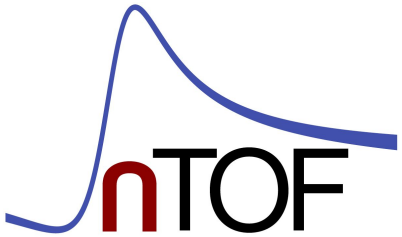
Letter of Intent to the ISOLDE and Neutron Time-of-Flight Committee

Measurement of the radiation background at the n_TOF-NEAR facility to study the feasibility of cyclic activation experiments

J. Lerendegui-Marco[1], M. Bacak[2], V. Alcayne[3], D. Cano-Ott[3], A. Casanovas[4], G. Cortés[4], C. Domingo-Pardo[1], C. Guerrero[5], C. Massimi[6,7], E. Mendoza[3], A. Mengoni[8], A. Musumarra[6], N. Patronis[9], A. Tarifeno-Saldivia[1], and the n_TOF Collaboration[10]



VNIVERSITAT DE VALÈNCIA

CSIC

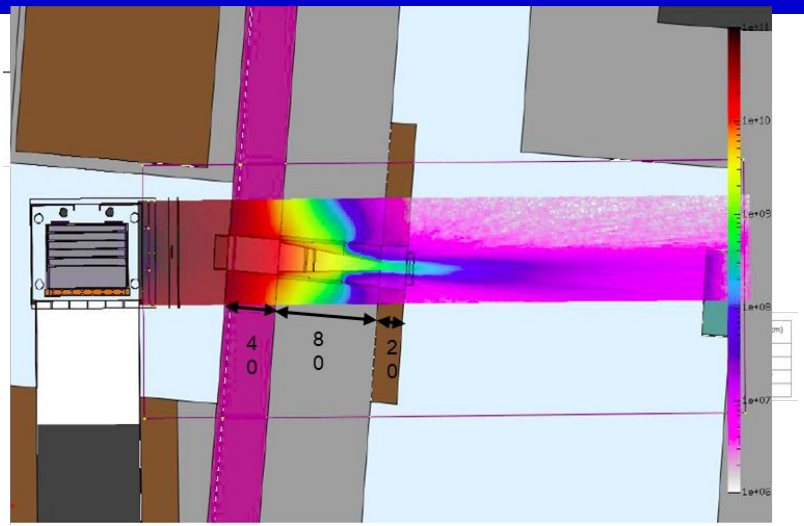
CONSEJO SUPERIOR DE INVESTIGACIONES CIENTÍFICAS

Collaboration Board Meeting, CERN. 4th May 2022

Outline

- Motivation: Cyclic activation station for (n,g) measurements at NEAR
- Experimental conditions in the NEAR
- Proposed setup & plan
- Summary and proton request

Motivation: (n,g) activation at NEAR



Physics at the NEAR:

- High flux (x~100 EAR2 outside the collimator)
- Activation measurements
- Small mass
- Unstable isotopes

e.g. s-process branchings not accessible via TOF

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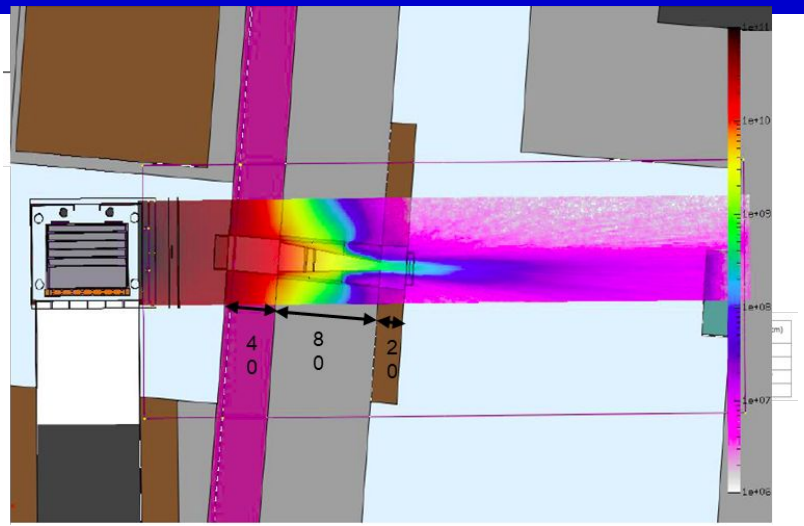

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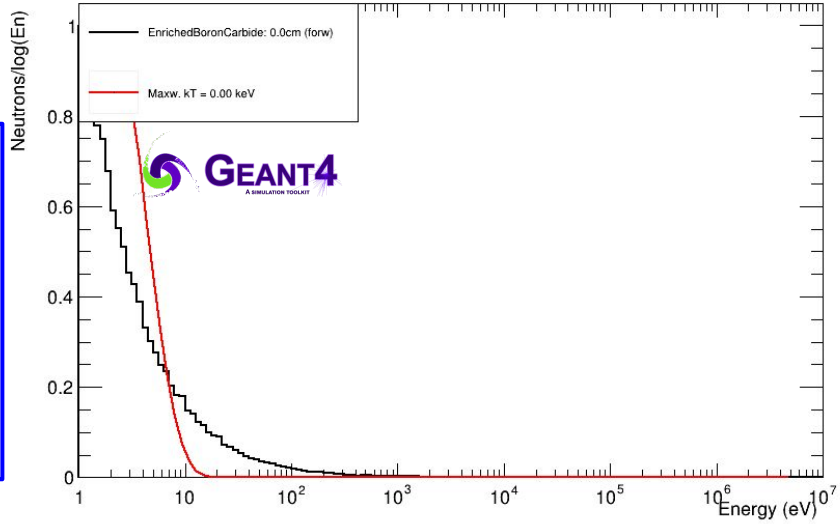
Neutron spectra + filter (B, B4C, …) after the collimator exit:

- Measure SACS @ various stellar temperatures from 0.1 to few hundreds of keV.

- E. Stamati et al.,[CERN-INTC-2022-008; INTC-P-623 (2022)]: benchmark with long-lived (n,g) products



Motivation: Cyclic activation station

Activations up to now:

- Long (days, weeks) irradiations
- Cooling down + transport to detectors located outside
- Long measurements

Main limitation:

- Not able to measure activation with short lived targets (s, min) (n,g) products

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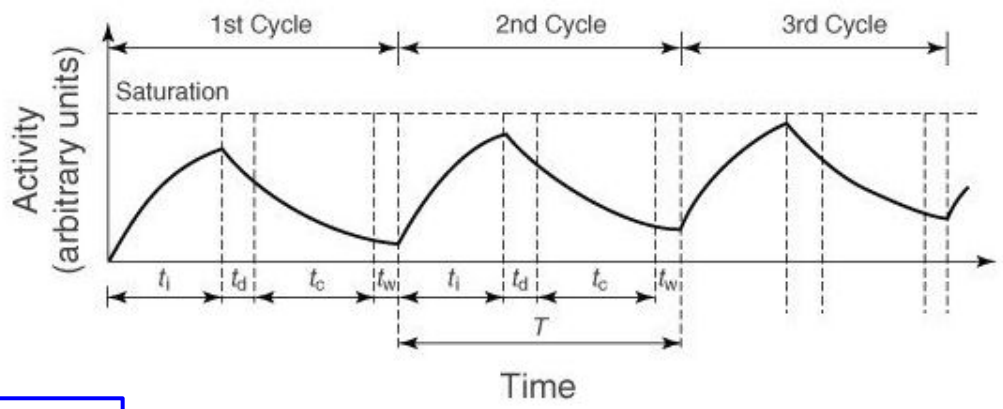

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CYCLING: CYCLIc activation for (N,G) measurements
- repetition of short irradiation **(ti)** + rapid transport to detector **(td)** + counting the decay **(tc)** and transport back to the irradiating beam **(tw)**

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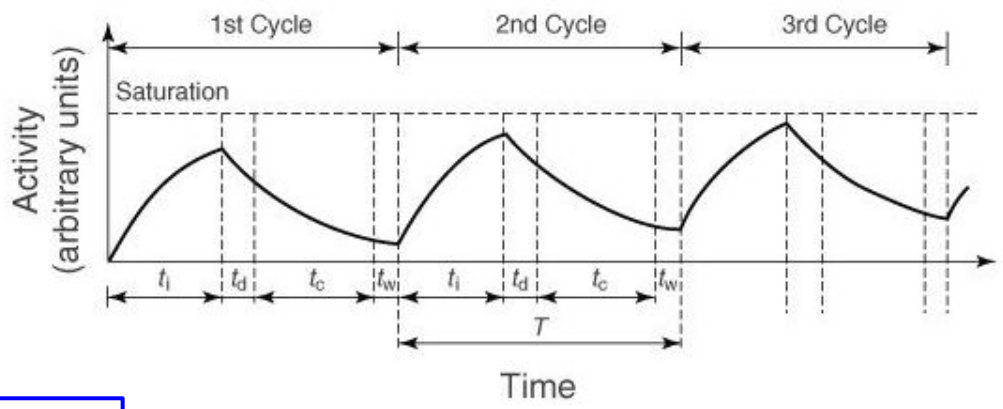

