

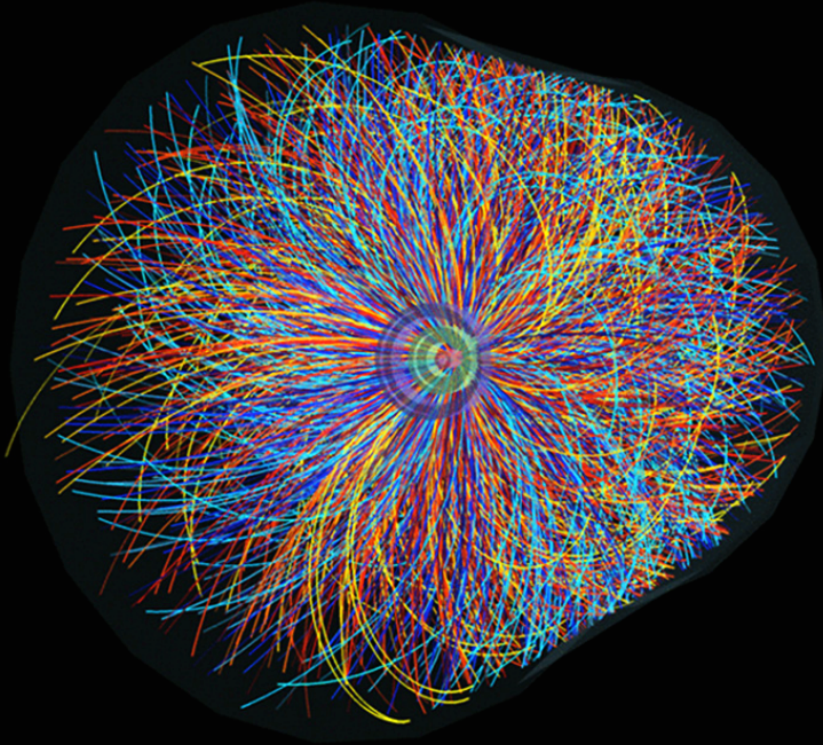
# Ultrapерipheral Physics at ALICE

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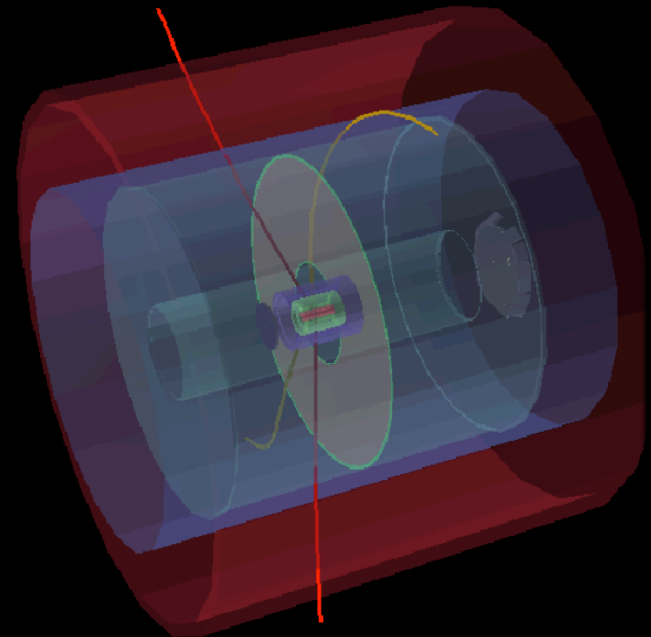


# Central vs. Ultraperipheral Collisions

Central

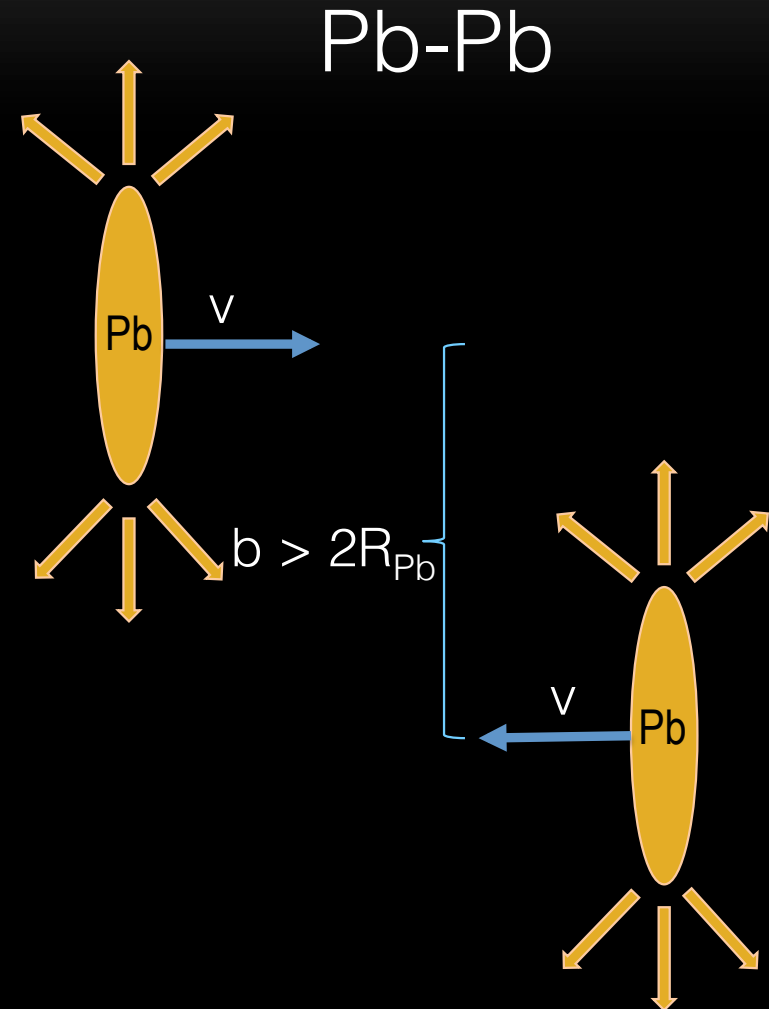


Ultraperipheral



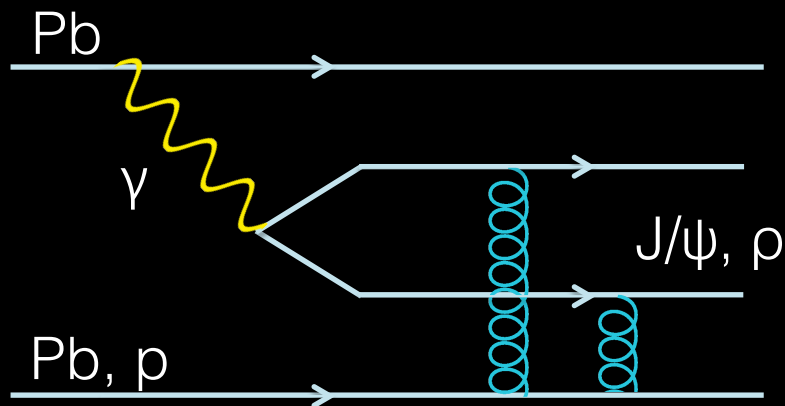
# Ultrapерipheral Collisions

- Impact Parameter :
  - $b > R_1 + R_2$
- Weizäcker-Williams (Fermi)
  - Treatment of electromagnetic field as flux of virtual photons
  - Virtual photon flux  $\rightarrow Z^2$
  - Hadronic interaction is strongly suppressed

