PRIMA, High-Intensity Electron Beamline at DESY

BTTB12, 15.04.2024 Edinburgh
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Motivation of High Intensity Beam

Why is a Powerful Beamline needed?

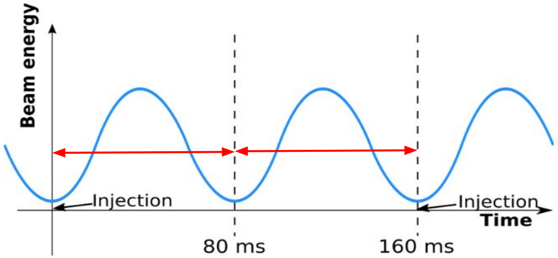
High number of particles/electrons

1. For precise measurement to characterise small detectors
2. To verify readout performances of sensors with high intensity beams
3. To irradiate sensors with high energetic electrons

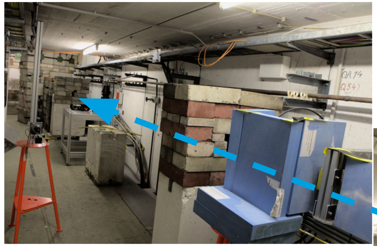
High Intensity Electron Beamline

PRIMary-beam test Area : PRIMA

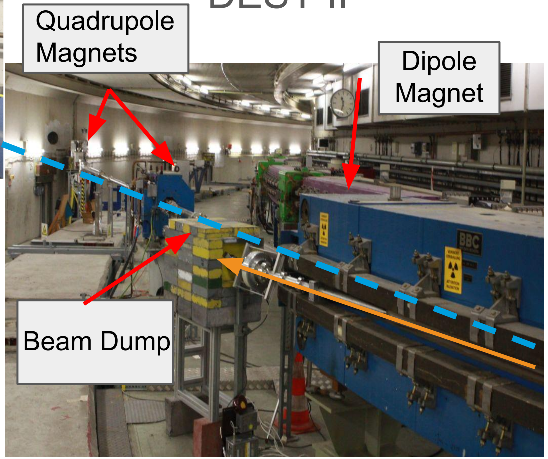
- PRIMary-beam test Area(PRIMA)
  - Injected electron beam cycles around DESY II ring
  - Beam is extracted to a dump at DESY II, if it not transported
    - Beam can be upcycled
    - Dipole and two quadrupole magnets transport beam into PRIMA facility
- Extracted beam from DESY II
    - 1×10^5 to 3×10^{10} e/bunch
    - 6.25 Hz extraction rate
    - Extraction between 500 MeV and 6 GeV



