Central Exclusive Production at LHCb

Ronan McNulty (UCD Dublin)
on behalf of the LHCb collaboration

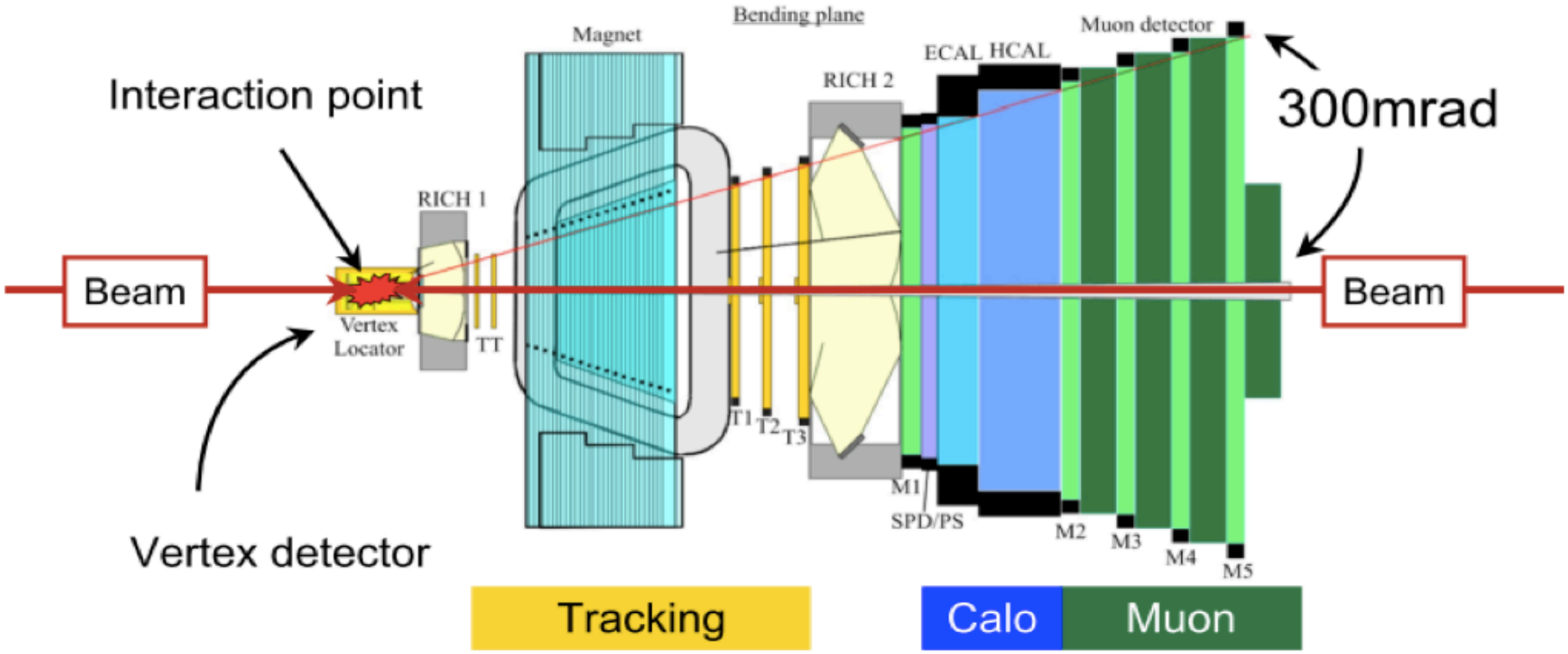
LHC Forward Physics and Diffraction
7-8 Dec 2017.

Outline

- Introduction
- Herschel Detector
- Run 2: Results at 13 TeV
  - Exclusive J/ψ and ψ(2S) at 13 TeV LHCb-CONF-2016-007
- Prospects for CEP in future

