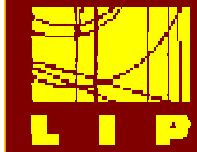

Mars Radiation Environment Characterization
A GEANT4 based Model

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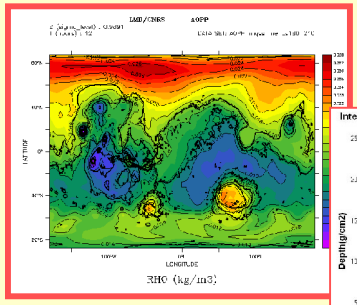
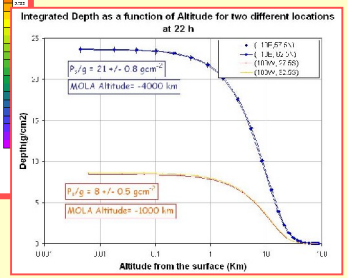
Overview

- Radiation-induced failure of sensitive instrument, spacecraft/missions : (e.g. Marie instruments-Oct./Nov.03 and Nozomi-3 Dec. 03);
- ESA, NASA and others have flown or plan many missions to Mars
- Model features include:
  - Geant4 particle transport;
  - Time, position, solar longitude;
  - Solar cycle modulated cosmic ray and solar particle event spectra;
  - 4-D atmosphere and geology.
- Outputs : Energy and Species spectra, Fluence maps, Dose calculations

Atmospheric Database





- European Martian Climate Database (EMCD)
  - Temperature, density, pressure, etc
  - Stored on a 5ºx5 º, longitude-latitude grid from the surface to 120km
  - Vertical coordinate for the 3D variables is defined as

$$\sigma = p/p_0,$$

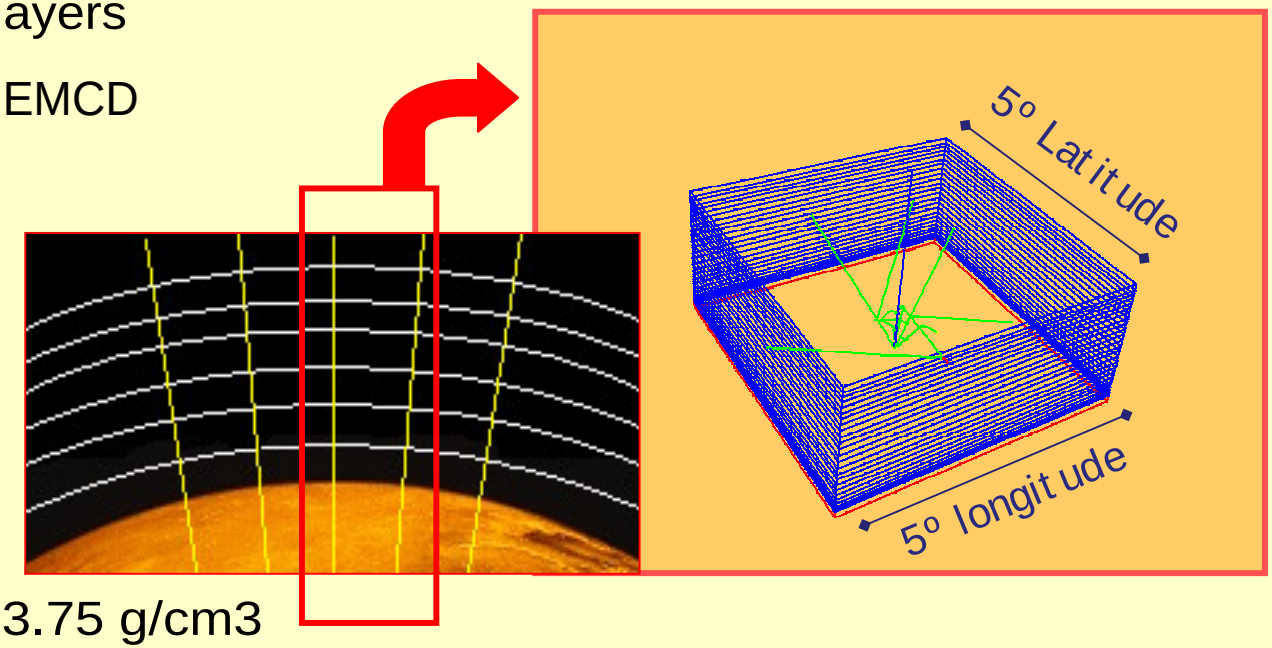
p = atmospheric pressure , p_0 =surface pressure.

