Vector Meson production in Ultra-Peripheral Collisions in ALICE

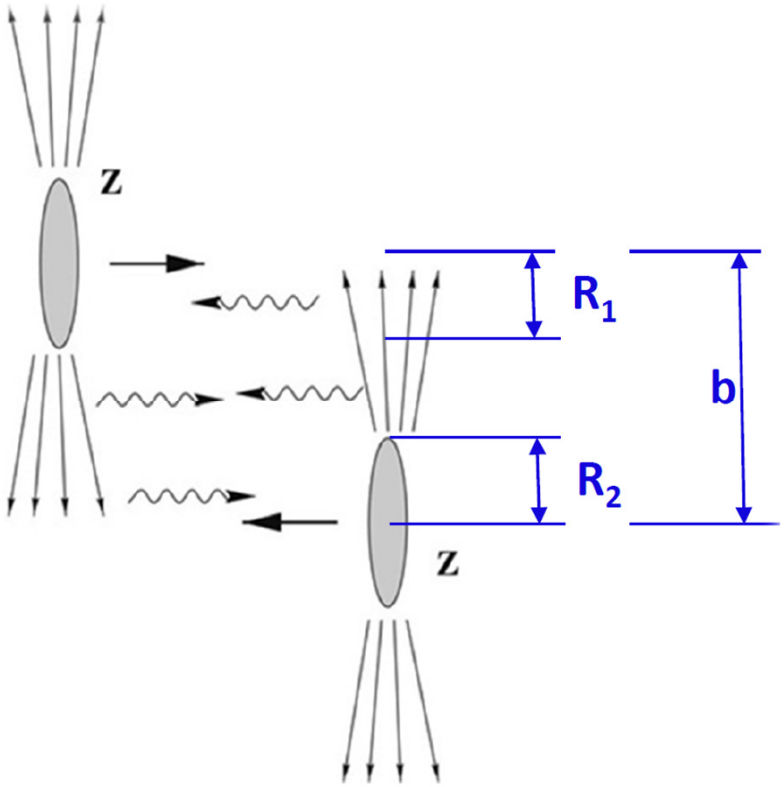
June 30th 2016

O. Villalobos Baillie
University of Birmingham
for the ALICE Collaboration

Plan of Talk

- Introduction
- ALICE trigger configuration
- J/ψ results
- ψ(2S) results
- ρ^0 results
- Summary

Ultra-Peripheral Production

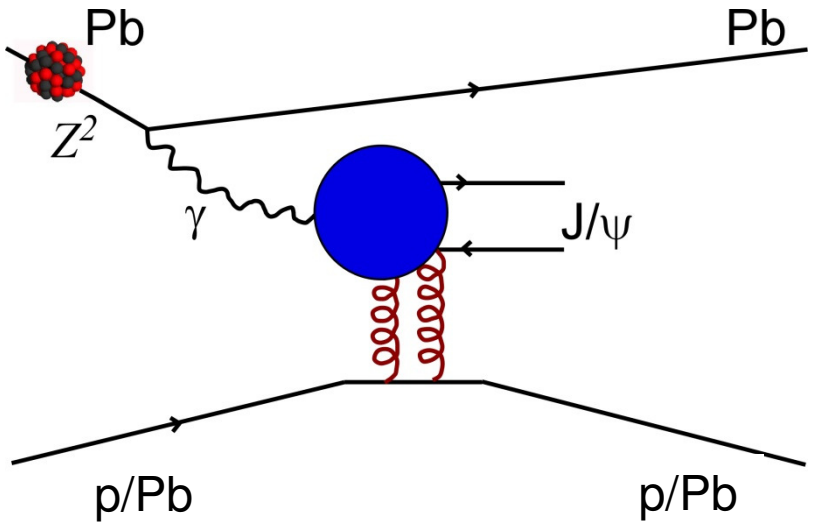


- In Ultra-Peripheral Collisions (UPC), the projectiles (Pb-Pb, p-Pb or pp) are at large impact parameters, $b > R_1 + R_2$, and so hadronic processes are greatly suppressed
- Photon flux $\propto Z^2$
- Photon virtuality $Q^2 = (\hbar c/R)^2 \approx (35\ \text{MeV})^2$ for γ from Pb

UltraPeripheral production

$$\frac{\mathrm{d}\sigma_{\gamma^* \mathrm{p/Pb}}(t=0)}{\mathrm{d}t} = \frac{16\Gamma_{ee}\pi^3}{3\alpha_{\mathrm{em}}M_{J/\psi}^5}\left\{\alpha_s\left(Q^2\right)xG_{\mathrm{p/Pb}}\left(x,Q^2\right)\right\}^2$$

