# Measurement of exclusive vector meson photoproduction in pPb collisions with the CMS experiment


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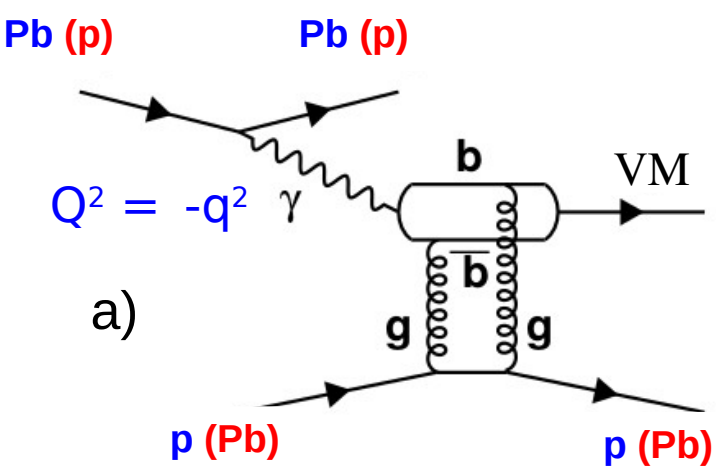
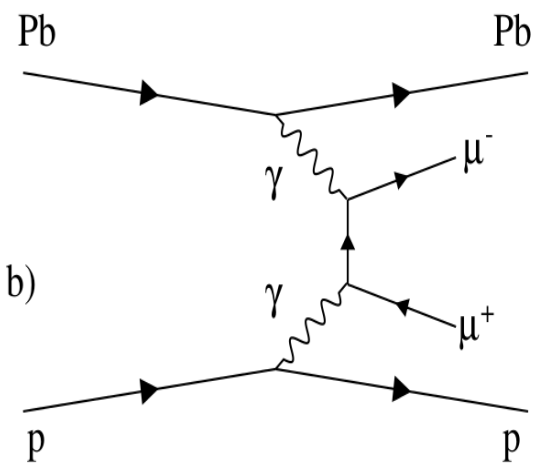
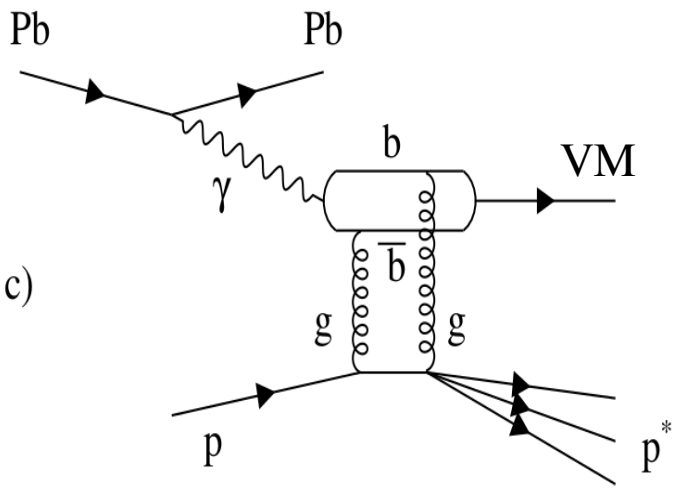
On behalf of the CMS collaboration


**7th April 2022**

# Vector Meson photoproduction in UPC



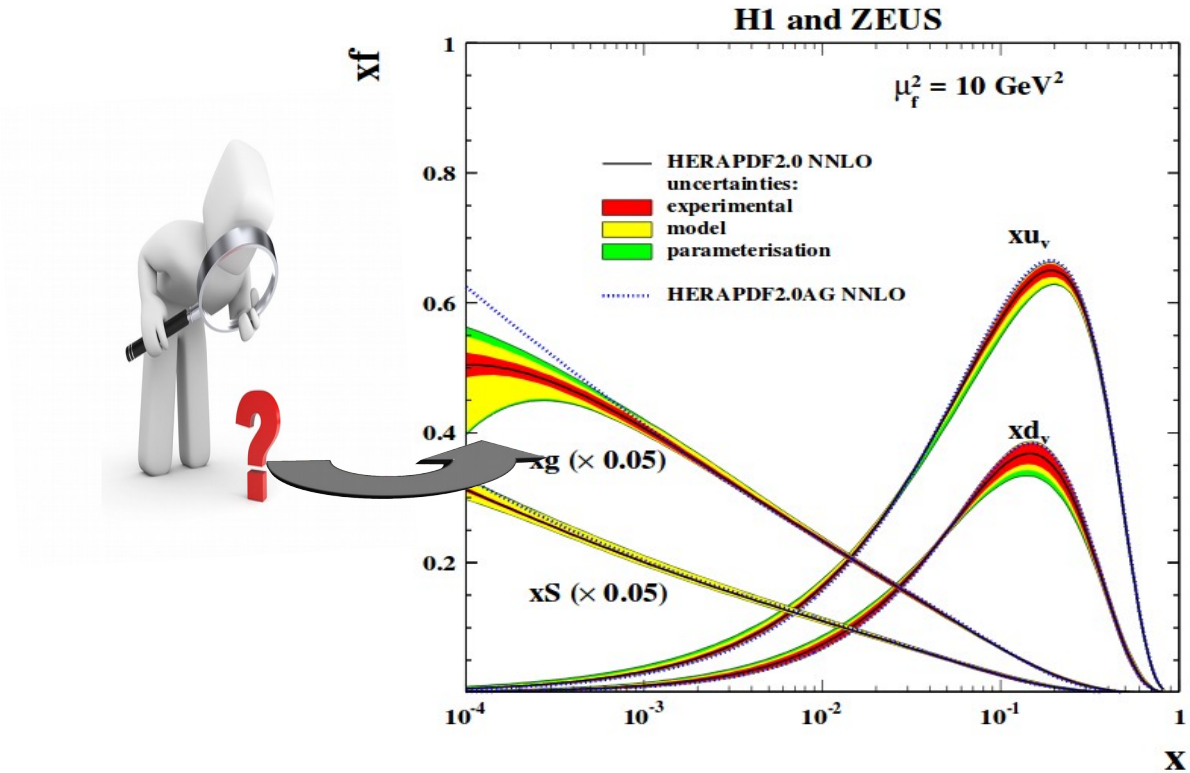




**Photon-Nuclear Interaction (Signal)**

**Photon-Photon Interaction** **Proton** (and/or **Lead**) **dissociation**

**(Background)**

# Probing the target's gluon density




EPJC 75 (2015) 580

- In leading logarithmic approximation of pQCD

$$\left.\frac{d\sigma_{\gamma p\to\gamma pVM}}{dt}\right|_{t=0} = C(\mu^2)[xG(x,\mu^2)]^2$$

