Austrian Academy of Sciences

Annual Report 2010

Stefan Meyer Institute (SMI)
for Subatomic Physics

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Contents

1. Mission Statement

The Stefan Meyer Institute (SMI) is devoted to method-oriented basic research in the field of subatomic physics. Our research focuses on the study of ***fundamental symmetries and interactions***, addressing the following questions:

- What are the properties of the forces that exist in nature?
- What is the origin of the masses of the visible universe?
- Why do the remains of the Big Bang consist only of matter and not of antimatter?

We specialize in precision spectroscopy of ***exotic atoms*** and ***exotic meson-nucleus bound states*** as an integral part of international collaborations at large-scale research facilities including

- CERN (Geneva, Switzerland),
- LNF-INFN (Frascati, Italy),
- J-PARC (Tokai, Japan),
- GSI (Darmstadt, Germany),

and, in the future,

- FAIR (Darmstadt, Germany).

These are among the world's leading facilities for subatomic physics and our projects are subject to rigorous annual evaluation to monitor their progress in a dynamic and expanding field.

We aspire to perform research that increases the understanding of fundamental physics principles while simultaneously providing opportunities for young Austrians to obtain valuable experience at institutes unavailable to them at home.

The current three main fields of activity at SMI are:

- **Matter-antimatter symmetry**, especially the study of the underlying **CPT symmetry**. This symmetry is a property of all field theories used hitherto to describe nature, but is in contrast to the observed matter dominance of the visible universe. Furthermore, not all mathematical prerequisites of the CPT theorem are valid in modern theories like string theory or quantum gravity. Experimentally the matter-antimatter symmetry is investigated by precision measurements of properties of the antiproton (mass, charge, magnetic moment) in antiprotonic atoms and antihydrogen, comparing them to known properties of the proton and of hydrogen.
- **Hadron physics:** here we study the strong interaction and its corresponding theory, quantum chromodynamics (QCD), at low energies in the non-perturbative regime and at intermediate energies. Chiral symmetry and its breaking or restoration plays an important role. They contribute to the origin of the masses of hadrons. The sum of the masses of the three current quarks adds up to only a few percent of the measured hadron mass, which originates mainly from the dynamic interaction between the quarks and the exchange particles of the strong interaction, the gluons. The underlying mechanism is, to date, not understood at all. The experimental approach is the spectroscopy of meson-nucleus bound states using large 4π detectors like FOPI and PANDA, and the measurement of the effect of the strong interaction on the low-lying atomic states of simple exotic atoms by X-ray spectroscopy.
- **Advanced instrumentation:** progress in experimental physics needs new or improved instrumentation and methodology. In this field we currently work on three experimental projects funded within the EU FP7 Integrated Activity HadronPhysics2 and one computer grid project. Currently five out of eight Ph.D. students work in this field.

Further activities include an underground laboratory experiment at Laboratori Nazionali di Gran Sasso (Italy) on a high-sensitivity test of the Pauli principle, in the VIP (Violation of the Pauli Principle) experiment. SMI also participates in the analysis of an experiment investigating two-body decays of stored and cooled ions at GSI.

2. Scientific Activity 2010

2.1. Zusammenfassung des wissenschaftlichen Berichts 2010

Röntgenspektroskopie von kaonischen Atomen – Das SIDDHARTA Experiment

Kaonen gehören zu der Teilchengruppe der Mesonen und unterliegen daher der starken Wechselwirkung. Sie enthalten ein sogenanntes "Strange"-Quark und sind etwa halb so schwer wie ein Proton. Sobald ein Kaon in Materie eindringt, wird es abgebremst und ersetzt ein Hüllenelektron – ein kaonisches Atom wird gebildet. Während Elektronen nur elektromagnetisch wechselwirken, tritt in kaonischen Atomen zusätzlich die starke Wechselwirkung auf und führt zu einer Modifikation der Energien der emittierten Röntgenstrahlen. Diese sogenannte Kaon-Nukleon-Wechselwirkung kann über genaue Messungen eben jener Röntgenenergien quantitativ untersucht werden.

Auf theoretischer Seite ist eine Beschreibung dieser Prozesse mittels Quantenchromodynamik (QCD) auf Basis von Quarks und Gluonen nicht ausreichend. Deshalb werden auf experimentellen Daten beruhende "effektive Feldtheorien" angewandt. Die Bedeutung dieser experimentellen Daten liegt in der Möglichkeit Informationen zur "Chiralen Symmetriebrechung" und damit Aufschluss über die Erzeugung von Hadronenmassen (sichtbare Masse des Universums) zu gewinnen.

Ziel des SIDDHARTA Projektes war eine genaue Messung der Röntgenenergien in kaonischem Wasserstoff, Deuterium und Helium. Unter Mithilfe des SMI wurden hierfür innerhalb eines EU-Projektes neuartige Röntgendetektoren sowie die dazugehörige Elektronik entwickelt. Nachdem die Datenaufnahme am Elektron-Positron-Beschleuniger DAFNE in Frascati 2009 beendet wurde, konnten präzise Resultate zu kaonischem ^{4}He und weltweit erstmals zu kaonischem ^{3}He ermittelt werden. Beide bereits publizierten Resultate sind in Übereinstimmung mit theoretischen Vorhersagen, sowie mit dem jüngsten Experiment am KEK über kaonisches ^{4}He. Die Auswertung der Messung von kaonischem Wasserstoff wird in Kürze abgeschlossen, die Publikation ist in Vorbereitung und wird das bisher genaueste Resultat liefern.

Neue experimentelle Daten zum lange gesuchten kaonischen Kernzustand

Eine anhaltende Frage betreffend einen kaonischen Kern-Bindungszustand könnte in eine neue Phase eintreten. Der fundamentalste kaonische Kernzustand – bezeichnet als K^-pp – wurde in den Daten des DISTO Experiments in der exklusiven Reaktion $p+p \rightarrow p+\Lambda+K^+$ bei 2.85 GeV gesucht. Die Datenanalyse fand eine unbekannte Resonanz, die als möglicher Kandidat für K^-pp mit einer Masse von 2267 MeV/c^2 und einer Breite von 118 MeV interpretiert wird und 2010 publiziert wurde. Die Forschungsgruppe setzte die Analyse auch der Daten fort, die bei verschiedenen Strahlenergien gemessen wurden. Die Resultate erregten Interesse und Diskussionen in der Hadronenphysik-Community.

Erste erfolgreiche Hyperfeinspektroskopie von antiprotonischem ^{3}He

Antiprotonisches Helium ist ein neutrales exotisches Atom, welches aus einem Heliumkern, einem Elektron und einem Antiproton besteht. Innerhalb der internationalen Kollaboration ASACUSA werden derzeit Übergangsfrequenzen in diesem Atom mittels Laser- und Mikrowellenspektroskopie am „Antiproton Decelerator“ am CERN (Genf) gemessen. Aus dem Vergleich zwischen theoretischen und gemessenen Werten der Übergangsfrequenzen können fundamentale Eigenschaften des Antiprotons, wie Masse, Ladung oder magnetisches Moment bestimmt werden. Der Vergleich des Antiprotons mit den korrespondierenden Eigenschaften des Protons ermöglicht eine Untersuchung der Materie-Antimaterie-Symmetrie, welche offensichtlich im Universum „verletzt“ ist, da der uns bekannte Kosmos ausschließlich aus Materie aufgebaut ist.

Ein weiterer Gegenstand aktueller Forschung ist das antiprotonische magnetische Moment. Die Wechselwirkung des magnetischen Moments des Antiprotons mit denen der andern Bestandteile führt zur Hyperfeinstruktur (HFS). Im Jahr 2010 wurde innerhalb von ASACUSA am CERN zum ersten Mal erfolgreich Hyperfeinübergänge in antiprotonischem ^{3}He beobachtet. Zusammen mit Messungen von zwei weiteren Übergängen, die für 2011 geplant sind, werden diese Ergebnisse einen ersten aussagekräftigen Test der Dreikörper-QED Theorie im komplexen antiprotonischen Helium-System erlauben.

Erste Produktion von Antiwasserstoff in einer „cusp trap“ durch ASACUSA

Als einen potentiell viel präziseren Test der CPT Symmetrie bereitet ASACUSA eine Messung der Hyperfeinstruktur von Antiwasserstoff vor. Diese Größe ist für Wasserstoff bis zu einer relativen Genauigkeit von 10^{-12} bekannt. Ein großer Durchbruch wurde

2010 durch die erstmalige, erfolgreiche Produktion von Antiwasserstoff in einer sogenannten „cusp trap“ erreicht. Diese Vorrichtung ist eine spezielle Falle für geladene und neutrale Teilchen, die für die Produktion des im Experiment benötigten Antiwasserstoffstrahls geeignet ist.

PANDA bei FAIR

2010 wurde die lang erwartete formelle Gründung der internationalen FAIR Einrichtung in Darmstadt bekannt gegeben. SMI ist am PANDA Experiment beteiligt, welches in der Startphase von FAIR enthalten ist und daher muss nun der Bau des Detektors in Angriff genommen werden. PANDA untersucht eine breite Palette an Forschungsthemen (QCD Bindungszustände, nicht-störungstheoretische QCD-Dynamik, Hadronen in Kernmaterie, Hyperkerne, elektromagnetische Prozesse und die Struktur von Nukleonen). Wichtige Forschungs- und Entwicklungsstudien werden seit 2009 innerhalb des EU Projektes zum 7. Rahmenprogramms „Hadronphysics2“ finanziert, in dem das SMI zwei Teilprojekte leitet.

Konferenzen und Veranstaltungen 2010

In 2010 hat das SMI den 100. Geburtstag seines Vorgängers, des Institutes für Radiumforschung, gefeiert. Zu diesem Anlass wurde eine eigene Veranstaltung mit Vorträgen und Präsentationen von Historikern und Forschern zur zeitgeschichtlichen Betrachtung der subatomaren Physik organisiert. Ein Höhepunkt der Veranstaltung war der Vortrag eines der Gründer der Astro- Teilchenphysik, des Nobelpreisträgers Jim Cronin. Im Oktober 2010 wurde ein internationaler Workshop am „European Centre for Theoretical Studies in Nuclear Physics and Related Areas“ ECT* in Trento mit der Beteiligung einer Vielzahl von internationalen Wissenschaftlern veranstaltet. Bei diesem Workshop wurde die Frage über das Verhalten des Strange-Quarks in Atomkernen behandelt.

2.2. Highlights 2010

Erfolgreicher Abschluss des SIDDHARTA Experiments am LN Frascati

Das SIDDHARTA-Experiment untersucht die Röntgenstrahlung von exotischen Atomen, die ein Kaon enthalten. Die beobachtete Verschiebung und Verbreiterung sind ein Maß für die Stärke der Wechselwirkung zwischen Kaonen und Nukleonen bei niedrigsten Energien. Nach mehreren Jahren Vorbereitung und einem Jahr Datenaufnahme lieferte SIDDHARTA genaueste Resultate für ^{4}He und – zum ersten Mal überhaupt – ^{3}He, sowie für Wasserstoff, wo neue Werte gemessen wurden, die viel näher bei theoretischen Voraussagen liegen als frühere Experimenten.

Die 5 besten Publikationen 2010:

1. Y. Enomoto, N. Kuroda, K. Michishio, C. H. Kim, H. Higaki, Y. Nagata, Y. Kanai, H. A. Torii, M. Corradini, M. Leali, E. Lodi-Rizzini, V. Mascagna, L. Venturelli, N. Zurlo, K. Fujii, M. Ohtsuka, K. Tanaka, H. Imao, Y. Nagashima, Y. Matsuda, B. Juhász, A. Mohri, and Y. Yamazaki,
   "Synthesis of Cold Antihydrogen in a Cusp Trap,"
   Physical Review Letters **105**, 243401 (2010).

   Erstmals gelang die Produktion von Antiwasserstoff durch die ASACUSA Kollaboration mittels einer speziellen Teilchenfalle („cusp trap“), die es erlaubt, einen Antiwasserstoffstrahl zu erzeugen. Die Veröffentlichung wurde – zusammen mit dem Bericht der ALPHA-Kollaboration über den ersten gelungenen Einfang von Antiwasserstoff in einer Neutralatomfalle – von PhysicsWorld zum Durchbruch des Jahres gewählt.

2. B. Juhász, J. Marton, K. Suzuki, E. Widmann, and J. Zmeskal (eds),
   EXA/LEAP 2008 Proceedings. (Springer, 2010).

   Die Proceedings der zwei Konferenzen “Exotic Atoms and Related Topics – EXA08” und “Low-Energy Antiproton Physics – LEAP08”, die das Stefan-Meyer-Institut im Herbst 2008 zeitlich überlappend organisierte, erschienen 2010 (99 Beiträge, 693 Seiten) als Nachdruck der Zeitschrift „Hyperfine Interactions“ (Springer), Vols. 193,194 (2009).

3. Th. Strauch, F. D. Amaro, D. F. Anagnostopoulos, P. Buhler, D. S. Covita, H. Gorke, D. Gotta, A. Gruber, A. Hirtl, P. Indelicato, E. O. Le Bigot, M. Nekipelov, J. M. F. dos Santos, S. Schlesser, Ph Schmid, L. M. Simons, M. Trassinelli, J. F. C. A. Veloso, and J. Zmeskal,
"Precision determination of the dπ<-->NN transition strength at threshold,"
<u>Physical Review Letters</u> **104**, 142503 (2010).

   Die Pion-Nukleon-Wechselwirkung wurde sowohl experimentell als auch theoretisch untersucht. Das Verständnis der starken Wechselwirkung im Bereich des Confinement verbesserte sich durch die Weiterentwicklung der Stöhrungstheorie im Rahmen der QCD, und ermöghlichte dadurch Rechnunge bei niedrigen Energien in Pion_nukleon System. Präzisionsexperimente wie die Röntgenspektroskopie von pionischem Wasserstoff und Deuterium sind essentiell um klare Vorgaben für diese Berechnungen zu geben.

4. T. Yamazaki, M. Maggiora, P. Kienle, K. Suzuki, A. Amoroso, M. Alexeev, F. Balestra, Y. Bedfer, R. Bertini, L. C. Bland, A. Brenschede, F. Brochard, M. P. Bussa, S. Choi, M. L. Colantoni, R. Dressler, M. Dzemidzic, J. C. Faivre, L. Ferrero, J. Foryciarz, I. Frohlich, V. Frolov, R. Garfagnini, A. Grasso, S. Heinz, W. W. Jacobs, W. Kuhn, A. Maggiora, D. Panzieri, H. W. Pfaff, G. Pontecorvo, A. Popov, J. Ritman, P. Salabura, S. Sosio, V. Tchalyshev, and S. E. Vigdor,
"Indication of a deeply bound and compact K^-pp state formed in the pp -> p Λ K^+ reaction at 2.85 GeV,"
<u>Physical Review Letters</u> **104**, 132502 (2010).

   Die mögliche Existenz tief gebundener Zustände von $\overline{K}$ in Kernen ist ein zugleich altes und junges Feld, das über die letzte Dekade intensiv untersucht wurde. Die exotischen gebundenen Zustände besitzen möglicherweise hohe Dichten jenseits normaler Kerndichte. Eine intensive Suche ist immer noch im Gange. Diese Veröffentlichung berichtet über einen möglichen Kandidaten für den einfachsten gebundenen Zustand, K^-pp, der in der exklusiven Reaktion $p+p \rightarrow p+\Lambda+K^+$ in Daten des DISTO-Experiments bei 2.85 GeV Protonenenergie beobachtet wurde.

