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Ultraperipheral collisions & Central Exclusive Production

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on behalf of the LHCb Collaboration

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Implications of LHCb measurements and future prospects
CERN, 17th October 2018

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

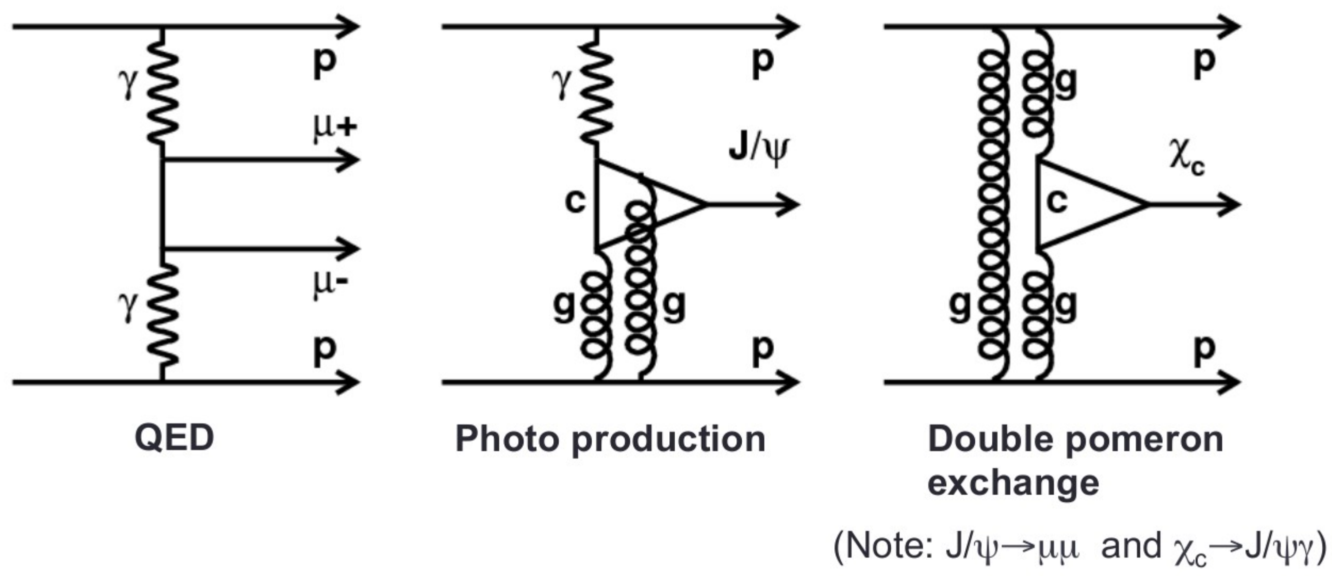
- Introduction
- CEP at LHCb in pp
- CEP at LHCb in Ions
- Prospects for the future
- Ideas?

Introduction (1)