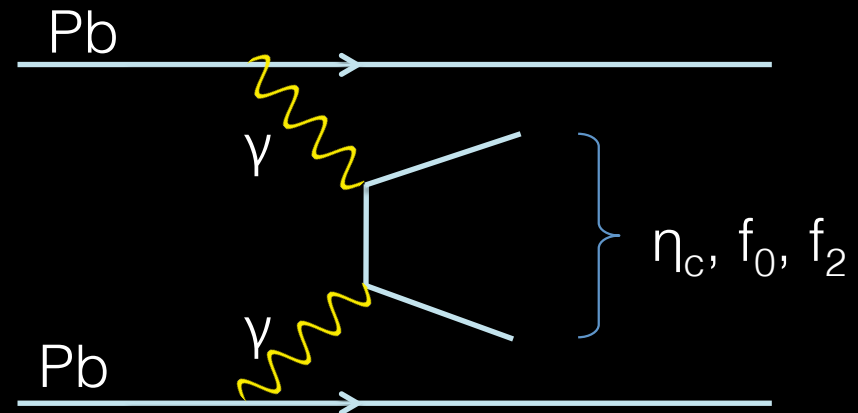


# Types of UPC Interactions

## Photonuclear

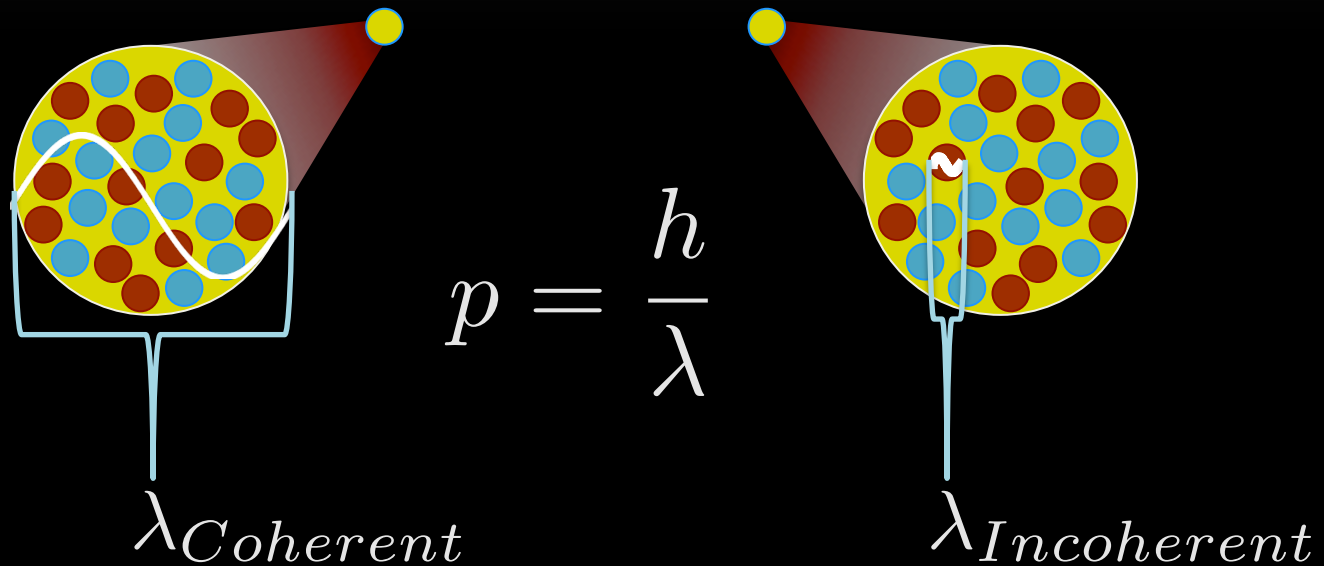


## Two-photon



- Two gluons can be exchanged without color transfer
  - Exchange of a Pomeron

# Photon Source



## Coherent Production

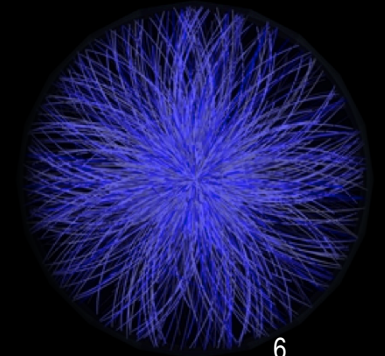
- Photon couples to nucleus
- Very low  $p_T$

## Incoherent Production

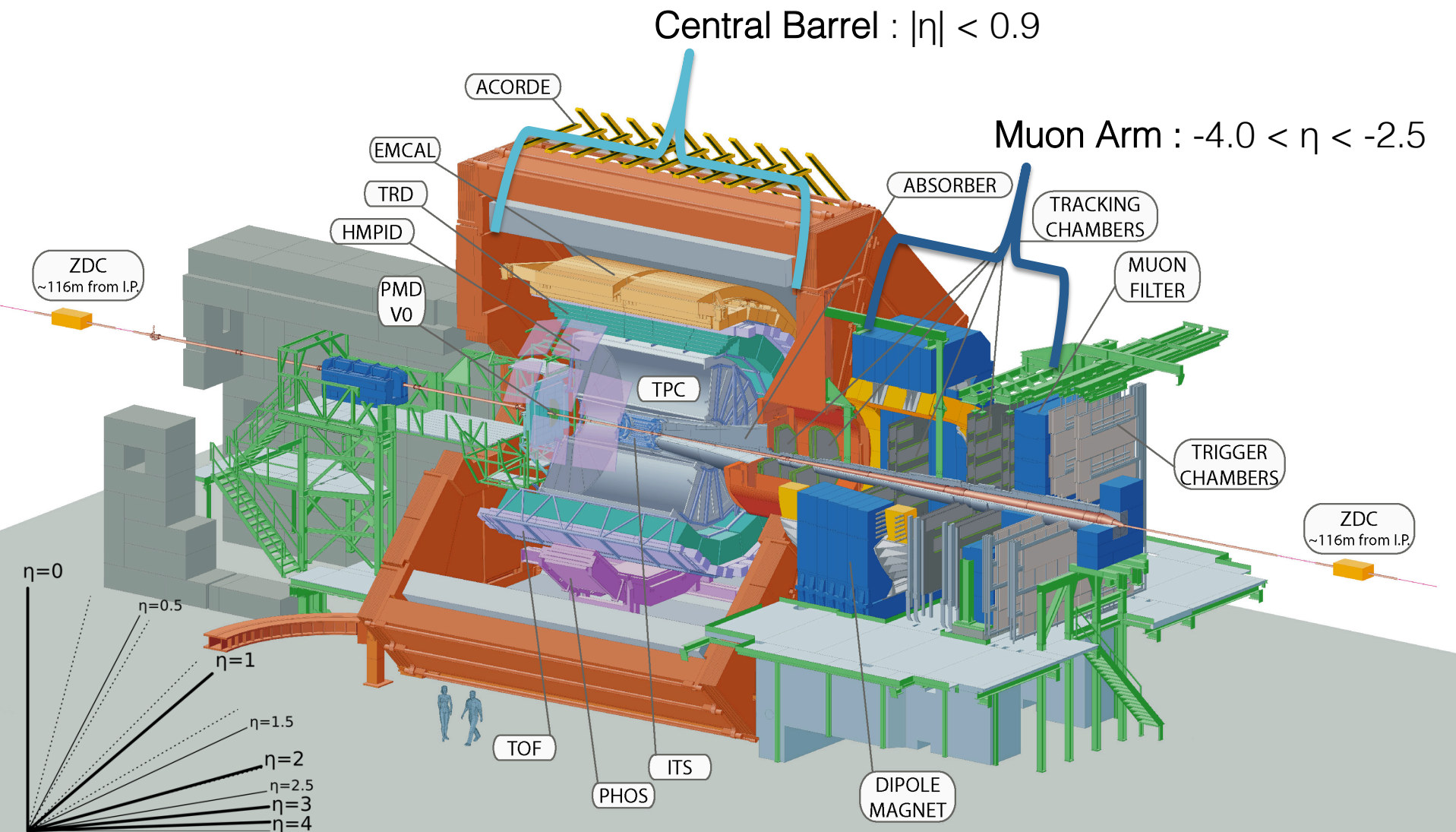
- Photon couples to part of the nucleus
- Larger  $p_T$

