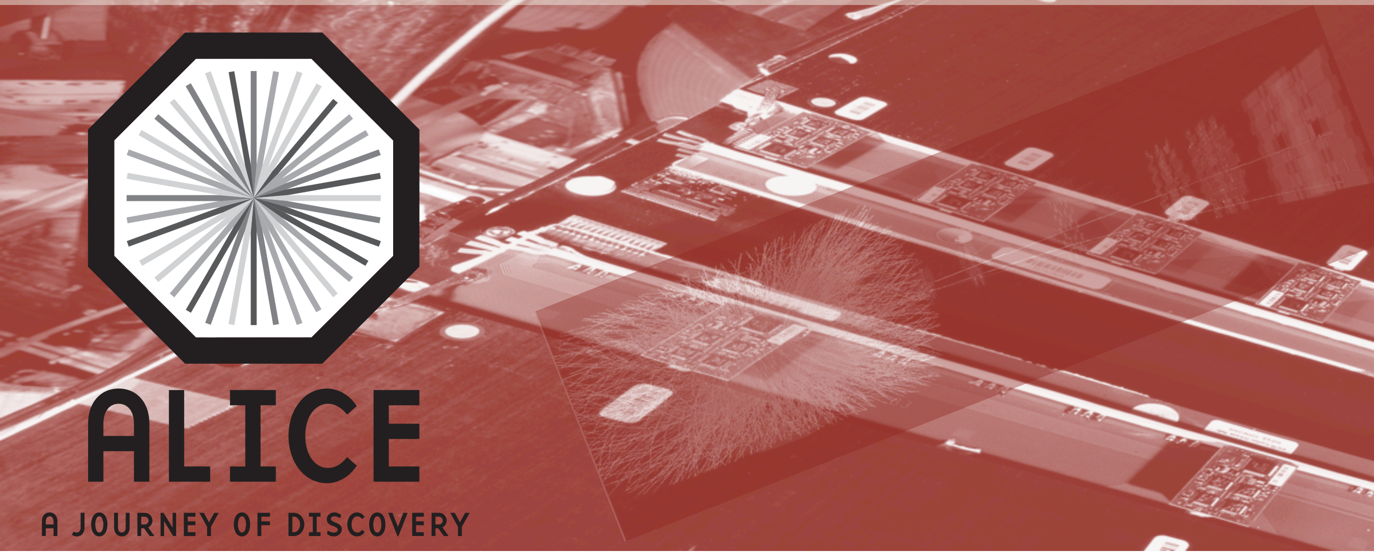
International Conference on New Frontiers in Physics
10-16 June 2012 *Kolymbari, Crete, Greece*



Outline
- Physics motivations
- ALICE detector
- Analysis of data
- Summary

J/ψ **photo production in ultra-peripheral heavy-ion collisions at forward rapidity with the ALICE experiment**

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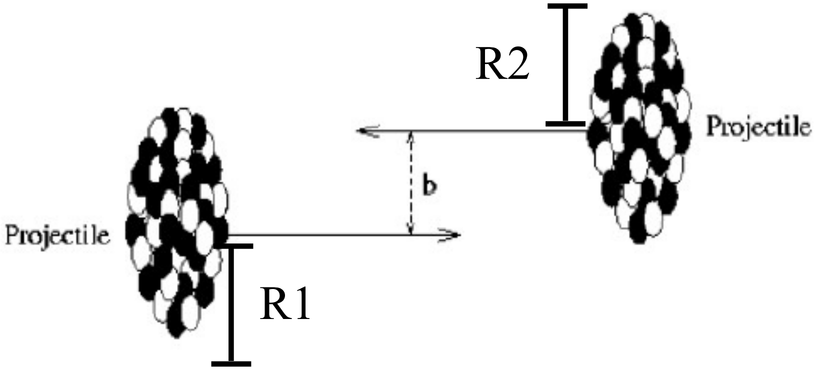
JUNE 15th - ICFP 2012

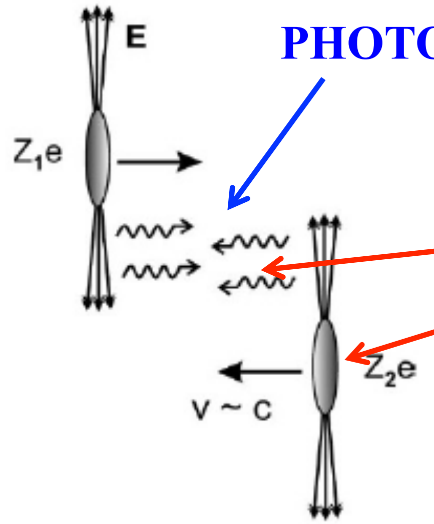
Physics Motivations



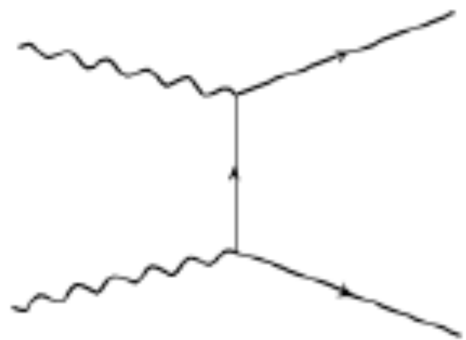
The ultra peripheral collisions occur if b >R1+R2 ➔ the photons and nuclei can interact in several ways.

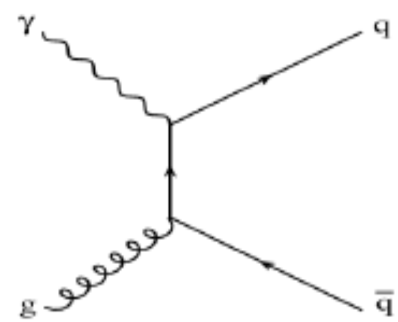
Physics Motivations

PHOTON-PHOTON COLLISIONS



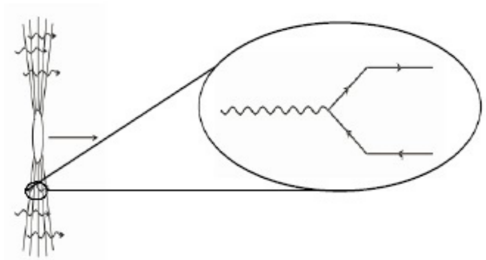
Two ions (or protons) pass by each other with impact parameters b > 2R





1. Electromagnetic interaction: $\gamma + \gamma$

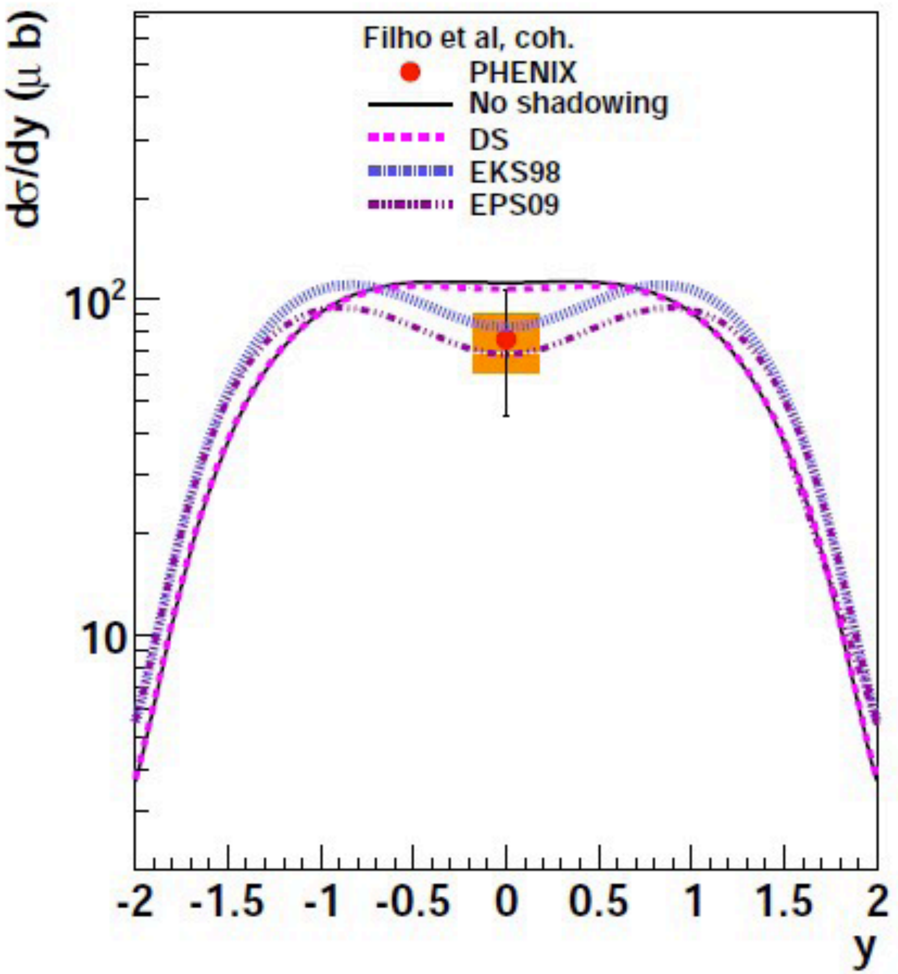
2. Direct photonuclear interaction: γ +*parton* (γ+*g* → *qq*, *g*+*q* →*jet*+*jet*)

