Charged and neutral particle production in p-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV with ALICE

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The VI$^{th}$ International Conference on the Initial Stages of High-Energy Nuclear Collisions
Particle production at LHC energies:

- Resulting from the interplay between hard and soft QCD processes
  - Hard QCD process
    - Described by pQCD calculations
  - Soft QCD process
    - $p_T < \sim 1-2$ GeV
    - Need the help of non pQCD based model calculations
  - $P \ (N)$ and $dN/d\eta$ put constraints to these models describing particle production mechanisms

Measurements in p-Pb collisions:

- Serve as a baseline to interpret Pb–Pb results
- Probing low-\(x\) dense gluonic fields inside Pb nuclei

Inclusive photon (mostly from $\pi^0$) measurement is complementary to the charged particle measurement
A Large Ion Collider Experiment

THE ALICE DETECTOR

- High detector granularity
- Low transverse momentum threshold $p_T^{\text{Min}} \approx 0.1 \text{ GeV/c}$
- PID capability for several hadron species
- Magnetic field $B = 0.5 \text{ T}$

A Large Ion Collider Experiment

Detectors used
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Scintillator Detectors (V0A & V0C)
Used for event selection
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Photon Multiplicity Detector (PMD)
Measure photons
A Large Ion Collider Experiment

Detectors used

- Scintillator Detectors (V0A & V0C)
  - Used for event selection
- Photon Multiplicity Detector (PMD)
  - Measure photons
- Silicon Pixel Detector (SPD)
  - Measure charged particle
- Forward Multiplicity Detector (FMD)
  - Measure charged particle
Detecting photons

PMD measures multiplicity and spatial distributions of photons event-by-event

- Sensitive medium: Gas (Ar+CO₂ in the ratio 70:30)
- Total no. of cells: 152 k
- Coverage: 2.3 < η < 3.9 (full Φ)
- Converter: 3X₀ thick Pb plate

Working Principle

- Photons passing through the Pb converter initiate EM shower and produce signals on several cells of the PRE plane
- Hadrons normally affect only one cell and produce a signal representing minimum ionizing particles

Detecting charged particles

FMD & SPD measure multiplicity distributions and pseudorapidity density of charged particles

FMD
- Silicon strip detector in 5 rings
- Total no. of strips: 51200
- Full azimuthal coverage
- Pseudorapidity coverage: $-3.4 < \eta < -1.7$
  $+1.7 < \eta < +5.0$

SPD
- Two innermost layers of ITS
- Total no. of pixels: 10 M
- Full azimuthal coverage
- Pseudorapidity coverage: $|\eta| < +2.0$ (Inner layer)
  $|\eta| < +1.4$ (Outer layer)

Using FMD + SPD we can achieve a uniquely wide pseudorapidity range at the LHC of more than eight $\eta$ units, $-3.4 < \eta < 5.0$


Results have been derived for minimum bias (MB) events (specifically NSD events) and different centrality classes.

Centrality classes are estimated using Forward Scintillator Detector (V0A).

VZERO-A amplitude distribution and classification in centrality bins.
Photon reconstruction

**Analysis flow chart**

Data → Event selection → Particle selection → Raw dist. → Unfolding → Trigger & vertex efficiency correction → True dist.

**Graphs and Images:**
- Graph (a): ALICE Collaboration, EPJC 75 (2015) 146, showing energy deposition (ADC) vs. number of events for 3 GeV π and Landau fit with MPV: 72 ± 2.
- Graph (b): Histogram showing 3 GeV π (Data) counts with Mean: 1.09 and RMS: 5.01.
- Graph (c): Probability distribution for 3 GeV electron (Simulation) and 3 GeV electron (Data).
- Graph (d): Histogram for 3 GeV electron (Data) with Mean: 11.1 and RMS: 5.01.

