Diffractive and photon-induced physics at ALICE

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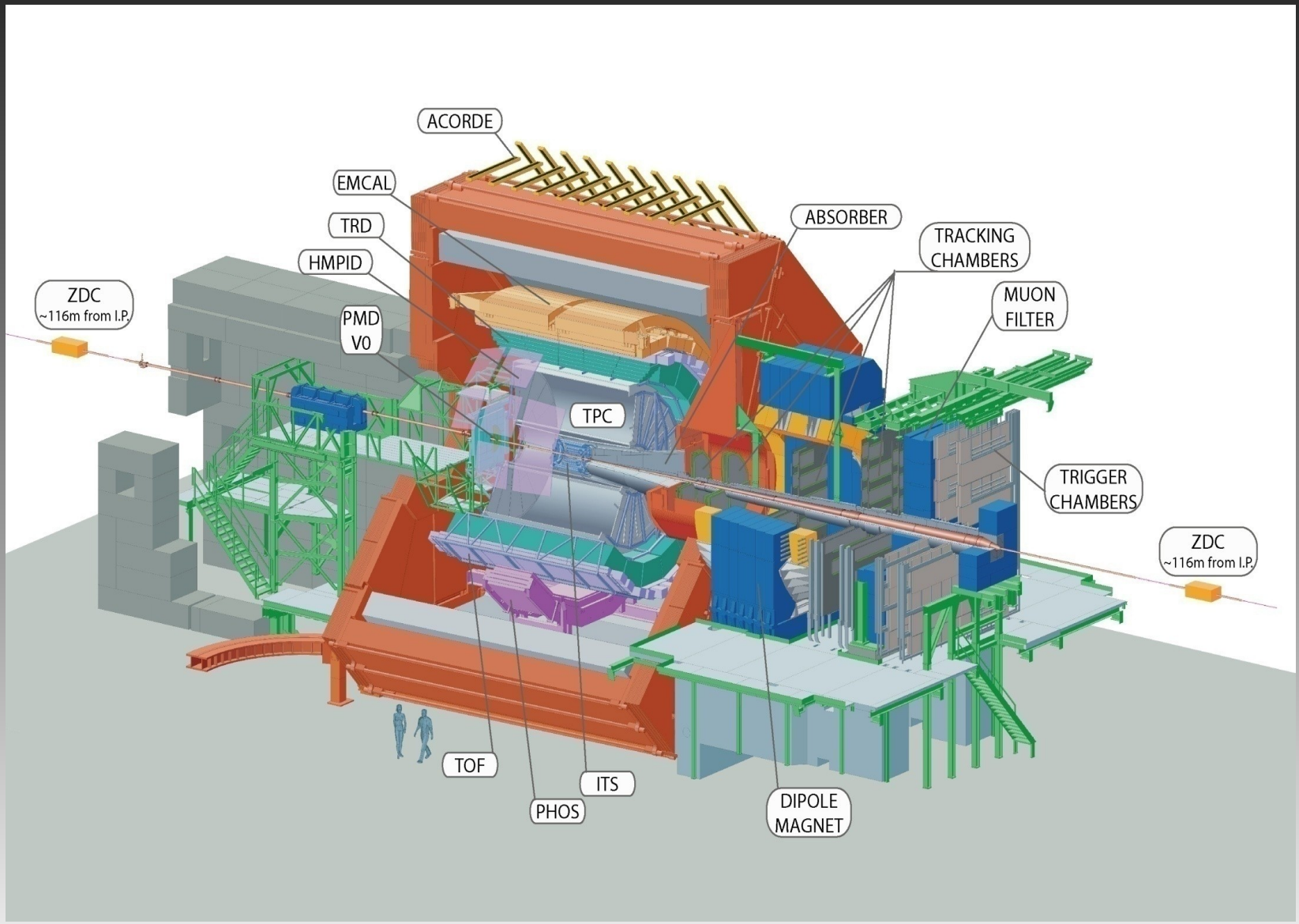
IPN Orsay (CNRS/IN2P3) – Paris XI

Heavy-ion physics meeting - Paris region
29 April 2011

Plan of this talk

- The ALICE experiment
- Exclusive resonance production in p+p collisions at 7 TeV
- Exclusive resonance production in ultra-peripheral Pb+Pb at 2.76 TeV
  - Summary of J. Nystrand presentation at DIS 2011
  - New results on J/ψ production in UPC Pb+Pb
- Summary and outlook

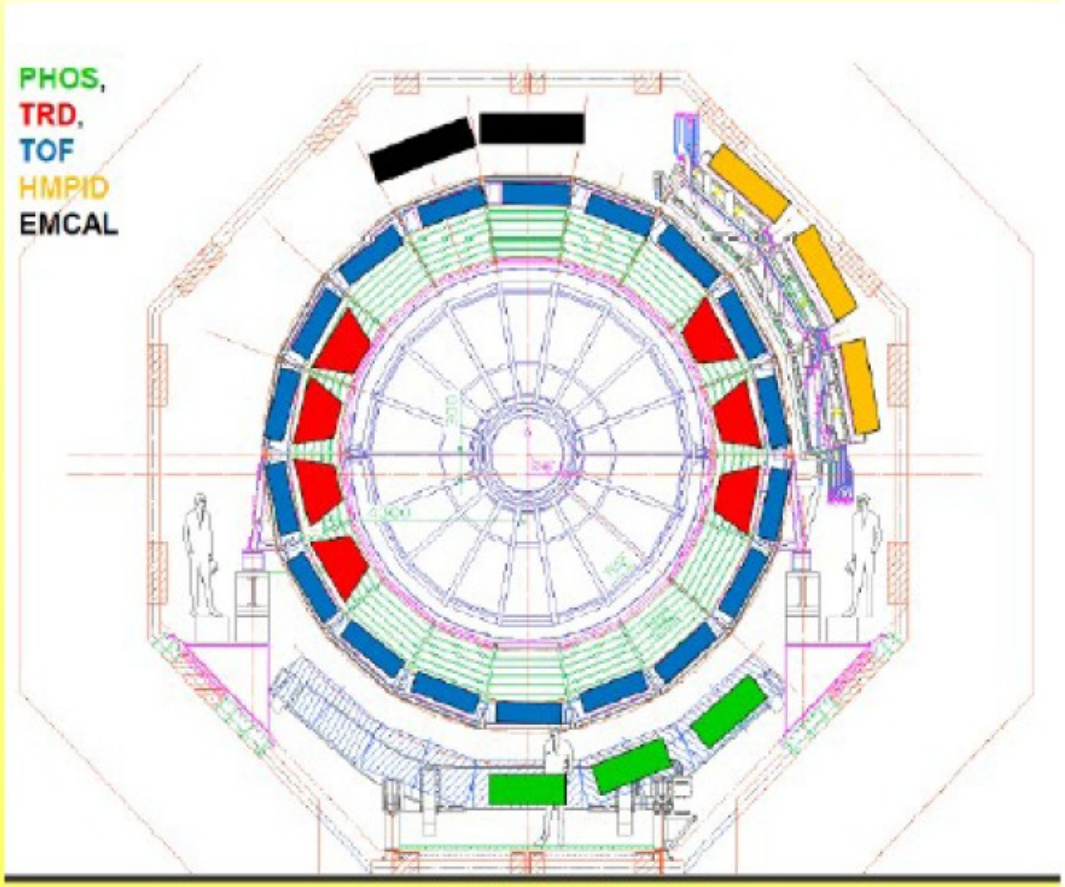
A Large Ion Collider Experiment



ALICE 2010

- ITS, TPC, TOF, HMPID, MUON, V0, T0, FMD, PMD, ZDC (100%)
- TRD* (7/18)
- EMCAL* (4/12)
- PHOS (3/5)

*upgrade to the original setup



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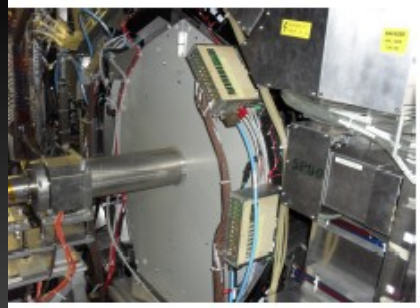
Diffractive Physics Today

