A Large Ion Collider Experiment

European Organisation for Nuclear Research

Vector meson production in ALICE at the LHC

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Outline

- ALICE and the Quark Gluon Plasma
- Interest of vector mesons study
- The ALICE detector
- Channels for vector mesons study
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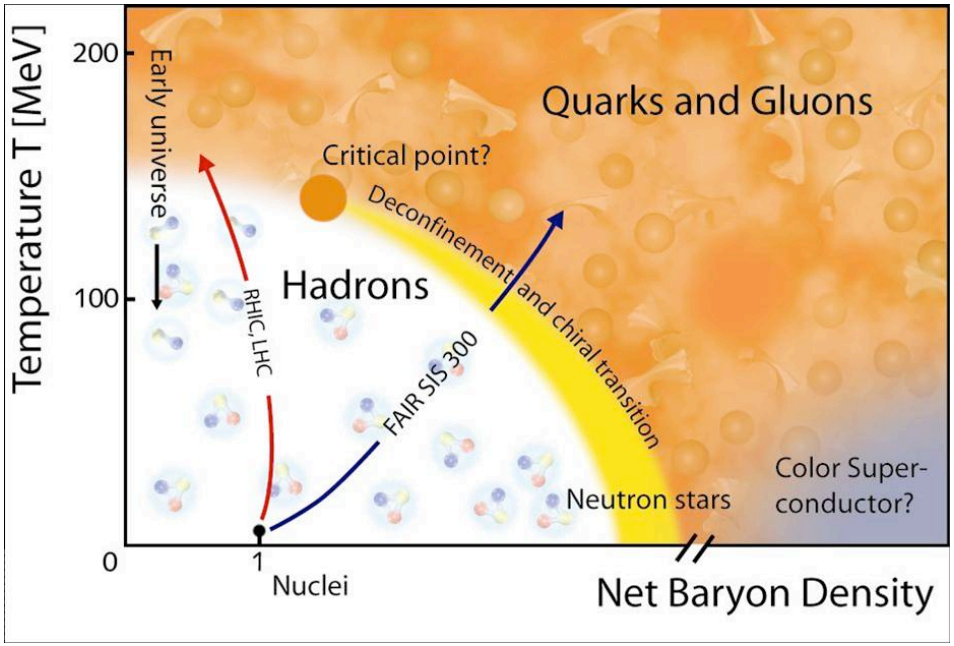
- Ultraperipheral collisions in Pb-Pb collisions
- Low mass dielectron analysis in p-p collisions
- Low mass dimuon analysis in p-p collisions
- Status of the low mass dimuon analysis in Pb-Pb collisions

ALICE and the Quark Gluon Plasma

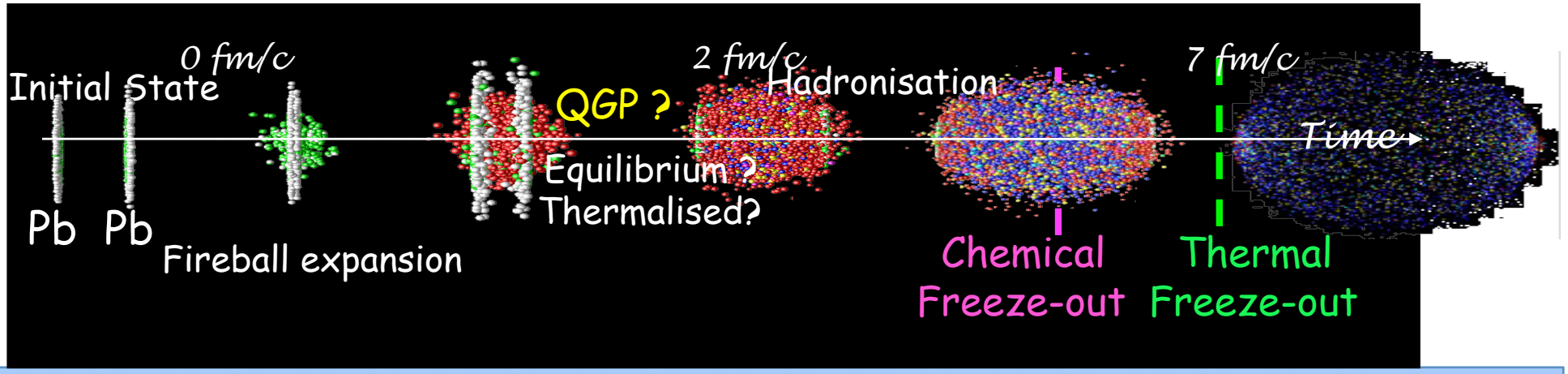
- Quark Gluon Plasma (QGP) : deconfined state of nuclear matter (quark and gluons)

- Goal of ALICE (A Large Ion Collider Experiment) : measure the properties of the QGP

- Need : Increase temperature and density



- Relativistic heavy ion collisions to probe the nuclear matter phase diagram



Interest of vector mesons study

- Directly accessible by e^+e^- and $\mu^+\mu^-$ measurement
  → Negligible final state interactions for leptons
- Focus on Light Vector Mesons :

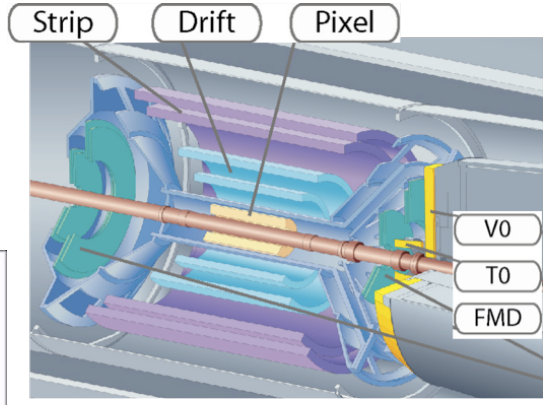
Resonance	Mass (MeV/c^2)	Width (MeV/c^2)	$c\tau$ (fm)	B.R. $\mu^+\mu^-$ (%)	B.R. e^+e^- (%)
ρ	775	149	1.3	$(4.6 \pm 0.3) \times 10^{-3}$	$(4.7 \pm 0.1) \times 10^{-3}$
ω	783	8.5	23.5	$(9.0 \pm 3.1) \times 10^{-3}$	$(7.2 \pm 0.1) \times 10^{-3}$
ϕ	1019	4.3	46	$(2.9 \pm 0.2) \times 10^{-2}$	$(3.0 \pm 0.1) \times 10^{-2}$

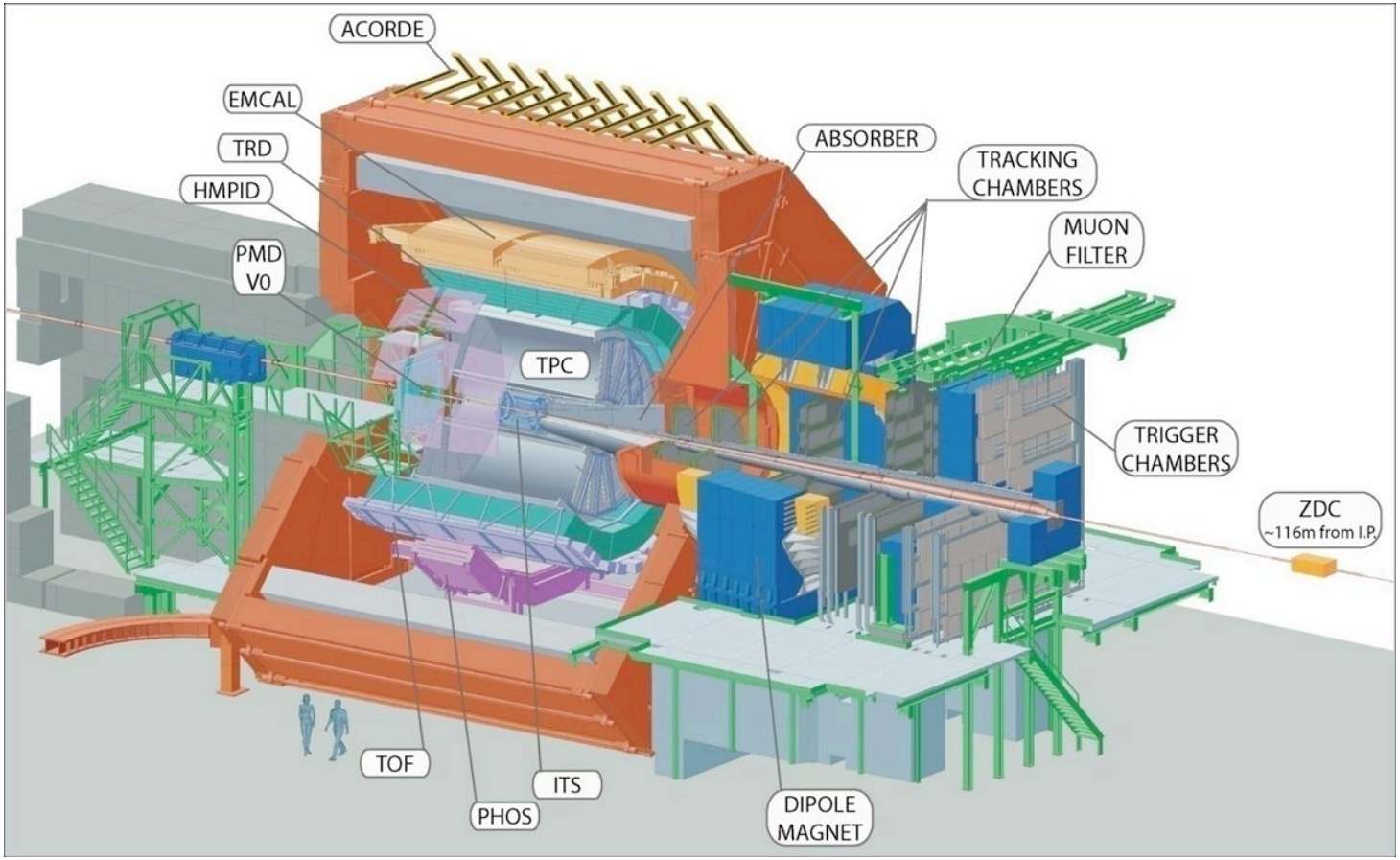
→ Short lifetime (1 to 50 fm/c) : modification of yields and spectral function by the hot hadronic and QGP medium (QGP lifetime at LHC ~ 10 fm/c)

→ Study of $N_\phi/N_{\rho+\omega}$: strangeness enhancement as a function of centrality?

