



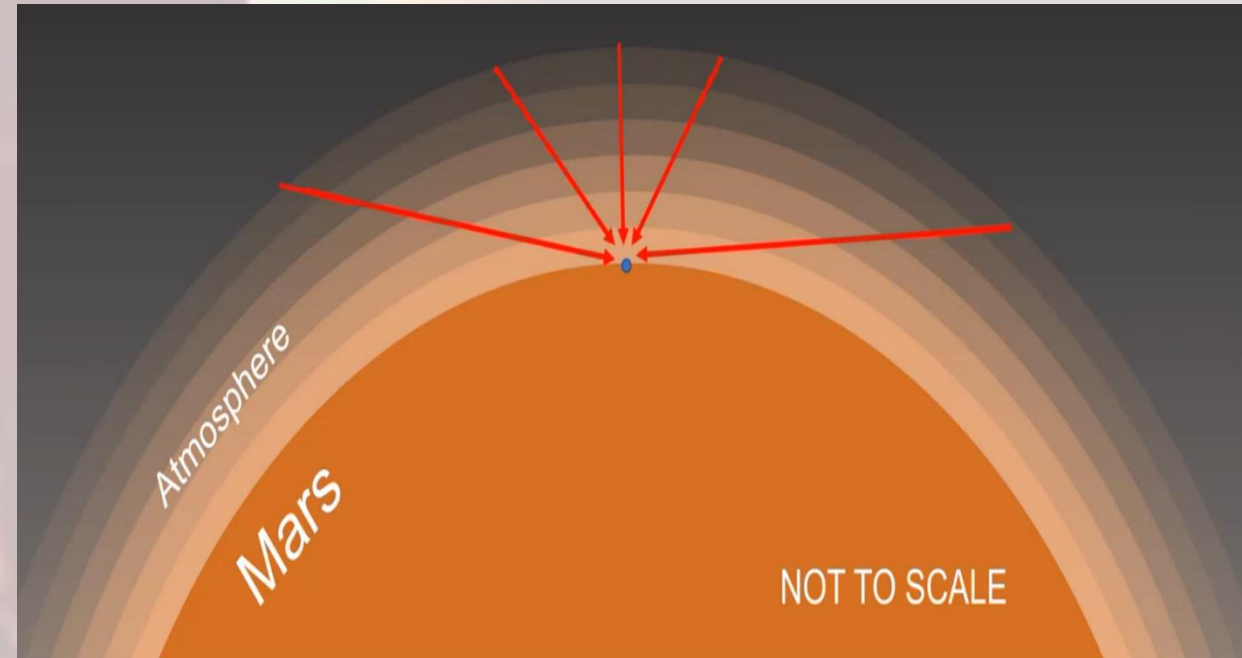
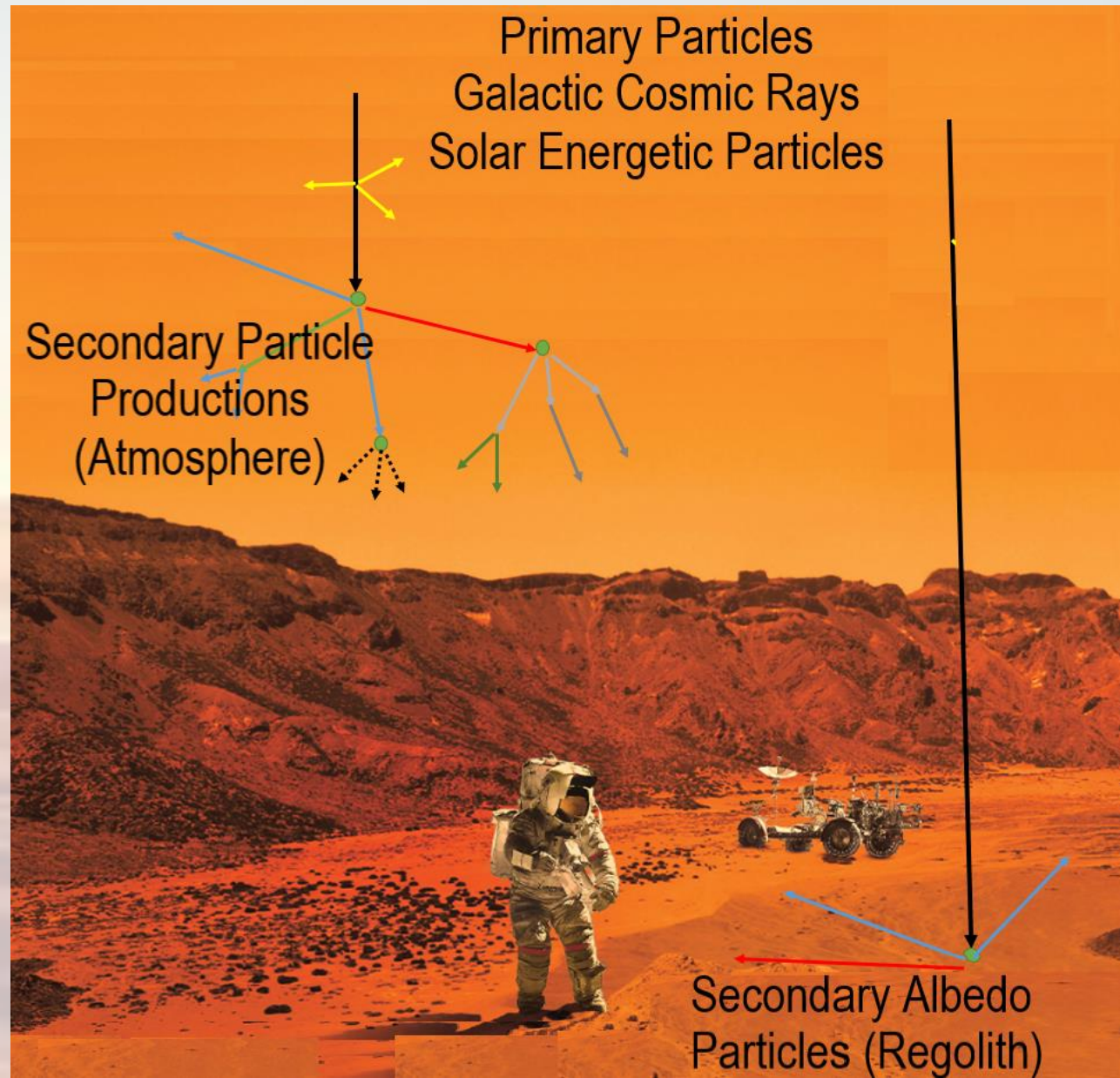
The Martian Surface Radiation Environment: Zenith Angle Dependence of Fluxes of Different Secondary Particle Species Produced in the Mars Atmosphere