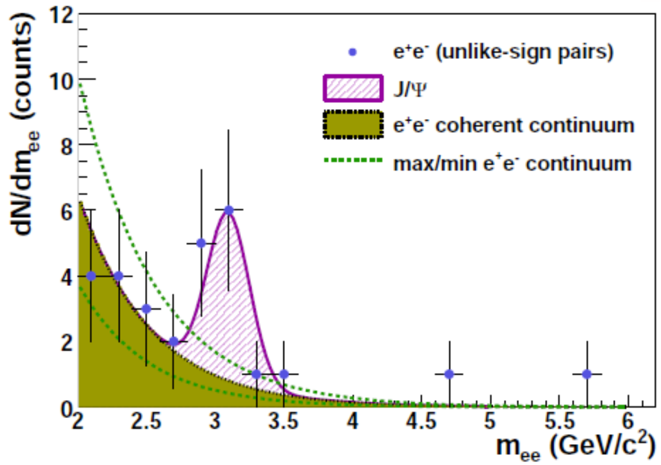


3. Resolved photonuclear interaction (VMD), elastic or inelastic

Physics Motivations

RHIC - PHENIX RESULTS





- Two processes
  - **Coherent:** $\gamma + A \rightarrow J/\psi + A$
  - **Incoherent:** $\gamma + A \rightarrow J/\psi + X$, dominated by $\gamma + N \rightarrow J/\psi + N$
- Predicted cross sections
  - Models differ by the way shadowing is taken into account

Au+Au collisions at 200 GeV
PHENIX study:
PLB Vol 679, issue 4, p. 321-333

Physics Motivations

Probe the gluon distribution of the nuclei

Total J/ψ cross section: 23 mb (STARLIGHT) *v* 10.3 mb Strikman, Zhalov, et al.

$$\frac{d\sigma_{\gamma T \to J/\psi T}(t=0)}{dt} = \frac{16\Gamma_{ee}\pi^3}{3\alpha_{em}M_{J/\psi}^5}\left[\alpha_s(\mu^2)xG_T(x,\mu^2)\right]^2$$

At leading order perturbative QCD, it depends quadratically on the gluon distribution

LHC: W,max ~ 950 GeV

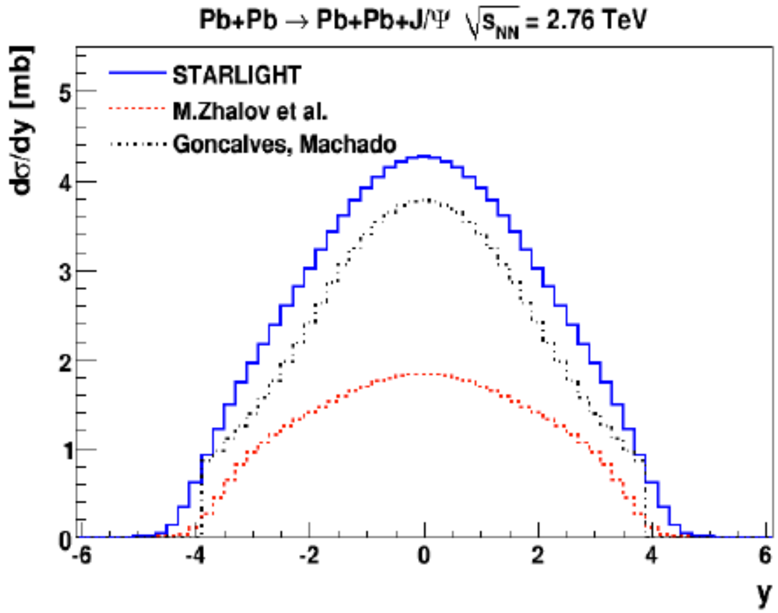
HERA: W,max ~ 300 GeV

RICH : W,max ~ 34 GeV

STARLIGHT: S.R.Klein, J.Nystrand Phys. Rev. C 60 (1999) 014903.

L. Frankfurt, M. Strikman, M. Zhalov Phys. Lett. B 626 (2005) 72.

V.P. Goncalves, M.V.T. Machado Phys. Rev. C 84 (2011) 011902.

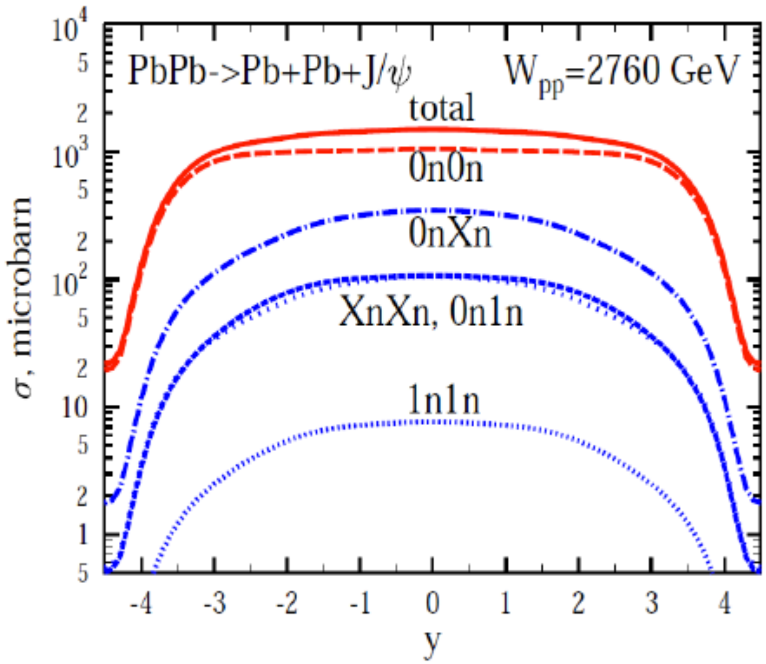


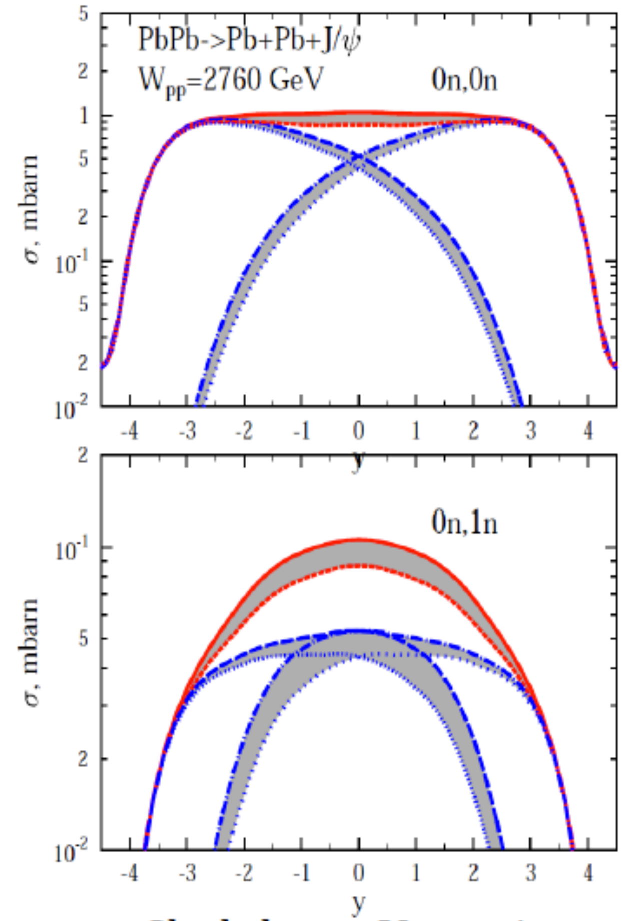
Should provide a measure of the nuclear gluon shadowing

Physics Motivations

ALICE

Using Zero Degree Calorimeters (ZDC) it is possible to select coherent production with ion excitation, where neutrons are emitted from at least one of the nuclei





Different configurations:

1n1n: one neutron emission by each ion;

XnXn: emission of several neutrons;

