Numerical Beam Studies Using a Collimator at the High Intensity Test-Beam Facility, PRIMA

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High Intensity Electron Beamline

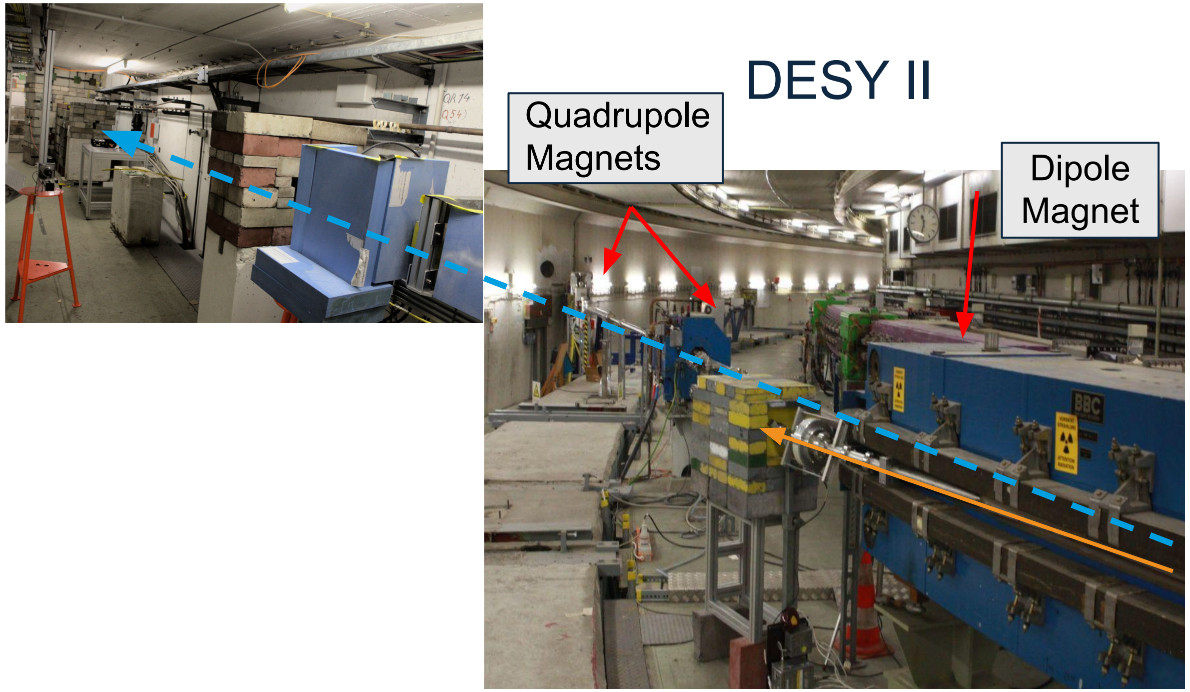
PRIMary-beam test Area : PRIMA

- Extracted beam from DESY II
  - 1 x 10^9 to 3 x 10^{10} e^- per bunch in normal operation
  - 6.25 Hz extraction rate
  - Energy between 450 MeV and 6 GeV

- PRIMary-beam test Area(PRIMA)
  - Previously transferred particles from DESY II to DORIS
    - Primary beam only for expert-operation
    - Detector tests at high rates, radiation damage studies and studies related to beam-dump & shielding

PRIMA Facility

DESY II



Motivation

PRIMA R-WEG

Why do we need a collimator?

❋ **Collimator: a device to control the intensity, shape and direction of a beam**

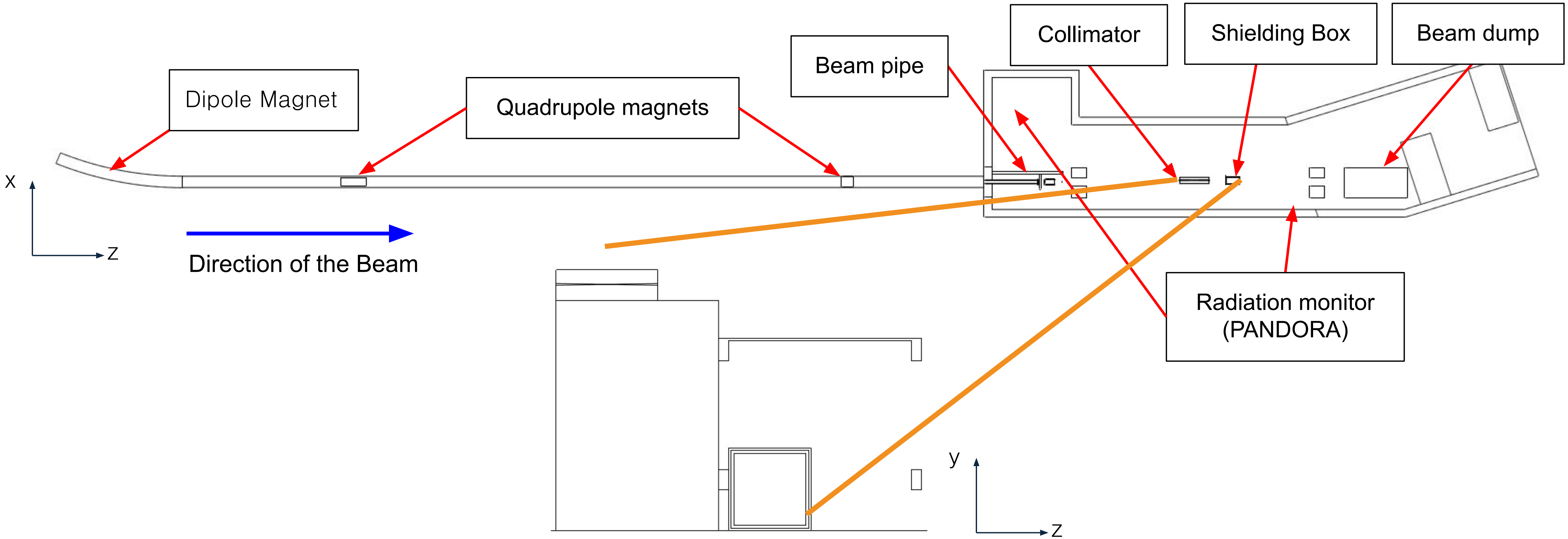
1. To reduce beam intensity → detector R&Ds
2. To trim the beam size

\+ Background radiation and shielding studies

Simulation and Modelling

FLUKA

- FLUKA is a Monte Carlo framework for the interaction and transport of particles in materials
  - Optimized for analyzing radiation environments
- Simulated beam energy: 3 GeV & 6 GeV
- Geometry of PRIMA facility



Validity of Simulation

Is it okay to only use simulation results without actual experiments?

