Study of isospin fluctuations in Au + Au collisions at $\sqrt{S_{NN}} = 200$GeV

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- History of Centauro Search
- Search Strategy
- Observable and Analysis Method
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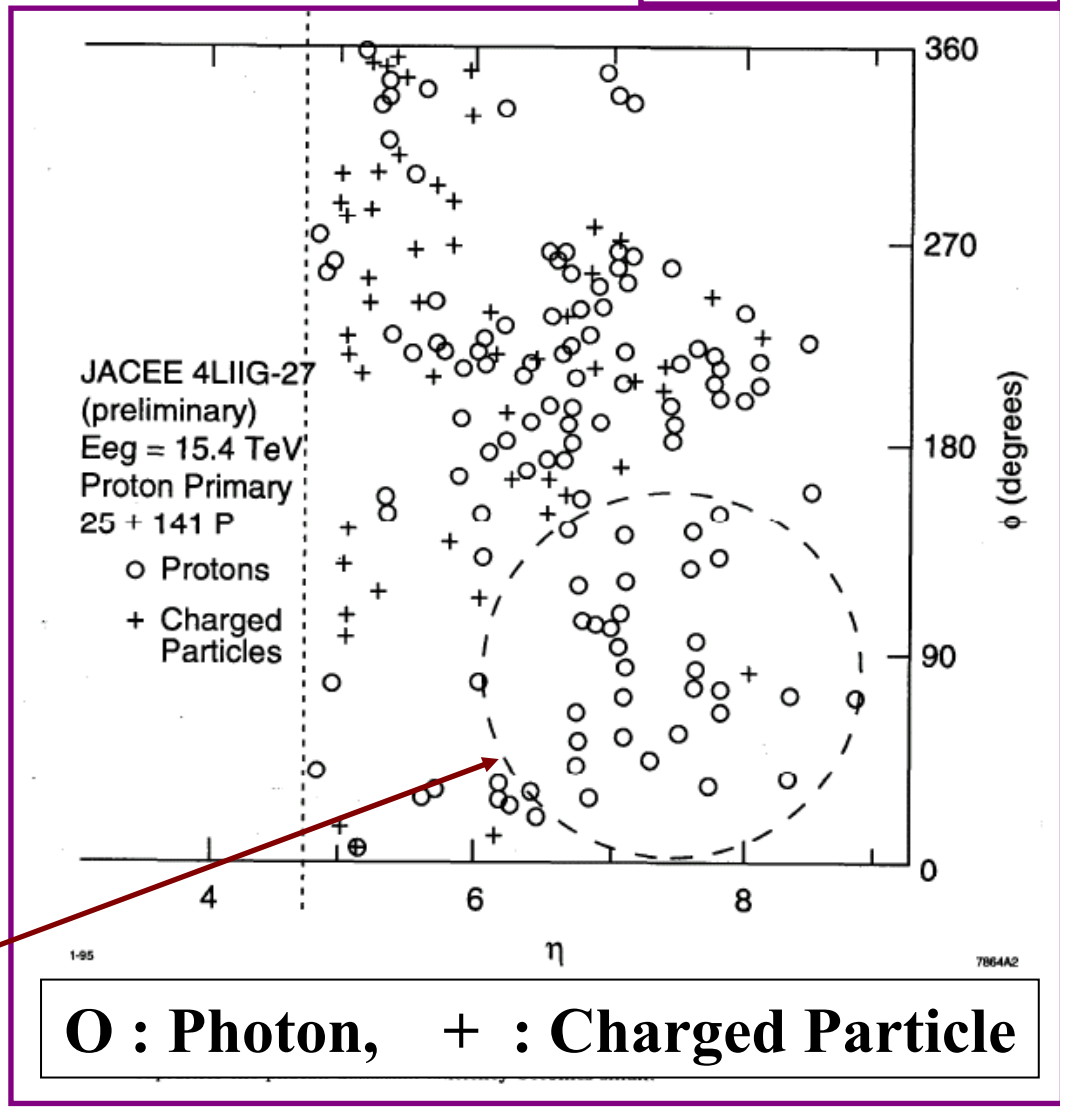
Centauro /Anti Centauro Event

(Cosmic ray experiment)

- (Brazil-Japan collaboration in Bolivia) Y.Fujimoto and S.Hasegawa, Phys. Rep. 65, 151 (1980)
- (JACEE) J.J.Lord and Iwai, Paper No. 515, International Conference on High Energy Physics, Dallas (1992)

This is anomalous region assuming isospin symmetry.

Anti Centauro

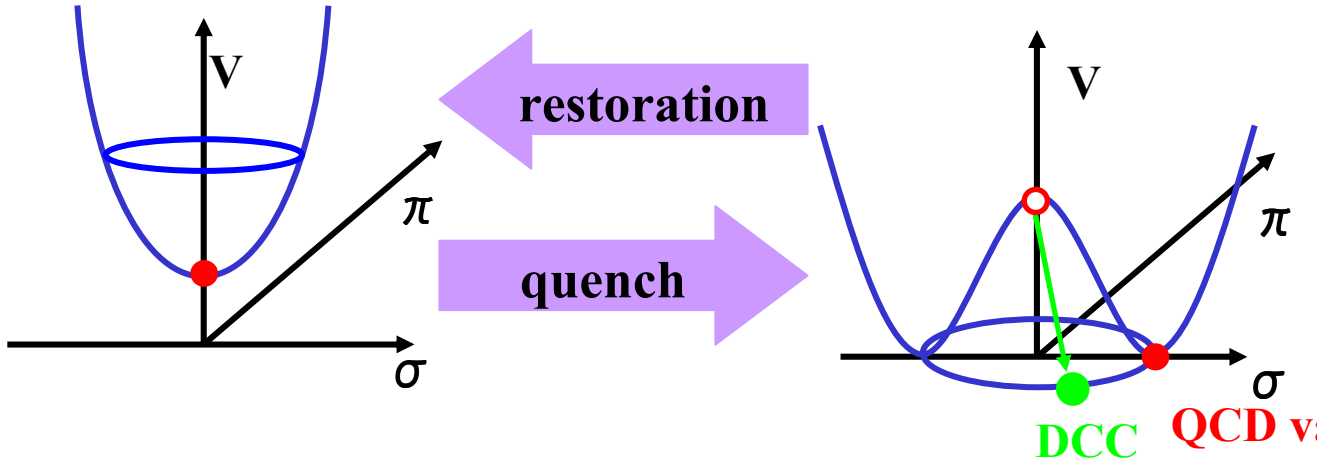


O : Photon, + : Charged Particle

List of Centauro Searches

	Experiment	Collaboration	CM Energy	Search Region (η , ϕ)
1980	Mt. Chacaltaya	Brazil-Japan	$\sqrt{s} \geqq 1.7$ TeV	----------
1992	Balloon	JACEE	----------	$5.0 < \eta < 9.0$ $\Delta\phi < 2\pi$
1982	$SP\bar{P}S$	UA5	$\sqrt{s} = 540$ GeV	$\lvert\eta\rvert < 5.0$
1983	$SP\bar{P}S$	UA1	$\sqrt{s} = 540$ GeV	$\lvert\eta\rvert < 3.1$
1986	$SP\bar{P}S$	UA5	$\sqrt{s} = 900$ GeV	$\lvert\eta\rvert < 5.0$
1996	TEVATRON	CDF	$\sqrt{s} = 1.8$ TeV	$\lvert\eta\rvert < 4.2$, $\Delta\phi < 2\pi$
1997	TEVATRON	MINIMAX	$\sqrt{s} = 1.8$ TeV	$3.4 < \eta < 4.2$
1998	SPS	WA98	$\sqrt{s} = 3.5$ TeV (Pb+Pb)	$2.80 < \eta < 3.75$ $\Delta\phi < \pi$
2001	RHIC	PHENIX	$\sqrt{s} = 39.4$ TeV (Run2) (Au+Au)	$\lvert\eta\rvert < 0.35$ $\Delta\phi < 1/2\pi$ ($\times 2$ arm)

