

JARA-FAME

Jülich Aachen Research Alliance for

Forces and Matter Experiments

Annual Report 2015

Forschungszentrum Jülich

RWTH Aachen

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Jülich Aachen Research Alliance for Forces and Matter Experiments
Annual Report 2015

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JARA-FAME Highlights 2015

New Insights into the Formation of Heavy Elements

Nature Study: Researchers simulate the scattering of helium nuclei inside stars for the first time

Serdar Elhatisari, Dean Lee, Gautam Rupak, Evgeny Epelbaum, Hermann Krebs, Timo A. Lähde, Thomas Luu & Ulf-G. Meißner

Alpha particles, which is what helium atoms are also called, play a decisive role in the formation of heavy elements. Carbon, for example, results from the fusion of three alpha particles. If another helium nucleus is involved, oxygen is formed – another prerequisite for life on Earth. An international team of researchers presents a new method in the current issue of Nature that uses supercomputers to produce detailed simulations of this birth process inside stars. The method reduces the cost of computation and made it possible for the first time to calculate the scattering process of two alpha particles ab initio with Jülich's supercomputer JUQUEEN.

Nature **528** (2015) 111

AMS experiment

Henning Gast

Two major papers by the AMS Collaboration have appeared in 2015. They deal with measurements of the cosmic-ray proton and helium spectra. In the conventional picture of cosmic rays, both species are accelerated at supernova remnants, a process that should lead to a simple, smooth power law spectrum with a constant spectral index. During the subsequent propagation in turbulent interstellar magnetic fields, the index is softened but the form of the spectrum should be preserved.

Surprisingly, in both proton and helium spectra, the AMS measurements reveal a progressive hardening of the spectral indices at high energies, with high precision (Fig. 1). Remarkably, the spectral index of the proton to helium flux ratio increases with rigidity up to 45 GV and then becomes constant.

Both papers have been selected as Editor's Suggestion by Physical Review Letters.

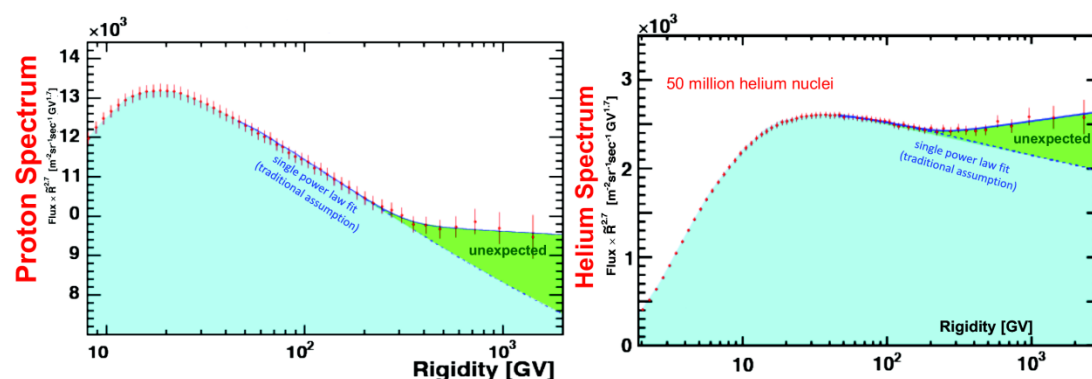


Fig: Rigidity (momentum per charge) spectra of cosmic-ray protons (left) and helium (right) as measured by the AMS experiment.

Finalized Design of RFWF

Dirk Heberling and Jamal Slim

In the run of 2015, the support structure of the inner part of the RFWF has been finished. The aim was to create a structure that is strong enough to hold the electrodes and the ferrite blocks and has the minimal effects on the field quality. The leakage of the electromagnetic field from the central section to the components of the support structure induced current that is time and space variation. For example, one of the problems were the special clamps created to hold the ferrites blocks. These clamps were highly asymmetric and so does the current was to flow on. Extra parasitic fields were generated which distorted the

main field (e.g. the parasitic electric field increased 0.8 to 75 V/m locally). To cope with this problem the length of the ferrite blocks was increased to cover the whole inner section to minimize the field leakage from the rear and front side of the Wien filter. Secondly forcing the clamps to be symmetric canceled out the effect of the current circulation. Now, the old mechanism used to fulfill the Wien filter condition based on the length of the ferrites does not hold any more and a new concept is established. The final model with the support structure are shown in figures 1 and 2 respectively.

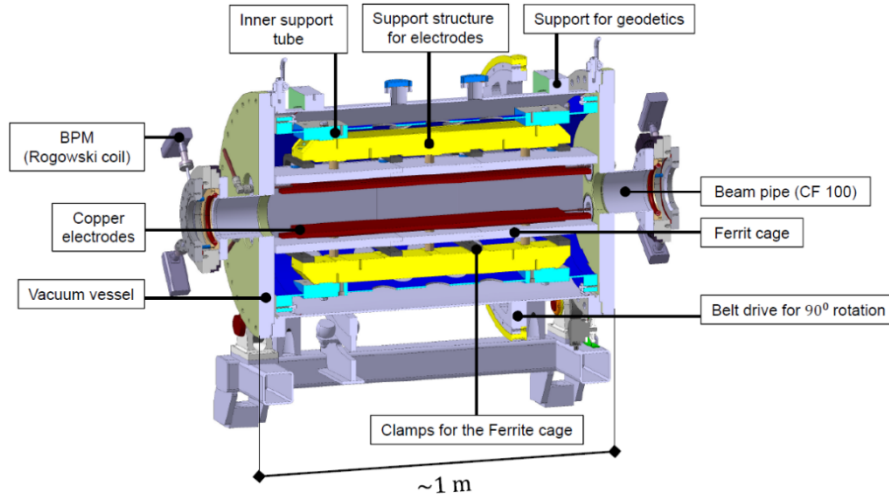


Fig.1 Final model of the waveguide RF Wien filter

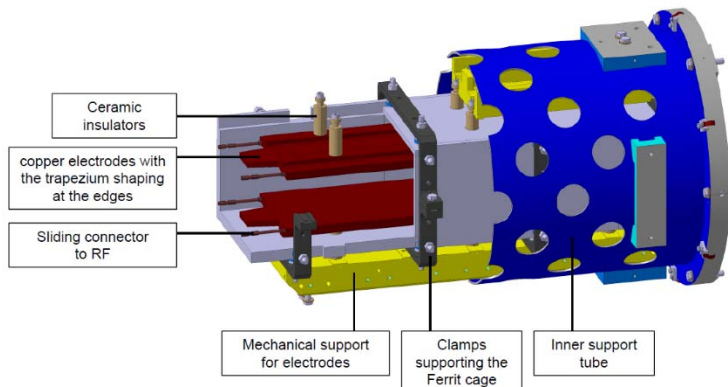


Fig. 2 Detailed view of the inner support structure of the waveguide RF Wien filter

Beam-Based Homogeneity Evaluation

Having the high values of the field homogeneity and low net Lorentz force computed with the electromagnetic simulator, the particle's simulation was a necessary step to evaluate the performance of the intended Wien filter based on realistic basis. The phase space ellipse of the section were the RF Wien filter is planned to be installed in the COSY ring (PAX low-beta section) were extracted. 5000 particles have been tracked with the realistic field of the RF Wien filter. Three observables were monitored namely the phase space ellipse and the homogeneities of the electric and magnetic fields.

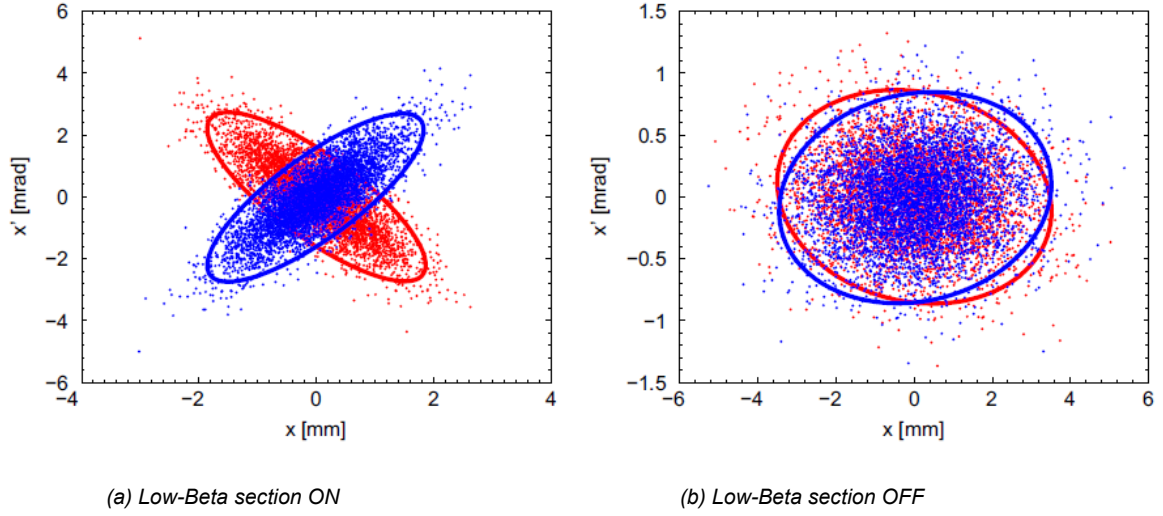


Fig. 3 phase space ellipse of the particles entering and exiting the RF Wien filter

The red and blue points in Fig. 3 represent the particles entering and exiting the RF Wien filter respectively. The red dots represent the input particles' population sampled using a 2D Gaussian distribution. Two cases have been considered; small beam size with large angular variation (low- β section ON) and (relatively) large beam size with low angular variation (low- β section OFF). The estimated phase space ellipses (blue ellipses) show the same behavior as the field-free case. This means that the Wien filter is not altering the particles passing through it indicating minimal influence on the particles.

