PDF4LHC:
Recent results from LHCb

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PDF4LHC Meeting
13 September 2016.

Outline

- New results from LHCb since last PDF4LHC
  - Z cross-section (e and μ) at 13 TeV
  - W cross-section at 8 TeV (in e-channel)
  - W/Z+jet cross-section at 8 TeV
  - Exclusive J/ψ at 13 TeV

Z cross-section at 13 TeV

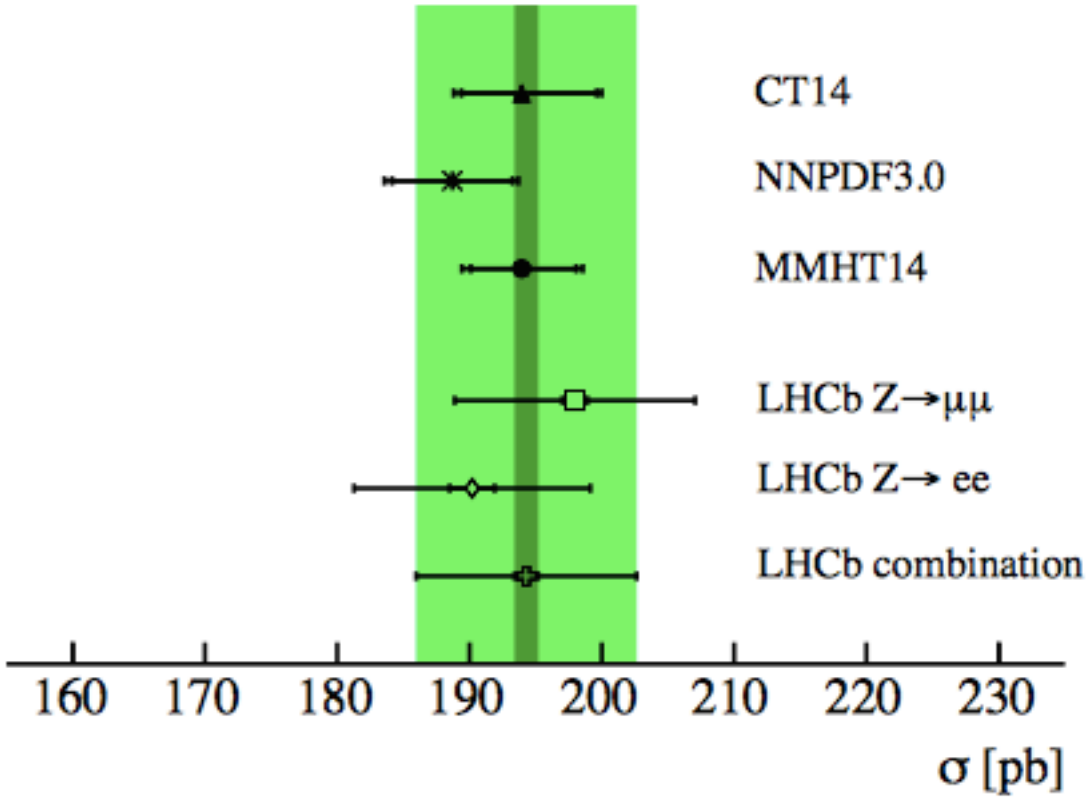
- Dimuon and Dielectron final states, pT>20 GeV, 2<η<4.5
- L=294+-11pb^{-1}
- Average pile-up is 1.08
- Similar techniques to 7 and 8 TeV analyses.
- Efficiencies mainly from data through tag-and-probe.
- 43,643 Z->μμ with purity of 99.2%
- 16,395 Z->ee with purity 92.2%

Source	$\Delta\sigma_Z^{\mu\mu}$ [%]	$\Delta\sigma_Z^{ee}$ [%]
Statistical	0.5	0.9
Reconstruction efficiencies	2.4	2.4
Purity	0.2	0.5
FSR	0.1	0.2
Total systematic (excl. lumi.)	2.4	2.5
Luminosity	3.9	3.9

Z cross-section at 13 TeV

$$\sigma_Z^{\ell\ell} = 194.3 \pm 0.9 \pm 3.3 \pm 7.6\,\text{pb},$$

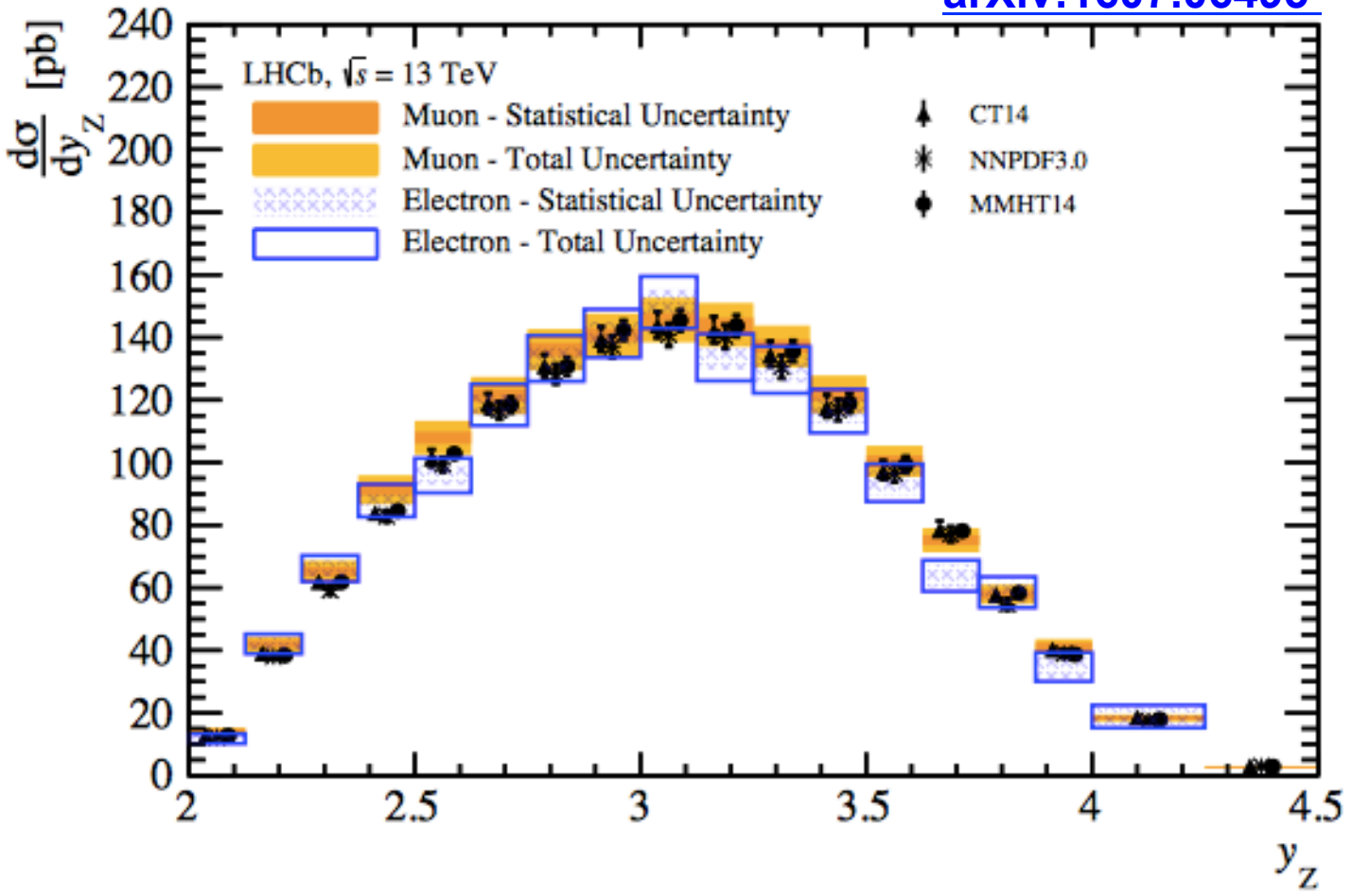
- Result (green bands) compared to different PDFs



Differential with rapidity

- Good agreement between electrons and muons
- Good agreement with different PDFs

