

József Gábor Szűcs

Muographers 2026

Budapest, 1–5 June

Muography on Mars and on the Moon

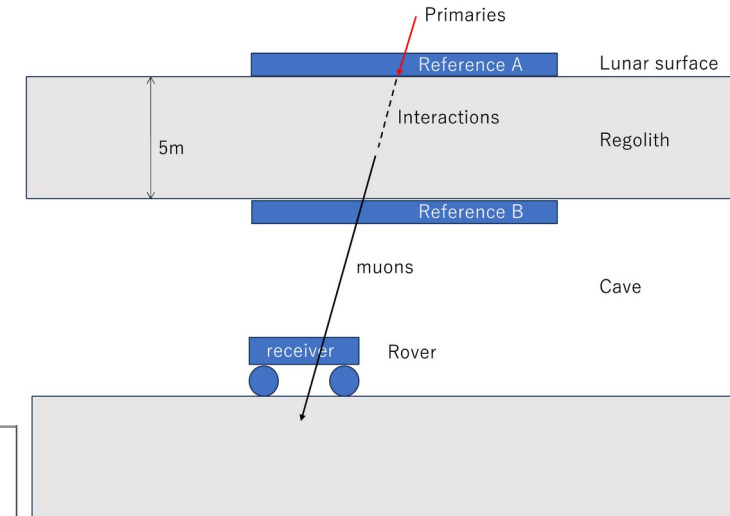
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1. HUN-REN Wigner Research Centre for Physics Department of High Energy Experimental Particle and Heavy Ion Physics, 1121 Budapest, Konkoly-Thege Miklós út 29-33.

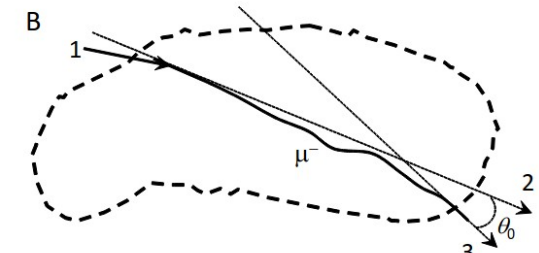
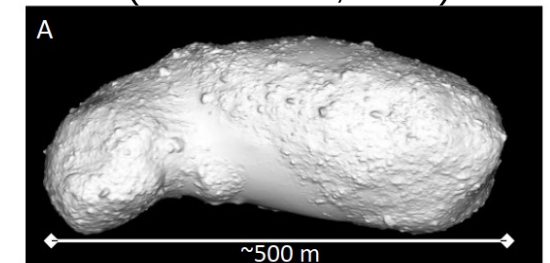
- I. Is there an analogy in muon creation in the atmosphere between Earth and Mars?**
- II. How muons are generated on the Moon?**
- III. How muon flux compares on Mars and the Moon to Earth?**
- IV. What is the background like on Mars and the Moon?**

Muography outside Earth

- Geological surveys for science, engineering, raw materials
- MuWNS: subsurface navigation



(Leone et al., 2025)



(Prettyman et al., 2014)

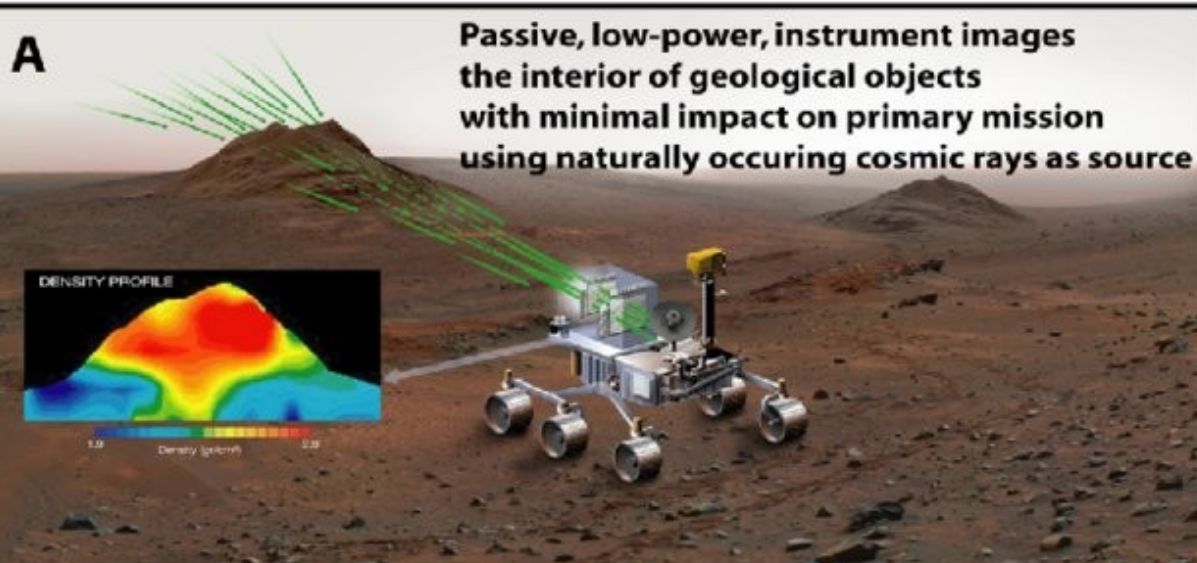


installation of primary airlock



certification of initial facility

(Baiden et al., 2010)

