Measurement of exclusive vector meson photo-production in pPb collisions with the CMS experiment

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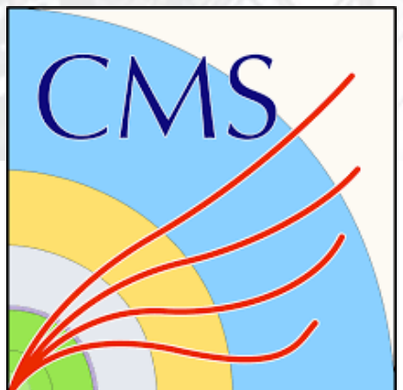
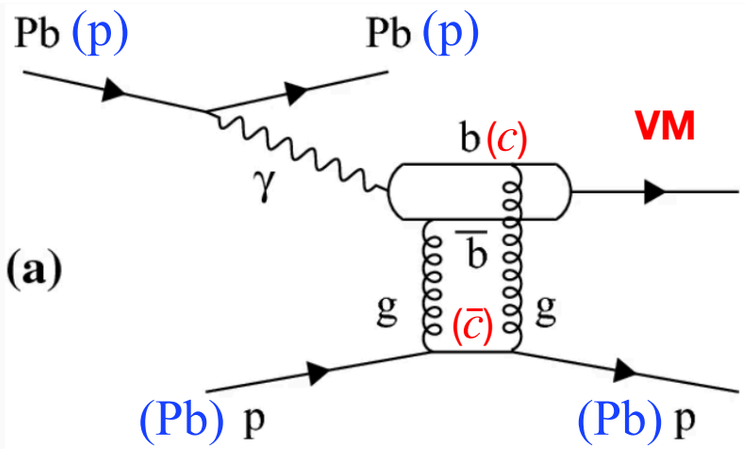
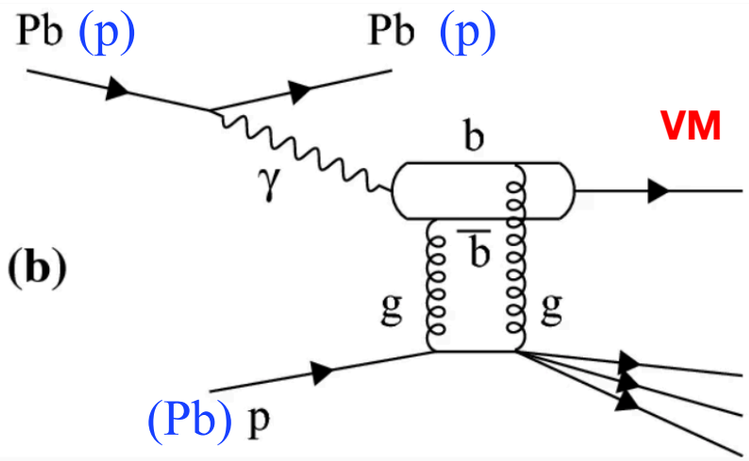


Outline:

- Introduction
- Ultra peripheral collisions at LHC
- Exclusive quarkonia photo-production
- Summary

