

Physics at a muon collider

1 Muon Collider

In this project we will study the following process of production of a pair of bottom quarks $b\bar{b}$ in $\mu^+\mu^-$ collisions at a potential future muon collider

$$\mu^+\mu^- \rightarrow b\bar{b} \quad (1)$$

1.1 Transition Amplitudes

Draw all the lowest order Feynman graphs contributing to the process in (1).

Write down the various transition amplitudes.

1.2 Differential Cross Section

Apply the Dirac- γ -matrix trace formalism and the completeness relations for Dirac spinors to calculate the differential cross section(s),

$$\frac{d\sigma}{d\cos\theta} \quad (2)$$

Draw the differential cross section, (2), as a function of $\cos\theta$ for the various processes. Remember to also include interference effects.

1.3 Forward-Backward Asymmetry

Derive the forward-backward asymmetry,

$$A_{FB} = \frac{\sigma_{\theta>\pi/2} - \sigma_{\theta<\pi/2}}{\sigma_{\theta>\pi/2} + \sigma_{\theta<\pi/2}} \quad (3)$$

and discuss the various processes. Draw A_{FB} as a function of the centre-of-mass energy, \sqrt{s} . Compare the process in (1) with annihilation processes into $c\bar{c}$ and e^+e^- . What about the $\mu^+\mu^- \rightarrow \mu^+\mu^-$ case?

1.4 Total Cross Section

Calculate and plot the total cross section of the process in (1) as a function of \sqrt{s} . Discuss the results.

1.5 Comparison with a computational tool

Run the CompHEP program for the process (1) and compare all your results above with those obtained with CompHep.

1.6 New Physics

Assume the existence of a new gauge boson, Z' , mediating a new hypothetical weak interaction. Implement such a new particle into CompHep and draw the following quantities:

1. the differential cross section, (2), as a function of $\cos \theta$
2. total cross section as a function of \sqrt{s}
3. the forward-backward asymmetry as a function of \sqrt{s} .

Discuss the results.

1.7 Comparing with publications (**FYS9555 students only!** **Optional for others.**)

Compare the results from the previous exercises to measurements performed at e^+e^- colliders. Compare to $p\bar{p}$ and pp collisions. Discuss some ATLAS results related to the topics above.

Hint: ATLAS public web pages: <https://twiki.cern.ch/twiki/bin/view/AtlasPublic>