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

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The VIth International Conference on the Initial Stages of High-Energy Nuclear Collisions

Motivation

Particle production at LHC energies:

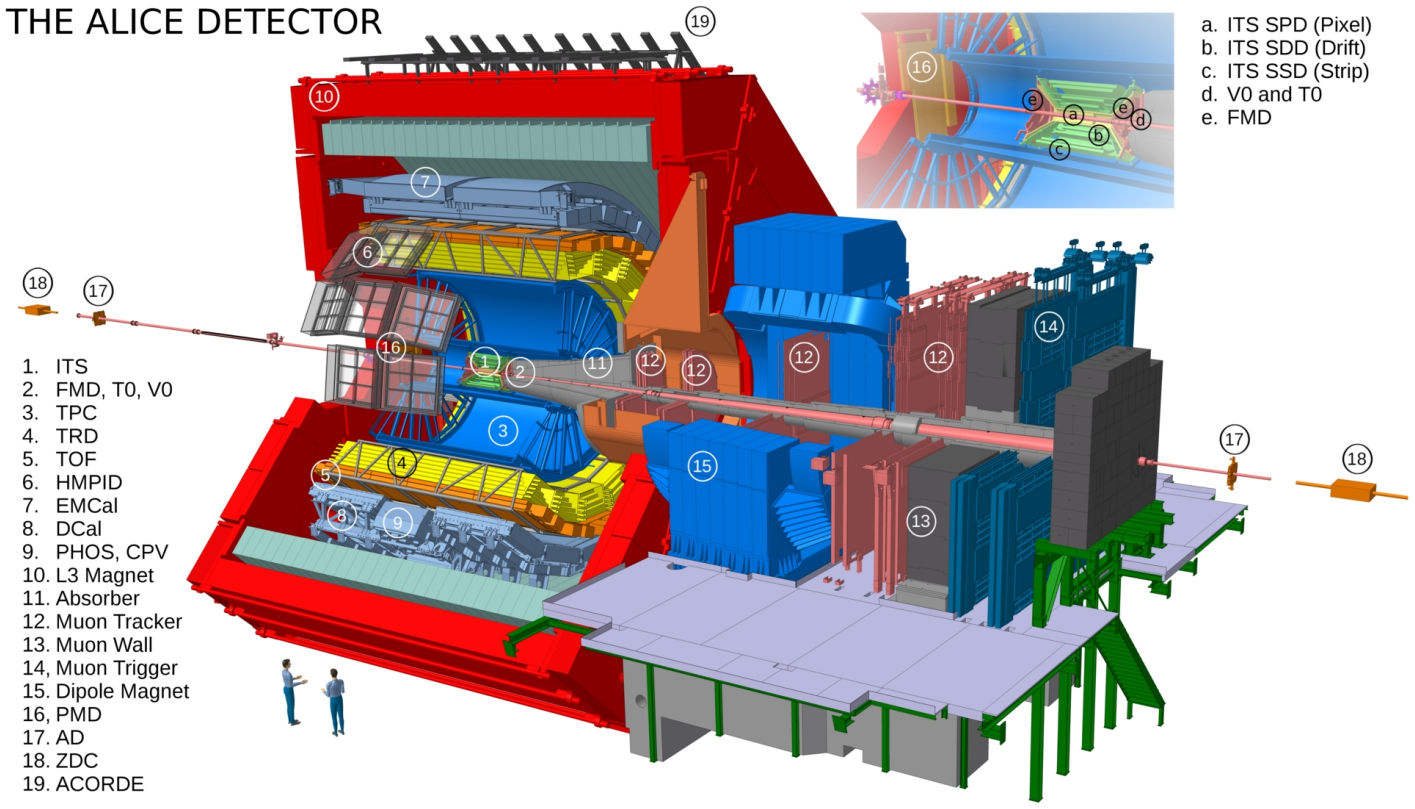
- **Resulting from the interplay between hard and soft QCD processes**
  - ✔ **Hard QCD process**
    - Described by pQCD calculations
  - ✔ **Soft QCD process**
    - $p_T <$ ~ 1-2 GeV
    - Need the help of non pQCD based model calculations
- **P (N) and dN/dη put constraints to these models describing 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 π^0) measurement is complementary to the charged particle measurement

