The PLANETOCOSMICS
Geant4 application

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Outline

Description of the code
Simulation results for the Earth + validation
Simulation results for Mars
Simulation results for Mercury
First results for Jupiter and Europa
Motivation to model the interactions of energetic particles with planets

- Atmosphere ionisation
- Sputtering of atmosphere and surface
- Production of cosmogenic nuclides
- Measurements of the soil composition

- Quantify the radiation environment of planets
  - Albedo, CRAND process
  - Dose for aircrew and space mission
  - Dose vs depth in soil
GEANT4 Monte Carlo Toolkit

C++ library for computing by Monte Carlo simulation the electromagnetic and hadronic interactions of energetic particles (250 eV - 10 TeV) with matter.

Effect of the magnetic and electric fields can be taken into account.

Developed by a world-wide collaboration of physicists.
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Interaction of energetic particles with Planet Atmospheres and...
PLANTEOCOSMICS Geant4 Application

Propagation of charged particles in the Planet Magnetosphere
PLANETOCOSMICS

- Interaction of energetic particles with Earth, Mars, Mercury
- Fluxes of secondary particles at user defined altitudes, atmospheric depths, and soil depths
- Energy deposited vs atmospheric depth and vs soil depth
- Propagation in magnetic field
- Different coordinate system relative to planets
- Visualisation of particle trajectories and field lines
Flux of ionising particles over Moscow in 2000

[Graph showing the omnidirectional flux of particles vs. atmospheric depth]
Atmosphere ionisation induced by GCR

Ionisation over Durham NH May, 1969

Ionisation rate [ion pairs cm\(^{-3}\) s\(^{-1}\)]

- Lowder experiment
- Computed - GCR model 1
- Computed - GCR model 2
- Computed - GCR model 2 + heavy ions

atmospheric depth [g cm\(^{-2}\)]
Neutron flux at 56 g cm\(^{-2}\) \(R_c = 0.8\) GV in June 1997
Atmospheric ionisation at 300 g cm\(^{-2}\) at 06:57 on January 20\(^{th}\), 2005
Contribution of different particle types to Ambient equivalent dose on Mars

![Graph showing contributions of different particle types to ambient equivalent dose over depth](image-url)
10 MeV $e^-$ in the most magnetized region of Mars
Magnetic shielding on Mars at -47.8 N and 174 E

Tracking of $10^7$ downward mono-energetic particles starting at 300 km altitude

Detection of number of particles that hits the ground in function of position

10 MeV protons 10 MeV $e^-$
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Mercury Soil + Dipole $B_0 = 300$ nT

e\(- \rightarrow 1$ MeV
e\(+ \rightarrow 1$ MeV
proton $> 10$ MeV

10 GeV protons from dayside
Quasi trapped $e^-$ in Mercury dipole

Gurtner et al, 2006
Albedo Neutral radiation

- 10 GeV protons
- Neutrons
- Gammas
Effective Vertical Cut-off Rigidity at Jupiter

Gurtner et al, 2006
Radiations at Europa (~9.4 \( R_J \))

- Jupiter electrons (Divine and Garret 1983)
- Jupiter protons
- EPD Galileo
- GCR protons

Directional flux [nb part/s/cm²/MeV/sr]

Energy [MeV]
Dose in Europa soil (ice)

Gurtner et al, 2006
More informations on

cosray.unibe.ch/~laurent/planetocosmics

Gurner et al, 2005