ToyFlow MC tool for FIT

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Introductions

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Motivation

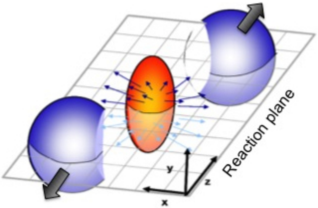
- Because of the initial pressure gradients and fluctuations, the particle azimuthal distribution is not isotropic.
- This is why it is customary to expand it in a Fourier series:

$$E\frac{\mathrm{d}^3N}{\mathrm{d}^3p} = \frac{1}{2\pi}\frac{\mathrm{d}^2N}{p_\mathrm{T}\mathrm{d}p_\mathrm{T}\mathrm{d}y}\left(1+\sum_{n=1}^{\infty}2v_n\cos\left(n\left(\phi-\Psi_\mathrm{RP}\right)\right)\right)$$

where

$$v_n = \langle\cos\left[n\left(\phi_i-\Psi_\mathrm{RP}\right)\right]\rangle$$

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 $\mathbf{Q_n} \in \mathbb{C}$:

$$Q_{n,x} = \sum_{i \in \mathrm{particles}} w_i \cos(n\phi_i) = |\mathbf{Q_n}| \cos(n\Psi_n)$$

$$Q_{n,y} = \sum_{i \in \mathrm{particles}} w_i \sin(n\phi_i) = |\mathbf{Q_n}| \sin(n\Psi_n),$$

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

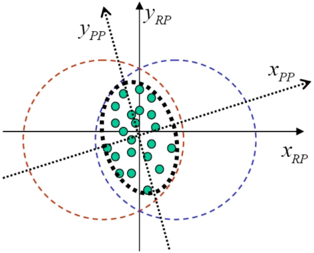


Figure: From arXiv:0809.2949v2

Event plane

- Now we have

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

and now the observed v_n can be calculated using

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

- Autocorrelations need to be removed when using this equation.

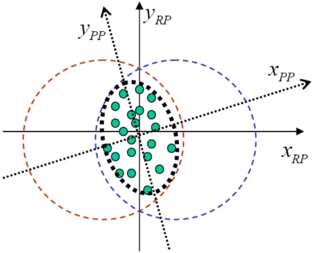


Figure: From arXiv:0809.2949v2

Event plane

- It is easily shown that there is a relation

$$v_n^{\mathrm{obs}} = v_n \cos\left[n\left(\Psi_n - \Psi_{\mathrm{RP}}\right)\right].$$

To help, a resolution parameter is defined as

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

so that

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

The above definition of R_n can only be used with simulations as the Ψ_{RP} is unknown.

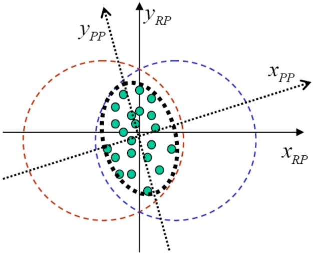


Figure: From arXiv:0809.2949v2

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.

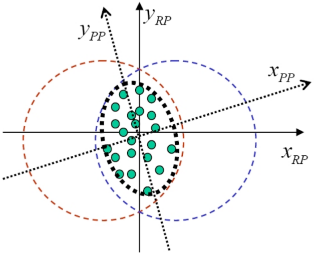


Figure: From arXiv:0809.2949v2

Event plane

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

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

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

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

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

and

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

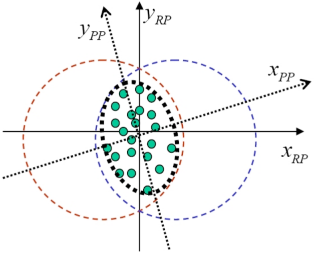


Figure: From arXiv:0809.2949v2

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 $R_{n,true}$.

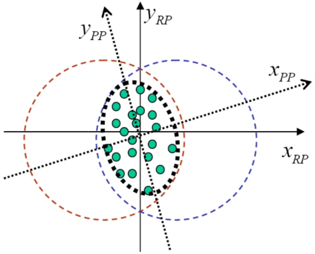


Figure: From arXiv:0809.2949v2

How the event is formed

- validating

FIT V0+

- Ideal vs. gran
- Compare to Maciej

TODO

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

The end

Thank you for listening

Questions?

Event Plane method

- Another way to calculate v_n:

$$\left\langle \mathbf{Q_n} \frac{\mathbf{Q_{n,A}}^*}{|\mathbf{Q_{n,A}}|} \right\rangle = \left\langle \mathbf{Q_n} e^{-in\Psi_n} \right\rangle \left\langle \frac{\mathbf{Q_{n,A}}}{|\mathbf{Q_{n,A}}|} e^{-in\Psi_n} \right\rangle^* = v_n R_{n,\mathrm{A}}$$

  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

$$\left\langle \frac{\mathbf{Q_{n,A}}}{|\mathbf{Q_{n,A}}|} \frac{\mathbf{Q_{n,B}}^*}{|\mathbf{Q_{n,B}}|} \right\rangle = \left\langle \frac{\mathbf{Q_{n,A}}}{|\mathbf{Q_{n,A}}|} e^{-in\Psi_n} \right\rangle \left\langle \frac{\mathbf{Q_{n,B}}}{|\mathbf{Q_{n,B}}|} e^{-in\Psi_n} \right\rangle^* = \left| \left\langle \frac{\mathbf{Q_{n,A}}}{|\mathbf{Q_{n,A}}|} e^{-in\Psi_n} \right\rangle \right|^2 = R_{n,\mathrm{A}}^2$$

Event Plane method

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

$$v_n\{\mathrm{EP}\} = \left\langle \mathbf{Q_n} \frac{\mathbf{Q_{n,A}}^*}{|\mathbf{Q_{n,A}}|} \right\rangle \Bigg/ \sqrt{\left\langle \frac{\mathbf{Q_{n,A}}}{|\mathbf{Q_{n,A}}|} \frac{\mathbf{Q_{n,B}}^*}{|\mathbf{Q_{n,B}}|} \right\rangle} .$$

- 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.

Corrections

- For an imperfect detector system, there are some corrections done.
- First an acceptance function $A(\phi)$ is determined so that

$$\int \frac{\mathrm{d}\phi}{2\pi} A(\phi) = 1.$$

- Then define

$$\bar{c}_n = \int \frac{\mathrm{d}\phi}{2\pi} A(\phi)\cos(m\phi), \qquad \bar{s}_n = \int \frac{\mathrm{d}\phi}{2\pi} A(\phi)\sin(m\phi)$$

$$a_{2n}^{\pm} = 1 \pm \bar{c}_{2n} \tag{1}$$

$$\lambda_{2n}^{s\pm} = \frac{\bar{s}_{2n}}{a_{2n}^{\pm}}$$

Corrections

- Now the shift corrections is

$$Q'_{n,x} = Q_{n,x} - \bar{c}_n, \qquad Q'_{n,y} = Q_{n,y} - \bar{s}_n \tag{2}$$

twist

$$Q''_{n,x} = \frac{Q'_{n,x} - \lambda^{s-}_{2n}}{1 - \lambda^{s-}_{2n}\lambda^{s+}_{2n}}, \qquad Q''_{n,y} = \frac{Q'_{n,y} - \lambda^{s+}_{2n}}{1 - \lambda^{s-}_{2n}\lambda^{s+}_{2n}} \tag{3}$$

and rescaling

$$Q'''_{n,x} = \frac{Q''_{n,x}}{a^{+}_{2n}}, \qquad Q'''_{n,y} = \frac{Q''_{n,y}}{a^{-}_{2n}}. \tag{4}$$