CENTRAL EXCLUSIVE PRODUCTION OF ϕ MESONS AT 13 TEV*

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This document presents the LHCb results for the published analyses of Central Exclusive Production of J/ψ and $\psi(2S)$ mesons with 13 TeV pp data, together with a summary of the ongoing $\phi \to \mu\mu$ analysis. The first results in a unique LHCb acceptance at as-of-today highest collision energies make a valuable contribution to probe QCD predictions.

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1. Introduction

Central Exclusive Production (CEP) [1] is a class of diffractive processes where both particles survive the collision. A unique feature of Central Exclusive Production is that such a phenomenon results in a very central system, which, coupled with outgoing protons, leads to an occurrence of large regions devoided of any activity, the so-called rapidity gaps. There are three types of CEP, as shown in Fig. 1 — photon fusion, photoproduction, and double Pomeron exchange. Photoproduction, which is a dominant process at LHC energies, can be described using perturbative Quantum Chromodynamics (QCD). At the Leading-Order (LO), it is supposed to proceed via Pomeron exchange. CEP processes offer a clean experimental environment to probe the low-energy QCD regime. As the theoretical predictions depend on the gluon–parton density function (PDF), experimental results are useful to set some constraints on it. Central Exclusive Production processes can be useful in many other studies, *i.e.* investigating various saturation effects and studying Pomeron and its gluonic nature.

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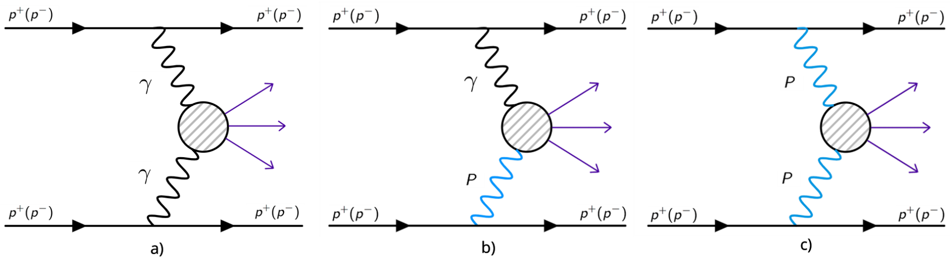

Fig. 1. Central Exclusive Production processes: photon fusion (QED) (a), photoproduction (vector mesons) (b), and double Pomeron exchange (c).

2. CEP in LHCb

Many CEP analyses in different systems and collision energies have already been performed at the LHCb [2]. The forward acceptance of the LHCb detector with full particle identification allows it to study CEP processes in a unique kinematic range, complementary to other LHC experiments. It is fully instrumented within the range of pseudorapidity $2 < \eta < 5$ with additional backward tracking. In Run 2, LHCb was upgraded with High Rapidity Shower Counters for LHCb (HeRSCHeL) [3], which has significantly expanded the overall acceptance. HeRSCheL is able to detect forward particle showers and to veto inelastic interactions in the pseudorapidity ranges $-10 < \eta < -5$ and $5 < \eta < 10$, increasing the effective rapidity gap detection. Proton dissociation, which is the main source of background in CEP measurements, can be approximately halved by leveraging on the showering in the beam pipe and the surrounding elements it produces.

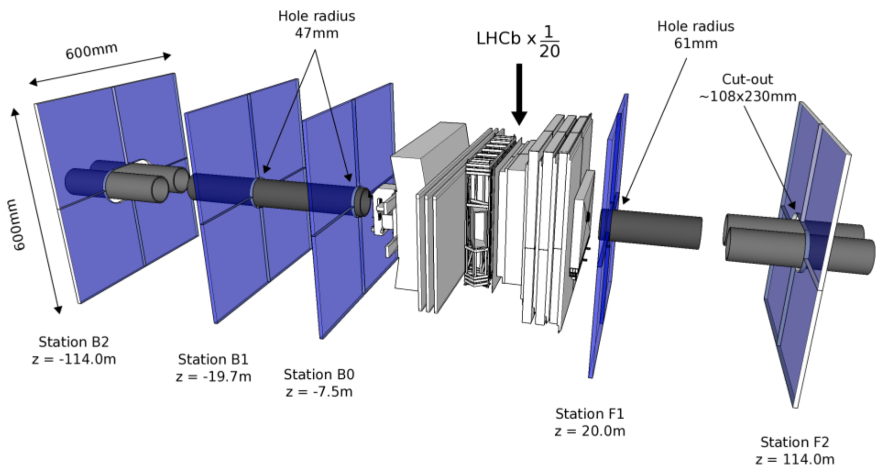

Fig. 2. HeRSCheL scheme.

