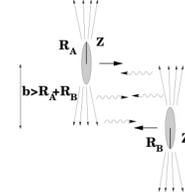


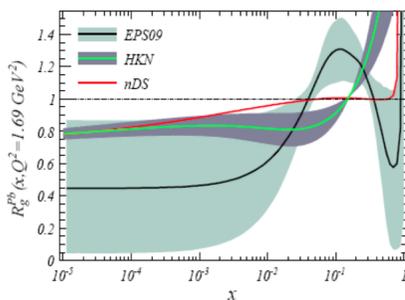
## Physics motivation

- Ultra-peripheral heavy ion collisions (UPC)
  - experimental opportunity to create high energy photonuclear reactions ( $\sqrt{s_{NN}} \sim 500$  GeV)
  - impact parameter  $b$  larger than sum of nuclear radii
  - hadronic interactions suppressed, but strong electromagnetic field
- Virtual photons by Weizsäcker-Williams method
  - field of quasi-real photons with low virtuality  $\sim 1/R_{Pb} = 30$  MeV/c
  - photon spectrum



$$\frac{d^3 N_\gamma}{dk d^2 r} = \frac{Z^2 \alpha w^2}{\pi^2 k r^2} \left[ K_0^2(w) + \frac{1}{\gamma_L^2} K_1^2(w) \right]$$

where  $K_0$  and  $K_1$  are modified Bessel functions,  $r$  the impact parameter of the two colliding ions boosted with a Lorentz factor  $\gamma_L$  and  $w = kr/\gamma_L$



- Nuclear gluon distribution at low Bjorken- $x$ 
  - pQCD, two-gluon exchange with no net color transfer
  - for an exclusive  $J/\psi$  produced in  $-3.6 < y < -2.6$ , Bjorken- $x = \frac{M_{J/\psi}}{\sqrt{s_{NN}}} e^{-y}$  takes values  $x \sim 10^{-2}$  or  $x \sim 10^{-5}$ , depending on the direction of the nucleus emitting the photon
  - exclusive vector meson production in heavy-ion interactions is expected to probe nuclear gluon distribution at low- $x$  where gluon shadowing effect could be relevant

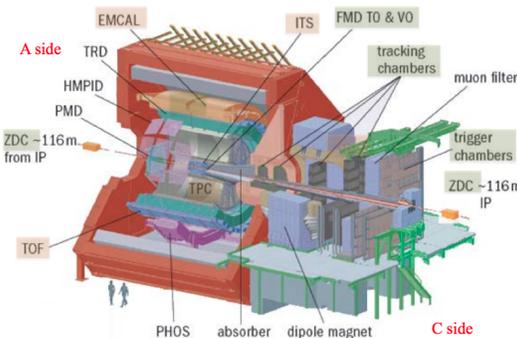
## ALICE detectors involved in the analysis

### Central detectors

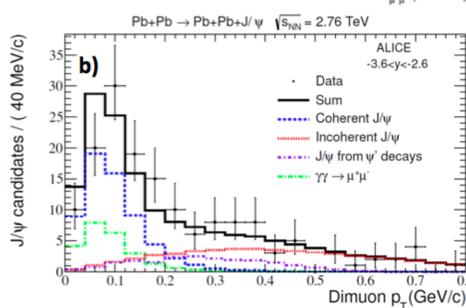
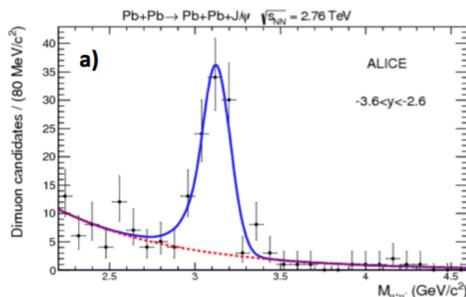
- ITS: Inner Tracking System ( $Si$  detector)
- TPC: Time Projection Chamber
- TOF: Time-Of-Flight
- EMCAL: electromagnetic calorimeter

### Forward detectors

- V0: Large- $\eta$  scintillators
- FMD: Forward Multiplicity Detector
- ZDC: Zero Degree Calorimeter
- Muon Arm: muon trigger and tracker



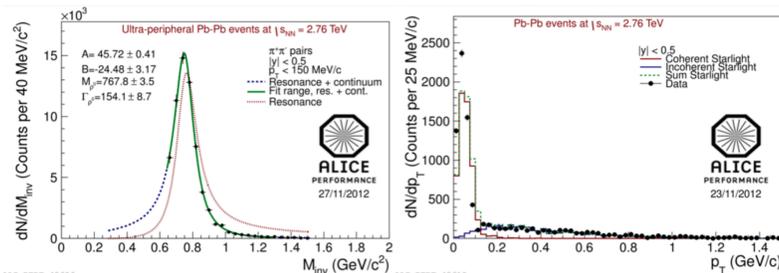
## $J/\psi$ at forward rapidity - Phys. Lett. B718 (2013) 1273