→ Chiral symmetry restoration : ρ spectral function modification

The ALICE detector





Central Detectors :
Inner Tracking System
Time projection Chamber
Time-of-Flight
Transition Radiation Detector

Spectrometers :
High Momentum PID
Photon Multiplicity
Forward Multiplicity
Muon spectrometer

Calorimeters :
EM Calorimeter
Photon Spectrometer
ZDC

Triggers :
SPD (pixels)
V0A + V0C (scintillators)
Muon Trigger

Acceptance of the central barrel : $0 < \phi < 2\pi \quad |\eta| < 0.9$
Acceptance of the muon spectrometer : $0 < \phi < 2\pi \quad -4 < \eta < -2.5$

Channels for vector mesons study

Central barrel

$\phi \rightarrow K^+K^-$

$K^{*0} \rightarrow K^+ \pi^-$

$\underline{K}^{*0} \rightarrow K^- \pi^+$

$\phi \rightarrow e^+e^-$

$\rho^0 \rightarrow e^+e^-$

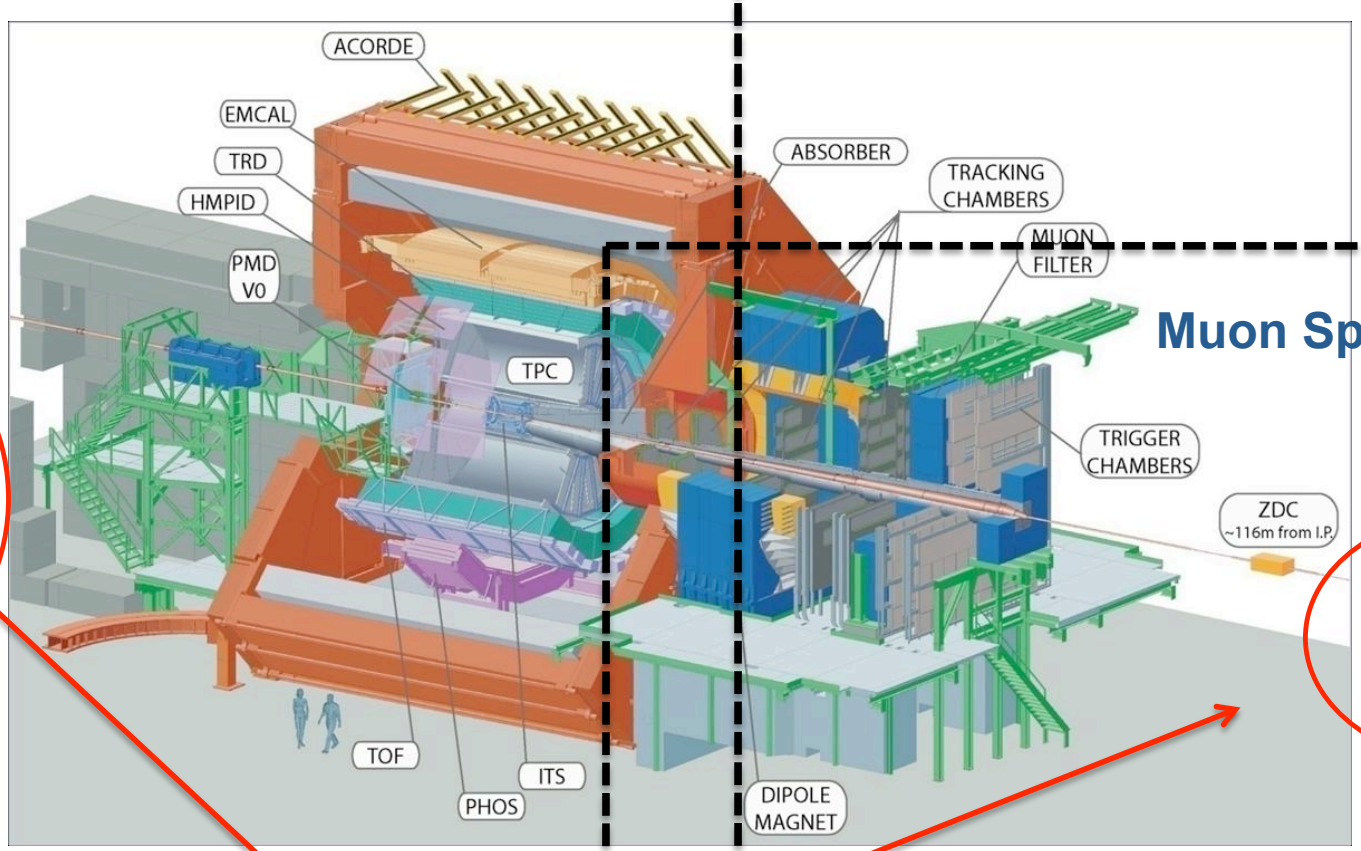
$\omega \rightarrow e^+e^-$

$\rho^0 \rightarrow \pi^+ \pi^-$

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

$D^{*+} \rightarrow D^0 \pi^+_s$

$D^{*-} \rightarrow D^0 \pi^-_s$



Muon Spectrometer

$\phi \rightarrow \mu^+\mu^-$

$\rho^0 \rightarrow \mu^+\mu^-$

$\omega \rightarrow \mu^+\mu^-$

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

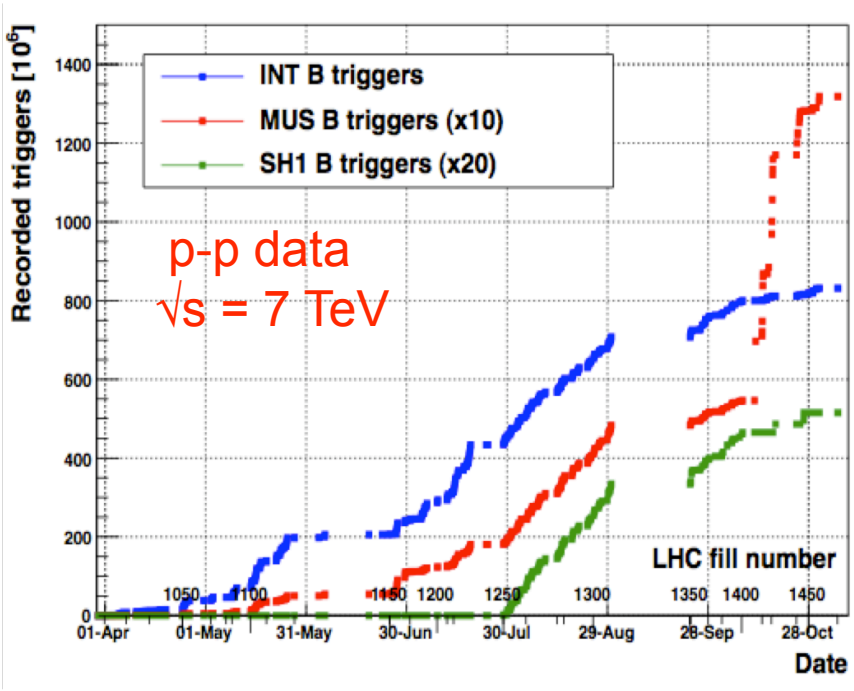
$\Upsilon \rightarrow \mu^+\mu^-$

Focus of this talk

Data taking and trigger scheme

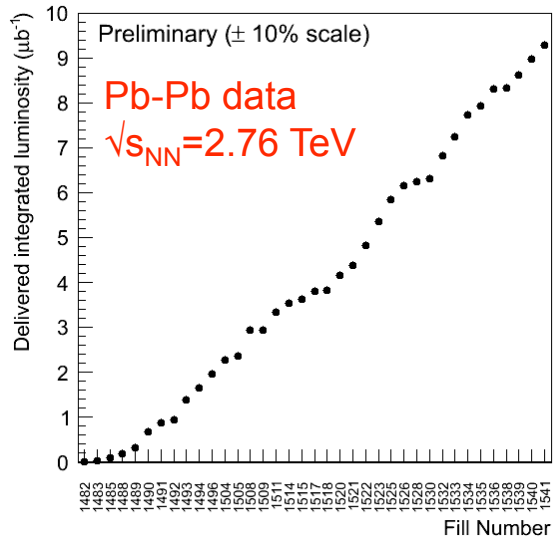
p-p data taking :

- ❑ Interaction trigger reading all detector (INTB)
  SPD (min bias) or V0A or V0C
  At least one charged particle in 8 pseudo-rapidity units
- ❑ **Single muon trigger** reading MUON, SPD, V0, FMD, ZDC (MUSB) :
  Single muon, low Pt threshold, in the muon arm in coincidence with interaction trigger
- ❑ High Multiplicity trigger (SH1B)
- ❑ Coincidence with 'bunch crossing'
  > **800 Millions MB interactions**
  > **100 Millions muon trigger**
  > 25 Millions High Multiplicity



Pb-Pb data taking :

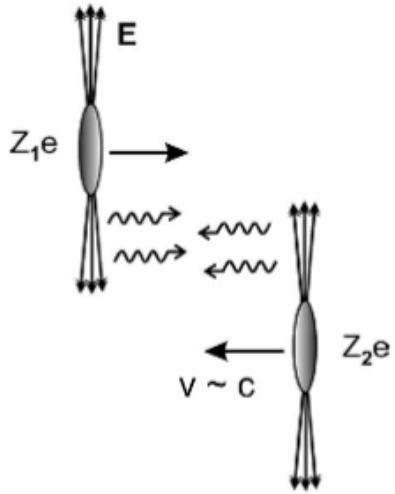
- ❑ Stricter conditions with increasing luminosity
- ❑ MB Trigger : Combination of 3 detectors
  SPD (1 or 2 hits in outer layer) + V0A + V0C
- ❑ High Multiplicity trigger
- ❑ **Ultraperipheral trigger**



