A New High Rate Electron Beamline at DESY II

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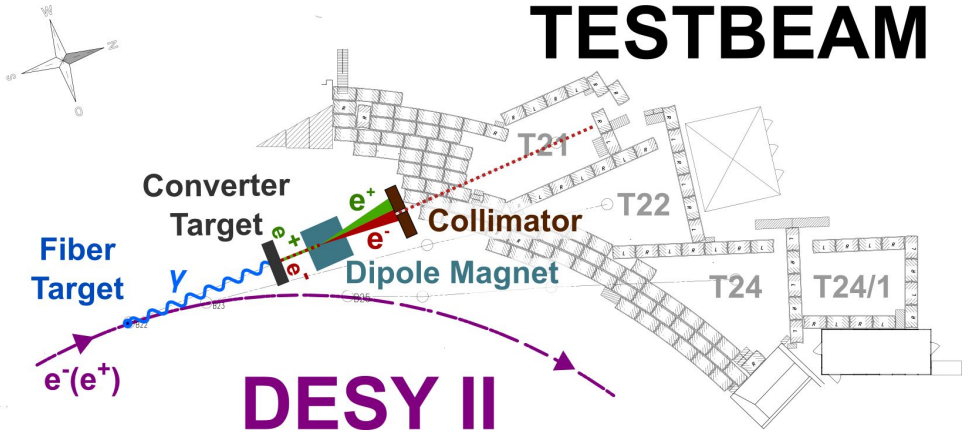
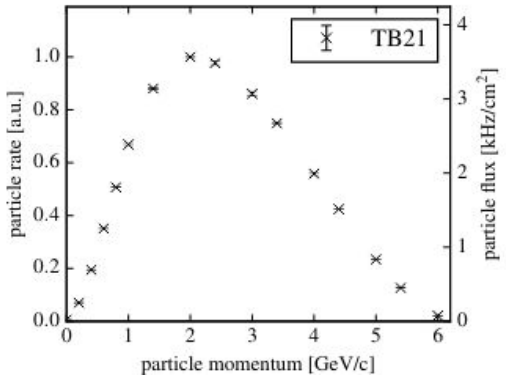
FTX-Testbeam and Telescope (TBT)
DPG Session T 94.7
Mar. 24. 2022

The DESY II Testbeam Facility

- DESY provides three testbeam lines (T21, T22 and T24) with single electrons
- Primary and secondary target
  - Fiber target : carbon fiber
    - Bremsstrahlung photons
  - Conversion target : Cu, Al
- Enables choice of momentum
  - Current of the dipole magnet
- limits rate to a few 10 kHz
- How to increase rate?

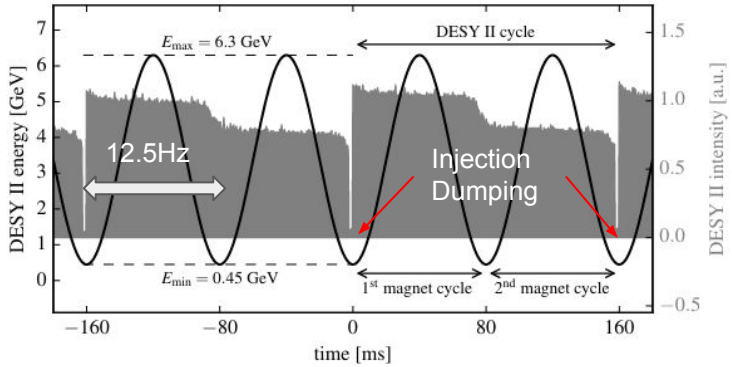


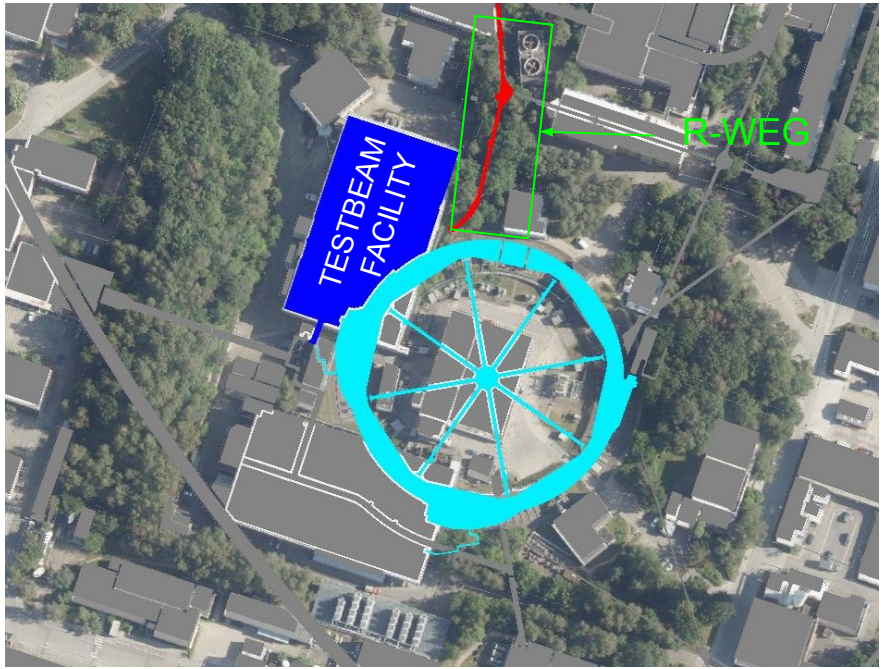


[The DESY II Test Beam Facility]

The R-Weg

- Former Extraction beamline from DESY II to DORIS
- Injected Beam from LINAC is dumped after 2nd magnet cycle in DESY II
  - Is it possible to upcycle this beam?
- Feasibility studies in order to test usability as a new test beam line
- Installation of equipments in 2021
  - Shutter, Interlock, power etc.
  - Radiation monitors





The R-Weg

- Direct extraction beam from DESY II into the R-Weg
- Beam is dumped at the R-Weg
- Radiation safety concerns
  - Interlock door is located far from beam dump
  - Labyrinth with two walls
  - Radiation monitors : PANDORAs
- PANDORA
  - Measuring dose of gammas and neutrons
  - Two detectors
    - Moderated ^{3}He tube
    - Scintillator
  - Measurable energy
    - Gamma > 50 keV
    - Low energetic neutron < 20 MeV
    - High energetic neutron > 20 MeV

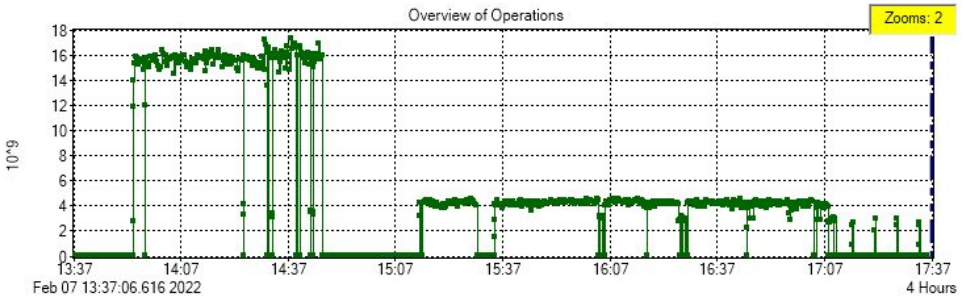
Time structure / Type of radiation	Continuous Total response, no pileup	Burst Delayed response only
High energy neutrons > 20 MeV	Scintillator: H(n,n)H → recoil protons	Scintillator: ^{12}C(n,p)^{12}B → ^{12}C + β + ν
Low energy neutrons < 20 MeV	Moderated ^{3}He – tube: ^{3}He(n,p)^{3}T	Moderated ^{3}He – tube: ^{3}He(n,p)^{3}T delayed by TOF

