central exclusive ultraperipheral results and prospects

second heavy ion and fixed target workshop, Chia, Sardinia

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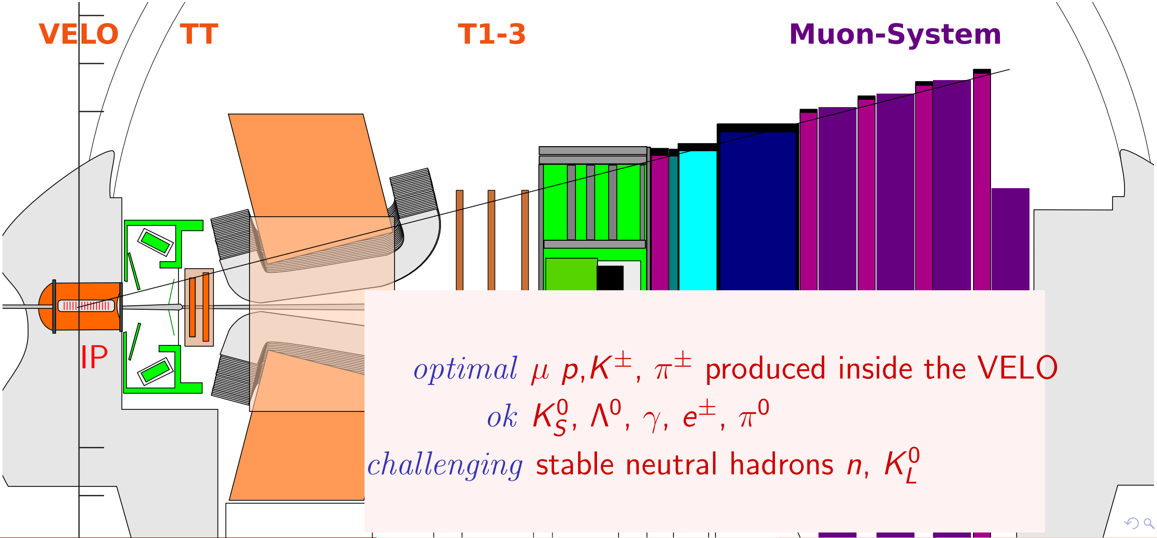
1. *the past*
   - LHCb detector
   - 2015 preliminary ultraperipheral J/ψ
2. *the present*
   - HeRSCheL - forward scintillators
   - 2015 ultraperipheral J/ψ paper
   - 2018 ultraperipheral J/ψ paper
3. *the future*
   - general

as Sergio Leone didn't say...

LHCb experiment



optimal μ p, $K^{\pm}$, $\pi^{\pm}$ produced inside the VELO

ok K_S^0, Λ^0, γ, $e^{\pm}$, π^0

challenging stable neutral hadrons n, K_L^0

the past

event selection

- $J/\psi \to \mu^+\mu^-$ events with no additional activity from the same vertex
- muon selection
  - $p_{\mathrm{T}\,\mu} > 500$ MeV
  - $2.0 < \eta_\mu < 4.5$
- J/ψ selection
  - $p_{\mathrm{T}\,J/\psi} < 1$ GeV

Using data taken in lead-lead collisions at $\sqrt{s_{NN}} = 5.02\,\mathrm{TeV}$ in 2015

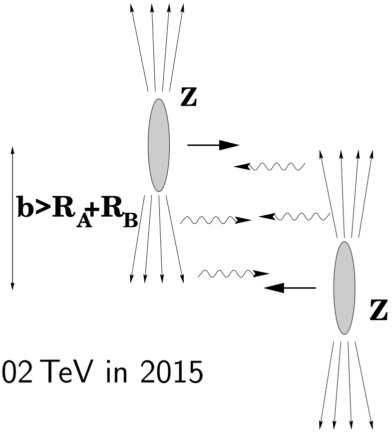
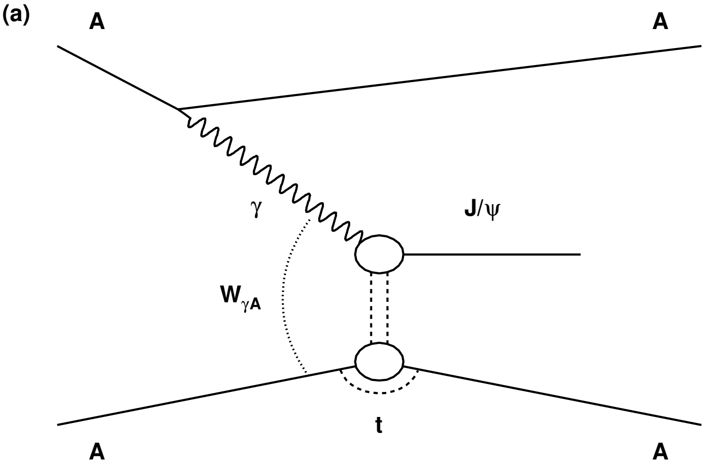