5. H. Yim, H. Bhang, J. Chiba, S. Choi, Y. Fukuda, T. Hanaki, R. S. Hayano, M. Iio, T. Ishikawa, S. Ishimoto, T. Ishiwatari, K. Itahashi, M. Iwai, M. Iwasaki, P. Kienle, J. H. Kim, Y. Matsuda, H. Ohnishi, S. Okada, H. Outa, M. Sato, S. Suzuki, T. Suzuki, D. Tomono, E. Widmann, and T. Yamazaki,
"Search for strange tribaryons in the ^{4}He (K^-_{stop}, n $\pi^\pm$) reaction,"
<u>Physics Letters B</u> **688**, 43-49 (2010).

   Abschluss der endgültigen Analyse des E549 Experiment am KEK, in dem negative Kaonen in flüssigem ^{4}He gestoppt wurden und ein ausgehendes Neutron in Koinzidenz mit im Absorptionsprozess erzeugten Pionen nachgewiesen wurde. Die E471 Kollaboration hatte früher eine Struktur publiziert, die einem gebundenen Tribarionenzustand“ mit Strangeness –1 zugeschrieben wurde. In der neuen Messung konnte solch ein Zustand mir hoher Empfindlichkeit ausgeschlossen werden.

2.3. Summary of the scientific report 2010

X-ray spectroscopy of kaonic atoms – the SIDDHARTA experiment

Kaons are strongly interacting particles containing a “strange” quark. When implanted in matter they are slowed down and form kaonic atoms by replacing an electron of the atom. While electrons do not feel the strong interaction, the atomic structure of kaonic atoms is changed, leading to a modification of the energy of emitted X-rays. Measuring this energy modification we can gain information on the kaon-nucleon interaction. Quantum Chromodynamics (QCD) cannot describe this low-energy process quantitatively using quarks and gluons. Instead “effective models” are used which need experimental data as input. The special importance of these processes lies in the possibility to obtain information on “chiral symmetry breaking” and thus on the mechanism of hadron mass generation (e.g. protons or neutrons). The measurement of X-rays of kaonic hydrogen, deuterium and helium was the goal of the SIDDHARTA project. For that we developed novel X-ray detectors and electronics within an EU project. Data taking was finished at the electron-positron collider DAFNE in Frascati in 2009, and data analysis produced new results in kaonic ^{4}He and – recently accepted for publication – the first ever result for kaonic ^{3}He, both in agreement with a recent experiment on ^{4}He at KEK and all theoretical predictions. The analysis of kaonic hydrogen, where some discrepancy between earlier experiments exists, is close to final and will provide the most precise result so far.

New experimental data on the long-searched kaonic nuclear state

A persistent quest for the kaonic nuclear bound state may have come to a new phase. The most fundamental dibaryonic kaonic nuclear state – called $K^{-}pp$ – was searched in the exclusive data sample of $p+p \rightarrow p+\Lambda+K^{+}$ at 2.85 GeV collected by the DISTO experiment. The data analysis found an unknown resonance that is interpreted as a possible candidate of the $K^{-}pp$ with a mass of 2267 MeV/c^2 and a width of 118 MeV, which was published early 2010. The group continued in examining the data also at different beam energies. The results aroused interest and discussions among the hadron physics community.

First successful hyperfine spectroscopy of antiprotonic ^{3}He

Antiprotonic helium is a neutral exotic atom consisting of a helium nucleus, an electron and an antiproton. It is being studied at the "Antiproton Decelerator" at CERN (Geneva) within the international collaboration ASACUSA using laser and microwave spectroscopy. By comparing the measured transition frequencies with theoretical calculations, fundamental properties of the antiproton like mass, charge or magnetic moment can be obtained. Comparing them to the corresponding properties of the proton yields a test of matter-antimatter symmetry, which is obviously violated in the cosmos since the known universe consists entirely of matter. The interaction of the magnetic moment of the antiproton with those of the other constituents leads to a *hyperfine structure* (HFS). In 2010 we succeeded for the first time to observe two hyperfine transitions in antiprotonic ^{3}He. Together with two transitions planned to be measured in 2011 the results will constitute a first stringent test of three-body QED theory in the most complex antiprotonic helium system.

First production of antihydrogen in a "cusp trap" by ASACUSA

As a potentially much more precise test of CPT symmetry, ASACUSA is preparing a measurement of the hyperfine structure of antihydrogen, a quantity which is known for ordinary hydrogen to relative precision of 10^{-12}. A major breakthrough was achieved in 2010 when we for the first time succeeded in producing antihydrogen in a "cusp trap", a special charged and neutral particle trap suitable for the production of an antihydrogen beam needed for the planned experiment.

PANDA at FAIR

2010 marked the long-awaited formal foundation of the international FAIR facility in Darmstadt. SMI is involved in the PANDA experiment, which is part of the start phase and where now construction of the detector must commence. PANDA investigates a broad range of research themes (QCD bound states, non-perturbative QCD dynamics, hadrons in nuclear matter, hypernuclei, electromagnetic processes and the structure of nucleons). Important R&D studies are funded since 2009 within the EU project in the 7. Framework Programme "Hadronphysics2", where SMI is leading two working packages.

Symposia and events 2010

In 2010 SMI celebrated the 100th anniversary of the Institute for Radium Research, our predecessor founded in 1910, with a special symposium comprising both talks by historians of science and presentations of contemporary subatomic physics, including a review by one of the founders of particle astrophysics, Nobel Laureate Jim Cronin. In October 2010 an international workshop was organized at the „European Centre for Theoretical Studies in Nuclear Physics and Related Areas" ECT* (Trento). It focussed on strangeness in nuclei and attracted numerous international scientists.

2.4. Highlights 2010

Successful completion of the SIDDHARTA experiment at LN Frascati

The SIDDHARTA experiment measures the X-rays from exotic atoms containing a kaon. The observed energy shift and broadening are a measure of the strength of the strong interaction of kaons and nucleons in the low-energy limit. After several years of preparations and one year of data taking, SIDDHARTA provided new precise results for two helium isotopes, ^{4}He and – for the first time ever – ^{3}He, as well as for hydrogen, where new values were obtained that is much closer to theoretical predictions than earlier measurements.

Five best publications in 2010:

1. Y. Enomoto, N. Kuroda, K. Michishio, C. H. Kim, H. Higaki, Y. Nagata, Y. Kanai, H. A. Torii, M. Corradini, M. Leali, E. Lodi-Rizzini, V. Mascagna, L. Venturelli, N. Zurlo, K. Fujii, M. Ohtsuka, K. Tanaka, H. Imao, Y. Nagashima, Y. Matsuda, B. Juhász, A. Mohri, and Y. Yamazaki,
   "Synthesis of Cold Antihydrogen in a Cusp Trap,"
   Physical Review Letters **105**, 243401 (2010).

   This paper presents the first production of antihydrogen atoms by the ASACUSA collaboration using a „cusp trap" suitable to produce an antihydrogen beam. It was chosen, together with the announcement of the first successful trapping of antihydrogen by the ALPHA collaboration, as breakthrough of the year by PhysicsWorld.

2. B. Juhász, J. Marton, K. Suzuki, E. Widmann, and J. Zmeskal (eds),
   EXA/LEAP 2008 Proceedings. (Springer, 2010).

   The proceedings of the two conferences "Exotic Atoms and Related Topics – EXA08" and "Low-Energy Antiproton Physics – LEAP08" organized together by the Stefan Meyer Institute in fall of 2008 appeared in 2010 (99 contributions, 693 pages) as a reprint from the journal Hyperfine Interactions (Springer), Vols. 193-194 (2009).

3. Th. Strauch, F. D. Amaro, D. F. Anagnostopoulos, P. Buhler, D. S. Covita, H. Gorke, D. Gotta, A. Gruber, A. Hirtl, P. Indelicato, E. O. Le Bigot, M. Nekipelov, J. M. F. dos Santos, S. Schlesser, Ph Schmid, L. M. Simons, M. Trassinelli, J. F. C. A. Veloso, and J. Zmeskal,
   "Precision determination of the dπ<-->NN transition strength at threshold,"
   Physical Review Letters **104**, 142503 (2010).

   The pion-nucleon interaction has been subject both to experimental and theoretical studies. The understanding of strong interaction in the confinement regime has advanced, as chiral perturbation theory was developed (in the framework of QCD) to perform calculations at low energies in the pion-nucleon system. Precision experiments like pionic hydrogen and deuterium are essential to set tight constraints to theory.

4. T. Yamazaki, M. Maggiora, P. Kienle, K. Suzuki, A. Amoroso, M. Alexeev, F. Balestra, Y. Bedfer, R. Bertini, L. C. Bland, A. Brenschede, F. Brochard, M. P. Bussa, S. Choi, M. L. Colantoni, R. Dressler, M. Dzemidzic, J. C. Faivre, L. Ferrero, J. Foryciarz, I. Frohlich, V. Frolov, R. Garfagnini, A. Grasso, S. Heinz, W. W. Jacobs, W. Kuhn, A. Maggiora, D. Panzieri, H. W. Pfaff, G. Pontecorvo, A. Popov, J. Ritman, P. Salabura, S. Sosio, V. Tchalyshev, and S. E. Vigdor,
   "Indication of a deeply bound and compact K^-pp state formed in the pp -> p Λ K^+ reaction at 2.85 GeV,"
   Physical Review Letters **104**, 132502 (2010).

   The possible existence of deeply bound nuclear $\overline{K}$ states is an old and new topic that has been intensively investigated over the last decade. The exotic bound states may have a unique high density feature beyond normal nuclear density. An eager search is still ongoing. This paper reports on a possible candidate of the most fundamental kaonic nuclear states, K^-pp, found in the exclusive $p+p \rightarrow p+\Lambda+K^+$ data sample at 2.85 GeV collected by DISTO experiment.

5. H. Yim, H. Bhang, J. Chiba, S. Choi, Y. Fukuda, T. Hanaki, R. S. Hayano, M. Iio, T. Ishikawa, S. Ishimoto, T. Ishiwa-tari, K. Itahashi, M. Iwai, M. Iwasaki, P. Kienle, J. H. Kim, Y. Matsuda, H. Ohnishi, S. Okada, H. Outa, M. Sato, S. Suzuki, T. Suzuki, D. Tomono, E. Widmann, and T. Yamazaki,
   "Search for strange tribaryons in the ^4He (K^-_{stop}, n $\pi^\pm$) reaction,"
   Physics Letters B **688**, 43-49 (2010).

   Final analysis result of the E549 experiment at KEK of stopping a negative kaon in liquid ^4He and observing an outgoing neutron in coincidence with pions created in the absorption process. Previously the E471 collaboration reported a structure that was assigned to a "tri-baryon state" with strangeness –1. In this measurement such a structure was excluded with high sensitivity.

2.5. Report on the scientific activity during 2010

The research program of our institute consists of two main research topics ("Forschungsschwerpunkte"): **Matter-antimatter symmetry** (ASACUSA @ CERN), and **Hadron physics**. Both are divided into several individual projects. A third main topic is **Advanced instrumentation**, and there are also some smaller research projects.

2.5.1. Matter–Antimatter Symmetry: ASACUSA @ CERN-AD

(Supported by bm_wf)

This is one of the main scientific programs at SMI. Within the ASACUSA program, SMI is involved in the precision laser and microwave 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. SMI is the leading institute in the antiprotonic helium microwave spectroscopy experiment and the antihydrogen project.

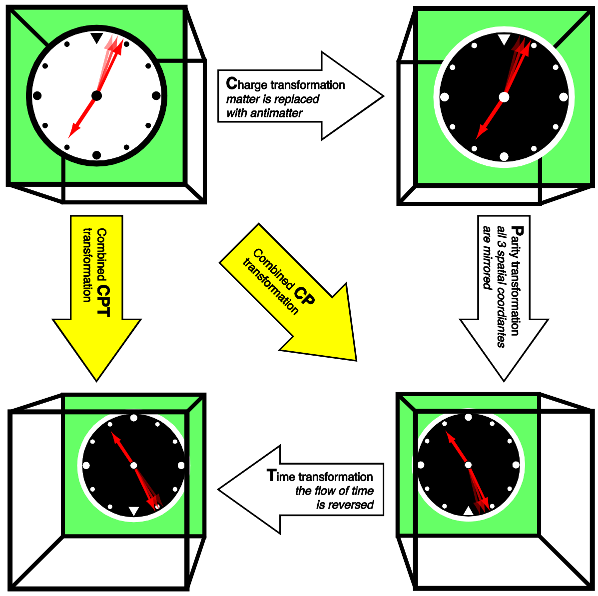

Fig. 1: Illustration of the CP and CPT symmetries.

Antiprotonic helium is a neutral three-body system consisting of a helium nucleus, an antiproton and an electron. The energy levels of the antiproton have been measured by precision laser spectroscopy to an accuracy of about 10^{-8}. Furthermore, each level is split into quadruplet (octuplet) sublevels in ^{4}He (^{3}He) due to the magnetic interaction of the electron spin, the antiproton angular momentum and the antiproton spin (and the helium nucleus). The energy difference between these sublevels can be measured with microwave spectroscopy, and from the obtained transition frequencies, the antiproton magnetic moment can be determined.

Antihydrogen, the simplest antimatter atom consisting of a positron and an antiproton, is a promising tool for testing CPT symmetry, because its CPT conjugate system, hydrogen, has been measured to a precision of $\sim10^{-14}$ for the 1s-2s two-photon laser transition and $\sim10^{-12}$ for the ground-state hyperfine structure. Even if antihydrogen cannot be measured to this high precision, it can rival the best CPT tests in the absolute scale.

2.5.1.1. Antiprotonic helium

Microwave spectroscopy

(Supported by FWF grant I198)

(Ph.D. thesis of S. Friedreich)

A precise measurement of the antiprotonic helium hyperfine structure (HFS) can be compared with three-body quantum electrodynamics (QED) calculations as a test of their predictions. The hyperfine structure of antiprotonic helium ($\bar{p}He^+$) was investigated by a laser-microwave-laser spectroscopy method[1], where a first laser pulse was used to depopulate one of the hyperfine (HF) states. A microwave pulse transferred population between two of the SSHF substates (see Fig. 2). Afterwards a second laser pulse to the same transition as before measured the population change caused by the microwave pulse. A comparison between the measured transition frequencies and three-body QED calculations can be used to determine the antiproton spin magnetic moment μ_p. In $\bar{p}^3He^+$ eight super-super-hyperfine (SSHF) states exist and thus four electron spin flip transitions can be stimulated with an oscillating magnetic field. The additional spin of the nucleus compared to $\bar{p}^4He^+$ leads to a more complex structure for $\bar{p}^3He^+$ and thus this system provides a more stringent test of the theory. In 2010 the first microwave spectroscopic measurement of the hyperfine structure of $\bar{p}^3He^+$ was successfully performed. Two of the four SSHF resonance transitions were observed and are in agreement with the-

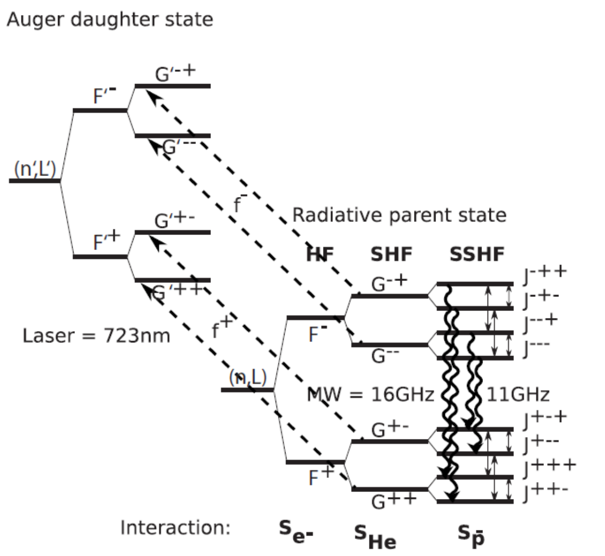

Fig. 2: Laser-microwave-laser method, illustrated for the transition between the $(n,l) = (36,34)$ state and the $(n',l') = (37,33)$ state in antiprotonic ^{3}He.

ory. The measured frequencies of the individual transitions are 11.12559(14) Ghz and 11.15839(18) GHz, less than 1 MHz higher than the current theoretical values, but still within their estimated errors. Also the frequency difference between the two SSHF lines, which is important due to its proportionality to the magnetic moment of the antiproton, agrees with theoretical calculations. However, the experimental error for this difference is still considerably larger than the theoretical error. A systematic study of these transitions and improved statistics will allow a higher precision, in particular for the difference between the SSHF transition frequencies. It is further planned to measure also the two SSHF transitions at 16 GHz.

