Elliptic flow measurement in ALICE

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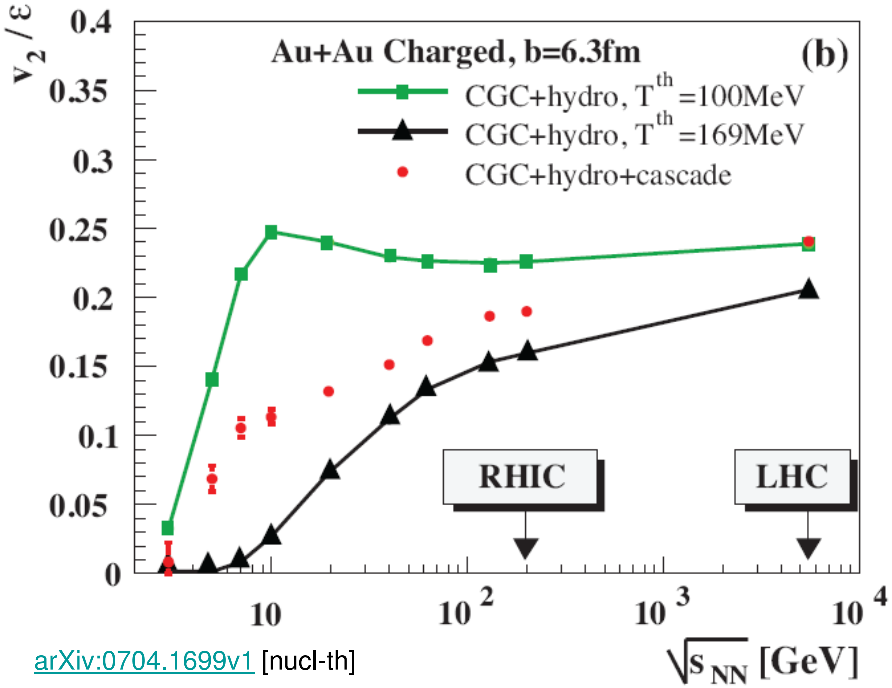
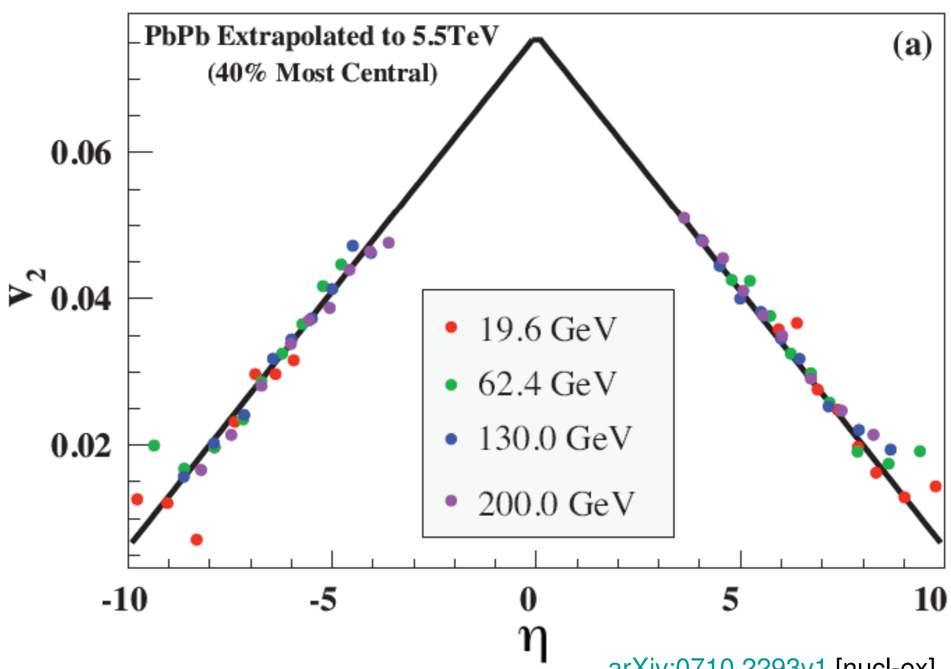
Elliptic flow at the LHC

- Elliptic flow is predicted to be ~10% to 50% higher at the LHC compared to RHIC



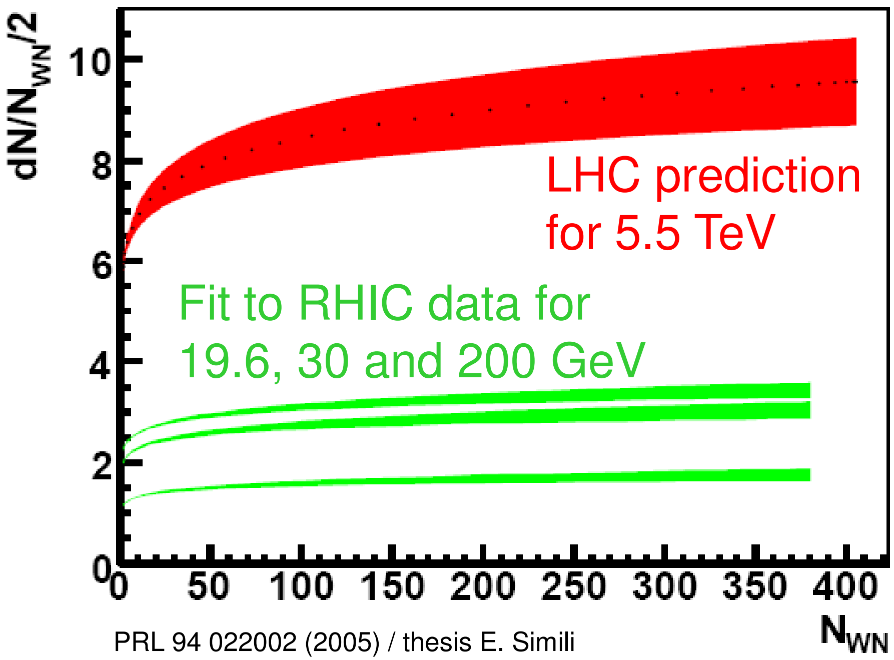
arXiv:0704.1699v1 [nucl-th]



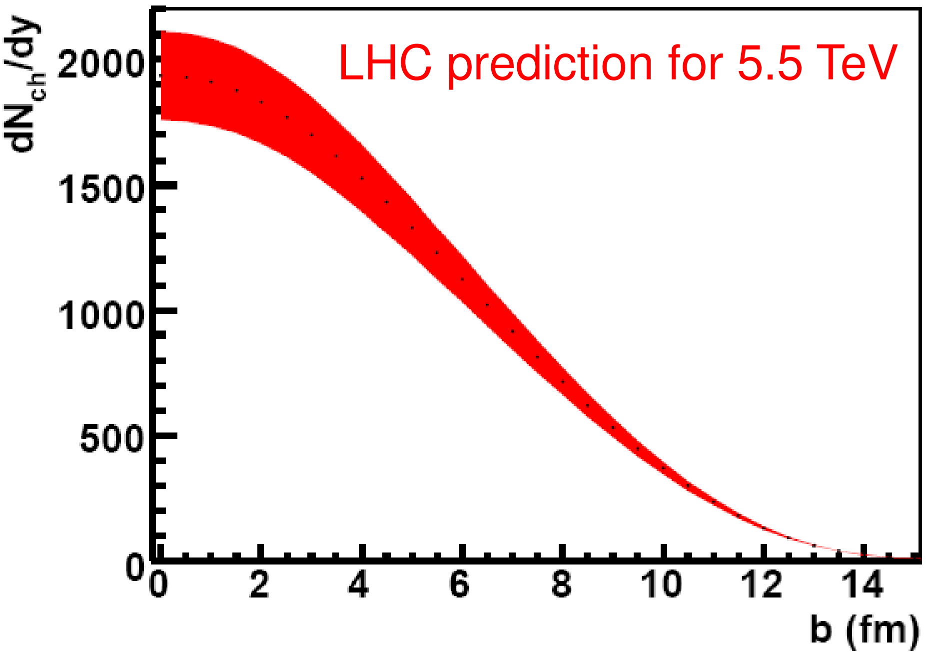
arXiv:0710.2293v1 [nucl-ex]

