LHCb Status & Plans for Yellow Report

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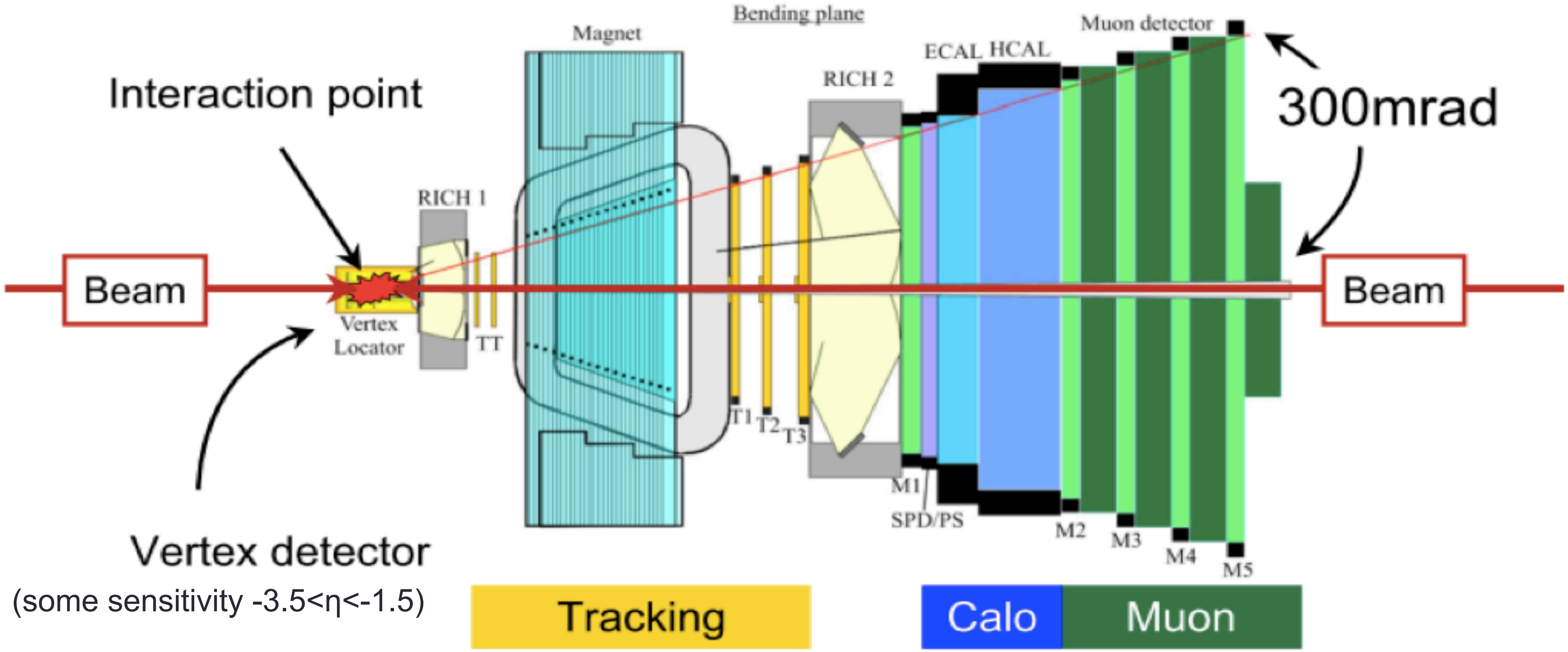
on behalf of the LHCb collaboration

LHC Forward physics & diffraction.
19th February 2013

Outline

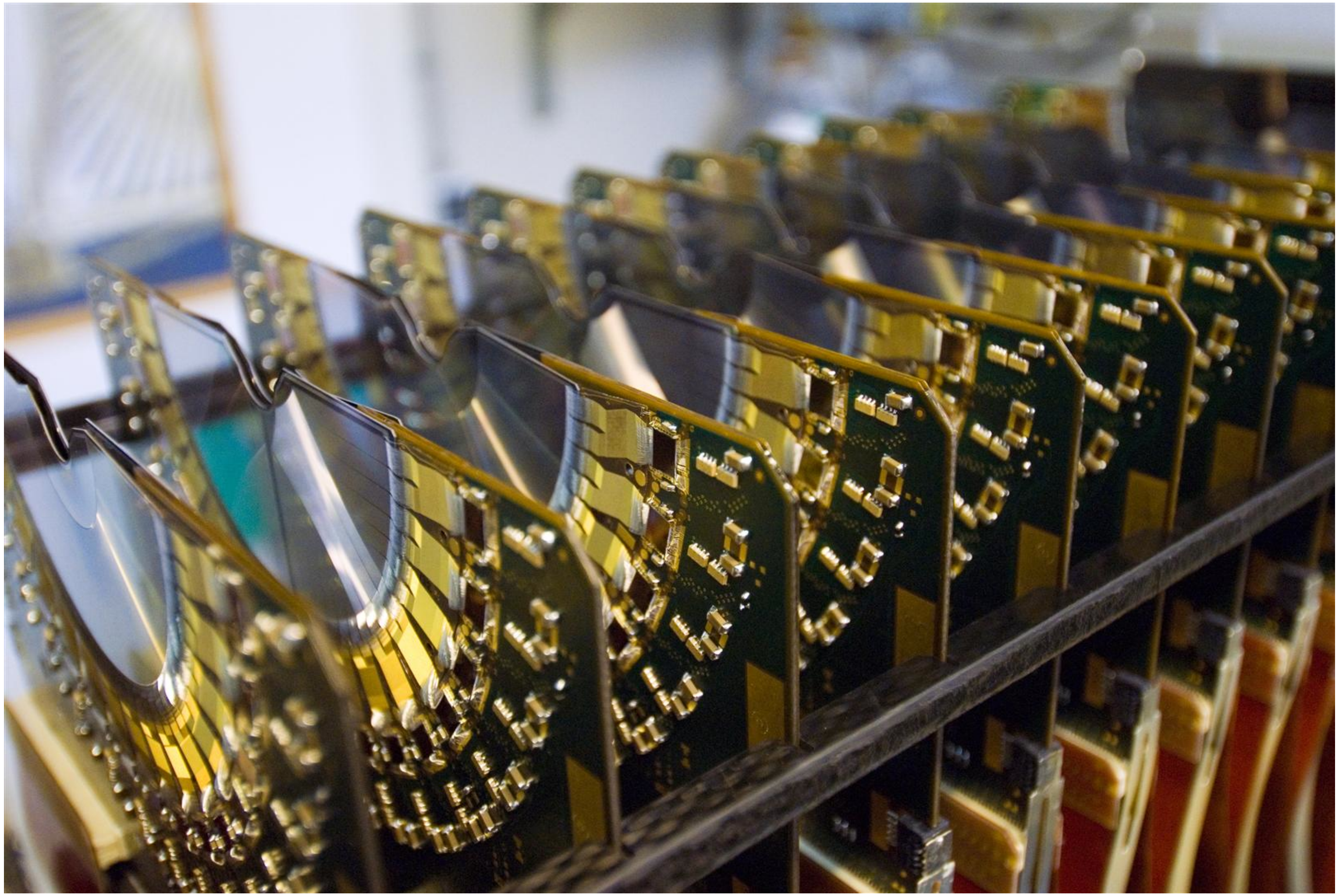
- General comments on LHCb
- Recent results on Central Exclusive Production
- Detector improvements
- Plans for Yellow Report
  - Focus on Chapter 5: Future CEP measurements

The LHCb detector



Fully instrumented from $2 < \eta < 5$
Trigger on e,h,μ,γ of few 100 MeV
Low pile-up
Ideal for low mass CEP

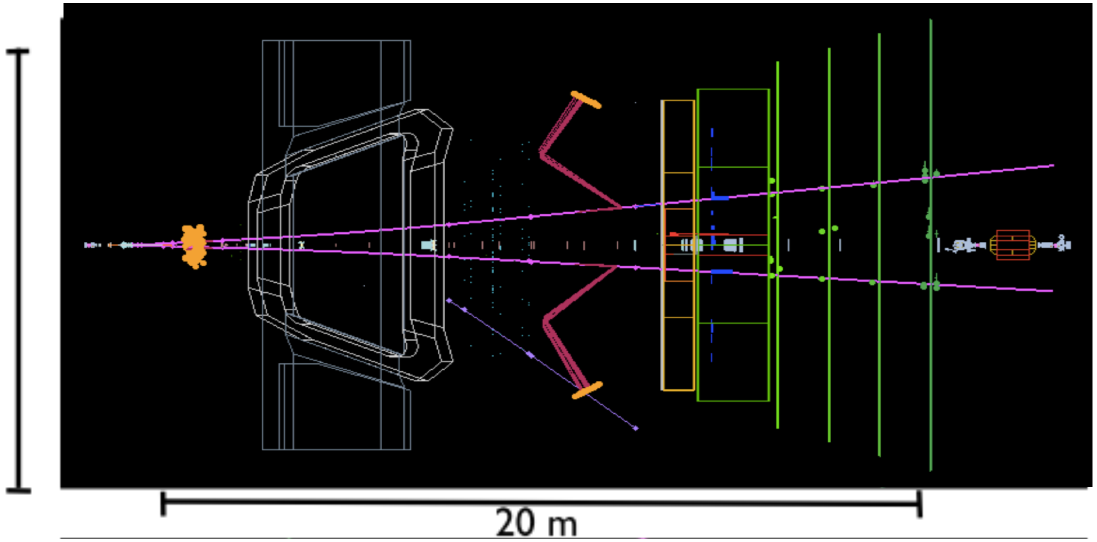
VELO sub-detector



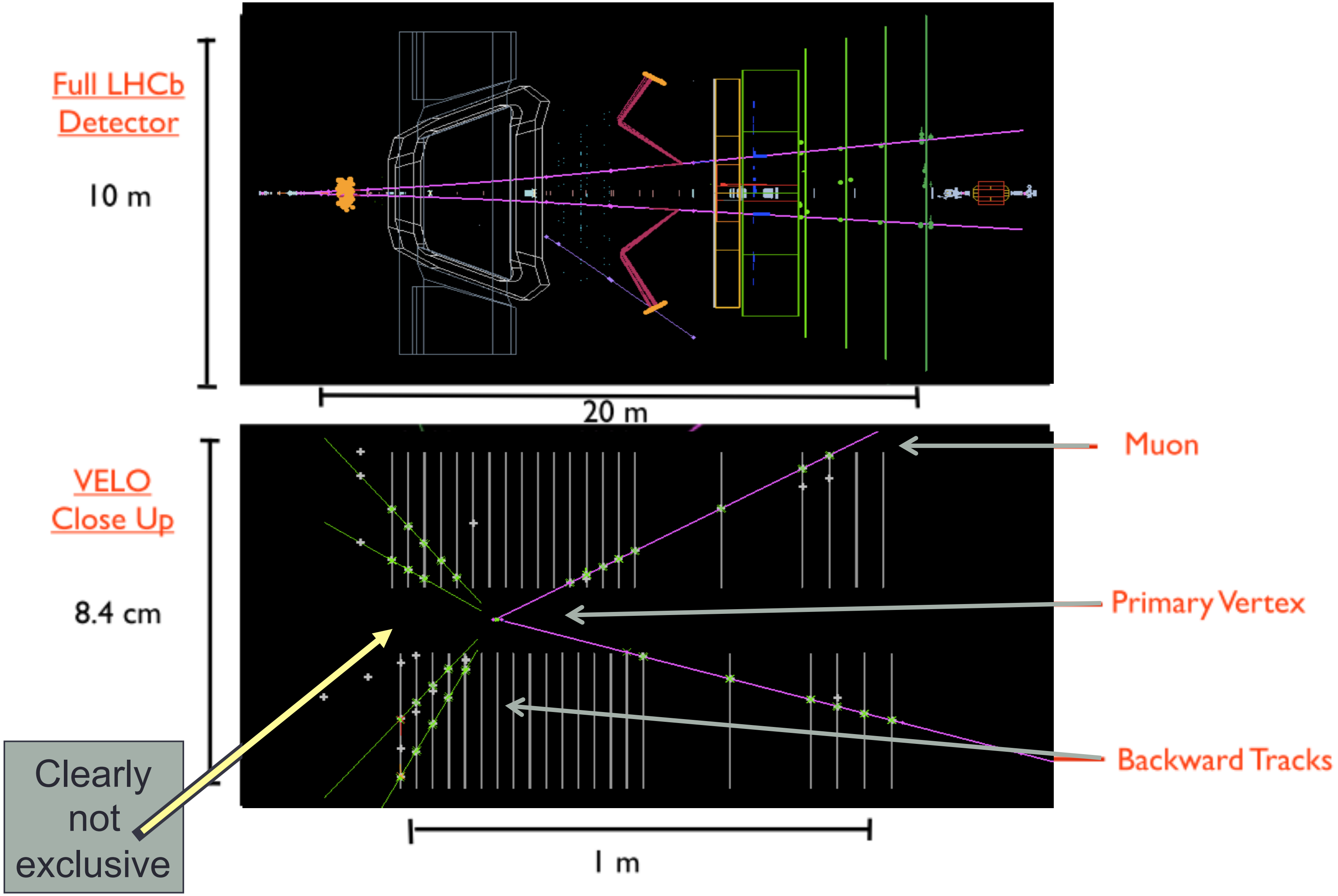
Use of backwards tracks

Full LHCb Detector

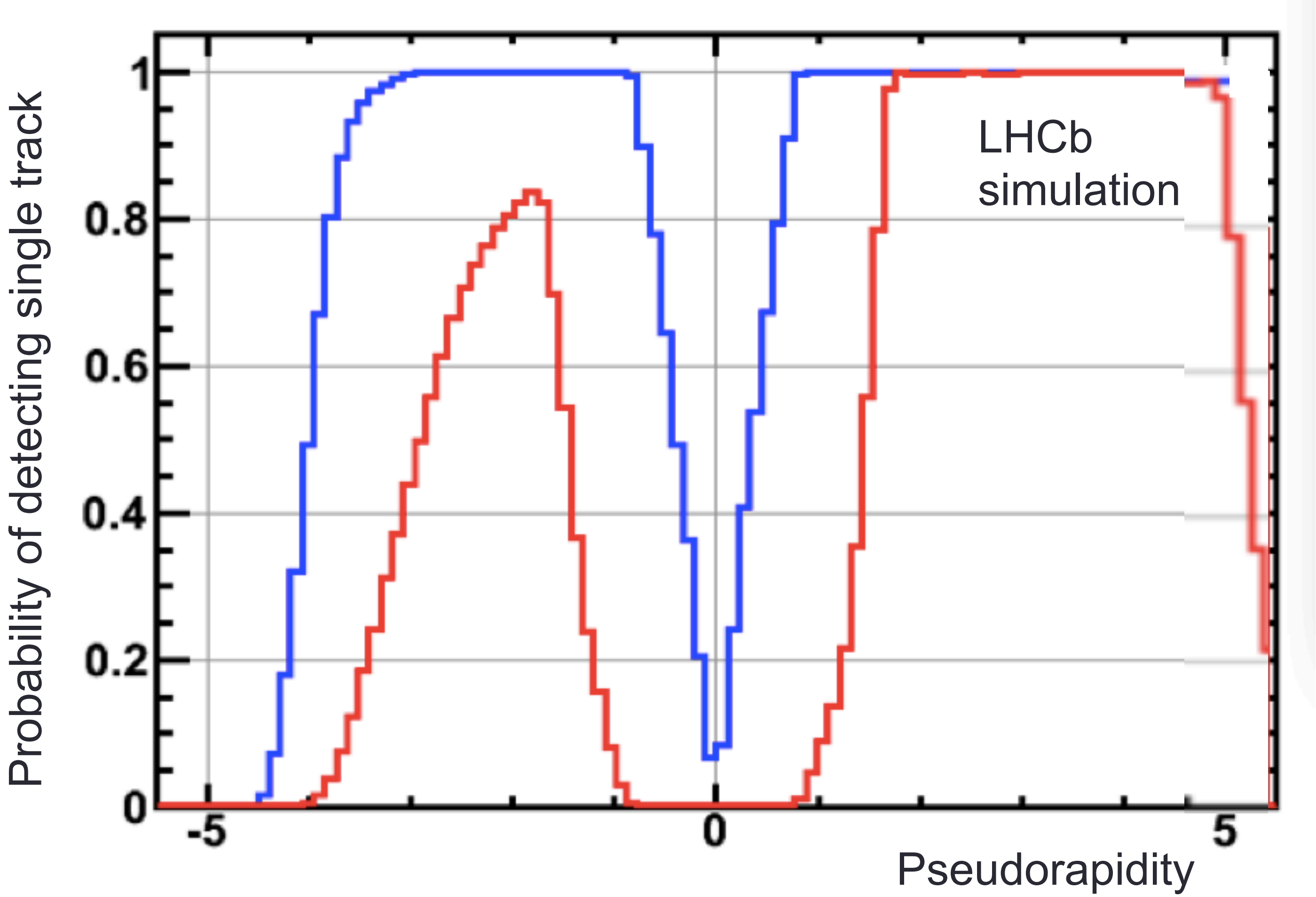
10 m



Use of backwards tracks



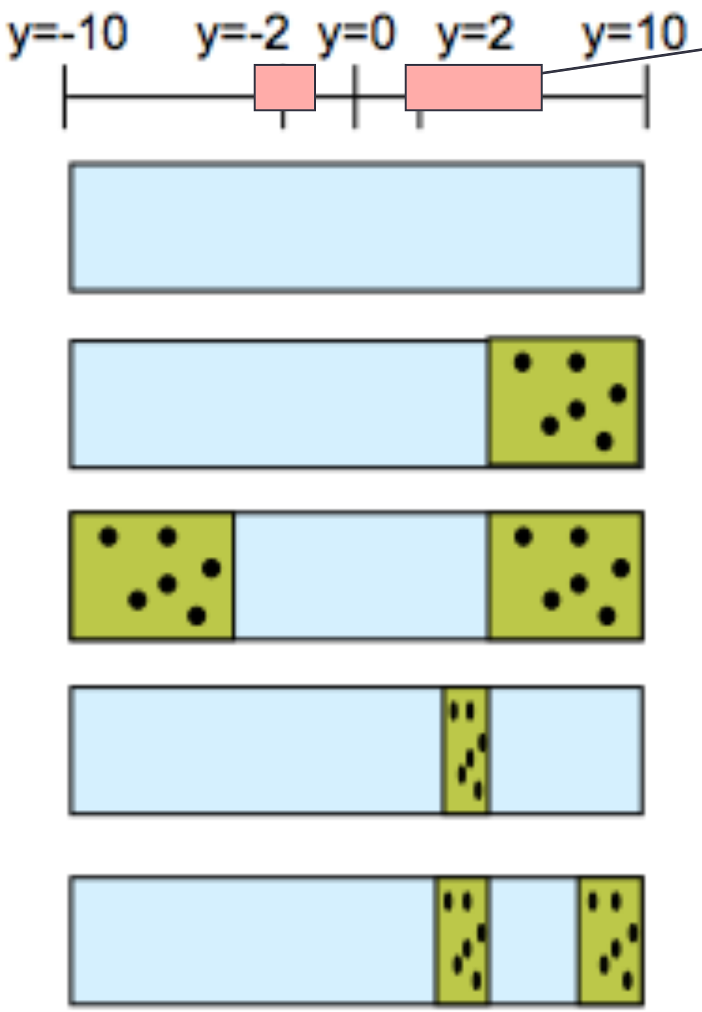
Pseudorapidity veto range



All results I show imply red region void, (except for muons from signal).

Graphical Representation

Rough LHCb coverage



Elastic Scattering

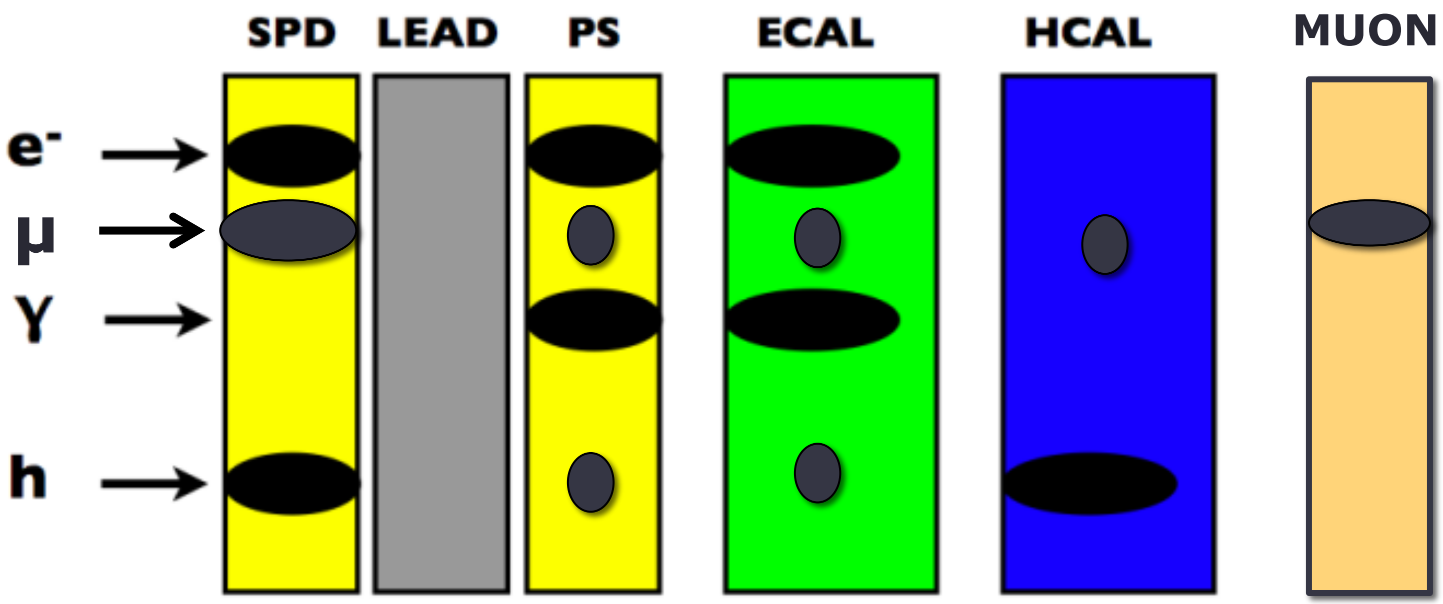
Single Diffraction

Double Diffraction

Central Exclusive Production (elastic)

Central Exclusive Production (inelastic)

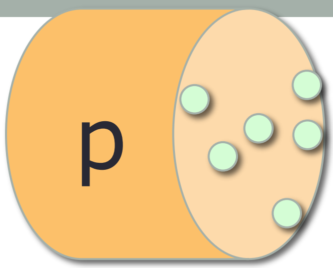
Calorimeter System in LHCb



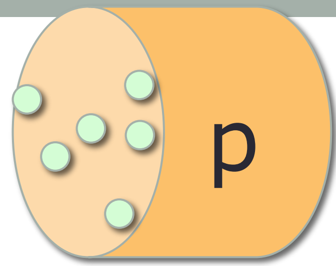
Scintillation Pad Detector.
If a charged particle goes through, we get a signal.
Rough count of number of charged particles.