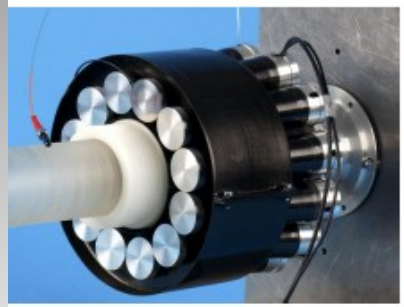
V0A $2.8 < \eta < 5.1$



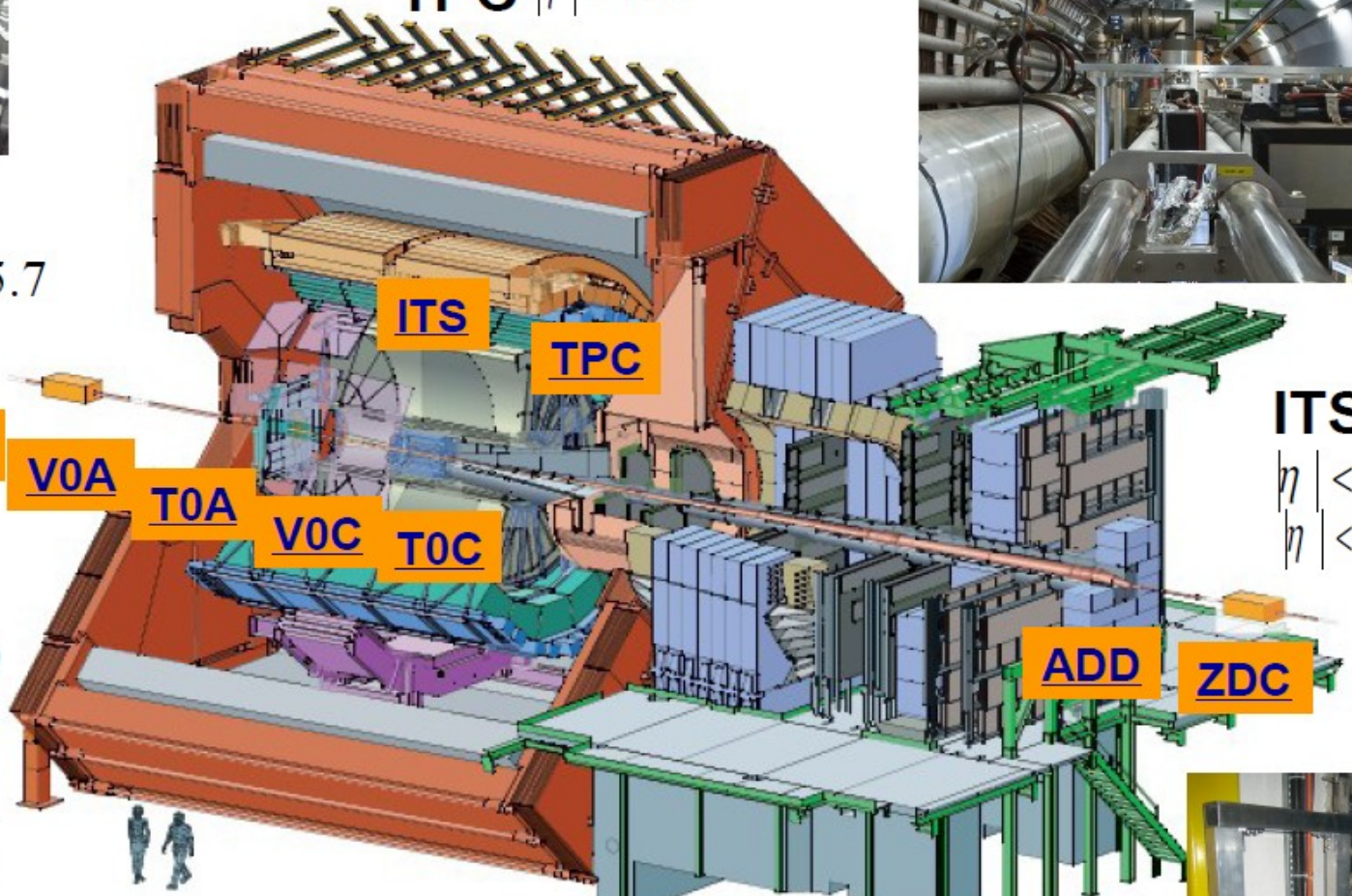
ZEM $4.8 < \eta < 5.7$

T0A $4.5 < \eta < 5.0$

T0C $-2.9 < \eta < -3.3$



TPC $|\eta| < 0.9$



V0C $-1.7 < \eta < -3.7$

FMD $1.7 < \eta < 5.0$ $-3.4 < \eta < -1.7$

ADD $-4.9 < \eta < -6.0$

ZN $|\eta| > 8.7$ **ZP** $|\eta| > 8.4$

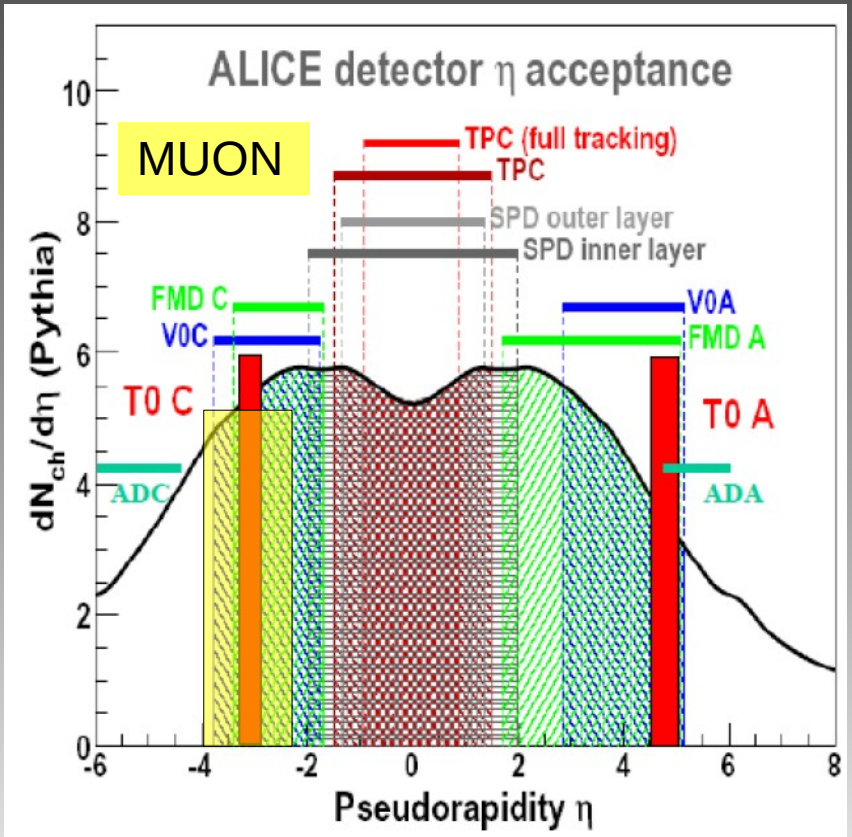
ITS

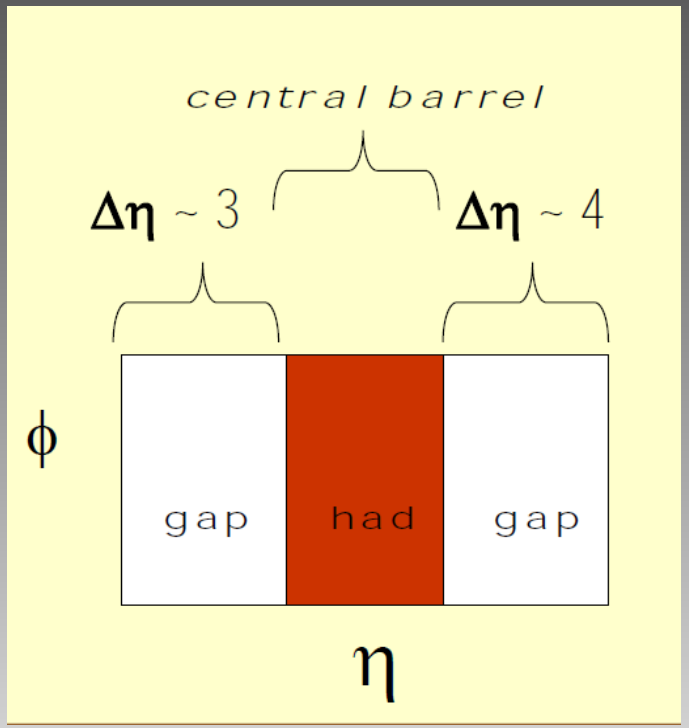
$|\eta| < 1.4$

$|\eta| < 2.0$

Rapidity gaps

ALICE is well suited to construct **rapidity gaps**

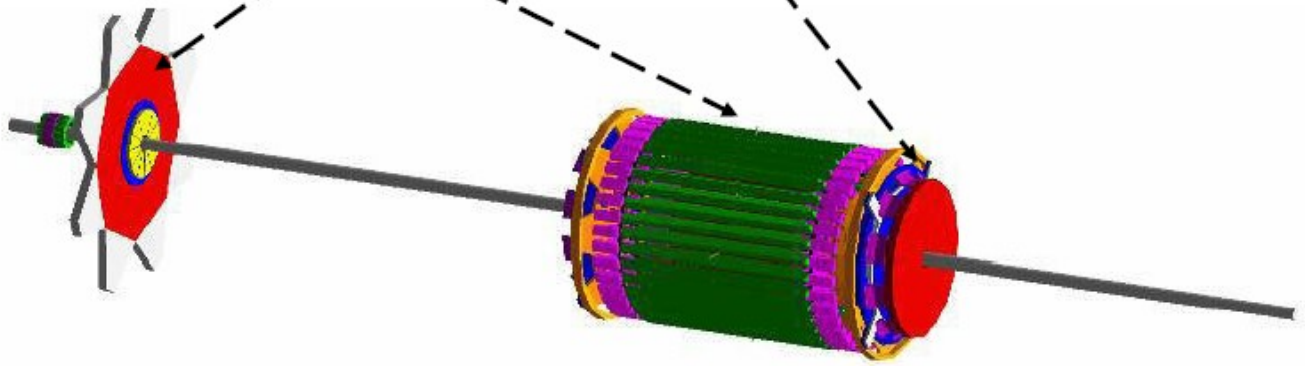




In p+p, ALICE is unique as pile-up is kept small. Excellent particle ID

MB triggers during the p+p runs this year 2010

Minimum Bias Triggers	MB1	SPD or (V0A or V0C)
	MB3	SPD and (V0A and V0C)