The LHCb detector

Int. J. Mod. Phys. A 30 (2015) 1530022

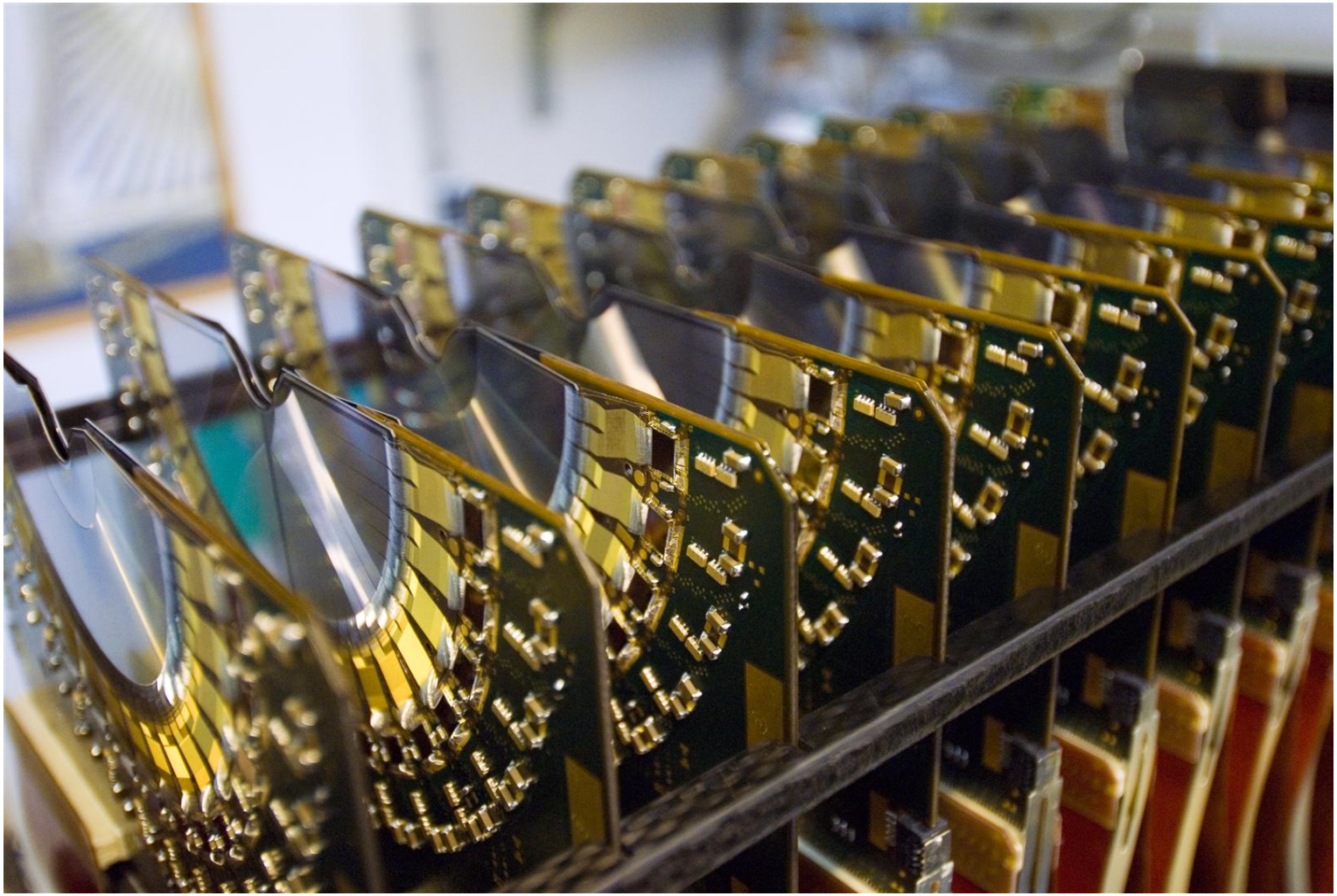


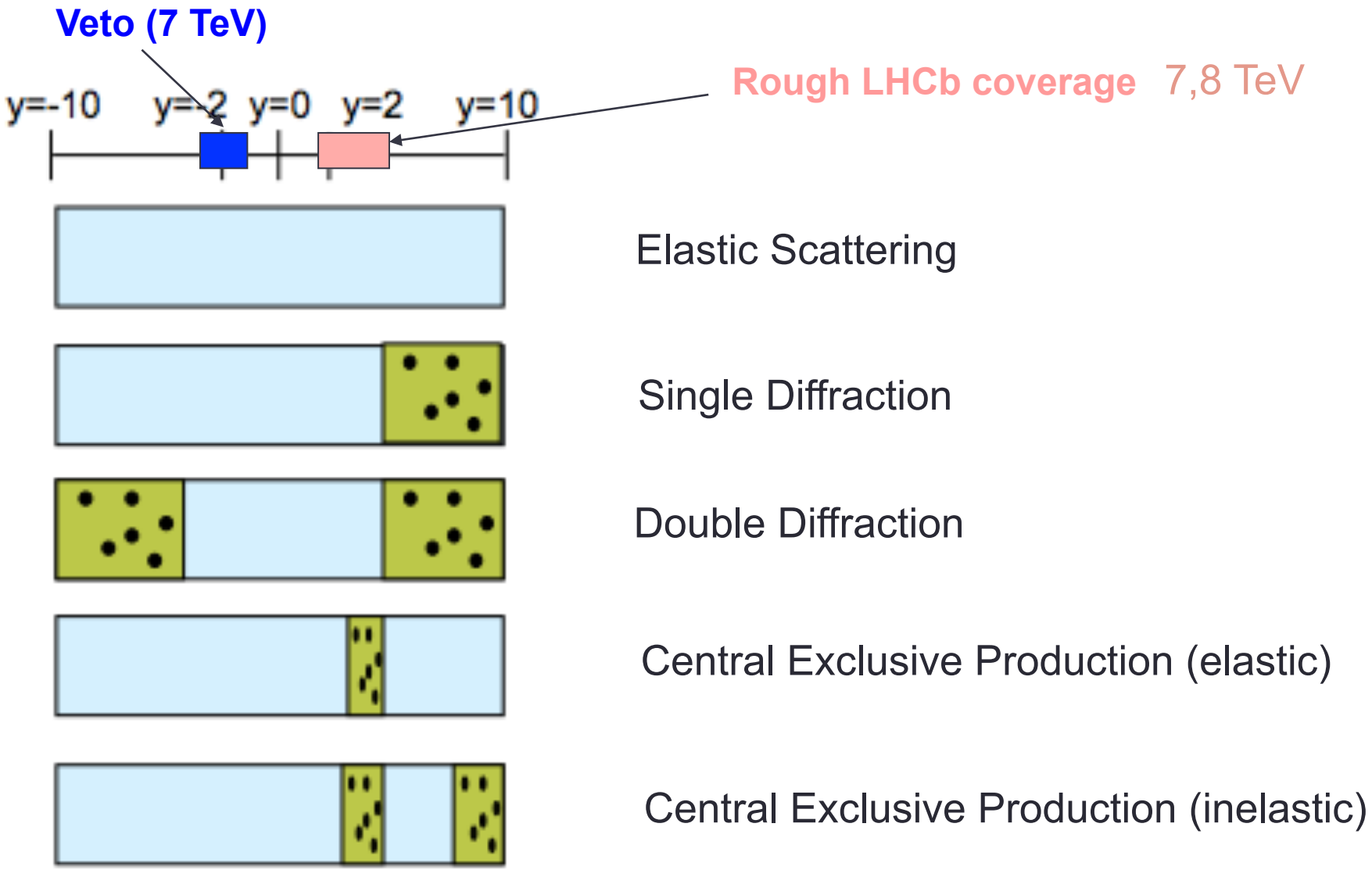
Fully instrumented: $2 < \eta < 5$

Veto region (Run 1): $-3.5 < \eta < -1.5$

Veto region (Run 2): $-10 < \eta < -5,\ 5 < \eta < 10$

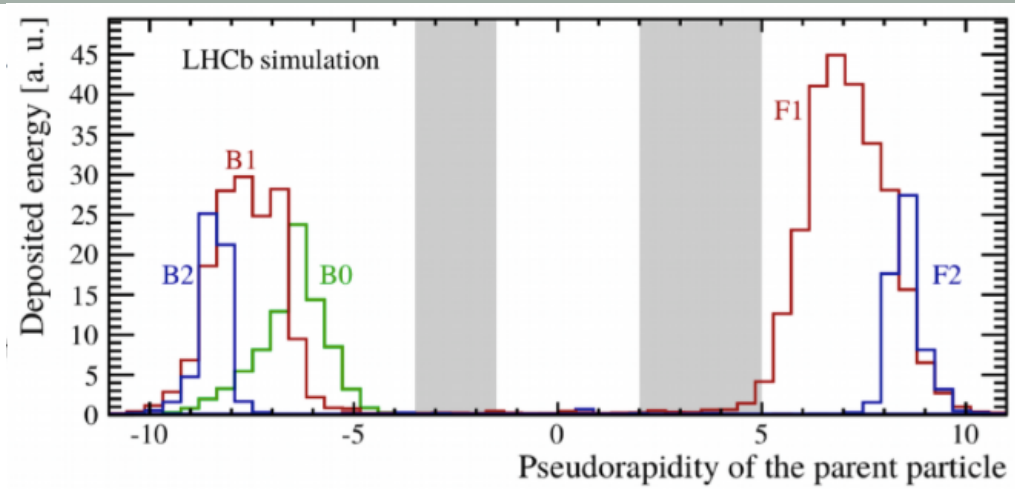
VELO sub-detector

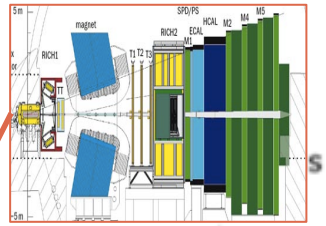


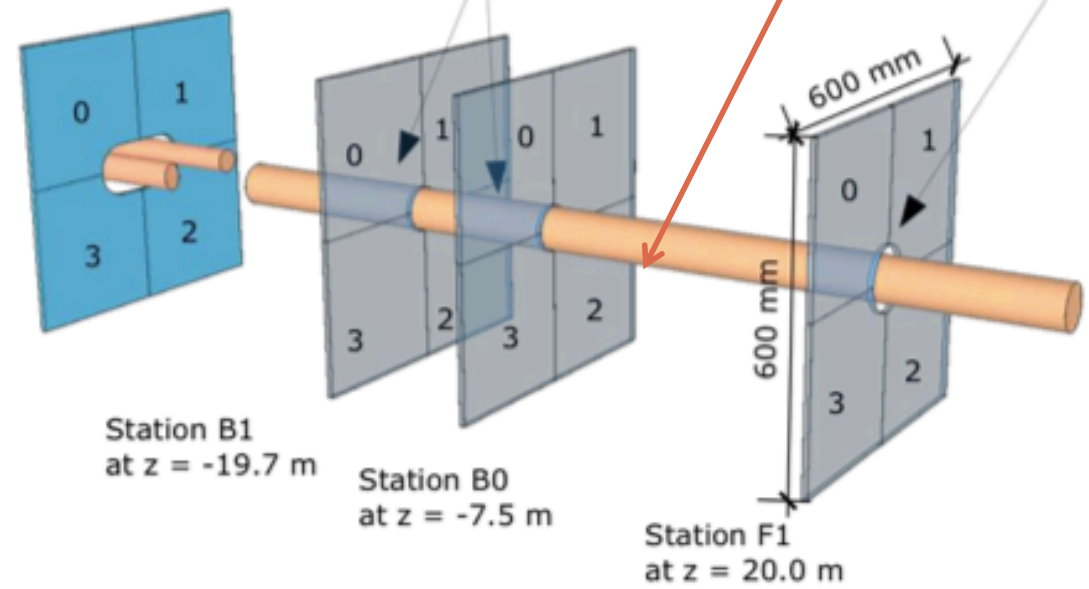

Veto (7 TeV)
y=-10
y=-2
y=0
y=2
y=10
Rough LHCb coverage 7,8 TeV
Elastic Scattering
Single Diffraction
Double Diffraction
Central Exclusive Production (elastic)
Central Exclusive Production (inelastic)

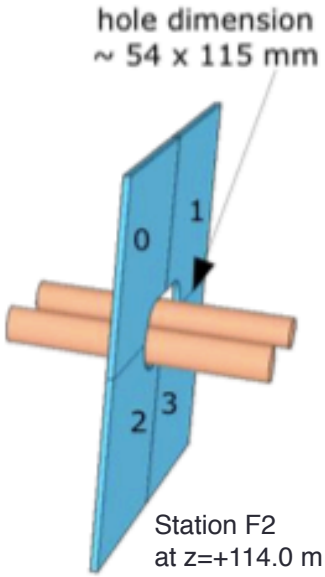
Herschel: High rapidity shower counters for LHCb

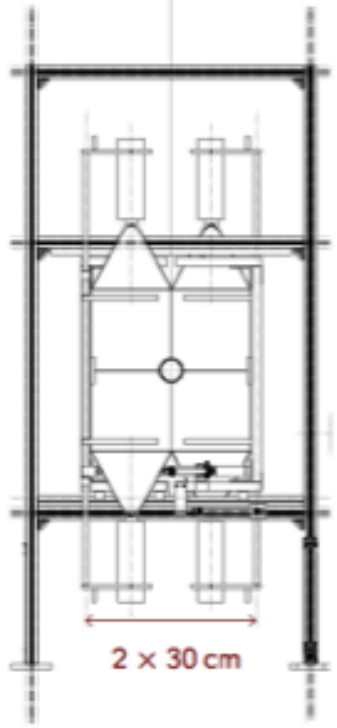
- Increase rapidity gap with scintillators in forward region
- Detects secondary particles



