Inclusive photon multiplicity at forward rapidities in p-Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV with ALICE

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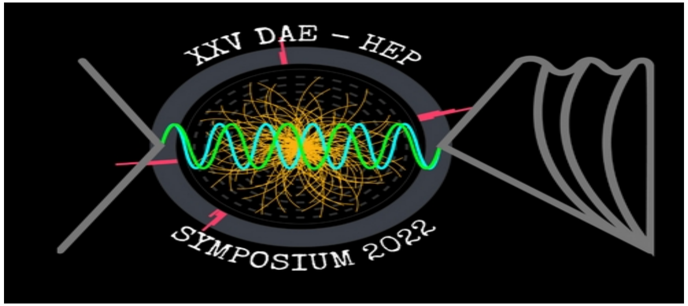

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Physics Motivation

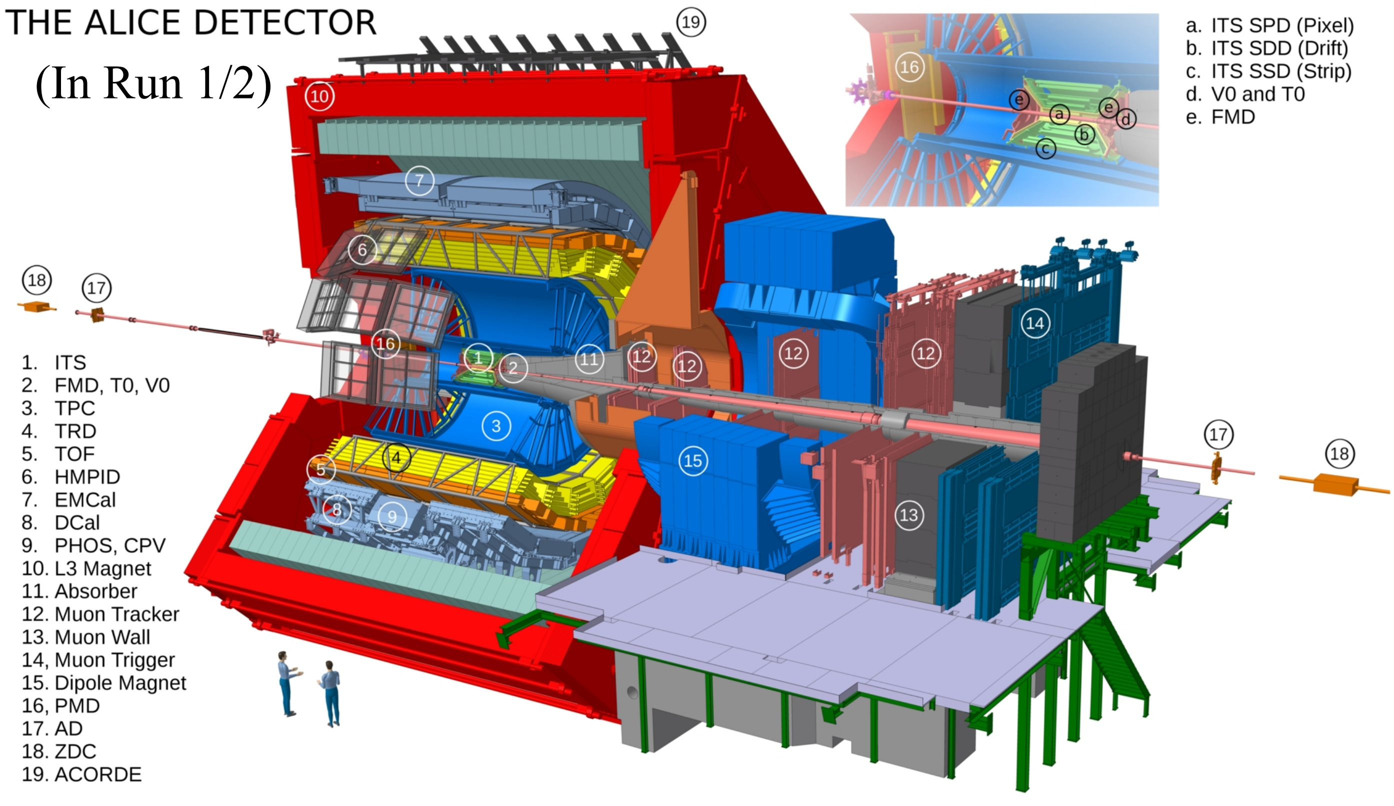
Particle production in high energy collisions is governed by

- Hard processes
  - Large momentum transfer
  - Well described by pQCD
- Soft processes
  - Dominant mode for bulk production: $p_{\mathrm{T}} \leq 2$ GeV/c
  - Non perturbative production → Need for QCD-based phenomenological models or effective theories

Observables sensitive to particle production

1. Multiplicity distribution: P(N)
2. Pseudorapidity distributions: dN/dη
   - Constrain phenomenological models and allow for tuning of model parameters
   - Measurements in p-Pb collisions serve as a baseline to interpret Pb-Pb results
   - Inclusive photon (mostly from π^0) measurement is complementary to the charged-particle measurement

