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Neutral pion production in pp and Pb-Pb collisions at LHC

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IHEP Protvino

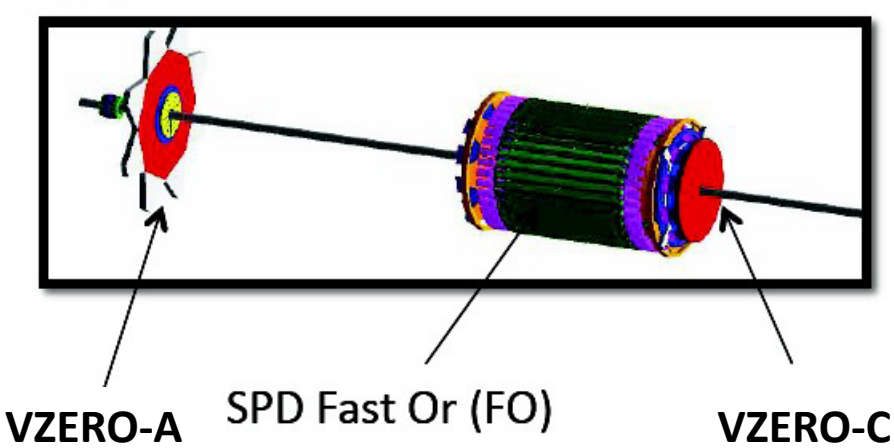
Physics motivation: why neutral mesons?

- Inclusive indentified hadron production is a reliable **probe for NLO pQCD**
  - π^0 and η can be detected via photonic decay channels in a wider p_t range.
  - At LHC, the PDF and FF can be probed at lower x and z than it was at previous colliders, and thus provide further constraints on these functions, which are crucial for pQCD predictions for LHC energies.
  - Pion production at LHC energies is dominated by gluon fragmentation at p_t < 100 GeV/c: Constraints on gluon FF
  - η meson spectrum imposes constraints on strange quark FF.
- Precise measurement of neutral meson spectra is important for studying the decay photon (electron) background for a **direct photon (charm and beauty) measurement**
- Neutral pion spectrum in AA collisions, reveal **medium-induced modifications** of hadron properties.

Data samples and trigger

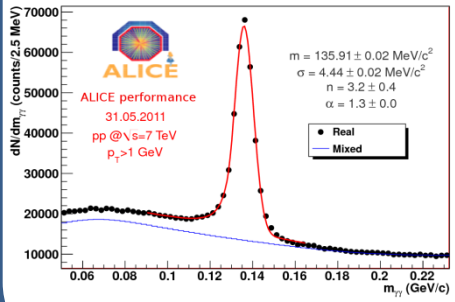
Collision system	∫LdT	Run #
pp at $\sqrt{s}$=0.9 TeV	0.14 nb^{-1}	May 2010
pp at $\sqrt{s}$=2.76 TeV	0.7 nb^{-1}	Apr 2011
pp at $\sqrt{s}$=7 TeV	5.5 nb^{-1}	Jun-Aug 2010
Pb-Pb at $\sqrt{s_{NN}}$=2.76 TeV	2 μb^{-1}	Nov 2010

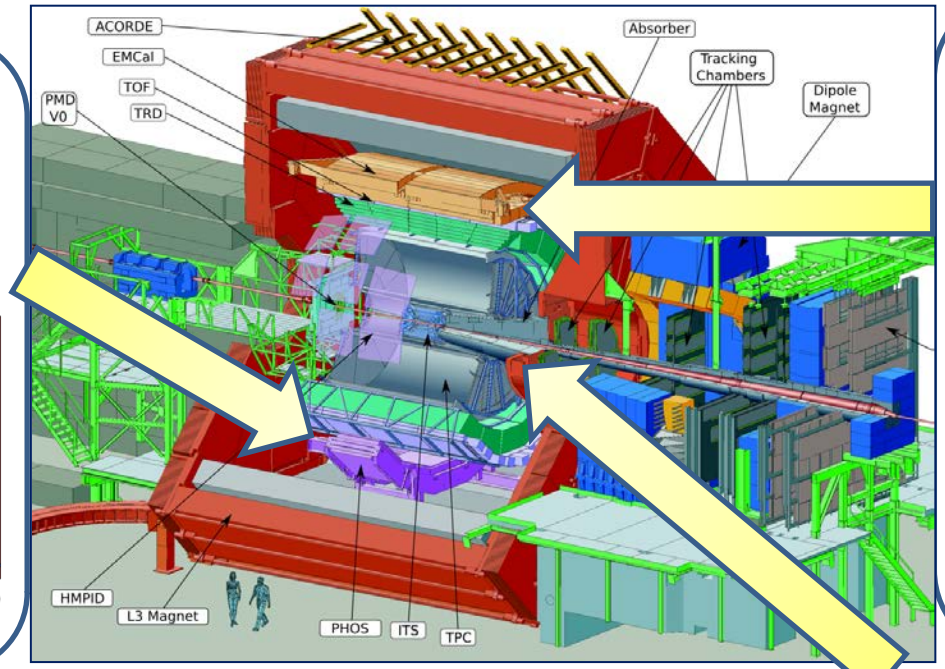
- Triggers: minimum bias in pp and Pb-Pb.
  - Trigger detectors: **SPD | VZERO-A | VZERO-C**



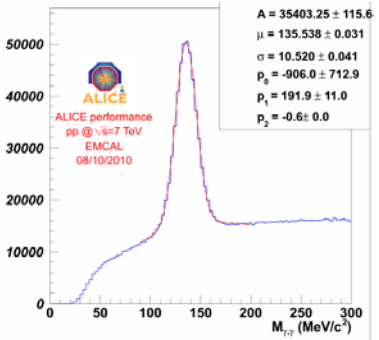
Detectors used in analysis

PHOS

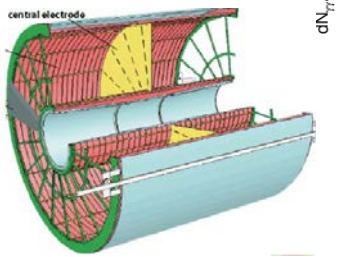


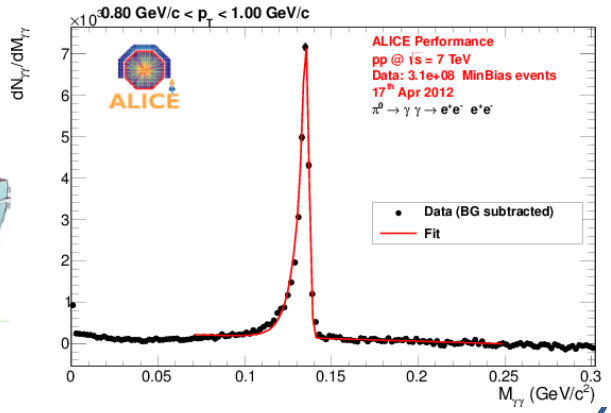


EMCAL



Central tracker





Three detectors provide complementary methods with different resolution and different systematic uncertainties.

π^0 detection in ALICE calorimeters

PHOS

- **Active element**: crystal of lead tungstate ($PbWO_4$) 2.2×2.2×18 cm^2.
- **Geometry**: 3 modules 64×56 crystals each; distance from IP to active surface: 460 cm
- **Aperture**: $|\eta|<0.13$, $260°<\varphi<320°$
- **Energy range**: 0<E<100 GeV
- **Material budget** from IP to PHOS: $0.2X_0$.

EMCAL

- **Active element**: tower of 77 layers 1.4mm lead + 1.7 mm scintillator 6×6×25 cm^2.
- **Geometry**: 10 modules 24×48 towers each; distance from IP to active surface: 450 cm
- **Aperture**: $|\eta|<0.7$, $80°<\varphi<180°$.
- **Energy range**: 0<E<250 GeV
- **Material budget** from IP to EMCAL: $0.8X_0$.

