Measuring Histograms of the Number of Pairs of Particles, Constructing Ratios of Histograms, and the relationship to Correlations – PART 2

Lanny Ray
STAR Event Structure Physics Working Group
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OUTLINE

- Define two-particle correlations and density ratios of the number of pairs of particles.
- Describe sibling and mixed pairs of particles and number of pair densities and histograms.
- Application to transverse momentum (p_t) space.

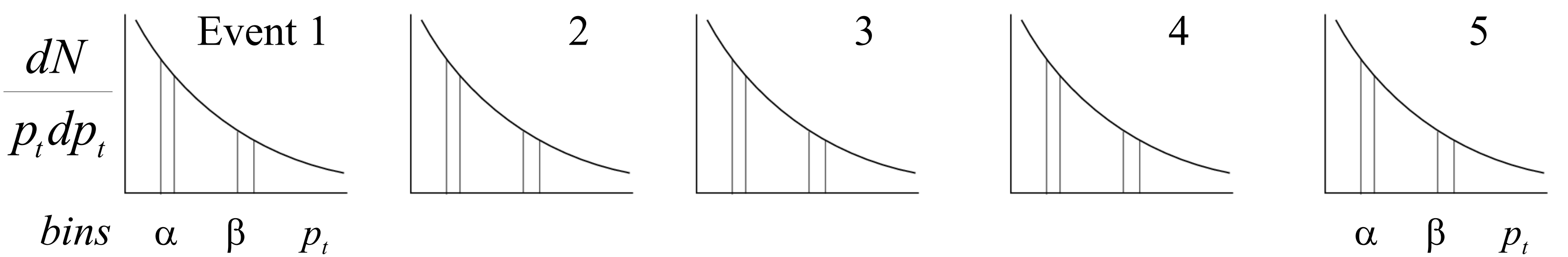
- **Technical issues including:**
  - Kinematic projections
  - Event mixing cuts
  - Two-track separation cuts
  - Small scale correlation cuts

Measuring the Ratio of Histograms of Number of Pairs of Particles:
Projections onto Transverse momentum (p_t) space

Rather than projecting onto relative coordinates as in Tutorial 2 we may instead construct ***two-point correlations*** which are two-dimensional projections using one momentum component of each particle in the pair.

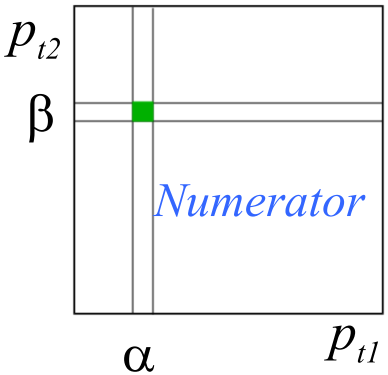
For example, consider the pair of transverse momentum components (p_{t1},p_{t2}) for arbitrary particles 1 and 2 from the same event. Including all such pairs from all events in the subset of Z_{vertex},N_{ch} events populates a two-dimensional histogram on p_{t1} versus p_{t2}.

A much more computationally efficient way to sum the number of pairs in each two-dimensional p_{t1} *vs* p_{t2} bin is to compute, event-by-event, the product of the number of particles in the appropriate pair of bins of the one-dimensional p_t distributions. Consider the p_t distributions of 5 typical events and arbitrary bins α and β on p_t (same α,β bins used for all events):

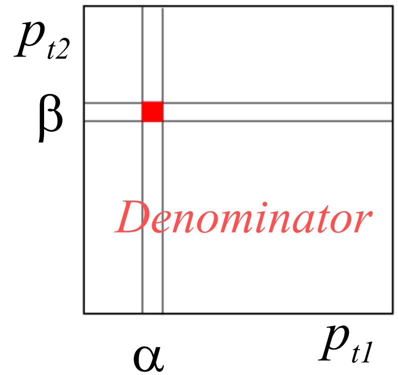


Projections onto Transverse momentum (p_t) space (continued):

Determine the number of sibling-pairs in two-dimensional bin (α,β) from the *same* event; repeat for all events.



