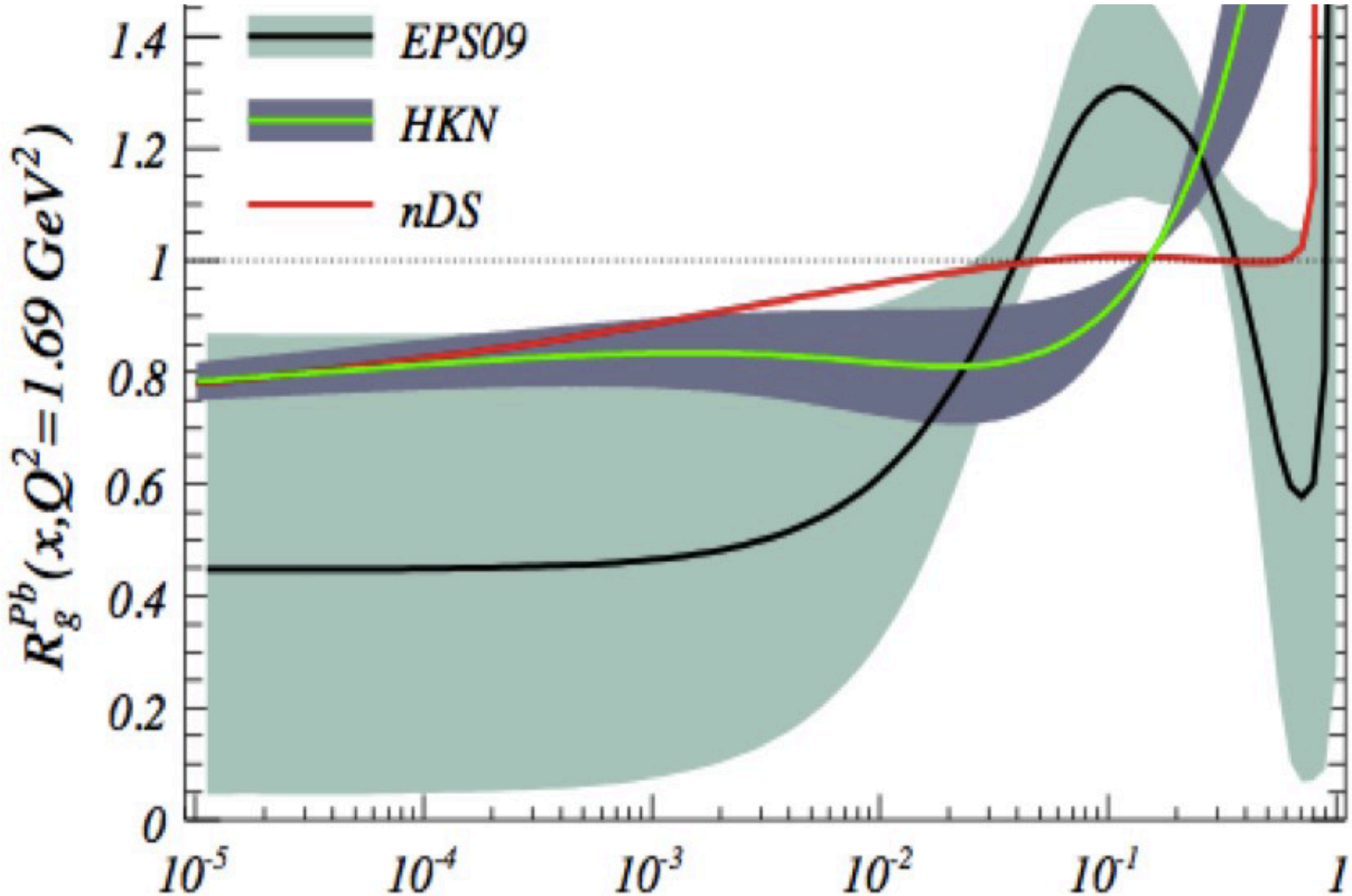
Nuclear PDFs at the LHC



Michael Murray University of Kansas

What we have learned about Nuclear PDFs at the LHC

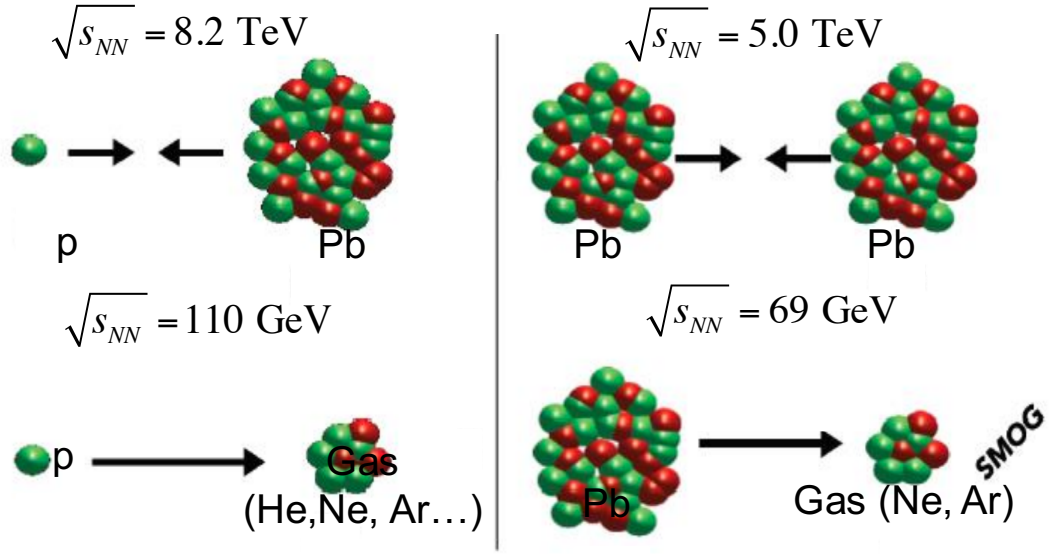
- PDFs can be proved by quarkonia, electroweak bosons, jets, and Drell Yan production.
- Experimental systems for studying these are pPb and photon lead collisions.
- Besides the nuclear PDFs there are other effects that effect the data, eg radiative energy loss, Cronin effect,r adiative or coherent energy loss and interaction with comovers.
- Measure as many probes as possible over the widest possible range of rapidity and p_T.

Running modes

Collider

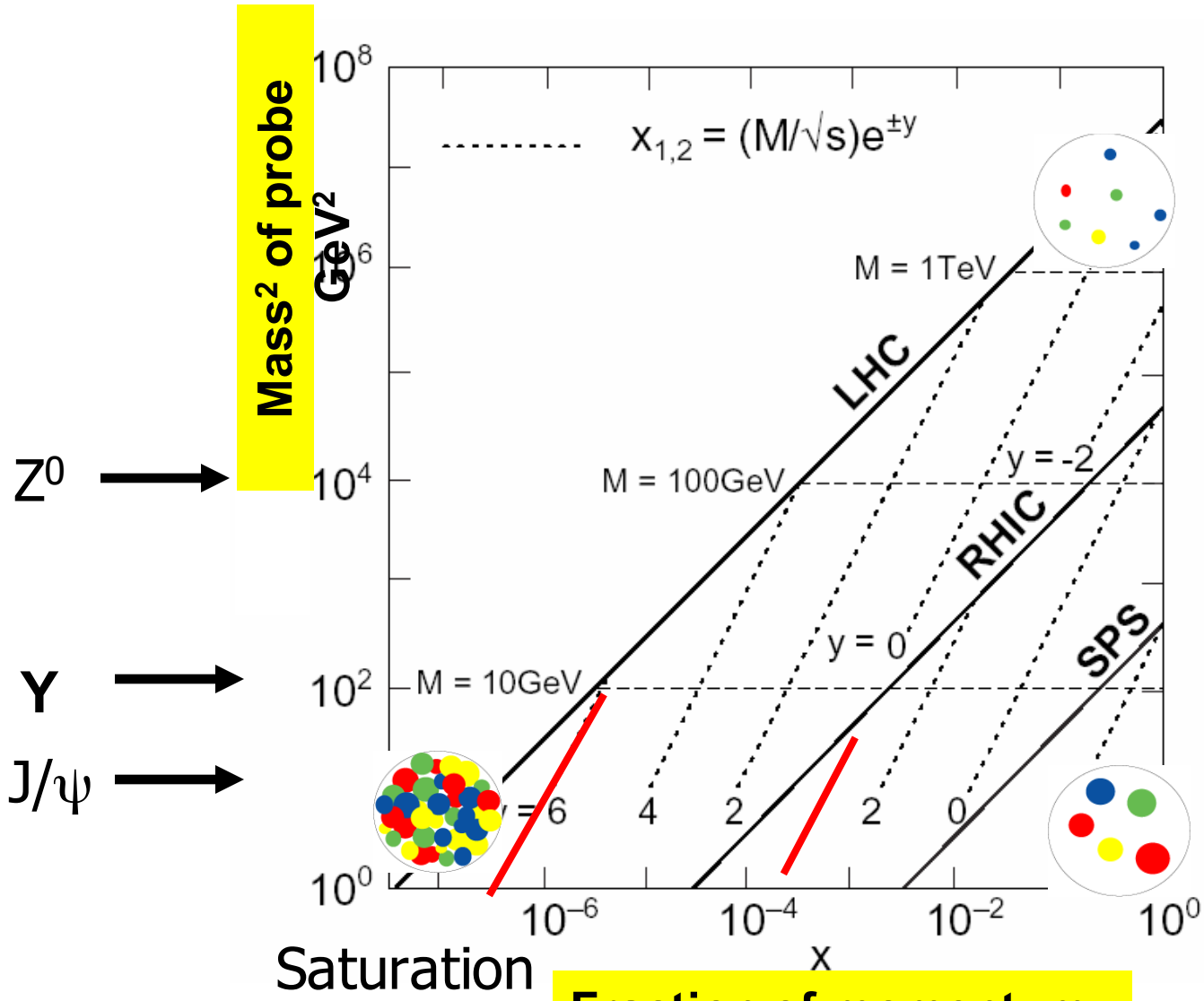
Fixed target

LHCb



In addition ultra-peripheral collisions produce photon – lead collisions with an energy range $W_{\gamma p}$ = 20 – 800 GeV

