Inclusive Photon production in ALICE

Inclusive photon production at forward rapidities in pp collisions at $\sqrt{s}$ = 0.9, 2.76 and 7 TeV

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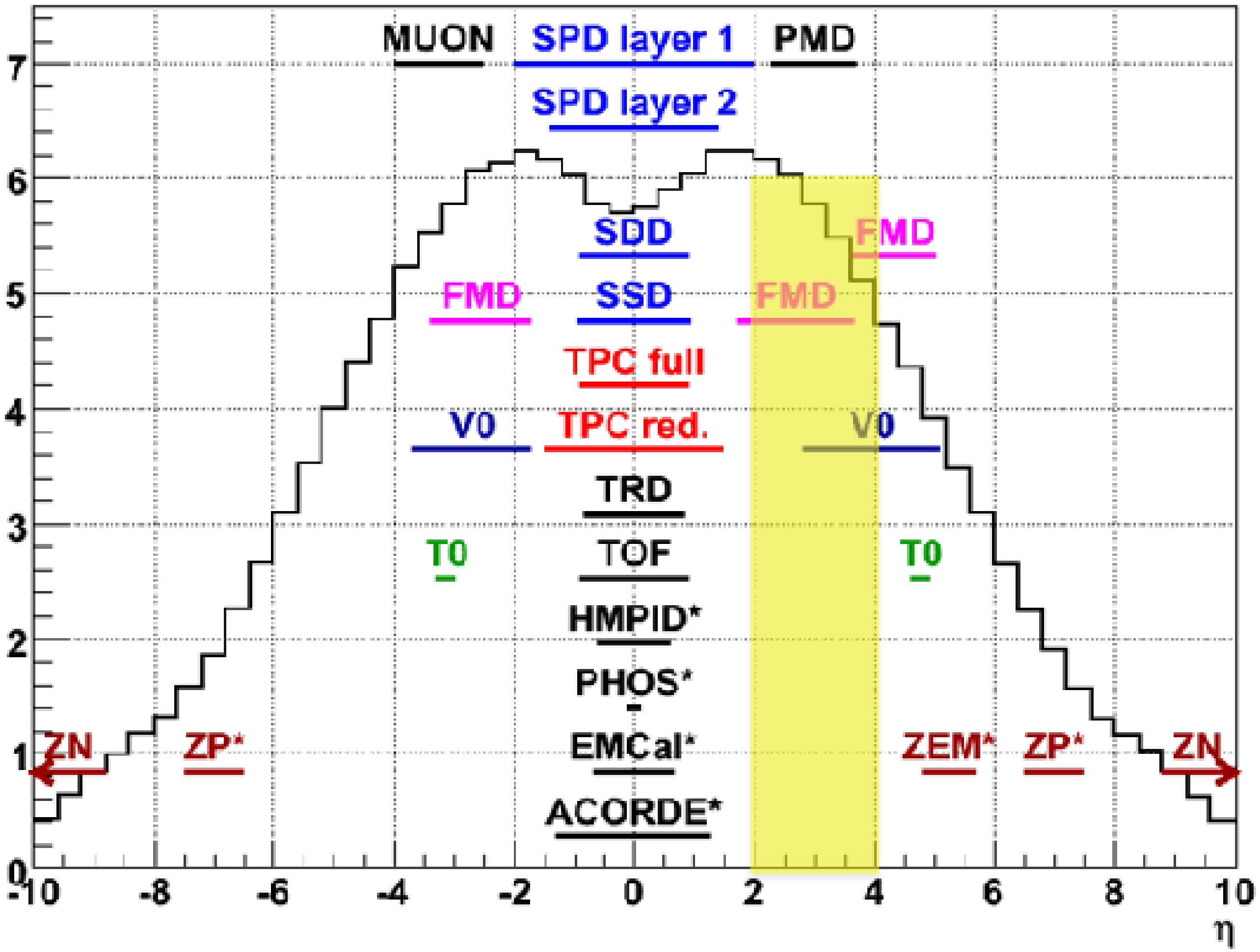
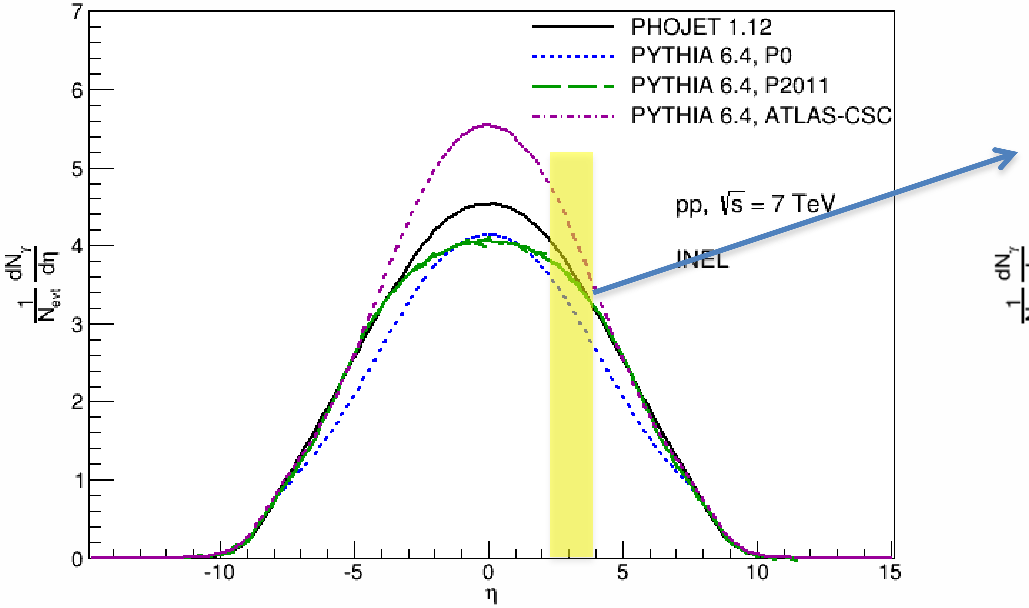
22nd October, 2014

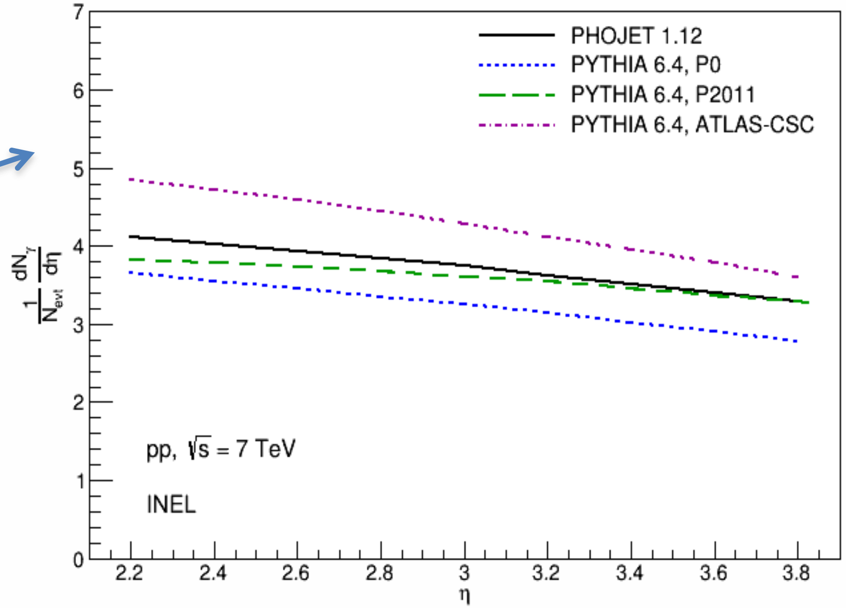
Motivation



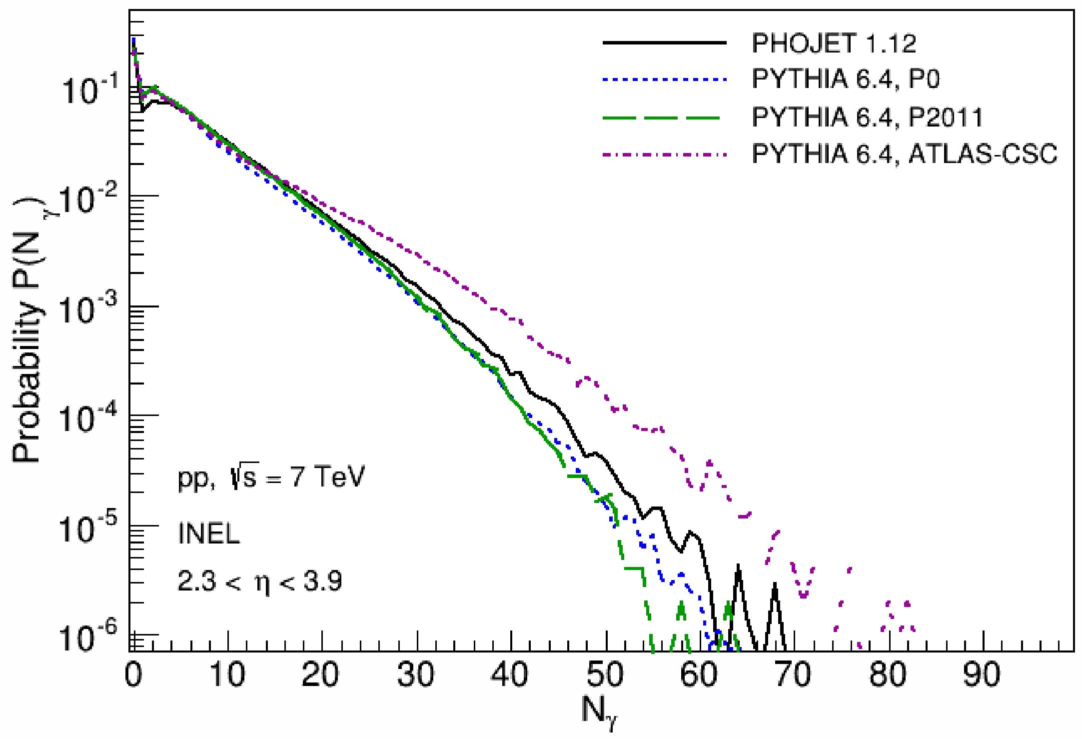
MUON
SPD layer 1
PMD
SPD layer 2
SDD
FMD
FMD
SSD
FMD
TPC full
V0
TPC red.
V0
TRD
T0
TOF
T0
HMPID*
PHOS*
ZN
ZP*
EMCal*
ZEM*
ZP*
ZN
ACORDE*
0
1
2
3
4
5
6
7
-10
-8
-6
-4
-2
0
2
4
6
8
10
η

Pseudorapidity distribution of inclusive photons





Multiplicity spectra of inclusive photons



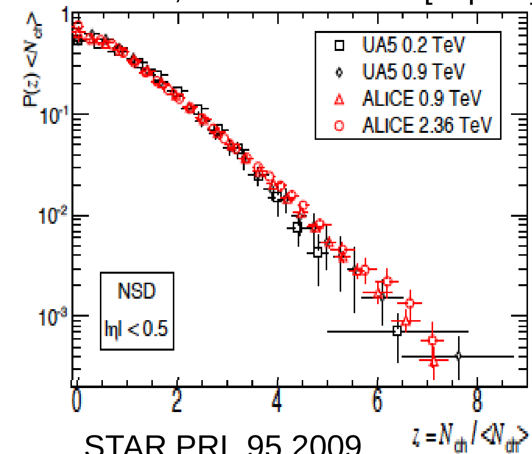
Motivation

PMD is the only detector in ALICE which can measure the inclusive photon multiplicity in forward rapidity.
Using these measurements following Physics issues can be addressed in pp collision

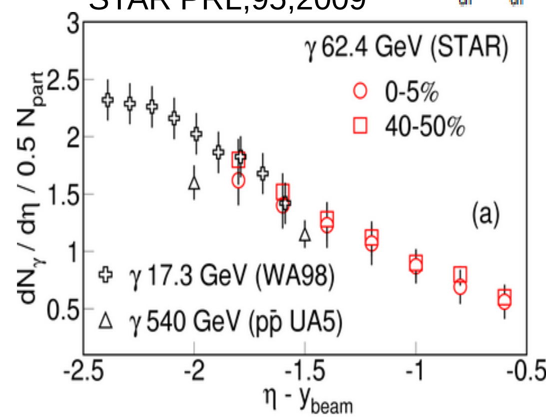
- ➢ Study of photon production in forward rapidity in LHC energies.
- ➢ KNO(Koba, Nielsen, Olesen) scaling behavior of photon multiplicity
- ➢ Limiting fragmentation behavior of photons in pp collisions.
- ➢ Beam energy dependence of photons in forward rapidity
- ➢ Along with the charged particles measurement in Forward Multiplicity Detector (FMD) of ALICE, photon-hadron correlation can be studied.

These measurements also provide a good base line for heavy ion collision at LHC.

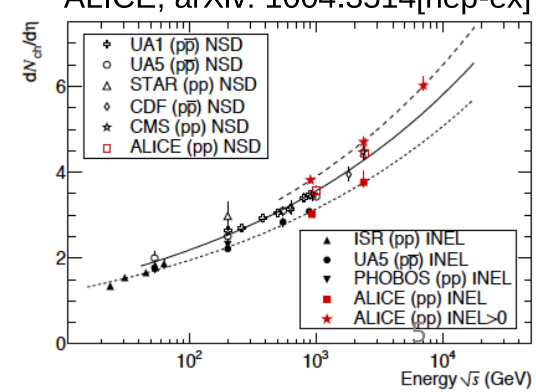
ALICE, arXiv:1004.3034[hep-ex]

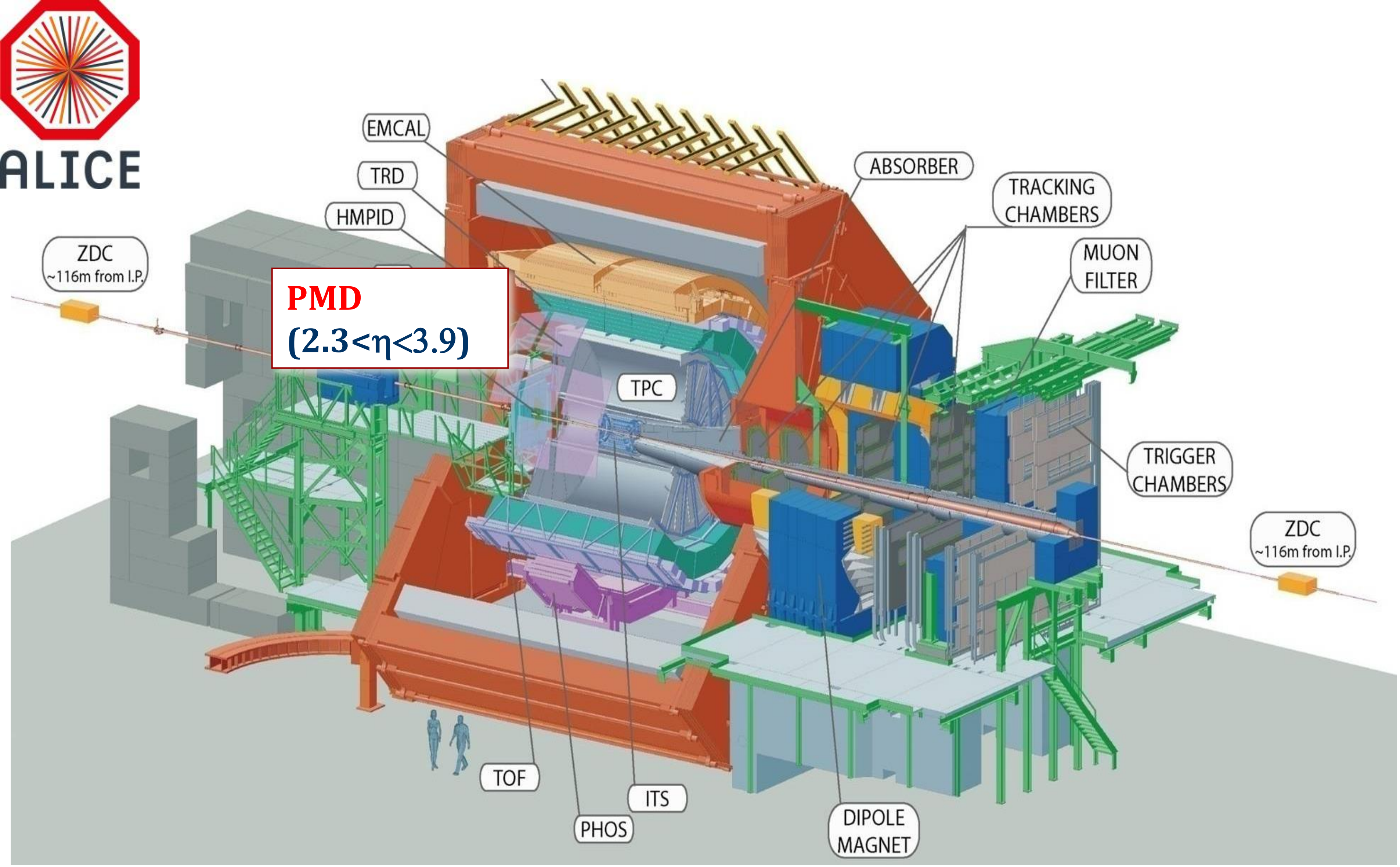


STAR PRL,95,2009

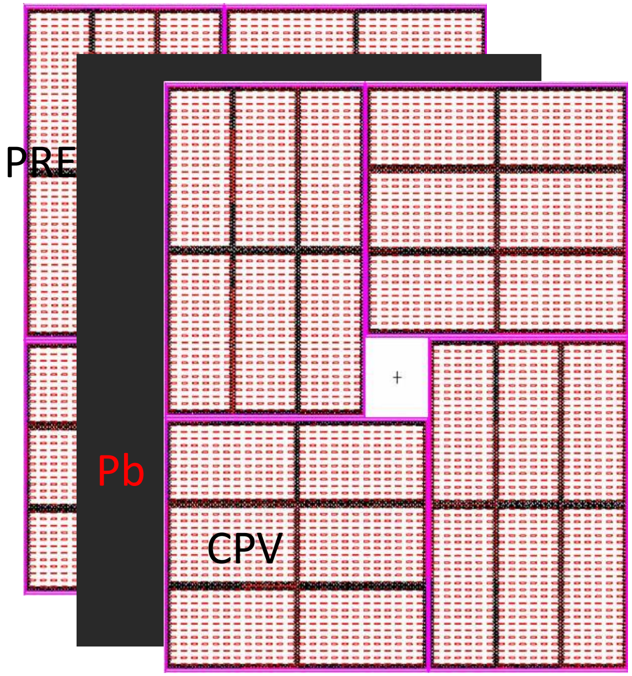


ALICE, arXiv: 1004.3514[hep-ex]