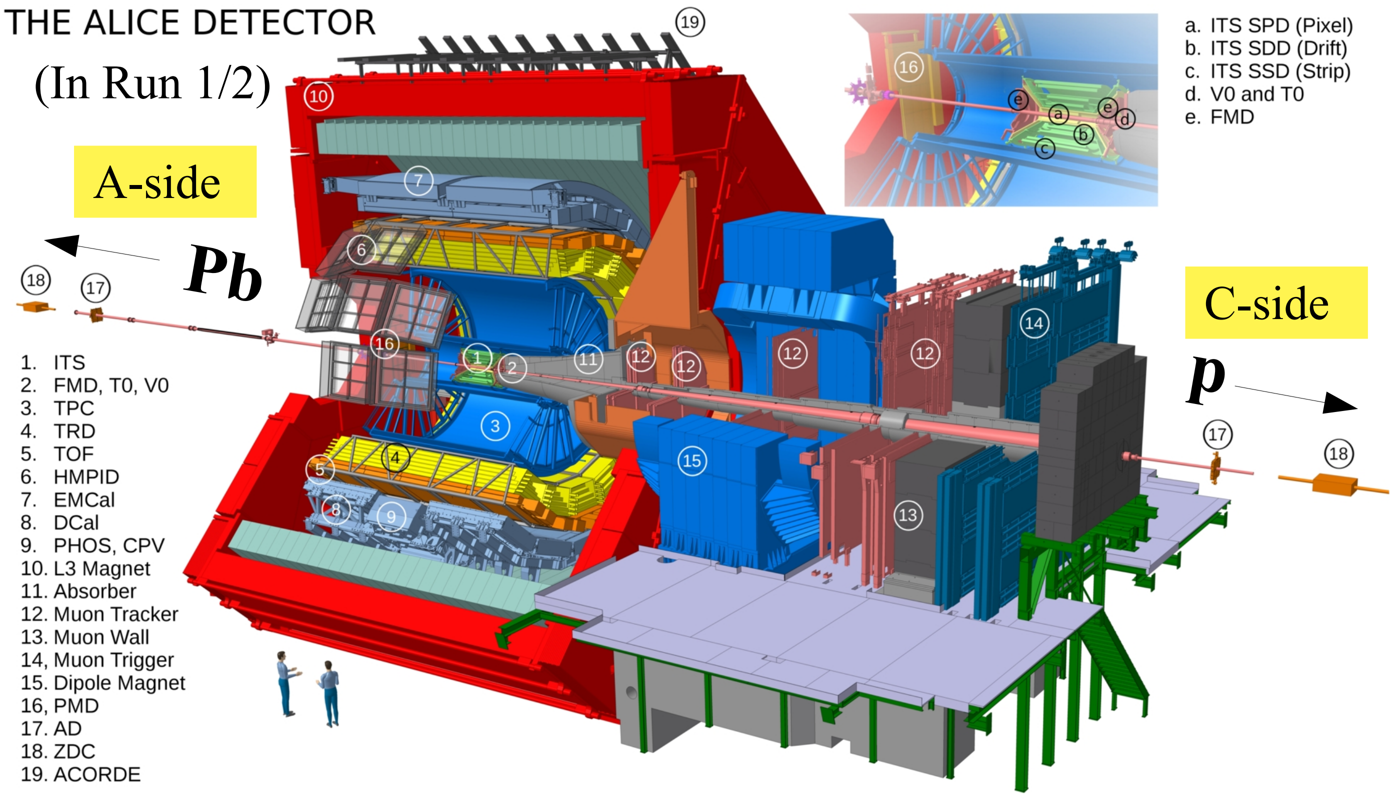
A Large Ion Collider Experiment



- High detector granularity
- Low transverse momentum threshold $p_T^{Min} \approx 0.15$ GeV/c
- PID capabilities
- Magnetic field $B = 0.5$ T

A Large Ion Collider Experiment

For p-Pb configuration



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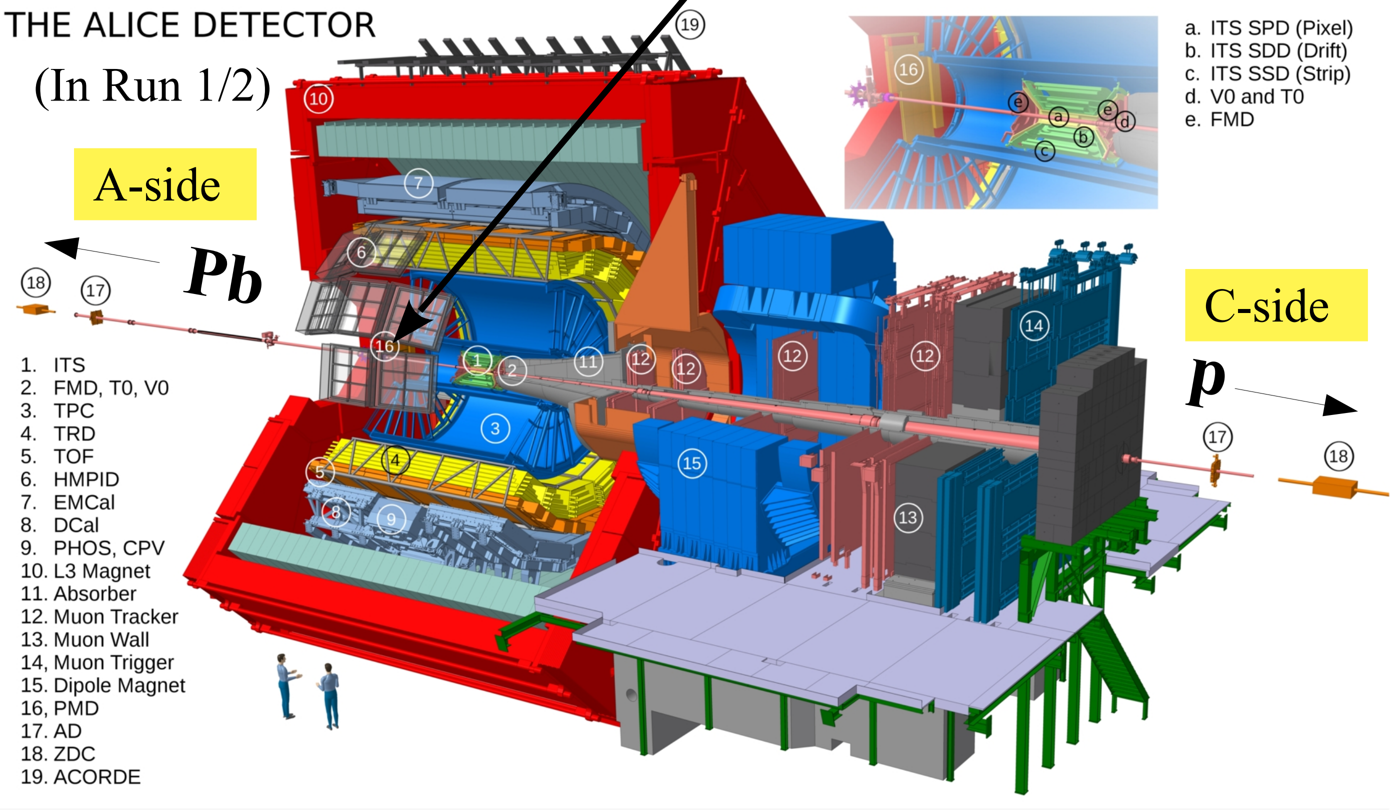
For p-Pb configuration

Photon Multiplicity Detector (PMD)



- High detector granularity
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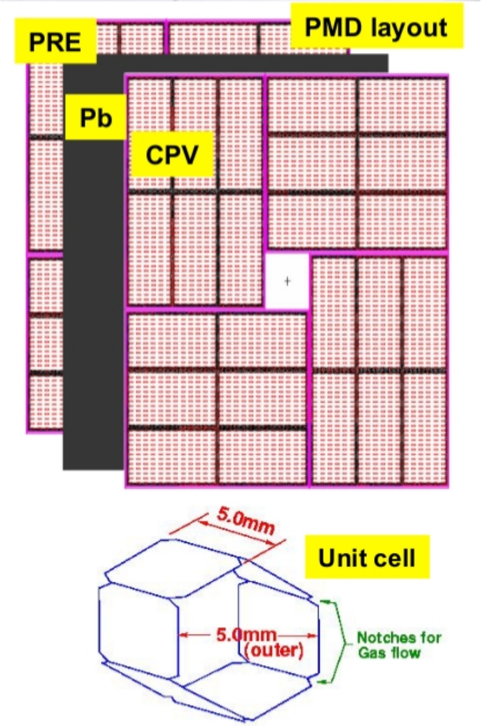
Detection of photons

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



Sensitive medium: Gas (Ar+CO_2 in the ratio 70:30)

Two planes:

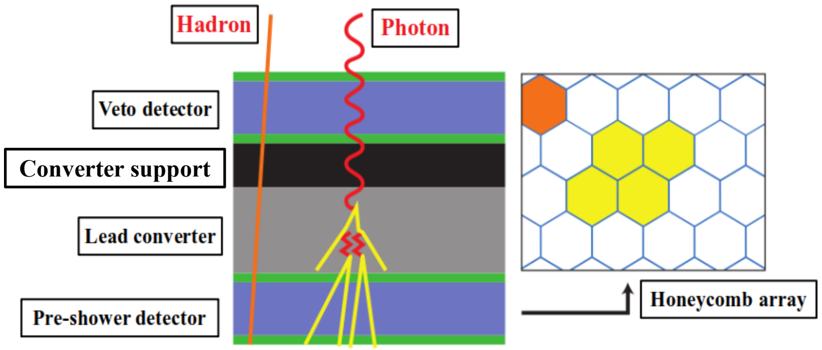
1. Preshower plane (PRE)
2. Charged particle veto (CPV)

Total no. of cells: 152 k

Coverage: $2.3 < \eta < 3.9$ (full φ)

Converter: $3X_0$ thick Pb plate

Working Principle

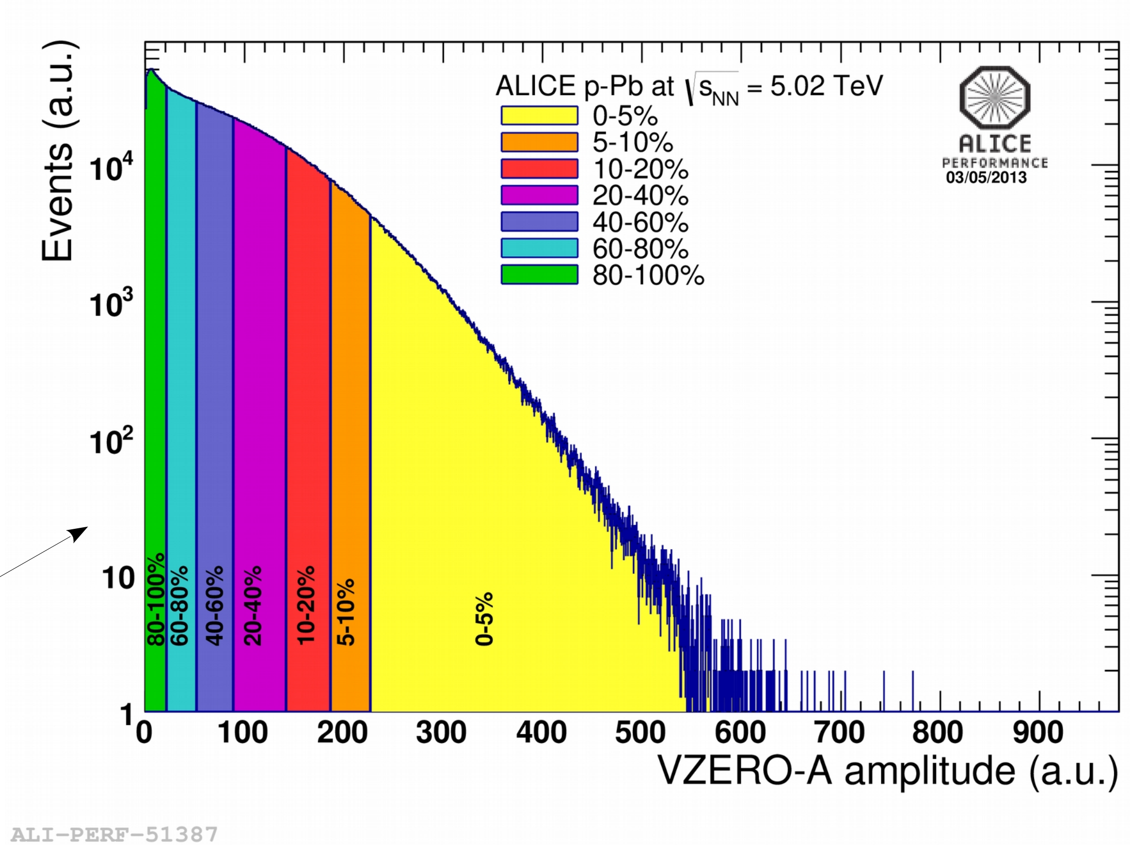


- Photons initiate EM shower in Pb converter and produce signals on several cells of the PRE plane
- Hadrons normally affect only one cell in PRE plane and produce a signal representing minimum ionizing particles

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

Multiplicity selection

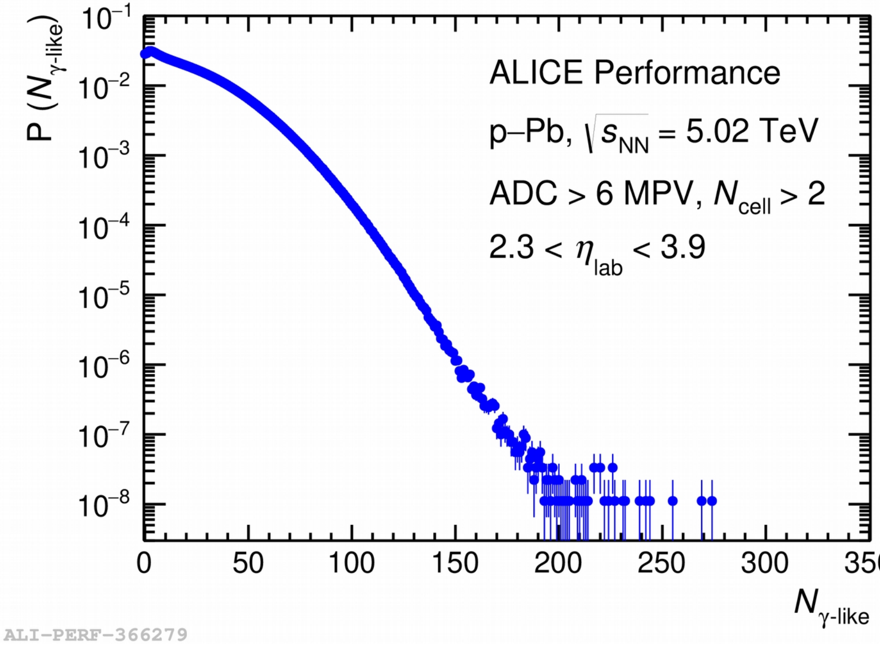
- Results are obtained for NSD minimum bias (MB) events
- Events are categorized in multiplicity classes, estimated using Forward Scintillator Detector (VZERO) placed on A-side (Pb fragmentation region)



