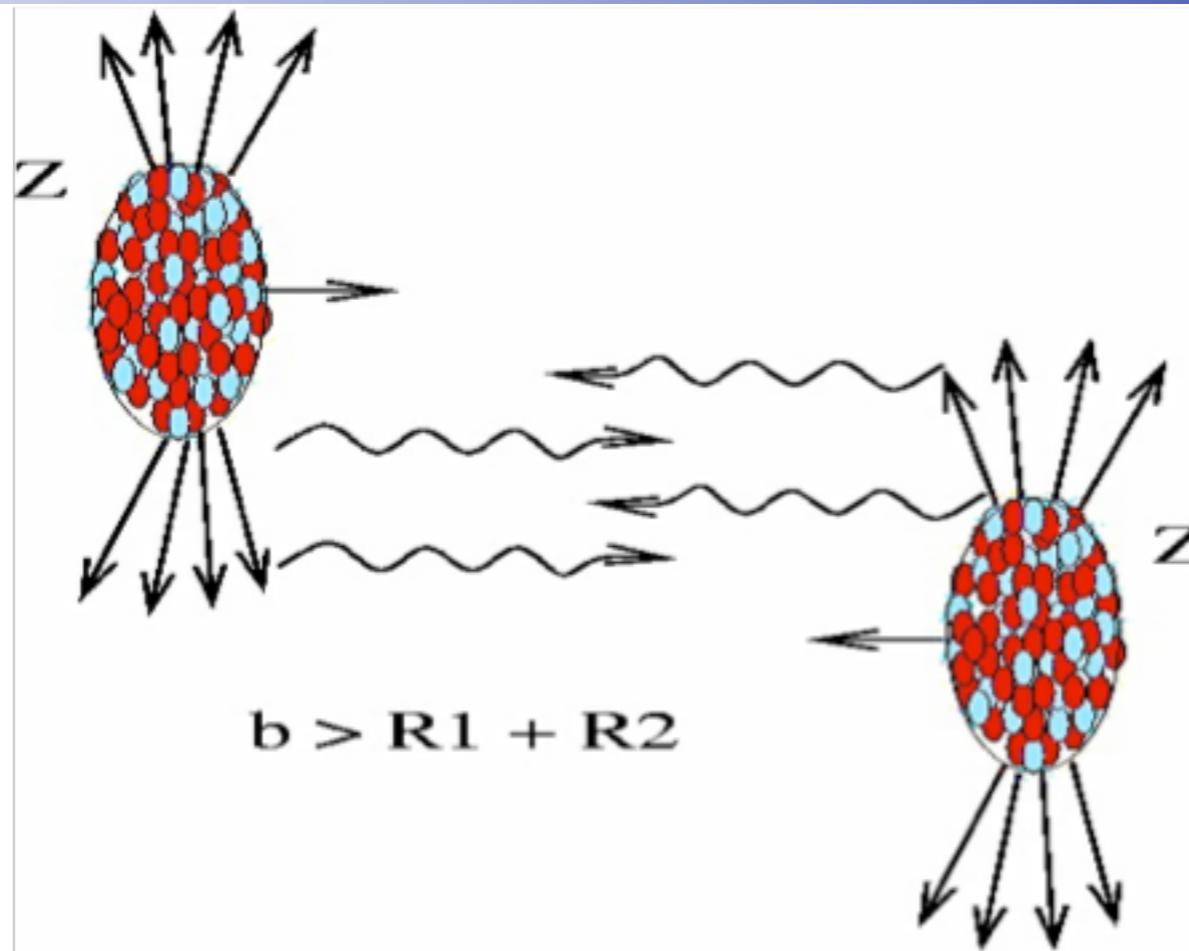


Ultra-peripheral heavy-ion collisions with CMS

Daniel Tapia Takaki
University of Kansas

XXIV International Workshop on Deep Inelastic Scattering
and related subjects (DIS) 2016
DESY, Hamburg, Germany - 13 April, 2016

LHC: the most energetic photon source ever built



For gamma-A: c.m.s energy $W < 500$ GeV (PbPb)

For gamma-p: c.m.s energy $W < 1.5$ TeV (pPb)

UPC studies using heavy ions with CMS at DIS 2016

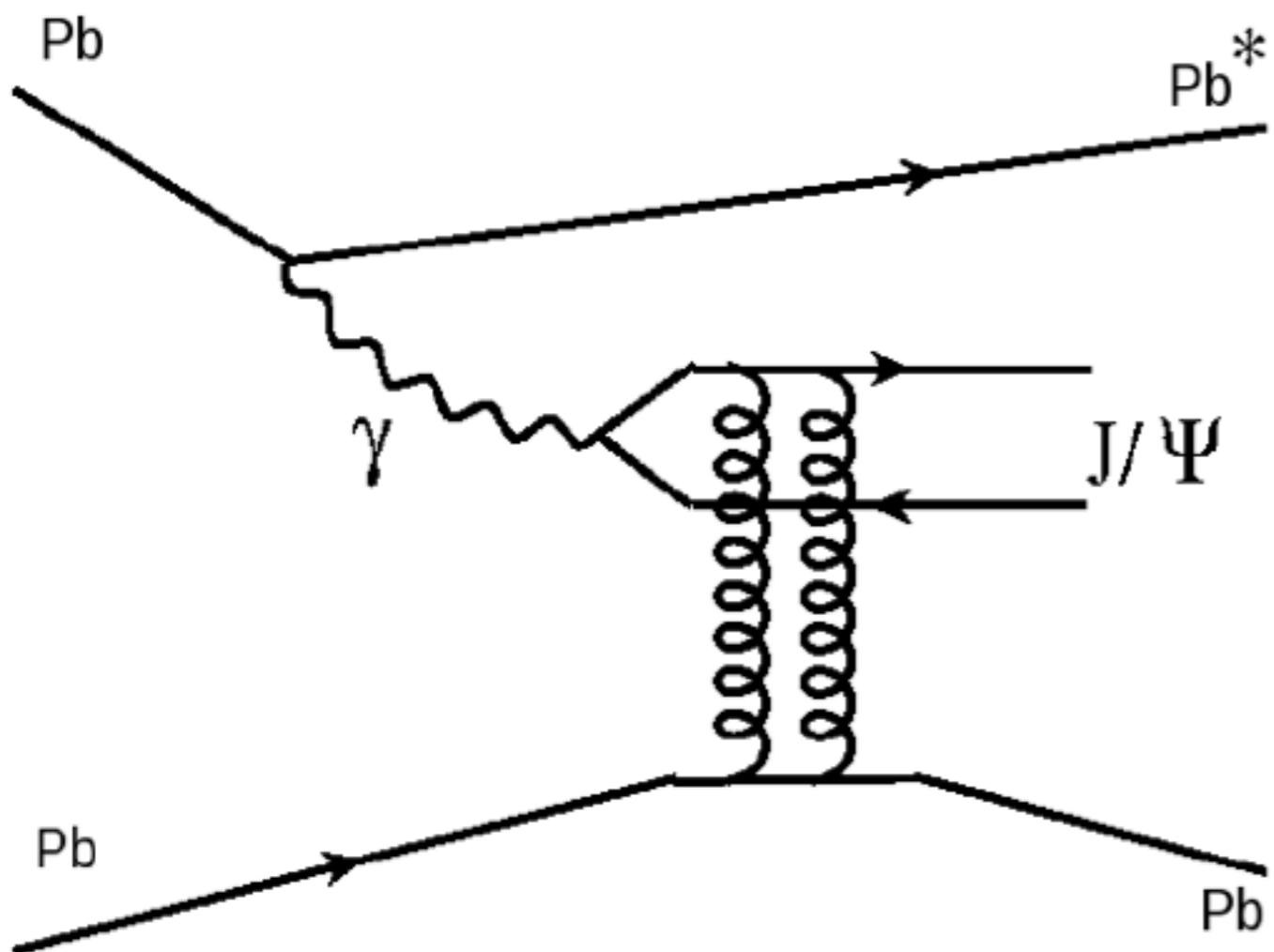
- *Coherent J/ψ photoproduction in ultra-peripheral Pb-Pb collisions at $s_{NN}=2.76 \text{ TeV}$*
HIN-12-009
<http://cds.cern.ch/record/1971267>
- *Exclusive Upsilon in ultra-peripheral p-Pb collisions at 5.02 TeV* **FSQ-13-009**

This talk

See Ruchi Chudasama's talk

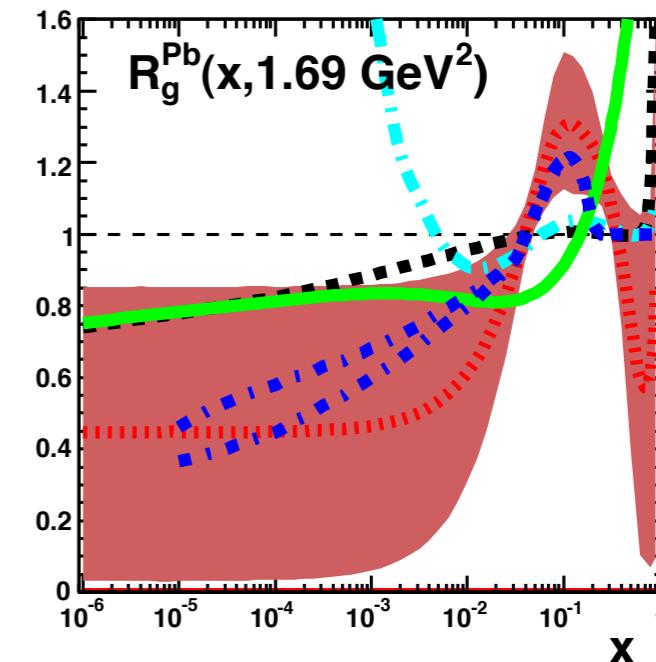
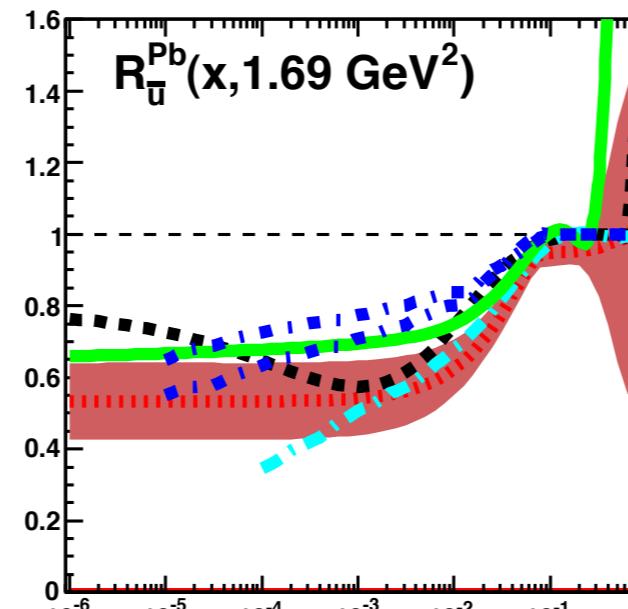
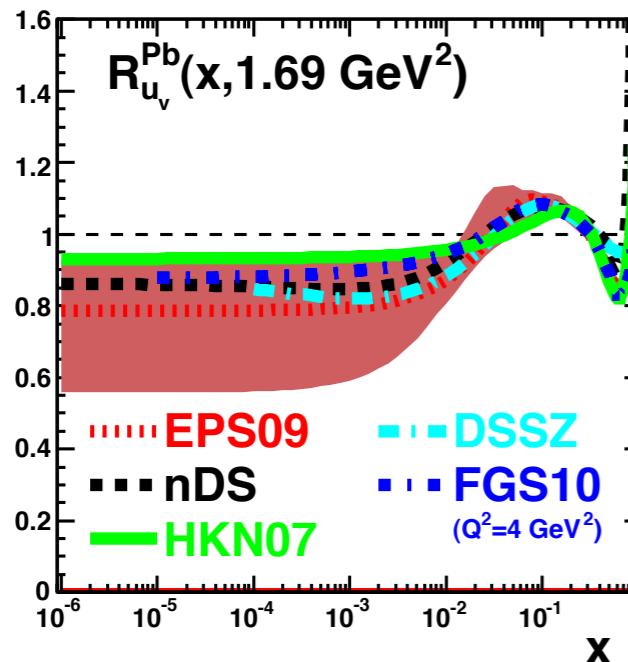
Vector meson photoproduction

