Non-identical particle correlations in STAR as a probe of emission asymmetries and radial flow

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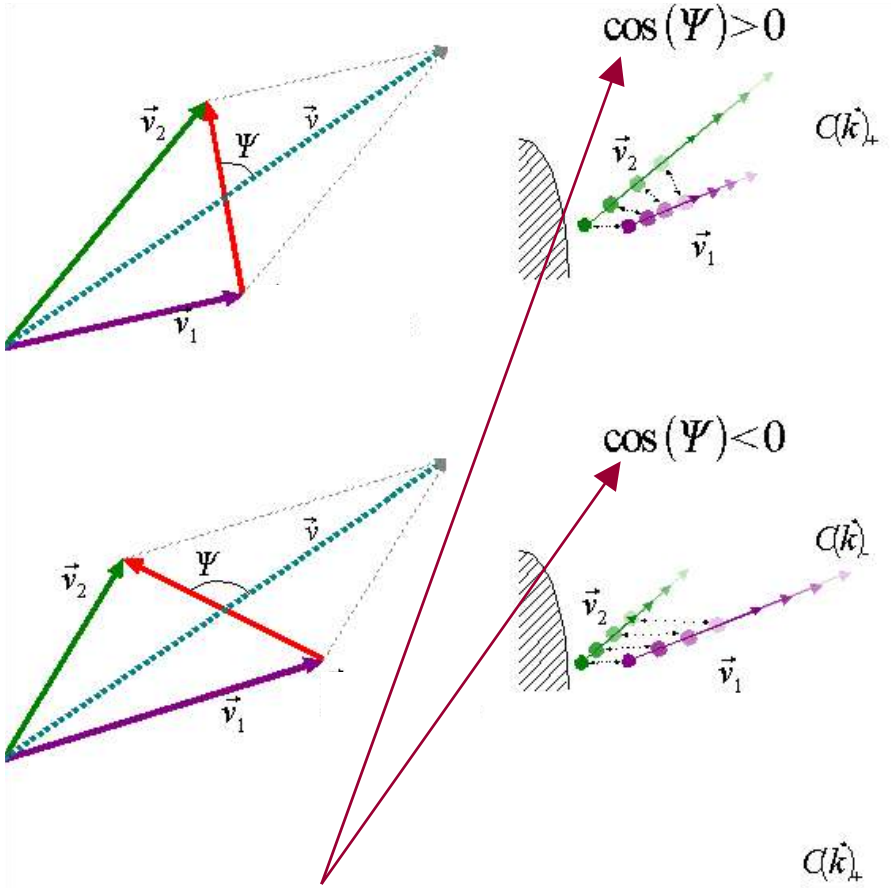
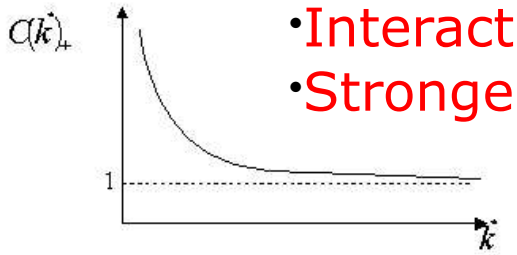
Outline

- Non-identical particle correlations
  - Measuring emission asymmetry
  - Connection to flow
- Data analysis at STAR
  - Pion-Kaon
  - Pion-Proton
  - Preliminary Kaon-Proton
- Fitting procedure
- Modeling emission asymmetry
  - Blast-wave – the flow baseline
  - Rescattering models
  - Comparing with data
- Summary