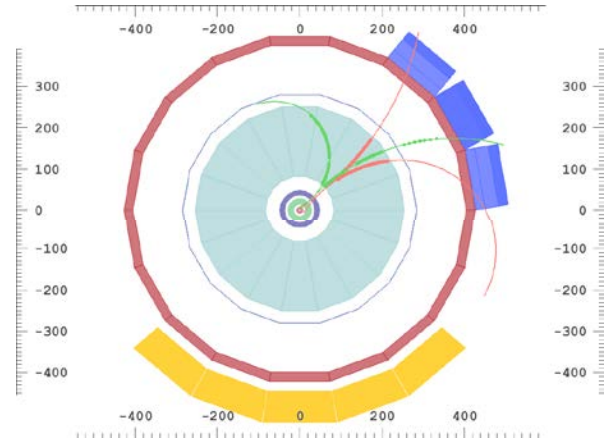
π^0 spectrum can be measured via invariant mass method up to p_t~50 GeV/c in PHOS and ~25 GeV/c in EMCAL.

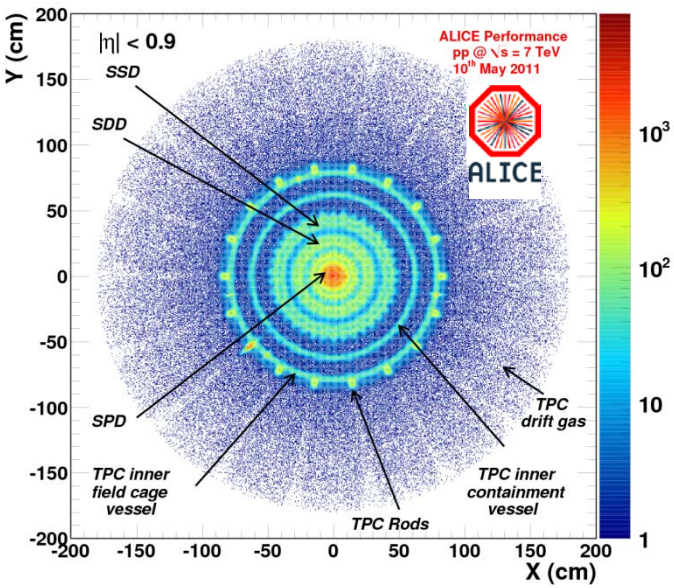
π^0 detection via converted photons

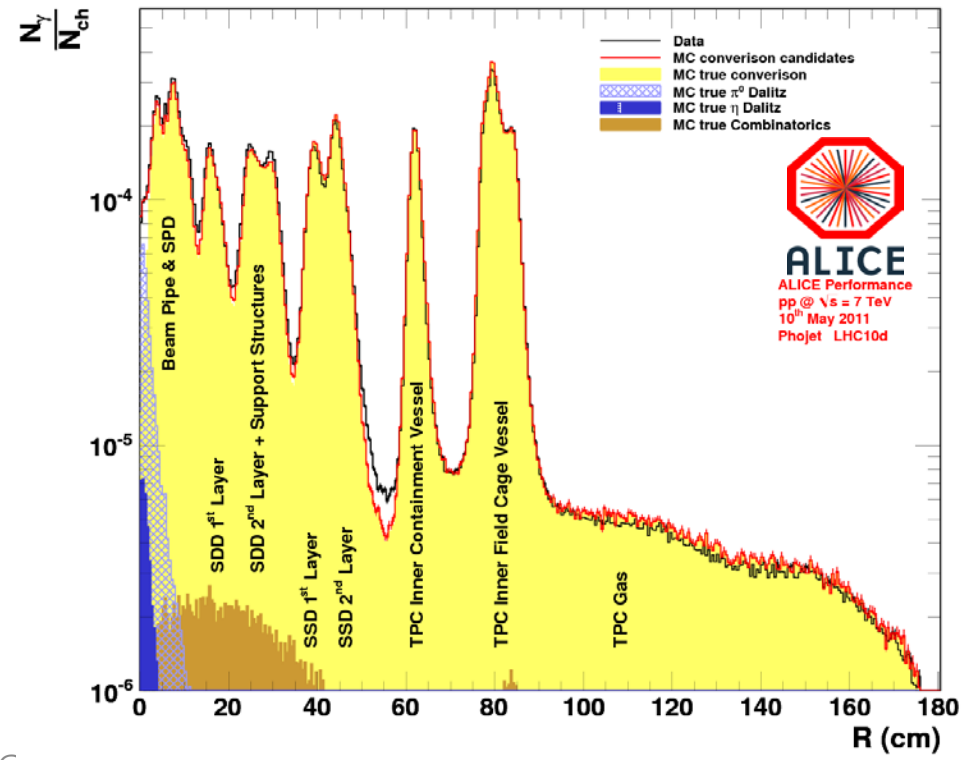
$$pp \rightarrow \pi^0 X$$

$$\pi^0 \rightarrow \gamma\gamma \rightarrow e^+e^- + e^+e^-$$

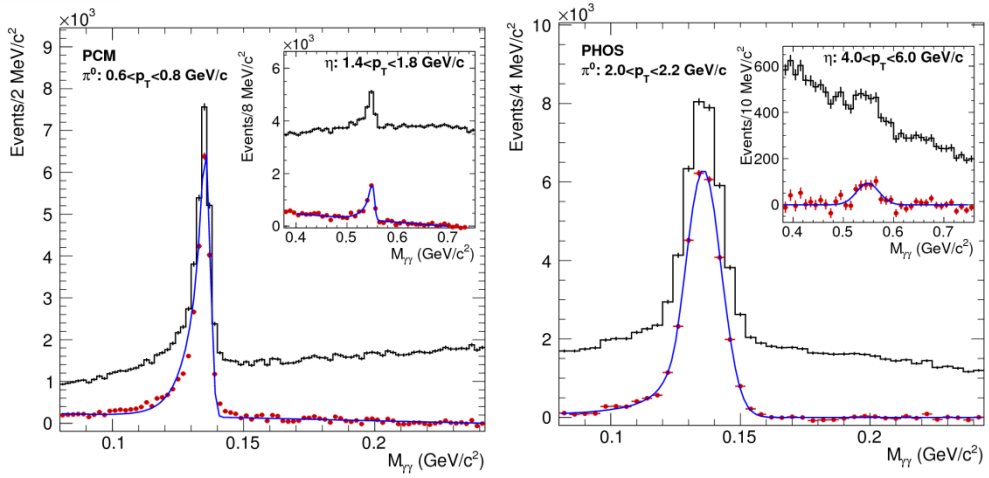
- Photons convert in the medium of the ALICE detectors;
- Reconstructed converted photons $\Rightarrow$ gamma tomography of the ALICE medium;
- ALICE material budget (11.4%X_0 up to middle of TPC) is well described in GEANT;
- π^0 is reconstructed via invariant mass spectra of photon pairs.