Salman Khaksarighiri

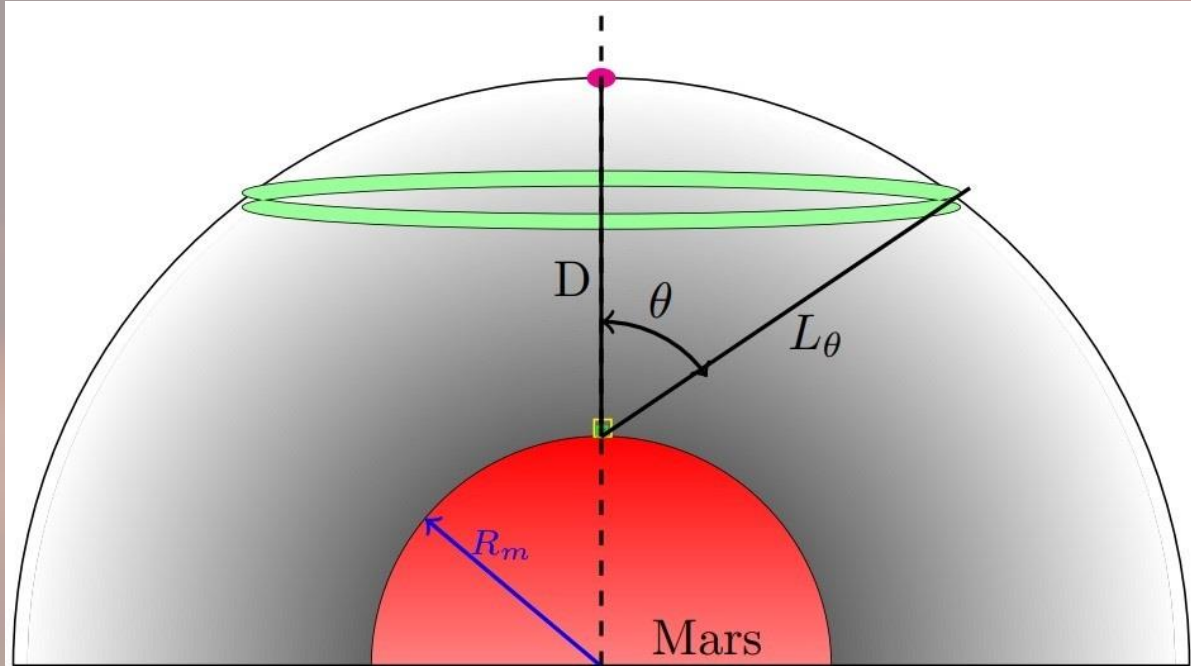
Robert Wimmer-Schweingruber, Timothy J Stubbs, Mark D. Looper , Phillip H. Phipps, Jingnan Guo,
Donald M. Hassler, Bent Ehresmann, Cary Zeitlin, Daniel Matthiä, Thomas Berger,
Günther Reitz, Sven Löffler , Jan Leo Löwe

EGU 2024

Characterizing Radiation Environment on the Martian Surface



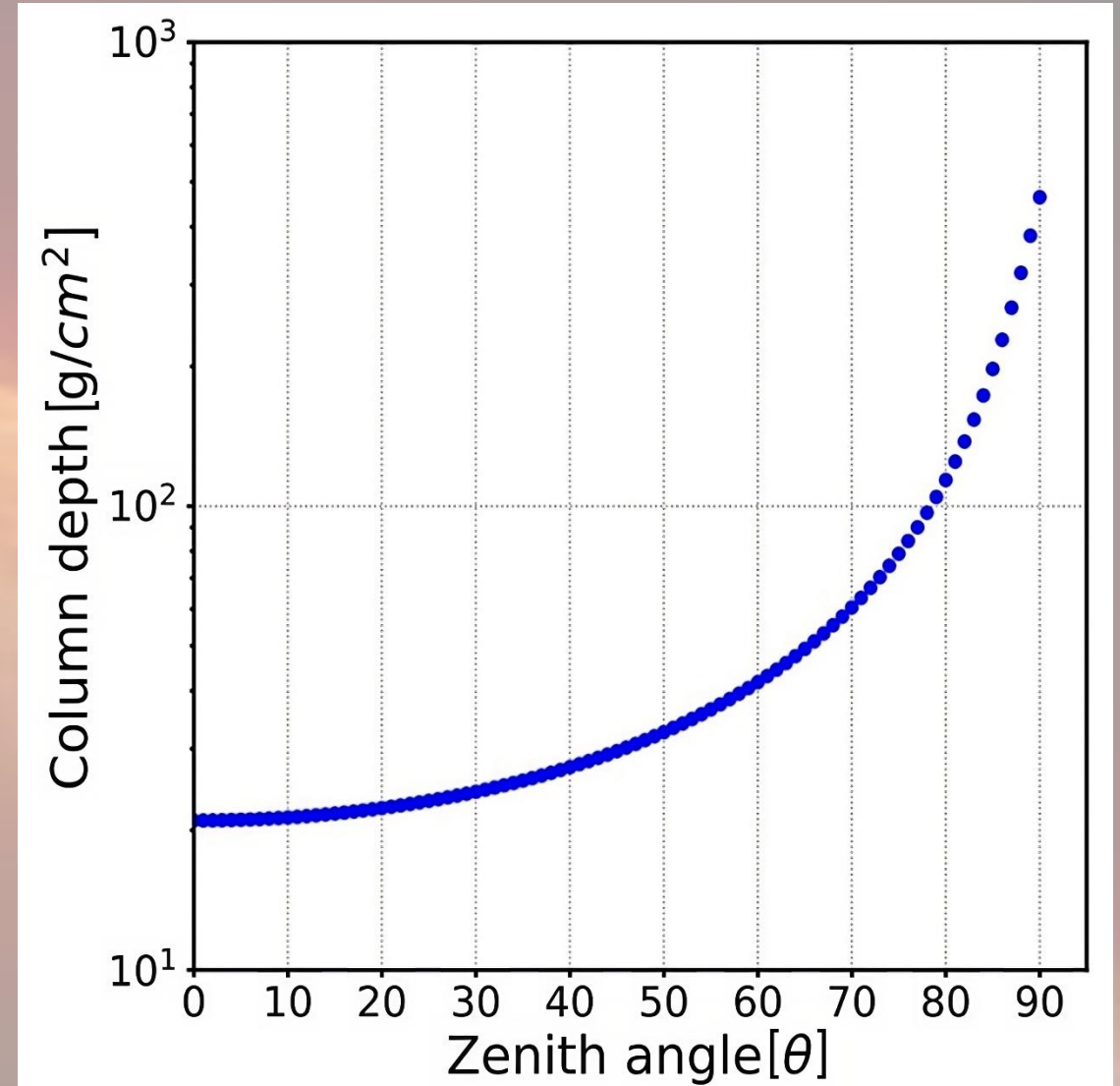
Atmospheric Column Depth in Different Zenith Angles



D : Distance between the RAD and magenta point

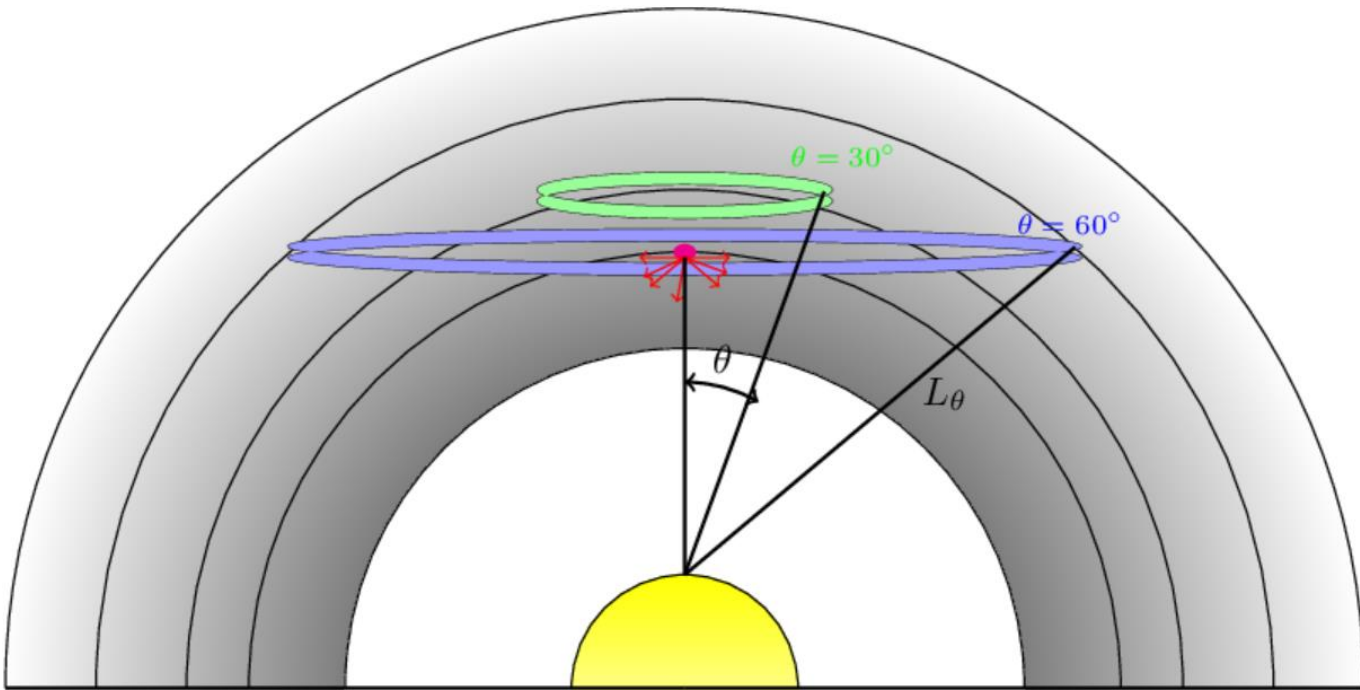
L_θ : Effective scale height depends on the zenith angle θ