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

$$pp \to p + X + p \text{ (rapidity gaps and protons intact)}$$

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



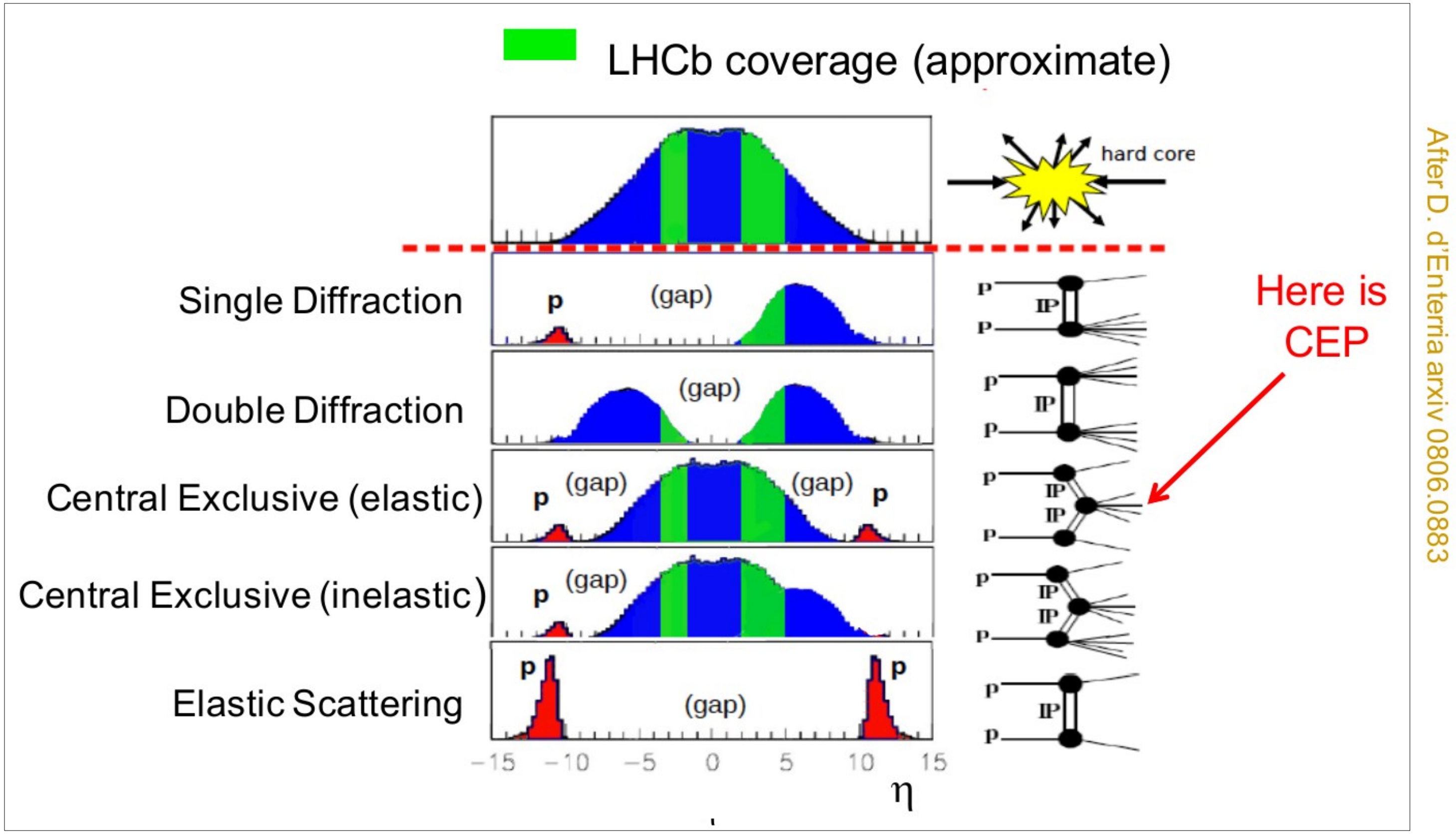
Related phenomena where the colourless object creates a particle

Introduction (2)

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

$$pp \rightarrow p + X + p \; \textit{(rapidity gaps and protons intact)}$$

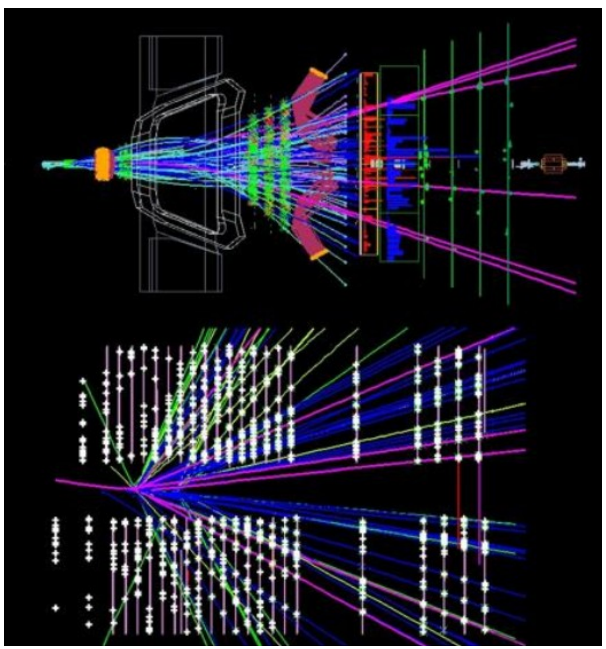
- Different processes compared with the acceptance of the LHCb detector