Ultra-peripheral collisions in Pb-Pb

Photonuclear interaction

$$Pb+Pb \rightarrow Pb+Pb+\rho^0$$



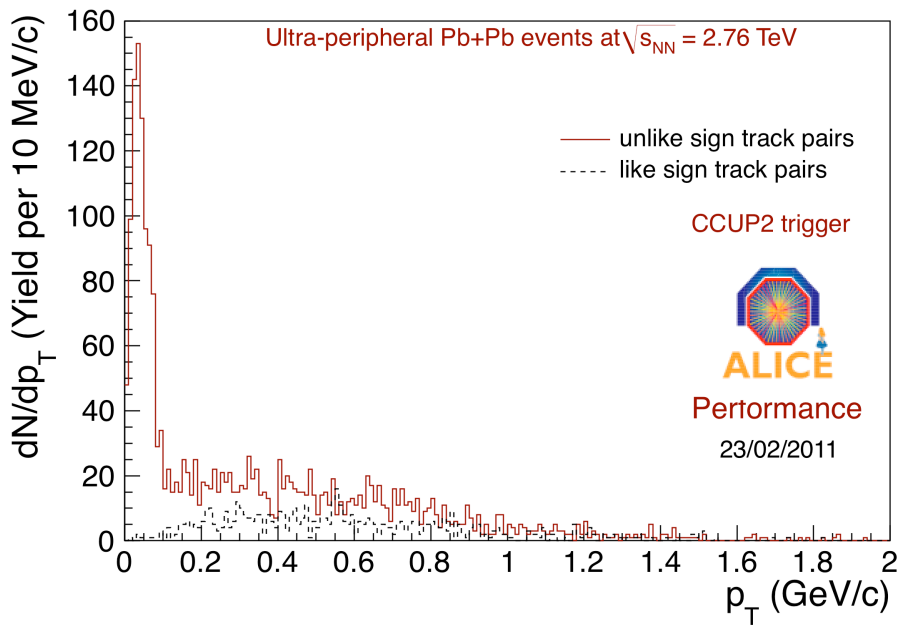
Analysis of events with 2 primary tracks (Pion mass assumed)

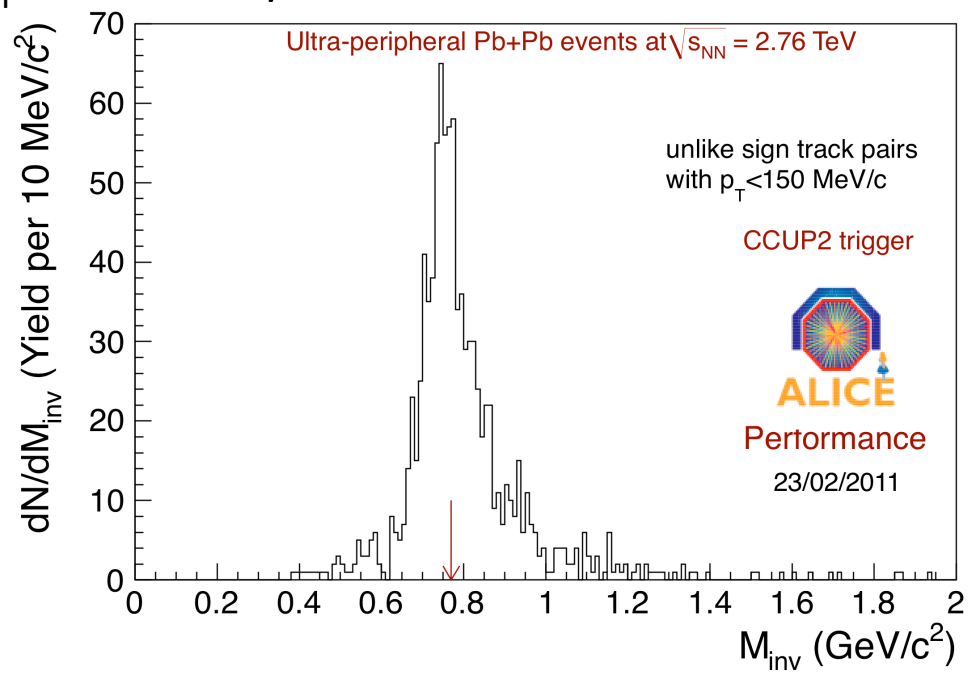
Trigger : both tracks must produce hits in TPC and TOF

Clusters in ITS >= 3

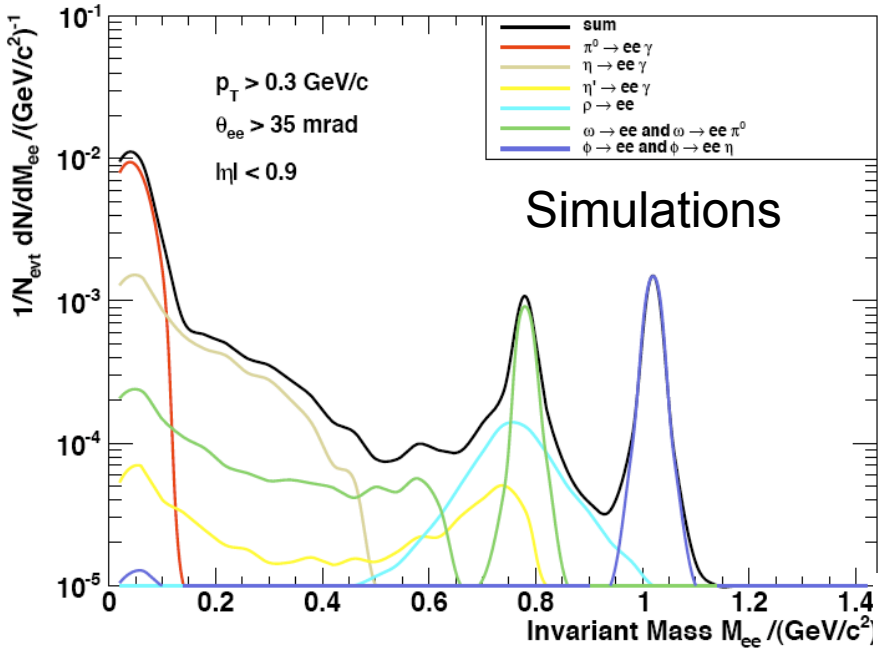
Clusters in TPC >= 50

Reconstruction of Unlike Sign events with p_T < 0.15 GeV/c





Low mass dielectron (ρ,ω,ϕ) in p-p collisions

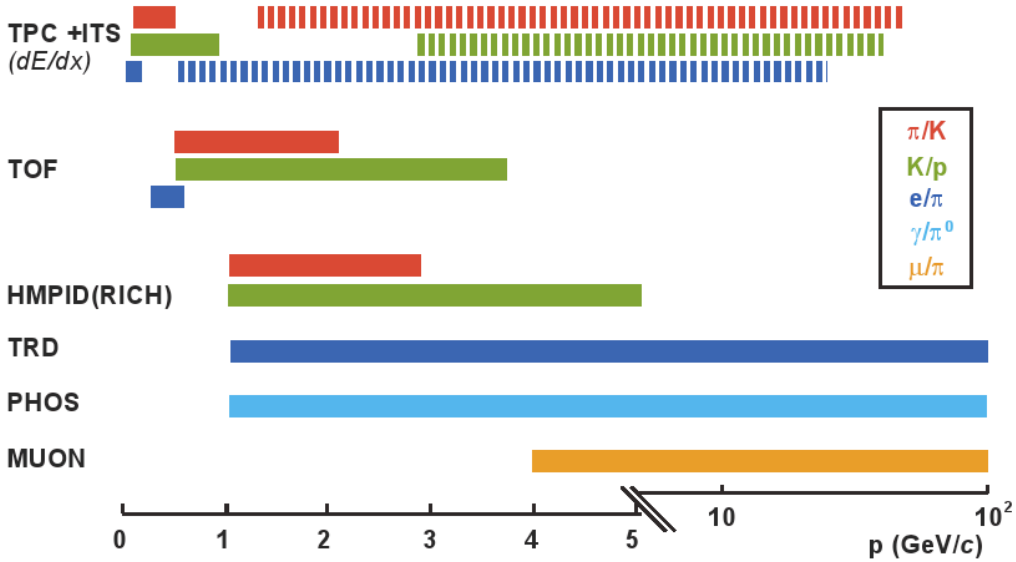


Dielectron cocktail :
Several contributions to the dielectron spectra in the low mass region

$\pi^0 \to e^+e^-\gamma$
$\eta \to e^+e^-\gamma$
$\eta' \to e^+e^-\gamma$
$\rho \to e^+e^-$
$\omega \to e^+e^-$ and $\omega \to e^+e^-\pi^0$
$\Phi \to e^+e^-$ and $\phi \to e^+e^-\eta$

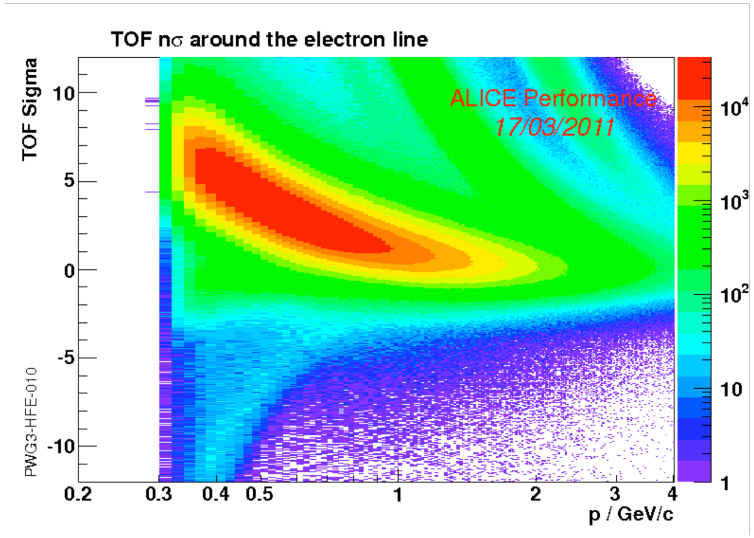
Particle Identification in ALICE
Which detectors for electron identification?

