Measurement of inelastic cross sections at LHCb

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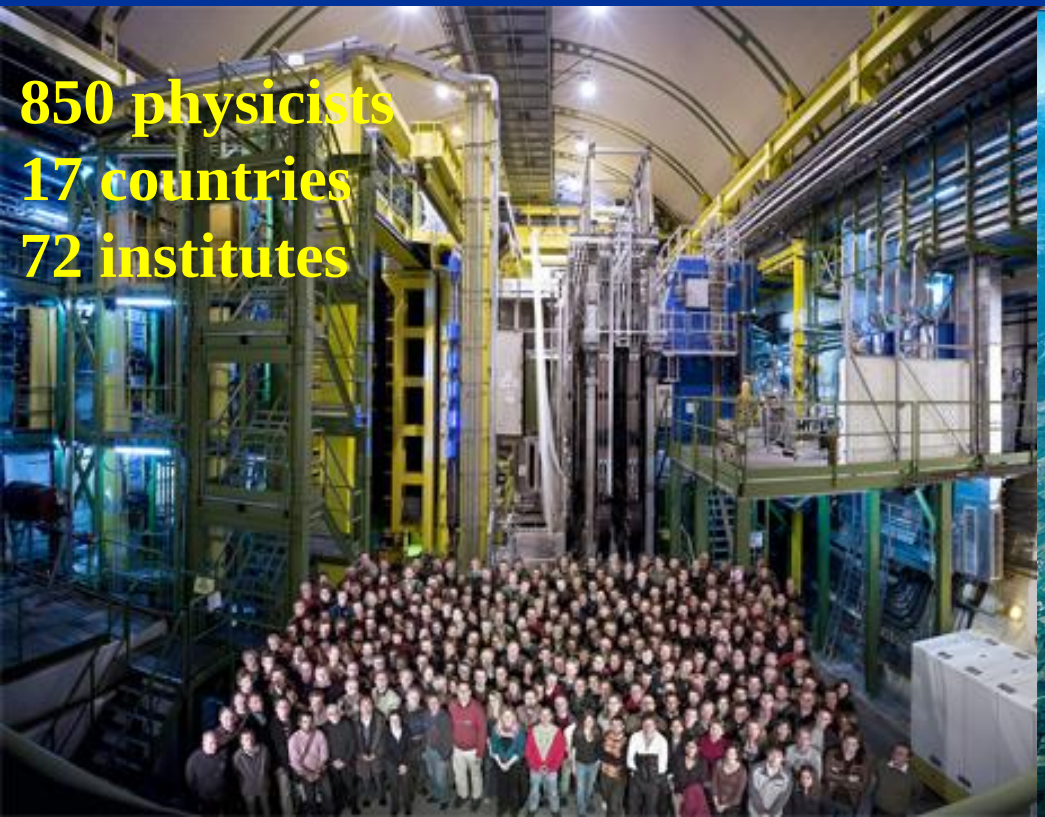
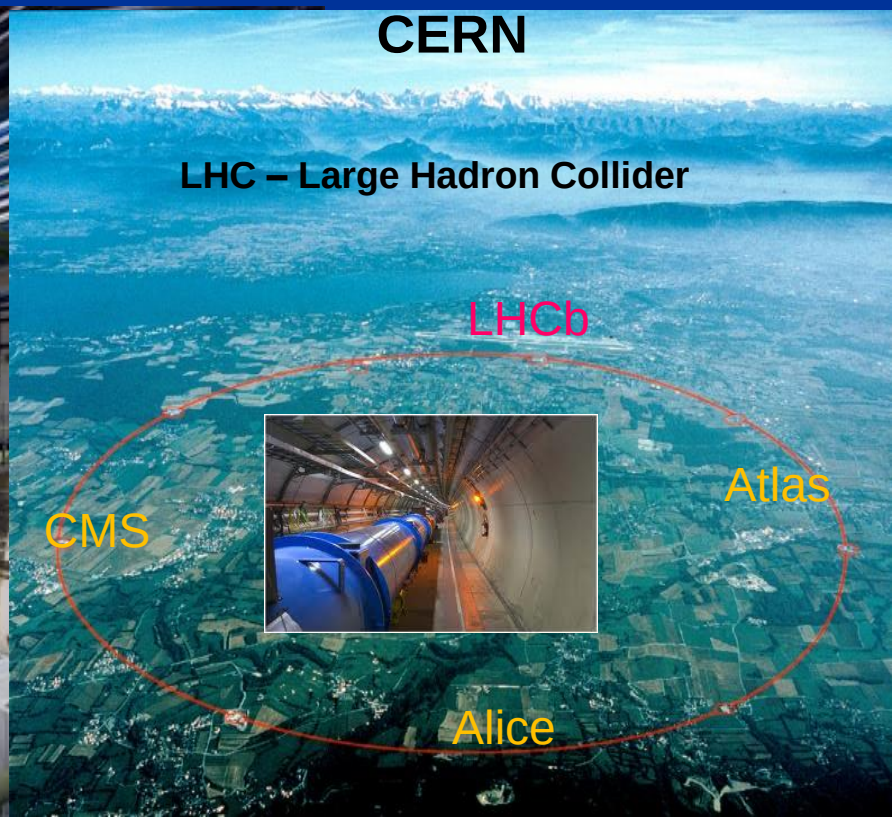
On behalf of LHCb Collaboration