  - 12 times a day Mars Universal Time at longitude 0º;
  - 12 Martian "seasons"
  - Each season covers 30º in solar longitude (L_s)

Simulation Setup

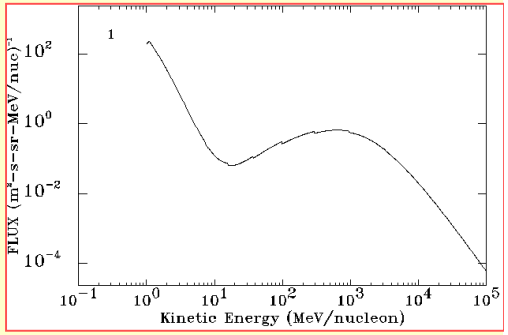
The geometry implemented in Geant4 program takes into account:

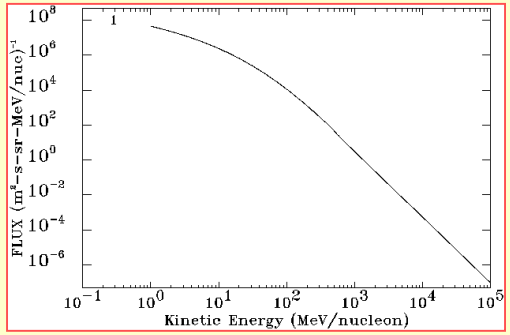
- 32 atmospheric layers
- Properties from EMCD
- Composition
  - 95% CO2
  - 2.5% N2
  - 1.25% Ar
  - 1.15% O2
  - 0.07% CO
  - 0.03% H2O
- Soil : Density of 3.75 g/cm3
- 30% Fe_2O_3 and 70% of SiO2



