2015 European Nuclear Physics Conference - Groningen 31 August – 4 September

Flow analysis in CBM experiment at FAIR

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Outline

1. The CBM experiment at FAIR.

2. Flow analysis motivation.Eliptic flow. Methods for flow analysis.

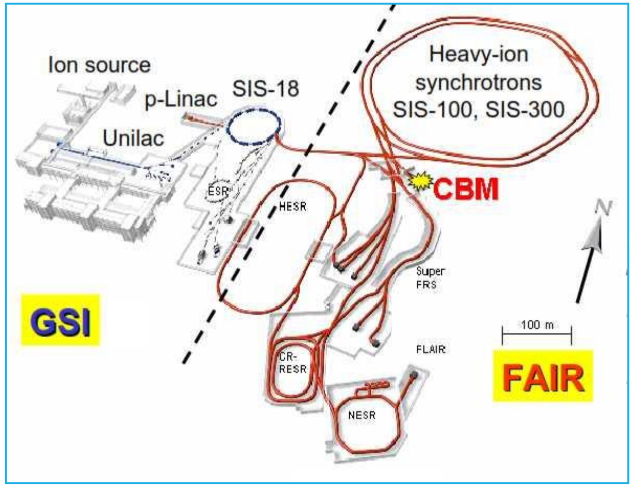
3. Simulations for eliptic flow using multiparticles correlations in CBM experiment.

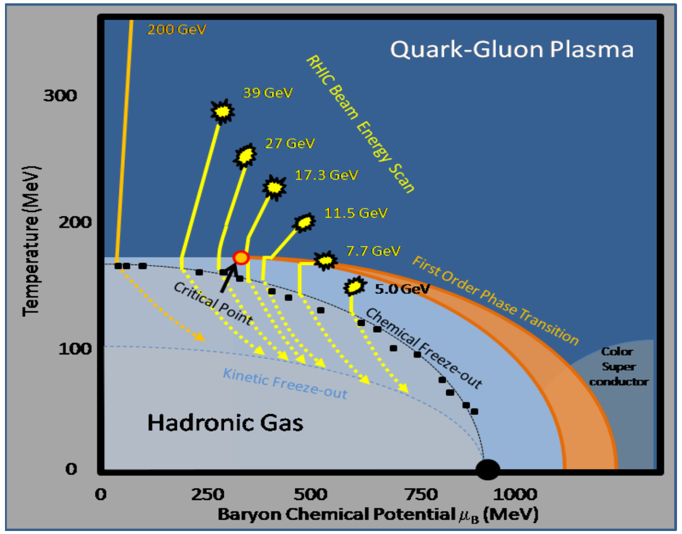
4. Conclusions.

CBM Experiment /FAIR

The Compressed Baryonic Matter Experiment

FAIR - *The International Facility for Antiproton and Ion Research*

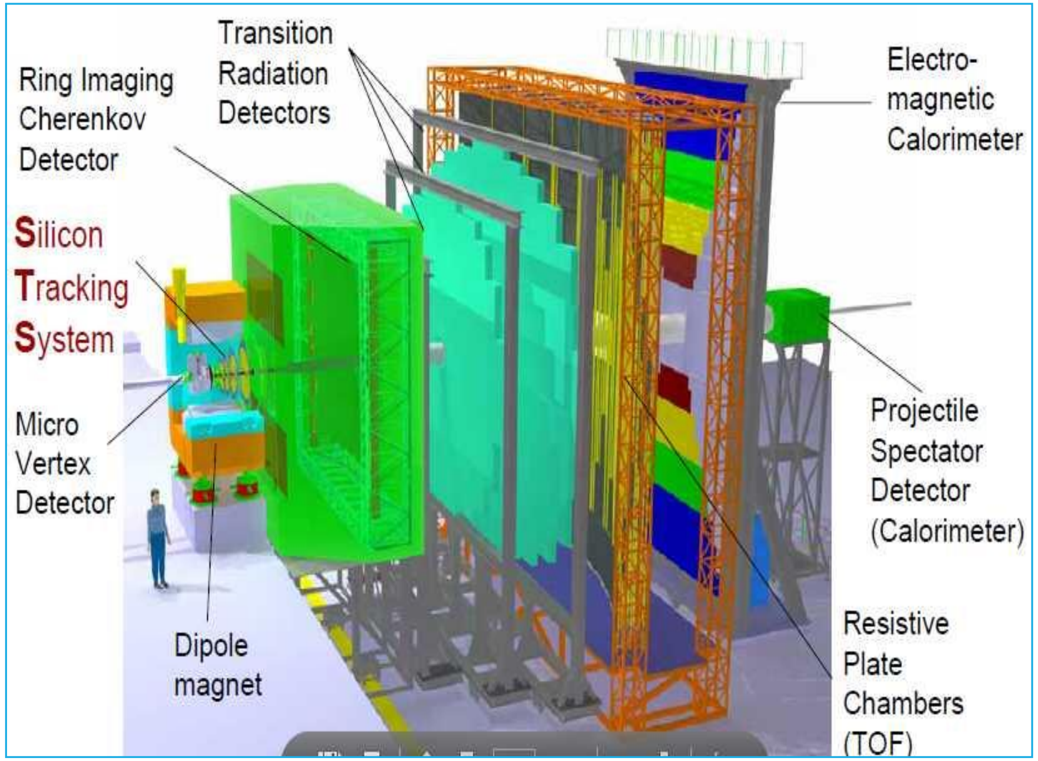




An Experimental Exploration of the QCD Phase Diagram

nucl-ex > arXiv:1007.2613

FIX Target Experiment



SIS-100 10^9 ions/s beam intensity

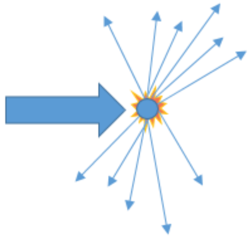
Beam	Plab,max	$\sqrt{s_{NN}}$ max
Heavy ions (Au)	11AGeV	4.7 GeV
Light ions (Z/A =5)	14AGeV	5.3 GeV
Protons	29AGeV	7.5 GeV