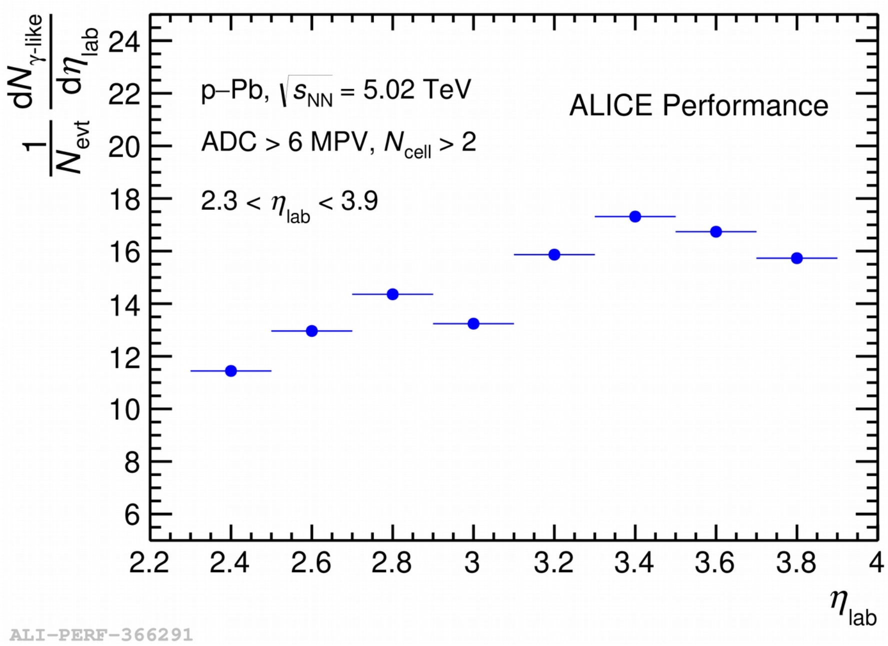
VZERO-A amplitude distribution and classification in centrality bins

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 multiplicity dependent results

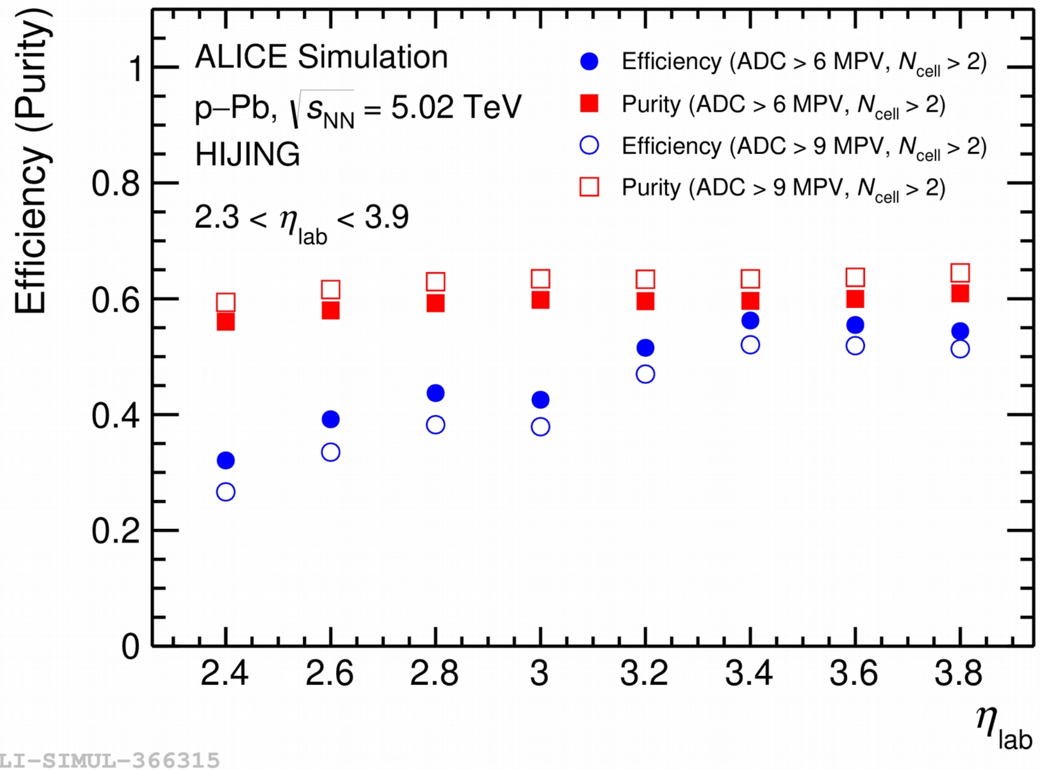
Correction procedure

Bin by bin correction using Efficiency and Purity

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

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

- Efficiency varies with η whereas purity is almost independent of η
- Sensitive to photon-hadron discrimination thresholds
- Mild dependence on multiplicity classes (see slide 15)



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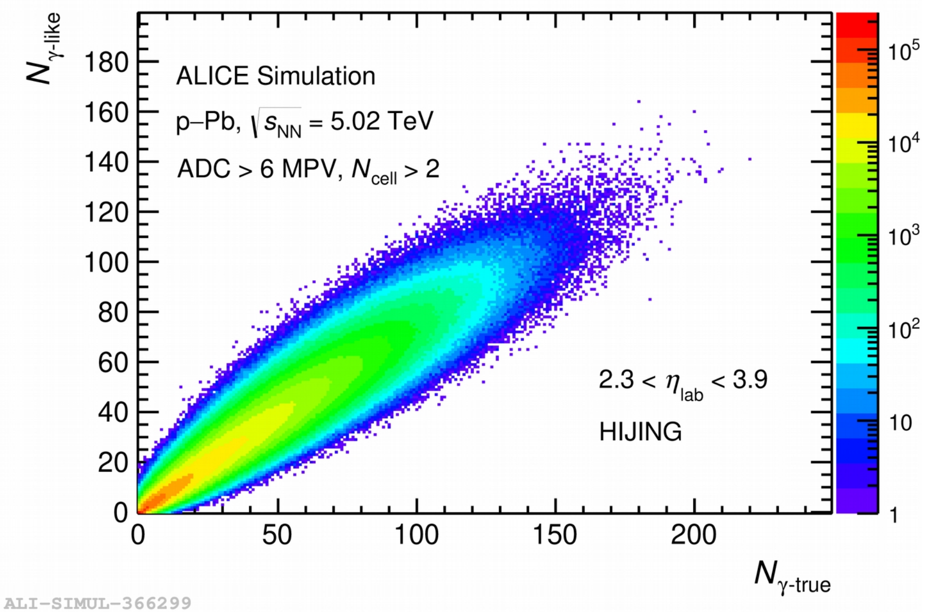
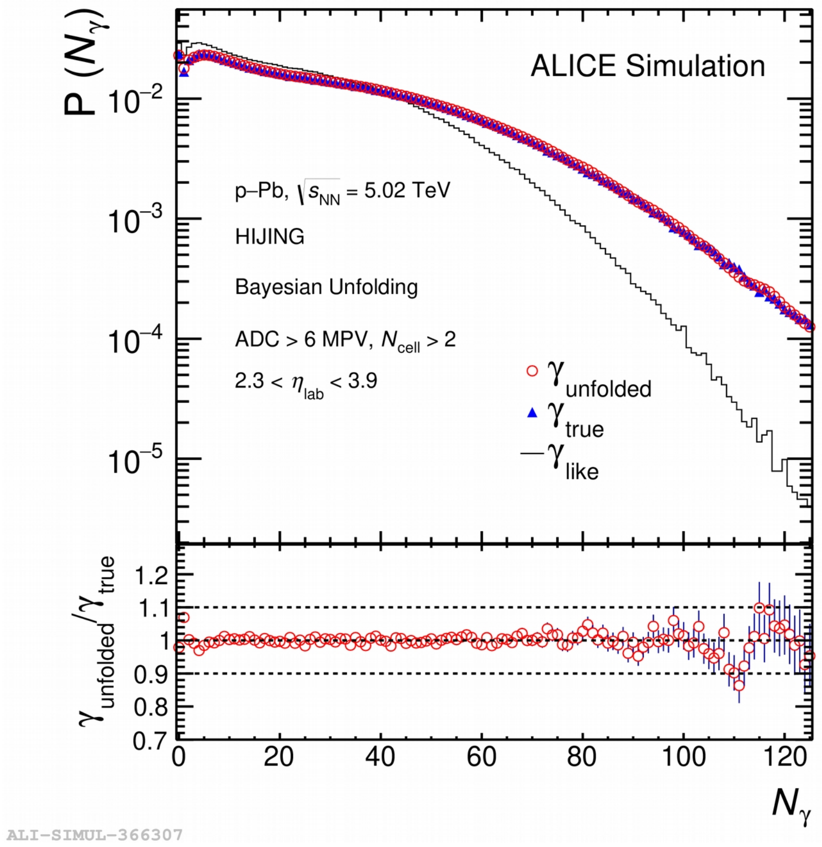
Correction procedure

