Geant4 simulation for electron background suppression of the wide field view X-ray monitor on HiZ-GUNDAM

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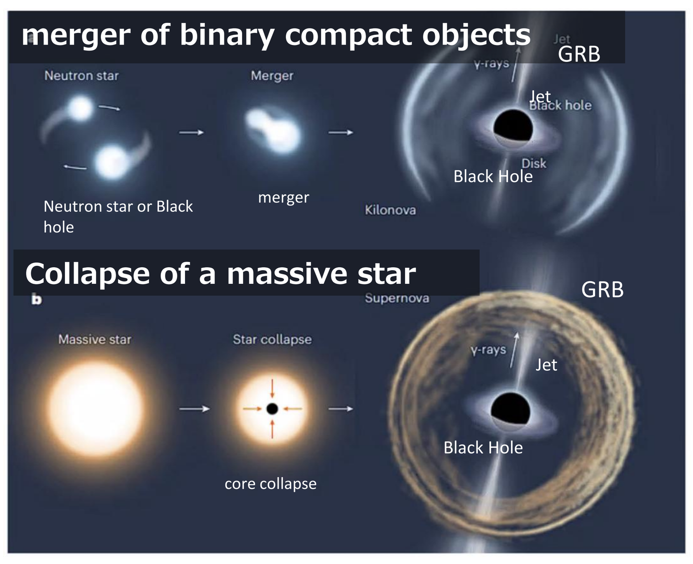
Abstract

Gamma-Ray Bursts (GRBs) are transient phenomena that release radiation energy on the order of 10^{52} ergs and brightest in the universe. The HiZ-GUNDAM project is a future satellite mission aims at contributing to multi messenger astronomy and early universe exploration through observations of GRBs. The HiZ-GUNDAM satellite operate in a sun-synchronous orbit to satisfy the temperature requirements of MONSTER. However, this orbit includes the auroral oval and the South Atlantic Anomaly, where many electrons exist. These electrons and their secondary particles increase the background. In the auroral oval, where electron flux is particularly high, for efficient detection by EAGLE, address the electron background with (i) choosing the thickness and material of the EAGLE cabinet wall, and (ii) the installation of a magnetic diverter that prevents electron incidence on the detector by Lorentz force. In this poster, we report on progress of background electron estimation and countermeasure studies using Geant4 simulations.

1. Introduction

I. Gamma ray bursts (GRBs)

- Transient phenomena
- Release the radiation energy on the order of 10^{52}.
- Known as the brightest explosion in the universe.
- **Can be source of the early universe exploration and Multi-messenger Astronomy**



https://www.nature.com/articles/d41586-022-04165-7#ref-CR5

Fig1 : Origine of GRB

II. *HiZ-GUNDAM*

Wide-field X-Ray monitor EAGLE

1. Detect soft X-Ray from GRBs with wide Field of View(FoV).
2. Localize GRBs with a precision of 3 arcmin.
3. Point toward the GRB

・Parameters
Energy band : **0.4-4 keV**
FoV(1 module) : 0.0333 str
=**3.94e5 arcmin²**
FoV(16 module) : **0.53 str**
Sensitivity : **1e-10 erg/cm²/s (for 100 s exposure)**
Frame Rate : **100 ms/frame**

Multiband Optical and Near-Infrared Simultaneous Telescope MONSTER

4. Follow-up observation.
5. Measure spectroscopic redshift.
6. Localize GRBs with a precision of a few arcsecond.

・Requirement
Pass the Sun-synchronous orbit for cooling.

