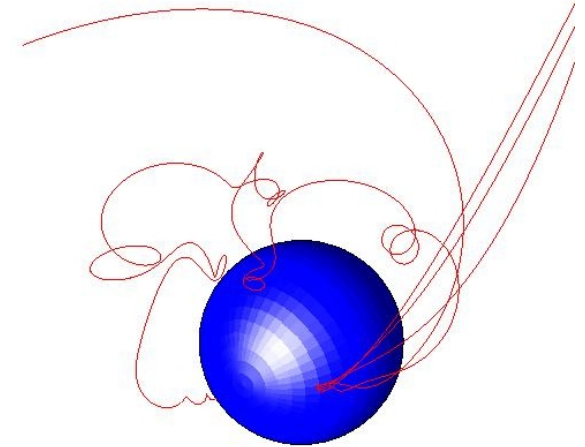# *Geant4 Simulations for Cosmic Rays*

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Overview

- **Cosmic ray propagation through the magnetosphere**
- **Cosmic ray propagation through the atmosphere**
- **Conclusions**

Propagation through the magnetosphere

- Tracing of charged particle motion in magnetospheric magnetic field model: IGRF+Tsyganenko
- Visualisation of trajectories and magnetic field lines
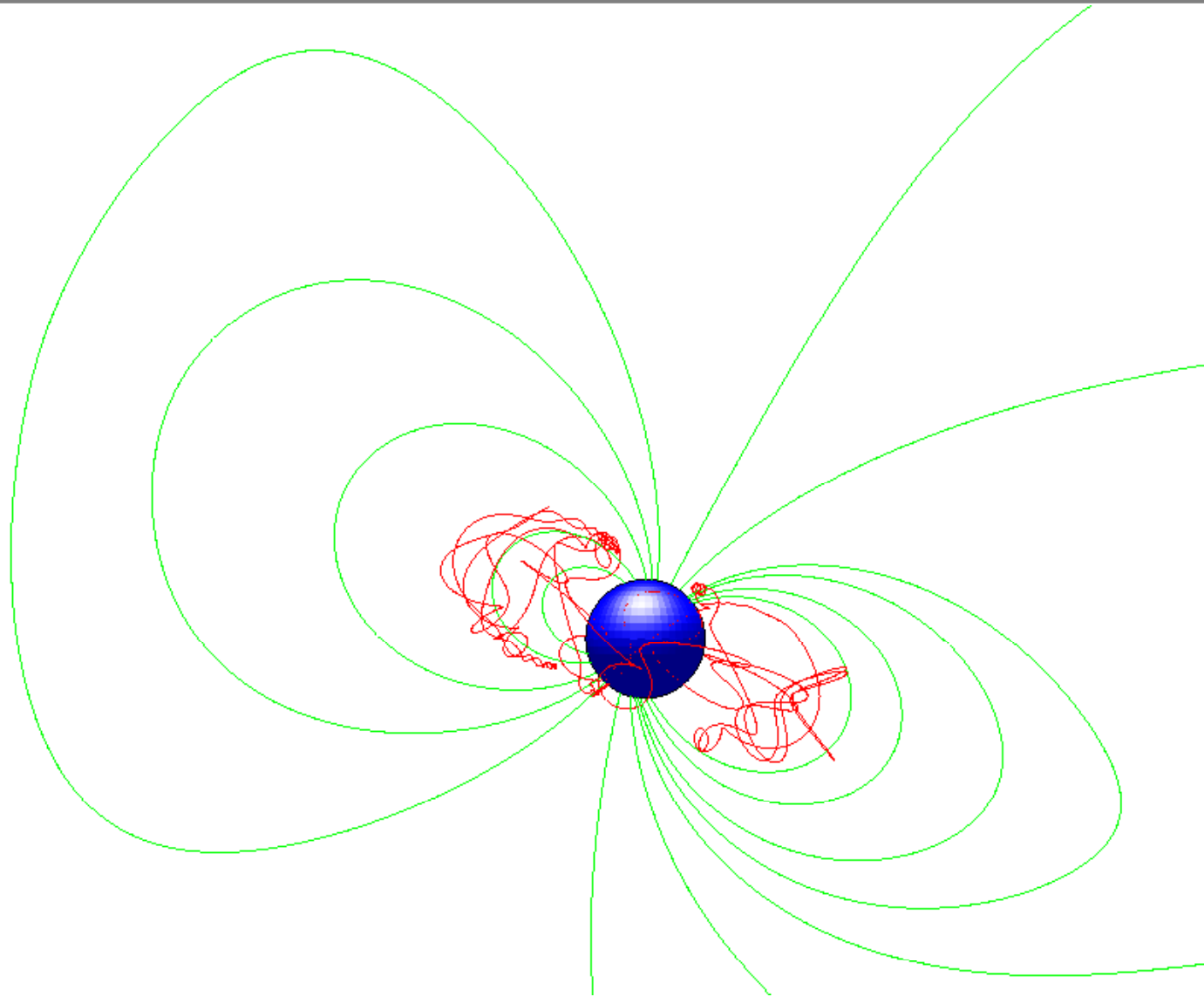- Computation of cosmic ray cutoff rigidities and asymptotic directions

Interactive Commands

- **Selection of magnetospheric Model**
- **Selection of time period**
- **Definition of geomagnetic activity**
- **Rigidity cutoff computation for different position, directions and time**
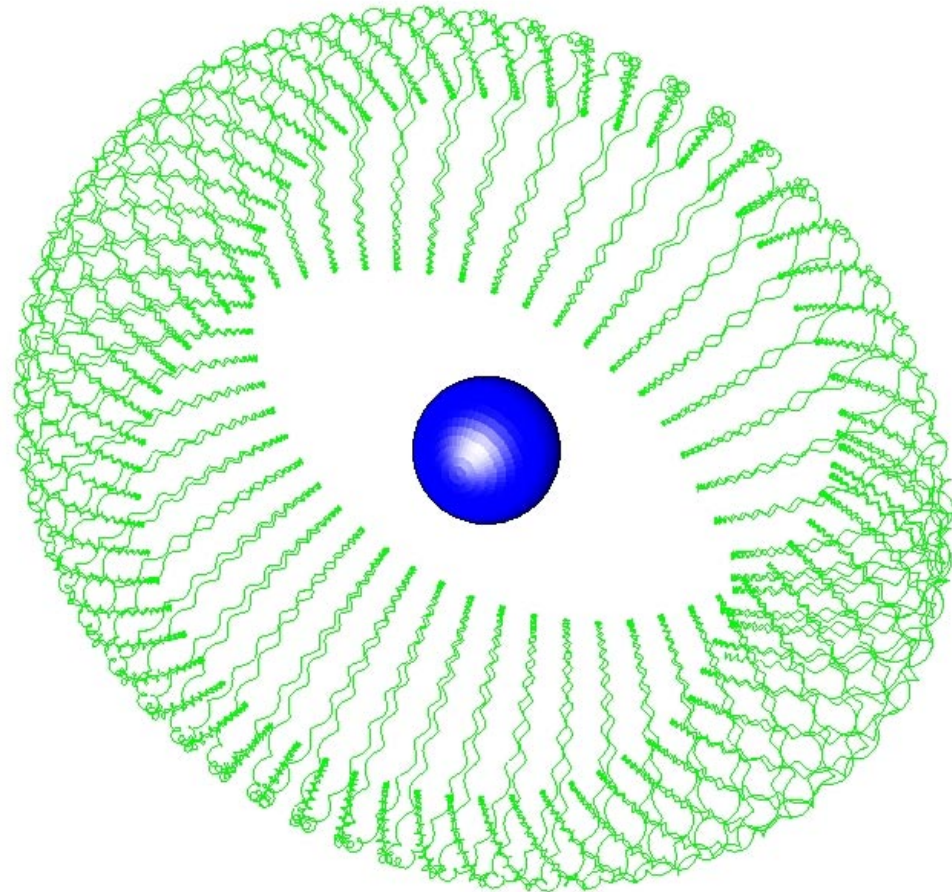- **Trajectory and bline visualisation**