PRIMA Facility

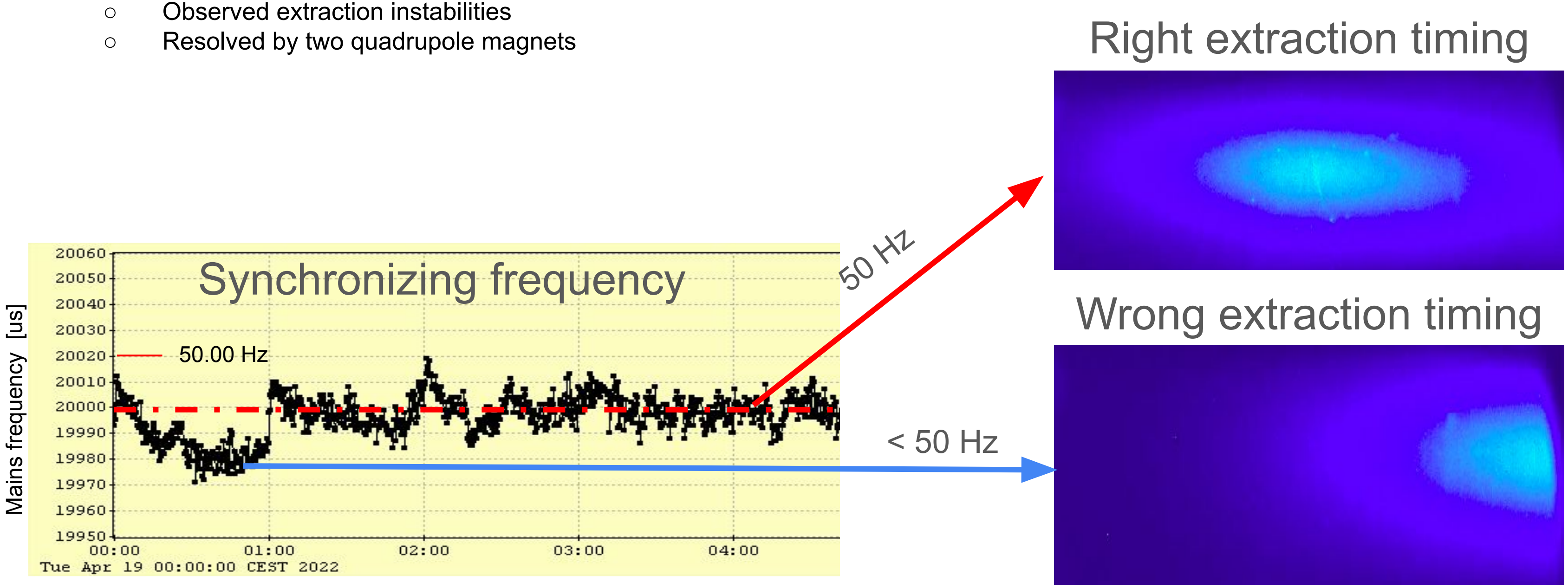


DESY II



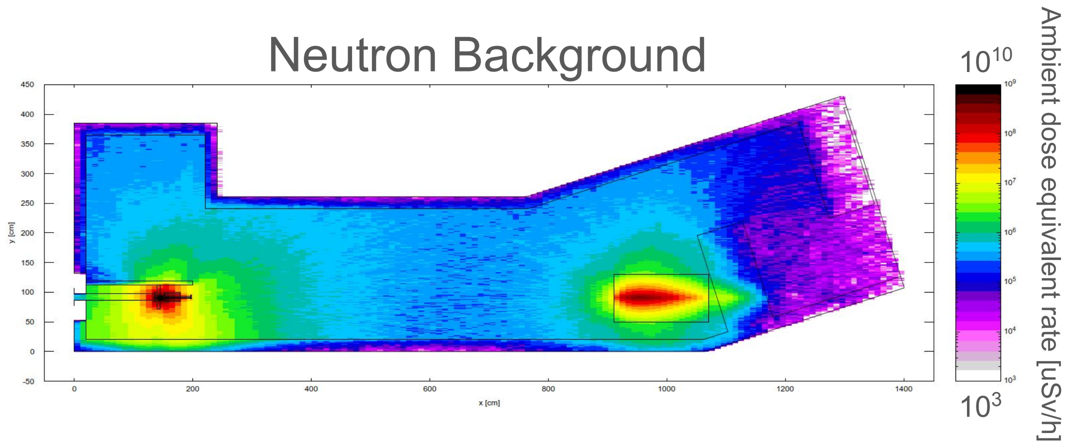
User Facility Requirement

- Precise knowledge of beam position
  - Observed extraction instabilities
  - Resolved by two quadrupole magnets



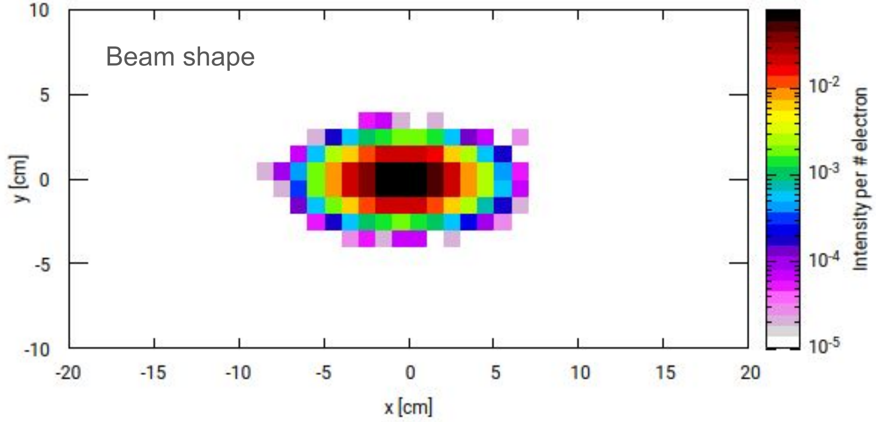
User Facility Requirement

- Precise knowledge of beam position
  - Observed extraction instabilities
  - Resolved by two quadrupole magnets
- Understanding radiation environments
- Providing possibly small, homogeneous dose over a DUT



