European Organization for Nuclear Research

Central Exclusive Processes (CEP) in proton-proton collisions at $\sqrt{s} = 13$ TeV

Project Report

Presented By

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Introduction

The successful operation of the *Large Hadron Collider* (LHC) during the past years allowed to explore particle interaction in a new energy regime. Measurements of important Standard Model processes like the production of highP_t jets, W and Z bosons and top and b-quarks were performed by the LHC experiments. In addition, the high collision energy allowed to search for new particles in so far unexplored mass regions. Important constraints on the existence of new particles predicted in many models of physics beyond the Standard Model could be established. With integrated luminosities reaching values around $5ifb$ in 2011, the experiments reached as well sensitivity to probe the existence of the Standard Model Higgs boson over a large mass range. In the present report the major outlines followed to studying Central Exclusive Production in the ALICE experiment are presented.

Chapter 1

Central Exclusive Production

1.1 Context

Central Exclusive Processes (CEP) are described using the interaction:

$$pp \to p + X + p$$

where + signs are used to denote the presence of large rapidity gaps, separating the system X from the intact outgoing protons (anti–protons). Over the last decade there has been a steady rise of theoretical and experimental interest in studies of this process in high–energy hadronic collisions. Theoretically, the study of CEP requires the development of a framework which is quite different from that used to describe the inclusive processes more commonly considered at hadron colliders. Moreover, the dynamics of the CEP process leads to unique predictions and effects which are not seen in the inclusive mode. Experimentally, CEP represents a very clean signal, with just the object X and no other hadronic activity seen in the central detector (in the absence of pile up).

The jets produced from CEPs are supposed to be always gluon jets, the purity vs. light quark jets is calculated to be of the order of 103. The CEP jet final states can therefore be used for investigating gluon jets in detail. Observables such as jet multiplicities, flavour and baryon number suppression can be accurately measured and compared to the inclusive minimum bias interactions.

The CEP process requires the t–channel exchange of a color–singlet object, so that the outgoing protons can remain intact. One possibility to achieve this is the two–photon fusion process $\gamma\gamma \to X$, where the radiated photons couple to the electromagnetic charge of the whole protons. Alternatively, the process may be mediated purely by the strong interaction: provided the object X mass is large enough, this can be considered in the framework of pQCD, via the so–called Durham model. Finally it is possible for 'photoproduction' reactions to occur, where one proton interacts electromagnetically and one interacts strongly.

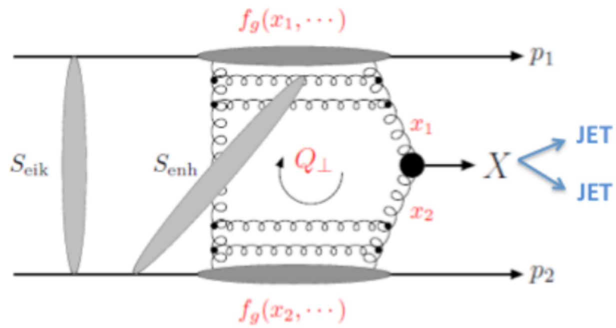

Fig. 1.1: Central Exclusive Production of jets

The respective cross section for the process mentioned before is calculated as the convolution of the effective luminosity $L(gg)$, and the square of the matrix element of the corresponding subprocess. Predictions for the CEP jet cross sections are given in Figure 1.2, and Table 1 for jet pseudorapidities of $|\eta_j| < 2.5$(anti-kt algorithm with R = 0.6 used):

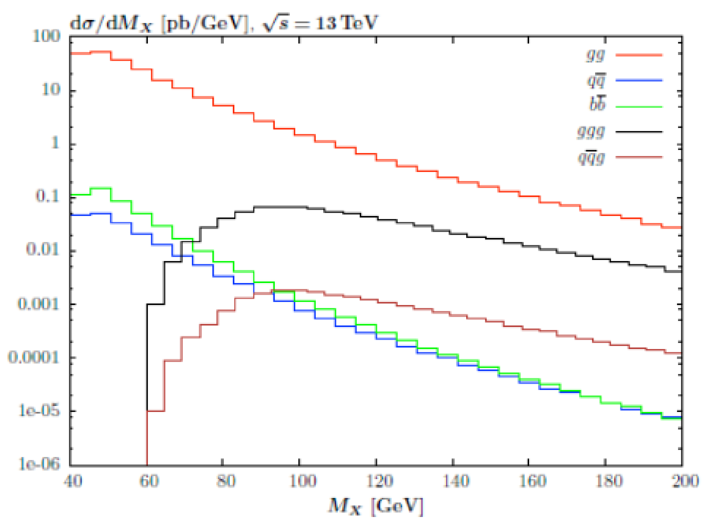

Fig. 1.2: Central Exclusive Production of jets

1.2 SuperChic

In any detailed phenomenological study of processes such as the CEPs, it is important to have a Monte Carlo (MC) implementation, so that theoretical predictions can be compared more directly with experimental measurements. For this reason the authors have previously produced the publicly available SuperChic MC, for the CEP of lighter Standard Model (SM) objects within the Durham model.
However, there exist a wider range of processes that are not included in earlier versions of SuperChic, but which have much phenomenological relevance, in particular in the light of the measurement possibilities for exclusive processes during Run–II of the LHC. Here, exclusive events may be measured using rapidity gap vetoes to select a dominantly exclusive event sample. This possibility is in particular relevant at LHCb, for which the relatively low instantaneous luminosity and wide rapidity coverage allowed by the newly installed HERSCHEL forward detectors are highly favourable, while similar scintillation counters are also installed at ALICE.

1.3 The Simulation

Simulating such processes starts with inserting the right process parameters in Superchic's input data file, and then merging the output within Pythia to make it do the hadronisation process which gives data that we filter according to the central detectors parameters in order to get plots which should match the ones we see in the experiment, then we use this matching process to understand whether this process is produced or not.
During my project I have worked on understanding the underlying theoretical concpets lying behind CEPs, verifying a few calculations I used in Superchic of the cross section of the target process and other parameters. Then, moving to ROOT which is a data analysis platform developped by CERN, I started getting familiar with it for further use and with the package of ALICE software which exists in the AliBuild library.
Moving to SuperChic, and learning to get around it to modify its input and producing output for many processes, and then contributing to the installation guide writing (cf. Appendix) and reaching out to the creator of SuperChic to help an obscure problem that has to do with the LHAPDF library installation on Mac OS.
Then I helped creating and modifying a C++ code which is used to launch SuperChic using ROOT and to write input to it then being able to read raw data and present it in the form of histograms and plots.
One of the biggest problems was the unexpected huge calculation cost, which took me hours to get around using my personal laptop, and then losing that latter one at some point lost me a big part of my work which made me redo it all.

Conclusion

Many tasks were accomplished during this internship. I started by understanding the different concepts of CEPs. Moving to work on ROOT and writing a few modules in it then working on ROOT as a part of the AliBuild platform. Movng on to Superchic and the struggle with its dependencies then to writing input and producing output using it.
Covering more than one field during the internship was the most interesting aspect since I got to know many things I would not have had the chance to know otherwise.

Bibliography

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