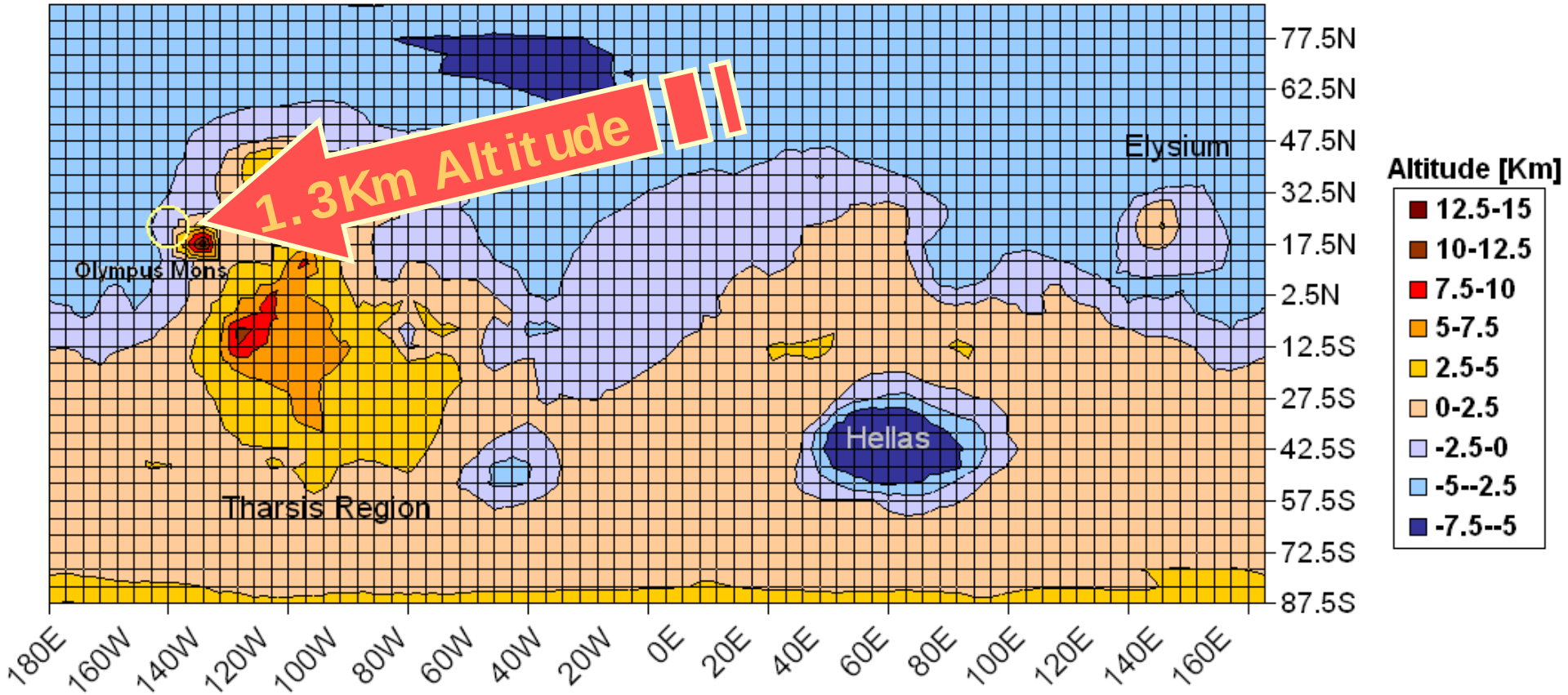
Radiation inputs

- CREME96 for near-Earth interplanetary locations.
- Galactic cosmic rays (GCR)
  - Solar-quiet proton flux in the solar maximum
  - Simulated as isotropic momentum distribution: 10^5protons
- Particle events (SPE)
  - Energetic protons : "worst week" model
  - Simulated perpendicularly to the surface : 10^5protons
- Models are based on measurements at Earth (1AU)
- The phasing in the solar cycle : foreseen for ExoMars.





Olympus Mons Cliff (12h, Ls=180-210)



GCR: Radiation Environment at the Surface

At low energies:

- Neutrons
- Photons
- Electrons

At high energies (> 10^3MeV):

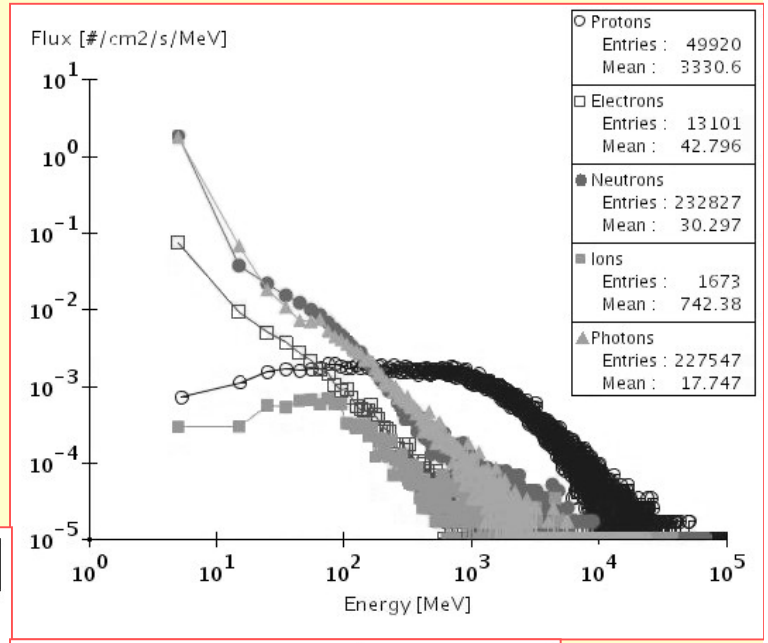
- Protons

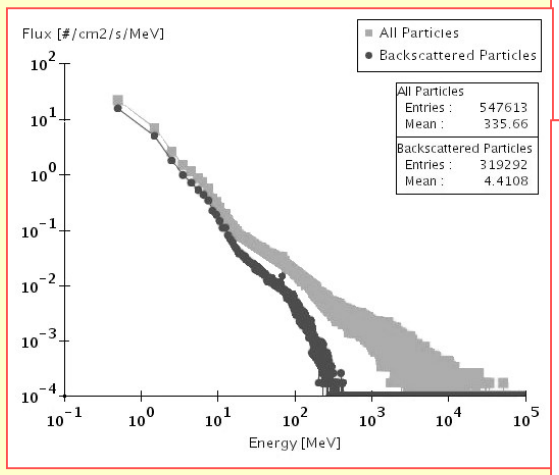
The Ions are mainly:

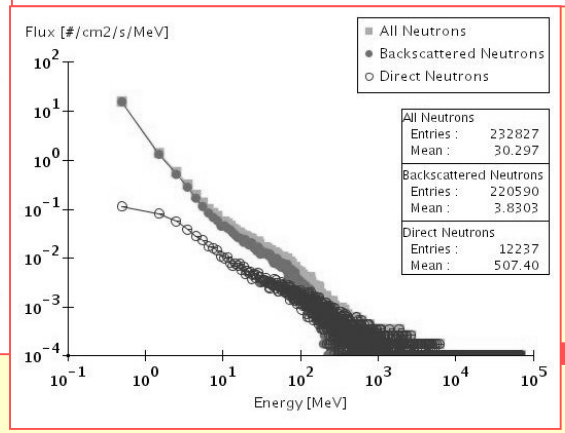
- Deuteron, Triton
- Alpha

Backscattering

- 60% All particles
- 96% Neutrons







SEP: Radiation Environment at the Surface

At low energies:

- Neutrons
- Photons
- Electrons

At high energies (10^2-10^3MeV):

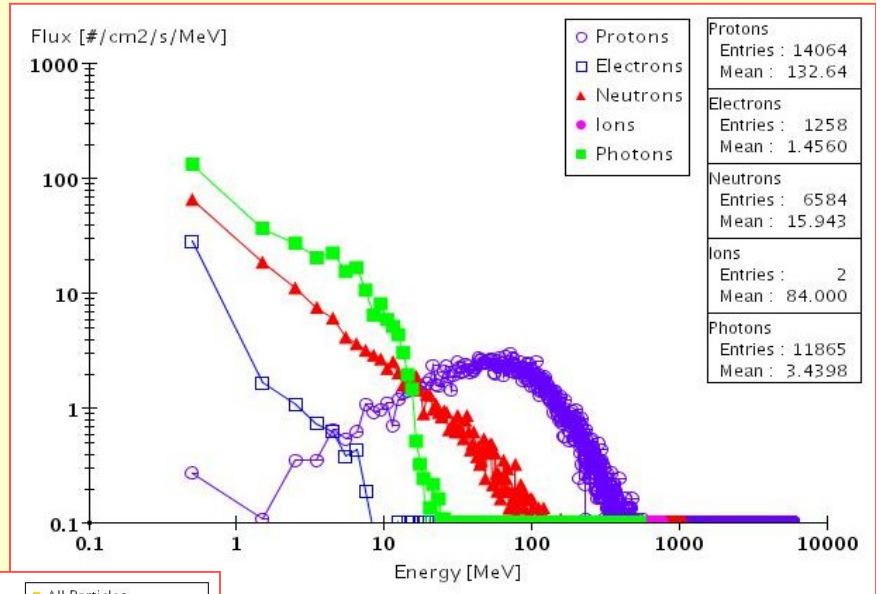
- Protons

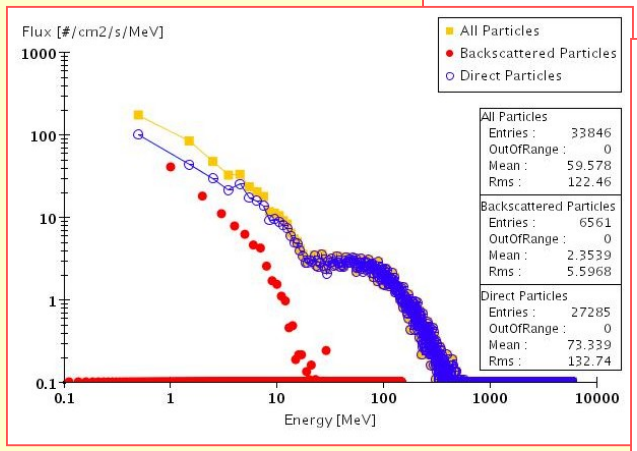
No significant signature

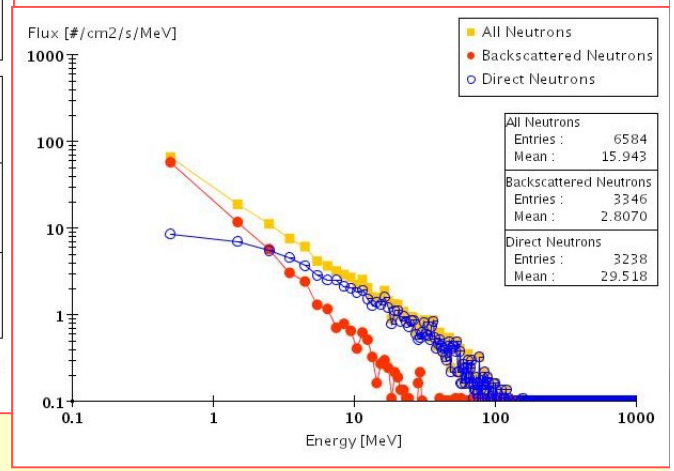
- Ions

Backscattering

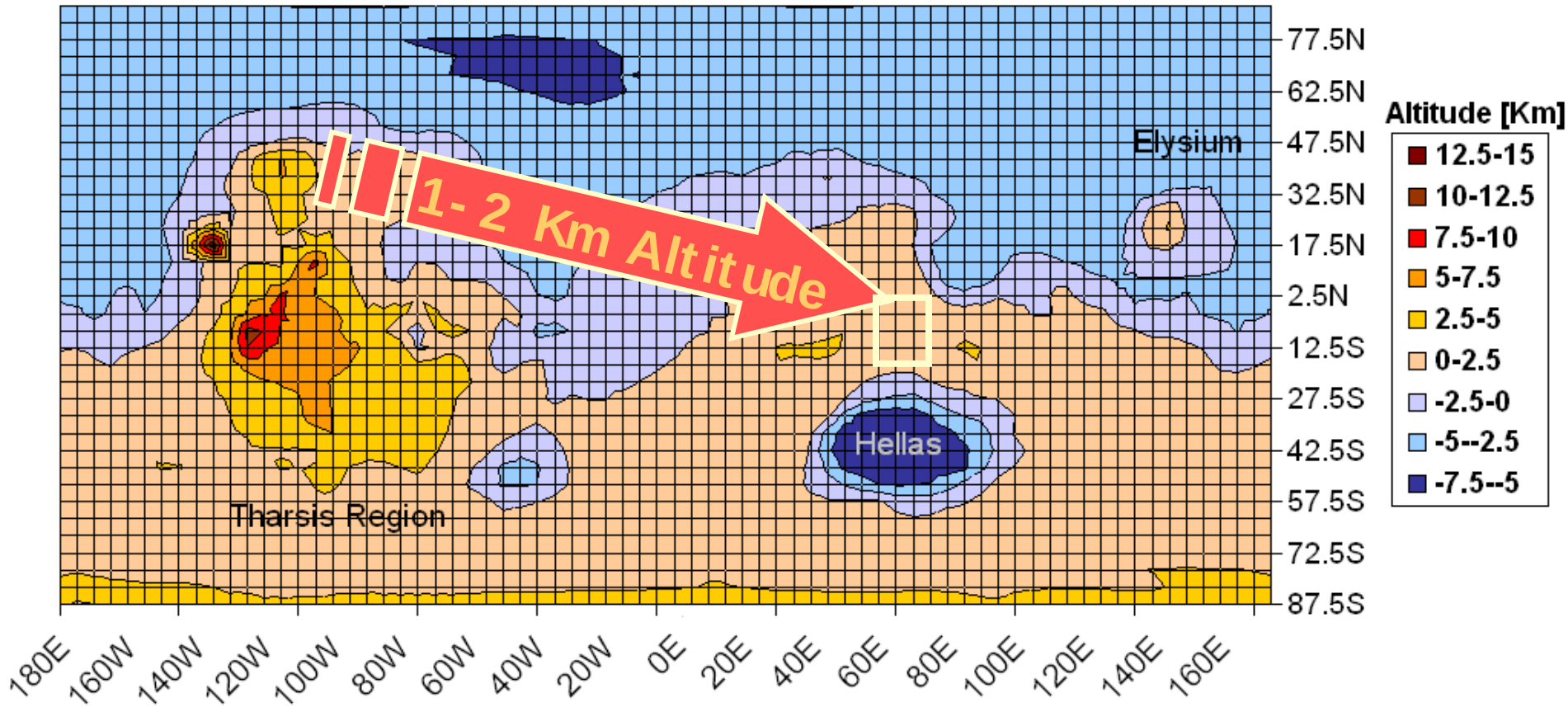
- 19% All particles