Laser spectroscopy

Physical laws are believed to be invariant under the combined transformations of charge, parity, and time reversal. This CPT symmetry implies that antimatter particles have exactly the same mass and charge as their particle counterparts. For the first time $\bar{p}^3He^+$ and $\bar{p}^4He^+$ isotopes were irradiated with two counter-propagating laser beams, thereby exciting some non-linear two-photon transitions of the antiproton of the type $(n, l) = (n-2, l-2)$ at the deep UV wavelengths λ = 139.8, 193.0 and 197.0 nm. This partially cancelled the Doppler broadening of the laser resonance caused by the thermal motions of the atoms. The resulting narrow spectral lines allowed to measure three transition frequencies with fractional precisions of 2.3–5 parts in 10^9. By comparing the results with three-body QED calculations, the antiproton-to-electron mass ratio can be derived. The data analysis has been finished, and a publication with the new antiproton-to-electron mass ratio is being prepared.

[1] T. Pask et al., Phys. Lett. B 678, 6 (2009); K. Nakamura et al. (Particle Data Group), J. Phys. G 37, 075021 (2010)

2.5.1.2. Antihydrogen

The ground-state hyperfine splitting (GS-HFS) of antihydrogen is caused by the interaction between the antiproton spin magnetic moment and the positron spin magnetic moment, and (in the first order) directly proportional to the antiproton magnetic moment. Thus by measuring the antihydrogen GS-HFS, which in itself is a good CPT test, we can also obtain a value for the antiproton magnetic moment, which is currently know to a precision of only 0.3%.

The ASACUSA collaboration at CERN’s Antiproton Decelerator is planning to measure the ground-state hyperfine splitting (GS-HFS) of antihydrogen ($\overline{H}$) using an atomic beam apparatus[2] similar to the ones which were used in the early days of hydrogen HFS spectroscopy. The apparatus will use antihydrogen atoms produced in a superconducting cusp trap (i.e. anti-Helmholtz coils), which has been developed by collaborators from the University of Tokyo. Due to the strongly inhomogeneous magnetic field of this trap, the antihydrogen atoms emerging from the trap will either be focussed onto a 1.42-GHz radiofrequency resonator, or defocussed, depending on their spin direction. Thus the H beam entering the resonator will be partially polarized. The oscillating magnetic field in the resonator can flip the spin of the $\overline{H}$ atoms when it is on resonance with one of the hyperfine transitions. A superconducting sextupole magnet installed after the resonator will then act as a spin analyzer, and will focus the atoms onto an antihydrogen detector, or defocus them, depending on their spin direction. This forms the basis of the spectroscopy method: when the radiofrequency field in the resonator is on resonance with one of the ground-state hyperfine transitions, fewer atoms will reach the antihydrogen detector.

In 2010, antihydrogen atoms could be successfully produced by the ASACUSA collaboration[3]. They were created in a cusp trap by mixing antiprotons coming from an antiproton catching trap, and positrons coming from a positron accumulator. The antiproton annihilations were observed by a 3D tracking detector surrounding the cusp trap. This is an important step towards the antihydrogen GS-HFS spectroscopy, and it was selected, together with the trapping of antihydrogen by the ALPHA experiment at CERN, as the **“Breakthrough of the Year”** by PhysicsWorld. The antihy-

Fig. 3: Photo of the antihydrogen radiofrequency resonator. One of the vacuum flanges closing the chamber is removed so the inside can be seen.

drogen production efficiency was ~2%, thus on average appr. 30 $\overline{\mathrm{H}}$ atoms per second were created.

Parallel to the antihydrogen synthesis, the design of the radiofrequency resonator has been finalized, and construction has been started at CERN. The major parts have been manufactured, and the main structure of the resonator has been assembled. Only a few smaller pieces still need to be manufactured or ordered. Fig. 3 shows a photo of the opened resonator, with two parallel plates which shape the radiofrequency field inside.

The superconducting sextupole magnet has been ordered in 2009 through CERN from Tesla Engineering in the UK. After many delays, the magnet is expected to arrive to CERN in March, 2011.

[2] B. Juhász, E. Widmann, Hyp. Int. 193, 305 (2009)
[3] Y. Enomoto et al., Phys. Rev. Lett. 105, 243401 (2010)

2.5.2. Hadron Physics

The physics of strongly interacting particles – hadrons – is dealing with topics which have profound consequences for understanding basic questions like the generation of the mass of the visible Universe or the structure of exotic objects – e.g. neutron stars – in the Universe. To gain information on how strong interaction works, exotic atoms with strangeness provide a unique insight. For example the low-energy observables of the strong interaction of the negatively charged kaon with the proton can be extracted from X-ray spectroscopy of kaonic hydrogen atoms with very high precision. On the other hand, new dedicated experiments are devoted to the search of systems bound by the attractive interaction of negatively charged kaons with nuclei. Many experiments are in preparation at different facilities at J-PARC, GSI and LNF. Moreover, the strong interaction in the field of charm quarks will be studied in the PANDA experiment at FAIR. Equally important is the further development of the theory of strong interaction in the field of strange and charm quarks, especially in the low energy regime (low-energy QCD). A networking activity LEANNIS – which is led by SMI – in the European integrated activity HadronPhysics2 bridges the gap between experimental and theoretical studies.

2.5.2.1. Kaonic atoms: SIDDHARTA, E17

(Supported by EU-FP7 HadronPhysics2; BMBWK 650962/0001 VI/2/2009; FWF P20651)

Kaonic atom X-ray measurements can explore the $\overline{K}N$ interaction at low-energy without extrapolation, giving important quantitative constrains for theoretical approaches. The aim of SIDDHARTA was to measure kaonic hydrogen and deuterium X-rays in order to explore the K^--proton (K^-p) and K^--neutron (K^-n) interactions near threshold and to connect QCD-based chiral approaches to low energy K^--nucleon physics.

Particularly important data is the strong-interaction shift and width of the kaonic hydrogen 1s state. The physics of the I = 0 $\overline{K}N$ channel can be well studied together with the experimental data of low-energy K^-p scattering, πΣ mass spectra, and K^-p threshold decay ratios. This is also related to recent hot topics of the 2-pole structure of the $\Lambda(1405)$ resonance, and possible deeply bound kaonic systems. Concerning kaonic helium, no data was available for kaonic ^{3}He. A possible shift (up to 10 eV) on either the kaonic ^{3}He or ^{4}He 2p state predicted by one calculation should be examined experimentally.

To provide experimental data on the above issues, the SIDDHARTA experiment measured kaonic atom X-rays using 4 gaseous targets of hydrogen, deuterium, ^{3}He, and ^{4}He, using newly developed large-area silicon drift detectors (SDDs). With coincidence of back-to-back correlated K^+K^- pairs produced by DAΦNE, background events could be highly suppressed.

Fig. 4 shows an X-ray energy spectrum of kaonic hydrogen. The kaonic hydrogen X-ray transitions to the 1s state are clearly seen, as indicated in the figure. These X-ray lines were fitted with a convolution function of a Lorentzian presenting a strong-interaction width and X-ray response functions obtained from calibration data. As a result, the up-to-now most accu-

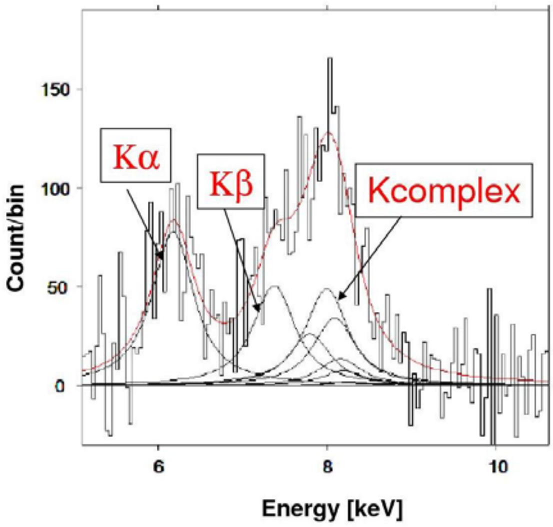

Fig. 4: X-ray energy spectrum of kaonic hydrogen. The transition lines are indicated.

rate values for the shift and width will be obtained. Effects of fit methods related to treatments of *K*-complex lines, as well as contaminations of kaonic carbon/oxygen lines are under study. This new result will provide tight constrains for the low-energy $\overline{K}N$ interaction in theoretical approaches.

Kaonic ^{3}He X-ray transition to the 2p state was measured in the last few days of the beam time. This is the world's first measurement of kaonic ^{3}He. The strong-interaction shift of the kaonic ^{3}He 2p state was determined to be ΔE_{2p} = −2 ± 2 (stat) ± 4 (syst) eV. Using the same setup, the kaonic ^{4}He X-rays were measured, and the shift of the kaonic ^{4}He 2p state was determined to be ΔE_{2p} = +5 ± 3 (stat) ± 4 (syst) eV. Both results are consistent with 0 eV within the errors, which also agrees with theoretical predictions, but a possible shift of more than 1 eV predicted by the theory cannot be completely excluded within the errors.

Because of the insufficient precision of the kaonic He results by SIDDHARTA to compare different theoretical models, further reductions of the statistical and systematic errors are required. The J-PARC E17 experiment will aim at a determination of the shift of both kaonic ^{3}He and ^{4}He with statistical and systematic error of 1 eV each. The possible isotopic effect indicated by the SIDDHARTA could be clarified. A detailed performance check of the SDD response was studied using the kaon beams at the J-PARC K1.8BR. The data taking of the kaonic helium X-rays in J-PARC is planned in 2011 to 2012.

The measurement of kaonic deuterium data in SIDDHARTA was limited in terms of signal-to-background ratio. To observe kaonic deuterium X-ray signals, at least a factor 10 improvement in background reduction is necessary. A new experiment proposed by the SIDDHARTA2 collaboration in June 2010 uses a new system composed of improved SDDs and target systems, as well as K^+ detection, etc., in a new interaction point. Developments of the new system are in progress.

2.5.2.2. Kaonic nuclei: DISTO, FOPI

(Partly supported by FWF grant P21457)

A well-constrained $\overline{K}N$ interaction, as a fundamental interaction of kaon physics, induces research interests on kaonic few- and many-body systems with a notable example of exotic kaonic nuclear systems. About a decade of eager works advanced the understanding of a few interconnected issues: kaon two-body absorption processes, the nature of the $\Lambda(1405)$ and its role, new chirally motivated calculations of the $\overline{K}N$ interaction, and kaonic bound states. The main target, namely the property of kaonic nuclear systems, however, is still debated.

In year 2010, new data started to arrive. We search for the most basic dibaryon system $(\overline{K}NN)_{S=0,\ I=1/2}$, often called K^-pp, in the exclusive data samples of the reaction $p+p \rightarrow p+\Lambda+K^+$. The K^-pp could be produced in an exotic two body reaction: $p+p \rightarrow K^-pp + K^+$ which goes into the same final state products: $p + \Lambda + K^+$. The resonance would have such features like: produced in a large momentum transfer, a large cross section. These signatures can be cross checked by its production channel (missing mass) and its decay channel (invariant mass) independently.

We analysed the exclusive data samples of the reaction: $p+p \rightarrow p+\Lambda+K^+$ collected by the DISTO experiment at T_p = 2.85 GeV and found indeed such a resonance that fulfils the above expectations[4].

The analysis went further on the DISTO data to clarify the nature of the observed resonance whose mass and width are so far not consistent with theories. A more detailed analysis of the 2.85 GeV data and a new analysis of the 2.5 GeV data were presented at the one-week international workshop at ECT*, Trento, Italy[5].

We measured at the end of year 2009 the same reaction: $p+p \rightarrow p+\Lambda+K^+$ using the FOPI apparatus at GSI, Darmstadt, Germany, at T_p = 3.1 GeV, where the signal-to-noise ratio is more optimized. The data analysis improved the Λ invariant mass spectroscopy and the charged kaon identification. An analysis status was reported at several national/international conferences[6].

The E15 experiment located at J-PARC, Tokai, Japan, whose goal is to search for the $K^{-}pp$ state with the $^{3}He(^{in\text{-}flight}K^{-}, n)$ reaction using a newly available high intensity, high quality kaon beam, made a significant progress in its preparation. The K1.8BR beam line has obtained an optimum parameter for the K^{-} beam. A central detector system, which consists of a 0.5-T superconducting magnet, a cylindrical drift chamber and a cylindrical time-of-flight barrel, was successfully commissioned. A Λ invariant mass spectrum as a benchmark reaction demonstrated the design value of 3.5 MeV/c^2 mass resolution. The apparatus is now ready for the beam.

The AMADEUS experiment at LNF-INFN (Frascati, Italy) is a project to perform a complete study of the decay modes of the kaonic nuclei, in particular the Σ-π channel, which will be missing in its preceding experiments. The AMADEUS apparatus works in combination with the existing KLOE detector and cylindrical cryogenic target system, inner tracker and trigger counter. The detector R&D has been accelerated by a collaboration of LNF-INFN and SMI. The behaviour of the silicon photomultiplier (SiPM) which reads out the scintillating fibers at extreme high rates is being investigated. A GEM detector for an inner tracker system is also under preparation.

The FOPI collaboration also investigates the production and propagation of strangeness in a nuclear matter using π-induced reaction on nuclei. For an understanding of the QCD phase diagram this is one of the central themes of hadron physics. The measurement should provide information on the Φ vector meson modified properties inside the nuclear environment by studying the “transparency ratio”. It measures also a K^0 inclusive cross section that can be also sensitive to medium modifications. A beam tracker system using silicon strip detector is developed. In 2010 it turned out to be impossible to carry out the experiment due to technical problems at the SIS accelerator.

Hence, the beam time is re-scheduled for 2011. The GEM-TPC detector that has been newly developed and successfully tested in November 2010 is going to be used in this measurement. This will drastically improve the forward tracking resolution of the existing FOPI apparatus.

[4] T. Yamazaki et al., Phys. Rev. Lett. 104, 132502 (2010)
[5] Strangeness in Nuclei, 4-8 Oct. 2010, ECT*, Trento, Italy
[6] One of them is the „New frontier in QCD 2010” conference, 18 Jan. – 19 Mar. 2010, Yukawa institute for theoretical physics, Kyoto, Japan.

2.5.2.3. The PANDA experiment

(Partly supported by EU-FP7 HadronPhysics2)

The PANDA[7] Experiment is one of the large scale projects at FAIR[8]. It will study antiproton annihilations on nucleons and nuclei in the energy range of strange and charmed hadrons. A synchrotron and storage ring (HESR) will provide an antiproton beam with very small momentum spread (2×10^{-5}) or high luminosity (2×10^{32} cm^{-2}s^{-1}).

