JARA-FAME

Jülich Aachen Research Alliance for

Forces and Matter Experiments

Annual Report 2014

Forschungszentrum Jülich

RWTH Aachen

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JARA-FAME Highlights 2014

Unraveling models of CP violation through electric dipole moments of light nuclei.

Werner Bernreuther, RWTH Aachen

A particle with non-zero spin can have an electric dipole moment (EDM) only if the parity and time-reversal symmetries are violated. This statement holds both for elementary and composite particles, i.e., leptons, nuclei, atoms, and molecules, as long as the respective state has no energy degeneracies other than those due to rotational invariance. Within the Standard Model of particle physics, both parity (P) and time-reversal (T) are, in fact, violated by the charged weak quark currents which couple to W bosons. This T-violating or, equivalently, CP-violating interaction explains all observed T- and CP-violating phenomena in K and B meson decays - but it predicts also that particle EDMs are tiny, that is, unobservable in the foreseeable future. However, as is well known, there are indications for the existence of `new physics' besides the known fundamental interactions.

The Standard Model (SM) of particle physics fails to explain several striking phenomena, including the matter-antimatter asymmetry, or baryon asymmetry of the universe. Many new physics models (i.e., models which are extensions of the SM) that can successfully explain the observed baryon asymmetry of the universe require and thus predict new CP-violating interactions and, in turn, non-zero particle EDMs. So far, non-zero particle EDMs have not been observed. To date, the most sensitive results are due to the search for an EDM of the neutron and of certain paramagnetic (and diamagnetic) atoms and molecules. The interpretation of the experimental upper bounds on the EDMs of atoms and molecules in terms of particle physics models is not straightforward. For getting deeper insight into new physics models and, in case, for disentangling new CP-violating interactions, it would be highly desirable to have direct experimental information not only on the neutron EDM but also on the EDM of the proton and of light nuclei. The measurement of these EDMS with a precision which matches and eventually supersedes the present experimental precision on the neutron EDM is the long-term goal of the JEDI collaboration within JARA-FAME.

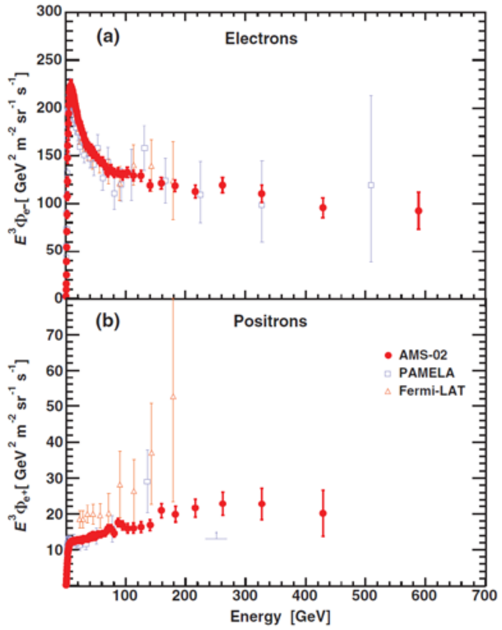
In this context a joint project was carried out with researchers at IKP-3/IAS-4 of FZ Juelich on the theoretical investigation of electric dipole moments (EDM) of light nuclei. The goal was to explore how the proposed measurements of the electric dipole moments of light nuclei in storage rings would eventually allow to discriminate between various scenarios for non-standard CP violation. For a number of extensions of the Standard Model of particle physics the resulting low-enery P- and T-violating quark and gluon interactions were computed. With these effective low energy interactions the EDMs of the neutron, proton, deuteron, helion, and triton were determined. Based on these results, strategies for future measurements and for improved calculations (using lattice QCD) were proposed. The project was successfully finished and results were published in 2014.

New results from AMS

Henning Gast and Stefan Schael, RWTH Aachen

In a series of three papers that have appeared in 2014, the AMS Collaboration has studied the behaviour of the cosmic-ray electron and positron fluxes in great detail. The results are based on almost 10 million electrons and positrons that have been identified in a data sample comprising more then 40 billion particles. They now cover an energy range extending from 0.5 gigaelectronvolts (GeV) up to 1 teraelectronvolt, greatly extending the range covered by particle spectrometers before. The enormous level of detail in the data have allowed us to accurately study how the behaviour of the cosmic-ray fluxes of electrons and positrons changes with energy.

In summary, the electron flux and the positron flux each require a description beyond a single power-law spectrum. Both the electron flux and the positron flux change their behavior at ~30 GeV, but the fluxes are significantly different in their magnitude and energy dependence. Between 20 and 200 GeV, the positron spectral index is significantly harder than the electron spectral index. These precise measurements show that the rise in the positron fraction, observed in an earlier measurement by AMS, is due to the hardening of the positron spectrum and not to the softening of the electron spectrum above 10 GeV. The determination of the differing behavior of the spectral indices versus energy is a new observation and provides important information on the origins of cosmic-ray electrons and positrons.



AMS has recorded more than 60 billion individual particle crossings until now. The computing power required to analyze these data has been provided by the JUROPA cluster at the Jülich Supercomputing Centre (JSC) in the context of JARA-FAME.

Illustration 1: Electron and positron fluxes (multiplied by the third power of energy for illustration purposes), measured by the AMS experiment on the International Space Station.

Design of a high precision RF Wien for spin manipulation at COSY

Dirk Heberling, RWTH Aachen

In 2014, at the IHF, the full electromagnetic design and simulation of the intended RF Wien filter including the support structure has been performed. The resulting electric and magnetic fields' profiles are shown in figure 1 and figure 2 respectively. The peak electric and magnetic fields read approximately 4100 V/m and 23.7 A/m respectively.

