ISBN: 978-3-95450-205-9 doi:10.18429/JACoW-Cyclotrons2019-TUP019

RECENT EXTENSIONS OF JULIC FOR HBS INVESTIGATIONS

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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 station 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 target 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 accelerator-based neutron source capable to support the large scale facilities and provide an efficient network of small and medium neutron sources throughout Europa.

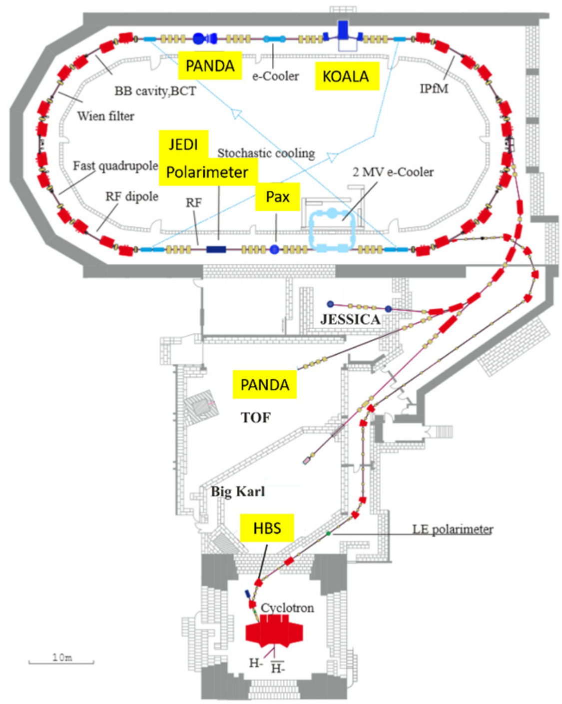

Figure 1: Layout of the COSY facility with the new beam-line from the cyclotron into the Big Karl Experiment area

The HBS JULIC Neutron Platform is going to be 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 planned experimental setup in Big Karl-area.

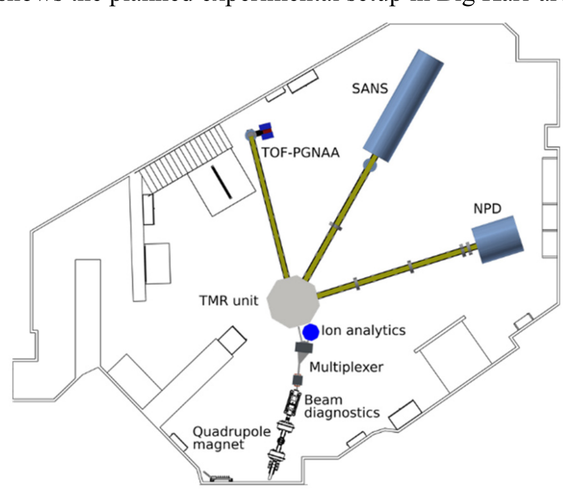

Figure 2: Planned experimental setup in Big Karl area.

ISBN: 978-3-95450-205-9 doi:10.18429/JACoW-Cyclotrons2019-TUP019

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 has been finalized (Fig. 3).and is shown later in the text. It is in use since beginning of 2019 in the Big Karl area.