7. Alert the direction to GRB and the spectroscopic redshift to a large telescope

→ Contribution to the early universe exploration and Multi-messenger Astronomy

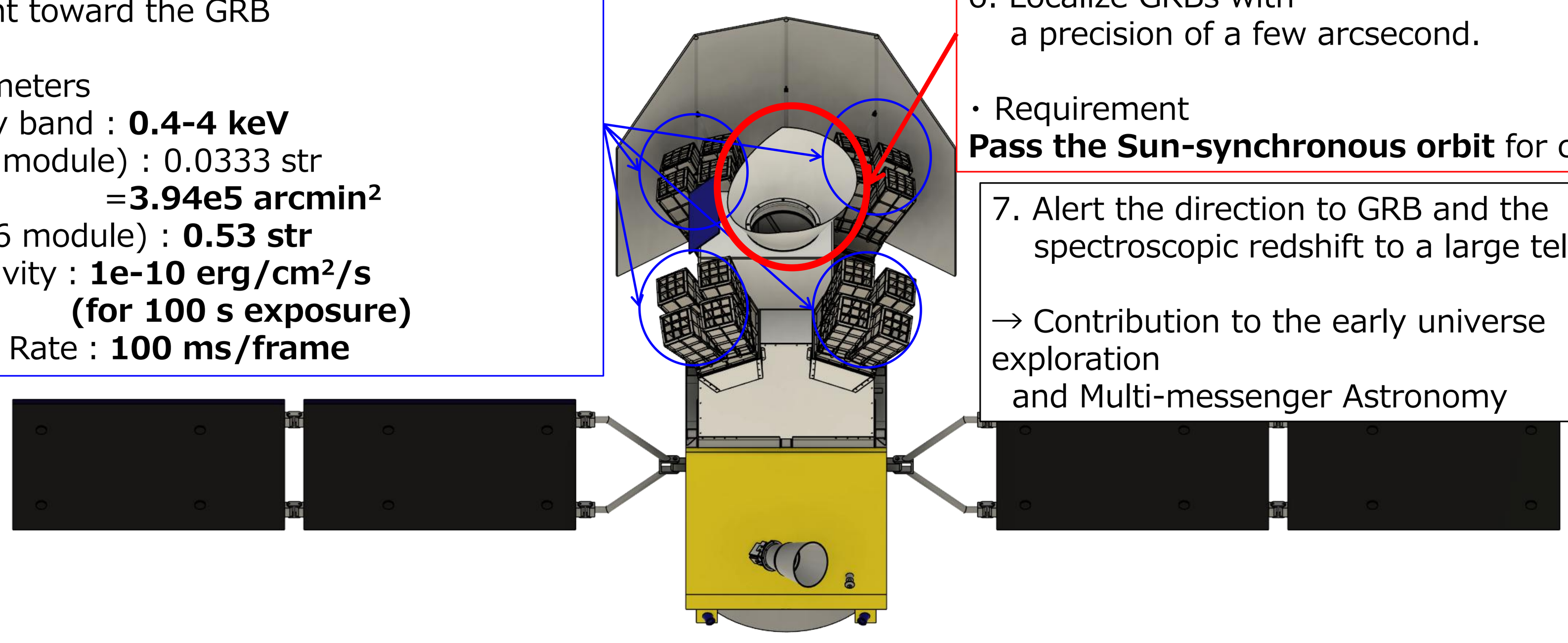


