The Bern Medical Cyclotron as an irradiation facility for High Energy Physics

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The Bern Medical Cyclotron and its Beam Transfer Line

- The Bern cyclotron [1] is an IBA Cyclone 18/18. It accelerates H^- ions to 18 MeV and reaches a maximum extracted current of 150 µA. Proton extraction is achieved by electron stripping.
- Its main function is the production of radioisotopes for PET diagnostics overnight, while research activities are carried out during the day.
- Irradiations for research are conducted in a separate bunker, adjacent to the cyclotron. The extracted beam is transported by a 6.5 m long beam transfer line (BTL), as depicted in Fig. 1.

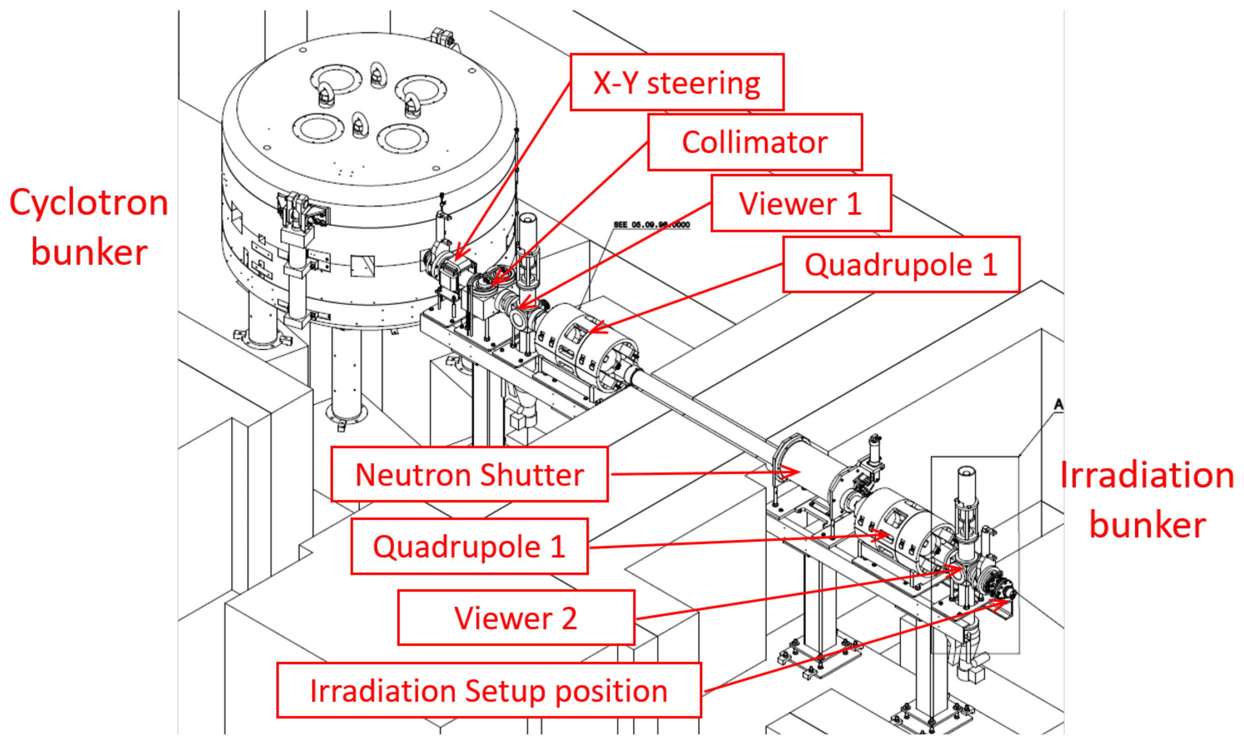

Figure 1: BTL detail. The steering and focusing magnets enable a fine tuning of the beam profile from a few mm^2 to 3x3 cm^2. Two beam viewers are present in the line allowing for beam current measurements.

