Physics at COSY-Jülich

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Abstract. COSY, a storage and cooler synchrotron, which is fed by an injector cyclotron, is operated at Forschungszentrum Jülich (Germany). It provides phase space cooled polarized or unpolarized beams of protons and deuterons with momenta between 0.3 and 3.7 GeV/c for internal experiments and to external target stations. The major experimental facilities, used for the ongoing physics program, are ANKE and WASA (internal) and TOF (external). A new internal target station to investigate polarization build-up by spin-filtering (PAX) has recently been commissioned. COSY is *the* machine for hadron spin physics on a world-wide scale, which is also used for tests in conjunction with plans to build a dedicated storage ring for electric dipole moment (EDM) measurements of proton, deuteron and ^{3}He. In this contribution recent results as well as future plans are summarized.

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INTRODUCTION

The COSY facility at Forschungszentrum Jülich (Germany) comprises sources for unpolarized and polarized beams, an injector cyclotron (JULIC) and the storage and cooler ring with a circumference of about 184 m [1] (see Fig.1). It stores, accelerates and cools beams of protons and deuterons, which may be polarized, and provides them at internal target stations or extracts them for use at external targets and detectors. With a maximum beam momentum of 3.7 GeV/c, it is well suited for a wide range of hadron physics with hadronic probes – in fact it can be considered *the* hadron spin physics machine because of its possibilities to produce, accelerate, manipulate and use polarized beams and targets.

EXPERIMENTAL FACILITIES

Different detection systems have been exploited or are still in use at COSY. While the first generation equipment (BIG KARL [2], COSY-11 [3], EDDA [4]) have been decommissioned during the recent past (EDDA is, however, still in use as an internal polarimeter), and a second generation detector (PISA [5]) has been transferred to CSR in Lanzhou (China), the third generation spectrometers ANKE, TOF and WASA (see below) are heavily used for hadron physics experiments. In addition, a new internal so called low-ß section has been built and commissioned recently, which houses the PAX set-up.

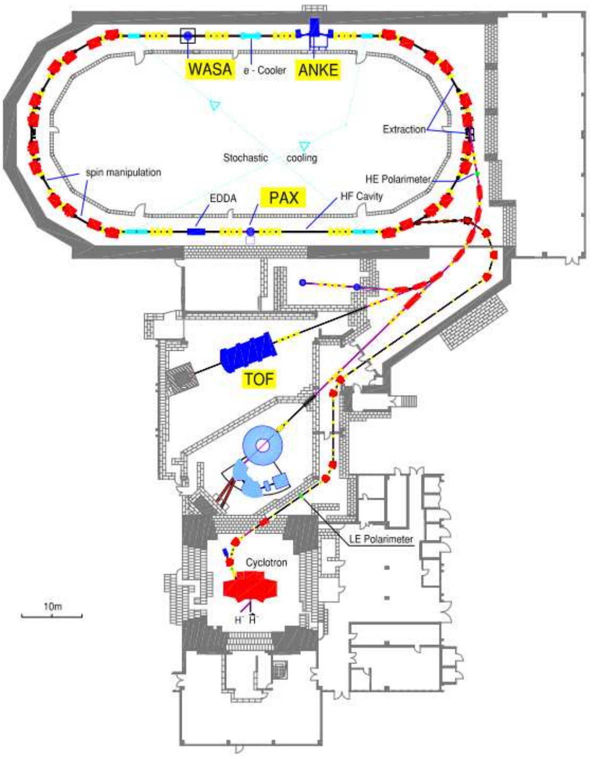

FIGURE 1. Floor plan of the cooler synchrotron COSY at Forschungszentrum Jülich (Germany). In addition to the injector cyclotron, the locations of the major detector facilities are indicated.

Internal Experiments

Internal experiments are the unique possibility available at a storage ring like COSY: they allow measurements with thin gas targets very close to threshold, where the recoil energies are very small. They also permit experiments on neutrons via the use of deuterium and detection of the spectator proton.

The Magnetic Spectrometer ANKE

ANKE (Apparatus for Studies of Nucleon and Kaon Ejectiles) [6] is a large acceptance forward spectrometer in the COSY ring. The central dipole is movable to adjust the momenta of the detected particles independent of the beam momentum. Gas targets and thin foil targets as well as a polarized internal target with a storage cell can be used. The latter allows double-polarized experiments to be performed.

The ANKE experimental program focuses on: (i) nucleon-nucleon scattering, in particular with di-proton final states, (ii) deuteron breakup, also with di-protons, (iii) meson production without and with strangeness on nucleons and in proton-nuclear collisions.