User Facility Requirement

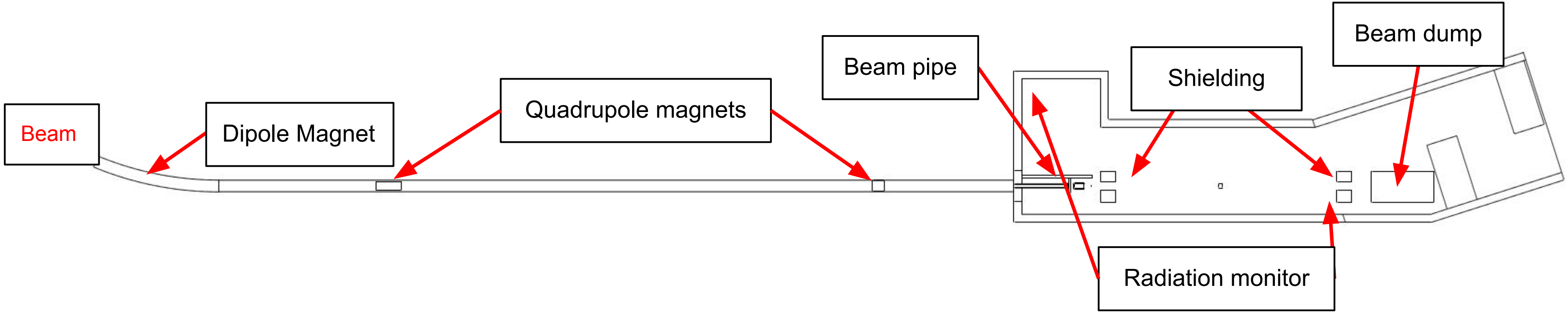
- Precise knowledge of beam position
  - Observed extraction instabilities
  - Resolved by two quadrupole magnets
- Understanding radiation environments
- Providing possibly small, homogeneous dose over a DUT
- Beam Monitoring



Simulation and Modelling

FLUKA

- FLUKA is MC framework for the interaction and transport of particles in materials
    - It is optimized for calculation of radiation environments
    - It estimates the beam profile after transport and interaction in materials
- Full Beamline implemented including detailed structures close to the beam in FLUKA



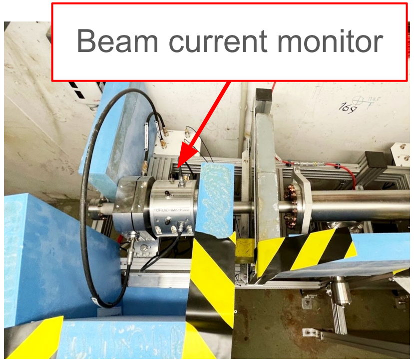
Measurement Devices

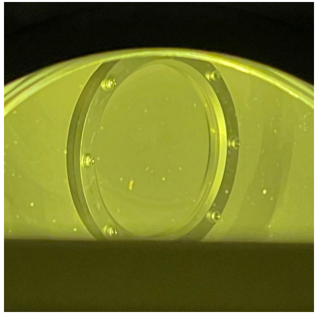
- Radiation monitor, PANDORA
  - Scintillator
    - Photon > 50 keV
    - High energetic neutron > 20 MeV
  - Moderated ^{3}He tube
    - Low energetic neutron < 20 MeV
- Beam current monitor
- Beam screen