A facility for radiation hardness studies

- Proton flux adjustable from 10^6 $cm^{-2}s^{-1}$ to 6×10^{10} $cm^{-2}s^{-1}$ (from 4 mGy s^{-1} to 0.8 MGy h^{-1} of Total Ionizing Dose in Si).
- Irradiation setup with dedicated beam current and beam profile monitoring devices (Fig. 2)
- Beam extraction in air and Device Under Test (DUT) mounted on a 2D remote controlled stage.
- Passive irradiations or with active readout are possible.
- Proton energy on DUT between 16.7 MeV and 17.5 MeV depending on the extraction window.
- A characterization laboratory at the facility allows to perform *in situ* studies on the DUT after the irradiation.

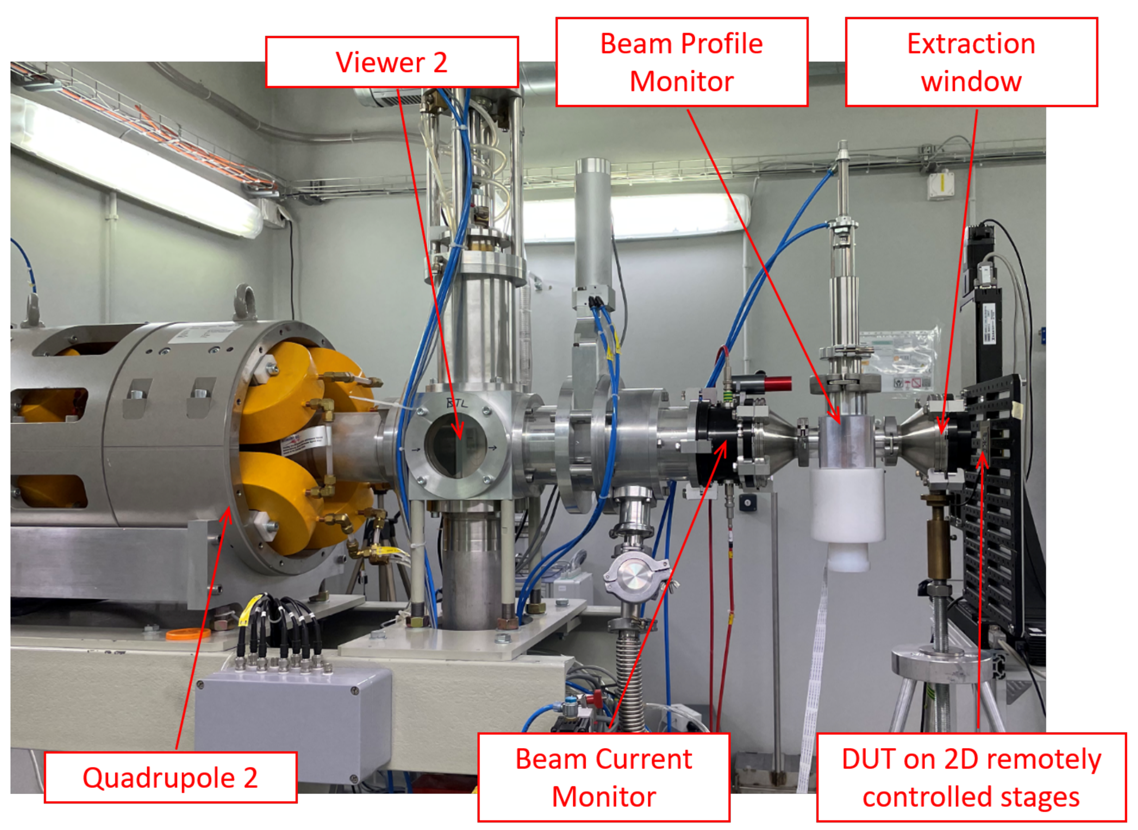

Figure 2: Typical irradiation setup. Custom beam current and beam profile monitors are mounted before the extraction window in order to monitor the proton flux on the DUT.

Beam current monitoring

The beam current is measured with the collimator shown in Fig. 3. The dump ring is connected to a picoammeter, thus measuring the proton flux stopped by the collimator, while the bias ring is biased at −100 V in order to prevent secondary electron emission from the dump ring. Several collimator apertures are available, from 5 mm × 5 mm to 30 mm × 30 mm.

