MISIS - New Technologies for New Physics

Exercise O.Steinkamp November 18, 2020

Problem 1

Calculate the center-of-mass energy for fixed-target proton-proton collisions at the LHC, colliding one of the two LHC beams on a target at rest (this is actually done in LHCb, see e.g. https://cerncourier.com/a/new-smog-on-the-horizon/).

Problem 2

Estimate the expected mass resolution for the $\Upsilon(1S)$ in LHCb. As shown in the slides, the mass of a particle decaying into a μ^+ and a μ^- can be calculated from the measured momenta of the two muons as

$$m_{\mu^+\mu^-} = \sqrt{(E_{\mu^+} + E_{\mu^-})^2 - (\vec{p}_{\mu^+} + \vec{p}_{\mu^-})^2}$$

with

$$E_{\mu^\pm} = \sqrt{|\vec{p}_{\mu^\pm}|^2 + m_\mu^2}$$

Use the approximation $|\vec{p}_{\mu^\pm}| >> m_\mu$ to express $m_{\mu^+\mu^-}$ as a function of $|\vec{p}_{\mu^+}|, |\vec{p}_{\mu^-}|$ and $\cos\theta_{\mu^+\mu^-}$, where $\theta_{\mu^+\mu^-}$ is the opening angle between $\vec{p}_{\mu^+}$ and $\vec{p}_{\mu^-}$.

Assume $m_{\mu^+\mu^-} = 10$ GeV (i.e. approximately the mass of the $\Upsilon(1S)$ resonance) and $|\vec{p}_{\mu^+}| = |\vec{p}_{\mu^-}| = 50$ GeV. Calculate $\cos\theta_{\mu^+\mu^-}$. In the plot shown on slide 35 of the lecture you can see that the relative momentum resolution for a 50 GeV particle in LHCb is about 0.7%. Assume further that $\theta_{\mu^+\mu^-}$ can be measured with relative precision 3×10^{-4}. Estimate the expected uncertainty on $m_{\mu^+\mu^-}$ using Gaussian error propagation. Which of the two uncertainties (that on $|\vec{p}_{\mu^\pm}|$ or that on $\theta_{\mu^+\mu^-}$) dominates the mass resolution? Compare your result with the measured mass resolution for the $\Upsilon(1S)$ of about 47 MeV (see e.g. https://lhcb-public.web.cern.ch/Images_2012/Images_2010/UpsilonLHCb2.png).