HADRON 2017, 25-29 September, Salamanca, Spain



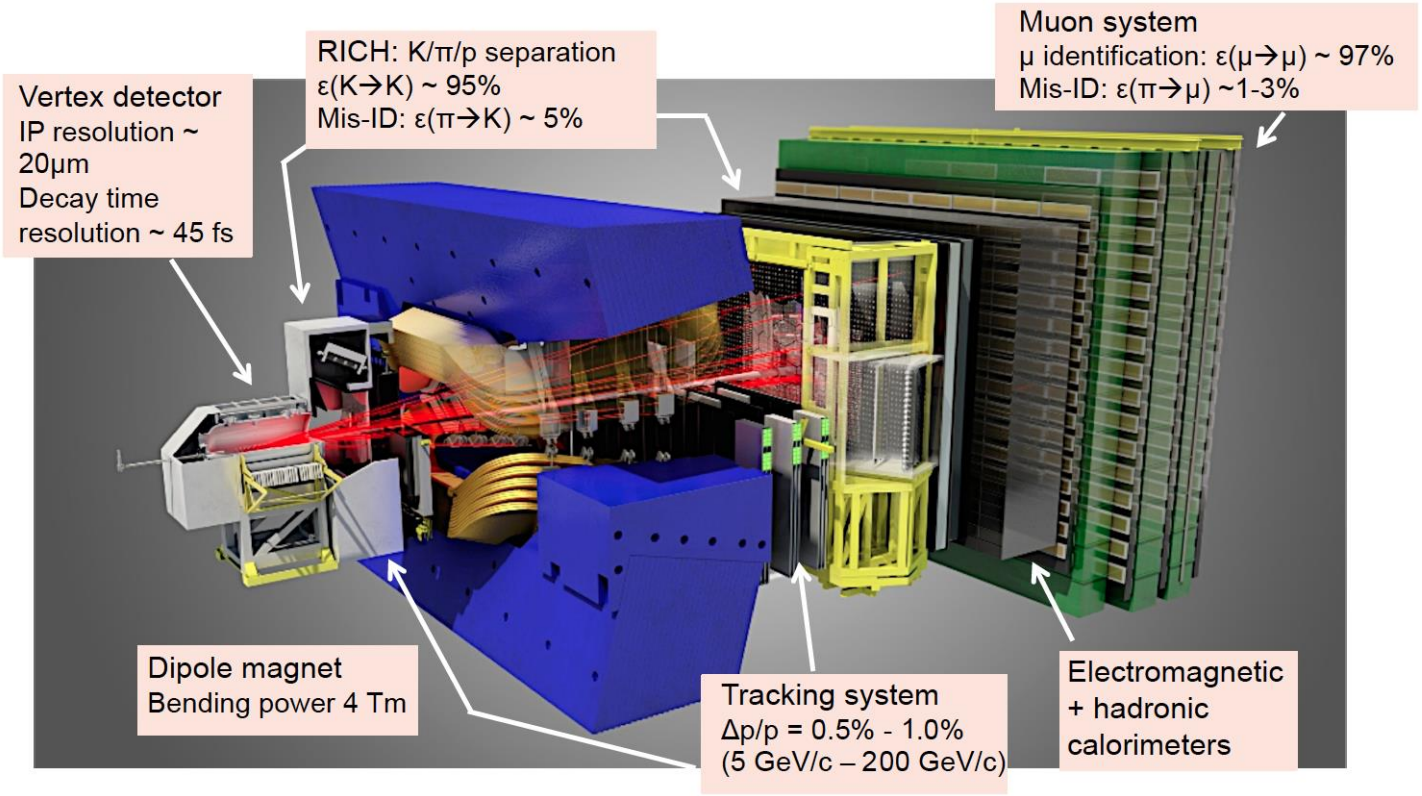


Outline

- LHCb detector
- Inelastic cross-section
- Central Exclusive Production
- Summary

The LHCb detector

Primary goal of LHCb: **Precision Measurements of CP-Violation, search for New Physics in CPV processes and rare decays.**



JINST 3 (2008) S08005, IJMPA 30 (2015) 1530022

But LHCb is fully instrumented in $2 < \eta < 5$, therefore it can serve as a general purpose detector in the forward region.

Inelastic cross-section

Motivation

- Fundamental observable in high-energy hadronic interactions
- LHCb provides results in the mid- to forward rapidity range
- Important for models of cosmic rays showers in atmosphere

Dataset

- pp collisions at $\sqrt{s}$ = 7 TeV, $\mathcal{L}_{int}$ = 1.87 nb^{-1}
- Low pile-up data: ~0.1 interactions with at least one track in the detector, 1.05 visible interactions per triggered event
- Hardware trigger accepts 100% of beam-beam crossing
- Software trigger requires at least one reconstructed track segment in vertex detector.

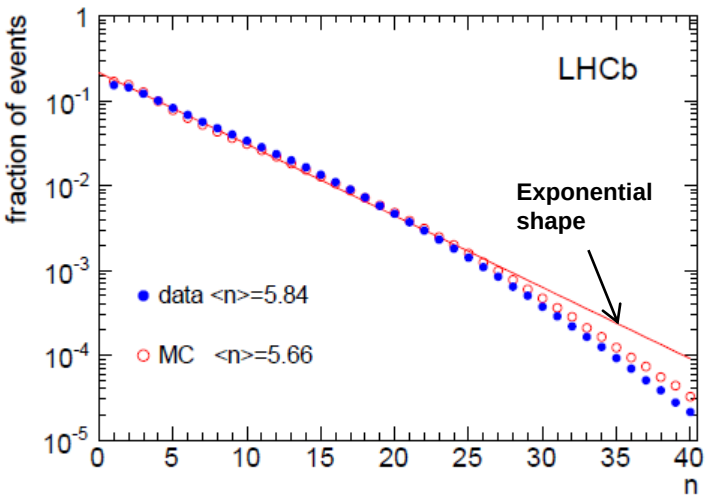
Fiducial cross-section

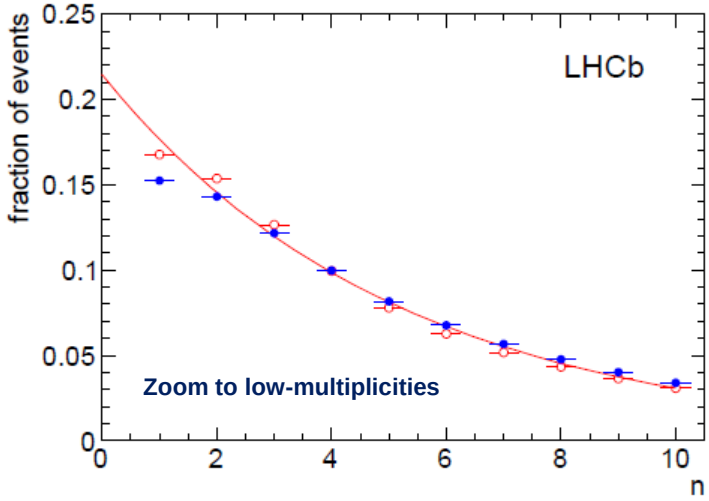
- At least one long lived prompt charged particle form luminous region
  - Distance from beam-line < 200 μm
- Transverse momentum p_T > 200 MeV/c
- Pseudorapidity range 2.0 < η < 4.5

Fiducial cross-section

Observed multiplicities in fiducial region

JHEP 02(2015)129





- Normalized track multiplicity distributions with n>0 tracks.
- Good agreement between data and simulation.

