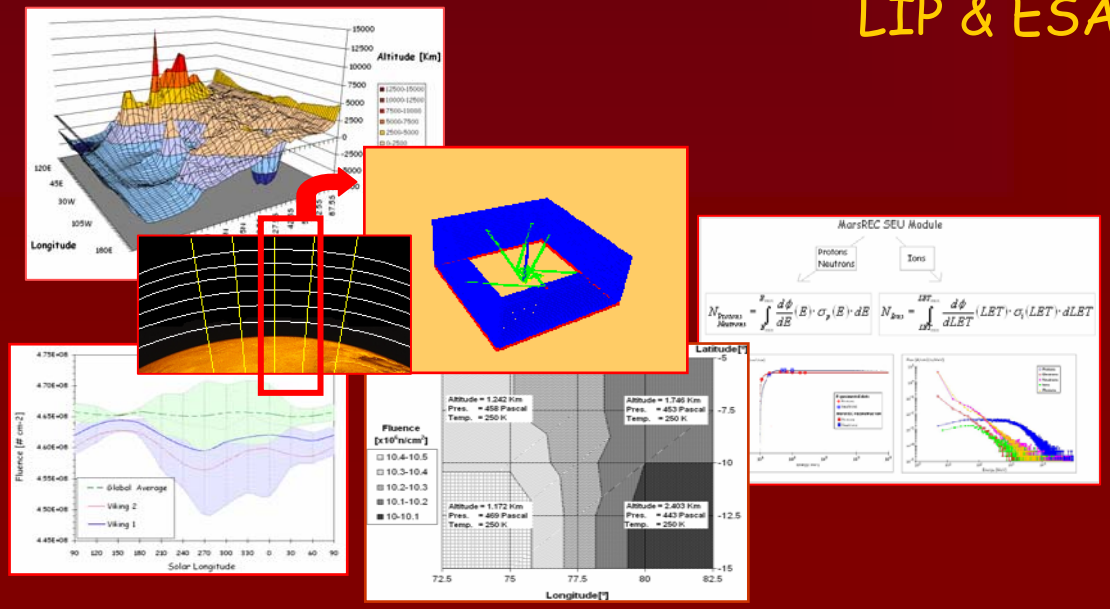
MarsREC

An integrated tool for Mars Radiation Environment Characterization and Effects

LIP & ESA 18121/04/NL/CH



keating@lip.pt

MarsREC: Motivation & Challenge

- Integrated simulation tool for Mars Radiation Environment and Radiation induced Effect in EEE Components.
  - landing locations, time and season of the Martian year.

Two Modules:

- Radiation Environment Characterization
- Radiation Effects

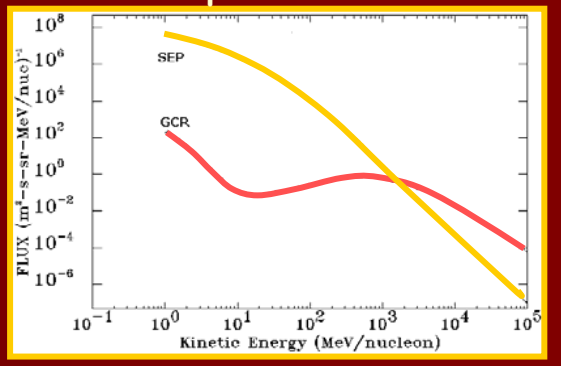
Outputs:

- Environment description, Doses and SEU rate predictions.

Outline

- MarsREC : Environment Module
  - Summary and results review
- MarsREC : Effect Module
  - Description
  - Principle of SEU rate calculation
  - Results
- Mission scenario
- Comparisons / Verification
- GEANT4 problem Report
- Conclusions