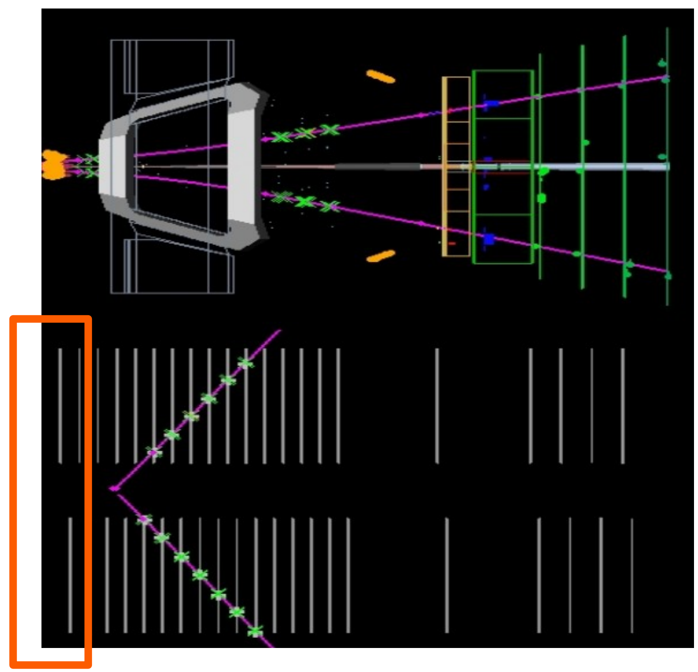
Experimental challenges

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

Typical Event



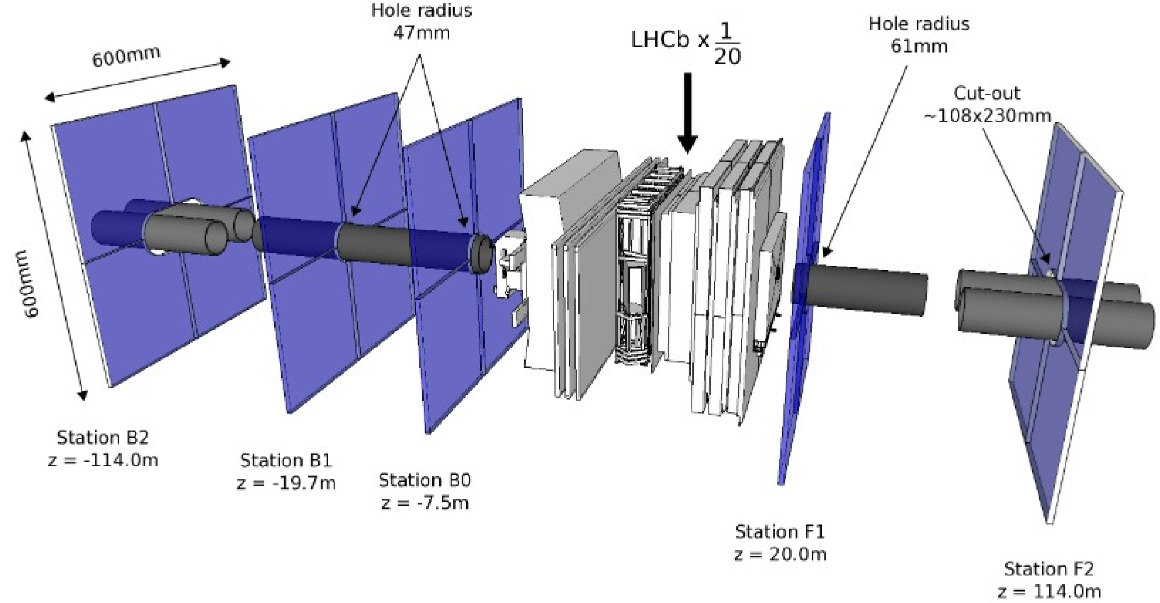
CEP-like event: 2muons



Herschel Detector (1)

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

- Forward detector installed for Run2: increase η 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