# Motivation

- Higher virtual photon density at LHC
- Probe our understanding of very intense electric fields – QED
- Meson (Quarkonium) photoproduction
- Provide a clean environment to study nuclear structure
  - Nuclear gluon shadowing (Pb-Pb)
  - Nuclear parton distribution (p-Pb)
- Opportunity to search for exotic particles



# ALICE



Excellent low  $p_T$  performance :  $0.1 \text{ GeV}/c \leq p_T \leq 100 \text{ GeV}/c$  7

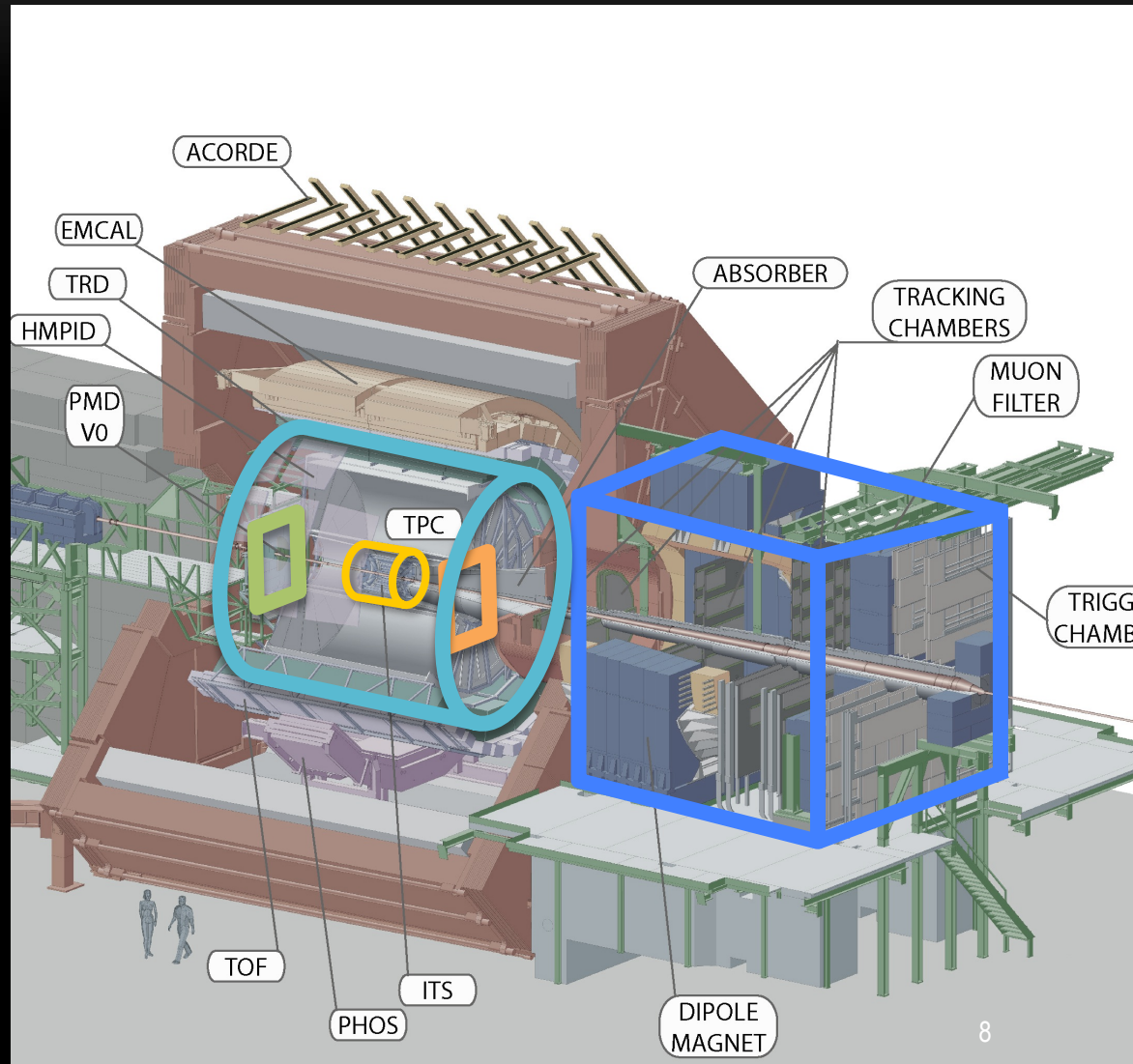
# UPC Trigger

## Central Barrel Trigger

- **TOF**  $\geq 2$  hits
  - 2 back-to-back in  $\phi$
- **SPD**  $\geq 2$  hits
- **VZERO-C** – Veto
  - $-3.7 < \eta < -1.7$
- **VZERO-A** – Veto
  - $2.8 < \eta < 5.1$

## Forward Trigger

- **Muon Arm**  $\geq 1$  unlike sign dimuon candidate
  - Track  $p_T > 0.5$  GeV/c
- **VZERO-C** –  $\geq 1$  cell
- **VZERO-A** – Veto

