

# PLANETOCOSMICS

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## Outline

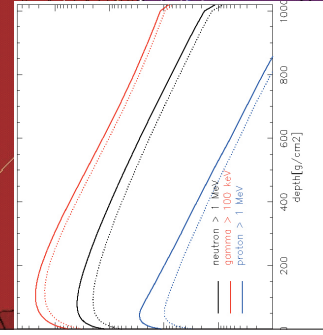
- Motivation
- Description of the code
- Simulation results for the Earth + validation
- Simulation results for Mars
- Simulation results for Mercury
- Results for Jupiter and Europa
- Other G4 developments by SpaceIT

## Motivation : model the interactions of energetic particles with planets

- Atmosphere ionisation
- Production of cosmogenic nuclides
- Measurements of the soil composition, neutron measurements, gamma spectroscopy
- Sputtering of atmosphere and surface
- Quantify the radiation environment of planets
  - Albedo, CRAND process
  - Dose for aircrew and space mission
  - Dose vs depth in soil (astrobiology, luminescence)

## PLANETOCOSMICS GEANT4 Application

Interaction of energetic particles with Planet Atmos



## PLANETOCOSMICS Geant4 Application

Propagation of charged particles in the Planet Magnetosphere

## PLANETOCOSMICS

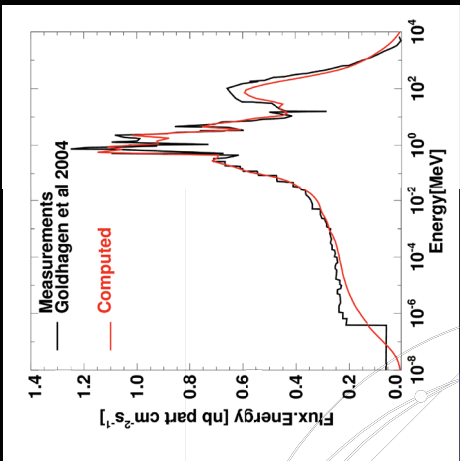
- Interaction of energetic particles with Earth, Mars, Mercury
- Fluxes of secondary particles at user defined altitudes  
atmospheric depths, and soil depths
- Energy deposited vs atmospheric depth and vs soil depth
- Propagation in magnetic field
- Different coordinate system relative to planets
- Visualisation of particle trajectories and field lines
- Analysis based on Root or AIDA

## Flux of ionising particles over Moscow in 2000

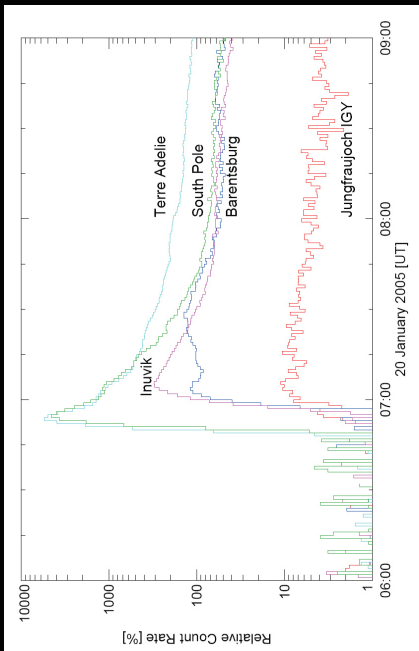
## Atmosphere ionisation induced by GCR

### Ionisation over Durham NH May, 1969

### Neutron flux at 56 g cm<sup>-2</sup> R<sub>c</sub> = 0.8 GV in June 1997



### The 20<sup>th</sup> January 2005 Ground Level Enhancement Neutron Monitor Observations



### January 20, 2005 GLE: The Method

From NM data we deduce the characteristic of the solar proton population outside the magnetosphere:

- apparent source
- pitch angle distribution
- rigidity spectrum

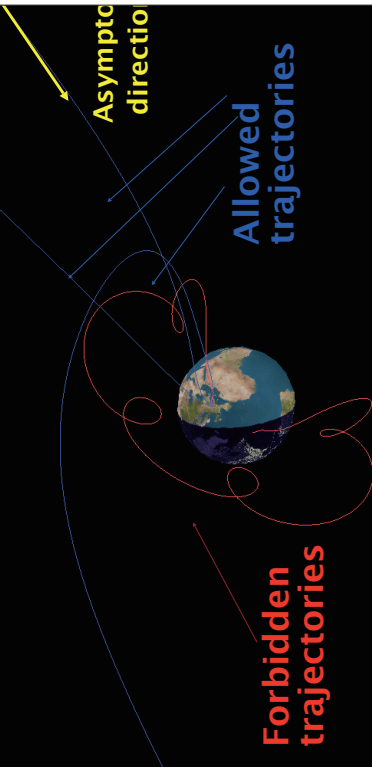
Propagation in the magnetosphere with PLANETOCOSMICS