Determine the number of mixed-event pairs in bin (α,β) for one pair of similar, but *different* events; repeat for all pairs of similar but different events.

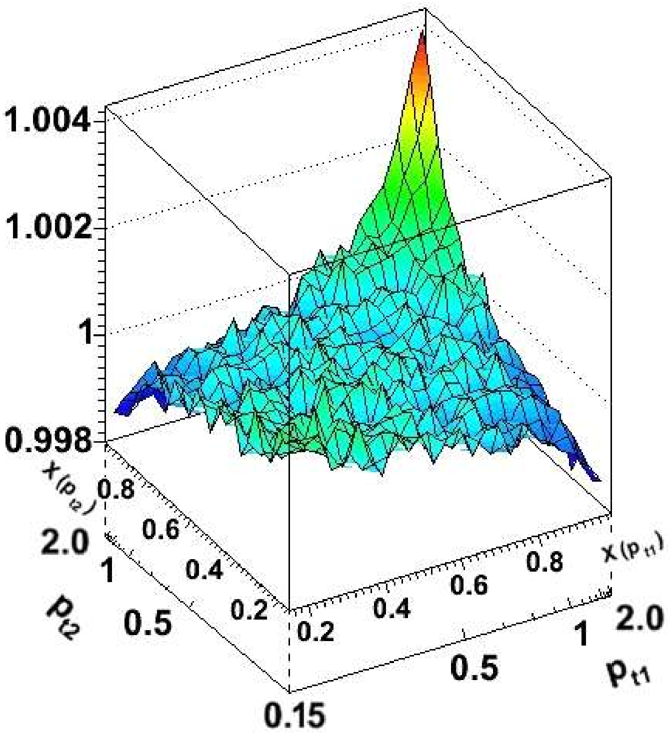


The two-dimensional bin populations of the number of pairs of particles are obtained as the product of (# particles in bin-α) x (# particles in bin-β). When α=β the correct number of sibling pairs, n(n-1), is used. When summed over all similar events in each Z_{vertex},N_{ch} subset, and summed over all similar event subsets in the centrality bin, and normalized as described in Tutorial 2, the numerator to denominator ratio yields the Ratio of Histograms of Number of Pairs of Particles, or the **Pair Number Histogram Ratio**

Construct the Ratio

Sum numerator and denominator over all events in all Z_{vertex}, N_{ch} subsets, divide, and normalize using total number of sibling and mixed event pairs as described on slide 6 of Tutorial 2.

Differences from 1.0 indicate correlations.



STAR data for 130 GeV Au-Au central collisions

We can do this for measures other than multiplicity, *e.g.* p_t, $\langle p_t \rangle$, E, net charge, ...

Summary of event and track selection criteria:

Event Selection:

- Primary vertex $|z| < 75$ cm; $|x|,|y| < 1$ cm (for year 1 data)
- Centrality assignment based on number of primary tracks at mid-rapidity, usually for $|\eta| < 0.5$.
- Subsets of similar events for constructing mixed-event pairs of particles are required to have primary vertex z coordinates within 7.5 cm and multiplicities in the acceptance within 50.

Track Selection:

- iflag > 0 ("good" tracks)
- Number of hits used in fit > 10
- Ratio of number of hits used to maximum number of hits expected > 0.51
- Distance of closest approach (DCA) to primary vertex < 3 cm.
- Acceptance typically $0.15 < p_t < 2$ GeV/c, $|\eta| < 1.3$, full 2π azimuth

Summary of two-track selection and cuts:

The purpose of these cuts is to remove mixed-event pairs of particles from the uncorrelated reference in a manner which simulates two-track detection inefficiency in the TPC for sibling pairs of particles.