A major step toward the realization of the facility and thus the experiment has happened in October 2010, when the FAIR contract has been signed by the international partner countries. The start of construction of the FAIR modularized start version is envisaged for fall 2011.

The SMI activities in the PANDA project are contributions to the software framework and simulation/analysis, contributing to the development of the PANDAGrid[9] computing network and maintaining a PANDAGrid site, as well as R&D activities for the hydrogen cluster jet target, applications of the GEM technique to tracking detectors and Cherenkov counters of the DIRC type.

The software framework of the PANDA experiment is called PANDARoot, which is based on the ROOT[10] software package from CERN. It contains the detector description as well as the full data reconstruction and analysis chain which will be used also for real experimental data to come. One application studied at SMI is the evaluation of the charmonium (J/ψ) dissociation in nuclear matter, which is shown schematically in Fig. 5. The incoming antiproton beam with a certain momentum spread forms with a certain probability a J/ψ in matter, which on its way out can dissociate. The surviving J/ψ's are measured (dilepton decay channel). A model has been developed to account for the nucleons' Fermi momentum and the path in the nucleus the formed J/ψ has to travel. A feasibility study for this measurement has been published within the PANDA physics book[11].

Furthermore, a work to evaluate the absorbed energy dose of the PANDA detector components during operation has been started.

An interface to read in events calculated in the FLUKA[12] code for further transport in PANDARoot has been successfully implemented.

For the PANDAGrid network, an additional Austrian site (UBIK, Innsbruck) has been established, and the number of available computing processors and data storage at the SMI has been increased significantly.

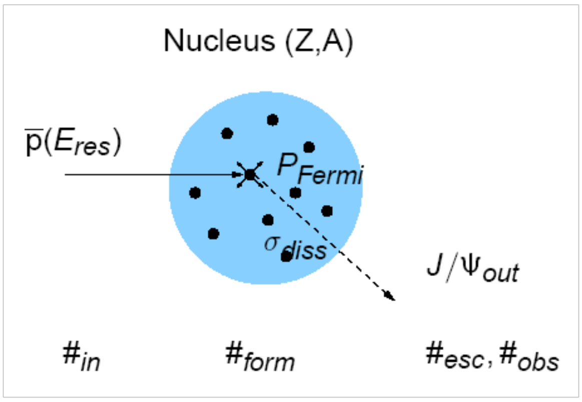

Fig. 5: Illustration of a measurement on the charmonium dissociation in nuclear matter.

The technical design report (TDR) for the PANDA targets has advanced in the reporting period and will be submitted for review in the first half of 2011. SMI is responsible for the vacuum chapter of the TDR. Detailed vacuum calculations[13] have been done, resulting in pressure profiles for the hydrogen cluster jet and the hydrogen pellet target, with and without target operation. Nonetheless being in a very advanced stage, additional effects related to the beam pipe vacuum could be included in the simulations. Based on the vacuum calculations, a study of beam particle neutralization due to the presence of rest gas ions in the PANDA interaction zone has been performed at FZ Jülich, Germany.
A 1:1 model of the PANDA interaction zone is prepared and will be used for experimental tests of the discussed calculations.
For more details about the related R&D projects for the PANDA detector please refer to Section 2.5.3 of this report.

[7] http://www-panda.gsi.de/
[8] http://www.fair-center.org/
[9] http://mlr2.gla.ac.uk/
[10] http://root.cern.ch
[11] arXiv:0903.3905v1
[12] www.fluka.org
[13] A. Gruber, Ph.D. thesis, university Vienna, in preparation

2.5.3. Advanced Instrumentation

(Supported by EU-FP7 HadronPhysics2)

The Stefan Meyer Institute has well equipped mechanic and electronic workshops, perfect suited for the needs of our Institute doing experimental work in the field of subatomic physics. Together with our design and construction unit we are able to produce the important parts for our experiments at foreign accelerator facilities, like: CERN-AD, Switzerland; GSI, Germany; LNF, Italy and J-PARC, Japan.
For the measurements of the hyperfine splitting in the anti-proton helium system at the CERN-AD a new cryogenic target system was developed and built at SMI as well as the microwave target cell.
In addition R&D work is performed mainly in the framework of "Joint Research Activities", within the 7th Framework Programme of the EU: HadronPhysics2. The Institute participates in 3 work packages:

- WP19: FutureJet – Cryogenic jets of nano- and micrometer-sized particles for hadron physics
- WP24: JointGEM – Ultra-light and ultra-large tracking systems based on GEM technology
- WP28: SiPM – Avalanche Micro-Pixel Photo-Diodes for Frontier Detector Systems.

WP24 is led by SMI. In total six PhD students are involved in these R&D work.
For the next EU call within FP7, a proposal was submitted in November 2010, called HadronPhysics3, in which we plan to extend our work on FutureJet, JointGEM and SiPM. If accepted, this joint research activity will start in 2012.

2.5.3.1. WP19 – FutureJet

Within WP19 FutureJet our Institute contributes to the optimisation studies of the (hydrogen) cluster-jet target of PANDA and to the design of the complete PANDA vacuum and pumping system. The effect on the rest gas conditions in the antiproton beam line are evaluated for both targets (cluster-jet – see Fig. 6 – and pellet target) within the PANDA section. These calculations triggered already big efforts on the target side to minimise the gas flow into the accelerator beam line.

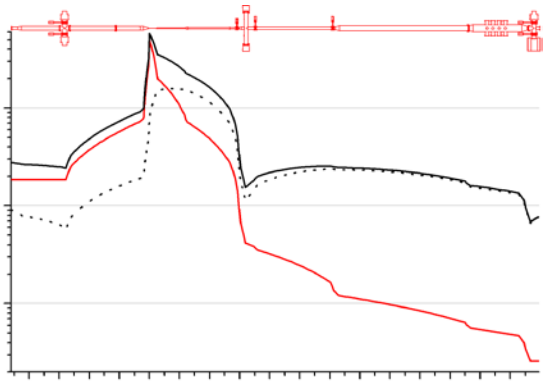

Fig. 6: Calculation of the rest gas contribution in the antiproton ring around the PANDA interaction zone (black: total pressure; red: cluster-jet contribution, hydrogen; black-points: rest gas pressure).

Beside this work SMI was involved in the upgrade of the INFN-SMI-GSI cluster-jet device at GSI to improve the apparatus to investigate higher cluster-jet densities and to make it possible to measure the cluster size and the velocity of the produced hydrogen beam.

2.5.3.2. WP24 – JointGEM

The next generation of experiments in hadron physics aims at studying rare processes with drastically improved sensitivity. The technical requirements to reach this goal include high beam intensities and luminosities, fast detectors with large acceptance and high resolution. Examples are: AMADEUS experiments at DAFNE-LNF, Frascati, Italy, and PANDA at FAIR, Darmstadt, Germany. An essential part of all these experiments is a detector for charged particles with excellent tracking capabilities covering large areas or volumes with an extremely low material budget in order not to spoil the energy and mass resolution of the apparatus. In addition the rate capability has to match the required high luminosities.

All these detectors have very similar stringent requirements originating from the physics goals of the respective experiments:

- active areas of the order of m^2,
- spatial resolutions of ~100 µm to 500 µm,
- time resolutions of the order of a few ns,
- low material budget inside the active area, 1.5% of a radiation length for the whole tracking detector,
- rate capability up to several tens of kHz per mm^2.

The Institute is involved in the developments of a high-rate Time Projection Chamber (TPC) with GEM (Gas Electron Multiplier) readout, as planned for the inner tracker of AMADEUS at LNF and PANDA at FAIR. In addition R&D work is ongoing of large-area planar GEM detectors capable of withstanding very high beam rates, as envisaged for the forward tracking system of PANDA or E15 at J-PARC.

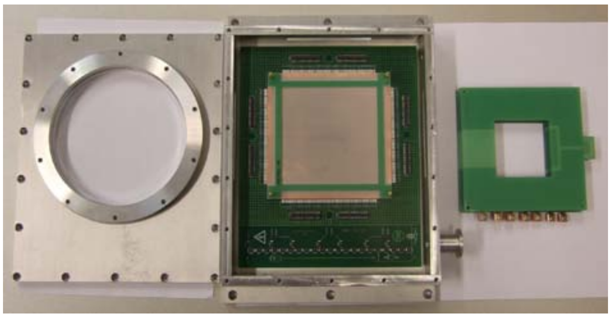

Fig. 7: Multipurpose test chamber for GEM foils. Left: Upper part of the test chamber with thin entrance window (75 µm Hostaphan); middle: chamber body with x-y-readout; right: support frames to be equipped with GEM foils.

Testing equipment was developed at SMI during the reporting period like a GEM foil stretching unit with an attached mechanism for support frame gluing with high accuracy. A multi-purpose test chamber was designed and built at SMI for the characterization of GEM foils (see Fig. 7).

For the first test measurement of the GEM-TPC at GSI under beam conditions, a gas-mixing unit was build at SMI with a quadrupole mass spectrometer (QMS) attached to the gas outlet to monitor the gas composition of the TPC gas mixture. Finally, a closed cycle gas system is under development with a special gas cleaning device to keep the impurity level of the TPC gas mixture in the level of a few ppm.

2.5.3.3. WP28 – Silicon Photomultiplers

New photon detectors – Geiger mode operated avalanche micro-pixel photo sensor matrices (AMPD), also called silicon photo multipliers (SiPM) – are ideally suited for future photonic systems in a broad field

of basic science in physics, especially in hadron physics. These devices combine performances of traditional phototubes like high quantum efficiency and signal amplification with extremely important features like low-cost voltage supply and electronics. Contrary to photomultipliers, this device is insensitive to magnetic fields and mechanically robust thus suitable for harsh environments. Therefore, the possible applications of these devices cover also other fields, like space research, biology, medical diagnostics and eventually environmental technology.
The important tasks of investigation with the SiPM sensor under participation of the SMI are the following:

- Development and test of new SiPMs, integrated in arrays that are compatible with the demands of position sensitive detectors (e.g. single-photon detectors, scintillating fiber detectors, gamma-ray detectors using state-of-the-art crystals like LSO)
- Optimization of the timing performance with resolution below 100 ps (see Fig. 8).
- Development and test of the performance as single photon counters.
- Investigation and characterization of the intrinsic and induced noise behavior.
- Development of associated electronics for the supply/readout as well as data acquisition.

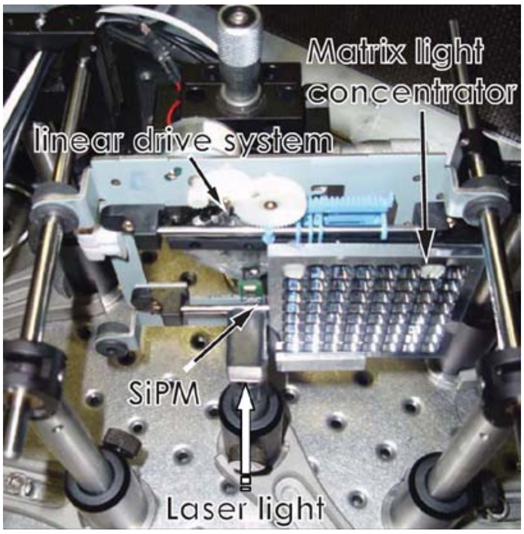

Fig. 8: Test setup for time resolution study of different types of SiPMs, with light concentrators and a blue laser light pulse of 32 ps at 408 nm.

2.5.3.4. Silicon Drift Detectors

Silicon Drift Detectors were already successfully used in the SIDDHARTA experiment to measure the X-ray transitions to the ground state in kaonic hydrogen in order to extract the strong interaction induced shift and width. In addition measurements of kaonic ^{4}He and for the first time of kaonic ^{3}He were performed. To confirm the findings in ^{3}He, for the E-17 experiment at J-PARC a new X-ray detector system was built and tested at SMI using Silicon Drift Detectors (SDDs) manufactured by KETEK (see Fig. 9).
To achieve the claimed stability and energy resolution the pre-amplifier board has to be adapted to run under vacuum conditions, as close as possible to the cooled SDDs.
Eight SDDs are installed, surrounding the liquid ^{3}He target cell, at J-PARC. First beam test were already successfully performed, showing a very good performance of the SDD system under (test) beam conditions.

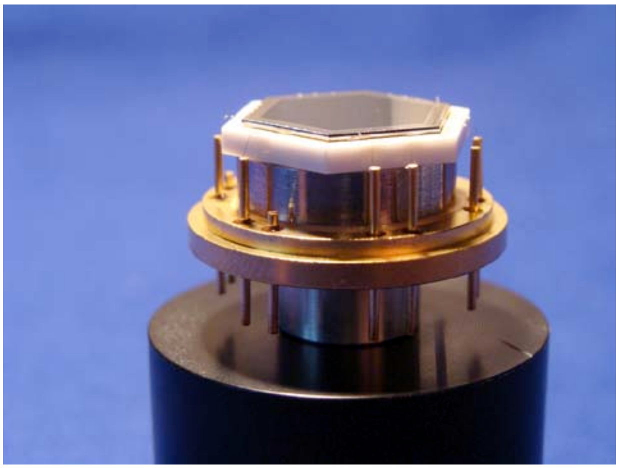

Fig. 9: KETEK SDD with an active area of 1 cm^2.

2.5.3.5. FOPI

Using pion-induced reaction on nuclei to measure the strangeness production and propagation in a nuclear medium, the FOPI detector system has to be enlarged with the GEM-TPC (developed in WP24: JointGEM; SMI is participating in the development of the GEM-TPC – see Fig. 10).
An additional beam veto counter has to be developed at SMI to suppress the background produced by pions stopping in material, surrounding the target. The veto counter is under construction using SiPM for detecting the light from the plastic scintillators (experience gained from WP28: SiPM).

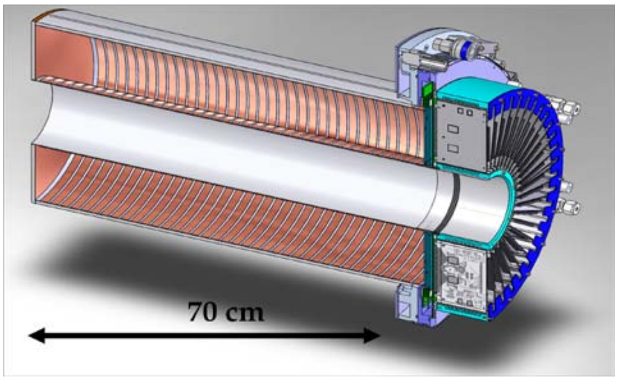

Fig. 10: GEM-TPC prototype under test at GSI, installed at FOPI.

2.5.3.6. Medical applications

To improve the spatial resolution of a PET (Positron Emission Tomography) device, a promising way might be to use the ToF (Time-of-Flight) technique. That means the time resolution of the (PET) detector system has to be improved drastically to get a good spatial resolution measurement. Using the fast Cherenkov process instead of the timing given by the scintillation light, it might be possible to obtain a time resolution in the order of 100 picoseconds (see Fig. 11), which of course will be ideal suited for this application.
Studies will be performed in 2011 to improve the time resolution by taking into account the faster light collection of the Cherenkov light. This work will be done in collaboration with the Medical University of Vienna.

