



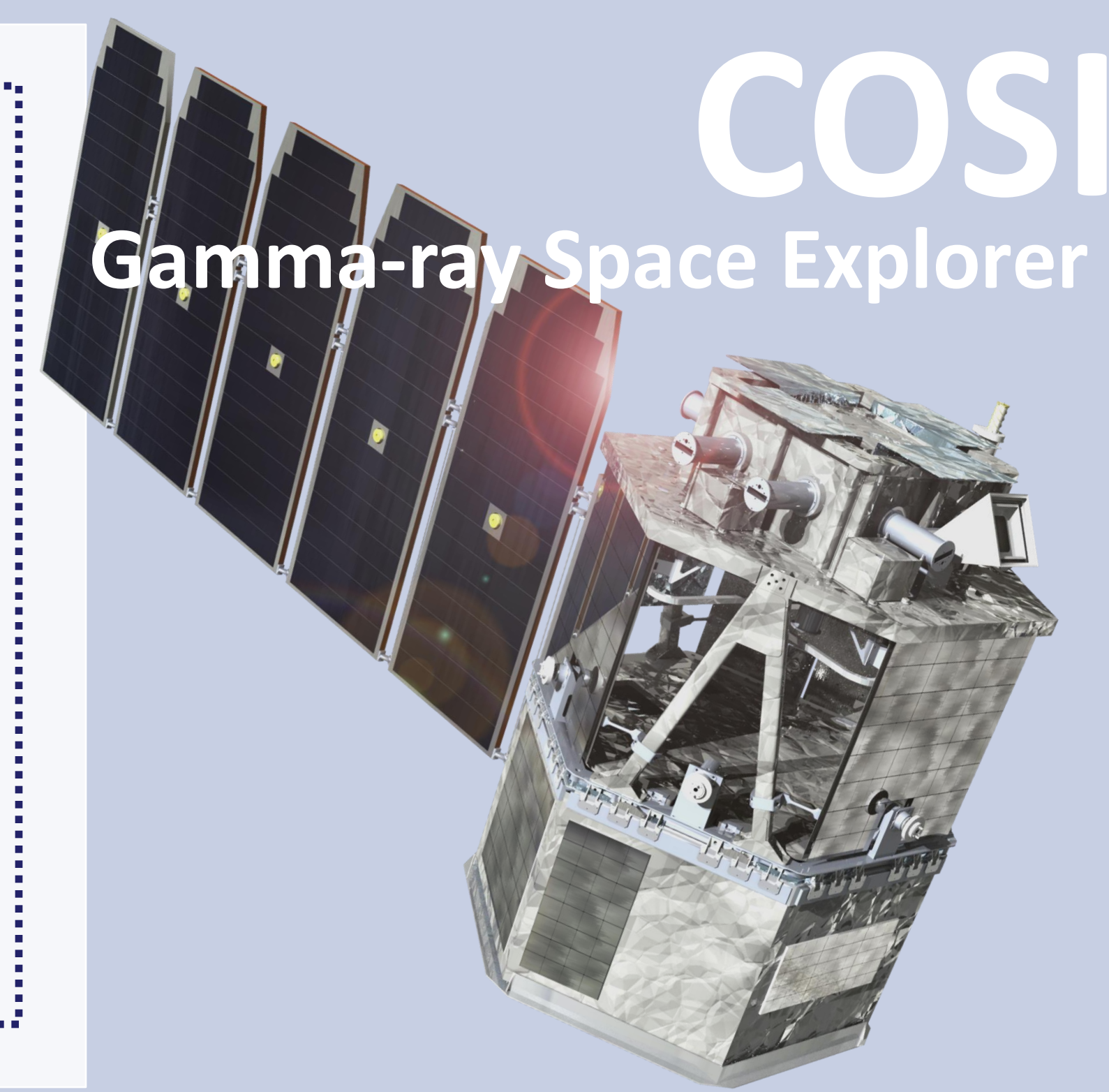
# MeV gamma-ray background from the Moon, its effects in indirect dark matter detection

