Central Exclusive Production measurements in LHCb

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Central Exclusive Production

Photon Fusion (QED)

Double Pomeron Exchange

Photoproduction (vector mesons)
Signal signature:

- Central system
- Large rapidity gaps between central system and outgoing protons

CEP background:

- Diffractive processes involving proton dissociation

Possibilities:

- Study of soft QCD – transition between soft and hard pomeron
- Search for glueballs
- Analyses benefiting highly from the very clean final state signature
Detector:

- Single arm forward spectrometer
- Fully instrumented in the range of $2 < \eta < 5$ with additional backward tracking
- Ability to trigger on particles with low $P_t$ ($P_t > 400$ MeV)
- Low number of interactions per bunch crossing – about 20% of total luminosity constitute single interaction events

CEP events selection strategy:

- Low charged particles multiplicity and the presence of large rapidity gaps in the covered $\eta$ range
- Muons with $P_t > 400$ MeV
- Energy deposit in hadronic or EM calorimeter above 1 GeV coupled with less than 10 counts total in the scintilating pads
Run 2 upgrades:

- Proton dissociation leads to showering in the beam-pipe and surrounding elements – very forward activity
- A set of High Rapidity Shower Counters (HeRSChel) installed along the beam, both sides of the IP
- Inelastic interactions veto improved
- Effective range of rapidity gap detection expanded by $(-10 < \eta < -5) \land (5 < \eta < 10)$
## LHCb measurements

### Run 1

<table>
<thead>
<tr>
<th>Process</th>
<th>Energy</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>$J/\psi$, $\psi(2S)$ photoproduction</td>
<td>7 TeV</td>
<td>JPG 41 (2014) 055002</td>
</tr>
<tr>
<td>Upsilon photoproduction</td>
<td>7 and 8 TeV</td>
<td>JHEP 1509 (2015) 084</td>
</tr>
<tr>
<td>Double charmonium</td>
<td>7 and 8 TeV</td>
<td>JPG 40 (2013) 045001</td>
</tr>
<tr>
<td>$\chi_c$</td>
<td>7 TeV</td>
<td>LHCb-CONF-2011-022</td>
</tr>
<tr>
<td>Dimuon (QED)</td>
<td>7 TeV</td>
<td>LHCb-CONF-2011-022</td>
</tr>
</tbody>
</table>

### Run 2

- $J/\psi$, $\psi(2S)$ photoproduction 13 TeV LHCb-CONF-2016-007
  - update available soon
Ongoing analyses

pp data:

• 3.71 fb$^{-1}$
• Exclusive double open-charm meson production
• Exclusive $X(3872) \rightarrow J/\psi \pi^+\pi^-$ and $D\bar{D} \rightarrow [K\pi][K\pi]$ production
• Exclusive $\chi_c$ meson production

Ion data:

• 32.31 nb$^{-1}$
• Exclusive $J/\psi$ production in pA and Ap collisions
• Exclusive $\rho$ in pA collisions
Run 2 \( J/\psi \) and \( \psi(2S) \) measurement

- LHCb-CONF-2016-007

Dataset:
- 300 pb\(^{-1}\) of 13 TeV data with 1.1 average visible interactions (about (20-35)% of data are single interaction events)

Selection requirements:
- Two muons within \( 2 < \eta < 4.5 \) with no other activity
- Dimuon with \( p_t^2 < 0.8 \text{ GeV}^2 \) and mass within 65 MeV of the meson mass
- HeRSChel activity below threshold (improved in update)
HeRSCheL activity requirement

\[ \Sigma_H = \sum_{i=1}^{20} \left( \frac{\text{ADC}_i}{2.5 \text{ RMS}_i} \right)^2 \]

- less overall activity \( \iff \) lower value
Background:

- QED, feed-down and proton dissociation
- Fit to meson $p_t^2$
- Dissociation background halved by HeRSCheL requirement!

**J/ψ composition:**
- QED (0.9%)
- Feed-down of $ψ(2S)$, $χ_c$ (5.9%)
- Dissociation (20%)

**ψ(2S) composition:**
- QED (17.5%)
- Feed-down negligible
- Dissociation (21%)
Results

- \( \sigma_{J/\psi \rightarrow \mu^+\mu^-} \left( 2.0 < \eta_{\mu^+}, \eta_{\mu^-} < 4.5 \right) = 407 \pm 8 \pm 24 \pm 16 \text{ pb} \)
- \( \sigma_{\psi(2S) \rightarrow \mu^+\mu^-} \left( 2.0 < \eta_{\mu^+}, \eta_{\mu^-} < 4.5 \right) = 9.4 \pm 0.9 \pm 0.6 \pm 0.4 \text{ pb} \)
- Uncertainties: statistical, systematic, luminosity determination
LbGenEx – GenEx event generator in LHCb.

- Work in progress – expected to be available soon
- Kinematics from GenEx Light:
- Focused strictly on CEP
- Class-based approach (C++)
- Easy implementation of new theoretical models

Standalone version is being developed alongside, including among others:

- Multithreading support
- Multiple output formats
- Model classes compatible between versions
LbGenEx - implemented processes

• Resonant $J/\Psi$ and $\phi$ production with decay

• $f_0 (980) \rightarrow \pi\pi$ and non-resonant $\pi\pi$ production with tensor amplitudes
  • Model – Phys. Rev. D 93 (2016) 054015
  • Implementation – Krzysztof Cieśla at Challenges in photon induced interactions conference (https://indico.cern.ch/event/642764)