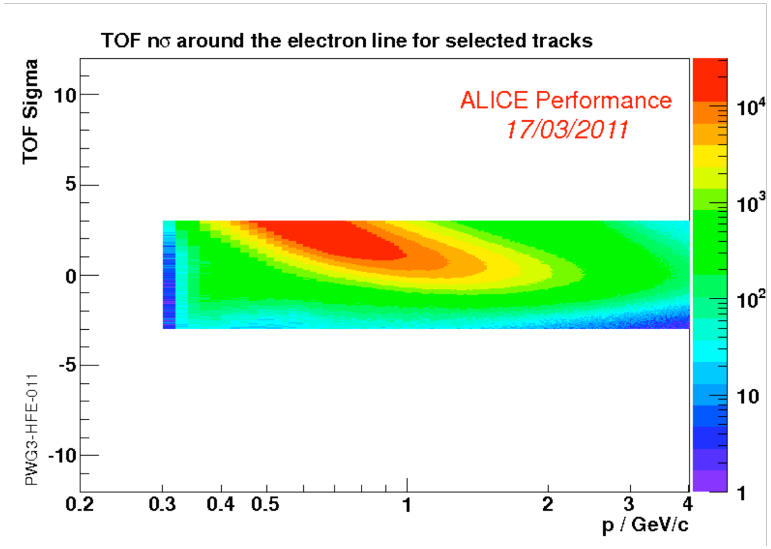
+ EMCAL



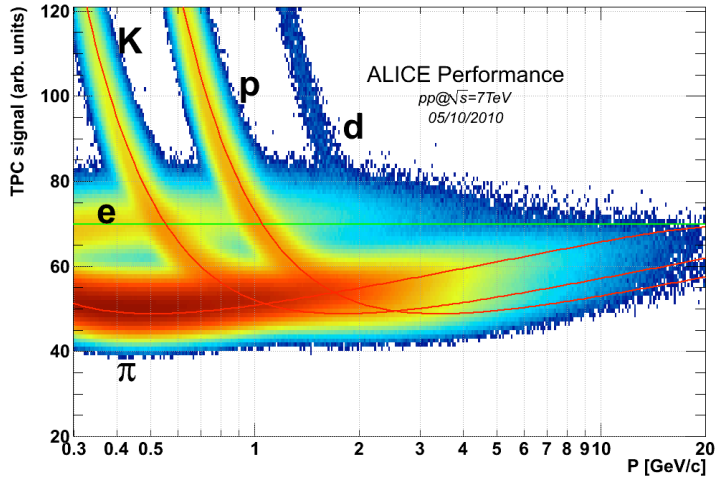
Electron identification : Use of TPC and TOF to identify single-electrons

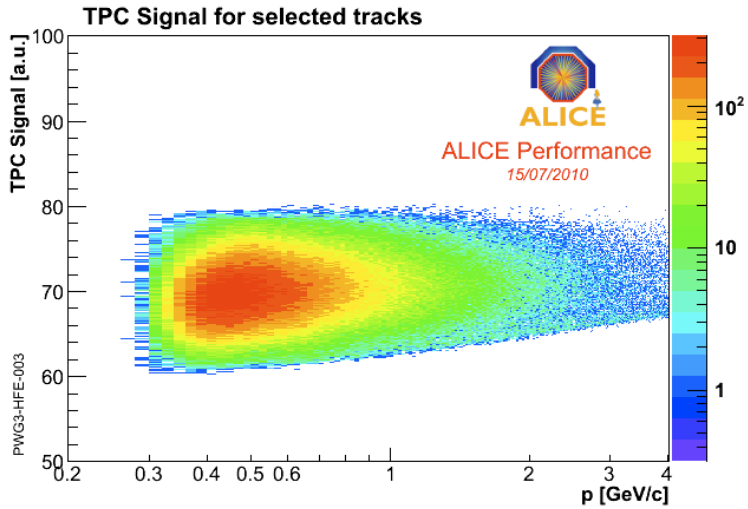
- TOF : 3 σ electron inclusion, efficiency loss < 400 MeV/c





- TPC : Pion rejection → asymetric cut around the electron line (momentum dependent function for the lower boundary)

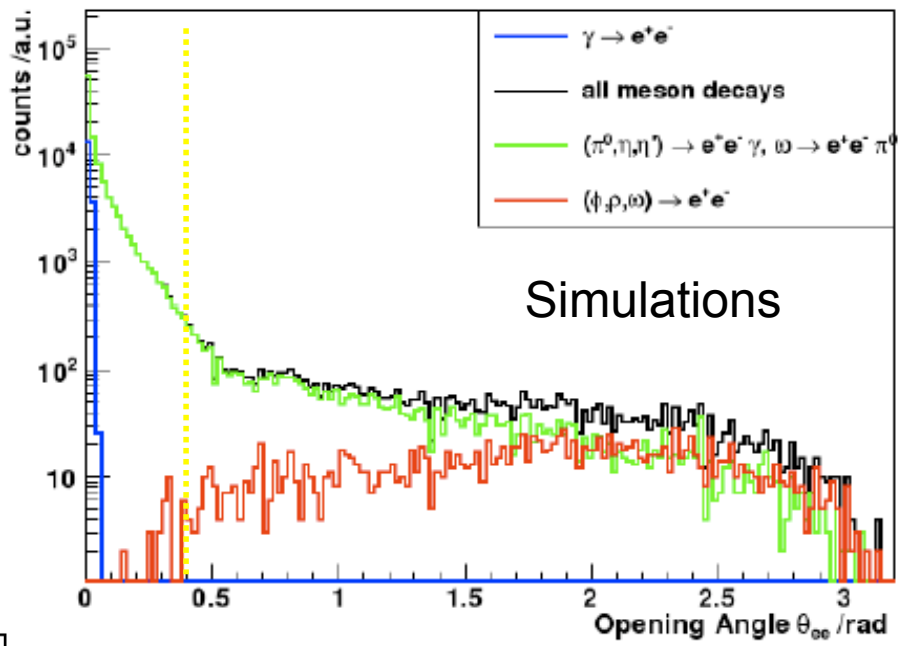


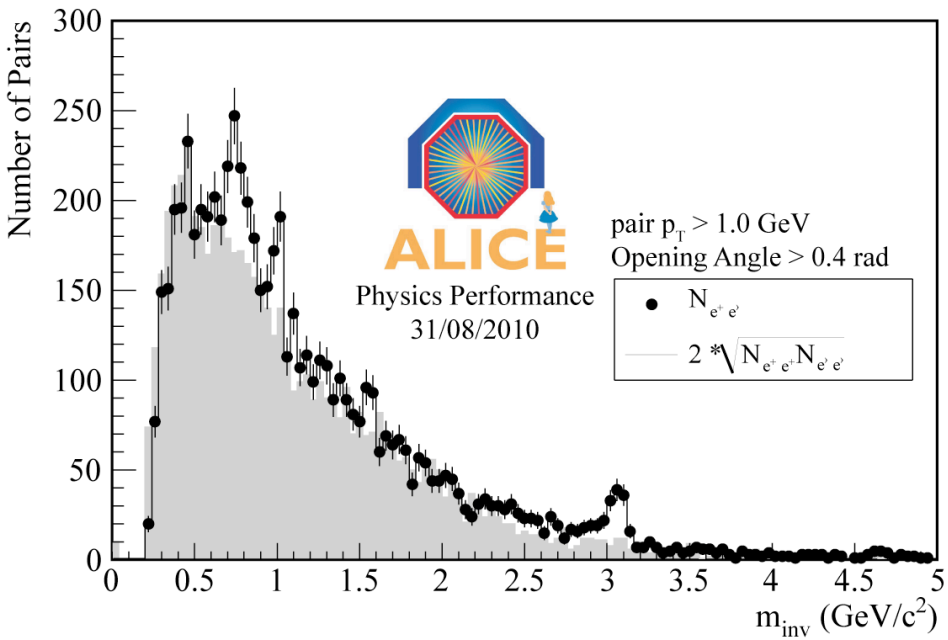


Rejection of Dalitz π^0 decay and rejection of photon conversion

π^0 decay Dalitz important source of Dielectron Background
Localized at :
M_{inv} < 200 MeV/c^2

Cut on opening angle (0.4 rad)
→Reject photon conversion
p_T cut to reject gamma conversion and Dalitz decay