Fig2 HiZ-GUNDAM Satellite

III. Electron Background

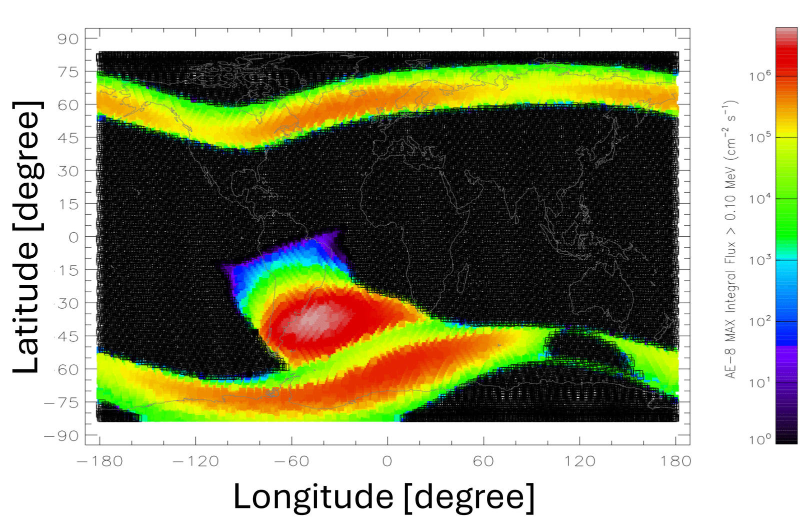


Fig3 Cosmic Electron Distribution (AE-8) @550km

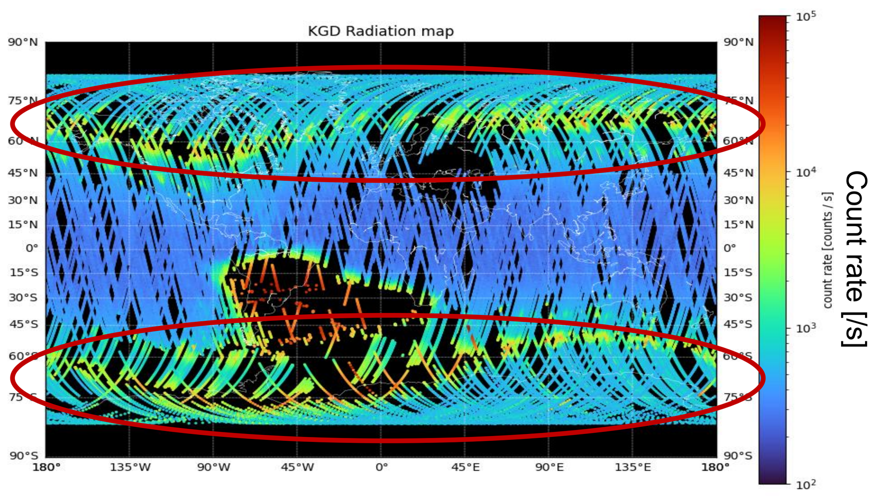
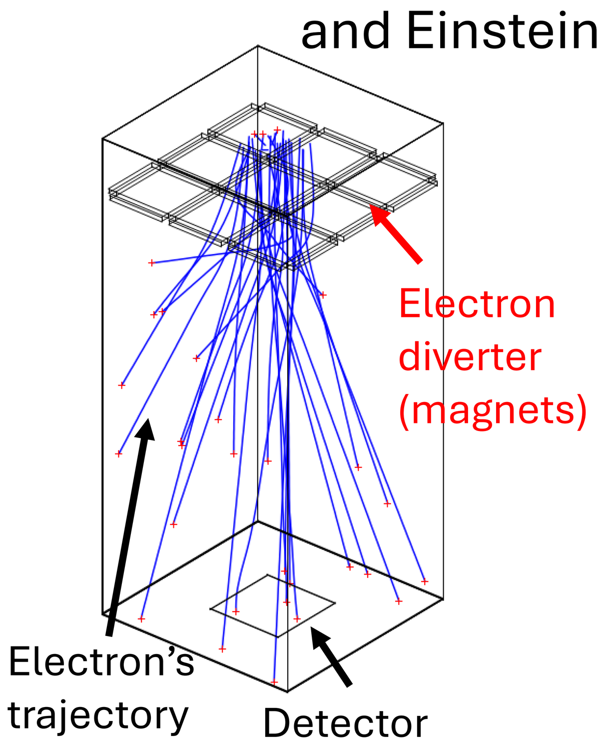


