Exclusive Dimuon production at LHCb

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We report on preliminary results for the measurement of exclusive dimuon production at LHCb. Cross-section measurements for exclusive J/ψ, $\psi\prime$ and for non-resonant production $p + p \rightarrow p + \mu^+\mu^- + p$ are presented and comparisons made with theory. The additional requirement of a single photon allows the the cross-section for exclusive χ_c production to be measured and also the relative contribution of χ_c^0,χ_c^1,χ_c^2 to be determined.

1 Introduction

LHCb is one of the experiments located on the Large Hadron Collider at CERN [1]. It is a forward arm spectrometer covering a pseudorapidity of $1.9 < \eta < 4.9$, with some backward acceptance to charged particles in the region $-4 < \eta < -1.5$. Collisions with a centre of mass energy of 7 TeV began at the LHC in March 2010 with a total integrated luminosity of 37 ± 3.7 pb^{-1} collected in that year.

Exclusive production in proton-proton collisions are elastic processes in which the protons remain intact, and the additional particles are created through photon and/or pomeron propagators. Dimuons can be produced by diphoton fusion giving rise to a continuous dimuon invariant mass spectrum, while photon-pomeron fusion can produce $J/\psi, \psi\prime$ which decay to two muons. Double pomeron fusion can produce χ_c that decay to J/ψ plus a photon. The final state protons are only marginally deflected, go down the beam-pipe, and remain undetected. The experimental signal therefore in LHCb is a completely empty event except for two muons and possibly a photon. As LHCb is not hermetic, there will be sizeable backgrounds from inelastic processes where the other particles travel outside the detector acceptance. However the transverse momentum (Pt) of the centrally produced object is generally smaller in an elastic collision. Therefore the Pt distribution of exclusive candidates should display a peak at low momentum values corresponding to elastic production and a tail at higher momentum values corresponding to inelastic production.

In the following we outline cross-section measurements of the exclusive processes mentioned above where the final state particles have pseudorapidities between 2 and 4.5. The full data sample collected in 2010 is used in this study. However as we are interested in events with a single primary vertex the data under consideration is limited to beam crossings without multiple interactions. The average number of interactions per beam crossing, μ, was generally high ($\mu = 2$) in 2010 with the result that much of the data is unusable for this study. The exclusive trigger used in 2010 required a dimuon in coincidence with a low charged particle multiplicity (< 20).

2 Exclusive J/ψ and $\psi\prime$ selection

We select J/ψ and $\psi\prime$ candidates as those dimuons with a mass within 65 MeV of the PDG value. Exclusive candidates are selected by requiring no backward tracks, just two forward tracks and no photons in the event. The left hand plot in Figure 1 displays the Pt spectrum for the J/ψ candidates. We have fit the spectrum with two shapes representing the elastic (green) and inelastic (red) contributions. The shape for the elastic signal is taken from the Starlight generator [2] while the shape for the inelastic background is taken from data by requiring greater than two forward tracks. The dimuon Pt is required to be less than 900 MeV/c giving a signal purity of 80 $\pm$ 3 %.

Exclusive $\psi\prime$ decays such as $\psi\prime \rightarrow J/\psi\pi^+\pi^-$ contribute a significant background to the exclusive J/ψ measurement. The amount of feed down from the $\psi\prime$ is estimated from simulation using the number of observed exclusive $\psi\prime \rightarrow \mu^+\mu^-$ candidates in data. Other exclusive resonances which can feed down to give J/ψ in the final state are the χ_c family, via the decay $\chi_c \rightarrow J/\psi\gamma$ where the photon is outside the LHCb acceptance or is undetected. The χ_c feeddown is estimated from simulation using the number of observed exclusive $\chi_c \rightarrow J/\psi\gamma$ candidates. Non-resonant backgrounds are estimated by fitting crystal ball functions to the mass peaks and exponentials to the background.

3 Exclusive diphoton dimuon selection

To select exclusive dimuon events in the continuum, a cut is placed requiring the invariant mass of the dimuons to be further than 100 MeV/c^2 away from the J/ψ and $\psi\prime$. The signal events, produced through di-photon fusion, are peaked to low invariant masses where the background from pion kaon mis-identification is significant. Even though LHCb can trigger down to a mass of 1 GeV/c^2, a higher mass cut of 2.5 GeV/c^2 is used to suppress mis-id to a negligible level. As for the J/ψ and $\psi\prime$, exclusive candidates are selected by requiring no backward tracks, just two forward tracks and no photons in the event. The right hand plot in Figure 1 displays the Pt spectrum for the diphoton dimuon candidates. The spectrum is fit to the elastic signal shape as provided by the LPAIR generator [3] and the inelastic background shape provided from data by requiring greater than two forward tracks. A clear excess of signal events is observed below 100 MeV/c where a cut is placed in order to select events with a purity of $97 \pm 1\%$.

4 Exclusive χ_c selection

Exclusive χ_c candidates are selected by requiring dimuons with masses within 65 MeV of the J/ψ PDG value in events with no backward tracks, just two forward tracks and a single photon. The plot in Figure 2 shows the invariant mass of the photon plus J/ψ system. A fit is performed to the spectrum using the shapes as given by the SuperChiC generator [4] for χ_c^0,χ_c^1,χ_c^2 aswell as the feed-down from the $\psi\prime$. The ratio of χ_c^0:χ_c^1:χ_c^2 is 1: 2.2$\pm$0.8: 3.9$\pm$1.1. The inelastic contribution is determined in the same way as for the J/ψ. The fraction of exclusive events below 900 MeV/c is 0.39 ± 0.13.

