ISBN: 978-3-95450-212-7 ISSN: 2673-5482 doi:10.18429/JACoW-CYCLOTRONS2022-THPO005

JULIC – DRIVER ACCELERATOR FOR HBS

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Abstract

At the Forschungszentrum Jülich (FZJ) the energy variable cyclotron JULIC is used as injector of the Cooler Synchrotron (COSY) and for low to medium current irradiations of different types. Recently a new target-moderator-reflector-station (TMR) was set up and is mainly used for tests of new target materials, neutron target development and neutron yield investigations with high power proton or deuteron beam in perspective of a high brilliance accelerator based neutron source (HBS) with the Jülich Centre for Neutron Science (JCNS). Beside this, ToF-experiments are performed to investigate and optimize the pulsing structure for HBS. The TMR-station is installed inside an Experimental area close to the cyclotron bunker, offering space for complex detector and component setups for nuclear and neutron related experiments. It is used for other purposes like electronic or detector tests and irradiation as well. This report briefly summarizes the history of JULIC and the activities for its future perspectives.

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 hadron physics program at the Cooler Synchrotron COSY exploits the internal experimental setups PAX, KOALA and the PANDA Cluster-Jet Target Development. The Jülich Electric Dipole Moment Investigation project (JEDI) [3] profits from the availability of polarized beams from the injector cyclotron and the unique capabilities and experiences at the COSY facility. The extracted beam is used for the PANDA experiment, detector tests and for high-energy irradiation in the area of the finished TOF experiment. The JESSICA and Big Karl-Experiment areas are also used with extracted beam for other FAIR related detector tests and developments like CBM e.g., Fig. 1 presents the layout of the COSY facility with the JULIC cyclotron and the experimental areas.

The COSY accelerator facility [4], operated by the Institute for Nuclear Physics at the Forschungszentrum Jülich, consists of the injector cyclotron JULIC and the Cooler Synchrotron COSY. Both accelerators are originally dedicated to fundamental research in the field of hadron, particle, and nuclear physics, to study the properties and behaviour of hadrons in an energy range that resides between the nuclear and the high energy regime. Operation of the cyclotron JULIC started 1968 and it provides mainly 45 MeV H^- respectively 76 MeV D^- with beam currents up to ~10 µA.

Within the framework of the High Brilliance neutron Source project [5], Jülich is developing a scalable pulsed

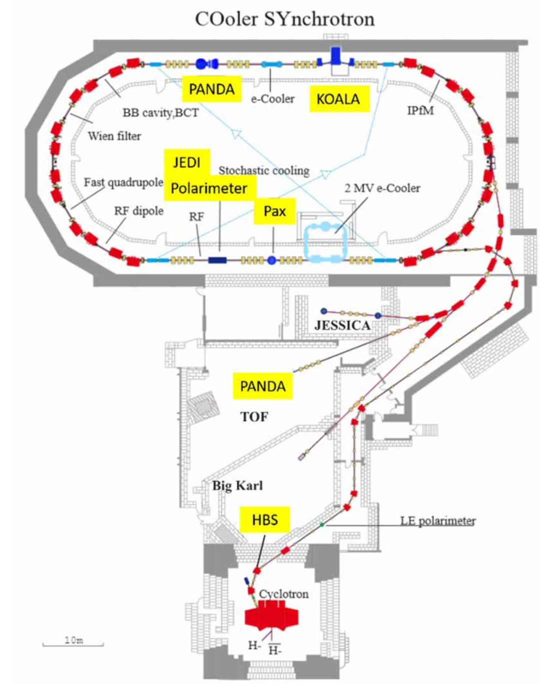

Figure 1: Layout of the COSY facility with the new beamline from the cyclotron into the Big Karl Experiment area.

accelerator-based neutron source capable of supporting thelarge scale facilities and providing an efficient network of small and medium neutron sources throughout Europa.

The HBS JULIC Neutron Platform is installed at the Big Karl experimental area aside the JULIC cyclotron providing experimental space for the development, testing and operation of components of pulsed accelerator-based neutron sources within the HBS project together with the Jülich Centre for Neutron Science.

Figure 2 shows the experimental setup in Big Karl-area with the Target-Moderator-Reflector-Setup (TMR) and possible experimental setups at different neutron beamlines like ToF-PGNAA or reflectometer, e.g., it further allows the design, construction and operation of basic scientific neutron scattering and neutron analytic instruments for development, training, education, and research in collaboration with university groups and industry.

CURRENT STATUS OF HBS ACTIVITIES

For experiments related to the HBS project, a dedicated beam line at the JULIC cyclotron at the COSY facility into the Big Karl area (Fig. 3) has been built in beginning of 2019.

At this beamline, experimental validations of cross section measurements and component tests for the HBS target development had been performed. With installation of the TMR the beamline was extended with additional kicker

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and dipole magnets and a dedicated three field permanent magnet [6] (Figs. 4 and 5) to connect the TMR directly to the cyclotron.