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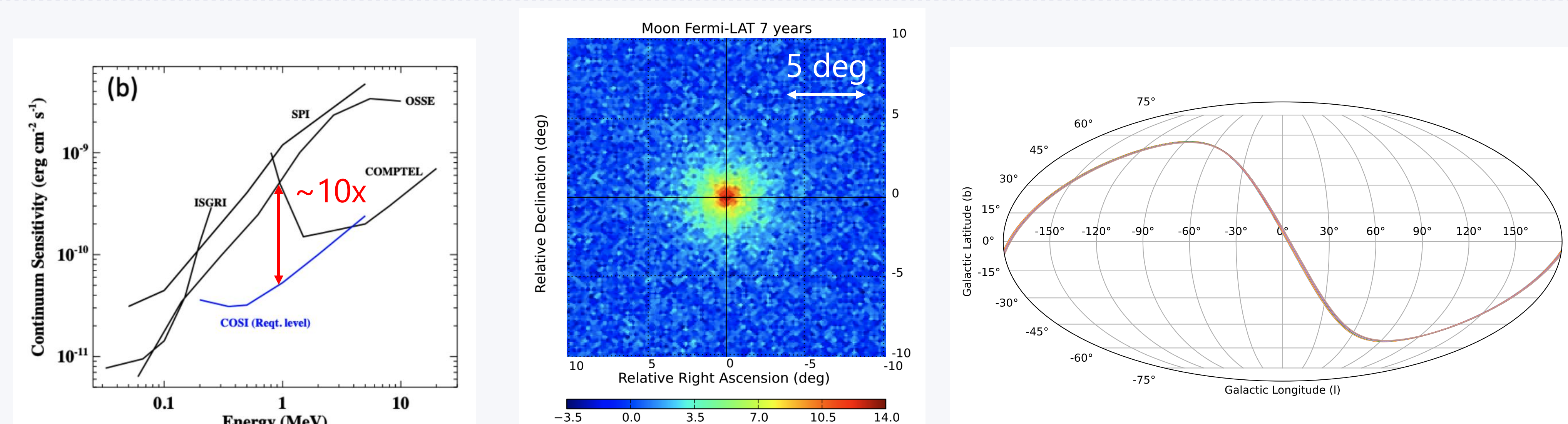


Summary

Gamma-ray space observation is one of the most promising approaches for indirect detection of dark matter (DM). MeV gamma-ray including the 511 keV positron annihilation line is especially attractive for the MeV-scale DM survey. The Compton Spectrometer and Imager (COSI), MeV gamma-ray satellite, is scheduled for launch in 2027 and is expected to greatly advance observations. The key to the indirect detection with MeV gamma rays is a detailed background understanding. In recent years, it has been pointed out that not only Earth's albedo, instrumental and extragalactic backgrounds but also our solar system objects can be sources of steady gamma-ray backgrounds [1]. In this study, we focus on the Moon and predict the spectrum in the energy band of COSI, and discuss it as one of the background sources in the DM searches. In addition to the steady emission, we predict an increase in the lunar albedo caused by energetic particles from solar flares and discuss the possibility of observing them with COSI. As a result, we found that COSI can detect both steady emission and increased gamma rays by 2 years and 12 hours of exposure respectively. This means the Moon can be the background for the DM survey.



Introduction



**Fig. 1:** The continuum sensitivity of COSI in 2 years [2] **Fig. 2:** The lunar gamma-ray image with Fermi-LAT [3] **Fig. 3:** The orbits of the Moon in galactic coordinate in 2028.

- COSI will be launched in 2027 and contribute to MeV DM survey with  $\sim 10\times$  higher sensitivity in MeV band. (Fig. 1)
  - Lunar GeV gamma rays induced by galactic cosmic rays (GCRs) have been observed with Fermi-LAT. (Fig. 2)
  - Moon passes close to the galactic center, up to 2.5 deg in 2028. (Fig. 3)
- Lunar MeV gamma rays could be a background source for COSI, especially for DM search from the galactic center region.