Photon interactions





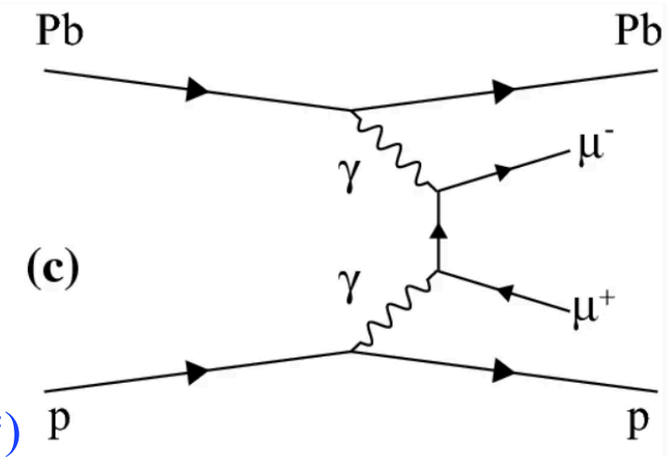


Photo-nuclear interactions → Signal

Proton dissociations, Photon-photon interactions → Background

Ultra peripheral collisions at LHC

Region of interest in CMS

- CMS kinematic bridge

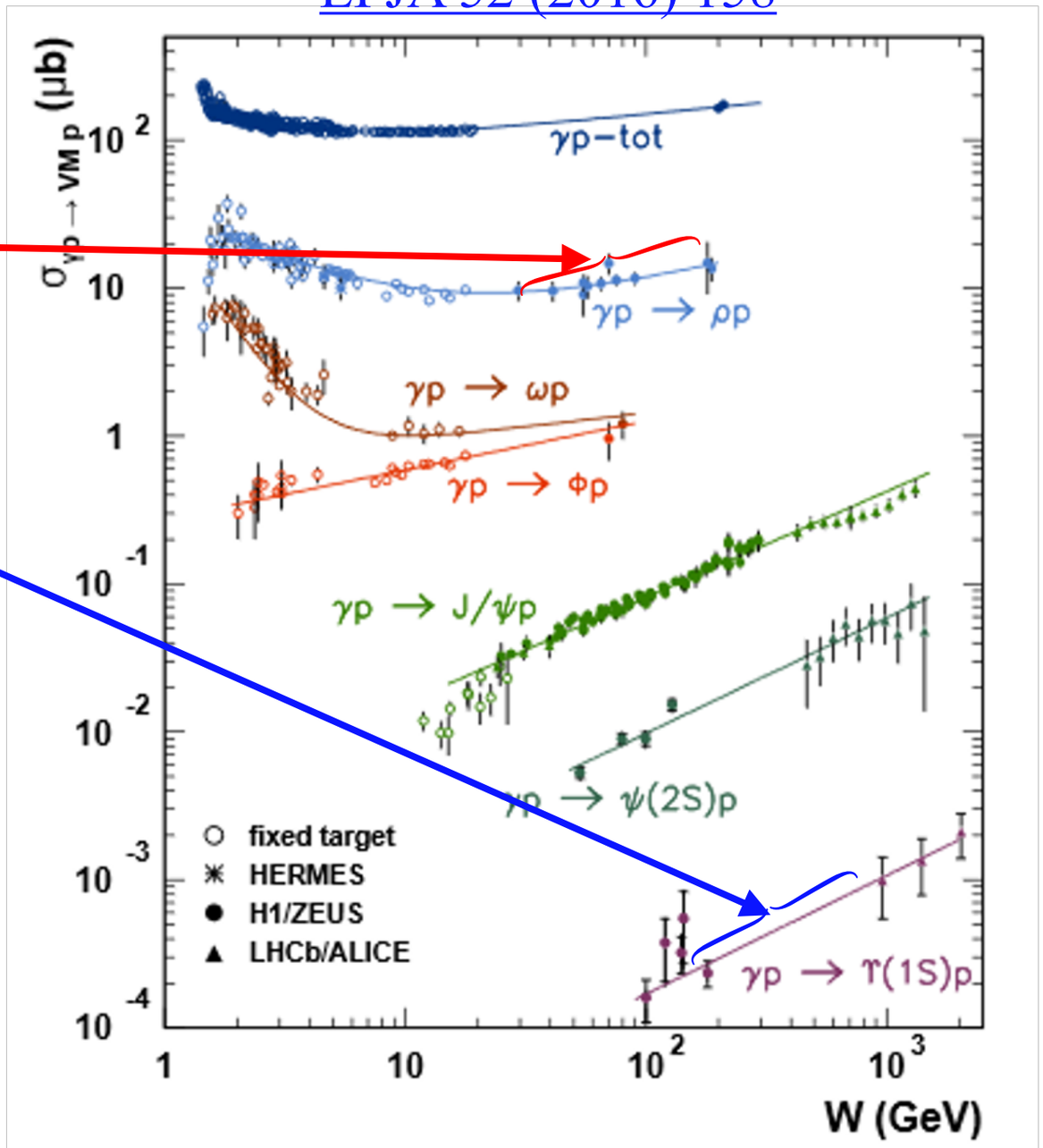
previous measurements

$$W_{\gamma p}^2 = 2E_p M_{VM} exp(\pm y) \qquad x = (M_{VM}/W_{\gamma p})^2$$

$W_{\gamma p} = 29 - 213\ GeV/c\ , \rho^0$

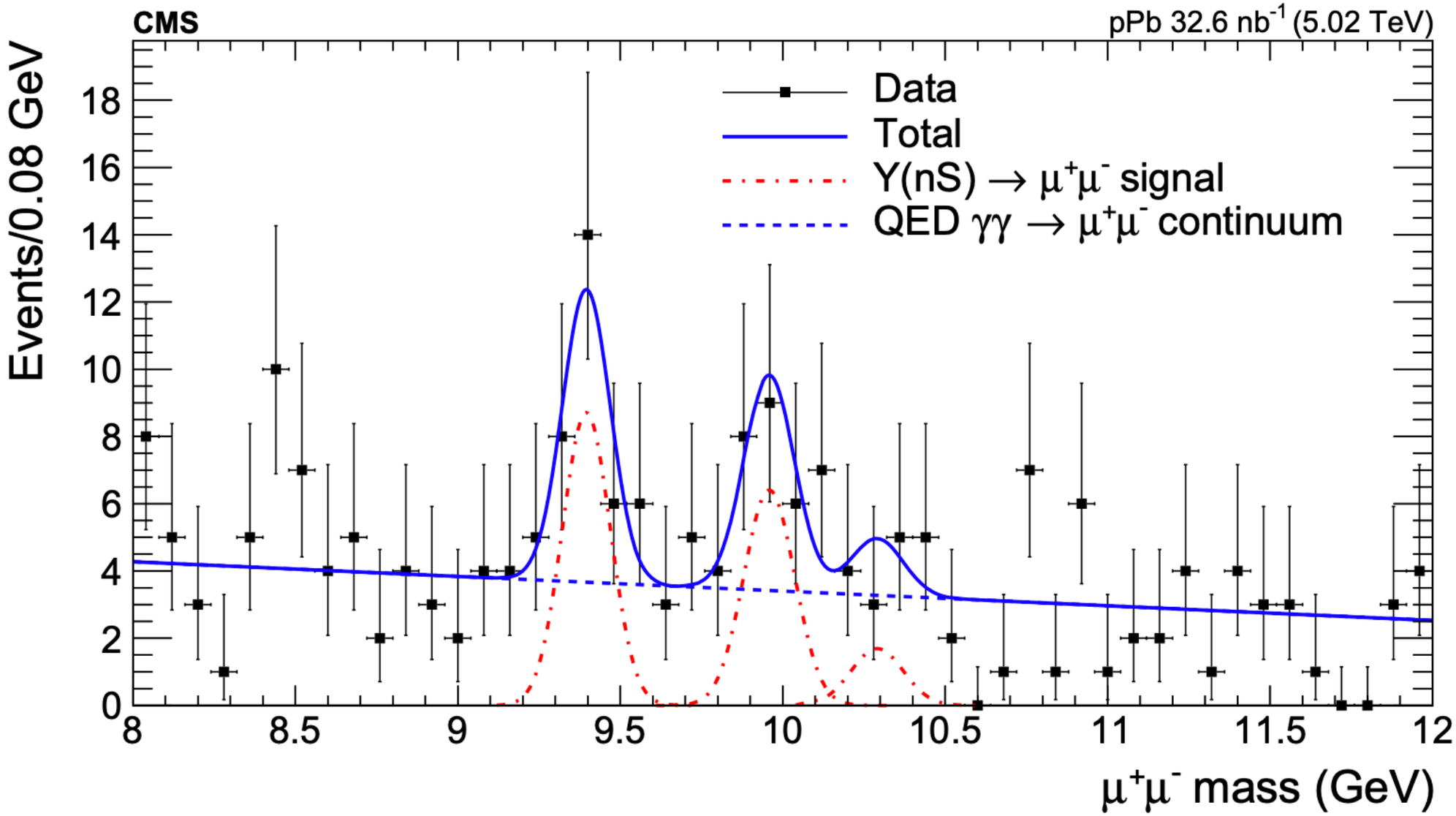
$W_{\gamma p} = 91 - 826\ GeV/c\ , \Upsilon$

EPJA 52 (2016) 158



Exclusive Upsilon in pPb collisions

Eur. Phys. J. C (2019) 79:277



- Di-muon p_T selection 0.1 < p_T < 1.0 GeV/c
- Lower and higher p_T cut applied to have good signal/background ratio and suppress background from inclusive Υ or proton dissociation.

|t| dependence

Cross-section with p_T^2 study in 5.02 TeV pPb

$$\frac{d\sigma_{\Upsilon}(nS)}{dp_T^2} B_{\Upsilon}(nS) \to \mu^+\mu^- = \frac{N^{corr}_{\Upsilon(sum)}}{\mathscr{L} \times \Delta p_T^2}$$

