Exclusive Production at LHCb

Philip Ilten
on behalf of the LHCb Collaboration

Massachusetts Institute of Technology

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MULTIPLE PARTONIC INTERACTIONS AT THE LHC

Outline

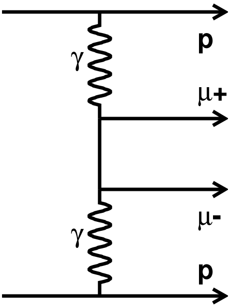
- motivation
- LHCb detector
- datasets

- dimuon continuum
- χ_{cJ} production
- J/ψ and $\psi(2S)$ production
- double J/ψ and $\psi(2S)$ production
- J/ψ and $\psi(2S)$ production at 13 TeV

Central Exclusive Production

$$pp \to pXp$$

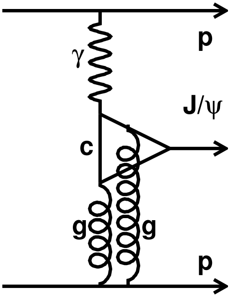
γ-γ



$\ell\ell$, WW

photon PDF, QED tests

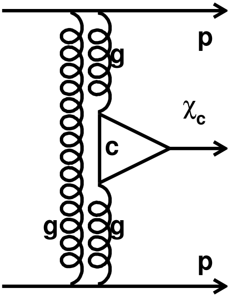
γ-pomeron



J/ψ, Υ, ρ, Z, $\ldots$

diffractive PDF, odderon searches

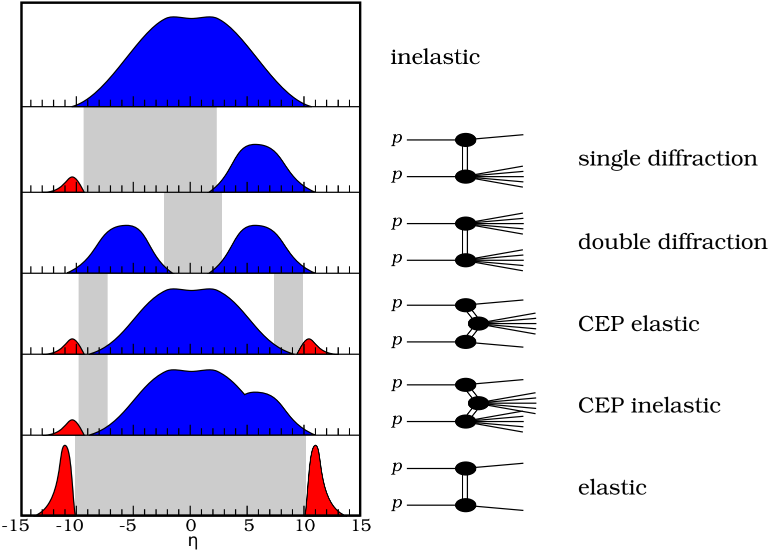
pomeron-pomeron



χ_{cJ}, χ_{bJ}, gg, $\ldots$

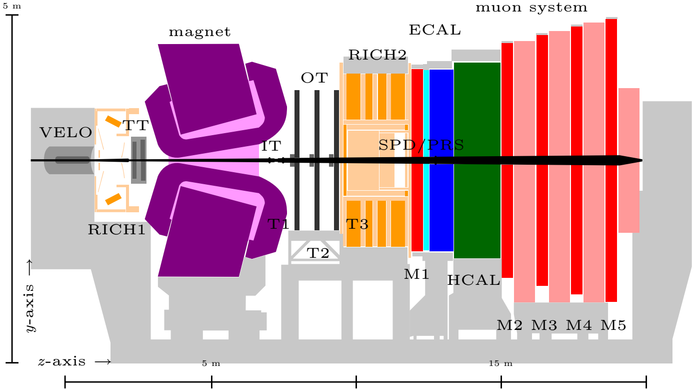
gluon PDF, glueball searches, QCD tests

Event Signatures



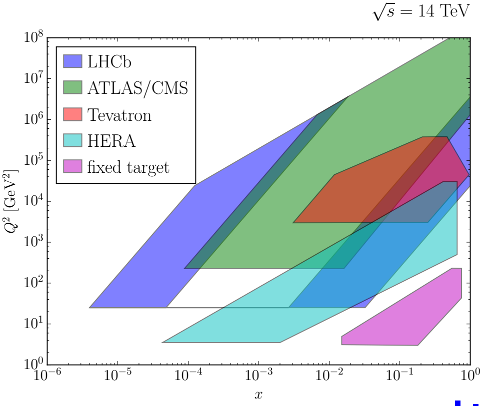
Detector

JINST **3** (2008) S08005



- fully instrumented between $2 < \eta < 5$
- momentum resolution between 0.4% at 5 GeV to 1% at 300 GeV
- secondary vertex precision of $0.01 - 0.05(0.1 - 0.3)$ mm in $xy(z)$
- dedicated CEP trigger lines