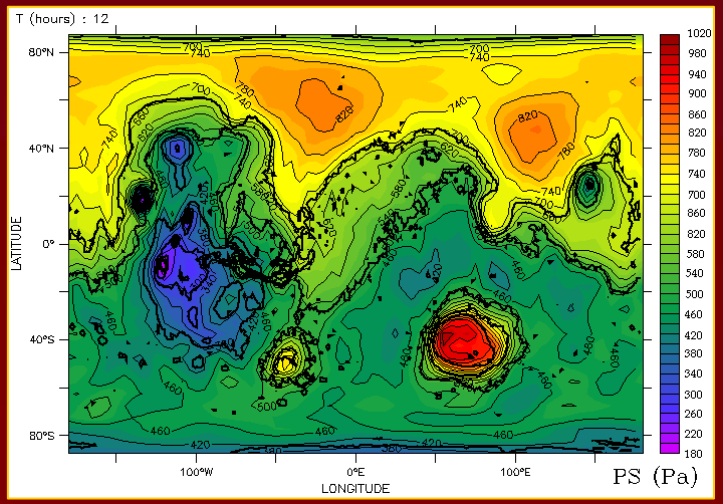
Radiation inputs - CREME96



https://creme96.nrl.navy.mil/

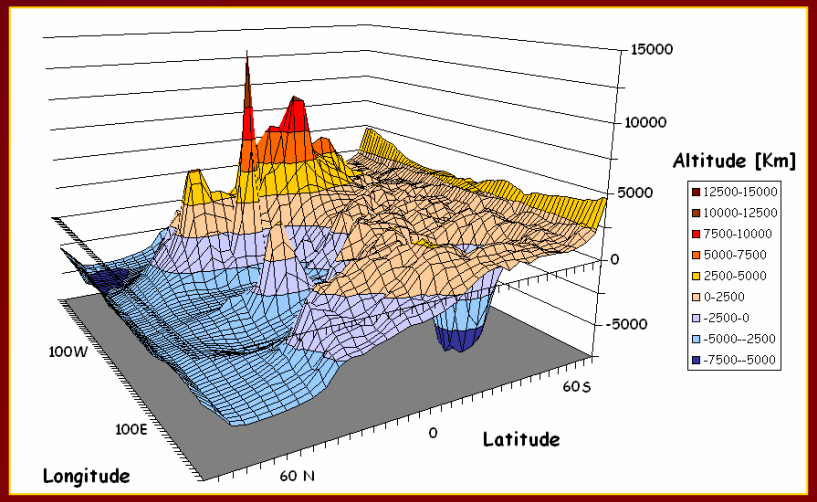
MarsREC: Environment Module

Atmosphere – MCD



http://www-mars.lmd.jussieu.fr/

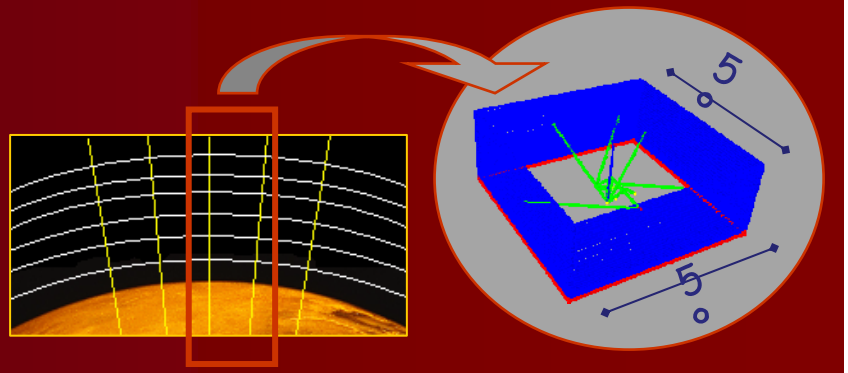
Soil - MOLA



http://geant4.web.cern.ch/geant4/

GEANT4 and set-up

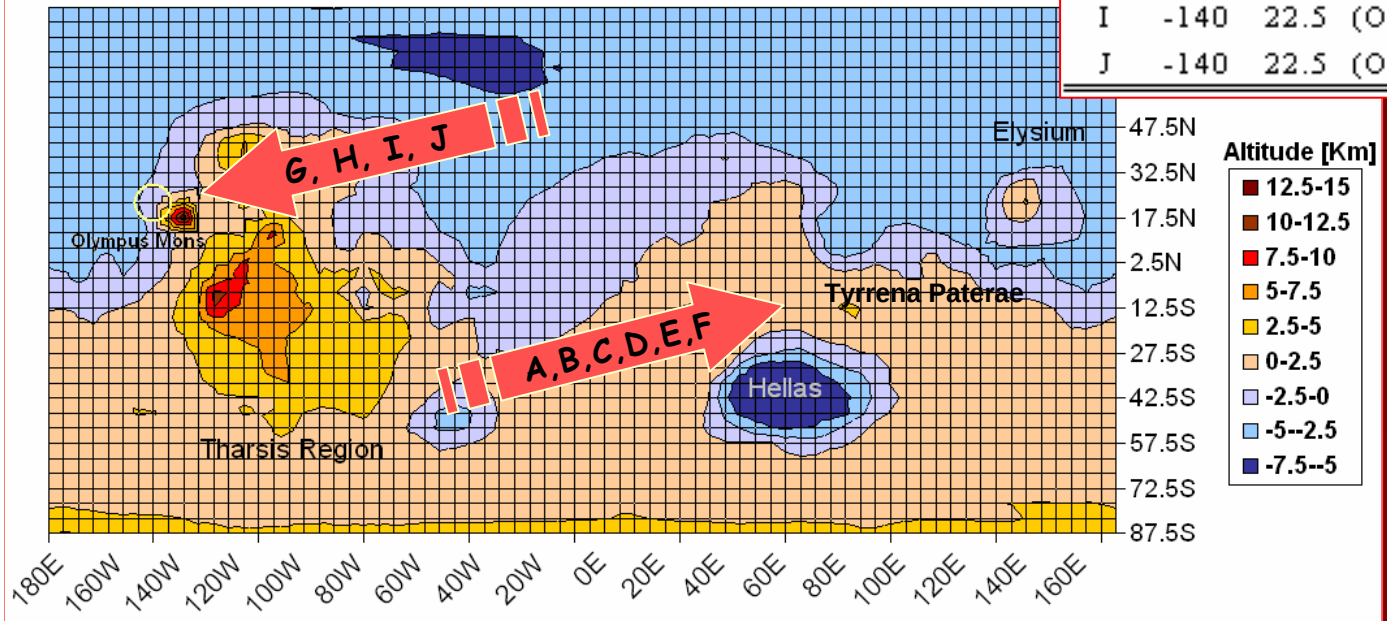
Regime	Model	Application
Hadron-nucleon or hadron-nuclear	Parameterised	Cosmic ray nuclei and secondaries; Trapped protons and secondaries
	Parton-string (>10GeV)	
	Kinetic/INC (10MeV-10GeV)	
	Abrasion/Ablation	
	Pre-compound (2-100 MeV)	
	Low-energy neutron (thermal - 20 MeV)	Secondary neutrons, including atmospheric/planetary albedo neutrons
	Isotope production	Induced radioactive background calculations
Electromagnetic	Ionisation	Important for treatment of SEE (microdosimetry from nucl. recoil and evap. prods); Trapped electron effects; Induced and natural radioactive backgrounds
	Multiple scattering	
	δ-ray production	
	Bremsstrahlung	
	Annihilation	
	Photo-electric effect	
	Compton scattering	
	Rayleigh scattering	
	Pair-production	
	Atomic relaxation	



Analysed Locations

- 6 different Locations
- North and South, East& West
- Solar Longitude 180°-210°

Case	Long [°E]	Lat [°N]	Name	Solar Longitude	Time [Hours]	Depth [g/cm²]
A	75	-7.5	(TP)	180°-210°	12	14.12
B	75	-12.5	(TP)	180°-210°	12	14.46
C	80	-7.5	(TP)	180°-210°	02	14.63
D	80	-7.5	(TP)	180°-210°	12	13.95
E	80	-7.5	(TP)	180°-210°	22	14.46
F	80	-12.5	(TP)	180°-210°	12	13.65
G	-105	22.5	(OM)	180°-210°	12	9.60
H	-140	22.5	(OM)	180°-210°	02	16.46
I	-140	22.5	(OM)	180°-210°	12	16.63
J	-140	22.5	(OM)	180°-210°	22	17.44



Different times of the Martian day at Long. 0°:

- 02h, 12h, 22h

MarsREC Results

Fluences

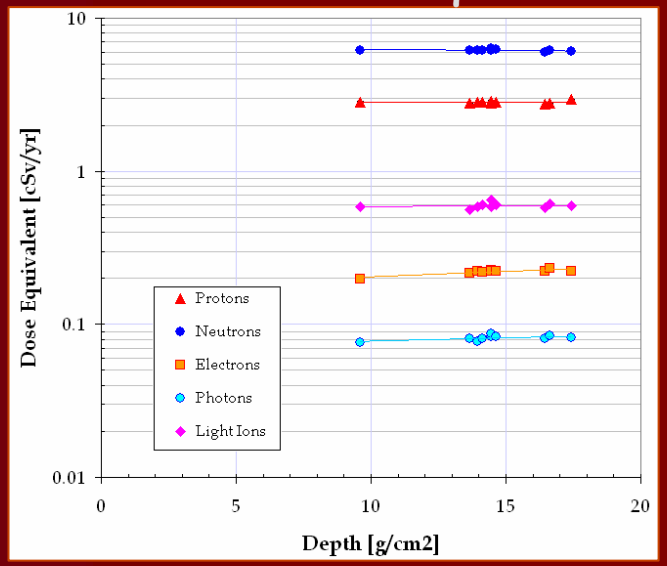
Particles Species	GCR Fluence per year [x10^8 #/cm^2]	SEP* Fluence per event [x10^8 #/cm^2]
Protons	4.666	7.425
Electrons	0.132	0.663
Neutrons	2.177	3.475
Ions	0.018	0.001
Photons	2.120	6.262

