Central Exclusive Production of Φ mesons at 13 TeV

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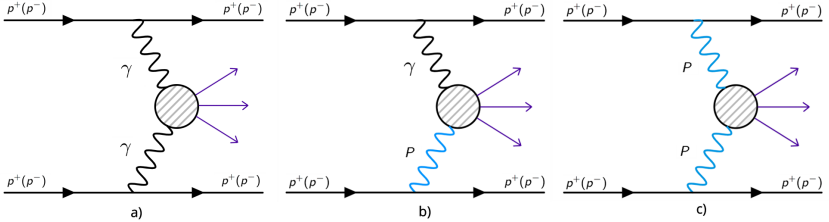
Outlook:

CEP processes

Central Exclusive Production (CEP) is a class of diffractive processes where both particles remain intact after the collision.



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

- Very central system with occurrence of rapidity gaps.
- Clean experimental environment.
- Can be calculated in perturbative quantum chromodynamics (pQCD).
- Predictions depends on the gluon-parton density function.

CEP and searching for new physics

CEP analysis may provide important insight in the following studies:

- test QCD theoretical models,
- investigating the saturation effects,
- constraining the gluon - parton density function,
- investigate the nature of pomeron,
- some measurements are sensitive to the presence of oderon.

LHCb results

Run 1: pp collisions at 7,8 TeV (2011-2012)

- Measurement of the exclusive production cross-section at 7 TeV and 8 TeV
[JHEP 1509 (2015) 084]
- Observation of charmonium pairs produced exclusively in pp collisions
[J. Phys. G41 (2014) no.11, 115002]
- Updated measurements of exclusive J/ψ and ψ(2S) production cross-sections in pp at 7 TeV
[J. Phys. G41 (2014) 055002]
- Exclusive dimuon measurements: non-resonant and χc
[LHCb-CONF-2011-022]

Run 2: pp collisions at 13 TeV, PbPb collisions at 5 TeV (2015)

- Study of coherent J/ψ production in lead-lead collisions at 5 TeV
[arXiv:2107.03223]
- Central exclusive production of J/ψ and ψ(2S) mesons in pp collisions at 13 TeV
[JHEP 1810 (2018) 167]
- Coherent charmonium production in ultra-peripheral lead-lead collisions
[arXiv:2206.08221]

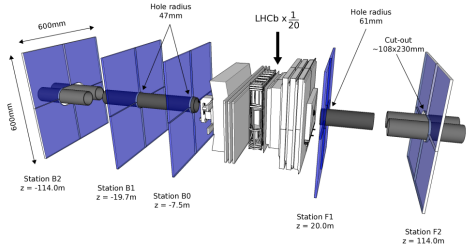
Why LHCb?

[JINST 13 (2018) 04, P04017]

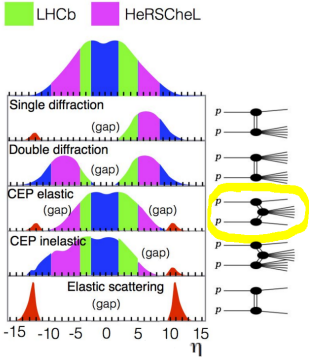
- Fully instrumented in the range of $2 < \eta < 5$ with additional backward tracking.
- Momentum resolution between 0.4% at 5 GeV to 0.6% at 100 GeV.

Run 2 upgrades:

- **HeRSCheL** – high rapidity shower counters – backgrounds from diffractive processes significantly reduced.



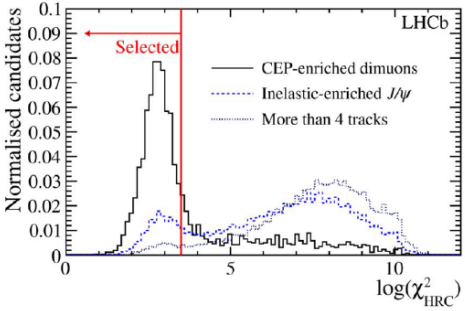
- Effective range of rapidity gap detection expanded by $-10 < \eta < -5$ and $5 < \eta < 10$.
- Able to detect forward particle showers and veto events.



Production of J/ψ and $\psi(2S)$ at 13 TeV

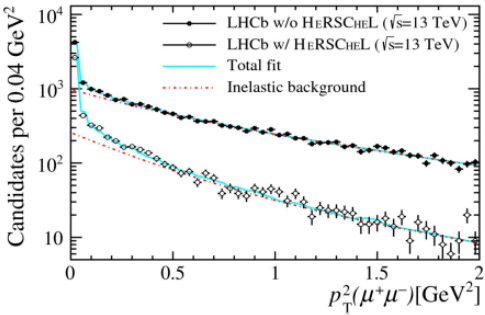
[JHEP 1810 (2018) 167]

- Presence of large rapidity gaps.
- 2 muons within $2 < \eta < 4.5$.
- Muons with P_T>400 MeV.
- No additional tracks or energy.



