Outline:

- Momentum Correlations
- Relationship to Angular Corr.
- Implications for ridge

Two-particle correlations on log(p_t) and the log(p_t) dependence of angular (η,Φ) correlation features in Au+Au at $\sqrt{s_{NN}} = 200$ GeV at STAR

Elizabeth Oldag for the STAR Collaboration

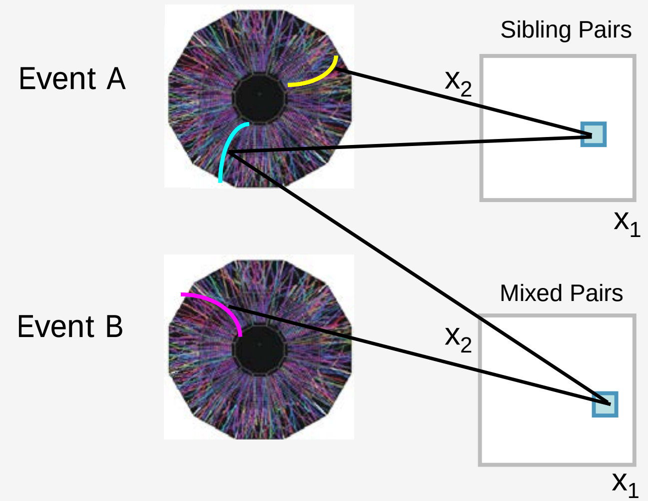
May 7, 2012

Two-particle correlation measure

- Correlation Measure:

$$\frac{\rho_{sib}-\rho_{mix}}{\sqrt{\rho_{ref}}} = \frac{\Delta\rho}{\sqrt{\rho_{ref}}} \rightarrow \sqrt{\rho'_{ref}}\,\frac{\Delta\rho}{\rho_{ref}}$$

↑ Efficiency corrected ref. dist.



- Number of correlated pairs *per* final state particle

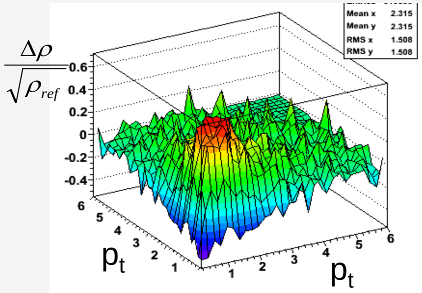
- Reference Pairs
  - Angular correlations use mixed pairs (tracks from two different but similar events)
  - Mixed pairs in momentum space show an enhancement in the two-particle distribution due to physics
    - We hypothesize our signal of interest is jets and therefore need to select a reference that is absent of jets
      - Soft particle spectrum of the two-component model (ref:arXiv:0710.4504v1[hep-ph]).

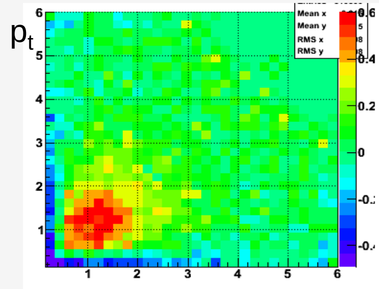
$$\frac{\Delta\rho}{\sqrt{\rho_{ref}}} = \sqrt{\rho'_{soft}}\,\frac{\rho'_{tot}}{\rho'_{soft}} \times \sum_{\Delta Nch,\Delta z,...}\frac{\Delta\rho}{\rho_{mix}}$$

- Data Set: Au+Au Collisions at 200 GeV, ~11.5 Million Minimum Bias Events, p_t>0.15 GeV/c, |η| < 1, full φ

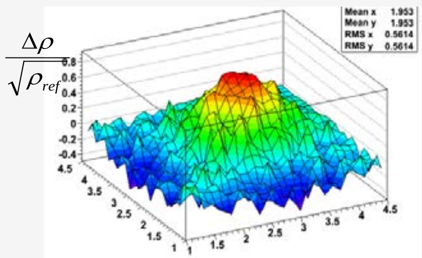
Motivation for a log(p_t) measure

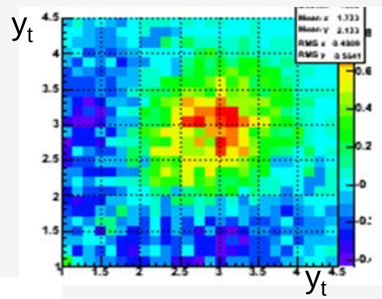
p_t





y_t





$$y_t = \ln\left(\frac{m_t + p_t}{m_\pi}\right), \quad \text{where } m_t = \sqrt{p_t^2 + m_\pi^2}$$

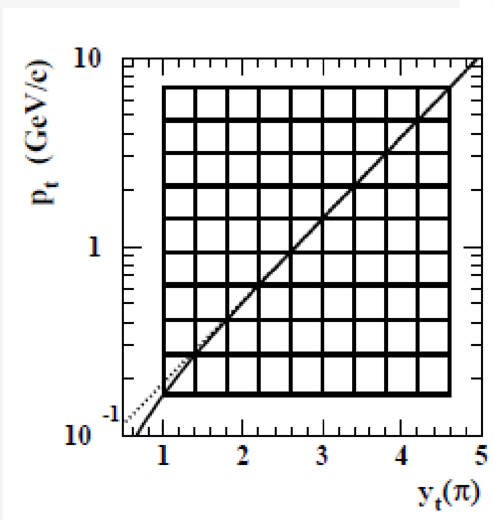


Fig. p_t vs. y_t, the dotted line indicates a log(p_t) reference

(y_t,y_t) correlations – Analysis Details

- The reference distribution was event normalized with a correction factor

$$\frac{\Delta\rho}{\sqrt{\rho}} = \frac{\alpha\overline{n_{sib}(y_{t1},y_{t2})} - \overline{n_{ref}(y_{t1},y_{t2})}}{\sqrt{\overline{n_{ref}(y_{t1},y_{t2})}}}, \quad \alpha = \frac{\overline{N_{ch}}^2}{\overline{N_{ch}(N_{ch}-1)}}$$

  - α ensures the correlation measure is zero in the absence of true correlations

Centrality Bin	N_{ch} Range	$\overline{N_{sib}}$ / $\overline{N_{mix}}$
0	[2,15)	1.078
1	[15,35)	1.014
2	[35,68)	1.014
3	[68,117)	1.012
4	[117,152)	0.998
	[152,187)	0.998
…	…	…

Find $\overline{N_{sib}} = \overline{N_{ch}(N_{ch}-1)}$

and $\overline{N_{mix}} = \overline{N_{ch}}^2$

from the real event multiplicity distribution in each multiplicity bin

=1 with the bias correction

For centrality info refer to arXiv:1109.4380

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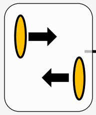
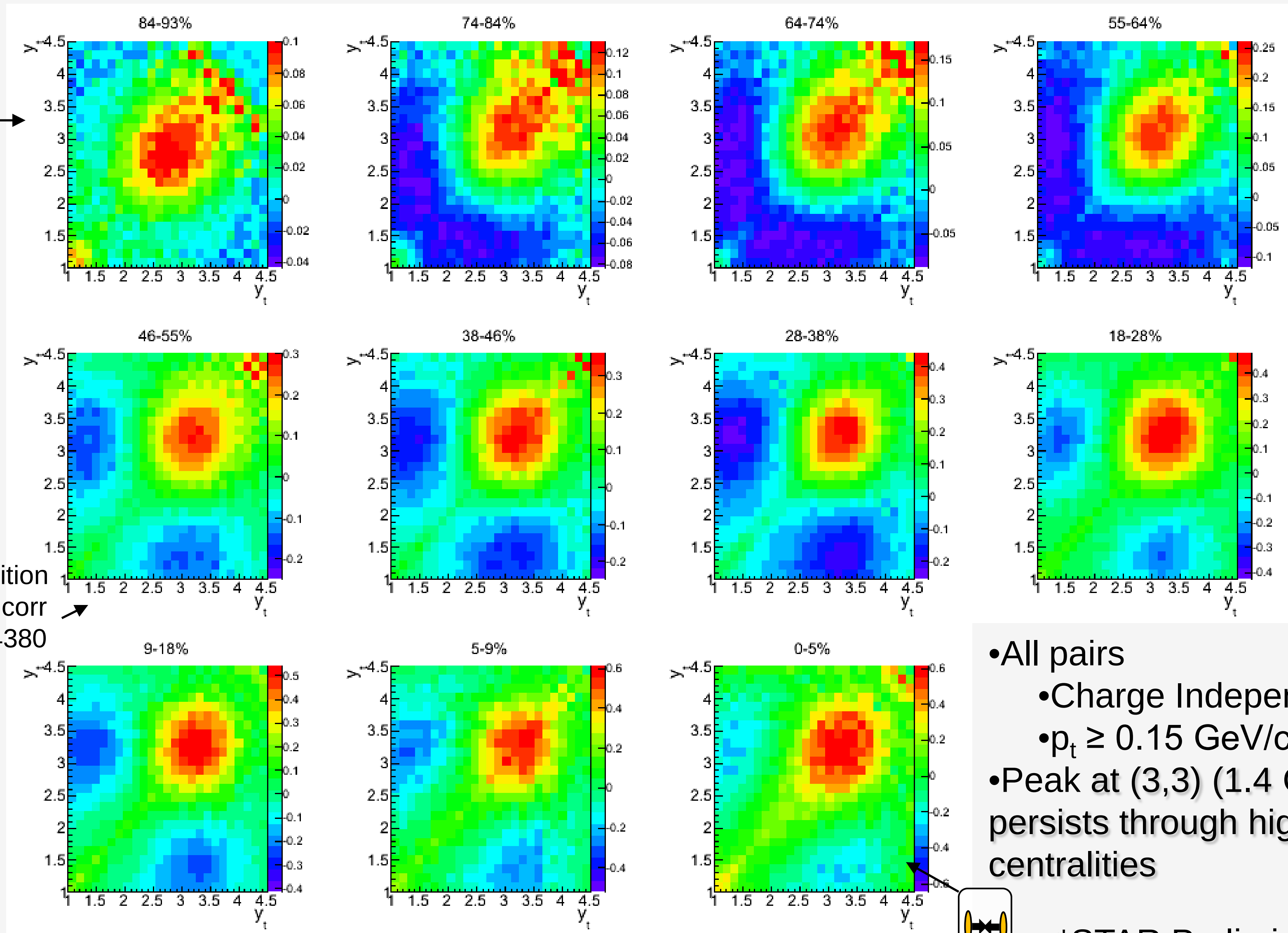
Charge Independent (y_t,y_t) correlations



