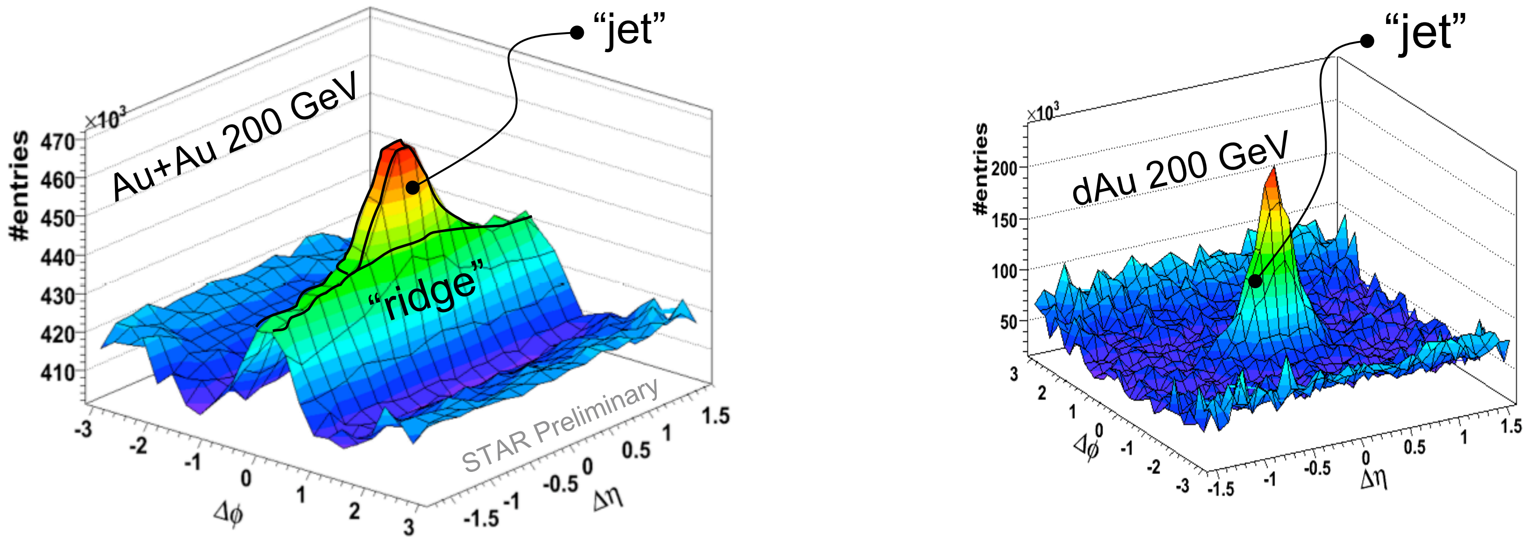
Elliptic flow of jet triggered events produced in heavy-ion collisions at RHIC energies

Navneet Kumar Pruthi
Panjab University,
Chandigarh-INDIA

for the STAR Collaboration

2-D Correlations



p+p & d+Au collisions:

a symmetric 2-D Gaussian at $|\Delta\eta| < 0.7$

Au+Au collisions:

ridge-like correlation extending across the STAR acceptance!

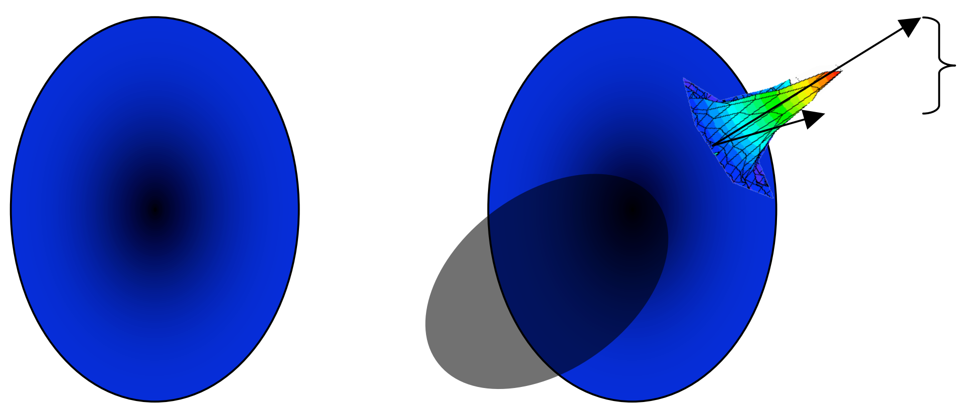
Categories : **Ridge+jet events : $|\Delta\eta|<0.7$**

Ridge events : $|\Delta\eta|>0.7$

- the "ridge" is calculated by projecting $|\Delta\eta|>0.7$ correlation to $|\Delta\eta|<0.7$
- the "jet" is the remaining correlation at $|\Delta\eta|<0.7$ after subtracting the "ridge"

Motivation

1. Is the Ridge structure related to jet fragmentation?
2. Do the jets modify the event-structure as they traverse the medium?
3. Is the ridge related to this modification?

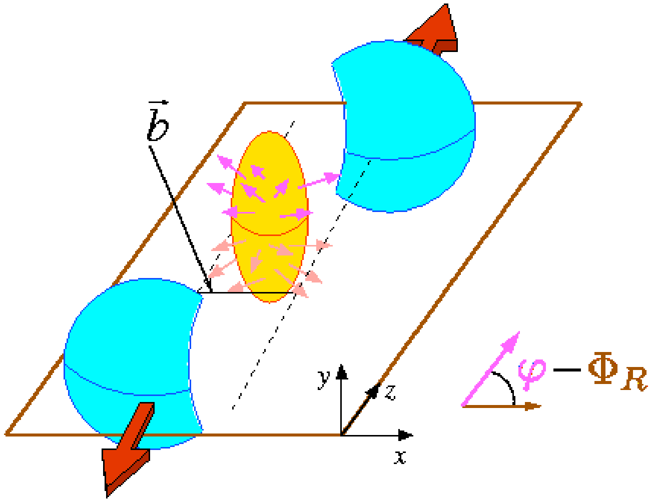


Do events with correlated pairs have the same structure as those without?

Can the jet modify the medium?

We will look for evidence of event-structure modification associated with high momentum correlated pairs

Measuring Azimuthal Event Anisotropy



Fourier transform of momentum distribution of the the particles :

$$E\frac{dN}{d^3p} \propto \frac{dN}{p_T dp_T dy}\left[1 + 2v_1\cos(\varphi - \Phi_R) + 2v_2\cos 2(\varphi - \Phi_R) + \ldots\right]$$

We access information v_2 by summing the x and y of the momentum vectors and looking at the distribution of the length of this vector |q|

$$q_x = \frac{1}{\sqrt{M}}\sum_{i=1}^{M}\cos(2*\varphi_i) \qquad q_y = \frac{1}{\sqrt{M}}\sum_{i=1}^{M}\sin(2*\varphi_i)$$

Fitting the distribution yields two parameters: $v_2\{q\}^2$ and $\delta+2\sigma_v^2$

$v_2\{q\}^2$ is related to the event-wise anisotropy

$\delta+2\sigma_v^2$ is related to correlations and fluctuations v_2

Method

$$\frac{dN}{q_2 dq_2} = \frac{1}{\sqrt{\pi}\sigma_x\sigma_y} e^{-\frac{1}{2}\left(\frac{q_2{}^2 + Mv_2{}^2}{\sigma_x{}^2}\right)} \sum_{k=0,2,4....}^{\infty} \left(1 - \frac{\sigma_x{}^2}{\sigma_y{}^2}\right)^2 \left(\frac{q_2}{v_2\sqrt{M}}\right)^k \frac{1}{k!}\Gamma\left(\frac{2k+1}{2}\right) I_k\left(\frac{q_2 v_2\sqrt{M}}{\sigma_x{}^2}\right)$$

$$\sigma_x{}^2 = \frac{1}{2}\left(1 + v_4 - 2v_2{}^2 + (M-1)*\sigma_{dyn}^2\right) \qquad \sigma_y{}^2 = \frac{1}{2}\left(1 + v_4 + (M-1)*\sigma_{dyn}^2\right)$$

