Azimuthally-sensitive pion HBT in STAR

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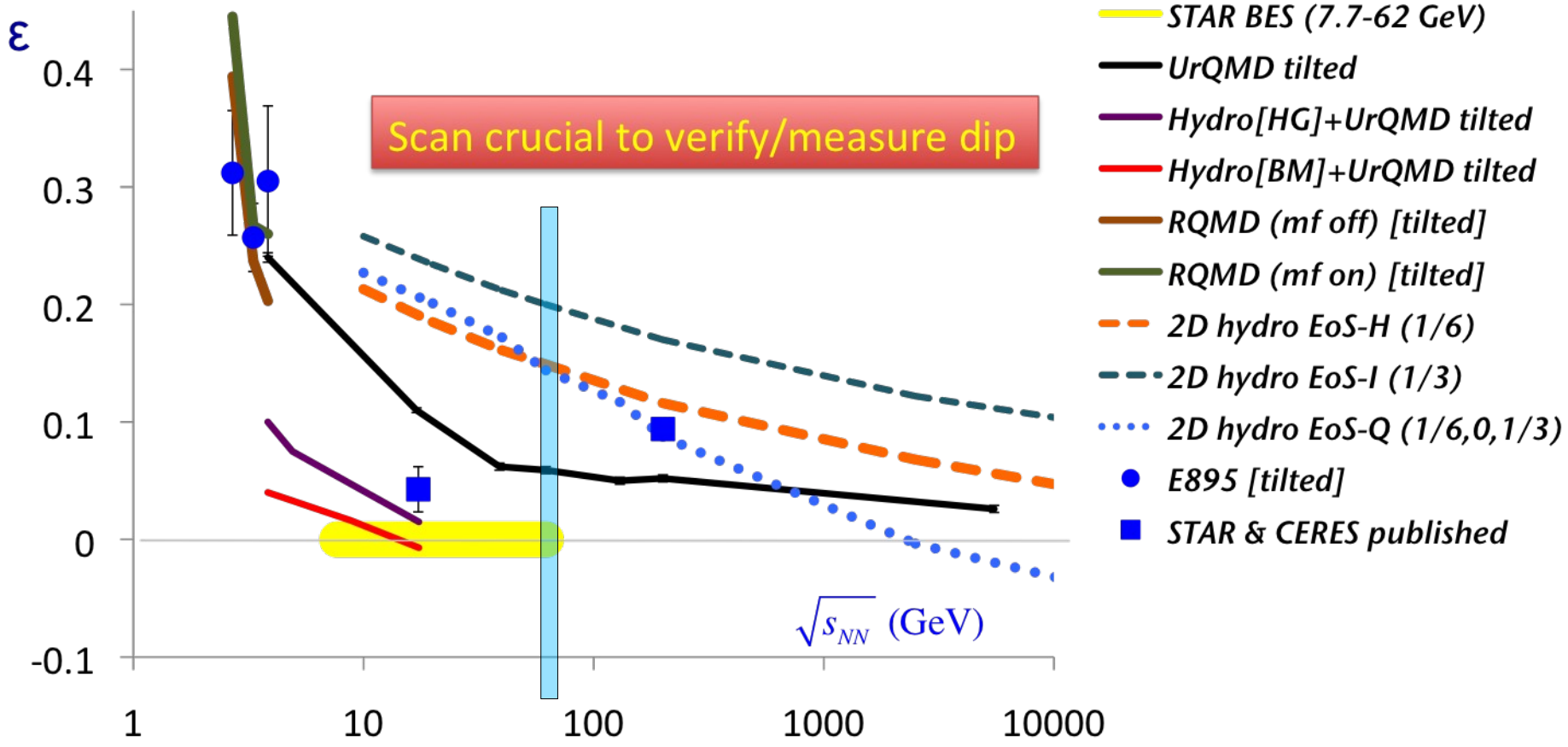
Outline

- Reconstructing the Reaction Plane
- HBT analysis and corrections for
  - effects from v_2 and number of particles on reaction plane resolution
  - effects from finite bin width
- Year 4 and Year 2 comparison, 200 GeV
- Year 4, 62.4 GeV results
- Excitation function

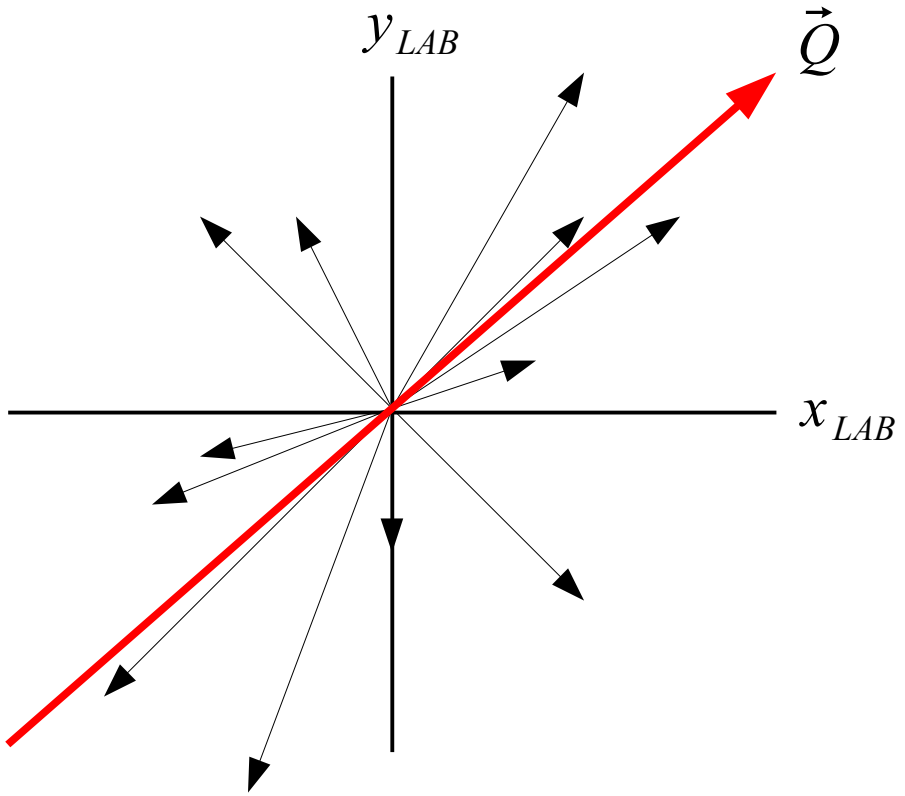
Motivation

•Energy dependence eccentricity at freeze-out constrains models

•Non-monotonic behavior may indicate interesting physics



Computing the reaction plane



Reaction plane vector components are

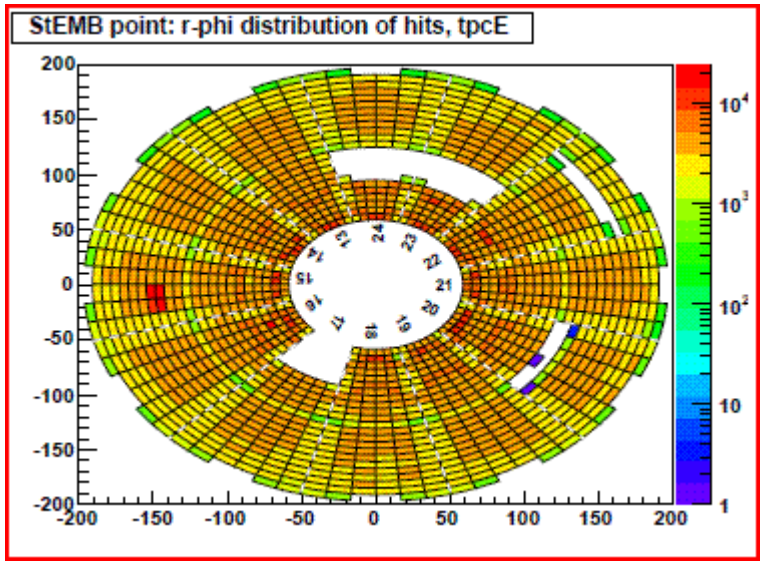
$$Q_x = \sum_{n=1}^{N_{particles}} w_\phi \, p_t \cos(2\phi_n)$$

$$Q_y = \sum_{n=1}^{N_{particles}} w_\phi \, p_t \sin(2\phi_n)$$

Finite number of particles and detector inefficiencies affect accuracy of reaction plane determination.

Use charged particles in TPC (cuts on upcoming slide)

Correcting the reaction plane for detector effects

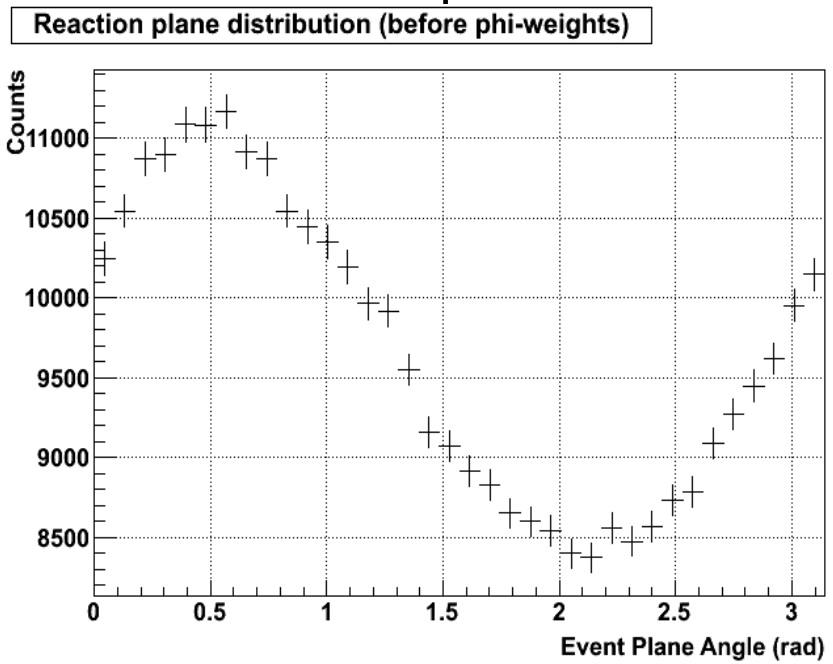


Track reconstruction inefficiency biases reaction plane in certain directions.

Phi-weight tracks with $w_\phi = \frac{\langle N \rangle_{\phi,\,avg}}{N_\phi}$

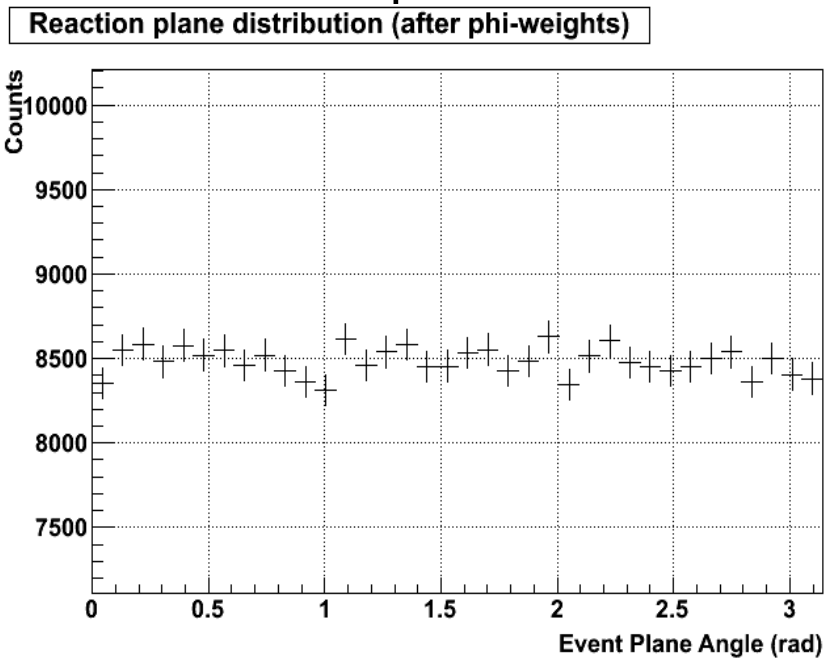
Phi weighting makes reaction plane distribution isotropic.

Reaction planes before



25% effect

Reaction planes after



Event, track, and pair cuts

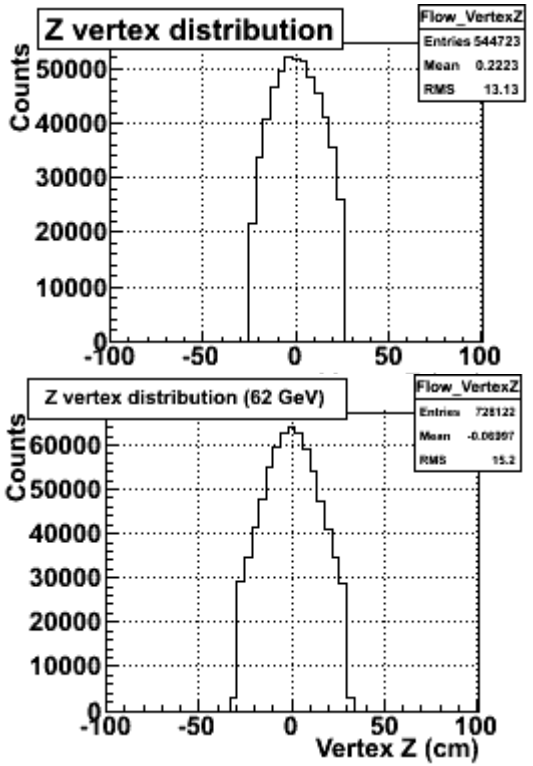
Event Cuts:

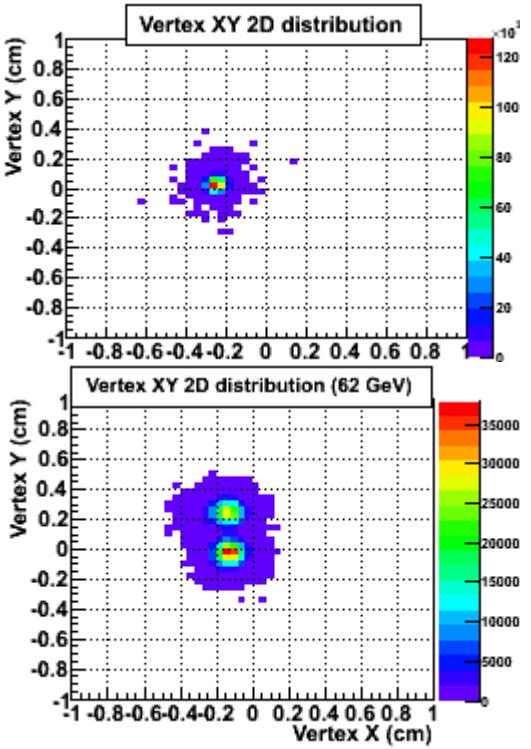
$|V_z| < 25$ cm (200 GeV)

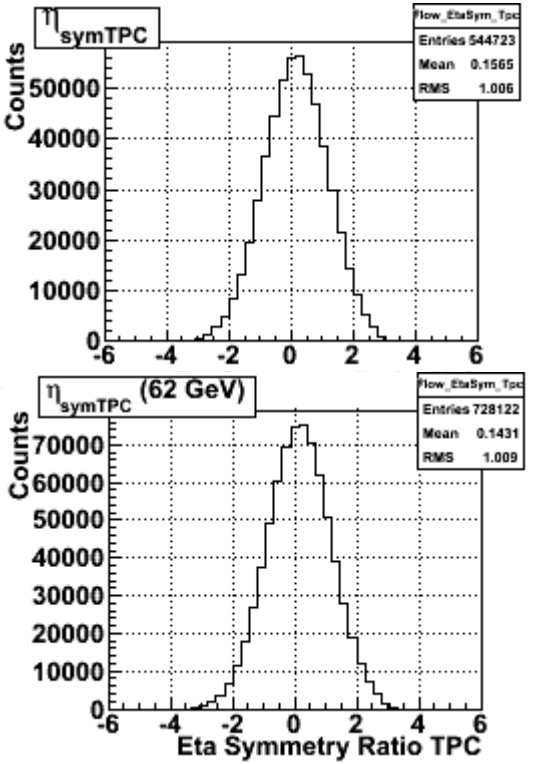
$|V_z| < 30$ cm (62 GeV)

$|V_x|$ & $|Vy| < 1$ cm

$|\eta_{SymTPC}| < 3$







Track Cuts:

<u>Reaction Plane</u>

$0.15<P_t<12.0$ GeV/c

$|\eta|<1.3$

$15<nFitPts<50$

$0.52<nFitOverMax<1.05$

<u>HBT analysis</u>

$0.1 < P_t < 1.0$ GeV/c

$|y| < 0.5$

nHits >= 10

2D DCA < 3.0 cm

Sigma π <= 2

Sigma k,p,e > 2

Pair Cuts:

<u>HBT analysis</u>

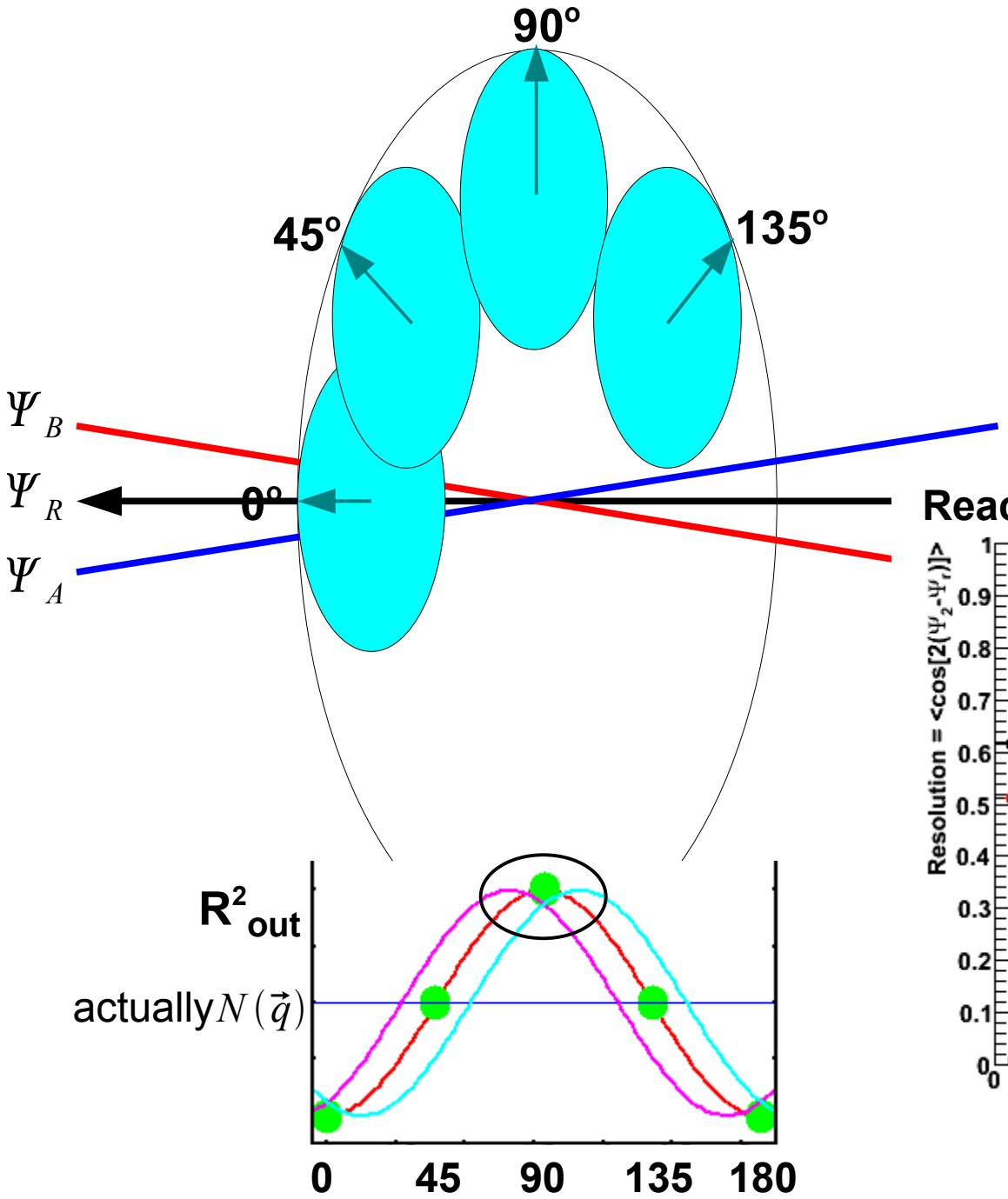
$0.15 < K_t < 0.6$ GeV/c

Anti-merging

maxFracMergedPair=0.1

$-0.5<Quality<0.6$

Reaction Plane resolution and finite angular bins



Oscillations reduced by

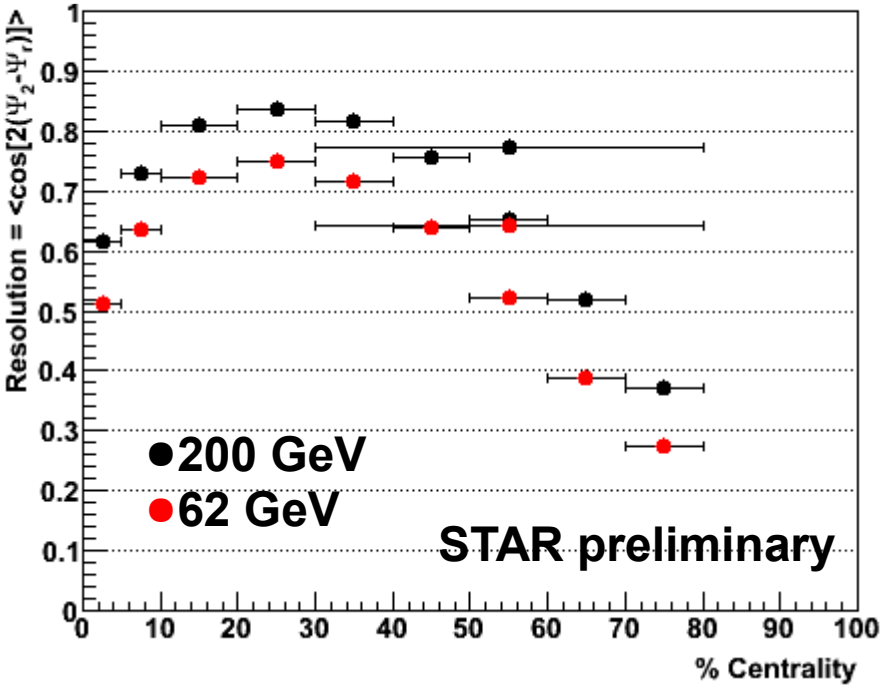
- reaction plane resolution

$$\langle \cos[2(\Psi_m - \Psi_R)] \rangle$$

- and finite angular bins

$$\frac{\sin(n\Delta/2)}{n\Delta/2}$$

Reaction Plane resolution vs. Centrality



Correction scheme

Expand the correlation function with Fourier series

$$N_{\exp}(\vec{q},\Phi_j)=N_0^{\exp}(\vec{q})+2\sum_{n=1}^{n_{bins}/2}\left[N_{c,n}^{\exp}(\vec{q})\cos(n\Phi_j)+N_{s,n}^{\exp}(\vec{q})\sin(n\Phi_j)\right]$$

where

$$N_{c,n}^{\exp}(\vec{q})=\frac{1}{n_{bins}}\sum_{j=1}^{n_{bins}}N_{\exp}(\vec{q},\Phi_j)\cos(n\Phi_j)$$

$$N_{s,n}^{\exp}(\vec{q})=\frac{1}{n_{bins}}\sum_{j=1}^{n_{bins}}N_{\exp}(\vec{q},\Phi_j)\sin(n\Phi_j)$$

The true numerator is then given by

$$N(\vec{q},\Phi_j)=N_{\exp}(\vec{q})+2\sum_{n=1}^{n_{bins}/2}\zeta_{n,m}\left[N_{c,n}^{\exp}(\vec{q})\cos(n\Phi_j)+N_{s,n}^{\exp}(\vec{q})\sin(n\Phi_j)\right]$$

where the correction term is

$$\zeta_{n,m}=\frac{n\Delta/2}{\sin(n\Delta/2)}\frac{1}{\langle\cos[n(\Psi_m-\Psi_R)]\rangle}-1$$

Repeat for denominator and Coulomb “interaction” histogram.

Correction Method from
U. Heinz, A. Hummel, M.A. Lisa, and U. A. Wiedemann, Phys. Rev. C 52, 2694 (1995).

Fitting procedure

$$C(q_o, q_s, q_l) = \frac{N(\vec{q})}{D(\vec{q})} = (1-\lambda) + \lambda K_{Coul}(q_{inv})\left(1 + e^{-q_o^2 R_o^2 - q_s^2 R_s^2 - q_l^2 R_l^2 - 2 q_o q_s R_{os}^2}\right)$$

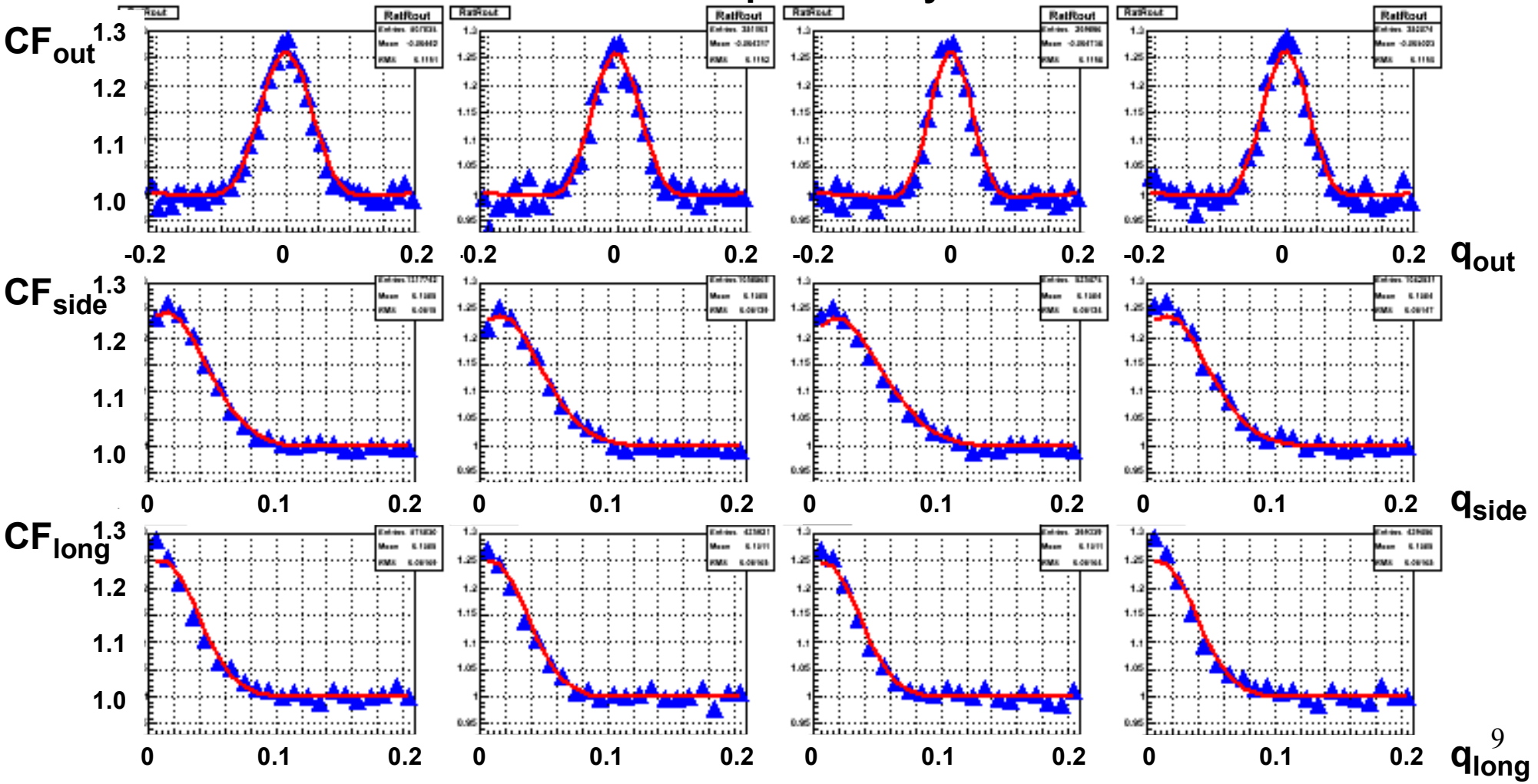
Refit with $\lambda = \langle\lambda\rangle_{avg}$

Centrality = 30-80% Kt = 0

Au+Au 200 GeV

Phi = 0 Phi = 45 Phi = 90 Phi = 135

STAR preliminary



Computing Fourier Coefficients

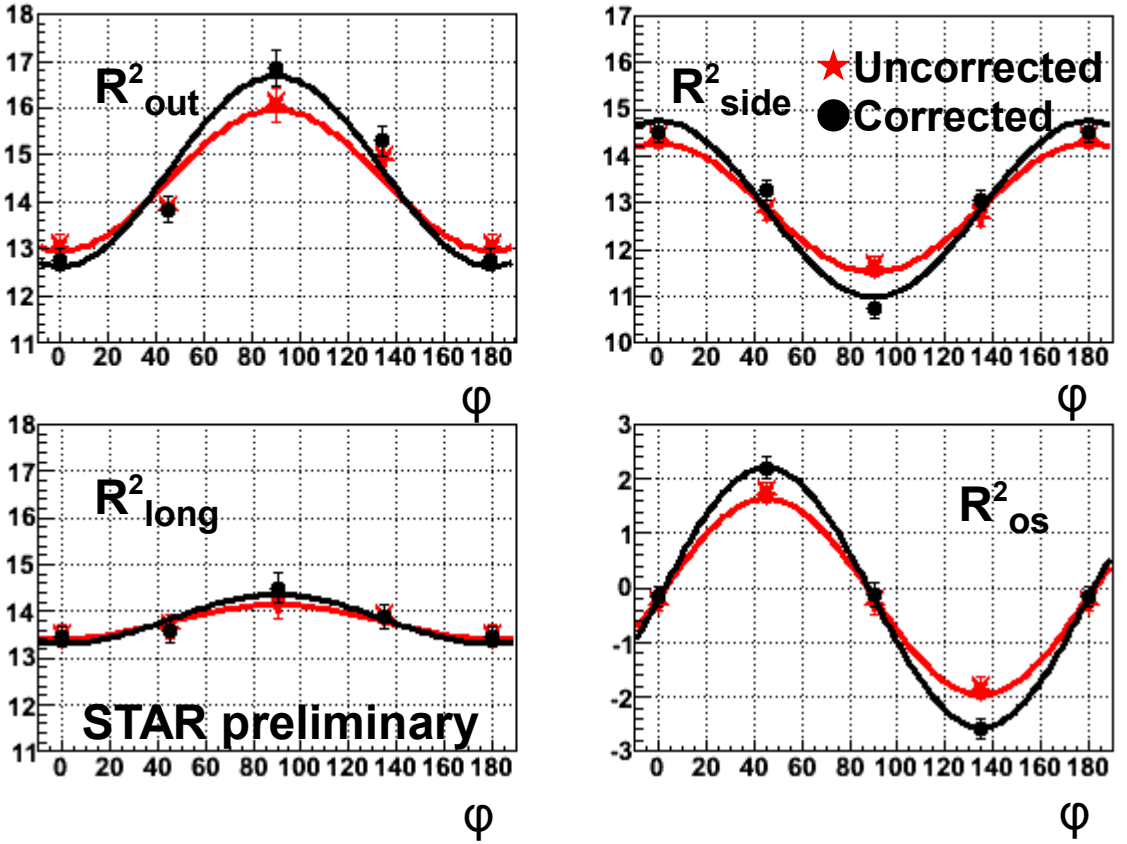
Fourier coefficients computed from radii:

$$R^2_{0,i} = \sum_{j=1}^{N_{bins}} R^2_i(\Phi_j) \qquad i = o, s, l, os$$

$$R^2_{2,i} = \sum_{j=1}^{N_{bins}} R^2_i(\Phi_j)\cos(2\Phi_j) \qquad i = o, s, l$$

$$R^2_{2,i} = \sum_{j=1}^{N_{bins}} R^2_i(\Phi_j)\sin(2\Phi_j) \qquad i = os$$

Au+Au 200 GeV
Oscillations for 20-30% Centrality and K_t = 0.35-0.60 GeV/c



Computing eccentricity at freeze-out

Eccentricity from Blast-wave model:

$$\varepsilon = \frac{R_y^2 - R_x^2}{R_y^2 + R_x^2} = 2\frac{R_{s,2}^2}{R_{s,0}^2}$$