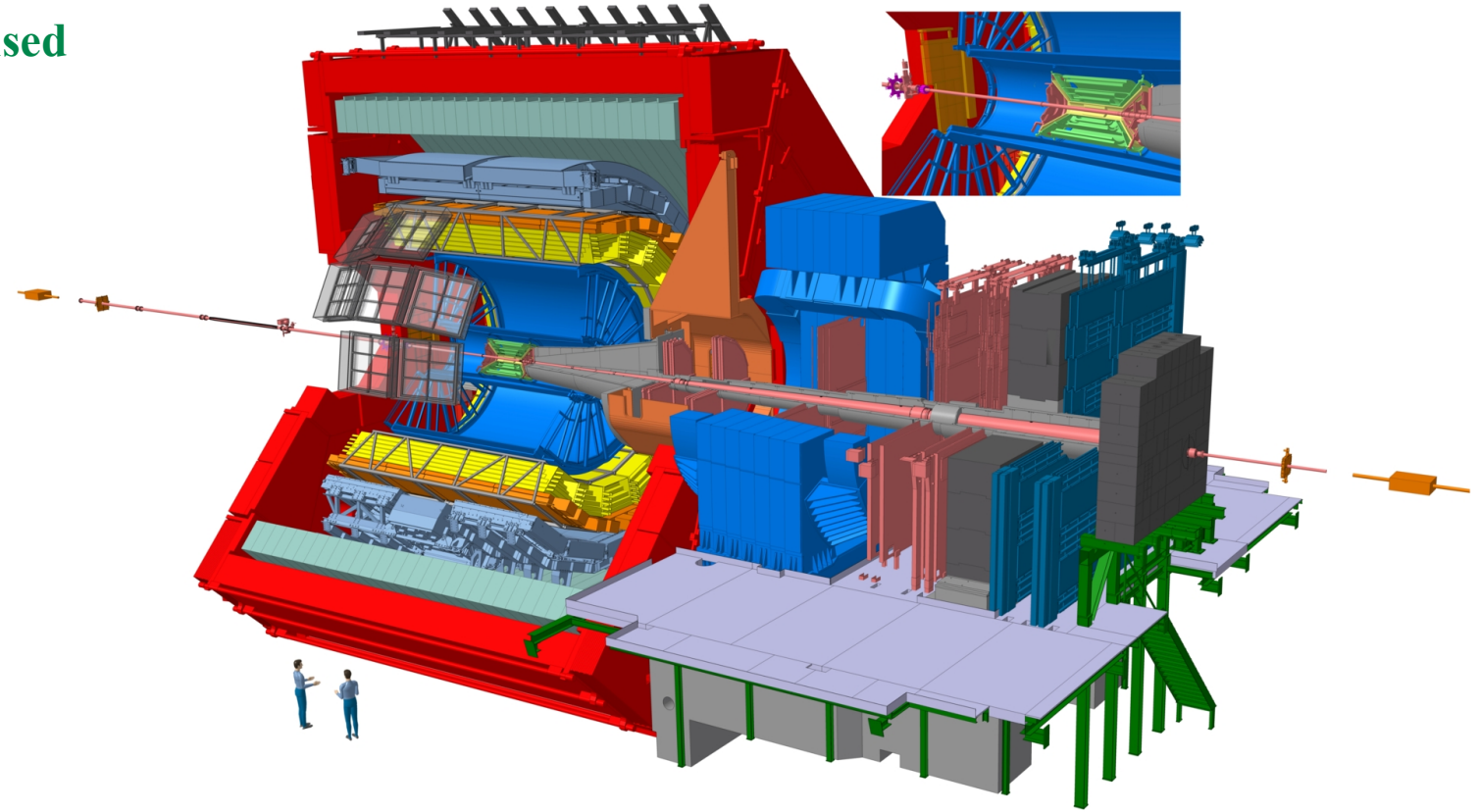
A Large Ion Collider Experiment



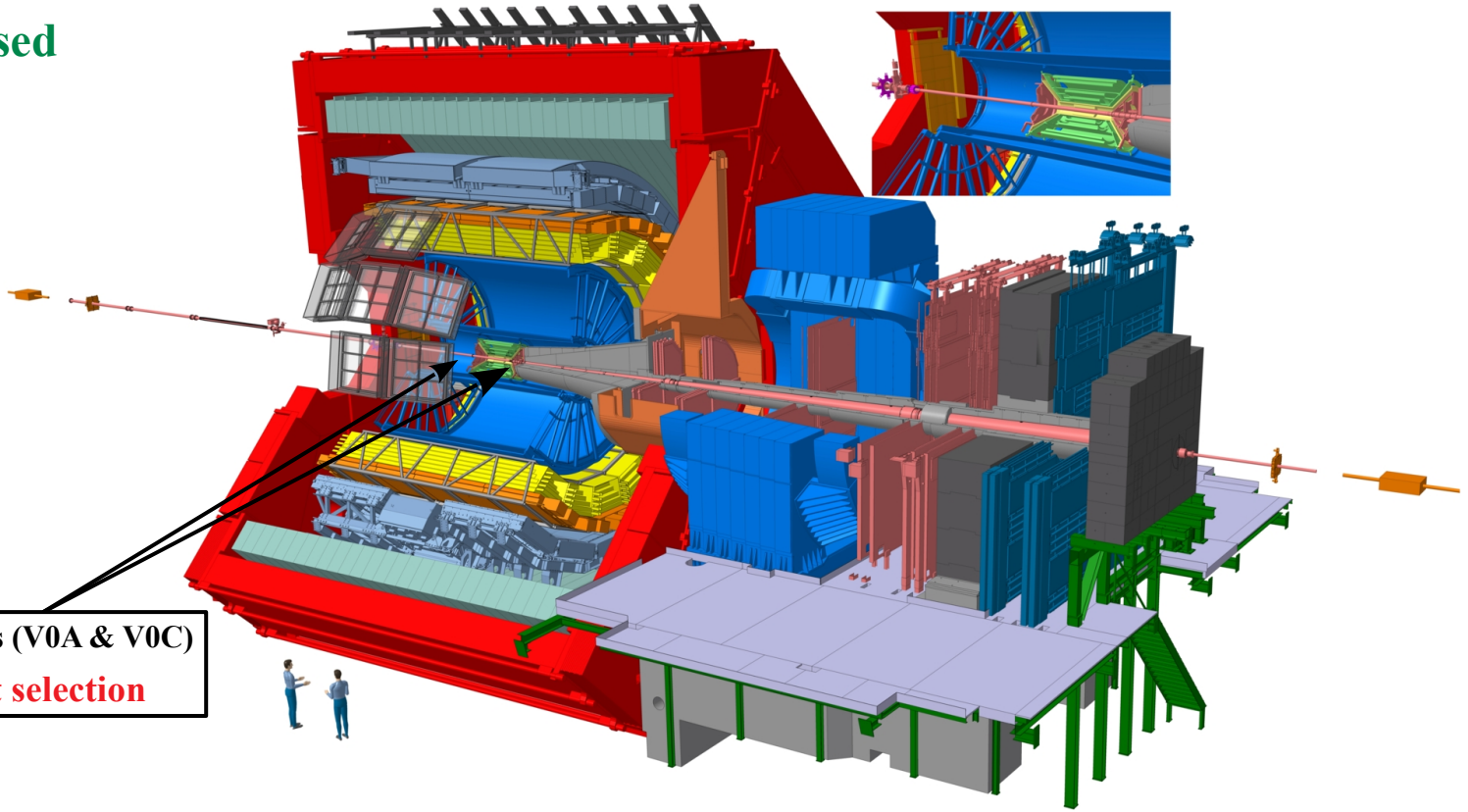
- High detector granularity
- Low transverse momentum threshold $p_T^{Min} \approx 0.1$ GeV/c
- PID capability for several hadron species
- Magnetic field B = 0.5 T

ALICE Collaboration, JINST 3, S08002 (2008).

Detectors used



Detectors used

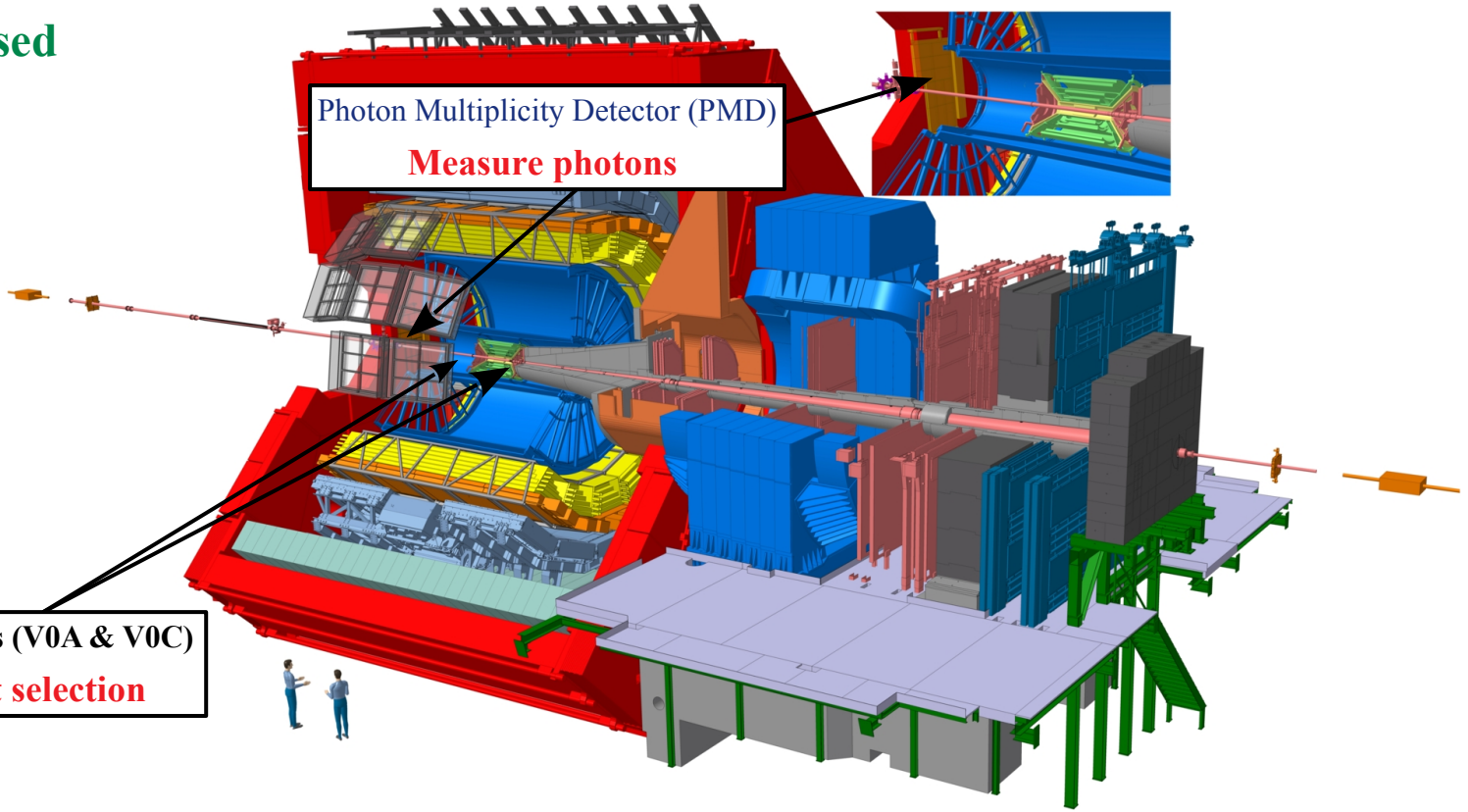


Scintilator Detectors (V0A & V0C)