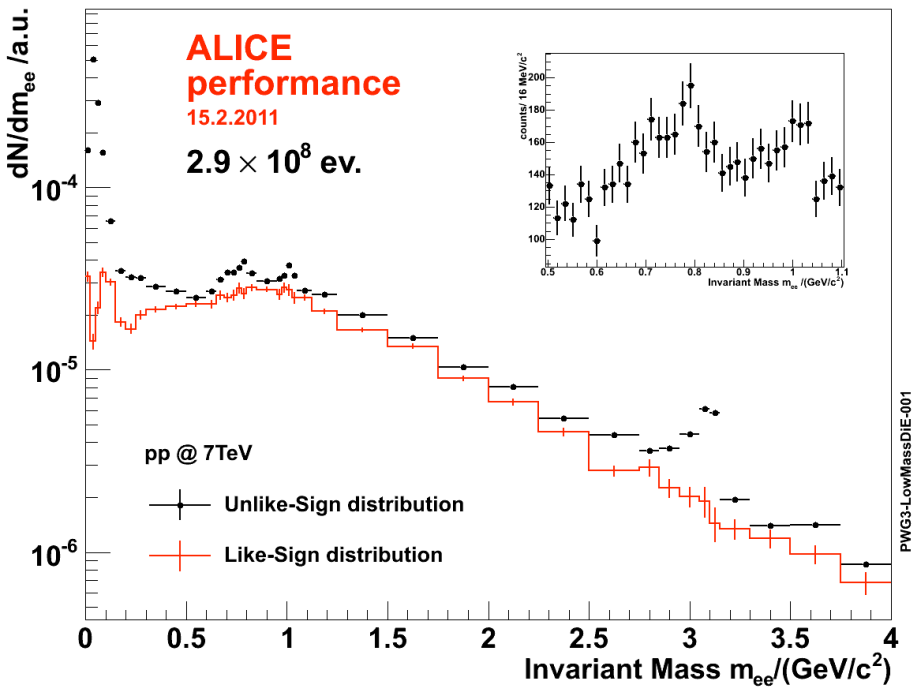


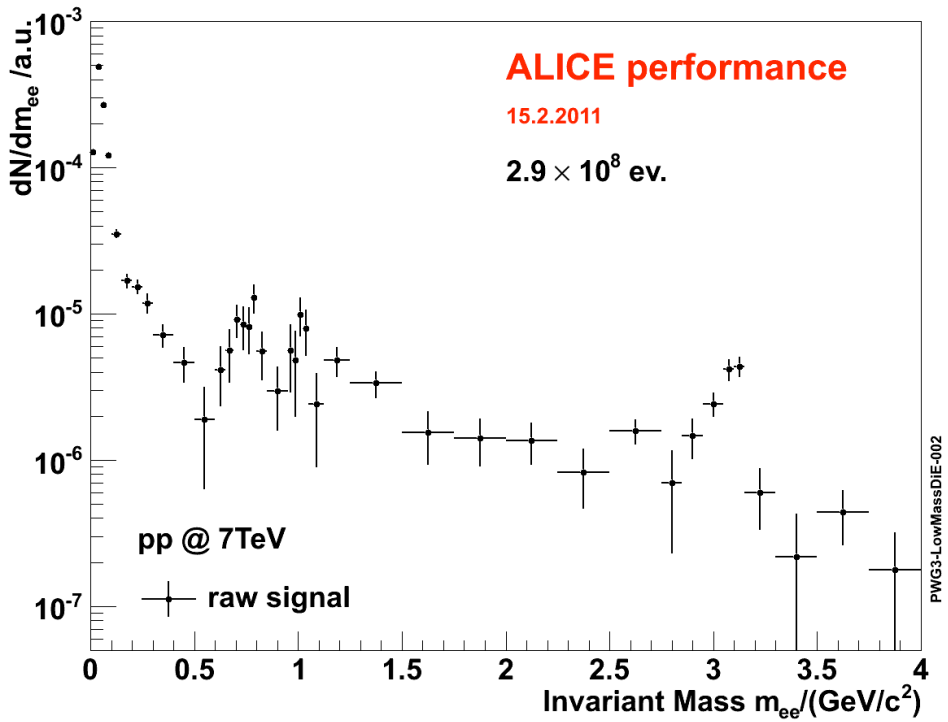
Other global cuts :
→ Hits in first ITS-SPD layer + 3 clusters (conversion rejection)
→ Cut on DCA (rejection of secondaries)
→ Combinatorial background evaluated with the LS electron pairs
450 Millions events

Signal extraction

Invariant mass dielectron spectra for 2.9×10^8 events
Combinatorial background estimated with the Like Sign dielectrons
Plot with variable bin sizes normalized to the number of events and bin size

Raw signal after background subtraction



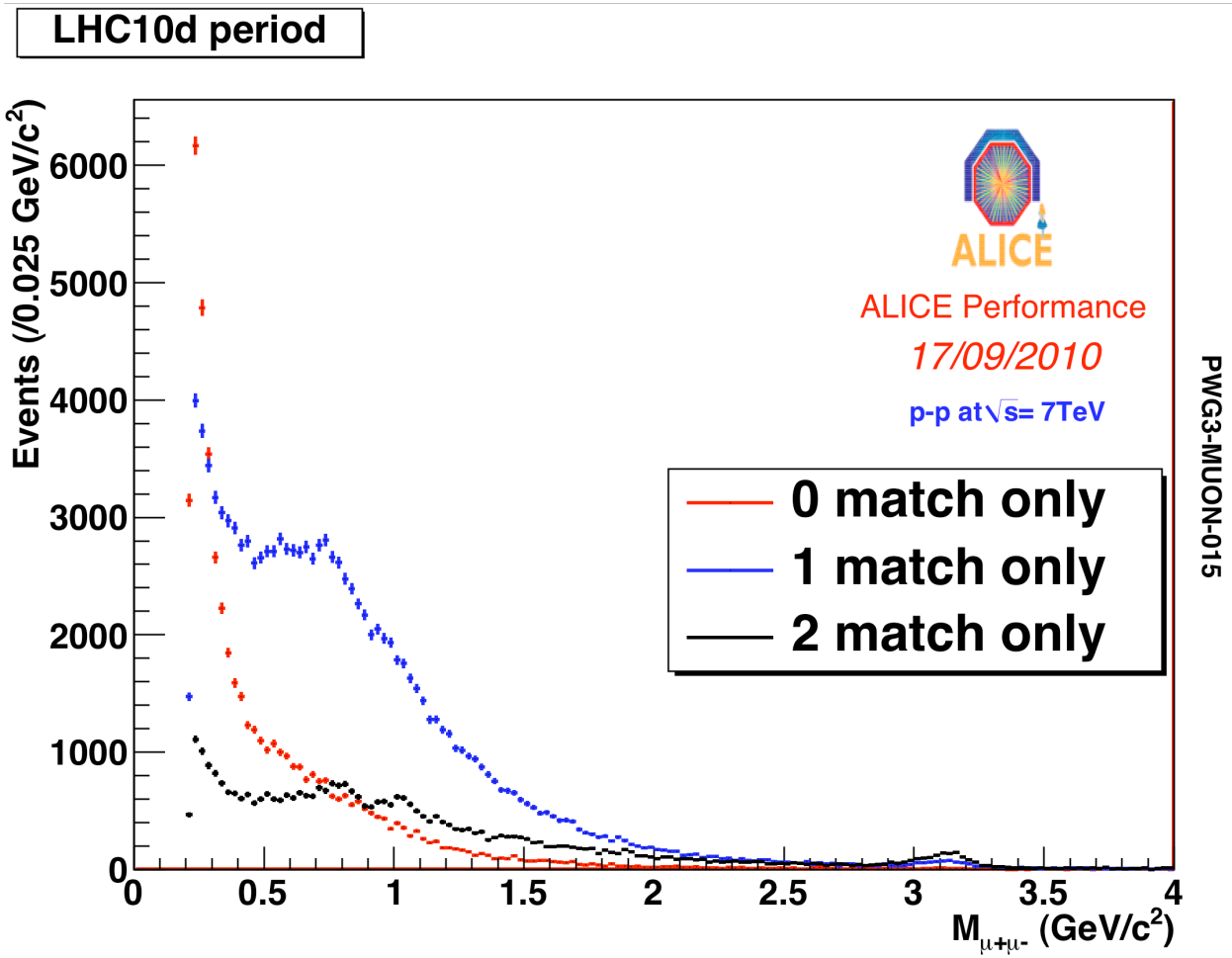


Low mass dimuons analysis in p-p collisions

Analysis conditions

5 p-p data taking periods analyzed up to know (326 runs) :
$1.4*10^5$ OS two matched dimuons
Lint ~ 85 nb^{-1}
(only the low intensity beam period)
→ Rejection of Beam-Gas background with V0
→ Cut on the rapidity of the single muon :
$-4 < \eta < -2.5$

Importance of the muon trigger



Background evaluation :

1st method : Use of the real **Like Sign Dimuons**.

This evaluation is done by calculating : $N_{+-}^{comb} = 2R\sqrt{N_{++}N_{--}}$
bin of mass per bin of mass

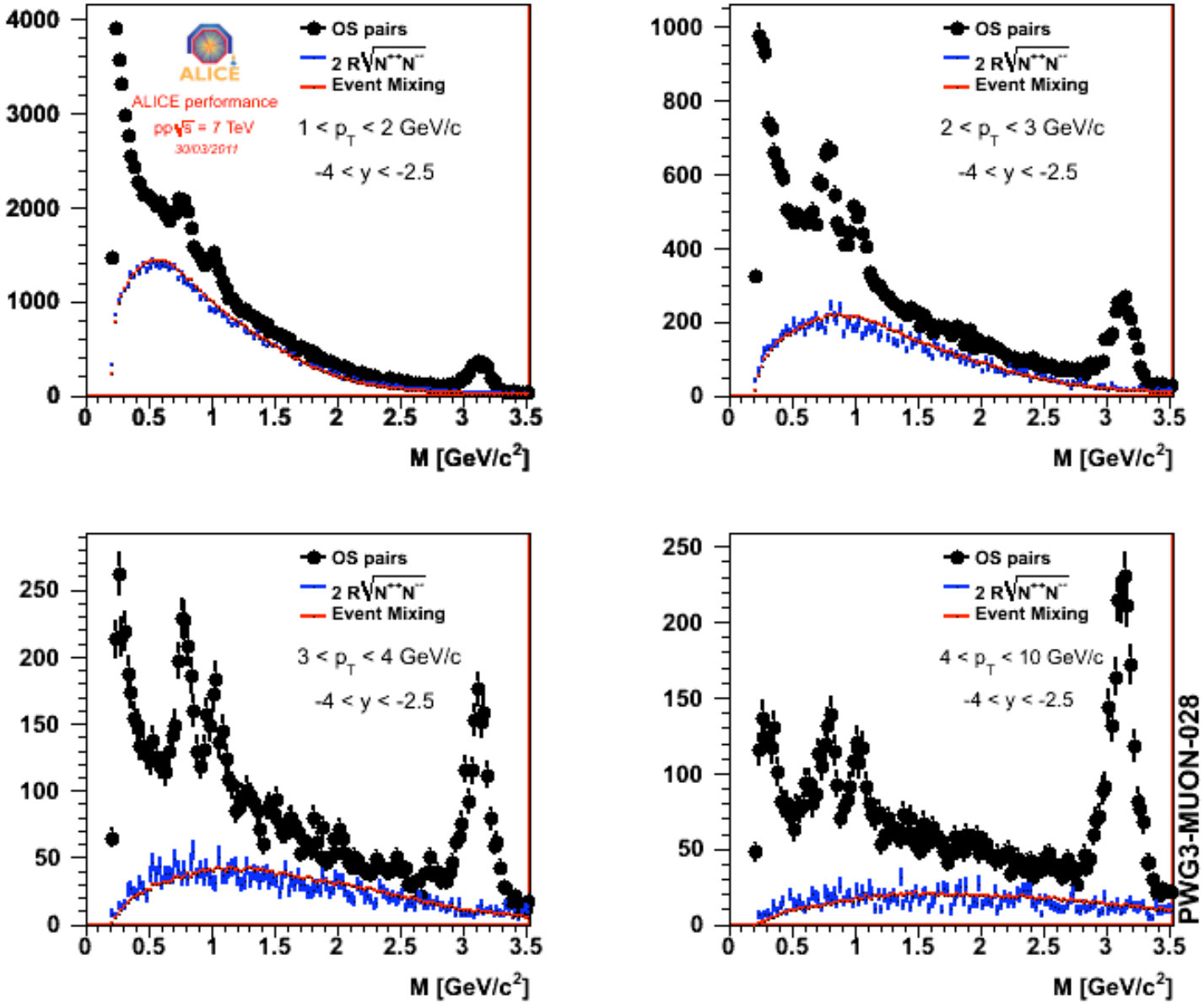
where N_{+-}^{comb} is the number of background opposite sign muon pairs
N++ (N--) are the number of like sign muon positive (negative) pairs respectively
The R factor is defined as :

$$R = \frac{A^{+-}}{\sqrt{A^{++}A^{--}}}$$

with A^{+-}, A^{++}, A^{--} are the acceptances for the + -, ++, - - muon pairs

2nd method : The background is evaluated with the **event mixing** technique.
Only events containing single muons (matching the trigger) are mixed to produce uncorrelated dimuons.
The normalization is calculated as the integral of the combinatorial background evaluated with the LS pairs