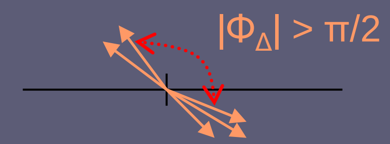


Sharp Transition (ST) in ang. corr
arXiv:1109.4380
~46-55%

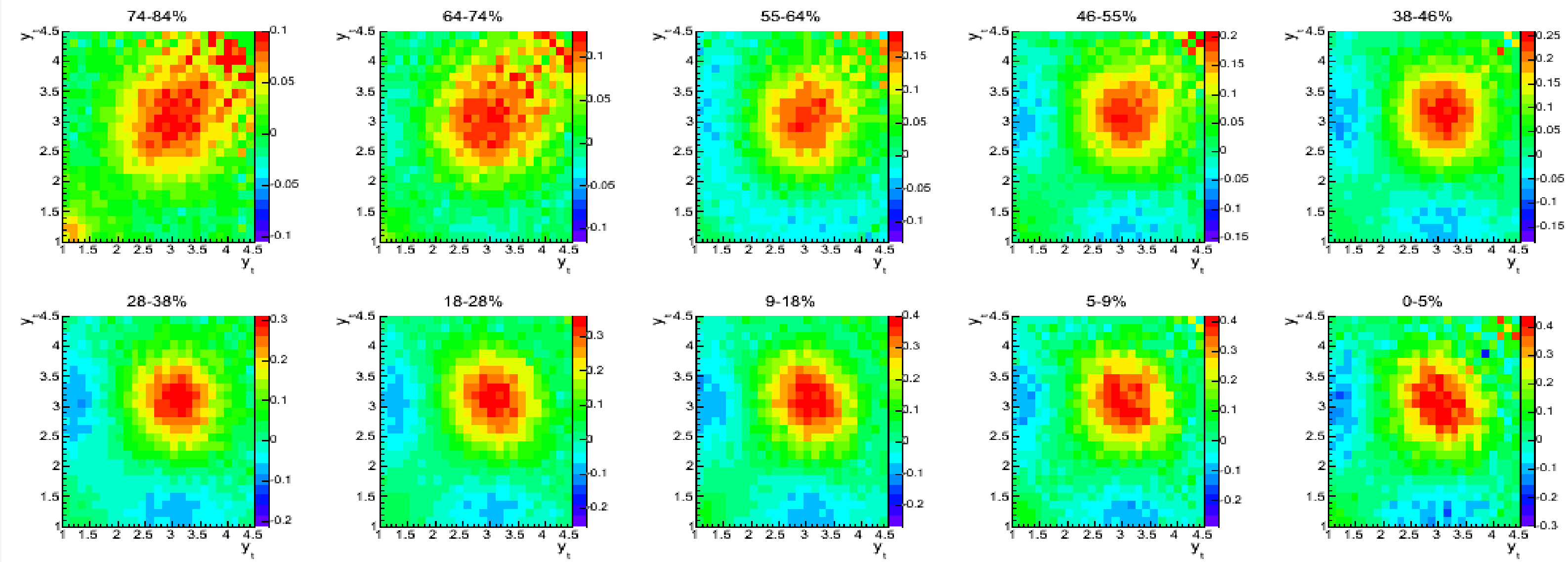
- All pairs
  - Charge Independent
  - $p_t \geq 0.15$ GeV/c
- Peak at (3,3) (1.4 GeV/c) persists through higher centralities

*STAR Preliminary

(y_t, y_t) Away-side

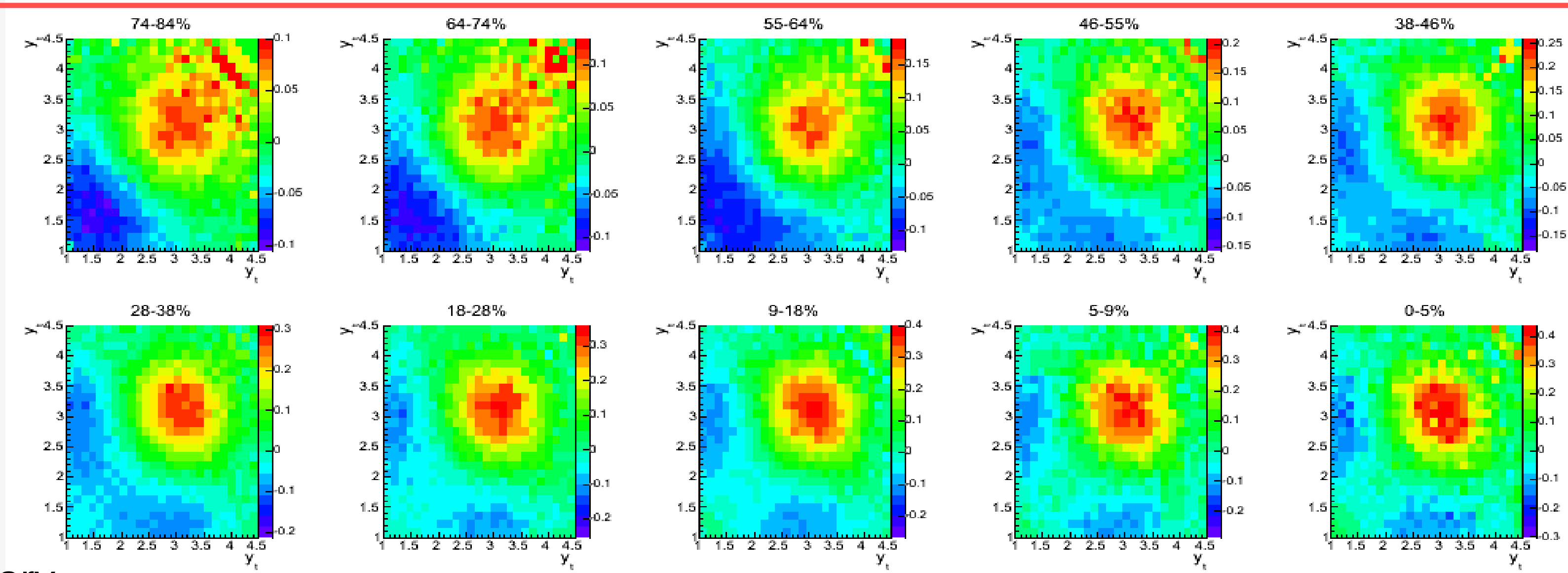


US



- Peak ranging from 2.5 to 3.5 in y_t (~1.0-2.5 GeV/C)
- Amplitude grows as centrality increases but little change in peak position.

LS



- Similar behavior to US pairs

*STAR Preliminary

Outline:
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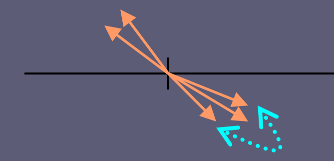
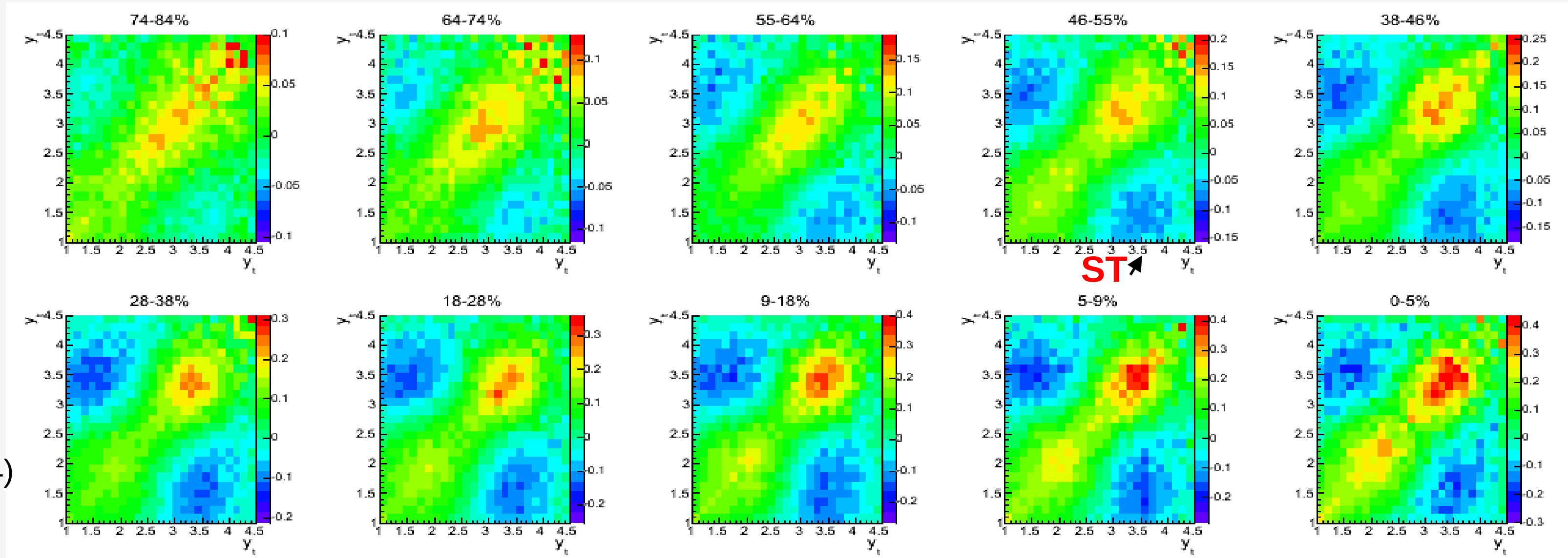
(y_t, y_t) Same-side