Used for event selection

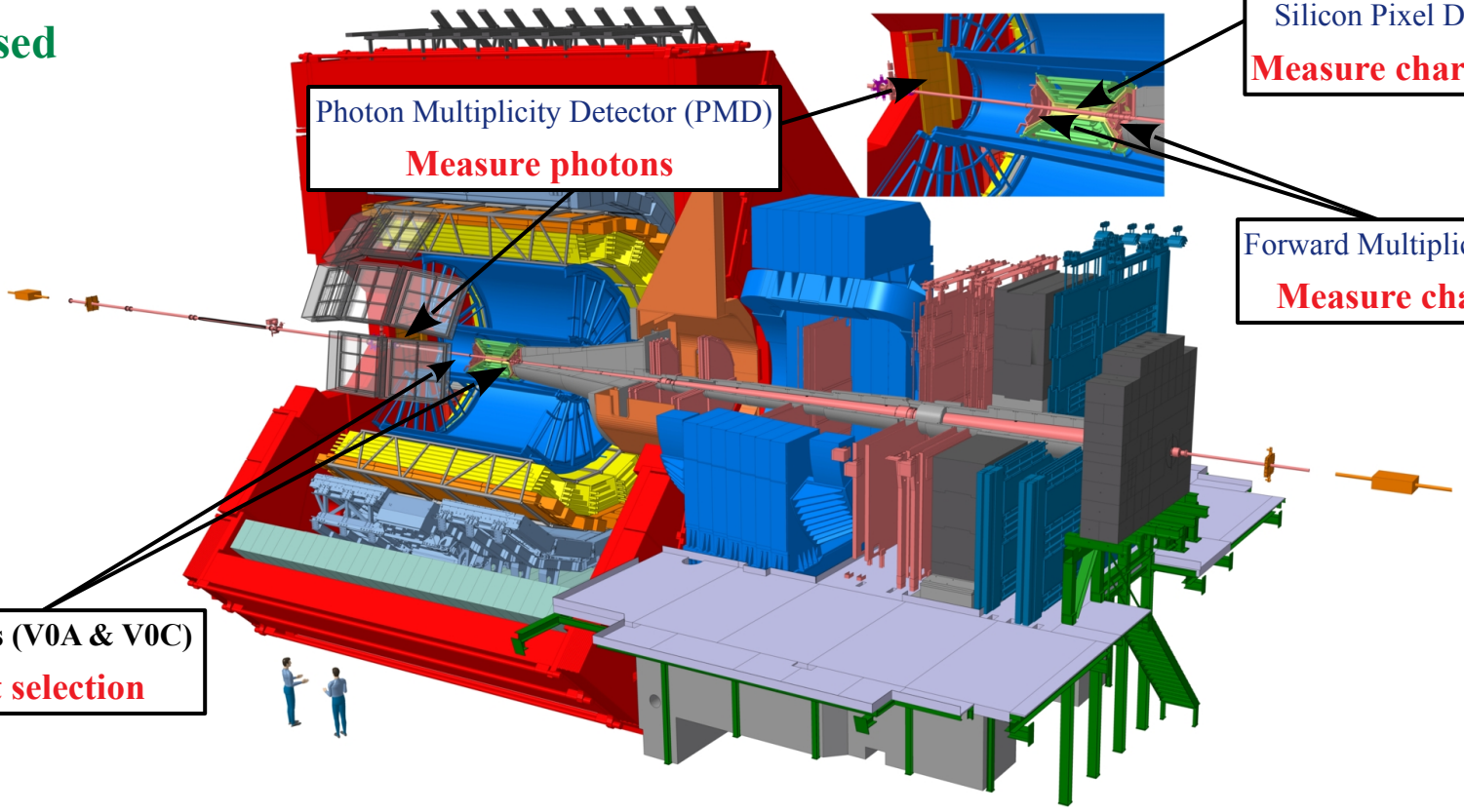
A Large Ion Collider Experiment

Detectors used



A Large Ion Collider Experiment

Detectors used



Silicon Pixel Detector (SPD)
Measure charged particle

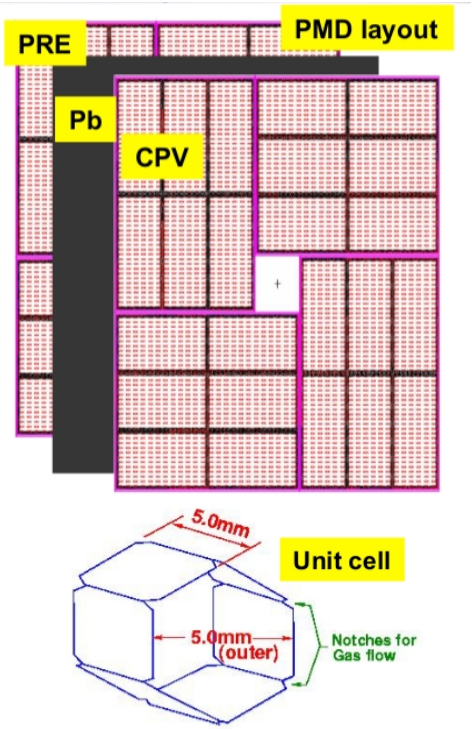
Photon Multiplicity Detector (PMD)
Measure photons

Forward Multiplicity Detector (FMD)
Measure charged particle

Scintilator Detectors (V0A & V0C)
Used for event selection

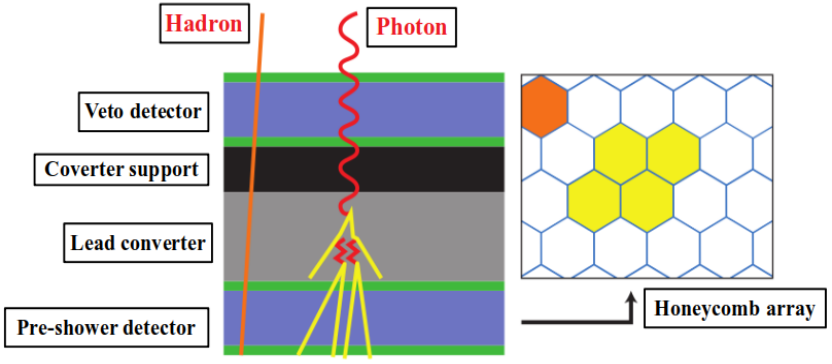
Detecting photons

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



- Sensitive medium: **Gas ($Ar+CO_2$ in the ratio 70:30)**
- Total no. of cells: **152 k**
- Coverage: **$2.3 < \eta < 3.9$ (full Φ)**
- Converter: **$3X_0$ thick Pb plate**

Working Principle

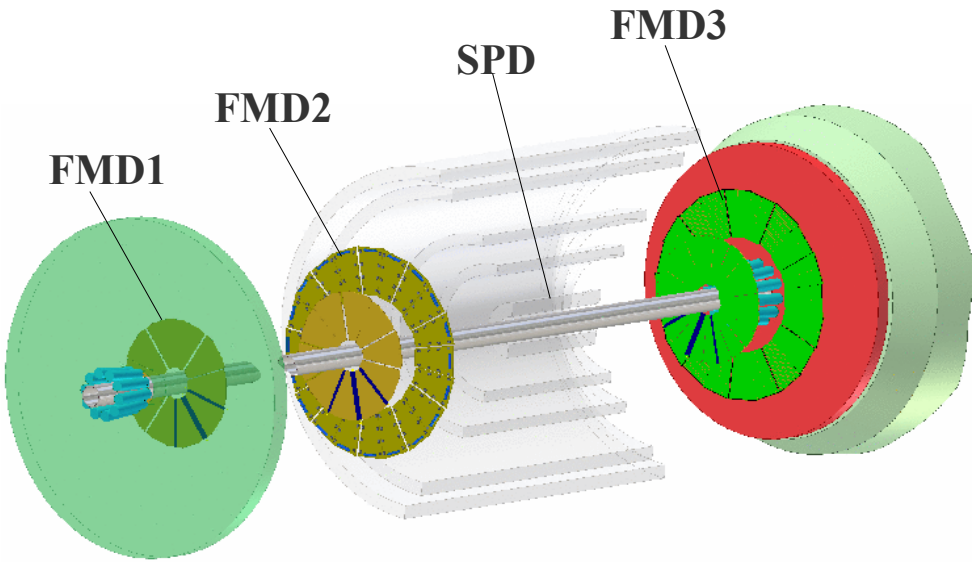


- **Photons passing through the Pb converter initiate EM shower and produce signals on several cells of the PRE plane**
- **Hadrons normally affect only one cell and produce a signal representing minimum ionizing particles**

ALICE Collaboration, "ALICE technical design report: photon multiplicity detector (PMD)," CERN-LHCC-99-032 (1999)

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 η units, $-3.4 < \eta < 5.0$

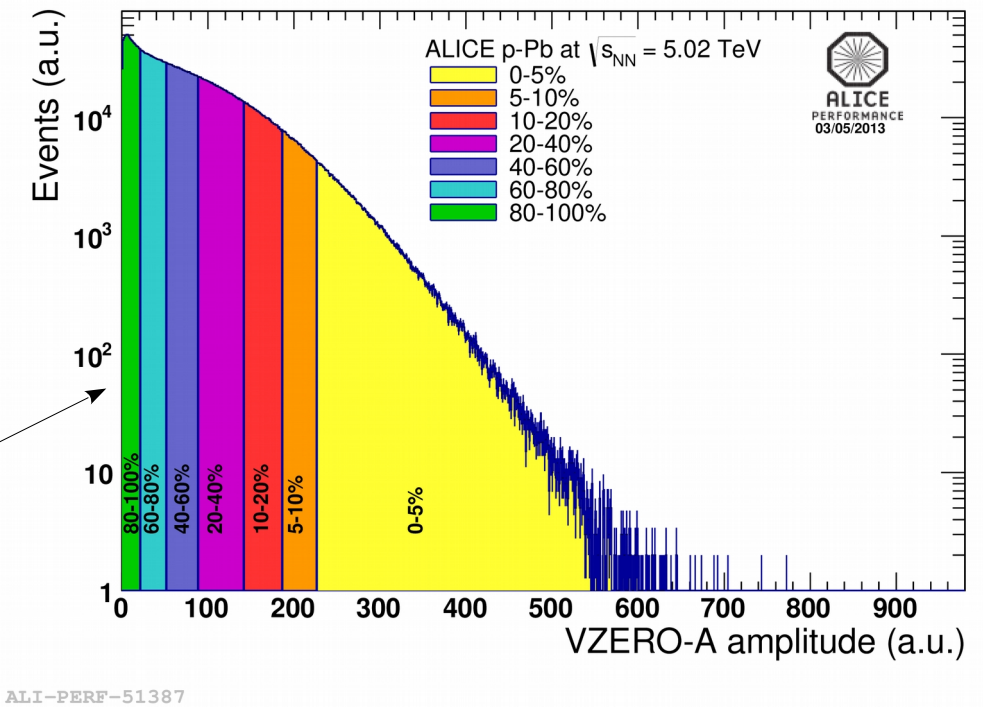
ALICE Collaboration, "ALICE technical design report on forward detectors: FMD, T0 and V0," CERN-LHCC-2004-025 (2004).

