offers several advantages and only a few disadvantages. It was also important to make sure that the fringe magnetic field of the two sextupoles will not be too high for the nearby superconducting trap. The simulations showed that with an adequate design of the magnet, the fringe field can be low enough while the field strength inside the magnets can reach the desired value. Moreover, the fringe field can be decreased further with magnetic shielding; this was also carefully simulated.

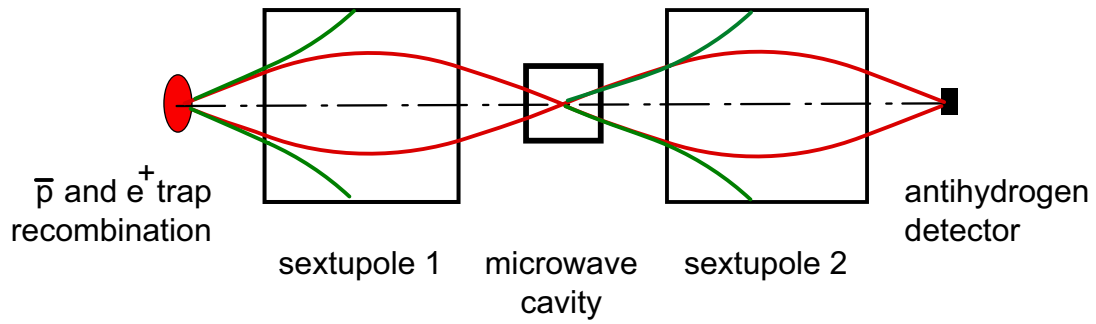


Fig. 11: Schematic layout of the antihydrogen ground-state hyperfine splitting experiment

### 1.3.3 Long-term scientific program: Antiprotons at FAIR

FAIR, the Facility for Antiproton and Ion Research, is being planned at the Gesellschaft für Schwerionenforschung (GSI) at Darmstadt. It is intended to be an international research institute in nuclear and hadron physics where 25 % of the construction cost comes from countries outside Germany. FAIR has a wide physics program covering high – energy heavy ion collisions (CBM), radioactive ion beams for nuclear structure studies (NUSTAR), high-energy antiproton beams for hadron physics in the charmonium range to search for the origin of nucleon masses (PANDA), low-energy antiproton beams for fundamental symmetries and atomic physics (FLAIR), and atomic physics with highly charged ions (SPARC / FLAIR). FAIR will become the most important center for hadron physics in Europe. The discussions with potential member states is progressing, and the German government just announced that their part of the funding has been fixed now in the budget of the ministry. The time schedule foresees an end of construction in 2014, where the antiproton part will be ready already in 2011. The Stefan Meyer Institute is interested in the physics program with antiprotons and is involved in FLAIR, PANDA, and the Antiproton Ion Collider which is part of NUSTAR.

- ***PANDA - antiProton ANnihilation at DArmstadt***

With PANDA we propose to study fundamental questions of hadron and nuclear physics in interactions with nucleons and nuclei, using the universal PANDA detector. Gluonic excitations and the physics of strange and charm quarks will become accessible with unprecedented accuracy, thereby allowing high-precision tests of strong interaction. PANDA will use antiproton-proton annihilation to create gluonic degrees of freedom as well as particle-antiparticle pairs, allowing spectroscopic studies with utmost statistics and precision. Antiprotons of 1 -15 GeV/c will therefore be an excellent tool to study the open problems with the foreseen experiments:

- Charmonium spectroscopy: precision measurement of mass, width and decay branches of all charmonium states, especially for extracting information on the quark-confining potential.
- Establishment of the QCD-predicted gluonic excitations (charmed hybrids, glueballs) in the charmonium mass range (3-5GeV/c<sup>2</sup>) using high statistics in combination with spin-parity analysis in fully exclusive measurements.
- Search for modifications of meson properties in the nuclear medium and their possible relationship to partial restoration of chiral symmetry.

Our institute is part of the international PANDA collaboration using the future antiproton installation HESR (High Energy Storage Ring), which is a major part of the planned FAIR facility at Darmstadt. Within the 6<sup>th</sup> framework program of the EU, the institute contributes to the following tasks: Optimisation studies of the hydrogen cluster-jet target (I3-Hadron Physics), design of the PANDA interaction zone and the development of imaging Cherenkov detectors (DIRACsecondary Beams).

The work at SMI related to PANDA during 2005 can be subdivided into 4 projects:



## 1) nozzle tests

In order to reach the desired target density ( $\sim 10^{15}$  protons/cm<sup>2</sup> to achieve the anticipated luminosity of  $L > 10^{32}$  cm<sup>-2</sup>s<sup>-1</sup>) an optimization of the used nozzle as well as the nozzle skimmer arrangement is essential. Therefore, a system to measure the jet-profile after the nozzle has been designed and was installed during the year, using a pumping system (Leybold TRIVAC D65B & Leybold RUVAC WAU501) borrowed from GSI. The profile measurements will be

done with a Pitot-Tube (Prantl'sches Staurohr) mounted on a movable table. By moving the tube through the gas cluster-jet its density distribution can be recorded.

A first test of the system was successfully done, measuring the gas-jet profile of a capillary tube at room temperature (see Fig. 12).

It is planned to measure different types of gases (hydrogen, argon ...) with different inlet pressures up to 20 bar in the temperature range from 100 K to 20

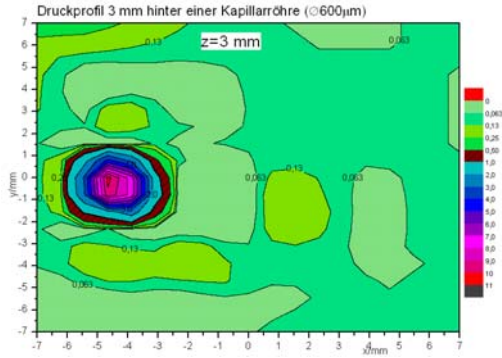


Fig. 12: Pressure profile 3 mm behind a capillary tube

K.

## 2) test setup: PANDA interaction zone with NEG-coated pipes

Non-evaporative-getter material (NEG) is usually an alloy of zirconium. In our case we use a Ti-V-Zr alloy, because of its low activation temperature, high pumping speed and storage capacity for H<sub>2</sub>.

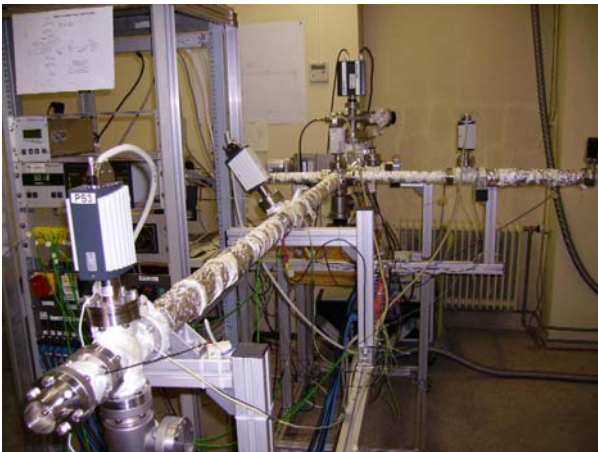


Fig. 13: NEG-pipes and heating system.

tested successfully end of 2005. First test measurements of pumping and reactivation cycles are planned for 2006.

In 2005 6 NEG-coated pipes were delivered from SAES Getters, Italy (similar pipes are used in the LHC at CERN). A vacuum system with an oil-free roughing pump, a Turbo-Pump, a QMS system and was prepared to attach the NEG-coated pipes with 5 UHV pressure sensors installed at different positions, as shown in the Fig. 13. In order to absorb the residual gas molecules the getter needs to be activated by heating to about 200°C. Therefore, a heating system was developed and installed, which allows each side arm to be controlled separately. The setup was

### 3) *Genova Cluster-Jet Target at GSI*

The Genova/Fermilab cluster-jet target was set up at GSI with contribution from SMI and is operational now. Cluster beams of both Ne and H<sub>2</sub> have been made. Hydrogen clusters were formed between 2 and 6 bars input pressure at temperatures slightly above the phase transition boundary from liquid to gas (28 K at 6 bar). Since the pumping speed may have changed from earlier values, we cannot yet deduce the achieved jet density. It will be one of the next steps to measure the pumping speed for hydrogen in the individual sections of the jet vacuum chamber.

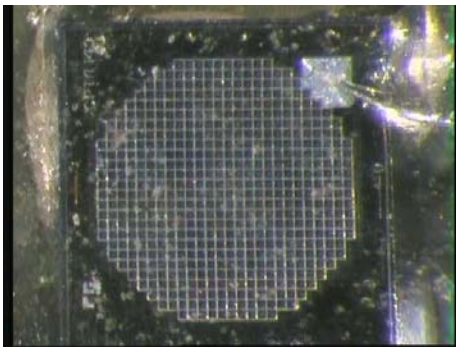
A new hydrogen purification system was developed and built in Vienna will be installed at GSI for the next testing period in spring 2006.

### 4) *Imaging Cherenkov Detectors (DIRACSecondary beams)*

Our institute participates in the EU Design Study “DIRACsecondaryBeams” which is part of the technical developments for the new FAIR facility at GSI. We are partner in the international collaboration for the task PANDA 1 within this design study. This sub-project is aiming at the development of imaging Cherenkov detectors proposed for the DIRC (detection of internally reflected Cherenkov light) and for the forward RICH detector [24]. The DIRC in the PANDA detector system is incorporated in the barrel section of the target spectrometer and will cover the angular range from 22° to 140°. The DIRC allows the determination of the particle velocity and together with the momentum information from the tracking detectors the identification of the particle mass.

One of the milestones of the project is the choice of the photon detector to be reached in the end of 2006. We are studying the application of new Geiger-mode avalanche photodetectors for the photodetection in DIRC applications. This photodetector is an integrated device consisting of an array of micropixels each working in the limited Geiger mode and is also called silicon photomultiplier (SiPM). It exhibits a high gain in the order of  $10^6$  for single photons comparable with the gain of photomultipliers. However the complexity of SiPMs is low (no vacuum tube, no high voltage necessary) and therefore the costs for detector and electronic are advantageous.

In the BABAR experiment at Stanford the read-out of the DIRC system was done by 11000 photomultipliers which resulted in enormous efforts and costs. For the smaller PANDA



**Fig. 14:** *Microscope picture of the pixel structure of a 1 mm<sup>2</sup> Geiger-mode APD (Fa. Photonique).*

DIRC however still about 7000 photomultipliers would be necessary. A possible solution could be the implementation of arrays of Geiger-mode APDs reading out the radiator slabs directly on one end, thus providing spatial resolution and very good timing resolution of about 0.1 ns which might allow the use of time-of propagation (TOP) information. In principle this kind of photodetectors is very promising for DIRC applications due to the features like insensitivity for magnetic fields, single photon response, fast timing and position sensitive capability due to the high granularity (e.g. arrays of 1 mm<sup>2</sup> SiPMs).

The development of SiPMs is proceeding fast and new photon detectors with larger sensitive area and opti-

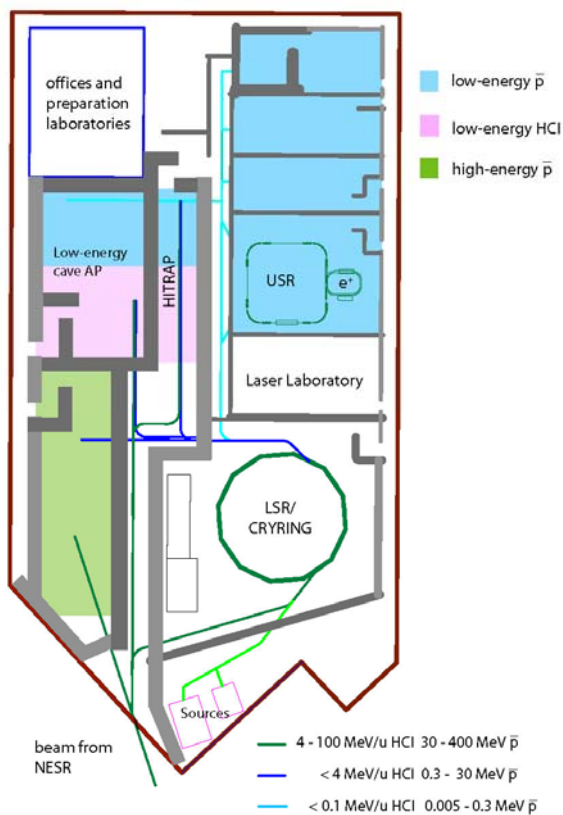


mized for the short wavelengths will be available soon. For the design study we have to test the newest generation of SiPMs (dark count rate, photo detection efficiency, sub-nanosecond timing resolution, temperature effects etc.). For first tests of Geiger-mode APDs, power supplies and electronics were selected and purchased. Holders and adapters for light guides as well as preamplifiers were prepared. A test assembly will setup in spring 2006.

- **FLAIR**

The proposed Facility for Low-energy Antiproton and Heavy-Ion Research combines low energy antiproton beams and stable and instable highly-charged ions for atomic, nuclear and particle physics research. The key features of the facility will be the cooled, highly intense beams of antiprotons and bare and few-electron heavy ions. The combination of two decelerators- the Low-energy Storage Ring LSR and the Ultra-low energy Storage Ring, USR- and different ion/ antiproton traps will provide beams of excellent emittance covering energies from 100 MeV/u down to few eV. Over 15 different experiments have been proposed to be located at FLAIR and use the provided beams. Details about scientific goal and technical aspects of these experiments are presented in the FLAIR Technical Proposal [25].

Based on the recommendations of the Program Advisory Committee (APPA-PAC), the Scientific and Technical Issues committee (STI) decided in summer 2005 to include the proposed research program with low-energy antiprotons as an integral part of the FAIR project. Due to the fact the FLAIR and SPARC research programs rely largely on the same accelerator infrastructure the committee suggested a strong cooperation between the two collaborations.



**Fig. 15** New layout of the FLAIR building.

antiproton and ion beams will be delivered via LSR and USR. The large diversity of the ex-

With this decision, the FLAIR collaboration received the 'green light' to proceed to the preparation of the technical developments. As an immediate consequence of this decision, the FLAIR building was integrated in the FAIR general layout and became part of the civil construction planning. Based on the experimental needs presented in the Technical Proposal by different experiments, a concerted activity for design optimisation of the facility was performed during the second half of 2005. The optimised building layout presented in Fig. 15 tries to satisfy the requests of the planned experimental setups under the observance of security and radiation protection rules and cost saving. Together with the radiation Protection group at GSI, detailed simulations of radiation field produced in the different experimental areas and the needed shielding have been performed.