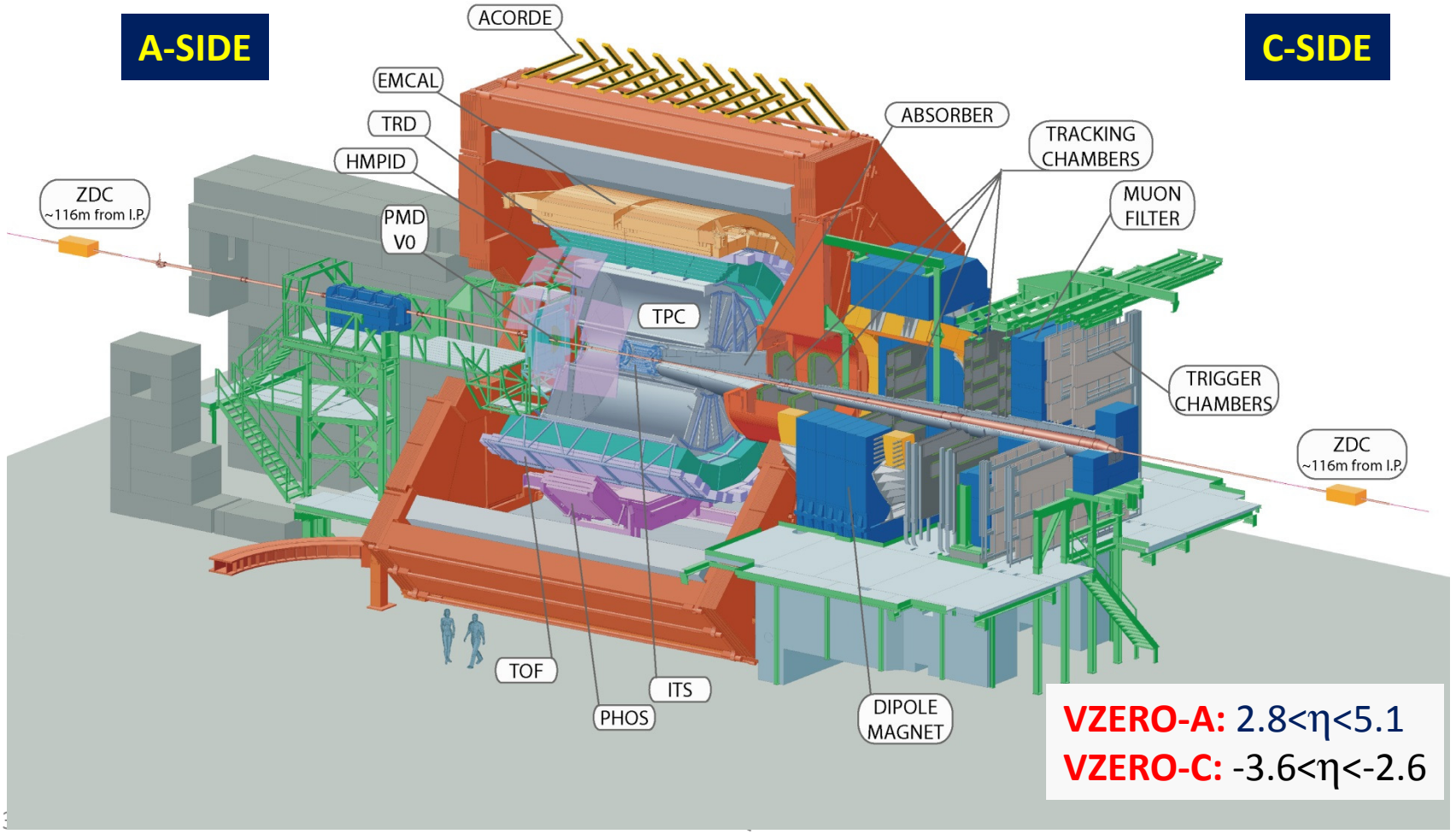
LEADING ORDER



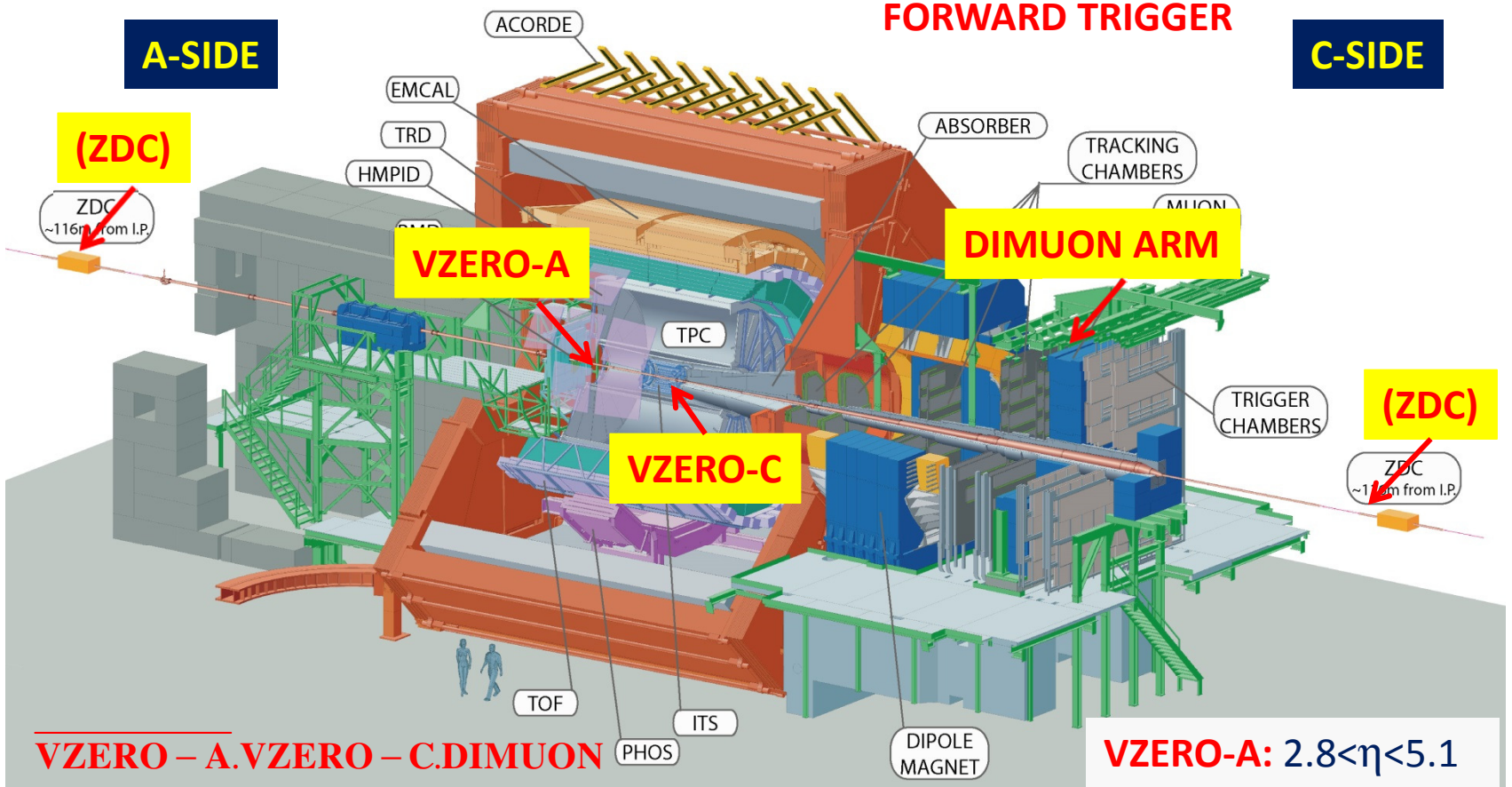
- Essentially the same process as ep, except that the photon is emitted by a proton or *a nucleus.*
- The photon emitted by one nucleus couples to a vector meson
- At LO, the cross-section is proportional to the gluon PDF squared
- Hard scale for the J/ψ of $Q^2 \sim (M_{J/\psi}^2/4) \sim 2.5\ \mathrm{GeV}^2$
  - Model dependence for lighter particles (e.g. ρ)

