Photon-Hadron Discrimination in PMD using Machine Learning

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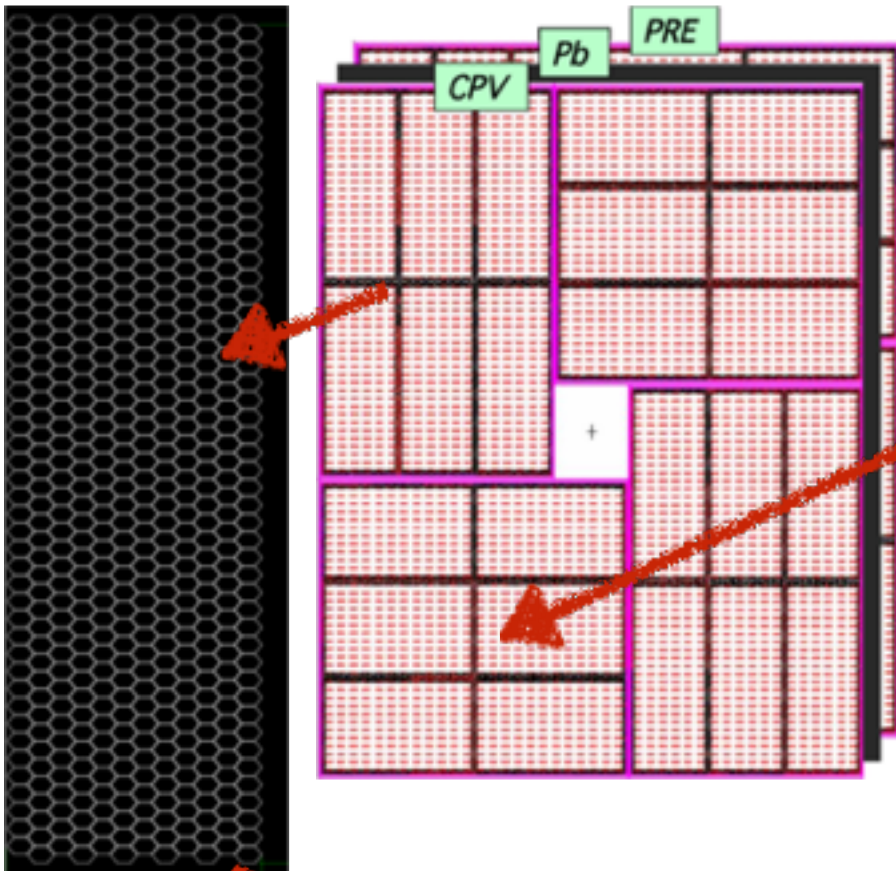
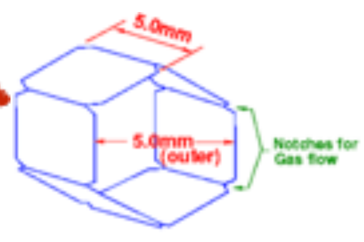
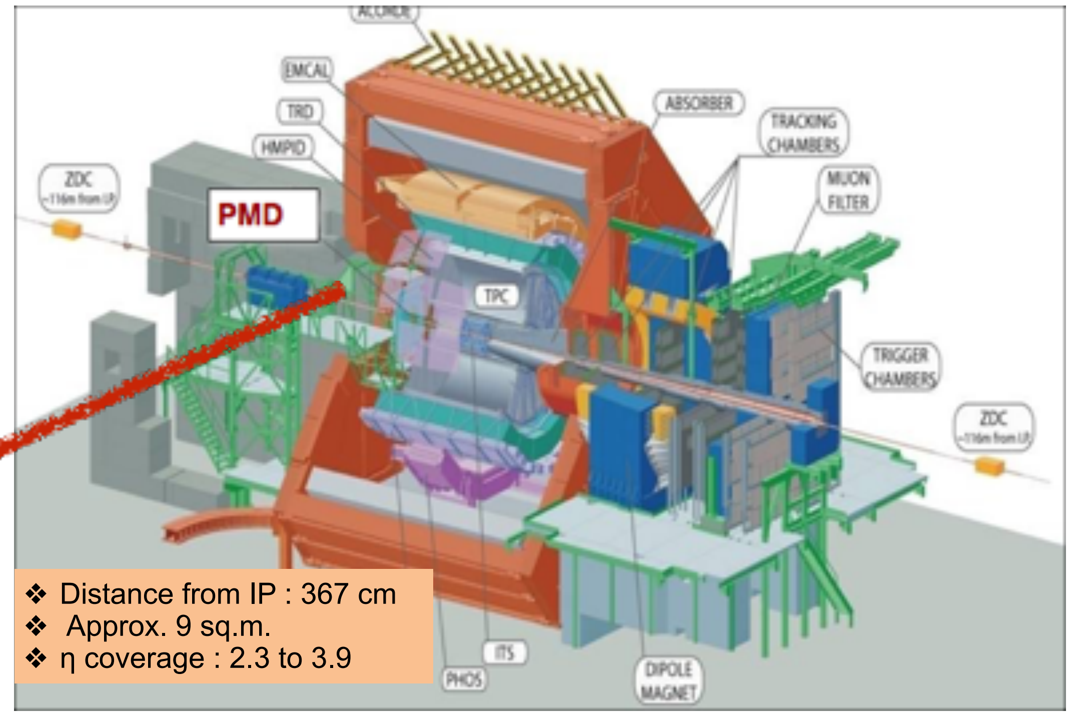
PMD Description and its position





Honeycomb chamber
(48×96 cells)



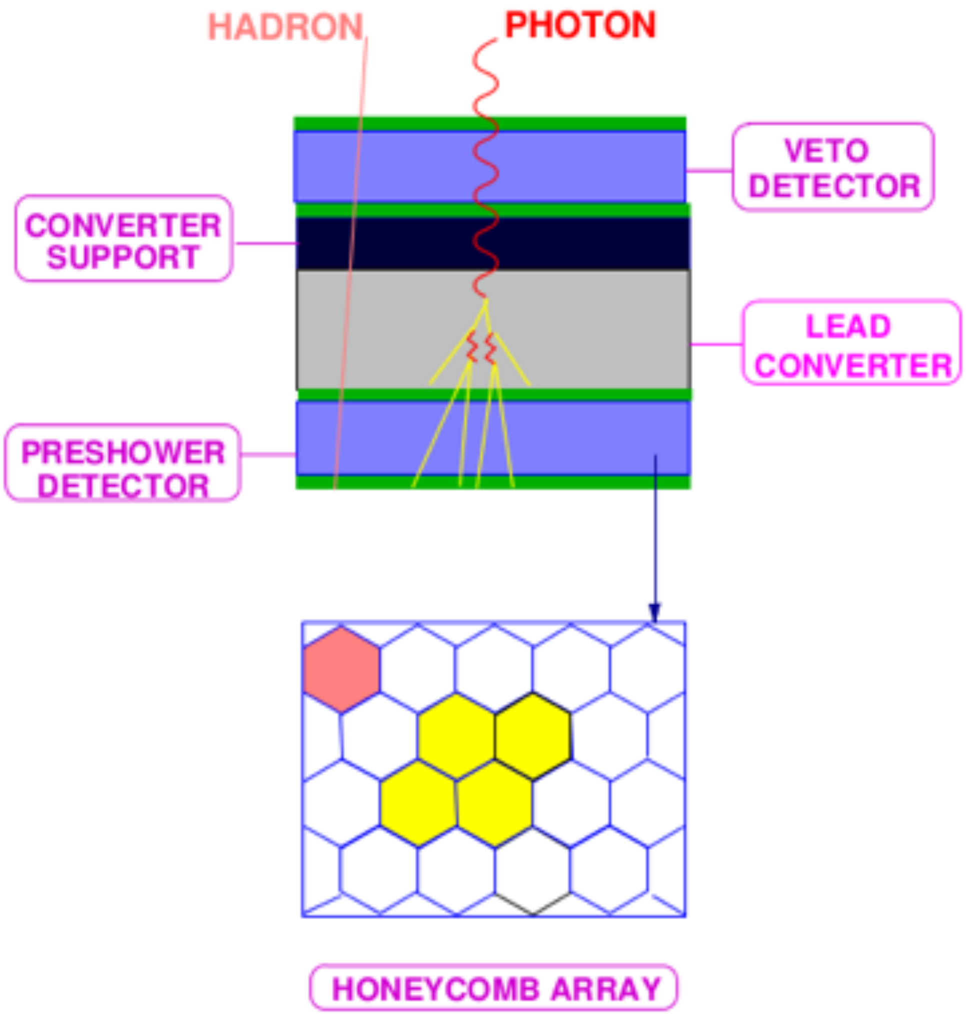
❖ Distance from IP : 367 cm
❖ Approx. 9 sq.m.
❖ η coverage : 2.3 to 3.9

PMD can measure:
- Event-by-event number of photons production
- Spatial distribution of photons (η, φ)

Other Capabilities:
- Pseudo-rapidity density
- Fluctuation in the ratio of N_γ/N_{ch} in same coverage PMD & FMD
- Azimuthal anisotropy and event plane determination
- Charged particle multiplicity

Has two layers of detectors with a similar honeycomb structure – CPV and PS, separated by ~ 3 radiation length lead plate.

Design principle



The hadrons pass through and give single hits in both the planes.

The photons shower in the lead plate and give multiple hits in the PS plane.

The hits have to be clustered for tracking to be possible.

Particle/Detector	CPV	PS
Photon	No	Yes
Charged Hadron	Yes	Yes
Variables	# of Cells	# of Cells
	Energy Deposited	Energy Deposited

Current measurement and possible improvement !!

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THE EUROPEAN PHYSICAL JOURNAL C

Regular Article - Experimental Physics

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

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CERN, 1211 Geneva 23, Switzerland

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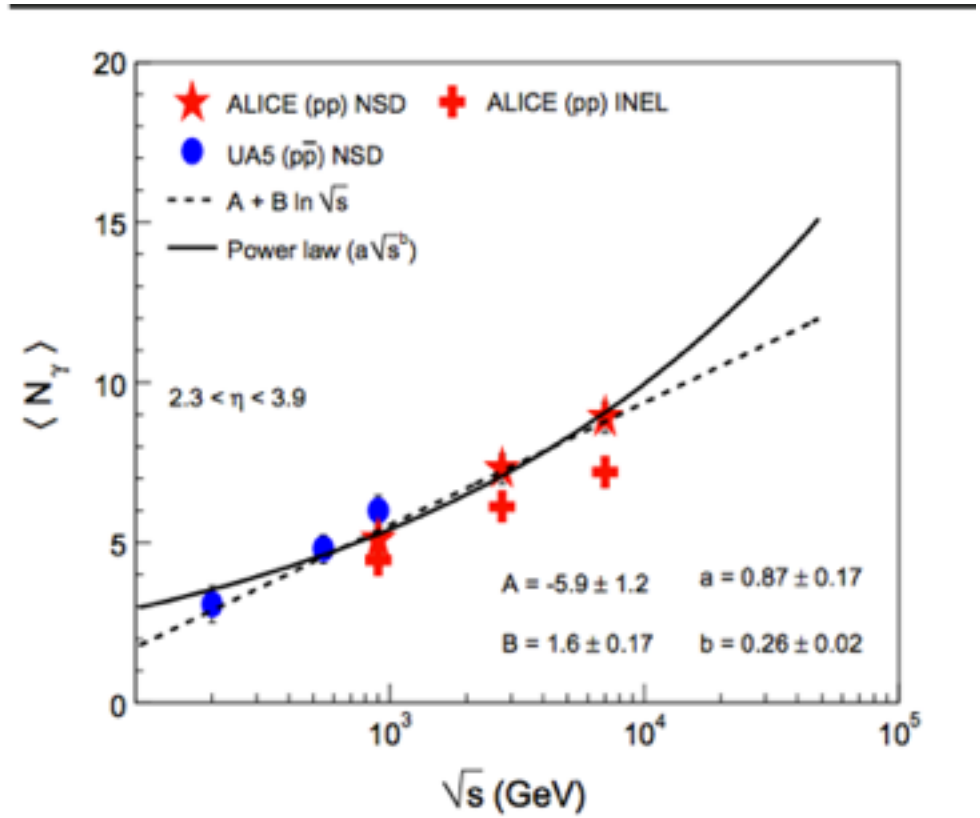
Abstract The multiplicity and pseudorapidity distributions of inclusive photons have been measured at forward rapidities ($2.3 < \eta < 3.9$) in proton-proton collisions at three center-of-mass energies, $\sqrt{s}$ = 0.9, 2.76 and 7 TeV using the ALICE detector. It is observed that the increase in the average photon multiplicity as a function of beam energy is compatible with both a logarithmic and a power-law dependence. The relative increase in average photon multiplicity produced in inelastic pp collisions at 2.76 and 7 TeV center-of-mass energies with respect to 0.9 TeV are 37.2 ± 0.3 % (stat) ± 8.8 % (sys) and 61.2 ± 0.3 % (stat) ± 7.6 % (sys), respectively. The photon multiplicity distributions for all center-of-mass energies are well described by negative binomial distributions. The multiplicity distributions are also presented in terms of KNO variables. The results are compared to model predictions, which are found in general to underestimate the data at large photon multiplicities, in particular at the highest center-of-mass energy. Limiting fragmentation behavior of photons has been explored with the data, but is not observed in the measured pseudorapidity range.

ticles as the majority of the photons are decay products of neutral pions. Measurements at forward rapidities enable an extension of the study of particle production mechanisms carried out at mid-rapidities.