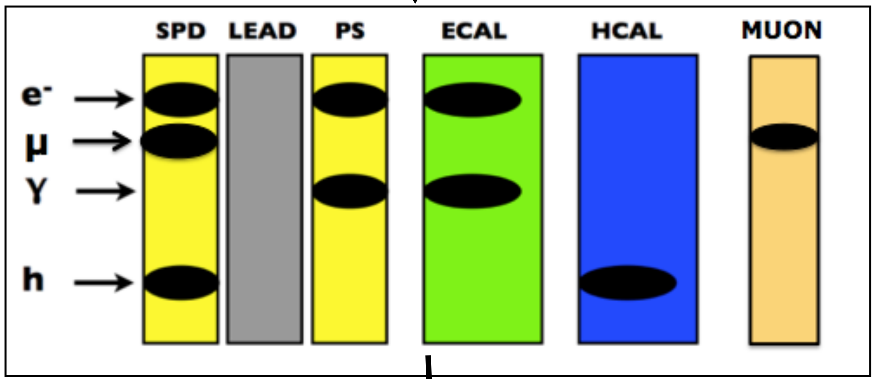
Use in trigger to select **low multiplicity** events for CEP. <10 hits

Triggering



40 MHz



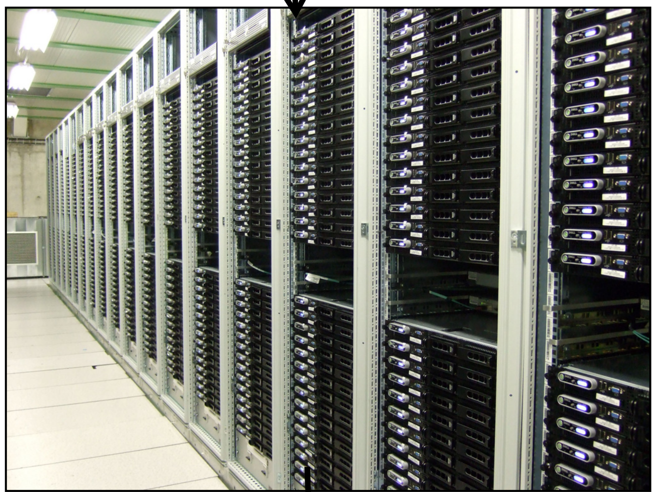


L0 Trigger:

$p_T^{\mu}>400$ MeV
#SPD<10

Hardware:
Fast electronics

~1 MHz



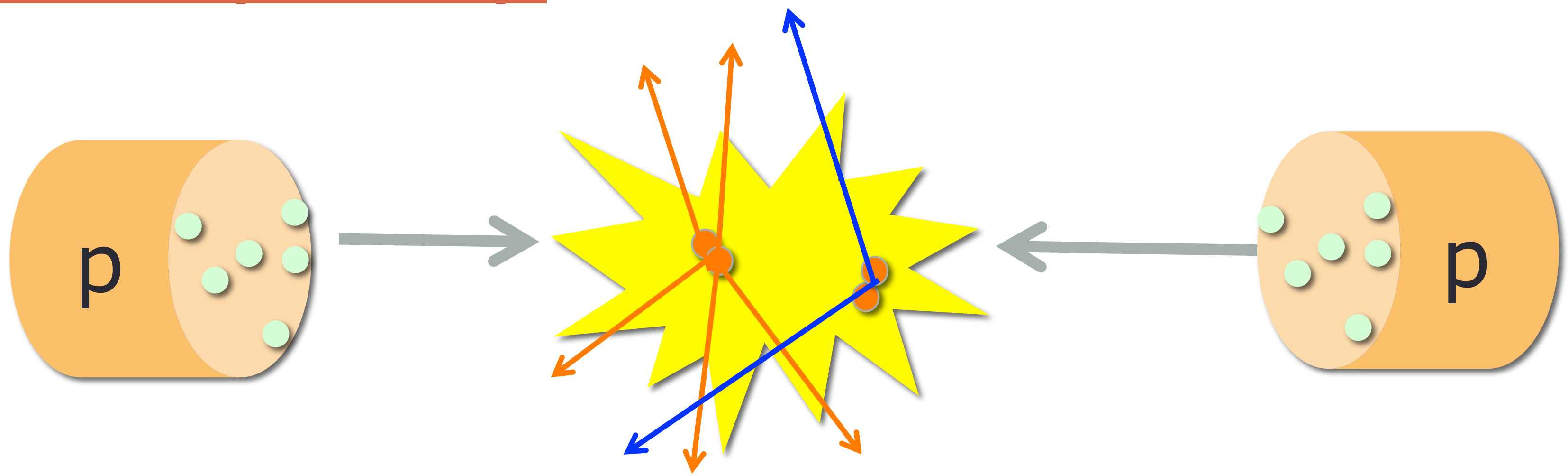
HLT Trigger:

Two muons
with p_T > 400 MeV

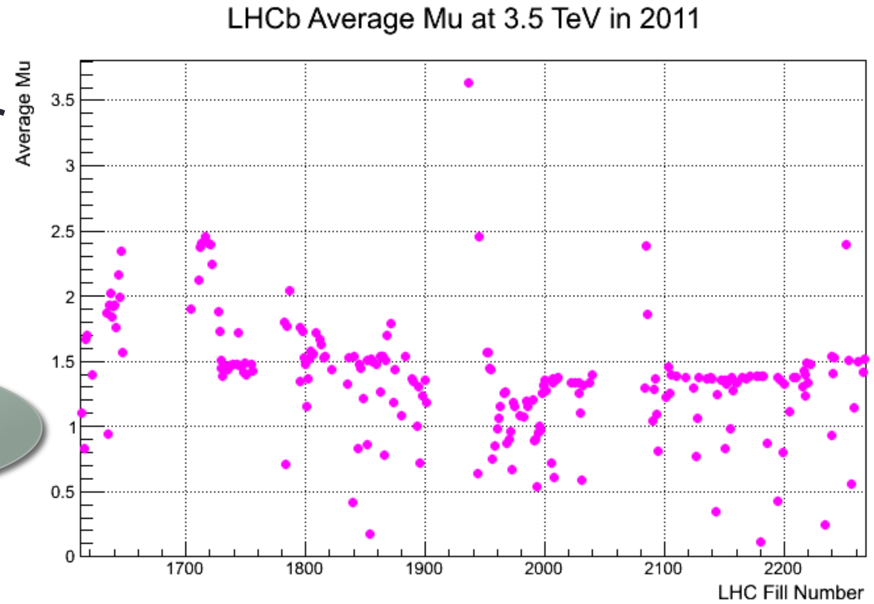
Software:
Parallel processing

~2 kHz

Beam pile-up



High luminosity requires multiple proton interactions per beam-crossing.



Number of interactions (N) /crossings, distributed

Average #interactions

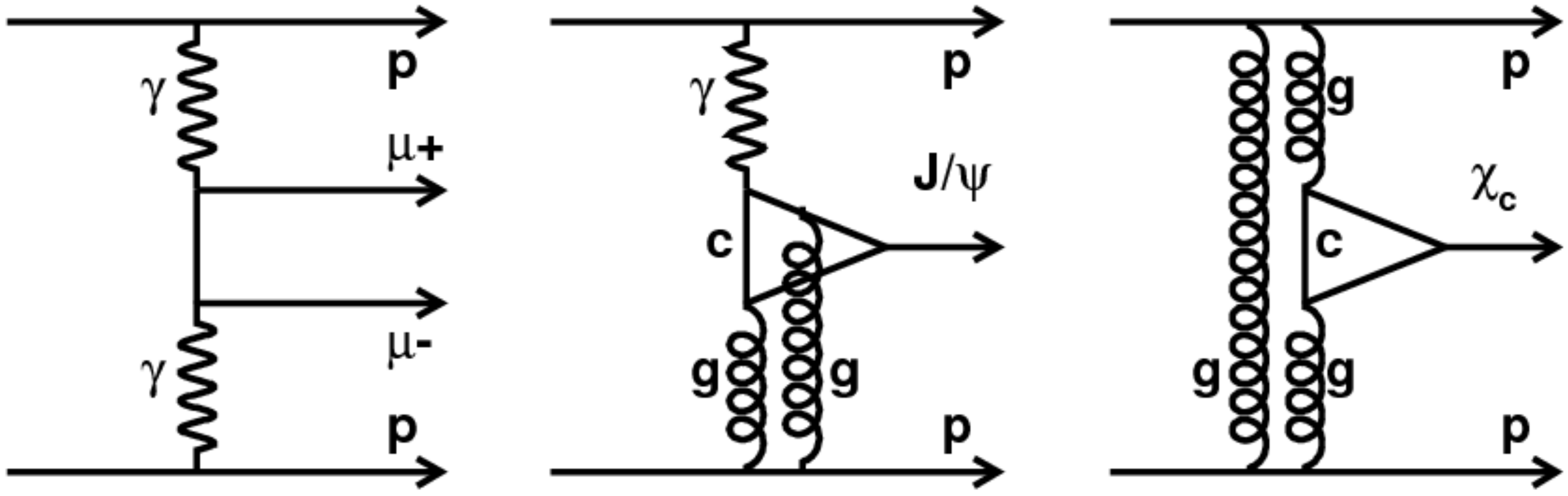
$$f(N) = \frac{e^{\mu}\mu^{N}}{N!}$$

For LHCb in 2011, $\bar{\mu}$=1.4

Central Exclusive Production of J/ψ and $\psi(2S)$ mesons

Data-taking year	Energy	Integrated Luminosity	Paper
2010	7 TeV	$37pb^{-1}$	JPG 40 (2013) 045001
2011	7 TeV	$930pb^{-1}$	arXiv: 1401.3288 (accepted by JPG)

Central Exclusive Production with Dimuon final states



QED

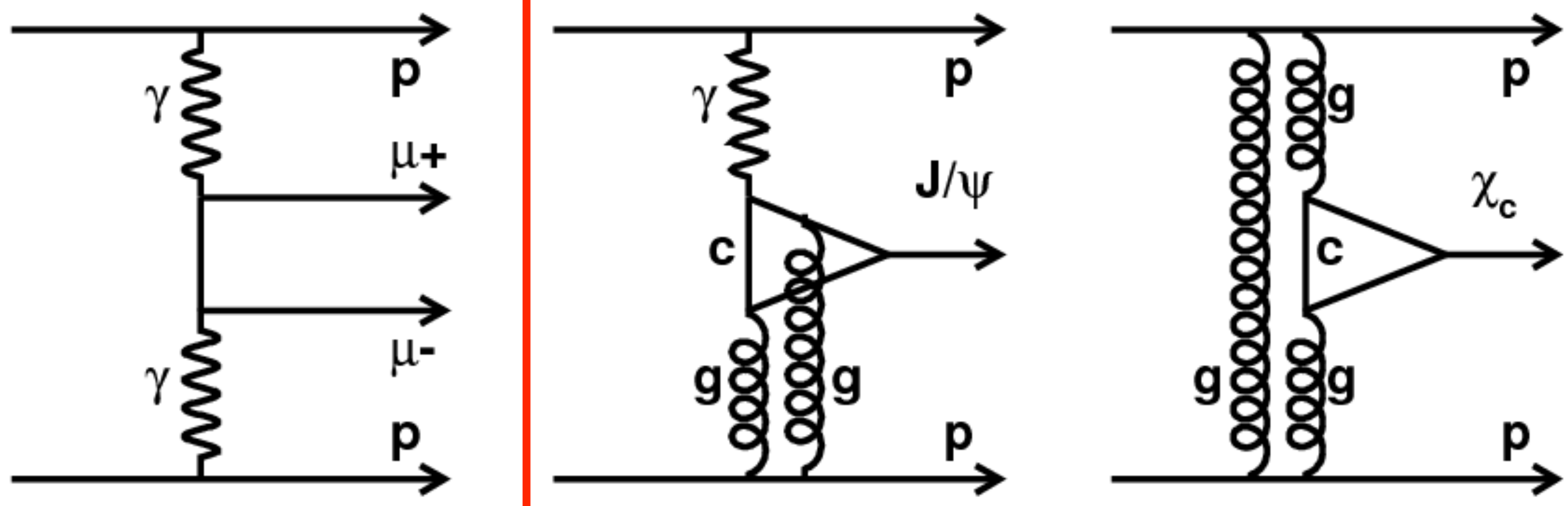
Photo production

Double pomeron exchange

(Note: $J/\psi \rightarrow \mu\mu$ and $\chi_c \rightarrow J/\psi\gamma$)

Related phenomena where the colourless object creates a particle

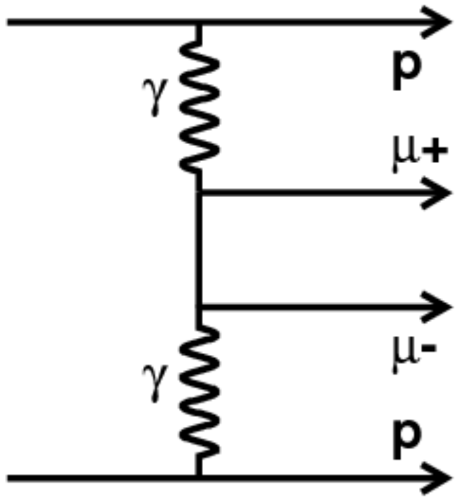
Central Exclusive Production with Dimuon final states



QED   Photo production   Double pomeron exchange

- QED process. Can be predicted with high accuracy (~1%)
- Candidate process for very precise luminosity determination at LHC

Central Exclusive Production with Dimuon final states



QED

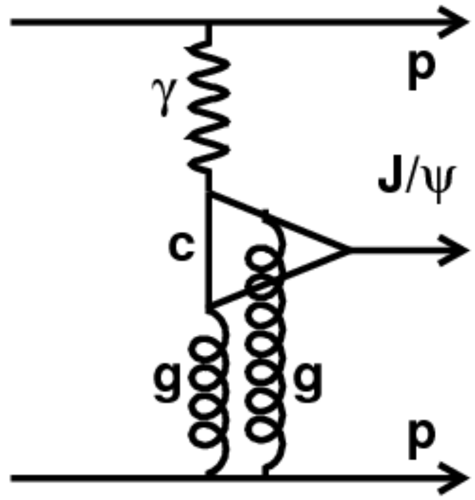
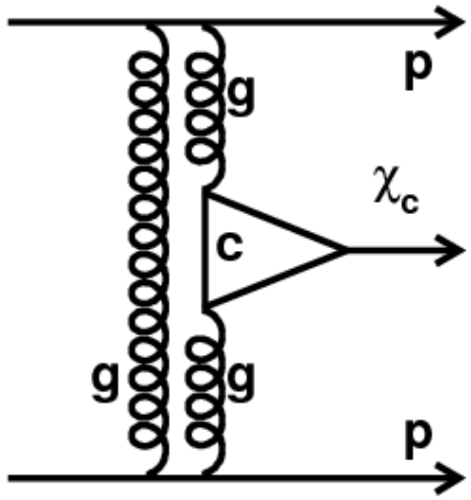


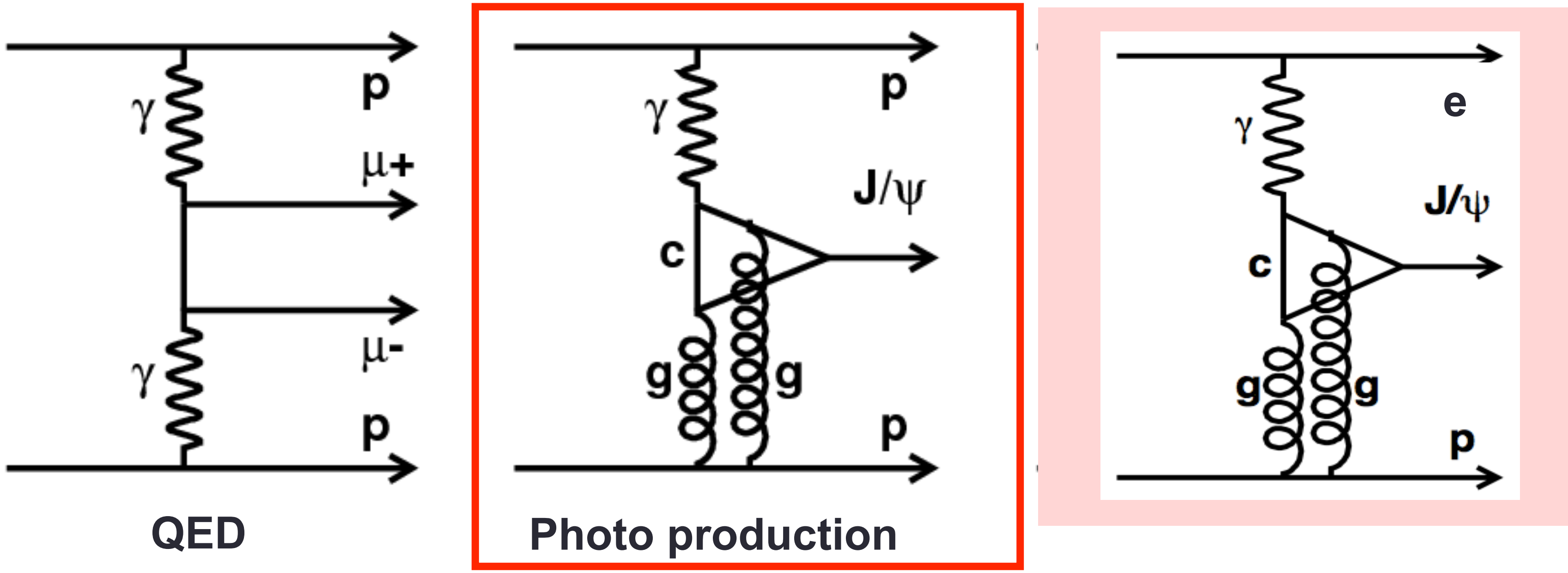
Photo production



Double pomeron exchange

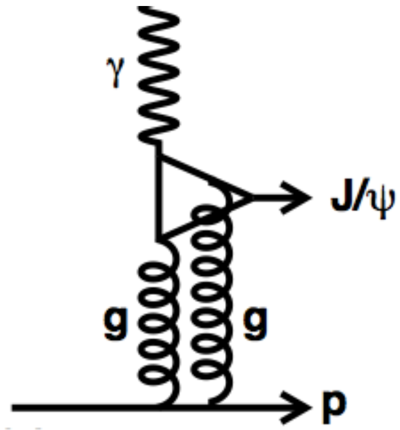
- Double pomeron exchange.
- Unambiguous evidence for pomeron
- ‘Standard Candle’ for other DPE processes, in particular, Higgs.

Central Exclusive Production with Dimuon final states



- Test of QCD and pomeron in clean environment
- Sensitive to diffractive PDF at very low x (to 5×10^{-6})
- Search for the odderon and saturation effects
- Measured at HERA/Tevatron but at different photon-proton energy, W

Photo-production cross-section

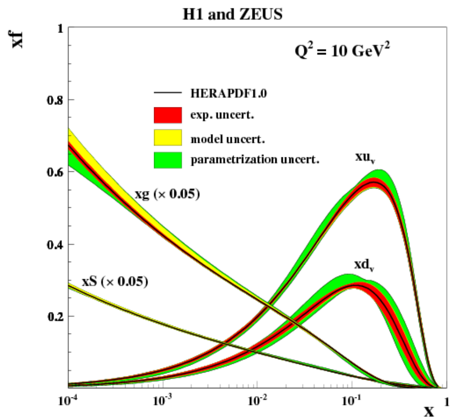


$$\frac{d\sigma}{dt}(\gamma^* p \to J/\psi\ p)\Big|_{t=0} = \frac{\Gamma_{ee} M^3_{J/\psi} \pi^3}{48\alpha}\left[\frac{\alpha_s(\bar{Q}^2)}{\bar{Q}^4} xg(x,\bar{Q}^2)\right]^2 \left(1 + \frac{Q^2}{M^2_{J/\psi}}\right)$$

$$\bar{Q}^2 = (Q^2 + M^2_{J/\psi})/4, \qquad x = (Q^2 + M^2_{J/\psi})/(W^2 + M^2_{J/\psi}).$$

Cross-section proportional to gluon² $\sigma \sim (xg)^2$

and so $\sigma \sim x^{\lambda}$



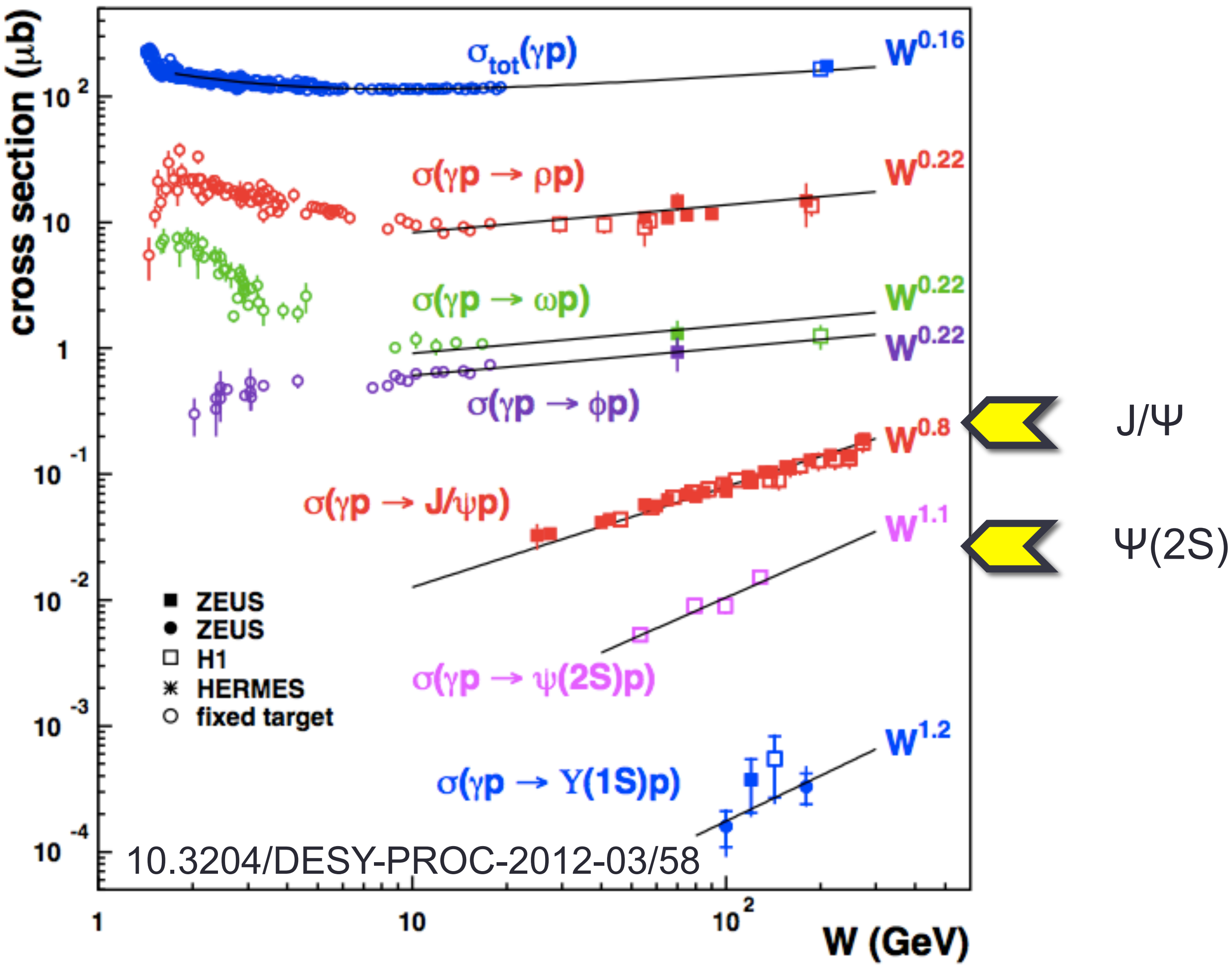
[1] Martin A D, Nockles C, Ryskin M and Teubner T 2008 Small x gluon from exclusive J/ψ production *Phys. Lett.* B **662** 252 (arXiv:0709.4406)

[2] Ryskin M G 1993 J/ψ electroproduction in LLA QCD *Z. Phys.* C **57** 89

[3] Ryskin M G, Roberts R G, Martin A D and Levin E M 1997 Diffractive J/ψ photoproduction as a probe of the gluon density *Z. Phys.* C **76** 231 (arXiv:hep-ph/9511228)

[4] S. Jones, A. Martin, M. Ryskin, and T. Teubner, *Probes of the small x gluon via exclusive J/ψ and Υ production at HERA and the LHC*, JHEP **1311** (2013) 085, arXiv:1307.7099.

