NEGATIVE ION SOURCES AT THE INJECTOR CYCLOTRON FOR THE COOLER SYNCHROTRON COSY/JÜLICH

R. Gebel, O. Felden, R. Maier, P. von Rossen, Institute for Nuclear Physics (IKP),

Forschungszentrum Jülich GmbH, Jülich, Germany

Abstract

The cyclotron JULIC operates more than 7500 hours per year as the injector of polarized and unpolarized H^- or D^- beams for the cooler synchrotron COSY at the IKP of the Forschungszentrum Jülich since January 1996. Usually about 8 µA of unpolarized or 1 µA of polarized H^- and D^- ions are delivered at 45 MeV and 75 MeV, respectively, for charge-exchange injection into COSY. Recently polarizations in excess of 90 % were measured for protons inside the synchrotron COSY. Additionally, polarized and unpolarized D^- ions injected at 75 MeV were delivered to experiments. A sequence of up to eight different polarization states was realized.

INTRODUCTION

The accelerator facility [1,2] consists of the injector cyclotron JULIC, the synchrotron and storage ring COSY and experimental areas. Unpolarized and polarized protons and deuterons are accelerated in the momentum range from 0.3 to 3.65 GeV/c. The floor plan of COSY with its 4 internal and 3 external experimental areas is shown in figure 1. 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 experiments on the circulating beam at high momenta by use of the stochastic cooling system are two of the outstanding features of unique facility COSY.

The cyclotron JULIC has accumulated over 204000 working hours in different modes of operation since its commissioning in 1968. During 1990/91 JULIC was converted to its present use as injector for the synchrotron COSY [3-5]. The H^- operation started in 1996 after the installation of external filament driven multicusp sources for H^- and D^-. This allows the use of nuclear polarized H^- and D^- from a colliding beams source (CBS) [6-9].

OPERATIONAL PROPERTIES

The operation as the injector for COSY implies beam pulsing at a maximum repetition rate of 0.5 Hz with a macro pulse duration of 10 to 20 ms. Almost all cyclotron systems operate continuously. The macro beam pulses are generated by switching the extraction voltage for the ion sources. A chopper in the beam line (QBL) between the ion sources and the cyclotron can be operated with micro pulsing to reduce the beam intensity in COSY. H^- and D^- ions are injected at 4.5 keV and 7.6 keV, respectively. The unbunched beam from any source is matched to the RF-phase acceptance of the cyclotron using a double gap buncher with sinusoidal voltage, a combination with a special saw tooth buncher is possible. Both are located below the cyclotron. For the final injection onto a constant orbit a hyperbolic inflector (HI) near the cyclotron centre is used. The schematic layout of the injector is depicted in figure 2.

In the H^-/D^- mode JULIC has already accumulated over 68500 hours of operation since beginning of 1996. The operational demands give usually very little time for detailed measurements or experiments. During routine operation only amplitude or frequency of the RF system sometimes must be slightly corrected to maintain optimum beam conditions for COSY.

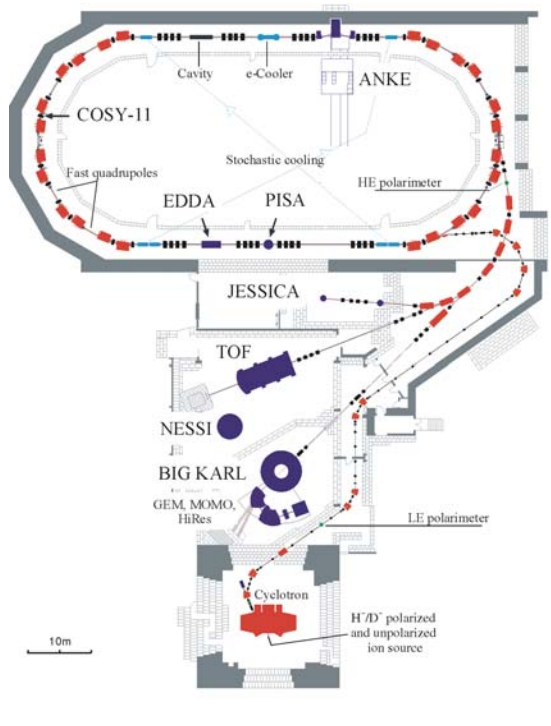

Figure 1: The floor-plan of the COSY facility with the synchrotron of 184 m circumference, the cyclotron and four internal and external experimental areas.