HeRSCheL activity requirement

- J/ψ $P_T^2 < 0.8$ GeV^2
- Energy deposit in calorimeters above 1 GeV and less than 10 counts total in scintilating pads.



ratio of fits, efficiency of the veto $= 0.723 \pm 0.08$

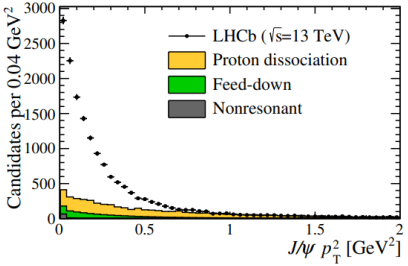
Production of J/ψ and $\psi(2S)$ at 13 TeV

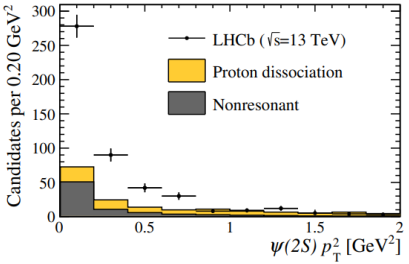
[JHEP 1810 (2018) 167]

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

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

Candidates when data is below the HeRSCheL threshold:





The implementation of HeRSCheL decreases the amount of background (mostly proton dissociation) in the sample which leads to a lower systematic uncertainty from 8% to 0.7%.

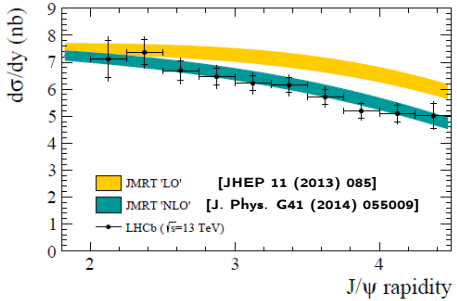
Production of J/ψ and $\psi(2S)$ at 13 TeV

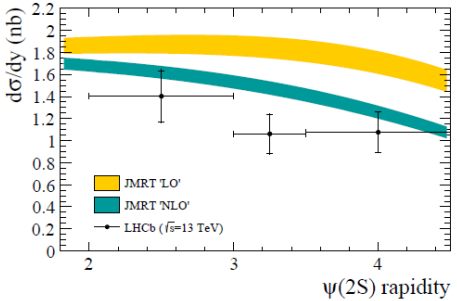
[JHEP 1810 (2018) 167]

Integrated cross-sections:

$$\sigma_{J/\psi\to\mu^+\mu^-}(2<\eta<4.5) = 435 \pm 18 \pm 11 \pm 17\,\text{pb}$$
$$\sigma_{\psi(2S)\to\mu^+\mu^-}(2<\eta<4.5) = 11.1 \pm 1.1 \pm 0.3 \pm 0.4\,\text{pb}.$$

Cross-sections as function of meson rapidity, compared to LO and NLO theory prediction:





Production of Φ mesons at $\sqrt{13}$ TeV

Central Exclusive Production of Φ mesons in $\Phi \to \mu\mu$ decay at 13 TeV analysis is currently in progress.

- Data sample of pp collisions at 13 TeV.
- Φ meson reconstructed from decay to muons (simmilar as J/ψ and $\psi(2S)$).
- Data-driven analysis.
- $\Phi \to \mu\mu$ process already implemented in SuperChic v4.
  [Eur. Phys. J. C 80 (2020) 925]
- This will be first measurement in the forward region.

Production of Φ mesons at 13 TeV

Analysis follows the one for J/ψ and $\psi(2S)$ photoproduction at 13 TeV analysis, in particular:

- Analysis strategy:
  - presence of large rapidity gaps,
  - 2 muons within $2 < \eta < 4.5$,
  - muons with $P_T > 400$ MeV,
  - no additional tracks or energy.

Summary

Central Exclucive Production processes are very conducive to testing theoretical models and searching for new physics.

Studying LHCb data from Run 2 may provide precise measurement of CEP effects.

- Many studies performed for different systems and collision energies.
- LHCb equipped with HeRSCheL yields unique accpetance that covers rapidity gap regions.
- Moreover, background from proton dissociation significantly reduced.

New study of Φ photoproduction already started. In general, analysis strategy will follow the one for J/ψ and $\psi(2S)$ photoproduction in 13 TeV.