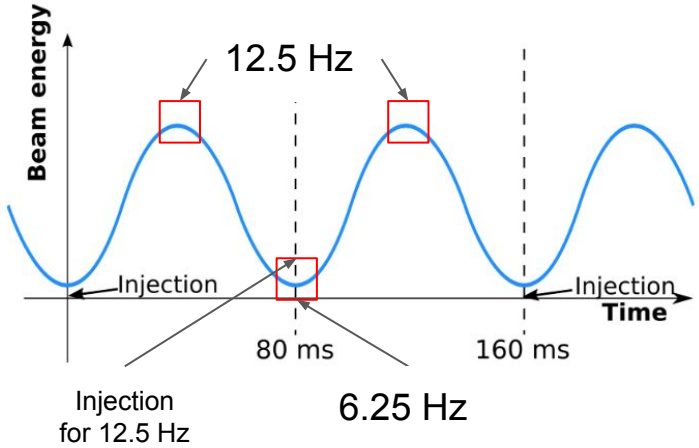
Table 1 – Overview of the LB 6419 responses due to neutron radi

[Dose rate measurements around the elec extraction at FLASH, A. Leuschner]

Beam Operation at the R-Weg

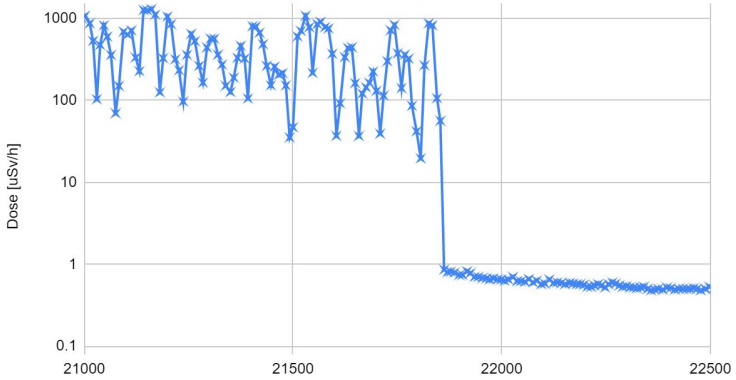
- # Particles
  - Min. : 1x10^{8} e / bunch
  - Max.: 3x10^{10}e / bunch
- Bunch length < 100 ps
- Rate of extraction : 6.25 Hz or 12.5 Hz
  - Current : 6.25 Hz
  - Concerns of stability for 12.5Hz
- Energy of beam Between 0.45 GeV and 6.3 GeV

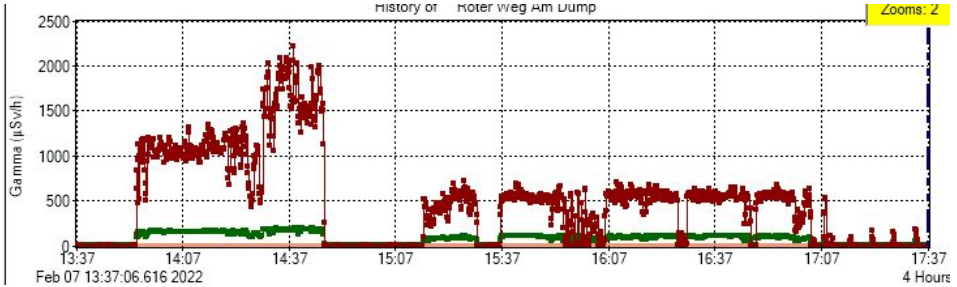




Radiation Safety and Beam Stability

- Radiation
  - How many neutrons and gammas
    - Resonance of photonuclear reaction
  - Measurement and simulation
    - PANDORA & FLUKA





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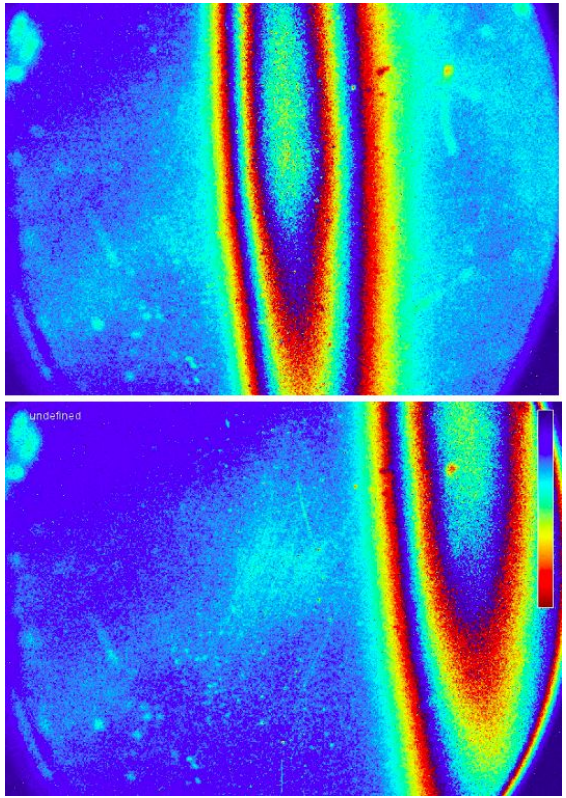
- Beam stability
  - Fluctuation of netz frequency
    - Fluctuation in the beam position
    - Mismatch between beam energy and kicker magnet strength
  - Beam structure
  - Exclude impact on normal operation stability
  - Beam only for a few hours per day



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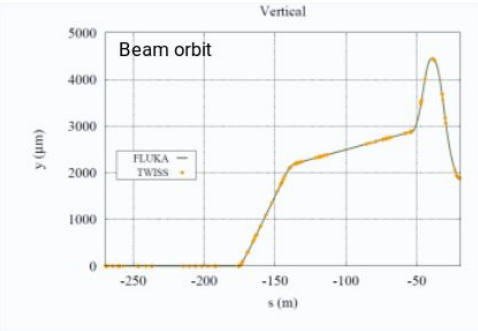
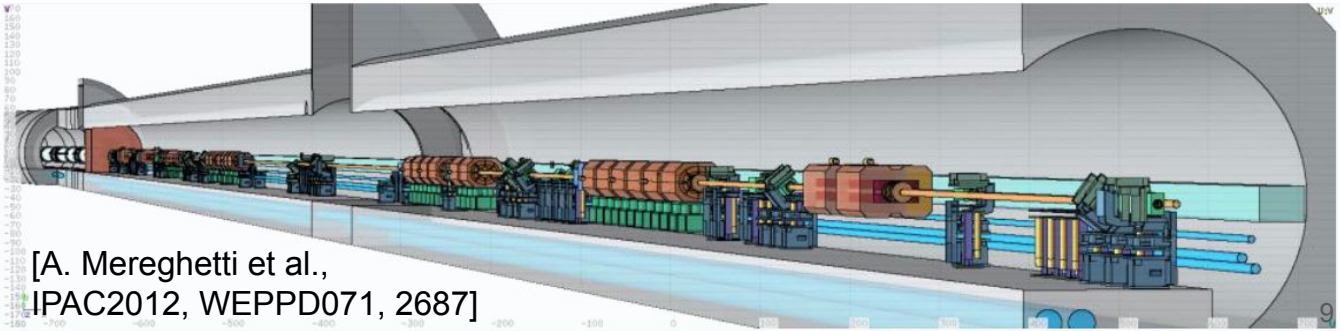
  - Beam only for a few hours per day
- How to develop the R-Weg from an expert into a user facility?