at least 1 charged particle in 8 rapidity units

Aat least 2 pixels in coincidence with beams

V0A $2.8 < \eta < 5.1$

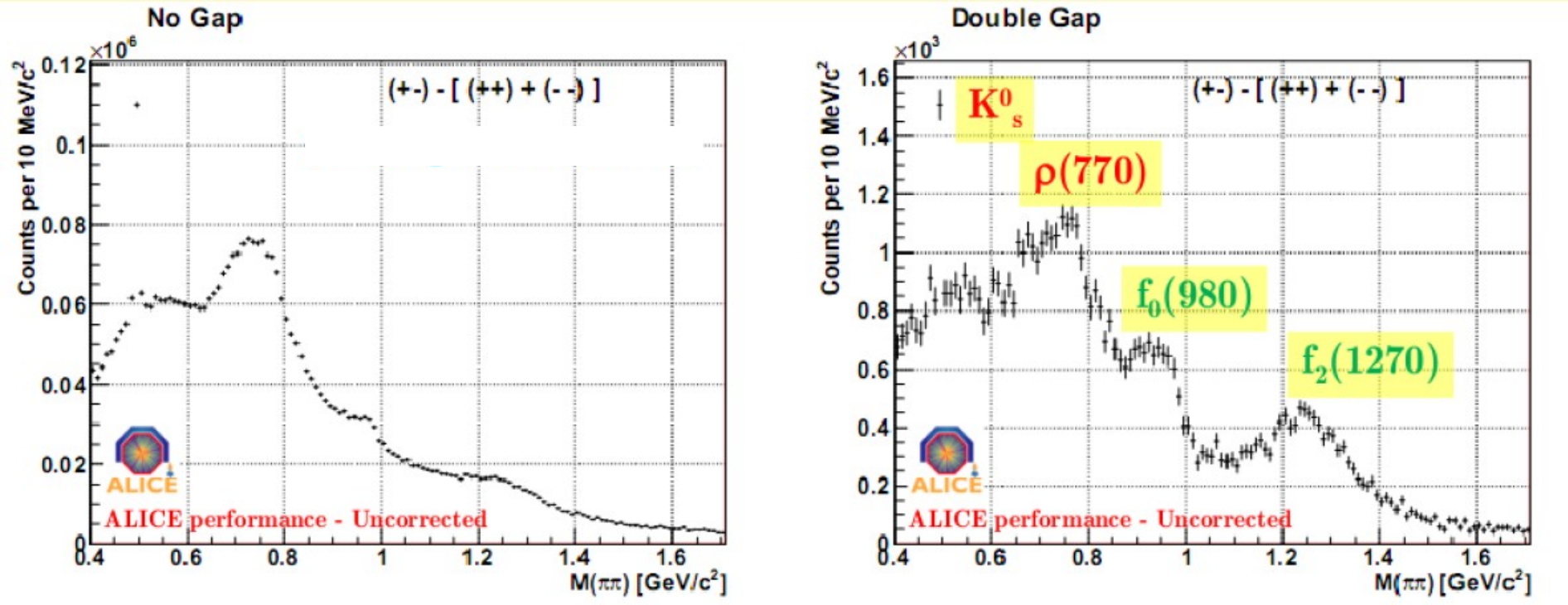
V0C $-1.7 < \eta < -3.7$

Global Fast Or (GFO) is the trigger from the Silicon Pixel Detector (SPD)

Exclusive resonance production in p+p collisions at 7 TeV

- 361 M events with the MB trigger
- 32.3 M events selected with primary vertex and exactly 2 TPC+ITS tracks
- 29.2 M events with no gap
  - 1.6 M events with gap on A-side
  - 1.4 M events with gap on C-side
  - 0.15 M events with gaps on both sides
- *Investigate particle production in events with exactly 2 tracks and gaps on both sides*

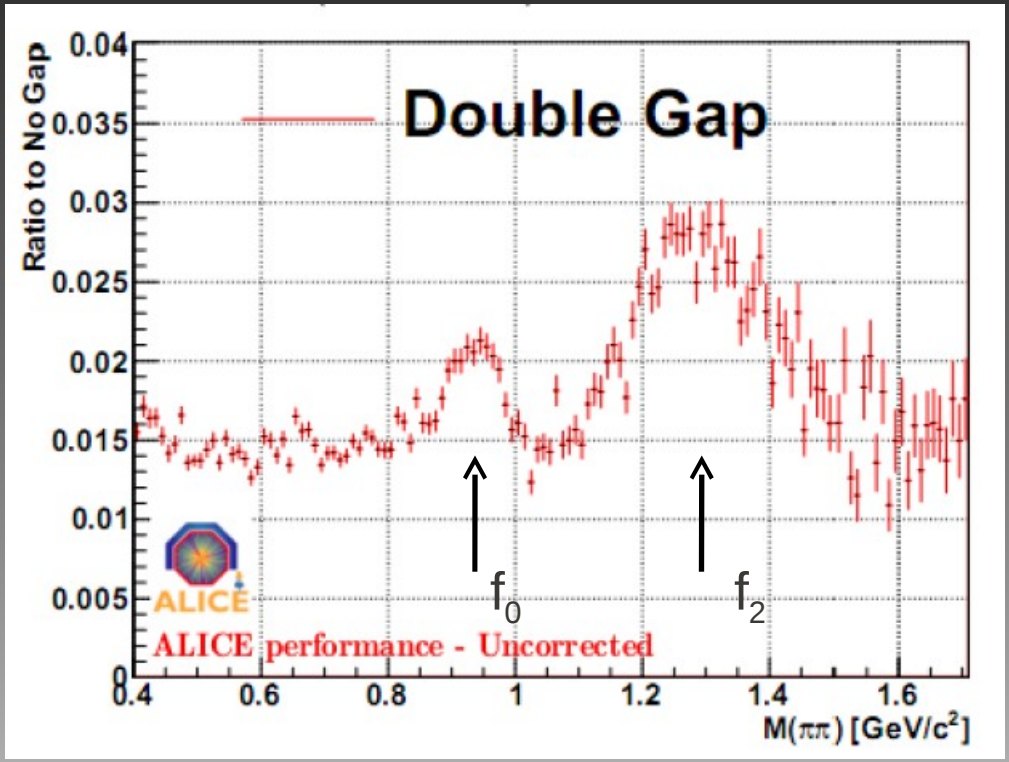
Exclusive resonance production in p+p collisions at 7 TeV



M_{inv} distribution for 2-track events without gaps. Like-sign contribution subtracted.

M_{inv} distribution for 2-track events with gaps on both sides. Like-sign contribution subtracted.

Exclusive resonance production in p+p collisions at 7 TeV

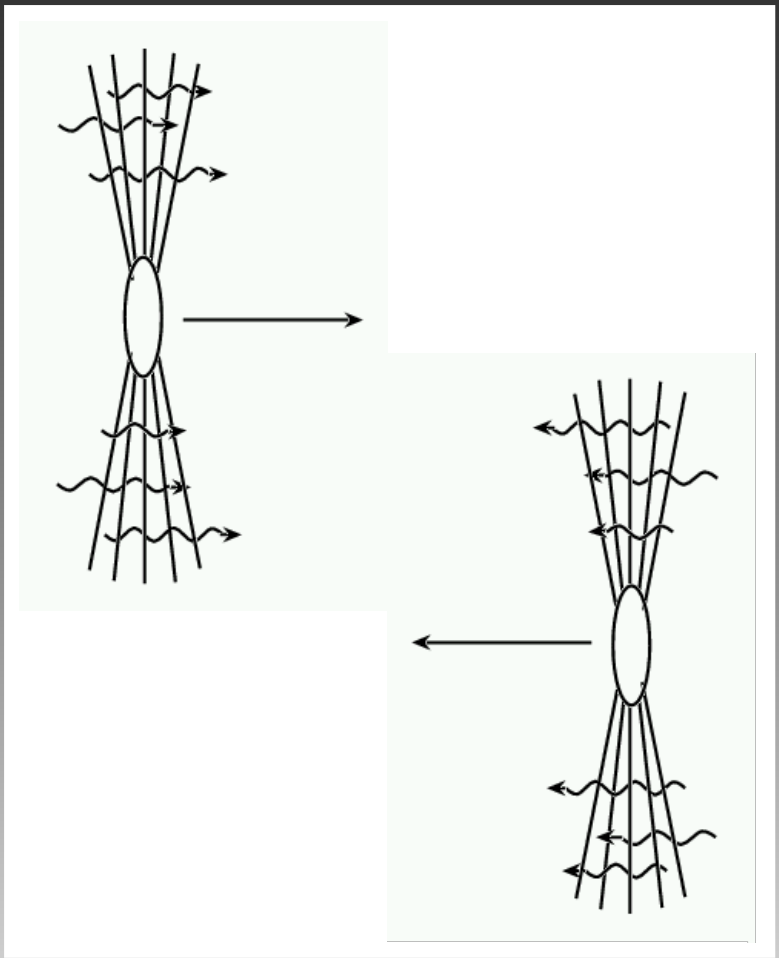


Ratio of M_{inv} distribution for 2-track events with gaps on both sides to events without gaps.