Another important activity of the collaboration is connected to the integration of the LSR in the larger frame of the FAIR accelerator system. For most of the FLAIR experiments, the

periments planned at FLAIR requires a complex beam sharing inside the facility and a good matching with the FAIR accelerator system.

In December 2005 a FLAIR-SPARC meeting was organised at GSI. Part of the meeting was dedicated to presentation of experiment proposals with highly-charged ions at FLAIR. Also the building layout and the Baseline Technical Report, due December 15, 2005, were discussed and accepted by the participants.

- ***Antiproton Ion Collider - AIC***

An antiproton-ion collider is proposed to independently determine rms radii for pro-

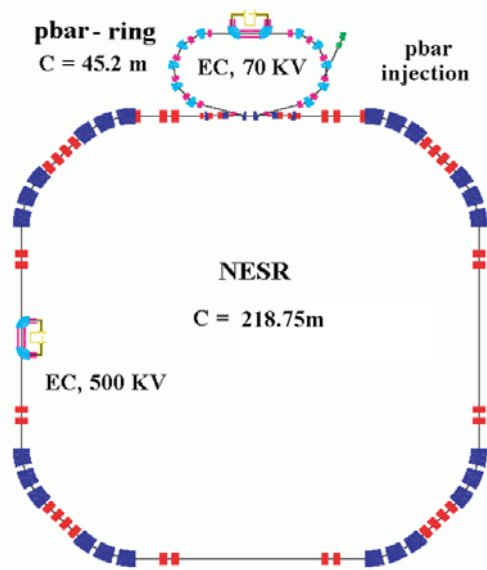


Fig.: 16 *Layout of the AIC.*

tons and neutrons in stable and short lived nuclei by means of antiproton absorption at medium energies. The experiment will use the electron ion collider complex (ELISE LoI) with appropriate modifications of the electron ring to store, cool and collide antiprotons of 30 MeV energy with 740A MeV ions in the NESR. Antiprotons are collected, in the RESR and will be cooled and slowed to 30 MeV by an additional electron cooler. Hereafter the 30 MeV antiprotons are transferred to the electron storage ring using a new transfer line.

Radioactive nuclei are produced by projectile fragmentation and projectile fission of 1.5A GeV primary beams and separated in the Super FRS. The separated beams are transferred to the collector ring (CR) and cooled at 740A MeV and transported via the RESR to NESR, in which

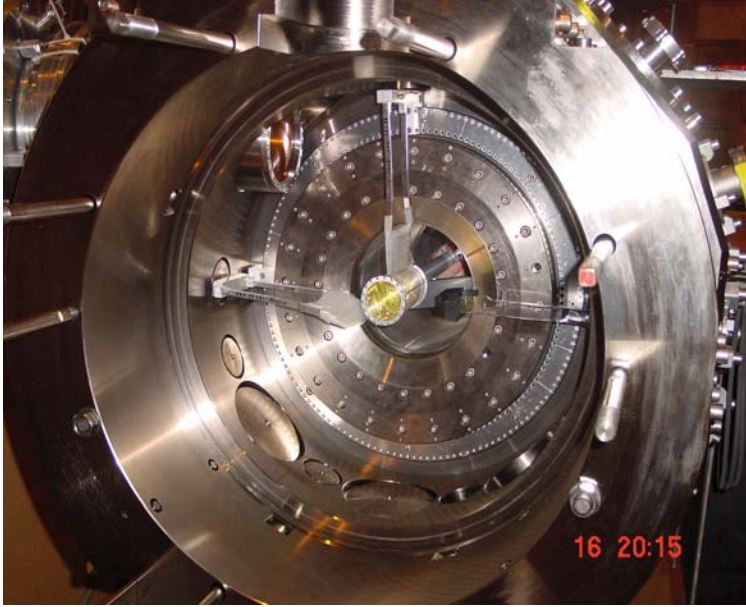
especially short lived nuclei are accumulated continuously to increase the luminosity.

The total absorption cross-section for antiprotons on the stored ions with mass A will be measured by detecting the loss of stored ions by means of the Schottky method. Cross sections for the absorption on protons and neutrons, respectively, will be measured by the detection of residual nuclei with A-1 either by the Schottky method or by detecting them in recoil detectors after the first dipole stage of the NESR following the interaction zone.

The scientific goals and technical feasibility studies are presented in detail in the technical proposal submitted in 2005 [26]. P. Kienle is project manager and J. Zmeskal deputy spokesperson of this project.

### 1.3.4 Other programs

- *Pion-Nucleon Interaction: Pionic Hydrogen*



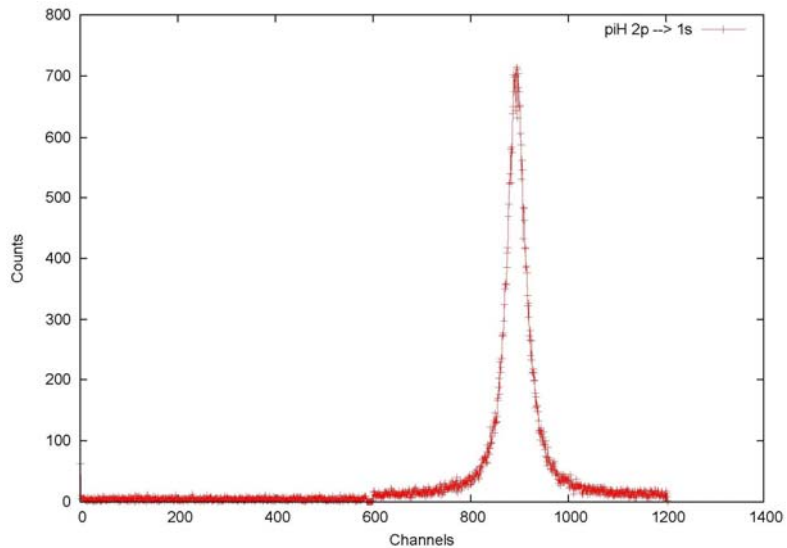
**Fig. 17:** Photograph of the target cell mounted inside the target chamber.

The final goal of the pionic hydrogen experiment is the determination of the strong interaction width of the ground state in pionic hydrogen with an accuracy of about 10 meV. From this width determination a precise value of the isovector scattering length can be extracted directly, having the advantage of small theoretical uncertainties. Furthermore, from the isovector scattering length an improved value of the pion nucleon coupling constant can be deduced.

The necessary accuracy can only be achieved by using a high resolution Bragg spectrometer, measuring the energy of radiative transitions ( $2p \rightarrow 1s$ ,  $3p \rightarrow 1s$  and  $4p \rightarrow 1s$ ) feeding the ground state. A view of the target chamber is shown in Fig. 17.

In 2005 the experimental activities focused on a high statistics measurement of the

$2p \rightarrow 1s$  transition of pionic hydrogen in September and October 2005. To perform this high precision measurement, it was necessary to study the response function of the applied crystals. Therefore, the crystals were characterized using an ECRIT (Electron Cyclotron Resonance Ion Trap) setup, which delivers X-ray lines with very well known energy and width. The knowledge of the



**Fig. 18:** Sum spectrum of the  $2p \rightarrow 1s$  transition in pionic hydrogen measured in 2005 (one channel corresponds to 28,9 meV).

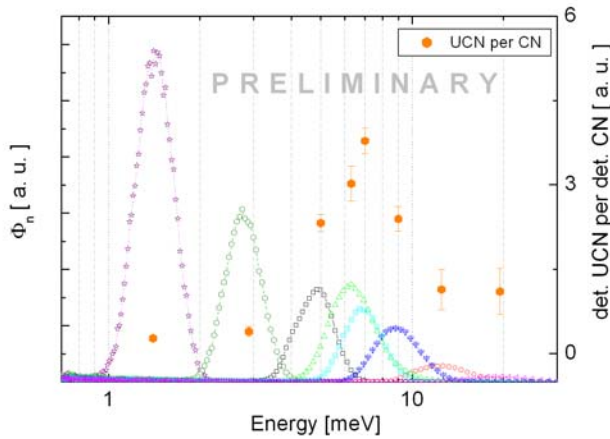
response function of the used crystals is of utmost importance in order to achieve the desired accuracy.

From the experience made during the past measurement periods, it turned out to be necessary to quantify the effect of the ice layer on the window of the cryogenic target, which accumulated with time and decreased the count rate significantly. This resulted in a series of short measurement periods from late spring until early summer 2005.

Fig. 18 shows the sum spectrum for the  $2p \rightarrow 1s$  transition in pionic hydrogen taken in the high statistics measurement in autumn 2005.

- *Ultra cold neutron production efficiency of solid  $D_2$ ,  $CD_4$  and  $O_2$*

A high intensity ultra cold neutron (UCN) source based on solid deuterium as a UCN production medium is currently under construction at the Paul Scherrer Institute (PSI). In order to optimize the source performance it is important to know the UCN production cross section. SMI is involved in the project through a Ph. D. student financed half by PSI and half by us.



**Fig. 19** Cold neutron flux versus energy at different velocity selector positions together with the energy dependent UCN production data in sD2. From online analysis, the observed dependence for solid D2 seems to agree with downscattering and phonon excitation according to a simple Debye model density of states.

from differently prepared targets and compared  $D_2$  frozen from the gas phase and from the liquid. The UCN production was measured also for the gas and liquid phase of all three materials. Moreover for solid  $D_2$  we measured CN energy dependent production of UCN (Fig. 19). The attempt to measure the UCN polarization failed for reasons presently unknown. For all targets we have also measured the CN transmission. The setup used during this experiment was essentially the same as the one we have used during the test experiment in 2004.

Except solid deuterium, two other cryogenic materials: oxygen and heavy methane, are foreseen as good candidates for UCN converters. Properties of solid  $D_2$ ,  $O_2$  and  $CD_4$  have been the subject of the UCN production experiment performed in autumn 2005 at the FUNSPIN beam at SINQ (PSI). UCN production data was measured successfully for all targets at different temperatures and for various preparation methods.

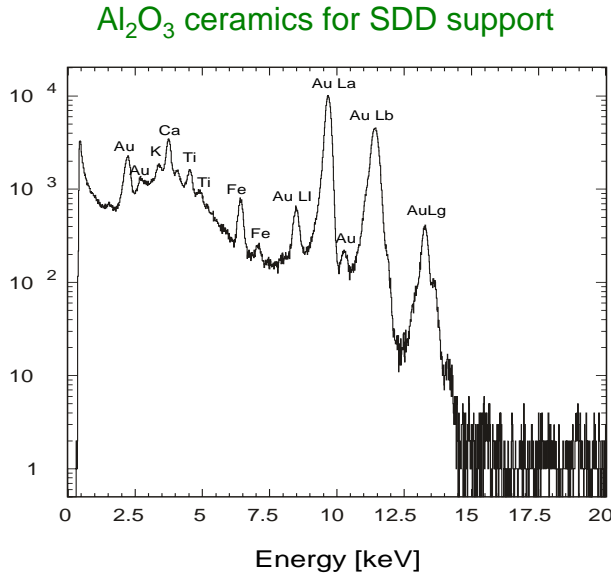
During 5 weeks of beam time we measured the production of UCN by a cold neutron (CN) beam on the cryogenic solids  $D_2$ ,  $O_2$  and  $CD_4$ . We investigated the UCN extraction

- *PIXE at VERA*

In the measurements of kaonic atom X-rays, materials of the experimental setup must be carefully selected. The energies of the kaonic H, D, He atom X-ray lines are about 6-8 keV. There exist materials that emit fluorescence X-ray lines in this energy region, and these materials (e.g. Fe, Cu) are used in normal experimental apparatus. However, for the measurement of kaonic atom X-rays these materials should not be used, because even small contamination of these materials in the setup may make difficulty in the extraction of the kaonic X-ray peaks. In particular, the energy of the kaonic helium 3d-2p X-ray line is very close to the Fe  $K\alpha$  X-ray energy, use of the lowest iron contents is very crucial.

To make in-beam calibration lines in the energy spectra, metal foils that emit well-known fluorescence X-ray lines will be installed. The concentration measurement of these metal foils is also important.

The measurements of the concentration analysis are performed by the PIXE (Proton Induced X-ray Emission Spectroscopy) method using the 3-MeV proton beam at VERA (Vienna Environmental Research Accelerator). Amptek XR-100CR was used as the X-ray detector. As targets, metal foils (e.g. Al, Ti, Fe, Co, Ni, Cu, Zr), plastics (e.g. epoxy fiber, carbon fiber, PVC), and some ceramics alloys ( $Al_2O_3$  compounds) were used. In addition, the SDD support plate ( $Al_2O_3$  base), which is designed for the SIDDHARTA experiment, was also measured.



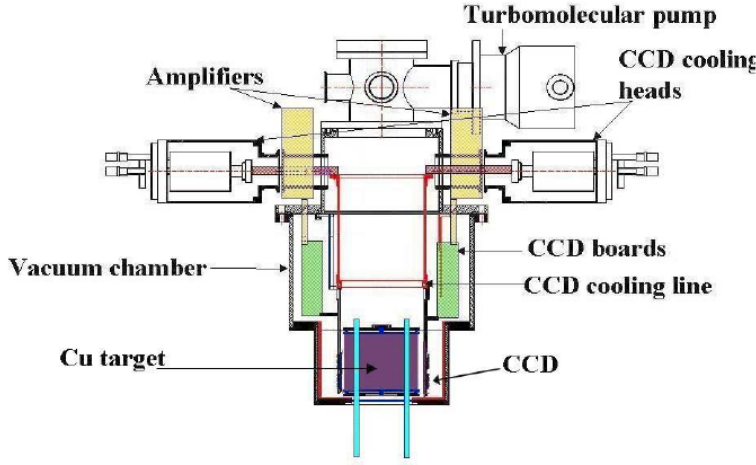
**Fig. 20** PIXE spectrum of a  $Al_2O_3$  ceramics plate.

Comparing the results of the simulation that calculates the X-ray production rates, X-ray absorption, and X-ray detection efficiency, preliminary results of the concentrations in the targets were obtained. The energy spectrum of the  $Al_2O_3$  ceramics plate for the SDDs is shown in Fig. 20.

The materials with well-known concentrations will be measured to check the results of the simulation. The effects of satellite peaks and the  $K\alpha/K\beta$  ratio by changing the target thickness will be studied. In addition, measurements using SDDs are also planned.



- *Violation of the Pauli exclusion principle - VIP*



**Fig. 21:** *VIP setup, using the DEAR vacuum chamber, CCD detector system and cooling unit.*

The Pauli Exclusion Principle (PEP) represents one of the fundamental principles of modern physics and much of our comprehension of the matter is based on it. Even today there are no compelling reasons to doubt its validity, but there is still a lively debate on its limits going on, due to the lack of an explanation of PEP based on fundamental principles. Therefore, it

is possible to speculate that PEP might represent only an approximation of a more fundamental law, and consequently, to search for possible tiny violations is very important.