- Fit to an exponential function $exp(-b\,|t|)$ with χ^2 minimisation

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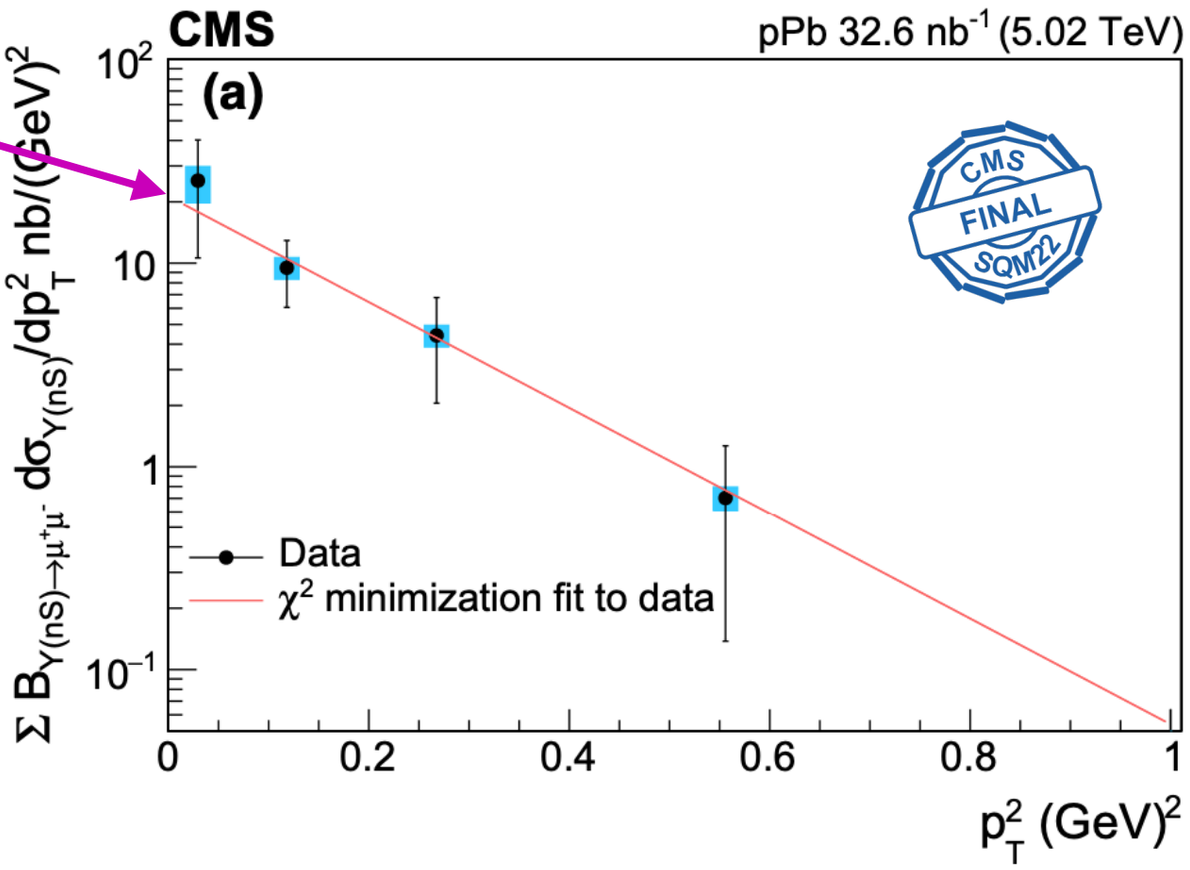


👉 slope parameter b provides information on the parton transverse density profile of the proton.

$b = 6.0 \pm 2.1\ \ (stat) \pm 0.3\ \ (syst)\ \ GeV^{-2}$

ZEUS measurements for $\Upsilon(1S), b = 4.3^{+2.0}_{-1.3}\ \ (stat)$

- Data is in agreement with the previous ZEUS measurements
- Qualitatively consistent with the predictions based on pQCD model

PLB 708 (2012) 14

JHEP **11** 085 (2013)

Rapidity dependence

Eur. Phys. J. C (2019) 79:277

- fIP sat : color glass condensate (CGC) formalism to incorporate gluon saturation at low x.

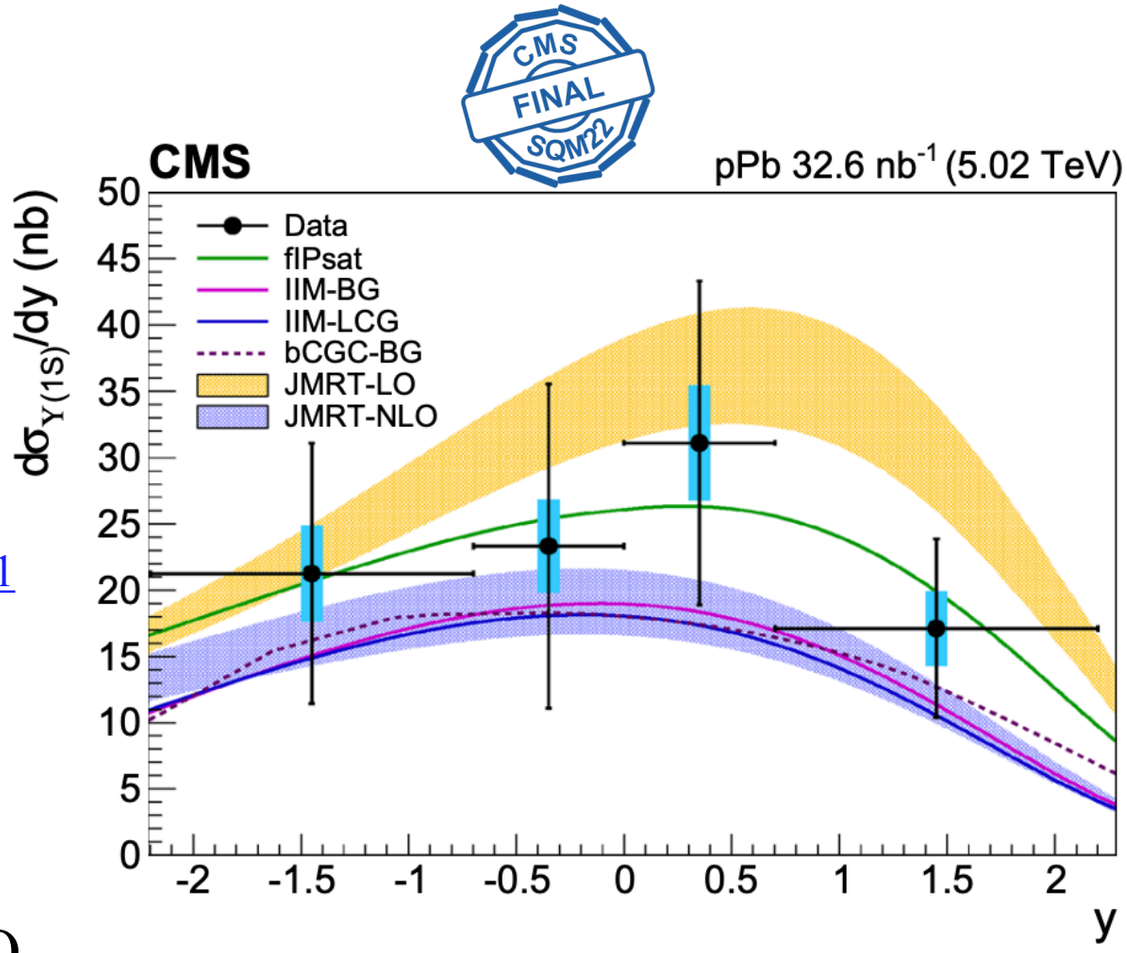
  [PRC 83 (2011) 065202, PRC 87 (2013) 032201