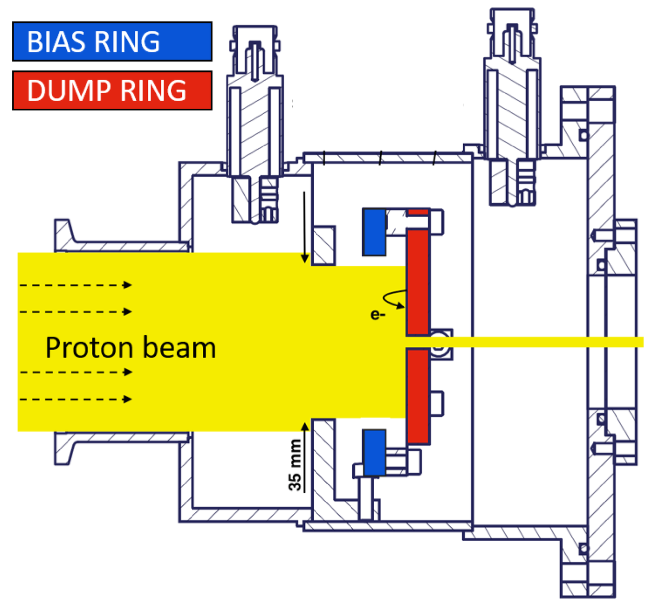

Figure 3: Cross-section of the collimator used for the beam current measurement.

Beam profile monitoring

- The UniBEaM [2] monitor uses a scintillating fibre to continuously scan the beam along one axis, according to the scheme shown in Fig. 4 (right). The scintillating light, proportional to the intercepted beam intensity, is read out using a photo-sensor and a dedicated software reconstructs the beam profile. The system was developed at LHEP and commercialized by D-PACE. The commercial version, shown in the picture (left), features 2 staggered fibres in order to monitor the horizontal and vertical beam profiles.
- The π^2 [3] monitor is based on a 15-µm-thick aluminum foil placed at a 45° angle with respect to the beam axis. The foil is coated with a thin layer of P47 scintillating compound (Y2SiO5:Ce,Tb). The beam footprint on the scintillator is imaged with a commercial CMOS camera. A dedicated software corrects the image for perspective effects and provides real time display of the beam profile.

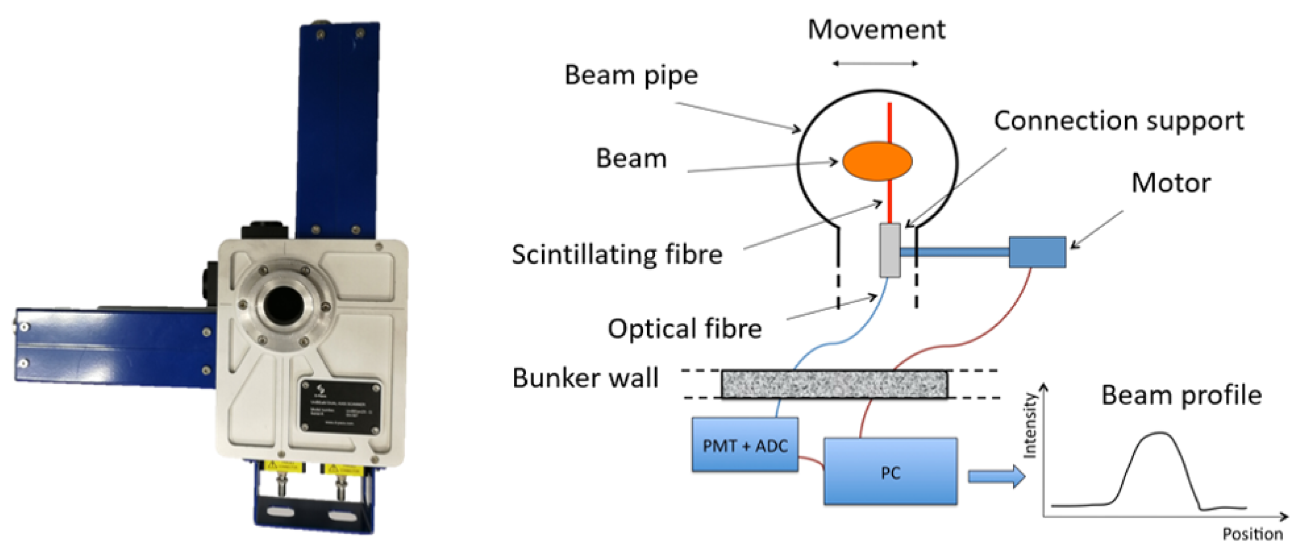

Figure 4: Left, the UniBEaM monitor commercialized by D-PACE. Right, a scheme of the UniBEaM working principle.

