Ultraperipheral collisions & Central Exclusive Production

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Implications of LHCb measurements and future prospects
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Outline

• Quite a broad topic... main goal is to stimulate discussion
• Bright future ahead → what can we do with LHCb (now and future)?
• A shopping list of ideas, apologies if too many
• Comments and Idea very welcome!

Comments

This talk is heavily based on the work done by many people
Really special thanks to whoever contributed to the slides shown here
In particular: Albert Bursche and Michael Winn
I hope I will do justice to them!

Shopping List

• Introduction
• CEP at LHCb in pp
• CEP at LHCb in Ions
• Prospects for the future
• Ideas?
Introduction (1)

- A complete introduction on CEP is beyond the scope of this talk
- A quick recap: what do we look for?

\[ pp \rightarrow p + X + p \text{ (rapidity gaps and protons intact)} \]

- Colourless objects in QCD, Very low PT objects, Clean experimental environment
- Rich Physics: Photon-Pomeron, Double-Pomeron, Photoproduction, Glueballs, Exotica

Related phenomena where the colourless object creates a particle

(Note: \( J/\psi \rightarrow \mu\mu \) and \( \chi_c \rightarrow J/\psi\gamma \))
A complete introduction on CEP is beyond the scope of this talk

A quick recap: what do we look for?

\[ pp \rightarrow p + X + p \text{ (rapidity gaps and protons intact)} \]

Different processes compared with the acceptance of the LHCb detector
Experimental challenges

• How do we select / trigger these events?
• Protons $\rightarrow$ escape in the beampipe (need to extend coverage)
• Events with low activity in detector
• Look at backwards tracks in the VELO (some $\eta$ coverage)
• Size of detectable gaps is critical

 Typical Event

 CEP-like event: 2muons
Herschel Detector (1)

The HeRSCheL detector: high-rapidity shower counters for LHCb
JINST 13 (2018) P04017

- Forward detector installed for Run2: increase $\eta$ coverage
- Idea: scintillators in the tunnel where beampipe is accessible
- High Rapidity Shower Counters for LHCb: HERSCHEL
- Five planes of scintillators: 4 quadrants, 20mm thick
- Built in 2014 and installed at the beginning of 2015.
- Use same electronics of Preshower Detector
- Can be used to veto forward and backward activity
**Herschel Detector (2)**

- New detector installed for Run2 → Increase $\eta$ coverage in the forward region

To get an idea on distances

To get an idea on the coverage
Selected Physics results

- LHCb has published several analyses on CEP
- Both on Run1 and Run2 with different final states
- Mainly final states with muons → now moving to hadrons
- Limited by understanding exclusivity

- CEP: $J/\psi$ and $\psi(2S)$ mesons in Run1
  JPG 41 (2014) 055002

- CEP: $\Upsilon$ mesons in Run1
  JHEP 1509 (2015) 084

- Double charmonia in Run1
  JHEP 1509 (2015) 084

- Most recently: $J/\psi$ and $\psi(2S)$ mesons in Run2
  arXiv:1806.04079
J/ψ CEP in pp collisions at 13TeV

- Far from complete and beyond the scope of this talk, but a brief recap is necessary

\[
\frac{d\sigma_{\psi\rightarrow\mu^+\mu^-}}{dy}(2.0 < \eta_\mu < 4.5) = \frac{\mathcal{P}N}{\epsilon_{rec}\epsilon_{sol}\Delta\eta\epsilon_{single}\mathcal{L}_{tot}}
\]

\[
\sigma_{J/\psi\rightarrow\mu^+\mu^-}(2 < \eta < 4.5) = 399 \pm 16 \pm 10 \pm 16 \text{ pb},
\]

\[
\sigma_{\psi(2S)\rightarrow\mu^+\mu^-}(2 < \eta < 4.5) = 10.2 \pm 1.0 \pm 0.3 \pm 0.4 \text{ pb}
\]
J/ψ in PbPb collisions

