XXVI International Workshop on Deep Inelastic Scattering and Related Subjects

Kobe (Japan), April 16th- 20th 2018

Exclusive measurements with CMS

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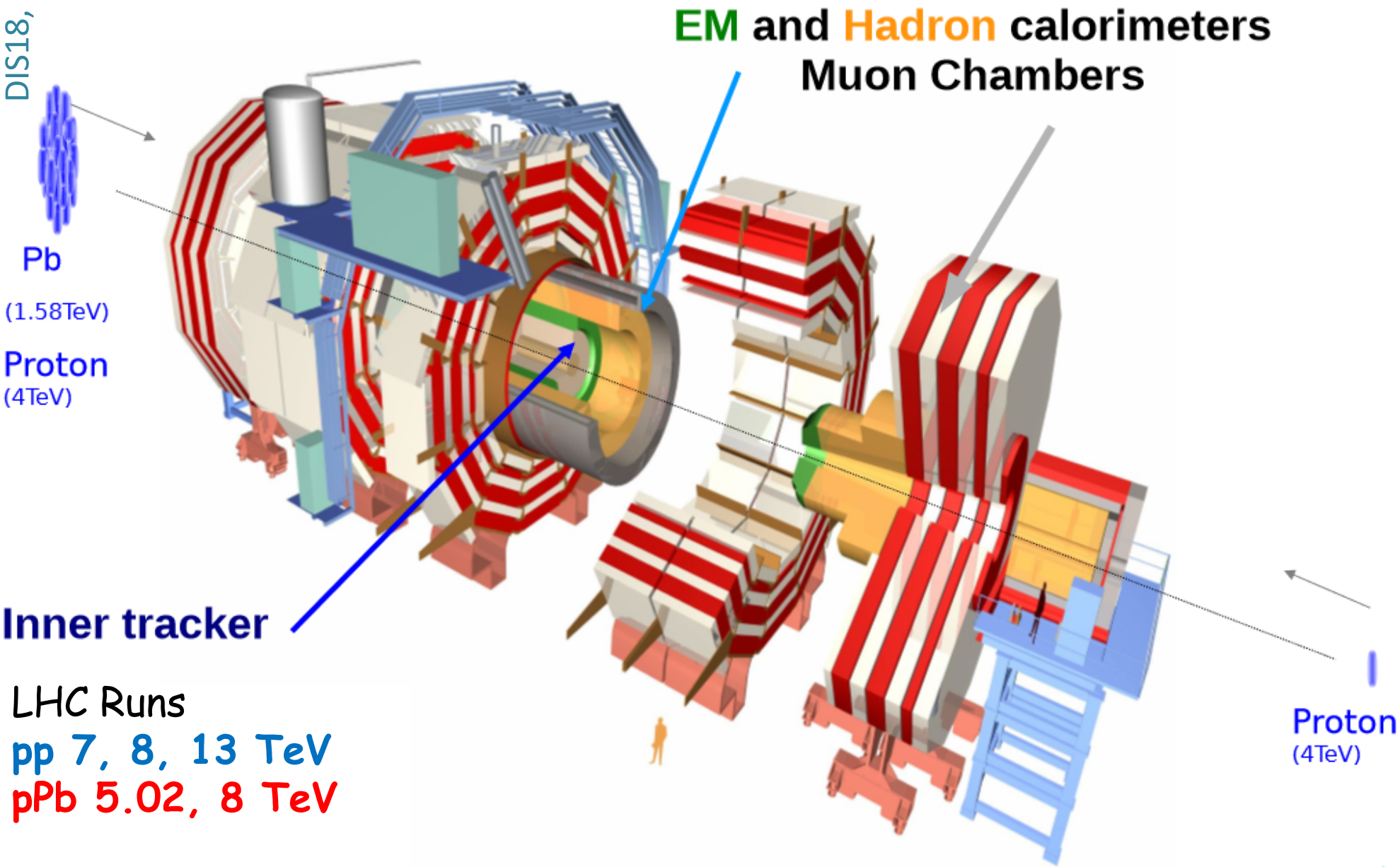
on behalf of the CMS Collaboration

Outline

- Introduction
- CMS detector and forward instrumentation
- Exclusive $\pi^+\pi^-$ production at 7 TeV
  [CMS FSQ-12-004, submitted to PRD, arXiv: 1706.08310]
- Exclusive Y production in pPb at 5.02 TeV
  [CMS FSQ-13-009]

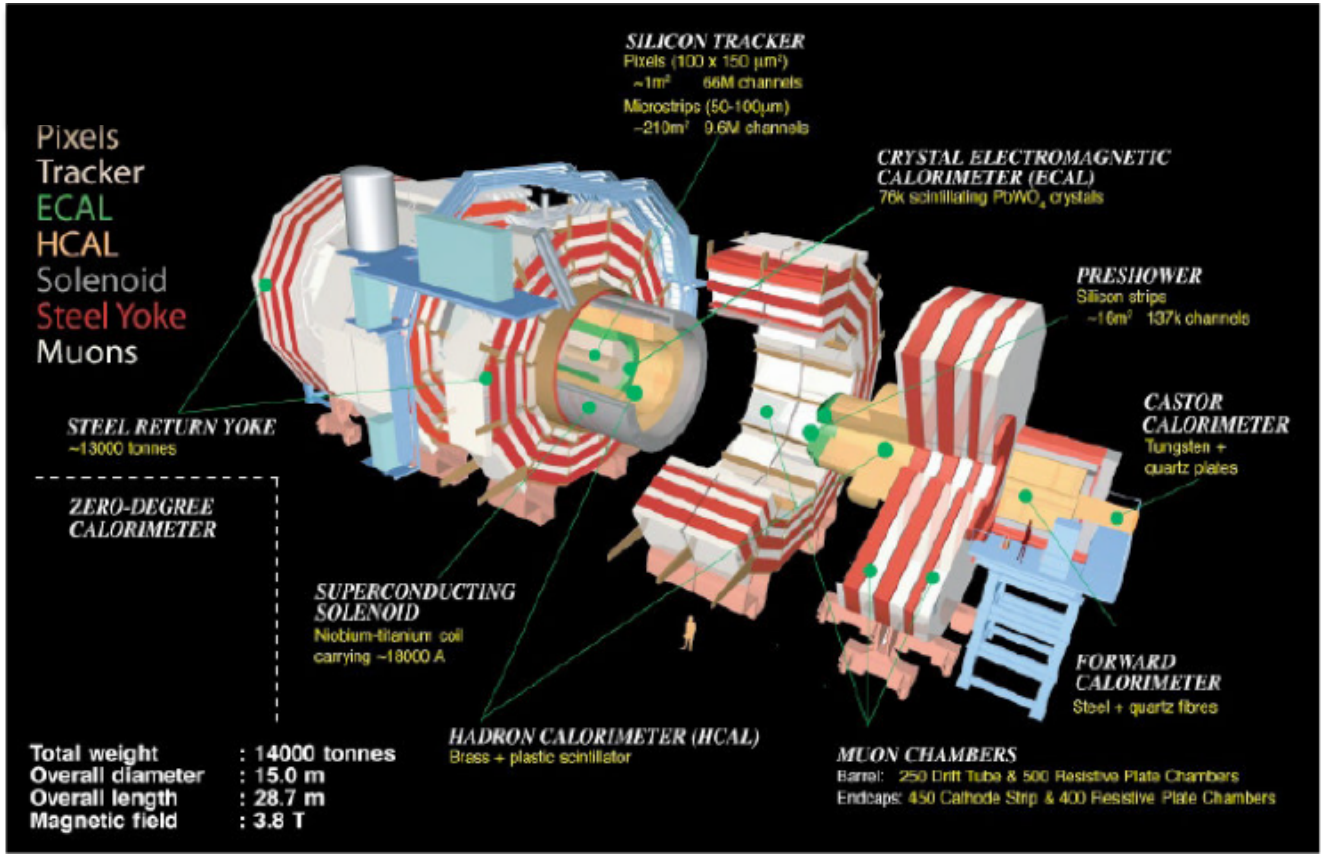
https://cms-results.web.cern.ch/cms-results/public-results/publications/FSQ/index.html

