HelmholtzZentrum münchen
German Research Center for Environmental Health

Simulation of Secondary Cosmic Rays at Earth Atmosphere

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13th Geant4 Space User Workshop, Houston, Texas
28-30 November 2018

HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

Cosmic Rays at Earth

Environmental Research Station
Schneefernerhaus – Zugspitze (Germany)

Kugelalm 2650 m a.s.l.


Photo: V. Mares

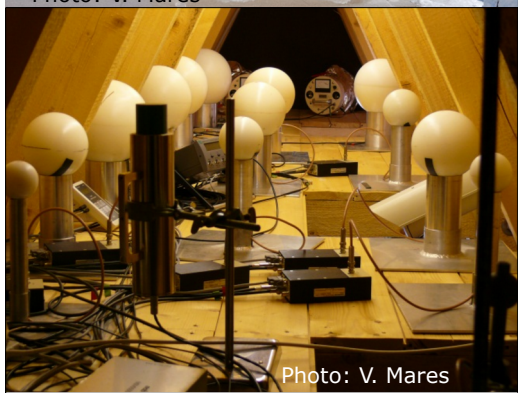
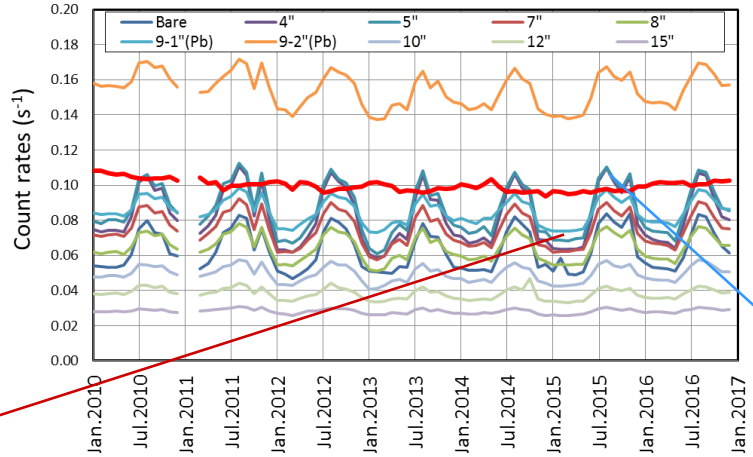
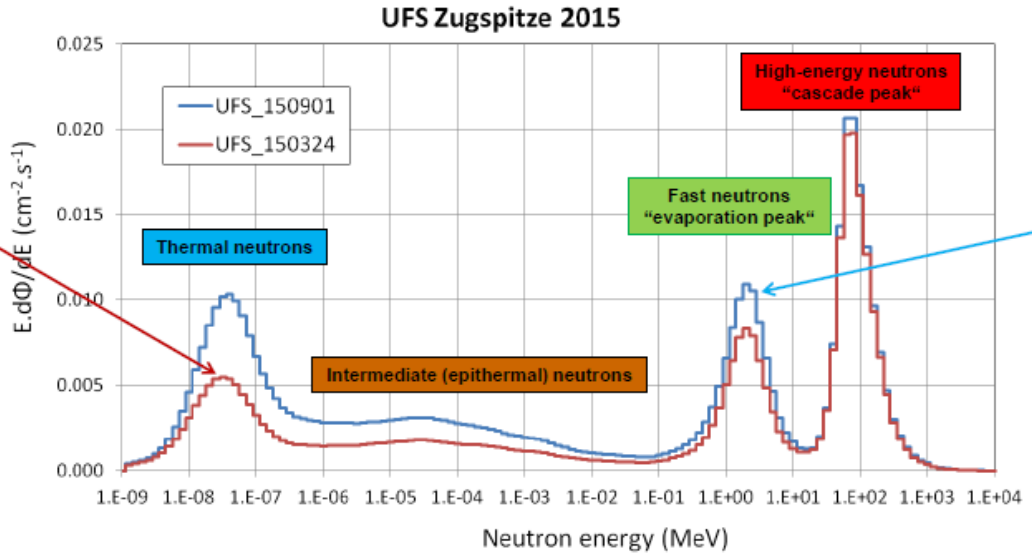


Photo: V. Mares

Cosmic Rays at Earth



24th March 2015
Neutron fluence rate:
$7.7 \cdot 10^{-02}$ cm^{-2}.s^{-1}
H(10)* rate: 60 nSv/h