arXiv:1607.06495



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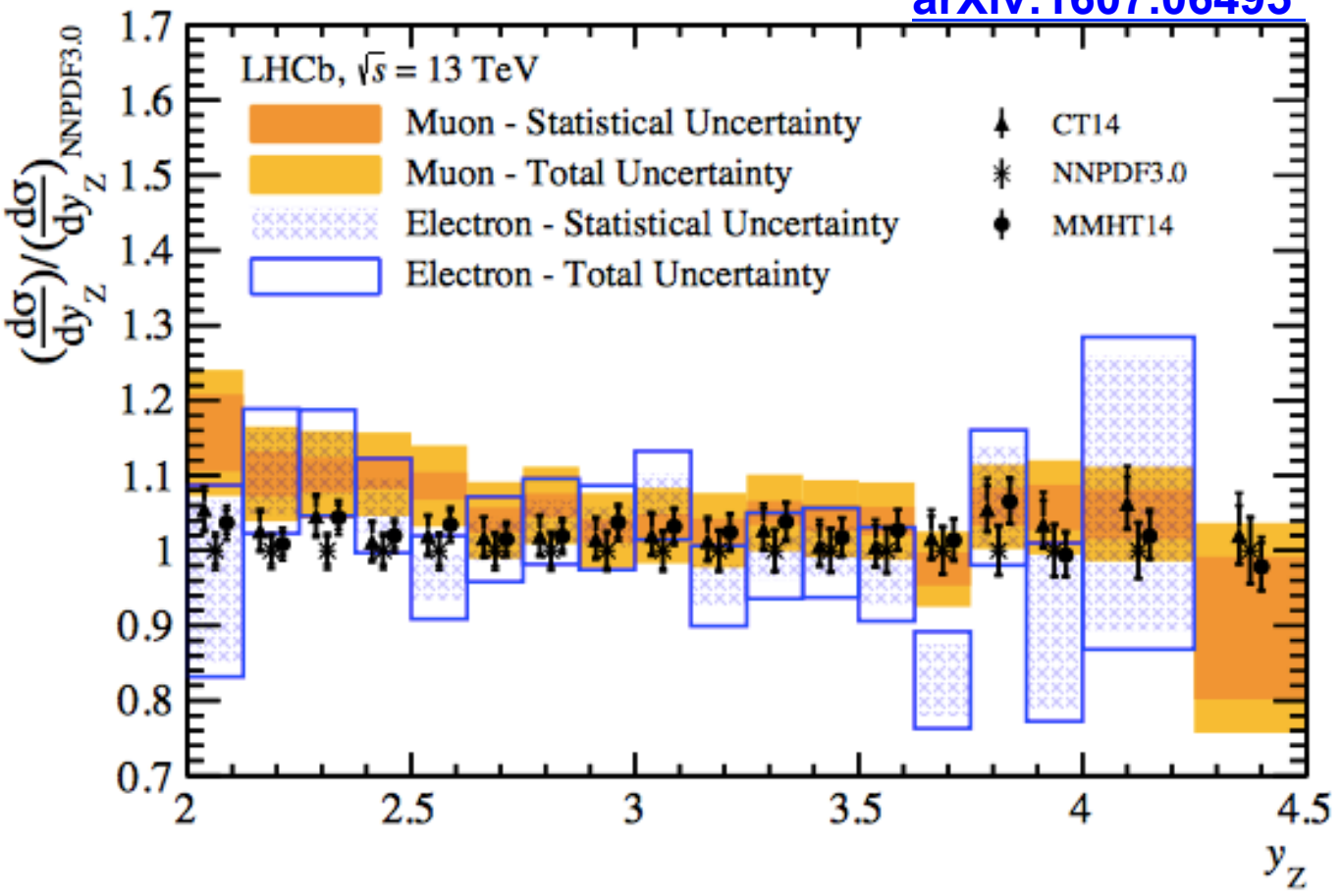
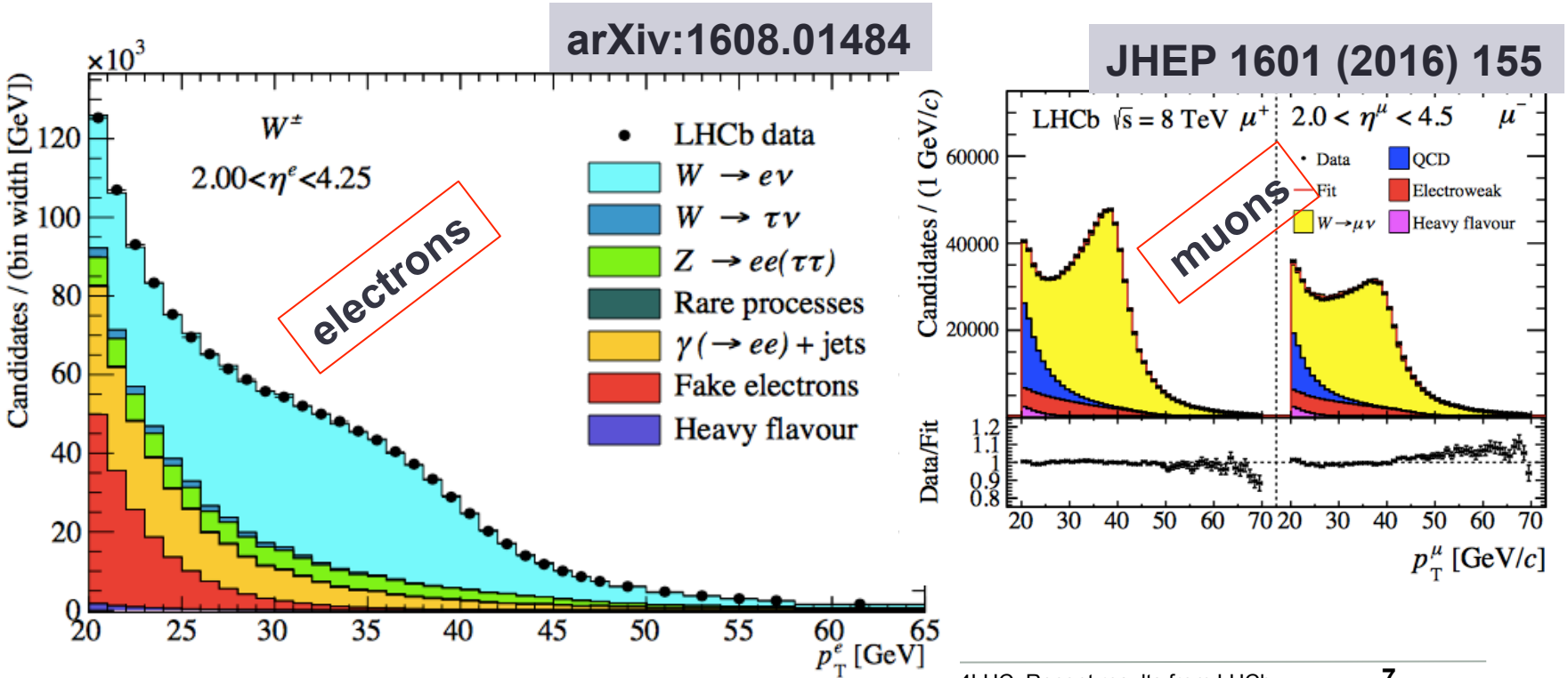


W cross-section at 8 TeV (e-channel)

- Electron channel, complementary to muon channel published previously.
- Purity poorer than muon channel but different systematics.



W cross-section at 8 TeV (e-channel)

stat sys beam-energy lumi

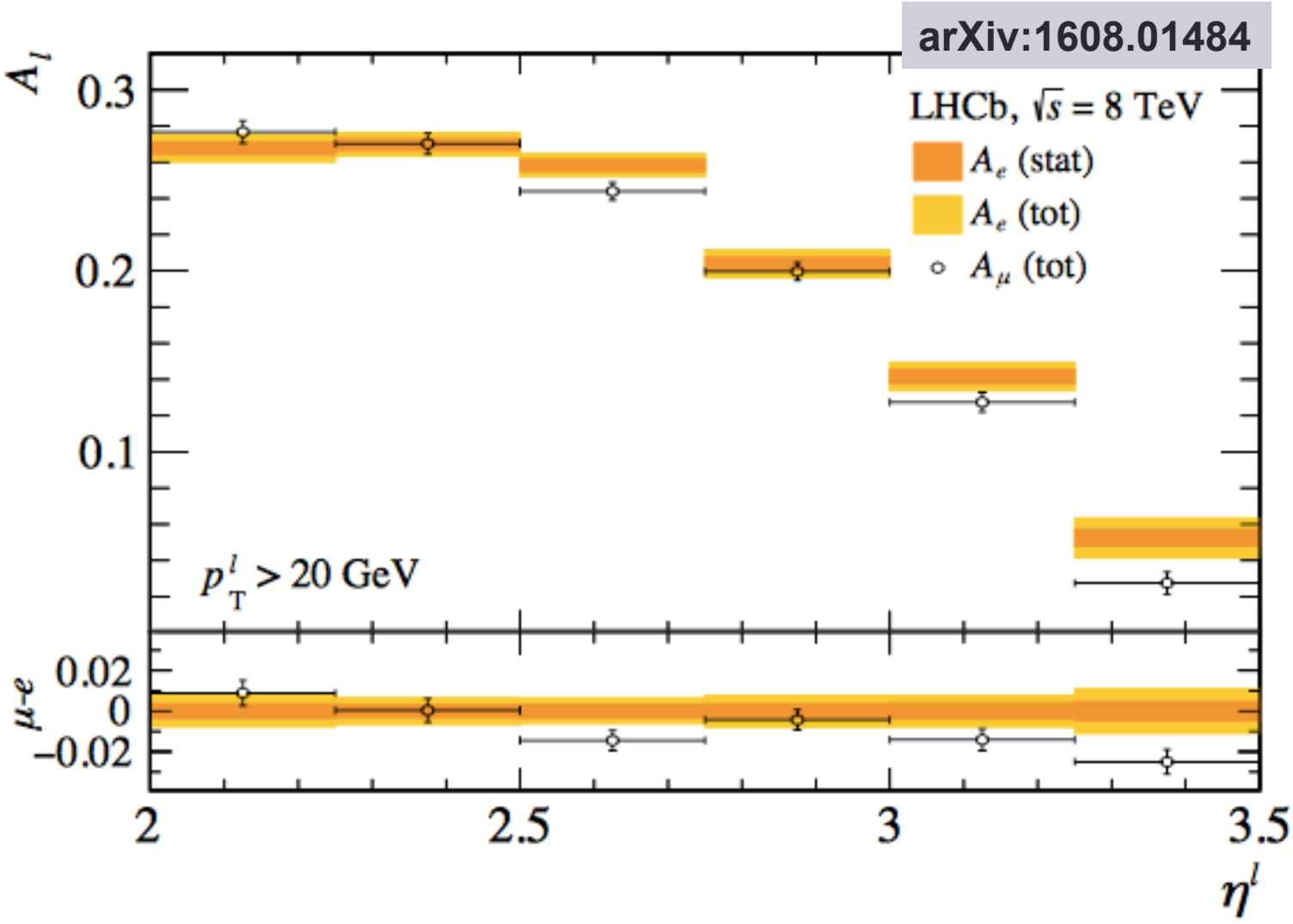
$$\sigma_{W^+\to e^+\nu_e} = 1124.4 \pm 2.1 \pm 21.5 \pm 11.2 \pm 13.0\,\text{pb},$$
$$\sigma_{W^-\to e^-\overline{\nu}_e} = 809.0 \pm 1.9 \pm 18.1 \pm 7.0 \pm 9.4\,\text{pb},$$
$$\sigma_{W\to e\nu} = 1933.3 \pm 2.9 \pm 38.2 \pm 18.2 \pm 22.4\,\text{pb},$$

$$R_{W^\pm} = 1.390 \pm 0.004 \pm 0.013 \pm 0.002,$$

$$A_e \equiv \frac{\sigma_{W^+\to e^+\nu_e} - \sigma_{W^-\to e^-\overline{\nu}_e}}{\sigma_{W^+\to e^+\nu_e} + \sigma_{W^-\to e^-\overline{\nu}_e}}.$$

W asymmetry at 8 TeV (e-channel)

Muons and electrons compared where the bins are the same



W asymmetry at 8 TeV (e-channel)