Elliptic flow at the LHC

- Multiplicity is predicted to be ~2.5 times higher than at RHIC



PRL 94 022002 (2005) / thesis E. Simili

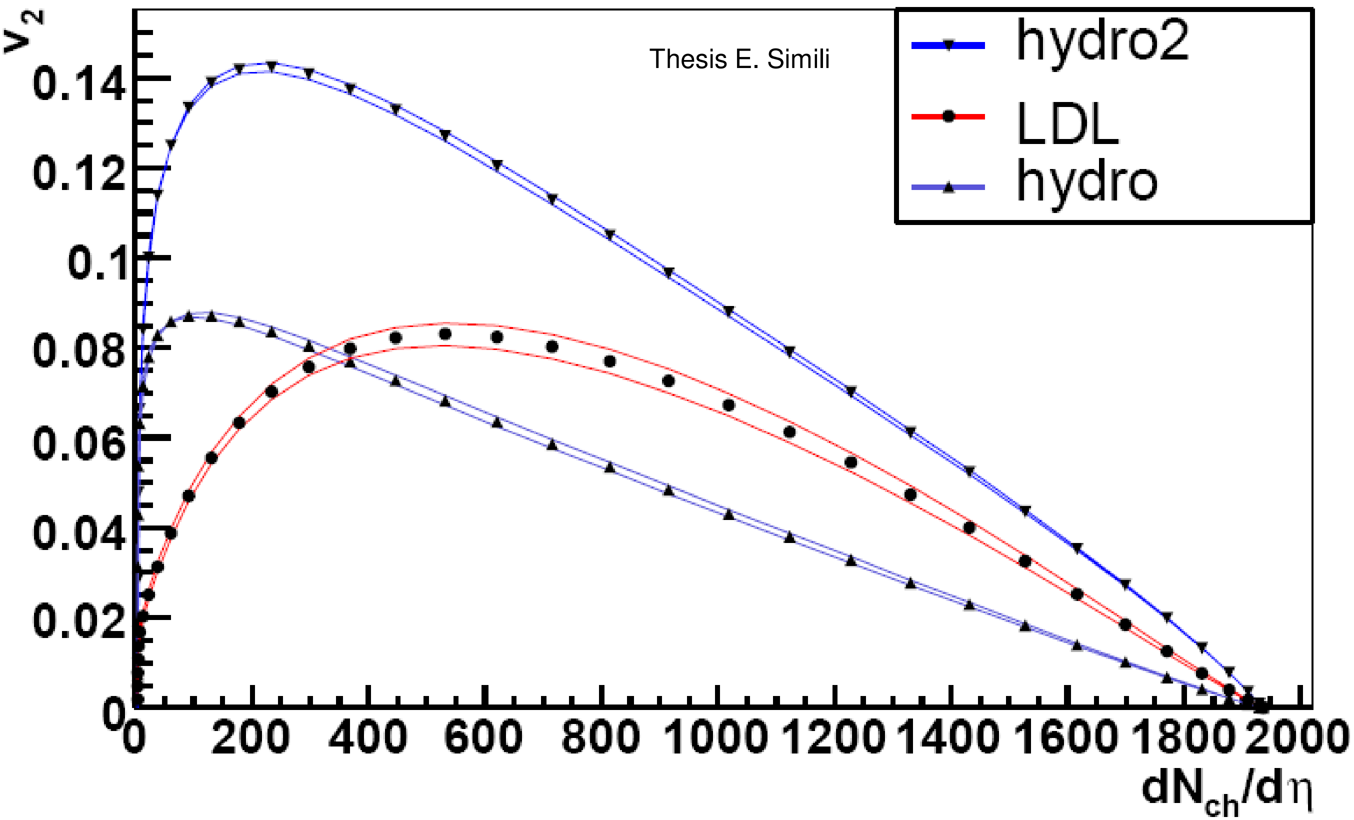


Elliptic flow at the LHC

- Flow can be estimated:
  - From 2-particle correlations if $v_2 >> 1/M^{\frac{1}{2}}$
  - From 4-particle correlations if $v_2 >> 1/M^{\frac{3}{4}}$
  - From genuine multiparticle correlations if

$$v_2 >> 1/M$$

Elliptic flow at the LHC



Hydro $c_s^2 = 0.22$

Hydro2 $c_s^2 = 0.33$

- Elliptic flow measurements are possible for intermediate centralities

Elliptic flow measurement

- If only flow correlations are present:

$$\left\langle\left\langle e^{in(\phi_1-\phi_2)}\right\rangle\right\rangle = \left\langle\left\langle e^{in(\phi_1-\Psi_{\mathrm{RP}}-(\phi_2-\Psi_{\mathrm{RP}}))}\right\rangle\right\rangle$$
$$= \left\langle\left\langle e^{in(\phi_1-\Psi_{\mathrm{RP}})}\right\rangle\right\rangle\left\langle\left\langle e^{-in(\phi_2-\Psi_{\mathrm{RP}})}\right\rangle\right\rangle = \left\langle v_n^2\right\rangle$$

- However, statistical flow fluctuations are present:

$$\left\langle v_n^2\right\rangle = \left\langle v_n\right\rangle^2 + \sigma_{v_n}^2$$

- And nonflow is present:

$$\left\langle\left\langle e^{in(\phi_1-\phi_2)}\right\rangle\right\rangle = \left\langle v_n^2\right\rangle + \delta_2$$

Elliptic flow measurement

- Multiparticle correlation methods can eliminate nonflow
  - If there are only flow and 2-particle nonflow correlations present, than the measured 2- and 4-particle correlations are:

$$\left\langle\left\langle e^{in(\phi_1-\phi_2)}\right\rangle\right\rangle = v_n^2+\delta_2$$

$$\left\langle\left\langle e^{in(\phi_1+\phi_2-\phi_3-\phi_4)}\right\rangle\right\rangle = v_n^4+4v_n^2\delta_2+2\delta_2^2$$

  - By definition the 2nd and 4th order cumulant are given by

$$c_n\{2\} \equiv \left\langle\left\langle e^{in(\phi_1-\phi_2)}\right\rangle\right\rangle = v_n^2+\delta_2$$