- Neutron Background Simulation vs. Measurement(location: PANDORA)

3 GeV Electron Beam (11.6 ± 1.68 10^{10} per bunch)	Eq-Dose [mSv/h]
Simulation	6.04 ± 1.8
Measurement	7.21 ± 1.4

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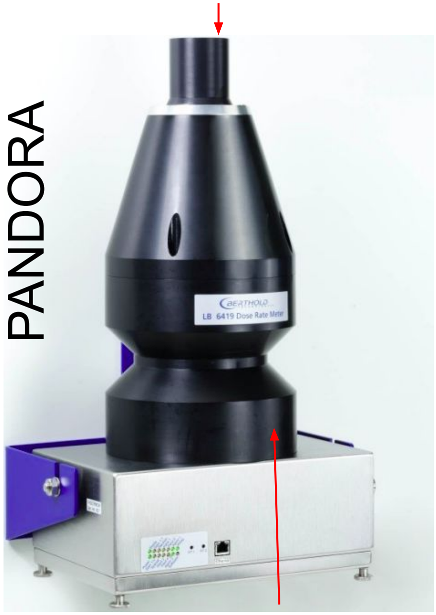
Measurement Devices

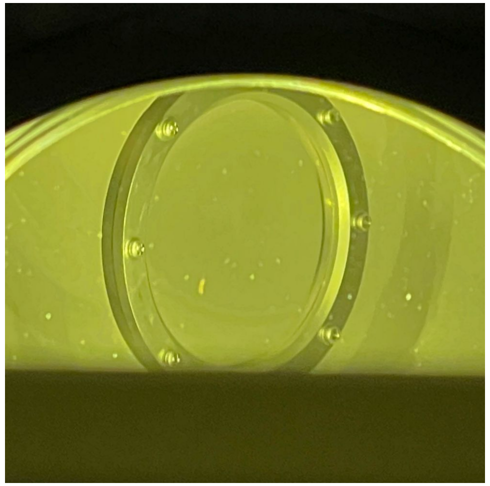
- Radiation monitor, PANDORA
  - Scintillator
    - High energy neutron (> 20 MeV)
  - ^{3}He tube
    - Low energy neutron (< 20 MeV)
    - $^{3}He + N = {}^{1}H + {}^{3}H + Q$

- Beam Screen
  - Measures beam size & shape by scintillating process

Scintillator



^{3}He Tube



Collimator

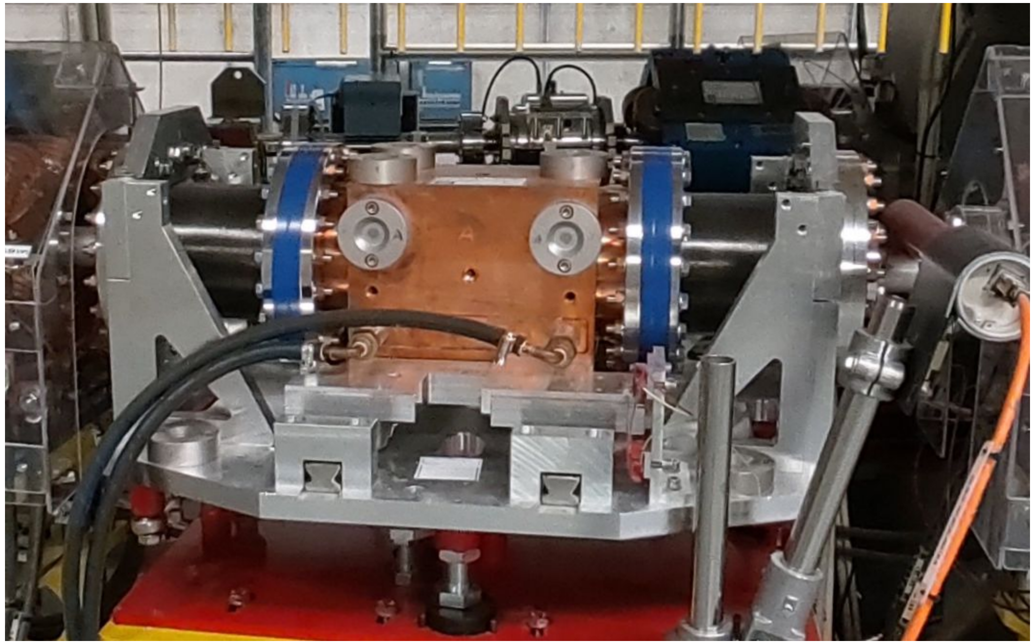
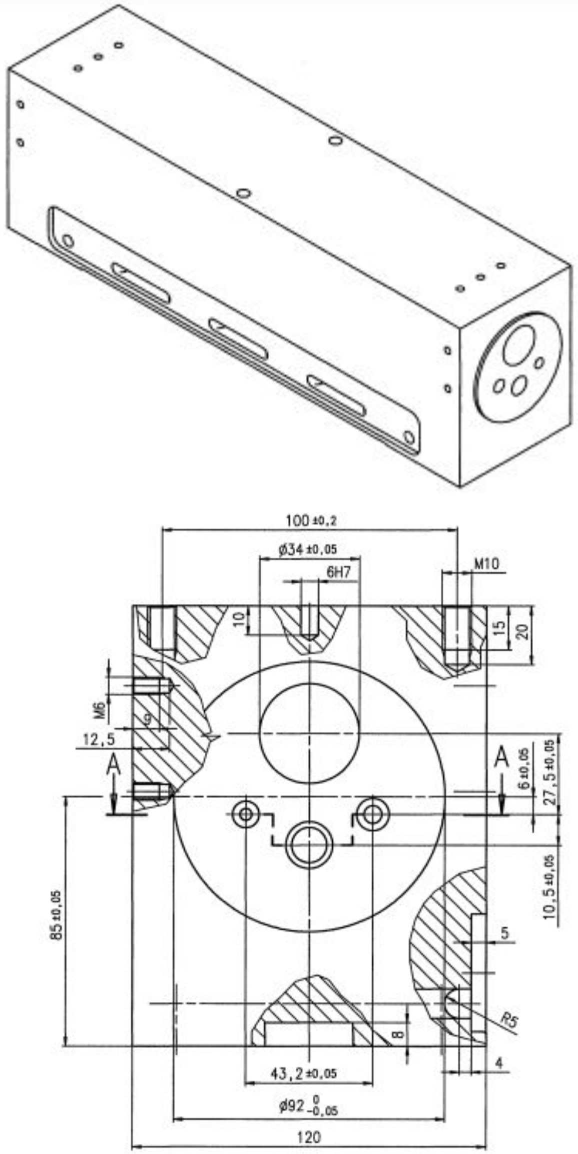