3. J/ψ and $\psi(2S)$ photoproduction at 13 TeV

The analysis of J/ψ and $\psi(2S)$ photoproduction at 13 TeV was performed using 300 pb^{-1} of data selected as single interaction events [4]. Mesons are reconstructed from their decay to muons. The selection requires the pair of muons to be in the $2 < \eta < 4.5$ region, with an invariant mass within ± 65 MeV of the known J/ψ or $\psi(2S)$ mass. Another important selection requirement is based on the discriminating variable (related to the activity in HeRSCheL), that quantifies the activity above the noise, taking into account correlations between the counters. The requirement on such a variable (see Fig. 3) allowed for effectively halving the dissociation background as compared to the measurements with Run 1 data. The efficiency of HeRSCheL veto is defined as the ratio of dimuons' transverse momentum squared with and without HeRSCheL veto applied.

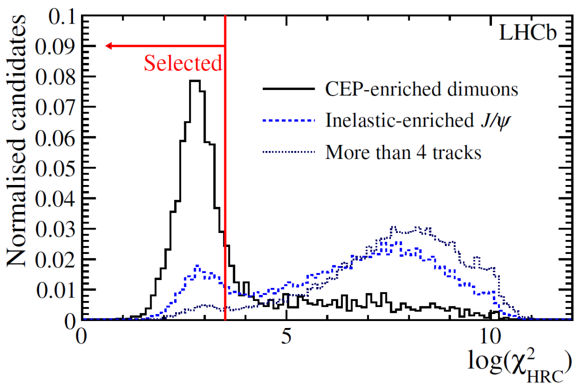

Fig. 3. (Colour on-line) HeRSCheL activity requirement, denoted with the red straight vertical line. The response of three classes of events is shown. Figure taken from [4].

The signal and background contributions were estimated from fitting transverse momentum squared distributions with and without HeRSChel, with two exponential functions. The background considered non-resonant muons, feed-downs (from exclusive production of other mesons), and undetected interacting protons. The main background contribution comes from proton dissociation processes and stands for 20% (J/ψ) and 21% ($\psi(2S)$) of the total background.

The measured cross sections of J/ψ and $\psi(2S)$ photoproduction are:

$$\sigma_{J/\psi\to\mu^+\mu^-}(2<\eta<4.5)=435\pm18\pm11\pm17\ \text{pb}\,,$$
$$\sigma_{\psi(2S)\to\mu^+\mu^-}(2<\eta<4.5)=11.1\pm1.1\pm0.3\pm0.4\ \text{pb}\,.$$

The uncertainties are, respectively, statistical, systematic, and related to luminosity determination. In order to compare data to theoretical predictions, differential cross sections as a function of meson rapidity were constructed and compared with LO and Next-to-Leading-Order (NLO) predictions, as shown in Fig. 4. The results show a better agreement with the next-to-leading order predictions [5, 6]. A model-dependent determination of J/ψ photoproduction cross section was determined from the LHCb differential cross-section measurement, assuming the power-law result from a fit to the HERA data [7]. A deviation from a pure power-law extrapolation of lower energy data is observed (see Fig. 4).

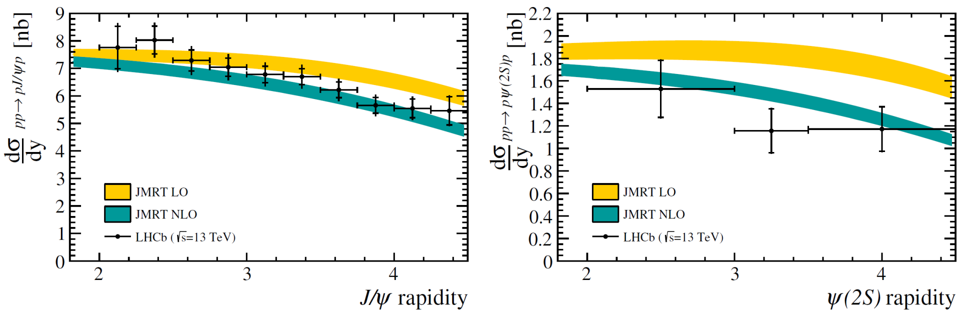

Fig. 4. Differential cross sections for J/ψ and $\psi(2S)$ as a function of meson rapidity, compared to LO and NLO theory prediction.

4. Production of ϕ mesons at 13 TeV

The new study of ϕ mesons CEP in their decay to muons is currently in progress. It will be the first measurement of ϕ photoproduction in the forward region covered by LHCb. The used data consists of pp collisions at 13 TeV that come from Run 2 LHCb from 2016–2018, and so it enables detection in the very forward region. The methodology is similar to that used in the previous LHCb analysis, in particular in the production of J/ψ and $\psi(2S)$ at 13 TeV. Event selection is based on the HeRSCheL discriminating variable, allowing for a reduction of the background from proton dissociation. The analysis is meant to be fully data-driven, and the Monte Carlo sample is going to be used only for the study of some systematic effects.

5. Summary

Central Exclusive Processes are a gateway to the study of many phenomena. They are very exploitable in testing theoretical models and open the possibilities in searches for new physics. Precise measurements of CEP effects can be performed using LHCb data in different systems and collision energies. With HeRSCheL, LHCb yields unique acceptance that covers rapidity gaps. To take advantage of those possibilities, a new study of ϕ photoproduction is being performed. The strategy follows in general that of photoproduction of J/ψ and $\psi(2S)$.

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