



Radiation Simulation
for experimental area

The University of Tokyo, M1

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1. Introduction

2. Calculation Methods

3. Results

4. Summary

Introduction

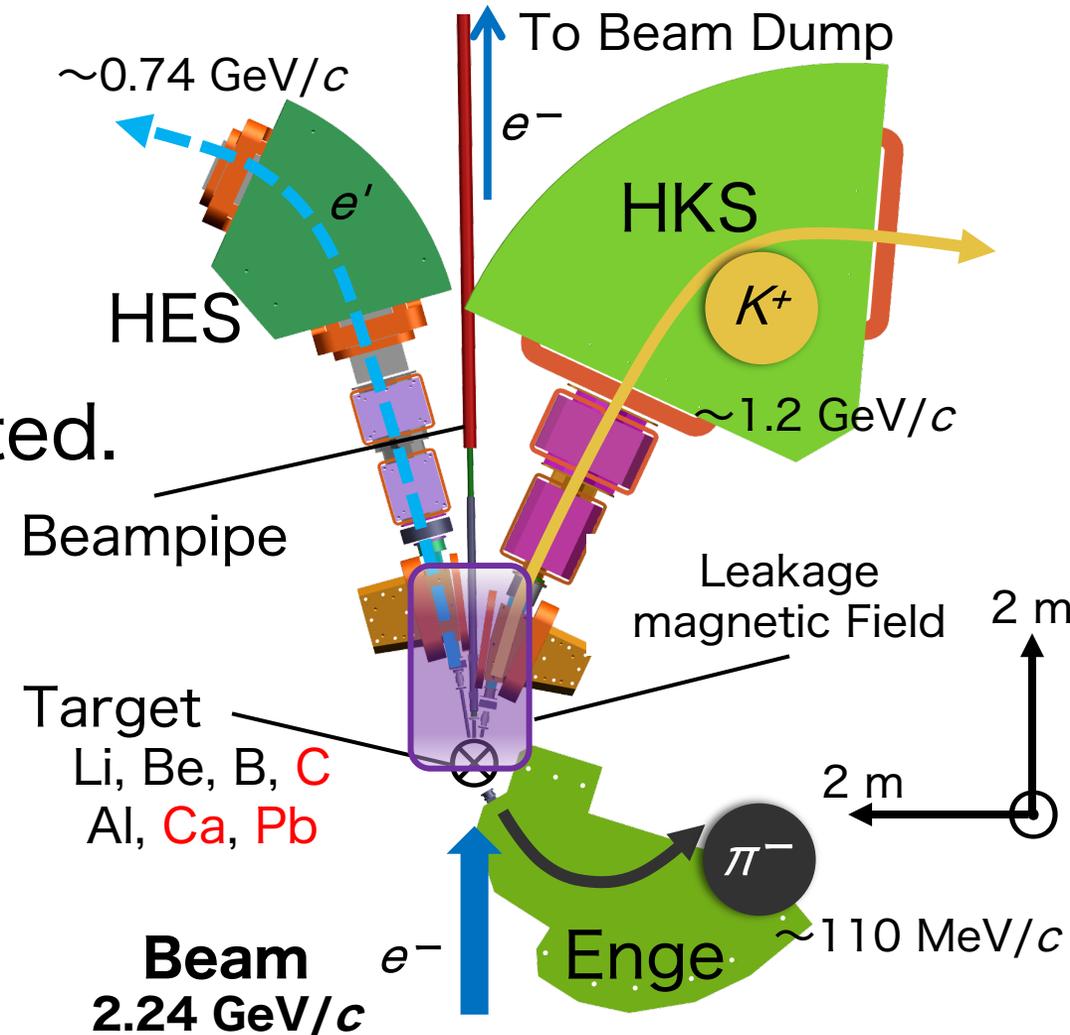
We use

- C, $^{40,48}\text{Ca}$, ^{208}Pb target...
- 2.24 GeV/c e^- beam (50 uA)

→ A **High radiation dose** is expected.

~ Impact of Radiation ~

1. Human Health
2. Electronics & Power Systems
3. Detectors



How to Evaluate Radiation

Obtained Monte-Carlo(MC)
 Φ ; Fluence [counts/cm²]

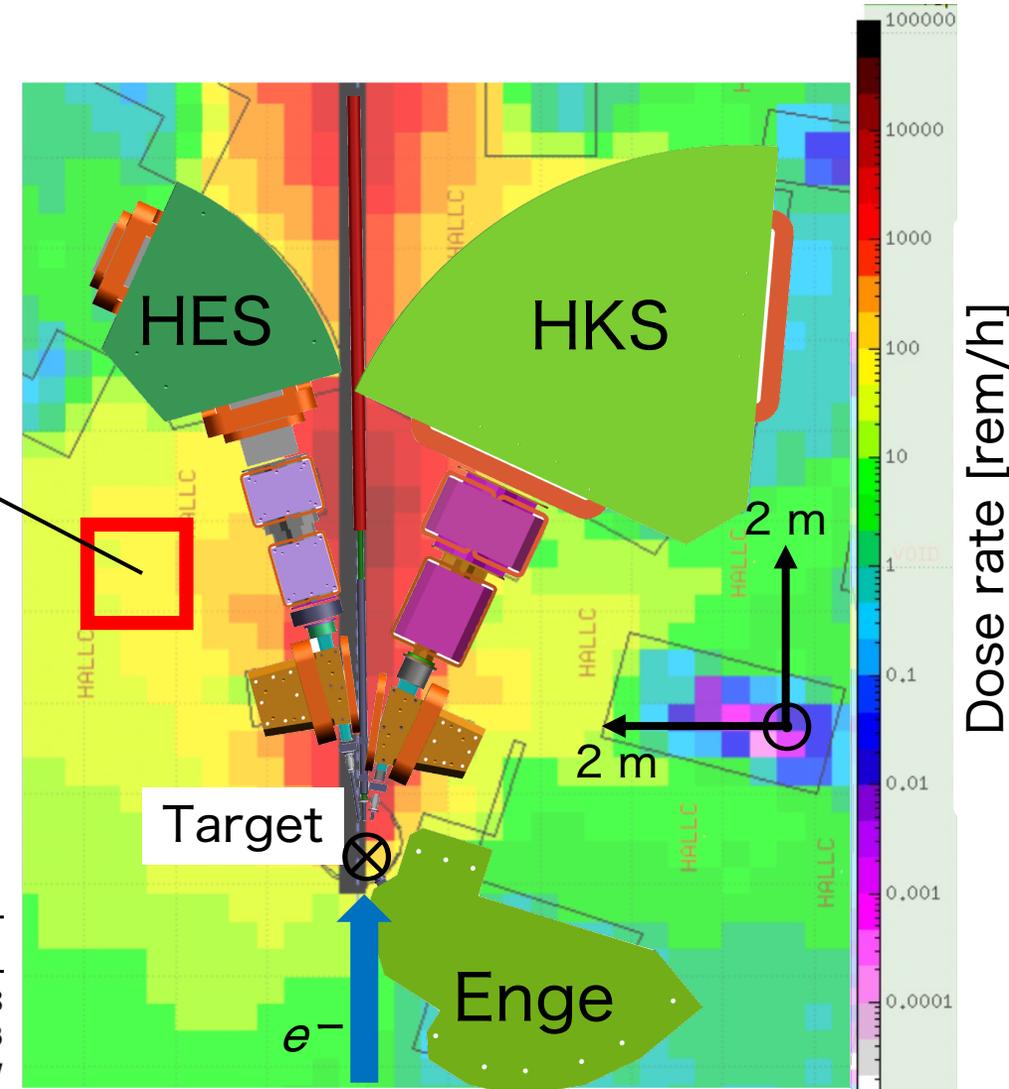
$$H = \sum_{\gamma, e^{\pm}, n, p, \dots} \Phi(E) \cdot w(E)$$

Conversion factor
 w ; Fluence to rem, Gy, ... etc.
 ※ Use reference data (e.g. ICRP)

Electrons effective dose per fluence

Source : Conversion Coefficients for Radiological Protection Quantities for External Radiation Exposures, ICRP (2010)

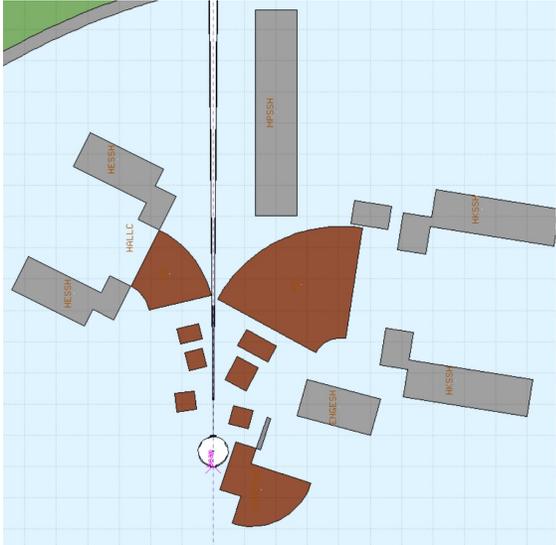
Energy (MeV)	AP	PA	ISO
0.01	0.0269	0.0268	0.0188
0.015	0.0404	0.0402	0.0283
0.02	0.0539	0.0535	0.0377
0.03	0.0810	0.0801	0.0567
0.04	0.108	0.107	0.0758
0.05	0.135	0.133	0.0948
0.06	0.163	0.160	0.114
0.08	0.218	0.213	0.152
0.1	0.275	0.267	0.191



Dose rate map near the Target

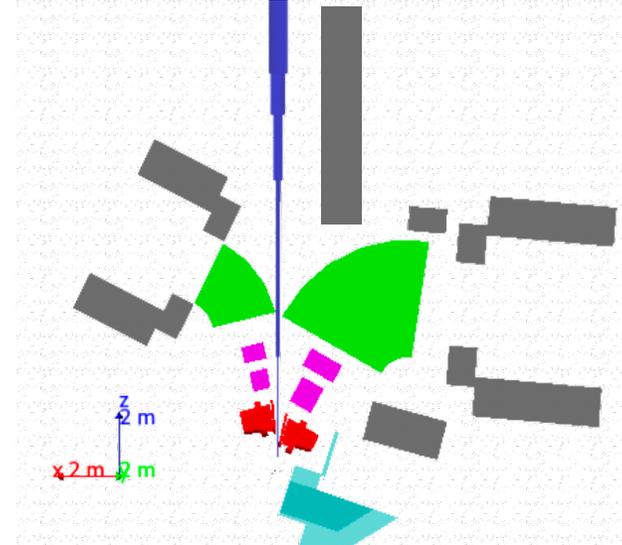
Two Simulation Codes

FLUKA

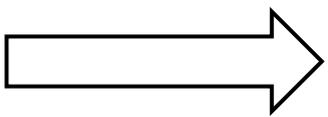


- Reliable for **radiation** calculation at JLab
- **Macro**scopic result

Geant4



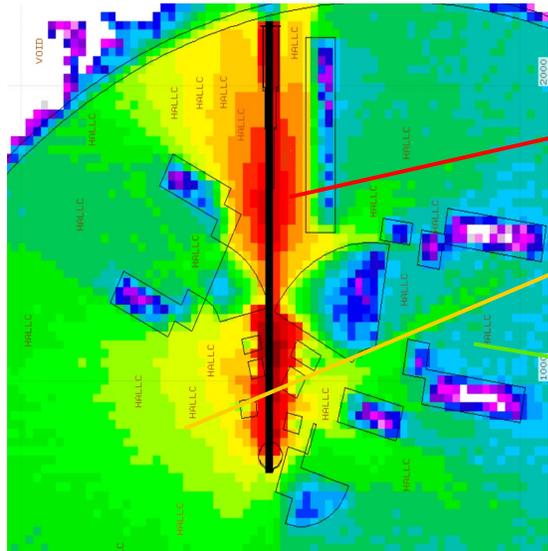
- Reliable for **detector** response with experimental data in our group.
- **Micro**scopic result



- **Cross-check**
- Use them as appropriate to the situation

Two Simulation Codes

FLUKA



In the Exp. area,

~ 10^4 rem/h

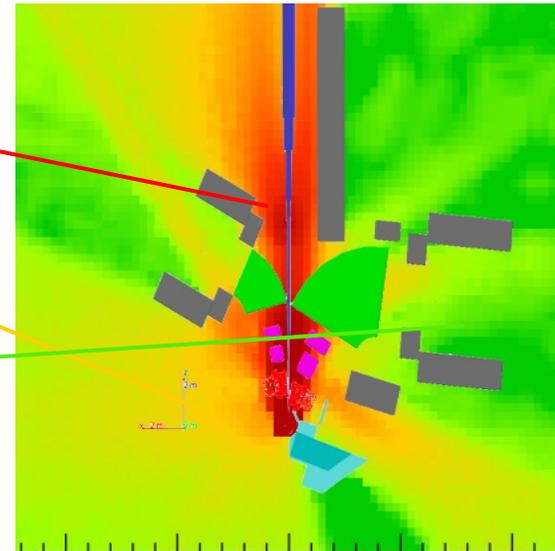
~ 10^2 rem/h

~ 1 rem/h

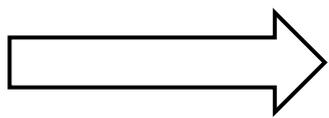
Consistent !