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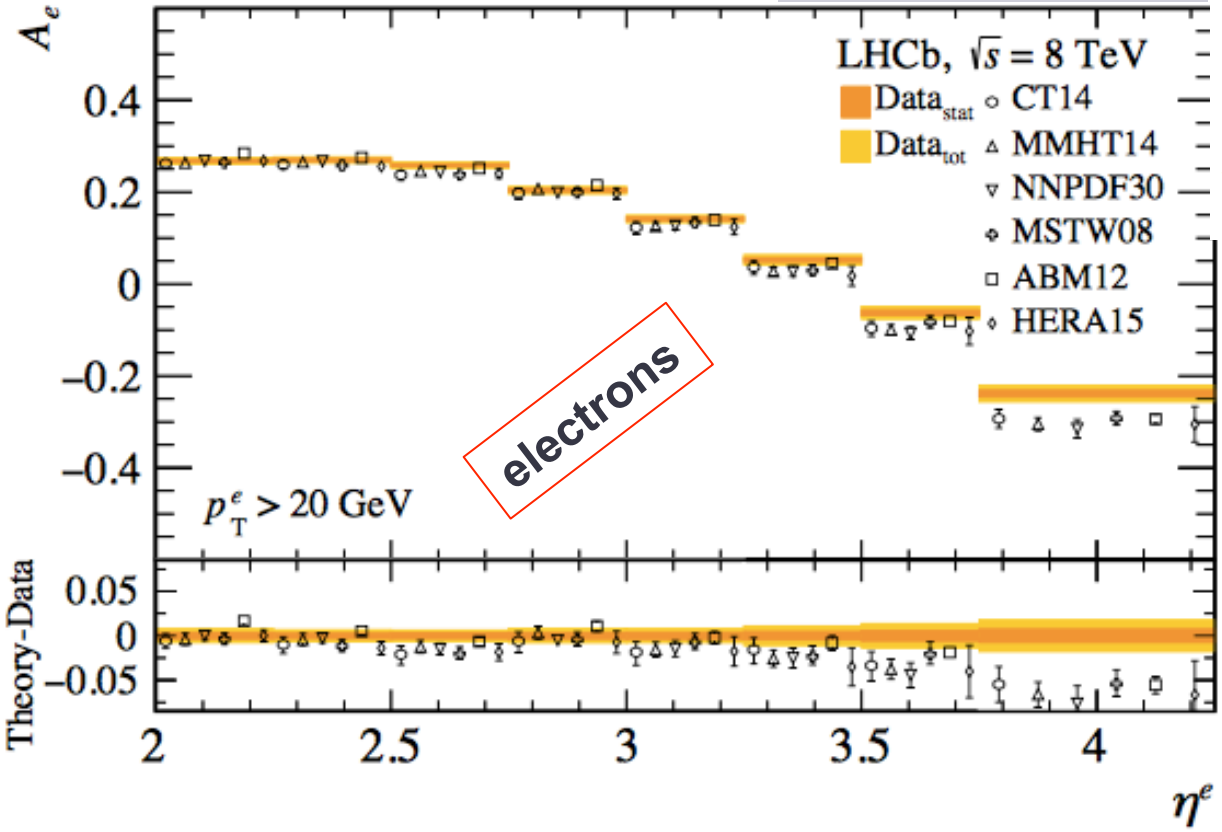
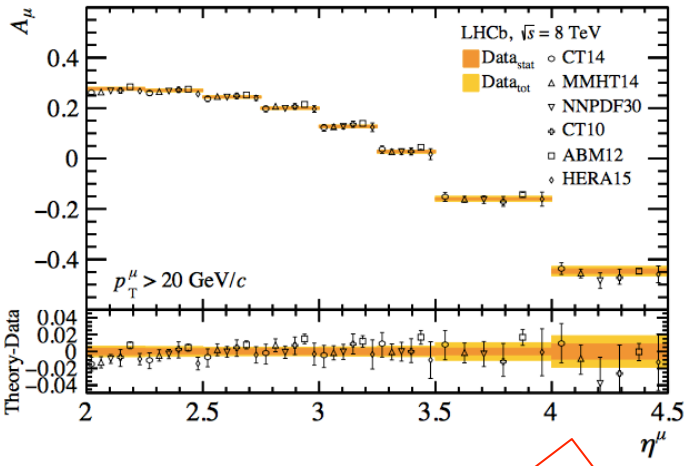
arXiv:1608.01484



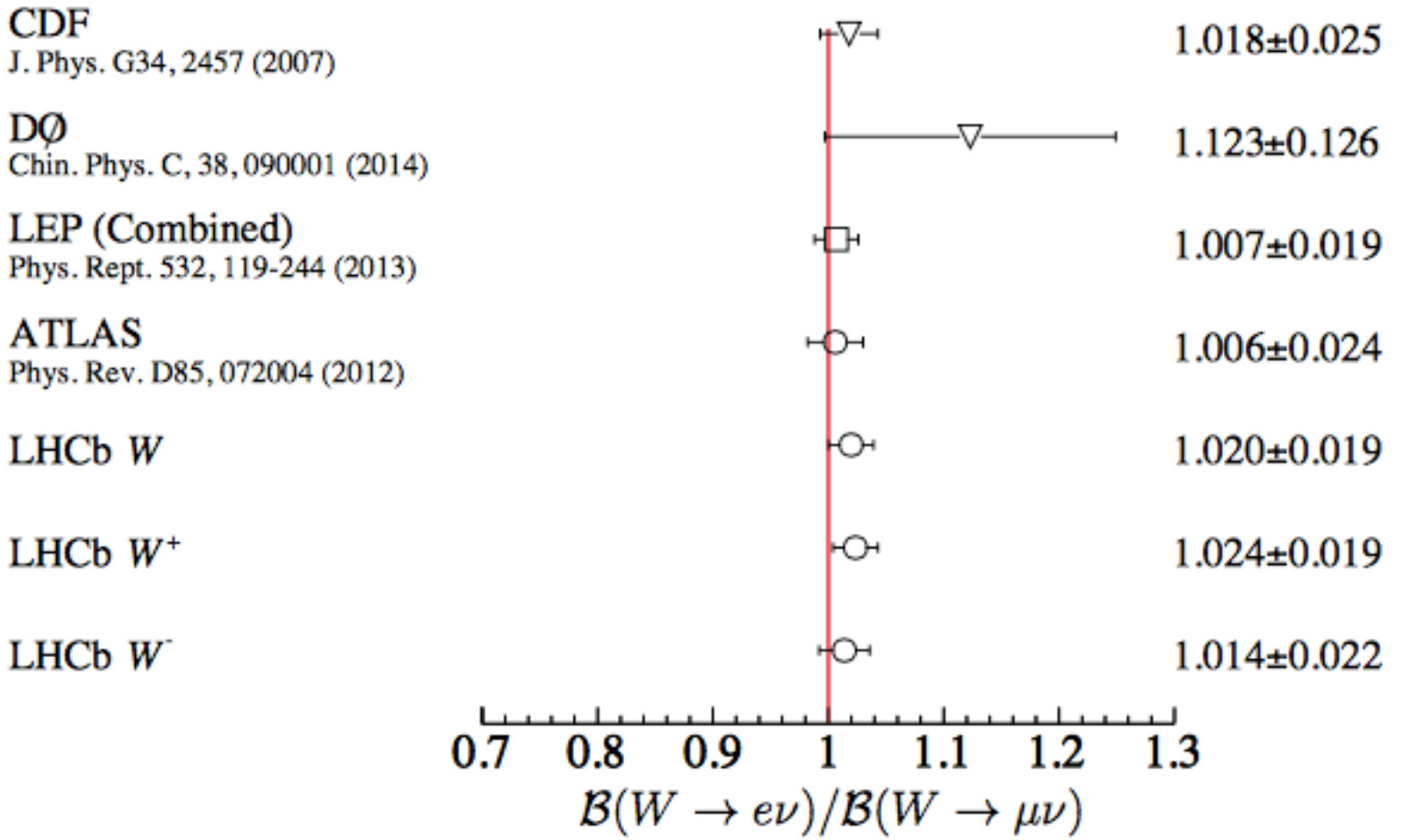
electrons



muons

Test of Lepton Universality

arXiv:1608.01484



W/Z + jets cross-section at 8 TeV

Selection

- W/Z identified through muons, p_T>20 GeV, 2<η<4.5
- Jets (anti-kT, R=0.5) have p_T>20 GeV, 2.2<η<4.2
- Jets separated from leptons by R=0.5
- For W: $p_T^{\mu\text{-Jet} + J}$ >20 GeV. Also no extra muons.

- L=1980+-20pb^{-1}
- Average pile-up is 1.4 (Jet and muons must share vertex)

- 8,162 Z+jet with purity of 97.8%
- 133746 (99,683) W+(W-) +jet with purity 46.7 (36.5) % (depends on p_T η)

Purity of W samples

- Purity depends on p_T^J, η^J, η^μ
- Found by fit to “isolation-variation”

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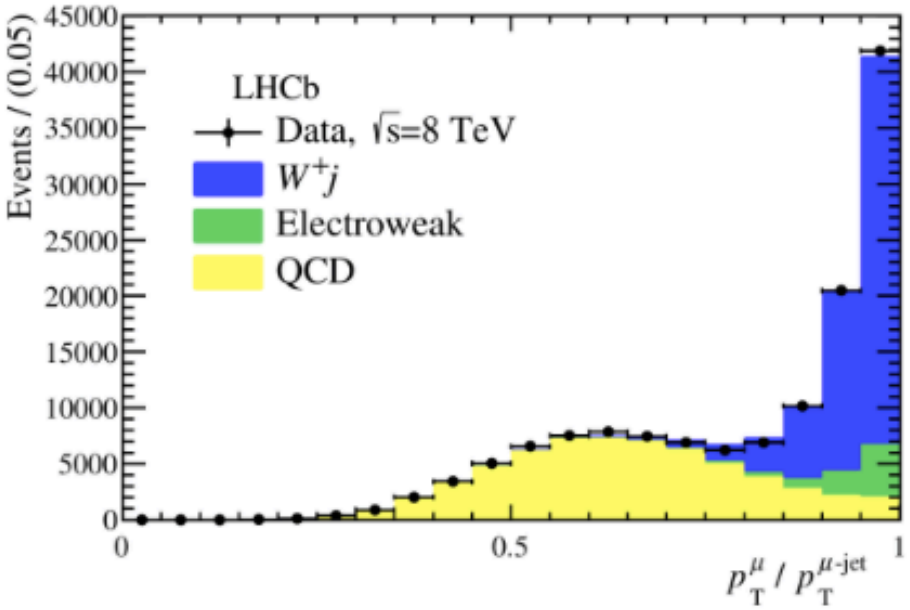
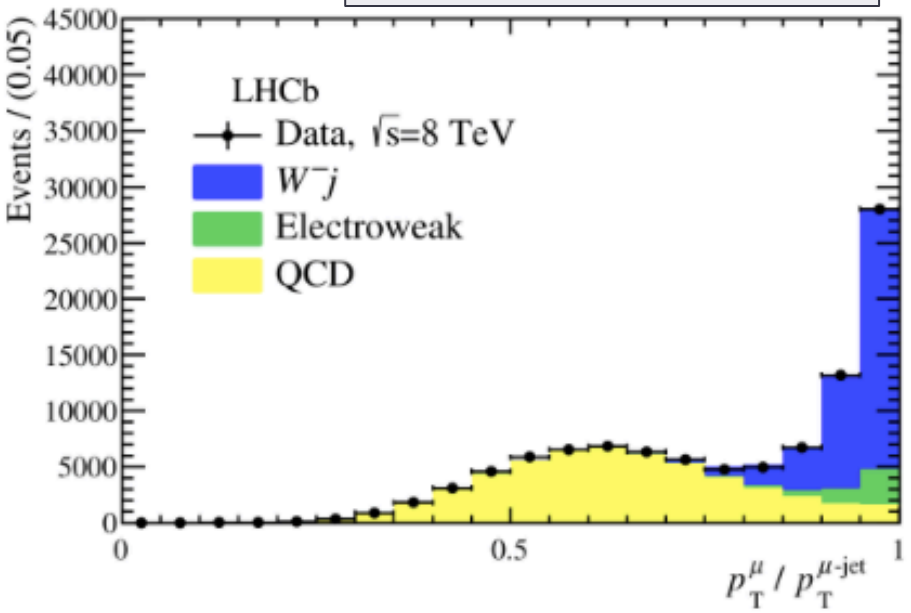




Efficiency of selections

- W and Z efficiency found as in inclusive analyses
- Jet efficiency found from simulation calibrated with data
- W analysis cross-checked with pseudo-W from Z sample where one muon is masked.