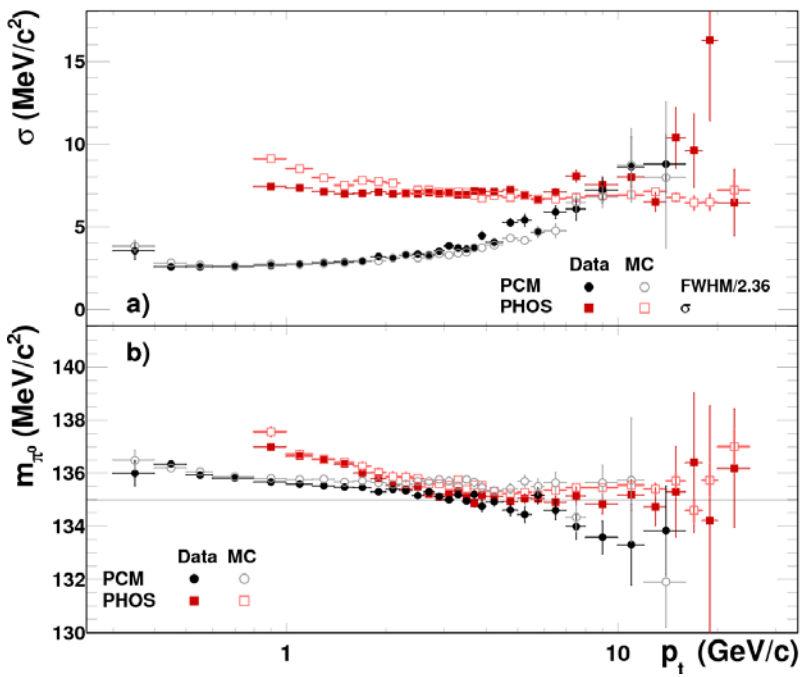






Efficiency and Monte Carlo tuning

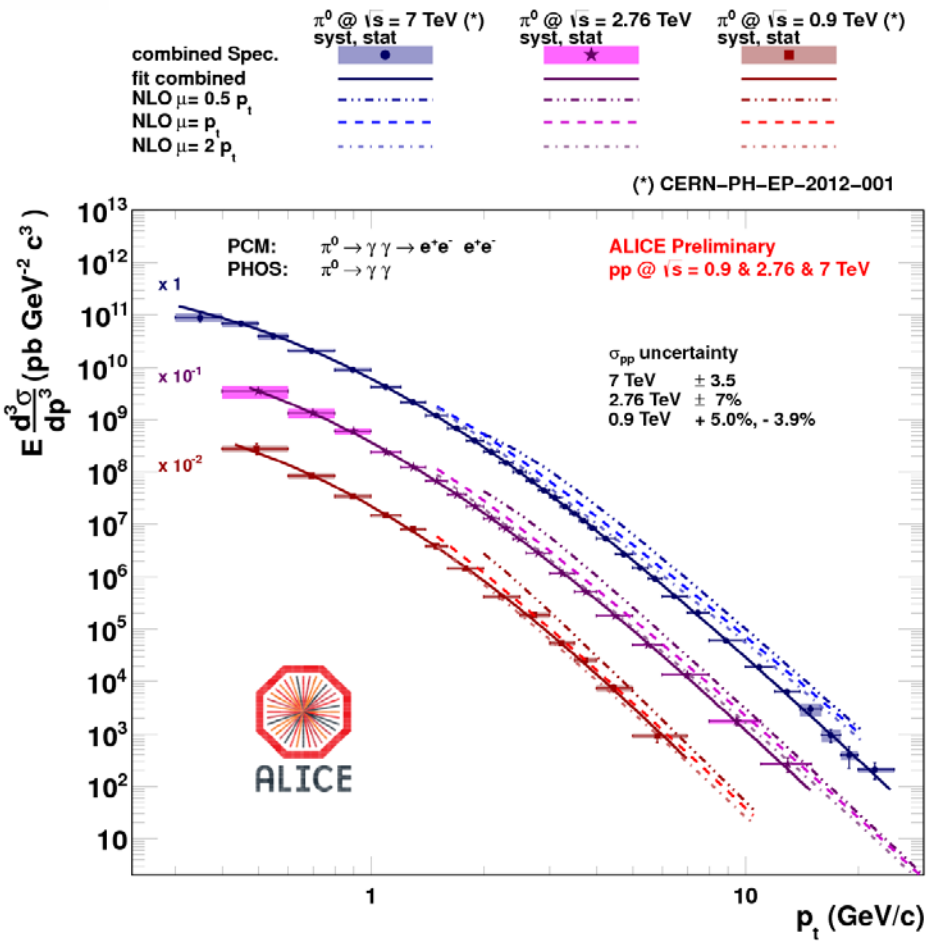


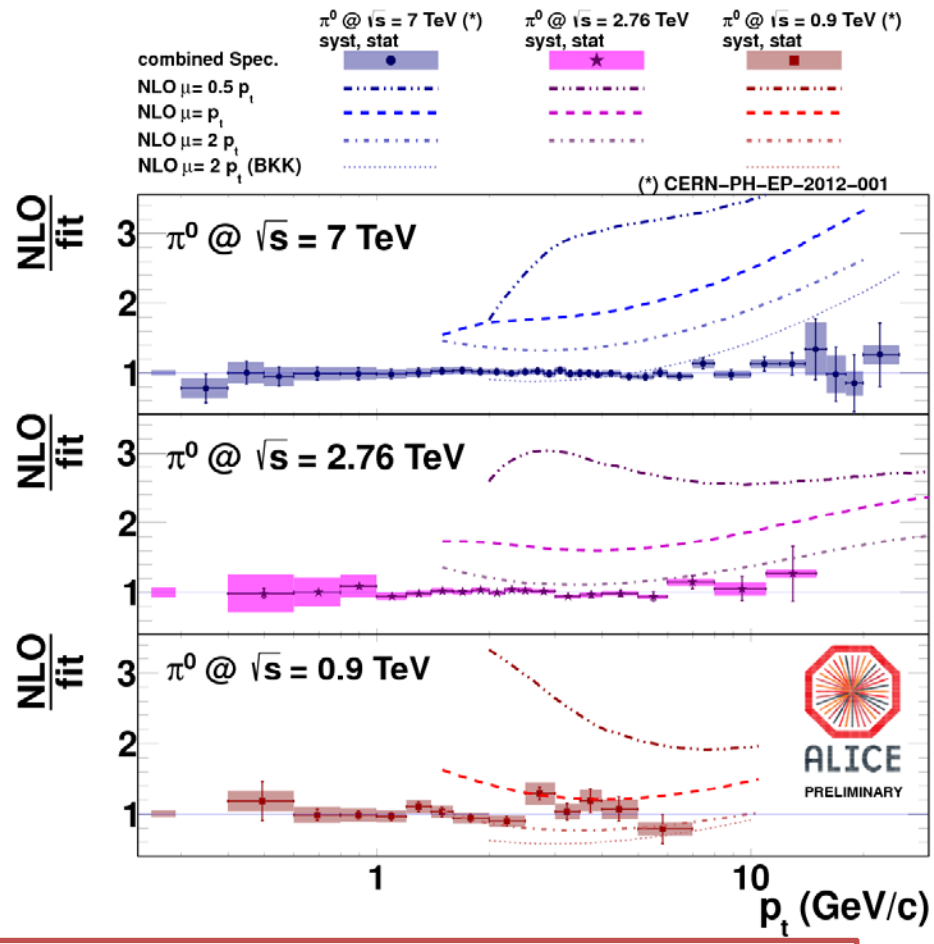


- Detailed description of the ALICE environment is important for precise efficiency calculation
- Residual calibration and alignment is also taken into account in simulations
- Peak position and width of π^0 and η mesons on invariant mass spectra were used to tune Monte Carlo simulations.