ALICE Collaboration, "ALICE technical design report on Inner Tracking System (ITS)," , CERN-LHCC-99-012 (1999).

Centrality selection

- 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)**

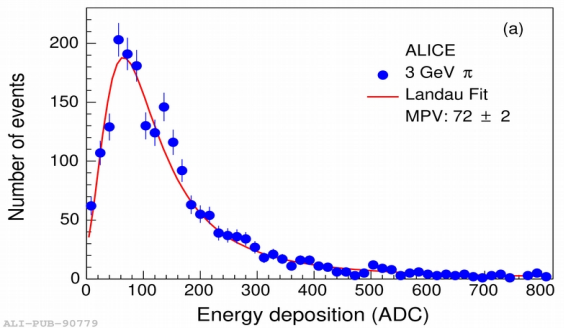
VZERO-A amplitude distribution and classification in centrality bins

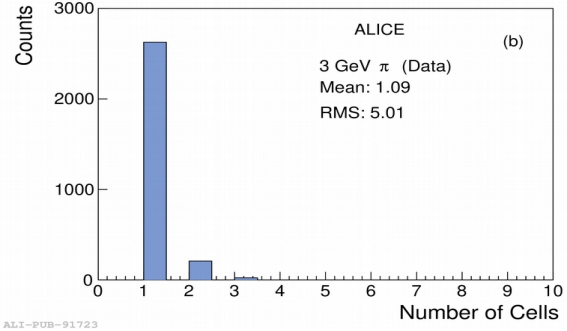


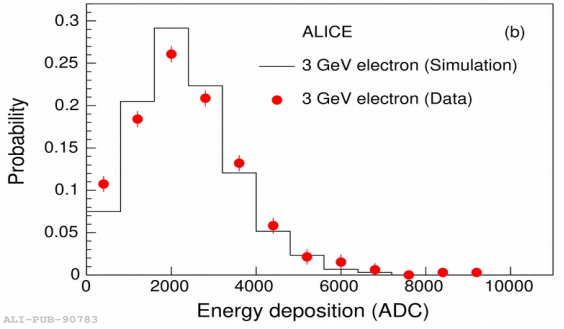
Photon reconstruction

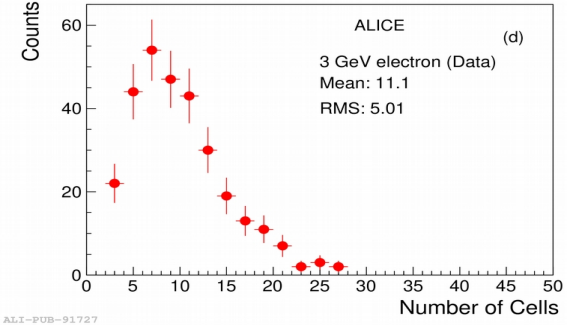
Analysis flow chart

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









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

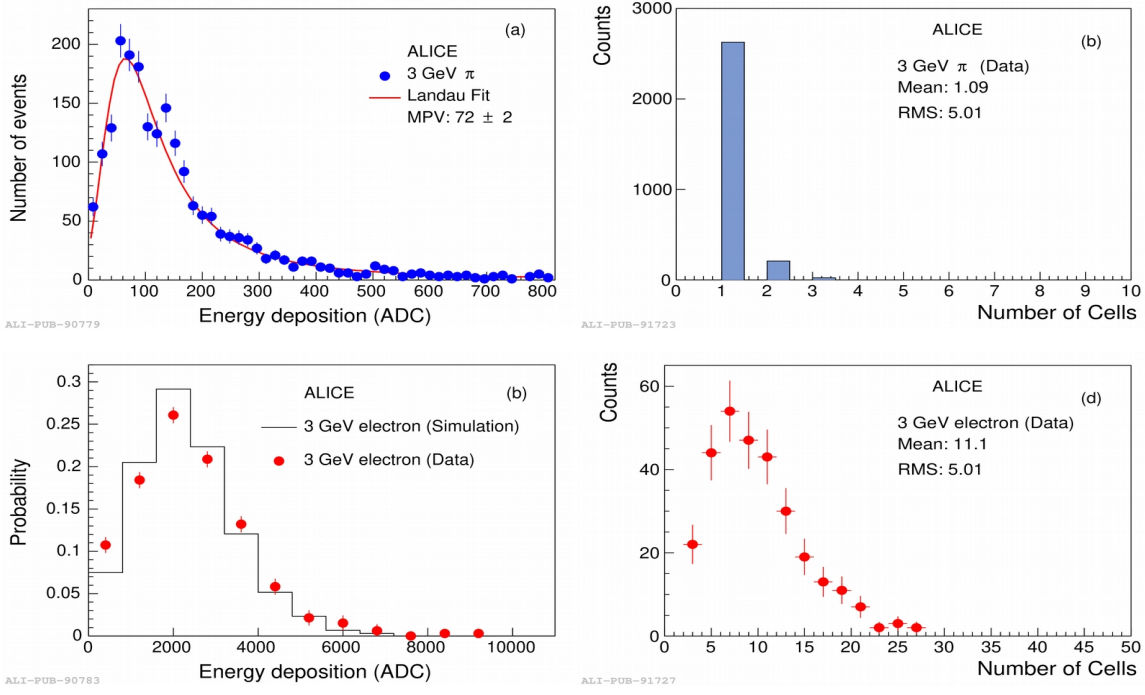
ALICE Collaboration, EPJC 75 (2015) 146

Photon reconstruction

Analysis flow chart

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

- 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)
- γ_{like}**:** The clusters which satisfy the photon-hadron discrimination threshold condition

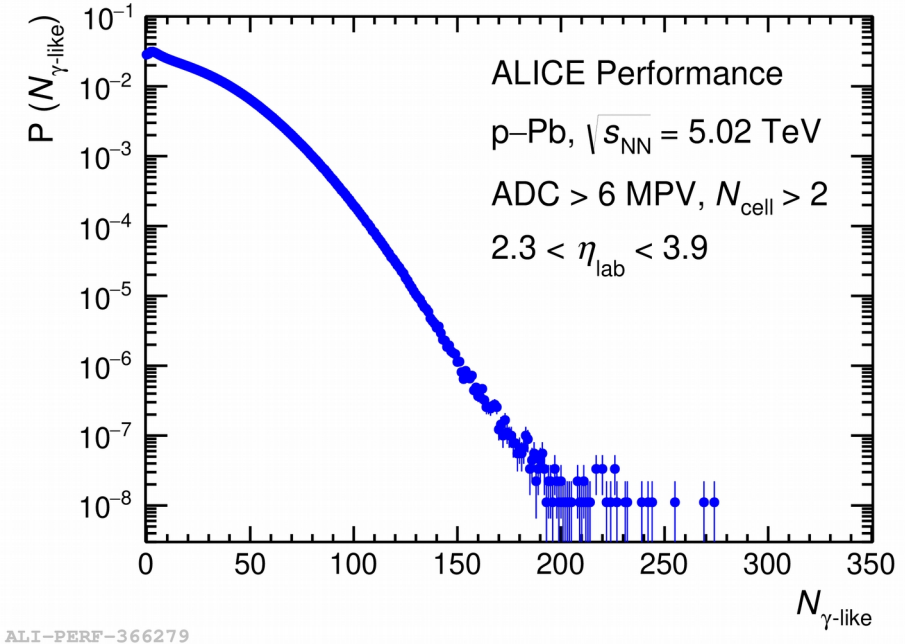


Responses of the PRE plane of the PMD to the incident charged pions and electrons of energy 3 GeV each

