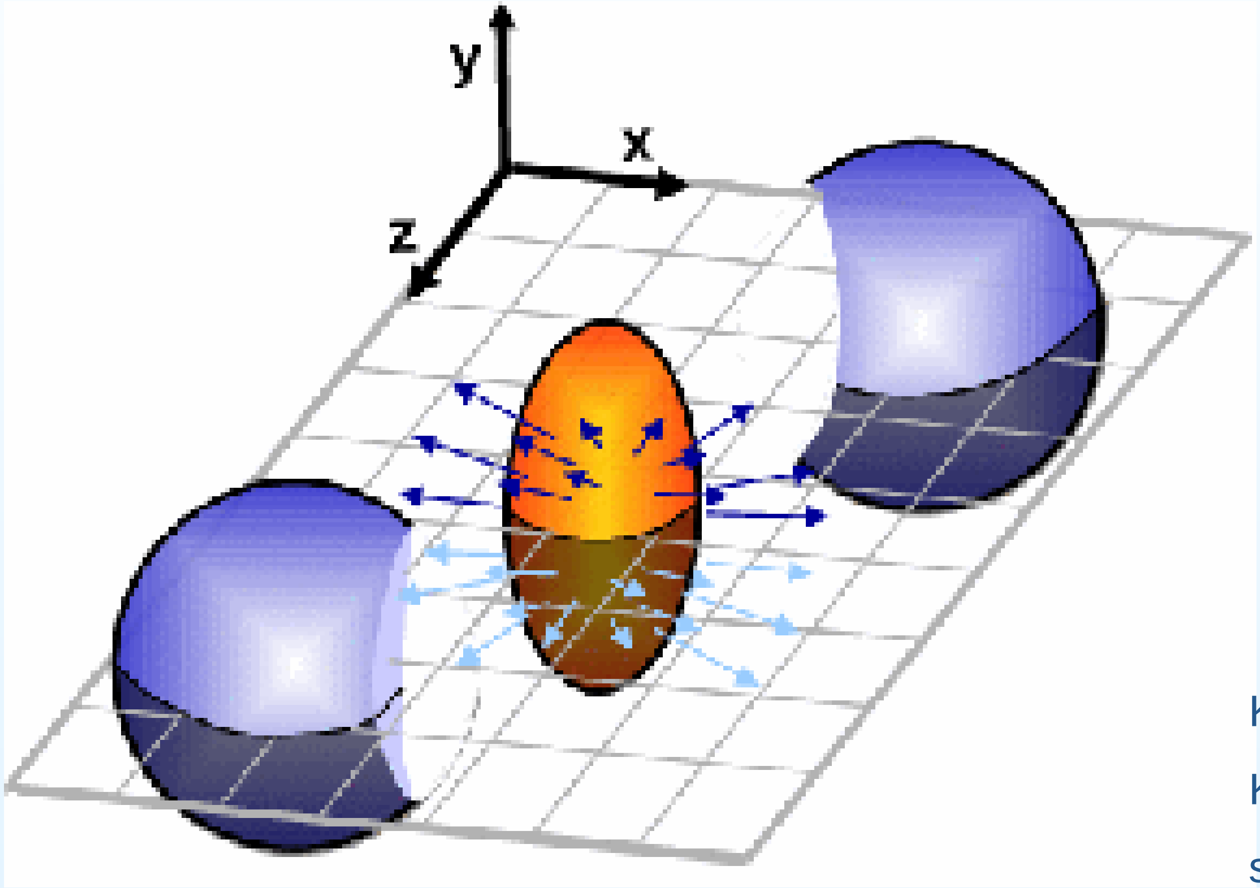
How to measure elliptic flow in pp@LHC?

Jovan Milošević

University of Oslo, Norway

A schematic view of a non-central nucleus-nucleus collision

- Does in TeV regime proton-proton collision looks like that?