Visualisation

- **1 GeV proton**
- **IGRF + Tsy89**
- **1982 January 1ˢᵗ**

Gyration, bounce, and Drift

500 keV proton @ 5.5 Re
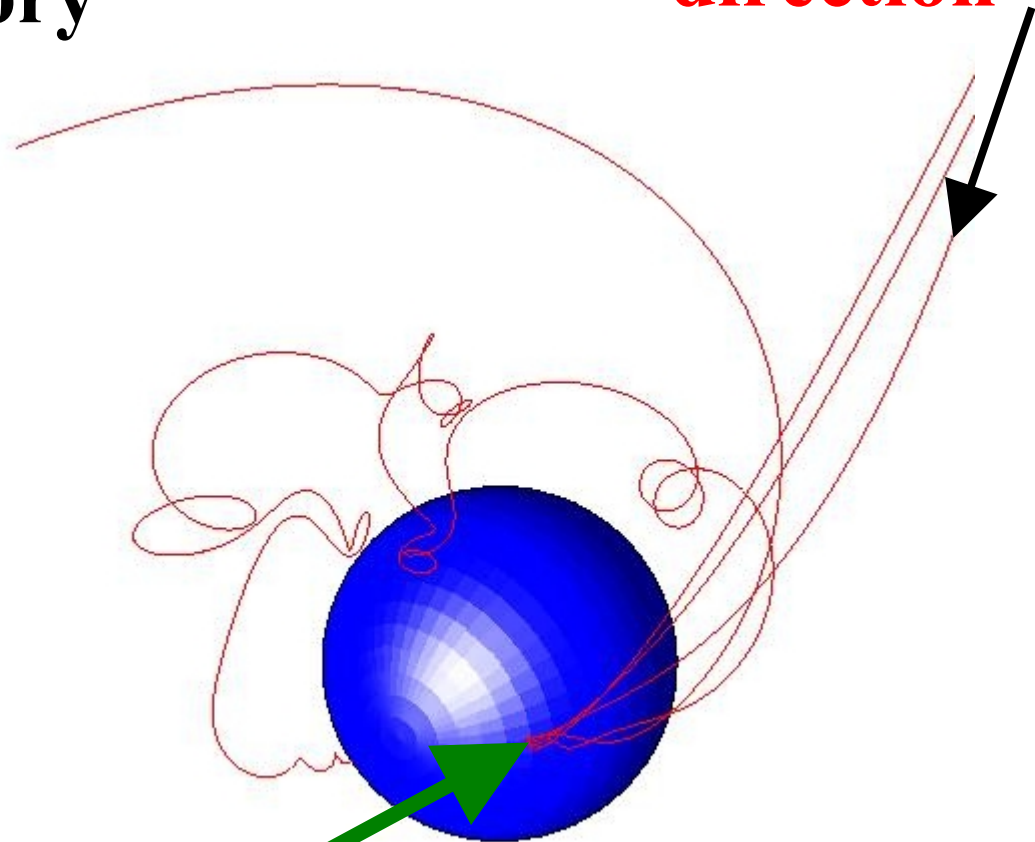
Cutoff rigidities and asymptotic directions