- Flux at the top of the atmosphere

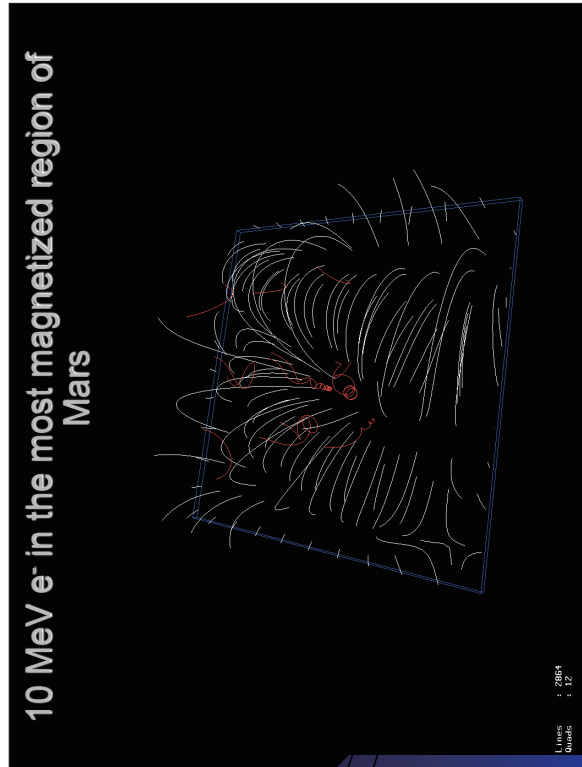
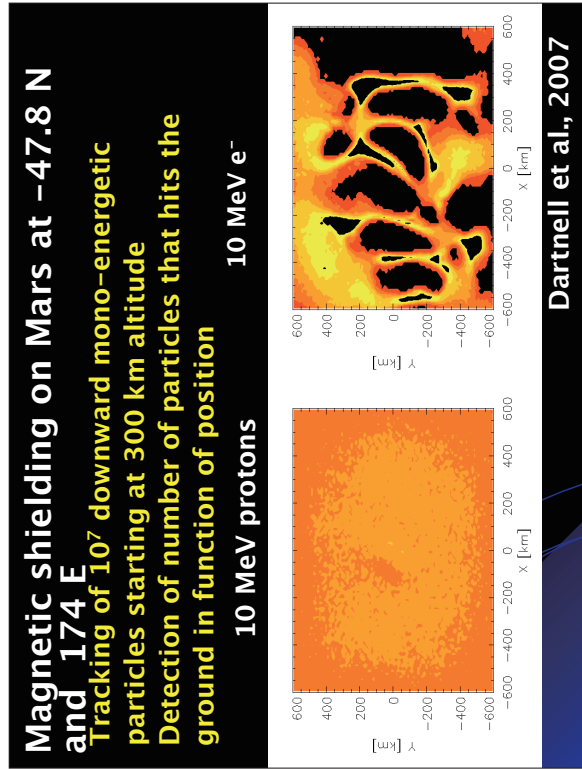
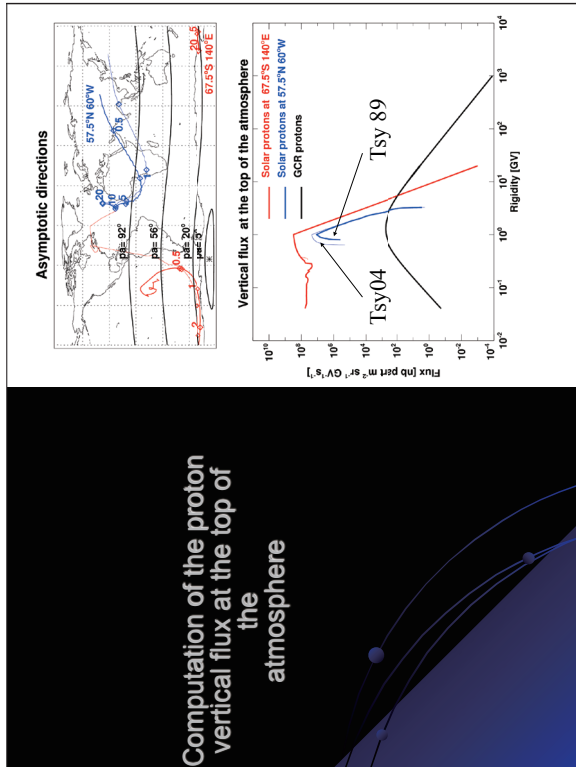
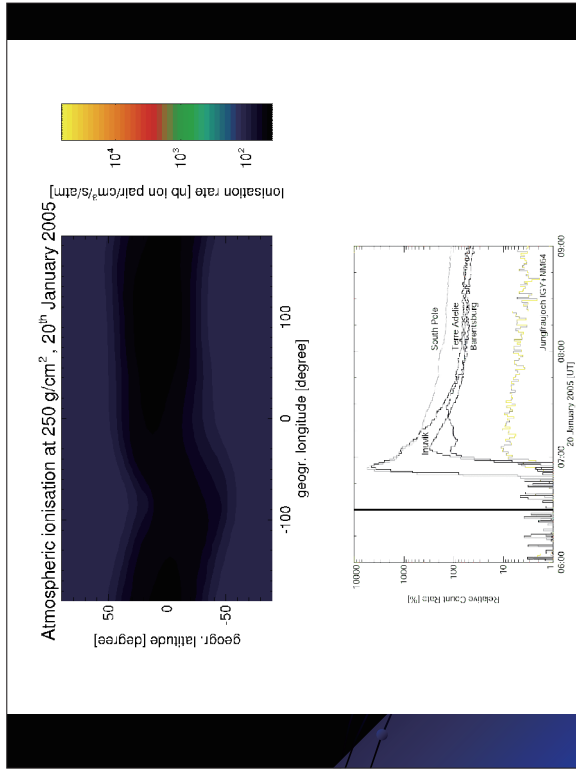
Air shower computed with PLANETOCOSMICS