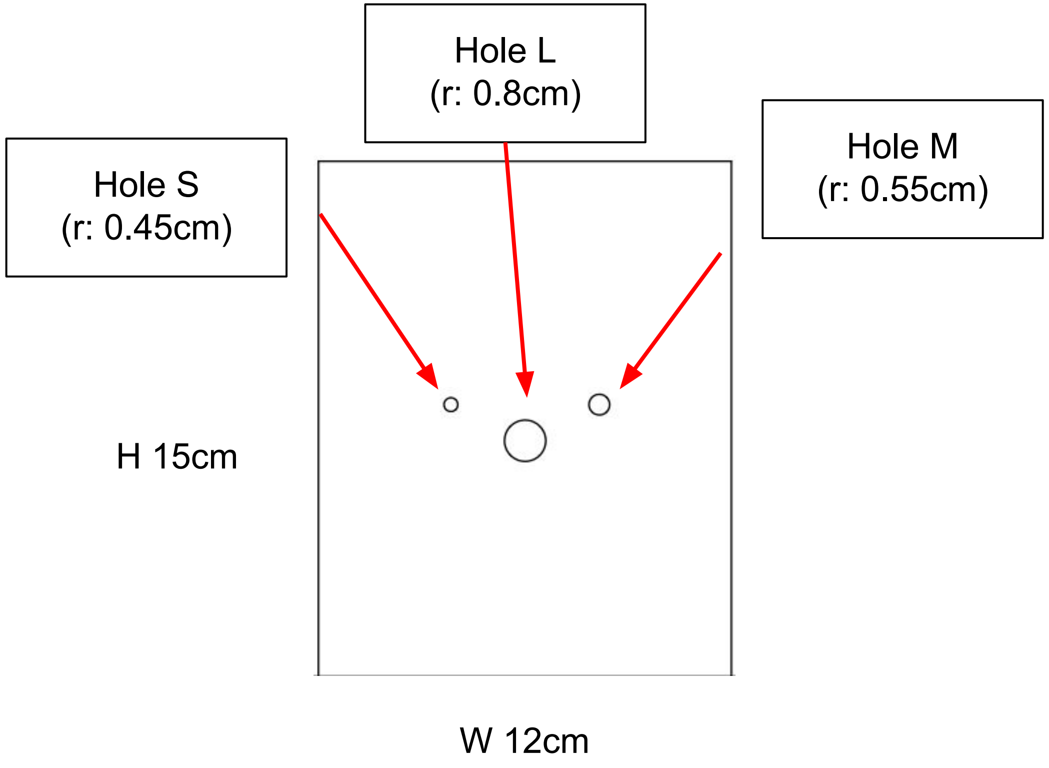
Image of the Collimator

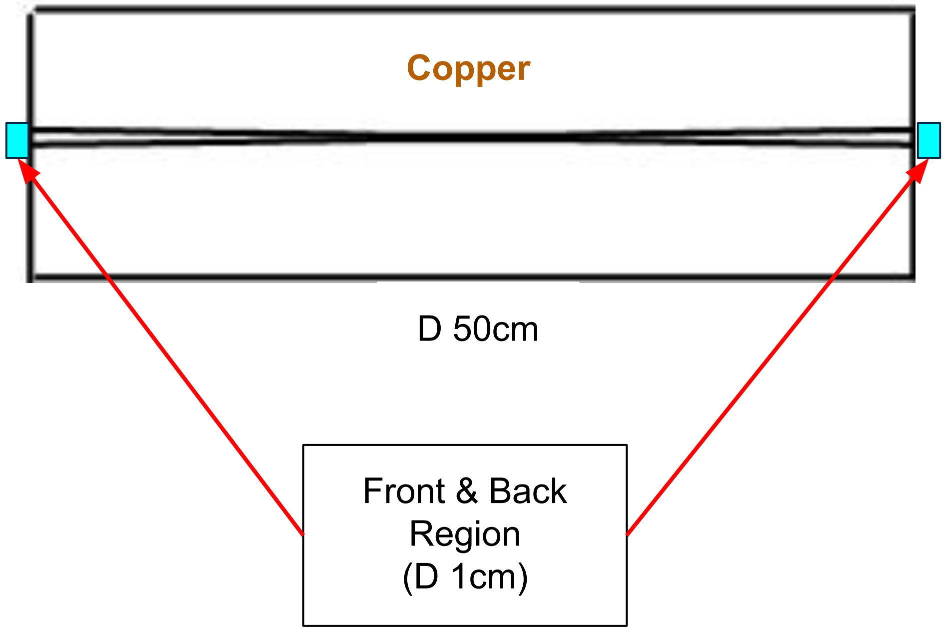


Schematic of the Collimator

Collimator

Geometry of the collimator in simulation

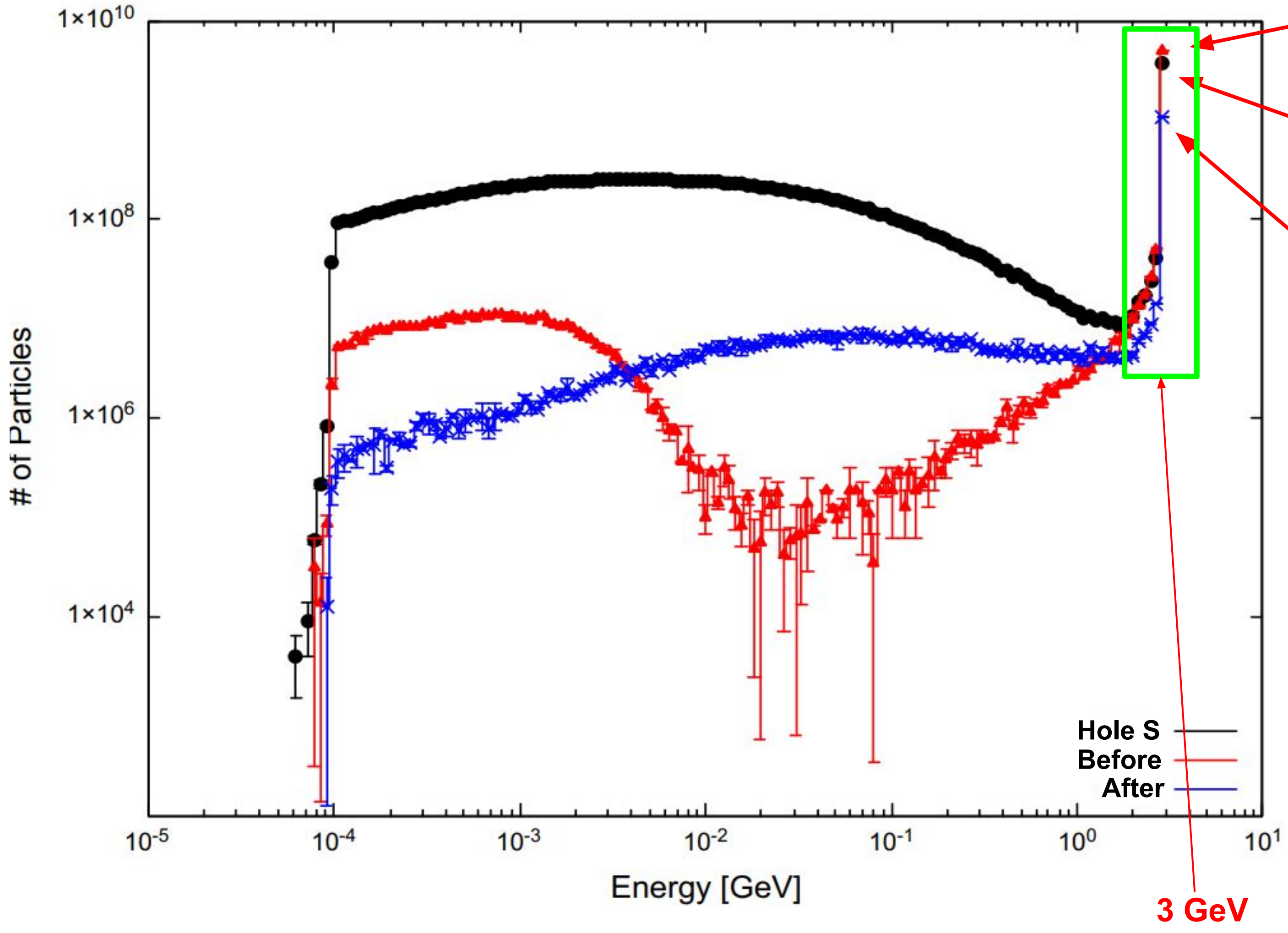




Collimation

Beam Reduction