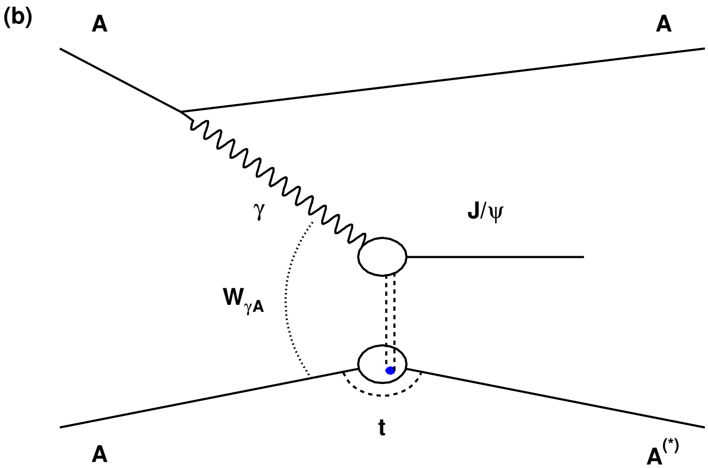
diagram from Phys.Rept. 458 (2008) 1-171

introduction



diagrams from Cepila, Jan et al. Phys.Rev. C97 (2018) no.2, 024901

introduction



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mass fit

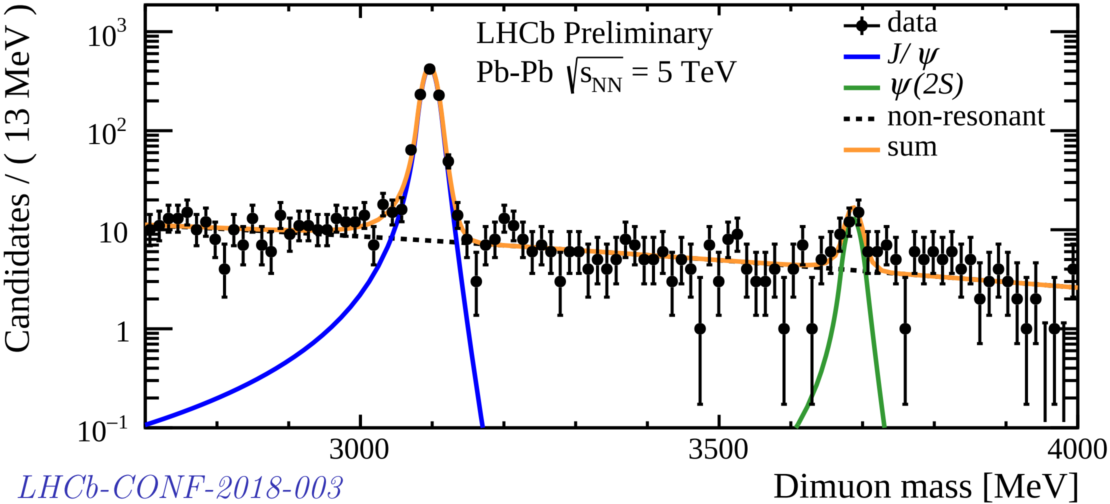
- *invariant mass fit* discriminate $\gamma\,\gamma \rightarrow \mu^{+}\mu^{-}$ process from J/ψ production

  non-resonant Exponential times straight line

  J/ψ Double sided Crystal Ball function

  $\psi(2S)$ Double sided Crystal Ball function with all parameters apart from normalisation and mean constrained to be identical to J/ψ

the mass fit



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transverse momentum fit

- *transverse momentum fit* to determine the number of coherent events

  non-resonant STARlight template, normalisation is fixed by Gaussian constraint to the result of the mass fit