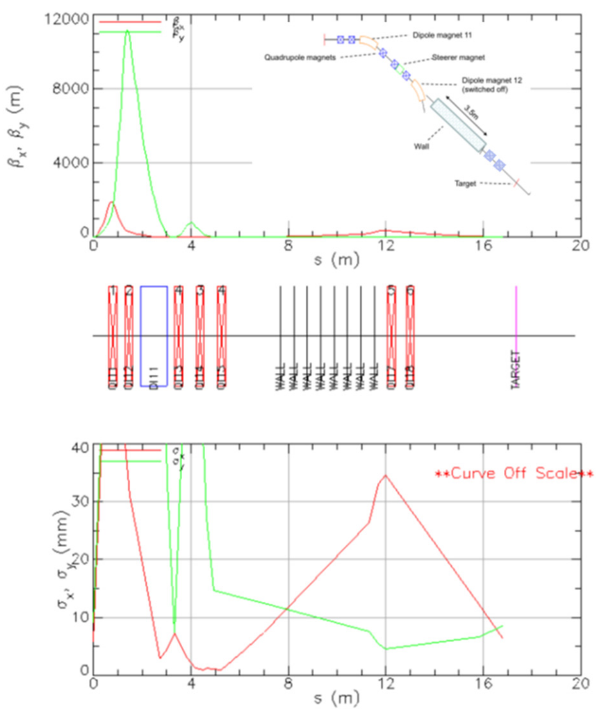

Figure 3: Beamline to Big Karl area. The figure shows the simulation results of transport calculations starting at the cyclotron, passing the shielding wall as well as the quadrupole setup.

At this beamline, experimental validations of cross section measurements and component tests for the HBS target development are being performed and will be used further for such experiments.

The needed proton and deuteron energies are obtained by use of an energy degrader providing fixed energies of 10, 20, 30 and 40 MeV for both species (Fig. 4) and enabling fast switching between these energies instead of changing the working point of JULIC. The frameless energy degrader is made from graphite giving maximum beam spots of 15 mm reducing halo particles. The necessary material thicknesses to obtain the different energy degradations have been calculated with SRIM [6] and checked with Bragg Peak-measurements of the protons respectively deuterons penetrating into PMMA using GAFchromic® films (Fig. 5).

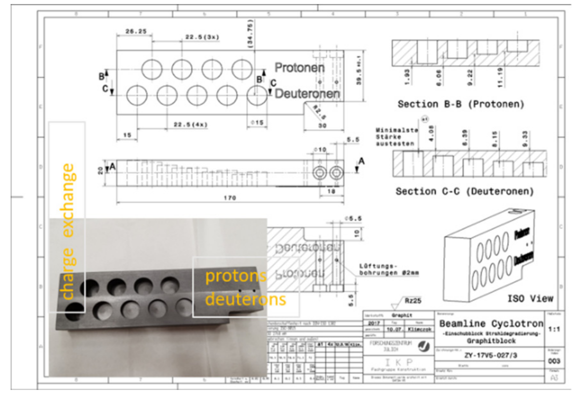

Figure 4: Frameless energy degrader made from graphite.

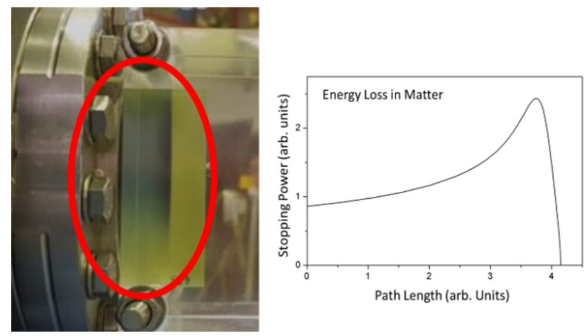

Figure 5: Determination of the proton energy by measurement of penetrating depth into PMMA using GAFchromic® films and comparison with SRIM-calculation.

To reduce the neutron background at the detector setup in the Big Karl-area the degrader is installed inside the Cyclotron bunker right behind the cyclotron exit. The protons and deuterons are deflected by ~30° with a dipole magnet into the Big Karl Experiment area while the neutrons, produced inside the graphite are going straight and will be stopped in the bunker shielding walls (Fig. 6).

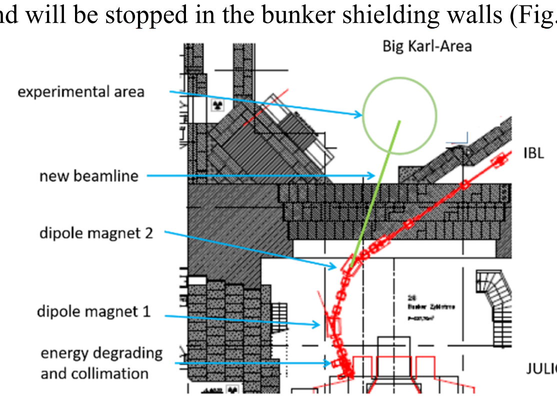

Figure 6: Beamline into Big Karl area with energy degrader and dipole magnets inside the cyclotron bunker.

