

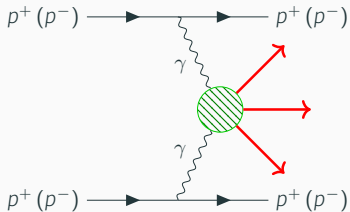
Central Exclusive Production measurements in LHCb

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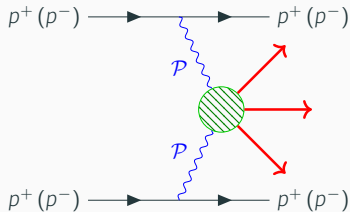
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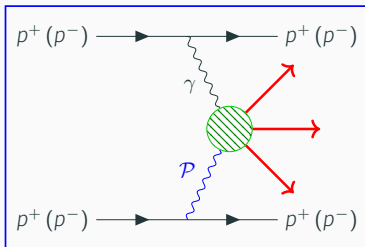
Central Exclusive Production



Photon Fusion (QED)



Double Pomeron Exchange



Photoproduction (vector mesons)

Signal signature:

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

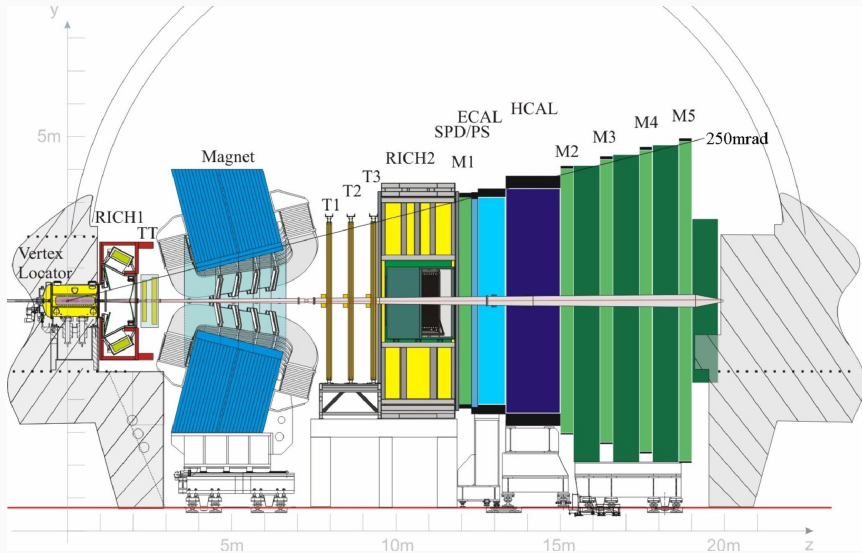
CEP background:

- 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

CEP at LHCb



Detector:

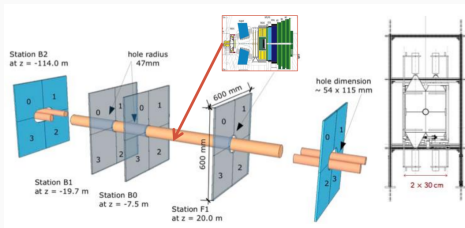
- Single arm forward spectrometer
- Fully instrumented in the range of $2 < \eta < 5$ with additional backward tracking
- Ability to trigger on particles with low P_t ($P_t > 400$ MeV)
- Low number of interactions per bunch crossing – about 20% of total luminosity constitute single interaction events

CEP events selection strategy:

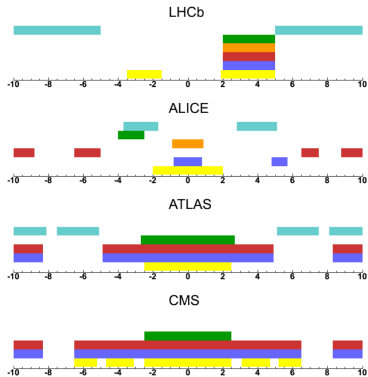
- Low charged particles multiplicity and the presence of large rapidity gaps in the covered η range
- Muons with $P_t > 400$ MeV
- Energy deposit in hadronic or EM calorimeter above 1 GeV coupled with less than 10 counts total in the scintilating pads

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 $(-10 < \eta < -5) \wedge (5 < \eta < 10)$



Tracking
 ECAL
 HCAL
 Hadron PID
 Muon
 Counters



LHCb measurements

Run 1

$J/\psi, \psi(2S)$ photoproduction	7 TeV	JPG 41 (2014) 055002
Upsilon photoproduction	7 and 8 TeV	JHEP 1509 (2015) 084
Double charmonium	7 and 8 TeV	JPG 40 (2013) 045001
χ_c	7 TeV	LHCb-CONF-2011-022
Dimuon (QED)	7 TeV	LHCb-CONF-2011-022

Run 2

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

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 χ_c meson production

ion data:

- 32.31 nb^{-1}
- Exclusive J/ψ production in pA and Ap collisions
- Exclusive ρ in pA collisions