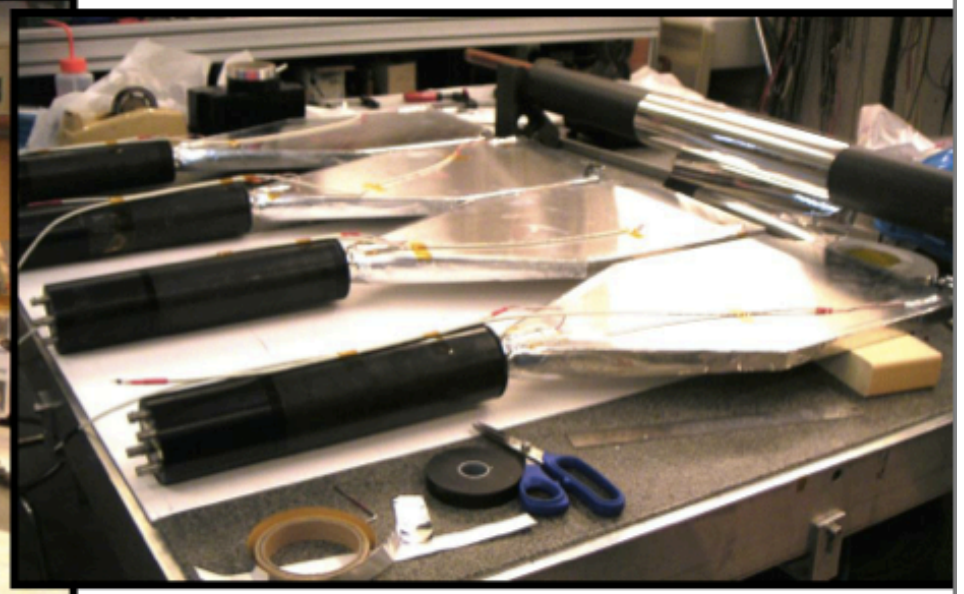






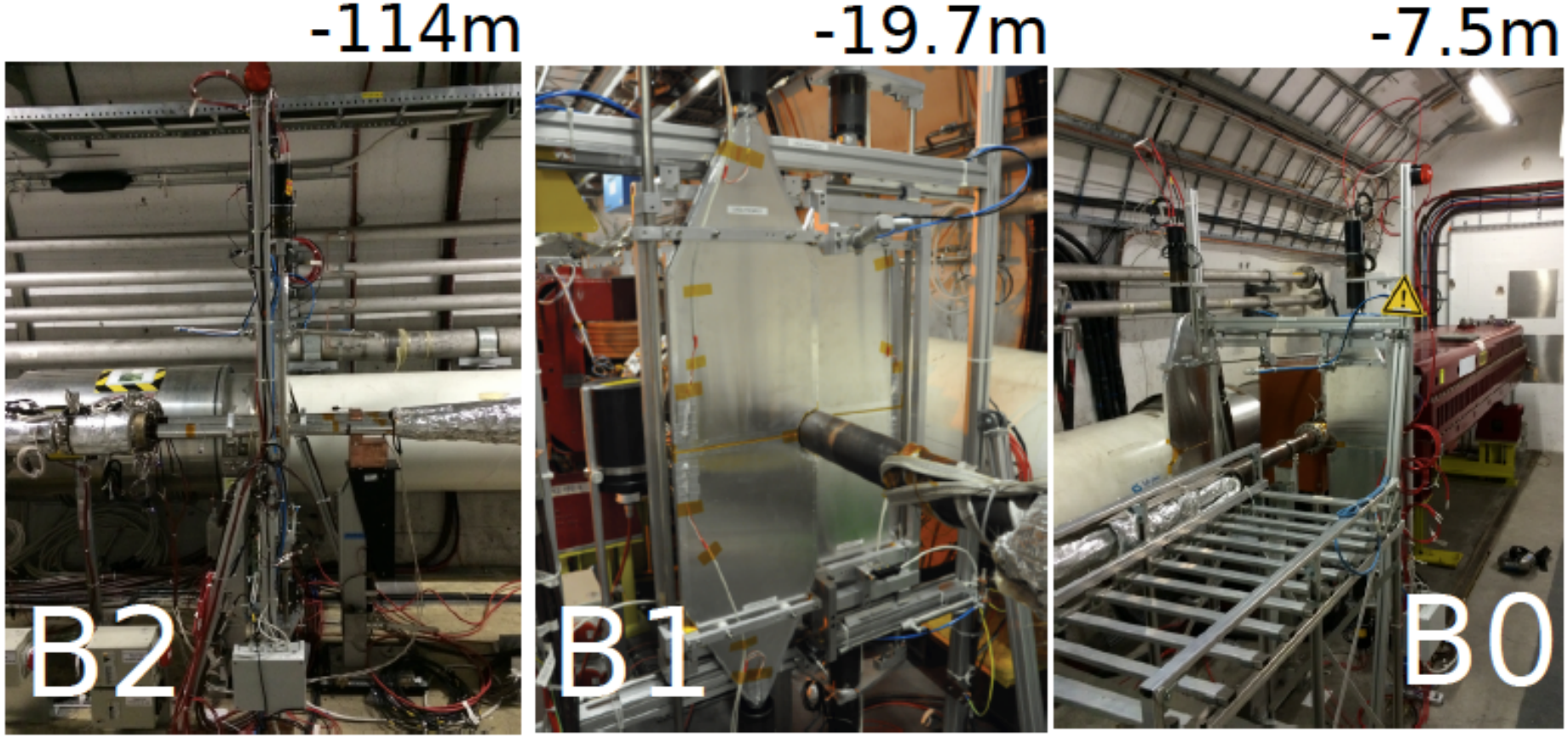


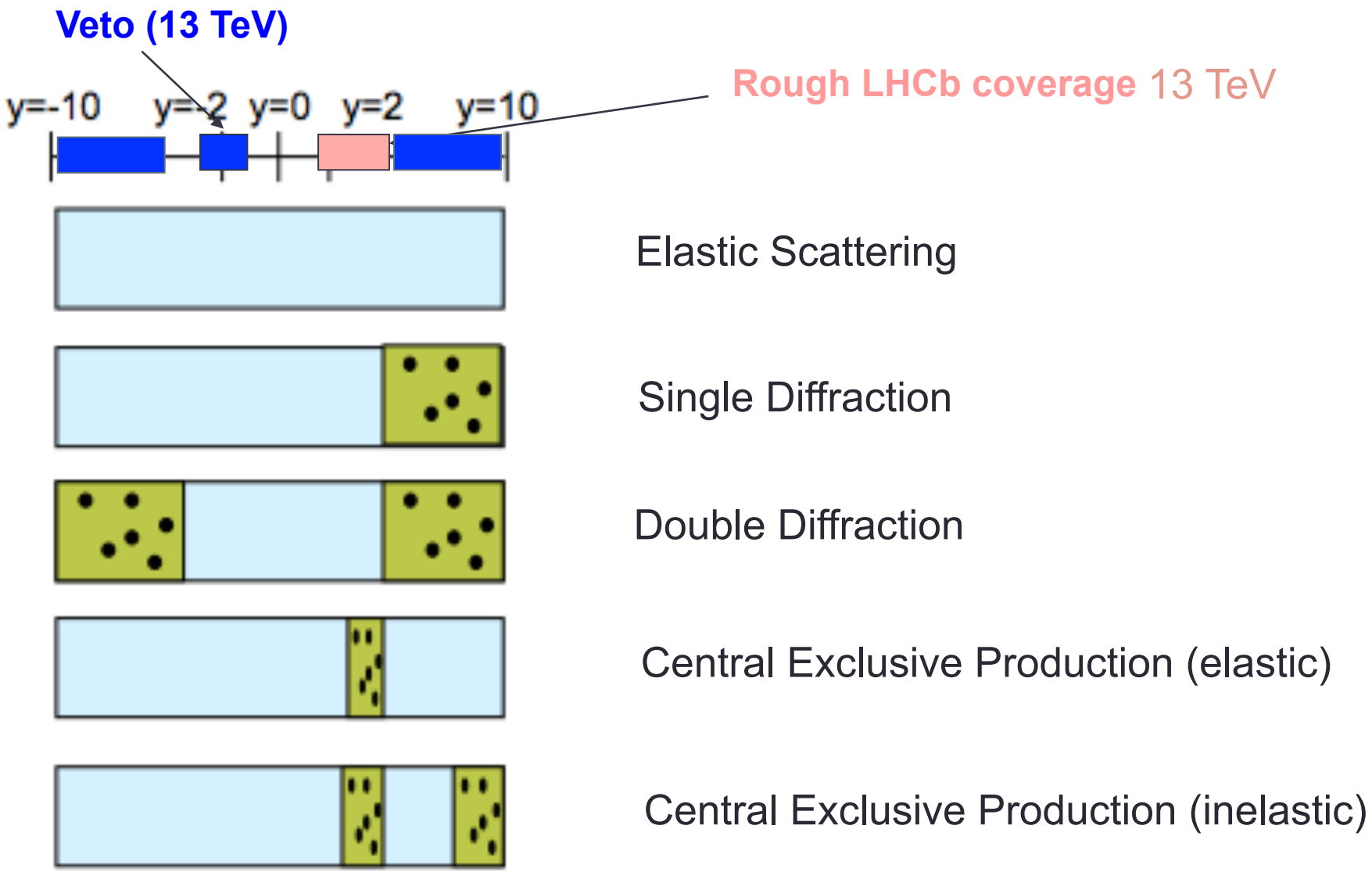
Scintillators and PMTs



Backward Stations

Installation finished in 2014

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Rough LHCb coverage 13 TeV
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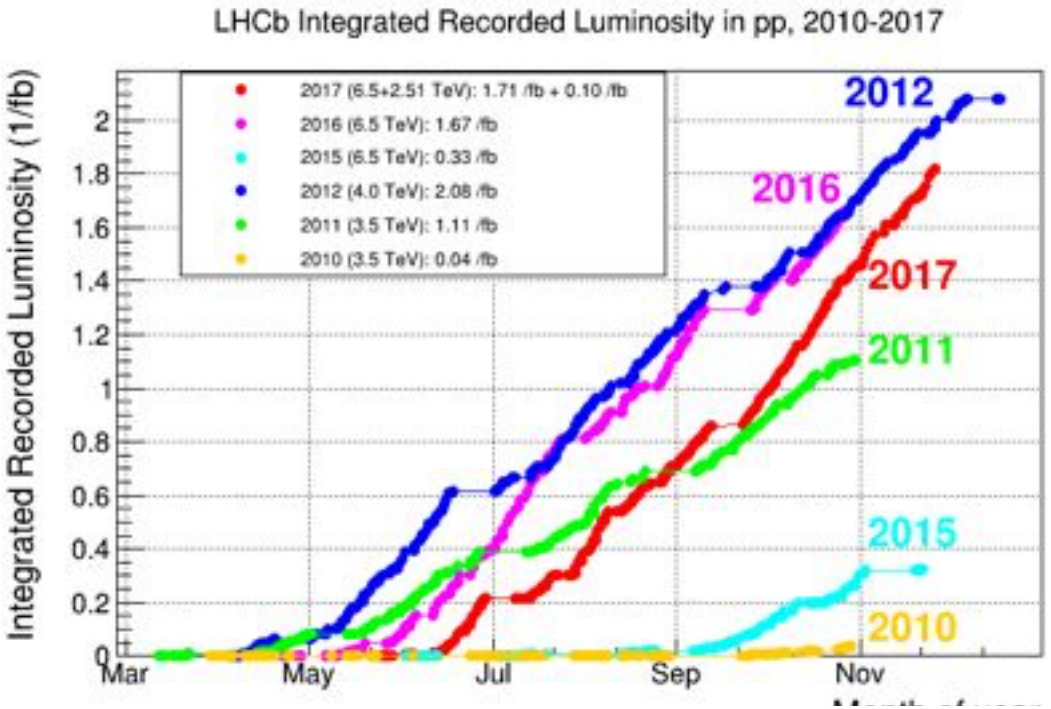
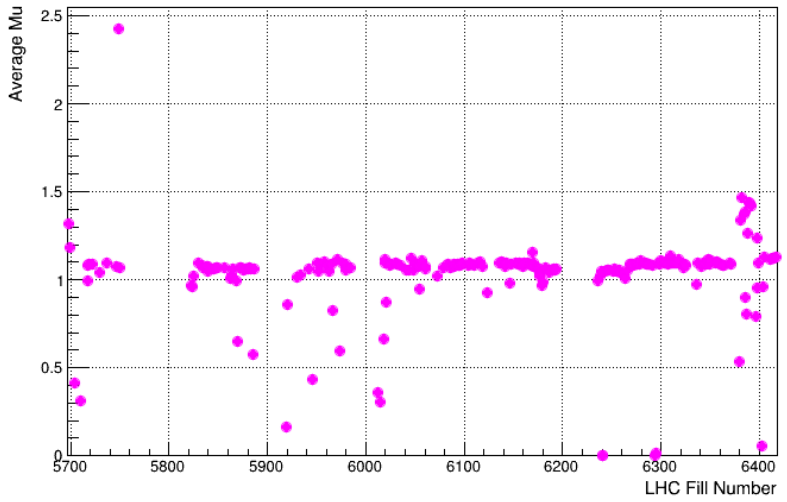
pp data-taking