In the present work, we report the measurement of inclusive photon production in the forward pseudorapidity region, $2.3 < \eta < 3.9$, for pp collisions at $\sqrt{s}$ = 0.9, 2.76 and 7 TeV, with the ALICE detector. Multiplicity and spatial distribution of photons are measured on an event-by-event basis by the Photon Multiplicity Detector (PMD), which exploits the pre-shower photon measurement technique. We present the beam-energy dependence of the average photon multiplicity and pseudorapidity distributions of photons. The pseudorapidity distributions, plotted with respect to the corresponding beam rapidities, are used to test the predictions of the limiting fragmentation behavior [7]. The results are compared to different tunings of PYTHIA [8] and PHOJET [9,10] models.

This paper is organized as follows. Section 2 describes the experimental setup for the measurement of photons using the PMD. Event selection and trigger settings are discussed in



… To enrich the photon samples in the data, suitable photon-hadron discrimination thresholds on the number of hit cells and on the energy deposited in clusters, have been applied…

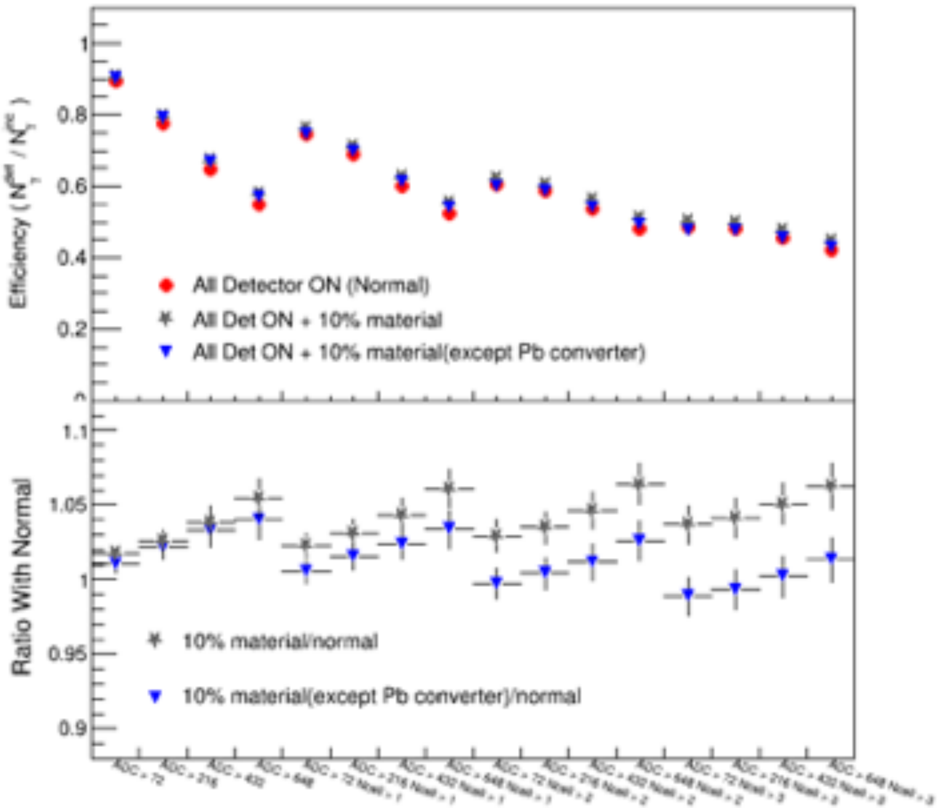
Photon reconstruction

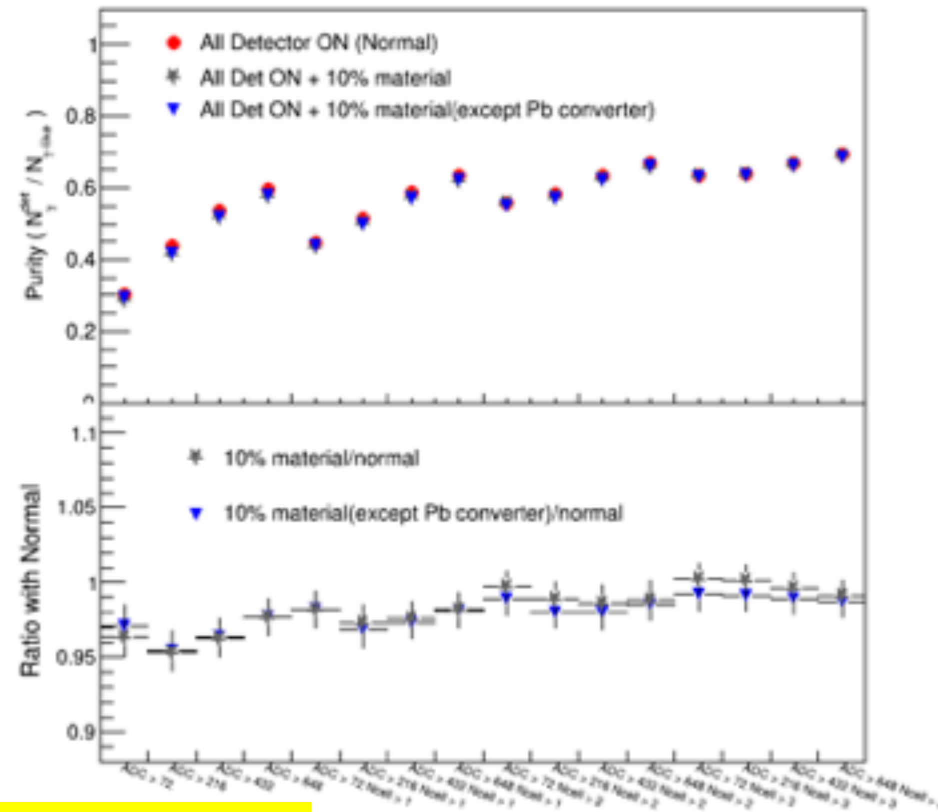
For the present pp data (cut based analysis): CPV was not used.

$$Efficiency = \frac{N_\gamma(detected)}{N_\gamma(incident)} \qquad Purity = \frac{N_\gamma(detected)}{N_\gamma(like)}$$

Current measurement and possible improvement !!

.. so observed values for the efficiency and purity for photon sample in pp collision @ 900 GeV ~ 60%





https://aliceinfo.cern.ch/Notes/node/149

It could be as low as 50% (earlier simulation predictions) for higher center of mass energies pp collisions (lower for pA and AA collisions).

Photon reconstruction w/ TMVA ?

- Use TMVA tools in Photon hadrons discrimination instead of cutting ADC and nCell.
- Use additional PMD CPV information for the hadrons (charge particle): better discrimination ?
- Improvement in efficiency and purity ?

Inputs needed for the PMD-TMVA Analysis

For this we basically require most sensitive parameters of PMD tracks that could be used to teach the machine how to discriminate photons and hadrons.

They have to be correlated

Choose ADC and nCell value of each PMD track in CPV and PS (4 parameters).

BUT PROBLEM !! PMD track information is written separately for the CPV and the PS. So we don't have all 4 correlated parameter of each track..

Solutions ? Track Matching

Matching of CPV and PS tracks by Track radius or other method

Two obtain correlated hits the radius of the centroid of cluster in the PS plane was obtained using $r = \sqrt{x^2 + y^2}$

Any CPV hit lying in a window of (r ± 0.75) is chosen as correlated hit

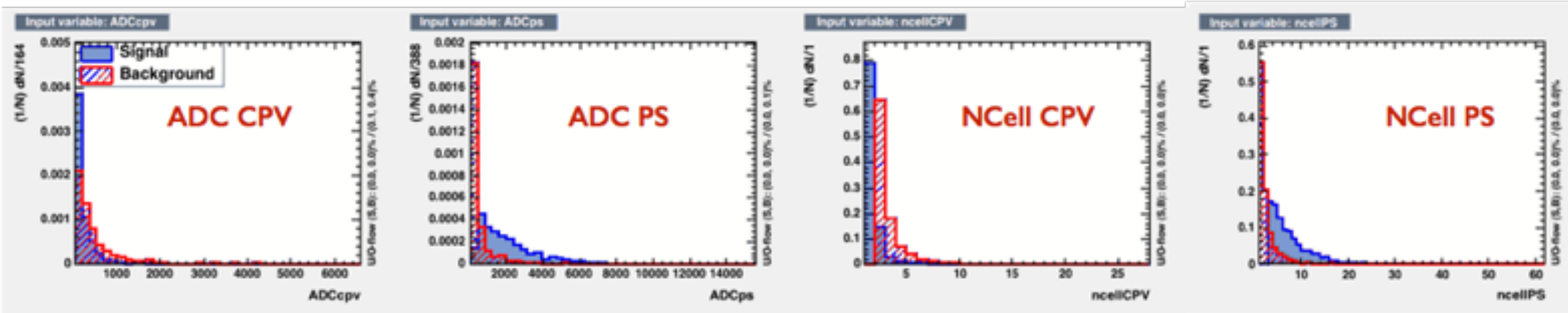
Check this using the information from kinematics.root and AliESDs.root trackID & trackPID. Presently for hadrons even that is not available for PMD

Assume that our procedure is correct & Proceed

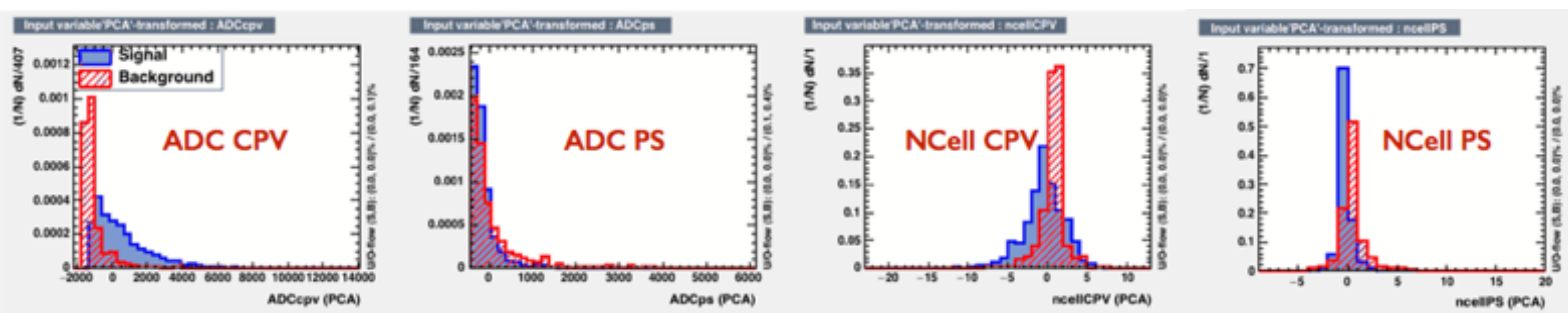
An attempt with pp @ 7 TeV:

Machines was trained using different algorithms (SVM, ANN and BDT) throwing $\pi^+, \pi^- \& \gamma$ one at a time

Four variables as seen by the detectors Charged pions (background) Photons (Signal)



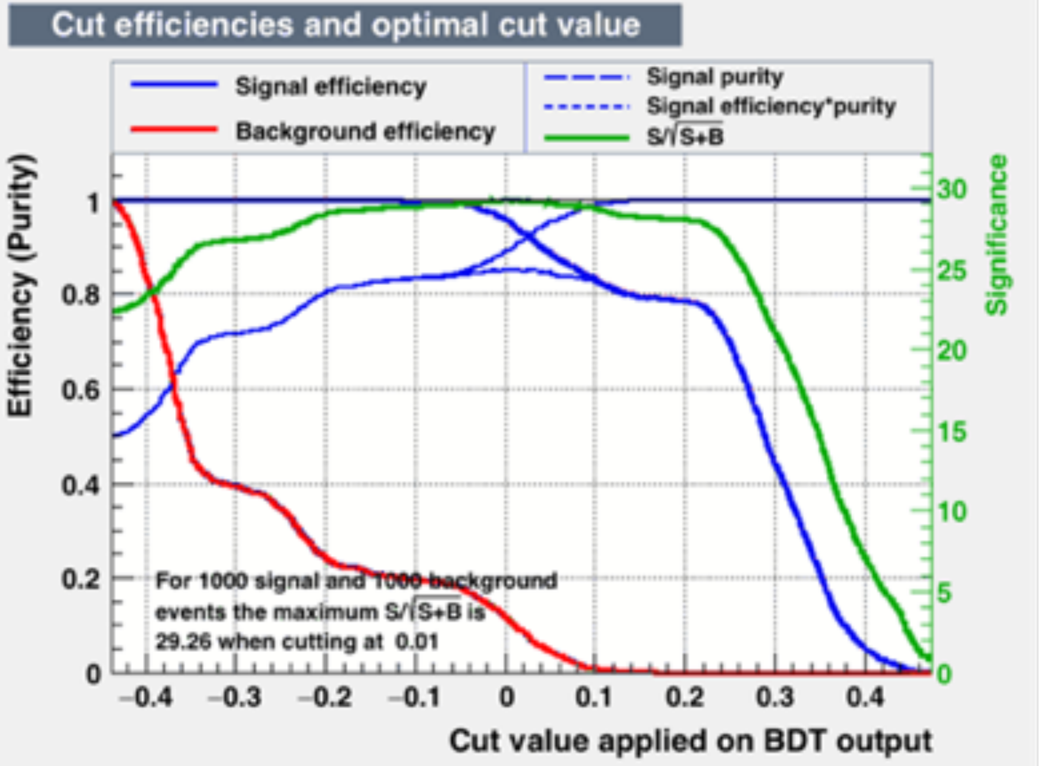
Same Variables after Principal Component Analysis

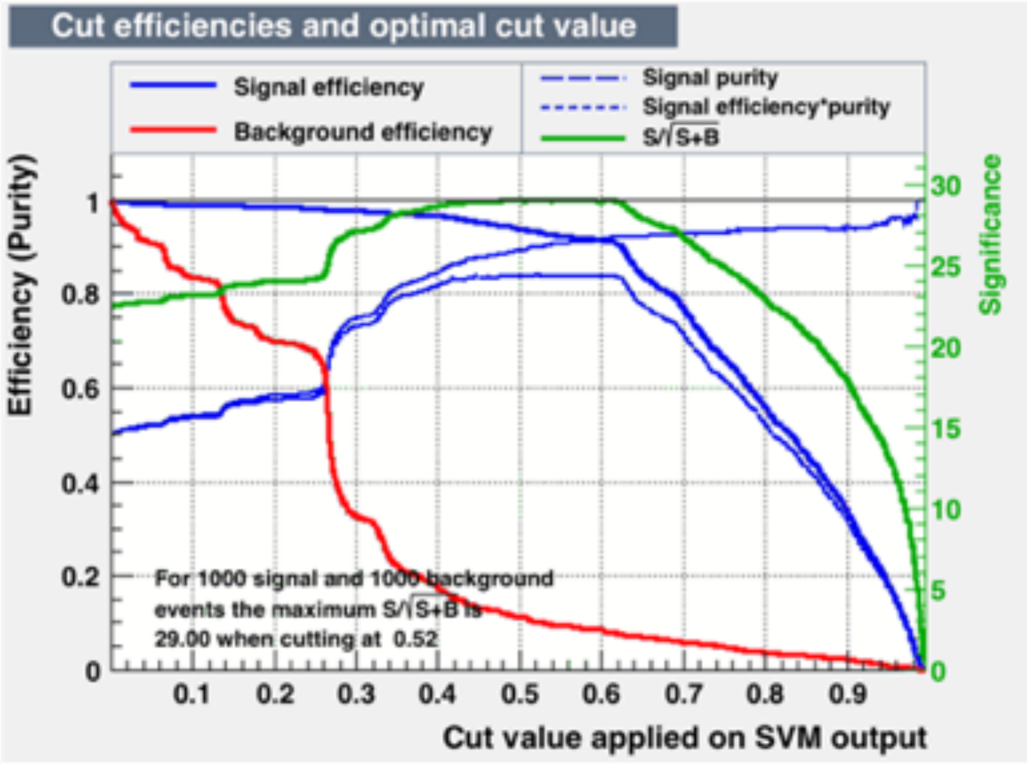


CPV a better discriminator than PS ??

Photon Hadron Classification using TMVA

Correlated Signal (photon) and Bkg (charged particle) information extracted on the basis of R matching
Matching training and classification has been performed for the BDT, SVM and MLP methods.



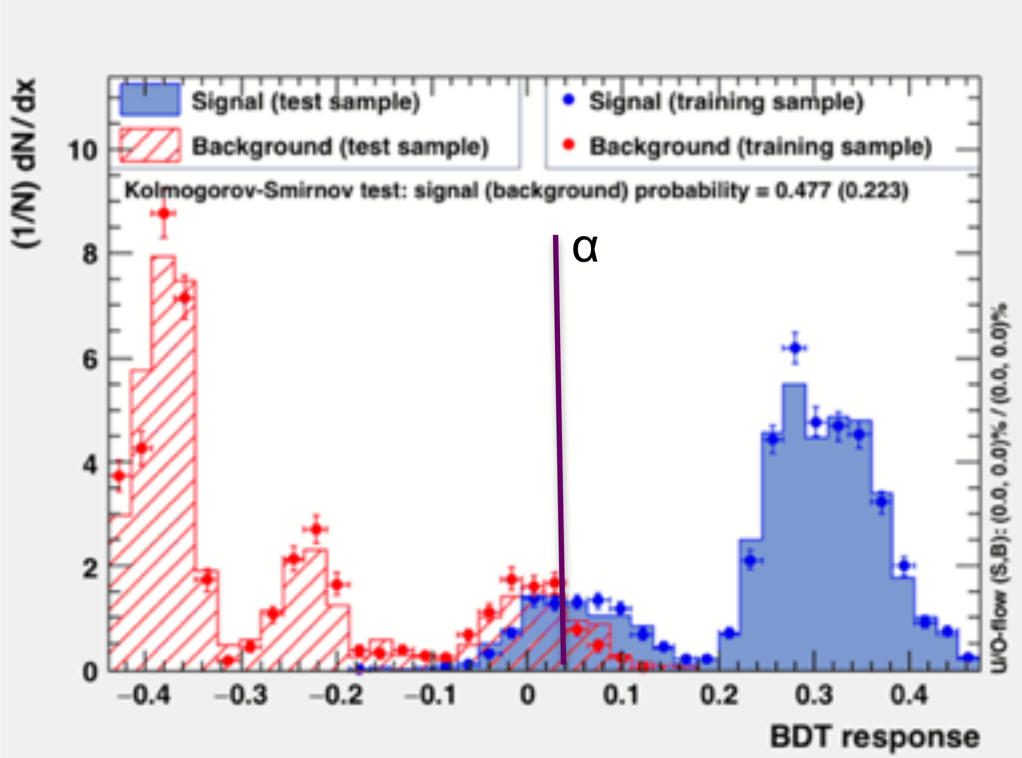


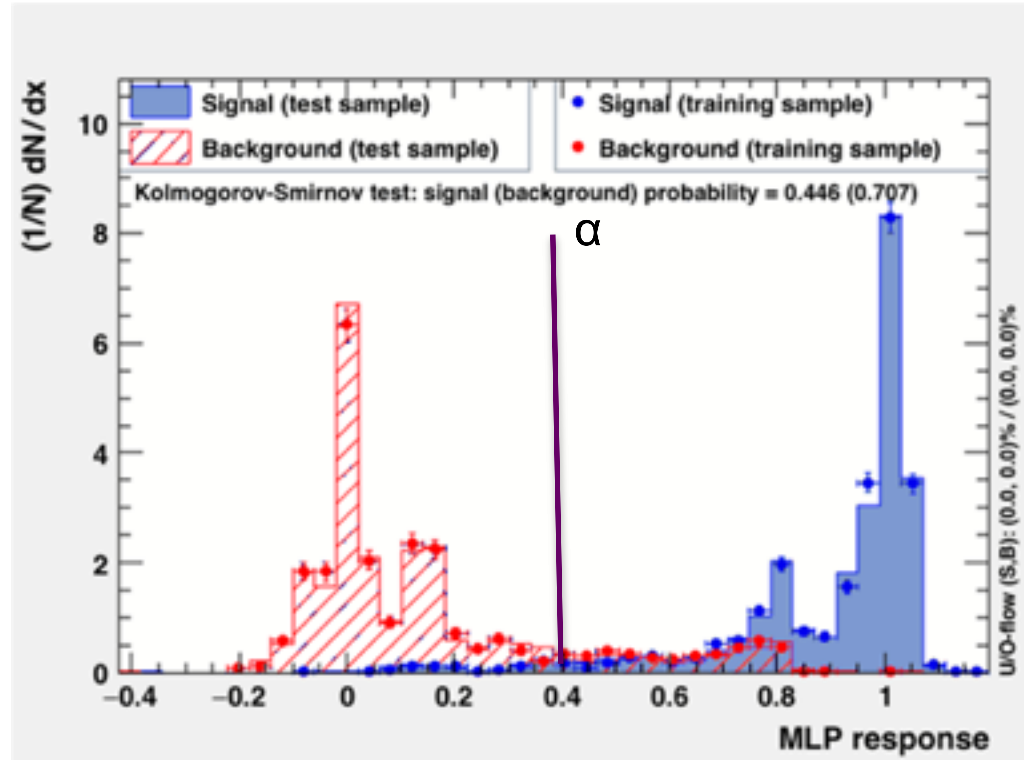
Nice improvement of efficiency & purity of (~90%)