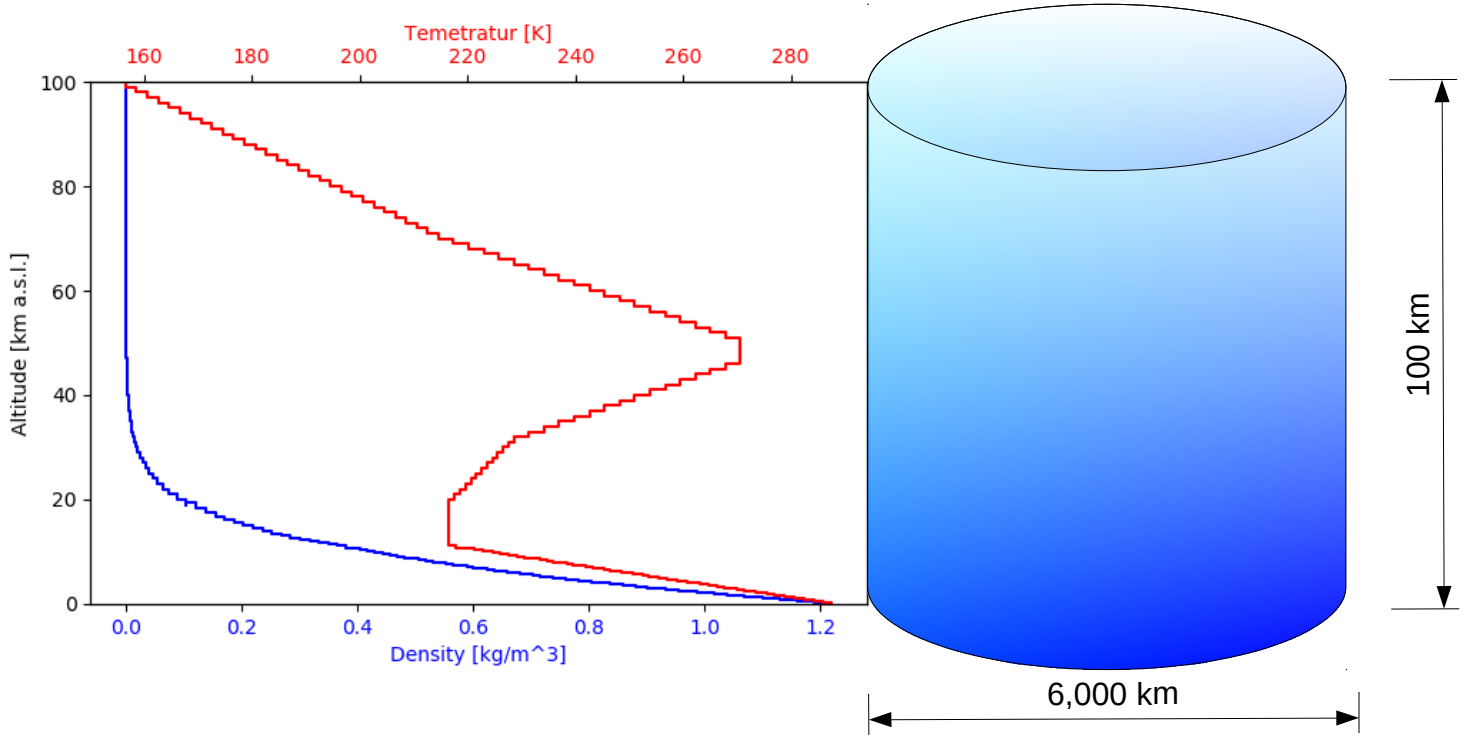
1th September 2015
Neutron fluence rate:
$10.9 \cdot 10^{-02}$ cm^{-2}.s^{-1}
H(10)* rate: 71 nSv/h

Geant 4 Simulation

- Simulate the secondary cosmic ray field at ground level
  - Quantify environmental effects of BSS measurement
- Starts with primary CR at 100 km a.s.l.
- Calculate through Earth Atmosphere (Layer model) down to 5 km a.s.l. in first simulation
- Calculate from 5 km a.s.l. to ground level environment in a second simulation