Eccentricity equation derived in
Retiere and Lisa, nucl-th/0312024

K_t Average Method:

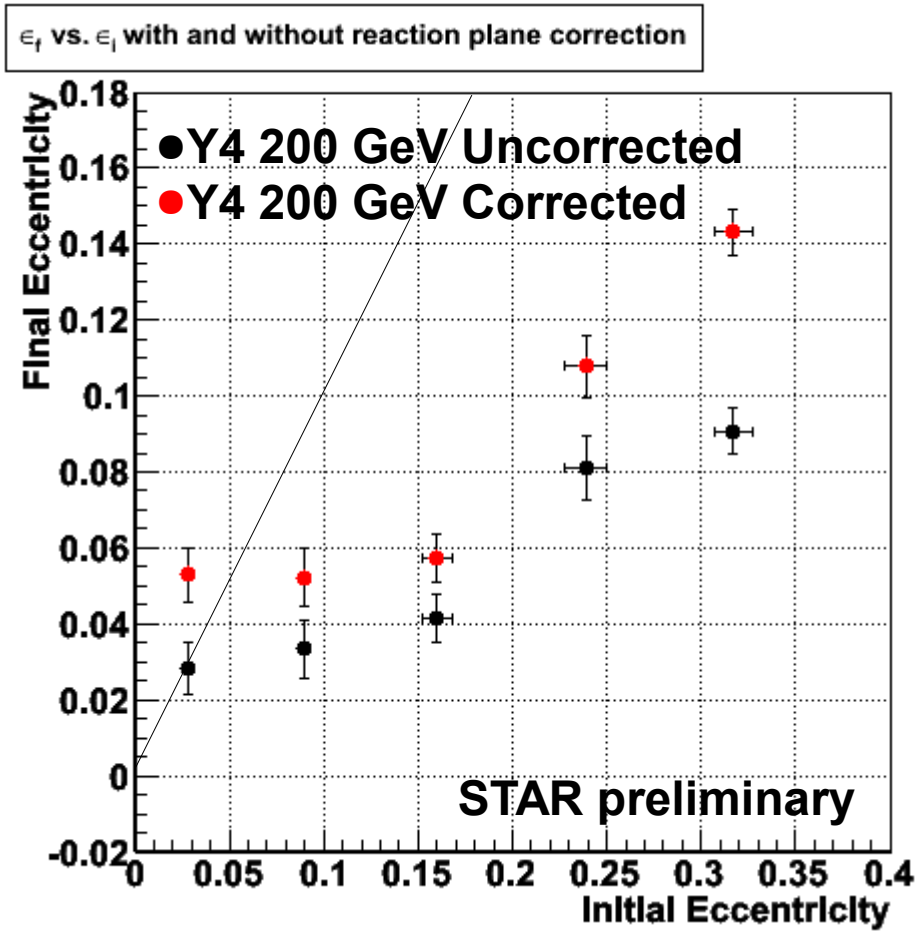
- Compute ε_f for the three K_t bins separately
- Simply average

$$\epsilon_{KtAvg} = \frac{(\epsilon_{Kt1} + \epsilon_{Kt2} + \epsilon_{Kt3})}{3}$$

K_t Integrated Method:

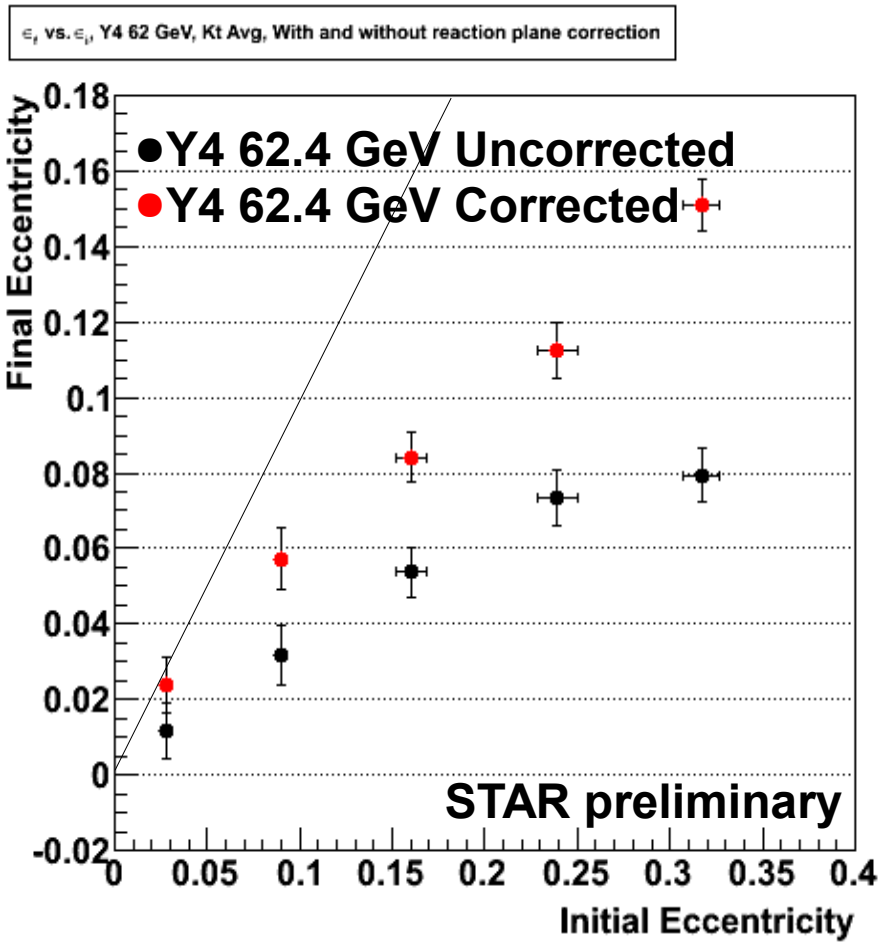
- Compute ε_f for one K_t Integrated correlation function

Y4 at 200 GeV
Uncorrected vs Corrected



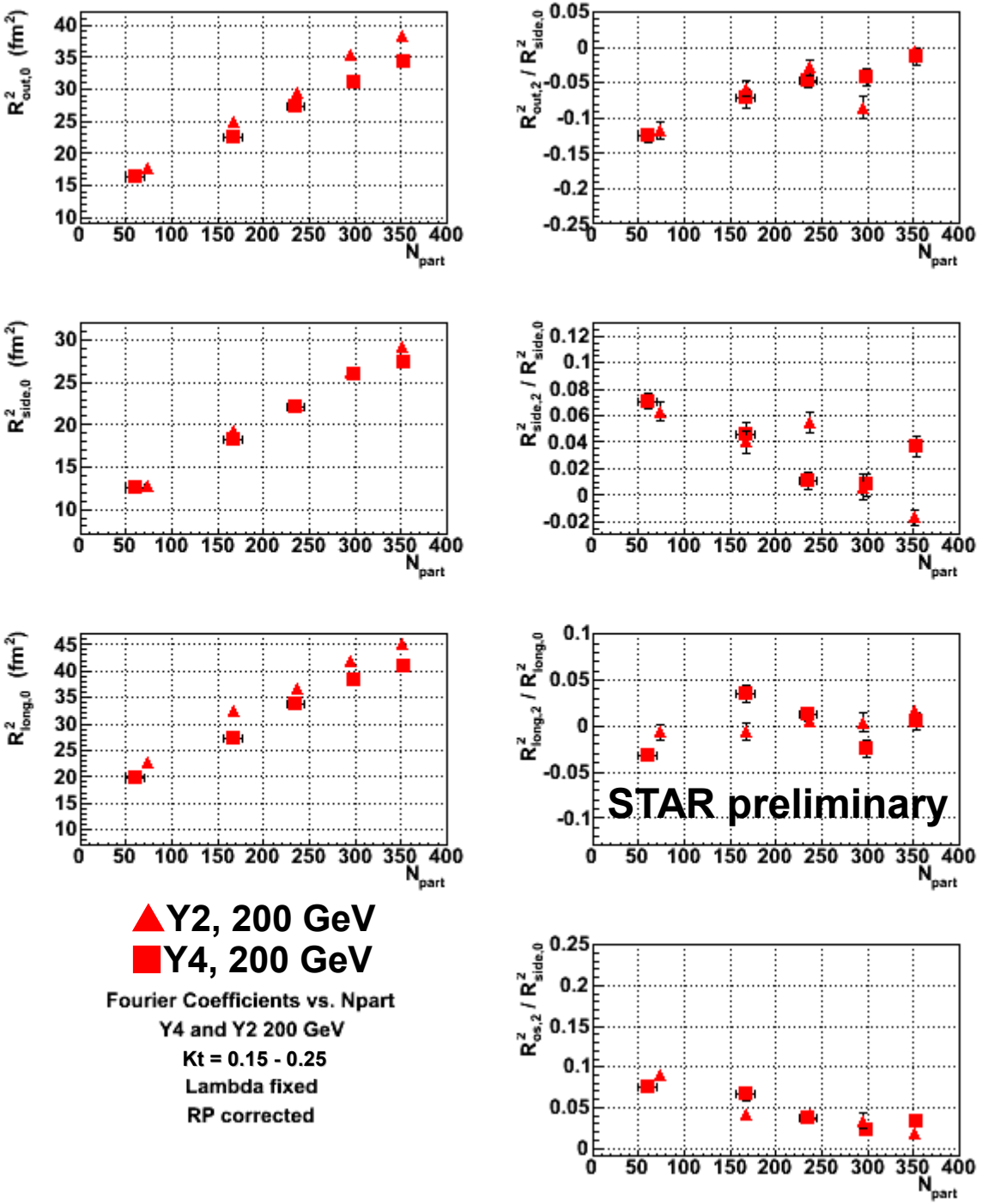
The correction scheme increases the oscillations and therefore the eccentricities.

Y4 at 62.4 GeV
Uncorrected vs Corrected



The correction scheme increases the oscillations and therefore the eccentricities.

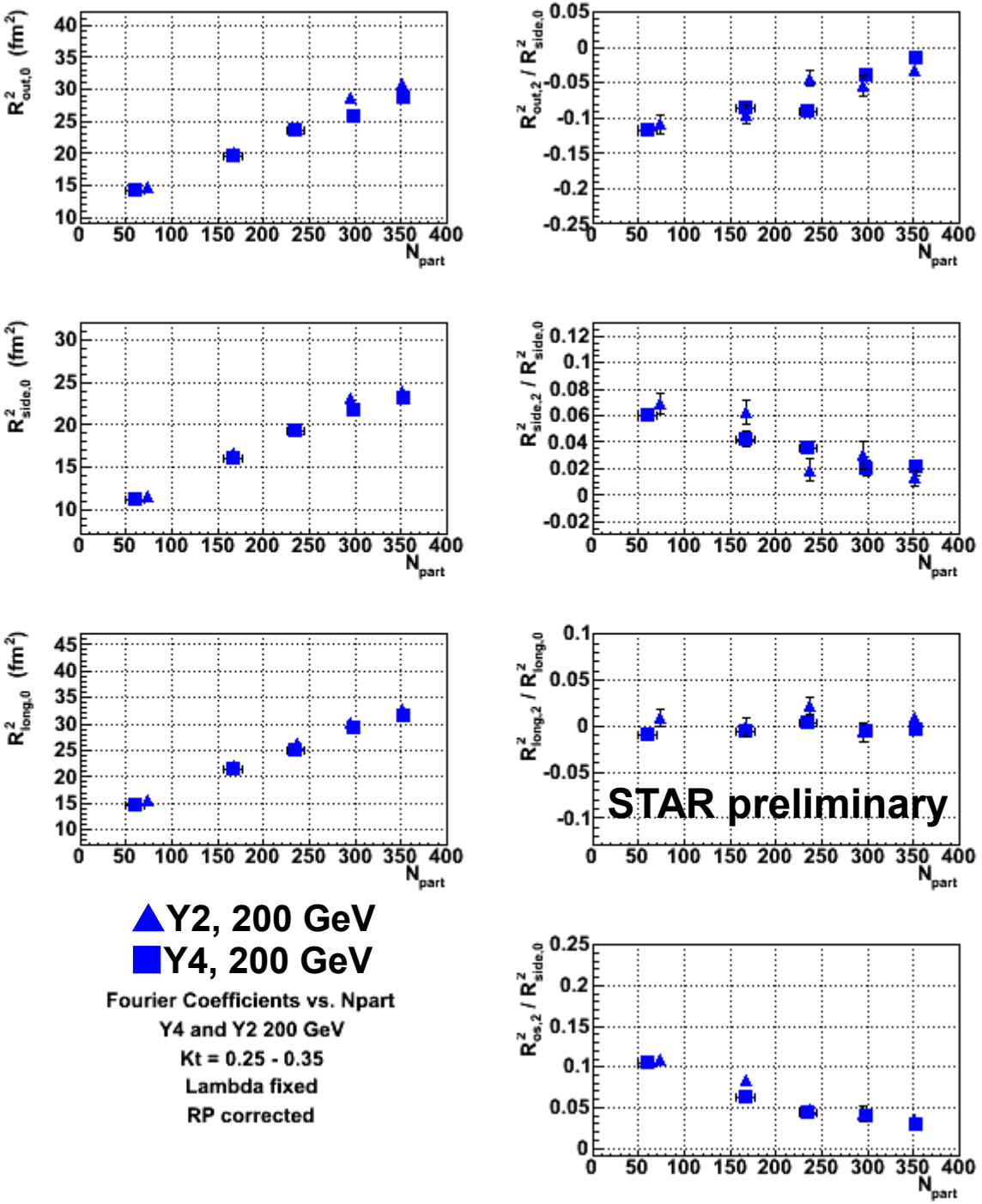
Y4 vs Y2 at 200 GeV



- Lowest K_t bin
- 0^{th} order R_{out} and R_{long} a bit low
- Some differences present in the 2^{nd} order / 0^{th} order

Year 2 data from
J. Adams *et al.* (STAR Collaboration), Phys. Rev. Lett. **93**, 012301 (2004)

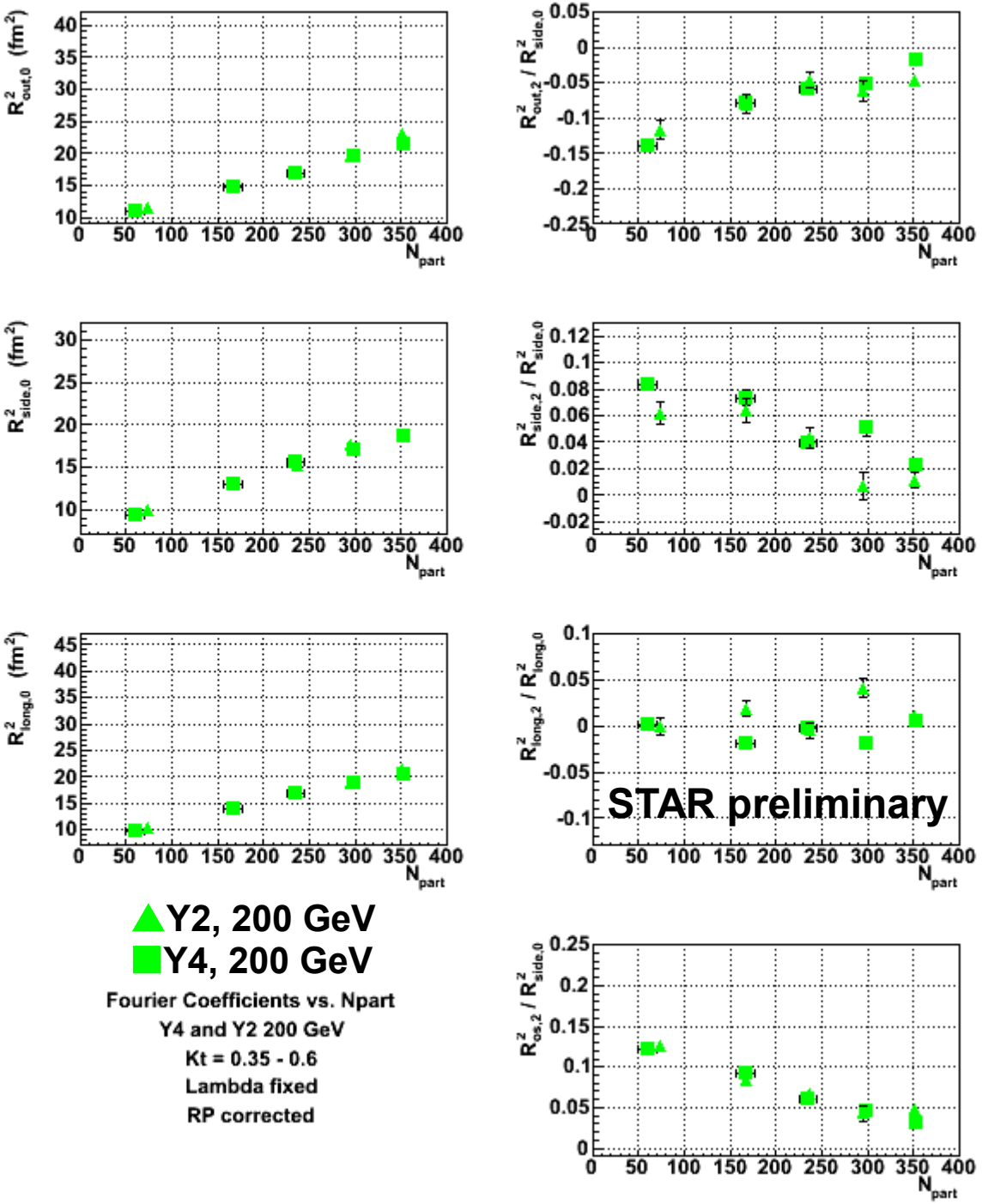
Y4 vs Y2 at 200 GeV



- Middle K_t bin
- 0^{th} order agree pretty well
- Some differences present in the 2^{nd} order / 0^{th} order