**Text:**
Responses of the PRE plane of the PMD to the incident charged pions and electrons of energy 3 GeV each.

*ALICE Collaboration, EPJC 75 (2015) 146*
Photon reconstruction

- No. of affected cells and energy deposition by incident charged pion is much less than an incident photon
- Photon are selected by putting conditions on $N_{cell} (> 2)$ and cluster ADC ($> 6$ MPV)
- MPV: Most Probable Value of the charged pion ADC distribution (72 ADC)
- $\gamma_{like}$: The clusters which satisfy the photon-hadron discrimination threshold condition

Responses of the PRE plane of the PMD to the incident charged pions and electrons of energy 3 GeV each
Uncorrected photon multiplicity

N\textsubscript{γ-like} clusters obtained by applying the photon-hadron discrimination thresholds

Unfolding method is used for the correction of MB results

Efficiency-Purity method is used to correct centrality dependent results
Correction procedure

**Bin by bin correction using Efficiency and Purity**

**Efficiency**
\[
\text{Efficiency} = \frac{N_{\gamma-\text{detected}}^{\text{Simulation}}}{N_{\gamma-\text{incident}}^{\text{Simulation}}}
\]

**Purity**
\[
Purity = \frac{N_{\gamma-\text{detected}}^{\text{Simulation}}}{N_{\gamma-\text{like}}^{\text{Simulation}}}
\]

\[N_{\gamma-\text{corrected}} = \frac{\text{Purity}}{\text{Efficiency}} \times N_{\gamma-\text{like}}^{\text{Data}}\]

- \(N_{\gamma-\text{detected}}^{\text{Simulation}}\): No. of detected photon clusters above discrimination threshold
- \(N_{\gamma-\text{incident}}^{\text{Simulation}}\): No. of incident photons within the PMD coverage

- Efficiency varies with \(\eta\) whereas purity is almost independent of \(\eta\)
- Sensitive to photon-hadron discrimination thresholds
- Mild dependence on centrality
Correction procedure

Unfolding method

- Method used: Bayesian theorem
- Best parameters are obtained from simulation

Unfolding procedure is able to recover the true distribution well within $\pm 10\%$
MB photons multiplicity results

Both models underestimate the data in the region where diffractive processes occur.

HIJING describes the data slightly better than DPMJET.
MB photons multiplicity results
DPMJET slightly overestimates the photon production towards midrapidity.
Pseudorapidity distribution

Comparing forward photons with charged particles at midrapidity

➢ DPMJET slightly overestimates the photon production towards midrapidity
➢ Both DPMJET and HIJING describe the charged-particle production at midrapidity well
In forward rapidity region (2.3 < η < 3.9), photon (mostly from π⁰) and charged-particle production has similar dependence on centrality.
Centrality dependent results

In forward rapidity region ($2.3 < \eta < 3.9$), photon (mostly from $\pi^0$) and charged-particle production has similar dependence on centrality.

$pp, \sqrt{s} = 7 \text{ TeV (Pythia8 simulation)}$

- Fraction of direct photons $\sim 0.05\%$
- Fraction of decay photons $\sim 99.95\%$
- Fractions of decay photons coming from $\pi^0$ $\sim 94\%$

- In forward rapidity region ($2.3 < \eta < 3.9$), photon (mostly from $\pi^0$) and charged-particle production has similar dependence on centrality.
Centrality dependent results

New
Centrality dependent results

New

ALICE Preliminary
p-Pb, $\sqrt{s_{NN}} = 5.02$ TeV
VOA

$\frac{1}{N_{\text{evt}}} \frac{dN}{d\eta_{\text{lab}}}$
Centrality dependent results

Both DPMJET and HIJING underpredict the data
P (N_{γ}) and dN_{γ}/dη are measured at forward rapidity in p-Pb collisions at \( \sqrt{s_{NN}} = 5.02 \) TeV

Centrality dependent dN_{γ}/dη and dN_{ch}/dη are studied and compared and they are compatible with each other

Results are compared with HIJING and DPMJET Monte Carlo predictions

- Both MC models underestimate P (N_{γ}) at low multiplicity (N_{γ} < 10)
- HIJING describes the data slightly better than DPMJET

dN_{ch}/dη is well described by both MC models whereas dN_{γ}/dη is overestimated by DPMJET at lower pseudorapidity region

None of the models considered could explain the centrality dependent evolution of photon and charged-particle production

Thank you for your kind attention!
Back up slides
Sources of systematic uncertainties

1. Discrimination thresholds
   ➢ Cluster ADC > 9 MPV and Cluster N_{cell} > 2

2. Unfolding methods
   ➢ $\chi^2$ minimization

3. Parameter used in unfolding method
   ➢ Change the bayesian unfolding parameters (smoothing and no. of iterations)

4. Effect of upstream material
   ➢ Effect of upstream material in front of the PMD is increased by 10%

Total systematic uncertainties are calculated by adding systematic uncertainties from individual sources in quadrature and it is found to vary:

➢ 4.4 – 57% for Multiplicity distribution.
➢ 7.37 – 7.4% for pseudorapidity distribution.