Run 2 J/ψ and $\psi(2S)$ measurement

- LHCb-CONF-2016-007

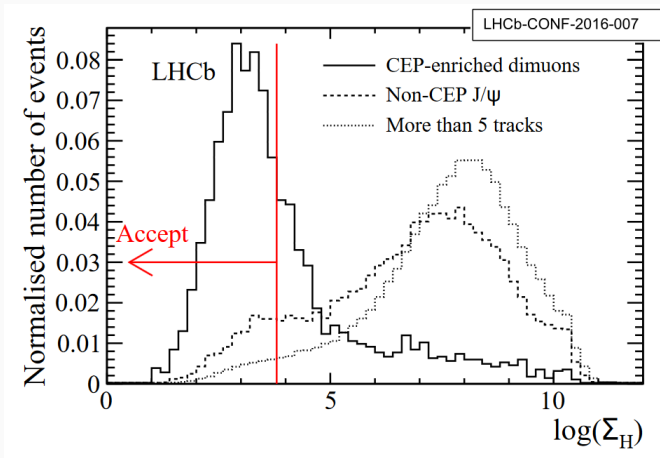
Dataset:

- 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

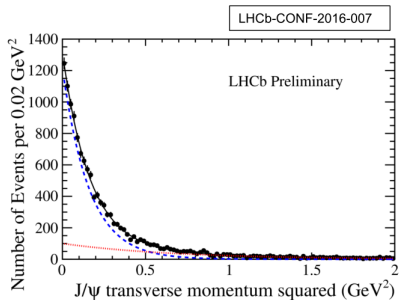


$$\cdot \Sigma_H = \sum_{i=1}^{20} \left(\frac{\text{ADC}_i}{2.5 \text{RMS}_i} \right)^2$$

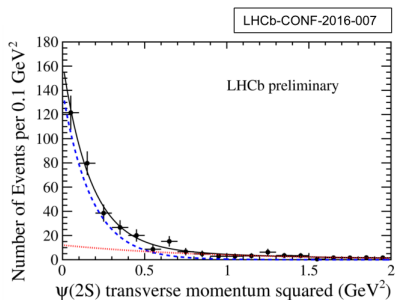
• less overall activity \Rightarrow lower value

Background:

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

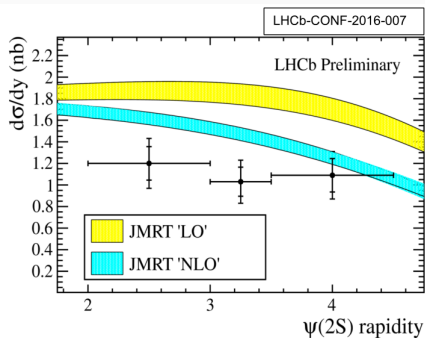
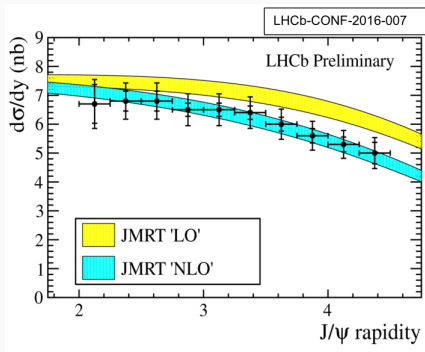


J/ψ composition:
QED (0.9%)
Feed-down of $\psi(2S)$, χ_c (5.9%)
Dissociation (20%)



$\psi(2S)$ composition:
QED (17.5%)
Feed-down negligible
Dissociation (21%)

Results



- $\sigma_{J/\psi \rightarrow \mu^+ \mu^-} (2.0 < \eta_{\mu^+}, \eta_{\mu^-} < 4.5) = 407 \pm 8 \pm 24 \pm 16$ pb
- $\sigma_{\psi(2S) \rightarrow \mu^+ \mu^-} (2.0 < \eta_{\mu^+}, \eta_{\mu^-} < 4.5) = 9.4 \pm 0.9 \pm 0.6 \pm 0.4$ pb
- Uncertainties: statistical, systematic, luminosity determination

LbGenEx – GenEx event generator in LHCb.

- Work in progress – expected to be available soon
- Kinematics from GenEx Light:
R. A. Kycią, J. Turnau, J. J. Chwastowski, R. Staszewski, and M. Trzebiński, “The adaptive Monte Carlo toolbox for phase space integration and generation” 2017 (arXiv:1711.06087)
- 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/Ψ and ϕ production with decay
 - A. Cisek, W. Schäfer, and A. Szczurek, “Exclusive photoproduction of ϕ meson in $\gamma p \rightarrow \phi p$ and $pp \rightarrow p\phi p$ reactions,” Phys. Lett., vol. B690, pp. 168–174, 2010.
 - A. Cisek, W. Schäfer, and A. Szczurek, “Exclusive photoproduction of charmonia in $\gamma p \rightarrow Vp$ and $pp \rightarrow pVp$ reactions within k t -factorization approach,” JHEP, vol. 04, p. 159, 2015.
- $f_0(980) \rightarrow \pi\pi$ and non-resonant $\pi\pi$ production with tensor amplitudes
 - Model – Phys. Rev. D 93 (2016) 054015
 - Implementation – Krzysztof Cieřla at *Challenges in photon induced interactions* conference (<https://indico.cern.ch/event/642764>)