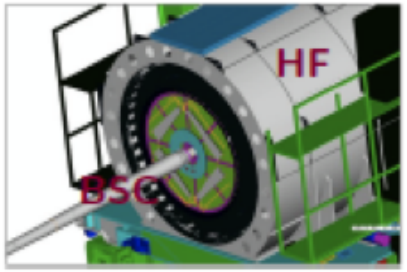
CMS detector

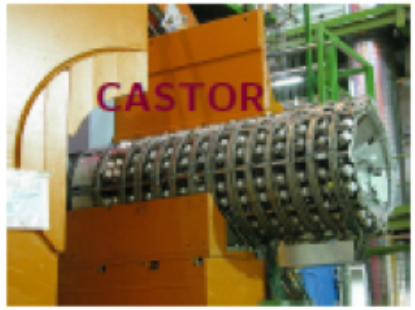


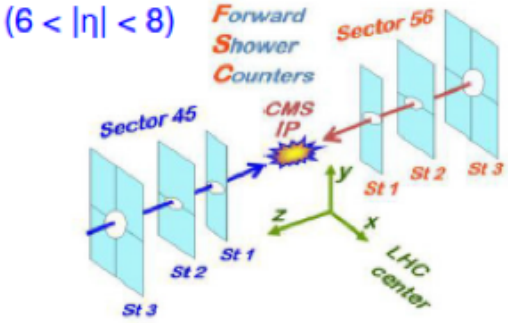
LHC Runs
pp 7, 8, 13 TeV
pPb 5.02, 8 TeV

CMS detector forward instrumentation





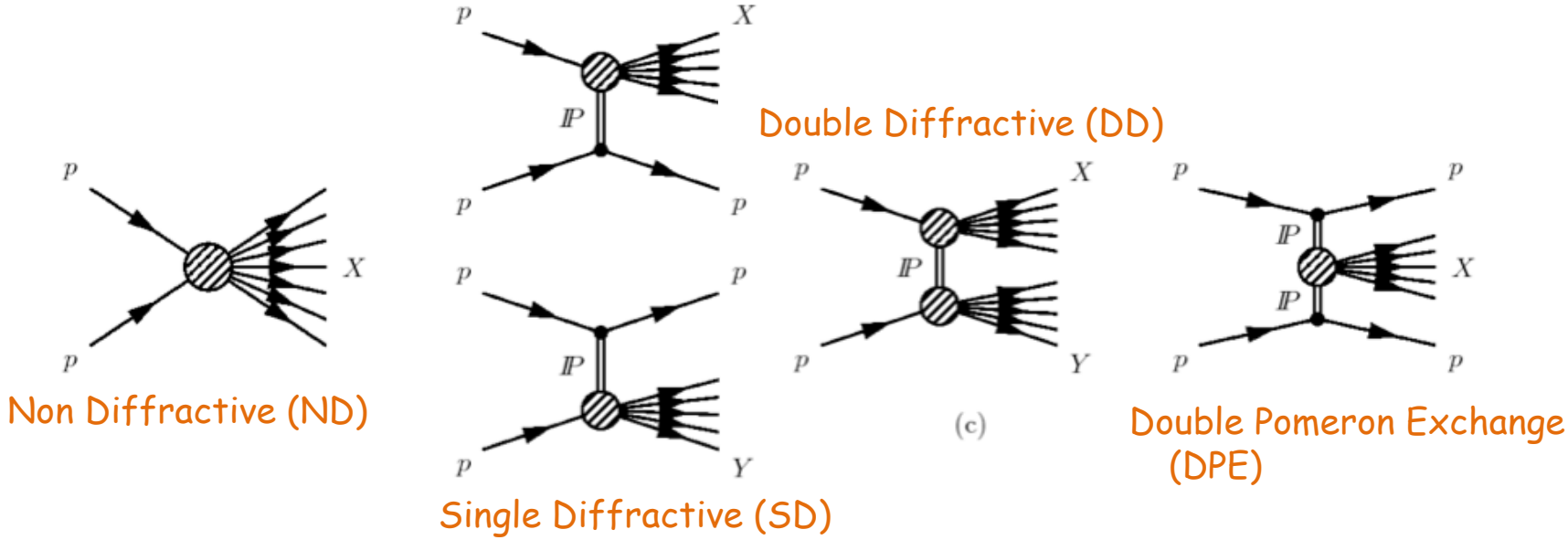




- **Hadron Forward calorimeter (HF):** 2.9 < |η| < 5.2 (10 m from IP)
- **Beam Scintillator Counters BSC :** 3.2 < |η| < 4.7 (in front of HF)
- **CASTOR calorimeter:** -6.6 < |η| < -5.2 (14.4 m from IP, one side only)
- **Forward Shower Counters FSC:** 6 < |η| < 8 (59-114 m from IP)
- **Zero Degree calorimeter:** |η| > 8.1 (140 m from IP)

+ TOTEM detector
(see Enrico's talk)

About diffractive and…



- Energy of scattered protons ≈ beam energy (within a few %) → **protons in the final state**

  Pomeron exchange (IP), **Large Rapidity Gap (LRG)**

- **If X = anything:**
  - Measure fundamental quantities of soft QCD
  - Contributes significantly to pile-up, underlying event (SD ~ 15 mb, DD ~ 10 mb)

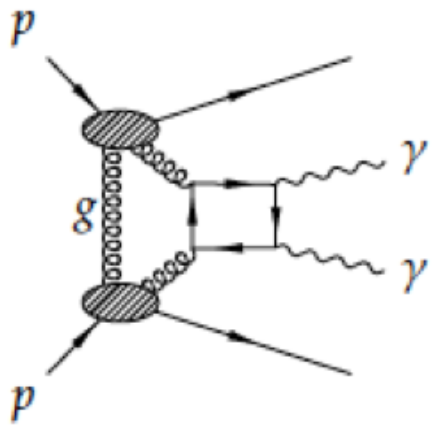
- **If X includes jets, W's, Z's:**
  - **Hard processes, calculable in perturbative QCD**
  - **Measure proton structure, QCD at high parton densities, discovery physics**