⇒ Some structure appears indicating IP+IP production of f_0 and f_2

⇒ Purity and backgrounds have to be investigated further

Ultra-peripheral heavy-ion collisions



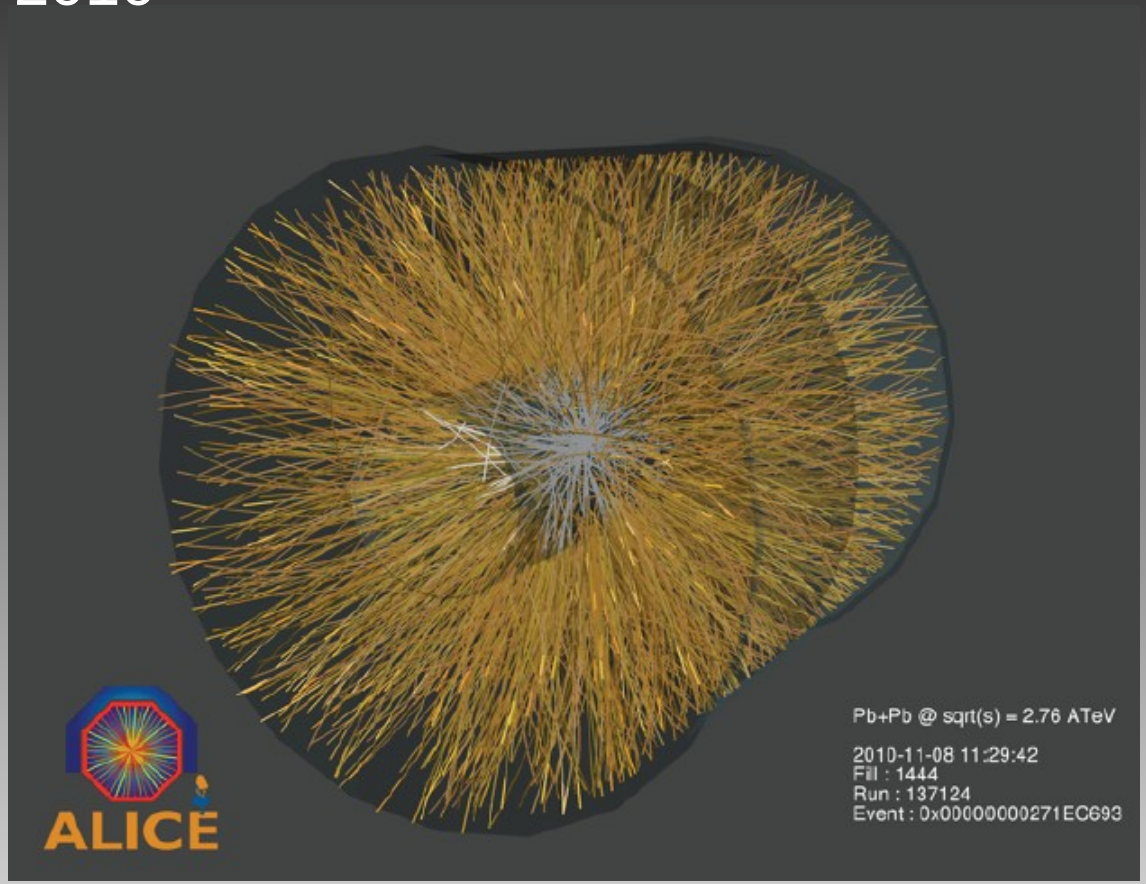
Two ions (or protons) pass by each other with impact parameters $b > 2R$

Only Electromagnetic interactions are possible

Number of photons scales like Z^2 for a single source ⇒ exclusive particle production in heavy-ion collisions dominated by electromagnetic interactions.

First heavy-ion collisions at the LHC on 8 Nov 2010

About 12 M min. bias collisions collected by ALICE between Nov and Dec 2010



Tracks in the ALICE TPC in a central Pb+Pb collision

Exclusive resonance production in UPC Pb+Pb collisions at 2.76 TeV

- ***3 UPC triggers were active:***
- OM2: TOF only trigger >= 2 hits in TOF
- CCUP2: TOF + SPD + V0 trigger: >= 2 hits in TOF + >= 2 hits in SPD + veto on V0A and V0C
- CMUP1: Muon arm + V0 trigger: at least one muon candidate + veto on V0A
- OM2 applied during the early, low-luminosity part of the run, CMUP1 and CCUP2 applied during the later parts, CCUP2 scaled down by factor 5-30

The UPC triggers sensitive to a variety of final states:

$\gamma\gamma \rightarrow e^+e^-$, $\gamma\gamma \rightarrow \mu^+\mu^-$, $\gamma\gamma \rightarrow f_2(1270) \rightarrow \pi^+\pi^-$,

$\gamma I\!P \rightarrow J/\Psi \rightarrow e^+e^-$ etc.

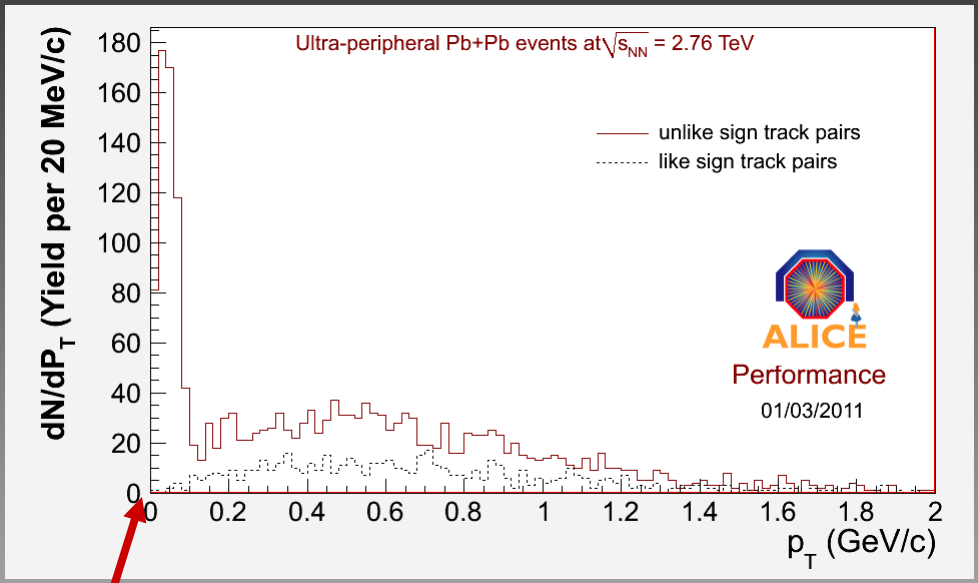
But the dominant channel will be exclusive photoproduction of $\rho^0 \rightarrow \pi^+\pi^-$. Total cross section: 3.9 b.

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

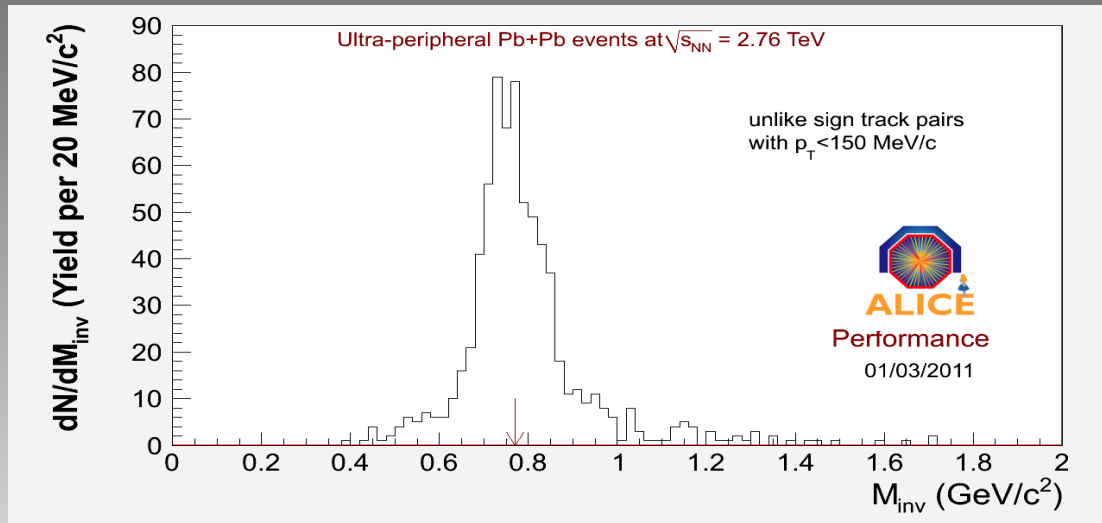
ALICE Acceptance: ≈ 9%.