Exclusive process: we go to very *low* multiplicities

ALICE Apparatus



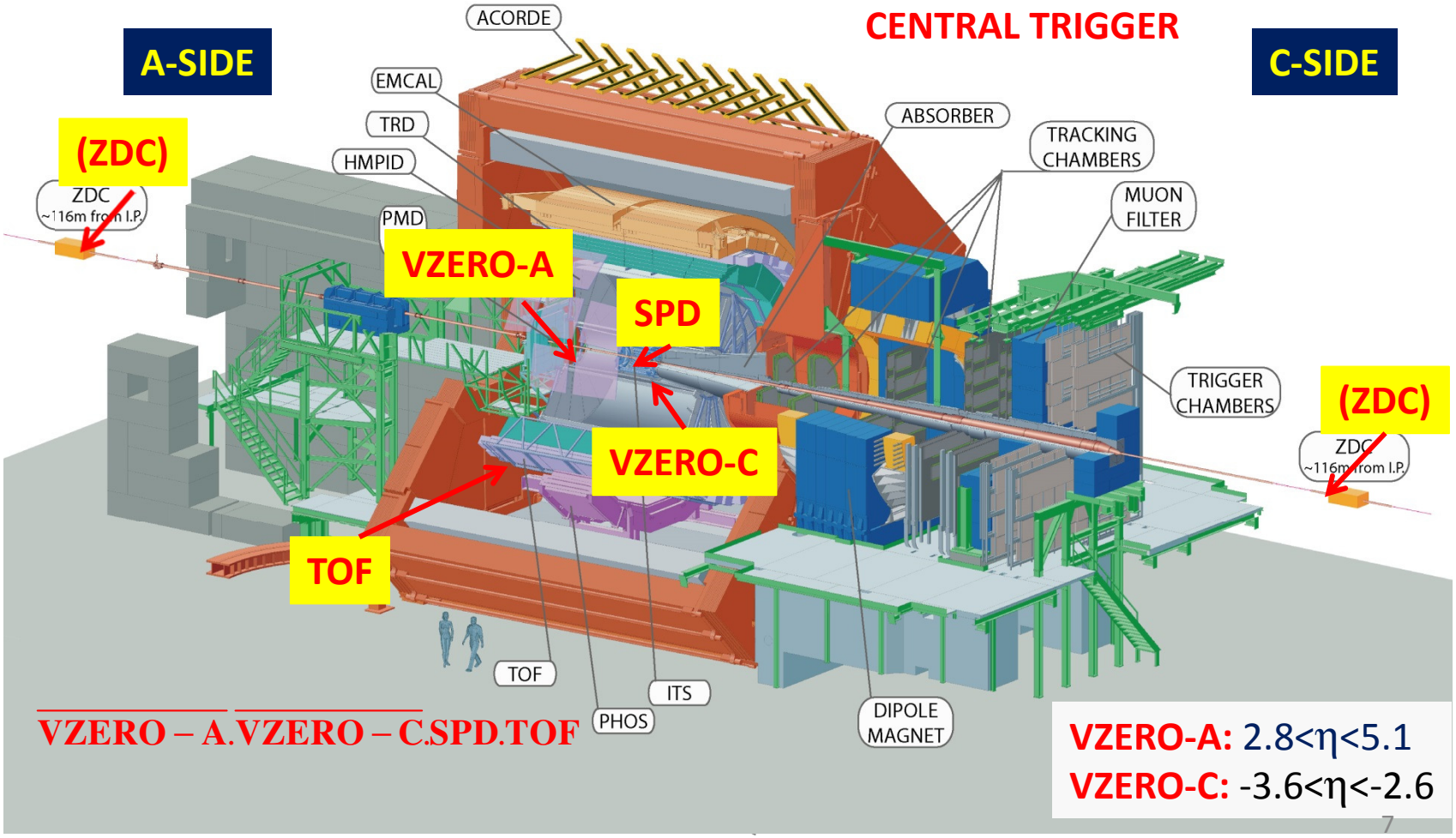
ALICE Apparatus



VZERO-A: $2.8<\eta<5.1$
VZERO-C: $-3.6<\eta<-2.6$

Also **AD** veto counters in Run 2, extending veto to **η~7**

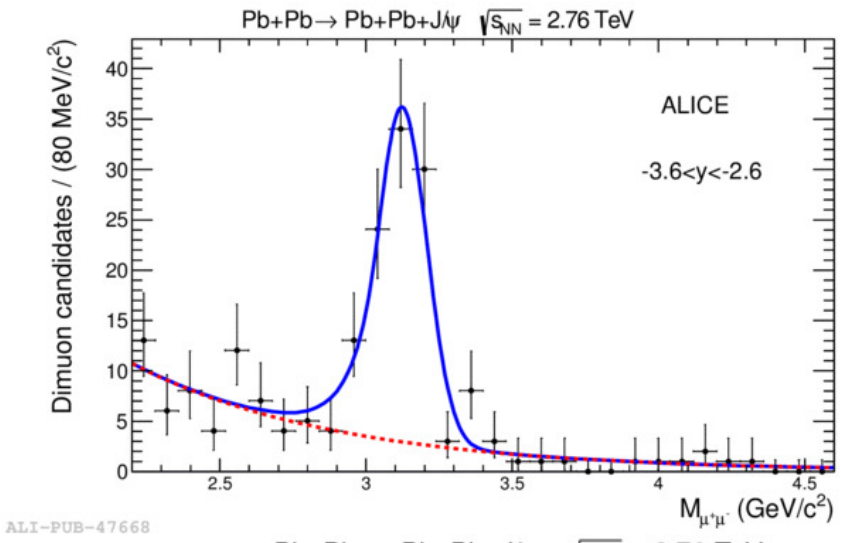
ALICE Apparatus

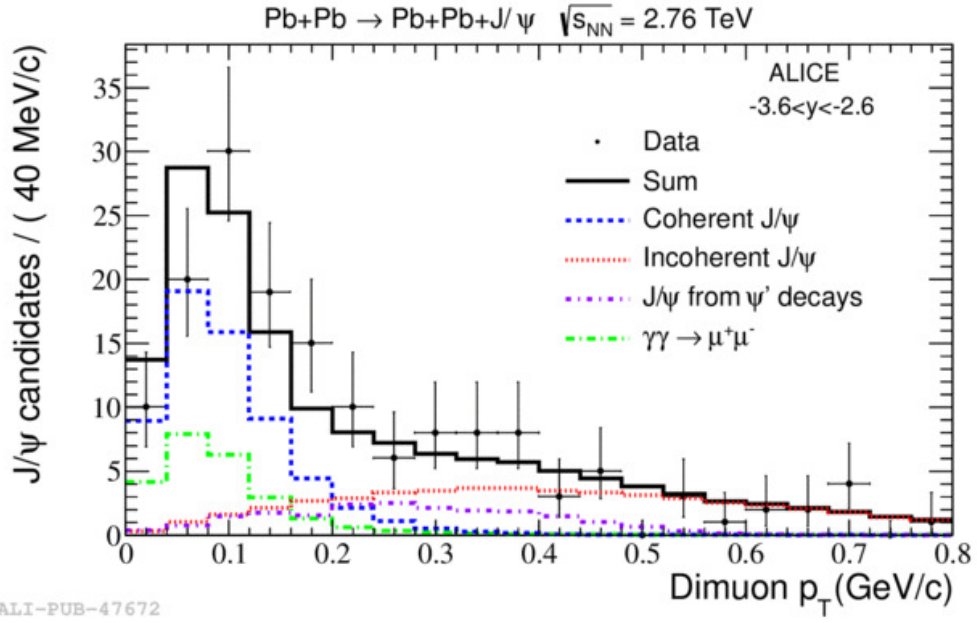


Pb-Pb Measurements

J/ψ forward	B. Abelev et al., Phys. Lett. **B718** (2013) 1273
J/ψ central	E. Abbas et al., Eur. Phys Journal **C73** (2013) 2617
ψ(2S) central	J. Adam et al., Phys.Lett. **B751** (2015) 358
ρ^0 central	J. Adam et al., JHEP **09** (2015) 095