ALICE data: CERN-PH-EP-2012-001, arXiv.1205.5724

π^0 spectrum in pp @ 0.9, 2.76, 7 TeV



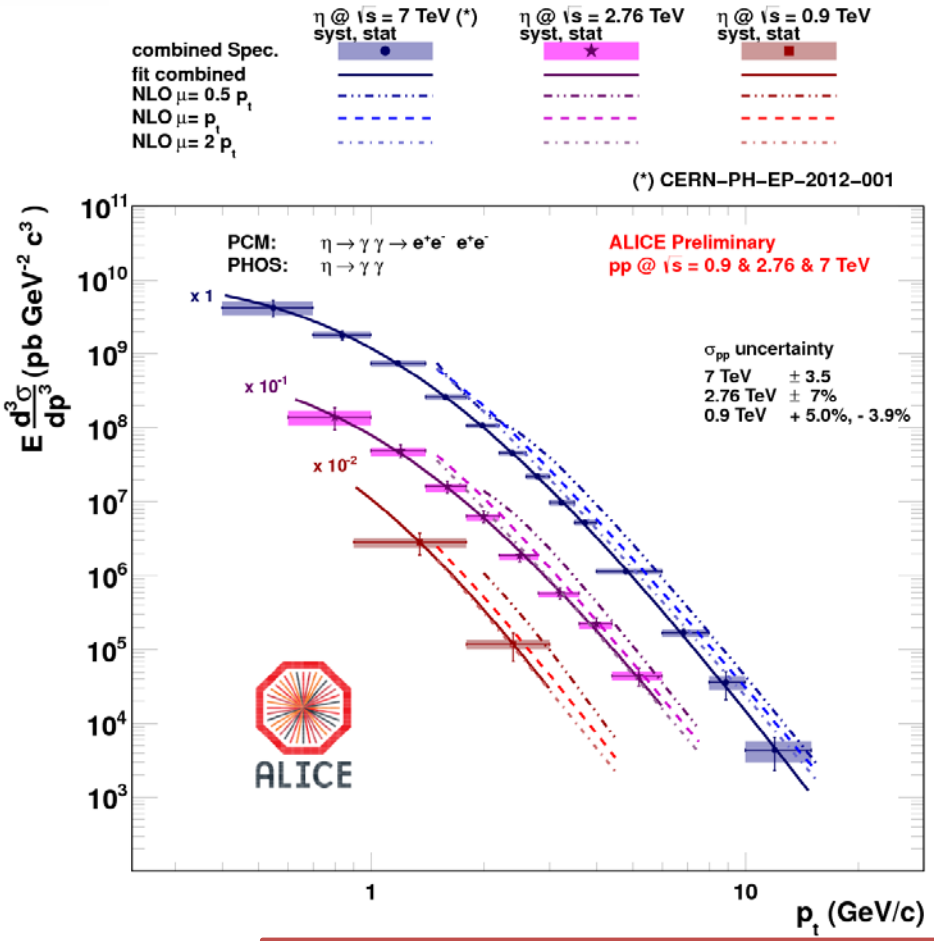


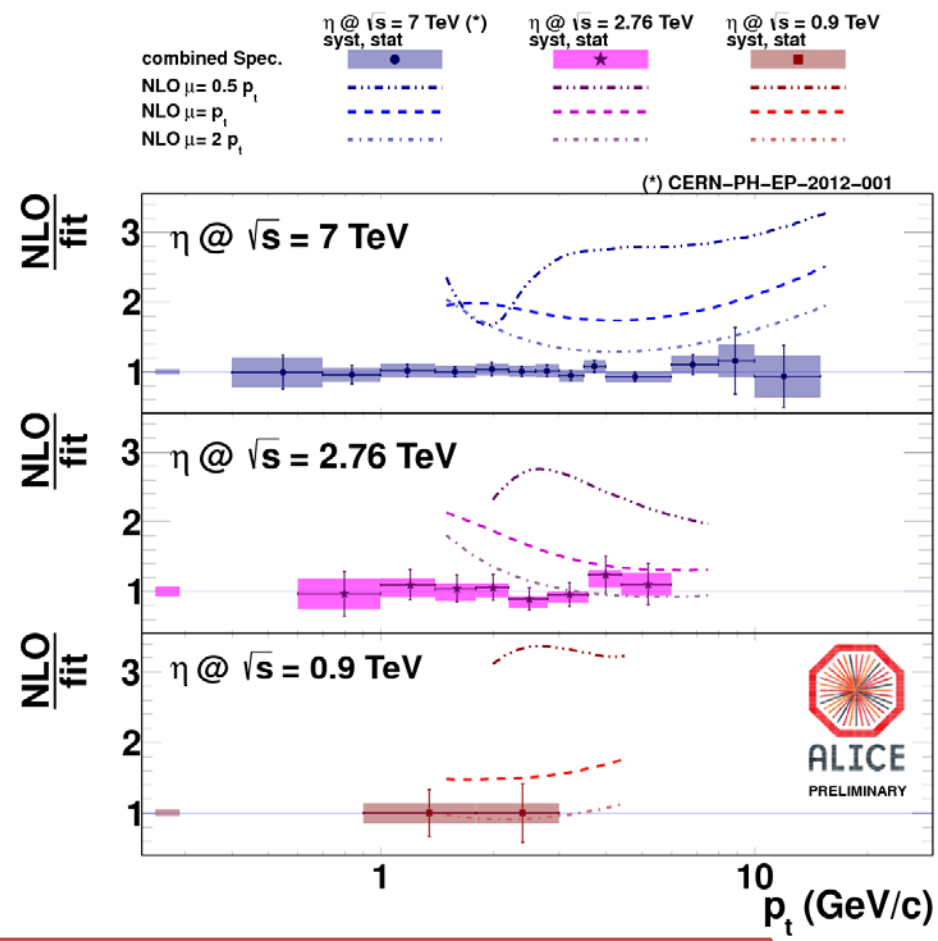
pQCD NLO calculations [*] can reproduce data at $\sqrt{s}$=900 GeV, but overestimate π^0 spectrum at $\sqrt{s}$=2.76 and 7 TeV.

[*] P. Aurenche et al., Eur. Phys. J. C13, 347-355 309 (2000).

ALICE data: CERN-PH-EP-2012-001, arXiv.1205.5724

η spectrum in pp @ 0.9, 2.76, 7 TeV

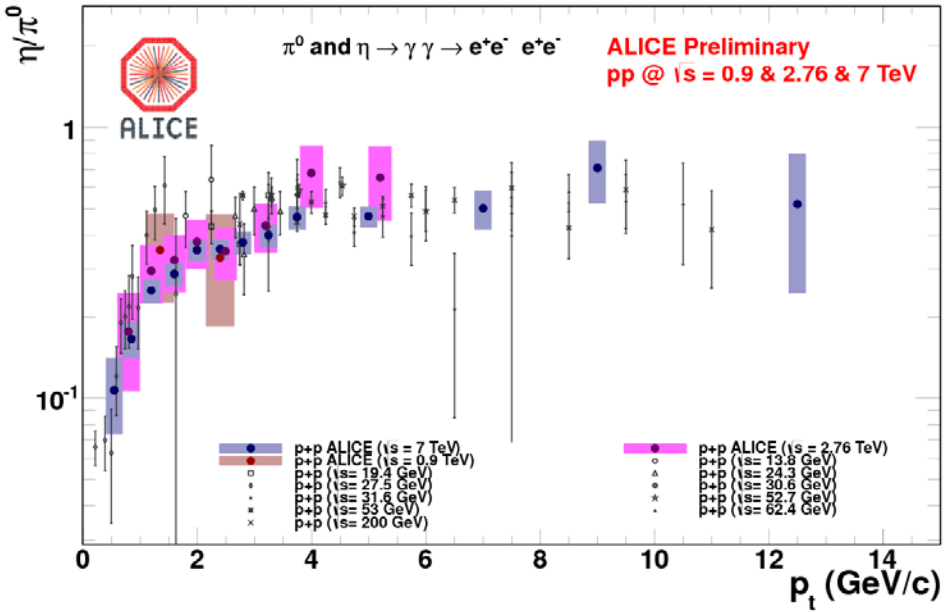




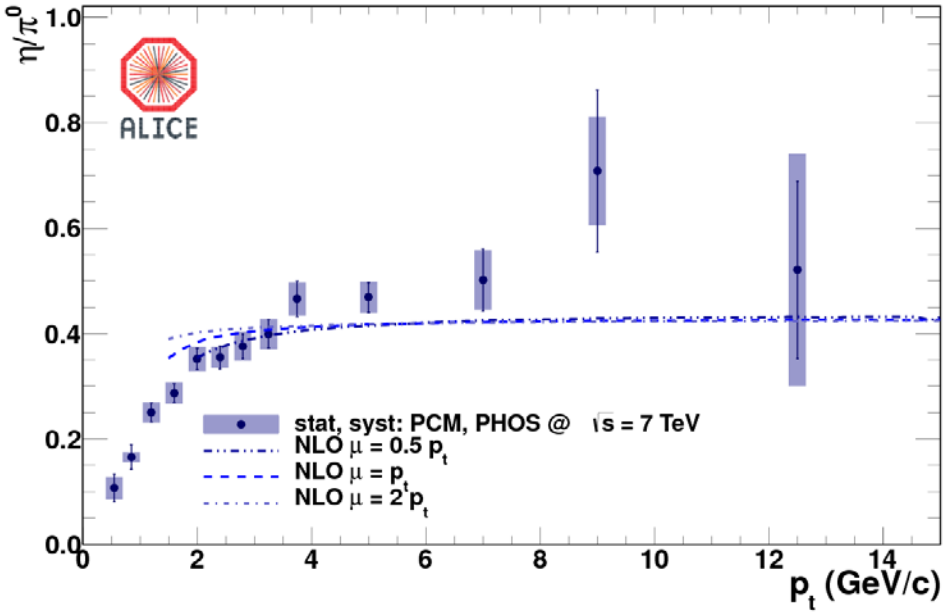
pQCD NLO calculations can reproduce data at √s=900 GeV, but overestimate η spectrum at √s=2.76 and 7 TeV.
ALICE data: CERN-PH-EP-2012-001, arXiv.1205.5724