Number of Electrons According to Energy (HoleS, 3 GeV)
(electron #: 10^{10} per bunch with repeat frequency of 6.25 Hz)



2.31×10^{10} e⁻/s (error 0.11%)

1.73×10^{10} e⁻/s (error 0.13%)

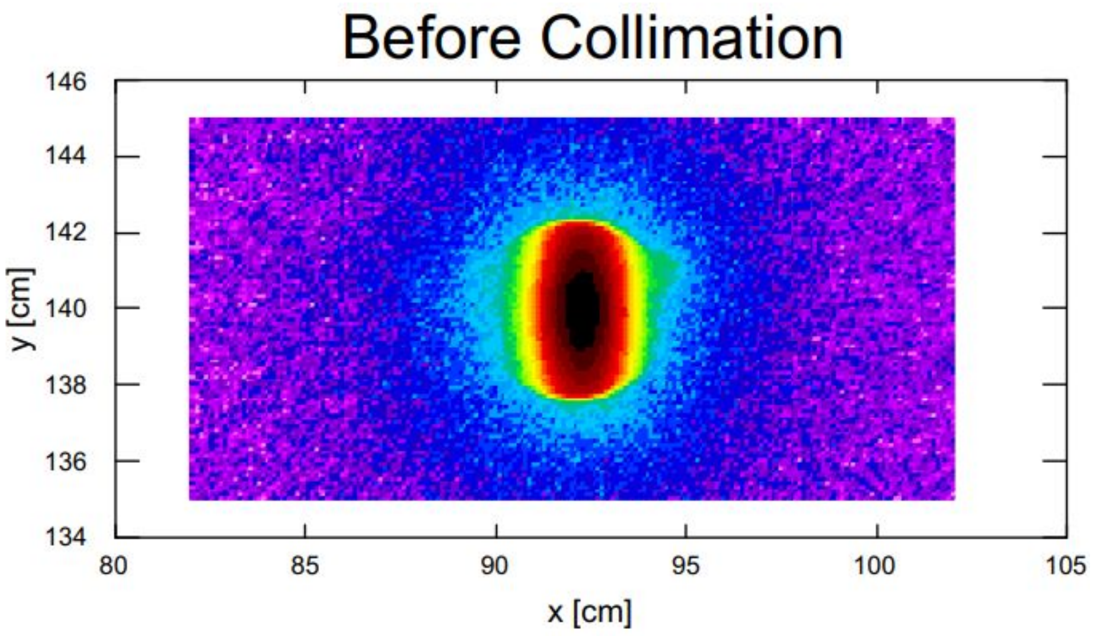
0.50×10^{10} e⁻/s (error 0.40%)

