Kick-off workshop for the search of a muon EDM using the frozen spin technique at PSI

Monday, 17 February 2020 - Wednesday, 19 February 2020

Book of Abstracts

Contents

Welcome and Overview / **1**

The seach of the muon EDM using the frozen spin technique at PSI.

Author: Philipp Schmidt-Wellenburg[1]

[1] *Paul Scherrer Institut*

A permanent EDM of an elementary particle violates parity (P) and time reversal (T) symmetry, and assuming CPT invariance, T violation implies CP violation. EDM predicted by the Standard Model (SM) are far too small to be detected with current experimental techniques, therefore, any observation of non-zero EDMs would strongly indicate the existence of physics beyond the SM (BSM).
The muon is of particular interest and is the only fundamental particle which reasonably allows to measure the EDM directly. The current best upper limit of the μEDM, $1.8 \times 10^{-19} e{\cdot}\mathrm{cm}$ (95% C.L.), was obtained parasitically in the "$(g-2)$" measurement of the muon at Brookhaven. This leaves the muon EDM as one of the least tested areas of the SM.
In my talk I will sketch the ideas and possibilities for a dedicated search of the muon EDM using the frozen spin technique at PSI.

Storage ring dynamics / **2**

Novel techniques for injecting or extracting beams from a circular ring

Author: Massimo Giovannozzi[1]

[1] *CERN*

In recent years, non-linear beam dynamics has been used to design novel manipulations that exploit multiple stable orbits in a single ring. In this presentation, an overview of the methods that have been developed will be carried out focusing on the possibility of devising new means for injecting or extracting beams from a circular accelerator.

Storage ring dynamics / **3**

Polarized Beams at RHIC, and Electron Beams at the Future EIC

Author: Francois Meot[1]

[1] *Brookhaven National Laboratory*

A status of polarized proton beams at RHIC, and on-going 3He developments. Review of polarized beam plans and studies for the EIC, including electron beam transfer, acceleration, and polarization lifetime at store. Add some insight into spin dynamics computational tools and methods.

Storage ring dynamics / **4**

The magnetic field measurement for the Muon g-2 experiment with precision NMR

Author: Peter Winter[1]

[1] *Argonne National Laboratory*

The Muon g-2 experiment E989 at Fermilab will measure the anomalous magnetic moment of the muon, a_μ, with about four times better precision than former experiments. The aim is to resolve the discrepancy of more than 3 standard deviations between the previous measurements dominated by the Brookhaven E821 result and the Standard Model calculation of a_μ.
The experimental concept uses a polarized muon beam at the magic momentum which is stored in the extremely homogeneous magnetic field of the storage ring. Parity violation in the weak decay is used as a spin analyzer; the detected rate of the decay electrons oscillates with the frequency, ω_a, in the magnetic field expressed in terms of the equivalent free proton Larmor frequency, ω_p. Since a_μ is derived from the ratio of ω_a and ω_p, both are equally important and systematic uncertainties must be kept below 70 ppb for each observable.
A magnetic field measurement system was developed to measure the magnetic field experienced by the muons. A set of 378 new Nuclear Magnetic Resonance (NMR) probes constantly monitor the field at all times around the storage ring. An upgraded in-vacuum field mapping system scans the muon storage region over the full azimuth of the magnet. A special water-based NMR probe which has a well-measured geometry and low magnetic perturbation was designed to calibrate the probes of the field mapping system. All systems were successfully commissioned, and were in full operation for the first physics data taking runs in 2018 and 2019. This presentation will provide details of the challenging measurement and analysis of the averaged magnetic field and discuss aspects that will be relevant for the future muon EDM measurement. The special challenges of the radial field measurement will be discussed in a separate talk at this workshop.

Particle triggering, detection and tracking / **5**

The MuPix Pixel Sensors, the Mu3e DAQ and tracking in multiple-scattering dominated environments

Author: Niklaus Berger[1]

[1] *Mainz University, Insititute for Nuclear Physics*

The Mu3e collaboration is building an ultra thin ˜300 million pixel tracking detector in order to search for the the lepton-flavour violating decay of a positive muon to two positrons and and an electron at PSI. To this end, we have designed and tested a series of high-voltage active monolithic pixel sensors (HV-MAPS), the MuPix chips. The talk will present results from the latest fully characterized prototype, the MuPix8 and give an outlook to the MuPix10 chip expected for this summer. It will also discuss some insights into tracking in multiple Coulomb scattering dominated envionments gained by Mu3e and bits and pieces of the Mu3e data acquisition system that might be useful for a muon EDM experiment.