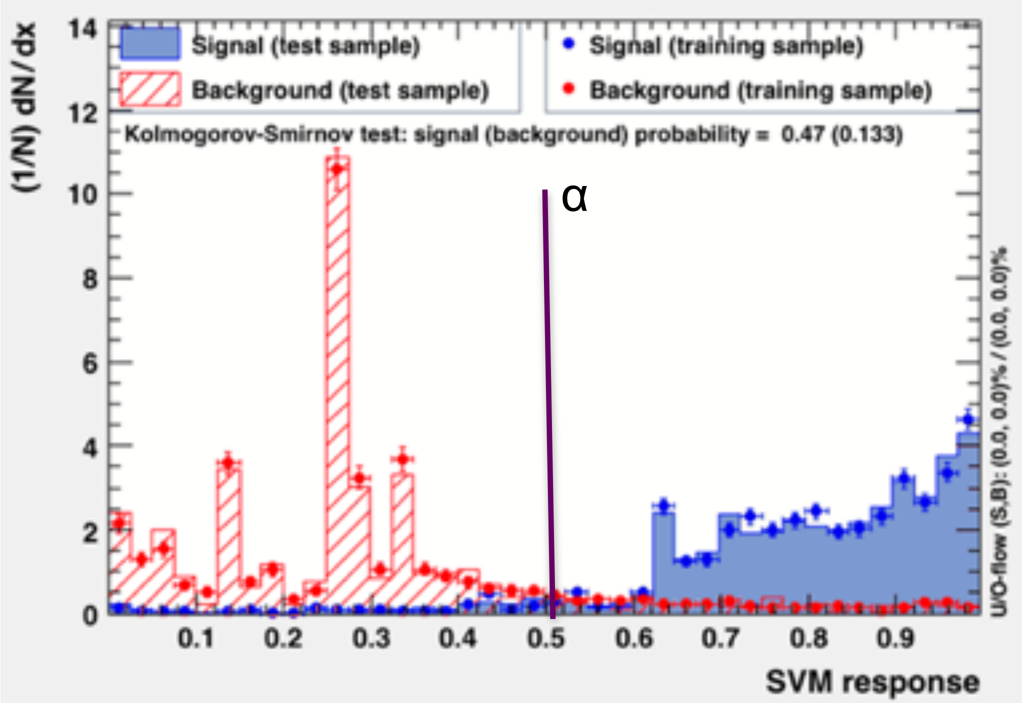
Started to compare the numbers of single w/ and w/o TMVA (cut based analysis)

Coupled Aliroot to TMVA output and wanted the code used for cut based analysis But could not get

Parameter Needed for Photon Hadron Discrimination







This is the parameter we need to classify photons and hadrons

Has been coupled with the regular analysis

Based on this MLP is the best algorithm for classification

Clustering in PMD

However, visually looking at the cluster hits in CPV & PS we found that we could often Correlate TWO, sometimes THREE and sometimes even FOUR clusters with one cluster in PS

One way to check which was true or falsely correlated hits would be to check the cluster PID. But the PMD software does not pass on the cluster PID information to AliESDs.root for charged hadrons.

Our Discrimination is going to be as good as the correlated hits. We need one-one correlation.

Throw one particle at a time and see if there is one cluster in CPV and PS. Even then there were on an average three clusters in both planes irrespective of whether it was photon or charged hadron

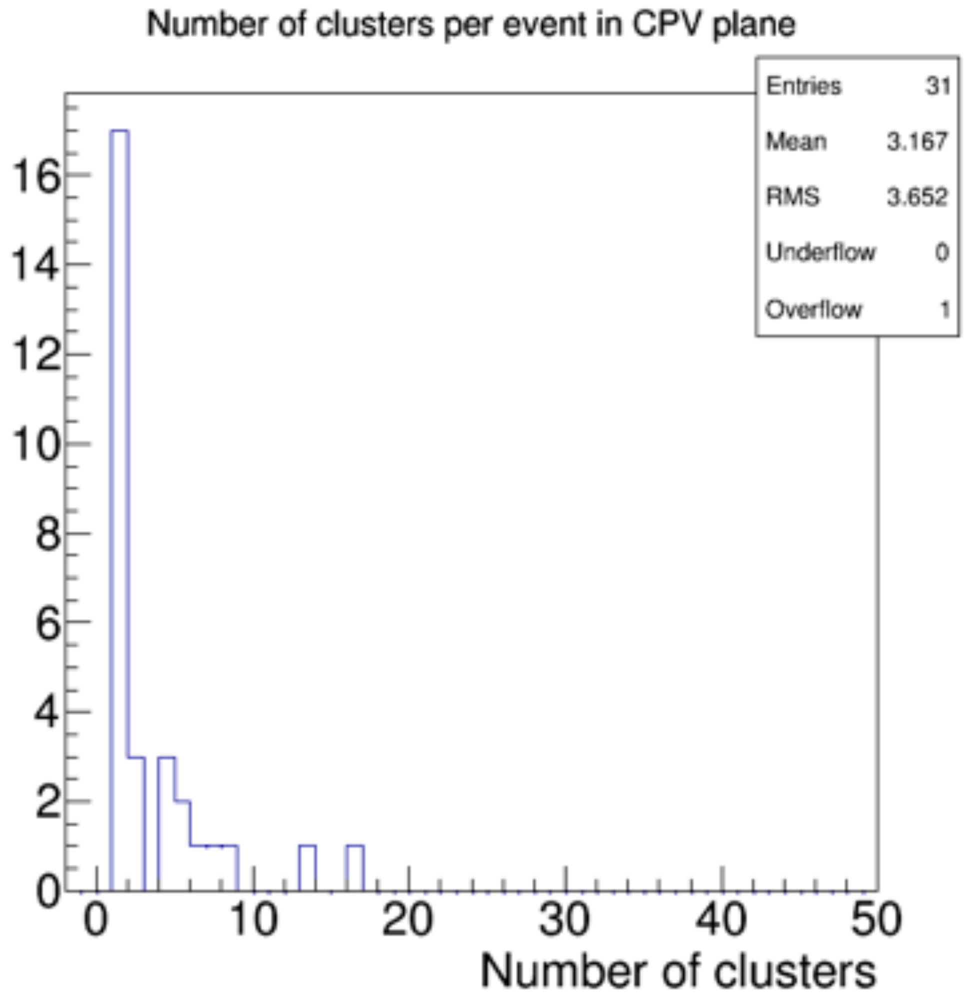
The current clustering is based on a nearest-neighbour algorithm. In the first pass a search is made for local maxima. After the search for all the maxima in the entire detector, the energy depositions in cells, which are common to more than one local maximum, are redistributed by assuming a Gaussian energy deposition profile.