J/ψ production

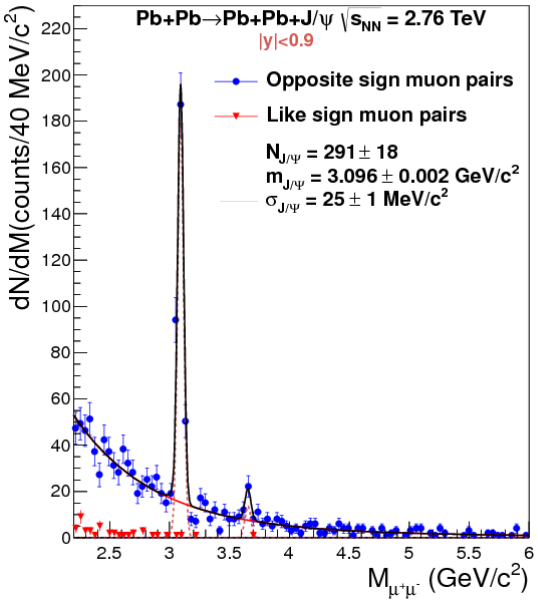


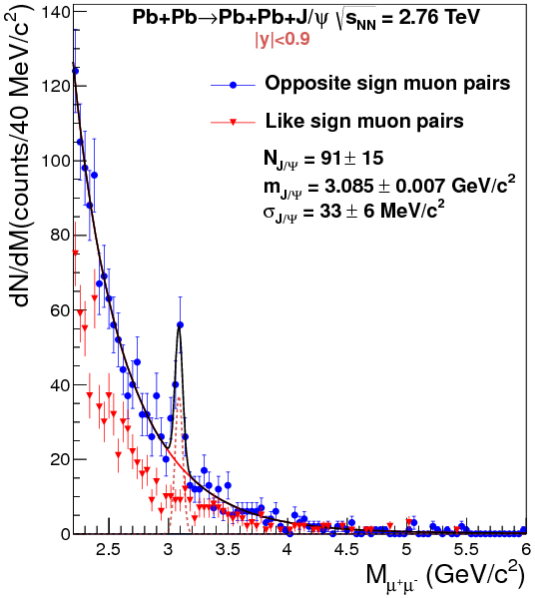


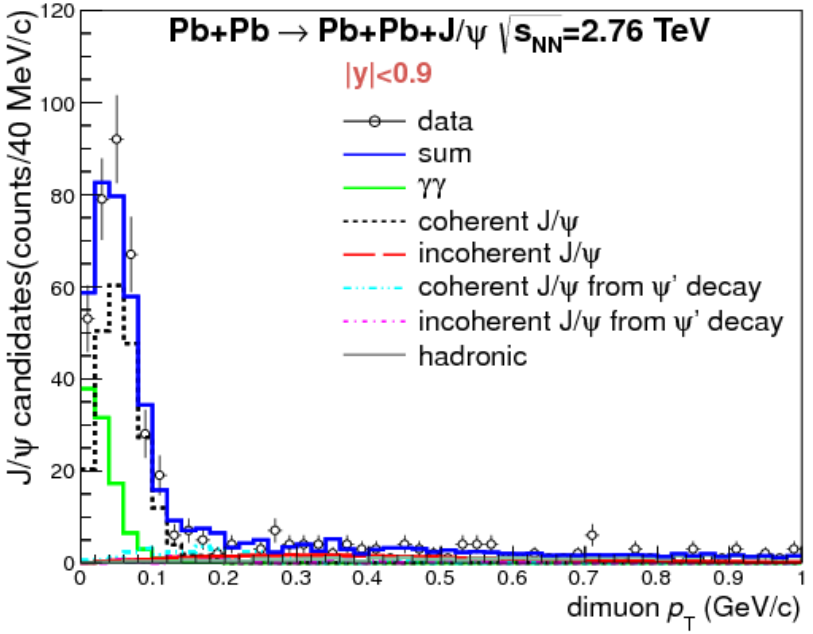
- **Forward** (2.6<y<3.6)
- Clear mass peak on exponentially dropping background
- p_T spectrum for J/ψ candidates shows peak at low p_T corresponding to coherent interactions
  - (Scatter off the whole nucleus.)

B. Abelev et al., Phys. Lett. B718 (2013) 1273

J/ψ Production





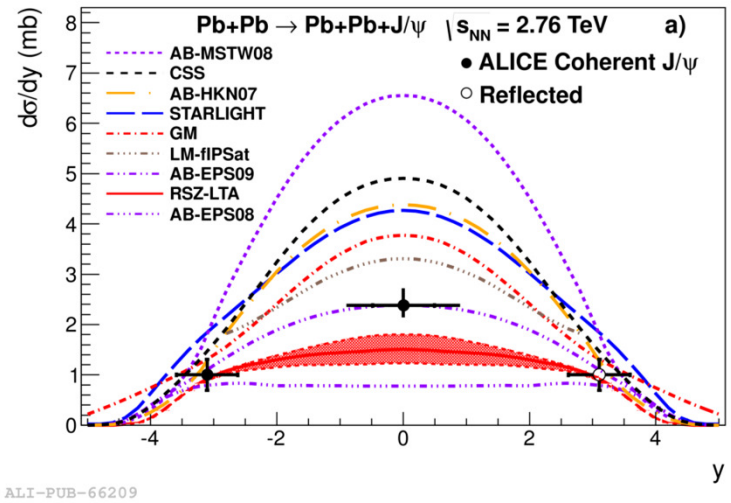


mid-rapidity
(|y|<0.9)

- Much more comprehensive measurements at central rapidities.
- Both dimuon and dielectron channels have been studied.
- Analysis has been carried out both for coherent and incoherent J/ψ production.

E. Abbas et al., Eur. Phys Journal C73 (2013) 2617

J/ψ Production



COHERENT

Agreement is best for models incorporating nuclear gluon shadowing.

- **STARLIGHT: Klein, Nystrand, PRC60 (1999) 014903**
- VDM + Glauber approach where J/ψ+p cross section is
- obtained from a parameterization of HERA data

- • **GM: Gonçalves, Machado, PRC84 (2011) 011902**
- color dipole model, dipole nucleon cross section taken
- from the IIM saturation model

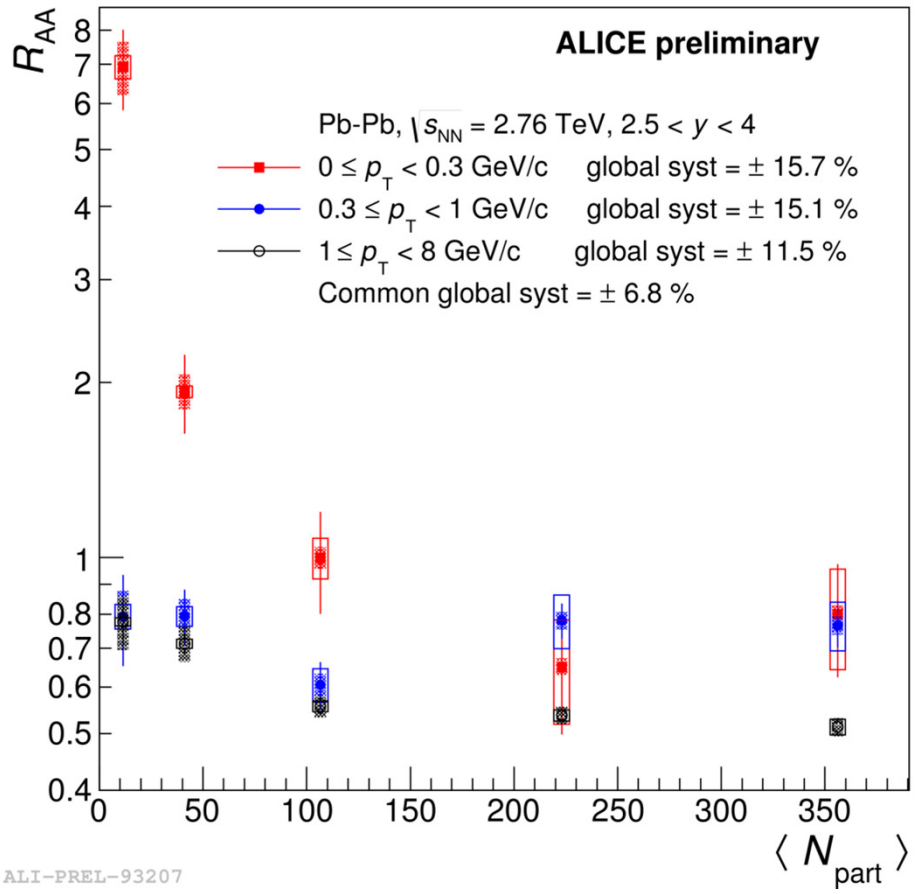
- • **AB: Adeluyi and Bertulani, PRC85 (2012) 044904**
- LO pQCD calculations: AB-MSTW08 assumes no
- nuclear effects for the gluon distribution, other AB
- models incorporate gluon shadowing effects according
- to the EPS08, EPS09 or HKN07 parameterizations

- • **CSS: Cisek, Szczurek, Schäfer, PRC86 (2012) 014905**
- Glauber approach accounting $c\bar{c}g$ intermediate states

- • **RSZ: Rebyakova, Strikman, Zhalov, PLB 710 (2012) 252**
- LO pQCD calculations with nuclear gluon shadowing
- computed in the leading twist approximation

- • **Lappi, Mäntysaari, PRC87 (2013) 032201**: color dipole
- model + saturation