For example :
irradiation of Si-based sensors with high energy electrons

Simulating the R-Weg

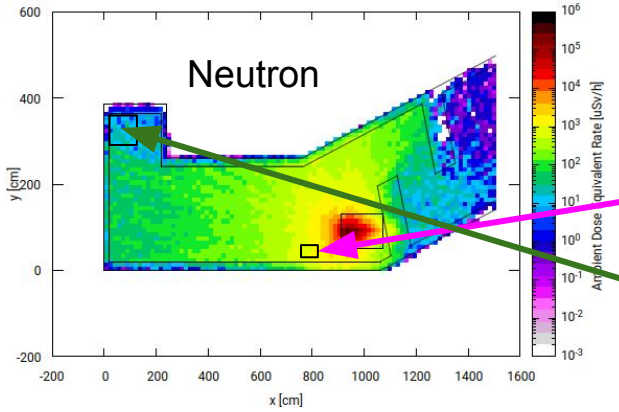
- MC framework for the interaction and transport of particles in materials
  - Based on Fortran
  - Photo interactions > 100eV
  - Electron interactions > 1 keV
  - Low energy neutron interaction < 20 MeV
- Applications
  - Accelerator design
  - Radiation protection (shielding, activation)
  - Radiation damage or electronics effects
  - etc.

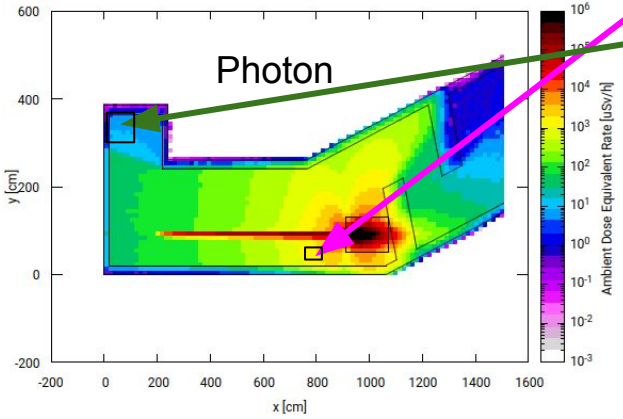


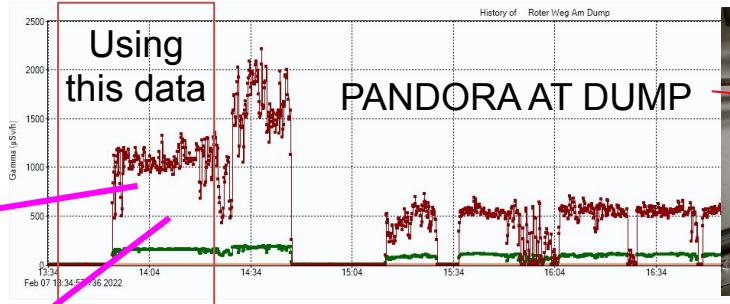


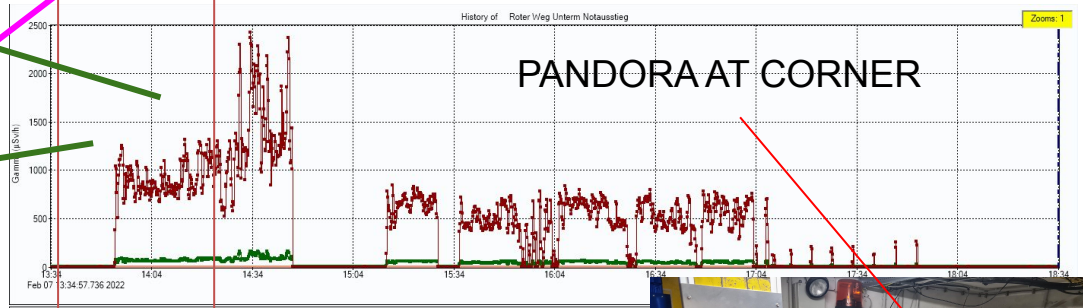
[A. Mereghetti et al., IPAC2012, WEPPD071, 2687]