One possible experiment is to measure the violation of PEP with electrons. Greenberg and Mohapatra [27] examined all these experimental data up to 1987. Their analysis concluded that the probability for a new electron added to an antisymmetric collection of  $N$  electrons to form a mixed symmetry state is  $< 10^{-9}$ . In 1988, Ramberg and Snow [28] have drastically improved this limit with a dedicated experiment, looking for anomalous X-rays emission, signaling a small violation of the PEP in a copper conductor. The result of the experiment was a probability limit  $< 1.7 \times 10^{-26}$  that a new electron circulating in the conductor would form a mixed symmetry state with the remaining copper electrons.

We have decided to repeat this experiment with higher sensitivity. Our aim is to lower the limit by 4 orders of magnitude by using high resolution charge-coupled devices (CCD) as soft X-rays detectors. To decrease the background only carefully chosen materials were used and the measurement will be performed in an underground laboratory.

The idea of the new VIP experiment was originated by the availability of the CCD detector system used for the DEAR (DAΦNE Exotic Atom Research) experiment, which had just successfully completed its program at the DAΦNE collider at LNF-INFN [10].

The experimental method consists of introducing new electrons into a copper strip and to look for X-rays resulting from the  $2p \rightarrow 1s$  anomalous X-rays transitions emitted if one of the new electrons would be captured by a Cu atom and cascades down to the  $1s$  state already filled with two electrons of opposite spin. The energy of this transition would differ from the normal  $K\alpha$ -transition by about 400 eV (7.64 keV instead of 8.04 keV), providing an unambiguous signal of the PEP violation. The measurement alternates periods with no current in the Cu strip, in order to evaluate the X-ray background in conditions where no PEP violating transitions are expected to occur, with periods with current through the Cu strips, thus providing "fresh" electrons, which might possibly violate PEP. The rather straightforward analysis consists on the evaluation of the statistical significance of the normalized subtraction of the two spectra in the region of interest.

To perform VIP the DEAR setup has slightly to be modified. The cryogenic target cell has been replaced by a copper cylinder, acting as target, 4.5 cm in radius, 50  $\mu\text{m}$  thick, 8.8 cm high, surrounded by 16 equally spaced CCDs of type 55. The CCDs are at a distance of 2.3 cm from the copper cylinder, grouped in units of two chips vertically positioned. The setup is enclosed, using the DEAR vacuum chamber with the existing cooling system for the CCDs, which are cooled to about 168 K. The apparatus is shown in Fig. 21.

A first test measurement was performed at LNF in November and December 2005. The data analysis is in progress. Already with this measurement we expect an improvement of one order of magnitude compared to the limit quoted by Ramberg and Snow [28].

- *Theoretical studies on low energy QCD (cooperation with TU Wien)*

The successful collaboration with theoreticians of the Atomic Institute of TU Vienna was continued in 2005. The theoretical work was focussed on kaonic atoms (kaonic hydrogen and deuterium) and kaonic nuclear clusters in order to support our experimental research program on the theoretical side. The research resulted in publications on the following topics: kaonic deuterium [29], isospin breaking corrections to the shift of the ground state of kaonic hydrogen [30], radiative transitions in kaonic atoms [31] and energy level displacement of excited np states of kaonic hydrogen [32].

A phenomenological quantum field theoretic model of the kaonic nuclear cluster  $K^-pp$  was developed. First results on the binding energy and partial widths caused by the non-mesonic decay channels were obtained.

- *MedAUSTRON*

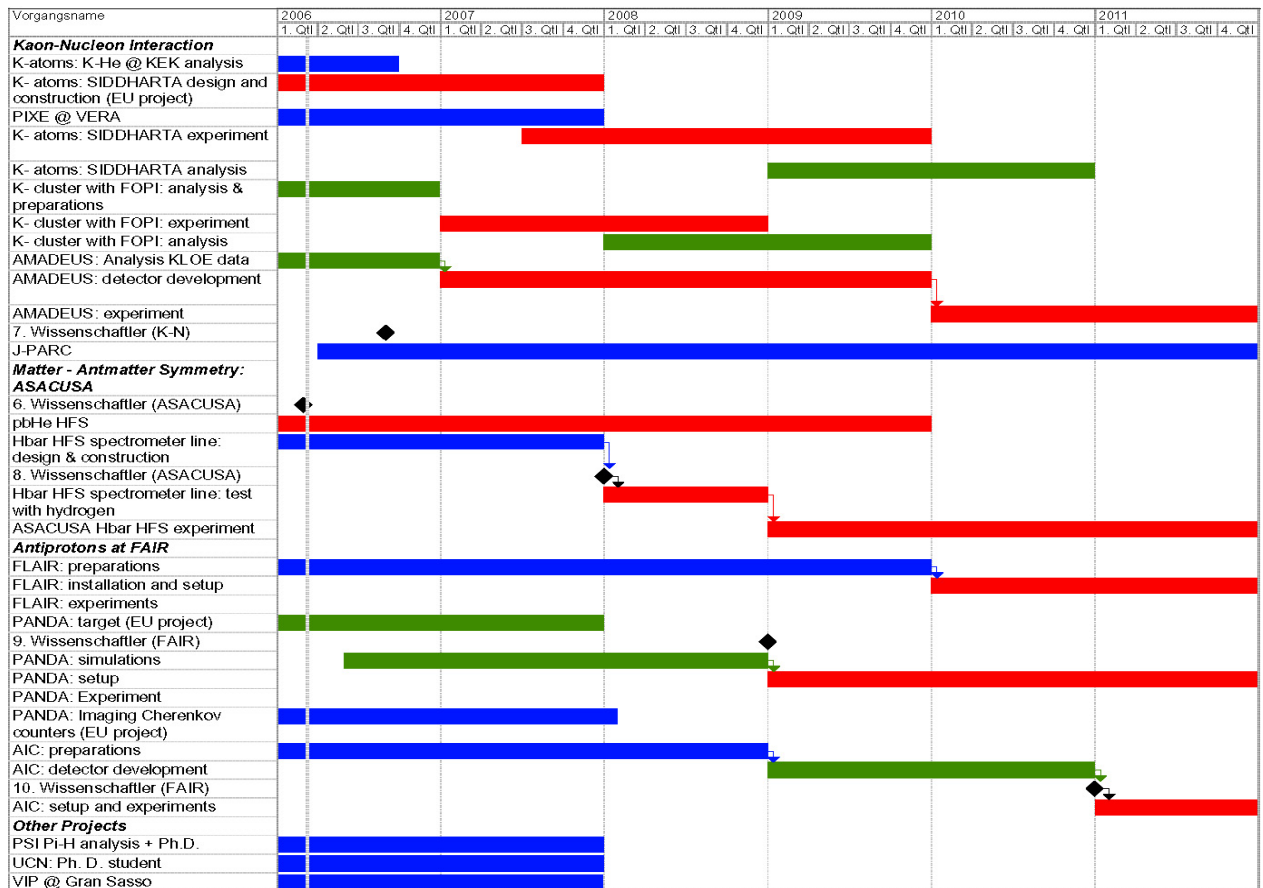
MedAUSTRON is a facility dedicated to tumour treatment with carbon and proton beams, which is planned to be built in Wiener Neustadt. A workshop on the scientific usage (outside the necessary clinical R&D for therapy) was held on September 15, 2005, in Wiener Neustadt. E. Widmann described the possible use of the MedAUSTRON beam outside therapy hours for hadron and particle physics, representing both SMI and the Institute for High-energy Physics (Hephy) of the Austrian Academy of Sciences. While Hephy is mainly interested in beams of minimum ionizing particles for detector tests, SMI presented in addition a proposal to use proton beams of energy  $> 800$  MeV for the determination of nuclear *matter* (i.e. the sum of proton and neutron) radii by proton diffraction, which is a simple, model independent way of determining matter radii [33]. This is especially interesting as there are many methods to determine charge (i.e. proton) radii, but data on neutron radii are scarce.

Even though the magnetic rigidity of the planned accelerator would be large enough to accelerate protons up to  $\sim 1$  GeV, the necessary additional shielding is currently not part of the project cost as it was submitted for public tender. During the meeting of the Austrian Physical Society in end of September, a special session on MedAUSTRON was held and a letter was written by the FAKT (Fachausschuss für Kern- und Teilchenphysik) to stress that the option of using higher energies should be kept open in the design of MedAUSTRON. So far no reaction or feedback was received, and the future development in the respect is unknown to us.

## 1.4 Preview of the scientific program 2006 – 2011

The following figure gives an overview of the different projects of the institute, their duration and the necessary manpower. The colour of the bars corresponds to the manpower needed for the different projects:

- blue: less then one FTE (full time equivalent)
- green: 1 – 2 FTEs
- red: more than 2 FTEs



**Fig. 22: Overview of the scientific program in the years 2006 – 2011. The diamond marks correspond to times when additional manpower is needed.**



### 1.4.1 Kaon-Nucleon Interaction: Kaonic atoms and kaonic nuclei

- *Kaonic hydrogen: SIDDHARTA*

To proceed towards precision spectroscopy we started to develop a new detector system - Large Area Silicon Drift Detectors -, which will allow us to perform a percent-level measurement of shift and width in kaonic hydrogen and to measure for the first time kaonic deuterium to test the chiral symmetry breaking scenario in systems with strangeness. In addition, precise measurements of kaonic  $^3\text{He}$  and  $^4\text{He}$  will be made with utmost precision. These measurements are also of great interest for the ongoing search of deeply bound kaonic states.

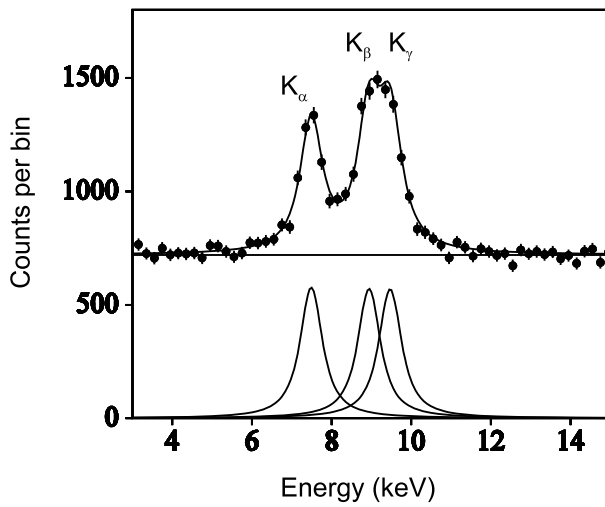


Fig. 23: Monte Carlo simulation of the kaonic deuterium X-ray spectrum.

The main work of the SIDDHARTA project until 2007 will be the characterization of all SDDs including the spectroscopic test measurements, which will take place at SMI. In addition the cryogenic target cell has to be build and tested. Furthermore, the vacuum chamber and the SDD cooling mounts have to be fabricated and tested. The design work is almost fin-

ished, but some slight modifications might still be necessary.

A first tests of the whole apparatus with beam (trigger and background tests) might take place end of 2007 if the DAΦNE operation proceeds as foreseen. The main experimental work is expected to start in 2008 and 2009. The analysis of the data should be finished end of 2010.

Fig. 23 shows a Monte Carlo simulation of the expected kaonic deuterium X-ray spectrum, which will be obtained in 30 days of beam time.

- *Deeply bound kaonic nuclei with FOPI at GSI*

With the first test experiments carried out at GSI in 2005 we were able to check the experimental setup in the FOPI environment and gain first insights into the production rates of kaonic clusters in the investigated reactions.

In the coming years we plan to apply for further beamtime at GSI to continue the search for kaonic clusters in (p,d) collisions in collaboration with the Technische Universität München and the FOPI collaboration. Following actions will be taken to improve the experimental setup:

1. Build a beam profile monitor as well as a new anticoincidence counter to better control the focussing and to obtain a better trigger for the delivered proton beam from GSI.

2. Improve on the setup of the Silicon Array to achieve a better signal to background ratio, this will be done in collaboration with our colleagues at the Technische Universität München.
3. Improve the target cell design

A new proposal will be submitted to the GSI Experimentierausschuss during 2006. On acceptance the experiment could take place in the first half-year of 2007.

In addition we plan to investigate with FOPI the production of proton induced deeply bound kaonic states in the  $p+^{12}\text{C}$  reaction. In this experiment with 4.6 GeV protons,  $\Lambda^*$  are produced which collide with the residual nucleus. Through knock-on reactions like e.g.  $\Lambda^* + \text{"ppN"} \rightarrow \text{pppK}^- + \text{N}$ , kaonic clusters are produced which can be identified by Invariant Mass spectroscopy of their decay products. The timeline for this experiment is 2007 - 2009.

### • AMADEUS

In the year 2006 the LoI to LNF-INFN will be finished and the preparation of a proposal to the EU within the 7-th framework program has to be worked out, with the main topic to study the modifications of the inner region of the KLOE apparatus for AMADEUS.

The AMADEUS setup within KLOE will use an inner-tracker detector, which track the kaons previous to their arrival to the target and integrates the information coming from the existent KLOE detectors. The design, test and construction of this detector will be done in a common effort with the KLOE collaboration, which already started in this direction. This detector has a different role in the KLOE experiment and in the AMADEUS project. Different geometric solutions satisfying all requests are under study.

Possible solutions under study are a silicon-strip detector; a long drift chamber or a TPC with GEM read-out (cylindrical GEM). AMADEUS favors a small TPC-GEM detector with a

scintillating fiber kaon trigger. A prototype of such a detector will be designed and individual components could be tested within 2006.

Such a detector will be of interest not only for AMADEUS/KLOE – but also for other experiments in Europe (GSI-FAIR, FOPI) and world-wide (for example in Japan, at J-PARC).

In addition two other main items have to be clarified:

The KLOE electro magnetic calorimeter (EMC) (Fig. 24) plays an important role in the AMADEUS measurement of neutral particles.

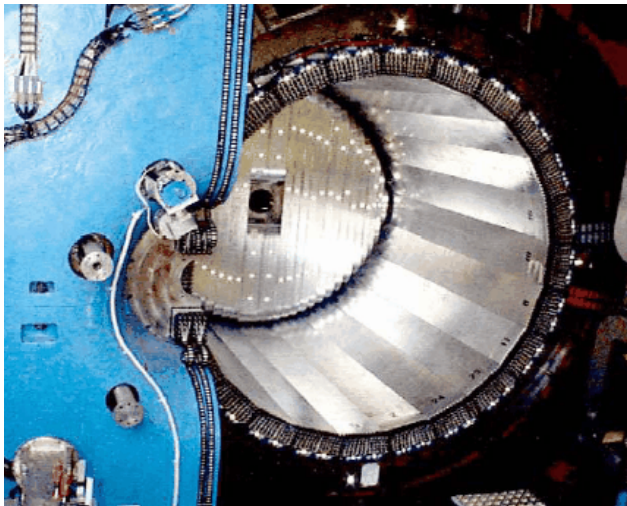


Fig. 24: KLOE EMC (24 barrel modules).