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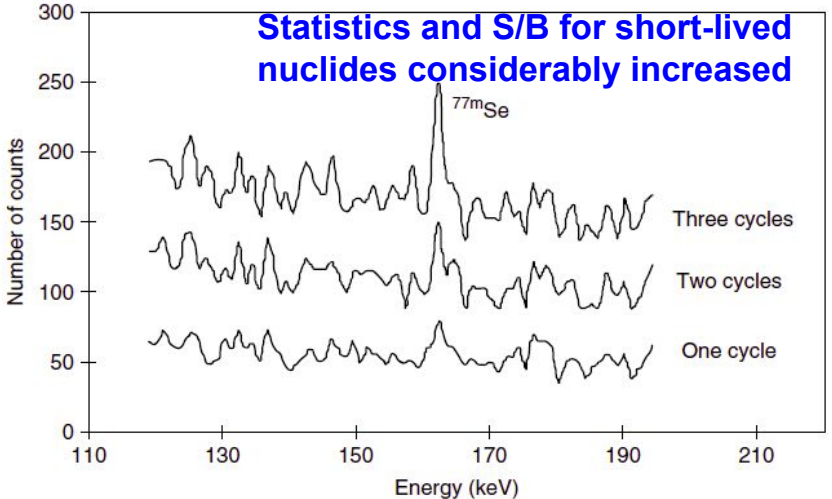
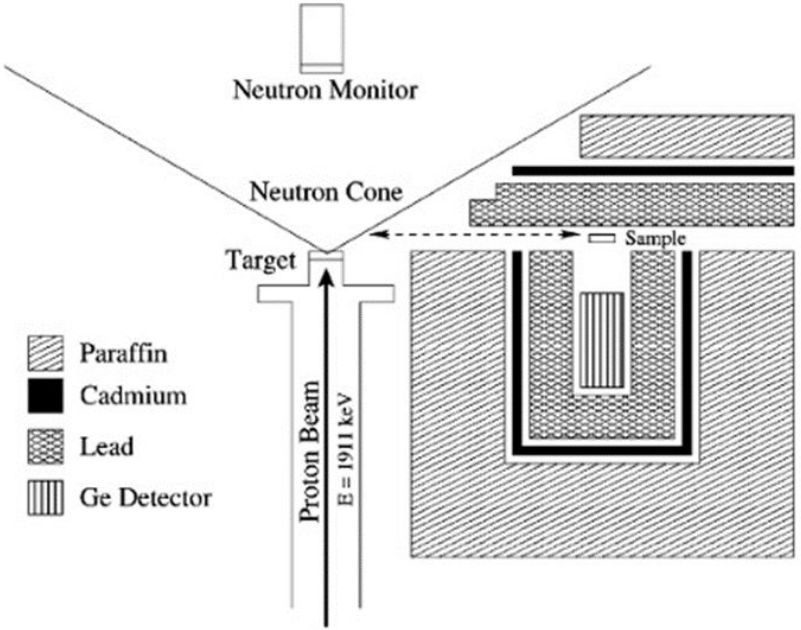


Motivation: Cycling activation station

The fast cyclic neutron activation technique at the Karlsruhe 3.75 MV Van de Graaff accelerator and the measurement of the ^{107,109}Ag(n, γ)^{108,110}Ag cross sections at $kT = 25$ keV

Hermann Beer *[a], G. Rupp [a], G. Walter [b], F. Voss [a], F. Käppeler [a]
[a] Kernforschungszentrum Karlsruhe, Institut für Kernphysik, P O.B. 3640, D-7500 Karlsruhe 1, Germany
[b] Firma Bosch Reutlingen, Germany



Requisites

- Beam period: Rep. rate of n_TOF (max 0.8 Hz) is well suited for short lived (seconds)

- Operate a high resolution g-ray detector (ideally HPGe) in the harsh radiation environment in the NEAR bunker

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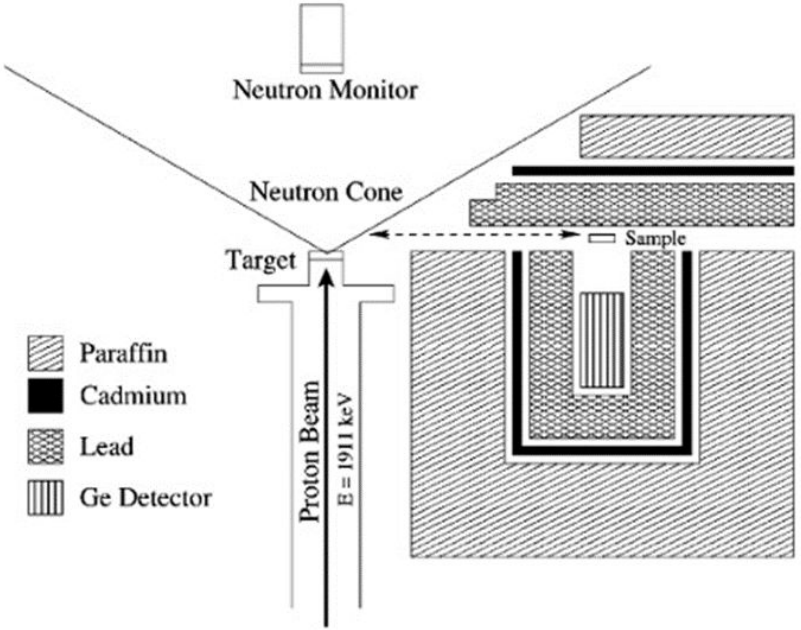

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- Operate a high resolution g-ray detector (ideally HPGe) in **the harsh radiation environment in the NEAR bunker**

AIM of this LOI:
Characterize the off-beam neutron and g-ray backgrounds to study the feasibility to install active detectors for CYCLING

Motivation: Potential physics cases

Target isotope	(n,γ) product $T_{1/2}$	Description
^{74}Ge	82.78 m	stable target, TOF at EAR1
^{80}Se	18.45 m	stable target, TOF at EAR1
^{205}Tl	4.199 m	stable target, TOF at EAR1
^{99}Tc	15.8 s	long-lived target, TOF at ORNL
^{109}Ag	24.6 s	stable target, sample available [4]
^{103}Rh	42.3 s	stable target, sample available [4]
^{19}F	11.00 s	stable target, challenging [8]
^{60}Fe	5.98 m	long-lived target, challenging [8]
^{137}Cs	33.41 m	unstable target
^{132}Te	12.5 m	short lived target

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Hermann Beer *,[a], G. Rupp [a], G. Walter [b], F. Voss [a], F. Käppeler [a]

The activation method for cross section measurements in nuclear astrophysics

Gy. Gyürky[1,a], Zs. Fülöp[1], F. Käppeler[2], G.G. Kiss[1], and A. Wallner[3]

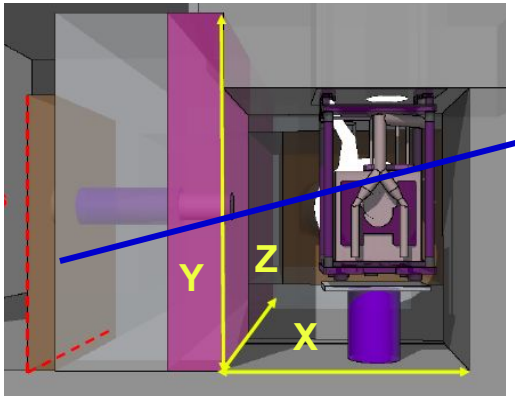
- benchmarks of the technique,, TOF data available.

- stable samples, available at n_TOF (from list of Ref. [4])

- Challenging & astrophysical interest, already measured (from Ref. [8])

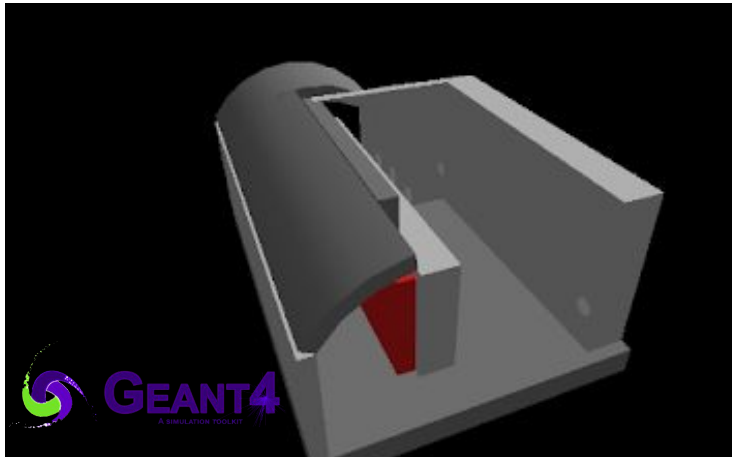
- examples of unstable targets of astrophysical interest.

Experimental conditions at n_TOF NEAR



Input: Latest FLUKA simulations provided by Matteo

1 m radius scoring between concrete and the marble



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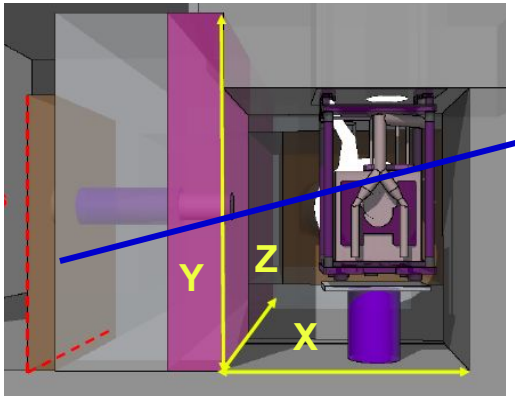