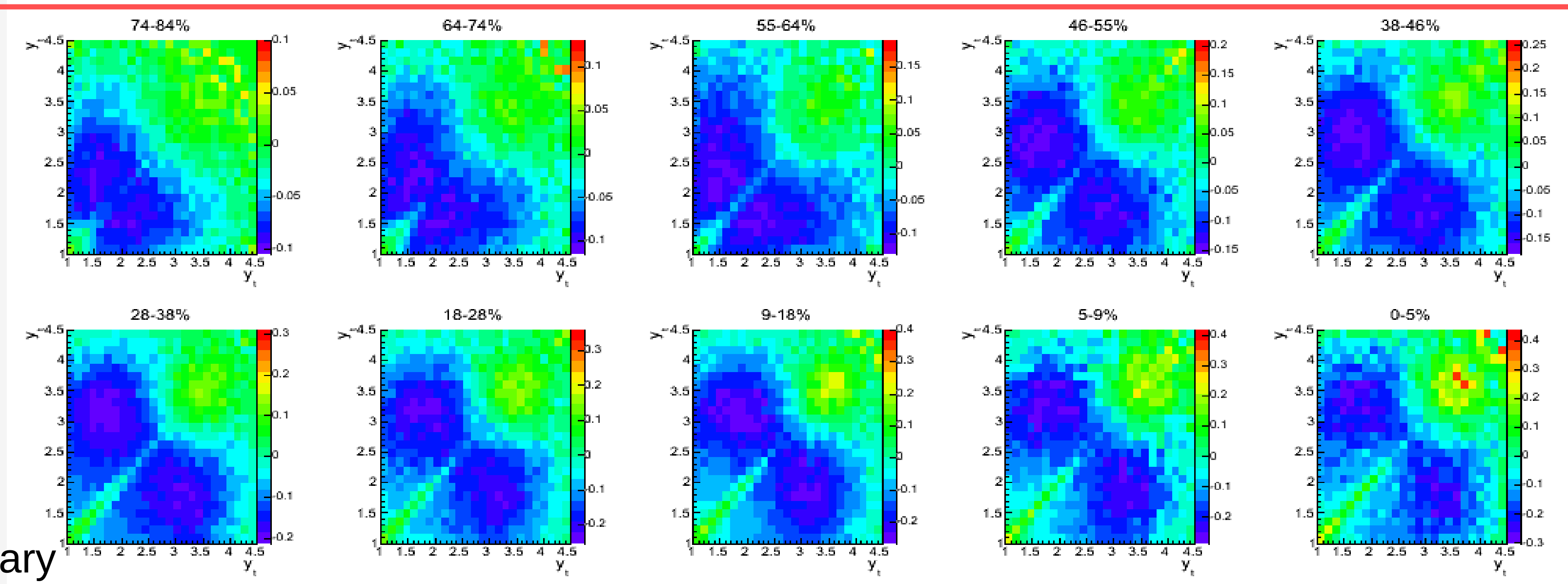
US

- Two peaks appear from mid- to most-central collisions.
- Raises the question if this is a separation of pion and proton pairs (tbd from PID results)
(ref: arXiv:0710.4504)



LS

- Signals from HBT evident along the diagonal.



*STAR Preliminary

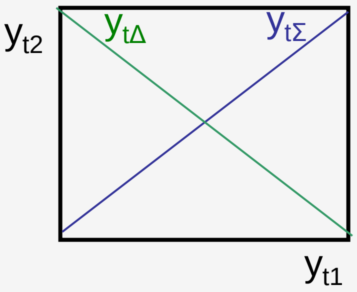
(y_t, y_t) Fitting Model

- Goal: To fit the correlations with a simple fit function that quantifies the main features of the correlation (the bump at (y_t , y_t) ~ (3,3)).
  - A cut window will allow us to exclude soft correlation structures and edges.
- Fit Function:

$$fit = A_0 + A_1 e^{-0.5*(((y_{t\Sigma} - 2*y_{t,0})/\sigma_{y_{t\Sigma}})^2 + (y_{t\Delta}/\sigma_{y_{t\Delta}})^2)}$$

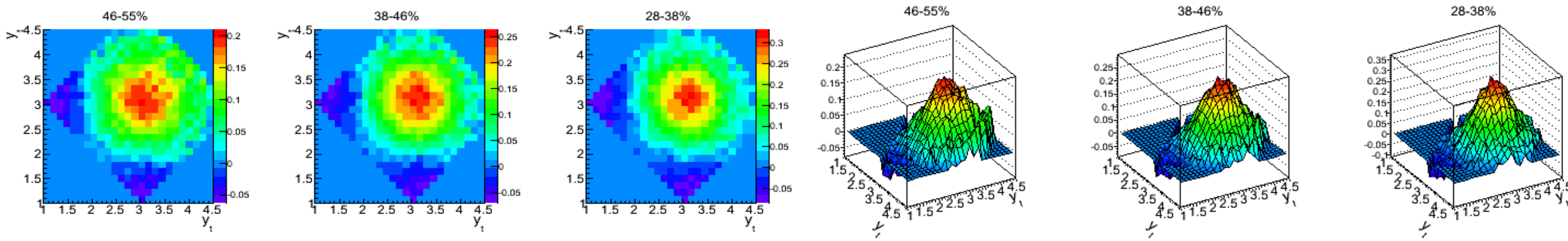
$$y_{t\Sigma} = y_{t1} + y_{t2}$$

$$y_{t\Delta} = y_{t1} - y_{t2}$$

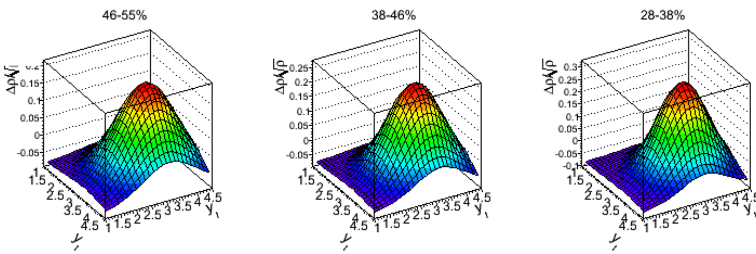


Fitting Results (Unlike-sign away-side)