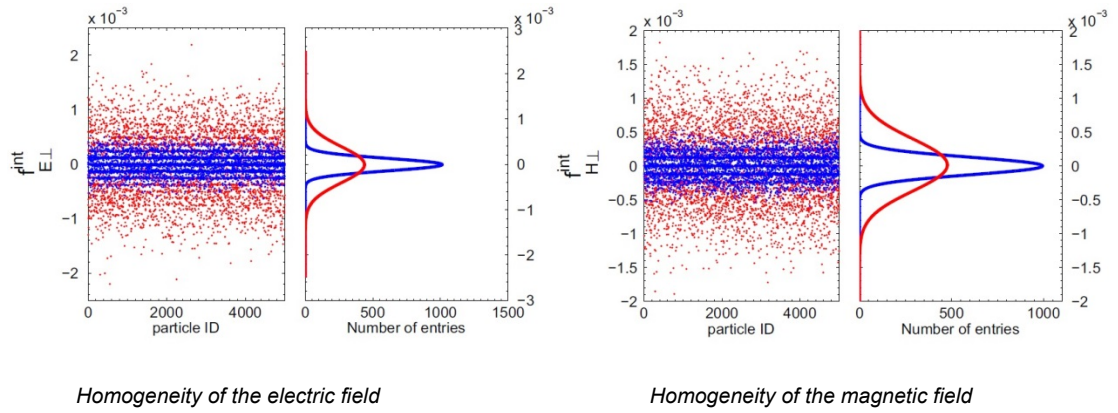


Fig. 4 Field homogeneities based on beam simulations

The fields' homogeneity was also calculated as a result of the particles simulations according to:

$$f_{E_{\perp}}^{\text{int}} = \frac{\int |\vec{E}_{\perp}| d\ell'}{\int |\vec{E}| d\ell'} \quad f_{H_{\perp}}^{\text{int}} = \frac{\int |\vec{H}_{\perp}| d\ell'}{\int |\vec{H}| d\ell'}$$

with

$$\vec{E}_{\perp} = \begin{pmatrix} 0 \\ E_y \\ E_z \end{pmatrix} \quad \vec{H}_{\perp} = \begin{pmatrix} H_x \\ 0 \\ H_z \end{pmatrix}$$

The fields each particle sees while passing through the device were recorded; particularly (Ex, Ey Ez, Hx, Hy, Hz). The result of the magnetic field homogeneity is shown in figure 4 and summarized in table 1.

Table 1: Homogeneity values of the waveguide RF Wien filter-

	$J_{E\perp}^{\text{int}}$		$J_{H\perp}^{\text{int}}$	
	mean μ	width σ	mean μ	width σ
low- β ON	$(-1.1 \pm 0.8) \times 10^{-5}$	5.7×10^{-4}	$(1.4 \pm 0.8) \times 10^{-5}$	5.5×10^{-4}
low- β OFF	$(4.1 \pm 2.5) \times 10^{-6}$	1.8×10^{-4}	$(0.8 \pm 2.6) \times 10^{-6}$	1.8×10^{-4}

Towards a High-Accuracy RF Wien Filter for Spin Manipulation at COSY Jülich

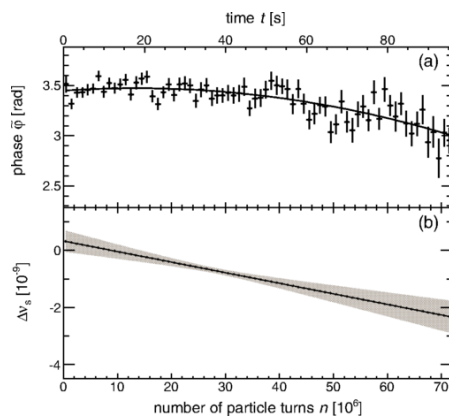
Dirk Heberling and Jamal Slim

The JEDI collaboration is aiming for electric dipole moment (EDM) measurements of deuterons and protons at COSY-Jülich. A high accuracy RF Wien filter, operating at the spin harmonic frequencies is planned to be integrated in the COSY ring at the Forschungszentrum Jülich. This RF Wien filter is intended for spin tune modulation purposes allowing to perform EDM measurements. Because of the smallness of the EDM signal, critical requirements on this Wien filter have been imposed both in terms of field homogeneity and orthogonality. The transverse electromagnetic (TEM) mode of a parallel-plates waveguide fulfills the requirements. This work will show both the electrodynamics analysis together with the engineering design.

New Method for a Continuous Determination of the Spin Tune in Storage Rings and Implications for Precision Experiments

D. Eversmann et al. (JEDI collaboration)

A new method to determine the spin tune is described and tested. In an ideal planar magnetic ring, the spin tune—defined as the number of spin precessions per turn—is given by $\nu_s = \gamma G$ (γ is the Lorentz factor, G the gyromagnetic anomaly). At 970 MeV/c, the deuteron spins coherently precess at a frequency of ≈ 120 kHz in the Cooler Synchrotron COSY. The spin tune is deduced from the up-down asymmetry of deuteron-carbon scattering. In a time interval of 2.6 s, the spin tune was determined with a precision of the order 10^{-8} , and to 1×10^{-10} for a continuous 100 s accelerator cycle. This renders the presented method a new precision tool for accelerator physics; controlling the spin motion of particles to high precision is mandatory, in particular, for the measurement of electric dipole moments of charged particles in a storage ring.



(a) spin phase vs. turn number/time, (b) resulting spin tune change. The average spin tune can be determined with a precision of 10^{-10} in a 100s cycle.

Phys. Rev. Lett. **115**, 094801

Development of a JUNO detector read-out IC

Stefan van Waasen, Christian Grewing

The first version of the read-out IC Vulcan for the JUNO detector (Jiangmen Underground Neutrino Observatory) was developed and produced. The requirements were developed and finally successfully reviewed in international the project team.

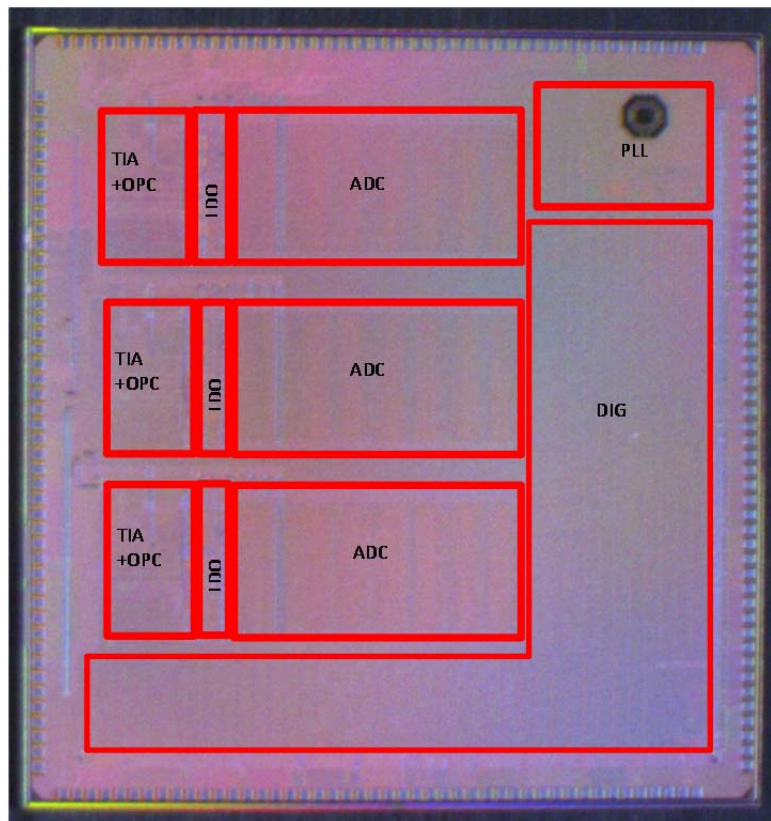


Fig. 1: chip photograph of the Vulcan Chips

The target of the project is the development of a System-on-Chip (SoC) solution for a photomultiplier read-out which includes the whole signal processing chain of the corresponding output signal. It includes e.g. a very low ohmic front-end transimpedance amplifier (TIA) with extremely linear characteristics, 3 8-bit analog-digital converters (ADC) with 1 GS/s and all voltage regulators for the supply. The additional included overshoot compensation significantly reduces distortions generated by the AC-coupling at the input and included in a patent application. The complete frequency synthesis with a fully integrated phase-locked loop (PLL) including oscillator (VCO) is also on-chip. The digital part includes a complex signal processing for data rate reduction and conversion for the high-rate LVDS interface. The complete chip consists out of more than 7 million transistors. The project is part of the JUNO DFG research group in collaboration with groups all over Germany.

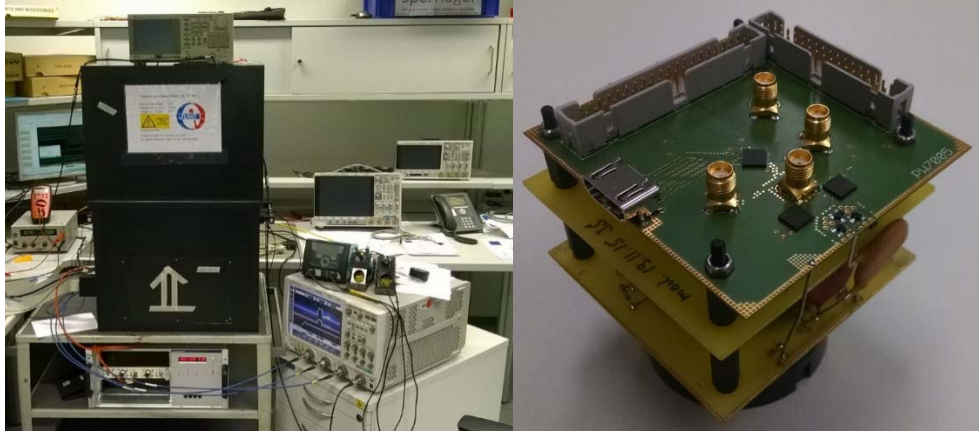


Fig. 2: Measurements set-up for characterization of the first TIA prototype with photomultiplier tube

All project team members and especially the doctoral researchers presented the methods and results of this work on several collaboration meetings as well as international conferences.

A Secure Remote Access System with Strong Two-factor Authentication

Anke Schmeink

Nowadays, the remote access to a network or a certain computer is very common and necessary for both organizations and individuals. For example, one may need to access to his office network from home in order to continue his work. Therefore, the security of this access is extremely important as we do not want an unauthorized person to enter our system. The two-factor Authentication (2FA) mechanism provides an extra layer of security, which may be a good way to keep the unauthorized person out.

In this project, the Secure Shell (SSH) is utilized for establishing the remote connection. Traditional SSH connection only requires username and password (or certificate) to conduct the authentication. In order to enhance the security level, 2FA with different protocols can be introduced to the conventional SSH system, such as HMAC-based one-time password (HOTP) algorithm, time-based one-time password (TOTP) algorithm and Pretty Good Privacy (PGP) encryption. These protocols will be tested and evaluated in both real and virtual machines. Meanwhile, a role-based access control system can be realized by merging the SSH connection with various authentication methods appropriately, which is of great use for the organization with several groups whose access rights of the system are different.