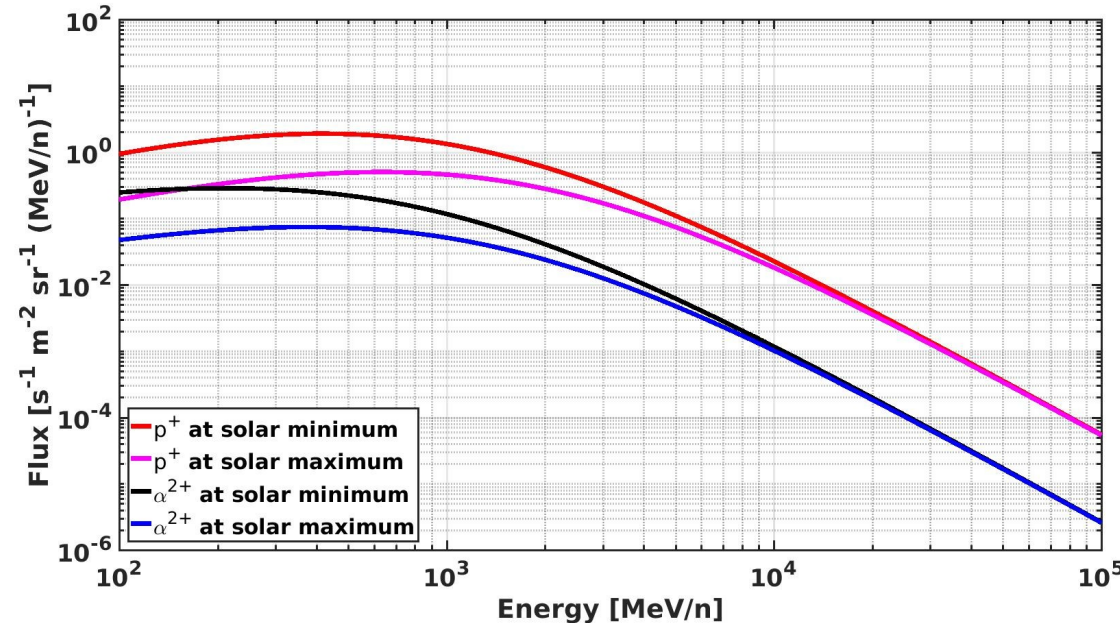
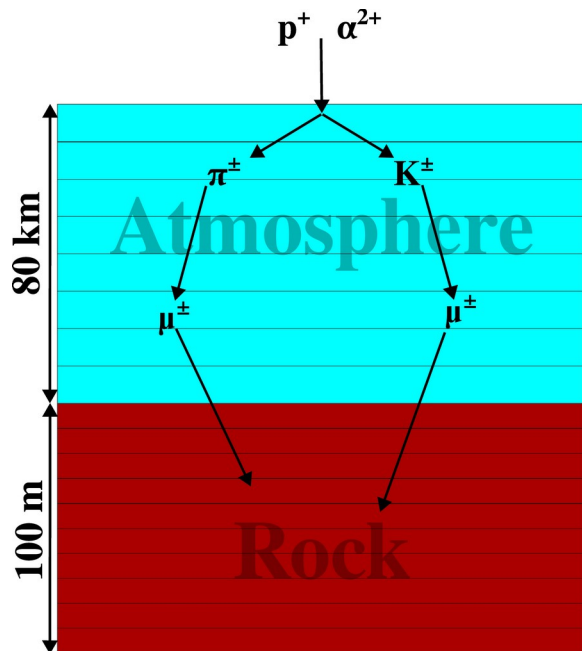


(Kedar et al., 2013)

Simulation model



- Primary source: p^+ and α^{2+} particles from Papini et al., 1996
- Atmosphere: 1976 US standard (Earth), European Mars climate database



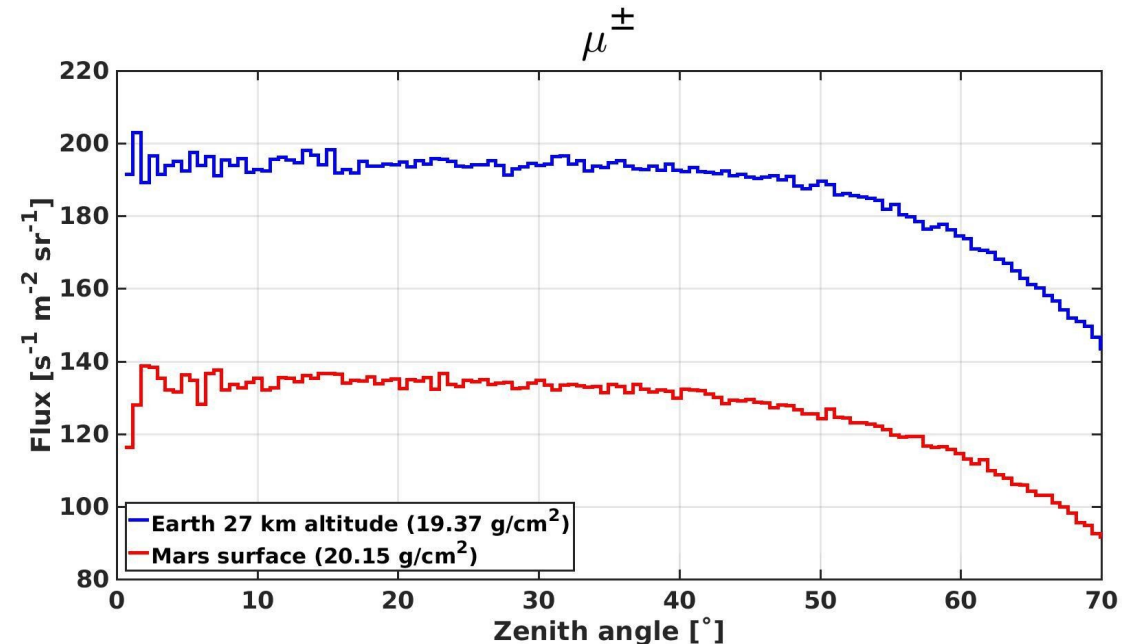
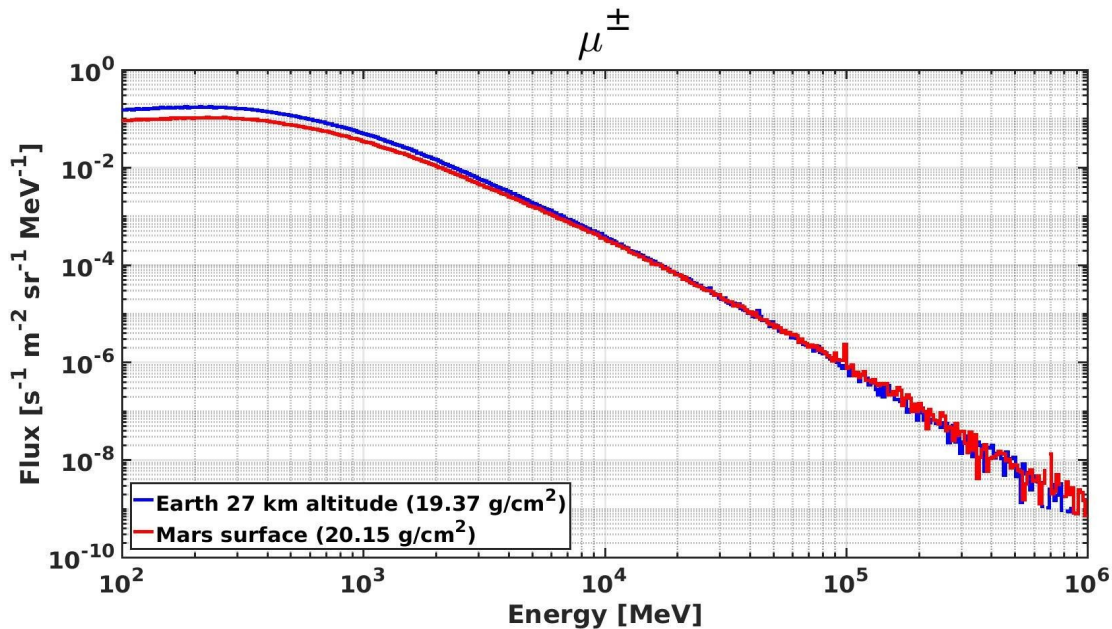
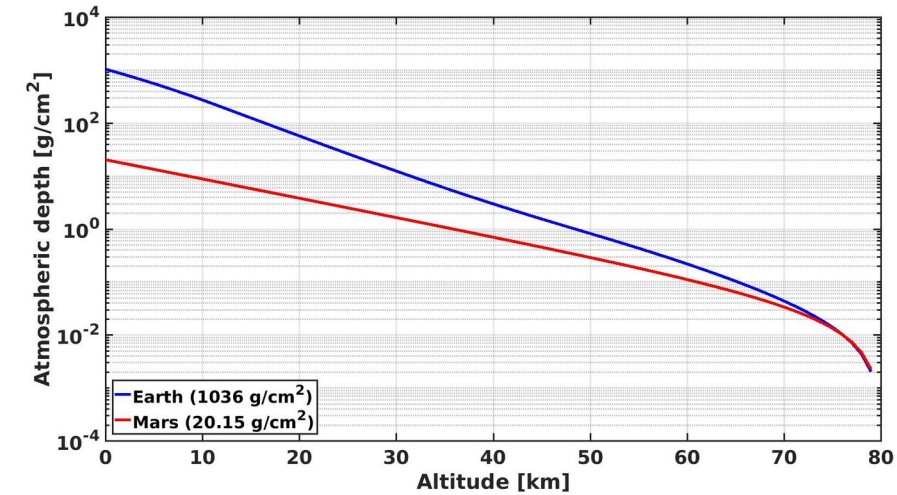
Element	Weight fractions of elements		
	Earth	Mars	Moon
O	0.533	0.468	0.427
Si	0.467	0.239	0.203
K	0	0.071	0
Fe	0	0.065	0.117
Al	0	0.049	0.076
Na	0	0.042	0.003
Ca	0	0.036	0.077
Mg	0	0.022	0.061
H	0	0.008	0
Ti	0	0	0.032
Cr	0	0	0.003
Mn	0	0	0.001