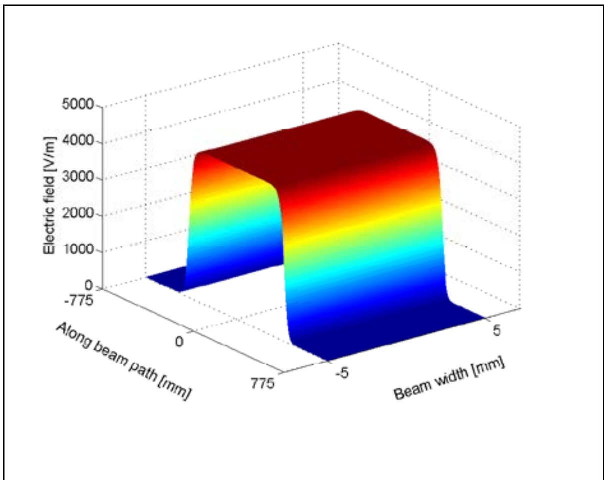


Fig.1: Electric field profile

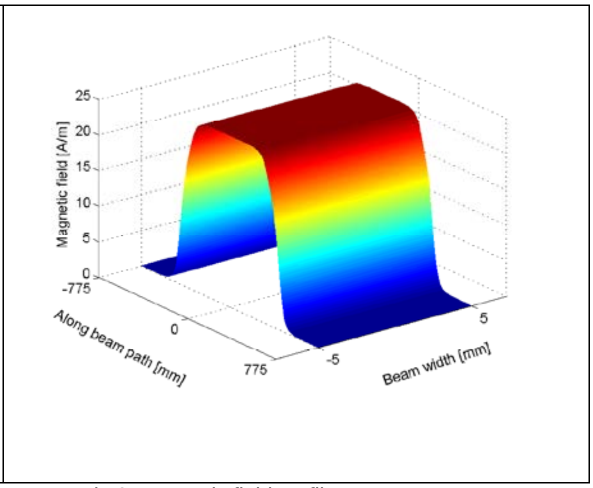


Fig.2: Magnetic field profile

The parasitic field has been analyzed to get the required homogeneity. High homogeneity has been achieved as can be seen in figures 3 and 4 showing the ratio between the main field components and the parasitic components in the transversal plane. Locally the values are in the rage of 10^{-5}.

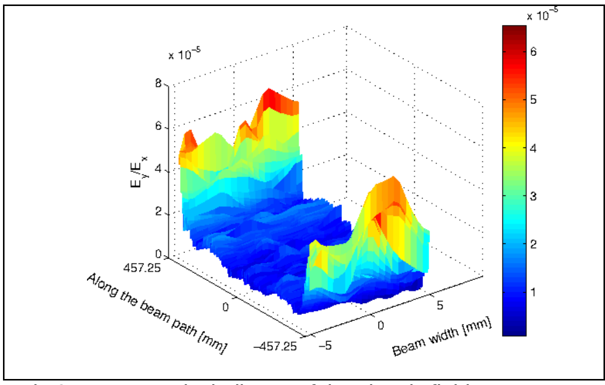


Fig.3: Homogeneity indicator of the electric field

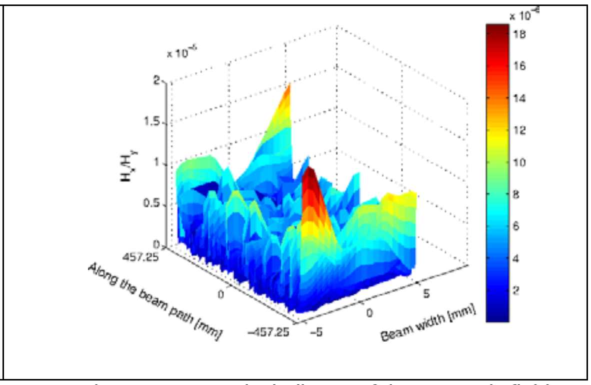


Fig.4: Homogeneity indicator of the magnetic field

Inside the Wien filter, a homogeneous field quotient is maintained. This ensures a negligible Lorentz force at that region as shown in figure 5. At the edges, to get a net Lorentz force as near to zero as possible, the plates were shaped so that the electric and magnetic force lines cross. The net Lorentz force was in the order of 10^{-3} eV/m. Considering the full beam width (figure 6), average Lorentz force is 0.6 eV/m.