Average number of interactions per beam-crossing in 2017



Ion data-taking

Collider

- pA/Ap beam-beam collisions
  - 2013 p-Pb /Pb-p run @ 5 TeV (~1nb^{-1})
  - 2016 p-Pb /Pb-p run @ 5 and 8 TeV (~30nb^{-1})
- A-A collisions
  - 2015 Pb-Pb run @ 5 TeV (~4ub^{-1})
  - 2017 Xe-Xe run @ 5.4 TeV (~0.4ub^{-1})

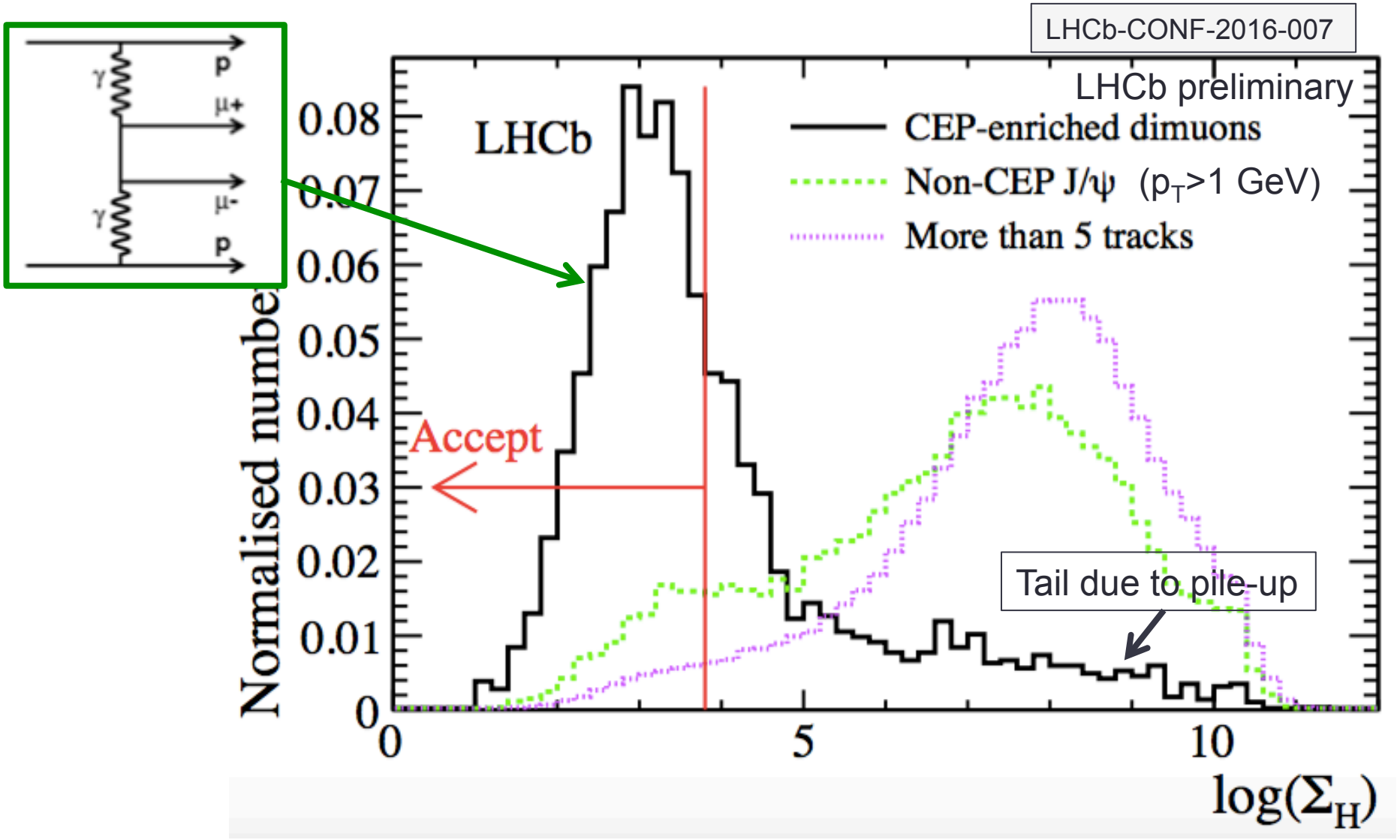
CEP:
Enhanced photon induced processes in pA
Strongly enhanced γγ in AA