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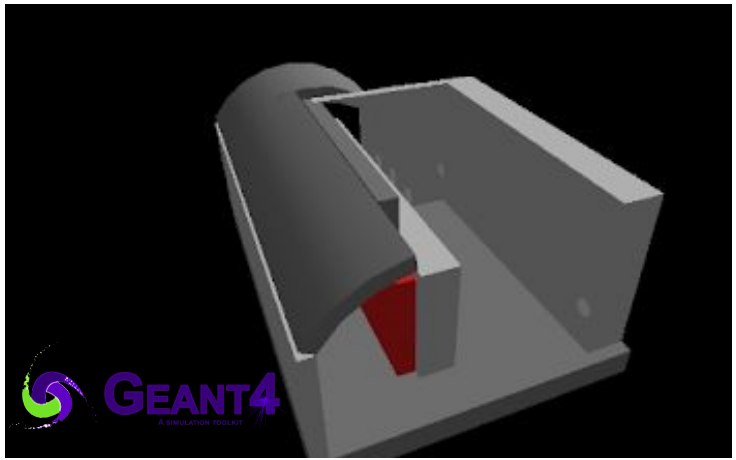
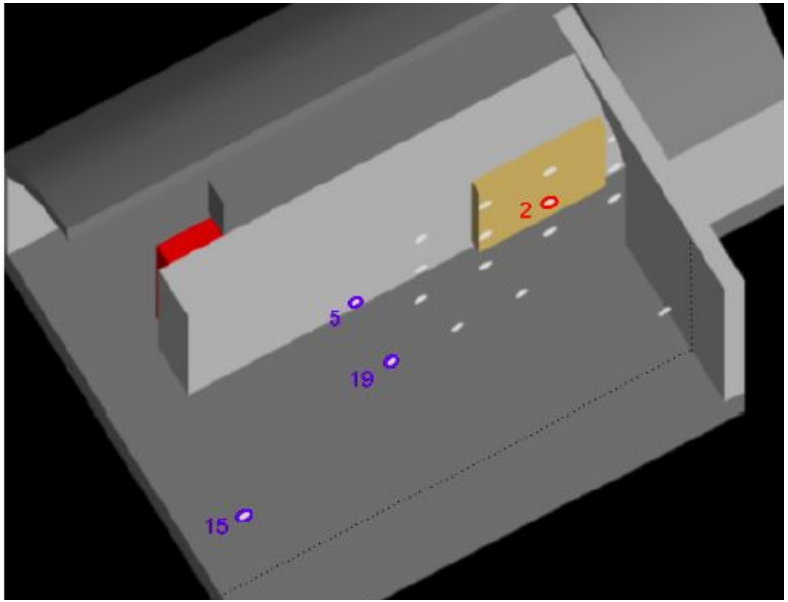
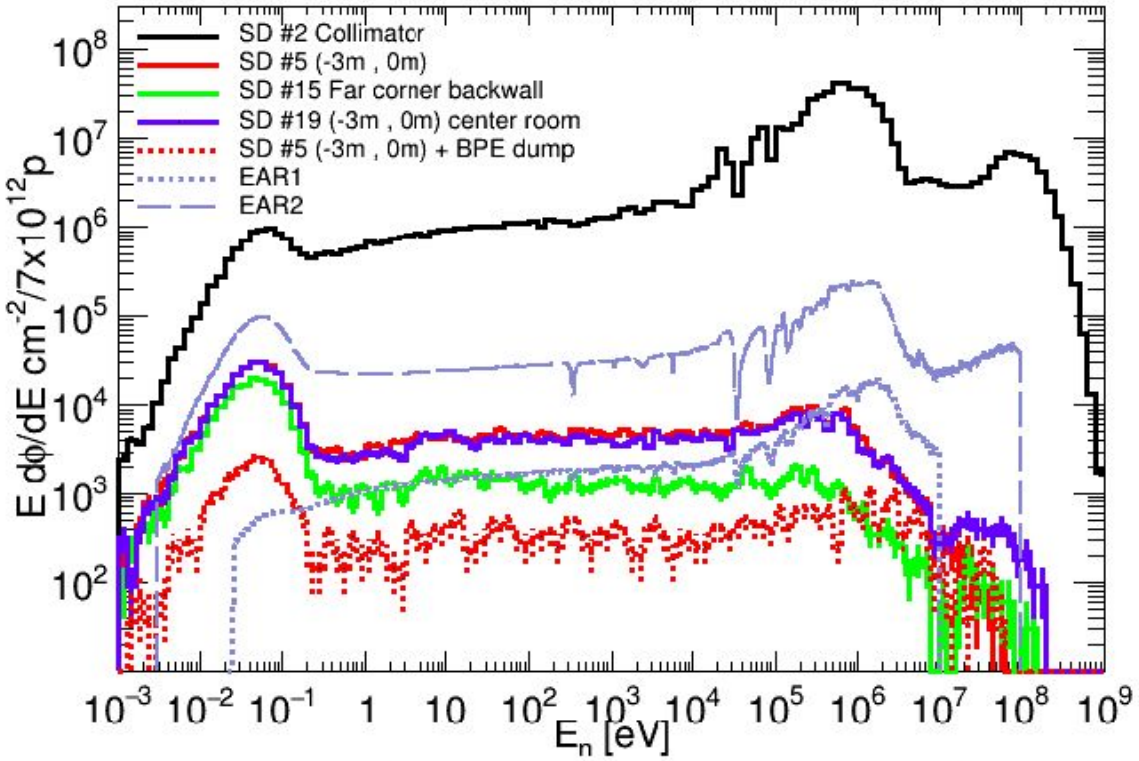
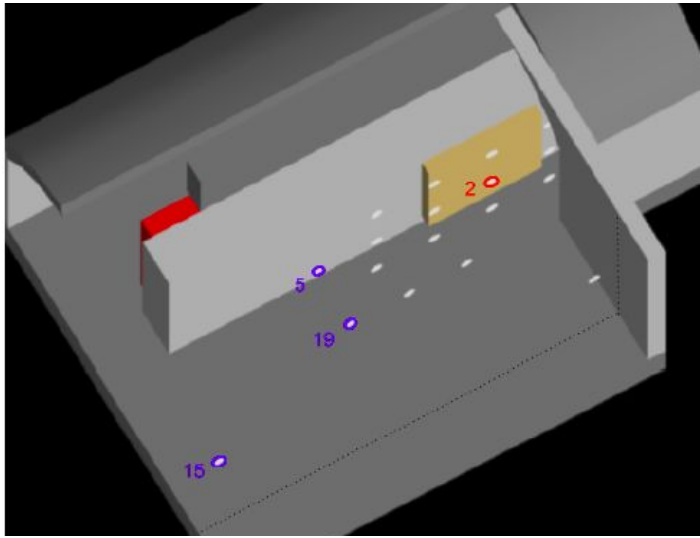




Results: **in-beam flux (2)** and the **off-beam positions with the minimum neutron flux (5, 15, 19)**

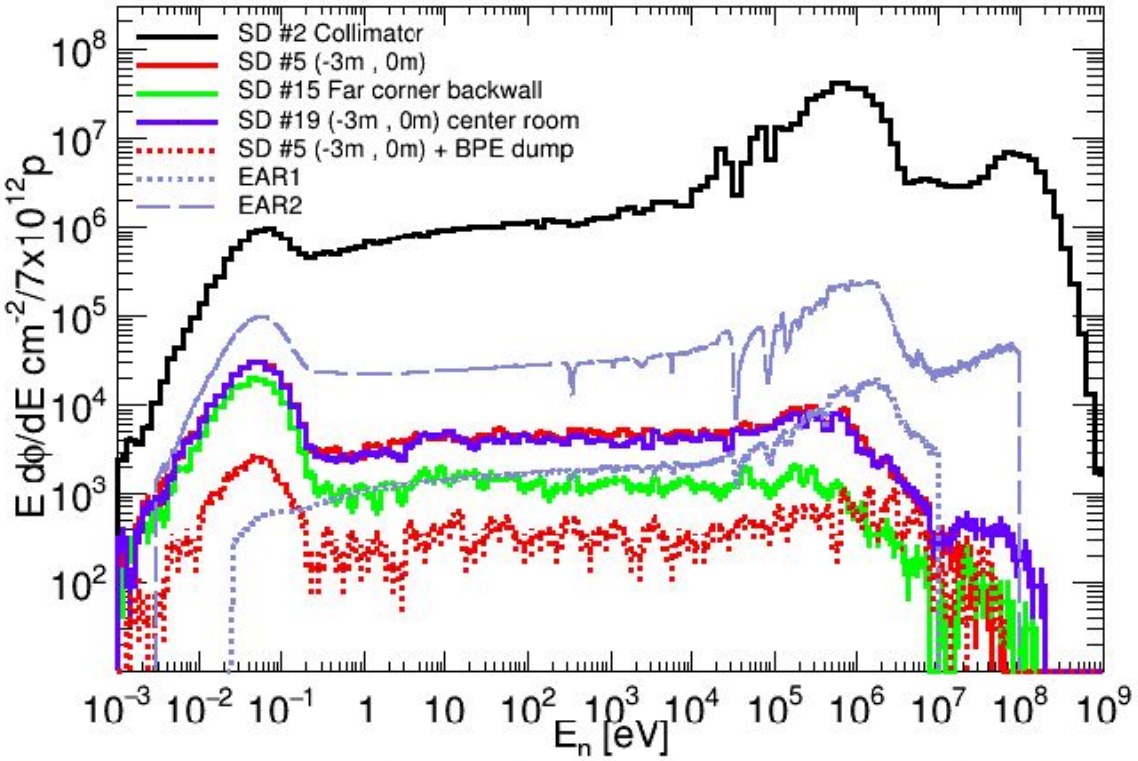
Experimental conditions at n_TOF NEAR

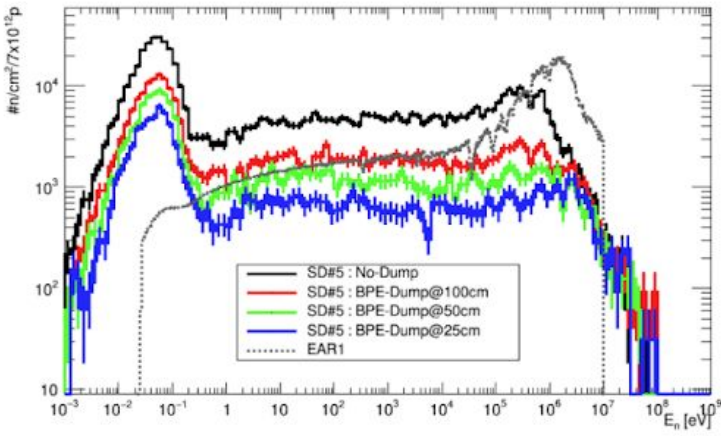




Initial situation: Minimum off-beam flux (SD 5,15,19) is similar to that of EAR1 (in-beam) or higher

Experimental conditions at n_TOF NEAR





Borated Polyethylene (BPE) Dump (less than 1m^3)

Most relevant: Reduce diistance from the collimator exit to the dump

After adding a BPE dump:
Reduction of a factor ~10

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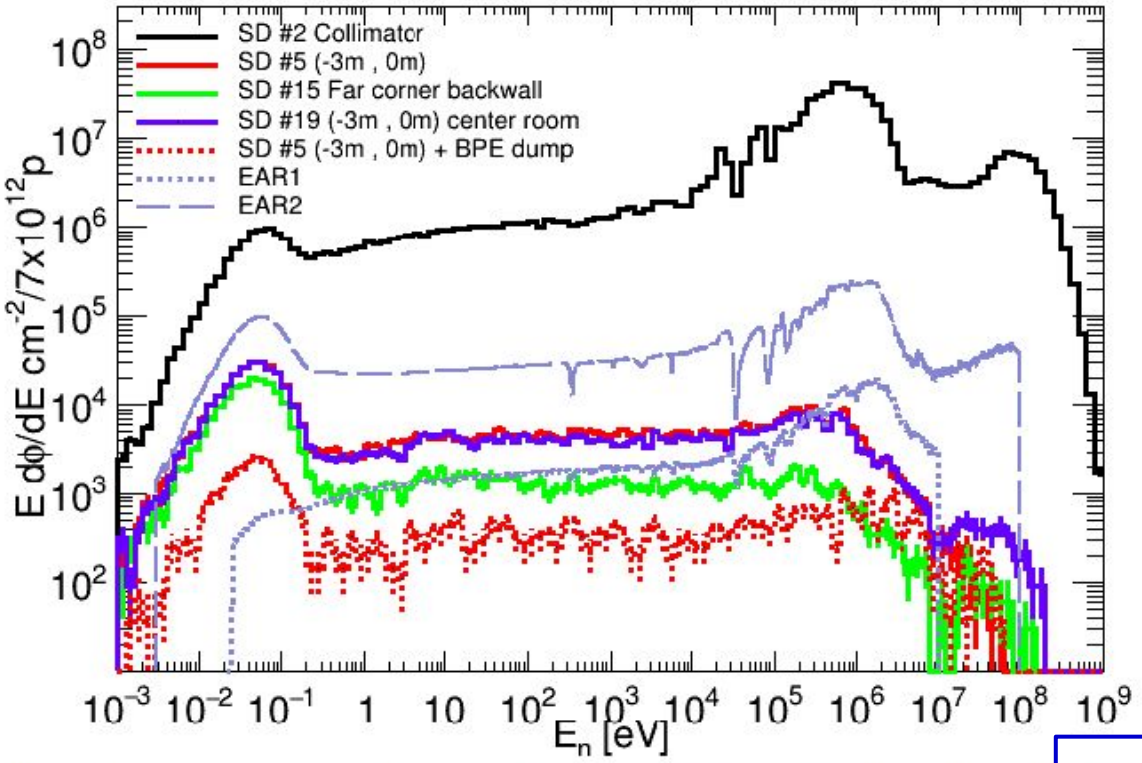