Asymptotic direction

Reverse time trajectory tracing

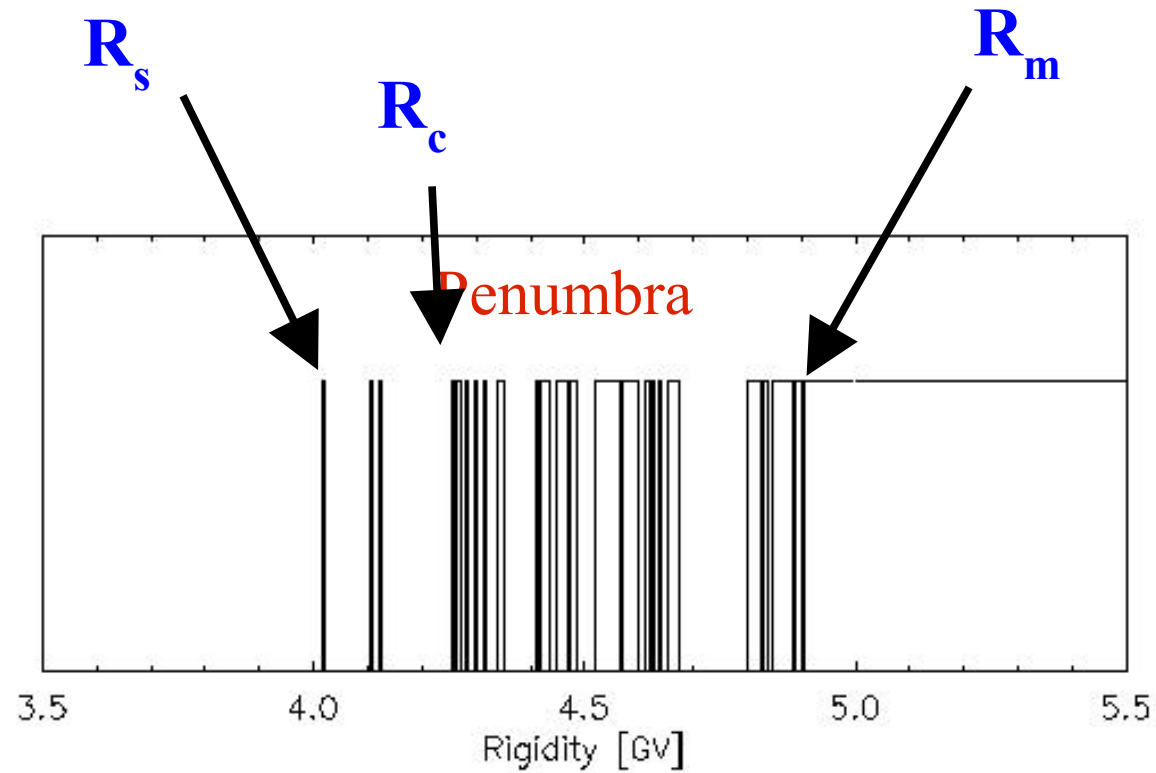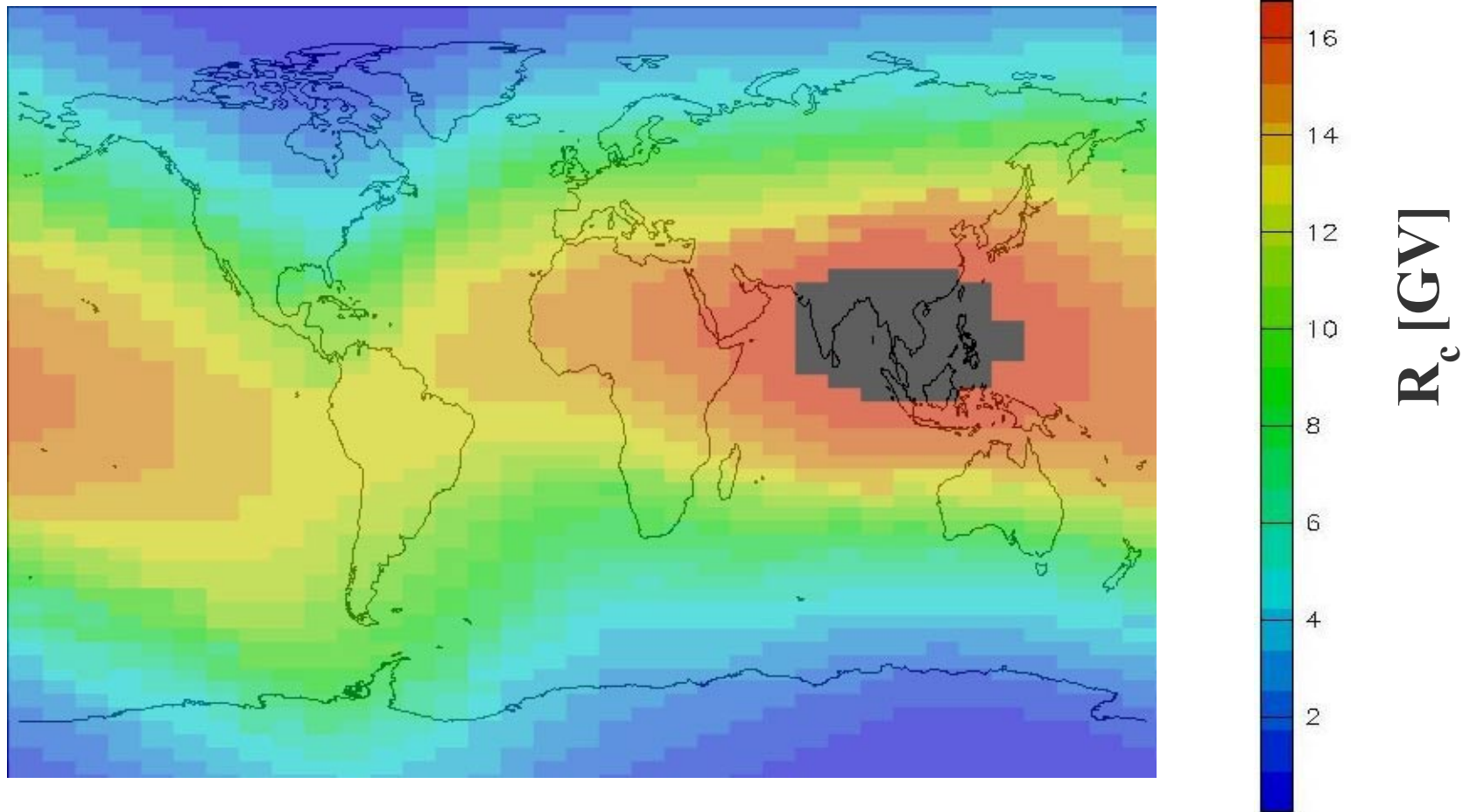**Computation of rigidity cutoff**
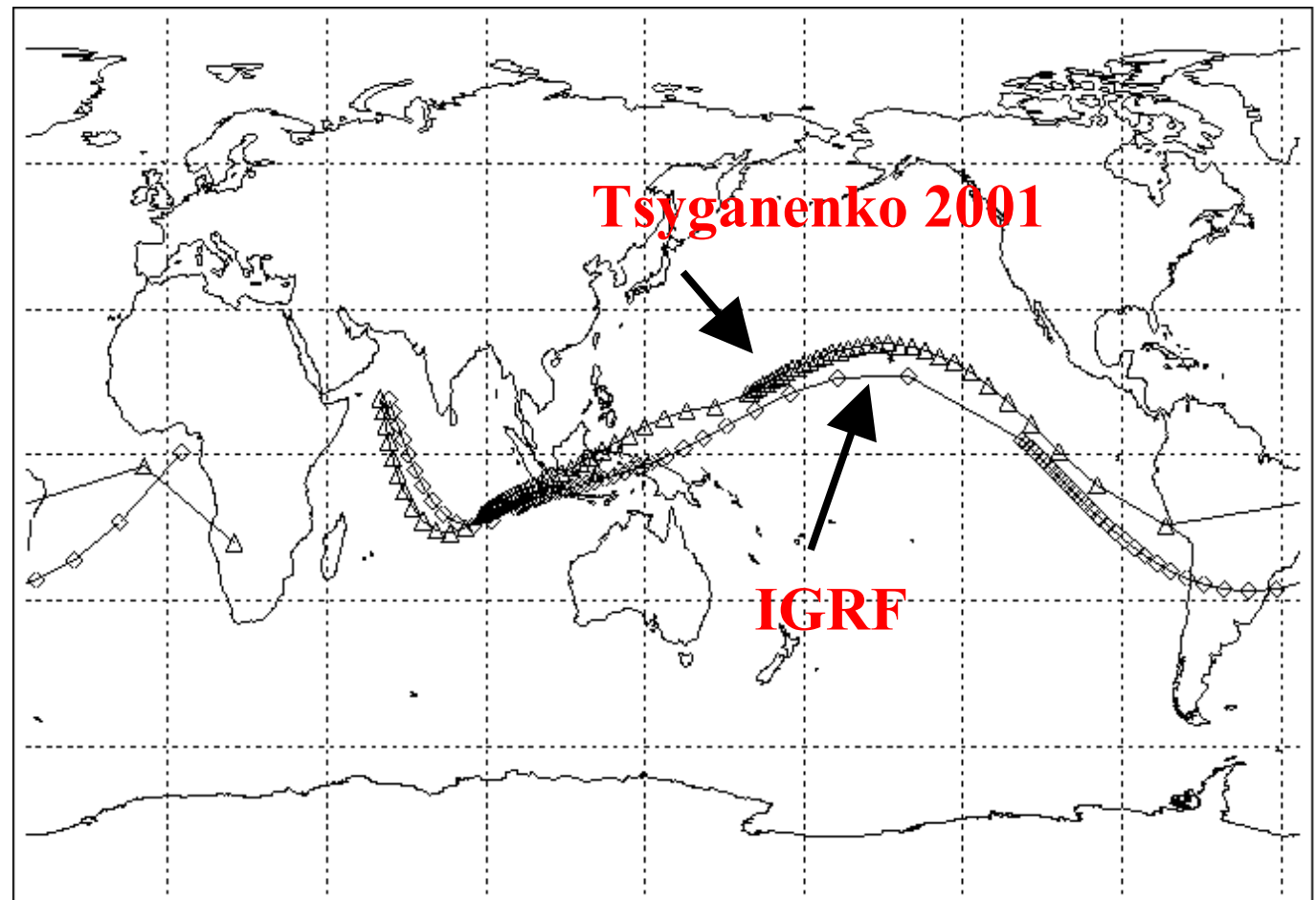
Jungfraujoch