near future – (2 -10/11) AGeV

SIS-300

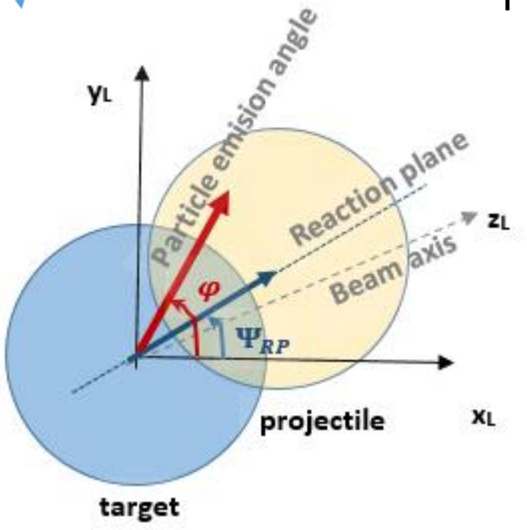
Nuclei Z/A = 0,5(0,4) till 45 GeV A

Protons till 89 GeV



Flow analysis - motivation

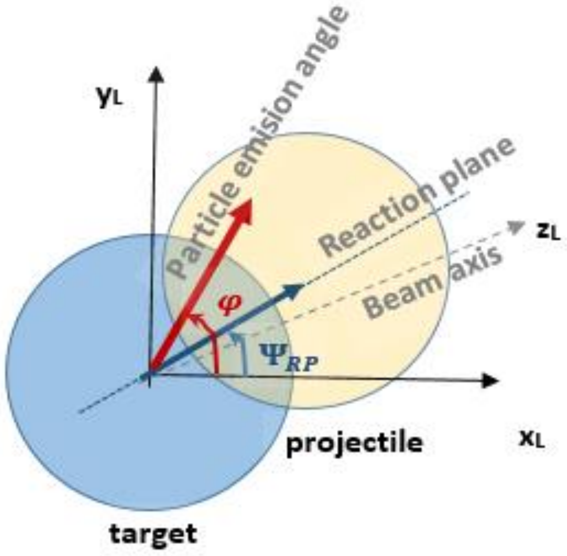
Flow analysis = the study of the azimuthal distribution of particles emitted after collisions relative to the reaction plane



Anisotropies distribution of outgoing particles → carry information about

- **EOS**
- Termalization ???
- Signature of quark-gluon plasma ↔ **Strong collective flow**
- Exotic phenomena
- Parity or time - reversal violation

Anisotropic flow



$$E\frac{d^3N}{d^3p}(b) = \frac{dN}{d\Phi} = \frac{1}{2\pi}\frac{d^2N}{p_t dp_t dy}(b)\left(1 + 2\sum_{n=1}^{\infty} v_n \cos\left[n(\varphi - \Psi_{RP}\right]\right)$$

$$v_n(p_t, y) = \frac{\int d\Phi \cos(n\Phi)\frac{dN}{d\Phi}}{\int d\Phi \frac{dN}{d\Phi}} = \langle \cos\left(n(\varphi - \Psi_{RP}\right))\rangle_{specia\ p}$$

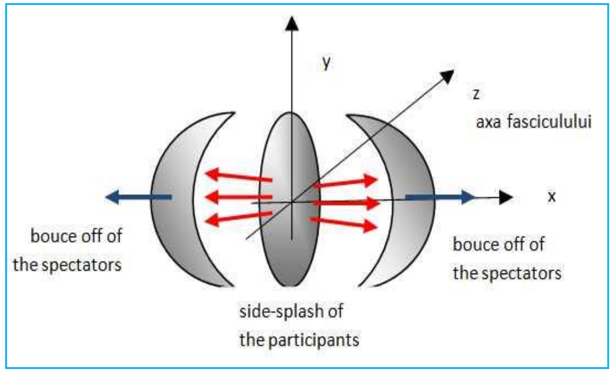
flow coefficients measure the anisotropy degree

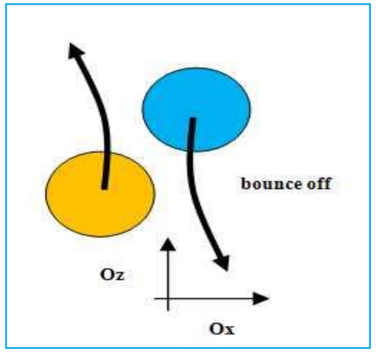
Reaction plane angle , can only be estimated

Directed flow

average

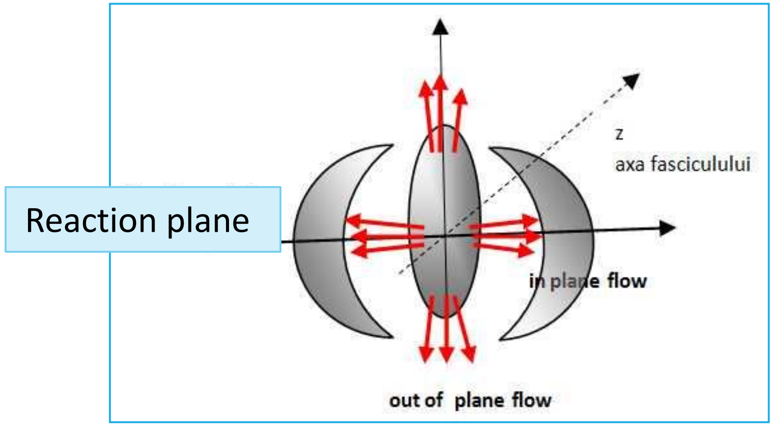
$$v_1(p_T, y) = \left\langle \langle \cos(\varphi_i - \Psi_{RP}\rangle_{particles} \right\rangle_{events}$$





Eliptic flow

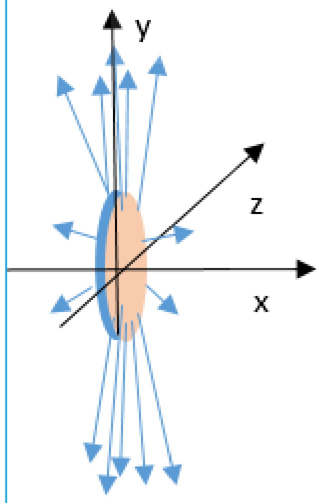
$$v_2(p_T, y) = \left\langle \langle \cos 2(\varphi_i - \Psi_{RP}\rangle_{particles} \right\rangle_{events}$$



