Azimuthal Anisotropies in Pb+Pb Collisions at $\sqrt{s_{NN}}$ = 5.5 TeV

Monte Carlo Studies:

Part I: Analysis of Generated HIJING Events with the Elliptic Flow Afterburner – **DONE**

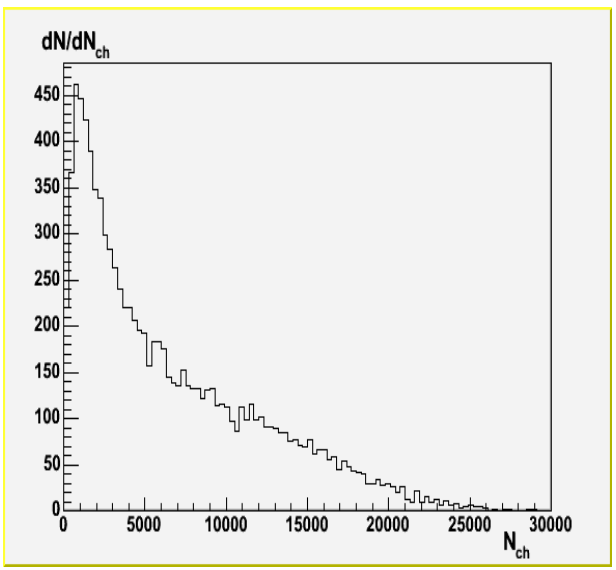
Part II: Analysis of Simulated Events with the ATLAS Detector Response – **IN WORK**

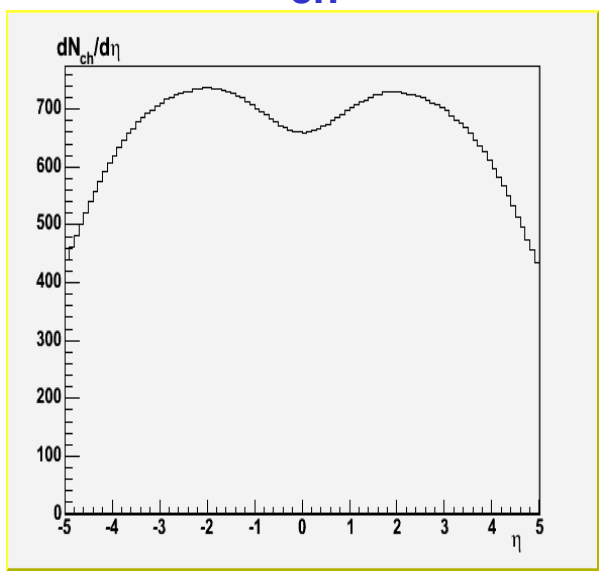
HIJING Generated Events

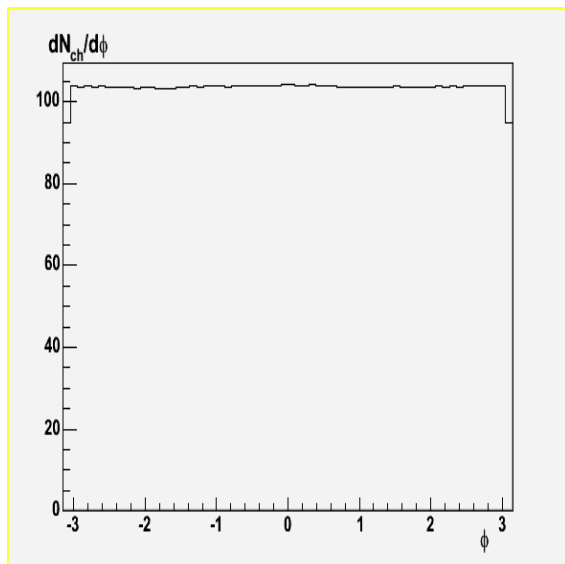
10,000 Pb+Pb events
b=10-15 fm (49.6% of σ_{inel})

