STATUS OF THE COOLER SYNCHROTRON COSY-JUELICH

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Abstract

The cooler synchrotron COSY accelerates and stores unpolarized and polarized protons and deuterons in the momentum range between 300 MeV/c to 3.65 GeV/c. To provide high quality beams, an Electron Cooler at injection and a Stochastic Cooling System from 1.5 GeV/c up to maximum momentum are available. Vertically polarized proton beams with a polarization of more than 0.80 are delivered to internal and external experimental areas at different momenta. Externally, the maximum momentum is up to date restricted to approximately 3.4 GeV/c by the extraction elements installed in COSY. In 2003 deuteron beams with different combinations of vector and tensor polarization were made available for internal and external experiments. An rf dipole was installed, which is used to induce artificial depolarizing resonances. It can be used for an accurate determination of the momentum of the stored beams. The status of the cooler synchrotron COSY is presented and future plans are discussed.

INTRODUCTION

The accelerator facility COSY [1,2] consists of the injector cyclotron and the synchrotron and storage ring with 184 m circumference. It accelerates unpolarized and polarized protons and deuterons in the momentum range between 300 and 3650 MeV/c. The floor plan of COSY with its 4 internal and 3 external experimantal areas is shown in figure 1.

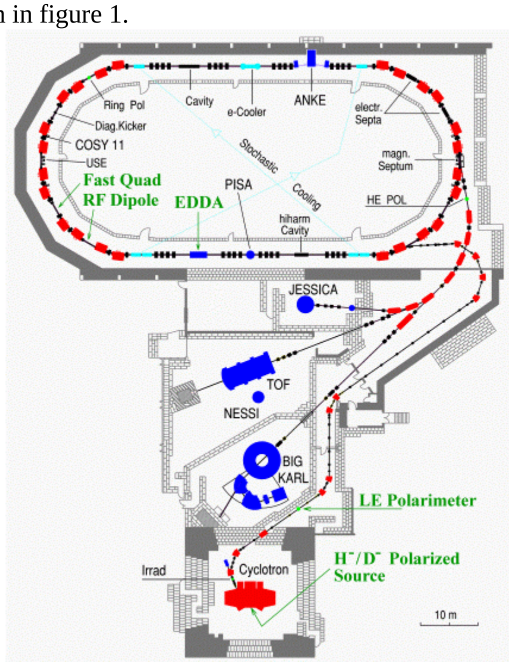

Figure 1: The COSY floorplan

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The main topic of research is the production and interaction of strange mesons close to production threshold. Increasing the phase space density by electron cooling at injection momentum and conservation of beam emittance during internal experiments at high momenta by use of a stochastic cooling system are the two outstanding features of COSY.

BEAM TIME STATISTICS

COSY has improved its yearly running over the 11 years of operation from 3500 h per year in 1993 up to 7500 h in 2003. The past reliability of COSY increased from 80 % in the first year of operation to more than 90 % afterwards. Approximately 2/3 of the year is dedicated to user operation. Figure 2 shows the beam time distribution during the year 2003.

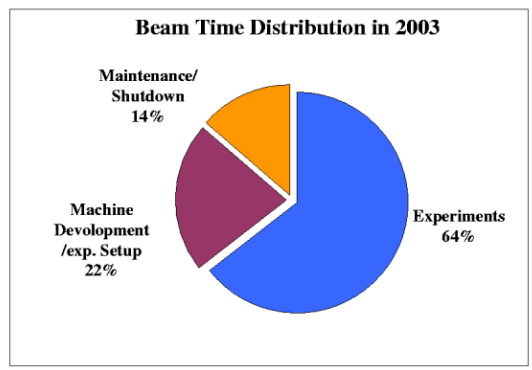

Figure 2: Beam time distribution

In the first years of COSY operation, only unpolarized protons were requested by the experiments. This has changed over the years, as the demand for polarized proton beams and deuteron beams increased. After making unpolarized deuterons available during previous years, 2003 was the first year polarized deuterons with different combinations of vector and tensor polarization were successfully delivered to experiments (Figure 3).