Disoriented Chiral Condensate



(Quench Mechanism)
K.Rajagopal and
F.Wilczek : Nucl. Phys.
B379, 395 (1993)

Chiral transformation

$$\begin{pmatrix} u \\ d \end{pmatrix} \rightarrow e^{i\gamma^5 \tau\cdot\theta} \begin{pmatrix} u \\ d \end{pmatrix}$$

Linear sigma model

$$\vec{\phi}_i = (\sigma, \pi)$$

$$L = \frac{1}{2}\partial_\mu \phi_i \partial^\mu \phi_i - \frac{1}{4}\left(\phi^2 - v^2\right)^2 + H\sigma$$

Chiral symmetry breaking term due to finite masses

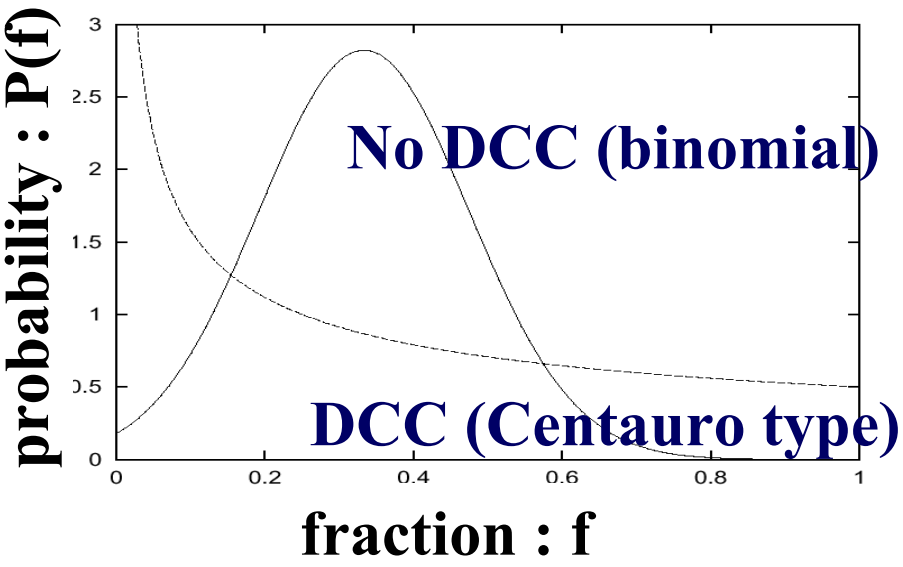
Search Strategy

If every event could contain largely deviated domains on isospin symmetry and most of domains per event could be detected within a limited detector acceptance, we would be able to discuss anomaly based on the probability distribution by the statistical treatment like:

$$fraction\ :\ f = \frac{n_{\pi^0}}{n_{\pi^0} + n_{\pi^+} + n_{\pi^-}}$$

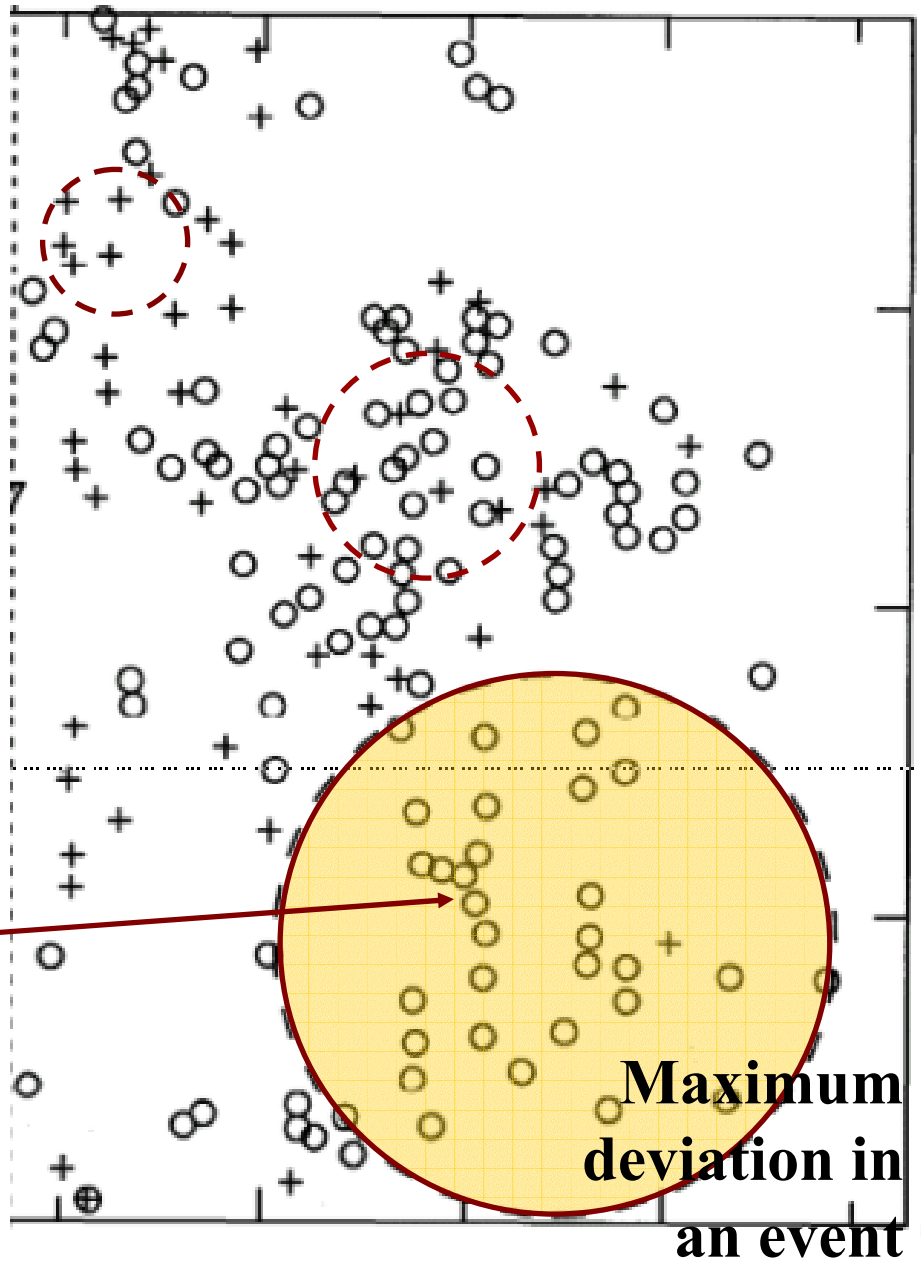
$$probabilit\ y : P(f)df = \frac{1}{2\sqrt{f}}df$$

However, we do not know domain information on the numbers and sizes a priory, and our detector acceptance is very limited. Therefore we need to search for rare events containing anomalous domain like cosmic ray experiments rather than statistical treatment above.