R_m : Mars radius



(Khaksarighiri, et.al, 2023)

Mars surface modeled in Geant4



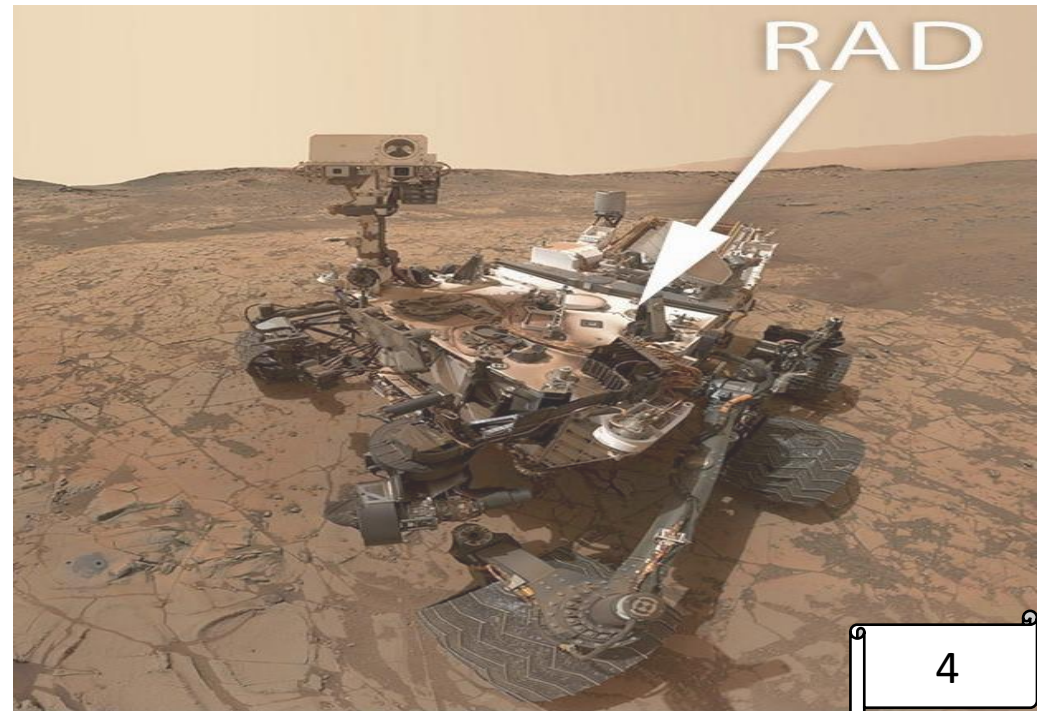
Particle Sources

Energy range : 1-100 GeV for proton and He

Energy distribution : 62 log bins with power-law index of $\alpha = -1$

Particle Number : 10^6 per bin, total of 6.2×10^7 particles

Our Model has been validated with the RAD measurement on the Martian surface in a previous research (Khaksarighiri, et.al, 2023)



Implications for Deep Space Radiation

- The folding is done using:

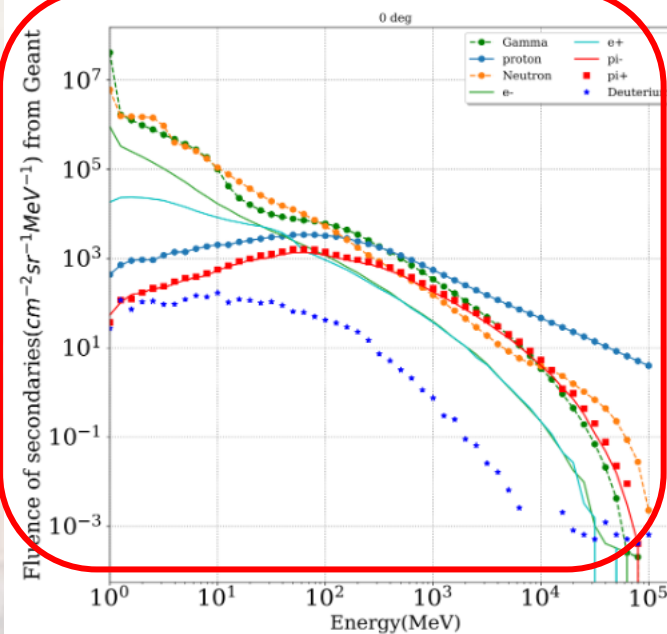
$$\dot{F} = \left\{ \frac{F_m}{f} \right\} \times F$$

F_m : Fluence of produced species on the surface of Mars
(# $cm^{-2} sr^{-1} MeV^{-1}$)

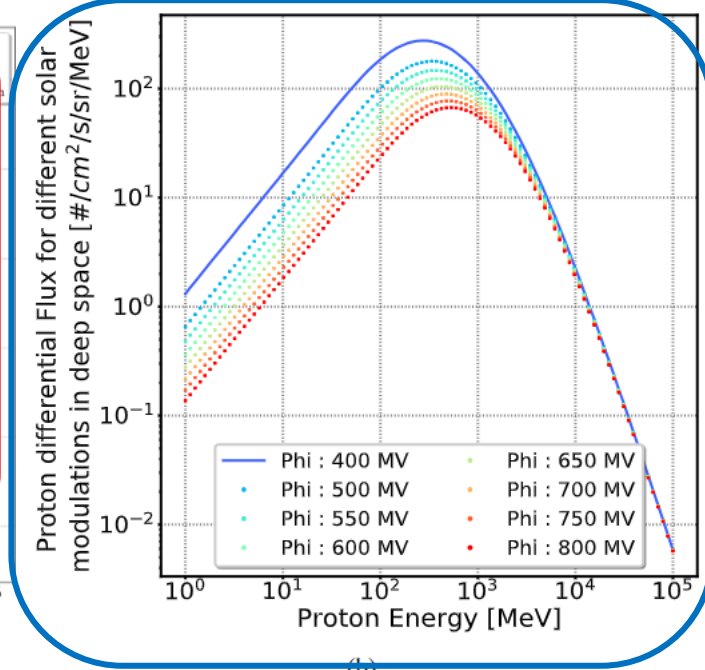
f : Fluence of the primary source (# $cm^{-2} sr^{-1} MeV^{-1}$)