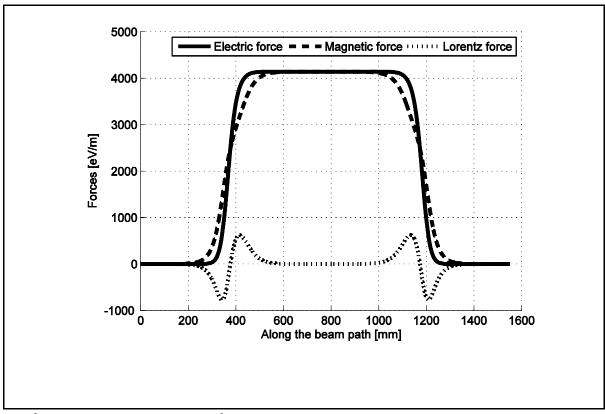


Fig.5: 1D Transversal Lorentz Force

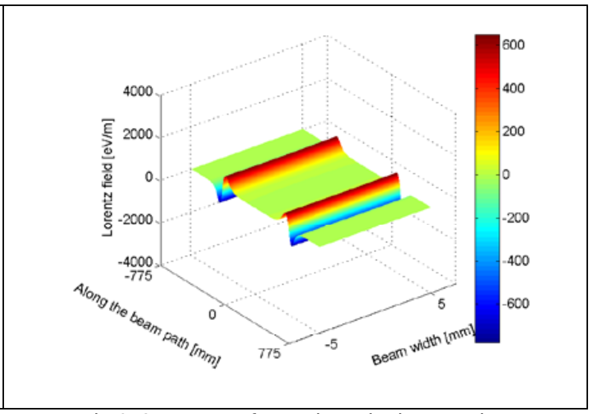


Fig.6: 2D Lorentz force along the beam axis

Spin Tune Measurement and its Applications

The spin tune v_s is defined as the number of spin revolutions relative to the momentum vector per particle revolution around the invariant spin axis. In an ideal planar magnetic ring $v_s = \gamma \cdot G$ with γ being the Lorentz factor and G the magnetic anomaly. Aiming at a high sensitivity of EDM searches using storage rings, one of the limiting factor is the control of the spin motion in the presence of small fluctuations of electric and magnetic fields. Thus, a precise determination of the spin tune as a function of time in the accelerator cycle is one important tool for the R&D activities at COSY towards a first precursor experiment and the design of a dedicated ring.

In order to determine the spin tune, asymmetries are formed using the time-dependent counts of the up (U) and down (D) detector quadrants of EDDA. As the high precession frequency of $\gamma \cdot G \cdot f_{rev} \approx 120$ kHz makes it impossible to use detector rate asymmetries accumulated over time intervals in the order of seconds, a sophisticated read-out system has been developed, which can time stamp the individual event arrival times with respect to the beginning of each cycle. This was achieved by using one long-range time-to-digital converter (TDC) in a dedicated continuous mode, which is also recording the frequency of the COSY rf cavity with the same reference clock. This information was then used to unambiguously assign the number of orbit revolutions n since the start of the cycle to each recorded event. Further details on the experimental setup can be found in Phys. Rev. STAB **17** 052803 (2014).

It is not possible to determine the spin tune v_s from the observed event rates $R_{U,D}(t)$ directly by a simple fit, because at a detector rate of ≈ 5 s^{-1} only about one event is detected per 24 spin revolutions. Instead, the analysis uses a pre-assumed, fixed spin tune v_s^0 to calculated for each event the spin phase advance $\phi s = 2\pi v_s^0 n$. In the further analysis, the information from both detector quadrants are combined such, that the spin precession is reflected in a harmonic oscillation around zero. Finally, the signals are mapped into a phase interval of 2π for fitting. This is done separately for intervals of $\Delta n = 10^6$ corresponding to 2.6 s. In a next step, a range of spin tunes are tested around the nominal value of $vs = \gamma \cdot G$ and the one yielding the largest asymmetry in the fit is used as a first esti- mate with an uncertainty of $\Delta\nu s \approx 10^{-6}$. The precision can be further improved to about 10^{-10} by analyzing the phase advance of the fit throughout the cycle. As an example, the deviation of the spin tune from the assumed one is shown in Fig. 1 as function of time in the cycle.

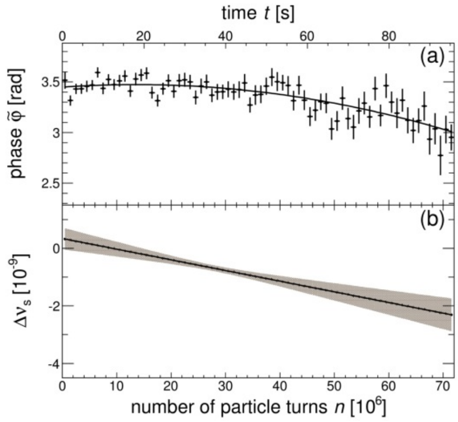


Fig. 1: Phase of the asymmetry fit (a) and deviation $\Delta\nu s$ of the spin tune from the value of $\nu_s^{fix} = -0.160975407$ (b) as a function of turn number in the cycle. The grey band includes statistical errors only

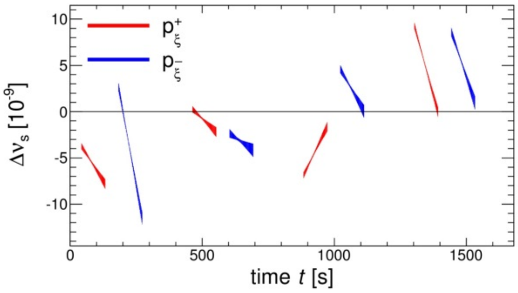


Fig. 2: Walk of the spin tune during eight consecutive cycles with alternating initial vector polarization. The third cycle is depicted in Fig. 1 as well. Cycles with unpo- larized beam that followed the down state (blue) are not shown.

As a first application this method can be used to monitor the stability of the spin tune in the accelerator for longer time periods. Figure 2 shows the observed spin tune changes from cycle to cycle, which are of about the same order (10^{-8} to 10^{-9}) as those within a single cycle. This is remarkable because COSY was never intended to provide a level of stability below $\approx 10^{-6}$ with respect to magnetic fields, orbit corrections, and stabilization of power supplies. Investigations are presently underway to understand the observed variations and to study possible means to stabilize them even further, e.g. by the development of a feedback system to COSY. Figures 1 and 2 are taken from Phys. Rev. Lett. **115** 094801 (2015) — further details can be found in there.

As discussed above the spin motion in a storage ring is perturbed by spin kicks from the imperfection fields in the ring. This leads to a tilt of the invariant spin axis with respect to the vertical axis of a perfect ring. One measurement followed the idea to probe the in-plane imperfections by adding well-known artificial imperfections and to observe the effects on the spin tune. As artificial imperfections the solenoids of the old and the new electron cooler have been used. These have been switched on during the measurement period for certain time resulting in a jump of the measured spin tune. This is depicted in Fig. 3: the magnetic field of the solenoids are given in the lower panel while the effect on the spin tune is plotted above. After switching off the solenoids the spin tune restores to its original values. A two-dimensional scan varying both fields independently can be used to determine the direction of invariant spin axis in the ring.

