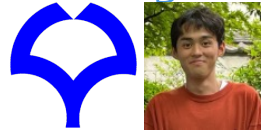


# MeV Gamma-Ray Emission: A New Window for Local MeV Cosmic Rays

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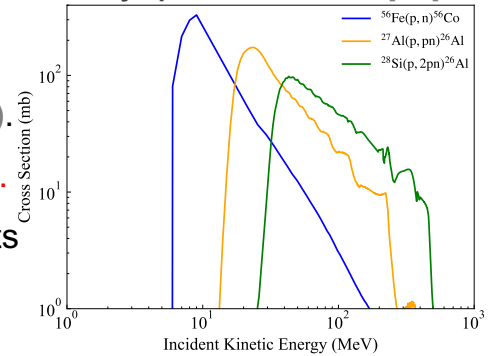
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## MeV CR Irradiation on the Lunar Surface

- Galactic CRs induce nuclear reactions on lunar surface [1-2].
- MeV CRs cause nuclear excitation and spallation (right figure).  
→ Subsequent MeV gamma-ray lines serve as MeV CR tracers.
- We explore the potential of future MeV gamma-ray instruments for solar-terrestrial MeV CR searches.

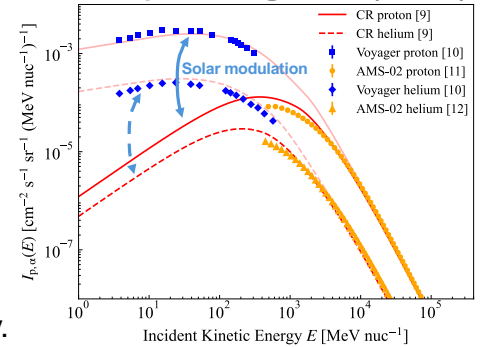
$^{56}\text{Co}$ ,  $^{26}\text{Al}$  production cross section by spallation reaction [3-4]



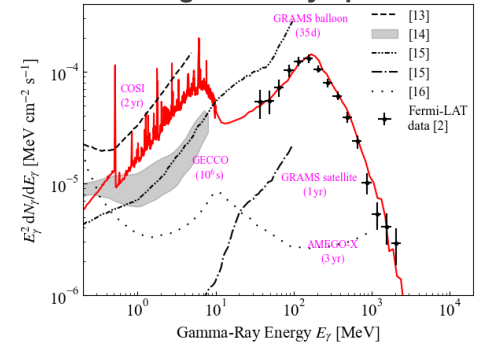
## Lunar MeV-GeV Gamma-Ray Spectrum

- Using Geant4 Monte Carlo particle simulations, we calculate gamma-ray yields arising from CR interactions.
  - Geant4 toolkit simulates passage of particles through matter [5-7].
  - CR  $p$  &  $^4\text{He}$  hit material with lunar surface composition [8].
  - Consider hadronic interactions, EM processes, & radioactive decay.
- We derive the lunar MeV-GeV gamma-ray spectrum assuming time-independent CR intensity (right figures).
- Future observations will detect Moon's MeV continuum.
- Several key line features:  $e^+$ ,  $^{56}\text{Co}$ ,  $^{26}\text{Al}$  would be observable by a possible GRAMS satellite mission [15].

CR spectrum @ Moon (model)



Lunar gamma-ray spectrum



## Prospect for Lunar MeV Gamma-Ray Observations

- Galactic CRs in  $10 \text{ MeV} \lesssim E \lesssim 1 \text{ GeV}$  contribute to production of lunar MeV gamma-ray lines (right figure).
- Due to varying radioactive lifetimes  $\tau$ , observations of different MeV lines can offer insight into CR history over  $\sim \tau_{\text{max}}$ .
- Future MeV missions will measure  $\lesssim \text{GeV}$  Galactic CR flux & its long-term evolution via lunar MeV gamma-ray observations.

Impact of CR (proton) on MeV gamma-ray line formation