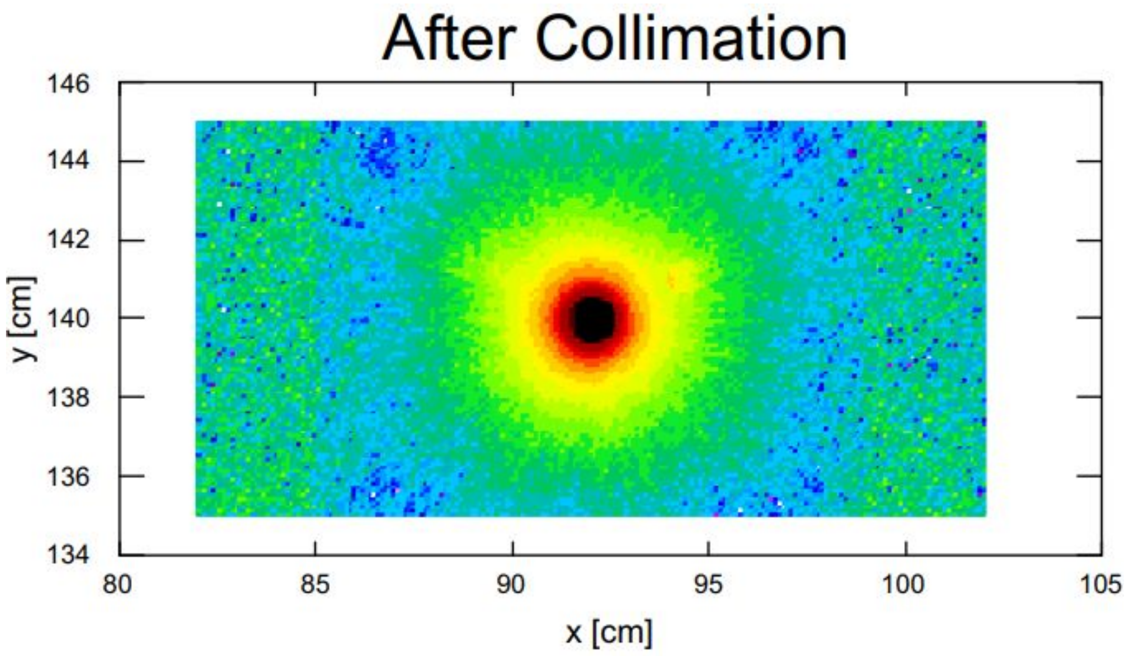
78% reduction

3 GeV Electron Beam (10^{10} per bunch)	Intensity Reduction Rate
Hole S (r: 0.45cm)	78%
Hole M (r: 0.55cm)	67%
Hole L (r: 0.80cm)	35%

Collimation

Beam Shape



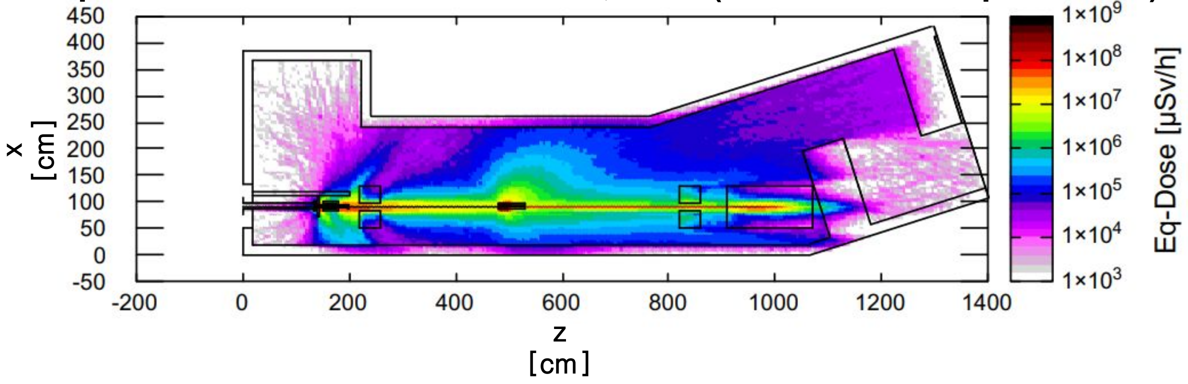


Collimation

Background Radiation

Original & background particles

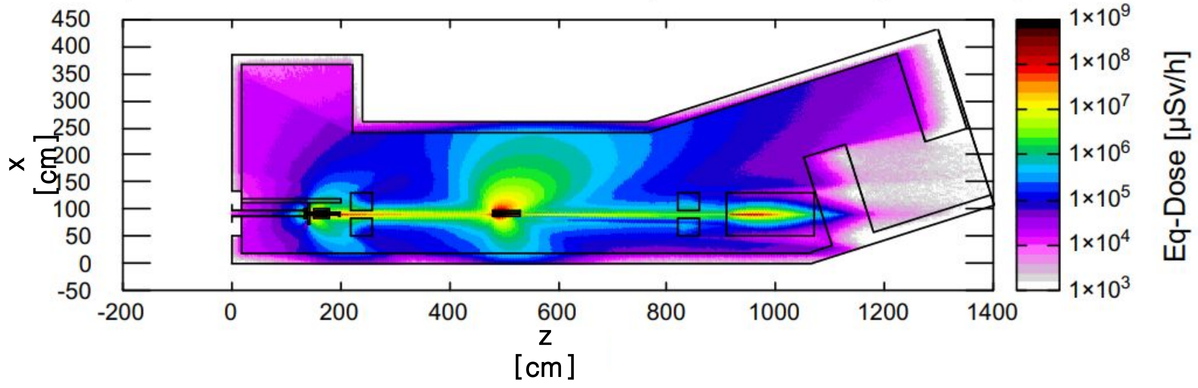
Eq-Dose of Electrons from Hole M, 3GeV(electron #: 10^{10} per bunch)