- Ionisation
- secondary flux
- Effective dose

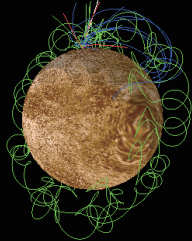
### Cosmic ray access to a position



- Computation of reverse trajectories in function of rigidity  $R=p/qc$

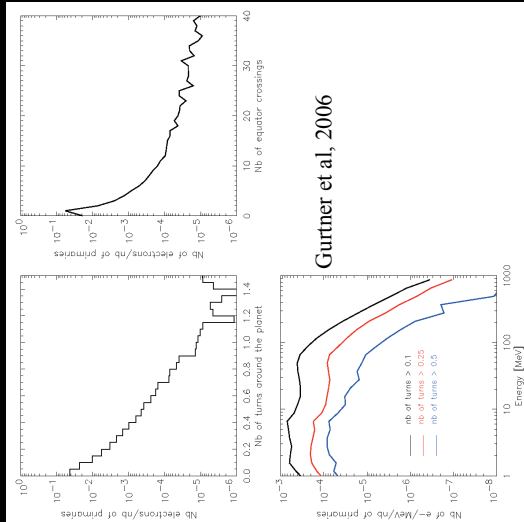


### Mercury Soil + Dipole B0= 300 nT

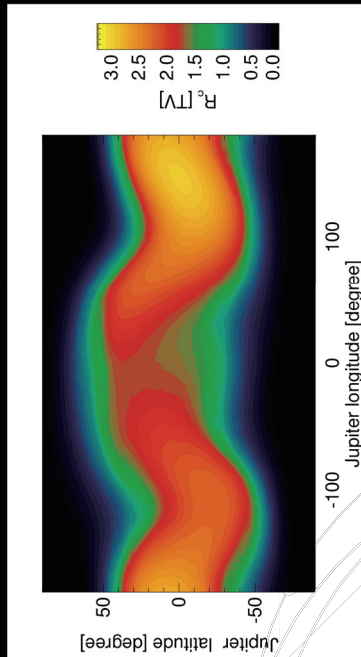


e- > 1 MeV  
e+ > 1 MeV  
proton > 10 MeV  
 10 GeV protons from dayside

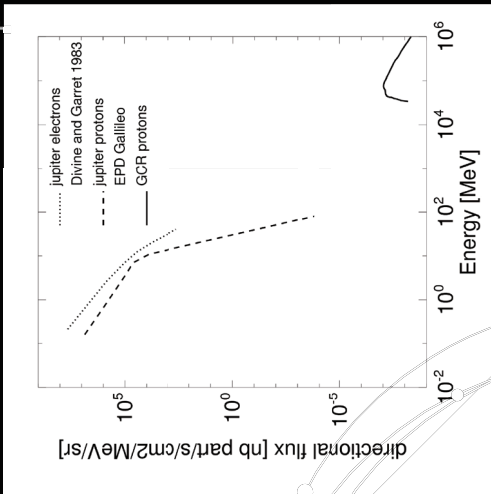
### Quasi trapped e- in Mercury dipole



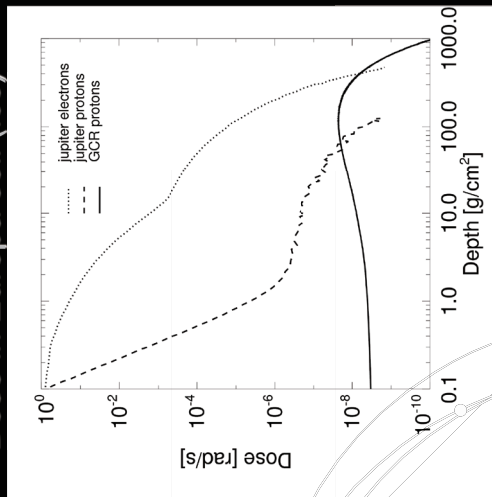
### Effective Vertical Cut-off Rigidity at Jupiter



### Radiations at Europa (~9.4 R<sub>J</sub>)



## Dose in Europa soil (ice)



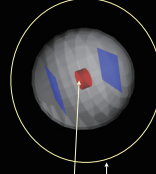
## Future developments and requirements

- Release of new version with Jupiter
- Add Saturn and Titan case
- Implement new Ion physics development in the physics list
- Improvement in the physics of gamma ray line production
- Effect of the gravitation field