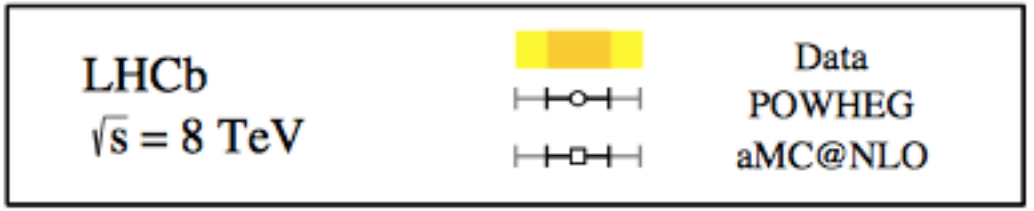
- Largest systematic uncertainties from jet energy scale and purity of W sample.

Results and systematics

- Cross-sections for W+j W-j and Zj are presented and also for the various ratios where different systematics cancel (luminosity cancels totally)

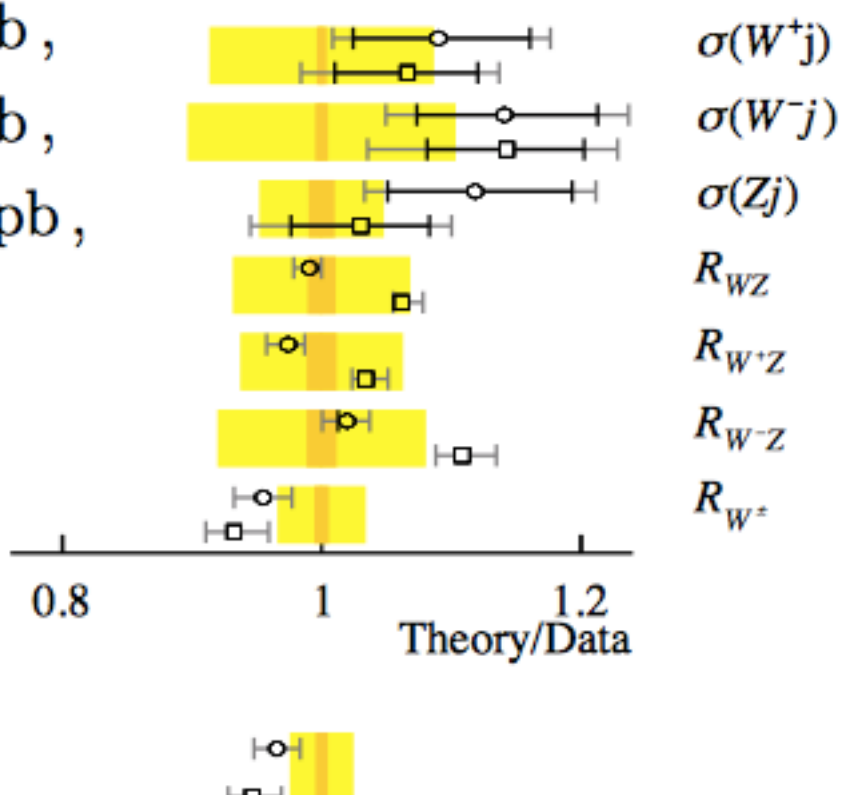
Source	σ_{W^+j}	σ_{W^-j}	σ_{Zj}	R_{WZ}	$R_{W^\pm}$
Statistical	0.4	0.5	1.1	1.2	0.7
Muon reconstruction	1.3	1.3	0.6	0.9	0.0
Jet reconstruction	1.9	1.9	1.9	0.0	0.0
Selection	1.0	1.0	0.0	1.0	0.0
GEC	0.5	0.5	0.4	0.2	0.1
Purity	5.5	7.0	0.4	6.0	2.5
Acceptance	0.6	0.6	0.0	0.6	0.0
Unfolding	0.8	0.8	0.8	0.0	0.2
Jet energy	6.5	7.7	4.3	3.4	1.2
Total Systematic	8.9	10.7	4.8	7.0	3.3
Luminosity	1.2	1.2	1.2	–	–

Results

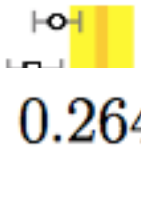


$$\sigma_{W^+j} = 56.9 \pm 0.2 \pm 5.1 \pm 0.7\,\text{pb},$$
$$\sigma_{W^-j} = 33.1 \pm 0.2 \pm 3.5 \pm 0.4\,\text{pb},$$
$$\sigma_{Zj} = 5.71 \pm 0.06 \pm 0.27 \pm 0.07\,\text{pb},$$

$$R_{WZ} = 15.8 \pm 0.2 \pm 1.1,$$
$$R_{W^+Z} = 10.0 \pm 0.1 \pm 0.6,$$
$$R_{W^-Z} = 5.8 \pm 0.1 \pm 0.5,$$
$$R_{W^\pm} = 1.72 \pm 0.01 \pm 0.06,$$



$$A(Wj) \equiv (\sigma_{W^+j} - \sigma_{W^-j})/(\sigma_{W^+j} + \sigma_{W^-j}) = 0.264 \pm 0.003 \pm 0.015.$$



Results

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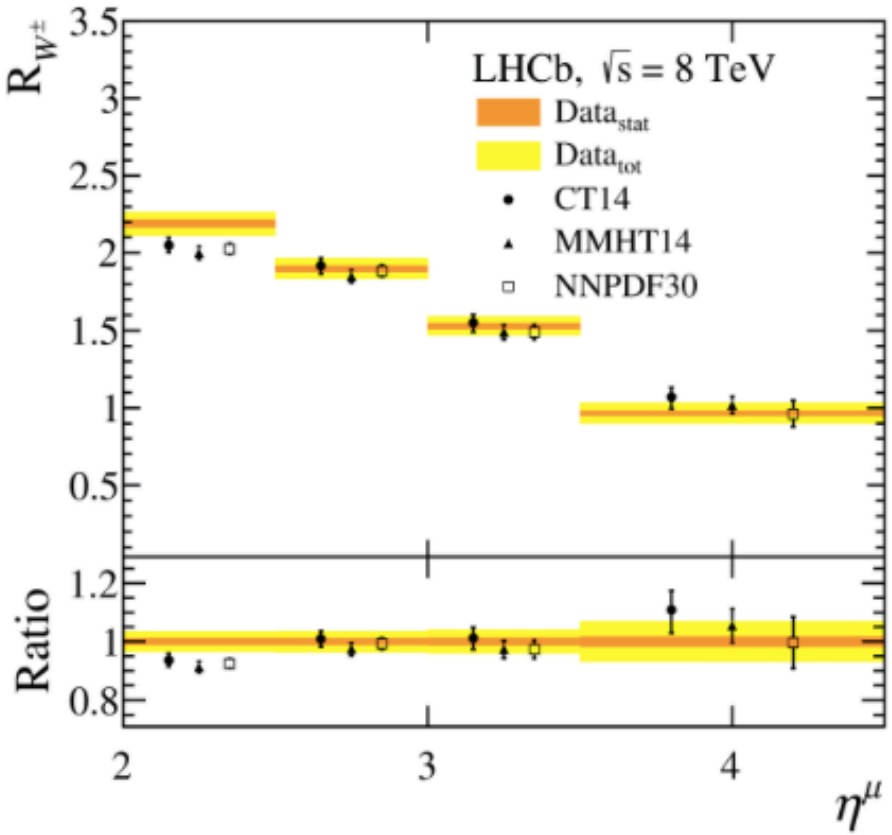
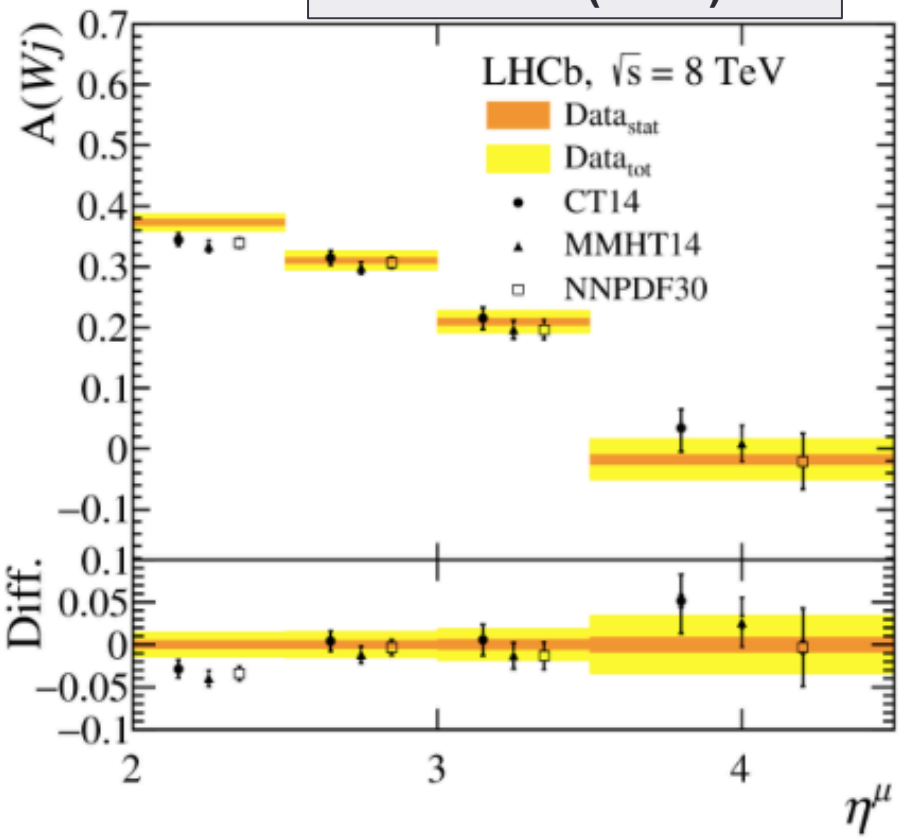