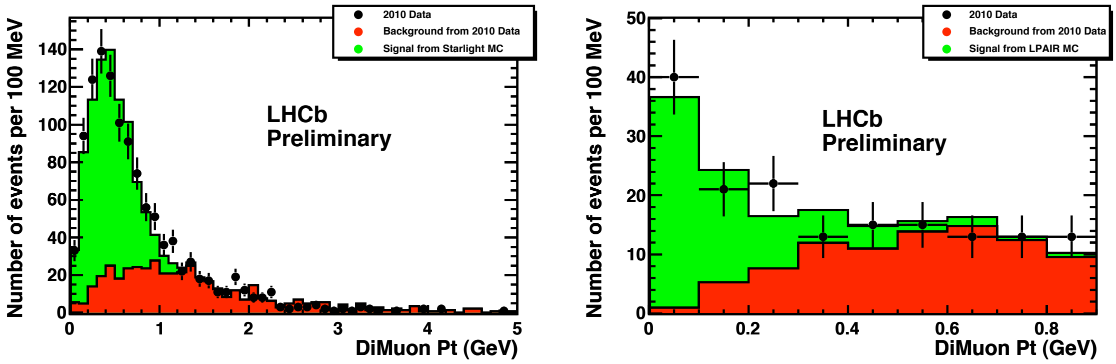

Figure 1: Left: Transverse momentum distribution for exclusive J/ψ candidates. Right: Transverse momentum distribution for exclusive diphoton dimuon candidates.

	J/ψ	$\psi\prime$	χ_c^0	χ_c^1	χ_c^2	diγ diμ
Efficiency	0.71 ± 0.07	0.71 ± 0.07	0.34 ± 0.06	0.43 ± 0.05	0.44 ± 0.04	0.25 ± 0.03
#Events	1468 ± 38	40 ± 6	25 ± 6	56 ± 18	99 ± 29	40 ± 6
Purity	0.71 ± 0.03	0.67 ± 0.03	0.39 ± 0.13	0.39 ± 0.13	0.39 ± 0.13	0.97 ± 0.01
$L_{eff}(\text{pb}^{-1})$	3.1 ± 0.6	3.1 ± 0.6	3.1 ± 0.6	3.1 ± 0.6	3.1 ± 0.6	2.3 ± 0.5
Cross-section	474 ± 12	12.2 ± 1.8	9.3 ± 2.2	16.4 ± 5.3	28.0 ± 5.4	67 ± 10
x BR (pb)	$\pm 51 \pm 92$	$\pm 1.3 \pm 2.4$	$\pm 3.5 \pm 1.8$	$\pm 5.8 \pm 3.2$	$\pm 9.7 \pm 5.4$	$\pm 7 \pm 15$

Table 1: Summary of cross-section calculation. The uncertainty on the cross-section measurement is split into three parts, the first is statistical, the second is systematic and the third relates to the luminosity estimate.

5 Cross-section calculations

The selection, reconstruction and trigger efficiencies have been determined from simulation, with systematic uncertainties applied based on data MC comparison studies [5]. The effective luminosity is determined by the trigger efficiencies and by the μ factor. The evaluation of μ leads to a large systematic uncertainty on the luminosity for this study. The number of events, efficiency, purity, luminosity and cross-section are summarised in Table 1. The uncertainty on the cross-section measurement is split into three parts, the first is statistical, the second is systematic and the third relates to the luminosity estimate.

We have found our measurements to be consistent with the predictions of Starlight, Motyka and Watt [6] , Schafer and Szczurek [7] (J/ψ and $\psi\prime$ predictions), SuperChiC (J/ψ and χ_c predictions) and LPAIR (diphoton dimuon prediction). The LPAIR theoretical prediction for diphoton dimuon production has an uncertainty of less than 1%. However the uncertainties on the other predictions are quite large.

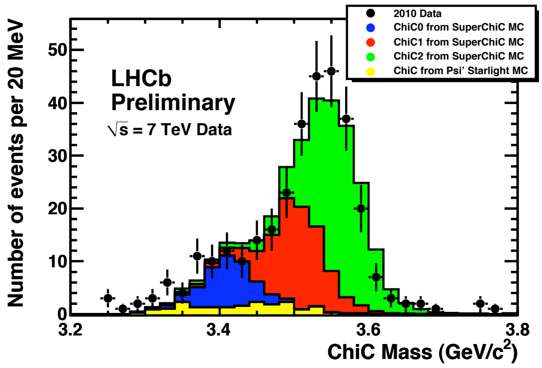

Figure 2: Invariant mass of J/ψ plus photon system. Also shown is a fit to the spectrum using the SuperChic predictions for χ_c^0,χ_c^1,χ_c^2 aswell as the feed-down from the $\psi\prime$.

6 Conclusion

We have observed clear signals for exclusive J/ψ ,$\psi\prime$ and χ_c. Preliminary results show the measured cross-sections to be in agreement with the theoretical predictions which have large uncertainties. The measured cross-section for diphoton produced dimuons is consistent with the theoretical estimate.

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