Cutoff rigidities

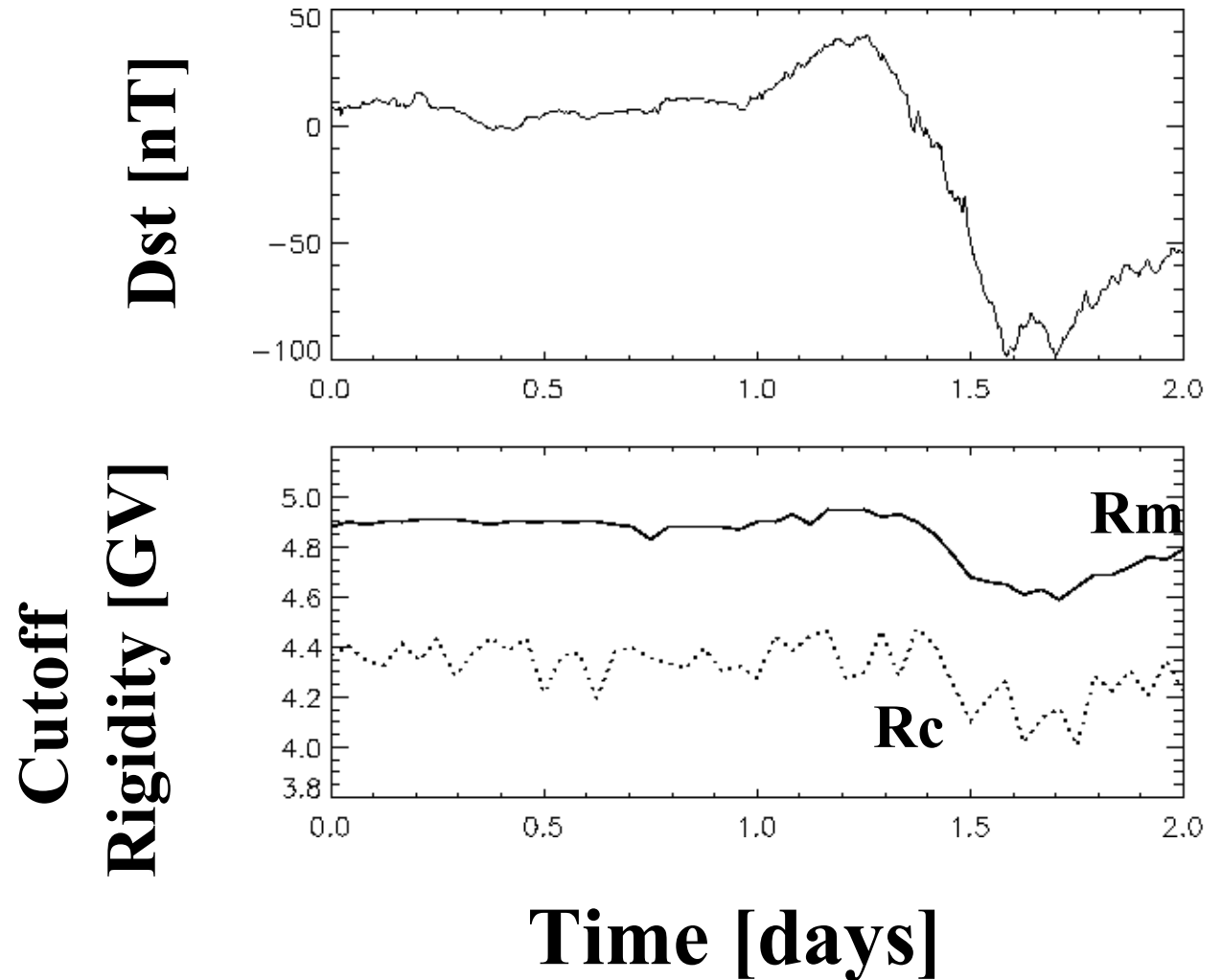# *Cutoff Rigidities vs position*

IGRF 82

Asymptotic directions

Alt.: 20. km
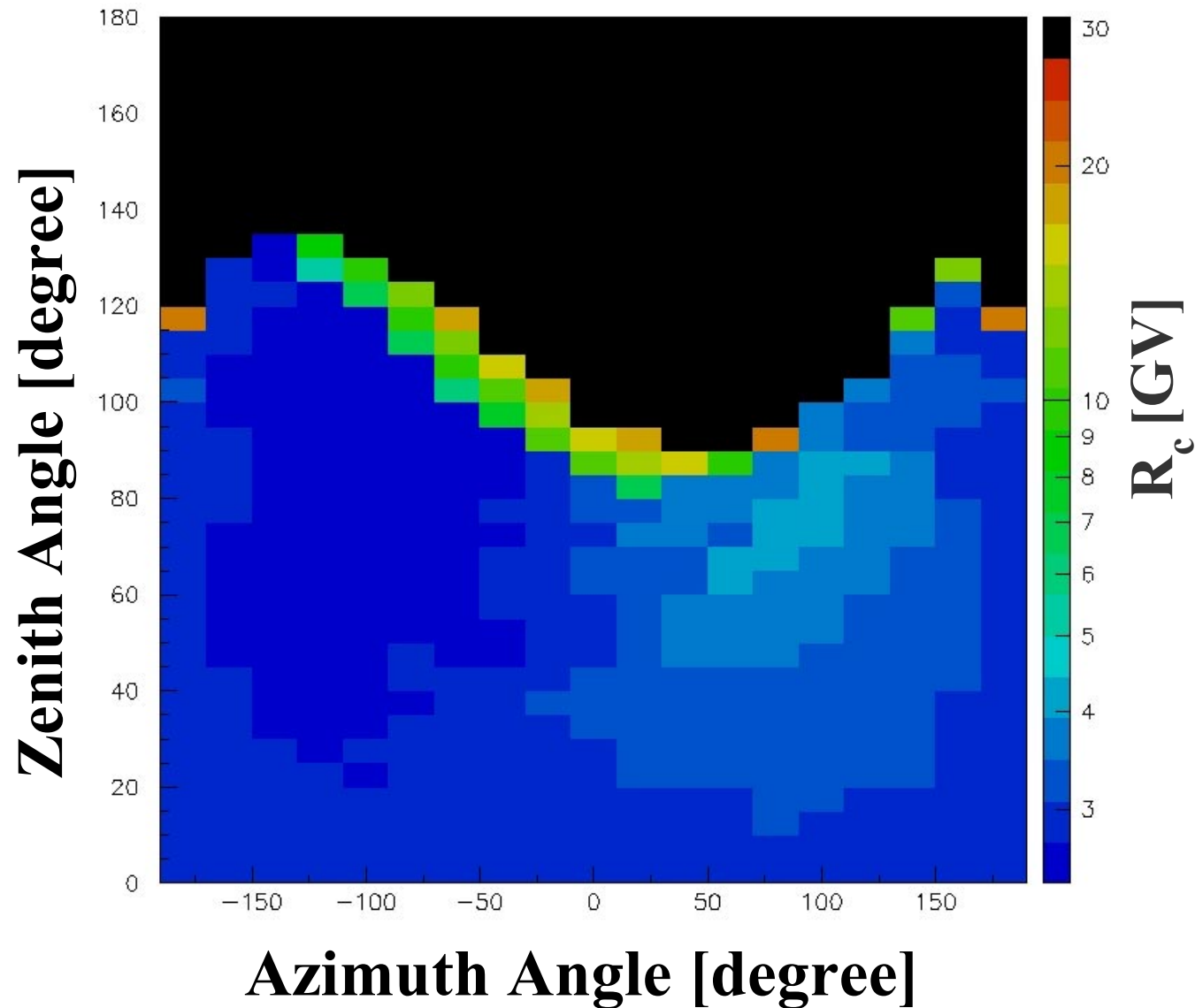**Lat: 46.55 N**
Long:7.98 E
March 26, 1995, 18 h