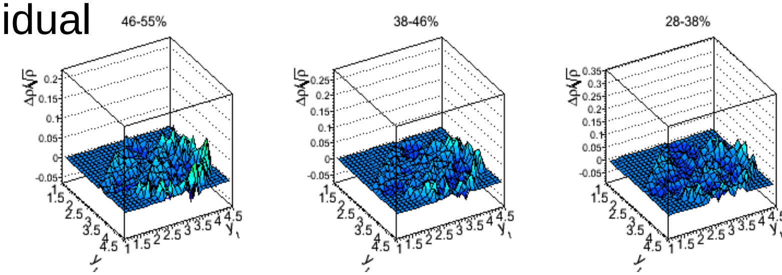
Data

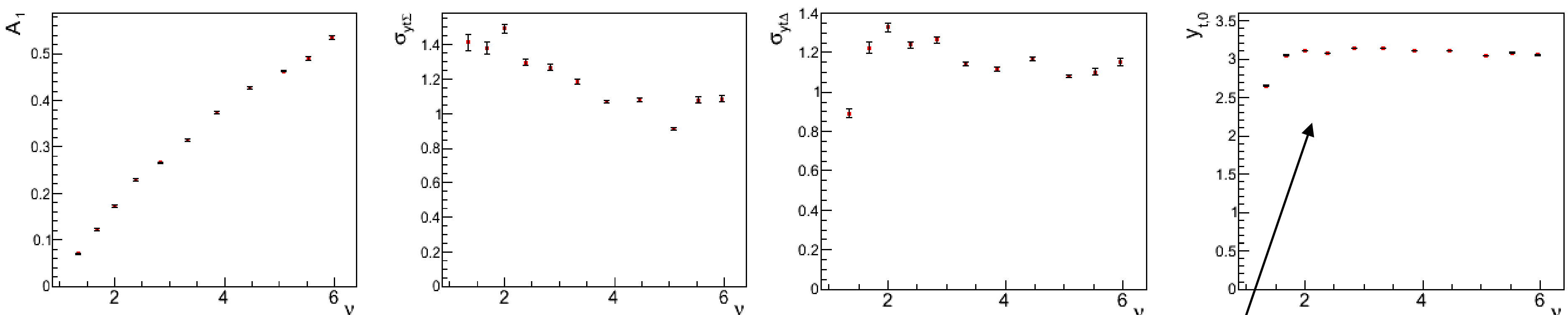


Model



Residual





$$\nu \equiv \frac{\langle N_{bin} \rangle}{\langle N_{part}/2 \rangle}$$

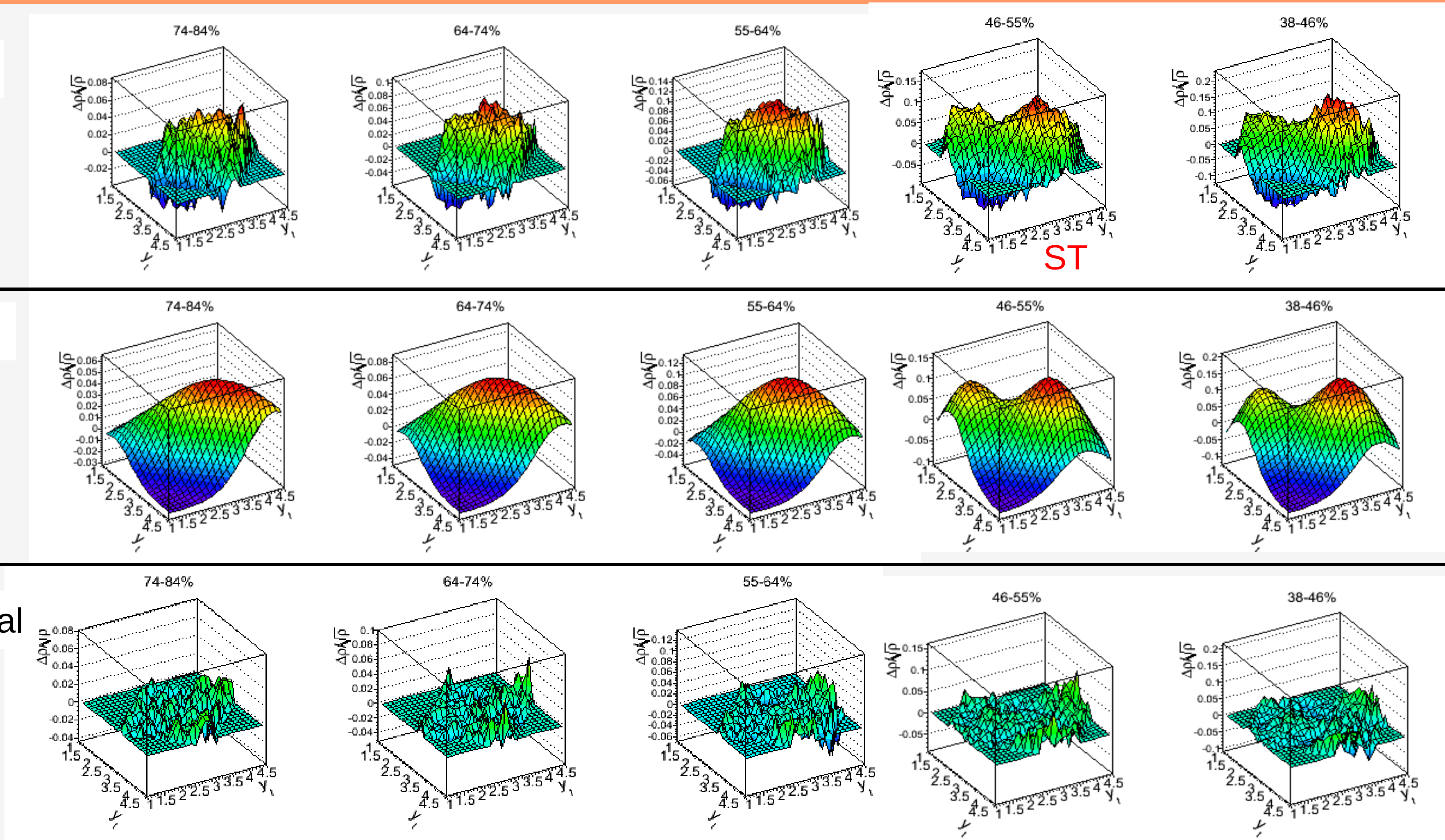
Peak position remains steady, similar results for LS AS

Fitting Results (Unlike-sign same-side)

Data

Model

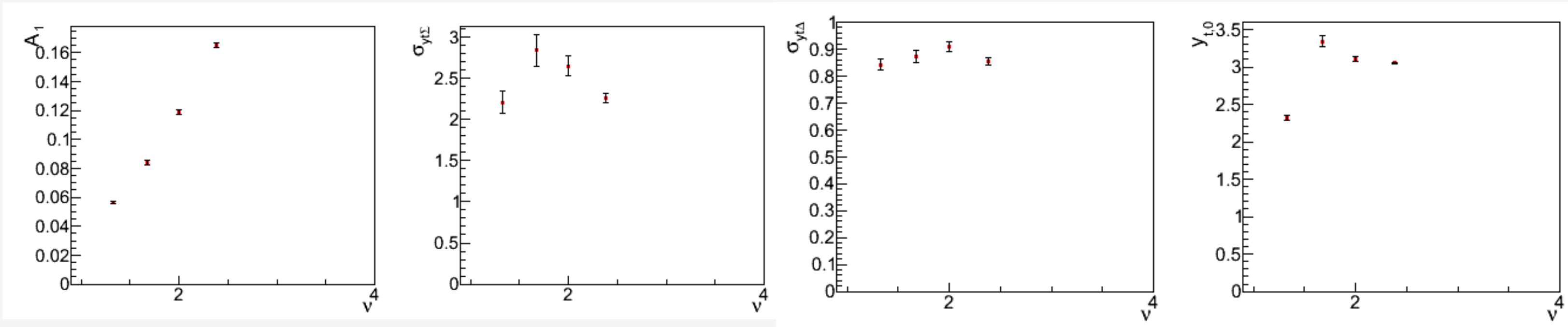
Residual



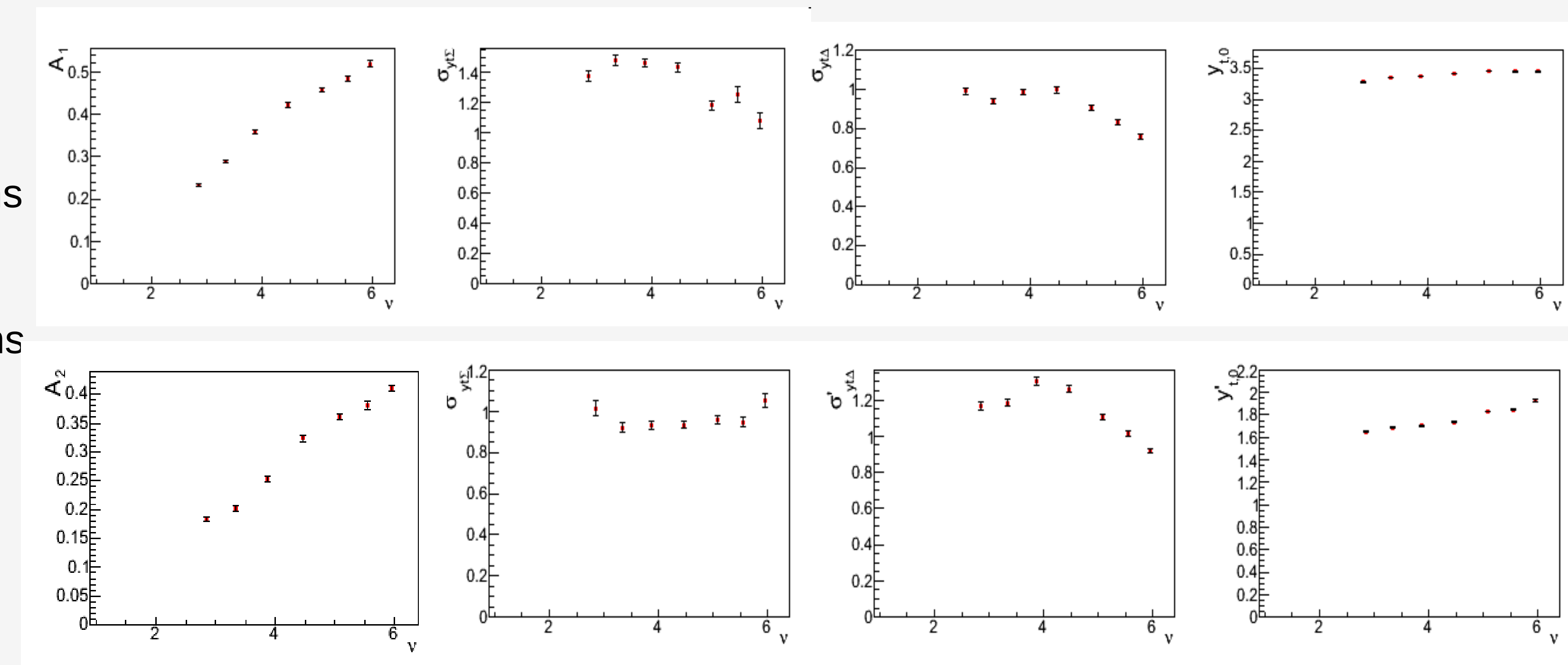
*STAR Preliminary

Fitting Results (Unlike-sign same-side)