By fitting the q - distribution with the above equation we can extract two parameters v_2 and σ_{dyn}

Global ellipticity

$$(= \delta_2 + 2\sigma_{v_2}^2)$$

Correlation and fluctuation term

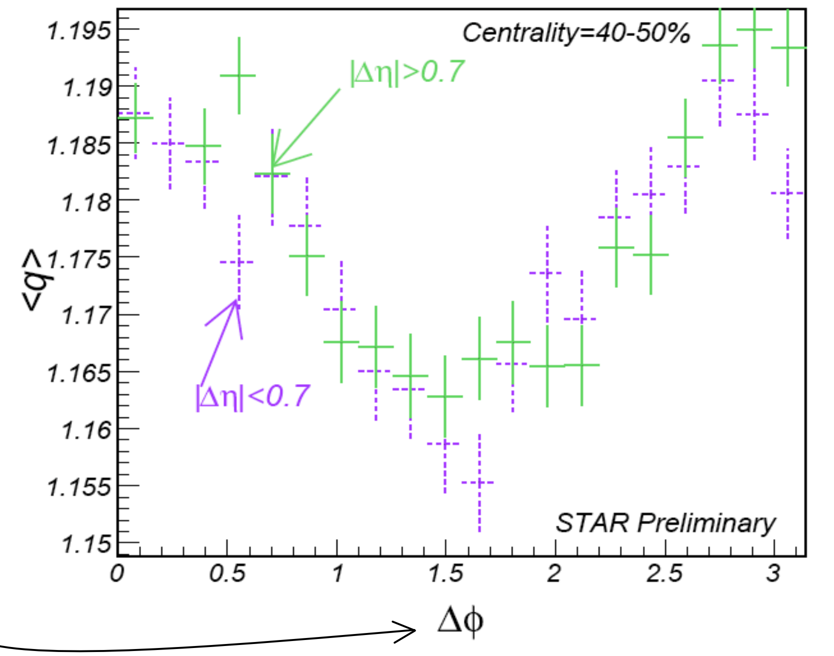
Analysis details

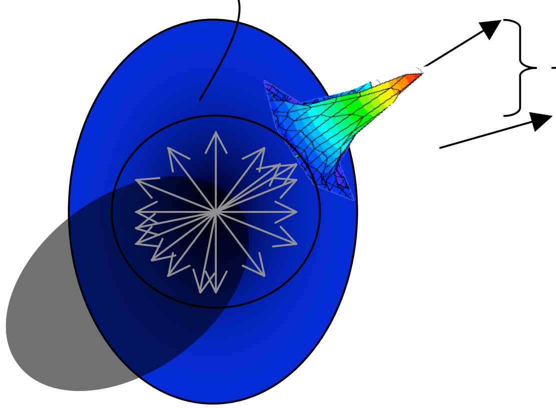
- Collisions: Au+Au 200GeV
- Events required to have two tracks with p_T > 2 GeV/c.
- Event-wide anisotropy studied for the tracks with p_T<2GeV
- Correlations formed with the leading and next-to-leading hadron $\rightarrow$ each event used only once i.e. 1 pair=1 event
- Statistically measure dn/d|q| for events with correlated pairs and events with uncorrelated pairs

1st observation!

<q> of the event changes with the angle between the high p_T tracks $\Delta\phi$

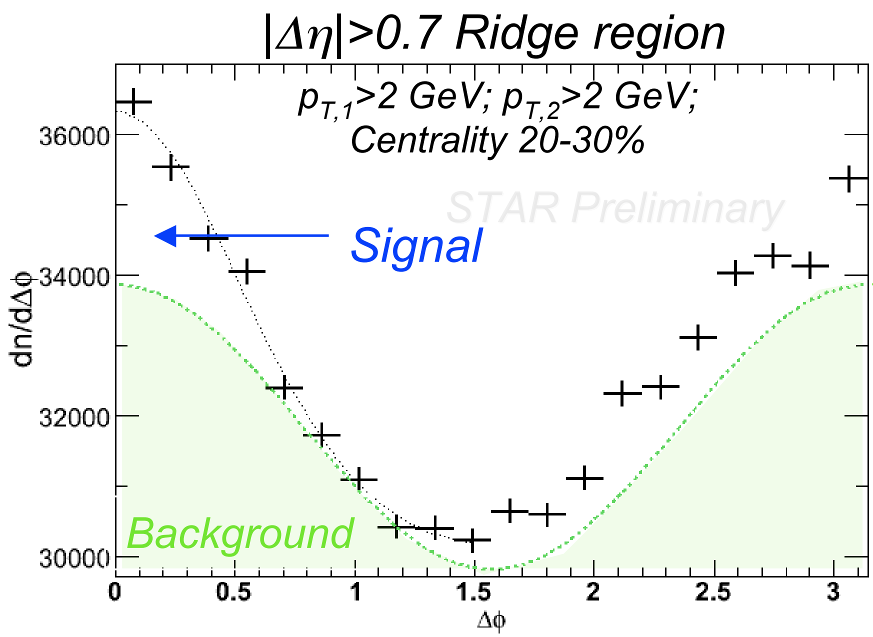
mean magnitude of the event-wise anisotropy





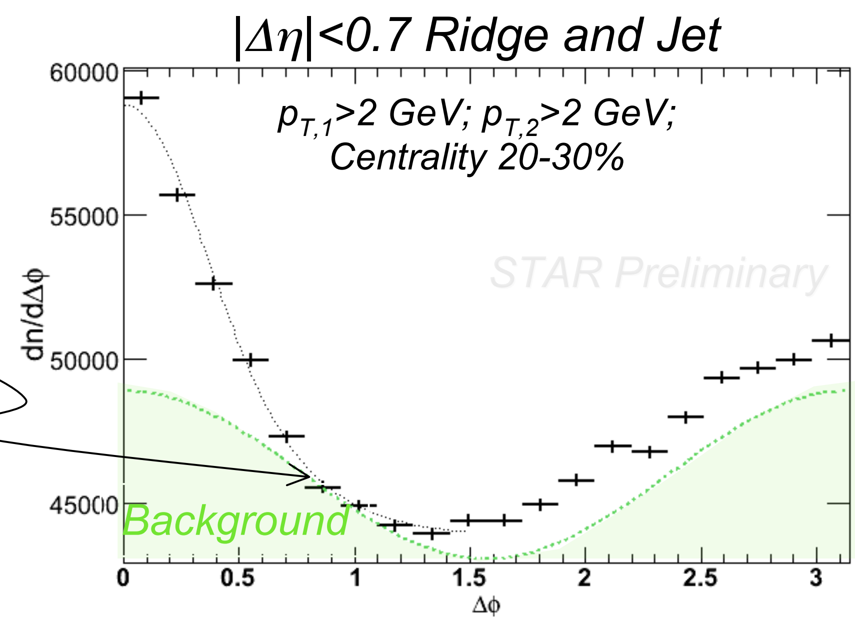
angle between high p_T tracks

Signal and background



Combinatorial background with v_2 modulation

$$C(\Delta\phi) = b_{\circ}(1 + 2\langle v_2^{trig} v_2^{asso}\rangle \cos(2\Delta\phi))$$



Background normalization determined by assuming zero yield at the minimum of the correlation (ZYAM)