Tsyganenko 2001

IGRF

Time Variation

- **26/03/1995**
- **Magnetic storm**
- **IGRF + Tsy 2001**

Cutoff vs Direction

- **400 km, 50 N, 0 E**
- **Tsyganenko 89**
- **25 March 1995**
- **0 UT**

Propagation through Atmosphere

- **Propagation of galactic and solar cosmic rays through Earth's atmosphere**
- **Visualisation**
- **Computing flux of secondaries at any altitude**
- **Energy deposited vs altitude**
- **Isotope production**
- **Solar event study, neutron albedo, radiation environment estimation, isotope production, cloud formation study, ...**
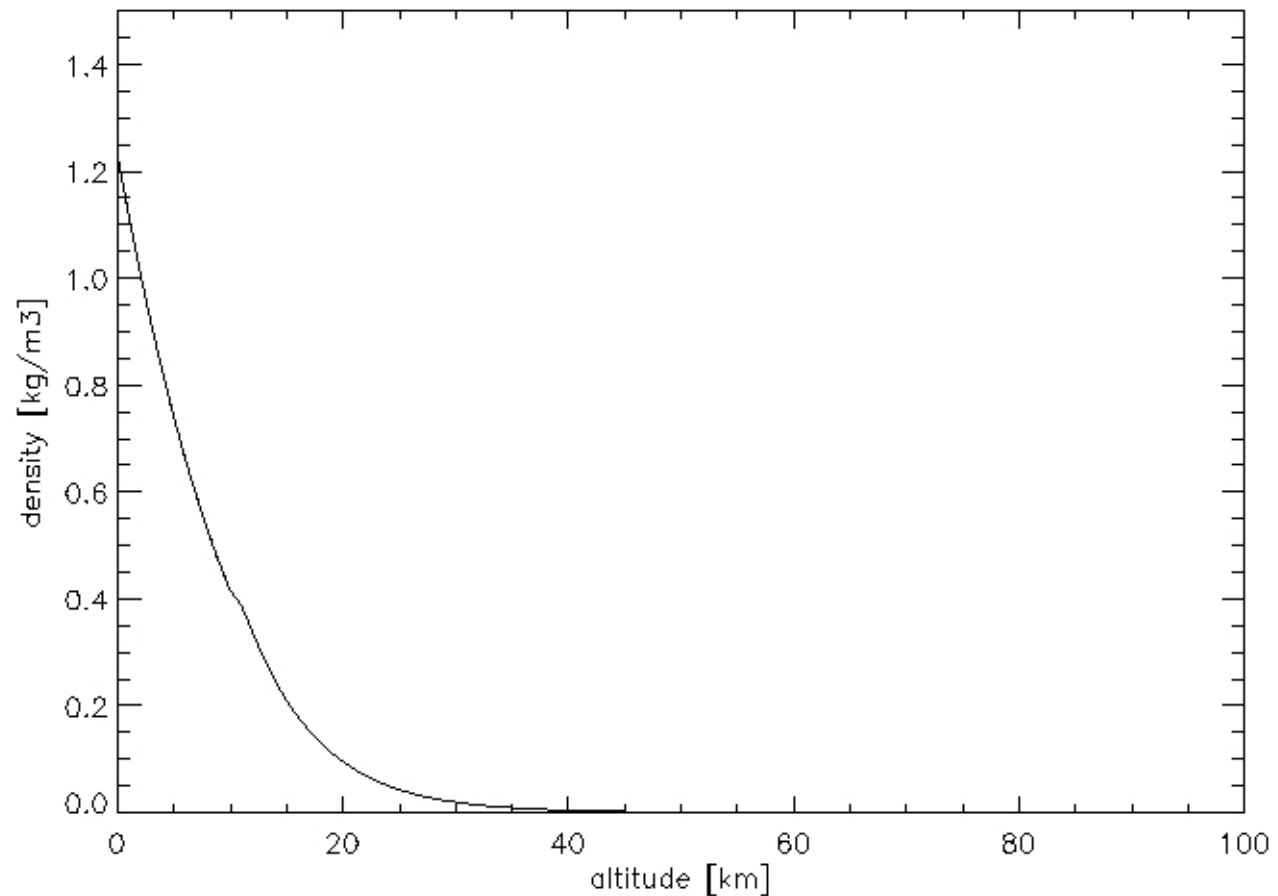
Analysis

- **Aida 3.0 compliant**
- **User defined histograms:**
  - **Secondary information at selected altitude**
  - **Energy, angular distribution**
  - **Isotope production for all the atmosphere**
  - **Energy deposited vs altitude**
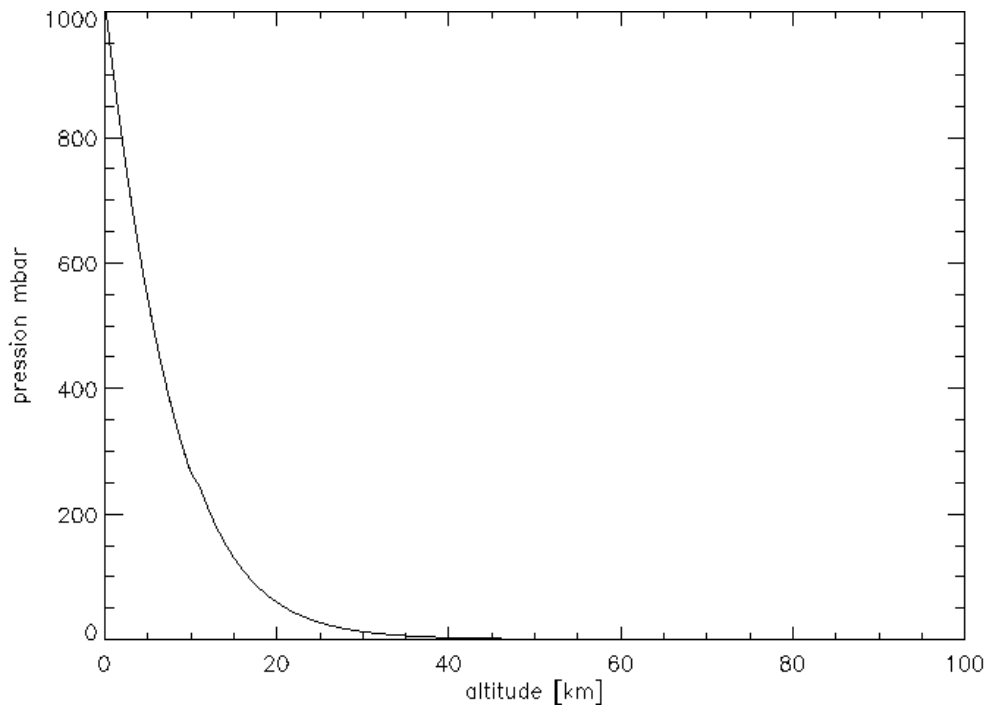
Atmospheric model

