CENTRAL EXCLUSIVE PRODUCTION AT LHCB

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INTRODUCTION

➤ CEP is the process in which particles are produced by colourless propagators via the reaction

\[ pp \rightarrow p + X + p \]

➤ the protons do not disintegrate

➤ the central system X is well isolated in rapidity

➤ very clean final state
CEP is the process in which particles are produced by colourless propagators via the reaction

\[ pp \rightarrow p + X + p \]

DPE processes limit the states allowed to particles with \( 0^{++}, 2^{++}, \ldots \) and \( I=0 \)

Gluc-rich processes mediated by pomerons with a reduced number of resonances in the final state
INTRODUCTION

➤ CEP is the process in which particles are produced by colourless propagators via the reaction

\[ pp \rightarrow p + X + p \]

➤ Spin-1 final states are allowed in the case of photo-production with the exchange of a pomeron and a \( \gamma \)

➤ its x-section should depend strongly on rapidity
The study of central exclusive production can provide essential information regarding the description of both soft- and hard-QCD effects

- conventional and “exotic” quarkonium production
- production of low mass resonances and glueballs
- gluon and diffractive PDFs
- and more …
Central Exclusive Production at LHCb

- The LHCb experiment is rapidly becoming a major actor in CEP searches
  - large rapidity range (complementary to other experiments)
  - great tracking precision with the VELO
  - great PID performances with the RICH
  - very large amount of \( pp \) collisions already recorded in Run II
The LHCb experiment is rapidly becoming a major actor in CEP searches.

- new high rapidity shower counters in Run II
The HeRSCheL subdetector is now allowing to reduce the non-CEP background to a minimum.

- 5 stations of scintillating planes located along the beampipe.
Detecting a CEP event requires the detection of *rapidity gaps* in the distribution of the final state particles.

HeRSCheL largely extends the ability to veto diffractive final states.
LHCb CENTRAL EXCLUSIVE PRODUCTION PUBLISHED RESULTS

J/ψ and ψ(2S) Production at 7 TeV

- 930 pb\(^{-1}\) of 2011 data at \(\sqrt{s} = 7\) TeV
- exactly two muons in the acceptance
- \(p_T(\mu) > 400\) MeV/c

➤ Selection of Run I results
➤ The J/ψ and ψ(2S) charmonium resonances are produced via proto-production
➤ The \(\chi_c\) via double pomeron exchange

\(\chi_{cJ}\) production at 7 TeV

Double \(\psi\) Production

- 1 fb\(^{-1}\) of 2011 data at \(\sqrt{s} = 7\) TeV
- 2 fb\(^{-1}\) of 2012 data at \(\sqrt{s} = 8\) TeV

\[\sigma_{J/\psi,J/\psi} = 58 \pm 6\) pb\]
\[\sigma_{J/\psi,\psi(2S)} = 63^{+27}_{-18} \pm 10\) pb\]
\[\sigma_{\chi_c\chi_c} < 69\) nb\]
\[\sigma_{\chi_c\chi_c} < 45\) nb\]
\[\sigma_{\chi_c\chi_c} < 141\) nb\]

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Central Exclusive Production at LHCb
First Run II analysis with the HeRSCheL information

Many more under review, to be presented soon
ONGOING STUDIES: FINDING A GLUEBALL CANDIDATE

➤ Central exclusive production can open the way to the discovery of the first glueball

➤ The existence of gluon bound states with no valence quarks is foreseen by the SM

  ➤ the lightest glueball state is predicted at $\sim 1700$ MeV (lattice)


➤ A clear experimental evidence for glueballs is still missing, despite many years of searches

  ➤ limited statistics for the existing datasets
  ➤ complicated description of soft-QCD effects
ONGOING STUDIES: FINDING A GLUEBALL CANDIDATE

➤ The lightest glueball is expected to be a low-mass scalar with quantum numbers $0^{++}$
  ➤ CEP via DPE is particularly fit to this task

➤ Glueball candidates should, naively, have about the same probability to decay to centrally produced dipion ($\pi^+\pi^-$) and dikaon ($K^+K^-$) states
  ➤ no valence quarks
  ➤ can the $f_0(1500)$ or the $f_0(1710)$ resonances be glueballs ?
  ➤ can we confirm the existence of the $f_0(1370)$ ?

