

STATUS OF THE COSY/JÜLICH INJECTOR CYCLOTRON JULIC

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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). From 1993 to 2014 JULIC provides in 24/7 operation 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 cyclotron has reached in spring 2016 in total about 285000 hours of operation since commissioning in 1968. 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 parallel the COSY beam and the cyclotron beam are also used for irradiation and nuclide production for fundamental research purposes. For that purpose the irradiation capabilities and diagnostic tools have been upgraded in the last years. Experience with special rf devices and pulsed ion sources for JULIC enables the development of dedicated tools for experiments and other accelerators, e. g. a pulsed 100 keV source for protons and negative ions for the ELENA project at CERN.

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-up PAX. The extracted beam is used for the PANDA experiment and also for high energy irradiation in the area of the finished TOF experiment. IKP is part of the new section “Forces And Matter Experiments” (FAME) at 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 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.

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CYCLOTRON OPERATION

Since 1968 the Cyclotron JULIC (see Fig. 1) has been operational and provided overall more than 285000 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. 2. In the first 4 years on H_2^+ -beams were used for the stripping injection into the synchrotron ring. Two negative ion sources provide beam for routine unpolarized operation [7]. A source of the charge exchange type provides polarized particles beam.



Figure 1: The isochronous cyclotron JULIC.

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 and failures in the rf subsystem. The time for septum exchanges has substantially decreased after essential improvements have been done.

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. A new rf generator has been installed in 1992. Wear-out symptoms have been observed, analysed and fixed during the last decade. The vacuum system and its control system have been upgraded with respect to oil-free operation. The central adjustable air-line tuner has been replaced in 2007.

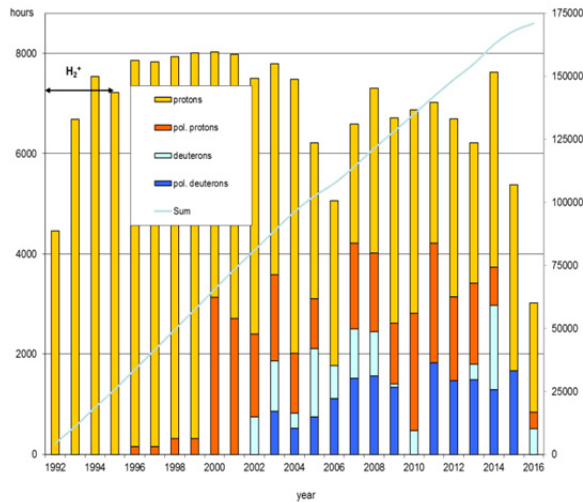


Figure 2: Provided beam hours from the cyclotron since start-up for COSY operation.

A laser station for cleaning of surfaces was bought in 2012. This equipment enables an excellent and smooth cleaning of surfaces, which have been contaminated during the beam operation, without mechanical damages and chemical remains. For this reason the reliable function of high loaded components like tungsten buttons of the pol. ion source, the hyperboloid inflector of the injection and high voltage insulators could be improved.

Septum Deflector Progress

Like other systems of the cyclotron the septum was optimized for $Q/A = 1/2$ 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. The current septum is a significantly improved version. It is formed by a tungsten wire fence in a titanium support and. 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 Flourinert FC770. These and many detail modification increased the standing time. The current septum was mounted in 2011 and it functions without serious mistakes till present.

ION SOURCE DEVELOPMENT

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 H₂⁺ beam without any significant downtime. After 1996, two independent sources for unpolarized beams have been installed. 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.

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 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 caesium 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⁻.

Improvements of the Ion Source Control

Actual activities are the replacement of the partially DOS based control systems for the ion sources and their vacuum equipment to a STEP7-PLC. A graphical user interface (GUI) based on WinCC enables easy and reproducible operation and monitoring (see Figs. 3 and 4).

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 further deceleration of 5.3 MeV antiprotons delivered by the CERN Antiproton Decelerator down to 100 keV [9]. A new source for commissioning of the small synchrotron was developed and installed at CERN in 2015. It is shown in Fig. 5. It is designed to provide μs pulses of 100 keV p and H⁻ beams with high brilliance.

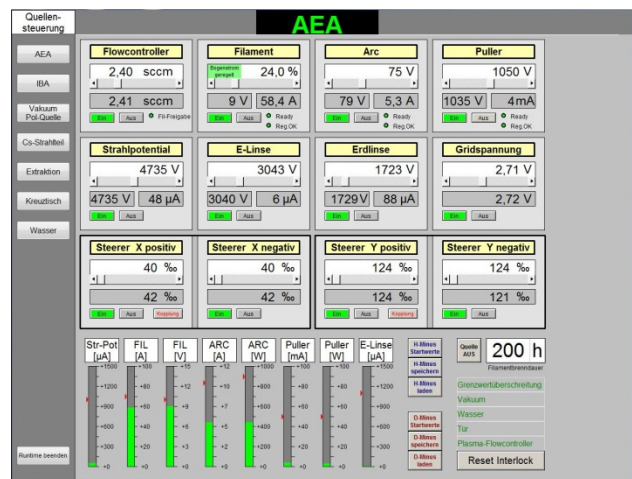


Figure 3: GUI for ion source operation parameter.