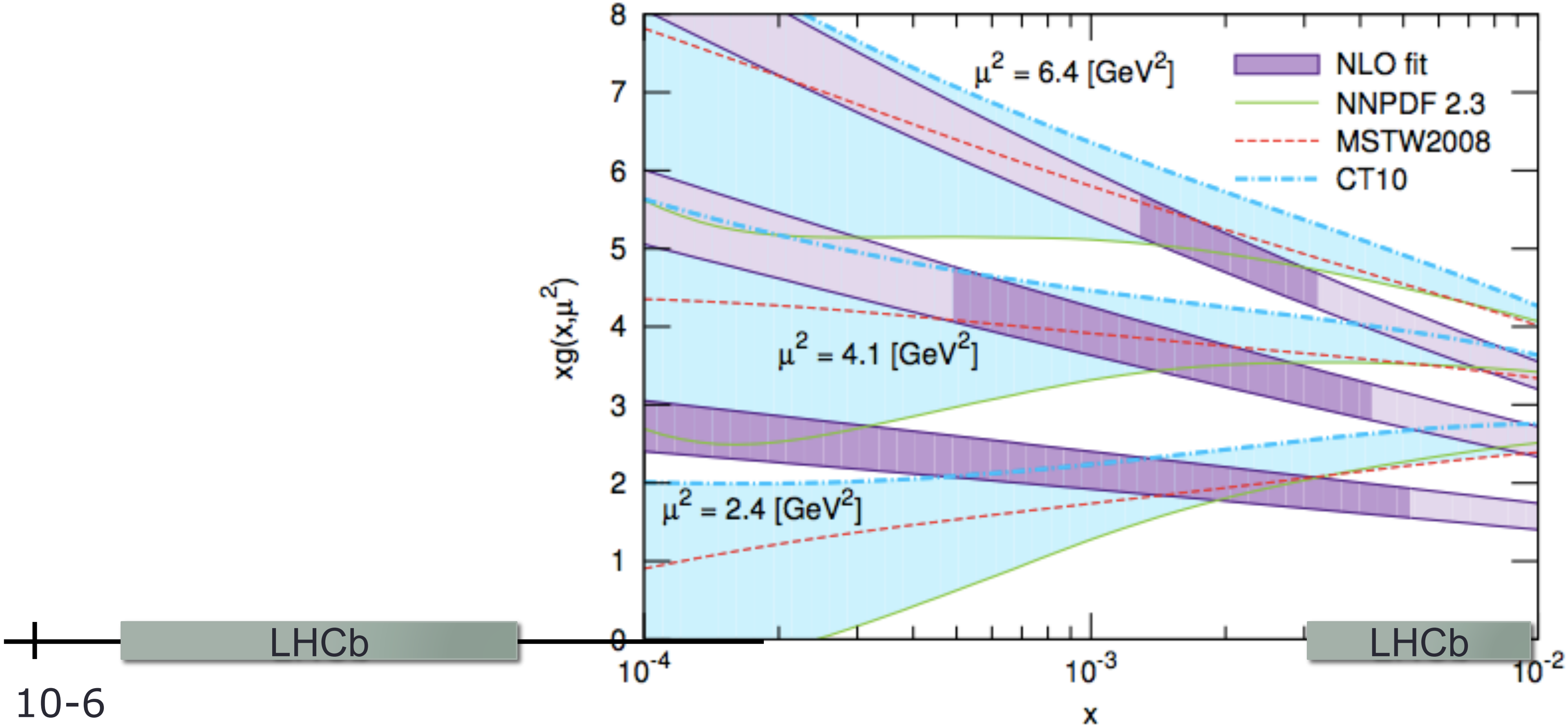
HERA vector meson photo-production results



Note:

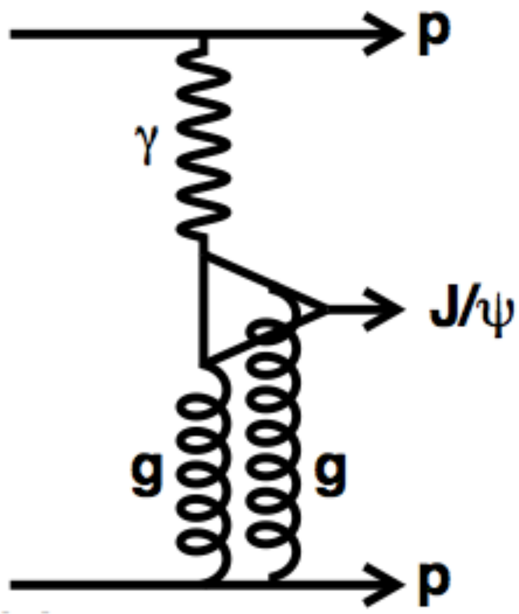
- $\sigma \sim x^{\lambda}$
- soft/hard
- $g(x,Q^2)$

Sensitivity to gluon pdf (arXiv: 1307.7099)



S. Jones, A. Martin, M. Ryskin, and T. Teubner, *Probes of the small x gluon via exclusive J/ψ and Υ production at HERA and the LHC*, JHEP **1311** (2013) 085, arXiv:1307.7099.

Simple Selection Criteria

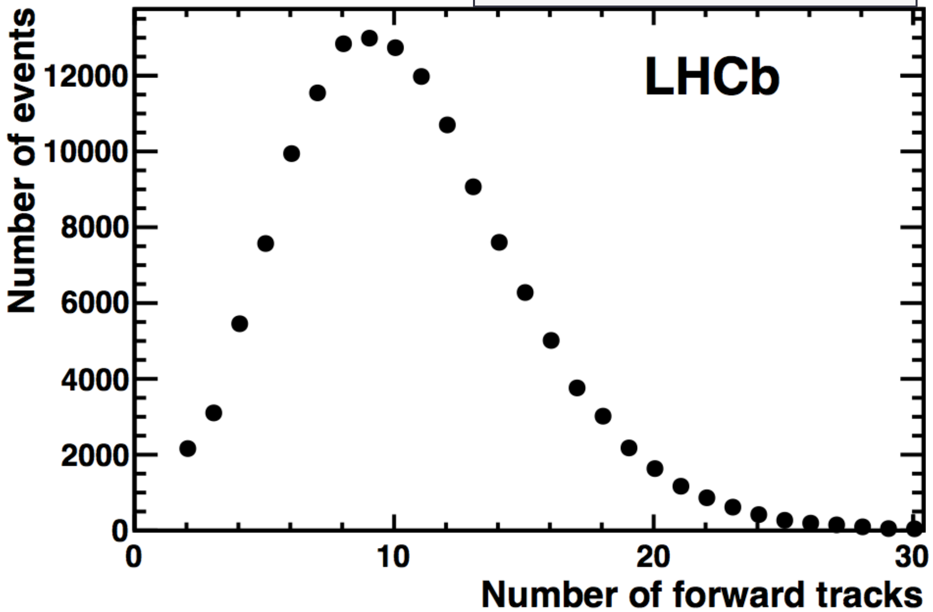


- **Precisely two forward muons**
- **No backward tracks**
- No photons
- p_T^2 of dimuon < 0.8 GeV^2
- Mass of dimuon within 65 MeV of J/ψ or ψ(2S)

2 forward gaps that sum to 3.5 units of rapidity + a backward <gap> of 1.7

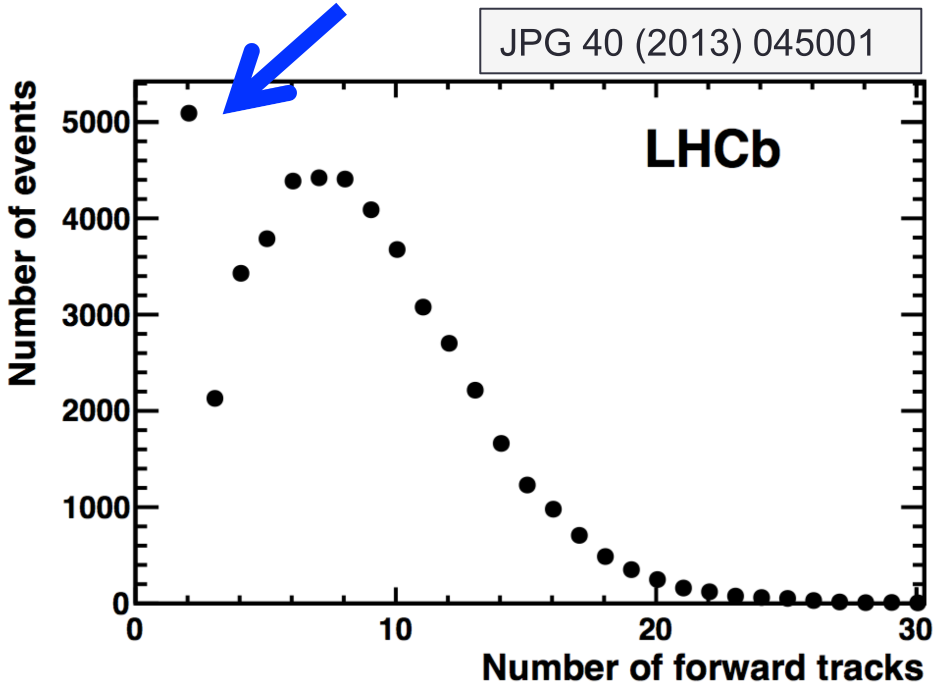
Effect of rapidity gap requirement on low multiplicity muon triggered events

JPG 40 (2013) 045001



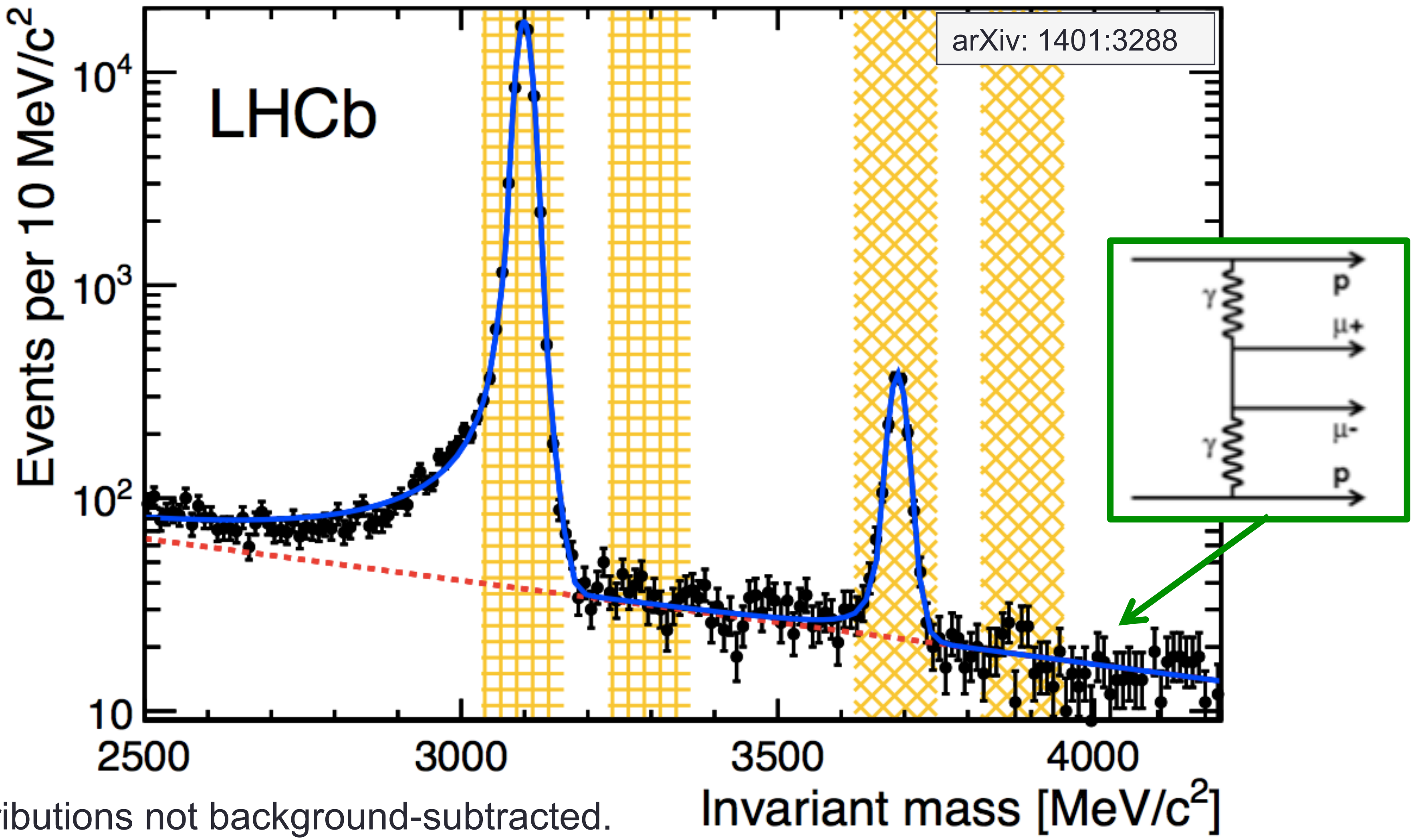
All triggered events

JPG 40 (2013) 045001



With veto on backward tracks

Non-resonant background very small



Distributions not background-subtracted.
55985 J/ψ and 1565 ψ(2s)

Cross-section measurement J/ψ / ψ(2S)

$$\frac{d\sigma}{dy} = \frac{pN}{A\varepsilon L\Delta y}$$

Number of events observed

Luminosity

Acceptance (MC)

Cross-section measurement J/ψ / ψ(2S)

$$\frac{d\sigma}{dy} = \frac{pN}{A\varepsilon L\Delta y}$$

Number of events observed

Luminosity

Acceptance (MC)

Efficiency: (found from data)

1. Trigger
2. Muon identification
3. Single interaction beam-crossing

$$P(1) = \mu^1 e^{-\mu} / 1!$$

Cross-section measurement J/ψ / ψ(2S)

Purity: (found from data)
1. non-resonant bkg (1% / 17%)
2. Feeddown (10% / 2%)
3. Inelastic Jpsi production (40% / 40%)

Number of events observed

$$\frac{d\sigma}{dy} = \frac{pN}{A\varepsilon L\Delta y}$$

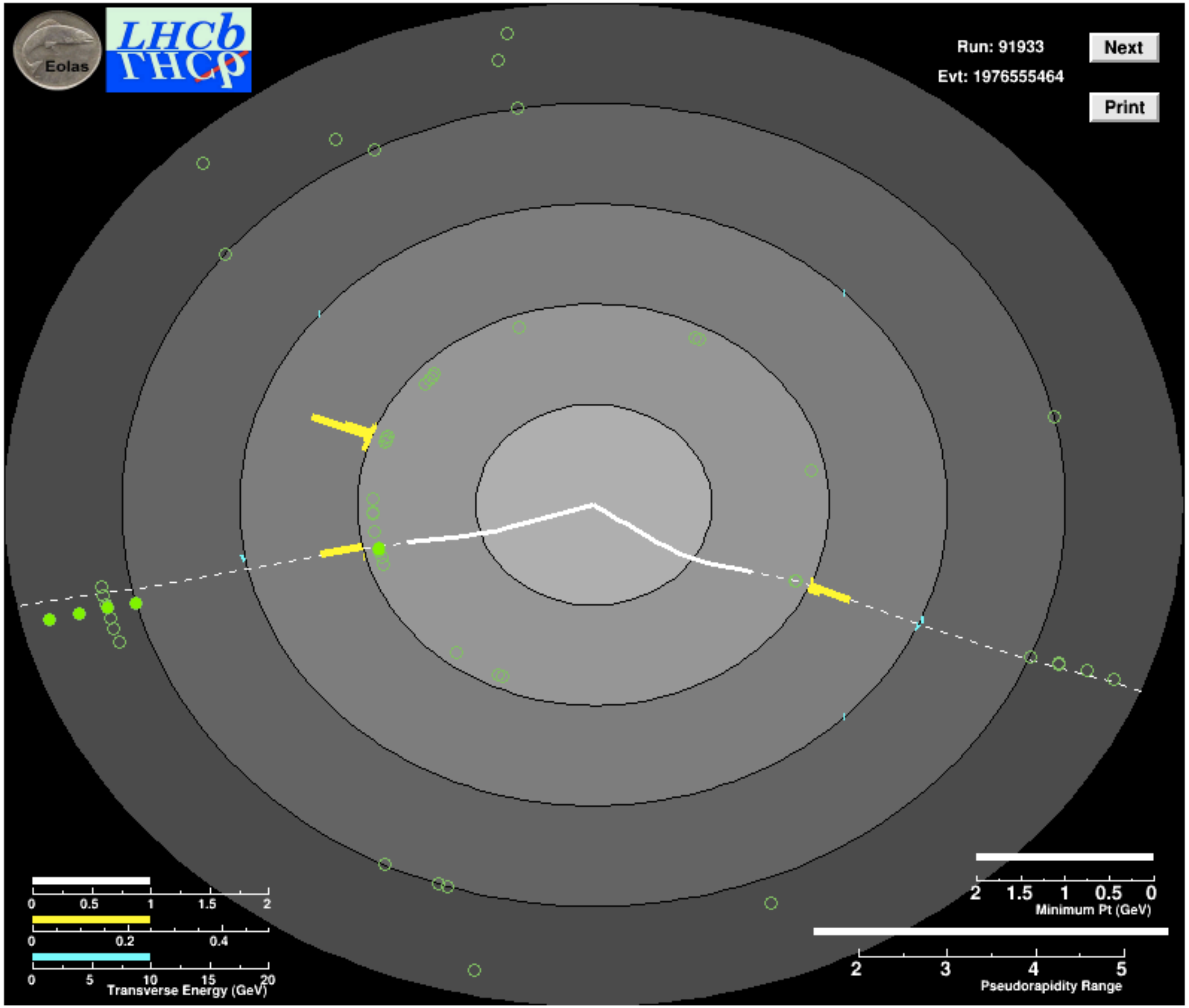
Luminosity

Acceptance (MC)

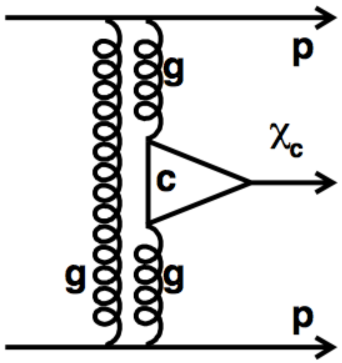
Efficiency: (found from data)
1. Trigger
2. Tracking & muon id.
3. Single interaction beam-crossing