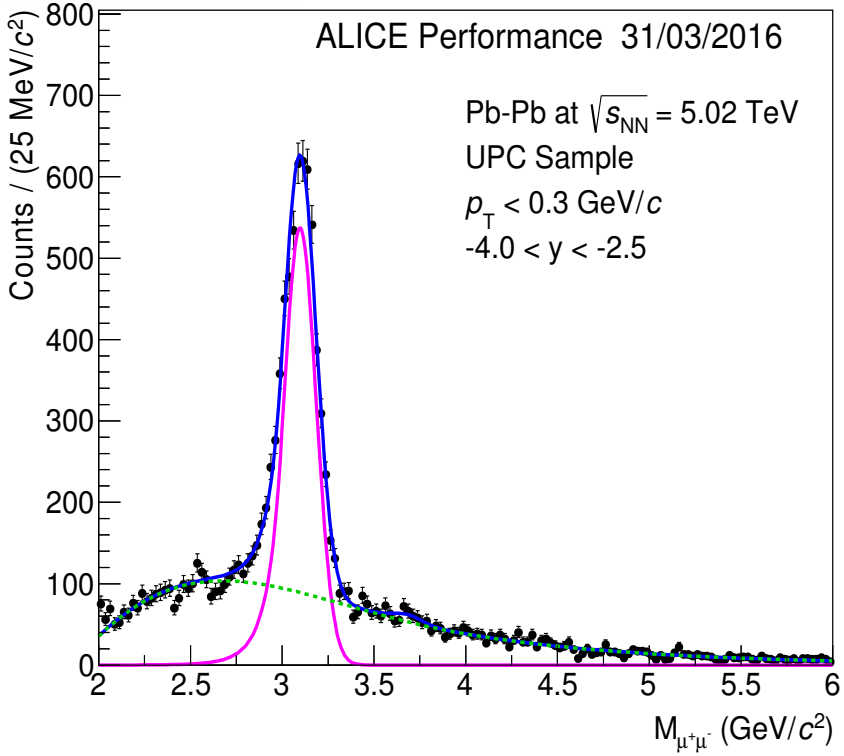
Coherent Production in Peripheral Interactions

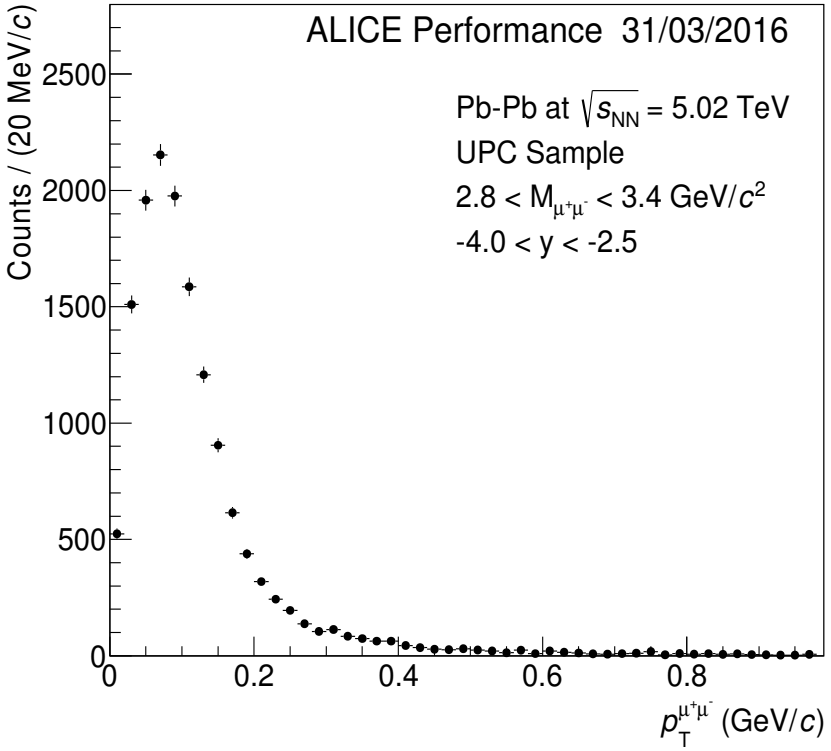


- Coherent production can also occur in *peripheral* collisions ($b<R_1+R_2$)
- Large enhancement seen for $p_T< 0.3$ GeV/c, not explained by normal models for hadronic production
- Magnitude and p_T range consistent with a photonuclear reaction (like with UPC)
- First such observation in hadronic interactions.

J/ψ at 5.02 TeV

Forward (2.5<y<4.0)

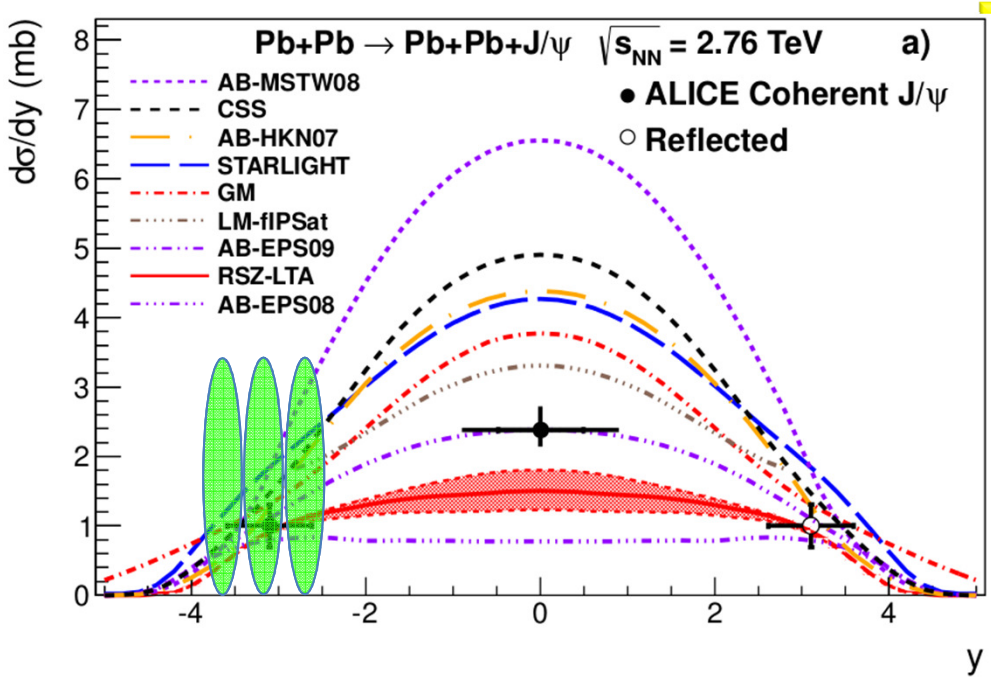




2015 Pb-Pb ANALYSIS IN PROGRESS

- p_T < 0.3 GeV/c to select coherent J/ψ
- Modified trigger requirements extend rapidity range
- **~50 times as many J/ψs as Run 1 analysis**

