

ToyFlow MC tool for FIT

Heidi Rytönen, Oskari Saarimäki and Sami Räsänen

University of Jyväskylä
& Helsinki Institute of Physics

August 13, 2019



Introductions

Heidi Rytkönen

- PhD. student

Oskari Saarimäki

- PhD. student

Dong Jo Kim

- Senior researcher

Jasper Parkkila

- PhD. student

Sami Räsänen

- Senior researcher

Motivation

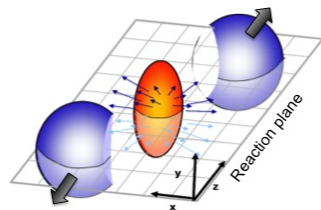
- The particle azimuthal distribution is not isotropic.
- It is customary to expand it in a Fourier series:

$$E \frac{d^3 N}{d^3 p} \propto 1 + \sum_{n=1}^{\infty} 2v_n \cos(n(\phi - \psi_{\text{RP}}))$$

where

$$v_n = \langle \cos[n(\phi_i - \psi_{\text{RP}})] \rangle$$

and angled brackets mean an average over all particles in all events.



Event plane

- Problem: Ψ_{RP} is unknown when using real data.
- Define the event flow vector $\mathbf{Q}_n \in \mathbb{C}$:

$$\mathbf{Q}_n = w_i e^{in\Psi_n} \quad (1)$$

where w_i are the weights and optimally $w_i \approx v_n(p_T, y) \propto p_T$, with small p_T . Many times it is set $w_i = 1$ for all i .

$$\Psi_n = \frac{1}{n} \arctan \left(\frac{Q_{n,y}}{Q_{n,x}} \right)$$

- Now we have and now the observed v_n can be calculated using

$$v_n^{\text{obs}} = \langle \cos [n(\phi_i - \Psi_n)] \rangle$$

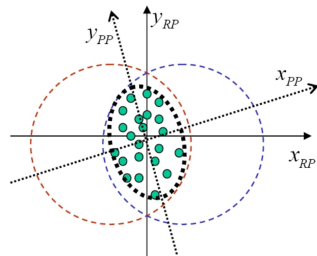


Figure: From
arXiv:0809.2949v2

Event plane

A resolution parameter is defined

$$R_{n,true} = \langle \cos [n (\Psi_n - \Psi_{RP})] \rangle ,$$

so that

$$v_n = \frac{v_n^{\text{obs}}}{R_{n,true}} .$$

The above definition of R_n can only be used with simulations as the Ψ_{RP} is unknown, but it can also be evaluated without the information of reaction plane by using subevents A and B.

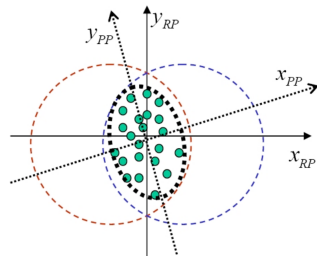


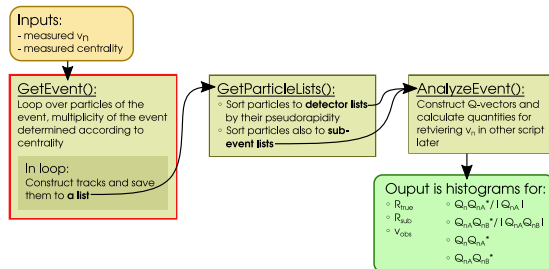
Figure: From
arXiv:0809.2949v2

Toy Monte Carlo

- Toy MC to study the resolution parameter and flow coefficients
- Uses measured data for v_n and multiplicity from arXiv:1804.02944 and arXiv:1509.07299
- Available at <https://github.com/hrytkone/ToyFlow>

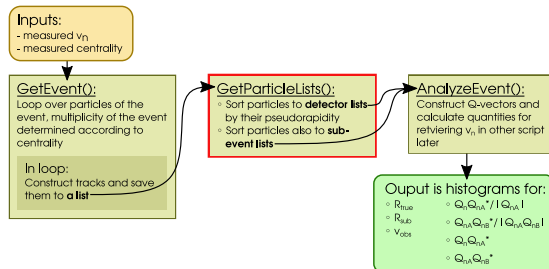
How the event is formed

- Event multiplicity taken from data according to centrality
- Then for each particle in the event
 - ϕ is taken from the Fourier series
 - η is taken from multiplicity distribution