Storage ring dynamics / **6**

Overview of muon EDM searches - the past, the present, and the future

Author: Kim Siang Khaw[1]

[1] *Tsung-Dao Lee Institute, Shanghai Jiao Tong University*

Electric dipole moment (EDM) of the muon is one of the least tested areas of the Standard Model (SM) of Particle Physics and any detected signal is a strong hint of physics beyond the SM. In this

presentation, I will review the history of the searches for a muon EDM, current status of efforts at Fermilab and J-PARC, and the new effort at PSI.

EDM in storage rings / **7**

Electric dipole moment searches using storage rings (Part I)

Authors: Frank Rathmann[1]; Alexander Nass[2]

[1] *Institute for Nuklear Physik, Forschungszentrum Jülich*

[2] *Institute for nuclear physics, Forschungszentrum Jülich*

The Standard Model (SM) of Particle Physics is not capable to account for the apparent matter-antimatter asymmetry of our Universe. Physics beyond the SM is required and is either probed by employing highest energies (e.g., at LHC), or by striving for ultimate precision and sensitivity (e.g., in the search for electric dipole moments). Permanent electric dipole moments (EDMs) of particles violate both time reversal (T) and parity (P) invariance, and are via the CPT-theorem also CP-violating. Finding an EDM would be a strong indication for physics beyond the SM, and pushing upper limits further provides crucial tests for any corresponding theoretical model, e.g., SUSY.
Up to now, EDM searches focused on neutral systems (neutrons, atoms, and molecules). Storage rings, however, oer the possibility to measure EDMs of charged particles by observing the in
uence of the EDM on the spin motion in the ring [1, 2, 3]. Direct searches of proton and deuteron EDMs bear the potential to reach sensitivities beyond 10E-29 e cm. Since the Cooler Synchrotron COSY at the Forschungszentrum Julich provides polarized protons and deuterons up to momenta of 3.7 GeV/c, it constitutes an ideal testing ground and starting point for such an experimental program.
The collaboration is presently aiming at a rst direct (precursor) measurement of the deuteron EDM in COSY[4], using an RF Wien lter that was specically designed for that purpose [5, 6, 7]. Beyond that, the technical design of a prototype EDM storage ring [8] constitutes the next major milestone of the JEDI research program, which shall be addressed together with CERN in the framework of a newly formed CPEDM collaboration1.
The talk will present the JEDI plans for the measurement of charged hadron EDMs, and discuss the various technical developments, and also show recent results.

EDM in storage rings / **8**

The muon EDM measurement at Fermilab

Author: Joe Price[1]

[1] *University of liverpool*

An overview of the forthcoming measurement of the muon EDM using the g-2 storage ring at Fermilab. The new tracking detectors, together with improved segmented calorimeters, allow for increased sensitivity to a precession plane tilt.

Storage ring dynamics / **9**

Radial magnetic field measurements in the Muon g-2 experiment at FNAL

Author: Martin Fertl[1]

[1] *Johannes Gutenberg Universität Mainz*

The muon g-2 experiment at Fermi National Accelerator Laboratory (FNAL E989) is using a superferric magnet to generate the nominally vertical precision magnetic field of 1.45 T which confines the muon beam in the horizontal plane (radial direction). A segmented electrostatic quadrupole system is employed to prevent the muon beam from spiraling out of the storage region in the vertical direction and to center the muon beam in the nominal storage orbit volume defined by physical beam collimators. A non-vanishing horizontal magnetic field component displaces the muon beam center from the geometric center of the muon storage region, shrinking the effective muon storage volume and leading to complications in the control of several systematic effects related to the dynamics of the muon beam. The presentation will describe the instrumentation developed to measure the radial magnetic field during the commissioning of the muon storage ring magnet, the passive means implemented to reduce the averaged radial magnetic field component, and the surface coil current system used to actively compensate the radial field components during science data run time.