New analysis plans



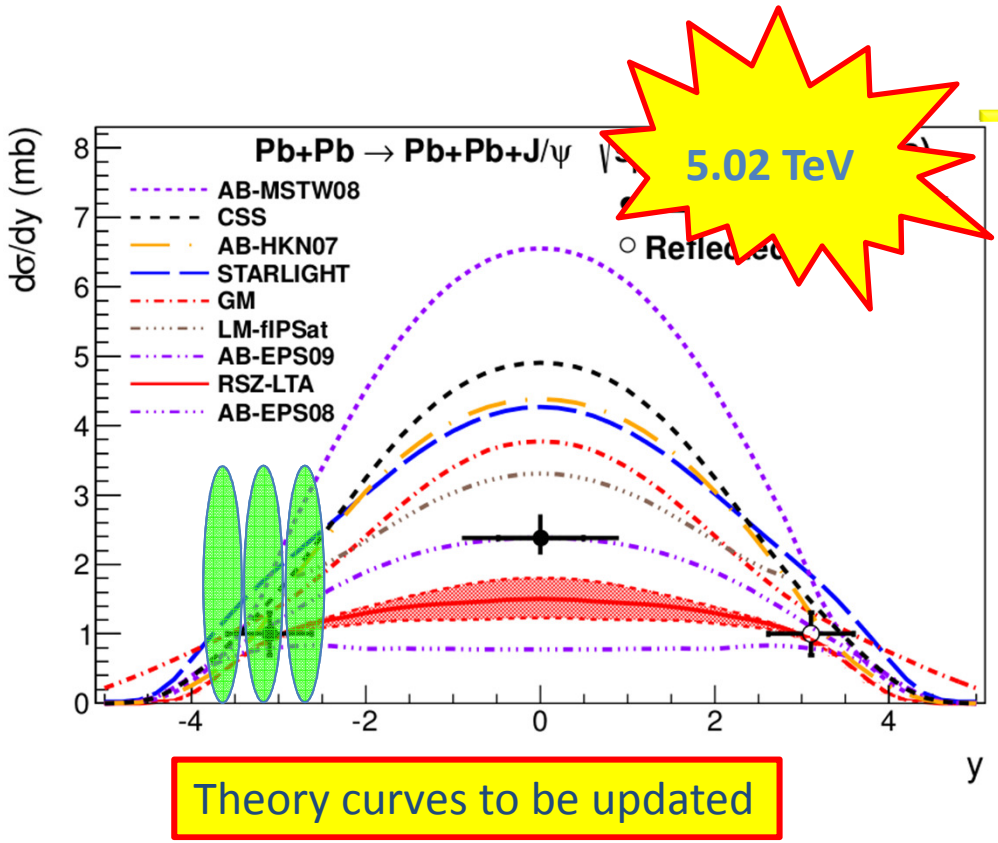
Run 2 data allow cross sections to be measured in **3 bins** of forward rapidity

Predictions so far made by:

- Guzey *et al* (arXiv:1602.01456v2)
- Thomas *et al* (arXiv:1603.01919v1)
- STARLIGHT (http://starlight.hepforge.org)
- Lappi & Mantysaari (Phys.Rev.C87 032201)

Analysis well underway!

New analysis plans



Theory curves to be updated

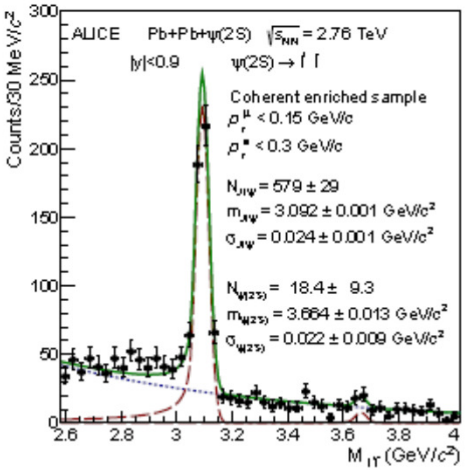
Run 2 data allow cross sections to be measured in **3 bins** of forward rapidity

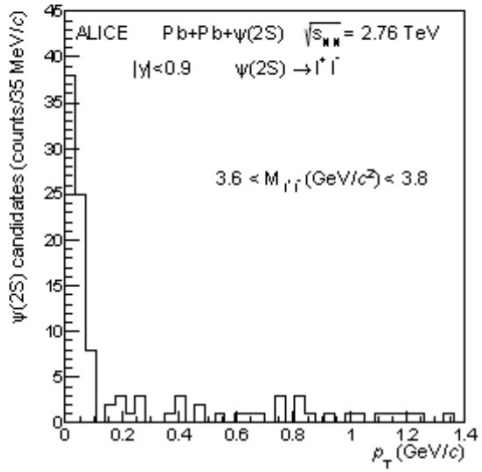
Predictions so far made by:

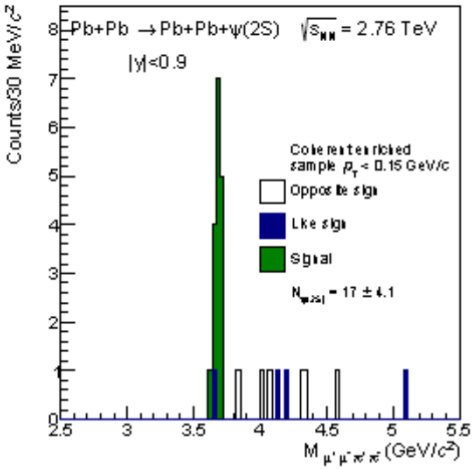
- Guzey *et al* (arXiv:1602.01456v2)
- Thomas *et al* (arXiv:1603.01919v1)
- STARLIGHT (http://starlight.hepforge.org)
- Lappi & Mantysaari (Phys.Rev.C87 032201)

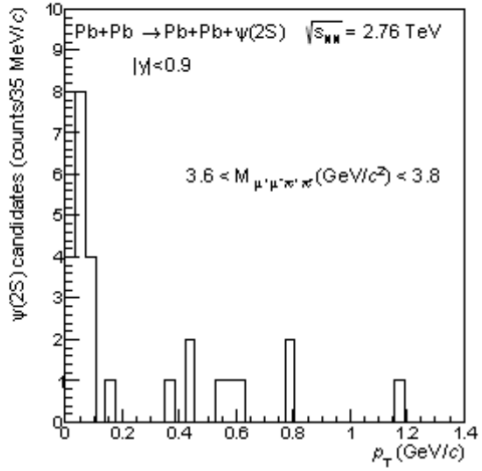
Analysis well underway!

ψ(2S) Production







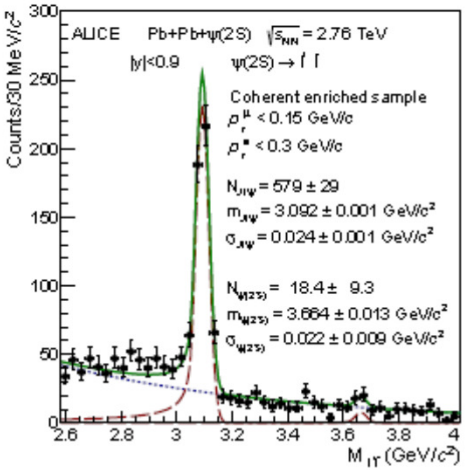


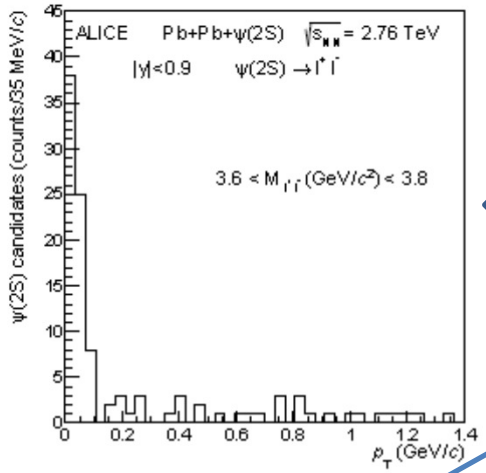
- Several channels used:
  - $\psi(2S) \rightarrow \mu^+\mu^-$
  - $\psi(2S) \rightarrow e^+e^-$
  - $\psi(2S) \rightarrow J/\psi\pi^+\pi^-$; $J/\psi \rightarrow \mu^+\mu^-$
  - $\psi(2S) \rightarrow J/\psi\pi^+\pi^-$; $J/\psi \rightarrow e^+e^-$
- Corrected yields checked for consistency