$$\frac{d\sigma_{\gamma A \rightarrow J/\Psi A}}{dt} \Big|_{t=0} = \xi_{J/\Psi} \left(\frac{16\pi^3 \alpha_s^2 \Gamma_{l+l^-}}{3\alpha M_{J/\Psi}^5} \right) [xG_A(x, \mu^2)]^2$$

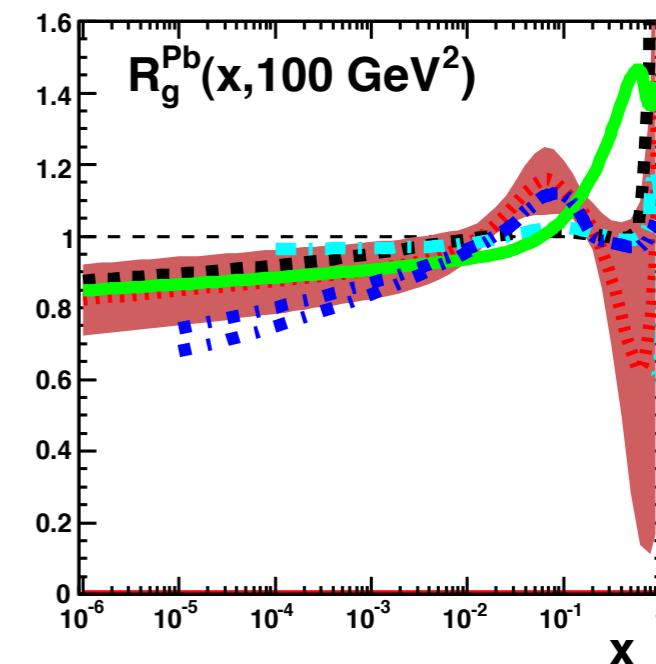
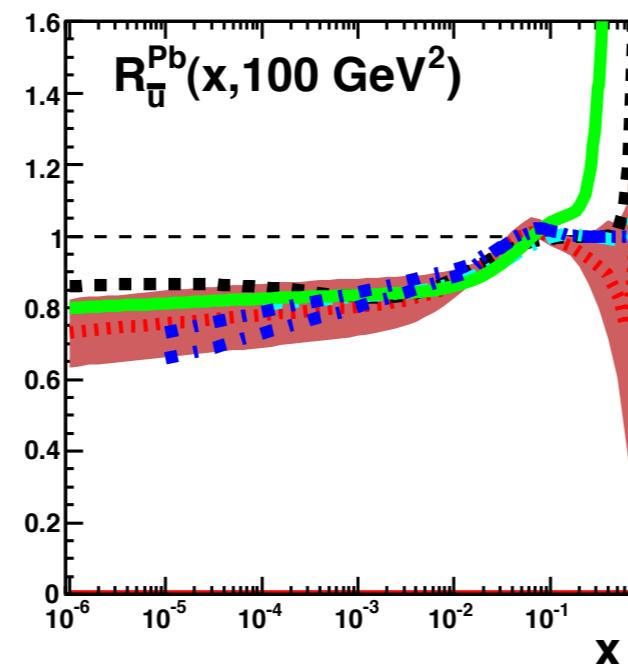
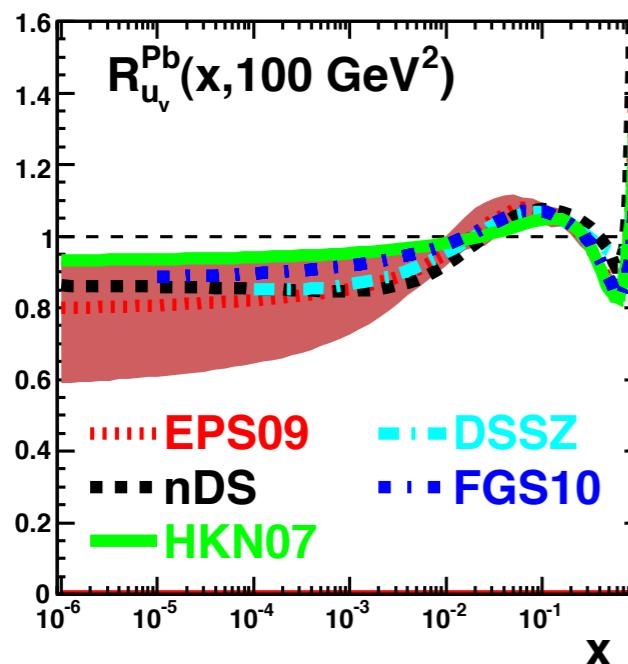


Nuclear PDFs

$$R = \frac{f_i/A}{Af_i/p} \approx \frac{\text{measured}}{\text{expected if no nuclear effects}}$$