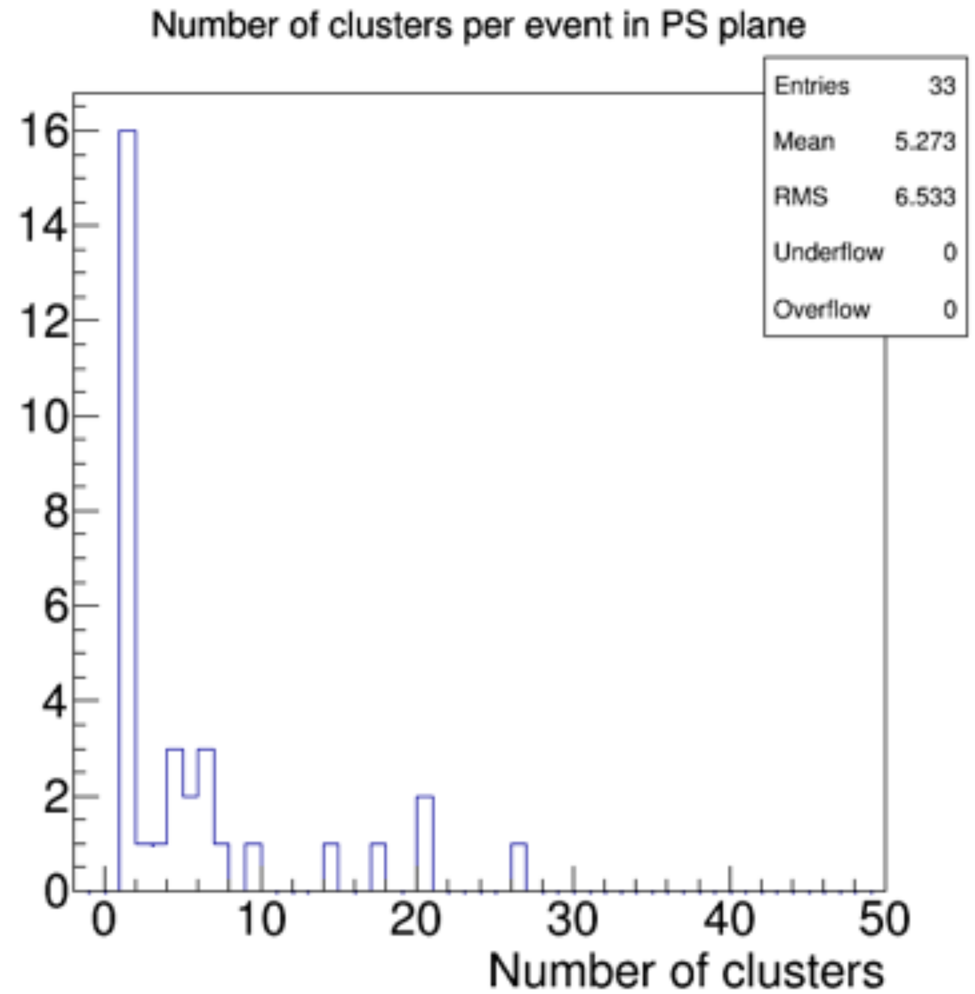
Results from the Current Algorithm

Particles incident one at a time

Incident Energy of particles used = 7 TeV

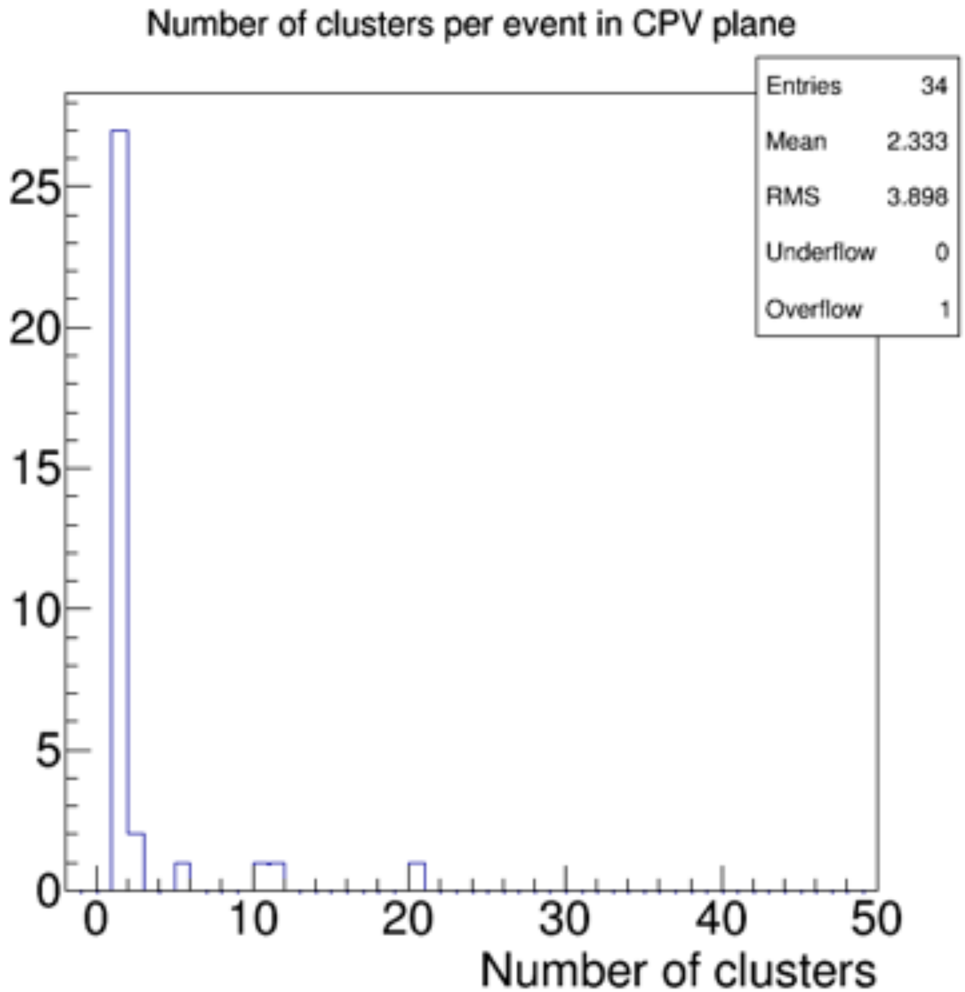
PiPlus

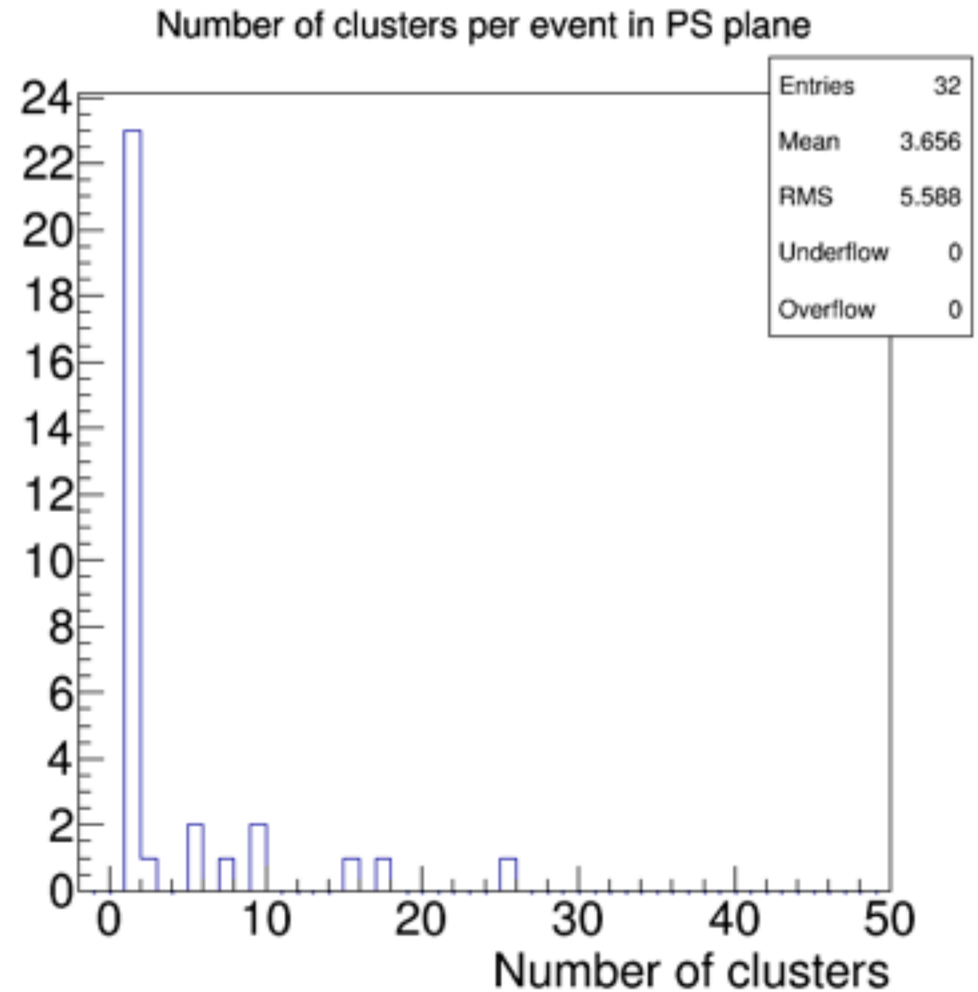




Note the number of entries in both the plots

PiMinus





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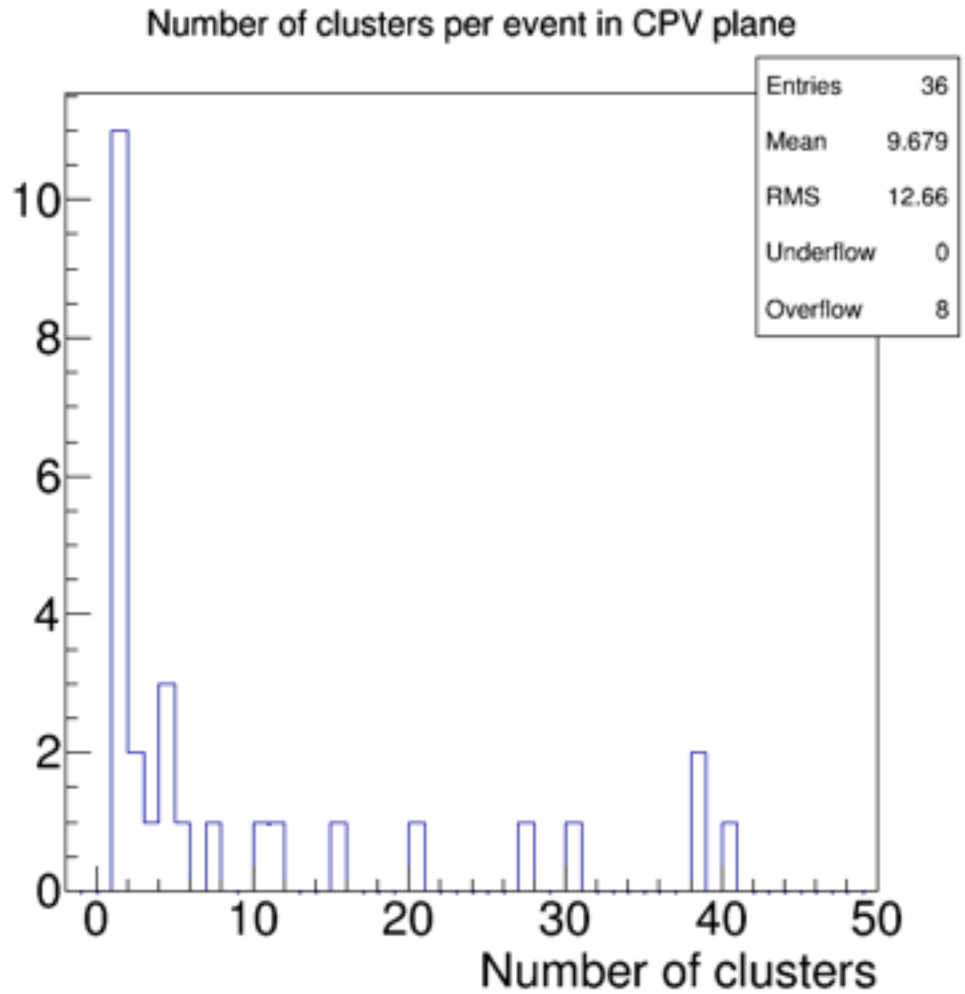
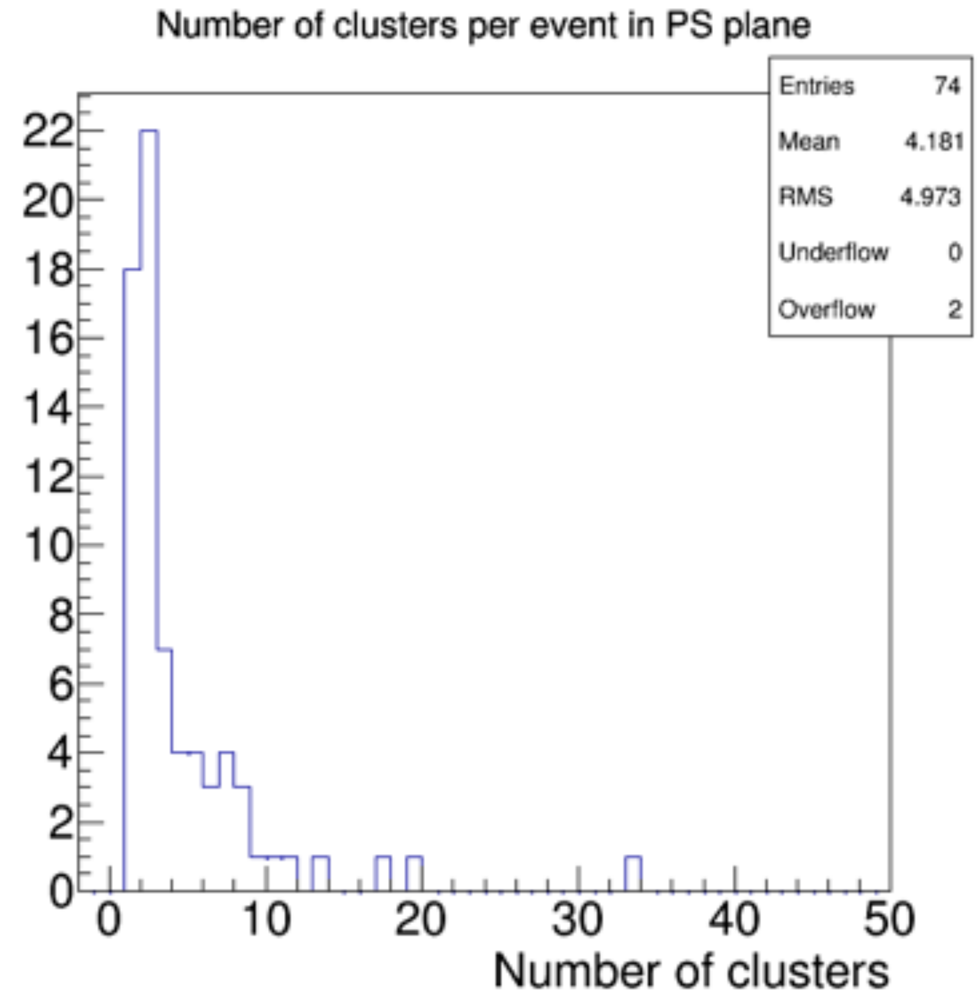
Gamma