Fixed target

Type	√s	Lumi (μb^{-1})
p-Ne	86.6 GeV	
Pb-Ne	54.5 GeV	0.05
p-Ne	110 GeV	0.5
p-He	110 GeV	0.5
p-Ar	110 GeV	~3
p-Ar	68.6 GeV	~0.05
Pb-Ar	68.6 GeV	~0.05
p-He	110 GeV	1.7
p-He	86.6 GeV	~17
p-He	110 GeV	0.07
p-Ne	110 GeV	~1.0
p-Ne	68.6 GeV	~200

(indicative luminosities)

Sum Herschel deposits in quadrature



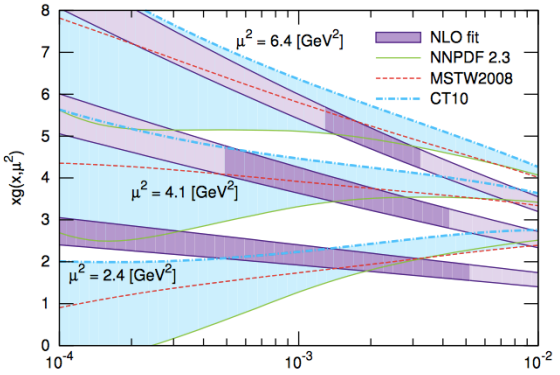
HERA vector meson photo-production results

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

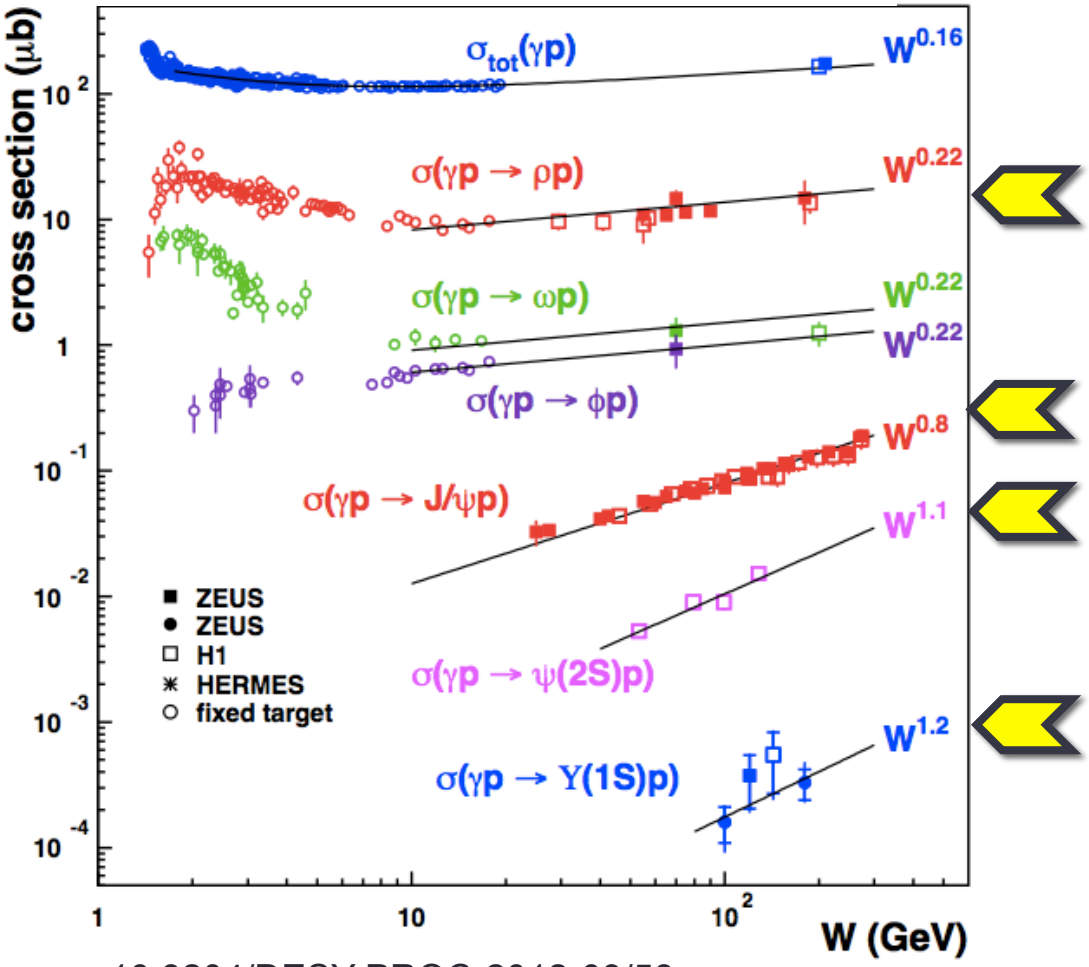
Note:

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

  (down to x=2E-6)