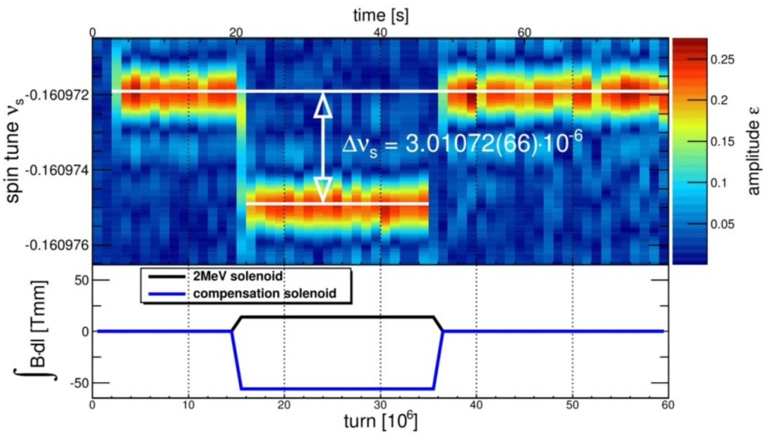


Fig. 3: Measurement of the spin tune jump (top) caused by the artificial imperfections originating from the ad- ditional solenoid fields (bottom) as described in the text. An enlarged version of this figure is shown on the front cover of this annual report.

JARA-FAME Institutes

I. Physikalisches Institut B , RWTH Aachen

Prof. Stefan Schael, Prof. 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.

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 experiments at the COSY facility at Jülich and their analysis. This includes the COSY-TOF experiment which has been terminated in 2013 and the WASA-at-COSY experiment. Hyperon production data taken at COSY-TOF have been analyzed concerning spin resolved proton-Lambda scattering length and reaction mechanism. At the WASA-at-COSY experiments further measurements of charge symmetry breaking and eta productions have been performed and the analyses in various reaction channels is ongoing.

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 have done 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 have also been granted sizeable amounts for two different projects on

JUQUEEN that intend to calculate the proton and neutron EDM at physical quark masses based on very different approaches (imaginary theta-angle and Lüscher flow method).

Using the first method, we have calculated the neutron EDM and submitted a paper to Phys. Rev. Lett. (published in 2015). This was accompanied by studying the finite volume effects for the nucleon EDMs. These studies are of course pertinent to the EDM storage ring project at FZ Jülich. We have also calculated B_l4 decays in dispersion theory and unitarized chiral perturbation theory for extracting the CKM matrix element V_ub.

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 Universita degli Studi di Ferrara Italy, Ivane Javakhishvili Tbilisi State University Georgia, Krakow Uniwersytet Jagiellonski w Krakowie Poland, Grenoble Centre National de la Recherche Scientifique France and others).

Scientific Results

Theory

$B_s \to K^{(*)} e\bar{\nu}$, angular analysis, S-wave contributions and $|V_{ub}|$

Meißner U.-G., Wang W.

JHEP 1401 (2014) 107

We analyse the $\overline{B}_s^0 \to K^+ l^- \bar{\nu}$ and $\overline{B}_s^0 \to K^{*+}(\to K\pi)\ell^-\bar{\nu}$ decays that are valuable for extracting the CKM matrix element $|V_{\rm ub}|$. We calculate the differential and integrated partial widths in units of $|V_{\rm ub}|^2$ based on various calculations of hadronic form factors and in particular the latest Lattice QCD calculation of the $B_s \to K^*$ form factors. For the decay $\overline{B}_s^0 \to K\pi\ell\bar{\nu}$, we formulate the general angular distributions with the inclusion of the various partial-wave $K\pi$ contributions. Using the results for the $K\pi$ scalar form factor calculated from unitarized chiral perturbation theory, we explore the S-wave effects on angular distribution variables and demonstrate that they may not be negligible, considering the high precision expected in future measurements. We also briefly discuss the impact of the S-wave $\pi\pi$ contributions in the $B^- \to \pi^+\pi^-\ell\bar{\nu}$ decay and provide estimates for the mode $B^- \to K^+K^-\ell\bar{\nu}$. The studies of these channels in future can not only be used to determine $|V_{\rm ub}|$, but may also provide valuable information on the $K\pi$ and $\pi\pi$ phase shifts

DOI: 10.1007/JHEP01(2014)107

Determination of the Higgs CP-mixing angle in the tau decay channels at the LHC including the Drell–Yan background

Berge S., Bernreuther W., Kirchner S.

Eur. Phys. J. C74 (2014) 11

We investigate how precisely the CP nature of the 125 GeV Higgs boson resonance h can be unraveled at the LHC in its decays to tau pairs. We use a method which allows to determine the scalar-pseudoscalar Higgs mixing angle in this decay mode. This mixing angle can be extracted from the distribution of a signed angle, which we analyze for the major charged-prong tau decays. For definiteness, we consider Higgs-boson production by gluon fusion at NLO QCD. We take into account also the irreducible background from Drell-Yan production at NLO QCD. We compute, for the signal and background reactions, angular and energy correlations of the charged prongs and analyze which type of cuts suppress the Drell-Yan background. An important feature of this background is that its contribution to the distribution of our observable is a flat line, also at NLO QCD. By separating the Drell-Yan events into two different sets, two different non-trivial distributions are obtained. Based on this observation we propose to use these sets for calibration purposes. By Monte Carlo simulation we study also the effect of measurement uncertainties on this distribution. We estimate that the Higgs mixing angle can be determined with our method to a precision of 14 degree (5 degree) at the high luminosity LHC (14 TeV) with an integrated luminosity of 500 inverse fb (3 inverse ab).