Unfolding method

- Method used: Bayesian theorem
- Response matrix estimated through MC is used to correct data

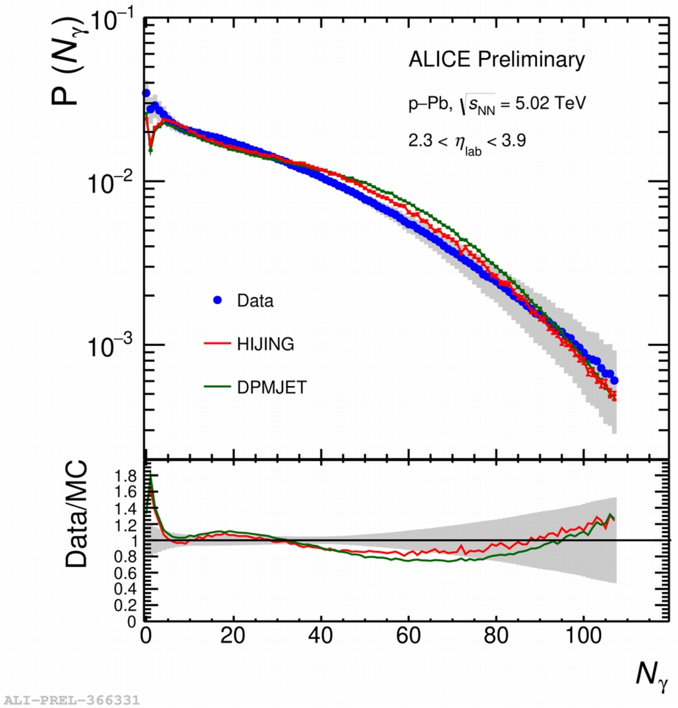
Response Matrix

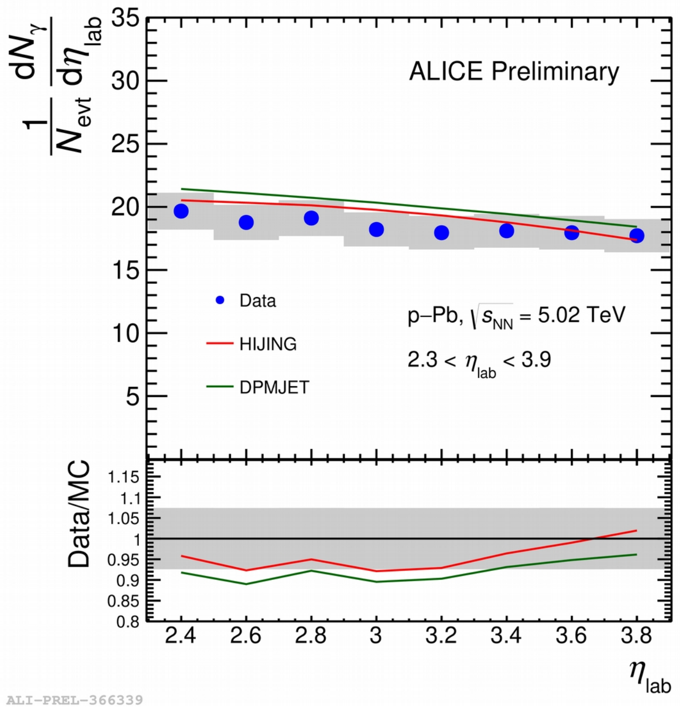


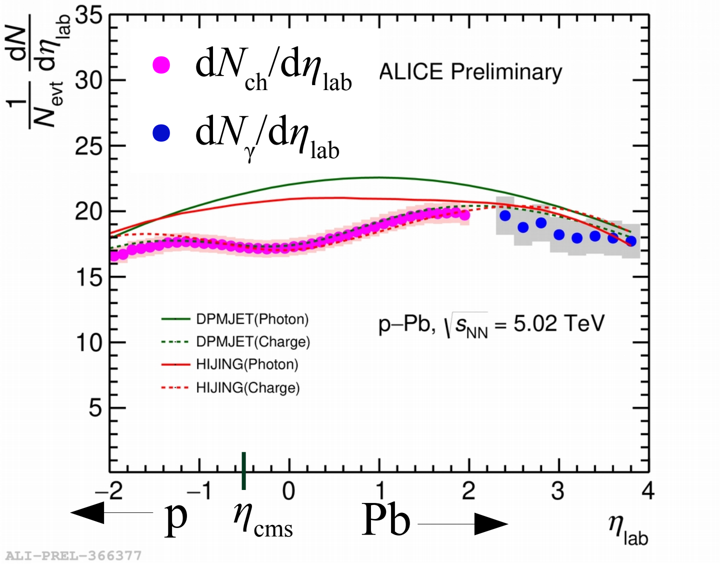


Unfolding procedure is able to recover the true distribution well over the whole range. Close to the edges a larger discrepancy (<10%) is found