…exclusive reactions

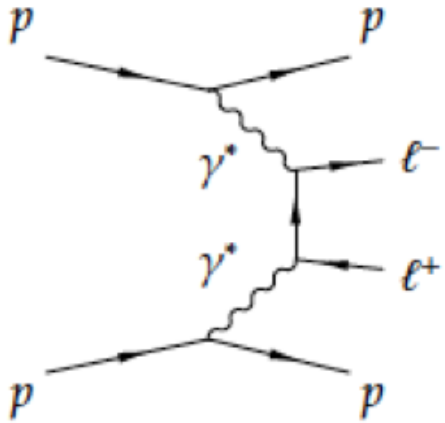
Study the reaction

$$pp \rightarrow p^{(*)}Xp^{(*)}$$

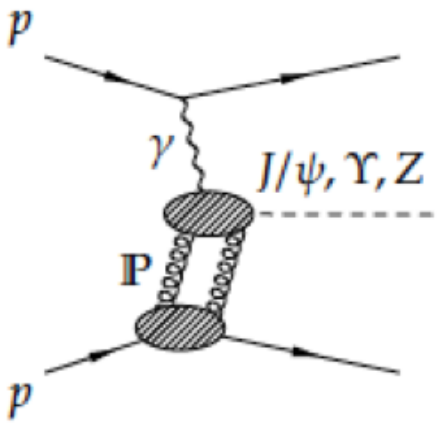
where numerous production mechanisms can contribute to produce the central system
$X = e^+e^-, \mu^+\mu^-, \gamma\gamma, W^+W^-, \ldots$



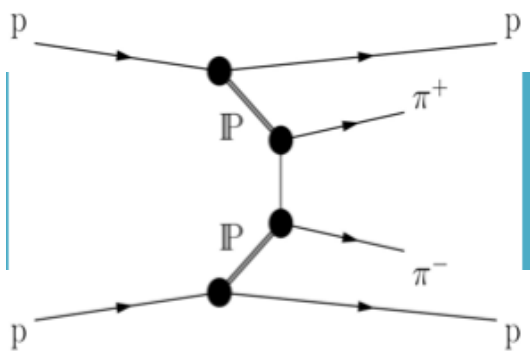
IPIP exchanges



γγ interactions



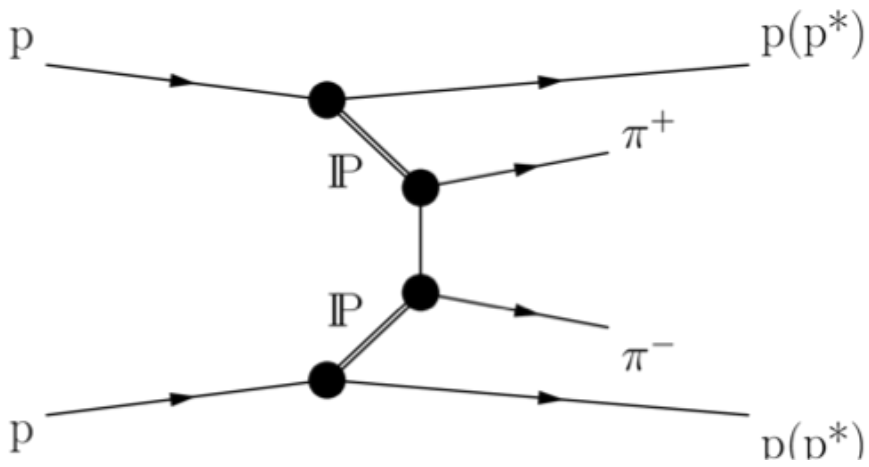
γIP fusion

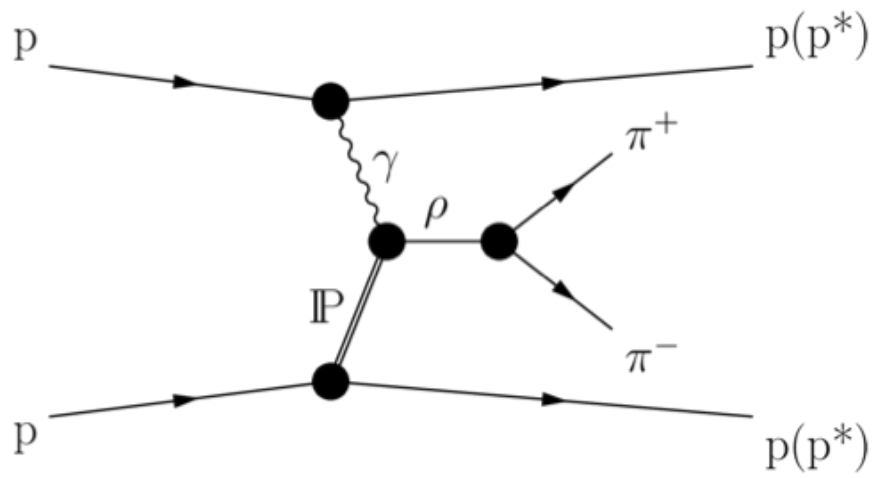


Exclusive π+π- production at 7 TeV

Experimental signature

Described in terms of Double Pomeron Exchange (DPE) at low scales or pertubatively in "CEP"





Low PU 2010 data @7 TeV, L ~ 505 μb^{-1}
Two opposite-sign pions with $p_T > 0.2$ GeV, $|y|<2$
Exclusivity: no other tracks and no energy above thresholds in calorimeter

Monte Carlo Models:
PYTHIA 8C, PYTHIA 8 MBR, Dime for DPE
STARLight for fotoproduction