DOI: 10.1140/epjc/s10052-014-3164-0

B_{l4} decays and the extraction of $|V_{ub}|$

Kang X. W., Kubis B., Hanhart C. and Meißner U.-G.

Phys. Rev. D 89 (2014) 053015

The Cabibbo-Kobayashi-Maskawa matrix element $|V_{\rm ub}|$ is not well determined yet. It can be extracted from both inclusive or exclusive decays, like $B \to \pi(\rho) l\bar{\nu}_l$. However, the exclusive determination from $B \to \rho l\bar{\nu}_l$, in particular, suffers from a large model dependence. In this paper, we propose to extract jVubj from the four-body semileptonic decay $B \to \pi\pi l\bar{\nu}_l$, where the form factors for the pion-pion system are treated in dispersion theory. This is a model-independent approach that takes into account the $\pi\pi$ rescattering effects, as well as the effect of the ρ meson. We demonstrate that both finite-width effects of the ρ meson as well as scalar $\pi\pi$ contributions can be considered completely in this way.

DOI: 10.1103/PhysRevD.89.053015

Finite-volume corrections to the CP-odd nucleon matrix elements of the electromagnetic current from the QCD vacuum angle

Akan T., Guo F. K., Meißner U.-G.

Nucleon electric dipole moments originating from strong CP-violation are being calculated by several groups using lattice QCD. We revisit the finite volume corrections to the CP-odd nucleon matrix elements of the electromagnetic current, which can be related to the electric dipole moments in the continuum, in the framework of chiral perturbation theory up to next-to-leading order taking into account the breaking of Lorentz symmetry. A chiral extrapolation of the recent lattice results of both the neutron and proton electric dipole moments is performed, which results in $d_n=(-2.7\pm1.2)\times10^{-16}e\theta_0$ cm and $d_p=(2.1\pm1.2)\times10^{-16}e\theta_0$cm.

DOI: 10.1016/j.physletb.2014.07.022

Unraveling models of CP violation through electric dipole moments of light nuclei

Dekens W., de Vries J., Bsaisou J., Bernreuther W., Hanhart C., Meißner U.G., Nogga A., Wirzba A.

JHEP **07** (2014) 069

We show that the proposed measurements of the electric dipole moments of light nuclei in storage rings would put strong constraints on models of flavor-diagonal CP violation. Our analysis is exemplified by a comparison of the Standard Model including the QCD theta term, the minimal left-right symmetric model, a specific version of the so-called aligned two-Higgs doublet model, and briefly the minimal supersymmetric extension of the Standard Model. By using effective field theory techniques we demonstrate to what extend measurements of the electric dipole moments of the nucleons, the deuteron, and helion could discriminate between these scenarios. We discuss how measurements of electric dipole moments of other systems relate to the light-nuclear measurements.

DOI: 10.1007/JHEP07(2014)069

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.

JHEP **1503** (2015) 104

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

Electroweak fragmentation functions for dark matter annihilation

Ali Cavasonza L., Krämer, M., Pellen, M.

Journal of Cosmology and Astroparticle Physics JCAP **1502** (2015) 02, 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

EDM Experiment

Measuring the polarization of a rapidly precessing deuteron beam

Z. Bagdazarian et al.

This paper describes a time-marking system that enables a measurement of the in-plane (horizontal) polarization of a 0.97−GeV/c deuteron beam circulating in the Cooler Synchrotron (COSY) at the Forschungszentrum Jülich. The clock time of each polarimeter event is used to unfold the 120-kHz spin precession and assign events to bins according to the direction of the horizontal polarization. After accumulation for one or more seconds, the down-up scattering asymmetry can be calculated for each direction and matched to a sinusoidal function whose magnitude is proportional to the horizontal polarization. This requires prior knowledge of the spin tune or polarization precession rate. An initial estimate is refined by resorting the events as the spin tune is adjusted across a narrow range and searching for the maximum polarization magnitude. The result is biased toward polarization values that are too large, in part because of statistical fluctuations but also because sinusoidal fits to even random data will produce sizable magnitudes when the phase is left free to vary. An analysis procedure is described that matches the time dependence of the horizontal polarization to templates based on emittance-driven polarization loss while correcting for the positive bias. This information will be used to study ways to extend the horizontal polarization lifetime by correcting spin tune spread using ring sextupole fields and thereby to support the feasibility of searching for an intrinsic electric dipole moment using polarized beams in a storage ring. This paper is a combined effort of the Storage Ring EDM collaboration and the JEDI collaboration.

Physical Review Special Topicas – Accelerators and Beams **17** (2014) 052803

DOI: 10.1103/PhysRevSTAB.17.052803

AMS Experiment

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

M. Aguilar et al.

Physical Review Letters 113 (2014) 221102

We present a measurement of the cosmic ray ($e^+ + e^-$) flux in the range 0.5 GeV to 1 TeV based on the analysis of 10.6 million ($e^+ + e^-$) events collected by AMS. The statistics and the resolution of AMS provide a precision measurement of the flux. The flux is smooth and reveals new and distinct information. Above 30.2 GeV, the flux can be described by a single power law with a spectral index $\gamma=-3.170\pm0.008$(stat+syst)±0.008 (energy scale).