Fig4 Background Distribution of KOYOH satellite

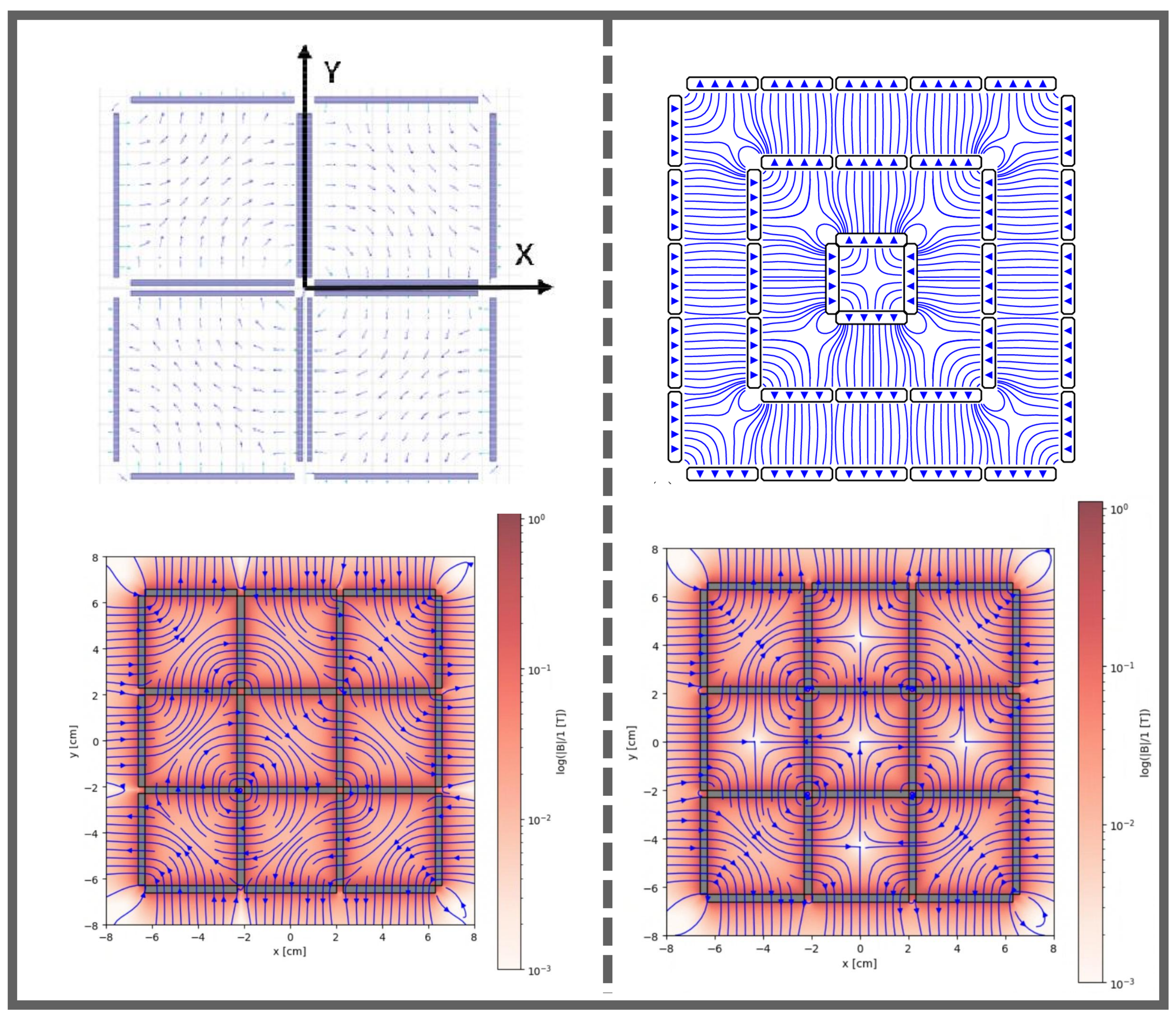
For efficient detection, we want to keep EAGLE's sensitivity of 1e-9 erg/cm2/s as wide range as possible on the orbit.
→Measures against cosmic electron is necessary.