We search for a most largely deviated domain per event by looking at differences between number of charged and photon-like clusters by changing regions of interest as we do by eyes, because we don't know what the size is and where the position is.

We want to extract this region. We must do this search in several million events.



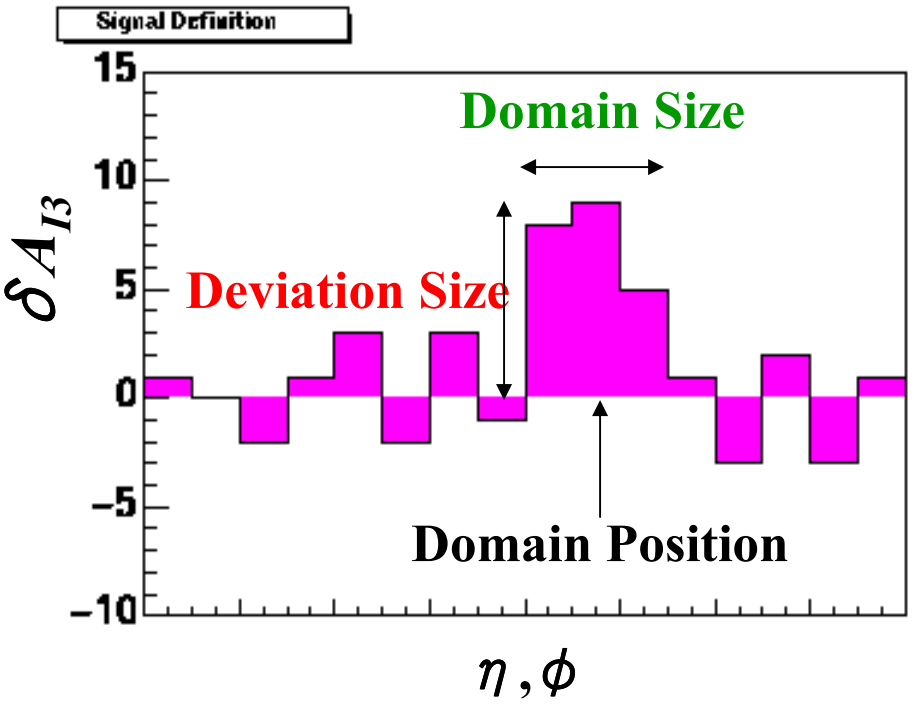
Observables

Definition of asymmetry between number of charged tracks and neutral clusters event-by-event base as a function of subdivided eta-phi phase spaces normalized by 1 sigma of standard deviation for given multiplicity.

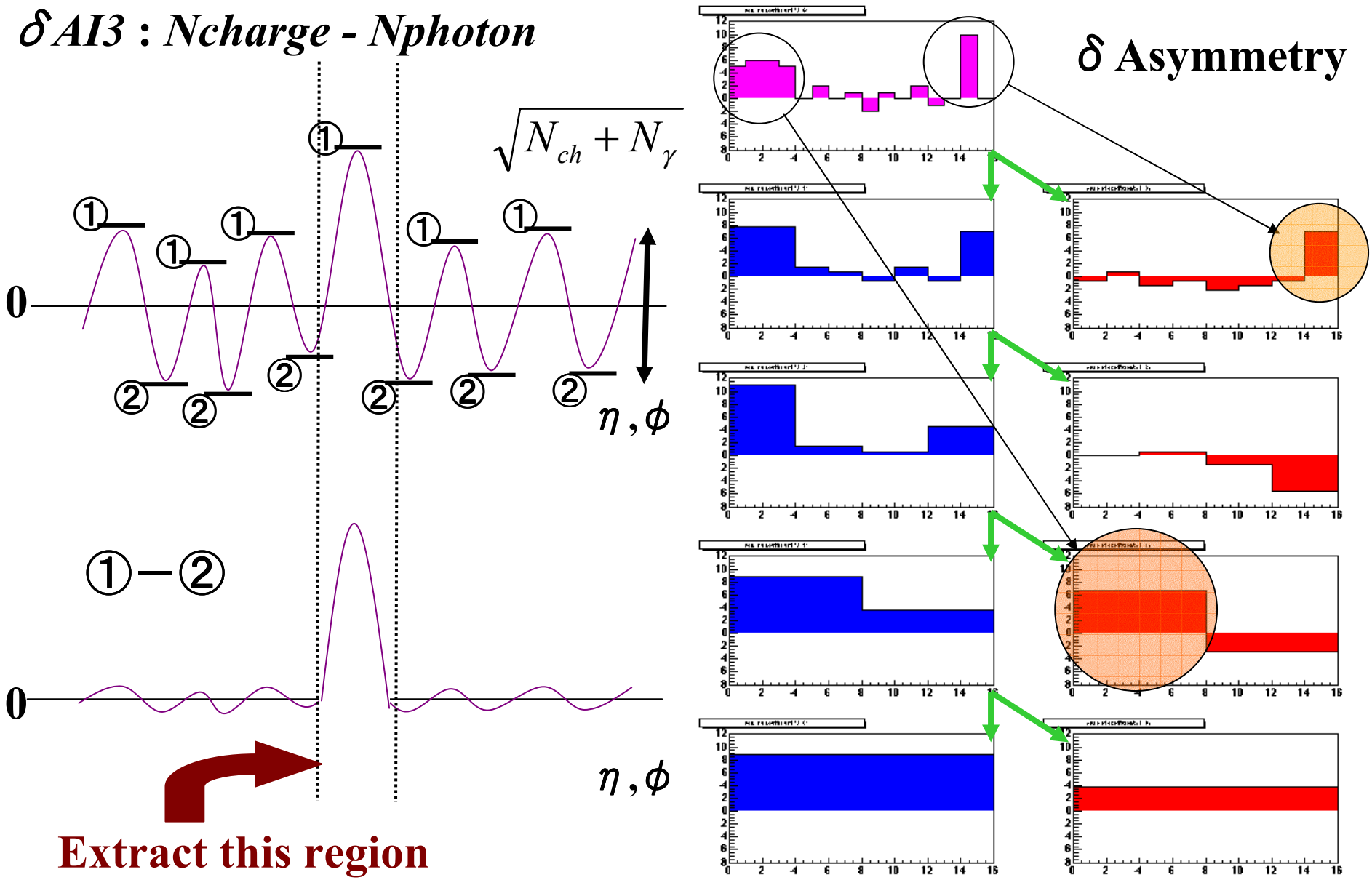
$$\delta A_{I_3}(\Delta\eta\Delta\phi) \equiv \frac{N_{\pi^\pm}(\Delta\eta\Delta\phi) - N_\gamma(\Delta\eta\Delta\phi)}{\sqrt{N_{\pi^\pm} + N_\gamma}}$$

$$\approx \frac{N_{ch}(\Delta\eta\Delta\phi) - N_\gamma(\Delta\eta\Delta\phi)}{\sqrt{N_{ch} + N_\gamma}}$$

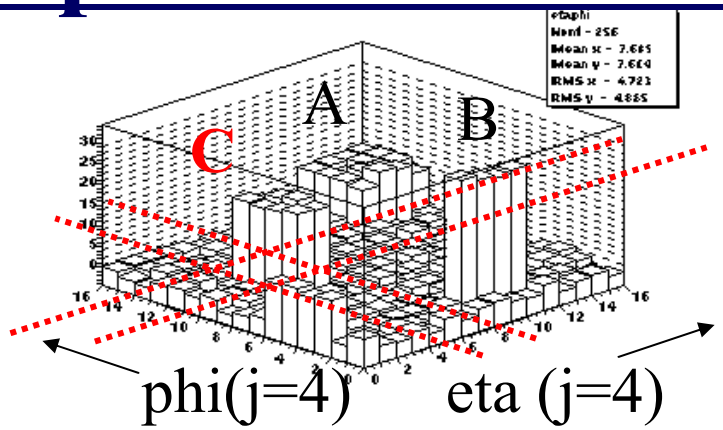
Domain Size and Domain Position of large deviated region can be obtained at the same time by using Multi Resolution Analysis (MRA) technique.