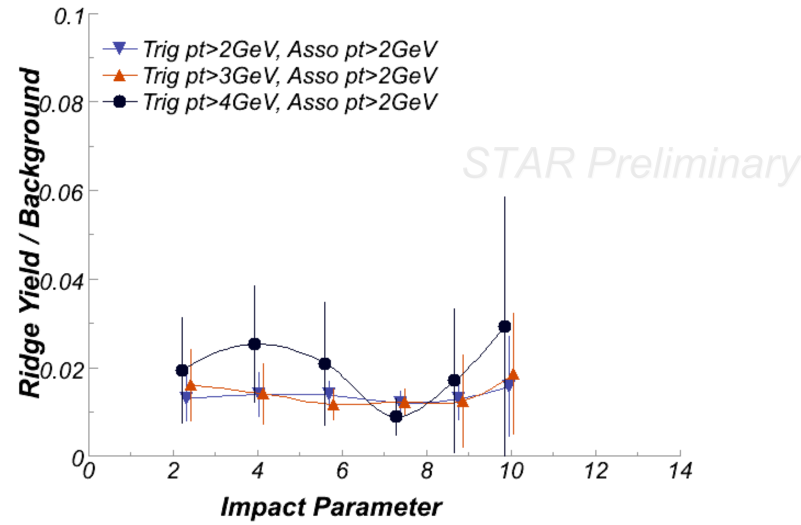
Systematic uncertainties applied based on normalization uncertainty

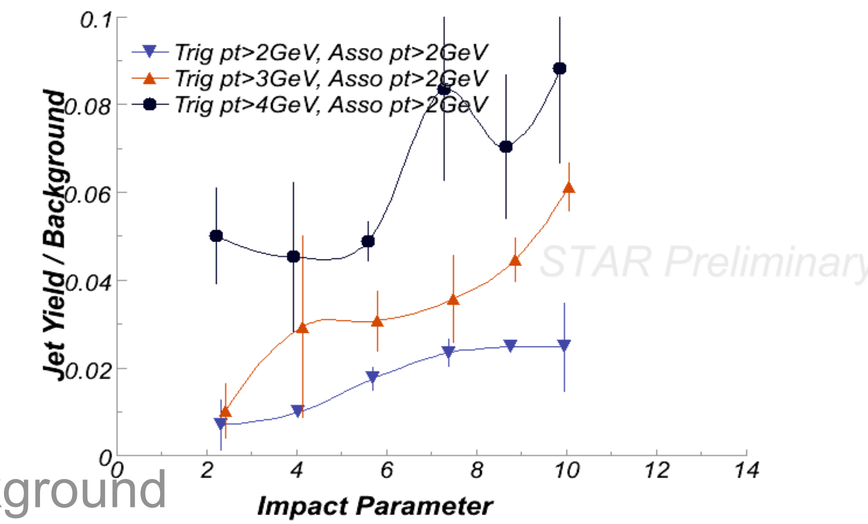
Ridge and Jet yields

Ridge area scales with the background!
Ridge ratio is independent of minimum p_T cut

Jet signal diluted by combinatorics as expected
Jet ratio grows with minimum p_T cut

Caution: this is leading and sub-leading di-hadrons (different quantity than usual associate particle yields)





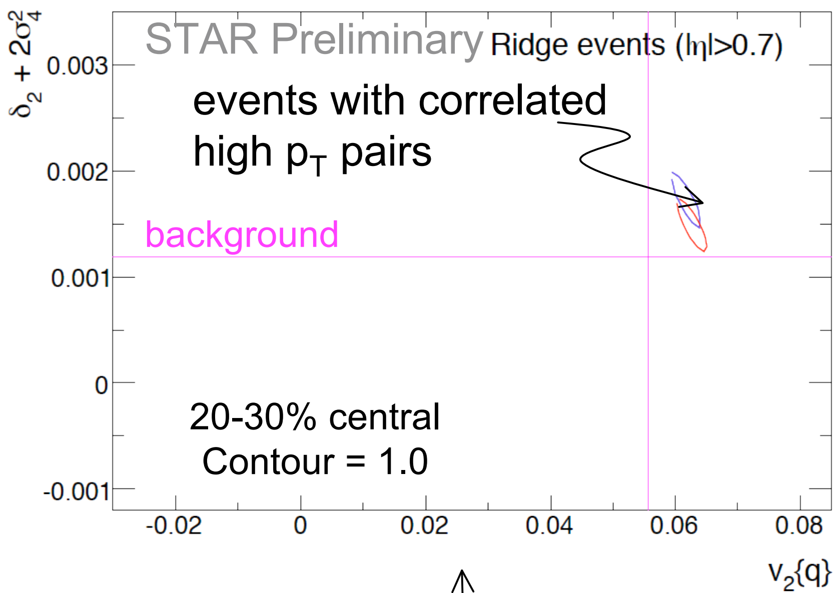
Background =>
Total ($|\Delta\eta|<2.0$) near-side($\Delta\phi<1.5$) background

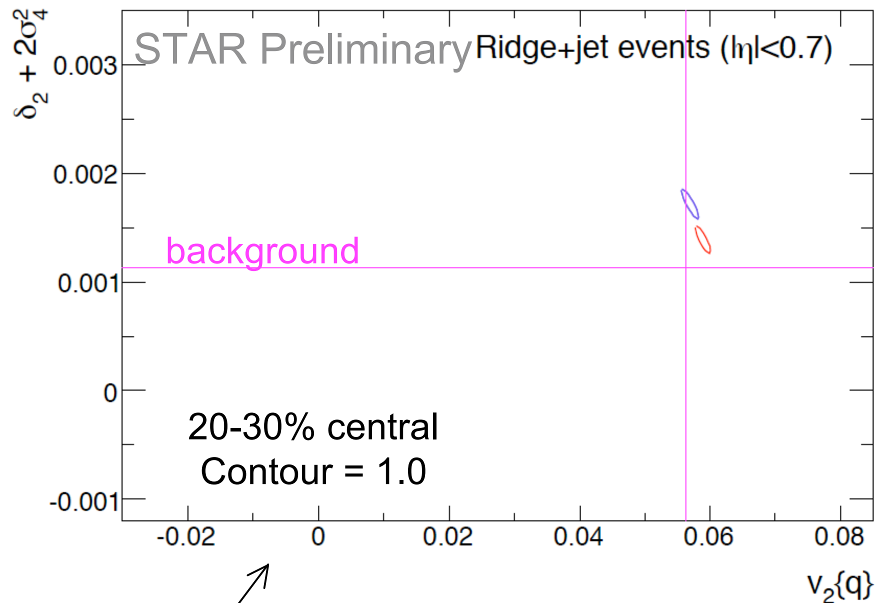
Analysis details

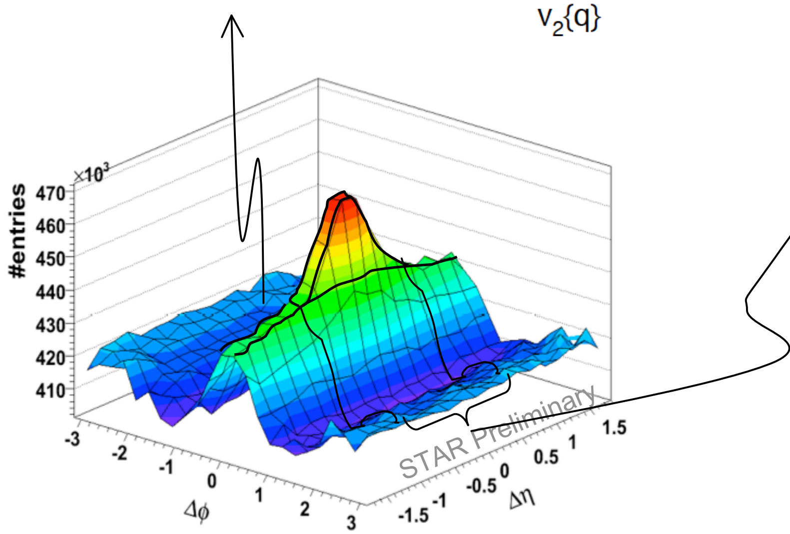
- We estimate the signal and background from $dN/d\Delta\phi$
- We measure dN/dq for different $\Delta\phi$ slices
- We use the S/B ratio and dN/dq from $\Delta\phi$ slices to determine dN/dq for Signal and dN/dq for Background
- It's just solving two equations for two unknowns
- This allows us the determine $v_2\{q\}$ and $\delta+2\sigma_v^2$ for the signal and background separately
- Are they the same? Is the <q> variation with $\Delta\phi$ caused by the v_2 term or the fluctuations and correlations term? or both?