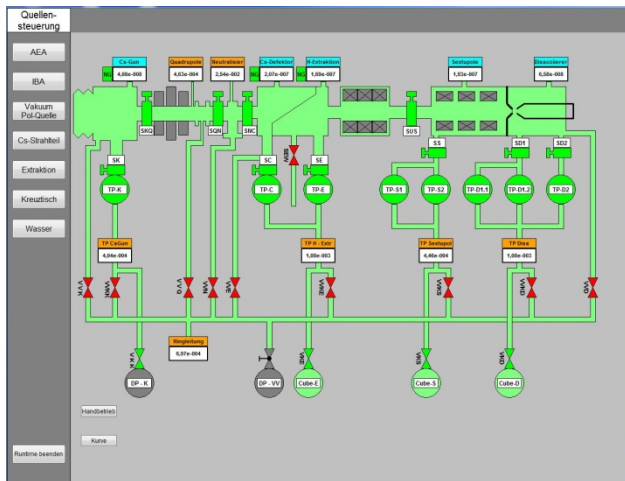


Figure 4: GUI for vacuum operation of polarized source.

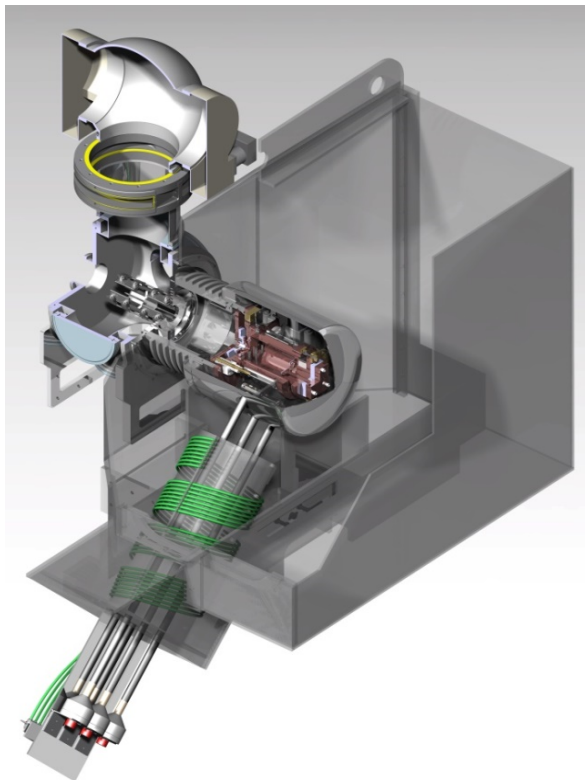


Figure 5: 100keV ion source for CERN's ELENA project.

FURTHER ACTIVITIES

Irradiations

The cyclotron is equipped with a target behind the septum, which provides special support for fast exchange of irradiated target constructions. An overview of the actual activities for irradiation and nuclide production are described in [10].

Monitoring and Diagnosis

To get a better understanding of the correlation of beam behaviour and external influences on the cyclotron a new,

more comfortable monitoring system based on LabView shall be installed. In the first step a system for monitoring and fine control of the main magnetic field was installed. It controls the B-field in between a range of 0.4 μT and shows deviations e. g. caused by internal magnetic steerers for beam displacement (see Fig. 6).

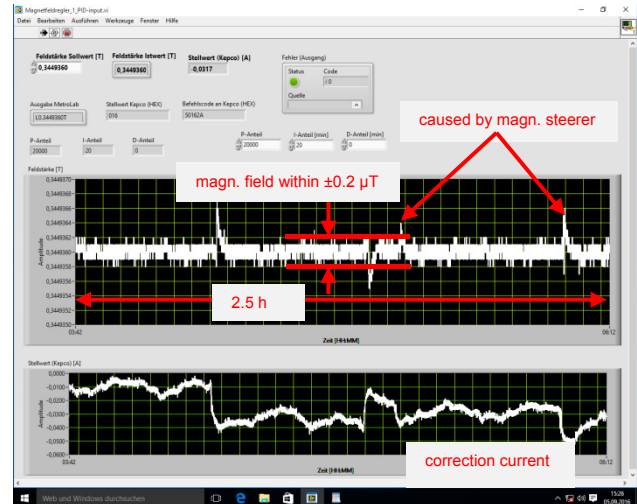


Figure 6: Magnetic field fine regulation by LabView controller during extraction optimization with internal steering magnets.

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