F : differential flux of GCRs

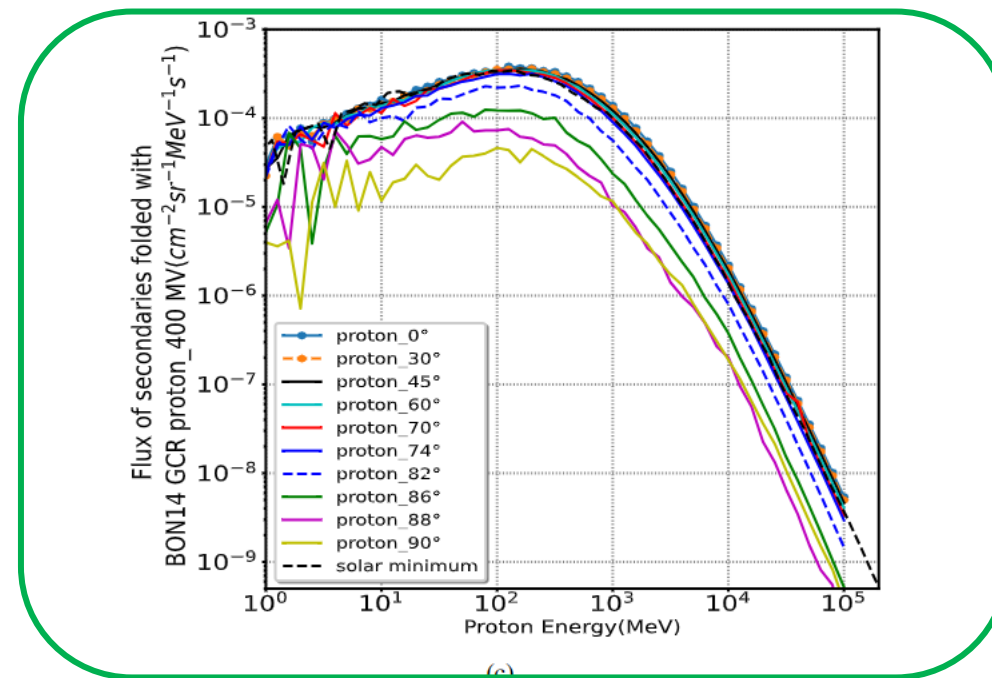
\dot{F} : flux of secondaries per energy bin that reach the surface of Mars in each zenith angle



(a)

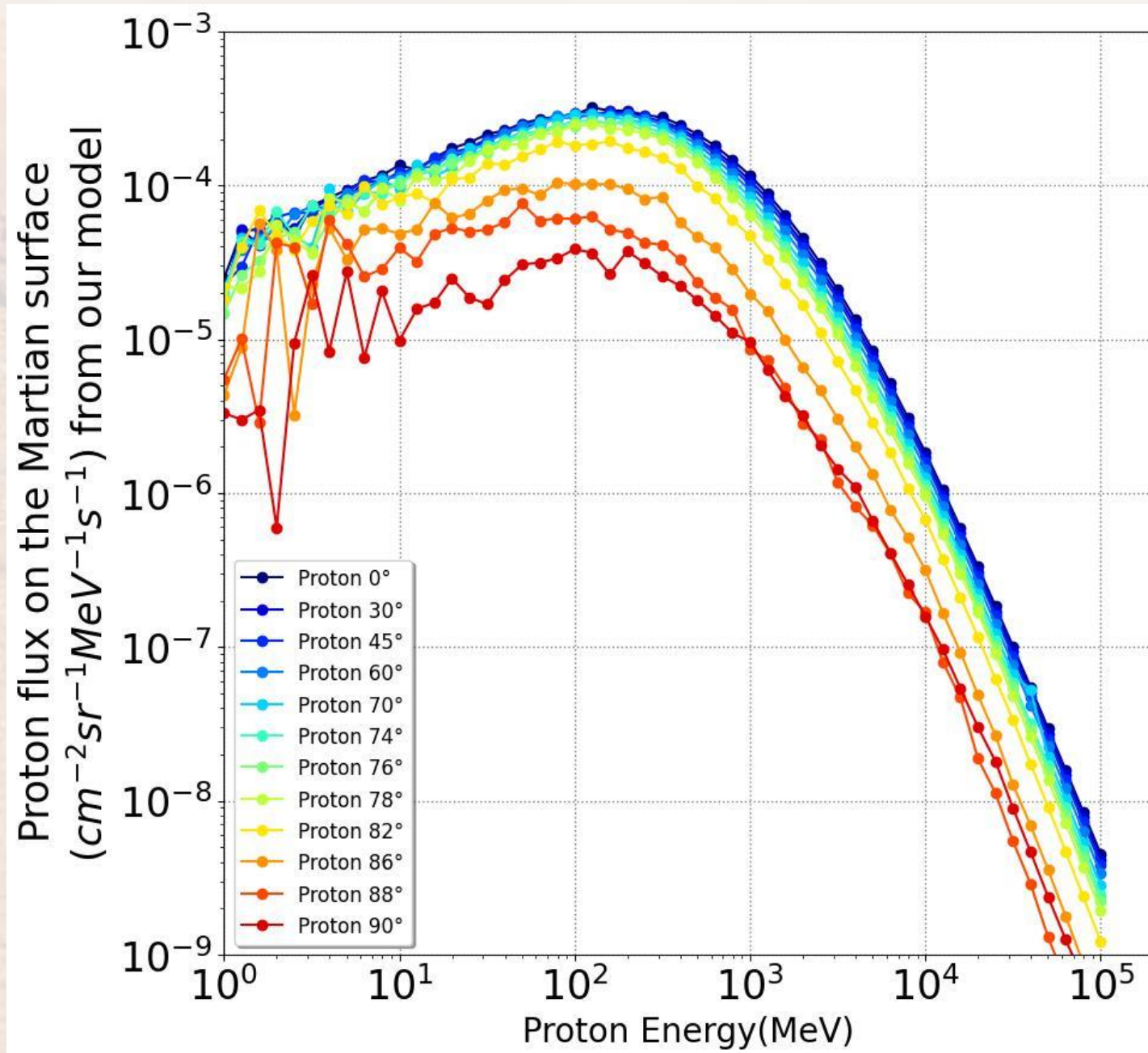


(b)