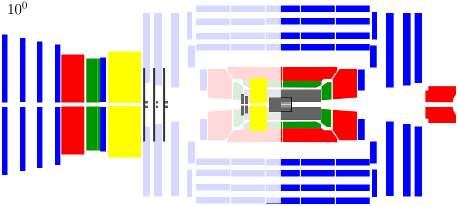
Forward Kinematics



$$Q^2(x) = e^{\pm 2y} x^2 s$$

$$\sigma = \int xfx(f_1, x_1, Q^2)\, xfx(f_2, x_2, Q^2)\hat{\sigma}\, \mathrm{d}x_1 \mathrm{d}x_2$$

$Q \equiv$ momentum transfer
$xfx \equiv$ parton PDF for flavor f
$x \equiv$ momentum fraction



Backward Tracks

LHCb

10 m

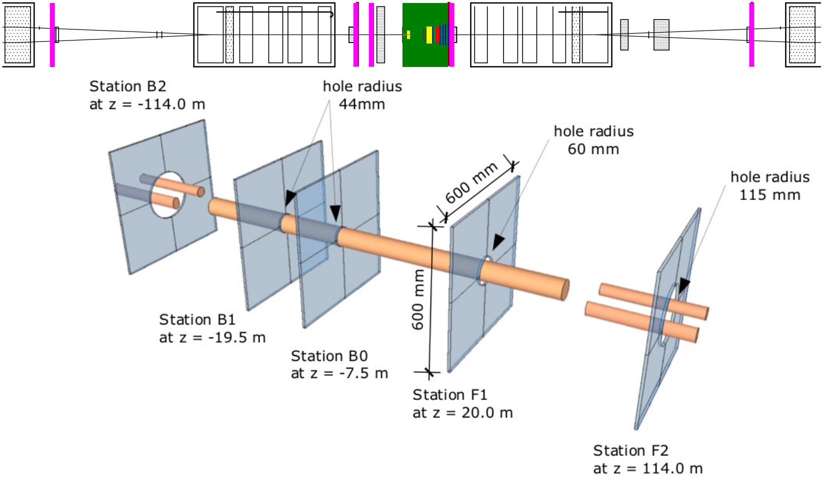
20 m

VELO

8.4 cm

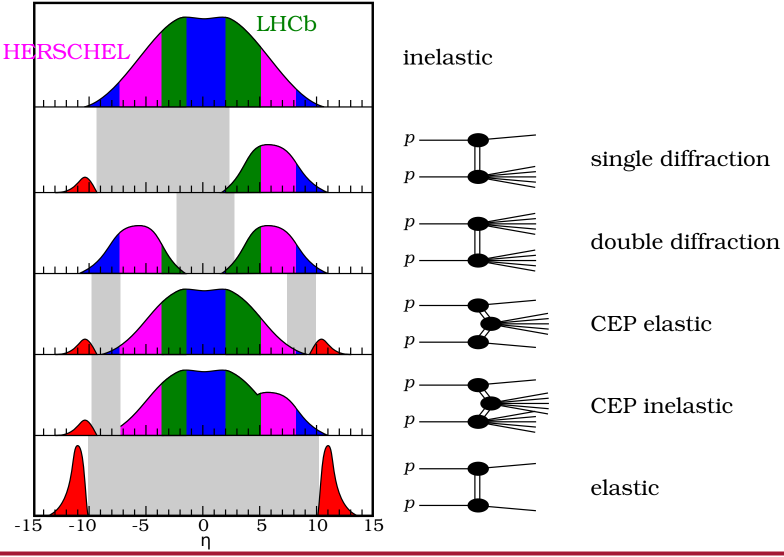
1 m

HERSCHEL



- high rapidity shower counters for LHCb

LHCb Rapidity Gap

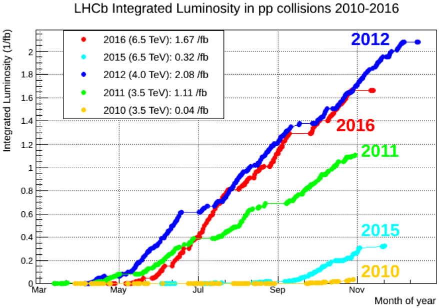


Datasets

JINST **9** (2014) 12, P12005

- 36 pb^{-1} at $\sqrt{s} = 7$ TeV (2010)
- 1 fb^{-1} at $\sqrt{s} = 7$ TeV (2011)
- 2 fb^{-1} at $\sqrt{s} = 7$ TeV (2012)
- 200 pb^{-1} at $\sqrt{s} = 13$ TeV (2015)

$$\mathcal{P}(N) = \frac{e^{\mu}\mu^{N}}{N!}$$

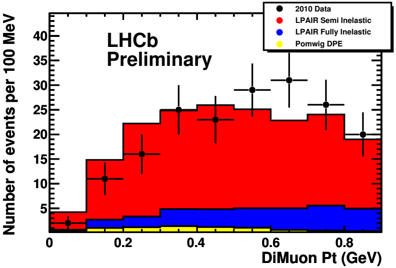


- 2010 $\mu = 1.6$ $\mathcal{P}(1) \approx 21\%$
- 2011 $\mu = 1.4$ $\mathcal{P}(1) \approx 25\%$
- 2012 $\mu = 1.7$ $\mathcal{P}(1) \approx 19\%$
- 2015 $\mu = 1.08$