ALICE
EMCAL
TRD
HMPID
ZDC
~116m from I.P.
PMD
(2.3<η<3.9)
TPC
ABSORBER
TRACKING
CHAMBERS
MUON
FILTER
TRIGGER
CHAMBERS
ZDC
~116m from I.P.
TOF
ITS
PHOS
DIPOLE
MAGNET

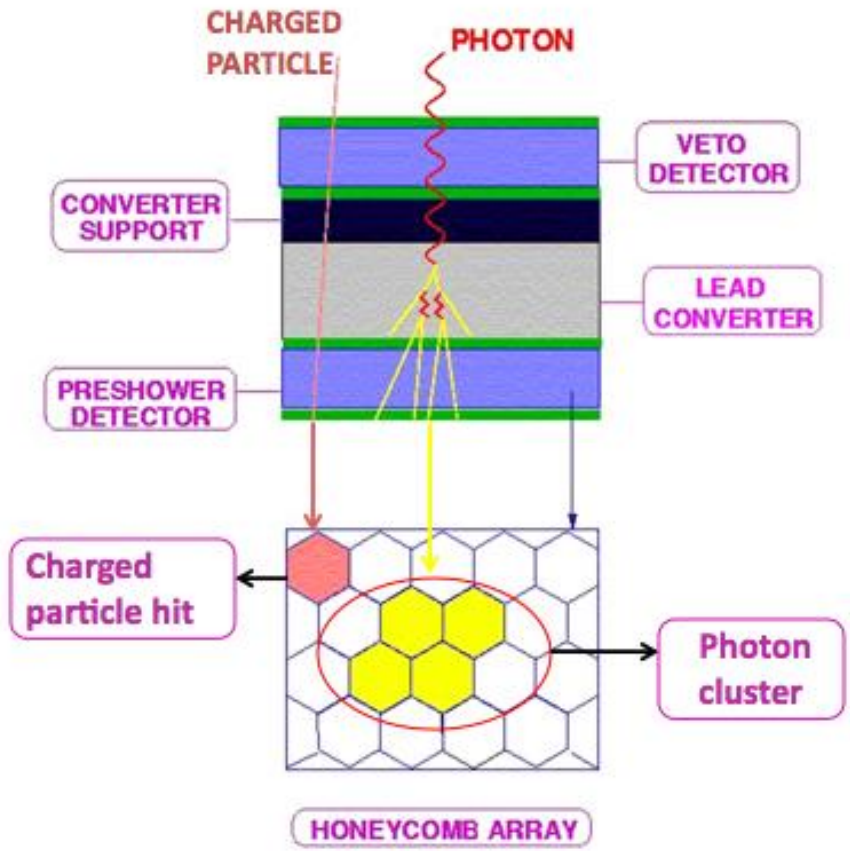
Photon Multiplicity Detector



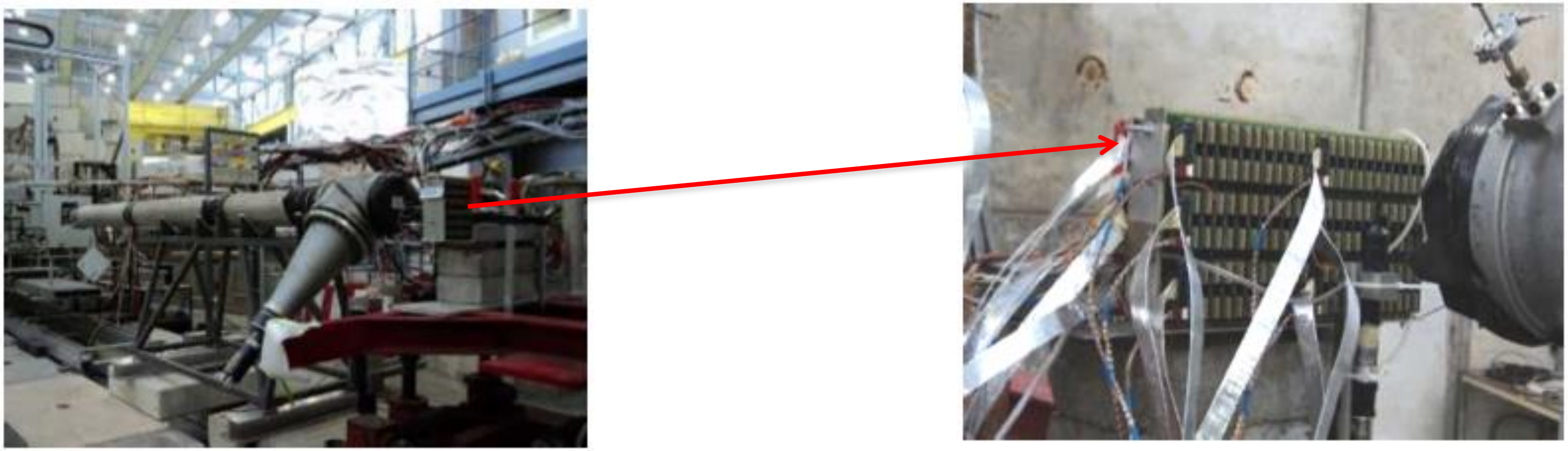
Z = 367 cm from IP
η = 2.3 to 3.9
Full Φ

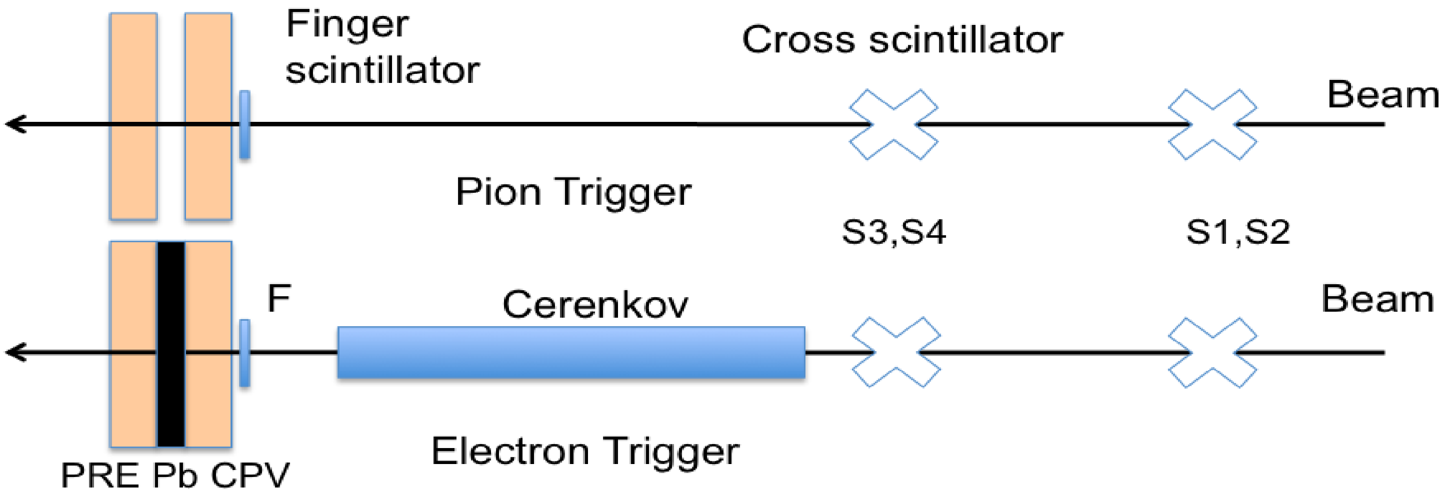
- Total number of modules = 40
- Total no of honeycomb cells = 184320
- Cell depth = 0.5 cm
- Cell Cross section = 0.23 cm^2
- 1 module = 4608 cells read
- 1 module read by 72 FEE boards
- 1 FEE board = 64 cells (4 MANAS Chips).
- Each MANAS reads 16 channels
- Sensitive medium : Gas ($Ar+CO_2$ in the ratio 70:30)

Working principle



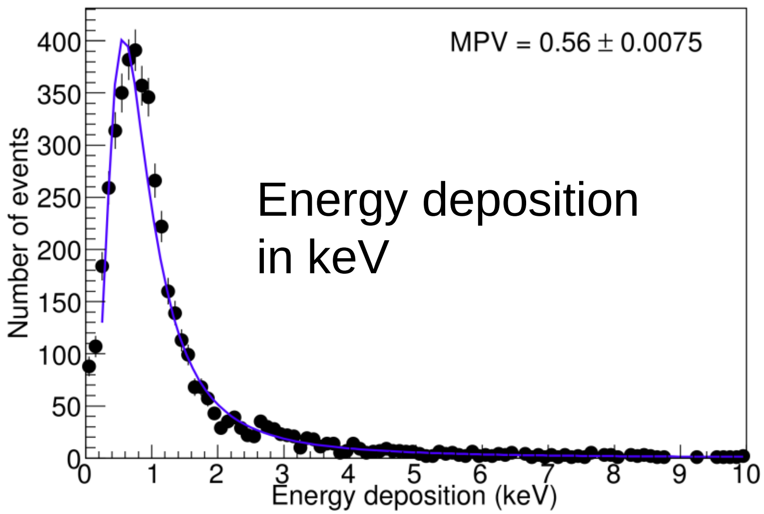
PMD Module and Beam Tests in T10 of CERN