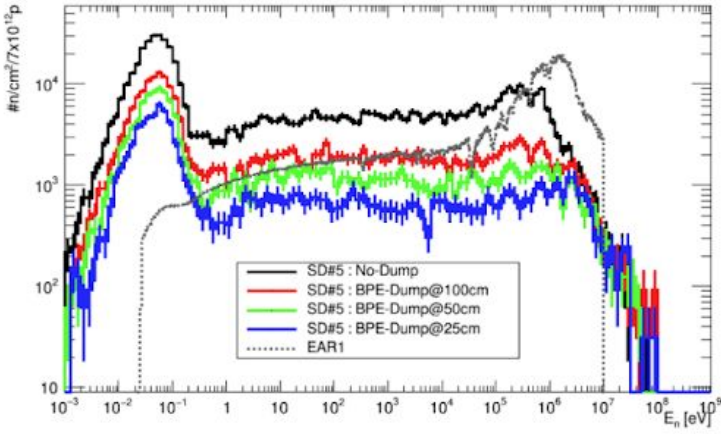

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Facilitate Active neutron detectors
characterize off-beam flux + γ-ray detectors to evaluate the conditions for decay station

Proposed setup & plan

Characterization of the **neutron and γ-ray field in positions of interest** for the CYCLING station will be carried out with different **active** and **passive** detectors:

system	type	sensitivity		comment
		neutrons	γ-rays	
CR39	passive	thermal / fast	no	-
Diamond	active	thermal – fast	yes	n/γ discrimination
TARAT	active	fast	yes	n/γ discrimination and energy resolved
$LaBr_3$	active	no	yes	potential final detector
BC501	active	fast	yes	n/γ discrimination
^{3}He3	active	thermal – fast	no	-

2-step-campaign:

- **2022: initial conditions**
- Some active detectors not ideal performance
- Install Cd-sheets to remove thermal.

- **Outlook: After installing a dump**
- Compare to initial situation.
- Assess the feasibility in real conditions for CYCLING

Summary and proton request

- NEAR opens the door to activation measurements with small masses or on radioactive targets (e.g. MACS measurements of astrophysical interest).

- Cyclic activation experiments allow the measurement of capture cross sections of isotopes with unstable (n,γ) products with short half-lives of the order of several seconds or minutes.

- NEAR is well suited for cyclic experiments due to the low repetition rate but active detectors are required in close proximity to the NEAR beam, with harsh radiation conditions, especially during beam-on periods.

- The beam-on neutron background conditions at NEAR have been estimated with Monte Carlo simulations and indicate that the installation of the dump can reduce in a factor of 10 the off-beam neutron fluence.

- Measurements are required to validate the neutron flux & the the beam-off g-ray background to assess the feasibility of a Cyclic activation station.

- Thus we propose to characterize the neutron and γ-ray radiation field in the n TOF NEAR facility at several off-beam positions of interest with active and passive detection systems in a two step process.

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Requested protons: 7×10^{17}

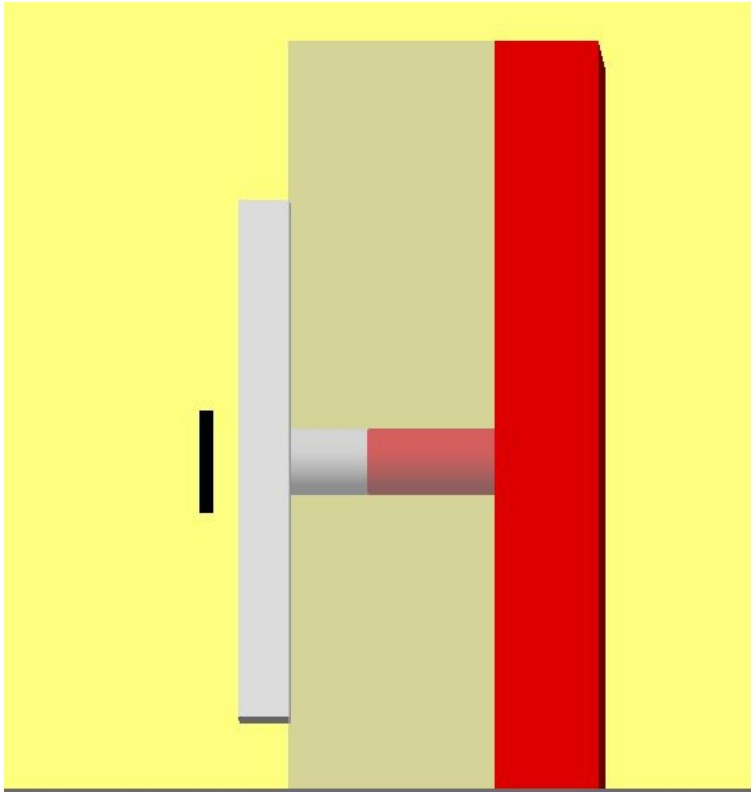
(parasitic to other NEAR activities and will therefore not disturb the ongoing irradiations)

Measurement of the radiation background at the n_TOF-NEAR facility to study the feasibility of cyclic activation experiments

BACK-UP

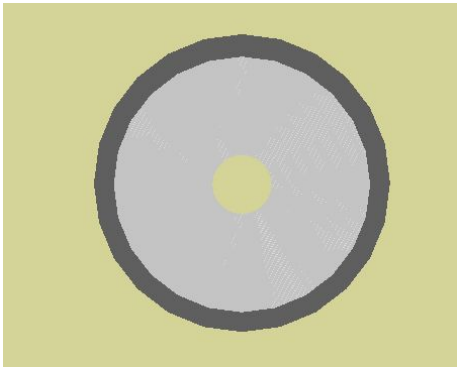
Collaboration Board Meeting, CERN. 4th May 2022