Kinematic Range of LHC

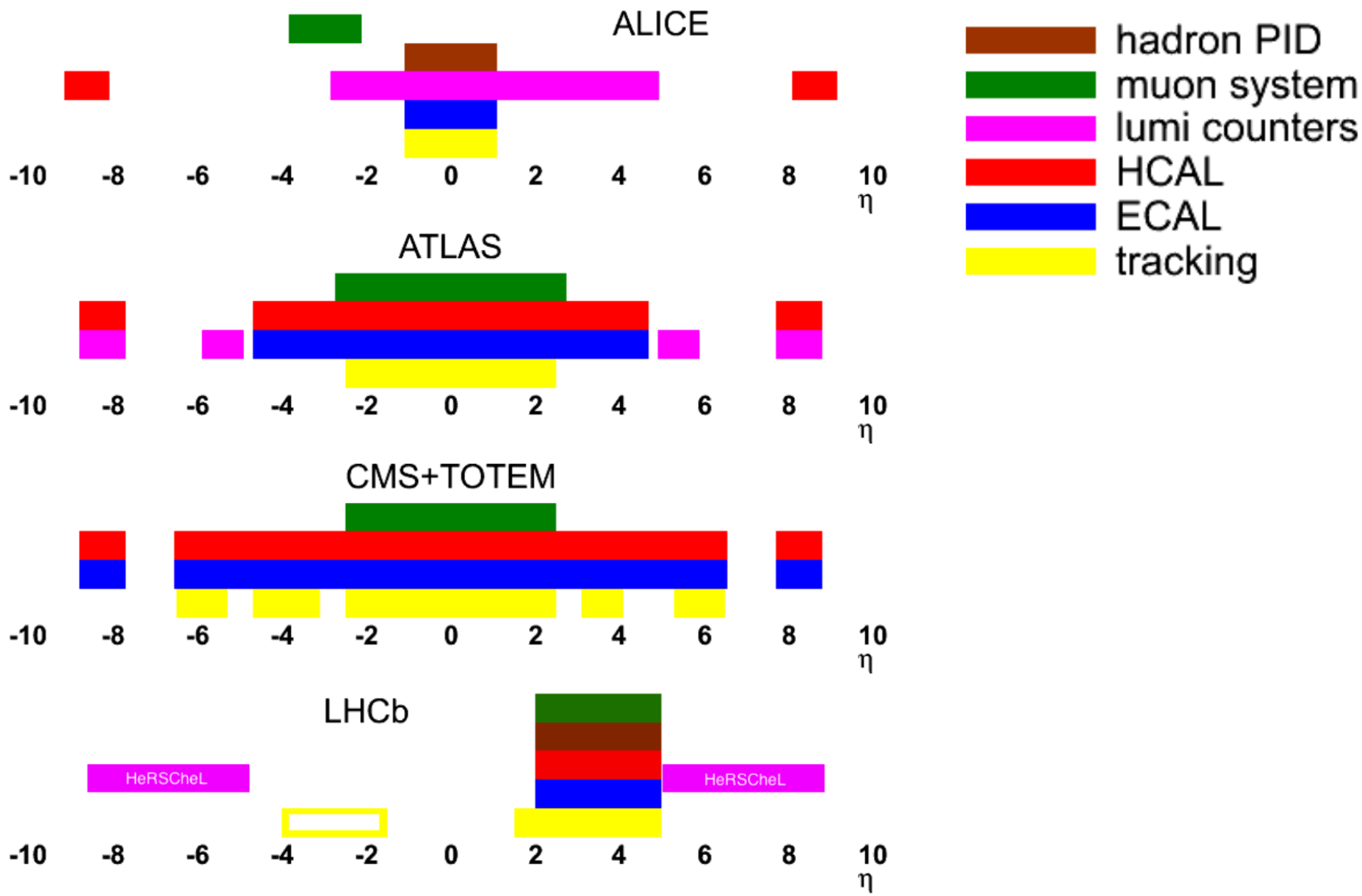


In this talk I will start at high Q^2 and y=0 and move to lower Q^2 and forward rapidity.

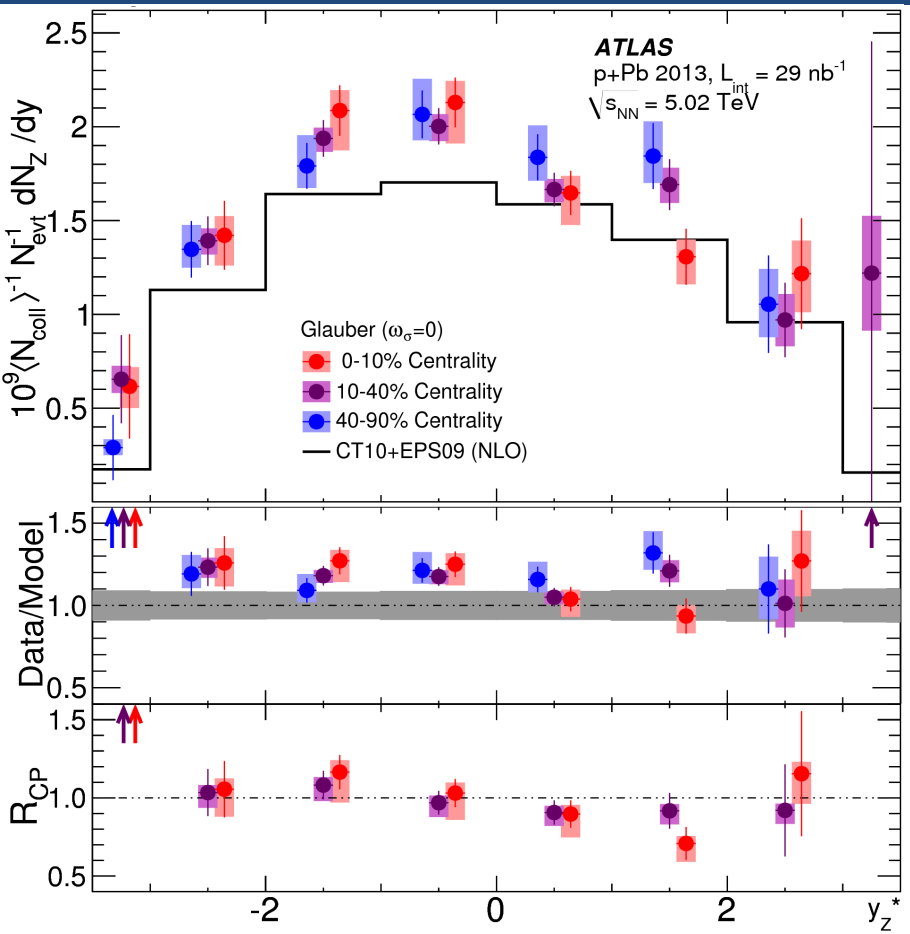
Apologies for missing references and CMS centric talk.

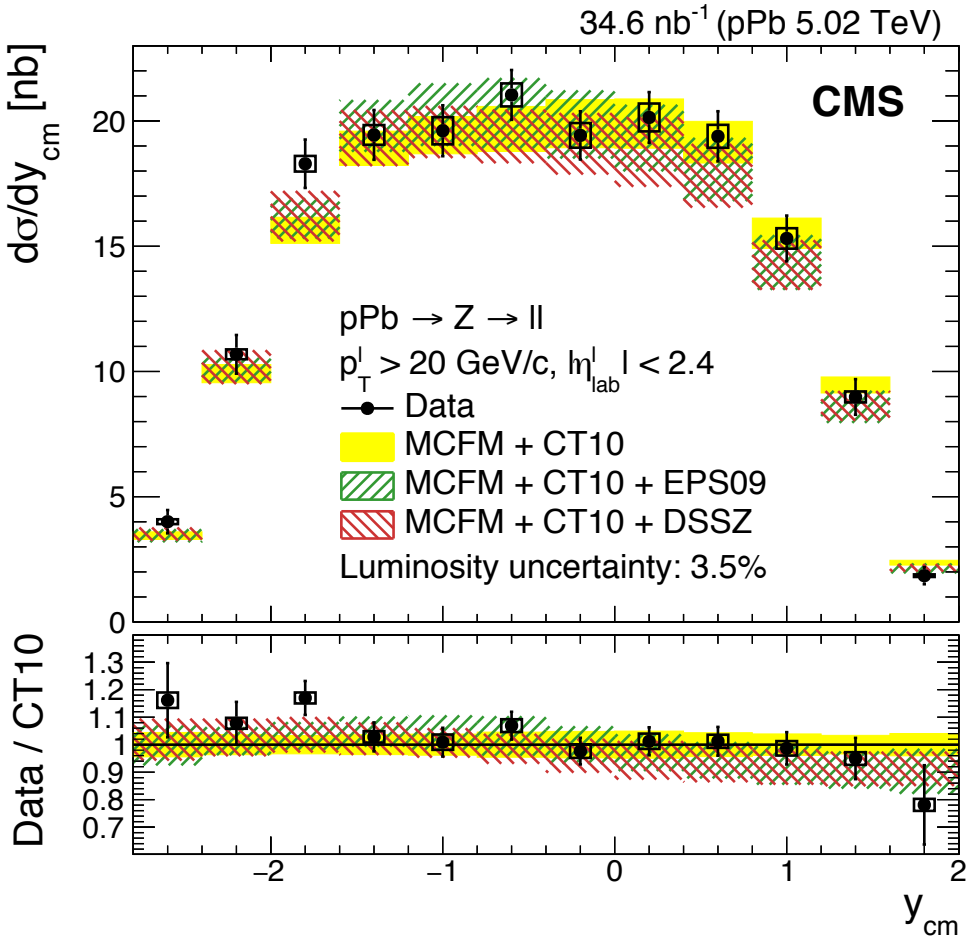
Gluon density has to saturate at low x

Coverage of LHC experiments



pPb => Z at $\sqrt{s_{NN}}$ = 5.02 TeV

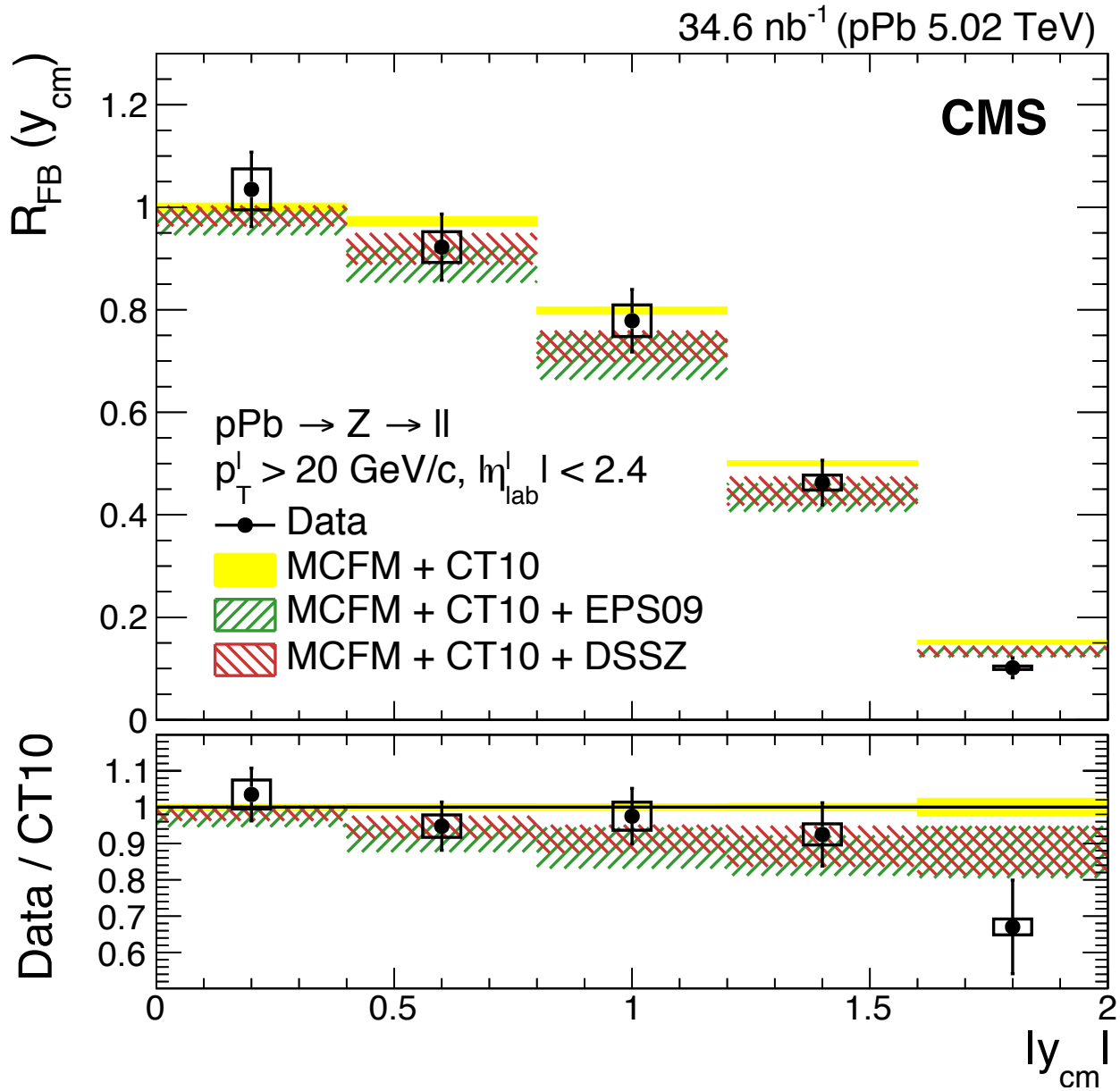




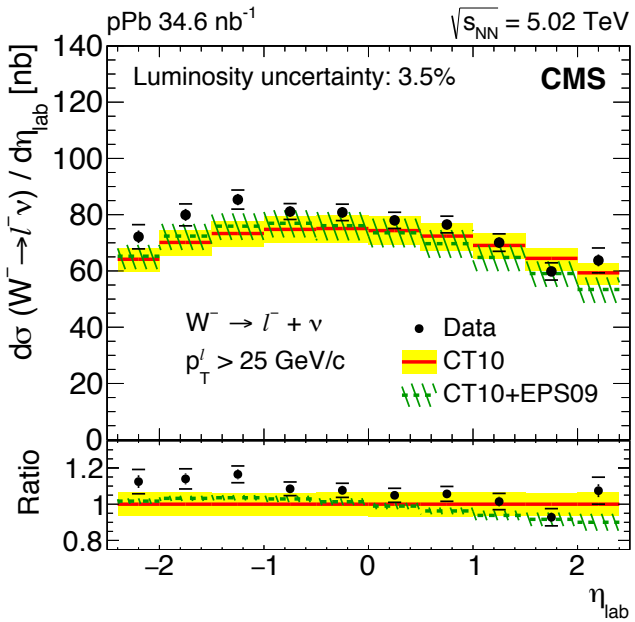
[Phys. Rev. C 92, 044915 (2015)](#)