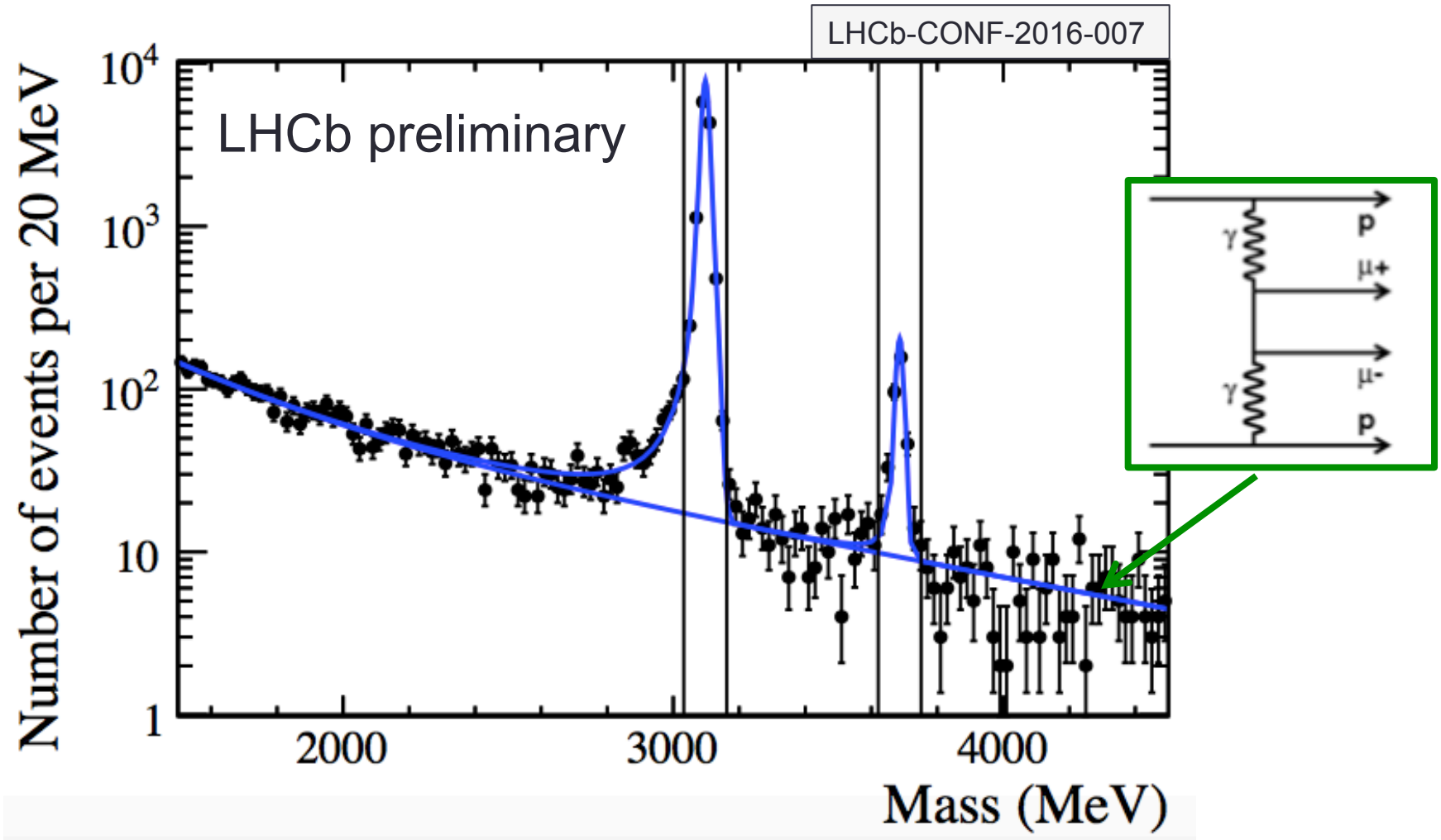


JHEP 1311 (2013) 085

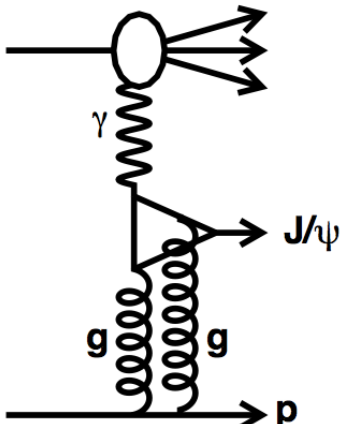


10.3204/DESY-PROC-2012-03/58

J/ψ and ψ(2S) at 13TeV

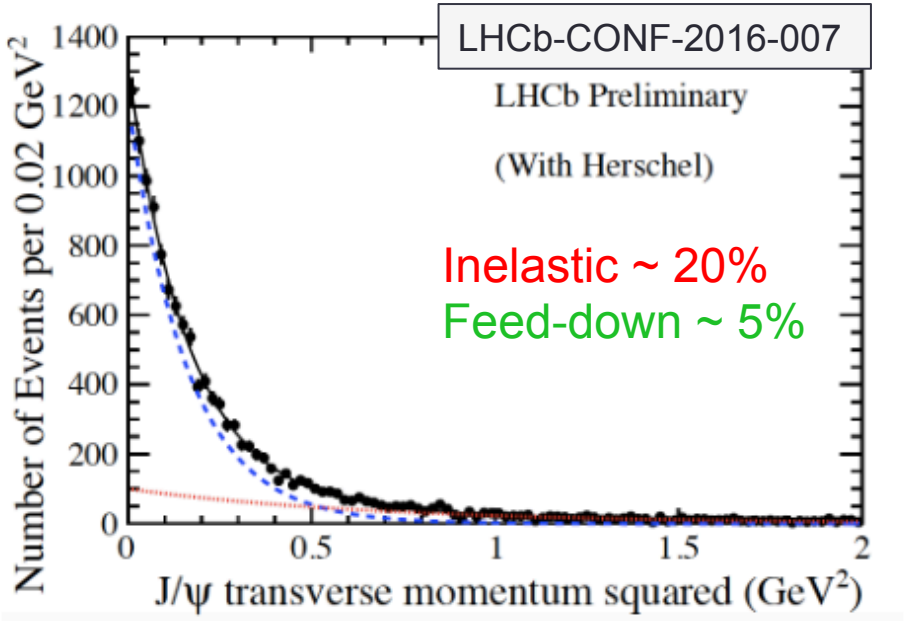


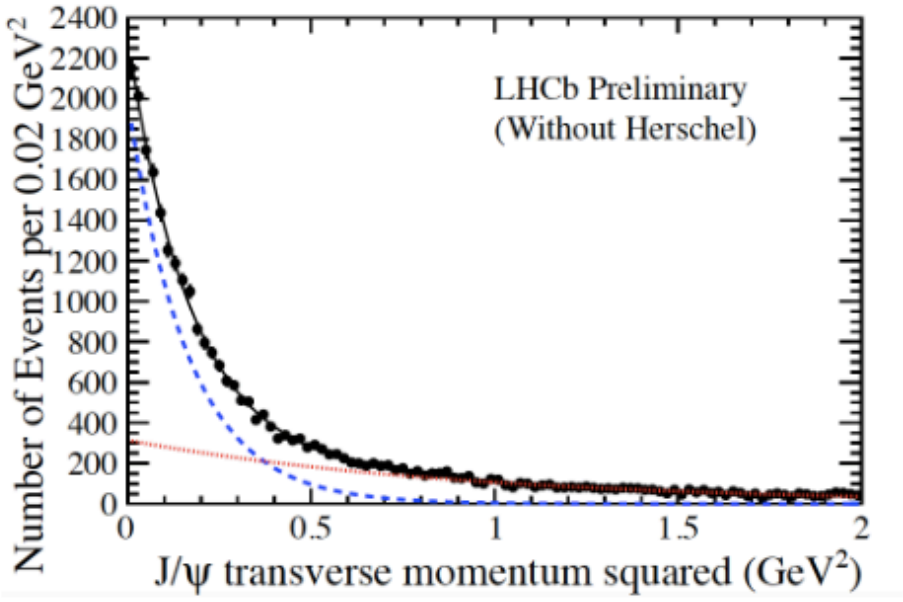
Inelastic background J/ψ



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)





Consistent cross-section results with/without Herschel.
Backgrounds roughly halved using Herschel (but not eliminated.....)

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

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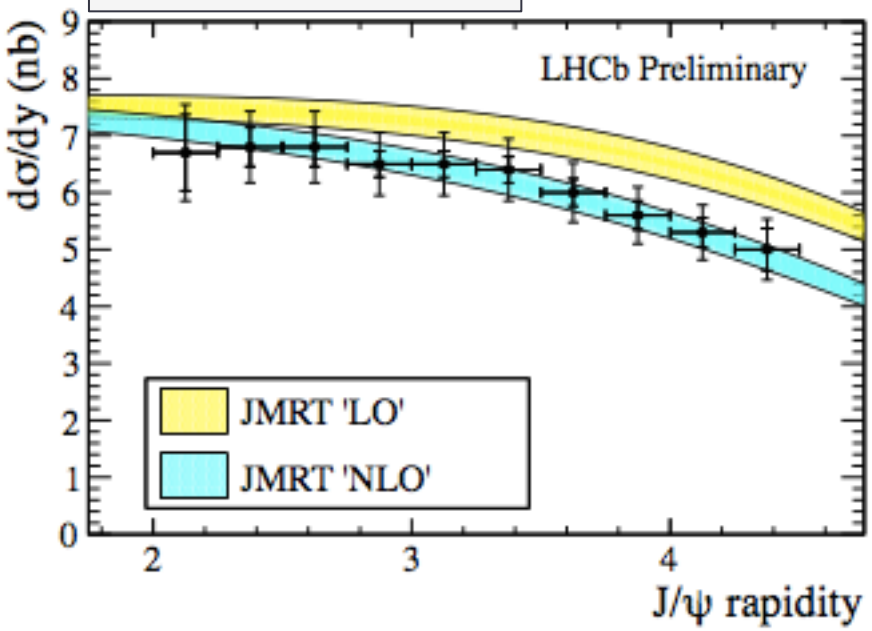
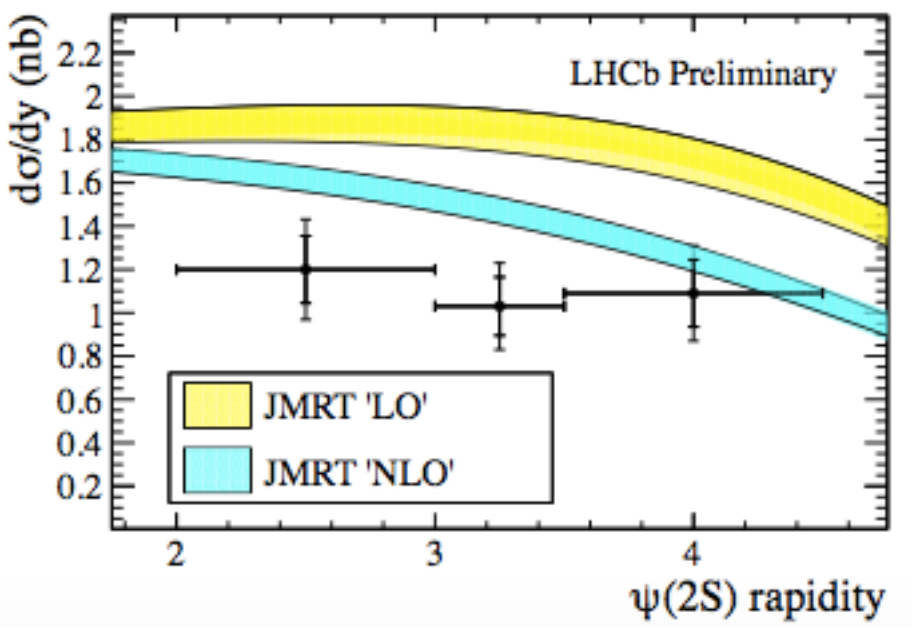


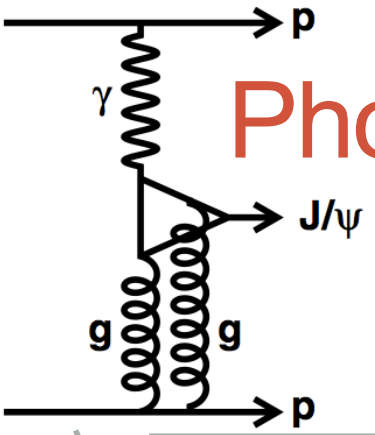


NLO agrees better than LO

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

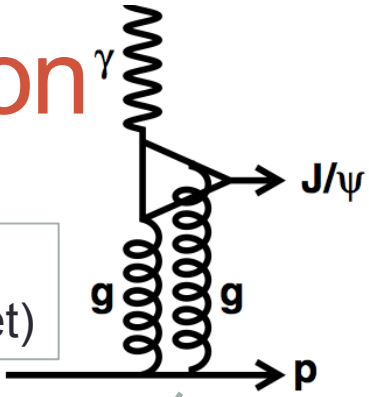


Photo-production
(HERA / fixed target)