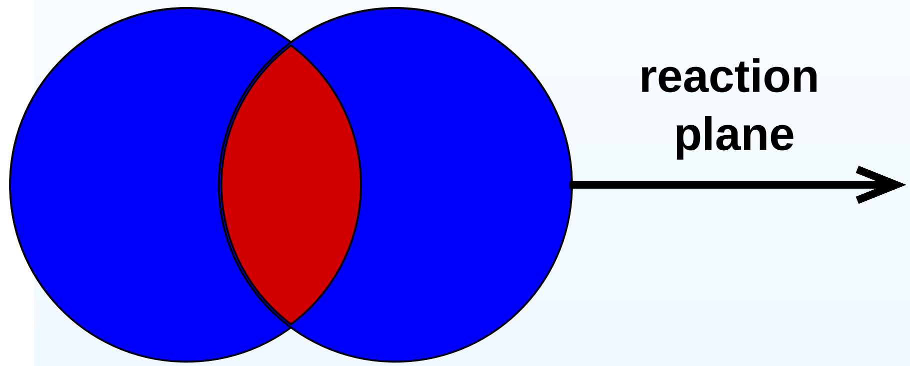


- With an increase of the incident energy the edge of the overlapping region becomes sharper and the smearing of it, due to the strong QCD interactions, becomes smaller

K. Boreskov, A. B. Kaidalov and O. Kancheli, Elliptic flow in pp collisions, *in preparation*

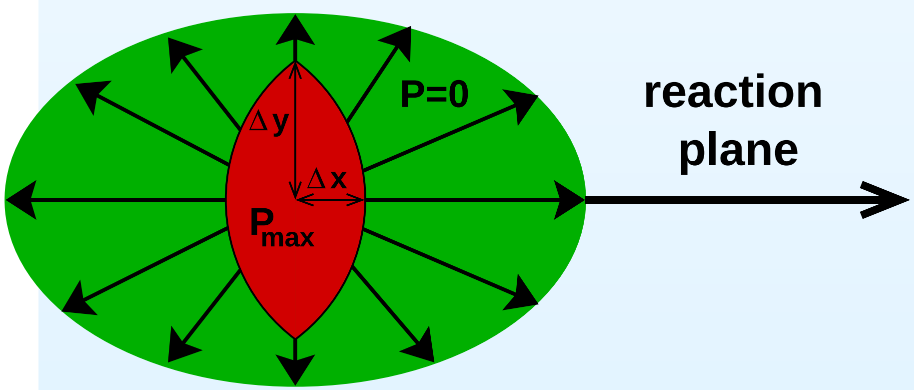
Building of the anisotropic flow

- Asymmetry in coordinate space (overlap region) develops into an asymmetry in momentum space due to the collective interactions (pressure gradients)



space asymmetry

- The initial compression $\longrightarrow$ pressure p $\longrightarrow$ collective flow
- Non-central collisions $\longrightarrow \nabla p_x > \nabla p_y \longrightarrow$ anisotropic flow
- Fourier decomposition: $dN/d\phi = N_0\{1 + \sum_{n=0}^{+\infty} 2v_n \cos[n(\phi - \Phi)]\}$
- Quadrupole component $v_2 = \langle \cos[2(\phi - \Phi)] \rangle$ is called elliptic flow