χ^2 Contours

$p_{T,1}$ > 2 GeV; $p_{T,2}$ > 2 GeV







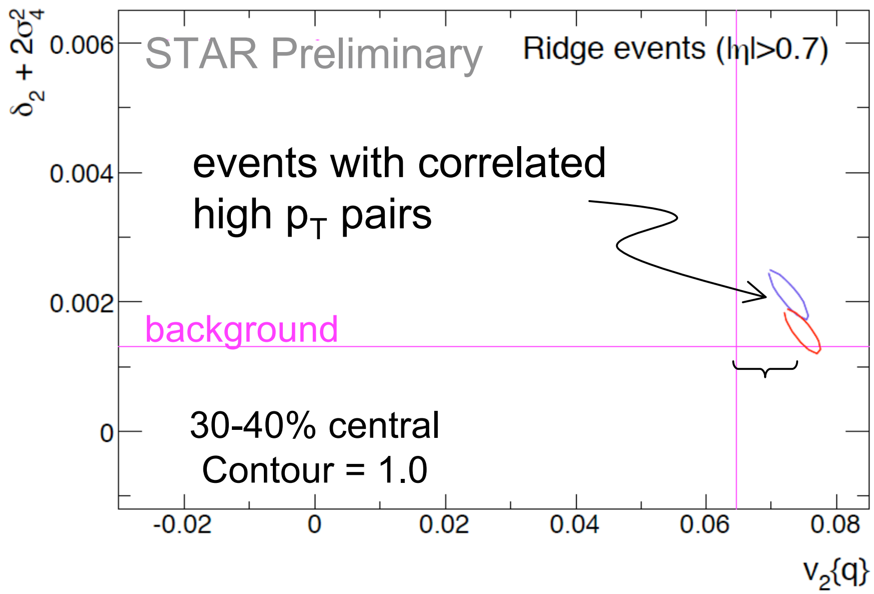
pink lines show fit values for events yielding pairs in the background

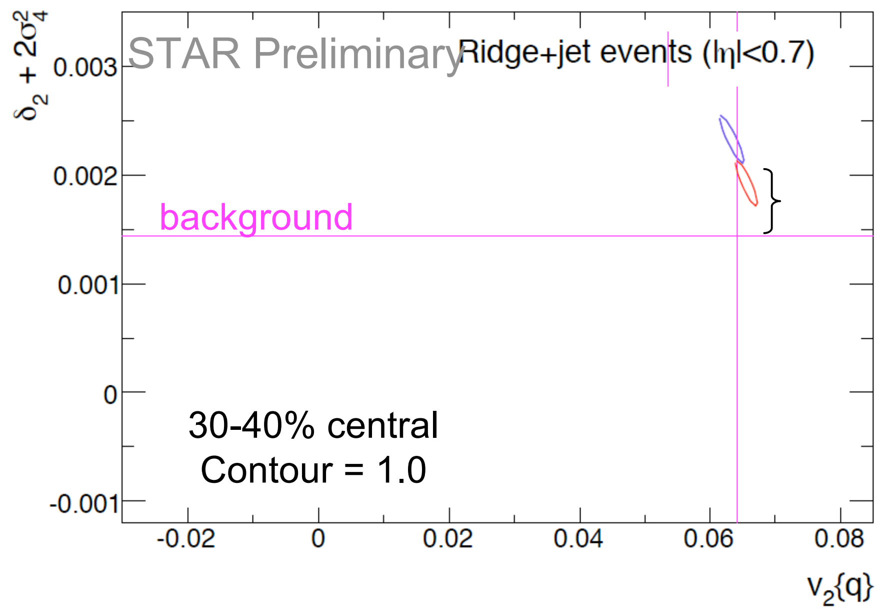
blue and red contours show range of allowed values for events yielding correlated pairs

different contours are for different background normalizations

χ^2 Contours

$p_{T,1} > 2$ GeV; $p_{T,2} > 2$ GeV





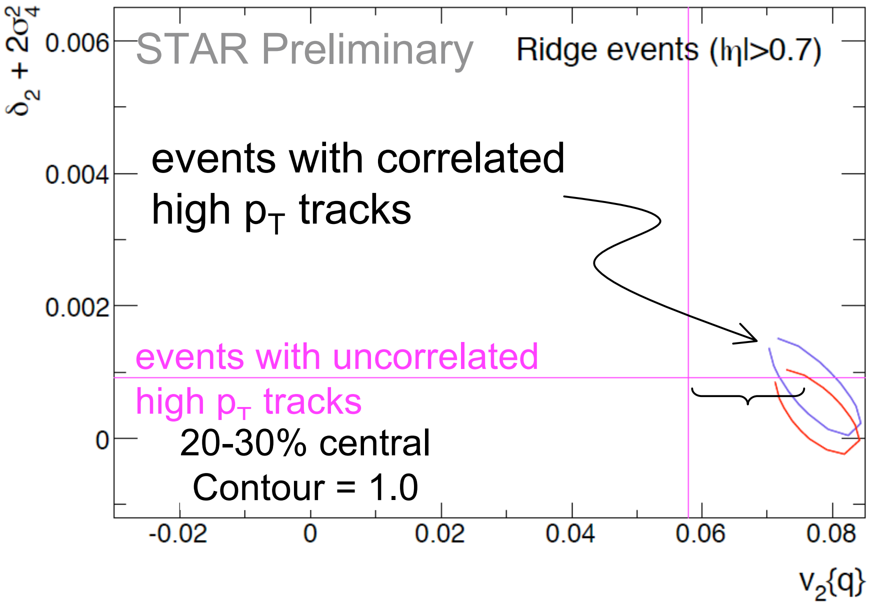
For events with pairs correlated at small $\Delta\eta$: the fluctuations and correlations seem larger

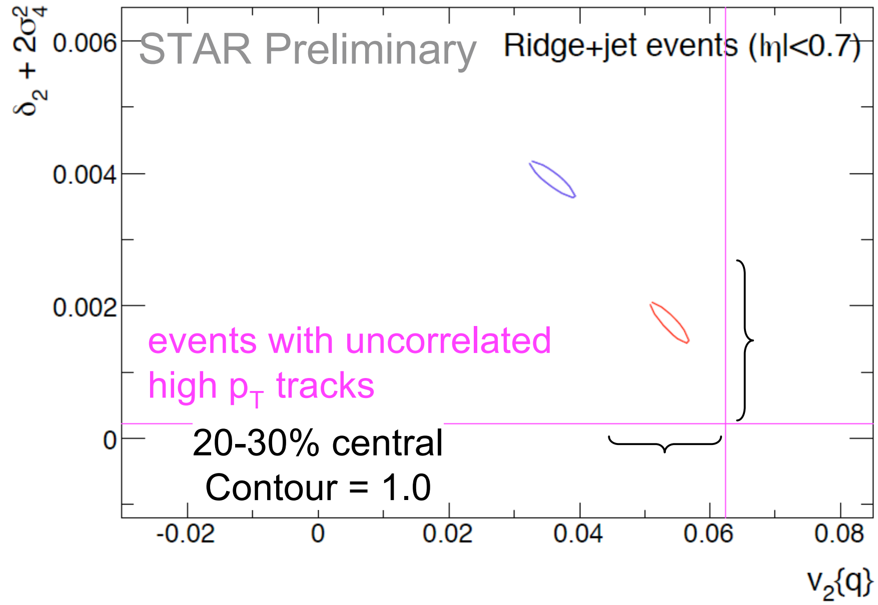
For events with pairs correlated at large $\Delta\eta$: the event-wise anisotropy may be larger

statistical and systematics errors are too large however to make a strong conclusions