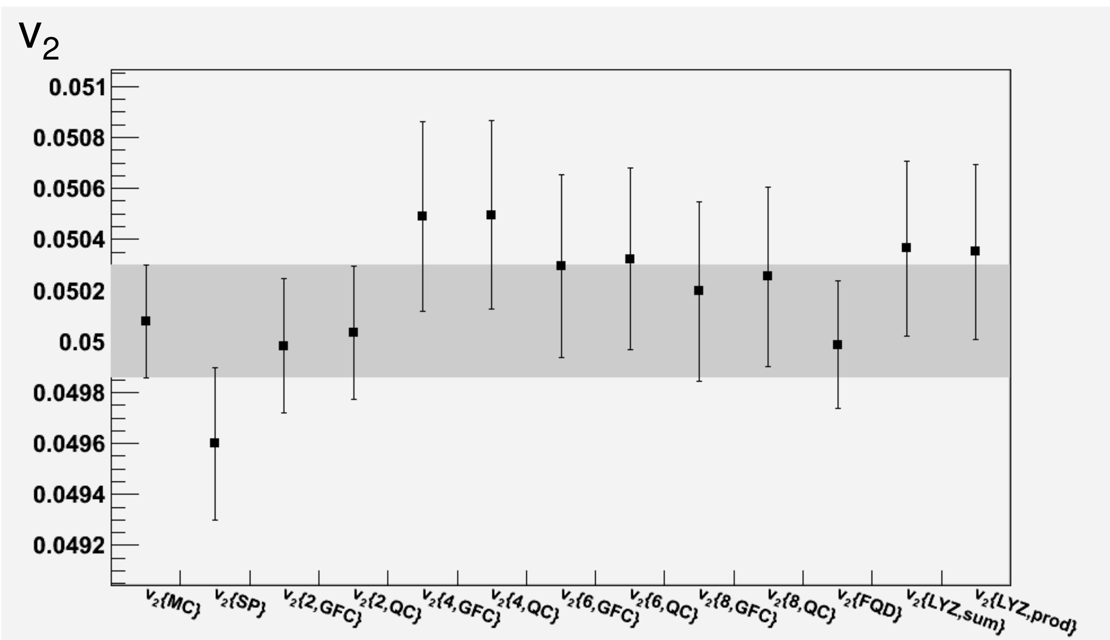
$$\begin{aligned} c_n\{4\} &\equiv \left\langle\left\langle e^{in(\phi_1+\phi_2-\phi_3-\phi_4)}\right\rangle\right\rangle - 2\left\langle\left\langle e^{in(\phi_1-\phi_2)}\right\rangle\right\rangle^2 \\ &= v_n^4+4v_n^2\delta_2+2\delta_2^2-2(v_n^2+\delta_2)^2 \\ &= -v_n^4 \end{aligned}$$

Analysis methods

- For flow analysis in ALICE the following methods are available:
- Based on 2-particle correlations
  - Event Plane and Scalar product (SP)
  - 2nd order cumulant (GFC, QC)
- Based on multiparticle correlations
  - Cumulants (GFC, QC)
  - Fitting q-distribution (FQD)
  - Lee-Yang Zeroes (LYZ)
- As a reference
  - Monte Carlo event plane (MCEP)

Performance

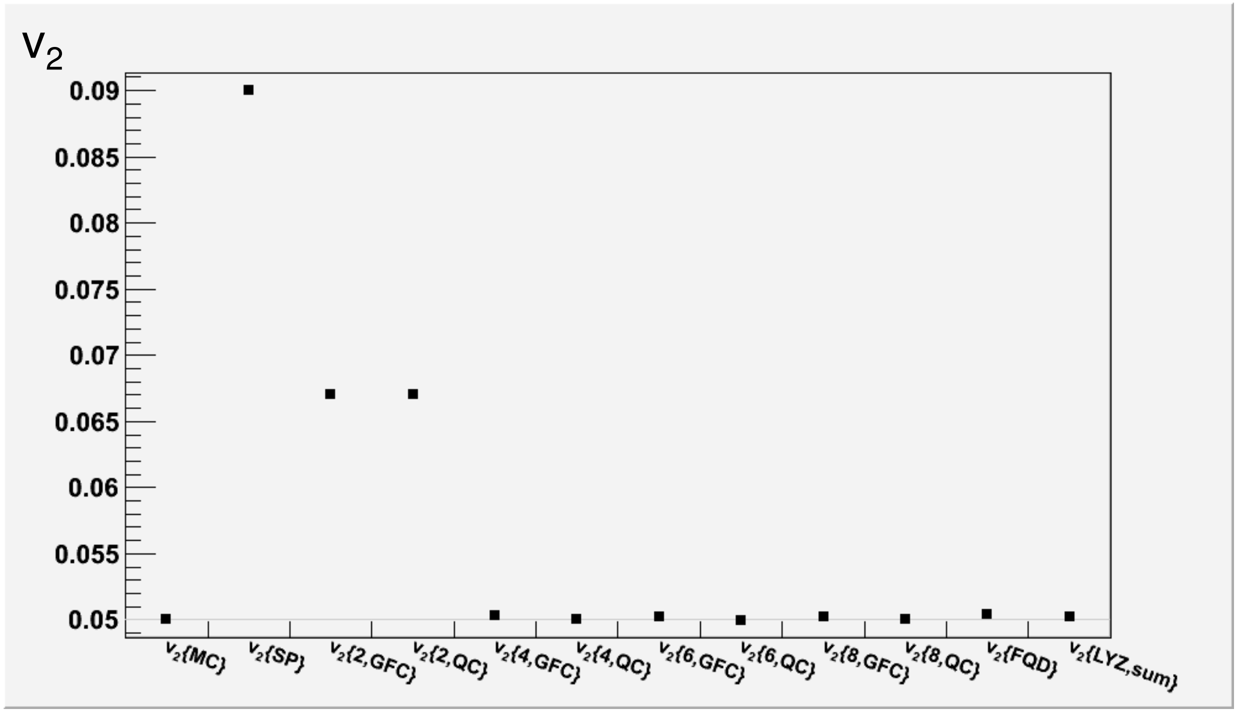
- Simple model
  - Tracks sampled from a thermal distribution containing only known correlations



M = 500, v2 = 0.05,
N = 20000

Nonflow

- $v_2 = 0.05$, $M = 500$, $N = 5 \times 10^6$
- nonflow is simulated by taking each particle twice
- As expected only the 2-particle estimates are biased