0n1n and 0nXn: excitation and decay of one of the ions, and

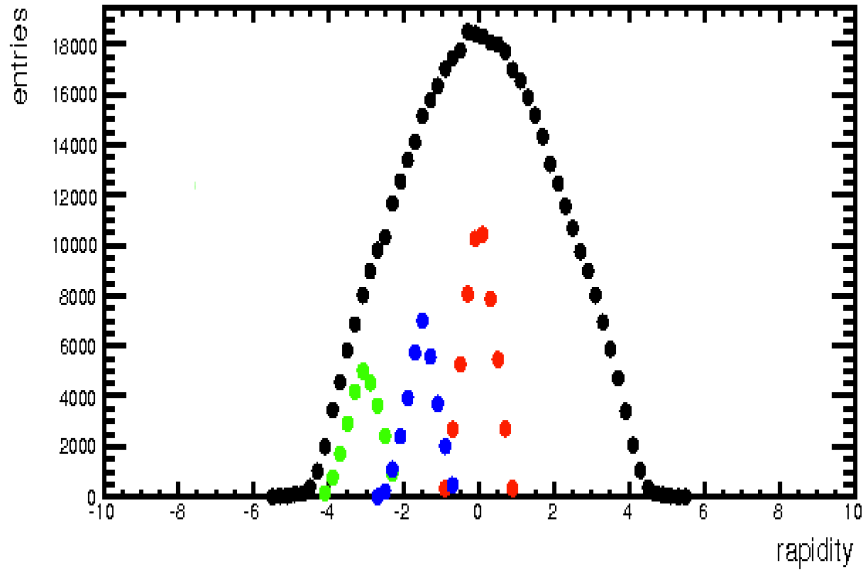
0n0n: no neutron emission

V. Rebyakova, M. Strikman and M. Zhalov
ArXiv:1109.0737, Sept 2011

Shaded area: Uncertainty on nuclear gluon shadowing

Physics Motivations

Starlight simulations for coherent *J/ψ*

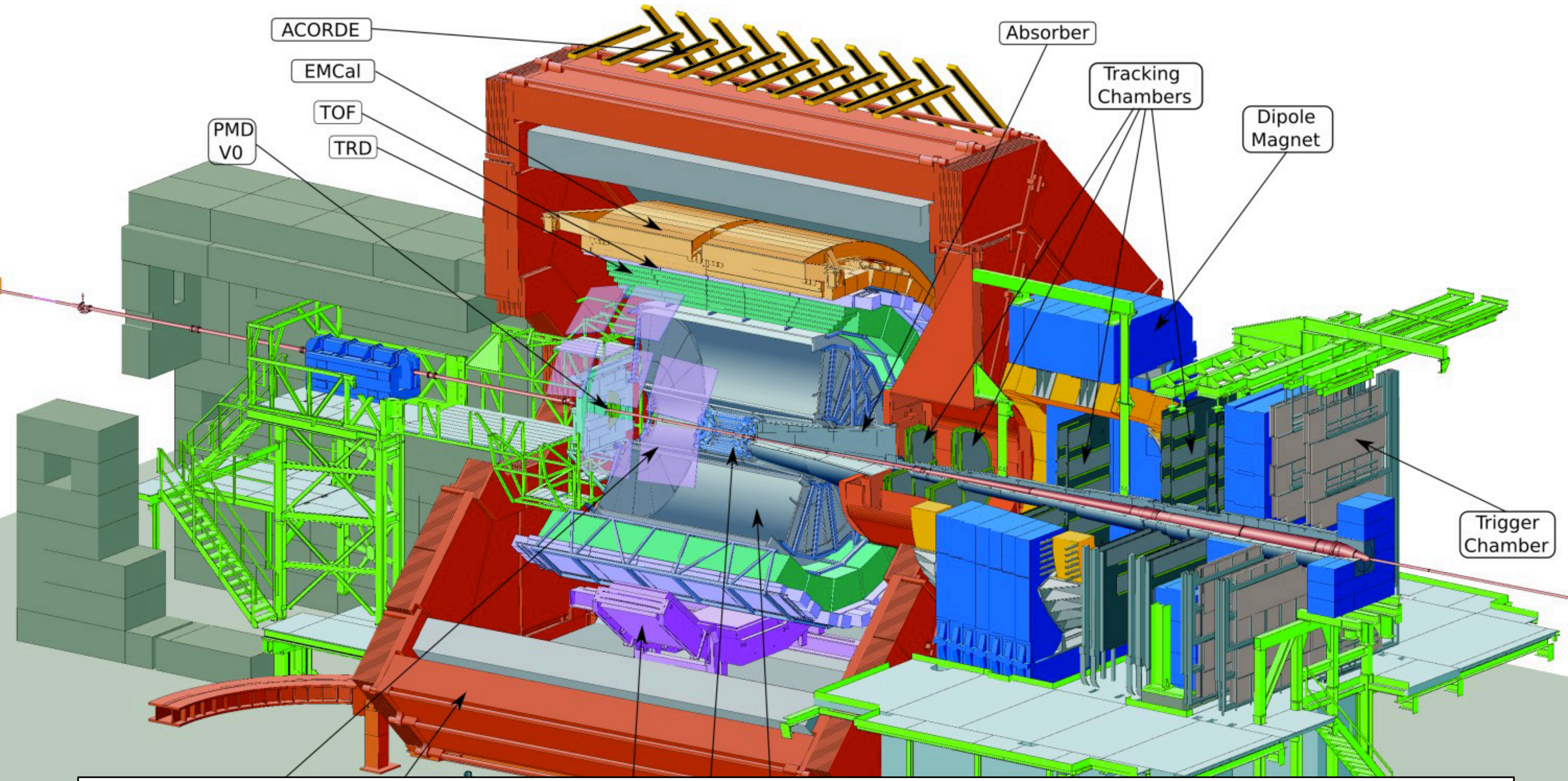


Three *J/ψ* analysis are possible in ALICE

1. **Both dileptons (muons or electrons) at central rapidity, -0.9<y<0.9**
2. **Both muons at forward rapidity, -4.0 <y< -2.5**

3.- One forward muon and the other at mid-rapidity

ALICE detector



For further details see the Panos **CHRISTAKOGLOU talk** (https://indico.cern.ch/contributionDisplay.py?sessionId=22&contribId=280&confId=176361)

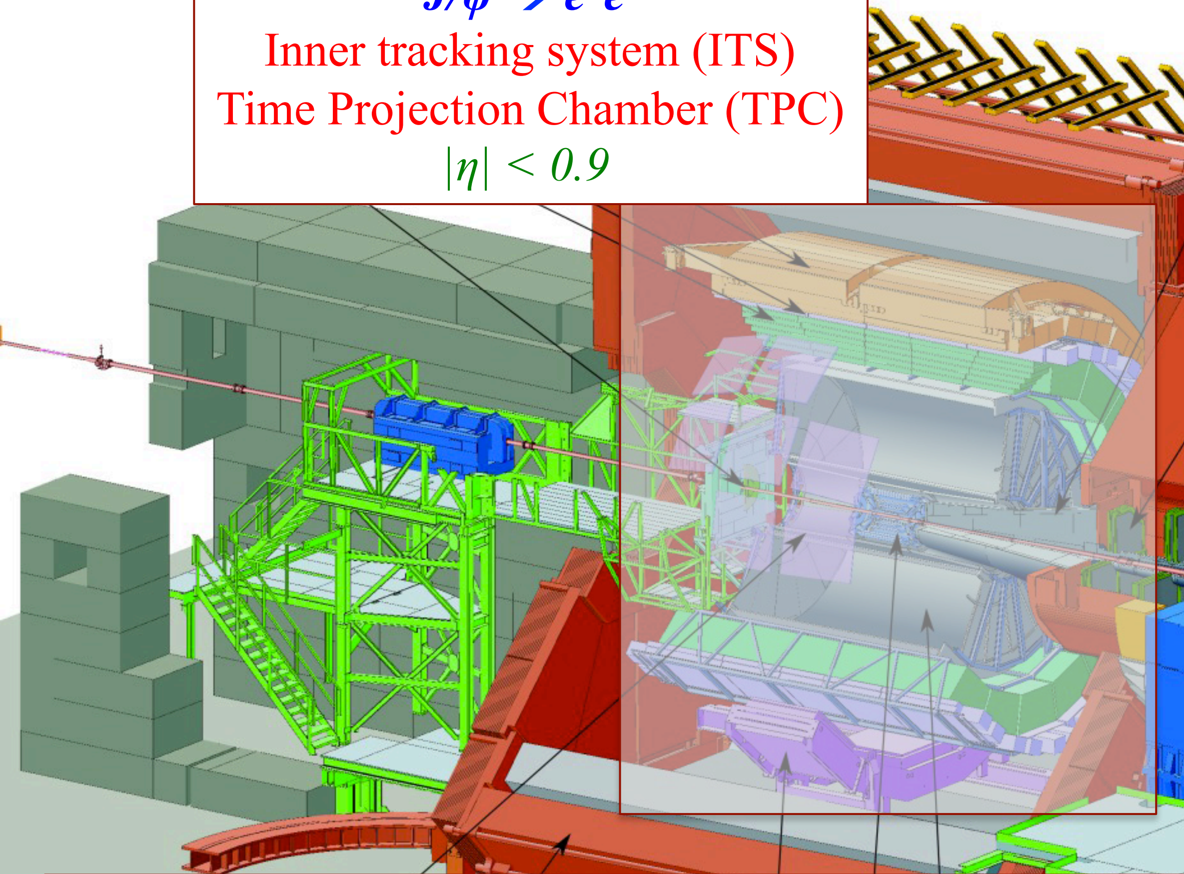
ALICE detector

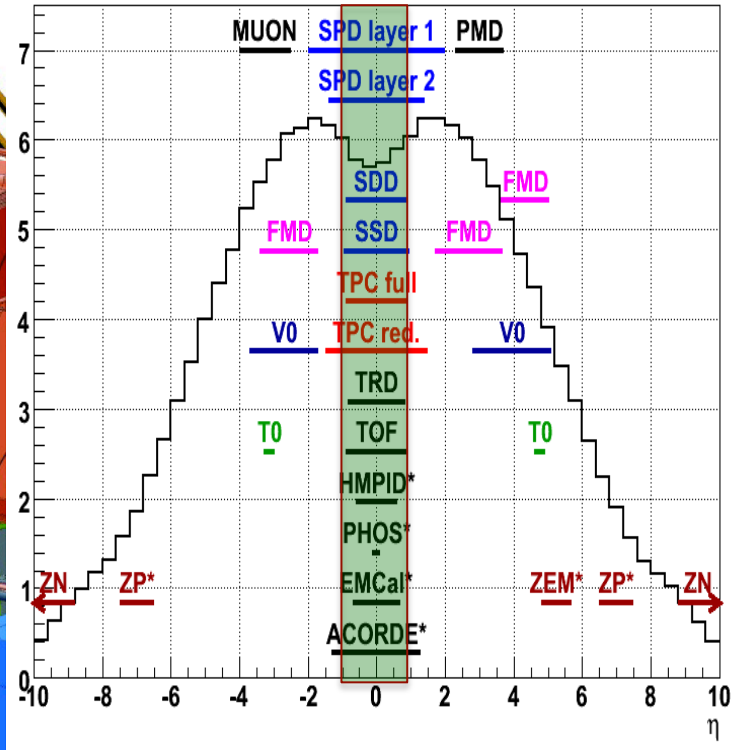
J/ψ → e⁺e⁻

Inner tracking system (ITS)