DOI: 10.1103/PhysRevLett.113.221102

High Statistics Measurement of the Positron Fraction in Primary Cosmic Rays of 0.5 – 500 GeV with the Alpha Magnetic Spectrometer on the International Space Station

L. Accardo et al.

Physical Review Letters 113 (2014) 121101

A precision measurement by AMS of the positron fraction in primary cosmic rays in the energy range from 0.5 to 500 GeV based on 10.9 million positron and electron events is presented. This measurement extends the energy range of our previous observation and increases its precision. The new results show, for the first time, that above ∼200 GeV the positron fraction no longer exhibits an increase with energy.

DOI: 10.1103/PhysRevLett.113.121101

Electron and Positron Fluxes in Primary Cosmic Rays Measured with the Alpha Magnetic Spectrometer on the International Space Station

M. Aguilar et al

Physical Review Letters 113 (2014) 121102

Precision measurements by the Alpha Magnetic Spectrometer on the International Space Station of the primary cosmic-ray electron flux in the range 0.5 to 700 GeV and the positron flux in the range 0.5 to 500 GeV are presented. The electron flux and the positron flux each require a description beyond a single power-law spectrum. Both the electron flux and the positron flux change their behavior at ~30 GeV but the fluxes are significantly different in their magnitude and energy dependence. Between 20 and 200 GeV the positron spectral index is significantly harder than the electron spectral index. The determination of the differing behavior of the spectral indices versus energy is a new observation and provides important information on the origins of cosmic-ray electrons and positrons.

DOI: 10.1103/PhysRevLett.113.121102

Hadron Physics Experiments

Charge symmetry breaking in dd → $^4He\pi^0$ with WASA-at-COSY

Adlarson P., Augustyniak W., Bardan W., Bashkanov M., Bergmann F.S., Berłowski M., Bhatt H., Bondar A., Büscher M., Calén H., et al.

Physics Letters B 739 (2014) 44

Charge symmetry breaking (CSB) observables are a suitable experimental tool to examine effects induced by quark masses on the nuclear level. Previous high precision data from TRIUMF and IUCF are currently used to develop a consistent description of CSB within the framework of chiral perturbation theory. In this work the experimental studies on the reaction dd → $^4He\ \pi^0$ have been extended towards higher excess energies in order to provide information on the contribution of p-waves in the final state. For this, an exclusive measurement has been carried out at a beam momentum of pd = 1.2 GeV/c using the WASA-at-COSY facility. The total cross section amounts to $\sigma_{tot} = (118 \pm 18_{stat} \pm 13_{sys} \pm 8_{ext})$ pb and first data on the differential cross section are consistent with s-wave pion production.

DOI: 10.1016/j.physletb.2014.10.029

Determination of the η′-proton scattering length in free space

Czerwiński E., Moskal P., Silarski M., Bass S. D., Grzonka D., Kamys B., Khoukaz A., Klaja J., Krzemień W., Oelert W., et al.

Phys.Rev.Lett. 113 (2014) 062004

Taking advantage of both the high mass resolution of the COSY–11 detector and the high energy resolution of the low-emittance proton-beam of the Cooler Synchrotron COSY the excitation function for the pp→ ppη′ reaction close-to-threshold was determined. Combining these data with previous results we extract the scattering length for the η′-proton potential in free space to be Re(a′)=0 (± 0.43) fm and Im(a′)=0.37 (+0.40/-0.16) fm.

DOI: 10.1103/PhysRevLett.113.062004

Measurement of the $np \to np\pi^0\pi^0$ 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., et al.

Physics Letters B 743 (2015) 325

Exclusive measurements of the quasi-free $np \to np\pi^0\pi^0$ reaction have been performed by means of dp collisions at T_d = 2.27 GeV using the WASA detector setup at COSY. Total and differential cross sections have been obtained covering the energy region 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.

DOI:10.1016/j.physletb.2015.02.067

Measurement of the η→π+π−π0 Dalitz plot distribution

Adlarson P., Augustyniak W., Bardan W., Bashkanov M., Bergmann F.S., Berłowski M., Bhatt H., Bondar A., Büscher M., Calén H., et al.

Phys. Rev. C 90 (2014) 045207

Dalitz plot distribution of the $\eta \to \pi^+\pi^-\pi^0$ decay is determined using a data sample of $1.2 \cdot 10^7$ η mesons from $pd \to {}^3He\,\eta$ reaction at 1 GeV collected by the WASA detector at COSY.

DOI: 10.1103/PhysRevC.90.045207

Overview Conferences, Awards and Offers

Conferences

Henning Gast, „The AMS project on the ISS: A Big Data Challenge“, LSDMA (Large Scale Data-Management and Analysis) Community Forum, FZ Juelich, 1 April 2014

Henning Gast, „Cosmic-ray research with AMS-02 on the International Space Station“, XXX-th International Workshop on High Energy Physics "Particle and Astroparticle Physics, Gravitation and Cosmology: Predictions, Observations and New Projects", 23 to 27 June 2014, Protvino, Russian Federation

Henning Gast, „Search for Dark Matter with Charged Particles“, The Variable Sky: From Tiny Variations to Big Explosions, Annual Meeting of the Astronomische Gesellschaft, Bamberg, 25 September 2014

Andreas Lehrach, “Storage Ring Based EDM Search - Achievements and Goals”, SPIN2014, 21st International Symposium on Spin Physics, October 20 - 25, 2014, Beijing (China)

Andreas Lehrach, “Beam and Spin Dynamics for Hadron Storage Rings”, CPO-9, “International Conference on Charged Particle Optics 2014”, August 31 - September 5, 2014, Brno (Czech Republic)

Joerg Pretz, “Electric Dipole Moments Measurements at Storage Rings”, DPG Frühjahrstagung “Hadronen und Kerne”, March 17 - 21, 2014, Frankfurt

Joerg Pretz, “Electric Dipole Moments Measurements at Storage Rings”, STORI 2014, 9th International Conference on Nuclear Physics with Storage Rings, September 29 - October 3, 2014, St. Goar (Germany)

Stefan Schael, „First Results from the AMS Experiment” eingeladener Hauptvortrag auf der Tagung der Deutschen Physikalischen Gesellschaft, Mainz, März 2014.