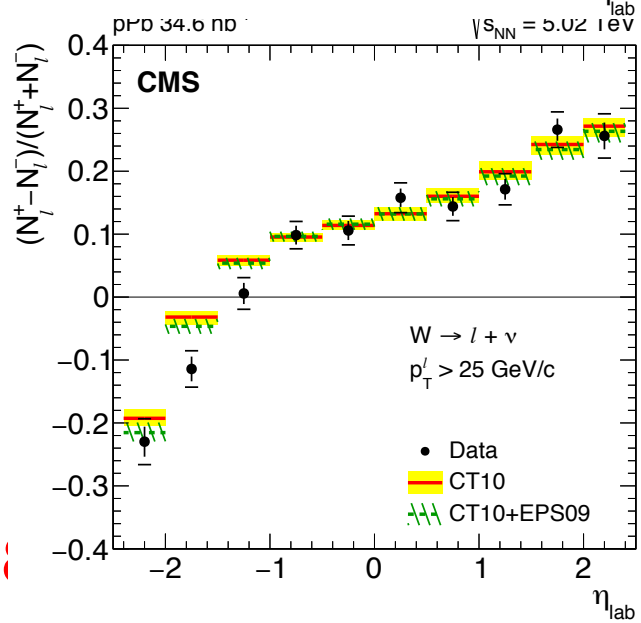
[Phys. Lett. B 759 (2016) 36](#)

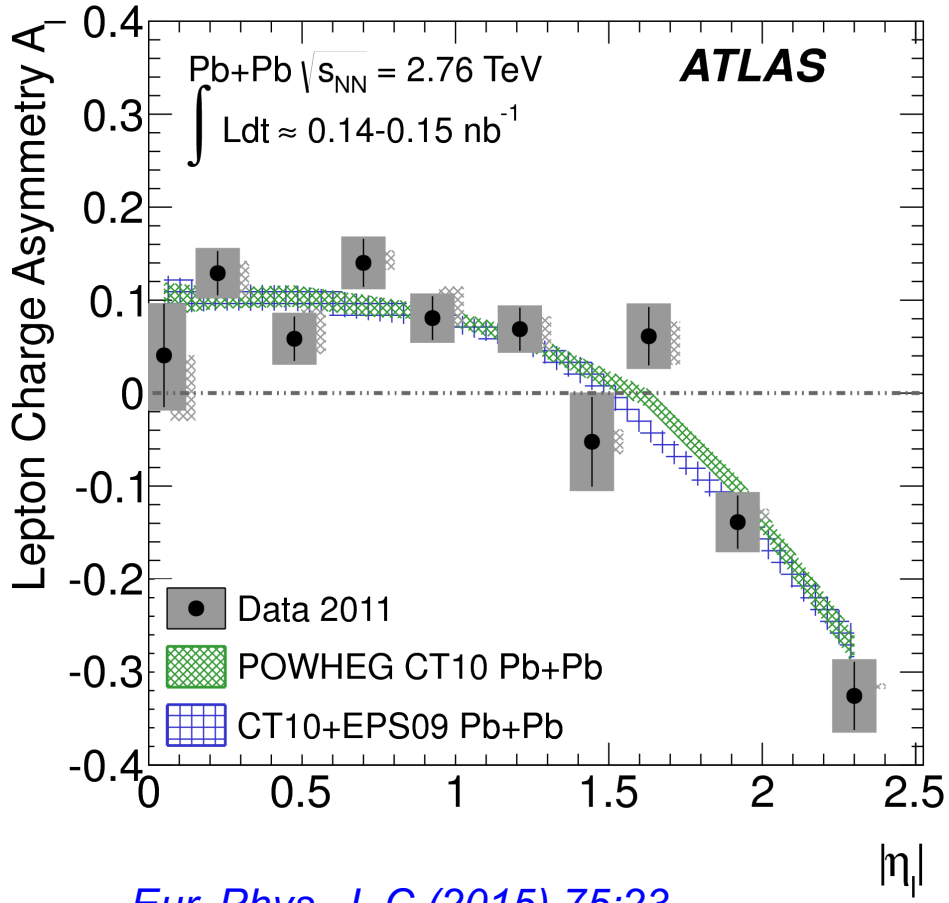
pPb => Z, forward/backward ratio



pPb => W at $\sqrt{s_{NN}}$ = 5.02 TeV



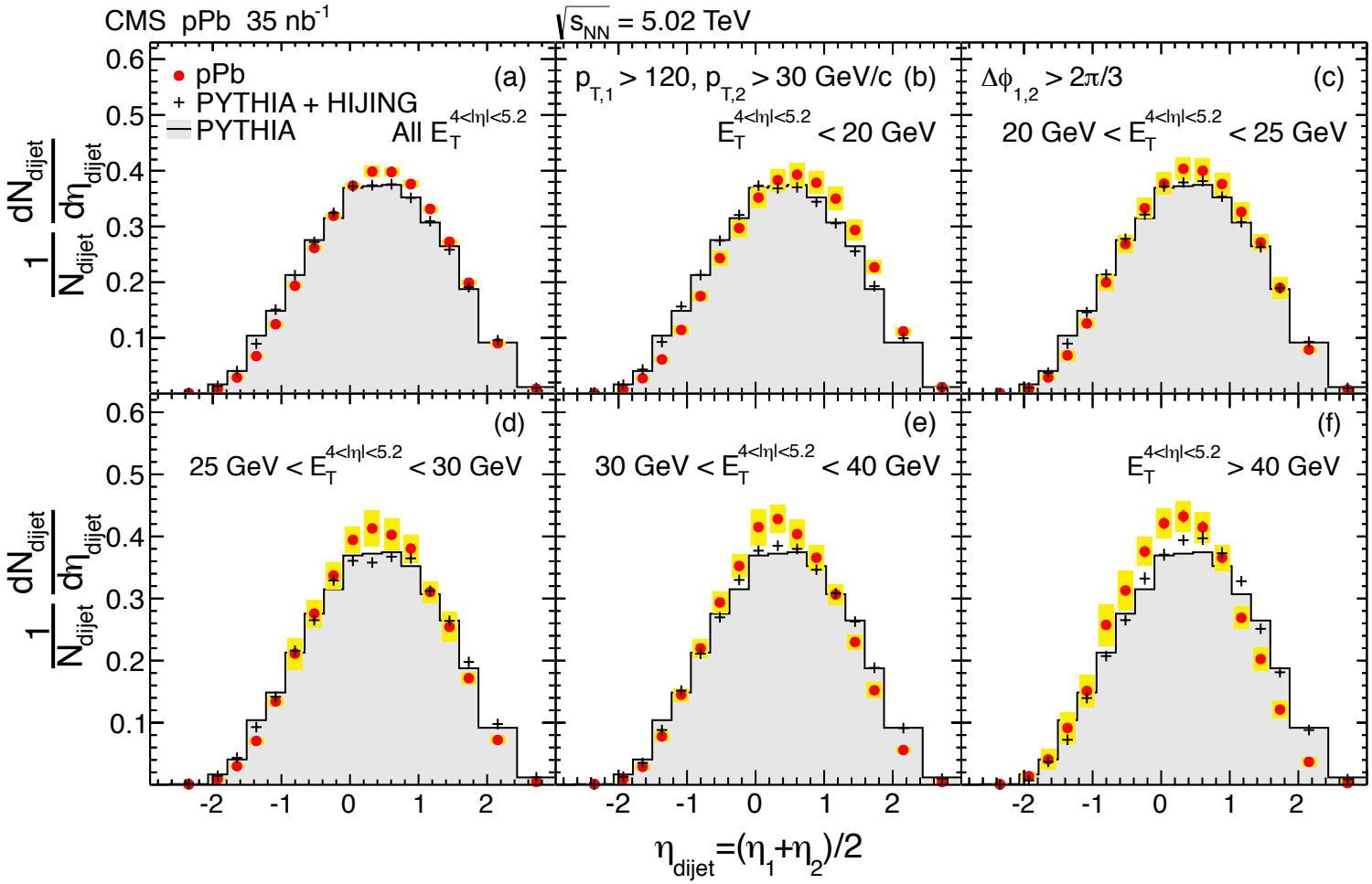




Eur. Phys. J. C (2015) 75:23

PLB 750 (2015) 565

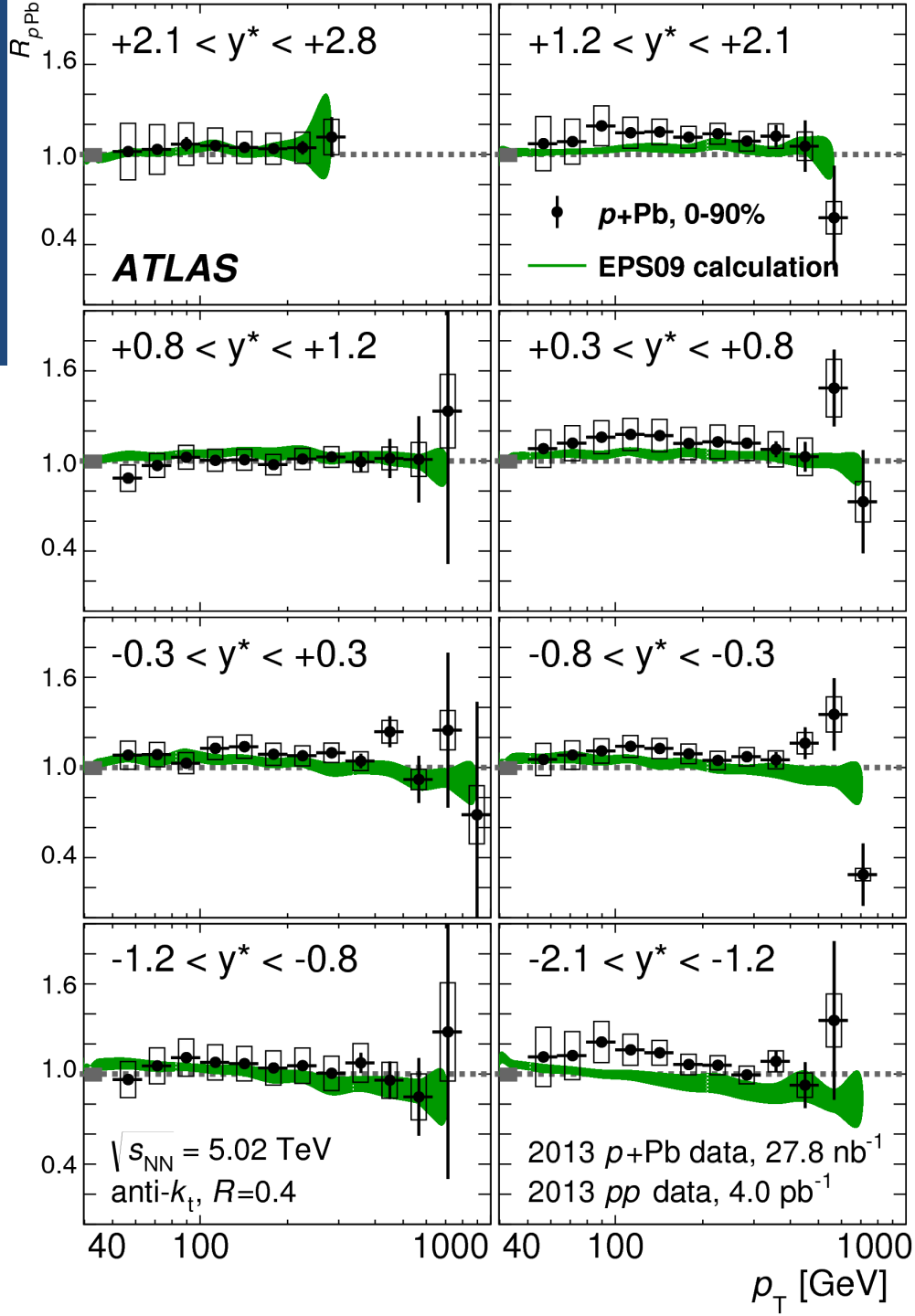
pPb => dijets at $\sqrt{s_{NN}}$ = 5.02 TeV