- Reliable for **radiation** calculation at JLab
- **Macro**scopic result

Geant4



- Reliable for **detector** response with experimental data in our group.
- **Micro**scopic result



✓ **Cross-check**

- Use them as appropriate to the situation

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[Results]

1. Target dependence

2. Shielding Effects

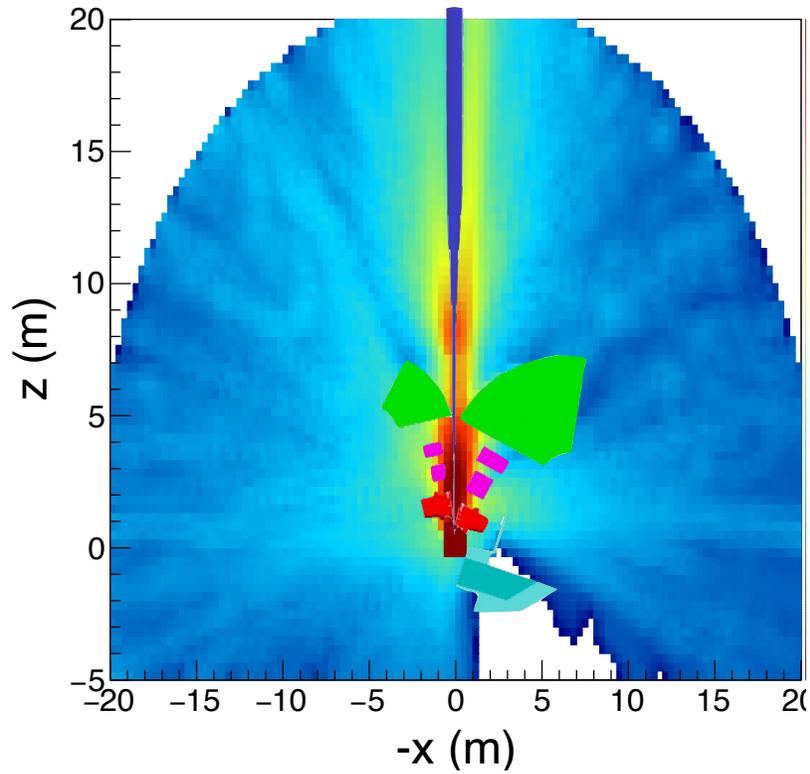
3. Single rate

~ Event rate in the hodoscope ~

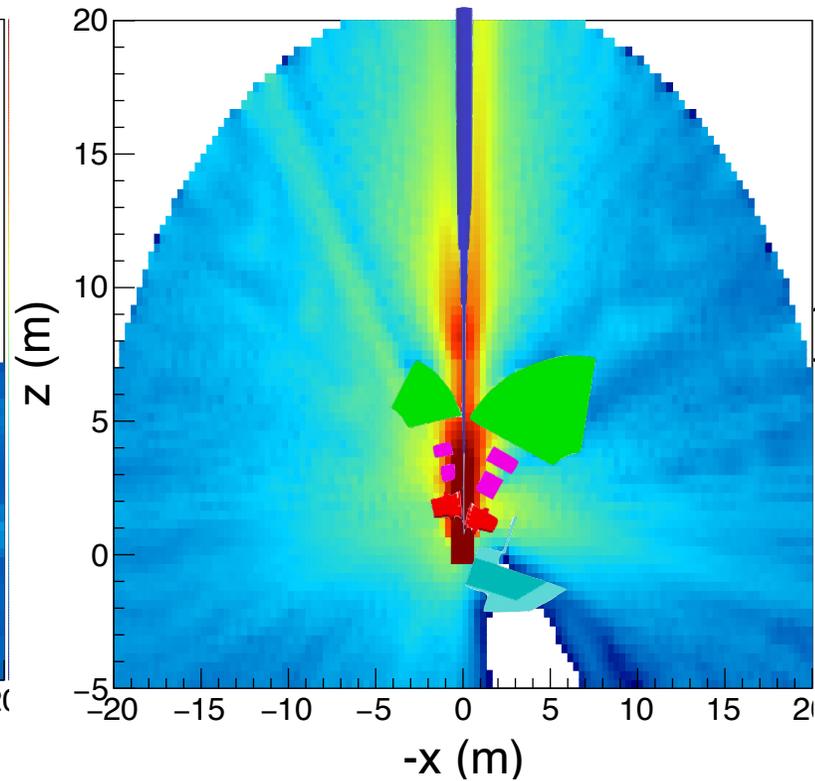
4. FLUKA results

~ Radiation dose outside the hall ~

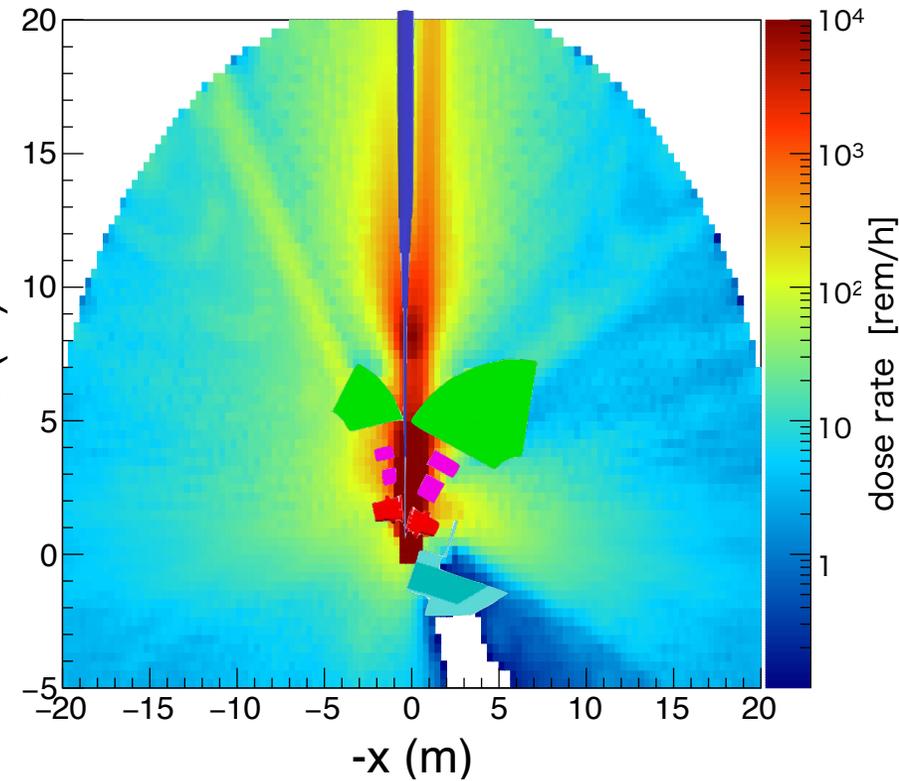
Results1. Target dependence



C Target

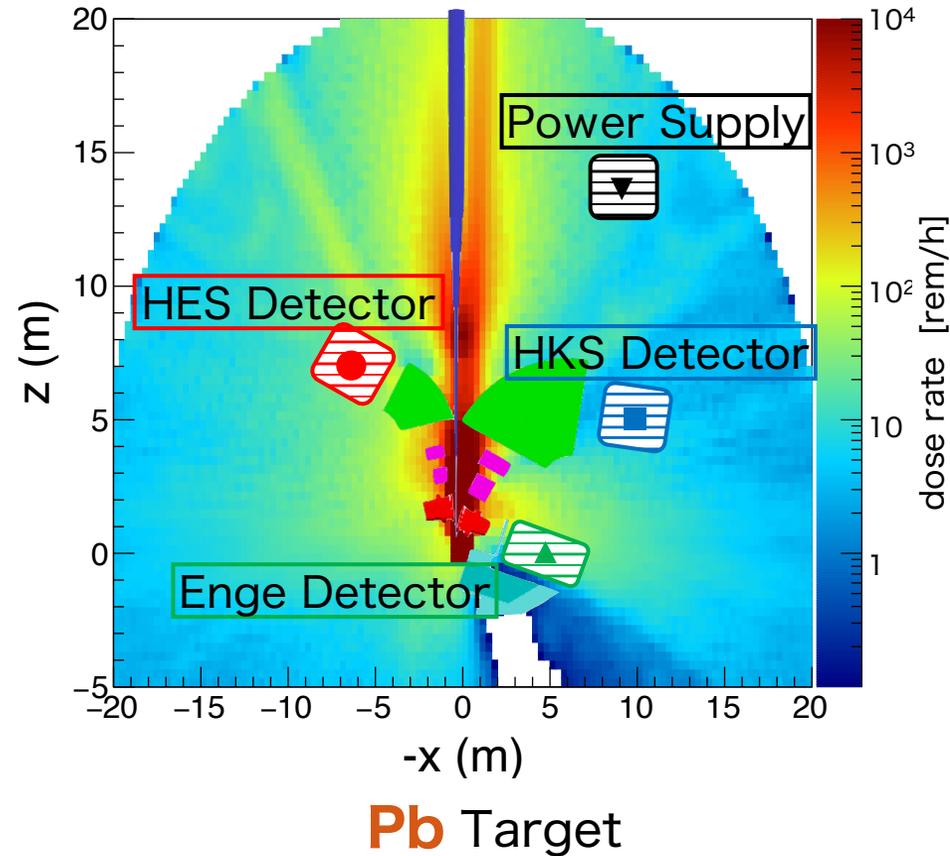
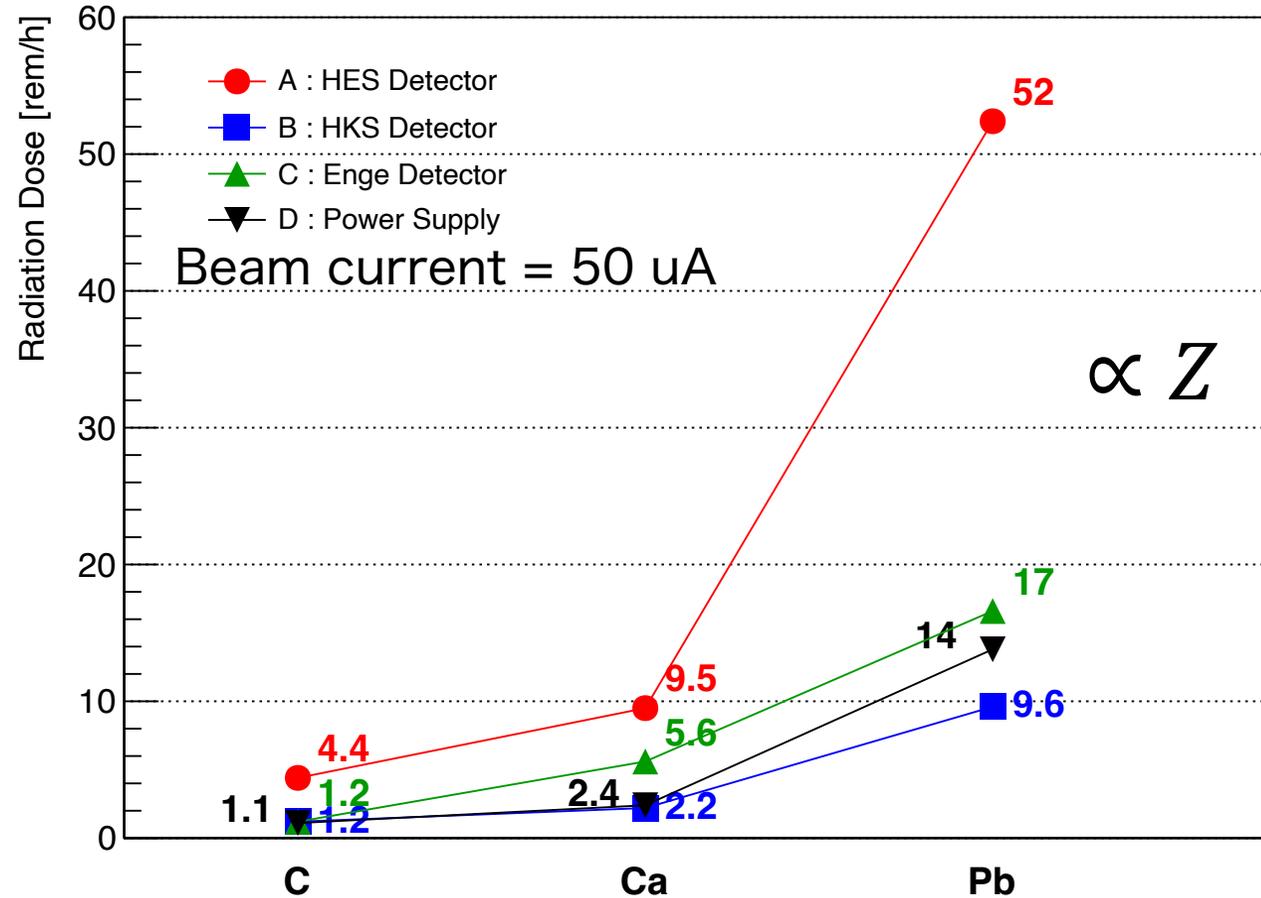