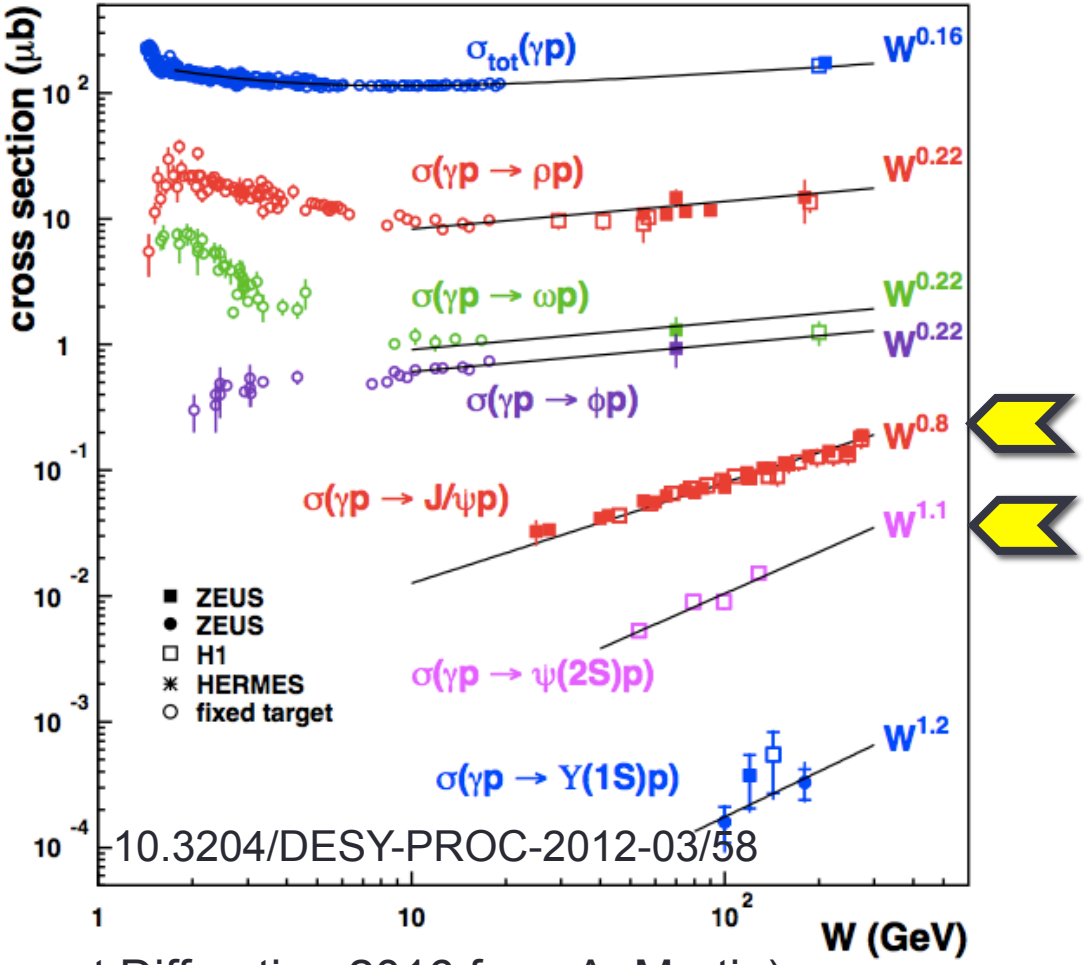
HERA vector meson photo-production results

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

Note:

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

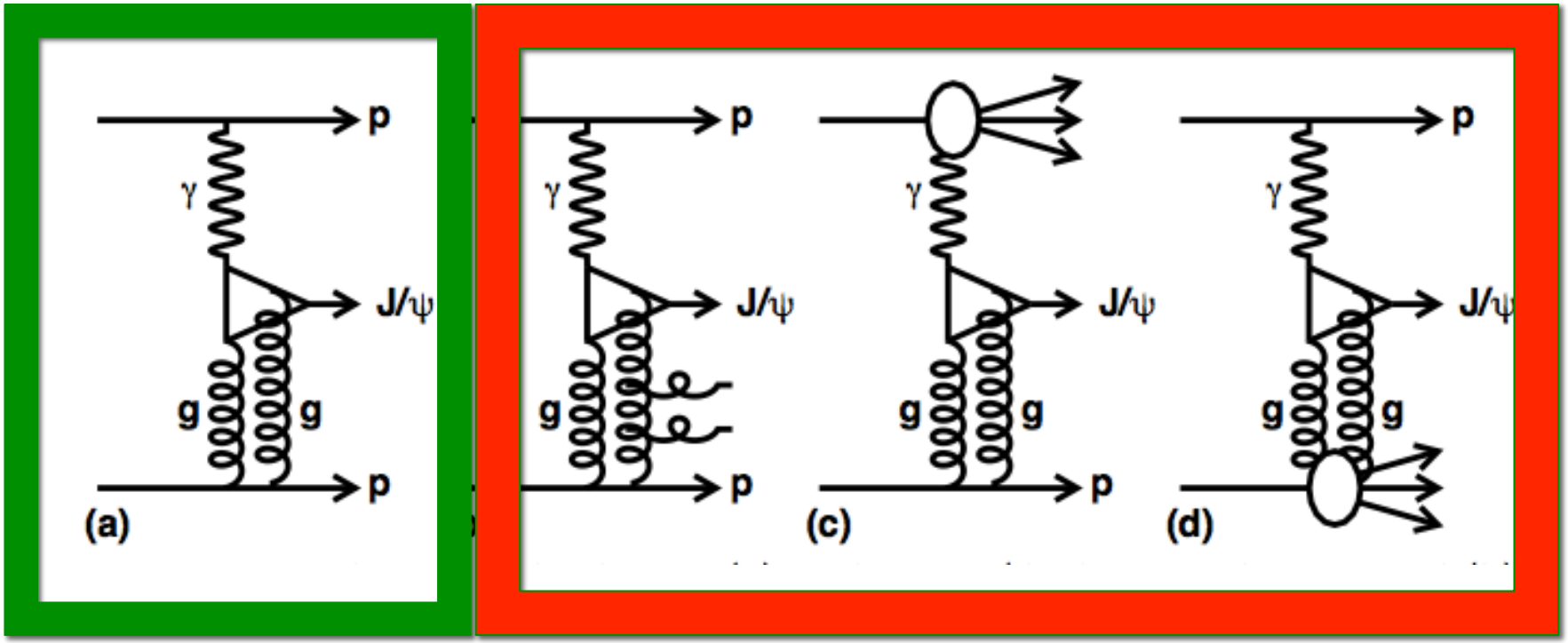
  (down to x=2E-6)



10.3204/DESY-PROC-2012-03/58

(Theory status: see presentation at Diffraction 2016 from A. Martin)