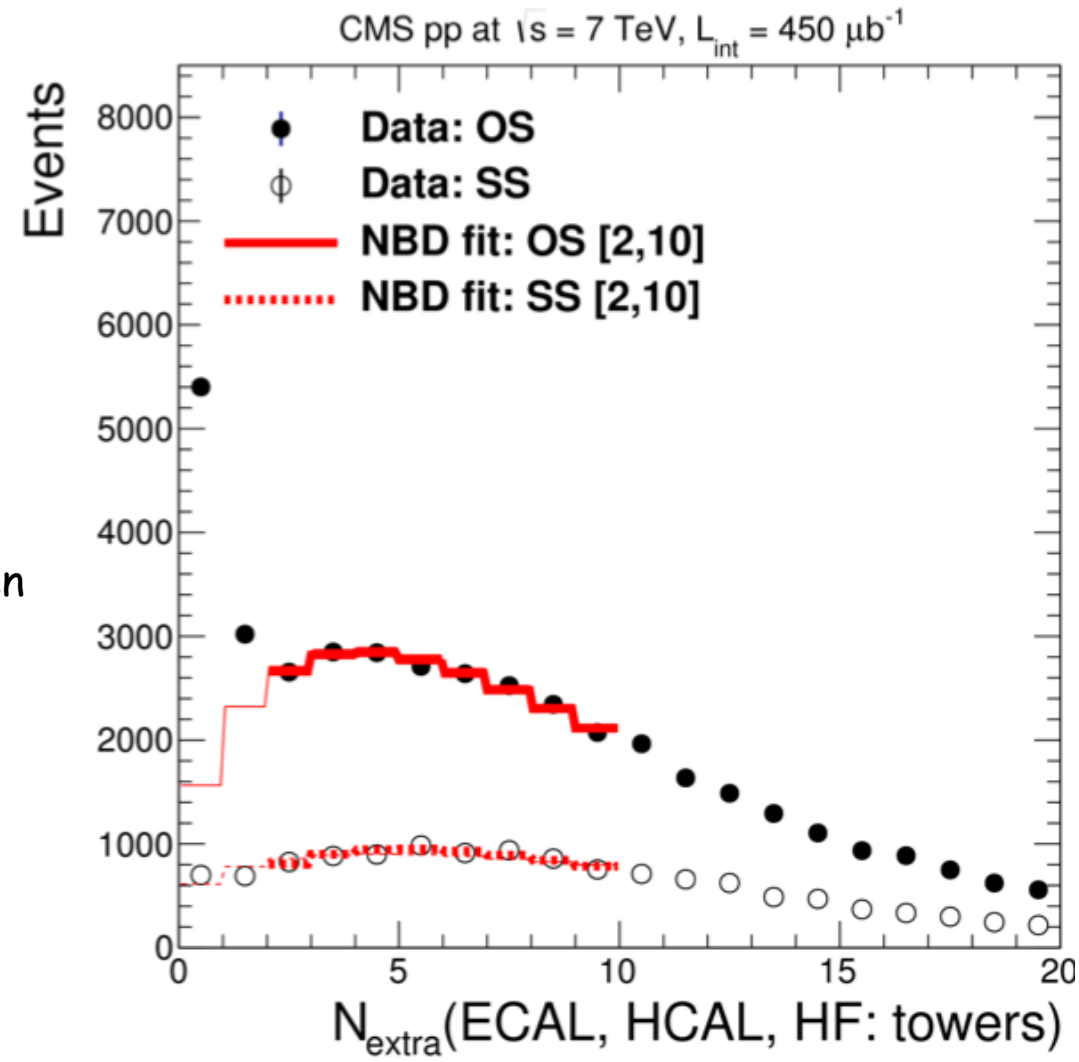
Background estimation

OS: Opposite Sign, signal
SS: Same Sign, background

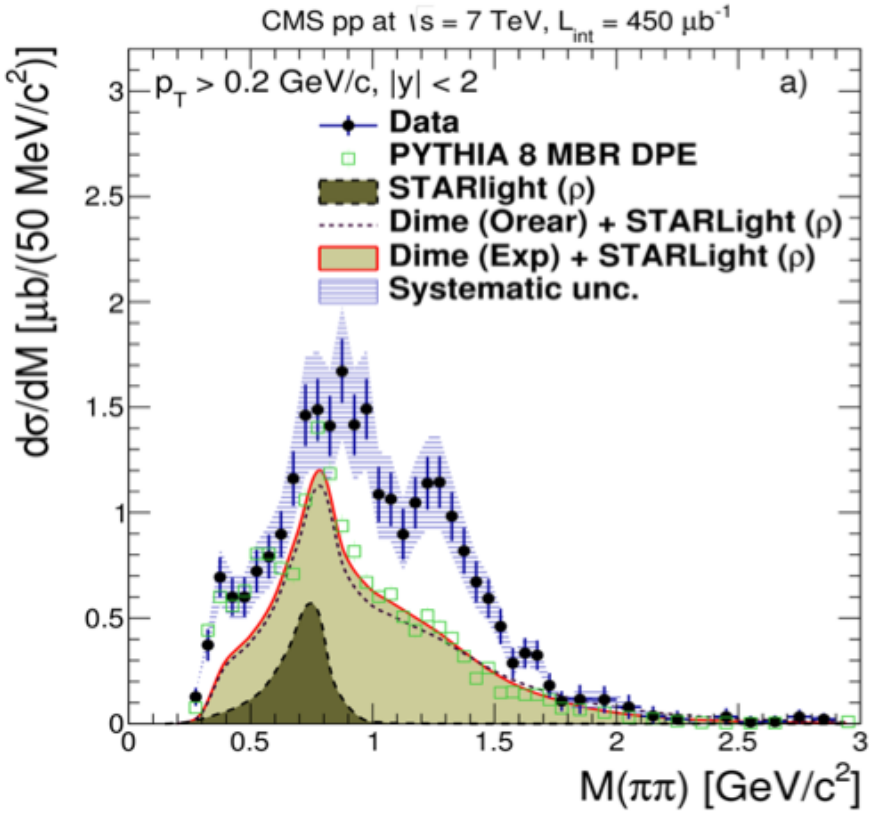
Data driven background subtraction looking at N of extra CAL towers above noise threshold

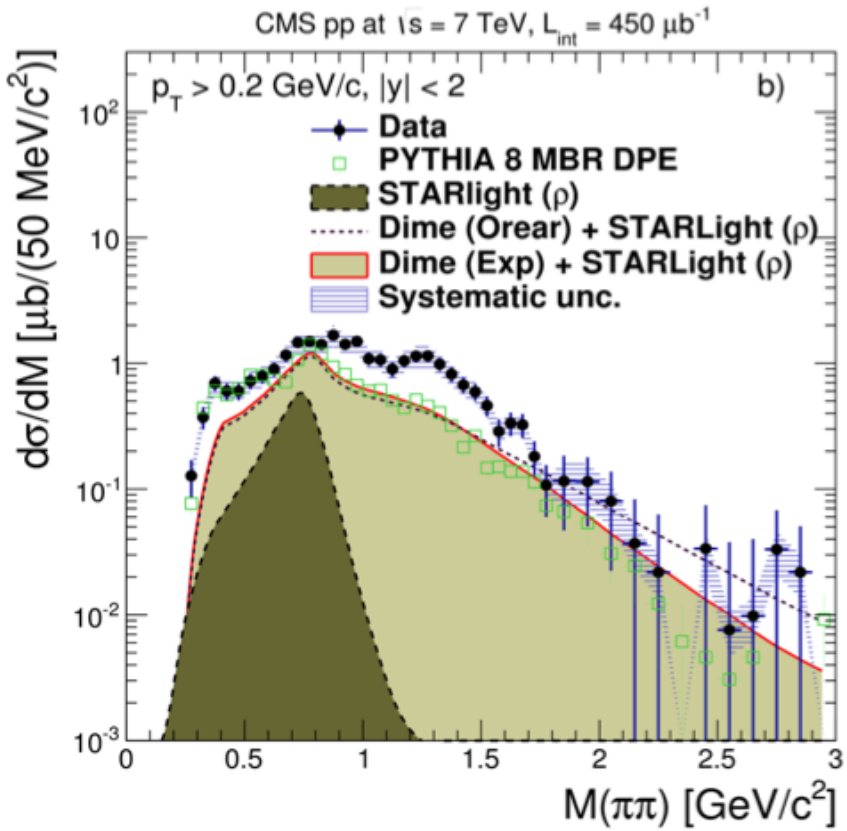
N_{extra} > 1 well described by NBD between 2 and 10

Extrapolation of NBD to 0, 1 in OS sample provides background estimation



$d\sigma/dM$



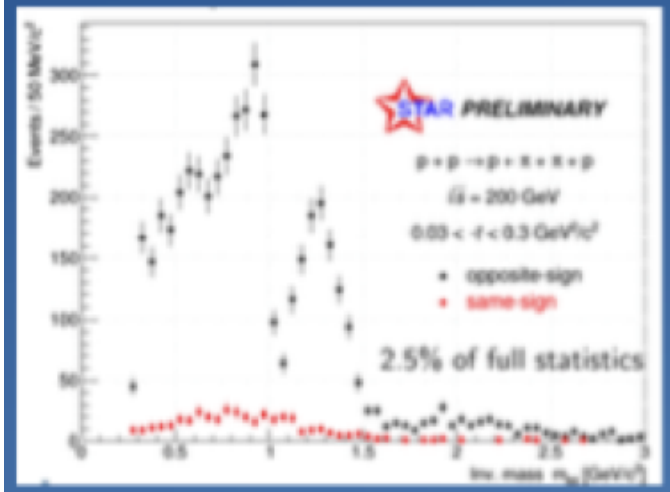


Compared to predictions of
Dime and PYTHIA (DPE)
STARLight (rho photoproduction)