momentum asymmetry

Simulated data

- ”Flow” + ”Hijing” simulation
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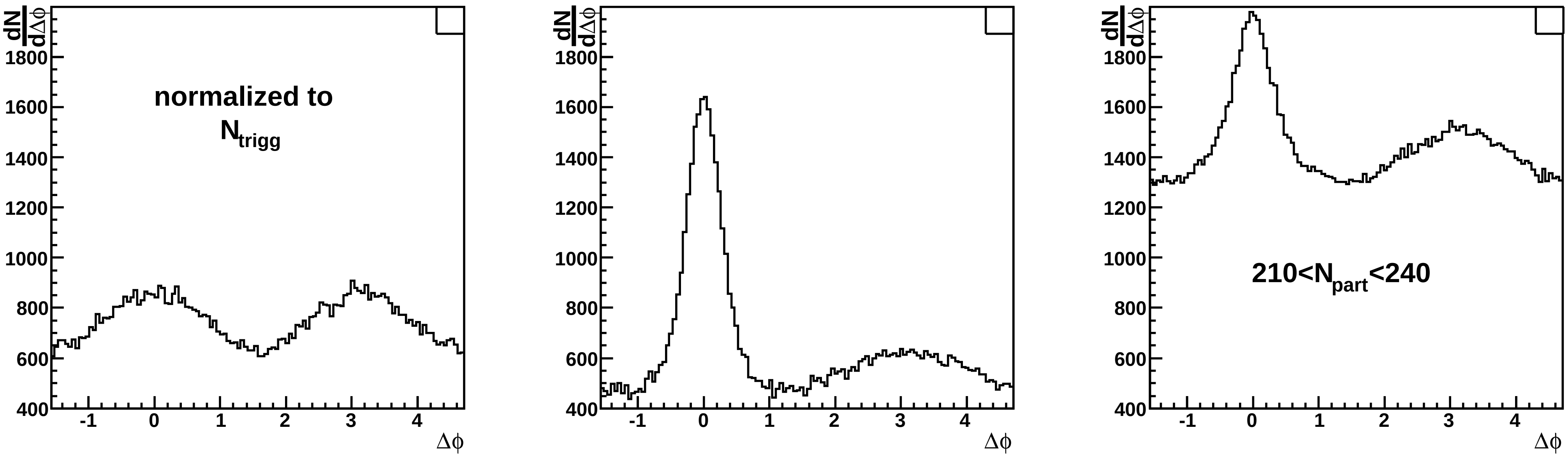
  - The intention is to check could LYZ Method remove the contribution of Jet (Hijing) particles from the flow.

Two particle azimuthal distributions

Flow particles Jet particles ”Jet+Flow” particles



- Simulated event: Huge elliptic flow signal (left) is hidden by the signal coming from the jet particles (middle) in the final distributions of both kind of particles taken together
- Real event: Strictly speaking, there is no possibility, by means of cuts, to distinguish between flow and jet particles

Lee-Yang Zero Method

- Integrated flow $V_2 = \langle \sum_{j=1}^{M} w_j \cos[2(\phi_j - \Phi)] \rangle$ is connected with the Fourier coefficient v_2 via: $V_2 = M_w v_2$, where $M_w = \sum_{j=1}^{M} w_j$.

N.Borghini, R.S.Bhalerao, and J.-Y.Ollitrault, nucl-th/0402053 (2004)

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- for each event one calculates the complex-valued function $g^\theta(ir) = \prod_{j=1}^{M} \{1 + irw_j \cos[2(\phi_j - \theta)]\}$ for various values of the real positive variable r and of the reference angle θ ($0 \leq \theta \leq \pi/2$). The ϕ_j is the measured laboratory azimuthal angle of a particle and the product goes over all detected particles.

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- One has to average $g^\theta(ir)$ over events for each value of r and θ: $G^\theta(ir) \equiv \langle g^\theta(ir) \rangle = \frac{1}{N} \sum_{events} g^\theta(ir)$

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Lee-Yang Zero Method

- For each θ, the position of r_0^θ of the first minimum of the modulus $|G^\theta(ir)|$ has to be found. Then the estimate of the integrated flow V_2 is given by: $V_2^\theta\{\infty\} \equiv \frac{j_{01}}{r_0^\theta}$ where $j_{01} \approx 2.40483$ is the first zero of the Bessel function J_0.

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- Once the integrated flow is obtained, the differential flow analysis can be done.

$$v_2^\theta\{\infty\} = V_2^\theta\{\infty\}\frac{J_1(j_{01})}{J_2(j_{01})}\mathcal{R}e\left(\frac{\langle g^\theta(ir_0^\theta)\frac{\cos(2(\psi-\theta))}{1+ir_0^\theta w_\psi \cos(2(\psi-\theta))}\rangle_\theta}{\langle g^\theta(ir_0^\theta)\sum_j \frac{w_j \cos(2(\phi_j-\theta))}{1+ir_0^\theta w_j \cos(2(\phi_j-\theta))}\rangle_{evts}\rangle}\right)$$