Scintillator

PANDORA

^{3}He Tube



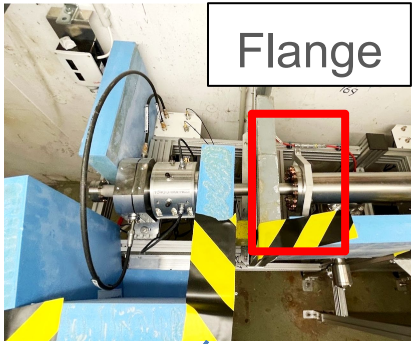


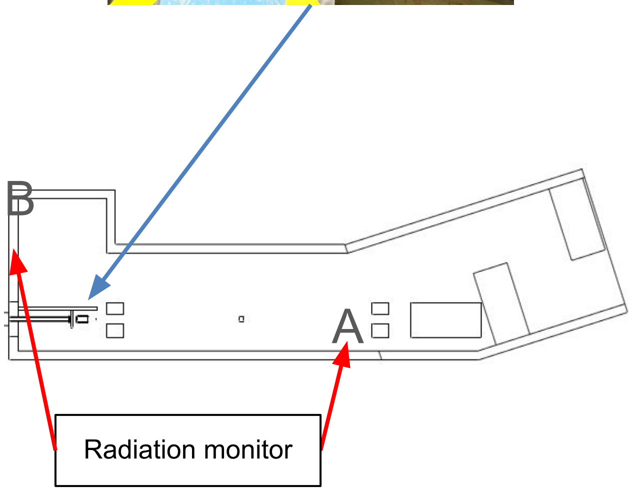
Radiation Background Study

Comparing simulation and real data

- Radiation background study
  - Number of extracted electrons are provided by DESY II
  - Beam size in simulation is tuned to particle ratio of PANDORA neutron background measurement

Neutron Background Study		6 GeV Electron Beam		500 MeV Electron Beam	
		Eq-Dose [mSv/h]	# ex. electrons [10^9/bunch]	Eq-Dose [mSv/h]	# ex. electrons [10^9/bunch]
Position A	Simulation	18.3 ± 0.9	9,8	1.85 ±0.08	11.6
	Measurement	19.3 ± 0.4	9,7 ± 0.2	1.95 ± 0.09	11.6 ± 0.5
Position B	Simulation	10.8 ± 0.7	9.6	1.82 ± 0.01	9.6
	Measurement	14.6 ± 1.2	9.6 ± 0.2	2.00 ± 0.11	9.6 ± 0.2



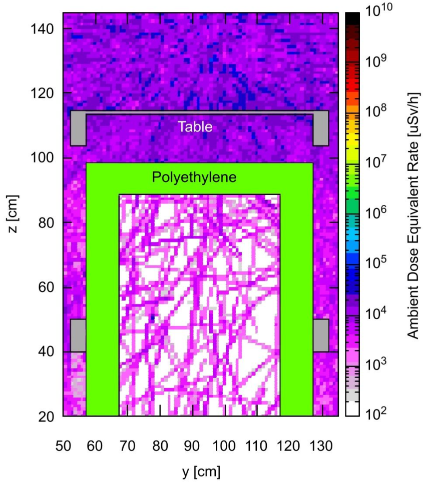


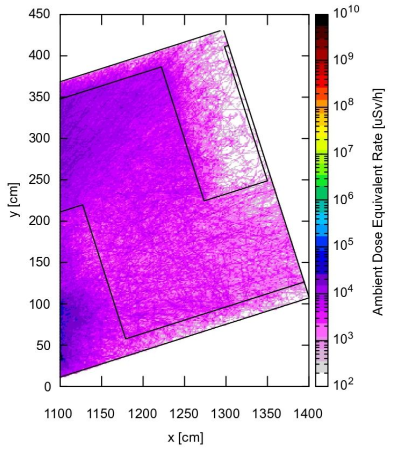
Good agreement of simulation and data

Shielding

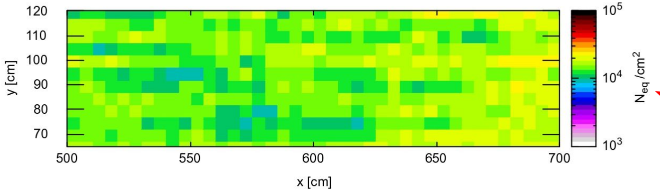
Simulation & Measurement

- Harsh radiation environment
  - Need to protect electronics from neutrons
  - Need to eliminate neutron in the area to study effects of electrons only
    - Two concrete blocks
    - Boronated Polyethylene under DUT table