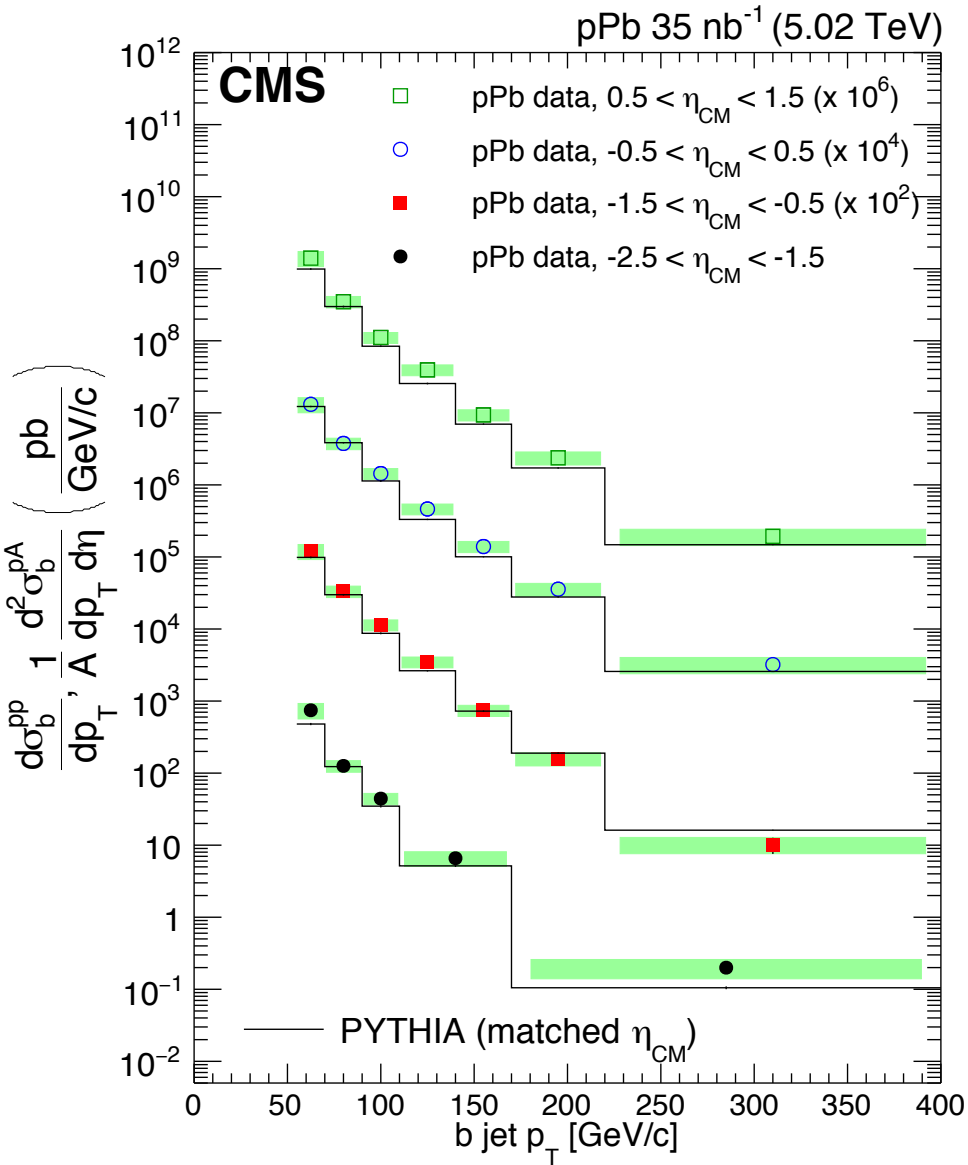
Eur. Phys. J. C 74 (2014) 2951

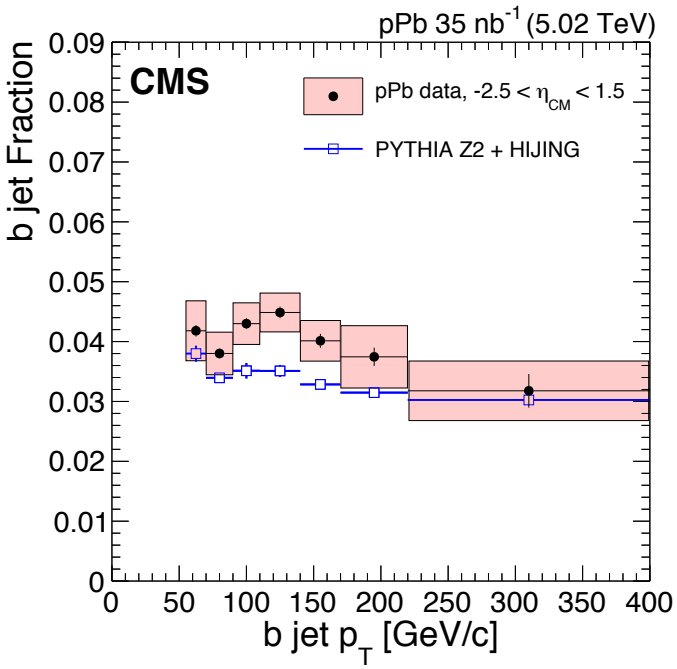
pPb => dijets at 5.02 TeV

PRL 114 (2015) 072302



pPb => b jets at $\sqrt{s_{NN}}$ = 5.02 TeV





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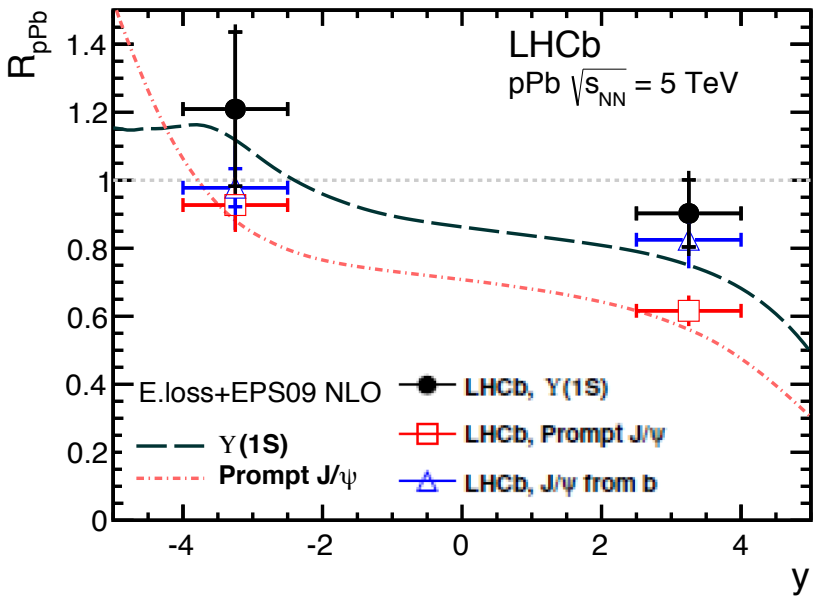
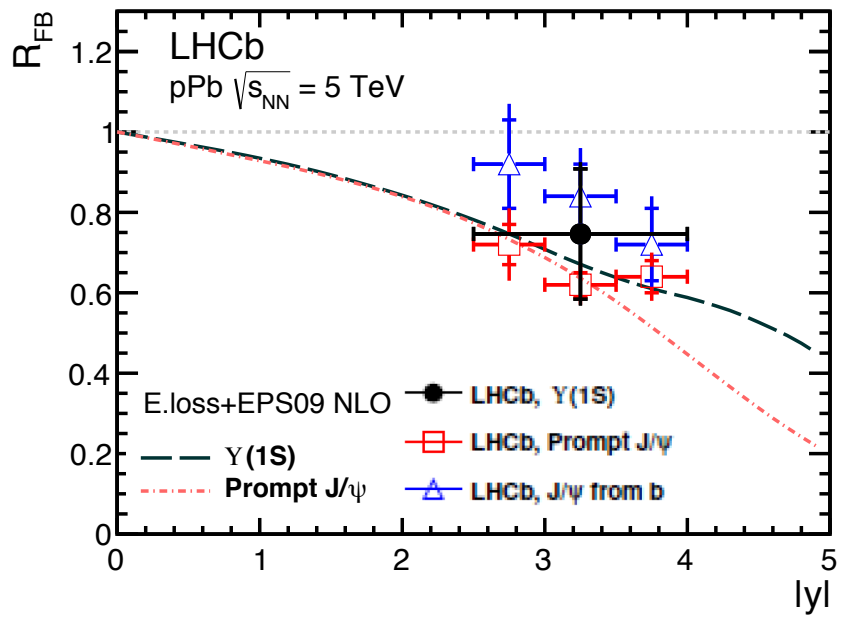
Υ(1S) R_{pPb} and R_{FB} at 5.02 TeV





Υ(1S) is also sensitive to CNM effects

R_{pPb} versus rapidity:

Suppression in forward region is smaller than for J/ψ

Central value in forward region close to that of J/ψ from b → CNM effects on b hadrons

Indication of enhancement in the backward region → could be attributed to anti-shadowing

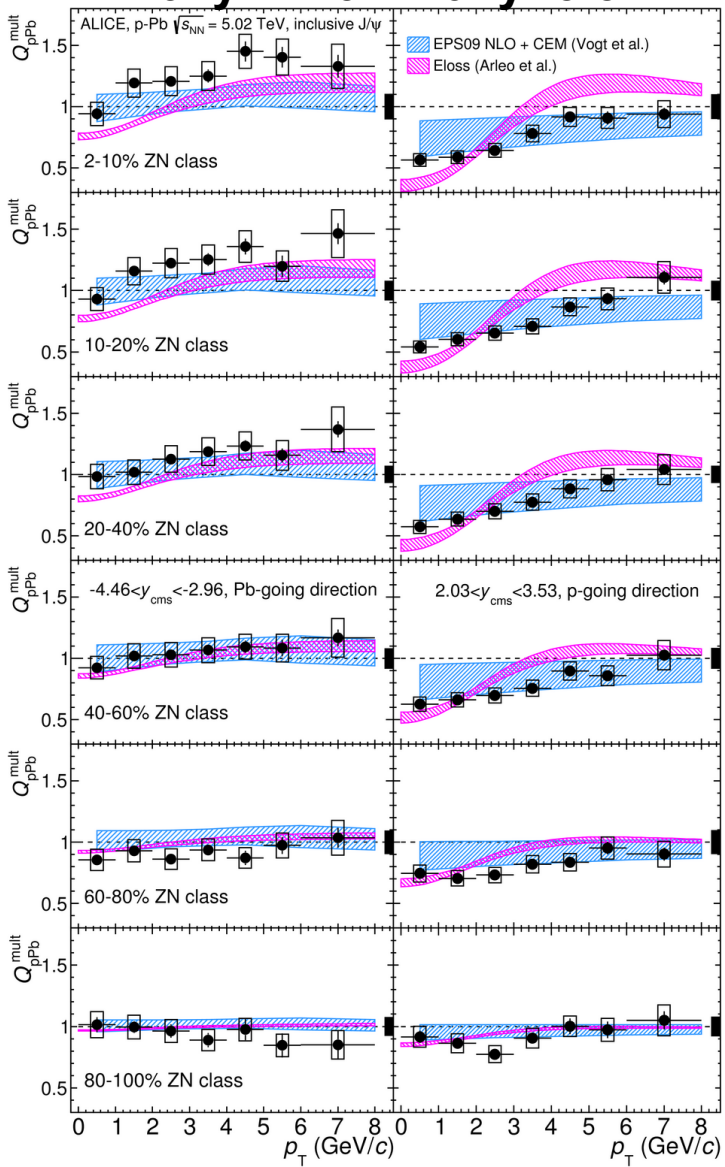
R_{FB} versus rapidity:

Ratio in agreement with predictions of E. loss + shadowing (EPSO9 NLO)

Inclusive J/ψ from pPb at 5.02 TeV

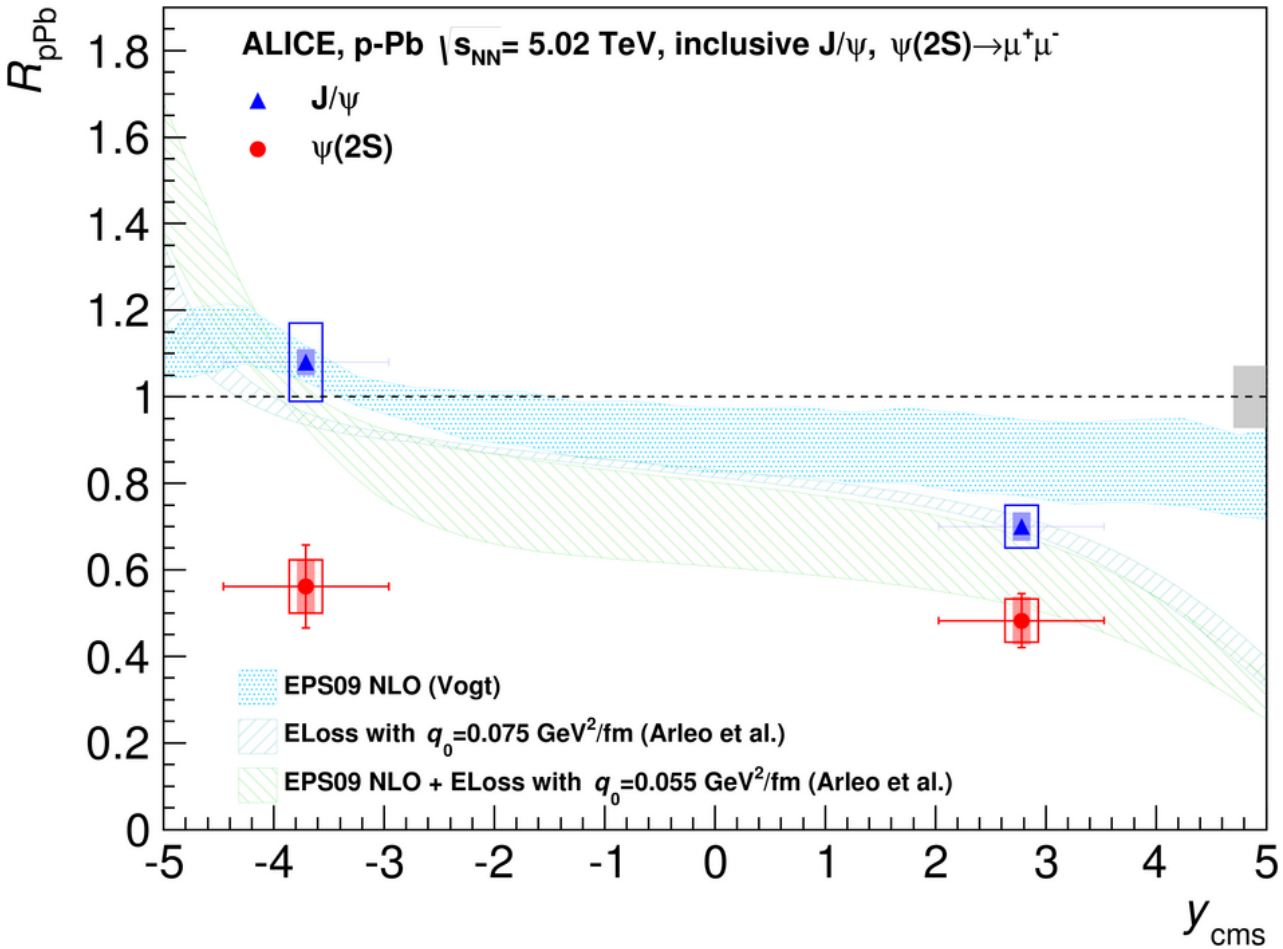
-4.6<y< -2.9 2.0<y<3.5

Centrality =>

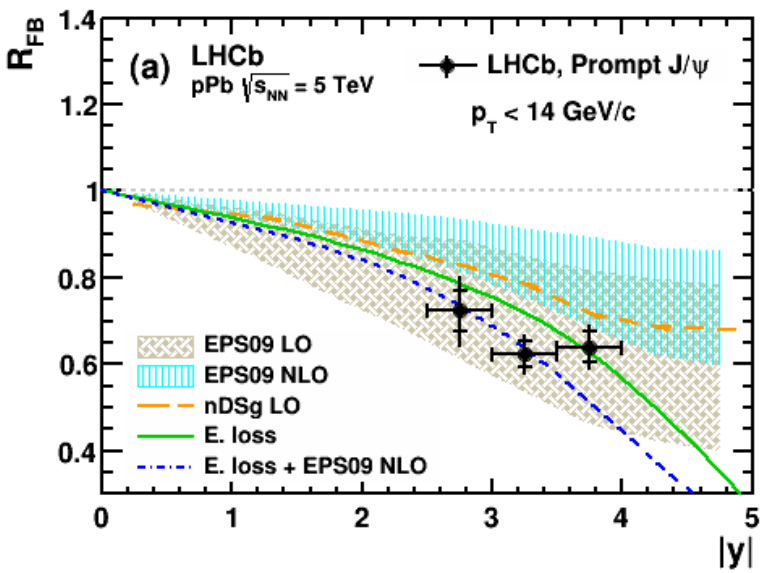


JHEP 06 (2015) 55

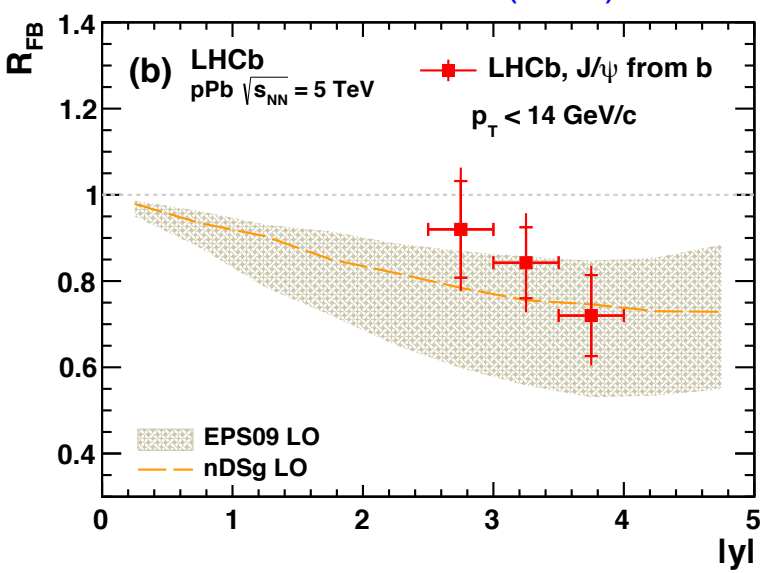
R_{pPb} from J/ψ and ψ(2s) at 5TeV

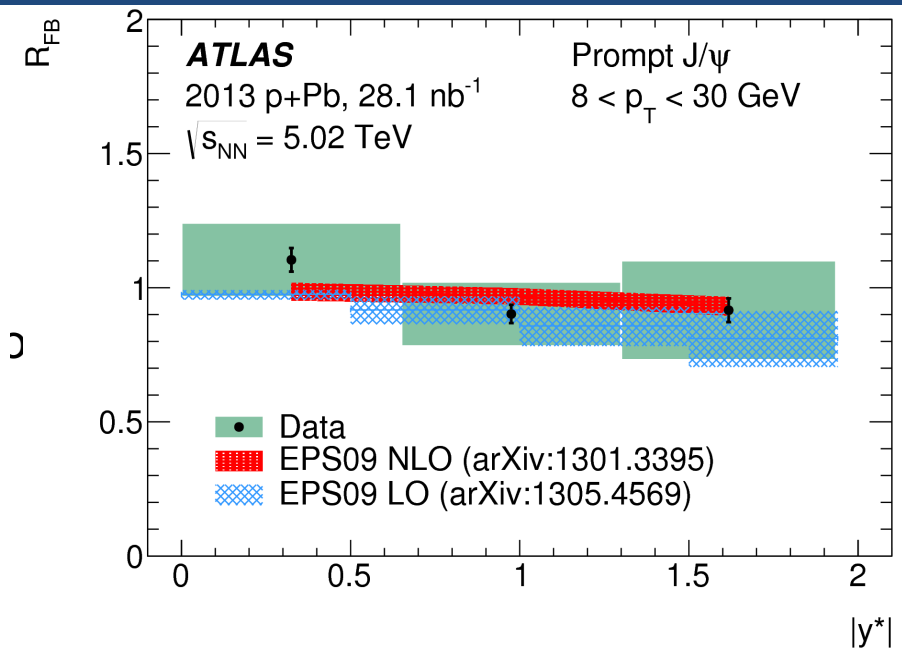


J/ψ forward/backward, pPb at 5TeV



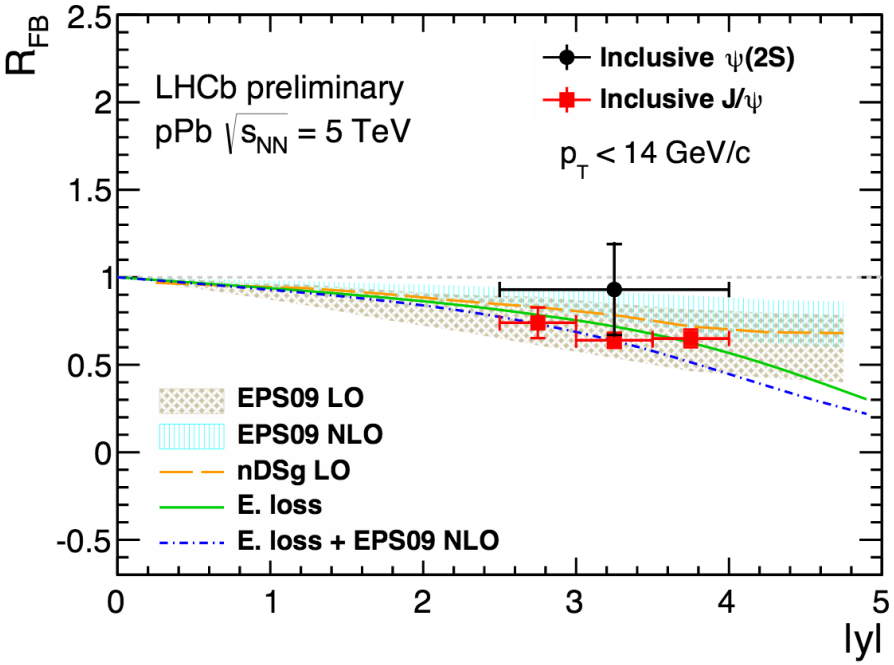
JHEP 02 (2014) 072