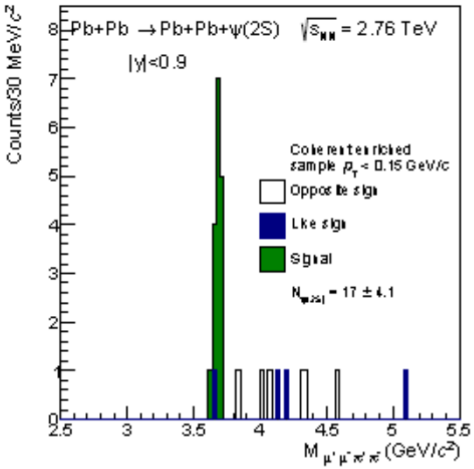
|y|<0.9

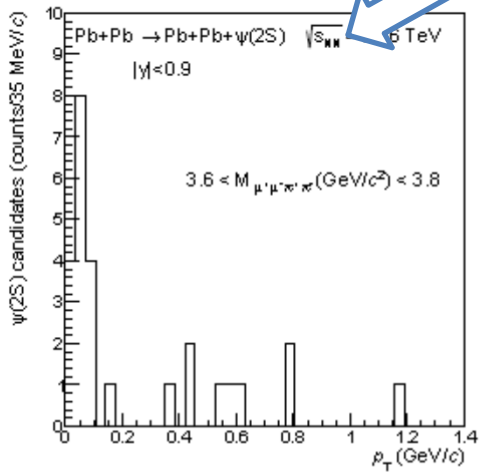
Phys. Lett. B751 (2015) 358

ψ(2S) Production









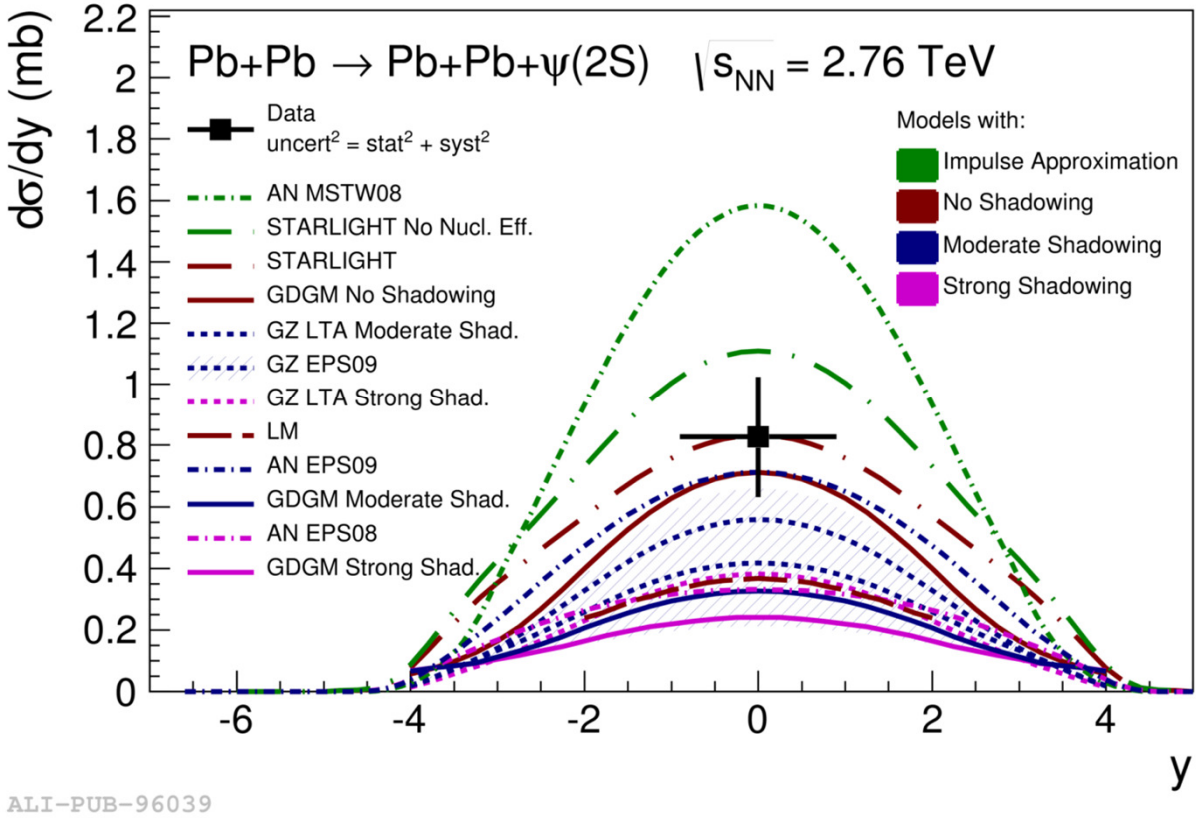
- Several channels used:
  - ψ(2S)→$\mu^+\mu^-$
  - ψ(2S)→e^+e^-
  - ψ(2S)→J/ψ$\pi^+\pi^-$; J/ψ→$\mu^+\mu^-$
  - ψ(2S)→J/ψ$\pi^+\pi^-$; J/ψ→e^+e^-