Stefab Schael, “Auf der Suche nach Antimaterie Galaxien – Das AMS Experiment auf der Internationalen Raumstation”, 27. Hellmut-Weese-Gedächtnisvorlesung, Tagung der Deutsche Gesellschaft für Anästhesiologie und Intensivmedizin, Leipzig, Mai 2014.

Stefan Schael, „First Results from the AMS Experiment”, Latest Results in Dark Matter Searches, Stockholm, May 2014.

Stefan Schael, “AMS und die Teilchen der Dunklen Materie”, 27. Raumfahrtkolloquium der FH Aachen, November 2014.

Organisation of Conferences

6th Georgian-German School and Workshop in Basic Science, July 7-12, 2014, Tbilisi (Georgia)

Hadron Physics Summer School (HPSS2014), September 1-5, 2014, Rauischholzhausen

Awards and Offers

Prof. Mei Bai is director of the Nuclear Physics Institute – Large-Scale Nuclear Physics Equipment (IKP-4) since December 2014. She took over from acting director Prof. Andreas Lehrach, head of the spin dynamics group. Prof. Bai is an accelerator physicist and previously worked on the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory in the USA.

Prof. Rudolf Maier (IKP-4) was awarded an honorary doctorate at the end of September 2014 by the Scientific Council of the Joint Institute for Nuclear Research (JINR) in Dubna in recognition of the outstanding contribution to the advancement of science and the education of young scientists.

Prof. Sebastian M. Schmidt, member of the Board of Directors of Forschungszentrum Jülich, and Prof. Hans Ströher, director at Jülich’s Nuclear Physics Institute (IKP), were awarded honorary doctorates by the Georgian Technical University (GTU) in Tbilisi today for their many years of commitment to the scientific exchange between Germany and Georgia. Prof. Schmidt and the Georgian Minister of Education and Science Tamar Sanikidze agreed to further consolidate cooperation over the next few years.

Dr. Rolf Stassen (IKP-4) was awarded the Encouraging Prize together with colleagues from Russia and Japan at the end September 2014 by the Joint Institute of Nuclear Research (JINR) in Dubna for „Development and Start-up of the Stochastic Cooling System for Nuclotron Ion Beams at the NICA Accelerator Complex“

PhD- and Master Theses

Jan Bsaisou, “Electric Dipole Moments of Light Nuclei in Chiral Effective Field Theory”, PhD, University of Bonn (2014)

Tobias Dato, “Is the η double off–shell form factor separable?” Bachelor, University of Bonn (2014)

Simone Esch, “Evaluation of the PANDA Silicon Pixel Front-End Electronics and Investigation of the Lambda bar Lambda Final State”, PhD, University of Bochum (2014)

Nils Hempelmann, “Phase Space Reconstruction of a Particle Beam Using Elastic Scattering“, Master, RWTH Aachen University (2014)

Simon Henssler, “Entwicklung und Evaluierung eines Verfahrens für kinematische Anpassung von Teilchenreaktionen basierend auf dem Verfahren von Nelder und Mead“, Master, University of Aachen (2014)

Visiting Scientists

Andersson, Walter Ikegami	Uppsala University, Sweden	30.03. - 07.04.2014
Bai, Mei	Brookhaven National Laboratory (BNL), USA	16.08.- 29.08.2014
Balanutsa, Pavel	Institute for Theoretical and Experimental Physics	17.11. - 13.12.2014
Balanutsa, Vladimir	Budker Institute (BINP), Russia	17.11. - 13.12.2014
Barniakov, Mikhail	Novosibirsk State University, Novosibirsk, Russia	31.07. - 05.08.2014
Bass, Steven	Stefan Meyer Institut für subatomare Physik, Wien, Austria	28.01. - 01.02.2014 10.06. - 20.06.2014
Bekhtenev, Evgeny	Budker Institute (BINP), Russia	18.01. - 03.02.2014
Belostotski, Stanislav	Petersburg Nuclear Physics Insitute (PNPI), Russia	01.10. - 28.10.2014
Biernat, Jacek	AGH University Krakaw, Poland	20.07. - 29.07.2014
Bokuchava, Tengiz	Tiblisi State University, Georgia	14.09. - 05.10.2014
Bryzgunov, Maxim	Budker Institute (BINP), Russia	15.06. - 19.07.2014
Bubley, Alexander	Budker Institute (BINP), Russia	20.06. - 19.07.2014
Burkert, Volker	Jefferson Lab, Newport News, USA	25.11. – 26.11.2014
Calén, Hans	Uppsala University, Sweden	06.04. - 10.04.2014
Cao, Lu	Southwest University, Chongqing, China	01.01. - 31.12.2014