Density

•**78% ^{14}N**
•**22% ^{16}O**
•**Divided into layers**
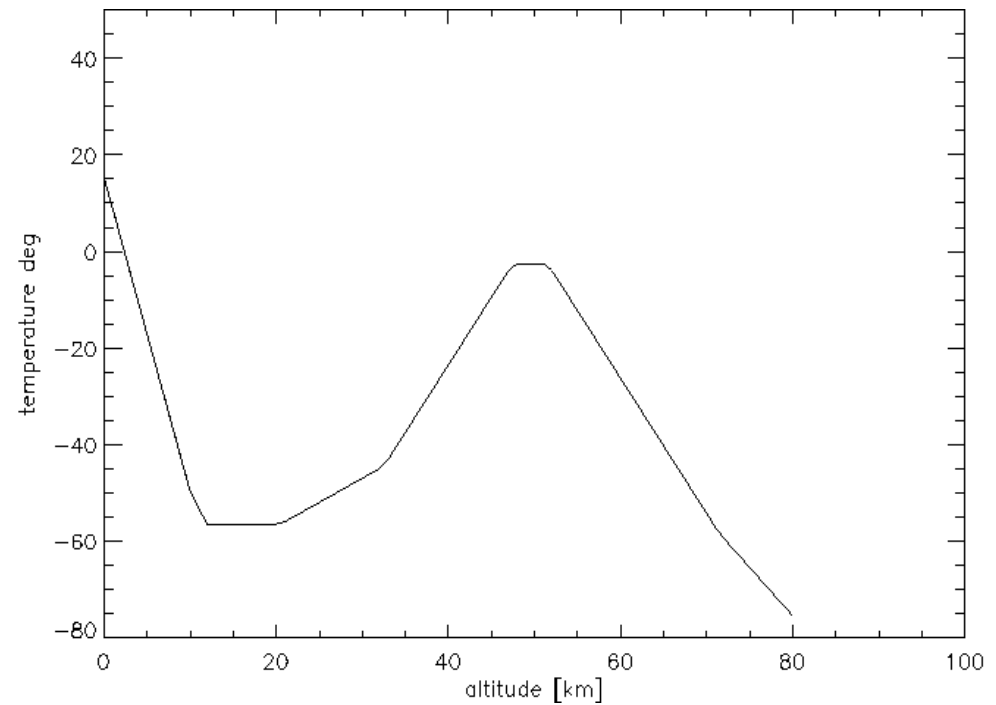•**Density, p and T vs**
altitude (STDATM76)
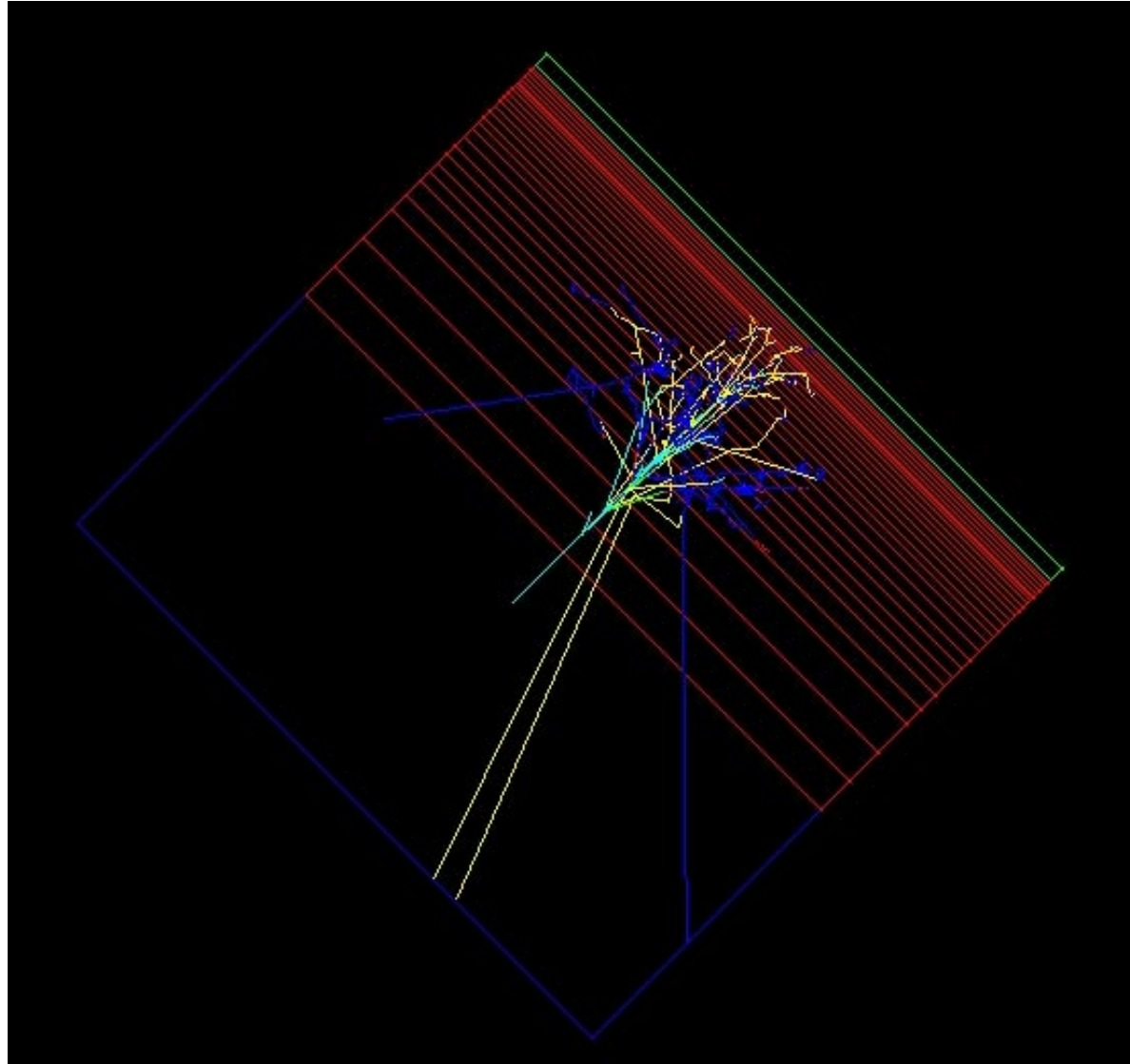
Atmospheric model

Pressure

Temperature

Hadronic PhysicsList

- **Low and High Energy model >5 GeV**
- **Bertini Cascade model 150 MeV- 5 GeV**
- **PreCompound model   0-150 MeV**
- **NeutronHP model for neutrons <20 MeV**

Visualisation

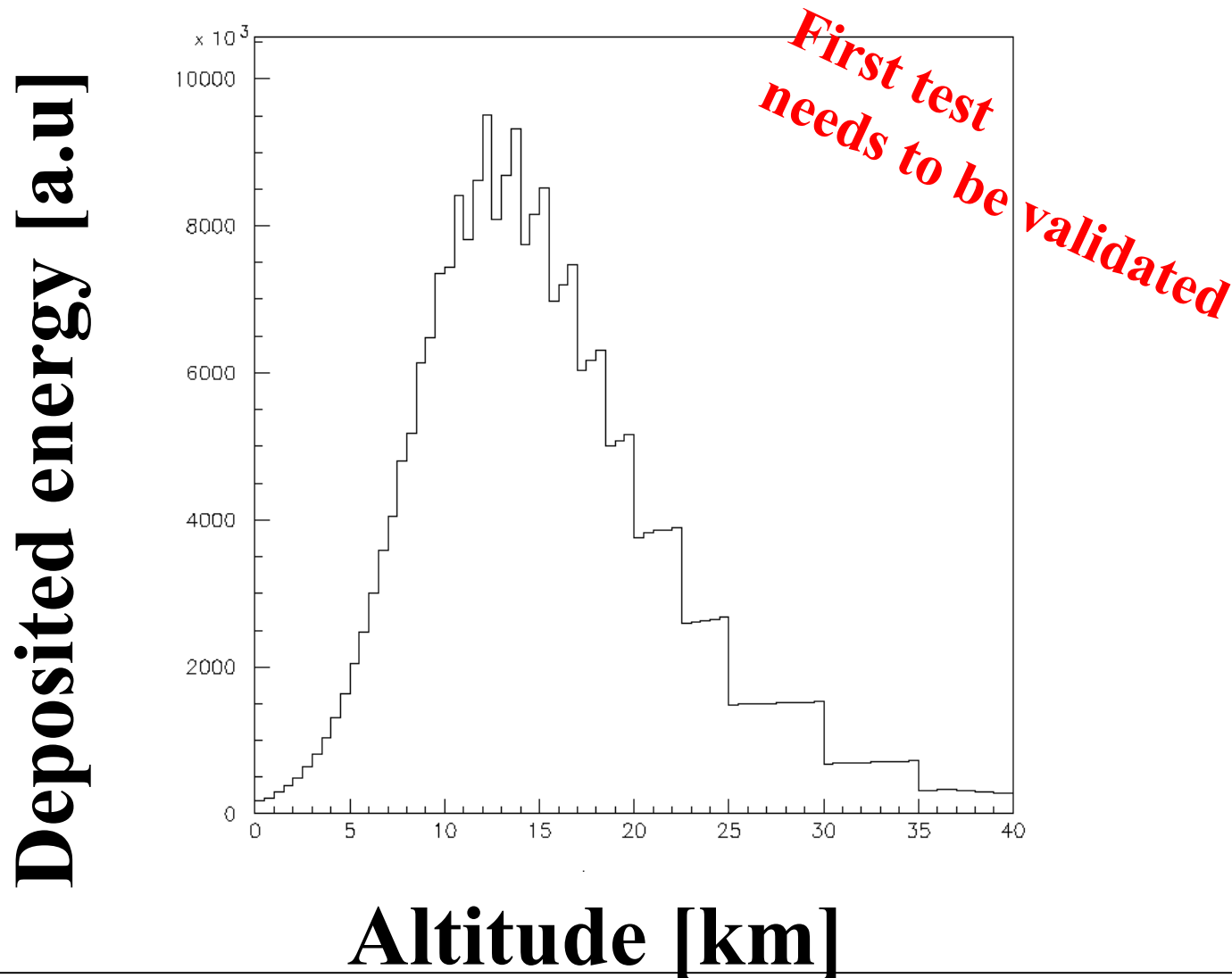- **2 GeV protons interacting with atmosphere**
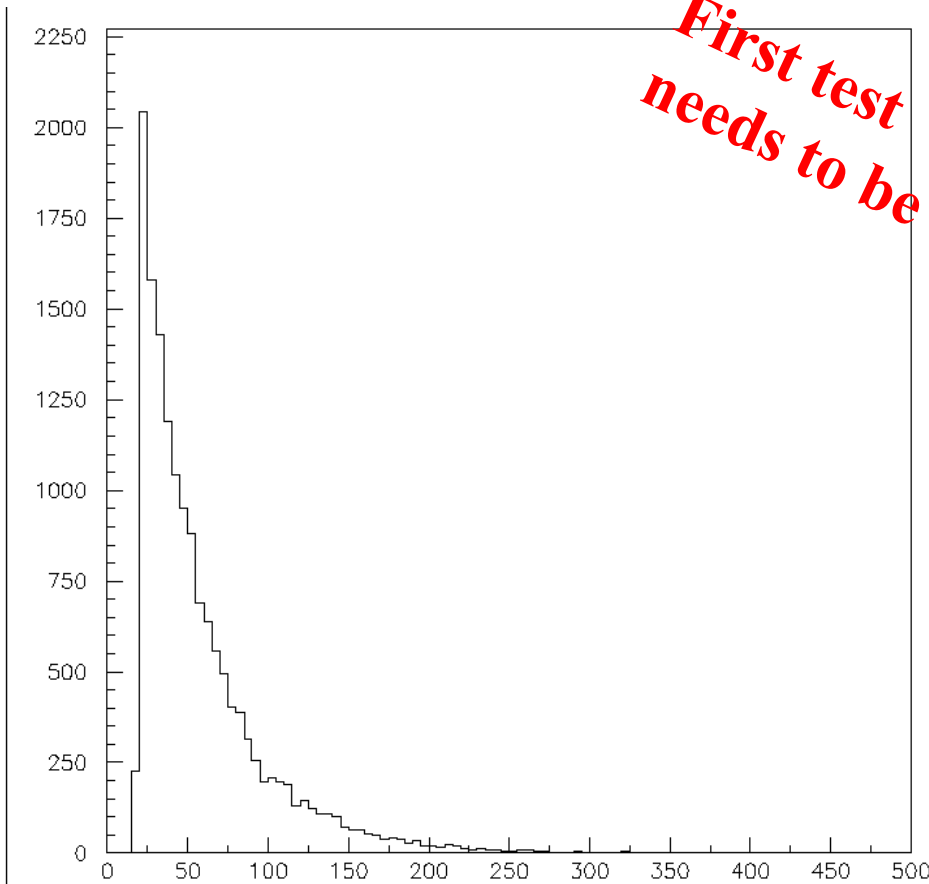
- **10 events**