*Considered event duration of 338 hours

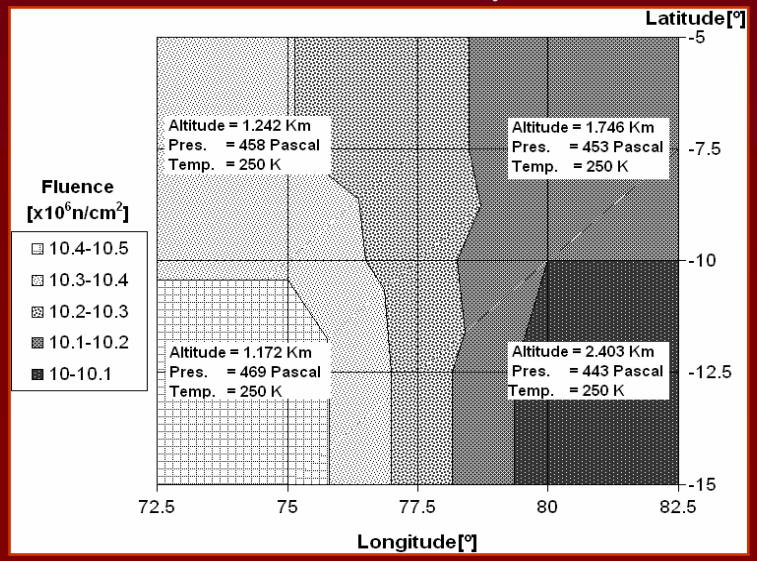
Doses due to GCR

Particles Species	Dose per year [Rad(SiO_2)]
All	2.80
Protons	2.07
Electrons	0.35
Ions	0.25