η/π^0 ratio in pp @ 7 TeV

Compilation of η/π^0 in pp at $\sqrt{s}$=13-7000 GeV



Comparison with NLO pQCD

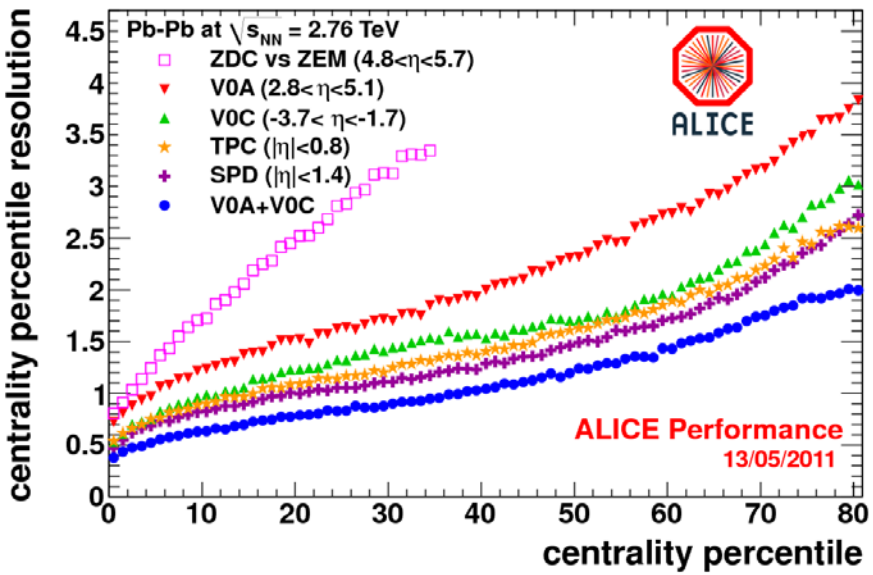


- ALICE measurement of the η/π^0 ratio is consistent with world results in pp collisions at all energies.

- The measured η/π^0 ratio is reproduced by pQCD.

ALICE data: CERN-PH-EP-2012-001, arXiv.1205.5724

Pb-Pb collisions: event characterization



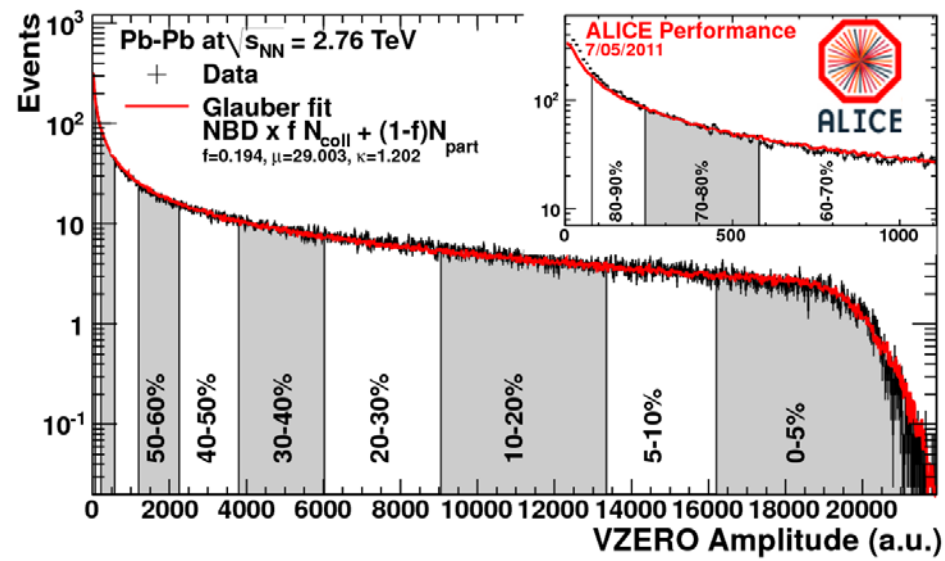
- Centrality of collisions is directly related to N_{part}, and thus characterize events by the density of the colliding system
- Centrality can be determined in ALICE by various estimator.

  [A.Toia et al., ALICE collaboration. J. Phys. G: Nucl. Part. Phys. 38 (2011) 124007]

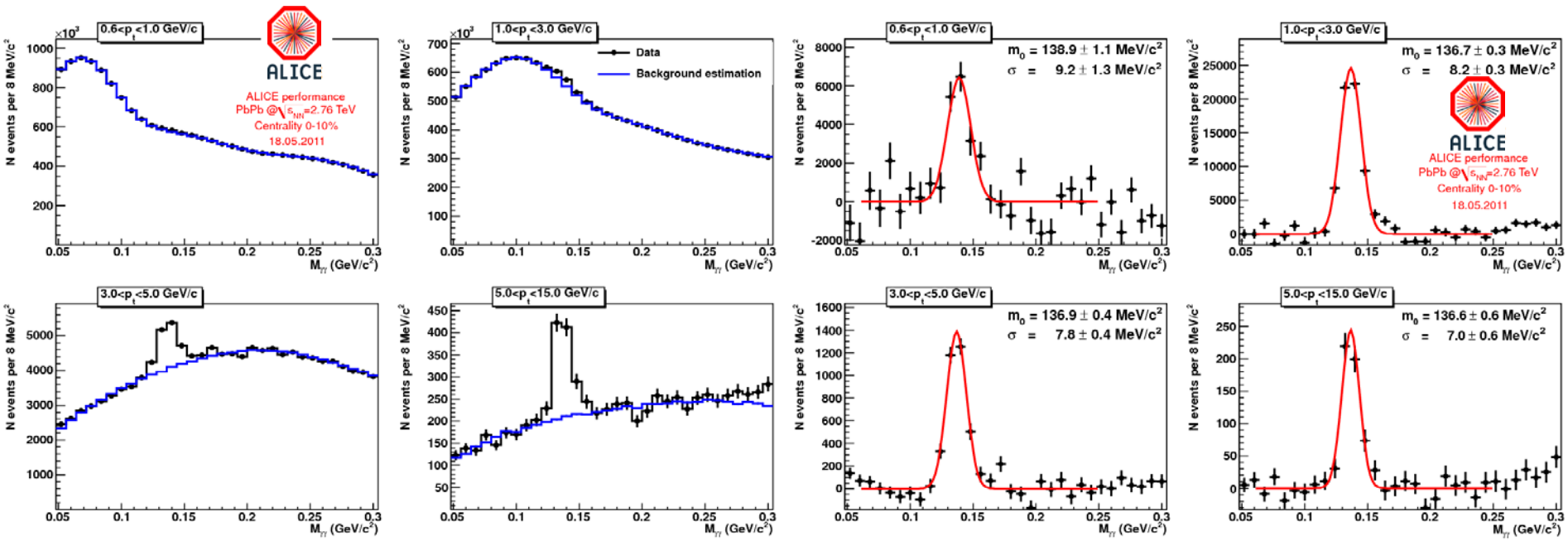
- The best centrality accuracy is provided by VZERO: from 0.5% in most central to 1.5% in most peripheral events

  [K.Aamodt et al., ALICE collaboration. PRL, 106, 032301 (2011)]