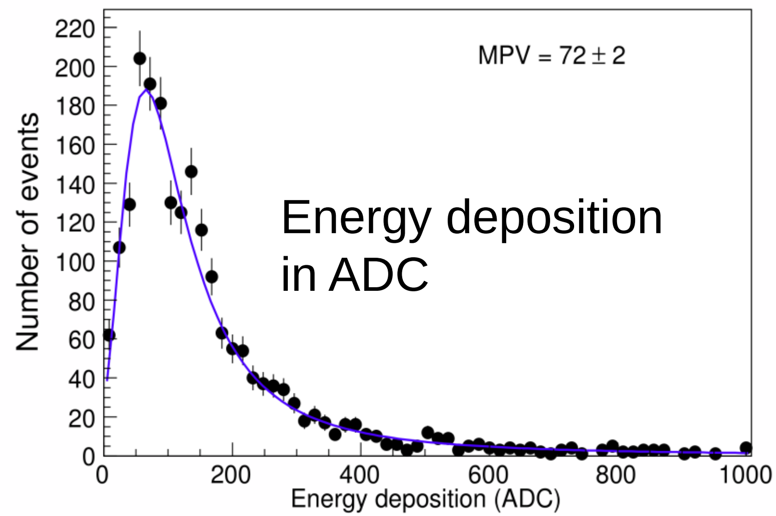


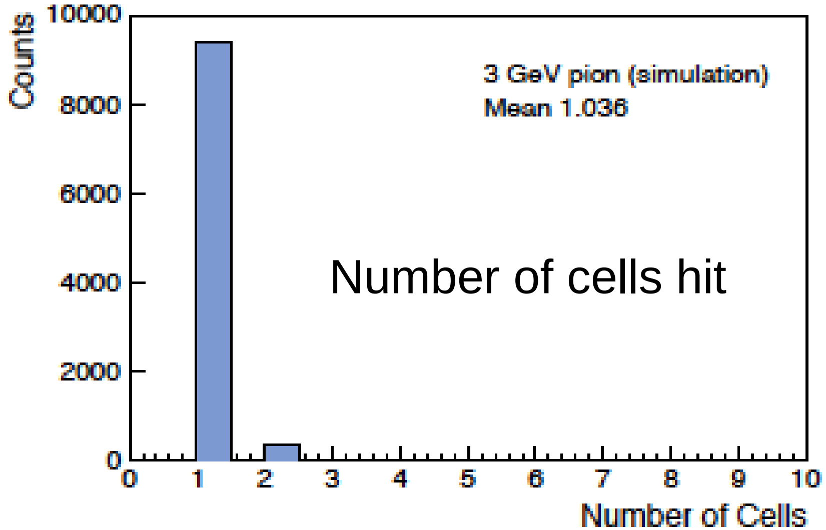
Response to pion beam

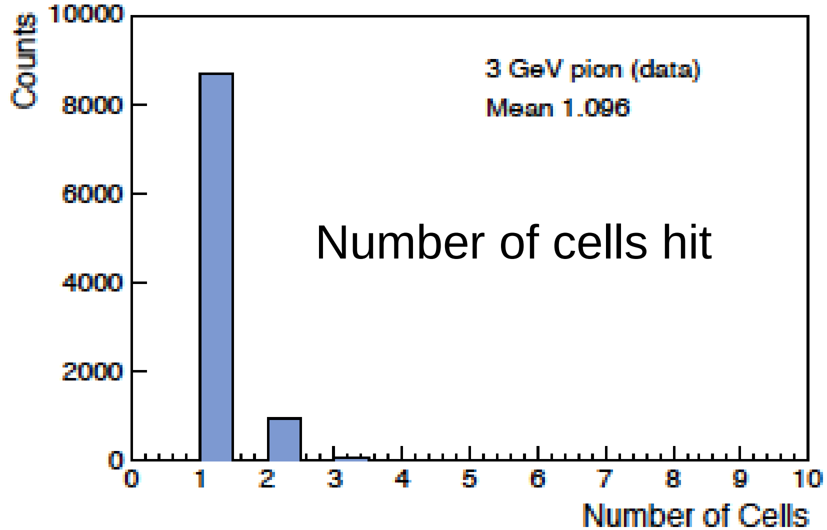
Simulation



Data

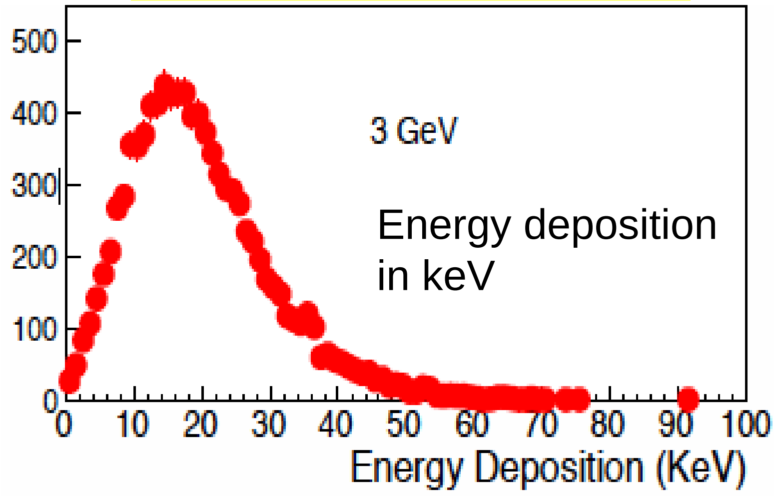




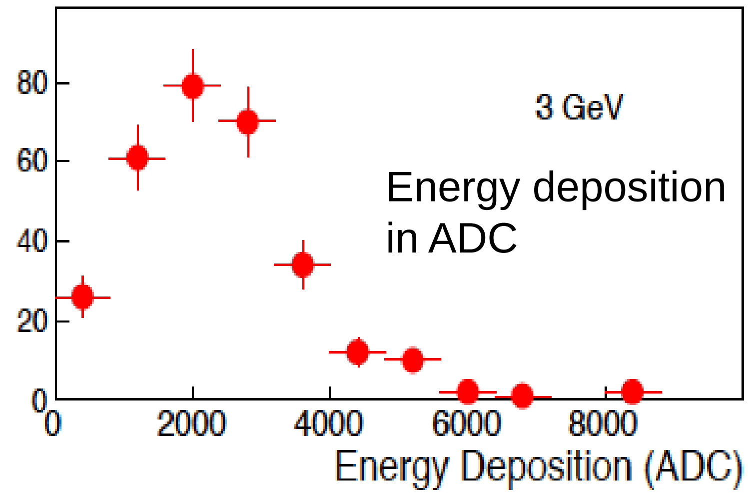


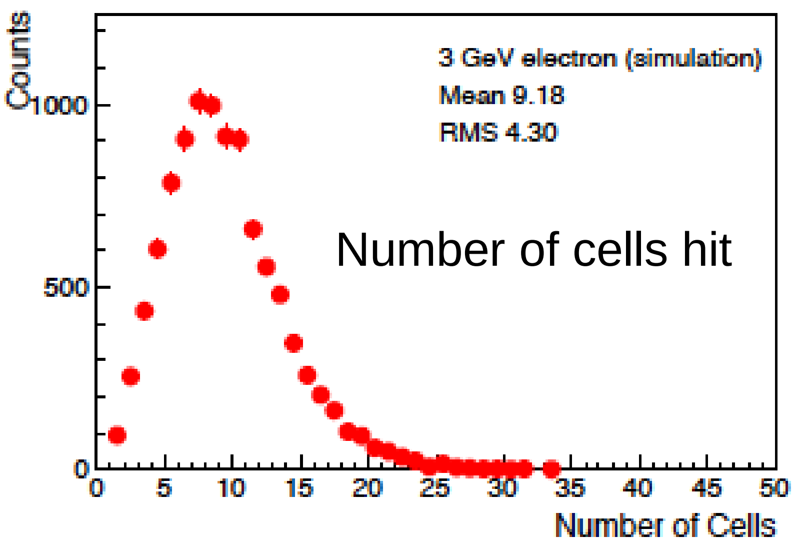
Response to electrons

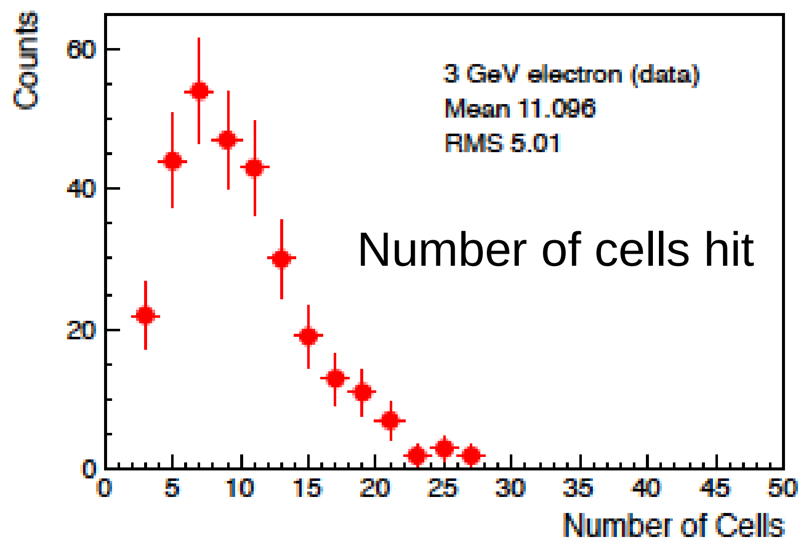
Simulation



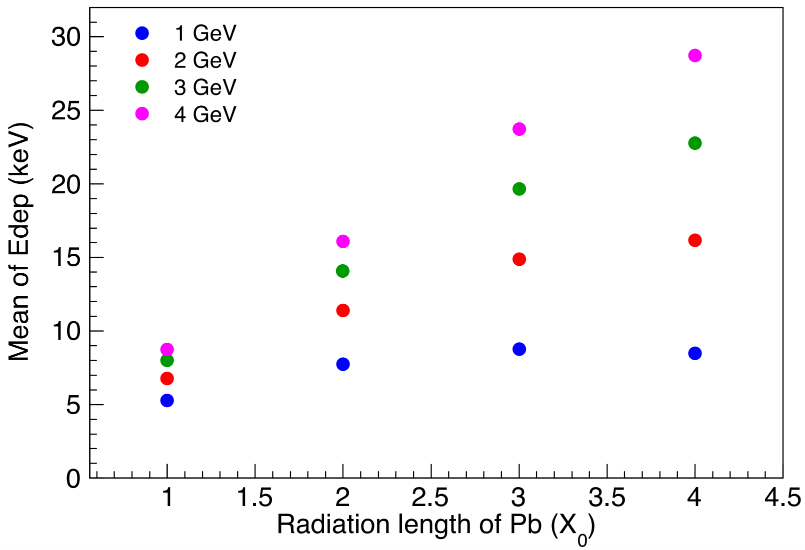
Data

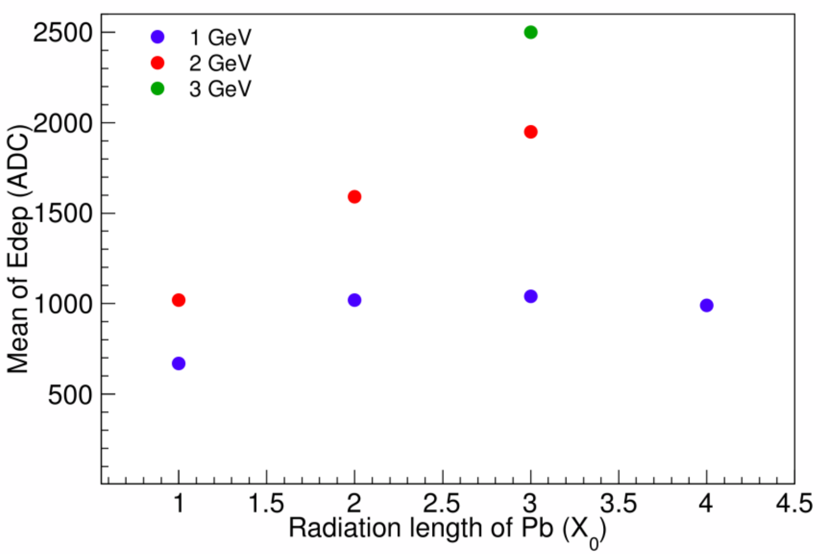


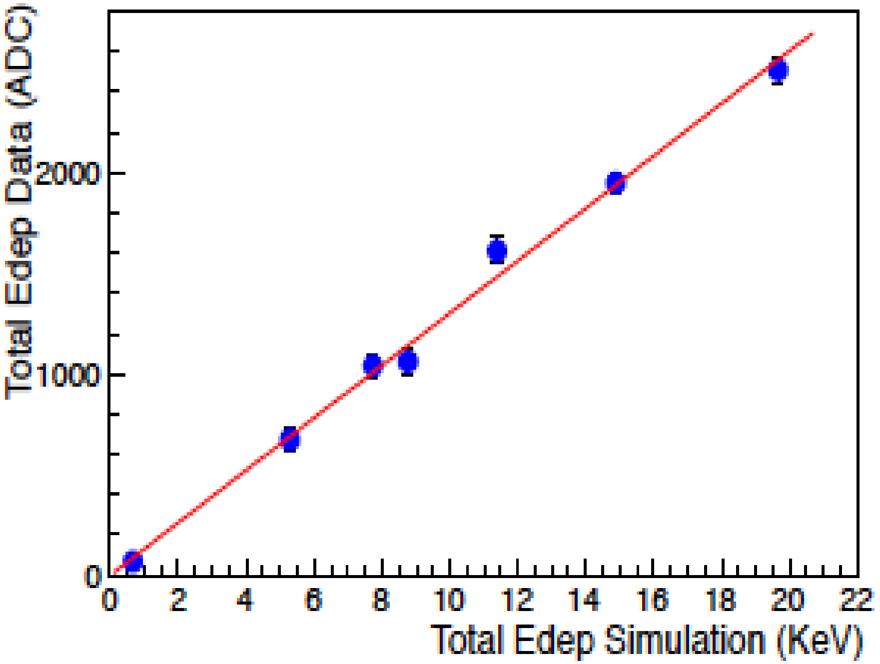




Conversion from keV to ADC







Conversion from keV to ADC is needed to make the simulated data in the same footing as the real experimental data

Data taking at the LHC

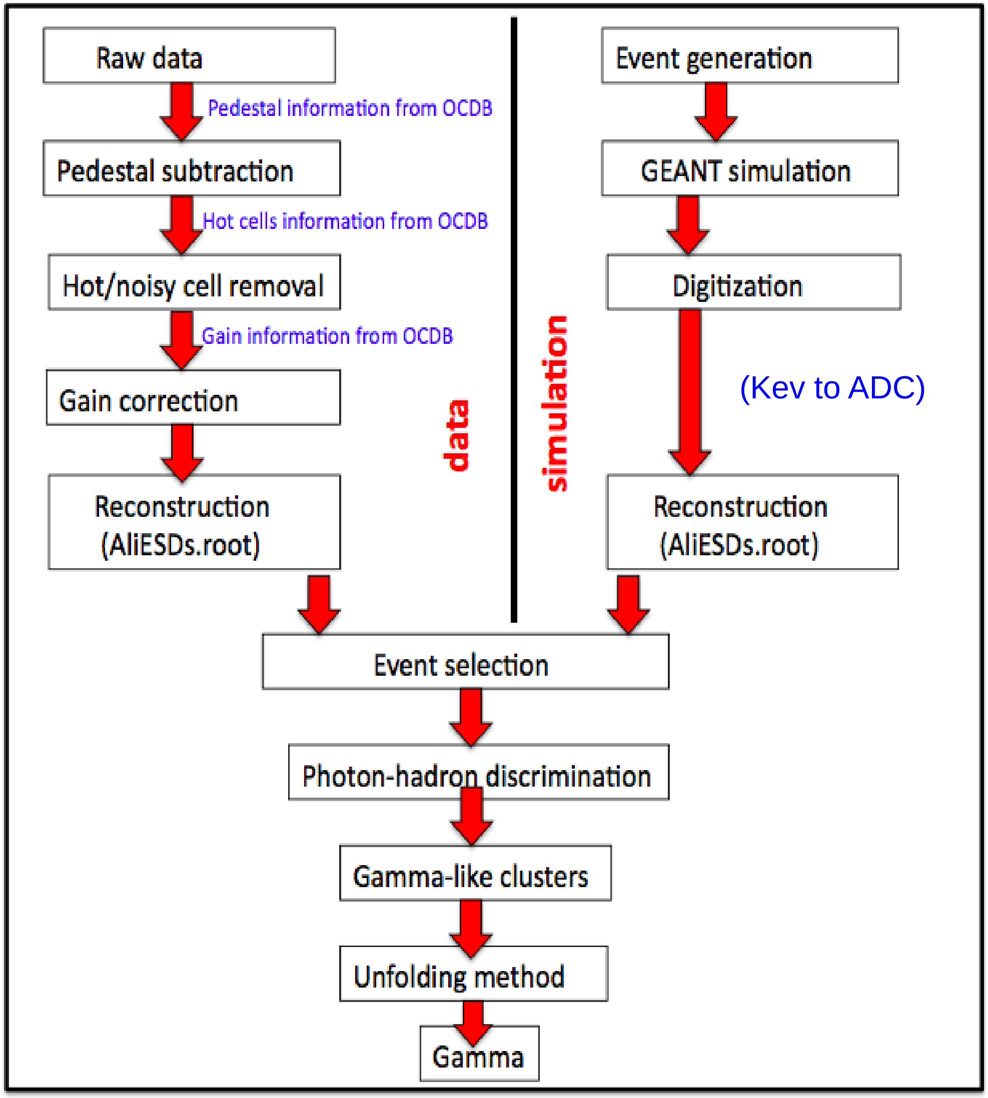
- p-p collision at 0.9 TeV
- p-p collision at 2.76 TeV
- p-p collision at 7 TeV

- Pb-Pb collision at 2.76 TeV
- p-Pb collisiion at 5.02 TeV

Energy :	$\sqrt{s}$ =0.9, 2.76 TeV and 7 TeV (pp)
Simulation :	Phojet and Pythia
Trigger Class :	INEL
Vertex Cut :	$\lvert V_z \rvert < 10$ cm
Eta range :	$2.3 < \eta < 3.9$
Phi range :	0 to 2π

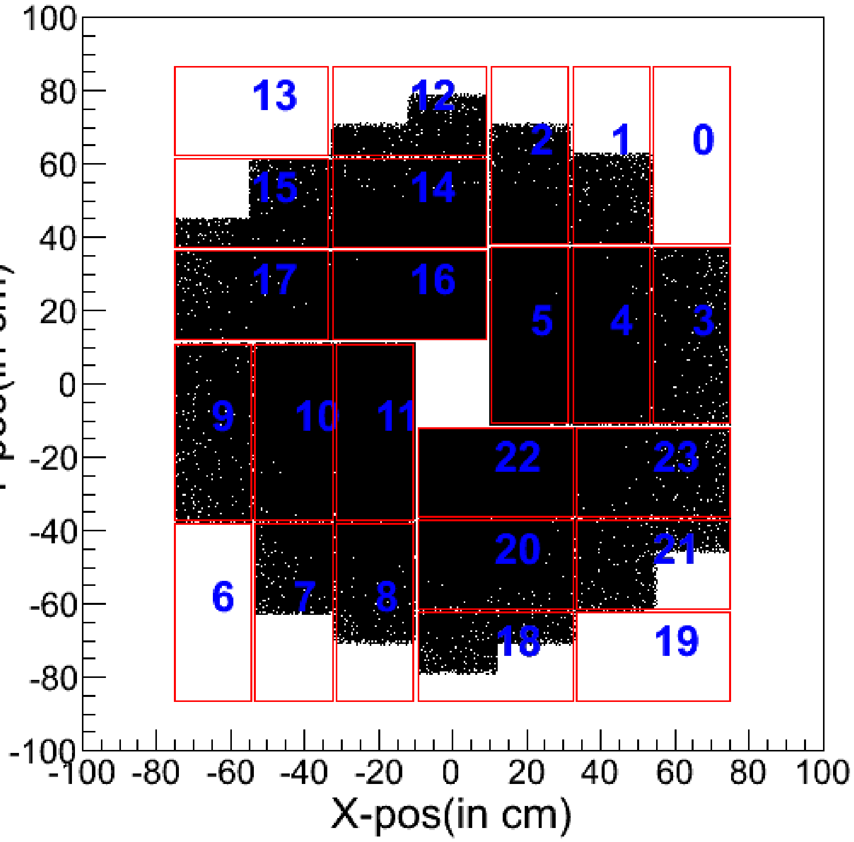
Photon hadron discrimination : We have used the Most Probable Value (MPV) of the MIP spectra as photon-hadron discrimination threshold