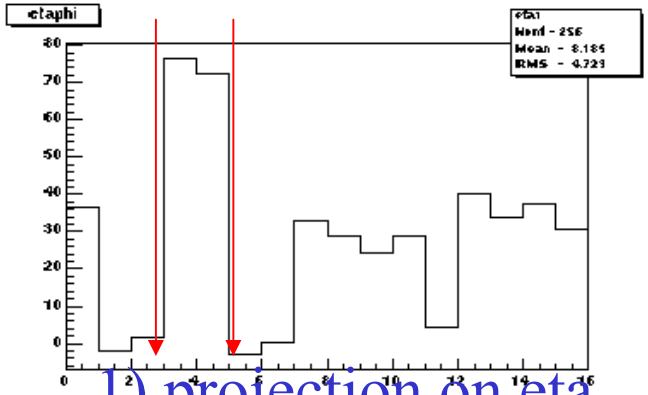
Multi Resolution Analysis (MRA)



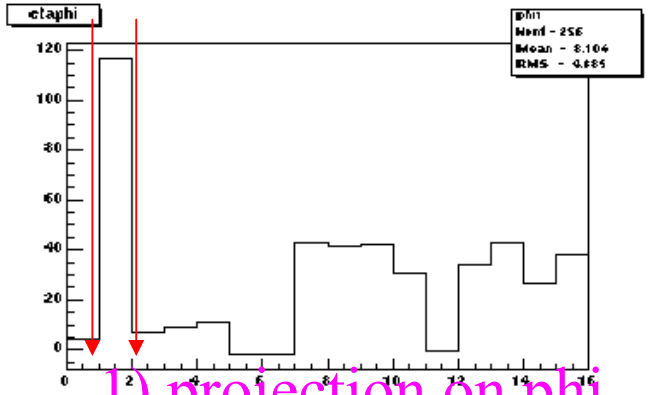
Example of 2D MRA



Domain C:
A_{I3}= ~20 x 8bins
$(\eta, \phi)=(3, 7)$
$(j_\eta , j_\phi)=(3, 2)$



1) projection on eta

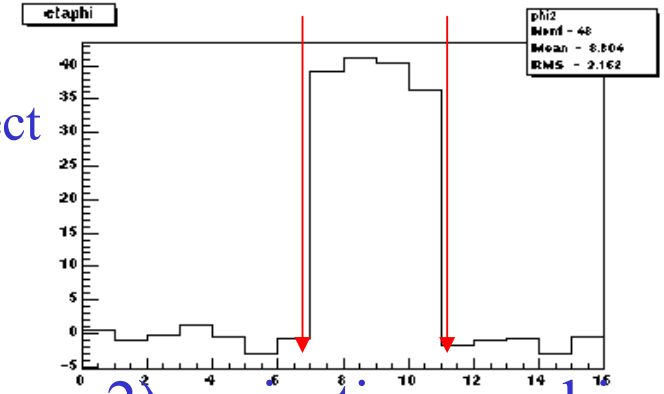


1) projection on phi

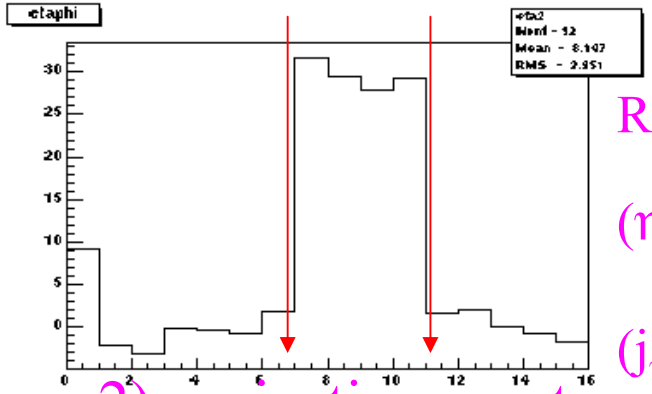
Result:Correct

$(\eta,\phi)=(3,7)$

$(j_\eta,j_\phi)=(3,2)$



2) projection on phi



2) projection on eta

Result:Wrong

$(\eta,\phi)=(7,1)$

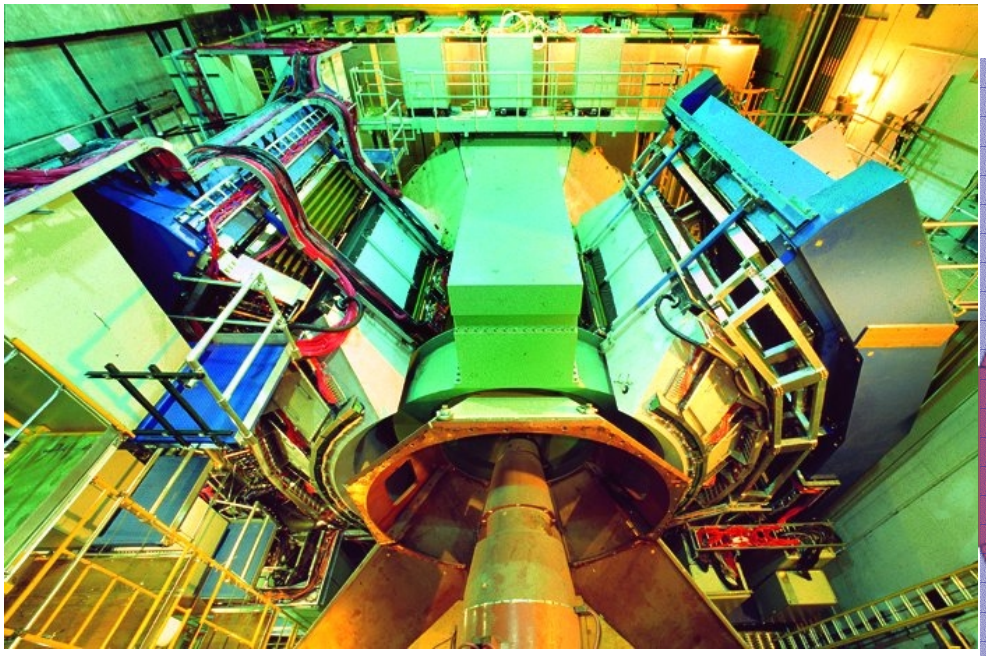
$(j_\eta,j_\phi)=(2,4)$

PHENIX Experiment at Run2

Using Magnetic Field-off data

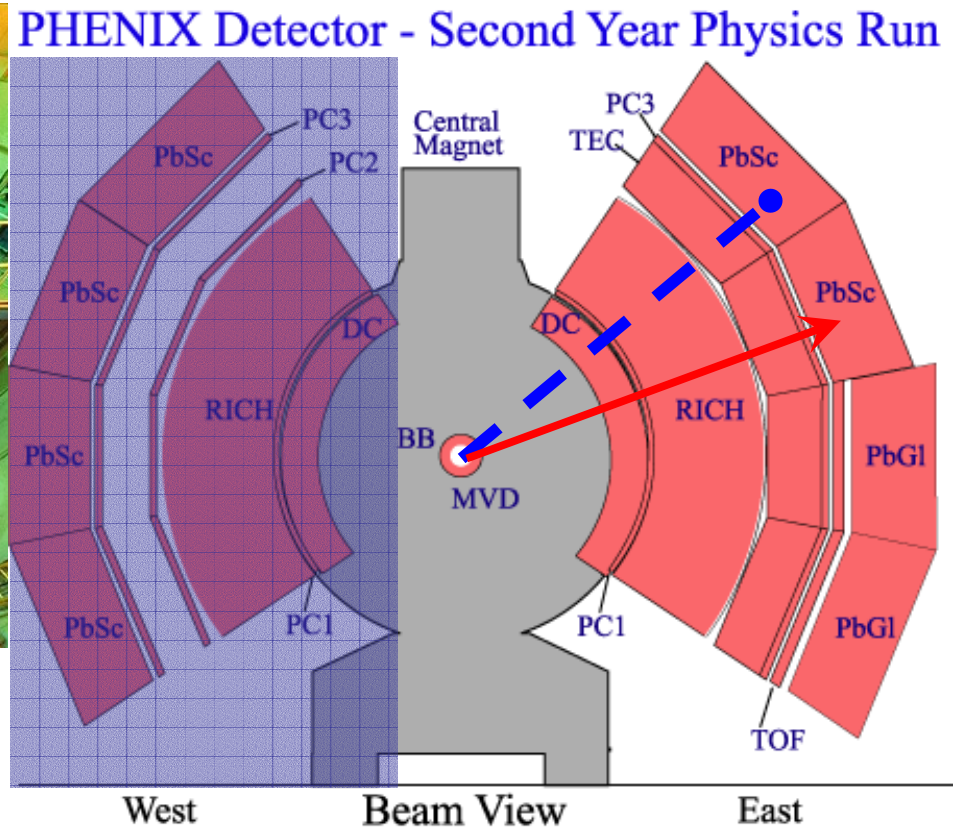
Charged Track (BBC Z-Vertex, Drift Chamber and Pad Chamber1)