Further highlights can be found on the official JARA-FAME homepage (in German only):
http://www.jara.org/no_cache/de/research/jara-fame/nachrichten/

- Using the hadron collider COSY (Cooler Synchrotron) for the JEDI project (Juelich Electric Dipole Investigations)
<http://www.jara.org/de/research/jara-fame/nachrichten/details/2015/cosy-elektrisches-dipolmoment/>
- Funding by DFG: Support of neutrino physics within the JUNO collaboration
<http://www.jara.org/de/research/jara-fame/nachrichten/details/2015/neutrinos/>

JARA-FAME Institutes

I. Physikalisches Institut B, RWTH Aachen

Prof. Stefan Schael, Dr. Henning Gast

Supercomputing Center, Forschungszentrum Jülich

Prof. Thomas Lippert

The combined effort of the I. Physics Institute of RWTH Aachen and of the Jülich Supercomputing Centre builds one of the leading research groups in the Alpha Magnetic Spectrometer (AMS) Project on the International Space Station. AMS, is a general purpose high energy particle physics detector. After a construction period of 15 years it was installed on the International Space Station, ISS, on 19 May 2011 to conduct a unique long duration mission (20 years) of fundamental physics research in space. The main scientific focus is the search for anti matter and dark matter. The work of 25 scientists and PhD students is coordinated by Prof. Dr. S. Schael with significant external funding by the German Space Agency DLR.

III. Physikalisches Institut B , RWTH Aachen

Prof. Achim Stahl and Prof. Rudolf Maier

The institute of experimental particle physics is active in the development of particle detectors, Experiments in Collider Physics (LHC at CERN) and Neutrino Physics (DoubleChooz, T2K, IceCube, JUNO, LENA). Recently, the search for CP-violation with the JEDI collaboration was started as a new activity.

Within JARA-FAME the group of Prof. Stahl focuses on the development of the electrostatic deflectors of the JEDI storage ring.

Prof. Jörg Pretz

The group of Prof. Pretz is working on various aspects of the storage ring EDM project, covering simulations of spin dynamics in accelerators, hardware development for a first charged particle EDM experiment at COSY, beam instrumentation, polarimetry and analysis.

Prof. Sebastian M. Schmidt

Sebastian M. Schmidt is member of the board of directors of FZJ and active in research on theoretical physics. His focus in JARA-FAME is the education of students by organizing a laboratory course on spin physics.

Institut für Hochfrequenztechnik, RWTH Aachen

Prof. Dirk Heberling

The Institute of High Frequency Technology (IHF) is concerned with the simulation, design, fabrication and measurement of microwave components. Topics range from antennas, waveguides, resonators, RF coils, radar cross section measurements, metamaterials. In terms of simulation methods, various simulations systems exists with different computational methods including the finite integration methods (CST Suite), the finite difference time domain method (Empire) and method of moments (FEKO). The IHF is also equipped with Small GPU cluster for faster simulations. The labs at IHF are fully equipped with many devices including for instance, network analyzers covering very high frequencies up to 110 GHz. One of the most remarkable research facilities at IHF, is an anechoic chamber for antenna measurements (the best in German universities).

Institut für Hochspannungstechnik , RWTH Aachen

Prof. Armin Schnettler

The main focus concerning research and teaching at the Institute for High Voltage Technology (IFHT) is on components, power equipment and system aspects for a sustainable energy supply. A broad spectrum includes the development of newly-created systems and methods as well as the evaluation and optimization of established techniques. Mathematical simulations serve as an important tool for research and

development, although high priority is placed on the experimental analysis in order to verify the simulation results. Due to close cooperation with world-wide operating manufacturers, a high degree of practical application is guaranteed.

Divided into four departments, more than fifty scientific employees work at the IFHT. The Department of Electrical Equipment and Diagnostics is responsible for the development of new insulation materials, electrical components and procedures evaluating their conditions. The Department of Switchgear and DC Technologies develops components and required equipment for electric grids whereas the departments Sustainable Distribution Systems and Sustainable Transmission Systems are in charge of the modelling and evaluation of energy supply systems seen from a systemic perspective.

Institut für Theoretische Teilchenphysik und Kosmologie, RWTH Aachen

Prof. Werner Bernreuther

The research of my group and myself is devoted to theoretical investigations of models for fundamental particles and interactions. Our main focus is predictions for high-energy reactions, in particular reactions that apply to the Large Hadron Collider, within the Standard Model of particle physics and extensions thereof. In particular, we investigate effects of non-standard CP-violating interactions in high-energy processes, but also on low-energy observables such as electric dipole moments of leptons and hadrons.

Prof. Michael Krämer

The group of Prof. Krämer, in particular, has started a comprehensive program to explore dark matter at colliders and in direct and indirect detection. Searches for antimatter in the Universe provide a powerful way to search for and constrain dark matter models, and are being pursued in close collaboration and interaction with members of the AMS collaboration within JARA-FAME.

Prof. Julien Lesgourgues

Dr. Julien Lesgourgues has been university professor of cosmology and astroparticle physics at the Faculty of Mathematics, Computer Science, and Natural Sciences at RWTH Aachen University since April 2015. His research focus is on modeling the development of cosmological disturbances starting from the point of their origin in the early universe to the point at which they can be observed in the cosmic background radiation and spacious structure of the universe.

Research Group (LFG) 'Information Theory and Systematic Design of Communication Systems', RWTH Aachen

Anke Schmeink

The main research areas of the group are in the field of information theory, and modeling, planning and optimization of modern communication networks. Current projects are about resource allocation in multi-tier networks, a cost effective design and performance evaluation for cooperative wireless sensor networks, machine-learning approaches in medical signal processing, big data and a secure real-time remote control.

Institut für Kernphysik, IKP-1, Forschungszentrum Jülich

Prof. Jim Ritman

The IKP-1 research group is mainly involved in experimental studies of hadron structure. One group of activities is connected to completing the analysis of experiments at the COSY facility at Jülich. This includes the COSY-TOF and the WASA-at-COSY experiments. Moreover, complimentary aspects of the symmetry breaking investigations with the WASA-at-COSY data are being pursued with existing data from the CLAS experiment at Jefferson Laboratory and planned CLAS12 measurements.

The other major pillar of activities is connected to preparation for the PANDA experiment, which will measure proton-antiproton annihilation in the charmonium mass range at the FAIR complex currently under construction. The main activities here are connected to detector development and simulation/computing. The detector developments are connected to charged particle tracking devices, such as silicon pixel and silicon strip devices, thick semiconducting energy detectors and large-volume gaseous tracking detectors. The computing activities are connected to detector simulations; data readout as well as GPU/FPGA based tracking acceleration.

Institut für Kernphysik, IKP-2, Forschungszentrum Jülich

Prof. Hans Ströher

IKP-2 is one of the two experimental institutes of IKP of FZJ. In the past it has been pursuing hadron physics with (polarized) proton and deuteron beams at COSY, exploiting the ANKE and WASA detection systems at internal target positions. These experiments have been finalized with the end of 2014. The PAX-project, which aims to provide a method to polarize antiproton beams has successfully finished the test phase with protons at COSY. Since of few years the group has put its focus on precision studies with polarized stored beams; in particular it is heavily involved in the JEDI-project, which intends to search for electric dipole moments of charged particles in storage rings. Together with IKP-4 and within the JEDI-collaboration, R&D measurements for the key technologies and preparations of a precursor experiment at COSY are performed and design studies for the dedicated precision storage ring are pursued.

Institut für Kernphysik, IKP-3, Forschungszentrum Jülich

Prof. Ulf-G. Meißner

In the IKP-3/IAS-4 group, we continue to make considerable progress in the calculation of the electric dipole moments (EDMs) of nucleons and light nuclei, combining methods from effective fields theories with lattice simulation data, if available. We successfully prolonged our two sizable HPC allocations on JUQUEEN that enable calculations of the proton and neutron EDM at physical quark masses based on very different approaches (imaginary theta-angle and Lüscher flow method).

We have also performed the first ab-initio calculation of alpha-alpha reaction relevant to the production of carbon. Our calculations are also elucidating the nature of alpha clustering within nuclei. These results ultimately give us a deeper understanding of the synthesis of elements relevant for life, and also on the role of physics beyond the standard model.

Institut für Kernphysik, IKP-4, Forschungszentrum Jülich

Prof. Mei Bai and Prof. Andreas Lehrach

IKP-4 is operating the Cooler Synchrotron COSY and leading laboratory for design, construction and commissioning of the High-Energy Storage Ring HESR at FAIR. Members of the HESR consortium are: HIM Mainz, GSI/FAIR, ICPE-CA Bucharest, FZJ/ZEA. COSY will be operated in the next funding period to test accelerator and detector components for HESR and FAIR as well as for R&D work and a precursor experiment for a first direct charged-particle EDM measurement in a storage ring. In addition a design study for a dedicated high-precision EDM storage ring will be performed together with partners (FZJ: IKP-2 and ZEA; RWTH Aachen, Ferrara Università degli Studi di Ferrara Italy, Ivane Javakhishvili Tbilisi State University Georgia, Krakow Uniwersytet Jagielloński w Krakowie Poland, Grenoble Centre National de la Recherche Scientifique France and others).

Zentralinstitut für Engineering, Elektronik und Analytik, ZEA-1, Forschungszentrum Jülich

Prof. Ghaleb Natour

ZEA-1 develops, designs, and builds technical equipment, instruments, setups and processes on a high level as an important contribution to successful scientific cutting-edge research. More than 160 people, mainly engineers, scientists and technicians are working closely together with the researchers of our scientific partner institutes and their external collaborators. Within JARA-FAME ZEA-1 makes major contributions in the construction and design of the vacuum system and the different magnets (dipoles, quadrupoles, sextupoles, and injection magnets) of the HESR accelerator at FAIR. In addition ZEA-1 manufactures other components like the stochastic cooling systems or the injection kicker.

In collaboration with IKP-1 ZEA-1 develops and builds components for the PANDA experiment, mainly the micro vertex detector

As a partner in the JEDI collaboration, ZEA-1 has developed new beam position monitors based on Rogowski coil. For the new RF-Wien filter ZEA-1 is responsible for the vacuum system and for the fabrication of the complete device.

**Zentralinstitut für Engineering, Elektronik und Analytik, ZEA-2,
Forschungszentrum Jülich**

Prof. Stefan van Waasen

The ZEA-2 as Electronic Systems Institute develops best possible solutions to support the experimental research in JARA FAME. The focus is the development of high integration solutions on commercial available CMOS processes. These are e.g. the base components for detector solutions with best possible performance and flexibility. The current focus project is the development of a System-on-Chip (SoC) read-out solution for the JUNO detector.