While its performance for the measurement of  $\gamma$ -rays and the reconstruction of  $\pi^0$  events were fully measured, understood and explored in many of the KLOE existent measurements, its performance for the neutron measurement were not investigated up to the present.

We therefore plan to experimentally extract the efficiency of the KLOE e.m. calorimeter for neutrons and a mixed KLOE-AMADEUS group is planning to perform a measurement on a

KLOE e.m. calorimeter prototype, consisting of half a KLOE-barrel, on a neutron beam. The prototype already exists – it was used at the beginning of KLOE already for testing its performance for KLOE-physics at PSI.

Few choices for the facility where this test could be done are under consideration: the neutron beam at TSL Uppsala, or the neutron facility at the Rutherford Appelton Laboratory in England. The possibility to use the TSL neutron beam is under investigation – specifically for what concerns the tagging of the neutrons and the possibility to normalize to the total neutron flux. The other facility will be studied as well to take a decision within spring 2006 – such as to perform the test within autumn 2006.

The drift chamber of KLOE, filled to 90% with helium, can be seen as an active target, where a fraction of stopped antikaons will form deeply bound antikaon nuclear clusters. The formation as well as the decay process is anticipated to be identified with the KLOE detector. To verify the existence of such deeply bound kaonic clusters, independently from first observations at KEK, LNF and GSI, we start a common effort with the help of the KLOE-analysis group to identify kaon cluster events inside the KLOE drift chamber. This program should give first results within 2007.

The design and construction of the AMADEUS setup might take place from 2007 to 2009. A first run is envisioned for 2010, depending on the machine status (upgrade DAΦNE2).

- *Deeply bound kaonic nuclear clusters at J-PARC*

The Japan Proton Accelerator Research Complex (J-PARC) is under construction in Tokai-mura, Ibaraki-ken, Japan. It contains a high-intensity 50 GeV proton synchrotron which will produce the world's most intense kaon beams. Among the "Day One" (highest priority) experiments which can expect to get first beam in 2009 is the Letter of Intent No. 10, "Study of Dense  $K^-$  Nuclear Systems", where SMI has participated. The collaboration, which evolved out of the E471/E549 collaborations at KEK, proposes to study kaonic nuclear clusters using  $(K^-, \pi^-)$ ,  $(\pi^+, K^+)$ , and  $(K^-, N)$  reactions with meson beams of about 1 GeV/c momentum, thus being a complementary approach to the proposed AMADEUS project at DAΦNE2. Double kaonic cluster containing two  $K^-$ , which are predicted to have even higher densities than the ones with only one  $K^-$ , can be investigated using  $(K^-, K^+)$  and  $(K^-, K^0_s)$  reactions at 2–3 GeV/c.

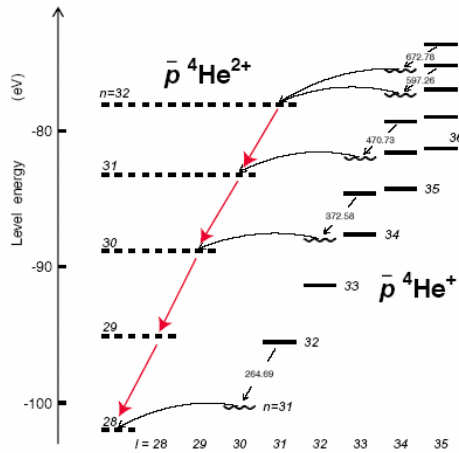
From the size of the effort needed to participate in such an experiment and the potential competing role of AMADEUS and the J-PARC proposal, SMI will only be able to strongly contribute to one of them and the J-PARC LoI is currently our second choice in case AMADEUS will not be approved. Nevertheless we are investigating possibilities to participate in building common components, i.e. an inner tracker.

## 1.4.2 Matter – Antimatter Symmetry – ASACUSA at CERN-AD

- *Laser spectroscopy of antiprotonic helium*

As described in section 1.3.2, the laser spectroscopy has reached a precision of 2 ppb for the relative deviation of the antiproton charge and mass using a newly developed pulse-amplified CW laser system. This corresponds to an absolute accuracy of the transition frequencies of about 10 MHz or better. In this situation, a further improvement using single-photon transitions is not feasible, since the Doppler broadening due to the movement of the atoms in the helium gas causes a line width of 300 MHz to 1 GHz. Efforts towards a Doppler-free two-photon spectroscopy, as e.g. employed for the spectroscopy of hydrogen atoms to a relative accuracy of  $10^{-14}$ , are under way at CERN, but the technical feasibility of such a measurement is not yet confirmed. Thus, attempts using two-photon spectroscopy for antiprotonic helium may start earliest 2007.

For 2006, another attempt at the spectroscopy of the antiprotonic helium ion,  $\bar{p}\text{He}^{++}$ ,



**Fig. 25:** Energy level diagrams of antiprotonic helium atoms and ions. The curved arrows denote Auger transitions and the red ones transitions within the ion.

will be undertaken. The  $\bar{p}\text{He}^{++}$  ion has the strong advantage that it is a two-body system, which makes the theoretical calculation of its structure much easier than in the case of the three-body system  $\bar{p}\text{He}^+$ .  $\bar{p}\text{He}^{++}$  ions have been observed in 2004 [34] in laser spectroscopy measurements, and it has been found that the collisional destruction cross sections depend on the quantum state. Therefore, in principle it is possible to produce an ion in a well defined quantum state (by inducing a laser transition in  $\bar{p}\text{He}^+$  to a state that undergoes fast Auger transitions thus creating a two-body ion, see Fig. 25) and transfer the ion by a second laser pulse to a state with shorter lifetime against collisional destruction. Such experiments have been tried once without success.

For 2006, numerous technical improvements have been implemented to enhance the sensitivity of the detectors, and a full 4 weeks of beam time are planned for 2006. A measurement of the transition energy in the ion would allow to extract a value of the antiproton mass without any theoretical ambiguities.

- *Hyperfine structure of antiprotonic helium*

Due to a reduction in available beam time at the AD ring, in 2006 a period of 13 shifts will be available for this experiment. The time in 2006 has therefore been allocated for preliminary measurements. A test of the laser beam, to confirm the depopulation efficiency at various densities, is planned. Also scheduled is one longer, low powered, microwave scan as a preliminary measurement. The scan should reveal information, hitherto only theoretical, about

dephasing collisions and whether measurements at a time length of the order of 500 ns are therefore possible.

In addition to improving the accuracy by which the hyperfine structure of antiprotonic helium can be measured and thus improving the knowledge of the magnetic moment of the antiproton, the future ambition of this experiment is to measure the microwave un-favoured transition and the HFS of antiprotonic  $^3\text{He}$ . The un-favoured transition between SHF levels of same total angular momentum  $J=L$  (cf. Fig. 8) requires an increase in microwave power, which is just possible with the current amplifier, but was not successful in previous tests. The measurement of this transition together with the previously measured HF transitions will allow to directly extract the SHF splitting and therefore will improve the accuracy for the determination of the antiproton magnetic moment.

The measurement of the four hyperfine states of antiprotonic  $^3\text{He}$  requires the production of a new resonant cavity and, for the higher frequency transitions, an upgrade of the vector network analyser, but the same experimental principle will be used as for  $^4\text{He}$ . Numerical simulations of antiprotonic  $^3\text{He}$  are planned to commence in the middle of 2006. The HF structure of antiprotonic  $^3\text{He}$  has never been measured before, and as discussed in section 1.3.2, the deviations in the laser transition frequencies between theory and experiment in antiprotonic  $^3\text{He}$  make this measurement especially interesting.

Provided the experimental tests in 2006 are successful, measurements of the hyperfine structure in antiprotonic  $^4\text{He}$  are planned for 2007 and in antiprotonic  $^3\text{He}$  for 2008.

- *Measurement of the ground-state hyperfine structure of antihydrogen*

The measurement of the ground-state hyperfine splitting of antihydrogen will be a strict test of the CPT symmetry in the baryon sector. The building of the experimental apparatus will require a close collaboration between many groups within ASACUSA. Two antihydrogen sources are being built now: one cusp trap (i.e. anti-Helmholtz coils) at RIKEN, Japan, and a superconducting two-frequency Paul trap at CERN, Switzerland, both by Japanese collaborators. The better one of these devices will be chosen for the measurement. The cusp trap will be tested with protons in 2006, and will be tested with antiprotons at the Antiproton Decelerator (AD) at CERN in 2007. The Paul trap could be tested with protons and antiprotons in 2007 and 2008, respectively. A positron source, which is essential for both traps, will be commissioned in Aarhus, Denmark, and will be operational at the AD by 2008, and the first antihydrogen atoms could be produced that year. SMI took responsibility to design, build and commission the spectrometer line (see section 1.3.2), which has to be ready and working by 2009, when it will be connected to the antihydrogen source. Thus the spectrometer line will have to be designed in 2006, built in 2007, and tested with hydrogen in 2008. The first measurements can already start in 2009, and will continue in 2010 and beyond.

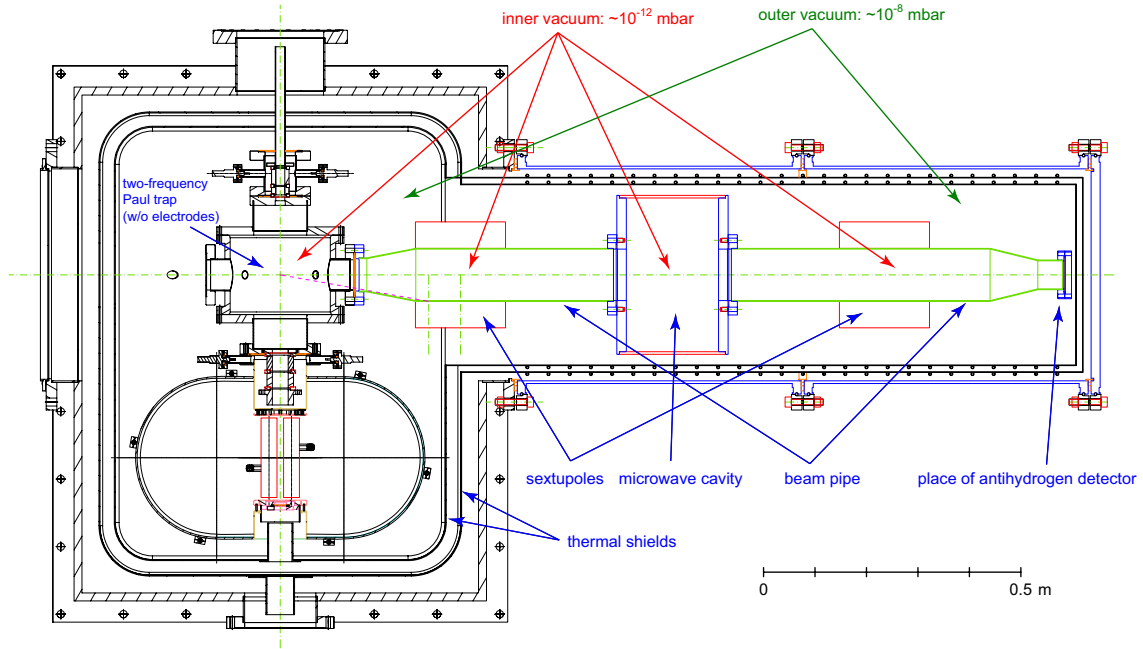


Fig. 26: Preliminary design of the antihydrogen recombination trap and the attached spectrometer line

Fig. 26 shows a preliminary design drawing of the spectrometer line. Many technical details like the support of the sextupoles and the microwave cavity, the antihydrogen detector etc. are not included, because these are not yet designed.

### 1.4.3 Long-term scientific program: Antiprotons at FAIR

- **PANDA**

The PANDA experiment at HESR of the FAIR facility addresses fundamental questions in strong interaction physics. Antiproton beams stored in the HESR for fixed target experiments with an internal target provide access to the heavier strange and charm quarks and to copious gluon production. In particular the formation of charmonium states with subsequent precision spectroscopy of their mass, life time, and branching ratios of decay, requires a well controlled coasting beam of anti-protons with small momentum spread and fine-focus for interactions with protons in ultra-high vacuum. This can be provided with sufficient luminosity by a hydrogen cluster-jet target.

During the years 2006 and 2007 beam profiles with different nozzle types and different diameters will be measured at SMI with the Pitot-Tube setup. Using these data and selected nozzles the final tests will be done with the Fermilab/INFN cluster-jet target at GSI. The outcome of this study is essential for the final design of the PANDA target. Improvements of the control and read-out system for the Fermilab/INFN cluster-jet target are planned for 2006.,

Studies of the NEG-coated pipes, which simulate the PANDA interaction zone, will be carried out with the setup at SMI. The hydrogen losses of the cluster-jet passing through the pipe will be simulated by introducing different gas-loads via an UHV-leak valve into the pipe and the resulting hydrogen distribution will be measured. The gas load in the intersection region has to be below  $10^{-6}$  mbar. In addition the gas-load dependency of the pumping speed of

the NEG-coated pipes as well as the hydrogen regeneration procedure will be studied. These essential measurements for the design of the PANDA interaction zone will be finished within 2007.

In 2006, simulation studies of charmonium states produced in antiproton proton collisions using the cluster-jet target will start in the framework of a Ph. D. thesis. From 2009 to 2012 the institute will participate in the construction and commissioning of the PANDA detector.

We will study the performance of Geiger-mode APDs: dark count rate, photo detection efficiency, timing resolution and temperature effects in 2006. The passive as well as active quenching of the photo-detectors will be studied. Together with colleagues from PSI, GSI and Russia the feasibility of the production of Geiger-mode APD arrays and the associated electronics and read-out will be investigated. Design studies of the optical readout of quartz slabs with arrays of Geiger-mode APDs using mirrors/lenses will be conducted. At the end of 2006 the feasibility study for Geiger-mode APDs has to be worked out in order to make the decision about the photon detector for DIRC.

As a spin-off, the possible application of this photo detector for the read-out of scintillating fiber assemblies will be tested. This study is very important in respect to the choice of tracking detectors for the AMADEUS project.

- **FLAIR**

After the approval of FLAIR by the APPA PAC of GSI/FAIR and the inclusion of the FLAIR building in the civil construction plans of FAIR, the next important issues are the formation of a collaboration and the planning of funding possibilities for the common infrastructure in the FLAIR hall, especially the common beam lines. For this a collaboration meeting is planned in spring of 2006. The FAIR management is also pushing the experimental collaborations to sign memoranda of understanding.