Solar Proton Event Simulation

- **April 15, 2001 Lockwood et al., 2002**
- **Rigidity Spectrum: Power Law index -6.4**
- **4.64 GV<P<20 GV**
- **Angular distribution: zenith angle < 30 degree**
- **Integral flux =1.8 x 10^{-3} cm^{-2} s^{-1}**
- **Nb of events 350000**
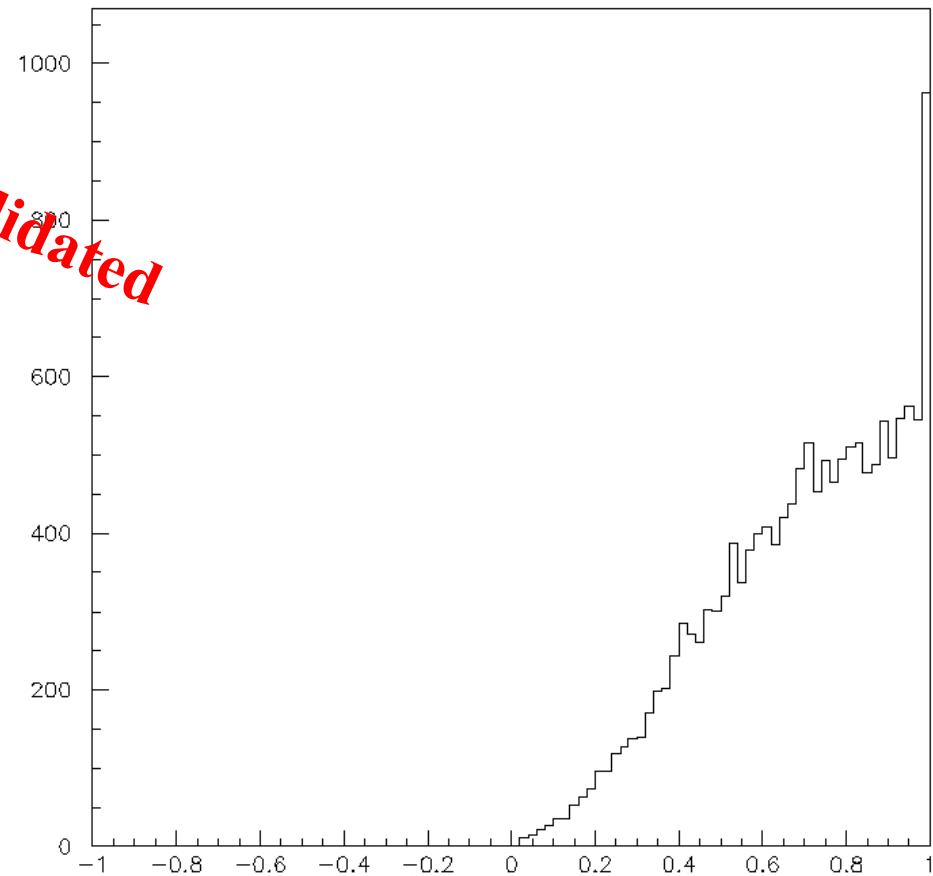
Deposited energy vs Altitude

Albedo neutrons

Energy [MeV]

cos(θ)