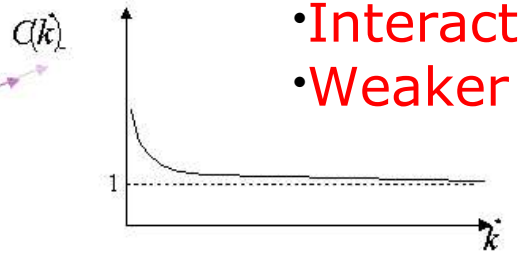
The asymmetry analysis





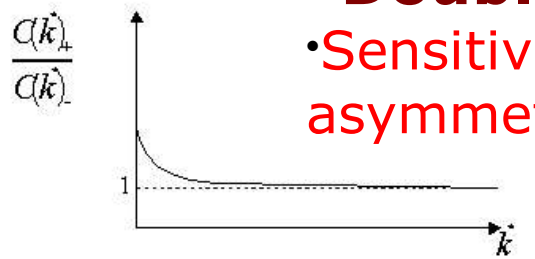
Catching up

- Interaction time larger
- Stronger correlation



Moving away

- Interaction time smaller
- Weaker correlation



"Double" ratio

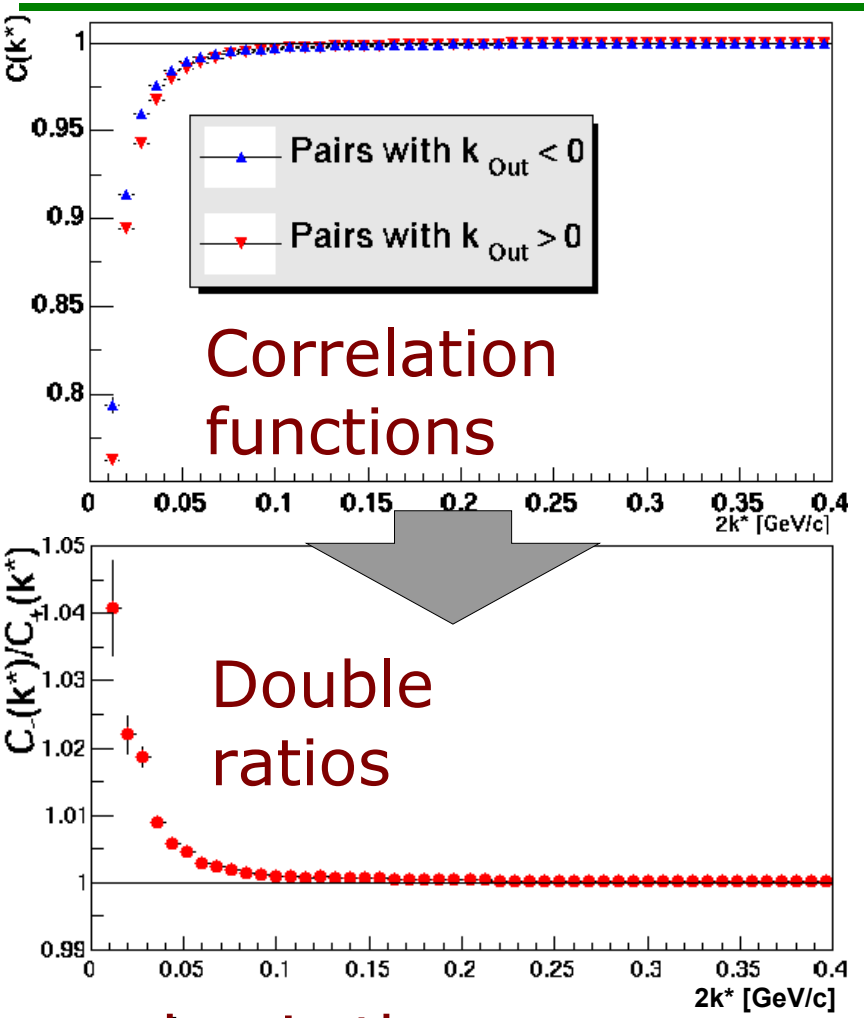
- Sensitive to the space-time asymmetry in the emission process

R.Lednicky, V. L.Lyuboshitz, B.Erazmus, D.Nouais, Phys.Lett. B373 (1996) 30.

Kinematics selection on any variable

e.g. k_{Out}, k_{Side}, cos(v,k)

