Simulation of neutron monitor using Geant4

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Abstract: The neutron monitors measure data that are of great importance for the study of the solar activity and the prediction of the space weather. Lately, the neutron monitors (NMs) have been organized in a network and their measurements are easily accessible by all of the scientific community through the Neutron Monitor Database (NMDB). Several applications which make use of these measurements have been developed and provide information about the cosmic rays and the prediction of the space weather. The study of the cosmic ray showers that are developed when a primary cosmic ray particle enters the atmosphere and the study of the neutron monitor response to the several cosmic ray particles that reach the Earth's surface are important for the use of the NM data by the space weather applications. A study based on simulations is presented in this work. The simulations are performed by using the well known Geant4 toolkit.

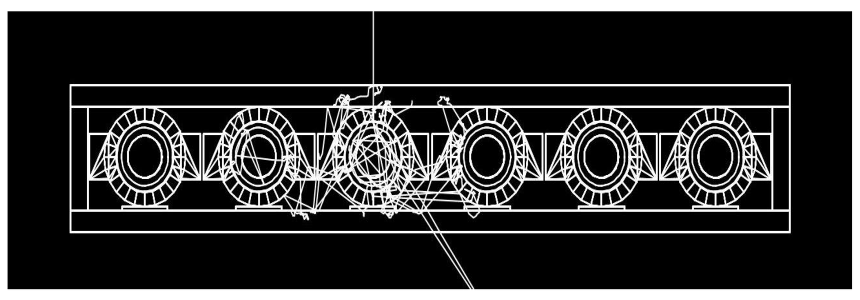
A. Detection efficiency of the 6NM-64 detector

General concept

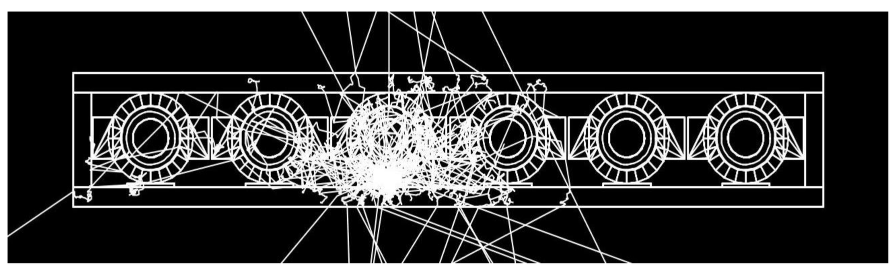
Monoenergetic particles of the same type and direction illuminate the NM as a whole or in parts → **User input** • Type of particles • Energy • Direction → **Output** • Number of particles that are captured in the counters • Number of counts in respect to the counter's dead time