McKenna-Lawlor et al., 2012 (Mars)

McKinney et al., 2006 (Moon)

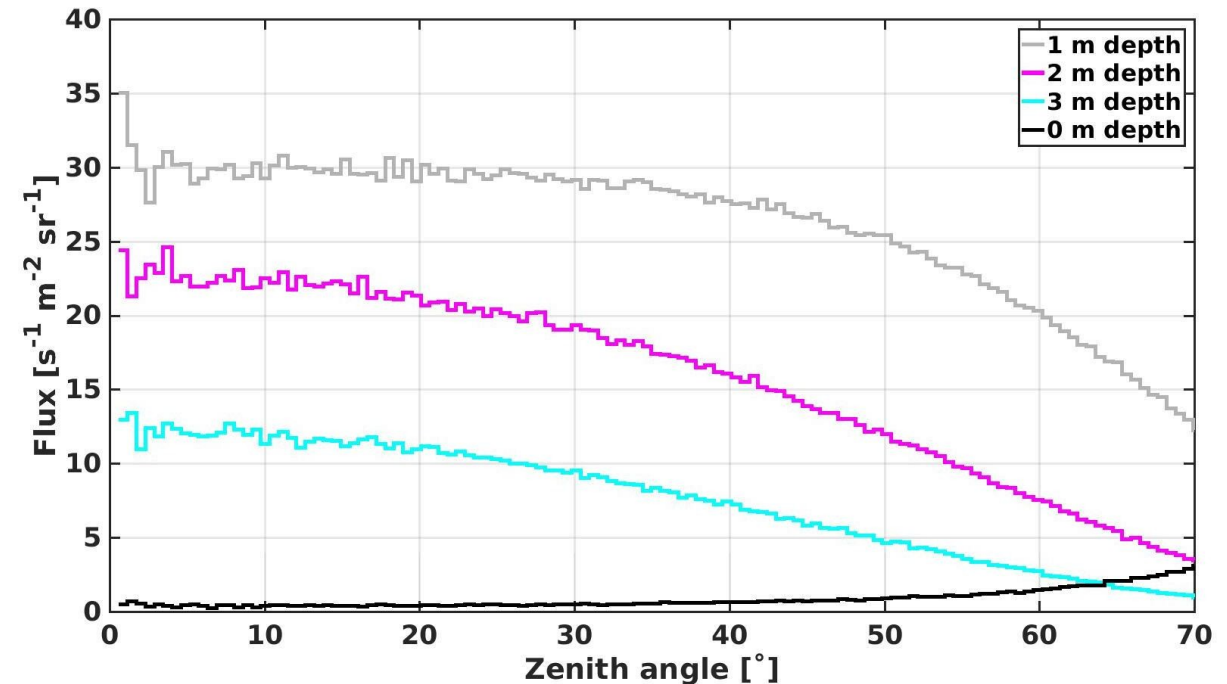
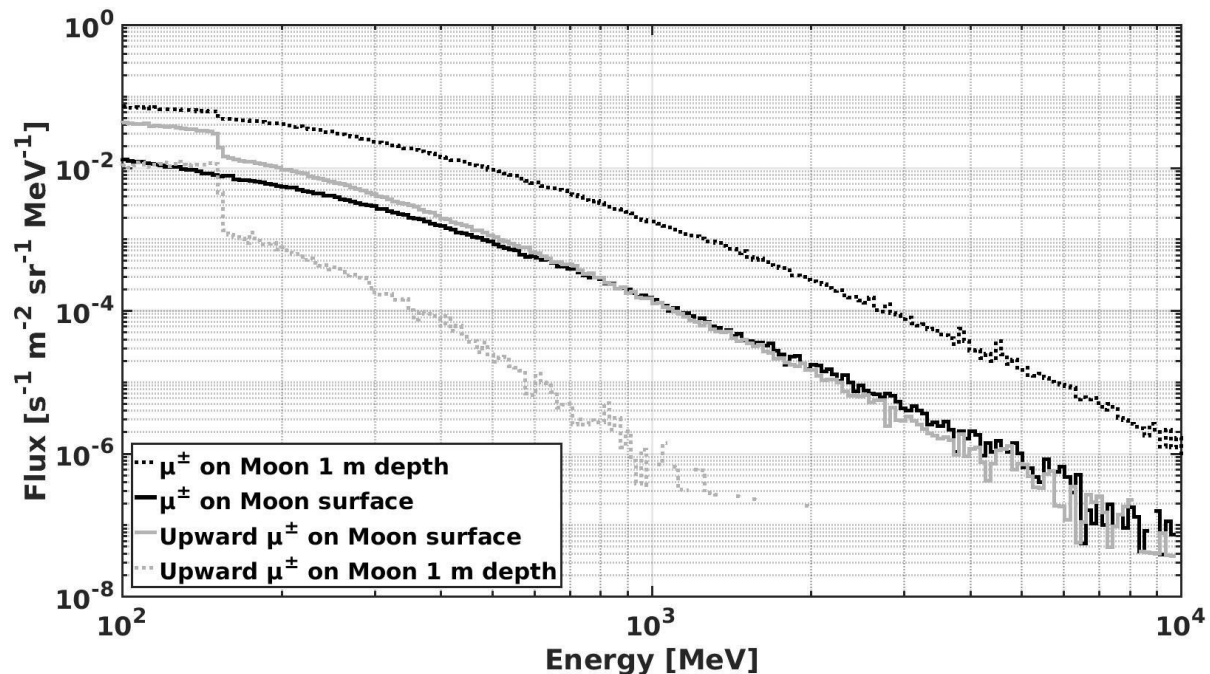
I. Earth-Mars analogy in muon creation