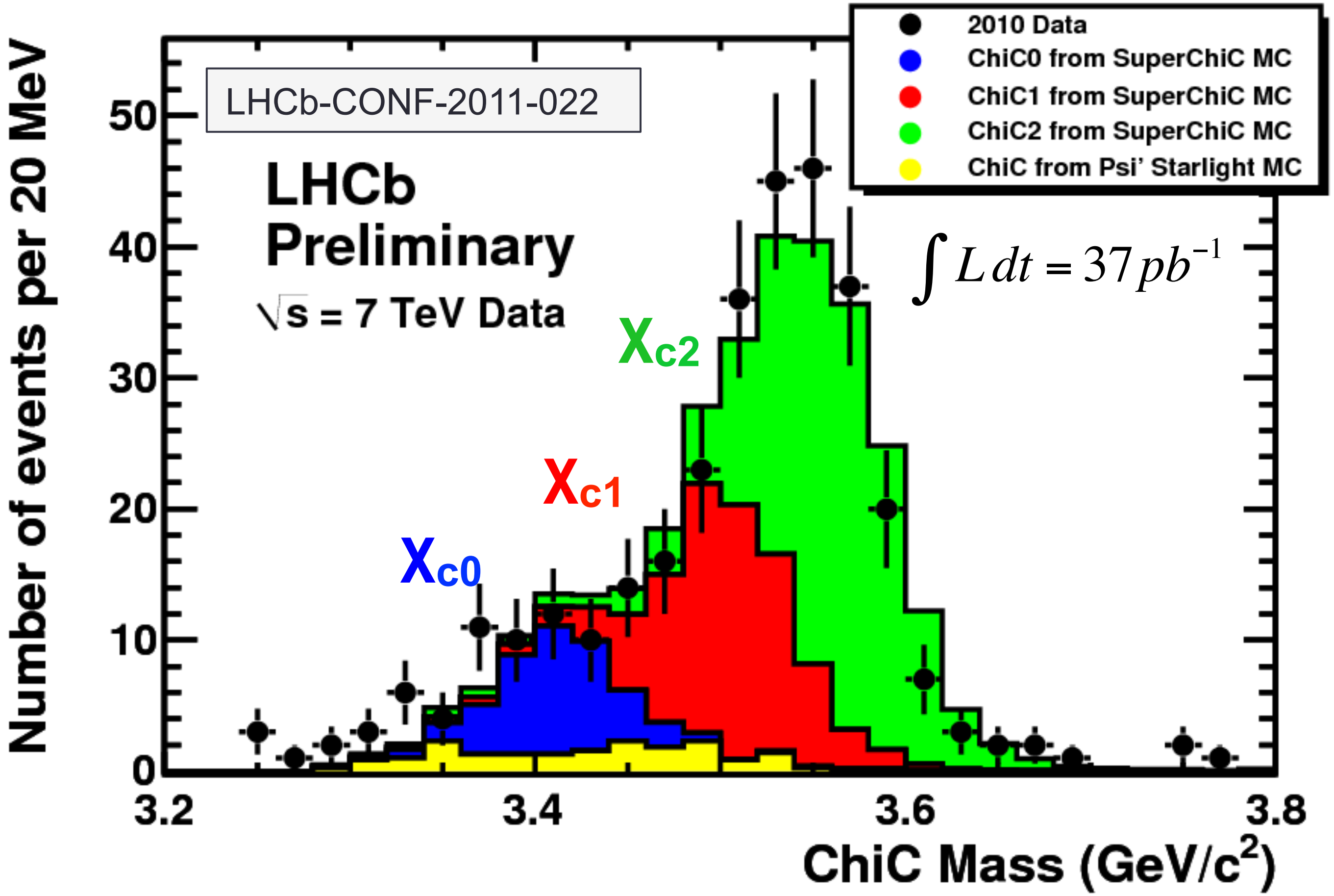
$$P(n) = \mu^n e^{-\mu} / n!$$

Candidate for χ_c decay to $J/\psi+\gamma$

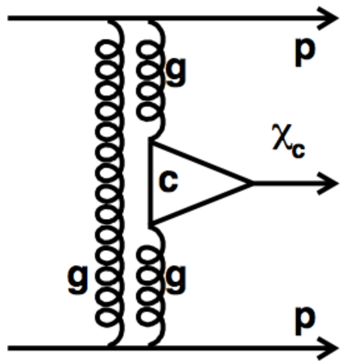


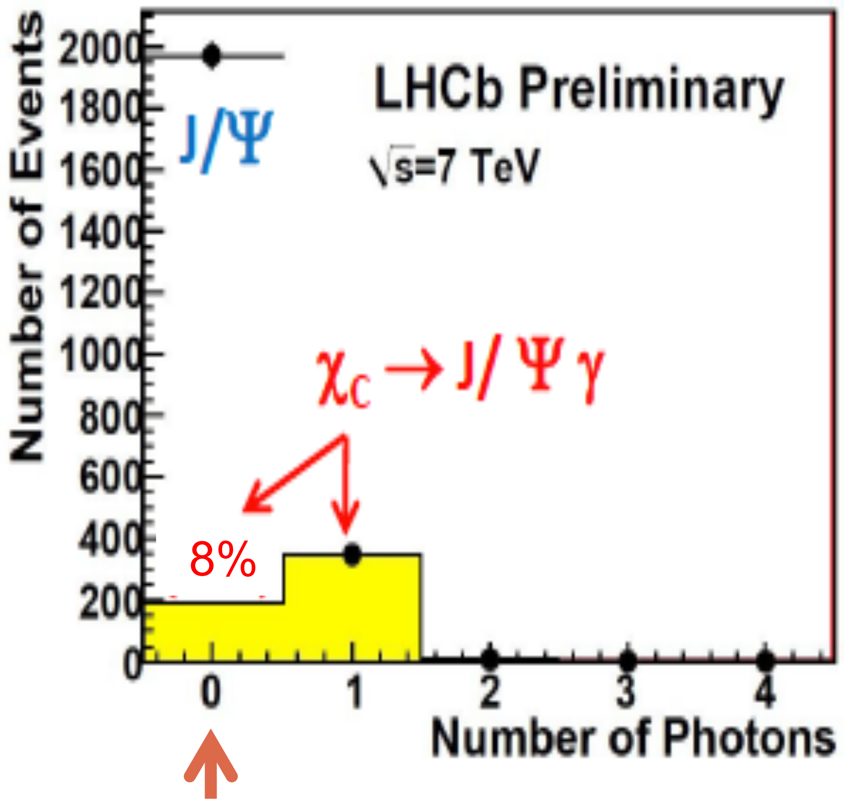
Selected $\chi_{c0,1,2}$ candidates





Feed-down background

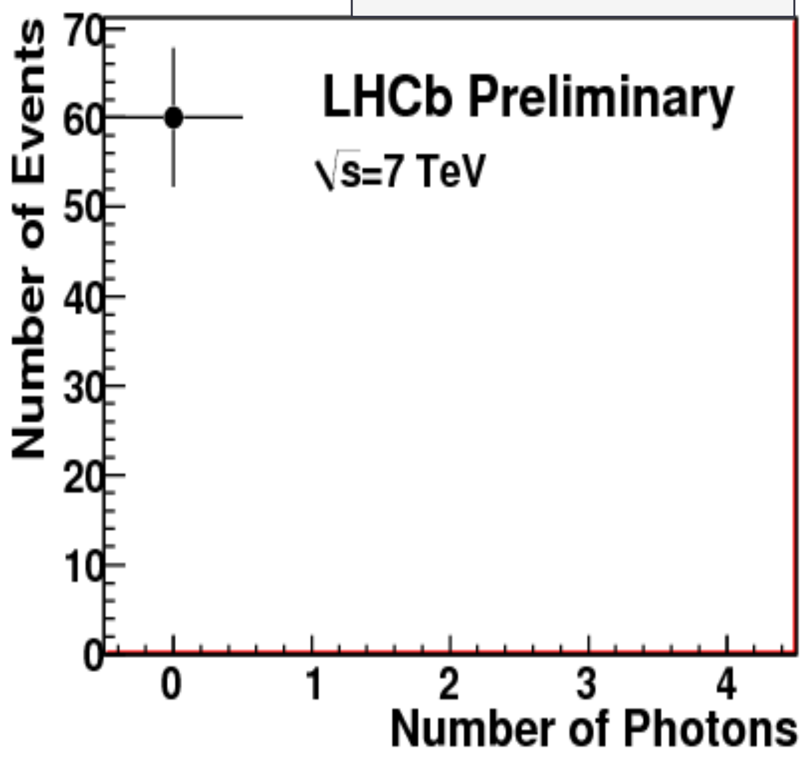




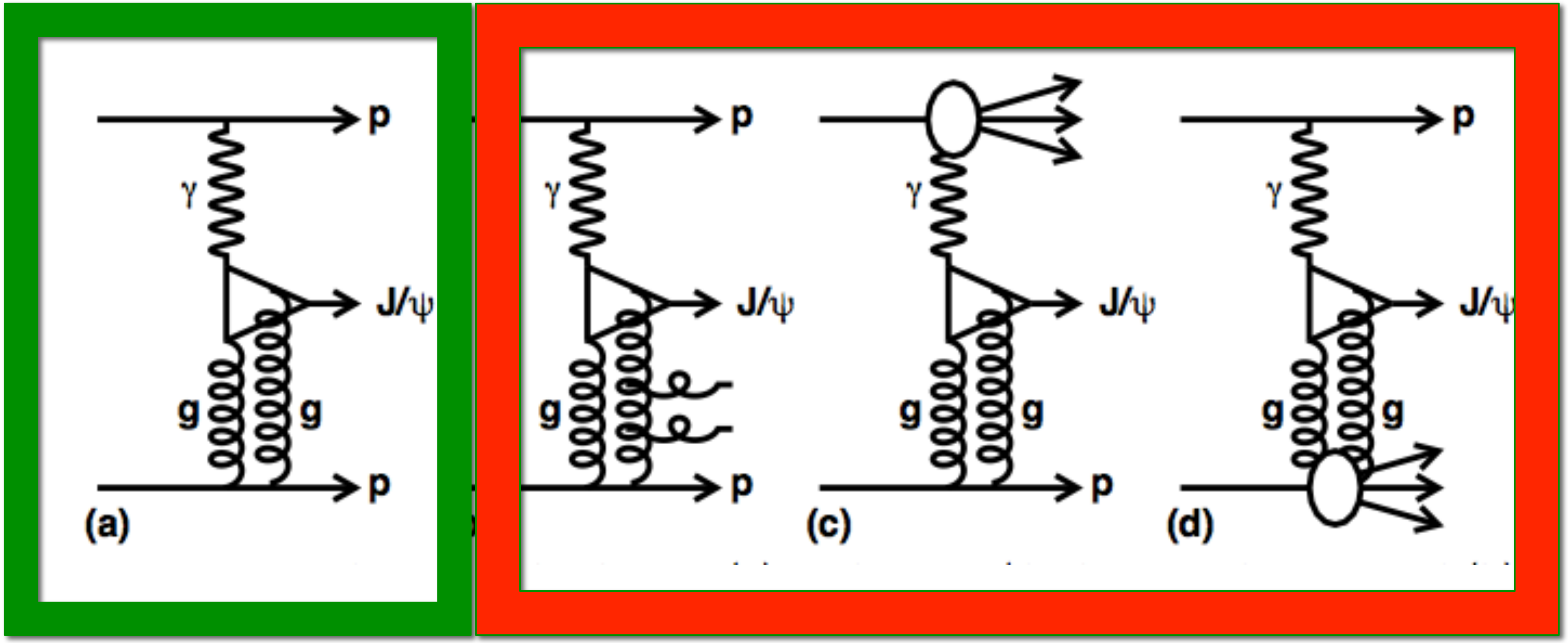
Estimated feeddown

ψ(2S)

LHCb-CONF-2011-022



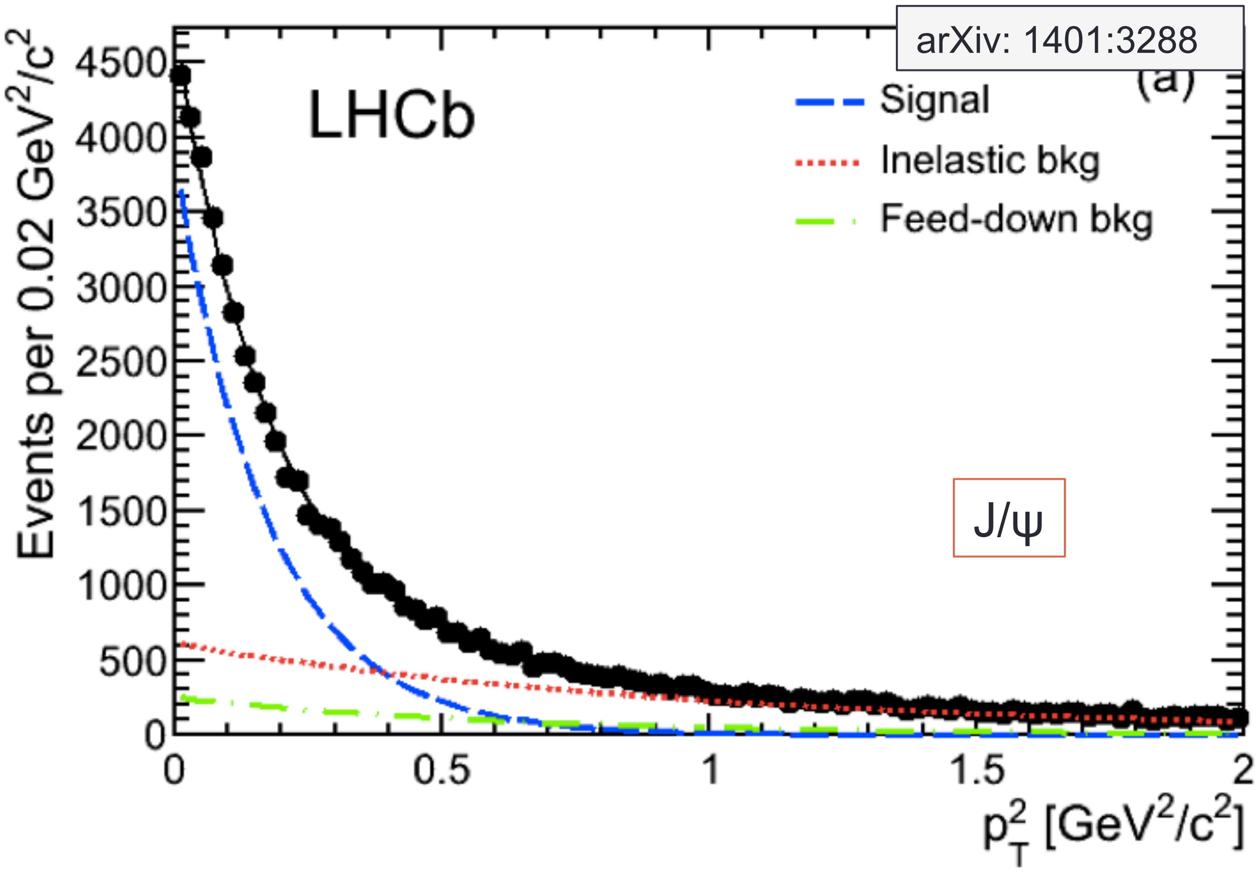
Inelastic background

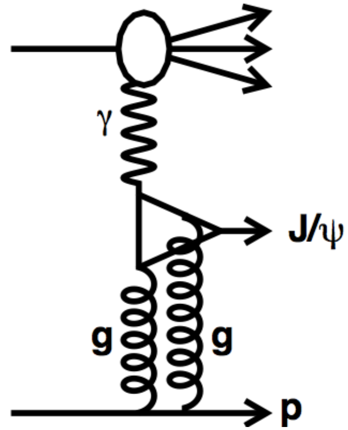


Signal

Background

Inelastic background J/ψ





Regge theory: $\frac{d\sigma}{dt} \sim e^{bt}$

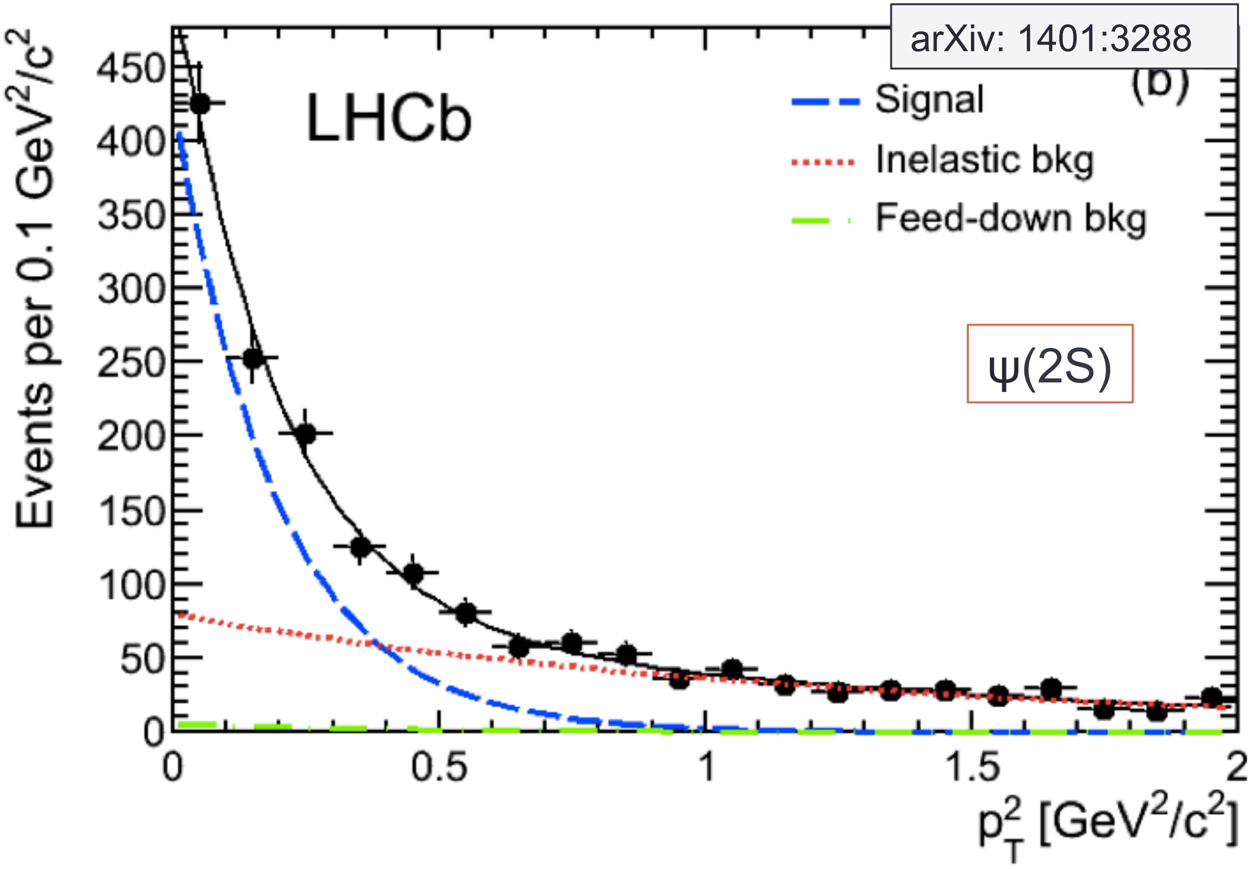
Systematic: Change signal to $(1 + b_{\rm pd} p_{\rm T}^2/n)^{-n}$

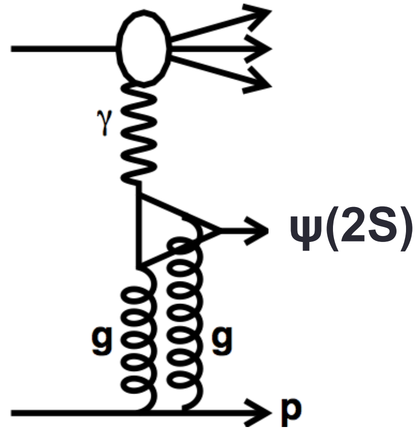
HERA measured:
b_s=4.9 GeV^{-2}
b_{pd}=1.1 GeV^{-2}

LHCb Expect:
b_s ~ 6 GeV^{-2}
b_{pd}~ 1 GeV^{-2}

LHCb Fit:
b_s=5.70±0.11 GeV^{-2}
b_{pd}=0.97±0.04 GeV^{-2}

Inelastic background ψ(2S)





$$\frac{d\sigma}{dt} \sim e^{bt}$$

<u>HERA measured:</u>
b_s=4.2 GeV^{-2}
b_{pd}=0.6 GeV^{-2}

<u>LHCb Expect:</u>
b_s ~ 5.5 GeV^{-2}
b_{pd}~ 0.6 GeV^{-2}

<u>LHCb Fit:</u>
b_s=5.1±0.7 GeV^{-2}
b_{pd}=0.8±0.2 GeV^{-2}

Numbers entering calculation

Table 1: Quantities entering the cross-section calculations as a function of meson rapidity.

y range (J/ψ)	[2.00, 2.25]	[2.25,2.50]	[2.50,2.75]	[2.75,3.00]	[3.00,3.25]
# Events	798	3911	6632	8600	9987
Acceptance	0.467 ± 0.009	0.653 ± 0.013	0.719 ± 0.014	0.718 ± 0.014	0.713 ± 0.014
$\epsilon^{\psi}_{\text{id}} \times \epsilon^{\psi}_{\text{trig}}$	0.71 ± 0.03	0.78 ± 0.02	0.81 ± 0.01	0.84 ± 0.01	0.85 ± 0.01
Purity			$0.592 \pm 0.012 \pm 0.030$		

y range (J/ψ)	[3.25, 3.50]	[3.50,3.75]	[3.75,4.00]	[4.00,4.25]	[4.25,4.50]
# Events	9877	7907	5181	2496	596
Acceptance	0.739 ± 0.015	0.734 ± 0.015	0.674 ± 0.014	0.566 ± 0.011	0.401 ± 0.008
$\epsilon^{\psi}_{\text{id}} \times \epsilon^{\psi}_{\text{trig}}$	0.87 ± 0.01	0.88 ± 0.01	0.87 ± 0.01	0.83 ± 0.02	0.81 ± 0.03
Purity			$0.592 \pm 0.012 \pm 0.030$		

y range ($\psi(2S)$)	[2.00, 2.25]	[2.25,2.50]	[2.50,2.75]	[2.75,3.00]	[3.00,3.25]
# Events	31	111	208	1287	268
Acceptance	0.678 ± 0.013	0.800 ± 0.016	0.834 ± 0.017	0.787 ± 0.016	0.755 ± 0.015
$\epsilon^{\psi}_{\text{id}} \times \epsilon^{\psi}_{\text{trig}}$	0.80 ± 0.03	0.83 ± 0.02	0.86 ± 0.01	0.88 ± 0.01	0.88 ± 0.01
Purity ($\psi(2S)$)			$0.52 \pm 0.07 \pm 0.03$		

y range($\psi(2S)$)	[3.25, 3.50]	[3.50,3.75]	[3.75,4.00]	[4.00,4.25]	[4.25,4.50]
# Events	282	201	105	61	11
Acceptance	0.748 ± 0.015	0.702 ± 0.014	0.628 ± 0.013	0.524 ± 0.010	0.384 ± 0.008
$\epsilon^{\psi}_{\text{id}} \times \epsilon^{\psi}_{\text{trig}}$	0.90 ± 0.01	0.89 ± 0.01	0.87 ± 0.01	0.84 ± 0.02	0.77 ± 0.03
Purity ($\psi(2S)$)			$0.52 \pm 0.07 \pm 0.03$		

y range (J/ψ and $\psi(2S)$)	[2.00, 4.50]
ϵ_{sel}	0.87 ± 0.01
ϵ_{single}	0.241 ± 0.003
L (pb^{-1})	929 ± 33

Cross-sections and systematics

Cross-section*BR for both muons in pseudorapidity range 2<η<4.5:

y range	[2.00, 2.25]	[2.25,2.50]	[2.50,2.75]	[2.75,3.00]	[3.00,3.25]
$\frac{d\sigma}{dy}$ J/ψ	29.3 ± 1.7	92.5 ± 2.4	137.8 ± 2.4	173.1 ± 2.6	198.0 ± 2.7
$\frac{d\sigma}{dy}$ $\psi(2S)$	0.56 ± 0.11	1.75 ± 0.17	3.06 ± 0.22	4.41 ± 0.26	4.24 ± 0.26

y range	[3.25, 3.50]	[3.50,3.75]	[3.75,4.00]	[4.00,4.25]	[4.25,4.50]
$\frac{d\sigma}{dy}$ J/ψ	187.6 ± 2.6	148.9 ± 2.4	107.4 ± 2.1	65.3 ± 2.0	21.9 ± 1.3
$\frac{d\sigma}{dy}$ $\psi(2S)$	4.51 ± 0.27	3.43 ± 0.25	2.05 ± 0.20	1.47 ± 0.19	0.36 ± 0.11

Correlated uncertainties expressed as a percentage of the final result	
ϵ_{sel}	1.4%
Purity determination (J/ψ)	2.0%
Purity determination ($\psi(2S)$)	13.0% ← ψ(2S)
*$\epsilon_{\mathrm{single}}$	1.0%
*Acceptance	2.0%
*Shape of the inelastic background	5.0% ← J/ψ
*Luminosity	3.5%
Total correlated statistical uncertainty (J/ψ)	2.4%
Total correlated statistical uncertainty ($\psi(2S)$)	13.0%
Total correlated systematic uncertainty	6.5%

Comparison to theory

V. P. Gonçalves and M. V. T. Machado, *Vector meson production in coherent hadronic interactions: an update on predictions for RHIC and LHC*, Phys. Rev. **C84** (2011) 011902, arXiv:1106.3036.

S. Jones, A. Martin, M. Ryskin, and T. Teubner, *Probes of the small x gluon via exclusive J/ψ and Υ production at HERA and the LHC*, JHEP **1311** (2013) 085, arXiv:1307.7099.

L. Motyka and G. Watt, *Exclusive photoproduction at the Fermilab Tevatron and CERN LHC within the dipole picture*, Phys. Rev. **D78** (2008) 014023, arXiv:0805.2113.