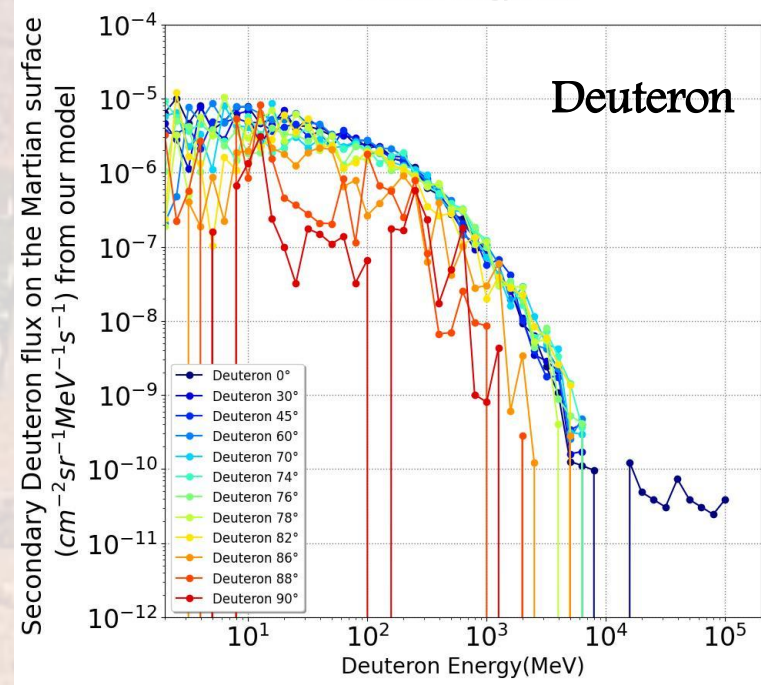
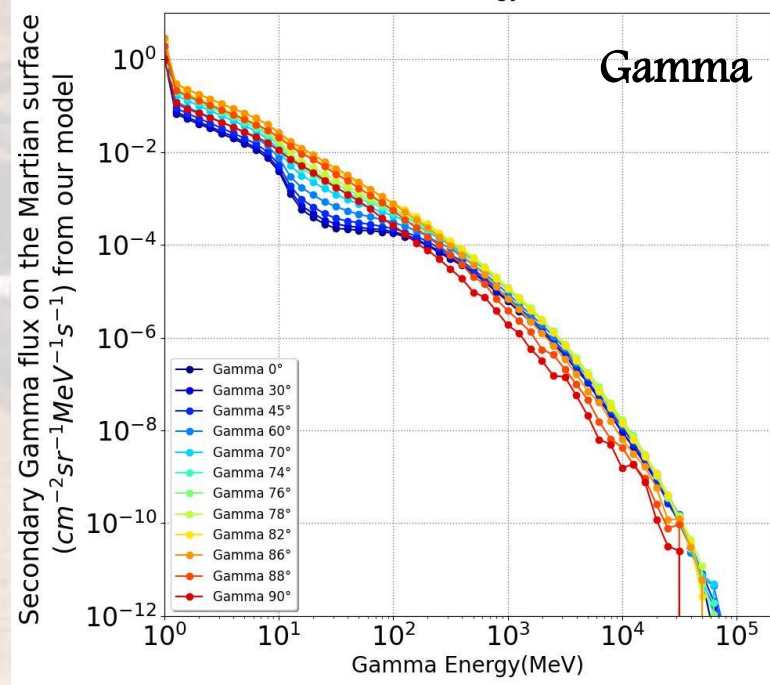
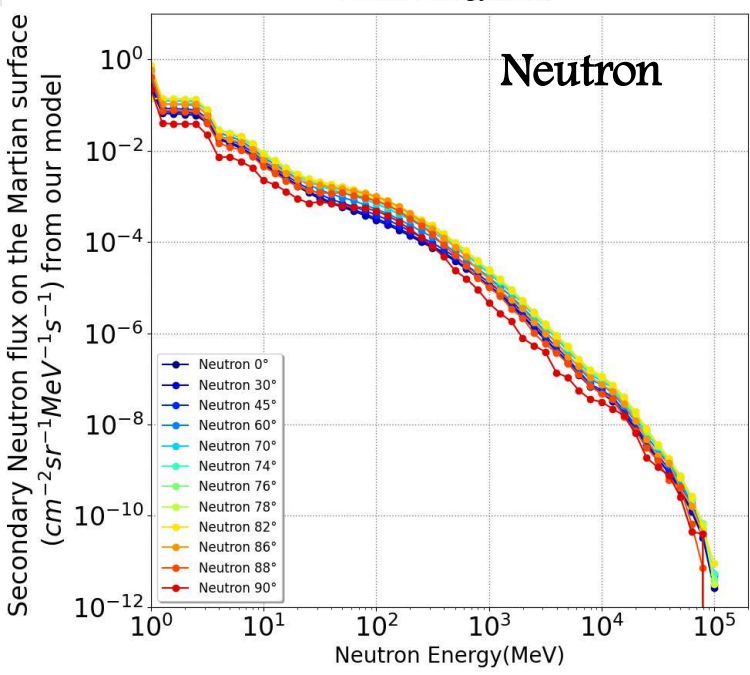
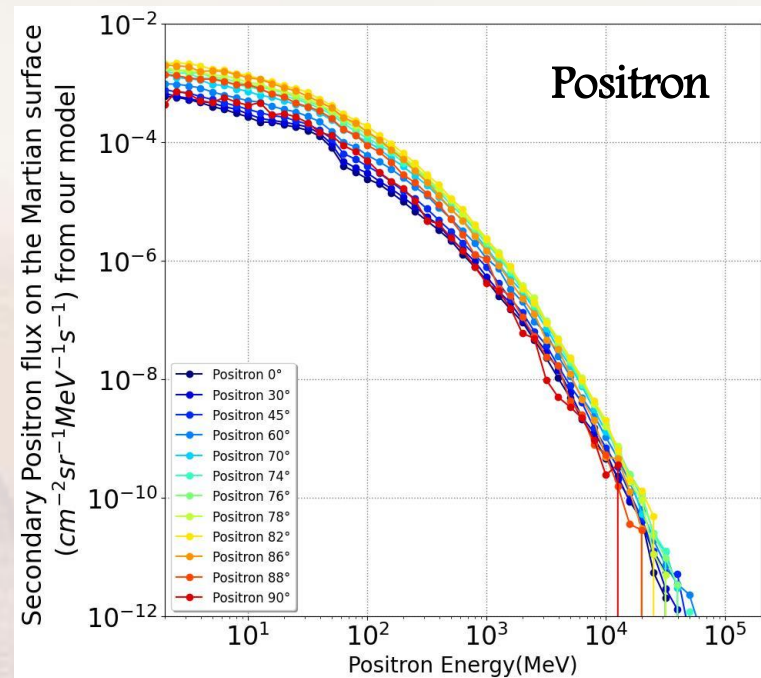
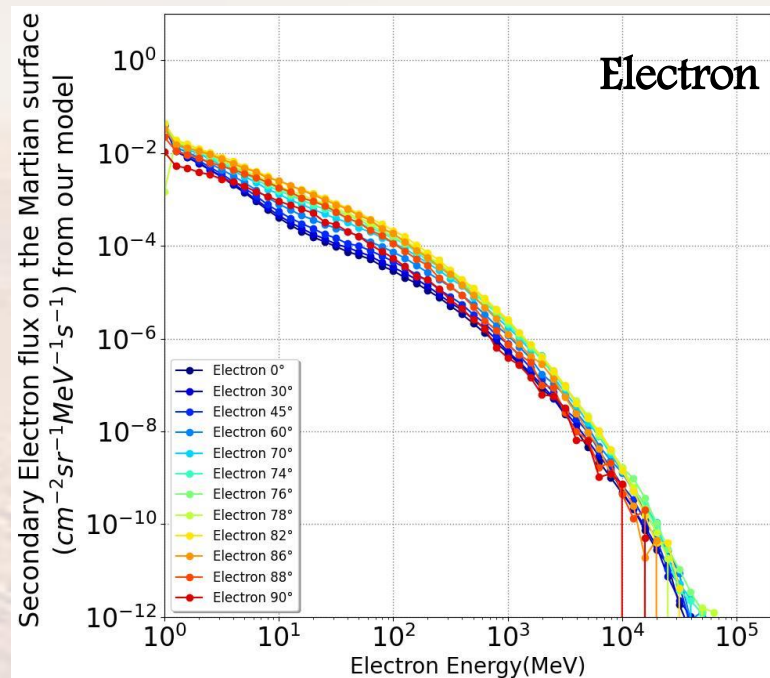
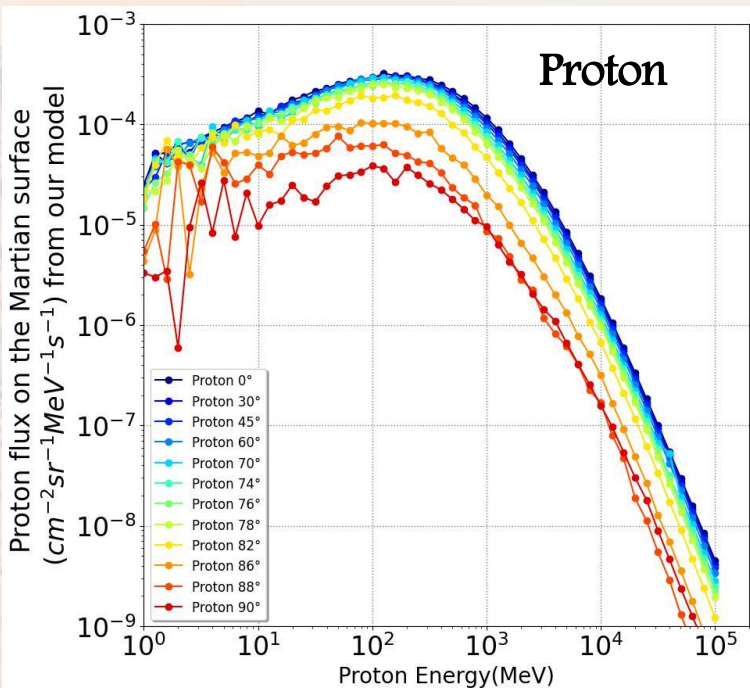