Photon-like Cluster (Electro-Magnetic Calorimeter)

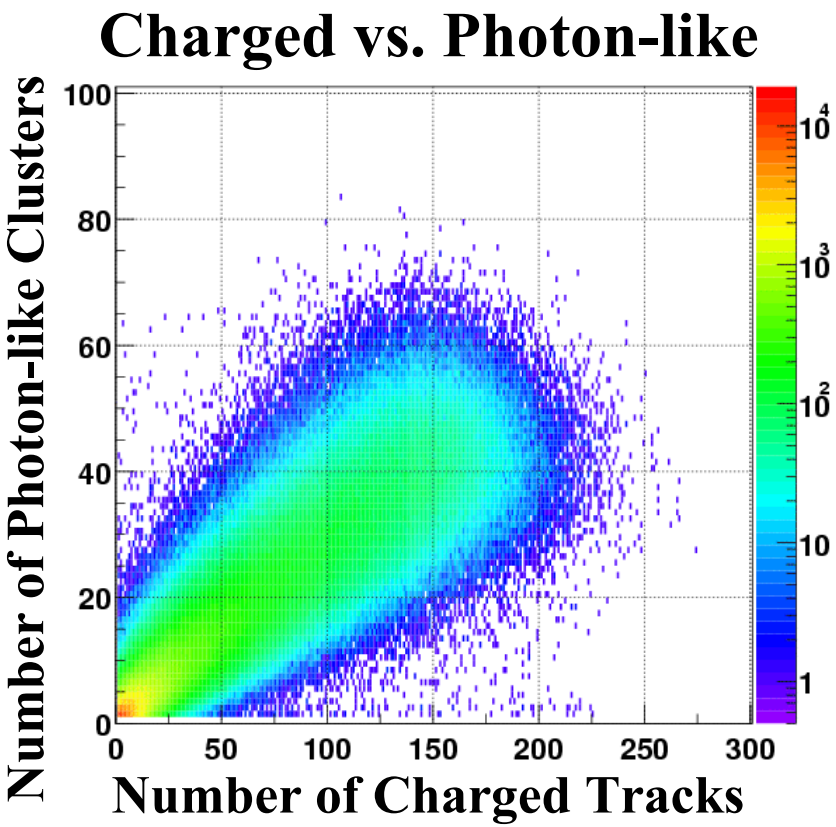


$$-0.35 < \eta < 0.35$$

$$\Delta\phi < 1/2\pi \quad \text{in each arm}$$



Data Sample



We can detect both charged tracks and photon-like clusters even below 100MeV/c.

- Magnetic Field-off
- Minimum bias 873,881 events

number of charged tracks > 0

number of photon-like clusters >0

- Charged Track

BBC Z-Vertex, Drift Chamber and

Pad Chamber1 associated straight-line track

- Photon-like Cluster

Cluster of Electro-Magnetic Calorimeter

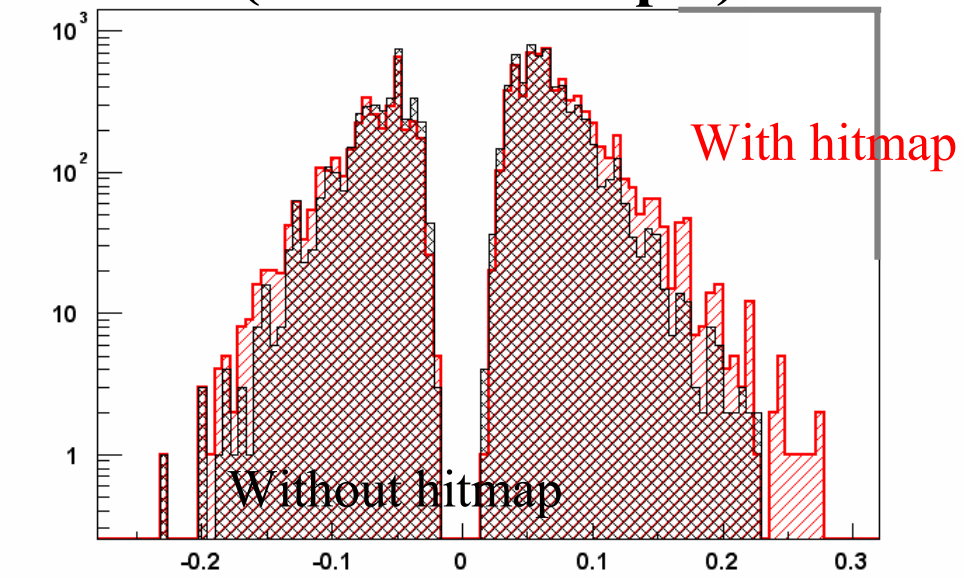
1) Cluster shower shape

2) Time of flight

3) Not associated with charged track

Binomial Distribution as a Baseline Fluctuation

Maximum Deviation Size (Binomial sample)