- 51% Neutrons





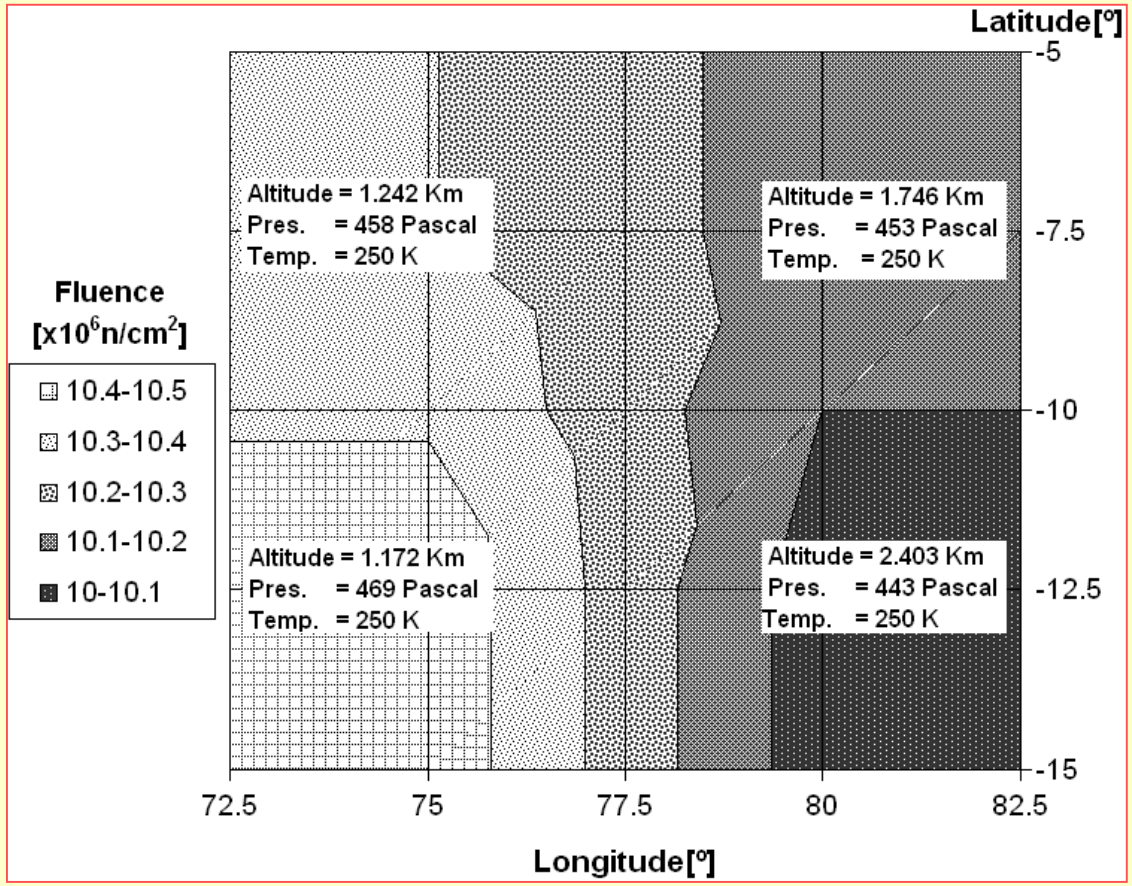


Tyrrhena Paterea (12h, Ls=180-210)



GCR : Fluence Maps at the Surface

- Neutrons E>30MeV
- Lower Altitude
- Higher Pressure
- Higher Fluences
- Fluences ~ 10^7n/cm^2 per year