- **Region of interest for PDFs in pPb:**
  -**Gluon distribution** in the proton at low Bjorken-$x$ ($10^{-2}$ to $10^{-4}$) and search for **saturation effects**

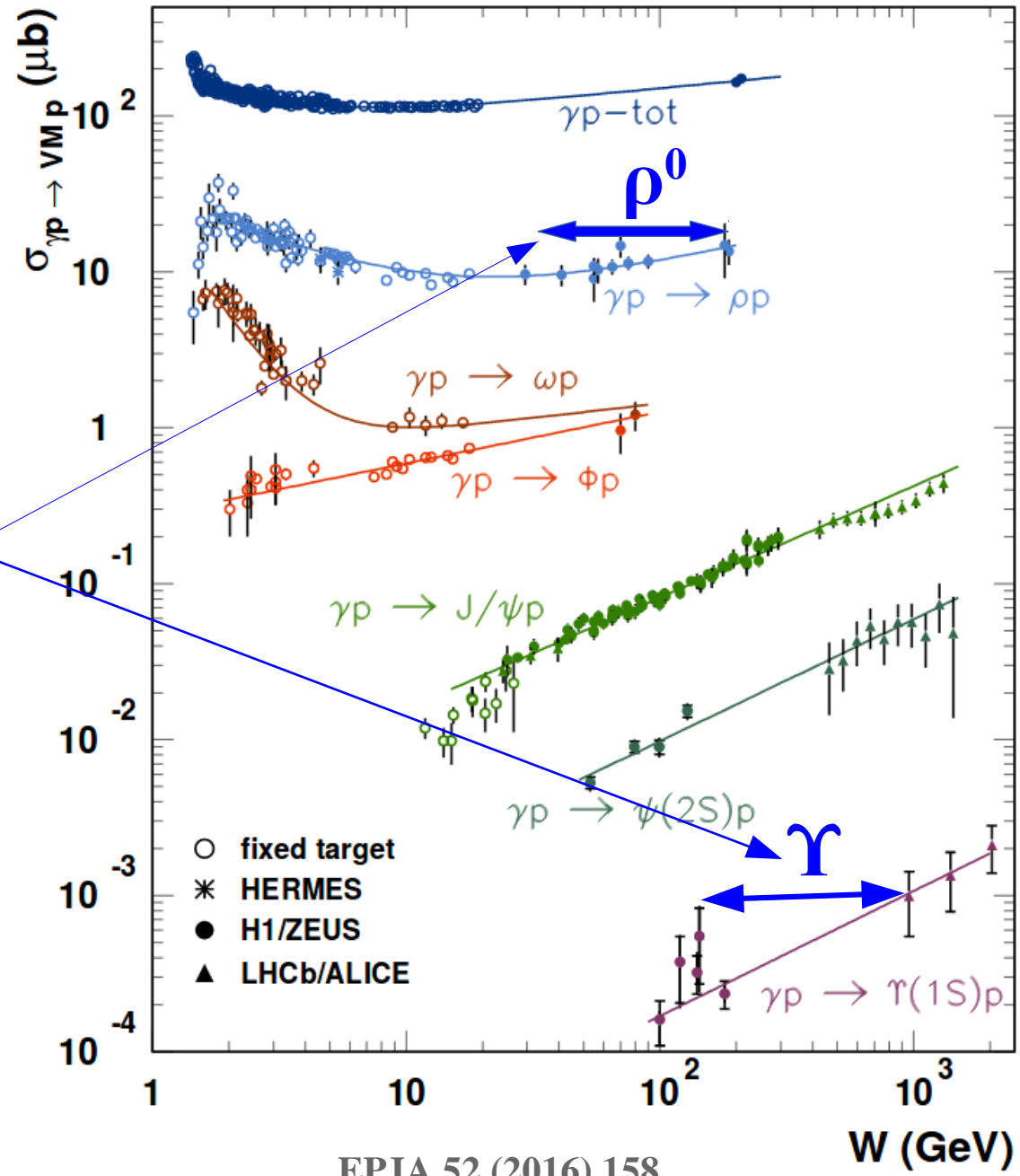
- **Nuclear shadowing in UPC PbPb**

# Exclusive Vector Meson (VM) photoproduction in pPb

- **Region of interest in CMS:**
  - $W_{\gamma p}$ : 29 – 213 GeV for $\rho^0$ and 91-826 GeV for $\Upsilon$

$$x = (M_{VM}/W_{\gamma p})^2 ,$$

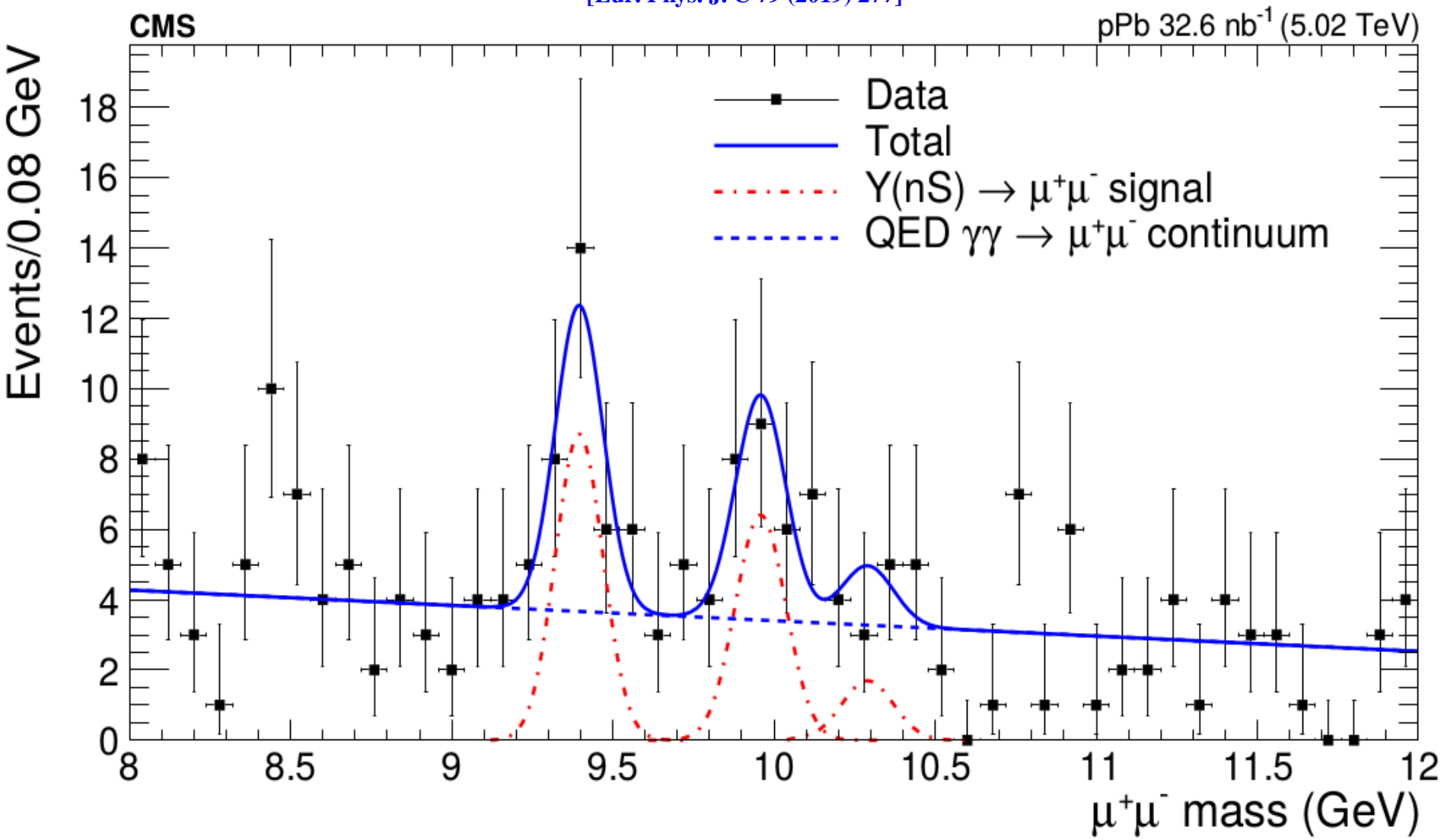
$$W_{\gamma p}^{\ 2} = 2E_p M_{VM} exp(\pm y)$$