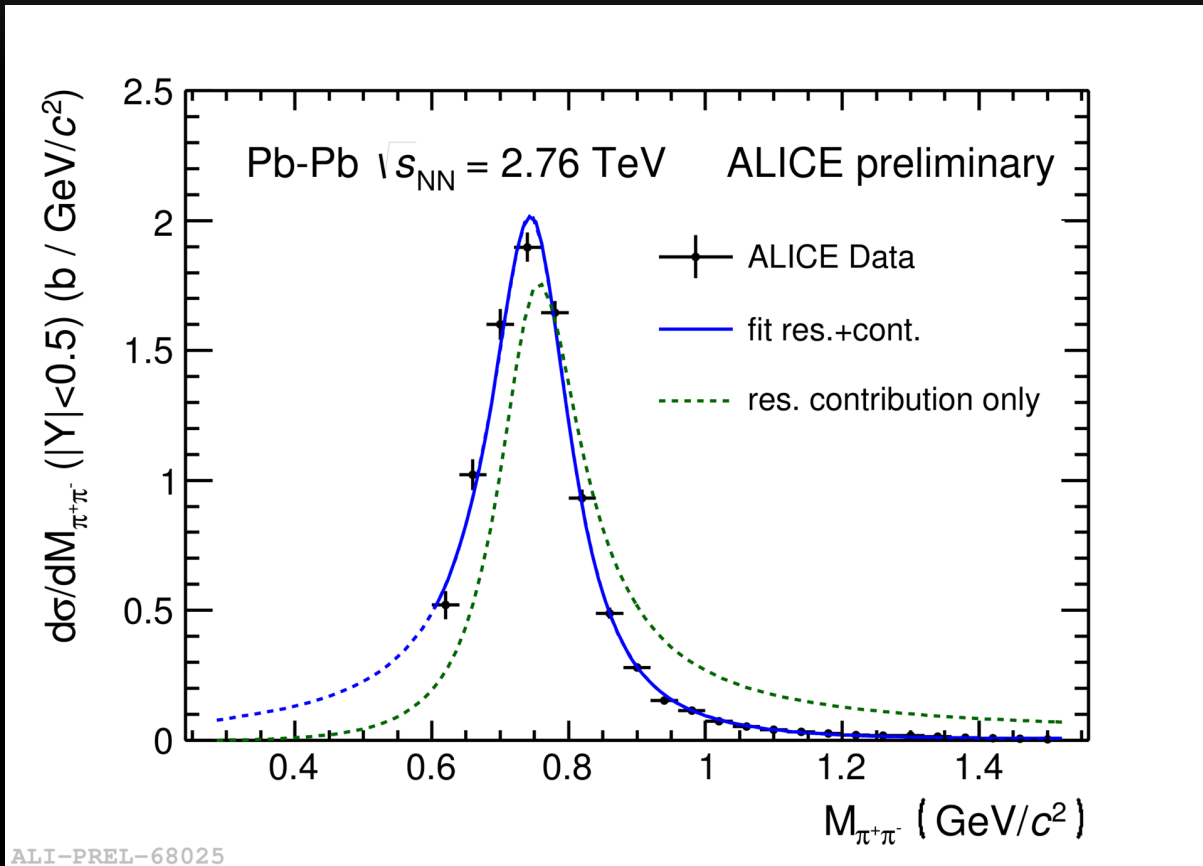




# $\rho^0$ production in Pb-Pb



- $\rho^0 \rightarrow \pi^+ \pi^-$
- Central Barrel Trigger
- Particle Identification:
  - dE/dx in TPC
- Interference with non resonant  $\pi^+ \pi^-$  production.

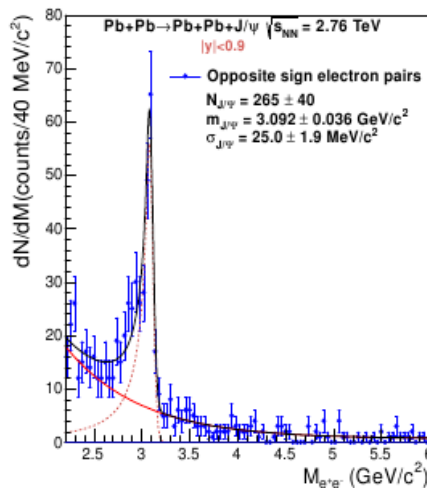
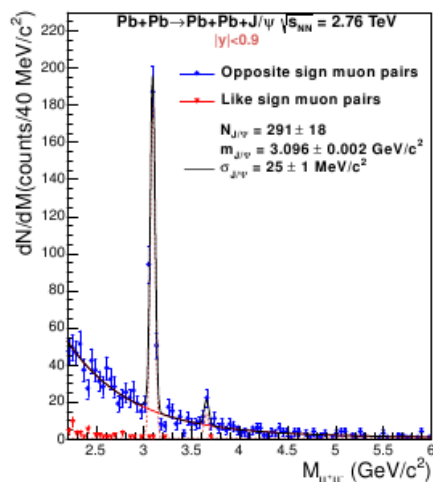


# J/ψ production in Pb-Pb

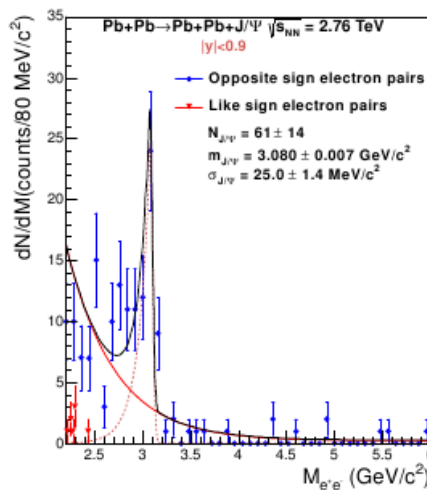
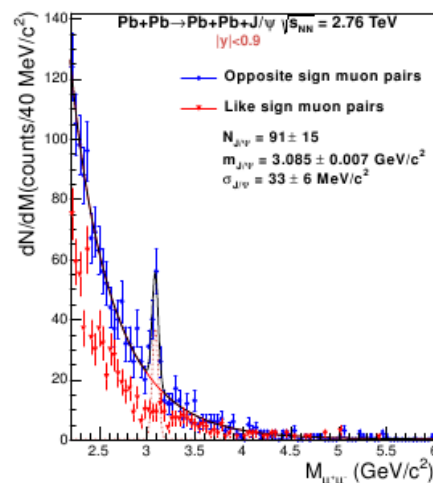
$$J/\psi \rightarrow \mu^+\mu^-$$

$$J/\psi \rightarrow e^+e^-$$

Coherent



Incoherent



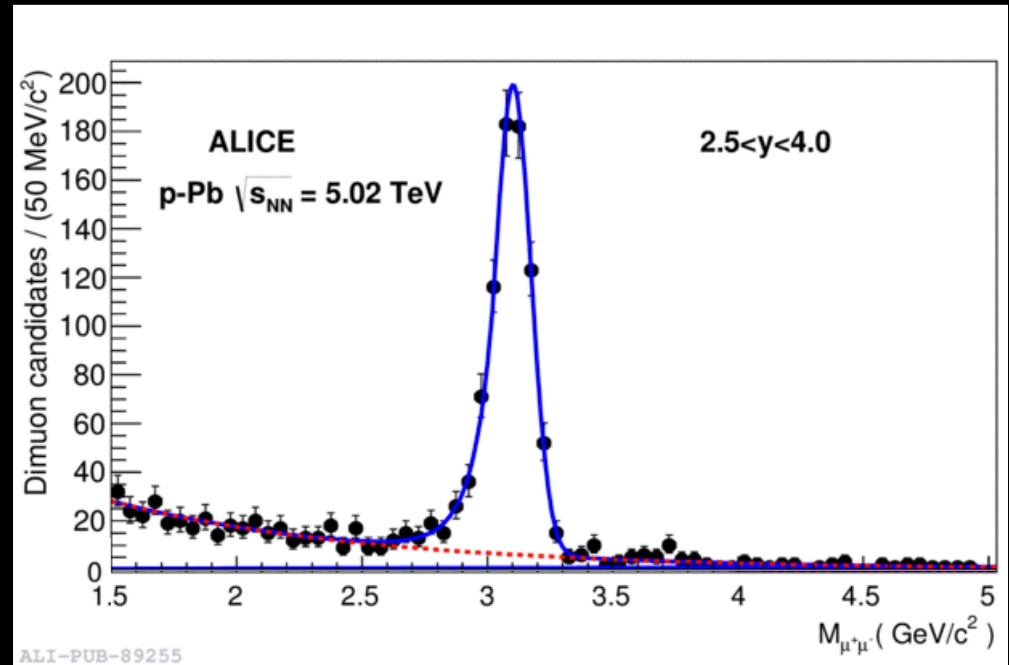
$$Pb + Pb \rightarrow Pb + Pb + J/\psi$$

- **Signal** : Opposite sign charges
- **Background** : Like sign charges
- Central Barrel
- Particle Identification:
  - dE/dx in TPC
- Coherent condition
  - p<sub>T</sub> < 200 MeV/c (muon)
  - p<sub>T</sub> < 300 MeV/c (electron)
  - ZDC < 6 neutrons
- EPJC73 (2013) 2617

# J/ $\Psi$ production in p-Pb



- $\gamma + p \rightarrow \text{J}/\Psi + p$ 
  - $\text{J}/\Psi \rightarrow \mu^+ \mu^-$
  - Pb produces a larger photon flux ( $Z^2$ )
- Muon spectrometer
- arXiv 1406.7819



