20 YEARS OF JULIC OPERATION AS COSY'S INJECTOR CYCLOTRON

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Abstract

The accelerator facility COSY/Jülich is based upon availability and performance of the isochronous Jülich Light Ion Cyclotron (JULIC) as pre-accelerator of the 3.7 GeV/c COoler SYnchrotron (COSY). The cyclotron has passed in total 262500 hours of operation since commissioning in 1968. JULIC provides routinely, for more than 6500 hours/year, polarized or unpolarized negatively charged light ions for COSY experiments in the field of fundamental research in hadron, particle and nuclear physics. The on-going program at the facility foresees increasing usage as a test facility for accelerator research and detector development for realization of the Facility for Antiproton and Ion Research (FAIR), and other novel experiments on the road map of the Helmholtz Association and international collaborations. In addition to the operation for COSY the cyclotron beam is used for irradiation, radiation effect testing and fundamental nuclide production for research purposes.

INTRODUCTION

The Institute for Nuclear Physics (IKP) [1] is focusing on the tasks given by the Helmholtz Association (HGF). This comprises the design and preparations for the High Energy Storage Ring (HESR) of FAIR) [2] with the PANDA experiment. The on-going hadron physics program at the Cooler Synchrotron COSY exploits the internal experimental set-ups ANKE, PAX and WASA as well as TOF with the extracted beam. The new 2 MV electron cooler has arrived from the Budker Institute (Novosibirsk, Russia) at COSY and will be commissioned during the year. IKP is part of the new section “Forces And Matter Experiments” (FAME) of the Jülich-Aachen Research Alliance (JARA). This joins scientists and engineers from RWTH Aachen and Forschungszentrum Jülich for experiments, theory and technical developments for anti-matter (AMS) and electric dipole moment experiments (EDM). The institute is member of the new HGF project Accelerator Research and Development (ARD) and pursues research on various accelerator components. The future project Jülich Electric Dipole Moment Investigation (JEDI) [3] will profit from the availability of polarized beams from the injector cyclotron and the unique capabilities and experiences at the COSY facility.

CYCLOTRON OPERATION

Since 1968 the cyclotron has been operational and provided overall more than 262500 hours availability for experiments and beam development [4-6]. The fraction of the run time since start of commissioning as COSY’s injector in 1992 is shown in Fig. 1. In the first 3 years only H_2^+-beams were used for the stripping injection into the synchrotron ring. For the acceleration of polarized particles beam is provided by a source of the charge exchange type. Two negative ion sources provide beam for routine unpolarized operation [7]. Table 1 reflects the availability of the cyclotron from 2010 to August 2013.

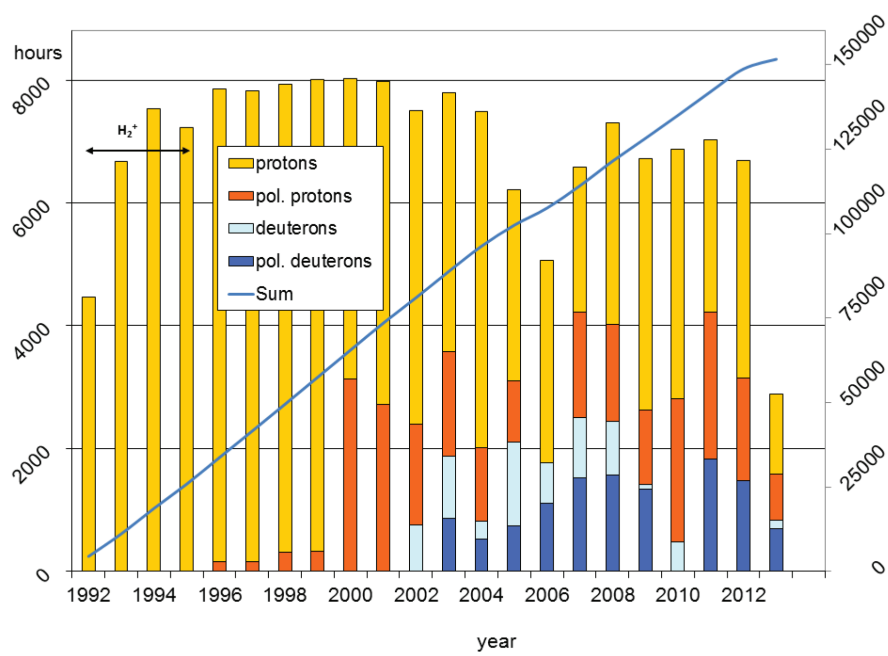

Figure 1: Provided beam hours from the cyclotron since start-up for COSY operation.

About 98 % of the scheduled beam time could be provided for experiments. Excluded were short events, like sparks, which are recovered automatically by rf control computer or by operator's reaction. The most common reasons for these events were power drops, shortage in water cooling, septum exchange and failures in the rf subsystems.

Table 1: Runtime and Failures

Year	Available / h	Unavailable / h
2010	6871	108
2011	7023	94
2012	6690	215
2013/08/11	2821	31
Since 1989	152660	-
Since 1968	262490	-

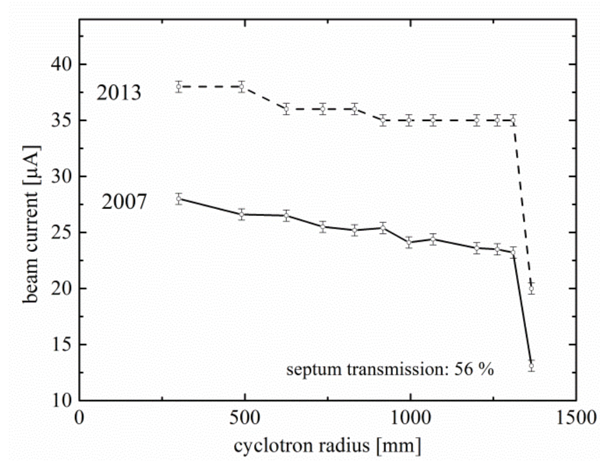

Figure 2: The transmission of deuteron beam through the cyclotron. The septum is installed at radius 1365 mm.