Time Projection Chamber (TPC)

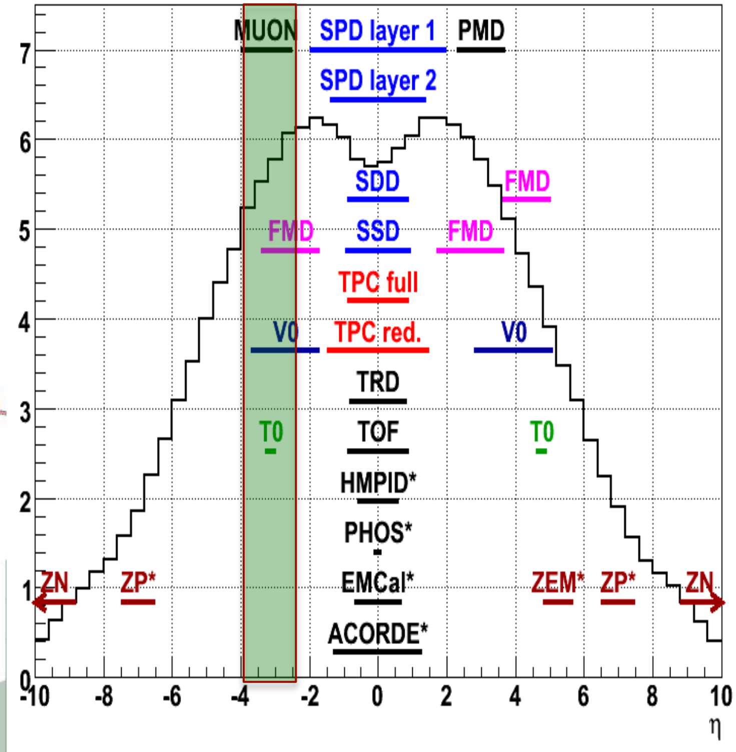
$|\eta| < 0.9$

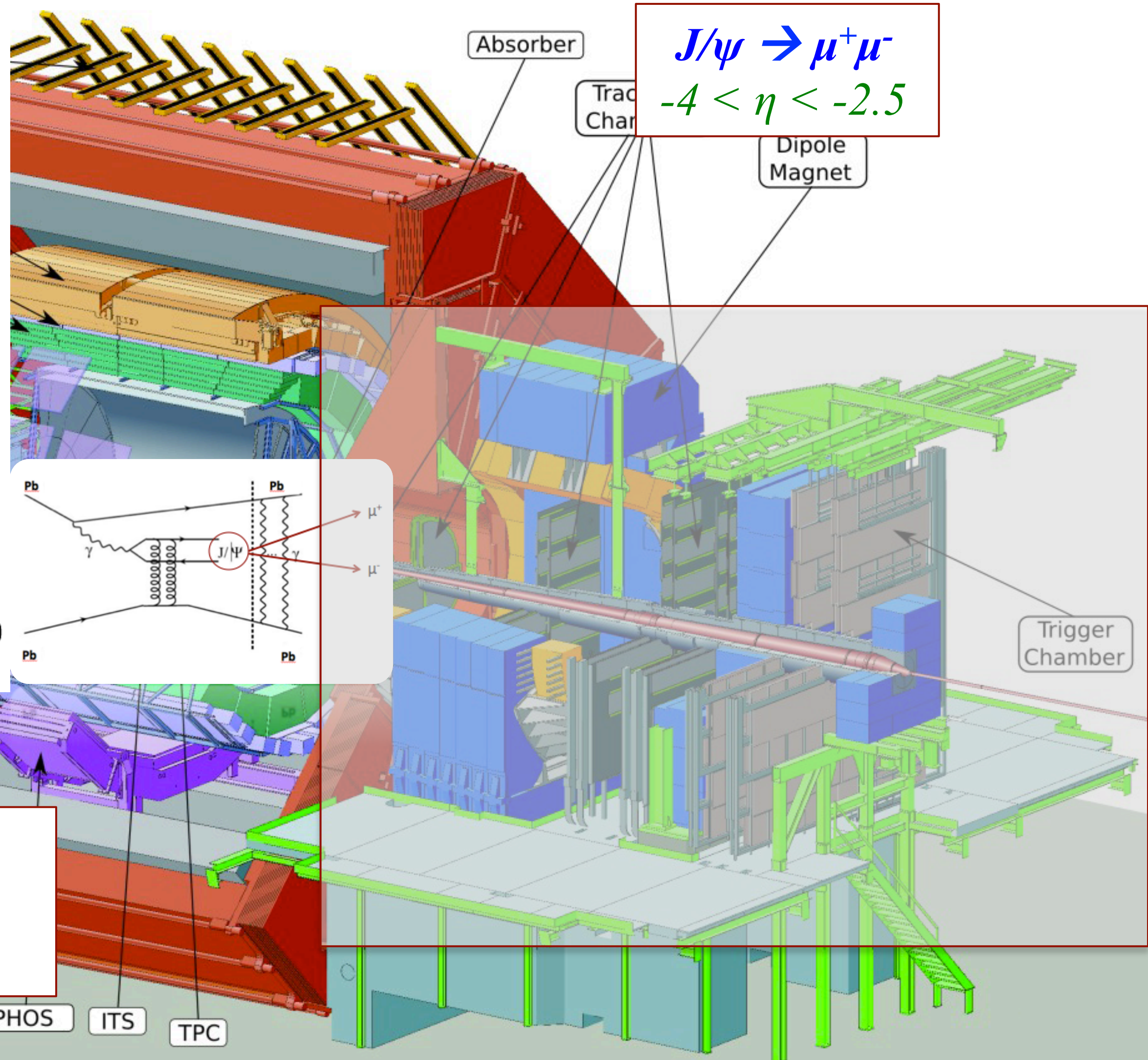




Central rapidity: TOF trigger requiring a hit multiplicity to be between 2 and 6, vetoing signals from both VZERO detectors, and with at least 2 hits in SPD. In addition, at least one of the triggered tracks by TOF has the angular correlation $150^0 < \Delta\varphi < 180^0$

ALICE detector





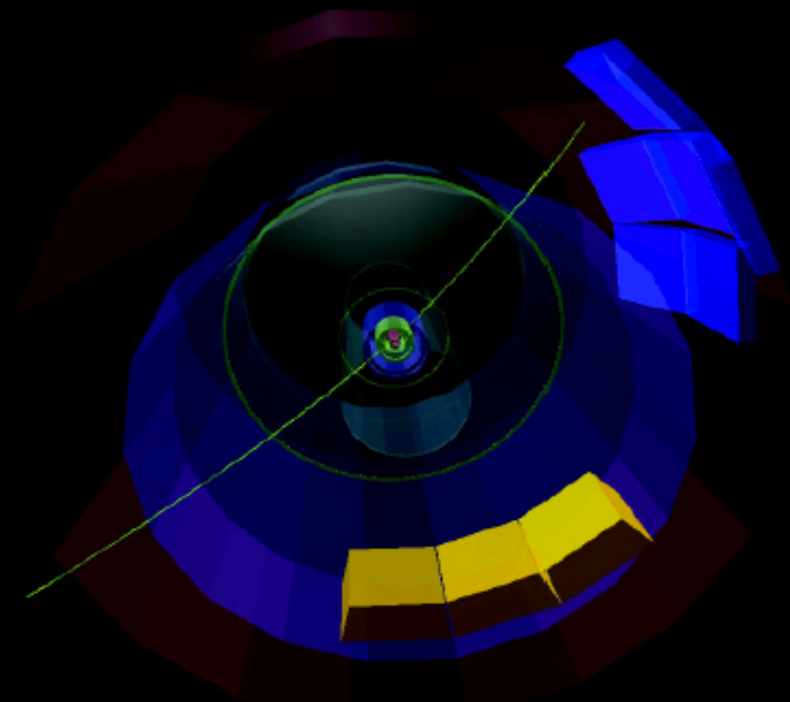
$J/\psi \rightarrow \mu^+\mu^-$

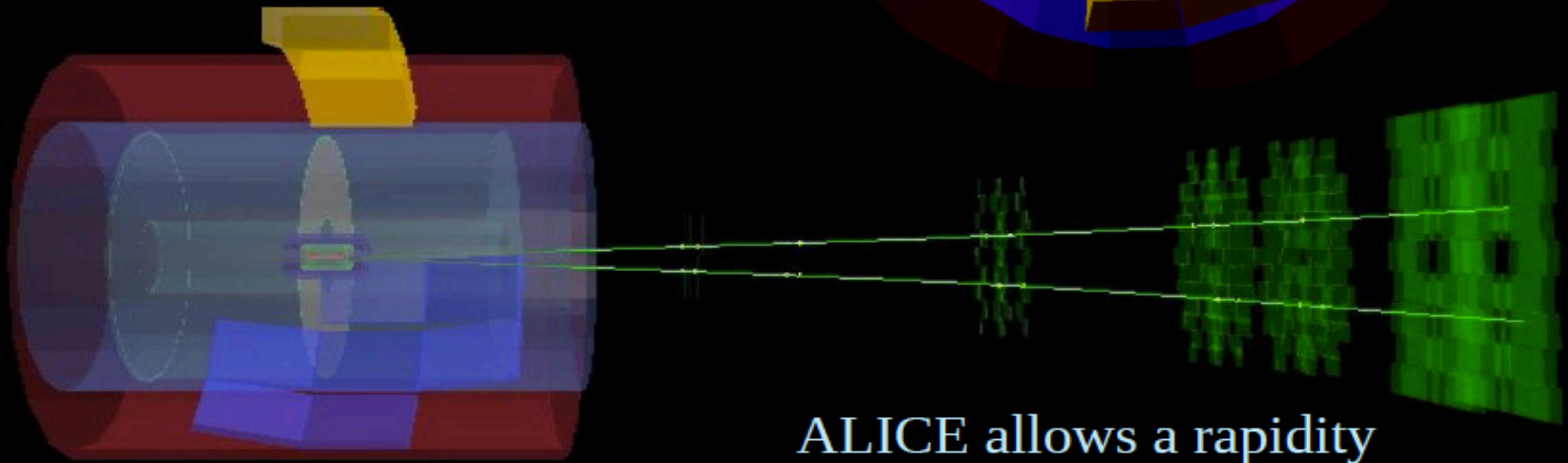
$-4 < \eta < -2.5$

Forward rapidity: Muon arm + VZERO trigger: at least one muon candidate + veto on VZERO-A.

