What flow to subtract from jet-correlation

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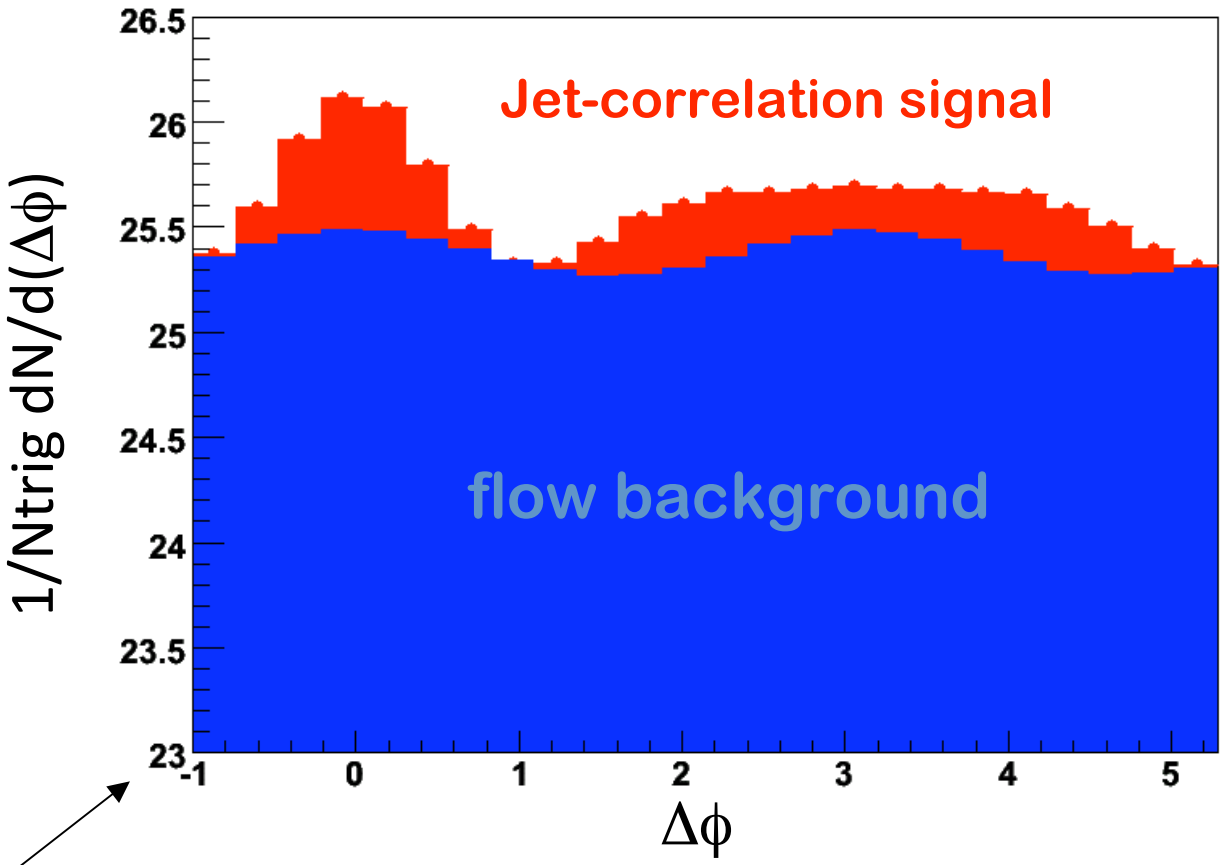
Outline

- Why look into this?
- Non-flow (arXiv:0812.1176)
- What flow to subtract from jet-correlation
- Summary

Subtraction of flow background is critical



$\frac{1}{100}$

5% flow = ½ signal

zero suppressed

Critically important to have background subtraction under control

Various v_2 measurements

v2{2}

v2{EP}

$v_2\{2\}^2 = v_2^2 + \sigma^2 + \text{nonflow}$

v2{BBC}

v2{FTPC}

some non-flow still present, ala ridge.

