Radboud Universiteit Nijmegen
Afdeling Sterrenkunde
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Astroparticle Physics – 2009/10

Werkcollege 8 – 23.04.2010

Problem 21 Electromagnetic cascades

High-energy electrons and photons impinging on matter initiate electromagnetic cascades.

Discuss the development for an incoming electron and a photon.

Assume a simple Heitler model for electromagnetic cascades and calculate the mean particle energy in the n^{th} shower generation.

The maximum number of particles is reached when the mean particle energy equals the critical energy. Calculate the depth of the shower maximum.

Calculate the number of electrons at shower maximum and the depth of the shower maximum of an electromagnetic cascade in air for an initial energy of $E_\gamma = 10$ TeV and 10 PeV, respectively. (in air: $X_0 = 36.66$ g/cm^2, $E_c^e = 85$N MeV)

Problem 22 Hadronic showers - Heitler model

As discussed in the lecture a Heitler-type model can be adopted to describe the development of hadronic showers in the atmosphere.

Calculate the number of electrons and muons at shower maximum for a primary particle with energy E and mass number A.

Calculate the depth of the shower maximum for a particle with energy E and mass number A.

How do the observed quantities (electron-to-muon ratio and shower maximum) depend on the mass of the shower-inducing particle?

Problem 23 Direction of incidence

Extensive air showers are registered with an array of detectors (dimension 200×200 m^2). The arrival times of the particles in the shower front are measured in the individual detectors.

Calculate the maximum time difference in the arrival times for showers with a zenith angle of $\Theta = 20°$.

Estimate the time resolution which is required to determine the direction of the shower with an accuracy of 0.5°.

The central electronics (trigger logic) is in the center of the array. A valid event is defined through coincident signals in several detectors. Estimate the maximum time required to notify all detectors to read out the signals (trigger impulse). The propagation speed in the cable is 2/3 c.

see reverse side!

Problem 24 Čerenkov detector

Particles are registered with a Čerenkov detector in an air shower experiment. The detector is filled with water (index of refraction $n = 1.33$). The particles move at the speed $\beta = v/c$ through the medium. Show that the angle Θ between the particle trajectory and the radiation direction of the Čerenkov radiation is given as

$$\cos\Theta = \frac{1}{\beta n}$$

Calculate Θ for relativistic particles.

Calculate the minimum energy of protons, muons, and electrons to radiate Čerenkov radiation (Čerenkov threshold).

Deliver answers to box "astroparticle physics" in front of secretariat Sterrenkunde HG 03.720 before 20.05.2010.

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Lecture web site: http://particle.astro.kun.nl/goto.html?astropart0910