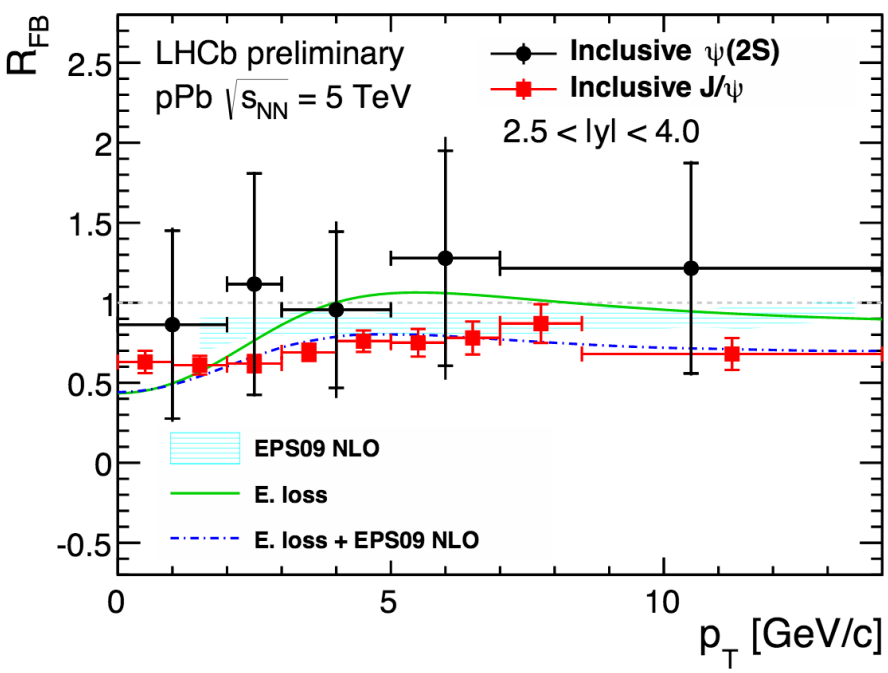




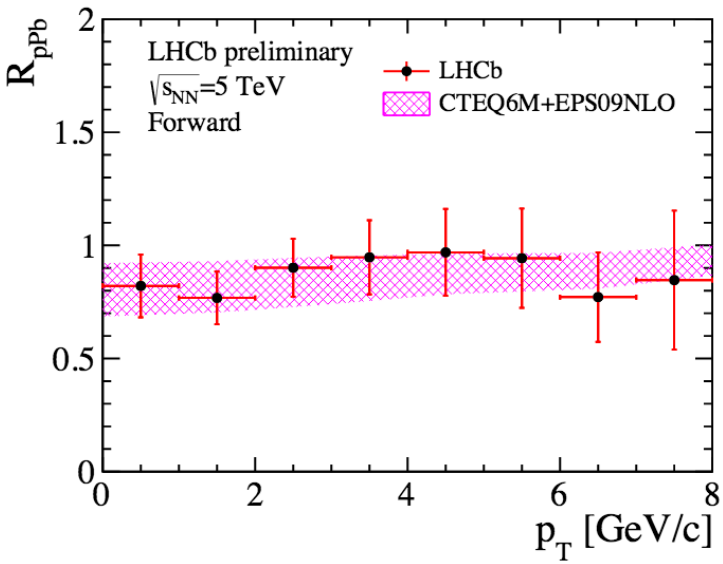
Ψ(2s) forward/backward, pPb at 5TeV

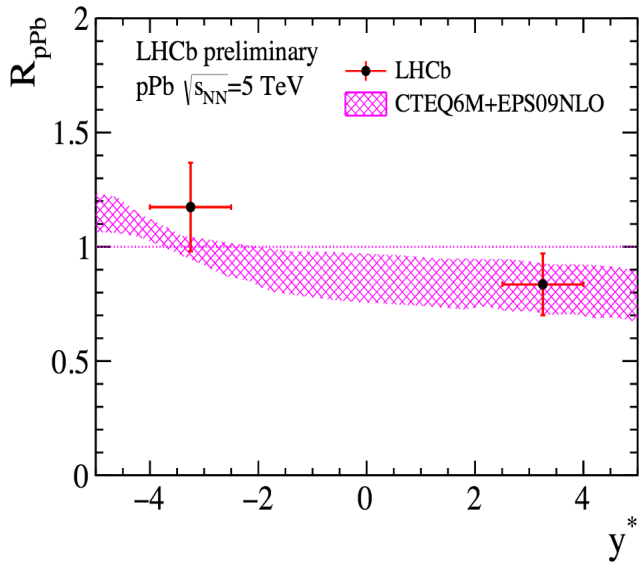
JHEP 1603 (2016) 133

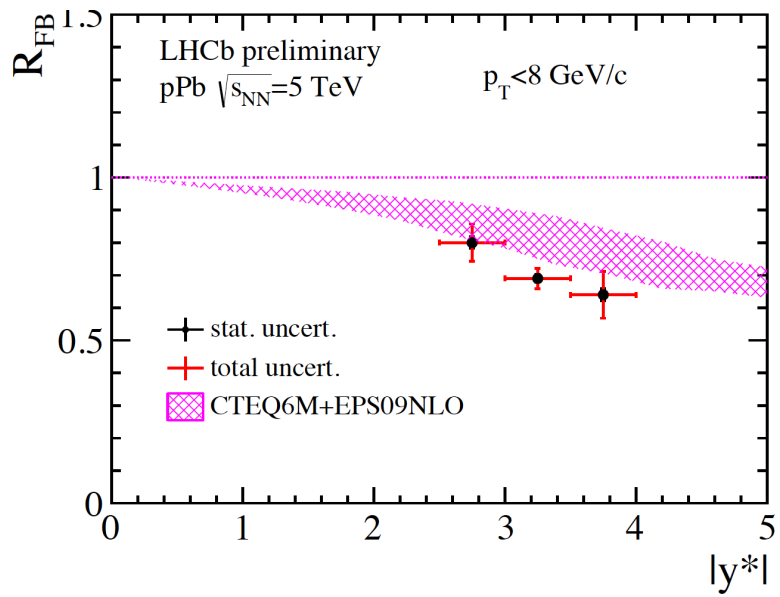




Prompt D^0 R_{pPb} , R_{FB}



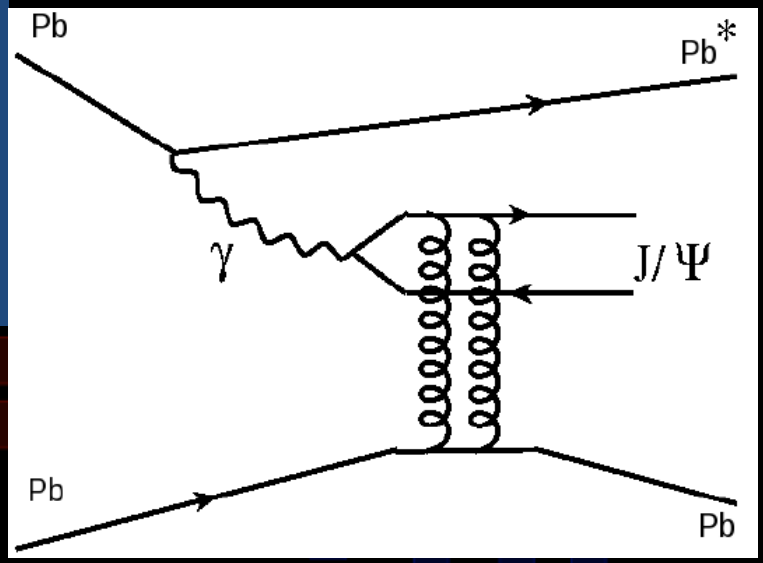


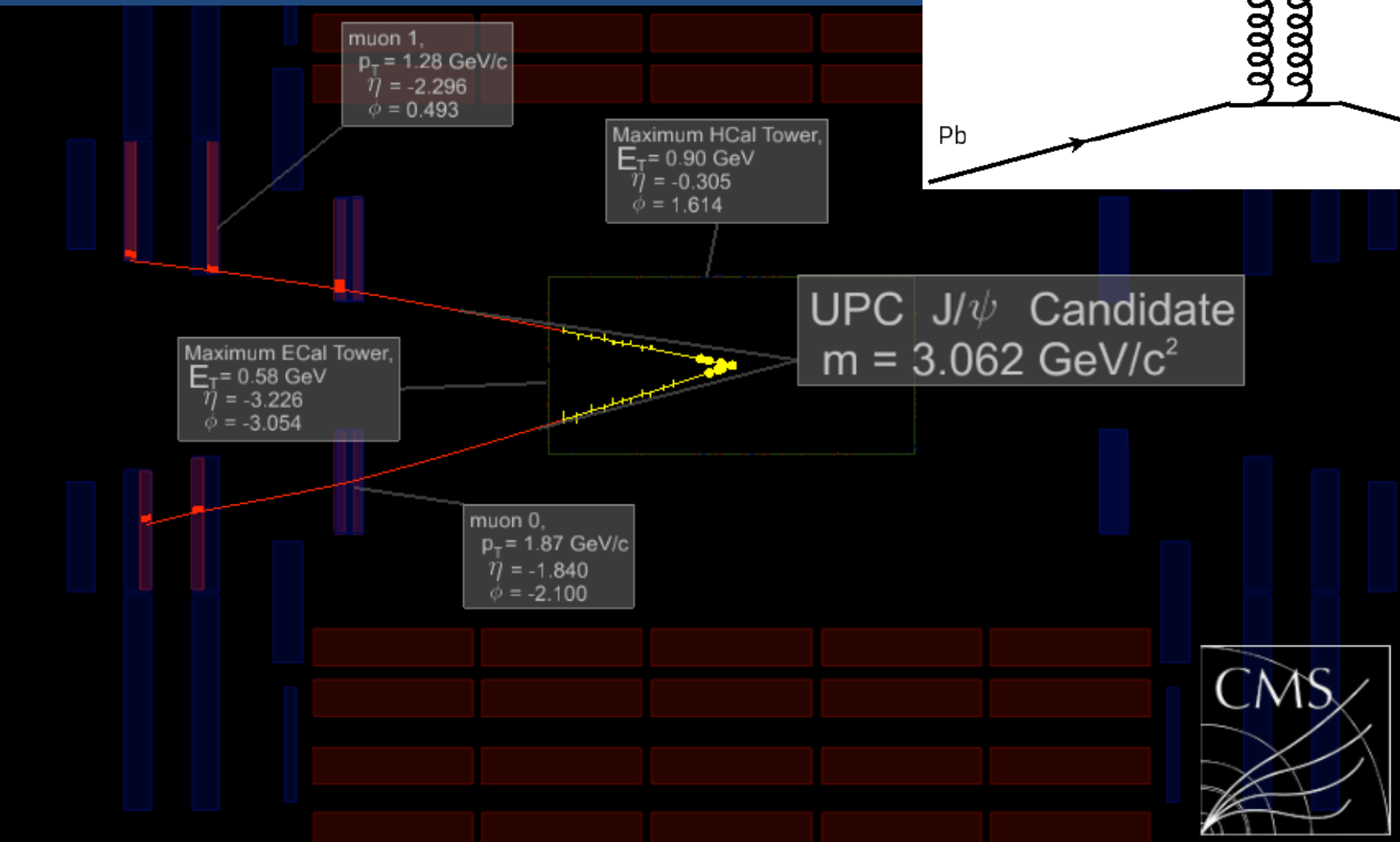


LHCB-CONF-2016-003-001

Theory CTEQ6M + EPS09NLO Nucl. Phys. B.373 (1992) 295, JHEP 10 (2003) 046, JHEP 04 (2009) 065

