Cancelled: Hadron Physics Summer School 2022

Monday, 12 September 2022 - Friday, 16 September 2022

Scientific Programme

During the summer school, the participants will work on one of the following projects. The goal of each project is to design a future measurement in hadron physics. To achieve this the working groups will receive introductory material on the theoretical and experimental aspects of their chosen measurement. They will then have to come up with a proposal for how such a measurement could be achieved. On Friday these proposals will be presented to the school.

Below is a list of available topics. More might become available.

WG1: Charm Magnetic Dipole Moment with Bent Crystals

The magnetic dipole moment (MDM) of a particle is a fundamental characteristic that determines the torque which particle experiences in an external magnetic field. For electrons the theory prediction agrees with the experimentally measured value up to very high precision. For muons the $g-2$ measurements at BNL and Fermilab disagrees with the Standard Model prediction by 3–4 standard deviations, which may suggest physics beyond the Standard Model.

For hadrons, the MDMs are measured for the baryon octet with $J^P=1/2^+. Historically, the fair agreement between the measured MDM and predictions of the quark model was a success for constituent quark models of the hadrons.
For short lived particles such as strange and charm baryons the usual $g-2$ measurement in a storage ring is not feasible, due to the short lifetime. An alternative technique has been demonstrated to measure the magnetic dipole moment of hyperons using channeling in bent silicon crystals. This technique has also been proposed to measure the magnetic dipole moment of charm baryons at the Large Hadron Collider. In this project we will investigate a future charm MDM experiment at the LHC.

WG2: Exotic Hadrons

The $\chi_{c1}(3872)$, also known as $X(3872)$, is one of the most studied candidates for an exotic state. However, even though various experiments have accumulated data on it from multiple channels, not even its pole parameters are determined. Accordingly, there is still a heated debate in the community on its nature. To improve our knowledge of the pole parameters a combined analysis of at least the two most relevant decay channels ($J/\psi \pi\pi$ and $D^*\bar D^0$) is compulsory. In the working group, we will prepare a proposal on how to perform such a combined analysis.

WG3: Measurement of Electric Dipole Moments in Storage Rings

Permanent Electric Dipole Moments (EDMs) of subatomic particles violate both time invariance and parity. Assuming the CPT theorem, the violation of time invariance implies CP violation. The CP violation of the Standard Model is orders of magnitude too small to be observed experimentally in EDMs in the foreseeable future. Since it is also too small to explain the observed excess of matter over antimatter in our universe, other mechanisms beyond the realm of the Standard Model must be at play. High precision measurements of EDMs therefore provide a valuable means to search for physics beyond the Standard Model such as supersymmetry or multi-Higgs models, for instance [1,2].

EDM experiments with charged hadrons are proposed at storage rings where polarized particles are exposed to a radial electric field [3]. If an electric dipole moment exists, the spin vector will experience a torque resulting in a change of the original spin direction, which can be determined using elastic scattering of the beam particles on a carbon target. Although the principle of the measurement is simple, the smallness of the expected expect makes this a challenging experiment requiring new developments in various experimental areas.

In this working group the spin motion for a first direct EDM measurement with a polarized deuteron beam in the Cooler Synchrotron COSY utilizing an RF Wien filter will be worked out [4,5]. One important ingredient is the required spin coherence time necessary to reach a certain statistical sensitivity: A particle ensemble with perfectly aligned spin vectors will decohere after a certain time. This time scale is described by the spin coherence time [6]. Another important quantity is the so-called spin tune. As in an NMR experiment, spin vectors precess in the magnetic field of the accelerator. The number of spin rotations per particle revolution is defined as the spin tune. Finally, the students should understand the relevance of charged particle EDMs and the basic principles of a measurement at storage rings.

References

[1] A. Wirzba, J. Bsaisou, A. Nogga, Int. J. Mod. Phys. E 26, 1740031 (2017), arXiv:1610.00794 [nucl-th].
[2] M. Pospelov and A. Ritz, Annals Phys. 318, 119 (2005) [hep-ph/0504231].
[3] F. Abusaif et al., “Storage ring to search for electric dipole moments of charged particles: Feasibility study”, CERN Courier Volume 56, No. 7, September 2016, arXiv:1912.07881
[4] M. Rosenthal, A. Lehrach, “Spin Tracking simulations towards electric dipole measurements at COSY”, Proceedings of IPAC2015, http://accelconf.web.cern.ch/AccelConf/IPAC2015/papers/thpf032.pdf;
[5] V. Poncza, A. Lehrach, “Simulation Model Improvements at the Cooler Synchrotron COSY using the LOCO Algorithm”, Proceedings of IPAC2021, https://accelconf.web.cern.ch/ipac2021/papers/thpab177.pdf
[6] G. Guidoboni et al., Phys. Rev. Lett. 117, 054801 (2016), https://journals.aps.org/prl/abstract/10.1103/PhysRevLett.117.054801

WG4: Baryon Spectroscopy

The goal of this working group is to devise and present an experiment, or better said an array of possible experiments, which facilitate an ideally fully model-independent determination of the (light-) baryon spectrum via amplitude analysis. An introduction will be provided to the students in the beginning of the working group, introducing the basics of spin-physics and coupled reaction-mechanisms necessary for devising a sufficient set of the usual plane-wave scattering experiments. One key-ingredient missing for a fully model-independent extraction of the transition matrices of the multiple coupled reactions under consideration is the overall-phase of each respective transition-matrix. This quantity is notoriously unmeasurable in usual plane-wave scattering. However, some proposals for rather exotic experiments capable of actually measuring these overall phases experimentally already exist in the literature.

Students will be provided with a full set of relevant papers for these proposals
and are then asked to think of (in principle) possible experimental apparatuses for measuring the

overall-phases. Although one should pay attention to the fundamental feasibility of the proposed experiments, it is certainly desirable to approach the design of the experiments with imagination. Even if the structures conceived by the students do not quite correspond to the conservative methods
of the research field, they should still be thought through and presented in the end in order to increase the fun factor.

The necessary theoretical background (basically: amplitude analysis & complete experiments) only requires basic knowledge from quantum-mechanics lectures (scattering theory from standard QM-lectures at German Universities). Principles and methods of amplitude analysis will also be introduced in addition within the two lectures of the main program of the summer school. Further knowledge of
detector physics is certainly helpful for the design of the proposed experiments, but not essential (i.e. enough supplementing literature will be provided in this direction).