Scientific Results

Theory

θ -dependence of the lightest meson resonances in QCD

Acharya, N. R.; Guo, F.-K.; Mai, M.; Meißner, U.-G.

Physical review / D 92(5), 054023 (2015)

We derive the pion mass and the elastic pion-pion scattering amplitude in the QCD θ -vacuum up to next-to-leading order in chiral perturbation theory. Using the modified inverse amplitude method, we study the θ -dependence of the mass and width of the light scalar meson $\sigma(500)$ and the vector meson $\rho(770)$.

DOI:10.1103/PhysRevD.92.054023

Nuclear electric dipole moments in chiral effective field theory

Bsaisou, J.; de Vries, J.; Hanhart, C.; Liebig, S.; Meißner, U.-G.; Minossi, D.; Nogga, A.; Wirzba, A.

Journal of high energy physics 2015(3), 104 (2015)

We provide a consistent and complete calculation of the electric dipole moments of the deuteron, helion, and triton in the framework of chiral effective field theory. The CP-conserving and CP-violating interactions are treated on equal footing and we consider CP-violating one-, two-, and three-nucleon operators up to next-to-leading-order in the chiral power counting. In particular, we calculate for the first time EDM contributions induced by the CP-violating three-pion operator. We find that effects of CP-violating nucleon-nucleon contact interactions are larger than those found in previous studies based on phenomenological models for the CP-conserving nucleon-nucleon interactions. Our results which apply to any model of CP violation in the hadronic sector can be used to test various scenarios of CP violation. As examples, we study the implications of our results on the QCD θ -term and the minimal left-right symmetric model.

DOI:10.1007/JHEP03(2015)104

P- and T-violating Lagrangians in chiral effective field theory and nuclear electric dipole moments

Bsaisou, J. ; Meißner, U.-G. ; Nogga, A. ; Wirzba, A.

Annals of physics **359**, 317 - 370 (2015)

A scheme to derive hadronic interactions induced by effective multi-quark terms is presented within the framework of chiral effective field theory. It is employed to work out the list of parity- and time-reversal-symmetry-violating hadronic interactions that are relevant for the computation of nuclear contributions to the electric dipole moments of the hydrogen-2, helium-3 and hydrogen-3 nuclei. We also derive the scattering and Faddeev equations required to compute electromagnetic form factors in general and electric dipole moments in particular.

DOI:10.1016/j.aop.2015.04.031

Parity violation in neutron capture on the proton: Determining the weak pion–nucleon coupling

de Vries, J. ; Li, N. ; Meißner, U.-G. ; Nogga, A. ; Epelbaum, E. ; Kaiser, N.

Physics letters / B **747**, 299 - 304 (2015)

We investigate the parity-violating analyzing power in neutron capture on the proton at thermal energies in the framework of chiral effective field theory. By combining this analysis with a previous analysis of parity

violation in proton–proton scattering, we are able to extract the size of the weak pion–nucleon coupling constant. The uncertainty is significant and dominated by the experimental error which is expected to be reduced soon.

DOI:10.1016/j.physletb.2015.05.074

Ab initio alpha–alpha scattering

Elhatisari, S.; Lee, D.; Rupak, G.; Epelbaum, E.; Krebs, H.; Lähde, T.; Luu, T.; Meissner, U.-G.

Nature 528(7580), 111 - 114 (2015)

Processes involving alpha particles and alpha-like nuclei comprise a major part of stellar nucleosynthesis and hypothesized mechanisms for thermonuclear supernovae. In an effort towards understanding alpha processes from first principles, we describe in this letter the first ab initio calculation of alpha-alpha scattering. We use lattice effective field theory to describe the low-energy interactions of nucleons and apply a technique called the adiabatic projection method to reduce the eight-body system to an effective two-cluster system. We find good agreement between lattice results and experimental phase shifts for S-wave and D-wave scattering. The computational scaling with particle number suggests that alpha processes involving heavier nuclei are also within reach in the near future.

DOI:10.1038/nature16067

Electric Dipole Moment of the Neutron from 2 + 1 Flavor Lattice QCD

Guo, F.-K. ; Horsley, R. ; Meißner, U.-G. ; Nakamura, Y. ; Perlt, H. ; Rakow, P. E. L. ; Schierholz, G. ; Schiller, A. ; Zanotti, J. M.

Physical review letters 115(6), 062001 (2015)

We compute the electric dipole moment d_n of the neutron from a fully dynamical simulation of lattice QCD with 2+1 flavors of clover fermions and nonvanishing θ term. The latter is rotated into the pseudo scalar density in the fermionic action using the axial anomaly. To make the action real, the vacuum angle θ is taken to be purely imaginary. The physical value of d_n is obtained by analytic continuation. We find $d_n = -3.9(2)(9) \times 10^{-16} \theta$ e cm, which, when combined with the experimental limit on d_n , leads to the upper bound $|\theta| \leq 7.4 \times 10^{-11}$.

DOI:10.1103/PhysRevLett.115.062001

Matching Pion-Nucleon Roy-Steiner Equations to Chiral Perturbation Theory

Hoferichter, M. ; Ruiz de Elvira, J. ; Kubis, B. ; Meißner, U.-G.

Physical review letters 115(19), 192301 (2015)

We match the results for the subthreshold parameters of pion-nucleon scattering obtained from a solution of Roy-Steiner equations to chiral perturbation theory up to next-to-next-to-next-to-leading order, to extract the pertinent low-energy constants including a comprehensive analysis of systematic uncertainties and correlations. We study the convergence of the chiral series by investigating the chiral expansion of threshold parameters up to the same order and discuss the role of the $\pi(1232)$ resonance in this context. Results for the low-energy constants are also presented in the counting scheme usually applied in chiral nuclear effective field theory, where they serve as crucial input to determine the long-range part of the nucleon-nucleon potential as well as three-nucleon forces.

DOI:10.1103/PhysRevLett.115.192301

Anthropic considerations in nuclear physics

Meissner, U.-G.

Science bulletin 60(1), 43 - 54 (2015)

In this short review, I discuss the sensitivity of the generation of the light and the life-relevant elements such as carbon and oxygen under changes of the parameters of the Standard Model pertinent to nuclear physics.

Chiral effective field theory allows for a systematic and precise description of the forces between two, three and four nucleons. In this framework, variations under the light quark masses and the electromagnetic fine-structure constant can also be consistently calculated. Combining chiral nuclear effective field theory with Monte Carlo simulations allows to further calculate the properties of nuclei, in particular of the Hoyle state in carbon, that plays a crucial role in the generation of the life-relevant elements in hot, old stars. The dependence of the triple-alpha process on the fundamental constants of nature is calculated, and some implications for our anthropic view of the Universe are discussed.

DOI:10.1007/s11434-014-0670-2

Prospects of constraining the Higgs boson's CP nature in the tau decay channel at the LHC

Berge, S., Bernreuther, W., Kirchner, S.

Phys. Rev. D 92 (2015) 096012

We investigate how precisely the CP nature of the 125 GeV Higgs boson, parametrized by a scalar-pseudoscalar Higgs mixing angle, can be determined in Higgs-to-tau-pair decay with subsequent tau-lepton decays to charged prongs at the Large Hadron Collider (LHC). We combine two methods in order to define an observable which is sensitive to this scalar-pseudoscalar mixing angle: We use the rho-decay plane method for tau-to-rho decays and the impact parameter method for all other major tau decays. For estimating the precision with which the mixing angle can be measured at the LHC (13 TeV) we take into account the background from Drell-Yan production and perform a Monte Carlo simulation of measurement uncertainties on the signal and background distributions. We obtain that the mixing angle can be determined with an uncertainty of 15 degree (9 degree) at the LHC with an integrated luminosity of 150 inverse fb (500 inverse fb), and with ~4 degree with 3 inverse ab. Future measurements of the scalar-pseudoscalar mixing angle yield direct information on whether or not there is an extended Higgs-boson sector with Higgs-sector CP violation. We analyze this in the context of a number of two-Higgs-doublet extensions of the Standard Model, namely the so-called aligned model and conventional two-Higgs-doublet extensions with tree-level neutral flavor conservation.

DOI: 10.1103/PhysRevD.92.096012

A set of top quark spin correlation and polarization observables for the LHC: Standard Model predictions and new physics contributions

Bernreuther, W., Heisler, D., Si, Z.-G.

JHEP 1512 (2015) 026

We consider top-antitop quark ($t\bar{t}$) production at the Large Hadron Collider (LHC) with subsequent decay into dileptonic and lepton plus jets final states. We present a set of leptonic angular correlations and distributions with which experiments can probe all the independent coefficient functions of the top-spin dependent parts of the $t\bar{t}$ production spin density matrices. We compute these angular correlations and distributions for LHC center-of-mass energies 8, 13, and 14 TeV within the Standard Model at next-to-leading order in the QCD coupling including the mixed QCD-weak corrections and for the transverse top-quark polarization and the $t\bar{t}$ charge asymmetry also the mixed QCD-QED corrections. In addition we analyze and compute the effects of new interactions on these observables in terms of a gauge-invariant effective Lagrangian which contains all operators relevant for hadronic $t\bar{t}$ production up to mass dimension six.

DOI:10.1007/JHEP12(2015)026

The electric dipole moment of the neutron from 2+1 flavor lattice QCD

F.-K. Guo, R. Horsley, U.-G. Meißner, Y. Nakamura, H. Perlt, P. E. L. Rakow, G. Schierholz, A. Schiller, J. M. Zanotti

Phys. Rev. Lett. 115 (2015) 062001

We compute the electric dipole moment d_n of the neutron from a fully dynamical simulation of lattice QCD with 2+1 flavors of clover fermions and nonvanishing θ term. The latter is rotated into the pseudoscalar density in the fermionic action using the axial anomaly. To make the action real, the vacuum angle θ is taken

to be purely imaginary. The physical value of d_n is obtained by analytic continuation. We find $d_n = -3.9(2)(9) \times 10^{-16} \theta \text{ e cm}$, which, when combined with the experimental limit on d_n , leads to the upper bound $\theta < 7.6 \times 10^{-11}$.