- The p^+ and α^{2+} fluxes are identical at a certain atm. depth
- π^\pm and μ^\pm flux is lower at the same atm. depth (higher decay due to less dense atmosphere)
- The μ^\pm production is similar, but the density profile of the atmosphere causes differences



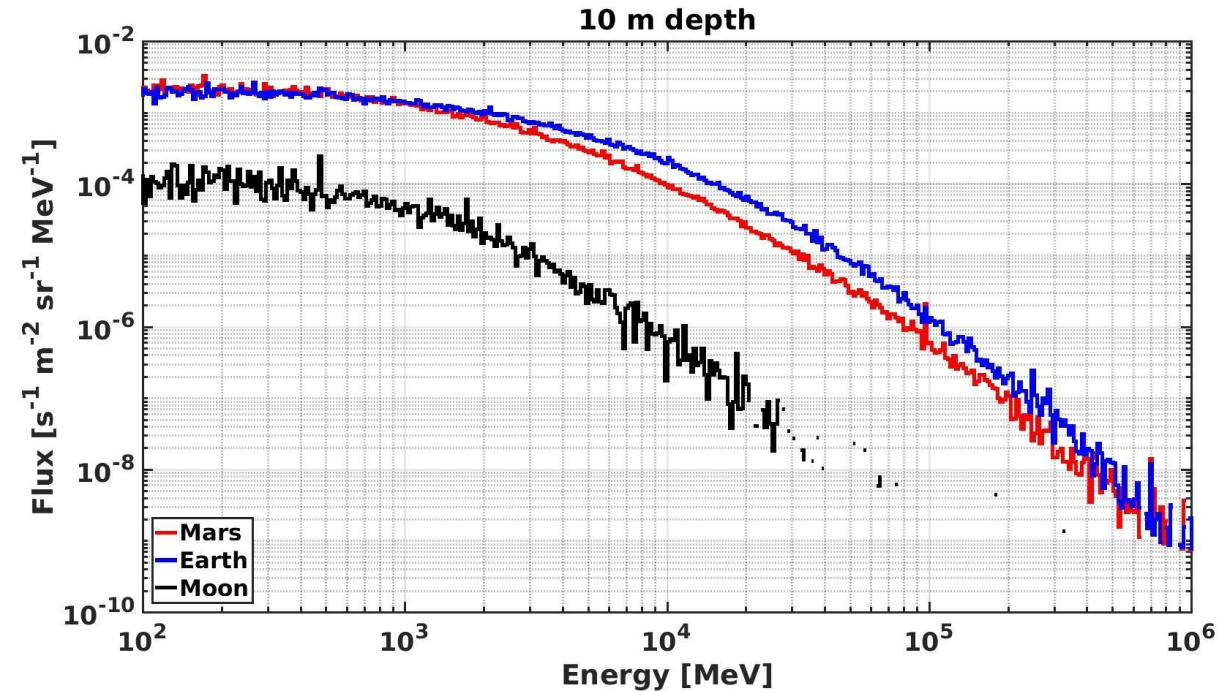
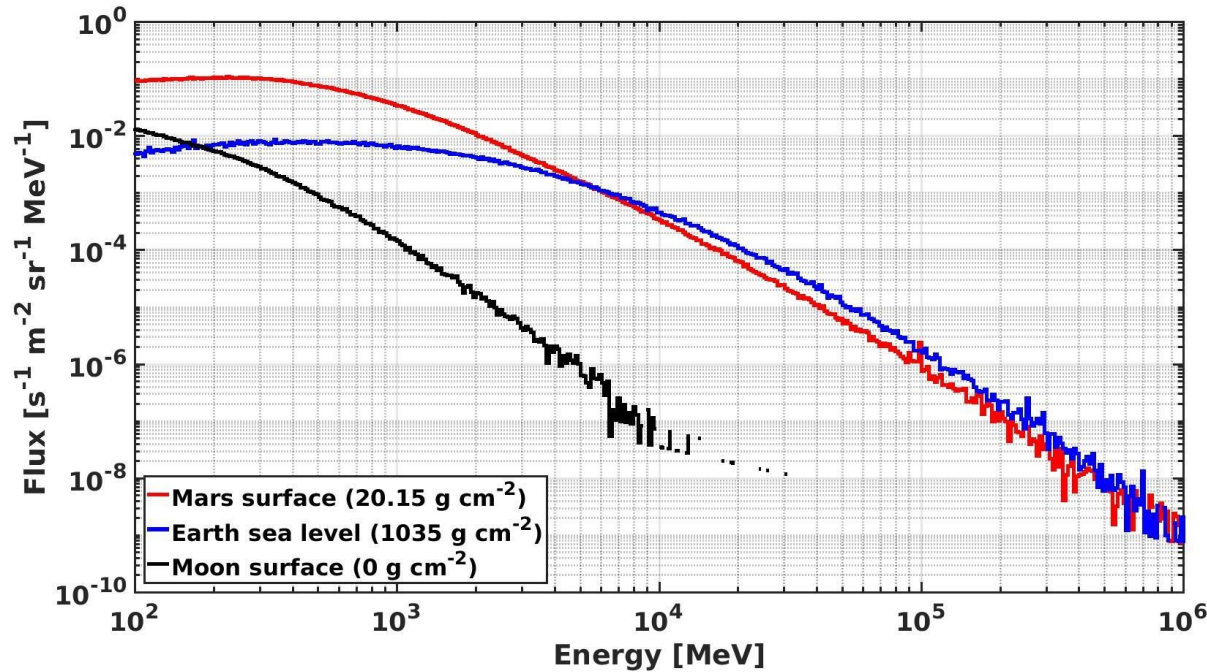
II. Muon production on the Moon