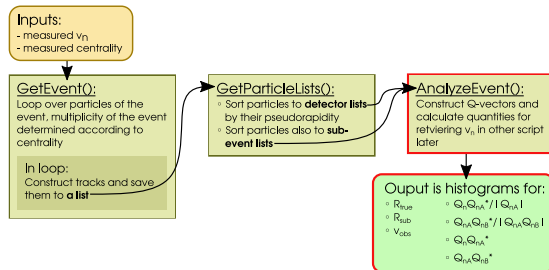
How the event is formed

- Particles in full event are divided into detector specific lists according to pseudorapidity
 - Detectors are TPC, FT0-A, FT0-C and FV0
- Particles are also divided into two sub events

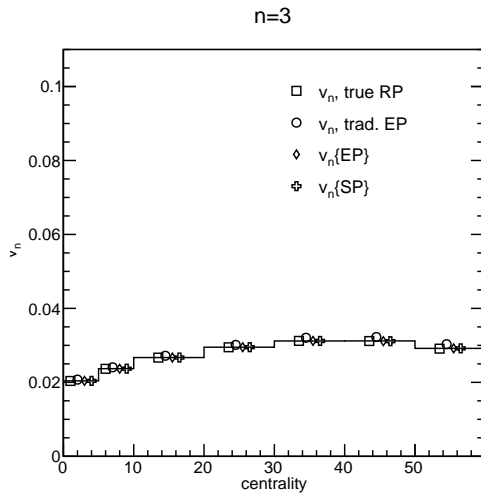
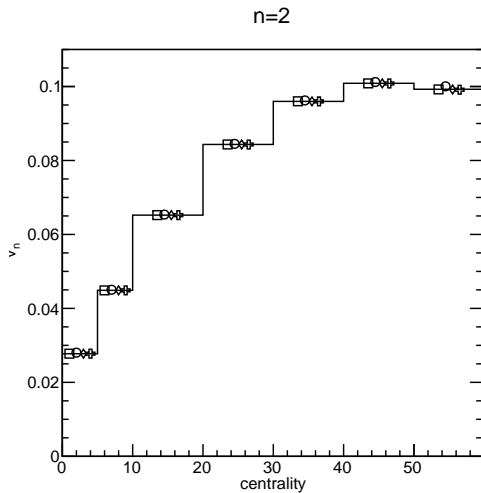


How the event is formed

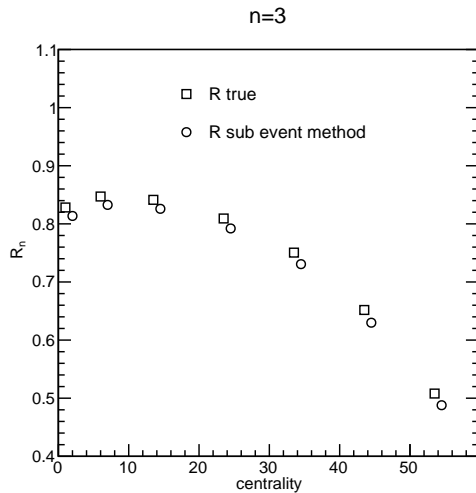
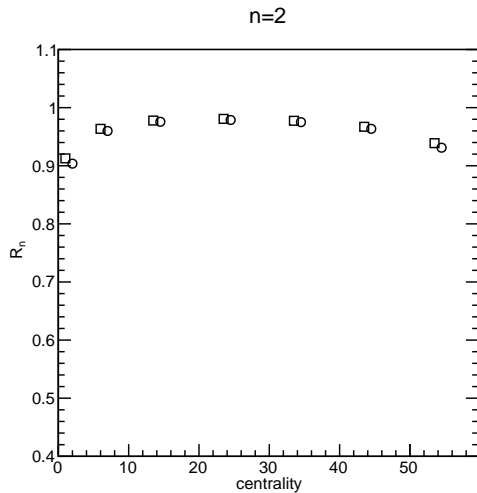
- Q-vectors are then calculated
- Relevant information for retrieving the flow coefficients is saved to the histograms