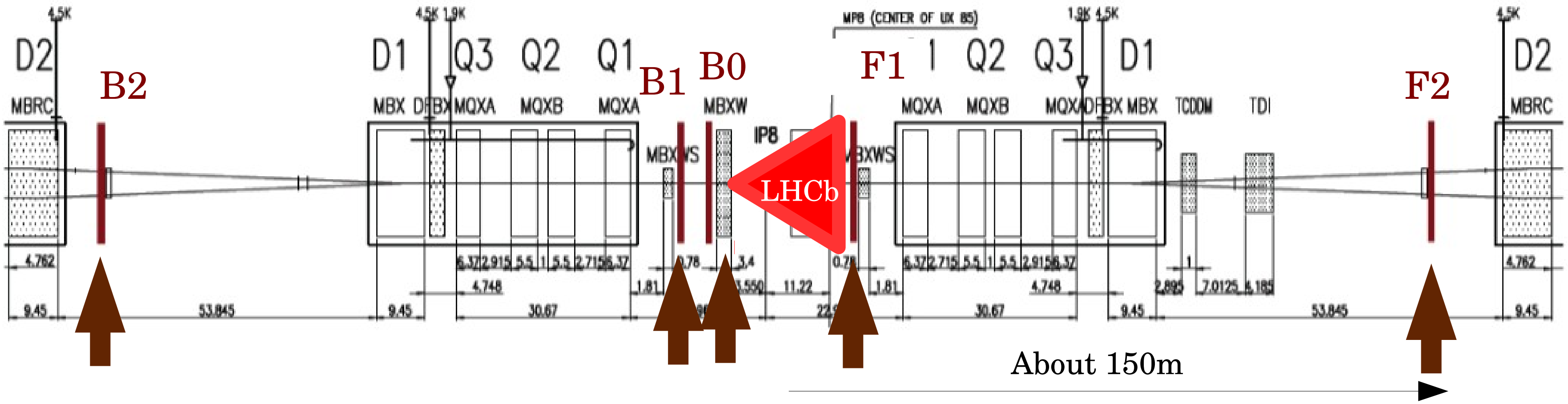


JINST 13 (2018) P04017

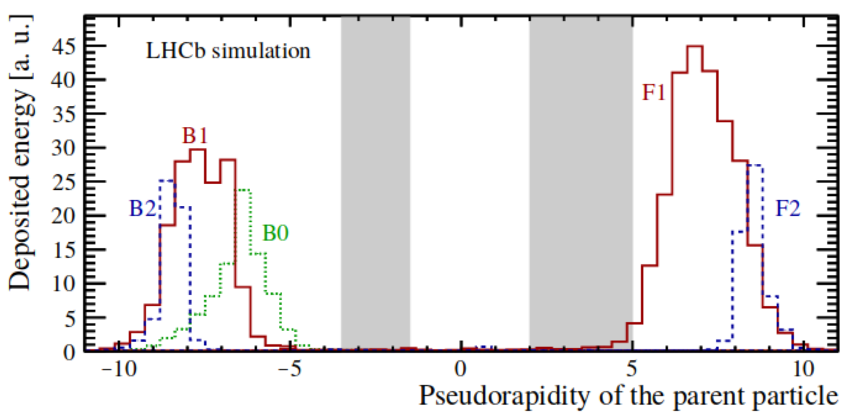
Herschel Detector (2)

- New detector installed for Run2 → Increase η coverage in the forward region

To get an idea on distances

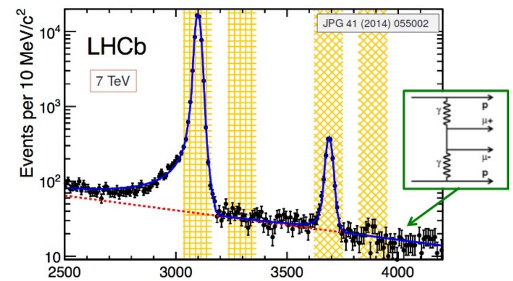


To get an idea on the coverage

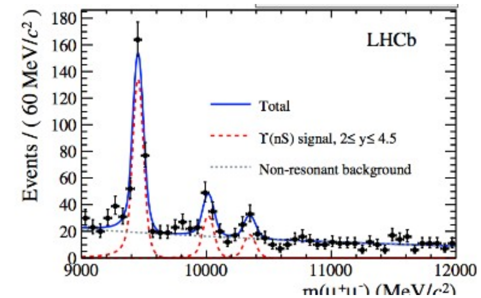


Selected Physics results

- 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

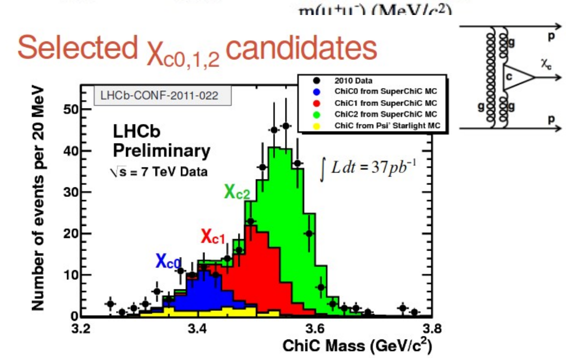


- CEP: J/ψ and ψ(2S) mesons in Run1
  JPG 41 (2014) 055002



- CEP: ϒ mesons in Run1
  JHEP 1509 (2015) 084

- Double charmonia in Run1
  JHEP 1509 (2015) 084

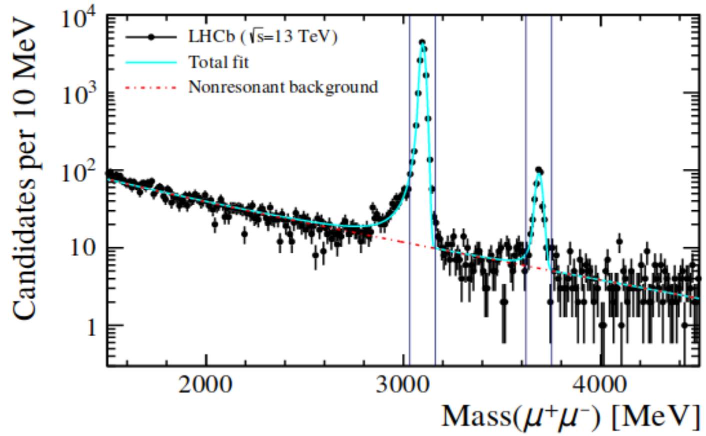


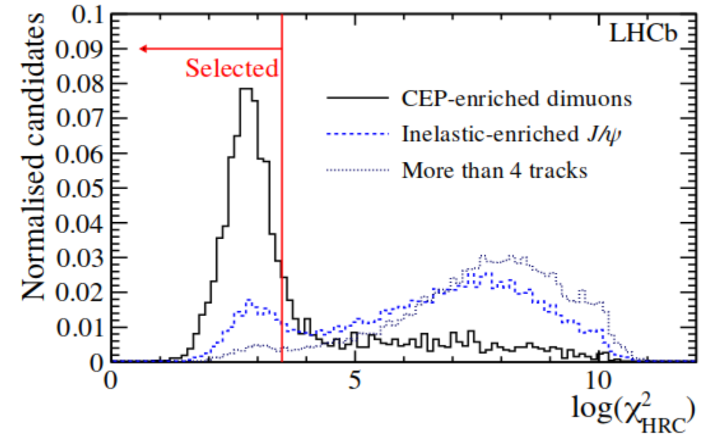
- Most recently: J/ψ and ψ(2S) mesons in Run2
  arXiv:1806.04079