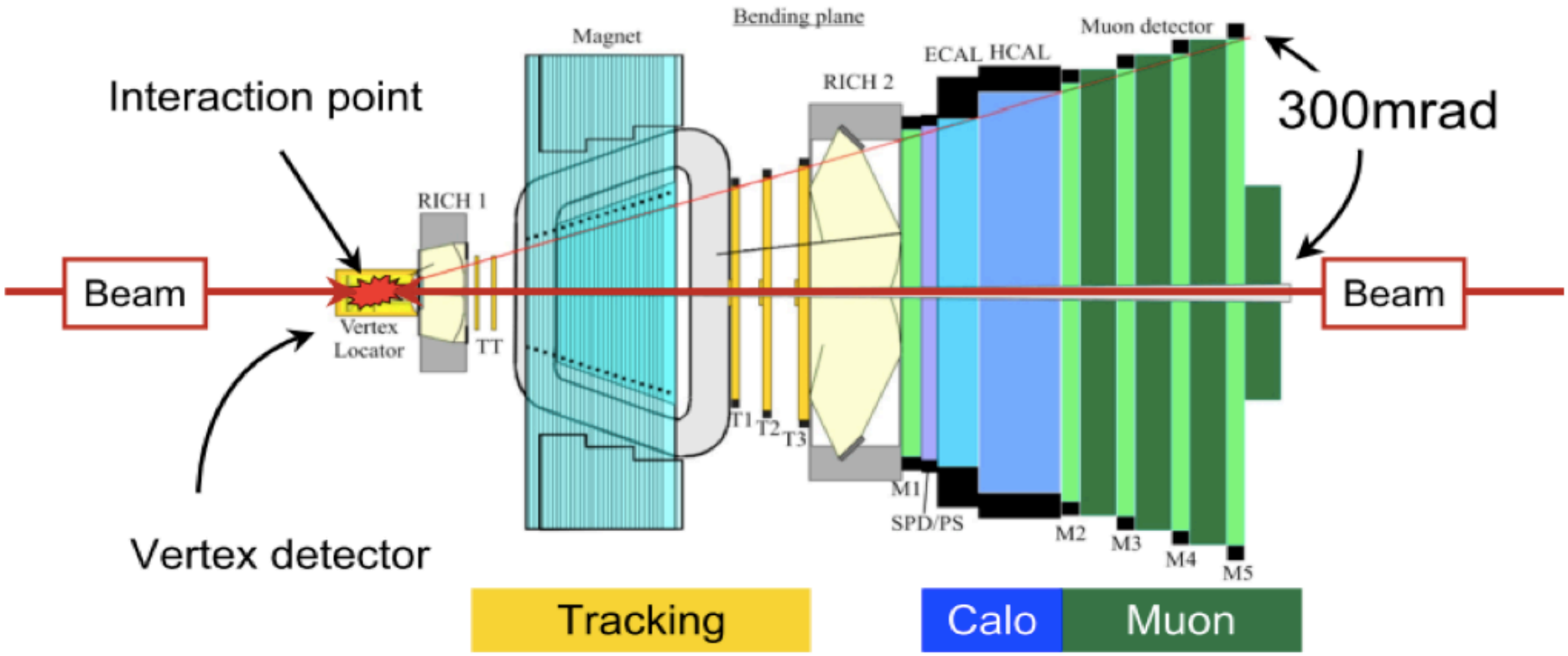
Inelastic background



Signal

Background

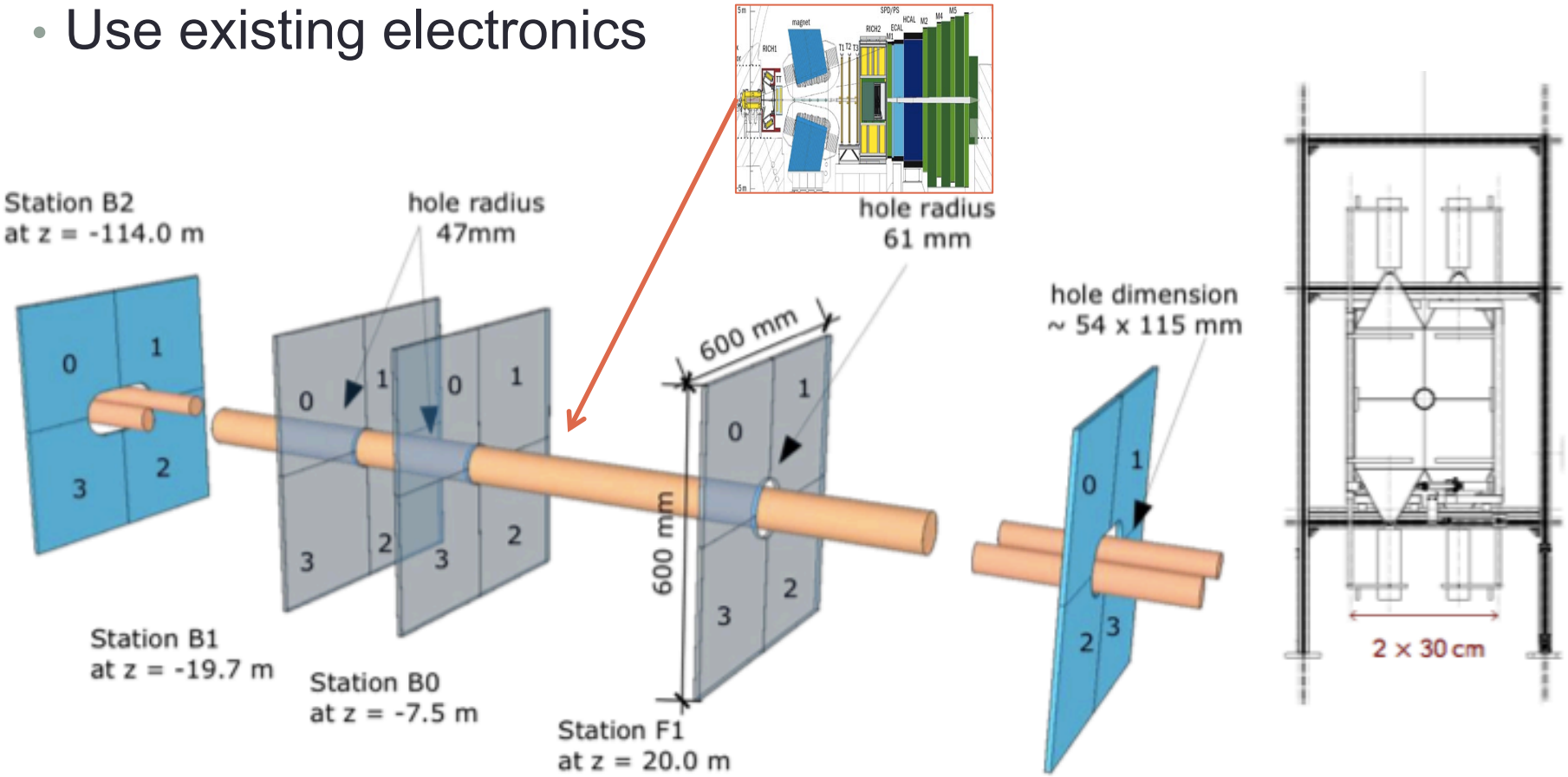
The LHCb detector



Fully instrumented: $2 < \eta < 5$
Veto region (< 2015): $-3.5 < \eta < -1.5$
Veto region (>= 2015): $-10 < \eta < -5,\ 5 < \eta < 10$

High rapidity shower counters for LHCb

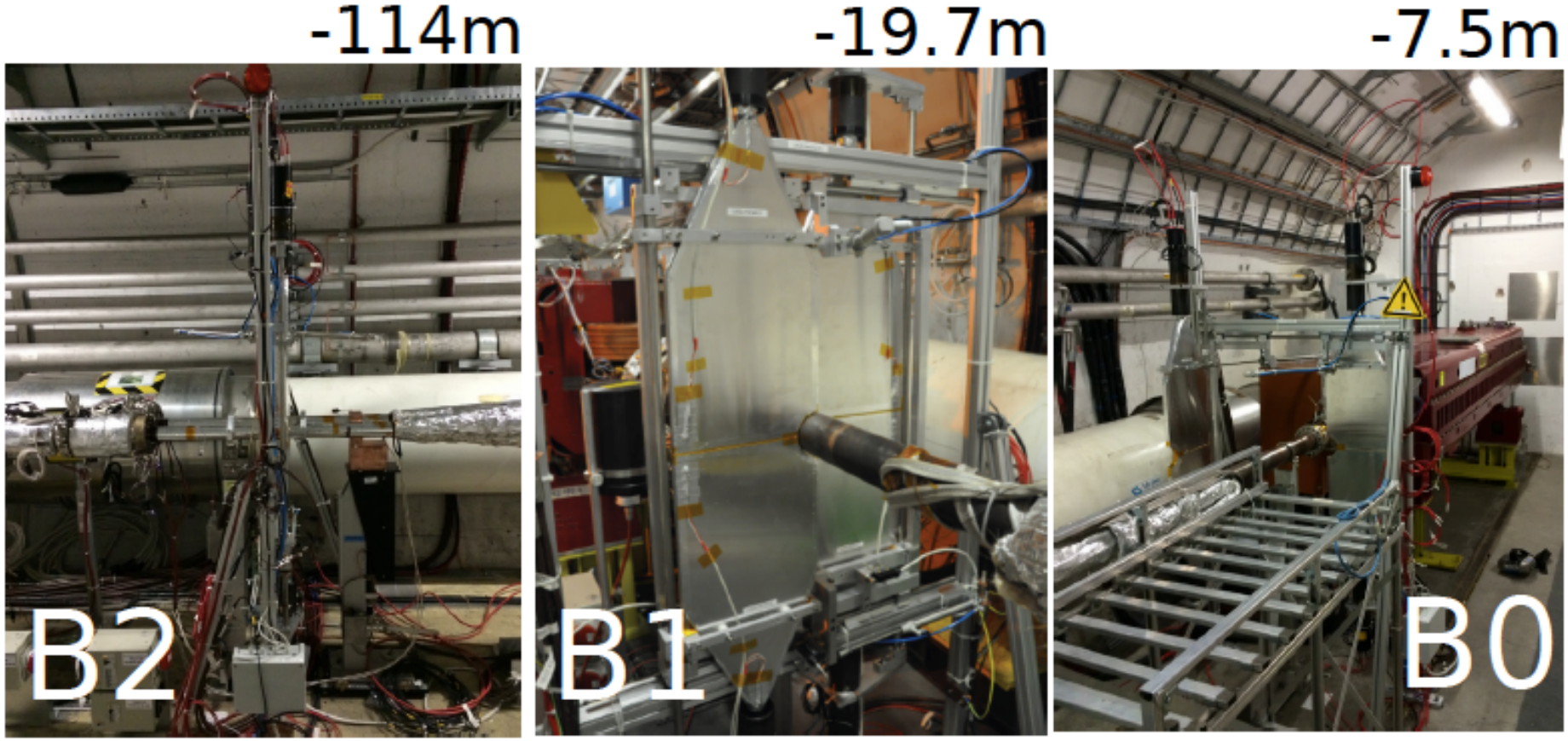
- Increase rapidity gap with scintillators in forward region
- Use existing electronics