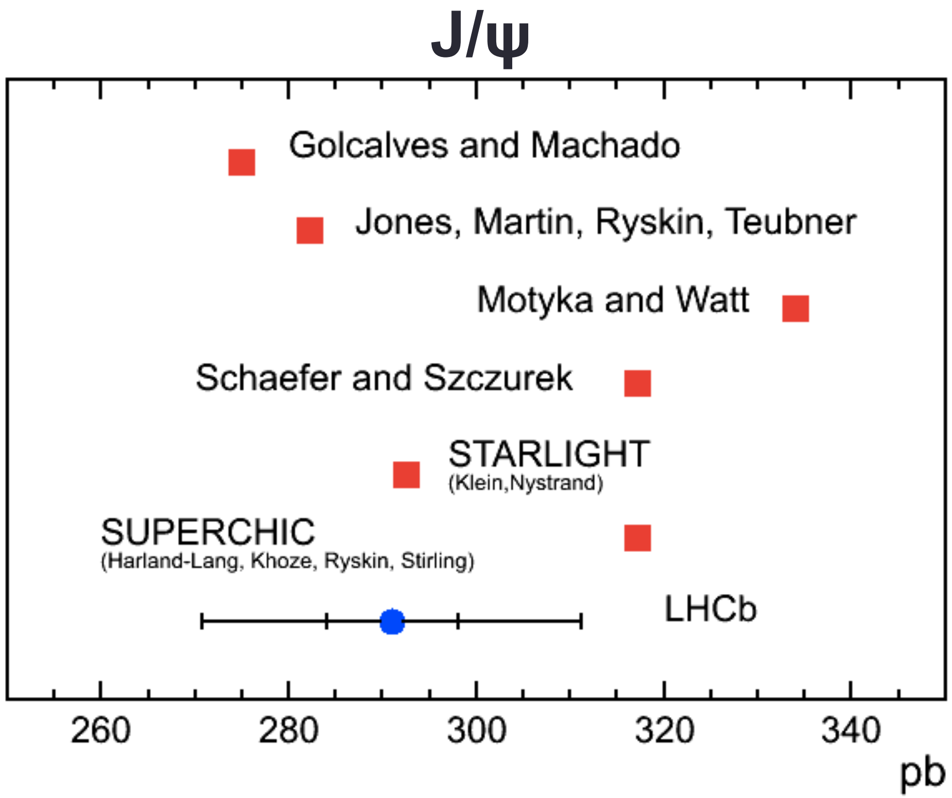
W. Schäfer and A. Szczurek, *Exclusive photoproduction of J/ψ in proton-proton and proton-antiproton scattering*, Phys. Rev. **D76** (2007) 094014, arXiv:0705.2887.

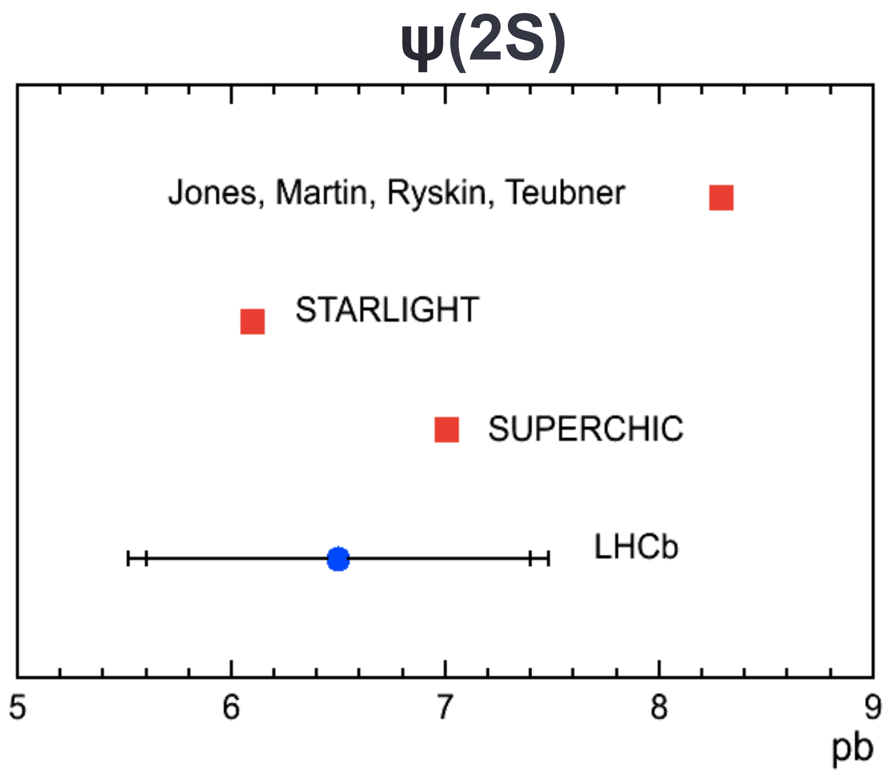
S. R. Klein and J. Nystrand, *Photoproduction of quarkonium in proton proton and nucleus nucleus collisions*, Phys. Rev. Lett. **92** (2004) 142003, arXiv:hep-ph/0311164.

L. A. Harland-Lang, V. A. Khoze, M. G. Ryskin, and W. J. Stirling, *Central exclusive χ_c meson production at the Tevatron revisited*, Eur. Phys. J. **C65** (2010) 433, arXiv:0909.4748.

Integrated Cross-sections

Cross-section*BR for both muons in pseudorapidity range 2<η<4.5:

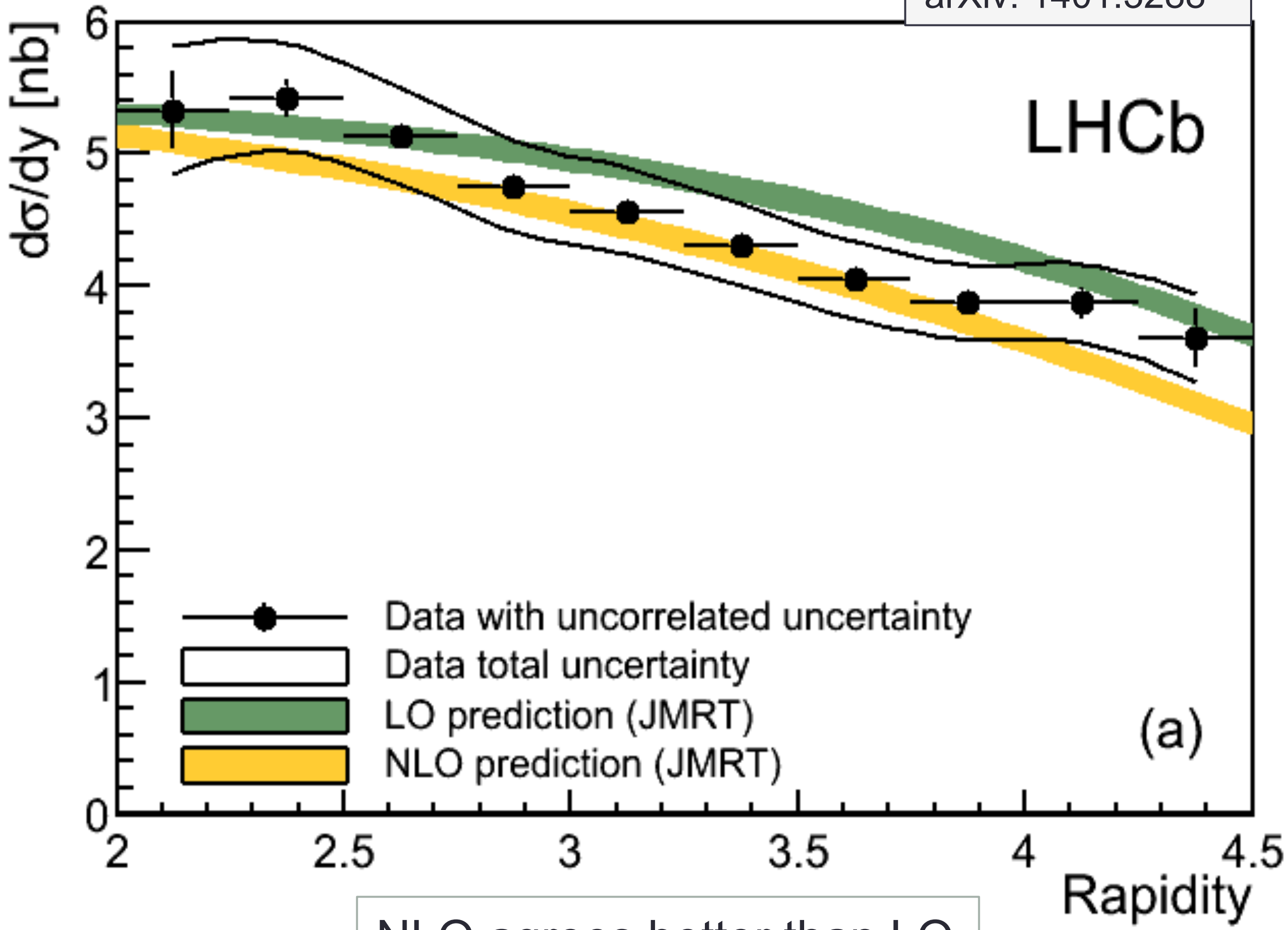




Good agreement with all theory estimates

Differential cross-sections J/ψ

arXiv: 1401:3288

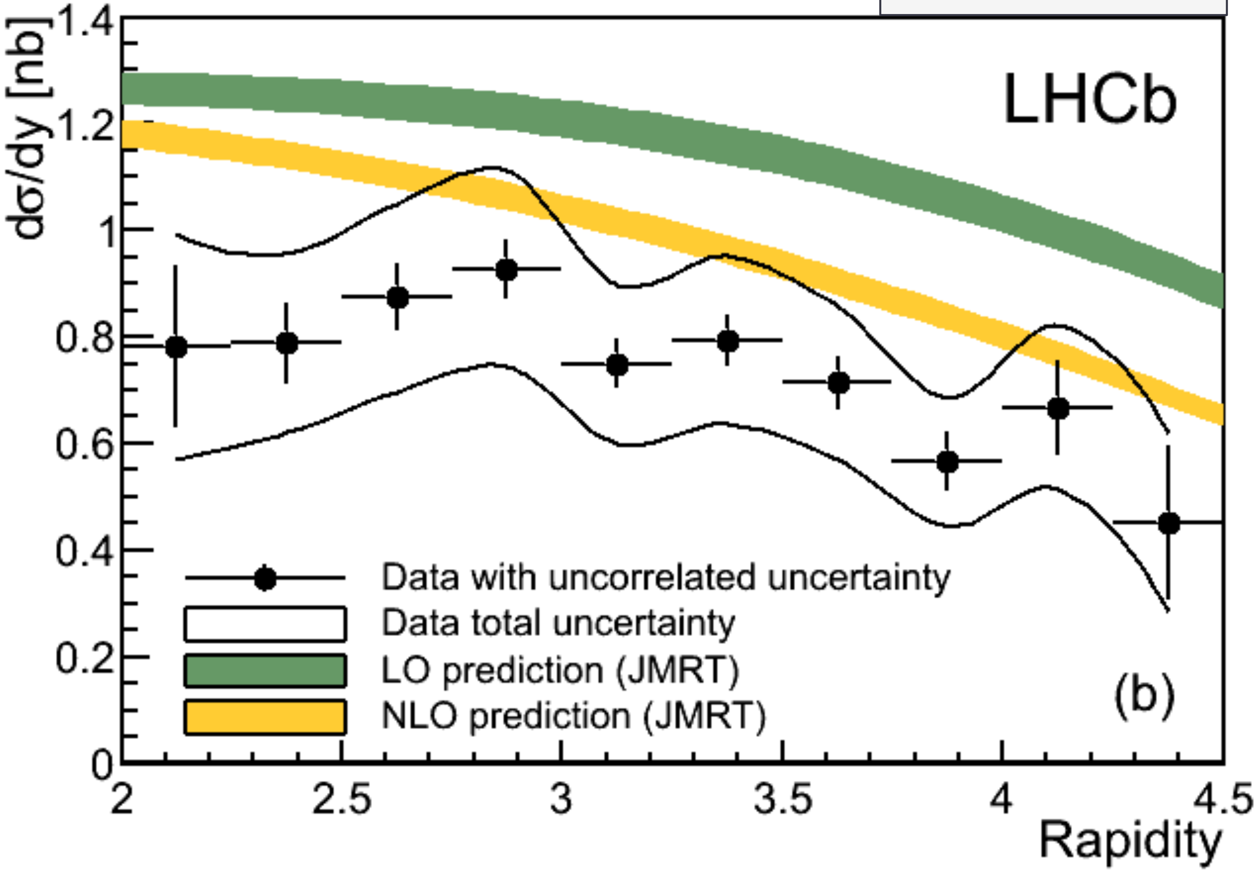


NLO agrees better than LO

S. Jones, A. Martin, M. Ryskin, and T. Teubner, *Probes of the small x gluon via exclusive J/ψ and Υ production at HERA and the LHC*, JHEP **1311** (2013) 085, arXiv:1307.7099.

Differential cross-sections ψ(2S)

arXiv: 1401:3288



NLO agrees better than LO

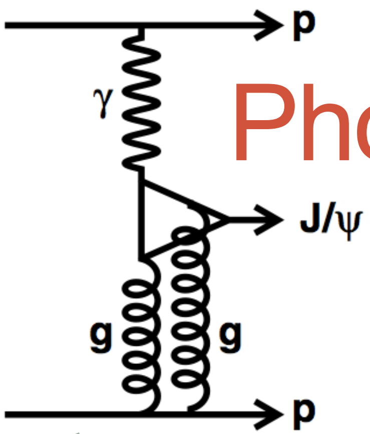


Photo-production cross-section

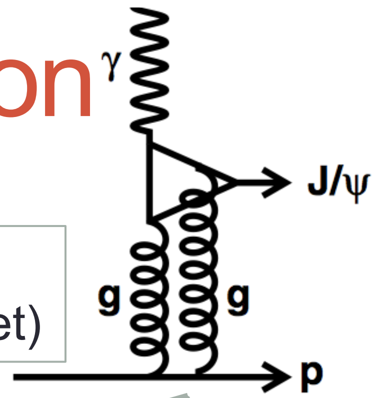


Photo-production (HERA / fixed target)

LHCb measure

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

Gap Survival

Photon Flux

HERA measured power-law: $\sigma_{\gamma p\rightarrow J/\psi p}(W) = 81(W/90\,\mathrm{GeV})^{0.67}\,\mathrm{nb}$

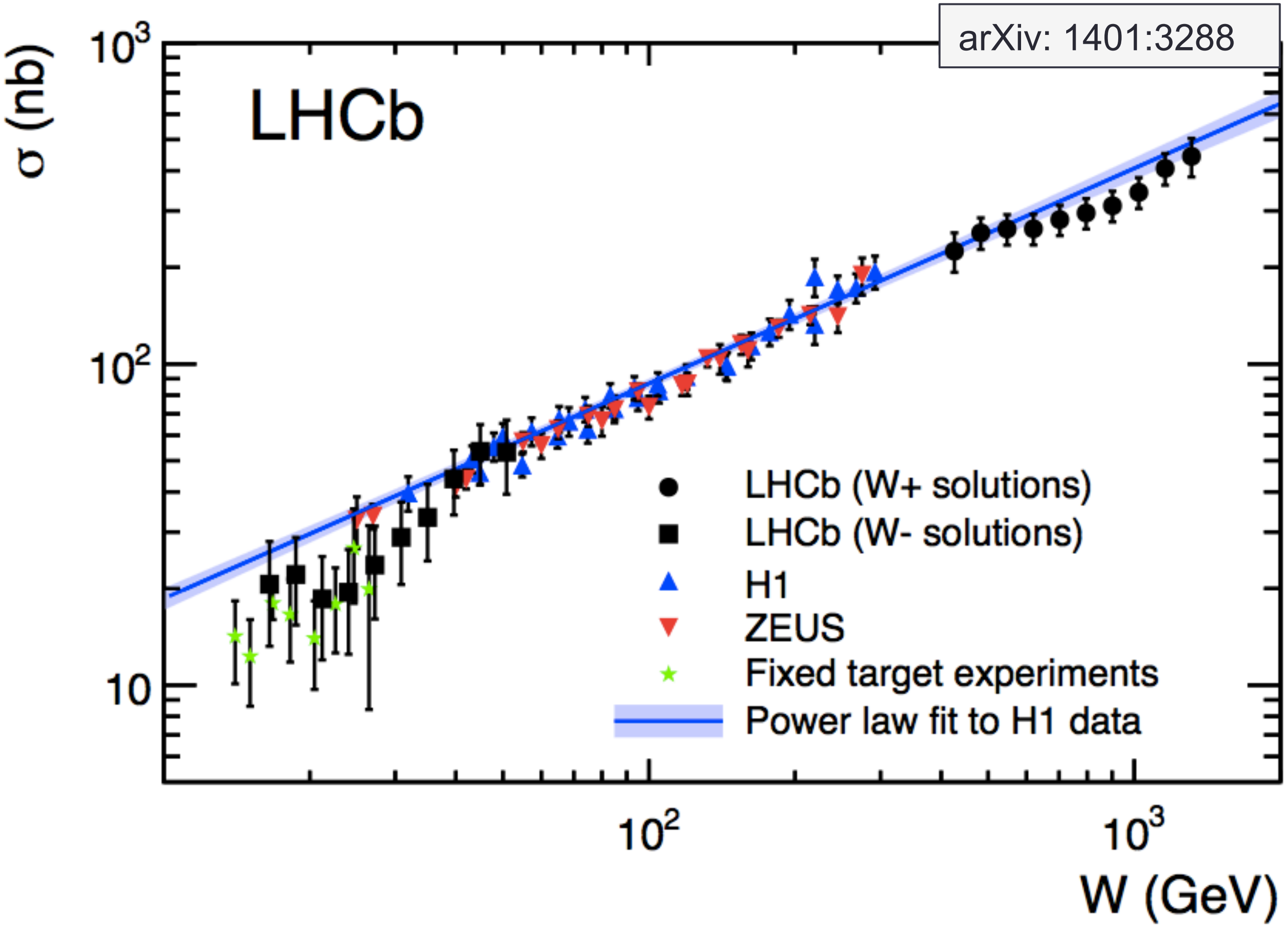
Use this for one cross-section on RHS – LHCb measure the other solution

Photo-production cross-section

Measure Plot HERA

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

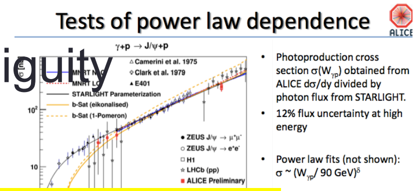
arXiv: 1401:3288



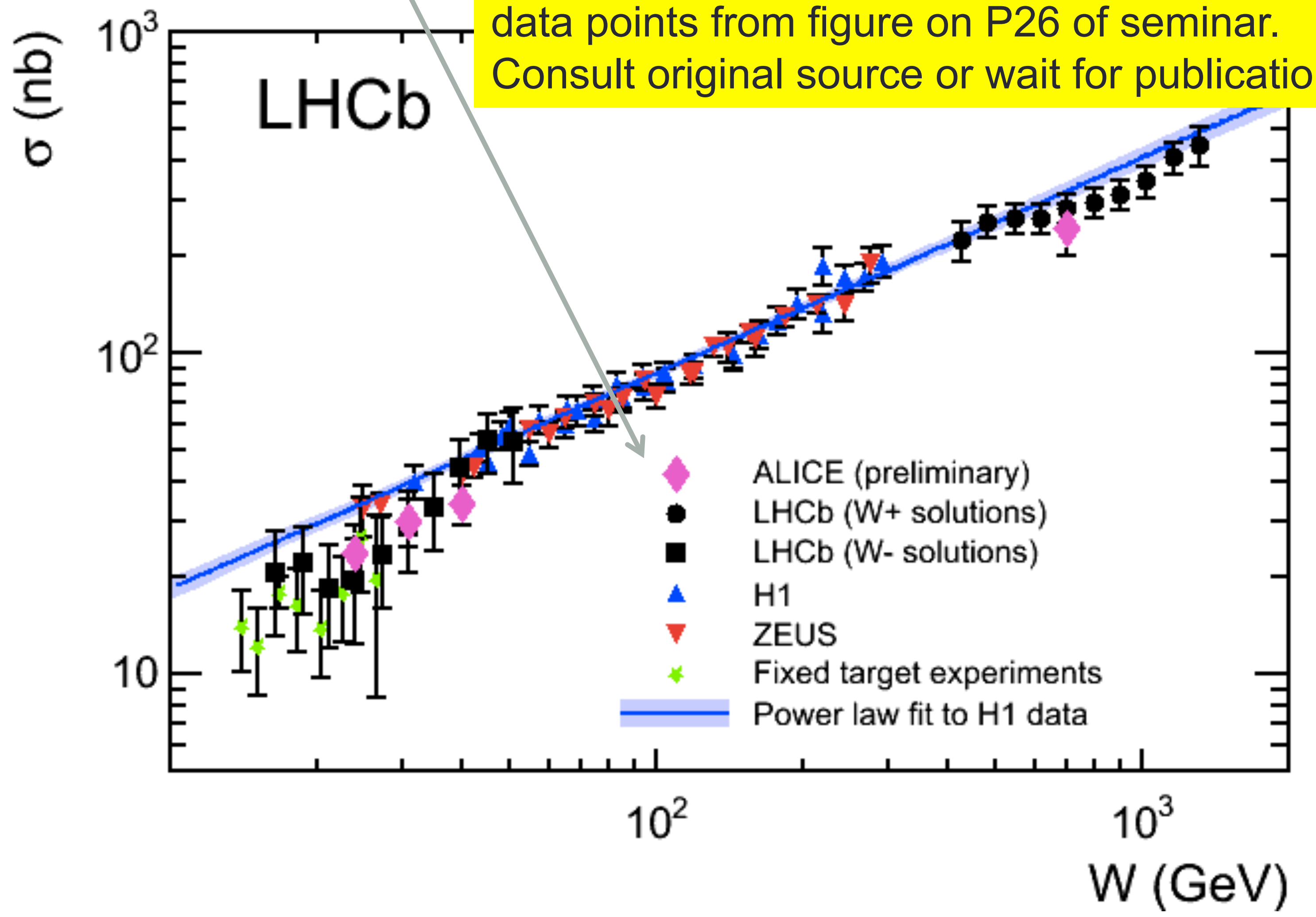
Deviation from pure power-law. i.e. NLO required or only power-law for $W>W_0$

Photo-production cross-section

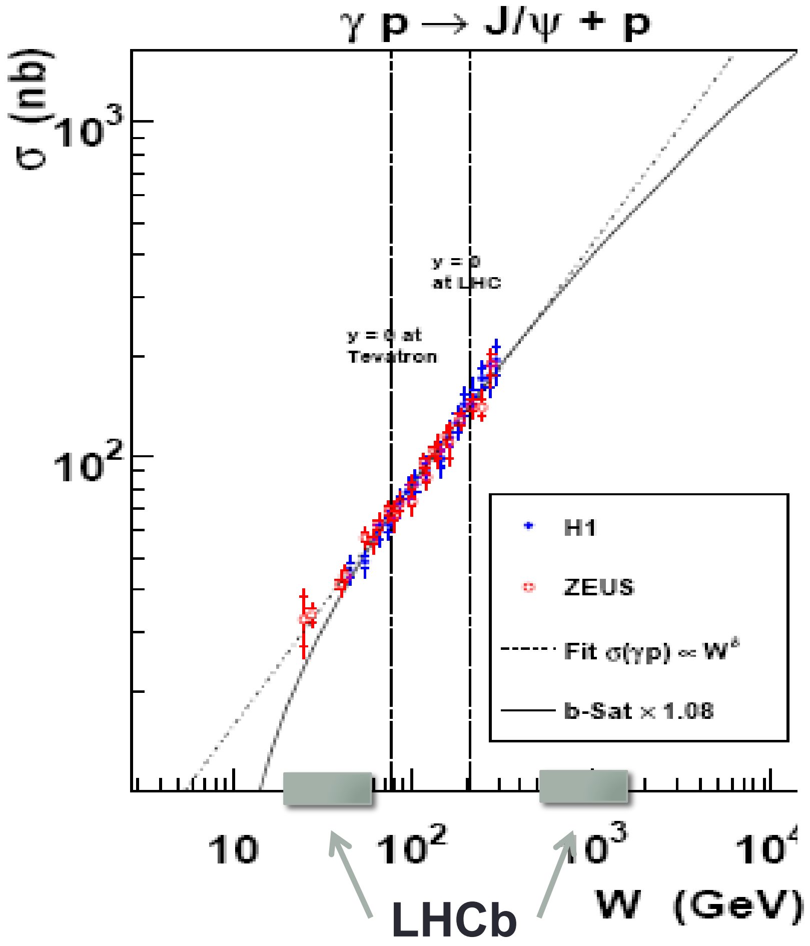
Add ALICE pPb perliminary data which does NOT have ambiguity
See: Evgeny Kryshen, LHC seminar, 17.12.2013.