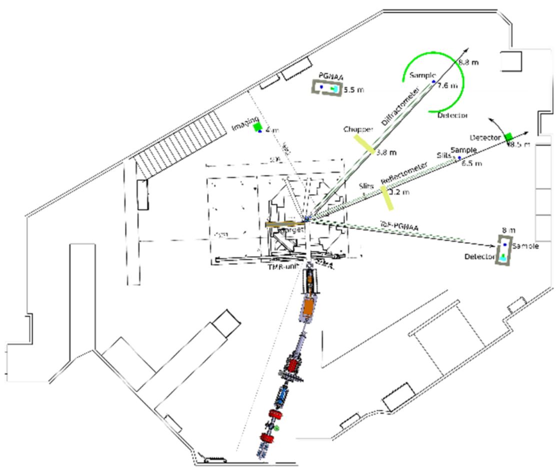

Figure 2: HBS-JULIC Neutron Platform in Big Karl area.

These additional magnets obtain the possibility to deflect the beam up to 40°, as foreseen in the proposed HBS-layout for driving three target stations.

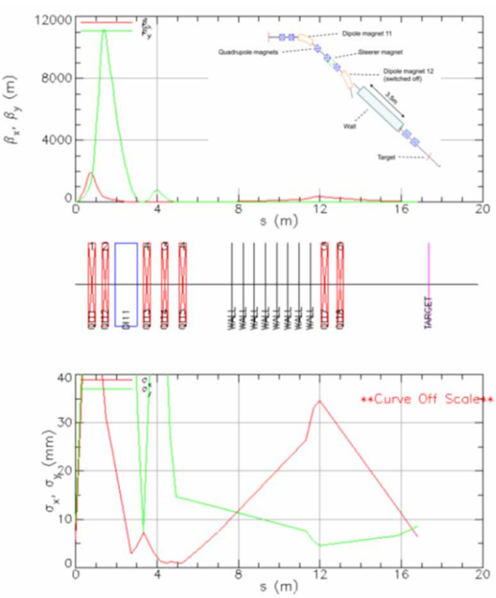

Figure 3: Beamline to Big Karl area. The figure shows the simulation results of transport calculations starting at the cyclotron, passing the shielding wall as well as the quadrupole setup.

The kicker magnet is used for testing the sophisticated timing scheme of HBS to run different target stations while the three-field permanent magnet obtains the possibility to bend the beam into three directions – straight, left- or right-handed [8]. For this purpose, the permanent magnet can be shifted using a stepper motor, so the beam enters the dedicated field region of the magnet.

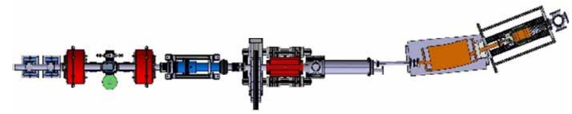

Figure 4: Beamline inside the Big Karl-Area with two quadrupoles, the Three-field, permanent magnet, fast Kicker and dipole-magnet to bend the beam into the TMR.

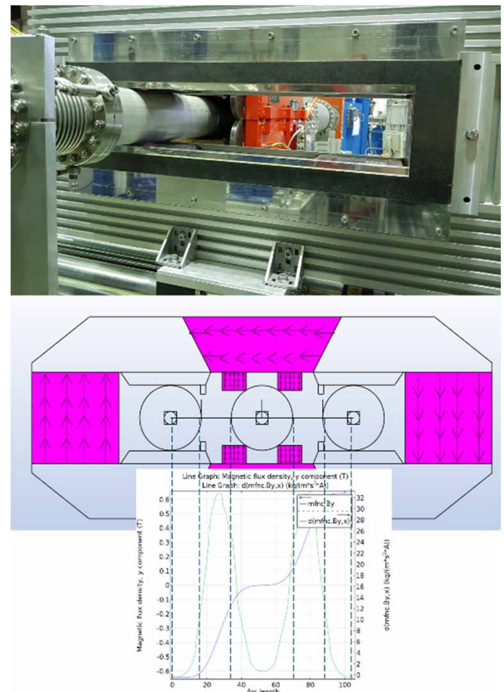

Figure 5: Three-field permanent magnet in position to bend the beam left-handed into the TMR. The lower sketch shows the dedicated field-regions and measured field-strength in the horizontal midplane.

For diagnostic purposes the beamline is equipped with current measurement as well as beam position and profile measurement tools.

Beam profile measurements (see Fig. 6) with a Multi Wire Proportional Chamber (MWPC) installed at the second exit window is used for optimizing the beam spot on target regarding to the experimental needs.

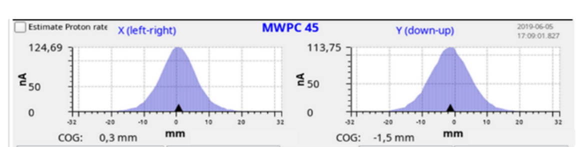

Figure 6: Beam profile at Big Karl target station. The beam size shown is ~15 mm FHWM.

Beam position is measured in both X and Y planes with a capacitive Beam Position Monitor System (BPM) [6, 7] (Fig. 7) utilizing four electrically isolated electrodes. Signal processing is done with preamplifiers FEMTO DHPVA-201 and lock-in-amplifiers Stanford Research SR844 [12] and data recorded via [13]. Newly developed graphical user interfaces based on [14] allow for display of measured beam orbit and currents.

