A Proton Irradiation Site for Si-Detectors Providing Precision Damage Application and Flexible Irradiation Procedures

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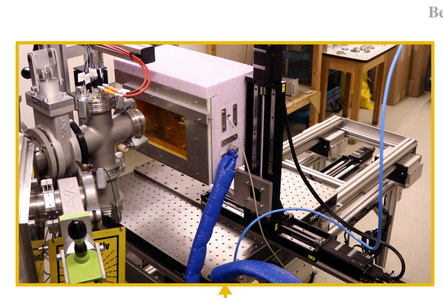
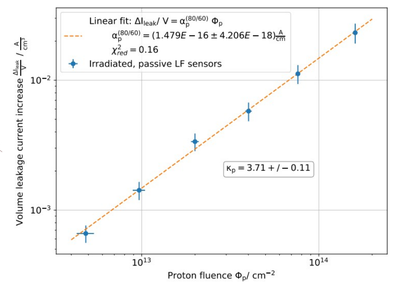
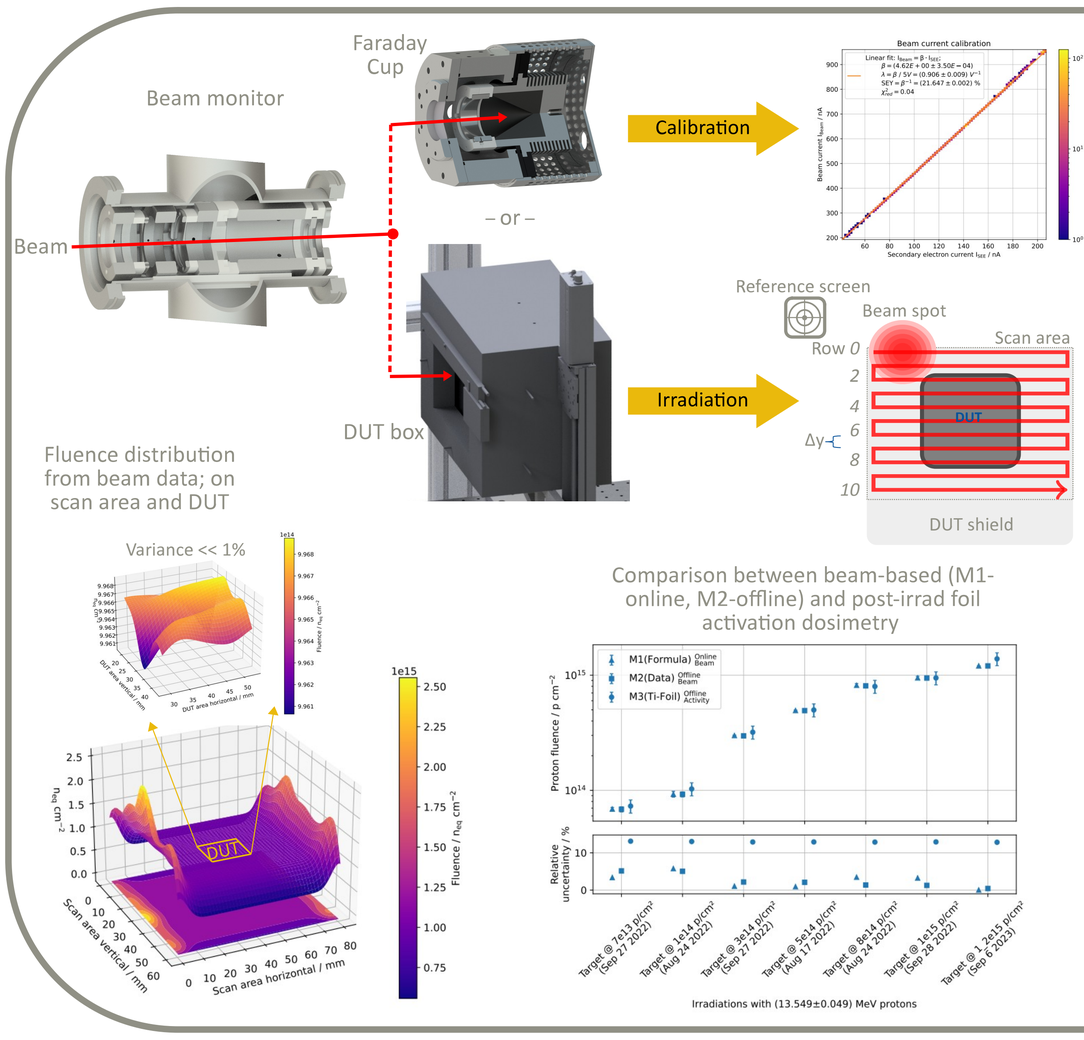
Facility & Site