Year 2 data from
J. Adams *et al.* (STAR Collaboration), Phys. Rev. Lett. **93**, 012301 (2004)

Y4 vs Y2 at 200 GeV

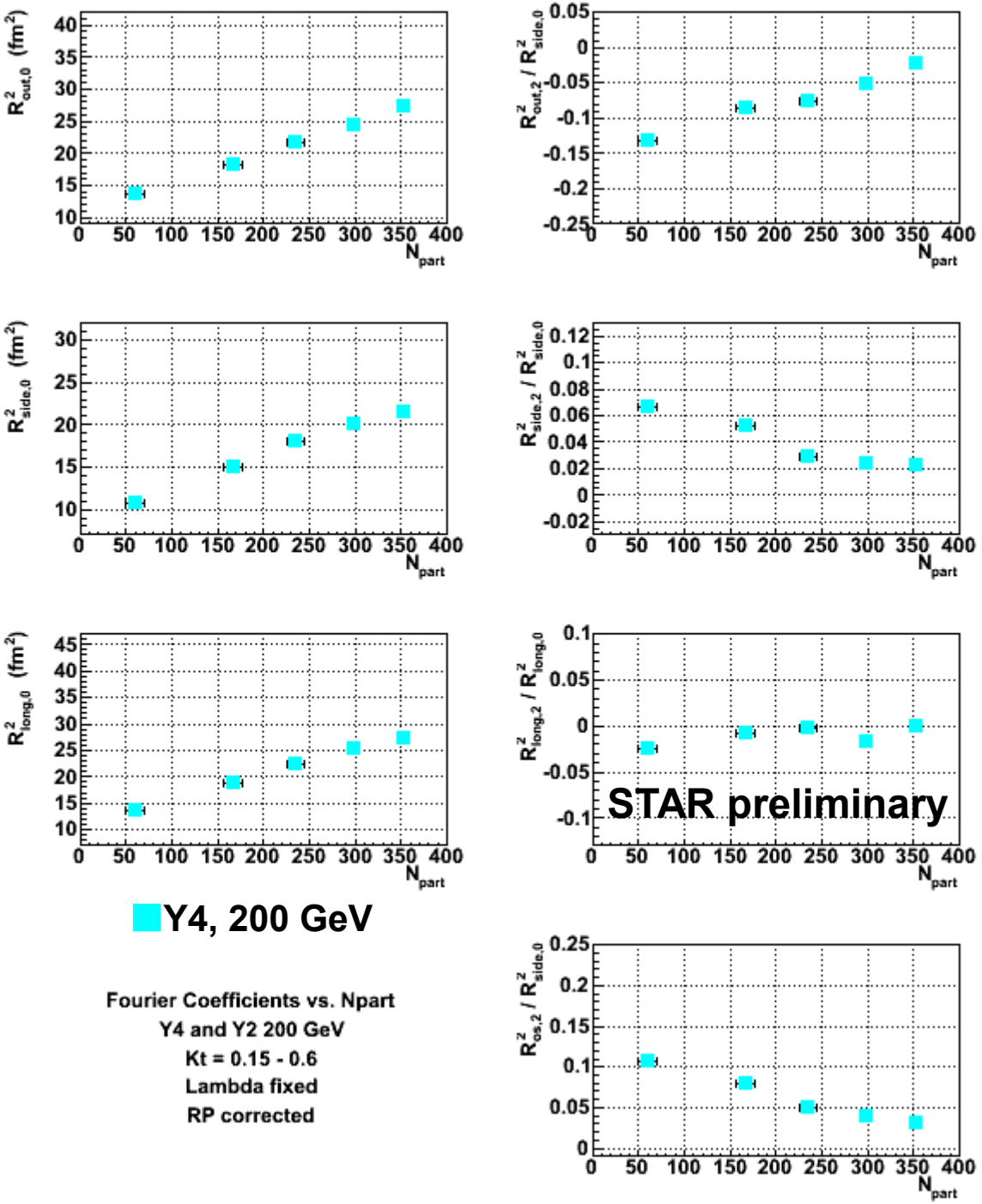


- Highest K_t bin
- 0^{th} agree well
- Some differences present in the 2^{nd} order / 0^{th} order

Year 2 data from
J. Adams *et al.* (STAR Collaboration), Phys. Rev. Lett. **93**, 012301 (2004)

Y4 at 200 GeV

- K_t Integrated



Year 2 data from
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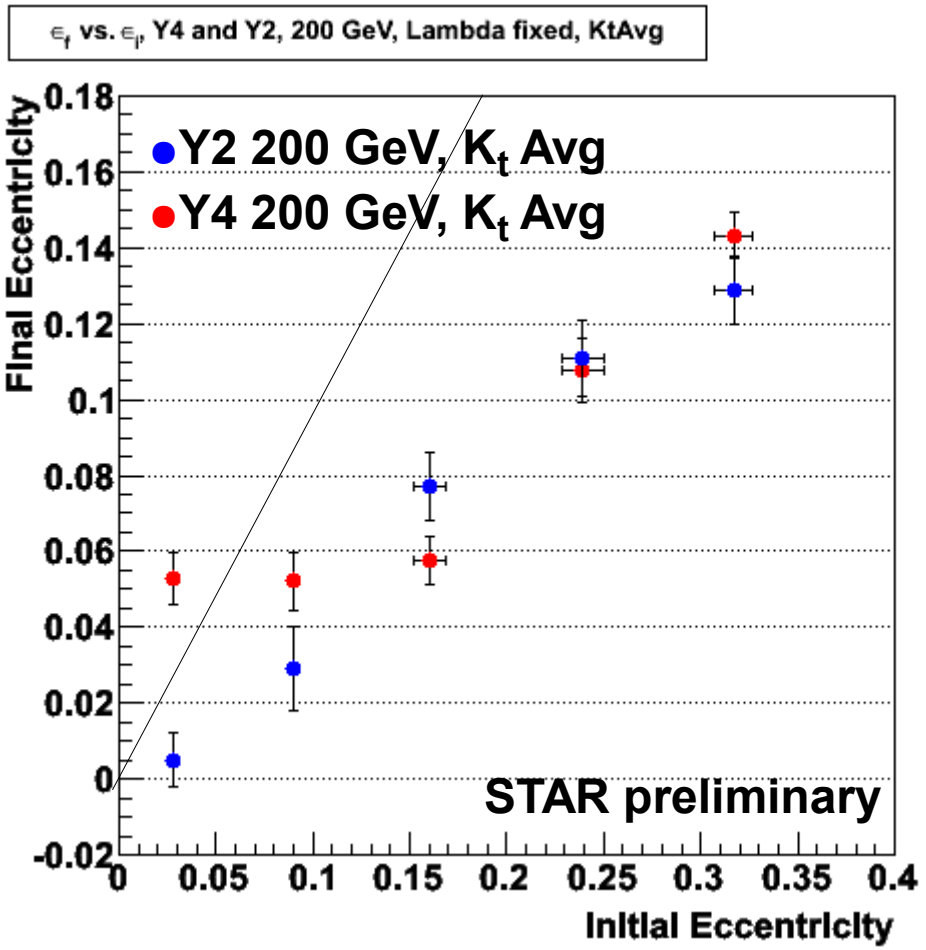
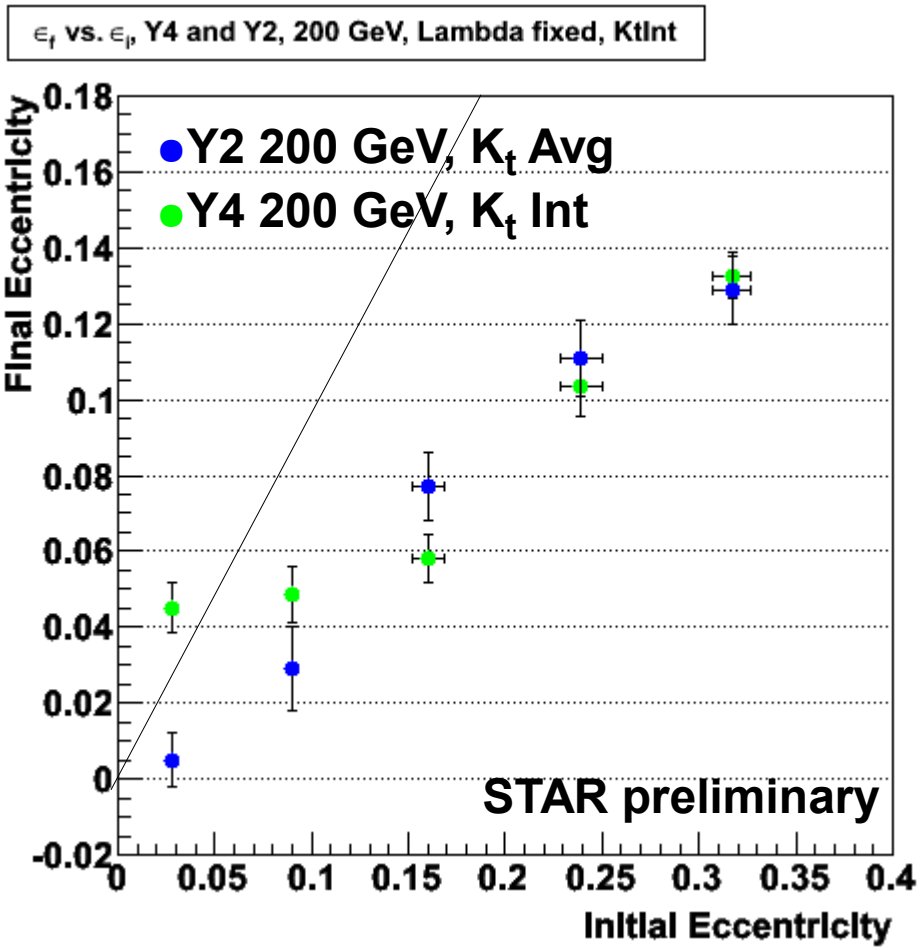
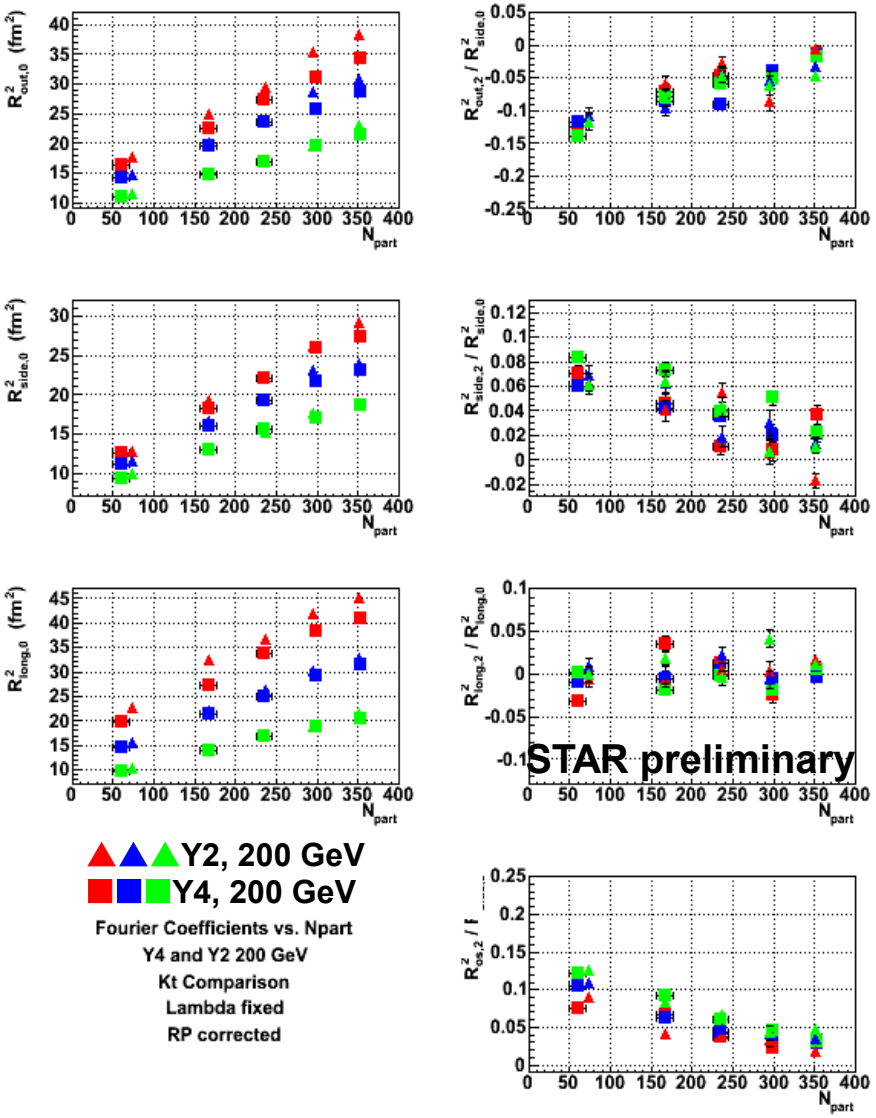
Y4 vs Y2 at 200 GeV



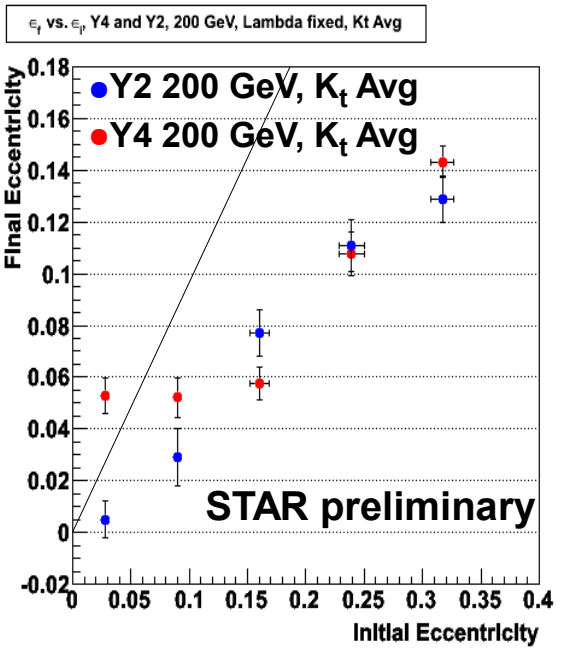


- Some differences (most central bin in particular)
- Physics extracted comes from 3rd and 4th bins which yield similar final eccentricity.