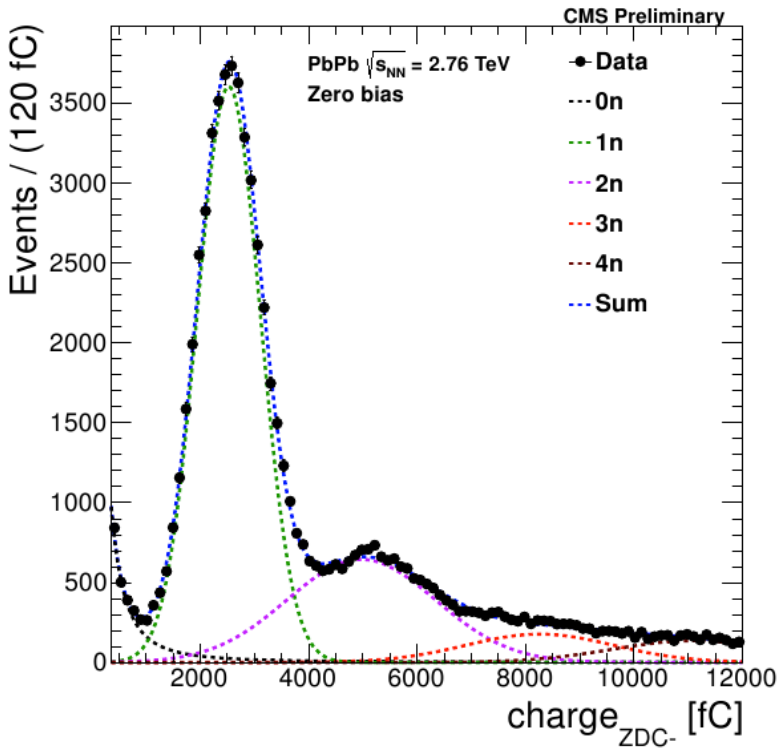
Ultra-peripheral PbPb





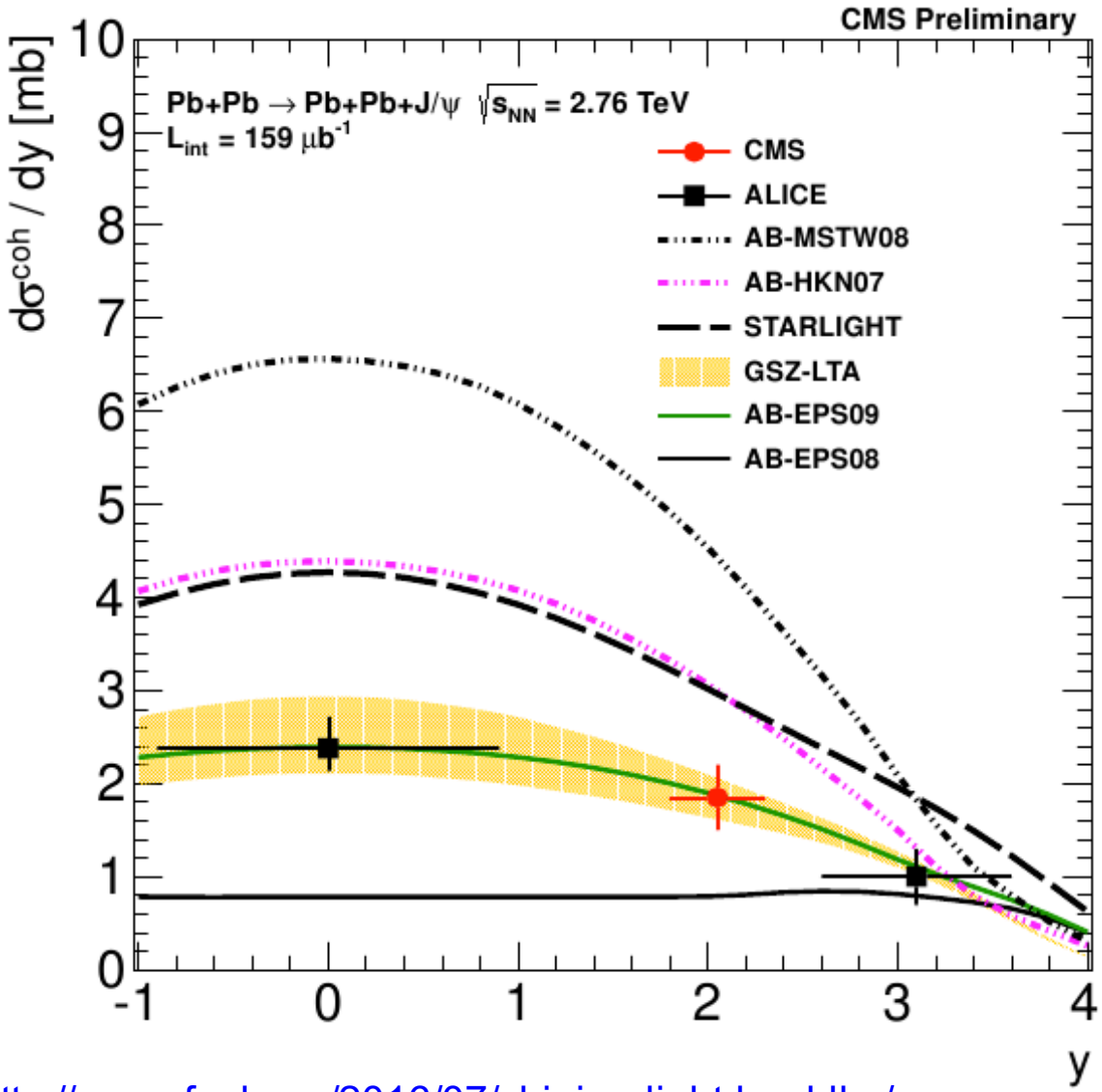
UPC J/ψ for different breakup modes

Xn0n single-sided any number of neutrons
XnXn double-sided any number of neutrons
1n0n single-sided exactly one neutron
1n1n double-sided one neutron each side



J/ψ with p_T <0.15 GeV/c	X_nX_n/X_n0_n	$1_n0_n/X_n0_n$	$1_n1_n/X_n0_n$
Data	0.36±0.04	0.26±0.03	0.03±0.01
STARLIGHT	0.37	N/A	0.02
GSZ	0.32	0.30	0.02

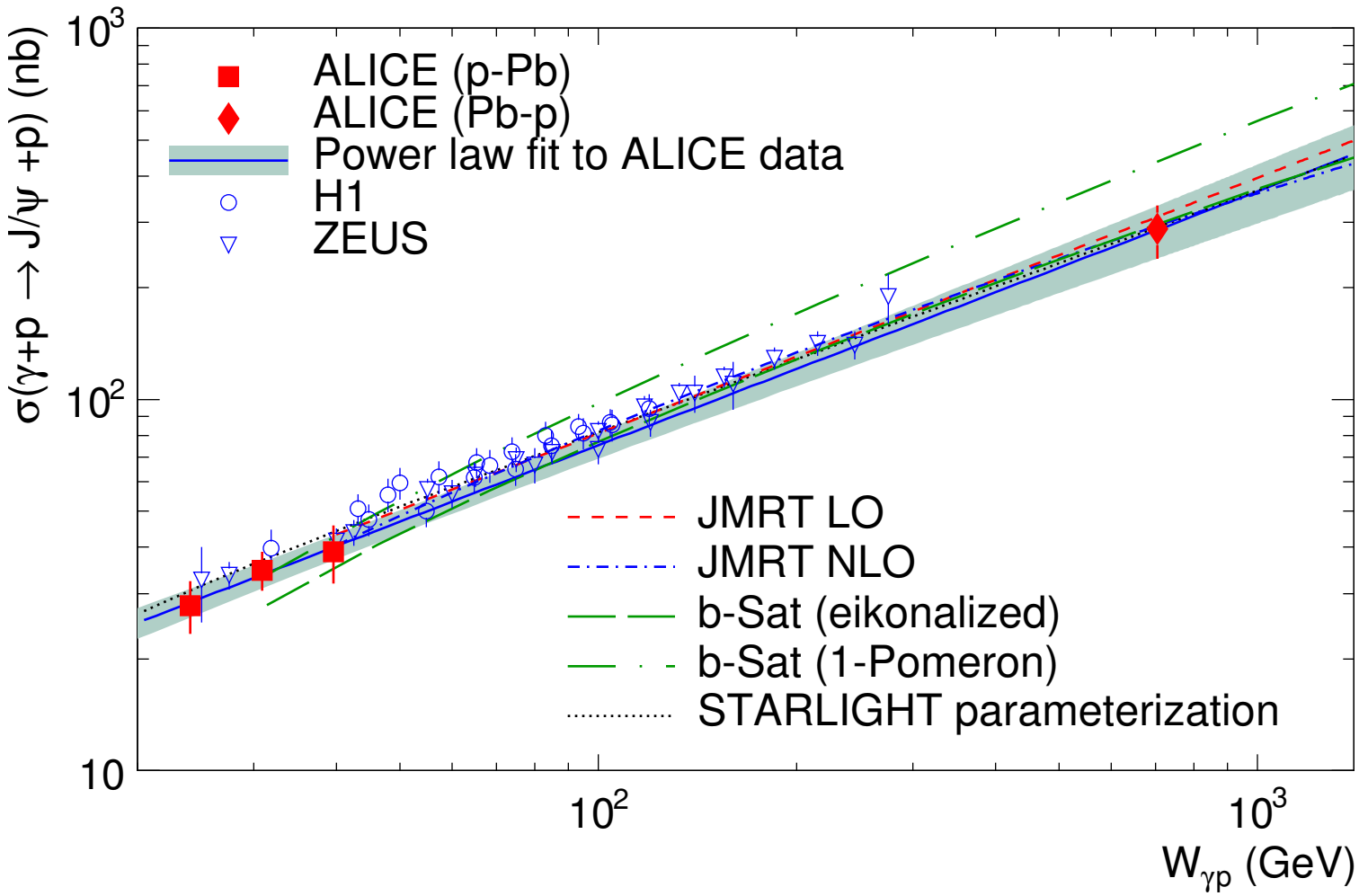
PbPb Ultra-peripheral J/ψ



ALICE: Eur.Phys.J. C73 (2013) 2617, Phys.Lett. B 718 (2013) 1273

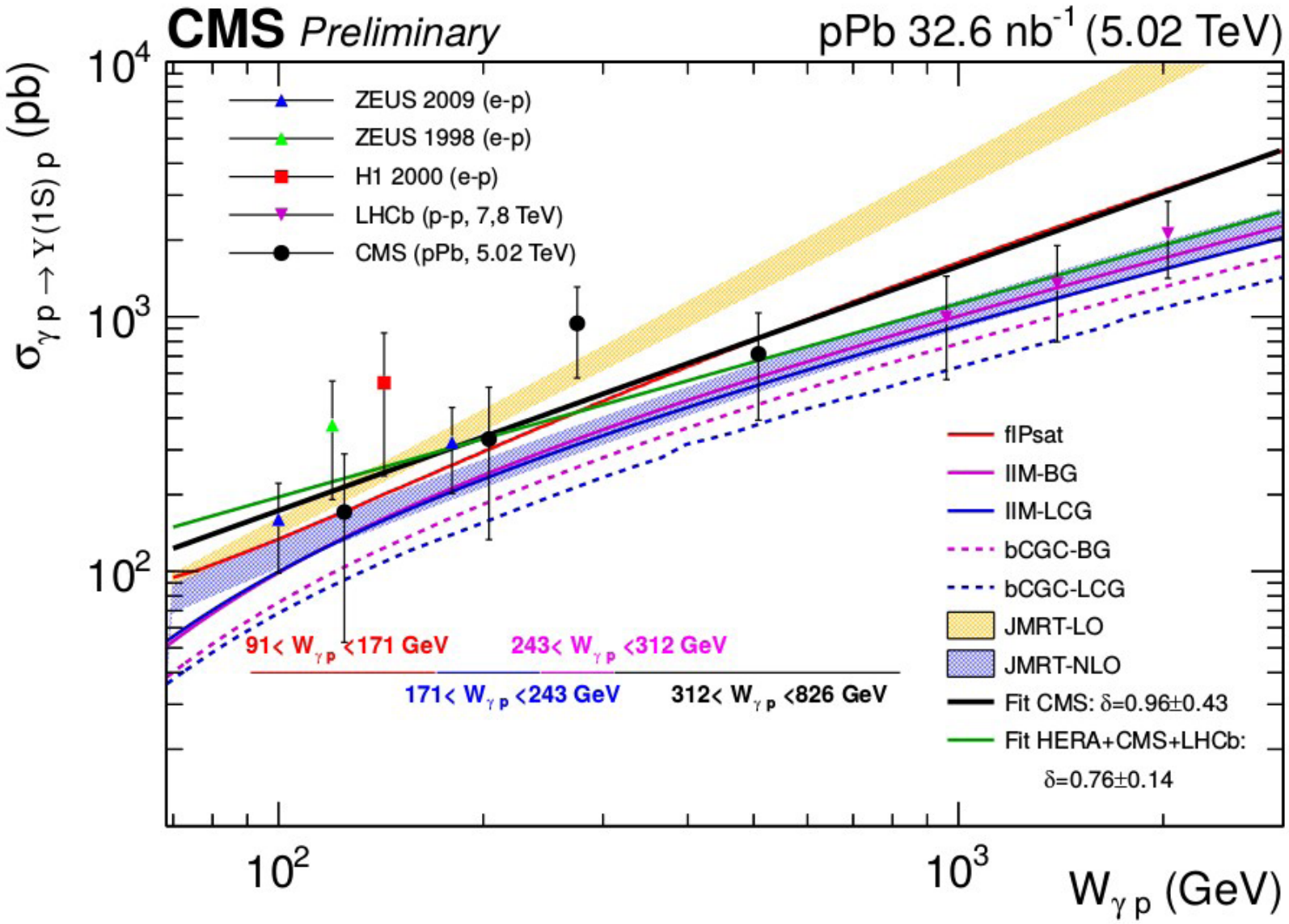
http://news.fnal.gov/2016/07/shining-light-lead-lhc/