Ca Target

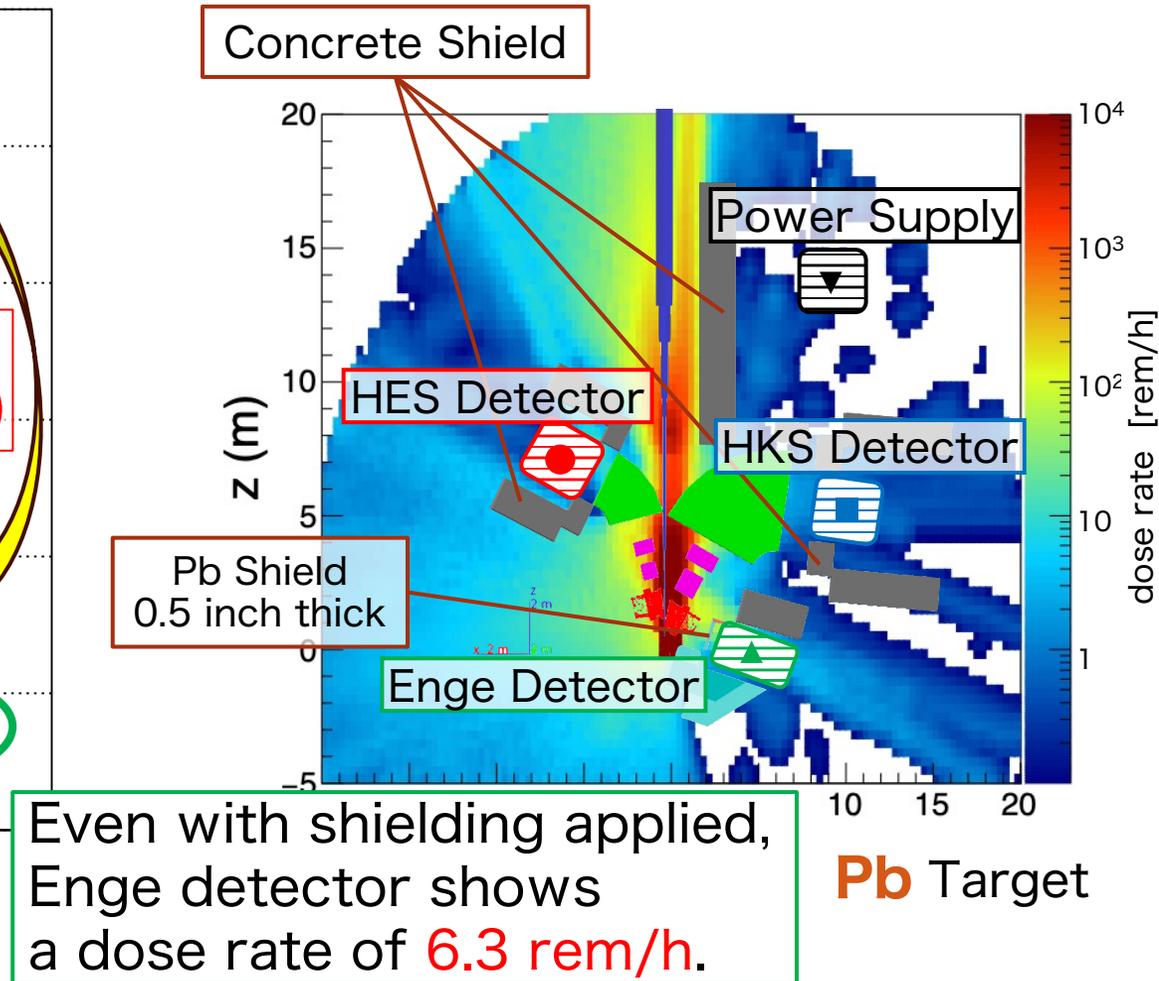
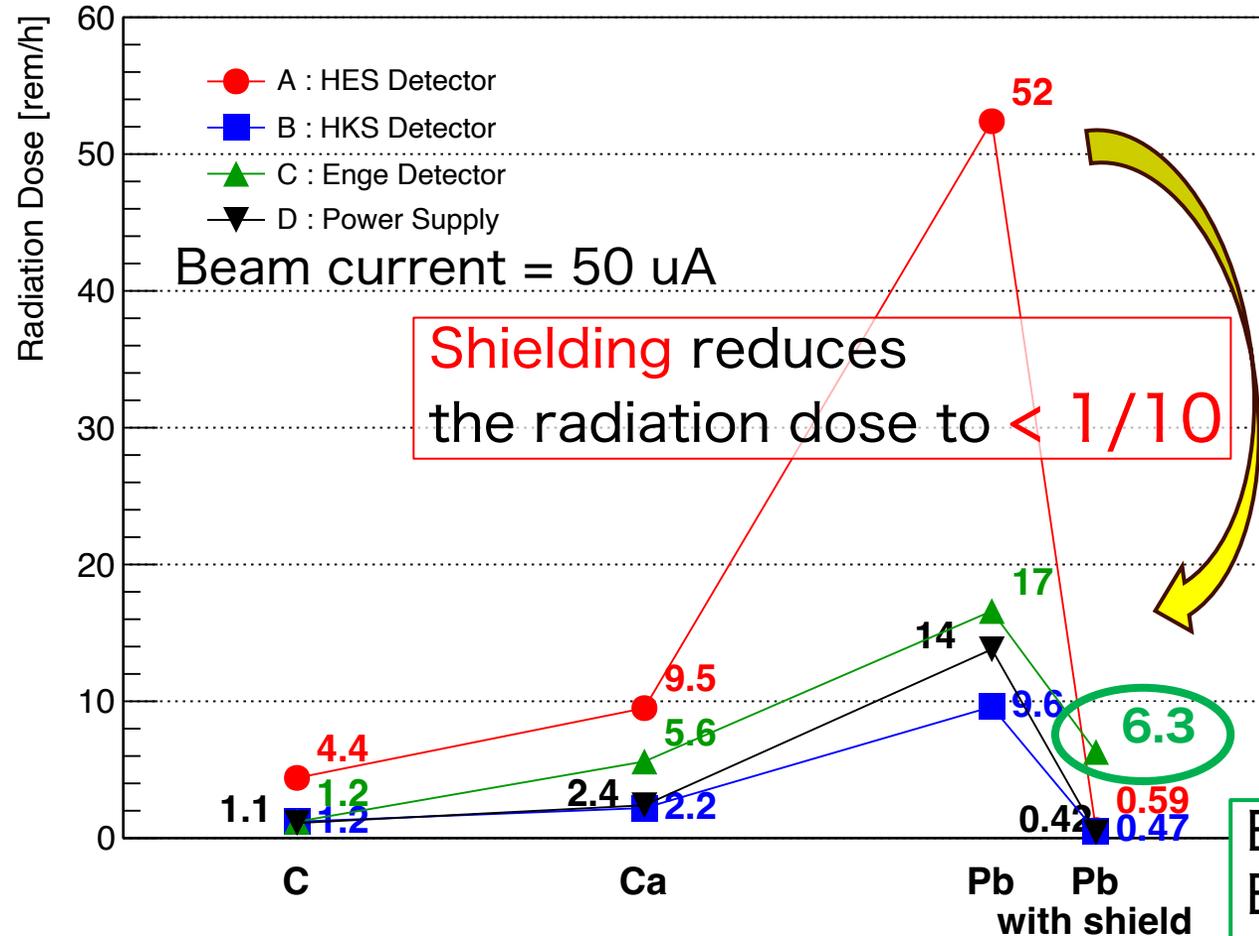


Pb Target

Results1. Target dependence



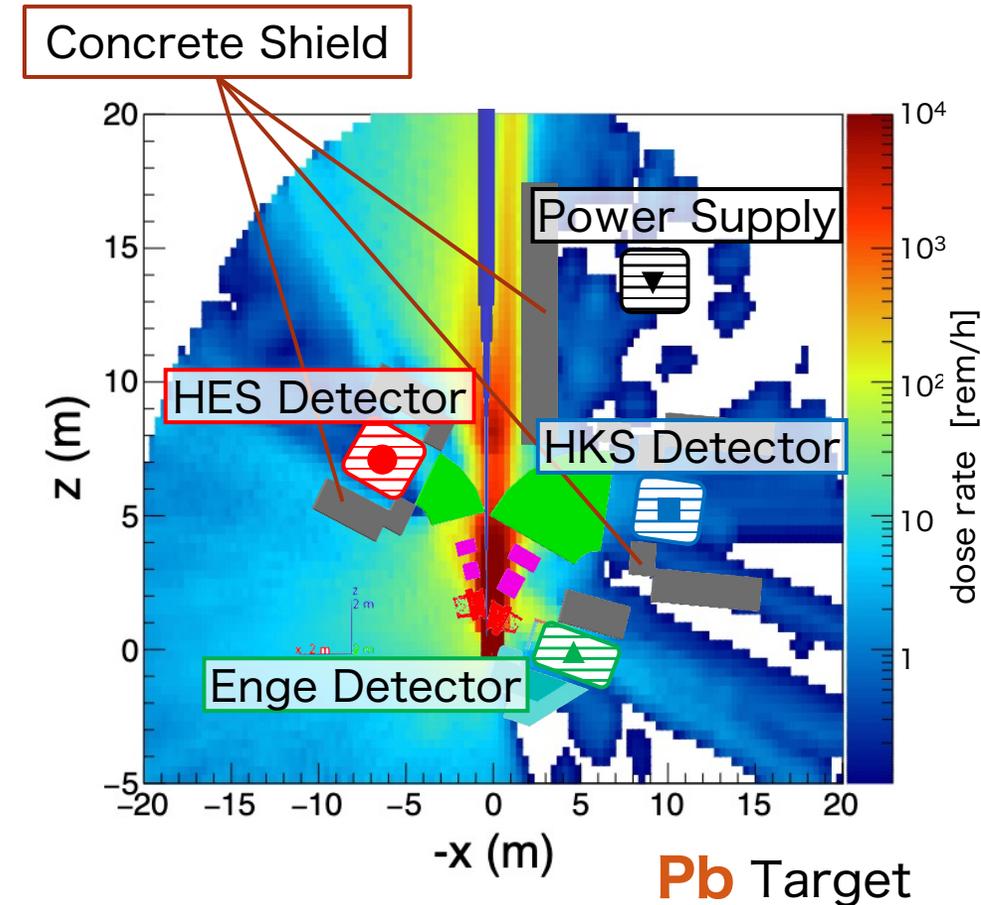
Results2. Shielding Effects



Results3. Single rate

- Put Hodoscope (30 * 50 * 300 mm³)
- Threshold Energy Deposit > 500 keV

	HES	HKS	Enge	Power supply
C	0.60 M	1.2 M	0.65 M	0.062 M
Ca	2.0 M	2.3 M	1.5 M	0.030 M
Pb	2.8 M	4.6 M	2.3 M	0.34 M



→ Signals can be generated at a rate of **MHz** or higher.