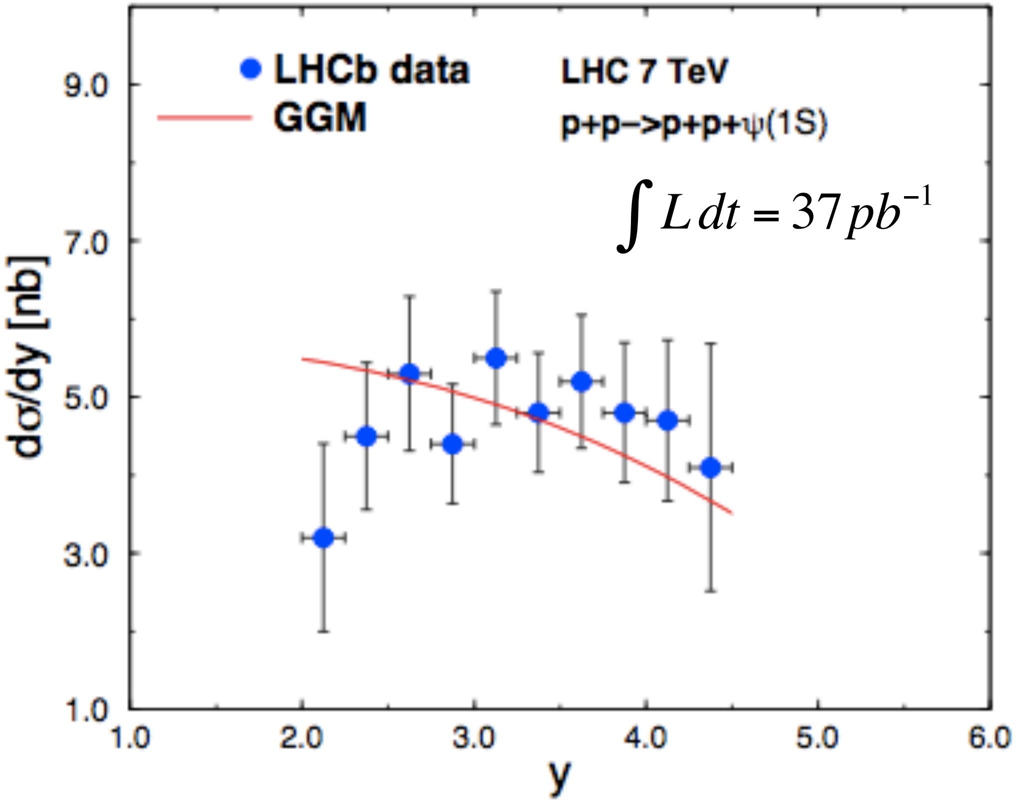
Health warning: This is my attempt to read data points from figure on P26 of seminar. Consult original source or wait for publication.



Sensitivity to saturation effects

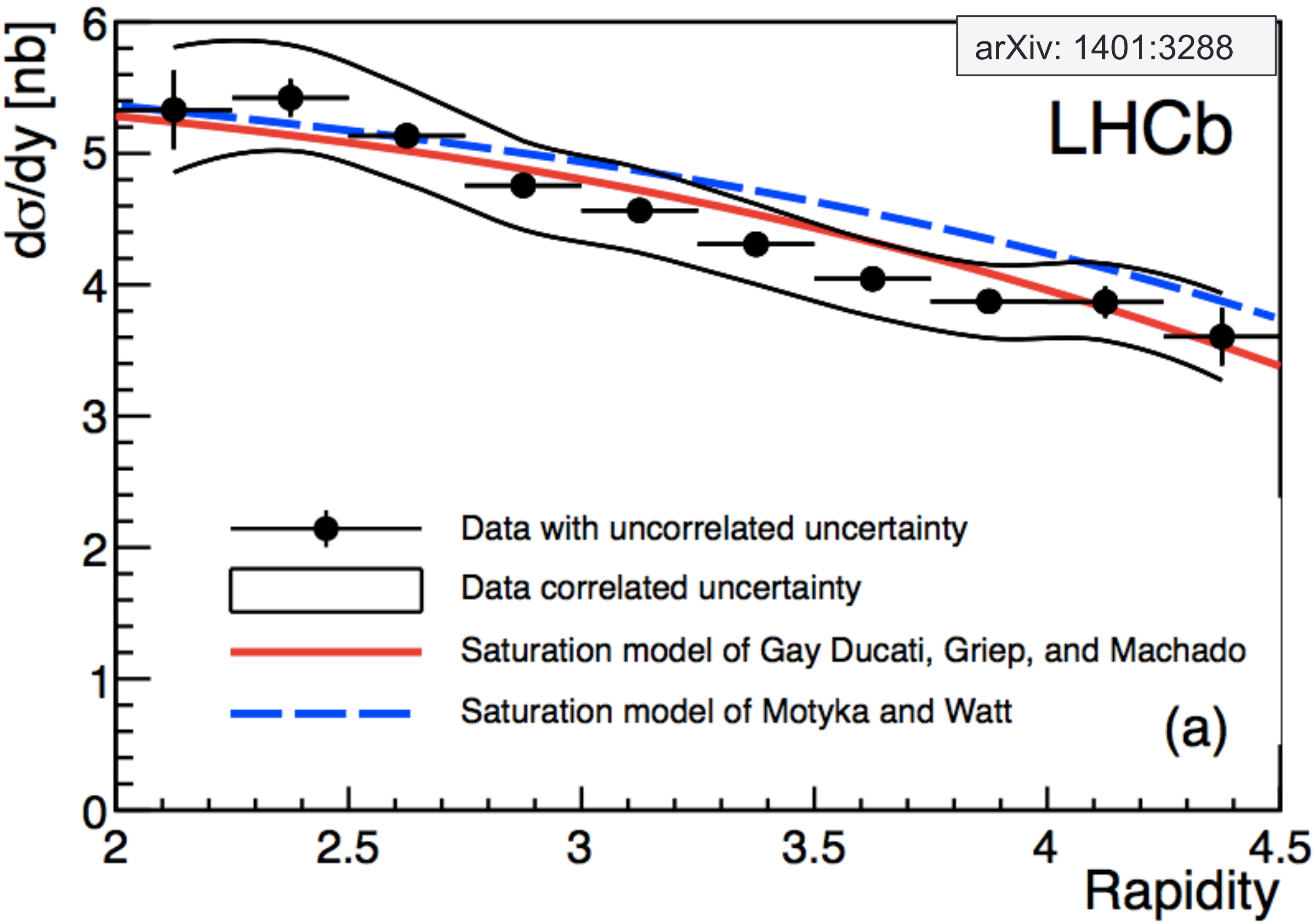


Motyka, Watt: PRD 78, 014023 (2008)



Gay Ducati et al., arXiv: 1305.4611

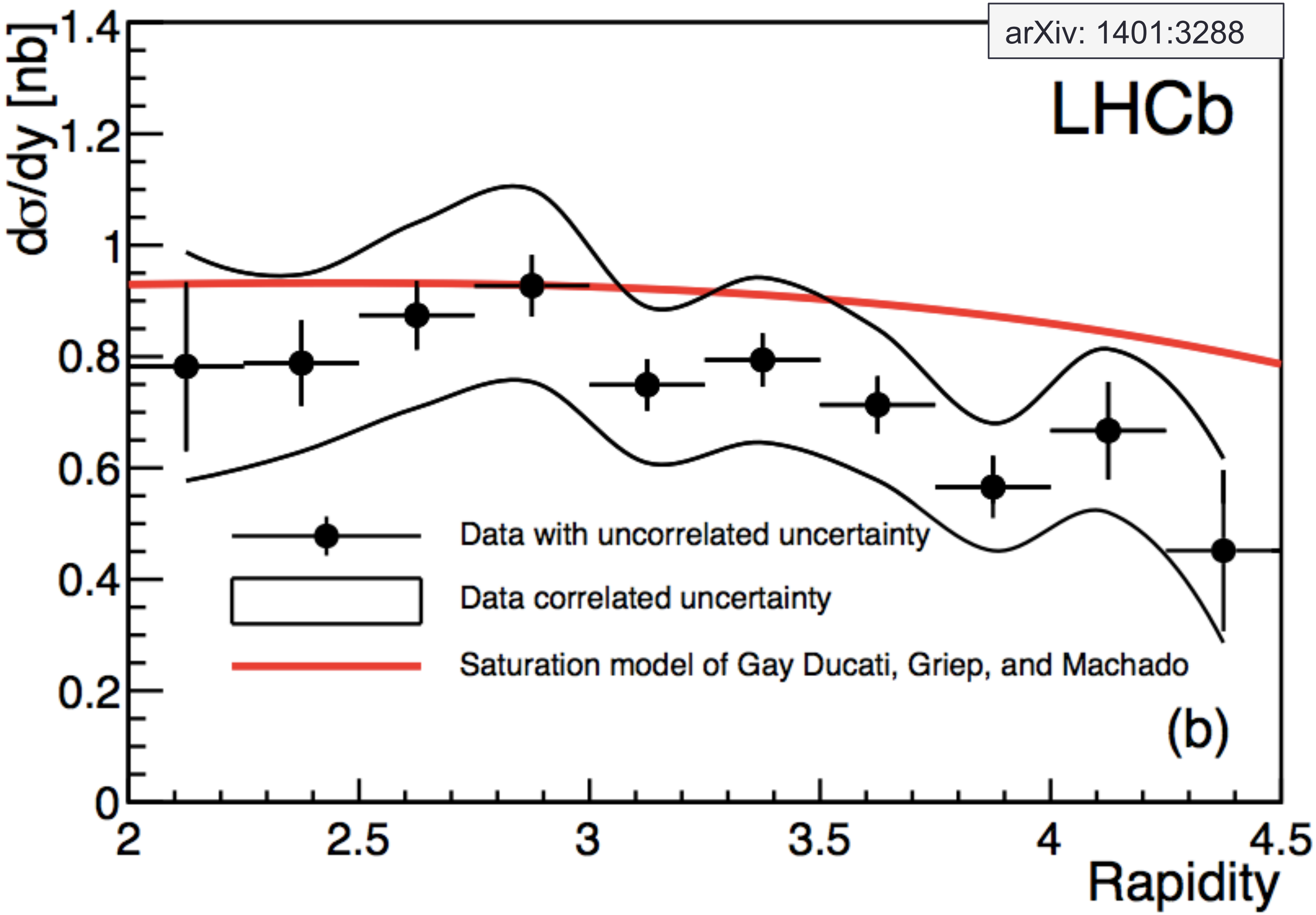
Sensitivity to saturation effects: J/ψ



L. Motyka and G. Watt, *Exclusive photoproduction at the Fermilab Tevatron and CERN LHC within the dipole picture*, Phys. Rev. **D78** (2008) 014023, arXiv:0805.2113.

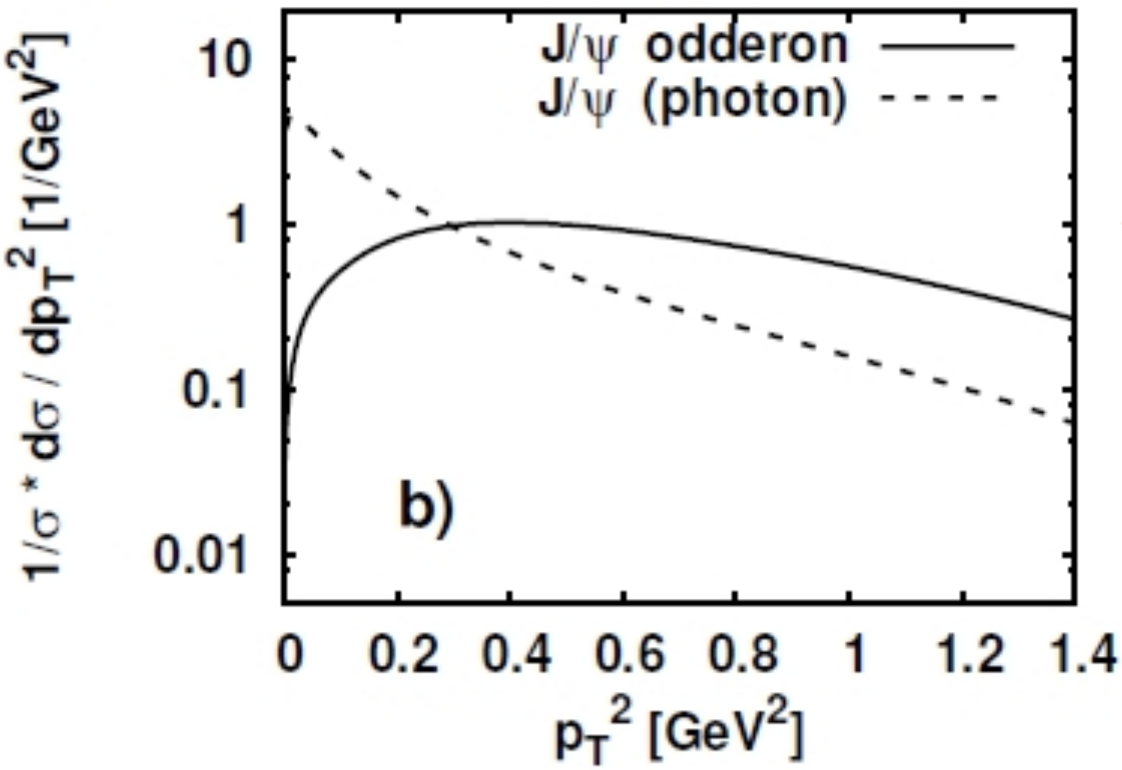
M. B. Gay Ducati, M. T. Griep, and M. V. T. Machado, *Exclusive photoproduction of J/ψ and ψ(2S) states in proton-proton collisions at the CERN LHC*, arXiv:1305.4611.

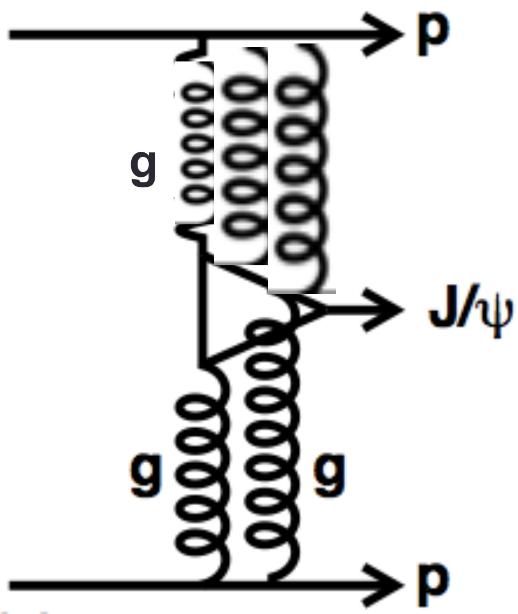
Sensitivity to saturation effects: ψ(2S)



Search for odderon

- Motyka, DIS 2008.





Detector Improvements

<u>What we have learnt from the past:</u>

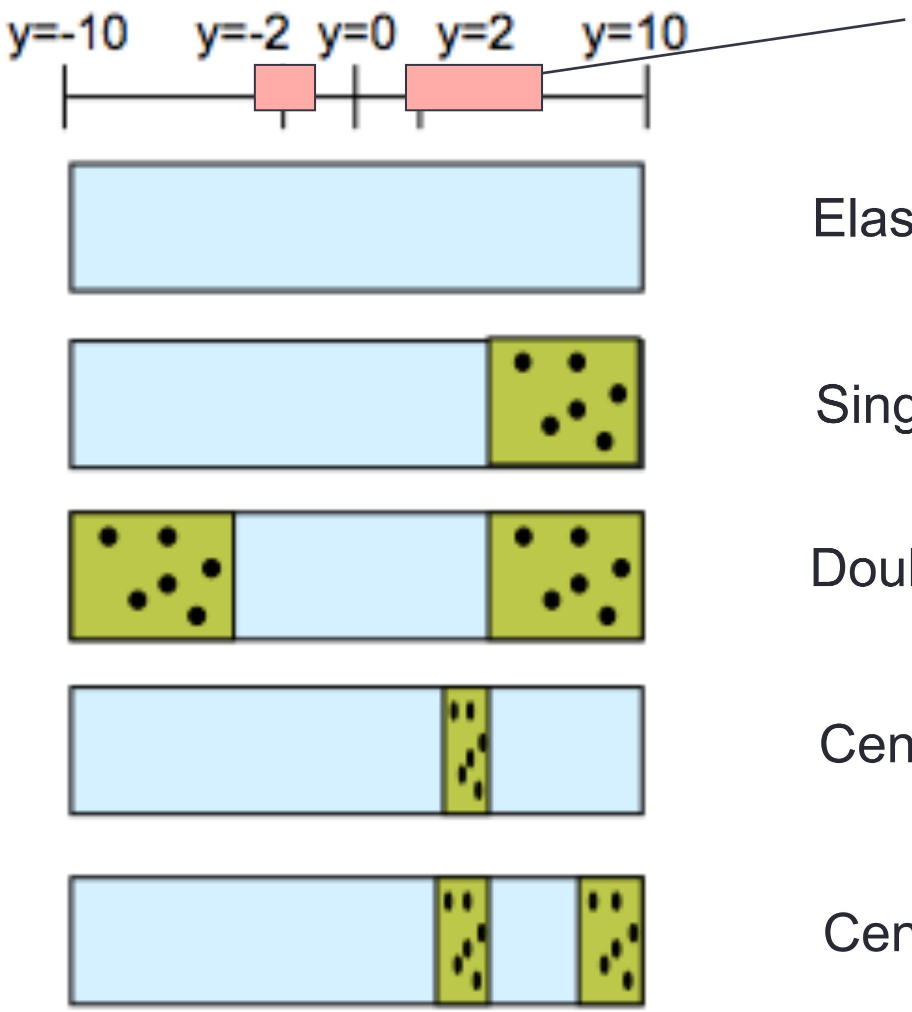
Inelastic background limits measurement and search for new phenomena

<u>How we can improve for future:</u>

Extend rapidity gap: currently ~ 5 units; future ~12 units?

Graphical Representation

Rough LHCb coverage



Elastic Scattering

Single Diffraction

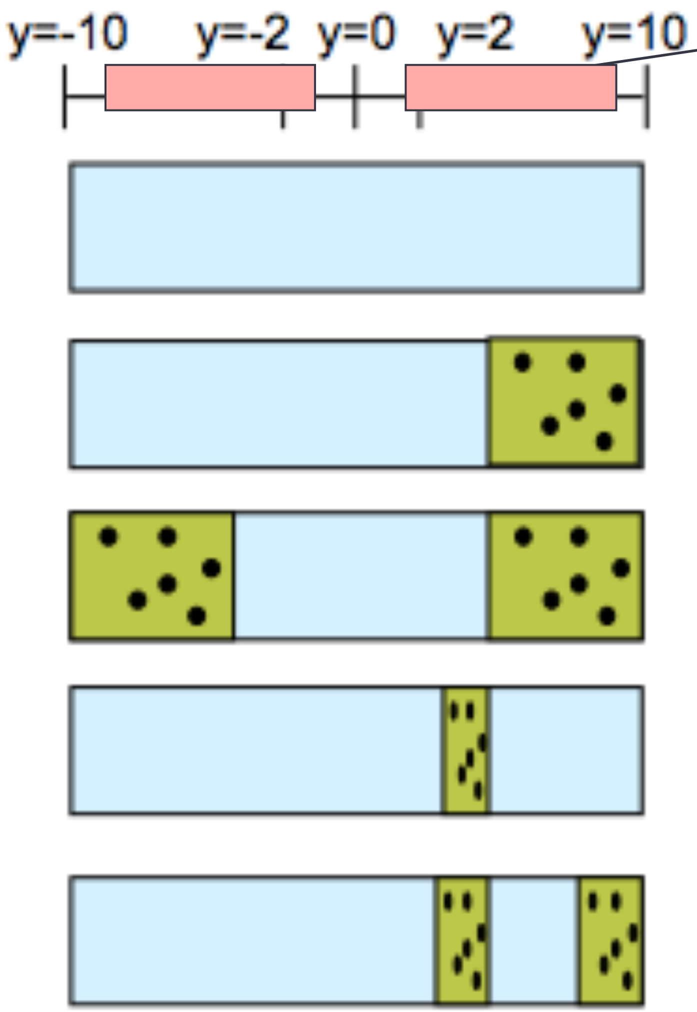
Double Diffraction

Central Exclusive Production (elastic)

Central Exclusive Production (inelastic)

Graphical Representation

Extend to y=8 ?