- **The Bonn Isochronous Cyclotron**
  - Electron-Cyclotron-Resonance (ECR) source provides **light ions up to C^{4+}**
  - Accelerator produces ion beams of **7 to 14 MeV** per nucleon
  - Beam handling system delivers to five available beamlines
  - *High-current-site* adjacent to accelerator for e.g. isotope production
  - Irradiation site located on beamline C
    - Proton beams of **20 nA to 1 µA** current and a **few mm FWHM** available
    - Proton hardness factor **κ = 3.71±0.11**
- **Irradiation Setup**
  - Table with optical breadboard on movable rail arrangement
  - DUT box, cooled by N_2 gas system, mounted on XY motorstage
  - External Faraday Cup (FC) installed on linear motorstage
  - Calibrated beam monitor mounted at extraction, preceding box
  - 19” rack with electrical interfaces to setup, feed-through into DUT box
  - Multiple fluorescent screens for beam-based alignment



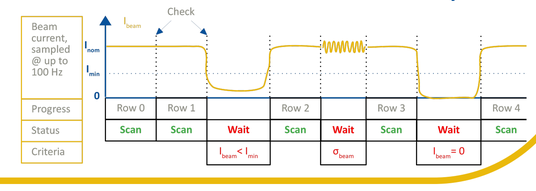


Dosimetry & Procedure



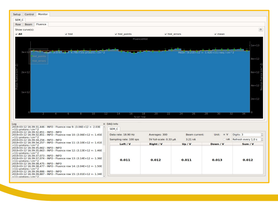
Comparison between beam-based (M1-online, M2-offline) and post-irrad foil activation dosimetry

- **Online beam monitoring**
  - Secondary-Electron-Emission (SEE)-based
  - Thin foil pairs penetrated by beam → $I_{SEE}=\alpha \cdot I_{Beam}$
  - Calibration using FC allows online monitoring
  - Foil segmentation provides position information
- **Beam-based dosimetry**
  - Sample beam parameters during scan
  - Calculate fluence per row online $\phi_p = \frac{I_{beam}}{q_e \cdot v \cdot \Delta y}$
    - Enables on-the-fly corrections with **1 dim.** res.
  - Store irradiation-related data for offline analysis
    - Allows to obtain fluence distribution in **2 dims.**
  - Compare w/ typical dosimetry via foil activation
    - **In agreement**, but foil method yields **higher uncertainty** and **no spatial resolution**
- **Irradiation procedure**
  - Perform calibration measurement
  - Align beam on reference screen
  - Construct scan grid over DUT area
  - Const. row separation **Δy << FWHM**
  - Scan row-wise with **const.** velocity v
- **Beam-driven scan routine**
  - Online monitoring of beam parameters enables irradiation to adapt
  - Condition checks between rows
  - Halt scan on shield/adjust if needed
    - Maximize fluence uniformity



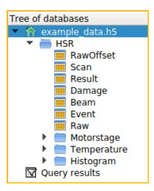
Flexibility & Devices

- **Flexible irradiation campaigns**
  - Powering/readout of DUTs during irradiation
  - Pausing of irradiation at specific fluence
  - Measurements in between irradiation steps
  - User-specific measurement setups on site
- **Control, DAQ and analysis software**
  - *irrad_control:* open-source, GUI-based SW
  - Controls hardware, visualizes data, performs beam driven irradiation routine
  - Storage of extensive data set for analysis
  - Provides offline data analysis to the user