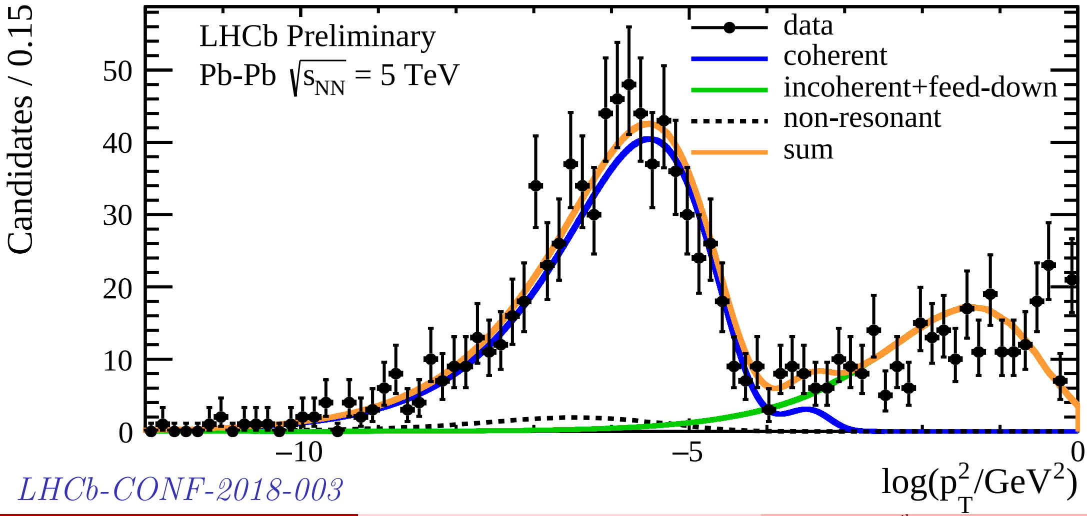
  incoherent J/ψ production STARlight template, this also accounts for feeddown $\psi(2S) \rightarrow J/\psi\ X$

  coherent J/ψ production STARlight template

  The STARlight templates are from the generated events smeared with a resolution model

$$\vec{p_\mu} = G(p_x, 10\,\mathrm{MeV})\vec{e_x} + G(p_y, 10\,\mathrm{MeV})\vec{e_y} + G(p_z, 10\,\mathrm{MeV})\vec{e_z} \qquad (1)$$

the transverse momentum fit



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differential coherent cross section

LHCb preliminary

$$\sigma = 5.27 \pm \underset{stat}{0.21} \pm \underset{sys}{0.49} \pm \underset{lumi}{0.68}\,\text{mb}$$

- The analysis is repeated in bins of half unit rapidity $y_{J/\psi}$
- Uncertainties for statistics, systematic and luminosity are of comparable magnitude
- The LHCb acceptance is interesting to discriminate between the models

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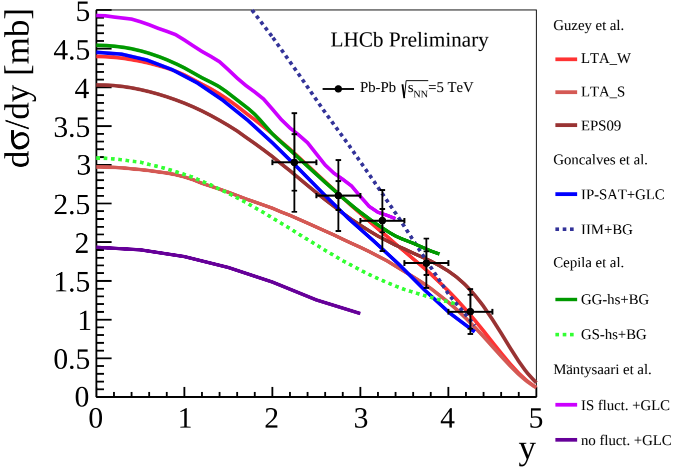

systematic uncertainties

Source	Relative uncertainty (%)
Selection efficiency	3.2
Reconstruction efficiency	2.1 – 4.5
Hardware trigger efficiency	3.0
Software trigger efficiency	1.6 – 5.3
Momentum smearing model	3.3
Mass fit model	3.9
Feed-down background	5.8
Branching fraction	0.6
Luminosity	13.0