Cent. Bins [0-3]
One 2D Gaussian



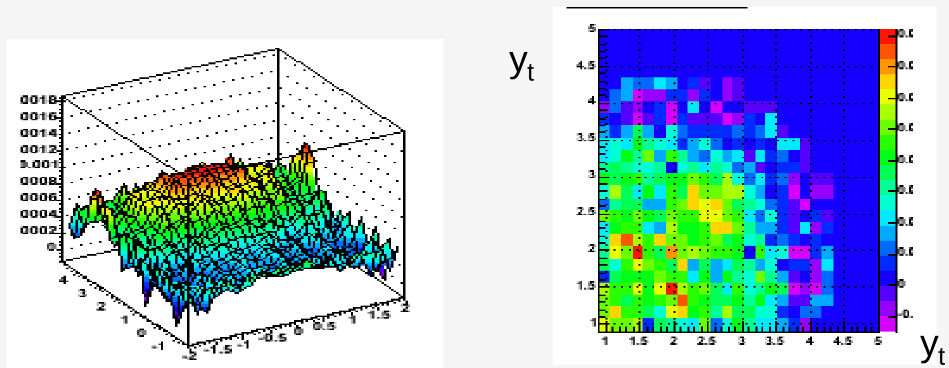
Cent. Bins [4-10],
Two 2D Gaussians



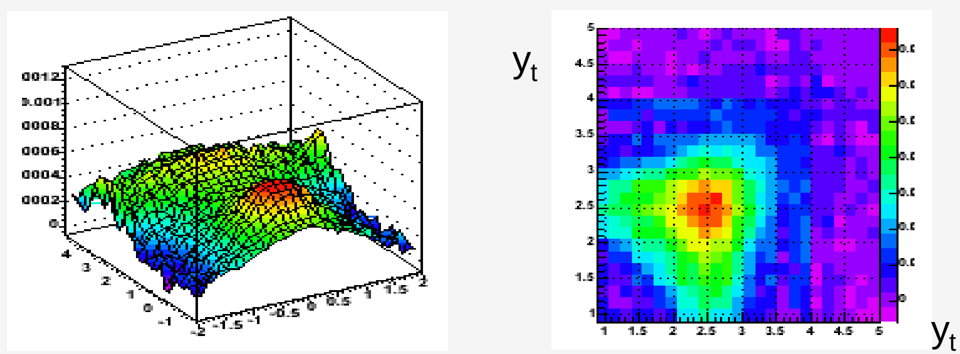
Model Comparisons

- Is the peak in (y_t, y_t) correlations from semi-hard jet fragmentation?
- HIJING

Jets Off



Jets On

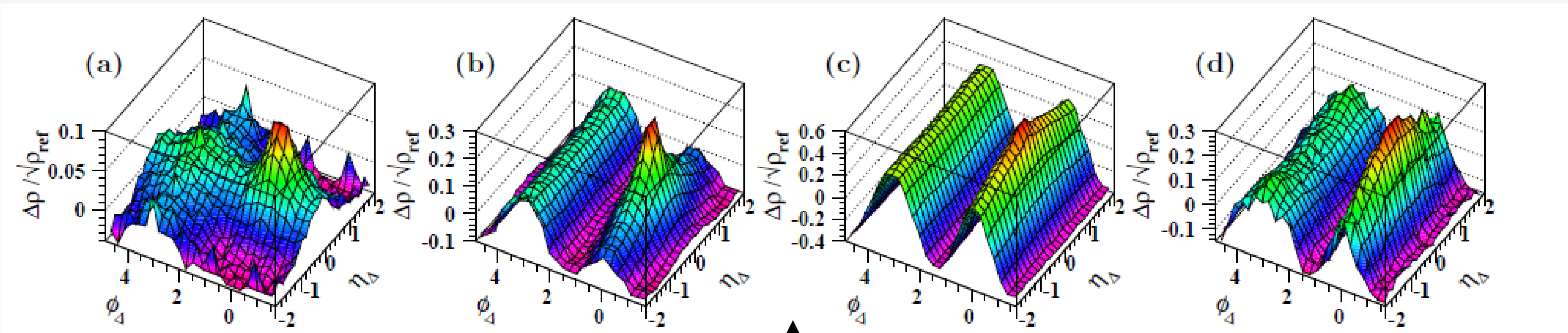


Plots from M. Daugherity

- Interested in exploring other models: AMPT (see Lanny's talk), SpheRio, NexSPheRio, HydJet

Angular Correlations

- Minimum bias angular correlations signal a change in the correlation structures as centrality increases from peripheral to central



84-93% 55-64% 18-28 % 0-5%

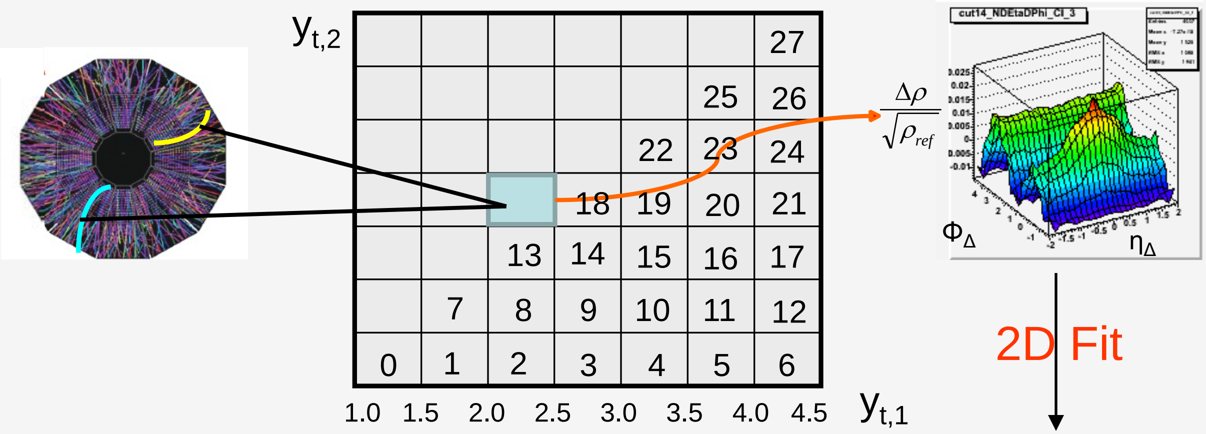
ST

arXiv:1109.4380

- How are the pairs that contribution to each of these correlation features distributed in momentum space?

- Further evidence gathered by selecting pairs from distinct momentum regions and fitting with a well studied 11 parameter fit function

Momentum dependence of angular correlation structures



$$\left.\frac{\Delta\rho}{\sqrt{\rho_{ref}}}\right|_{all,yt} \approx \sum_i \frac{N_{ref,i}}{N_{ref,tot}} \frac{\Delta\rho}{\sqrt{\rho_{ref}}}$$

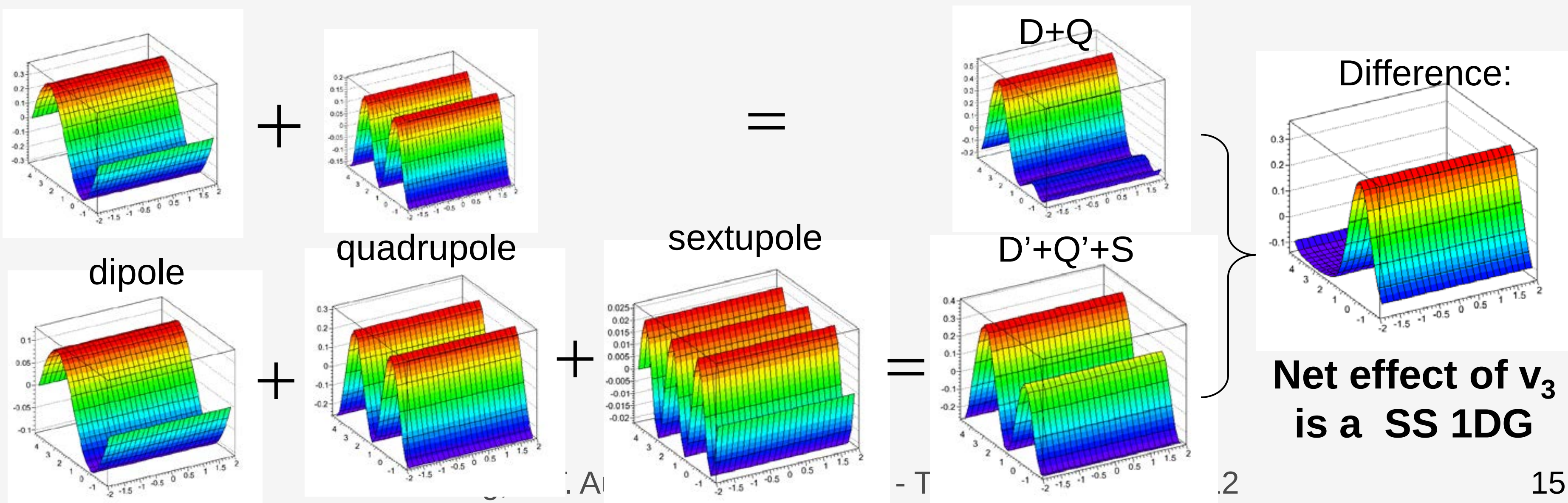
Weighting factors are applied to each cut bin to accurately compare fit values

1D Gaussian

2D Gaussian

Fitting ambiguities with higher order harmonics

- p+p and peripheral Au+Au data clearly show 4 corr structures which can be described with a choice of 4 fit model components. Each are required (otherwise the omitted structure appears in the residuals).
- With increasing centrality the fit model fails due to the development of an additional structure. Another model component is required that can describe it (we chose a quadrupole)
- The data *can* be fit with higher-order harmonics but in the absence of a clear signal in the residuals such terms are not required. Including them introduces fitting ambiguities.
  - v_3 conspires with v_1 and v_2 to fit the away-side structure which is fit equally well with just a v_1 and v_2 term.
  - v_3 on the same side is representing the η elongation of the same-side peak
  - The v_3 amplitude is not representing a required $\cos(3\Phi_\Delta)$ term and instead obscuring the interpretation of the other fit components.