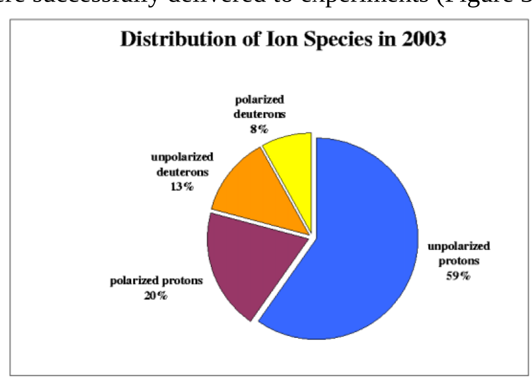

Figure 3: Beam time distribution amoung the ion species.

POLARIZED DEUTERONS

The colliding beam type proton ion source used at COSY [3] can without modification prepare negative deuteron ions and deliver them to the pre-accelerator. However, to prepare polarized deuterons with the desired vector and tensor polarizations (*Pz* and *Pzz*, respectively), the source needed to be equipped with new high frequency transitions operating at the magnetic fields and radio frequencies to exchange the occupation of the different hyperfine states in deuterium. By combination of the three different installed transitions, a large number of combinations of vector and tensor polarizations can be delivered by the source. In table 1 the combinations delivered to experiments are summarized.

Table 1: Summary of the deuteron polarization states available to the experiments during 2003

mode	**RFT1**	**RFT2**	**RFT3**	***Pz***	***Pzz***
0	Off	off	off	0	0
1	Off	off	On	-2/3	0
2	Off	on	Off	+1/3	+1
3	Off	on	On	-1/3	-1
4	On	on	Off	+1/2	-1/2
5	On	on	On	-1	+1
6	On	off	off	+1	+1
7	On	off	on	-1/2	-1/2

As the magnetic moment of the deuteron is much smaller than that of the proton, no depolarizing resonances are encountered during acceleration of the beam in the momentum range of COSY. To setup the polarized beam operation, an existing polarimeter in the injection path between the pre-accelerator cyclotron and the COSY synchrotron was modified to be able to measure deuteron polarization. To monitor the polarization in COSY, parts of the former EDDA detector were used. Existing polarization data at a beam momentum of 1042 MeV/c [4] were used to calibrate the measured polarization, and this absolute normalization was then exported to the experiments momentum of 1850 MeV/c, at which the polarization was measured during the experiment [5]. Table 2 shows the comparison of expected and measured polarization states, the unpolarized mode 0 is used for normalization purposes, therefore no polarization is given in the table.

BEAM FEEDBACK AND STACKING

The intensity of single injected, uncooled polarized beams in COSY is limited to approximately $1*10^{10}$ particles, because of the lower intensity of the polarized beam available at injection. At injection energy the beams can be electron cooled to increase the phase space density.

Table 2: Comparison of expected and measured vector and tensor polarizations for the different states.

mode	***Pz***	***Pzz***	***Pz* measured**	***Pzz* measured**
0	0	0		
1	-2/3	0	-0.499 +/- 0.021	0.057 +/- 0.051
2	+1/3	+1	0.290 +/- 0.023	0.594 +/- 0.050
3	-1/3	-1	-0.248 +/- 0.021	-0.634 +/- 0.051
4	+1/2	-1/2	0.381 +/- 0.022	-0.282 +/- 0.052
5	-1	+1	-0.682 +/- 0.022	0.537 +/- 0.052
6	+1	+1	0.764 +/- 0.022	0.545 +/- 0.050
7	-1/2	-1/2	-0.349 +/- 0.022	-0.499 +/- 0.053

However, the short beam lifetimes at injection energy and the long cooling time (several seconds), the intensity of the beam is reduced by approximately one order of magnitude. To increase this intensity, the method of stacking injection can be applied. Here the beam of a single strip injection is cooled by the electron cooling system for two seconds. Then the closed orbit of the stored beam can again be moved close to the injection foil without loosing the cooled stored beam, and a new strip injection can take place, adding intensity to the stored beam. This procedure can be repeated multiple times to increase the total intensity of the stored beam.