- Muon production mainly happens in the rock
- π^\pm and K^\pm can escape the rock, and decay above ground
- The μ^\pm flux changes rapidly a few meters underground



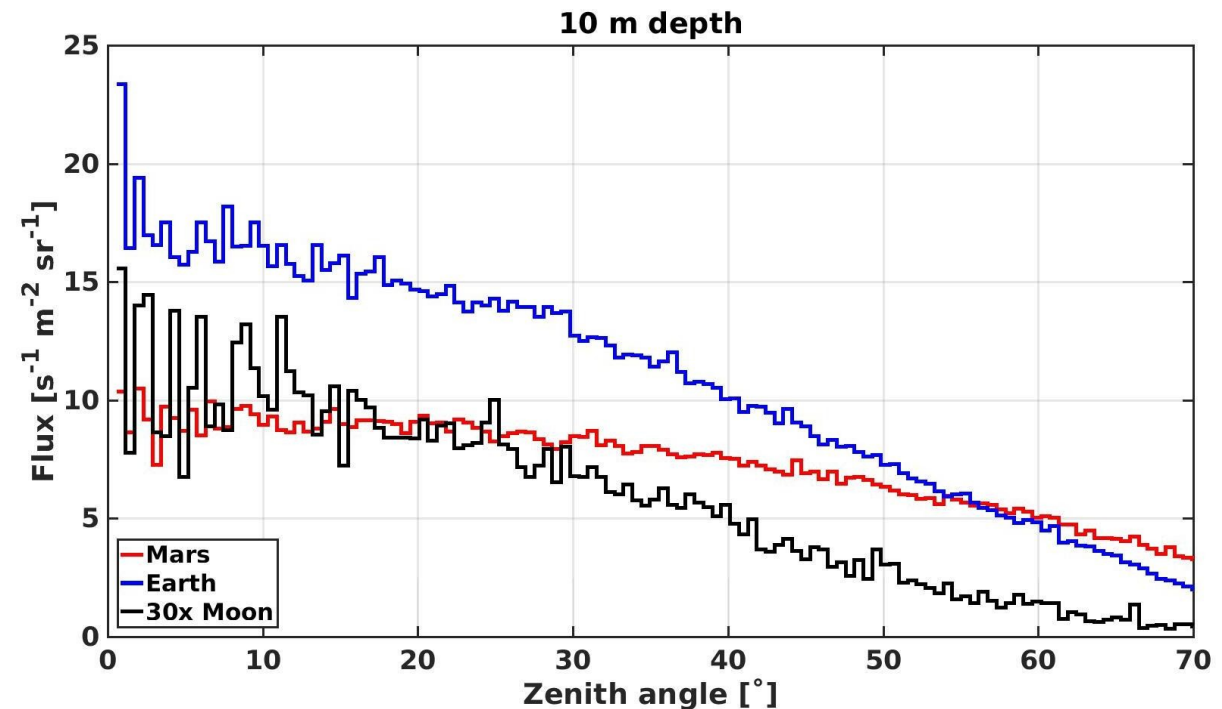
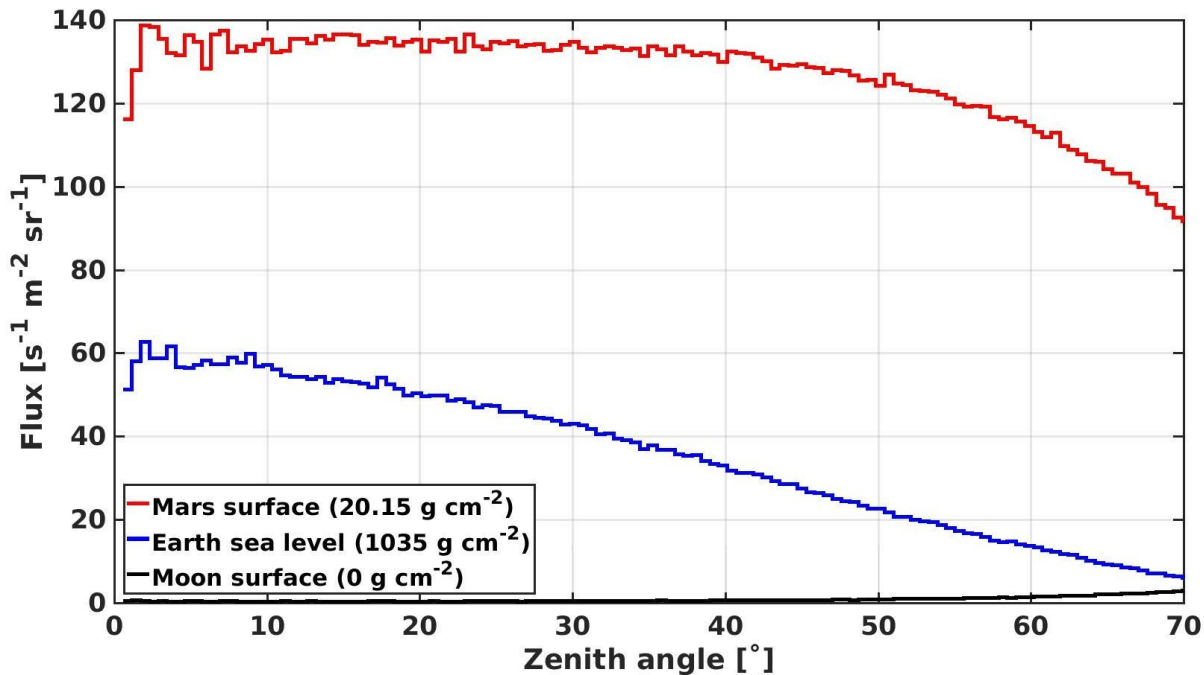
III. Comparisons with Earth (energy)