GCR: Low Energy Neutrons

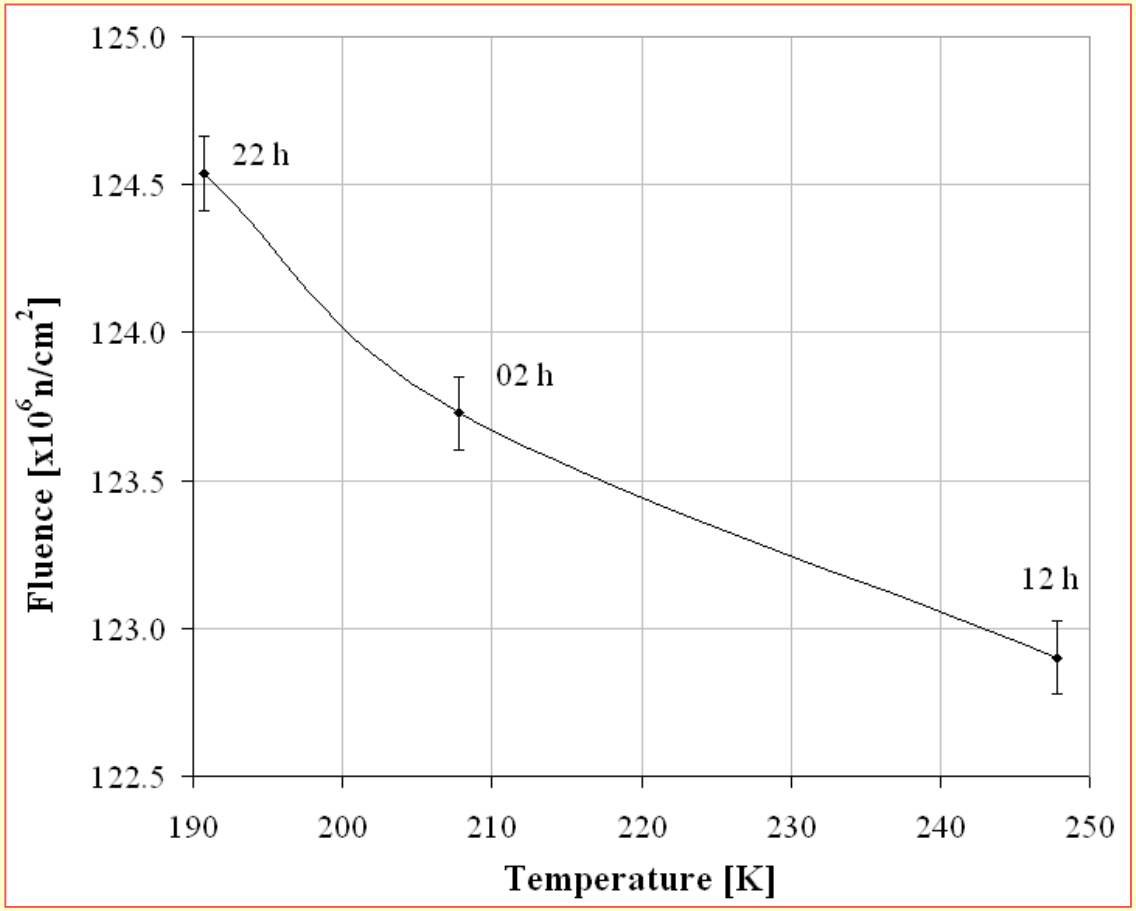
- Neutrons E< 30MeV
- Mars Univarsal Time

Martian Longitude 0º:

  - 22h : 191K
  - 02h : 208K
  - 12h : 248K
- Fluences Per year

  ~ 10^8n/cm^2
- Temperature changes

  -> 1%



Summary

Input	Site	High Lights
GCR	Tyrrhena Patera (80E, 7.5S)	▪ Doses per year: <10 rad(SiO2) ▪ Neutron (>30MeV) : 10^7 ▪ Neutron (<30MeV) : 10^8
GCR	Olympus Mons Cliff (140W, 22.5N)	▪ Tot.Fluences [x10^8 #/cm^2] per year : p = 0.3, e-= 0.1, n = 1.5, i < 0.1, γ = 1.5 ▪ Backsc: 96% neutrons, 60% all particles
SEP WW	Olympus Mons Cliff (140W, 22.5N)	▪ Tot.Fluences [x10^8 #/cm^2] per evt : p = 7.4, e-= 0.7, n = 3.5, i << 0.1, γ = 6.2 ▪ Backsc: 51% neutrons, 19% all particles

Conclusions

- Results show:
  - Energy Spectra and Particle Species at any location 5ºx5º.
  - Backscattered component : Very Important.
  - TID on the surface will probably not concern electronics
  - Proton and Neutron environments -> result in NIEL effects and in SEE.
- Methodology easily adaptable:
  - To evaluate dose equivalents and induced degradation on components;
  - To future improved knowledge of geology and atmosphere, e.g. local water ice content in the soil;
  - Direct adaptable for other planets and Moons such as Mercury and Europa

Spenvis Interface

- Methodology is intended to be :
  - Publicly available in the future
  - Interfaced with Spenvis.
- Discussion is needed