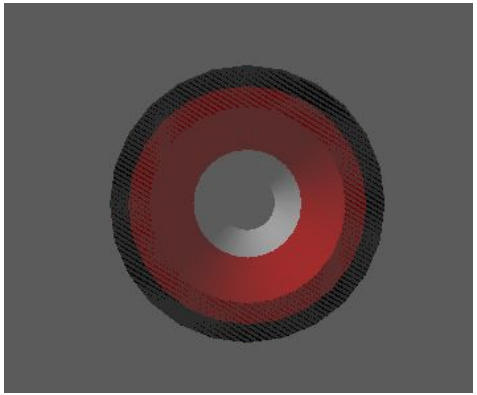
The NEAR Station: Geant4 Geometry model



Section of the shielding wall and collimator

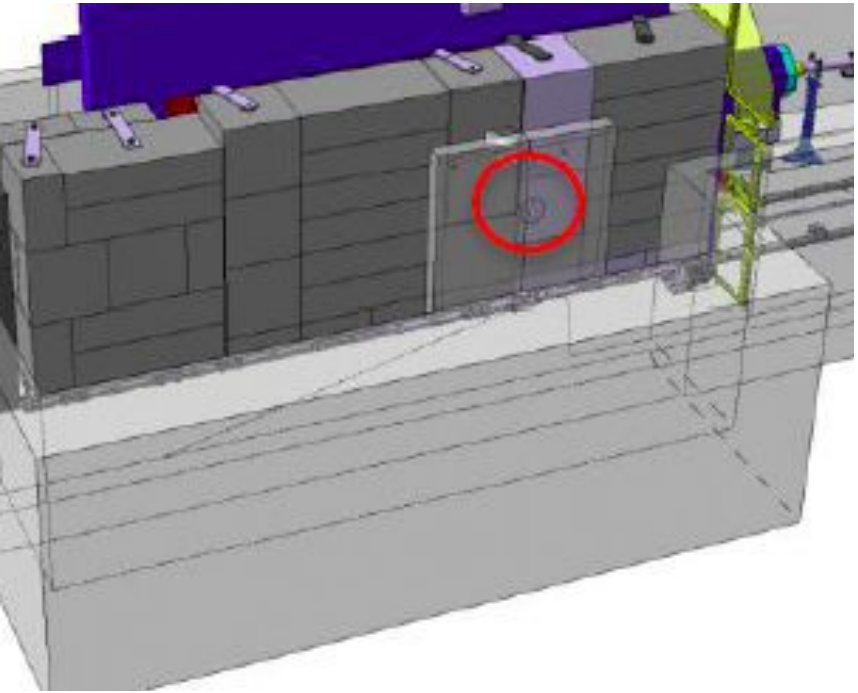
Collimator from NEAR side

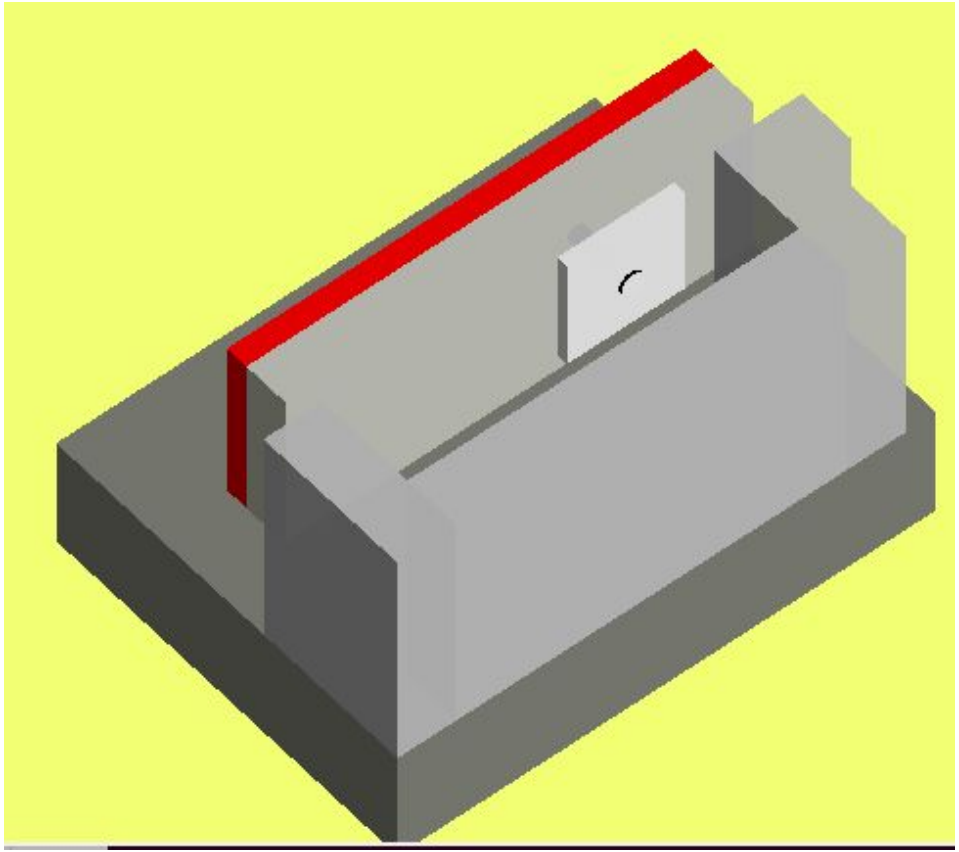




Collimator from the target side

The NEAR Station: Geant4 Geometry model vs drawings





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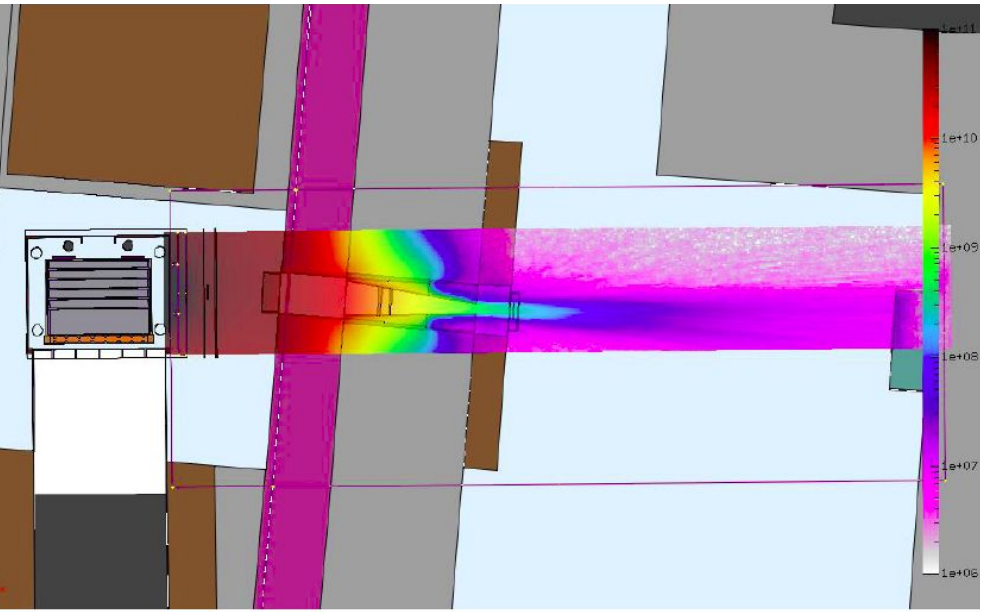
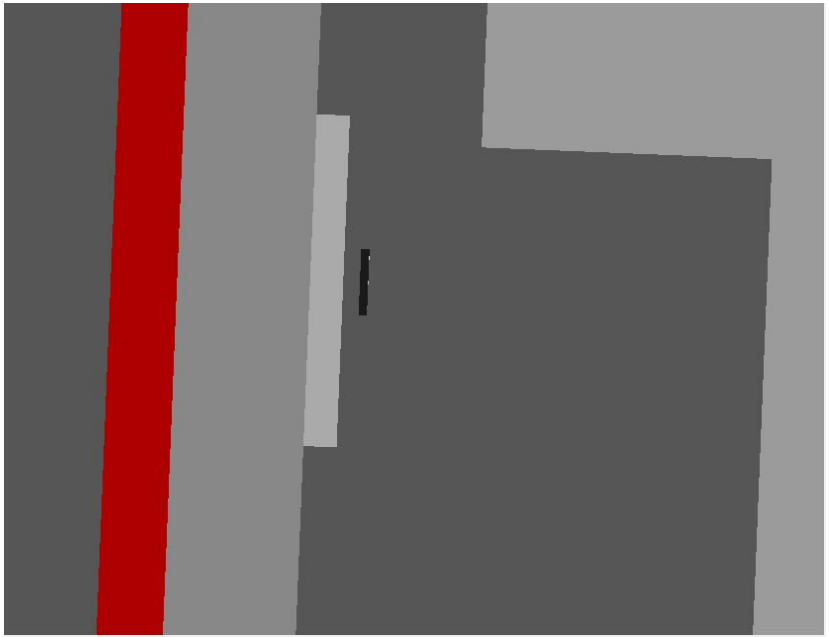
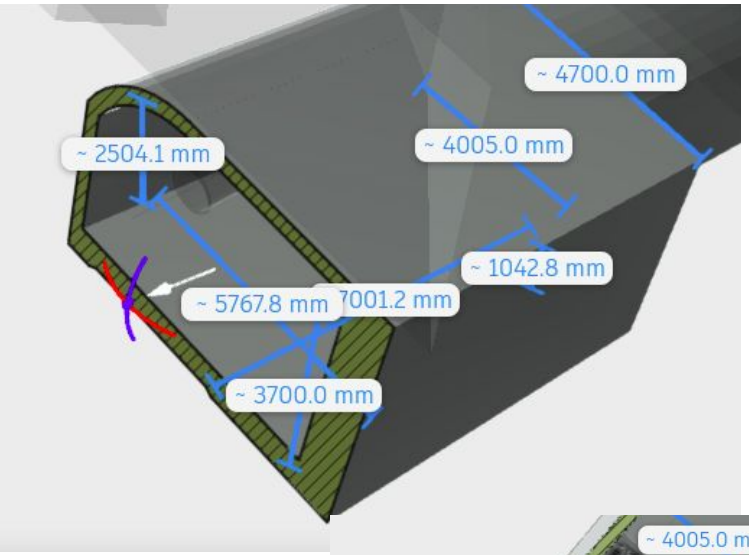
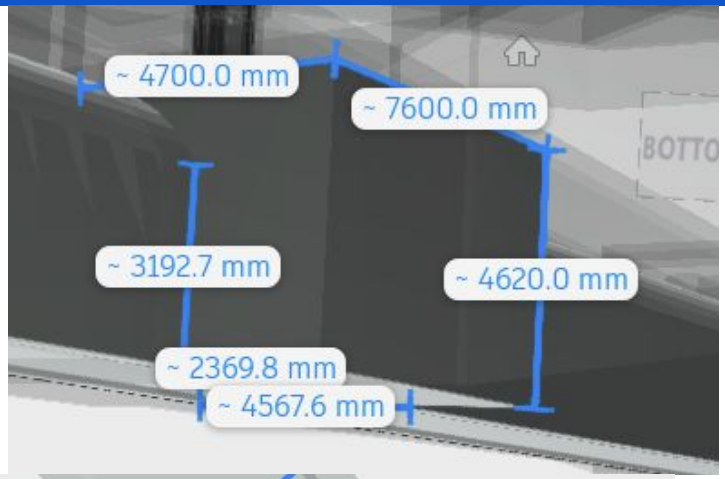
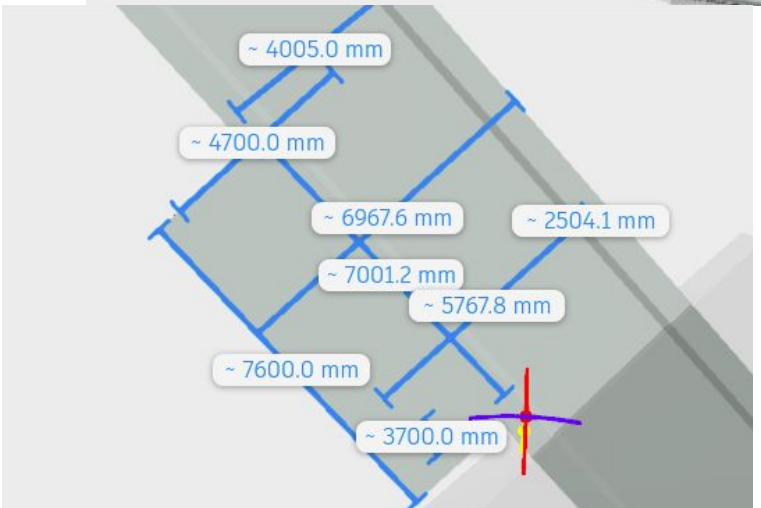