- The μ^\pm energy spectrum is softer on Mars compared to Earth
- The μ^\pm flux is only higher on Mars at low energies (<6 GeV) near the surface (<10 m depth)
- The μ^\pm flux on the Moon is up to 3 orders of magnitude lower than on Earth



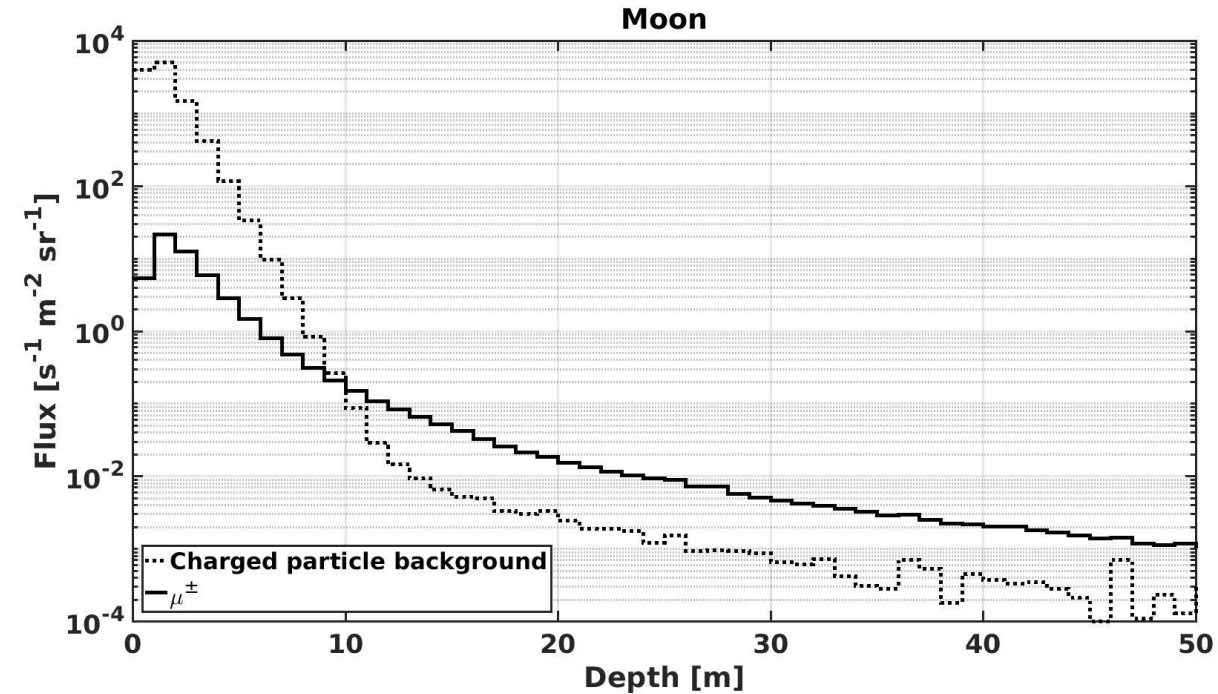
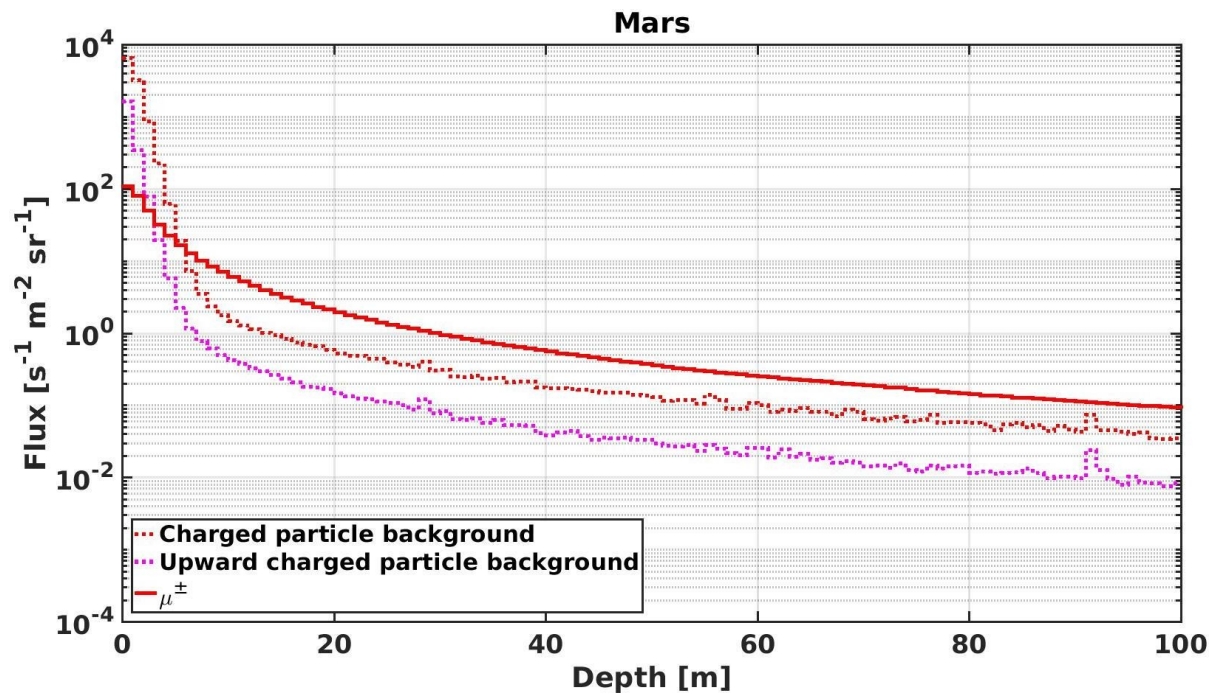
III. Comparisons with Earth (zenith angle)