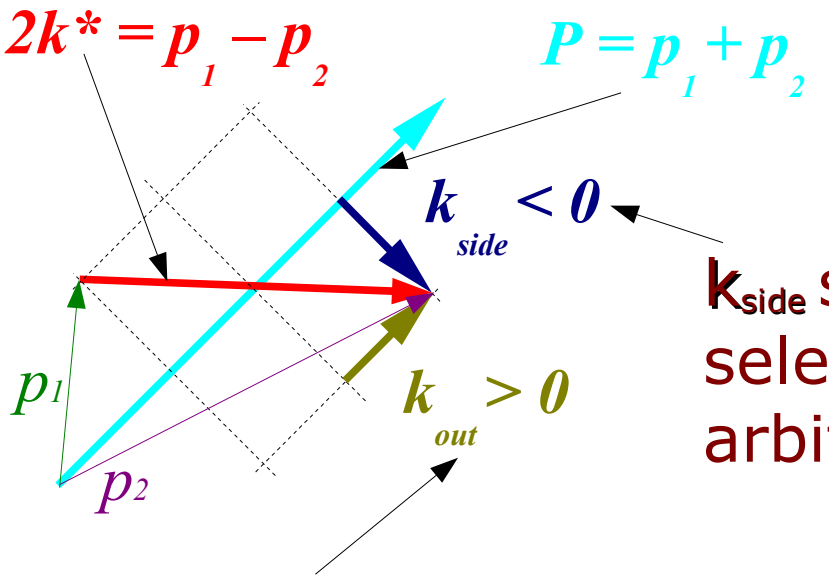
Double ratio definitions



Correlation functions

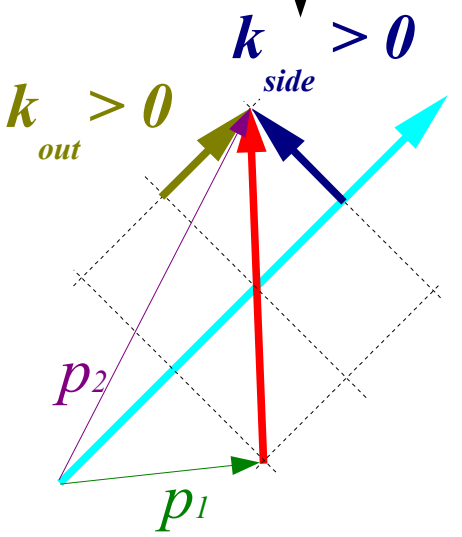
Double ratios

k_{long} is the z component of the momentum of first particle in LCMS



k_{side} sign selection arbitrary

k_{out} sign selection determined by the direction of the pair momentum *P*



What to expect from double ratios

- Initial separation in Pair Rest Frame (measured) can come from time shift and/or space shift in Source Frame (what we want to obtain)

$$\langle \Delta x^{*} \rangle = \langle \Delta x \rangle + v_T \langle \Delta t \rangle$$

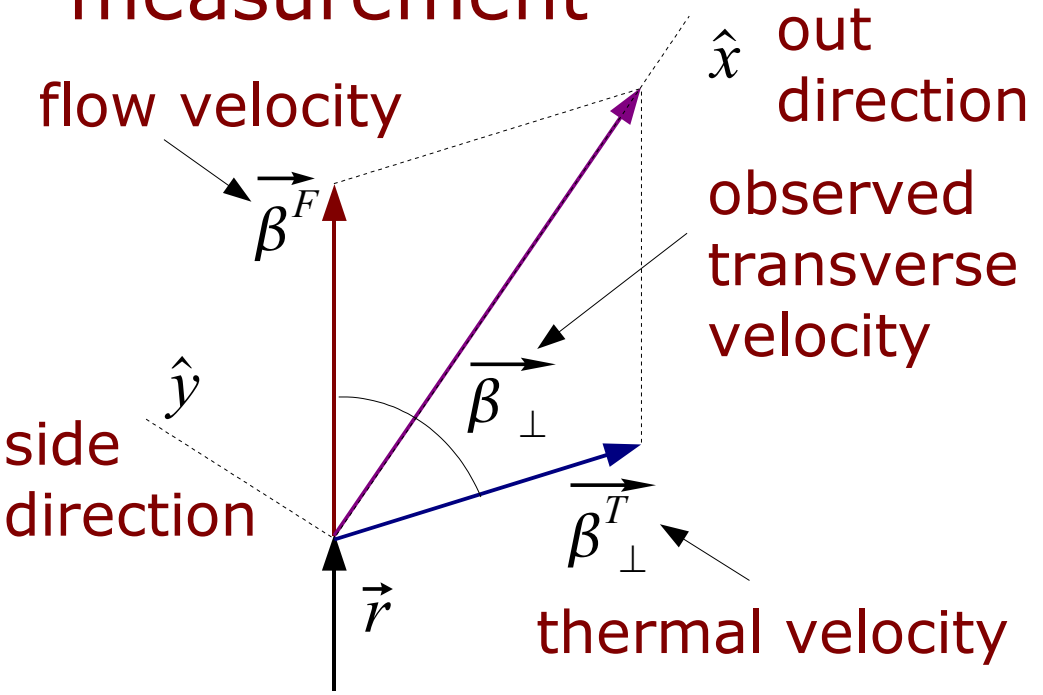
$$\langle x \rangle \equiv \langle \vec{r} \cdot \hat{x} \rangle \approx \langle r \frac{\beta^F + \beta^T_{\perp} \cos(\phi)}{\beta_{\perp}} \rangle$$

$$\approx \langle r \frac{\beta^F}{(\beta^{F2} + \beta^{T\,2}_{\perp})^{1/2}} \rangle$$

$$\langle y \rangle = \langle \vec{r} \cdot \hat{y} \rangle = \langle r \frac{\beta^T_{\perp} \sin(\phi)}{\beta_{\perp}} \rangle = 0$$

$$\langle z \rangle = \langle \tau_S \sinh(y_S) \rangle \approx \langle \sinh(y_S) \rangle \langle \tau_S \rangle = 0$$

- We are directly sensitive to time shift, the space shift arises from radial flow – possibility of a new radial flow measurement

