



Phenomenology of Particle Physics II

Exercise Sheet 11

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

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Lecturers: Dr. M. Dittmar, Dr. M. Grazzini

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www.itp.phys.ethz.ch/education/lectures_fs12/PPPII

Please read the article <http://arxiv.org/abs/1203.3976>.

Exercise 20 [Search for rare B decays at the LHC]

Both general purpose experiments at the LHC – ATLAS and CMS – are performing a search for the rare decays $B_d^0 \rightarrow \mu^+ \mu^-$ and $B_s^0 \rightarrow \mu^+ \mu^-$ that have the branching ratios of $(1.0 \pm 0.1) \times 10^{-10}$ and $(3.2 \pm 0.2) \times 10^{-9}$ respectively in the Standard Model. An event counting experiment is done ‘blindly’ where the signal region is not observed until all selection criteria are established. The (upper limit on) branching ratio of the decays is estimated using a ‘normalization’ channel $B^+ \rightarrow J/\Psi K^+$.

- (i) Draw the leading order Feynman diagrams for the decays $B_d^0 \rightarrow \mu^+ \mu^-$ and $B_s^0 \rightarrow \mu^+ \mu^-$. Explain why the decay ratios are so small. Explain also, how the flavor of the light quark influences the branching ratios $\text{Br}(B_s^0 \rightarrow \mu^+ \mu^-)$ and $\text{Br}(B_d^0 \rightarrow \mu^+ \mu^-)$.

Hint: One reason can be directly derived from the Feynman diagrams, another one results from the helicity configuration of the decay products.

- (ii) Explain why rare B decays are interesting to search for also at **general purpose** detectors at the LHC while the main goal of these detectors is the search for Higgs boson and (hints) for physics beyond the Standard Model.

- (iii) What are the features of the detectors that allow to study soft B decays?

Hint: Tracking system, muon trigger.

- (iv) Why is CMS using a normalization channel for the estimation of $\text{Br}(B^0 \rightarrow \mu^+ \mu^-)$?

- (v) Why does one use $B^+ \rightarrow J/\Psi K^+$ and not $B_s^0 \rightarrow J/\Psi \Phi$ as a normalization channel?

Hint: precision of measured branching ratios.

- (vi) Why it is crucial to demonstrate that various selection variables are pile-up independent?

- (vii) Guess about reasons to perform a blinded analysis in this case.

Hint: very few events expected hence a possibility to over-tuned cuts.

– please turn over –

Exercise 21 [*LHC kinematics with W and Z bosons*]

- (i) With $x_{1,2} = E_{\text{parton}}/E_{\text{beam}}$ determine the mass and rapidity of the produced hard system (e.g. the W and Z boson).
- (ii) Explain qualitatively the rapidity distributions in pp collisions for W^+ and W^- bosons. When looking at the observable charged leptons rapidity distributions from the W decays, explain why the positively charged leptons is found more often centrally than the negatively charged lepton.
Hint: Think about the initial states needed to produce W^\pm bosons and recall that on average valence partons have a bigger x than sea partons.

Exercise 22 [*Light Higgs at the LHC*]

The SM cross-section of inclusive light Higgs production at the LHC energy (7 TeV) is $\simeq 15$ pb. Calculate how many Higgs bosons will be produced (in case it exists) by the end of 2012 at the LHC (in both experiments ATLAS and CMS) assuming that each experiment will collect 20 fb^{-1} . Compare pros and cons for the light Higgs search in the following decay modes: $H \rightarrow b\bar{b}$, $H \rightarrow \tau^+\tau^-$, $H \rightarrow \gamma\gamma$ and $H \rightarrow \mu^+\mu^-$.

Hint: Look at branching ratios and background.

Informations relative to the exercises

Testat condition : 60% of the exercise sheets worked out and solve one exercise at the blackboard.

Exercises may be solved in groups of up to 3 people.

Teaching assistants:

Julián Cancino, HIT K21.4, cancinoj@itp.phys.ethz.ch

Lorenzo Tancredi, I36 K36, tancredi@physik.uzh.ch

Andrey Starodumov, HPK E27, starodumov@phys.ethz.ch