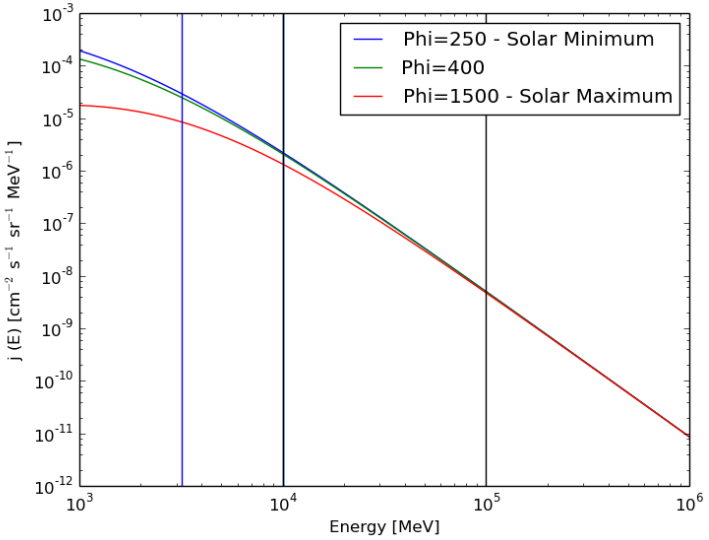
Geant4 - Geometry

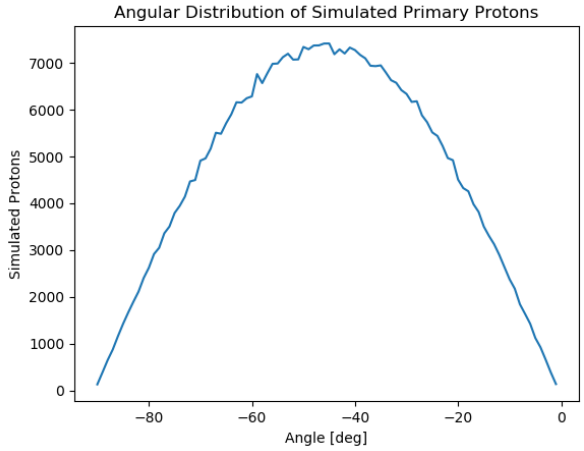
1976 U.S. Standard Atmosphere



Input spectrum

- Cutoff at local cutoff rigidity
- splitted in 3 groups to enhance statistics for high energies
- Protons and alphas calculated separate





•According to:[I. G. Usoskin, K. Alanko-Huotari, G. A. Kovaltsov,and K. Mursula, Heliospheric modulation of cosmic rays: Monthly reconstruction for 1951–2004