γp => J/ψ vs photon-p energy

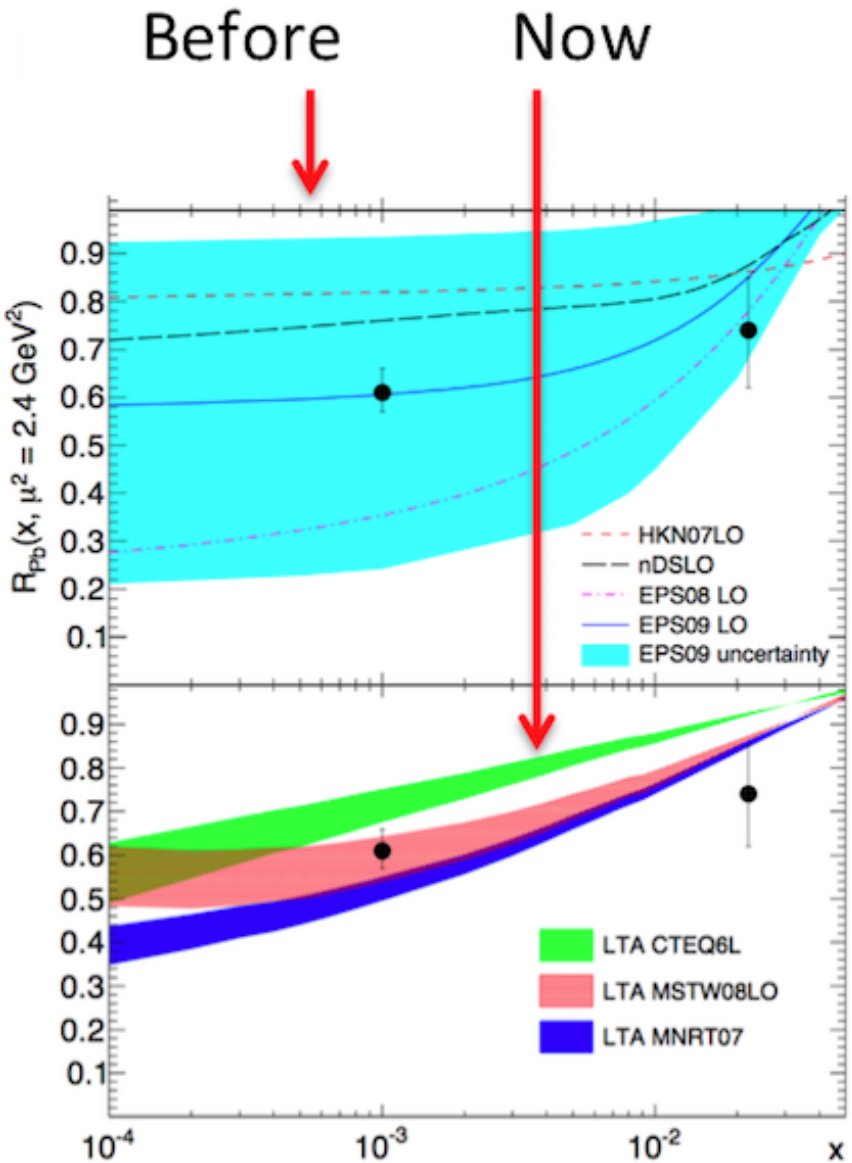


Phys. Rev. Lett. 113 (2014) 232504

γp => Upsilon vs photon-p energy



First attempt to use UPCs in nPDFs

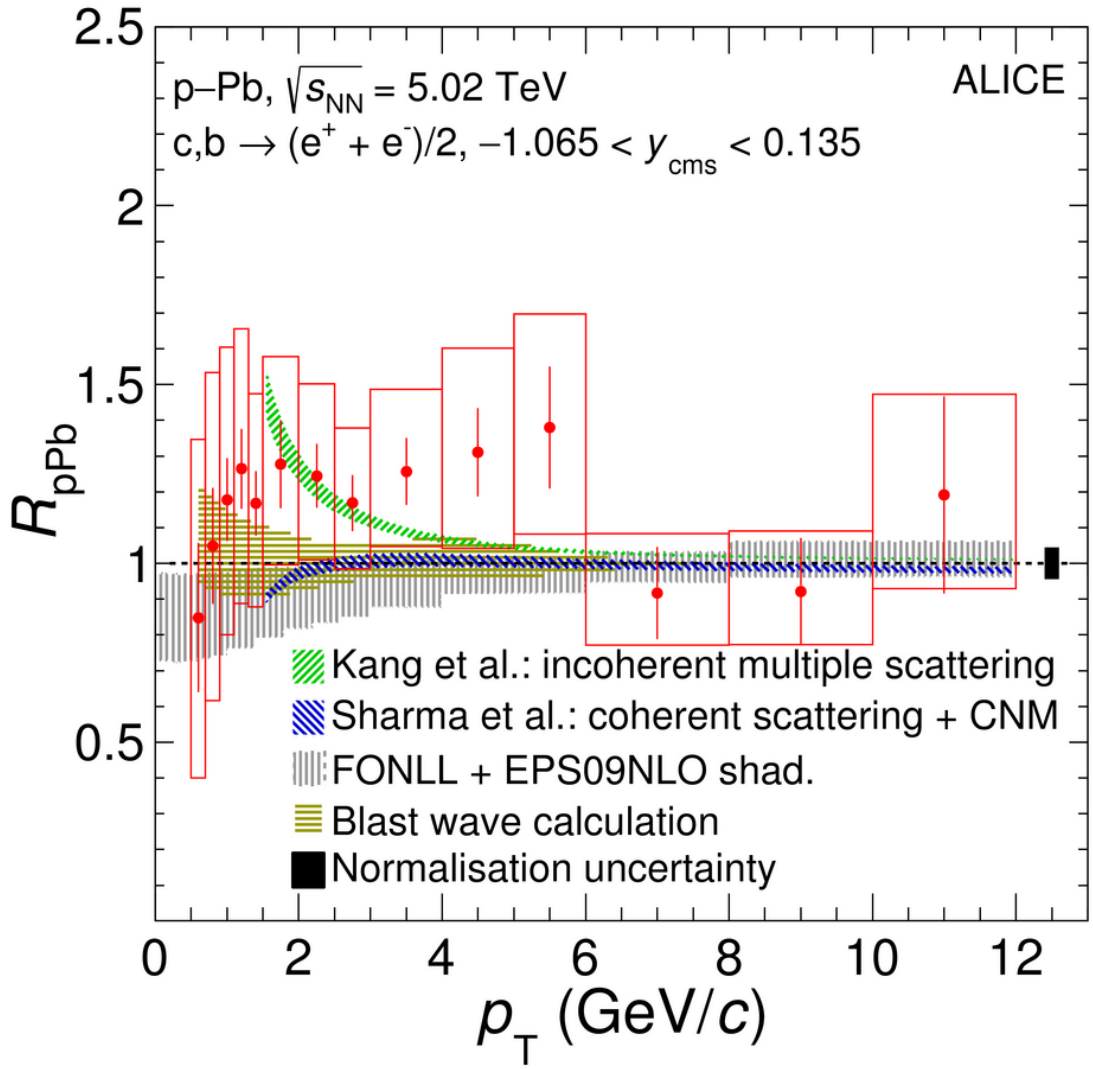


Summary

- There now exists a wide range pPb and γPb data covering a large x and Q^2 range
- So far EPS09 has been doing very well describing data.
- At low X and Q^2 ultra-peripheral data can impose significant constraints on nPDFs.
- New data on forward Zs and Jets and quarkonia and UPC jets should come soon.
- Looking for new ways to test PDFs, eg correlated production, incoherent UPCs.

Back up

pPb: Electrons from heavy flavor



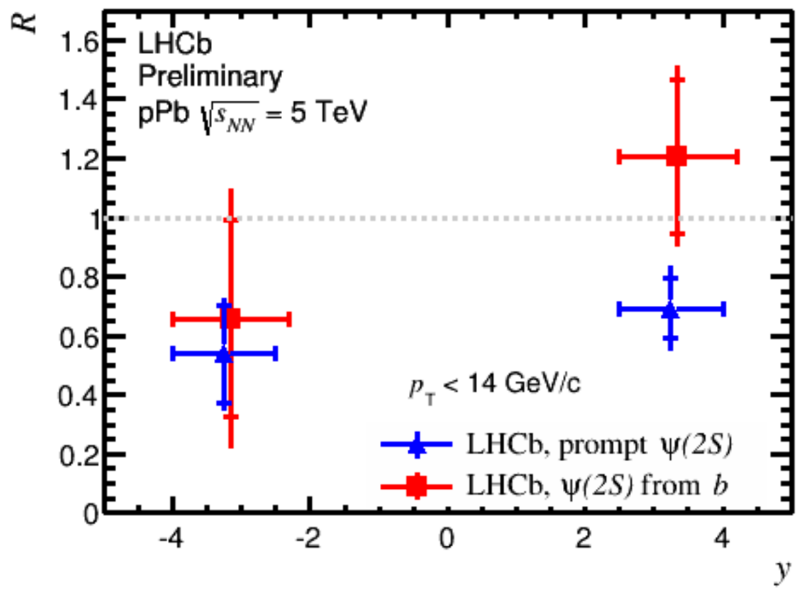
Phys. Lett. B 754 (2016) 81-93

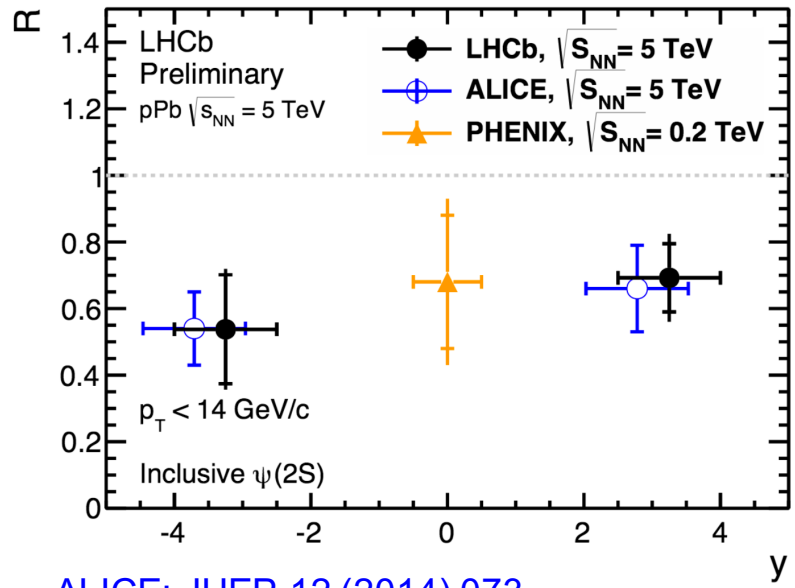
Ψ(2S) relative suppression wrt J/ψ

LHCb-CONF-2015-005

- Relative suppression is calculated as:

$$R = \frac{R_{pPb}^{\psi(2S)}}{R_{pPb}^{J/\Psi}} = \frac{\sigma_{pPb}^{\psi(2S)}(5\text{TeV})}{\sigma_{pPb}^{J/\Psi}(5\text{ TeV})}\frac{\sigma_{pp}^{J/\Psi}(5\text{ TeV})}{\sigma_{pp}^{\Psi(2S)}(5\text{ TeV})} \approx \frac{\sigma_{pPb}^{\psi(2S)}(5\text{TeV})}{\sigma_{pPb}^{J/\Psi}(5\text{ TeV})}\frac{\sigma_{pp}^{J/\Psi}(7\text{ TeV})}{\sigma_{pp}^{\Psi(2S)}(7\text{ TeV})}$$





ALICE: JHEP 12 (2014) 073
PHENIX: Phys. Rev. Lett. 111 (2013), no. 20 (202301)

Intriguing stronger suppression of prompt ψ(2S) than that of prompt J/ψ
Similar suppression for ψ(2S) from b and J/ψ from b
→ R compatible with 1 within large uncertainties
Results for inclusive ψ(2S) compatible with ALICE measurement