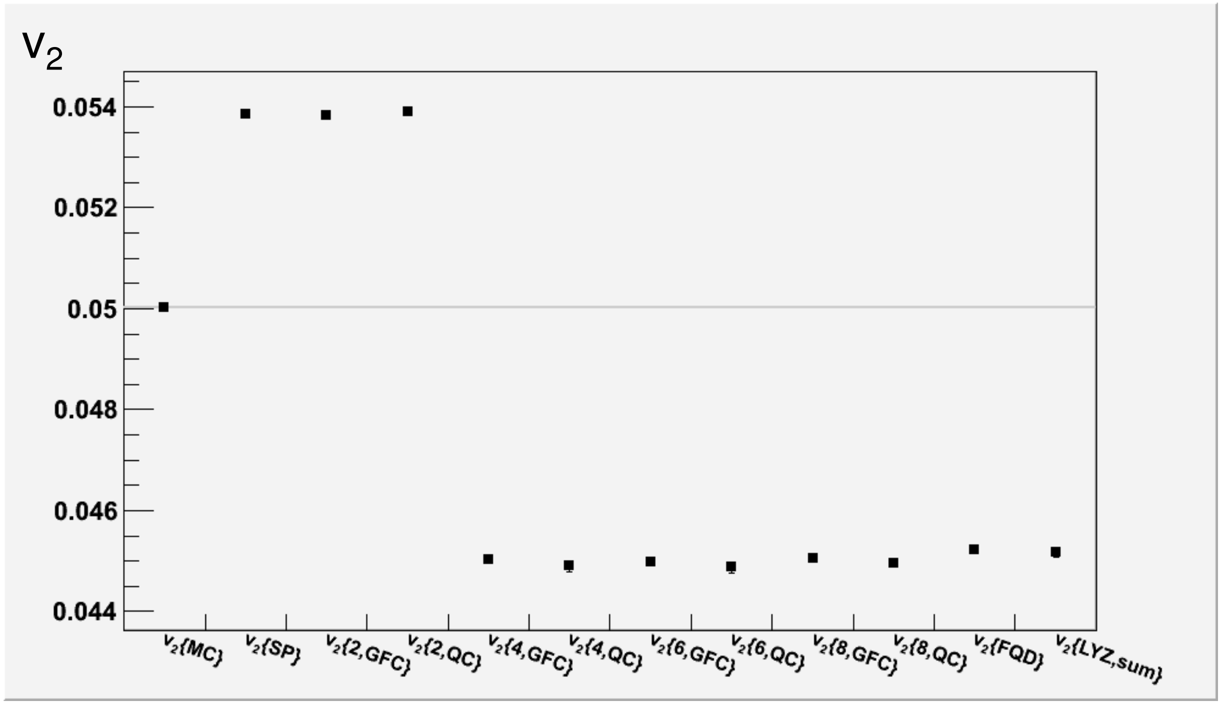


Flow fluctuations

- For Gaussian flow fluctuations:

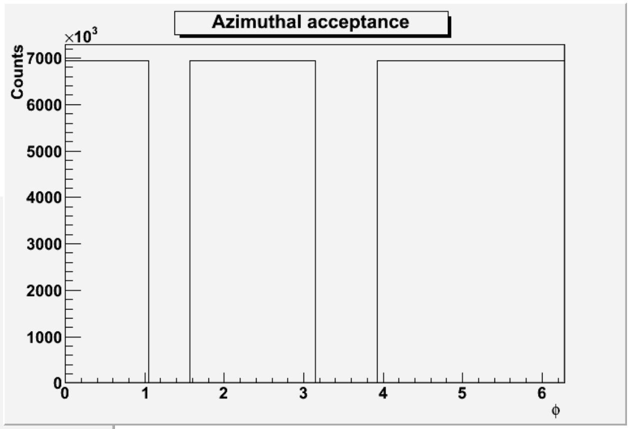
$$\text{2–particle}: \; v_2\{2\} = \langle v_2 \rangle + \sigma_{v_2}^2 / (2\langle v_2 \rangle)$$
$$\text{2k–particle}: \; v_2\{2k\} = \langle v_2 \rangle - \sigma_{v_2}^2 / (2\langle v_2 \rangle), \quad (k > 1)$$

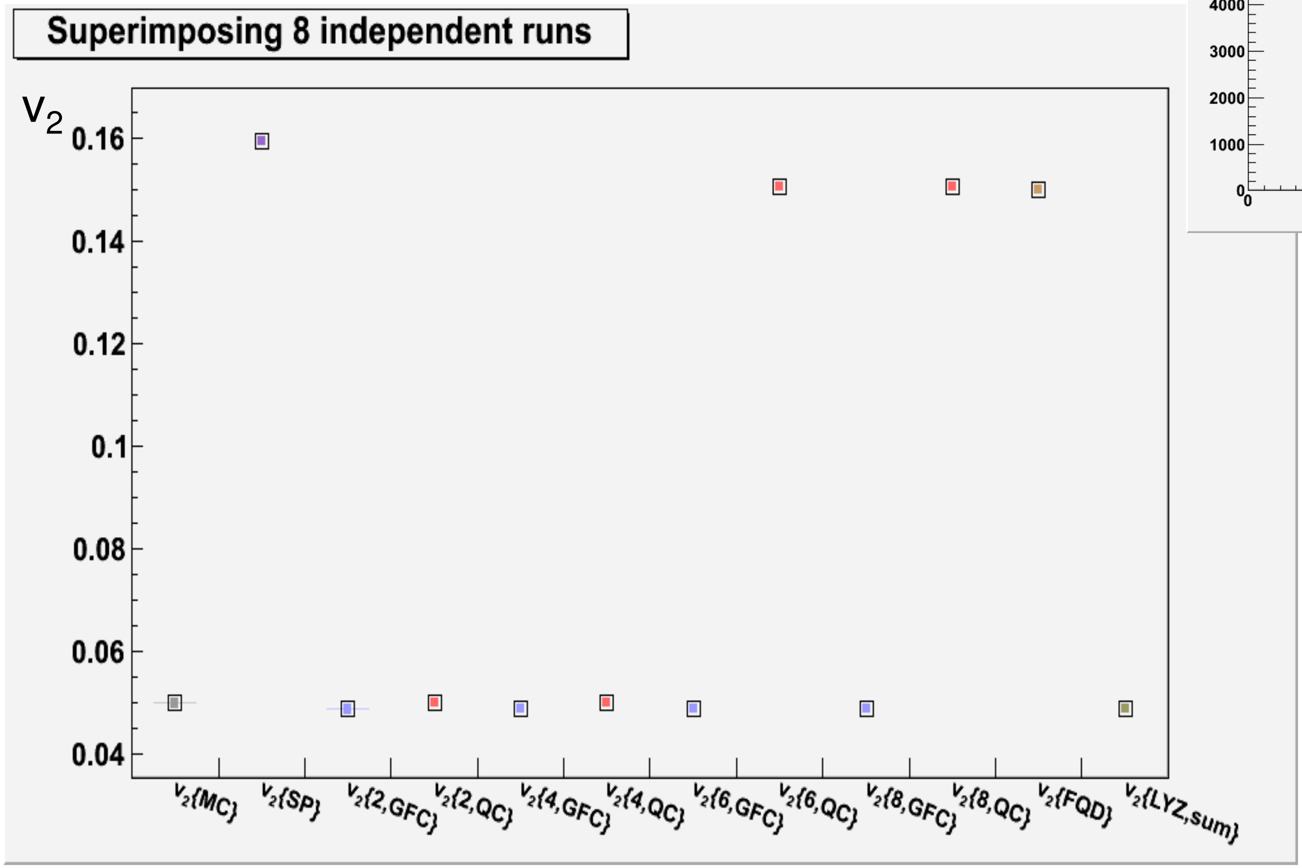
- $v_2 = 0.05 \pm 0.02$ (Gaussian), $M = 500$, $N = 10^6$
- The methods are affected as predicted