Flow at FAIR's energies

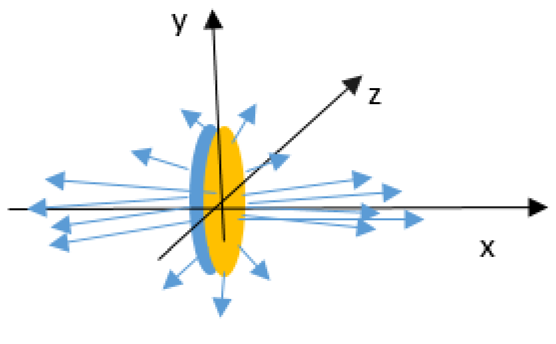
SIS-100

Beam	P_{lab},max	$\sqrt{s_{NN}}$ max
Heavy ions (Au)	11AGeV	4.7 GeV
Light ions (Z/A =5)	14AGeV	5.3 GeV
Protons	29AGeV	7.5 GeV



$v_2 < 0$

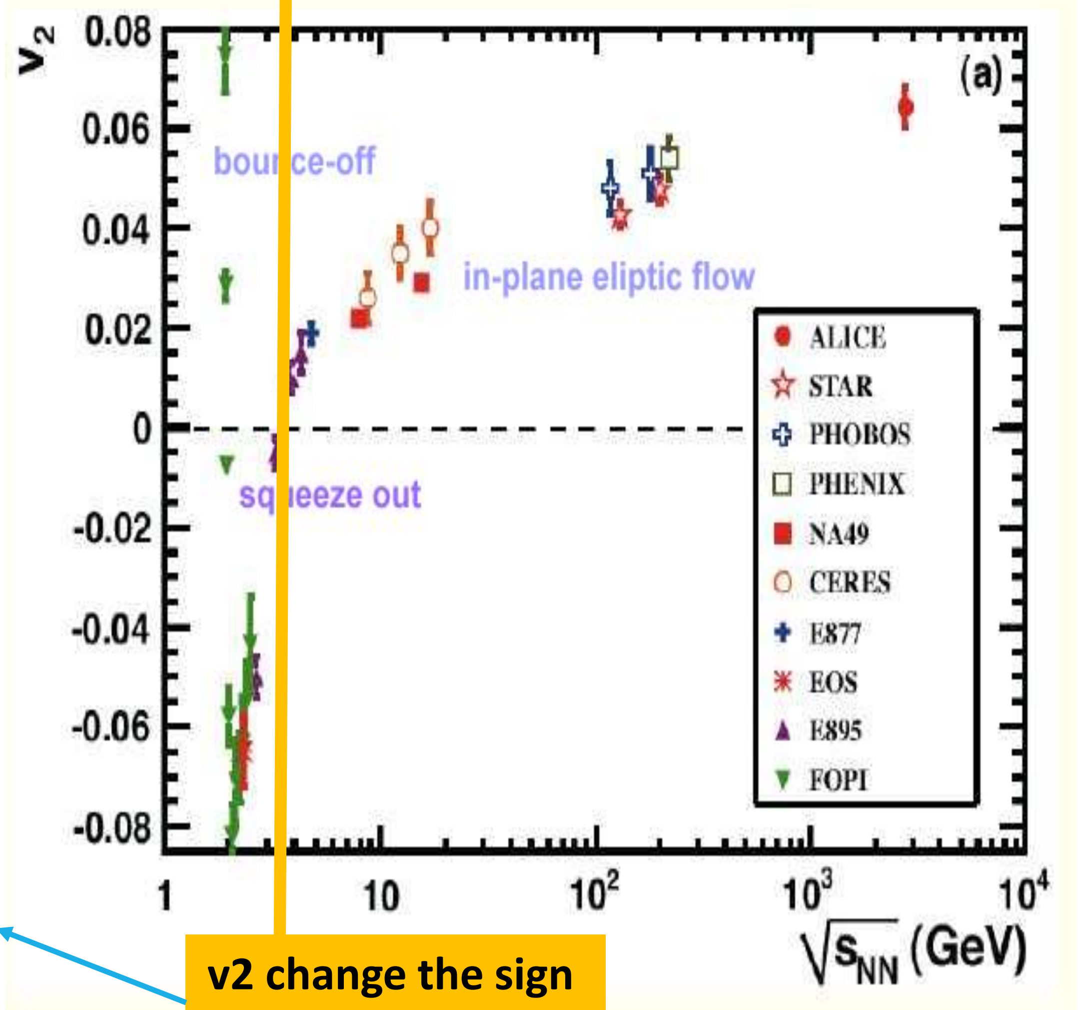
Out-of-plane emission



$v_2 > 0$

In-plane emission

PbPb 20-30% **nucl-ex/arXiv:1011.3914**



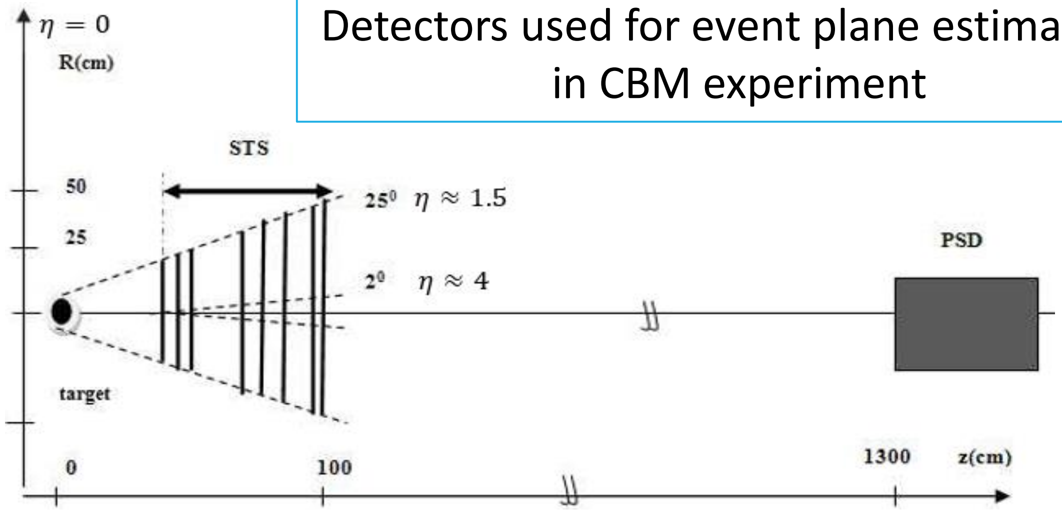
v2 change the sign ≈ 2 - 4 GeV

Methods for flow analysis

1. **Correlations with the event plane**
   Event Plane Method

$$v_n\{EP\} = \frac{\langle \cos[n(\varphi_i - \Psi^n_{EP})] \rangle}{R_n}$$

Detectors used for event plane estimations in CBM experiment

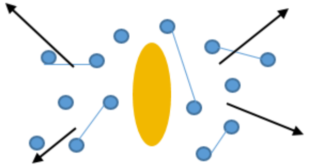


2. **Correlations between particles**

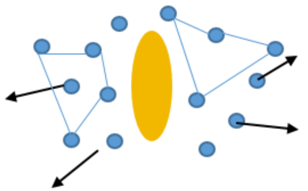
Two-particles correlations (2A)
Four-particles correlations (2B)
.... Multi-particles correlations

Cumulants method

(2A)

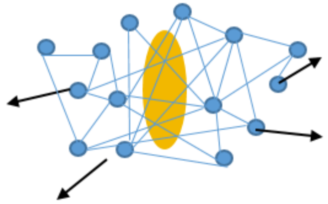


(2B)



All - particles correlations Lee-Yang Zeroes

This work



Non-flow effects wich affect the flow

✓ Resonance decays, Jets, Quatum statistics effects, Strong/Coulomb interactions

Lee-Yang Zeroes Method

R.S. Bhalerao, N. Borghini, J.Y. Ollitrault

validated from RHIC to LHC energies

1. For each event one define the global observable

$$Q^{\theta} = \sum_{i=1}^{M} \omega_i \cos n(\varphi_i - \theta) ,$$

n the Fourier harmonic under study, n=2 for eliptic flow, θ arbitrary reference direction

2. Construct a generating function $G_n^{\theta}(ir) = \left\langle e^{irQ_n^{\theta}} \right\rangle_{events}$ $LYZS \quad sum$

or $G_n^{\theta}(ir) = \langle \prod_{i=1}^{M} (1 + ir\omega_i cos(n(\varphi_i - \theta)) \rangle_{events}$ LYZP product

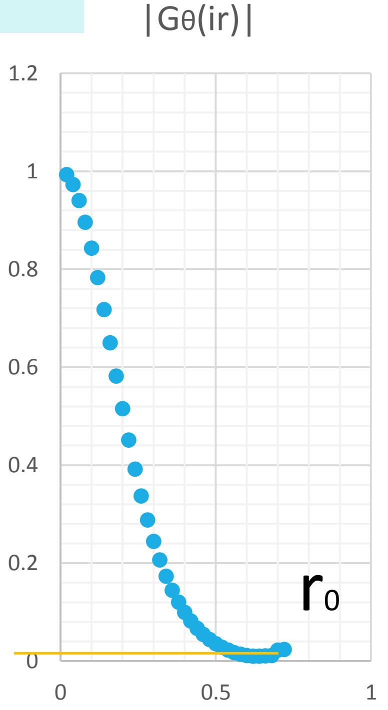