Fit Range Effects



- Fit Range: q < 0.15 GeV/c
- Lowest K_t, 0^{th} order disagree



Year 2 data from

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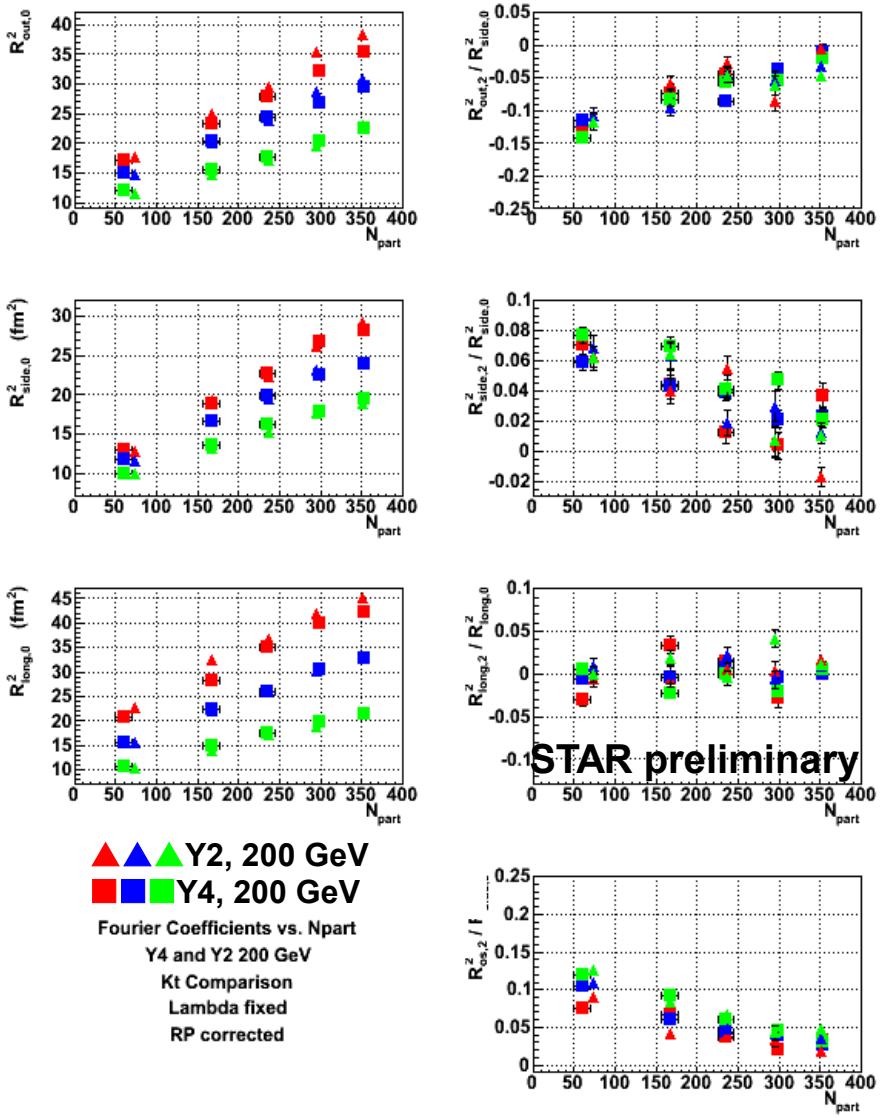
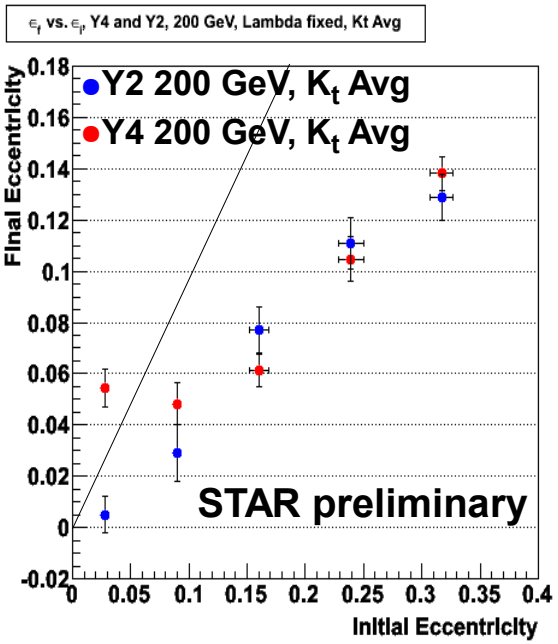
Fit Range Effects

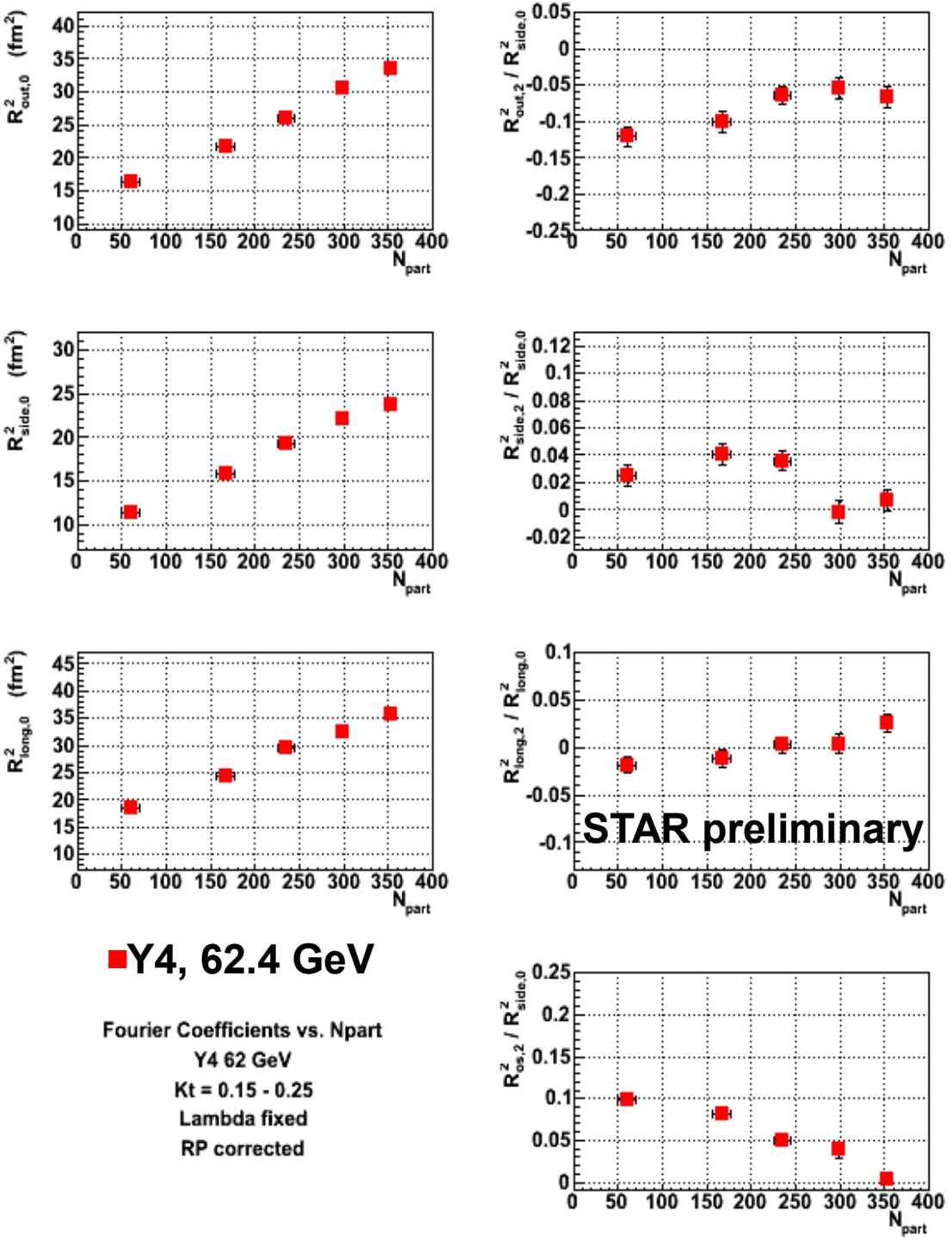


- Fit Range: q < 0.12 GeV/c
- Lowest K_t, 0^{th} order agree better
- ε almost unchanged



Year 2 data from
J. Adams *et al.* (STAR Collaboration), Phys. Rev. Lett. **93**, 012301 (2004)

Y4 at 62.4 GeV

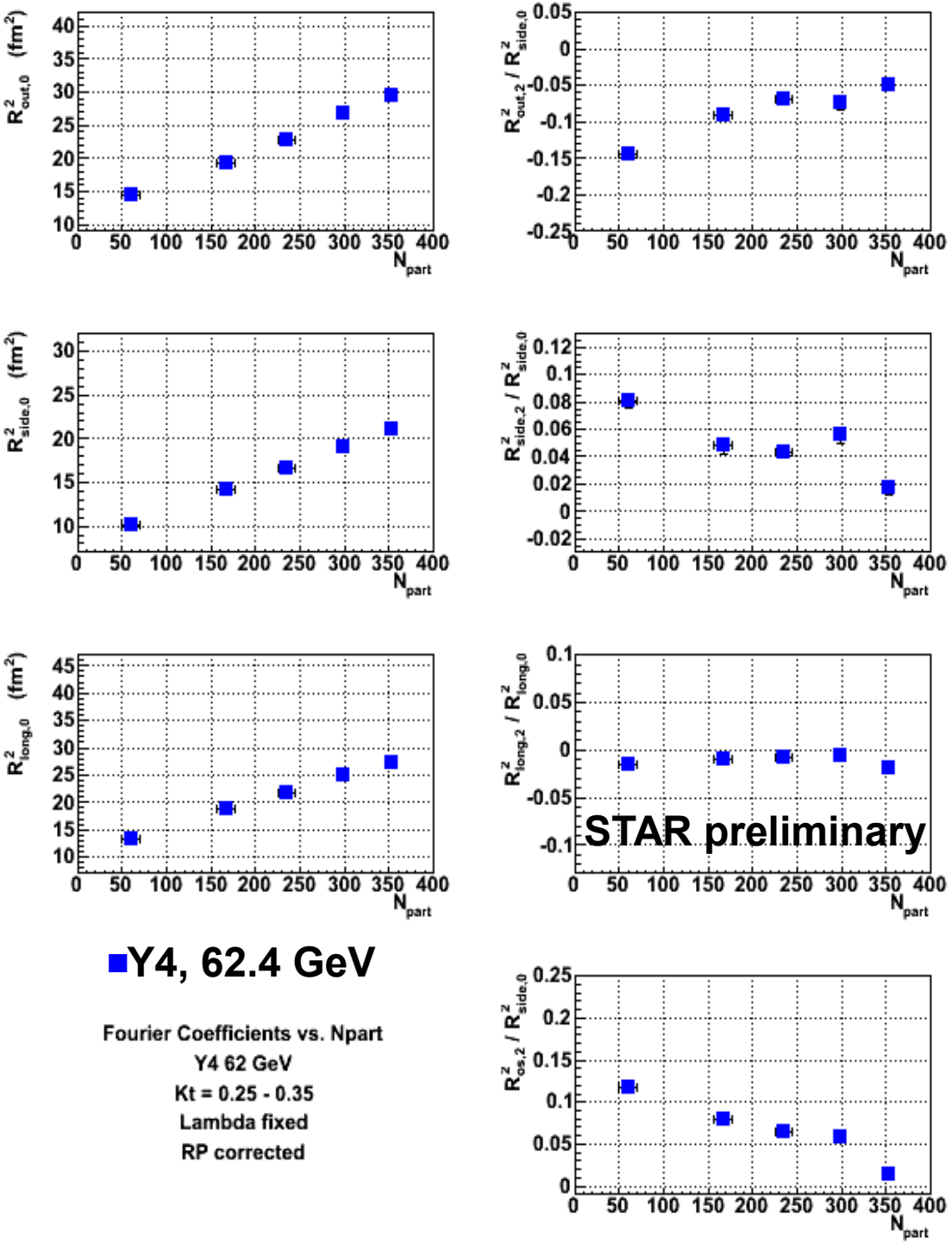


■Y4, 62.4 GeV

Fourier Coefficients vs. Npart
Y4 62 GeV
Kt = 0.15 - 0.25
Lambda fixed
RP corrected

- Fit Range: q < 0.15 GeV/c
- Lowest K_t bin
- Some scatter in $R^2_{s,2} / R^2_{s,0}$

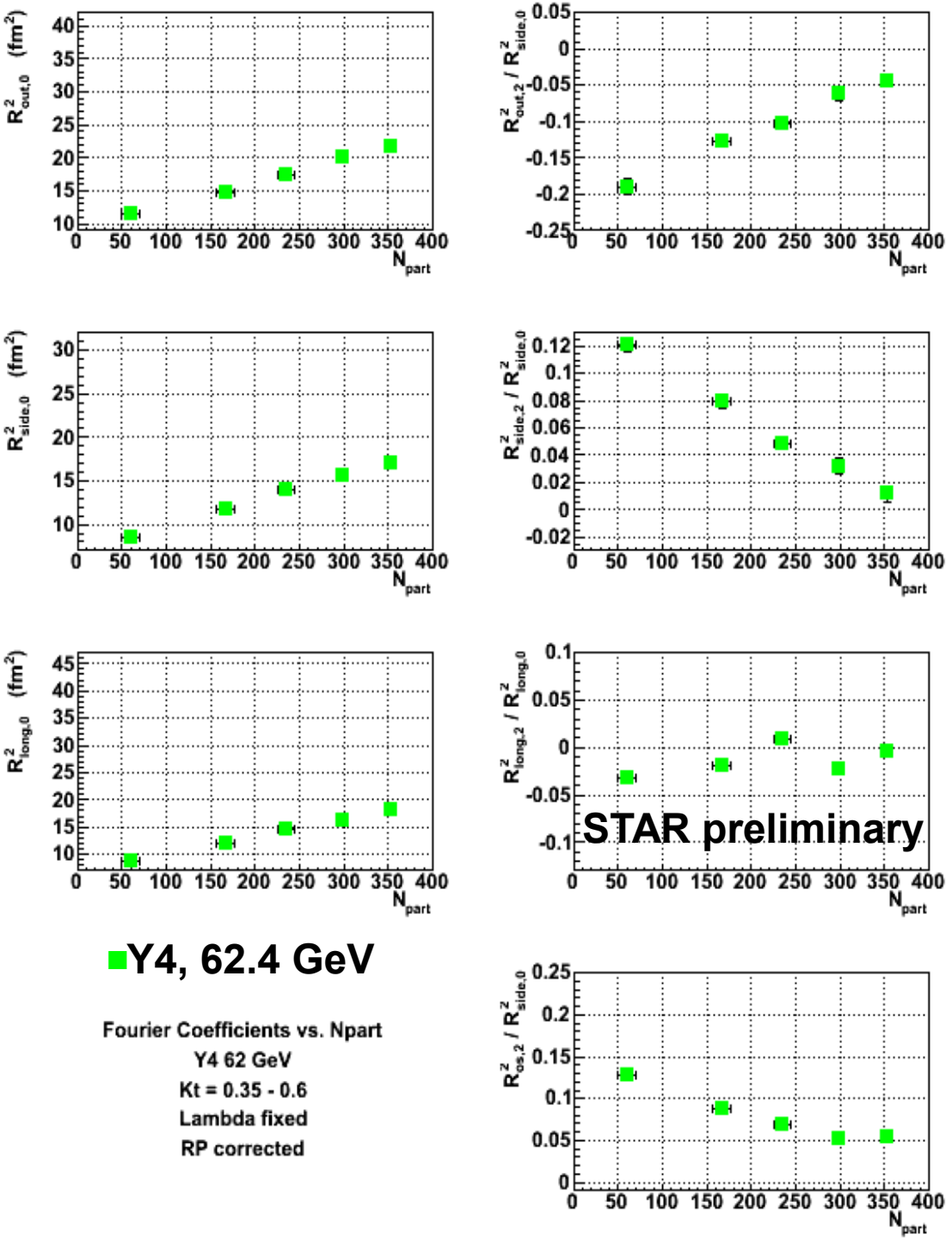
Y4 at 62.4 GeV



- Fit Range: $q < 0.15$ GeV/c
- Middle K_t bin
- Some scatter in $R^2_{s,2} / R^2_{s,0}$