χ^2 Contours

*$p_{T,1}$ > **4** GeV; $p_{T,2}$ > 2 GeV*

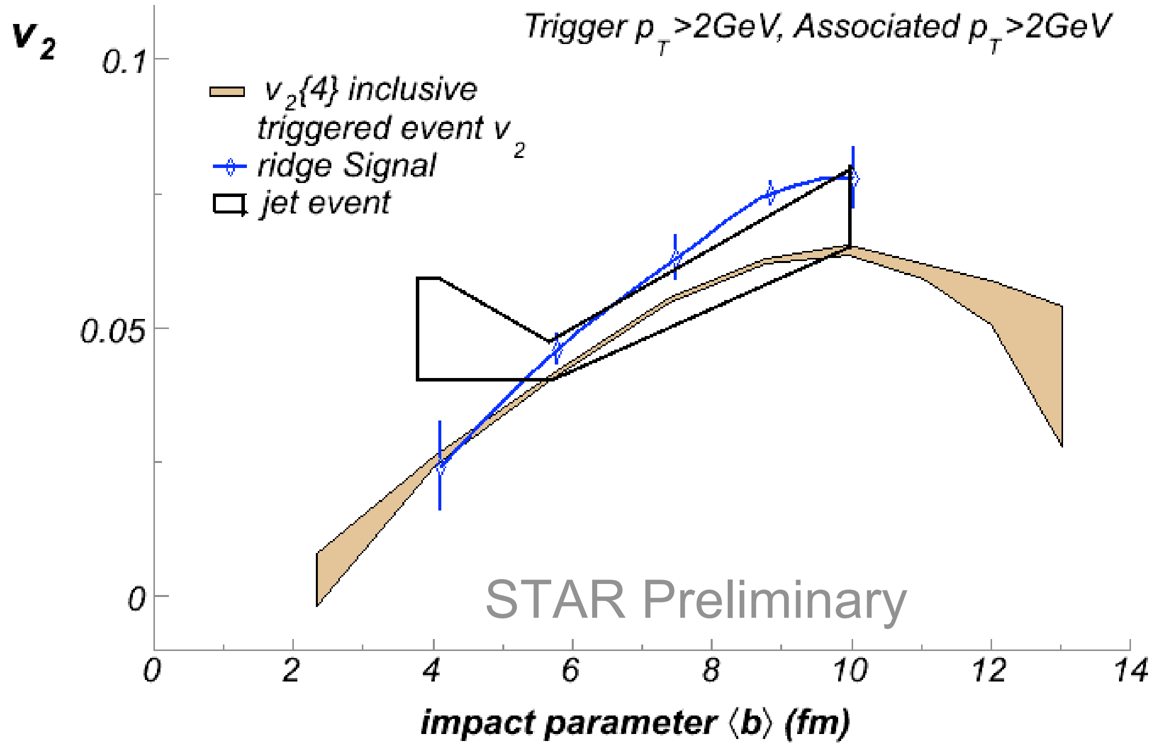




For events with higher p_T pairs correlated at small $\Delta\eta$, the fluctuations and correlations seem larger and the event-wise anisotropy seems smaller (but the systematic errors from background normalization are large)

For events with higher p_T pairs correlated at large $\Delta\eta$: the event-wise anisotropy still seems larger

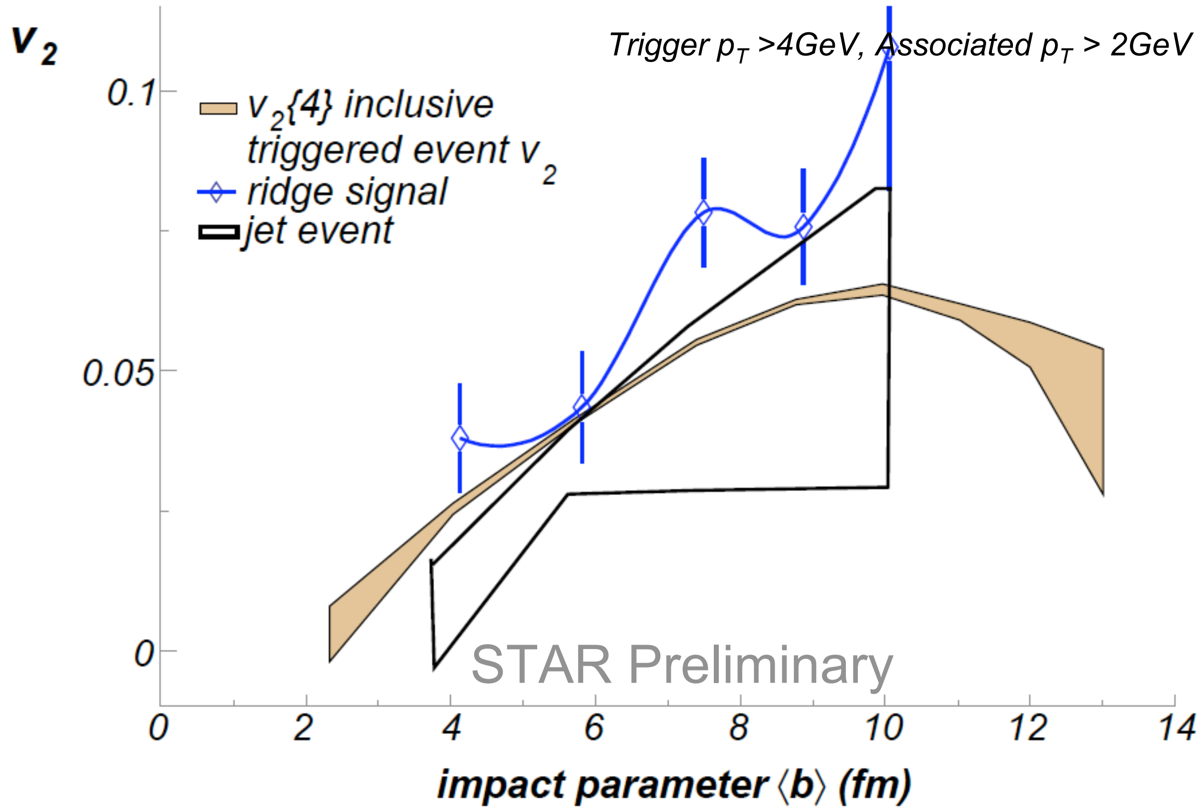
Centrality dependence



for $p_{T,1}$ > 2 GeV and $p_{T,2}$ > 2 GeV; events with pairs correlated at large $\Delta\eta$ may have larger event-wise anisotropy. Significance of the signal and systematics are still under investigation.

uncertainty is large on v_2 for events with pairs correlated in the jet-peak

Centrality dependence



for $p_{T,1}$ > 4 GeV and $p_{T,2}$ > 2 GeV; events with pairs correlated at large $\Delta\eta$ still may have larger event-wise anisotropy. Significance of the signal and systematics are still under investigation.

uncertainty is large on v_2 for events with pairs correlated in the jet-peak

Conclusions

- We have searched for indications of jets modifying the matter created in heavy ion collisions

- We find that when an event has two high p_T tracks
  - the probability that the tracks are correlated at large $\Delta\eta$ (in the ridge) is independent of collision centrality
  - the probability they are correlated in the jet-peak falls with centrality as expected from dilution by large multiplicities