Elastic Scattering

Single Diffraction

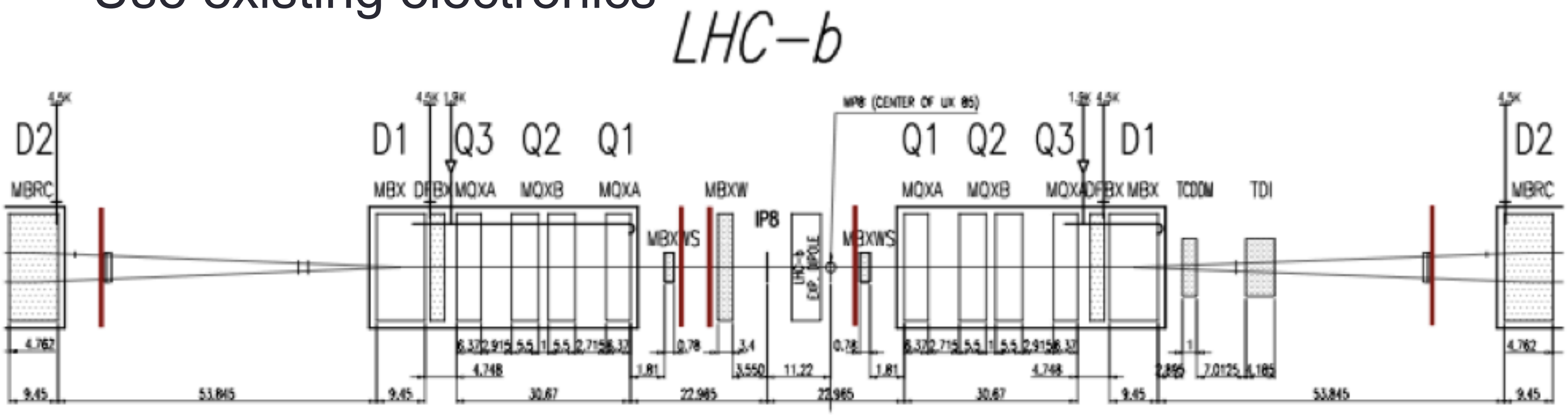
Double Diffraction

Central Exclusive Production (elastic)

Central Exclusive Production (inelastic)

High rapidity shower counters for LHCb

- Increase rapidity gap with scintillators in forward region
- Use existing electronics

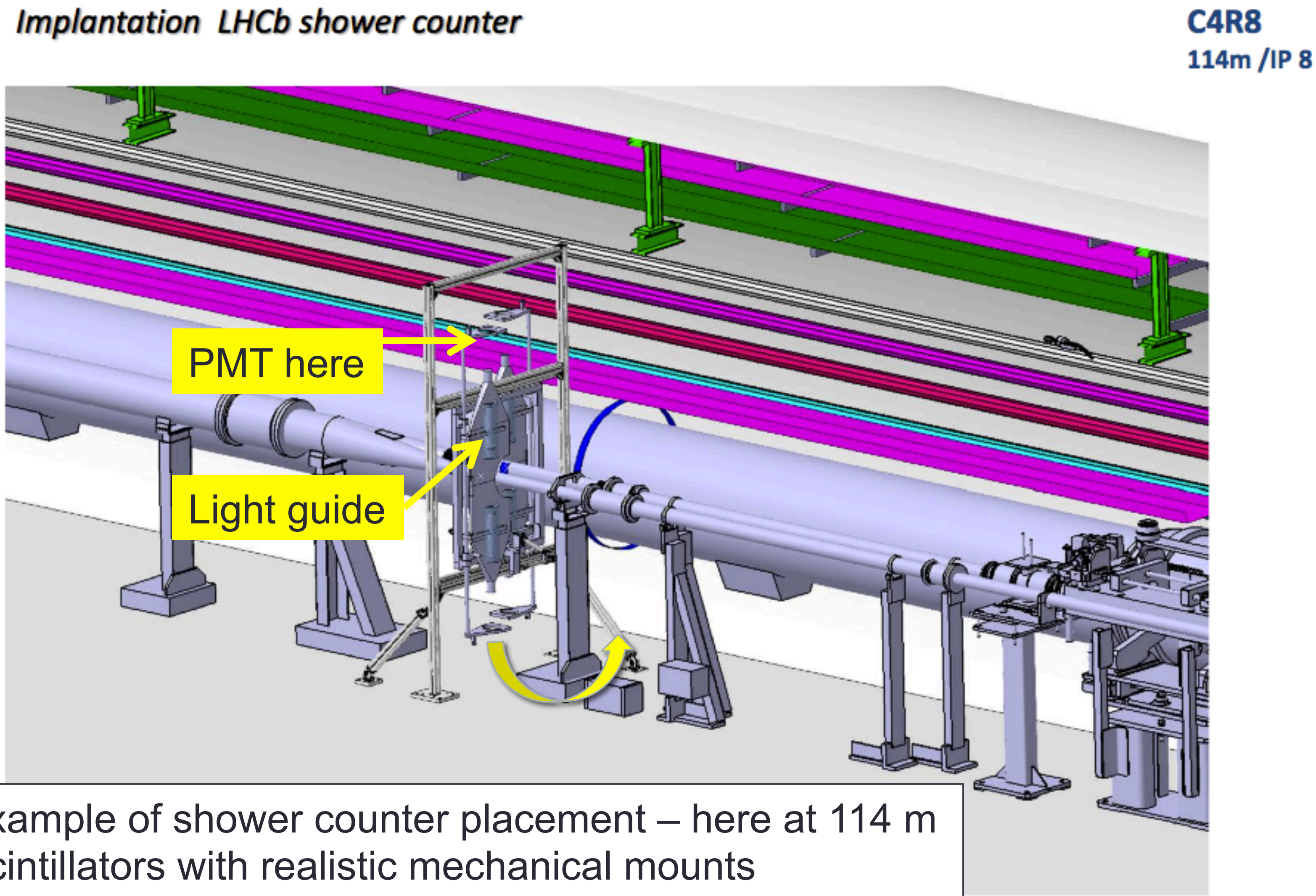


Left
1. z ~ -7.5 m (after MBXW)
2. z ~ -19m (before MBXWS)
3. z ~ -114m (after BRANS)

Right
1. z ~ 19 m (close to MBXWS)
2. z ~ 114m (after BRANS)

First simulations suggest veto region for charged and neutral particles can be extended to include $5<|\eta|<8$

Herschel Integration inside Tunnel



Example of shower counter placement – here at 114 m
Scintillators with realistic mechanical mounts
Scintillators open in case of harsh beam conditions

Summary LHCb contributions for yellow report

Yellow report contributions will have contributions from LHCb; contact persons Dima (Dmytro.Volyanskyy@cern.ch), Victor (Victor.Coco@cern.ch), Katharina (kmueller@physik.uzh.ch), Ronan (Ronan.Mcnulty@cern.ch), Paula (Paula.Collins@cern.ch), Heinrich (Heinrich.Schindler@cern.ch) plus many more contributors.

We plan to produce contributions for the following aspects:

- Chapter 1: Simulation of conditions in tunnel
  - For scintillator tagging of proton disassociation background for running after LS2, for CEP, possibly jets, and single diffractive physics (Paula)
  - Possible proton tagging in LS3 running
- Chapter 2: MC performance in the forward region (Dima, Victor)
- Chapter 3: Prospects for soft diffractive production studies with LHCb (Dima)
- Chapter 4: Prospects for diffractive electroweak boson production studies (Katharina)
- Chapter 5: Results and Prospects for central exclusive production (Ronan, Paula)
- Chapter 6: Results and prospects for Drell-Yan studies (Katharina)
- Results and prospects for inclusive jet studies (Victor)
- Chapter 7: Results and prospects for charged particle multiplicities and forward energy flow (Dima)
- Chapter 8: Results and prospects for pA studies (Heinrich)
- Chapter 9: HERSCHEL: High rapidity shower counters (Paula)

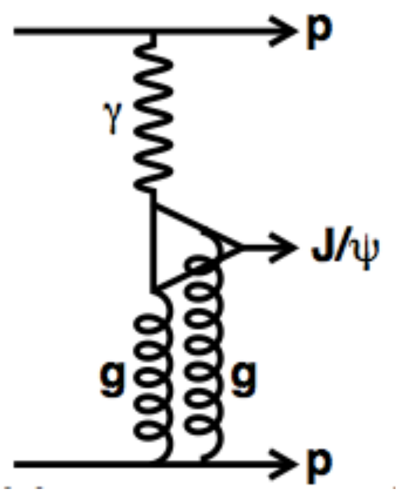
Chapter 5:
CEP Future physics measurements

CEP of vector mesons in leptonic modes

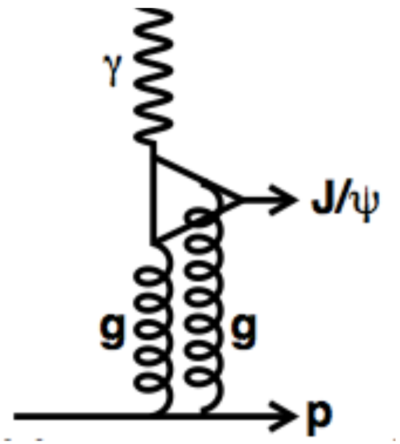
CEP of mesons in hadronic modes

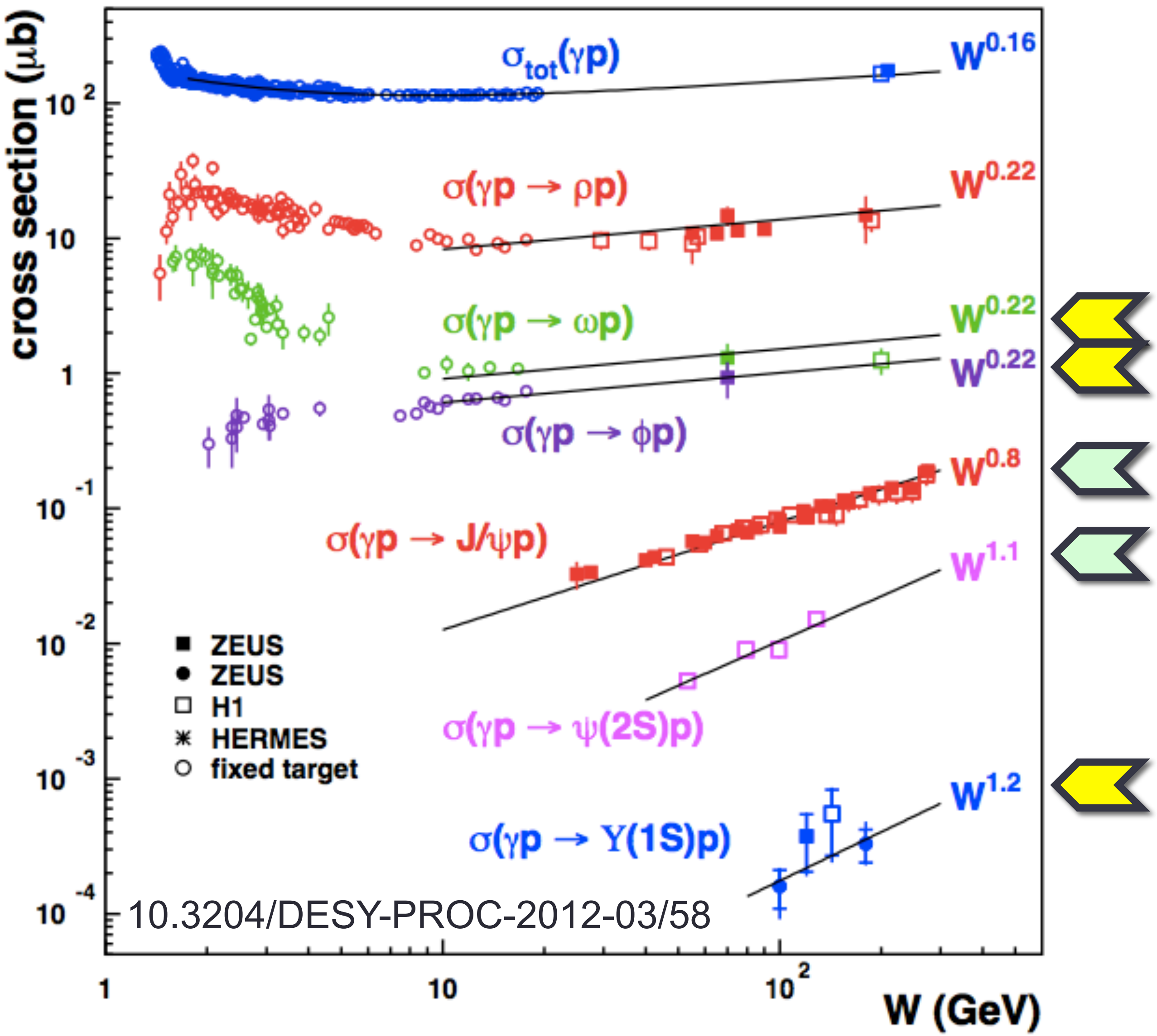
CEP of pairs of mesons

Investigate other vector mesons

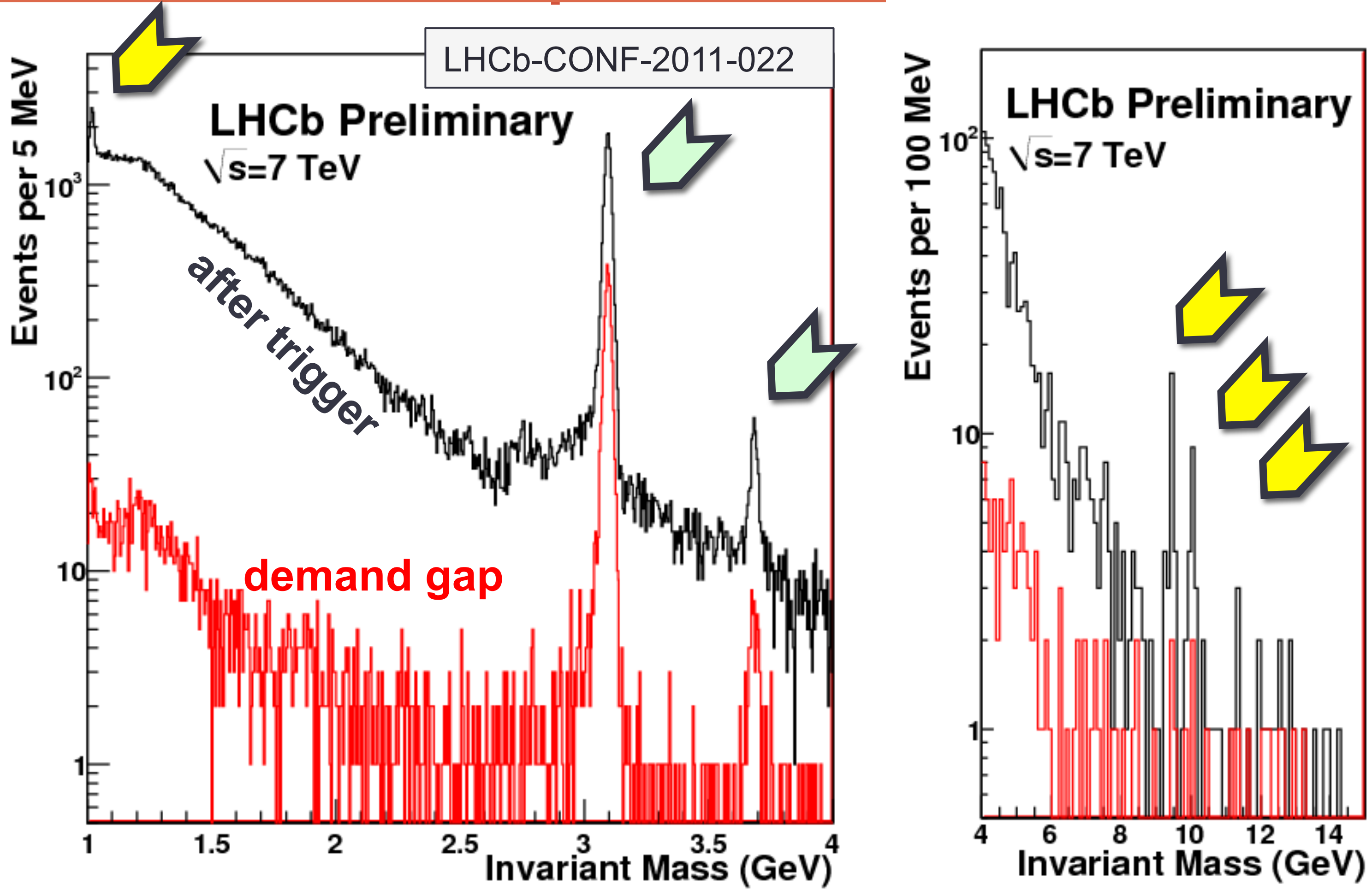


looks very like





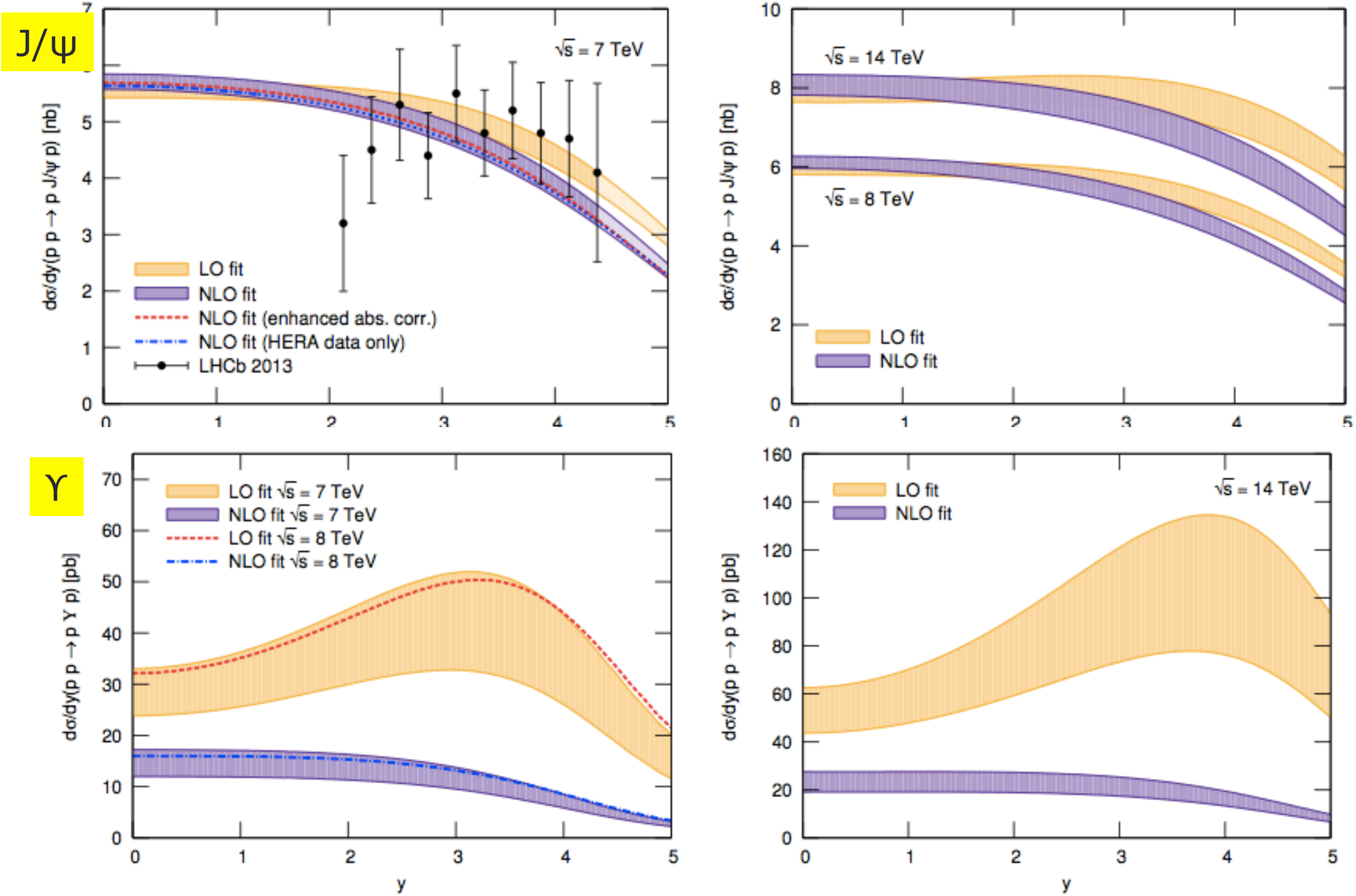
Dimuon Mass Spectrum



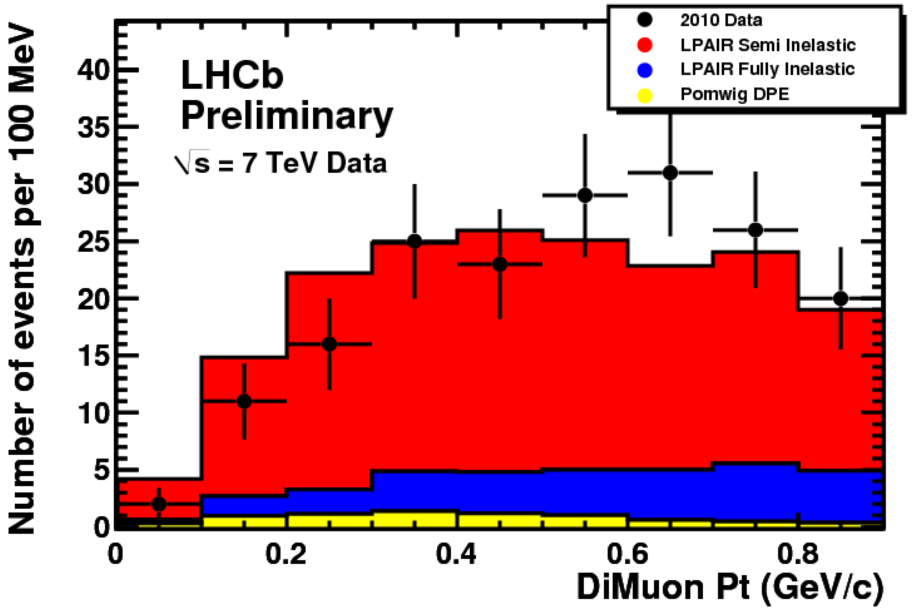
Factor ~ *100 data now available with 2011+2012 (~3fb^{-1})

Predictions (arXiv: 1307.7099)

(Jones, Martin, Ryskin, Teubner)

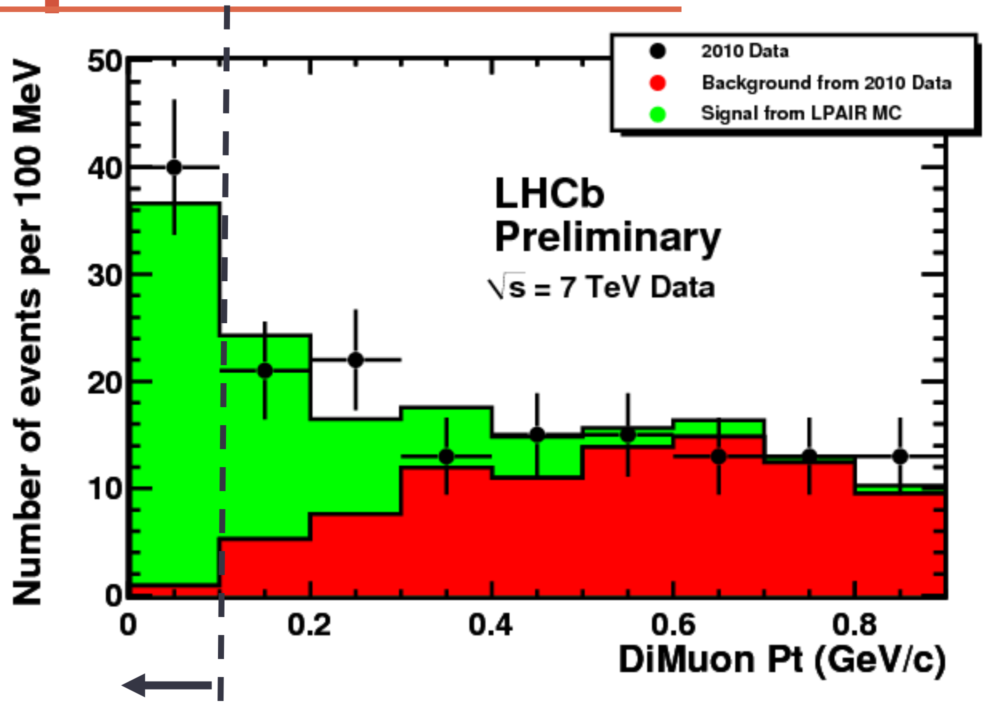


QED: pp->pμμp di-photon fusion



Shape for inelastic events

Note: this time we have simulation that predicts the shape for the three contributions.