Results in MB events





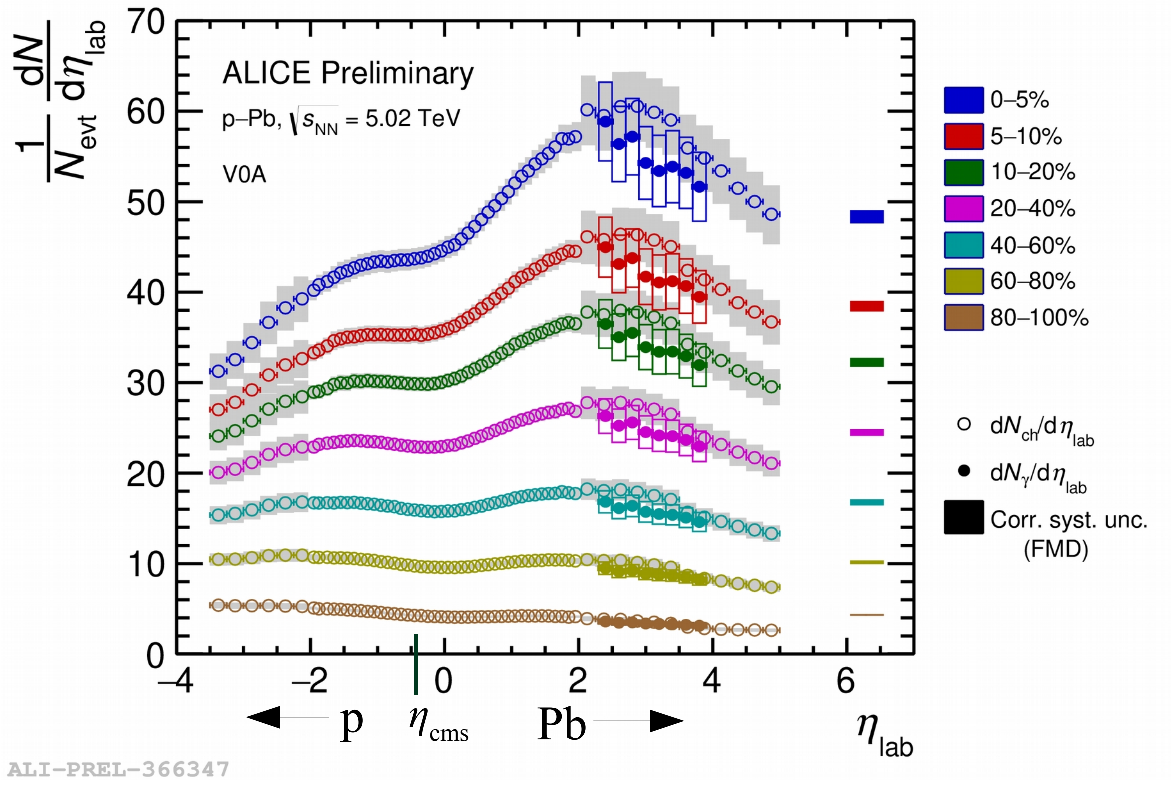


- Models underestimate P (N_γ) at low multiplicity ($N_\gamma < 10$)
- Models agree in the intermediate to high multiplicity bins within uncertainties

- HIJING agrees with the data within uncertainties
- DPMJET overpredicts the data points by ~10% towards midrapidity

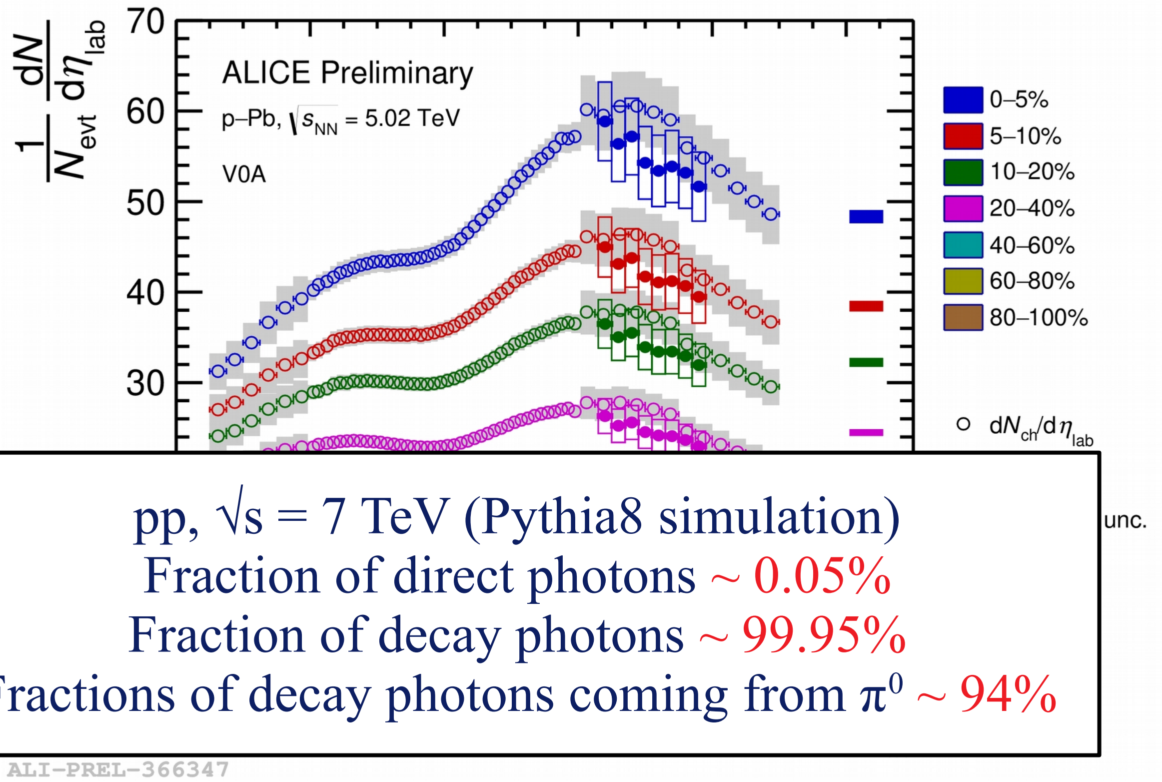
- $dN_{ch}/d\eta$ at midrapidity is compared with $dN_\gamma/d\eta$ at forward rapidity
- $dN_{ch}/d\eta$ is well described by both models

Multiplicity dependent results



- In forward rapidity region (2.3 < η < 3.9), photon (mostly from π^0) and charged-particle production have similar dependence on multiplicity classes