The NEAR Station: Refining the geometry with .stp file

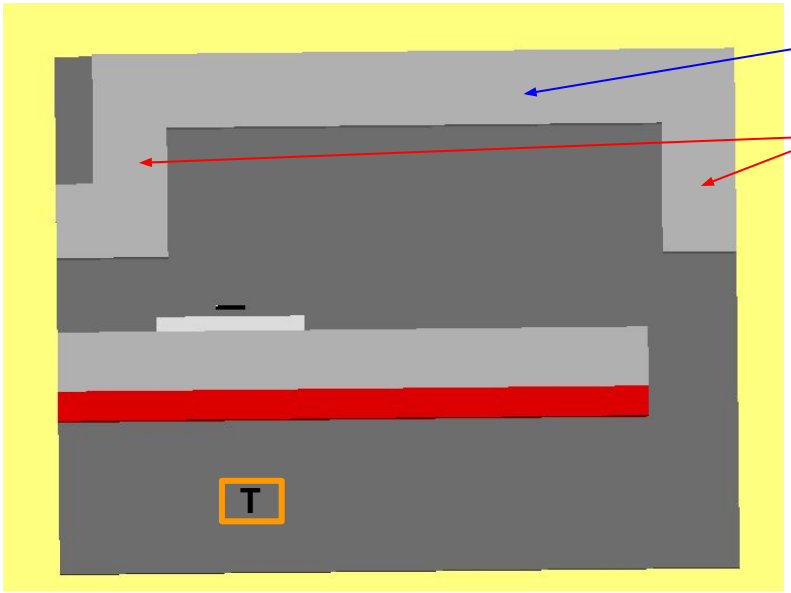




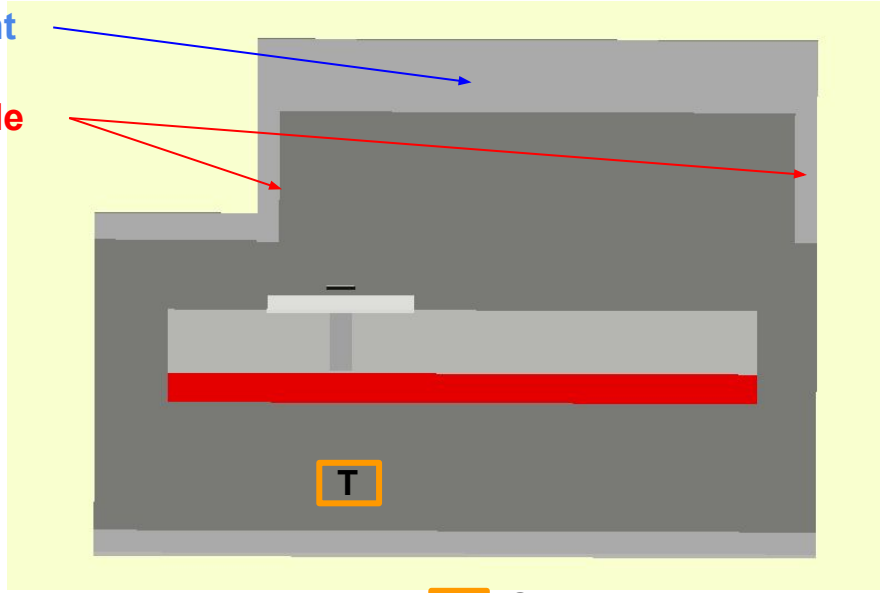


The NEAR Station: Refining the geometry with .stp file

Preliminary geometry



Corrected after .stp file



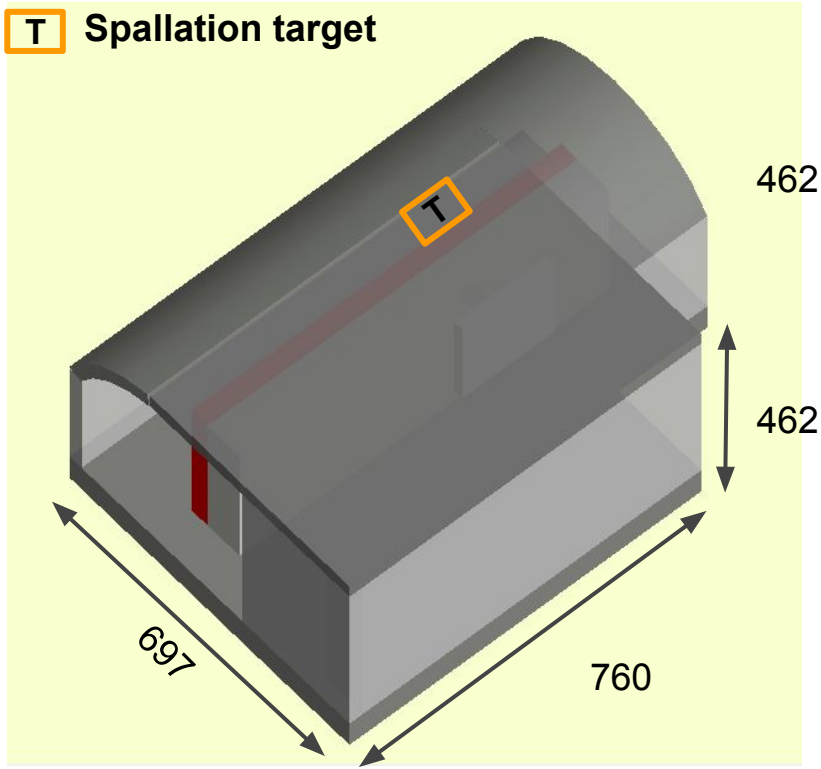
T **Spallation target**

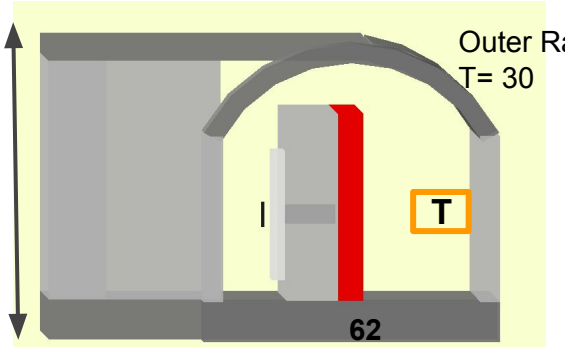
Main modification: Thickness of the side walls →

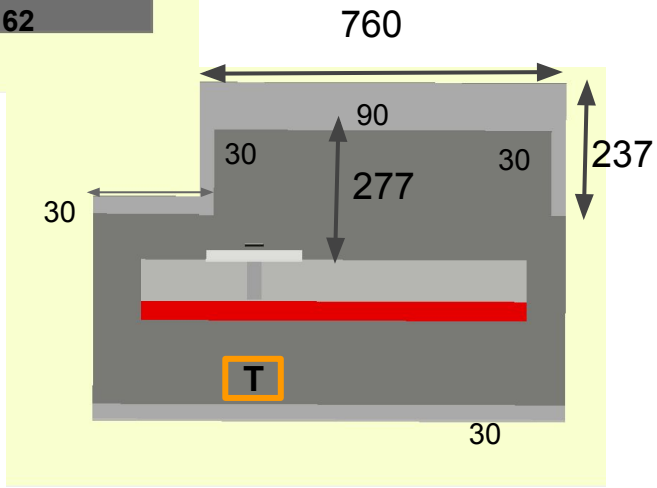
- .stp file: 90 cm for the **front** wall & 30 cm for the **side** ones
- geometry from the FLUKA simulations: All the walls same thickness (~90-100 cm)

to be cross checked with Oliver, Vasilis, Massimi

The NEAR Station: Refining the geometry with .stp file





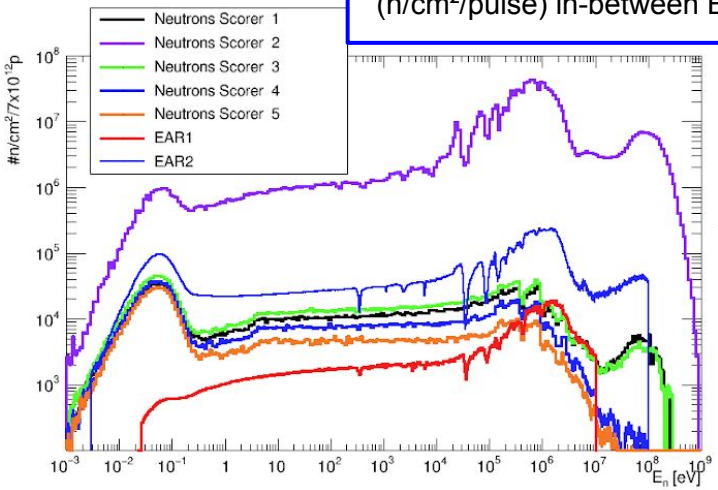


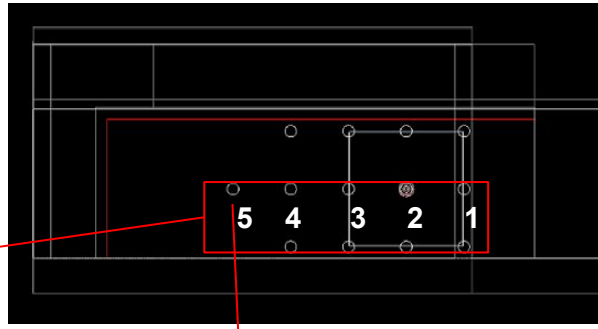
- Corrected the diameter of the hole in the iron shielding (12.5 cm→ 10.75 cm, M. Barbagallo)
- Included the semi-cylindrical ceiling + the wall on the target side + section of the tunnel

The NEAR Station: NEAR off-beam vs EAR1 and EAR2

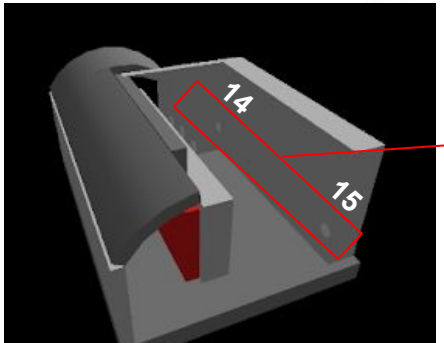
Long Simulations #1: NEAR off beam vs EAR1 and EAR2

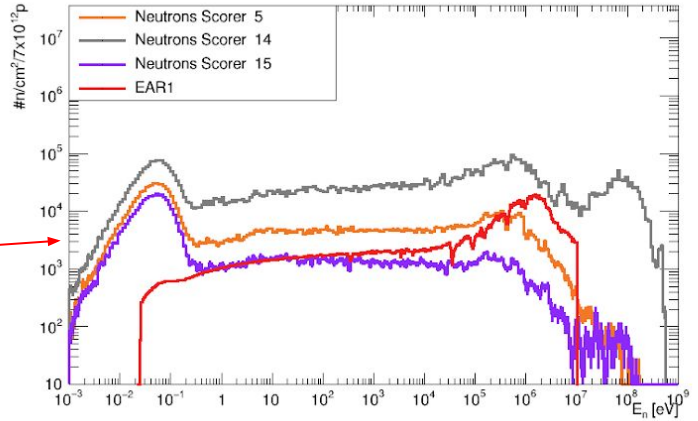
All the position at +/- 1m, -2m, -3m have a flux (n/cm²/pulse) in-between EAR1 and EAR2 (in beam)