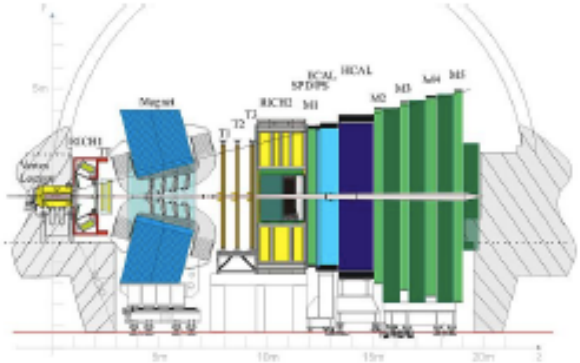
Scintillators and PMTs

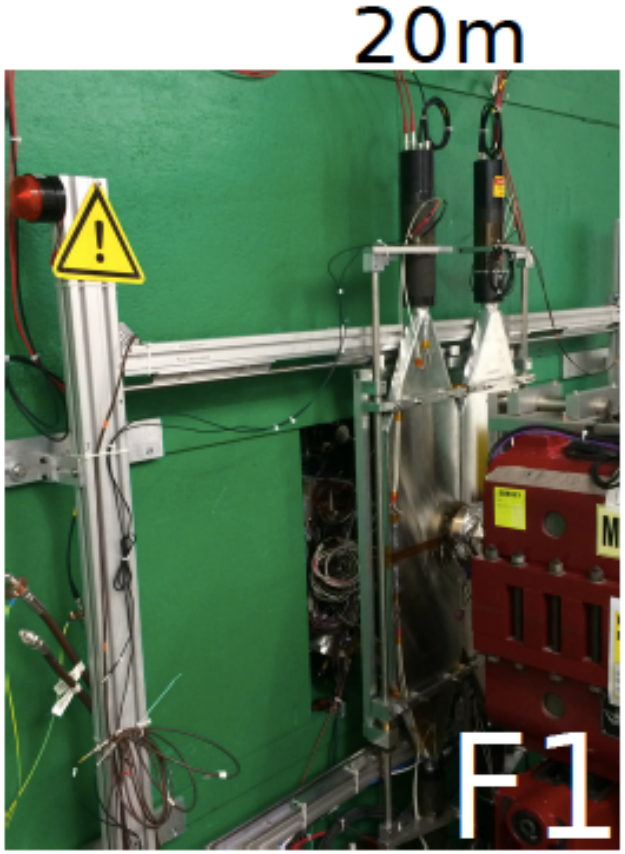
Backward Stations

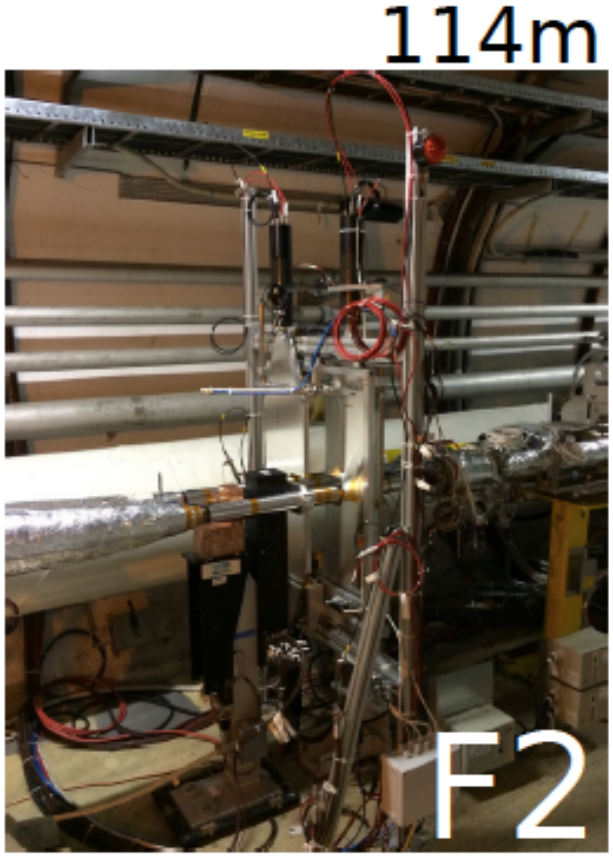
Installation finished in 2014



Forward Stations

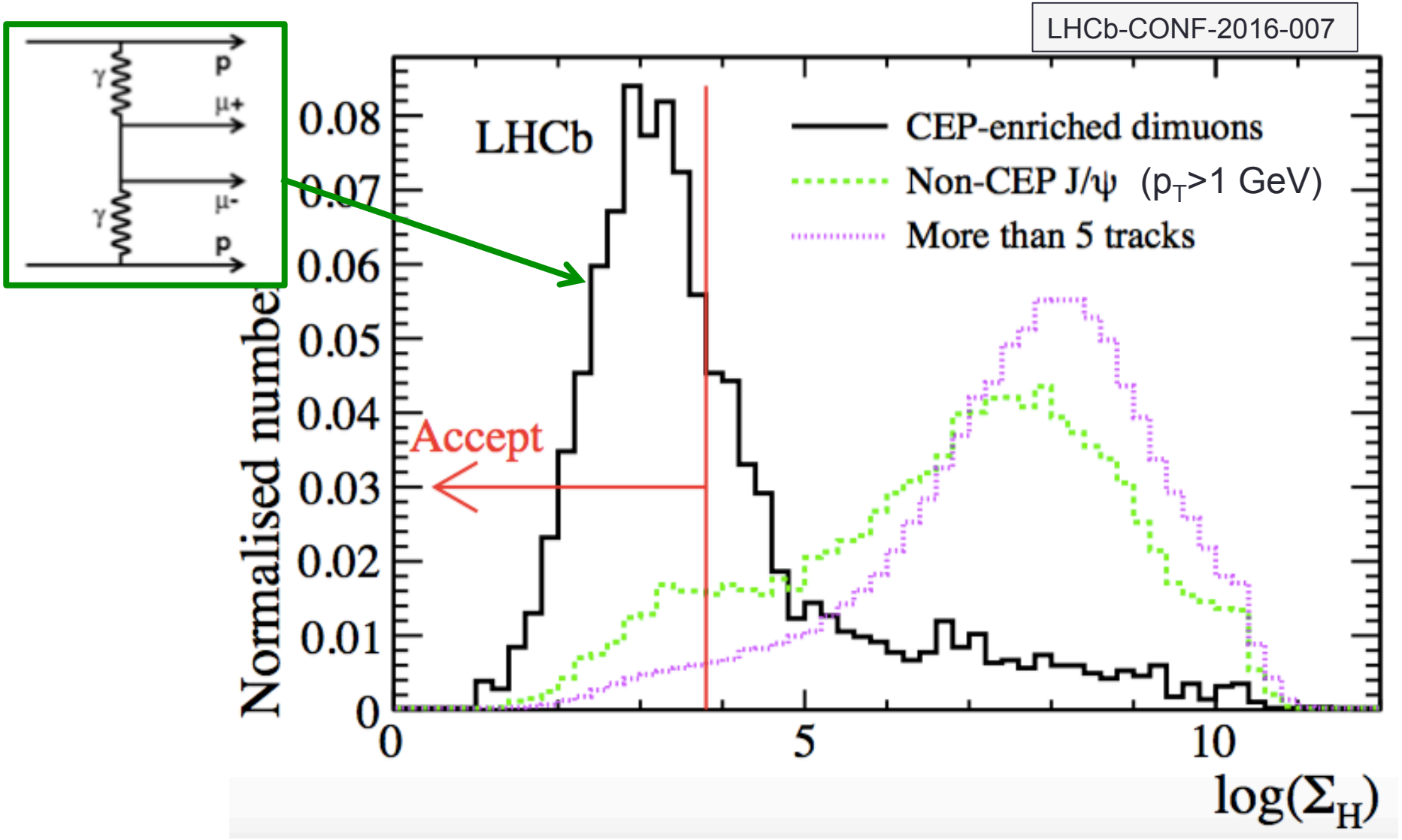




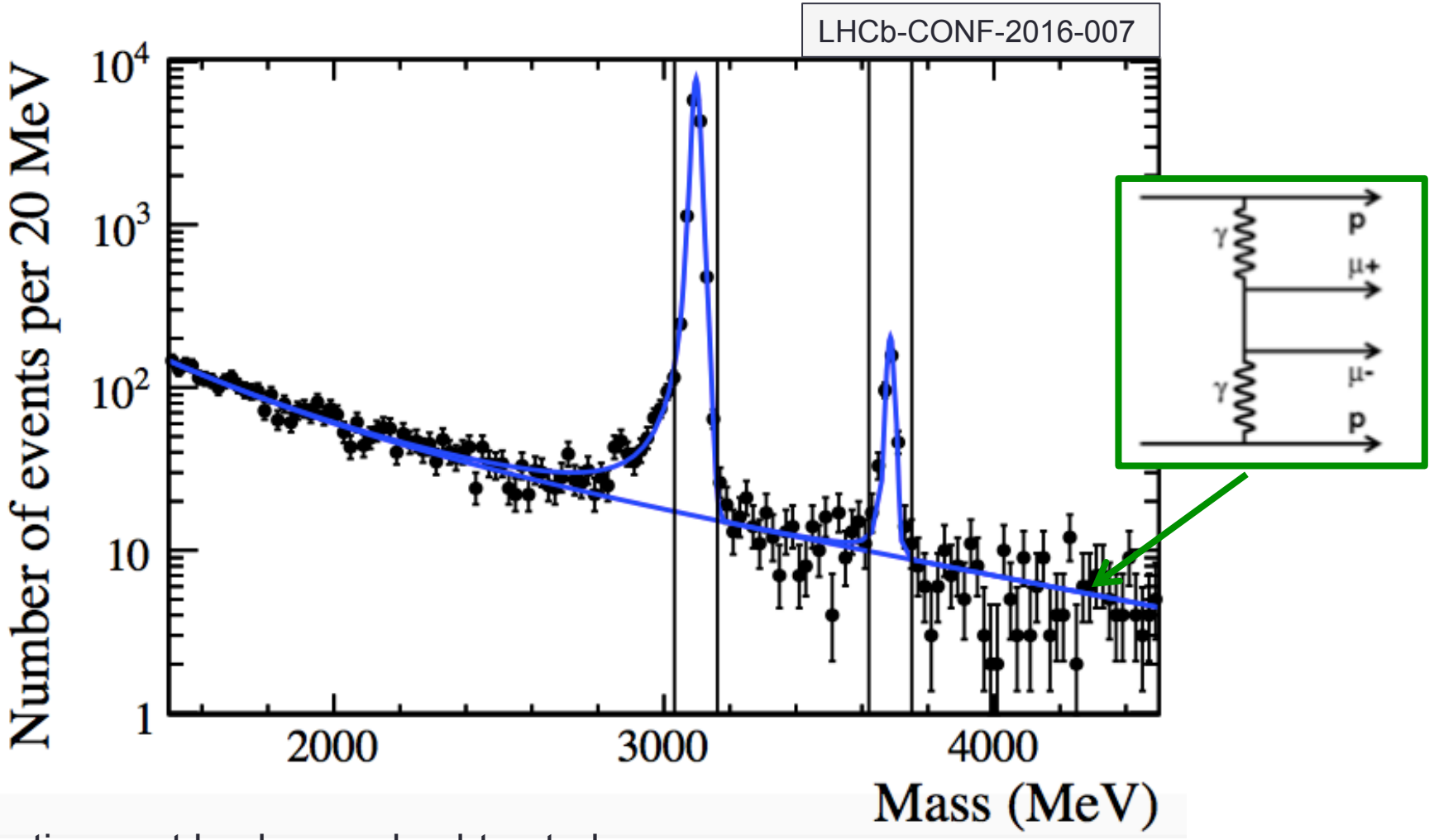


~200 pb^{-1} of data available with stable calibrations

Sum Herschel deposits in quadrature



Non-resonant background very small



Distributions not background-subtracted.
12992 J/ψ and 382 ψ(2s)

L=208 +- 4 pb^{-1}
Average pile-up 1.08

Cross-section measurement J/ψ / ψ(2S)

Purity: (found from data)
1. non-resonant bkg (1%)
2. Feeddown (6%)
3. Inelastic Jpsi production (21%)

Bkg HALVED FROM 7 TeV analysis

Number of events observed

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

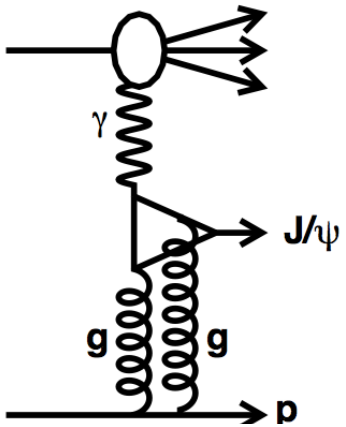
Luminosity

Acceptance (MC)