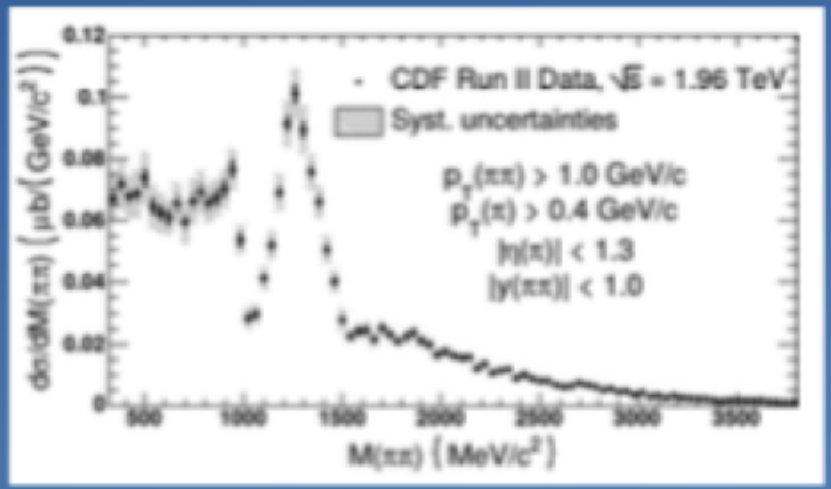
Beware: proton dissociation NOT in the models

Central, exclusive production in pp

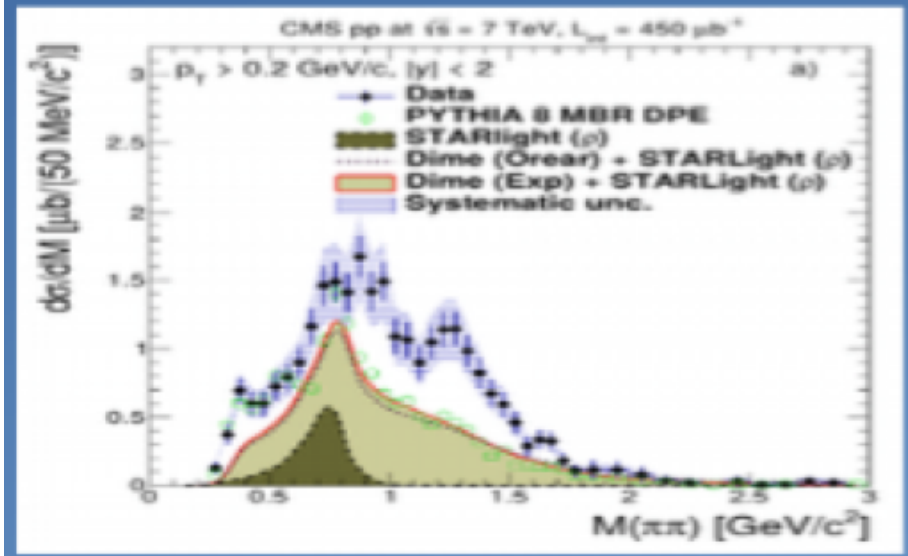
- Appears to be a universal, energy independent observation.
- Similar features observed at RHIC, Tevatron, LHC.



STAR, R. Sikora, Diffraction 2016.



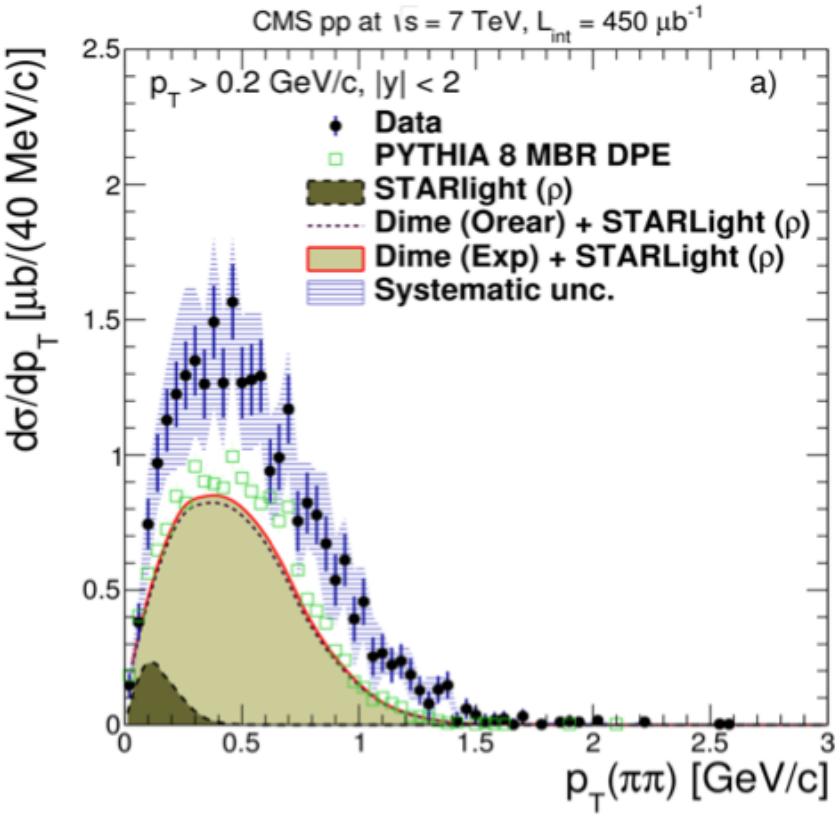
CDF, Phys. Rev. D 91 (2015) 091101.