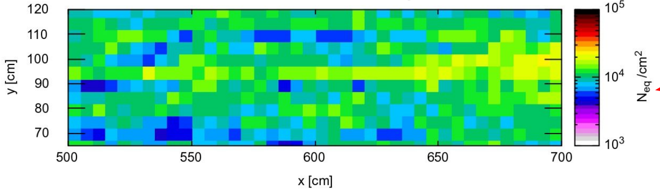


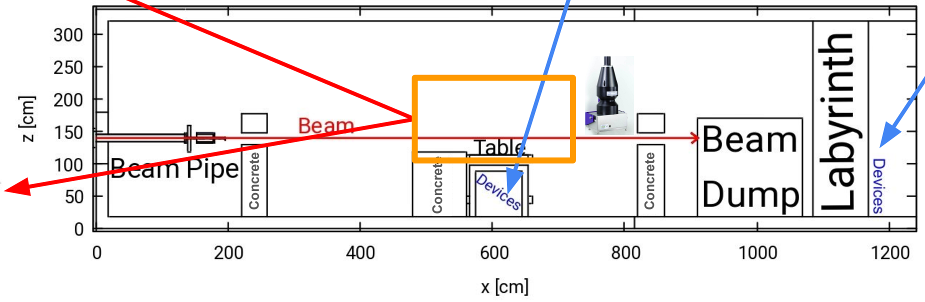


Before shielding



After shielding

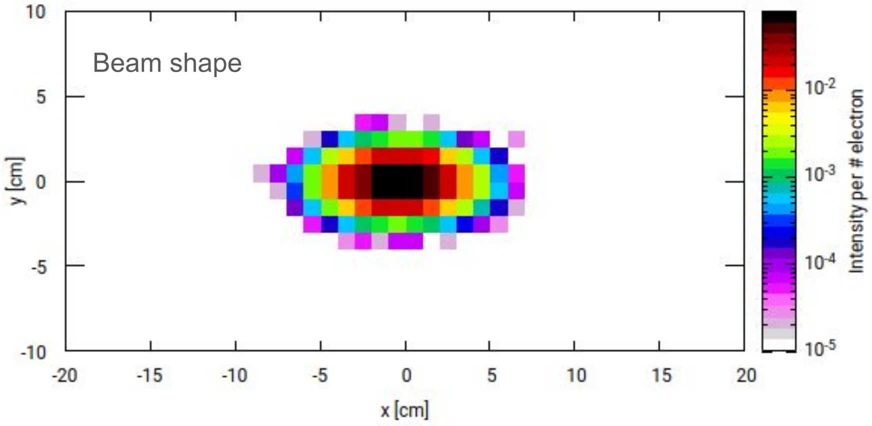


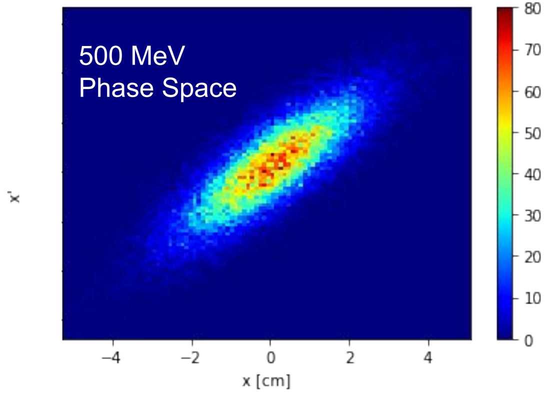


Ongoing Studies

Simulation & Measurement

- Beam profile
  - Beam size, divergence and emittance are going to measured using two scintillating screens
- Beam collimation to reduce beam intensity from GHz to MHz
  - Increased beam size by a quadrupole magnet will be collimated
  - It will be focused again by a quadrupole magnet