Visual representation of the simulation for an incident neutron

With 1 GeV



With 100 GeV



Results concerning the Detection Efficiency

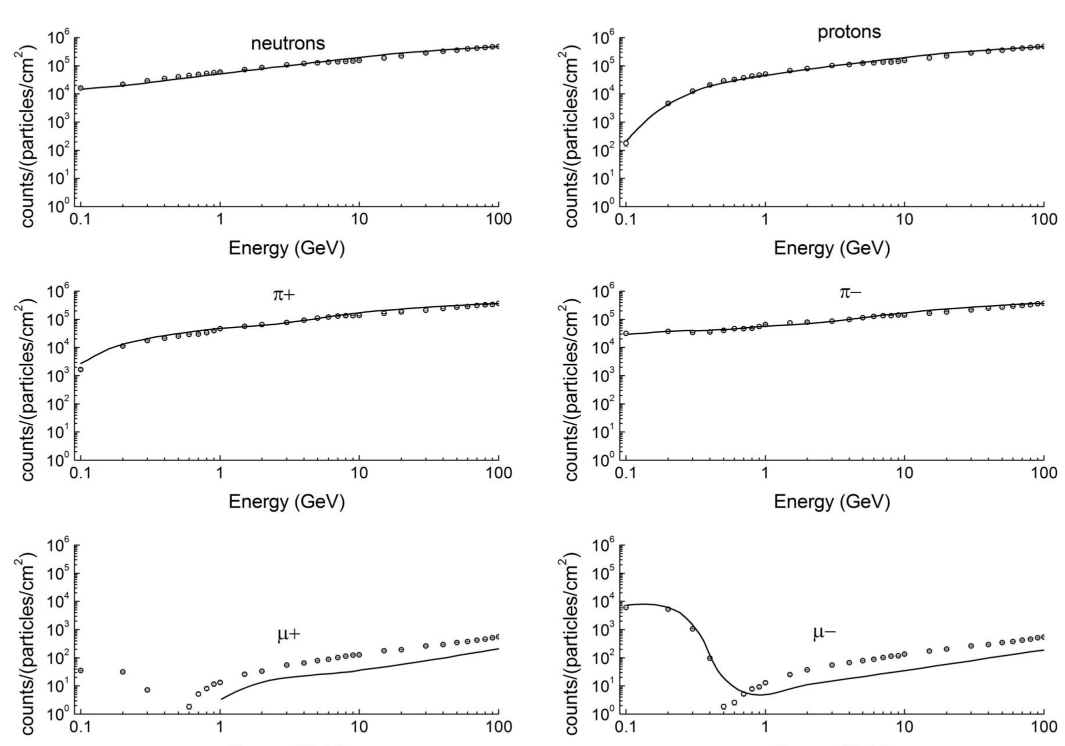


Figure 1: Detection efficiency of the 6NM-64 for several particle types and energies. The Geant4 results (lines) coincide with the results of Clem and Dorman (2000) (dots). The NM is sensitive to the hadronic component of the secondary cosmic rays (Paschalis et al., 2013a)

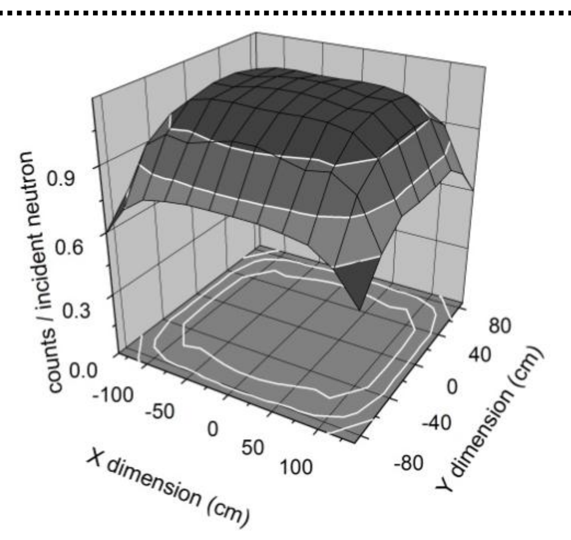


Figure 2: Dependence of the NM position that the particles enter.

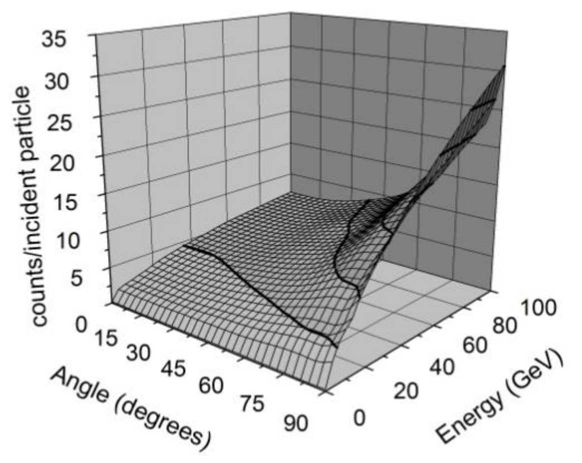


Figure 3: Dependence of the incoming zenith angle for an azimuth across the NM counters.