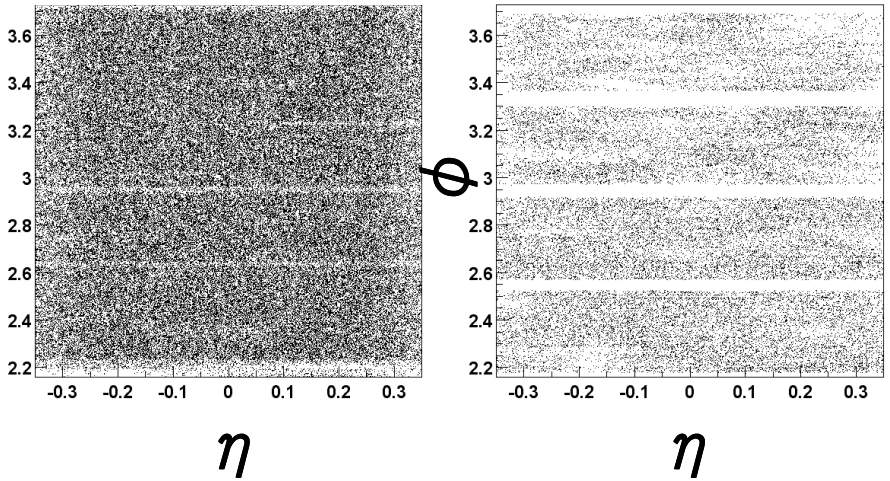


(Nch, Nphoton) = (200, 100)

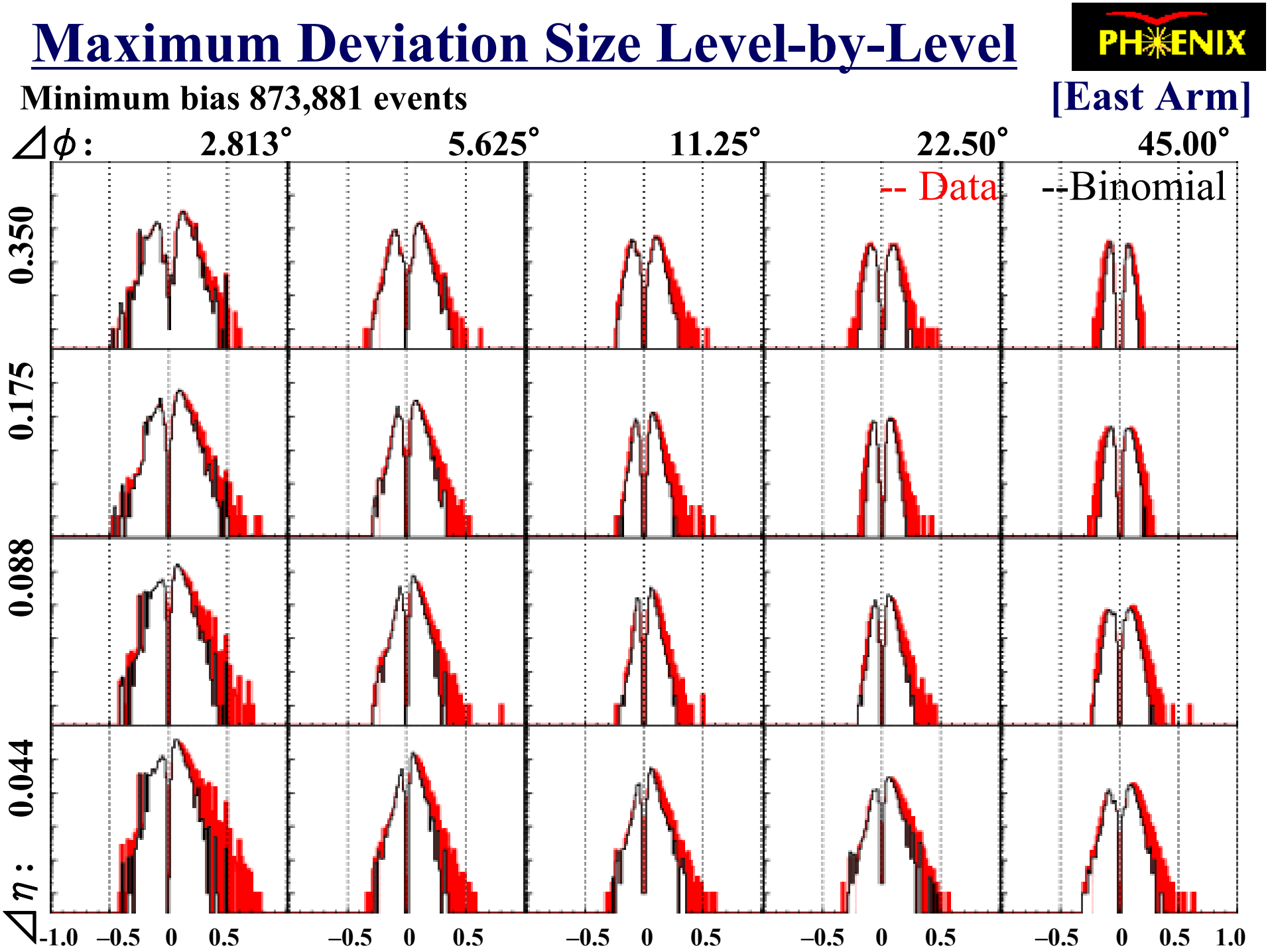
- **We need to define a degree of the anomaly quantitatively with a familiar statistical language.**
- **We have also taken care of detector bias in real data. Binomial samples are generated based on hit map of real data for ~3000 events term.**