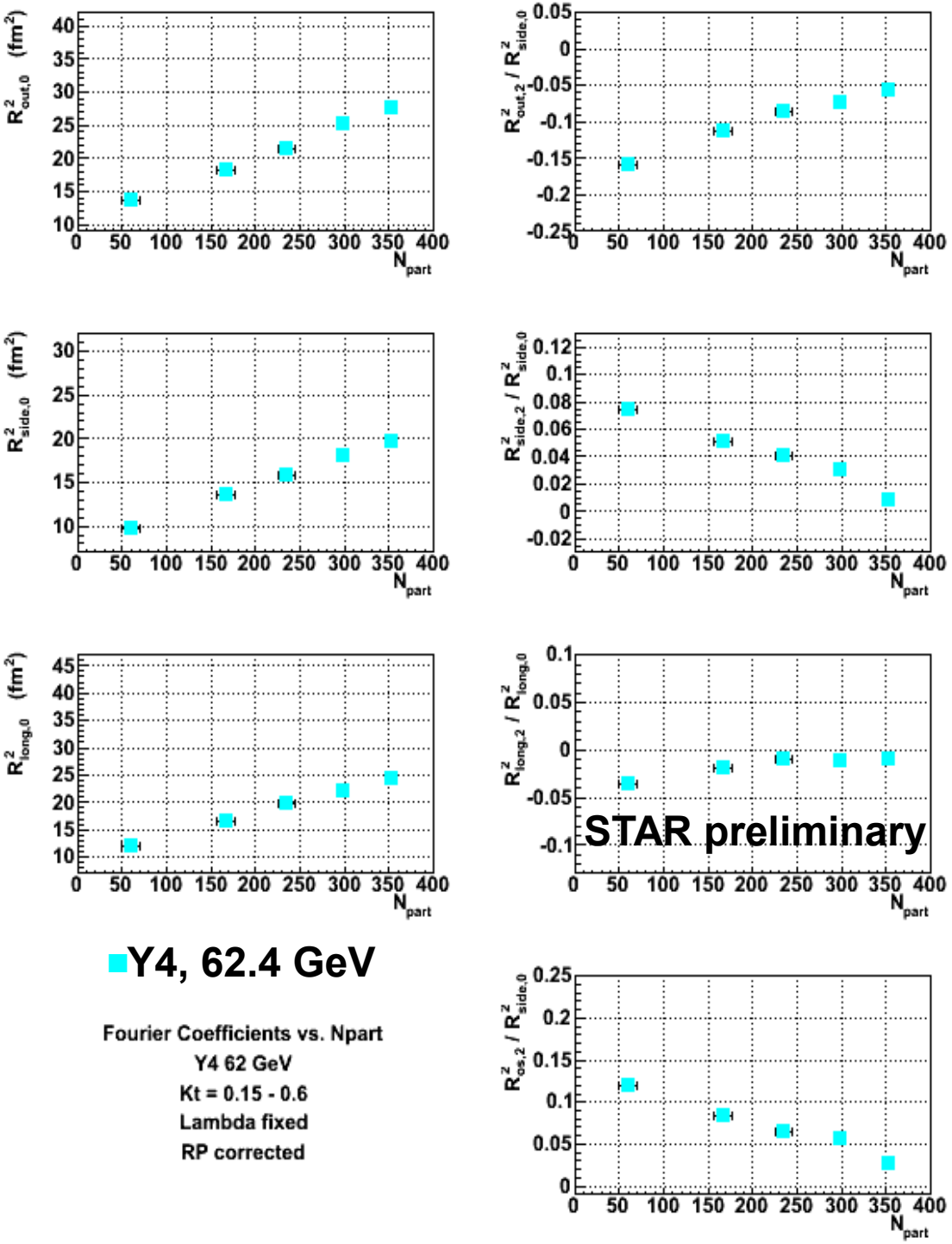
Y4 at 62.4 GeV

- Fit Range: q < 0.15 GeV/c
- Highest K_t bin



Y4 at 62.4 GeV

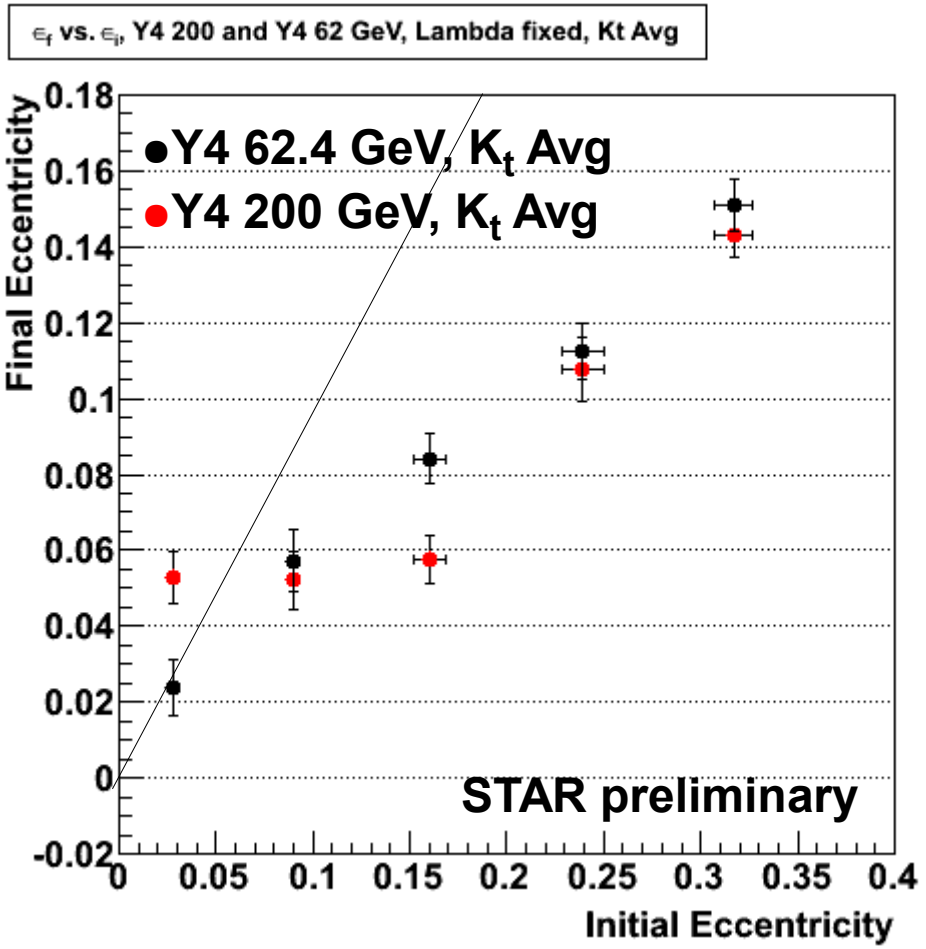
- Fit Range: q < 0.15 GeV/c
- K_t Integrated

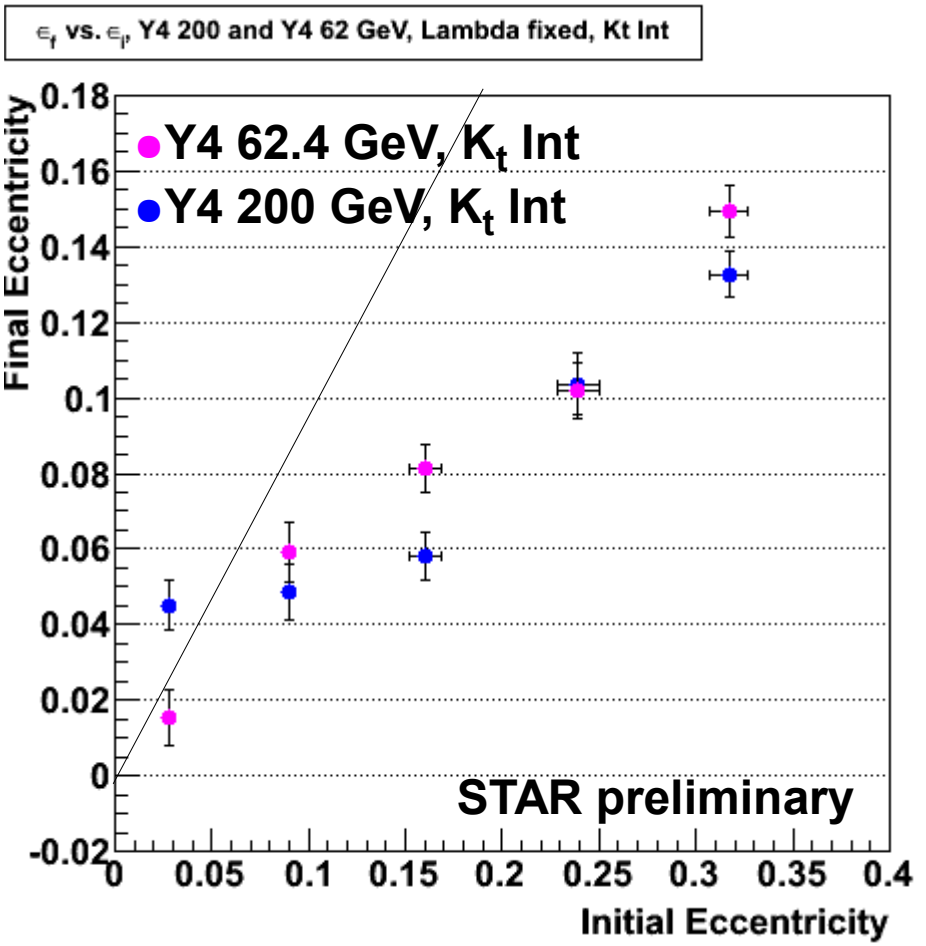


Y4, 62.4 GeV

Fourier Coefficients vs. Npart
Y4 62 GeV
Kt = 0.15 - 0.6
Lambda fixed
RP corrected

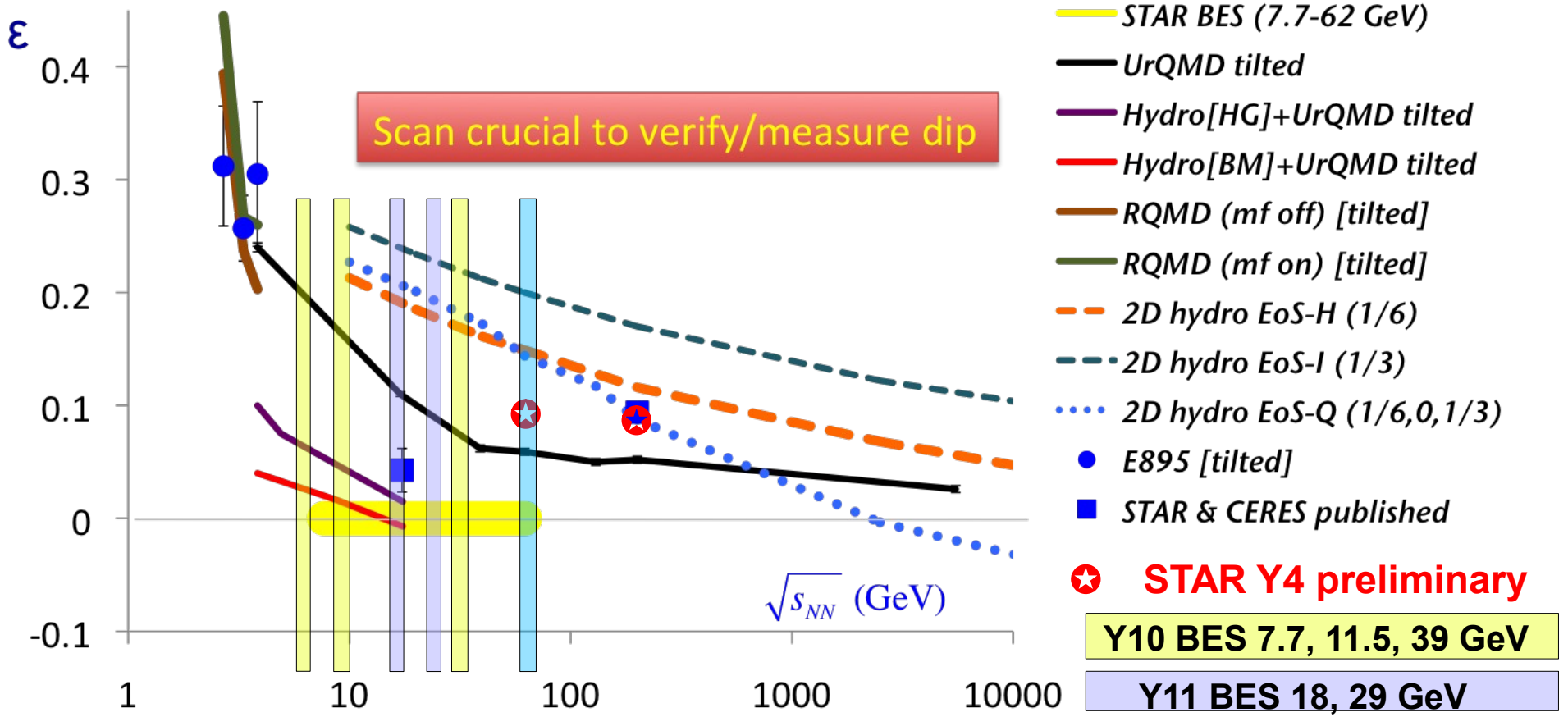
Y4 at 62.4 and 200 GeV





Excitation Function

- Y4 62.4 GeV greater than Y4 200 GeV (both K_t Avg and K_t Int cases)
- Y4 62.4 GeV slightly greater than Y2 200 GeV (K_t Avg case)



Conclusions

•Preliminary Y4 62.4 GeV and Y4 200 GeV results suggest the excitation function is constant or slightly decreases at the higher energy.

•Further systematic studies needed.

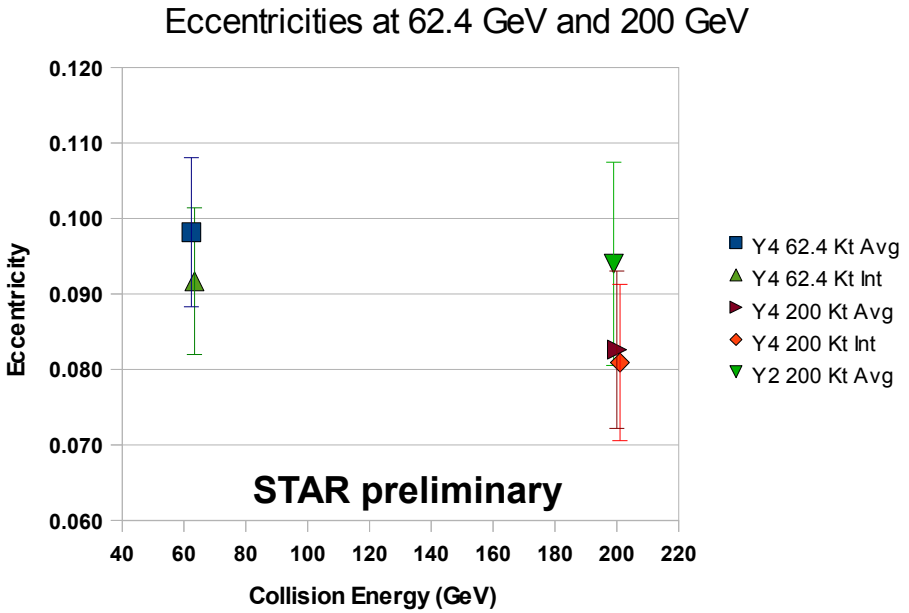
•Need lower energies to determine shape of excitation function.