non-uniform acceptance

- $v_2 = 0.05$, $M = 500$, $N = 8 \times 10^6$

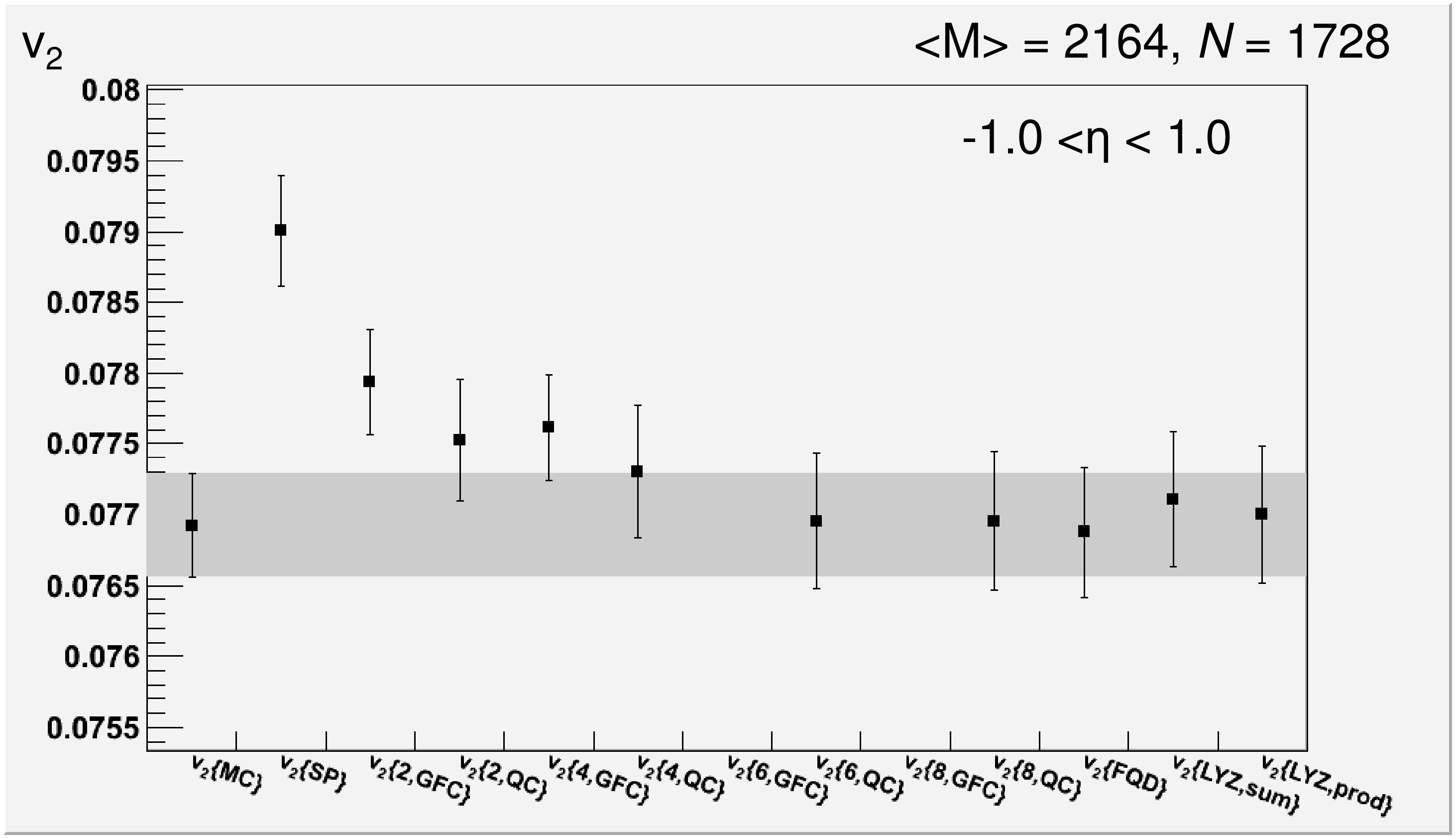




Performance

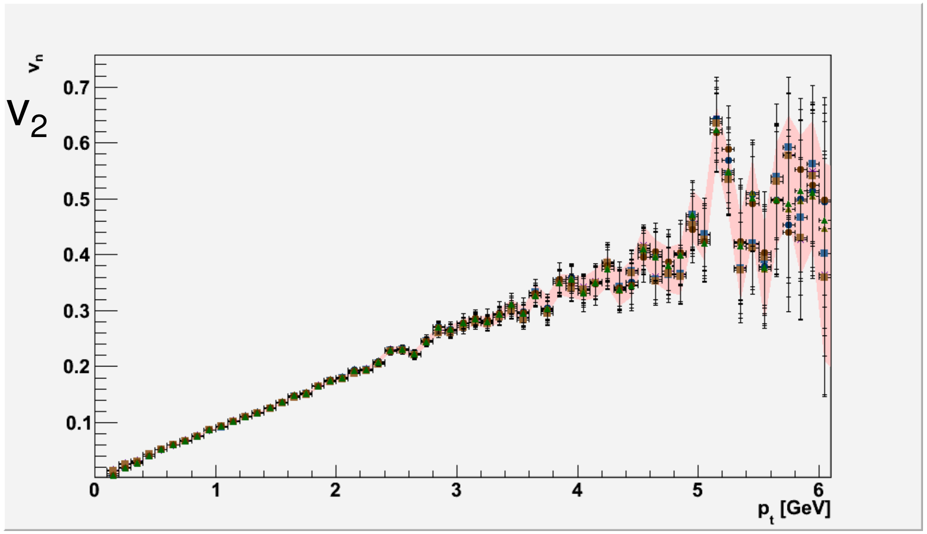
- Therminator (arXiv:nucl-th/0504047)
  - Realistic heavy-ion dataset from hydrodynamics containing correlations from resonance decays, HBT and anisotropic flow