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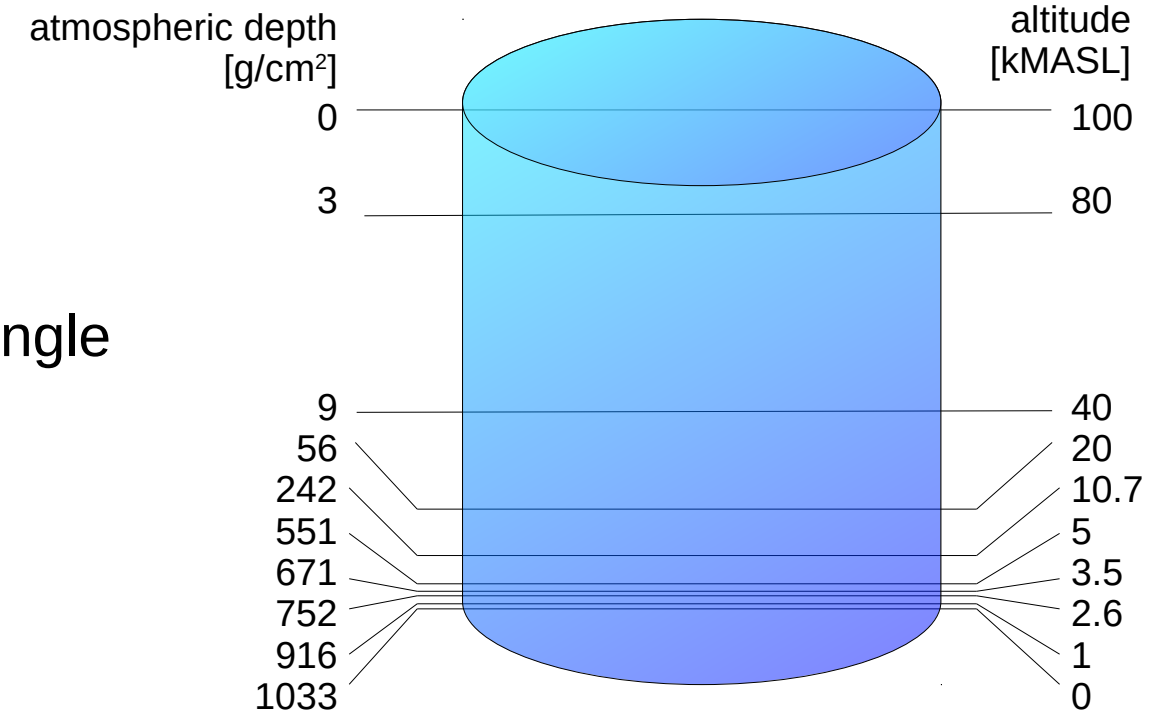
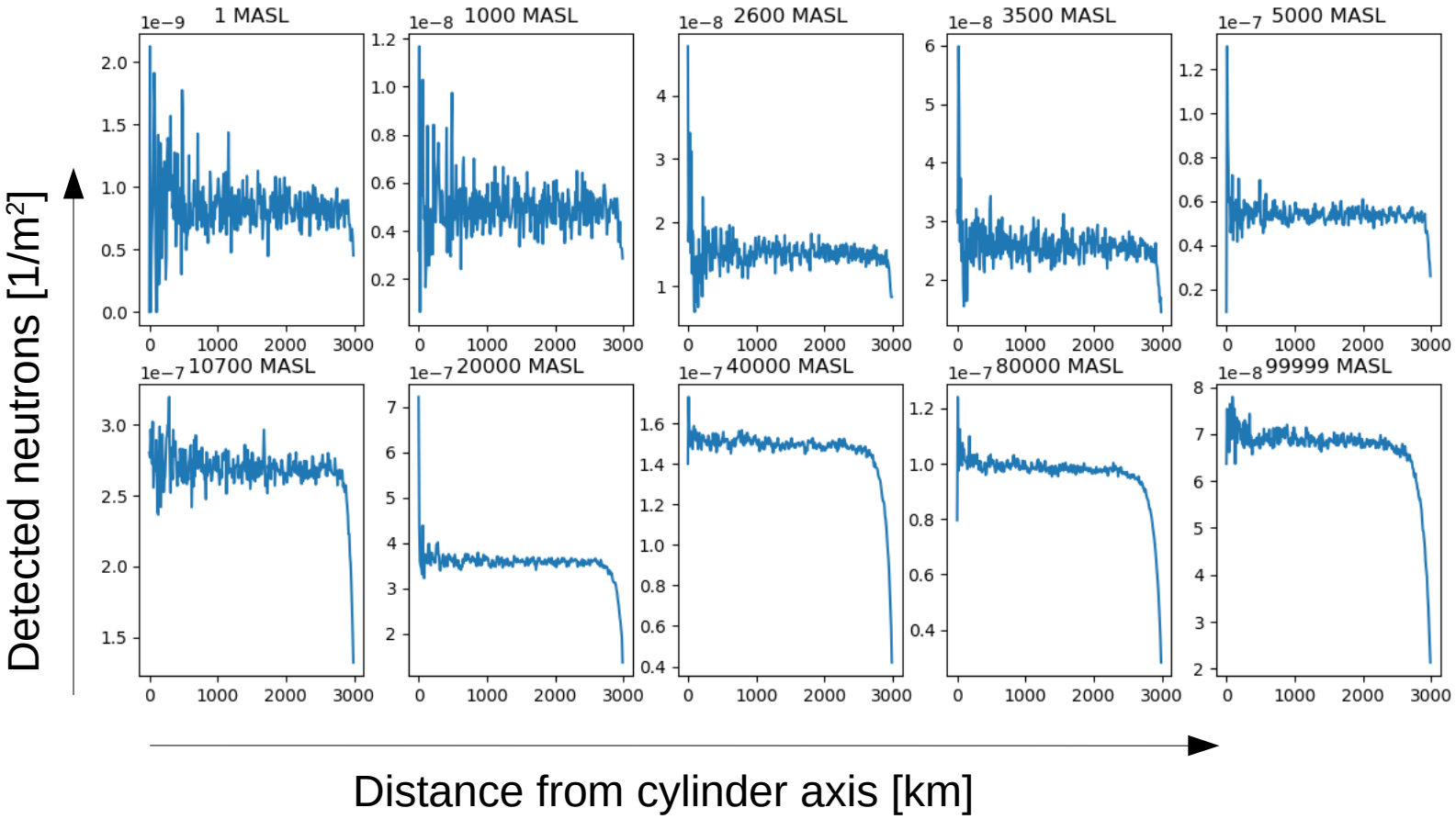
Scoring