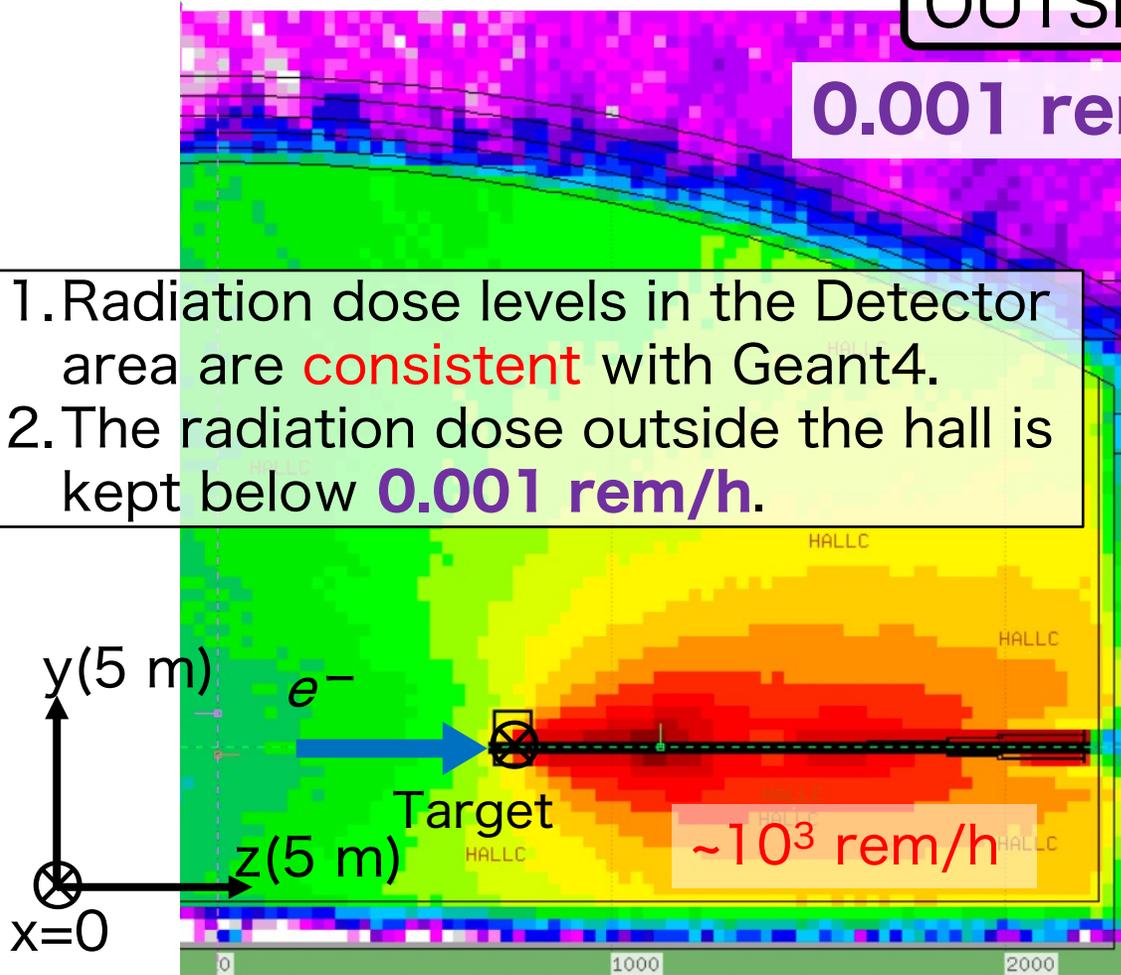
Results4. FLUKA Results

Side view

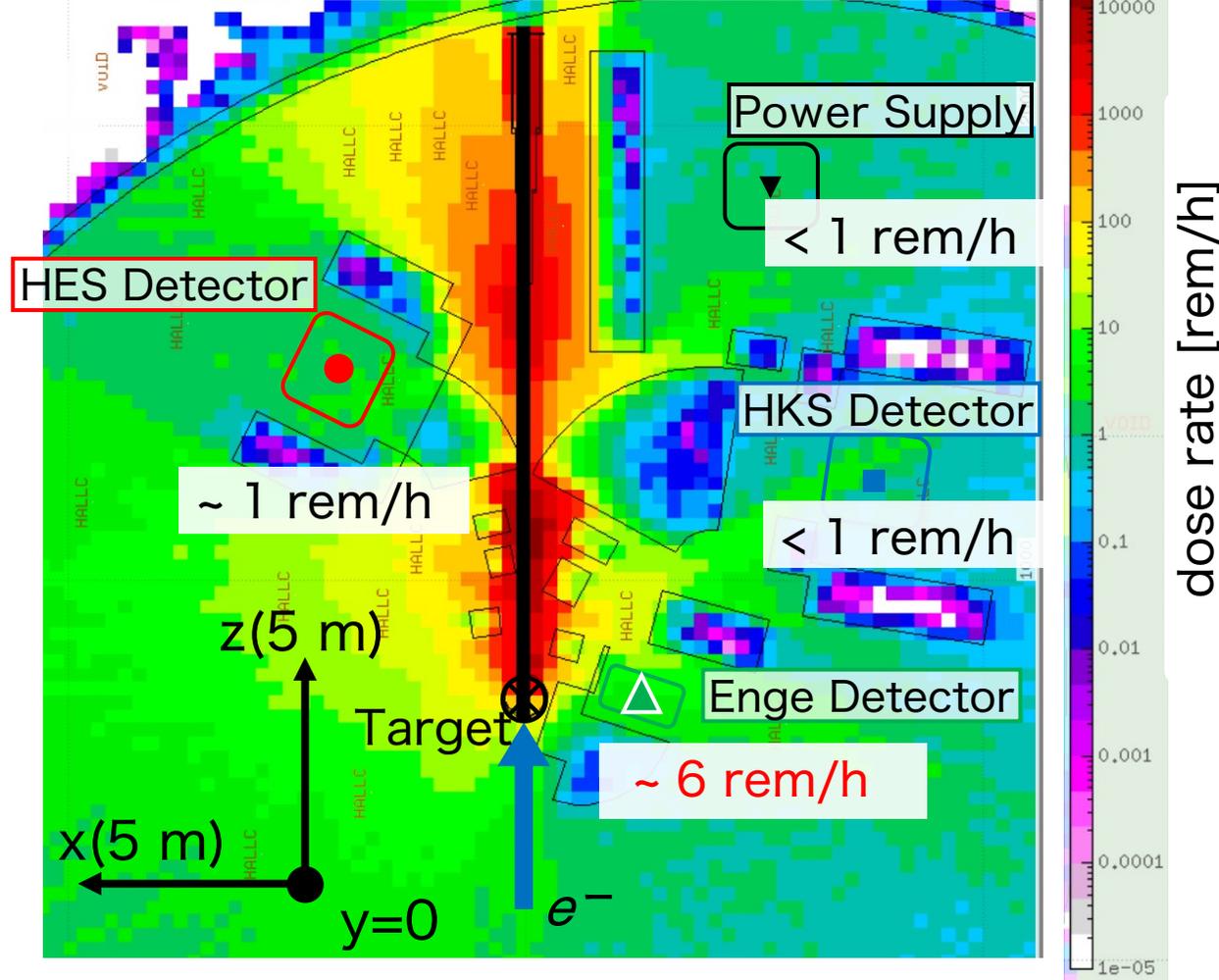
OUTSIDE

0.001 rem/h

1. Radiation dose levels in the Detector area are **consistent** with Geant4.
2. The radiation dose outside the hall is kept below **0.001 rem/h**.