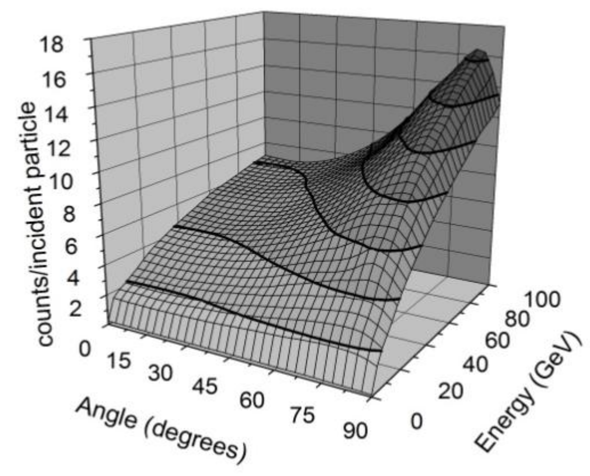
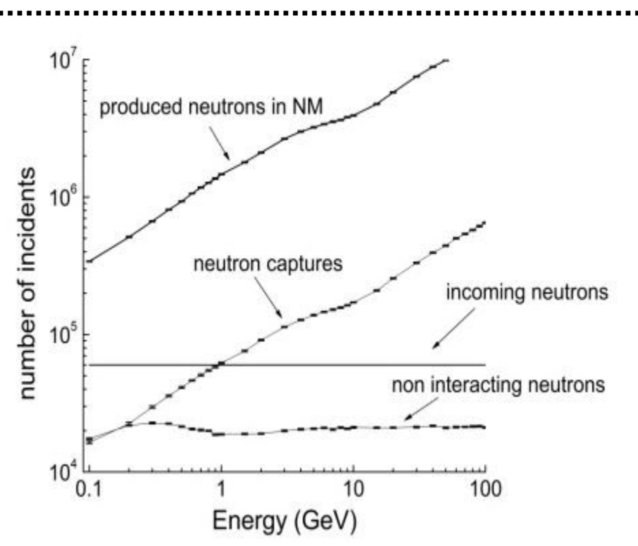
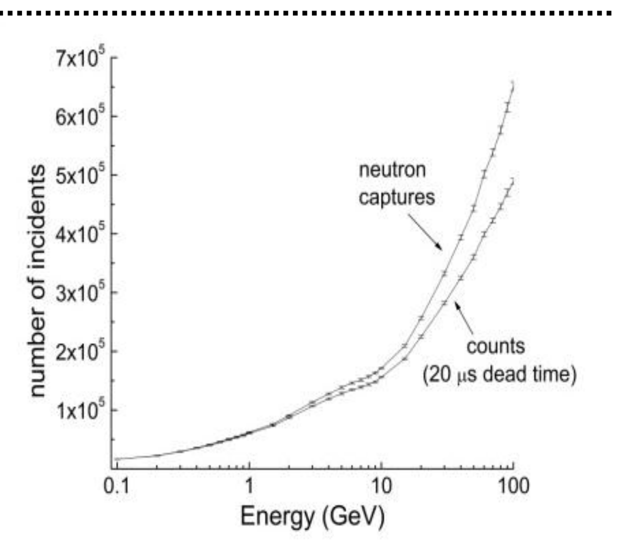


Figure 4: Dependence of the incoming zenith angle for an azimuth along the NM counters.

Figure 5: For a specific input beam neutrons are produced and captured in the NM after their interaction.

Figure 6: Affection of the dead time of the NM counting rate for a high energy beam.





B. Standalone application for the simulation of the cosmic ray showers in the atmosphere

General concept

User input
• Structure of the atmosphere
• Flat or spherical model
• Magnetic field
• Physical processes
• Energy cuts
• Incoming particles

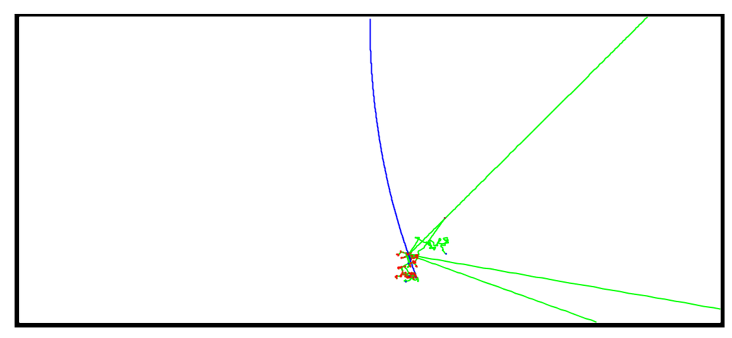
→ **Geant4** → **Output** CSV files

Key points
• Implementation in C++
• Definition of atmospheric structure via the temperature profiles of the atmosphere and the use of the hydrostatic equation.
• Use of Geant4 reference physics list
•Adjustable performance via the application of energy and range cuts with a tradeoff in accuracy

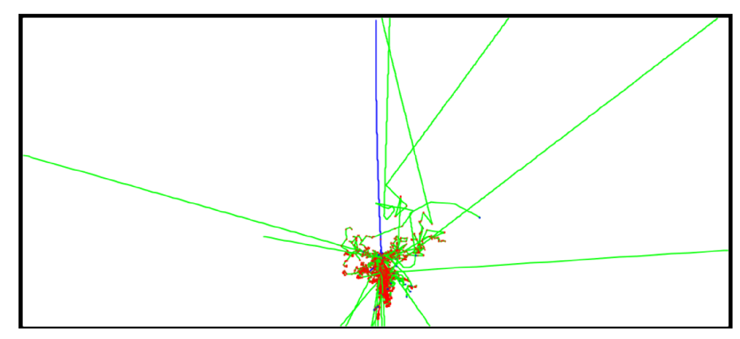
Advantages
• Easy to use
• Fully parameterized
• Plenty of output data