σ_{inel} = 55.0 ± 2.4 mb

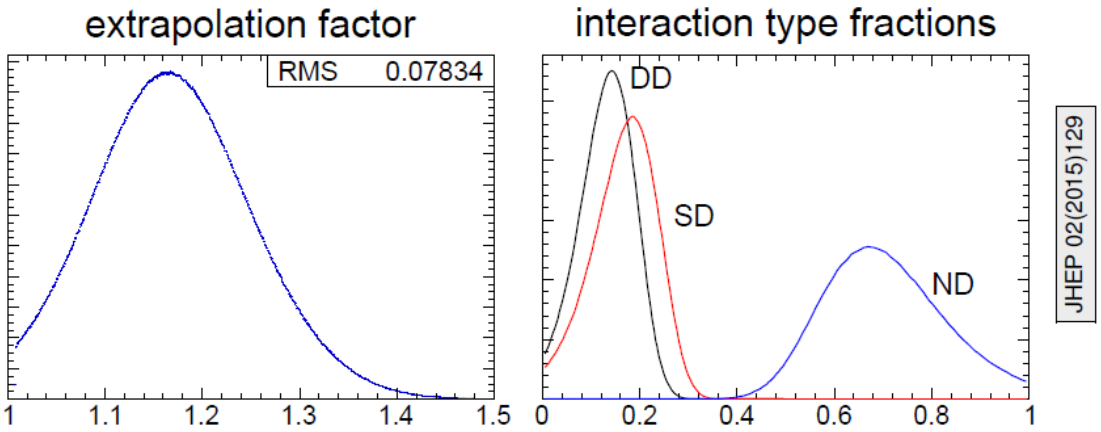
Inelastic pp cross-section with at least one prompt long-lived charged particle having $p_T > 200$ MeV/c and $2.0 < \eta < 4.5$

Extrapolation to full phase space

use only properties (not rates!) of non-diffractive, single- and double diffractive as modelled by different Pythia tunes (4Cx, Monash 2103, A2-CTEQ6L1, A2-MSTW2008LO, AU2-CTEQ6L1, AU2-MSTW2008LO, CUETP8S1-CTEQ6L1)

interaction type	$\langle n \rangle$	v	f
non-diffractive (ND)	12.22 ± 0.50	0.9925 ± 0.0003	0.713 ± 0.002
single-diffractive (SD)	5.94 ± 0.29	0.5059 ± 0.0049	0.173 ± 0.002
double-diffractive (DD)	4.78 ± 0.17	0.5819 ± 0.0062	0.114 ± 0.001

fluctuate mean values $\langle n \rangle$ and visibilities v within uncertainties
allow any combination event of fractions f that reproduce the measured average multiplicity in the fiducial region 10.93 ± 0.50



Extrapolation factor

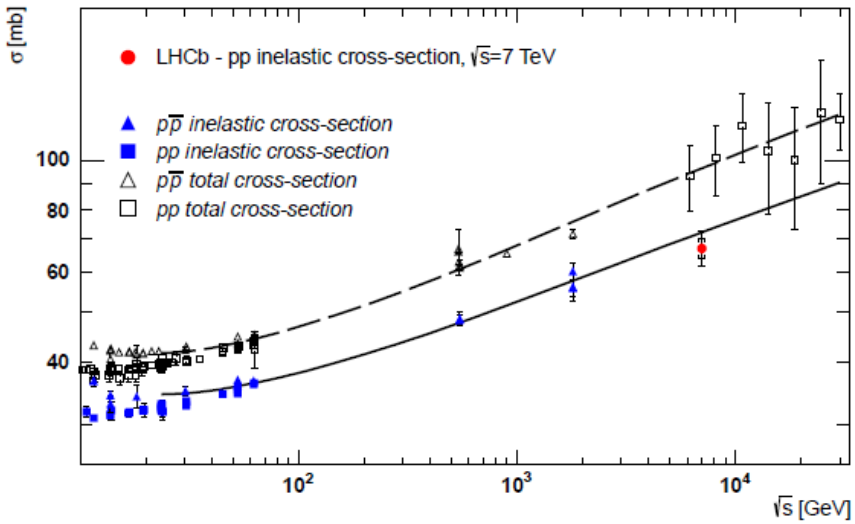
1.17 ± 0.08

LHCb results for 7 TeV

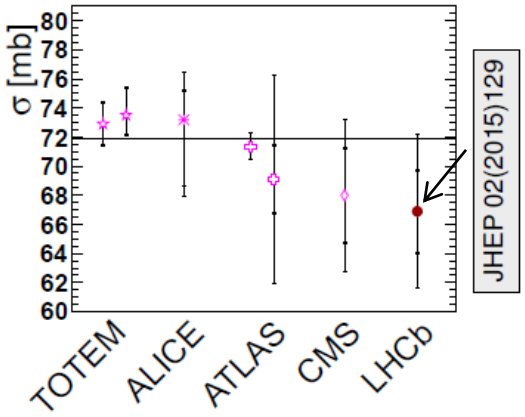
$$\sigma_{\text{inel}} = 66.9 \pm 2.9(\text{exp}) \pm 4.4(\text{extr})\,\text{mb}$$

Comparison with other experiments

PDG, Chin. Phys. C38 (2014) 090001



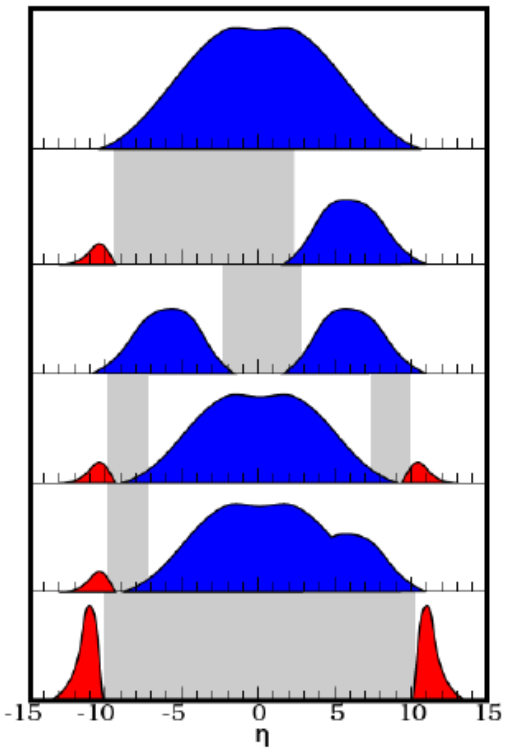
Phys. Rev. D84 (2011) 094009

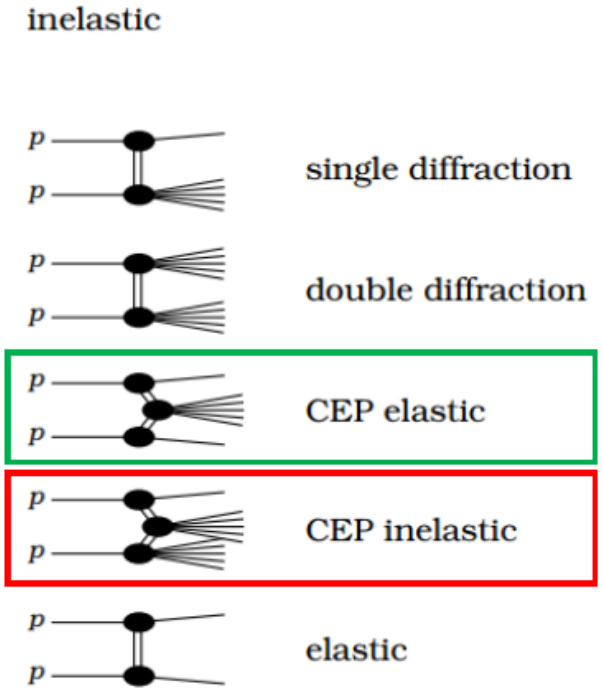


LHCb result at 7 TeV is consistent with other results.