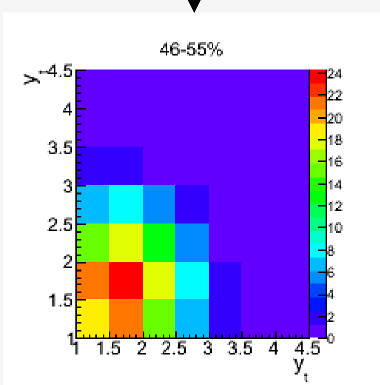


Displaying Fit Results

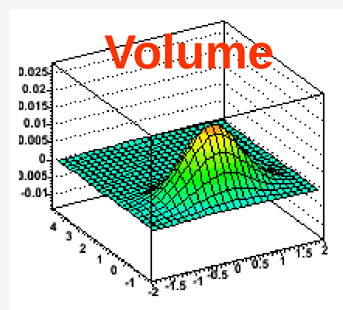
- Map back onto (y_t,y_t) space the features of interest, for example:
  - Volume of the 2D Gaussian
  - The integral of the 2D Gaussian over a range of η_Δ
  - Amplitude of the dipole, quadrupole

- Prefactor applied in order to get the number of correlated pairs in an angular correlation feature, for pairs in a (y_t,y_t) bin, per final state particle on y_t

$$\frac{1}{\sqrt{\frac{dN}{dy_{t,1,soft}}\frac{dN}{dy_{t,2,soft}}}}$$



$\times$



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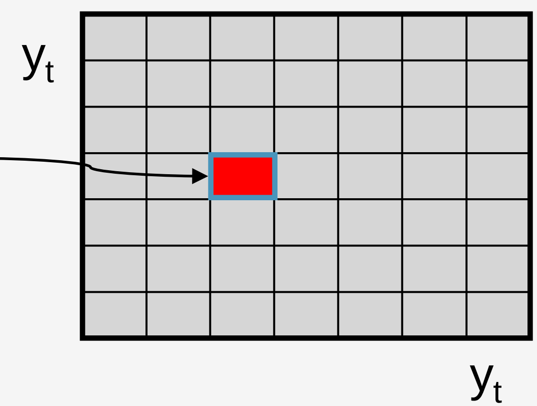
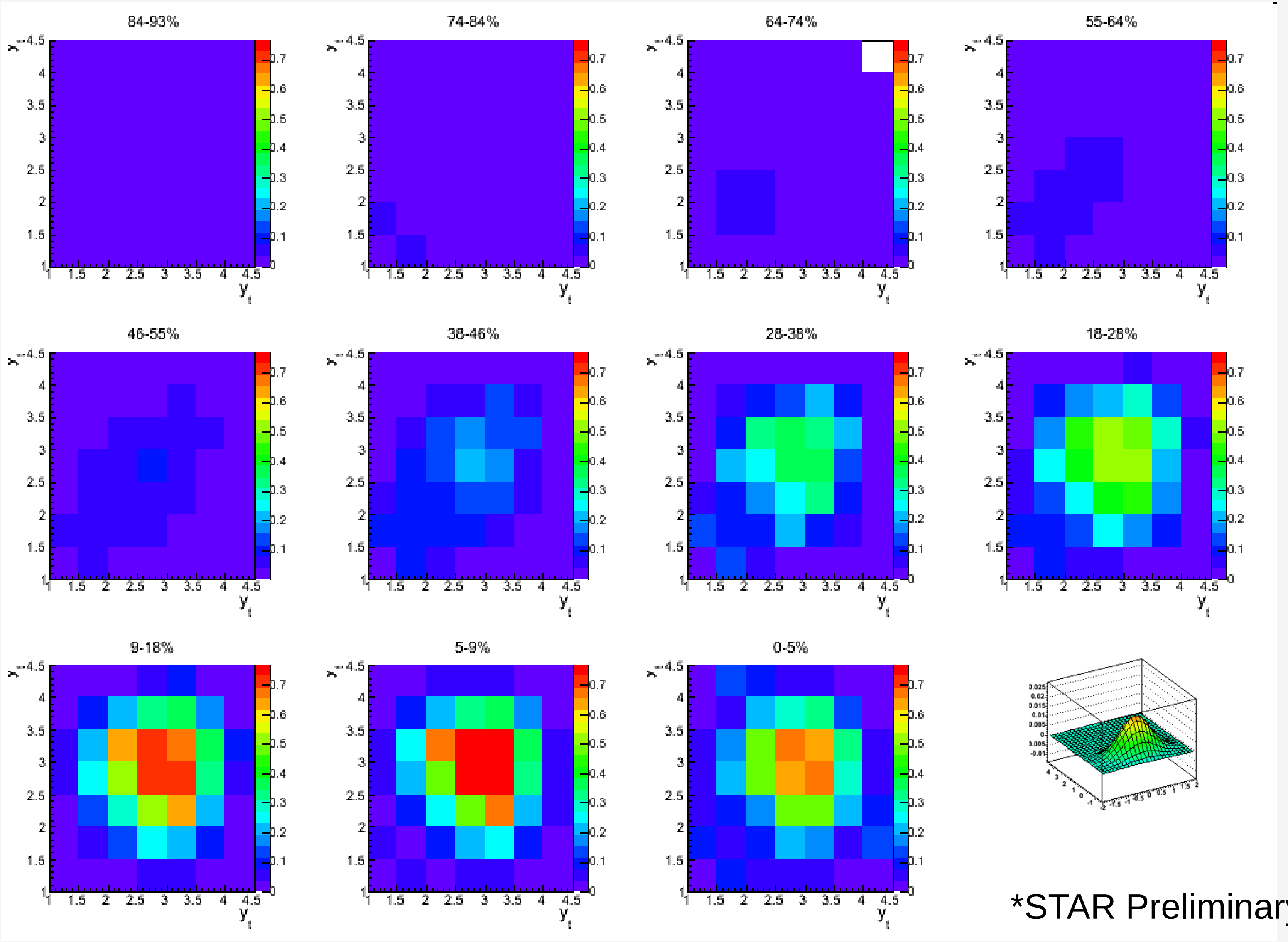


Momentum dependence of same-side peak



*STAR Preliminary

Outline:
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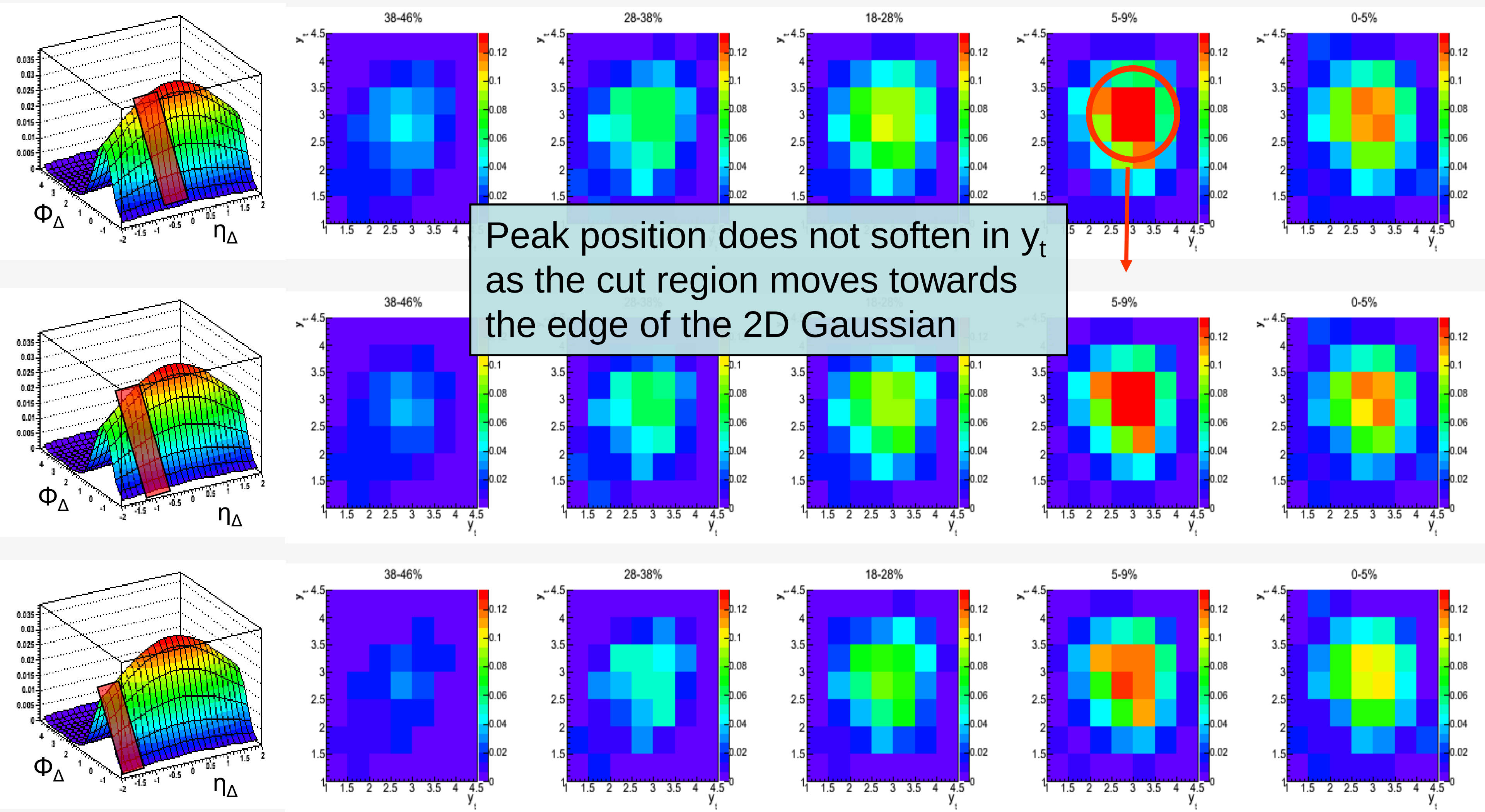
Momentum dependence of same-side peak as a function of η_Δ



Peak position does not soften in y_t as the cut region moves towards the edge of the 2D Gaussian