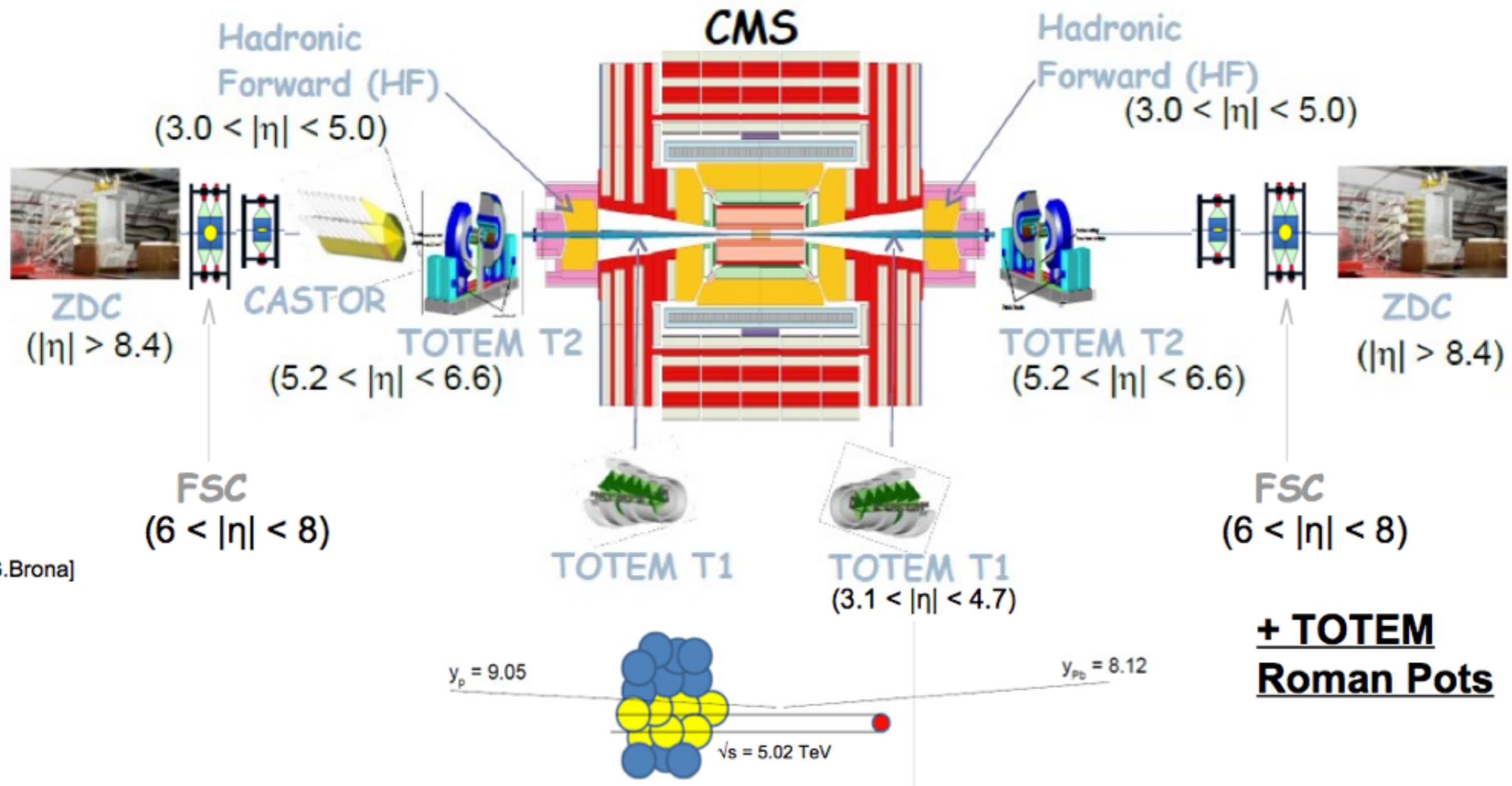


NLO analysis



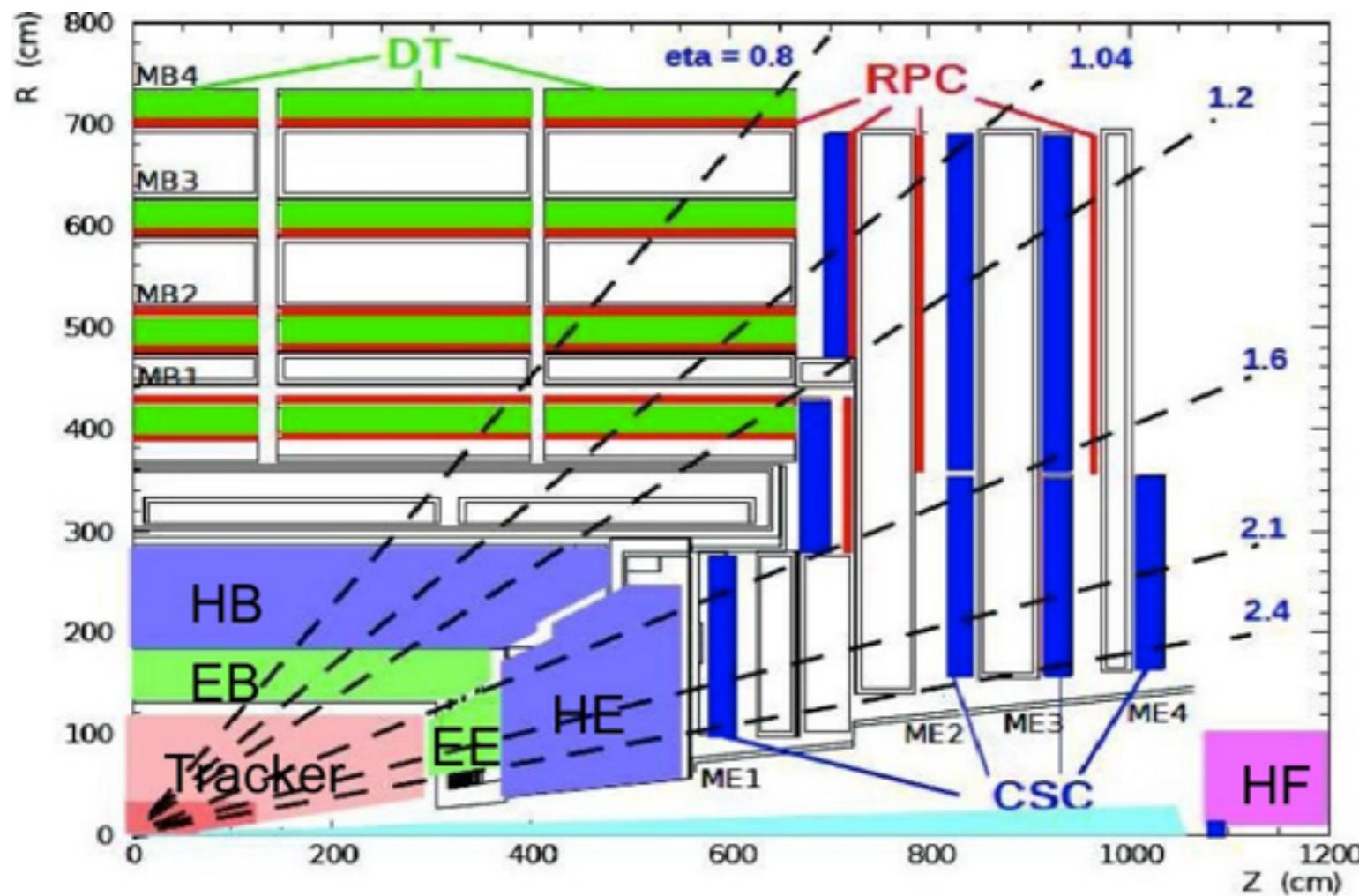
Available DGLAP analysis at NLO show large uncertainties at small scales and x