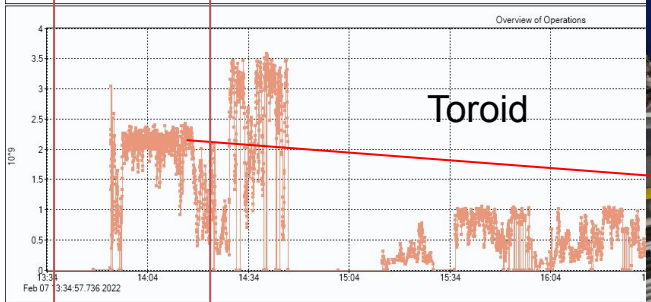
Compare to Doses During Beam Time

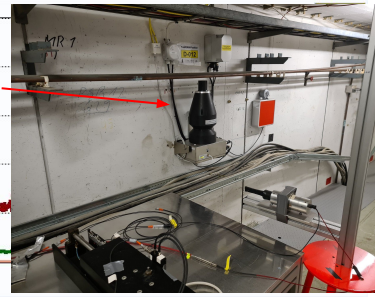






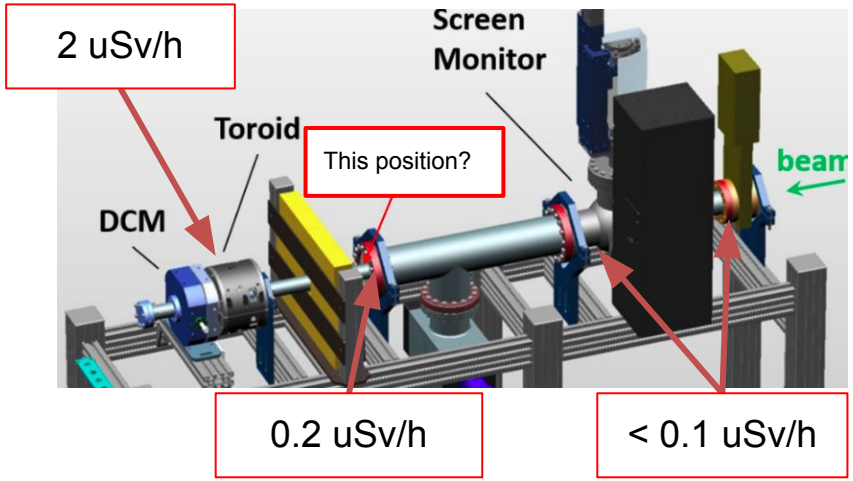


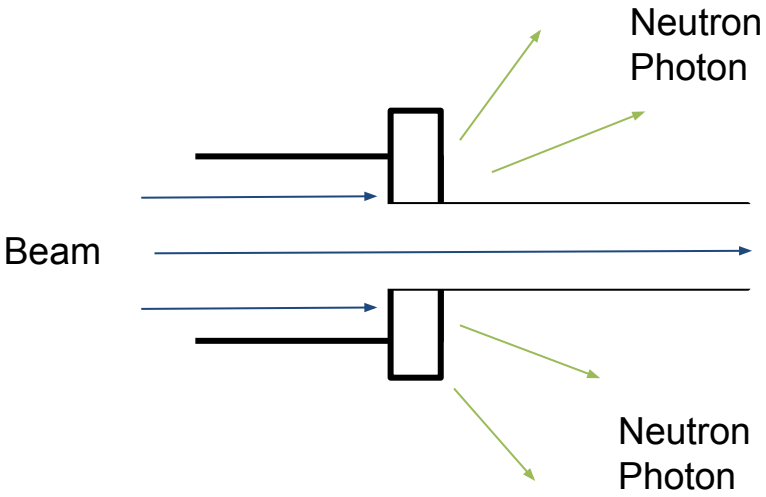


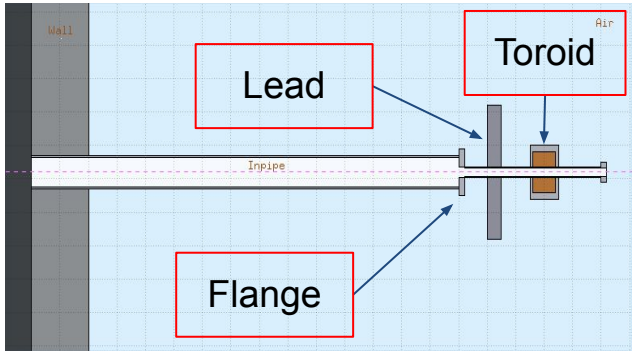


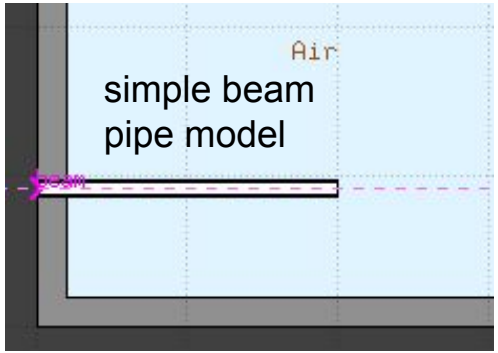
DESY.

Beam Line

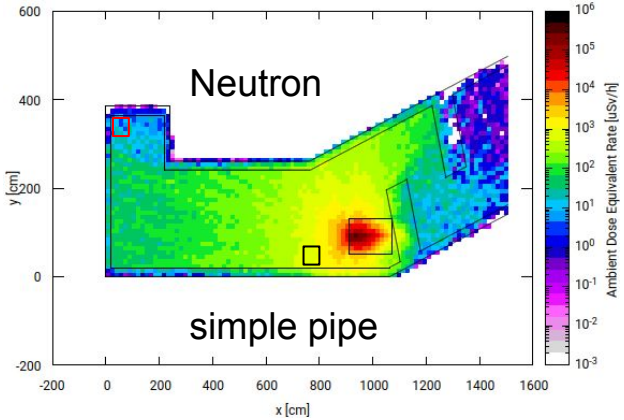

2 uSv/h
Screen
Monitor
Toroid
This position?
beam
DCM
0.2 uSv/h
< 0.1 uSv/h

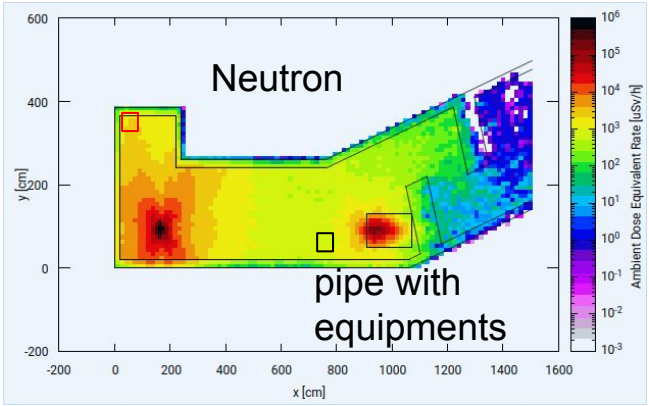

Neutron
Photon
Beam
Neutron
Photon


Wall
Air
Toroid
Lead
Inpipe
Flange


Air
simple beam
pipe model

Compare to Doses During Beam Time





□ PANDORA at the corner

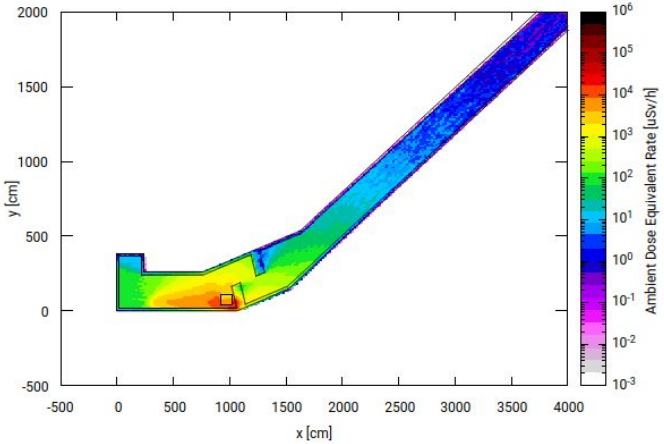
- Simulated dose with the equipments
  - Photon : 880 ± 20 uSv/h
  - Neutron : 1750 ± 100 uSv/h
- Simulated dose with simple pipe
  - Photon : 6 ± 0.5 uSv/h
  - Neutron : 12 ± 10 uSv/h
- Measured dose
  - Photon : ~70 uSv/h
  - Neutron : ~800 uSv/h

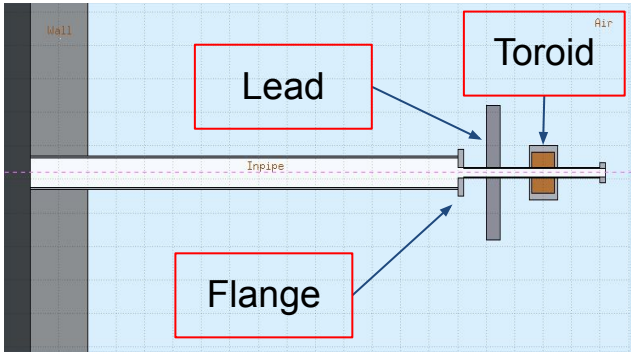
□ PANDORA at the dump

- Simulated dose with the equipments
  - Photon : 10250± 50 uSv/h
  - Neutron : 900 ± 100 uSv/h
- Simulated dose with simple pipe
  - Photon : 1300 ± 20 uSv/h
  - Neutron : 900 ± 100 uSv/h
- Measured dose
  - Photon : ~160 uSv/h
  - Neutron : ~1000 uSv/h