Detectability of the Moon

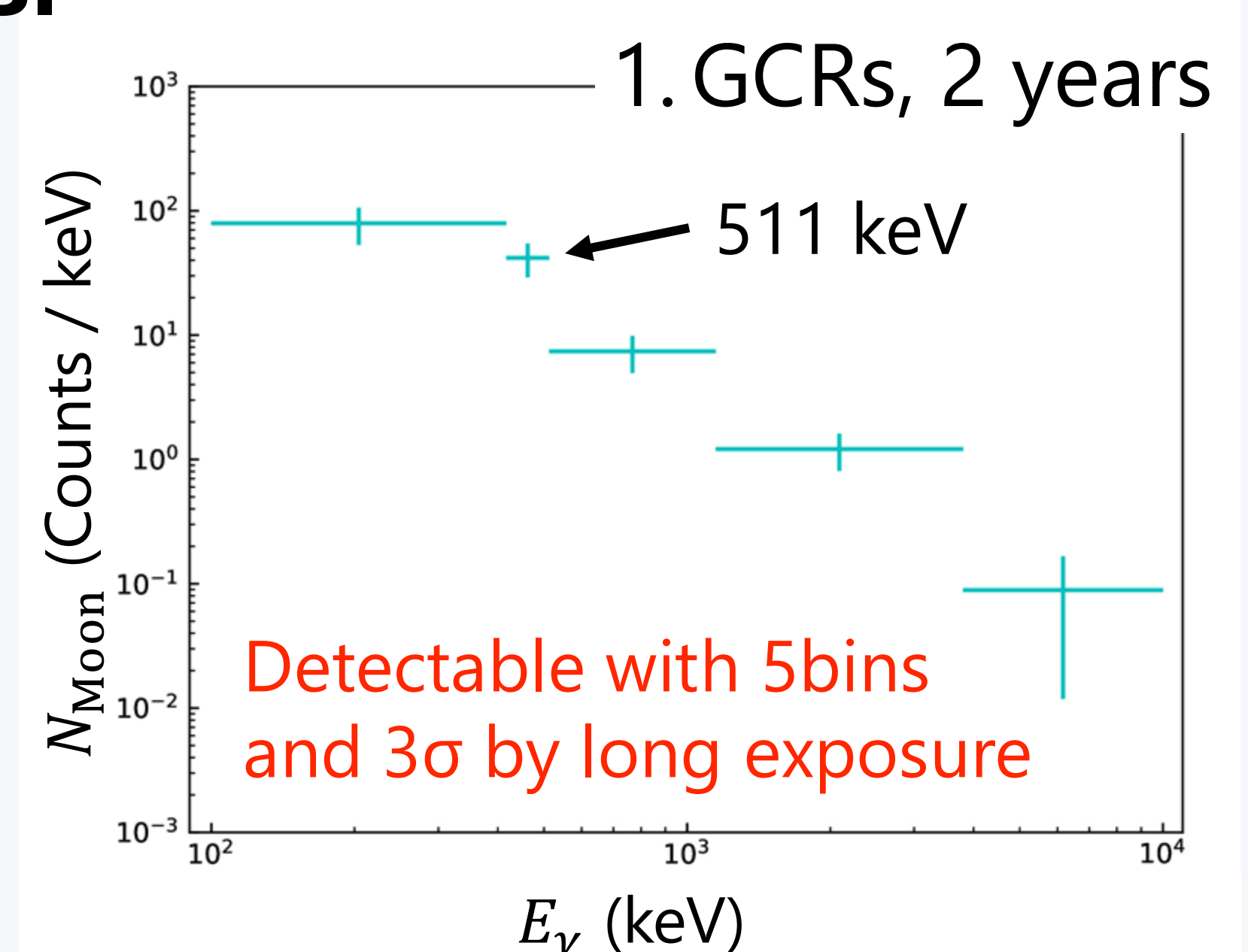
## Full detector simulation of lunar gamma rays with COSI