CMS: Compact Muon Solenoid

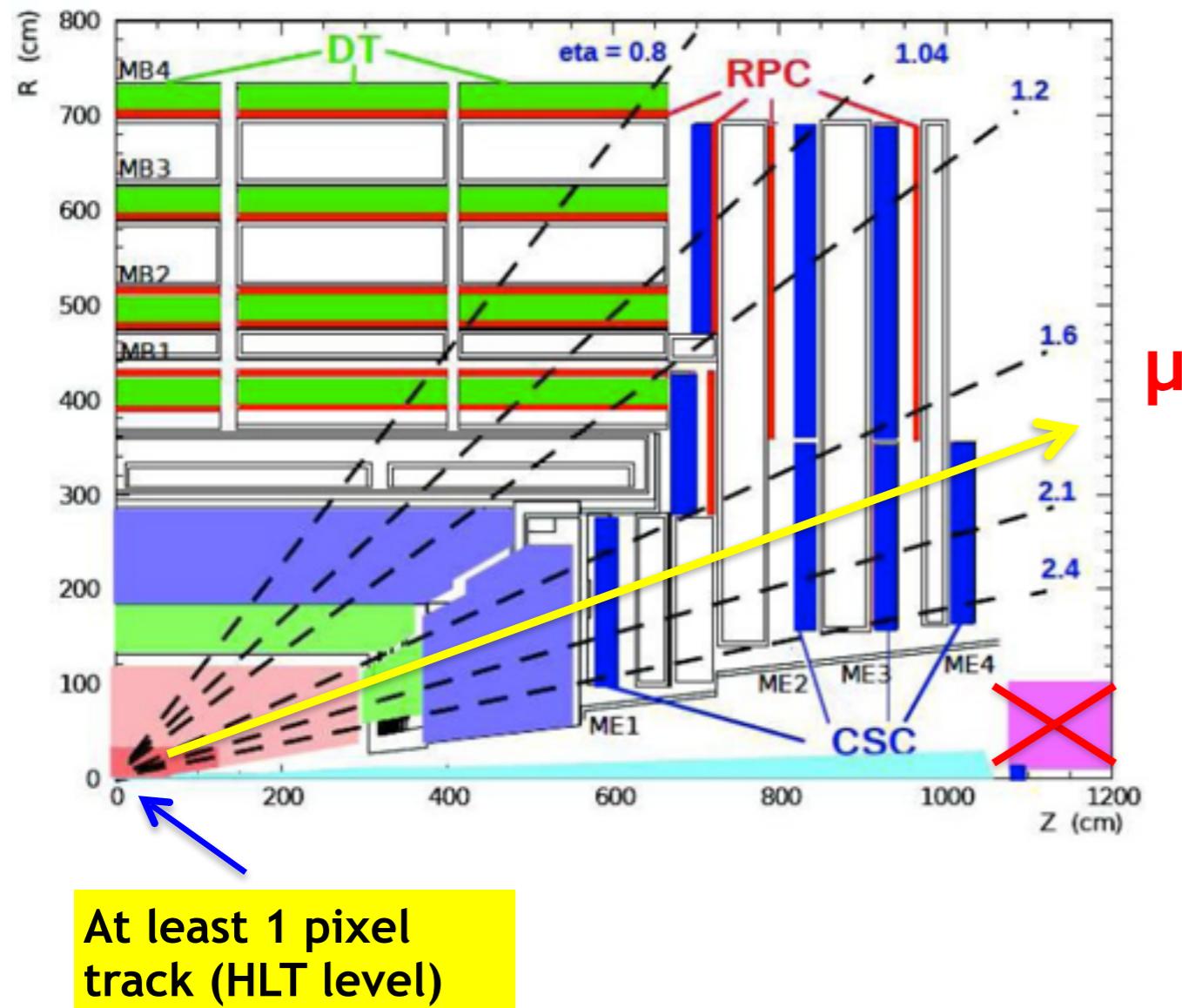


UPC trigger 2011 PbPb run

Tracker & calorimeter cuts ensure exclusivity, muons reconstruct J/ ψ



UPC trigger 2011 PbPb run



1 hit in muon chambers

Nothing in forward calorimeter

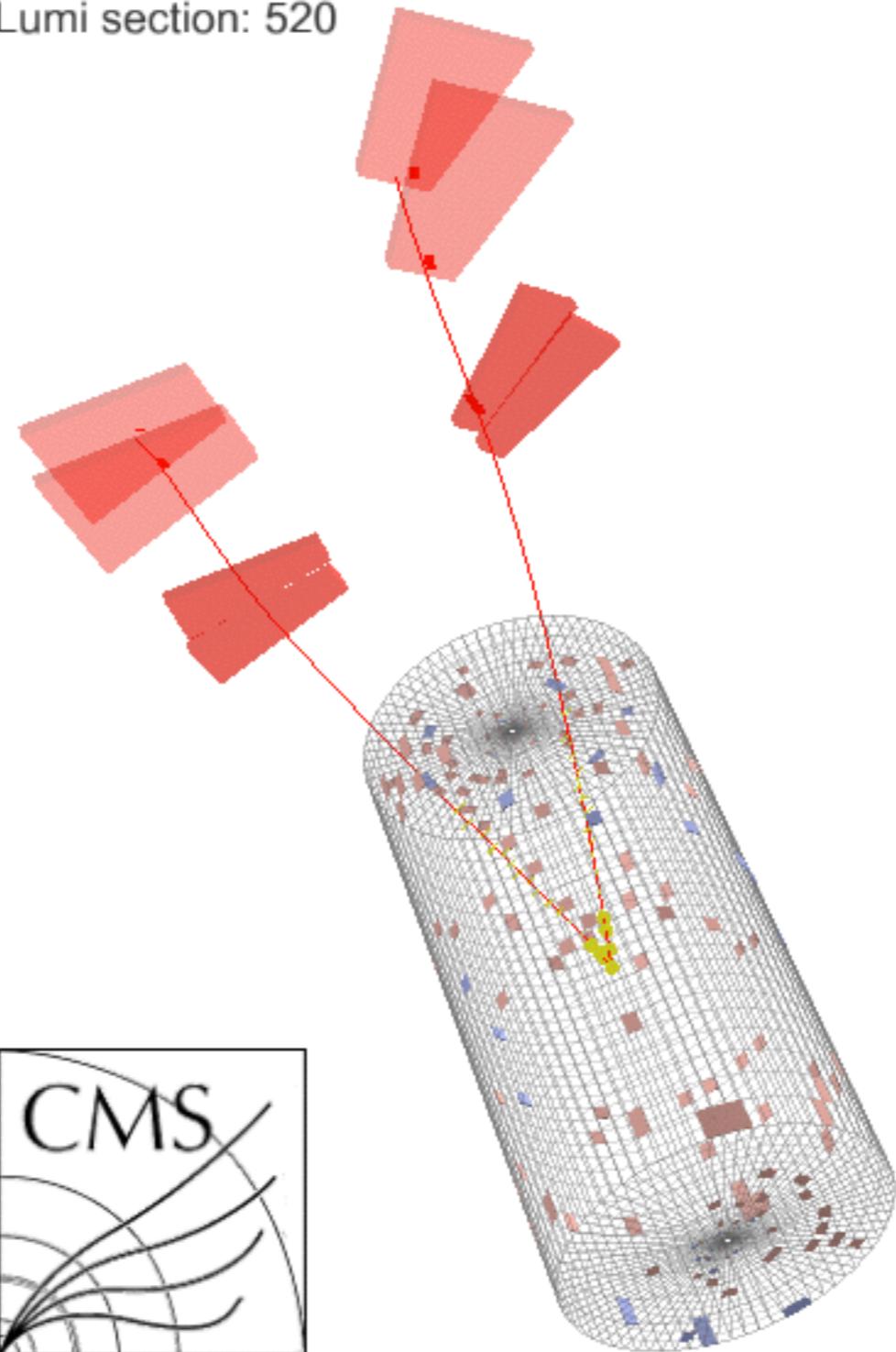


At least 1
forward neutron

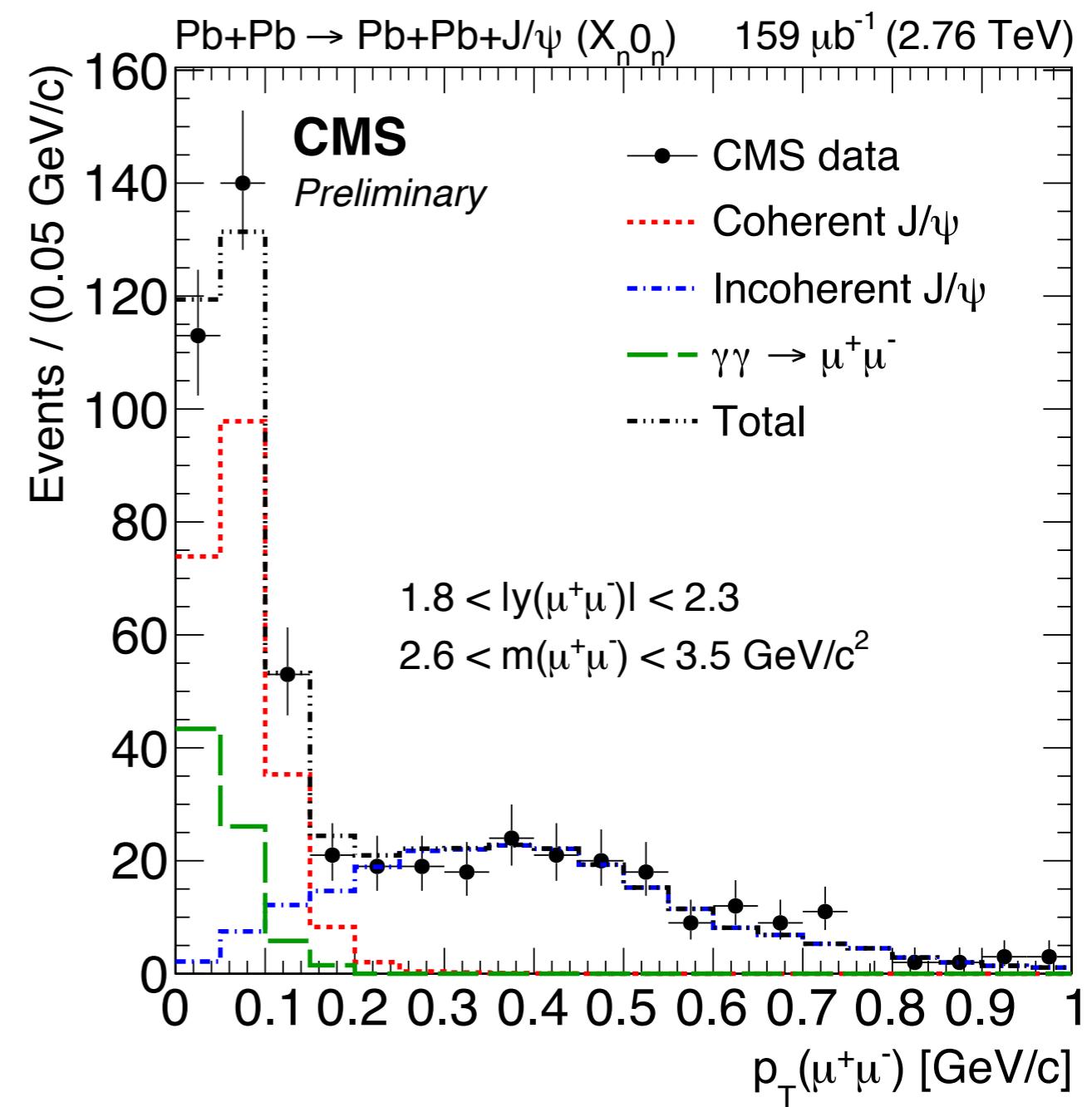
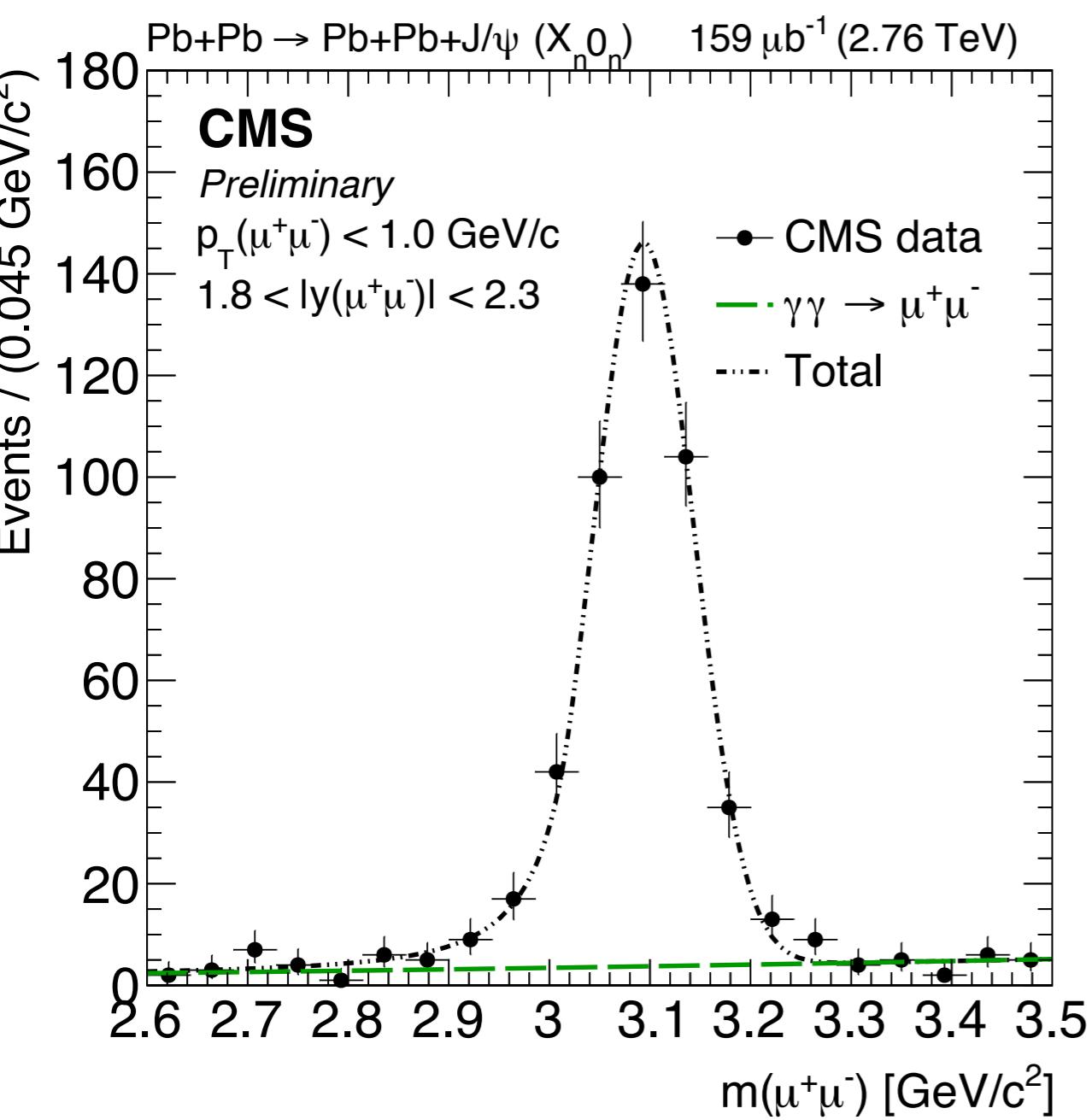


Coherent J/ Ψ photoproduction in Pb-Pb

CMS Experiment at LHC, CERN
Data recorded: Fri Nov 18 03:24:41 2011 CEST
Run/Event: 181969 / 18812570
Lumi section: 520



Coherent J/ Ψ photoproduction



Coherent J/ Ψ photoproduction

$$\frac{d\sigma_{X_n 0_n}^{coh}}{dy}(\text{J}/\psi) = \frac{N_{coh}^{\text{J}/\psi}}{BR(\text{J}/\psi \rightarrow \mu^+ \mu^-) \cdot \mathcal{L}_{int} \cdot \Delta y \cdot (A \times \varepsilon)^{\text{J}/\psi}}$$

- The acceptance and reconstruction efficiency are estimated from MC and found to be 12%
- The trigger efficiency is measured from data and found to be 50%