Analysis flow chart

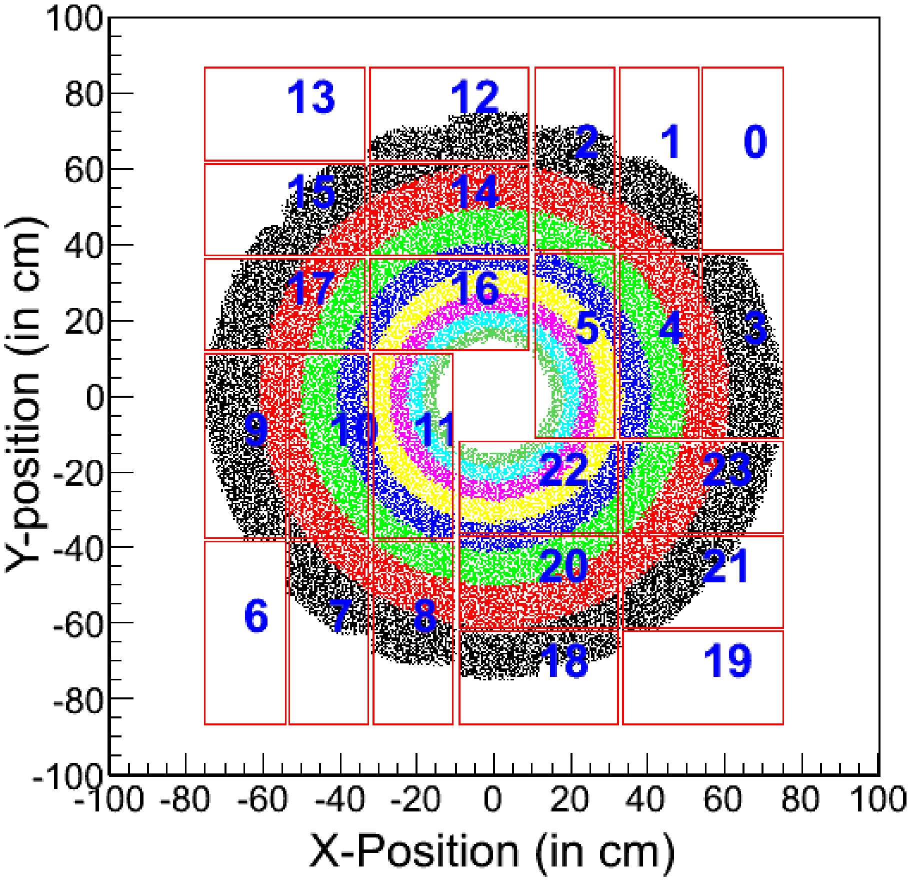


Acceptance of PMD

Ideal PMD



Different η rings on PMD

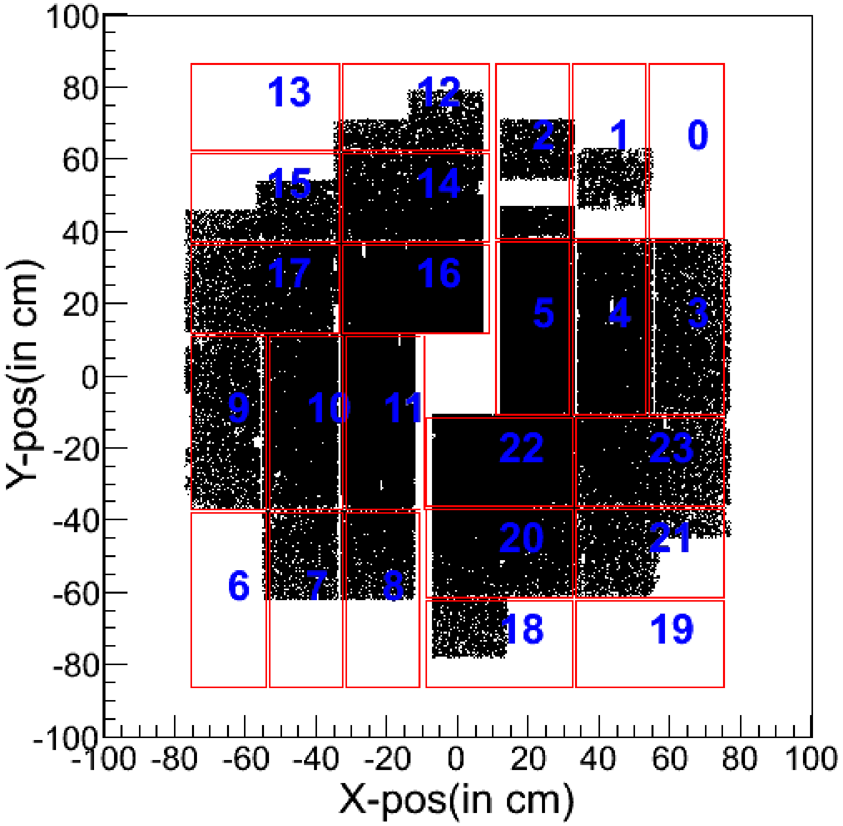


η rings are shown within $2.3<\eta<3.9$ of width 0.2 for full Φ

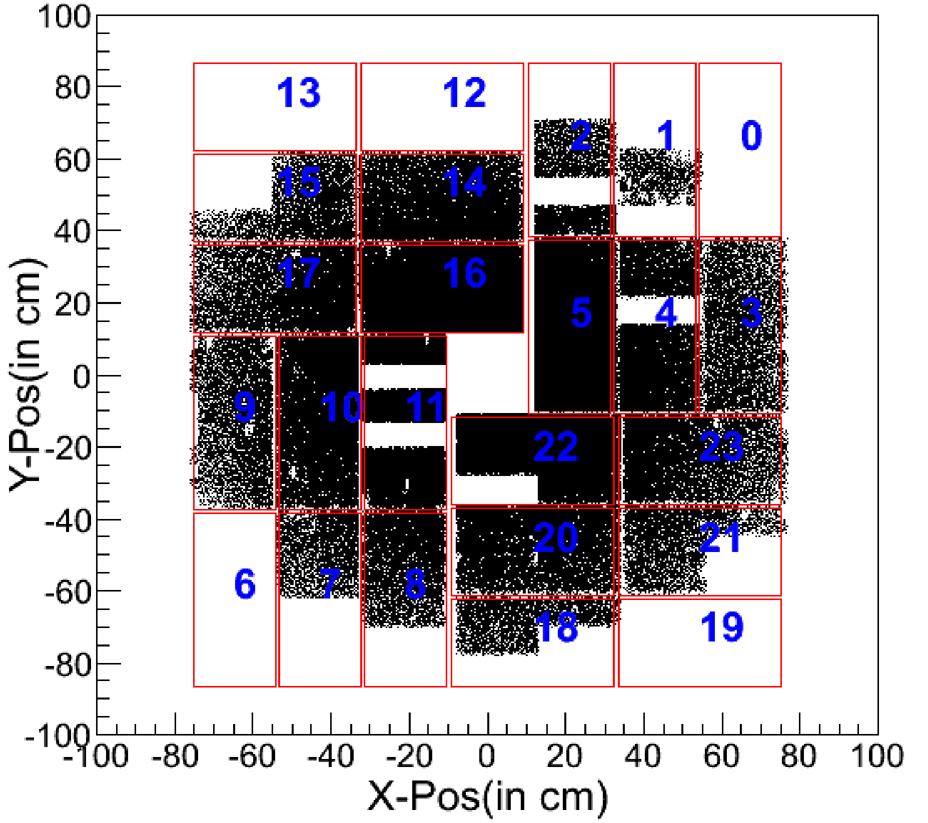
Acceptance of PMD

Real Data

2.76 TeV



7 TeV

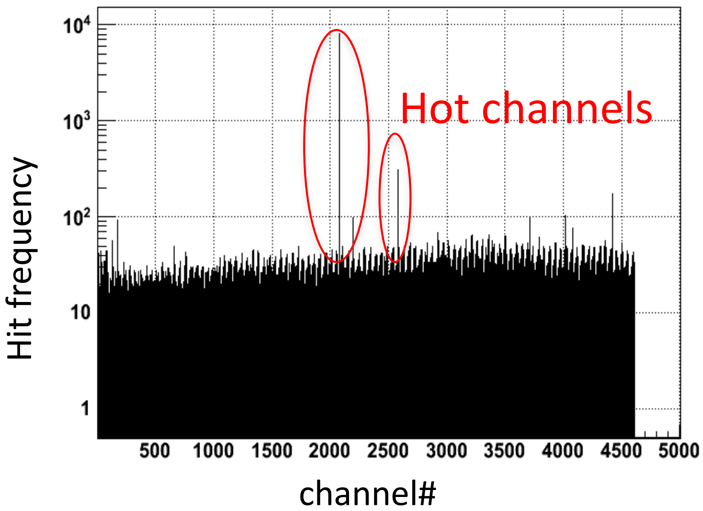


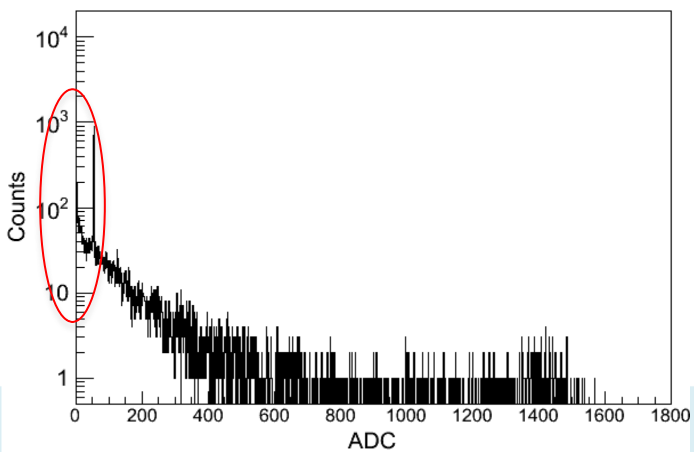
- In data some bad cells are removed to clean the data
- Acceptance correction is needed to get correct result

Data QA (Quality Assurance)

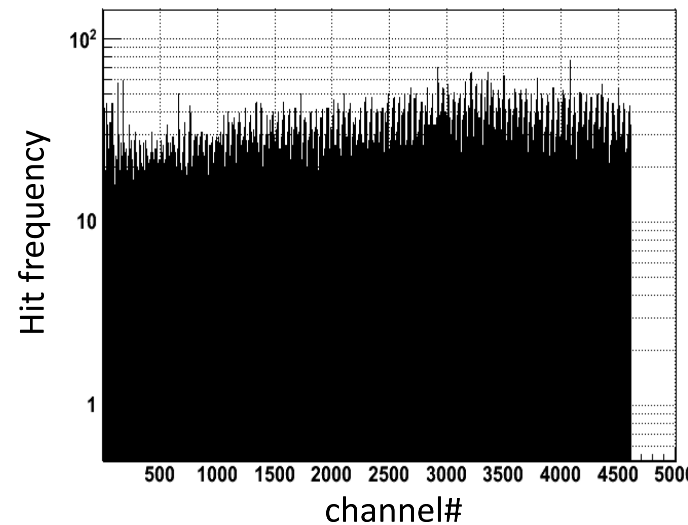
- Few cells show very high hit frequency, we call them Hot/Noisy cells
- These Hot/Noisy cells need to be removed before reconstruction

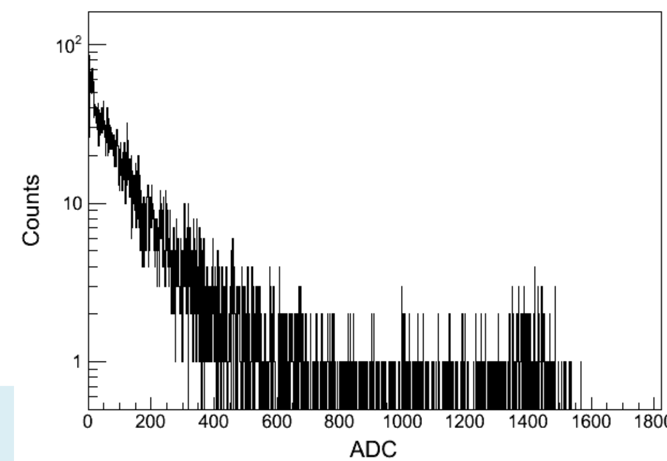
Raw Data



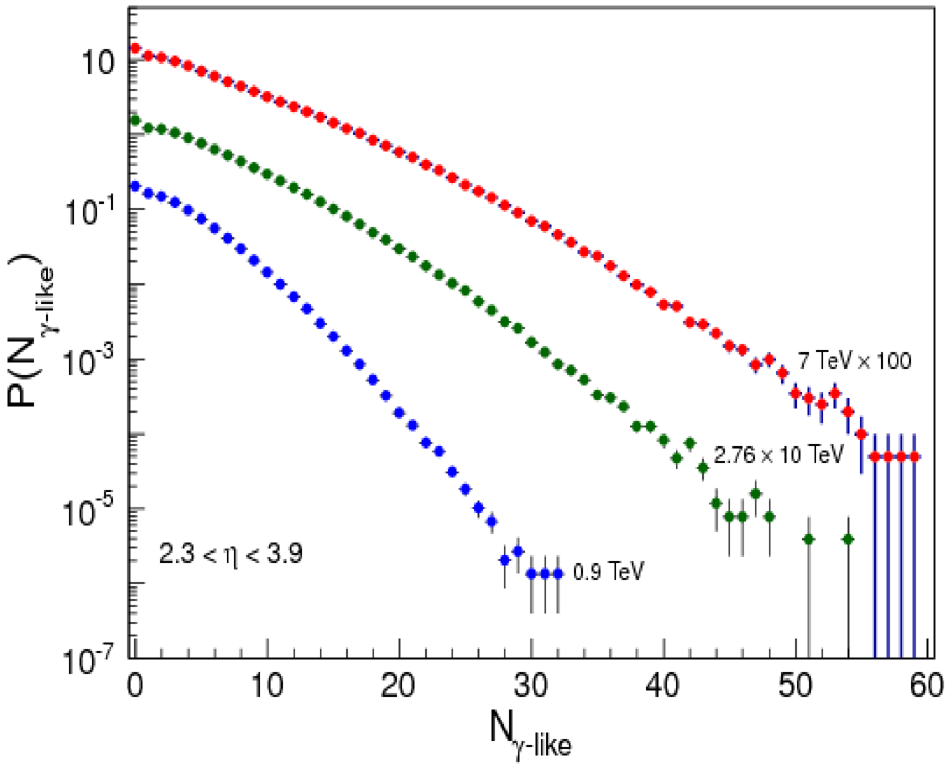


Raw data After cleanup





Uncorrected Photon multiplicity



- Photon hadron discrimination threshold is applied to get $N_{\gamma\text{-like}}$ distribution
- **Correction to get final photon multiplicity using Unfolding method**

Correction using simulation

This is the determination of true multiplicity from measured multiplicity using a detector response matrix

$$\hat{g} = A\hat{f} \quad \longrightarrow \quad \hat{f} = A^{-1}\hat{g}$$

f = true distribution g = measured distribution *A* = detector response matrix

Using minimization of a χ^2-function given as:

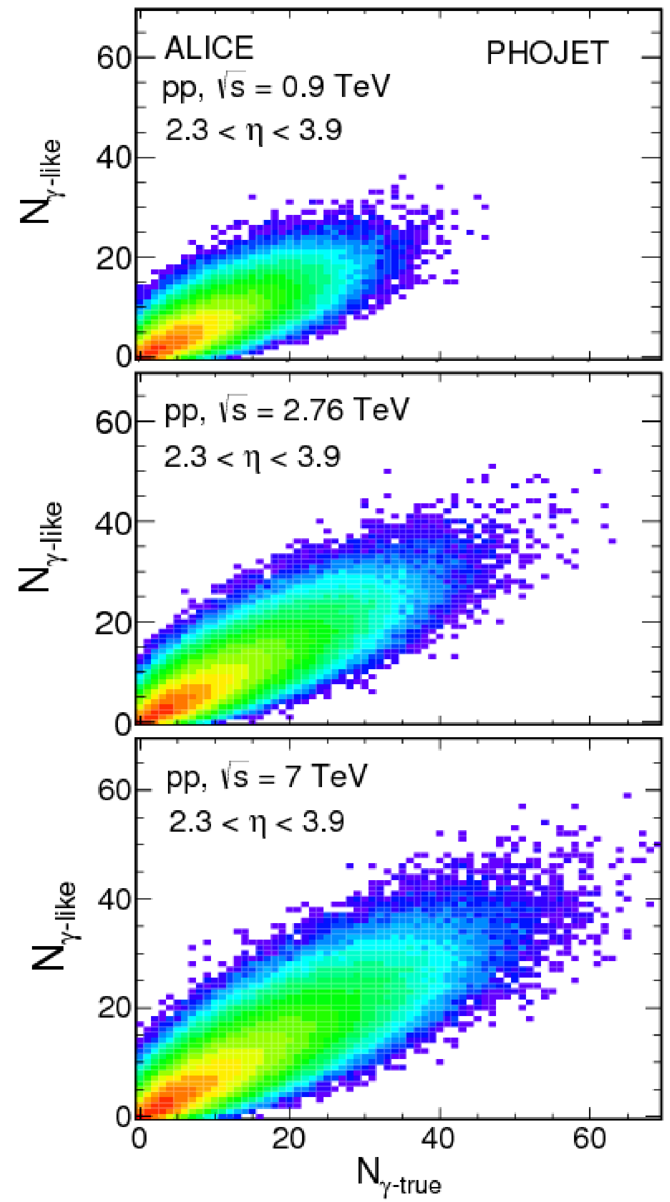
$$\hat{c}^2 = å_i \left(\frac{g_i - å_j A_{ij} f_j}{e_i}\right)^2$$

where ‘e_i’ is the error in measurement, and adding a regularization term P,

$$c^2 = \hat{c}^2 + bP$$

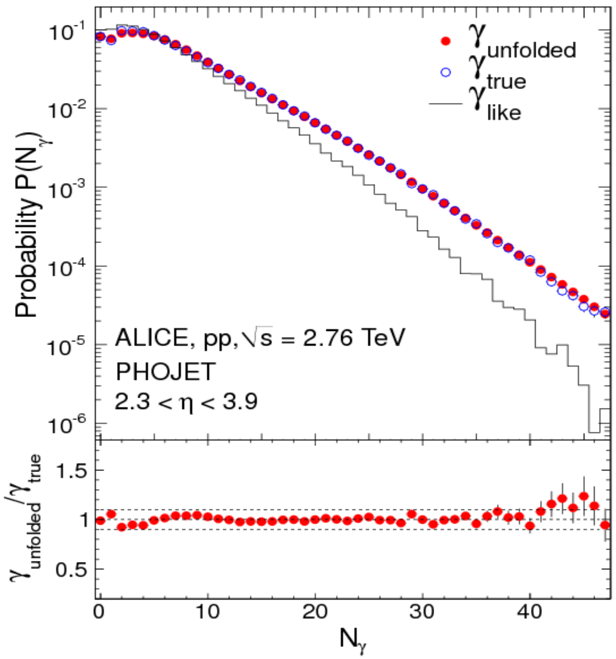
Where β is weight factor, the oscillations in the solutions are removed.

Response Matrix

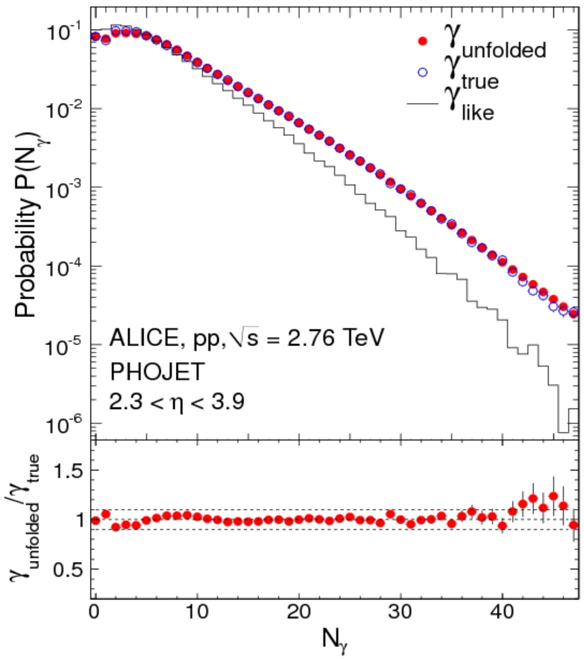


Test in simulation

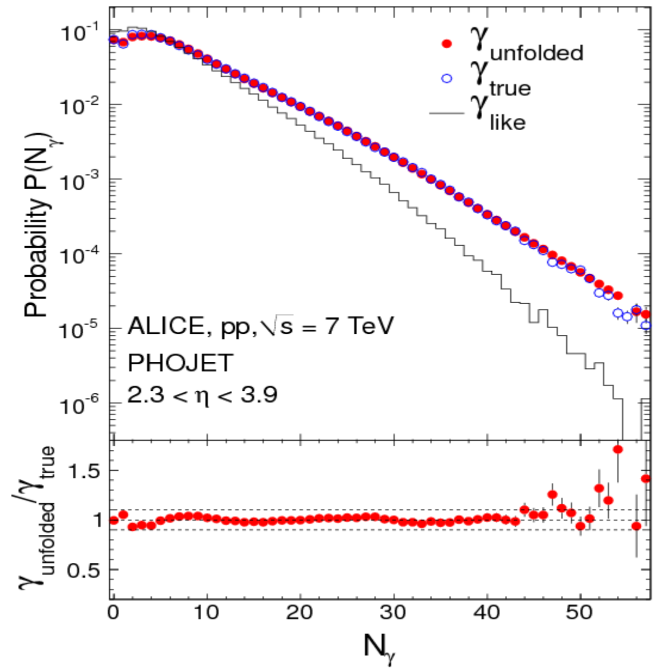
0.9 TeV



2.76 TeV



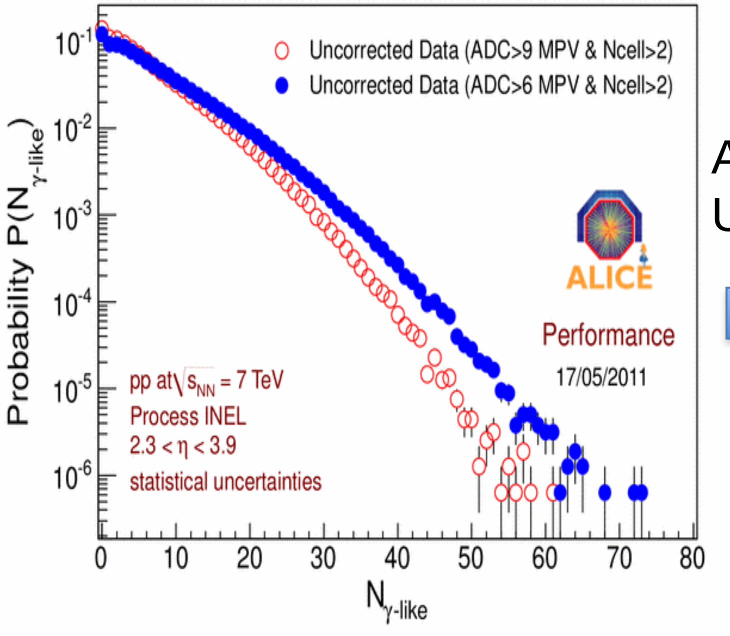
7 TeV



- Test of the unfolding method using PHOJET event generator.
- The measured, unfolded and true photon multiplicities are shown.
- The lower panels show the ratios of unfolded to true multiplicity distributions.

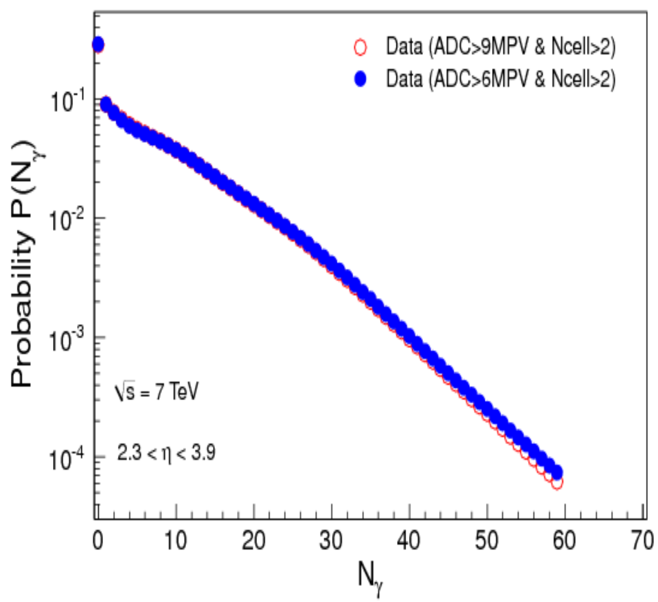
Correction using simulation

Uncorrected distribution



After correction
Using response matrix

corrected distribution



- After unfolding corrected multiplicity distribution is similar for two different threshold.