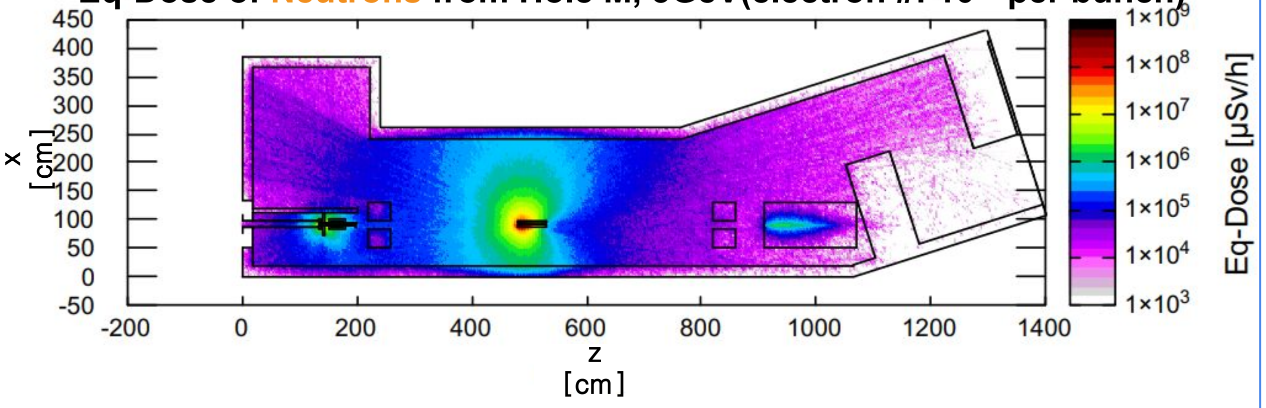
Unwanted particles produced by interaction between the primary beam and the environment mainly via **bremsstrahlung or ionization**

Background particles

Eq-Dose of Photons from Hole M, 3GeV(electron #: 10^{10} per bunch)



Eq-Dose of Neutrons from Hole M, 3GeV(electron #: 10^{10} per bunch)

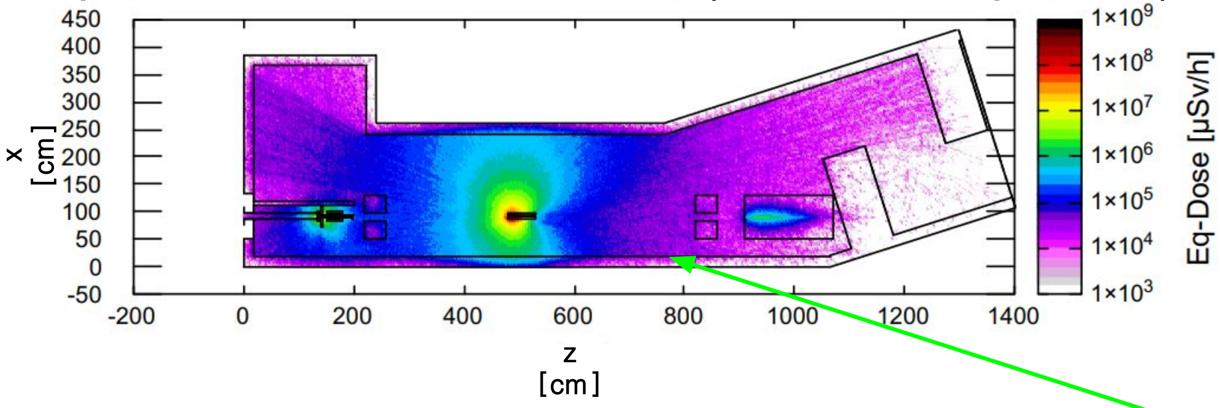


Collimation

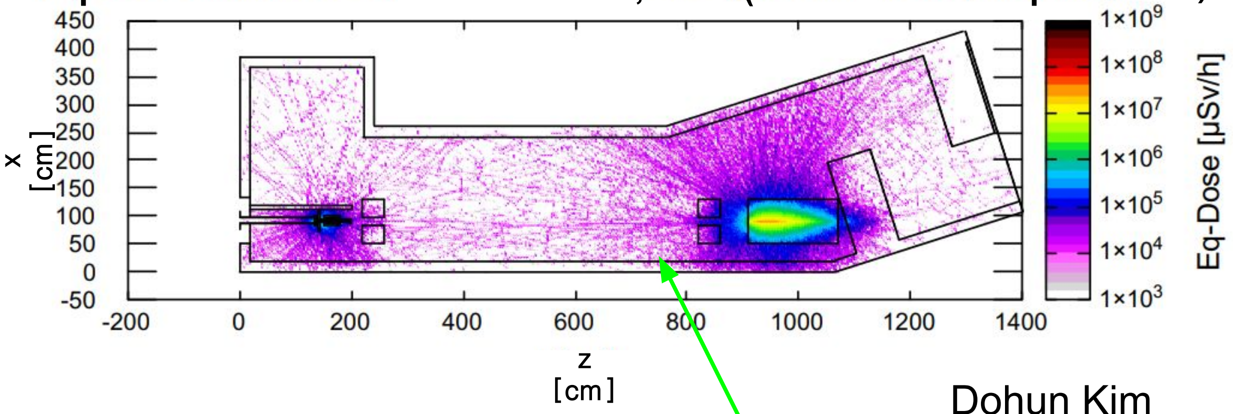
Background Radiation

- Neutron Background With vs. Without Collimator

Eq-Dose of Neutrons from Hole M, 3GeV(electron #: 1E10 per bunch)



Eq-Dose of Neutrons w/o Collimator, 3GeV(electron #: 1E10 per bunch)