  See M.Floris talk at HP2012

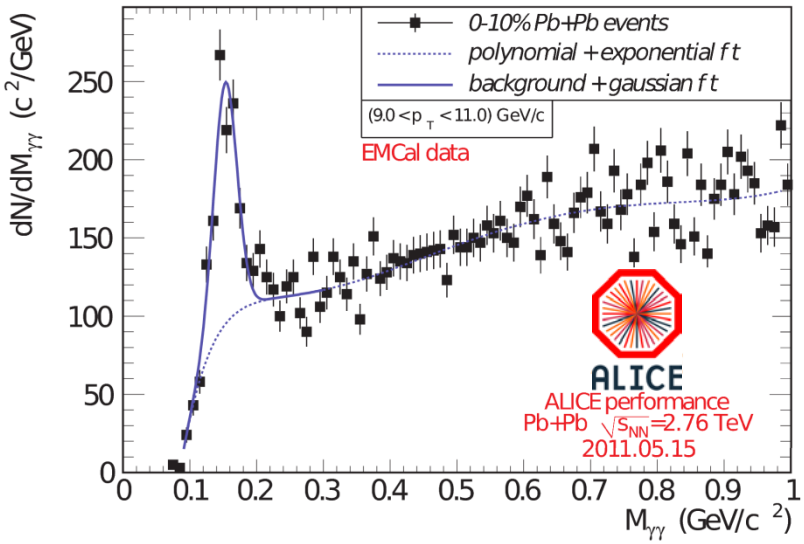


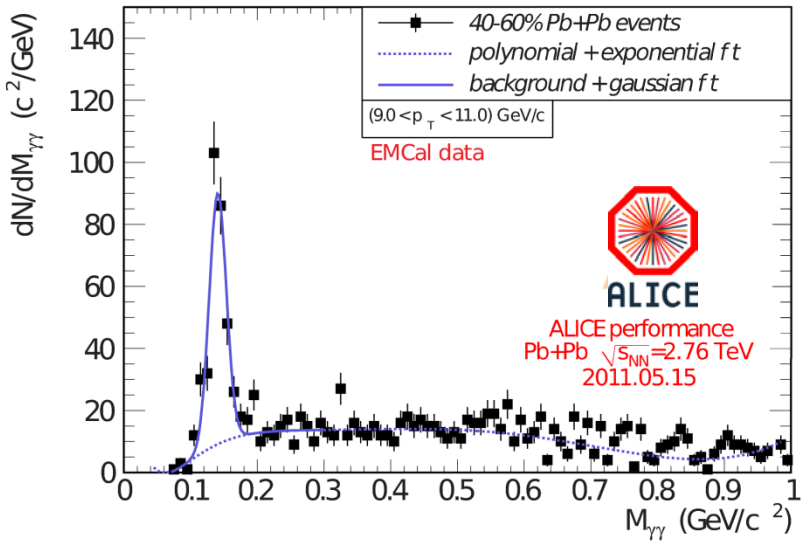
π^0 in Pb-Pb in PHOS



- High detector occupancy: up to 80 clusters in the whole PHOS acceptance per central event
- High combinatorial background in invariant mass spectra.
- Background is evaluated using mixed event technique.
- Efficiency is calculated via event embedding.

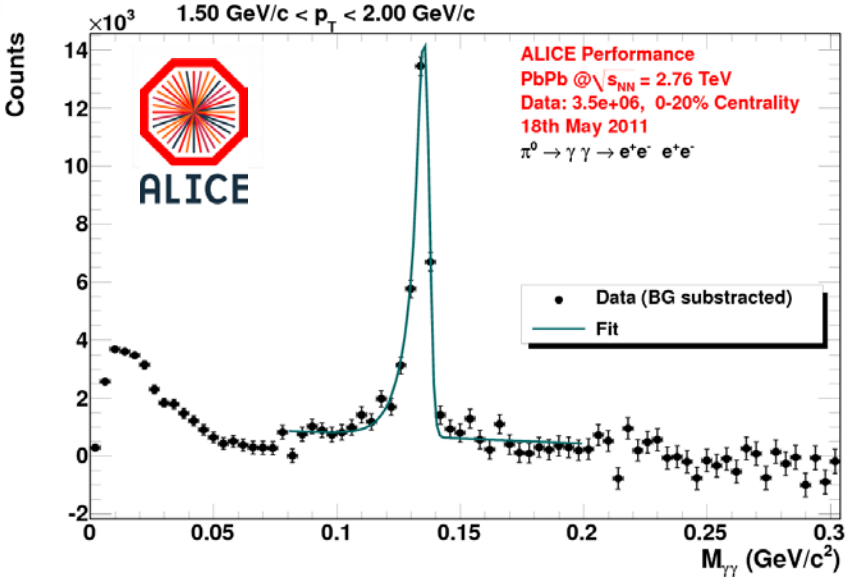
π^0 in Pb-Pb in EMCAL



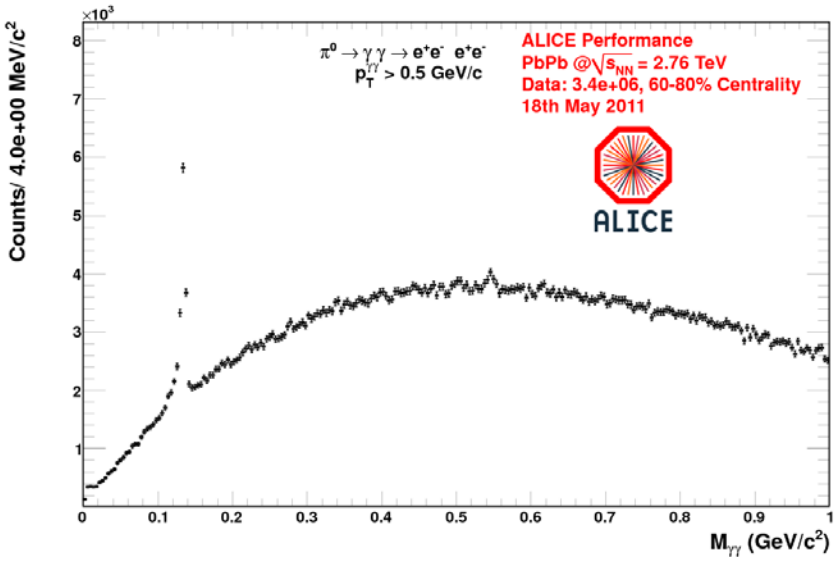


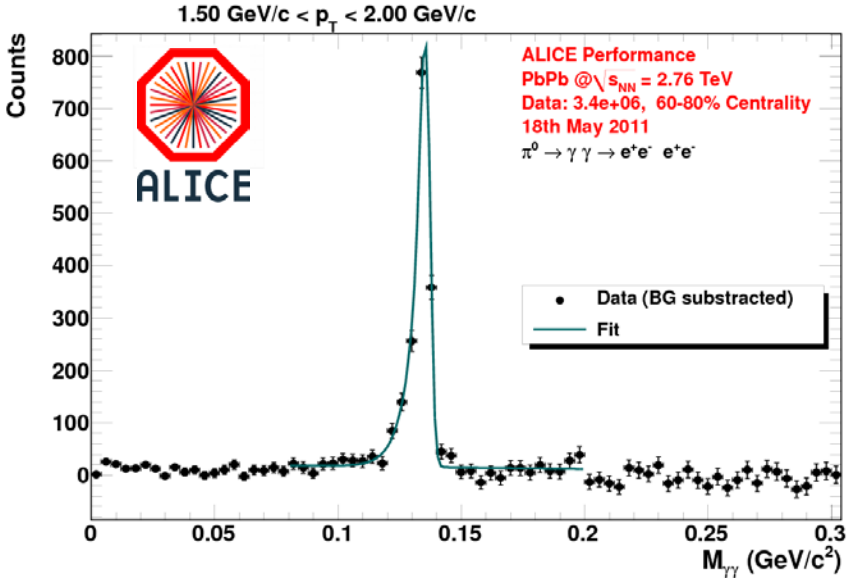
- Also high detector occupancy and high combinatorial background
- At high p_t the π^0 peak is seen even without background subtraction.