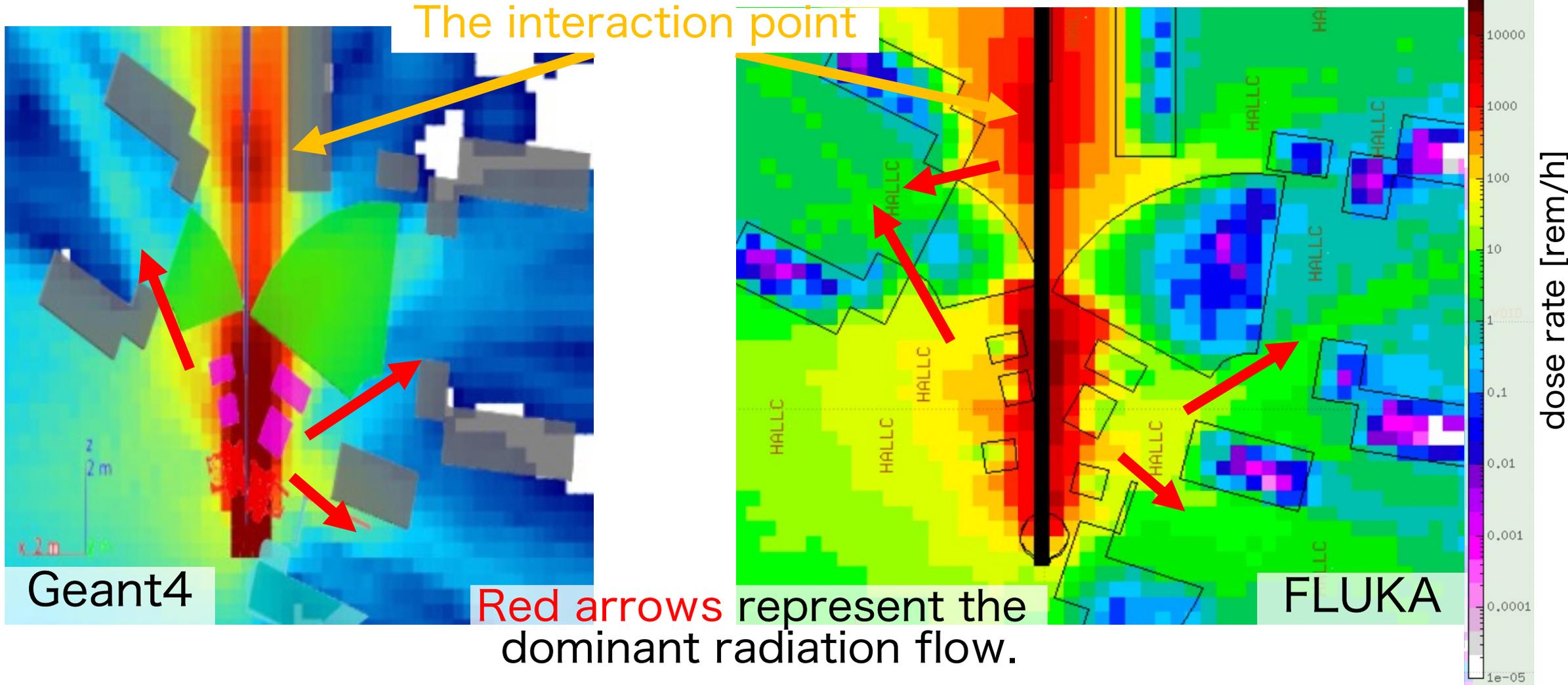


Top view



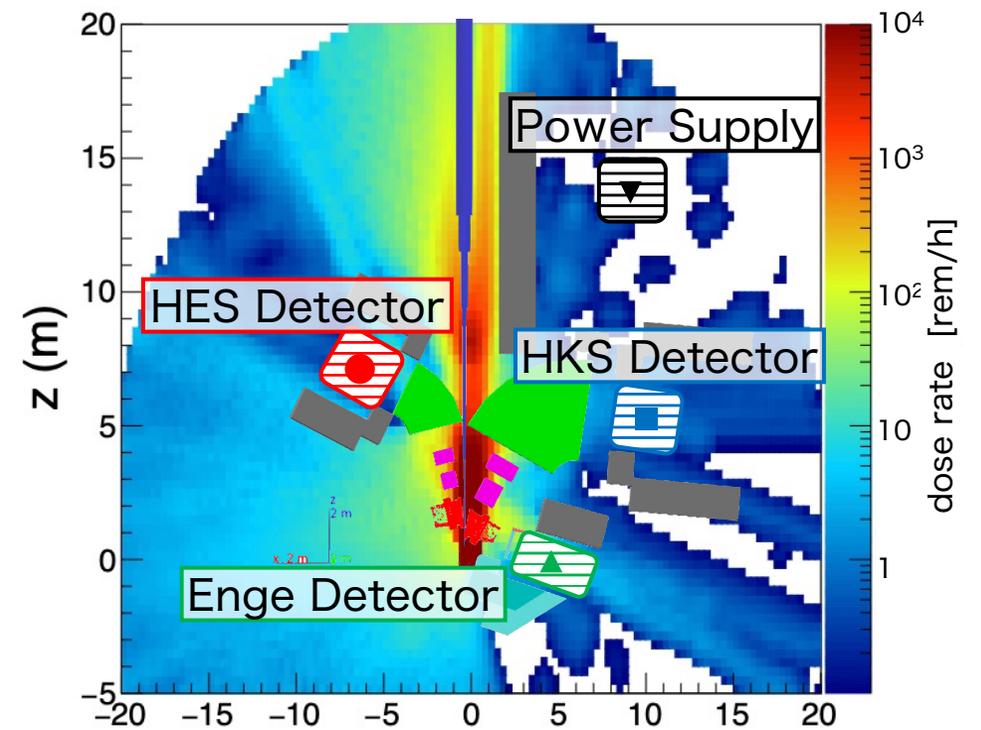
Dominant radiation flow

Beam current = 25 μ A
Pb Target with Shielding



Summary

1. Both Geant4 and FLUKA results are **consistent**.
2. **Pb targets** result in higher radiation dose, and **shielding** effectively reduces the dose.
3. Signal rates above **MHz** are expected.
→ More detail simulation & analysis
4. The radiation dose outside the hall is kept below **0.001 rem/h**.



Beam current = 50 uA, **Pb** Target with Shielding

	HES [rem/h]	HKS [rem/h]	Enge [rem/h]	Power Supply [rem/h]
γ	0.080	0.033	0.60	0.048
e^\pm	0.49	0.43	5.6	0.37
n	0.020	0.000014	0.11	0.00020
Total	0.59	0.47	6.3	0.42

Single rate @ Beam current = 50 uA with Shielding

	HES	HKS	Enge	Power supply
Pb	2.8 MHz	4.6 MHz	2.3 MHz	0.34 MHz

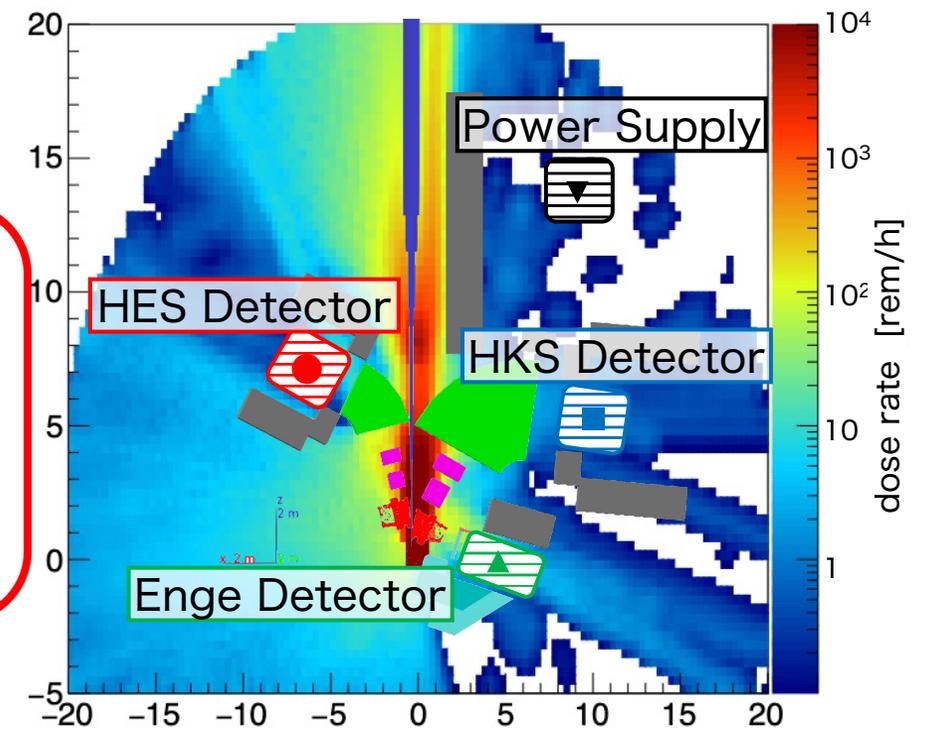
Summary & Outlook

Geometry Update

- Target Vacuum Chamber
- Beam pipe
- Radiation Shield
- Full Fringe Magnetic Field
- All detectors alignment

Data

- Single Rate when all detectors are placed.
- Primary arrival directions, types, and energy.
- Accidental Coincidence



3. Signal rate above MHz are expected.

→ More detail simulation & analysis

4. The radiation dose outside the hall is kept below 0.001 rem/h.

Beam current = 50 uA, Pb Target with Shielding

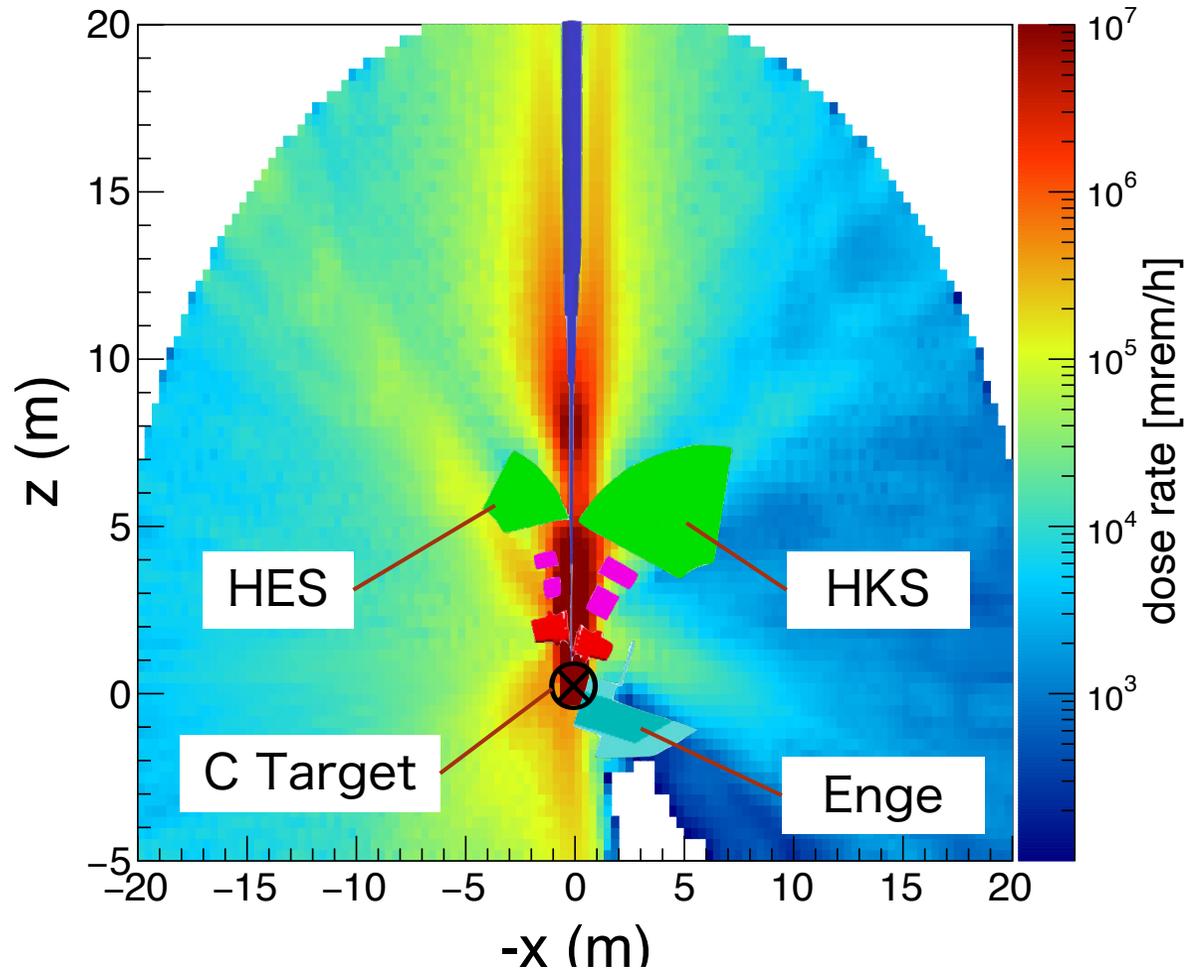
Single rate @ Beam current = 50 uA with Shielding

	HES	HKS	Enge	Power supply
Pb	2.8 MHz	4.6 MHz	2.3 MHz	0.34 MHz

	HES [rem/h]	HKS [rem/h]	Enge [rem/h]	Power Supply [rem/h]
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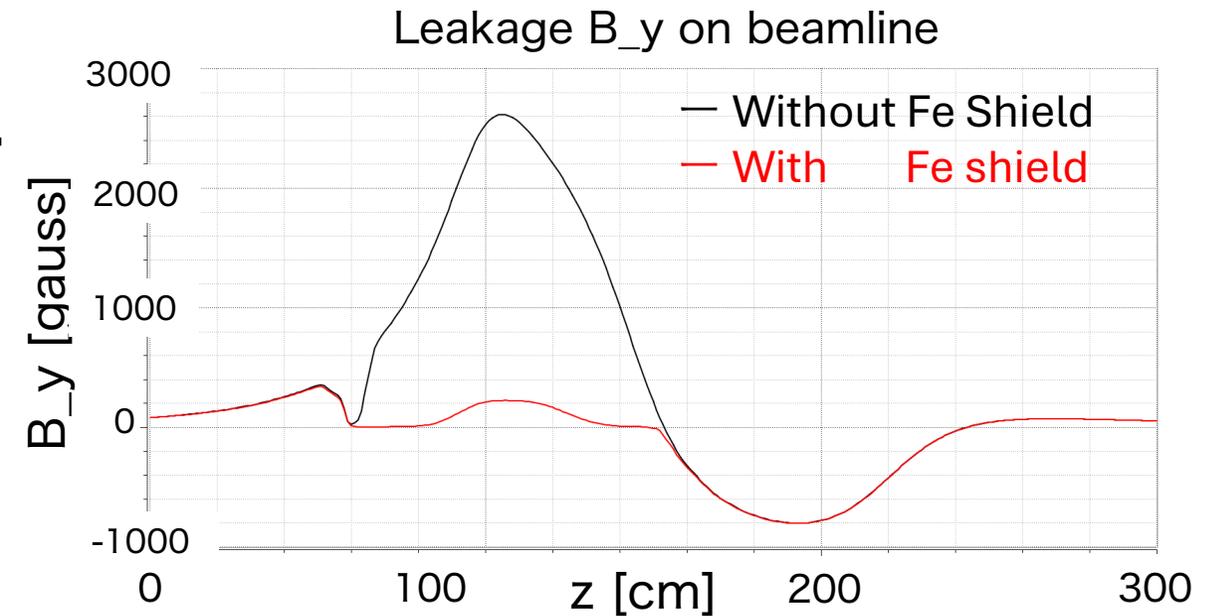
Backup