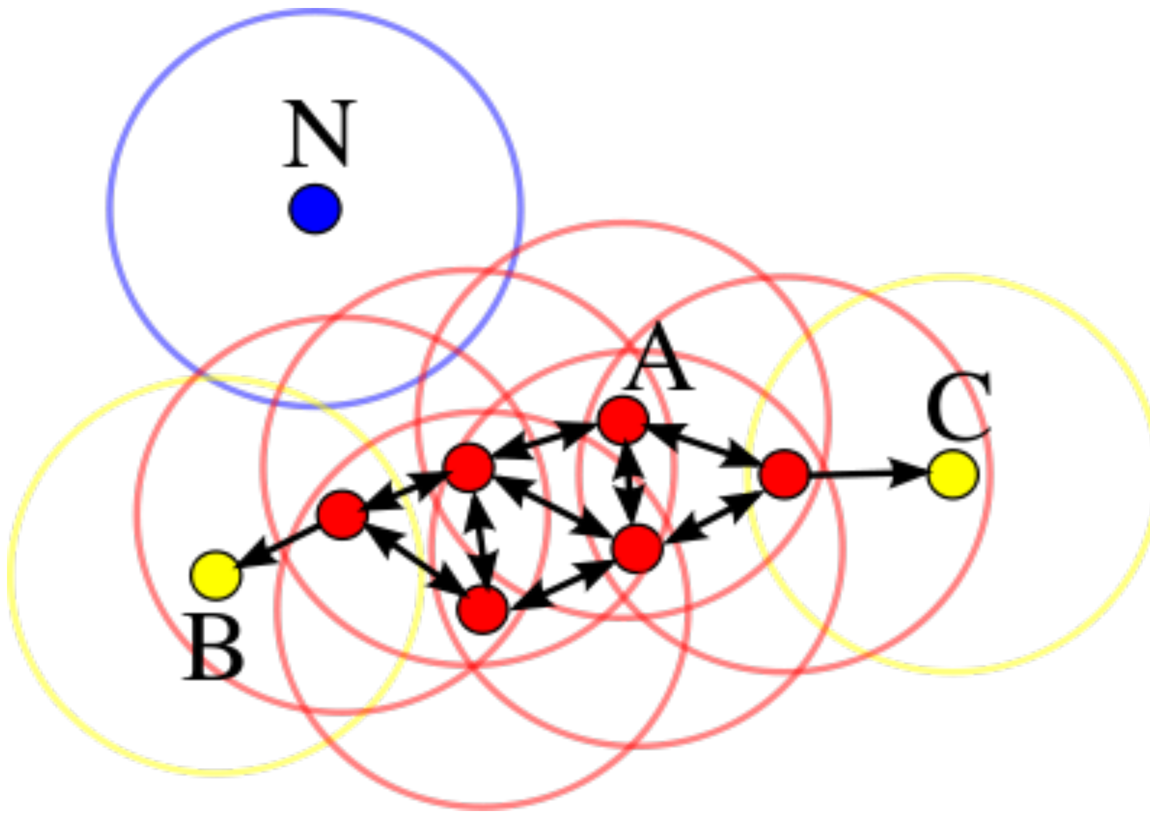
Note the number of entries in both the plots

Proposed Clustering Algorithm - DBSCAN

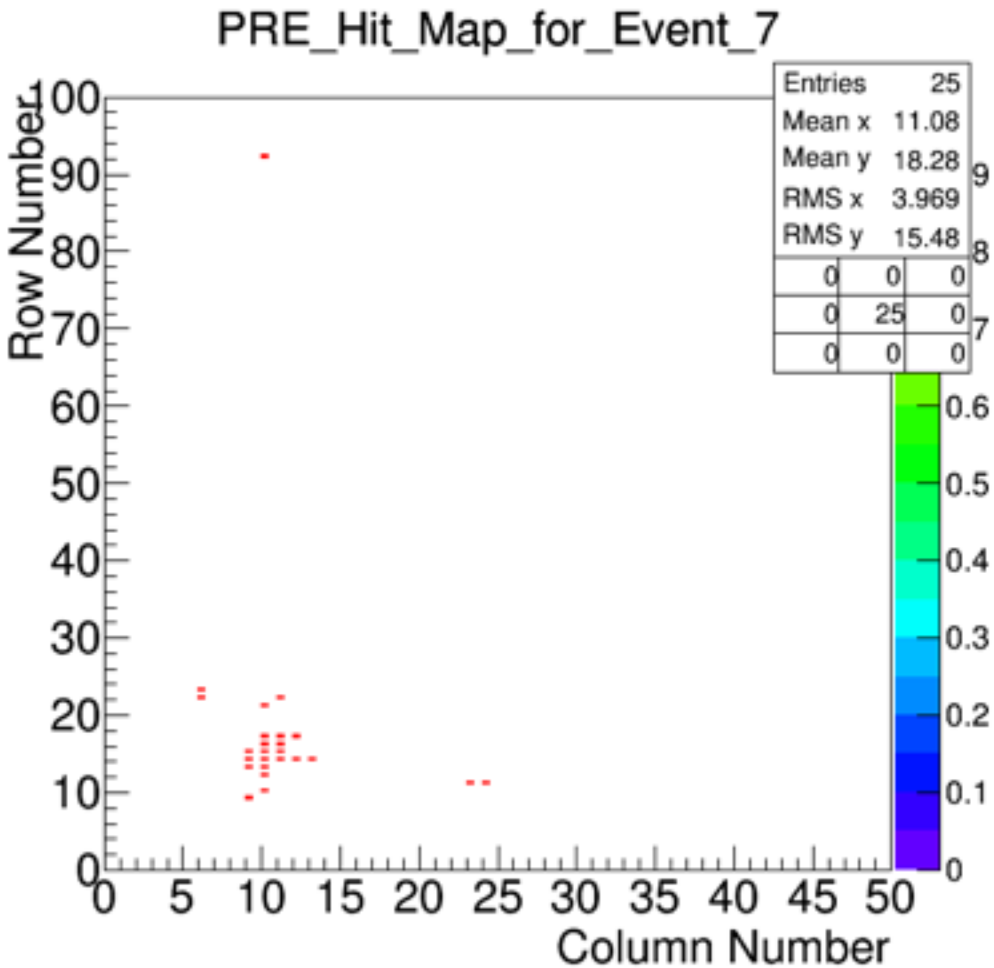
- DBSCAN stands for Density-based spatial clustering of applications with noise.
- DBSCAN classifies all points as either core points, non-core points or outliers based on number of points around a given point within a fixed radius.
- It is particularly helpful since it identifies noise and does not take outliers into account for clustering.

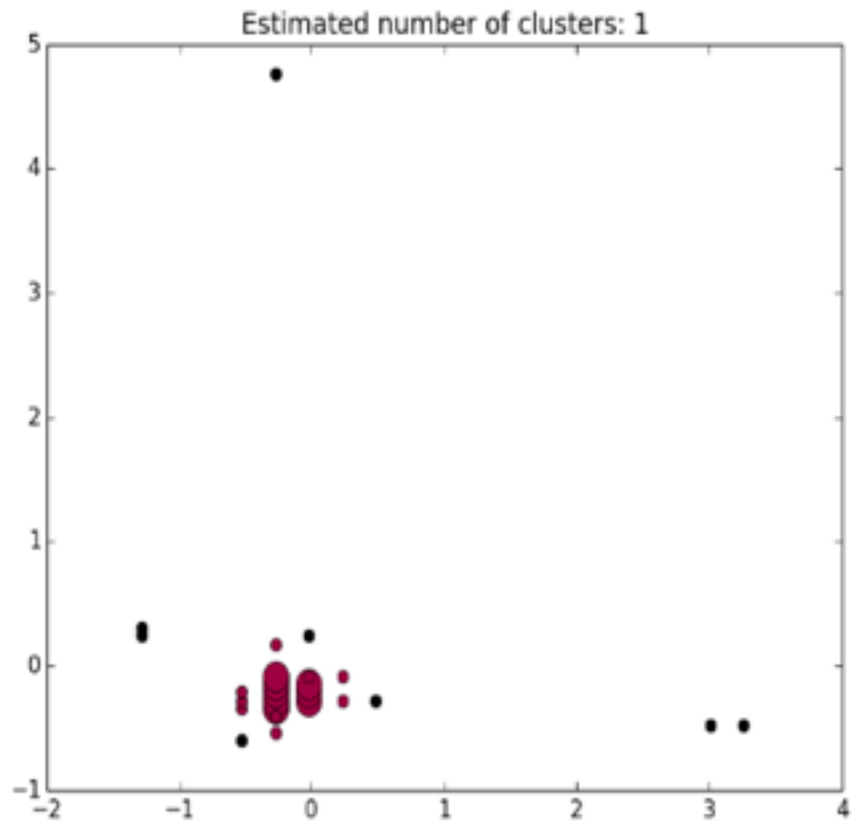
Proposed Clustering Algorithm - DBSCAN

- Point 'A' is a core point if at least “minPts” points are within distance ε of it and they are said to be directly reachable from 'A'.
- Point 'B' is a non-core point if it is directly reachable from a core point but does not satisfy the above condition.
- Point 'N' is an outlier if it is not directly reachable from any other point.