*STAR Preliminary

Outline:
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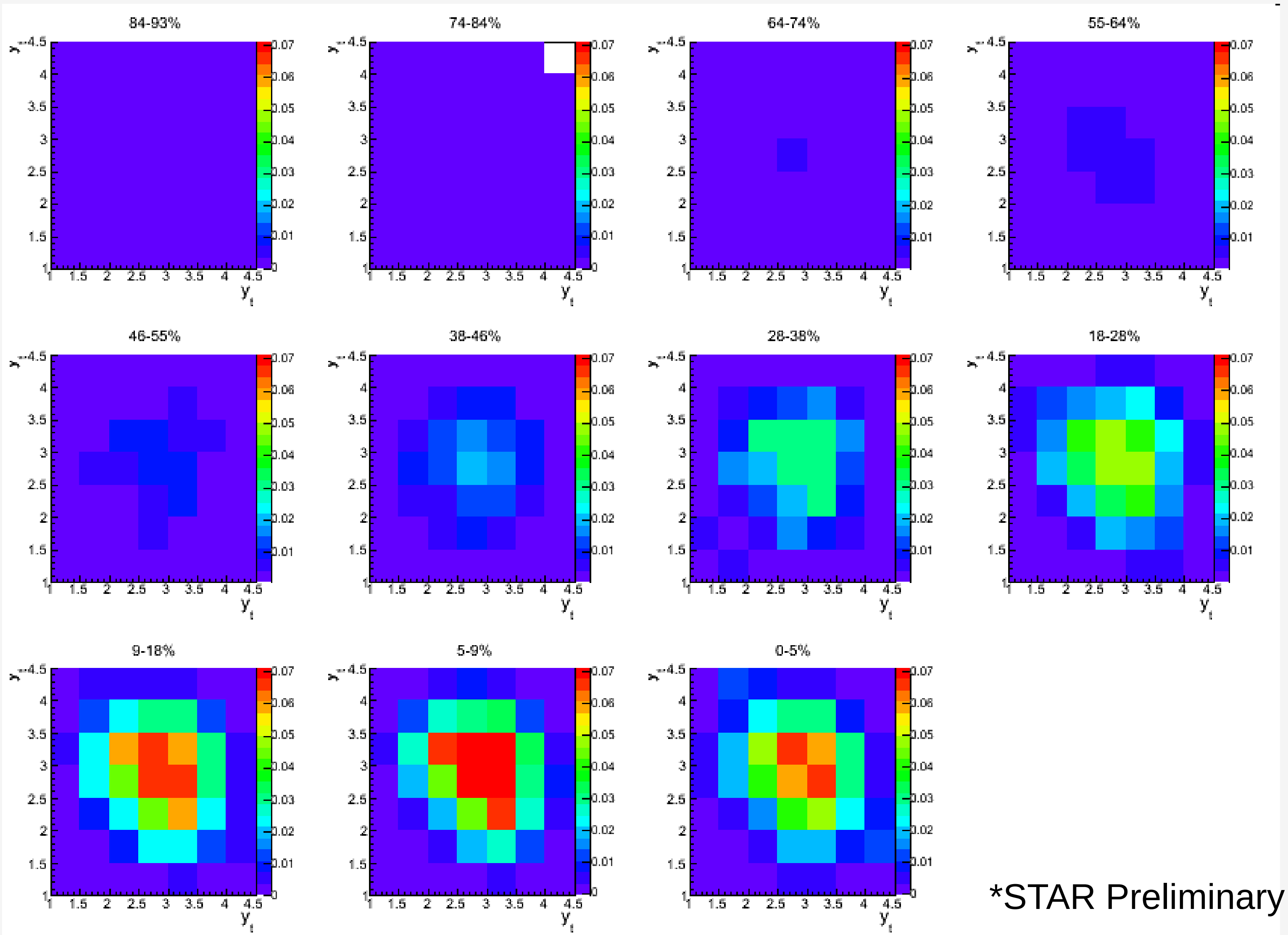
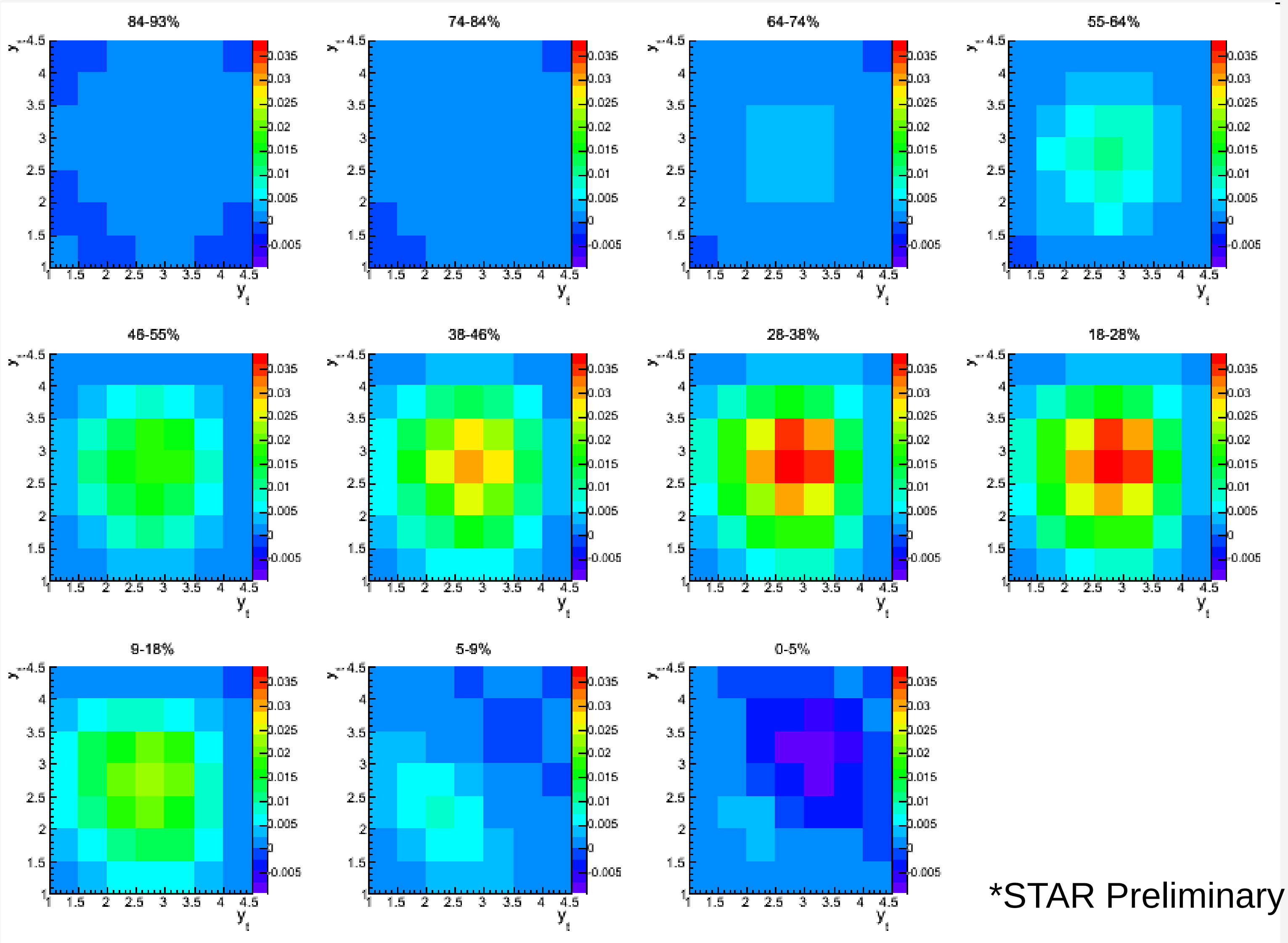
Momentum dependence of dipole



Momentum dependence of quadrupole



Ridge discussion

- The extended correlation on η_Δ, commonly referred to as the "ridge", is not comprised of softer pairs relative to the center of the 2D Gaussian peak.

- We are unable to determine if correlated pairs in the same-side structure originate from one or more physical processes.
  - Until then we should not assume that pairs beyond a certain η_Δ value are not correlated from jets

Conclusion

- Momentum correlations complete the six dimensional correlation space (p_{t1},Φ_1,η_1,p_{t2},Φ_2,η_2).
  - A broad peak is observed extending from y_t of 2-4 (0.5-4.0 GeV/c)
  - The peak position remains constant as centrality increases.
  - HIJING, which models peripheral Au+Au collisions, suggests this broad peak in ($y_{t,}$,y_t) is due to jet fragmentation.

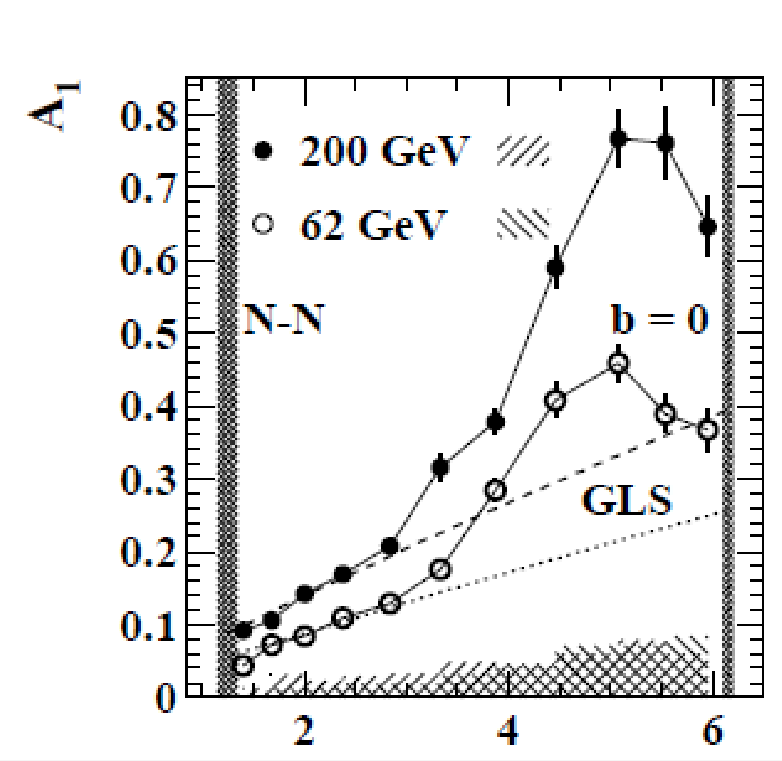
- The correlated pairs that contribute to the 2D Gaussian structure, hypothesized to be from minijets, have a momentum distribution peaked around ($y_{t,1}$,$y_{t,2}$)=(3,3) (1.4 GeV/c).