v2{4}

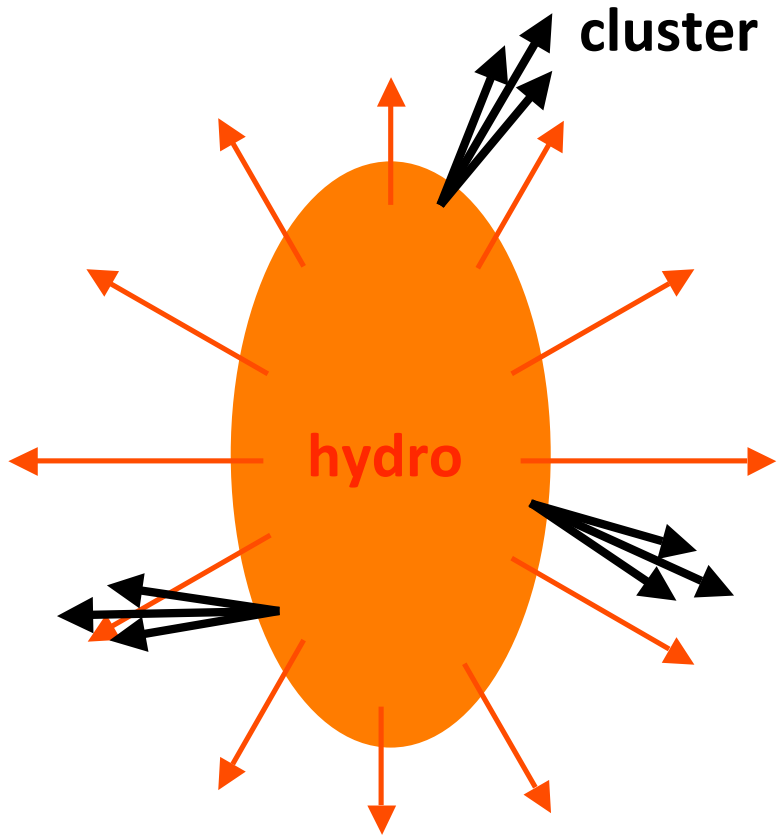
v2{2D}

$v_2\{4\}^2 = v_2^2 - \sigma^2$

current v_2 syst. uncertainty

Non-flow in a cluster model

FW, arXiv:0812.1176



decompose particle pairs

$$N^2 v_2^2\{2\}$$

- hydro particle pairs:

$$N_{hy}^2 v_2^2\{2\}_{hy}$$

- cluster particle pairs:

$$N_{cl} N_{a,cl}^2 \left\langle \cos 2\Delta\varphi_{ij} \right\rangle_{cl}$$

- cluster-hydro part. pairs:

$$2N_{hy} N_{cl} N_{a,cl} v_2\{2\}_{hy} v_2\{2\}_{a,cl}$$

- cluster-cluster part. pairs:

$$N_{cl}(N_{cl}-1) N_{a,cl}^2 v_2^2\{2\}_{a,cl}$$

Non-flow in cluster model

Two-particle angular correlation:

$$N^2 v_2^2\{2\} = N_{hy}^2 v_2^2\{2\}_{hy} + N_{cl} N_{a,cl}^2 \left\langle \cos 2\Delta\varphi_{ij} \right\rangle_{cl} + 2N_{cl} N_{hy} N_{a,cl} v_2\{2\}_{hy} v_2\{2\}_{a,cl} + N_{cl}(N_{cl}-1) N_{a,cl}^2 v_2^2\{2\}_{a,cl}$$

$$= \left(N_{hy} v_2\{2\}_{hy} + N_{cl} N_{a,cl} v_2\{2\}_{a,cl} \right)^2 + N_{cl} N_{a,cl}^2 \left(\left\langle \cos 2\Delta\varphi_{ij} \right\rangle_{cl} - v_2^2\{2\}_{a,cl} \right)$$

hydro particle pair — **cluster particle pair** — **cluster-hydro particle pair** — **cluster-cluster particle pair**

$$v_2^2\{2\} = \left(\frac{N_{hy}}{N_{bg}} v_2\{2\}_{hy} + \sum_{cl} \frac{N_{cl} N_{a,cl}}{N_{bg}} v_2\{2\}_{cl} \left\langle \cos 2\Delta\varphi \right\rangle_{cl} \right)^2 + \sum_{cl} \frac{N_{cl} N_{a,cl}^2}{N_{bg}^2} \left(\left\langle \cos 2\Delta\varphi_{ij} \right\rangle_{cl} - v_2^2\{2\}_{cl} \left\langle \cos 2\Delta\varphi \right\rangle_{cl}^2 \right)$$

v_2 related to RP — **v2 not related to RP**

$\neq v_2\{2\}_{hy}$!