Because of the reduced phase space density of the cooled beam, coherent vertical and horizontal oscillations of the stored beam are observed and cause particle losses and therefore limit the reachable intensity. During 2003 a wide band vertical kicker was installed to damp these coherent vertical oscillations. A beam position monitor (BPM) was used to detect the vertical oscillations, and a 70 MHz Amplifier connected to the vertical kicker damps the oscillation [6]. By use of this beam feedback system it was possible to reduce the particle losses and increase the intensity of the stacked beam to $1.2*10^{10}$ stored polarized protons. Table 3 shows a summary of the different operation modes and ion species with the achieved particle intensities

RF DIPOLE

During 2003 an RF dipole magnet for manipulation of the polarization was installed. It is used to study spin reversal (spin flipping) of the stored polarized proton and deuteron beams [7,8]. For this purpose a horizontal radio

Table 3: Particle intensity of the accelerated beam for the different ion species and operation modes.

ion species	mode	particle intensity
Unpolarized Protons	Single injection	$1.4*10^{11}$
	Single injection with electron cooling	$1.5*10^{10}$
	Multiple injection with electron cooling and stacking	$5.0*10^{10}$
Polarized Protons	Single injection	$1*10^{10}$
	Single injection with electron cooling	$5.0 *10^{9}$
	Multiple injection with electron cooling and stacking	$1.2*10^{10}$
Unpolarized Deuterons	Single injection	$1.3*10^{11}$
	Single injection with electron cooling	$4*10^{10}$
Polarized Deuterons	Single injection	$6*10^{9}$

frequency field is used to disturb the spin motion of the vertically polarized beams and induce a depolarizing resonance when the resonance condition $f = f_r (k - \gamma G)$ is fulfilled. Here f is the frequency of the rf dipole magnet, f_r the revolution frequency, γ the relativistic γ factor, and G the electromagnetic anomaly for the used ion species.

The dipole consists of eight water cooled copper conductors above and below a ceramic vacuum chamber. Conductors and chamber are surrounded by ferrite blocks to enhance the field strength on the axis of the accelerator. At a frequency of 916 kHz and 8 kV peak to peak at the dipole, a field integral of 0.52 Tmm (rms) is achieved [9].

This dipole magnet was successfully used for studies of spin flipping polarized protons as well as polarized deuterons during the year 2003 [7,8,10].

The location of the artificial depolarizing resonance is directly linked to the energy of the stored beam. The g-factor and thus the gyromagnetic anomaly $G=(g-2)/2$ of proton and deuteron is known to very good accuracy, and the revolution frequency f_r and dipole frequency f can be measured accurately. This will allow a precise determination of γ and therefore the momentum of the stored particle beam.

SUMMARY

COSY is a unique accelerator in the medium energy range for polarized and unpolarized beams of protons and deuterons. It delivers beam to users for over 5400 hours per year with a high reliability of more than 90 %. During 2003 the availability of polarized deuteron beams with different combinations of vector and tensor polarization for experiments at the COSY accelerator facility was added.

REFERENCES

[1] R. Maier, Cooler Synchrotron COSY – performance and perspectives, NIM A 390 (1997) 1-8

[2] H. Stockhorst et al., Progress and Developments at The Cooler Synchrotron COSY“, Proceedings of the 8th European Particle Accelerator Conference (EPAC 02)

[3] O. Felden et al., in Proceedings of PST 01, Nashville (World Scientific, Singapore, 2002), p. 200.

[4] K. Sekiguchi, et al., Phys. Rev. C65, 034003 (2002).

[5] H. Rohdjess, internal report.

[6] V. Kamerdzhiev, Untersuchung und Verbesserung des Stabilitaetsverhaltens eines intensiven elektronengekuehlten Teilchenstrahls in COSY, Dissertation Universitaet Dortmund (2003), Juel-4114, Februar 2004.

[7] K. Yonehara, et al., AIP Conf. Proc. 698, 763 (2003).

[8] V. S. Morozov, et al., Phys. Rev. ST Accel. Beams 7, 024002 (2004)

[9] A. Schnase et al., Ferrite loaded RF-Dipole for Spin-manipulation of Protons and Deuterons in Annual Report 2003, Juel 4109, 2004.

[10] V.S. Morozov et al., to be published.