Chekavinskiy, Vladimir	Budker Institute (BINP), Russia	18.01. - 03.02.2014
Chitashvili, Marine	Rustaveli National science Foundation, Georgia	12.05. - 16.05.2014
Dymov, Sergey	Joint Insitute for Nuclear Resarch, Russia	several times
Eliashvili, Merab	Rustaveli National science Foundation, Georgia	12.05. - 16.05.2014
Eltsov, Leonid	SPb STU Experimental Nuclear Physics dep., Russia	25.08. - 29.08.2014
Eydelman, Semen	Novosibirsk State University, Novosibirsk, Russia	24.09. - 03.10.2015
Fedorets, Pavel	ITEP, Institute for theroetical and experimental Physics, Russia	several times
Fransson, Kjell	Uppsala, University	16.02. - 20.02.2014
Fujioka, Hiroyuki	Kyoto University, Japan	08.01. - 15.02.2014
Georgadze, Ilya	Moscow State University, Russia	15.01. - 30.04.2014 01.09. - 15.12.2014
Giuseppe Ciullo	Universita' di Ferrara, Italien	08.09. - 21.09.2014
Guaraldo, Carlo	Laboratori Nazionali di Frascati, Italy	06.04. - 08.04.2014
Guidoboni, Greta	Universita' di Ferrara, Italien	03.02. - 09.03.2014
Hu, Qiang	Chinese Academy of Sciences, Lanzhou, China	01.09. - 31.12.2015
Itahashi, Kenta	RIKEN, Nishina-Center, Siatama, Japan	11.01. - 10.02.2014
Katayama, Takeshi	Nihon University, Narashino, Chiba, Japan	03.10. - 10.10.2014
Kondaurov, Mikhail	Budker Institute (BINP), Russia	25.01. - 10.02.2014
Kononov, Anton	SPb STU Experimental Nuclear Physics dep., Russia	25.08. - 29.08.2014
Kononov, Sergey	Novosibirsk State University, Novosibirsk, Russia	31.07. - 05.08.2014
Koop, Ivan	Budker Institute (BINP), Russia	03.03. - 08.03.2014
Kozlov, Vladimir	Moscow State University, Russia	15.01. - 30.04.2014 01.09. - 15.12.2014
Kumar, Ajay	Indian Institute of Technology Indore, Indien	06.09. - 20.11.2014
Kuyanov, Ivan	Budker Institute of Nuclear Physics, RAS, Novosibirsk, Russia	31.07. - 05.08.2014
Lenisa, Paolo	Universita' di Ferrara, Italien	several times
Lomidze, Nodar	High Energy Physics Institute of the Tbilisi State Uni., Georgia	04.11. - 25.11.2014
Mahler, Aaron	North Carolina State University (NCSU), USA	26.05. - 15.08.2014

Markhel, Andrey	Budker Institute, (BINP), Russia	04.05. - 03.06.2014
Mineev, Sergey	ITEP, Institute for theroetical and experimental Physics, Russia	17.11. - 02.12.2014
Nikolaev, Nikolai	Budker Institute, (BINP), Russia	several times
Nioradze, Miheil	Rustaveli National science Foundation, Georgia	12.05. - 16.05.2014
Nowakowski, Krzystof	Jagiellonian University, Poland	04.08. - 29.08.2014
Oelert, Walter	Johannes-Gutenberg-Universität Mainz, Germany	13.12. - 15.12.2014
Orfanitskiy, Sergey	Moscow State University, Russia	15.01. - 30.04.2014 01.09. - 15.12.2014
Pannunzio, Marco	Catholic University, Washington DC, USA	09.08. - 25.08.2014 22.11. - 30.11.2014
Park, SeongTae	KAIST, Korea	13.08. - 22.08.2014
Parkhomchuck, Vasily	Budker Institute (BINP), Russia	25.01.-10.02.2014
Pesce, Andrea	Universita' di Ferrara, Italien	several times
Podchaskiy, Satnislav	ITEP, Institute for theroetical and experimental Physics, Russia	17.11. - 13.12.2014
Prisekin, Viacheslav	Budker Institute of Nuclear Physics, RAS, Novosibirsk, Russia	31.07. - 05.08.2014
Reva, Vladimir	Budker Institute (BINP), Russia	21.06. - 29.07.2014 25.01. - 10.02.2014
Ron, Guy	Jefferson Lab, Newport News, USA	28.04. - 29.04.2014
Sakhelashvili, Otari	Tiblisi State University, Georgia	14.09. - 05.10.2014
Salabura, Piotr	Jagiellonian University Krakaw, Poland	20.07. - 23.07.2014
Smyrski, Jerzy	Jagiellonian University Krakaw, Poland	22.07. - 28.07.2014
Statera, Marco	Universita' di Ferrara, Italien	22.04. - 26.04.2014
Stechly, Michael	Jagiellonian University, Poland	04.08. - 29.08.2014
Stephenson, Edward	Indiana University, USA	several times
Strzempek, Pawel	Jagiellonian University Krakaw, Poland	18.07. - 25.07.2014
Suzuki, Ken	Stefan Meyer Institut für subatomare Physik, Wien, Austria	21.01 - 11.02.2014
Tabidze, Mirian	High Energy Physics Institute of the Tbilisi State Uni., Georgia	05.12. - 19.12.2014
Tanaka, Yoshiki	University of Tokyo, Japan	06.01. - 05.02.2014

Terashima, Satoru	Beihang University, Peking, China	22.01. - 02.02.2014
Thörngren Enggblom, Pia	Uppsala University, Sweden	26.08. - 31.08.2014
Uzikov, Yuriy	Joint Insitute for Nuclear Resarch, Russia	11.04. - 30.04.2014
Veretennikov, Denis	Petersburg Nuclear Physics Insitute (PNPI), Russia	01.10. - 28.10.2014
Watanabe, Yuni	Tokyo University, Japan	05.01. - 08.02.2014
Wilkin, Colin	University College London	14.05. - 22.05.2014
Wloch, Boguslaw	AGH University, Krakow, Poland	18.07. - 28.07.2014
Wolke, Magnus	Uppsala University, Sweden	27.03. - 03.04.2014
Wouter Dekens	Universtiy of Groningen, Niederlande	10.10. – 14.10.2014
Zink, Adrian	Universität Erlangen-Nürnberg, Germany	29.04. - 30.04.2014