DOI: 10.1103/PhysRevLett.115.062001

How to reveal the exotic nature of the $P_c(4450)$

F.-K. Guo, U.-G. Meißner, W. Wang, Z. Yang

Phys. Rev. D **92** (2015) 071502

The LHCb Collaboration announced two pentaquark-like structures in the J/ψ invariant mass distribution. We show that the current information on the narrow structure at 4.45 GeV is compatible with kinematical effects of the rescattering from $\chi_{c1} p$ to J/ψ : First, it is located exactly at the $\chi_{c1} p$ threshold. Second, the mass of the four-star well-established $\Lambda(1890)$ is such that a leading Landau singularity from a triangle diagram can coincidentally appear at the $\chi_{c1} p$ threshold, and third, there is a narrow structure at the $\chi_{c1} p$ threshold but not at the $\chi_{c0} p$ and $\chi_{c2} p$ thresholds. In order to check whether that structure corresponds to a real exotic resonance, one has to measure the process $\Lambda^0 b \rightarrow K - \chi_{c1} p$. If the $P_c(4450)$ structure exists in the $\chi_{c1} p$ invariant mass distribution as well, then the structure cannot be just a kinematical effect but is a real resonance, otherwise, one cannot conclude the $P_c(4450)$ to be another exotic hadron. In addition, it is also worthwhile to measure the decay $Y(1S) \rightarrow J/\psi p \bar{p}$: a narrow structure at 4.45 GeV but not at the $\chi_{c0} p$ and $\chi_{c2} p$ thresholds would exclude the possibility of a pure kinematical effect.

DOI: 10.1103/PhysRevD.92.071502

Testing the $\chi_{c1} p$ composite nature of the $P_c(4450)$

U.-G. Meißner, J. A. Oller

Phys. Lett. B **751** (2015) 59

Making use of a recently proposed formalism, we analyze the composite nature of the $P_c(4450)$ resonance observed by LHCb. We show that the present data suggest that this state is almost entirely made of a χ_{c1} and a proton, due to the close proximity to this threshold. This also suppresses the decay modes into other, lighter channels, in our study represented by $J/\psi p$. We further argue that this is very similar to the case of the scalar meson $f_0(980)$ which is located closely to the $K\bar{K}$ threshold and has a suppressed decay into the lighter $\pi\pi$ channel.

DOI: 10.1016/j.physletb.2015.10.015

Violations of discrete space-time symmetries in chiral effective field theory

J. de Vries, U.-G. Meißner

International Journal of Modern Physics E, Vol. **25** (2016) 1641008

We review recent progress in the theoretical description of the violation of discrete space-time symmetries in hadronic and nuclear systems. We focus on parity-violating and time-reversal-conserving interactions which are induced by the Standard Model weak interaction, and on parity- and time-reversal-violating interactions which can be caused by a nonzero QCD theta term or by beyond-the-Standard Model physics. We discuss the origins of such interactions and review the development of the chiral effective field theory extension that includes discrete symmetry violations. We discuss the construction of symmetry-violating chiral Lagrangians and nucleon-nucleon potentials and their applications in few-body systems.

DOI: 10.1142/S0218301316410081

Spectrum of three-body bound states in a finite volume

U.-G. Meißner, G. Ríos, A. Rusetsky

Phys. Rev. Lett. **114** (2015) 091602

The spectrum of a bound state of three identical particles with a mass m in a finite cubic box is studied. It is shown that in the unitary limit, the energy shift of a shallow bound state is given by $\Delta E = c(\kappa^2/m)(\kappa L)^{-3/2} |A|^2 \exp(-2\kappa L/\sqrt{3})$, where κ is the bound-state momentum, L is the box size, $|A|^2$ denotes the three-body analog of the asymptotic normalization coefficient of the bound state wave function and c is a numerical constant. The formula is valid for $\kappa L \gg 1$.

DOI: 10.1103/PhysRevLett.114.091602

Precision nucleon-nucleon potential at fifth order in the chiral expansion

E. Epelbaum, H. Krebs, U.-G. Meißner

Phys. Rev. Lett. **115** (2015) 122301

We present a nucleon-nucleon potential at fifth order in chiral effective field theory. We find a substantial improvement in the description of nucleon-nucleon phase shifts as compared to the fourth-order results of Ref. [E. Epelbaum, H. Krebs, U.-G. Meißner, Eur. Phys. J. A51 (2015) 53]. This provides clear evidence of the corresponding two-pion exchange contributions with all low-energy constants being determined from pion-nucleon scattering. The fifth-order corrections to nucleon-nucleon observables appear to be of a natural size which confirms the good convergence of the chiral expansion for nuclear forces. Furthermore, the obtained results provide strong support for the novel way of quantifying the theoretical uncertainty due to the truncation of the chiral expansion proposed in Ref. [E. Epelbaum, H. Krebs, U.-G. Meißner, Eur. Phys. J. A51 (2015) 53]. Our work opens up new perspectives for precision ab initio calculations in few- and many-nucleon systems and is especially relevant for ongoing efforts towards a quantitative understanding the structure of the three-nucleon force in the framework of chiral effective field theory.

DOI: 10.1103/PhysRevLett.115.122301

P- and T-Violating Lagrangians in Chiral Effective Field Theory and Nuclear Electric Dipole Moments

J. Bsaisou, Ulf-G. Meißner, A. Nogga, A. Wirzba

Annals of Physics **359** (2015) 317-370

A scheme to derive hadronic interactions induced by effective multi-quark terms is presented within the framework of chiral effective field theory. It is employed to work out the list of parity- and time-reversal-symmetry-violating hadronic interactions that are relevant for the computation of nuclear contributions to the electric dipole moments of the hydrogen-2, helium-3 and hydrogen-3 nuclei. We also derive the scattering and Faddeev equations required to compute electromagnetic form factors in general and electric dipole moments in particular.

DOI: 10.1016/j.aop.2015.04.031

Electroweak fragmentation functions for dark matter annihilation

L. A. Cavasonza, M. Krämer, M. Pellen

JCAP **1502** (2015) 021

Electroweak corrections can play a crucial role in dark matter annihilation. The emission of gauge bosons, in particular, leads to a secondary flux consisting of all Standard Model particles, and may be described by electroweak fragmentation functions. To assess the quality of the fragmentation function approximation to electroweak radiation in dark matter annihilation, we have calculated the flux of secondary particles from gauge-boson emission in models with Majorana fermion and vector dark matter, respectively. For both models, we have compared cross sections and energy spectra of positrons and antiprotons after propagation through the galactic halo in the fragmentation function approximation and in the full calculation. Fragmentation functions fail to describe the particle fluxes in the case of Majorana fermion annihilation into

light fermions: the helicity suppression of the lowest-order cross section in such models cannot be lifted by the leading logarithmic contributions included in the fragmentation function approach. However, for other classes of models like vector dark matter, where the lowest-order cross section is not suppressed, electroweak fragmentation functions provide a simple, model-independent and accurate description of secondary particle fluxes.

DOI: 10.1088/1475-7516/2015/02/021

AMS Experiment

Precision Measurement of the Proton Flux in Primary Cosmic Rays from Rigidity 1 GV to 1.8 TV with the Alpha Magnetic Spectrometer on the International Space Station

M. Aguilar et al.

Physical Review Letters 114 (2015) 171103

A precise measurement of the proton flux in primary cosmic rays with rigidity (momentum/charge) from 1 GV to 1.8 TV is presented based on 300 million events. Knowledge of the rigidity dependence of the proton flux is important in understanding the origin, acceleration, and propagation of cosmic rays. We present the detailed variation with rigidity of the flux spectral index for the first time. The spectral index progressively hardens at high rigidities.

DOI: 10.1103/PhysRevLett.114.171103

Precision Measurement of the Helium Flux in Primary Cosmic Rays of Rigidities 1.9 GV to 3 TV with the Alpha Magnetic Spectrometer on the International Space Station

M. Aguilar et al.

Physical Review Letters 115 (2015) 211101

Knowledge of the precise rigidity dependence of the helium flux is important in understanding the origin, acceleration, and propagation of cosmic rays. A precise measurement of the helium flux in primary cosmic rays with rigidity (momentum/charge) from 1.9 GV to 3 TV based on 50 million events is presented and compared to the proton flux. The detailed variation with rigidity of the helium flux spectral index is presented for the first time. The spectral index progressively hardens at rigidities larger than 100 GV. The rigidity dependence of the helium flux spectral index is similar to that of the proton spectral index though the magnitudes are different. Remarkably, the spectral index of the proton to helium flux ratio increases with rigidity up to 45 GV and then becomes constant; the flux ratio above 45 GV is well described by a single power law.

DOI: 10.1103/PhysRevLett.115.211101

EDM Experiment

New Method for a Continuous Determination of the Spin Tune in Storage Rings and Implications for Precision Experiments

Eversmann, D.; Hejny, V.; Hinder, F.; Kacharava, A.; Pretz, J.; Rathmann, F.; Rosenthal, M.; Trinkel, F.; Andrianov, S.; Augustyniak, W.; Bagdasarian, Z.; Bai, M.; Bernreuther, W.; Bertelli, S.; Berz, M.; Bsaisou, J.; Chekmenev, S.; Chiladze, D.; Ciullo, G.; Contalbrigo, M.; de Vries, J.; Dymov, S.; Engels, R. W.; Esser, F. M.; Felden, O.; Gaisser, M.; Gebel, R.; Glückler, H.; Goldenbaum, F.; Grigoryev, K.; Grzonka, D.; Guidoboni, G.; Hanhart, C.; Heberling, D.; Hempelmann, N.; Hetzel, J.; Hipple, R.; Hölscher, D.; Ivanov, A.; Kamedzhiev, V.; Kamys, B.; Keshelashvili, I.; Khokhlov, A.; Koop, I.; Krause, H.-J.; Krewald, S.; Kulikov, A.; Lehrach, A.; Lenisa, P.; Lomidze, N.; et al

Physical review letters 115 (9), (2015) 094801

A new method to determine the spin tune is described and tested. In an ideal planar magnetic ring, the spin tune—defined as the number of spin precessions per turn—is given by $\nu_s \approx \frac{1}{2} \gamma G$ (γ is the Lorentz factor, G the gyromagnetic anomaly). At 970 MeV/c, the deuteron spins coherently precess at a frequency of ≈ 120 kHz in the Cooler Synchrotron COSY. The spin tune is deduced from the up-down asymmetry of deuteron-carbon scattering. In a time interval of 2.6 s, the spin tune was determined with a precision of the order 10^{-8} , and to 1×10^{-10} for a continuous 100 s accelerator cycle. This renders the presented method a new precision tool for accelerator physics; controlling the spin motion of particles to high precision is mandatory, in particular, for the measurement of electric dipole moments of charged particles in a storage ring.