- Surface scorer, implemented in *G4UserSteppingAction*

- Scores
  - particle
  - energy
  - momentum → angle
  - position

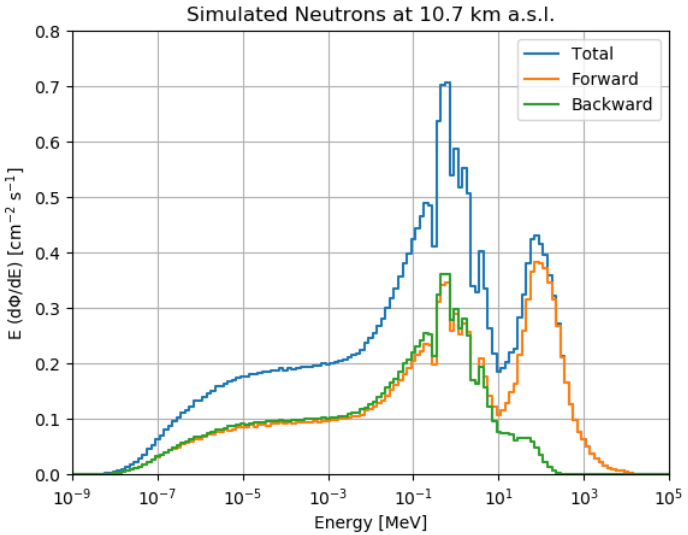


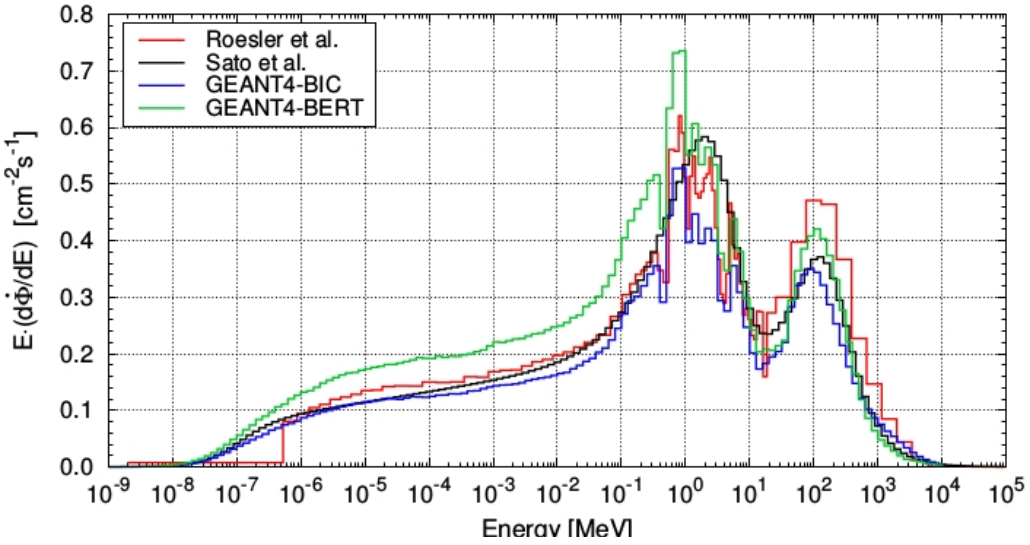
Boundary Effects



Neutron Spectra at Flight Altitude

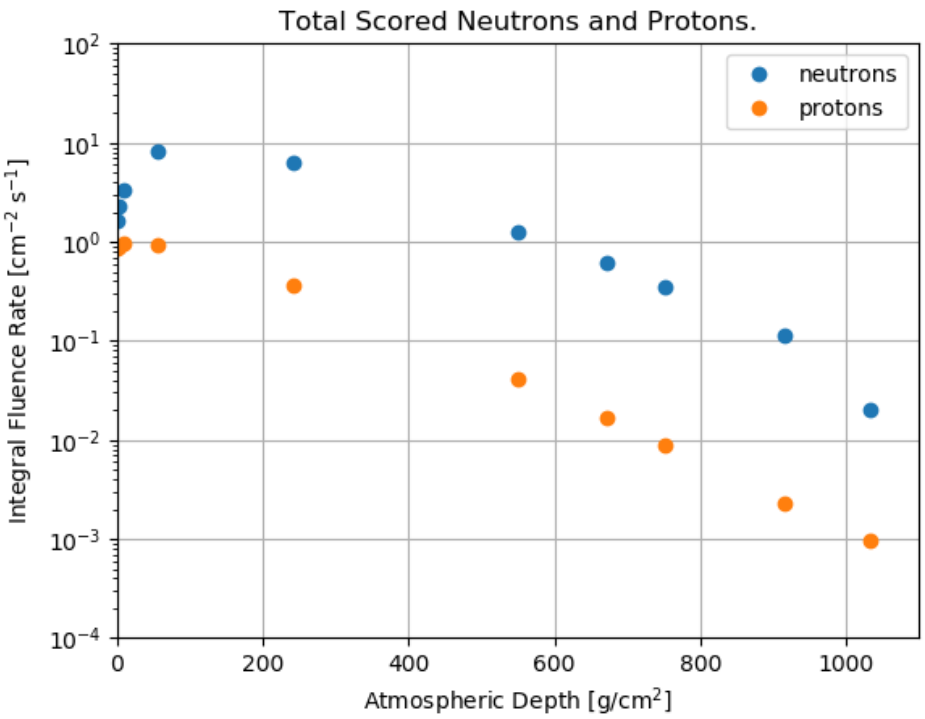