The following cuts are applied to *both* sibling and mixed-event pairs of particles, which approximately removes two-track detection inefficiency artifacts from the reported ratios and correlations.

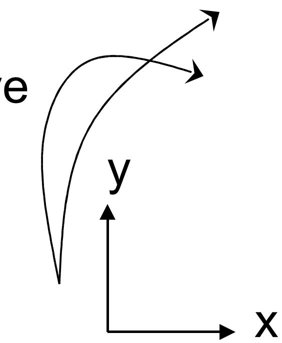
Magnitudes of the cut parameters are based both on studies of two-track inefficiency in the TPC as well as the stability of the resulting pair number histogram ratio. This procedure is the same one used in HBT analyses.

Summary of two-track selection and cuts (continued)**:**

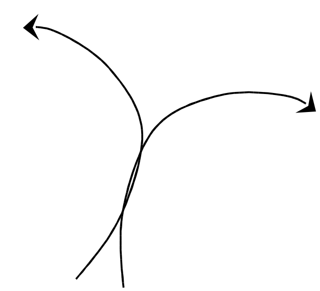
- Split tracks are removed by requiring nhits/nmax > 0.51.

- Like-charge-sign two-track merging cut: compute two-track separation distances in the TPC at 9 radii from 50 cm (entrance), to 200 cm (exit) and remove the pair if the average of these 9 separation distances is < 10 cm. Apply this cut to both sibling and mixed event pairs.

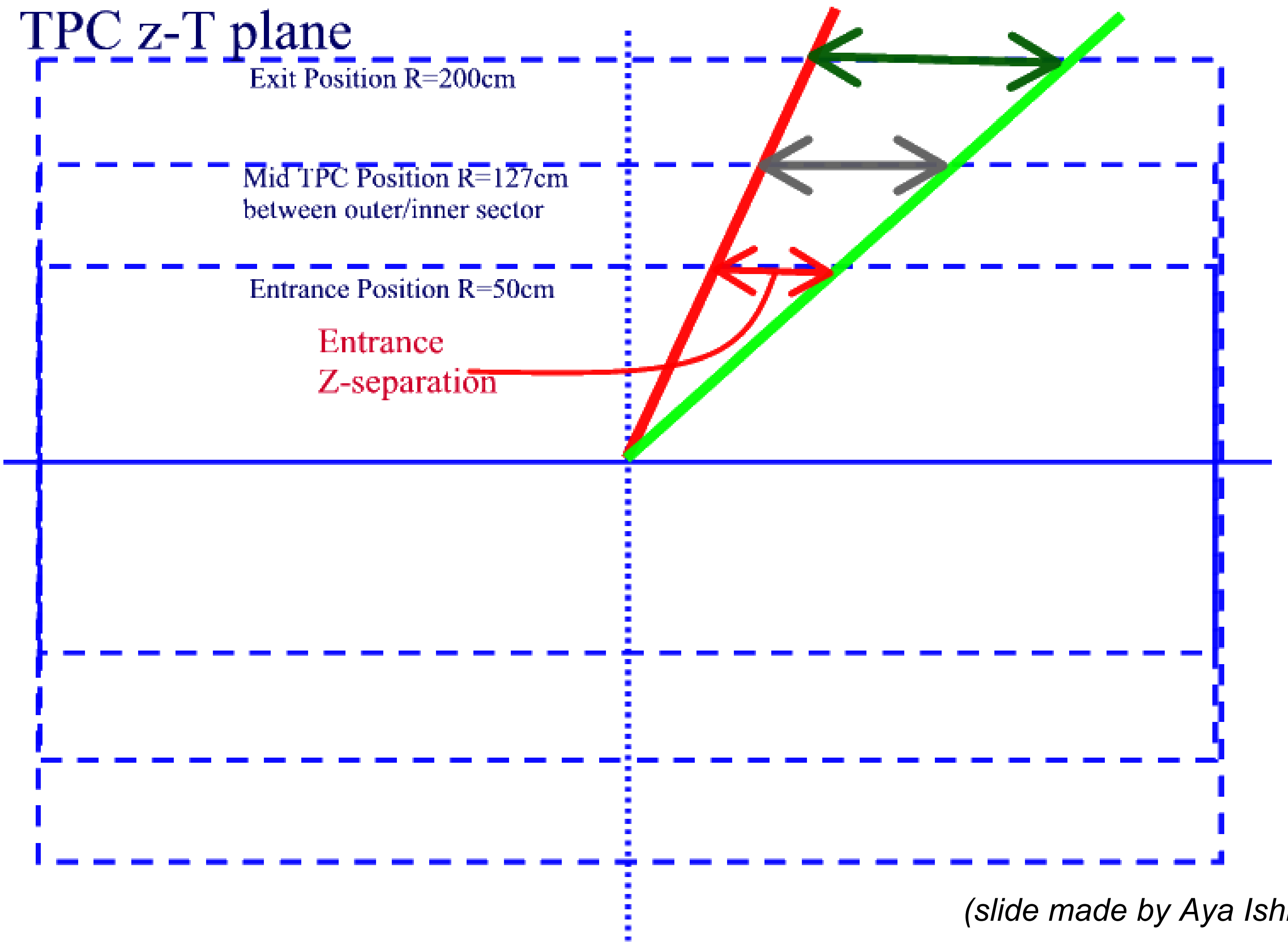
- Like-charge-sign two-track crossing cut: compute two-track separation distance at the mid-TPC radius (127 cm) and remove crossed pairs of tracks (see adjacent diagram) with x-y separation distance (see diagram on next slide) < 30 cm **and** longitudinal (z-axis) separation distance (see diagram on the slide after next) < 10 cm.