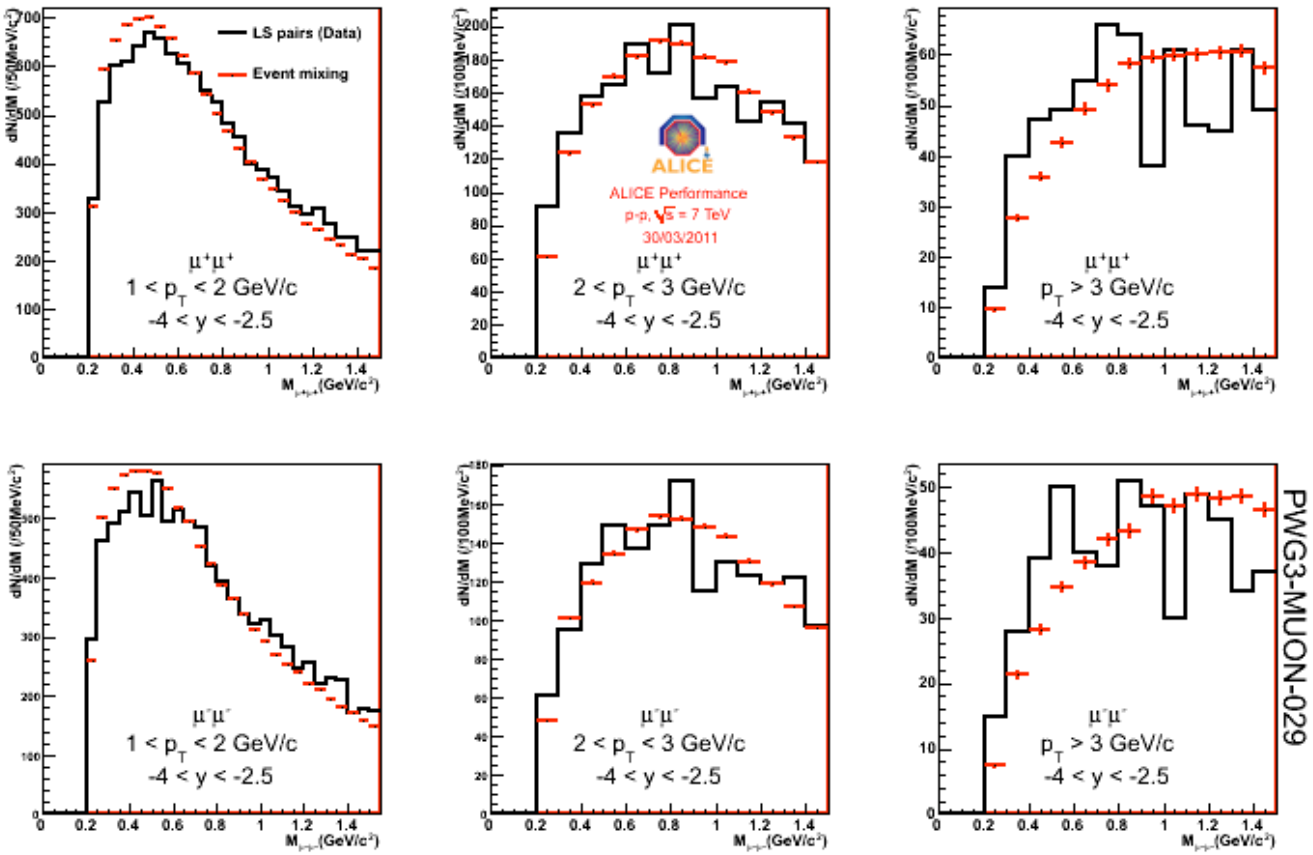
Background evaluation :

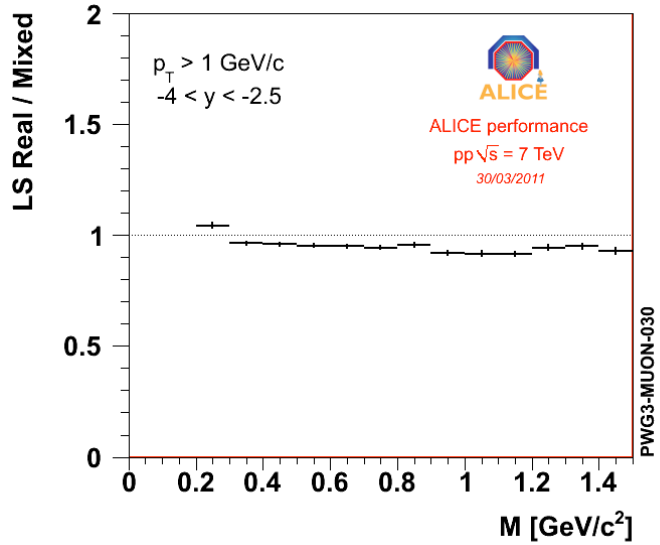


Good agreement between the two descriptions for muon p_T-pair > 1 GeV/c

Is the event mixing a good description of the combinatorial background?

Comparaison of the Like Sign real pairs and Like Sign mixed pairs

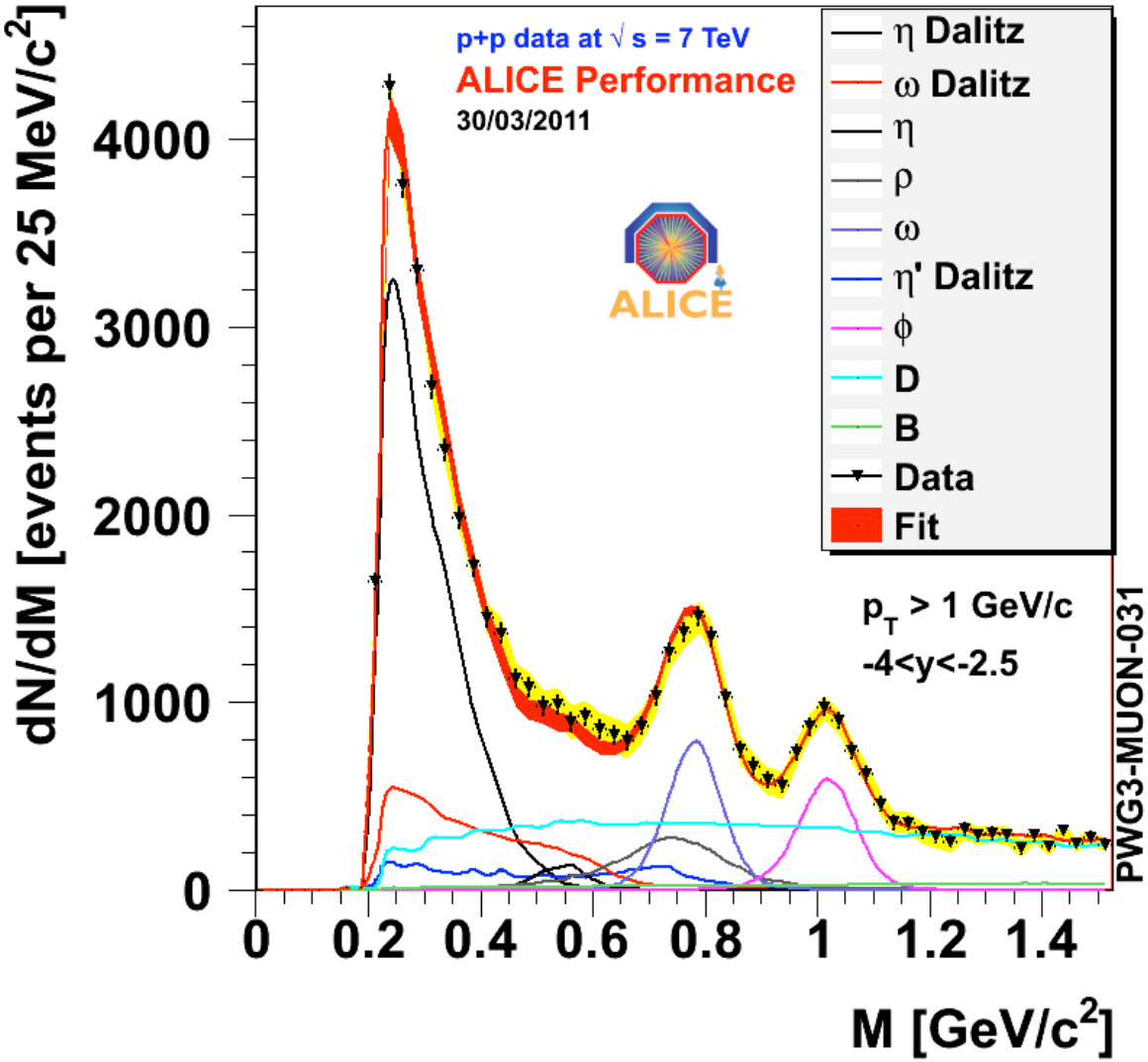




Event mixing is working properly for p_T > 1GeV/c and M < 1.5 GeV/c^2

Fit of invariant mass spectra

Background subraction performed with event mixing



Use of hadronic cocktail generator :

Free parameters for the fit :