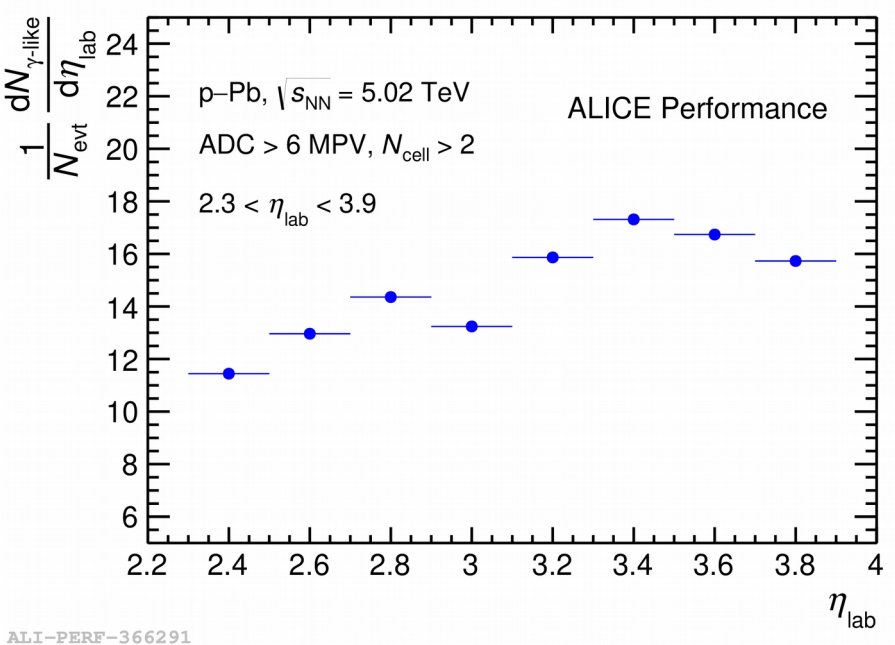
ALICE Collaboration, EPJC 75 (2015) 146

Uncorrected photon multiplicity

Multiplicity distribution



Pseudorapidity distribution



- $N_{\gamma\text{-like}}$ 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

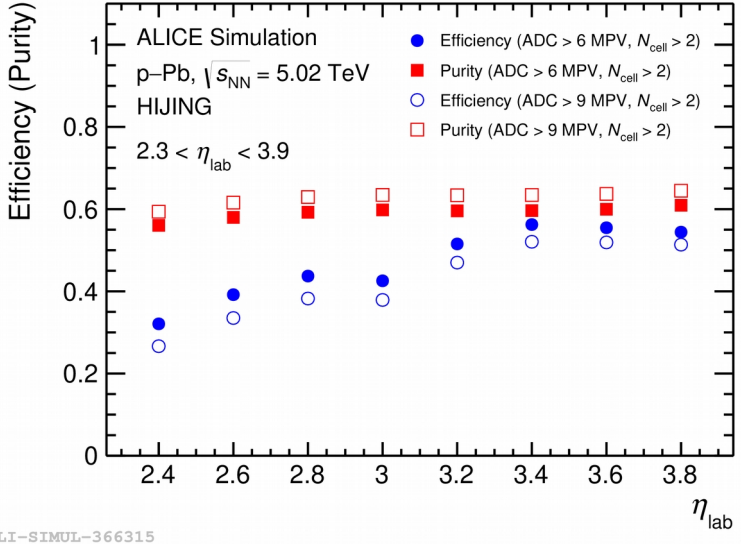
Correction procedure

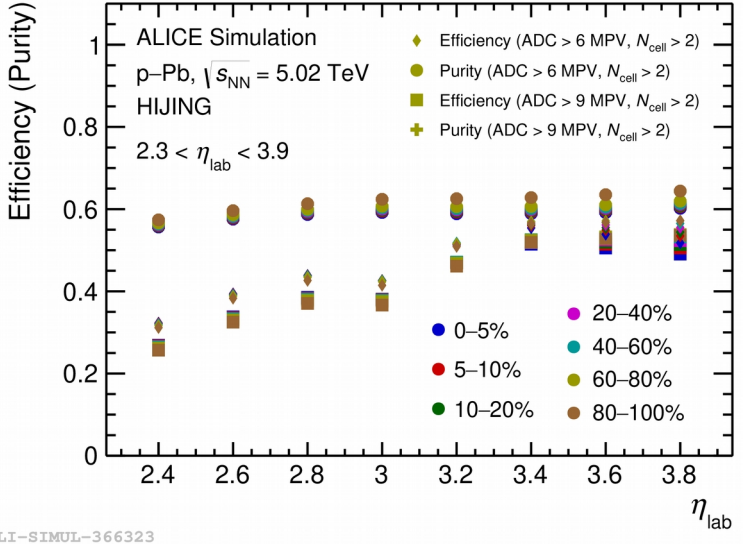
Bin by bin correction using Efficiency and Purity

$$Efficiency = \frac{N^{Simulation}_{\gamma-detected}}{N^{Simulation}_{\gamma-incident}} \qquad Purity = \frac{N^{Simulation}_{\gamma-detected}}{N^{Simulation}_{\gamma-like}}$$

$$N_{\gamma-corrected} = \frac{Purity}{Efficiency} \times N^{Data}_{\gamma-like}$$

- $N^{Simulation}_{\gamma-detected}$: **No. of detected photon clusters above discrimination threshold**
- $N^{Simulation}_{\gamma-incident}$: **No. of incident photons within the PMD coverage**





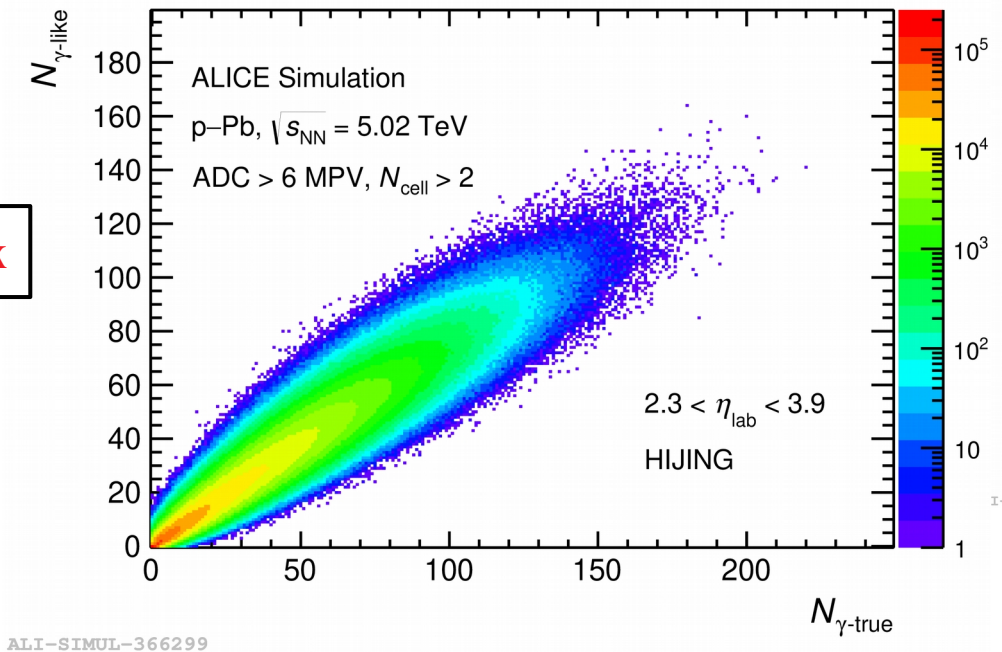
- Efficiency varies with η whereas purity is almost independent of η
- Sensitive to photon-hadron discrimination thresholds
- Mild dependence on centrality