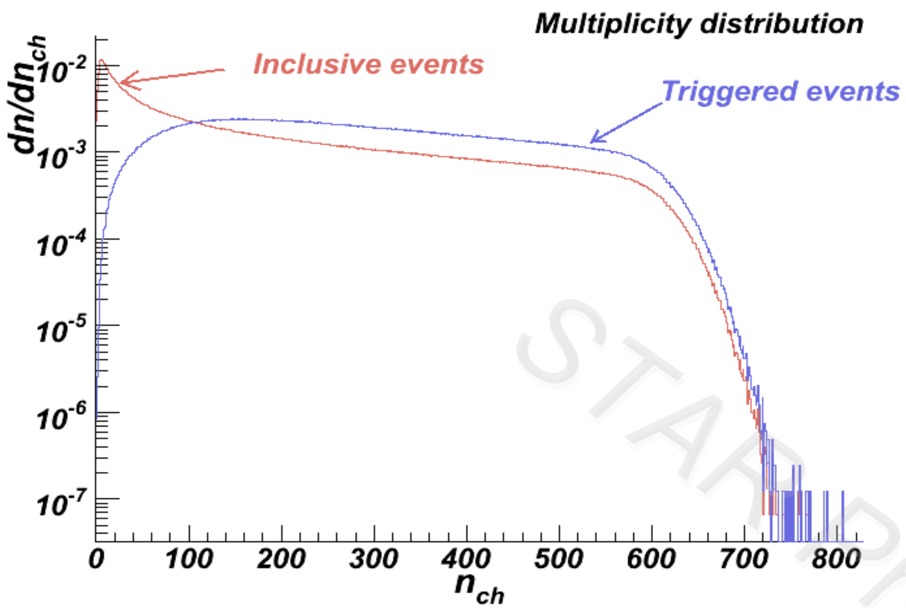
- The events yielding correlated pairs in the ridge seems to prefer larger event-wise anisotropy (than inclusive events) for some centralities. Significance of the signal and systematics are still under investigation.

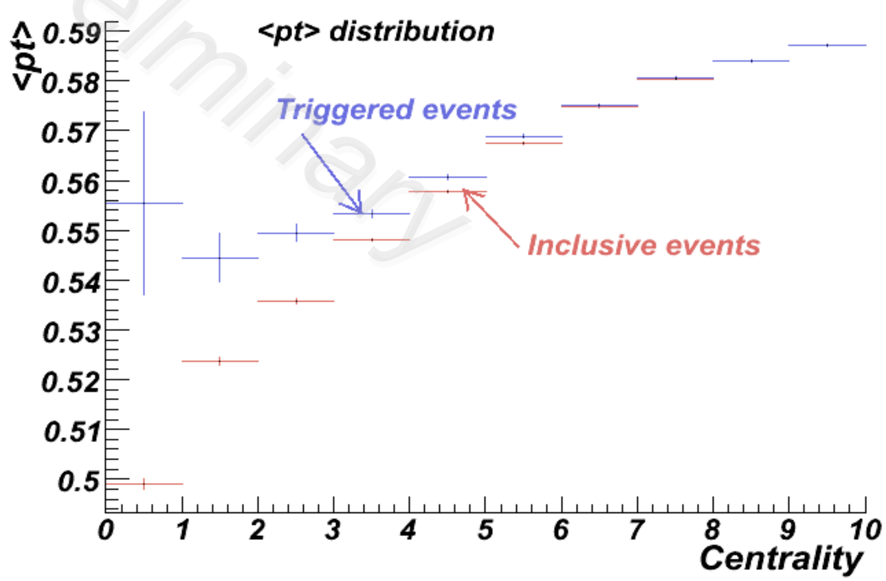
- Work in progress to understand the uncertainty on the event-wise anisotropy of events yielding pairs in the jet-peak

Thanks

Backup slides

How events different from inclusive





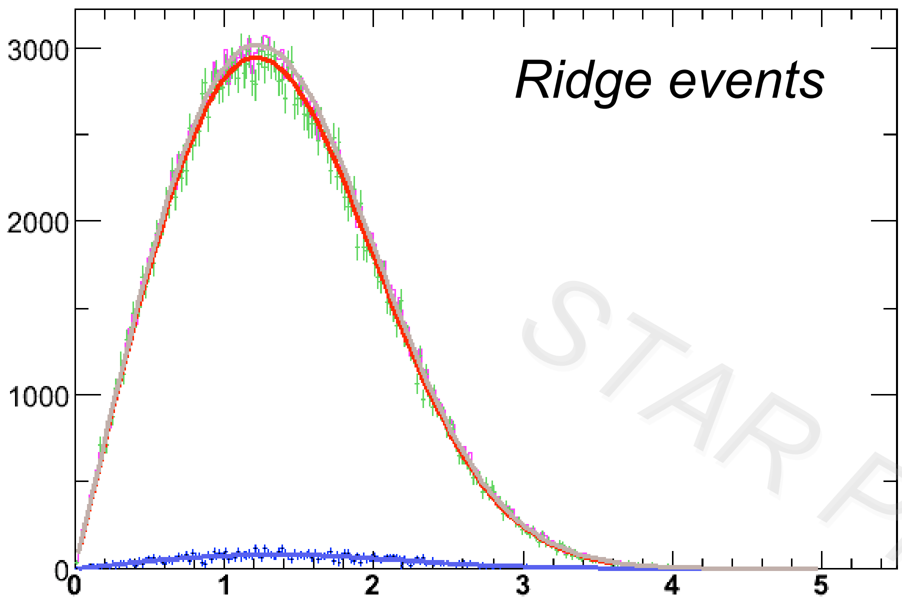
q - distribution study of signal and background

Calculating the number of events with correlated high pt pair (signals) and uncorrelated high pt pair(backgrounds) for each $\Delta\phi$ bin and q-distribution for corresponding $\Delta\phi$ bins, q - distribution for the events with correlated pair and uncorrelated high pt have been calculated by doing some algebra.

The equations used :

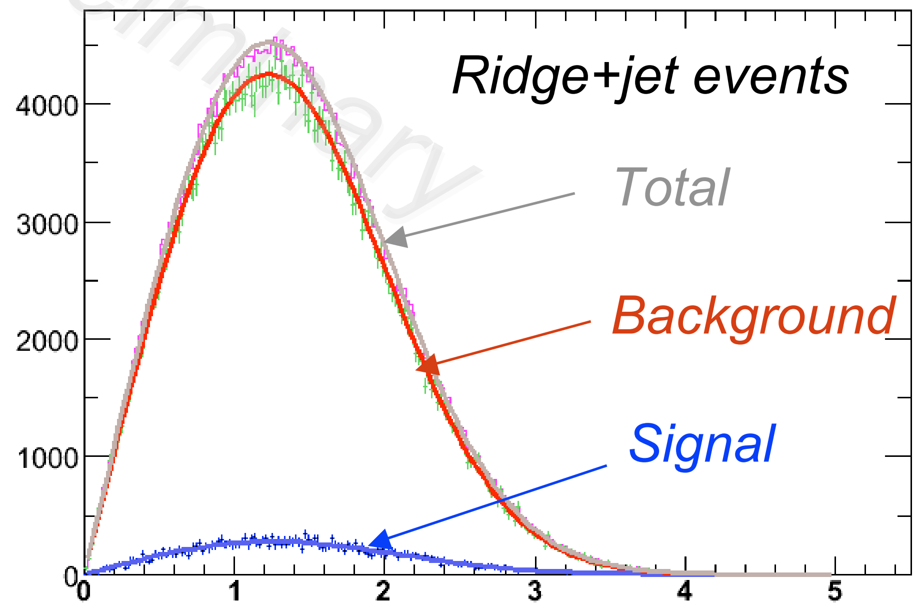
(S1+B1)*dN1 = S1*dNs + B1*dNb
(S2+B2)*dN2 = S2*dNs + B2*dNb

S1,2 is the number of events in bin 1,2 that had a correlated pair.
B1,2 is the number of events in bin 1,2 that had an uncorrelated pair.
dN1,2 is the q-distribution in bin 1,2.
dNs is the q-distribution of events that had a correlated pair.
dNb is the q-distribution of events that had an uncorrelated pair.