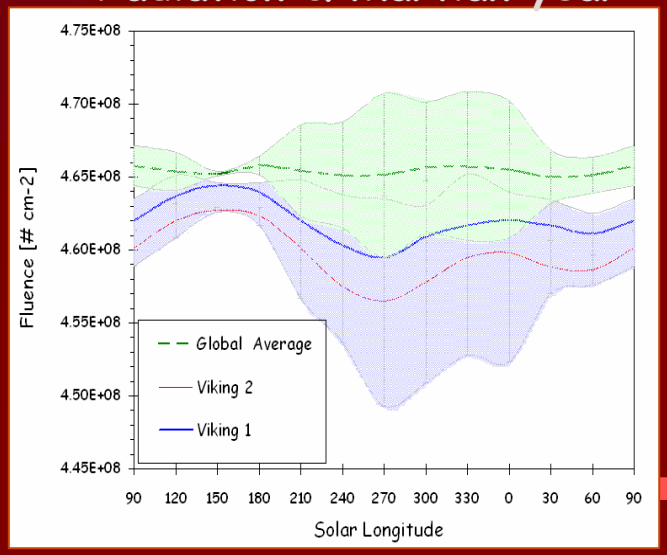
Ambient Dose Equivalent



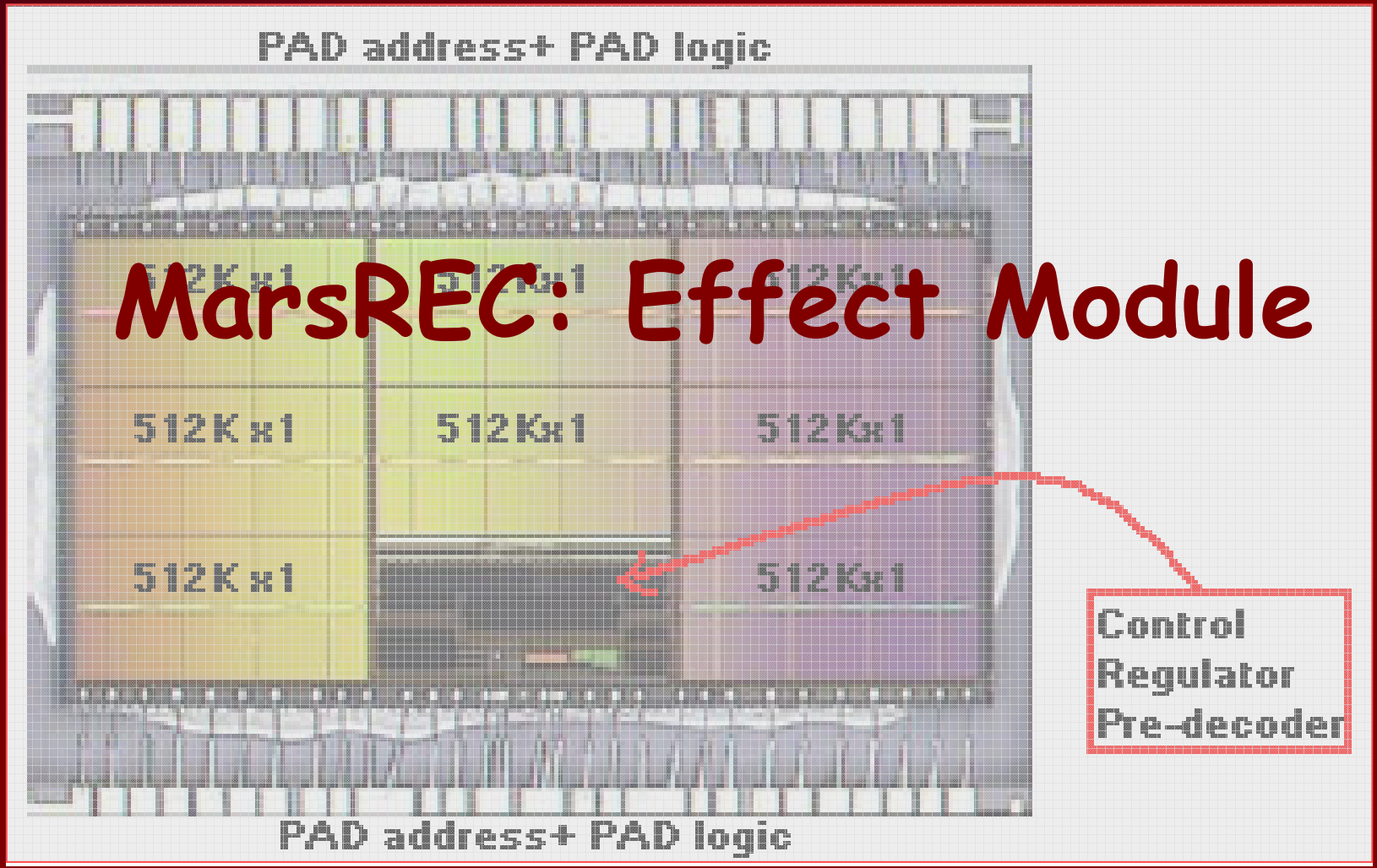
Fluence Maps



Radiation & Martian year

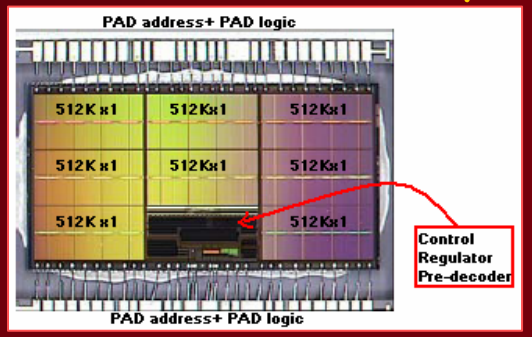


MarsREC: Effect Module



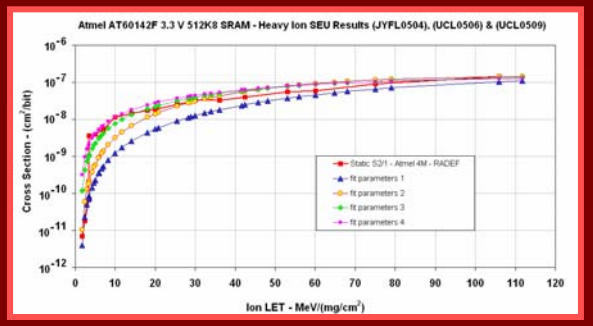
ATMEL SRAM description

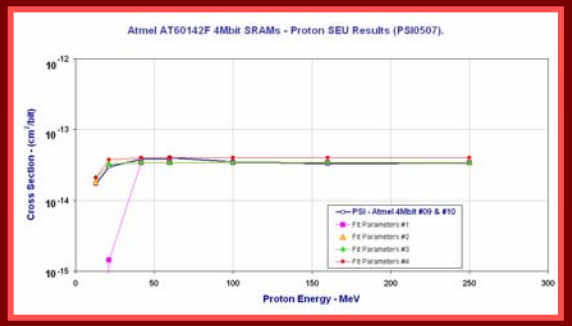
- The die is 6.1 x 11.2 mm² and the memory cell is 3.1 x 3.15 μm;

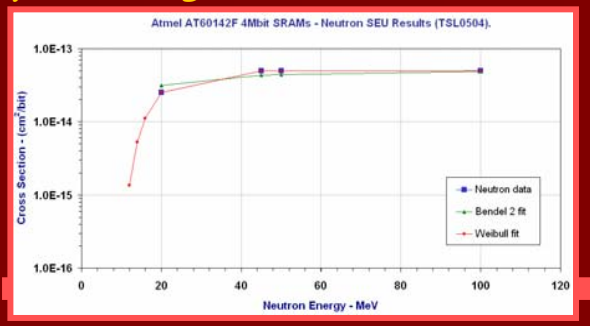


- The device was tested with Ions, Protons and Neutrons;
- SEU cross sections

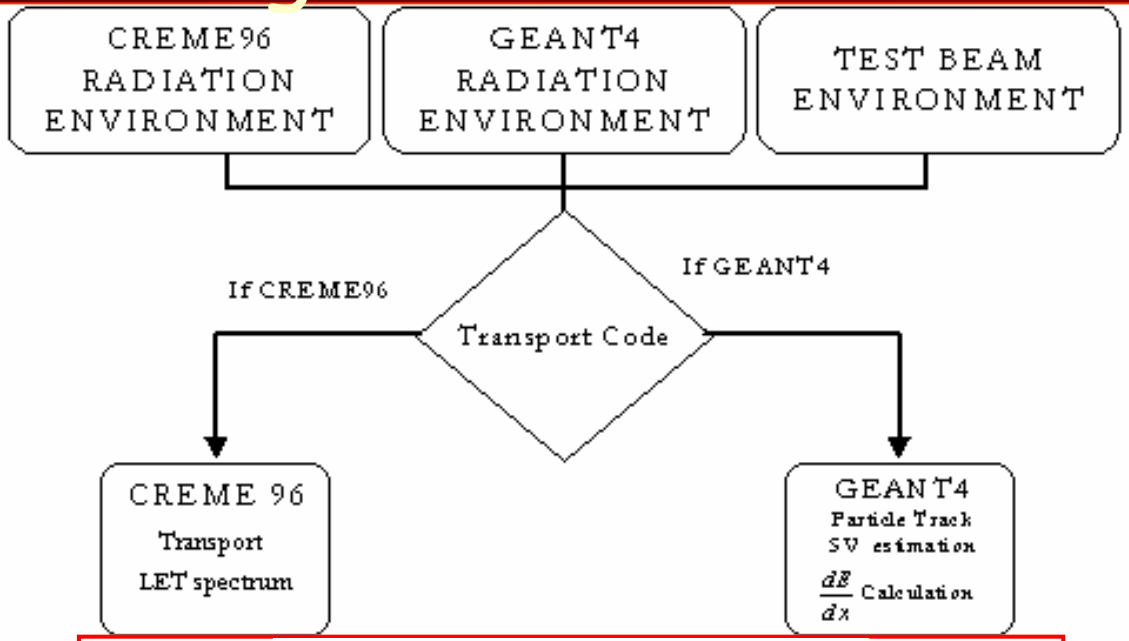
R. Harboe-Sørensen, proceedings, RADECS 2005.







Framework Design



$$F(x) = A\left(1 - \exp\{-[(x-x_0)/W]^S\}\right)$$

Weibull Method Parameters		Description	
		Protons/Neutrons	Ions
Variable	x	Energy [MeV]	LET [MeV/(mg/cm²)]
Plateaux Limiting σ	A	x10⁻¹²[cm²/bit]	[μm²/bit]
Onset parameter, F(x) = 0 for x < x₀	x0	Threshold Energy [MeV]	Threshold LET [MeV/(mg/cm²)]
With	W	With Parameter [MeV]	With Parameter [MeV/(mg/cm²)]
Exponent	s	Dimensionless parameter	