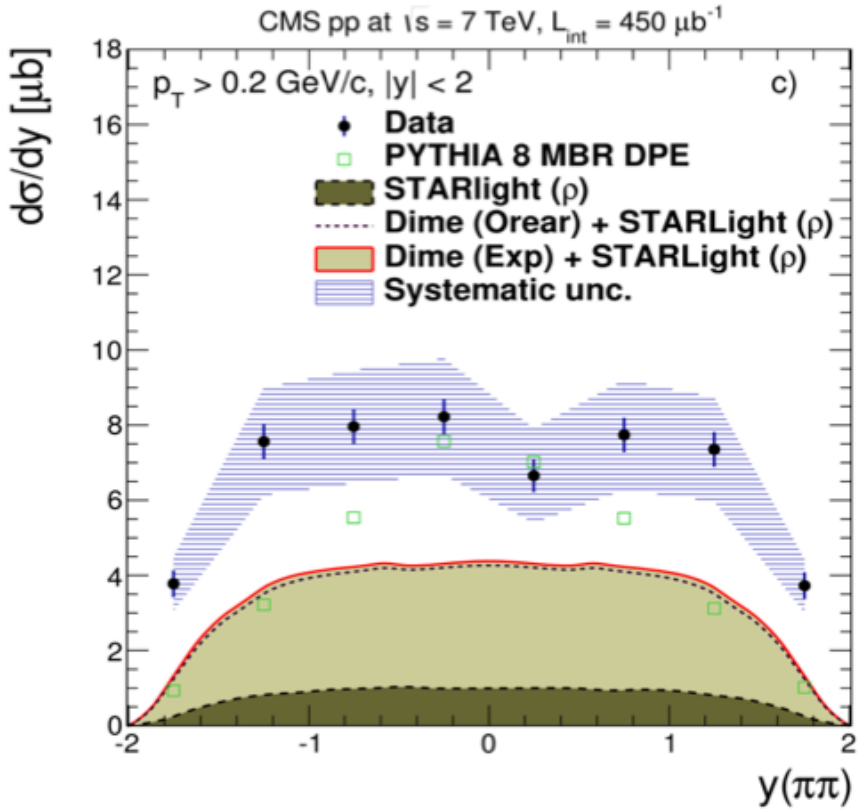


CMS, arXiv:1706.08310

From Monday's plenary by J. Nystrand

$d\sigma/dp_T, d\sigma/dy$



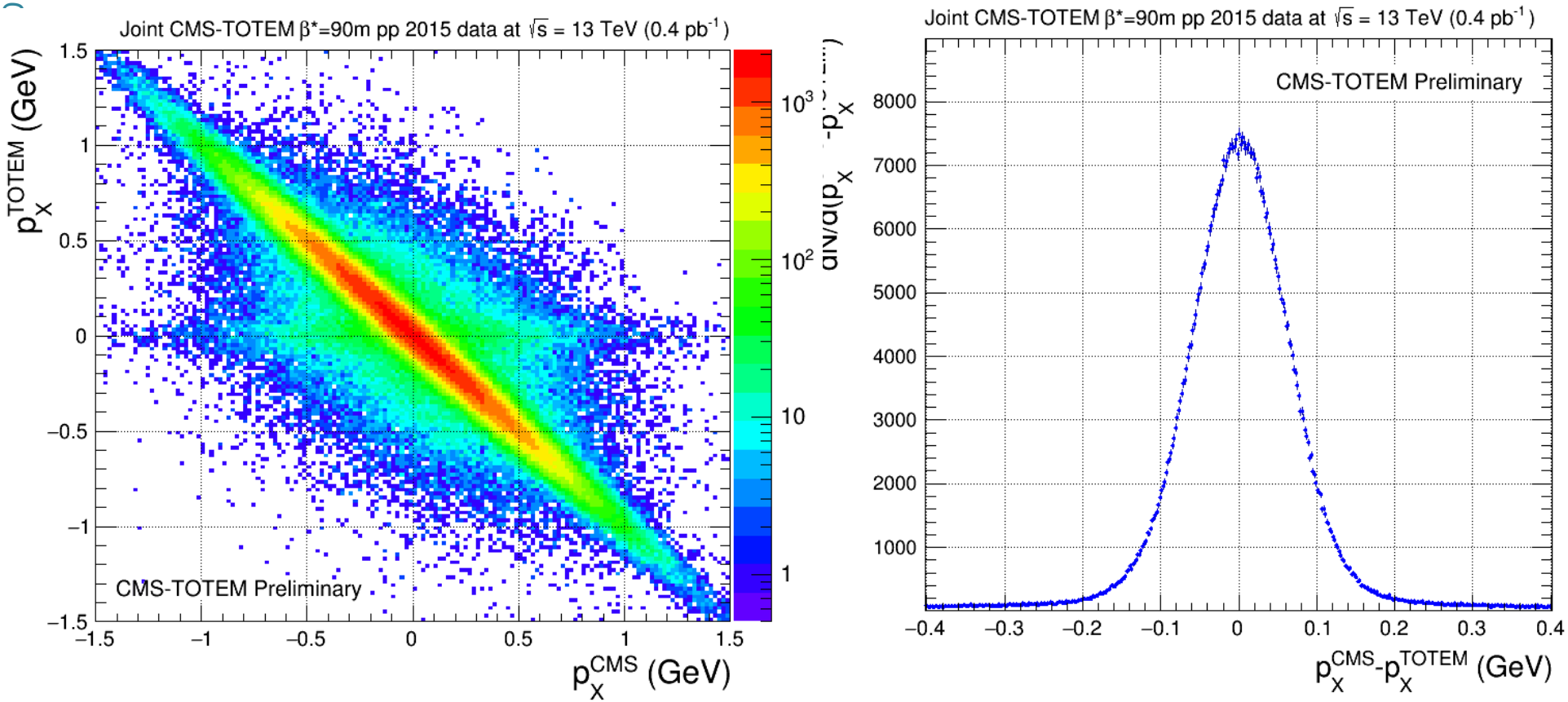


Compared to predictions of
Dime and PYTHIA (DPE)
STARLight (rho photoproduction)

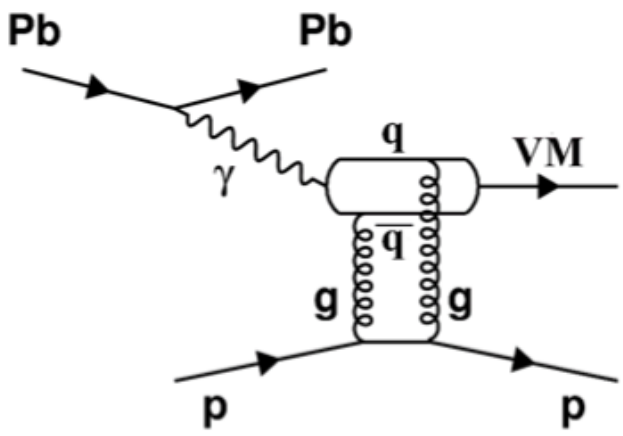
Beware: proton dissociation NOT in the models

Recent phenomenological developments, including continuum+resonances, indicate that data-model agreement can improve tuning IP-IP-f2 coupling
[P. Lebiedowicz, O. Nachtmann and A. Szcurek, PRD 93 (2016) 0504015]

Prospect: combined CMS+TOTEM data

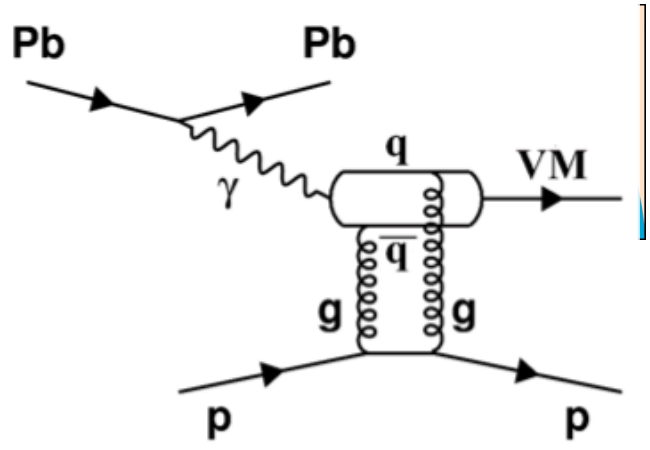


Requirement of transverse momentum balance applied to reject background and select events of central exclusive production, $pp \rightarrow ppX$ with $X=\pi^+\pi^-$, K^+K^-, $\pi^+\pi^-\pi^+\pi^-$, $K^+K^-K^+K^-$, … .