For safety reasons two beam stops are installed inside the bunker, which can be used as faraday cups for beam current measurement as well. Inside the Big Karl-area beam current is measured with a Bergoz Fast Current Transformer (FCT) [7, 8] and on the target directly.

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Beam profile measurements (see Fig. 7) with a Multi Wire Proportional Chamber (MWPC) is used for optimizing the beam spot on target regarding to the experimental needs.

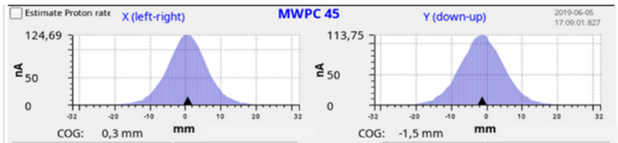

Figure 7: Beam profile at Big Karl target station. The beam size shown is ~15 mm FHWM.

Beam position is measured in both X and Y planes with a capacitive Beam Position Monitor System (BPM) [9, 10] (Fig. 8) utilizing four electrically isolated electrodes. Signal processing is done with preamplifiers FEMTO DHPVA-201 and lock-in-amplifiers Stanford Research SR844 [11] and data recorded via EPICS IOCs [12]. Newly developed graphical user interfaces based on Control System Studio (CSS) [13] allow for display of measured beam orbit and currents.

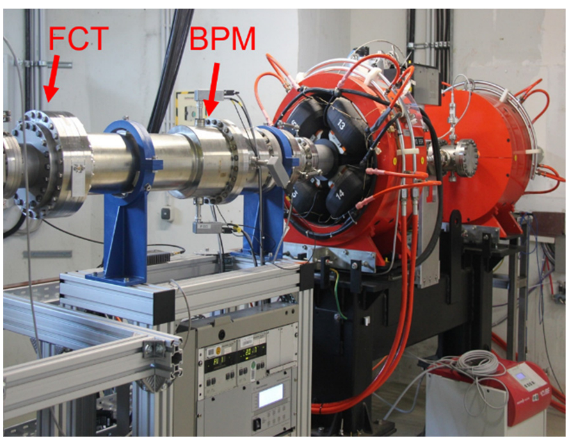

Figure 8: Beamline inside Big Karl area with Beam Position Monitor System (BPM) and Fast Current Transformer (FCT).

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 [14] or as existing accelerator based neutron facilities in Japan [15].

The pulsing scheme for proton beam of duration between 10 to 50 µsec has been realized

FUTURE ACTIVITIES

Based on the existing experimental station of the HBS project at the Big Karl area a prototype of the HBS target-moderator-reflector (TMR) assembly is intended. This assembly will allow to develop further 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 (see Fig. 9), deflects the beam up to 40° into a dedicated septa magnet, guiding the beam to three target stations is actually under construction at IKP and will be mounted in 2020.

The new platform allows designing, constructing and operating 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 per-mission process are in preparation.

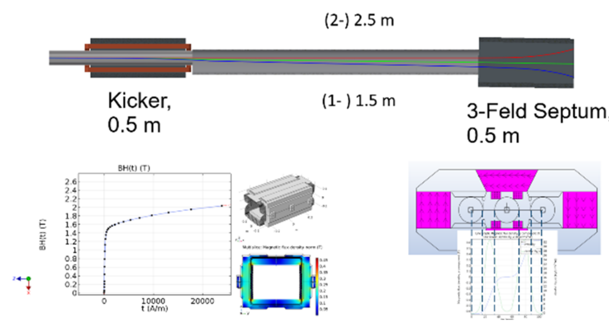

Figure 9: Multiplexer configuration with a fast kicker and a septa-magnet.

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, as listed in Table 1. 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.

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

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

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(76 MeV for deuterons) at COSY. This allows testing and developing 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 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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