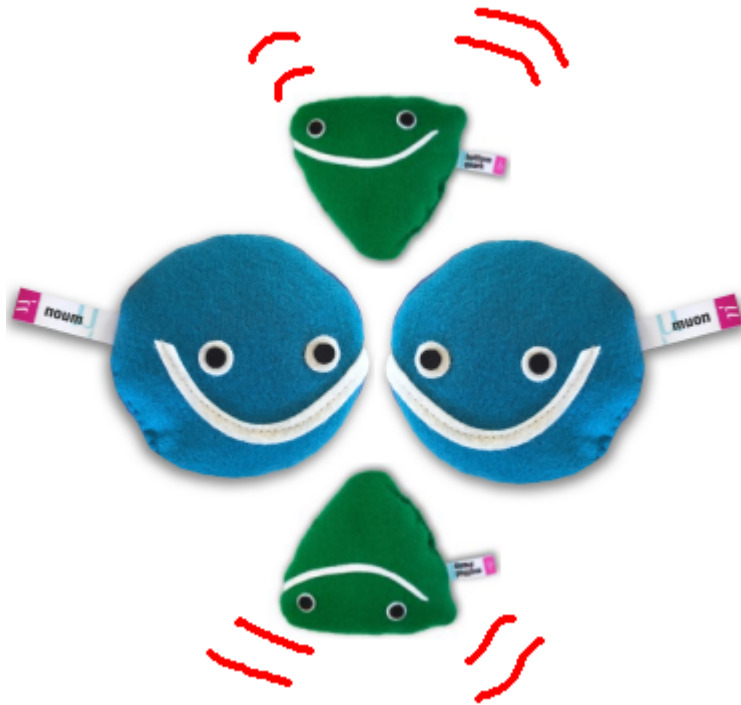


Physics at a muon collider

Compulsory Project I
FYS5555, Spring 2020

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Deadline: Monday March 2nd 2020
Assessment: 17% of final grade



1 Muon Collider

In this project we will study the following process at a 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),

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

Hint: See Chapter 6.5 in Thomson

Draw 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 into $c \bar{c}$ and $e^+ e^-$.

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.

Compare your results with calculations in CompHep.

1.5 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

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.

1.6 ATLAS Data Analysis

Analyse some ATLAS Data and plot the invariant mass distribution of di-leptons ($\mu^+\mu^-$ and e^+e^-). Compare to Standard Model predictions. Which processes contribute to such distributions?

1.7 Comparing with publications (FYS9555 students only!)

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>