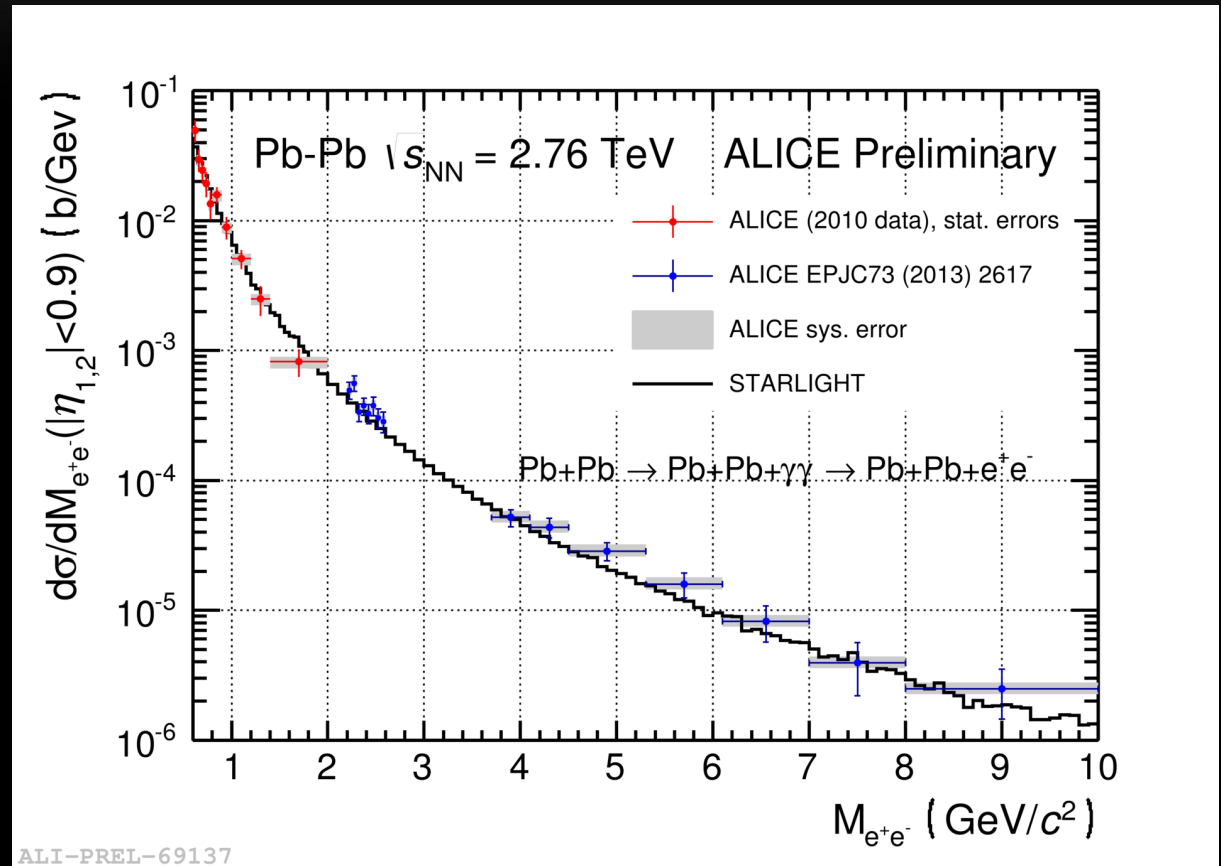
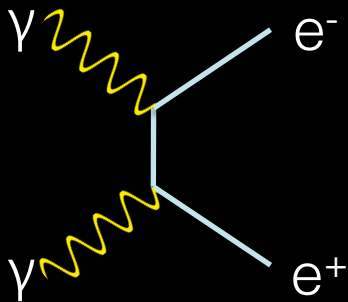
# $e^+ e^-$ production in Pb-Pb



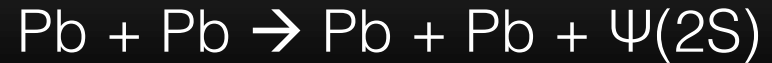
Invariant mass region  
around the  $J/\psi$   
excluded

Particle Identification:  
 $dE/dx$  in TPC

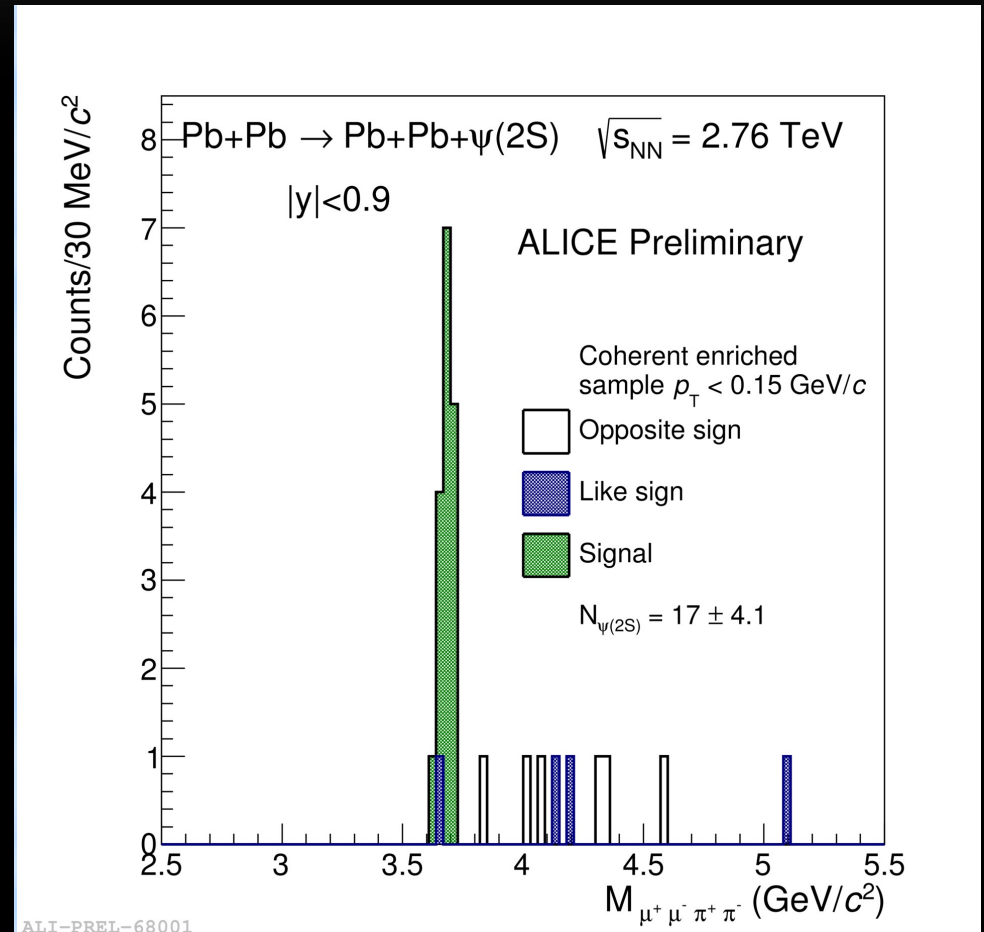
Central Barrel



# $\Psi(2S)$ production in Pb-Pb

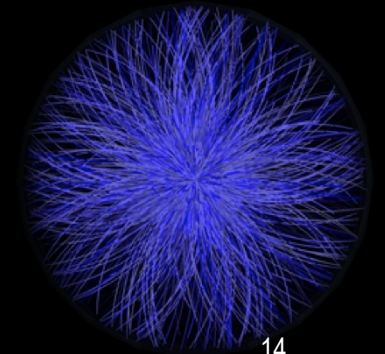


- $\Psi(2S) \rightarrow \text{J}/\Psi \pi^+ \pi^-$ 
  - $\text{J}/\Psi \rightarrow e^+e^-$
  - $\text{J}/\Psi \rightarrow \mu^+\mu^-$
- $\pi^+ \pi^-$ : low  $p_T$
- $\mu^+\mu^-$ ,  $e^+e^-$ : high  $p_T$
- $dE/dx$  in TPC
- $p_T < 0.15 \text{ GeV}/c$