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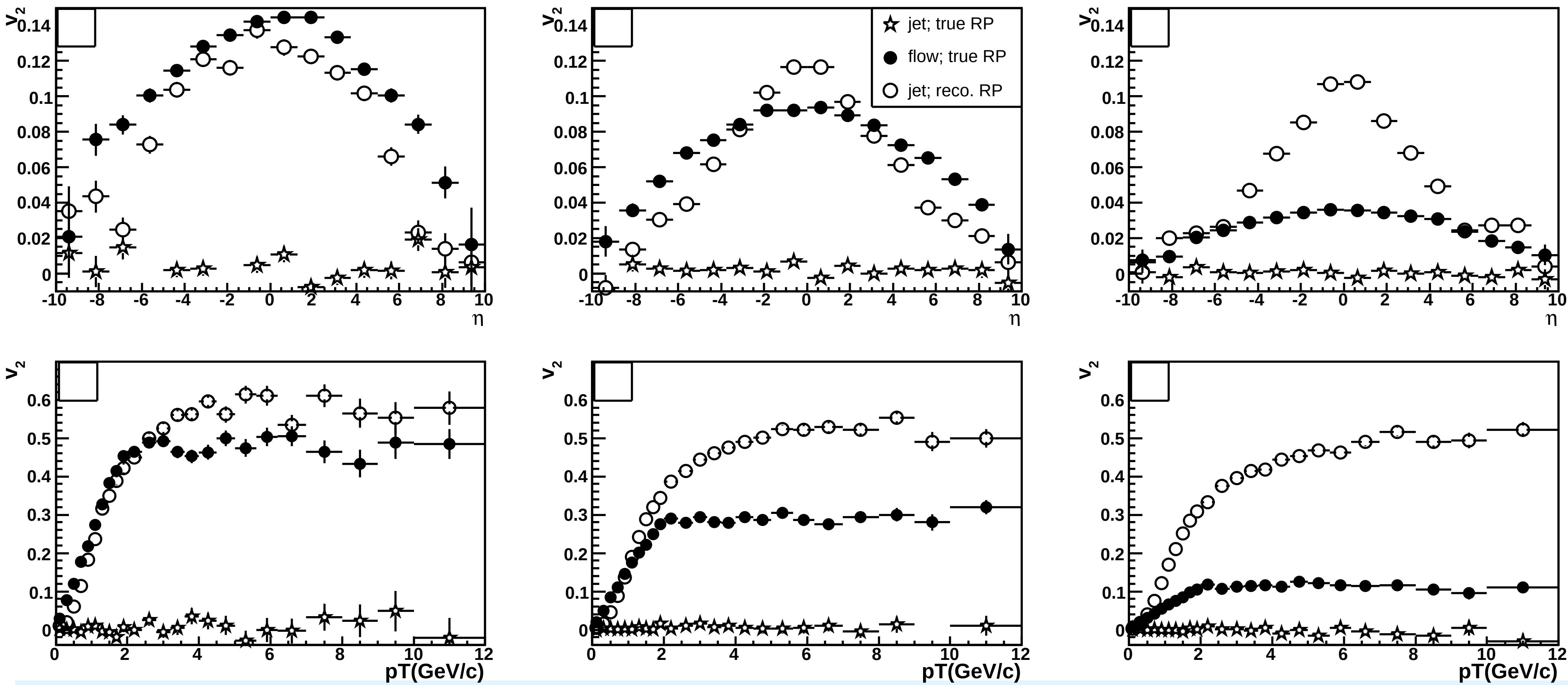
- The necessary statistics is given by the following inequality: $v_2^\theta > \frac{j_{01}}{\sqrt{2MlnN}}$ where M is multiplicity and N is the number of events.

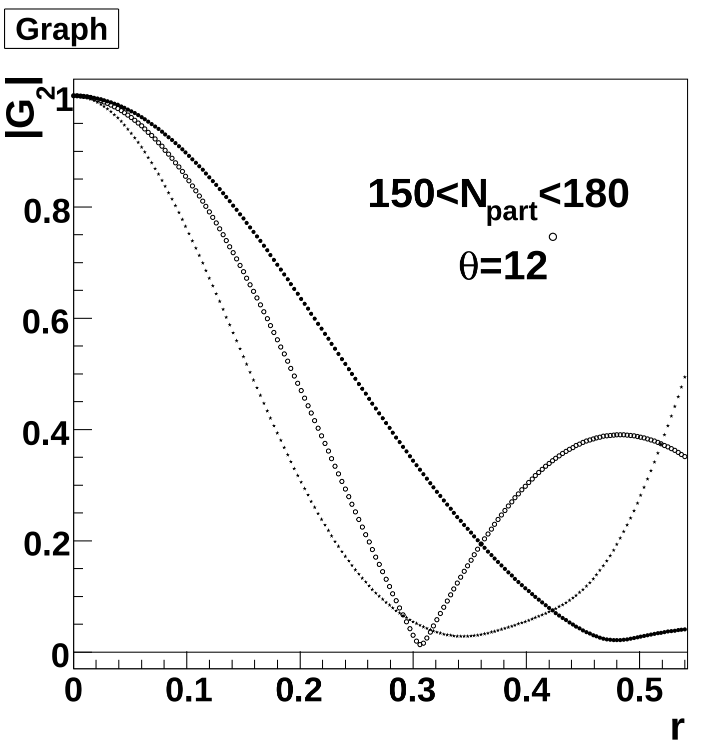
True and reconstructed v_2 coefficients vs η and p_T