The septum deflector presented one of the main difficulties to reliably operate JULIC over long periods with negative ions, especially at the higher deflector voltage necessary for D^-. Operation is routinely now in pulsed mode and replacement of the deflector is scheduled on a regular base to improve the reliability.

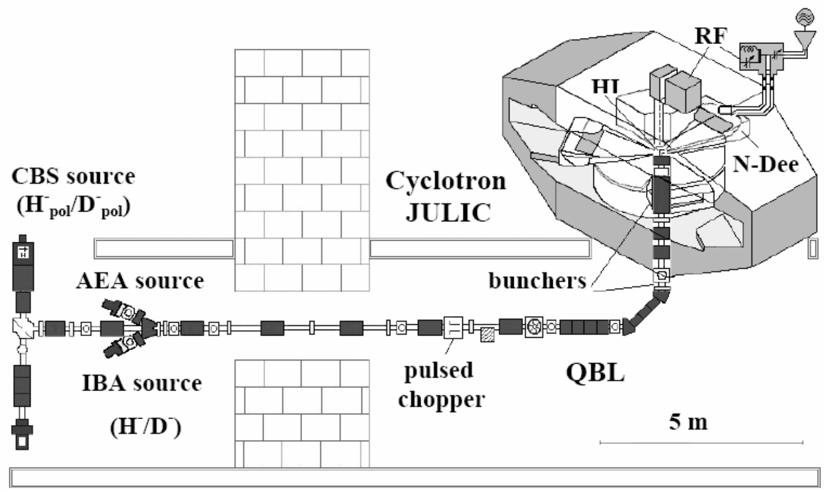

Figure 2: Schematic layout of the cyclotron JULIC as injector of negative ions for the cooler synchrotron COSY, with the ion sources, source beam line (QBL) and axial injection.

PERFORMANCE AND NEW OPTIONS

Almost all aspects affecting the beam intensity received attention over the past years. The performance of the negative ion sources was improved by tedious development, especially for the polarized beams. The multicusp ion sources deliver beam currents in the range of 200 to 400 µA with a geometric emittance around 60 π mm mrad. The polarized ion source in contrast delivers routinely 20 µA, but with better emittance and reduced energy spread. After the introduction of the saw tooth buncher with the buncher combination the bunching factor was almost doubled to a factor of 4.5.

The beam currents extracted from the cyclotron are close to 10 µA for H^- and D^- from the multicusp sources, with a transmission through the cyclotron of 5%. For polarized beams the transmission is typical ~15%, leading to extracted intensities of routinely 1 µA.

A high degree of polarization for proton beams was achieved by working out a special tune of the synchrotron, so that jump quadrupoles were able to shrink losses to a negligible amount. The polarization is measured during the acceleration ramp by the EDDA group [10,11]. The polarization inside COSY is depicted in figure 3. Modifications of the colliding beams source contributed too in achieving this high degree of polarization. A new 90° bending magnet replaced the former electrostatic deflection system used to bend the ions into the beam line for injection into the cyclotron [12]. The new alignment of the spin in the beam line reduced depolarising effects and resulted in a polarization of over 90% after the cyclotron.

The colliding beams type negative ion source can provide polarized hydrogen and deuteron beams without modification in comparable intensities. To prepare polarized deuterons with the required combinations of vector and tensor polarization the atomic beam part of the source needed to be equipped with new high frequency transitions. These radio frequency transition units (RFT) are operated at the magnetic fields and frequencies to allow exchange of the occupations of the different hyperfine states in deuterium beam. A set of three installed devices, RFT1 to RFT3, allows a large number of combinations to be delivered to experiments. Parts of the EDDA detector were used to monitor the polarization in COSY.