EPJA 52 (2016) 158

# Exclusive ϒ in ultraperipheral pPb at 5.02 TeV

[Eur. Phys. J. C 79 (2019) 277]

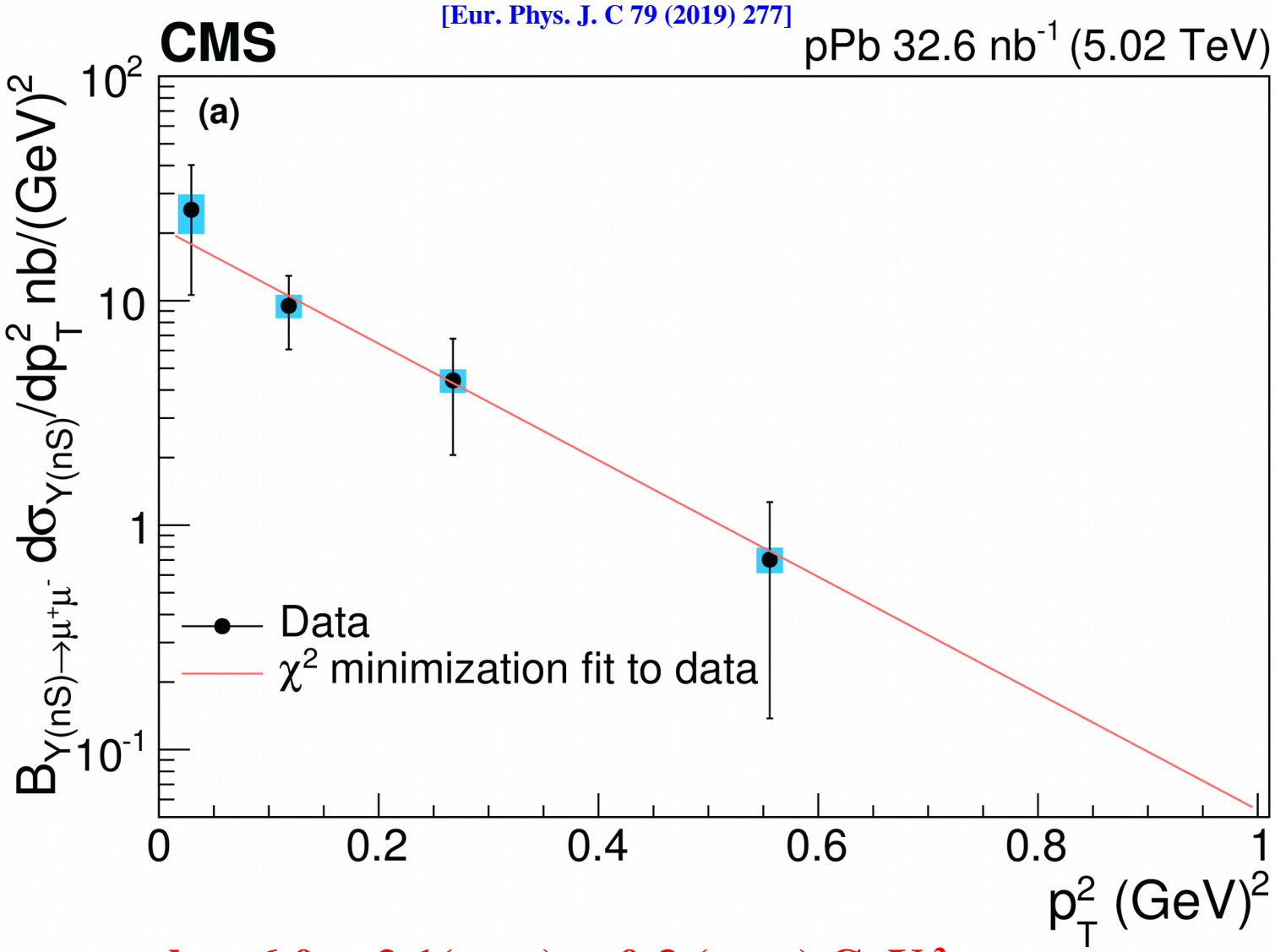



- **Dimuon $p_T$ cut:** $0.1 < p_T < 1.0$ GeV/c

  -Low $p_T$ cut to have good signal/background ratio, high $p_T$ cut to suppress background from **inclusive ϒ** and **Proton Dissociation** (PD)