Exclusive J/ψ production

Two tracks in otherwise an empty detector





ALICE allows a rapidity dependence study!

Data analysis

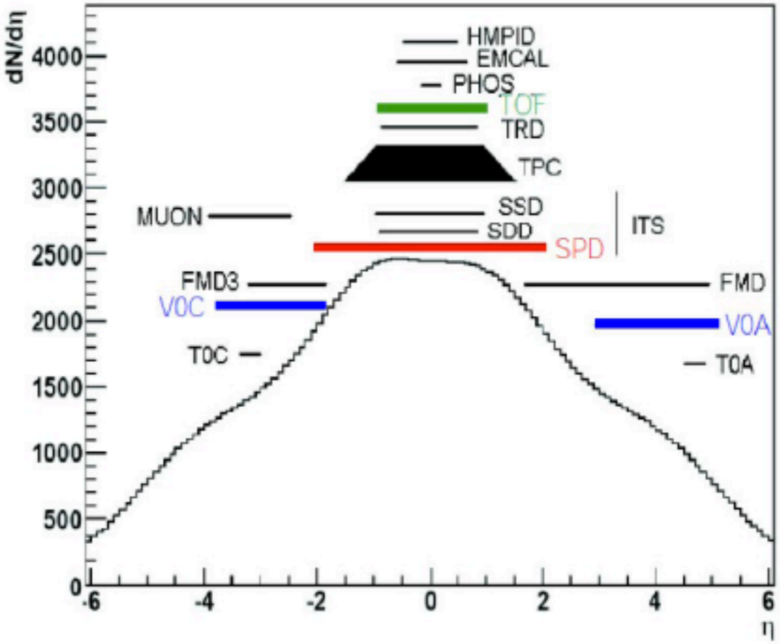
PERFORMANCE RESULTS: 2010

3 UPC triggers were active in 2010:

1. TOF-only trigger >= 2 hits in TOF

2. TOF + SPD + VZERO trigger:
>= 2 hits in TOF + >= 2 hits in SPD
+ veto on both VZERO detectors

3. Muon arm + VZERO trigger:
at least one muon candidate +
veto on VZERO-A



Exclusivity by vetoing on ALICE detectors at several rapidities
~ 8 units of rapidity → both online and offline selections

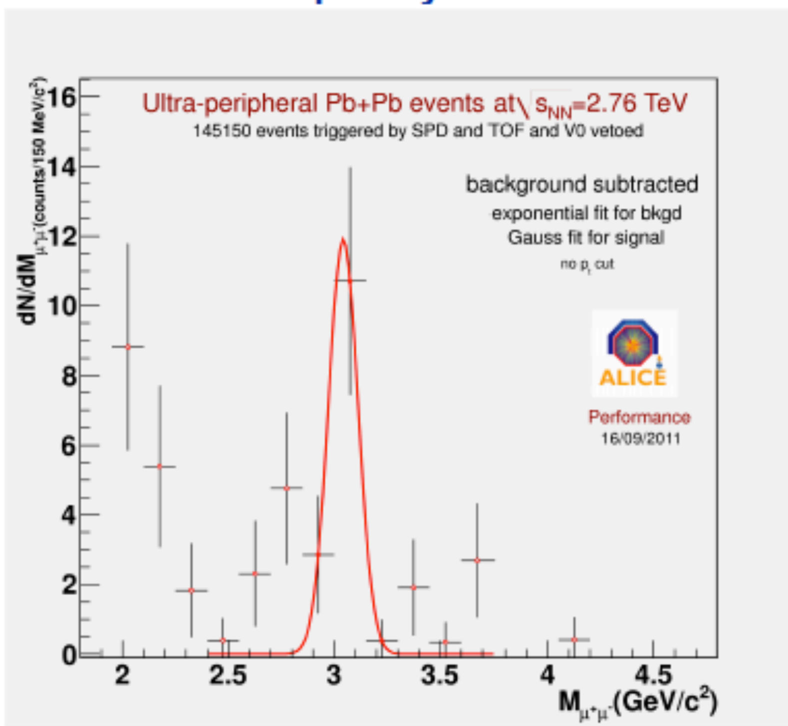
The UPC triggers sensitive to a variety of final states:
$\gamma\gamma \rightarrow e^+e^-$, $\gamma\gamma \rightarrow \mu^+\mu^-$, $\gamma\gamma \rightarrow f_2(1270) \rightarrow \pi^+\pi^-$,
$\gamma IP \rightarrow J/\Psi \rightarrow e^+e^-$ etc.

Data analysis

ALICE

PERFORMANCE RESULTS: 2010

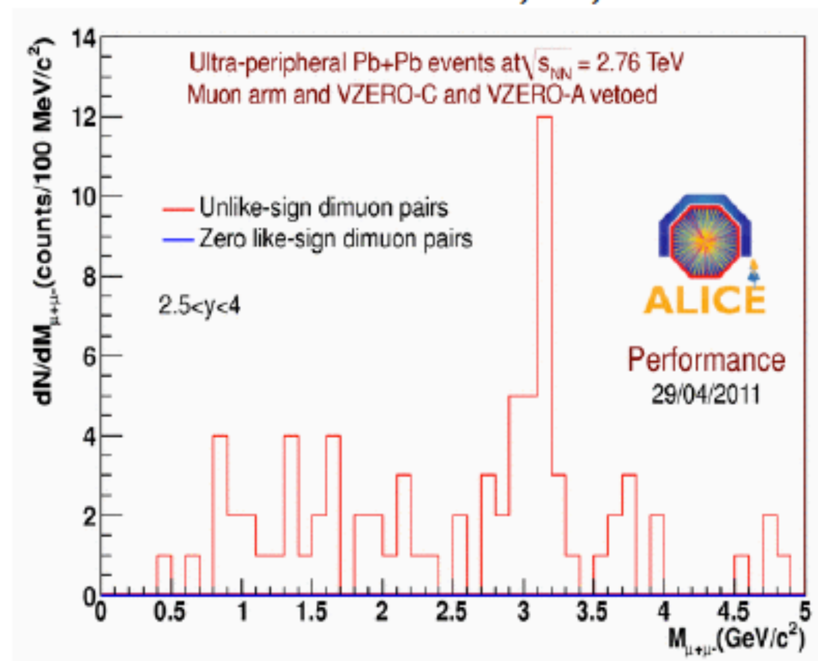
Central rapidity



Forward rapidity

trigger on Muon in coincidence with VZERO-C, but VZERO-A is vetoed

offline veto on TPC, ITS, FMD

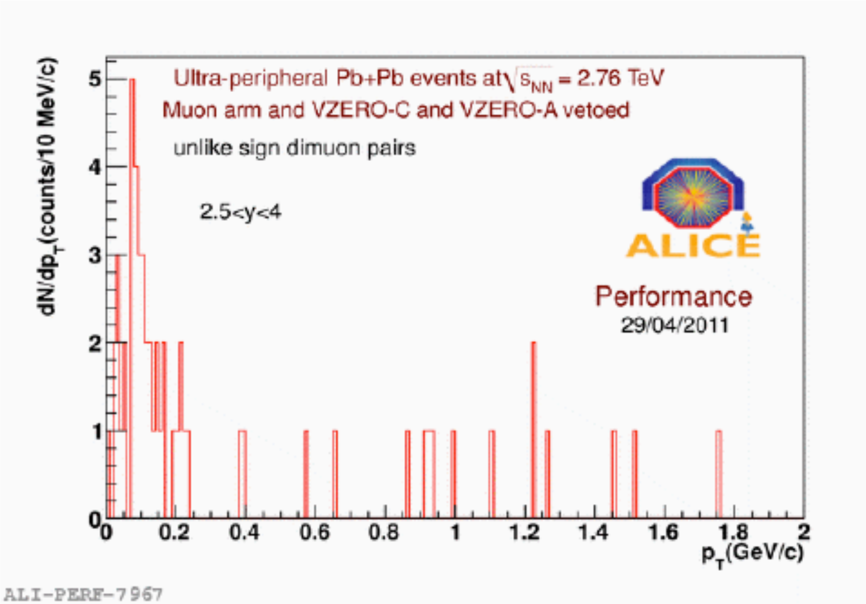


After background subtraction
No particle ID was applied

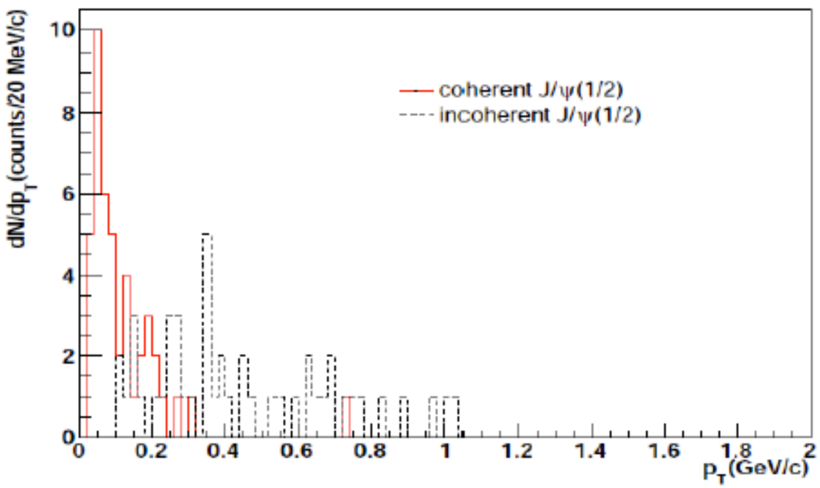
Data analysis

PERFORMANCE RESULTS: 2010

STARLIGHT gives for coherent σ = 23 mb, and σ = 11 mb for incoherent. So, roughly 2/3 for coherent and 1/3 for incoherent. The rapidity distribution is wider for the incoherent part, so in the muon arm the fraction of incoherent should be a bit larger.