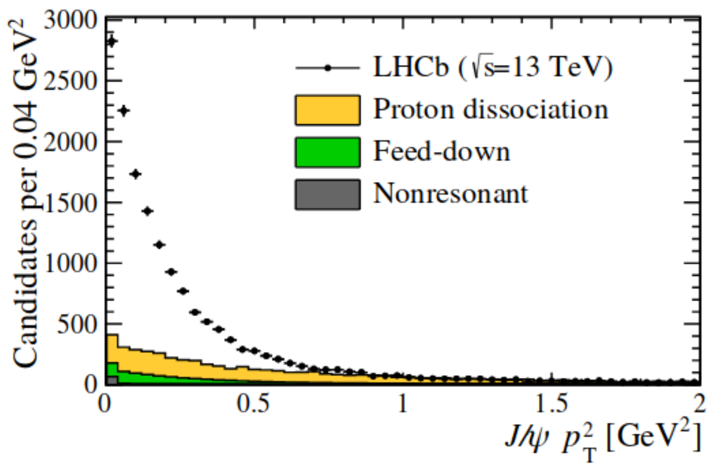
- Difficulty separating states and exclusive fractions

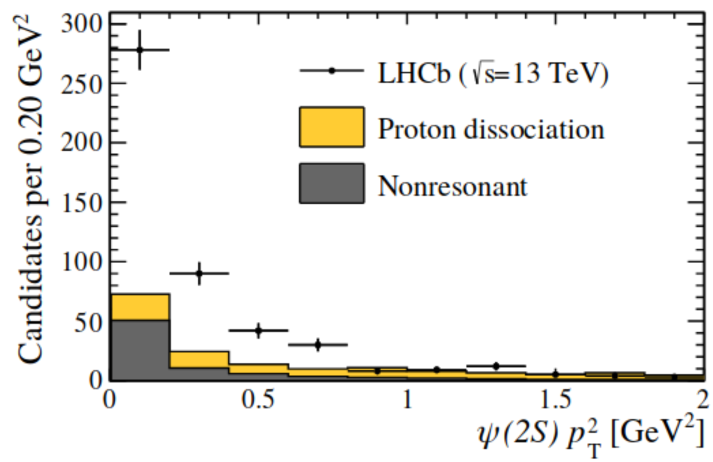
J/ψ CEP in pp collisions at 13TeV

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









$$\frac{d\sigma_{\psi\to\mu^+\mu^-}}{dy}(2.0 < \eta_\mu < 4.5) = \frac{\mathcal{P}N}{\epsilon_{rec}\epsilon_{sel}\Delta y \epsilon_{single}\mathcal{L}_{tot}}$$

$$\sigma_{J/\psi\to\mu^+\mu^-}(2 < \eta < 4.5) = 399 \pm 16 \pm 10 \pm 16 \text{ pb},$$
$$\sigma_{\psi(2S)\to\mu^+\mu^-}(2 < \eta < 4.5) = 10.2 \pm 1.0 \pm 0.3 \pm 0.4 \text{ pb}$$

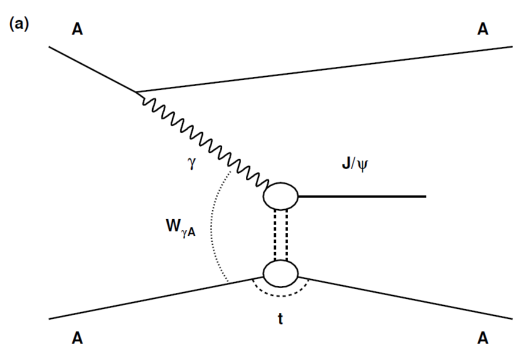
J/ψ in PbPb collisions

LHCb-CONF-2018-003

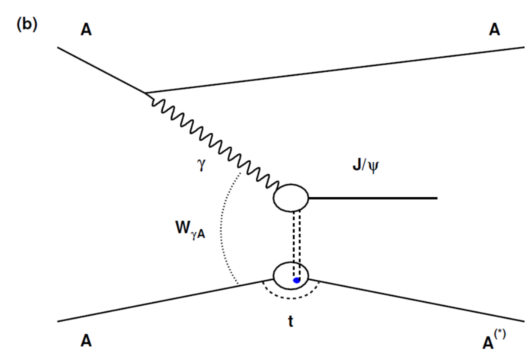
- Appeared this year → first preliminary result by LHCb on PbPb collisions
- Goal is to study coherent J/ψ production in PbPb collisions at $\sqrt{s}$(NN) = 5 TeV
- Integrated luminosity ~ 10 μb^{-1}
- Muons in acceptance. Pt(J/ψ) < 1 GeV. Rapidity 2.0 < y <4.5