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Beam current is measured with a Bergoz Fast Current Transformer (FCT) [10, 11] (Fig. 7) inside the Big Karl-area and on an isolated stainless steel foil separating target vacuum from cyclotron vacuum. At this foil H^- is stripped to H^+. A second, isolated stainless steel exit window and beam cup in the right-handed beam path gives another current measurement possibility. Data Acquisition is done with CAEN TetrAMMs [9], recorded via EPICS IOCs and visualized with Control System Studio (CSS).

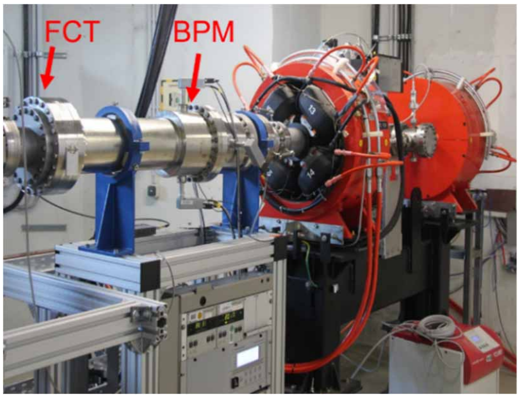

Figure 7: Beamline inside Big Karl area with Beam Position Monitor System (BPM) and Fast Current Transformer (FCT).

Additionally beam current is measured with different beam-cups which are installed along the beamline inside the cyclotron vault as well as inside the Big Karl-Area and the TMR (Fig. 8).

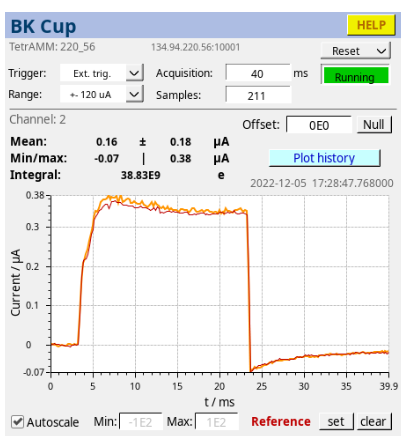

Figure 8: Beam current measurement at BigKarl Cup showing a pulsed beam of ~40nA.

The current permission for the radiation controlled area limits the operation to beam intensities of up to 10 nA. The area is going to be upgraded to the capabilities of the cyclotron.

Based on the routine parameters of the proton and deuteron beams offered by the JULIC the cyclotron can be used efficiently as part of a pulsed neutron source as in the concept for the NOVA ERA [15] or as existing accelerator based neutron facilities in Japan [16]. The pulsing scheme for proton beam of duration between 10 to 50 µsec has been realized.

Table 1: Parameters of the JULIC Neutron Platform

Description	Proton	Deuteron
Energy [MeV]	45	76
Current [µA]	10	10
Duty cycle [%]	4	4
Peak power [W]	450	760
Average power [W]	18	30

FUTURE ACTIVITIES

Based on the existing experimental station of the HBS project at the Big Karl area and the HBS target-moderator-reflector prototype (TMR) it is planned to further develop the compact neutron source concept with regards to targetry, neutron provision, moderator development and optimization of the TMR unit. Tests and developments of target handling, target cooling systems, biological shielding and any other development to improve neutron provision will be made possible. In addition, proton beam transport devices, beam control and dynamics, beam multiplexing or beam dump systems will be installed and tested at the platform. The multiplexer system, consisting of a fast kicker which deflects the beam up to 40° into a dedicated septa magnet, guiding the beam to three target stations will be tested and improved.

The new platform allows to design, construct and operate versatile neutron instruments for neutron scattering purposes as well as neutron analytics with competitive neutron flux. Shielding and Radiation protection calculations to run with 10 µA into the Big Karl-Area and permission process are in preparation.

Taking into account possible upgrades of the beam current of the JULIC cyclotron up to 10 µA beam power up to 30 W are achievable. This upgrade would promote the JULIC Neutron Platform in beam power and neutron flux an order of magnitude above current operated compact accelerator based neutron (CANS) facilities. It will allow for a full test of individual HBS structures including proof-of-principle experiments of components and performance tests of potential neutron scattering and analytic instruments an extension of the current installed experimental possibilities for HBS at the Big Karl area is in-tended. This extension will lead to a versatile platform for the operation and development of compact accelerator based neutron sources with dedicated neutron instrumentation used also by universities and industry for training, development and scientific service.

CONCLUSION

Using the JULIC cyclotron, it is possible to demonstrate a small accelerator-based neutron source with protons or deuterons in the energy range from 10 MeV to 45 MeV (76 MeV for deuterons) at COSY. This allows to test and develop critical components for the HBS project. In addition, it can provide access to neutron beam time for research and industry and with the expected performance of

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the neutron source at JULIC it is a unique option to strengthen the research with neutrons at the Forschungszentrum Jülich with the local universities, research institutions and industry.

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