- Offline relevant analysis cuts
  - hadronic rejection with ZDC and SPD
  - less than 6 neutrons in both ZDC for coherent candidates
- Invariant mass spectrum fitted using CrystalBall (signal) and exponential (di-lepton background) functions
- $p_T$  data distribution is reproduced summing four different MC templates
  - coherent and incoherent  $J/\psi$  production
  - $J/\psi$  from  $\psi'$  decay
  - QED continuum pair production  $\gamma\gamma \rightarrow \mu^+\mu^-$
- The measured coherent cross section is  $d\sigma_{coh}/dy = 1.00 \pm 0.18(stat)_{-0.26}^{+0.24}(sys)$  mb

## $\rho^0$ at central rapidity

The absolute cross section will be released soon



- coherent/incoherent template-pair- $p_T$  distributions from STARLIGHT
- 7% contribution from incoherent events with pair- $p_T < 150$  MeV/c $^{-1}$
- $p_T$  distribution in STARLIGHT broader than in data (similar trend in STAR, Annu. Rev. Nucl. Part. Sci. 55 (2005) 271)

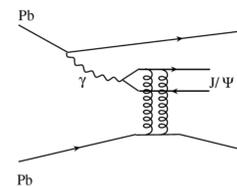
$$\frac{d\sigma}{dm_{\pi\pi}} = \left[ A \frac{\sqrt{m_{\pi\pi}} M_{\rho^0} \Gamma(m_{\pi\pi})}{m_{\pi\pi}^2 - M_{\rho^0}^2 + i M_{\rho^0} \Gamma(m_{\pi\pi})} + B \right]$$

A, amplitude of the Breit-Wigner function  
B, amplitude of the non resonant  $\pi\pi$  production

$$\Gamma(m_{\pi\pi}) = \Gamma_{\rho^0} \frac{M_{\rho^0}}{m_{\pi\pi}} \left( \frac{m_{\pi\pi}^2 - 4m_{\pi}^2}{M_{\rho^0}^2 - 4m_{\pi}^2} \right)^{3/2}$$

## Physics of ultra-peripheral collisions

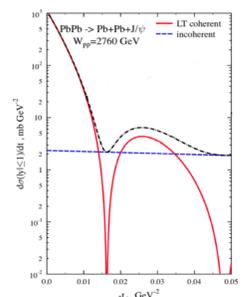
### Photoproduction cross section



- photoproduction cross section  $\sigma_X = \int dk (dN/dk) \sigma_X^2(k)$
  - given the process  $\gamma Pb \rightarrow J/\psi Pb$ , the general cross section is  $\frac{d\sigma(PbPb \rightarrow J/\psi Pb)}{dy} = N_\gamma(y) \sigma_{J/\psi}(y) + N_\gamma(-y) \sigma_{J/\psi}(-y)$  where  $N_\gamma$  is photon flux and  $y$  is  $J/\psi$  CM rapidity
  - from pQCD, photoproduction cross section proportional to the squared gluon density
- $$\sigma_{\gamma Pb \rightarrow J/\psi Pb}(s) = \frac{d\sigma_{N \rightarrow J/\psi N}(s, t_{min})}{dt} \cdot \left[ \frac{G_A(M_{J/\psi}/s, Q_{eff}^2)}{A G_N(M_{J/\psi}/s, Q_{eff}^2)} \right]^2 \cdot F_A^2$$
- where  $s$  is  $\gamma$ - $N$  scattering invariant energy and  $F_A$  is nuclear form factor

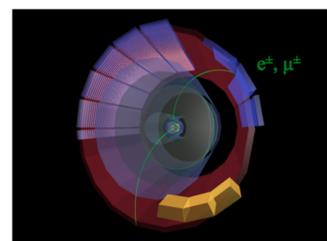
### Coherent vector meson production

- photon couples coherently to all nucleons ( $\lambda_\gamma > R_{Pb}$ )
- $\langle p_T \rangle \sim 1/R_{Pb} \sim 60$  MeV/c $^{-1}$
- no neutron emission in  $\sim 80\%$  of cases
- Incoherent vector meson production
  - photon couples to a single nucleon ( $\lambda_\gamma \sim r_{proton}$ )
  - $\langle p_T \rangle \sim 1/r_{proton} \sim 500$  MeV/c $^{-1}$
  - target nucleus normally breaks up

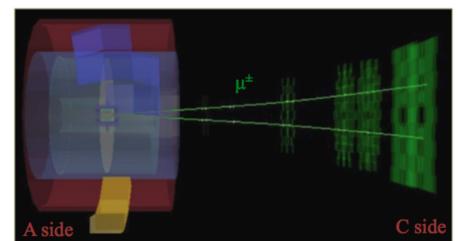


## Collected data samples

- Vector mesons produced at low  $p_T$ , clear back-to-back track configuration in the transverse plane (only two tracks in an otherwise empty detector)