So what flow to subtract in jet-correlation?

$$\frac{1}{N_{trig}}\frac{dN}{d\Delta\varphi} = \frac{dN_{hy}}{d\Delta\varphi} + \sum_{k\neq jet\in clus}\frac{dN_{a,k}}{d\Delta\varphi} + \sum_{k\neq t\in jet}\frac{dN_{a,k}}{d\Delta\varphi} + \frac{dN_{jet}}{d\Delta\varphi}$$

clusters

other jets

jet signal

$$\frac{1}{N_{trig}}\frac{dN}{d\Delta\varphi} = a\left(\frac{dN_{hy}}{d\Delta\varphi} + \sum_{k\neq jet\in clus}\frac{dN_{a,k}}{d\Delta\varphi} + \sum_{k\in jet}\frac{dN_{a,k}}{d\Delta\varphi}\right)_{inc} + \frac{dN_{jet}}{d\Delta\varphi}$$

$$\boxed{\frac{dN_{bg}}{d\Delta\varphi} = \frac{N_{bg}}{2\pi}\left[1 + 2v_{2,t}\left(\frac{N_{hy}}{N_{bg}}v_{2,hy} + \sum_{cl}\frac{N_{cl}N_{a,cl}}{N_{bg}}v_{2,a,cl}\right)\cos 2\Delta\varphi\right]}$$

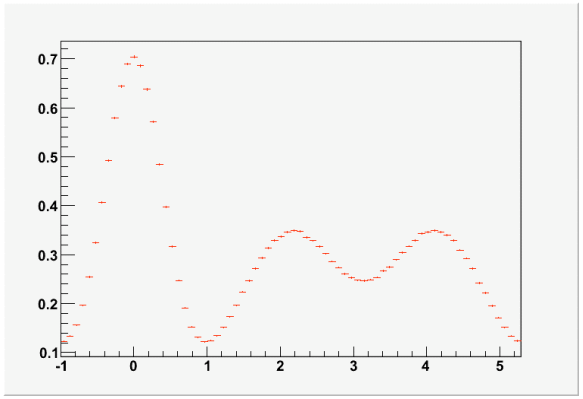
$$v_2^2\{2\} = \left(\frac{N_{hy}}{N_{bg}}v_2\{2\}_{hy} + \sum_{cl}\frac{N_{cl}N_{a,cl}}{N_{bg}}v_2\{2\}_{cl}\langle\cos 2\Delta\varphi\rangle_{cl}\right)^2 + \sum_{cl}\frac{N_{cl}N_{a,cl}^2}{N_{bg}^2}\left(\langle\cos 2\Delta\varphi_{ij}\rangle_{cl} - v_2^2\{2\}_{cl}\langle\cos 2\Delta\varphi\rangle_{cl}^2\right)$$

v_2 related to RP

Monte Carlo test

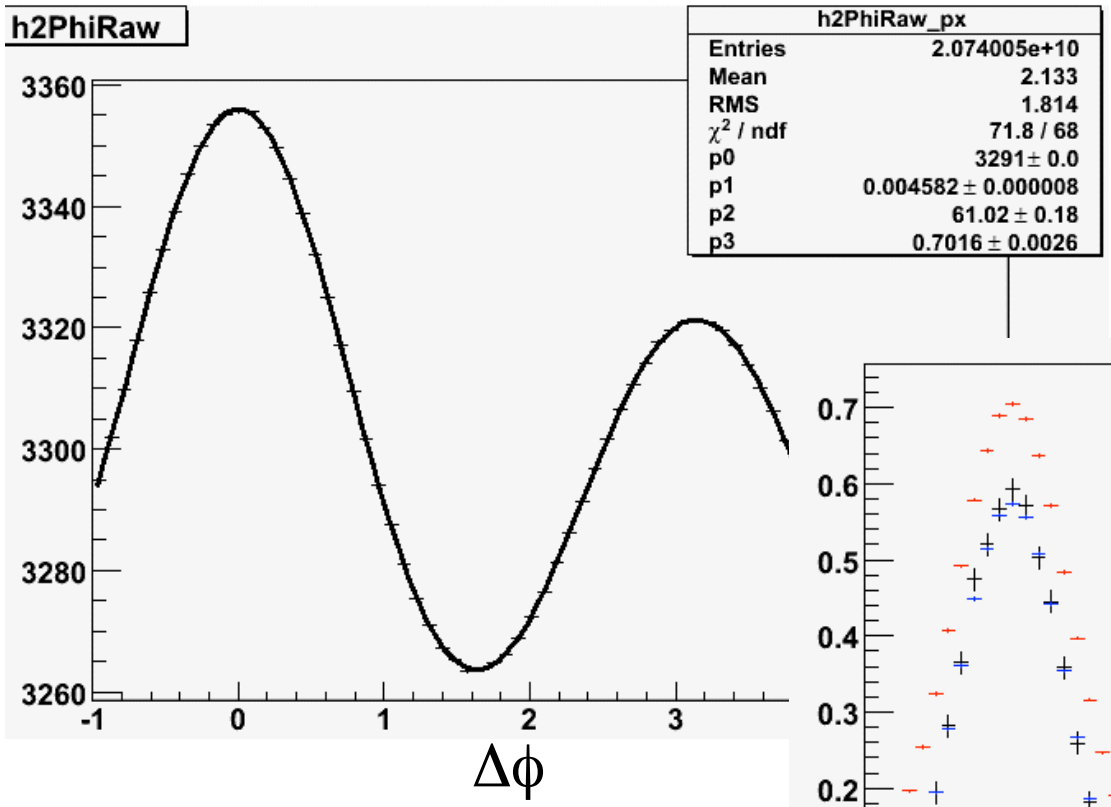
Input:

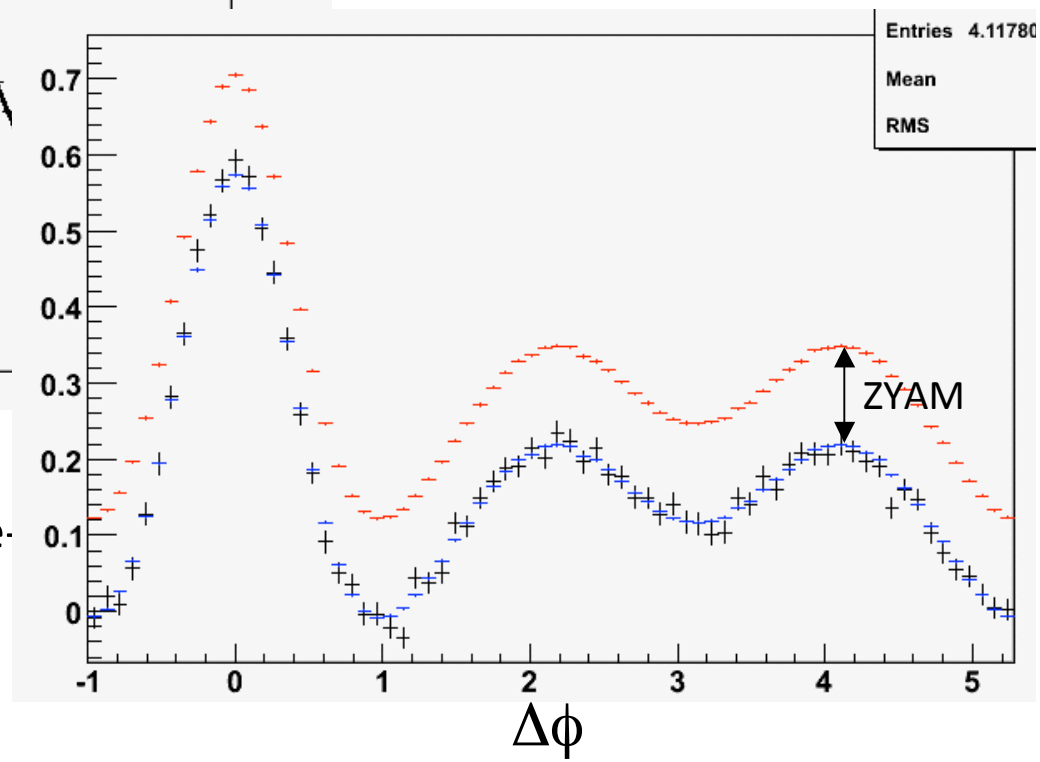
- **hydro background**, $\langle N_{hy} \rangle = 150$, $v_{2,hy} = 0.05$,
- number of **clusters** $\langle N_{cl} \rangle = 10$
  cluster $v_2 = 0.2$
  number of particles per cluster $\langle N_{a,cl} \rangle = 5$
  cluster shape Gaussian $\sigma_{cl} = 0.5$
- number of **trigger** particles $\langle N_{trig} \rangle = 2$
  trigger particle $v_2 = 0.5$
- **jet-correlation**:
  near-side Gaussian $\langle N_n \rangle = 0.7$, $\sigma_n = 0.4$
  away-side symmetric double-Gaussian $\langle N_a \rangle = 1.2$, $\sigma_a = 0.7$, $\theta = 1$ rad.
- Poisson fluctuation in multiplicity.
  No v_2 fluctuations yet.



$$v_{2,bg} = \frac{N_{hy}}{N_{bg}} v_2\{2\}_{hy} + \sum_{cl} \frac{N_{cl} N_{a,cl}}{N_{bg}} v_2\{2\}_{cl} \left\langle \cos 2\Delta\varphi \right\rangle_{cl} = 0.0681$$