STARLIGHT: full simulations



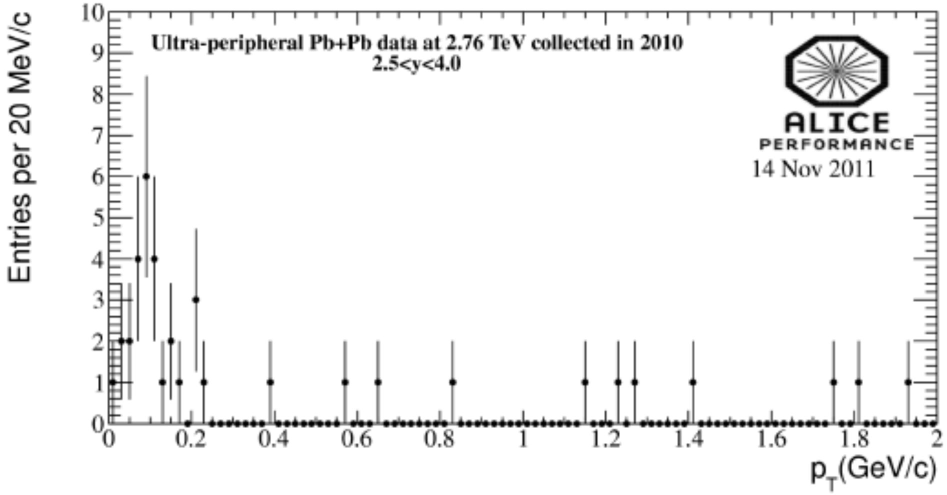
Strikman, Tverskoy, Zhalov (PLB 626 (2005) 72) found that 85% of the incoherent J/ψ should have a signal in one of the ZDCs. For coherent J/ψ it is only about 28%

To be confirmed by ZDC analysis ...

Data analysis

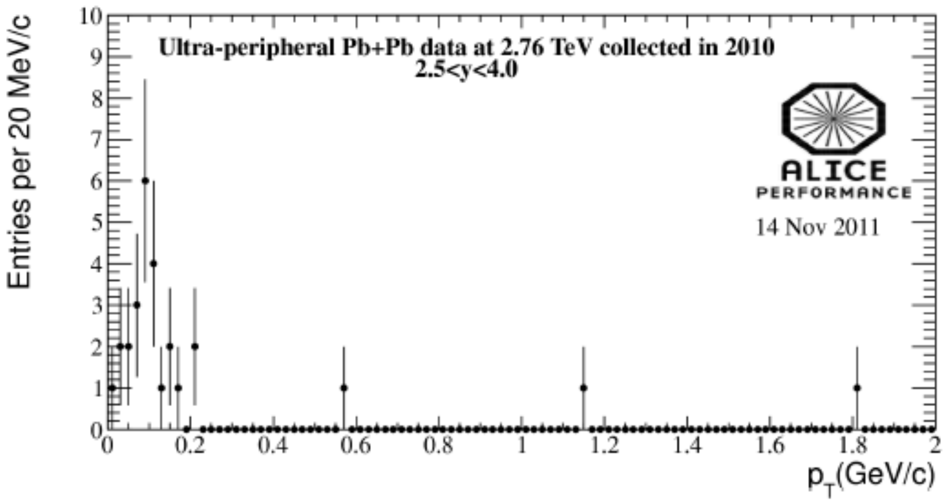
PERFORMANCE RESULTS: 2010

Coherent + incoherent production



ALICE can distinguish between coherent and incoherent components

Coherent-enhanced sample



Obtained after requiring no neutron emission measured by ZDC

Data analysis

PERFORMANCE RESULTS: 2011

2 ***UPC triggers were active in 2011:***

Central rapidity: TOF trigger requiring a hit multiplicity to be between 2 and 6, vetoing signals from both VZERO detectors, and with at least 2 hits in SPD. In addition, at least one of the triggered tracks by TOF has the angular correlation $150 < \Delta\phi < 180$ degrees

~8 M central barrel UPC triggers collected in 2011

Forward rapidity: Same as in 2010. Muon arm + VZERO trigger: at least one muon candidate + veto on VZERO-A.

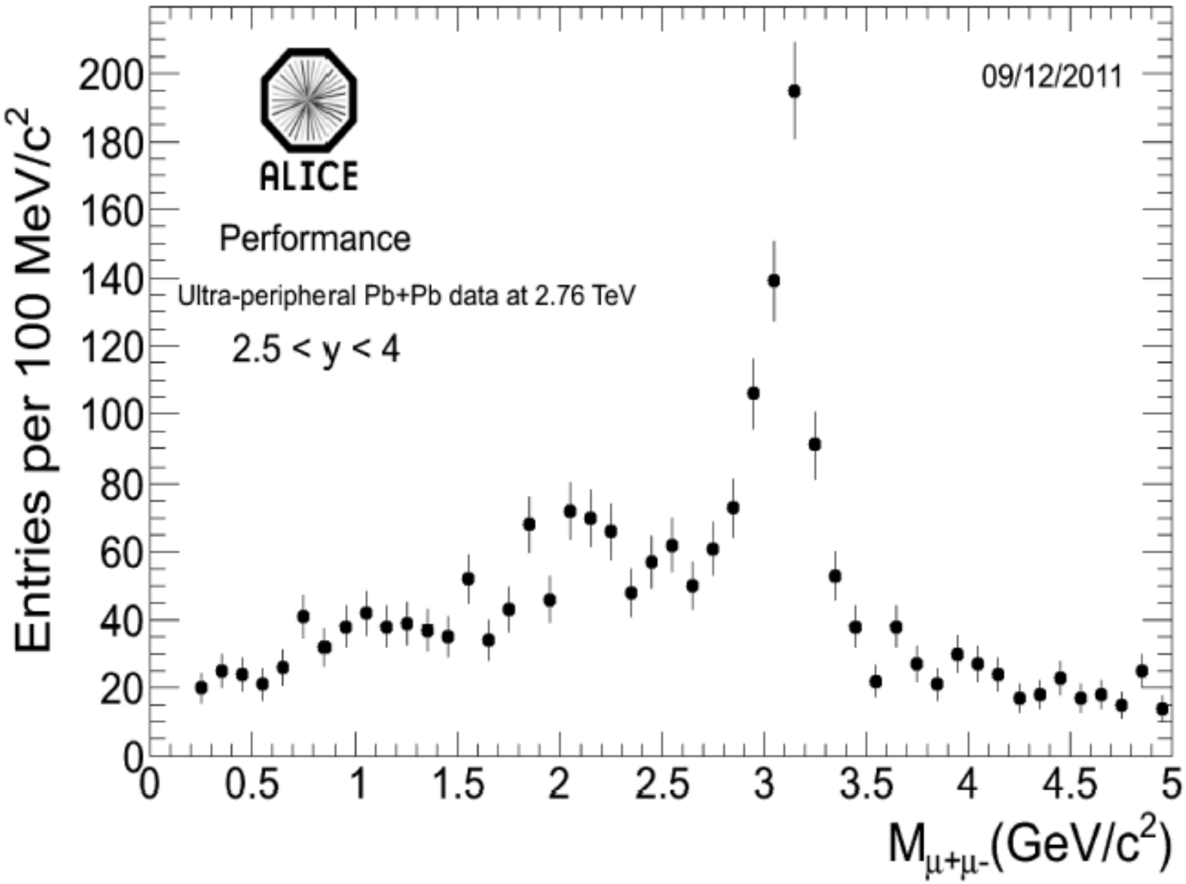
~ 3.4 M muon UPC triggers collected in 2011

Collected statistics:

an order of magnitude larger than in 2010

Data analysis

PERFORMANCE RESULTS: 2011



MUON in coincidence with VZERO-C, but VZERO-A vetoed

For the moment, no veto at central rapidity

Veto activity on VZERO-C outside muon acceptance
Exactly two good tracks in the muon acceptance
Both tracks match the trigger
At least one track has a $P_t >$ 1 GeV/*c*

Summary

The ALICE experiment allows the study of vector meson photoproduction in ultra-peripheral nucleus-nucleus collisions. Large rapidity gaps can be defined

Exclusive J/Ψ is being studied by ALICE at both central and forward rapidity ---> access to info on gluon density

2011 statistics: a order of magnitude larger than in 2010.