3. Evaluate $\left| G_n^{\theta}(ir) \right|$, r real positive number, plot $\left| G_n^{\theta}(ir) \right|$ function of r , find the first minimun r_0.

4. $\boldsymbol{v_n^{\theta} = \frac{j_{01}}{M r_0^{\theta}}}$, j_{01}=2.405 the first positive root of the Bessel function $J_0(x)$

5. Differential flow $$\frac{v_n^{\theta}(p_T, \eta)}{v_n^{\theta}\ M} = Re\left(\frac{\left\langle \left\langle \cos(n(\varphi_i - \theta)) e^{ir_0^{\theta} Q^{\theta}} \right\rangle_p \right\rangle_{events}}{\left\langle Q^{\theta} e^{ir_0^{\theta} Q^{\theta}} \right\rangle_{events}} \right) \quad LYZS$$

Average over all events

p means average for all particles in an event



Lee-Yang Zeroes Method

First analysis of anisotropic flow with Lee--Yang zeroes

N. Bastid, et al. (FOPI Collaboration) ; J.-Y. Ollitrault, N. Borghini

(Submitted on 1 Apr 2005)

Ru-Ru /1,69 AGeV/ FOPI detector – SIS18

We report on the first analysis of directed and elliptic flow with the new method of Lee--Yang zeroes. Experimental data are presented for Ru+Ru reactions at 1.69 AGeV measured with the FOPI detector at SIS/GSI. The results obtained with several methods, based on the event-plane reconstruction, on Lee--Yang zeroes, and on multi-particle cumulants (up to 5th order) applied for the first time at SIS energies, are compared. They show conclusive evidence that azimuthal correlations between nucleons and composite particles at this energy are largely dominated by anisotropic flow.

Method limitations

- **statistical errors**, if the flow and/or event multiplicity are too small.

- Resolution parameter χ, related to the event plan resolution
  1. $\chi > 1$, statistical error not a problem
  2. $0.5 < \chi < 1$, optimize weights ω_i, method can be used
  3. $\chi < 0.5$, statistical error large, increase nr events. !!!