Summary

PRIMA Facility

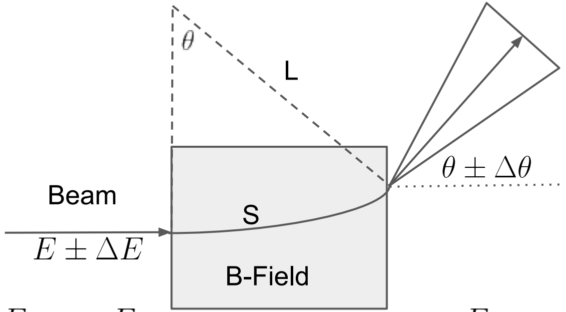
- Stable beam extraction has been established
    - Quadrupoles correct and stabilize beam position
- Simulation matches data and allows for predictions
- Background effects are suppressed by shielding
- First high rate studies to be performed after final beam commissioning
- Beam collimation study is ongoing to study particle rate

BACKUP

Beam Stability

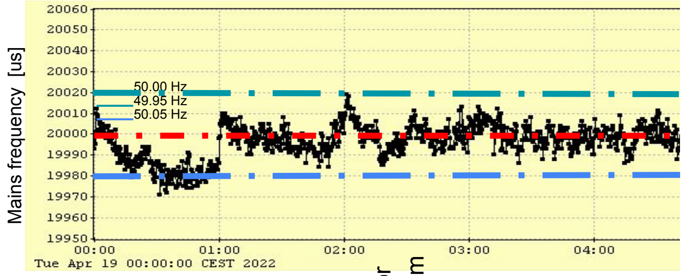
Beam Position and Size

- Mains frequency synchronizes all magnet system at DESY II
  - Its fluctuation correlates beam stability
  - Uncertainty of extracting time ~ extracting angle
    - It causes change of beam position and beam size
    - Increases unexpected hit to materials at beam pipe
    - Radiation background is changed

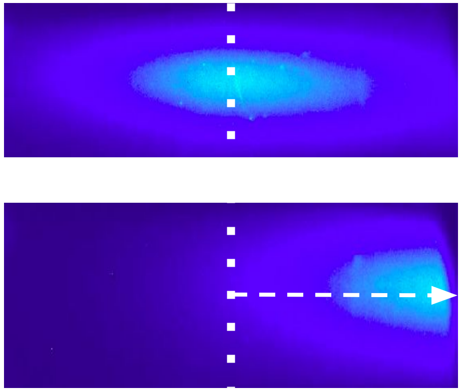


$$E(t) = \frac{E_{max} - E_{min}}{2} sin(2\pi f_m t_{ext} + \phi) + \frac{E_{max} + E_{min}}{2}$$

$$B[T] = \frac{E[GeV]}{0.3S[m]}\theta \rightarrow \frac{\Delta\theta}{\theta} = \frac{\Delta E}{E}$$

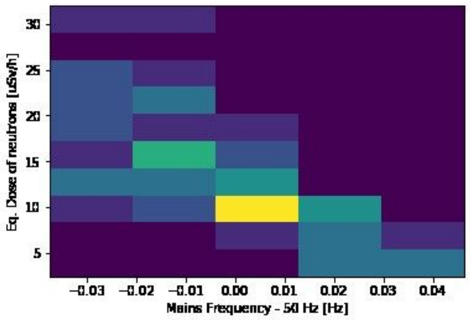


Current beam with energy of 500 MeV measured with beam camera



Correlation for 500 MeV beam

$\Delta t_{\text{ext}} \sim \Delta E \sim \Delta\theta$



Saturation Effect

6 GeV Electrons		10^7 per bunch	8.5×10^8 per bunch
Simulated Dose [μSv/h]	Photon	39.8 ± 0.3	1691.5 ± 12.8
	Neutron	60.9 ± 2.1	2588.3 ± 89.3
Measured Dose [μSv/h]	Photon	33.5 ± 3.9	220.1 ± 2.6
	Neutron	65.3 ± 19.3	2405.1 ± 134.1

Shielding

Simulation & Measurement

- Harsh radiation environment
  - Need to protect electronics from neutrons
  - Need to eliminate neutron in the area to study effects of electrons only
    - Two concrete blocks
    - Boronated Polyethylene under DUT table

Radiation Monitor nearby Beam Dump		
Neutron	Before Installation	After Installation
Simulated Eq-Dose [10^{-9} mSv/h per bunch]	3.05 ± 0.11	1.83 ± 0.06
Measured Eq-Dose [10^{-9} mSv/h per bunch]	2.87 ± 0.10	1.89 ± 0.10