- IIM : color dipole formalism with two sets of meson wave functions, BG and LCG incorporate saturation effects.

  PLB 590 (2004) 199, PRC 89 (2014) 025201, JPG 42 (2015) 105001

- bCGC-BG : takes into account the |t| dependence of differential cross-section.

  PRD 95 (2017) 054011, PRD 96 (2017) 094027



- JMRT model : a pQCD calculations LO and NLO Corrections, and gap survival factor account for exclusive production.

  JHEP 11 (2013) 085

- Data consistent with the various theoretical predictions.

$W_{\gamma p}$ dependence

$$\sigma_{\gamma p \to \Upsilon(1S)p} = \frac{1}{\varphi}\frac{\sigma\Upsilon(1S)}{dy}$$

φ = photon flux

$$W^2_{\gamma p} = 2\, E_p\, M_\gamma\, exp(\pm y)$$

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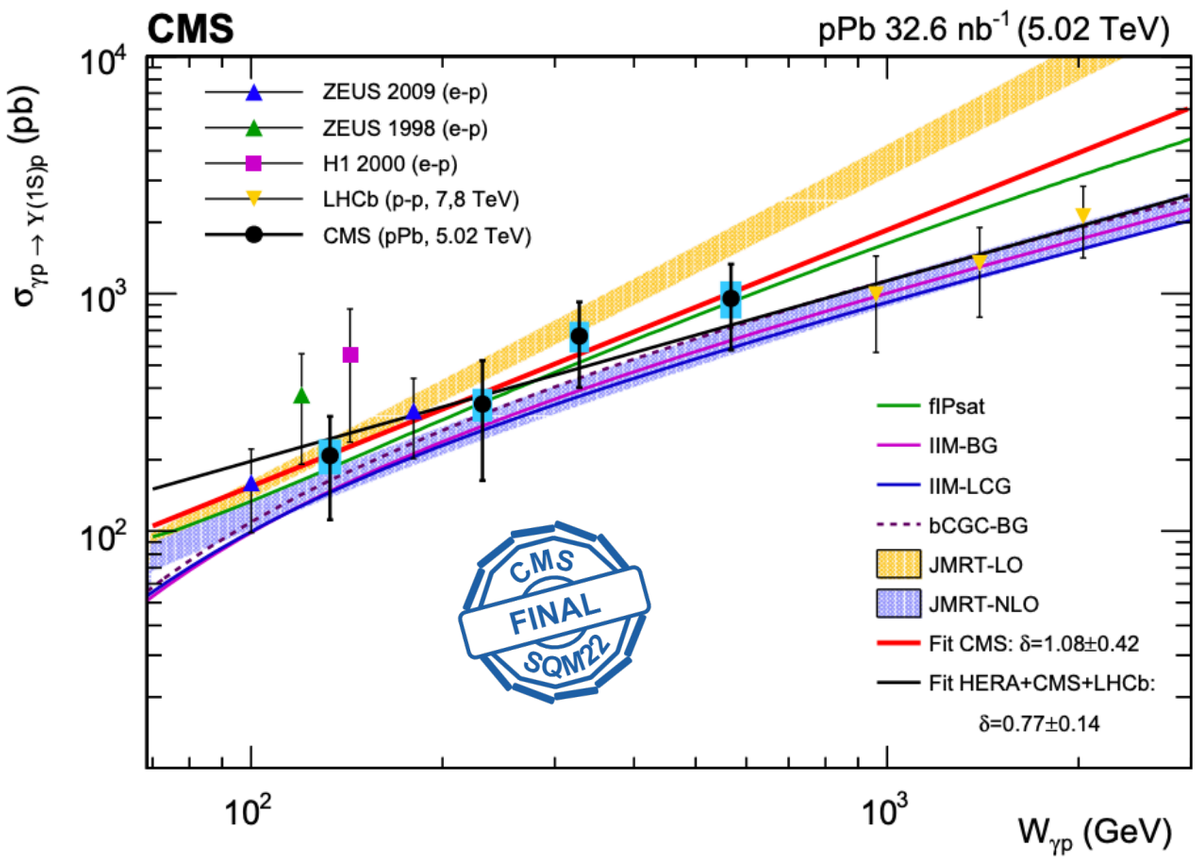