Calculated with QGSP_BERT_HP



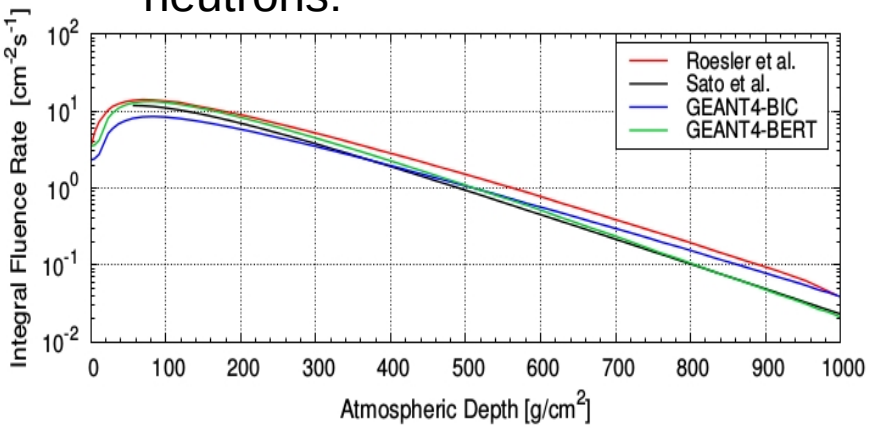


[C. Pioch Measurement and Simulation of the Radiation Environment in the Lower Atmosphere for Dose Assessment 2012; With data from Rösler et al 1998, Sato et al. 2008]

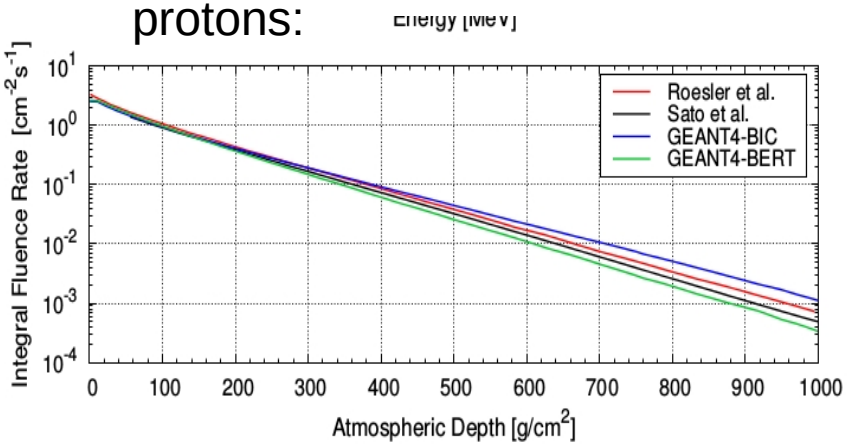
Integral Fluence Rates



neutrons:



protons:

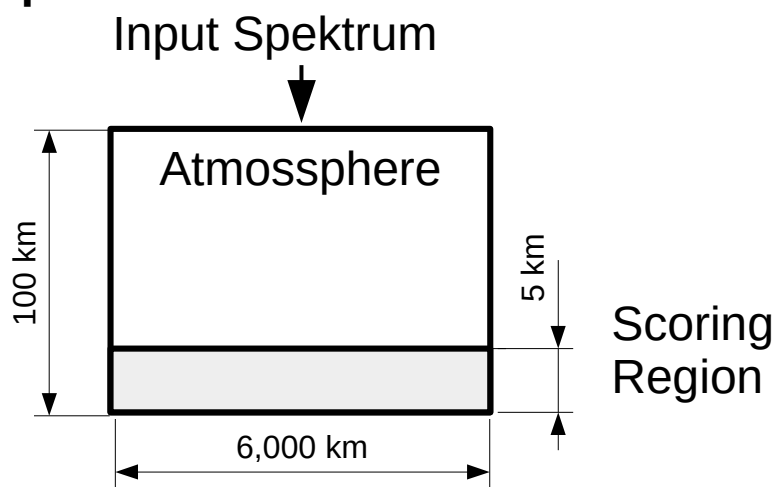


[C. Pioch Measurement and Simulation of the Radiation Environment in the Lower Atmosphere for Dose Assessment 2012; With data from Rösler et al 1998, Sato et al. 2008]

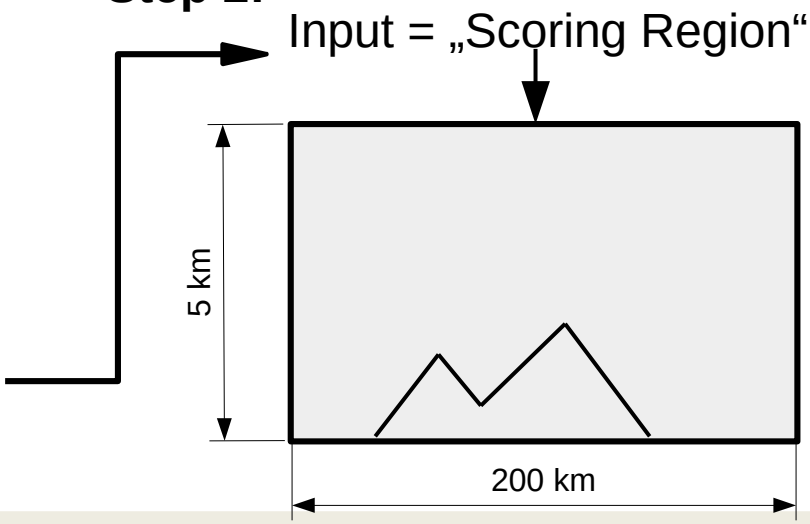
Simulation

- First calculation from 100 km a.s.l. to ground level
- Then reduce cylinder size and start calculation from 5 km a.s.l. down to Zugspitze and other locations
  - Simulate of different environmental parameter

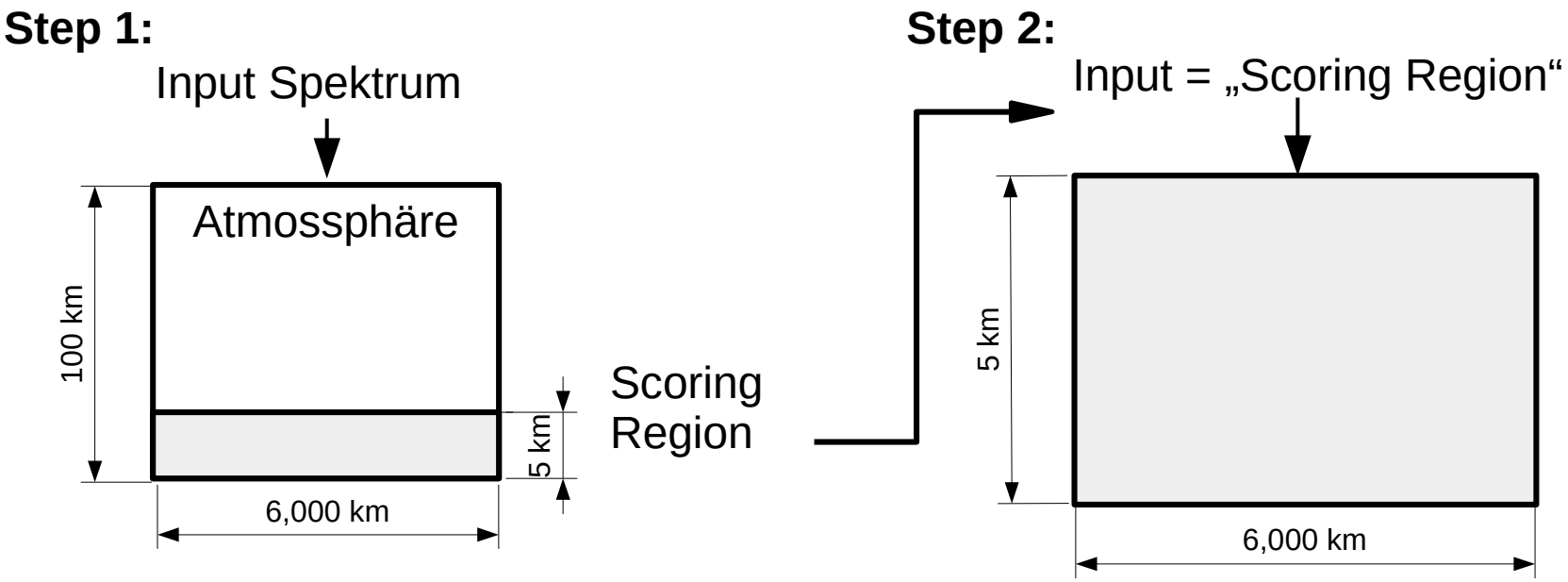
Step 1:



Step 2:

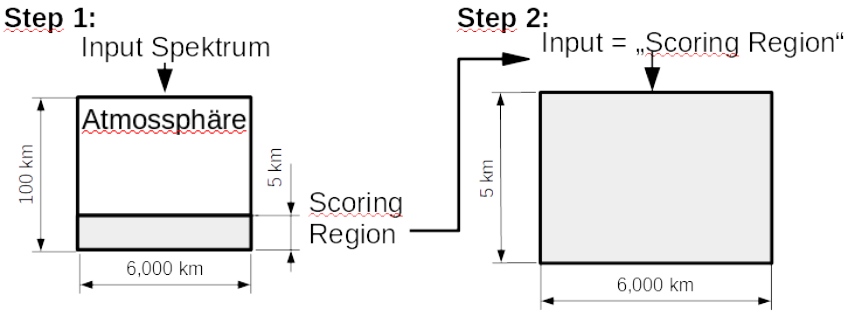


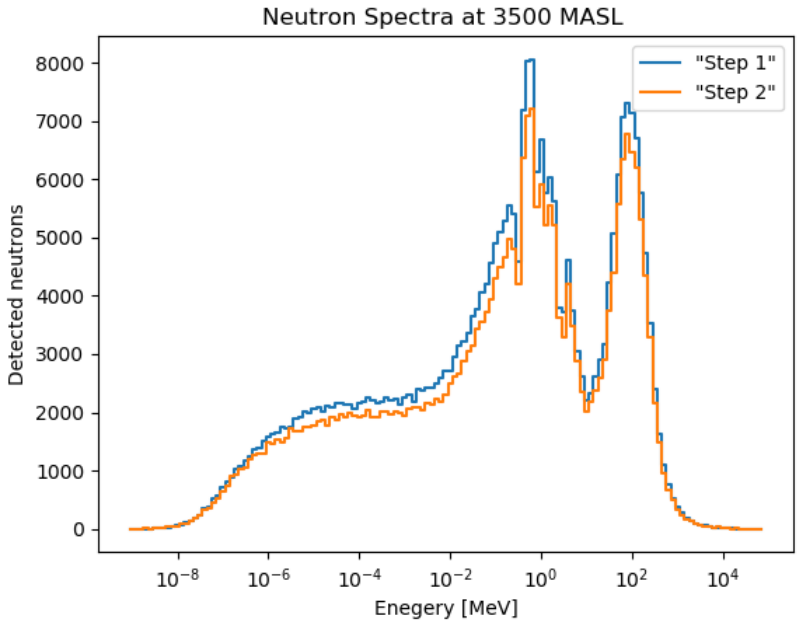
Test of Concept



- Test without reduced cylinder diameter and without environment at ground level
- Compare results at 3.5 km a.s.l.

Test of Concept





About 10 % lack of detected particles in Step 2

Further Plans

- Implement environment in simulation with different snow depths
- Test different physics lists (QGSP_BERT_HP, QGSP_BIC_HP)
- Compare with BSS measurements at ground
- Implement experimental data for primary cosmic rays (AMS-, PAMELA- experiment)
- Get cross sections out of Geant4 to compare with other codes

Conclusion

- Simulation from 100 km a.s.l. to ground gives reasonable results and repeatable results (C. Pioch 2012)

- Record the simulation at a certain point and start at this point again leads to lack of about 10 %

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