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Afdeling Sterrenkunde
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Astroparticle Physics – 2012/13

Werkcollege 7 – 07.11.2012

Problem 17 Particle decay

In an extensive air shower many particles are pions and muons.

In which particles decay pions and muons?

How far travels a pion and a muon (in average) in the atmosphere before it decays. Consider particles with energies of 10 TeV, 100 GeV, and 1 GeV.

Problem 18 Extensive air showers

A high-energy cosmic-ray particle impinges on the atmosphere of the Earth. Describe qualitatively the development of an extensive air shower.

Which particles are produced (dominantly) during hadronic interactions?

The secondary particles reaching ground level can be divided into three components: electromagnetic, muonic, and hadronic.

How are electromagnetic cascades, muons, and hadrons produced in an air shower?

In which processes are muons generated?

Which components feed the electromagnetic channel, i.e. in which processes are electrons generated?

Problem 19 Interaction of pions

Charged pions in an air shower have two possibilities for an interaction. They can decay into muons ($\tau_0 = 26$ ns) or they interact hadronically. Assume $\lambda_I = 120\,\mathrm{g/cm^2}$ being independent of the pion energy.

Calculate the energy E' for which the probability to decay is equal to the probability for a hadronic interaction.

The density of air as function of height is given through the barometric formula $\rho(h) = \rho_0 \exp(-h/H)$, with $H = 8005$ m and $\rho_0 = 1.3$ g/l.

Calculate the energy E' for sea level, as well as for an altitude of 1 km, 10 km, and 30 km. Which process dominates for $E_\pi < E'$ and which one for $E_\pi > E'$?

see reverse side!

Problem 20 Electron-to-muon ratio in air showers

Extensive air showers are initiated by interactions of high-energy cosmic rays with atomic nuclei in the atmosphere. Discuss qualitatively the difference between air showers induced by protons and by iron nuclei with the same total energy.

Which particle interacts (on average) higher up in the atmosphere? Hint: the cross section of a nucleus with mass number A is $\sigma_A \propto A^{2/3}$.

Which particle (proton or iron nucleus) yields on average secondary particles with a larger mean energy? How does this influence the decay of (unstable) secondary particles?

Consider the decay of pions into muons. Which primary particle (proton or iron nucleus) yields more muons in the atmosphere? Hint: the considerations related to Problem 19 are important.

Consider energy conservation, i.e. assume the total energy of an air shower is the sum of the energy in the electromagnetic and the muonic component. A useful quantity to characterize an air shower is the ratio of the number of electrons to the number of muons in the shower e/μ-ratio. Which primary particle (proton or iron nucleus) yields the larger e/μ-ratio?

The solutions will be discussed during the werkcollege on 07.11.2012 at 15:30 in HG02.028.
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Lecture web site: http://particle.astro.ru.nl/goto.html?astropart1213