Clustering results using DBSCAN

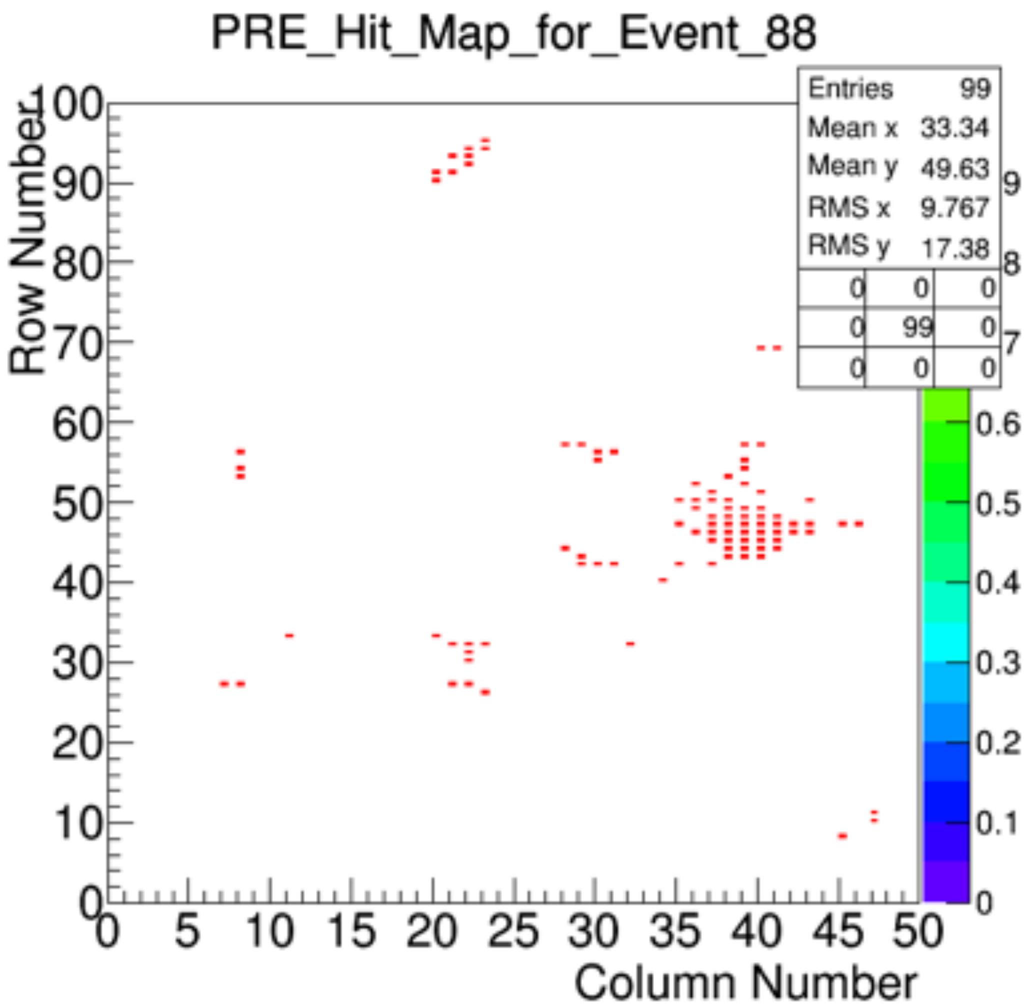


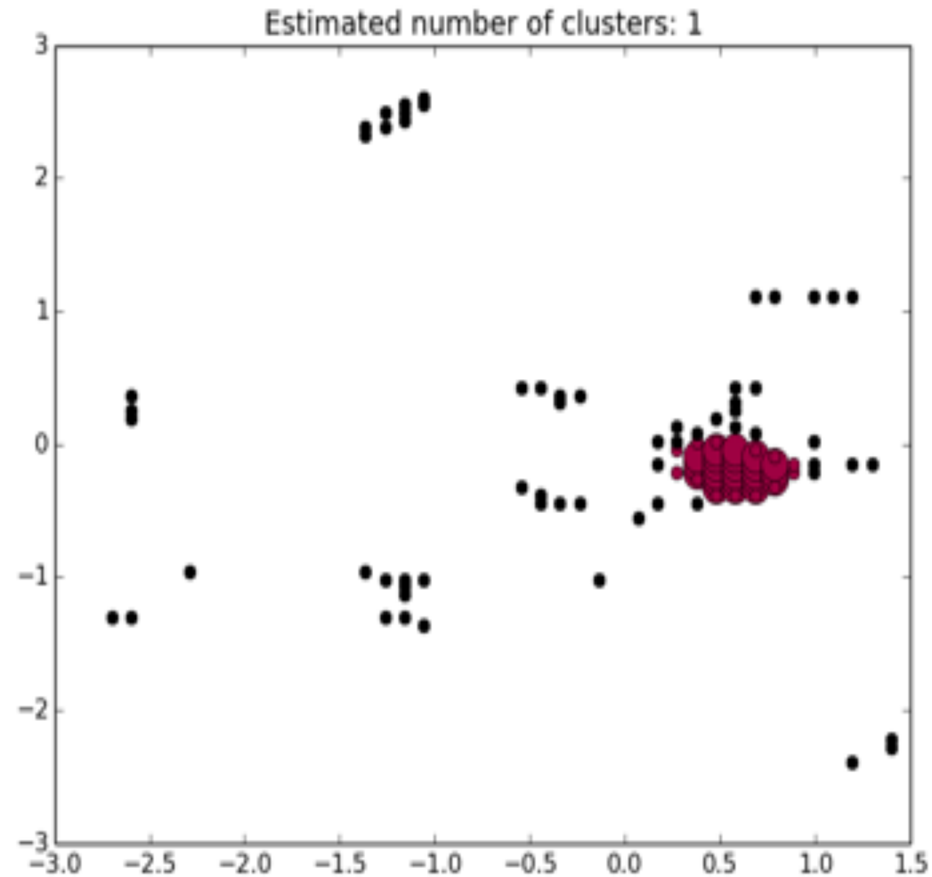


Number of incident particles -> 1 (charged pion)

With the current clustering algorithm, this event showed 5 clusters

Clustering results using DBSCAN



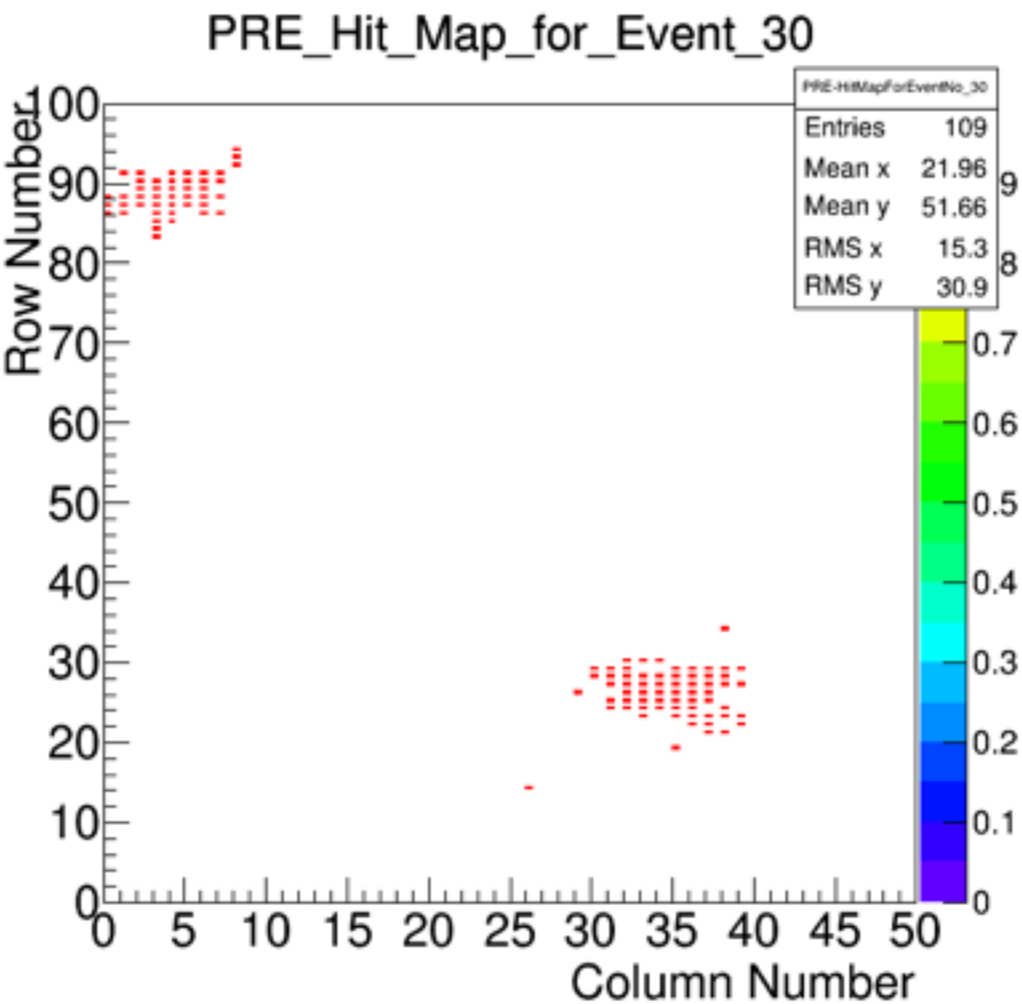


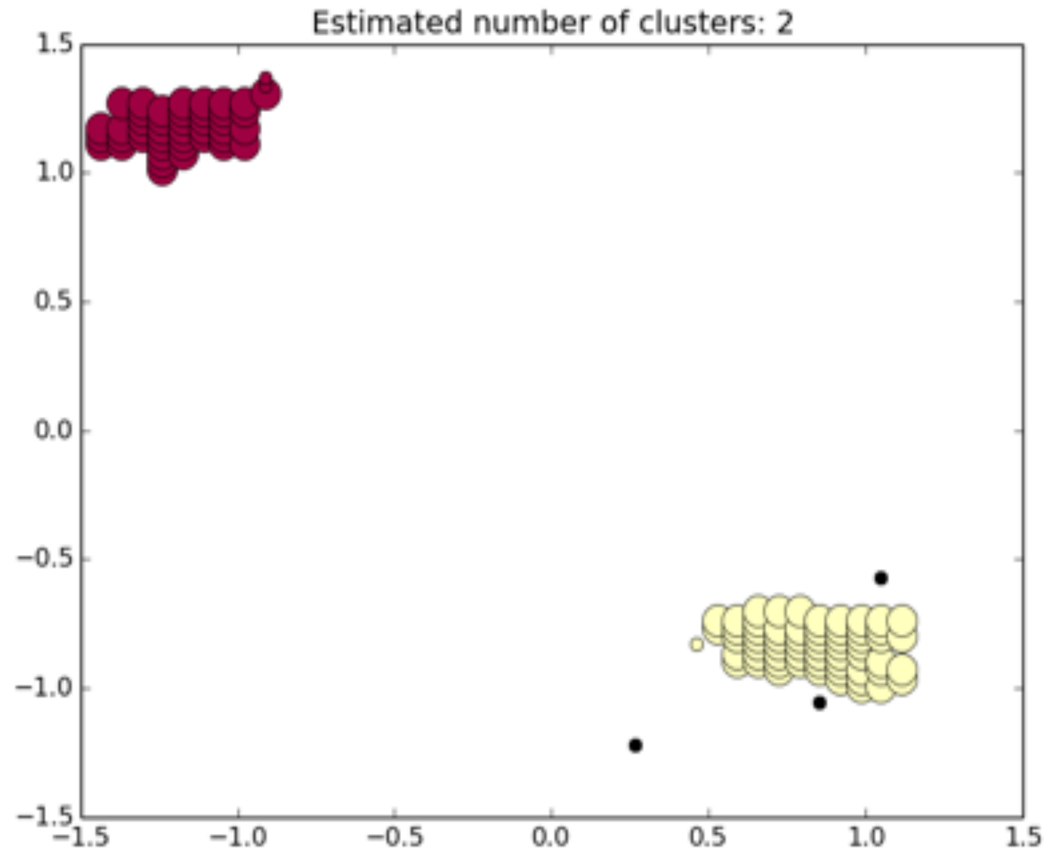
Number of incident particles - 1 photon

With the current clustering algorithm, this event showed 5-13 clusters based on the cuts