Visual representation of a shower initiated by a proton

With 1 GeV



With 10 GeV



Representative Results inside the Atmosphere

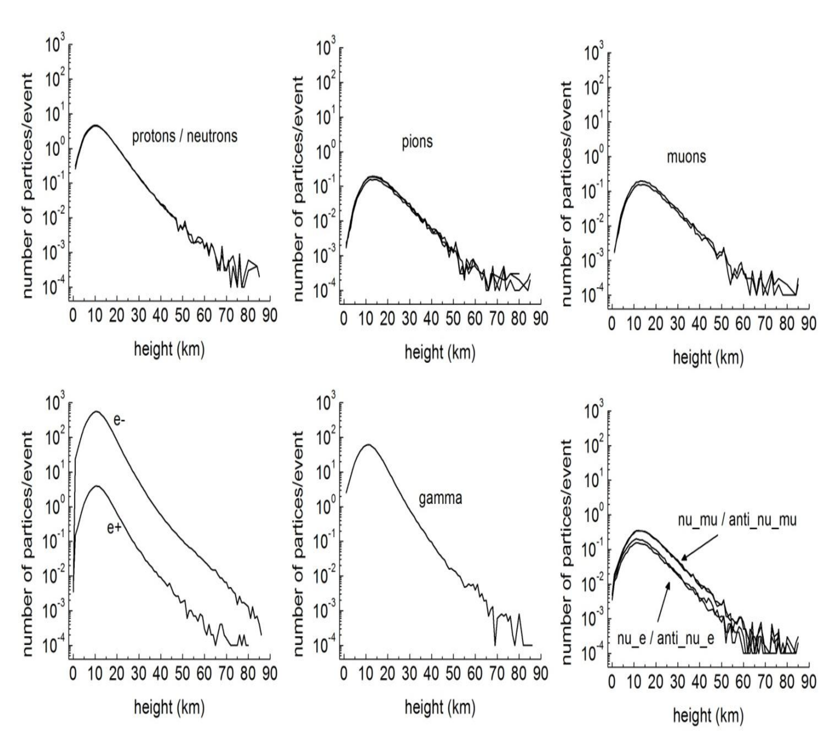


Figure 7: The application provides access to every possible variable of particles. Energy, position and direction of every particle is recorded when a new particle is generated or crosses a layer in a predefined altitude. The figure shows the number of secondary particles/incoming proton that are generated as a function of altitude from the ground, when a vertical proton beam of 10 GeV enters the atmosphere. (paschalis et al., 2013b)

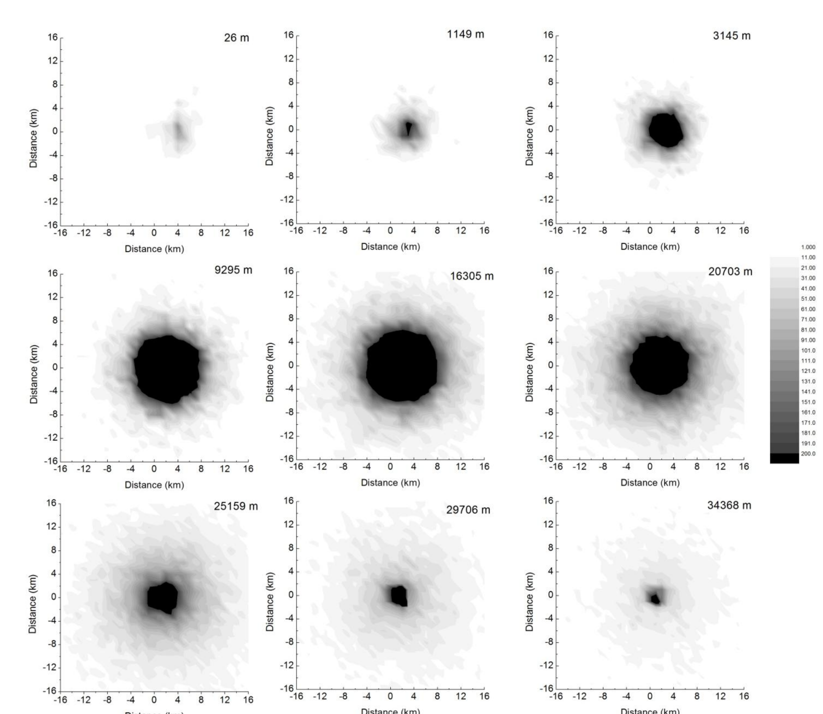


Figure 8: The application supports the definition of a beam consisting of particles that vary in type, energy and direction. The output data are exported in a detailed or in a synoptic form, ready to be used for plots, histograms or contour figures. The figure shows the spatial distribution of neutrons in several heights when a vertical proton beam of 10 GeV enters the atmosphere.

This source code is planning to be exported as a standalone application for the determination of the 6NM-64 detection efficiency

This application is planning to be extended to Dosimetry Measurements

References
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