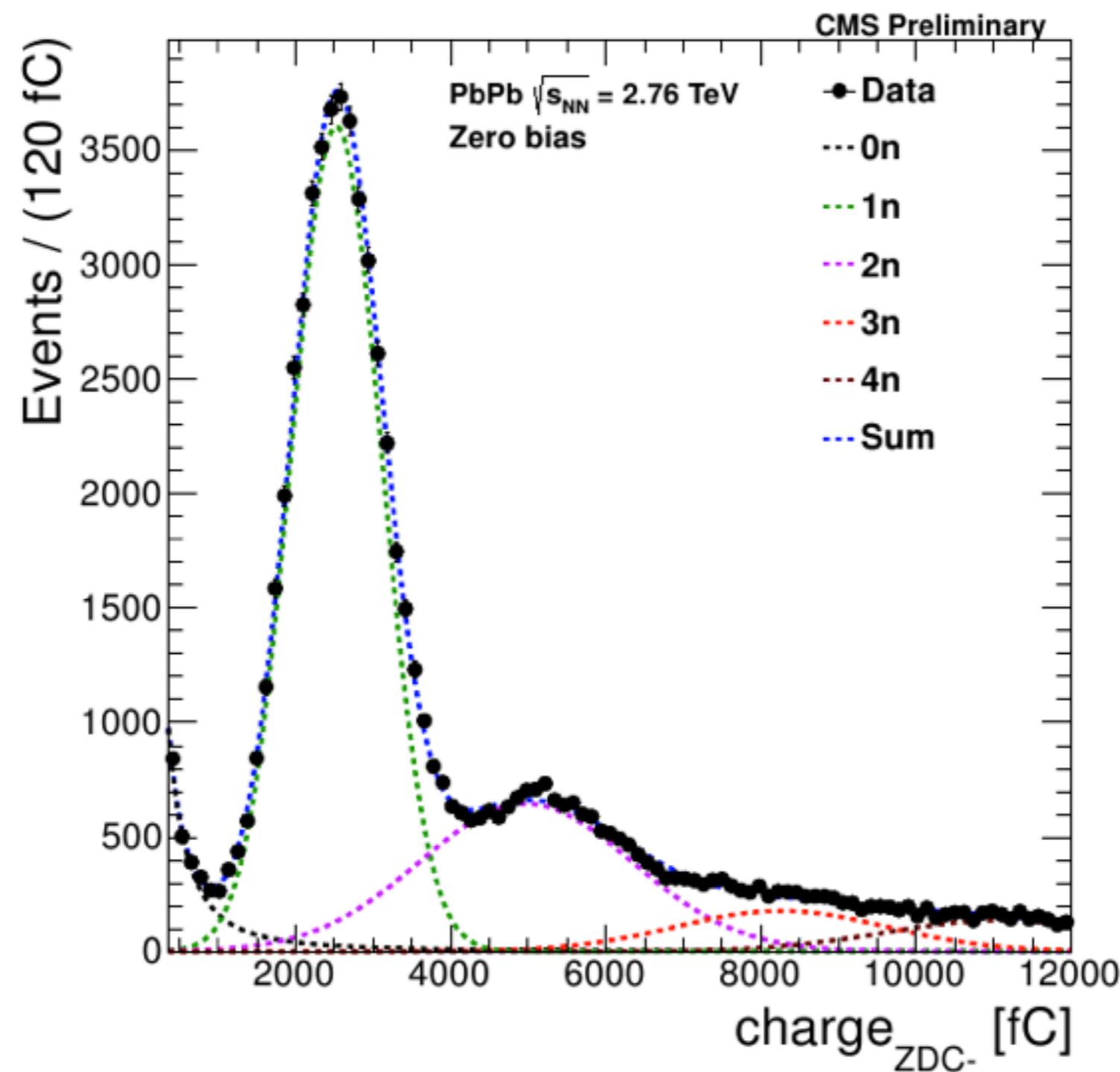
Coherent J/ Ψ photoproduction

Systematic uncertainties

Source	Uncertainty
(1) Signal extraction	5%
(2) Neutron tagging	6%
(3) HF energy threshold	2%
(4) MC acceptance corrections	1%
(5) ZDC efficiency estimation	3%
(6) Tracking reconstruction	4%
(7) Int. luminosity determination	5%
(8) Branching fraction	1%
Total	11%

Identifying neutrons with the ZDC

Thresholds
are set from
minimum bias
data



First measurement of break-up modes for UPC J/ ψ

Xn0n single-sided with any number of neutrons

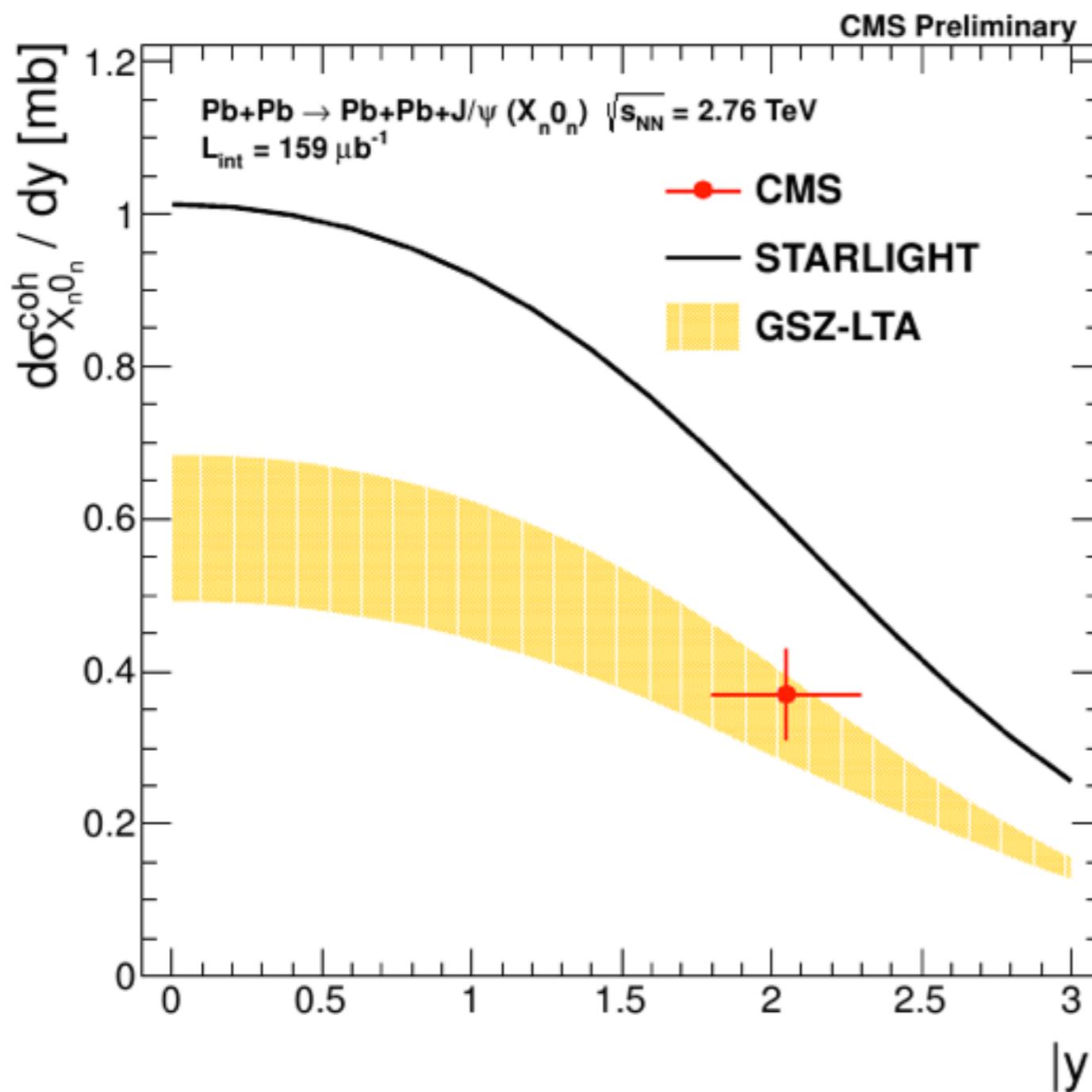
XnXn double-sided with any number of neutrons on either side

1n1n double-sided with only one neutron on each side

J/ ψ with $p_T < 0.15 \text{ GeV}/c$	$X_n X_n / X_n 0_n$	$1_n 1_n / X_n 0_n$
Data	0.36 ± 0.04	0.03 ± 0.01
STARLIGHT	0.37	0.02
GSZ	0.32	0.02

Coherent J/ Ψ photoproduction

CMS-PAS-HIN-12-009 (2014)

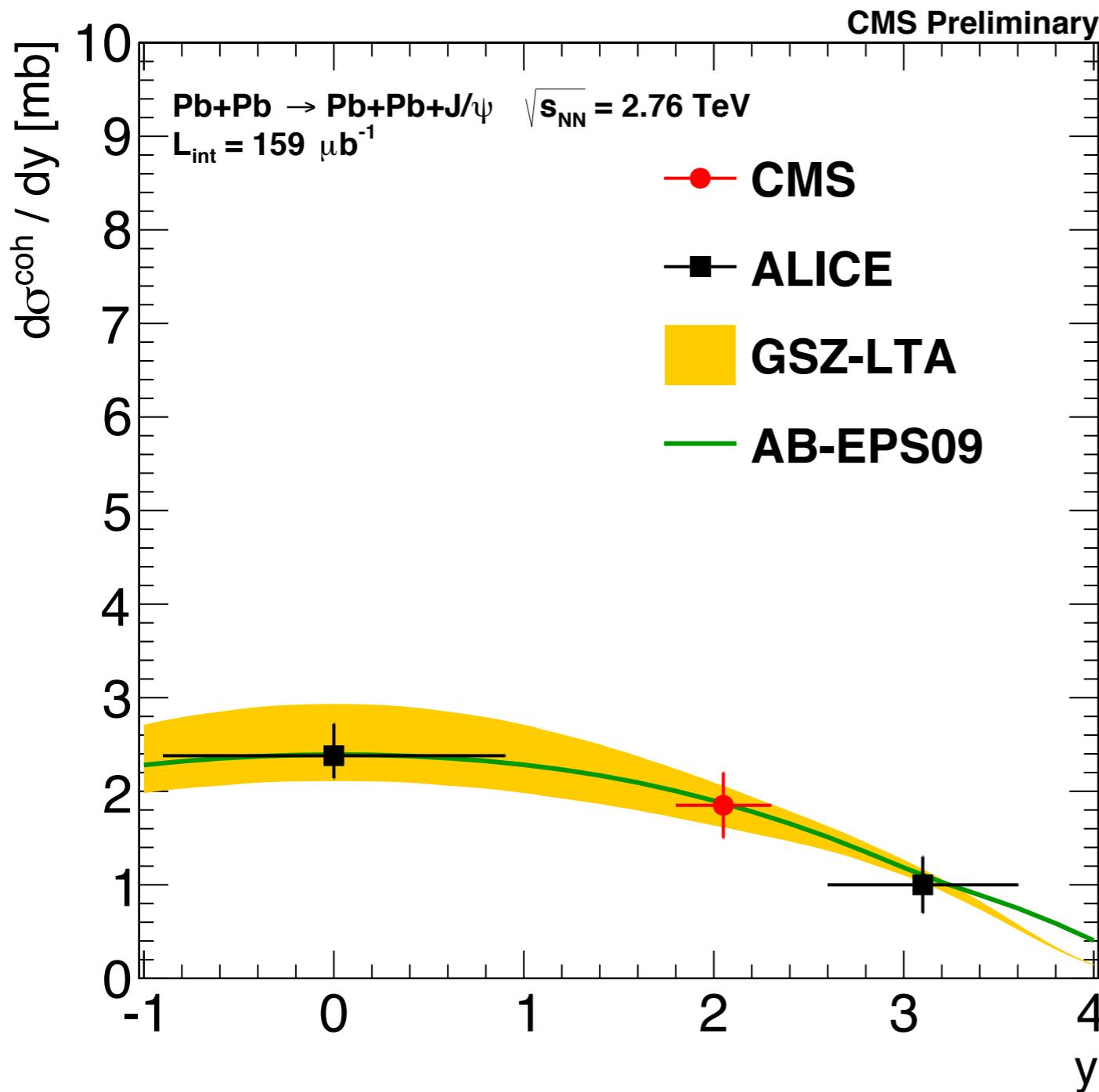


For the $X_n 0_n$ mode the
coherent cross section is
 $d\sigma/dy = 0.37 \pm 0.04 \text{ (stat)}$
 $\pm 0.04 \text{ (syst) mb}$