- On the surface: \cos^2 (Earth), isotropic (Mars) and horizontal (Moon)
- Underground: the μ^\pm flux on the Moon becomes \cos^2



IV. Charged particle background

- The background on the surface is orders of magnitude higher
- The optimal depth for background suppression is below 10 m



Conclusions

MARS

MOON

Surface Muography

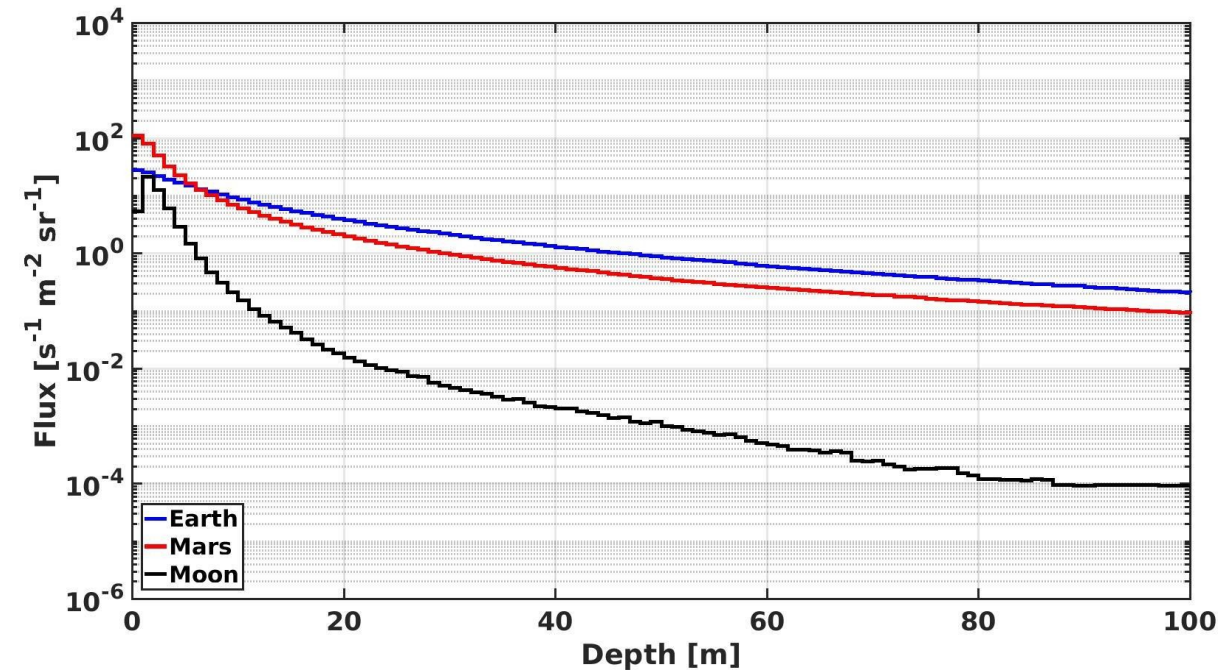
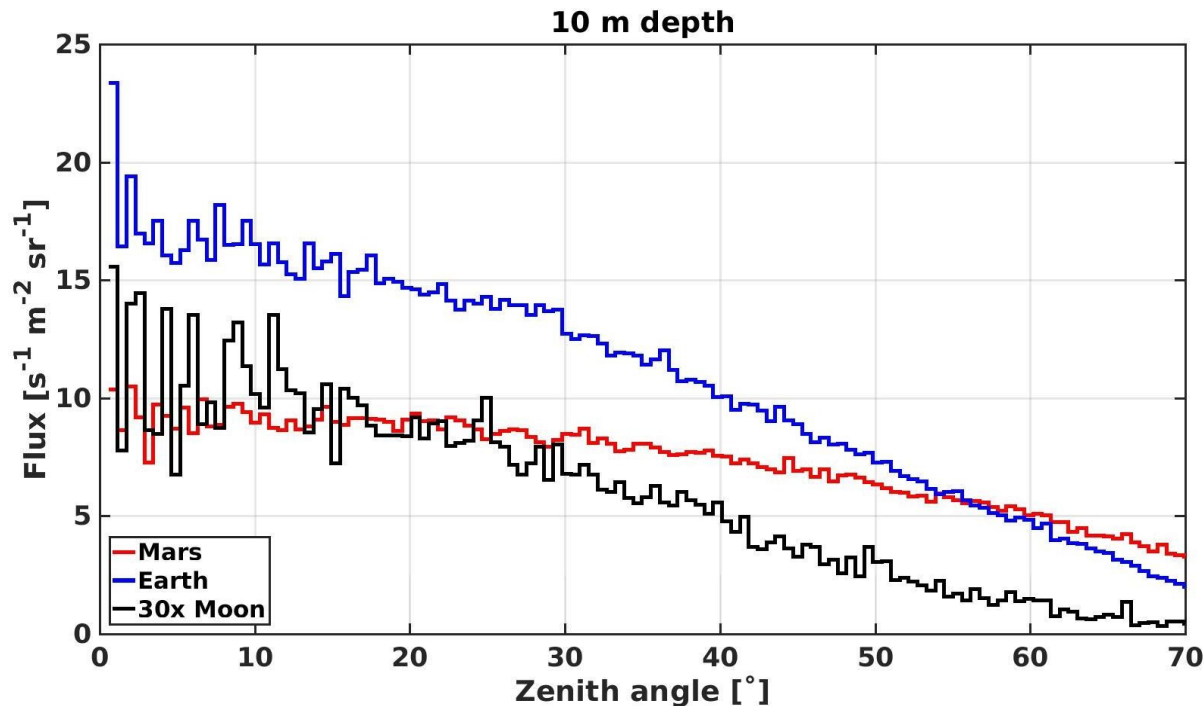
High flux, high background