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

Analysis of the events with UPC triggers:
Start with OM2 trigger (TOF only).
Select events with 2 reconstructed tracks.
Plot m_{inv} and total p_T for these events

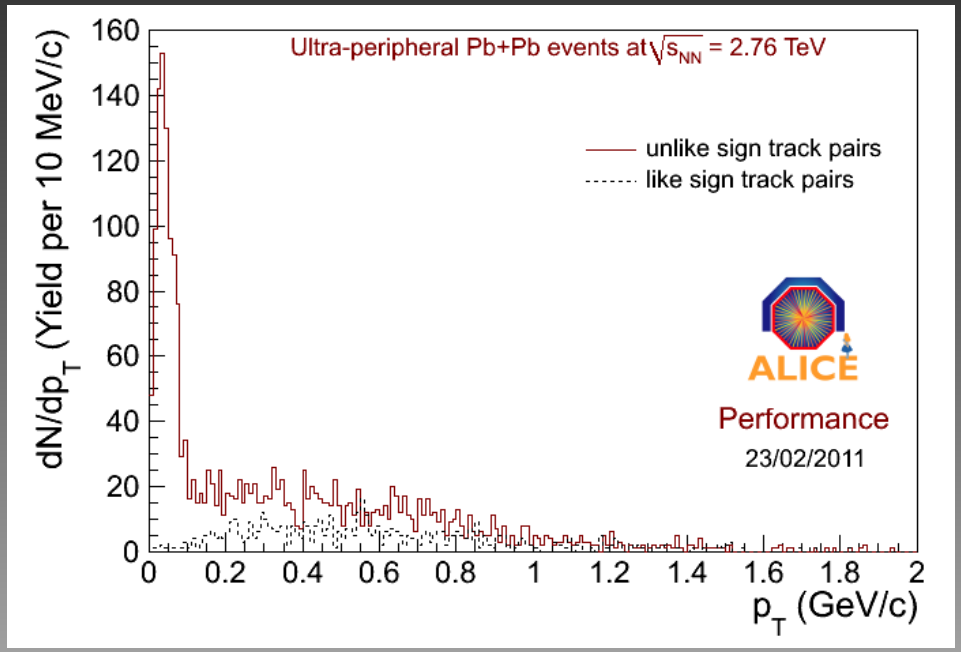


Uncorrected M_{inv} distribution of events in the low p_T peak indicates ρ^0 production. The peak may be distorted by experimental effects



Coherent peak at low p_T seen in unlike-sign combinations, absent in like-sign combinations.

Analysis of the events with UPC triggers:
Similar analysis for the CCUP2 trigger



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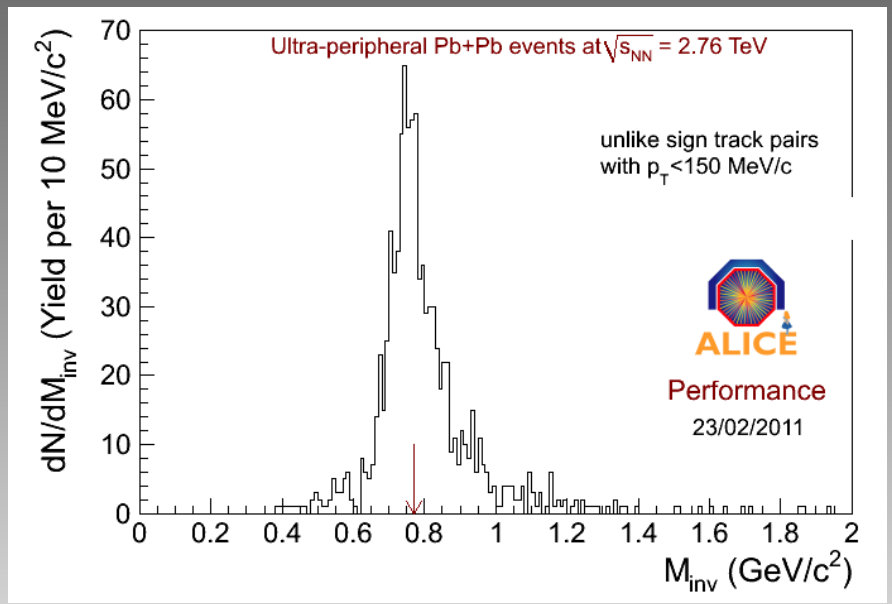
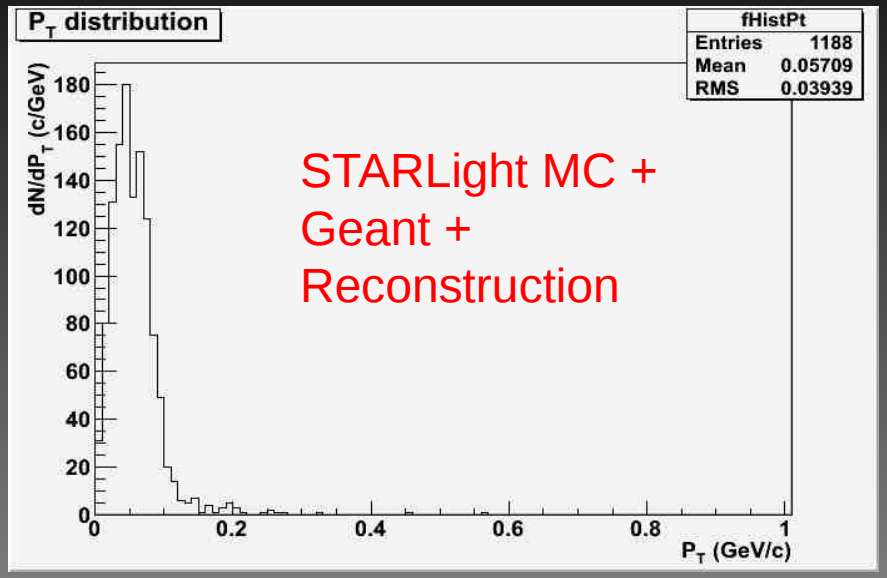
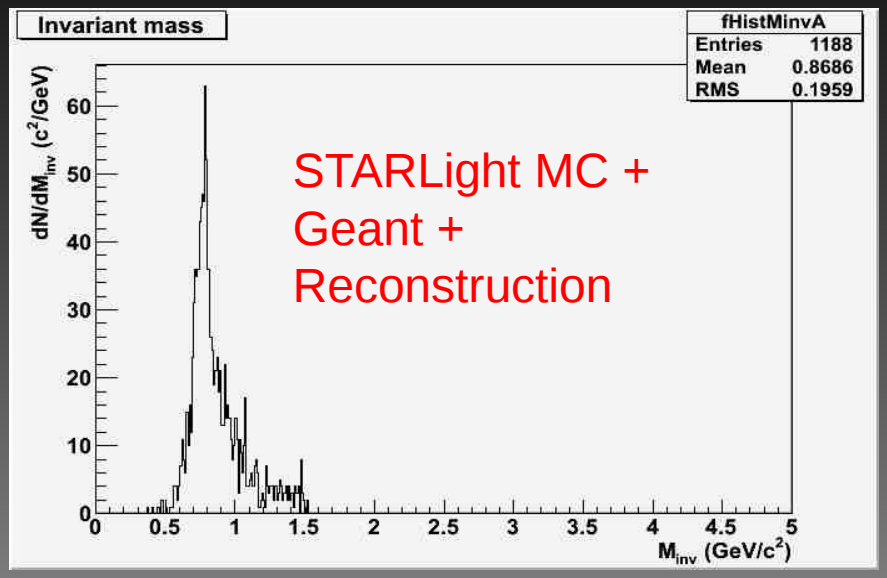
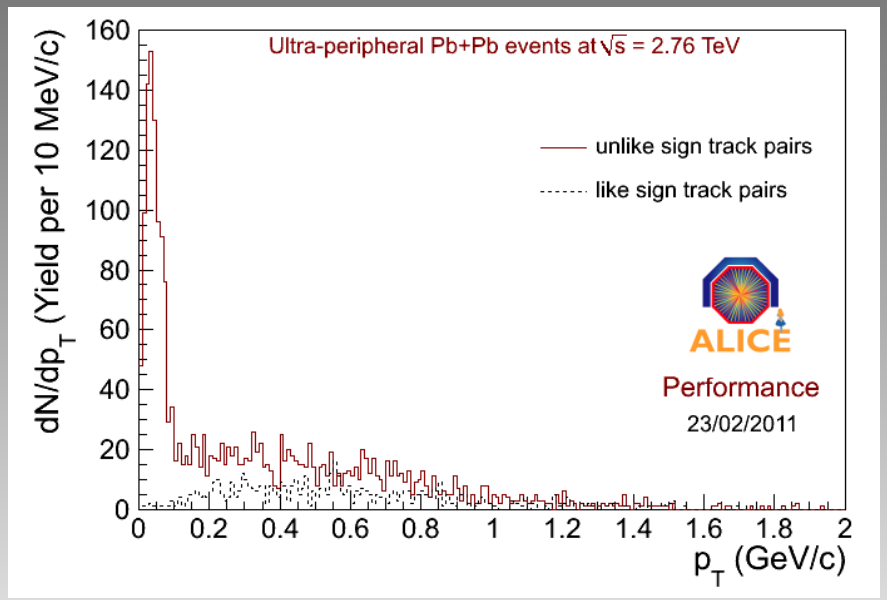


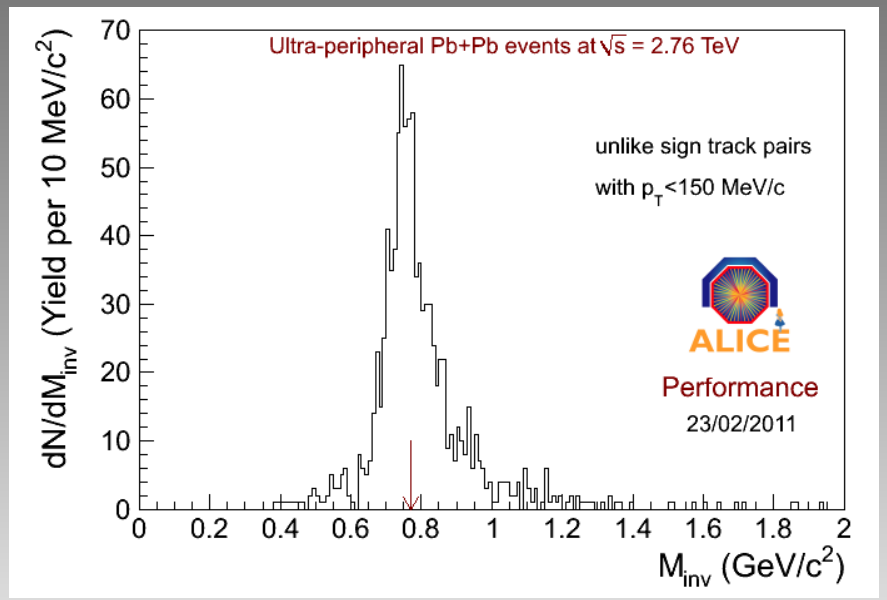
Both trigger samples show coherent photoproduction of ρ^0.