## More informations on

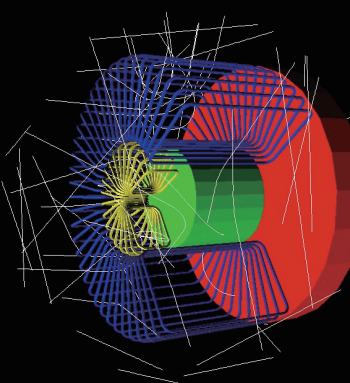
[cosray.unibe.ch/~laurent/planetocosmics](http://cosray.unibe.ch/~laurent/planetocosmics)

## Reverse Monte Carlo in G4

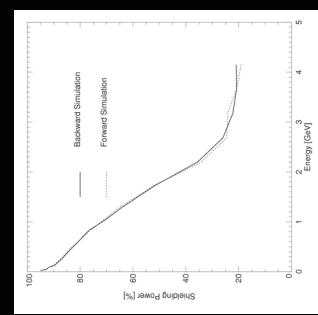


- Start from sensitive detector
- Reverse physics
- Stop at external source
- Much more rapid when sensitive part is small compared to the rest of the geometry
- First implementation in G4 for rapid e- dose computation
  - Continuous energy gain by ionisation and bremsstrahlung
  - Multiple scattering
- Discrete reverse ionisation, bremsstrahlung
- Discrete photo-electric, compton scattering

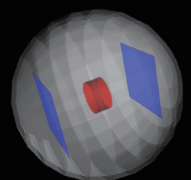
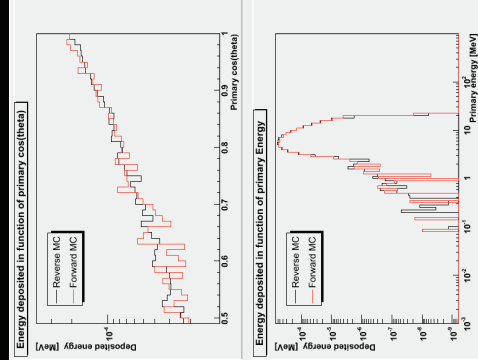
# Study of the shielding power of artificial magnetic field



## Development of a magnetic field model manager in G4 allowing to model complex assembly of Coils



# Reverse Monte Carlo in G4

# Magnetic field model manager in G4 allowing to model complex assembly of Coils