# LHC Run2

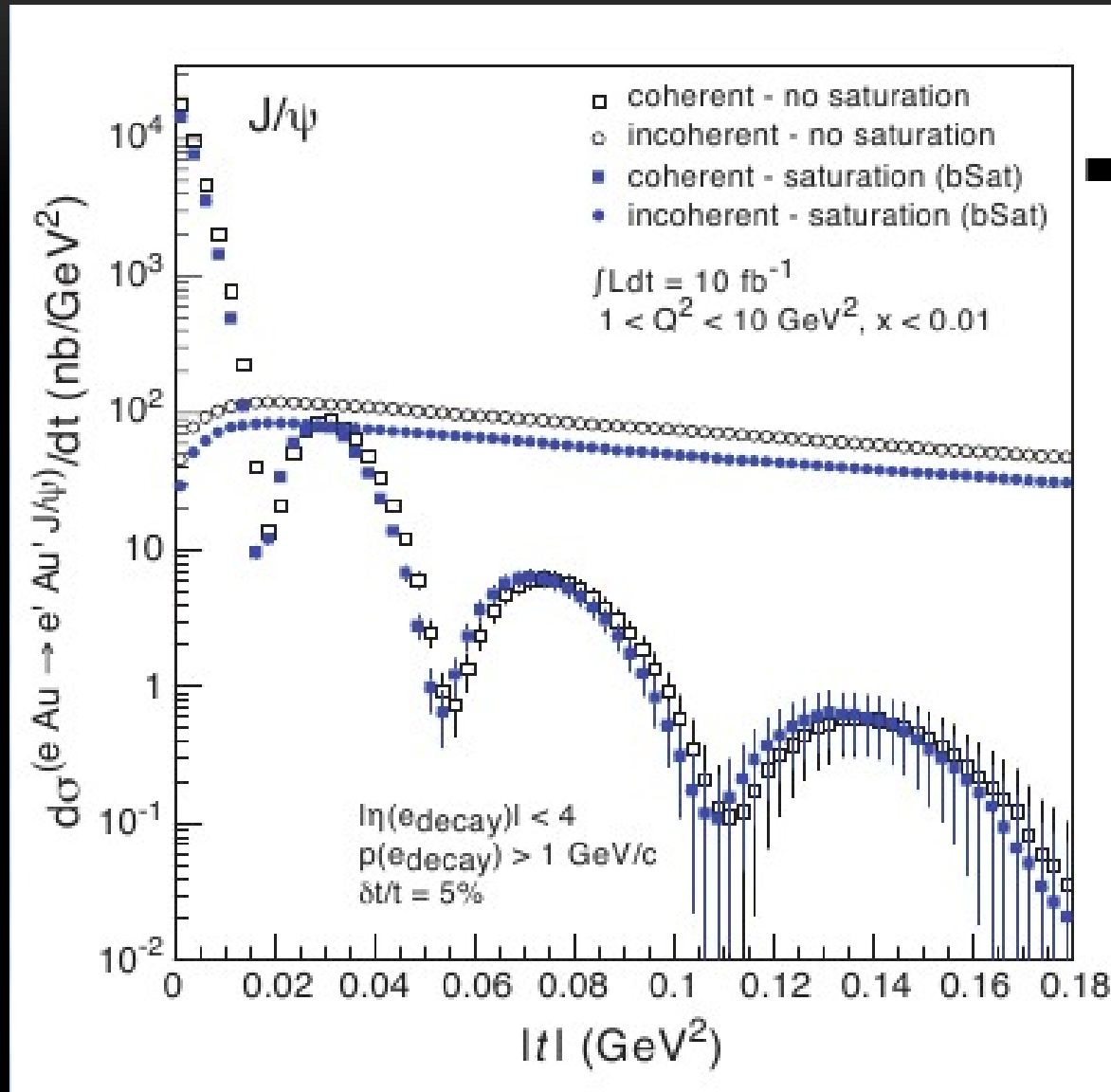
- Higher luminosity
  - Higher statistics in UPCs
- Measurements for gamma-gamma to spin 0 and spin 2 states
  - $\gamma\gamma \rightarrow \eta_c$
  - $\gamma\gamma \rightarrow f_2$
  - $\gamma\gamma \rightarrow f_0$
- Search for exotic states



# Backup

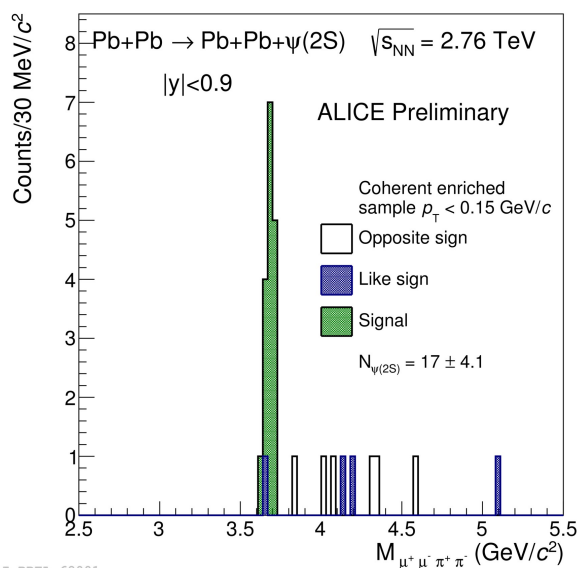
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# Coherent vs. Incoherent