Multiple particles per event

Clustering results using DBSCAN

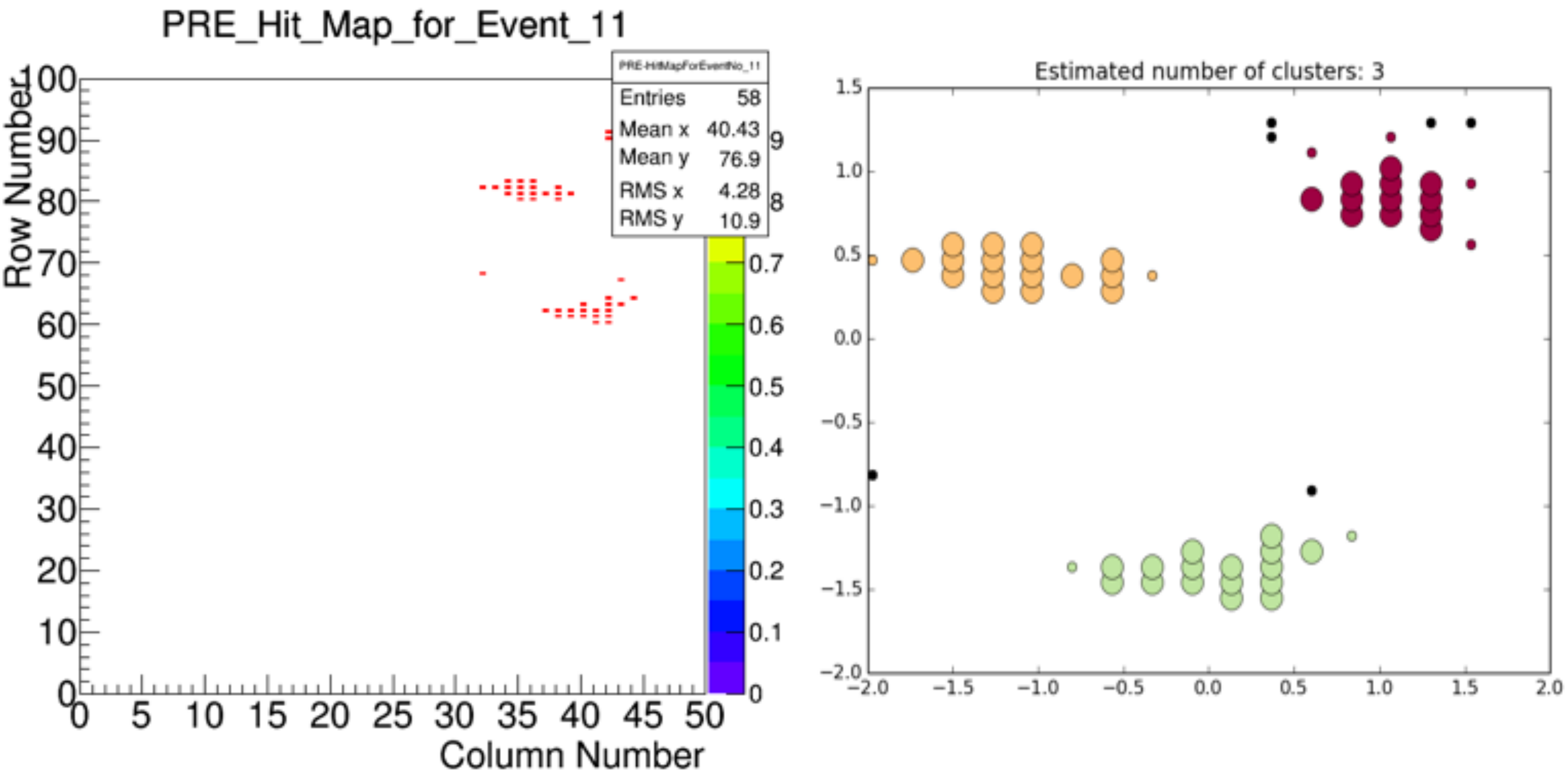




Number of incident particles -> 3 photons

The current algorithm gave exactly the same two clusters

Clustering results using DBSCAN



Number of incident particles -> 3 photons

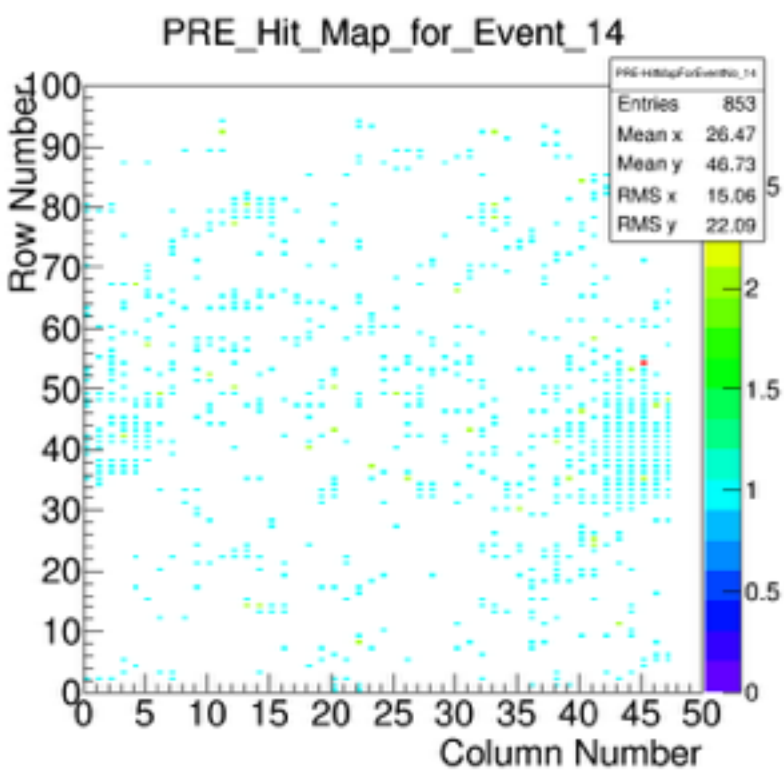
With the current clustering algorithm, this event showed 5 clusters

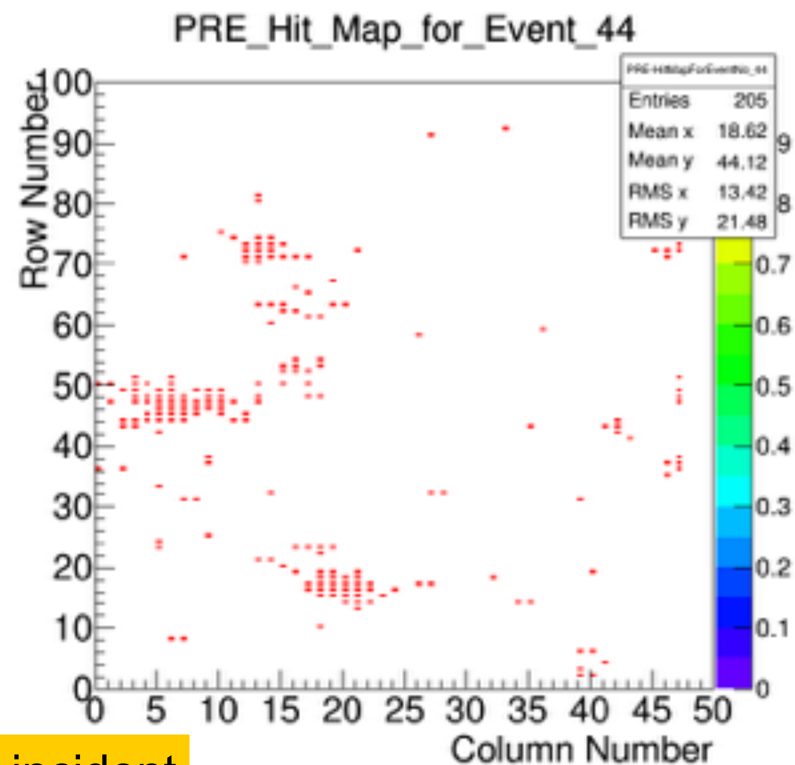
Events with large number of hits

Many events are observed to have a very large number of hits for the given number of incident particles.

However, some of them upon clustering give good results and some just cannot be clustered and must be discarded.

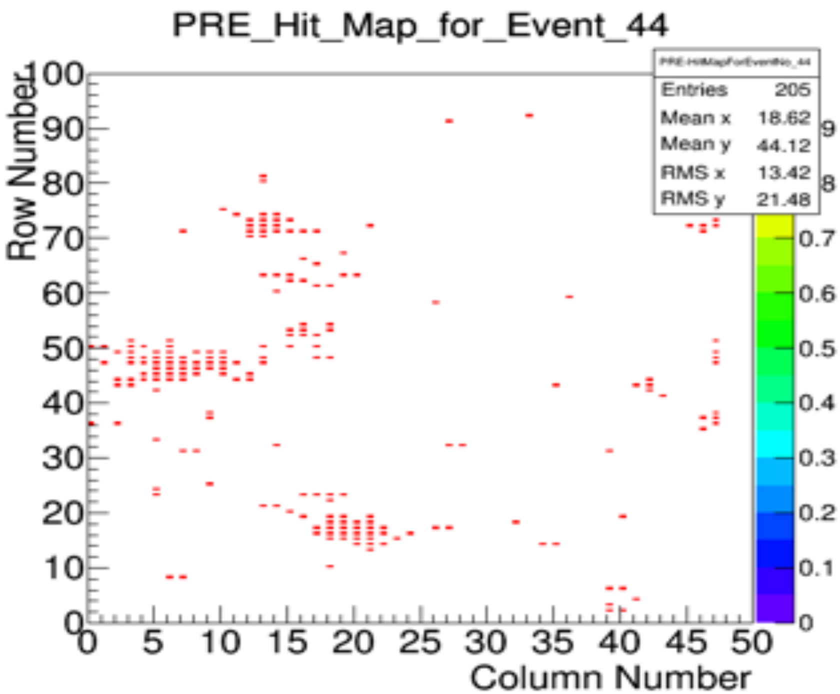
It then becomes an important task to segregate such events

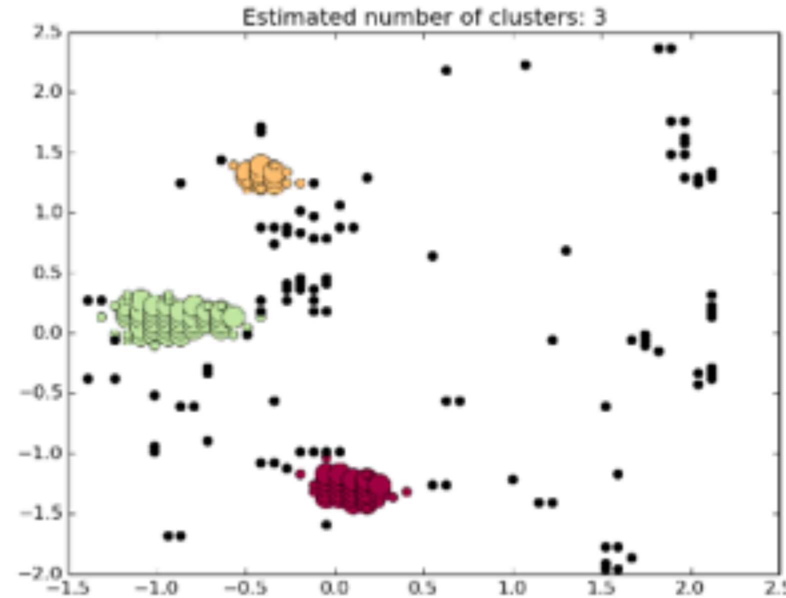


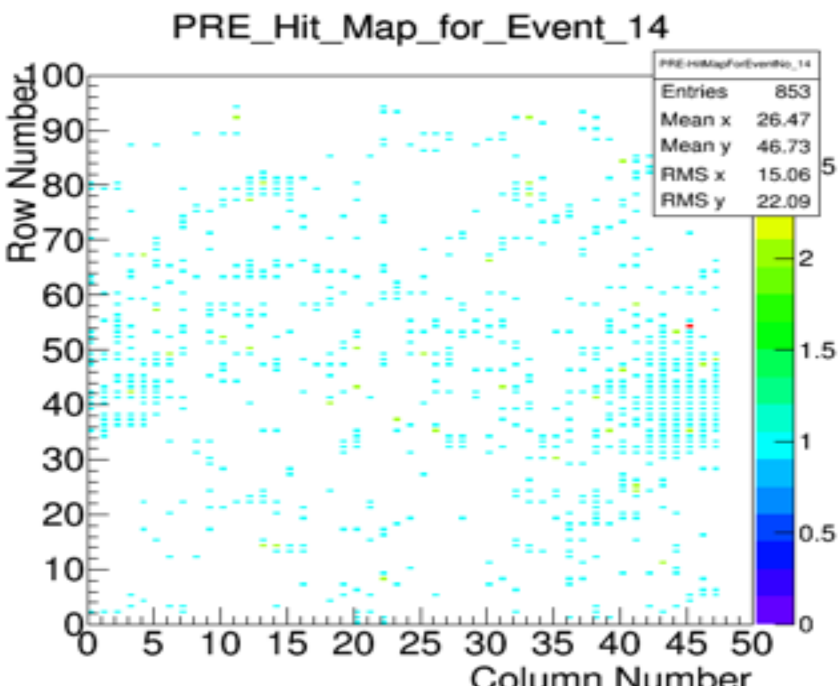


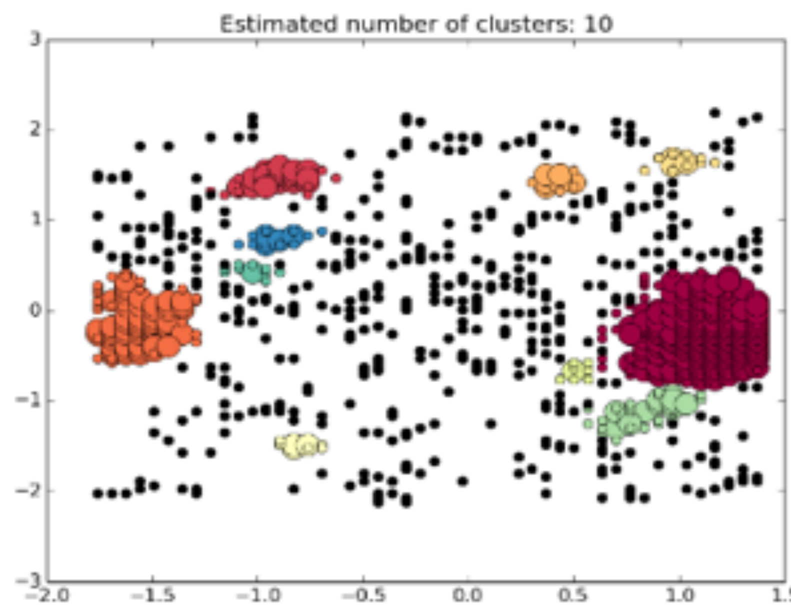
3 photons incident

Events with large number of hits









The step forward

We should start looking at the data from the CPV plane with this clustering information for better discriminating between photons and hadrons.

Studies so far have indicated positive results for individual events with varying number of incident particles.

Next, we plan to use machine learning techniques on the new proposed algorithm in order to attain better efficiency and purity

Thank you