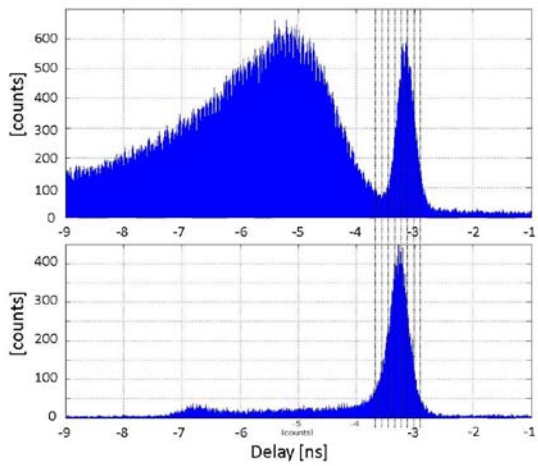

Fig. 11: Light output of different materials; upper: scintillation and Cherenkov light; lower: only Cherenkov light.

2.5.4. Smaller physics projects

2.5.4.1. VIP @ Gran Sasso (VIolation of the Pauli Exclusion Principle Experiment)

The VIP experiment at Gran Sasso National Laboratory delivered a new upper limit for a Pauli-Exclusion-Principle (PEP) violation for electrons of 5×10^{-29}, thus improving the previous limit by a factor of about 300.
A next step in the experimental program aims at a further lowering of the PEP violation limit by at least one order of magnitude. An improved experimental technique using SDDs (Silicon Drift Detectors), very thin current conductors and active shielding against radiation background was studied in 2010. Test measurements in the Gran Sasso National Laboratory (LNGS) gave solid information on background reduction factors. At SMI we worked out a Monte Carlo model to study active shielding for various anticounter configurations and models for the background radiation. We used measured published background profiles from LNGS. The simulation of the test measurement gave a reduction factor well consistent with the one obtained from our test measurements. This shows the validity of the simulation. The calculation for the proposed future VIP configuration yielded a reduction factor of about 3, which together with other planned improvements makes the goal of again lowering the PEP limit considerably look feasible.

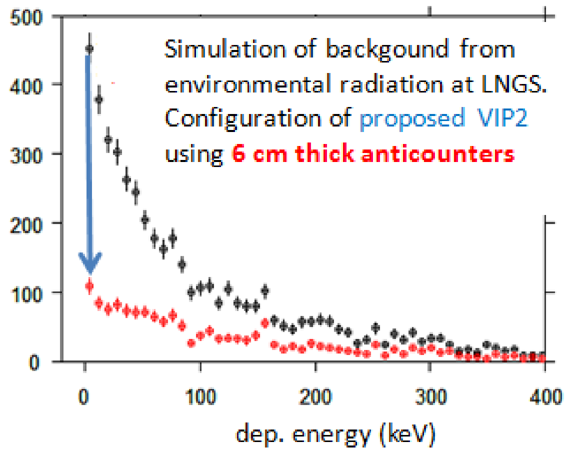

Fig. 12: Background reduction by active shielding. The test measurement at LNGS used 1.5 cm thick anticounters and a PIPS detector covering the range of 20-50 keV deposited energy. The simulation reproduced the test. For a VIP2 configuration with 6 cm thick anticounters the reduction factor at 8 keV is indicated by the arrow. Black dots: total spectrum, red: applied anticoincidence.

2.5.4.2. EC-decay of highly ionized atoms

At the GSI Helmholtzzentrum für Schwerionen-forschung in Darmstadt, Germany, lifetimes of unstable ions can be measured by high resolution time-resolved Schottky Mass Spectrometry (SMS). In the Schwerionen-synchrotron (SIS) ions are accelerated to a few hundred MeV/u and after extraction directed onto a target. The produced fragments are separated in the Fragment Separator (FRS) according to their mass and charge state. The ions of interest are selected and injected into the Experimental Storage Ring (ESR). There they are coolled (stochatic and electron cooling) and can be kept and observed until they decay. Their orbital frequency, which is measured with pick-up devices, is a direct measure of the mass. Changes in mass e.g. by decay can be detected by analysing the time evolution of the frequency content of the pick-up signal. Recently Electron Capture (EC) decay rates of H-like ^{140}Pr and ^{142}Pm have been measured. Surprisingly the decay curves in these cases did not follow a pure exponential law but were described by adding a modulation term to the expected exponential decay curve. In both cases the modulation period was T ~7 seconds with a modulation amplitude of roughly 20%[14]. In order to verify this result and to investigate the isospin dependence of the decay properties, EC decay curve measurements of H- and He-like ^{142}Pm ions were and performed in May 2010 (GSI experiment E078) with high statistics and modified equipment. In addition to the so far used pick-up coil, a new resonant pick-up was installed with a ~100-fold higher sensitivity[15]. The analysis of the more than

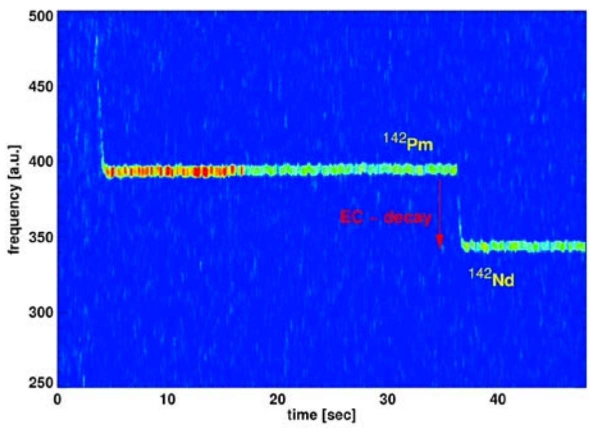

Fig. 13: Time evolution of the frequency (i.e. mass) spectrum of the ions in the ESR. A decay of a ^{142}Pm ion by EC to ^{142}Nd can be seen.

44000 acquired measurements of each 64 seconds is performed by groups at GSI and the Stefan Meyer Institute. Fig. 13 shows an example of a time-frequency plot representing one measurement of 64 seconds. The decay of the ^{142}Pm ion by EC to ^{142}Nd is manifest by a sudden change of the frequency distribution.

At SMI we are developing an automatized data analysis procedure. The analysis is ongoing and final results are expected to be presented in 2011.

[14] Yu. A. Litvinov et al., Phys. Lett. B 664, 162-168 (2008)
[15] GSI Scientific Report, 2010

2.5.4.3. Deeply bound pionic atoms

Deeply bound pionic atoms were discovered at GSI, Darmstadt in 1996 using the (d,^{3}He) reaction on heavy elements (Pb, Sn) against most of expectations. The precisely determined π-nucleus potential in comparison with the π-N potential leads to a very unique determination of a reduction of the quark condensation in a nuclear medium of ~35%[16]. In order to further improve the experimental precision and hence to better constrain the theoretical scenario of the dynamical generation of hadron masses from spontaneously broken chiral symmetry, a new experiment is proposed to make use of high-intensity deuteron beam which became recently available at the brand new RI beam facility and the fragment separator at RIKEN, Japan. In 2010 a pilot run took place in order to develop a beam optics with a superb resolution using a momentum-matching technique, making an important step forward for opening up a new series of precision deeply bound pionic atom study.

[16] K. Suzuki et al., Phys. Rev. Lett. 92, 072302 (2004)

2.6. Research program 2011

2.6.1. Matter–antimatter symmetry: ASACUSA @ CERN-AD

The microwave spectroscopy of the hyperfine levels of **antiprotonic ^{3}He** will continue in 2011. The two 11-GHz hyperfine transitions of the (n,l)= (36, 34) state will be re-measured with more statistics so that the transitions frequencies can be determined with higher precision. Furthermore, the two 16-GHz transitions will be measured for the first time. This way, a complete picture of the ^{3}He hyperfine structure will be obtained. For the 16 GHz measurements, a new microwave resonance cavity is needed, which is now under construction at SMI. It will be installed in the existing cryostat.

In ^{4}He, the transition frequencies do not show any dependence on the density of the helium gas target or on the power of the applied microwave field. A similar behaviour is expected in ^{3}He, but this will be verified by measuring at least one hyperfine transition at different target densities and microwave powers.

The **antihydrogen** ground-state hyperfine spectroscopy project will also continue in 2011. The radiofrequency resonator will be completed and tested. Inside the resonator, a weak, homogeneous static magnetic field needs to be present, therefore the strong stray magnetic field of the cusp trap at the position of the resonator needs to be decreased. A design of a magnetic shielding has been started, but it turned out to be much more complicated than expected, therefore most likely only the first component of the magnetic shielding will be installed in 2011. This will enable us to make the first hyperfine splitting measurements in 2011, but the high-resolution spectroscopy experiments will only commence from 2012.

The superconducting sextupole magnet is expected to be delivered to CERN in March 2011. After the magnet has arrived, it will be tested and commissioned, so that it is ready for the beam time in 2011.

The main goal of the 2011 antihydrogen beam time will be to optimize the antihydrogen production and thus increase the production rate, which will be necessary for the high resolution spectroscopy experiments. In the second half of the beam time, the radiofrequency resonator, the sextupole magnet, and the antihydrogen detector – which is already in operation – will be installed downstream of the cusp trap, so antihydrogen atoms emerging from the trap can be used for hyperfine studies. Even though these studies would only be preliminary, a successful observation of a ground-state hyperfine splitting transition would be the first ever spectroscopy measurement of antihydrogen.

2.6.2. Hadron Physics

Kaonic Atoms

A new strategy for the J-PARC E17 experiment was proposed in the PAC meeting January 2011. The goal of E17 is the determination of the 2p level shifts both of kaonic ^{3}He and ^{4}He with statistical and systematic errors of 1 eV each to clarify a possible isotopic shift indicated by the recent measurement of SIDDHARTA. The liquid ^{3}He target system would be ready by the end of March 2011, and other systems (e.g. SDDs) are already available. The beam tuning for optimization of stopped kaons will be done in April 2011. The kaonic He X-ray measurement will start in fall 2011.

The data taken by the SIDDHARTA experiment have been analyzed, and the results of kaonic ^{3}He data were published in February 2011. The most accurate results on kaonic hydrogen data are expected for 2011. In addition, publications on the shift and width of kaonic hydrogen, and on upper limits of kaonic deuterium, as well as X-ray yield determinations of kaonic ^{3}He and ^{4}He, etc. are envisaged.

The SIDDHARTA-2 experiment was proposed to measure the kaonic deuterium X-rays, as well as X-rays from other kaonic atoms. For the success of the measurement, a background suppression of at least a factor 10 is needed. Developments of Si strip, Si-PIN diodes, planar Si, and BaF detectors are taking place.

Kaonic nuclei and strangeness in nuclear matter

The analysis of the DISTO data on p+p reaction will still continue, focussing on the study of the beam energy dependence of the observed signal in the Λ-p invariant mass. The FOPI data set, which is also p+p at 3.1 GeV beam energy, will be analyzed further, putting special emphasis to the preparation of a clean K^+ identification which is important for the tagging of the

events of interest, namely the search for a two body final state of a K^+ and a possible kaonic nucleus (ppK^-). For June 2011, the FOPI experiment S339 which studies the pion induced production of strangeness ($\Phi(1020)$, K^+K^-, K^0) is scheduled for data taking. Complementary information on the in-medium potential of strange particles is expected from these data.
After a successful detector commissioning run in October 2010 at J-PARC K1.8BR, the E15 collaboration is now ready to run. A refined data taking programme starting with a 30 kW×week beam time as phase 1 to match the currently available beam intensity was positively accepted by the PAC and the collaboration is expecting to start soon the first data taking.
The AMADEUS experiment at DAΦNE will continue in 2011 with the detector R&D as well as a further optimization with detailed simulation works. Several test beam times are anticipated for the SciFi-SiPM trigger counter and the GEM detector.

PANDA

The detector design of PANDA, including all technical design reports, will be finalized during 2011. The formal Memorandum of Understanding to define the roles of the PANDA collaborators and the FAIR management will be negotiated, aiming for a conclusion in 2011.
The PANDA collaboration has decided to preassemble nearly the complete PANDA detector at a testing site of the FZ Jülich before the appropriate hall at FAIR will be available (which is foreseen for the end of 2016). Hence, the mass production of the detector components has to start very soon, where possible already in 2011. The still necessary R&D will continue in 2011 in parallel. An application for investments for the set up of the PANDA detector was submitted to BMWF in January 2011.
We plan to strengthen the analysis activities, especially in the sector of charmed and strange hadron spectroscopy. Contacts to the BELLE collaboration have been initiated, aiming at the analysis of data from e^+e^- annihilations, which technically is close to the concepts needed later on for PANDA data.
Further studies of channels from antiproton-nucleus reactions in simulations are in the planning, too, as well as contributions to the PANDARoot software framework.
In collaboration with the HEPHY we envisage to join the new Vienna Supercomputing Centre and use the common infrastructure for further (PANDA)Grid extensions and applications.

2.6.3. Advanced Instrumentation

The R&D work in the framework of "Joint Research Activities", within the 7th Framework Programme of the EU: HadronPhysics2 will be continued and ends with 31.12.2011. The milestones of the 3 work packages with involvement of SMI are on a good way to be fulfilled until the end of 2011. In addition a proposal named HadronPhysics3 (HP3) was handed-in in November 2010 (restricted call within the EU FP7 programme). The proposed work packages in the new proposal are essential for the planned experiments PANDA, AMADEUS and for compressed matter studies using antiproton annihilation at rest. An application for a National Research Network (NFN) dealing also with advanced instrumentation was submitted to FWF. Beside the work, related to the EU programmes, the R&D and construction work has to be mentioned for the setup of the planned measurements of the hyperfine splitting of antihydrogen.

WP19: FutureJet

An optimized time-of-flight setup at GSI will allow for extensive studies on the velocities of individual clusters. Systematic investigations have already resulted in a transition from almost mono-energetic cluster beams towards broader velocity distributions. With the new setup at GSI and the existent cluster beam target installations at the Westfälische Wilhelms-Universität, Münster, the studies will be completed and systematic nozzle tests have to be done. The measured cluster-jet properties directly behind the nozzle will then be compared to numerical calculations. These results are important to further improve the simulation code as well as the nozzle geometries and operation modes for the production of high-intense target beams.
The above mentioned evaluations and measurements will complete the joint research activity and has to be finished end of 2011.
The goal within the new application of FutureJet in HP3 is to achieve a significant further development in the science and technology of cryogenically cooled beam sources, with applications in several research fields, like FAIR (PANDA at HESR) and FZJ (WASA at COSY). Preparation work has to start already 2011 and will be continued completely, if the proposal is accepted by the EU, otherwise only a restricted work package could be fulfilled, mainly in the direction of the internal target for PANDA.

WP24: JointGEM

The setup of the PANDA prototype TPC for beam tests at GSI with FOPI was finished already last year. The TPC-GEM detector with the full readout of 10000 hexagonal pads for the PANDA prototype will be completed early 2011 as well as the complete implementation of the TPC DAQ into the FOPI DAQ for in-beam test experiments at GSI.

The commissioning phase with beam tests will start 2011, including the complete closed cycle gas system, with cleaning and analysis devices (under responsibility of SMI). The implementation of the new FE electronics for the GEM-TPC based on AFTER chip was finished. In addition the layout and test of the readout electronics based on the XYTER chip will start. To get first results on the usability of the further improved XYTER chip as soon as possible, we will setup at SMI, together with HEPHY, a 512 channel DAQ systems starting with the AVP25 chip, which will be replaced with the XYTER chip, as soon as the next improved version is available (summer 2011).

In addition there is a strong demand of large area GEM foils. For example large foils are required for the inner tracker for the upgrade of the KLOE and AMADEUS experiment as well as for large area planar GEM detectors foreseen for CBM and PANDA. SMI will participate in characterizing these newly developed foils.