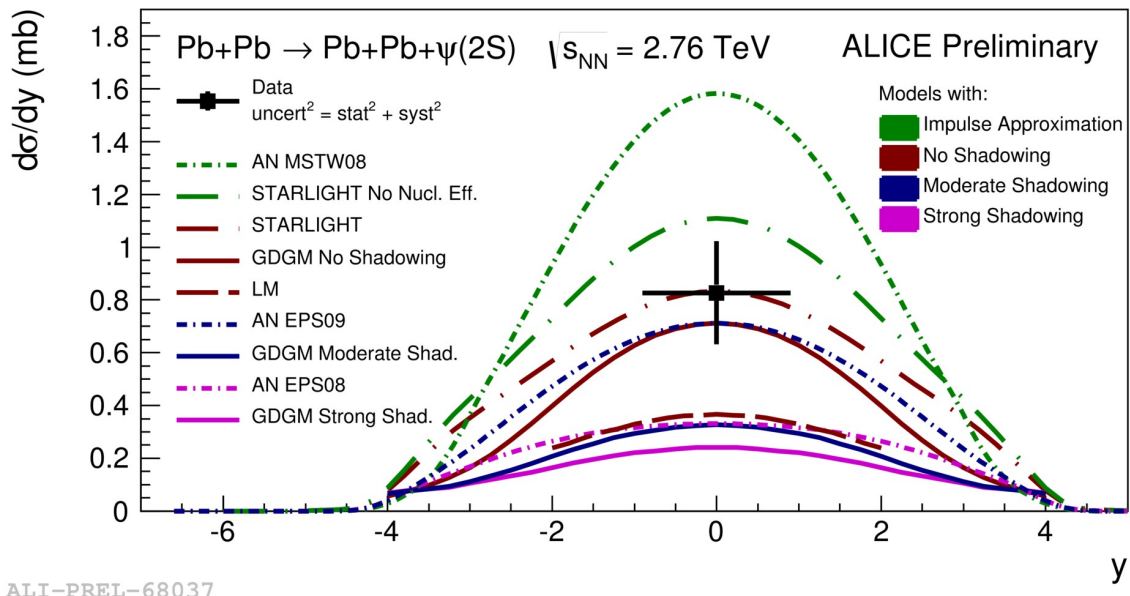




# $\Psi(2S)$ – Cross Section

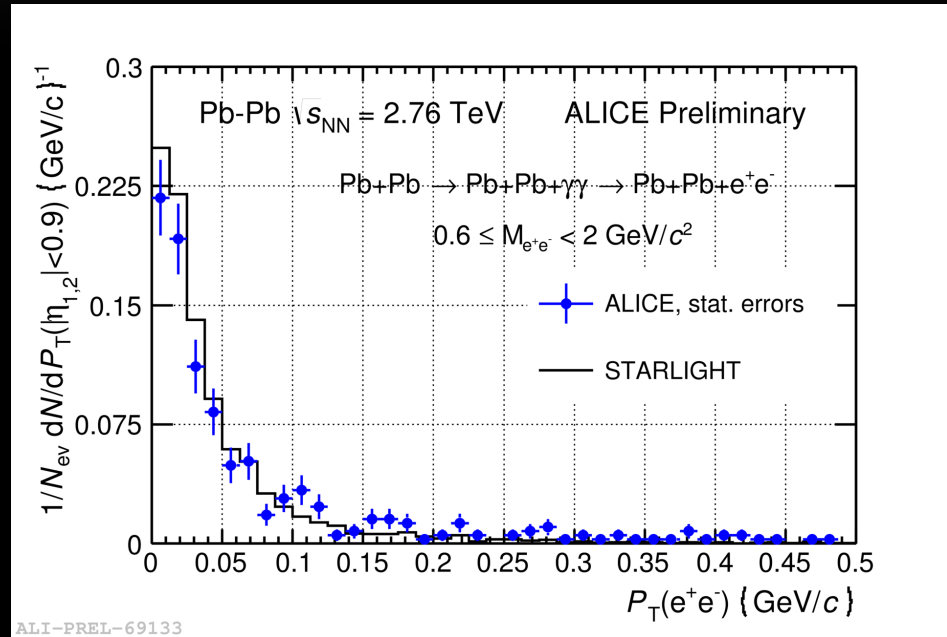
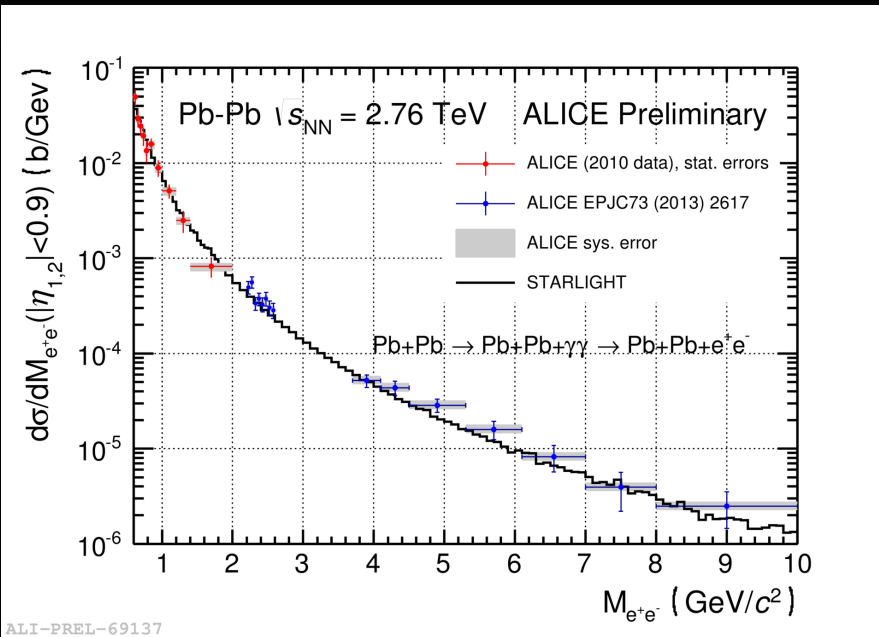


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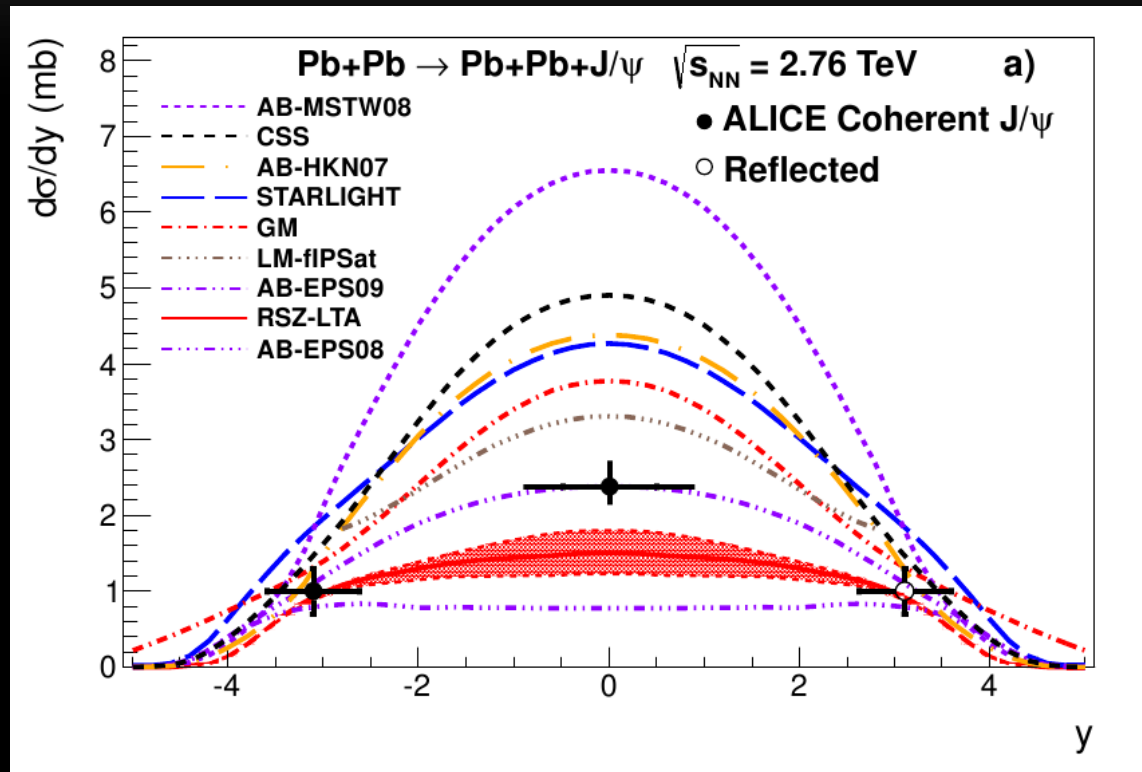
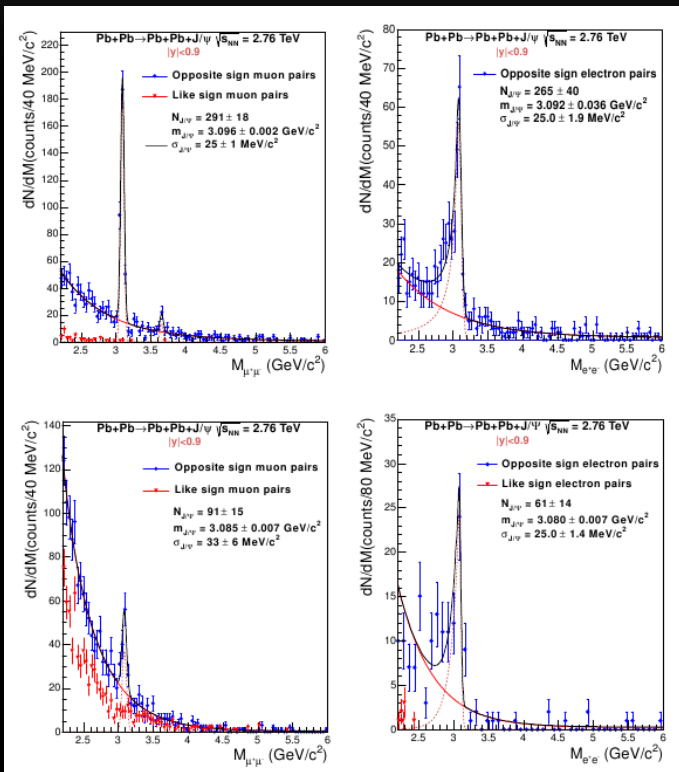