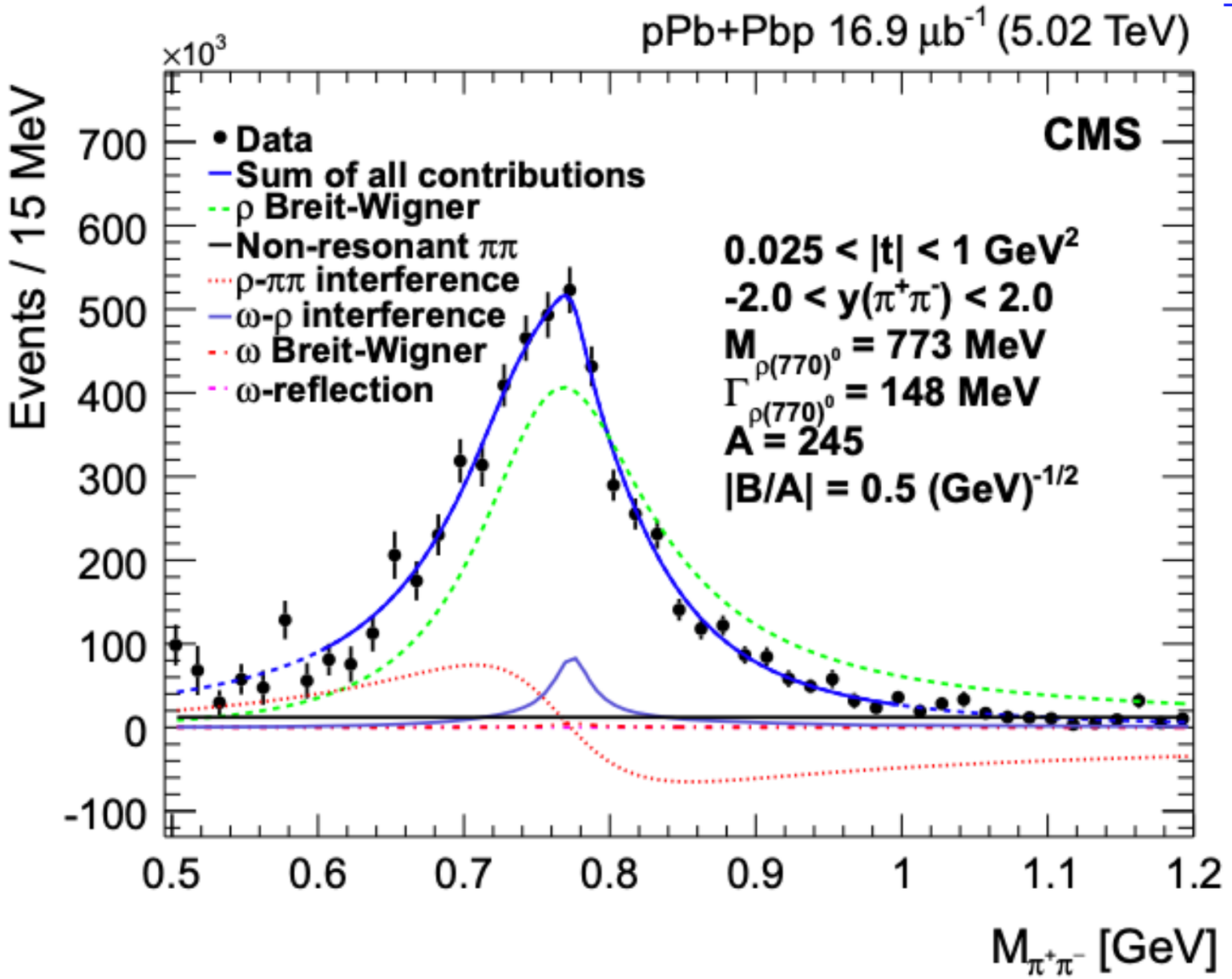
- Fit parameters of power law dependent cross section : $\sigma_\Upsilon(W_{\gamma p}) = A \times (W/400)^\delta$

  CMS : $\delta = 1.08 \pm 0.42$ and $A = 690 \pm 183$

  ZEUS : $\delta = 1.2 \pm 0.8$ PLB 680 (2009) 4
- Significantly reduced uncertainty compared to ZEUS and covered a wide range of W
- LO pQCD calculations disfavoured