Trigger pt=2GeV, Associated pt=2GeV

Centrality=20-30%



Elliptic flow of jet events

$$area^{(ridge+jet)} v_2^{(ridge+jet)} = area^{ridge} v_2^{ridge} + area^{jet} v_2^{jet}$$

$$v_2^{jet} = \frac{area^{(ridge+jet)}}{area^{jet}} v_2^{(ridge+jet)} - \frac{area^{ridge}}{area^{jet}} v_2^{ridge}$$

Where

$$area^{jet} = area^{(ridge+jet)} - area^{ridge} \text{ * acceptance factor}$$

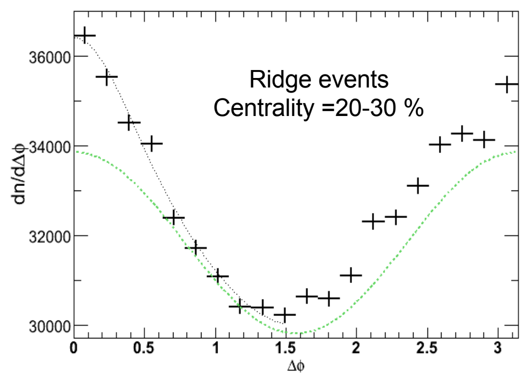
& Acceptance factor $= \dfrac{area^{(ridge+jet)(|\Delta\eta|<0.7)}}{area^{ridge(|\Delta\eta|>0.7)}}$

Systematic Uncertainties study

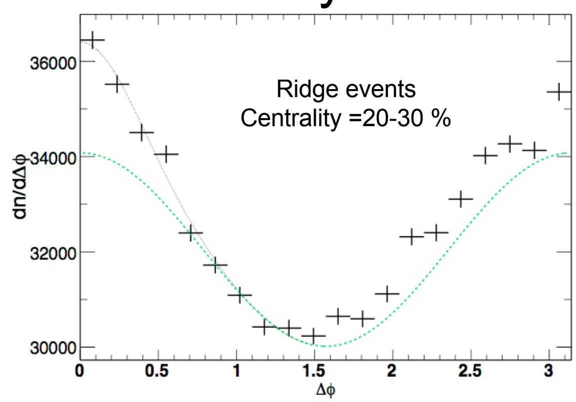
1. Yield Uncertainty (Fit-Zyam)
2. Track-merging