IV. Electron diverter

- Deflecting electron with Lorentz force.
- I evaluated two model of electron diverter inspired by SVOM's and Einstein Probe(EP)'s one with Geant4 simulation.



↑**Fig5 : Illustration of diverter deflecting electron**



→**Fig6 : Magnetic field of diverter{**
Top-left : EP original[1]
Top-right : SVOM original[2]
Bottom-left : Arrange EP's diverter for EAGLE
Bottom-left : Arrange SVOM's diverter for EAGLE}

V. Simulation setup

- Mass model : Takes after EAGLE
- Assume cosmic electron to be isotropic

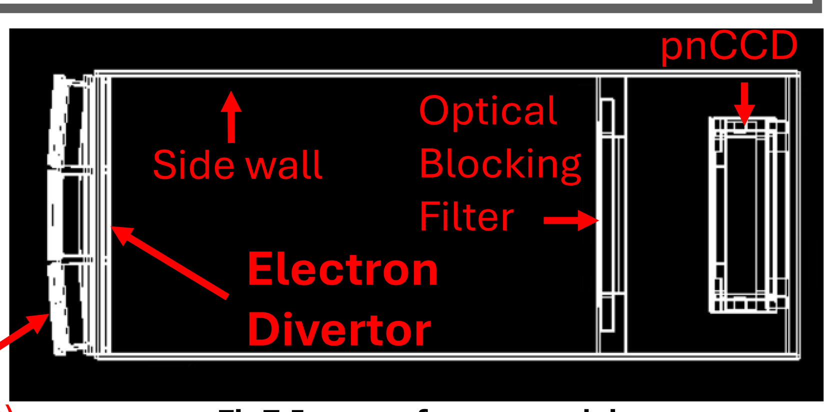


Fig7 Image of mass model

VI. Evaluation of electron background

- Deposits energy special continuously only in 3×3 pixel region on detector.
&
- Amount of energy deposit is within 0.4-40 keV
→ Count as background event.

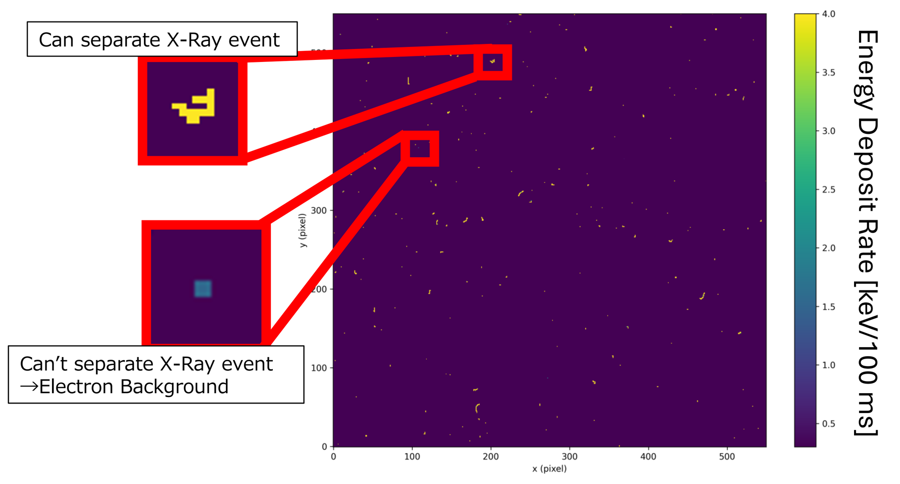
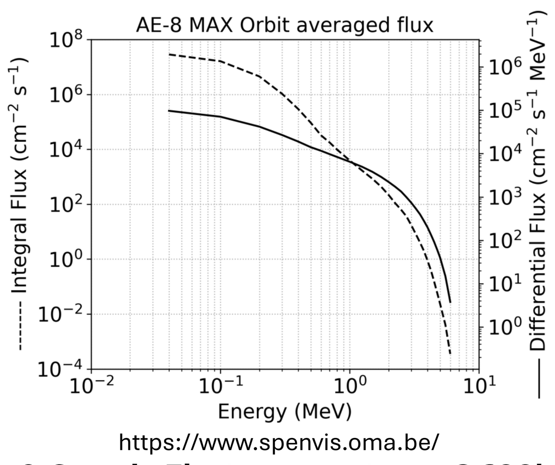


