Tutorial 6

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"Tests des Standardmodells der Teilchenphysik"

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Part 1: Neutrino Kinematics

High energy neutrino beams at colliders are produced by first forming a monoenergetic π^+, or K^+, beam and then allowing the pions to decay via

$$\pi^+ \to \mu^+ + \nu_\mu \ . \tag{1}$$

Suppose a π^+ beam produced with energy 200 GeV which is then used to produce neutrinos via the above decay. The lifetime of charged pion mesons is $\tau_{\pi^\pm} = 2.60 \times 10^{-8}$ s in the rest frame of the pion, and its rest energy is 139.6 MeV. The rest energy of the muon is 105.7 MeV, while the neutrino can be assumed to be massless.

1. Calculate the mean distance traveled by the pions before they disintegrate.
2. Calculate the maximum angle of the muon, relative to the pion direction, in the laboratory frame.
3. Calculate the minimum and maximum momenta that the emerged neutrinos can acquire.
4. Find the energy of a neutrino produced in the forward direction of the beam ($\theta = 0$).
5. Find the angle θ at which the neutrino's energy has fallen by a factor δ, for example $\delta = 2$, of its maximum energy.
6. The pions travel down a pipe of 500 m length where some of them decay to produce the neutrino beam for the neutrino detector located more than 1 km away. What fraction of the pions decay in the end of the pipe? What is the length of the decay pipe as measured be observers in the pion rest frame?
7. The neutrino detectors are on the average approximately 1500 m from the point where the pions decay. How large should the transverse dimension of the neutrino detector be in order to have a chance of detecting all neutrinos that are produced in the forward hemishpere in the pion rest frame?

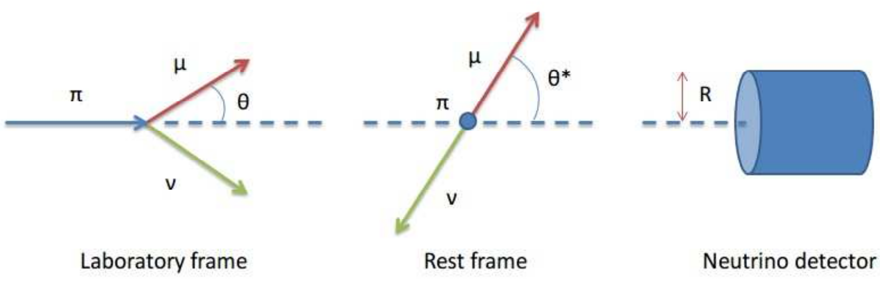

Figure 1: Pion decay in the laboratory and rest frame.

References

- *Introduction to High Energy Physics*, D. H. Perkins, 4th edition, Cambridge University Press, 2000 **Chapter 11**
- *Introduction to Elementary Particles*, D. J. Griffiths, Wiley-VCH, Second/Revised edition, 2013 **Chapter 3**
- *Modern Particle Physics*, Mark Thomson, Cambridge University Press, 2013 **Chapter 13**
- *Elementary Particles in a Nutshell*, Christopher G. Tully, Princeton University Press, 2011 **Chapter 5**