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

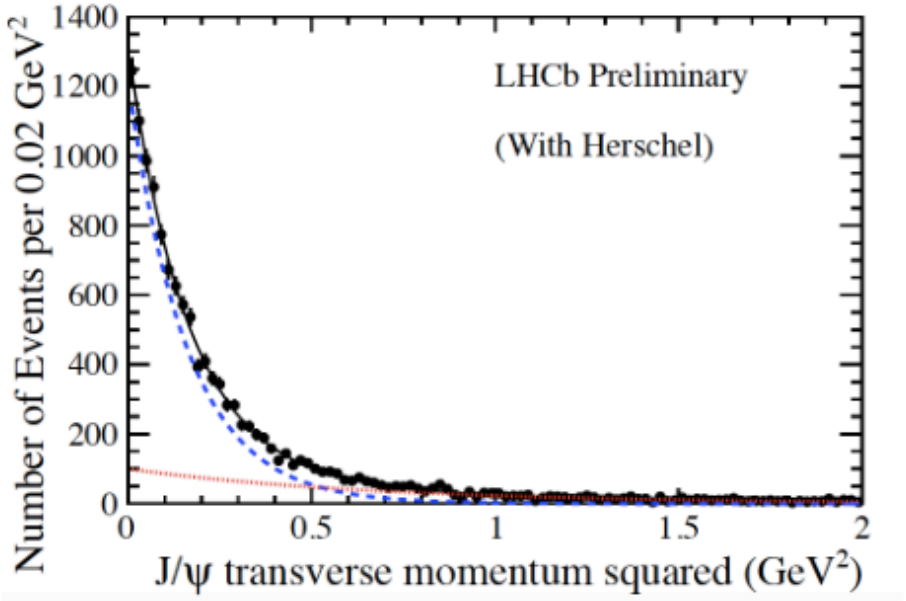
$$P(n) = \mu^n e^{-\mu} / n!$$

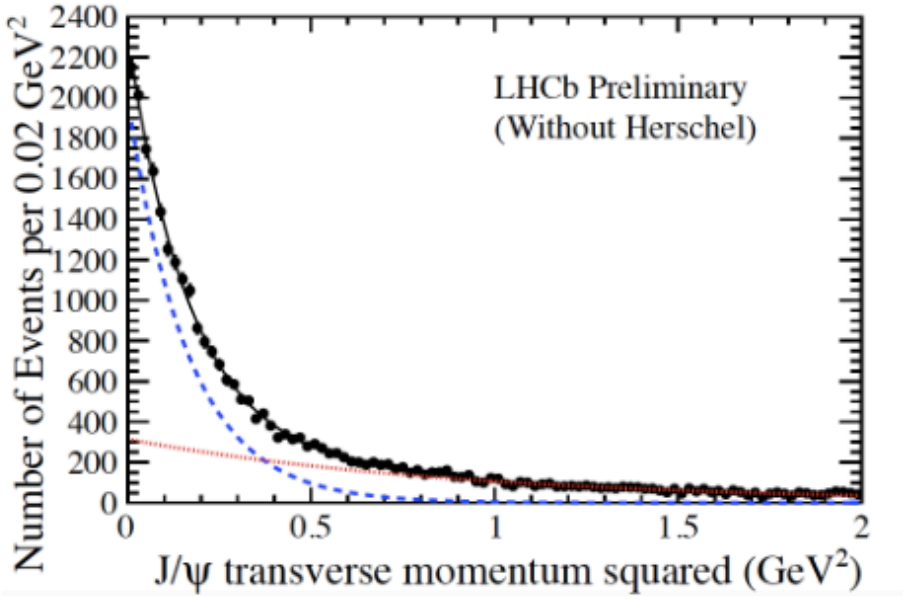
Inelastic background J/ψ



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

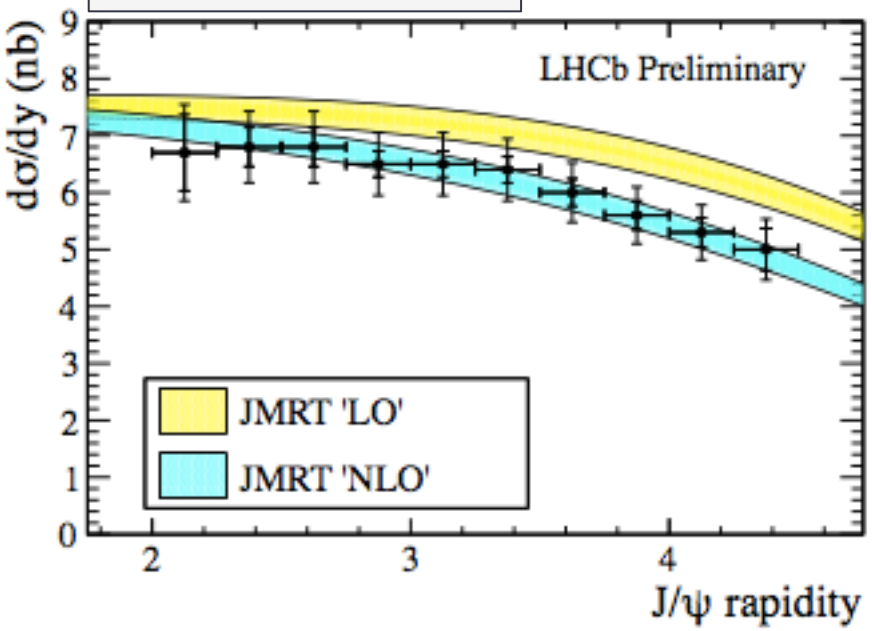
b-slope of signal is same with/without Herschel
b-slope of bkg changes (because you veto higher-pT events)

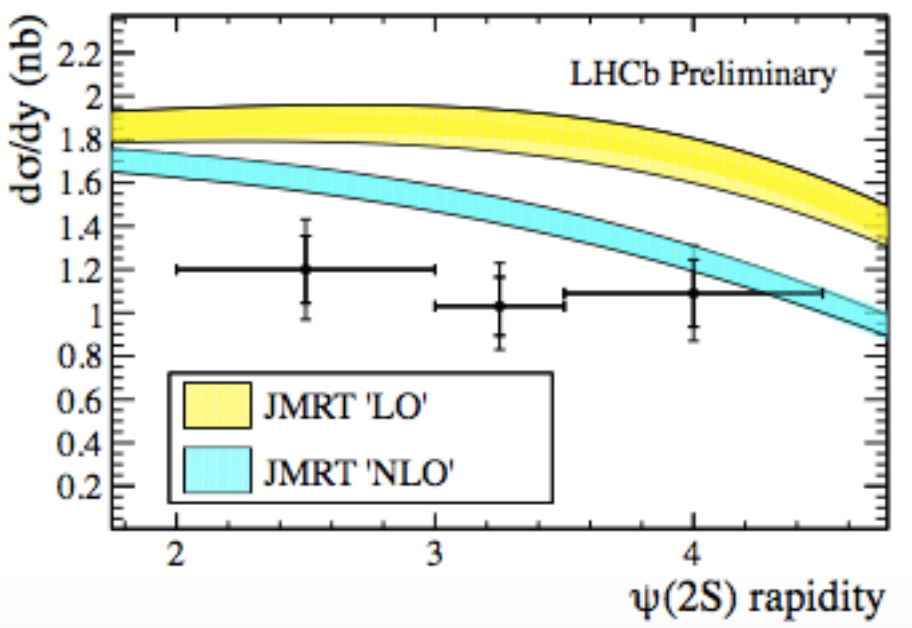




Differential cross-sections J/ψ and ψ(2S)

LHCb-CONF-2016-007



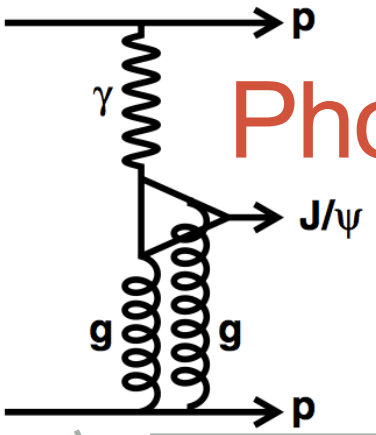


NLO agrees better than LO

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.

S. P. Jones, A. D. Martin, M. G. Ryskin, and T. Teubner, *Predictions of exclusive $\psi(2S)$ production at the LHC*, J. Phys. **G41** (2014) 055009, arXiv:1312.6795.

Photo-production cross-section



LHCb measure

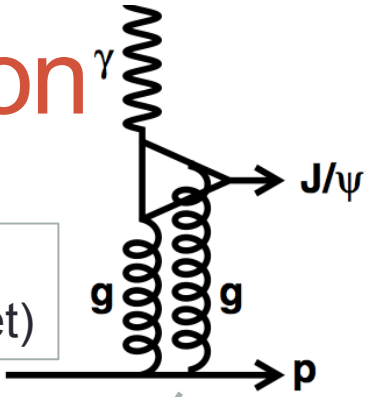


Photo-production
(HERA / fixed target)

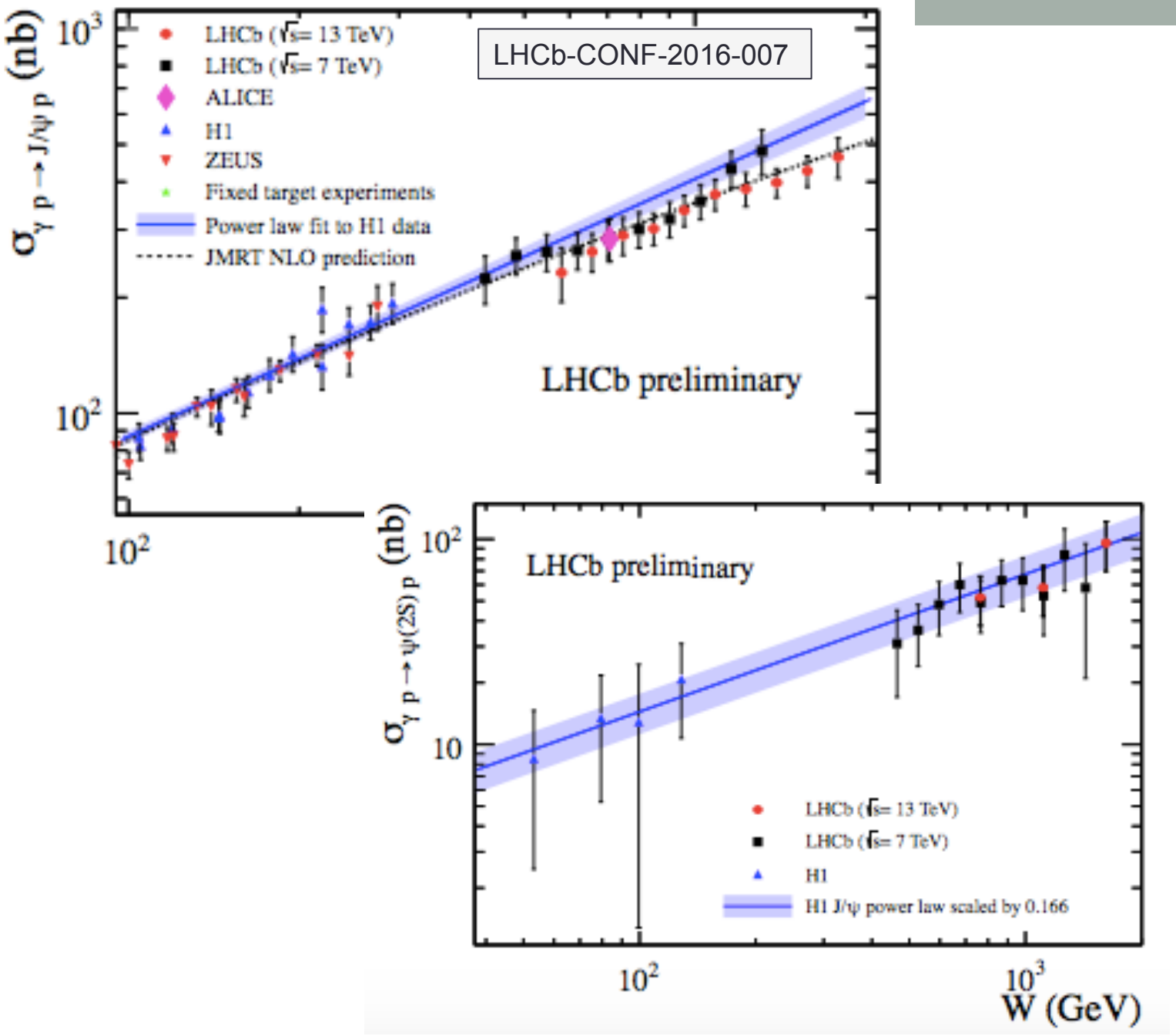
$$\frac{d\sigma}{dy}_{pp\to pJ/\psi p} = r_+ k_+ \frac{dn}{dk_+}\sigma_{\gamma p\to J/\psi p}(W_+) + r_- k_- \frac{dn}{dk_-}\sigma_{\gamma p\to J/\psi p}(W_-)$$

Gap Survival

Photon Flux

HERA measured power-law: $\sigma_{\gamma p\to J/\psi p}(W) = 81(W/90\,\mathrm{GeV})^{0.67}\,\mathrm{nb}$
Use this for W- solution (in previously measured region). LHCb measures W+

Photo-production cross-section



Conclusions

- New results from LHCb since last PDF4LHC
  - Z cross-section at 13 TeV
  - W cross-section at 8 TeV (in e-channel)
  - W/Z+jet cross-section at 8 TeV
  - Exclusive J/ψ at 13 TeV

- First three can be used immediately in PDF fits.
- We note theory improvements in the J/ψ since it was last reported on here.