Systematic uncertainties

- Upstream material in-front of the PMD

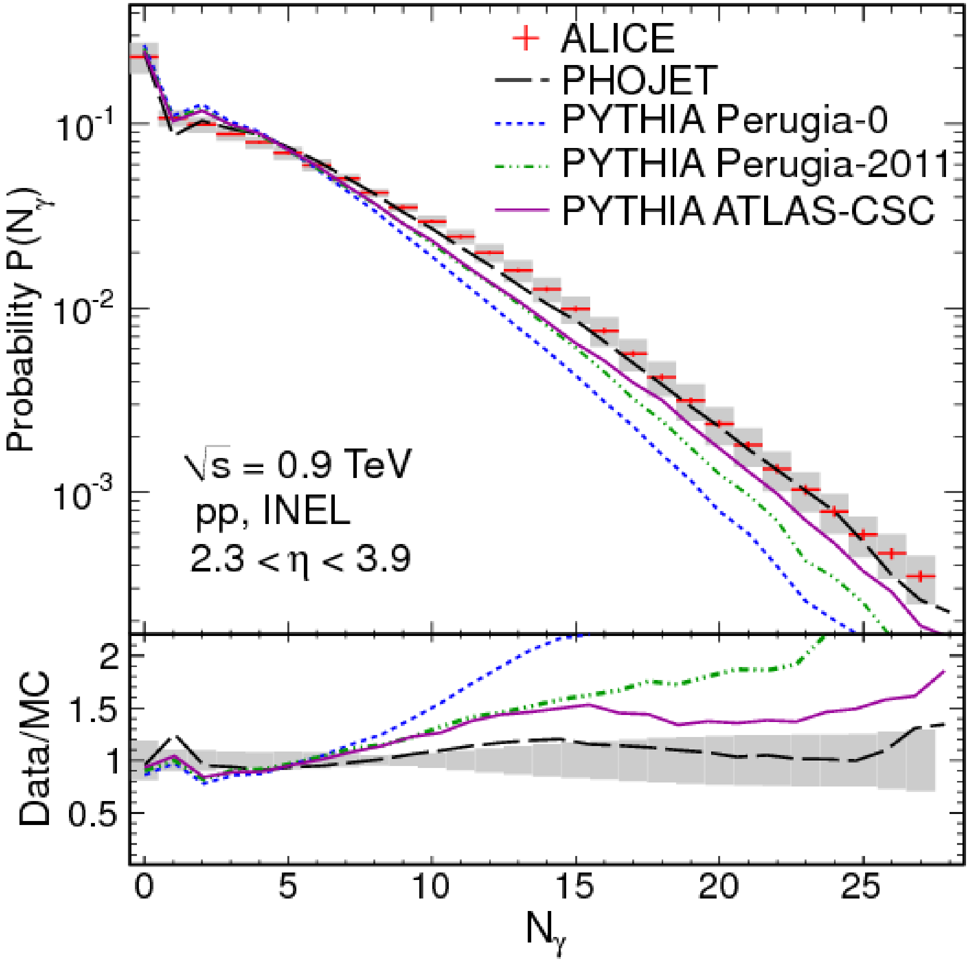
- Effect of discrimination thresholds Two different sets of thresholds are applied:
 (a) Cluster ADC>432 (6 times the MPV value of MIP) and ncell>2
 (a) Cluster ADC>648 (9 times the MPV value of MIP) and ncell>2

- Unfolding using different event generators
  Here PYTHIA and PHOJET event generators are used for unfold the data and the difference between the unfolded distributions are taken as uncertainties.

- Unfolding using different method.

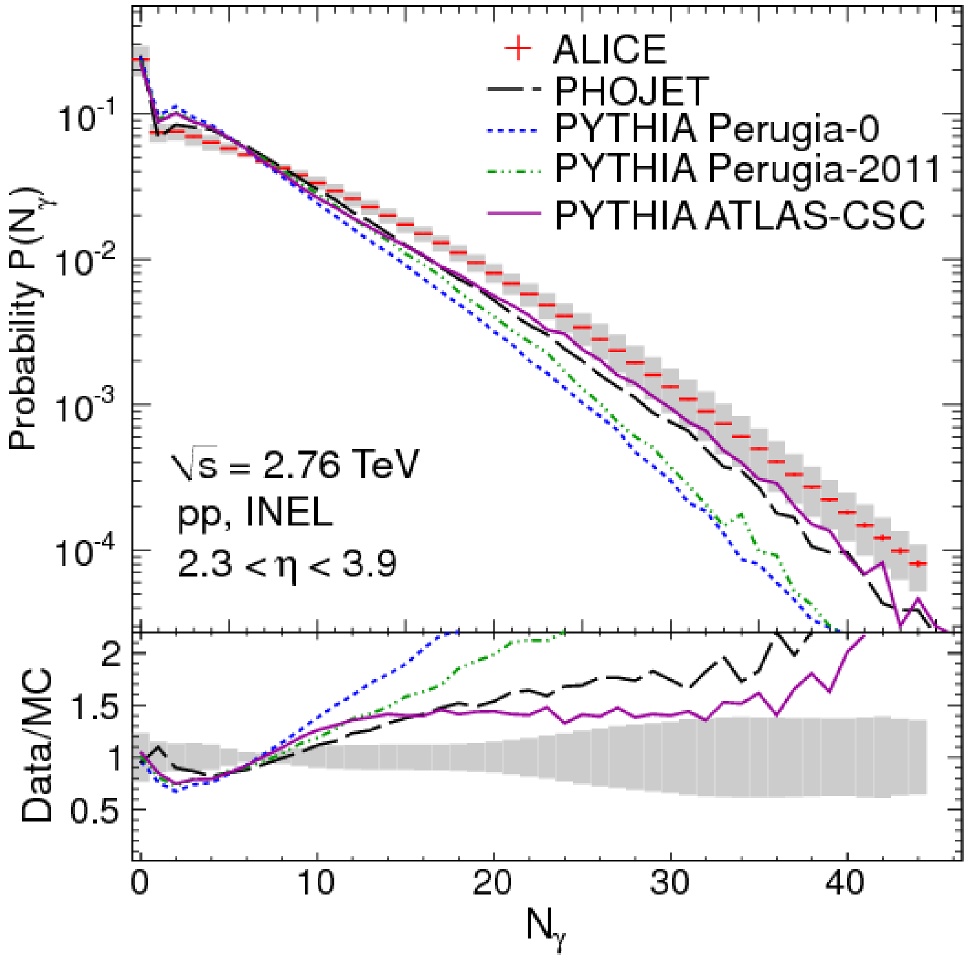
Corrected photon multiplicity distribution

0.9 TeV



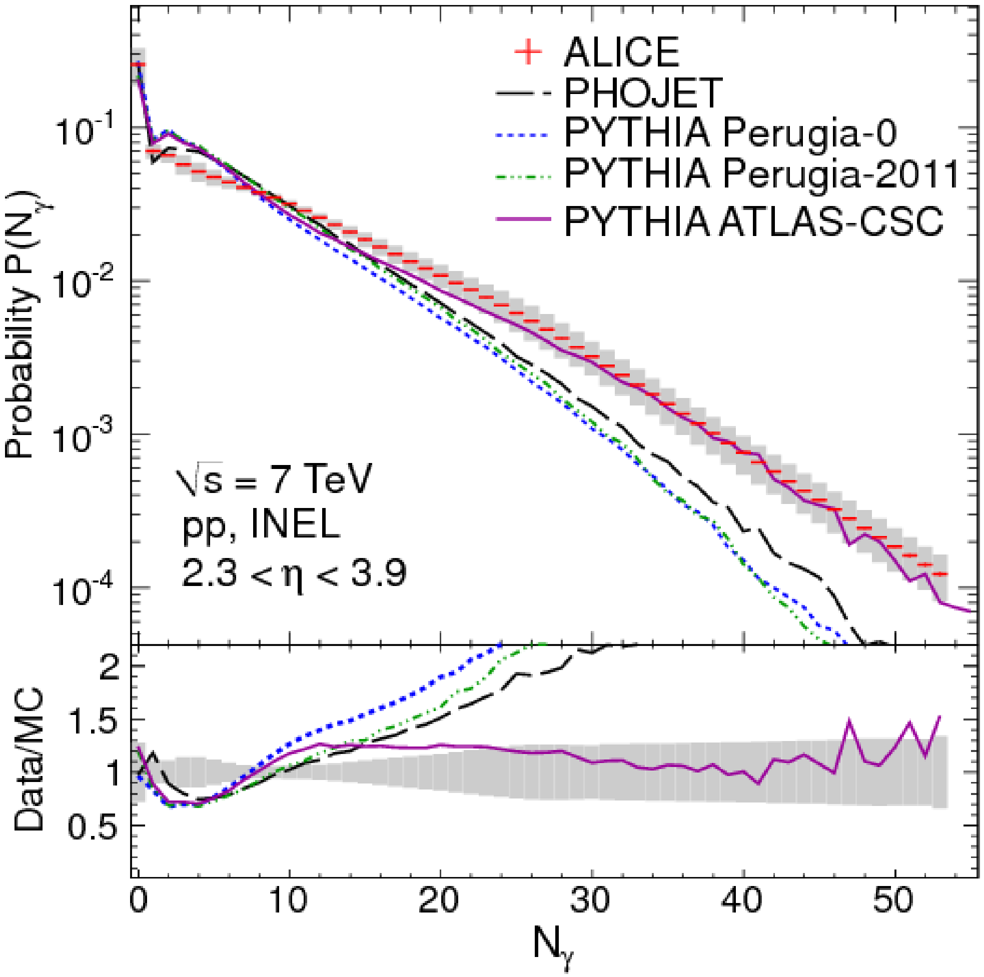
Corrected photon multiplicity distribution

2.76 TeV



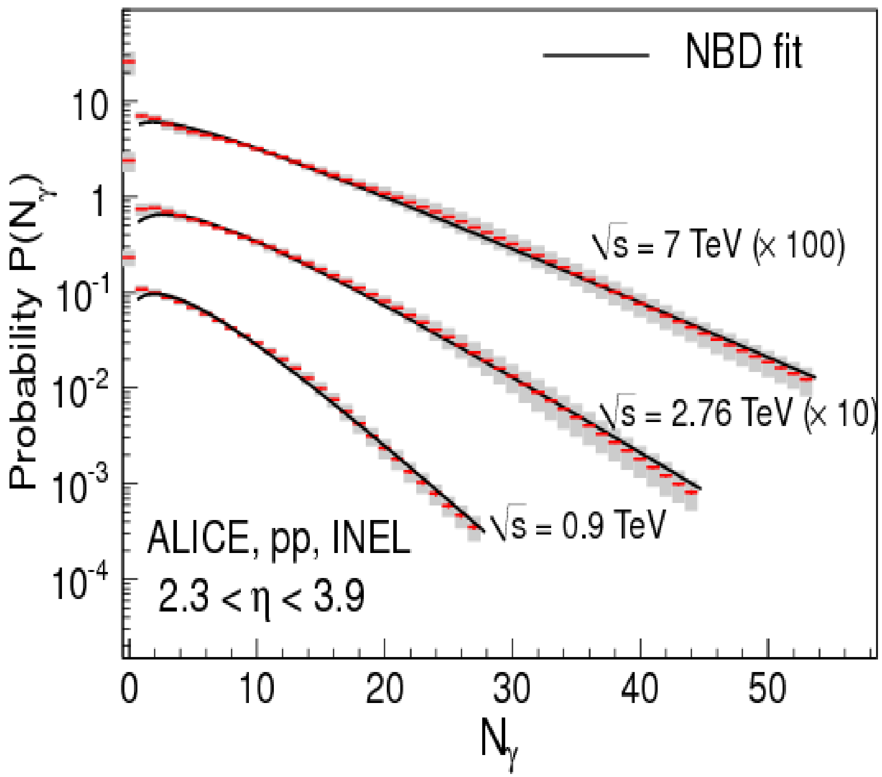
Corrected photon multiplicity distribution

7 TeV



Fitted With NBD

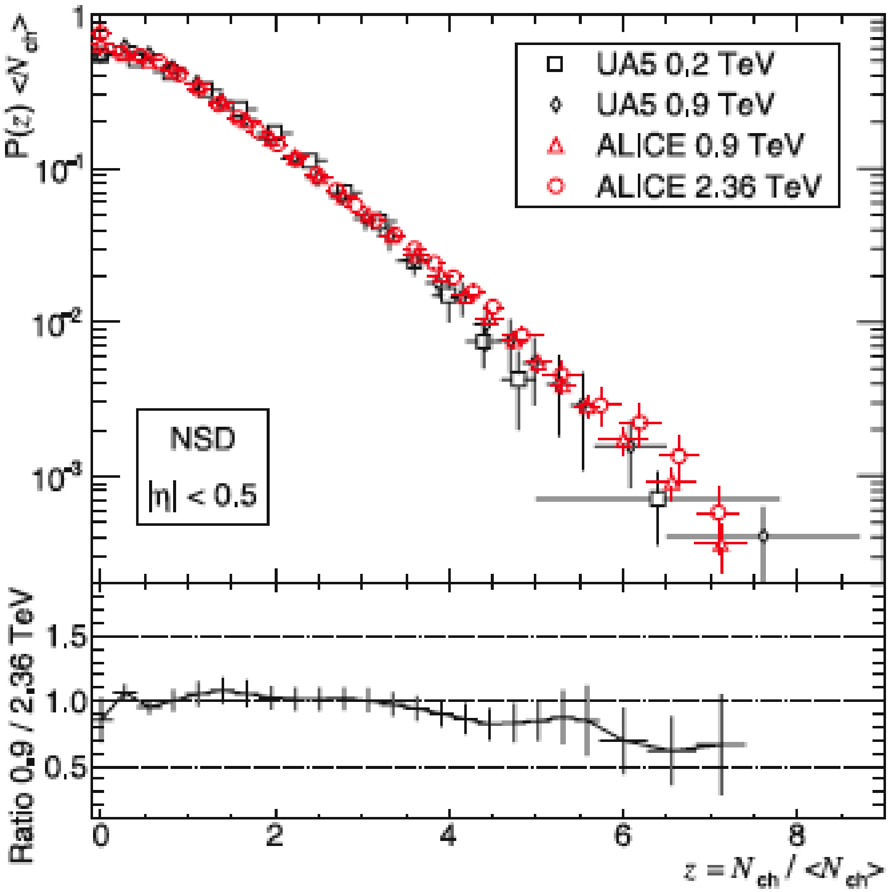
$$P_{NBD}(<N_\gamma>, k; n) = \frac{\Gamma(n+k)}{\Gamma(n+1)\Gamma(k)} \times \frac{(n/k)^n}{(n/k+1)^{n+k}}$$



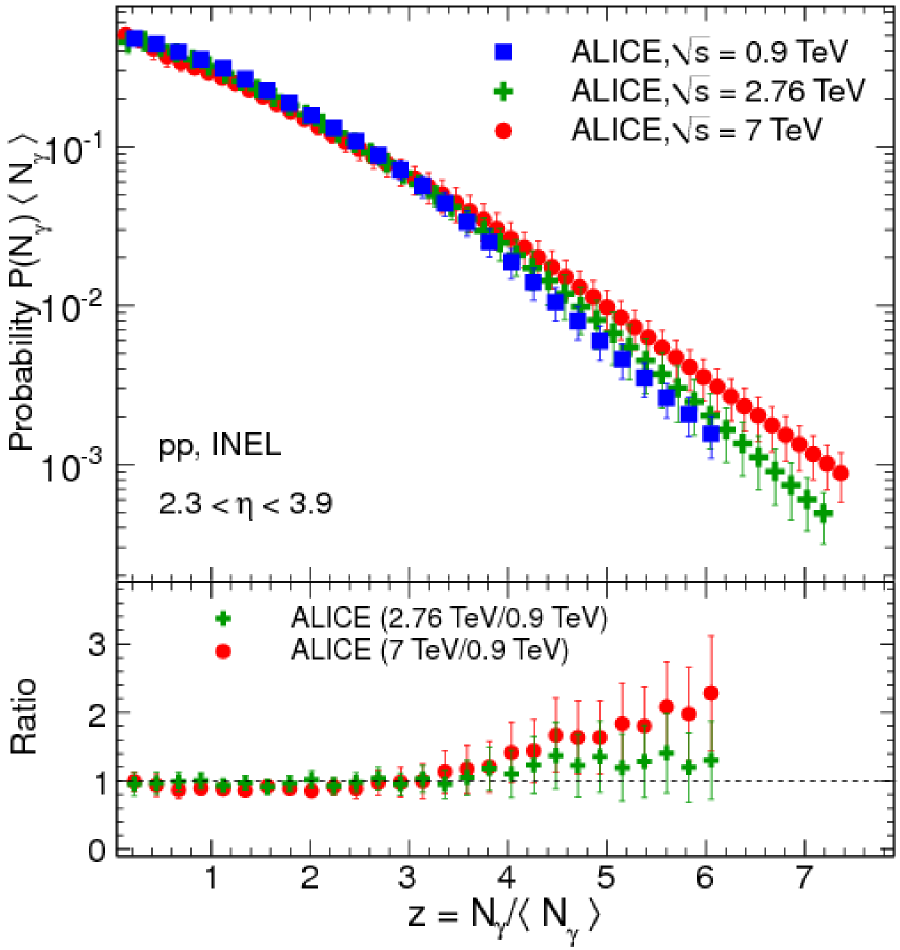
k → *determines the shape of distribution*

n → *Average photon multiplicity*

KNO scaling

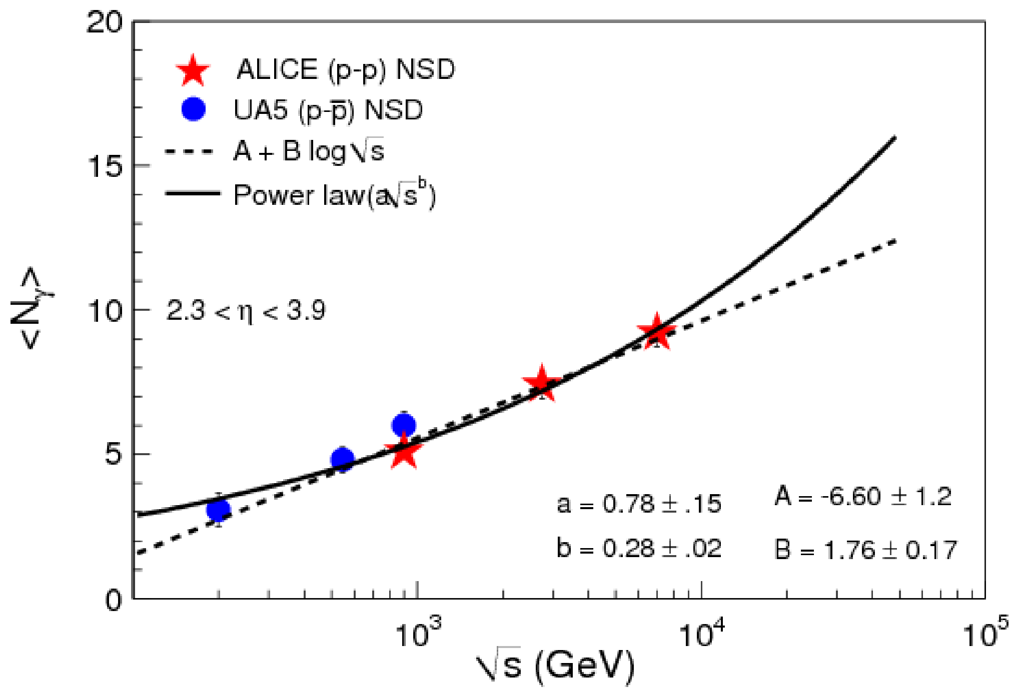


UA5 0.2 TeV
UA5 0.9 TeV
ALICE 0.9 TeV
ALICE 2.36 TeV
NSD
|η| < 0.5
P(z) <N_ch>
Ratio 0.9 / 2.36 TeV
z = N_ch / <N_ch>