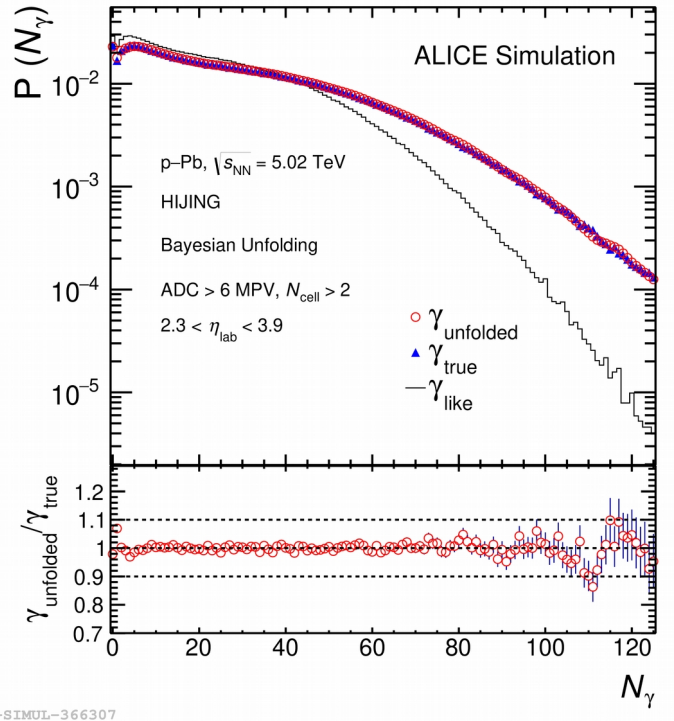
Correction procedure

Unfolding method

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

Response Matrix

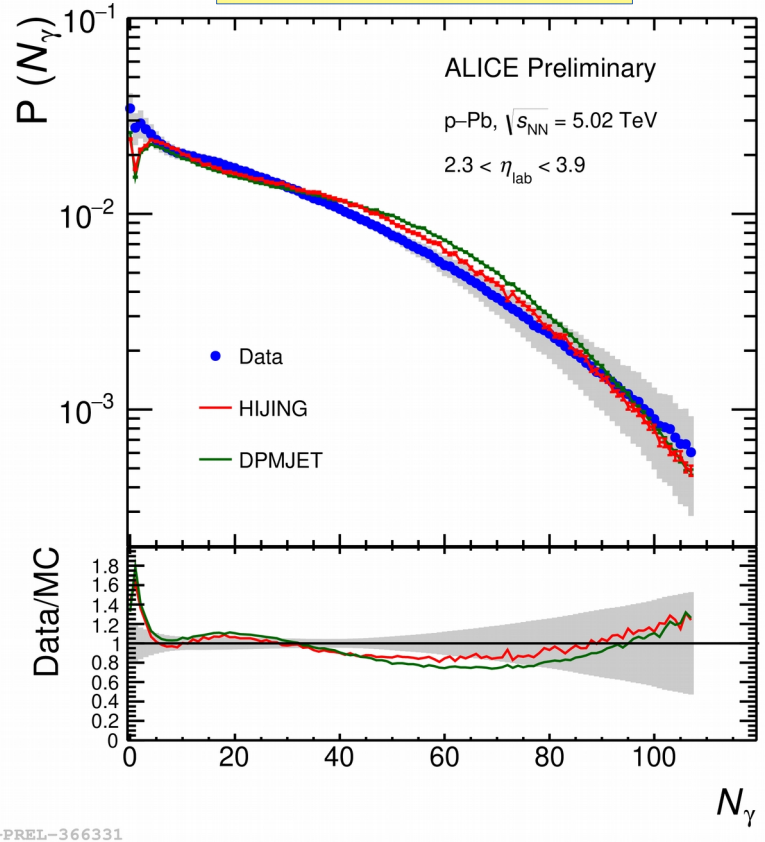




Unfolding procedure is able to recover the true distribution well within ± 10%

MB photons multiplicity results

Multiplicity distribution



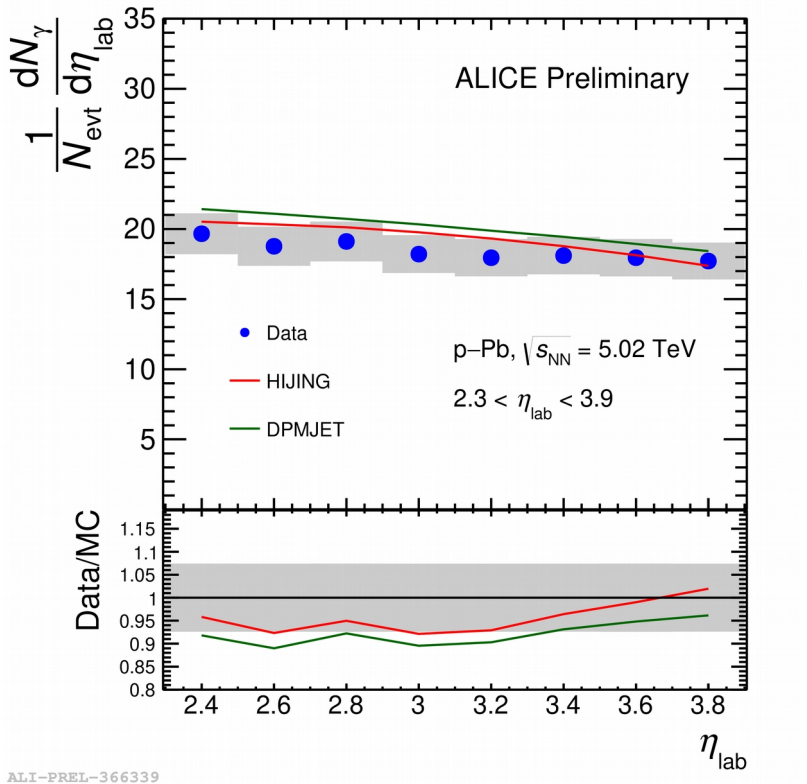
New

- Both models underestimate the data in the region where diffractive processes occur
- HIJING describes the data slightly better than DPMJET

MB photons multiplicity results

MB photons multiplicity results

Pseudorapidity distribution

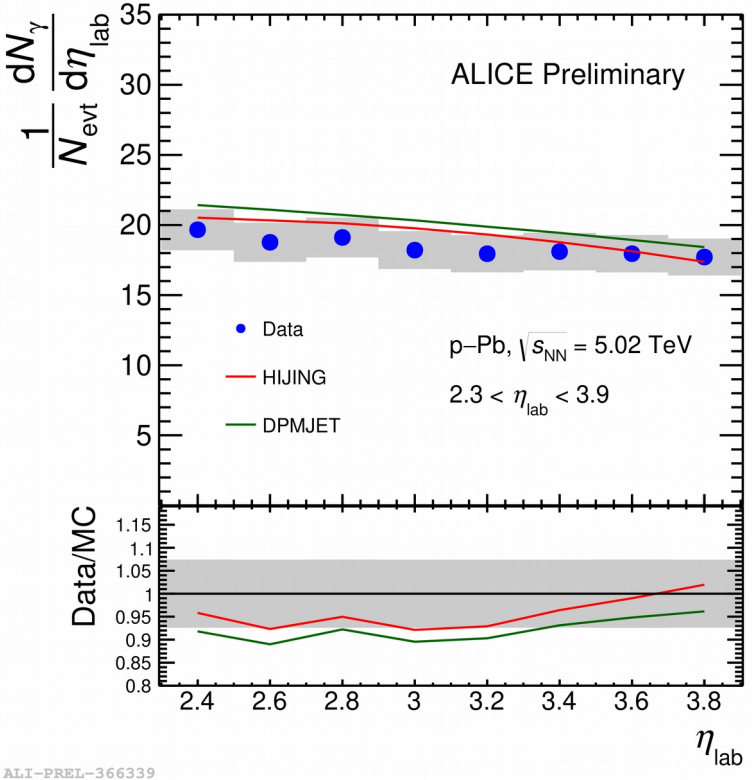


New

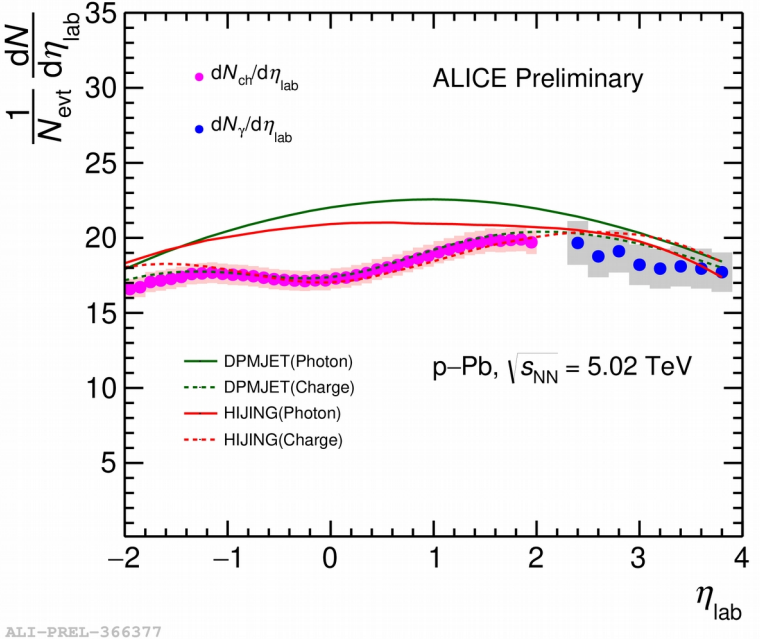
- DPMJET slightly overestimates the photon production towards midrapidity

MB photons multiplicity results

Pseudorapidity distribution



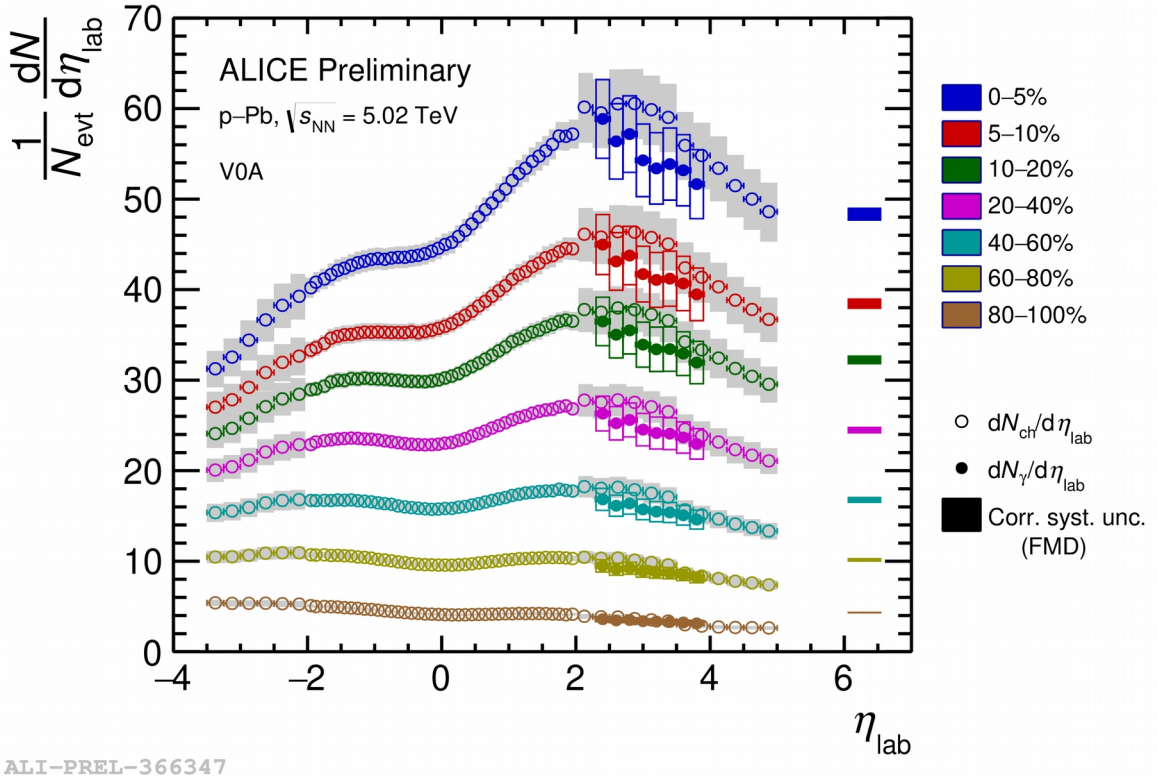
Comparing forward photons with charged particles at midrapidity