$$\langle N_{ch}(|\eta|<5)\rangle = 6618 \pm 56$$

A broad centrality selection: N_{ch} varies from ~20 up to 30000



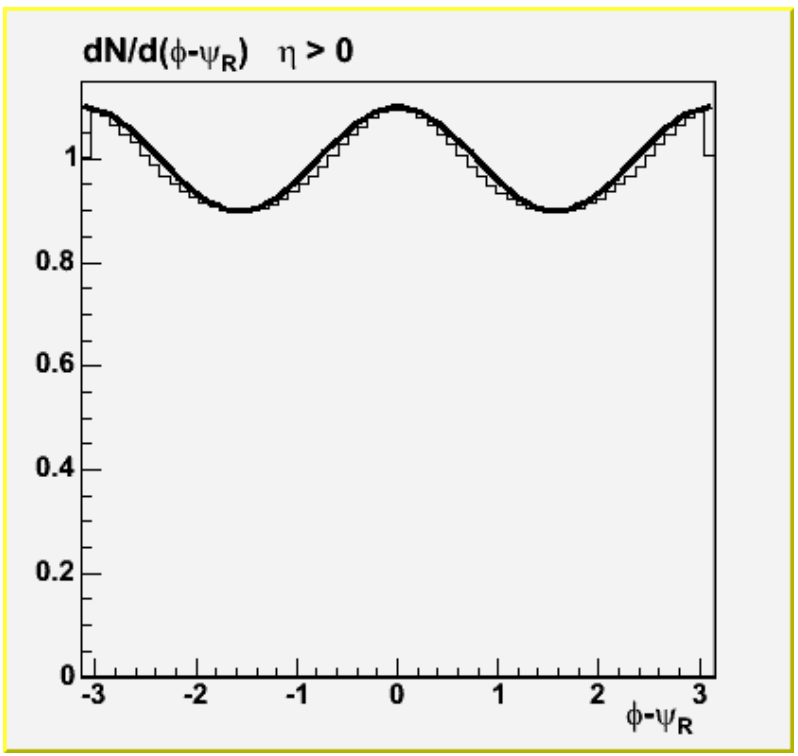


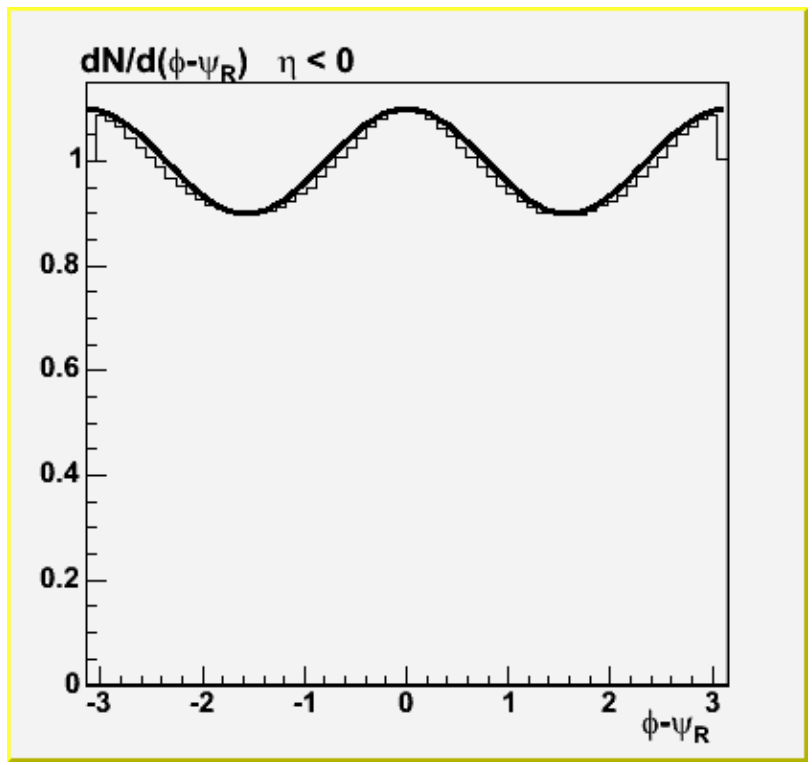


HIJING + Flow Afterburner

Input Flow: $v_1 = 0$

$v_2 = 0.05$ const(N_{ch}, η, y, p_T)



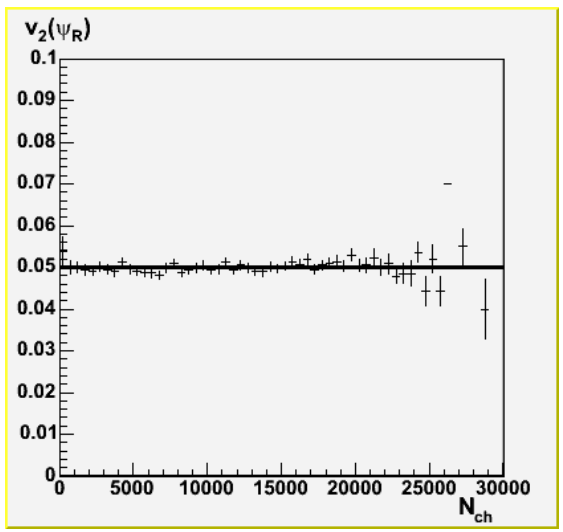


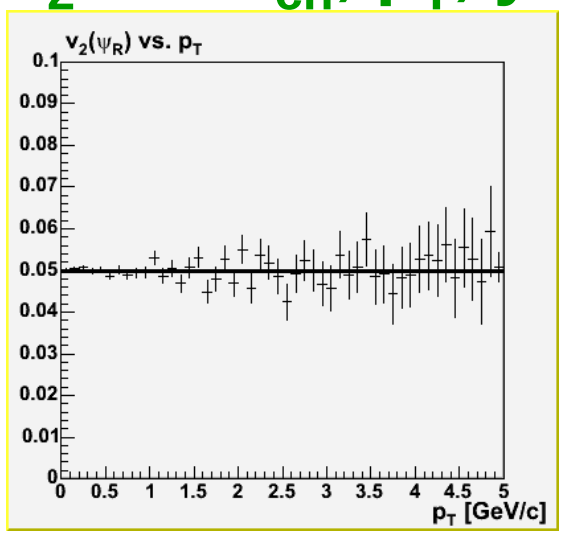
Elliptic Flow from the True Reaction Plane

