2018 ARBRA Workshop

From Measurement to Discovery – The Scientific Method in Physics

Topics discussed at Astroparticle Physics Exercises

1. **Shower Detection**

   How do detect showers? Why did Hess not detect showers? What is needed to detect showers? What is the time duration of the signals produced by a shower in a single detector? How to know that signals in different detectors are hit by a shower? Origin and rate of random noise in a detector? How to reduce noise through coincidence? Chance coincidence rate? Twofold, threefold coincidences?

   Direction distribution of shower particles at ground? How to reconstruct the direction of an air shower from arrival times? Coincidences with multiple detectors on top of each other? Coincidences with multiple detectors at distances from each other (the original experiment by Pierre Auger)? Estimate of energy of a shower from coincidence with detectors at 300 m distance?

2. **Decay point and interaction length distributions**

   What is the decay law of radioactive decays? Where does it come from? What are "decay constant", "life time", "half life" and "activity" of a decaying particle and how do they relate? What are their units? How can they be measured?

   Why does the interaction point distribution follow an exponential distribution? What is the average value of an exponential distribution? What is the interaction length? What is the decay probability per unit time? What is the Interaction probability per unit path length?

3. **Bethe-Heitler Shower Model for Electromagnetic Showers**

   Understand qualitative features of a shower with the Bethe-Heitler model. How do high-energy electrons and photons interact? Typical interaction length of photons? Radiation length of electrons? Units of interaction length and of path length? Relation of path length and density profile in atmosphere? Respective definitions for electrons and for photons? Definition of the critical energy? What is the critical energy in air?

   Particle number and particle energies as function of depth in the atmosphere? N_{max}, X_{max} as function of energy? For what energies do vertical shower particles reach the ground? For what energies do vertical shower particle have their shower maximum at ground level?

4. **Neutrino interactions**

   The "cross section" as interaction probability.

   In the Chlorine experiment, 15 neutrino reactions are detected per month.
   What is approximately the neutrino interaction probability?
   (610 t of C_2Cl_4 ; only 25% of natural Chlorine is $^{37}_{17}Cl$; total solar ν flux at Earth is $6.3 \times 10^{10}/(cm^2 s)$)

   The absorption cross-section of neutrinos ($\sim$ 10 MeV) on a nucleon (proton or neutron) is about $\sigma_{\nu n} = 6 \times 10^{-44}$ cm^2. What is the probability that such a neutrino is absorbed when traversing the full diameter of the Earth?
   ($r_{Earth} = 6370$ km, $\rho_{Earth} = 5.5$ g/cm^3)