Ultra-peripheral Pb+Pb Collisions – First Results









Outlook for the ρ^0 analysis

Data from 2010

Determine the ρ^0 photoproduction cross section

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.

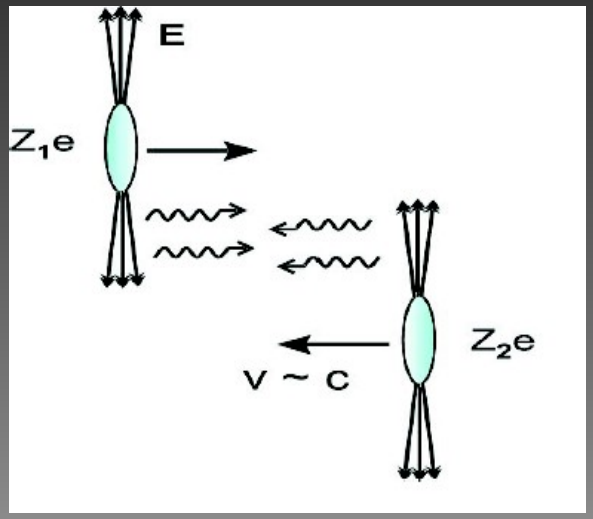
Use ZDC information to study production with and without nuclear break up

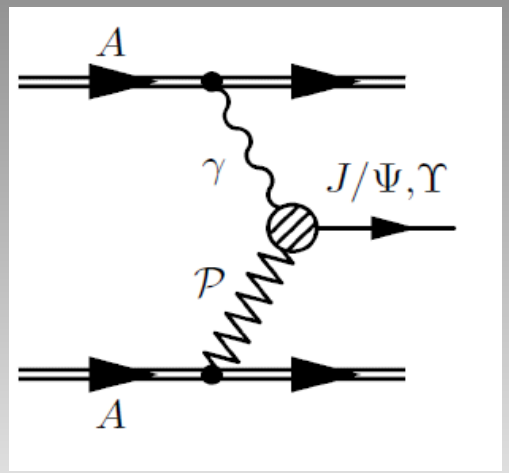
For 2011

Develop triggers to reduce background rates and avoid down scaling

Both SPD and TOF have the possibility to apply cuts on “topology” at Level-0.
Coherent production of high-mass particles have two tracks back-to-back in TOF.

Photoproduction of J/Ψ





- **Physics motivation:**
  - $\gamma p \rightarrow Qp \rightarrow \mu^+\mu^- p$ in p+p is proportional to the generalised gluon density of the proton

- **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

- Should provide a measure of the nuclear gluon shadowing

PHENIX paper: Physics Letters B, Volume 679, Issue 4, p. 321-329

Photoproduction of J/ψ and of high mass e^+e^- in ultra-peripheral Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV

Abstract

We present the first measurement of photoproduction of J/ψ and of two-photon production of high-mass e^+e^-–pairs in electromagnetic (or ultra-peripheral) nucleus-nucleus interactions, using Au+Au data at $\sqrt{s_{NN}} = 200$ GeV. The events are tagged with forward neutrons emitted following Coulomb excitation of one or both $Au^\star$ nuclei. The event sample consists of 28 events with $m_{e^+e^-} > 2$ GeV/c^2 with zero like-sign background. The measured cross sections at midrapidity of $d\sigma/dy\,(J/\psi + Xn, y = 0) = 76 \pm 33$ (stat) $\pm$ 11 (syst) μb and $d^2\sigma/dmdy\,(e^+e^- + Xn, y = 0) = 86 \pm 23$ (stat) $\pm$ 16 (syst) μb/(GeV/c^2) for $m_{e^+e^-} \in [2.0,2.8]$ GeV/c^2 are consistent with various theoretical predictions.

~ 10 J/ψ candidates
27% statistical error
19% systematic error

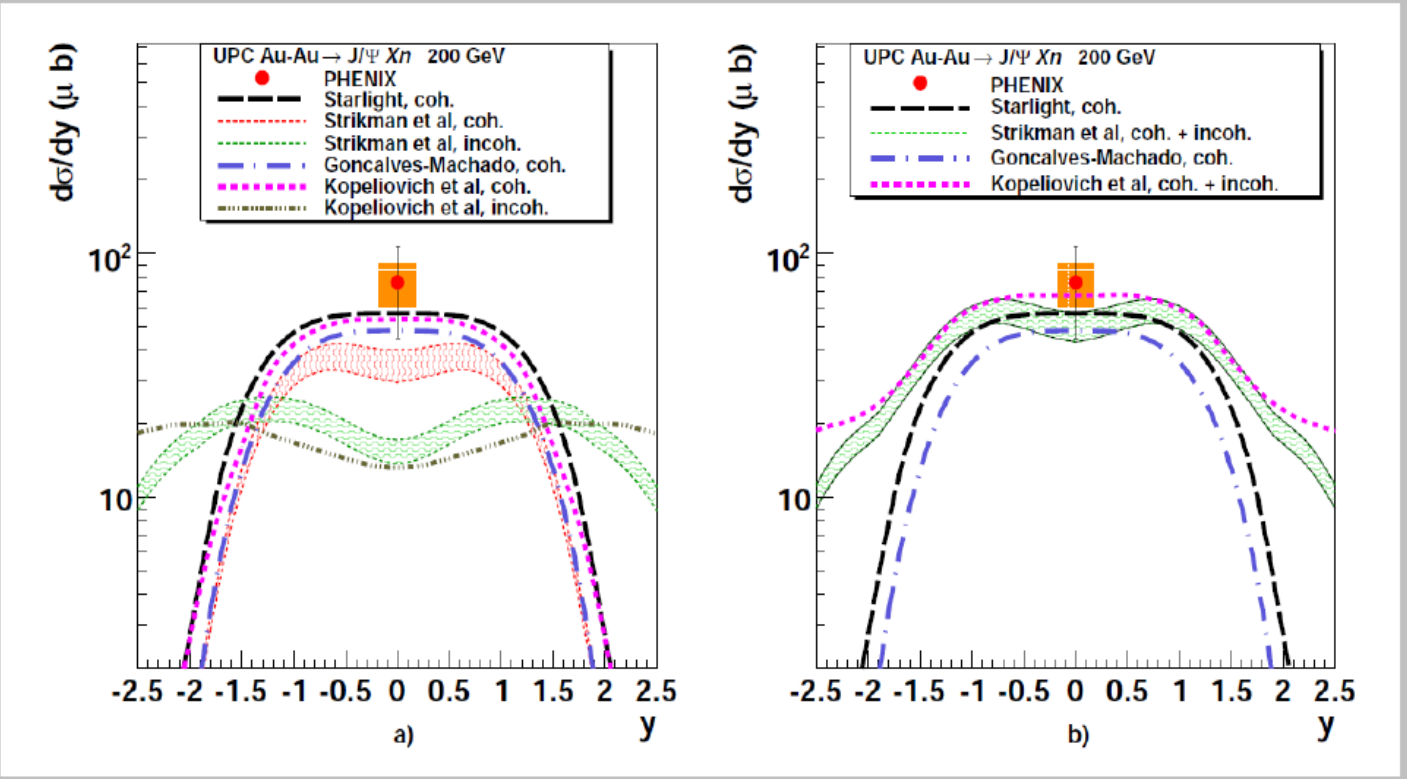
→ Such a large statistical error made impossible to distinguish between coherent and incoherent components

Comparing with RHIC results

PHENIX paper

Models for coherent and incoherent, separately

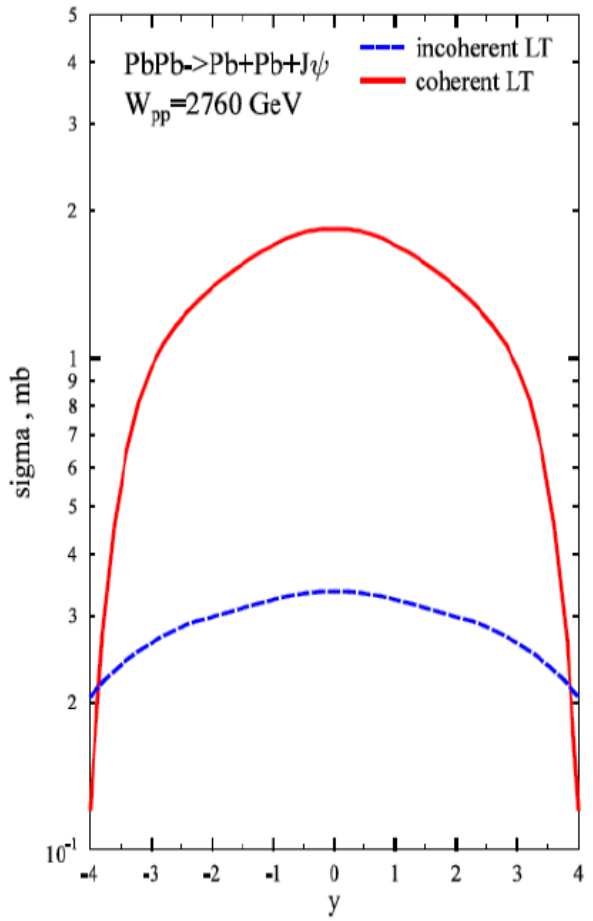
Sum of coherent and incoherent models



ALICE allows the measurements of
1. The rapidity dependence
2. Coherent and incoherent components, separately

→ **Only at the LHC**

Total J/ψ cross sections in Pb+Pb at 2.76 TeV



Total J/Ψ cross section:
10.2 mb.