CREME 96

HUP SEU rate by Ions

PUP SEU rate by Protons

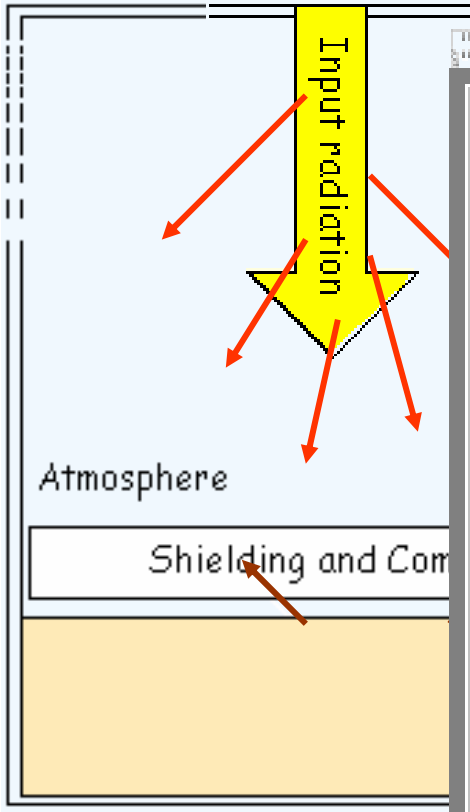
GEANT4

SEU rate by Ions

SEU rate by Protons

SEU rate by Neutrons

Principle of SEU Rate Calculation



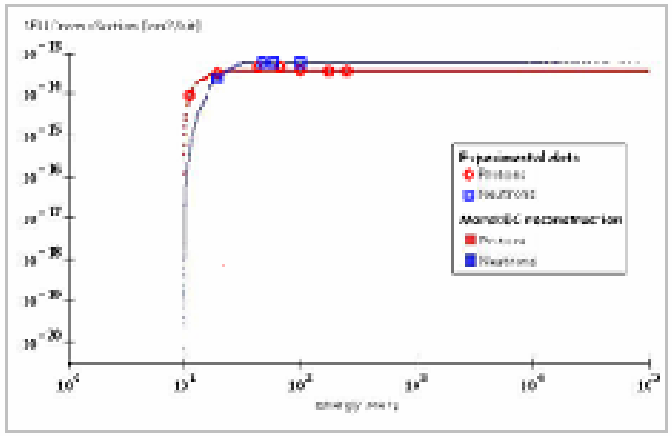
MarsREC SEU Module

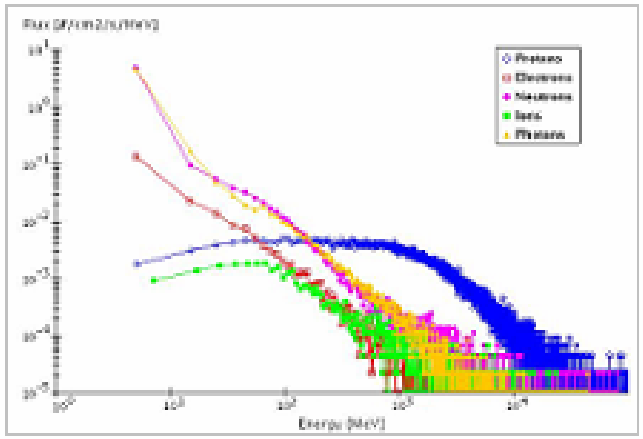
Protons
Neutrons

Ions

$$N_{\substack{Protons\\Neutrons}} = \int_{E_{min}}^{E_{max}} \frac{d\phi}{dE}(E)\cdot\sigma_p(E)\cdot dE$$

$$N_{Ions} = \int_{LET_{min}}^{LET_{max}} \frac{d\phi}{dLET}(LET)\cdot\sigma_i(LET)\cdot dLET$$





Problem with Ions

- GRAS interface with to implement Geant480.p01 physics list and run ions.
- Run Carbon (6,12), energy distribution - GCR spectrum
- Using LHEP_BIC_HP physics list

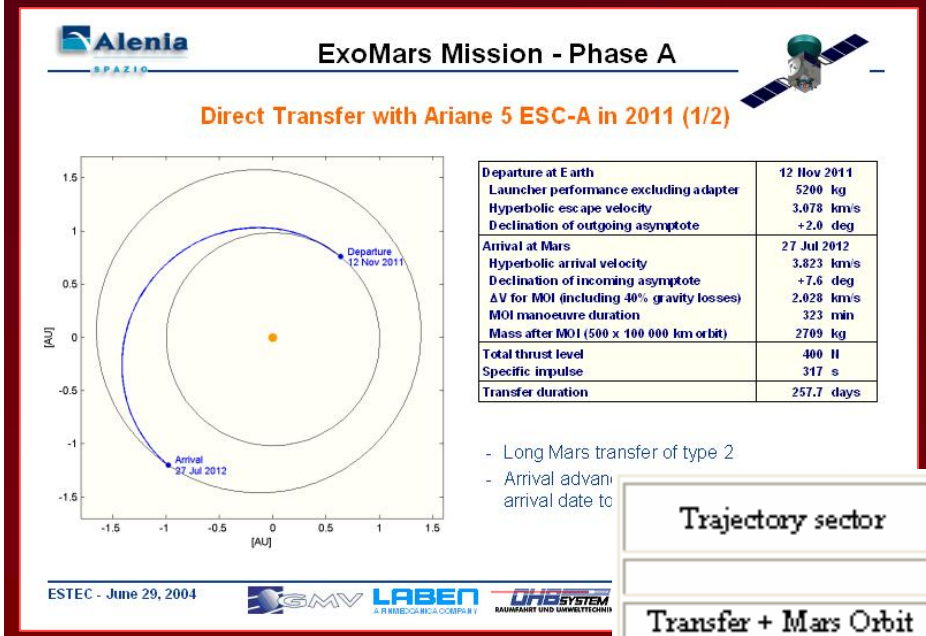
```
*** G4Exception : 007
      issued by : G4HadronCrossSections
      GetParticleCode: unsupported particle
*** Fatal Exception *** core dump ***
*** G4Exception: Aborting execution ***
```

In Hypernews - exactly the same

Discussion with Vladimir Ivantchenko

- This bug likely connect with the fact, that for some of nucleus default cross section is not available
- Should be fixed in the further releases!