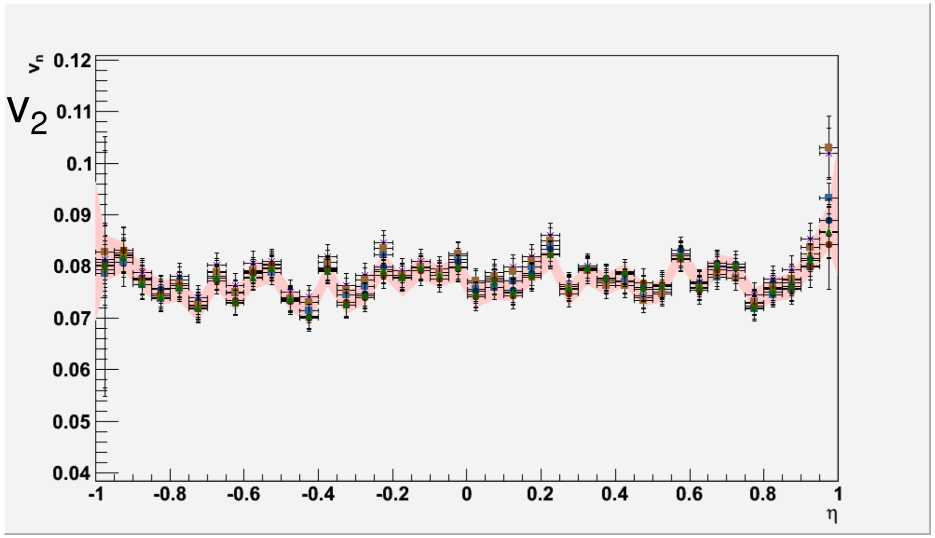
Therminator



- A clear advantage of multi-particle methods over 2-particle methods

Therminator



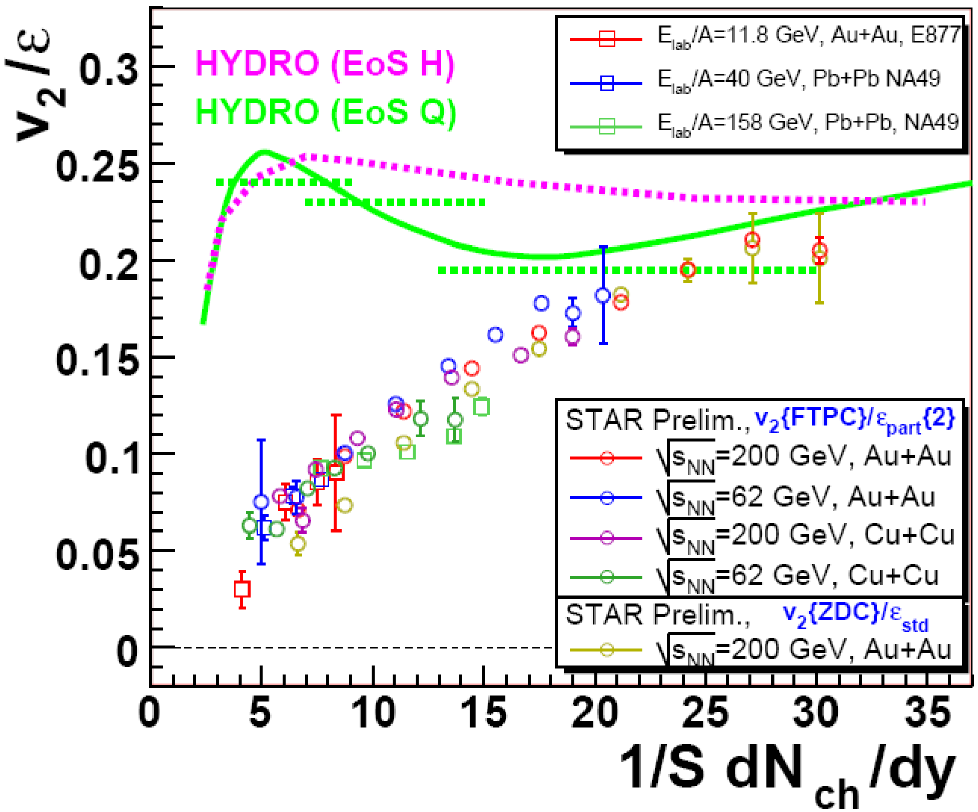


With a few minutes of good data taking a reliable measurement of flow can be done in ALICE

Elliptic flow in pp?

- Predictions for elliptic flow in proton-proton collisions at LHC are divers
  - The multiplicity for pp at LHC is comparable to that of CuCu at RHIC => sizeble flow
  - Because of the small system size viscosity effects will prevent flow developing => small flow

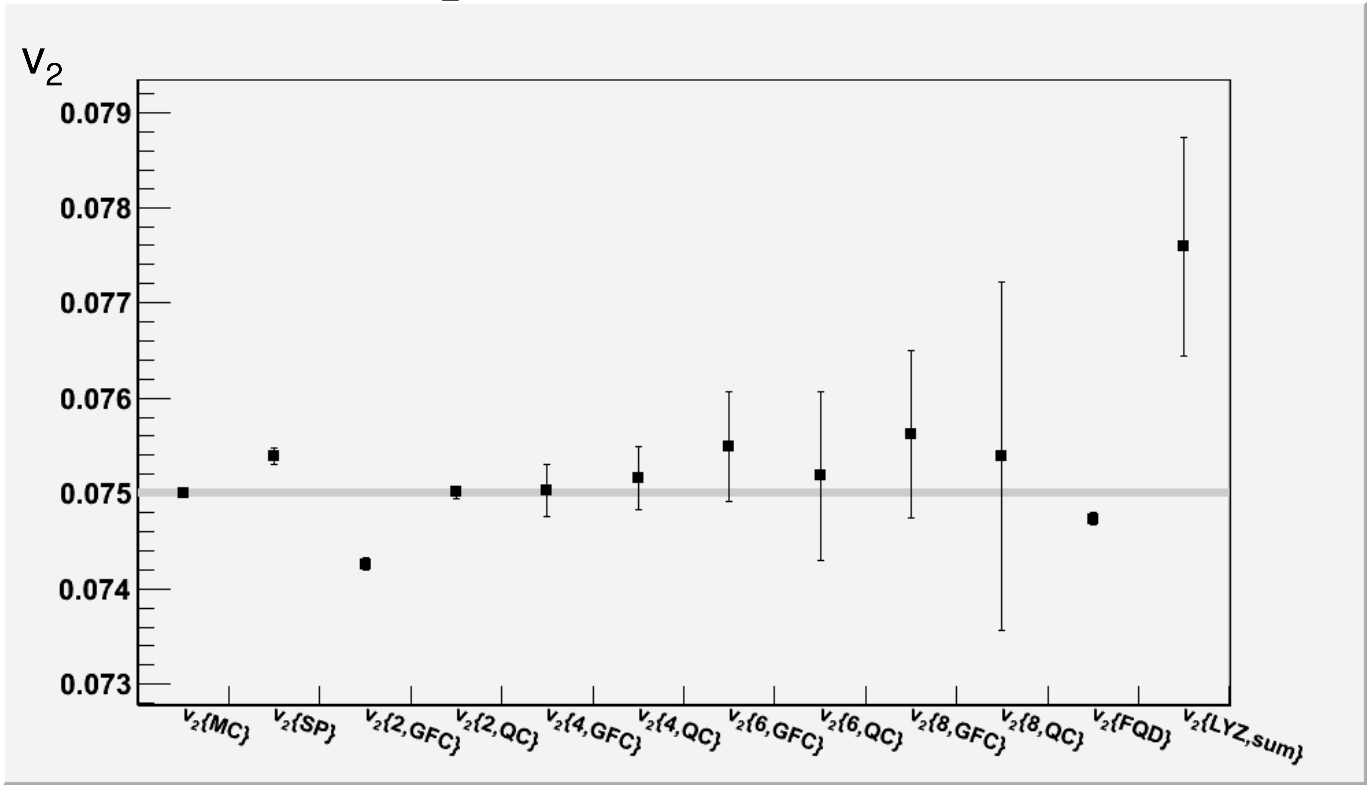
Will pp fit this scaling?



