The characteristics of the measurements of the charge particle fluxes in the wide angular range for the PAMELA calorimeter

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Abstract. For measurements of particle fluxes with the PAMELA calorimeter within the wide angular range it is important to estimate some parameters (energy and angular resolution, acceptance, efficiency of particle registration and so on). The GEANT 4 simulation allowed to get values of such parameters. Here we present results of this simulation.

1. Introduction
In the PAMELA experiment [1] there is a way to measure cosmic ray particles within the wide aperture provided by a calorimetric or S4 (lower scintillation counter) triggers [2]. In this case the magnetic analysis is not available and the calorimeter is the main source of information. To obtain the calorimeter features for the measurements in the wide aperture the GEANT4 [3] simulation of protons of various energies (up to 10 TeV) and incident angles interacting within the calorimeter was run. The particles were generated separately from two planes: a plane directly above the calorimeter and a plane located at a height of 80 cm above the calorimeter. The angles of incidence of the particles (the zenith angle - $\theta$, the azimuth one $\phi$) were measured according to the methodology described in [4]. The simulated events were underwent by a simple selection including the threshold cut for the total energy released inside the calorimeter and the requirement that the shower axis is within the calorimeter.

2. The angular resolution
The angular resolution was defined as the standard deviation of the measured values of the incident angles of the particles in the calorimeter from the position of the maximum intensity (for example see figures 1, 2). On average the angular resolution does not exceed 0.5 degrees as it shown for example in figures 3, 4 for the energies 0.5 and 3 TeV. With decreasing of the number of the hit planes the angular resolution deteriorates, but not essential, so even for the case when the particles traverse just a few planes it is still better than one degree. The dependance of the mean angular resolution on the proton energy is shown in figure 5.
Figure 1. The distribution of the reconstructed incident $\theta$ angle when the simulated incident $\theta$ angle = 60 degree (1.04 rad) while the simulated proton energy is 3 TeV.

Figure 2. The distribution of the reconstructed incident $\phi$ angle when the simulated incident $\theta$ angle = 60 degree while the simulated proton energy is 1 TeV.

Figure 3. The dependence of the angular resolution on the incident angle. Simulated energy 0.5 TeV.

Figure 4. The dependence of the angular resolution on the incident angle. Simulated energy 3 TeV.
Figure 5. The dependence of the mean angular resolution on the energy.

Figure 6. The dependence of the total deposited energy inside the calorimeter on the incident angle.

Figure 7. The dependence the registration efficiency on the incident angle for 1 TeV protons.

Figure 8. The dependence the registration efficiency on the incident angle for 3 TeV protons.
3. The energy resolution
With increasing incident angle the energy resolution gets worse, but not more than by 10% (when $\theta = 75$). Along with a decrease in the number of the hit planes the value of the total energy released in the calorimeter is proportionally decreasing. The mean total energy released in the calorimeter depends on the incident angle of the particle, reaching the peak value at 45 degrees. Thus, we can conclude that with increasing of the incident angle the energy resolution varies slightly but there is a significant change in the value of the total energy released in the calorimeter (see figure 6).

4. The efficiency of the registration
The registration efficiency (after the selection) was calculated as the number of the particles that have been selected - $N_i$ divided by the number of the particles generated in the simulation - $N_r$. The resulting dependencies of the efficiency on the incident angle $\theta$ for the proton energies 1 TeV, 3 TeV are shown in figures 7 and 8. The efficiency of the registration of high-energy particles at various angles depends on using of the trigger type (the calorimeter or S4). For particles passing through the magnet system the registration efficiency increases by the factor two.

5. The influence of the satellite body and the acceptance
With an increase of the proton energy a difference between the registration efficiencies for the directions “toward” and “backward” of the satellite decreases. Thus influence of the satellite body decreases while the particle energy increases and does not exceed 1% for the energy release above 100000 mip (minimum ionization particles). Acceptance of the calorimeter larger than the standard one (defined by the magnetic spectrometer) by the factor 100.

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References
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