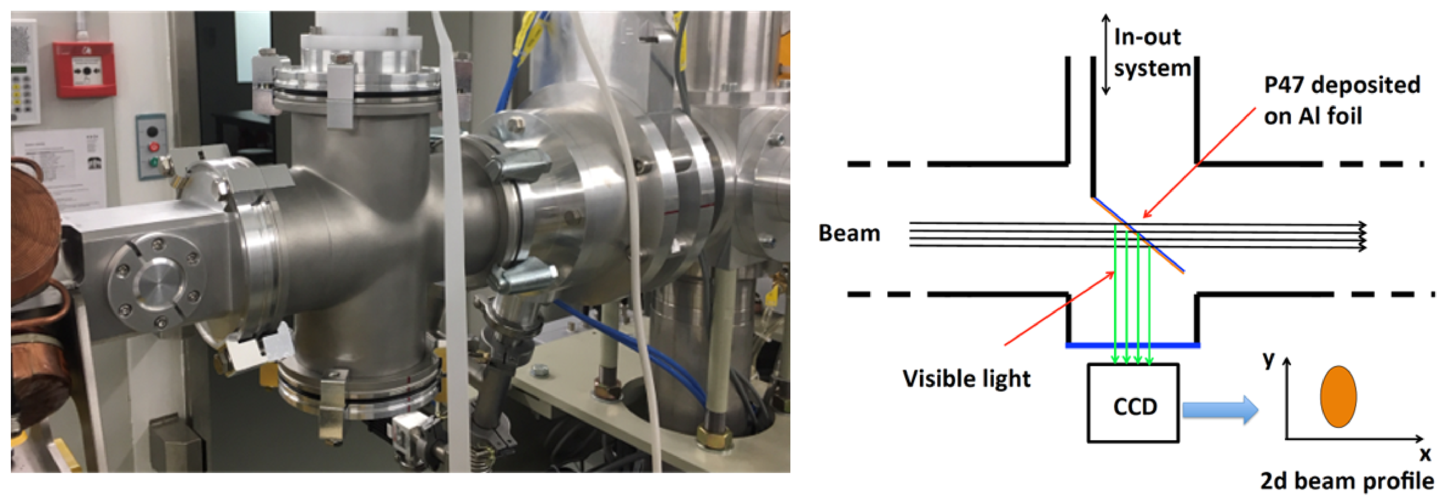

Figure 5: Left, the π^2 profile monitor installed on the BTL. Right, a schematic cross-section of the π^2 detector.

Dose calibration using radiochromic films

Fig. 6 shows the optical absorbance of FWT-60 radiochromic films after irradiation in the BTL against the Total Ionizing Dose (TID) determined from the beam current and beam profile measurements (red markers), compared to the calibration provided by the manufacturer (black markers). The agreement between the calculated dose and the one expected from the calibration at the same optical absorbance was found to be better than 15%.