This is the dominant mode
that has neutron emission

Coherent J/ Ψ photoproduction

Phys. Lett. B718 (2013) 1273-1283



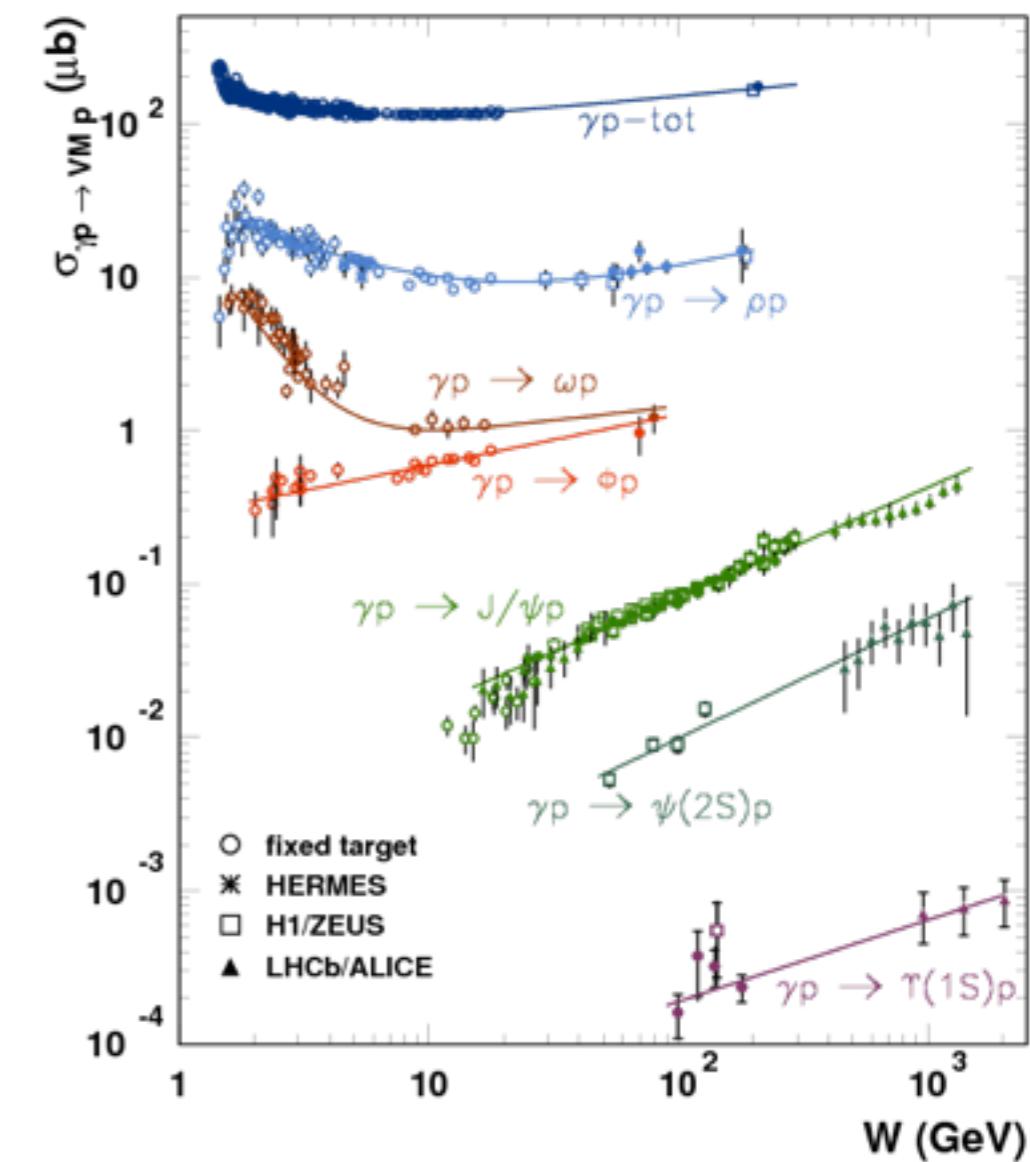
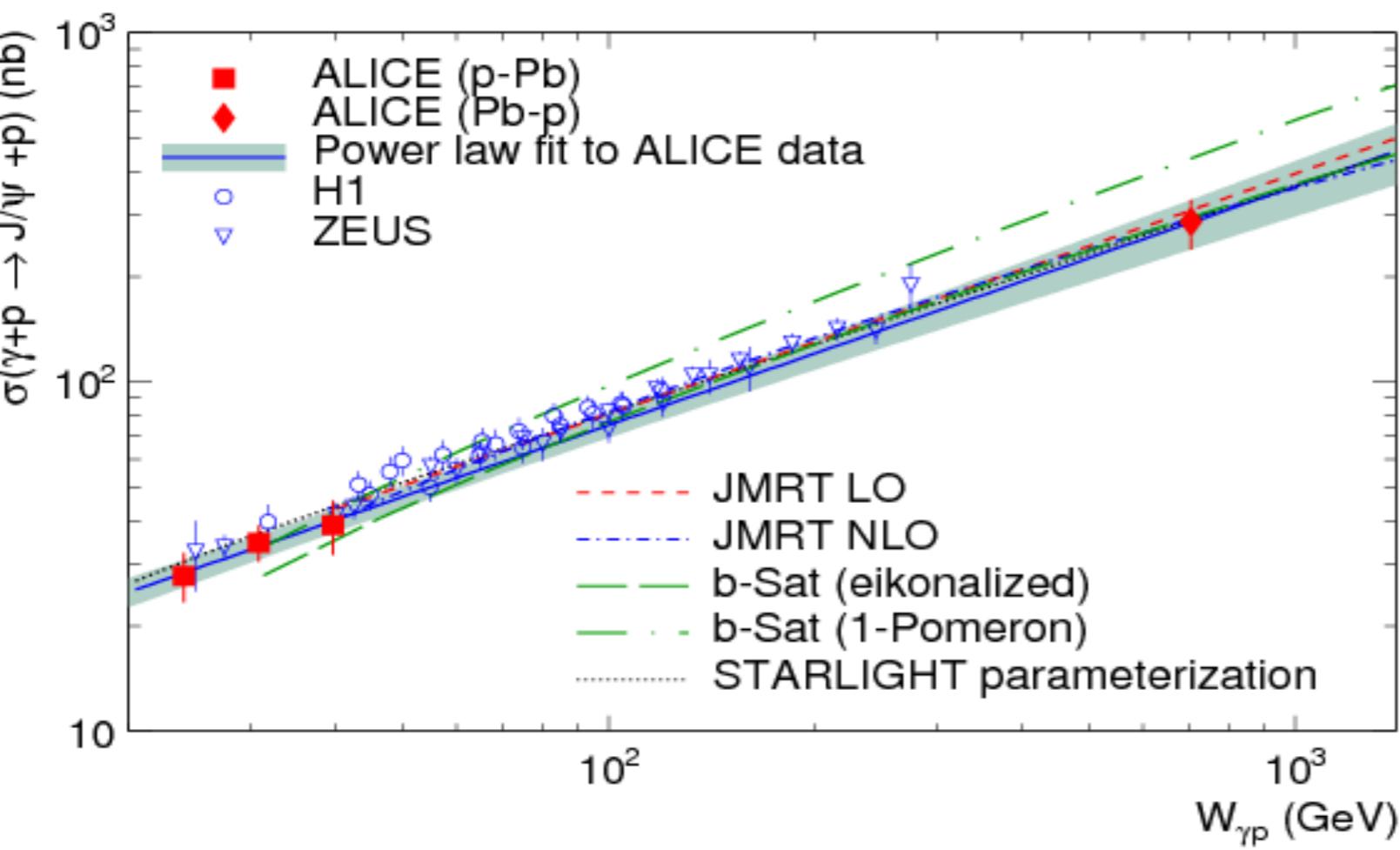
Eur. J. Phys. C73, 2617 (2013)

CMS-PAS-HIN-12-009 (2014)