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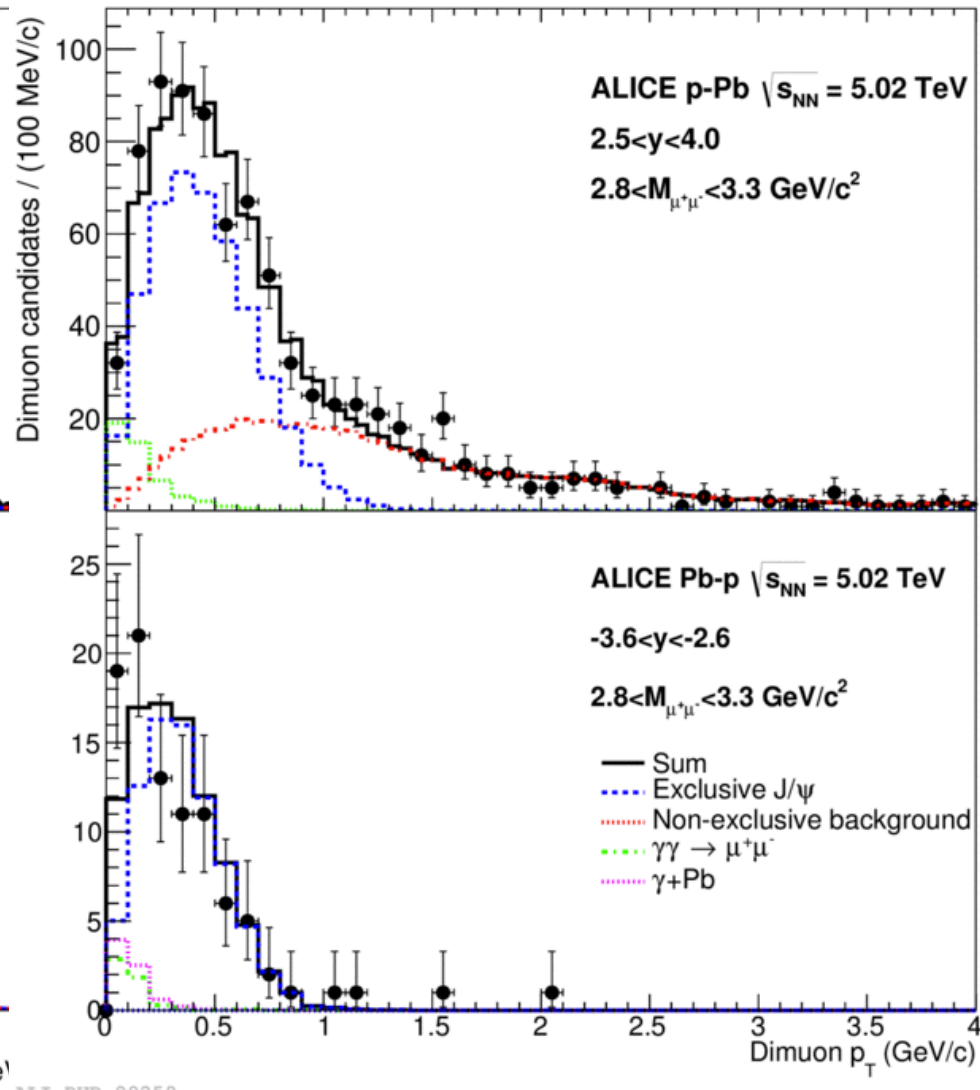
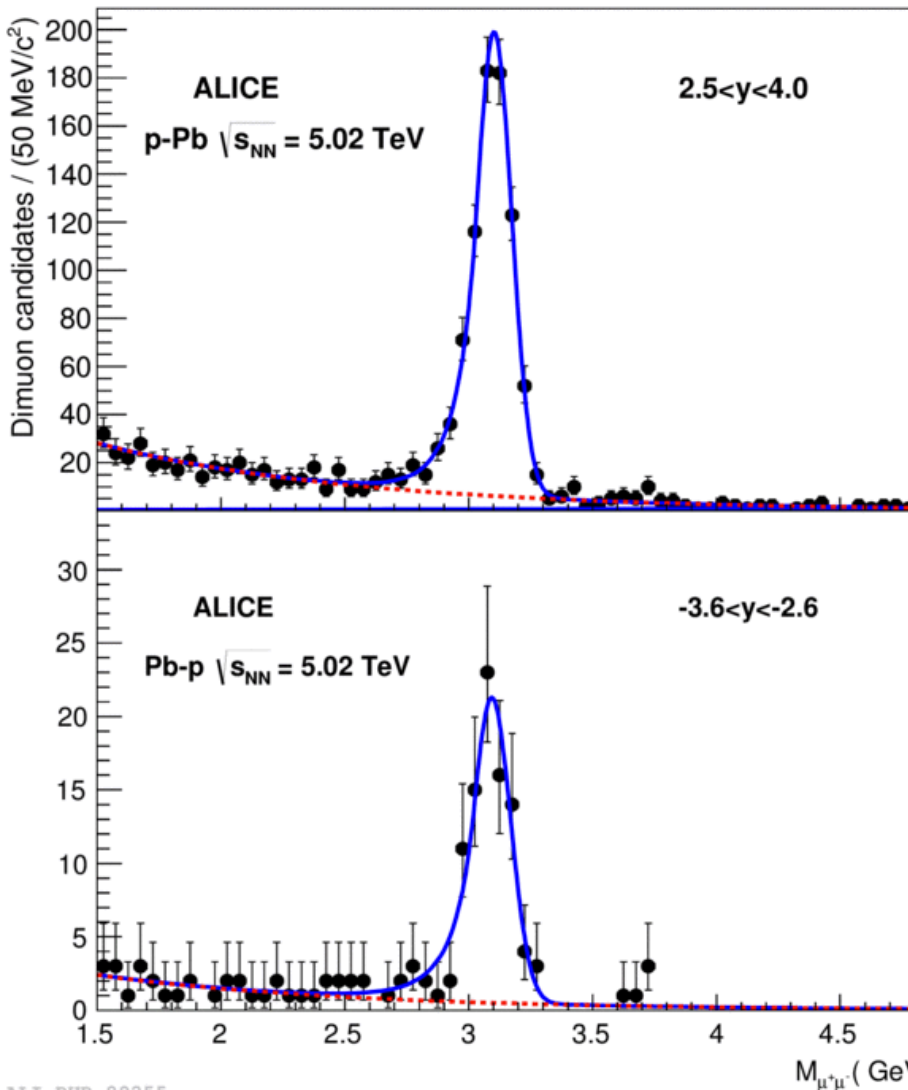
# $e^+e^-$ – Transverse Momentum



# J/ψ – Cross Section – Comparison of Models



# J/ψ – Invariant Mass p–Pb



# $\rho_0$ – Cross Section