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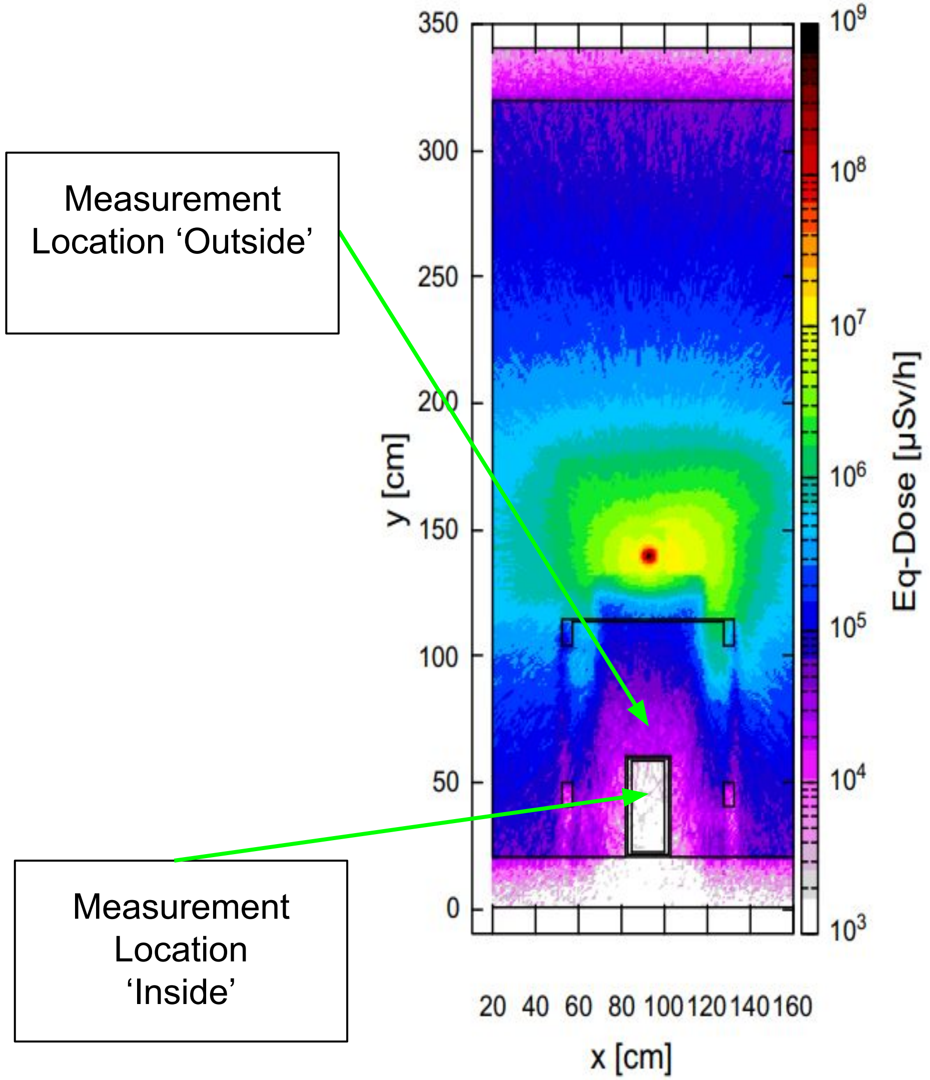
3 GeV Electron Beam ($11.6 \pm 1.68\ 10^{10}$ per bunch)	**with** collimator Eq-Dose [mSv/h]	**without** collimator Eq-Dose [mSv/h]
Simulation	42.3 ± 9.64	4.83 ± 0

Measurement Location

Shielding Box

Geometry & Effectiveness

Eq-Dose of Electrons from Hole L
(electron #: 10^{10} per bunch)



- Geometry: W 21cm, H 40cm, D 40cm
  - Lead(1cm) and boronated polyethylene(1.5cm)

6 GeV Electrons		10^{10} per bunch Eq-Dose [mSv/h]	
Electrons	Outside	17.4± 3.2	**97.3% reduction**
	Inside	0.47 ± 0.35	
Photons	Outside	34.9 ± 2.3	**88.5% reduction**
	Inside	4.0 ± 0.11	
Neutrons	Outside	87.5 ± 3.3	**60% reduction**
	Inside	35 ± 2	

Conclusions & Outlook

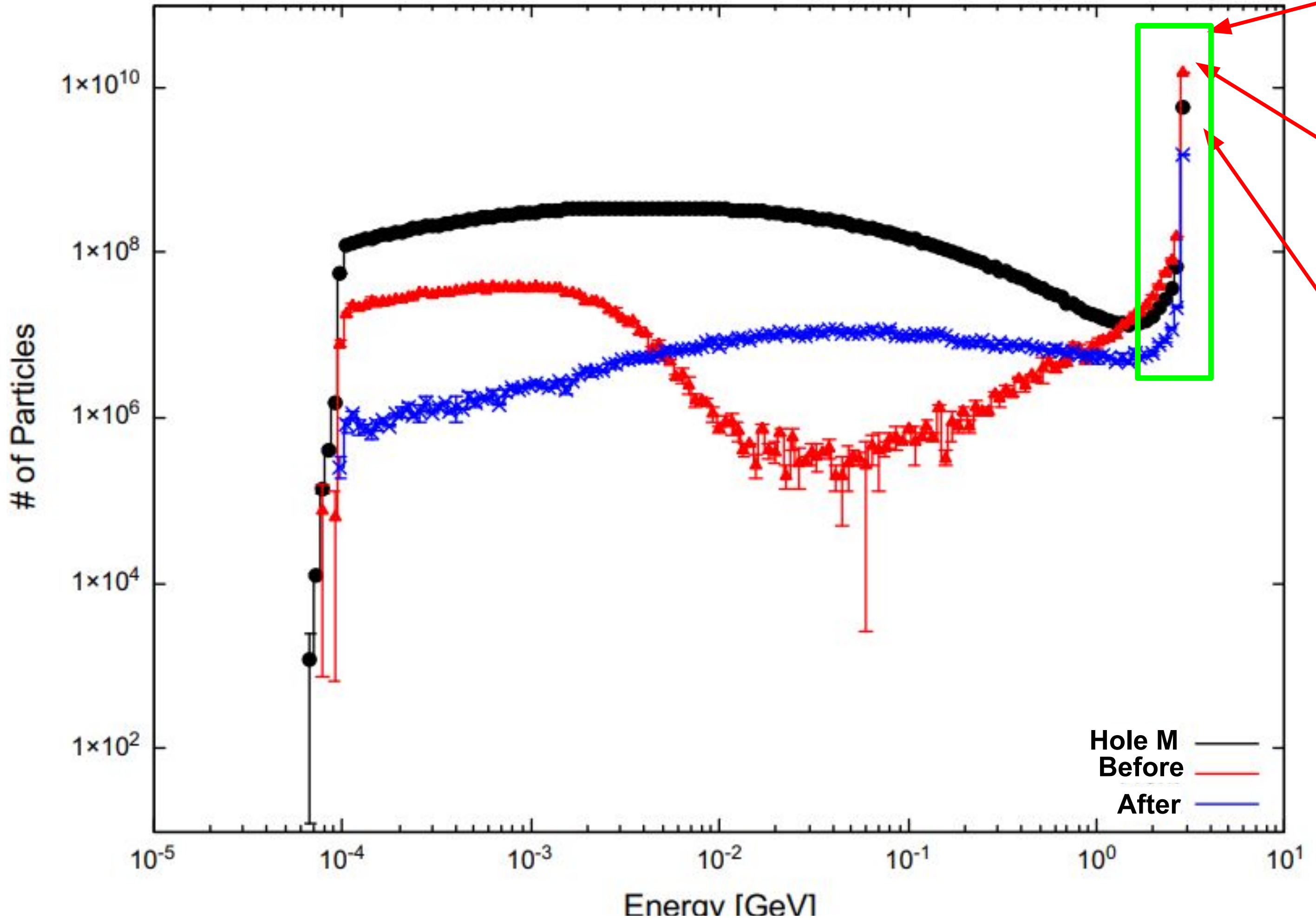
- Confirmed the effectiveness of the collimator in reducing beam intensities
- Increase in background radiation → the need for shielding
- Further validation of simulation results with real experiments