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

Coherent



Incoherent

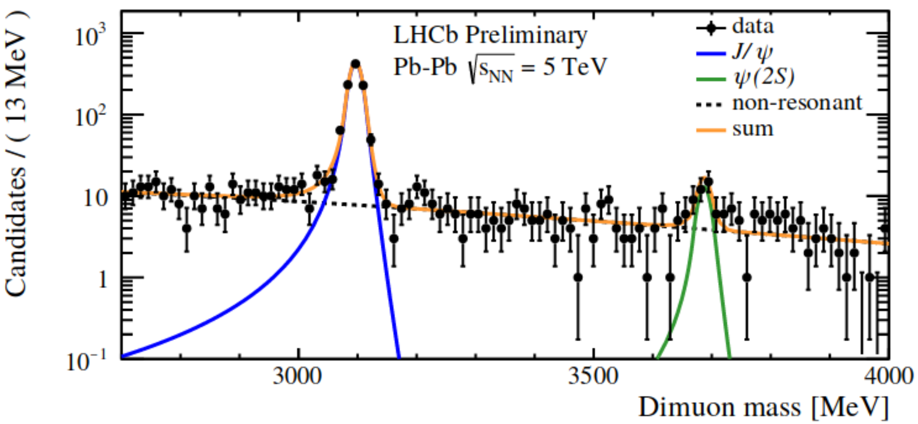


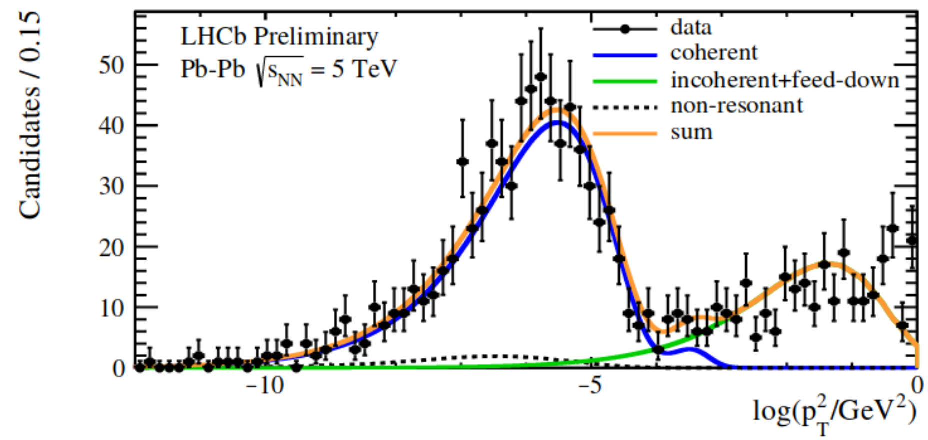
J/ψ in PbPb collisions

LHCb-CONF-2018-003

- For each of the processes a STARlight template is used for the Pt² 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 Pt²





$$\frac{d\sigma(\mathrm{PbPb} \to \mathrm{Pb} + J/\psi + \mathrm{Pb})}{dy} = \frac{n_{\mathrm{coh}}}{\varepsilon_y \cdot \Delta y \cdot \mathcal{L} \cdot \mathcal{B}}$$

$$\sigma = 5.3 \pm 0.2\ (\mathrm{stat}) \pm 0.5\ (\mathrm{syst}) \pm 0.7\ (\mathrm{lumi})\,\mathrm{mb}$$