GCR : Mission Scenario

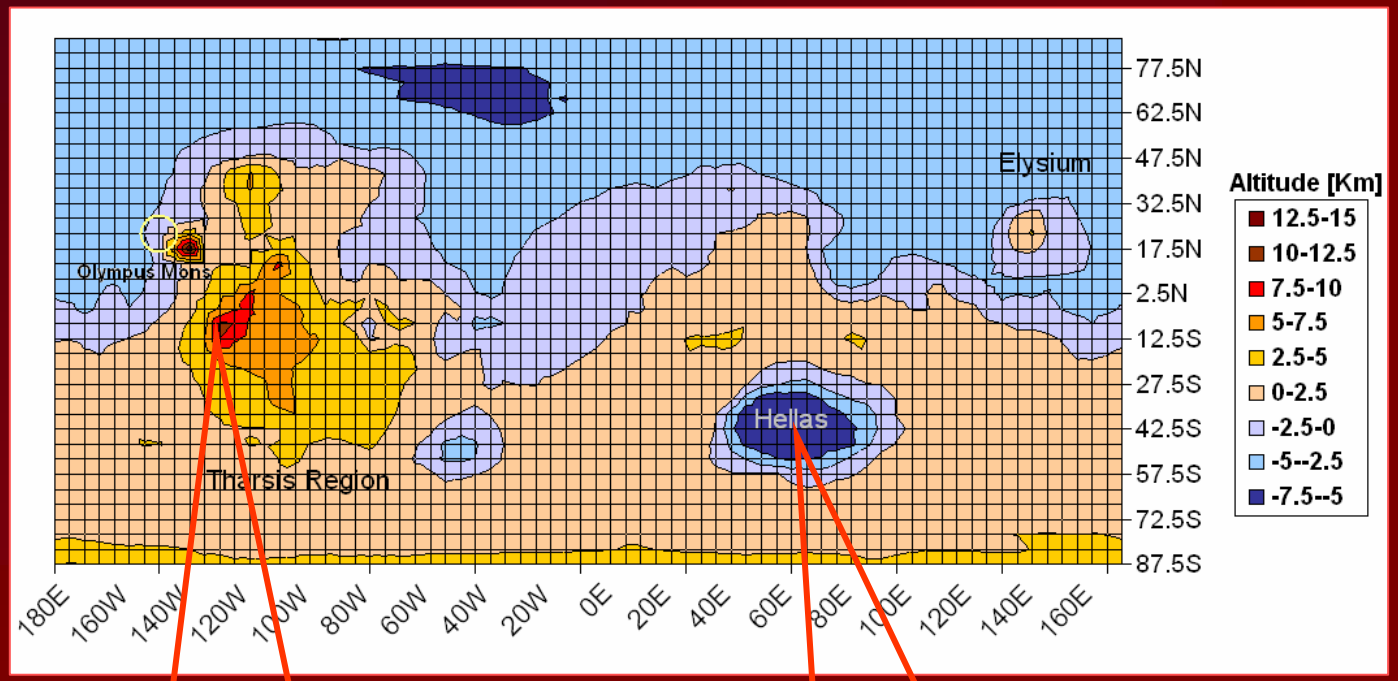


- Mission scenario -> foreseen for EXOMARS (2011)
  - slide from the ExoMars Mission-Phase A presentation by Alenia Spazio.
- SEU predictions for GCR Protons

SEU rates :
Mission Duration

Trajectory sector	Duration [Days]	Environment Type	SEU rate [/device/day]	SEU rate Per device
Protons				
Transfer + Mars Orbit	260	Interplanetary	2.06E-02	5.37E+00
Mars Landing	366	Mars Surface	1.36E-02	4.98E+00
Neutrons				
Transfer + Mars Orbit	260	Interplanetary	6.90E-04	1.79E-01
Mars Landing	366	Mars Surface	6.05E-03	2.21E+00
Total				1.27E+01

Dependence on lading site



Surface pressure = 189,4 Pa

Surface pressure = 1004 Pa

=> 35% Differences in fluence

In particular:

⇒N =57%

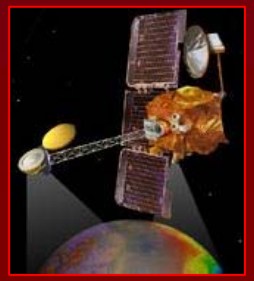
⇒P = 12%

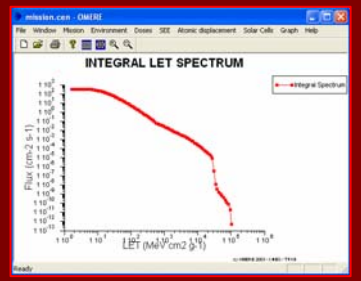
⇒E = 37%

⇒γ= 26%

Comparison/Verification

Evaluation MarsREC predictions in comparison with other predictions and experimental data.

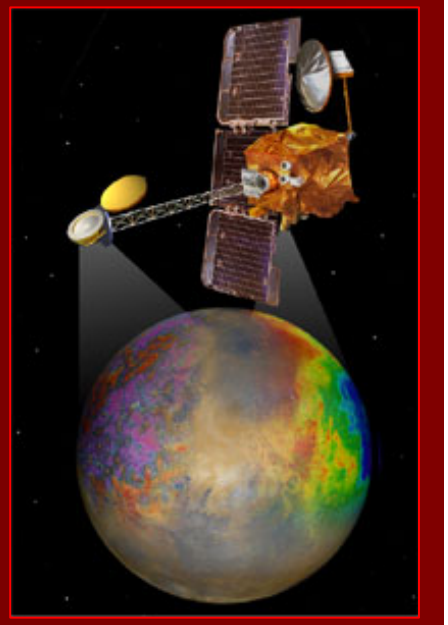




NOTE: Available/published results obtained in different conditions.

SO : Evaluation of orders of magnitude instead of accurate validation.

Experimental Data



MARIE Instrument in orbit (Mars Odyssey Orbiter)

- Measured doses in orbit of Mars : Dec. 2002 to Oct. 2003

MarsREC

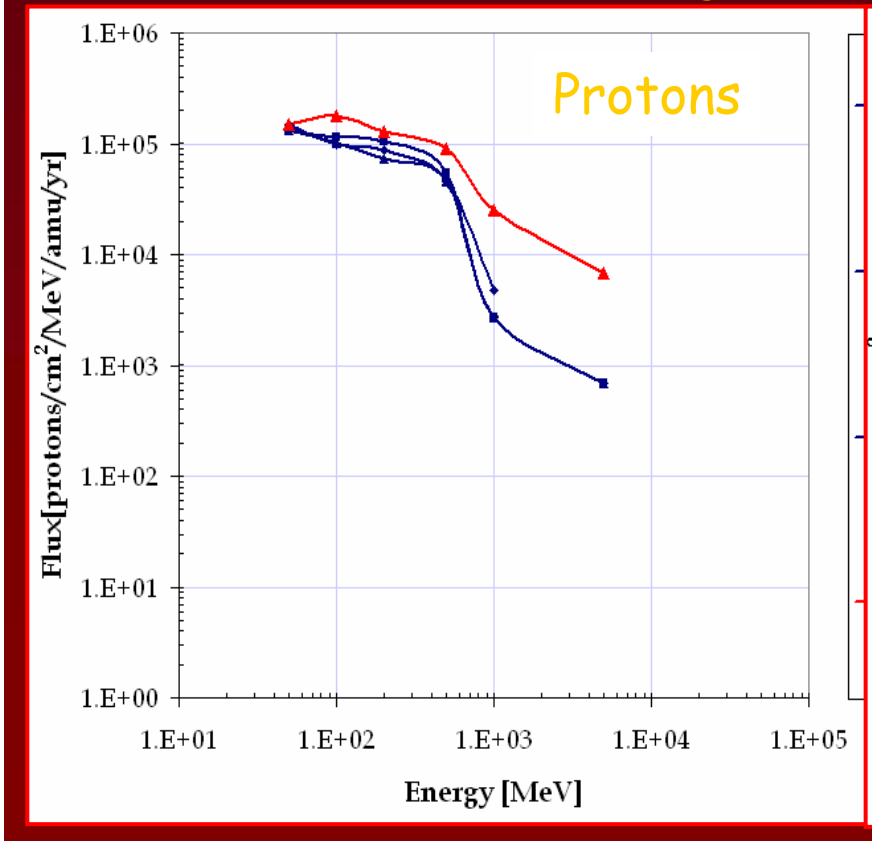
- Predicted dose rates at the surface
- For one location in Tyrrhena Paterae at 12h MUT (0°)