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

Gap Survival

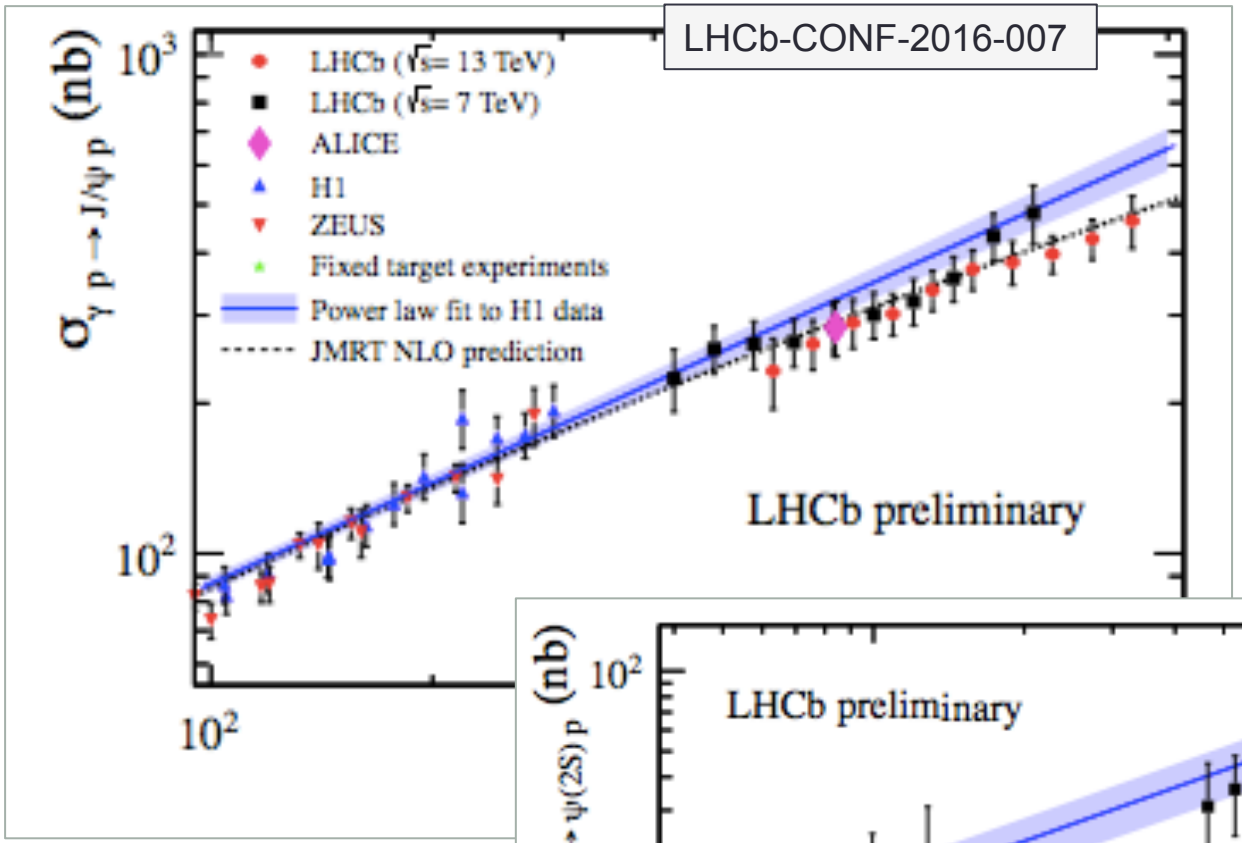
Photon Flux

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

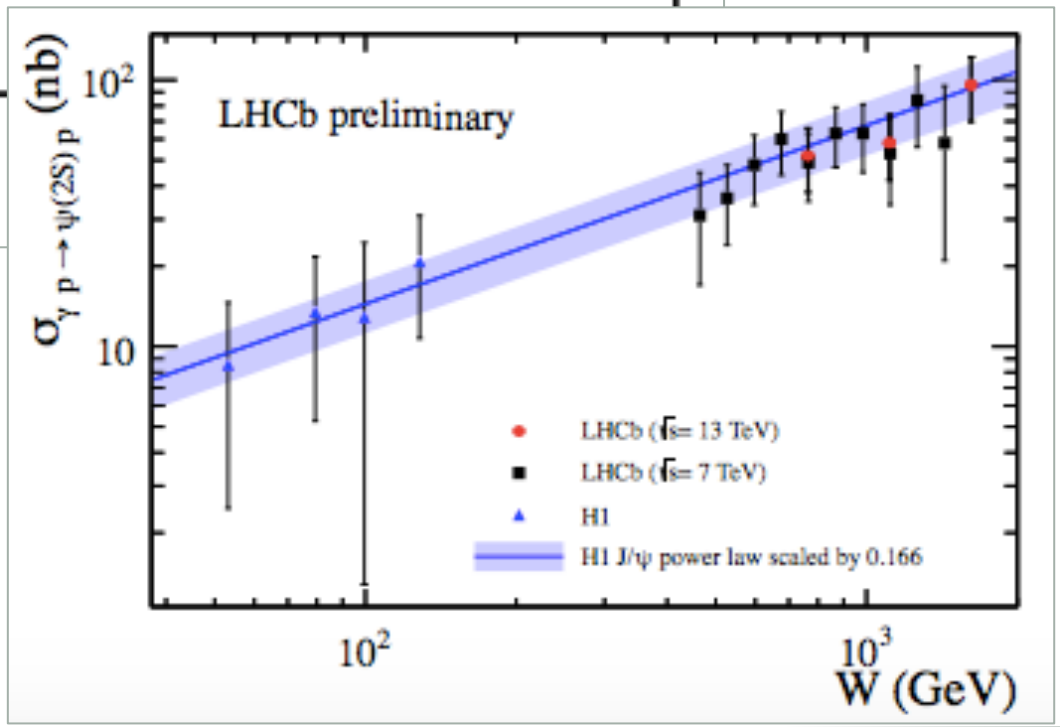
Use this for W- solution (in previously measured region). LHCb measures W+

Photo-production cross-section

LHCb-CONF-2016-007



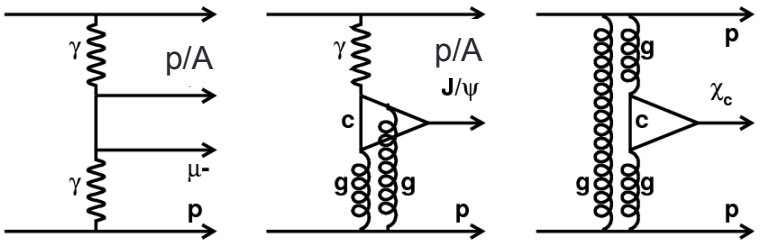
J/ψ



ψ(2S)