Fig8 Image of electron background

2. Electron incidents from side of EAGLE

I. Spectrum of incident electron

- Use the data from Spenvis (Fig 7)
- Electrons whose energy(E_e) < 40 keV don't incident in this simulation.
- Incident 10^{10} electrons.



https://www.spenvis.oma.be/

Fig9 Cosmic Electron spectrum @600km

II. Result

- Simulate with thickness of side wall of EAGLE = 5,10 mm
- Material of side wall : Al

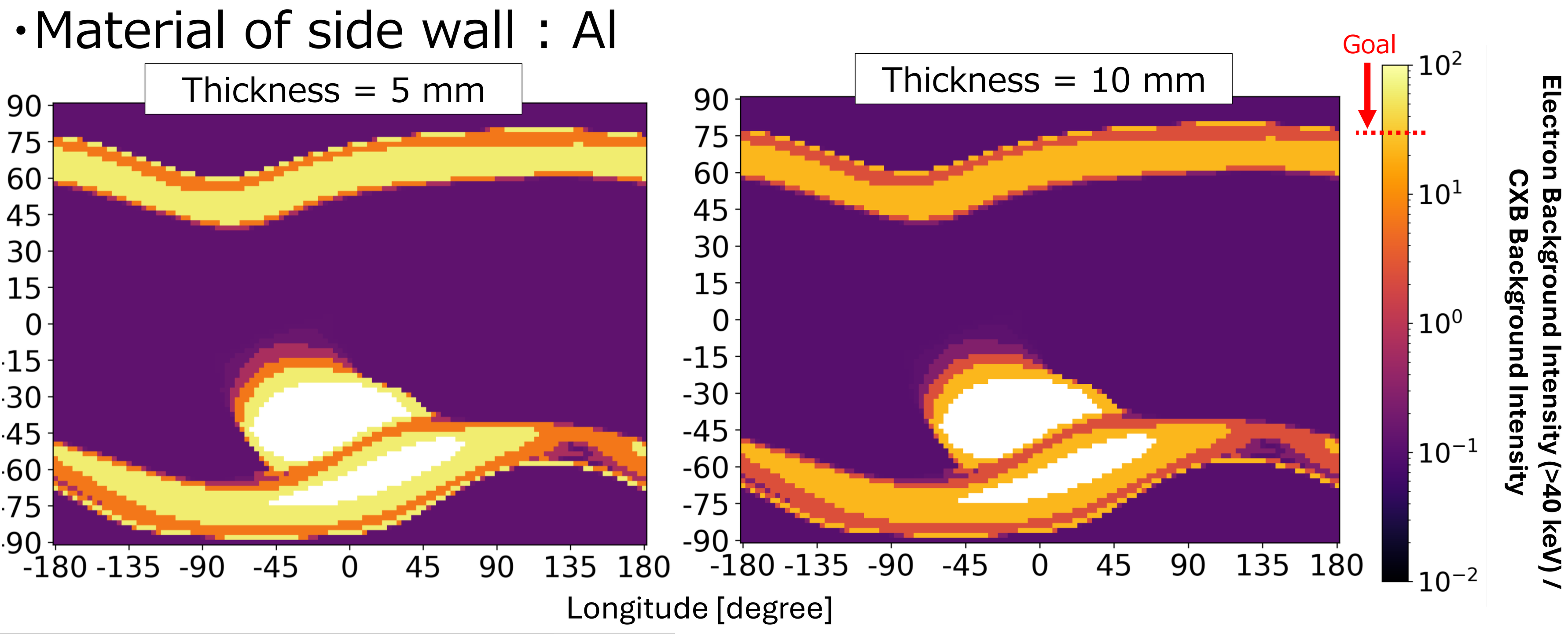


Fig10 Electron Background Intensity map @600km normalized by CXB Background Intensity =10^{-5} /sec/arcmin² [3].
White region means don't calclate intensity.