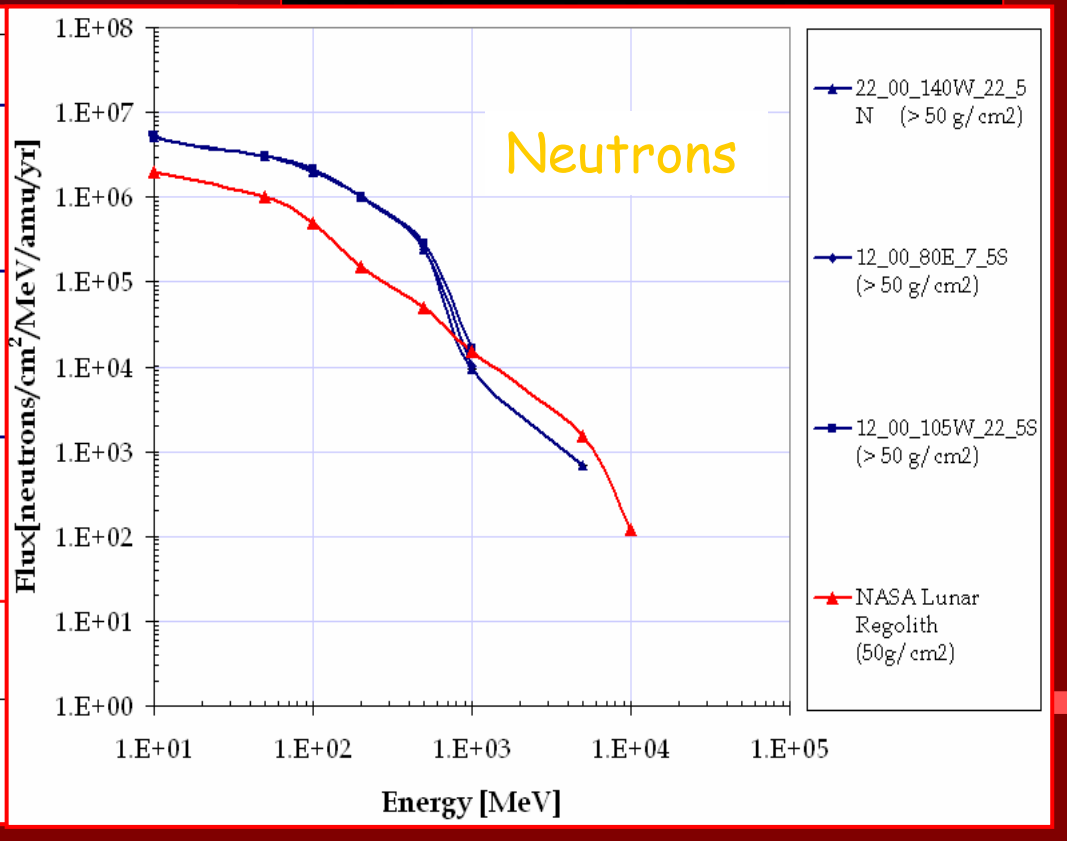
DATA/MARSREC	GCR	SEP	PEAK SEP
MARIE (Orbit)	15 – 22	20 – 30	> 1000
MARSREC (Surface)	10	5 -50*	100 – 1000*

* Depending on the Solar Event intensity

Regolith: Backscattered Radiation

- MarsREC : Mars > 50 g/cm²
- NASA : Moon = 50 g/cm²



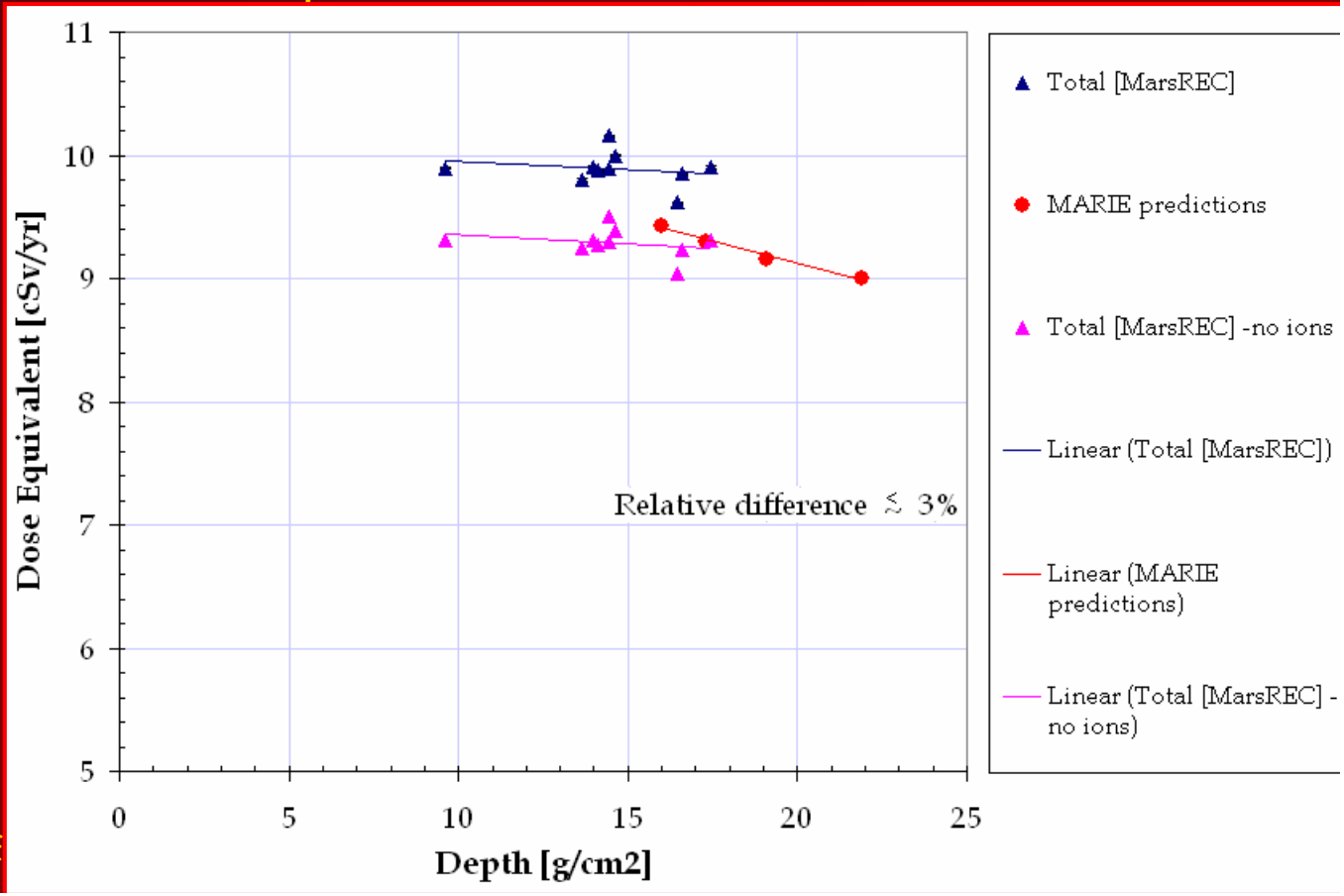


Comparing Dose Equivalent

- MarsREC fluences were converted to Dose Equivalents
- Using FLUKA fluence-to-dose equivalent conversion factors