• Appeared this year → first preliminary result by LHCb on PbPb collisions
• Goal is to study coherent J/ψ production in PbPb collisions at √s(NN) = 5 TeV
• Integrated luminosity ~ 10 μb⁻¹
• Muons in acceptance. Pt(J/ψ) < 1 GeV. Rapidity 2.0 < y < 4.5

• The collisions are either
  • coherent, where the photon couples coherently to all nucleons
  • or incoherent, where the photon couples to a single nucleon

![Coherent](image1.png)

![Incoherent](image2.png)
**J/ψ in PbPb collisions**

- For each of the processes a STARlight template is used for the $P_T^2$ shape
- Double sided Crystal Ball for the resonances
- Efficiencies are determined from simulated events generated with SuperCHIC
- + data calibration and several cross-checks

The signal yield is determined:

- a fit to the dimuon invariant mass
- a fit to the $J/ψ P_T^2$

\[
\frac{dσ(PbPb \to Pb + J/ψ + Pb)}{dy} = \frac{n_{coh}}{ε_y \cdot Δy \cdot L \cdot B}
\]

\[
σ = 5.3 \pm 0.2 \text{ (stat)} \pm 0.5 \text{ (syst)} \pm 0.7 \text{ (lumi)} \text{ mb}
\]
Figure 3: Differential cross-section for coherent $J/\psi$ production compared to different phenomenological predictions. The LHCb measurements are shown as points, where inner and outer error bars represent the statistical and the total uncertainties respectively.
pA collisions: dipion spectrum

- Central exclusive production in pA/Ap data is dominantly photoproduction
- Select events
  with precisely two tracks
  consistent with beam spot
- Herschel plays a big role here reducing diffraction

Cross-section measurement
Measure ρ parameters: this is unexpectedly clean
XeXe Collisions @ 5.44 TeV

- We started analysing the XeXe Run collected in 2017
- Collisions at 5.44 TeV and Luminosity 0.2-0.4 μb⁻¹
- We had a preliminary look at K+K- pairs: nice features appearing
- Preliminary plots, no background subtraction, etc.
- Very small $Q^2$ in the decay and is produced pretty much at rest
- We need to measure different states in each system to constrain the uncertainties from theory
Luminosities - Upgrade

• Non-official overview of what we can expect in the future
• Ion physics will happen at LHCb in the upgrade phase (Run 3,4)

Datasets

• PbPb the idea is to aim for an order of magnitude more in luminosity this November
• About 1.3 nb\(^{-1}\) integrated over all runs, this is 10% of ATLAS/CMS/ALICE
  this can be done in principle without big issues for the machine (but not confirmed)

• pPb: realistically 500 nb\(^{-1}\) in pPb/Pbp at 8.8 TeV (we got about 35 nb\(^{-1}\) at 8.16 TeV),
  close to the 2pb\(^{-1}\) for ATLAS/CMS
Ideas: Shopping list

• LHCb has some unique features: **acceptance, low Pt objects, excellent PID**
• An example of things on the shopping list:

  • Low-mass capability: $\phi$ and $\rho$ with very high statistics
    e.g. STAR paper: [https://journals.aps.org/prc/abstract/10.1103/PhysRevC.96.054904](https://journals.aps.org/prc/abstract/10.1103/PhysRevC.96.054904)

  • Capability of vector and non-vector meson states
    (also different initial state than gamma-pomeron, like gamma-gamma)
    Or more prongs or proton-proton

  • Resolution: e.g. allowing measuring gamma from Pb and pomeron from p even in pPb extend into phase space not covered in PbPb (which is at lower beam energy)

• Gamma-Gamma
  • Probably not competitive (g-2 photonic loops that are constrained)
  • BUT, we can go at very low invariant mass
  • ALSO, we can select objects with very low Pt
  • Maybe this are interesting features...
Conclusions

• Interesting datasets collected so far
• Prospects for many future analyses
• We always look forward to hearing from the theory community
• Comments and ideas are welcome!
• Help to prioritise the experimental effort!

So stay tuned...
exciting times ahead!

Thank for your attention!