→ Normalization of η

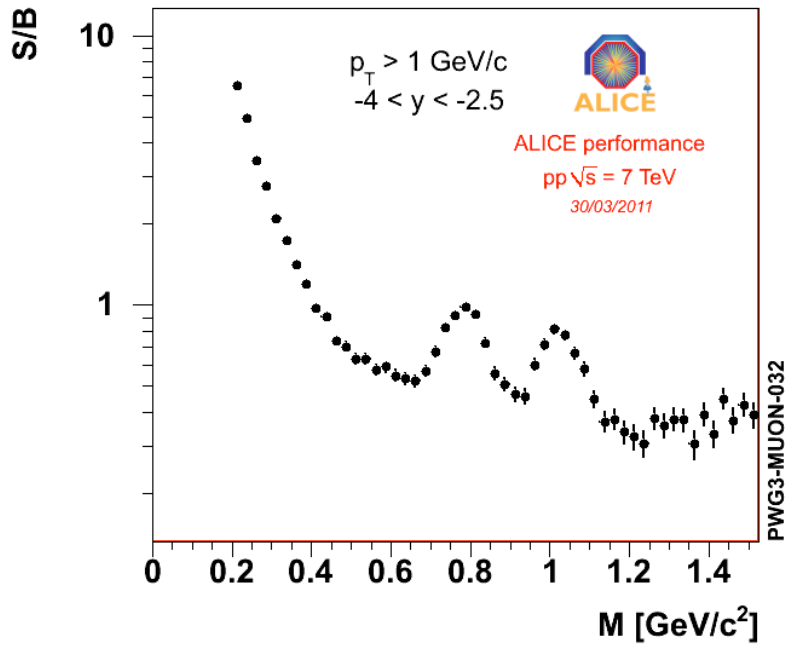
→ Normalization of ω

→ Normalization of Φ

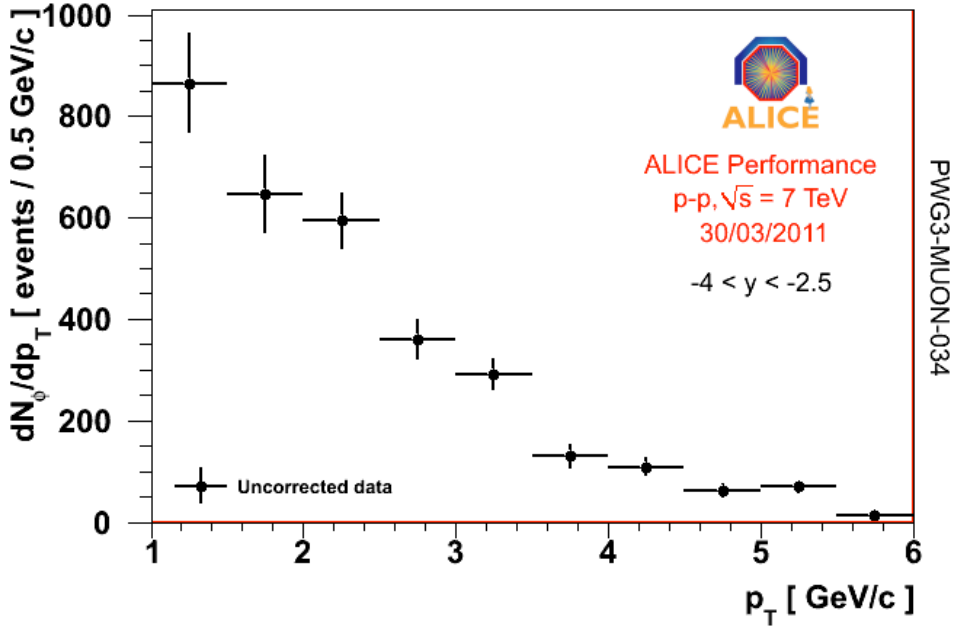
→ Normalization of charm

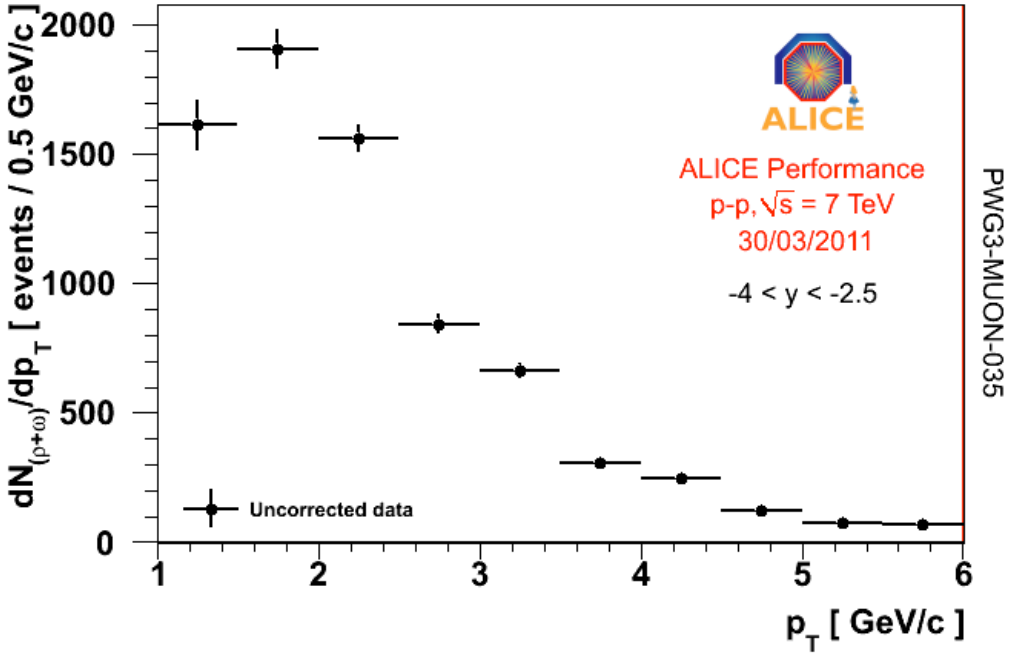
ρ is fixed with $\sigma_\rho/\sigma_\omega = 1$

LHCb measurement to fix open beauty/open charm ratio



Raw pT spectra of ϕ, ρ+ω and acceptance × efficiency corrections



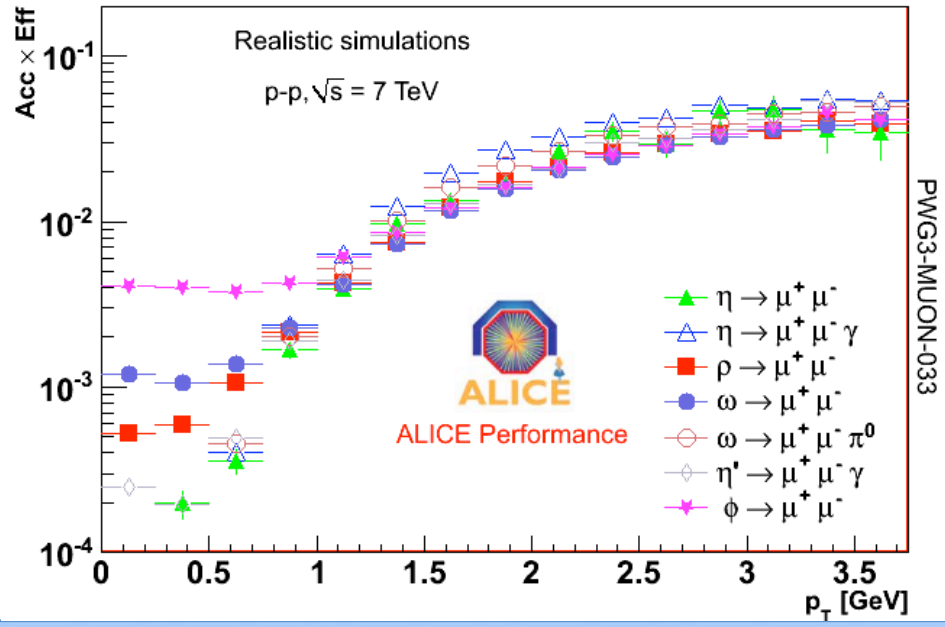


Raw p_T spectra of ϕ and ρ+ω extracted with the hadronic cocktail generator fit

Realistic simulations were performed in full rapidity for 3 different periods of p–p data taking