Online fluence monitor

HDF5 output data

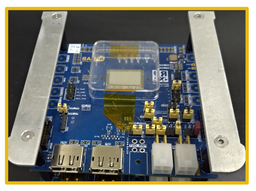


- **Variety of devices**
  - Bare sensors, test structures on PCB, single chip cards, diodes
  - DUT thickness limited by beam energy
    - **<= 300 µm Si** for stated hardness factor
- **Further information**

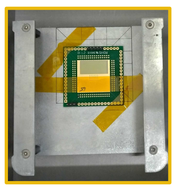
Cyclotron homepage

Publications & talks

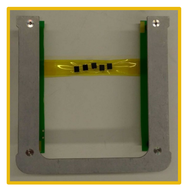
irrad_control GitHub



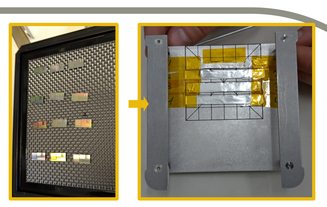
Assembly on SCC



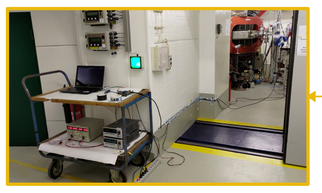
Sensor on surfboad



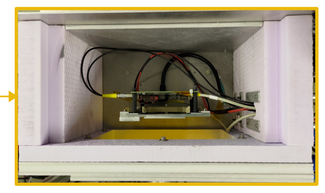
PiN-diodes on Kapton tape

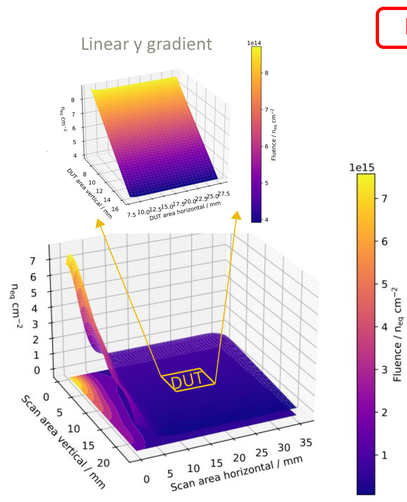


Bare sensors, wrapped in Al-foil

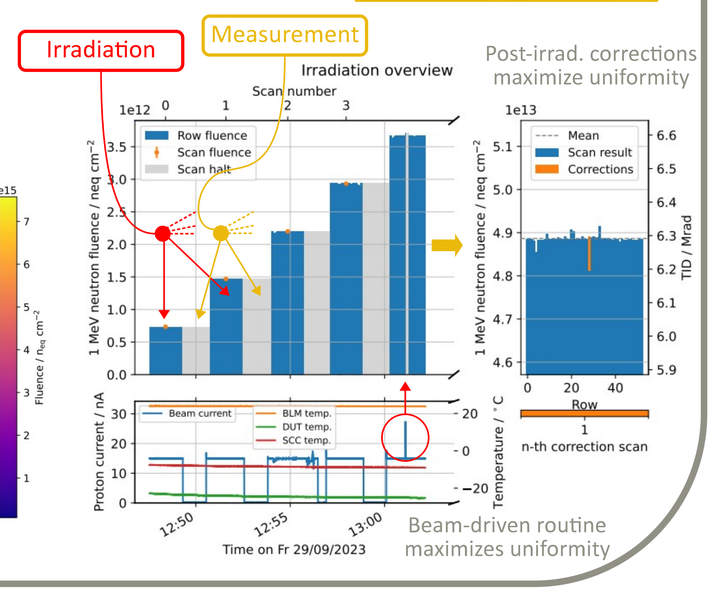


Dedicated setup for power / reading out / measuring detector between irradiation steps





Online dosimetry allows to apply custom profiles e.g. linear gradient



Beam-driven routine maximizes uniformity