

Monte Carlo simulation of the $\gamma\gamma \rightarrow \tau^+\tau^-$ process in e^+e^- collisions

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CERN Summer Student Programme, 17 August 2017

Abstract

Monte Carlo events for $\gamma\gamma \rightarrow \tau^+\tau^-$ process in e^+e^- collisions were generated with SuperChic and the cross-sections at different centre-of-mass energies of FCC-ee were obtained. Further τ decays were performed using Pythia8 generator. Events were stored in Root trees and prepared for future analysis.

Introduction

The Future Circular Collider (FCC) is a post-LHC accelerator project at CERN for high-energy frontier physics. One part and parcel of the FCC design study is the FCC-ee. It is a high-luminosity and high-precision e^+e^- circular collider foreseen in a new 80 – 100 km tunnel in the Geneva area. The centre-of-mass energy is predicted to be in the range of 90 GeV and 400 GeV, which could lead to the discoveries of physics beyond the Standard Model.

One of the processes that can occur in FCC-ee is tau pair production in photon-photon collisions. The Feynman diagram for that reaction is shown on Fig.1. It is called multiperipheral graph and represents the most relevant contribution for the $e^+e^- \tau^+ \tau^-$ final state in e^+e^- collisions.

Since the multiperipheral $e^+e^- \rightarrow e^+e^- \tau^+ \tau^-$ process diagram contains two $\gamma\tau\tau$ vertices, that are sensitive to the anomalous electromagnetic couplings of the τ lepton, the anomalous magnetic and electric dipole moments can be extracted by comparing QED expectations with the measured cross-section and our knowledge of physics beyond the SM can therewith be upgraded.

In this research we were running Monte Carlo tools for $\gamma\gamma \rightarrow \tau^+ \tau^-$ process in e^+e^- collisions at the following centre-of-mass energies of the FCC-ee: $\sqrt{s} = 91.2$ GeV, 160 GeV, 240 GeV and 350 GeV.

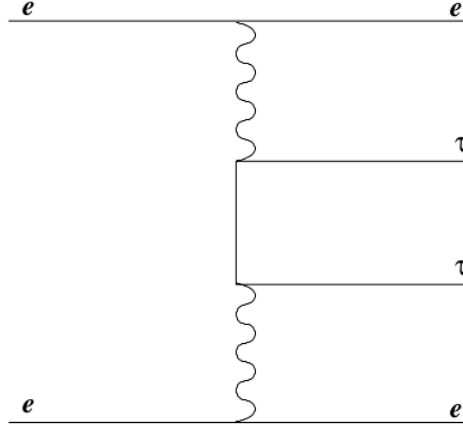


Figure 1: Multiperipheral graph for $e^+e^- \rightarrow e^+e^- \tau^+ \tau^-$ process.

Monte Carlo simulation

SuperChic event generator

SuperChic is a Fortran based Monte Carlo event generator for central exclusive production. It takes the input of several parameters, including the identification of the process that user wants to generate and the centre-of-mass energy of the collision. It also allows user to vary parameters it uses as part of its modeling scheme. The program makes use of the LHAPDF library. The output contains calculated cross-section for the process as well as unweighted events in Les Houches or HEPEVT format.

We were using version 2.05 to generate unweighted events in the Les Houches format for $e^+e^- \rightarrow e^+e^-\tau^+\tau^-$ process but without further decaying of τ leptons. Pythia8 was used for τ lepton decays, as discribed later in the paper. As we did not need any PDF sets for the process mentioned above, it was possible to run SuperChic without using the LHAPDF library by setting 'PDFINPUT' flag in the makefile to 'USER' instead of the default 'LHAPDF'. Because it runs the files with user as a suffix in the 'PDFs/' folder, we also needed to create empty files with the right names ('hgin.dat', 'screeningin.dat' and 'sudakovin.dat') in the 'bin/inputs' directory to run the program.

In this study, general cuts were applied on invariant mass of τ pairs which had to be less than 40 GeV/c². Two body cuts on the final-state τ leptons were performed for rapidity $|\eta| < 2.5$. The calculated cross-sections for different energies are shown in Table 1.

$\sqrt{s}$ [GeV]	91.2	160	240	350
σ [pb]	190 ± 2	232 ± 2	260 ± 2	285 ± 2

Table 1: Centre-of-mass energies and associated cross-sections calculated with SuperChic generator.

The obtained LHE output file was in every event missing two lines that should belong to the incoming "partons", which in this case are e^+e^- . Thus, we had to modify SuperChic code in 'unwprint.f' file, which is located in 'src/unw' directory. Furthermore, we had to replace the 93 code by the more appropriate 23 for a Z^0 boson. We also had to intervene in two mother indices and two daughter indices for every particle because of some occurred mismatches.

Analysis with Pythia and Root

The τ decay was simulated by Pythia8. It is another Monte Carlo generator, that has a procedure for reading Les Houches event files, which contain

complete initialization and event information. With that input information, Pythia8 can process external parton-level events. The program outputs a list of daughter particles along with their respective energies and momenta. To analyze the data, we primarily wanted to use Pythia8226 as a plug-in to Root 6.08.06. Unfortunately, Root cannot properly read initialization information from the Les Houches event file, such that events cannot be generated as they would be if we used Pythia8 in standalone mode. That is why we finally decided to use the Pythia8175 version, which has a built-in 'rootexamples/' subdirectory, that provides a way to store entire Pythia events in Root trees. By making a Root tree, we set up an environment for further and deeper physical analysis of this process.

Conclusion

We have studied the reaction $e^+e^- \rightarrow e^+e^-\tau^+\tau^-$ by using Monte Carlo tools to generate events and cross-sections on different centre-of-mass energies. At this stage in the study, it is difficult to draw any definitive conclusions. However, this research gives us more insights into the SuperChic and Pythia8 programs and difficulties that can occur when trying to merge two different programs for physical researches. For future analysis, it would be interesting to extract limits on the anomalous magnetic and electric dipole moments of the τ lepton by comparing measured cross-sections with the Monte Carlo results.

Acknowledgments

I would like to thank my supervisor, David d'Enterria, for his guidance through-out the course of this research.

I would also like to thank the CMS collaboration and the CERN Summer Student Programme for making this research possible.

References

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