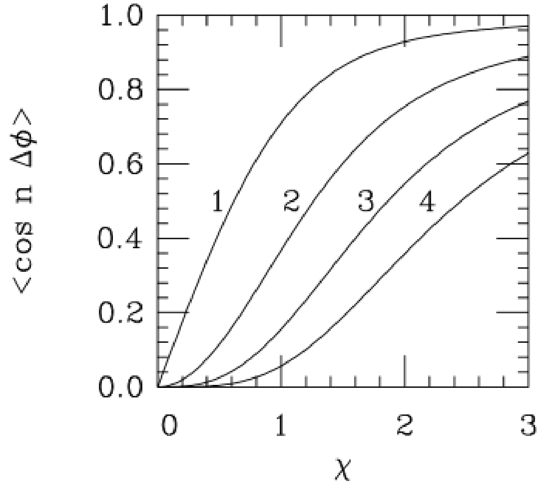
Ilya Selyuzhenkov, 25th CBM Collaboration meeting,20 April 2015

$$v_n\{EP\} = \frac{\langle \cos[n(\varphi_i - \Psi^n_{EP})] \rangle}{R_n}$$

R_n - event plane resolution correction factor

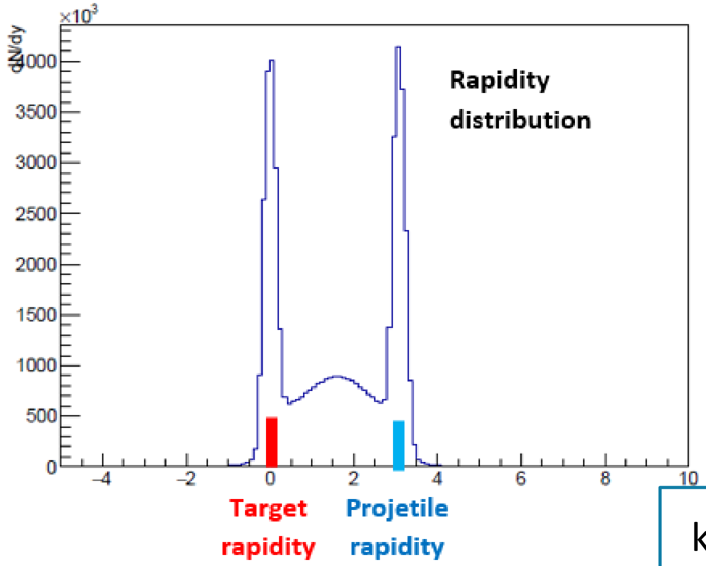
2nd order event plane resolution with PSD is good (~0.4)

$\chi \approx 1.1$



Simulations AuAu 10 AGeV – Urqmd 3.4

100 000 events minbias   0.6 < y < 2.6
all charges particles

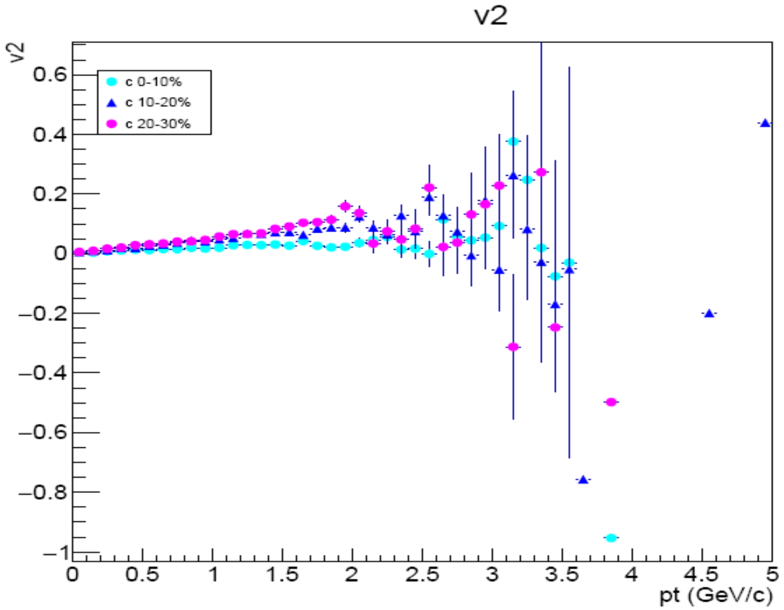


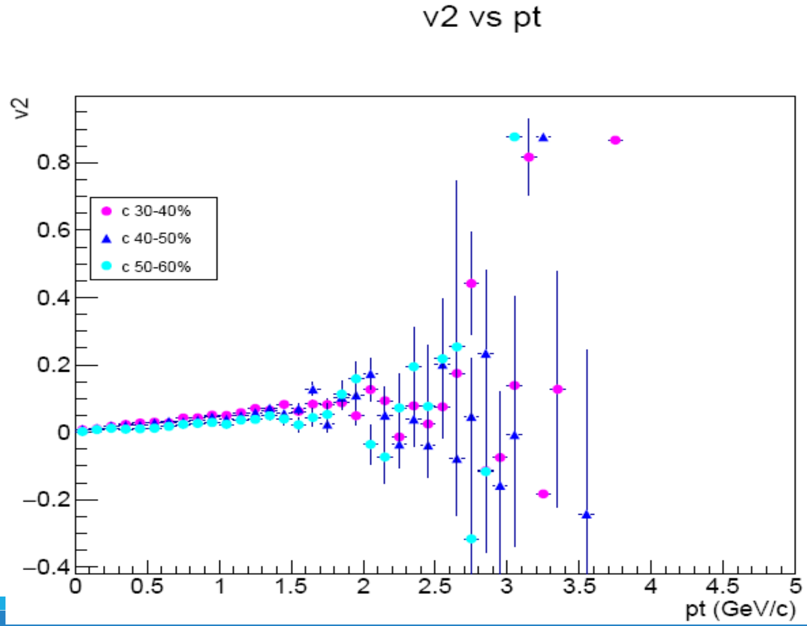
known in Urqmd

$$v_2(p_T, y) = \left\langle \langle \cos 2(\varphi_i - \Psi_{RP} \rangle_{particles} \right\rangle_{events}$$

b(fm)	c	v2 integral
0 - 4.5	10-20%	0.0119
4.5 - 6.4	20-30%	0.0244
6.4 - 7.8	30-40%	0.0276
7.8 - 9.05	40-50%	0.0270
9.05 - 10.13	50-60%	0.0247
10.10-11.08	60-70%	0.0135
11.05-12	70-80%	0.0065