Summary

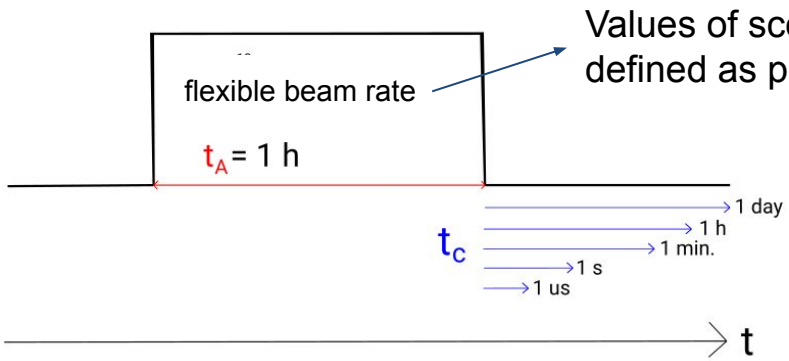
- R-Weg provides a high rate e-beam
- High energy and high rate electron beam
  - High potential utility
  - Ongoing study of Radiation safety & beam stability
    - FLUKA simulation
- Simulation & measurement
  - Simulation results in an overestimation of photons
  - A lot of neutron at the corner
    - Beam hits flange
    - Lost of some beam
  - Activated toroid and flange



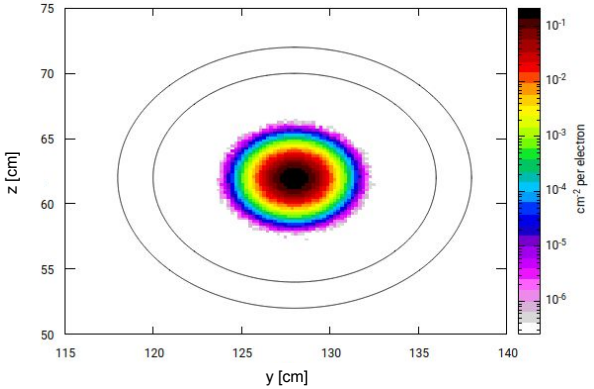


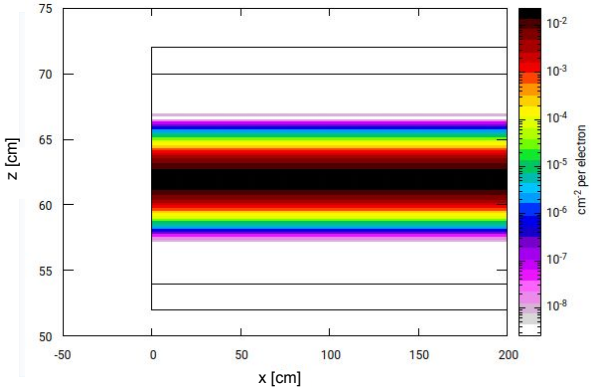
Backup

Beam-Parameters



- Electron-Beam
- Energy : 500 MeV
- Gaussian Distribution
  - FWHM in x-, y-axis : 2cm
- Beam times : 1 h
- Several different cooling times





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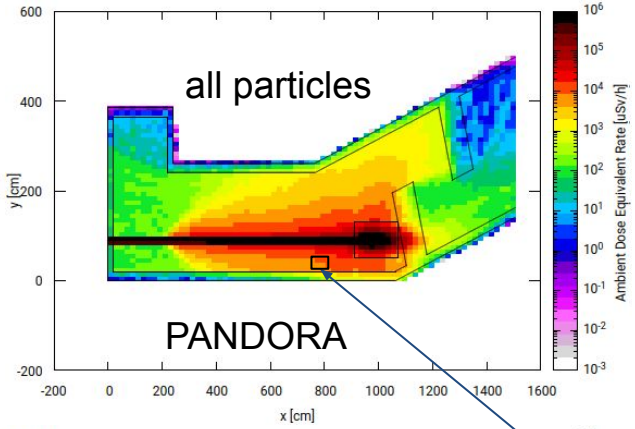
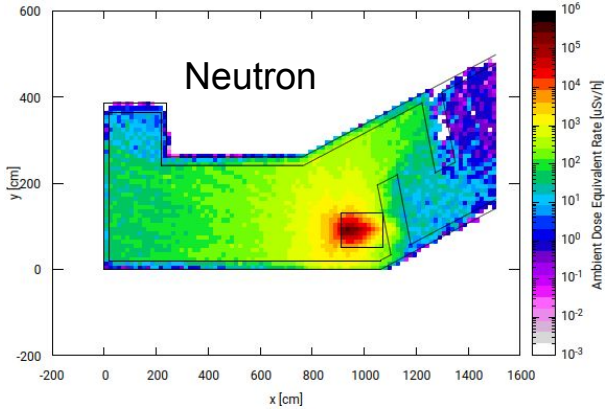
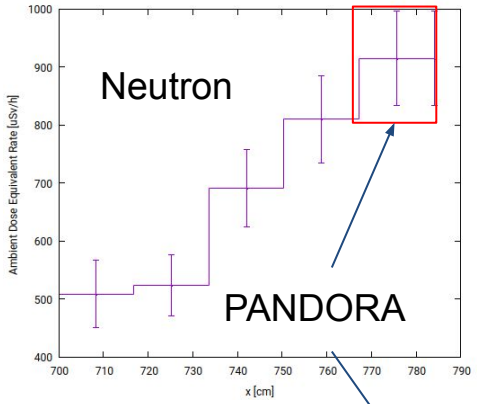
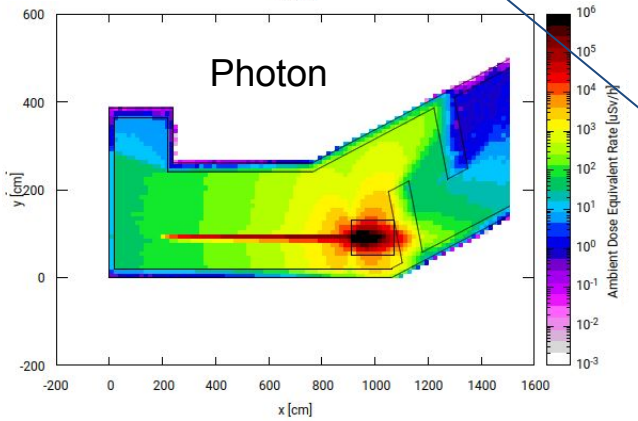
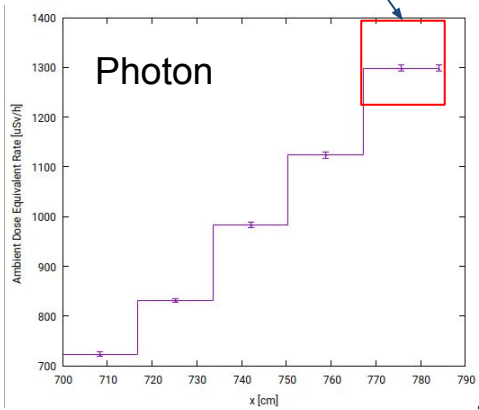








- The mean of dose
  - between z = 120cm and z = 140cm
- Measured dose from PANDORA (07.02.2021)
  - Photon ~ 160 uSv/h
  - Neutron ~1000 uSv/h
- Simulated dose
  - Photon : 1300 ± 20 uSv/h
  - Neutron : 900 ± 100 uSv/h