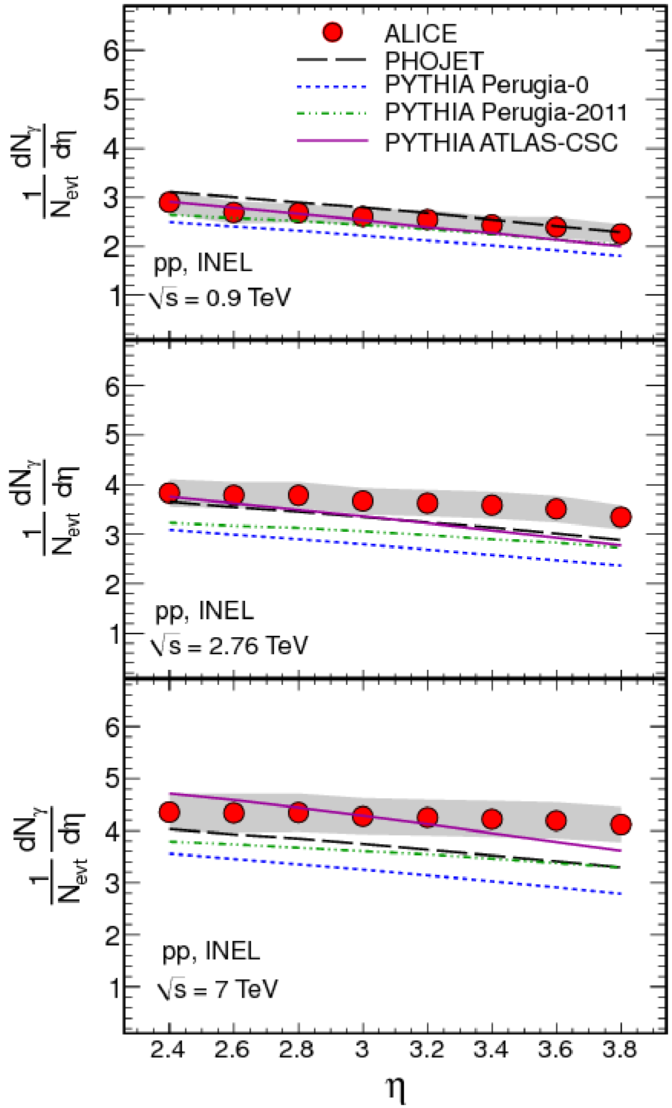
ALICE, √s = 0.9 TeV
ALICE, √s = 2.76 TeV
ALICE, √s = 7 TeV
pp, INEL
2.3 < η < 3.9
Probability P(N_γ) ⟨ N_γ ⟩
ALICE (2.76 TeV/0.9 TeV)
ALICE (7 TeV/0.9 TeV)
Ratio
z = N_γ/⟨ N_γ ⟩

Beam energy dependence

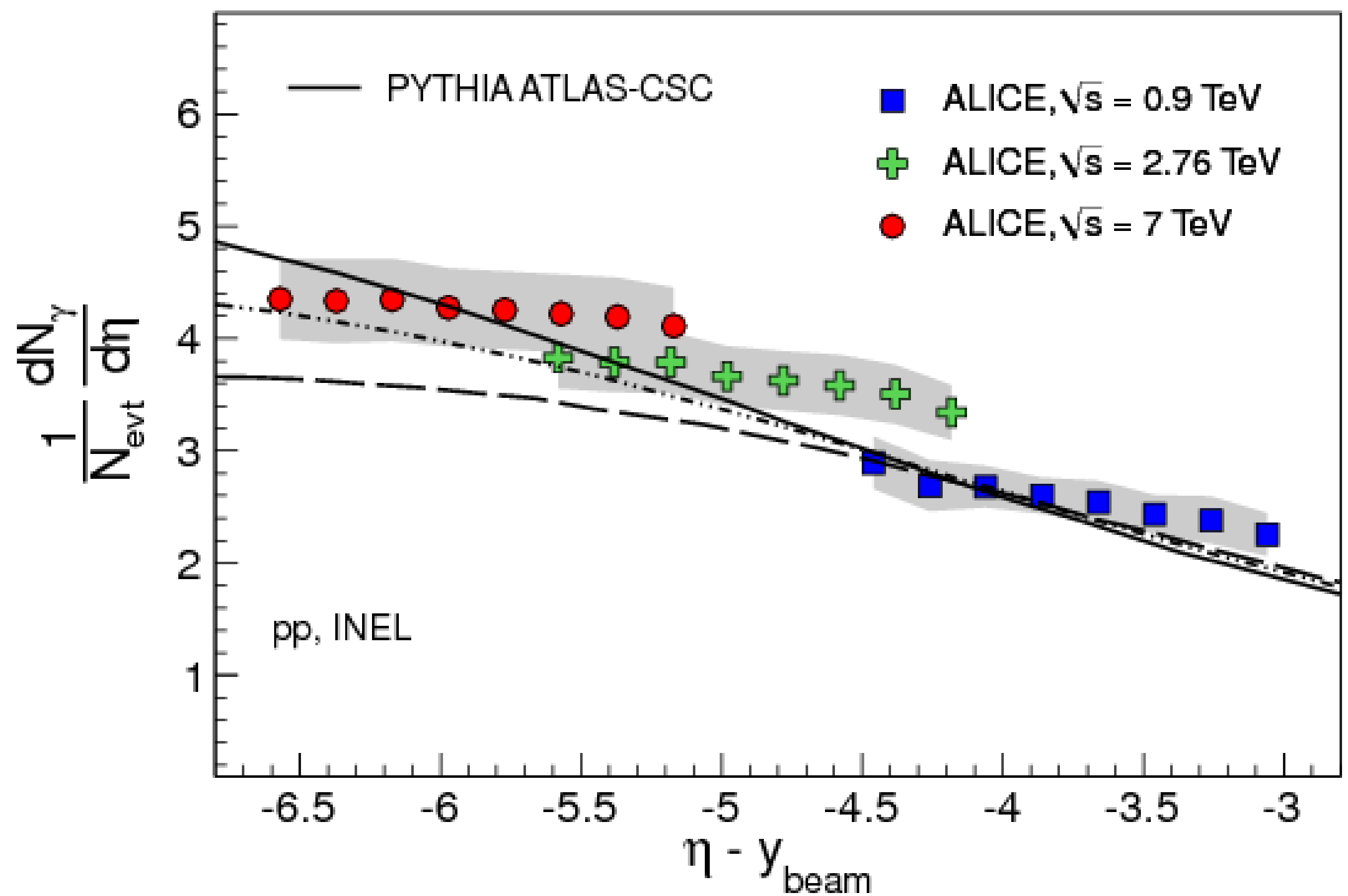


➢ **Average photon multiplicity in pp collisions (within $2.3<\eta<3.9$) increases with $\sqrt{s}$ as $\ln\sqrt{s}$.**

Pseudo rapidity distribution



Limiting fragmentation behavior

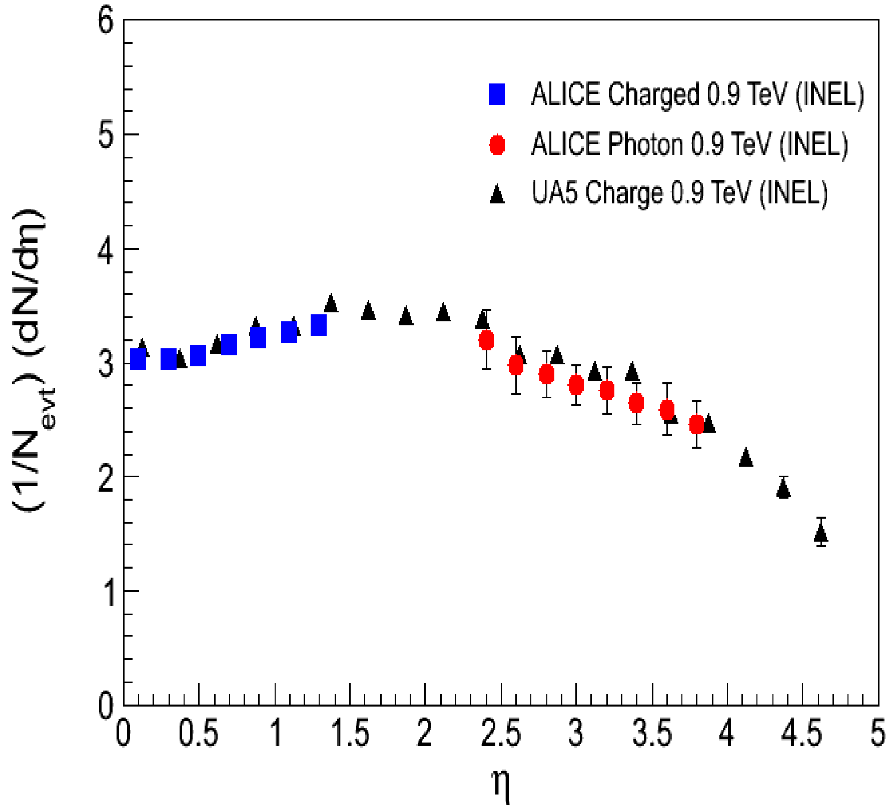


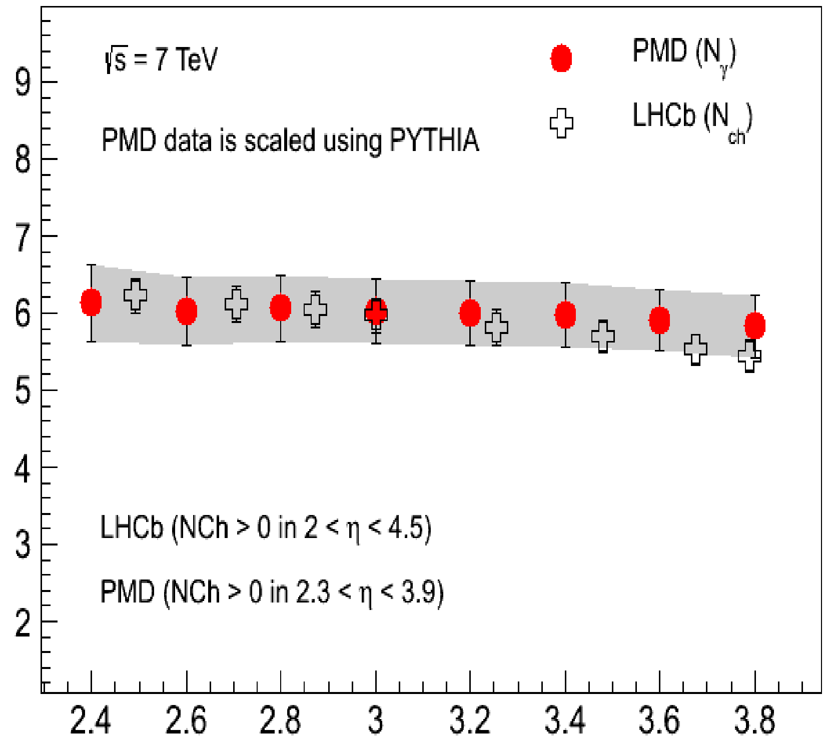
y_{beam} at 0.9 TeV = 6.86
y_{beam} at 2.76 TeV = 7.98
y_{beam} at 7 TeV = 8.97

Comparison with Charged particle production

0.9 TeV

7 TeV





- Inclusive photon production and charged particle production are comparable in forward rapidity region

Summary

- Obtained the photon multiplicity and eta distributions in the forward rapidity region using ALICE-PMD

- PHOJET is closer to data at 0.9 TeV but PYTHIA ATLAS-CSC is closer to data at higher energies.

- $\langle N\gamma \rangle$ increases with $\sqrt{s}$ as $s^{0.14}$ as well as $\ln\sqrt{s}$

- Limiting fragmentation behavior has not been seen within this eta-acceptance.

Photon production at forward rapidities in p-Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV

Efficiency-purity method has been used to correct the data

N_{clus}: the total number of clusters

$N_{\gamma\text{-like}}$: Number clusters above thresholds on number of cells and Cluster ADC.

$N_{\gamma\text{-det}}$: Number of photons detected above the threshold

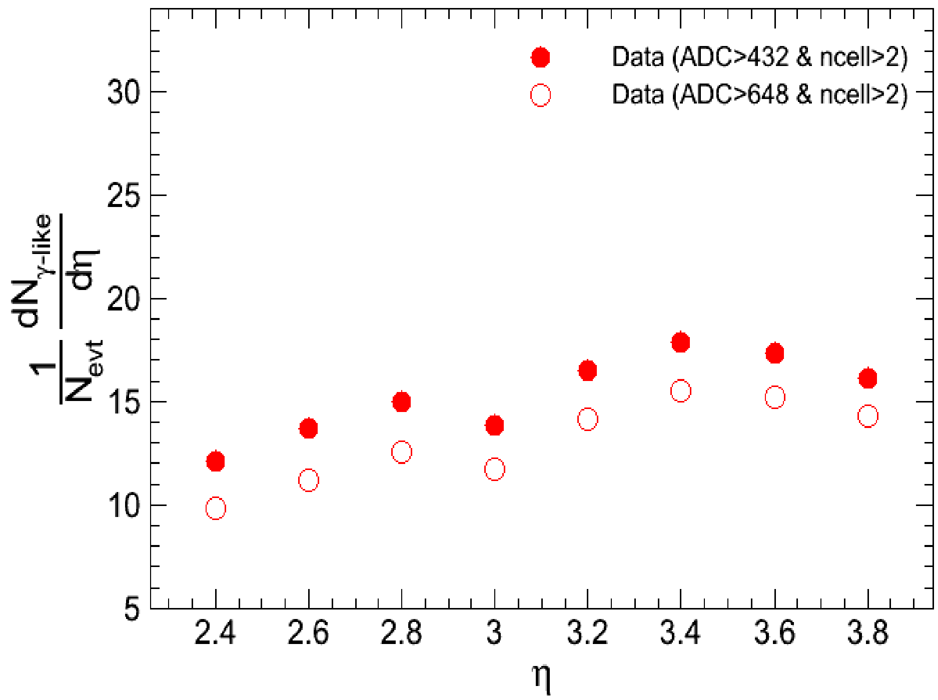
$N_{\gamma\text{-true}}$: Number of photons incident

purity = $N_{\gamma\text{-det}} / N_{\gamma\text{-like}}$

Efficiency = $N_{\gamma\text{-det}} / N_{\gamma\text{-true}}$

Correction of Data

$N_{\gamma\text{-like}}$ distribution of photons

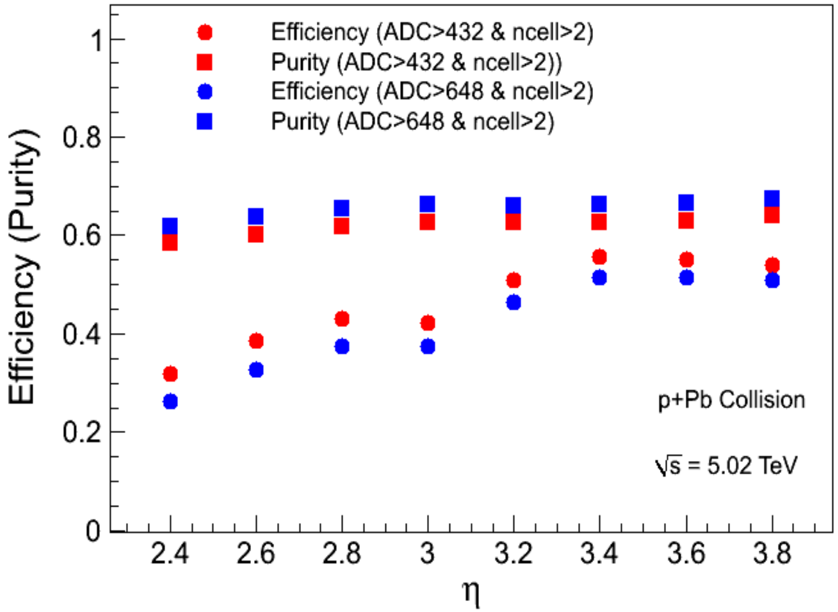


From the experiment we have $N_{\gamma\text{-like}}$ which is corrected using simulation and we get