Result for 13 TeV soon. Measurement at 5 TeV possible.

Central Exclusive Production



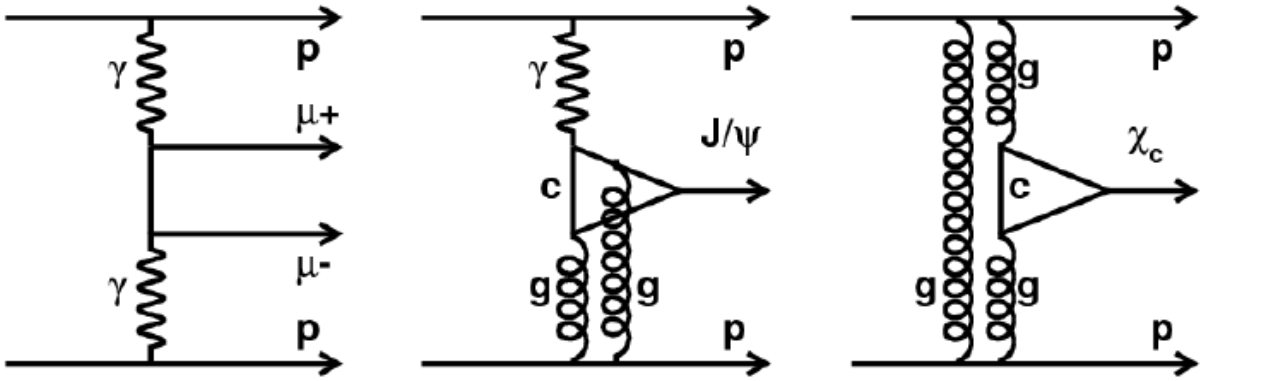


Motivation

- Test of QCD and pomeron exchange in clean environment
- Sensitive to diffractive PDF at very low x (to 5 x 10^{-6})
- Search for saturation effects

CEP measurement

Hadronic interactions without (net) colour exchange



QED photoproduction Double Pomeron Exchange

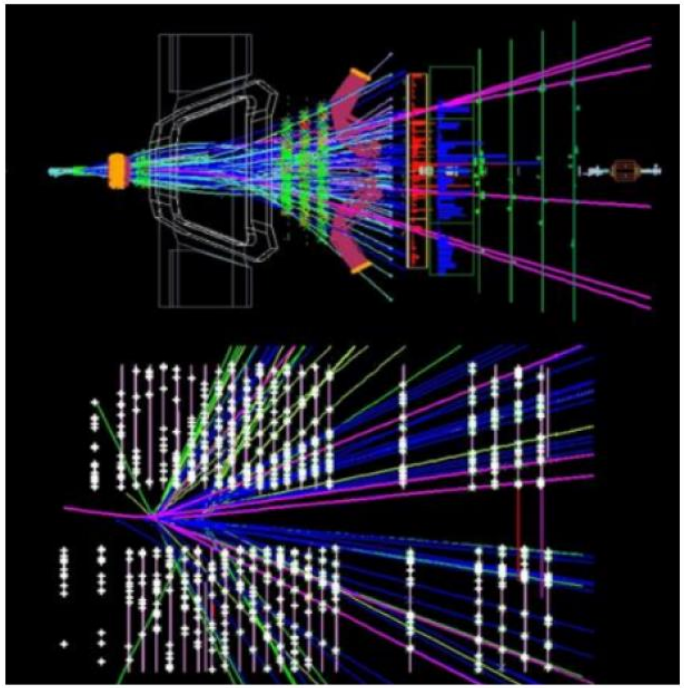
Signal: central system with rapidity gaps (focus on J/ψ, ψ(2S))

Background: diffractive processes and finite detector acceptance

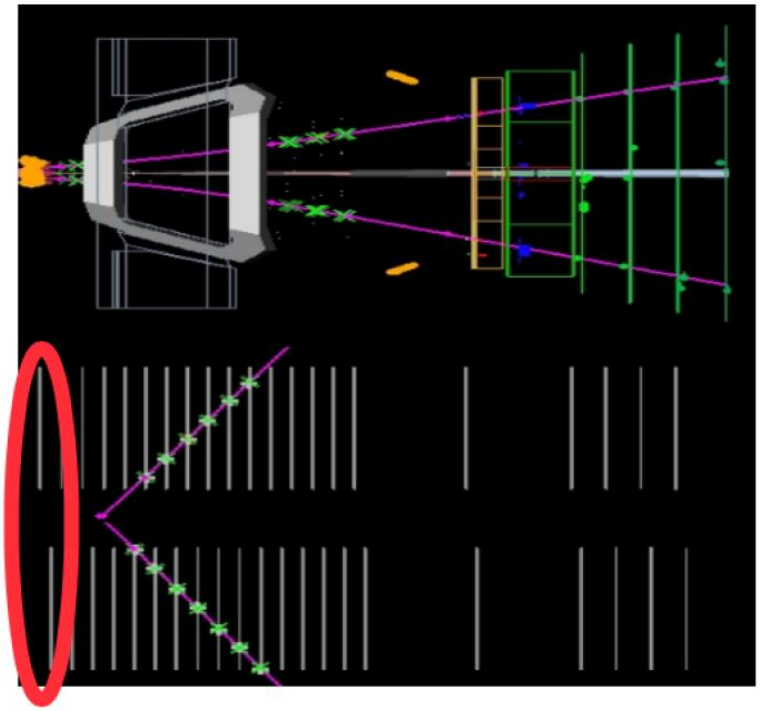
Experimental task: detection of rapidity gaps