Particle triggering, detection and tracking / **10**

DMAPS technologies for uEDM positron tracker

Authors: Malte Backhaus[1]; Branislav Ristic[2]

[1] *ETHZ - ETH Zürich*

[2] *ETH Zurich*

A short summary of technologies for Depleted Monolithic Pixel Sensors (DMAPS) will provided in the talk.

Particle triggering, detection and tracking / **11**

Scintillator based detector developments for the most recent muon physics searches

Plastic scintillators (including scintillating fibers) coupled to photosensors provide flexible, fast and high granularity detectors which are able to work in high rate environment. The advent of Silicon PhotoMultipliers (SiPMs) has had a strong impact in the development of what we can call a “new age” of plastic scintillator based detectors. Improved detector performances (better spatial and timing resolutions) can be reached with respect to previous detectors, where PhotoMultipliers (PMs) were used, thanks namely to (1) the small photosensor size which allows to couple each single element to its own SiPM and (2) the reduced transit time spread of the photosensor itself. The straightforward application of such a detectors is as a trigger tools. Furthermore the possibility of using SiPMs in magnetic fields strongly simplifies the implementation of such detectors used as tracker devices or to complement the latter, where usually a magnetic field is needed. Finally new beam monitoring detectors able to sustain very high beam intensities can be built. In this talk a review of scintillator based detectors used on the most recent muon physics searches will be given.

EDM in storage rings / **12**

Search for EDM of unstable particles at the LHCb

EDM in storage rings / 13

Electric dipole moment searches using storage rings (Part II)

Authors: Frank Rathmann[1]; Alexander Nass[2]

[1] *Institute for Nuklear Physik, Forschungszentrum Jülich*

[2] *Institute for nuclear physics, Forschungszentrum Jülich*

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Welcome and Overview / 14

Theoretical Motivation for measuring the muon EDM

We consider possible beyond-the-Standard-Model (BSM) effects that can accommodate both the long-standing tension in the anomalous magnetic moment of the muon, aμ=(g−2)μ/2, as well as the emerging 2.5σ deviation in its electron counterpart, ae=(g−2)e/2. After performing an EFT analysis, we consider BSM physics realized above the electroweak scale and find that a simultaneous explanation becomes possible in models with chiral enhancement. However, this requires a decoupling of the muon and electron BSM sectors to avoid the strong constraints from μ⟶eγ. In particular, this decoupling implies that there is no reason to expect the muon electric dipole moment (EDM) dμ to be correlated with the electron EDM de, avoiding the very stringent limits for the latter. While some of the parameter space for dμ favored by aμ could be tested at the (g−2)μ experiments at Fermilab and J-PARC, a dedicated muon EDM experiment at PSI would be able to probe most of this region. In fact, only muon EDM experiments are capable to test the associated effective operator, giving strong motiations for such a measurement.

Welcome and Overview / 15

Welcome to PSI

Information for the workshop

EDM in storage rings / **16**

Status of muon EDM experiment at J-PARC

I will present the status and prospects of the muon EDM experiment by using a reaccelerated thermal muon beam at J-PARC

EDM in storage rings / **17**

First result from beam tests at PSI

Author: Mikio Sakurai[1]

[1] *ETH Zürich*

In 2019 we have measured the beam profiles of two potential muon beamlines at PSI. These measurements will permit the extraction of the transverse phase space for calculations of injection into a compact storage ring.

Particle triggering, detection and tracking / **18**

Development of a Dedicated Precision Polarimeter for Charged Particle EDM searches at COSY

The international JEDI (Jülich Electric Dipole moment Investigation) collaboration is preparing a first-ever direct measurement of the deuteron Electric Dipole Moment (EDM), using the COSY storage ring at Forschungszentrum Jülich (Germany).
A new polarimeter is required to detect the very slow and minuscule polarization change with time: starting
in 2016, we have designed, built and commissioned a new modular type storage ring EDM polarimeter based
on LYSO inorganic scintillator crystals. The polarimeter concept exploits LYSO modules (3x3x8 cm3), individually coupled to modern large area SiPM arrays which are operating at low voltage.
The detector system and its vacuum system have radial symmetry and a thin exit window, making the polarimeter very efficient for online up-down and left-right asymmetry measurements.
After several tests at the external COSY beam, we have recently installed the complete system in the COSY ring for use with internal beams.
In this talk, I will summarize the achievements of our group and discuss the latest results.