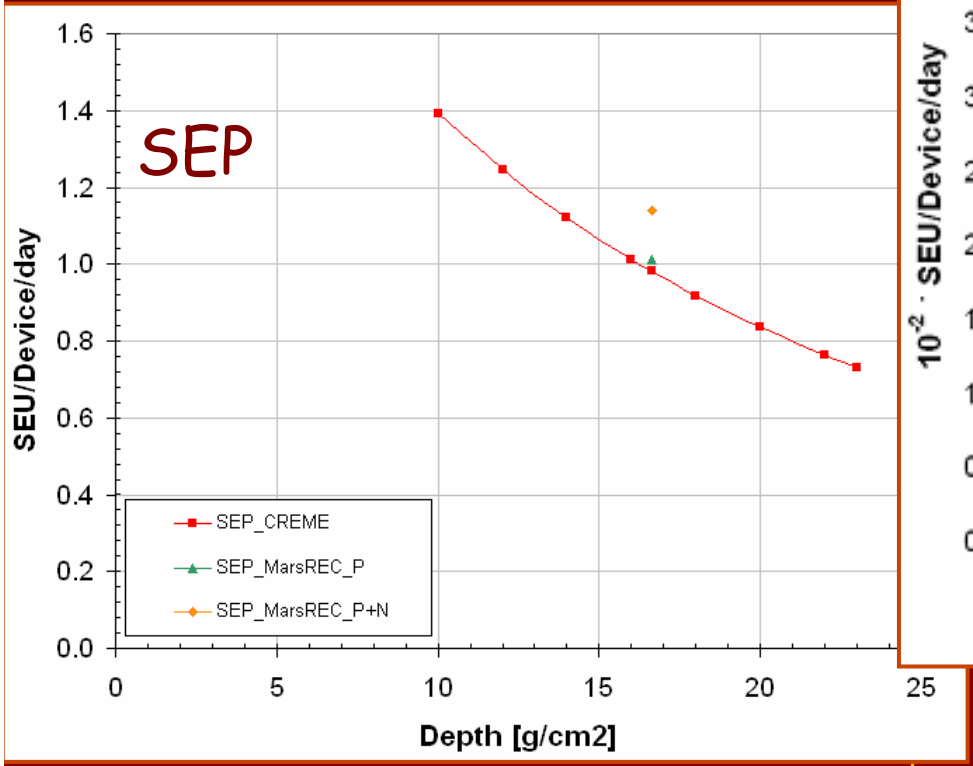
Considereations:

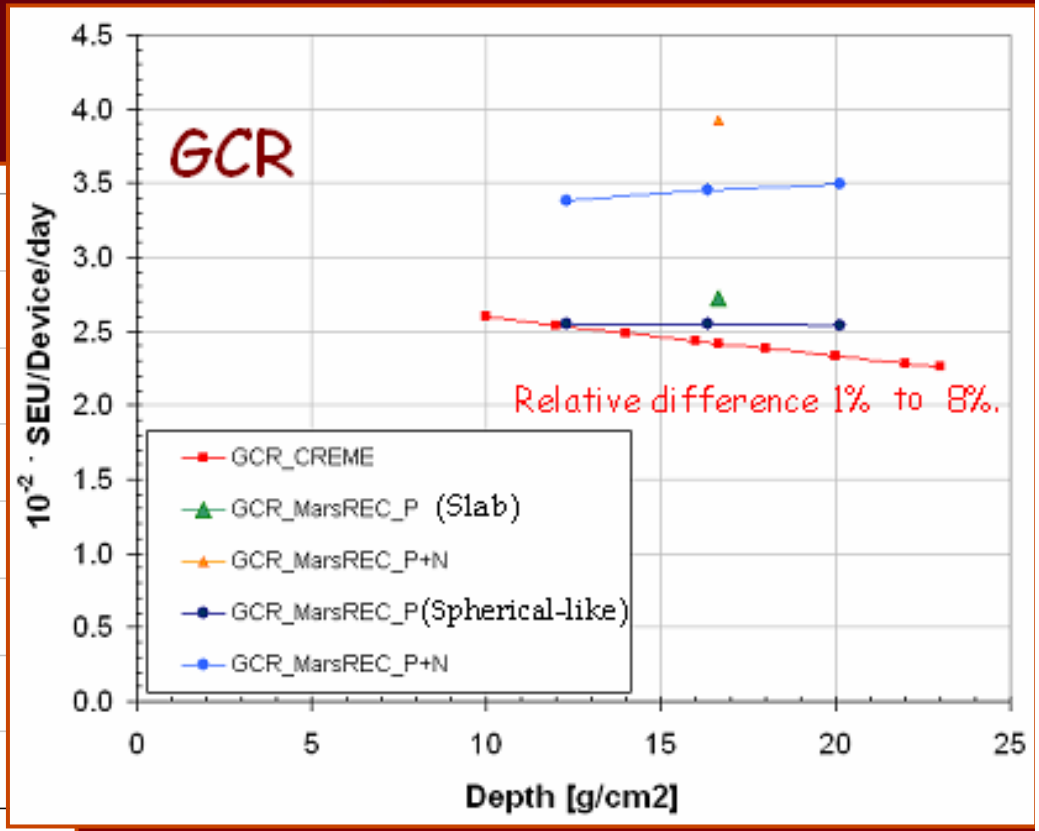
- MarsREC With/Without Ions
- MARIE predictions before flight



SEU rate : MarsREC vs CREME96

- SEP and GCR protons and protons+neutrons
- Normalization considerations
- Perpendicular and Isotropic





Conclusions

- MarsREC - integrated simulation tool for Mars Radiation Environment and Radiation induced Effect in EEE Components.
  - comprehensive method to provide SEU Rate prediction for EEE components on Mars
  - secondary particles generated in various shielding configurations, the Martian atmosphere and soil.
- Results show Very good agreement with other software predictions
- Landing site dependence -> important for SEE's and Equivalent Dose
- Ion physics needed!