CEP event topology

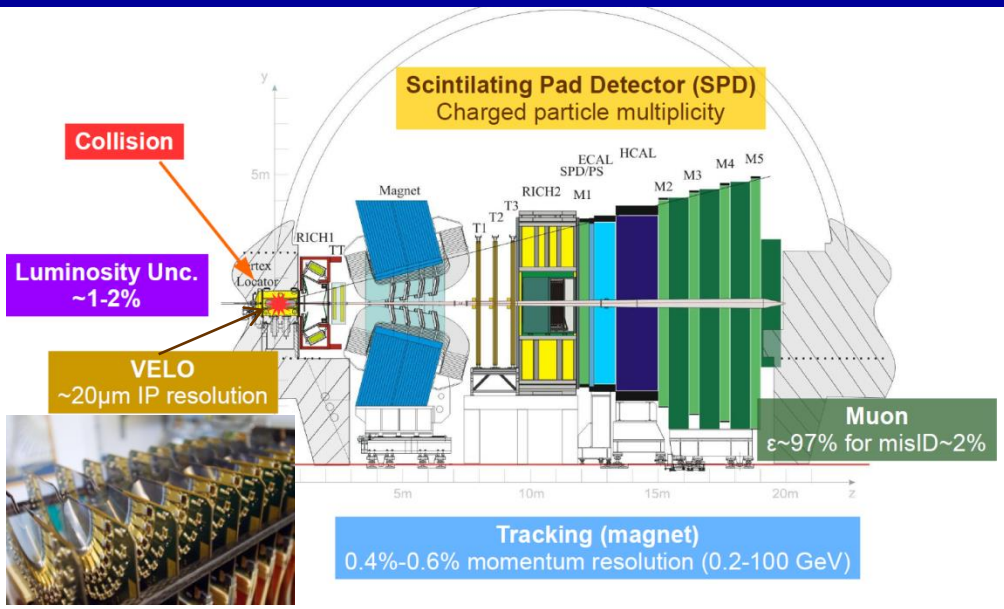
Typical Event

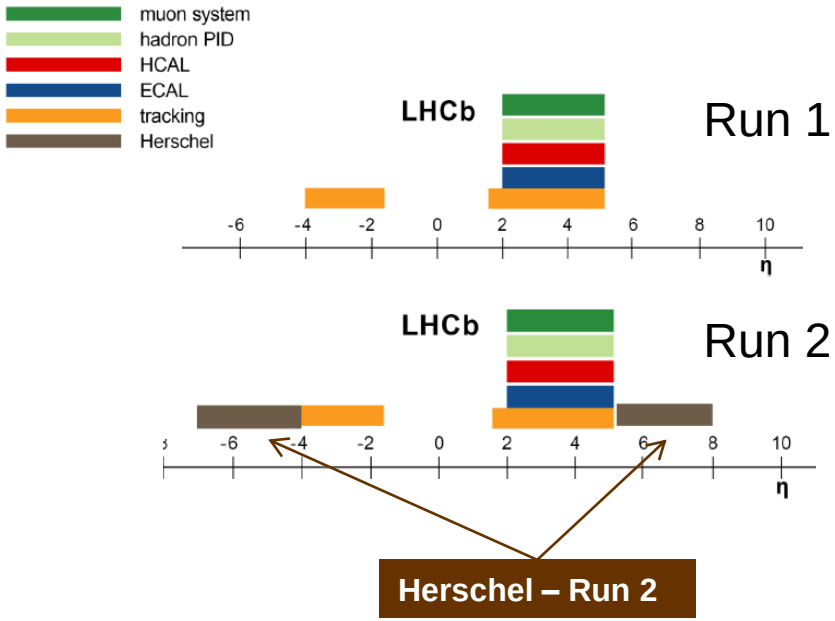


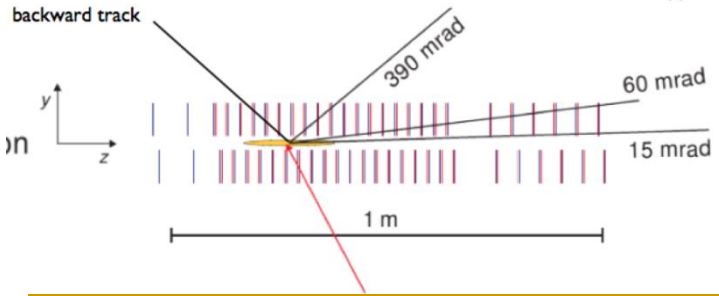
CEP-like event: 2muons



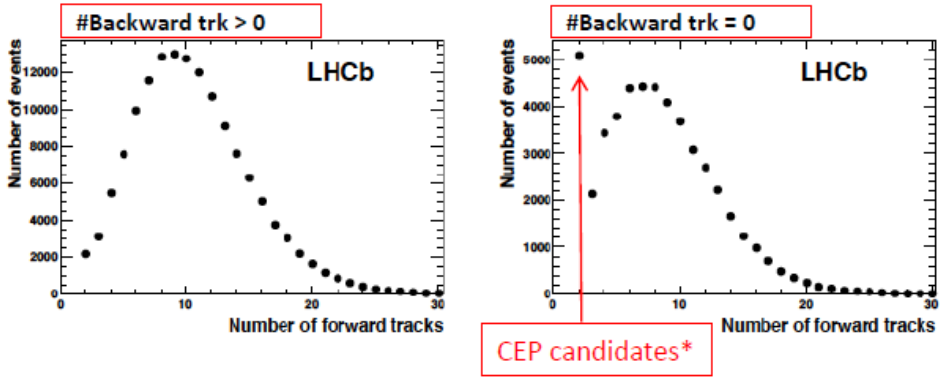
Measuring exclusivity with LHCb







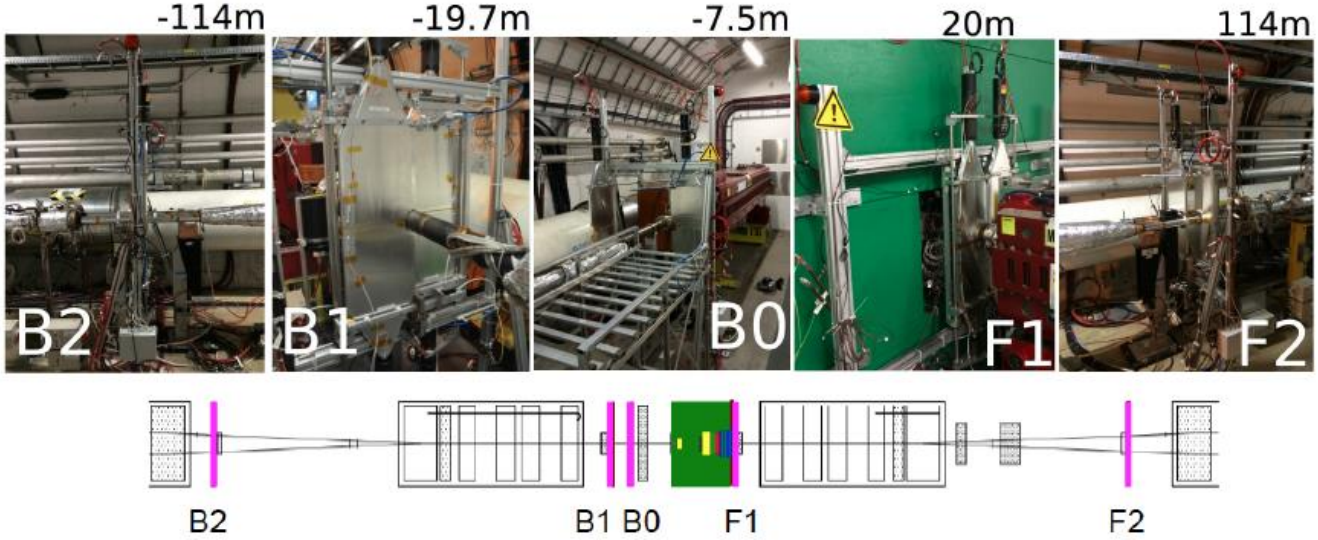
VELO
- ➔surrounds the interaction point
- ➔no magnetic field
- ➔allows backward tracks $(-3.5<\eta<-1.5)$