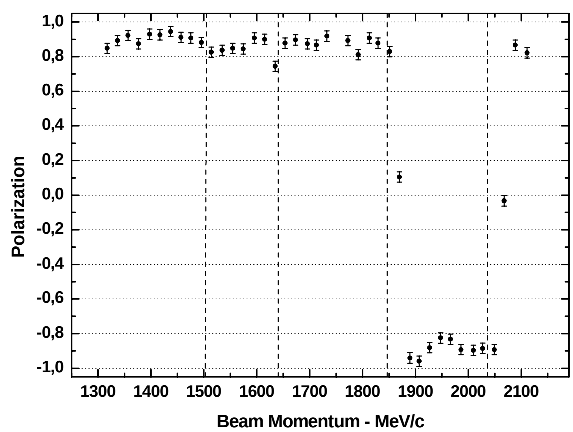

Figure 3: Polarization during the acceleration ramp with spin flip around 1.88 and 2.08 GeV/c. The averaged polarization up to the first strong resonance is 91.4 ±0.3 %.

Table 1 shows a summary of the different operation modes and ion species with the achieved particle intensities. A study of the behaviour of vector and tensor polarized beams inside the synchrotron has been conducted [13,14].

CONCLUSION

The operation of the cyclotron JULIC as the COSY injector for H^- and D^- ions has been successful and reliable over the past years. The cyclotron systems like the RF system, the vacuum pumps and drive systems show increasing signs of age and need progressively more attention. The exchange of the most essential systems has been started.

Mode	P_z	P_{zz}	RFT1	RFT2	RFT3	Measured P_Z	Measured P_{ZZ}
			Transition			EDDA@1042MeV/c	
D1	0	0	Off	Off	Off	-0.002±0.003	
D2	-2/3	0	Off	Off	On	-0.533±0.004	0.057±0.051
D3	+2/3	0	Off	On	Off	0.438±0.014	
D4	+1/3	+1	Off	On	Off	0.285±0.032	0.594±0.050
D5	-1/3	-1	Off	On	On	-0.294±0.003	-0.634±0.051
D6	+1/3	-1	Off	On	Off	0.285±0.039	
D10	+1	+1	On	On	Off	0.764±0.022	0.545±0.050
D11	-1	+1	On	Off	On	-0.701±0.032	-0.537±0.052
D16	-1/2	-1/2	On	On	On	-0.349±0.022	-0.499±0.053
D17	1/2	-1/2	On	Off	Off	0.378±0.036	-0.282±0.052
P 1	+1	-	Off	On	Off	0.914 ± 0.022 ± 0.03 average in COSY	
P 2	-1	-	Off	Off	On		

Table 1: A subset of polarization modes for the polarized ion source for deuterons (D) and protons (P). Mode P1/2 shows the averaged performance for polarized protons stored in COSY. All Data are taken from measurements with the EDDA detector [11,13,14].

The performance especially for polarized H^- has been continuously improved and showed good beam availability. The collection of light ion beams has been successfully improved by a set of vector and tensor polarized D^- beams.

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REFERENCES

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

[2] H. Stockhorst et al., “Progress and Developments at The Cooler Synchrotron COSY“, 8th EPAC (2002)

[3] W. Bräutigam et al; “H^- operation of the cyclotron JULIC as injector for the cooler synchrotron COSY-Jülich; Proc. of Cyclotrons and their Applications 1998, Caen, IOP (1999): 654

[4] W. Bräutigam et al.; “Extraction of D^- beams from the cyclotron JULIC for injection into the cooler synchrotron COSY”. Proc. of Cyclotrons and their Applications 2001, East Lansing, AIP 600 (2001) 123

[5] W. Bräutigam et al.; “Status and perspectives of the cyclotron JULIC as COSY injector; Proc. of: XXXIII ECPM in Poland, (2002)

[6] P.D. Eversheim et al, Proc. of Polarized Beams and Polarized Gas Targets, Köln; (1995), 224

[7] P.D. Eversheim et al., The Polarized Ion-Source for COSY, Proc. SPIN 1996 Symposium, Amsterdam.

[8] R. Weidmann et al., Rev. Sci. Instrum.,67 p.II,(1996), 1357

[9] O. Felden et al., in Proc. of the 9th International Workshop on Polarized Sources and Targets, Nashville, (2002), 200

[10] V. Schwarz et al., Proc. SPIN 98; (1998), 560

[11] H. Rohdjess et al., "EDDA@COSY Results", AIP Conf. Proc., (2003), 665

[12] G. de Villiers, Collaboration Report (2002), IKP / iThemba LABS., Faure, South Africa

[13] K. Yonehara et al., Proc. of the 8th Conference on the Intersections of Particle and Nuclear Physics, New York, 2003 AIP Conf. Proc. 698 (2003), 763

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