- The measurement of flow in pp is a good test of our understanding of how flow develops

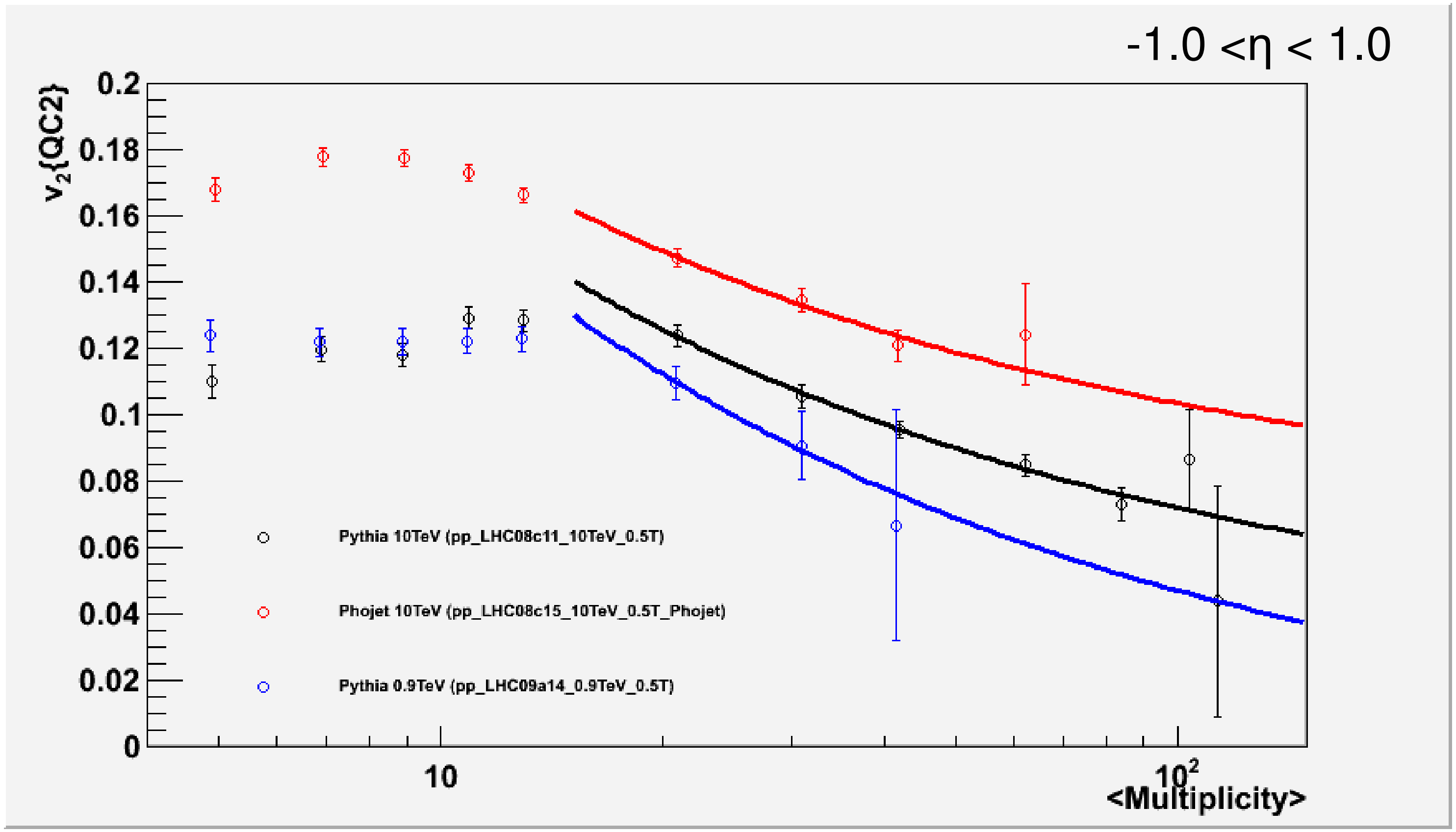
Flow measurement at low multiplicity

- The analysis methods are limited: $v_n >> 1/M^{\frac{1}{2}}$
- For our ideal model flow can be measured
- $M = 50$ +/- 10 (Gaussian), $v_2 = 0.075$, $N = 7 \times 10^6$