# $p_T^2$ differential cross-section

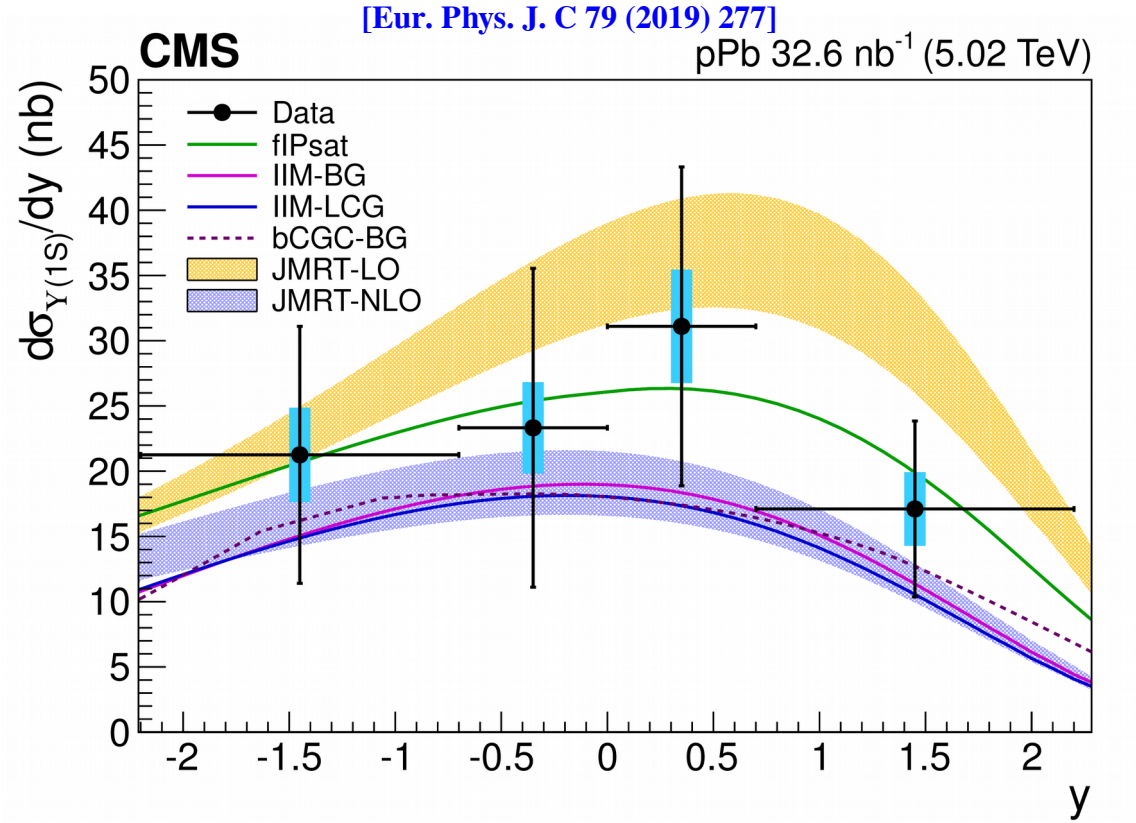
[Eur. Phys. J. C 79 (2019) 277]




- Result for $\Upsilon$(nS): **b = 6.0 ± 2.1(stat.) ± 0.3 (syst.) GeV$^{-2}$**
- Consistent with ZEUS measurement for $\Upsilon$(1S): b = $4.3_{-1.3}^{+2.0}$ (stat.) GeV$^{-2}$ [PLB 708 (2012) 14]
- Exponential slope-b provides information on the transverse density profile of the proton [JHEP 03 (2001) 045, PRD 58 (1998) 114001]

# Rapidity dependence

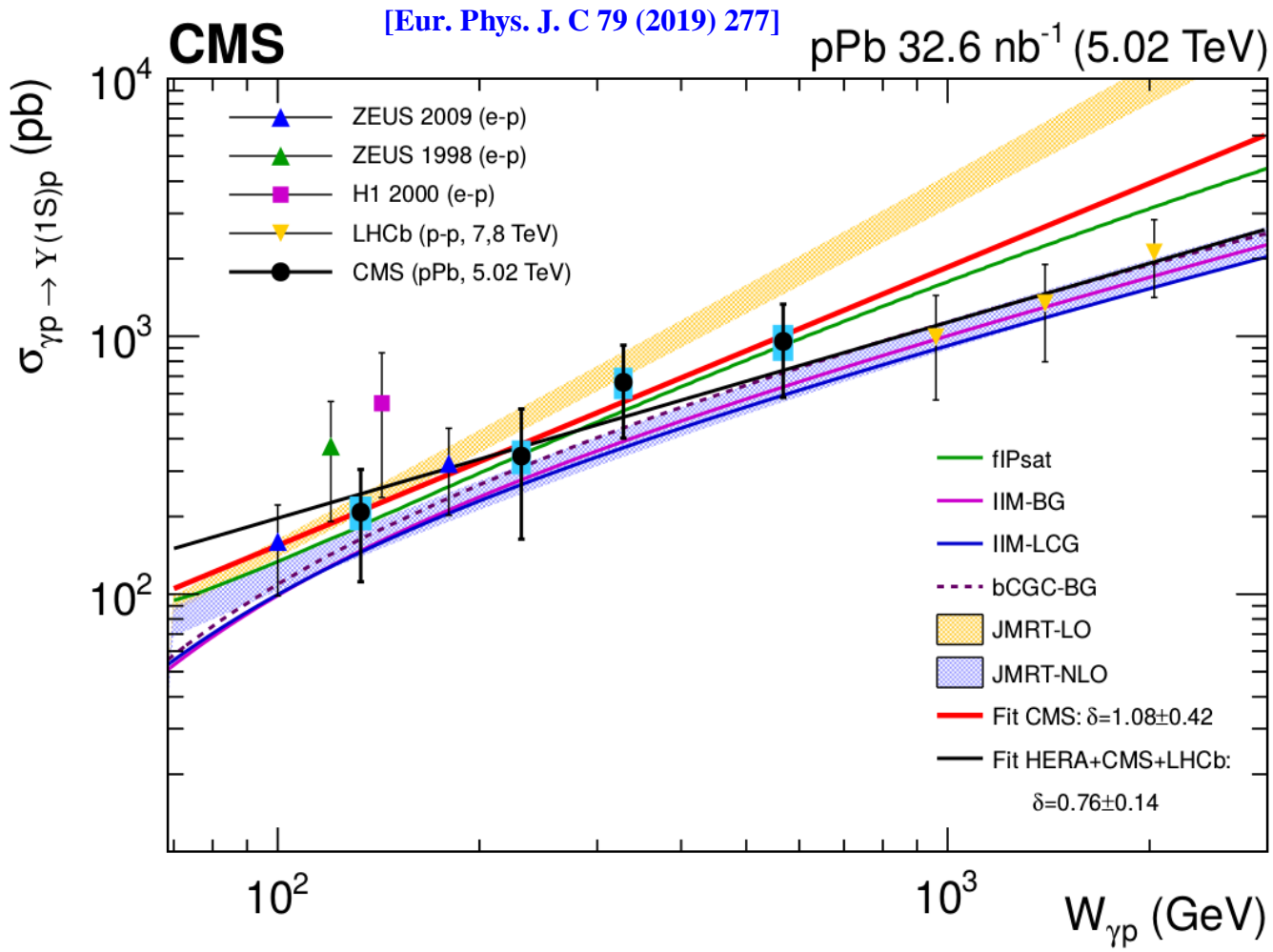
[Eur. Phys. J. C 79 (2019) 277]