CYCLOTRON MAINTENANCE

The cyclotron is in use since end of 1968. Most of the systems for injection and acceleration were improved and refurbished between 1980 and 1992. Wear-out symptoms have been observed, analyzed and fixed during the last decade. The vacuum system has been upgraded with respect to oil-free operation and the control system has been updated. After identification and repair of a severe vacuum leak in a welding seam of the main vacuum chamber of the cyclotron in 2006, operation and beam transmission has been improved substantially. Broken contact springs, scratches and burn-out forced replacement of the central adjustable air-line tuner of the cyclotron in 2007. The old construction has been replaced completely, including the capacitor unit, and provides still stable operation and tuning capabilities.

Septum Deflector Progress

The improvement of the electrostatic extraction septum is a long term activity. Like other systems of the cyclotron the septum was optimized for Q/A = ½ and the transmission for H^- does not reach the quality of D^- extraction, where 70 % can be reached. Sparking and high dark current, due to depositions on the isolator, limit the usability of the septum for operation at voltages above 30 kV. Improved differential pumping, the vacuum recovery in 2006, as well as many detail modification increased the standing time from months up to over two years. The current septum is formed by a tungsten wire fence in a titanium support and is a significantly improved version of the septum operated in JULIC for many years. The high voltage electrode is supported by ceramic insulators. A method has been developed to make a vacuum tight joint between the ceramic and titanium end caps without any additional material. The ceramic supports are also used for the cooling fluid Fluorinert FC77. Today, three identical septa are available for quick exchange.

ION SOURCEDEVELOPMENT

Unpolarized Ions

For commissioning of COSY, and for the first three years of the experimental program, an in-house developed 2.45 GHz microwave source delivered H_2^+ beam without any significant downtime. After 1996, two independent sources for unpolarized beams have been installed, minimizing the beam time losses caused by the unavoidable exchange of source filaments after 3 to 4 weeks. Both sources are of the multi cusp type and have been delivered by IBA, Louvain-La-Neuve (Belgium), and AEA, Culham (England). Both provide at least 300 µA in pulsed operation. With 150 µA at the injection of the cyclotron, 10 µA extracted beam current can be achieved. This current is sufficient to obtain $2 \cdot 10^{11}$ stored ions in the synchrotron. A record value of 20 µA deuterons has been reached on extraction radius in August 2013 during set-up for EDM experiments. The recent transmission of deuterons inside the cyclotron is depicted in Fig. 2 including the former reference reached in 2007.

Polarized Ions

The polarized ion source has been built and set in operation by a collaboration of groups from Bonn, Erlangen and Cologne. The source is designed to deliver polarized H^- or D^- within the acceptance of the cyclotron during the 10..20 ms injection period of COSY. High polarization and brilliance is provided by the colliding beams source. In a charge exchange reaction between a ground-state nuclear polarized hydrogen, or deuterium, beam and a fast neutral cesium beam, a negatively charged beam is produced with high selectivity. Brilliance and polarization can be adjusted. The original design value of 30 µA at the exit of the source has been surpassed in routine operation in 2005 and peak values around 50 µA have been achieved [8]. The peak intensities of polarized beams extracted from the cyclotron have exceeded 2 µA for H^- and D^-.

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New Ion Sources

Within the framework of the Helmholtz Association's ARD program, new ion sources for future projects like ELENA at CERN and for FAIR are under development. ELENA is a compact ring for cooling and further deceleration of 5.3 MeV antiprotons delivered by the CERN Antiproton Decelerator down to 100 keV [9]. The new source for commissioning of the small synchrotron, currently under development, is shown in Figure 3. It is designed to provide µs pulses of 100 keV p or H^- beams with high brilliance. In addition to the on-going improvement of the COSY sources, design studies for new and improved polarized ion sources have been pursued and are foreseen to continue for the upcoming funding periods.

Figure 3: Ion source for CERN's ELENA project.

FURTHER ACTIVITIES

RF Dipole for COSY

In support of the JEDI-Collaboration [3], a RF-Dipole for spin manipulation in COSY is currently being developed. To influence the spin without altering the beam properties, the RF dipole is realized with high frequency crossed electric and magnetic fields in Wien-Filter configuration, matched to whole momentum range of COSY and able to excite different spin harmonics.

Irradiations

The cyclotron is equipped with 4 ports for radial moveable targets. Today only two targets are used routinely. The target behind the septum provides special support for fast exchange of irradiated target constructions. Table 2 gives an overview of irradiation sessions at JULIC. A report about radiation effect testing at JULIC is part of these proceedings [10].

Table 2: Irradiations at JULIC

Year	Internal	external
2010	4	5
2011	5	5
2012	14	4
2013/08/31	1	17
Since 1973	255	68

Cyclotrons for Education

Within the Project COLUMBUS [11], a small, low cost cyclotron for teaching purposes at high-school level has been realized by pupils as an extracurricular activity at the Gymnasium Ernestinum in Coburg, Germany. The hardware development was substantially supported by the Forschungszentrum. Additionally, the pupils' lab JuLAB at the FZJ is developing a pedagogical concept in collaboration with the Ernestinum for integrating a similar cyclotron into their curriculum. The development of this cyclotron will take place at JULIC and will in turn be used for educational programs for undergraduates at the COSY facility in cooperation with the RWTH Aachen.

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