(c)

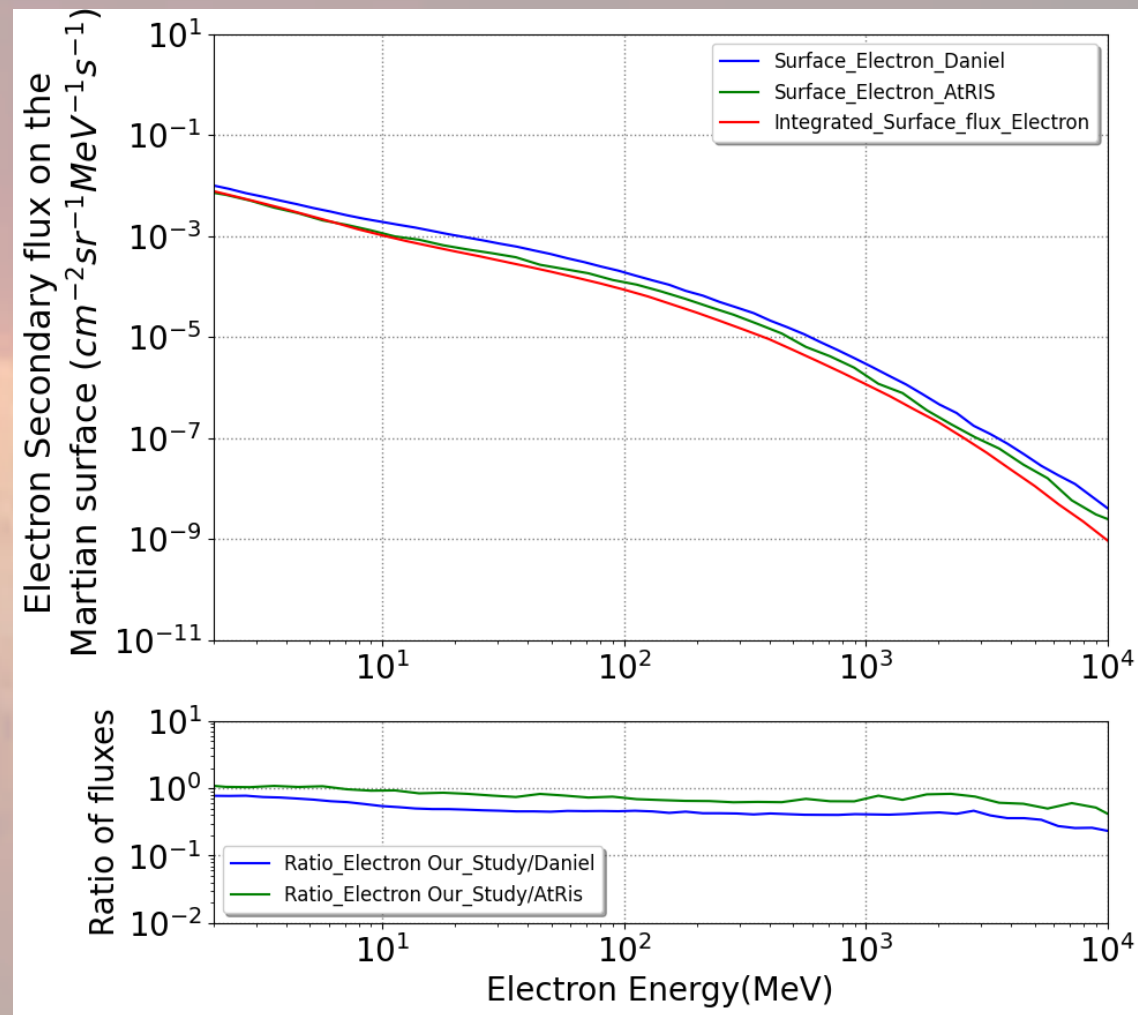
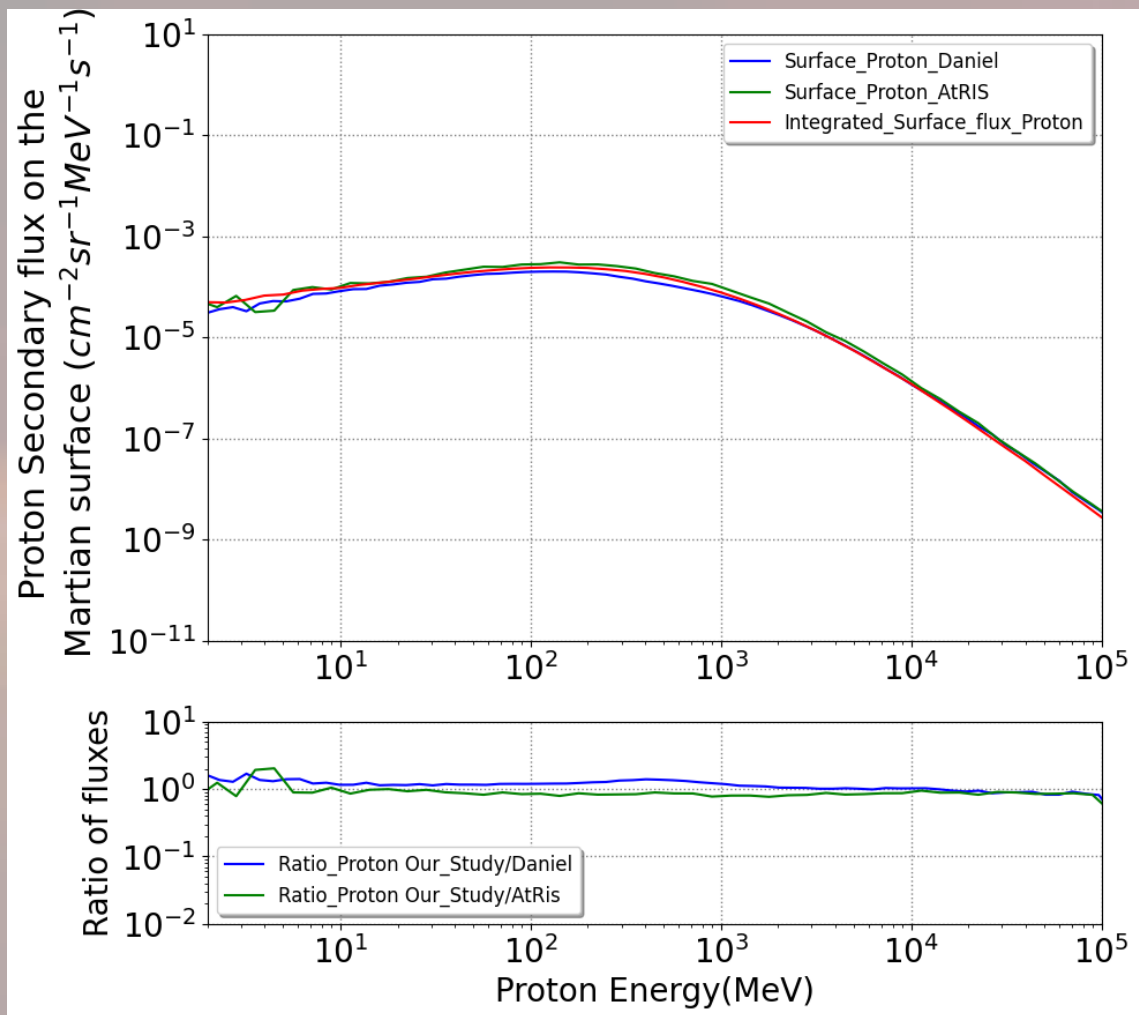
Flux of secondaries on the Martian surface