J/ψ in PbPb collisions

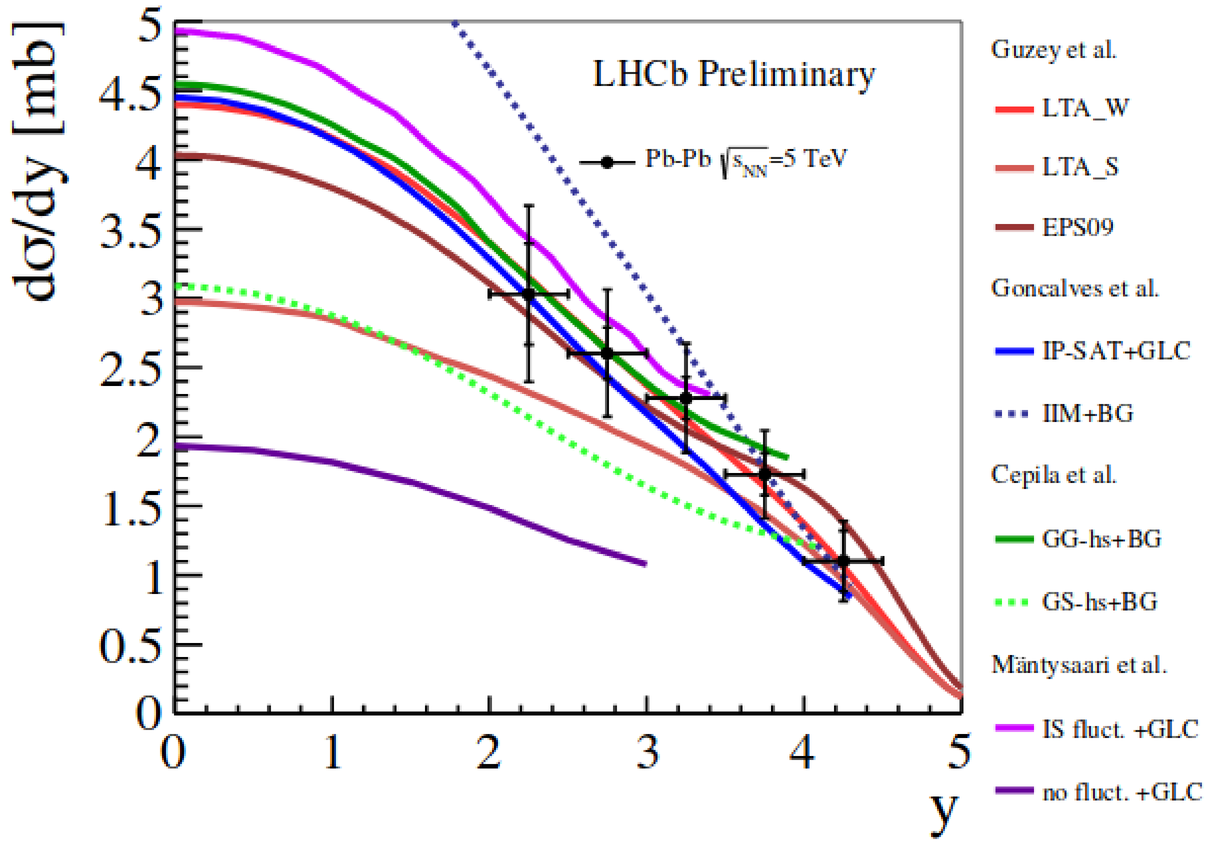
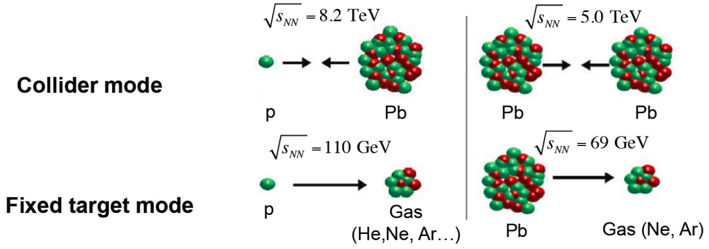


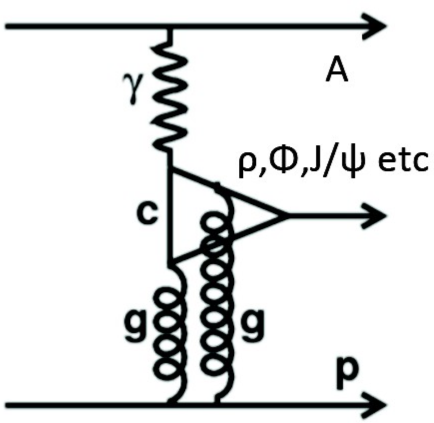
Figure 3: Differential cross-section for coherent J/ψ production compared to different phenomenological predictions. The LHCb measurements are shown as points, where inner and outer error bars represent the statistical and the total uncertainties respectively.