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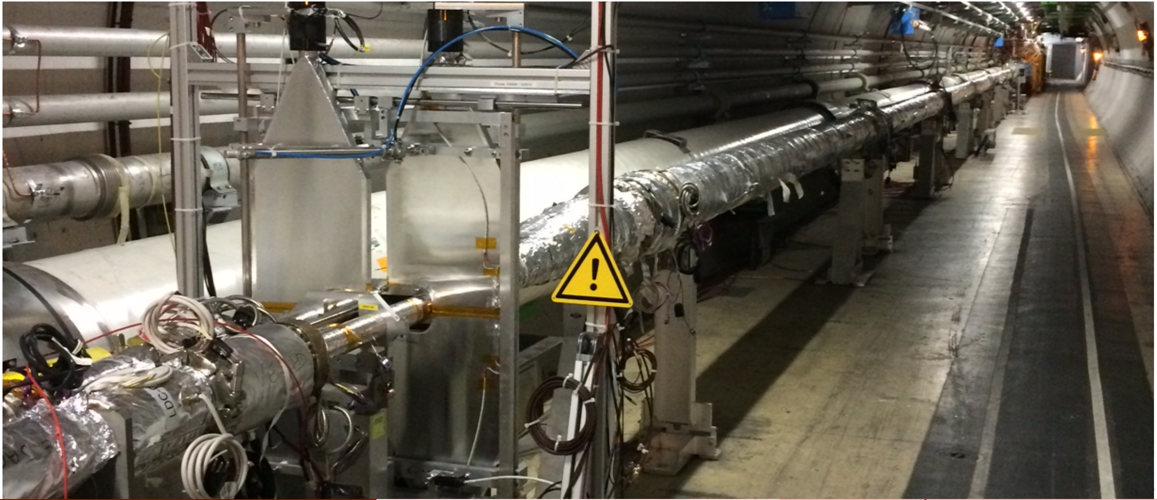
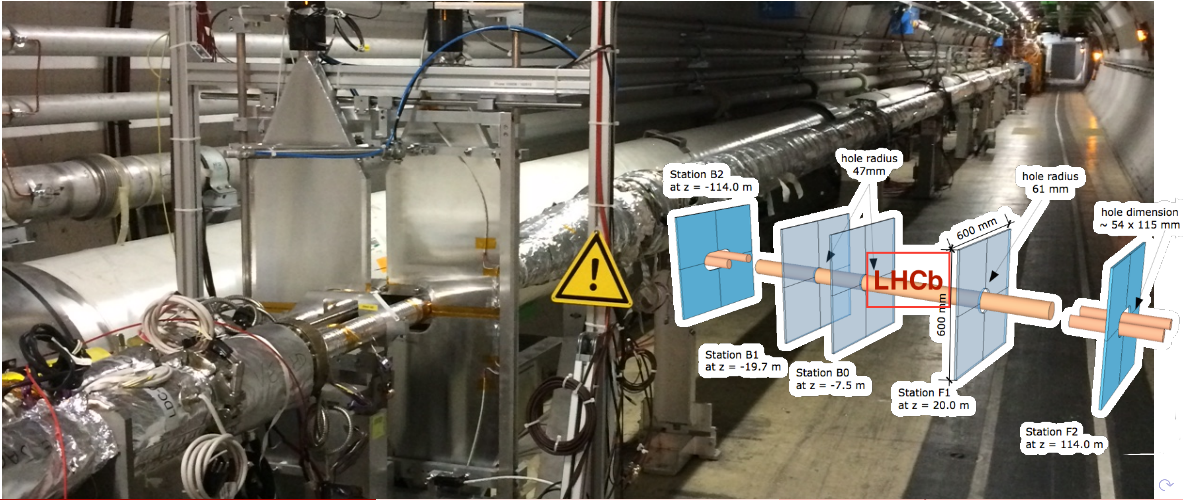
the present