➤ Let’s start from the study of the dipion spectrum
The CEP selection is very simple

- two long tracks in the final state that fire the LowMultiplicity trigger lines (with HeRSCheL)
- no additional activity in the VELO
- track PID and track quality
- beamspot consistency

event display
CENTRALLY PRODUCED DIPION IN 2016 DATA

Mass of the dipion system in the full rapidity range

very large contribution from photo-production

LHCb unofficial

$\sim 0.7 \text{ fb}^{-1} 2016$ data

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NON-CEP BACKGROUND FROM WRONG SIGN DATA

➤ The distributions for some relevant variables in data and WS data have been compared to understand the shape of the background.

➤ The wrong sign distributions are used to represent the non-CEP background in data.

➤ The idea is to remove the non-CEP background from the data by subtracting the WS histogram from the data one.

➤ This assumption is currently being tested on simulation.
Mass of the dipion system

- the wrong sign background is shown: \( \sim 8\% \) contamination
$pp \rightarrow p + X(\rightarrow \pi^+\pi^-) + p$

**CEP DIPION IN 2016 DATA – BKG SUBTRACTION**

Mass of the dipion system after non-CEP background subtraction

$\rho_0(770)$  $f_0(980)$  $f_2(1270)$  $f_0(1500)$  $f_0(1710)$

LHCb unofficial

$\sim 0.7 \text{ fb}^{-1}$ 2016 data

$\pi\pi$ mass spectrum bkg-subtracted

Candidates/6.6 MeV

$M_{\pi\pi}$ [MeV]

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CEP DIPION IN 2016 DATA

➤ Bkg-subtracted mass of the dipion system in bins of rapidity

➤ Rapidity-dependence of $\rho_0(770)$ photo-production is observed
CEP DIPION IN 2016 DATA AT LOW Y

\[ pp \rightarrow p + X(\rightarrow \pi^+\pi^-) + p \]

\( \pi\pi \) mass spectrum at low rapidity

- similar to what already seen by other experiment
- low photo-production background

\( \rho_0(770) \)

\( f_0(980) \)

\( f_0(1370) \) ?

\( f_0(1710) \)

\( f_2(1270) \)

LHCb unofficial

\(~ 0.7 \text{ fb}^{-1} \) 2016 data

\([M. \text{Albrow et al., CDF Public Note 11034}]\)

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The next step will be to evaluate the efficiencies needed in the calculation of the dipion cross section.

\[
\frac{d\sigma}{dm} = \frac{N \times \epsilon_{\text{acceptance}} \times \epsilon_{\text{tracking}} \times \epsilon_{\text{PID}} \times \epsilon_{L0} \times \epsilon_{\text{HLT}}}{\mathcal{L}}
\]

We are also interested in determining this cross-section as a function of rapidity and $p_T$. HeRSChel is in the HLT trigger.
WHAT ABOUT THE DIKAON?

The LHCb CEP dikaon sample is also very large

$pp \rightarrow p + X(\rightarrow K^+K^-) + p$

$LHCb$

unofficial

$\sim 0.7 \text{ fb}^{-1}$ 2016 data

- $\Phi(1020)$
- $f_0(1500)$
- $f_0(1710)$
- $f_2(1270)$
- $f_0(2220)$

$\times 10^3$ Candidates/6.6 MeV

$250$

$200$

$150$

$100$

$50$

The LHCb CEP dikaon sample is also very large

- The shape does not change with rapidity
PARTIAL WAVE ANALYSIS

➤ The following step will be to perform a Partial Wave Analysis
➤ needed to separate the resonances in the di-hadron spectra according to their wave through a Fourier decomposition of the final state

\[ \pi\pi \text{ mass spectrum at low rapidity} \]

\[ \text{KK mass spectrum bkg-subtracted} \]

LHCb unofficial

\( \sim 0.7 \, \text{fb}^{-1} \, 2016 \, \text{data} \)
The following step will be to perform a Partial Wave Analysis needed to separate the resonances in the di-hadron spectra according to their wave through a Fourier decomposition of the final state.

The idea is to fit a simplified model with S, P, D waves and $m=\pm 1$ separately in all $\pi\pi$ (and $KK$) mass bins, then fit them independently.

The nature of the scalar resonances will be investigated comparing their x-sections in $\pi\pi$ and $KK$. 
CONCLUSIONS

➤ LHCb has a very interesting CEP program that is now becoming more and more interesting

➤ The first results with the HeRSCheL information are now being finalised and will be presented later this year

➤ The Oxford group is very active on both the detector and data analysis sides

➤ the searches for glueballs are now ongoing and can count on the largest CEP data sample ever recorded

➤ stay tuned!