The FAIR management together with the various committees is now preparing a detailed planning of the construction of FAIR. The German government has just announced the start of construction for FAIR in 2007 to finish it in 2014. In 2006, the convention that defines the structure and operation of FAIR as an international facility with strong contributions by external partners will be finalized.

In this scenario, the FLAIR building will be built in phase 1 (2007 – 2011), while the antiproton target and accumulation complex is scheduled in phase 2 (2011 – 2013).

- **AIC**

One of the major questions in the study of nuclei far off stability concerns the evolution of the density distributions of protons and neutrons. In light nuclei the wave functions of loosely bound nucleons extends to larger radii, giving rise to the occurrence of nuclear halos while in heavier neutron rich nuclei one expects the formation of neutron skins at the nuclear surface.

With the AIC project a novel method is proposed to measure neutron and proton distributions of stable and unstable nuclei, the latter produced by projectile fragmentation or projectile fission, by studying medium energy antiproton absorption in a collider mode. This new approach allows an independent measurement of proton and neutron radii within the same experiment. This is of utmost importance since most nuclear matter radii are deduced with

different techniques than the charge radii of the same nucleus, making a direct comparison often difficult.

2006 and 2007 will be devoted to design studies of the involved storage rings, interaction zone and last but not least of the connecting beam lines. This work will be done at GSI and Budker Institute of Nuclear Physics, Novosibirsk, Russia. In addition the design of the luminosity monitor and the recoil detector will be done at the TU-Munich and SMI. The construction phase of storage rings (EC and NESR) at GSI is foreseen to start 2008 and should be finished 2011.

#### 1.4.4 Other programs

- *Pionic deuterium and pionic hydrogen*

In 2006 the experimental activity will be focused on the measurement of pionic deuterium. An eight week measuring period is planned and approved by the PSI – “Benutzerversammlung” and will take place in July and August. The goal of the experiment is a significant improvement of the precision of the hadronic shift and width of the ground state in pionic deuterium. With measurements at different densities the question of possible influence of molecular effects in the shift determination can be studied. The hadronic shift will give an additional band of values for the isospin dependent scattering length, which is an independent test of the results coming from the pionic hydrogen precision experiment. Substantial input for the development of the theoretical description can be awaited.

Parallel to the experimental activity the analysis of the pionic hydrogen data is in progress. For this purpose an analysis program was developed at SMI, which allows the measured response function to be included in the analysis procedure.

With the completion of the analysis the pionic hydrogen project reaches its final stage and should be finished end of 2007.

- *SUNS*

The presented results as described in section 2.3 are preliminary, the data analysis is ongoing, and the final results can be expected by mid of 2006. The extraction of absolute UCN production cross section from the experimental data requires proper normalization and a detailed Monte Carlo simulation. The UCN polarization is still an open issue; we consider making a request for around 2 weeks of beam time in 2007 to resolve this problem. The project is expected to finish end of 2007 with the end of the Ph. D. thesis of M. Kasprzak.

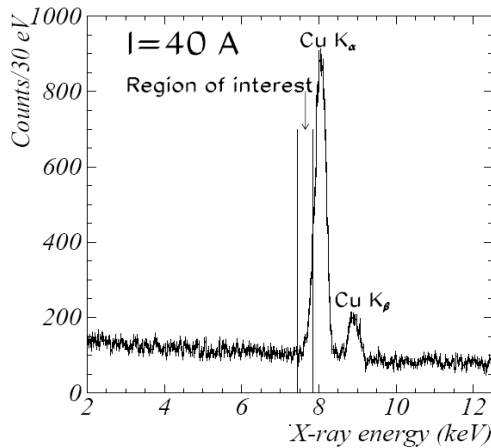


- *PIXE at VERA*

The PIXE method requires comparison between the measured X-ray intensities and the calculated X-ray intensities to extract concentrations in the target materials. The measurements of the materials with well-known concentrations are important for the reliability of the simulation codes. In 2006, the concentration measurements of these materials will be performed. The Ti and Ni foils used for the E570 experiment will be measured to see the effects of the small contaminations of these foils, using the VERA proton beam. In addition, the emission rates of the satellite peaks, and the  $K_{\alpha}/K_{\beta}$  ratio of the X-ray lines will be measured by changing the target thickness. X-ray measurements using SDDs (Silicon Drift Detectors) are also planned.

- *VIP*

The analysis of the test experiment at LNF with the adapted DEAR apparatus will be finished spring 2006.



**Fig. 27:** X-ray spectrum of a measurement with current ( $I=40$  A).

A preliminary result gives a limit of  $< 3.3 \times 10^{-28}$ , which improves the existing limit by almost two orders of magnitude (see Fig. 27 measured X-ray spectrum). A publication describing this experiment is in preparation and will be published in Physics Letters.

The installation of the VIP setup will take place in the LNGS-INFN underground laboratory in February 2006 (already successfully finished). The measurement will be performed with higher integrated currents and of course with reduced background. From preliminary tests, it results that the X-ray background in the LNGS environment is a factor 10-100 lower than in the

LNF laboratory.

A VIP measurement of two years (always alternating between measurements with and without current) at LNGS, to start in spring 2006, will then bring the limit on PEP violation for electrons into the  $10^{-30}$  -  $10^{-31}$  region, which will be of particular interest for all those theories related to possible PEP violation coming from new physics. The data analysis will be finished end of 2008.

- *Theoretical studies on low energy QCD (cooperation with TU Wien)*

The common theoretical work will be continued. The theoretical research will be focused on deeply bound kaonic nuclear clusters. A publication on the results from a phenomenological model for  $K^-pp$  is in preparation. The work will be extended and will provide important input data for the planning of our experimental research on kaonic nuclear clusters done with the FOPI detector and the AMADEUS detector in the future.

## 1.5 Personalstand 2005

<i>Name</i>	<i>Funktion<sup>1</sup></i>
Cargnelli, Michael, Dipl. Ing. Dr.	Wiss.
Fuhrmann, Hermann, Mag.	Wiss.
Gruber, Alexander, Mag.	FWM
Gsell, Roland, Ing.	Techniker
Hirtl, Albert, Dipl. Ing.	Wiss.
Ishiwatari, Tomoichi, MS PhD	FWM
Juhasz, Bertalan, Dr.	FWM
Kasprzak, Malgorzata	FWM
Kienle, Paul, Prof. Dr.-Ing.	FWM
Marton, Johann, Dipl.Ing. Dr.	Stellv. Direktor
Panzenböck, Petra	Sekretärin
Pask, Thomas	FWM
Schmid, Philipp	FWM
Schneider, Herbert, Ing.	Techniker
Stohwasser, Leopold, Feinmechaniker	Techniker
Stückler, Doris	Technikerin
Widmann, Eberhard, Prof. Dr.	Direktor
Zmeskal, Johann, Dr.	Wiss.

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<sup>1</sup> FWM: Freier wissenschaftlicher Mitarbeiter bzw. Freie wissenschaftliche Mitarbeiterin.

## 1.6 Publikationen 2005

Entnommen aus der Datenbank AkademIS.

### 1.6.1 Veröffentlichungen

#### Beitrag in Fachzeitschrift

Atchison, F; van den Brandt, B; Brys, T; Daum, M; Fierlinger, P et al. (2005) Production of ultracold neutrons from a cold neutron beam on a H-2(2) target. *Physical Review C* 71, S. 054601. [wissenschaftlich, referiert]

Beer, George; Bragadireanu, A.M.; Cargnelli, Michael; Curceanu, Catalina; Egger, J.-P. et al. (2005) Measurement of the Kaonic Hydrogen X-Ray Spectrum. *Physical Review Letters* 94, S. 212302. [wissenschaftlich, referiert]

Blau, B.; van den Brandt, B.; Brys, T.; Daum, M.; Fierlinger, P. et al. (2005) Measured total cross sections of slow neutrons scattered by solid deuterium and implications for ultracold neutron sources. *Physical Review Letters* 95, S. 182502. [wissenschaftlich, referiert]

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## Herausgeberschaft (von Einzelwerken)

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Krücken, R.; Bosch, F.; Cargnelli, Michael; Fabbietti, Laura; Faestermann, T. et al. (15.06.2005) The Antiproton-Ion-Collider at FAIR. (LEAP 05).; Bonn: American Institute of Physics. [wissenschaftlich, nicht referiert]

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Widmann, E. (15.06.2005) FLAIR, a Facility for Low-energy Antiproton and Ion Research. (6th International Conference on Nuclear Physics at Storage Rings (STORI 05)).. [wissenschaftlich, eingeladen]



Widmann, Eberhard (15.06.2005) FLAIR, a Facility for Low-energy Antiproton and Ion Research. (International conference on Low Energy Antiproton Physics (LEAP '05) ).; Bonn: American Institute of Physics. [wissenschaftlich, nicht referiert]

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## **1.6.2 Diplomarbeiten**

Gruber, Alexander (2005) *Coulomb-Explosion in pionischen Kohlenstoff*. Diplomarbeit, Stefan Meyer Institut, Universität Wien, Wien. [wissenschaftlich, referiert].

## 1.7 Wissenschaftliche Zusammenarbeit 2005

### 1.7.1 Zusammenarbeit mit in- und ausländischen Instituten

- *Kaonische Atome: SIDDHARTA*

Untersuchung Kaonischer Wasserstoffatome, Laboratori Nazionali di Frascati

**Beteiligte Institutsmitarbeiter:**

M. Cargnelli, H. Fuhrmann, A. Hirtl, T. Ishiwatari, P. Kienle, J. Marton, E. Widmann, J. Zmeskal

**Internationale Kooperation:**

INFN, Laboratori Nazionali di Frascati, Italien, Dipartimento di Fisica, Univ. di Trieste und INFN, Trieste, Italien, Inst. de Physique, Univ. de Fribourg, Schweiz, Inst. de Physique, Univ. de Neuchâtel, Schweiz, Department of High Energy Physics, Inst. of Physics and Nuclear Engineering, Bukarest, Rumänien, Inst. of Physical and Chemical Research (RIKEN), Saitama, Japan, Department of Physics, Hokkaido Univ., Sapporo, Japan, Department of Physics, Univ. of Tokyo, Japan, Tokyo Inst. of Technology, Japan, KEK, High Energy Accelerator Research Organization, Tokyo, Japan, Department of Physics and Astronomy, Univ. of Victoria, Kanada, W. K. Kellogg Radiation Laboratory, California Institute of Technology Pasadena, USA, Department of Physics and Astrophysics, California State Univ. Northridge, USA

- *Kaonisches Helium: Experiment E570 am KEK*

Messung der Verschiebung des 3d-2p Überganges in kaonischen Helium.

**Beteiligte Institutsmitarbeiter:**

M. Cargnelli, T. Ishiwatari, B. Juhasz, J. Marton, P. Schmid, E. Widmann, J. Zmeskal

**Internationale Kooperation:**

Tokyo Institute of Technology, Japan, INFN, Laboratori Nazionali di Frascati, Italien, Saitama, Inst. of Physical and Chemical Research (RIKEN), Japan, Department of Physics, Univ. of Tokyo, Japan, KEK, High Energy Accelerator Research Organization, Japan, Seoul National University, Südkorea

- *Kaonische Kern-Cluster: Experiment E549 am KEK*

Suche nach tiefgebundenen Kern Clustern mit in  $^4\text{He}$  gestoppten  $K^-$ .

**Beteiligte Institutsmitarbeiter:**

T. Ishiwatari, B. Juhasz, J. Marton, P. Schmid, E. Widmann, J. Zmeskal

**Internationale Kooperation:**

Tokyo Institute of Technology, Japan, Saitama, Inst. of Physical and Chemical Research (RIKEN), Japan, Department of Physics, Univ. of Tokyo, Japan, KEK, High Energy Accelerator Research Organization, Japan, Seoul National University, Südkorea

- *Search for antikaon nuclear clusters with FOPI*

**Beteiligte Institutsmitarbeiter:**

Michael Cargnelli, Paul Kienle, Johann Marton, Eberhard Widmann, Johann Zmeskal

**Internationale Kooperation:**

TU-München, GSI, Darmstadt, Univ. Heidelberg, TU-München, Univ. Tokyo, RIKEN

- *AMADEUS an DAPHNE2*

**Beteiligte Institutsmitarbeiter:**

Paul Bühler, Michael Cargnelli, Paul Kienle, Johann Marton, Eberhard Widmann, Johann Zmeskal

**Internationale Kooperation:**

Italien, Frascati, INFN, Laboratori Nazionali di Frascati

- *Study of dense  $\bar{K}$  nuclear systems (J-PARC)*

**Beteiligte Institutsmitarbeiter:**

M. Cargnelli, P. Kienle, J. Marton, E. Widmann, J. Zmeskal

**Internationale Kooperation:**

KEK, Japan, RIKEN, Japan, Osaka E-C, Japan, Osaka University, Japan, Tokio University, Japan, Seoul, Korea, University, Temple University, USA.

- *ASACUSA*

**Beteiligte Institutsmitarbeiter:**

M. Cargnelli, H. Fuhrmann, B. Juhasz, J. Marton, T. Pask, E. Widmann, J. Zmeskal

**Internationale Kooperation:**

Department of Physics and Astronomy, University of Aarhus, Aarhus, Denmark, Institute for Storage Ring Facilities, University of Aarhus, Aarhus, Denmark, Niels Bohr Institute, Copenhagen, Denmark, MPI für Kernphysik (MPI-K), Heidelberg, Germany, Research Institute for Particle and Nuclear Physics, Budapest, Hungary, Institute of Nuclear Research (ATOMKI), Debrecen, Hungary, Dipartimento di Chimica e Fisica per l'Ingegneria e per i Materiali, Università di Brescia, Italy, Department of Physics, University of Tokyo, Tokyo, Japan, Institute of Physics, University of Tokyo, Tokyo, Japan, Atomic Physics Laboratory, RIKEN, Wako, Japan, RI Beam Science Laboratory, RIKEN, Wako, Japan, CERN, Geneva, Switzerland, Department of

Physics, University of Wales, Swansea, Wales UK, The Queen's University of Belfast Belfast N. Ireland.

- **PANDA**

**Beteiligte Institutsmitarbeiter:**

M. Cargnelli, H. Fuhrmann, A. Gruber, P. Kienle, J. Marton, E. Widmann, J. Zmeskal

**Internationale Kooperation:**

Uppsala Univ., Schweden, LNF-INFN, Italien, GSI, Deutschland, KVI Kroningen, Niederlande, Univ. Brescia, Italien, Univ. Catania, Italien, Univ. Torino, Italien, TU Dresden, Deutschland, Univ. Frankfurt, Deutschland, TSL Uppsala, Schweden, Univ. Erlangen, Deutschland, Univ. Münster, Deutschland, FZ Jülich, Deutschland, LANL Los Alamos, USA, Politecnico Torino, Italien, Univ. Cracow, Polen, Univ. Silesia, Polen, Ruhr-Univ. Bochum, Deutschland, Univ. Genova, Italien, Univ. Trieste, Italien, Univ. Tübingen, Deutschland, TU München, Deutschland, Univ. Mainz, Deutschland, Univ. Gießen, Deutschland, Univ. Bonn, Deutschland, Univ. Glasgow, England, Univ. Pavia, Italien, JINR Dubna, Russland, Northwestern Univ. Evanston, USA, BINR Dubna, Russland, SINS Warsaw, Polen.