Future Analyses

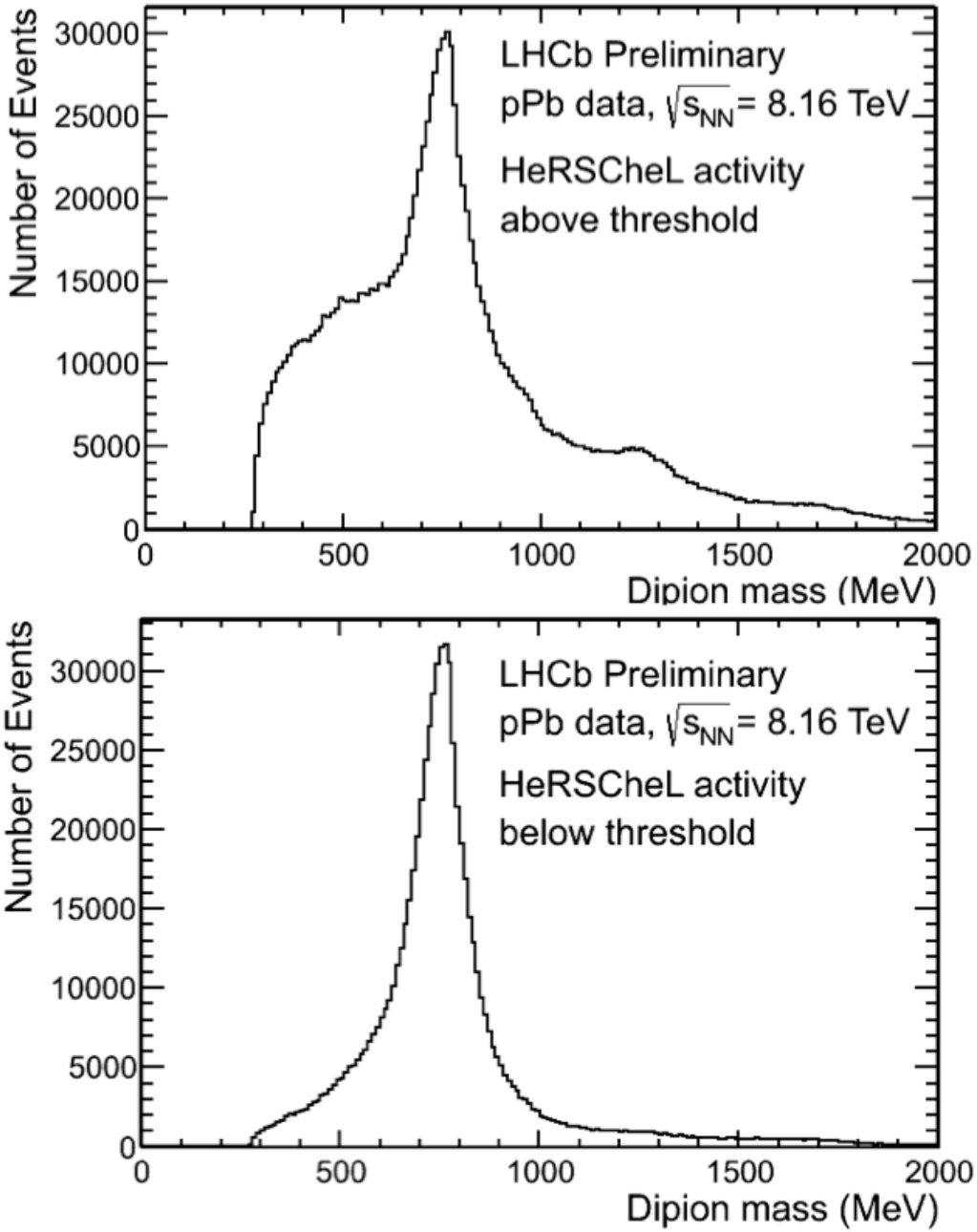
- Low mass and charm spectroscopy
  - New hadronic triggers selecting pions with pT>100 MeV
  - Electromagnetic trigger for photons/ electrons pT>1GeV
  - Ability of Herschel to suppress non-exclusive backgrounds
- Complementarity of pp, pA, AA
  - e.g. rho production



Future Analyses

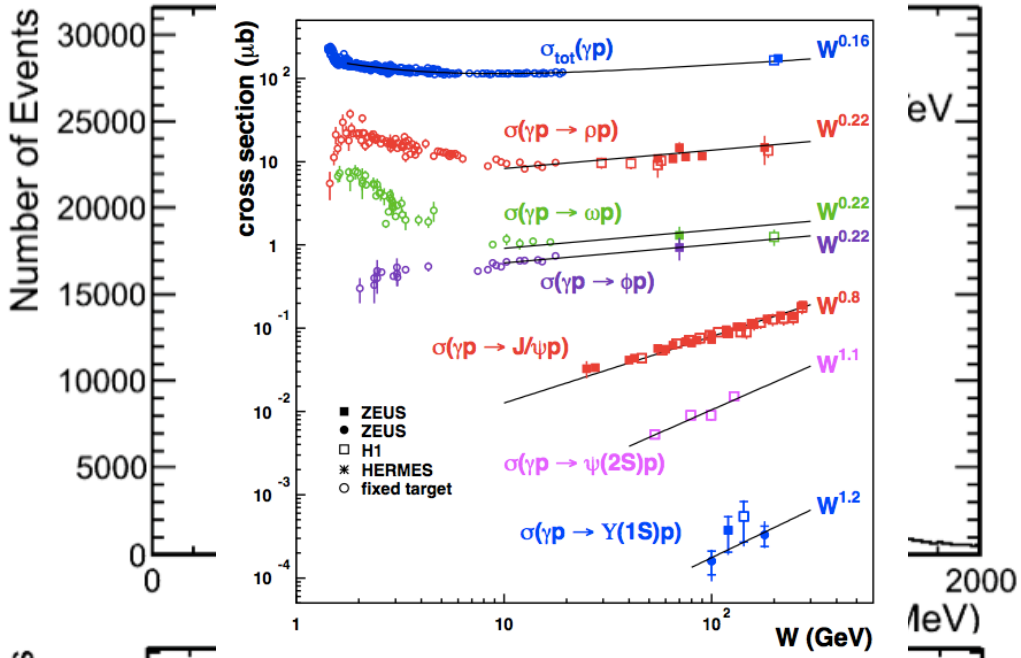
- pp->p(ππ)p has contributions from DPE (f0, f2 etc) and photoproduction (ρ).
- Difficult to disentangle (e.g. f0 appearing as shoulder on ρ)
- Difficult to separate exclusive from dissociation

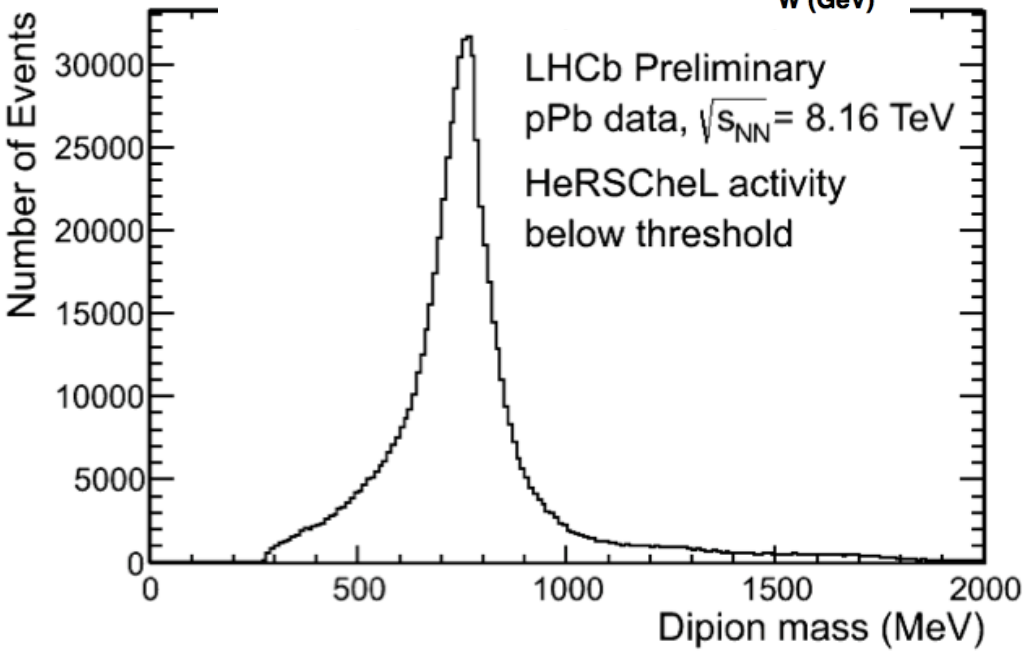
- pA->p(ππ)A has enhanced photoproduction
- Remarkably clean resonance
- x down to 10^{-6}, W up to 1 TeV



Future Analyses

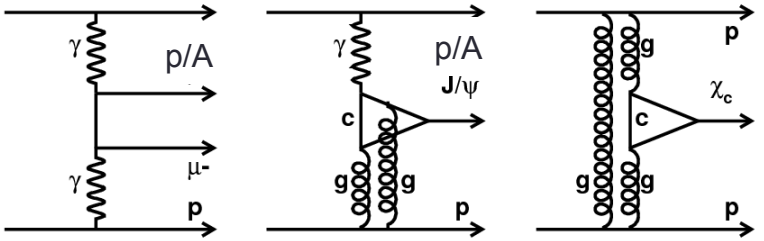
- Determine rho parameters (e.g. interference with continuum)
- x down to 10^{-6},
- W up to 1 TeV
- Measure γp->ρp
  - Compare ρ photoproduction at 1 TeV to HERA results
  - Search for saturation
- Measure γA->ρA
  - nuclear suppression effects





Future Analyses

- CEP production mechanisms
  - Double pomeron exchange
  - Photoproduction
  - Gamma-gamma physics
  - Odderon enhancements
- CEP and CEP-like final states
  - Glueballs
  - Tetraquarks, hybrids, exotics
  - Saturation
- LHCb has excellent low pT triggers and PID
  - μμ, ππ, KK, pp, γγ, ee.
  - π0, η ω etc
  - Exclusive reconstruction possible in low multiplicity enivornments



Summary

- Several CEP pp measurements at 7 and 8 TeV using muons.
- Limited by understanding exclusivity.
- New Herschel detector for Run 2.
- First measurement at 13 TeV with lower backgrounds.
- Excellent prospects for future, including hadronic modes.