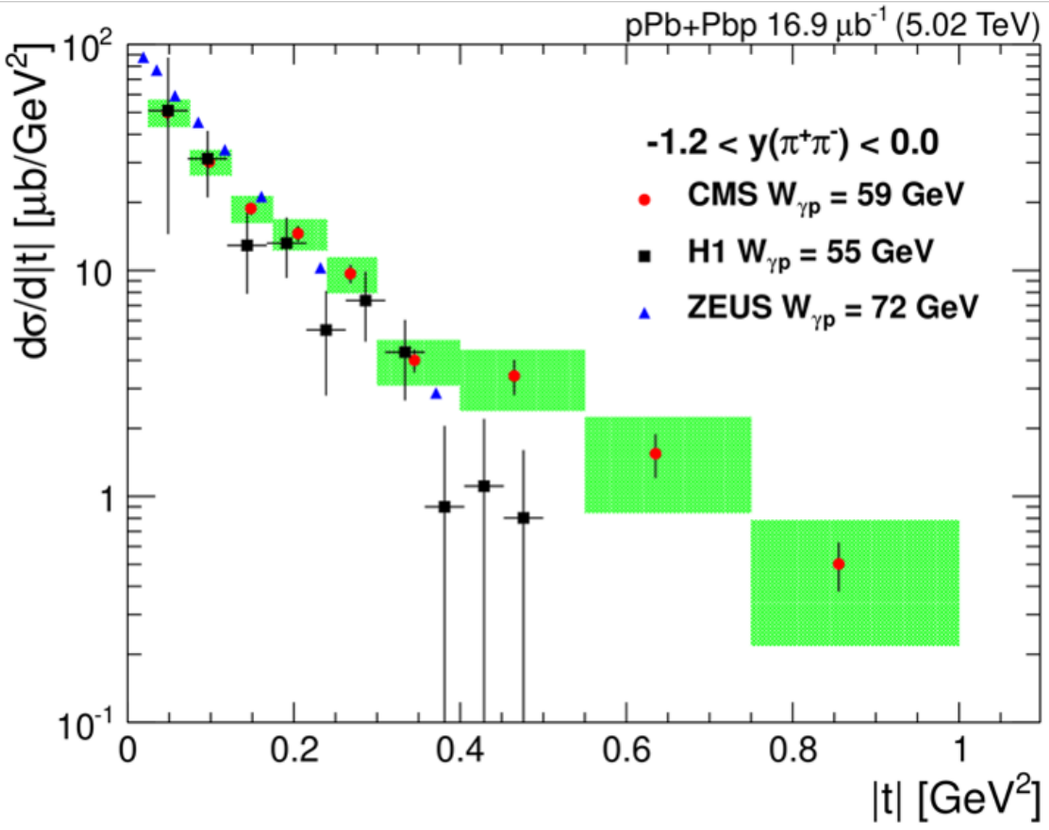
ρ^0 photo-production at 5.02 TeV

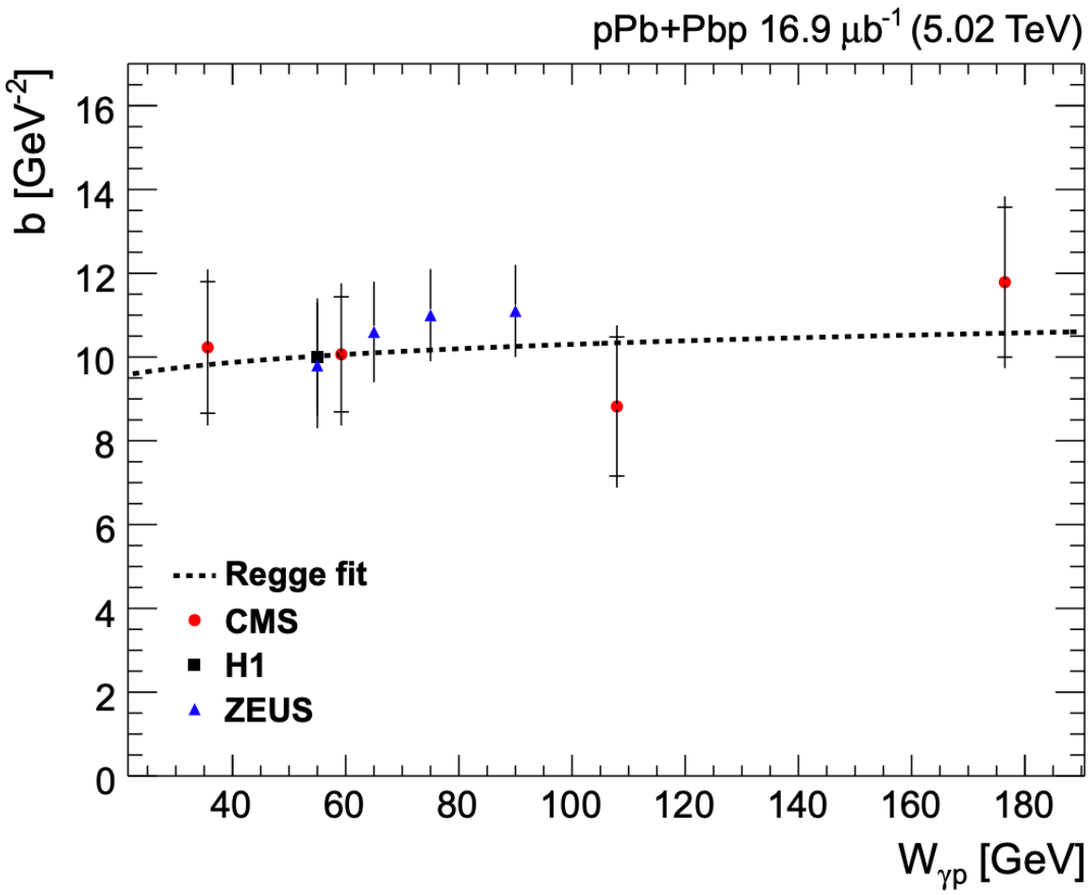
Eur. Phys. J. C (2019) 79 :702



- Complex signal extraction due to the interference with the $\omega(783)$ meson

|t| dependence of ρ^0





Eur. Phys. J. C (2019) 79 :702

- Fitted with an exponential function $Ae^{(-bt + ct^2)}$

  $b = 9.2 \pm 0.7$ (stat) GeV^{-2} , $c = 4.6 \pm 1.6$ (stat) GeV^{-4}

- From Regge formula $b = b_0 + 2\alpha' \, ln(W_{\gamma p}/W_0)^2$

  $W_0 = 92.6$ GeV, $\alpha' = 0.28 \pm 0.11$ $(stat) \pm 0.12$ $(syst)$ GeV^2

- Consistent with ZEUS data and Regge expectations. EPJC 2 (1998) 247, PR 101 (1983) 169

$W_{\gamma p}$ dependence

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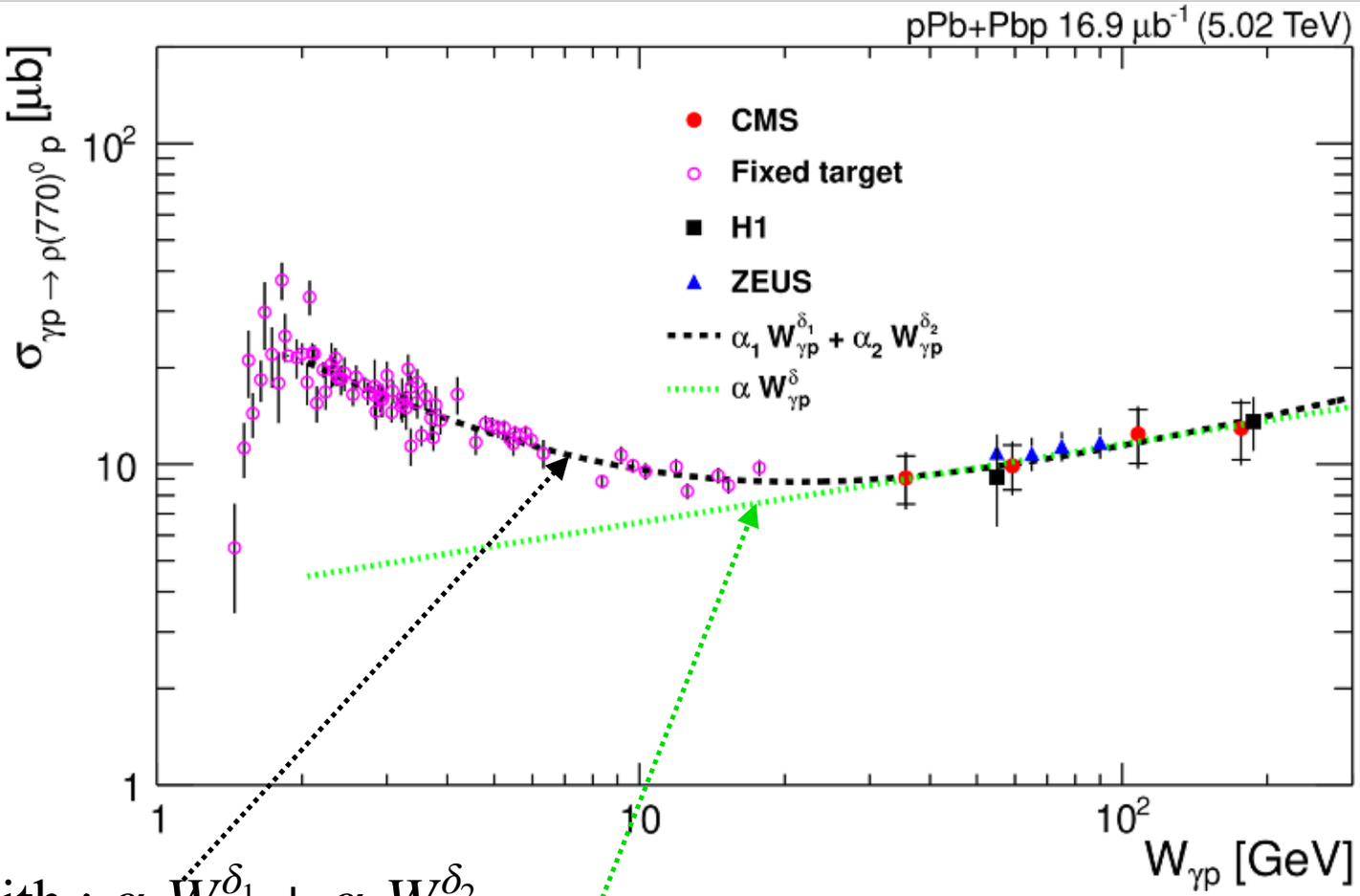