Corrected yields checked for consistency

|y|<0.9

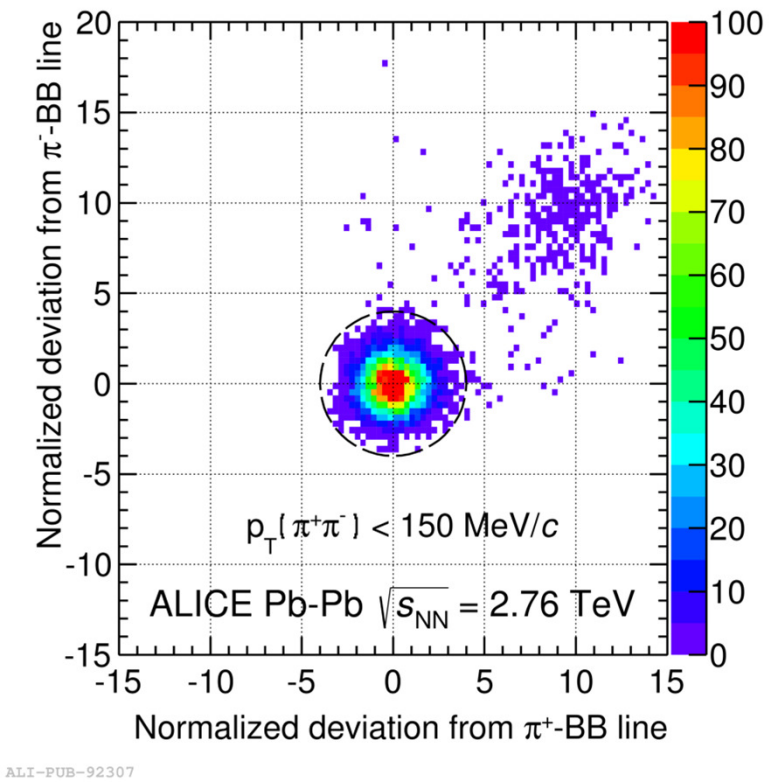
Phys. Lett. B751 (2015) 358

ψ(2S) Production



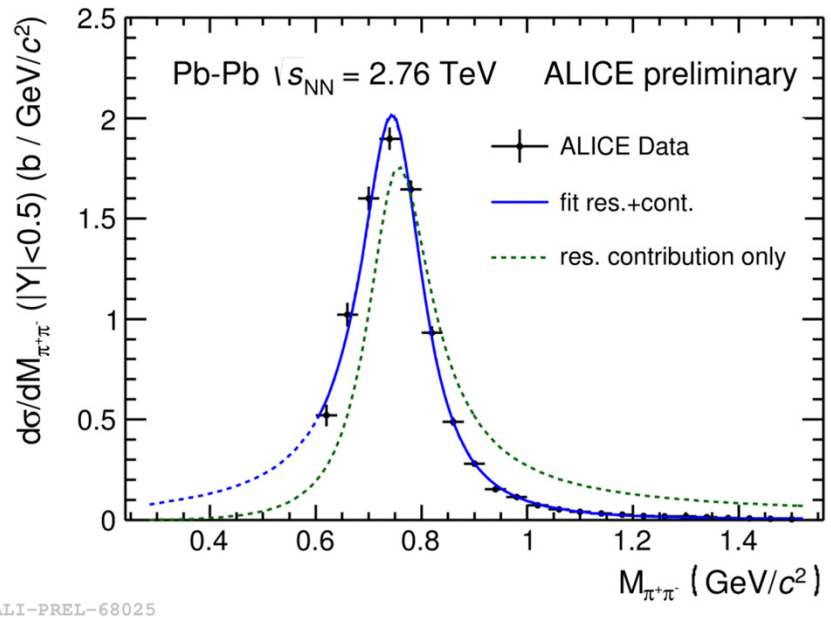
- First measurement of ψ(2S) production at LHC energies
- Models with moderate shadowing favoured.

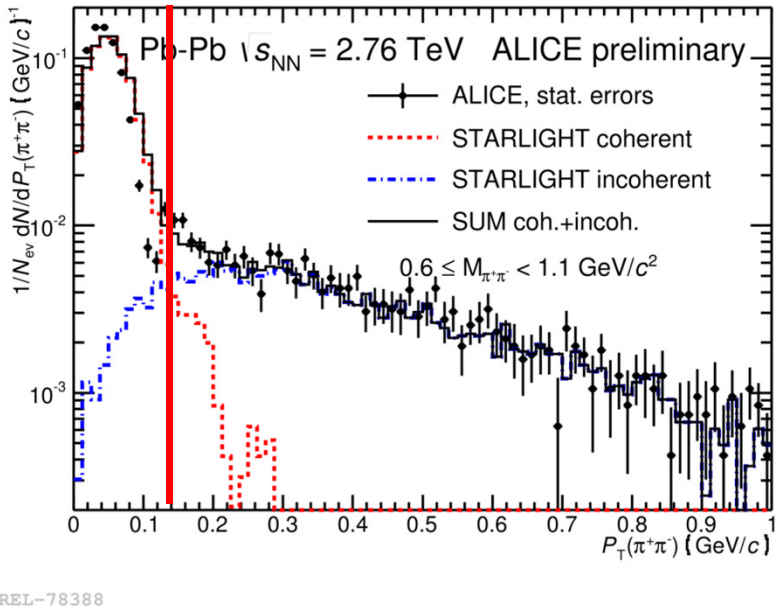
ρ^0 Production



- Measure decay $\rho^0 \rightarrow \pi^+\pi^-$ at mid-rapidity.
- Pions selected by d*E*/d*x*. Good separation between pions and electrons.

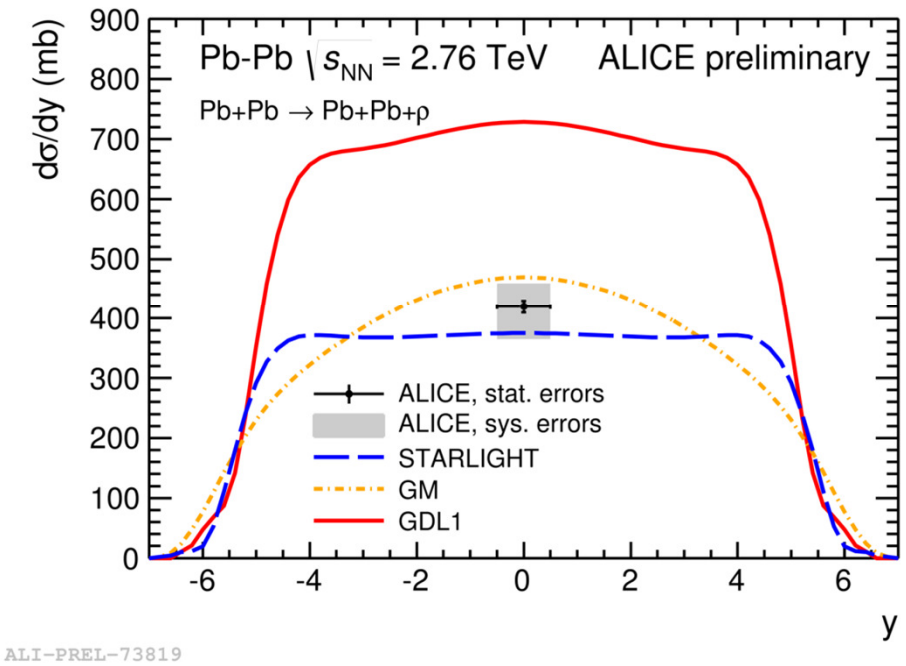
ρ^0 Production

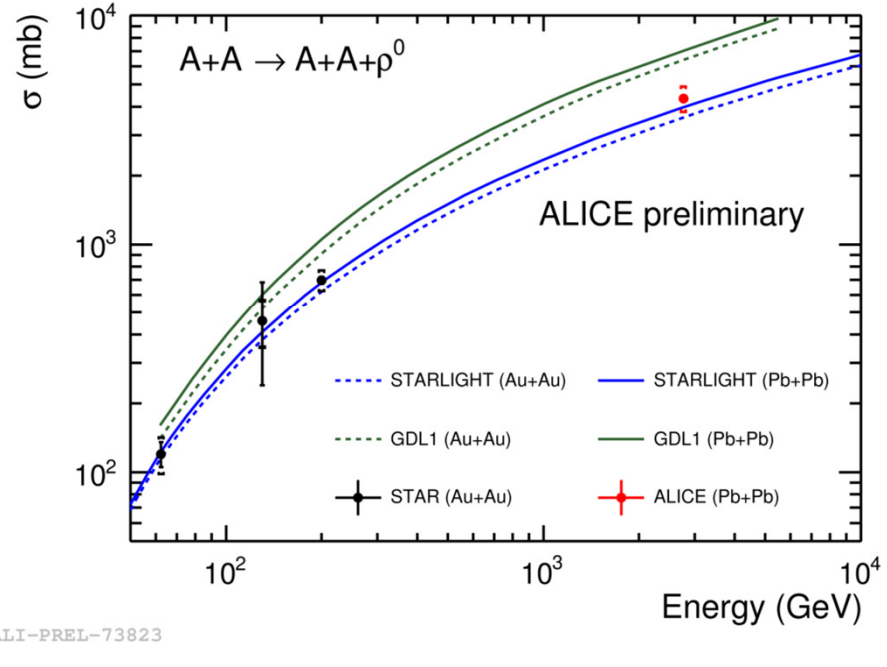




- ρ^0 shape described with either Söding (B.E.) correction or Ross-Stodolsky form.
- Coherent sample selected using $p_T < 150$ MeV/c cut

ρ^0 Production





- First measurement of mid-rapidity d*N*/d*y* at LHC (consistent with GM (colour dipole) and STARLIGHT)
- Energy dependence consistent with STARLIGHT

Summary

- Ultra-peripheral production of vector mesons studied for several different meson species (J/ψ, $\psi(2S)$ and ρ^0)
- Data for J/ψ and $\psi(2S)$ consistent with moderate nuclear shadowing
- STARLIGHT in good agreement with $\psi(2S)$ and ρ^0 dN/dy, describes ρ^0 energy dependence but overpredicts J/ψ.
- Much more data on all vector mesons to come from Run 2.