For the next steps of JointGEM in HP3 we plan to extend our work in the direction of an "active target" TPC using the experience already gained from the previous JRA. Such a new detector/target concept has important impacts not only for AMADEUS at LNF but also for new planned experiments at CERN-AD and FAIR to search for strangeness production in antiproton annihilation at rest. In addition possible applications in homeland security are an interesting side effect.

WP28: SiPM

The work will be concentrated on the development and testing of Cherenkov detectors employing SiPM for fast timing readout. First detector prototype tests with 500 MeV electrons at the Beam Test Facility in Frascati were successfully pointing in the right direction. Timing resolution of below 300 ps were achieved, which represents a first step in the development of fast Cherenkov trigger detectors suitable for the operation in the vicinity of strong magnetic fields. These tests will be done in a combined effort with the Medical University of Vienna, because fast timing signals using Cherenkov light are important for the improvement of PET devices using the ToF technique.

As a next step position-sensitive Cherenkov light detection has to be tested with an 8x8 SiPM matrix with light concentrating cones (which were manufactured at SMI).

2.7. Publications/talks/poster presentations 2010

2.7.1. Publications in peer-reviewed journals or collections

S. Bartalucci, S. Bertolucci, M. Bragadireanu, M. Cargnelli, C. Curceanu (Petrascu), S. Di Matteo, J.-P. Egger, C. Guaraldo, M. Iliescu, T. Ishiwatari, M. Laubenstein, J. Marton, E. Milotti, D. Pietreanu, T. Ponta, A. Romero Vidal, D.L. Sirghi, F. Sirghi, L. Sperandio, O. Vazquez Doce, E. Widmann, J. Zmeskal
The VIP Experimental Limit on the Pauli Exclusion Principle Violation by Electrons
Foundations of Physics **40**, 765 (2010).

M. Cargnelli, M. Bazzi, G. Beer, L. Bombelli, A.M. Bragadireanu, C. Curceanu Petrascu, C. Fiorini, T. Frizzi, F. Ghio, B. Girolami, C. Guaraldo, R. Hayano, M. Iliescu, T. Ishiwatari, M. Iwasaki, P. Kienle, P. Lechner, P. Levi Sandri, A. Longoni, V. Lucherini, et al.
Kaonic atoms studies at DAFNE by the SIDDHARTA experiment
Nuclear Physics A **835**, 27 (2010).

M. Maggiora, P. Kienle, K. Suzuki, T. Yamazaki, M. Alexeev, A. Amoroso, F. Balestra, Y. Bedfer, R. Bertini, L.C. Bland, A. Brenschede, F. Brochard, M.P. Bussa, S. Choi, M.L. Colantoni, R. Dressler, M. Dzemidzic, J.Cl. Faivre, L. Ferrero, J. Foryciarz, I. Frohlich, V. Frolov, R. Garfagnini, A. Grasso, S. Heinz, W.W. Jacobs, W. Kuhn, A. Maggiora, D. Panzieri, S. Sosio, H.W. Pfaff, G. Pontecorvo, A. Popov, J. Ritman, P. Salabura, V. Tchalyshev, S.E. Vigdor
DISTO data on K^-pp
Nuclear Physics A **835**, 43 (2010).

J. Zmeskal, M. Bazzi, M. Bragadireanu, P. Buhler, M. Cargnelli, C. Curceanu, F. Ghio, C. Guaraldo, M. Iliescu, T. Ishiwatari, P. Kienle, P. Levi Sandri, J. Marton, P. Mullner, K. Suzuki, S. Okada, D. Pietreanu, M. Poli Lener, A. Rizzo, O. Vazquez Doce, A. Romero Vidal, A. Scordo, F. Sirghi, D. Sirghi, A. d'Ufizzi, E. Widmann, B. Wunschek
The AMADEUS experiment - precision measurements of low-energy antikaon nucleus/nucleon interactions
Nuclear Physics A **835**, 410 (2010).

M. Poli Lener, G. Corradi, C. Curceneau, A. Romero Vidal, A. Rizzo, D. Tagnani, J. Zmeskal
Performances of a GEM-based TPC prototype for new high-rate particle experiments
Nuclear Instruments and Methods in Physics Research Section A **617**, 183 (2010).

R. Münzer, L. Fabbietti, M. Berger, O. Hartmann
SiΛViO: A trigger for Λ-Hyperons
Nuclear Instruments and Methods in Physics Research Section A **617**, 300 (2010).

M. Bazzi, G. Beer, L. Bombelli, A.M. Bragadireanu, M. Cargnelli, G. Corradi, C. Curceanu (Petrascu), A. d'Uffizi, C. Fiorini, T. Frizzi, F. Ghio, B. Girolami, C. Guaraldo, R.S. Hayano, M. Iliescu, T. Ishiwatari, M. Iwasaki, P. Kienle, P. Levi Sandri, A. Longoni, V. Lucherini, J. Marton, S. Okada, D. Pietreanu, T. Ponta, A. Rizzo, A. Romero Vidal, A. Scordo, H. Shi, D.L. Sirghi, F. Sirghi, H. Tatsuno, A. Tudorache, V. Tudorache, O. Vazquez Doce, E. Widmann, J. Zmeskal
Performance of silicon-drift detectors in kaonic atom X-ray measurements
Nuclear Instruments and Methods in Physics Research Section A **628**, 264 (2010).

X. Lopez, N. Herrmann, K. Piasecki, A. Andronic, V. Barret, Z. Basrak, N. Bastid, M. L. Benabderrahmane, P. Buehler, M. Cargnelli, R. Čaplar, P. Crochet, P. Dupieux, M. Dželalija, L. Fabbietti, I. Fijał-Kirejczyk, Z. Fodor, P. Gasik, I. Gašparić, Y. Grishkin, O. N. Hartmann, K. D. Hildenbrand, B. Hong, T. I. Kang, J. Kecskemeti, M. Kirejczyk, Y. J. Kim, M. Kiš, P. Koczon, M. Korolija, R. Kotte, A. Lebedev, Y. Leifels, V. Manko, J. Marton, T. Matulewicz, M. Merschmeyer, W. Neubert, D. Pelte, M. Petrovici, F. Rami, W. Reisdorf, M. S. Ryu, P. Schmidt, A. Schüttauf, Z. Seres, B. Sikora, K. S. Sim, V. Simion, K. Siwek-Wilczyńska, V. Smolyankin, K. Suzuki, Z. Tyminski, P. Wagner, E. Widmann, K. Wiśniewski, Z. G. Xiao, I. Yushmanov, X. Y. Zhang, A. Zhilin, J. Zmeskal, P. Kienle, T. Yamazaki
Measurement of $K^*(892)^0$ and K^0 mesons in Al+Al collisions at 1.9A GeV
Physical Review C **81**, 061902 (2010).

T. Yamazaki, M. Maggiora, P. Kienle, K. Suzuki, A. Amoroso, M. Alexeev, F. Balestra, Y. Bedfer, R. Bertini, L. C. Bland, A. Brenschede, F. Brochard, M. P. Bussa, Seonho Choi, M. L. Colantoni, R. Dressler, M. Dzemidzic, J.-Cl. Faivre, L. Ferrero, J. Foryciarz, I. Fröhlich, V. Frolov, R. Garfagnini, A. Grasso, S. Heinz, W. W. Jacobs, W. Kühn, A. Maggiora, D. Panzieri, H.-W. Pfaff, G. Pontecorvo, A. Popov, J. Ritman, P. Salabura, S. Sosio, V. Tchalyshev, S. E. Vigdor
Indication of a Deeply Bound and Compact K^-pp State Formed in the $pp \to p\Lambda K^+$ Reaction at 2.85 GeV
Physical Review Letters **104**, 132502 (2010).

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Precision Determination of the $d\pi$-NN Transition Strength at Threshold
Physical Review Letters **104**, 142503 (2010).

Y. Enomoto, N. Kuroda, K. Michishio, C. H. Kim, H. Higaki, Y. Nagata, Y. Kanai, H. A. Torii, M. Corradini, M. Leali, E. Lodi-Rizzini, V. Mascagna, L. Venturelli, N. Zurlo, K. Fujii, M. Ohtsuka, K. Tanaka, H. Imao, Y. Nagashima, Y. Matsuda, B. Juhász, A. Mohri, Y. Yamazaki
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Physical Review Letters **105**, 243401 (2010).

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Search for strange tribaryons in the ^{4}He(K-stop,nπ^{+-}) reaction
Physics Letters B **688**, 43 (2010).

E. Widmann
Precision Physics with Low-energy Antiprotons - from AD to FLAIR
Acta Physica Polonica B **41**, 249 (2010).

P. Bühler, C. Curceanu, C. Guaraldo, O. Hartmann, K. Hicks, M. Iwasaki, T. Ishiwatari, P. Kienle, J. Marton, R. Muto, M. Niiyama, H. Noumi, H. Ohnishi, S. Okada, A. Romero Vidal, A. Sakaguchi, F. Sakuma, S. Sawada, D. Sirghi, F. Sirghi, K. Suzuki, K. Tsukada, D. J. Tedeschi, O. Vazquez Doce, E. Widmann, S. Yokkaichi and J. Zmeskal (J-PARC P29 Collaboration)
Search for φ-Meson Nuclear Bound States in the pbar + AZ $\to\varphi$+ A-1φ(Z-1) Reaction
Progress of Theoretical Physics Supplement **186**, 337 (2010).

K. Suzuki, M. Berger (for FOPI Collaboration)
Search for a Kaonic Nuclear Bound State at FOPI
Progress of Theoretical Physics Supplement **186**, 351 (2010).

C. Schwarz, G. Ahmed, A. Britting, P. Bühler, E. Cowie, V.Kh. Dodokhov, M. Düren, D. Dutta, W. Eyrich, K. Föhl, D.I. Glazier, A. Hayrapetyan, M. Hoek, R. Hohler, A. Lehmann, D. Lehmann, R. Kaiser, T. Keri, P. Koch, B. Kröck, J. Marton, O. Merle, R. Montgomery, K. Peters, S. Reinicke, G. Rosner, B. Roy, G. Schepers, L. Schmitt, J. Schwiening, B. Seitz, C. Sfienti, K. Suzuki, F. Uhlig, A.S. Vodopianov, D.P. Watts, W. Yu
Particle identification for the PANDA detector
Nuclear Instruments and Methods in Physics Research Section A, in press (2010).

2.7.2. Longer publications in non-peer-reviewed journals or collections

C. Curceanu (Petrascu), S. Bartalucci, S. Bertolucci, M. Bragadireanu, M. Cargnelli, et al.
New experimental limit on the Pauli Exclusion Principle violation by electrons—the VIP experiment
AIP conference proceedings **1232**, 206 (2010).

T. Ishiwatari, M. Bazzi, H. Bhang, G. Beer, L. Bombelli, A. M. Bragadireanu, M. Cargnelli, S. Choi, G. Corradi, C. Curceanu, A. d'Uffizi, S. Enomoto, C. Fiorini, T. Frizzi, H. Fujioka, Y. Fujiwara, F. Ghio, B. Girolami, C. Guaraldo, T. Hashimoto, R. S. Hayano, T. Hiraiwa, M. Iio, M. Iliescu, S. Ishimoto, K. Itahashi, M. Iwasaki, P. Kienle, H. Kou, P. Levi Sandri, A. Longoni, V. Lucherini, J. Marton, Y. Matsuda, H. Noumi, H. Ohnishi, S. Okada, H. Outa, D. Pietreanu, T. Ponta, A. Rizzo, A. Romero Vidal, F. Sakuma, M. Sato, A. Scordo, M. Sekimoto,H. Shi, D. L. Sirghi, F. Sirghi, T. Suzuki, K. Tanida, H. Tatsuno, M. Tokuda, D. Tomono, A. Toyoda, K. Tsukada, A. Tudorache, V. Tudorache, O. Vazquez Doce, E. Widmann, B. Wunschek, T. Yamazaki, J. Zmeskal
Precision spectroscopy of Kaonic helium-3 and helium-4 3d-2p X-rays
AIP conference proceedings **1257**, 765 (2010).

T. Ishiwatari, M. Bazzi, G. Beer, L. Bombelli, A. M. Bragadireanu, M. Cargnelli, G. Corradi, C. Curceanu (Petrascu), A. d'Uffizi, C. Fiorini, T. Frizzi, F. Ghio, B. Girolami, C. Guaraldo, R. S. Hayanoll, M. Iliescu, M. Iwasaki, P. Kienle, P. Levi Sandri, A. Longoni, V. Lucherini, J. Marton, S. Okada, D. Pietreanu, T. Ponta, A. Rizzo, A. Romero Vidal, A. Scordo, H. Shi, D. L. Sirghi, F. Sirghi, H. Tatsuno, A. Tudorache, V. Tudorache, O. Vazquez Doce, E. Widmann, J. Zmeskal
Precision spectroscopy of light kaonic atom X-rays in the SIDDHARTA experiment
AIP conference proceedings **1322**, 468 (2010).

T. Ishiwatari, M. Bazzi, G. Beer, L. Bombelli, A. M. Bragadireanu, M. Cargnelli, G. Corradi, C. Curceanu (Petrascu), A. d'Uffizi, C. Fiorini, T. Frizzi, F. Ghio, B. Girolami, C. Guaraldo, R. S. Hayanoll, M. Iliescu, M. Iwasaki, P. Kienle, P. Levi Sandri, A. Longoni, V. Lucherini, J. Marton, S. Okada, D. Pietreanu, T. Ponta, A. Rizzo, A. Romero Vidal, A. Scordo, H. Shi, D. L. Sirghi, F. Sirghi, H. Tatsuno, A. Tudorache, V. Tudorache, O. Vazquez Doce, E. Widmann, J. Zmeskal
Precision spectroscopy of light kaonic atom X-rays in the SIDDHARTA experiment
AIP conference proceedings **1322**, 468 (2010).