- The dipole (hypothesized to be the dijet away-side) does not soften with an increase in centrality.

- In Progress: Repeat same cut scheme but with identified particles. Study correlations of baryons vs. mesons and strange vs. non-strange particles.

Back-Up Slides

p_t integrated 2D Gaussian amplitude versus centrality



arXiv:1109.4380

arXiv:0710.4504

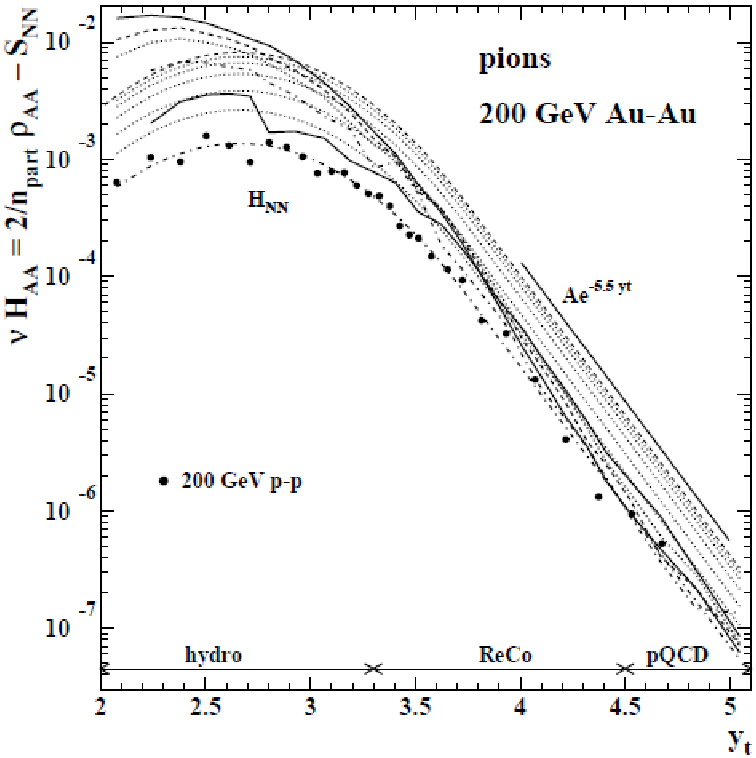


FIG. 4: The hard component of pion y_t spectra in the form νH_{AA} (thicker curves with changing line style) compared to two-component reference νH_{NN} (dotted curves). The dashed reference curves are limiting cases for $\nu = 1, 6$.

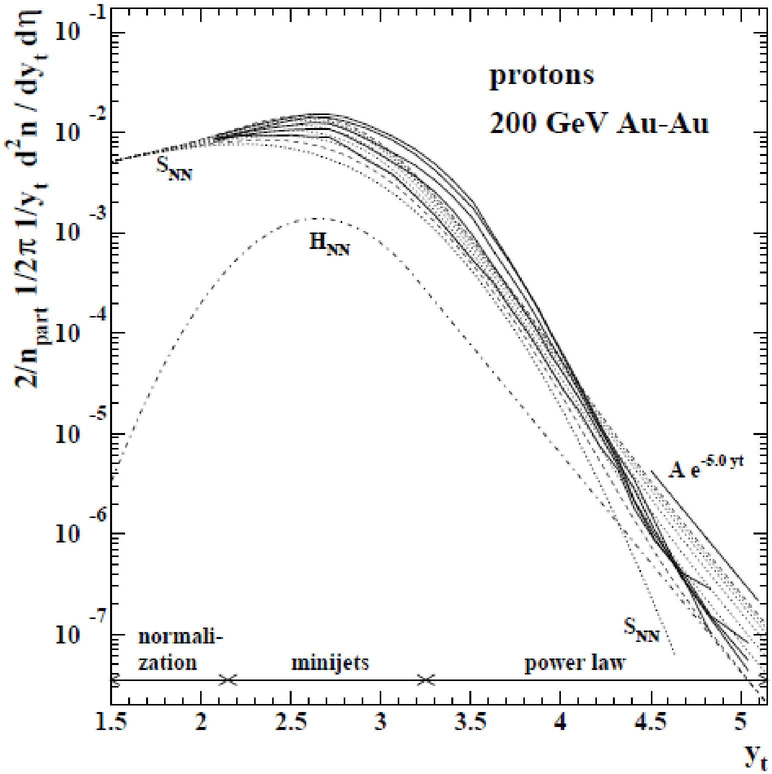


FIG. 6: Proton y_t spectra for five Au-Au centralities (solid curves). The general features are comparable to Fig. 2.

Comparing X^2 of fit model with and without sextupole

- Corresponding to slide 15
  - 9-18% Au-Au 200 GeV
    - No sextupole (standard model) X^2/dof = 3.91
    - With sextupole X^2/dof = 3.67

Details to weighted sum of (yt,yt) dependent axial correlations (slide 14)

Construct ratio of 2D histograms:

$$\frac{n_{sib}(\eta_\Delta,\phi_\Delta)}{n_{ref}(\eta_\Delta,\phi_\Delta)} = \frac{\sum_i n_{sib,i}(\eta_\Delta,\phi_\Delta)}{\sum_i n_{ref,i}(\eta_\Delta,\phi_\Delta)}$$

Ratios of 2D histograms are computed bin-by-bin

$$\frac{N_{ref}}{N_{sib}}\frac{n_{sib}(\eta_\Delta,\phi_\Delta)}{n_{ref}(\eta_\Delta,\phi_\Delta)} = \frac{N_{ref}}{N_{sib}}\frac{\sum_i n_{sib,i}(\eta_\Delta,\phi_\Delta)}{\sum_i n_{ref,i}(\eta_\Delta,\phi_\Delta)}$$

$$\frac{N_{ref}}{N_{sib}}\frac{n_{sib}(\eta_\Delta,\phi_\Delta)}{n_{ref}(\eta_\Delta,\phi_\Delta)} - 1 = \frac{N_{ref}}{N_{sib}}\frac{\sum_i n_{sib,i}(\eta_\Delta,\phi_\Delta)}{\sum_i n_{ref,i}(\eta_\Delta,\phi_\Delta)} - 1 = \frac{N_{ref}\sum_i n_{sib,i}(\eta_\Delta,\phi_\Delta) - N_{sib}\sum_i n_{ref,i}(\eta_\Delta,\phi_\Delta)}{N_{sib}\sum_i n_{ref,i}(\eta_\Delta,\phi_\Delta)}$$

$$= \frac{N_{ref}\sum_i \frac{N_{sib}}{N_{sib}}\frac{N_{sib,i}}{N_{sib,i}}\frac{N_{ref,i}}{N_{ref,i}}\frac{n_{ref,i}(\eta_\Delta,\phi_\Delta)}{n_{ref,i}(\eta_\Delta,\phi_\Delta)} n_{sib,i}(\eta_\Delta,\phi_\Delta) - N_{sib}\sum_i n_{ref,i}(\eta_\Delta,\phi_\Delta)}{N_{sib} n_{ref}(\eta_\Delta,\phi_\Delta)}$$

$$= \frac{N_{sib}\sum_i \left[n_{ref,i}(\eta_\Delta,\phi_\Delta)\left(\frac{N_{ref}}{N_{sib}}\frac{N_{sib,i}}{N_{sib,i}}\frac{N_{ref,i}}{N_{ref,i}}\frac{n_{sib,i}(\eta_\Delta,\phi_\Delta)}{n_{ref,i}(\eta_\Delta,\phi_\Delta)} - 1\right)\right]}{N_{sib} n_{ref}(\eta_\Delta,\phi_\Delta)}$$

$$= \sum_i \frac{n_{ref,i}(\eta_\Delta,\phi_\Delta)}{n_{ref}(\eta_\Delta,\phi_\Delta)}\left[\frac{N_{ref}}{N_{sib}}\frac{N_{sib,i}}{N_{ref,i}}\left(\frac{N_{ref,i}}{N_{sib,i}}\frac{n_{sib,i}(\eta_\Delta,\phi_\Delta)}{n_{ref,i}(\eta_\Delta,\phi_\Delta)}\right) - 1\right]$$

$$\sqrt{\rho'_{ref}}\left[\frac{N_{ref}}{N_{sib}}\frac{n_{sib}(\eta_\Delta,\phi_\Delta)}{n_{ref}(\eta_\Delta,\phi_\Delta)} - 1\right] \equiv \left[\frac{\Delta\rho}{\sqrt{\rho_{ref}}}\right]_{\text{All } y_t} = \sum_i \frac{n_{ref,i}(\eta_\Delta,\phi_\Delta)}{n_{ref}(\eta_\Delta,\phi_\Delta)}\sqrt{\rho'_{ref}}\left[\frac{N_{ref}}{N_{sib}}\frac{N_{sib,i}}{N_{ref,i}}\left(\frac{N_{ref,i}}{N_{sib,i}}\frac{n_{sib,i}(\eta_\Delta,\phi_\Delta)}{n_{ref,i}(\eta_\Delta,\phi_\Delta)}\right) - 1\right]$$

Exact decomposition