Muon flux --> topography

Underground Muography

<10 m depth, flux is 1/2 of Earth

<10 m depth, very small flux



Acknowledgements

HUN
REN

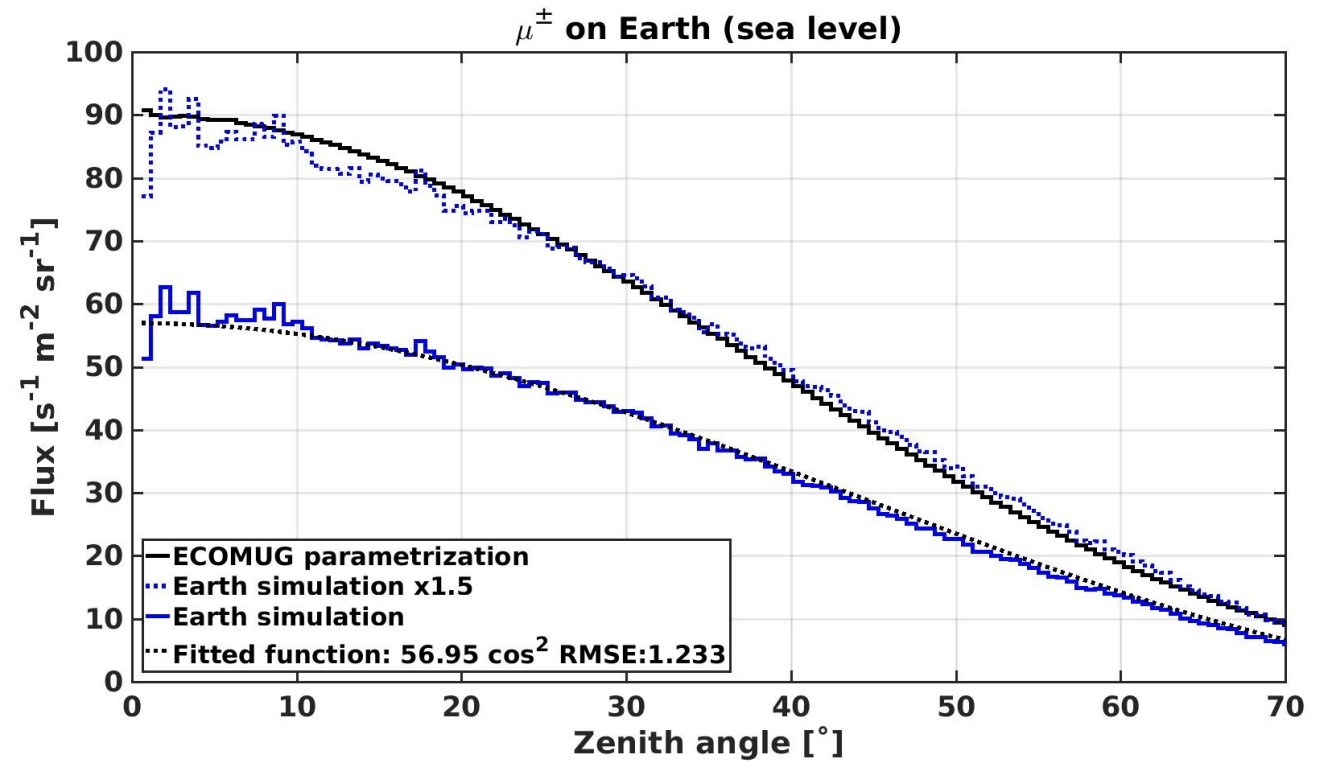
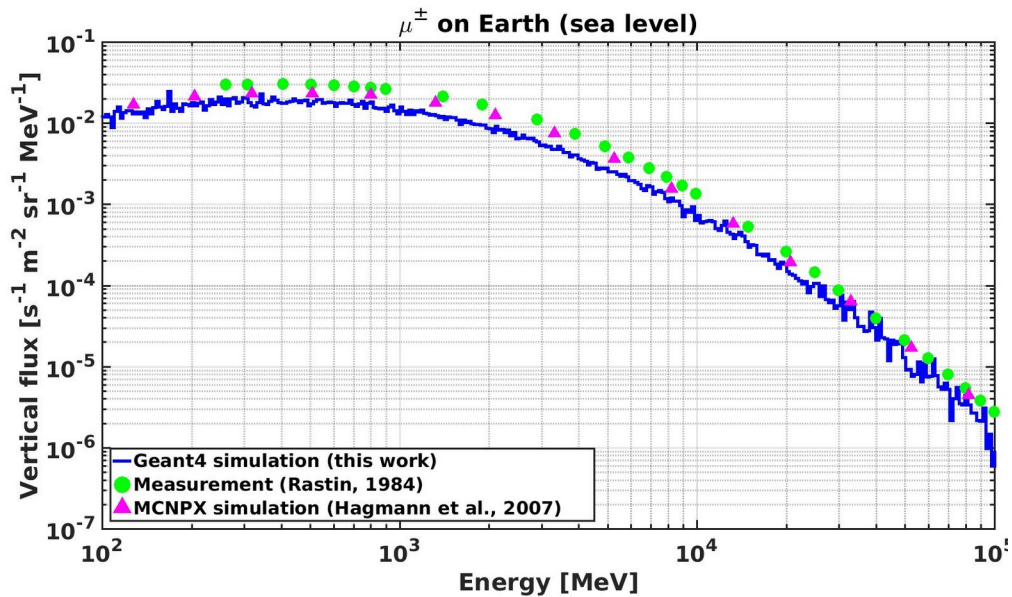
WIGNER

REGARD
INNOVATIVE GASEOUS DETECTORS

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Thank you for your attention!

Validation (Earth)



Comparison (Mars)