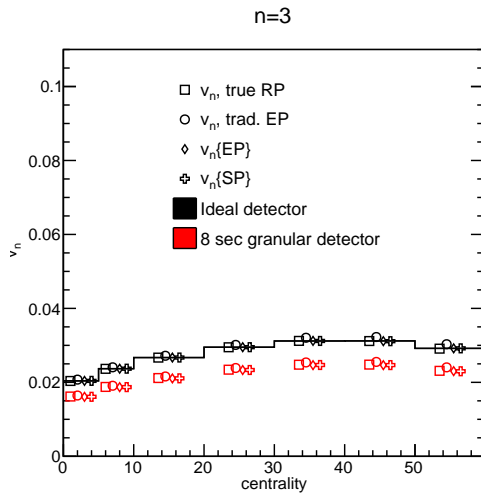
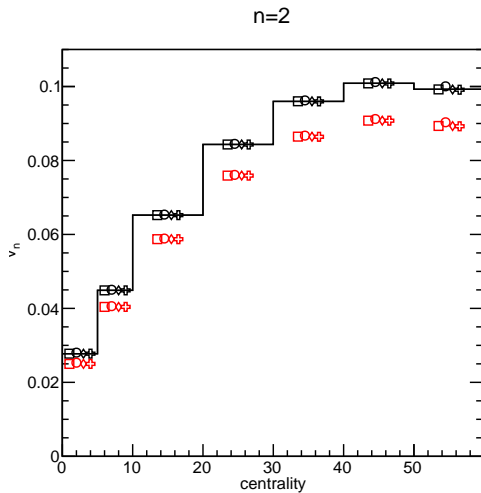
Validating



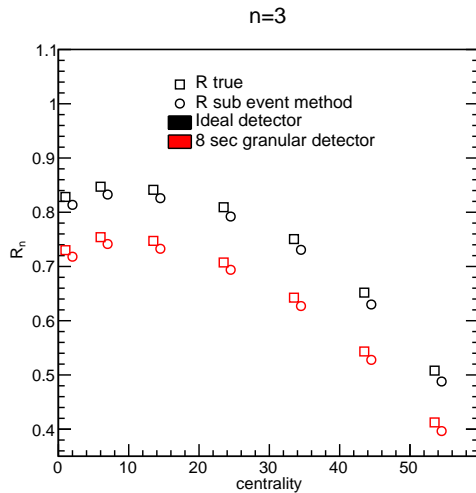
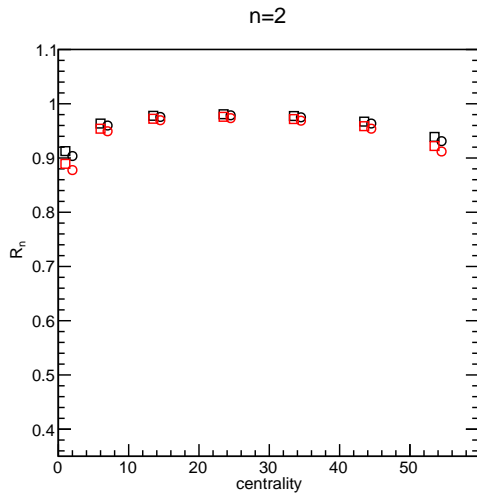
Validating (if needed)



Validating



Validating (if needed)



- Ideal vs. gran
- Compare to Maciej

TODO

- TODO:
 - Subevent handling
 - In FIT?
 - Realistic geometry.
- In the future:
 - Realistic simulation of FIT.

Thank you for listening

Questions?

Event plane

- R_n can also be written as

$$R_k(\chi) = \frac{\sqrt{\pi}}{2} \chi e^{-\frac{\chi^2}{2}} \left[I_{\frac{k-1}{2}} \left(\frac{\chi^2}{2} \right) + I_{\frac{k+1}{2}} \left(\frac{\chi^2}{2} \right) \right],$$

where I is the modified Bessel function and

$$\chi = v_n \sqrt{M}$$

where M is the multiplicity of the event. When comparing the same harmonic number correlation and event plane, $k = 1$ always.