・10 mm Al wall sufficiently suppress incident of electron.

3. Electron incidents from face of LEO

I. Spectrum of incident electron

- Electrons E_e < 40 keV → uniform spectrum.
- Electrons $E_e \geqq$ 40 keV → Fig9.

Incident 10^8 electrons both of energy band.

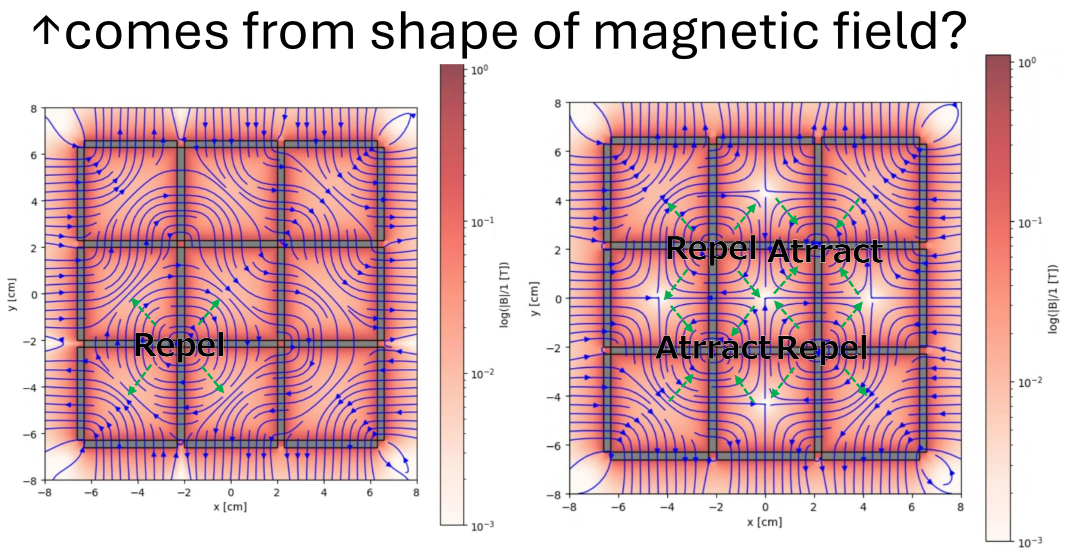
II. Result

10^8 electrons is not enough to calculate intensity of electron background in high latitude
→ Evaluate electron diverter by number of incident particle to detector

	No diverter	EP like	SVOM like
E_e < 40 keV	9705	0	9631
$E_e \geqq$ 40 keV	36746	39	21798

Table1 Number of incident particles to detector

- EP like diverter is more effective than SVOM like one.
↑comes from shape of magnetic field?



- Direction of Lorents force is related to direction of magnetic field.
- Counterclockwise magnetic field attract electrons.

Fig11 Relation of shape of magnetic field and moves of electrons.

4. Future Tasks

Incident more electrons from face of LEO and evaluate electron diverter with intensity.

5. Reference

[1] L. Wang, et al., 2020, "Design of the Permanent Magnet Diverter for Deflecting Electrons on Wide-Field X-Ray Telescope", IEEE
[2] V. Aslanyan, et al., 2019, "Design and implementation of electron diverters for lobster eye space-based X-ray optics", Review of Scientific Instruments
[3] T. Sawano, et al., 2020, "A detection algorithm for faint sources based on 1-d projection for a lobster-eye x-ray imaging system",SPIE