2.7.3. Keynote scientific talks

E. Widmann: *Flair und Antiprotonen I*
E. Widmann: *Flair und Antiprotonen II*
E. Widmann: *Flair und Antiprotonen III*
Arbeitstreffen Kernphysik, Schleching/GERMANY

E. Widmann: *Antimatter at CERN AD and the measurement of fundamental constants*
Joint European and National Meeting JENAM 2010, Lisbon/PORTUGAL

E. Widmann: *FLAIR*
Symposium on Ring Physics at FAIR, NUSTAR week, Lund/SWEDEN

J. Zmeskal: *Recent results and future plans for AMADEUS*
MESON 2010/POLAND

2.7.4. Invited scientific talks

P. Buehler: *Grid computing for PANDA*
Tier-2 WLCG Workshop/AUSTRIA

P. Buehler: *Measurement of the J/Psi-nucleon dissociation cross section with PANDA*
Seminar IKP I, FZ Juelich/GERMANY

O. Hartmann: *Status of T8 work package*
LEANNIS meeting, Frascati/ITALY

O. Hartmann: *Hadron Physics with Strange and Charmed Quarks - The PANDA Experiment*
HQL10/ITALY

O. Hartmann: *Kernphysik mit Antiprotonen*
Arbeitstreffen Kernphysik Schleching/GERMANY

T. Ishiwatari: *Kaonic Helium 3 and 4 - analysis of SIDDHARTA data*
ECT* Strangeness in Nuclei/ITALY

T. Ishiwatari: *KHe analysis and future plans*
LEANNIS meeting, Frascati/ITALY

B. Juhasz: *Testing the CPT symmetry with antimatter: ASACUSA collaboration at CERN*
SMI Seminar/AUSTRIA

J. Marton: *Status of the HP2-LEANNIS Network and LEANNIS2 in HP3*
ECT*, Trento/ITALY

J. Marton: *A renaissance of hadron spectroscopy at FAIR*
Institutsseminar (Technische Universität Wien, Atominstitut), Wien/AUSTRIA

K. Suzuki: *Double resonance structure in p-Lambda and Lambda-K+ in the formation of a K-pp state in the pp->pLambda*
ECT* Strangeness in Nuclei/ITALY

K. Suzuki: *DISTO Data Analysis*
LEANNIS meeting/ITALY

K. Suzuki: *pp->pLambdaK reaction in search for K-pp, quest for kaonic nuclei*
Baryon 2010/JAPAN

K. Suzuki: *Experimental search for the kaonic nuclear state, K-pp with FOPI*
MESON 2010/POLAND

K. Suzuki: *Kaonic nuclei search, status and future*
Seminar at Tokyo Institute of Technology/JAPAN

E. Widmann: *Formation and Spectroscopy of Antihydrogen - Studying Fundamental Symmetries with Atomic Physics Techniques*
Grazer Physikalisches Kolloquium/AUSTRIA

E. Widmann: *The antihydrogen program at CERN and advances in making cold antihydrogen*
SPARC 2010, Lanzhou/CHINA

J. Zmeskal: *Antikaon Nucleon/Nucleus Interaction – Experiments*
INPC 2010/CANADA

J. Zmeskal: *The AMADEUS Experiment at DAFNE*
ECT*, Trento/ITALY

J. Zmeskal: *SIDDHARTA – DUE and AMADEUS*
LEANNIS Meeting/ITALY

2.7.5. Other scientific talks

G. Ahmed: *SiPM timing performance systematic study*
FP7 meeting, Geiger-mode Avalanche photo diodes/ITALY

G. Ahmed: *Silicon Photomultiplier for Subatomic Physics Experiments - Performance Studies at SMI*
OEPG 2010, Salzburg/AUSTRIA

G. Ahmed: *Study of timing performance of Silicon Photomultiplier and application for a Cherenkov detector*
12th Vienna Conference on Instrumentation - VCI 2010/AUSTRIA

G. Ahmed: *Study of timing performance of Silicon Photomultiplier and application for a Cherenkov detector*
MAPD 2010, Prag/CZECH REPUBLIC

P. Buehler: *GRID activities at SMI*
GRID miniworkshop/AUSTRIA

P. Buehler: *Measurement of the J/Psi - Nucleon dissociation cross section with PANDA*
DPG Fruehjahrstagung, 2010 (Universitaet Bonn), Bonn/GERMANY

P. Buehler: *Analysis of experiment E078, May 2010 run*
Experiment meeting E078/GERMANY

M. Cargnelli: *Precision spectroscopy of light kaonic atom X-rays in the SIDDHARTA experiment*
MENU 2010/UNITED STATES

S. Friedreich: *Hyperfine structure spectroscopy with antiprotonic helium*
OEPG 2010/AUSTRIA

S. Friedreich: *Spectroscopy of Antiprotonic ^{3}He and ^{4}He*
TCP 2010, Saariselkae/FINLAND

S. Friedreich: *Spectroscopy with Antiprotons in 3He - Beamtime Request 2011*
ASACUSA Collaboration meeting, Geneva/SWITZERLAND

A. Gruber: *Dimensions of IP-cross revisited*
XXXV. PANDA Collaboration meeting, GSI, Darmstadt/GERMANY

A. Gruber: *PANDA: Target induced gas flow and vacuum*
FP7 FutureJet Meeting – Status and future plans for HP3, GSI, Darmstadt/GERMANY

O. Hartmann: *Hadron Beams on Nuclear Targets*
1st FLUKA Advanced Course and Workshop/PORTUGAL

O. Hartmann: *FLUKA as pbar A background generator*
XXXII PANDA collaboration meeting (GSI, Darmstadt), Darmstadt/GERMANY

O. Hartmann: *The FOPI Experiment at GSI-SIS*
OEPG 2010/AUSTRIA

O. Hartmann: *Outreach nell ambito di fisica sub-atomica in Austria*
Communicare Fisica 2010/ITALY

O. Hartmann: *Strangeness Production in Hadron Collisions*
FOPI collaboration meeting/GERMANY

T. Ishiwatari: *Kaonic atom experiment at DAFNE*
Strangeness Nuclear Physics 2010, KEK/JAPAN

T. Ishiwatari: *Performance of Silicon-Drift Detectors in kaonic atom X-ray measurements*
VCI 2010, Vienna/AUSTRIA

T. Ishiwatari: *Precision spectroscopy of light kaonic atom X-rays in the SIDDHARTA experiment*
CHIRAL 10/SPAIN

B. Juhasz*: Measurement of the ground state hyperfine splitting of antihydrogen*
Nordic winter meeting on FAIR, Björkliden/SWEDEN

B. Juhasz: *Precision laser spectroscopy of antiprotonic helium*
PSAS 2010, Les Houches/FRANCE

B. Juhasz: *Measurement of the ground state hyperfine splitting of antihydrogen*
PSI2010, PSI/SWITZERLAND

B. Juhasz: *Antihydrogen beamline: Status*
ASACUSA MUSASHI group meeting, Tokyo/JAPAN

B. Juhasz: *Antihydrogen beamline: Status*
ASACUSA collaboration meeting, CERN/SWITZERLAND

B. Juhasz: *Measurement of the ground state hyperfine splitting of antihydrogen*
DISCRETE 2010, Rome/ITALY

J. Marton: *Testing the Pauli Exclusion Principle for Electrons*
DISCRETE 10, Rome/ITALY

J. Marton: *LEANNIS Status and Perspectives*
LEANNIS Meeting, Frascati/ITALY

J. Marton: *LEANNIS Status*
LEANNIS Meeting, Frascati/ITALY

J. Marton: *A high sensitivity test of the Pauli Exclusion Principle for electrons*
AQT – Advances in Quantum Theory/SWEDEN

O. Massiczek: *A new cryogenic target and microwave cavity for hyperfine spectroscopy of antiprotonic helium*
OEPG 2010/AUSTRIA

K. Suzuki: *Status of kaonic nuclear state search at FOPI using proton induced reaction*
New Frontiers in QCD 2010, Kyoto/JAPAN

K. Suzuki: *Time calibration of S349 experiment*
FOPI collaboration meeting/GERMANY

B. Wuenschek: *Status and plans of experiment E17 at J-PARC*
OEPG 2010/AUSTRIA

B. Wuenschek: *Status and plans of experiment E17 at J-PARC*
MESON 2010, Krakow/POLAND

2.7.6. Poster presentations

T. Ishiwatari: *Performance of Silicon-Drift Detectors in kaonic atom X-ray measurements*
Vienna Conference on Instrumentation 2010/AUSTRIA

J. Marton, G. Ahmed, P. Buehler, K. Suzuki: *Characterization and application of Geiger-mode silicon photosensors in radiation detection*

Symposium on Radiation Measurements and Applications (SORMA 2010), University of Michigan, Ann Arbor, Michigan/UNITED STATES

J. Marton: *Application of Geiger-mode Photo Sensors in Cherenkov Detectors*
RICH 2010/FRANCE

P. Muellner: *GEM detector development for hadron-physics experiments*
OEPG 2010, Innsbruck/AUSTRIA

2.7.7. Edited publications

Proceedings of the International Conference on Exotic Atoms and Related Topics and International Conference on Low Energy Antiproton Physics (Springer)
Editors: B. Juhász, J. Marton, K. Suzuki, E. Widmann, J. Zmeskal

Perspectives of Nuclear Physics in Europe – NuPECC Long Range Plan 2010 (European Science Foundation)
Editors: A. Bracco, P. Chomaz, J. Gardehoe, P. Heenen, E. Widmann, G.-E. Körner

2.8. Scientific cooperation 2010

2.8.1. External partners in research programs

Andrzej Soltan Institute for Nuclear Studies, Warsaw, POLAND
FS3_e: FLAIR: Facility for Low-Energy Antiproton and Ion Research

Atomic Physics Laboratory, RIKEN, Saitama, JAPAN
FS1_f: Study of kaon-nucleon interaction @ J-PARC
FS2_d: Measurement of the ground-state hyperfine structure of antihydrogen
FS3_e: FLAIR: Facility for Low-Energy Antiproton and Ion Research

Atominstitut der Österreichischen Universitäten, Wien, AUSTRIA
X: Doktoratskolleg+ PI (DK-Plus)

BINP - Budker Institute of Nuclear Physics, Novosibirsk, Novosibirsk, RUSSIAN FEDERATION
FS3_b: PANDA: Proton Antiproton Annihilations at Darmstadt

CERN – European Organization for Nuclear Research / Laboratory for Particle Physics, Geneva, SWITZERLAND
FS2_b: Hyperfine structure of antiprotonic helium
FS2_c: Precision laser spectroscopy of antiprotonic helium
FS2_d: Measurement of the ground-state hyperfine structure of antihydrogen

D.I. Mendeleev Institute for Metrology (VNIIM), St. Petersburg, RUSSIAN FEDERATION
FS3_e: FLAIR: Facility for Low-Energy Antiproton and Ion Research

Department for Physics and Astronomy, Aarhus University, Aarhus, DENMARK
FS2_d: Measurement of the ground-state hyperfine structure of antihydrogen
FS3_e: FLAIR: Facility for Low-Energy Antiproton and Ion Research

Department of Atomic Physics, Stockholm University, Stockholm, SWEDEN
FS3_e: FLAIR: Facility for Low-Energy Antiproton and Ion Research

Department of Experimental Physics, University of Debrecen, Debrecen, HUNGARY
FS3_e: FLAIR: Facility for Low-Energy Antiproton and Ion Research

Department of Physics and Astronomy, York University, Toronto, CANADA
FS3_e: FLAIR: Facility for Low-Energy Antiproton and Ion Research

Department of Physics, Harvard University, Cambridge, Massachusetts, UNITED STATES
FS3_e: FLAIR: Facility for Low-Energy Antiproton and Ion Research

Department of Physics, St. Petersburg State University, St. Petersburg, RUSSIAN FEDERATION
FS3_e: FLAIR: Facility for Low-Energy Antiproton and Ion Research

Department of Physics, Stockholm University, Stockholm, SWEDEN
FS3_b: PANDA: Proton Antiproton Annihilations at Darmstadt

Department of Physics, Texas A&M University, College Station, Texas, UNITED STATES
FS3_e: FLAIR: Facility for Low-Energy Antiproton and Ion Research

Department of Physics, University of Tokyo, Tokyo, JAPAN
FS2_b: Hyperfine structure of antiprotonic helium
FS2_c: Precision laser spectroscopy of antiprotonic helium
FS2_d: Measurement of the ground-state hyperfine structure of antihydrogen
FS3_e: FLAIR: Facility for Low-Energy Antiproton and Ion Research

Department of Physics, University of Wales Swansea, Swansea, UNITED KINGDOM
FS2_d: Measurement of the ground-state hyperfine structure of antihydrogen
FS3_e: FLAIR: Facility for Low-Energy Antiproton and Ion Research

Dipartimento di Chimica e Fisica per l'Ingegneria e per i Materiali, Brescia, ITALY
FS2_d: Measurement of the ground-state hyperfine structure of antihydrogen
FS3_e: FLAIR: Facility for Low-Energy Antiproton and Ion Research

Dipartimento di Fisica, Laboratorio LENS, INFN, Universita’ degli Studi di Firenze, Florence, ITALY
FS3_e: FLAIR: Facility for Low-Energy Antiproton and Ion Research

Dipartimento di Fisica, Univ. di Trieste und INFN Trieste, Triest, ITALY
FS3_b: PANDA: Proton Antiproton Annihilations at Darmstadt

Dipartimento di Fisica, Università degli Studi di Milano e Sezione di Milano, INFN, Mailand, ITALY
FS3_b: PANDA: Proton Antiproton Annihilations at Darmstadt

FOM Institute for Atomic and Molecular Physics, Amsterdam, NETHERLANDS
FS3_e: FLAIR: Facility for Low-Energy Antiproton and Ion Research

Forschungszentrum Jülich GmbH, Jülich, GERMANY
FS3_b: PANDA: Proton Antiproton Annihilations at Darmstadt
FS3_e: FLAIR: Facility for Low-Energy Antiproton and Ion Research
FS4_d: PANDA Grid

GSI – Gesellschaft für Schwerionenforschung mbH, Darmstadt, GERMANY
FS1_c: Strangeness physics with FOPI at GSI
FS3_b: PANDA: Proton Antiproton Annihilations at Darmstadt
FS3_c: Hadrons in medium
FS3_d: Hadron spectroscopy
FS4_b: SiPM
FS4_d: PANDA Grid
O: Two-body decays of stored and cooled ions

Heavy Ion Laboratory, Warsaw University, Warsaw, POLAND
FS3_e: FLAIR: Facility for Low-Energy Antiproton and Ion Research

IFIC - Instituto de Fisica Corpuscular Edificio Institutos de Investigacion, Valencia, SPAIN
FS3_b: PANDA: Proton Antiproton Annihilations at Darmstadt

INFN, Laboratori Nazionali di Frascati, Frascati, ITALY
FS1_e: AMADEUS at DAPHNE2
FS3_b: PANDA: Proton Antiproton Annihilations at Darmstadt

Indiana University, Bloomington, Indiana, UNITED STATES
FS3_e: FLAIR: Facility for Low-Energy Antiproton and Ion Research

Institute of Nuclear Research (ATOMKI) of the Hungarian Academy of Sciences, Debrecen, HUNGARY
FS2_b: Hyperfine structure of antiprotonic helium
FS2_c: Precision laser spectroscopy of antiprotonic helium
FS2_d: Measurement of the ground-state hyperfine structure of antihydrogen
FS3_e: FLAIR: Facility for Low-Energy Antiproton and Ion Research

Institut für Angewandte Physik, Universität Frankfurt, Frankfurt, GERMANY
FS3_e: FLAIR: Facility for Low-Energy Antiproton and Ion Research

Institut für Kernchemie, Universität Mainz, Mainz, GERMANY
FS3_e: FLAIR: Facility for Low-Energy Antiproton and Ion Research

Institut für Kernphysik, Universität Frankfurt, Frankfurt, GERMANY
FS3_e: FLAIR: Facility for Low-Energy Antiproton and Ion Research
X: Probing Strongly Interacting Matter with Antiprotons and Ions

Institut für Kernphysik, Universität Gießen, Gießen, GERMANY
FS3_e: FLAIR: Facility for Low-Energy Antiproton and Ion Research

Institut für Physik, Humboldt-Universität zu Berlin, Berlin, GERMANY
FS3_e: FLAIR: Facility for Low-Energy Antiproton and Ion Research

Institut für Physik, Universität Mainz, Mainz, GERMANY
FS3_e: FLAIR: Facility for Low-Energy Antiproton and Ion Research

Institut für Theoretische Physik, TU Dresden, Dresden, GERMANY
FS3_e: FLAIR: Facility for Low-Energy Antiproton and Ion Research

Institut für Theoretische Physik, Wien, AUSTRIA
FS3_e: FLAIR: Facility for Low-Energy Antiproton and Ion Research

Institute for Experimental and Theoretical Physics, Moscow, RUSSIAN FEDERATION
FS3_e: FLAIR: Facility for Low-Energy Antiproton and Ion Research

Institute for Storage Ring Facilities (ISA), Aarhus, DENMARK
FS2_d: Measurement of the ground-state hyperfine structure of antihydrogen
FS3_e: FLAIR: Facility for Low-Energy Antiproton and Ion Research