Hit Map

Charged **Photon-like**



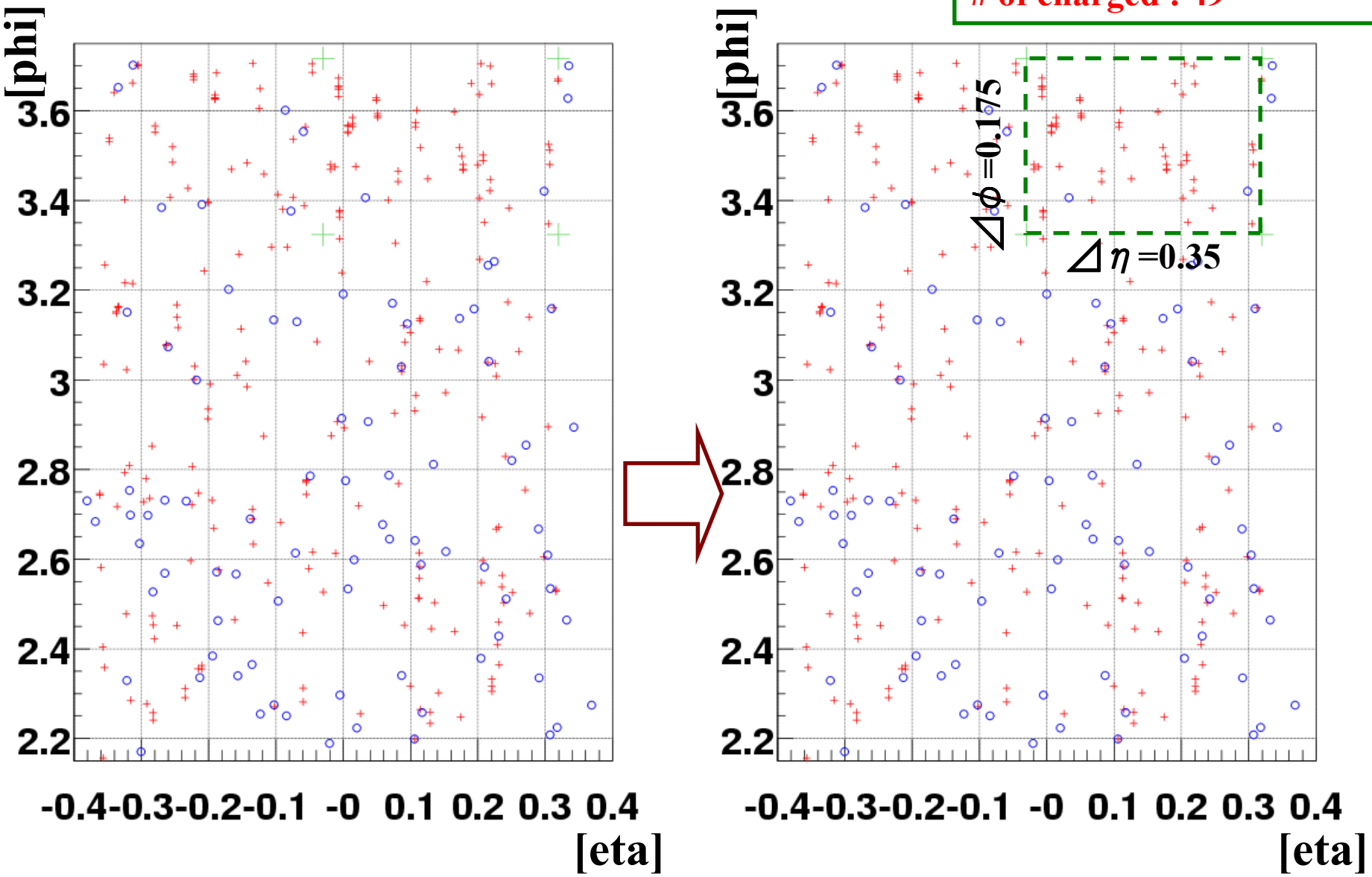
Maximum Deviation Size Level-by-Level



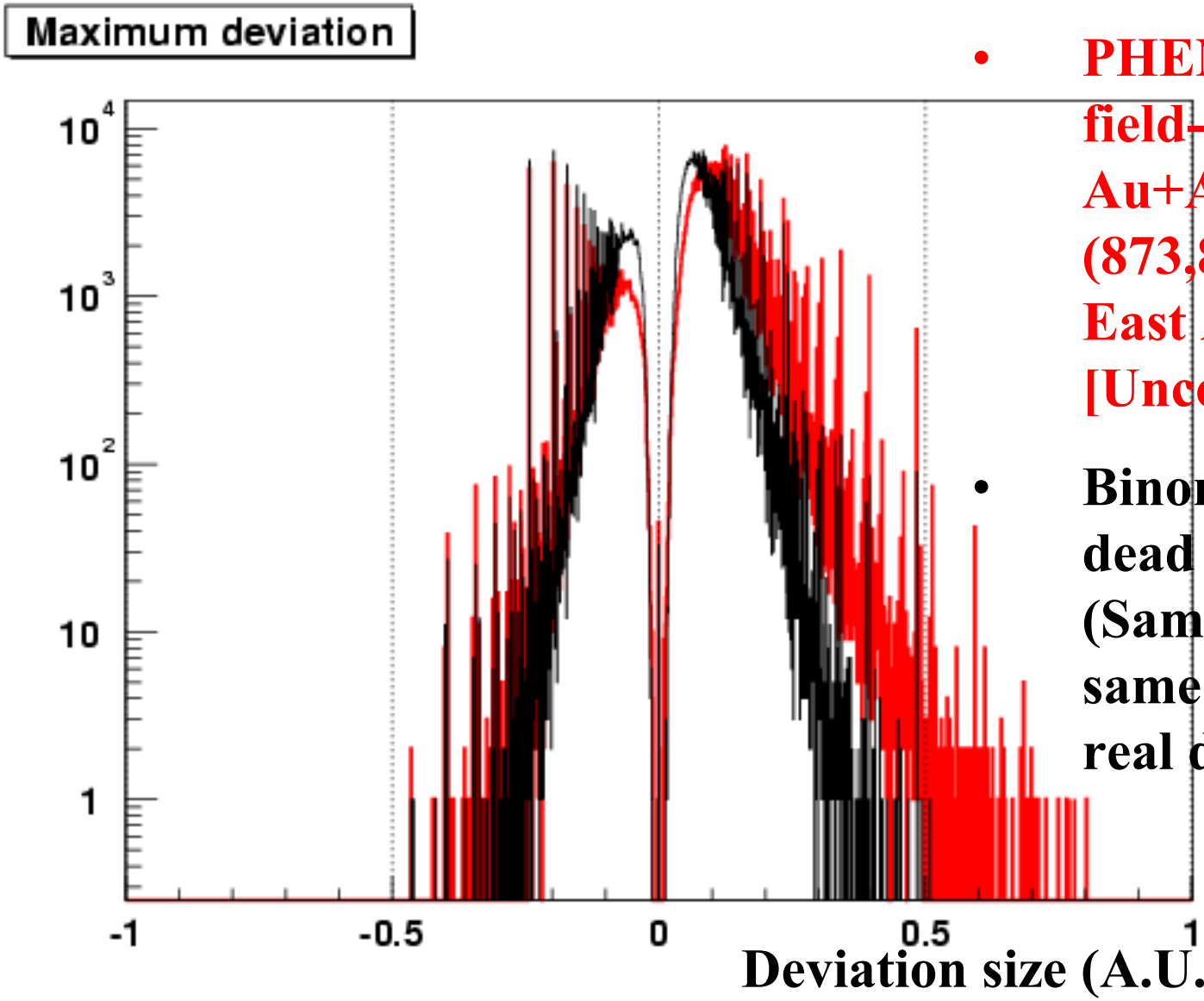
Event Display (East Arm)

of gamma-like : 2

# of charged : 49



Maximum Deviation Size charged/photon-like for all events



- PHENIX magnetic field-off minimum bias Au+Au 200 GeV data (873,881 events) East Arm [Uncorrected]
- Binomial sample with dead channel map (Same statistics and same multiplicity as real data)