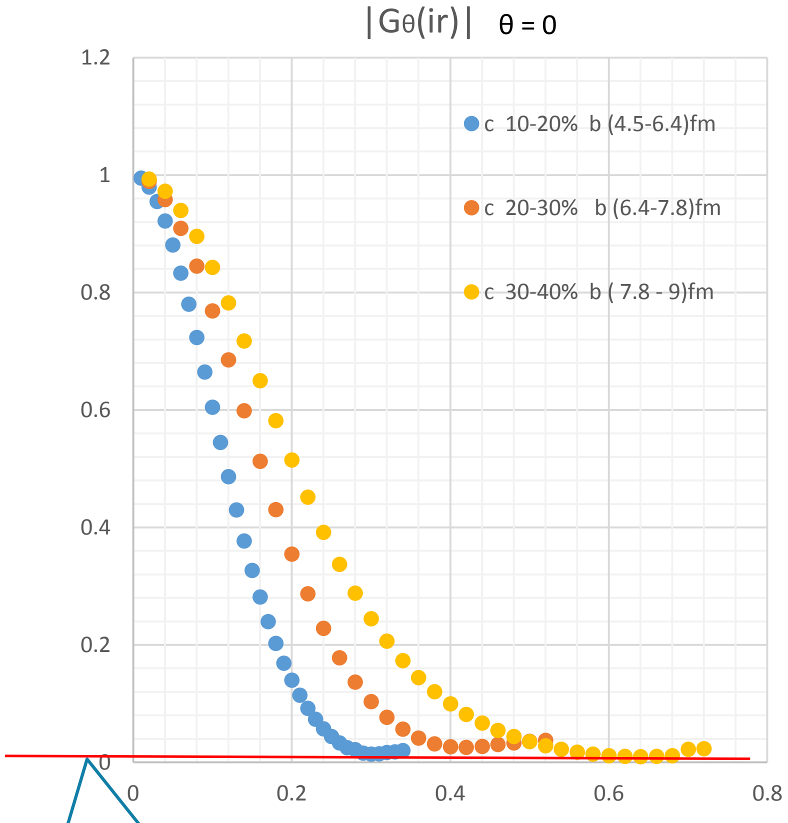
Diferential eliptic flow $v_2(p_T)$ (Urqmd)