Fit un-triggered pair correlation



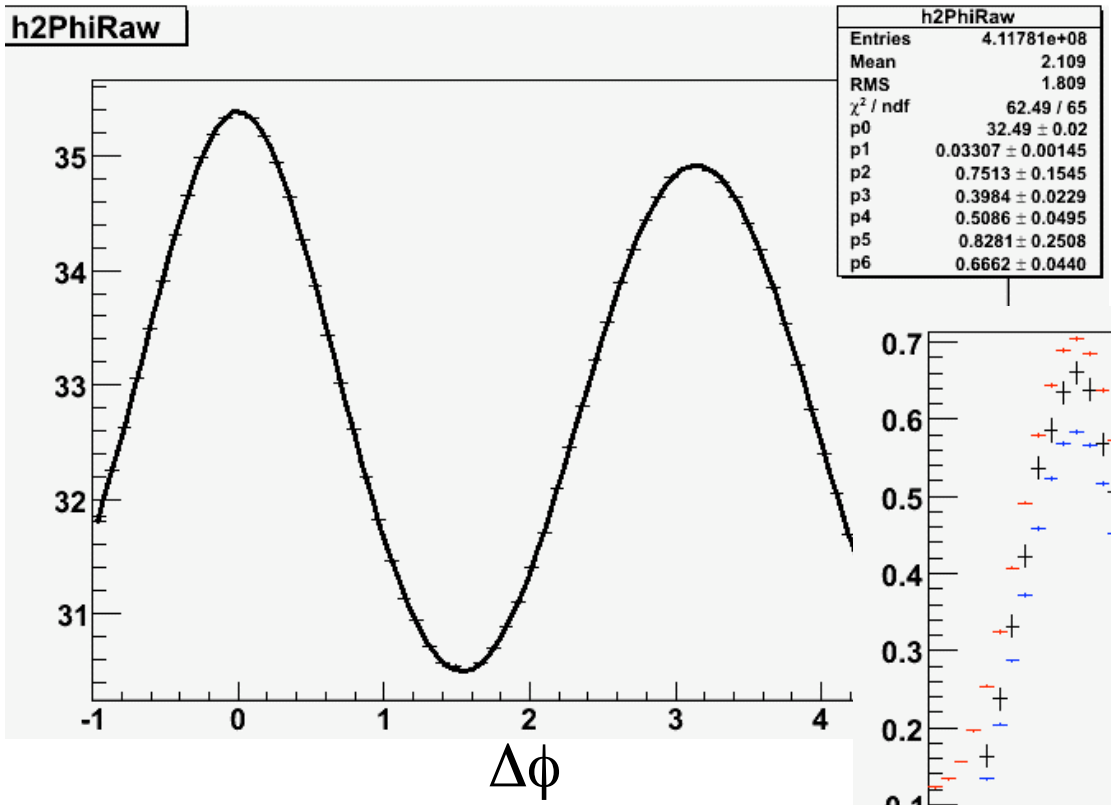


Fit to $B(1+2v_2^2\cos(2\Delta\phi))$ + near-side-

➔ **$v_2\{2D\}=0.0677$**

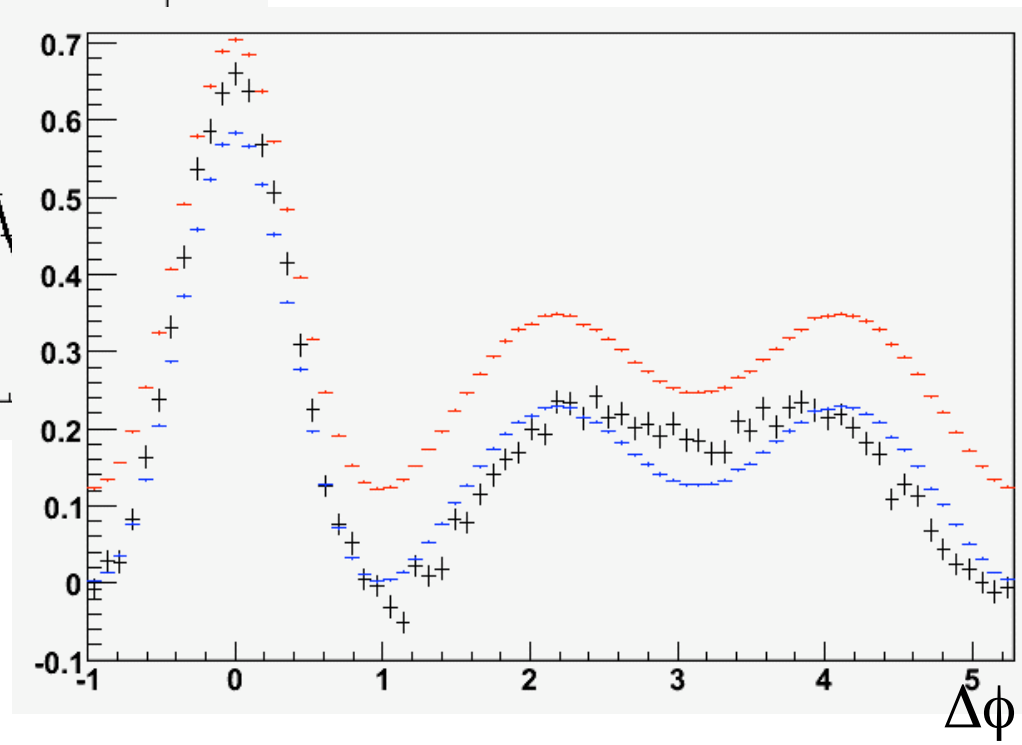
Calculated: $v_{2,bg}=0.0681$

Why not directly decompose flow and jet?



h2PhiRaw	
Entries	4.11781e+08
Mean	2.109
RMS	1.809
χ^2 / ndf	62.49 / 65
p0	32.49 ± 0.02
p1	0.03307 ± 0.00145
p2	0.7513 ± 0.1545
p3	0.3984 ± 0.0229
p4	0.5086 ± 0.0495
p5	0.8281 ± 0.2508
p6	0.6662 ± 0.0440

entangled jet-signal and flow. decomposition not easy nor unique.



➔ $v_{2,decompose}$=0.0661

Fit to $B(1+2v_2^2COS(2\Delta\phi)$ + near-side-Gaussian + away-side-double-Gaussian

Summary

- v_2 systematic uncertainty applied so far is conservative.
- Now better understanding of non-flow.
- Possible to reduce v_2 systematic uncertainty.

Backup

cluster $\tilde{\varphi}_k = \varphi_k - \psi$

within cluster $\Delta\varphi_i = \varphi_i - \varphi_k$

cluster particle pairs:

$$\sum_{(i\neq j)\in k} \cos 2(\Delta\varphi_{ij}) = \int_0^{2\pi} \wp_{cl}(\tilde{\varphi}_k)\rho_{cl}(\tilde{\varphi}_k)d\tilde{\varphi}_k \int_0^{2\pi} f_{cl}(\Delta\varphi_i,\tilde{\varphi}_k)d\Delta\varphi_i \int_0^{2\pi} f_{cl}(\Delta\varphi_j,\tilde{\varphi}_k)d\Delta\varphi_j \left[\cos 2(\Delta\varphi_i - \Delta\varphi_j)\right]$$

$$= \int_0^{2\pi} \wp_{cl}(\tilde{\varphi}_k)\rho_{cl}(\tilde{\varphi}_k)d\tilde{\varphi}_k \left[\left(\int_0^{2\pi} f_{cl}(\Delta\varphi,\tilde{\varphi}_k)\cos 2\Delta\varphi d\Delta\varphi\right)^2 + \left(\int_0^{2\pi}\left[f_{cl}(\Delta\varphi,\tilde{\varphi}_k)\sin 2\Delta\varphi d\Delta\varphi\right]\right)^2\right]$$

$$= \int_0^{2\pi} \wp_{cl}(\tilde{\varphi}_k)\left(\left\langle\cos 2\Delta\varphi\right\rangle_{\tilde{\varphi}_k}^2 + \left\langle\sin 2\Delta\varphi\right\rangle_{\tilde{\varphi}_k}^2\right)\rho_{cl}(\tilde{\varphi}_k)d\tilde{\varphi}_k \approx \wp_{cl}\left\langle\cos 2\Delta\varphi\right\rangle_{cl}^2$$

hydro-cluster particle pairs:

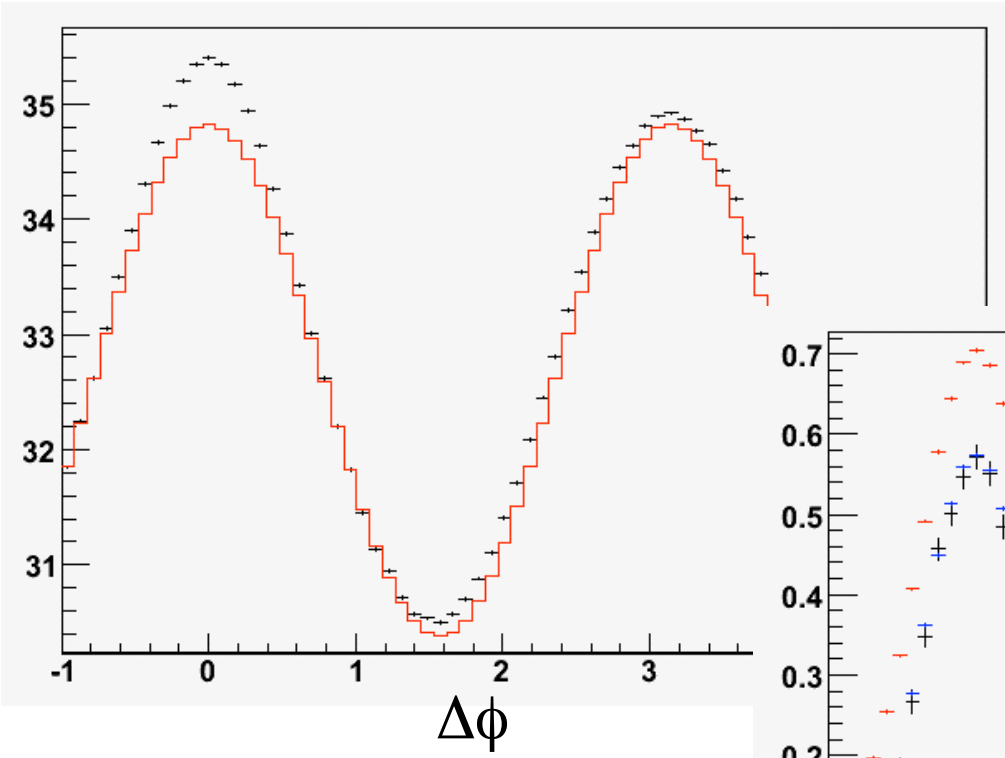
$$\sum_{i\in hy, j\in cl} \cos 2(\Delta\varphi_{ij}) = \int_0^{2\pi} N_{hy}(\tilde{\varphi}_{k=1,2\ldots})\rho_{hy}(\tilde{\varphi}_{hy})\cos 2\tilde{\varphi}_{hy}d\tilde{\varphi}_{hy}\int_0^{2\pi}\rho_{cl}(\tilde{\varphi}_k)d\tilde{\varphi}_k\int_0^{2\pi} N_{a,cl}(\tilde{\varphi}_k)f_{cl}(\Delta\varphi_i,\tilde{\varphi}_k)\cos 2(\Delta\varphi_i + \tilde{\varphi}_k)d\Delta\varphi_i$$

$$= N_{hy}N_{a,cl}v_{2,hy}v_{2,a,cl} \approx v_{2,cl}\left\langle\cos 2\Delta\varphi\right\rangle_{cl}$$

where $v_{2,a,cl} \equiv \left\langle\cos 2(\varphi - \psi_{\mathrm{RP}})\right\rangle = \dfrac{1}{N_{a,cl}}\displaystyle\int_0^{2\pi}\rho_{cl}(\tilde{\varphi}_k)d\tilde{\varphi}_k\int_0^{2\pi} N_{a,cl}(\tilde{\varphi}_k)f_{cl}(\Delta\varphi_i,\tilde{\varphi}_k)\cos 2(\Delta\varphi_i + \tilde{\varphi}_k)d\Delta\varphi_i$