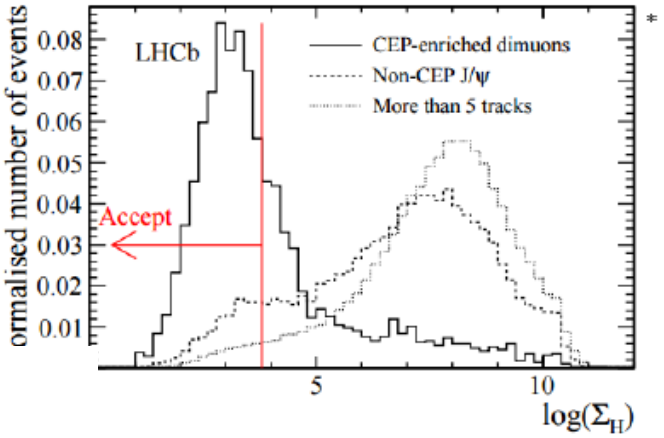
Herschel

High rapidity shower counters for LHCb

LHCb-DP-2016-003 in preparation



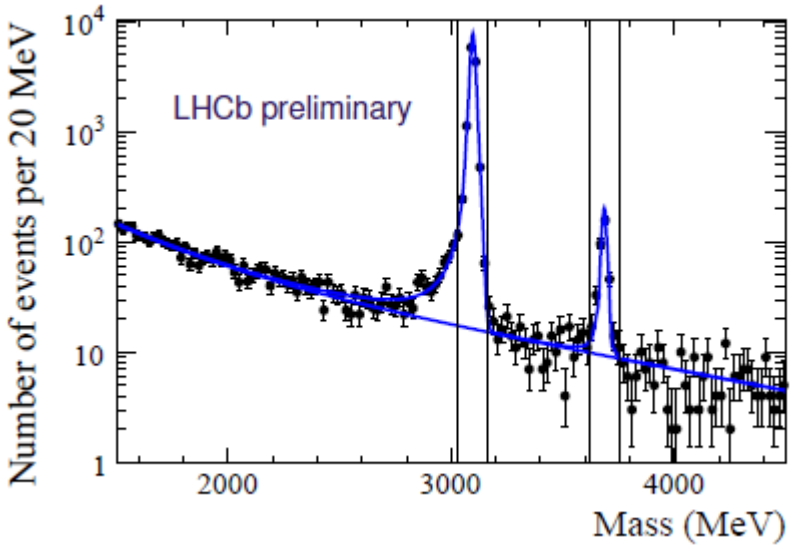
$$\Sigma_H = \sum_{i=1}^{20} \left(\frac{ADC_i}{2.5 RMS_i} \right)^2$$

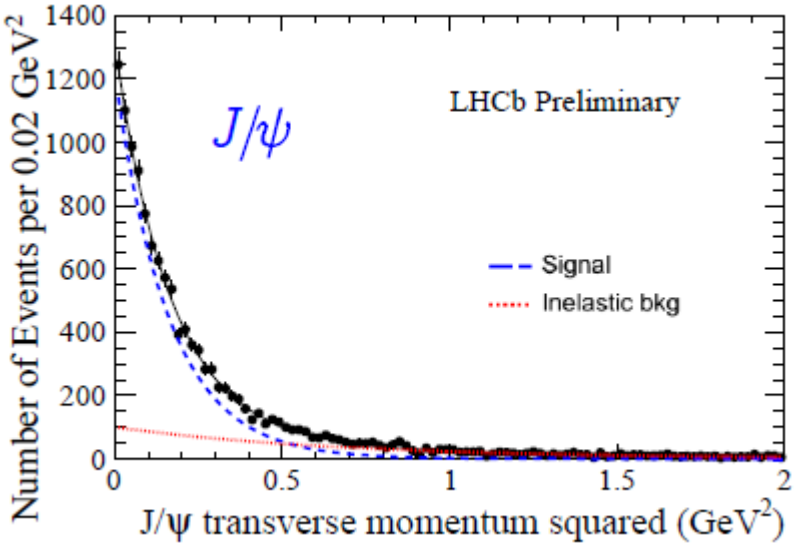


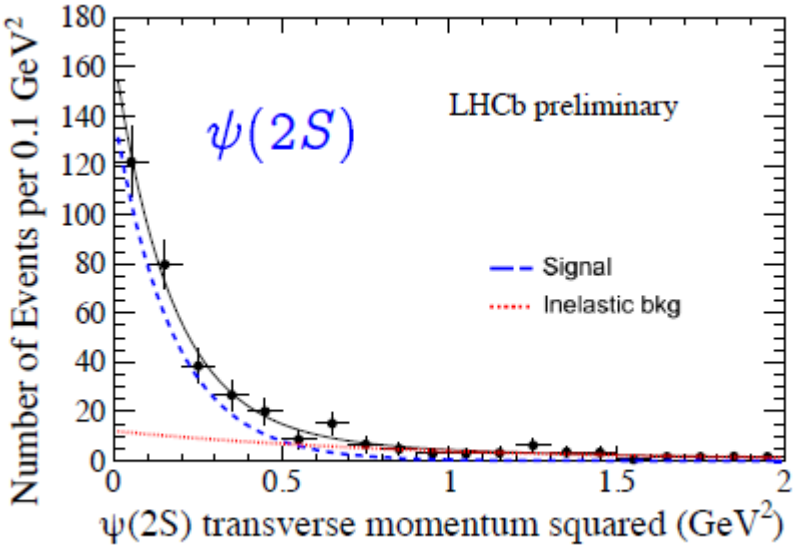
Herschel reduces background by a factor of ~2