- Unlike-charge-sign two-track crossing cut: same as preceding cut except for pairs of opposite sign charged particles which cross inside the TPC as indicated in the adjacent diagram.

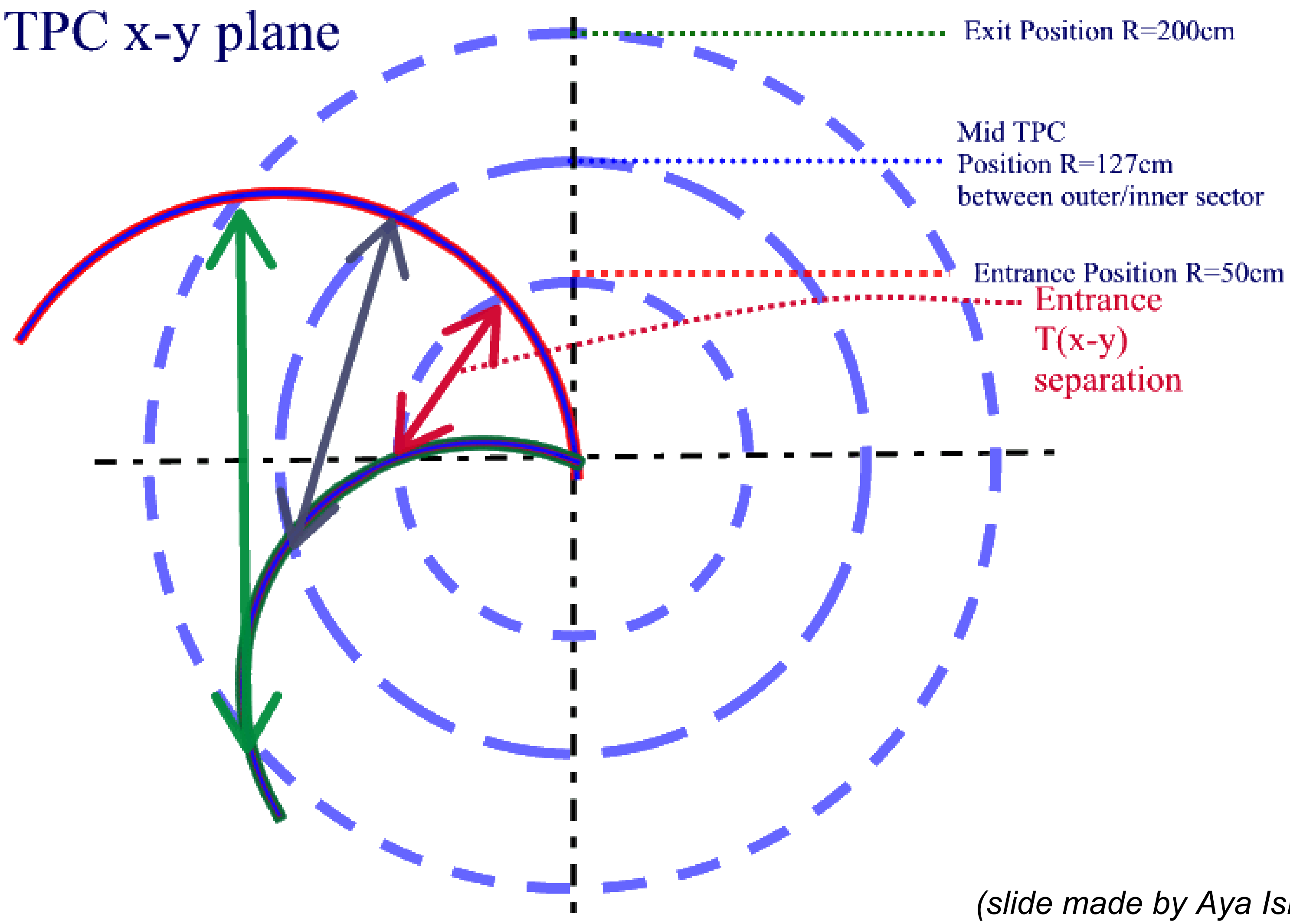


Longitudinal (beam axis or z-axis) separation distance between points where particle trajectories (helix assumed) intercept cylinders of varying radii:



(slide made by Aya Ishihara)

x-y separation distance between points where particle trajectories intercept cylinders of varying radii:

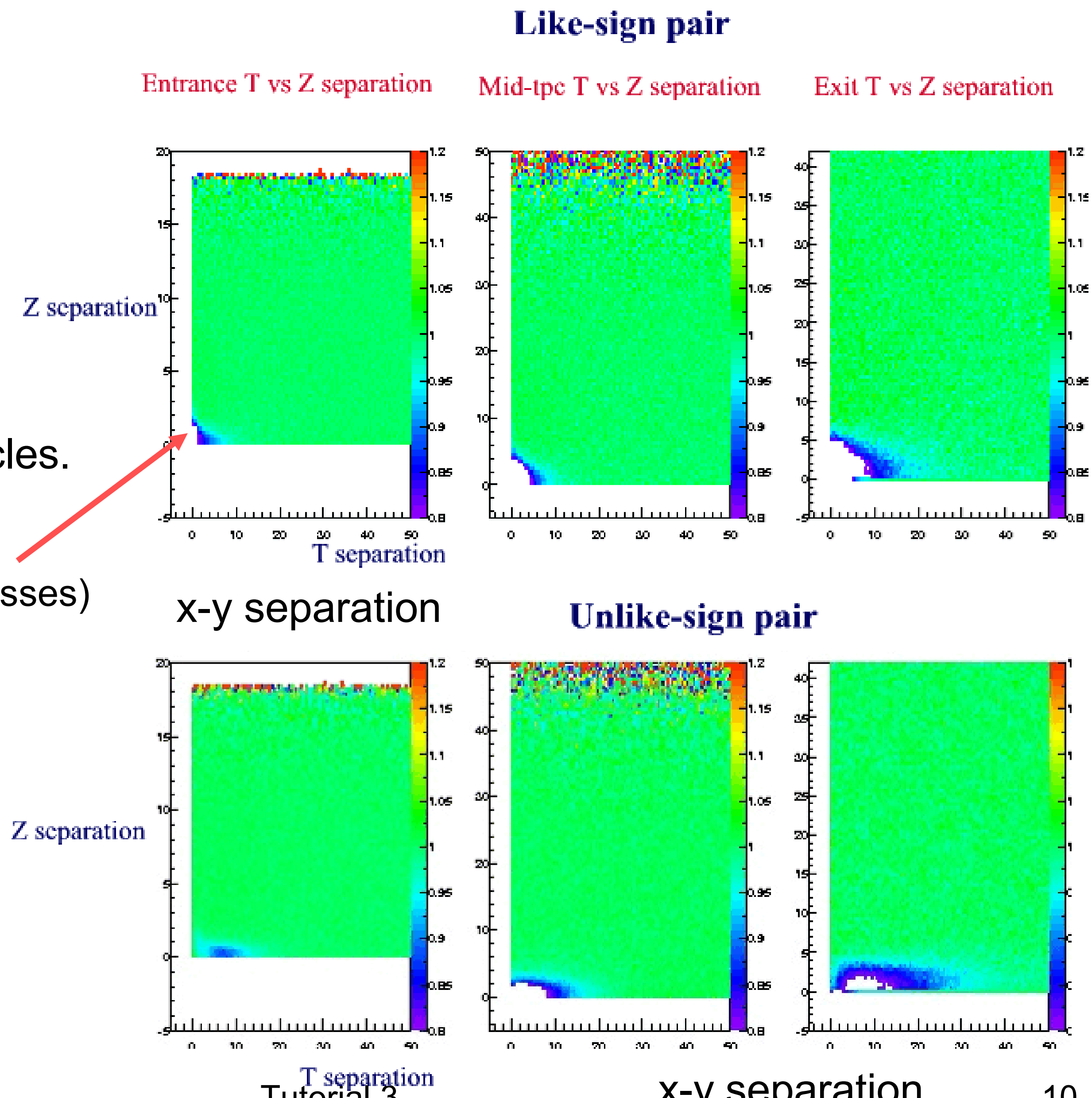


(slide made by Aya Ishihara)

Summary of two-track selection and cuts (continued):

The magnitudes (cm) of the two-track separation distance cuts are based on these and other, similar studies of two-track inefficiencies in the TPC for like and unlike sign pairs of particles.

(blue-white regions indicate two-track losses)



Summary of two-track selection and cuts (continued):

Another purpose for the two-track cuts is to remove pairs of sibling particles which are affected by quantum correlations and Coulomb interactions. The cuts are based on the STAR HBT analysis results and simulations. The following cuts are applied to *both* sibling and mixed-event pairs of particles.

For *charge-independent* correlations (includes both quantum and Coulomb correlations):

- Reject pairs with $|\eta_\Delta| < 0.3$ **and** $|\phi_\Delta| < \pi/6$ **and** $|p_{t1}-p_{t2}| < 0.15$ GeV/c when either p_{t1} or p_{t2} is less than 0.8 GeV/c.

For *charge-dependent* correlations (*i.e.* pairs of like-sign charges minus pairs of unlike-sign charges; primarily includes Coulomb correlations):

- Reject pairs with $|\eta_\Delta| < 1$ **and** $|\phi_\Delta| < 1$ **and** $|p_{t1}-p_{t2}| < 0.2$ GeV/c when either p_{t1} or p_{t2} is less than 0.8 GeV/c.

Application of these methods in STAR papers:

- “**Transverse momentum correlations and minijet dissipation in Au-Au collisions at sqrt(sNN) = 130 GeV,**”
  Submitted August 11, 2004
  e-Print Archives (nucl-ex/0408012)