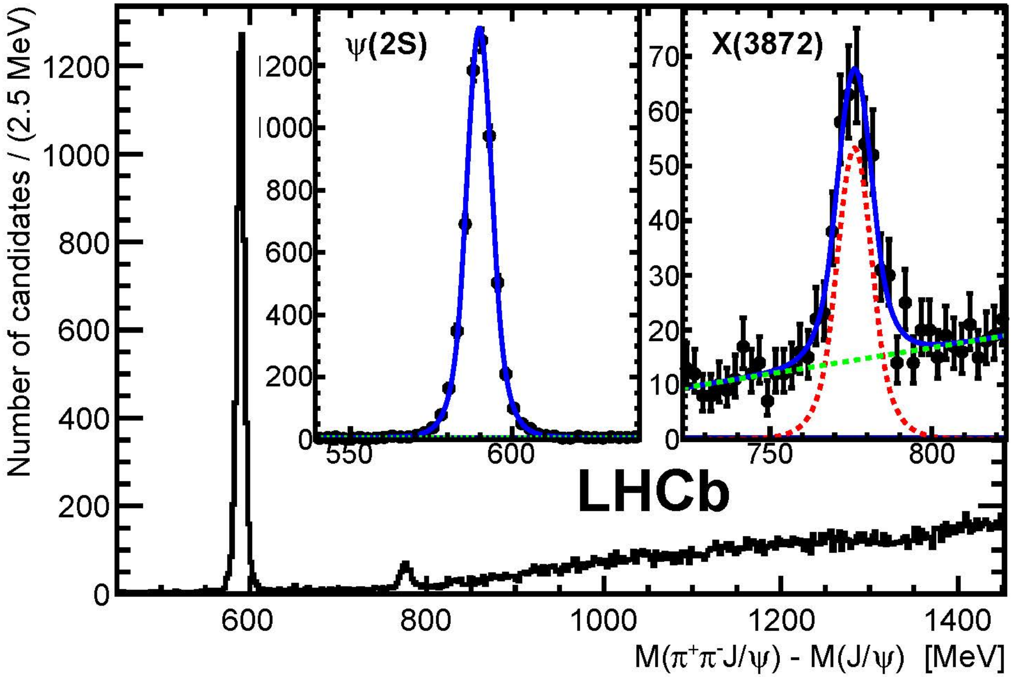


Fit to signal events

Background shape from data
Signal shape from simulation.

Measured cross-section pμμp: 67 +- 19 pb	LPAIR (J. Vermaseren) 42 pb

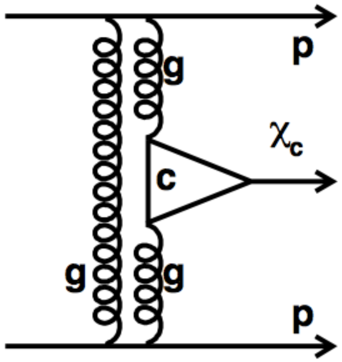
X(3872)



X(3872) observed inclusively. (arXiv:1112.5310) Could it be produced exclusively?

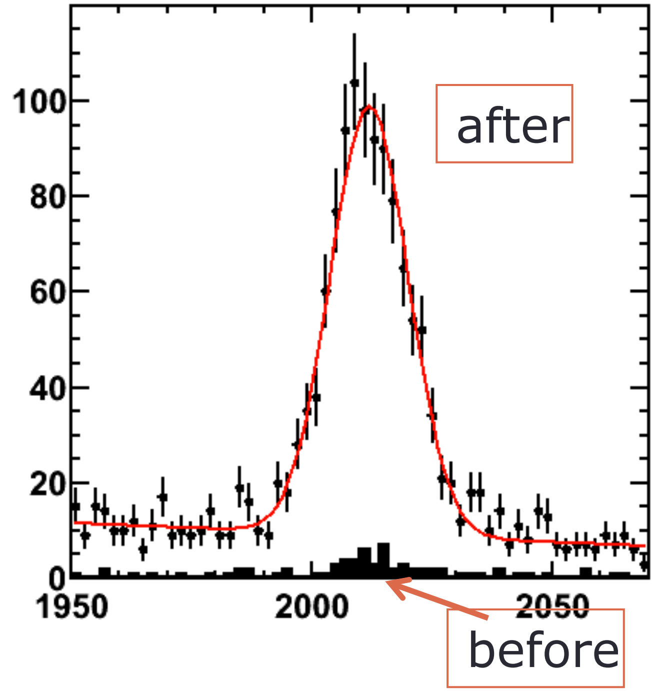
- J^{PC} of X(3872) shown by LHCb to be 1++ (arXiv:1302.6269)
- $\chi_{c(1++)}$ has been observed `exclusively' ?
- If X(3872) is a bound cc state, might expect to observe it in central exclusive production

χ_c meson



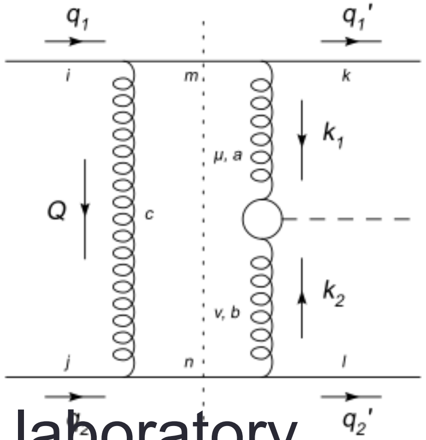
- Observation in $J/\psi+\gamma$ suffers
  - Large proton-dissociation background
  - Poor resolution to distinguish χ_{c0} χ_{c1} χ_{c2}
- To see χ_{c0}, choose more favourable decay:
  - $\chi_{c0}\to\pi\pi$ / KK ~1% while $\chi_{c2}\to\pi\pi$ / KK ~0.1%
  - Backgrounds ok? (arXiv: 1105.1626)
- New low pt trigger for 2012 to access hadronic modes

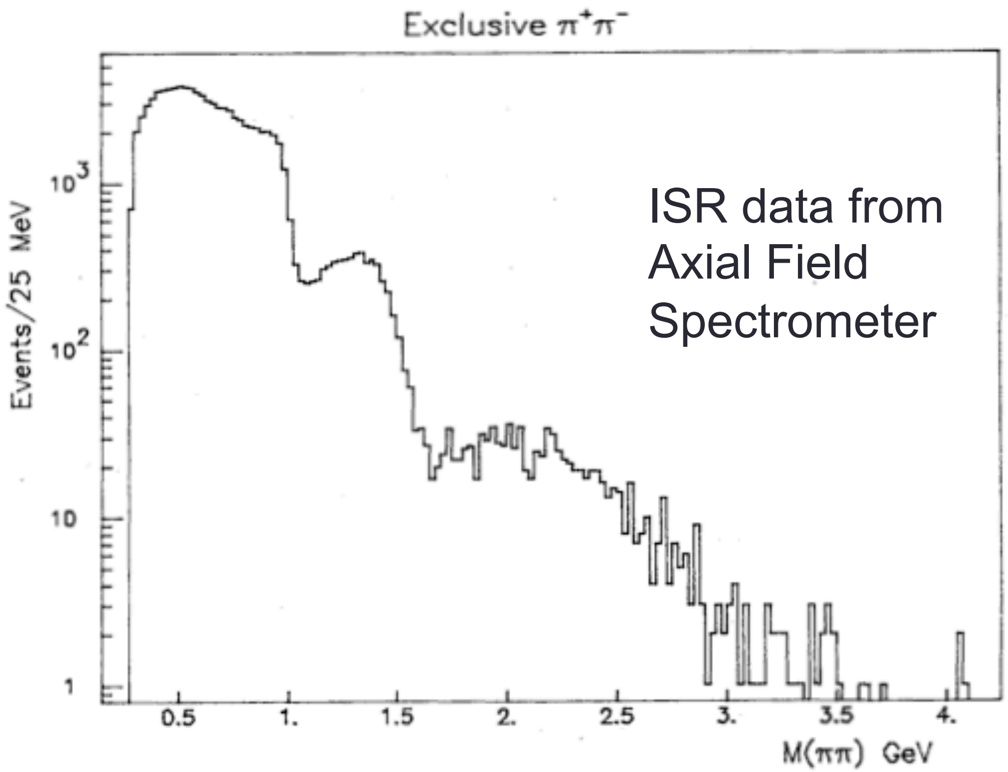
Example of $D^*\to K\pi\pi$ reconstruction in low multiplicity events



Low mass spectroscopy + glueballs

- Data from ISR/Tevatron
- Accessible at LHCb
- DPE, probing the nature of the vacuum





ISR data from Axial Field Spectrometer

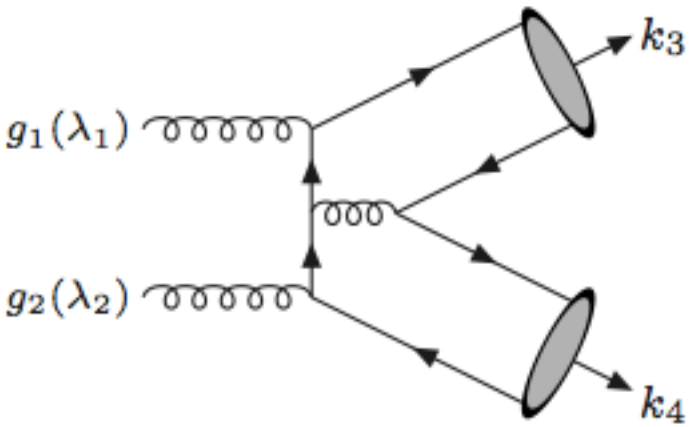
- Glue laboratory

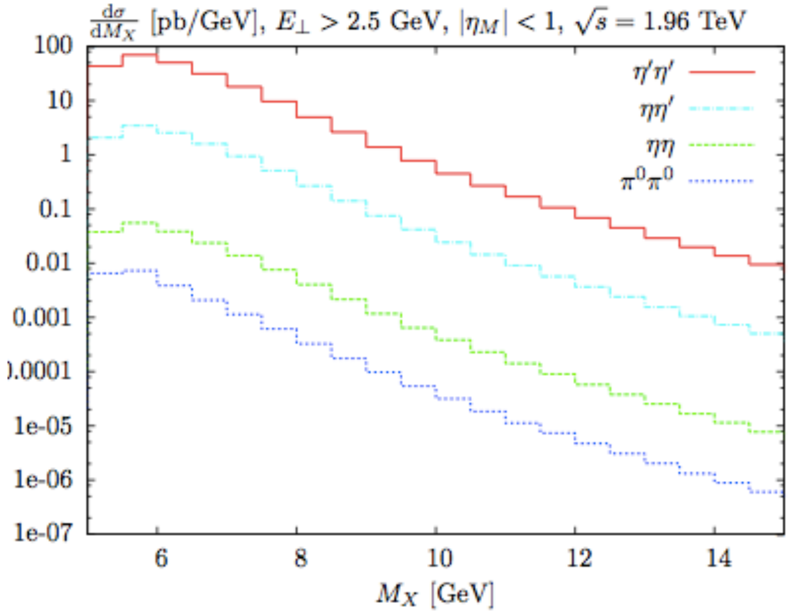
M.G. Albrow, T.D. Coughlin, and J.R. Forshaw, Prog. Part. Nucl. Phys. **65**, 149 (2010). arXiv: 1006.1289

[101] T. Akesson, et al., A search for glueballs and a study of double pomeron exchange at the CERN Intersecting Storage Rings, Nucl. Phys. B264 (1986) 154.

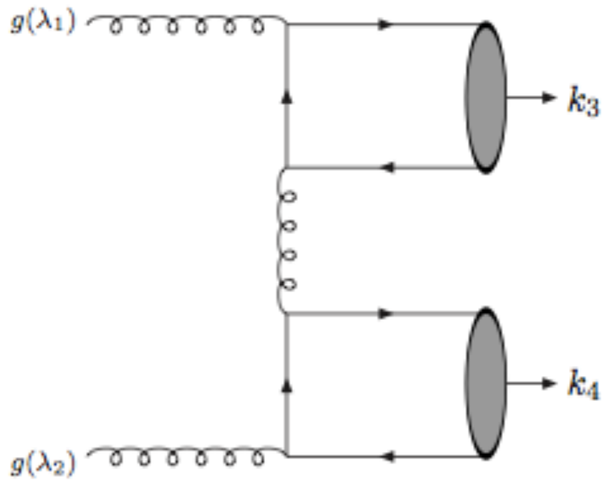
(Harland-Lang, Khoze, Ryskin, Stirling)

CEP meson-meson production arXiv:1105.1626





- Vanishing cs when gluons in J_z=0
- Flavour non-singlet mesons suppressed (thus ππ/KK small)
- Flavour singlet (e.g. η'η' production) can proceed via



Some approximate yields for Yellow Report

Assume $6fb^{-1}$ at 13 TeV with <μ>=1
Note: LHCb can use 40-100% of this luminosity, depending on whether crossings with single or few interactions are used.

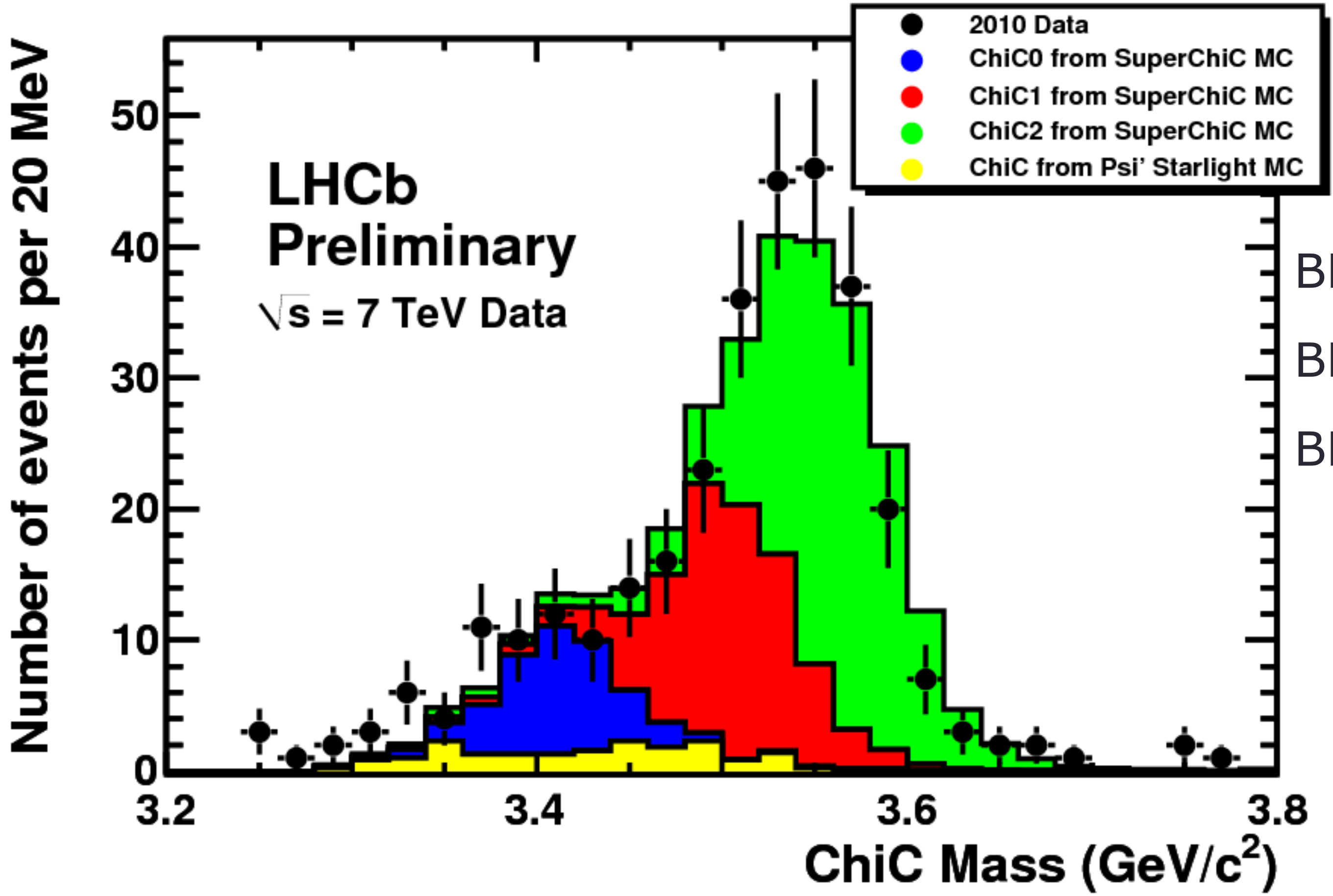
J/Ψ	2,500,000
Ψ(2S)	37,500
ϒ(1S)	2,000
ϒ(2S)	1,000
ϒ(3S)	500
pp->pμμp	20,000
χ_{c0}->J/Ψγ	20,000
χ_{c0}->ππ	80,000
χ_{c0}->KK	40,000
η'η'->(ππγγ)(ππγγ)	10000

Conclusions

- Two published measurements in CEP
- Several more in the pipeline
- Improvements to rapidity gap identification critical
- Yellow Report to include CEP + much more physics that will be discussed at Trento workshop.

Backup

χ_c: DiMuon+Photon Invariant Mass



BR(χc0->J/ψγ)=1.2%

BR(χc1->J/ψγ)=34.4%

BR(χc2->J/ψγ)=19.5%

Inelastic contribution appears to be much larger than for J/ψ.
In a first approximation it should be square of bkg in J/ψ process.

Theory v experiment

$\sigma_{\chi_{c0} \to \mu^+\mu^-\gamma}$ = 9.3 +/- 2.2 +/- 3.5 +/- 1.8 pb

$\sigma_{\chi_{c1} \to \mu^+\mu^-\gamma}$ = 16.4 +/- 5.3 +/- 5.8 +/- 3.2 pb

$\sigma_{\chi_{c2} \to \mu^+\mu^-\gamma}$ = 28.0 +/- 5.4 +/- 9.7 +/- 5.4 pb

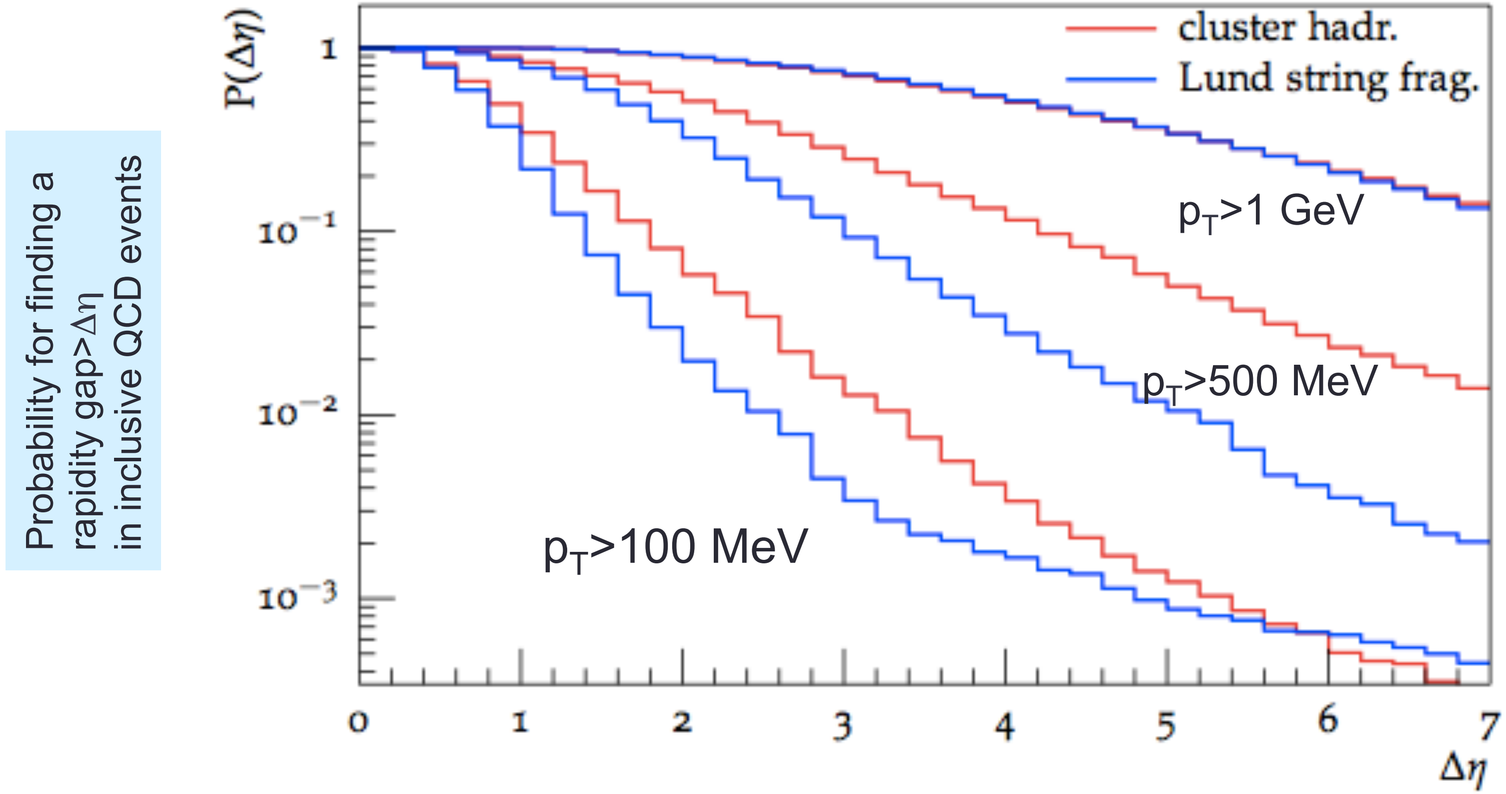
LHCb preliminary results with 2010 data

	χ_0: 9.3 +- 4.5 pb	χ_1: 16.4 +- 7.1 pb	χ_2: 28.0 +-12.3 pb
SuperChic:	14 pb	10 pb	3 pb

Large contribution due to X_{c0} is confirmed.

χ_{c2} larger than expected but note that non-elastic background has been assumed same for each resonance. More precise data required.

What’s a large gap?



- Khoze, Kraus, Martin, Ryskin, Zapp, “Diffraction and correlations at the LHC: definitions and observables”, arXiv:1005.4839v2
- Probability for inclusively produced J/ψ to give two muons and nothing else inside LHCb is < $\sim 10^{-5}$