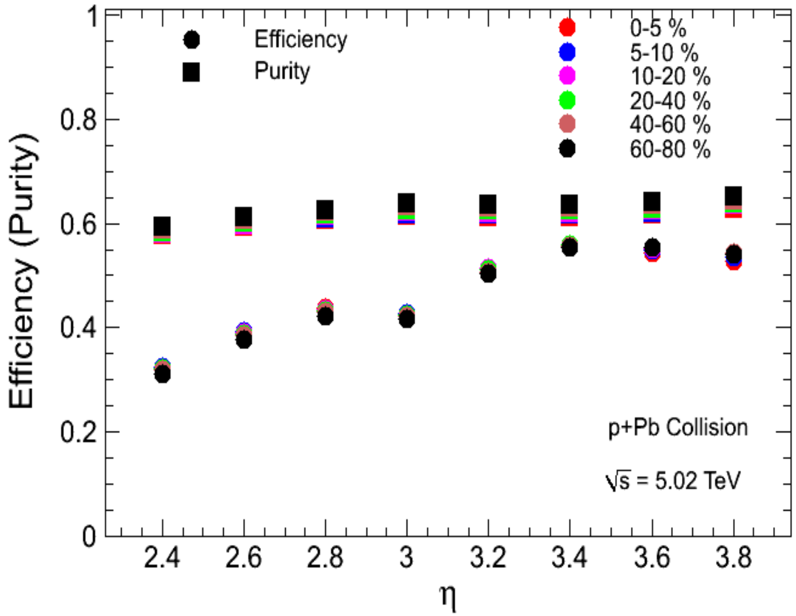
$$N_{\gamma} = N_{\gamma\text{-like}}(\text{data}) \times (\text{purity}/\text{Efficiency})$$

Efficiency Purity

Minimum bias



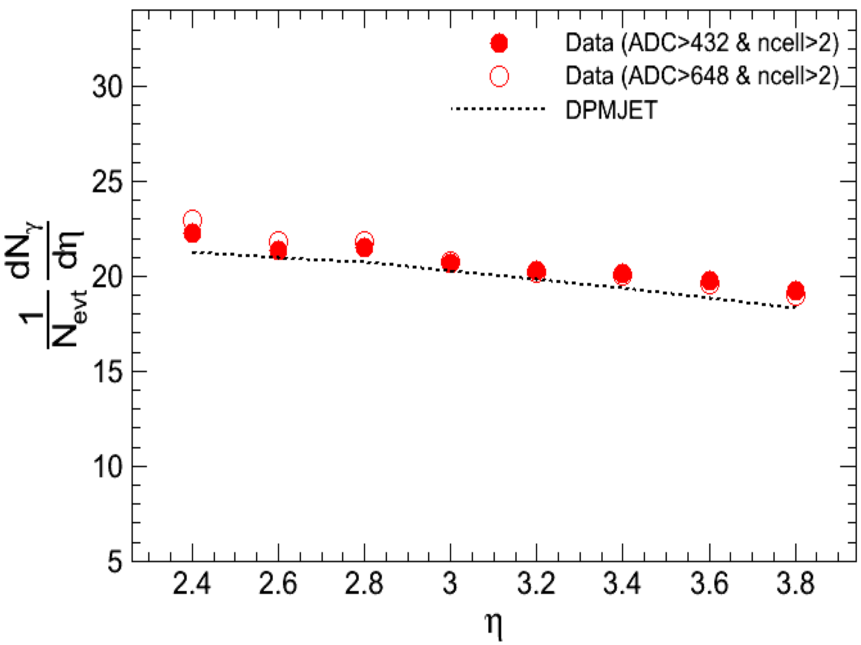
Different centrality classes



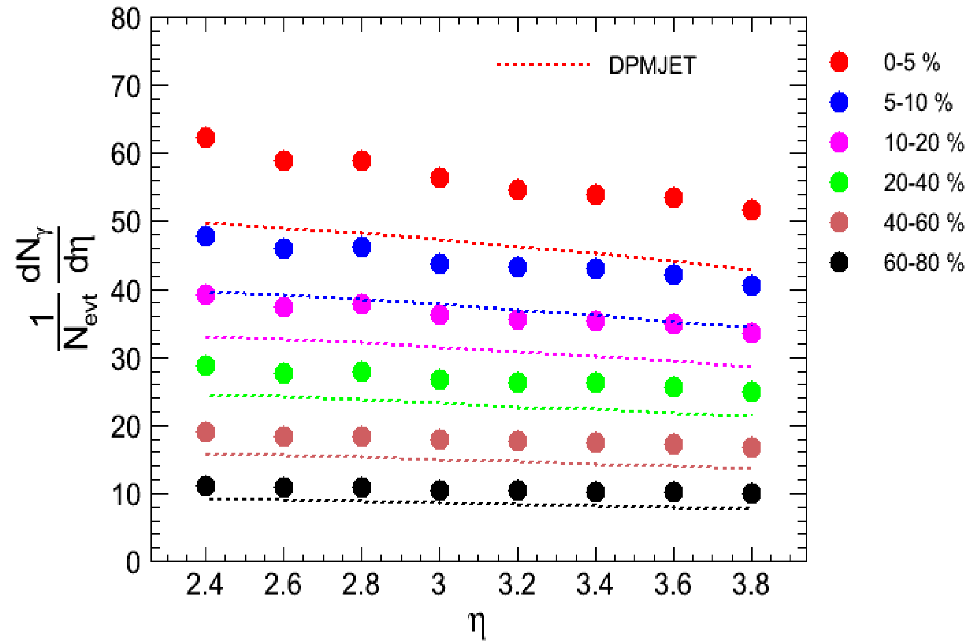
- Acceptance is folded in the efficiency and purity
- Efficiency and purity are centrality independent.

Pseudorapidity distribution of photons p+Pb at 5.02 TeV

Minimum Bias

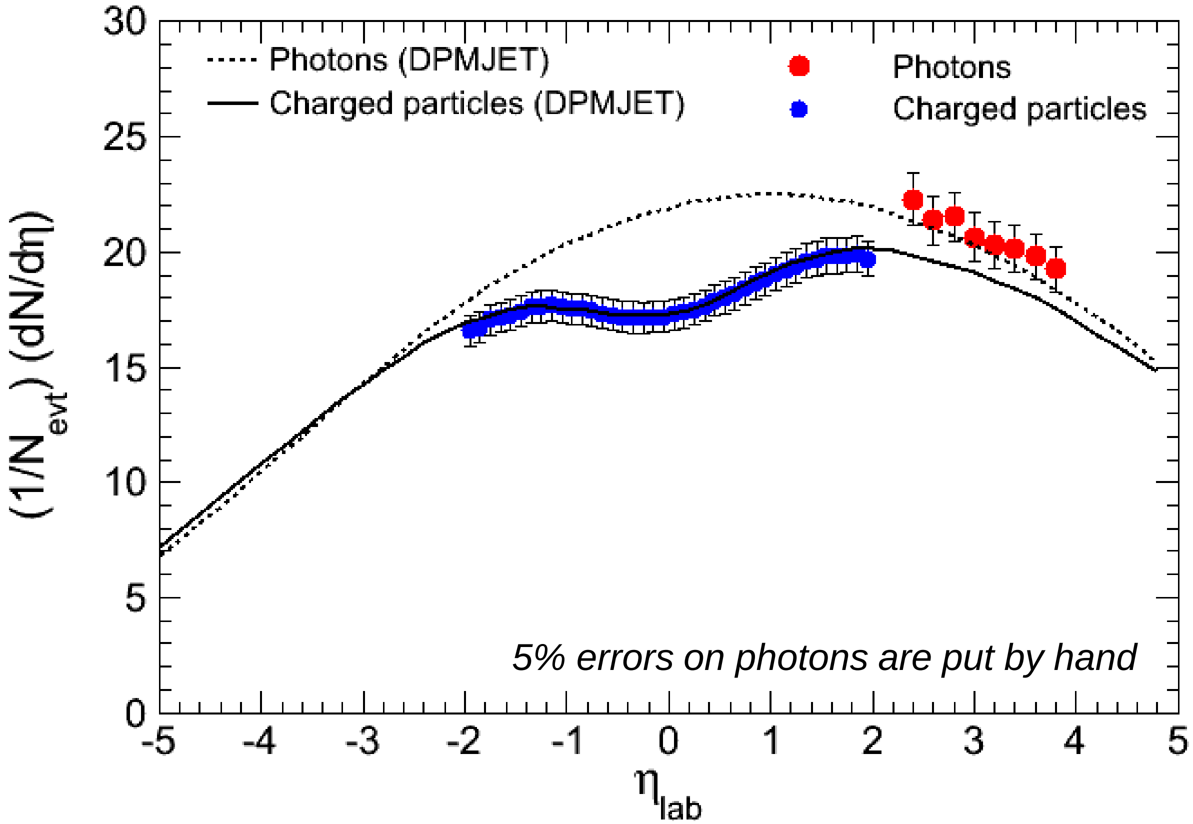


Different centrality classes



- DPMJET is closer the data for minimum bias
- DPMJET does not explain data for higher centrality classes

Comparison with charged particle production



- Results are compared to charged particle production in central rapidity (-2<η<2) region. and it is found that photon production is seems to be higher than that of charged particles productions
- Similar behavior is found in DPMJET also.

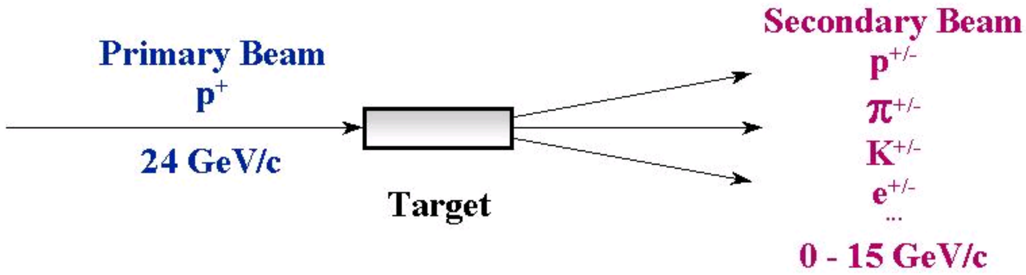
Summary

- **Photon Multiplicity Measurement (2.3<η<3.9) in p-Pb collisions**
  - Obtained the photon multiplicity and eta distributions for p-Pb collisions
  - DPMJET describes the data for MB events but under-predict the data at different centrality classes.

Back up

Update: 19/01/1998

Production of Secondary Beams



List of targets available for beams T9, T10, T11 (common target)

1	ZnS	Screen
2	Cu	Ø 4x25
3	Cu	Ø 4x50
4	Be	Ø 5x200 + W Ø 20x3 **
5	Al	Ø 5x150
6	Al	3x5x100 + W Ø 10x3 **
7	ZnS	screen
8	Cu	Ø 4x100
9	Al203	screen
10	Al	Ø 5x250 *
11	Al	Ø 5x200
12	Al	sheet Ø 80x1mm thick

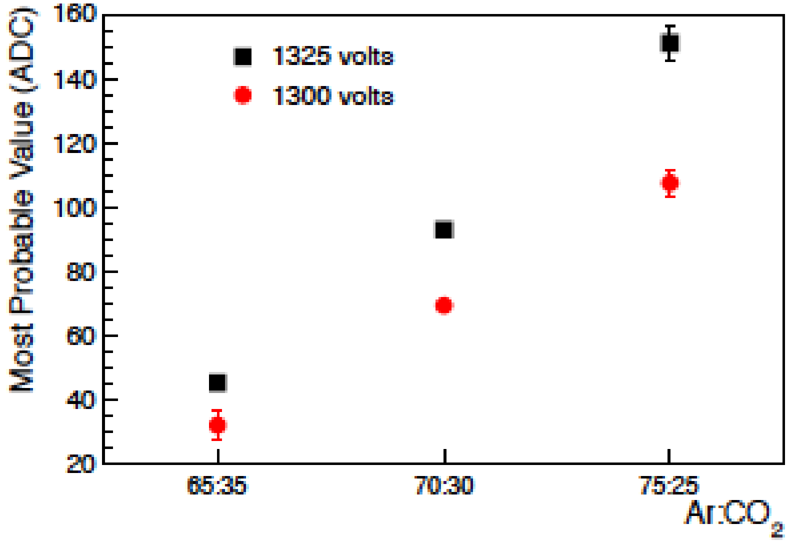
* normally used for maximum yield
** special targets : aluminium bar followed by a tungsten converter (more electrons)

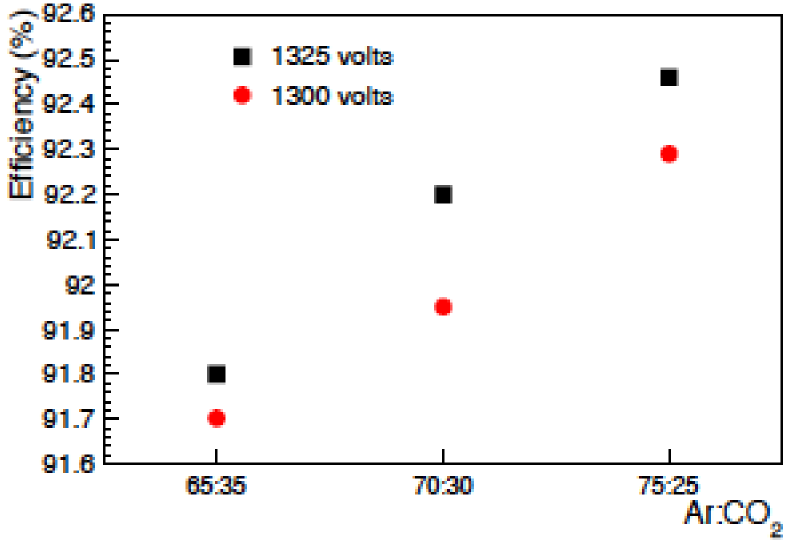
N.B. a) dimensions are in mm
Ø 5x150 = diameter 5 mm
= length 150 mm
3x5x200 = vertical 3mm, horizontal 5 mm, length 200 mm
b) Control of the targets : PS Main Control Room (MCR, Tel. 76677).

From PS/PA Note 93-21 D.J. Simon, L. Durieu

B08 J.-P. Riunaud PS/CA

Gas mixture study

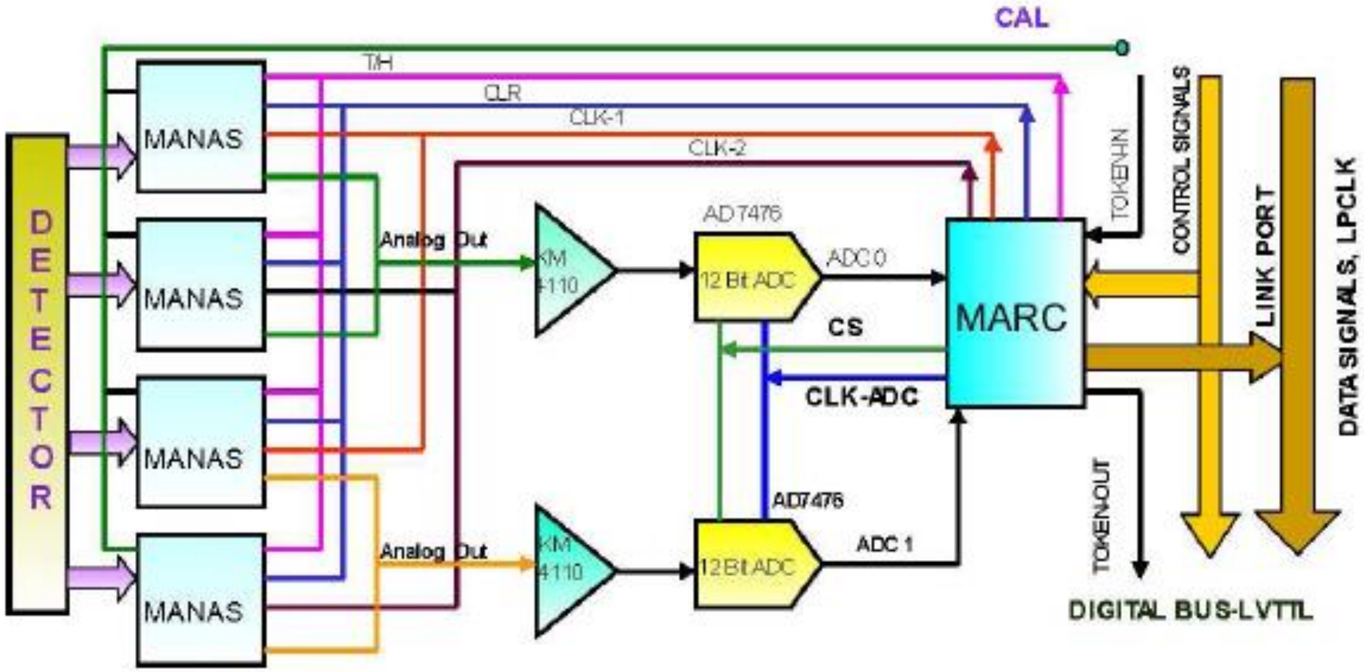


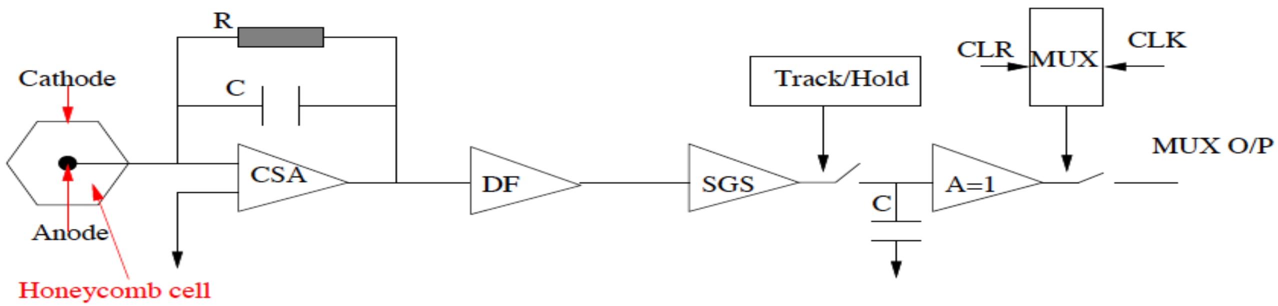


- MPV values are increasing with increasing the content of Ar gas as well as Operating voltage. But at the higher operating voltage and But the increasing of Ar content causes the increasing of spark rate.

- Efficiency is almost constant around 92% for all the cases.