J/ψ, ψ(2S) results at 13 TeV

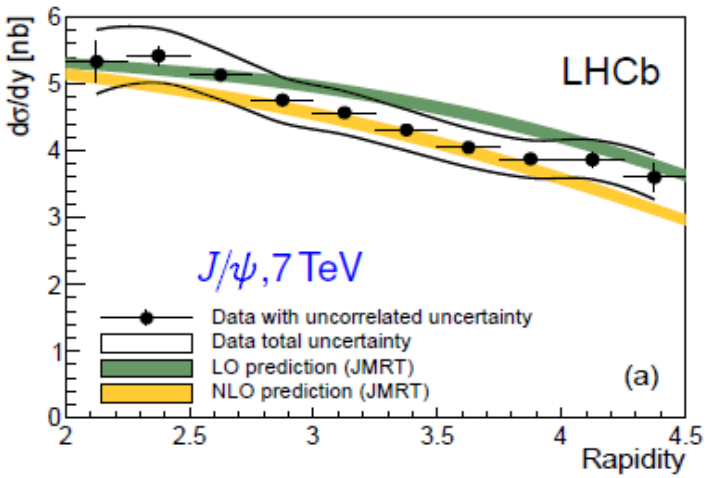
- $\mathcal{L}$ = 0.2 fb^{-1} (1 fb^{-1} at 7 TeV)
- Low-p_T CEP signature
- Inealstic: 20% (40% at 7 TeV)
- Feeddown: J/ψ 6% (10% at 7 TeV)

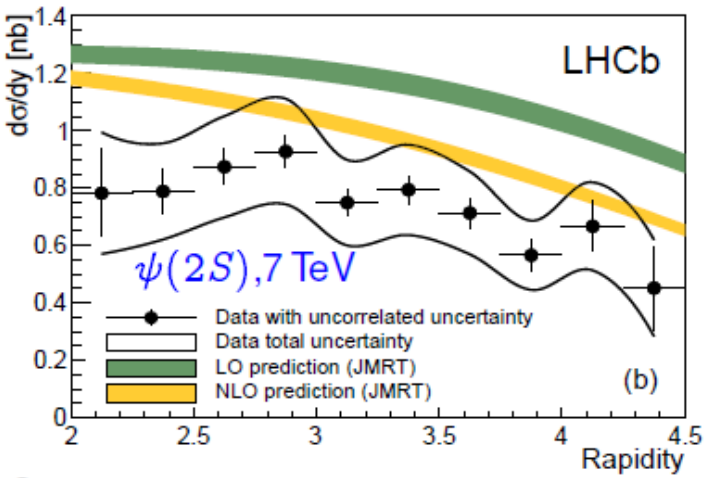




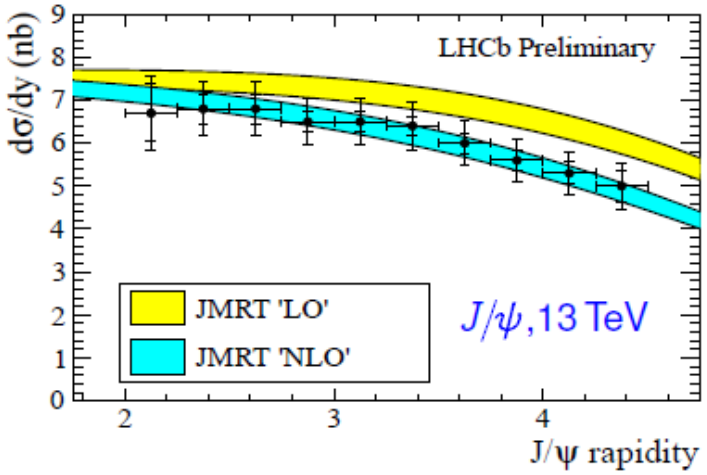


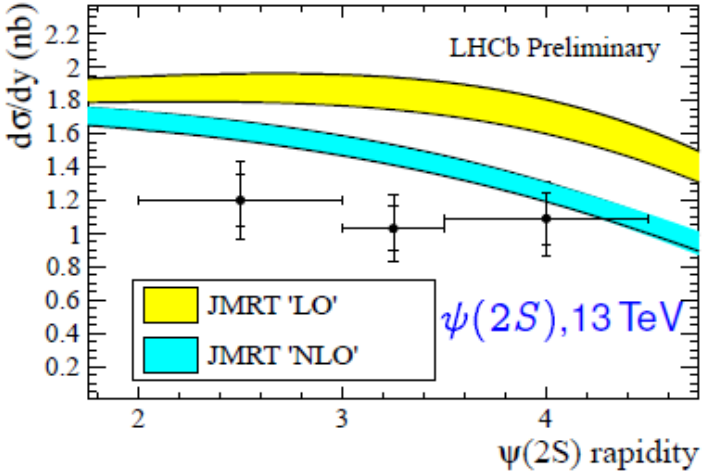
J/ψ, ψ(2S) @ 7 & 13 TeV





JPG 41(2014)055002





LHCb-CONF-2016-007

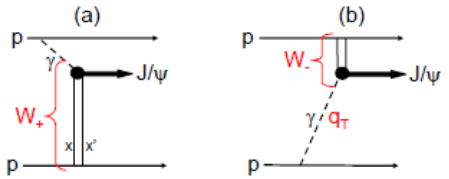
JMRT NLO (JHEP 11(2013)085) is preferred model

- uncertainties highly correlated between bins
- shape better described by NLO prediction or models including saturation

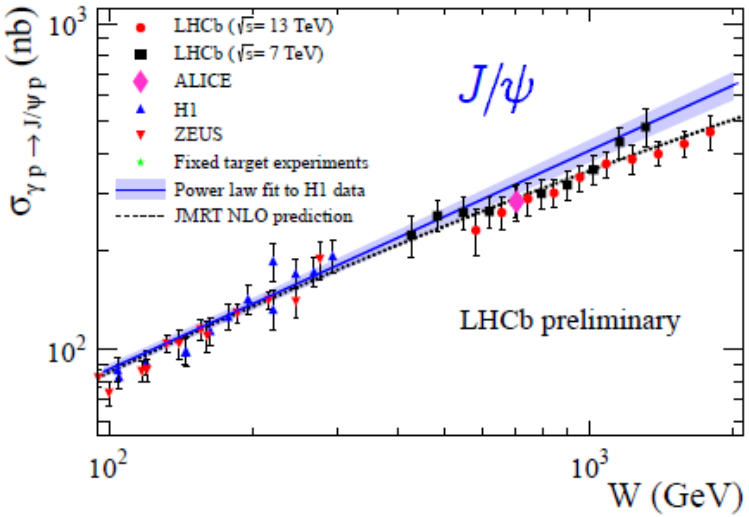
J/ψ, ψ(2S) photo-production x-section

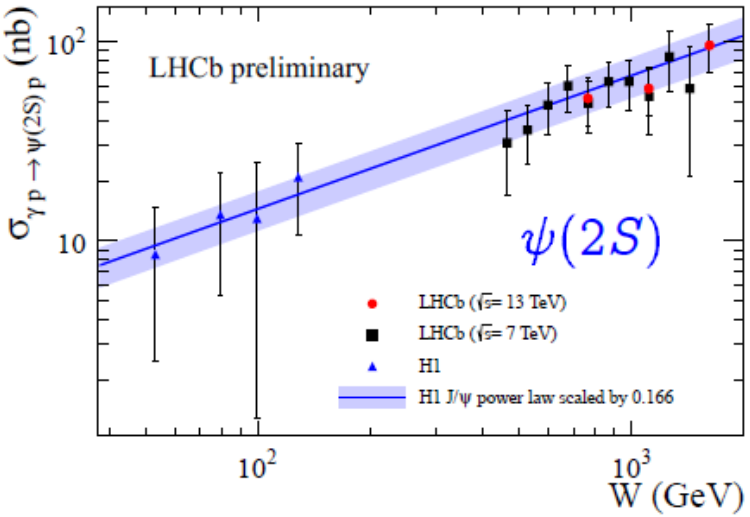
$$\frac{d\sigma}{dy_{pp\to pVp}} = r(y)\left[k_+\frac{dn}{dk_+}\sigma_{\gamma p\to Vp}(W_+) + k_-\frac{dn}{dk_-}\sigma_{\gamma p\to Vp}(W_-)\right]$$