- **FLAIR**

**Beteiligte Institutsmitarbeiter:**

M. Cargnelli, H. Fuhrmann, P. Kienle, J. Marton, E. Widmann, J. Zmeskal

**Internationale Kooperation:**

Institute for Theoretical Physics, Vienna University of Technology, Department of Physics and Astronomy, York University, Toronto, Canada, TRIUMF, Vancouver, Canada, Institute for Storage Ring Facilities, Aarhus University, Department for Physics and Astronomy, Aarhus University, Laboratoire Kastler-Brossel, École Normale Supérieure et Université P. et M. Curie, Paris, GSI Darmstadt, Institut für Theoretische Physik, Technische Universität Dresden, Institut für Angewandte Physik, Universität Frankfurt, Institut für Kernphysik, Universität Frankfurt, Max-Planck-Institut für Quantenoptik (MPQ), Garching, Institut für Kernphysik, Universität Giessen, MPI für Kernphysik (MPI-K), Heidelberg, Forschungszentrum Jülich, Institut für Physik, Universität Mainz, Physikalisches Institut, Universität Tübingen, Institut für Physik, Humboldt-Universität zu Berlin, KFKI Research Institute for Particle and Nuclear Physics, Budapest, Institute of Nuclear Research of the Hungarian Academy of Sciences (ATOMKI), Debrecen, Department of Experimental Physics, University of Debrecen, Dipartimento di Chimica e Fisica per l'Ingegneria e per i Materiali, Università di Brescia & INFN-Gruppo Collegato di Brescia, Dipartimento di Fisica, Laboratorio LENS, INFN, Università degli Studi di Firenze, Istituto Nazionale di Fisica Nucleare, Genova, Atomic Physics Laboratory, RIKEN, Wako, Institute of Physics, University of Tokyo, and Atomic Physics Laboratory, RIKEN, Wako, Department of Physics, University of Tokyo, Institute of Physics, University of Tokyo, Laser Centre Vrije Universiteit, Faculty of Science, Amsterdam, FOM Institute for Atomic and Molecular Physics, Amsterdam, Heavy Ion Laboratory, Warsaw University, Soltan Institute for Nuclear Studies, Warsaw, Institute of Theoretical Physics, Warsaw University, JINR Dubna, Institute of Nuclear Physics, Moscow State University, D.I. Mendelev Institute for Metrology (VNIIM), St.

Petersburg, Department of Physics, St. Petersburg State University, St. Petersburg Nuclear Physics Institute, Institute of Spectroscopy of the RAS, Troitsk, Institute for Experimental and Theoretical Physics, Moskva, Manne Siegbahn Laboratory (MSL), Stockholm, Department of Atomic Physics, Stockholm University, Queens University, Belfast, Ireland, Department of Physics, University of Wales Swansea, Department of Physics, Harvard University, Cambridge, Massachusetts, Pbar Labs, LLC Santa Fe, New Mexiko, University of New Mexico, Albuquerque, New Mexico, Department of Physics, Texas A&M University, College Station, Texas, Indiana University, Bloomington, Indiana

- *AIC – Antiproton Ion Collider*

**Beteiligte Institutsmitarbeiter:**

M. Cargnelli, H. Fuhrmann, A. Hirtl, P. Kienle, J. Marton, E. Widmann, J. Zmeskal

**Internationale Kooperation:**

Gesellschaft für Schwerionenforschung, Darmstadt, Germany (GSI), Technische Universität München, Munich, Germany (TUM), University of Tokyo, Tokyo, Japan (UoT), Justus-Liebig Universität Giessen., Giessen, Germany (JLU), Budker Institute of Nuclear Physics, Novosibirsk, Russia (BINP), University of Saitama, Saitama, Japan.(UoS), Andrzej Soltan Institute for Nuclear Studies, Warsaw, Poland (IPJ)

- *Pionischer Wasserstoff / PSI*

Measurement of the strong interaction width and shift of the ground state of pionic hydrogen, Experiment R98-01.1, Paul Scherrer Institut

**Beteiligte Institutsmitarbeiter:**

M. Cargnelli, H. Fuhrmann, M. Giersch, A.Gruber, A. Hirtl, P. Kienle, J. Marton, J. Zmeskal

**Internationale Kooperation:**

Institute of Physics, Aarhus Univ., Dänemark, Inst. of Nuclear Research (ATOMKI) of the Hungarian Acad. of Sciences, Debrecen, Ungarn, Univ. of Ioannina, Griechenland, Institut für Kernphysik, Jülich, Deutschland, Space Research Center, Department of Physics and Astronomy, Univ. of Leicester, Großbritannien, Institut de Physique, Univ. de Neuchâtel, Schweiz, EISI, St. Imier, Schweiz, Laboratoire Kastler-Brossel, Univ. Pierre et Marie Curie, Paris, Frankreich, PSI, Schweiz, Inst. für Teilchenphysik, Univ. Zürich, Schweiz.

- *SUNS – Spallation Ultra Cold Neutron Source at PSI, Source Development*

**Beteiligte Institutsmitarbeiter:**

M. Giersch, M. Kasprzak, J. Zmeskal

**Internationale Kooperation:**

Paul Scherrer Institut, Schweiz, PNPI St. Petersburg, Russland, Jagellonian Univ. Cracow, Polen, Inst. Laue-Langevin, Frankreich

- *Röntgenspektroskopie an der VERA – Beschleunigeranlage (PIXE)*

**Beteiligte Institutsmitarbeiter:**

M. Cargnelli, H. Fuhrmann, A. Hirtl, T. Ishiwatari, P. Kienle, J. Marton, H. Schneider, L. Stohwasser, J. Zmeskal

**Nationale Kooperation:**

Institut für Isotopenforschung und Kernphysik der Univ. Wien

- *VIP @ Gran Sasso (VIolation of the Pauli Exclusion Principle Experiment)*

**Beteiligte Institutsmitarbeiter:**

Michael Cargnelli, Johann Marton, Eberhard Widmann, Johann Zmeskal

**Internationale Kooperation:**

Inst. of Physics and Nuclear Engineering „Horia Hulubei“, Romania, LNF-INFN, Italien

- *Theoretical Studies of Low Energy QCD, Investigated with Exotic Atoms*

**Beteiligte Institutsmitarbeiter:**

M. Cargnelli, A. Hirtl, H. Fuhrmann, P. Kienle, J. Marton, E. Widmann, J. Zmeskal

**Nationale Kooperation:**

Atominstitut der Österreichischen Universitäten

## 1.7.2 Teilnahme an wissenschaftlichen Veranstaltungen

### Vortrag

Albert Hirtl (18.04.2005) Target-Ice Measurement. Vortrag: *piH Collaboration Meeting*, Coimbra/Portugal. [Beitrag ohne Auswahlverfahren (not selected/not refereed lecture), wissenschaftlich, Veranstaltung in kleinerem Rahmen (Seminar etc.)]

Alexander Gruber (29.04.2005) Coulombexplosion in pionischem Kohlenstoff. Vortrag: *Seminar zu aktuellen Themen der subatomaren Physik* (Stefan-Meyer-Institut für subatomare Physik), Wien/Österreich. [Beitrag ohne Auswahlverfahren (not selected/not refereed lecture), wissenschaftlich, Veranstaltung in kleinerem Rahmen (Seminar etc.)]

Andrei Ivanov (22.02.2005) Recent theoretical studies on hadronic atoms. Vortrag: *International Conference on Exotic Atoms - EXA05* (Stefan Meyer Institut für subatomare Physik), Wien/Österreich <<http://www.oeaw.ac.at/smi/exa05/index.htm>>. [Eingeladener Beitrag (Invited lecture), wissenschaftlich, Großveranstaltung (Konferenz, Kongress, Tagung, Symposium etc.)]

Andrei Ivanov (09.03.2005) On quantum field theoretic analysis of the deeply bound  $K^-pp$  state. Vortrag: *Seminar zu aktuellen Themen der subatomaren Physik* (Stefan Meyer Institut für subatomare Physik), Wien/Österreich. [Beitrag ohne Auswahlverfahren (not selected/not refereed lecture), wissenschaftlich, Veranstaltung in kleinerem Rahmen (Seminar etc.)]

Andrei Ivanov (13.05.2005) Phenomenological Quantum Field Theoretic Model of Strong Low-Energy  $K^-p$  interactions. Vortrag: *Seminar zu aktuellen Themen der subatomaren Physik* (Stefan Meyer Institut für subatomare Physik), Wien/Österreich. [Beitrag ohne Auswahlverfahren (not selected/not refereed lecture), wissenschaftlich, Veranstaltung in kleinerem Rahmen (Seminar etc.)]

Andrei Ivanov (22.12.2005) New theoretical studies on  $K^-pp$ . Vortrag: *Austrian-Japanese Workshop on Antikaon Mediated Bound Systems – Doorway to Kaon Condensation in Neutron Stars* (Stefan-Meyer-Institut für subatomare Physik), Wien/Österreich. [Eingeladener Beitrag (Invited lecture), wissenschaftlich, Veranstaltung in kleinerem Rahmen (Seminar etc.)]

Bertalan Juhász (16.11.2005) An atomic beamline to measure the ground-state hyperfine splitting of antihydrogen. Vortrag: *PST05, XIth International Workshop on Polarized Sources and Targets*, Tokyo/Japan. [Ausgewählter Beitrag (Selected/refereed lecture), wissenschaftlich, Veranstaltung in kleinerem Rahmen (Seminar etc.)]

Bertalan Juhász (20.12.2005) Antihydrogen GS-HFS measurement with an atomic beamline. Vortrag: *Workshop on "Antiprotonic Atoms" and ASACUSA collaboration meeting* (Stefan Meyer Institut für subatomare Physik), Wien/Österreich. [Beitrag ohne Auswahlverfahren (not selected/not refereed lecture), wissenschaftlich, Veranstaltung in kleinerem Rahmen (Seminar etc.)]

Eberhard Widmann (05.01.2005) Low energy antiproton physics I. Vortrag: *15th Nordic Meeting on intermediate and high energy nuclear physics*, Grävtöfjällen/Schweden. [Eingeladener Beitrag



(Invited lecture), wissenschaftlich, Vortragsveranstaltung, Teil einer Vortragsserie]

Eberhard Widmann (08.01.2005) Low energy antiproton physics II. Vortrag: *15th Nordic Meeting on intermediate and high energy nuclear physics*, Gravtövalen/Schweden. [Eingeladener Beitrag (Invited lecture), wissenschaftlich, Vortragsveranstaltung, Teil einer Vortragsserie]

Eberhard Widmann (14.01.2005) FLAIR, a facility for low-energy antiproton and ion research. Vortrag: *Seminar LNF*, Frascati/Italien. [Eingeladener Beitrag (Invited lecture), wissenschaftlich, Veranstaltung in kleinerem Rahmen (Seminar etc.)]

Eberhard Widmann (03.02.2005) Precision Spectroscopy of Antiprotonic Helium – A Sensitive Test of CPT Symmetry . Vortrag: *European Graduate School - Complex Systems of Hadrons and Nuclei*, Giessen/Deutschland. [Eingeladener Beitrag (Invited lecture), wissenschaftlich, Veranstaltung in kleinerem Rahmen (Seminar etc.)]

Eberhard Widmann (18.02.2005) Fundamental Symmetries and Antiprotons. Vortrag: *XXXVI. Arbeitstreffen Kernphysik*, Schleching/Deutschland. [Eingeladener Beitrag (Invited lecture), wissenschaftlich, Veranstaltung in kleinerem Rahmen (Seminar etc.)]

Eberhard Widmann (25.02.2005) FLAIR, a facility for low-energy antiproton and ion research. Vortrag: *International Conference on Exotic Atoms - EXA05* (Stefan Meyer Institut für subatomare Physik), Wien/Österreich. [Eingeladener Beitrag (Invited lecture), wissenschaftlich, Großveranstaltung (Konferenz, Kongress, Tagung, Symposium etc.)]

Eberhard Widmann (19.05.2005) FLAIR, a facility for low-energy antiproton and ion research. Vortrag: *International Conference in Low Energy Antiproton Physics - LEAP05*, Bonn – Jülich/Deutschland. [Ausgewählter Beitrag (Selected/refereed lecture), wissenschaftlich, Großveranstaltung (Konferenz, Kongress, Tagung, Symposium etc.)]

Eberhard Widmann (23.05.2005) FLAIR, a facility for low-energy antiproton and ion research. Vortrag: *6th International Conference on Nuclear Physics at Storage Rings - STORI05*, Jülich - Bonn/Deutschland. [Eingeladener Beitrag (Invited lecture), wissenschaftlich, Großveranstaltung (Konferenz, Kongress, Tagung, Symposium etc.)]

Eberhard Widmann (06.06.2005) Precision spectroscopy of antiprotonic helium. Vortrag: *QED 2005 - QED, Quantum Vacuum and the Search for New Forces*, Les Houches/Frankreich. [Ausgewählter Beitrag (Selected/refereed lecture), wissenschaftlich, Großveranstaltung (Konferenz, Kongress, Tagung, Symposium etc.)]

Eberhard Widmann (08.09.2005) Low-energy antiproton physics. Vortrag: *Workshop on Physics with Antiprotons - Probing QCD and fundamental symmetries* (GSI and European Graduate School), Darmstadt/Deutschland. [Eingeladener Beitrag (Invited lecture), wissenschaftlich, Veranstaltung in kleinerem Rahmen (Seminar etc.)]

Eberhard Widmann (09.09.2005) The Physics Program of FLAIR. Vortrag: *SPARC Workshop*, Piaski/Polen. [Eingeladener Beitrag (Invited lecture), wissenschaftlich, Veranstaltung in kleinerem Rahmen (Seminar etc.)]

Johann Marton (20.01.2005) Research on Kaonic Atoms at DAFNE – Results and Perspectives. Vortrag: *International Heraeus Seminar*, Bad Honnef/Deutschland. [Eingeladener Beitrag (Invited lecture), wissenschaftlich, Großveranstaltung (Konferenz, Kongress, Tagung, Symposium etc.)]