Outlook

Measurements of absolute and differential cross sections

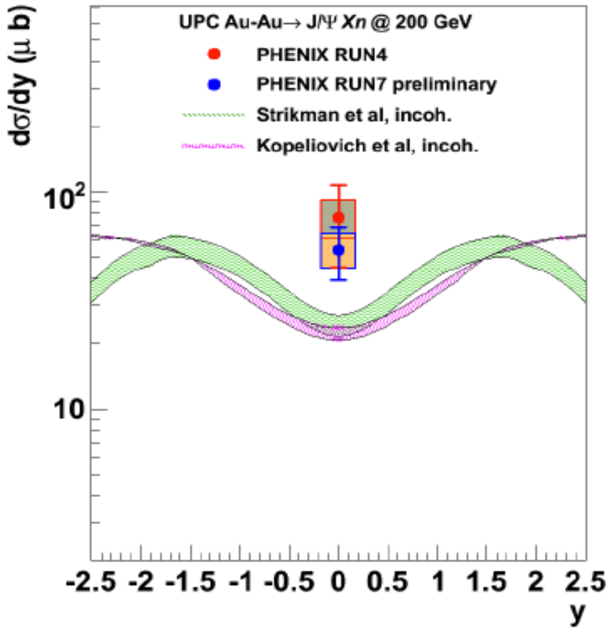
Study of ρ^0, J/Ψ as a function of neutron emission

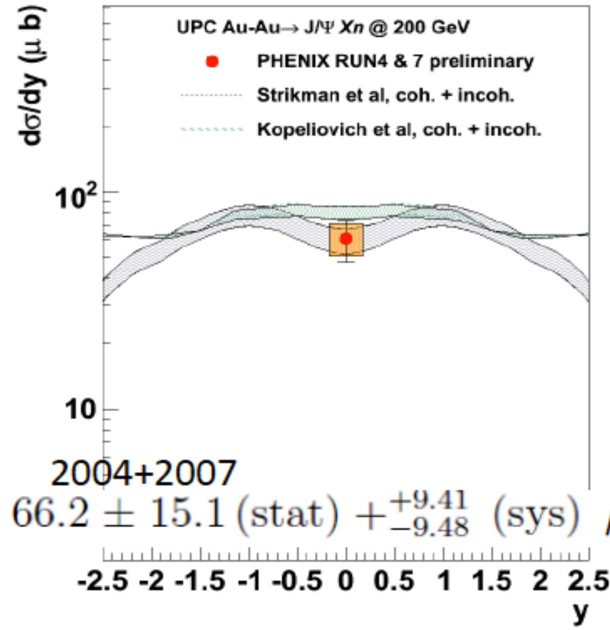
Backup

Integrated cross section

J/ψ +Xn Central 2004 & 2007

TAKAHARA, Akihisa
for the PHENIX Collaboration
(CNS, University of Tokyo and RIKEN)





2004+2007

$66.2 \pm 15.1\,(\mathrm{stat}) +^{+9.41}_{-9.48}\ (\mathrm{sys})\ \ \mu\mathrm{b}$

2004 PHENIX

76 ± 31 (stat) ± 15 (syst) μb

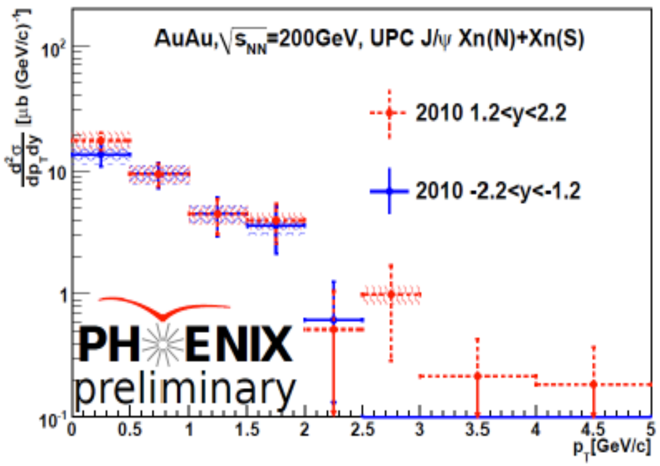
2007 PHENIX

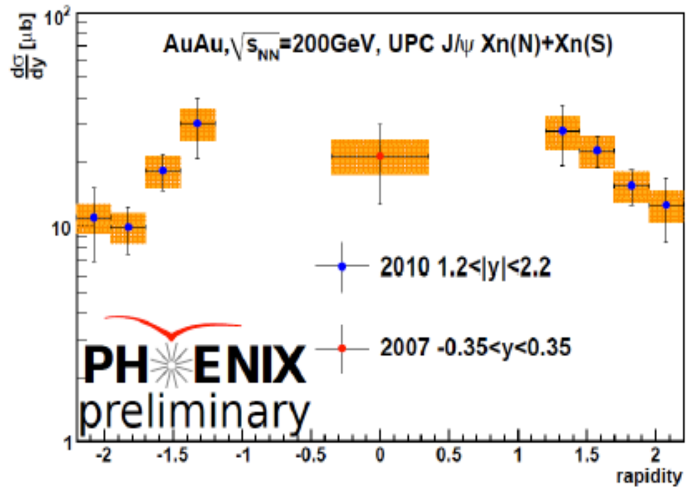
$61.8 \pm 17\,(\mathrm{stat}) +^{+8.7}_{-8.8}\ (\mathrm{sys})\ \ \mu\mathrm{b}$

J. Nystrand, Nucl. Phys. A 752(2005)470c; A.J. Baltz, S.R. Klein, J. Nystrand, PRL 89(2002)012301; S.R. Klein, J. Nystrand, Phys. Rev. C 60(1999)014903
M. Strikman, M. Tverskoy and M. Zhalov, Phys. Lett. B 626 72 (2005)
V. P. Goncalves and M. V. T. Machado, arXiv:0706.2810 (2007).
Yu. P. Ivanov, B. Z. Kopeliovich and I. Schmidt, arXiv:0706.1532 (2007).

J/ψ +Xn(y>0)Xn(y<0)

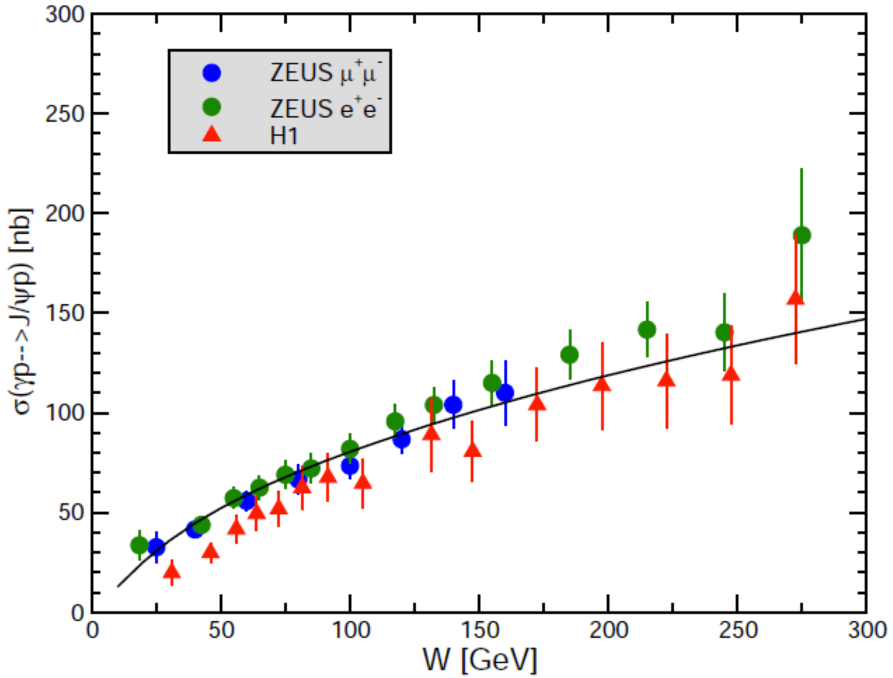
TAKAHARA, Akihisa
for the PHENIX Collaboration
(CNS, University of Tokyo and RIKEN)

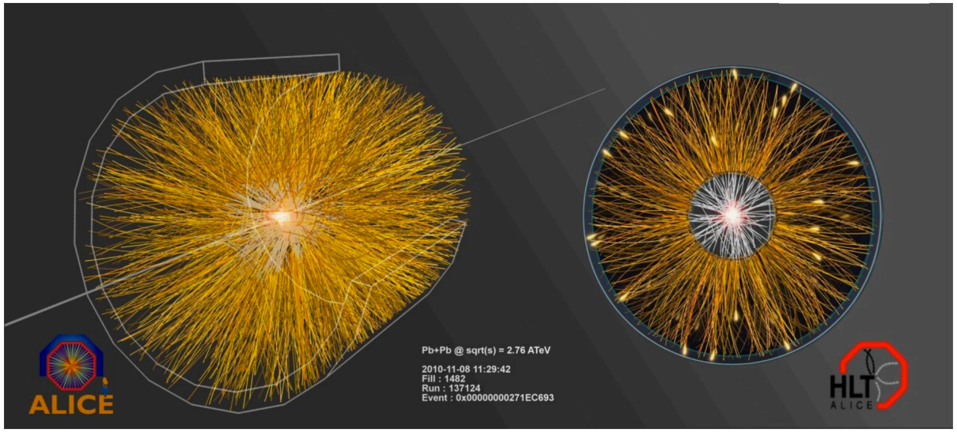




- The p_T distributions at forward rapidity shows that incoherent process is very visible at forward (can't see coherent peak)
- There are no theoretical predictions with XnXn condition

Backup





H1: A. Aktas *et al.* Eur.Phys. J.C46:585-603,2006
ZEUS:S. Chekanov et al., Nucl. Phys. B695 (2004)
A. Martin et al. Phys.Lett. B 662:252-258, 2008