In this study, we estimated detectability for 2 cases,

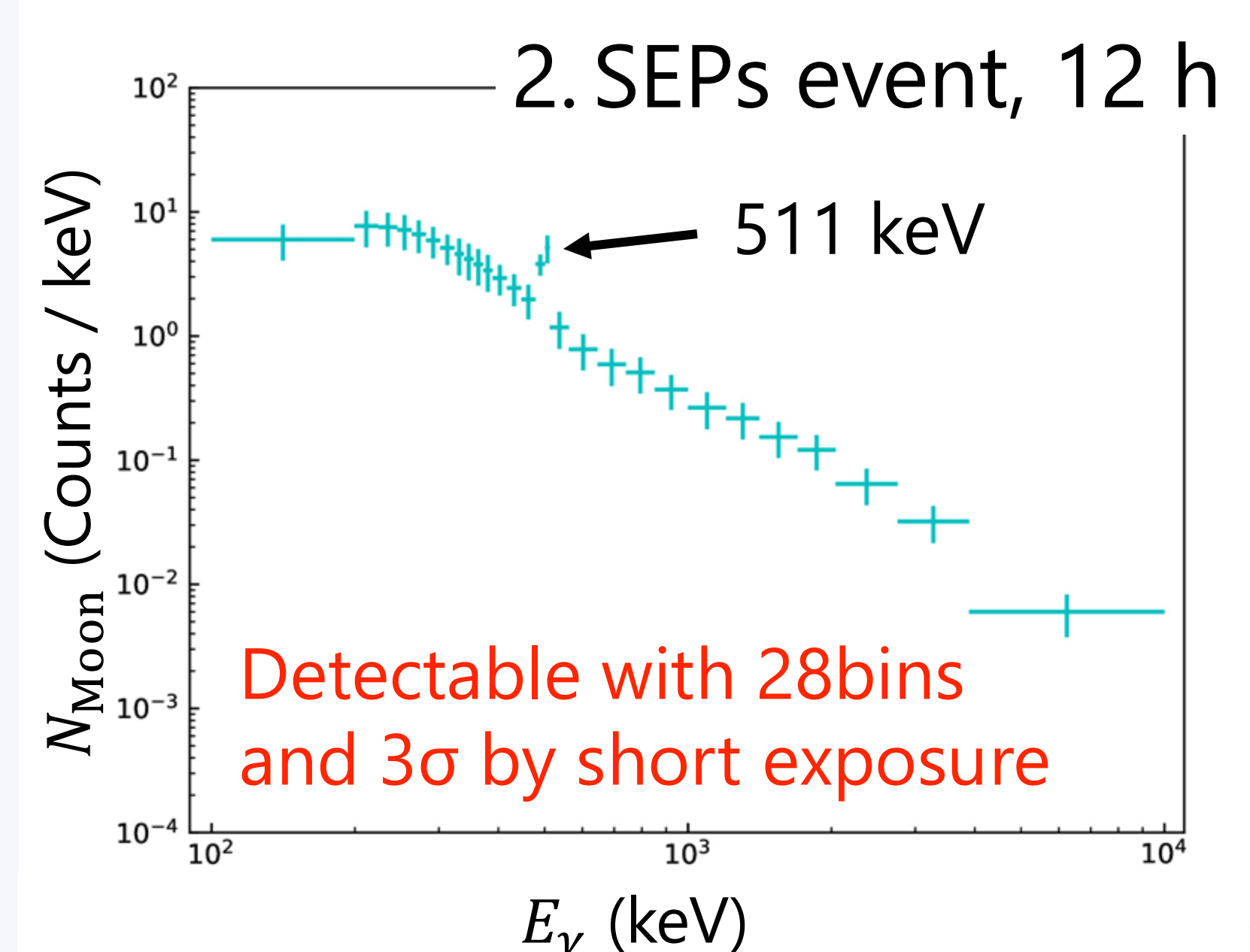
1. Lunar MeV gamma rays induced by **GCRs** with COSI.
2. Temporal lunar MeV gamma rays brightening by protons of Solar Energetic Particles (**SEPs**) event, assuming one of the brightest SEPs, Jan. 20, 2005 SEPs event.

using MEGALib simulation with COSI Data Challenge 2 setup

- Lunar position: the galactic center and no moving.
- Spectrum: simulated gamma rays induced by GCRs with 500 MV solar modulation (medium solar activity) [4].
- Background
  - Earth albedo, cosmic gamma rays, activation of satellite
- Data selection
  - Pointing: within 60 deg of COSI's line of sight
  - Angular resolution Measure (ARM): within  $\pm 0.5$  FWHM



**Fig. 4:** Expected steady lunar gamma-ray spectrum for 2 years.



**Fig. 5:** Expected lunar gamma-ray spectrum assuming the Jan. 20, 2005 SEPs event for 12 hours.

**COSI can detect both gamma rays by GCRs and SEPs.**

Discussion

## For indirect DM survey with COSI

1. GCRs: The lunar gamma rays by GCRs are not bright but detectable by 2-year order observation.
  - **The Moon should be considered as a background source.**
2. SEPs event: The lunar gamma rays by SEPs are bright and detectable by 1-day order observation.
  - **Data during bright SEPs event should be removed.**

## Future plans

- More detailed Moon model
  - Moving source, solar activity, particles other than proton, etc.
- Further consideration of background
  - Other solar system bodies, MeV celestial bodies, etc.

## References

- [1] Siegert (2023)
- [2] Tomsick et al. (2023), PoS(ICRC2023)
- [3] Loparco et al. (2017)
- [4] Moskalenko et al. (2008)