⇒ Consistent with theoretical predictions

- JMRT model : pQCD calculations at LO and NLO [JHEP 11 (2013) 085]
- fIPsat: CGC-based model for low-$x$ gluon saturation [PRC 83 (2011) 065202, PRC 87 (2013) 032201]
- IIM: Colour dipole formalism [PLB 590 (2004) 199] with two sets of meson wave functions (BG and LCG), which also incorporates saturation effects [PRC 89 (2014) 025201, JPG 42 (2015) 105001]
- bCGC: model accounting for the t-dependence of the differential cross section [PRD 95 (2017) 054011, PRD 96 (2017) 094027]

# Scaling with the photon-proton energy

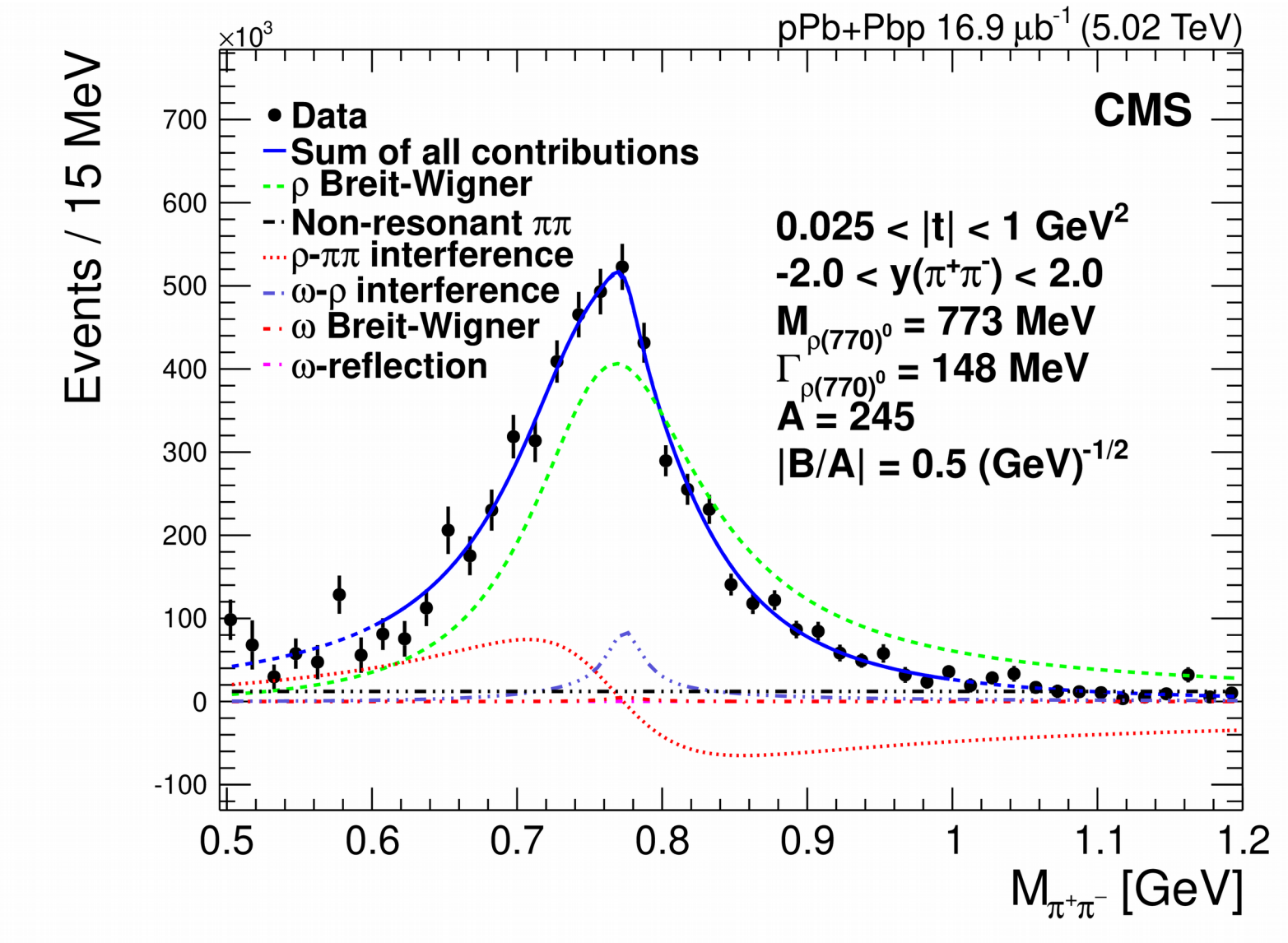



- Fit parameters of power law dependent cross section: $\sigma_{\Upsilon}(W_{\gamma p}) = A \times (W/400)^{\delta}$
  - CMS result: **$\delta = 1.08 \pm 0.42$, $A = 690 \pm 184$ pb**
  - ZEUS result: **$\delta = 1.2 \pm 0.8$** [PLB 680 (2009) 4]

  ⇒ It is consitent with other experimental results and most predictions
- Combined fit to all measurements (black line) disfavour the LO pQCD calculations [JHEP 11 (2013) 085]

# Exclusive ρ in ultraperipheral pPb at 5.02 TeV

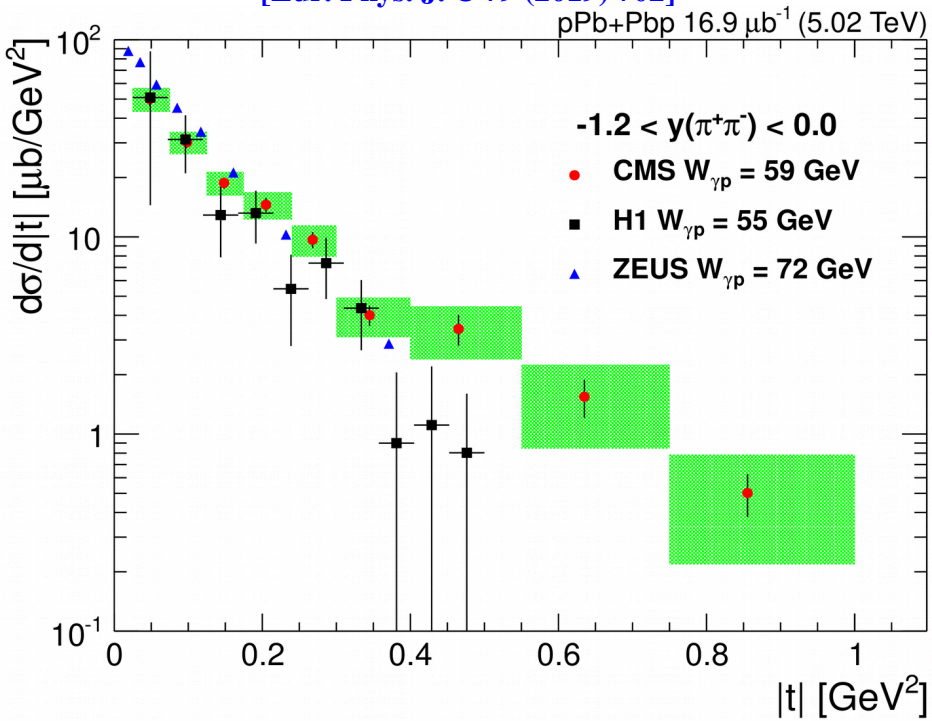
[Eur. Phys. J. C 79 (2019) 702]