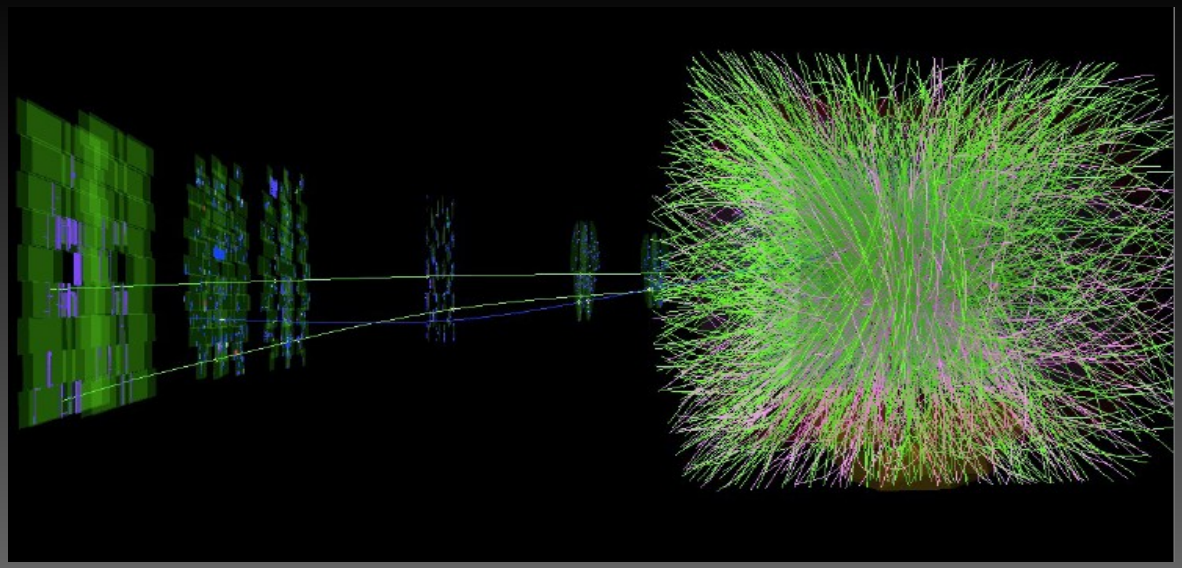
Starlight:
23 mb.

Two models

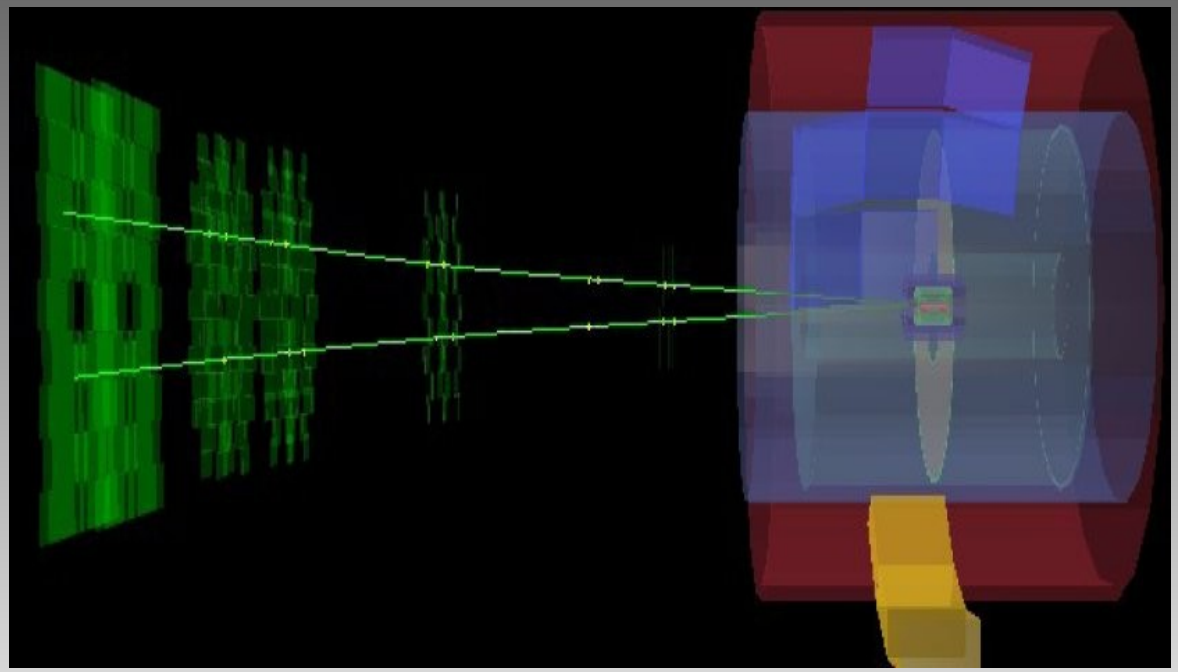
M. Zhalov, et al.

J. Nystrand, et al.

11

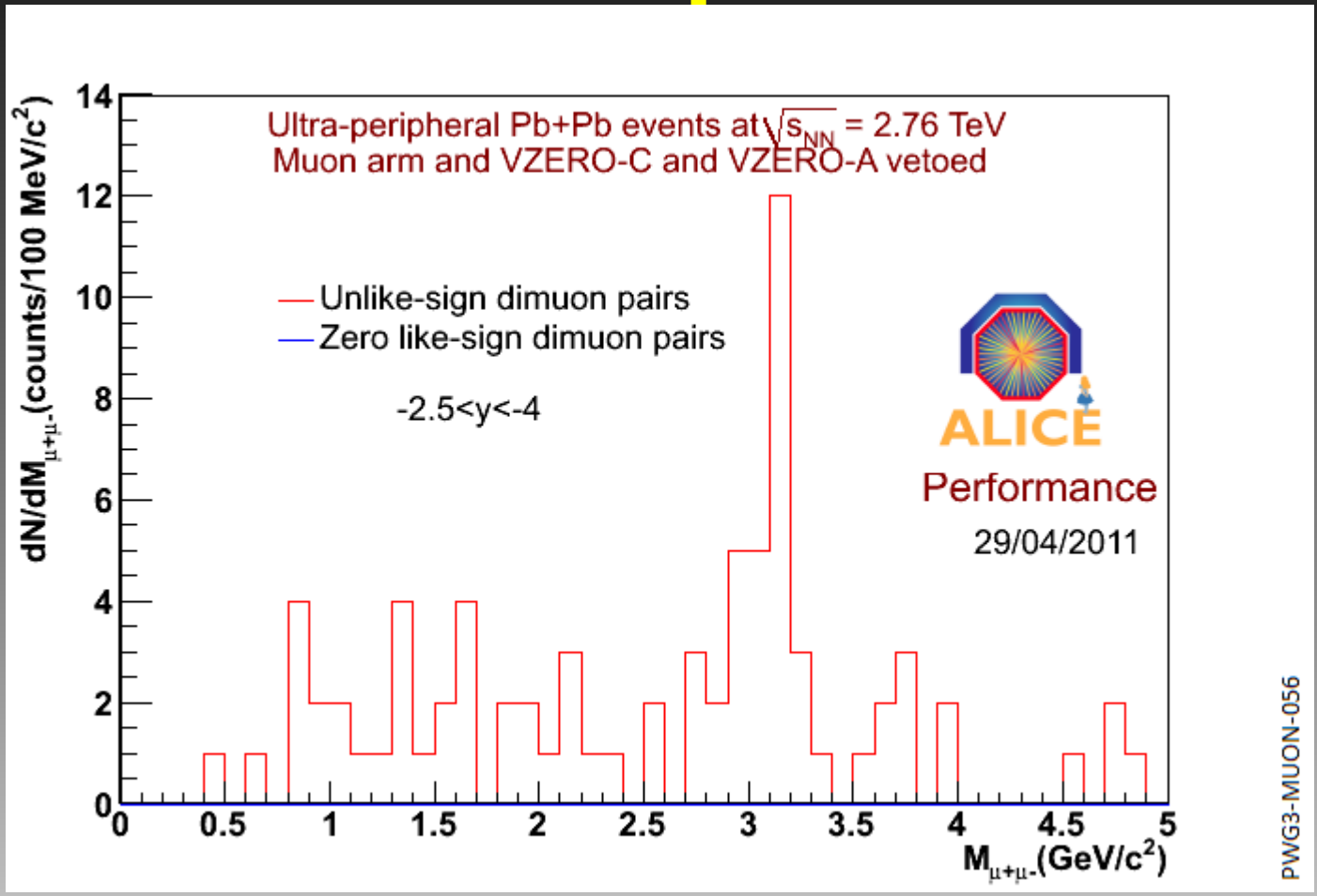


Inclusive reaction in Pb+Pb collisions at 2.76 TeV



Exclusive reaction in UPC Pb+Pb collisions at 2.76 TeV

Photoproduction of J/Ψ



Results shown for the first time!