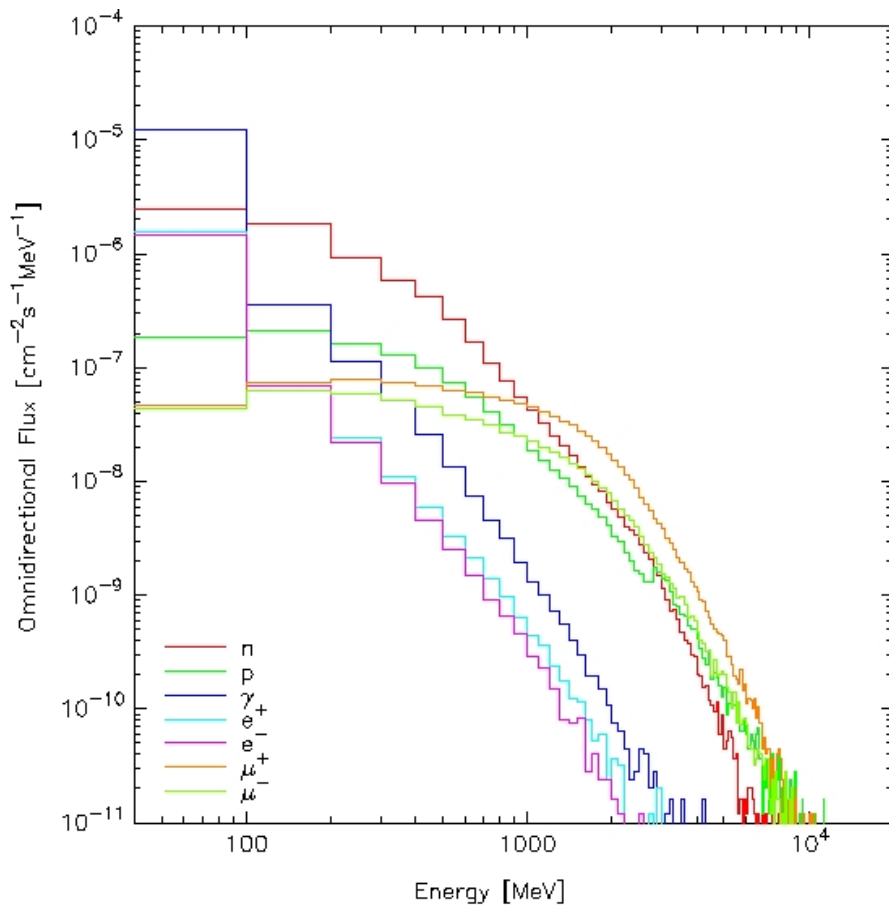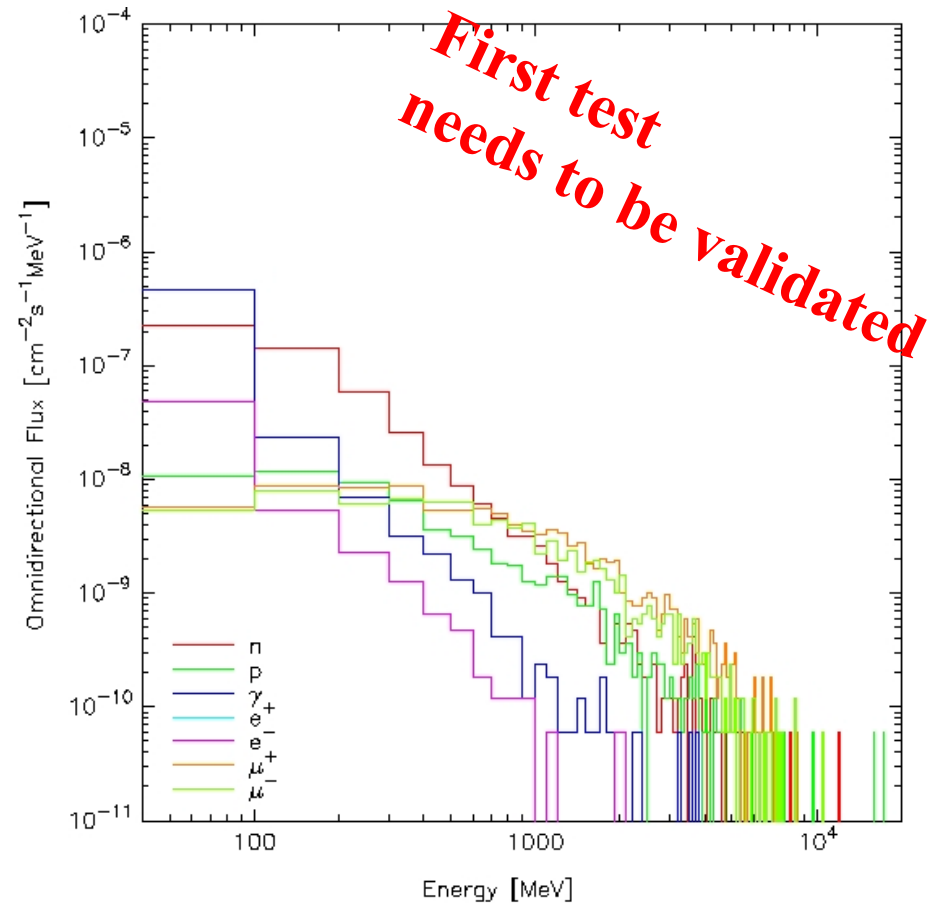First test
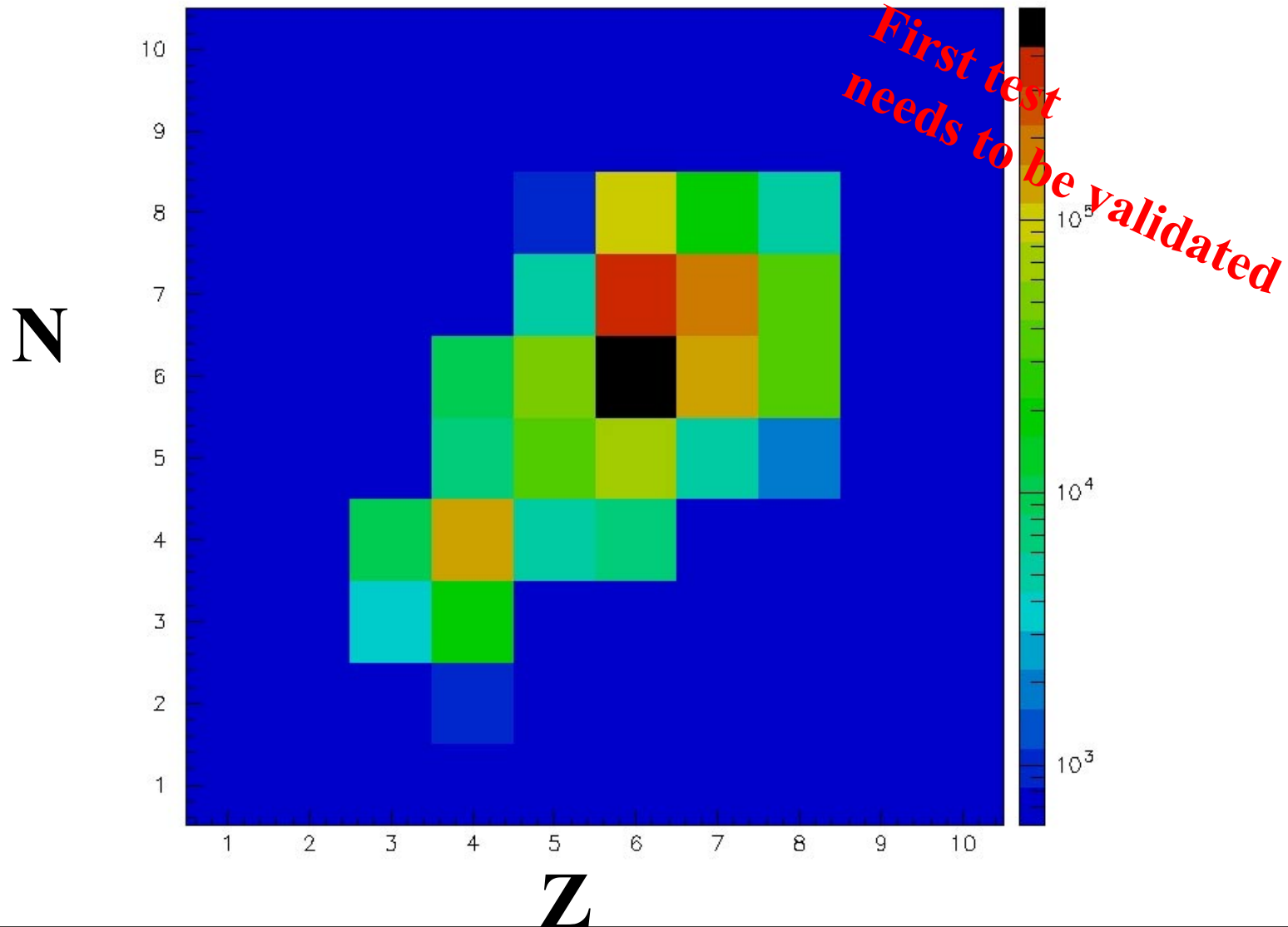needs to be validated

Secondary spectrum at 3130 m

G3 Fluka

G4

First test needs to be validated

Isotope Production

Conclusions

- We have developed two G4 applications for simulating cosmic ray physics.
- The G4 application simulating the propagation of cosmic rays through the Earth's magnetosphere allows to compute cutoff rigidities and asymptotic directions for user-defined positions, direction of incidence, and time period.
- The G4 application simulating the interaction of cosmic ray with the Earth's atmosphere needs to be validated.