•Beam Energy Scan energies will fill in the excitation function

- 7.7 GeV, 11.5 GeV, 39 GeV – Analysis in progress
- 18 GeV, 29 GeV – Scheduled for Run 11

Backup slides

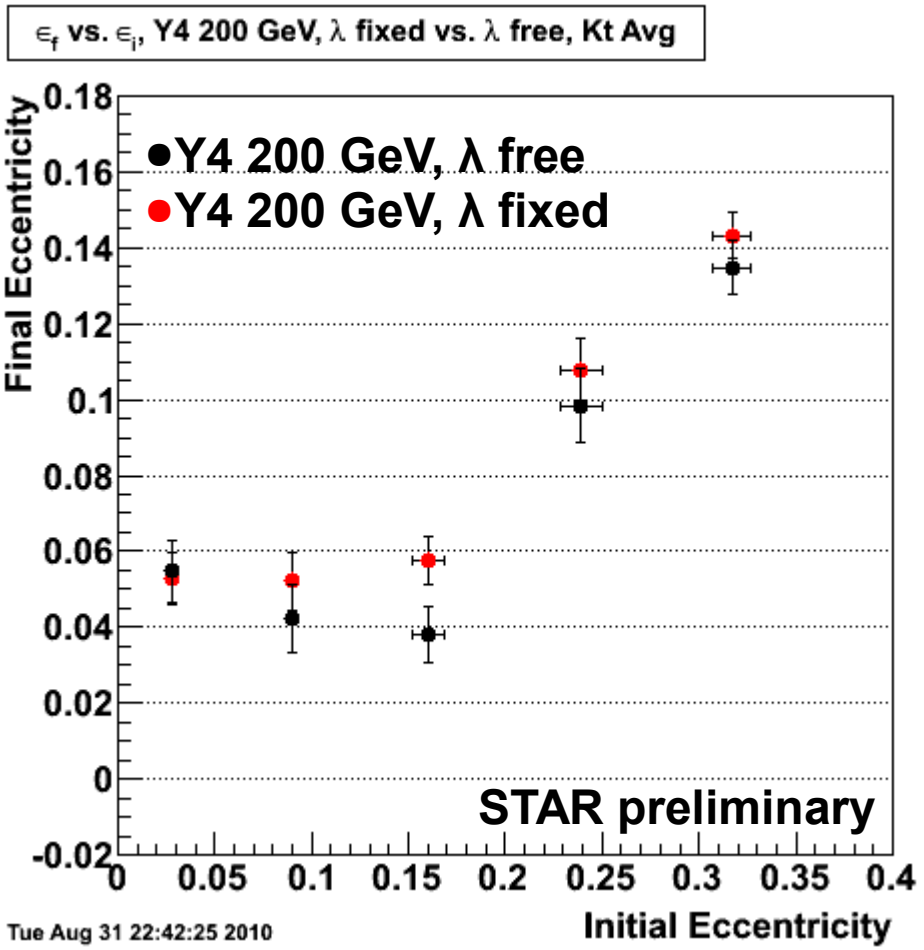
Close up of 62.4 and 200 GeV points

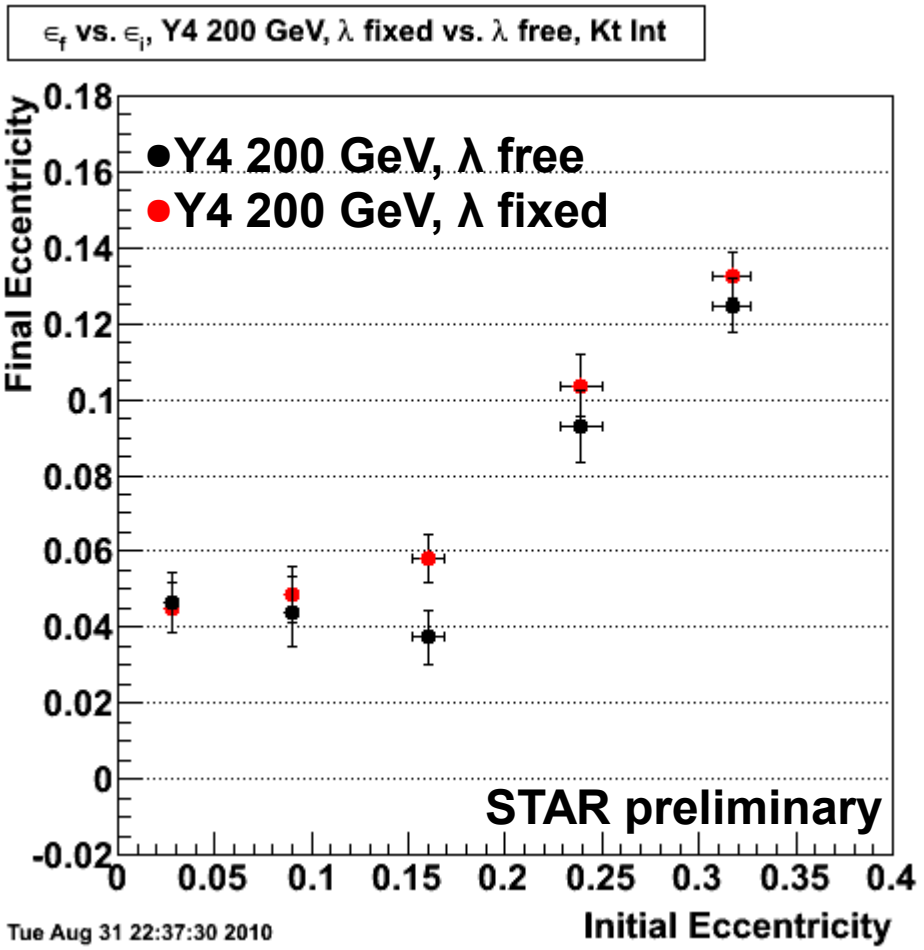


	Energy	Epsilon	EpsError
Y4 62.4 Kt Avg	62.4	0.098173750	0.009884212
Y4 62.4 Kt Int	62.4	0.091692000	0.009693387
Y4 200 Kt Avg	200	0.082621050	0.010419805
Y4 200 Kt Int	200	0.080916850	0.010353542
Y2 200 Kt Avg	200	0.094000000	0.013453624

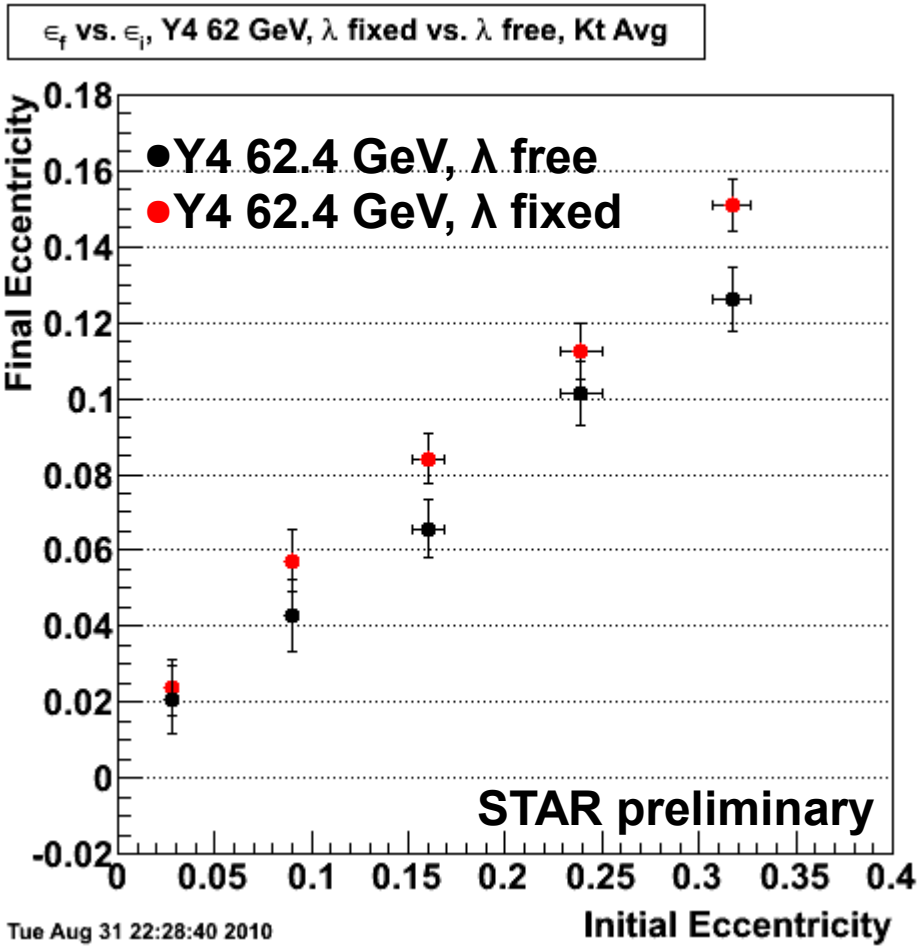
*Points in figure are slightly offset in energy for clarity.