HeRSCHeL - forward scintillators



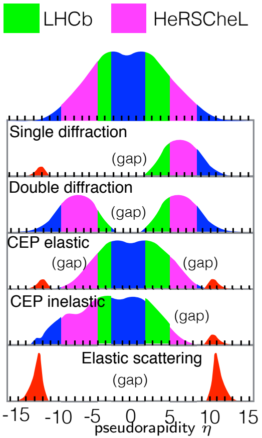
HeRSCHeL - forward scintillators



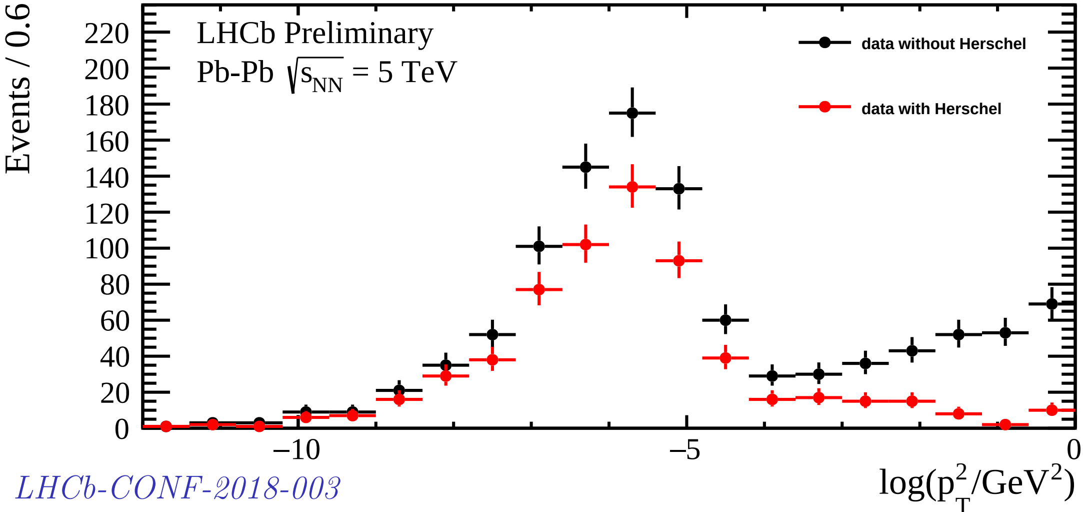
HeRSCheL concept

- If the nucleon breaks up it will leave debris in $5.0 < \eta < 7.5$
- Extend present LHCb to observe this debris
- Much easier than proton taggers inside the beam pipe ("Roman Pots")

illustration



separation of coherent and incoherent



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paper using 2015 dataset

the pathfinder

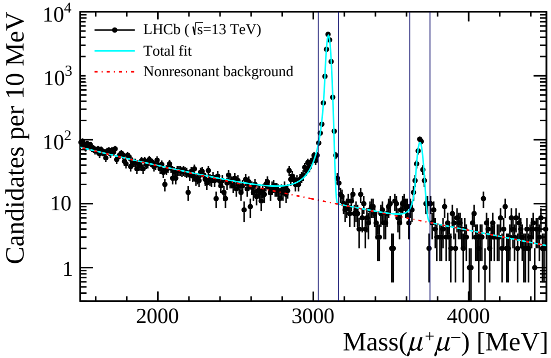
- Improved on most systematics (not lumi)
- Use of full simulation instead of smearing MS truth for templates
- Use of Herschel for better control of the background
- Luminosity uncertainty remains the limiting factor
- Internal review is progressing well

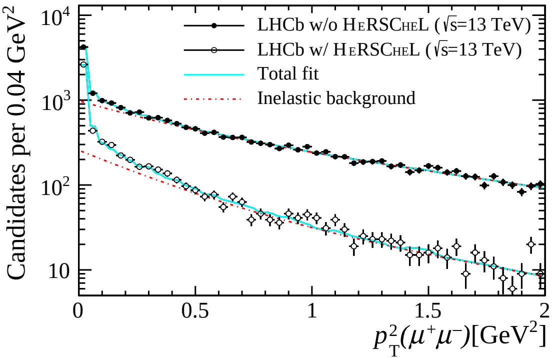
paper using 2018 dataset

the precision measurement

- Use the experience gained on 2015 to improve the result using an order of magnitude more data
- Start improvements at the trigger
- Will include $J/\psi\,/\psi(2S)$ cross section ratios
- Luminosity still to be determined
- Internal review imminent