Signal and background subtraction

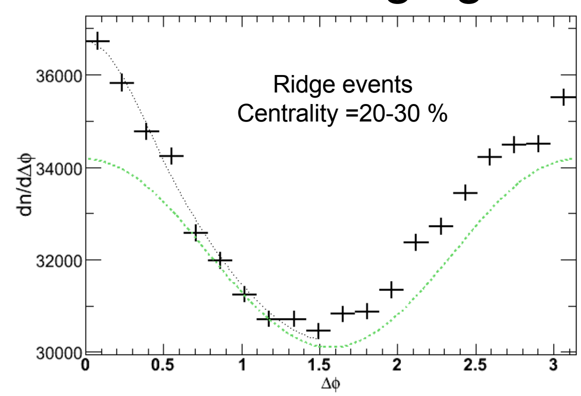
Standard Analysis

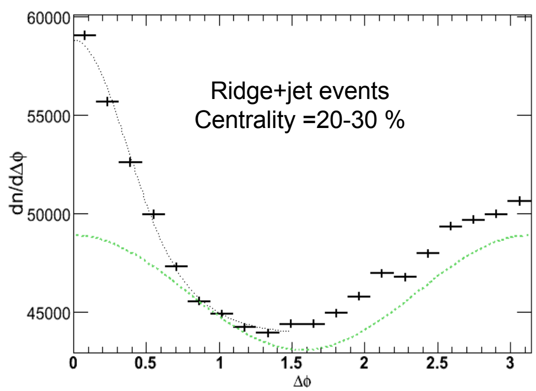


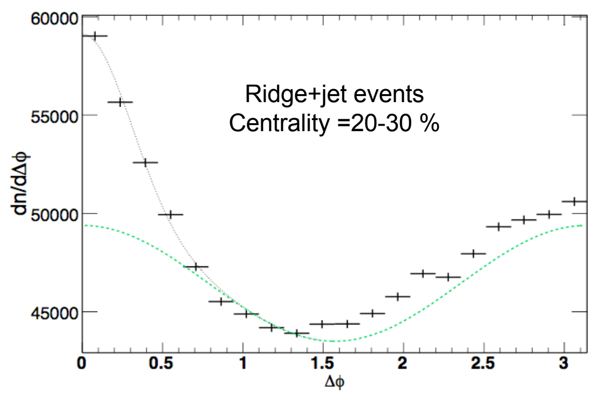
Fit-Zyam

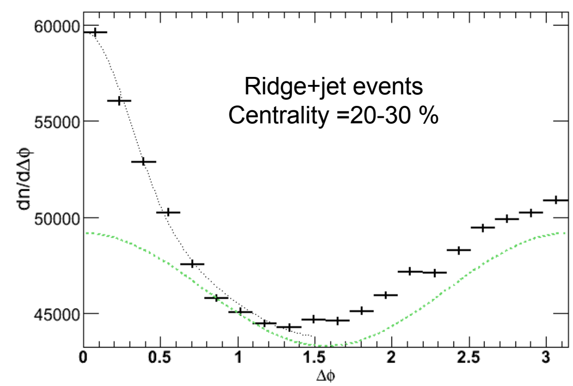


Track-Merging

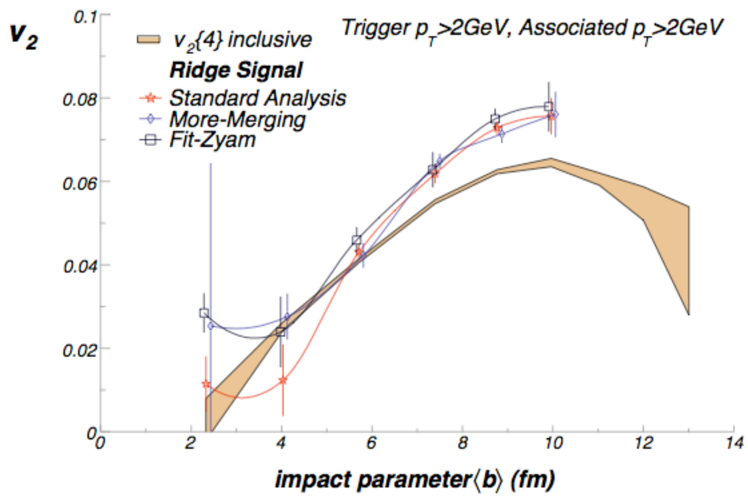




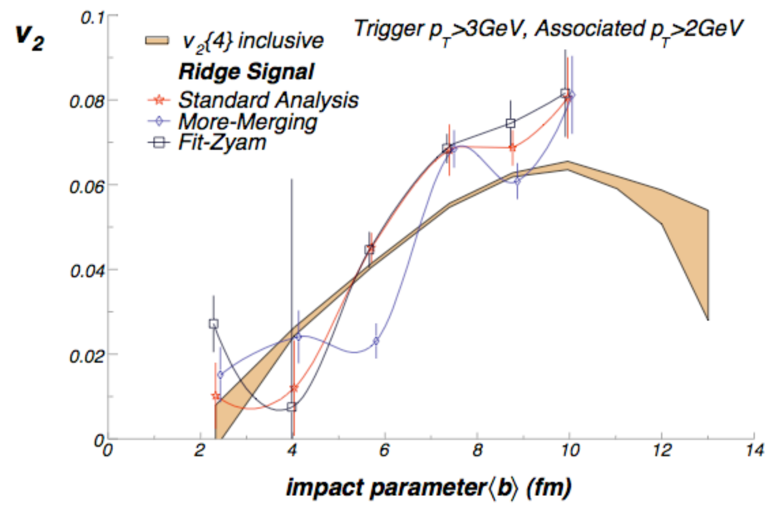




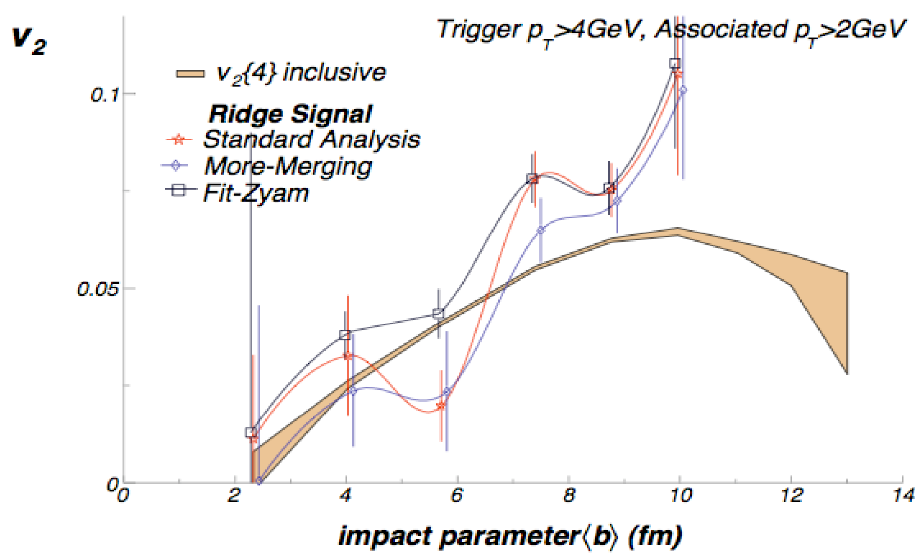
Ridge v_2



v_2
Trigger p_T>2GeV, Associated p_T>2GeV
$v_2\{4\}$ inclusive
Ridge Signal
Standard Analysis
More-Merging
Fit-Zyam
impact parameter⟨b⟩ (fm)

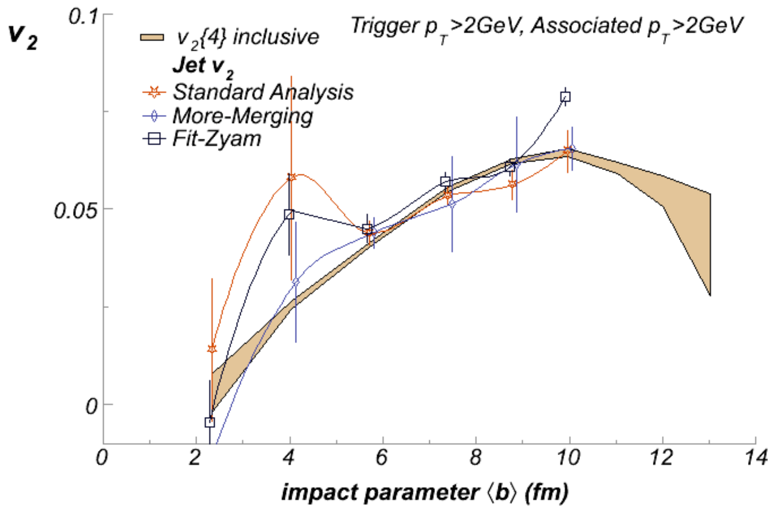


v_2
Trigger p_T>3GeV, Associated p_T>2GeV
$v_2\{4\}$ inclusive
Ridge Signal
Standard Analysis
More-Merging
Fit-Zyam
impact parameter⟨b⟩ (fm)

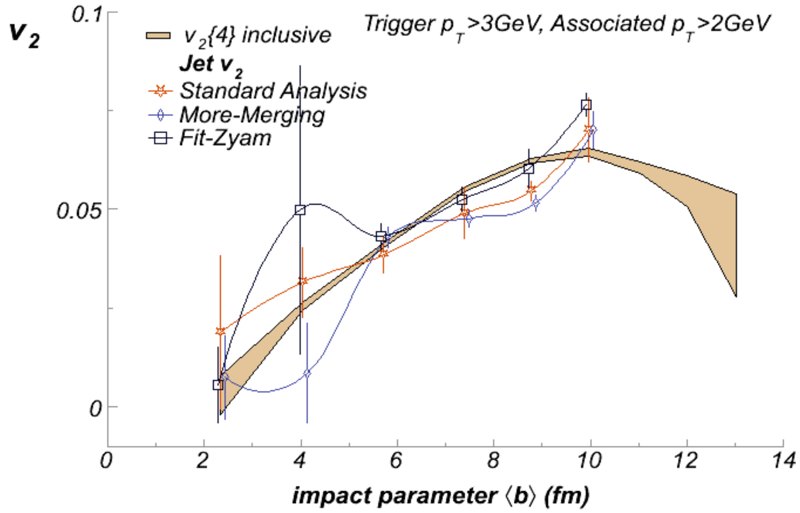


v_2
Trigger p_T>4GeV, Associated p_T>2GeV
$v_2\{4\}$ inclusive
Ridge Signal
Standard Analysis
More-Merging
Fit-Zyam
impact parameter⟨b⟩ (fm)

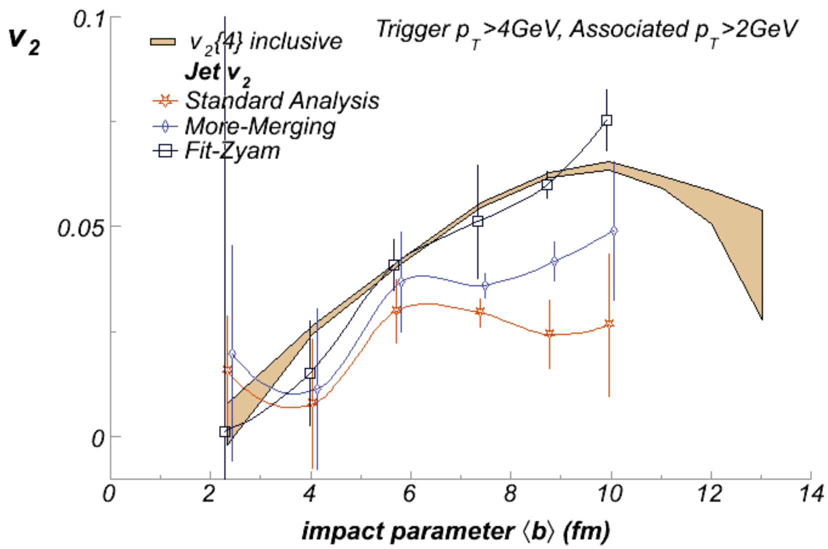
Jet v_2



v_2
$v_2\{4\}$ inclusive
Jet v_2
Standard Analysis
More-Merging
Fit-Zyam
Trigger p_T>2GeV, Associated p_T>2GeV
impact parameter ⟨b⟩ (fm)



v_2
$v_2\{4\}$ inclusive
Jet v_2
Standard Analysis
More-Merging
Fit-Zyam
Trigger p_T>3GeV, Associated p_T>2GeV
impact parameter ⟨b⟩ (fm)



v_2
$v_2\{4\}$ inclusive
Jet v_2
Standard Analysis
More-Merging
Fit-Zyam
Trigger p_T>4GeV, Associated p_T>2GeV
impact parameter ⟨b⟩ (fm)