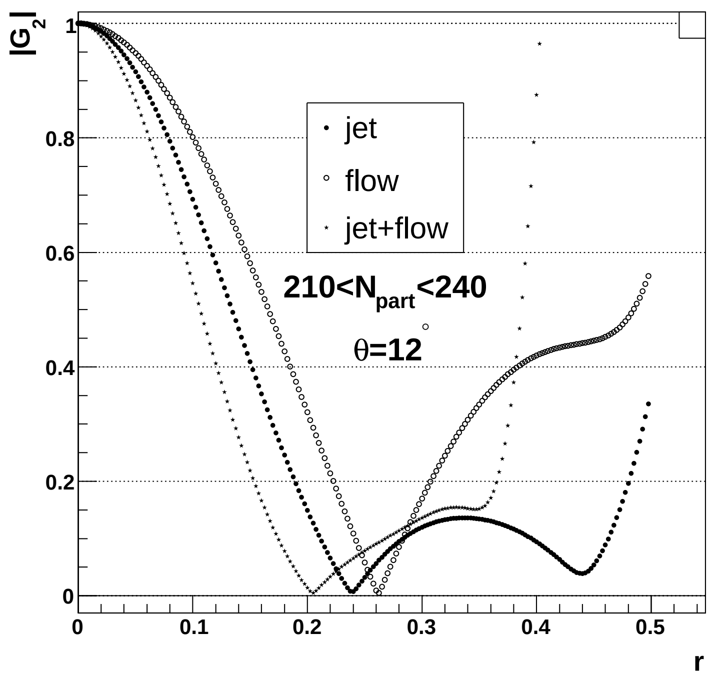
very peripheral	semicentral	rather central
$150 < N_{part} < 180$	$210 < N_{part} < 240$	$270 < N_{part} < 300$