$$\approx v_{2,cl}\left\langle\cos 2\Delta\varphi\right\rangle_{cl}$$

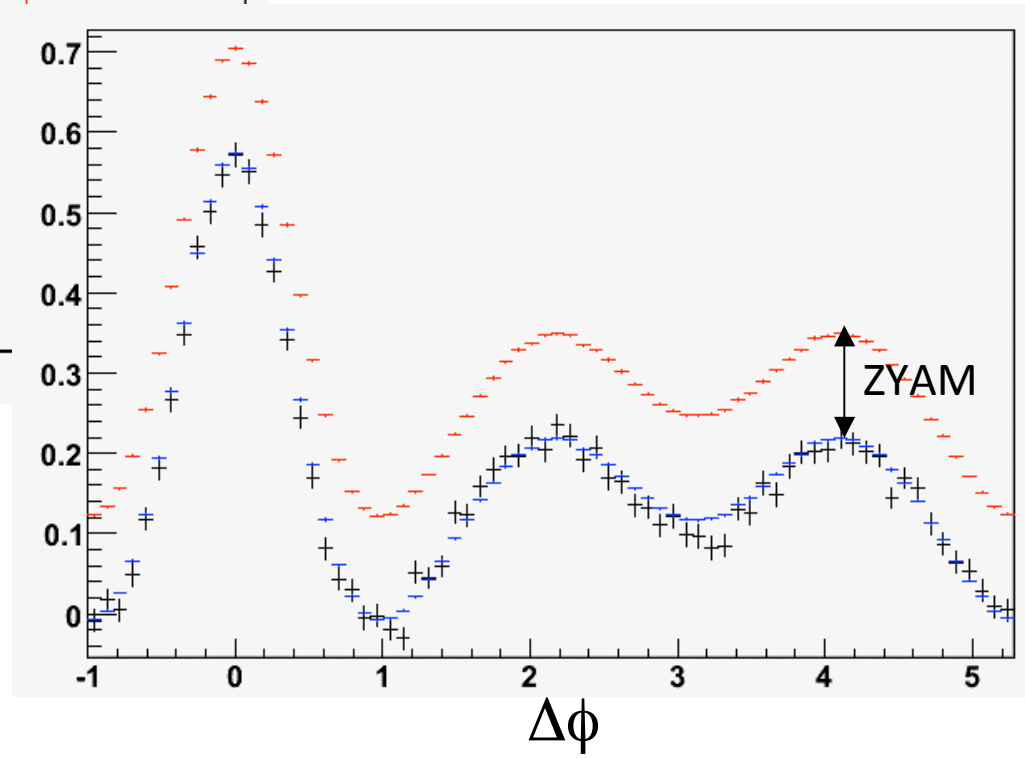
Is my derivation really correct?



Calculated: $v_{2,bg}$=0.0681

Fit to real bkgd: $v_{2,fit}$=0.0681

Yes, it is correct.



$v_2\{2\}$=0.0817

$$\frac{dN_{a,cl}}{d\Delta\varphi} = \int_0^{2\pi} d\tilde{\varphi}_t \rho_t(\tilde{\varphi}_t) \int_0^{2\pi} d\tilde{\varphi}_k \rho_{cl}(\tilde{\varphi}_k) \int_0^{2\pi} d\Delta\varphi_k f_{cl}(\Delta\varphi_k, \tilde{\varphi}_k) \times \frac{1}{2\pi} \delta(\Delta\varphi_k + \tilde{\varphi}_k - \Delta\varphi - \tilde{\varphi}_t)$$

$$\tilde{\varphi}_t = \varphi_t - \psi \qquad \tilde{\varphi}_k = \varphi_k - \psi \qquad \Delta\varphi_k = \varphi - \varphi_k$$

$$\frac{dN_{a,cl}}{d\Delta\varphi} = \frac{1}{2\pi} \int_0^{2\pi} d\tilde{\varphi}_k \rho_{cl}(\tilde{\varphi}_k) N_{a,cl}(\tilde{\varphi}_k) + \frac{2v_{2,t}}{2\pi} \cos 2\Delta\varphi \int_0^{2\pi} d\tilde{\varphi}_k \rho_{cl}(\tilde{\varphi}_k) \int_0^{2\pi} d\Delta\varphi_k f_{cl}(\Delta\varphi_k, \tilde{\varphi}_k) \cos 2(\Delta\varphi_k + \tilde{\varphi}_k)$$

General form:

$$v_{2,a,cl} \equiv \langle \varphi - \psi \rangle_{cl} = \frac{1}{N_{a,cl}} \int_0^{2\pi} d\tilde{\varphi}_k \rho_{cl}(\tilde{\varphi}_k) \int_0^{2\pi} d\Delta\varphi_k f_{cl}(\Delta\varphi_k, \tilde{\varphi}_k) \cos 2(\Delta\varphi_k + \tilde{\varphi}_k)$$

Approx.

$$v_{2,a,cl} \approx v_2\{2\}_{cl} \langle \cos 2\Delta\varphi \rangle_{cl}$$

$$\frac{dN_{a,cl}}{d\Delta\varphi} = \frac{N_{a,cl}}{2\pi} \left(1 + 2v_{2,t} v_{2,a,cl} \cos 2\Delta\varphi\right)$$

$$\frac{dN_{bg}}{d\Delta\varphi} = \frac{N_{bg}}{2\pi} \left[1 + 2v_{2,t} \left(\frac{N_{hy}}{N_{bg}} v_{2,hy} + \sum_{cl} \frac{N_{cl} N_{a,cl}}{N_{bg}} v_{2,a,cl} \right) \cos 2\Delta\varphi \right]$$

$$N_{bg} = N_{hy} + \sum_{cl} N_{cl} N_{a,cl}$$