Flux of secondaries on the Martian surface

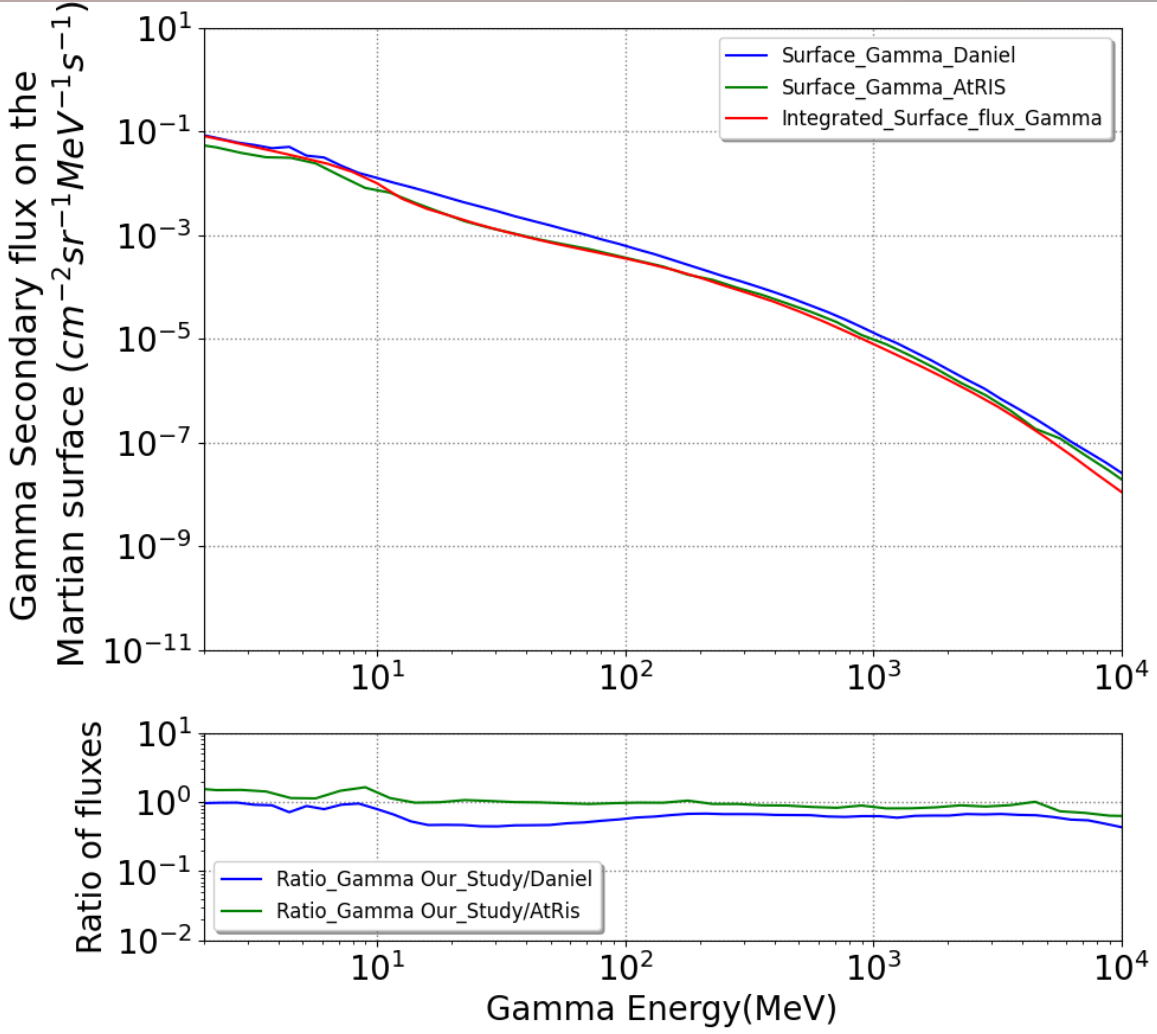
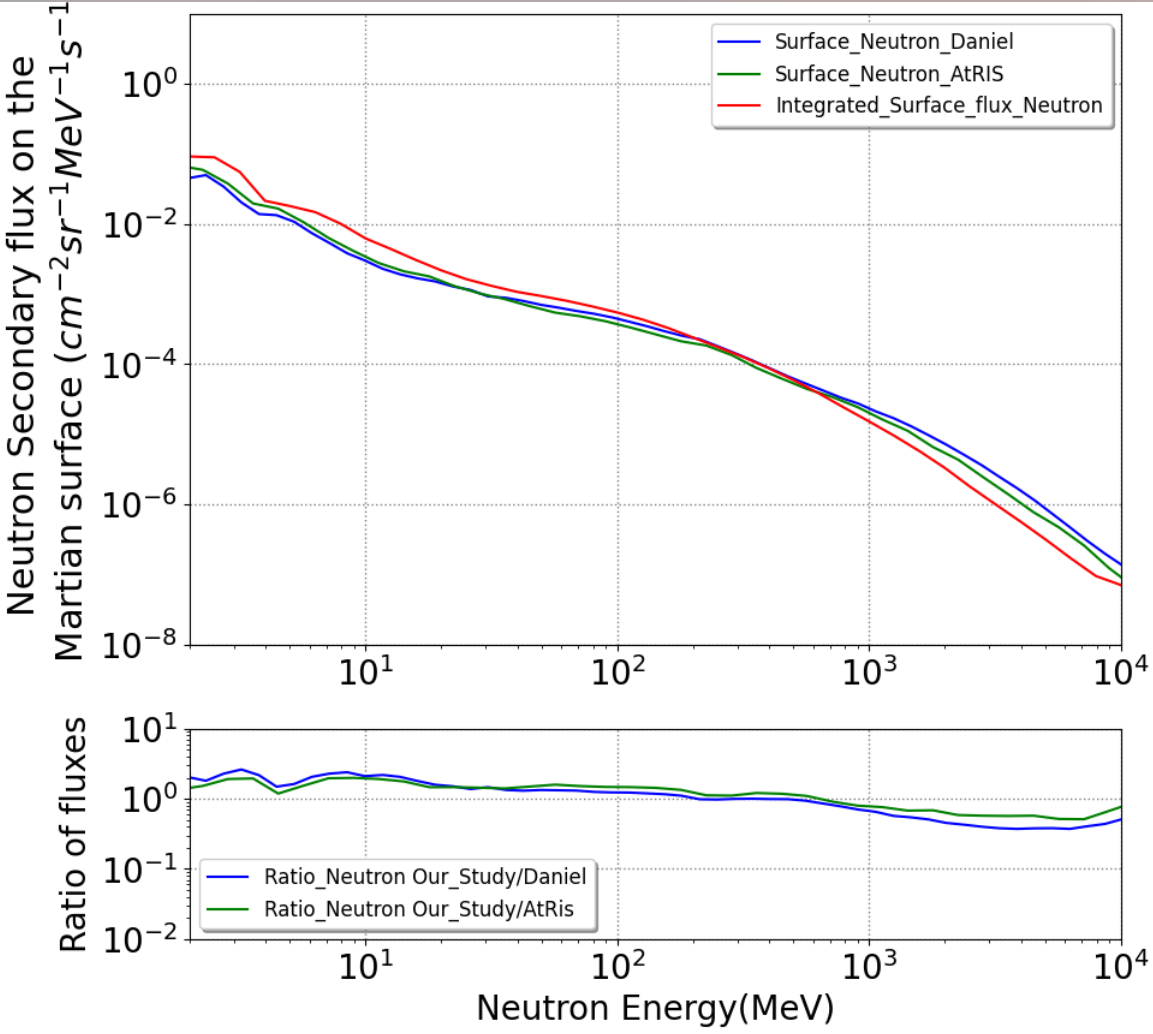