π^0 in Pb-Pb in PCM

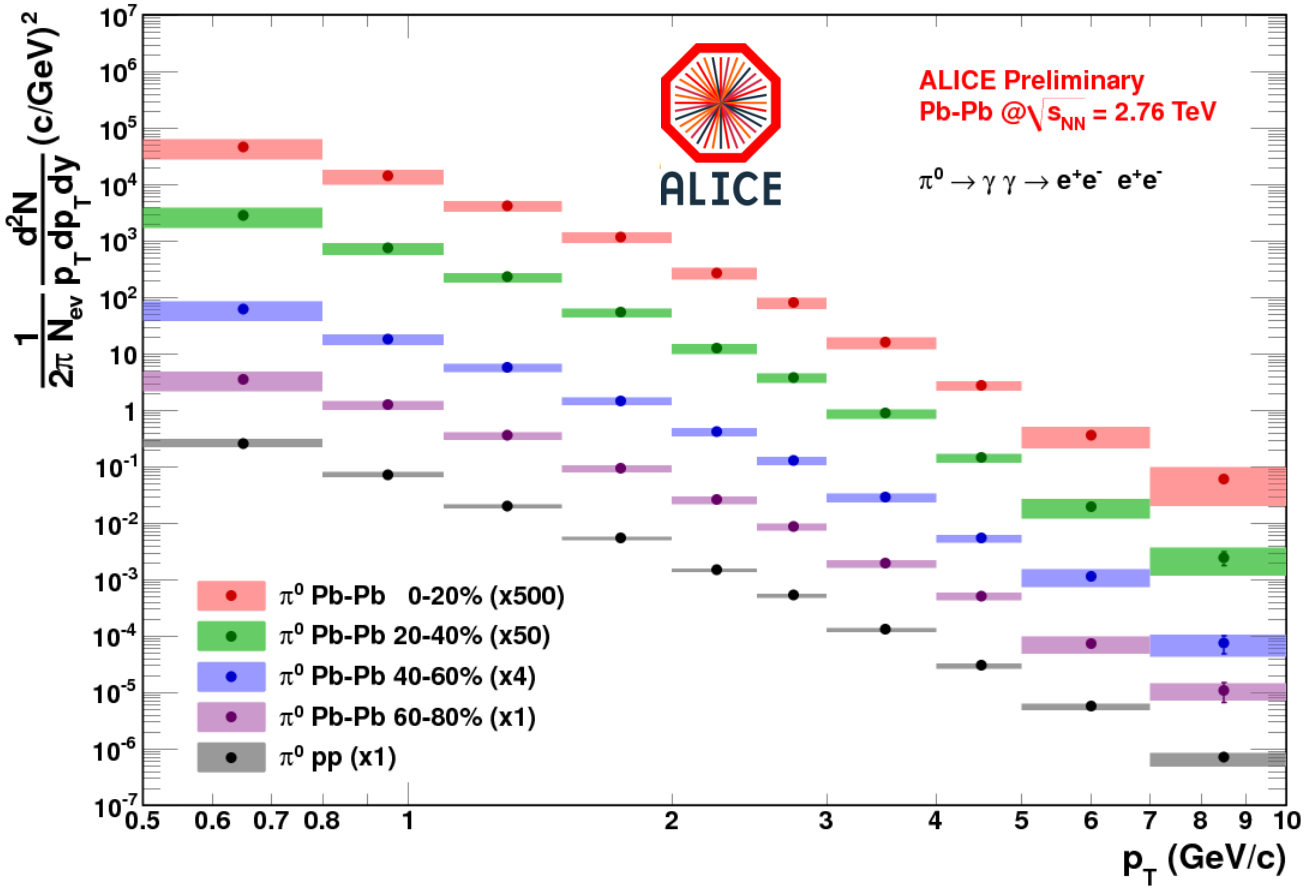


Advantage of the photon conversion method is precise photon tracking via converted e^+e^- and less background





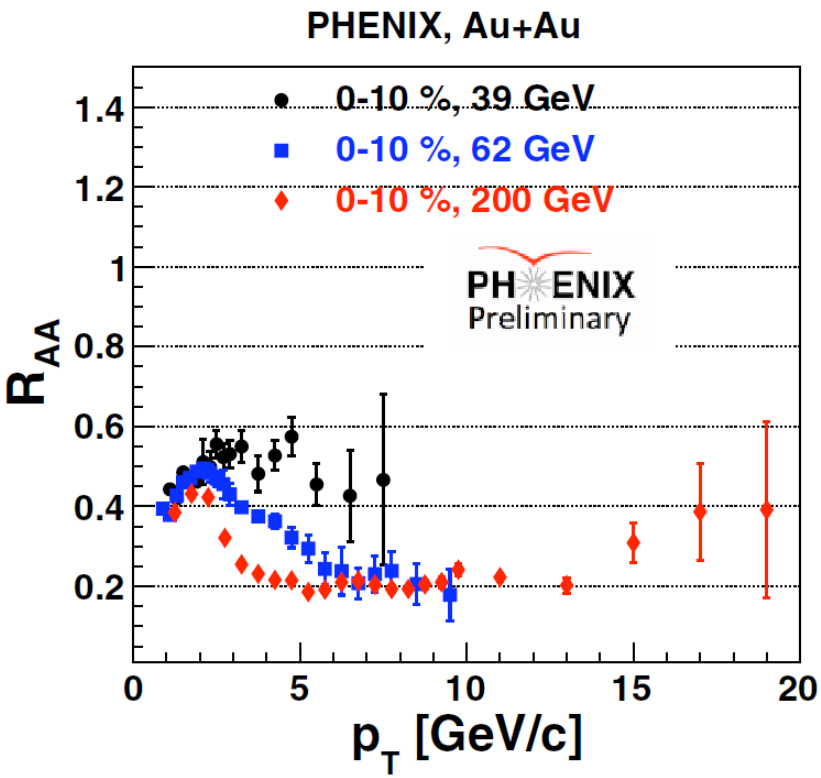
π^0 spectrum in Pb-Pb @ 2.76 TeV

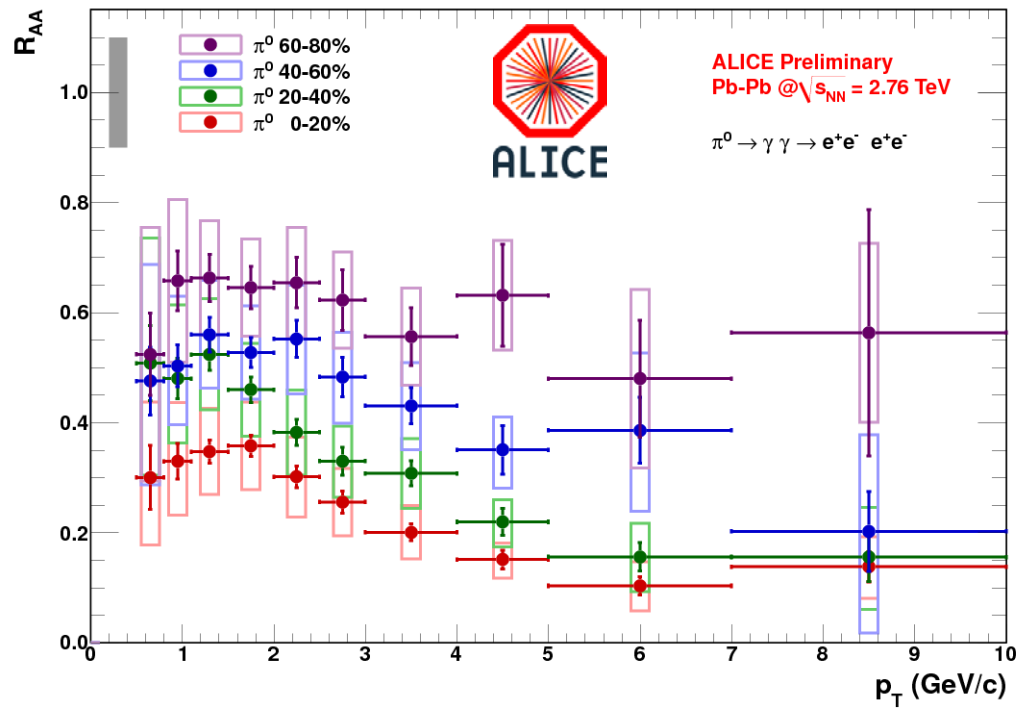


The first result on π^0 production in 4 centrality classes was obtained via photon conversion [G.Conesa Balbastre et al., ALICE collaboration. J. Phys. G: Nucl. Part. Phys. 38 (2011) 124117]

π^0 R_{AA} in Pb-Pb @ 2.76 TeV

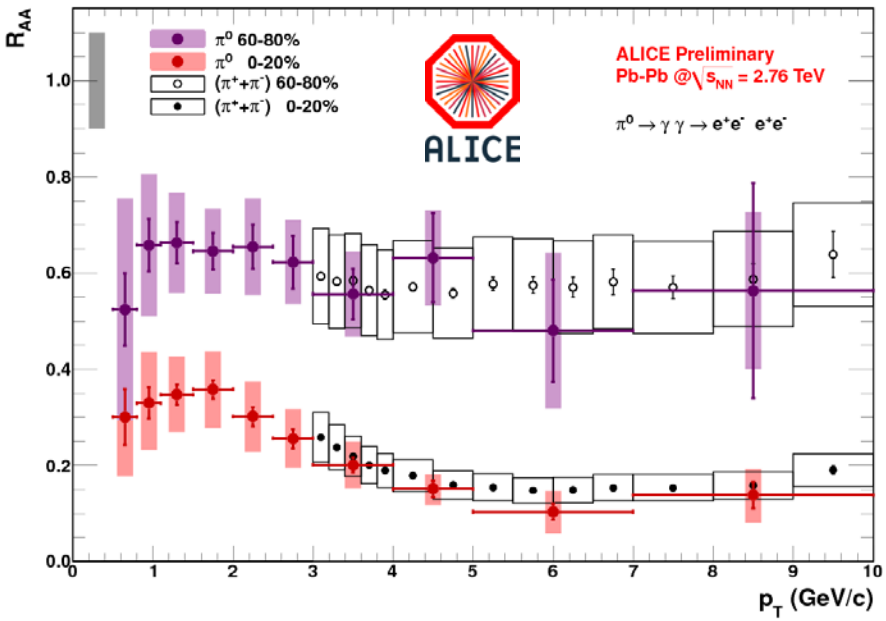
[S.Bathe et al., PHENIX collaboration.
J. Phys. G: Nucl. Part. Phys. 38 (2011) 124001]