$r(y)$: gap survival, $k_\pm$: photon energy, $dn/dk_\pm$: photon flux $W_\pm$: γp mass



arXiv:1307.7099v1 hep-ph



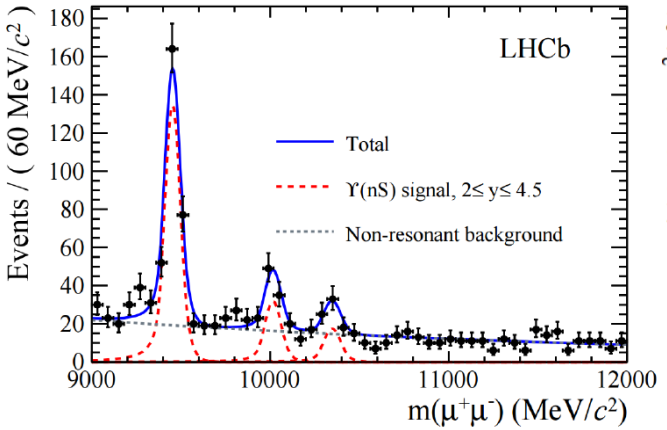


LHCb-CONF-2016-007

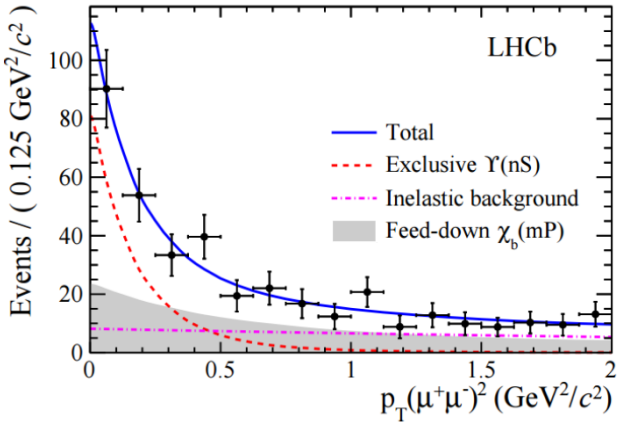
- 13 TeV data allows significant extension of the reach in W
- 7 & 13 TeV results are in agreement
- comparison with HERA → simple power law insufficient to describe J/ψ

$\Upsilon(nS)$ at @ 7 & 8 TeV

- Two muons with $\eta \in (2.0,4.5)$ $\quad 9 < M(\mu\mu) < 20$ GeV/c²
- No additional activity in detector
- Candidate $p_T^2 < 2\ \mathrm{GeV}^2/c^2$



Not background subtracted



Background subtracted – sPlot technique

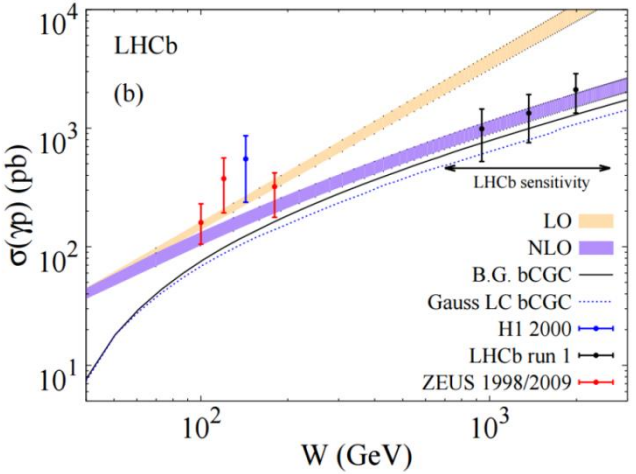
Integrated cross-sections:

$\sigma_{\Upsilon(1S)\to\mu^+\mu^-}\ (2.0 < \eta(\mu^\pm) < 4.5) = 9.0 \pm 2.1(stat) \pm 1.7(sys)$pb

$\sigma_{\Upsilon(2S)\to\mu^+\mu^-}\ (2.0 < \eta(\mu^\pm) < 4.5) = 1.3 \pm 0.8(stat) \pm 0.3(sys)$pb

Upper limit:

$\sigma_{\Upsilon(3S)\to\mu^+\mu^-}\ (2.0 < \eta(\mu^\pm) < 4.5) < 3.4$pb @ 95% C.L.



Summary

- Total inelastic cross-section at √s = 7 TeV, using extrapolation based on properties of non-diffractive, single- and double diffractive events

$$\sigma_{\text{inel}} = 66.9 \pm 2.9(\text{exp}) \pm 4.4(\text{extr})\,\text{mb}$$

JHEP 02(2015)129

- Central Exclusive Production at √s = 7 TeV and 13 TeV
  - LHCb's forward acceptance provides unique window on CEP
  - new HeRSCheL system to tag large rapidity gaps (√s = 13 TeV)
  - J/ψ, $\psi(2S)$, $\Upsilon(nS)$, measurements
  - very low-x gluon PDF

- Dimuon continuum @ $\sqrt{s}$=7 TeV, LHCb-CONF-2011-022
- $\chi_c(\rightarrow J/\psi\gamma)$ @ $\sqrt{s}$=7 TeV, LHCb-CONF-2011-022
- J/ψ and $\psi(2S)$ @ $\sqrt{s}$ = 7 TeV, J.Phys. G40 (2013) 045001, J.Phys. G41 (2014) 055002
- J/ψ and $\psi(2S)$ @ $\sqrt{s}$ = 13 TeV, LHCb-CONF-2016-007
- $\Upsilon(nS)$ @ $\sqrt{s}$=7 TeV and 8 TeV, JHEP 1509 (2015) 084
- Double charmonia @ $\sqrt{s}$ = 7 TeV and 8 TeV, J.Phys. G41 (2014) no.11, 115002

  - Ongoing Run1 & Run2 exclusive production analyses:
    - CEP with hadronic final states
    - CEP with photons
    - CEP in pA and Ap