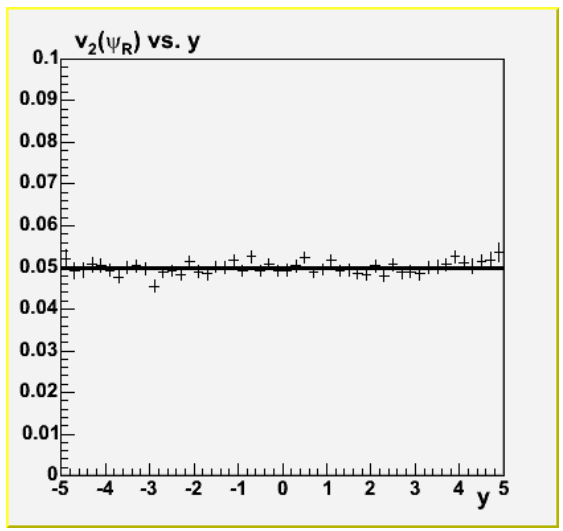
Average over all events:

$$\langle v_2 \rangle = \frac{1}{N_{ev}} \sum_{ev} \frac{1}{N_{ch}} \sum_{i=1}^{N_{ch}} \cos[2(\phi_i - \psi_R^{ev})] = 0.04996 \pm 0.00028$$

v_2 vs. N_{ch}, p_T, y:







Estimate of the Reaction Plane

- In the experimental data ψ_R is not known,
- It can be approximated by the Event Plane, ψ_2

Calculate event-by-event:

$$\psi_2 = 0.5 \cdot \tan^{-1}\left(\frac{\sum \sin(2\phi_i)}{\sum \cos(2\phi_i)}\right), \qquad i = 1,...N_{ch}$$

Correlation of every particle with the reaction plane induces correlations between particles.

But: $v_2(\psi_2) < v_2(\psi_R)$

- Well known effect, due to the finite number of particles
- Disappears after Resolution Correction

Event Plane Resolution Correction

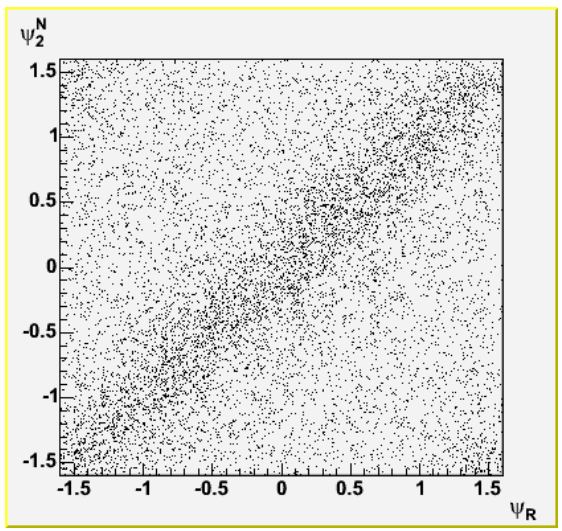
Define the two equal multiplicity sub-events:

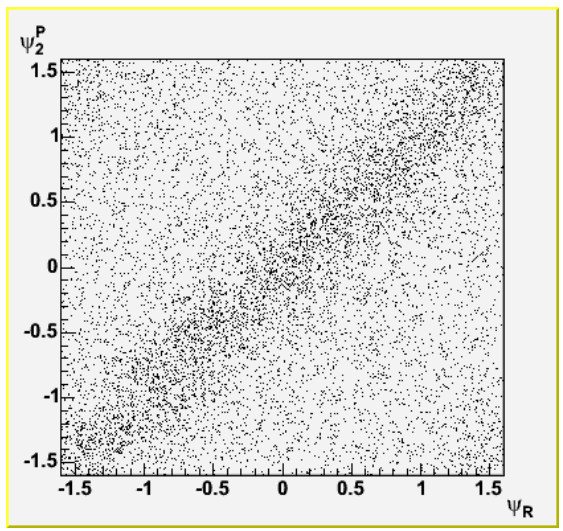
N - negative sub-event $-2<\eta<-0.2$

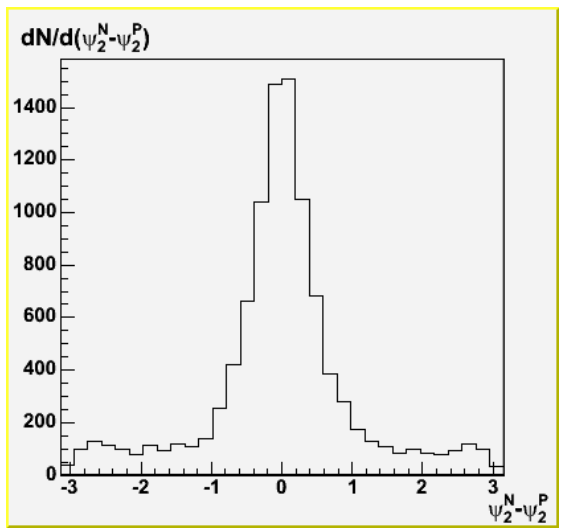
P - positive sub-event $0.2<\eta<2$

Calculate: ψ_2^N ψ_2^P

Check correlations with ψ_R

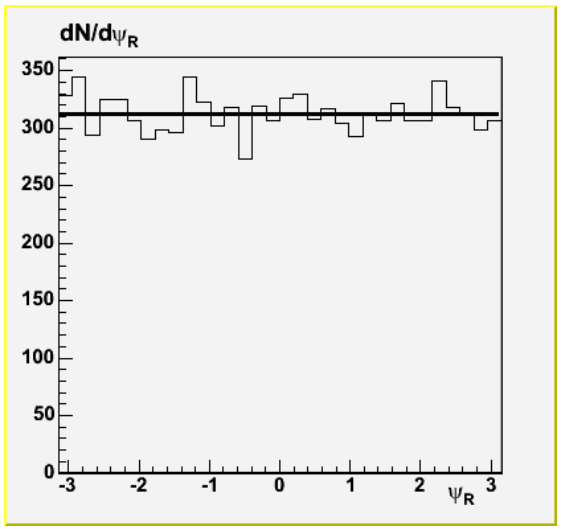


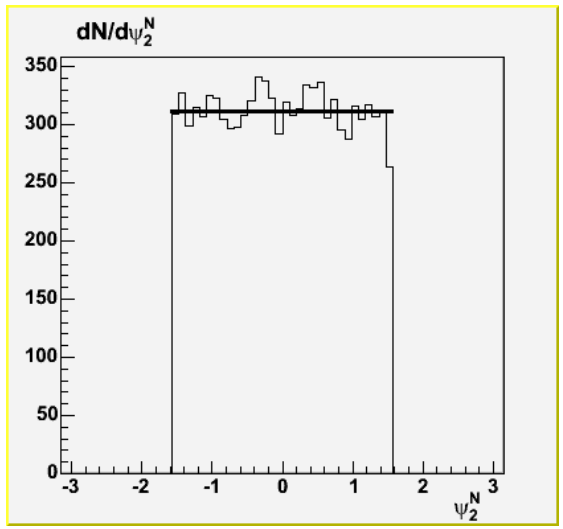


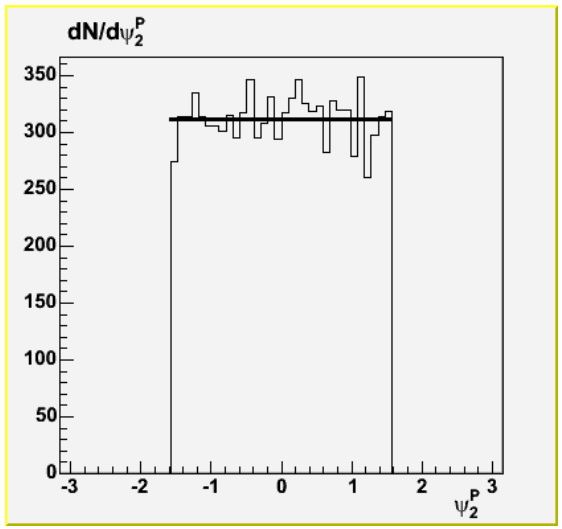


Event Plane Resolution Correction

Check uniformity of the event plane distribution







Event Plane Resolution: $\mathrm{Res} \equiv \left\langle \cos[2(\psi_2^N - \psi_2^P)] \right\rangle$

Resolution Corrected v_2: $v_2^{\mathrm{Res.Corr.}} = v_2(\psi_2) / \sqrt{\mathrm{Res}}$

Elliptic Flow from the Event Plane

To avoid autocorrelations:

use ψ_2^N to calculate $v_2(\eta \geq 0)$

use ψ_2^P to calculate $v_2(\eta < 0)$

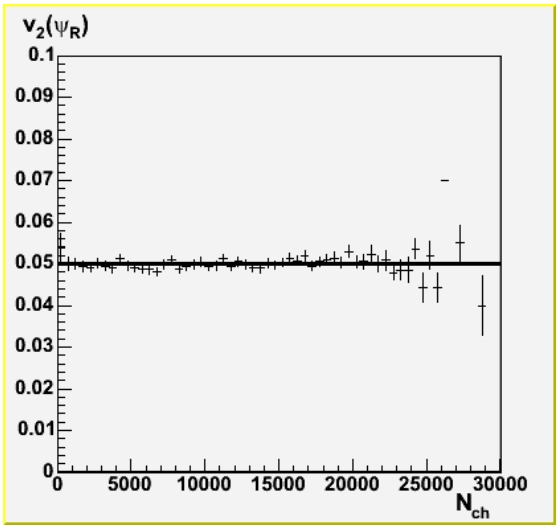
The procedure works well in average:

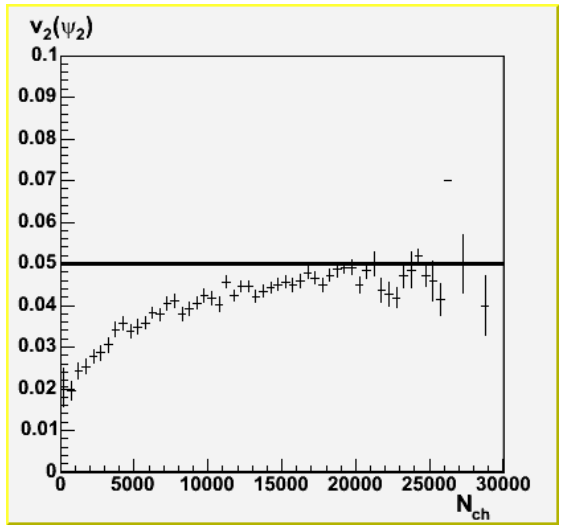
$$\langle v_2(\psi_R) \rangle = 0.04996 \pm 0.00028$$

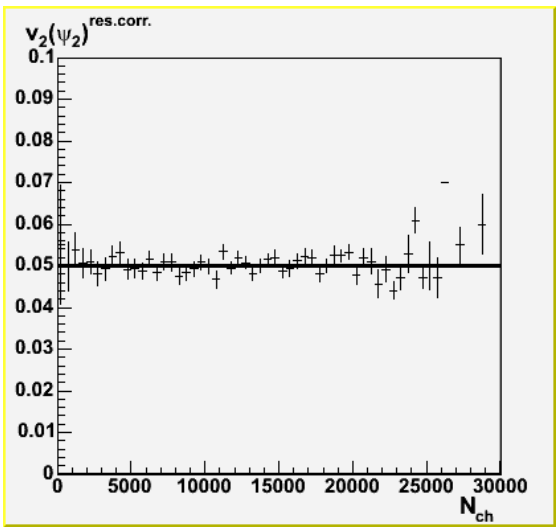
$$\langle v_2(\psi_2) \rangle = 0.03414 \pm 0.00039$$

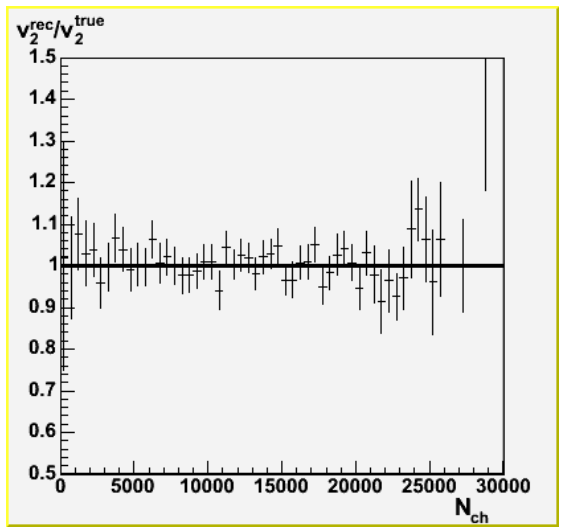
$$\langle v_2^{\text{Res.Corr.}}(\psi_2) \rangle = 0.05076 \pm 0.00091$$

$v_2(N_{ch})$ – Centrality Dependence









Must use:

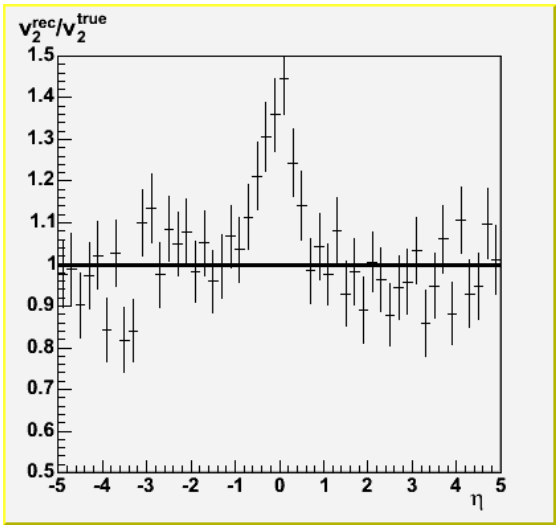
$Res(N_{ch})$

Resolution Correction depends on centrality (N_{ch})

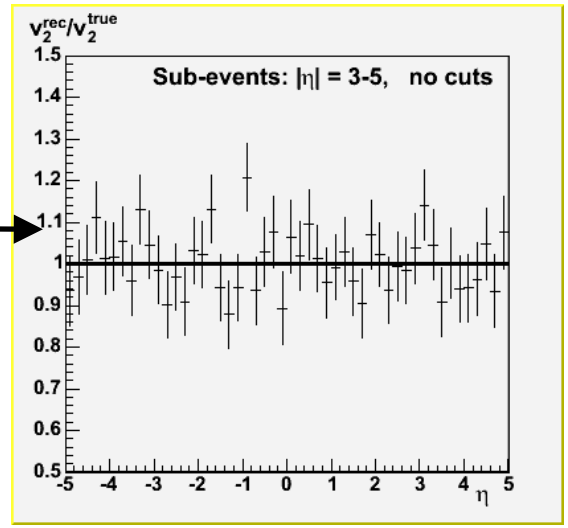
$v_2(\eta)$ – Different Choice of Sub-events