LHC: W,max ~ 950 GeV

HERA: W,max ~ 300 GeV

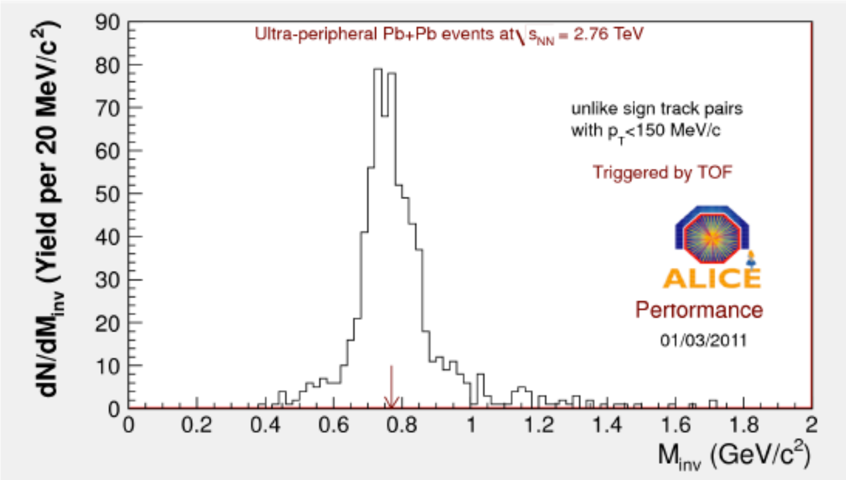
RICH : W,max ~ 34 GeV

Backup

ρ^0 production at central rapidity – 2010 data

Exclusive photoproduction of $\rho^0 \rightarrow \pi^+\pi^-$ is the dominant channel
Total cross section: 3.9 b.
S.R. Klein, J. Nystrand Phys. Rev. C 60 (1999) 014903

ALICE Acceptance: ≈ 9%.



Uncorrected M_{inv} distribution of events in the low p_T peak indicates ρ^0 production.

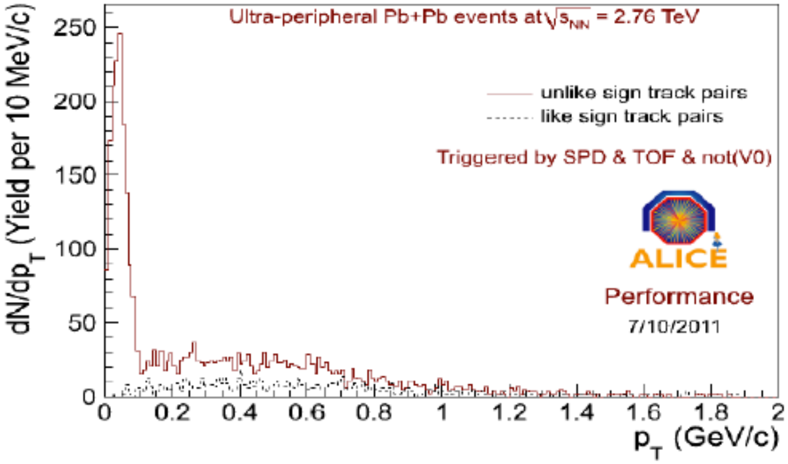
Both invariant mass and transverse momentum are described by STARLIGHT simulations

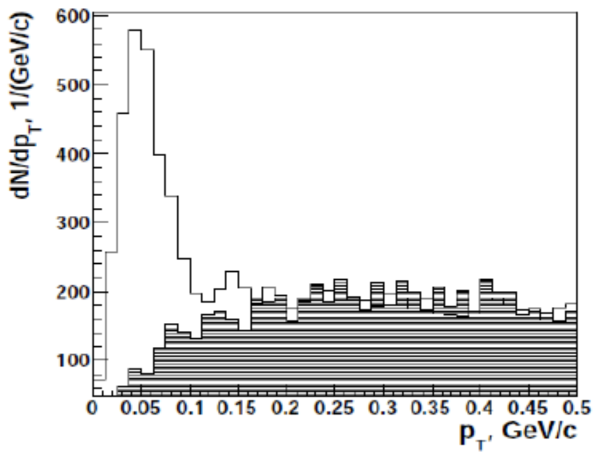
Mid-rapidity ↔ γ-nucleon CM energy
$W_{\gamma p}$ = 45 GeV

Earlier measurements with fixed target electron beams $W_{\gamma p}$ = 3 – 4 GeV and by STAR at RHIC $W_{\gamma p}$ = 12.5 GeV.

Backup

ρ^0 photo-production at central rapidity – 2010 data



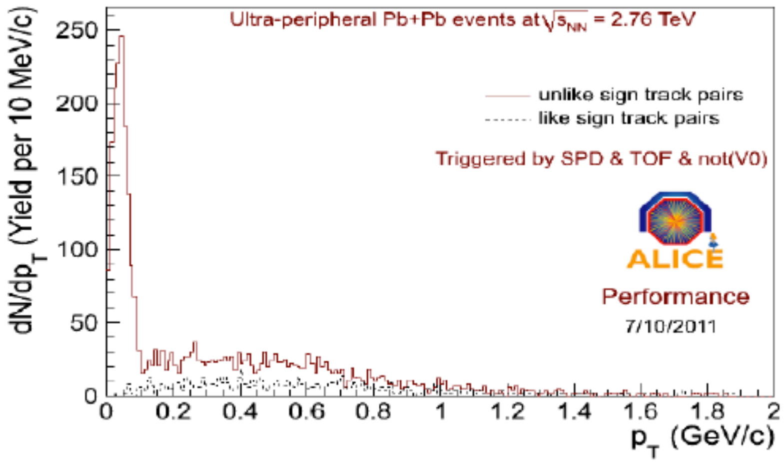


- Coherent production characterised by low transverse momentum of the final state, determined by the nuclear form factor, $p_T < \approx 100$ MeV/c.

- STAR results: arXiv:1107.4630 [nucl-ex] Jul 2011

Backup

ρ^0 photo-production at central rapidity – 2010 data



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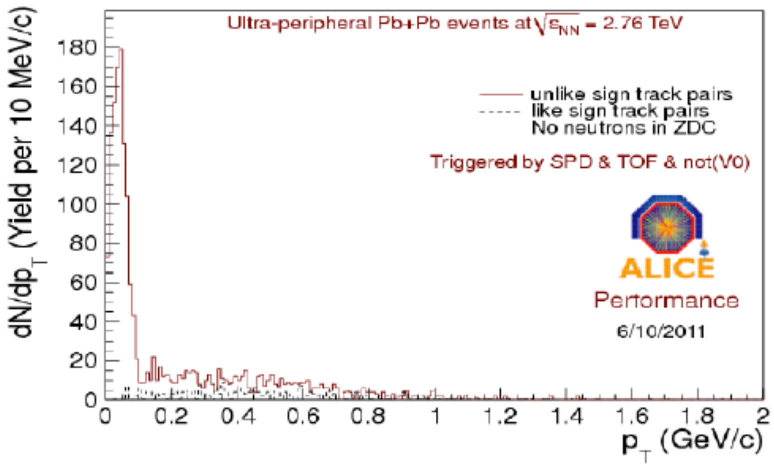
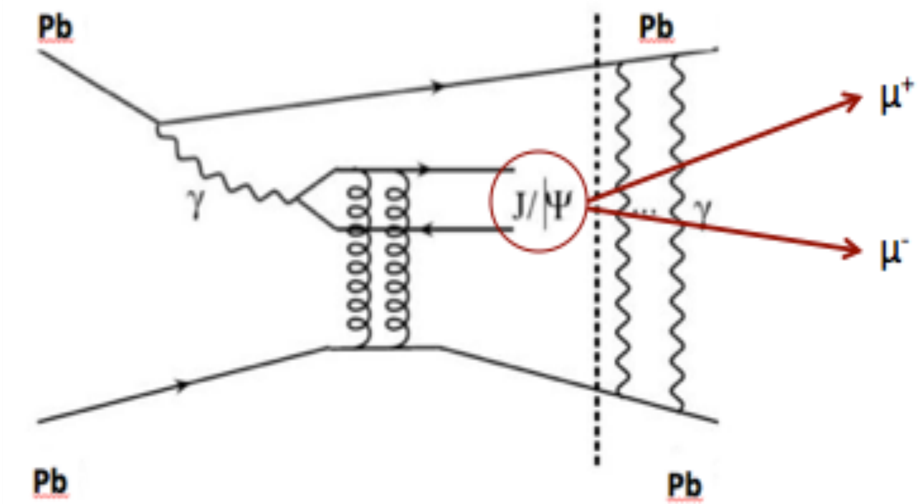


- Results after requiring no neutron emission using ZDCs, *i.e.* No neutron break-up
- Next step: Determine ρ^0 photoproduction cross section

Backup



- *J/ψ*, ϒ
- σ (γp→Vp) from pQCD
- 2-gluon exchange
- Sensitive probe of g(x), $g^2(x)$

$$\left.\frac{d\sigma(\gamma A \to VA)}{dt}\right|_{t=0} = \frac{\alpha_s^2 \Gamma_{ee}}{3\alpha M_V^5} 16\pi^3 \left[xG_A(x, Q^2) \right]^2 \text{, with } Q^2 = M_V^2/4 \text{, and } x = M_V^2/W_{\gamma A}^2$$

Ryskin, Roberts, Martin, Levin, Z. Phys C 76 (1997) 231, Frankfurt LL, McDermott MF, Strikman M, *J. High Energy Physics* 02:002 (1999) and Martin AD, Ryskin MG, Teubner T *Phys.Lett.* B454:339 (1999)