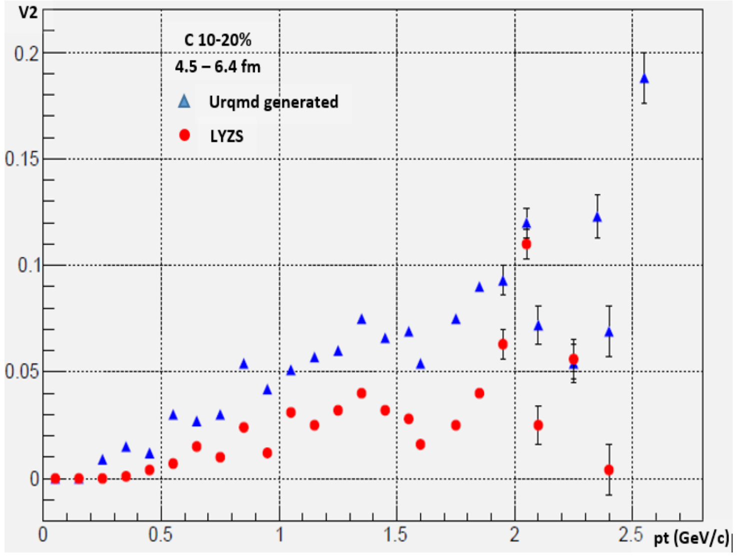


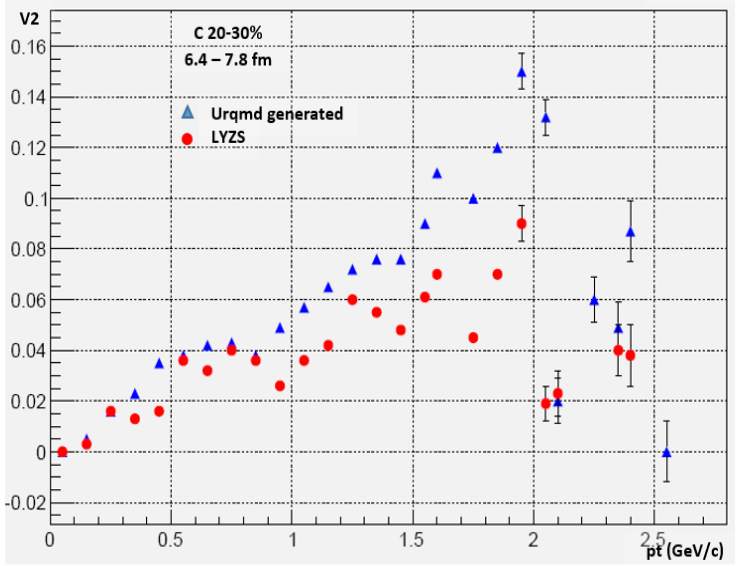
AuAu 10 GeV A – LYZS

10 000 events for each centrality class
0.6 < y < 2.6
all charges particles



is not zero

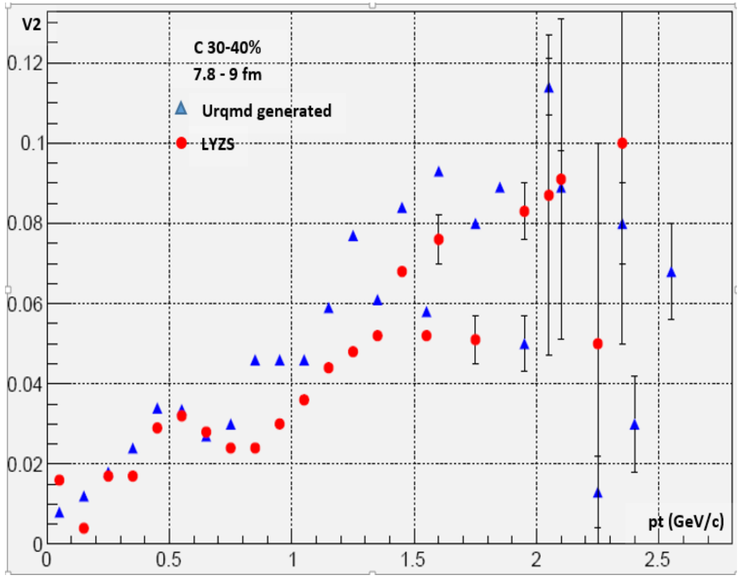




Integral eliptic flow

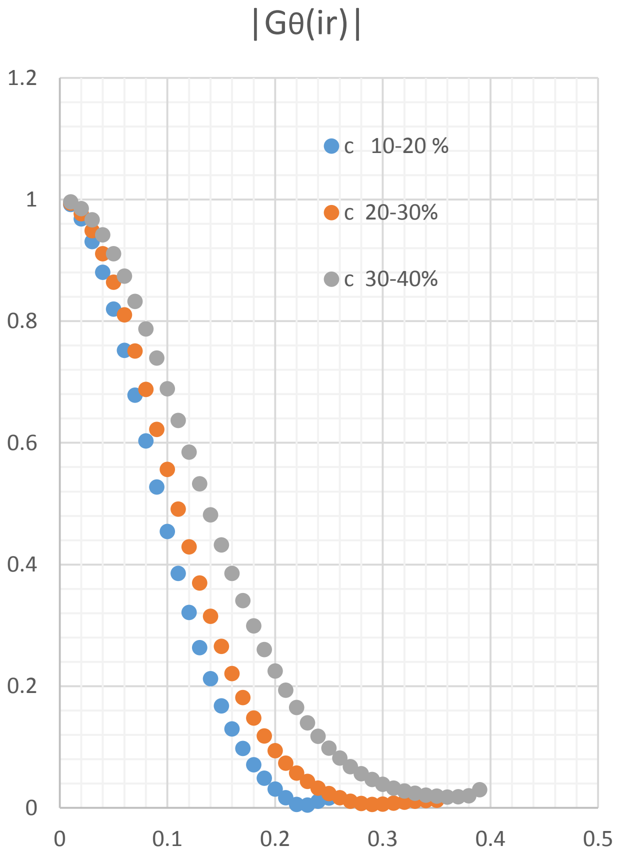
c	v2 Urqmd	v2 LYZS/flow only
10-20%	0.0119	
20-30%	**0.0244**	**0.0291±0,0005**
30-40%	**0.0276**	**0.0335±0,0005**
40-50%	**0.0270**	**0.0337±0,0005**
50-60%	0.0247	
60-70%	0.0135	
70-80%	0.0065	

Nr. Events for LYZS should be higher

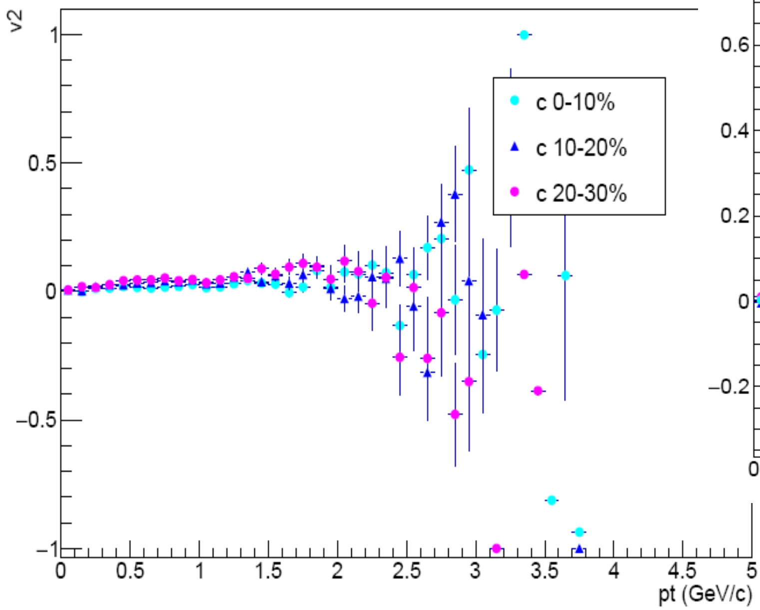


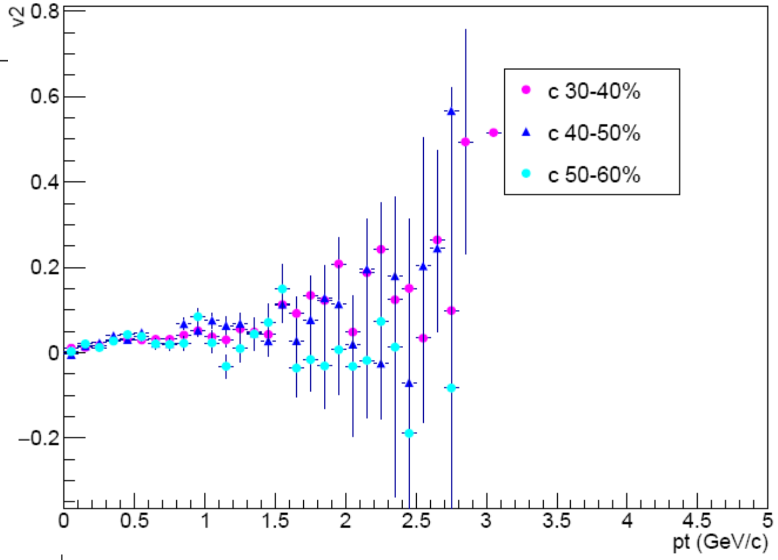
AuAu 30 GeV A – LYZS

1.1 < y < 3.1
all charges particles



Diferential eliptic flow $v_2(p_T)$ (Urqmd)