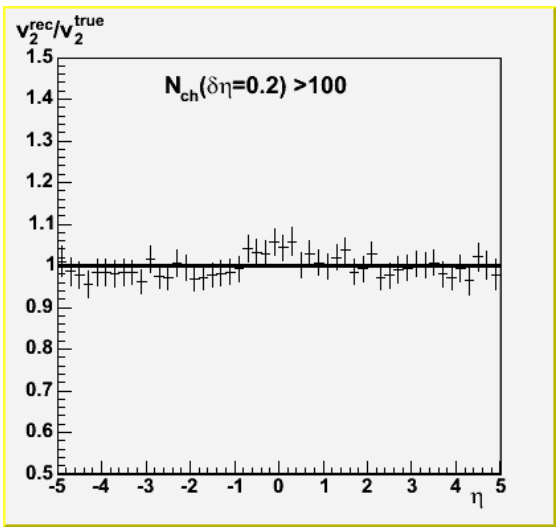
Sub-events: $|\eta|$=0.2 – 2

Sub-events: $|\eta|$=3 – 5

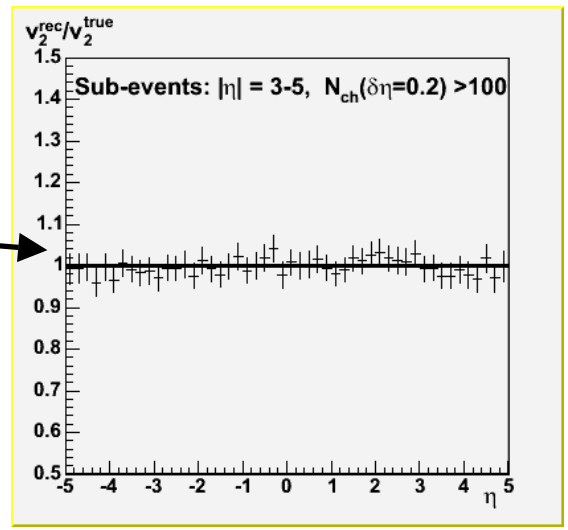


All events





$N_{ch}(\delta\eta=0.2)$ > 100



Summary of Part I

In an ideal situation:

(well defined particles, no backgrounds, no acceptance cracks)

- **Procedure of approximating the Reaction Plane by the Event Plane works well**
- **Event Plane resolution correction should be determined as a function of centrality**
- **Well separated sub-events have to be used in order to get rid of the short-range correlations**

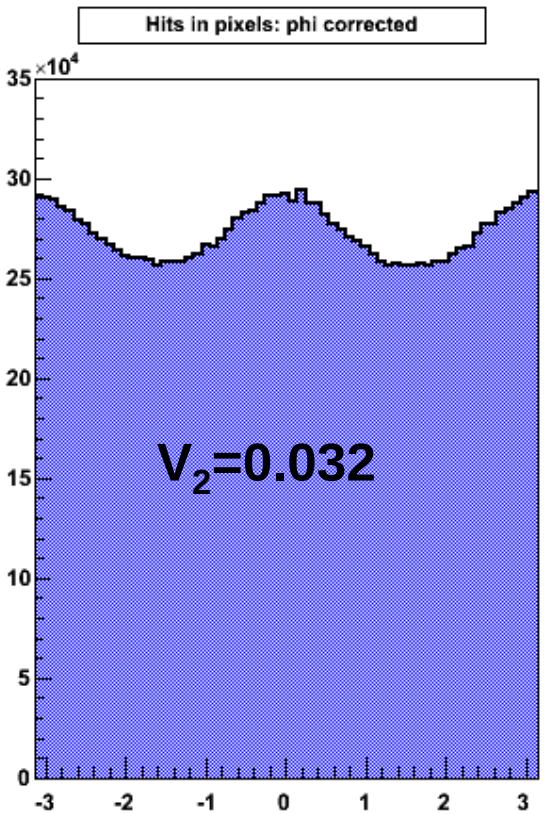
Part II: Analysis of Simulated Events

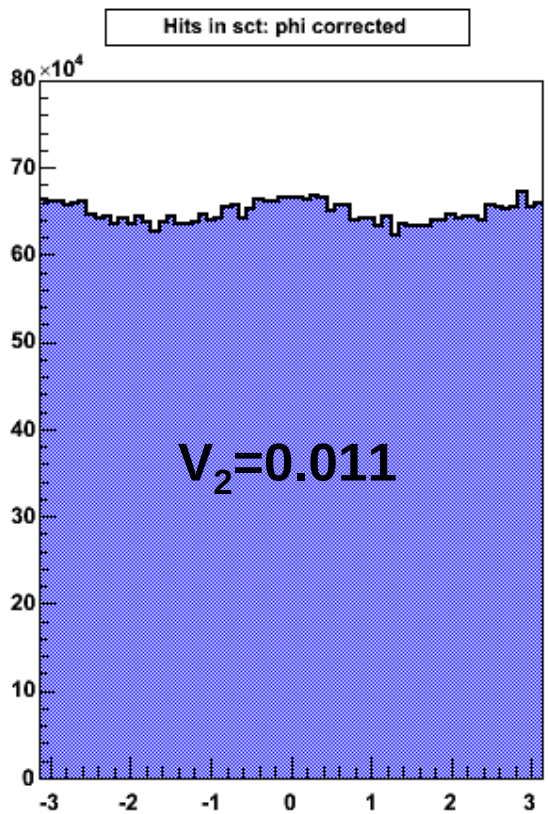
- **Flow Reconstruction in Si ID and Calorimeters**
  (Andrzej Olszewski)

  Prepared data summary trees with:
  – hits in silicon pixels
  – energy in calorimeters
  – combined energy in calorimeters

  Looked at raw flow signal calculated from:
  – position of hits in silicon pixels
  – Energy weighted position of hits in calorimeters
  Using the true reaction plane!