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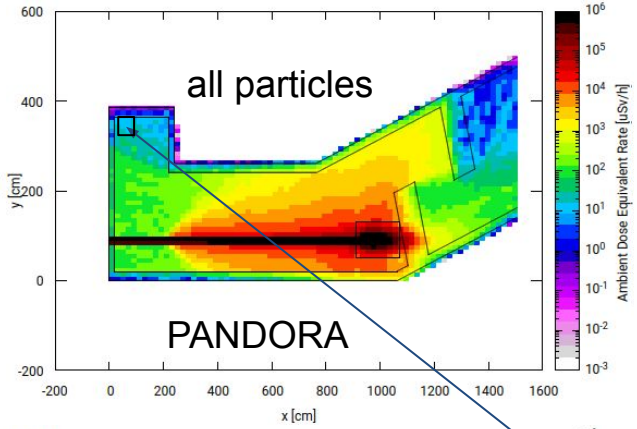
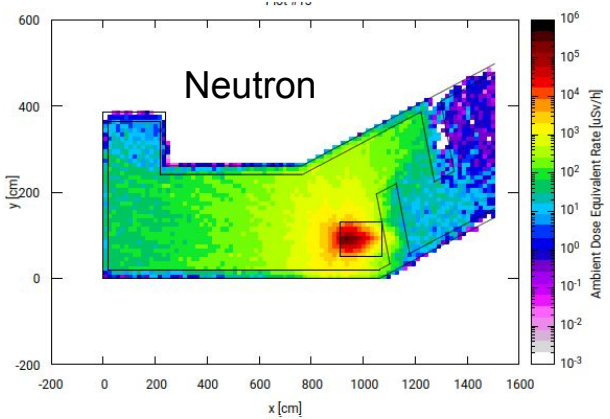
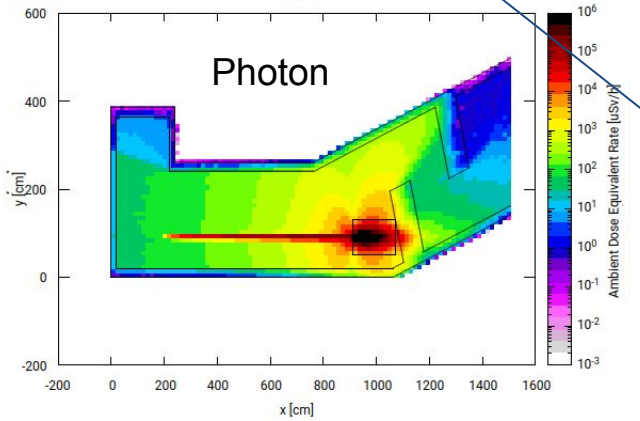


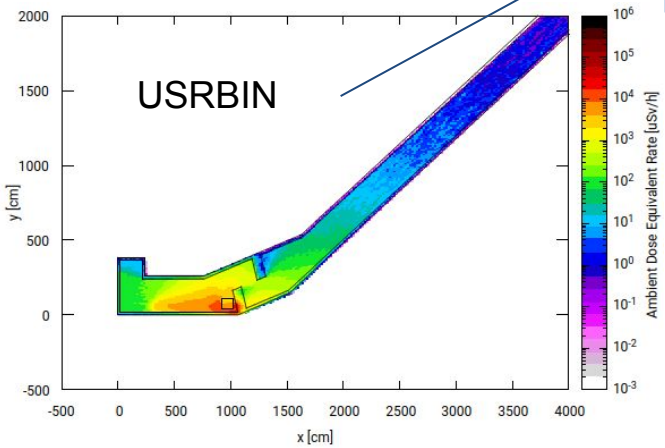




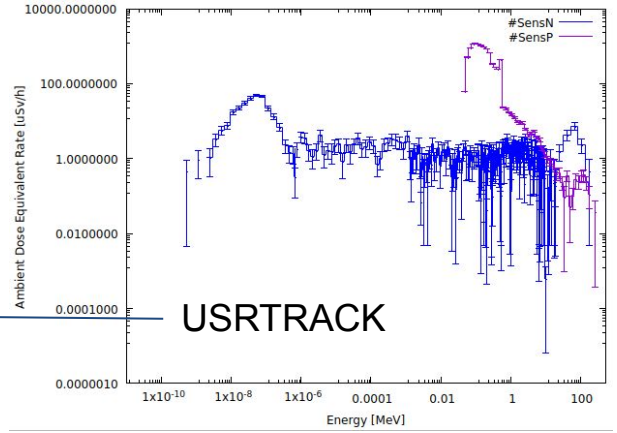
- The mean of dose
  - between z = 120cm and z = 140cm
- Measured dose from PANDORA at the corner (07.02.2021)
  - Photon ~ 70 uSv/h
  - Neutron ~ 800 uSv/h
- Simulated dose
  - Photon : 6 ± 0.5 uSv/h
  - Neutron : 12 ± 10 uSv/h

Extracting the Dose

- Total fluence
- Small bin size (21-24)
- (x,y,z) and Dose



- Differential fluence
- Large bin size (30-35)
- Energy and Dose



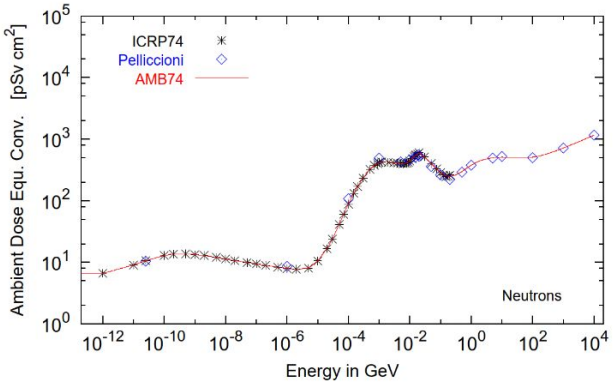
Definition of PANDORA in GEO & Sensitivity of PANDORA

- Distance between Dump & PANDORA
  - ~1.6m
- Volume
  - 10^3 cm^2
- Defined material in FLUKA
  - Air
  - Possible : scintillator

Simulated how many Particles with which energy pass through this volume

Using convert factor
the ambient dose is calculated

Using python code:
sensitivity * ambient dose
= expected ambient dose from PANDORA



[A FLUKA user-routine converting fluence into effective dose and ambient dose equivalent]