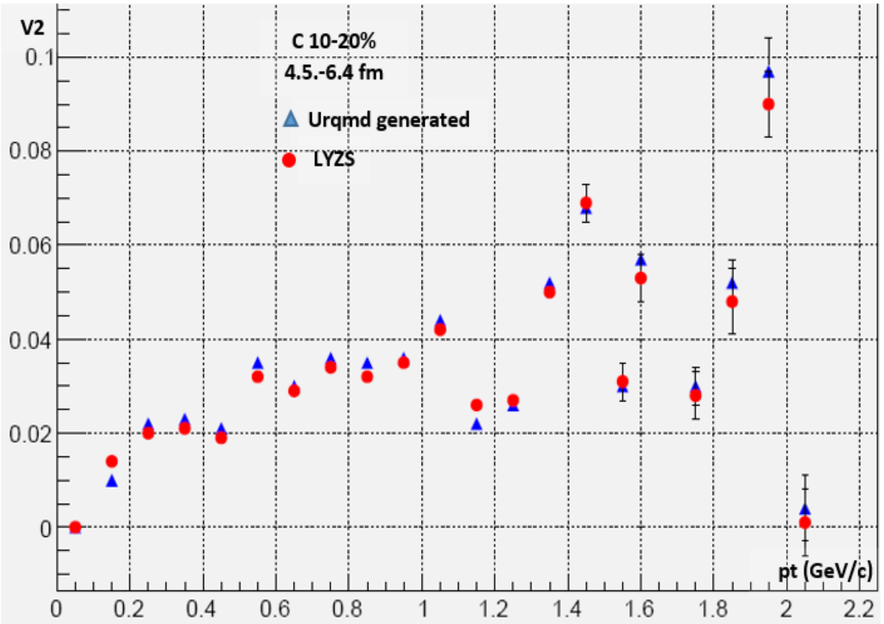


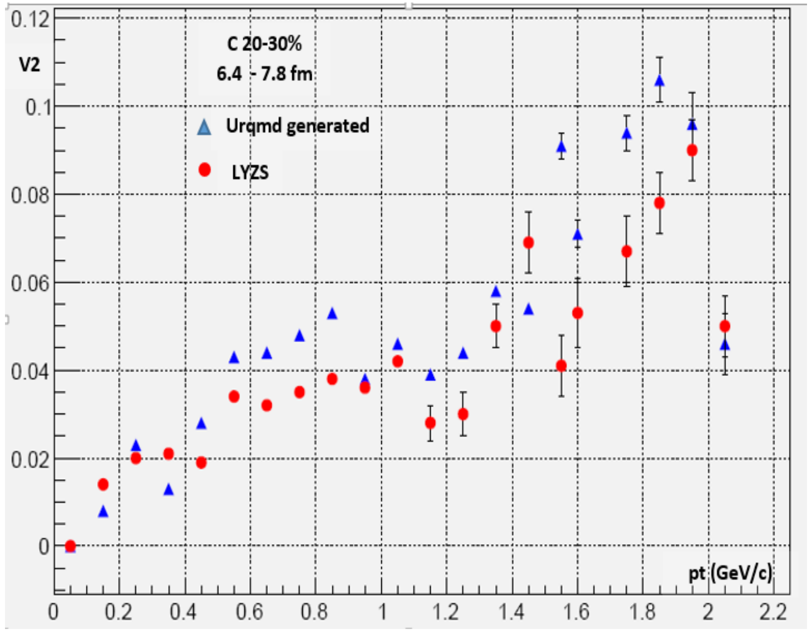


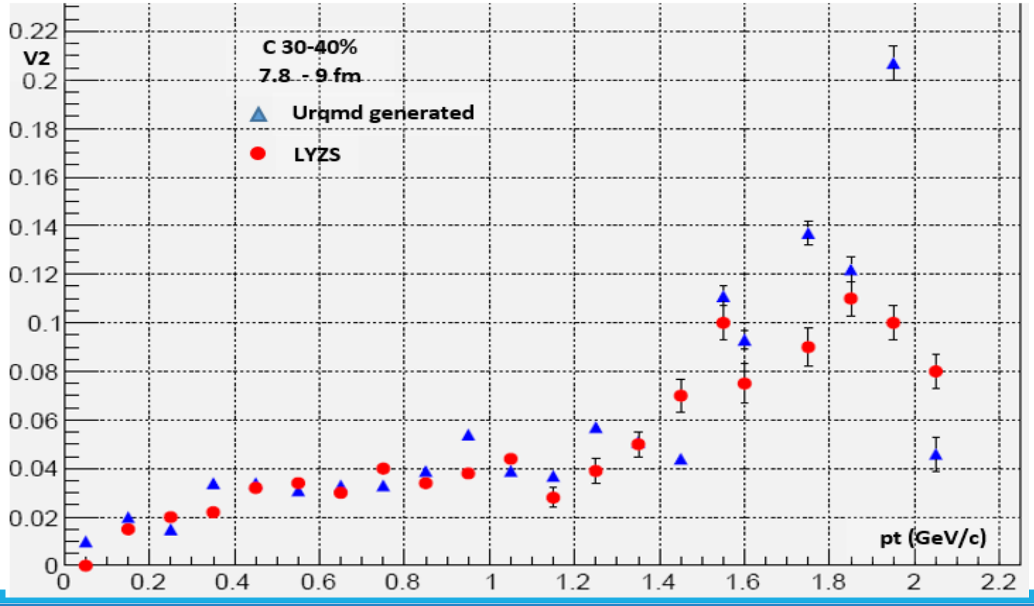
Integral eliptic flow

b(fm)	c	v2 Urqmd	v2 LYZS/flow only
0 - 4.5	10-20%	0.0124	
4.5 - 6.4	**20-30%**	**0.0238**	**0.02385±0,0005**
6.4 - 7.8	**30-40%**	**0.0305**	**0.03171±0,0005**
7.8 - 9.05	**40-50%**	**0.0263**	**0.03267±0,0005**
9.05 - 10.13	50-60%	0.0305	
10.10-11.08	60-70%	0.0239	
11.05-12	70-80%	0.0095	

Diferential eliptic flow







Conclusions

1. The aim of this presentation was to analyze the posibility of using multiparticles correlation method, Lee-Yang Zeroes, for the eliptic flow study as an alternative to Event Plan Method . Preliminary results on the feasibility of the LYZ applied on AuAu 10 and 30 GeV A are presented

2. The limitation of LYZ method is related to statistical fluctuations .

Small multiplicity

Statistical fluctuations decrease like $\frac{1}{\sqrt{M\,N_{ev}}}$

R.S. Bhalerao, N. Borghini, J.Y. Ollitrault

Necessary statistics $v_2^{\theta} > \frac{j_{01}}{\sqrt{2M\,lnN_{ev}}}$

The method doesn t work very well in central and peripheral events.

3. Need for more simulations (increase Nev), testing LYZP, need comparations with other methods, need analysis for nonflow components, interaction with detectors (CBMROOT simulations)