central exclusive production of J/ψ mesons and $\psi(2S)$ mesons at 13 TeV





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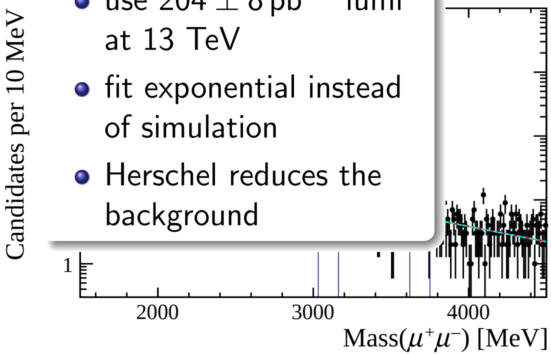
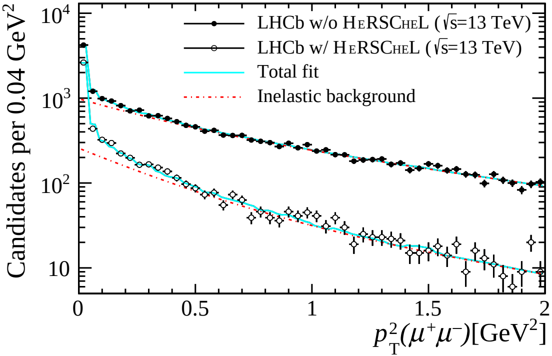
central exclusive production of J/ψ mesons and $\psi(2S)$ mesons at 13 TeV

similar game

- use $204 \pm 8\,\text{pb}^{-1}$ lumi at 13 TeV
- fit exponential instead of simulation
- Herschel reduces the background





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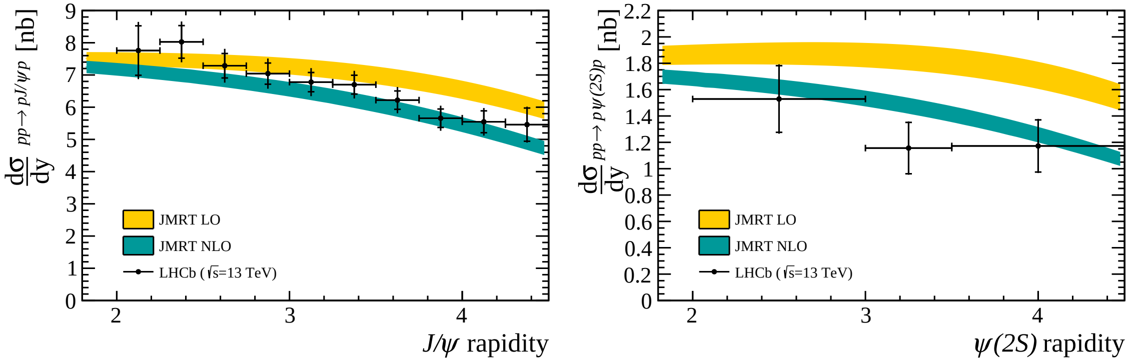

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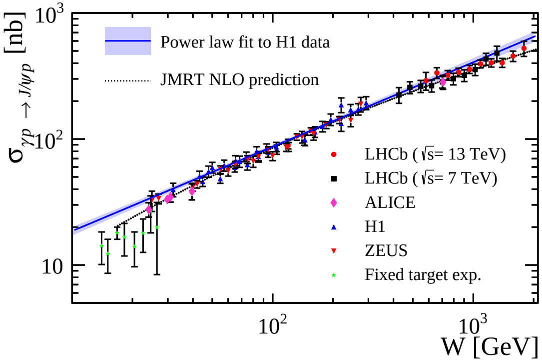

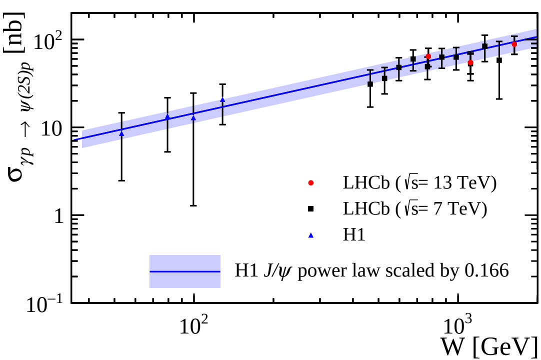

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the future

use hadronic final states

- Trigger was improved for PbPb 2018 run
- Trigger will be completely independent of the calorimeters in the upgrade
- There are narrow states; wide states; and opportunities for spectroscopy
- Cross sections are so high we run out of dimensions to measure differentially in

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The slides ahead are mildly edited for compliance with administrative measures

conclusion

- There are great LHCb results in the pipeline
- There are even more data there being analysed
- There are even better data to come