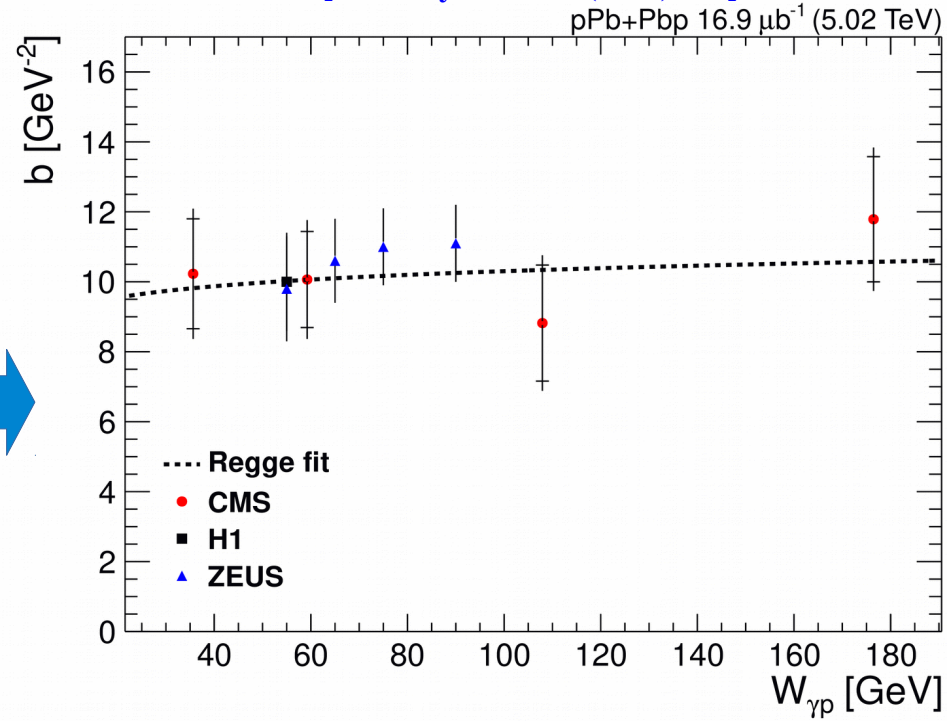

- Complex signal extraction due to the interference with the ω(783) meson

# Results: Exclusive $\rho(770)^0$ photoproduction at 5.02 TeV

[Eur. Phys. J. C 79 (2019) 702]




[Eur. Phys. J. C 79 (2019) 702]

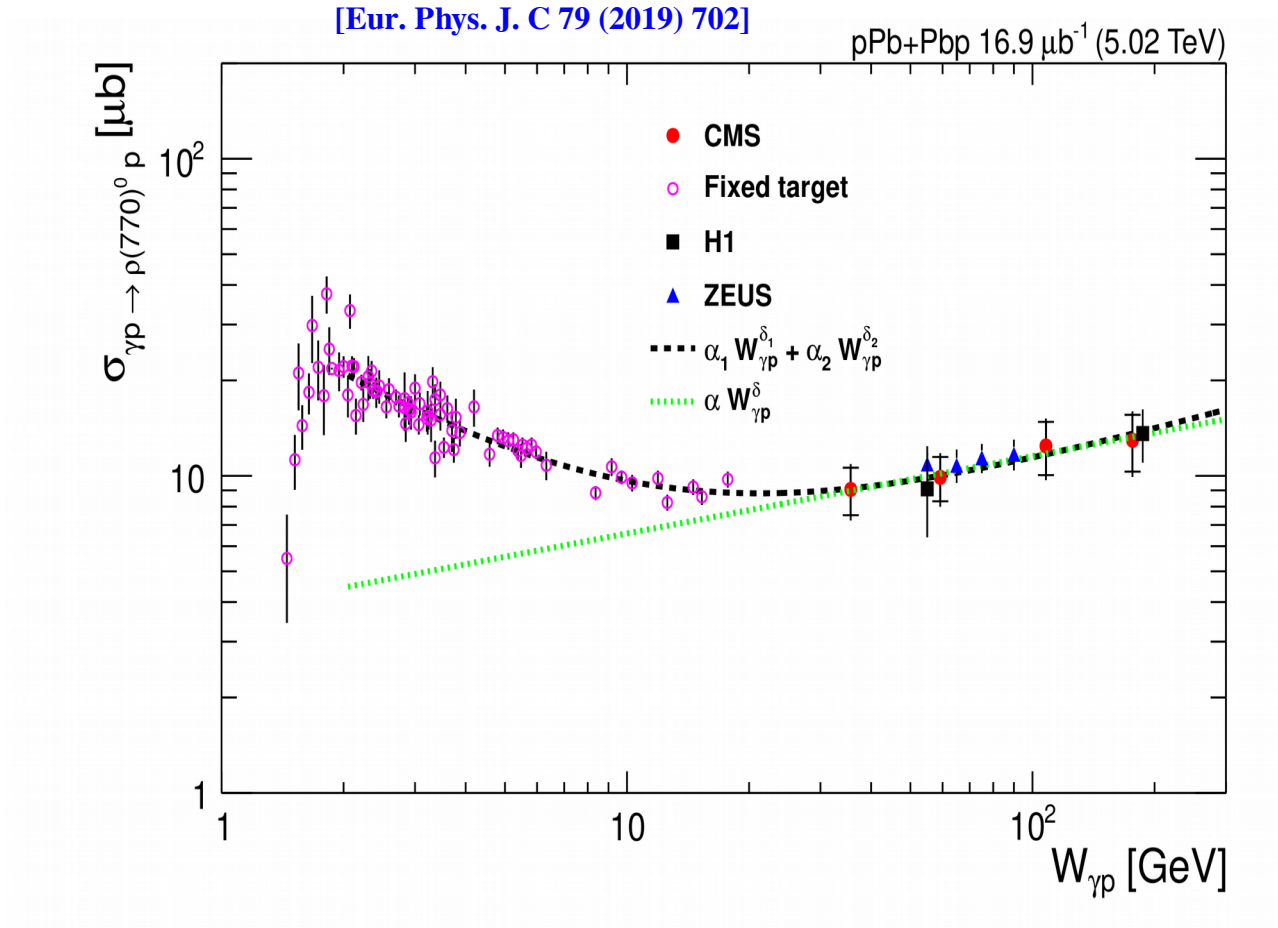



- Left plot is fitted with an exponential function $Ae^{(-b|t|+c|t|^2)}$
  - CMS result: b = 9.2 ± 0.7(stat.) GeV$^{-2}$, c = 4.6 ± 1.6(stat.) GeV$^{-4}$