  $\mathcal{P}(1) \approx 35\%$

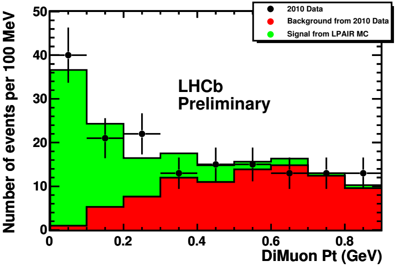
Dimuon Continuum

LHCb-CONF-2011-022

- uses 36 pb^{-1} of 2010 data at $\sqrt{s} = 7$ TeV
- no backwards tracks, two muons in acceptance, $p_{\mathrm{T}}(\mu) > 80$ MeV
- $m(\mu\mu) > 2.5$ GeV and exclude 100 MeV from resonances



more than two forward tracks

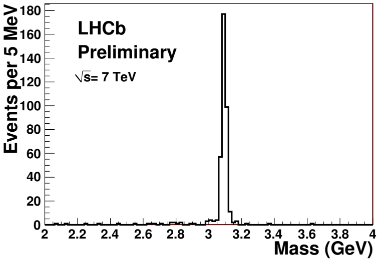


only two forward tracks

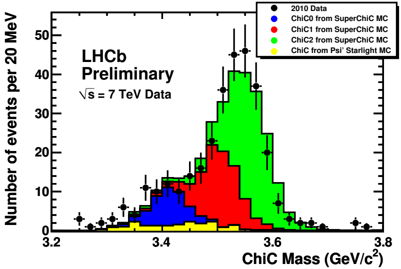
$$\sigma_{\mu\mu}(\text{data}) = 67 \pm 10 \pm 5 \pm 15\,\text{pb}$$
$$\sigma_{\mu\mu}(\text{LPAIR}) = 42 \pm 1$$

χ_{cJ} Production LHCb-CONF-2011-022

- same as dimuon but require exactly two muons and photon in acceptance



dimuon invariant mass

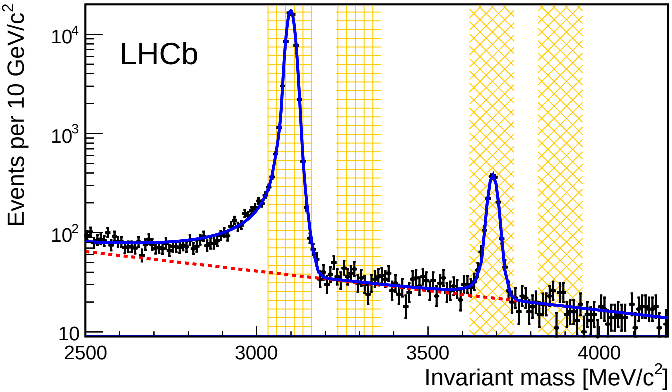


dimuon+photon invariant mass

$$
\begin{aligned}
\sigma_{\chi_{c0}\to\mu\mu\gamma} &= 9.3\pm2.2\pm3.5\pm1.8\,\text{pb} \\
\sigma_{\chi_{c1}\to\mu\mu\gamma} &= 16.4\pm5.3\pm5.8\pm3.2 \\
\sigma_{\chi_{c2}\to\mu\mu\gamma} &= 28.0\pm5.4\pm9.7\pm5.4
\end{aligned}
$$