Institute of High Energy Physics, Chinese Academy of Sciences, Beijing, CHINA
FS3_b: PANDA: Proton Antiproton Annihilations at Darmstadt

Institute of Nuclear Physics, Moscow State University, Moscow, RUSSIAN FEDERATION
FS3_b: FLAIR: Facility for Low-Energy Antiproton and Ion Research

Institute of Physics, University of Tokyo, Tokyo, JAPAN
FS2_b_A: Hyperfine structure of antiprotonic helium
FS2_c: Precision laser spectroscopy of antiprotonic helium
FS2_d: Measurement of the ground-state hyperfine structure of antihydrogen
FS3_e: FLAIR: Facility for Low-Energy Antiproton and Ion Research

Institute of Spectroscopy of the Russian Academy of Sience, Troitsk, Troitsk, RUSSIAN FEDERATION
FS3_e: FLAIR: Facility for Low-Energy Antiproton and Ion Research

Institute of Theoretical Physics, Warsaw University, Warsaw, POLAND
FS3_e: FLAIR: Facility for Low-Energy Antiproton and Ion Research

Istituto Nazionale di Fisica Nucleare – INFN, Genoa, ITALY
FS3_b: PANDA: Proton Antiproton Annihilations at Darmstadt
FS3_e: FLAIR: Facility for Low-Energy Antiproton and Ion Research

Istituto Nazionale di Fisica Nucleare Sezione di Ferrara (INFN), Ferrara, ITALY
FS3_b: PANDA: Proton Antiproton Annihilations at Darmstadt

J-PARC, Tokai-Mura, JAPAN
FS1_g: Precision spectroscopy of Kaonic He-3 (FWF Project)

JINR - Joint Institute for Nuclear Research, Dubna, RUSSIAN FEDERATION
FS3_b: PANDA: Proton Antiproton Annihilations at Darmstadt
FS3_e: FLAIR: Facility for Low-Energy Antiproton and Ion Research
Y: Hyperfine structure of antiprotonic helium (FWF)

KEK, High Energy Accelerator Research Organization, Tokyo, JAPAN
FS1_f: Study of kaon-nucleon interaction @ J-PARC

KFKI Research Institute for Particle and Nuclear Physics, Hungarian Academy of Sciences, Budapest, HUNGARY
FS2_b: Hyperfine structure of antiprotonic helium
FS2_c: Precision laser spectroscopy of antiprotonic helium
FS2_d: Measurement of the ground-state hyperfine structure of antihydrogen
FS3_e: FLAIR: Facility for Low-Energy Antiproton and Ion Research

KVI Kroningen, Kroningen, NETHERLANDS
FS3_b: PANDA: Proton Antiproton Annihilations at Darmstadt
FS4_d: PANDA Grid

LANL Los Alamos USA, Los Alamos, UNITED STATES
FS3_b: PANDA: Proton Antiproton Annihilations at Darmstadt

Laboratoire Kastler-Brossel, École Normale Supérieure et Univ. Pierre et Marie Curie, Paris, FRANCE
FS3_e: FLAIR: Facility for Low-Energy Antiproton and Ion Research

Laser Centre Vrije Universiteit, Faculty of Science, Amsterdam, NETHERLANDS
FS3_e: FLAIR: Facility for Low-Energy Antiproton and Ion Research

Manne Siegbahn Laboratory (MSL), Stockholm, SWEDEN
FS3_e: FLAIR: Facility for Low-Energy Antiproton and Ion Research

Massachusetts Institute of Technology, Duke University, North Carolina, UNITED STATES
FS3_e: FLAIR: Facility for Low-Energy Antiproton and Ion Research

Max-Planck-Institut für Kernphysik, Heidelberg, GERMANY
FS2_d: Measurement of the ground-state hyperfine structure of antihydrogen
FS3_e: FLAIR: Facility for Low-Energy Antiproton and Ion Research

Max-Planck-Institut für Quantenoptik, Garching, GERMANY
FS2_c: Precision laser spectroscopy of antiprotonic helium

Niels Bohr Institute, Copenhagen, DENMARK
FS2_d: Measurement of the ground-state hyperfine structure of antihydrogen

Northwestern Univ. Evanston, Evanston, UNITED STATES
FS3_b: PANDA: Proton Antiproton Annihilations at Darmstadt

Osaka E-C, Osaka, JAPAN
FS1_f: Study of kaon-nucleon interaction @ J-PARC

Osaka University, Osaka, JAPAN
FS1_f: Study of kaon-nucleon interaction @ J-PARC

Politechnico Torino, Turin, ITALY
FS3_b: PANDA: Proton Antiproton Annihilations at Darmstadt

Queens University, Belfast, IRELAND
FS2_d: Measurement of the ground-state hyperfine structure of antihydrogen
FS3_e: FLAIR: Facility for Low-Energy Antiproton and Ion Research

RIKEN NISHINA Center for Accelerator-Based Science, Wako, JAPAN
X: Isospin dependence of the kaon-nucleus interaction

Ruhr-Universität Bochum, Bochum, GERMANY
FS3_b: PANDA: Proton Antiproton Annihilations at Darmstadt

SINS, Warsaw, POLAND
FS3_b: PANDA: Proton Antiproton Annihilations at Darmstadt

Seoul National Univsersity, Seoul, REPUBLIC OF KOREA
FS1_f: Study of kaon-nucleon interaction @ J-PARC

St. Petersburg Nuclear Physics Institute (PNPI), St. Petersburg, RUSSIAN FEDERATION
FS3_b: PANDA: Proton Antiproton Annihilations at Darmstadt
FS3_e: FLAIR: Facility for Low-Energy Antiproton and Ion Research

TRIUMF, Vancouver, Vancouver, CANADA
FS3_e: FLAIR: Facility for Low-Energy Antiproton and Ion Research

TSL – The Svedberg Laboratory Uppsala, Uppsala, SWEDEN
FS3_b: PANDA: Proton Antiproton Annihilations at Darmstadt

Technische Universität Dresden, Dresden, GERMANY
FS3_b: PANDA: Proton Antiproton Annihilations at Darmstadt

Technische Universität München, Munich, GERMANY
FS1_c: Deeply bound kaonic nuclei with FOPI at GSI
FS1_d: DISTO data analysis
FS3_b: PANDA: Proton Antiproton Annihilations at Darmstadt

Temple University, Philadelphia, UNITED STATES
FS1_f: Study of kaon-nucleon interaction @ J-PARC

University Brescia, Brescia, ITALY
FS3_b: PANDA: Proton Antiproton Annihilations at Darmstadt

University Cracow, Cracow, POLAND
FS3_b: PANDA: Proton Antiproton Annihilations at Darmstadt

University Frankfurt, Frankfurt, GERMANY
FS3_b: PANDA: Proton Antiproton Annihilations at Darmstadt

University Silesia, Silesia, POLAND
FS3_b: PANDA: Proton Antiproton Annihilations at Darmstadt

Università di Torino, Turin, ITALY
FS1_d: DISTO data analysis
FS3_b: PANDA: Proton Antiproton Annihilations at Darmstadt

Universität Basel, Basel, SWITZERLAND
FS3_b: PANDA: Proton Antiproton Annihilations at Darmstadt

University Edinburgh, Edinburgh, UNITED KINGDOM
FS3_b: PANDA: Proton Antiproton Annihilations at Darmstadt

University Glasgow, Glasgow, UNITED KINGDOM
FS3_b: PANDA: Proton Antiproton Annihilations at Darmstadt
FS4_d: PANDA Grid

University of Helsinki - Helsinki Institute of Physics, Helsinki, FINLAND
FS3_b: PANDA: Proton Antiproton Annihilations at Darmstadt

University of New Mexico, Albuquerque, New Mexiko, UNITED STATES
FS3_e: FLAIR: Facility for Low-Energy Antiproton and Ion Research

University of Tokyo, Tokyo, JAPAN
FS1_d: DISTO data analysis
FS1_f: Study of kaon-nucleon interaction @ J-PARC

Università degli Studi di Trieste; Triest, ITALY
FS3_b: PANDA: Proton Antiproton Annihilations at Darmstadt

Università di Catania, Catania, ITALY
FS3_b: PANDA: Proton Antiproton Annihilations at Darmstadt

Università di Genova, Genoa, ITALY
FS3_b: PANDA: Proton Antiproton Annihilations at Darmstadt

Università di Pavia, Pavia, ITALY
FS3_b: PANDA: Proton Antiproton Annihilations at Darmstadt

Universität Bonn, Bonn, GERMANY
FS3_b: PANDA: Proton Antiproton Annihilations at Darmstadt

Universität Erlangen, Erlangen, GERMANY
FS3_b: PANDA: Proton Antiproton Annihilations at Darmstadt

Universität Gießen, Gießen, GERMANY
FS3_b: PANDA: Proton Antiproton Annihilations at Darmstadt

Universität Heidelberg, Heidelberg, GERMANY
FS1_c: Deeply bound kaonic nuclei with FOPI at GSI

Universität Mainz, Mainz, GERMANY
FS3_b: PANDA: Proton Antiproton Annihilations at Darmstadt

Universität Münster, Münster, GERMANY
FS3_b: PANDA: Proton Antiproton Annihilations at Darmstadt

Universität Tübingen, Tübingen, GERMANY
FS3_b: PANDA: Proton Antiproton Annihilations at Darmstadt

Universität Wien, Institut für Theoretische Physik, Wien, AUSTRIA
X: Probing Strongly Interacting Matter with Antiprotons and Ions

Uppsala University, Uppsala, SWEDEN
FS3_b: PANDA: Proton Antiproton Annihilations at Darmstadt

Variable Energy Cyclotron Center, Kolkata, Kolkata, INDIA
FS3_e: FLAIR: Facility for Low-Energy Antiproton and Ion Research

2.9. Conference organization 2010

2.9.1. 100th Anniversary of the Institute for Radium Research, Austrian Academy of Sciences, Vienna

A century ago, in 1910, the Institut für Radiumforschung of the Kaiserliche Akademie der Wissenschaften in Vienna was inaugurated. It represented the first institute for research in the new field of radioactivity and the Austrian counterpart to other famous research centres like the Cavendish Laboratory in Manchester, the Radium Institute in Paris and the Kaiser Wilhelm Institut in Berlin. The institute was lead by Stefan Meyer, a pioneer of radioactivity research, from the beginning.

Before the availability of particle accelerators the element radium was the only source of particle (alpha) radiation. The extraction of radium from pitch blend was extremely difficult and painstaking and required near-industrial methods. It can be seen as the starting point of a new era of experimental research in physics using particle radiation.

The institute started the operation in the building Boltzmanngasse 3 built in 1910 in the 9th district of Vienna, a place between the afterwards built institutes of physics and chemistry reflecting the hybrid role between chemistry and physics. This building was financed by the generous donation of Karl Kuppelwieser. He wrote in a letter to the Academy that he wants to "prevent the shame" of his country not conducting research in the new science field. Austria at that time possessed the Bohemian uranium mine in St. Joachimsthal – the material from this source was also used by the Curies and Rutherford.

This new science had a highly interdisciplinary character and comprehended physics, chemistry, geology, atmospheric research, and last but not least, medicine. Many famous scientists worked in the new institute like Stefan Meyer’s first assistant Viktor Franz Hess (1936 Nobel Prize for the discovery of cosmic rays), George de Hevesy (1943 Nobel Prize for the tracer method), Friedrich Paneth and others. The institute and Stefan Meyer could also attract many female scientists like Berta Karlik and Marietta Blau who gained international reputation. The institute was internationally oriented indicated by the prominent role in the International Radium Standard Commission (president E. Rutherford, secretary S. Meyer) and the hosting many and also famous guests from abroad.

After 100 years the philosophy of the institute working in the front line of research and devoted to excellence is vivid and an inspirational example for the succeeding institutes, the Stefan Meyer Institute for subatomic physics of the Austrian Academy of Sciences, and the Institute for Isotope Research and Nuclear Physics of the University of Vienna.

The 100th anniversary celebration organized by our institute took place on November 8, 2010, in the Theatersaal of the Academy and was opened by the president of the Austrian Academy. The program included on the one hand lectures on the history and scientific highlights of the Radium Institute (speaker: S. Fengler/University of Vienna, C. Forstner / Universität Jena and W. Kutschera/University of Vienna), on the other hand talks on subatomic physics the today's Stefan Meyer Institute of the Austrian Academy of Sciences (p. KIENLE/excellence cluster Technical University Munich, t. Yamazaki/RIKEN-Japan, U. Wiedner/University of Bochum, Jungmann/KVI Groningen and Physics Nobel Laureate James Cronin / University of Chicago).

Prof. J. Cronin, Nobel Laureate

2.9.2. Other organized conferences

On 5th-6th January, 2010, SMI hosted a meeting of the Working Group 5: Fundamental Interactions of the Long Range Plan 2010 of NUPECC.
Between 4th-8th October, 2010, our Institute organized, together with ECT* (European Centre for Theoretical Physics, Trento, Italy) a workshop titled "Strangeness in Nuclei" with approximately 40 participants.

2.10. Public outreach 2010

SMI is a member of the FAKT[17], a section of the Austrian Physical Society. FAKT has established an Outreach team, where each institute is represented. The team coordinates the Outreach of the FAKT institutes.
FAKT runs the teilchen.at[18] project, which comprises a webpage intended to disseminate information and news from the science field to the public. SMI is represented in the editorial office and contributes regularly to the news section. Within the teilchen.at initiative, a common touring exhibition[19] is established. In 2010, SMI contributed four 2×2 m^2 posters (see Fig. 14) describing its research projects in German language for the public, which were presented during the teilchen.at exhibition at the University of Salzburg in September 2010.

Also in 2010, SMI joined as a partner the Science Center Netzwerk[20], an Austrian initiative where partners from all fields of science are associated. Hands-on outreach activities and network meetings characterize the work of this organisation.
Two presentations in the framework of the "University meets Public" series have been given.
Furthermore, the "Thema des Monats" public relation project of the academy, received a contribution[21] of its June issue.

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[17] Fachausschuss für Kern- und Teilchenphysik
[18] http://www.teilchen.at
[19] http://events.teilchen.at
[20] http://www.science-center-net.at
[21] http://www.oeaw.ac.at/home/thema/thema_201006.html

Fig. 14: Preview of the 4 posters for the teilchen.at exhibition.

2.11. Scientific co-workers

Name	Position	Funding
Prof. Eberhard Widmann	Director	ÖAW
Priv. Doz. Johann Marton	Senior scientist, vice director	ÖAW
Priv. Doz. Johann Zmeskal	Senior scientist, workshop supervisor	ÖAW
Dr. Michael Cargnelli	Senior scientist	ÖAW
Dr. Paul Bühler	Junior scientist	ÖAW
Dr. Bertalan Juhasz	Junior scientist	ÖAW
Dr. Ken Suzuki	Junior scientist	ÖAW
Dr. Tomoichi Ishiwatari	Junior scientist	FWF
Dr. Olaf Hartmann	Junior scientist	EU/FWF
Stefan Brunner	Ph.D. student	EU
Susanne Friedreich	Ph.D. student	FWF
Alexander Gruber	Ph.D. student	EU
Lukas Gruber	Ph.D. student	EU
Philipp Müllner	Ph.D. student	EU
Barbara Wünschek	Ph.D. student	FWF
Gamal Saber Ahmed	Ph.D. student	Egypt
Silke Ferdemann	Ph.D. student	CERN
Oswald Massiczek	Diploma student	ÖAW