Exclusive Y production in pPb

Motivation



Ultraperipheral pPb collisions

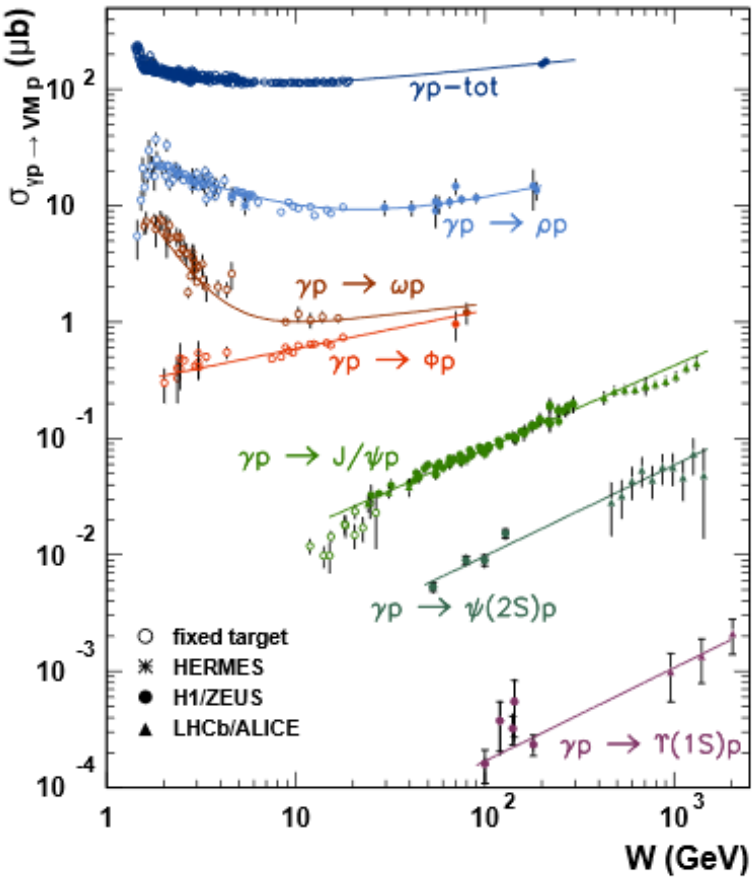
Photon flux grows with the square of the charge, Z^2

Photoproduction process sensitive to gluon density squared in nucleon (nucleus)

$$x = (M_Y / W_{\gamma p})^2$$

Photonuclear cross-section shows power-law dependence with $W_{\gamma p}$

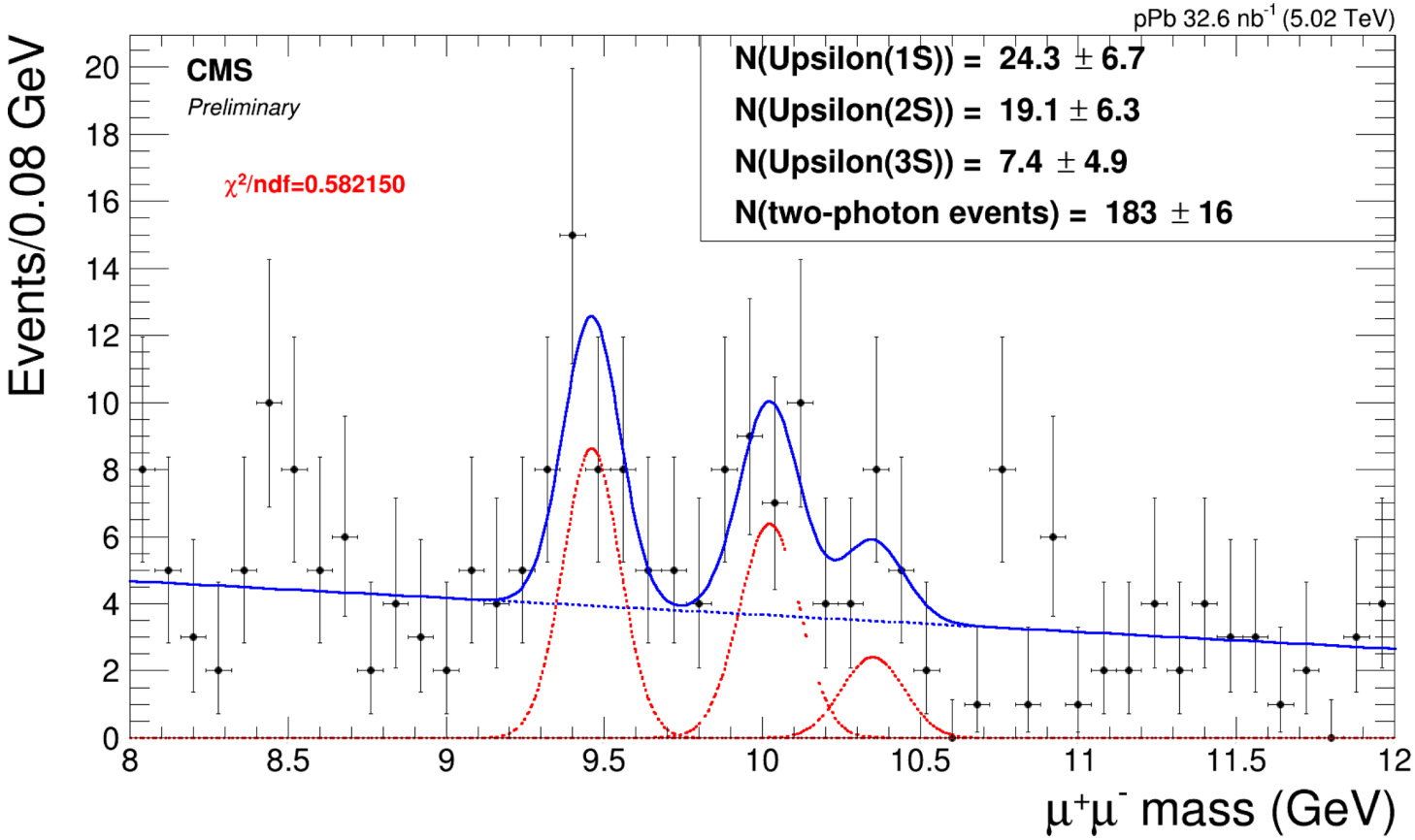
$$\sigma \propto W_{\gamma p}^{\delta}$$