→ same trend for the LMR processes

Acceptance × Efficiency below 1% for $p_T < 1.5$ GeV/c

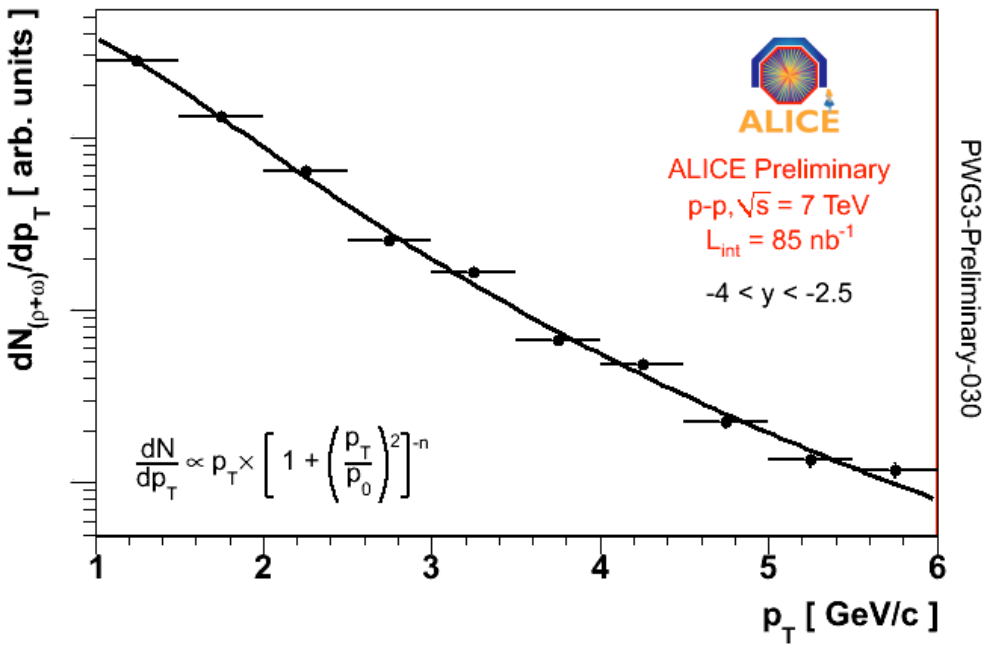


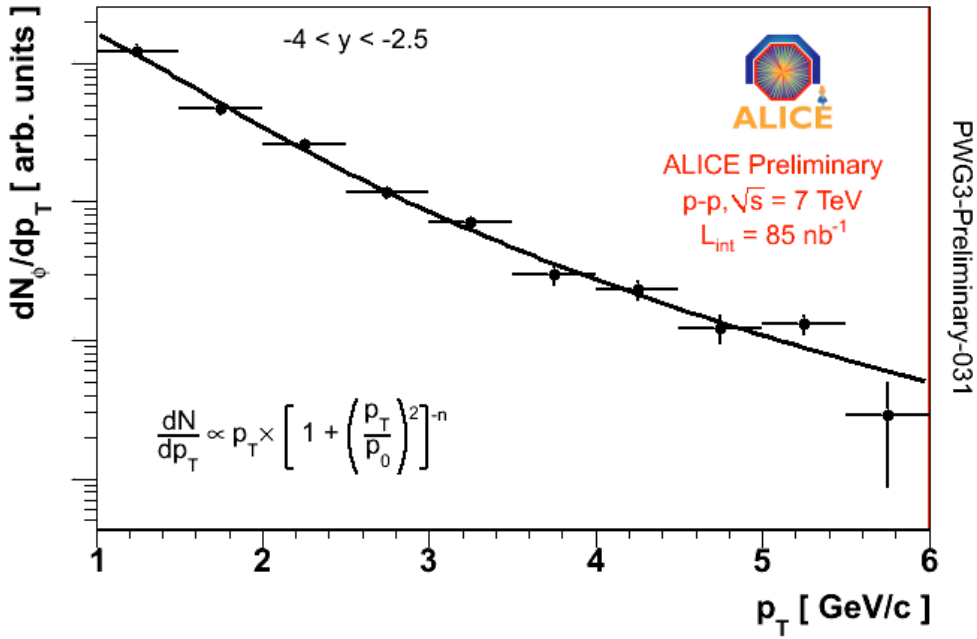
Pt distribution of Φ and ρ+ω

Fitting function : $$\frac{dN}{dp_T} \alpha \frac{p_T}{[1+(\frac{p_T}{p_0})^2]^n}$$

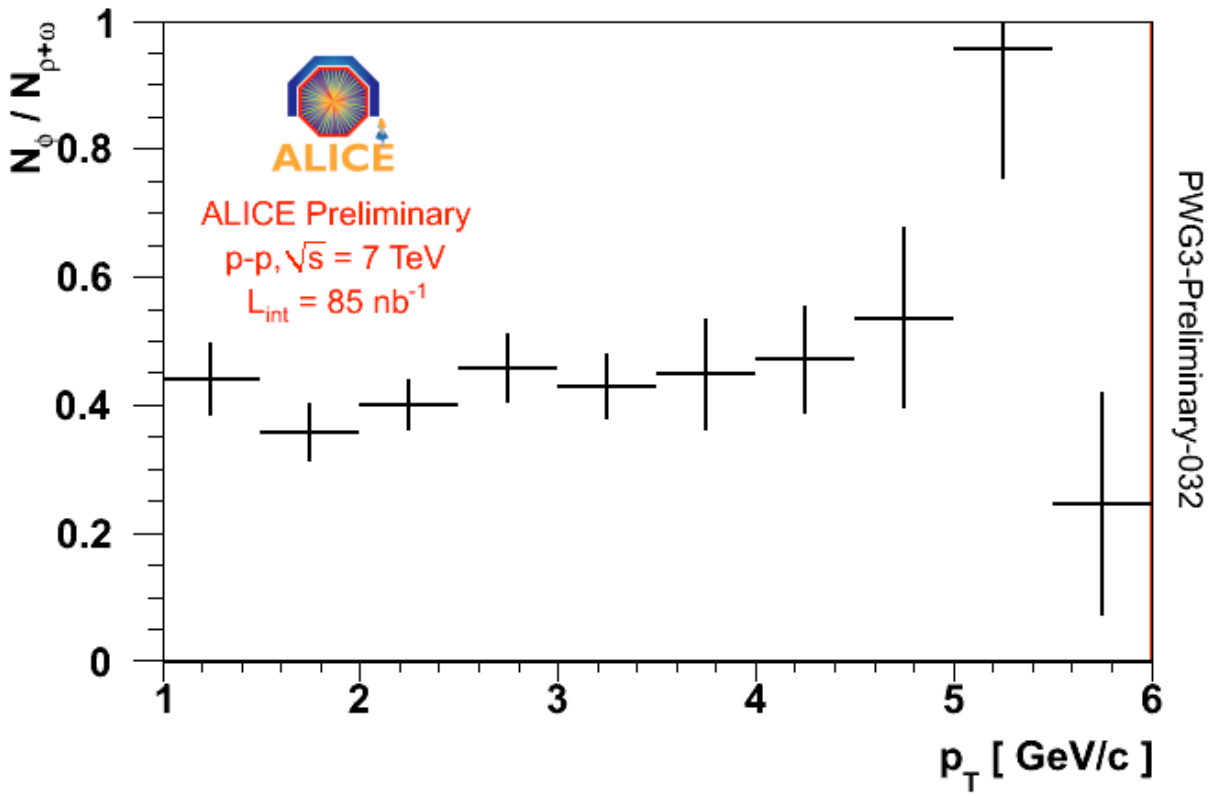
Fit coefficients

	p_o	n
ρ + ω	1.44 ± 0.10	3.16 ± 0.11
Φ	1.16 ± 0.23	2.74 ± 0.22





Ratio $N_\phi / N_{\rho+\omega}$ as a function of p_T



For $1 < p_T < 6$ (GeV/c)

$$\frac{BR_\phi \sigma_\phi}{BR_\rho \sigma_\rho + BR_\omega \sigma_\omega} = 0.42 \pm 0.02$$

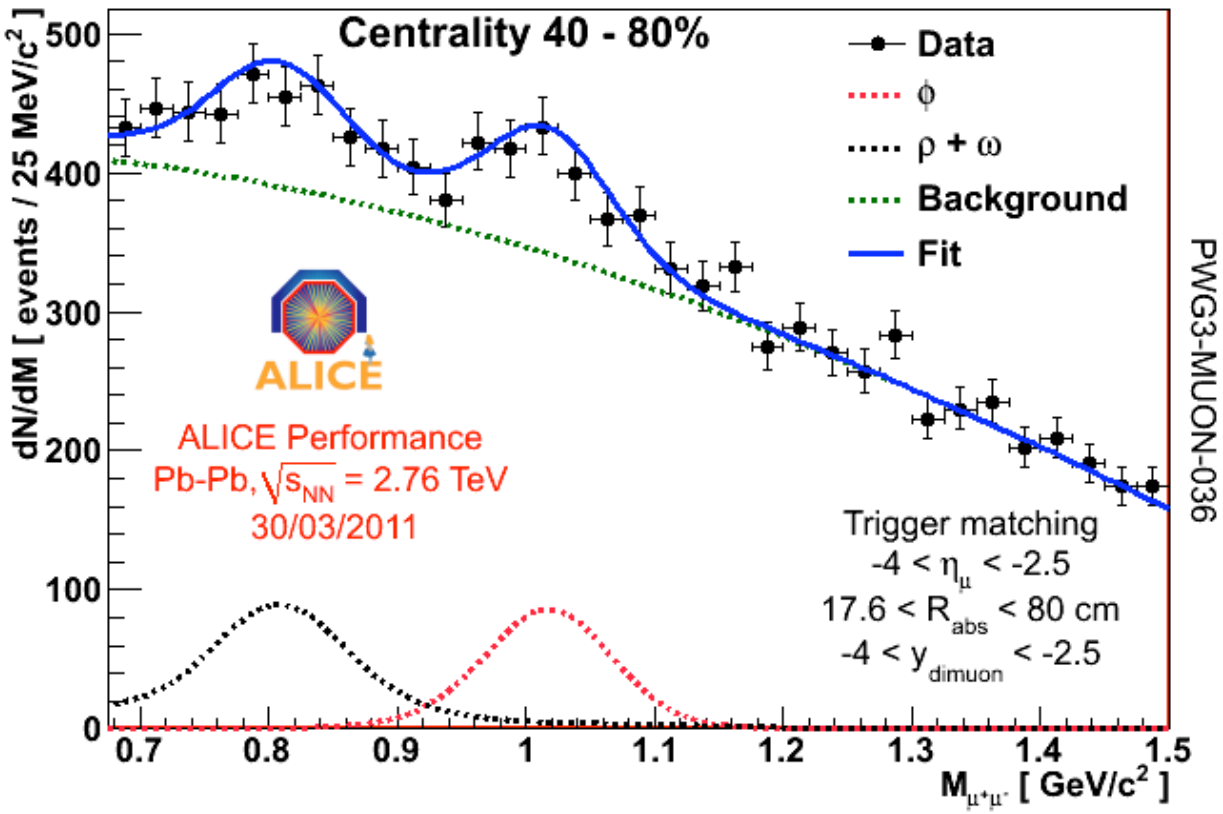
for Pythia

$$\frac{BR_\phi \sigma_\phi}{BR_\rho \sigma_\rho + BR_\omega \sigma_\omega} = 0.35$$

It is found to be constant with p_T

Status of the low mass dimuons analysis in Pb-Pb collisions

Statistic :
~ 6.6 × 10^6 MB V0 AND events
1Million OS dimuons
Background parametrized by a simple polynomial function
Pseudo gaussian fit is used for the resonances
Cuts :
- 4 < η < -2.5
17.6 < Rabs < 80 cm
2 muons matching the trigger
-4 < ydimuon < - 2.5
Centrality selection performed using V0 detector



40-80% → bmin=9.88fm, bmax=13.97fm → Npartmin~14, Npartmax~100

Conclusions

- ρ^0 production has been observed in ultra-peripheral collisions
- Light Vector Mesons are visible in the dielectron channel in p-p collisions. The background is under control.

  Pb-Pb analysis ongoing.
- In the dimuon channel in p-p collisions :

  The ϕ and $\rho+\omega$ p_T spectra were measured for p_T above 1 GeV/c

  The $\phi/(\rho+\omega)$ yield ratio was measured as a function of p_T
- Light Vector Mesons in the dimuon channel are visible in peripheral Pb-Pb collisions. Background is still under study.