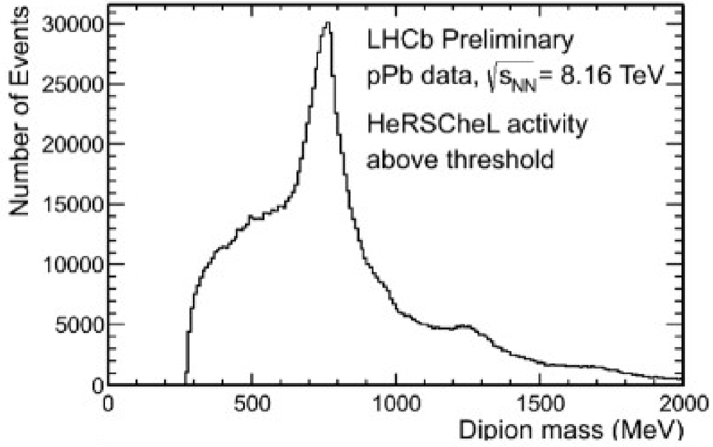
pA collisions: dipion spectrum

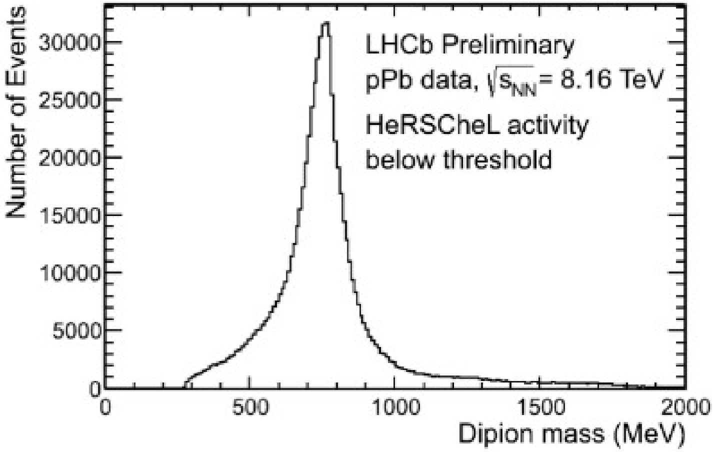
- Central exclusive production in pA/Ap data is dominantly photoproduction
- Select events
  - with precisely two tracks
  - consistent with beam spot

- Herschel plays a big role here reducing diffraction







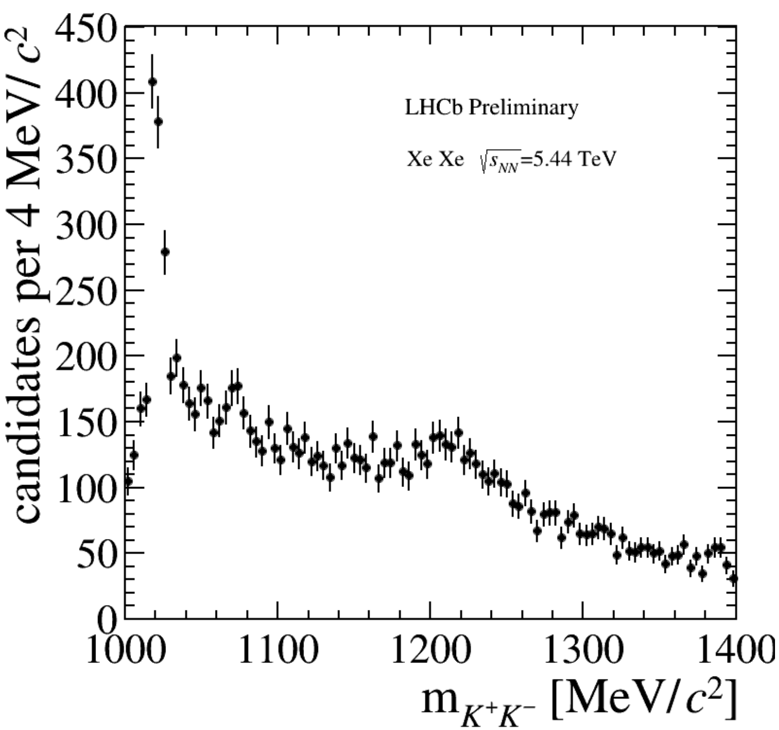


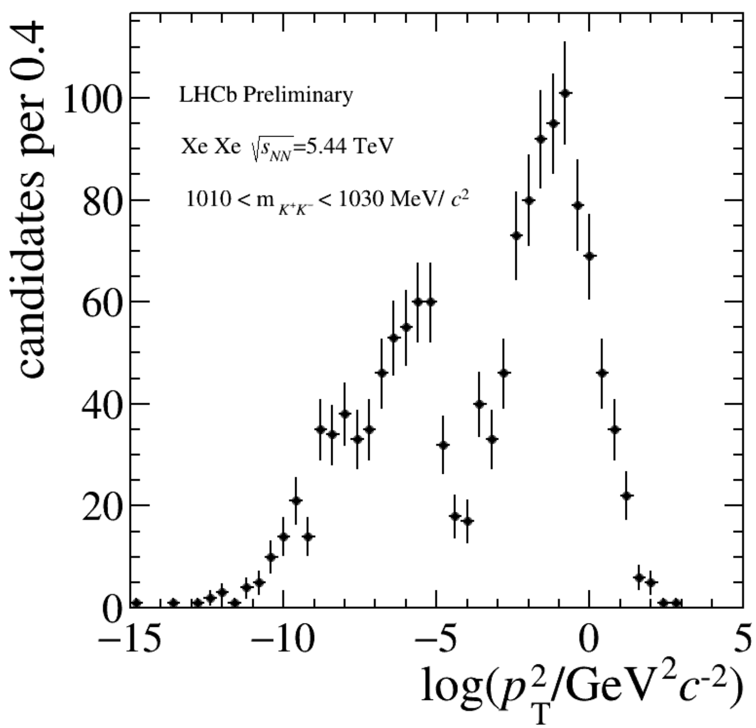
Cross-section measurement
Measure ρ parameters: this is unexpectedly clean

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: φ and ρ with very high statistics
  e.g. STAR paper: 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
  Nachtmann, Szczurek et al: https://arxiv.org/abs/1708.09836
  Goncalves et al: https://arxiv.org/abs/1710.10070

- 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 !