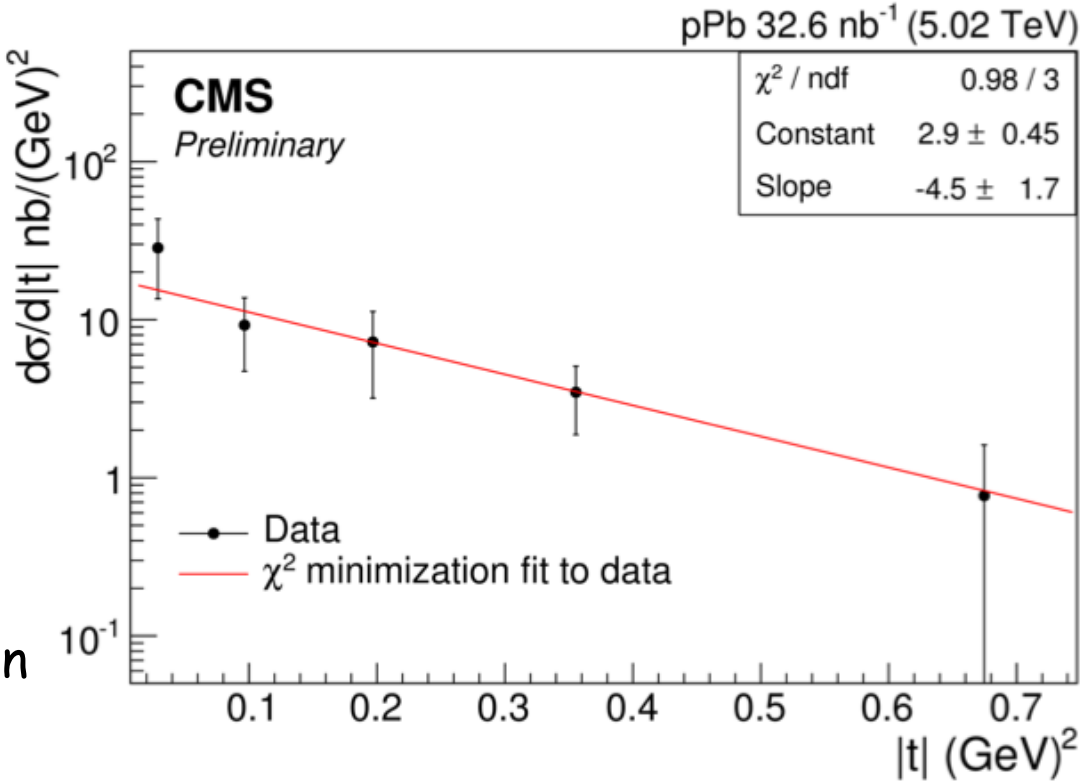
Data

2013 pPb data @5.02 TeV, L ~ 33 nb^{-1}, UPC trigger with two muons
Dimuons with $p_T(\mu)$> 3.3 GeV, |eta|<2.2, 0.1< pT(μμ)<1 GeV,
9.12<Mμμ<10.64 GeV, no extra tracks

STARLight for signal and QED continuum
Data-driven subtraction of proton-dissociation background



Photoproduction cross section vs |t|



$d\sigma/dt$ fitted with an exponential function, provides infos on the transverse profile of the interaction region

CMS Results
b= 4.5 ± 1.7 (stat.) ± 0.6 (syst.) GeV^{-2}
Data is in agreement with ZEUS measurements and consistent with predictions based on pQCD models

ZEUS for Y(1S)
b = $4.3^{+2.0}_{-1.3}$ (stat)
Phys.Lett.B 708 (2012) 14

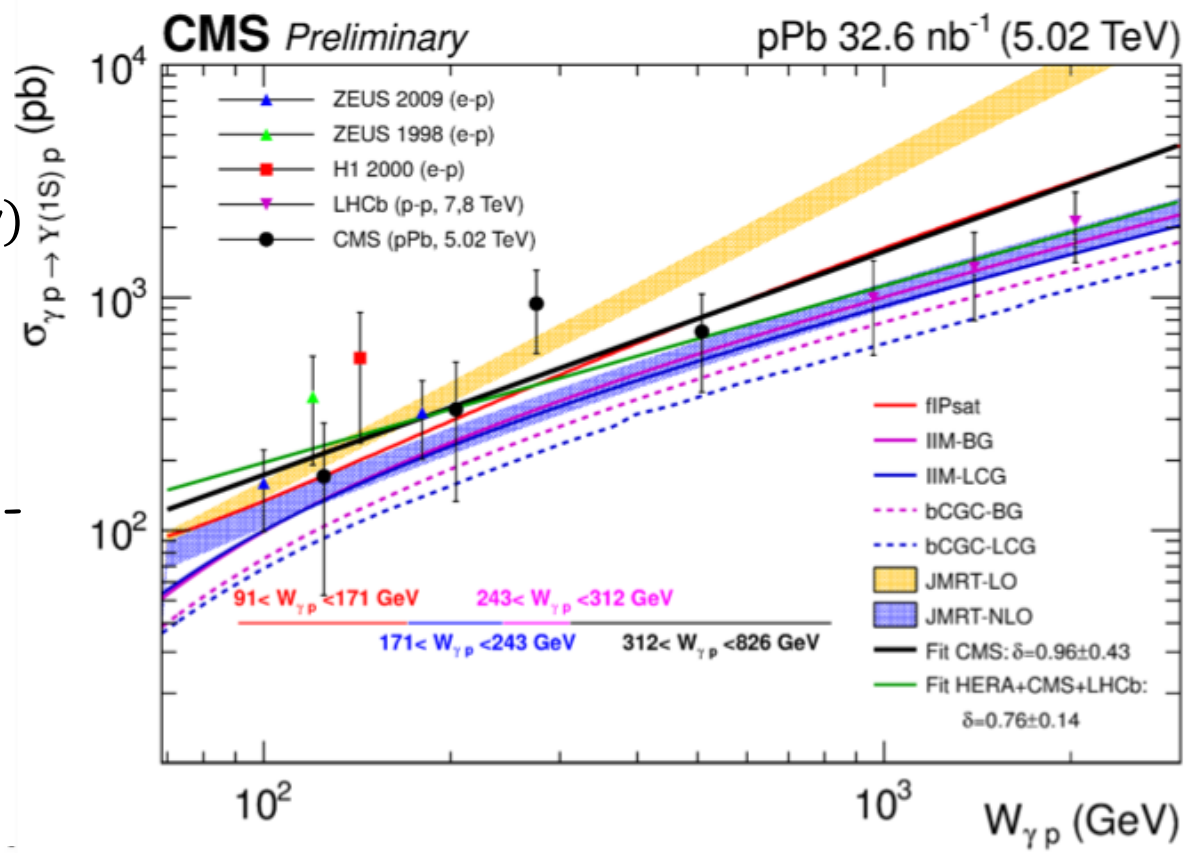
Photoproduction cross section vs $W_{\gamma p}$

Cross section estimated by

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

$$W_{\gamma p}^2 = 2 \cdot E_p \cdot M_\Upsilon \cdot exp(+/-y)$$

Cross-section corrected for muonic branching ratio, feed-down, upsilon (1S) fraction



A fit with power-law **A X (W/400)$^{\delta}$** to the CMS data

δ = (0.96 ± 0.43) , A = 655 ± 196

Data compatible with power-law dependence of $\sigma(W_{\gamma p})$, disfavours LO pQCD predictions

ZEUS

δ = 1.2 ± 0.8

[PLB 680(2009) 4-12]

Summary

- **Exclusive $\pi^+\pi^-$**
  - Differential cross-sections above exclusive $\pi^+\pi^- + \rho$ photoproduction predictions for high-pt
  - The invariant mass spectrum shows some features not included in the purely non-resonant predictions

- **Exclusive Υ in pPb**
  - Data compatible with power-law dependence of $\sigma_{\Upsilon(1S)}(W_{\gamma p})$ and previous measurements by HERA and LHCb
  - $d\sigma/dt$ in agreement with earlier measurements and consistent with predictions based on pQCD models