New

- DPMJET slightly overestimates the photon production towards midrapidity
- Both DPMJET and HIJING describe the charged-particle production at midrapidity well

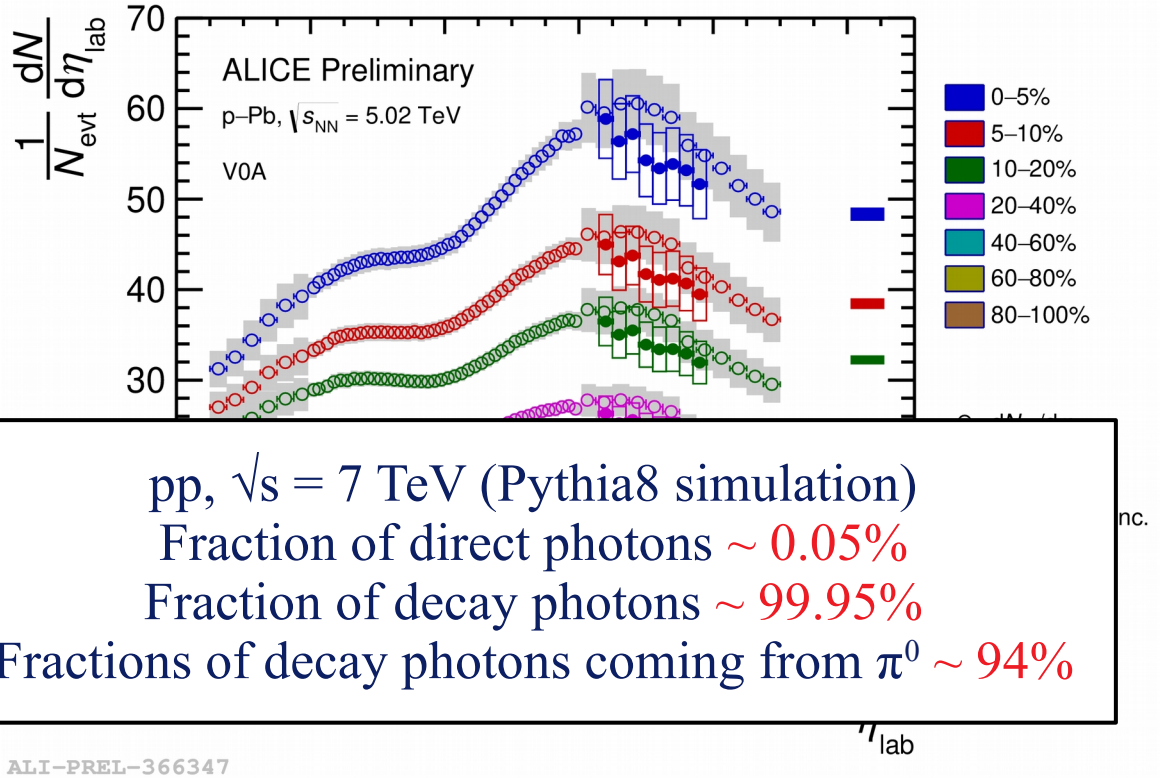
Centrality dependent results



New

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

Centrality dependent results



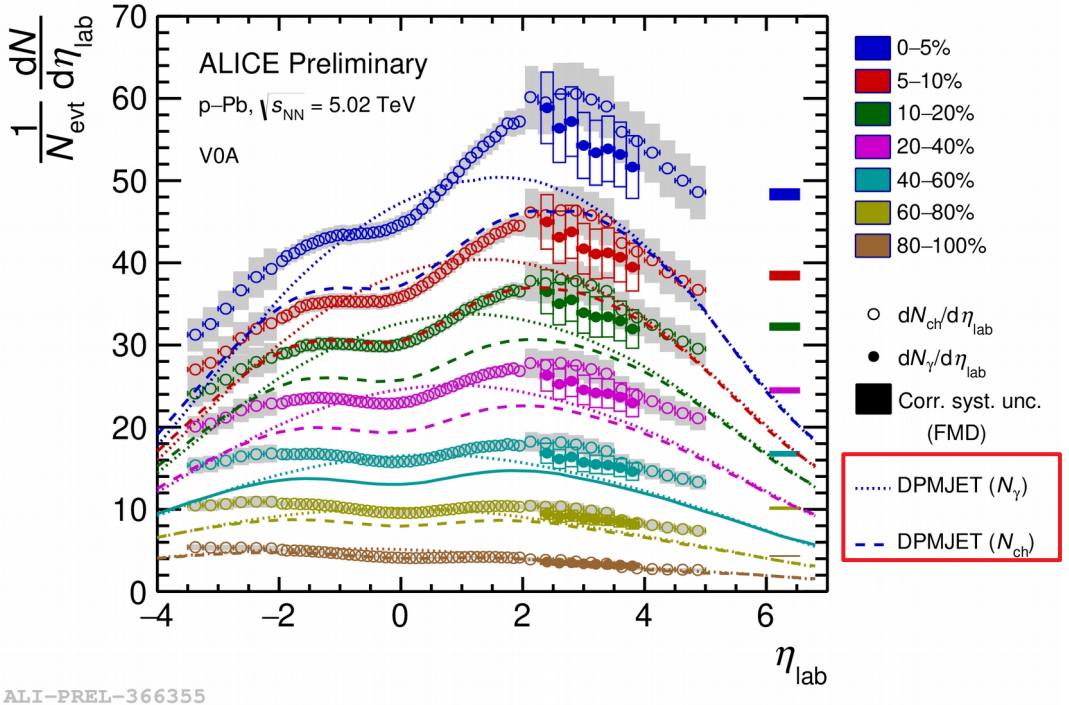
New

pp, √s = 7 TeV (Pythia8 simulation)
Fraction of direct photons ~ 0.05%
Fraction of decay photons ~ 99.95%
Fractions of decay photons coming from π^0 ~ 94%