- Fitted with : $\alpha_1 W_{\gamma p}^{\delta_1} + \alpha_2 W_{\gamma p}^{\delta_2}$
- Fitted with : $\alpha W_{\gamma p}^{\delta}$ (CMS and HERA combined)
- Data compatible with the power law dependence and previous HERA measurements.
- $\delta_1 = -0.81 \pm 0.04$ (stat) ± 0.09 (syst), $\delta_2 = 0.36 \pm 0.07$ (stat) ± 0.05 (syst)
- $\delta = 0.24 \pm 0.13$ (stat) ± 0.04 (syst)

Summary

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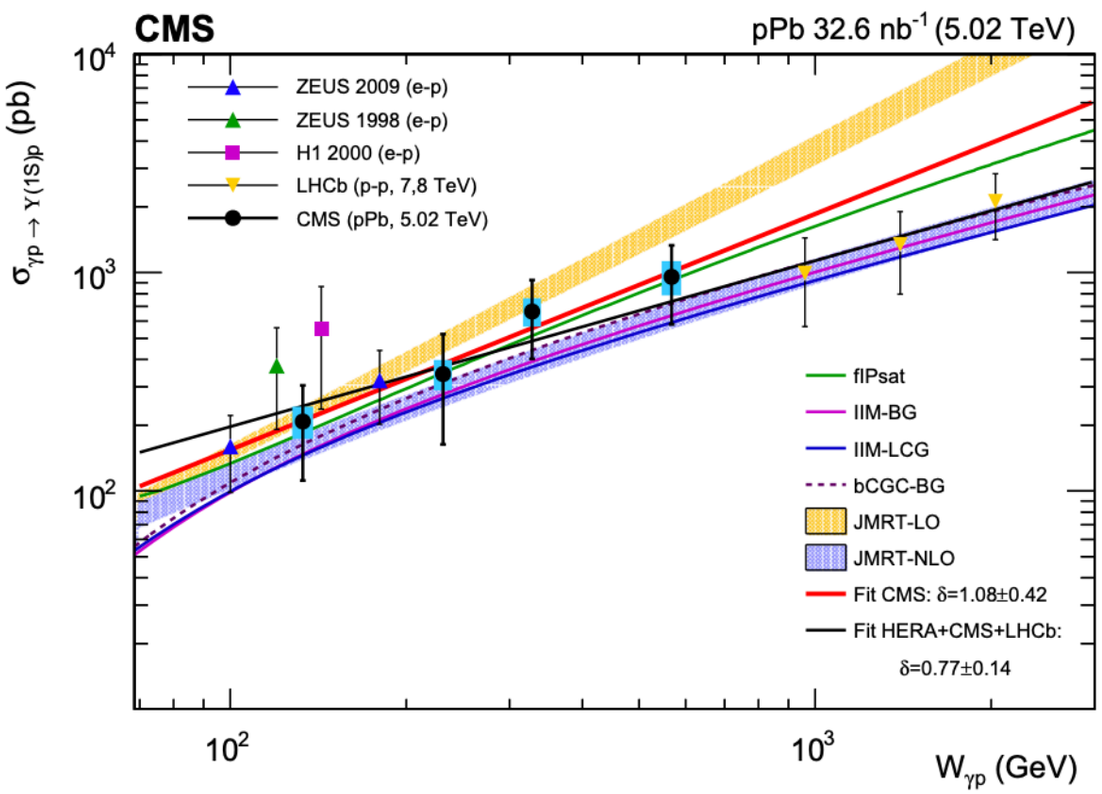

