Exercises for Experimental methods in Astroparticle Physics

Universität Heidelberg 16. October 2019 **Hand in:** 23. October 2019

Sheet 1

1. Propagation of Cosmic Rays

(a) Get familiar with typical length scales of our neighborhood. E.g. how far is it to Andromeda Galaxy? How large is our Local Group?

(b) Imagine a cosmic ray in the magnetic field of our Milky Way. Above which energies does the gyroradius become larger than the thickness of the galaxy's disk? How does this value change for more heavy nuclei? Comment on the spectrum in Fig. 1 based on your result.

2. GZK Cut-off

Estimate the mean free path of protons with an energy of about $10^{20}\,\mathrm{eV}$. The cross section at this energy for Δ^+-resonance with photons from the cosmic microwave background is $\sigma \sim 10^{-28}\,\mathrm{cm}^2$ and the number density of photons is $n_\gamma \sim 400\,\mathrm{cm}^{-3}$.

3. Energy Densities

(a) Calculate the energy density (in $\mathrm{eV/cm}^3$) of cosmic rays. You may use the range covered by Fig. 1 on the back.

(b) The spectrum of cosmic microwave background radiation follows a Planck distribution quite exactly. Calculate the energy density of this radiation, corresponding to a black body with a temperature of $2.7\,\mathrm{K}$.

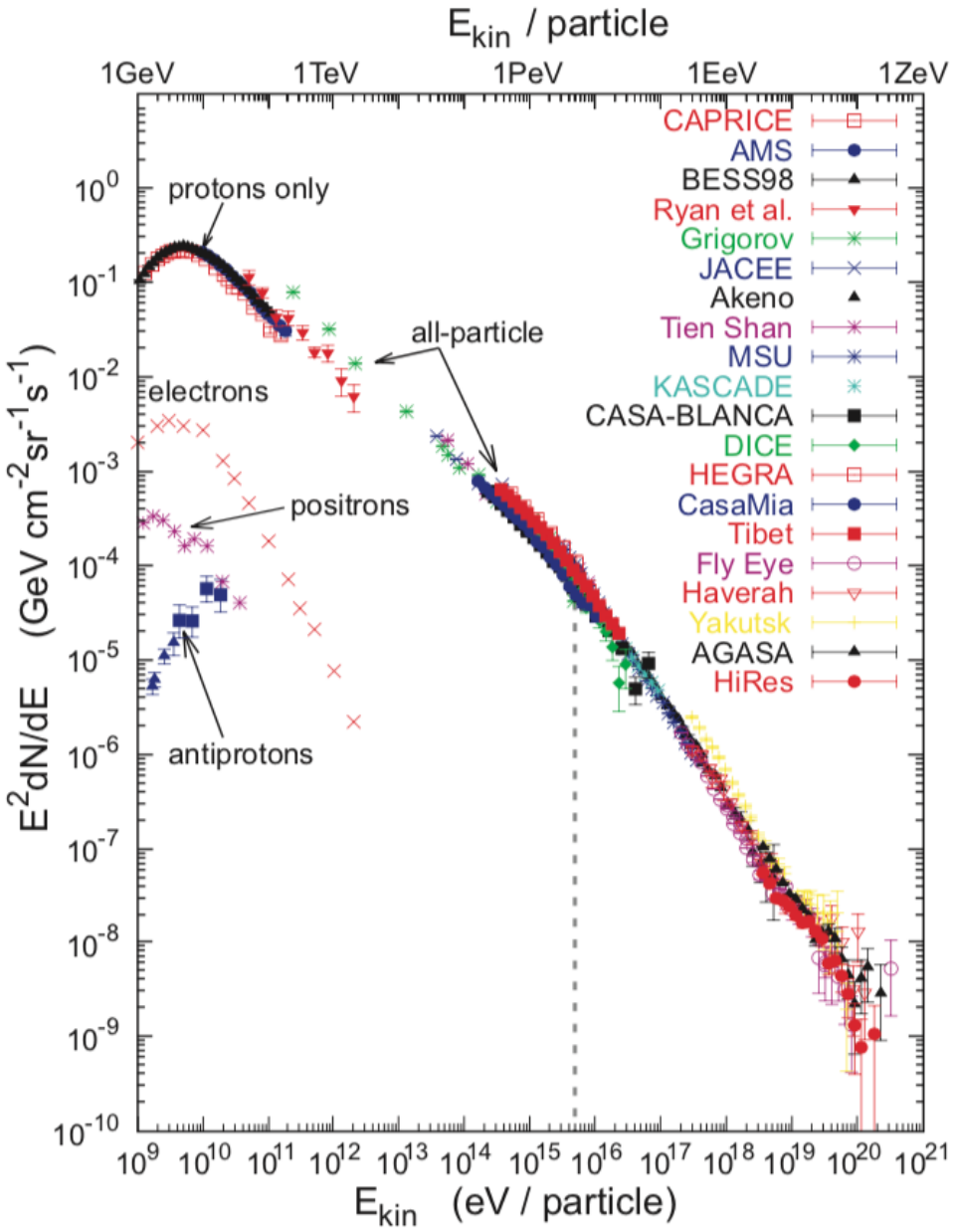

Figure 1: The differential particle flux of cosmic rays as measured by various experiments. As common in astroparticle physics, this flux has been multiplied by E^2 so that fluxes that are proportional to E^{-2} appear as a straight line. Note the vast energy flux range covered by the diagram! On that account various experiments are necessary to measure this spectrum, as indicated by different symbols. The spectrum follows a power law $dN/dE \propto E^{-2.7}$ for energies between several GeV and PeV. Above about $4\,\mathrm{PeV}$ this steepens to a spectrum $\propto E^{-3.1}$. This kink at about $4\,\mathrm{PeV}$ is called the *knee* of the spectrum. Diagram sneaked from Tom Gaisser.