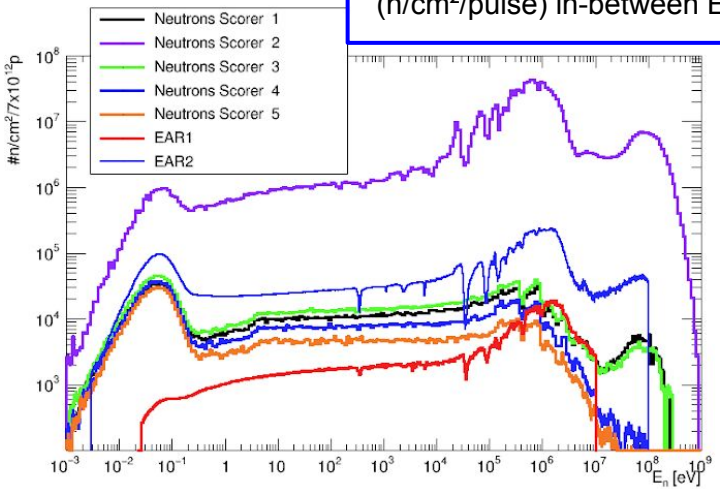
Minimum flux? Furthest corner < EAR1

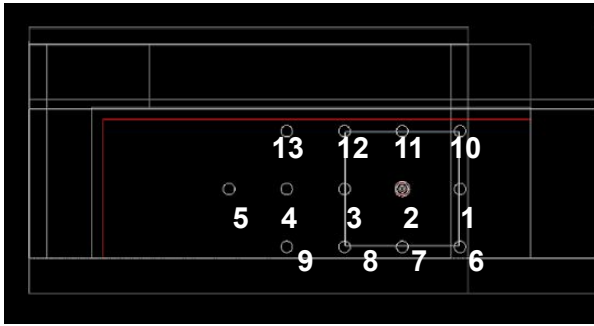


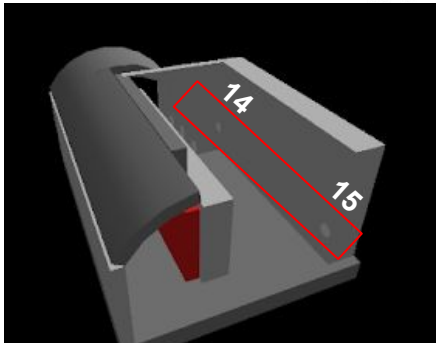


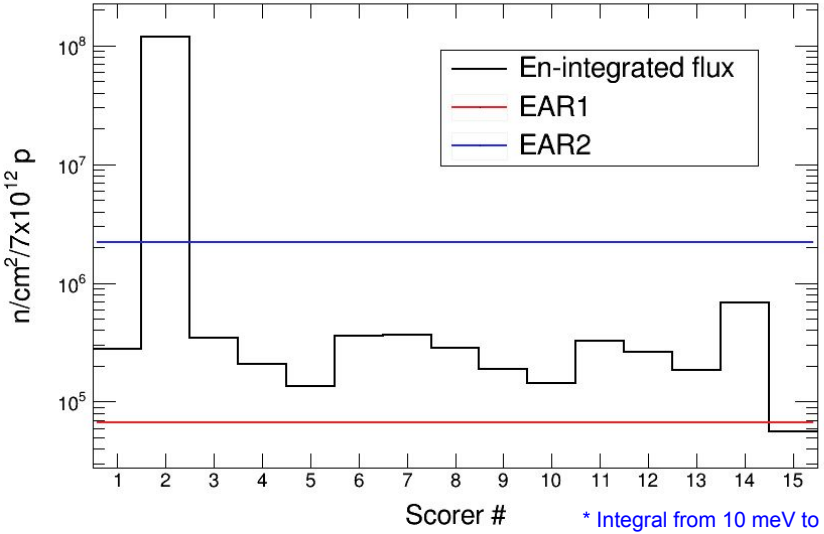
The NEAR Station: NEAR off-beam vs EAR1 and EAR2

All the position at +/- 1m, -2m, -3m have a flux (n/cm²/pulse) in-between EAR1 and EAR2 (in beam)









* Integral from 10 meV to 10 MeV

The NEAR Station: Dump design

- Previous designs

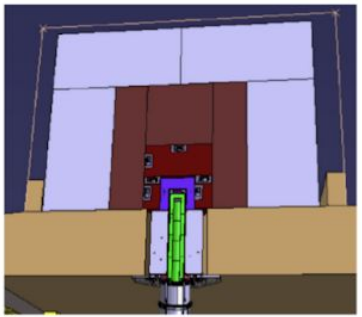


Fig. 5. Beam dump and last part of the EAR2 beam line. The last vacuum chamber contains additional shielding material (green) to reduce the background to the experiment from backscattered neutrons and photons. This chamber is installed in the roof of the building and penetrates the core of the beam dump. The beam dump, which is installed on the roof of the building contains three layers, as explained in the text. (For interpretation of the references to color in this figure caption, the reader is referred to the web version of this paper.)

- The core of the beam dump consists of a block of B-PE to slow down and to capture neutrons, both from the primary impinging beam and neutrons which are backscattered from the consecutive beam dump layers. The outer dimensions of the core are $400 \times 400 \times 400\ mm^3$. The B-PE block has a cylindrical hole at the entrance, 250 mm in height and 340 mm in diameter, where the last vacuum chamber of the beam line is inserted.
- The B-PE core is surrounded by Fe blocks to absorb the fast neutrons and photons of the beam. The outer dimensions of the Fe part is $1600 \times 1600 \times 1600\ mm^3$.
- The beam dump is finally shielded by concrete with outer dimensions of $3200 \times 3200 \times 2400\ mm^3$.

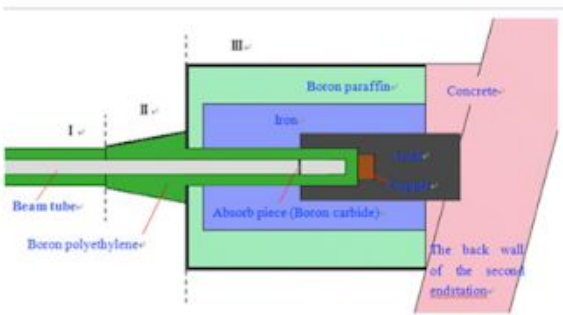


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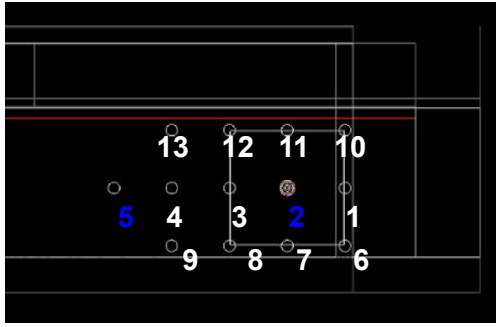
Fig. 6. Geometry structure of the white neutron beam dump.

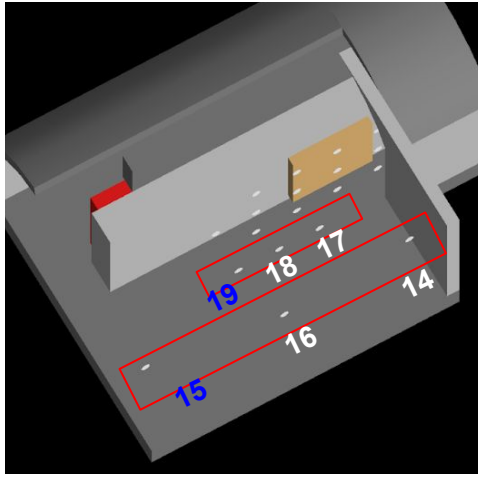
- Massive dumps
- Activation probably a drawback: increase background + RP limitations

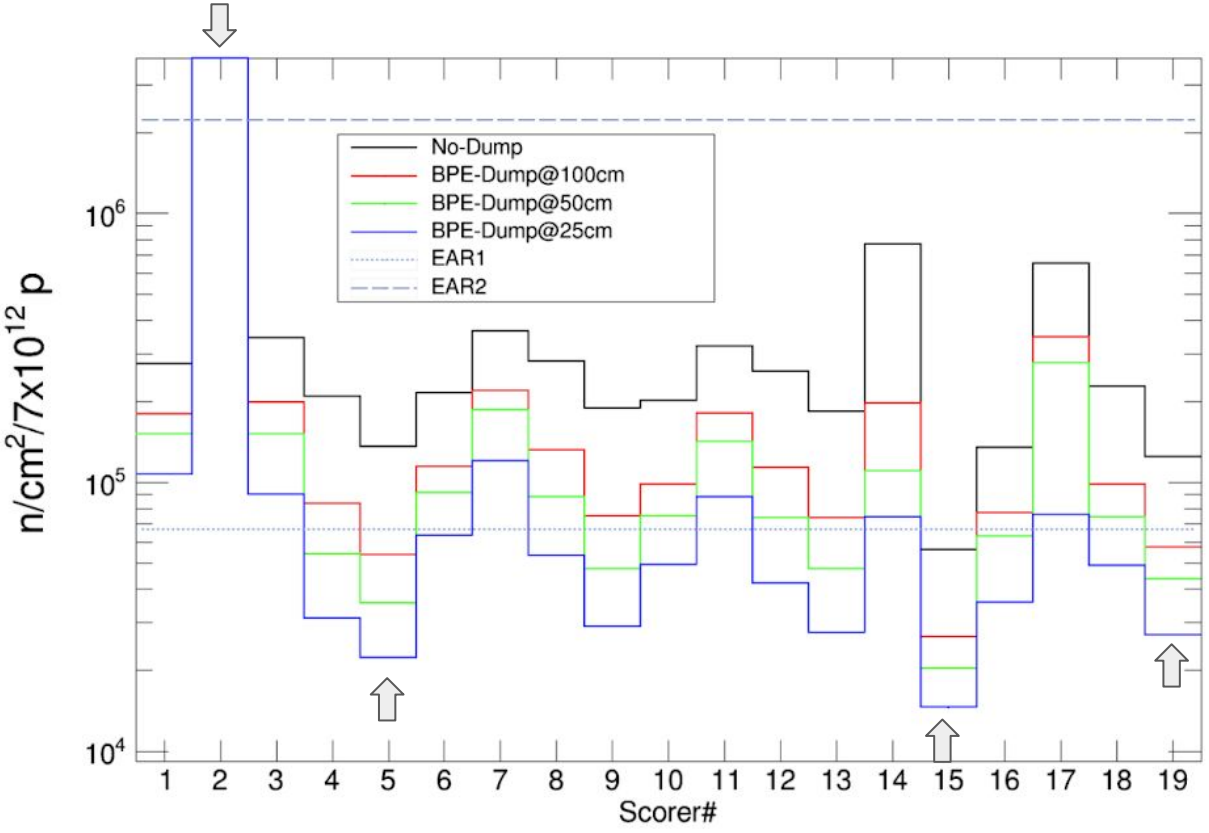
- Size could be reduced by getting closer to the sample
- Activation can be removed if only Borated PE + Lead shielding