Johann Marton (16.02.2005) Precision measurements with kaonic atoms. Vortrag: *HadAtom05 - Workshop on Hadronic Atoms*, Bern/Schweiz. [Eingeladener Beitrag (Invited lecture), wissenschaftlich, Großveranstaltung (Konferenz, Kongress, Tagung, Symposium etc.)]

Johann Marton (25.05.2005) Kaonic Atoms at DAFNE: DEAR und SIDDHARTA. Vortrag: *6th International Conference on Nuclear Physics at Storage Rings - STORI05* (Forschungszentrum Jülich), Bonn/Deutschland. [Ausgewählter Beitrag (Selected/refereed lecture), wissenschaftlich, Großveranstaltung (Konferenz, Kongress, Tagung, Symposium etc.)]

Johann Marton (27.09.2005) Präzisionsmessungen mit kaonischen Atomen - von DEAR zu SIDDHARTA. Vortrag: *Fachausschusstagung Kern- und Teilchenphysik 2005* (Österreichische Physikalische Gesellschaft), Wien/Österreich. [Beitrag ohne Auswahlverfahren (not selected/not refereed lecture), wissenschaftlich, Großveranstaltung (Konferenz, Kongress, Tagung, Symposium etc.)]

Johann Marton (27.09.2005) Pionischer Wasserstoff: Präzisionsmessung zur starken Wechselwirkung. Vortrag: *Fachausschusstagung Kern- und Teilchenphysik 2005* (Österreichische Physikalische Gesellschaft), Wien/Österreich. [Beitrag ohne Auswahlverfahren (not selected/not refereed lecture), wissenschaftlich, Großveranstaltung (Konferenz, Kongress, Tagung, Symposium etc.)]

Johann Marton (24.10.2005) Experimental Studies on Kaonic Atoms at DAPHNE: Recent Results and Perspectives. Vortrag: *PANIC05*, Santa Fe/USA. [Ausgewählter Beitrag (Selected/refereed lecture), wissenschaftlich, Großveranstaltung (Konferenz, Kongress, Tagung, Symposium etc.)]

Johann Marton (24.10.2005) Pionic Hydrogen - Precision Measurements at PSI. Vortrag: *PANIC05*, Santa Fe/USA. [Ausgewählter Beitrag (Selected/refereed lecture), wissenschaftlich, Großveranstaltung (Konferenz, Kongress, Tagung, Symposium etc.)]

Johann Zmeskal (14.01.2005) The SIDDHARTA setup. Vortrag: *SIDDHARTA group meeting*, Frascati/Italien. [Beitrag ohne Auswahlverfahren (not selected/not refereed lecture), wissenschaftlich, Veranstaltung in kleinerem Rahmen (Seminar etc.)]

Johann Zmeskal (09.03.2005) The SMI SDD test setup. Vortrag: *SIDDHARTA-Working group meeting*, Mailand/Italien. [Beitrag ohne Auswahlverfahren (not selected/not refereed lecture), wissenschaftlich, Veranstaltung in kleinerem Rahmen (Seminar etc.)]

Johann Zmeskal (20.04.2005) Precision experiments with kaonic atoms, from DEAR to SIDDHARTA. Vortrag: *Seminar im Rahmen des Einstein-Jahres*, Coimbra/Portugal. [Eingeladener Beitrag (Invited lecture), wissenschaftlich, Veranstaltung in kleinerem Rahmen (Seminar etc.)]

Johann Zmeskal (22.04.2005) Gluing and bonding techniques for the SIDDHARTA SDDs. Vortrag: *SIDDHARTA group meeting* (LNF-INFN), Frascati/Italien. [Beitrag ohne Auswahlverfahren (not selected/not refereed lecture), wissenschaftlich, Veranstaltung in kleinerem Rahmen (Seminar etc.)]

Johann Zmeskal (09.05.2005) The SDD ceramic layout, problems and solutions. Vortrag: *SIDDHARTA-Working group meeting*, Mailand/Italien. [Beitrag ohne Auswahlverfahren (not selected/not refereed lecture), wissenschaftlich, Veranstaltung in kleinerem Rahmen (Seminar etc.)]

Johann Zmeskal (06.06.2005) Cutting Edge Technology in the European Union . Vortrag: *Con-*

*gress of the Canadian Association of Physic* (Canadian Association of Physic), Vancouver/Kanada. [Eingeladener Beitrag (Invited lecture), wissenschaftlich, Großveranstaltung (Konferenz, Kongress, Tagung, Symposium etc.)]

Johann Zmeskal (07.06.2005) A large area silicon drift detector array for low-energy X-ray spectroscopy. Vortrag: *Seminar* (TRIUMF)/Kanada. [Eingeladener Beitrag (Invited lecture), wissenschaftlich, Veranstaltung in kleinerem Rahmen (Seminar etc.)]

Johann Zmeskal (29.08.2005) Final setup: CCD cooling and target design. Vortrag: *VIP- Violation of the Pauli Exclusion Principle, Group Meeting* (LNF-INFN), Frascati/Italien. [Beitrag ohne Auswahlverfahren (not selected/not refereed lecture), wissenschaftlich, Veranstaltung in kleinerem Rahmen (Seminar etc.)]

Johann Zmeskal (03.10.2005) PANDA interaction region, test setup at SMI. Vortrag: *PANDA: Target-Magnet-Beam, workgroup meeting*, Genua/Italien. [Beitrag ohne Auswahlverfahren (not selected/not refereed lecture), wissenschaftlich, Veranstaltung in kleinerem Rahmen (Seminar etc.)]

Johann Zmeskal (28.11.2005) From kaonic atoms to kaonic nuclei with DAFNE 2. Vortrag: *Scientific Committee Meeting* (LNF-INFN), Frascati/Italien. [Beitrag ohne Auswahlverfahren (not selected/not refereed lecture), wissenschaftlich, Veranstaltung in kleinerem Rahmen (Seminar etc.)]

Johann Zmeskal (12.12.2005) A LD2-target and beam monitor system for the search of deeply bound kaon nuclear cluster. Vortrag: *FOPi collaboration meeting* (GSI), Darmstadt/Deutschland. [Beitrag ohne Auswahlverfahren (not selected/not refereed lecture), wissenschaftlich, Veranstaltung in kleinerem Rahmen (Seminar etc.)]

Johann Zmeskal (22.12.2005) Using KLOE for the AMADEUS program. Vortrag: *Austrian-Japanese Workshop on Antikaon Mediated Bound Systems – Doorway to Kaon Condensation in Neutron Stars* (Stefan-Meyer-Institut für subatomare Physik), Wien/Österreich. [Eingeladener Beitrag (Invited lecture), wissenschaftlich, Veranstaltung in kleinerem Rahmen (Seminar etc.)]

Malgorzata Kasprzak (20.01.2005) Measurement of the ultracold neutron (UCN) production efficiency of solid D<sub>2</sub>, CD<sub>4</sub> and O<sub>2</sub>. Vortrag: *Seminar zu aktuellen Themen der subatomaren Physik* (Stefan-Meyer-Institut für subatomare Physik), Wien/Österreich. [Beitrag ohne Auswahlverfahren (not selected/not refereed lecture), wissenschaftlich, Veranstaltung in kleinerem Rahmen (Seminar etc.)]

Malgorzata Kasprzak (18.03.2005) Investigation of solid D<sub>2</sub> for UCN sources. Vortrag: *Seminar zu aktuellen Themen der subatomaren Physik* (Stefan-Meyer-Institut für subatomare Physik), Wien/Österreich. [Beitrag ohne Auswahlverfahren (not selected/not refereed lecture), wissenschaftlich, Veranstaltung in kleinerem Rahmen (Seminar etc.)]

Malgorzata Kasprzak (10.06.2005) Solid deuterium for the production of ultra-cold neutrons. Vortrag: *Seminar zu aktuellen Themen der subatomaren Physik* (Stefan-Meyer-Institut für subatomare Physik), Wien/Österreich. [Beitrag ohne Auswahlverfahren (not selected/not refereed lecture), wissenschaftlich, Veranstaltung in kleinerem Rahmen (Seminar etc.)]

Martin Giersch (02.05.2005) Raman spectroscopy and development of a moderator for ultra cold neutron-(UCN-) production. Vortrag: *Seminar zu aktuellen Themen der subatomaren Physik* (Stefan-Meyer-Institut für subatomare Physik), Wien/Österreich. [Beitrag ohne Auswahlver-

fahren (not selected/not refereed lecture), wissenschaftlich, Veranstaltung in kleinerem Rahmen (Seminar etc.)]

Michael Cargnelli (24.02.2005) Silicon drift detectors for hadronic atom research - SIDDARTA. Vortrag: *International Conference on Exotic Atoms and Related Topics - EXA05* (Stefan-Meyer-Institut für subatomare Physik), Wien/Österreich. [Eingeladener Beitrag (Invited lecture), wissenschaftlich, Großveranstaltung (Konferenz, Kongress, Tagung, Symposium etc.)]

Michael Cargnelli (23.04.2005) Silicon drift detectors for hadronic atom research. Monte Carlo studies of setup configurations. Vortrag: *SIDDHARTA Collaboration Meeting*, Frascati/Italien. [Beitrag ohne Auswahlverfahren (not selected/not refereed lecture), wissenschaftlich, Veranstaltung in kleinerem Rahmen (Seminar etc.)]

Michael Cargnelli (11.11.2005) How to measure x ray lines to 1 eV precision using SDDs. Vortrag: *SIDDHARTA Collaboration Meeting*, Frascati/Italien. [Beitrag ohne Auswahlverfahren (not selected/not refereed lecture), wissenschaftlich, Veranstaltung in kleinerem Rahmen (Seminar etc.)]

Paul Kienle (16.03.2005) An Antiproton Ion Collider (AIC) for Measuring Neutron and Proton Distributions in Stable and Radioactive Nuclei. Vortrag: *Physics with Ultra Slow Antiprotons*, Wako/Japan. [Eingeladener Beitrag (Invited lecture), wissenschaftlich, Großveranstaltung (Konferenz, Kongress, Tagung, Symposium etc.)]

Paul Kienle (21.05.2005) That was LEAP 05 (Conference summary). Vortrag: *International conference on Low Energy Antiproton Physics Low Energy Antiproton Physics/Deutschland*. [Eingeladener Beitrag (Invited lecture), wissenschaftlich, Großveranstaltung (Konferenz, Kongress, Tagung, Symposium etc.)]

Paul Kienle (22.05.2005) Exotische Atome: Rosen aus dem Blumengarten der subatomaren Physik. Vortrag: *International Conference on Exotic Atoms - EXA05* (Stefan Meyer Institut für subatomare Physik), Wien/Österreich <<http://www.oeaw.ac.at/smi/exa05/index.htm>>. [Eingeladener Beitrag (Invited lecture), populärwissenschaftlich, Großveranstaltung (Konferenz, Kongress, Tagung, Symposium etc.)]

Paul Kienle (07.12.2005) Antiproton Physics in a Nutshell!. Vortrag: *PANDA Workshop*, Darmstadt/Deutschland. [Eingeladener Beitrag (Invited lecture), wissenschaftlich, Veranstaltung in kleinerem Rahmen (Seminar etc.)]

Paul Kienle (21.12.2005) Experimental approach to antikaon bound systems. Vortrag: *Austrian-Japanese Workshop on Antikaon Mediated Bound Systems – Doorway to Kaon Condensation in Neutron Stars* (Stefan-Meyer-Institut für subatomare Physik), Wien/Österreich. [Eingeladener Beitrag (Invited lecture), wissenschaftlich, Veranstaltung in kleinerem Rahmen (Seminar etc.)]

Paul Kienle (22.12.2005) Density distribution of kaon nuclear clusters from 3-body decay. Vortrag: *Austrian-Japanese Workshop on Antikaon Mediated Bound Systems – Doorway to Kaon Condensation in Neutron Stars* (Stefan-Meyer-Institut für subatomare Physik), Wien/Österreich. [Eingeladener Beitrag (Invited lecture), wissenschaftlich, Veranstaltung in kleinerem Rahmen (Seminar etc.)]

Thomas Pask (28.02.2005) Metastable Helium Recoil Spectroscopy. Vortrag: *Seminar zu aktuellen Themen der subatomaren Physik* (Stefan-Meyer-Institut für subatomare Physik),

Wien/Österreich. [Beitrag ohne Auswahlverfahren (not selected/not refereed lecture), wissenschaftlich, Veranstaltung in kleinerem Rahmen (Seminar etc.)]

Thomas Pask (25.11.2005) Numerical Simulations of Laser-Microwave Triple Resonance Spectroscopy for the Determination of the Hyperfine Structure of Antiprotonic Helium. Vortrag: *Seminar zu aktuellen Themen der subatomaren Physik* (Stefan-Meyer-Institut für subatomare Physik), Wien/Österreich. [Beitrag ohne Auswahlverfahren (not selected/not refereed lecture), wissenschaftlich, Veranstaltung in kleinerem Rahmen (Seminar etc.)]

Tomoichi Ishiwatari (17.02.2005) Final results of the DEAR experiment and Future plans at the SIDDHARTA experiment. Vortrag: *Chiral Restoration in Nuclear Medium (Chiral05)*, Wako-shi/Japan. [Eingeladener Beitrag (Invited lecture), wissenschaftlich, Großveranstaltung (Konferenz, Kongress, Tagung, Symposium etc.)]

Tomoichi Ishiwatari (22.04.2005) Summary of the PIXE material tests. Vortrag: *SIDDHARTA Collaboration meeting*, Frascati/Italien. [Beitrag ohne Auswahlverfahren (not selected/not refereed lecture), wissenschaftlich, Veranstaltung in kleinerem Rahmen (Seminar etc.)]

Tomoichi Ishiwatari (12.11.2005) Report of SDDs response at KEK K5 beam line. Vortrag: *SIDDHARTA Collaboration meeting*, Frascati/Italien. [Beitrag ohne Auswahlverfahren (not selected/not refereed lecture), wissenschaftlich, Veranstaltung in kleinerem Rahmen (Seminar etc.)]

### Posterpräsentation

Bertalan Juhasz (22.02.2005) Indication of the Wigner threshold law in collisions between antiprotonic helium and hydrogenic molecules. Posterpräsentation: *International Conference on Exotic Atoms - EXA05* (Stefan Meyer Institut für subatomare Physik), Wien/Österreich. [Beitrag ohne Auswahlverfahren (not selected/not refereed lecture), wissenschaftlich, Großveranstaltung (Konferenz, Kongress, Tagung, Symposium etc.)]

Malgorzata Kasprzak (22.02.2005) Production of ultra-cold neutrons in solid deuterium. Posterpräsentation: *International Conference on Exotic Atoms - EXA05* (Stefan Meyer Institut für subatomare Physik), Wien/Österreich. [Beitrag ohne Auswahlverfahren (not selected/not refereed lecture), wissenschaftlich, Großveranstaltung (Konferenz, Kongress, Tagung, Symposium etc.)]