CMUP1:
Muon arm + V0 trigger, *i.e.* at least one muon candidate + veto on V0A

No like-sign background

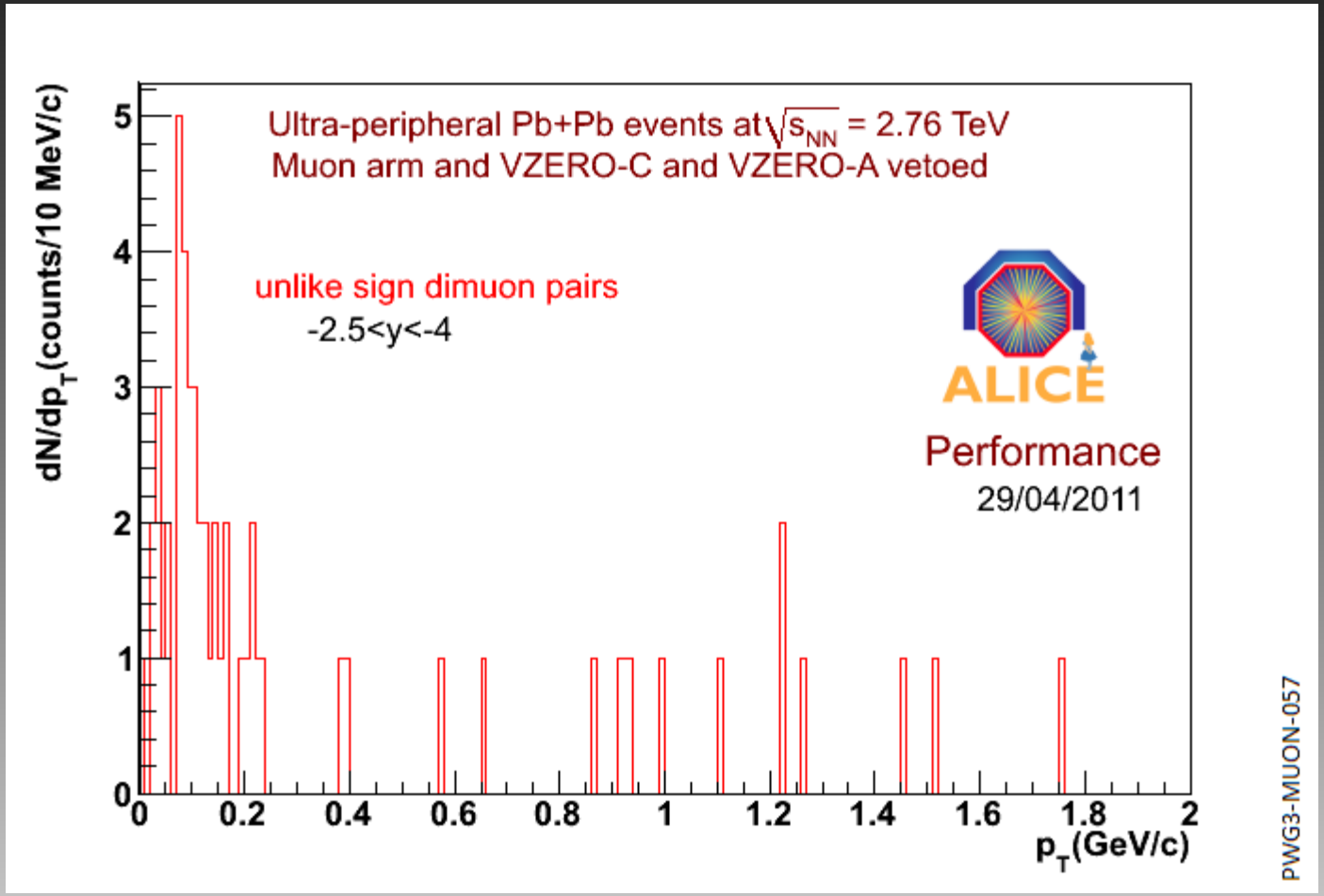
Exclusive events!

Already more J/ψ candidates than at RHIC

Additional selection to define exclusive reaction, offline
No ITS and TPC tracks at mid-rapidity
Veto on the two outer rings of V0C ($-2.7 < \eta < -1.7$)
No more than one FMD hits in $1.7 < \eta < 5.0$ and $-2.4 < \eta < -1.7$
Allow hits in $-3.4 < \eta < -2.4$.

Photoproduction of J/Ψ

Results shown for the first time!

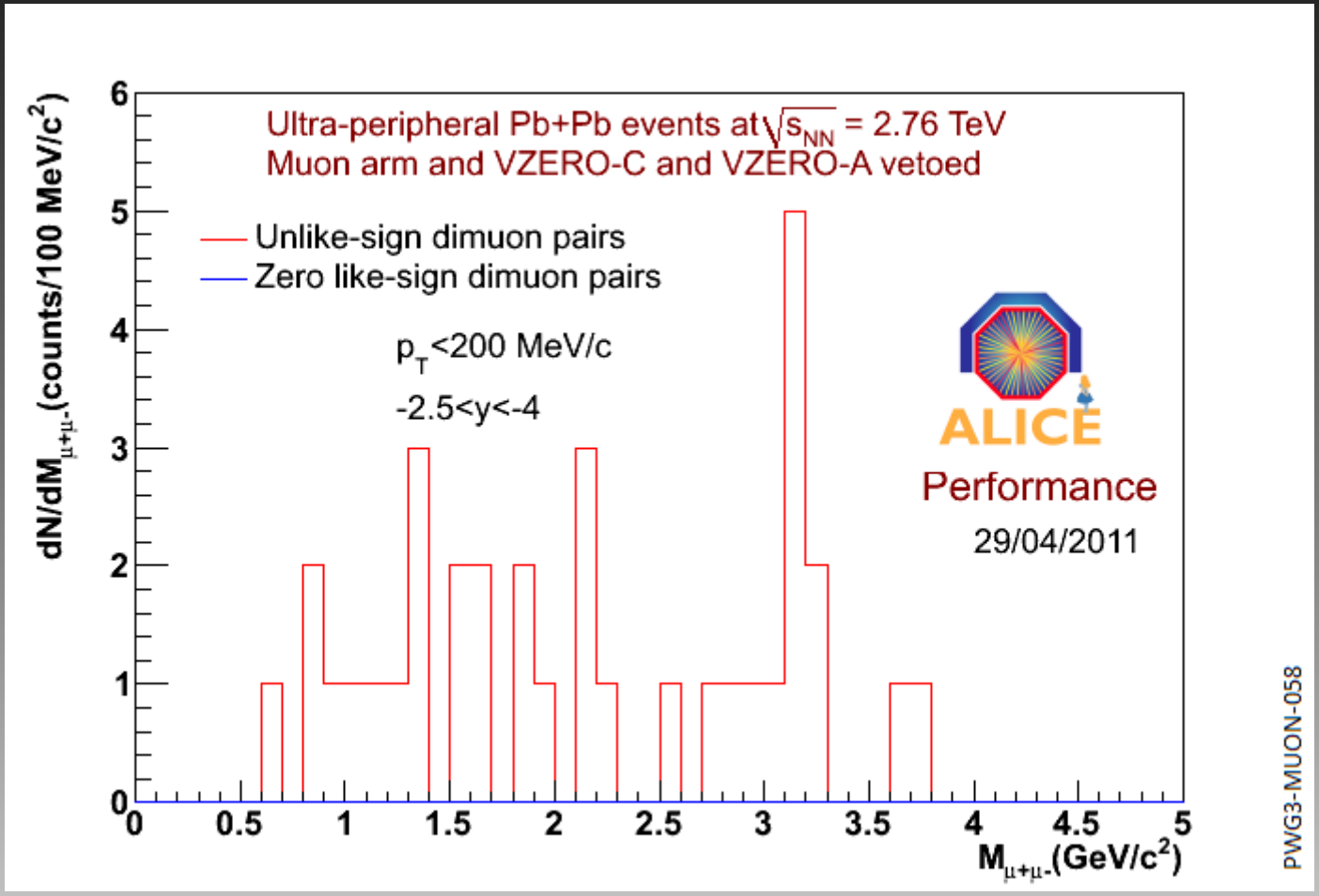


A typical P_T shape below 200 MeV/*c*

No like-sign background

Exclusive events!

Photoproduction of J/Ψ



Results shown for the first time !

It will be possible to study both coherent and incoherent components

→ *Next step: measure the absolute cross section*

Summary and outlook

- Study of central diffraction, by measuring resonance production in p+p collisions at 7 TeV, is ongoing
- Photoproduction of ρ^0 observed. Cross section to be determined
- Search ongoing for J/ Ψ and heavier states. Candidates have been found. Study at both central and forward rapidity. Very promising results. Cross section to be determined
- Improved UPC triggers and higher luminosities in future heavy-ion runs will enable rarer final states to be measured

BACKUP

4 stations of scintillator detectors