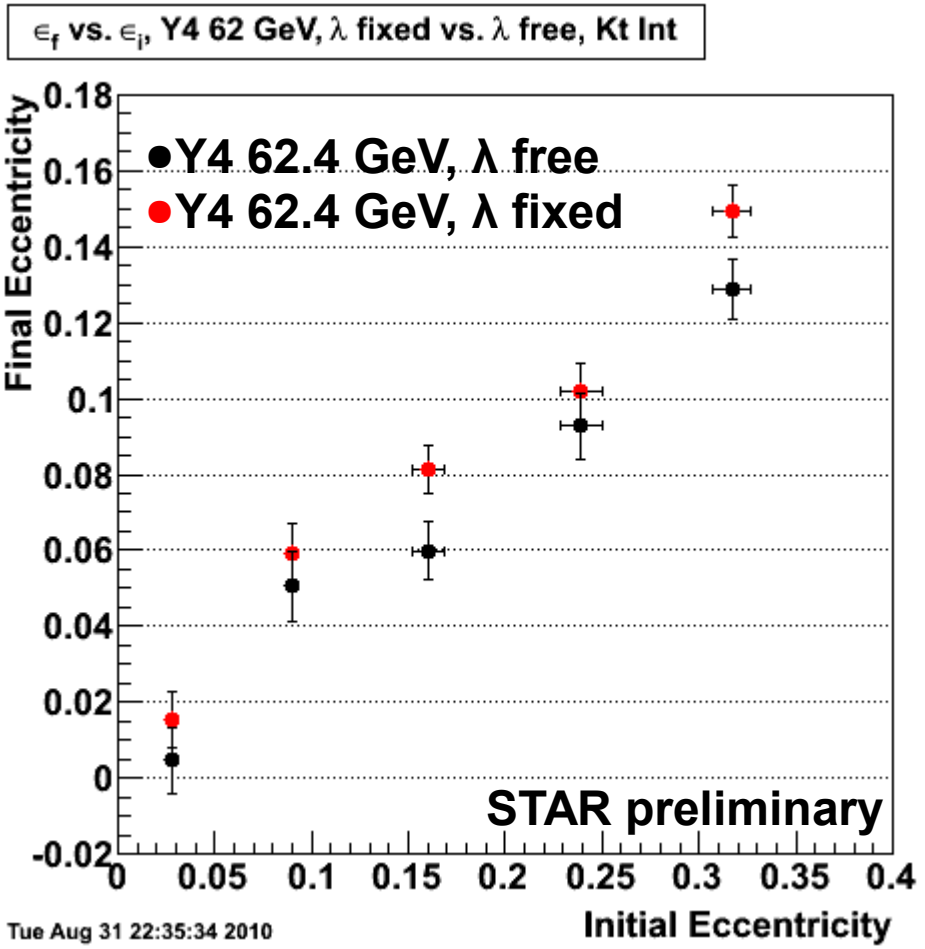
Y4 200 GeV – λ Fixed vs λ Free



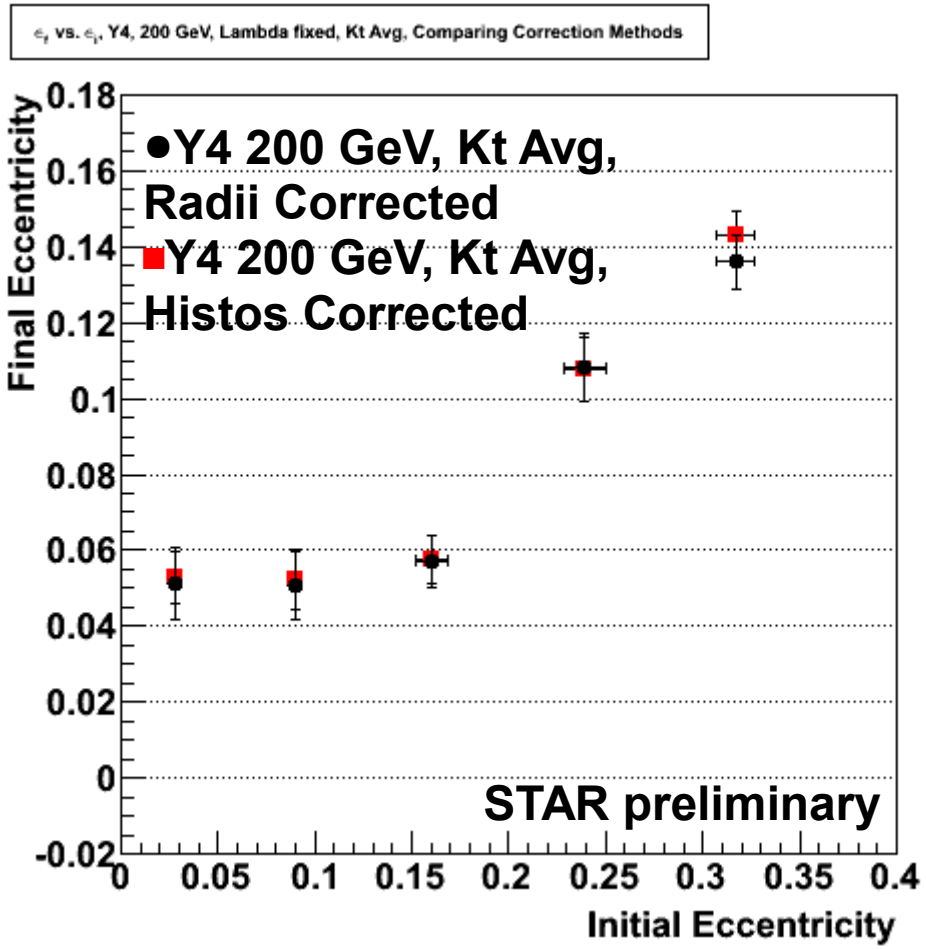


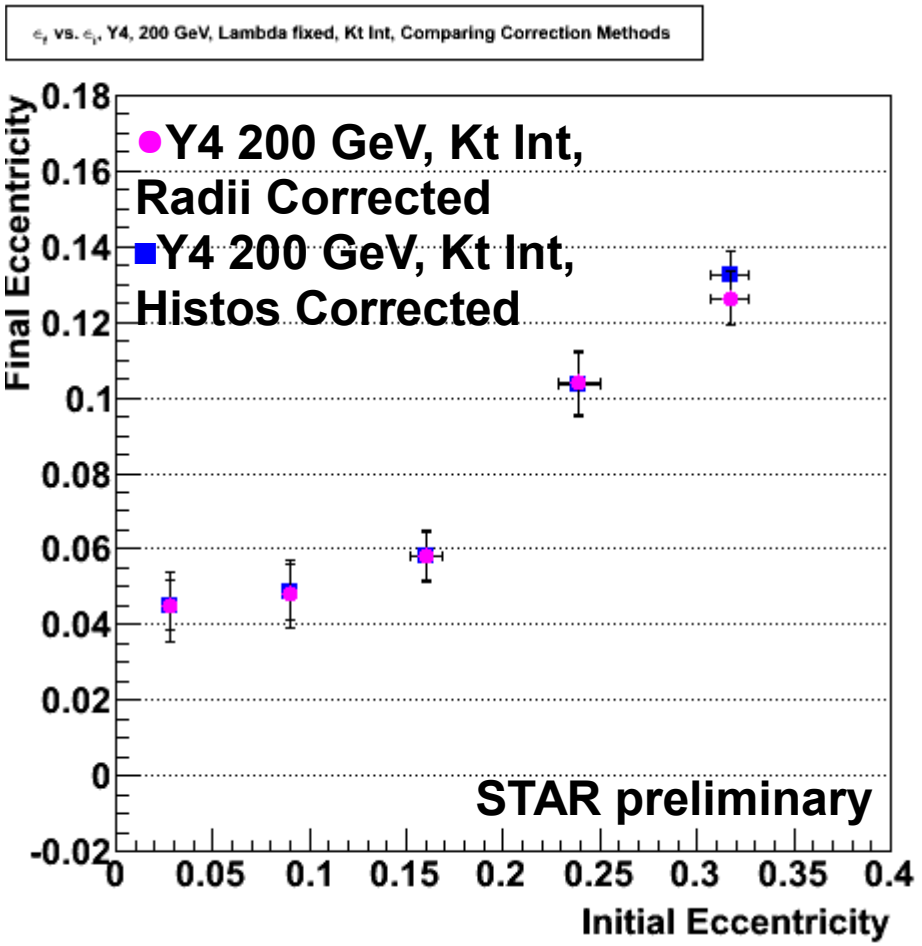
Y4 62.4 GeV – λ Fixed vs λ Free



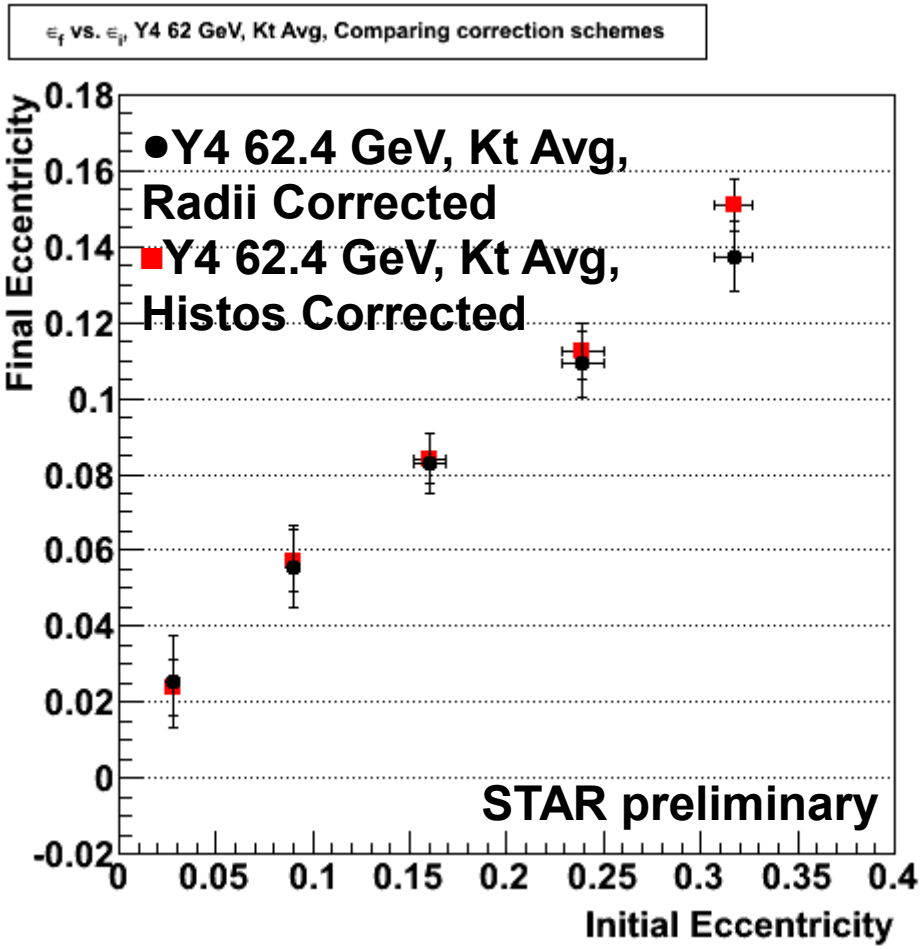


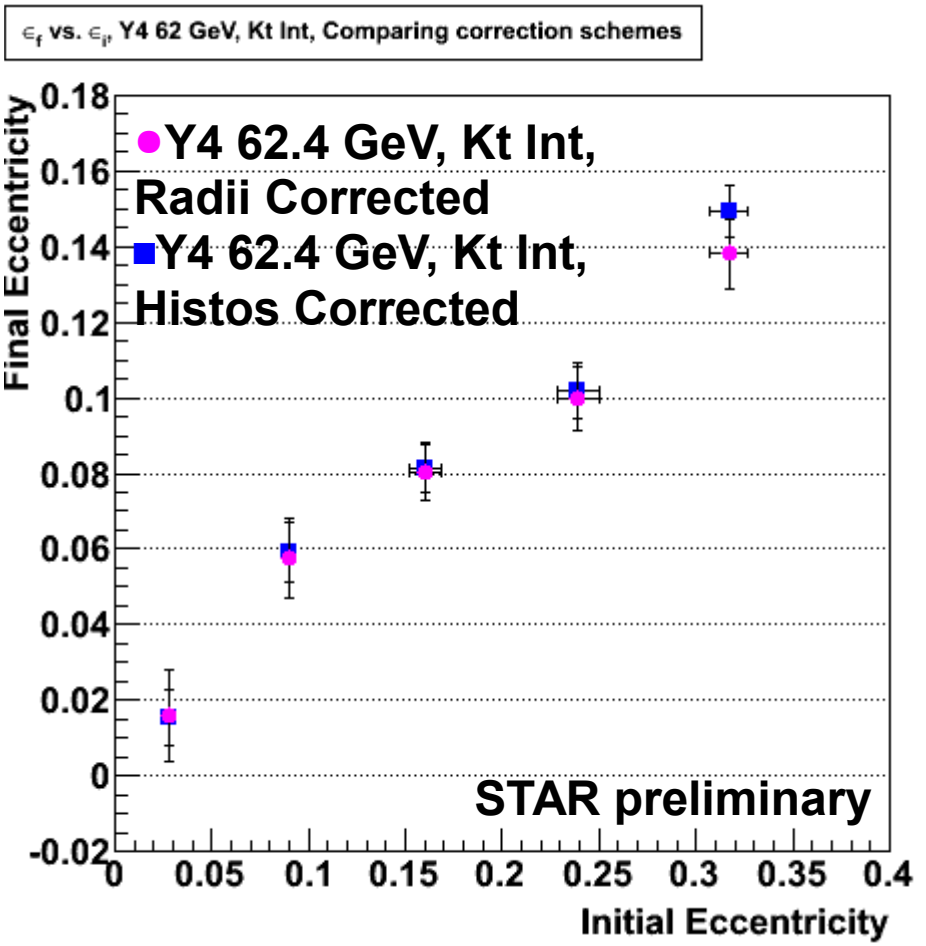
Y4 200 GeV – Two correction schemes



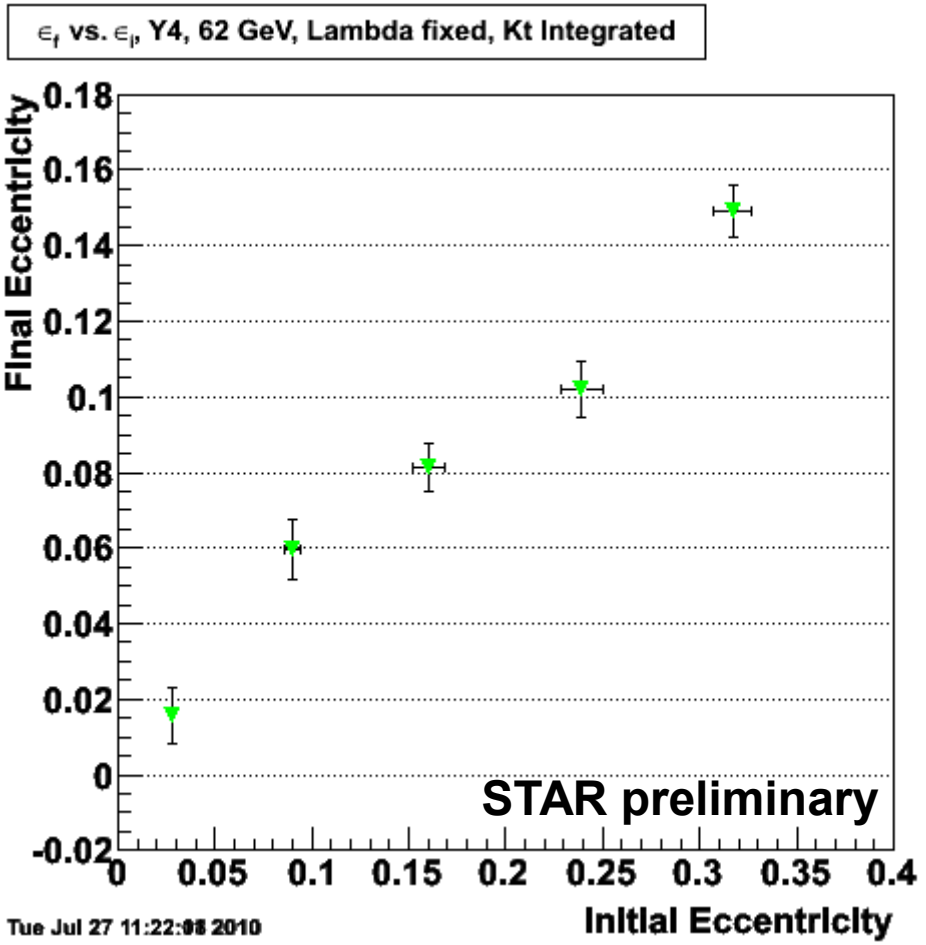


Y4 62.4 GeV – Two correction schemes

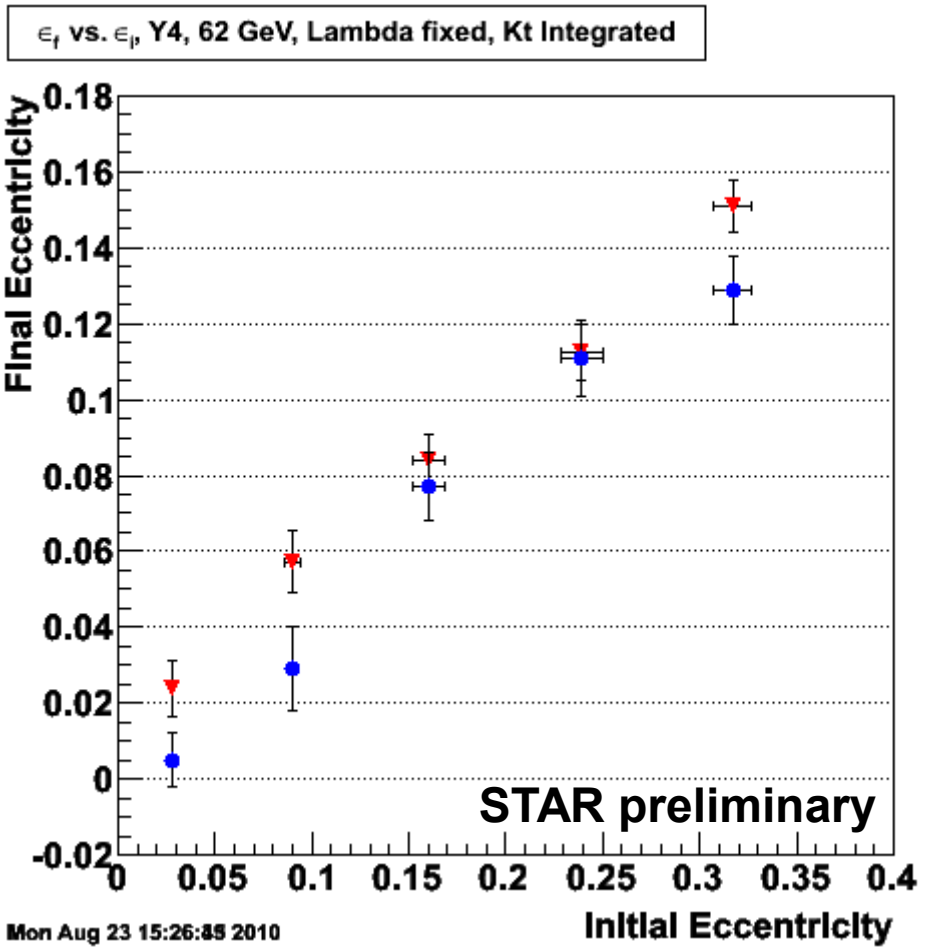




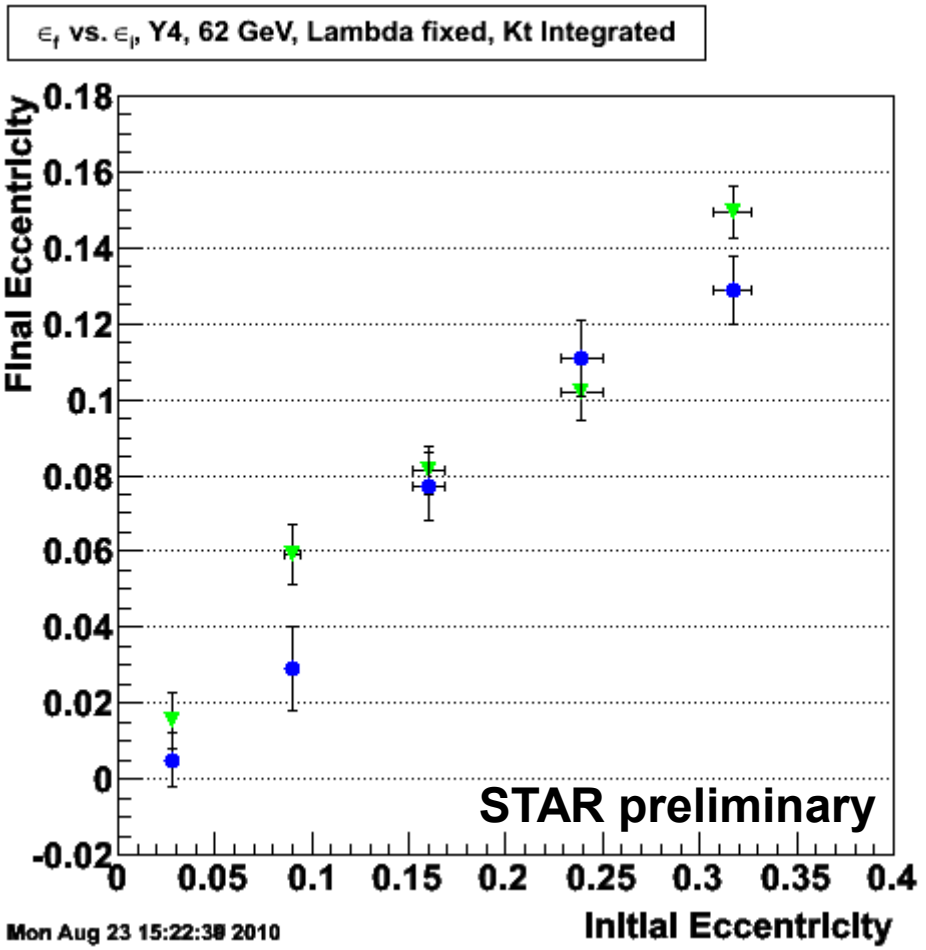
Y4 Kt Integrated at 62.4 GeV



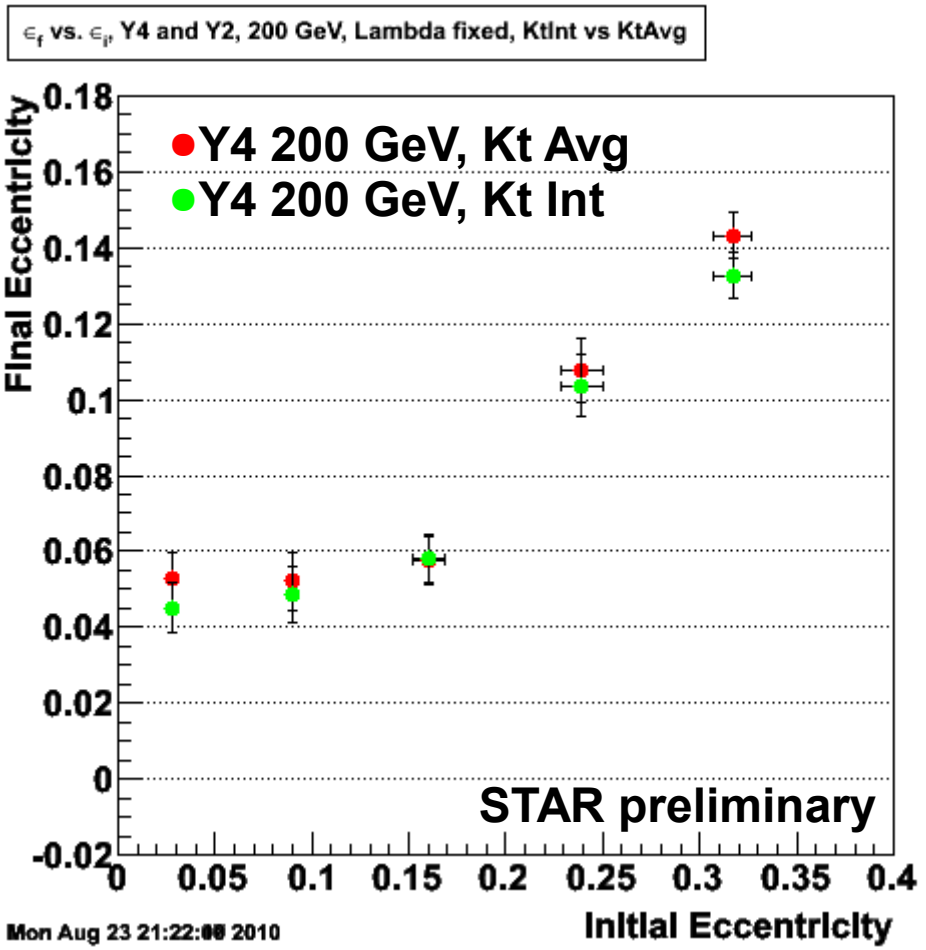
Y4 62.4 GeV vs Y2 200 GeV
Kt Averaged



Y4 62.4 GeV Kt Int vs Y2 200 GeV KtAvg



Y4 Kt Averaged vs. Kt Integrated



•Kt Integrated and Kt Averaged eccentricities are similar.