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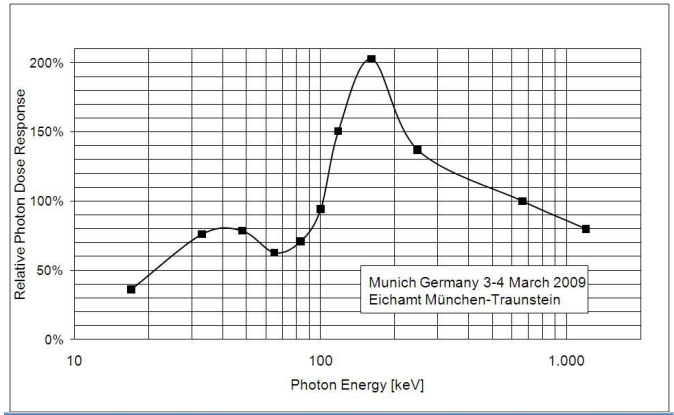
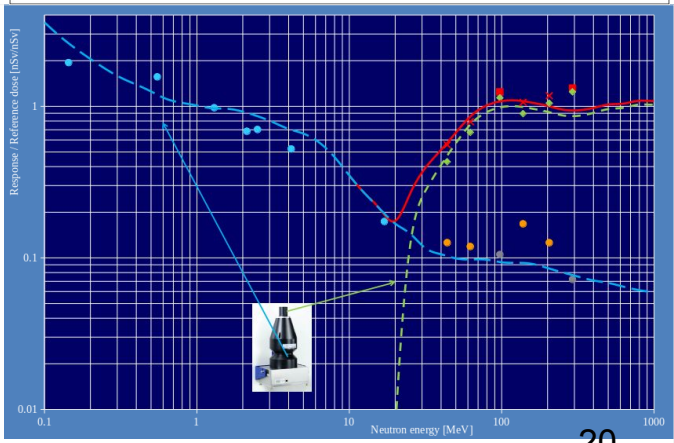
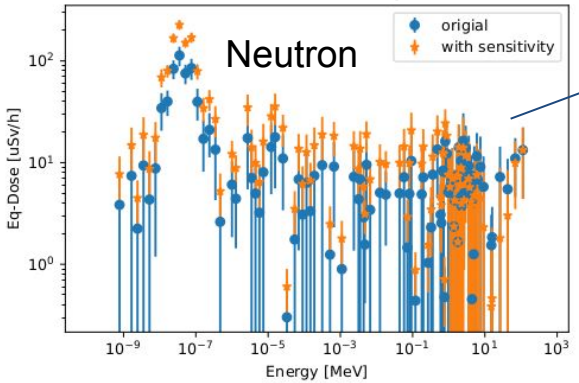




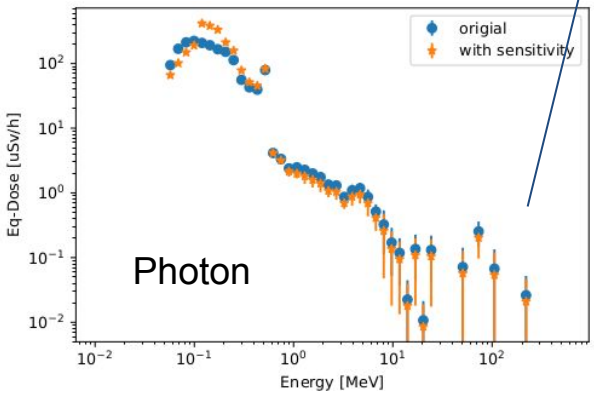
Energy vs Ambient Dose & Sensitivity

At the dump



Original simulated Dose : 1098.9 uSv/h
Corrected Dose : 1884.7 uSv/h
Error : 76.5 uSv/h

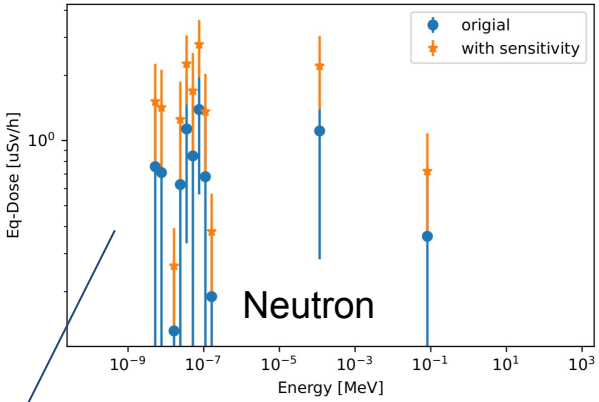
Original simulated Dose :1775.2 uSv/h
Corrected Dose :2291.1 uSv/h
Error :10.6 uSv/h

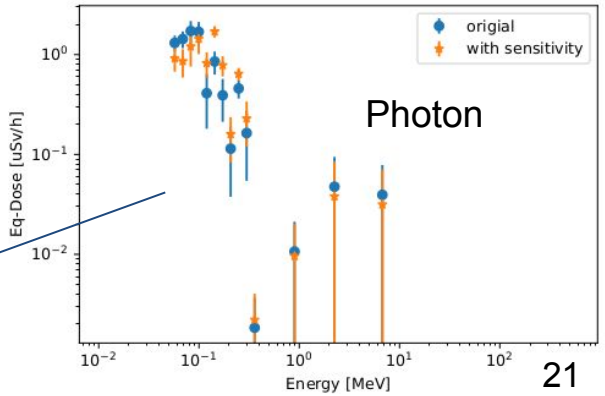


Original simulated Dose : 7.9 uSv/h
Corrected Dose : 15.9 uSv/h
Error : 2.2 uSv/h

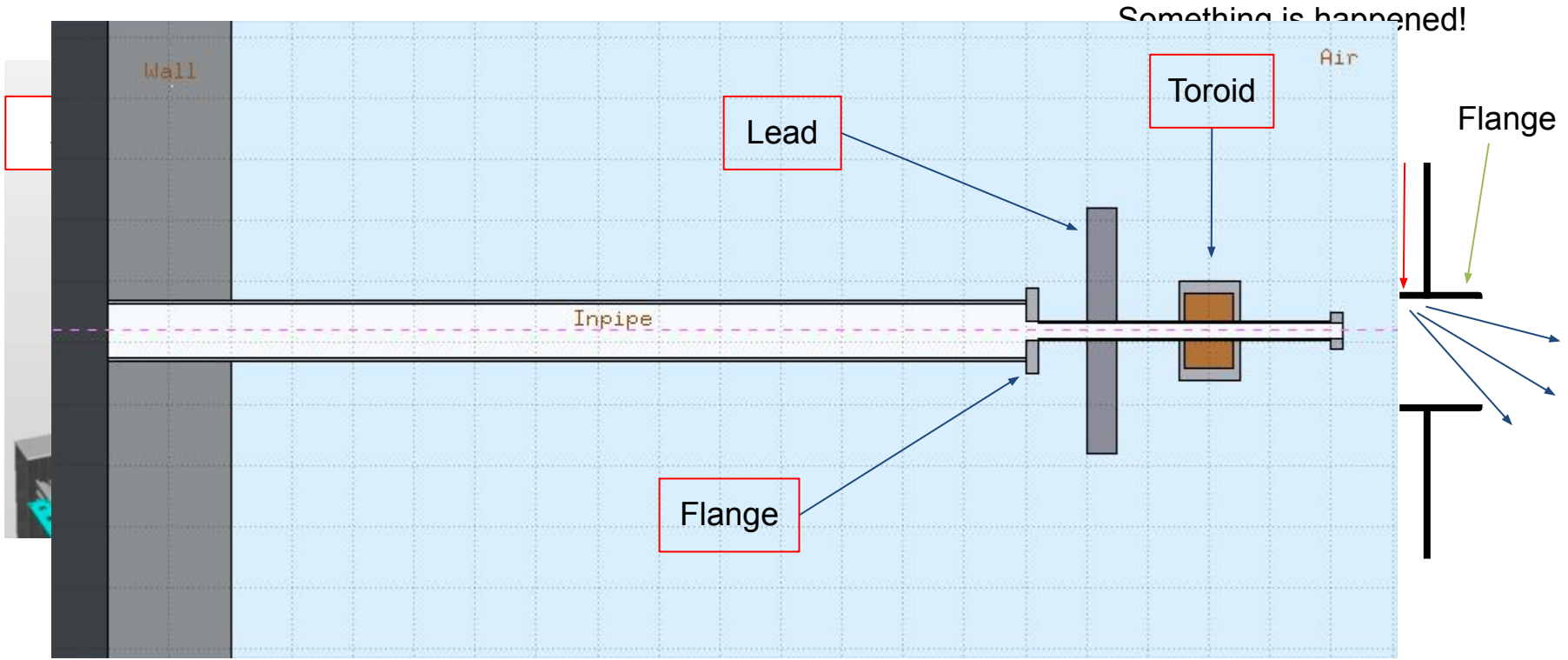
Original simulated Dose : 8.6 uSv/h
Corrected Dose : 8.8 uSv/h
Error : 0.8 uSv/h