Flow Pattern in Silicon



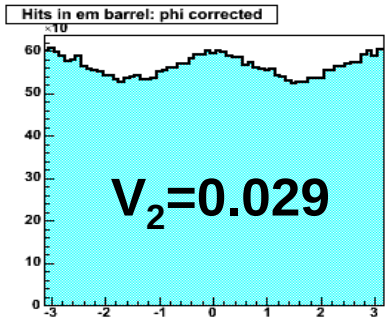


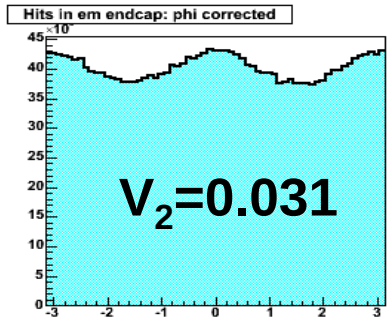
Sample: 1000 events
Flow v2 = 0.05

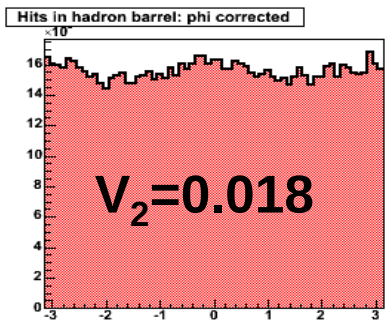
Plot:
for Pixels (left)
for SCT (right)

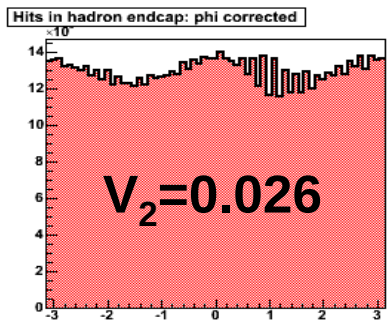
No of hits (ϕ - ψ_R)

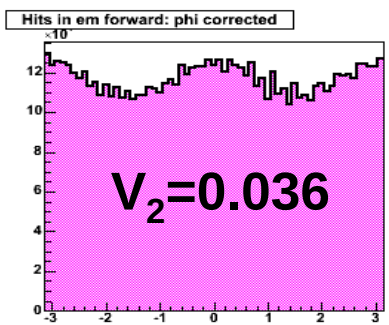
Flow Pattern in Calorimeters

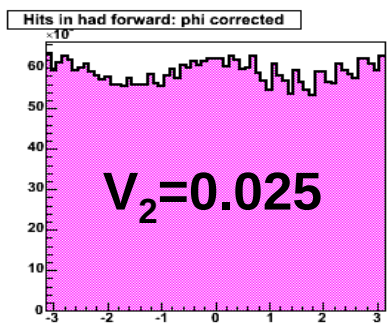












Sample: 1000 events
Flow v2 = 0.05

Plots:
- **EM Barrel (left), Endcap (right)**
- **HAD Barrel (left), Endcap (right)**
- **FWD EM (left), Had (right)**

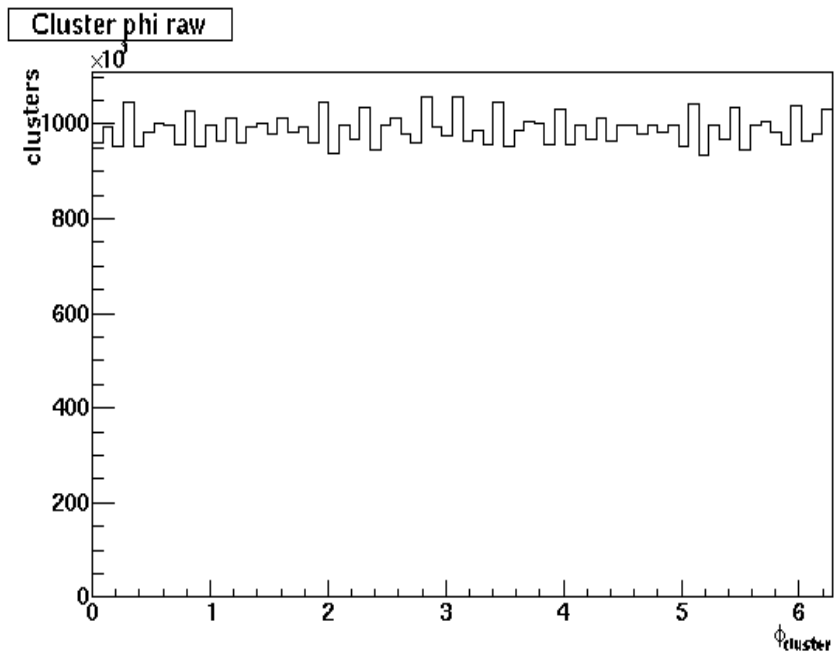
Energy of hits (ϕ - ψ_R)