DOI: 10.1103/PhysSpin coherence time studies of a horizontally polarized deuteron beam at COSY

Towards a High-Accuracy RF Wien Filter for Spin Manipulation at COSY Jülich

J. Slim and D. Heberling

In: XVIth International Workshop in Polarized Sources, Targets, and Polarimetry, PSTP2015, 14-18 September 2015, Bochum, Germany, Seiten/Artikel-Nr: PoS (PSTP2015) 033

The JEDI collaboration is aiming for electric dipole moment (EDM) measurements of deuterons and protons at COSY-Jülich. A high accuracy RF Wien filter, operating at the spin harmonic frequencies is planned to be integrated in the COSY ring at the Forschungszentrum Jülich. This RF Wien filter is intended for spin tune modulation purposes allowing to perform EDM measurements. Because of the smallness of the EDM signal, critical requirements on this Wien filter have been imposed both in terms of field homogeneity and orthogonality. The transverse electromagnetic (TEM) mode of a parallel-plates waveguide fulfills the requirements. This work will show both the electrodynamics analysis together with the engineering design.

Spin coherence time studies of a horizontally polarized deuteron beam at COSY

G Guidoboni on behalf of the JEDI Collaboration

Physica scripta T166 (2015) 014036

The measurement of a non-zero electric dipole moment (EDM) aligned along the spin of sub-atomic particles would probe new physics beyond the standard model. It has been proposed to search for the EDM of charged particles using a storage ring and a longitudinally polarized beam. The EDM signal would be a rotation of the polarization from the horizontal plane toward the vertical direction as a consequence of the radial electric field always present in the particle frame. This experiment requires ring conditions that can ensure a lifetime of the in-plane polarization (spin coherence time, SCT) up to 1000 s. A study has begun at the COoler SYNchrotron (COSY) located at the Forschungszentrum Jülich to examine the effects of emittance and momentum spread on the SCT of a polarized deuteron beam at 0.97 GeV c^{-1} . A special Data Acquisition has been developed in order to provide a direct measurement of a rapidly rotating horizontal polarization as a function of time. The set of data presented here shows how second-order effects from emittance and momentum spread of the beam affect the lifetime of the horizontal polarization of a bunched

beam. It has been demonstrated that sextupole fields can be used to correct for these depolarizing sources and increase the SCT up to hundreds of seconds.

DOI: 10.1088/0031-8949/2015/T166/014036

Measurement of electric dipole moments at storage rings

J. Pretz on behalf of the JEDI collaboration

Physica scripta T166 (2015) 014035

The electric dipole moment (EDM) is a fundamental property of a particle, like mass, charge and magnetic moment. What makes this property in particular interesting is the fact that a fundamental particle can only acquire an EDM via P and T violating processes. EDM measurements contribute to the understanding of the matter over anti-matter dominance in the universe, a question closely related to the violation of fundamental symmetries. Up to now measurements of EDMs have concentrated on neutral particles. Charged particle EDMs can be measured at storage ring. Plans at Forschungszentrum Jülich and results of first test measurements at the COoler SYnchrotron COSY will be presented.

DOI: 10.1088/0031-8949/2015/T166/014035

Features of cooling dynamics in a high-voltage electron cooling system of the COSY

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Technical Physics 60 (8), (2015) 1227–1233

An electron cooler designed at the Budker Institute of Nuclear Physics for the Cooler Synchrotron COSY (Jülich, Germany) has been put into operation. The aim of this cooling device is to prevent the beam scattering on an internal target up to the maximal energy of the transmitted beam. The device provides cooling in a strong longitudinal magnetic field generated in a high-voltage area. The motion of electrons in the magnetic field considerably improves the kinetics of electron—ion collisions, because their transverse velocity component (which is very high as a rule) does not participate in the process. First experiments on electron beam cooling on energy 200 MeV were made in 2013. Early in 2014, sessions on electron beam cooling to 200, 350, 580, and 1660 MeV were carried out. In other experiments, deuterium beams were cooled down. Experimental data for the cooling time are compared with the respective theoretical predictions. These results may be used in cooling projects for the Nuclotron-based Ion Collider fAcility (NICA), Joint Institute for Nuclear Research, Dubna, Russia, and the Facility for Antiproton and Ion Research (FAIR), Darmstadt, Germany.

DOI: 10.1134/S1063784215080046

Hadron and Accelerator Physics

ABC effect and resonance structure in the double-pionic fusion to ^3He

Adlarson, P.; Augustyniak, W.; Bardan, W.; Bashkanov, M.; Bergmann, F. S.; Berłowski, M.; Bhatt, H.; Bondar, A.; Büscher, M.; Calén, H.; Ciepał, I.; Clement, H.; Coderre, D.; Czerwiński, E.; Demmich, K.; Doroshkevich, E.; Engels, R.; Erven, A.; Eyrich, W.; Fedorets, P.; Föhl, K.; Fransson, K.; Goldenbaum, F.; Goslawski, P.; Goswami, A.; Grigoryev, K.; Gullström, C.-O.; Hauenstein, F.; Heijckenskjöld, L.; Hejny, V.; Höistad, B.; Hüskens, N.; Jarczyk, L.; Johansson, T.; Kamys, B.; Kemmerling, G.; Khan, F. A.; Khoukaz, A.; Kirillov, D. A.; Kistryn, S.; Kleines, H.; Kłos, B.; Krzemień, W.; Kulesa, P.; Kupść, A.; Kuzmin, A.; Lalwani, K.; Lersch, D.; Lorentz, B.; Magiera, A.; et al

Physical review / C 91 (1), (2015) 015201

Exclusive and kinematically complete measurements of the double pionic fusion to ^3He have been performed in the energy region of the so-called ABC effect, which denotes a pronounced low-mass enhancement in the $\pi\pi$ -invariant mass spectrum. The experiments were carried out with the WASA detector setup at COSY (the cooler synchrotron at Forschungszentrum Jülich). Similar to the observations in the basic $p n \rightarrow d \pi^0 \pi^0$ reaction and in the $d d \rightarrow ^4\text{He} \pi^0 \pi^0$ reaction, the data reveal a correlation between the ABC effect and a resonance-like energy dependence in the total cross section. Differential cross sections are well described by the hypothesis of d^* resonance formation during the reaction process in addition to the conventional t-channel $\Delta\Delta$ mechanism. The deduced d^* resonance width can be understood from collision broadening due to Fermi motion of the nucleons in initial and final nuclei.

DOI: 10.1103/PhysRevC.91.015201

Measurement of the $np \rightarrow np \pi^0 \pi^0$ reaction in search for the recently observed $d^*(2380)$ resonance

Adlarson, P.; Augustyniak, W.; Bardan, W.; Bashkanov, M.; Bergmann, F. S.; Berłowski, M.; Bhatt, H.; Bondar, A.; Büscher, M.; Calén, H.; Ciepał, I.; Clement, H.; Coderre, D.; Czerwiński, E.; Demmich, K.; Doroshkevich, E.; Engels, R. W.; Erven, A.; Erven, W.; Eyrich, W.; Fedorets, P.; Föhl, K.; Fransson, K.; Goldenbaum, F.; Goslawski, P.; Goswami, A.; Grigoryev, K.; Gullström, C. -.; Hauenstein, F.; Heijkenkjöld, L.; Hejny, V.; Höistad, B.; Hüken, N.; Jarczyk, L.; Johansson, T.; Kamys, B.; Kemmerling, G.; Khan, F. A.; Khokkaz, A.; Kirillov, D. A.; Kistryn, S.; Kleines, H.; Kłos, B.; Krzemień, W.; Kulessa, P.; Kupść, A.; Kuzmin, A.; Lalwani, K.; Lersch, D.; Lorentz, B.; et al

Physics letters / B **743** (2015) 325 - 332

Exclusive measurements of the quasi-free $np \rightarrow np \pi^0 \pi^0$ reaction have been performed by means of dp collisions at $T_d = 2.27 \text{ GeV}$ using the WASA detector setup at COSY. Total and differential cross sections have been obtained covering the energy region $\sqrt{s} = (2.35 - 2.46) \text{ GeV}$, which includes the region of the ABC effect and its associated $d^*(2380)$ resonance. Adding the d^* resonance amplitude to that for the conventional processes leads to a reasonable description of the data. The observed resonance effect in the total cross section is in agreement with the predictions of Fäldt and Wilkin as well with those of Albadajedo and Oset. The ABC effect, i.e. the low-mass enhancement in the $\pi^0 \pi^0$ -invariant mass spectrum, is found to be very modest – if present at all, which might pose a problem to some of its interpretations.

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A Monte-Carlo simulation of the equilibrium beam polarization in ultra-high energy electron (positron) storage rings

Z. Duana, M. Bai, D. P. Barberd, Q. Qin

Nuclear instruments & methods in physics research / A **793**, (2015) 81 - 91

With the recently emerging global interest in building a next generation of circular electron–positron colliders to study the properties of the Higgs boson, and other important topics in particle physics at ultra-high beam energies, it is also important to pursue the possibility of implementing polarized beams at this energy scale. It is therefore necessary to set up simulation tools to evaluate the beam polarization at these ultra-high beam energies. In this paper, a Monte-Carlo simulation of the equilibrium beam polarization based on the Polymorphic Tracking Code (PTC) (Schmidt et al., 2002 [1]) is described. The simulations are for a model storage ring with parameters similar to those of proposed circular colliders in this energy range, and they are compared with the suggestion (Derbenev et al., 1979 [2]) that there are different regimes for the spin dynamics underlying the polarization of a beam in the presence of synchrotron radiation at ultra-high beam energies. In particular, it has been suggested that the so-called “correlated” crossing of spin resonances during synchrotron oscillations at current energies evolves into “uncorrelated” crossing of spin resonances at ultra-high energies.

DOI: 10.1016/j.nima.2015.04.063

Antiproton chain of the FAIR storage rings

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Physica scripta T166 (2015) 014073

In the Modularized Start Version of the Facility of Antiproton and Ion Research (FAIR) at Darmstadt Germany, the 3 GeV antiprotons are precooled in the collector ring and accumulated in the high energy storage ring (HESR). They are further accelerated to 14 GeV or decelerated to 1 GeV for the experiments with a high-density internal target. The powerful beam cooling devices, stochastic cooling and electron cooling will support the provision of a high-resolution antiproton beam. The other option of FAIR is to prepare the low energy, 300 keV antiproton beam connecting the existing storage rings ESR and CRYRING with HESR. Beam physics issues related with these concepts are described.