At the corner



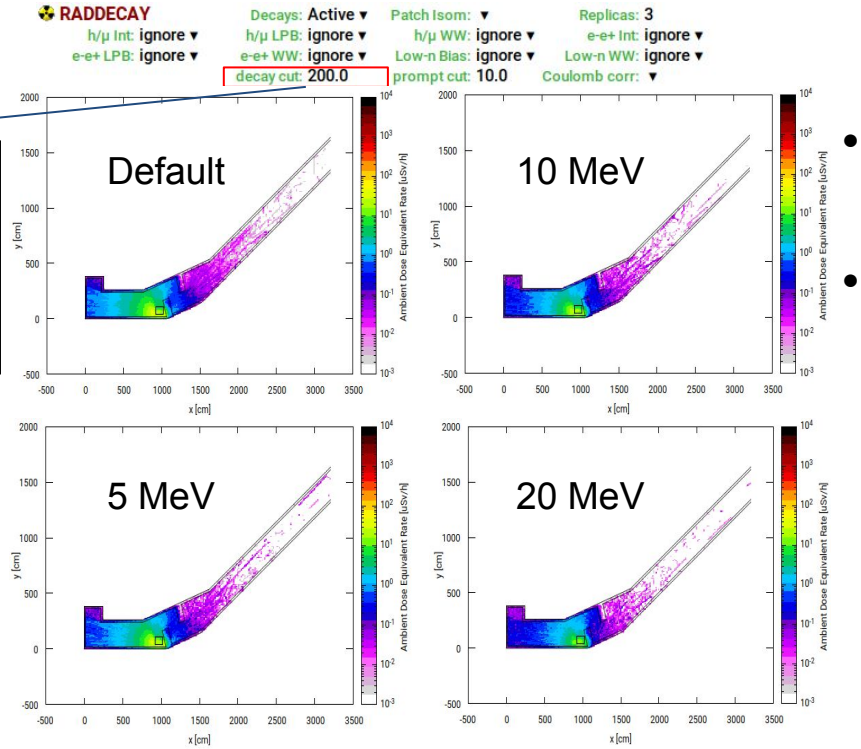


Beam Line in FLAIR



Decay Cut for Residual Decay

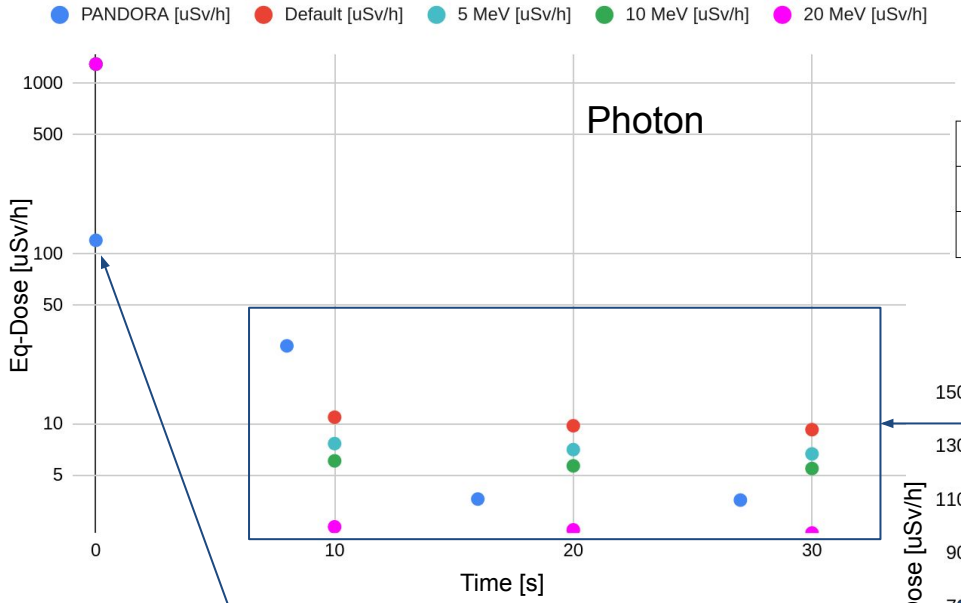
Cut energy of Residual Decay
1. Default : 1 MeV
2. 5 MeV
3. 10 MeV
4. 20 MeV



t_c = 10s

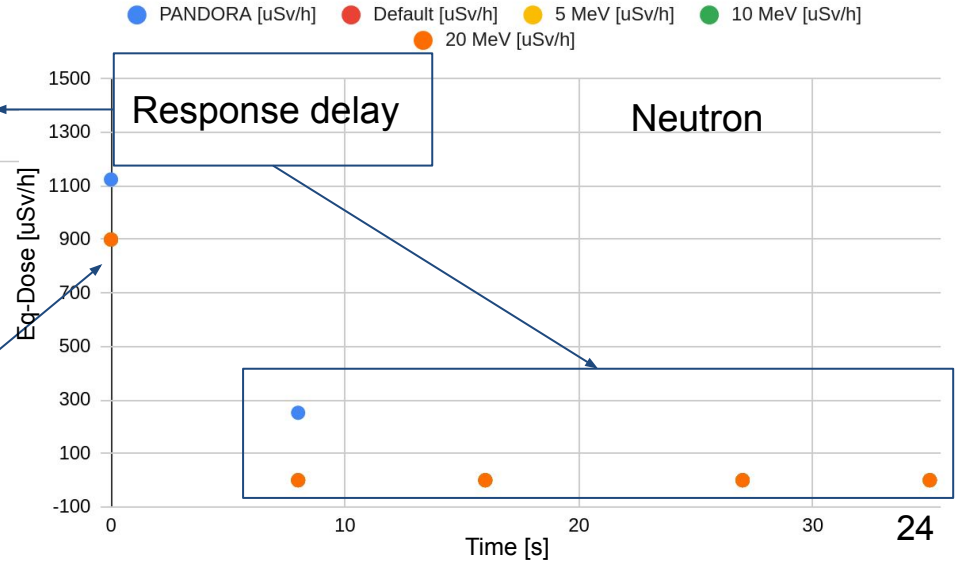
- Several different values of decay cut
  - Generated number of photons by the high value of decay cu are smaller
- Neutrons disappear immediately afte extraction stops beam

Compared Doses During Cooling Down



Type of radiation \ Time structure	Continuous Total response, no pileup	Burst Delayed response only
High energy neutrons > 20 MeV	Scintillator: H(n,n)H → recoil protons	Scintillator: $^{12}C(n,p)^{12}B \rightarrow {}^{12}C + \beta + \nu$
Low energy neutrons < 20 MeV	Moderated ^{3}He – tube: $^{3}He(n,p)^{3}T$	Moderated ^{3}He – tube: $^{3}He(n,p)^{3}T$ delayed by TOF

Table 1 – Overview of the LB 6419 responses due to neutron radiation.



Beam off after this time