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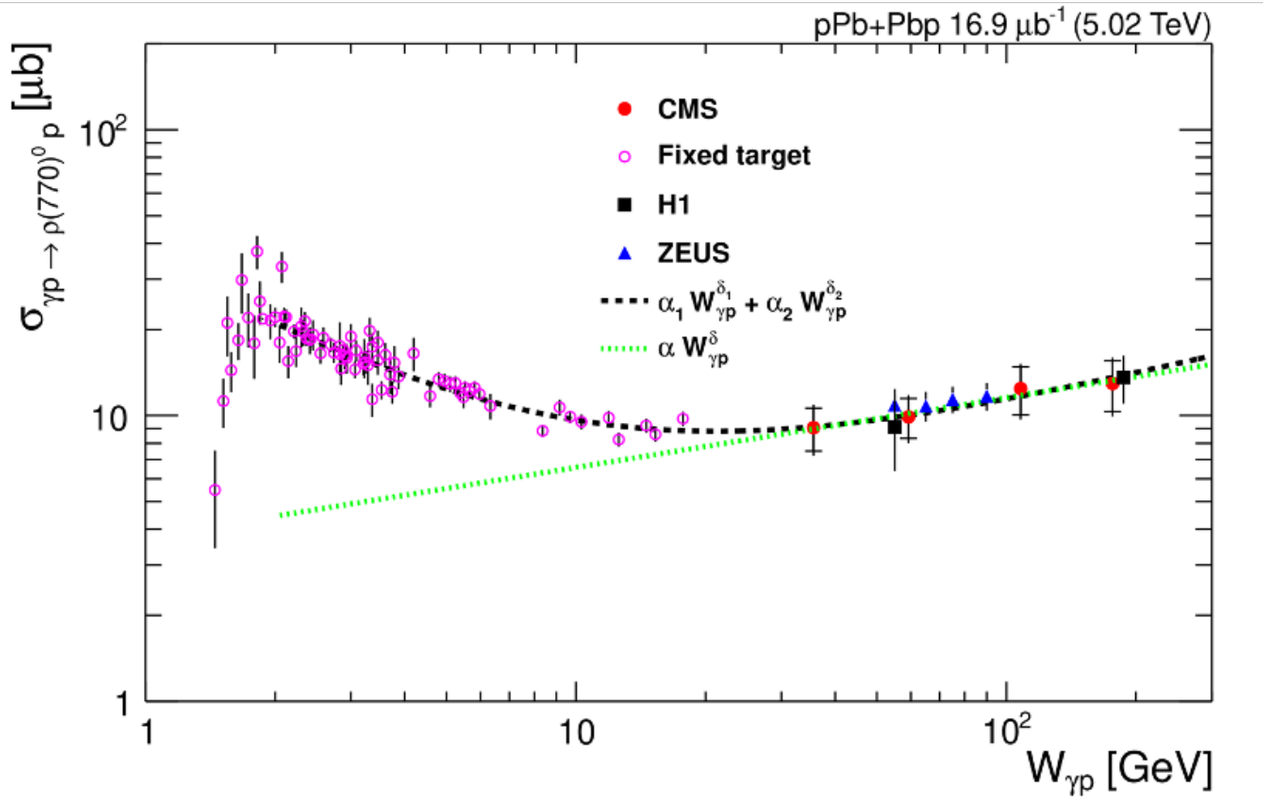


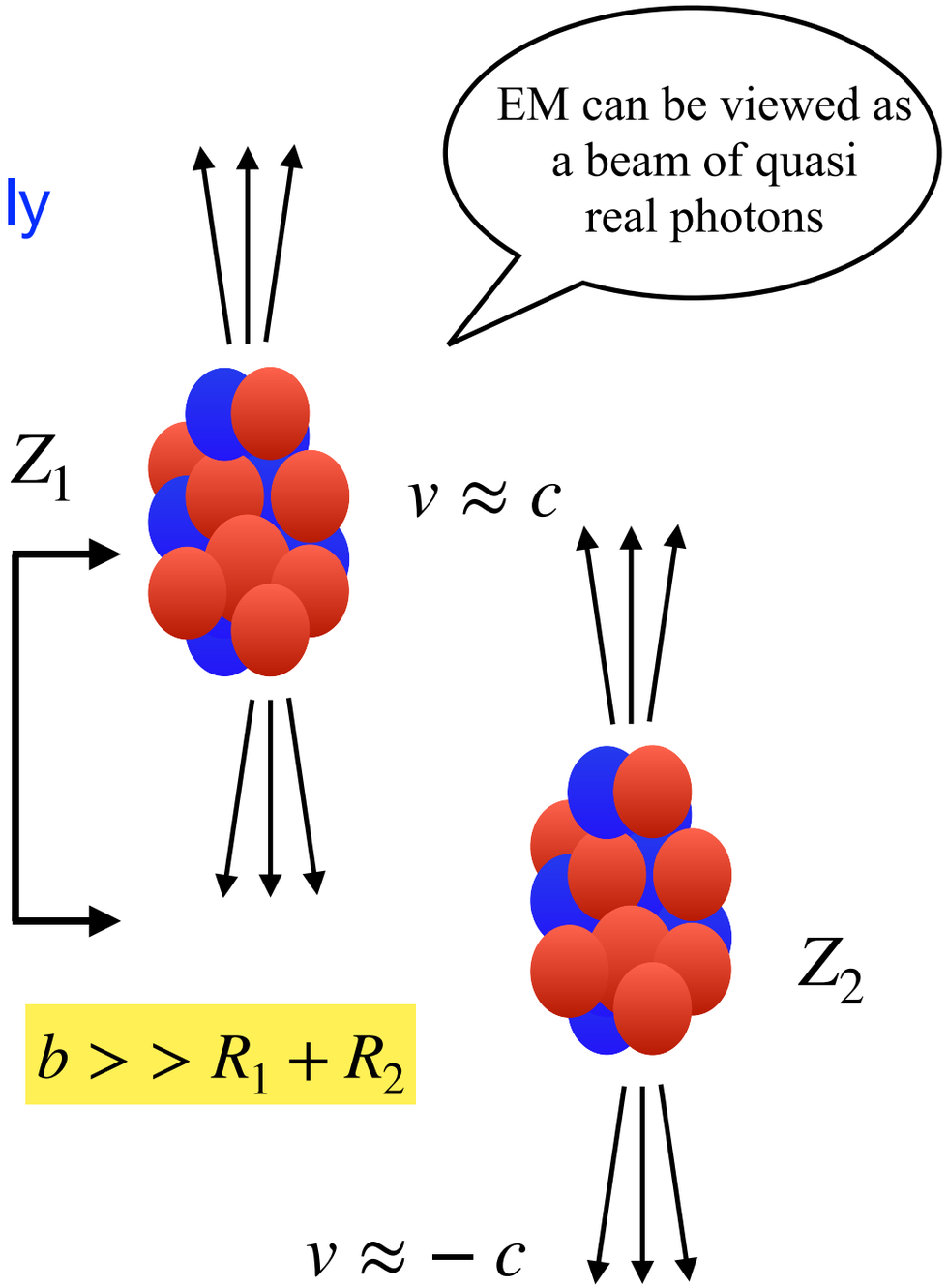
- The first time measurement of the exclusive vector meson in UPC 5.02 TeV with the CMS.
- Data results are consistent with pQCD approaches of the low-x gluon proton density.
- Ion-proton collisions can be used in the same way as electron proton ones, with ions acting as a sources of quasi real photon.

Stay tuned for new exclusive quarkonia results with large data samples.

Backup slides at glance!

Ultra peripheral collisions (UPC)

- Relativistic nuclei interact electromagnetically by physically missing each other
- Impact parameter $b > > R_1 + R_2$
- No hadronic interaction
- Boosted ions are the sources of photons
- Photon flux grows with the square of the charge and Z^2
- Sensitivity to gluon density in nucleon



Schematic diagram of UPC