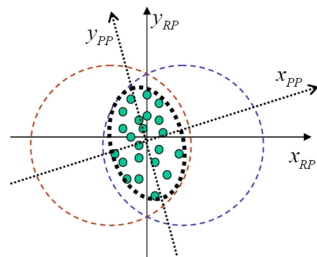


Figure: From
arXiv:0809.2949v2

Event plane

- By splitting the event into two equal size independent sub-events

$$R_{n,sub} = \sqrt{\langle \cos [n(\Psi_n^A - \Psi_n^B)] \rangle},$$

and then χ_{sub} can be solved iteratively from the previous page equation.

- Because $\chi \propto \sqrt{M}$, the full event $\chi = \sqrt{2} \chi_{sub}$, and so finally full event resolution

$$R_n = R_{k=1}(\chi)$$

and

$$v_n = \frac{v_n^{obs}}{R_n}$$

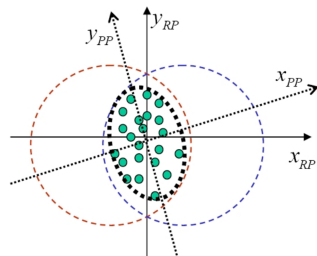


Figure: From
arXiv:0809.2949v2

Event plane

- Summary table:

Table: Is possible to use.

	Simulation	Data
Ψ_{RP}	x	
Ψ_n	x	x
$R_{n,true}$	x	
R_n	x	x

- When using a simulation the methods can be validated by comparing to the true values of reaction plane and $R_{n,true}$.

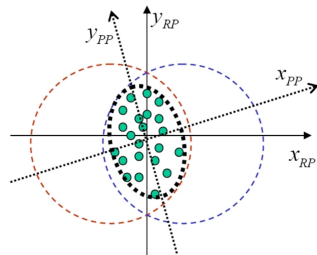


Figure: From
arXiv:0809.2949v2

Event Plane (Scalar Product) method

- Another way to calculate v_n :

$$\left\langle \mathbf{Q}_n \frac{\mathbf{Q}_{n,A}^*}{|\mathbf{Q}_{n,A}|} \right\rangle = \left\langle \mathbf{Q}_n e^{-in\psi_n} \right\rangle \left\langle \frac{\mathbf{Q}_{n,A}}{|\mathbf{Q}_{n,A}|} e^{-in\psi_n} \right\rangle^* = v_n R_{n,A}$$

where the last equality is valid when \mathbf{Q}_n and $\mathbf{Q}_{n,A}$ are uncorrelated, except for the common ψ_n .

- For two subevents with equal multiplicities

$$\left\langle \frac{\mathbf{Q}_{n,A}}{|\mathbf{Q}_{n,A}|} \frac{\mathbf{Q}_{n,B}^*}{|\mathbf{Q}_{n,B}|} \right\rangle = \left\langle \frac{\mathbf{Q}_{n,A}}{|\mathbf{Q}_{n,A}|} e^{-in\psi_n} \right\rangle \left\langle \frac{\mathbf{Q}_{n,B}}{|\mathbf{Q}_{n,B}|} e^{-in\psi_n} \right\rangle^* = \left| \left\langle \frac{\mathbf{Q}_{n,A}}{|\mathbf{Q}_{n,A}|} e^{-in\psi_n} \right\rangle \right|^2 = R_{n,A}^2$$

- The scalar product (SP) method uses the same equations but without the normalizations by the Q vector length.

Event Plane (Scalar Product) method

- Thus the v_n can be calculated using event-plane method by

$$v_n \{EP\} = \left\langle \mathbf{Q}_n \frac{\mathbf{Q}_{n,A}^*}{|\mathbf{Q}_{n,A}|} \right\rangle / \sqrt{\left\langle \frac{\mathbf{Q}_{n,A}}{|\mathbf{Q}_{n,A}|} \frac{\mathbf{Q}_{n,B}^*}{|\mathbf{Q}_{n,B}|} \right\rangle}.$$

- This means that to calculate v_n , one does not necessarily need the event plane information explicitly. Only the flow vectors are necessary.
- By comparing the v_n from different methods, the validation is better.