- From Regge formula $b = b_0 + 2\alpha \ ln(W_{\gamma p}/W_0)^2$
  - CMS result: $\alpha$ = 0.28 ± 0.11 (stat) ± 0.12 (syst) GeV$^{-2}$,
  
  ⇒ Consistent with Regge expectation [PR 101 (1983) 169] and ZEUS value [EPJC 2 (1998) 247]

# Scaling with the photon-proton energy

[Eur. Phys. J. C 79 (2019) 702]

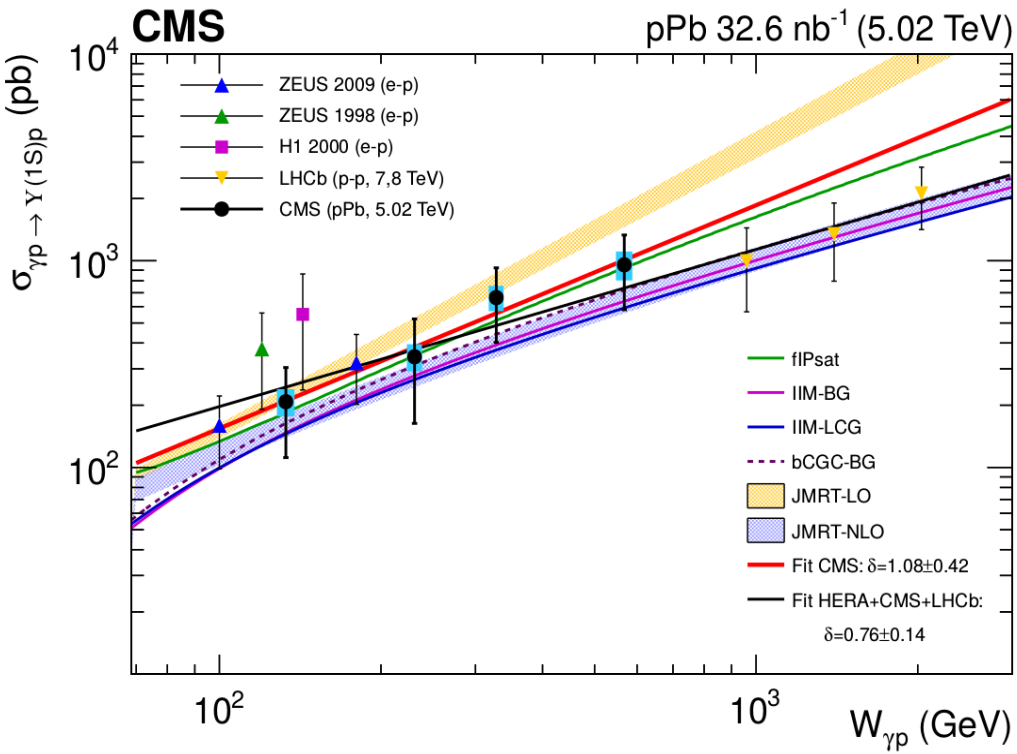



- Cross-section: $\sigma$ = 11 ± 1.4 (stat) ± 1.0 (syst) $\mu$b
  (within $W_{\gamma p}$ : *29 –213* GeV and 0 < |t| < 0.5 GeV$^2$)
- Results consistent with measurements at HERA [EPJC 2 (1998) 247, NPB 463 (1996) 3]
- Fit parameters of power law dependent cross section: $\sigma_\rho(W_{\gamma p}) = \alpha \times (W_{\gamma p})^\delta$

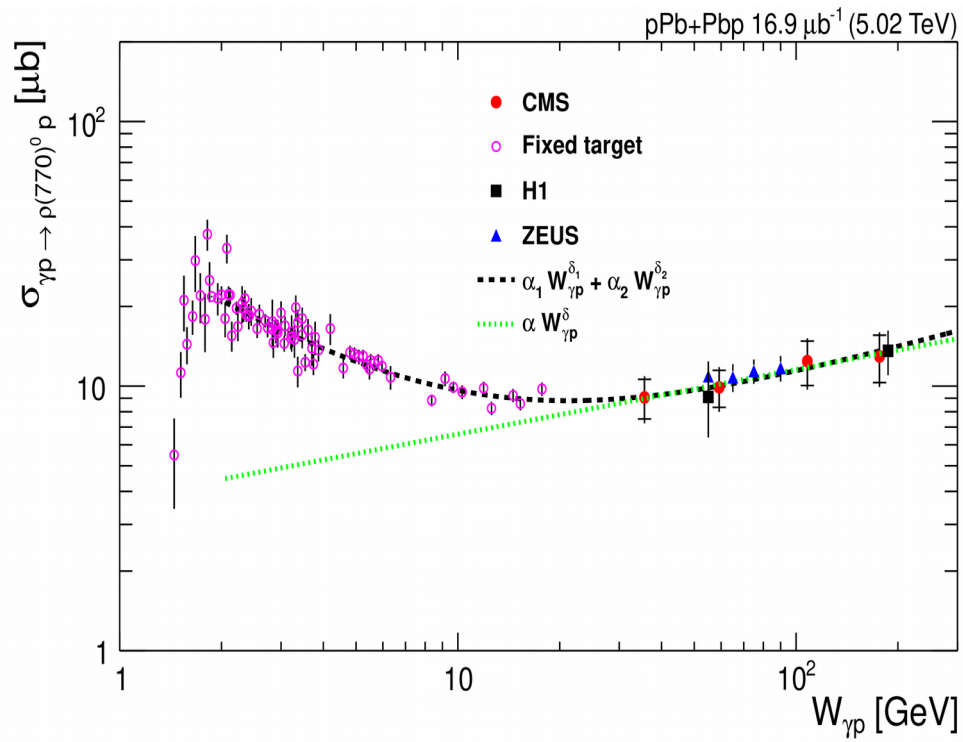
  $\delta$ = 0.24 ± 0.13 (stat) ± 0.04 (syst)

# Summary and Outlook

[Eur. Phys. J. C 79 (2019) 277]



