KTII - Exercise 6

Universität Zürich

Due: 15 May 2020

For particle information, including hadronic quark content, particle masses, particle lifetimes, or other physical constants not given in the problem, please consult the Particle Data Group's Review of Particle Physics. It is available for free on their website: http://pdg.lbl.gov/.

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1. **(2.5 points)** After UA1 and UA2, accelerator facilities were under design which would produce the neutral intermediate vector boson Z via the process

$$e^+ + e^- \to \mathrm{Z}$$

   (a) Find the energy of the electron beam needed for the colliding beam facility under construction.

   (b) Assume instead that a fixed target facility is to be built, such that a beam of e^+ will strike a target of e^- at rest. What is the required e^+ beam energy for this case?

   (c) What is the energy and velocity of the Z (in the laboratory) after production?

   (d) Find the maximum energy in the laboratory frame of muons from the subsequent decay $\mathrm{Z} \to \mu^+\mu^-$.

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2 **(2 points)**

How many electrons does a charged particle produce on average when crossing $100\,\mu$m of silicon assuming that its velocity is consitent with $\beta\gamma \sim 4$?

Hint:

$$-\frac{\mathrm{d}E}{\mathrm{d}x} \approx (0.307\,\mathrm{MeV\,mol^{-1}\,cm^2})\rho\frac{Z}{A}\frac{z^2}{\beta^2}\left[\ln\frac{2m_e c^2\gamma^2\beta^2}{l} - \beta^2\right].$$

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3 **(3 points)**

After having collected an integrated luminosity $\mathcal{L} = 10\,\mathrm{fb}^{-1}$, an analysis of $B_s^0 \to J/\psi K_S^0$, with $J/\psi \to \ell^+\ell^-$ and $K_S \to \pi^+\pi^-$, selects $N = 100$ candidate events. By using $N_{\mathrm{MC}} = 1000$ simulated events, the selection efficiency is estimated to be $\epsilon = 37\%$. What are the measured Branching Ratio for $B_s^0 \to J/\psi K_S^0$, the related statistical uncertainty, and the systematic uncertainty due to the finite number of simulated events? Assume $\sigma_{B^0} \approx 1\,\mathrm{nb}$. Assume that the Branching Ratios for $J/\psi \to \ell^+\ell^-$ and $K_S \to \pi^+\pi^-$ are known and take their values from the PDG.

4 **(2.5 points)**

Consider a proton-proton collider such as the LHC. Compute the average number of interactions per bunch crossing if the luminosity is $\mathcal{L} = 10^{34}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$, the total cross section $\sigma \approx 80\,\mathrm{mbarn}$ and the bunches cross every $25\,\mathrm{ns}$.

(a) What is the average number of collisions per bunch crossing for these conditions? These parameters are representative of the design conditions for LHC operation.

(b) During its recent operation periods the LHC has exceeded its design goal for instaneous luminosity, with the highest values reached being just above $2 \times 10^{34}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$. The average number of collisions per bunch crossing has sometimes increased by a factor even larger than what is expected from the increase in luminosity alone. Briefly explain what else caused the increase in collisions per bunch crossing.

(c) Under LHC conditions, with a luminosity of $1.5 \times 10^{34}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$ and a centre-of-mass energy of 13 TeV calculate the power dissipated by the collisions.