Thank you!

Collimation

Beam Reduction

Number of Electrons According to Energy (HoleM, 3 GeV)
(electron #: 10^{10} per bunch with repeat frequency of 6.25 Hz)



3.23×10^{10} e^-/s
(error 0.35%)

2.69×10^{10} e^-/s
error(0.45%)

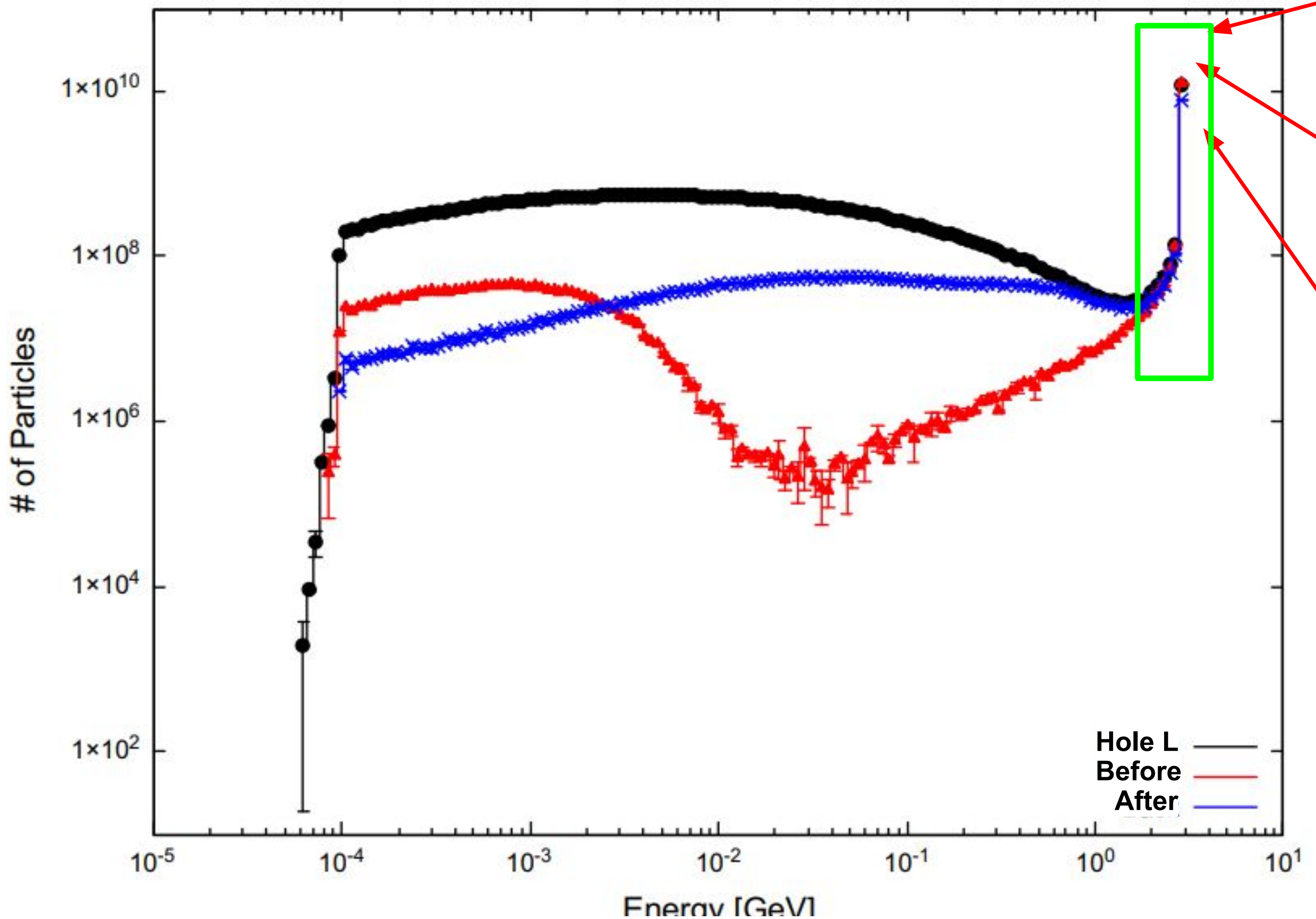
1.08×10^{10} e^-/s
(error 0.47%)

67% reduction

Collimation

Beam Reduction

Number of Electrons According to Energy (HoleL, 3 GeV)
(electron #: 10^{10} per bunch with repeat frequency of 6.25 Hz)



5.73×10^{10} e^-/s
(error 0.07%)

5.63×10^{10} e^-/s
(error 0.13%)

3.71×10^{10} e^-/s
(error 0.40%)

35% reduction