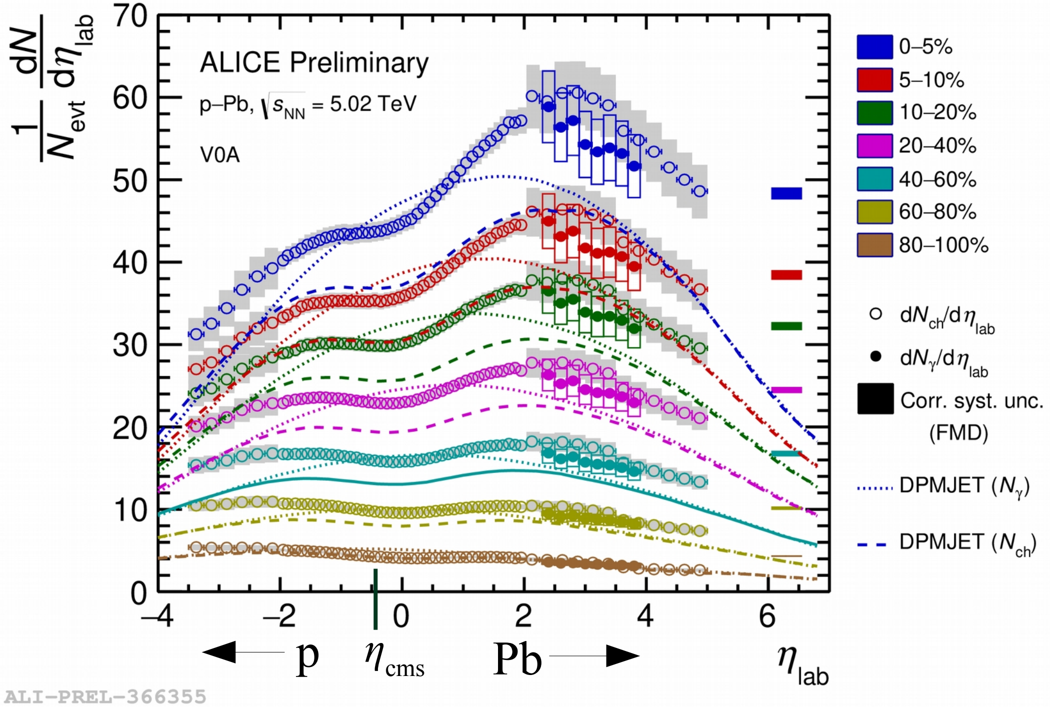
Multiplicity dependent results

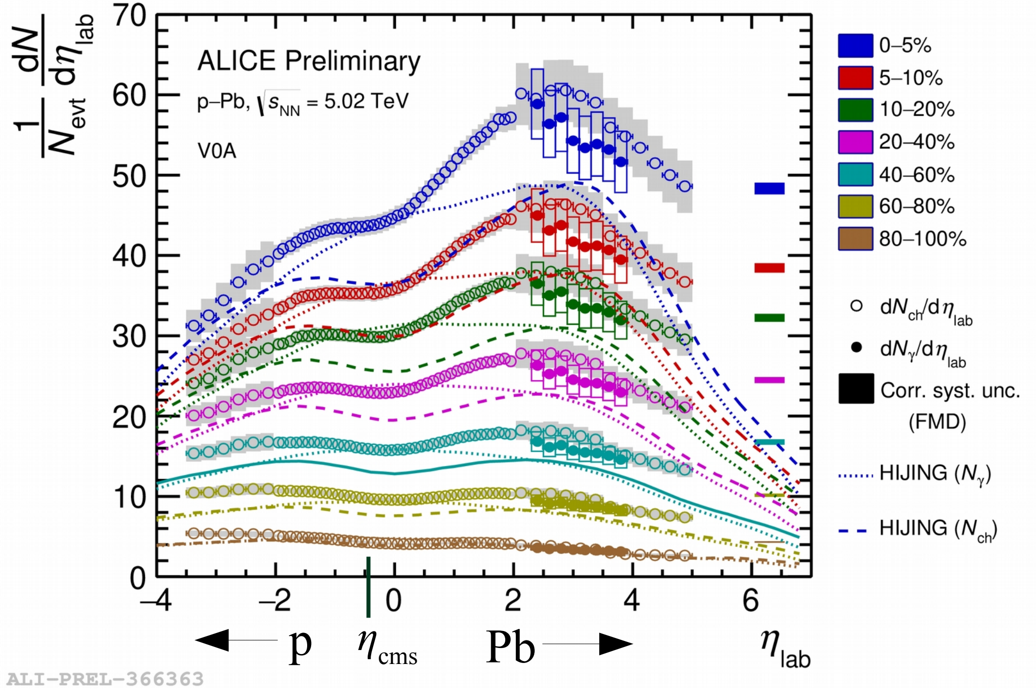


pp, √s = 7 TeV (Pythia8 simulation)
Fraction of direct photons ~ 0.05%
Fraction of decay photons ~ 99.95%
Fractions of decay photons coming from π^0 ~ 94%

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

Multiplicity dependent results





- Both HIJING and DPMJET underpredict the multiplicity dependent evolution of photon and charged-particle production except for low multiplicity event class

Conclusions

- Multiplicity dependent $dN_{\gamma}/d\eta$ and $dN_{ch}/d\eta$ are compatible in the common η region
- MC models considered here underpredict P (N_{γ}) at low multiplicity ($N_{\gamma} < 10$) and agree in higher multiplicity bins within uncertainties
- $dN_{ch}/d\eta$ is well described by both MC models whereas $dN_{\gamma}/d\eta$ is overestimated about 10% by DPMJET at lower pseudorapidity region
- None of the models considered could explain the multiplicity dependent evolution of photon and charged-particle production except for 80-100% centrality bin

Thank you for your kind attention!

Back up slides

Estimation of systematic uncertainties

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)

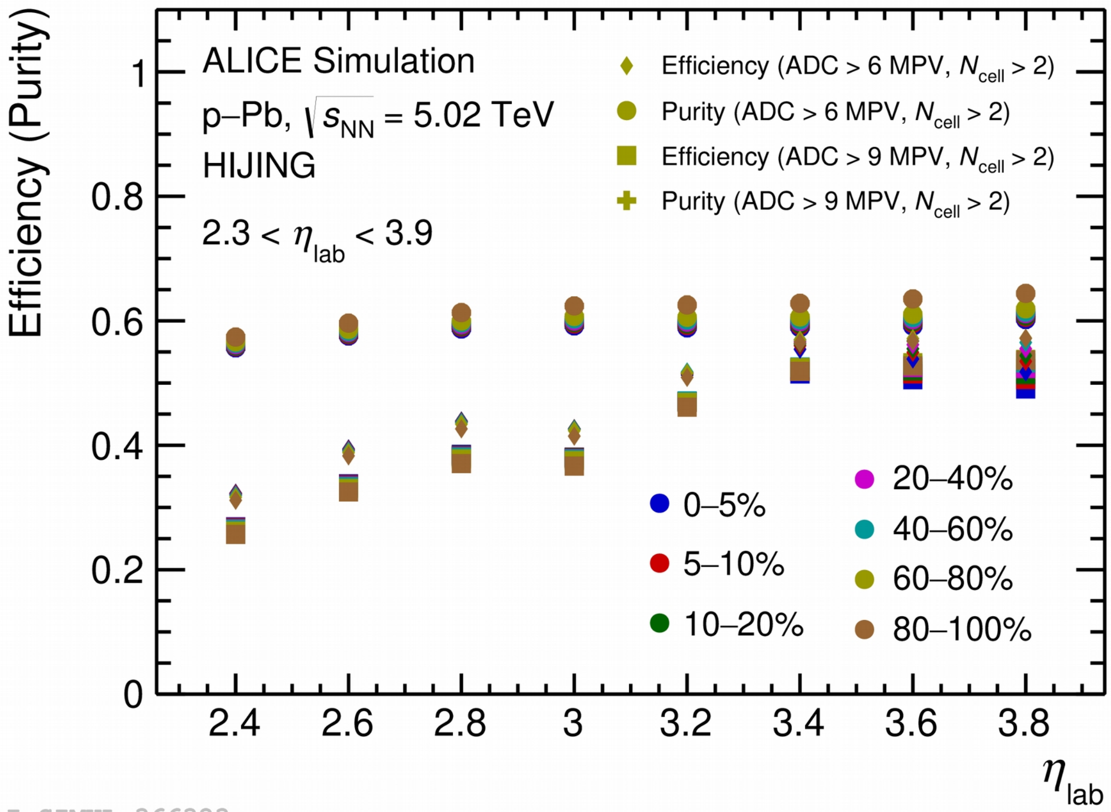
4. Effect of upstream material

- 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.