Tomoichi Ishiwatari (22.02.2005) Measurement of kaonic nitrogen X-ray lines using the gaseous target at DAΦ NE. Posterpräsentation: *International Conference on Exotic Atoms - EXA05* (Stefan Meyer Institut für subatomare Physik), Wien/Österreich. [Beitrag ohne Auswahlverfahren (not selected/not refereed lecture), wissenschaftlich, Großveranstaltung (Konferenz, Kongress, Tagung, Symposium etc.)]

### 1.7.3 Vorträge von Mitarbeitern an anderen Institutionen

Eberhard Widmann (20.06.2005) Testing Matter/Antimatter Symmetry with Antiprotons. Vortrag: *Quantenseminar Universität Wien*, Wien/Österreich. [Eingeladener Beitrag (Invited lecture), wissenschaftlich, Veranstaltung in kleinerem Rahmen (Seminar etc.)]

Eberhard Widmann (09.11.2005) Testing Matter/Antimatter Symmetry with Antiprotons. Vortrag: *Seminar des Instituts für Isotopenforschung und Kernphysik* (Institut für Isotopenforschung und Kernphysik, Universität Wien), Wien/Österreich. [Eingeladener Beitrag (Invited lecture), wissenschaftlich, Veranstaltung in kleinerem Rahmen (Seminar etc.)]

Johann Marton (21.06.2005) Experimentelle Untersuchungen von hadronischen Atomen – gegenwärtiger Stand und Perspektiven. Vortrag: *Institutsseminar* (Institut für theoretische Physik, Universität Wien), Wien/Österreich. [Eingeladener Beitrag (Invited lecture), wissenschaftlich, Veranstaltung in kleinerem Rahmen (Seminar etc.)]

Johann Marton (12.07.2005) Recent Topics of Exotic Atom Research. Vortrag: *Institutsseminar* (MUCATEX), Moskau/Russland. [Eingeladener Beitrag (Invited lecture), wissenschaftlich, Veranstaltung in kleinerem Rahmen (Seminar etc.)]

Johann Marton (22.11.2005) Experimentelle Untersuchungen der starken Wechselwirkung in hadronischen Atome. Vortrag: *Institutsseminar* (Technische Universität Wien, Atominstitut), Wien/Österreich. [Eingeladener Beitrag (Invited lecture), wissenschaftlich, Veranstaltung in kleinerem Rahmen (Seminar etc.)]

Johann Marton (10.01.2006) Exotische Wasserstoffatome – Präzisionsmessungen zur starken Wechselwirkung. Vortrag: *Institutsseminar* (Institut für Allgemeine Physik, TU Wien), Wien/Österreich. [Eingeladener Beitrag (Invited lecture), wissenschaftlich, Veranstaltung in kleinerem Rahmen (Seminar etc.)]

Johann Marton (17.01.2006) Hadronic Hydrogen Atoms – New Precision Studies of Studies of Strong Interaction. Vortrag: *Institutsseminar* (ETH Zurich), Zürich/Schweiz. [Eingeladener Beitrag (Invited lecture), wissenschaftlich, Veranstaltung in kleinerem Rahmen (Seminar etc.)]

Paul Kienle (28.03.2005) Testing Chiral Dynamics. Vortrag: *RIKEN Seminar*/Japan. [Eingeladener Beitrag (Invited lecture), wissenschaftlich, Veranstaltung in kleinerem Rahmen (Seminar etc.)]

Paul Kienle (08.04.2005) Pions in Nuclei Probes of Chiral Restoration. Vortrag: *Physics Colloquium* (Universität Tokyo), Tokyo/Japan. [Eingeladener Beitrag (Invited lecture), wissenschaftlich, Veranstaltung in kleinerem Rahmen (Seminar etc.)]

Paul Kienle (18.04.2005) Bound State Beta Decay- Astrophysical and Weak Interaction. Vortrag: *RIKEN Seminar*/Japan. [Eingeladener Beitrag (Invited lecture), wissenschaftlich, Veranstaltung in kleinerem Rahmen (Seminar etc.)]

Paul Kienle (28.04.2005) Pions in Nuclei, testing Chiral Dynamics. Vortrag: *Physics Colloquium at Sendai University*/Japan. [Eingeladener Beitrag (Invited lecture), wissenschaftlich, Veranstaltung in kleinerem Rahmen (Seminar etc.)]

Paul Kienle (07.06.2005) Precision Spectroscopy of Exotic Atoms. Vortrag: *Colloquium* (Research Center for Nuclear Physics), Osaka/Japan. [Eingeladener Beitrag (Invited lecture), wissenschaftlich, Veranstaltung in kleinerem Rahmen (Seminar etc.)]

Paul Kienle (08.06.2005) Exotic Atoms Roses from the Flower Garden of Subatomic Physics. Vortrag: *Colloquium at Nara Women's University*/Japan. [Eingeladener Beitrag (Invited lecture), wissenschaftlich, Veranstaltung in kleinerem Rahmen (Seminar etc.)]

Paul Kienle (21.06.2005) Pions in Nuclei, Probes of Chiral Restoration. Vortrag: *Nuclear Phy-*

sics Colloquium (RIKEN)/Japan. [Eingeladener Beitrag (Invited lecture), wissenschaftlich, Veranstaltung in kleinerem Rahmen (Seminar etc.)]

## 1.7.4 Vorträge von Gästen

Hide Sakai (04.03.2005) EPR paradoxon studied by two-proton spin correlation. Vortrag: *Seminar zu aktuellen Themen der subatomaren Physik* (Stefan Meyer Institut für subatomare Physik), Wien/Österreich. [Beitrag ohne Auswahlverfahren (not selected/not refereed lecture), wissenschaftlich, Veranstaltung in kleinerem Rahmen (Seminar etc.)]

Dimitar Bakalov (01.12.2005) Hyperfine structure of exotic atomic systems. Vortrag: *Seminar zu aktuellen Themen der subatomaren Physik* (Stefan-Meyer-Institut für subatomare Physik), Wien/Österreich. [Beitrag ohne Auswahlverfahren (not selected/not refereed lecture), wissenschaftlich, Veranstaltung in kleinerem Rahmen (Seminar etc.)]

G.Ya. Korenman (02.12.2005) Collisional Stark transitions of cold antiprotonic helium ions. Vortrag: *Seminar zu aktuellen Themen der subatomaren Physik* (Stefan-Meyer-Institut für subatomare Physik), Wien/Österreich. [Beitrag ohne Auswahlverfahren (not selected/not refereed lecture), wissenschaftlich, Veranstaltung in kleinerem Rahmen (Seminar etc.)]

Joachim Kuhn (09.05.2005) The Search for Exotic Mesons. Vortrag: *Seminar zu aktuellen Themen der subatomaren Physik* (Stefan-Meyer-Institut für subatomare Physik), Wien/Österreich. [Beitrag ohne Auswahlverfahren (not selected/not refereed lecture), wissenschaftlich, Veranstaltung in kleinerem Rahmen (Seminar etc.)]

Jun Imazato (19.07.2005) Search for T violation in kaon decays and a J-PARC experiment. Vortrag: *Seminar zu aktuellen Themen der subatomaren Physik* (Stefan-Meyer-Institut für subatomare Physik), Wien/Österreich. [Beitrag ohne Auswahlverfahren (not selected/not refereed lecture), wissenschaftlich, Veranstaltung in kleinerem Rahmen (Seminar etc.)]

Kanetada Nagamine (27.04.2005) Recent Progress in Muon Science. Vortrag: *Seminar zu aktuellen Themen der subatomaren Physik* (Stefan-Meyer-Institut für subatomare Physik), Wien/Österreich. [Beitrag ohne Auswahlverfahren (not selected/not refereed lecture), wissenschaftlich, Veranstaltung in kleinerem Rahmen (Seminar etc.)]

Klaus Peters (04.04.2005) Open Charm Spektroskopie an B-Fabriken. Vortrag: *Seminar zu aktuellen Themen der subatomaren Physik* (Stefan-Meyer-Institut für subatomare Physik), Wien/Österreich. [Beitrag ohne Auswahlverfahren (not selected/not refereed lecture), wissenschaftlich, Veranstaltung in kleinerem Rahmen (Seminar etc.)]

Leonid Nemenov (14.12.2005) Precise predictions of low energy QCD and their experimental check. Vortrag: *Seminar zu aktuellen Themen der subatomaren Physik* (Stefan-Meyer-Institut für subatomare Physik), Wien/Österreich. [Beitrag ohne Auswahlverfahren (not selected/not refereed lecture), wissenschaftlich, Veranstaltung in kleinerem Rahmen (Seminar etc.)]

Leonid Nemenov (16.12.2005) Precise predictions of low energy QCD and their experimental



check. Vortrag: *Seminar zu aktuellen Themen der subatomaren Physik* (Stefan-Meyer-Institut für subatomare Physik), Wien/Österreich. [Beitrag ohne Auswahlverfahren (not selected/not refereed lecture), wissenschaftlich, Veranstaltung in kleinerem Rahmen (Seminar etc.)]

Masaki Hori (11.03.2005) Precision laser spectroscopy of antiprotonic helium. Vortrag: *Seminar zu aktuellen Themen der subatomaren Physik* (Stefan-Meyer-Institut für subatomare Physik), Wien/Österreich. [Beitrag ohne Auswahlverfahren (not selected/not refereed lecture), wissenschaftlich, Veranstaltung in kleinerem Rahmen (Seminar etc.)]

Mortaza Raiesi (14.09.2005) Simulation of the cascade processes of muonic atoms in liquid mixture (D/T) by Monte Carlo method. Vortrag: *Seminar zu aktuellen Themen der subatomaren Physik* (Stefan-Meyer-Institut für subatomare Physik), Wien/Österreich. [Beitrag ohne Auswahlverfahren (not selected/not refereed lecture), wissenschaftlich, Veranstaltung in kleinerem Rahmen (Seminar etc.)]

Olaf N. Hartmann (19.08.2005) FOPI - GSI's working horse for nuclear reactions. Vortrag: *Seminar zu aktuellen Themen der subatomaren Physik* (Stefan-Meyer-Institut für subatomare Physik), Wien/Österreich. [Beitrag ohne Auswahlverfahren (not selected/not refereed lecture), wissenschaftlich, Veranstaltung in kleinerem Rahmen (Seminar etc.)]

Steven Bass (04.10.2005) Quark – glue content of the eta and eta' mesons and their interactions with nuclei. Vortrag: *Seminar zu aktuellen Themen der subatomaren Physik* (Stefan-Meyer-Institut für subatomare Physik), Wien/Österreich. [Beitrag ohne Auswahlverfahren (not selected/not refereed lecture), wissenschaftlich, Veranstaltung in kleinerem Rahmen (Seminar etc.)]

Vladimir I. Korobov (01.12.2005) Hyperfine splitting in (anti)hydrogen and helium atoms and finite size structure of (anti)proton. Vortrag: *Seminar zu aktuellen Themen der subatomaren Physik* (Stefan-Meyer-Institut für subatomare Physik), Wien/Österreich. [Beitrag ohne Auswahlverfahren (not selected/not refereed lecture), wissenschaftlich, Veranstaltung in kleinerem Rahmen (Seminar etc.)]

Vladimir I. Korobov (28.06.2005) Bound atomic systems with antiprotons. Vortrag: *Seminar zu aktuellen Themen der subatomaren Physik* (Stefan-Meyer-Institut für subatomare Physik), Wien/Österreich. [Beitrag ohne Auswahlverfahren (not selected/not refereed lecture), wissenschaftlich, Veranstaltung in kleinerem Rahmen (Seminar etc.)]

Werner Pirkel (15.04.2005) "PAUL FALLEN" zur Speicherung geladener Teilchen. Vortrag: *Seminar zu aktuellen Themen der subatomaren Physik* (Stefan-Meyer-Institut für subatomare Physik), Wien/Österreich. [Beitrag ohne Auswahlverfahren (not selected/not refereed lecture), wissenschaftlich, Veranstaltung in kleinerem Rahmen (Seminar etc.)]

Wolfgang Kühn (18.11.2005) Warum ist das Proton so schwer?. Vortrag: *Seminar zu aktuellen Themen der subatomaren Physik* (Stefan Meyer Institut für subatomare Physik), Wien/Österreich. [Beitrag ohne Auswahlverfahren (not selected/not refereed lecture), wissenschaftlich, Veranstaltung in kleinerem Rahmen (Seminar etc.)]

## 1.8 Aufenthalte von Gastwissenschaftlern

Name	Institut	Zeitraum
Bakalov Dimitar	Bulgarian Academy of Sciences	27.11.2005-11.12.2005 21.02.2005-27.02.2005
Faifman Mark	MUCATEX, Russland	10.02.2005-11.03.2005 17.11.2005-16.12.2005
Ivanov Andrei	State Polytechnic University of St. Petersburg, St. Petersburg, Russia	01.09.2005-30.11.2005
Korenman Grigory	Moscow State University	03.11.2005-24.12.2005
Korobov Vladimir	JINR Dubna	17.02.2005-19.03.2005 01.06.2005-30.06.2005 25.11.2005-16.12.2005

## 1.9 Ausbildung und Schulung 2005

In nachfolgender Tabelle sind die 2005 am Institut laufenden Diplomarbeiten und Dissertationen gelistet.

<i>Name</i>	<i>Herkunftsinst., Ausbildungsziel</i>
Mag. Hermann Fuhrmann	Univ. Wien, Doktorat
Mag Alexander Gruber	Univ. Wien, Doktorat
Martin Giersch	Univ. Wien, Diplom
DI Albert Hirtl	TU Wien, Doktorat
Mag. Malgorzata Kasprzak	Univ. Wien, Doktorat
B. Sc. with 1st degree honours Thomas Pask	Univ. Wien, Doktor
Philipp Schmid	Univ. Wien, Diplom

Im Berichtsjahr wurden nachfolgende Vorlesungen und Seminare abgehalten:

### **E. Widmann, Universität Wien**

Sommersemester 2005

562382 VO Experimente mit niederenergetischen Antiprotonen

562506 SE Seminar zu aktuellen Themen der subatomaren Physik

562507 SE Privatissimum für Diplomanden und Dissertanten

854502 SE Wissenschaftliche Arbeiten

Wintersemester 2005/06:

260002 PV Privatissimum für Diplomanden und Dissertanten

260153 VO Experimentelle Elementarteilchenphysik I

260195 SE Seminar zu aktuellen Themen der subatomaren Physik

260247 SE Wissenschaftliche Arbeiten

### **J. Marton, Technische Universität Wien,**

Wintersemester 2004/05

142072 VO Physics of Exotic Atoms (in englischer Sprache)

Wintersemester 2005/06

142072 VO Physics of Exotic Atoms (in englischer Sprache)

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