**Overall acceptance in  $|\eta| \leq 0.9$**   
**TOPOLOGICAL TRIGGER:**  
V0A veto & V0C veto & SPD & TOF  
Silicon Pix-Det triggers  $\geq 2$  hits  
TOF triggers:  $2 \leq N_{trig, pad} \leq 6$  in  $150 < \Delta\phi < 180$   
**Observed rapidity:  $|y| < 0.9$**



**Overall acceptance in  $-4 < \eta < -2.5$**   
**TRIGGER:**  
Muon\_Trg & V0C & V0A veto  
Single muon trigger above a 1 GeV/c  $p_T$ -threshold  
V0c  $\geq 1$  hit  
**Observed rapidity:  $-3.6 < y < -2.6$**

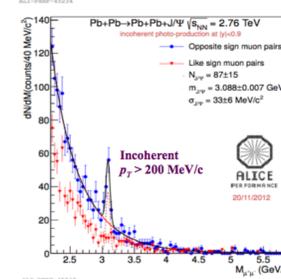
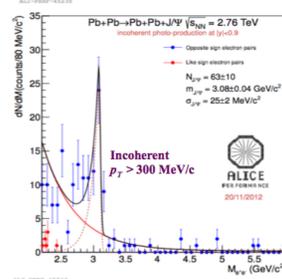
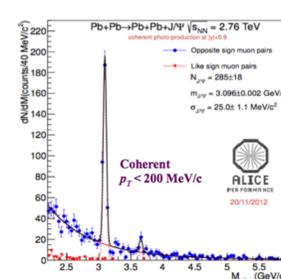
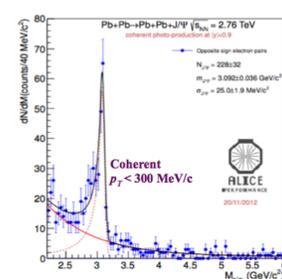
### $J/\psi$ photoproduction

- first LHC measurements in Pb-Pb collisions at  $\sqrt{s_{NN}} = 2.76$  TeV, both at forward and central rapidities
- $J/\psi \rightarrow \mu^+\mu^-$ , muon spectrometer, forward rapidity  $-3.6 < y < -2.6$
- $J/\psi \rightarrow l^+l^-$ , barrel detectors, central rapidity  $|y| < 0.9$
- 2011 Pb-Pb run integrated luminosity:  $55 \mu b^{-1}$  (forward),  $20 \mu b^{-1}$  (central)
- two low multiplicity triggers with topological request for the central barrel one

### $\rho^0$ photoproduction

- $\rho^0 \rightarrow \pi^+\pi^-$ , barrel detectors, rapidity  $|y| < 0.9$
- 2010 Pb-Pb run integrated luminosity:  $0.2 \mu b^{-1}$ , same central barrel trigger but no topological requests

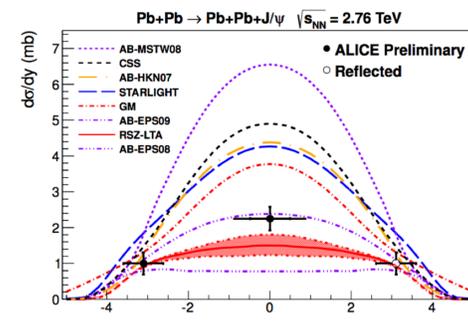
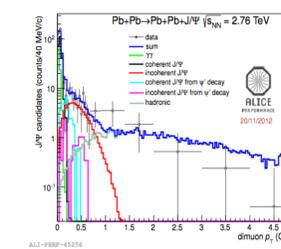
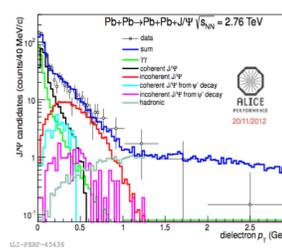
## $J/\psi$ at central rapidity and discussion on (preliminary) results



- Offline relevant analysis cuts
  - offline check on V0 timing
  - less than 6 neutrons in both ZDC for coherent candidates
  - $e/\mu$  identification via TPC energy loss

- Data points are reproduced summing six different Monte Carlo templates
  - VM photoproduction: coherent  $J/\psi$ , incoherent  $J/\psi$
  - feed down contributions: coherent and incoherent  $J/\psi$  from  $\psi'$  decay
  - di-lepton photoproduction:  $\gamma\gamma \rightarrow \mu^+\mu^-/e^+e^-$
  - peripheral events: hadronic  $J/\psi$

- The measured coherent cross section is  $d\sigma_{coh}/dy = 2.3 \pm 0.13(stat)_{-0.23}^{+0.25}(sys)$  mb



- Measurements vs model predictions
  - higher discrimination power in the central rapidity region
  - preliminary result in agreement with that one published for the forward region
  - The measured cross section is in good agreement with models which include nuclear gluon shadowing