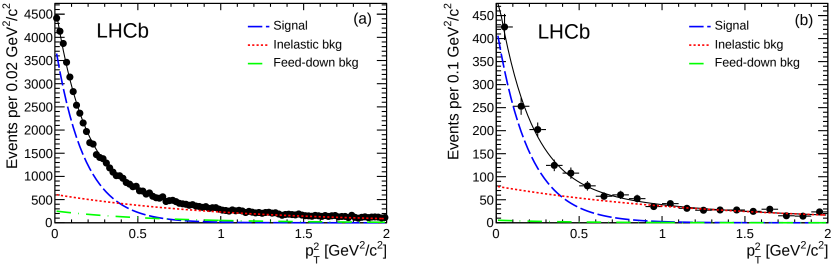
J/ψ and $\psi(2S)$ Production (1) J. Phys. G **41** (2014) 055002

- uses 930 pb^{-1} of 2011 data at $\sqrt{s} = 7$ TeV
- no backwards tracks, exactly two muons in acceptance, $p_{\mathrm{T}}(\mu) > 400$ MeV



J/ψ and $\psi(2S)$ Production (2) J. Phys. G **41** (2014) 055002

$$f_{\rm el}\, e^{-b_{\rm el} p_{\rm T}^2} + f_{\rm in}\, e^{-b_{\rm in} p_{\rm T}^2} + f_{\rm fd} \mathcal{P}_{\rm fd}(p_{\rm T}^2)$$



J/ψ

$b_{\rm el} = 5.70 \pm 0.11$ GeV^{-2}

$b_{\rm in} = 0.97 \pm 0.04$ GeV^{-2}

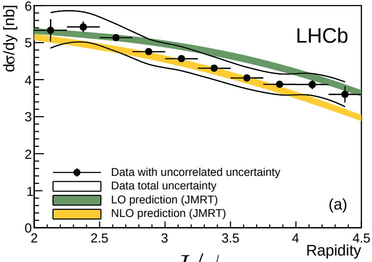
$\psi(2S)$

$b_{\rm el} = 5.1 \pm 0.7$ GeV^{-2}

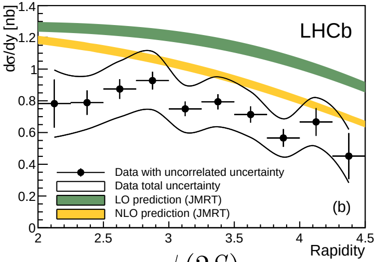
$b_{\rm in} = 0.8 \pm 0.2$ GeV^{-2}

- extrapolated from HERA $b_{\rm el} \approx 6$ GeV^{-2} and $b_{\rm in} \approx 1$ GeV^{-2}

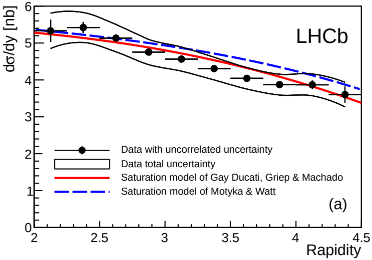
J/ψ and $\psi(2S)$ Production (3) J. Phys. G **41** (2014) 055002