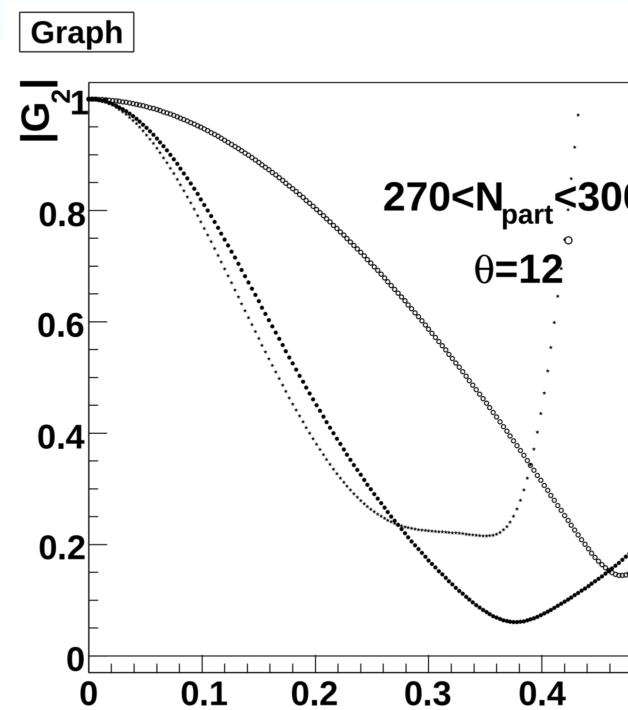


Generating functions

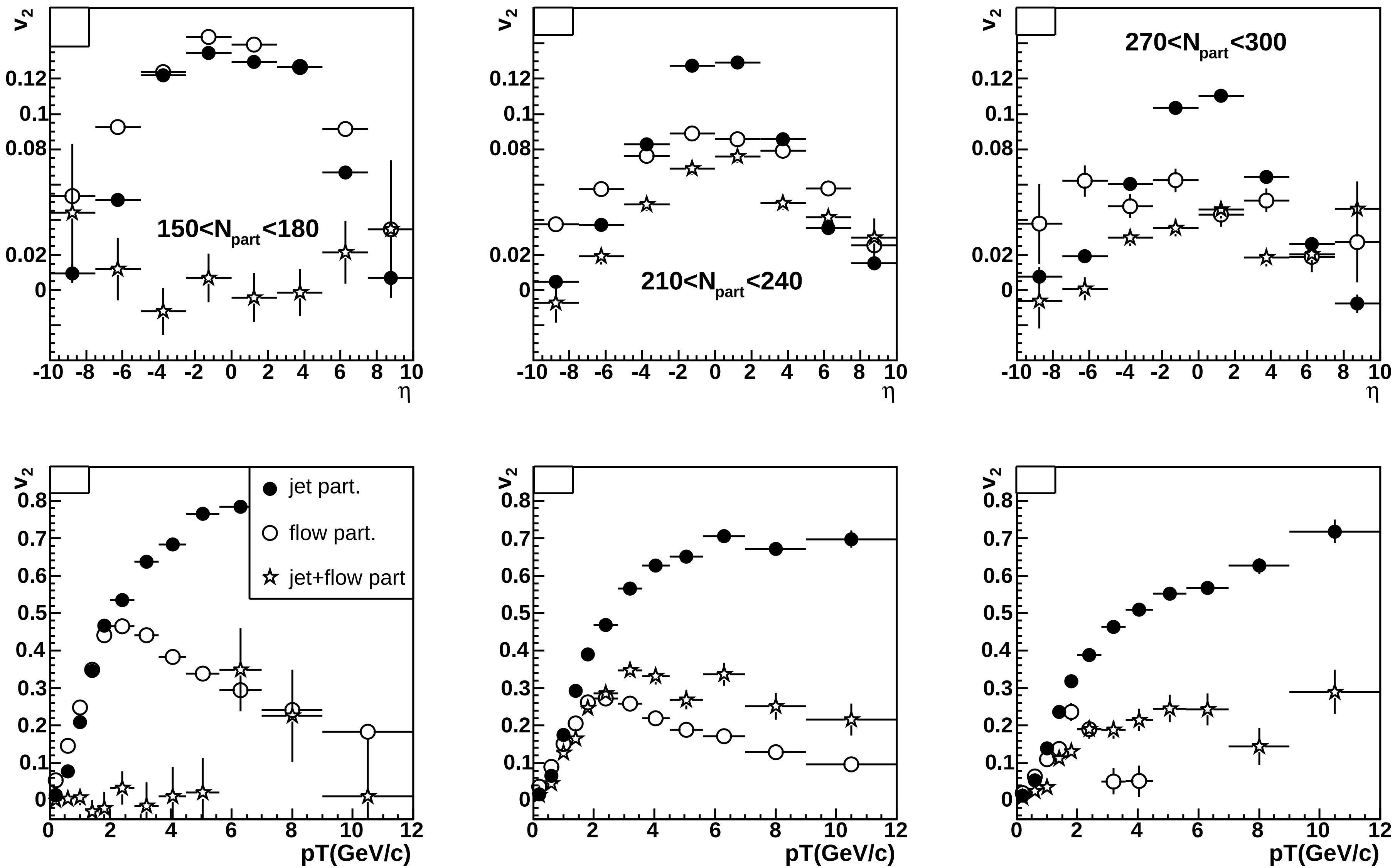
- Only when both, the magnitude of v_2 and the multiplicity are high enough, the generating function show a sharp minimum close to zero