Recent highlights are: inverse di-proton photodisintegration and near threshold pion production [7], Σ^+ production in proton-proton interactions [8], and nuclear ϕ-production [9]. Soon, final results on single polarized deuteron breakup with (di-proton, neutron) and (di-proton, Δ^0) final states will be available. A double-polarized d p → $\{pp\}_s$ n measurement is currently being analyzed. In strangeness production, as a new result, cross sections for the reaction p n → K^+ p Σ^- will be available in the near future.

The 4π Detector WASA

WASA (Wide Angle Shower Apparatus) [10] is an internal 4π spectrometer for charged and neutral particles. It was originally set up at CELSIUS of TSL in Uppsala (Sweden), and transferred to COSY in 2005. After refurbishment it is in operation since early 2007. WASA comprises an electromagnetic spectrometer, a very thin superconducting solenoid, inner and forward tracking and energy-loss detectors and a frozen (hydrogen or deuterium) pellet target.

The main emphasis of the WASA program is on symmetries in nuclear reactions and on pseudoscalar meson decays and search for and the investigation of symmetry breaking [11]. In addition the so called ABC-effect [12] is studied intensively in various fusion reactions: pn → d p ππ, pd → ^{3}He ππ, and dd → ^{4}He ππ.

A recent highlight is the measurement of the Dalitz-plot distribution of the $\eta \rightarrow 3\pi^0$ decay to determine the quadratic slope parameter [13]. In the near future, results on the decay $\eta \rightarrow \pi^+ \pi^- \gamma$ (to study the so called box anomaly) [14] and on single and double η Dalitz-decay [15] will be published.

External Experiments

Experiments exploiting extracted beams of a storage ring must use relatively thick targets to obtain similar or higher luminosities than internal experiments, which production measurements only at larger excess energies. Thus the two approaches are largely complementary. At external target stations, special limitations usually are not as severe, allowing the construction of large acceptance (forward) spectrometers.

The Non-magnetic Spectrometer TOF

TOF (Time of Flight) [16] is a non-magnetic spectrometer for extracted beams, which combines excellent tracking capabilities with large acceptance and full azimuthal symmetry. TOF is optimized for final states with strangeness, which allows the determination of complete Dalitz-plots. It is operated with cryogenic hydrogen and deuterium targets. Recently, a new straw-tube tracking system has been installed to significantly improve the mass resolution and reconstruction efficiency.

The TOF experimental program centers around meson production reactions with both unpolarized and polarized beams and in particular on those reactions with strange particles in the final state.

TOF highlights include: (i) production of Λ and Σ^0 hyperons in proton-proton collisions [17, 18], (ii) a systematic study of ω-production [19] and (iii) single [20] and double pion production [21]. TOF will finalize its experimental program during 2011/2012.

New Experimental Set-up

During the summer shut-down in 2010, a new internal target station has been set-up at COSY, which will be used for the PAX commissioning experiments on proton spin-filtering. This is the only viable method known to produce a beam of polarized anti-protons, after our precursor experiment at COSY [22] had shown that spin-flip from electrons (positrons) to protons (antiprotons) will not work.

The Low-β Section for PAX

In order to set-up the equipment for spin-filtering with antiprotons with the goal in order to determine and optimize the method to produce an intense beam of polarized antiprotons for a possible future HESR-at-FAIR upgrade, a so called low-ß section has been designed and constructed at COSY. This section houses: (i) magnetic quadrupole triplets, (ii) an atomic beam source (ABS) plus a Breit-Rabi polarimeter (BRP), (iii) an openable storage cell (SC), into which the polarized hydrogen or deuterium gas is injected and which is traversed by the COSY beam, and (iv) a silicon tracking detector system (STT), which is currently designed. (i) - (iii) have been commissioned in autumn 2010. With this set-up, proton spin-filtering [23] will be repeated, and subsequently the equipment will be transferred to CERN-AD to perform corresponding measurements with antiprotons.

FUTURE PLANS

The cooler synchrotron COSY not only is an important hadron spin physics facility, but it also provides an excellent basis for the new idea to search for light ion (p, d, ^{3}He) permanent electric dipole moments (EDM) [24]. This has been recognized by the Storage-Ring EDM (srEDM) collaboration at Brookhaven, which conducted test measurements on polarimetry [25], and has proposed further experiments to investigate the spin coherence time [26] at COSY. It is also seen as a future project by a recent review committee that was looking on the possible future of IKP/COSY [27].

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