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

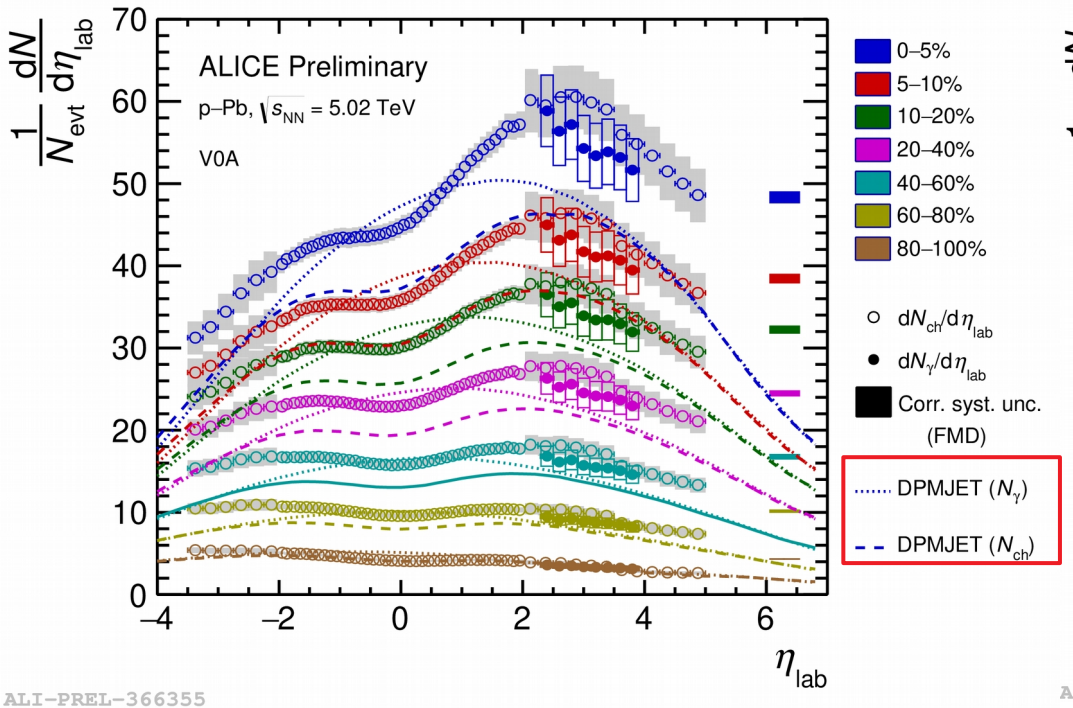
Centrality dependent results

New



Centrality dependent results

New



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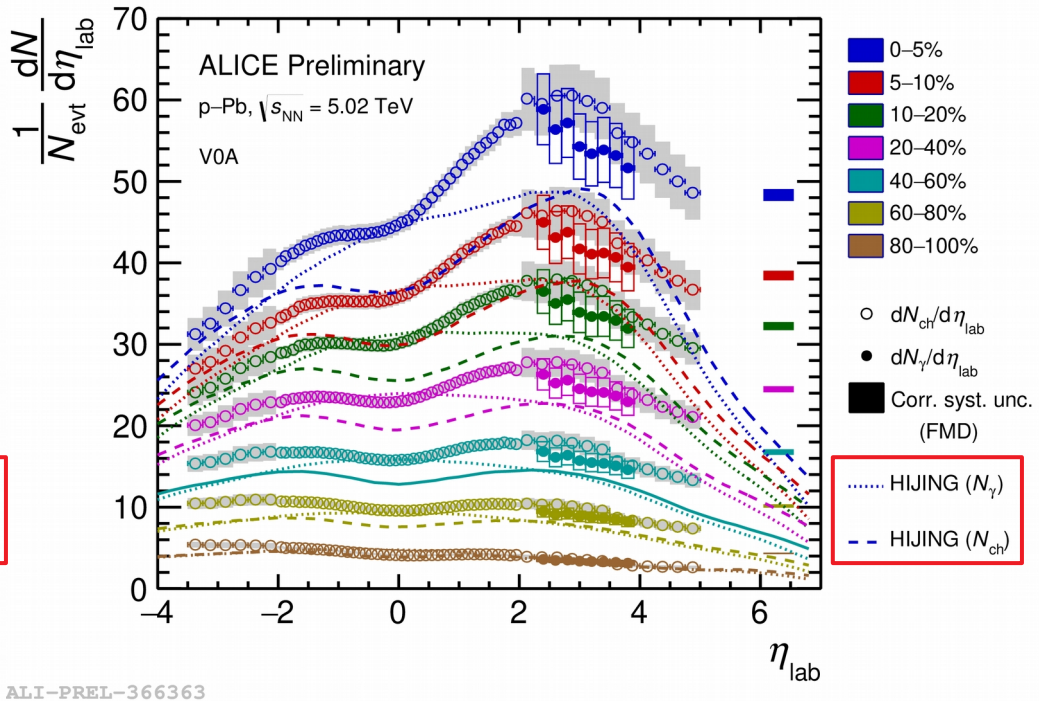
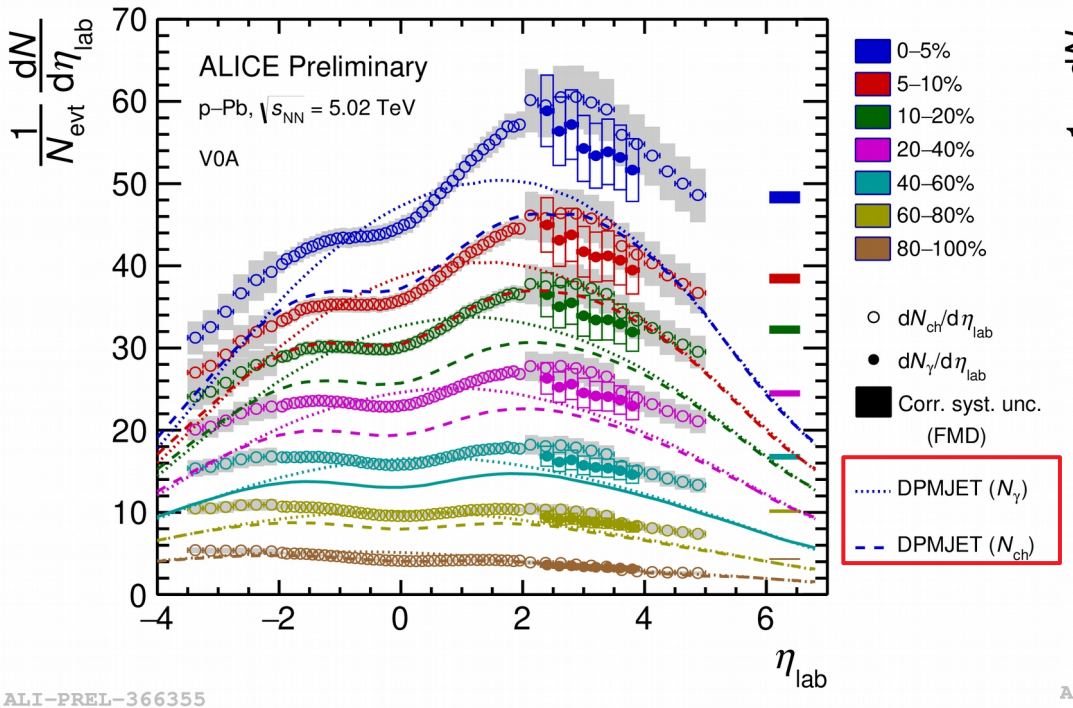
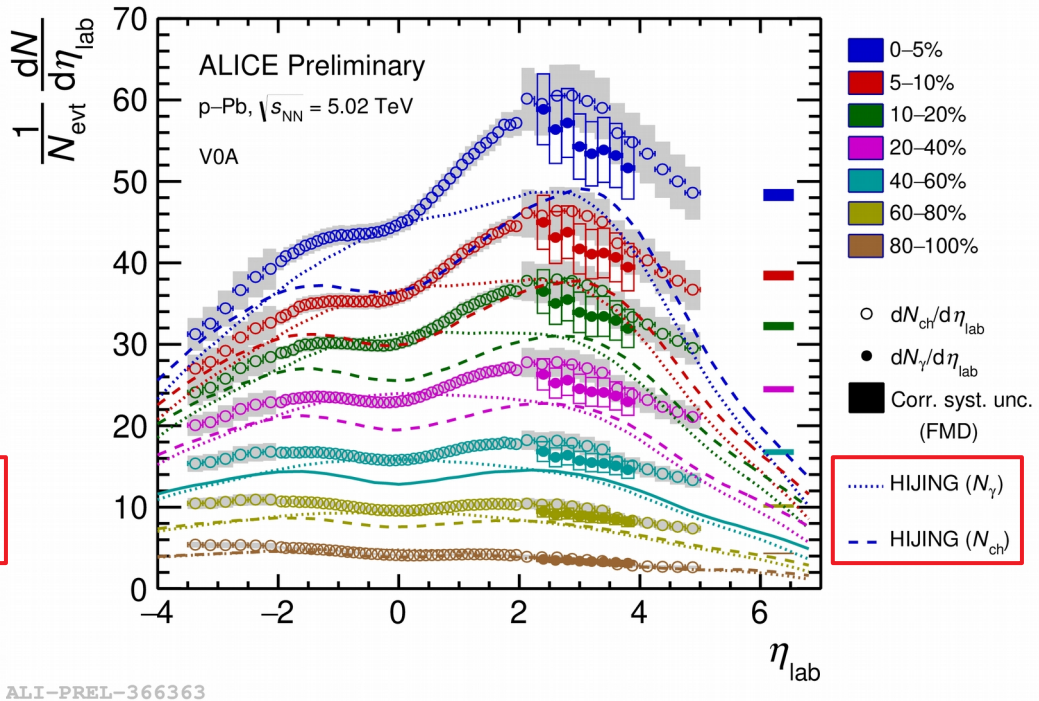


ALI-PREL-366363

Centrality dependent results

New





- Both DPMJET and HIJING underpredict the data

Summary

- P (N_γ) and $dN_\gamma/d\eta$ are measured at forward rapidity in p-Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV
- Centrality dependent $dN_\gamma/d\eta$ and $dN_{ch}/d\eta$ 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 ($N_\gamma < 10$)
  - ✔ HIJING describes the data slightly better than DPMJET
- $dN_{ch}/d\eta$ is well described by both MC models whereas $dN_\gamma/d\eta$ 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

Systematic Uncertainties Overview

Sources of systematic uncertainties

1. Discrimination thresholds

- Cluster ADC > 9 MPV and Cluster $N_{cell} > 2$

2. Unfolding methods

- χ^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 uptream material in front of the PMD is increased by 10%

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

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