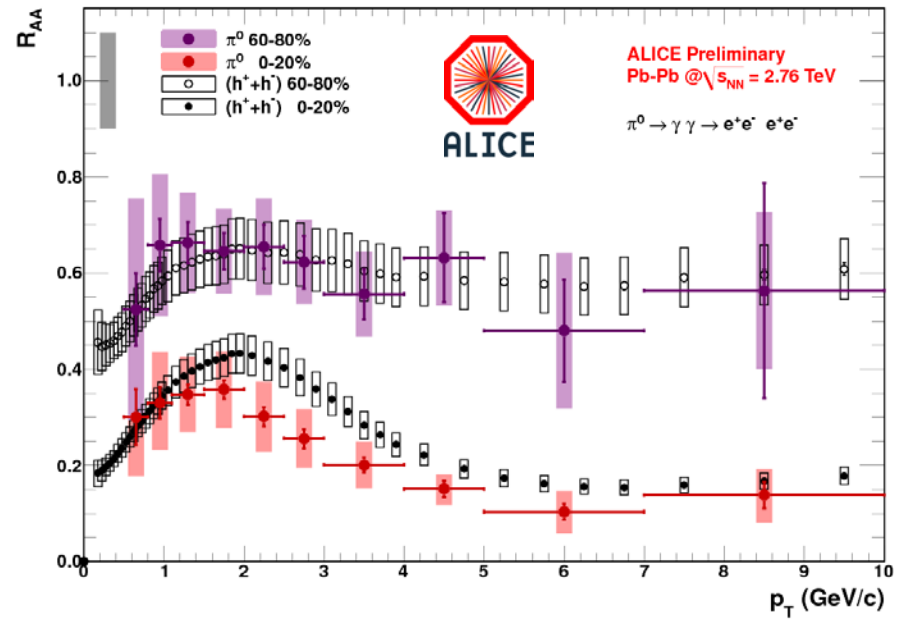




- Neutral pions at LHC suppression is qualitatively similar to that at RHIC.
- New data from ALICE are expected to come soon which will provide a more quantitative statement.

R_{AA} for π^0, $\pi^{\pm}$ and charged particles in Pb-Pb @ 2.76 TeV

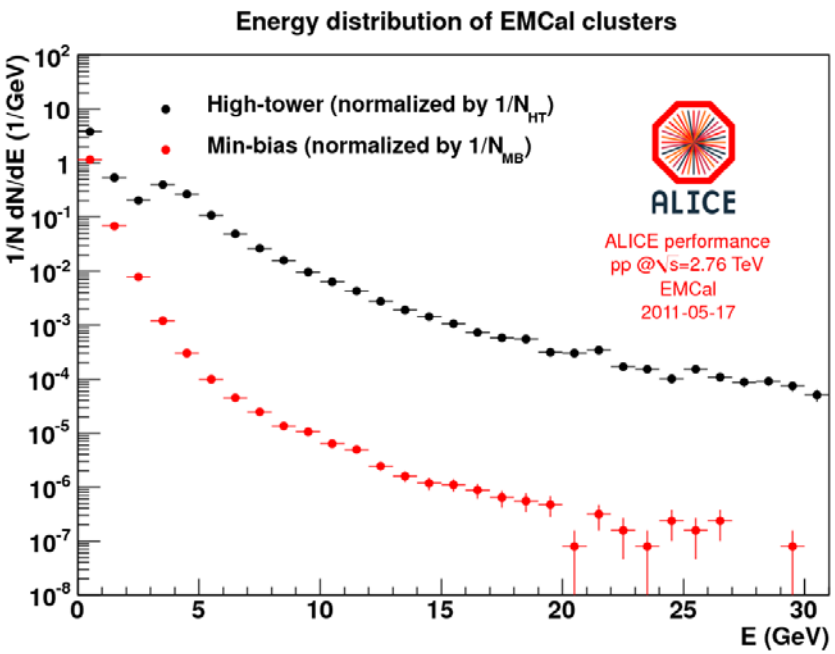


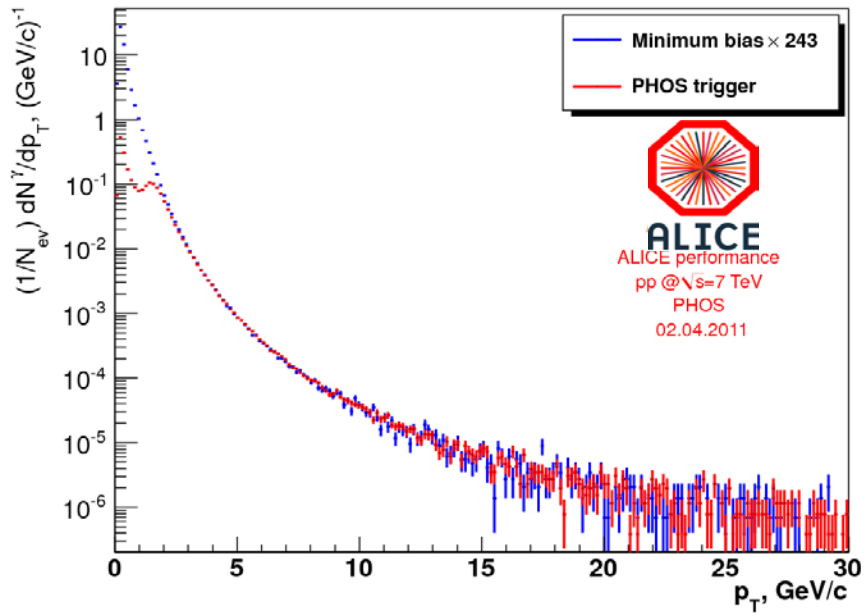


- Neutral and charged pions have similar suppression in Pb-Pb collisions, as expected
- At lower p_t, neutral pions are slightly more suppressed in the most central collisions compared to unidentified charged particles.

Triggers in EMCAL and PHOS

- Capabilities of the minimum bias trigger in ALICE:
  - Data taking rate is limited to effective luminosity $L=2\times10^{28}$ cm^{-2} s^{-1},
- Calorimeters L0 and L1 trigger capabilities:
  - Operate ALICE with full designe luminosity $L\sim10^{30}$ cm^{-2} s^{-1}., enrich photon and neutral meson statistics, extend p_t range.
- Rare events with high-energy clusters in the ALICE calorimeters can be selected by their triggers:





Integrated luminosity 5 pb^{-1} was recorded in 2011; similar value is expected in 2012.

More data – more results

- In 2011 ALICE collected data in pp at 7 TeV with rare event triggers: integrated luminosity is 5 pb^{-1}, i.e. 1000 times larger than in 2010.
  - Available statistics extends the π^0 spectrum up to p_t~40 GeV/c.
- 2011 PbPb data at 2.76 TeV: rare triggers on centrality, high-energy clusters in EMCAL and PHOS. Integrated luminosity: 100 μb^{-1}.
  - Available statistics extends the π^0 spectrum up to p_t~40 GeV/c.
- Analysis of pp and Pb-Pb data 2011 is going on.
- ALICE in 2012:
  - pp @ 8 TeV: 5 nb^{-1} with minimum bias trigger, 5 pb^{-1} with rare event triggers
  - p-Pb collisions @ 4.4 TeV.

Summary

- ALICE performs extensive measurements of identified particle spectra in pp, AA and pA collisions.
- Neutral meson spectra are measured by three complementary subsystems in a wide p_t range
- Comparison of measured spectra with NLO pQCD predictions show that pQCD describes well π^0 and η production in pp at $\sqrt{s}$=0.9 TeV, but overestimates at $\sqrt{s}$=2.76 and 7 TeV
- New measurements should initiate further constraints on PDF and FF, especially at low *x* and *z* respectively
- Suppression of π^0 in Pb-Pb at $\sqrt{s_{NN}}$=2.76 TeV strongly depends in centrality, and is similar to RHIC observations.
- New ALICE collected data exceeds the first data sample by 2 orders of magnitude. More exciting results are coming. Stay tuned.