Leakage magnetic field



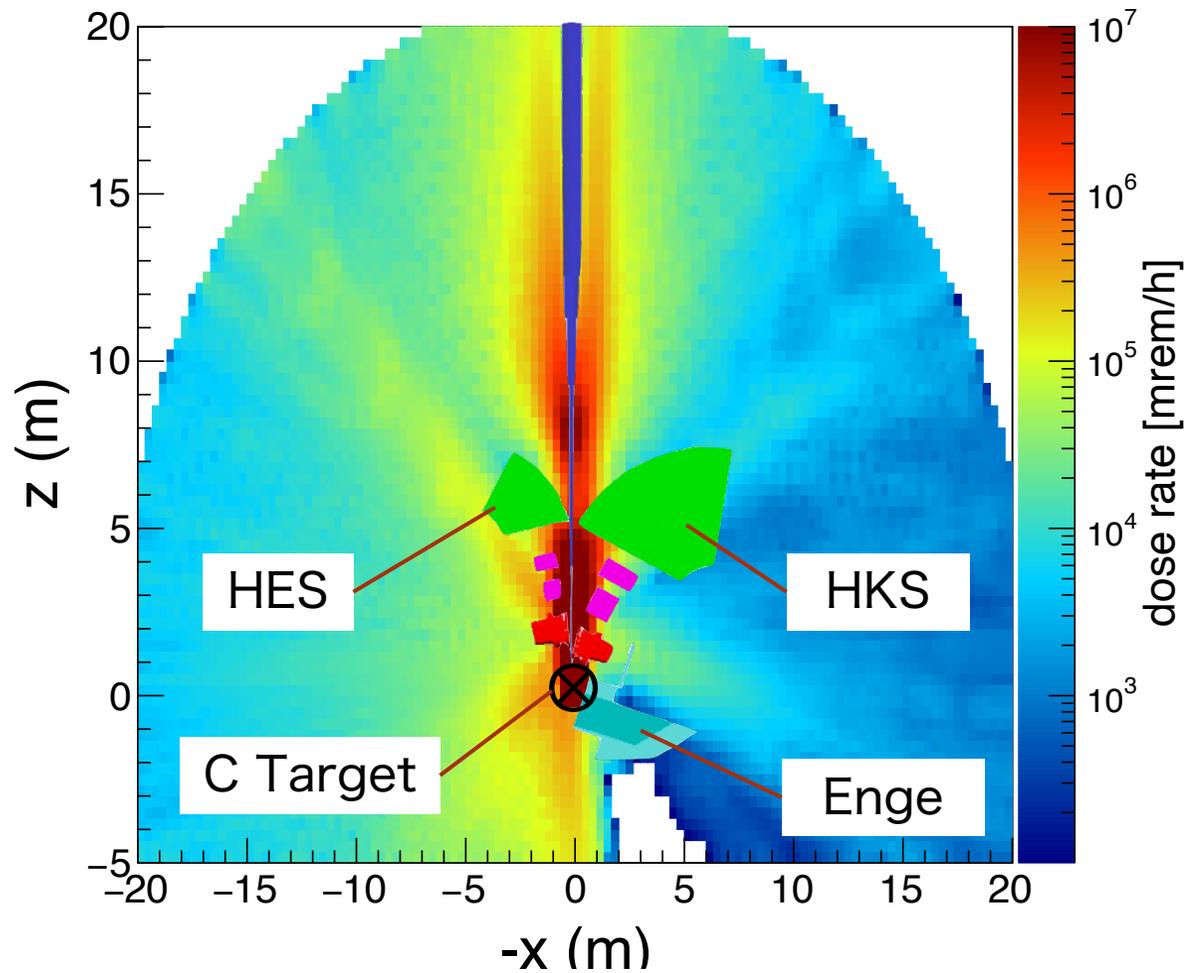
Without Fe Shield on beamline

- Only **PCS(K)** Magnetic field on
- Change the scale of the field on the beamline

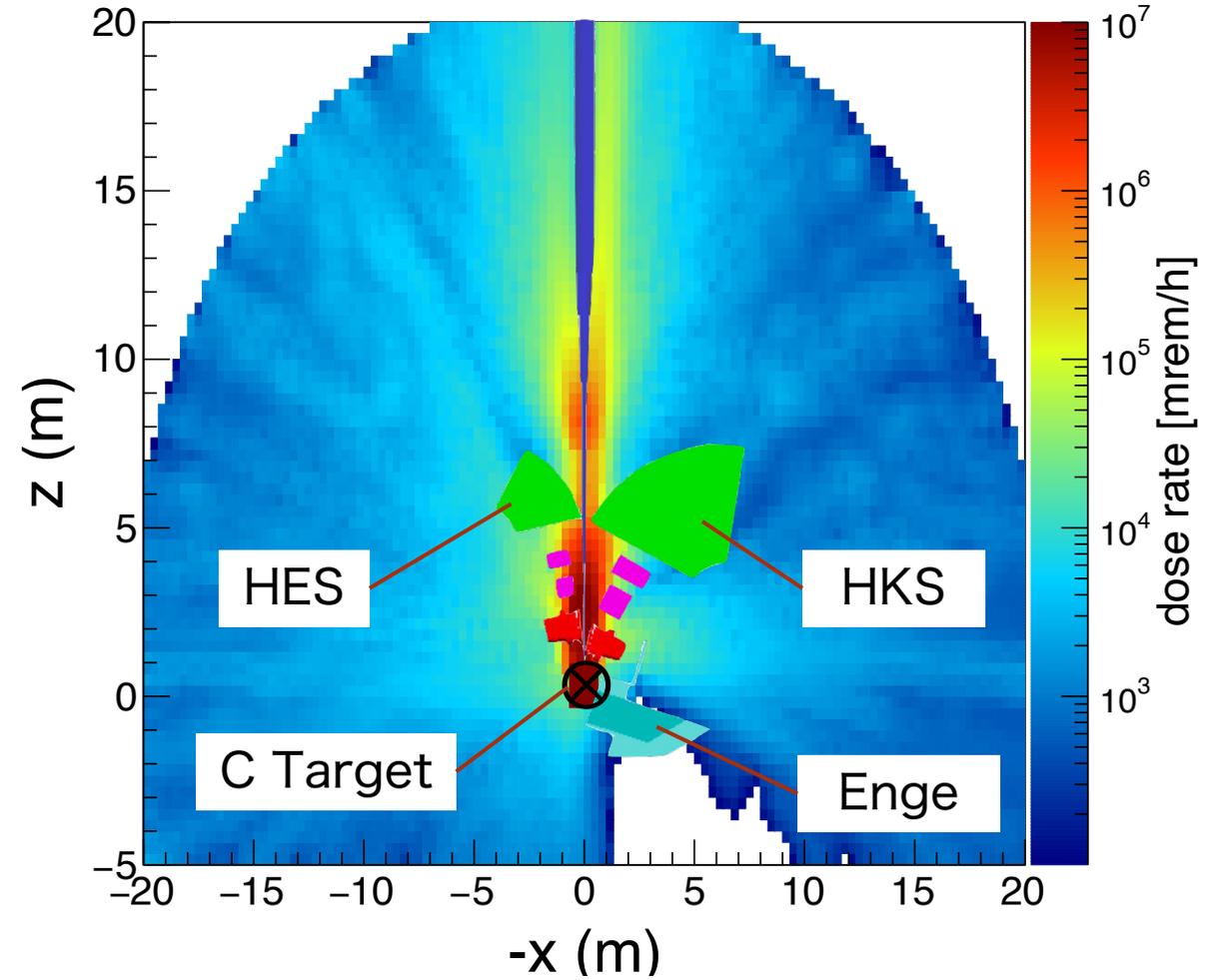


Private communication with Steven R. Lassiter

Leakage magnetic field

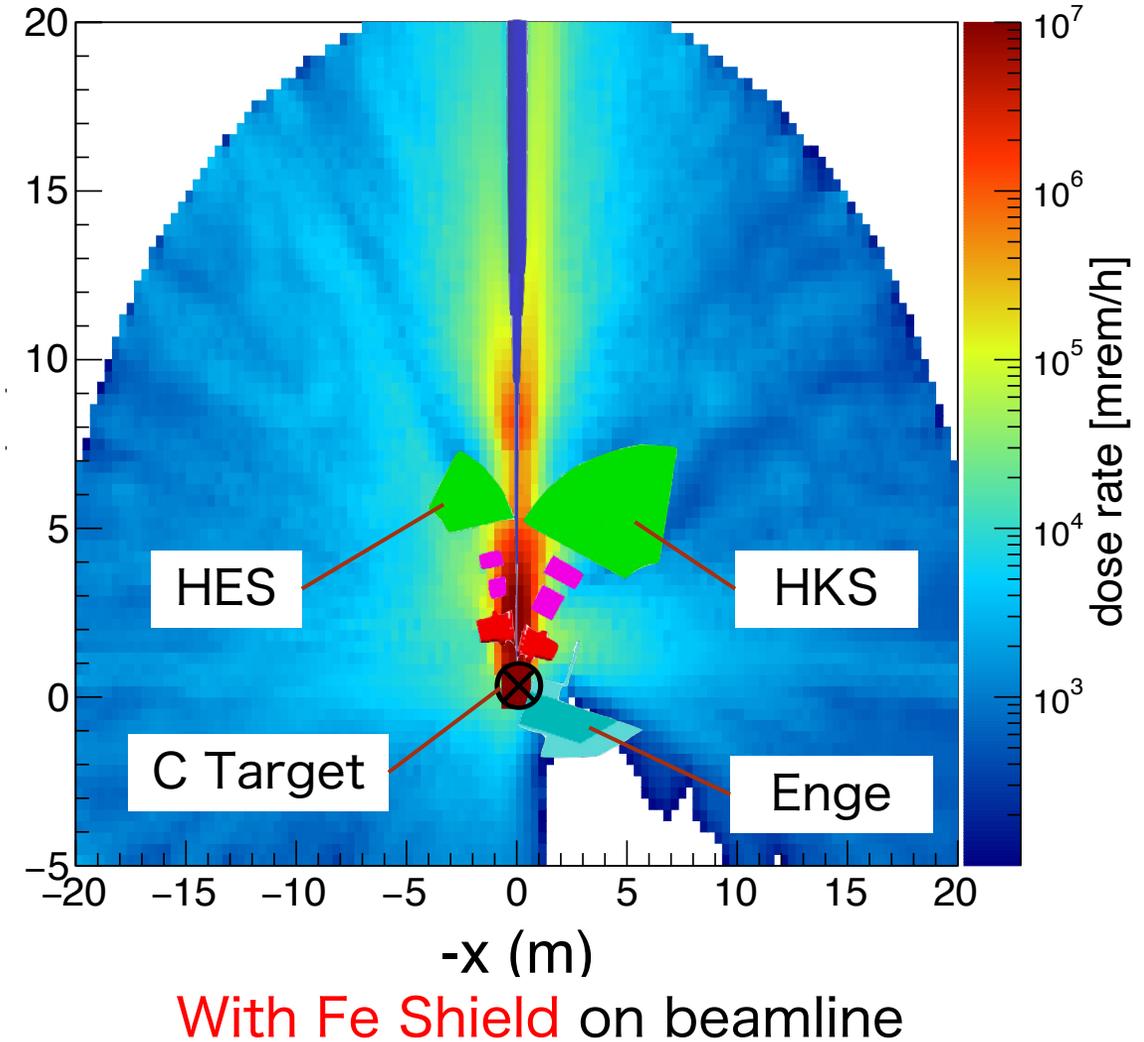
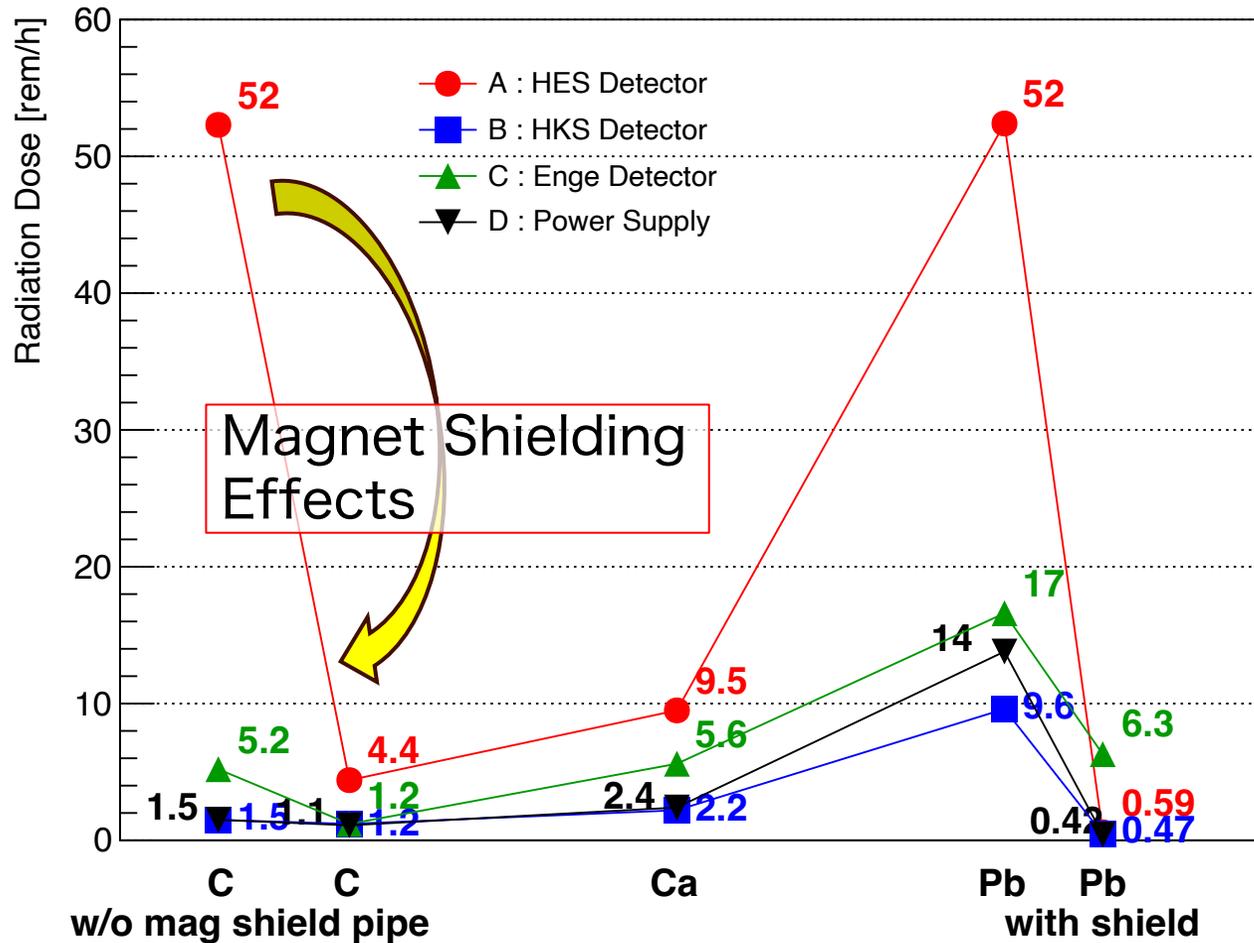


