NEUTRAL MESON PRODUCTION IN PP AND PB-PB COLLISIONS AT LHC

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Physics motivation: why neutral mesons?

- Inclusive identified hadron production is a probe for NLO pQCD
  - $\pi^0$, $\eta$ and $\omega$ can be detected and identified via photonic decay channels in a wide $p_T$ 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.
  - Meson production at LHC energies is dominated by gluon fragmentation at $p_{tT} < 100$ GeV/c: Constraints on gluon FF
  - $\eta$ 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 meson spectra in AA collisions, and $R_{AA}$ provide constraints on the energy loss models.
Detectors used in analysis

Three detectors provide complementary methods with different resolution and independent systematic uncertainties.
**π⁰ detection in ALICE calorimeters**

**PHOS**
- **Active element**: crystal of lead tungstate (PbWO₄)
  2.2×2.2×18 cm³
- **Geometry**: 3 modules 64×56 crystals each; distance from IP to active surface: 460 cm
- **Aperture**: |η|<0.13, 260°<φ<320°
- **Energy range**: 0<E<100 GeV
- **Material budget** from IP to PHOS: 0.2X₀
- **π⁰ reconstruction** via invariant mass method is possible up to pₜ~50 GeV/c

**EMCAL**
- **Active element**: tower of 77 layers
  1.4mm lead + 1.7 mm scintillator
  6×6×25 cm³
- **Geometry**: 10 modules 24×48 towers each; distance from IP to active surface: 450 cm
- **Aperture**: |η|<0.7, 80°<φ<180°
- **Energy range**: 0<E<250 GeV
- **Material budget** from IP to EMCAL: 0.8X₀
- **π⁰ reconstruction** via invariant mass method is possible up to pₜ~25 GeV/c

See poster 447 of P. Ganoti, 16 Aug 2012
π⁰ detection via converted photons

\[ pp \rightarrow π^0 X \]
\[ π^0 \rightarrow γγ \rightarrow e^+ e^- + e^+ e^- \]

- Photons convert in the medium of ALICE detectors
- Reconstructed converted photons \( \Rightarrow \) tomography of ALICE
- ALICE material budget is well described in GEANT
- \( π^0 \) is reconstructed via invariant mass spectra of photon pairs.
Comparison of spectra measured in PHOS and with conversion method

Neutral pion spectra measured in PHOS and Photon Conversion Method (PCM) agree within errors

ALICE data: CERN-PH-EP-2012-001, arXiv.1205.5724
pQCD NLO calculations [*] reproduce data at \( \sqrt{s} = 0.9 \) TeV, but overestimate \( \pi^0 \) spectrum at \( \sqrt{s} = 2.76 \) and 7 TeV.

[∗] P. Aurenche et al., Eur. Phys. J. C13, 347-355 309 (2000).
pQCD NLO calculations can reproduce data at $\sqrt{s}=0.9$ TeV, but overestimate $\eta$ spectrum at $\sqrt{s}=2.76$ and 7 TeV.
Compilation of $\eta/\pi^0$ in pp at $\sqrt{s}=13$-7000 GeV

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

ALICE Preliminary
pp, $\sqrt{s} = 0.9$ & 2.76 & 7 TeV

• ALICE measurement of the $\eta/\pi^0$ ratio is consistent with world results in pp collisions at all energies.

Comparison with NLO pQCD

• The measured $\eta/\pi^0$ ratio is reproduced by pQCD.
ω reconstruction in pp at 7 TeV

ω → π⁺π⁻π⁰

Using π± reconstructed in Central Tracking System and π⁰ – in PHOS Data collected in 2010:
~400 Mevents, ~ 6 nb⁻¹

See poster Satoshi Yano
Poster # 450 on 16 Aug 2012
Spectrum of $\omega$ has a slope consistent with that of $\pi^0$ above 4 GeV/c
Comparison of $\omega/\pi^0$ ratio

- ALICE measurement of the $\omega/\pi^0$ ratio is consistent with world results in pp collisions at all energies.
- Comparison to theory prediction would be interesting (NLO Fragmentation Function for $\omega$ is missing...).
Pb-Pb collisions

Pb-Pb @ sqrt(s) = 2.76 ATeV
2011-11-12 06:51:12
Fill : 2290
Run : 167693
Event : 0x3d94315a
• High combinatorial background in invariant mass spectra.
• Background is evaluated using mixed event technique.
• [PHOS] Efficiency is calculated via embedding.
π⁰ spectrum in Pb-Pb at 2.76 TeV

π⁰ → γ γ → e⁺e⁻ e⁺e⁻
$\pi^0$ $R_{AA}$ in Pb-Pb at 2.76 TeV

- Suppression follows the energy dependence seen at RHIC energies
- Suppression agrees with charged pion $R_{AA}$ within errors

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

- WHDG model reproduces both strength and centrality dependence
- Chen (HT) fails to reproduce centrality dependence
- Vitev’s model agrees with data in central collisions.

- W. A. Horowitz. Int.J.Mod.Phys. E16 (2007) 2193–2199, arXiv:nucl-th/0702084 [NUCL-TH].
- X.-F. Chen, T. Hirano, E. Wang, X.-N. Wang, and H. Zhang. Phys.Rev. C84 (2011) 034902, ArXiv:1102.5614 [nucl-th].
- R. Sharma, I. Vitev, and B.-W. Zhang. Phys.Rev. C80 (2009) 054902, arXiv:0904.0032[hep-ph].
Summary

- $\pi^0$, $\eta$ and $\omega$ spectra are measured over a wide $p_T$ range
  - Measurements performed by several complementary subsystems
  - NLO pQCD describes $\pi^0$, $\eta$ production in pp at $\sqrt{s}=0.9$ TeV
  - NLO pQCD overestimates $\pi^0$, $\eta$ production in pp at $\sqrt{s}=2.76$ and 7 TeV
  - NLO pQCD describes $\eta/\pi^0$ ratio at all energies
- Suppression of $\pi^0$ in Pb-Pb at $\sqrt{s_{NN}}=2.76$ TeV is stronger than one observed in RHIC
Data samples and trigger

| Collision system                  | ∫LdT     | Run #       |
|----------------------------------|----------|-------------|
| pp at √s=0.9 TeV                 | 0.14 nb⁻¹| May 2010    |
| pp at √s=2.76 TeV                | 0.7 nb⁻¹ | Apr 2011    |
| pp at √s=7 TeV                   | 5.5 nb⁻¹ | Jun-Aug 2010|
| Pb-Pb at √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

![Diagram of SPD and VZERO detectors](image)
Pb-Pb collisions: event characterization

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
Efficiency and Monte Carlo tuning

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

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