DOI: 10.1088/0031-8949/2015/T166/014073

Heavy ion storage and acceleration in the HESR with stochastic cooling and internal target

H. Stockhorst, T. Katayama, A. Lehrach, B. Lorentz, R. Maier, D. Prasuhn and R. Stassen

Physica scripta T166 (2015) 014041

Heavy ion stochastic momentum cooling is investigated under the constraint of the present concept of the high energy storage ring (HESR). A bare uranium beam is injected from the collector ring into the HESR at 740 MeV u^{-1} and a beam preparation for an internal target experiment is outlined. Further the acceleration of the ion beam to 4.5 GeV u^{-1} is considered and an internal target experiment is studied. The simulations include the beam-target interaction involved with a hydrogen target. The capability of momentum filter cooling is envisaged and the possibility of time-of-flight momentum cooling is examined at lower energies where the revolution harmonics begin to overlap.

DOI: 10.1088/0031-8949/2015/T166/014041

Overview Conferences, Awards and Offers

Conferences

Bai, M.: Accelerator Physics Challenges in Electric Dipole Moment Measurements. European Physical Society High Energy Physics conference, EPS HEP 2015, Vienna, Austria, 22 Jul 2015 - 29 Jul 2015 (2015)

Bai, M.: High Energy Polarized Beams Status and Challenges. The 2015 International Workshop on Polarized Sources, Targets & Polarimetry, PSTP 2015, Bochum, Deutschland, 14 Sep 2015 - 18 Sep 2015 (2015)

Gast, H.; Lehrach, A.: „Auf der Suche nach der Antimaterie „, JARA-Ringvorlesung im Rahmen der „RWTH extern“ Veranstaltungsreihe - November 24, 2015. Aachen (Germany)

Gillitzer, A.: Excited Hyperons at PANDA. EMMI Workshop "Resonances in QCD", Darmstadt, Germany, October 12 – 14, 2015

Gillitzer, A.: Hadrons in Nuclei - What Can Be Done with PANDA? Workshop "PANDA Physics Perspective at Stefan-Meyer-Institut", Vienna, Austria, February 19 – 20, 2015

Hejny, V.: Measurement of Electric Dipole Moments of Charged Particles at Storage Rings. DPG-Frühjahrstagung Heidelberg 2015, Heidelberg, Germany, 23 Mar 2015 - 27 Mar 2015 (2015)

Hejny, V.: Polarimetry for monitoring long coherent spin precession and polarisation based feedback. Beam Dynamics meets Diagnostics, Florence, Italy, 4 Nov 2015 - 6 Nov 2015 (2015)

Hejny, V.: Polarimetry for monitoring long coherent spin precession and polarisation based feedback. Beam Dynamics meets Diagnostics, Florence, Italy, 4 Nov 2015 - 6 Nov 2015 (2015)

Hempelmann, N.: FPGA-Based Upgrade of the Read-Out Electronics for the Low Energy Polarimeter at COSY/Jülich. The 2015 International Workshop on Polarized Sources, Targets & Polarimetry, PSTP 2015, Bochum, Germany, 14 Sep 2015 - 18 Sep 2015 (2015)

Hempelmann, N.: FPGA-Based Upgrade of the Read-Out Electronics for the Low Energy Polarimeter at the Cooler Synchrotron. DPG Frühjahrstagung Hadronen und Kerne, DPG, Heidelberg, Germany, 23 Mar 2015 - 27 Mar 2015 (2015)

Kacharava, A.: Juelich-HEPI TSU cooperation: from COSY to JEDI project. Modern Trends in Particle Physics, Tbilisi, Georgia, 26 Nov 2015 - 28 Nov 2015 (2015)

Keshelashvili, I.: "Towards JEDI Polarimetry", XVIth International Workshop on Polarized Sources, Targets and Polarimetry", September 14 – 18, 2015, Bochum (Germany)

Lehrach, A.: "Beam and Spin Dynamics for Charged Particle EDM Searches in Storage Rings", EUCARD workshop "Search for the electron EDM in an electrostatic storage ring", September 10-11, 2015, Mainz (Germany)

Lehrach, A.: "Beam and Spin Dynamics for Charged Particle EDM Searches in Storage Rings", EuCARD Workshop Search for the electron EDM in an electrostatic storage ring, November 9, 2015, Mainz (Germany)

Lehrach, A.: "Beam and Spin Dynamics for Storage Ring Based EDM Search", IPAC2015, 6th International Particle Accelerator Conference, May 3-8, 2015, Richmond (USA)

Lehrach, A.: "Challenges in optics requirement and control of storage ring for precision measurement of EDM", EuCARD2-ICFA workshop "Advanced Optics Control" CERN, EuCARD2-ICFA workshop "Advanced Optics Control, February 5-6, 2015, CERN, Geneve (Schweiz)

Lehrach, A.: "SEARCHING ELECTRIC DIPOLE MOMENTS IN STORAGE RINGS - CHALLENGES, STATUS AND COMPUTATIONAL NEEDS", ICAP2015, International Computational Accelerator Physics Conference, October 12-16, 2015, Shanghai (China)

Lehrach, A.: Beam and Spin Dynamics for Charged Particle EDM Searches in Storage Rings. EUCARD workshop "Search for the electron EDM in an electrostatic storage ring", Mainz, Germany, 11 Sep 2015 - 11 Sep 2015 (2015)

Lehrach, A.: Beam and Spin Dynamics for Storage Ring Based EDM Search. Sixth International Particle Accelerator Conference, IPAC'16, R, RWTH Aachen, Germany, 3 May 2015 - 8 May 2015 (2015)

Lehrach, A.: Challenges in optics requirement and control of storage ring for precision measurement of EDM. EuCARD2-ICFA workshop "Advanced Optics Control, Cern, Geneve, Schweiz, 5 Feb 2015 - 6 Feb 2015 (2015)

Lehrach, A.: Searching electric dipole moments in storage rings – Challenges, Status and computational needs. International Computational Accelerator Physics Conference, IPAC'16, Shanghai, RWTH Aachen, China, 12 Oct 2015 - 16 Oct 2015 (2015)

Mey, S.: An RF Wien Filter as Spin Manipulator. Matter and Technologies Student Retreat, DESY, Hamburg, RWTH Aachen, Germany, 23 Feb 2015 - 24 Feb 2015 (2015)

Mey, S.: High Precision Spin Manipulation at COSY. Matter and Technologies Kickoff Meeting, DESY, Hamburg, Germany, 23 Feb 2015 - 26 Feb 2015 (2015)

Mey, S.; Gebel, R.: "Towards an RF Wien Filter for EDM Experiments at COSY", Sixth International Particle Accelerator Conference, May 3 – 8, 2015, Richmond, VA (USA)

Mey, S.; Gebel, R.: Spin Manipulation with an RF Wien-Filter at COSY. The 2015 International Workshop on Polarized Sources, Targets & Polarimetry, PSTP 2015, Bochum, RWTH Aachen, Germany, 14 Sep 2015 - 18 Sep 2015 (2015) - 30 Sep 2015 (2015)

Mey, S.; Gebel, R.: Towards an RF Wien-Filter for EDM Searches in Storage Rings. DPG-Frühjahrstagung der Sektionen Didaktik der Physik, Extraterrestrische Physik, Strahlen- und Medizinphysik, Teilchenphysik und des Arbeitskreises Beschleunigerphysik, DPG Wuppertal 2015, Wuppertal, RWTH Aachen, Germany, 9 Mar 2015 - 13 Mar 2015 (2015)

Muralidharan, P.: "A Highly Integrated Receiver Chip with an Automatic Baseline Regulation" Neutrino 2016, July 16, 2016, London (England)

Parkalian, N.: "A 4-GHz LC-Based Voltage Controlled Oscillator & Frequency Divider for use in Neutrino Experiments" Analog 2016, September 12-14, 2016, Bremen (Deutschland)

Prencipe, E.: New spectroscopy with PANDA at FAIR. HADRON2015 XVI International Conference on Hadron Spectroscopy, Newport News, Virginia, USA, September 13 - 18 2015

Pretz, J.: "Charged Particle Electric Dipole Moment Searches in Storage Rings", XVIth International Workshop on Polarized Sources, Targets and Polarimetry", September 14 – 18, 2015, Bochum (Germany)

Rathmann, F.: Challenges of Electric Dipole Moment searches using Storage Rings. Beam Dynamics meets Diagnostics, Florence, Italy, 4 Nov 2015 - 6 Nov 2015 (2015)

Ritman, J.: Baryon Spectroscopy with PANDA.EMMI Workshop "Resonances in QCD", Darmstadt, Germany, October 12 – 14, 2015

Schael, St.: Precision Measurement of the (e^+e^-) Flux in Primary Cosmic Rays from 0.5 GeV to 1 TeV with the Alpha Magnetic Spectrometer on the International Space Station, 31 July 2015, 34th International Cosmic Ray Conference (ICRC), Den Haag, The Netherlands

Schael, St.: The e^- Spectrum and e^+ Spectrum from AMS, AMS Days at CERN, 15 April 2015, Switzerland

Senichev, Y.: "Quasi-frozen Spin Method for EDM Deuteron Search", IPAC2015, 6th International Particle Accelerator Conference, May 3-8, 2015, Richmond (USA)

Slim, J and Heberling, D.: "Towards a High-Accuracy RF Wien Filter for Spin Manipulation at COSY Jülich", PSTP2015, XVIth International Workshop in Polarized Sources, Targets, and Polarimetry, Bochum, September 14 - 18, Germany, 2015

Stroeher, H.: Cross Topic "Antimatter".Matter and the Universe - Annual Meeting, Jülich, Germany, 29 Sep 2015

Stroeher, H.: Electric Dipole Moments - A Window for New Physics. European Physical Society Conference on High Energy Physics 2015, Vienna, Austria, 22 Jul 2015 - 29 Jul 2015 (2015)

Stroeher, H.: Schicksal der Antimaterie - Wieso existieren wir? Wissenschaftliches Symposium im Rahmen des 20-jährigen Helmholtz-Jubiläums, Berlin, Germany, 25 Jun 2015 - 25 Jun 2015 (2015)

Wirzba, A.: „Electric Dipole Moments of Light Ions“, Bethe Workshop on Challenges in Strong Interaction Physics“, Sept. 29 – Oct. 2, 2015, Bad Honnef (Germany)

Organisation of Conferences

Topical meeting of Spin tracking for Precision Measurements”, satellite meeting of IPAC2015, organized by M. Bai, A. Lehrach, H. Stroeher, Y. Semertzidis, E. Stephenson; <https://indico.cern.ch/event/368912/> May 5-6, 2015, Richmond (USA)

Awards and Offers

M. Bai: Ernest Orlando Lawrence Award given by the U.S. Department of Energy

J. Haidenbauer: Outstanding Referee by the APS in January 2015

A. Herten: Awarded the “PANDA PhD Prize”

C. Köber: Awarded Bonn-Cologne Graduate School (BCGS) Stipend and accepted into Honors PhD program

L. Ludhova: Awarded “Recruitment initiative of the Helmholtz Association of 2015”

L. Ludhova: Accepted Professorship at Rheinisch-Westfälische Technische Hochschule Aachen

R. Maier: JARA-Seniorprofessor, RWTH-Aachen und Forschungszentrum Jülich GmbH, 30.01.2015

U.-G. Meißner: Awarded Professorship (honorary) under the Chinese Academy of Sciences President's International - Fellowship Initiative for Visiting Scientists in 2015

U.-G. Meißner: Editorial Board of EPJA, Managing Editor—Reviews

St. Schael: appointed Deputy Spokesperson of the AMS Collaboration in January 2015.