The NEAR Station: Improving the performance of the

A) Putting the dump closer: → at only 25 cm, just after the “activation scorer”

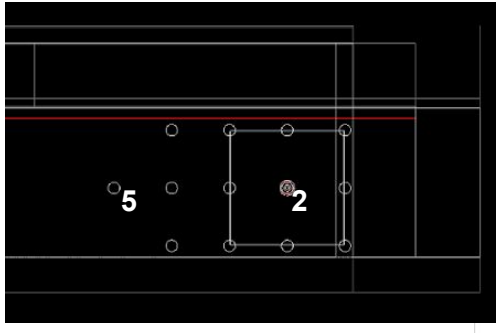


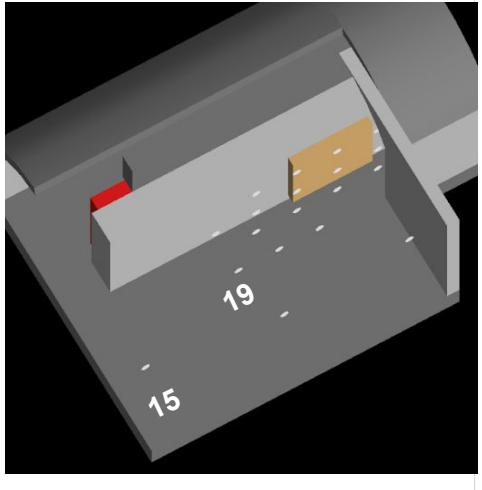


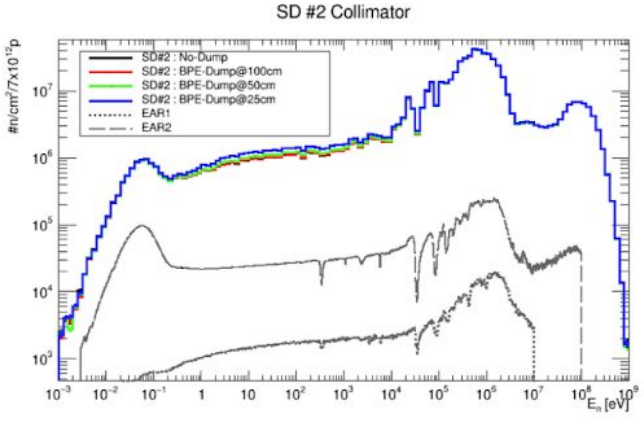


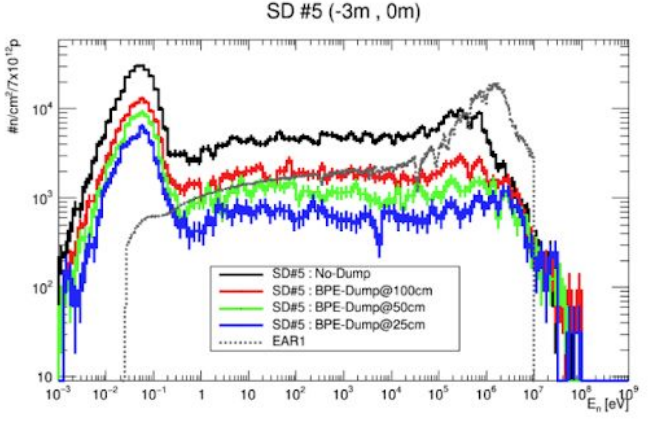
The NEAR Station: Improving the performance of the

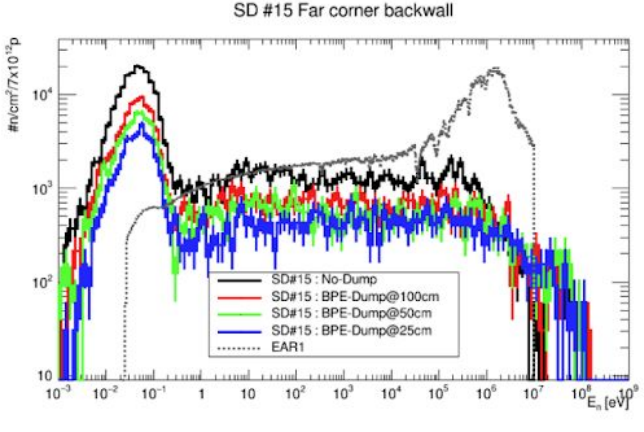
A) Putting the dump closer: → at only 25 cm, just after the “activation scorer”

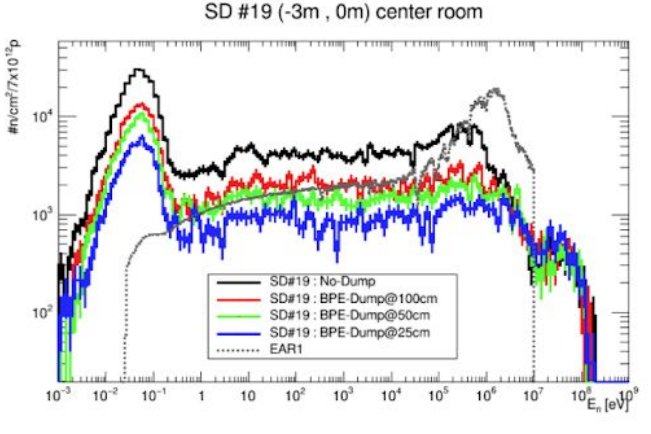






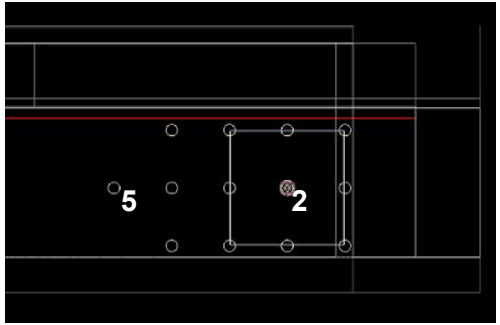


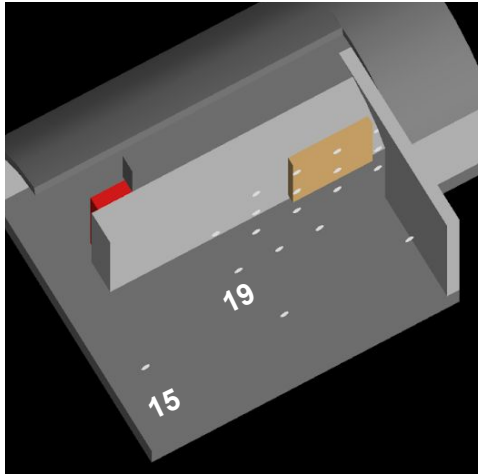


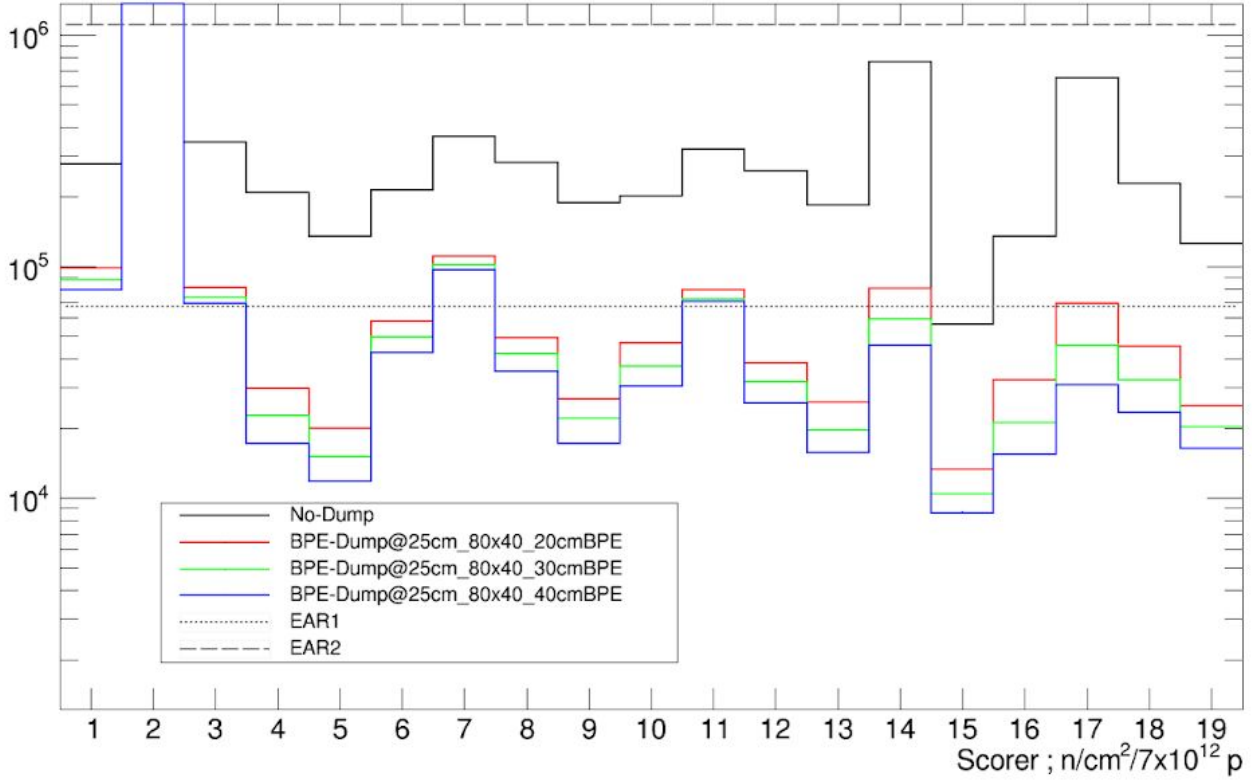


The NEAR Station: Improving the performance of the

D) Optimize the geometry: Thick of PE







The NEAR Station: Improving the performance of the

Best Dump up to now: Closest position of the dump, hole: 80x40, Thick: 40 cm