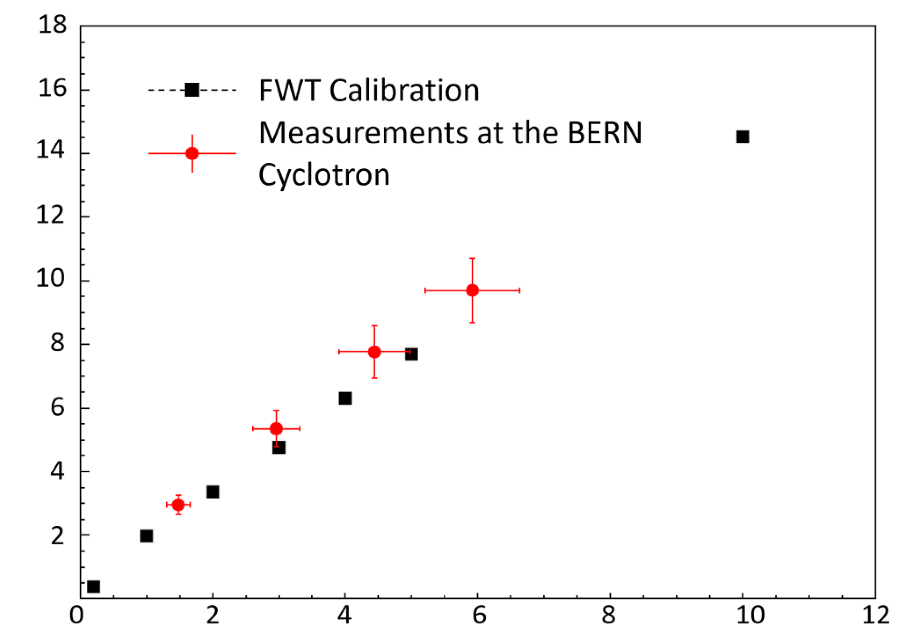

Figure 6: Comparison between the film calibration provided by Far West Technologies and the dose measurement at the Bern Medical Cyclotron.

Examples of Irradiation campaigns

- Radiation Hardness tests for the Neutral gas and Ion Mass spectrometer (NIM) onboard ESA's JUpiter ICy moonExplorer (JUICE) [4].
- Qualification of high-voltage CMOS pixel sensors for the HL-LHC, up to a fluence of 1.9×10^{15}1 MeV n_{eq}/cm^2 [5].
- Currently, an extensive irradiation campaign is ongoing to validate the data transmission chain of the ATLAS ITk pixel detector. Diverse components such as cable shieldings, connectors and electrical cables (Fig. 7) have been or will be irradiated. (see L. Halser, *Irradiation studies at the Bern Cyclotron for the ATLAS ITk Upgrade*, this conference).

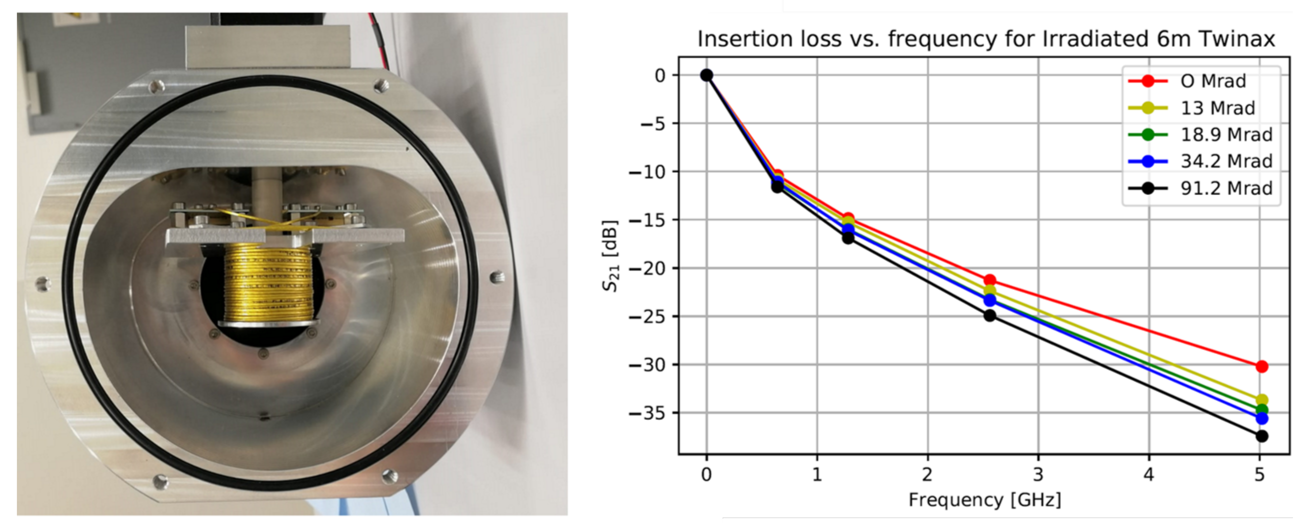

Figure 7: Left, setup used to irradiate a twinax cable for the ATLAS ITk pixel readout chain. Right, insertion loss measured with a Vector Network Analyzer at different dose levels.

References

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