Without Fe Shield on beamline

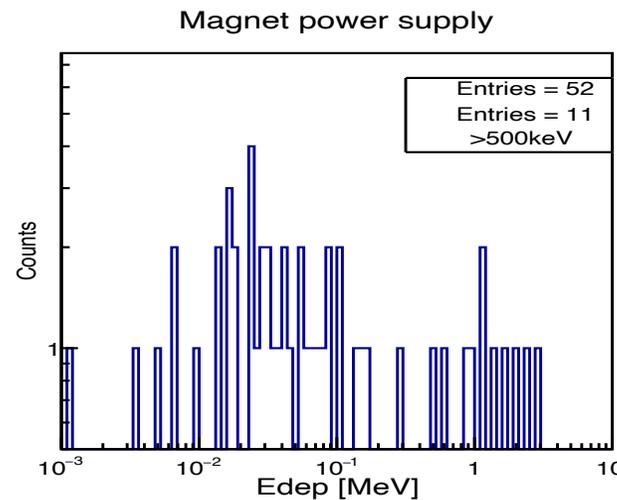
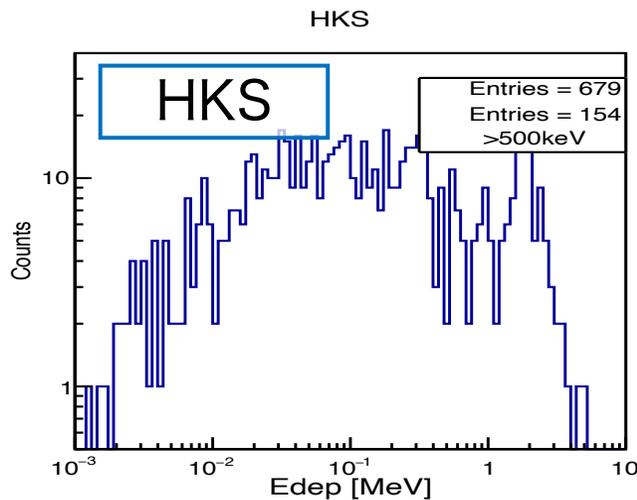
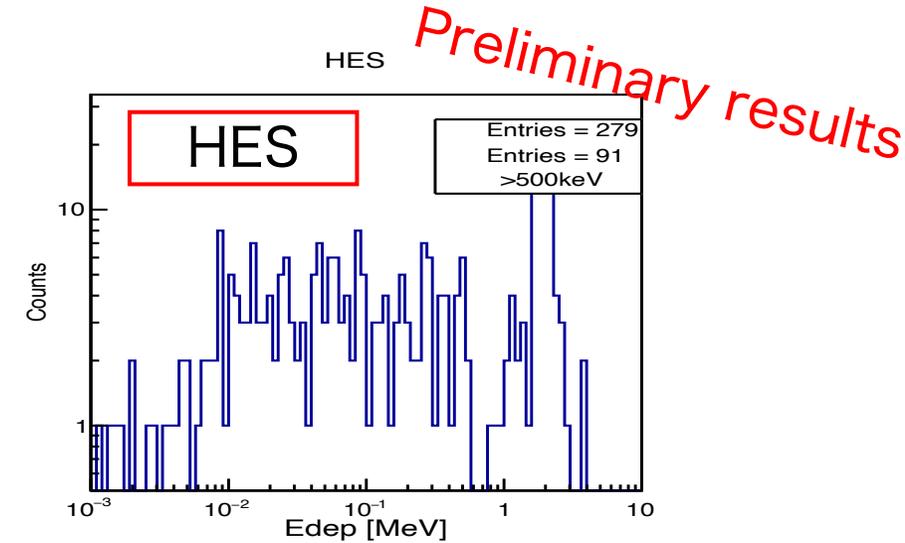
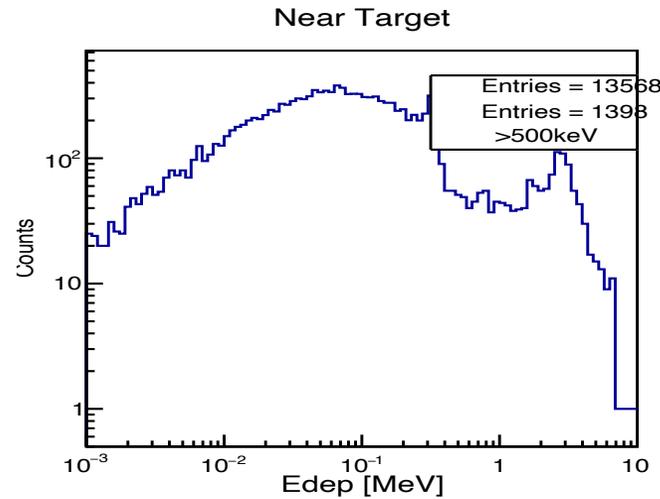
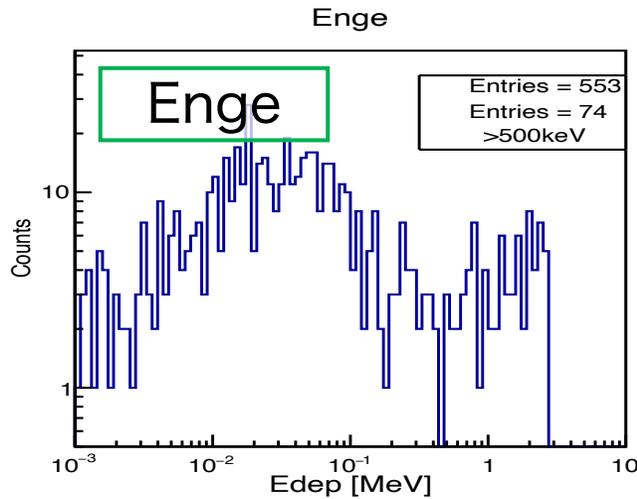


With Fe Shield on beamline

Leakage magnetic field



Single rate study ~ Energy Deposit ~

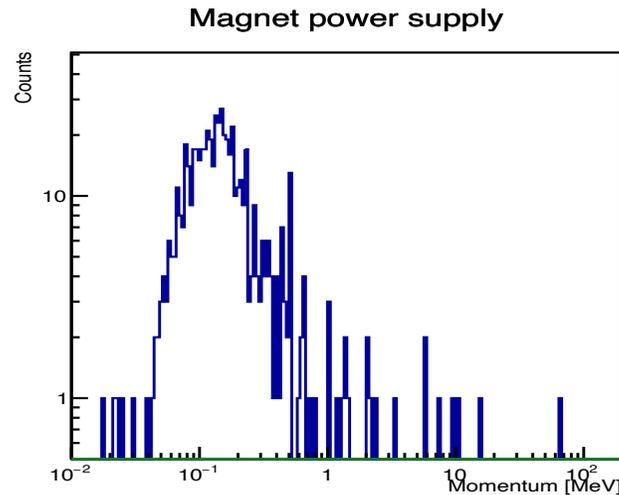
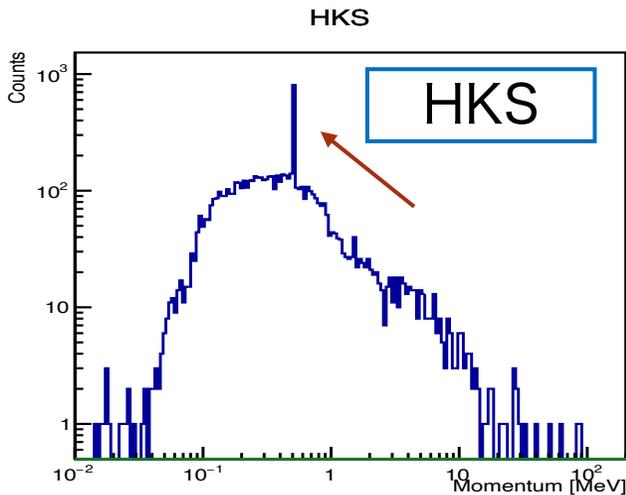
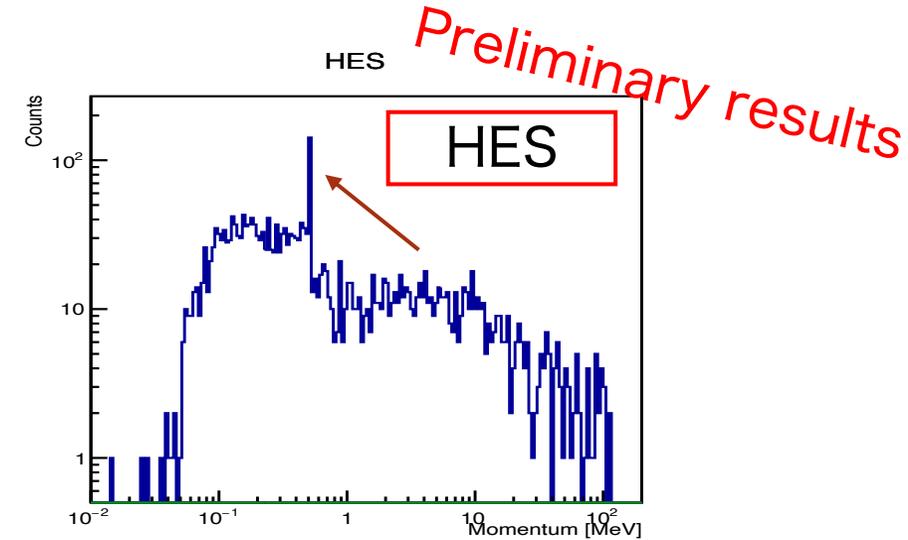
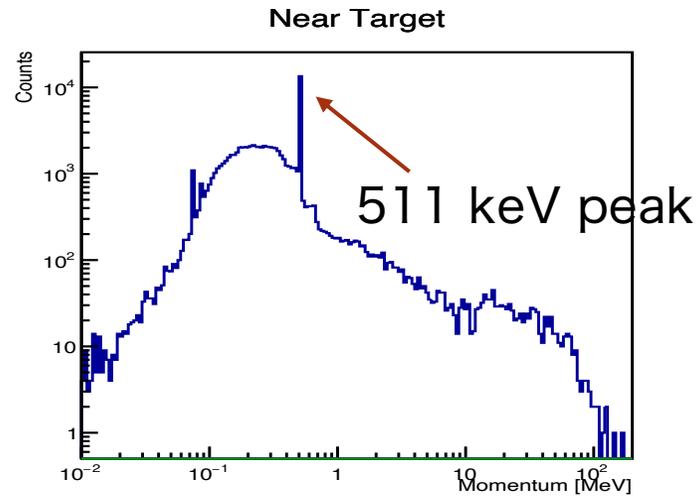
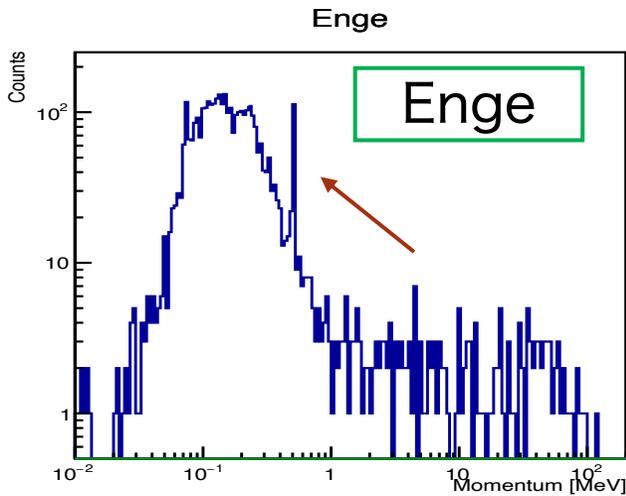