Results from Reconstructed Clusters

- **Results for 10000 HIJING events with artificially inserted flow** (Krzysztof Woźniak)

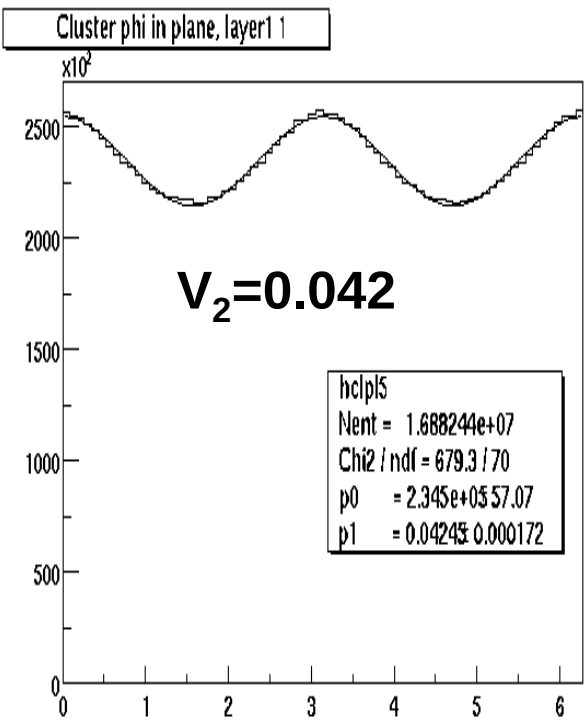
Algorithm of cluster reconstruction was applied for digitized data from Si pixel layers.

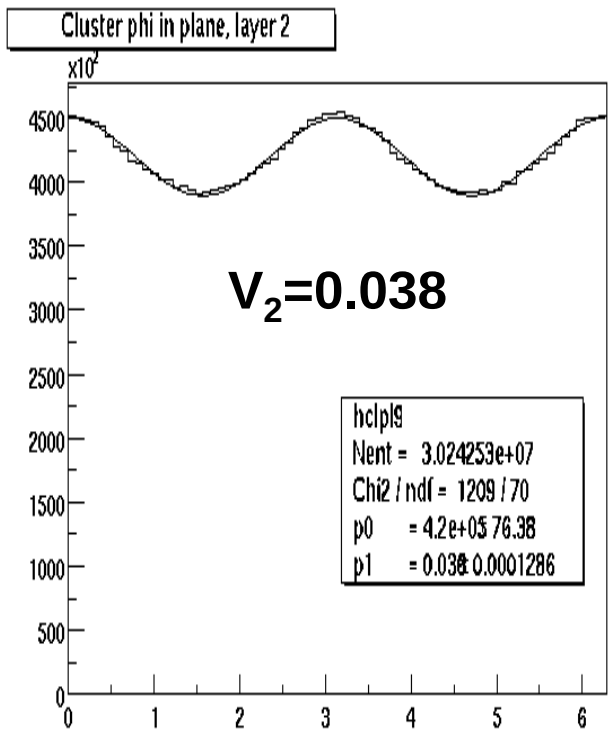
Raw distribution of phi angle for clusters is flat, has relatively large fluctuations due to digitized positions (set to center of the pixel)

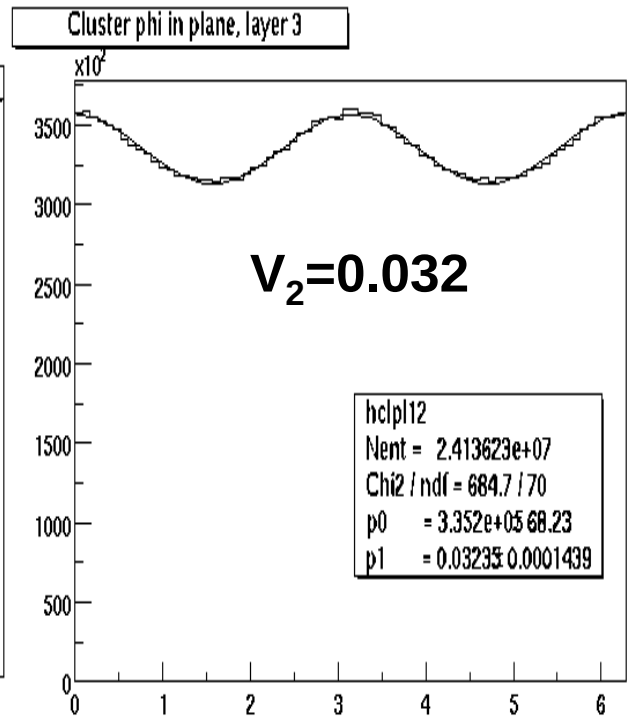


Flow Pattern in Reconstructed Clusters

Distribution of ϕ of the clusters relative to the true reaction plane clearly shows flow effects.







To do: Flow from the event plane.