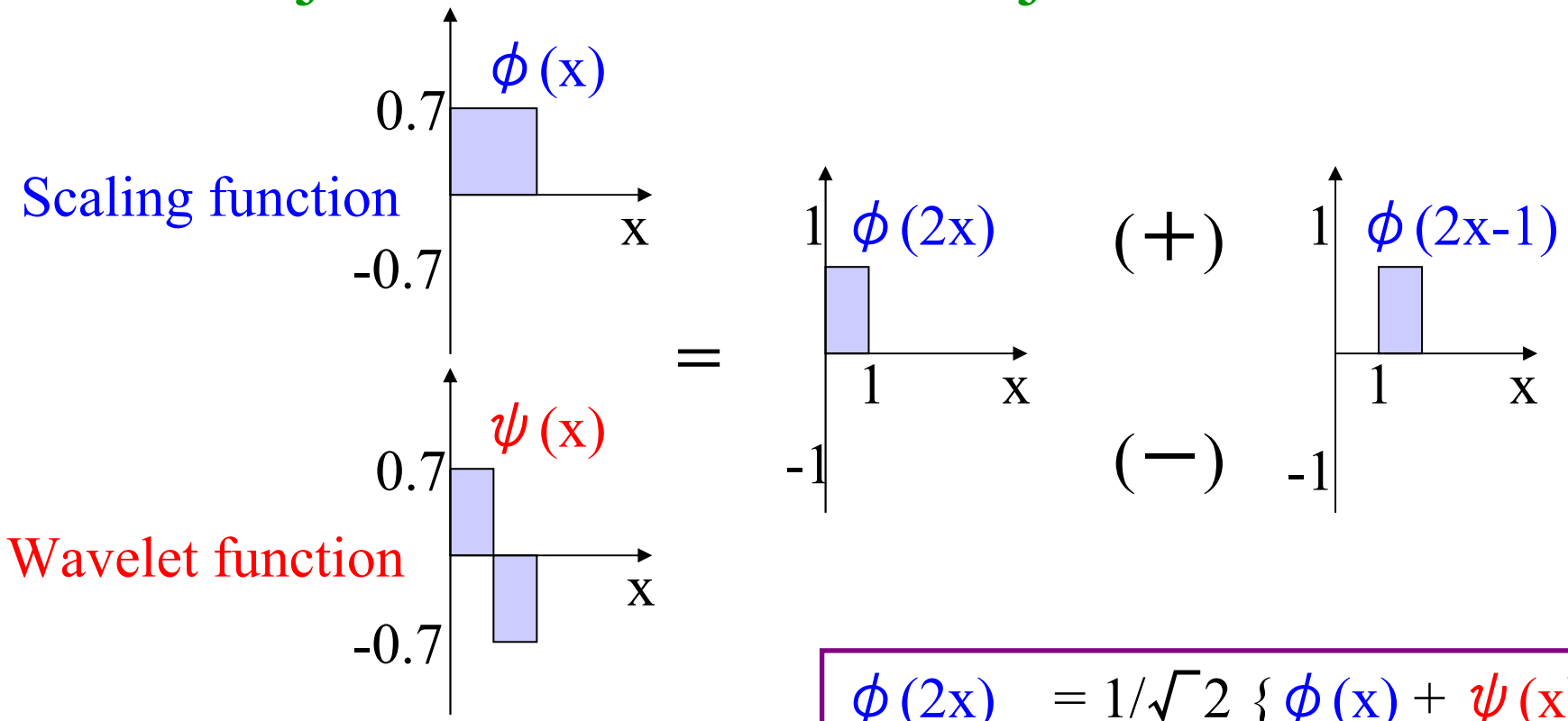
Summary and Future Plan

- We have demonstrated two dimensional multi-resolution analysis on the asymmetry between the number of charged tracks and γ-like clusters in the η-ϕ phase space for the PHENIX Au+Au 200GeV data.
- Set a reasonable significance level to define the degree of anomaly based on the physical models with normal fluctuations.
- Count the anomalous events above the significance level.
- For those events above the significance level, we will analyze the signal to background ratio ($S/\sqrt{B}$) as a function of centrality.
- Discuss the event characters of those events, if they are found.

Back up Slide

Multi Resolution Analysis (MRA)

Level j-1 : 2^{j-1} bins Level j : 2^{j} bins



$$\phi(2x) = 1/\sqrt{2}\,\{\phi(x) + \psi(x)\}$$
$$\phi(2x-1) = 1/\sqrt{2}\,\{\phi(x) - \psi(x)\}$$

Total number of bins is 2^{j}

Level j correspond to resolution level

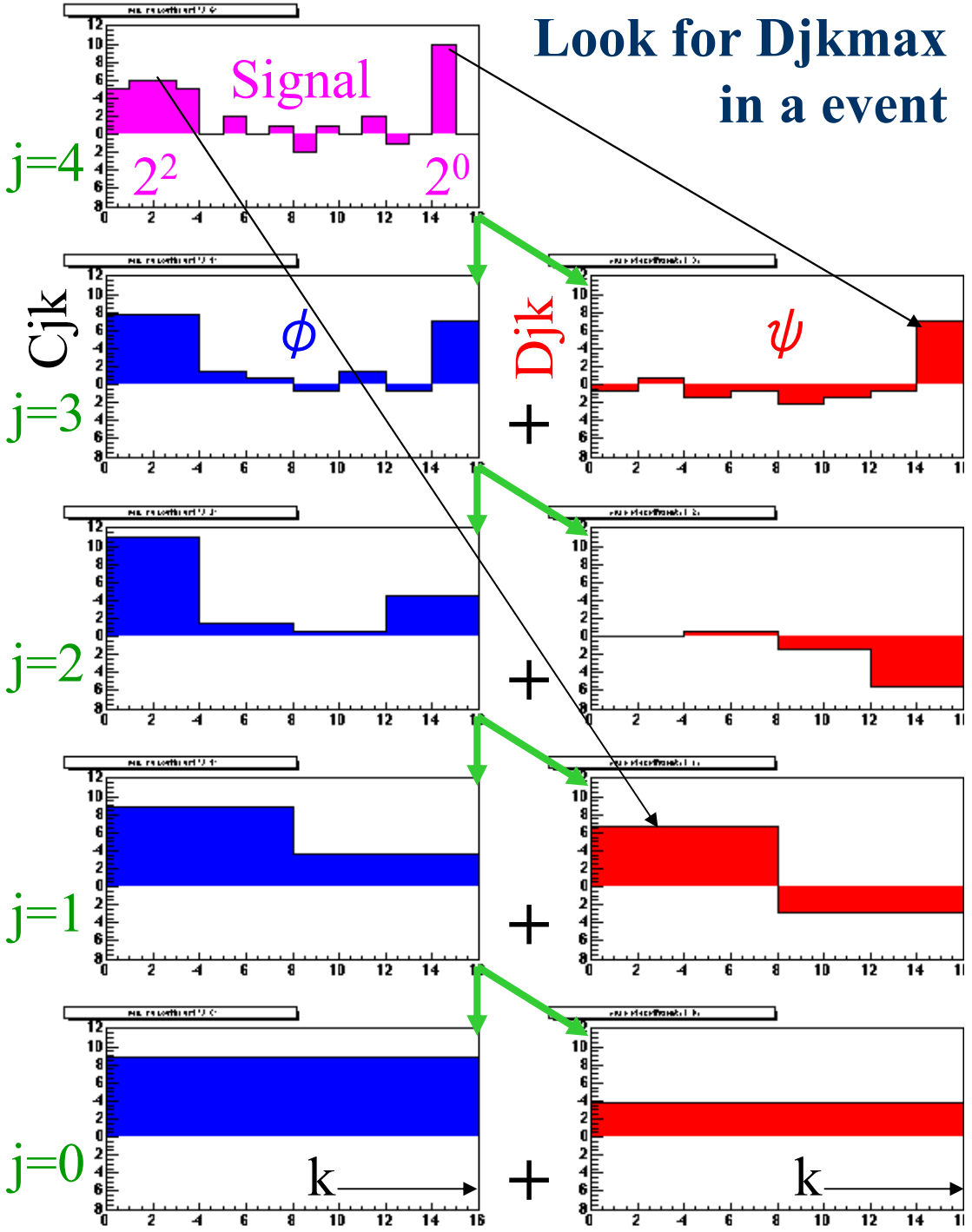
Signal Decomposition

j : resolution level
k : k-th bin in pseudo rapidity
Cjk : coefficients of ϕ
Djk : coefficients of ψ

1/2^j→ Domain Size

k → Phase Space Position

Djk → Deviation Size



Window Shift Method

Shift the start bin at each resolution level.

Find djk max among all of levels.

This can determine the level (domain size) with the largest deviation size.