Comparing Results with Previous Studies



(Daniel et.al 2017, Banjac et al. 2019 (AtRIS))

Comparing Results with Previous Studies



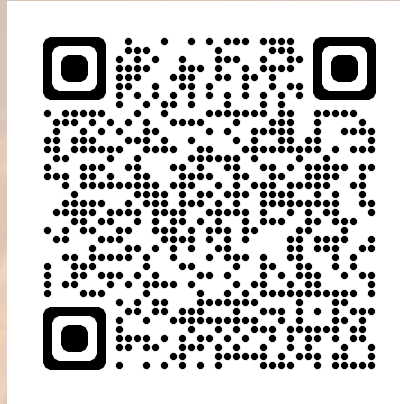
(Daniel et.al 2017, Banjac et al. 2019 (AtRIS))

Summary & Conclusions

- ✓ Radiation dose is non-isotropic on the Martian surface
- ✓ Martian surface radiation influence by topographical features
- ✓ HZE contribution are higher at smaller zenith angles : **Clever helmet design**

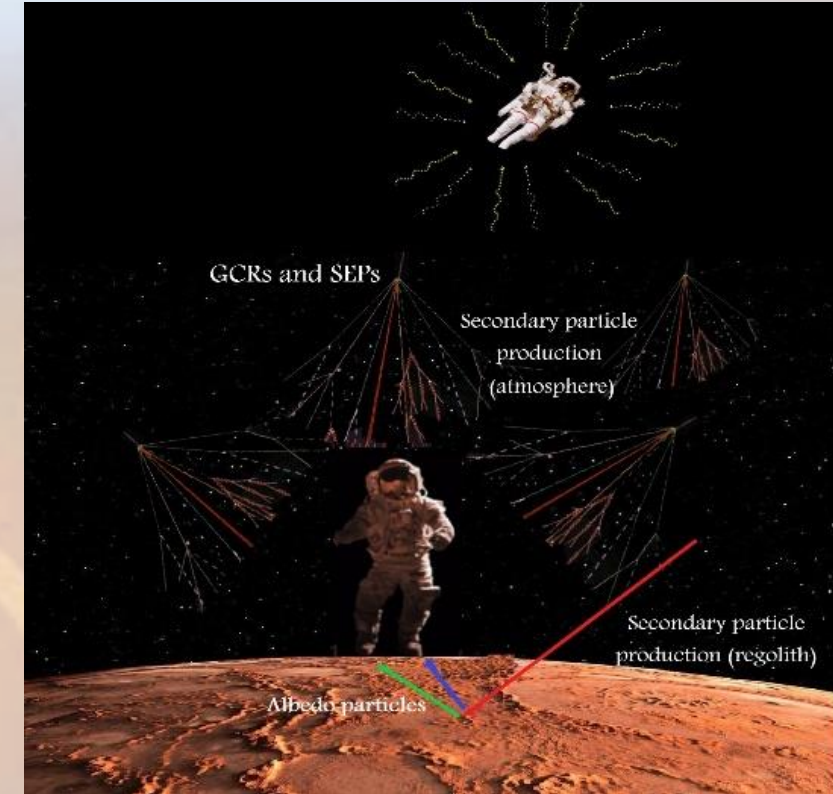
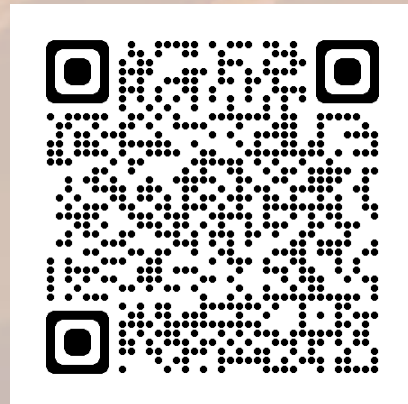
Select suitable landing sites

(Khaksarighiri 2023. et.al)

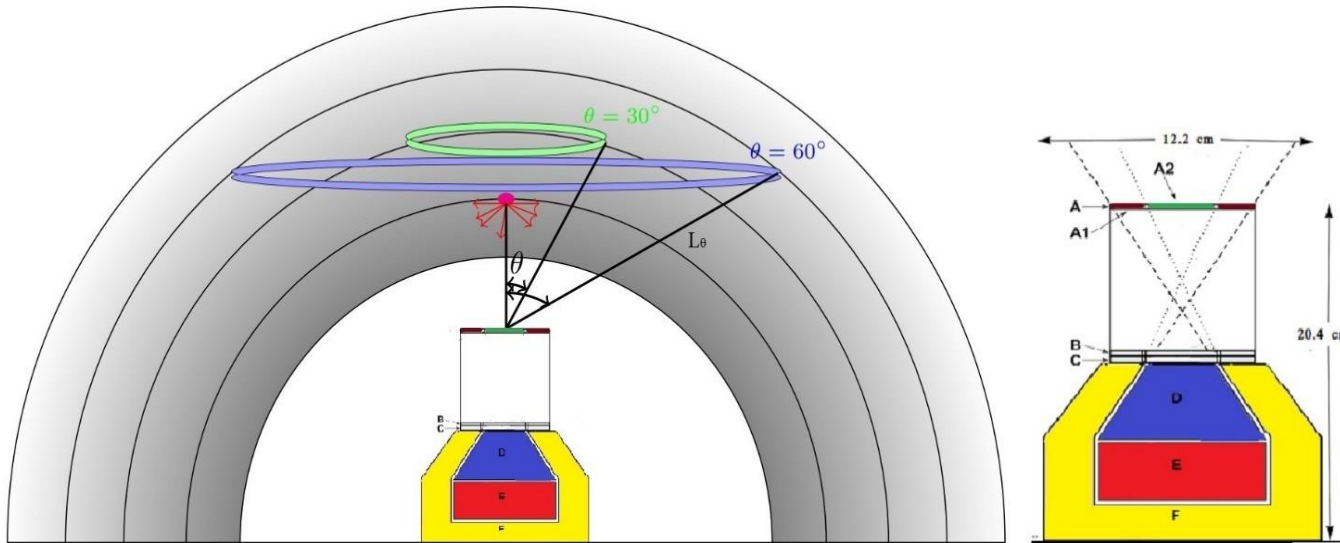


- ✓ The secondary albedo dose is about 19% of total Marian surface dose

(Jingnan Guo, Khaksarighiri 2021. et.al.)



Mars surface modeled in Geant4



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