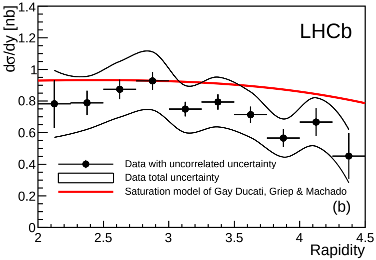


J/ψ



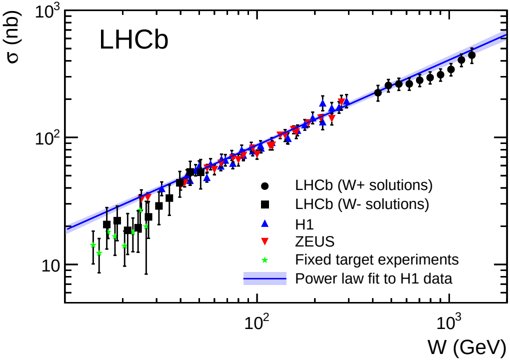
$\psi(2S)$





J/ψ and $\psi(2S)$ Production (4) J. Phys. G **41** (2014) 055002

$$\frac{d\sigma_{pp\to pJ/\psi p}}{dy} = r_+ k_+ \frac{dn}{dk_+}\sigma_{\gamma p\to J/\psi p}(W_+) + r_- k_- \frac{dn}{dk_-}\sigma_{\gamma p\to J/\psi p}(W_-)$$



- $\frac{dn}{dk_\pm}$ are photon fluxes, $k \approx m(J/\psi)/2e^{\pm|y|}$
- ${W_\pm}^2 = 2k_\pm\sqrt{s}$
- W_+ is photon emitter
- W_- is photon target
- $r_\pm$ are absorptive corrections

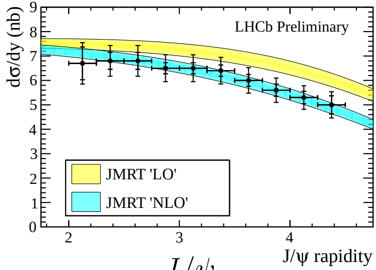
J/ψ and $\psi(2S)$ at 13 TeV (1) LHCb-CONF-2016-007

- uses 204 pb^{-1} of 2015 data at $\sqrt{s} = 13$ TeV
- HERSCHEL veto in place and used

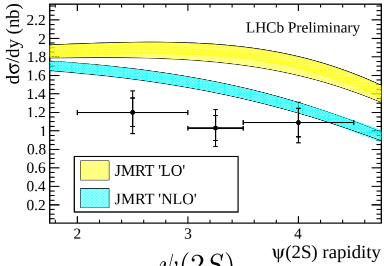
signal
background

without HERSCHEL *with HERSCHEL*

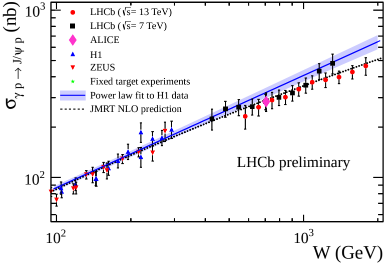
J/ψ and $\psi(2S)$ at 13 TeV (2) LHCb-CONF-2016-007

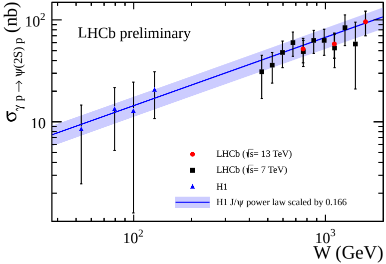


J/ψ



$\psi(2S)$

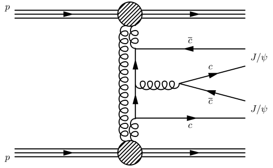


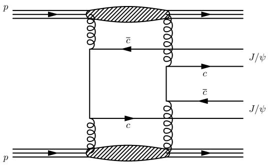


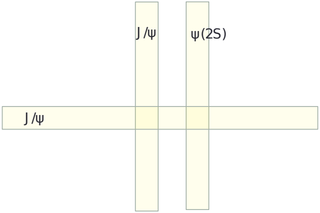
Double ψ Production

J. Phys. G **41** (2014) 15002

- uses 1 fb^{-1} of 2011 data at $\sqrt{s} = 7$ TeV
- uses 2 fb^{-1} of 2012 data at $\sqrt{s} = 8$ TeV







$$\sigma_{J/\psi,J/\psi} = 58 \pm 6 \text{ pb}$$

$$\sigma_{J/\psi,\psi(2S)} = 63^{+27}_{-18} \pm 10 \text{ pb}$$

$$\sigma_{\chi_{c0}\chi_{c0}} < 69 \text{ nb}$$

$$\sigma_{\chi_{c1}\chi_{c1}} < 45 \text{ nb}$$

$$\sigma_{\chi_{c2}\chi_{c2}} < 141 \text{ nb}$$

Outlook

- comprehensive exclusive production program at LHCb
- important for odderon and glueball searches
- provides data for understanding PDFs
- HERSCHEL performing well
- more results using final states other than muons and photons underway!

Thank you!