Electronics

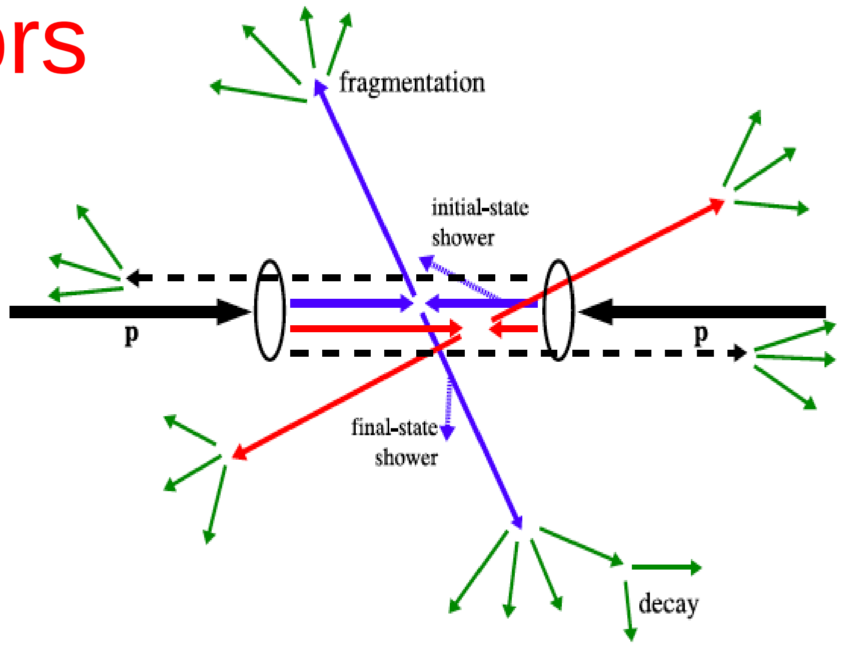




ADC saturation

- MANAS chip has an input internal calibration capacitance of 0.2 pf (pico Farad) capacitance.
- When we give input signal of "Y" mV (milli Volt). The total charge is given as Q = CV = 0.2 * Y fC (femto Coulomb).
- The gain of MANAS is 3.27 mV/fC.
- So the output signal in terms of mV will be 0.2 * Y * 3.27 mV
- We are using an ADC which has 4096 channels. This corresponds to 2.5 Volts or 2500 mV.
- This implies 1 channel corresponds to 0.6 mV.
- So the output in terms of ADC units one expects to get when an input signal is Y mV is (0.2 * Y * 3.27) / 0.6 ADC units .

Event Generators



Pythia

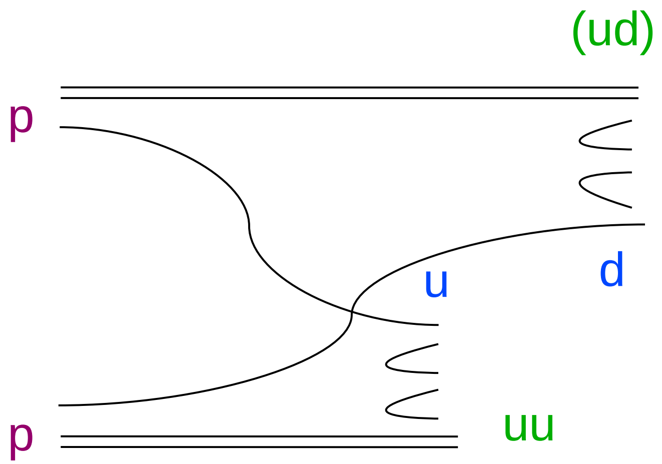
Pythia is an event generator that combines perturbative QCD and mostly phenomenologically motivated models.

Particle production through the description of possible hard interactions in $e^+ + e^-$, p+p(pbar), or e+p colliders

Pythia implements the so-called Lund-model for fragmentation process.

Phojet

The event generator Phojet is based on a two-component approach that describes high-energy collisions with a soft and a hard component.
The ideas of the Dual Parton Model are employed for the soft component.
The hard component is calculated by perturbative QCD like in Pythia.



Unfolding Method

To get correct Photon multiplicity

The true distribution $\hat{f}$ is corrupted by detector effects, described by a response Function, A. So the measured distribution $\hat{g}$ becomes,

$$\hat{g} = A\hat{f}$$

From detector we get only measured multiplicity $\hat{g}$

$$\hat{f} = A^{-1}\hat{g}$$

Determination of the true distribution $\hat{f}$ from the measured distribution $\hat{g}$ is called Unfolding .

In matrix notation,

$$f_i = \sum_j A_{ij}^{-1} g_j \Rightarrow \begin{pmatrix} f_1 \\ f_2 \\ .. \\ f_n \end{pmatrix} = \begin{pmatrix} A_{11} & A_{12} & .. & A_{1n} \\ A_{21} & .. & .. & .. \\ .. & .. & .. & .. \\ A_{m1} & A_{m2} & .. & A_{mn} \end{pmatrix}^{-1} \times \begin{pmatrix} g_1 \\ g_2 \\ .. \\ g_m \end{pmatrix}$$

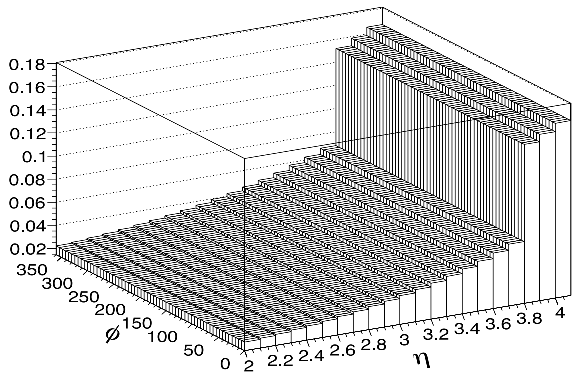
This matrix inversion can give large oscillation in result, because events with a given true multiplicity are smeared over a range of multiplicities in the observed distribution.

Regularization is needed to suppress the oscillation in the final result.

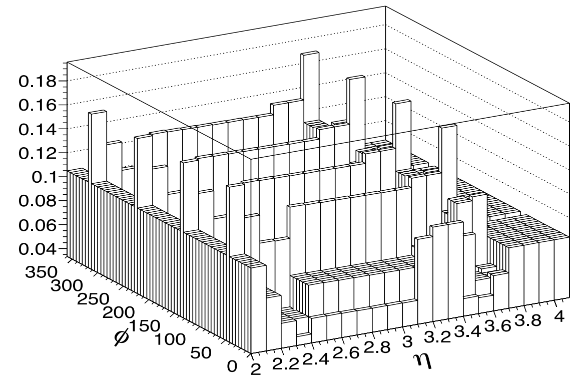
Upstream material in front of PMD

AliRoot v4-21-25-AN
Z = 360 cm ,δη = 0.1, δϕ = 6 degree

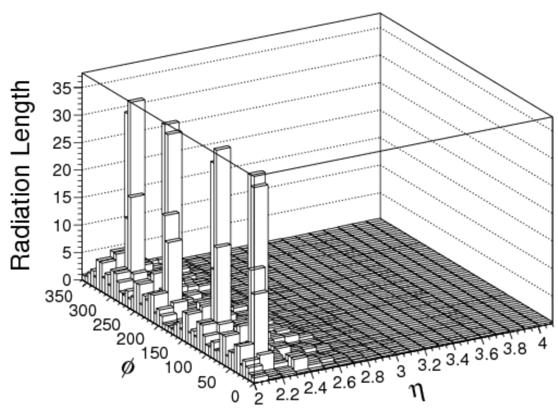
Beam pipe



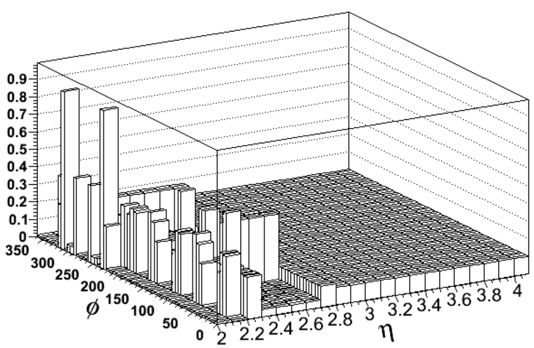
FMD (2.28 < η < 3.68)



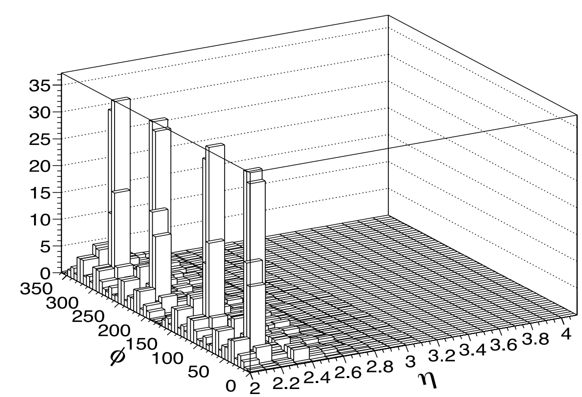
All detectors



V0 (2.8 < η < 5.1)

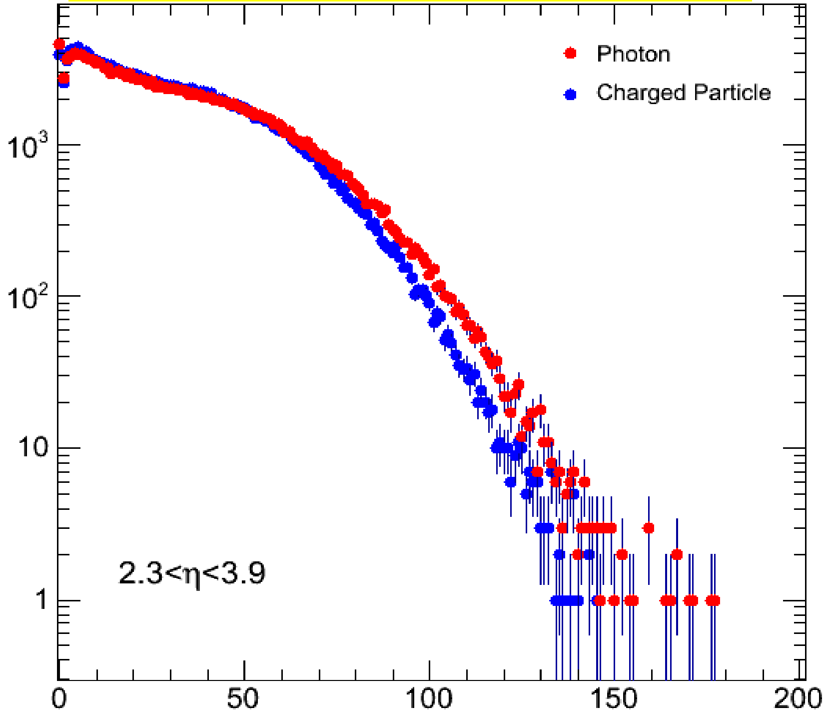


ITS(2.8 < η < 5.1**)**

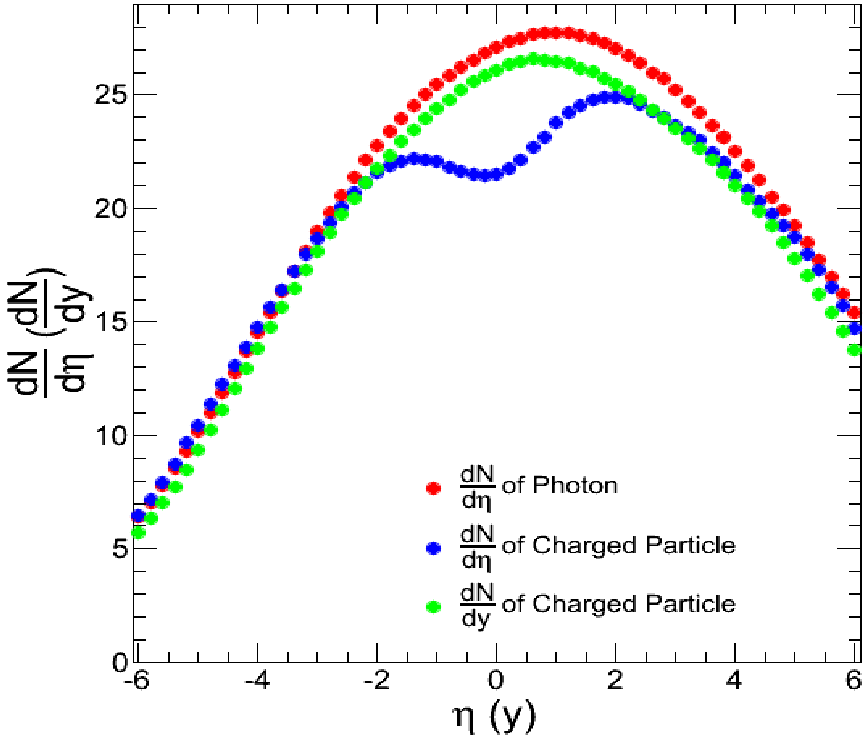


Expectation from DPMJET

Multiplicity distribution of photons

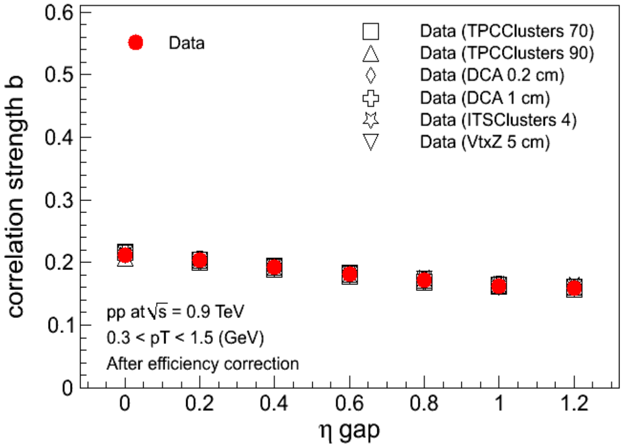


Pseudorapidity distribution of photons

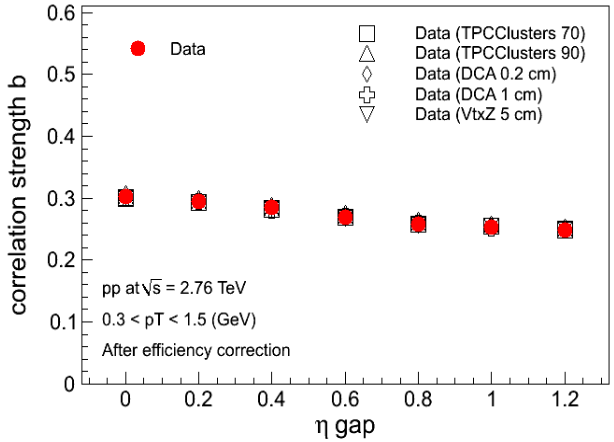


Systematic errors

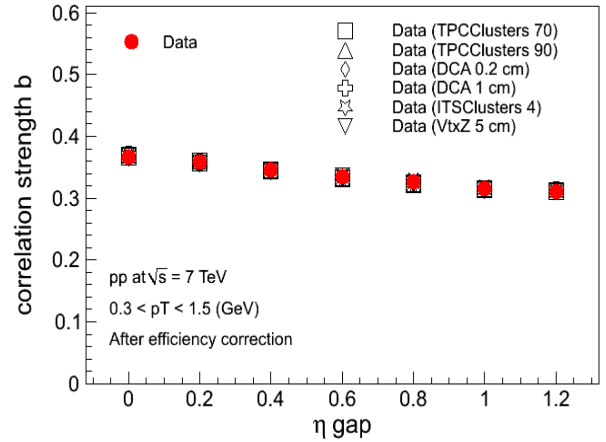
0.9 TeV



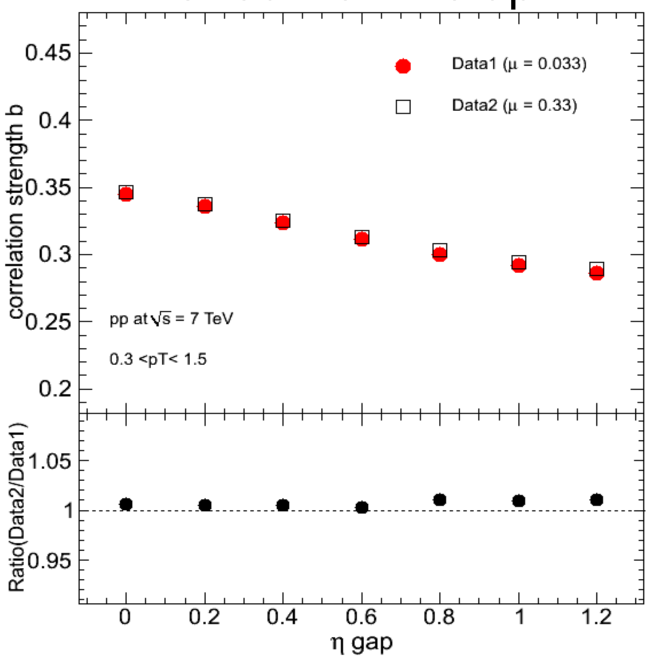
2.76 TeV



7 TeV



Check for Pile up



Sources	0.9 TeV	2.76 TeV	7 teV
TPC clusters	0.5-3.0%	0.01-0.13%	0.2-0.7%
ITS clusters	0.6-1.9%	–	0.15-1.4%
DCA	3.0-4.0%	0.98-1.8%	0.1-0.98%
VertexZ	0.2-1.1%	0.016-1%	0.015-0.7%
Method	2.5-4%	2.2-4.2%	1.6-2.8%
Pile Up	< 1%	< 1%	<1%
Total	3.4-4.5%	2.8-4.2%	2.0-3.0%

Motivation

The basic motivations of the test beam experiment are as follows:

- To understand the response of the charged hadrons to the detector.
- optimizing the thickness of the Pb converter to minimize the overlap of trans-verse showers
- To get the calibration relation between the energy deposition from simulation (in keV) and digitized electronic signal (in ADC) from real data
- To check the performance of the integrated electronics and Data AcQuisition (DAQ) of the PMD
- To optimize the detector parameters like operating voltage, gas mixture ratio etc.

- Multiplicity and pseudorapidity distribution of photons at forward rapidities are presented in p-p collisions at $\sqrt{s}$ = 2.76 and 7 TeV.
- Both models under-predict the data at $\sqrt{s}$ = 2.76 and 7 TeV.
- N_γ distributions are fitted with both single NBD and double NBD functions.
- $\langle N_\gamma \rangle$ grows as $\ln\sqrt{s}$ as well as the power law.
- Limiting fragmentation behavior of N_γ is studied and compared with PHOJET event generators.