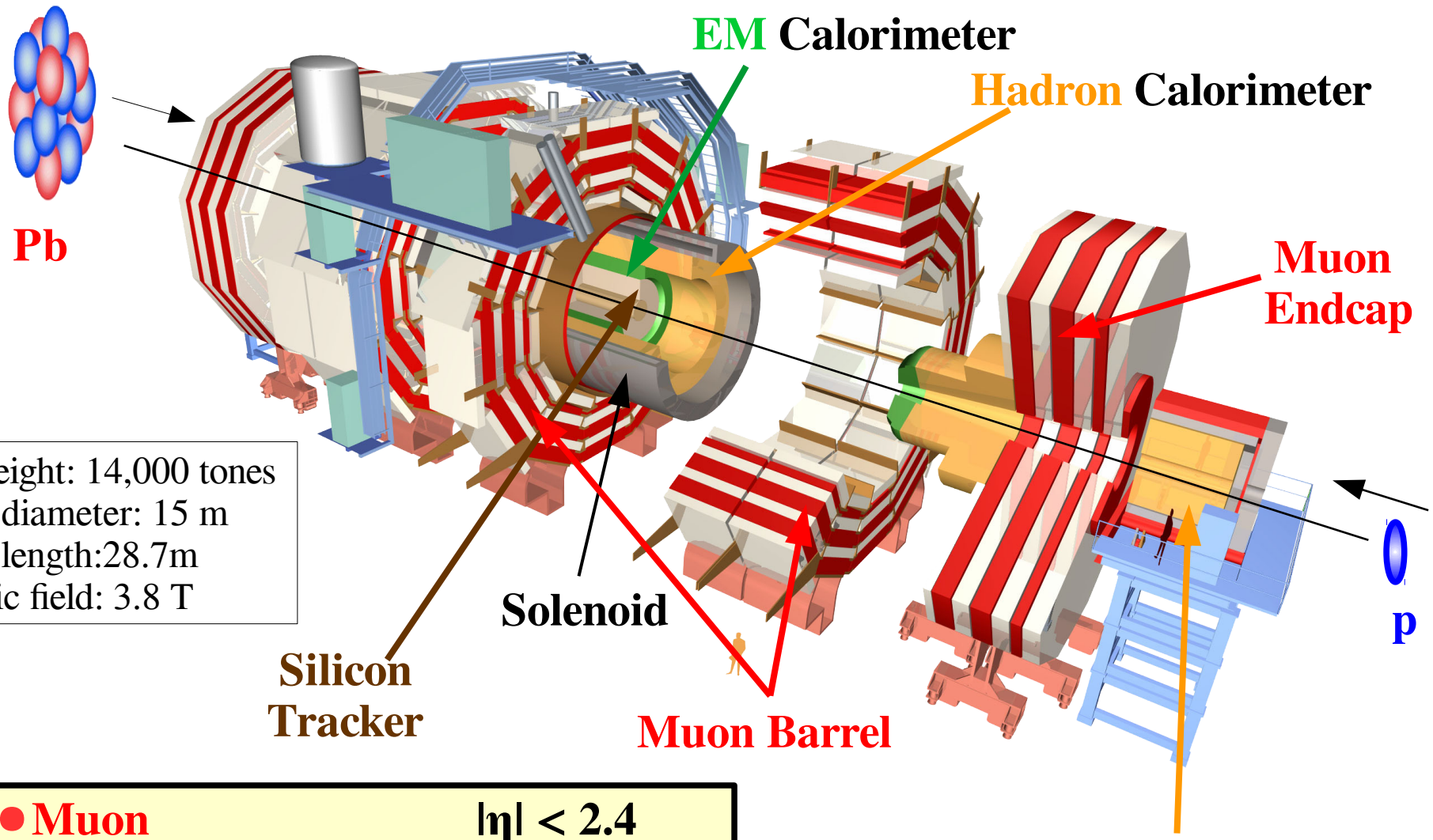

[Eur. Phys. J. C 79 (2019) 702]




- 1st measurement of **ϒ(nS)** and **ρ(770)$^0$** photoproduction in pPb collisions
- These cross-section measurements provide constraints on the evolution of the gluon density in the proton at low Bjorken-*x*
- Stay tuned for new exclusive quarkonium measurements with the large Run 2 data samples!

***Thank you for attention!***

# CMS Detector




Total weight: 14,000 tones
Overall diameter: 15 m
Overall length:28.7m
Magnetic field: 3.8 T

| | |
|---|---|
| ● Muon | $\lvert\eta\rvert < 2.4$ |
| ● ECAL | $\lvert\eta\rvert < 3.0$ |
| ● HCAL | $\lvert\eta\rvert < 5.2$ |
| ● TRACKER | $\lvert\eta\rvert < 2.5$ |

# Event Selection

- Data from pPb collisions at $\sqrt{S_{NN}}$ = 5.02 TeV in 2013
- Integrated luminosities: **32.6 nb$^{-1}$** for **ϒ** and **16.9 μb$^{-1}$** for **ρ**

## ϒ selection

- **Mass cut: 9.1 < Mass$_{\mu\mu}$ <10.6 GeV**
- **Exclusivity Cut:**
  - -(**N$_{Tracks}$=2**, trk **p$_T$ > 0.1** GeV/c)
  - -Leading tower Energy in HF calorimeter < 5.0 GeV
- **Muon selection**
  - **Single muon Cut:**
    - To have good muon efficiency
    - $\mu^+$, $\mu^-$ $p_T > 3.3$ GeV/c, $|\eta| < 2.2$
- **ϒ selection**
  - **Dimuon $p_T$ Cut:**
    - -Low $p_T$ cut to have good signal/background ratio, high $p_T$ cut to suppress background from **inclusive ϒ** and **Proton Dissociation** (PD)
    - -Dimuon $p_T$: $0.1 < p_T < 1.0$ GeV/c

## ρ(770)$^0$ selection

- **Mass cut: 0.5 < Mass$_{\pi\pi}$ <1.2 GeV**
- **Exclusivity Cut:**
  - -Opposite sign 2 tracks of pion in an event (**N$_{Tracks}$=2**)
  - -Leading tower Energy in HF<3.0 GeV, HE<1.95 GeV
  - -CASTOR<9 GeV, ZDC$^+$<500 GeV, ZDC$^-$<2000 GeV
- **Pion selection**
  - **Single muon Cut:**
    - To have good pion efficiency
    - $\pi^+$, $\pi^-$ $p_T^{Leading} > 0.4$ GeV/c and $p_T^{Subleading} > 0.2$ GeV/c, $|\eta| < 2.0$
- **ρ$^0$ selection**
  - **($\pi^+\pi^-$) $p_T$ Cut:**
    - -Low $p_T$ cut to have good signal/background ratio, high $p_T$ cut to suppress background from **inclusive ρ** and **Proton Dissociation** (PD)
    - -($\pi^+\pi^-$) $p_T^2$: $0.025 < p_T2 < 1.0$ GeV$^2$/c$^2$