Put Hodoscope
(30 * 50 * 300 mm³)

1 sec. scaling $\times 3.12 \times 10^4$

Ex.) @HKS 154 count satisfies
Edep > 500 keV or higher,
rate is $154 \times 3.12 \times 10^4 = 4.6 \text{ MHz}$

Single rate study ~ Momentum distribution~

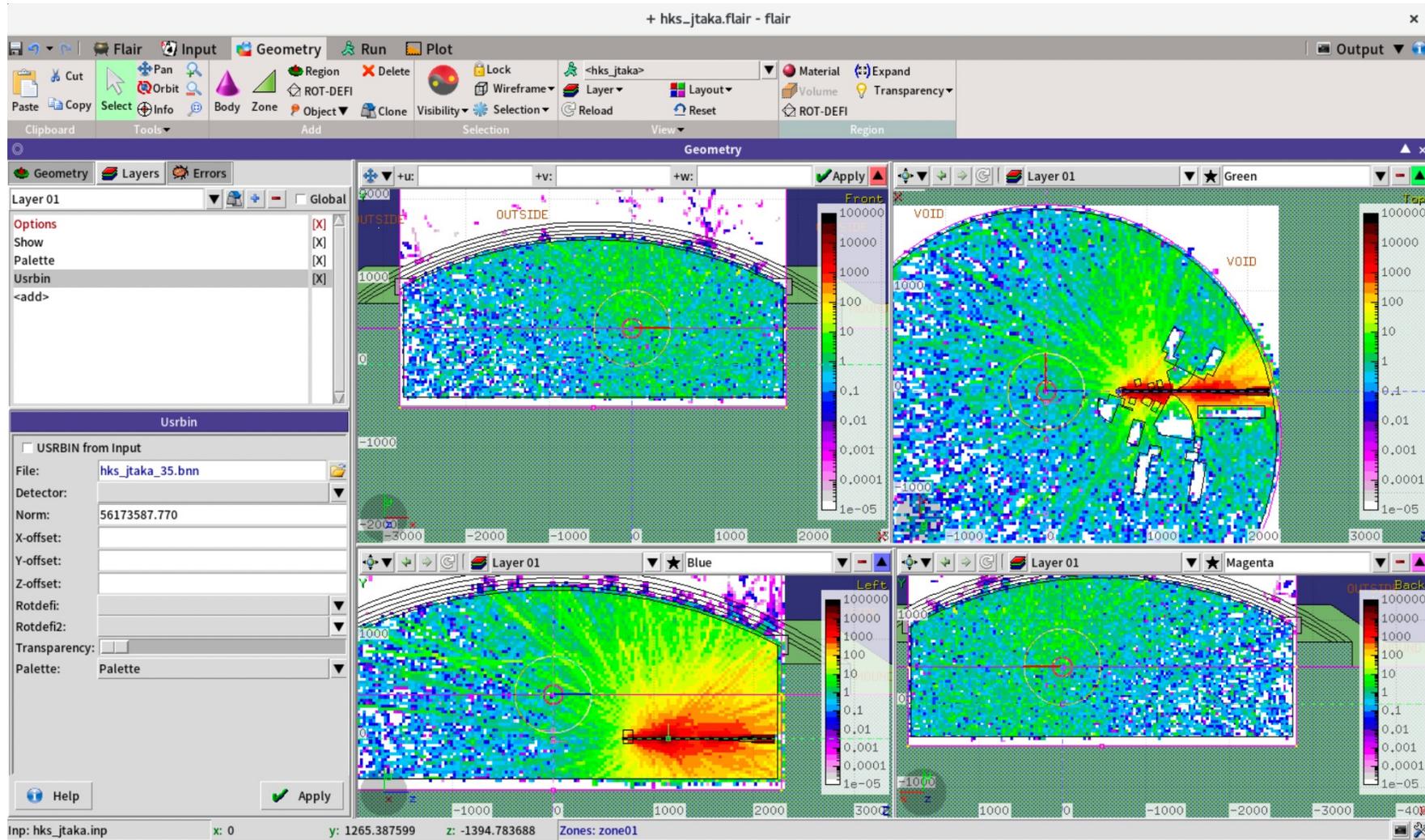


Put HES Hodo
(30 * 50 * 300 mm³)

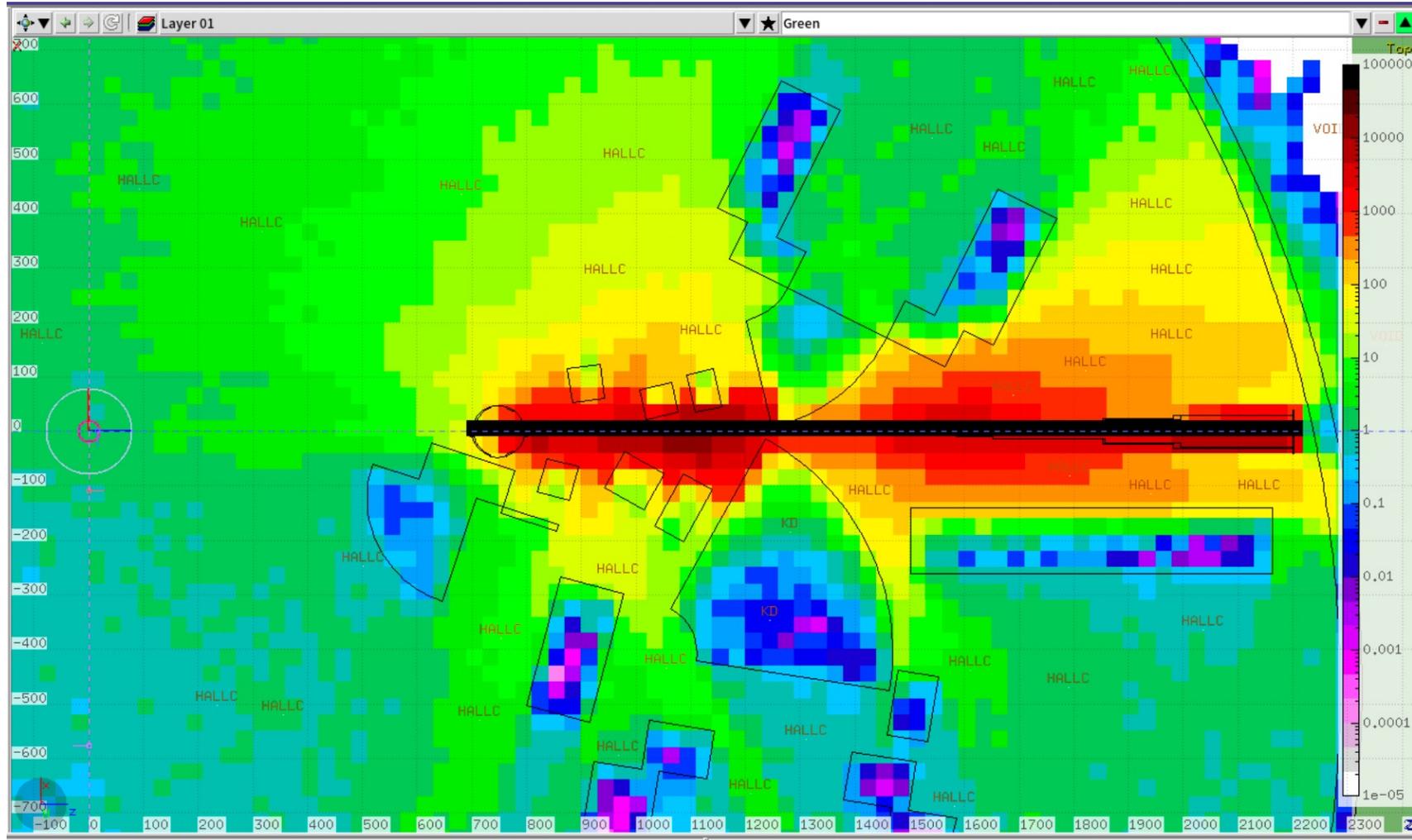
1 sec. scaling $\times 3.12 \times 10^4$

Failed to save root, unable to
decompose into individual
particle distributions...

Screenshot of FLUKA Results



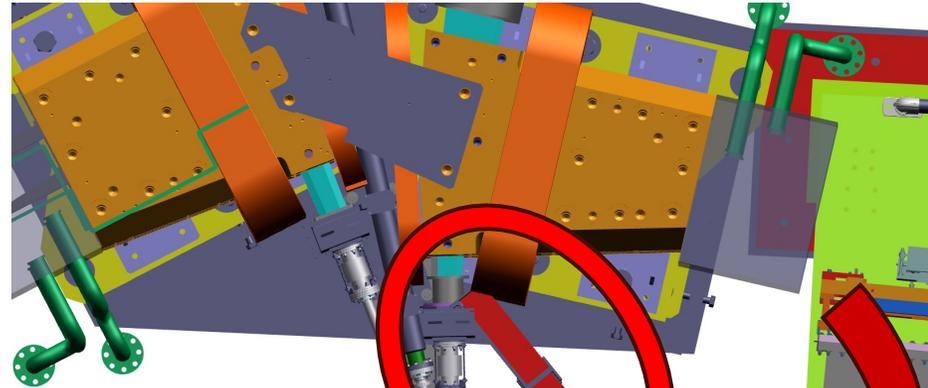
Screenshot of FLUKA Results



Enge Shield

Placing shielding too close to the target is likely undesirable

	[mrem/h]
γ	110
e^\pm	2.1 k
n	18



	[mrem/h]
γ	2811
e^\pm	24 k
n	180

12.7 mm thick Lead shield

Before

12.7 mm thick Lead shield

move

After