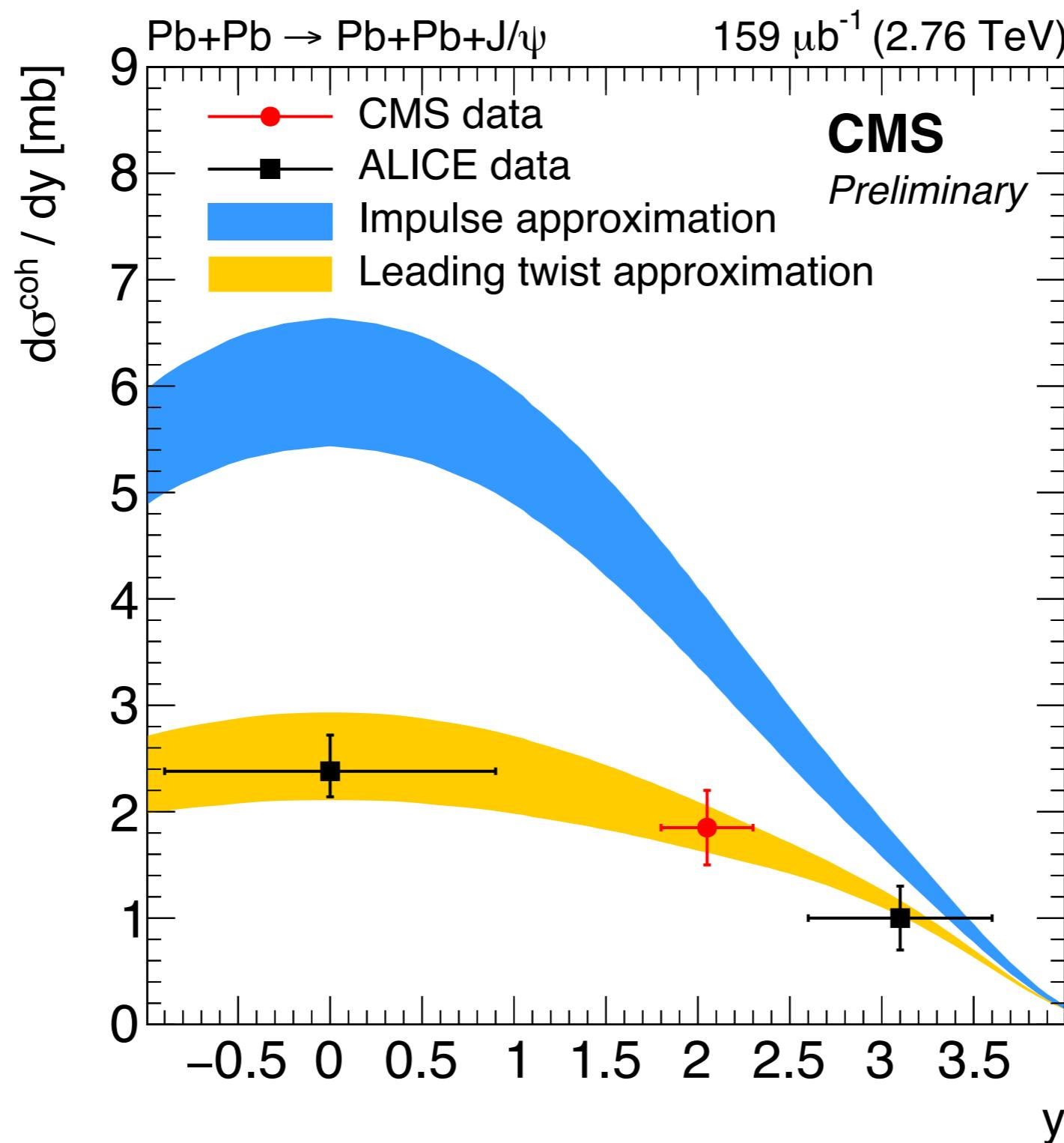
*Cross section for $Xn0n$ in CMS
is scaled up to the total cross section
STARLIGHT.*

Exclusive J/ Ψ in photon-proton

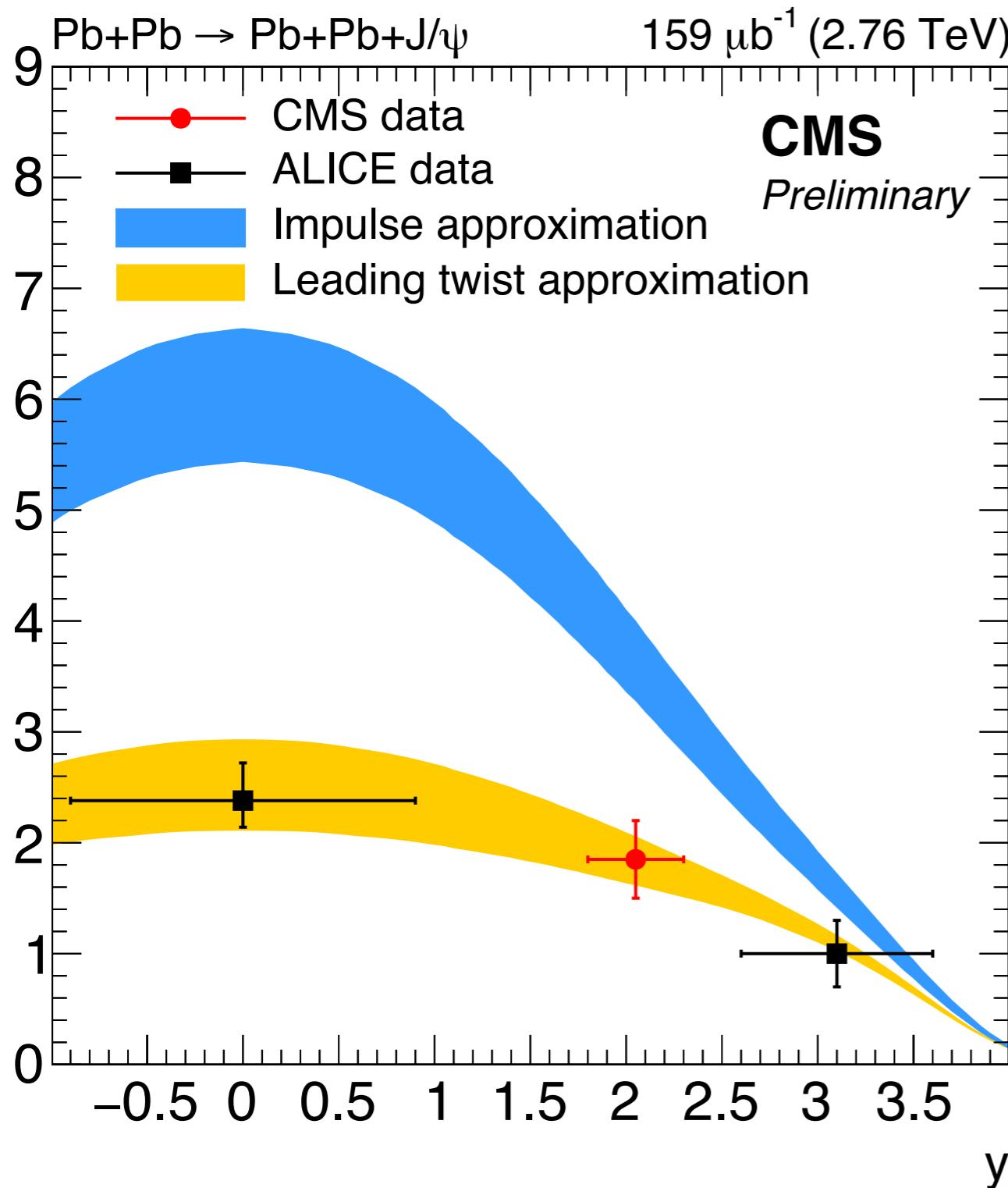
Phys. Rev. Lett. 113 (2014) 23, 232504



Coherent J/ Ψ photoproduction



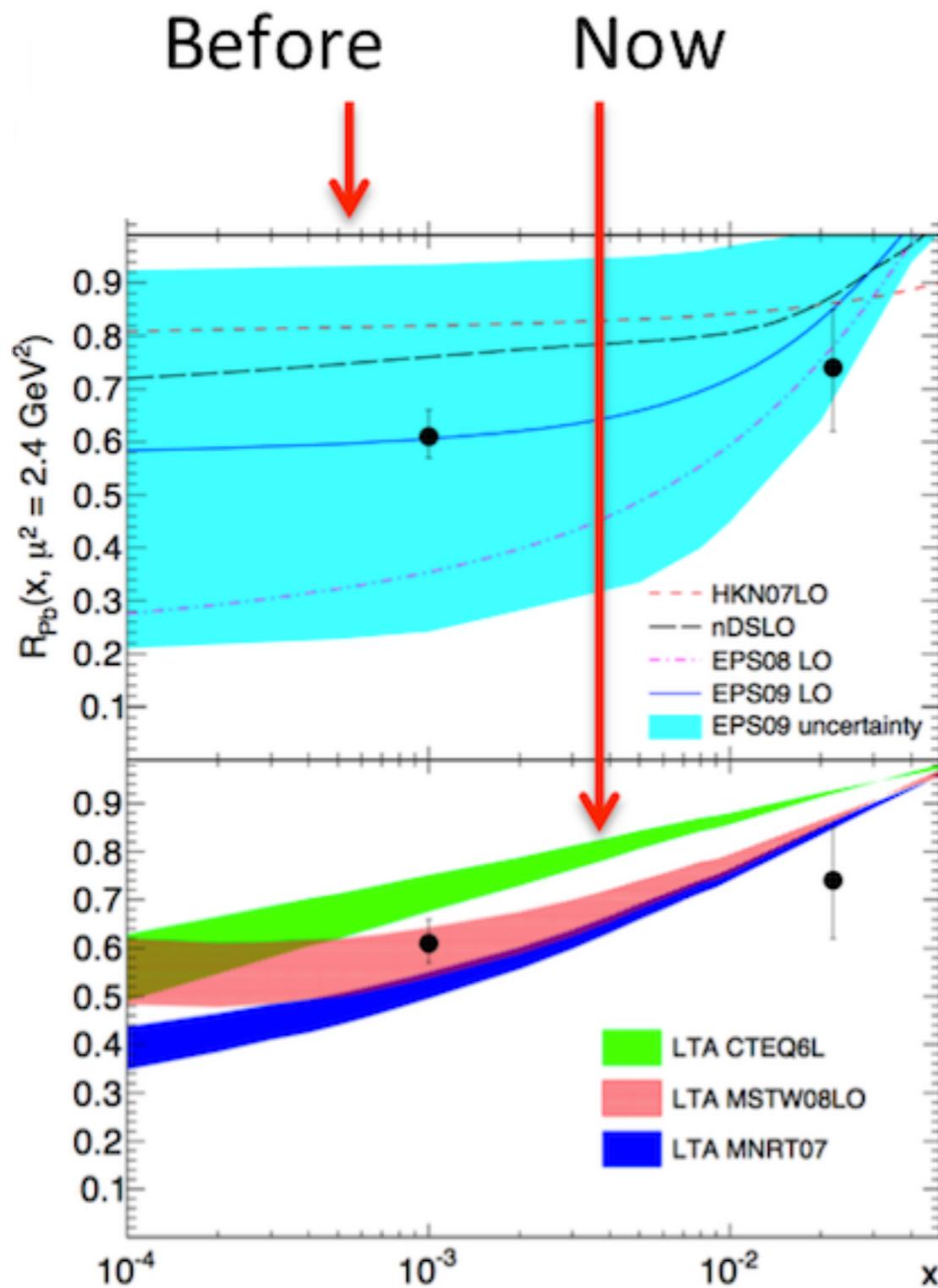
Coherent J/ Ψ photoproduction



Impulse approximation: Model independent
of exclusive J/ Ψ data in gamma-proton
i.e. No nuclear effects