H. Ströher: Editorial Board of EPJA, Co-Editor

J. de Vries: Awarded VENI grant from NWO (Nederlandse Organisatie voor Wetenschappelijk Onderzoek)

Q. Wang: Awarded “The Excellent PhD Thesis of the Chinese Academy of Sciences, 2015”

PhD- and Master Theses

Name	Title	JARA-FAME Institute
Clemens, Mellein	Production of heavy Higgs bosons and decay into top quarks at the LHC	Inst. f. Theor. Teilchenphysik u. Kosmologie, RWTH Aachen
Deermann, Dariusch	Development of the PANDA MVD Trapezoidal Sensors and a Feasibility Study of the $\bar{p} p \rightarrow \bar{\Lambda}_c \Lambda_c$ Reconstruction (Ruhr-Universität Bochum, Germany)	Institut für Kernphysik, IKP-1, Forschungszentrum Jülich
Herten, A.	GPU-based Online Track Reconstruction for PANDA and Application to the Analysis of $D \rightarrow K \pi \pi$ (Ruhr-Universität Bochum, Germany)	Institut für Kernphysik, IKP-1, Forschungszentrum Jülich
Hu, Q.	Development of the Recoil Detector for the HESR Day-One Experiment and Commissioning at COSY by Measuring pp Elastic Scattering (University of Chinese Academy of Sciences, China)	Institut für Kernphysik, IKP-1, Forschungszentrum Jülich
Machate, Fabian	Search for Cosmic Ray Positron Anisotropies with the Alpha Magnetic Spectrometer on the International Space Station	I. Physics Institute B, RWTH Aachen

Muralidharan, Pavithra	Digital Signal Processing and Mixed Signal Control of Read-Out Circuitry for Large Scale Particle Detectors (still ongoing)	Zentralinstitut für Engineering, Elektronik und Analytik, Systeme der Elektronik (ZEA-2), Forschungszentrum Jülich
Nielinger, Dennis	Modeling of a PLL in high level programming language (still ongoing)	Zentralinstitut für Engineering, Elektronik und Analytik, Systeme der Elektronik (ZEA-2), Forschungszentrum Jülich
Parkalian, Nina	Digitalized Frequency Synthesis for CMOS IC (still ongoing)	Zentralinstitut für Engineering, Elektronik und Analytik, Systeme der Elektronik (ZEA-2), Forschungszentrum Jülich
Schever, M.	Towards Measuring the Electromagnetic Structure of η' -Mesons with CLAS (RWTH Aachen University, Germany)	Institut für Kernphysik, IKP-1, Forschungszentrum Jülich
Schumann, J.	Beschleunigung eines Spurfindealgorithmus für den Straw Tube Tracker des PANDA-Detektors durch Parallelisierung mit CUDA C (Fachhochschule Aachen, Campus Jülich, Germany)	Institut für Kernphysik, IKP-1, Forschungszentrum Jülich
Vaidya, N.	Combined Analysis of Lorentz- and Stieltjes-transformed Electromagnetic Response Functions of Light Nuclei (German Research School for Simulation Sciences, Aachen, Germany)	Institut für Kernphysik, IKP-3, und Institute for Advanced Simulation (IAS-4) Forschungszentrum Jülich
Zambanini, A.	Development of a Free-Running Readout ASIC for the PANDA Micro Vertex Detector and Investigation of the Performance to Reconstruct Antiproton-Proton $\rightarrow \Xi + \Xi^-$ (1690) (Ruhr-Universität Bochum, Germany)	Institut für Kernphysik, IKP-1, Forschungszentrum Jülich

Visiting Scientists

Name	Homeuniversity, Country	Date/Duration		JARA-FAME Institute
Alfs, Dominika	Jagiellonian University Krakaw, Poland	10.11.2015	17.11.2015	IKP-1
Apostolou, Alexandros	KVI Groningen, The Netherlands	01.03.2015	31.12.2015	IKP-1
Bryzgunov, Maxim	Budker Institute of Nuclear Physics	27.02. - 23.03.2015		IKP-2 und IKP-4
Caho, Alexander	Stanford University	04.05. - 07.05.2015		IKP-2 und IKP-4
Cao, Lu	Southwest University, Chongqing, China	01.01.2015	31.12.2015	IKP-1
Cleven, Martin	Universität Bonn, Physikalisches Institut	06.09. - 26.09.2015		IKP-3 und IAS-4
Di Pietro, Valentino	Justus-Liebig-Universität Gießen, Germany	10.05.2015	18.05.2015	IKP-1

Franchetti, Giuliano	GSI Darmstadt	17.04. - 18.04.2015		IKP-2 und IKP-4
Galoian, Aida	JINR VBLHEP, Dubna, Moscow region, Russia	01.03.2015	14.03.2015	IKP-1
Georgadze, Ilya	Moscow State University, Russia	14.01.2015	30.04.2015	IKP-1
Georgadze, Ilya	Moscow State University, Russia	12.09.2015	15.12.2015	IKP-1
Gibson, Ben	Los Alamos National Laboratory, New Mexico, USA	15.08. - 22.08.2015		IKP-3 und IAS-5
Heinen, Stefan	RWTH Aachen	Multiple		ZEA-2
Herold, Christoph	Suranaree University of Technology, Nakhon Ratchasima, Thailand	17.08.2015	16.10.2015	IKP-1
Hu, Qiang	Chinese Academy of Sciences, Lanzhou, China	01.01.2015	31.12.2015	IKP-1
Ji, Daheng	Institute of High Energy Physics	21.09. - 14.11.2015		IKP-2 und IKP-4
Kesselkaul, Martin	Justus-Liebig-Universität Gießen, Germany	10.05.2015	18.05.2015	IKP-1
Kohno, Michio	Research Center for Nuclear Physics, Osaka, Japan	17.08. - 06.09.2015		IKP-3 und IAS-6
Kozlov, Vladimir	Moscow State University, Russia	12.09.2015	15.12.2015	IKP-1
Kozlov, Vladimir	Moscow State University, Russia	14.01.2015	30.04.2015	IKP-1
Kudryavtsev, Alexander	Institute for Theoretical and Experimental Physics, Moskau, Russland	25.10. - 03.12.2015		IKP-3 und IAS-7
Lebedev, Valeri	Fermi National Laboratory	11.03. - 17.03.2015		IKP-2 und IKP-4
Lu, Bing-Nan	University of Chinese Academy of Sciences, Peking, China	04.12.2015 - 11.01.2016		IKP-3 und IAS-8
Miyagawa, Kazuya	Okayama University of Science, Okayama, Japan	28.02. - 08.03.2015		IKP-3 und IAS-9
Morse, William	Brookhaven national Lab	02.09. - 09.09.2015		IKP-2 und IKP-4
Nasawad, Thanachot	Suranaree University of Technology, Nakhon Ratchasima, Thailand	17.08.2015	16.11.2015	IKP-1
Nefediev, Alexey	Institute for Theoretical and Experimental Physics, Moskau, Russland	19.11. - 04.12.2015		IKP-3 und IAS-10
Orfanitskiy, Sergey	Moscow State University, Russia	14.01.2015	30.04.2015	IKP-1
Orfanitskiy, Sergey	Moscow State University, Russia	12.09.2015	15.12.2015	IKP-1
Parkhomchuk, Vasily	Budker Institute of Nuclear Physics	08.03. - 22.03.2015		IKP-2 und IKP-4
Pedretti, Davide	INFN Italy	19.02.2016		ZEA-2
Qin, Quin	Institute of High Energy Physics	16.08. - 19.08.2015		IKP-2 und IKP-4
Quagli, Tommaso	Justus-Liebig-Universität Gießen, Germany	10.05.2015	18.05.2015	IKP-1
Reva, Vladimir	Budker Institute of Nuclear Physics	28.02. - 22.03.2015		IKP-2 und IKP-4
Riccardi, Alberto	Justus-Liebig-Universität Gießen, Germany	10.05.2015	18.05.2015	IKP-1
Schwickert, Marcus	GSI Darmstadt	18.11. - 20.11.2015		IKP-2 und IKP-4
Slim, Jamal	RWTH Aachen	22.02. - 24.02.2015		IKP-2 und IKP-4
Strzempek, Pawel	Jagiellonian University Krakaw, Poland	28.04.2015	08.05.2015	IKP-1
Valetov, Eremy	Michigan State University	10.10. - 21.10.2015		IKP-2 und IKP-4

Vejdani, Solmaz	KVI Groningen, The Netherlands	01.10.2015	31.12.2015	IKP-1
Veretennikov, Denis	Petersburg Nuclear Physics Institute (PNPI), Russia	01.01.2015	31.12.2015	IKP-1
Wang, Yifang	Institute of High Energy Physics	16.08. - 18.08.2015		IKP-2 und IKP-4
Wurm, Michael	Johannes Gutenberg University, Mainz	multiple		ZEa-2
Xiaoshan	IHEP, China	multiple		ZEa-2
Yifang	IHEP, China	30.03. - 07.04.2014		ZEa-2
Zaunick, Hans-Georg	Justus-Liebig-Universität Gießen, Germany	10.05.2015	18.05.2015	IKP-1
Zhao, Qiang	Institute of High Energy Physics, Peking, China	10.05. - 17.05.2015, 02.10. - 18.10.2015		IKP-3 und IAS-11
Zink, Adrian	Universität Erlangen-Nürnberg, Germany	14.06.2015	21.06.2015	IKP-1