Multiplicity dependent Efficiency and Purity factors



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Monte Carlo Models

HIJING:

- A pQCD inspired MC model aimed particularly at the study of jets and multiple minijets productions and their interactions with the dense partonic medium produced in heavy-ion collisions.
- In pA and AA collisions, multiple interactions are simulated using binary approximation and Glauber model
- Parton shadowing effects are taken into account using parameterized parton distribution function inside the nucleus HIJING uses PYTHIA to generate kinematic variables for hard scatterings and JETSET for jet fragmentation
- The soft interactions in HIJING are described by Lund FRITIOF and Dual Parton Model (DPM)
- For the jet fragmentation and hadronization, HIJING uses Lund fragmentation model

DPMJET:

- A multi-purpose MC model based on Dual Parton Model capable of simulating hadron-hadron, hadron-nucleus, nucleus-nucleus, photon-hadron, photon-photon and photon-nucleus interactions from a few GeV up to the highest cosmic-ray energies.
- It uses Glauber-Gribov multiple scattering formalisms to calculate the nuclear cross sections.
- It uses Reggeon theory for soft interactions and perturbative QCD for hard interactions.

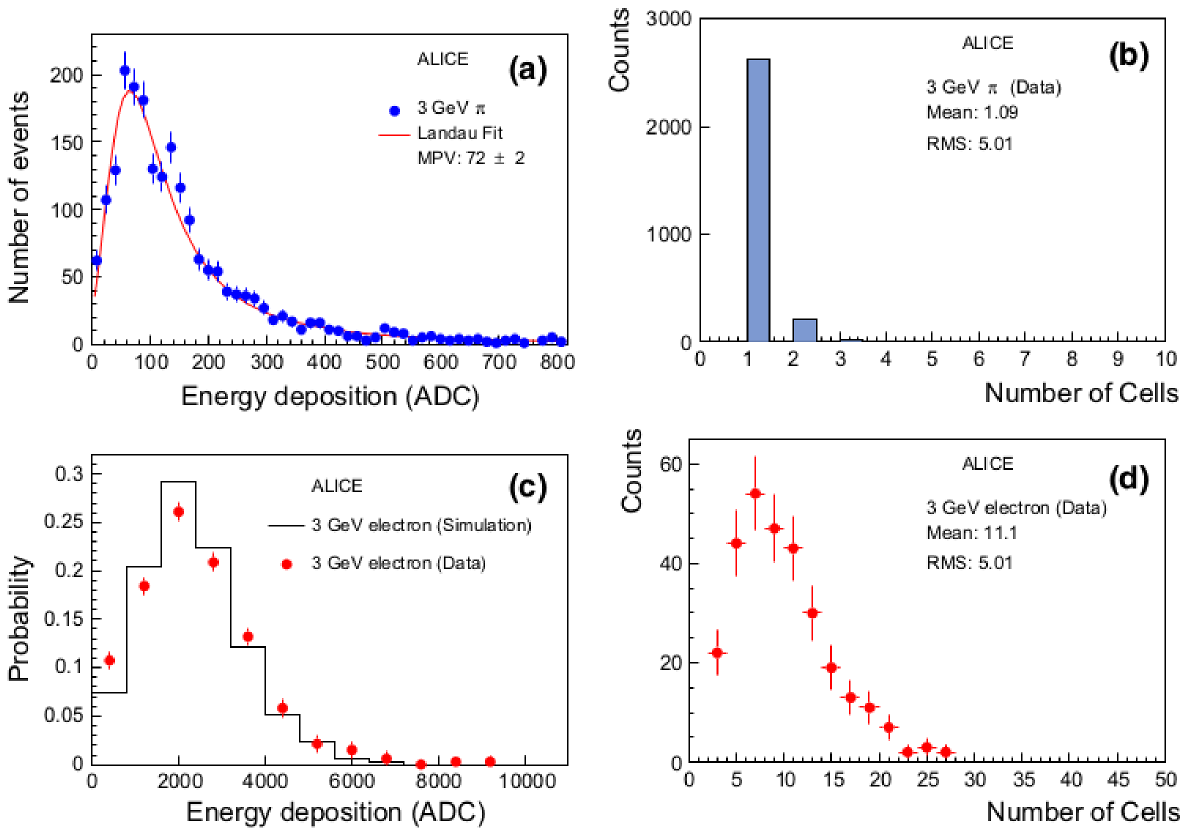

Fig. 1 **a, c** The energy depositions in the PMD module for 3 GeV pions and 3 GeV electrons, respectively. The pion distribution is fitted with a Landau fit, which gives the most probable value (MPV) of energy depositions by charged particles. For electrons, the result from the simulation is superimposed on the experimental data. **b, d** The number of cells hit for 3 GeV pions and 3 GeV electrons, respectively. Note the large difference in scales in the abscissa for pions and electrons

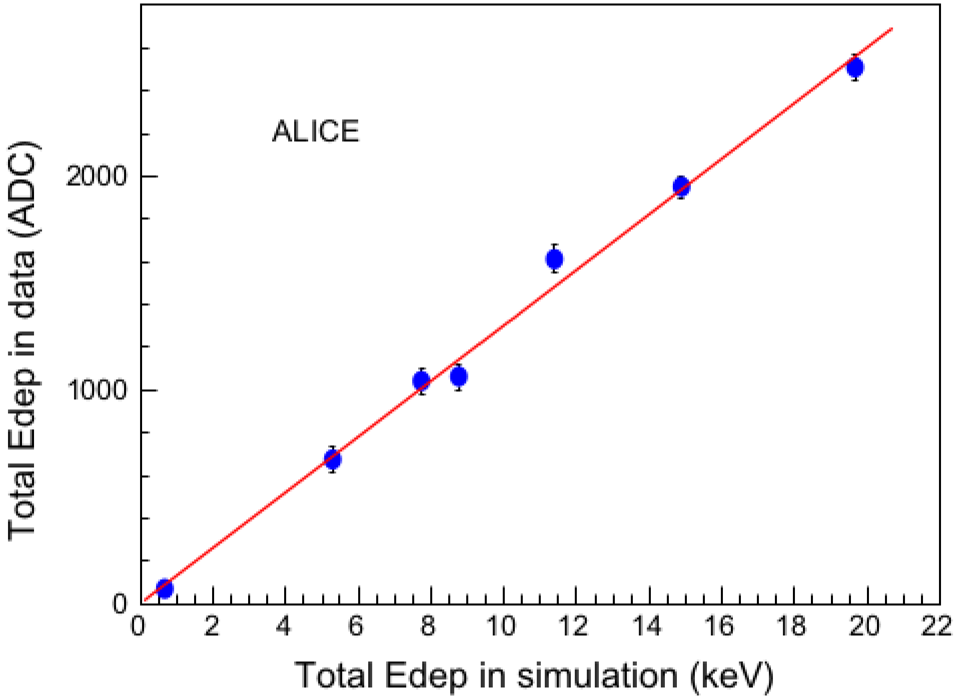

Fig. 2 Relationship between the mean energy depositions in the PMD modules obtained from simulated results (in keV) and experimental data (in ADC) for pion and electron beams of various energies