Experimental evidence of
nuclear effects in the Pb
at low Bjorken-x

Nuclear gluon density



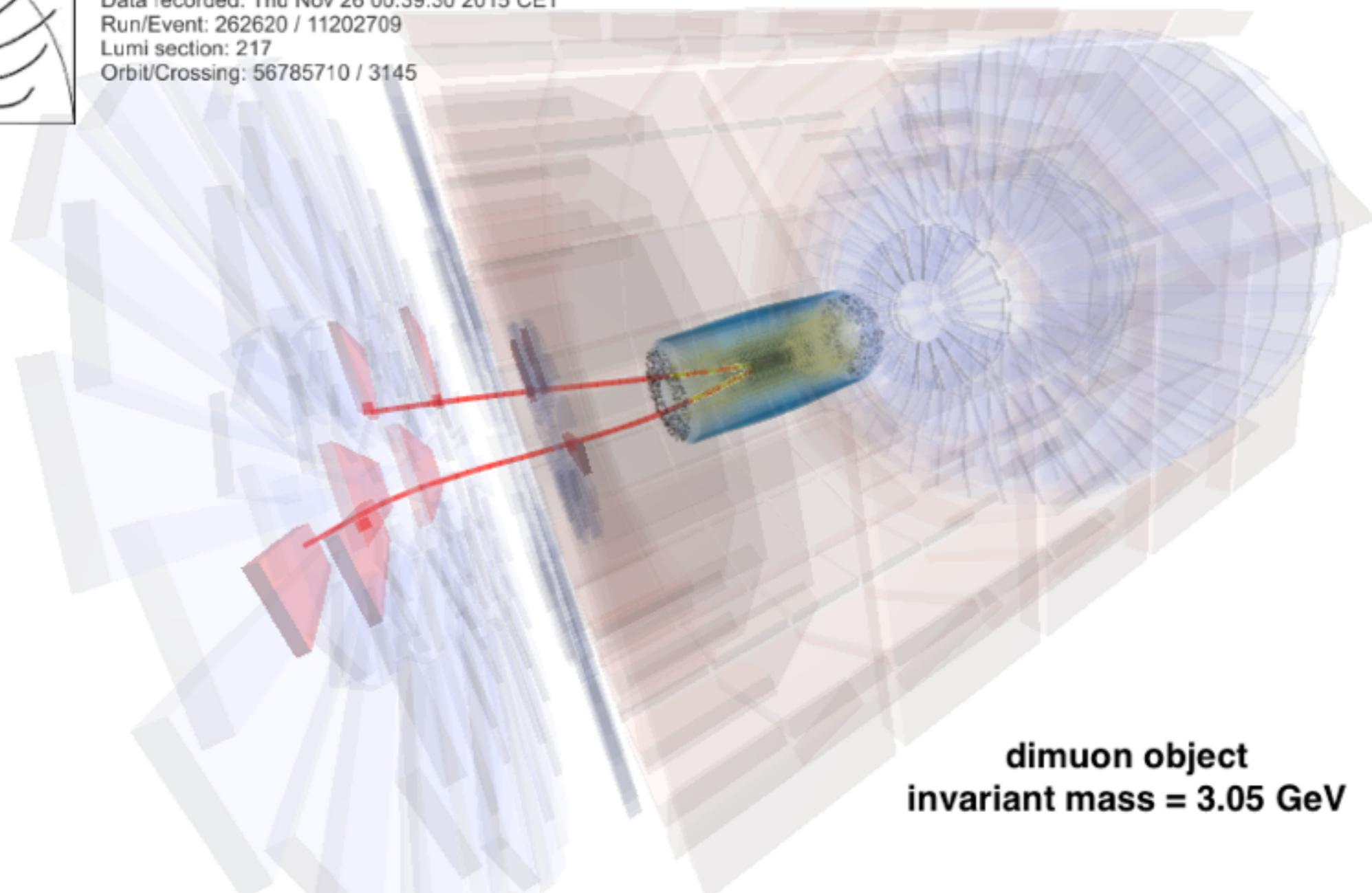
$$S_A(W_{\gamma p}) = \frac{G_A(x, \mu^2)}{AG_N(x, \mu^2)} = 0.61$$

For $x \sim 10^{-3}$ and $Q^2 = 3 \text{ GeV}^2$

Coherent J/ Ψ 2015 PbPb run

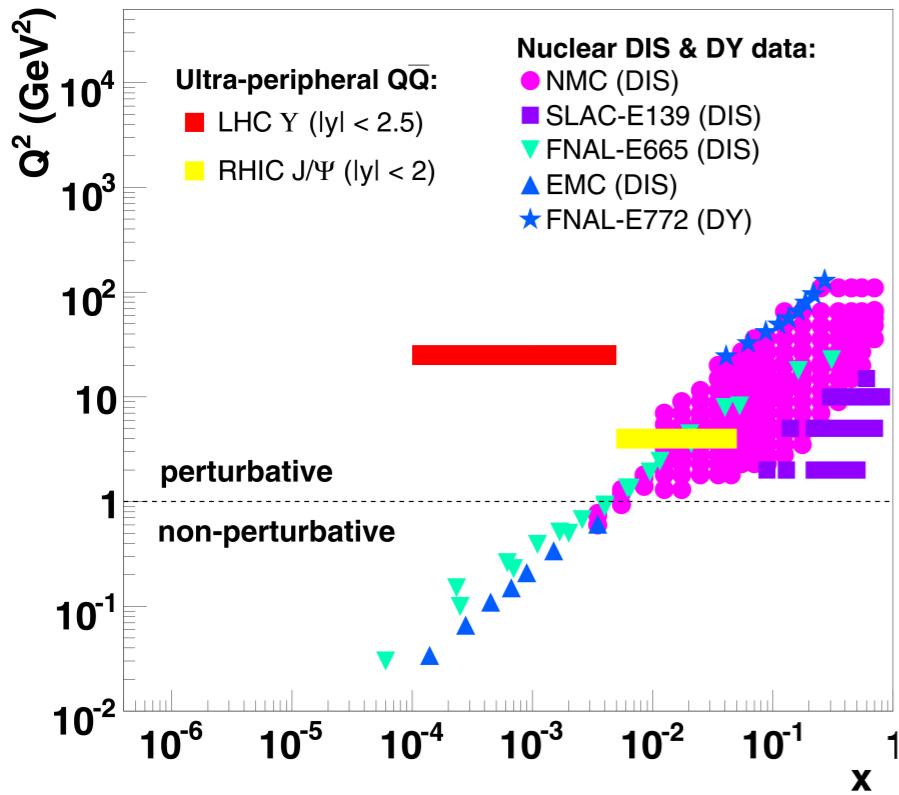


CMS Experiment at LHC, CERN
Data recorded: Thu Nov 26 00:39:30 2015 CET
Run/Event: 262620 / 11202709
Lumi section: 217
Orbit/Crossing: 56785710 / 3145

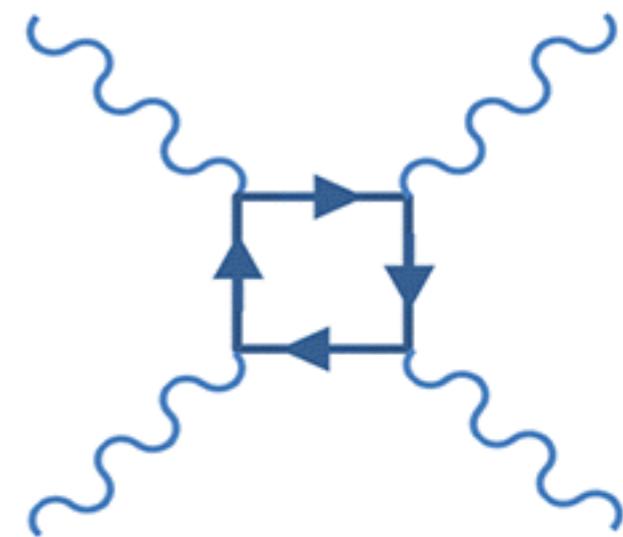


Many new channels will be available with innovative triggers in Run 2

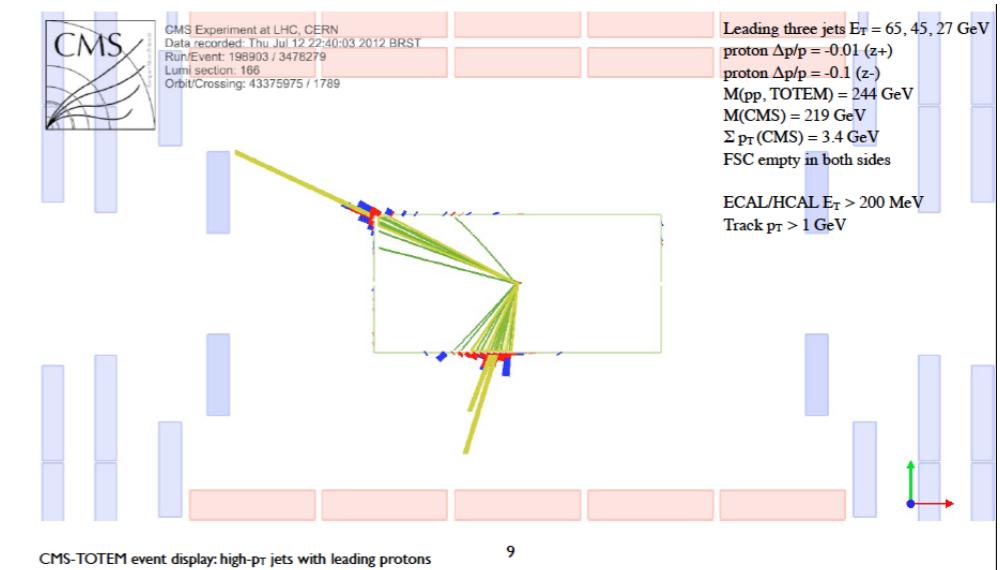
Vector meson photoproduction



Light-by-light



UPC DiJet



More info on the CERN Yellow Report on the
LHC Forward/Exclusive/Diffraction Physics
CERN-PH-LPCC-2015-001

Summary

- UPC quarkonia offer a clean probe of the initial state, in particular the nuclear gluon density
- ALICE and CMS coherent J/ ψ cross sections favors theoretical models including nuclear gluon shadowing
 - **Experimental evidence of nuclear effects in the Pb for small x**
- Break-up ratios are consistent with theoretical models using multiple photon exchange
- The 2015 PbPb run offers the opportunity to expand the UPC vector meson photoproduction program and potentially new objects like UPC diets and diphotons