LYZ reconstructed v_2 coefficients



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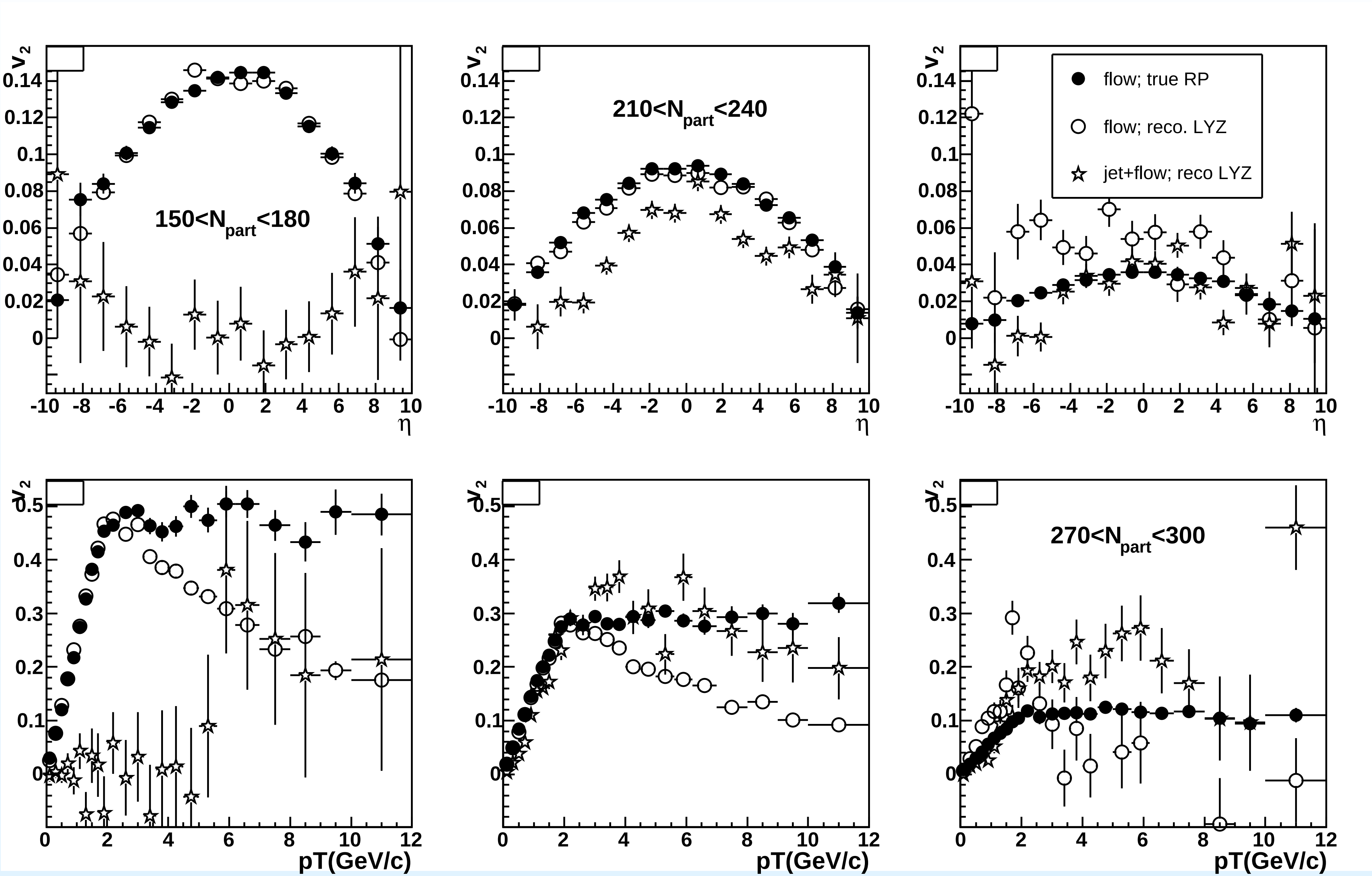

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- The LYZ method doesn't work for very peripheral events (due to the small multiplicity) and for rather central events (where one suppose a small anisotropy and consequently a small v_2 magnitude)
- In between these two extremes the shape of the differential v_2 has been reconstructed but it undershoots the true flow due to the multiplicity fluctuations and unremoved jet remnants
- If the theoretically predicted v_2 really exists in pp@LHC it will be a difficult task to extract it from the huge jet contribution which hides the flow