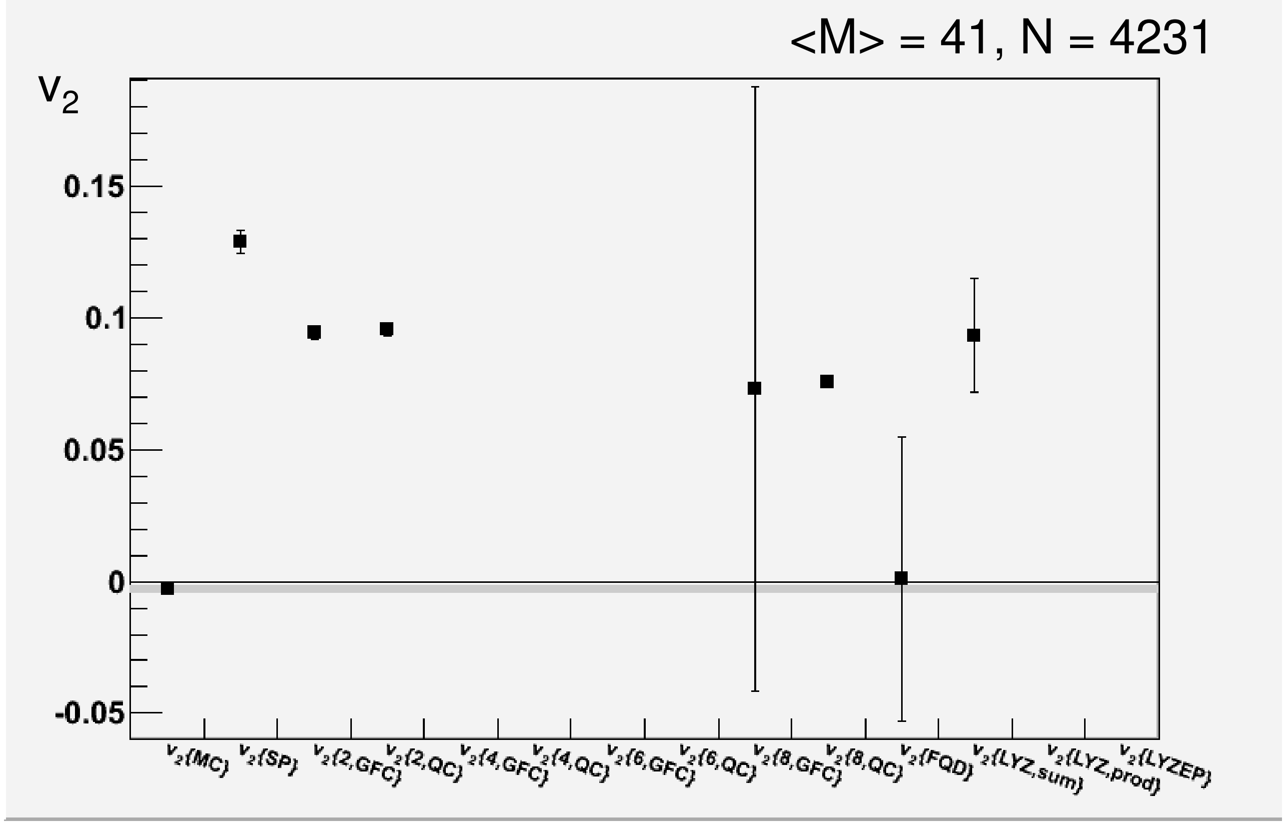
Pythia and Phojet results

- More realistic case
- no correlations with the reaction plane

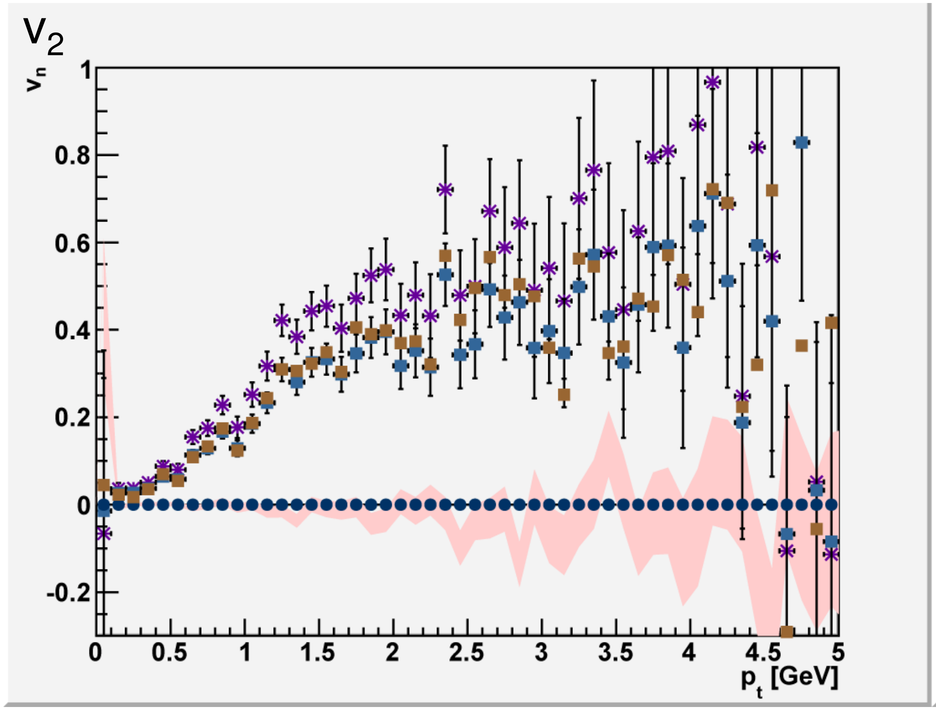


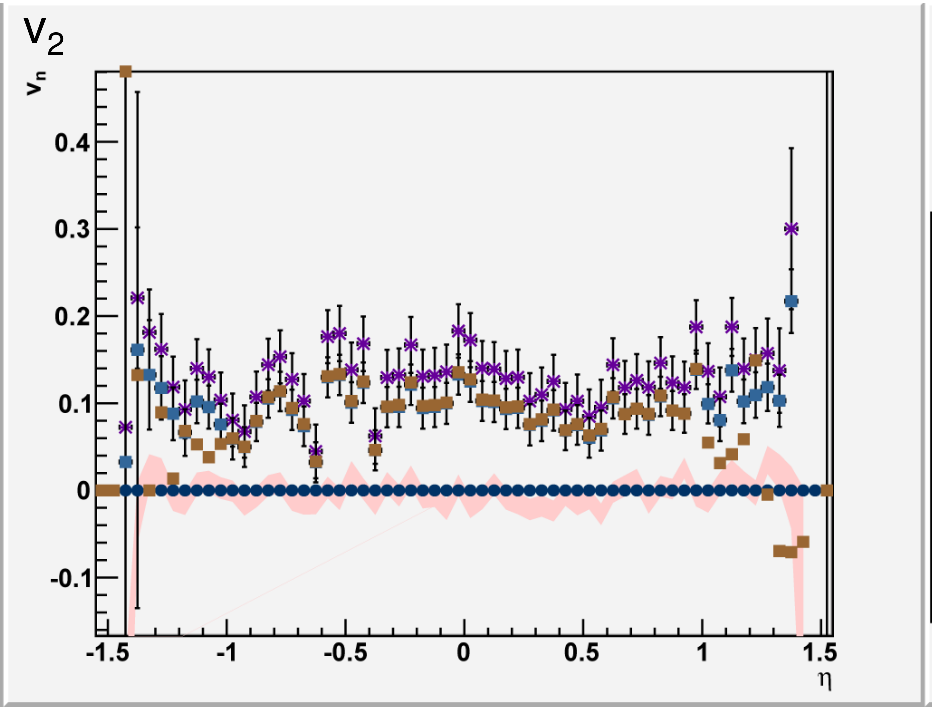
Pythia results 40 < M < 44

- Pythia 10TeV, 0.5T
- The methods don't converge



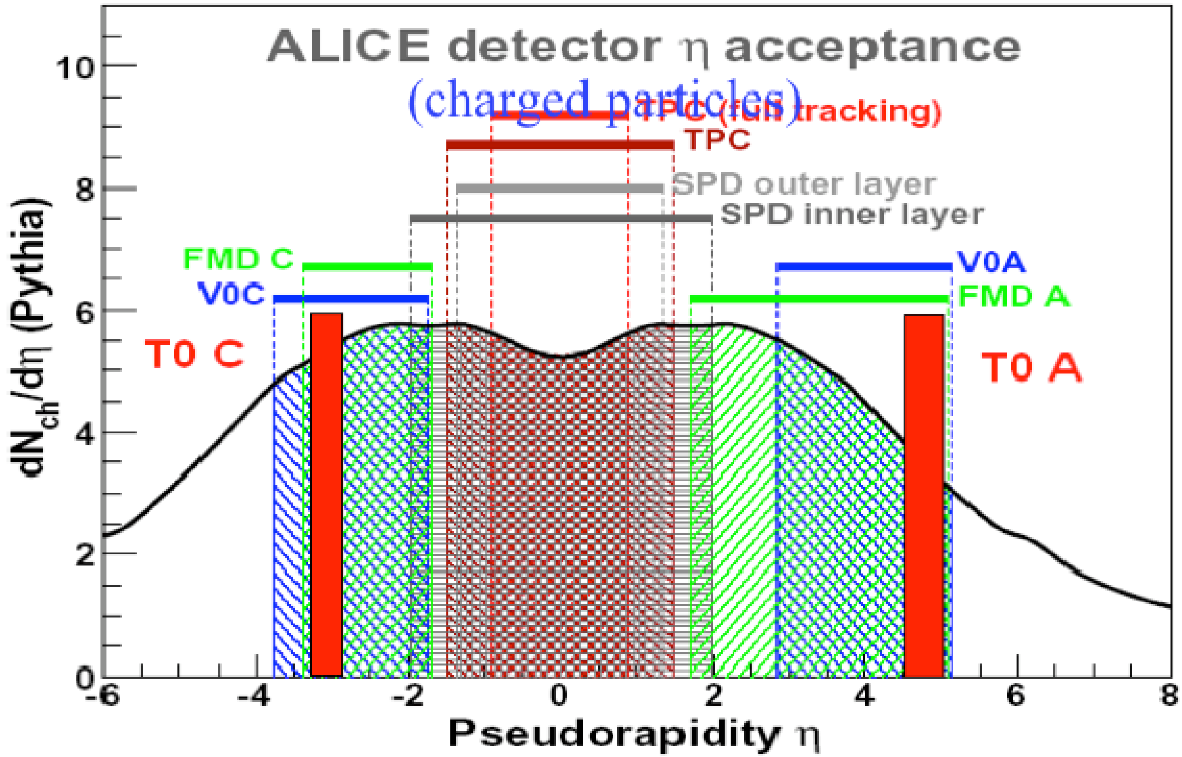
Pythia results 40 < M < 44





Rapidity gap needed

- Need to use ALICE's forward detectors
- Study ongoing with S.K.Prasad



Conclusions

- With the available analysis methods in ALICE flow can be measured well for PbPb collisions due to the high expected flow value and the high multiplicity
- The measurement of flow in pp collisions is much more challenging… but very interesting