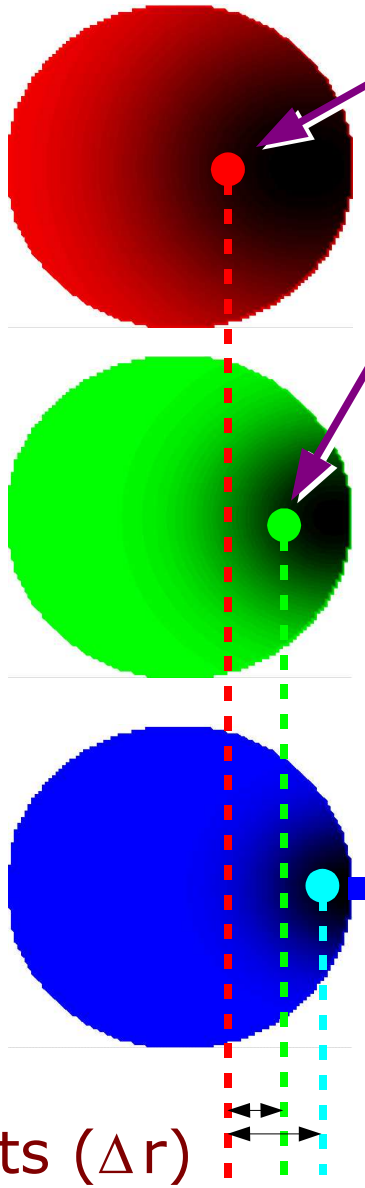


Blast wave: a flow model

Pion
$p_t = 0.15$ GeV/c
$\beta_t = 0.73$

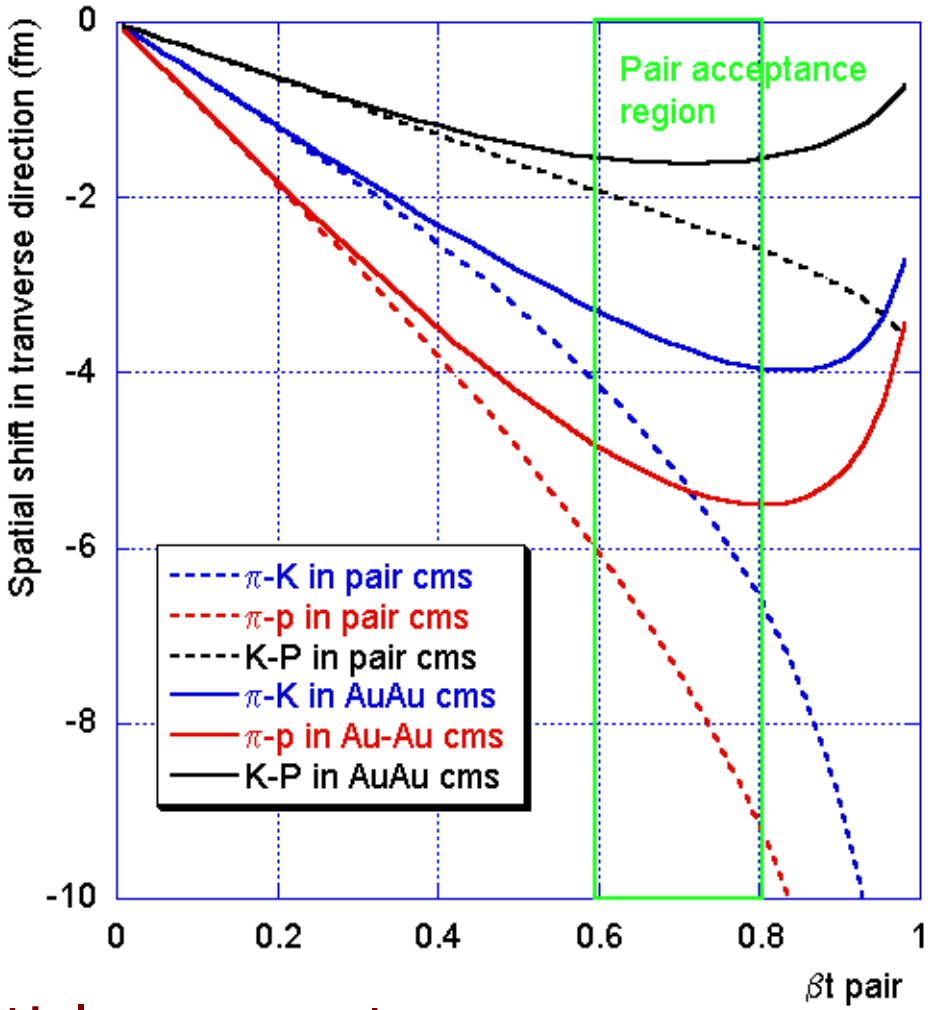
Kaon
$p_t = 0.5$ GeV/c
$\beta_t = 0.71$

Proton
$p_t = 1.$ GeV/c
$\beta_t = 0.73$



Average emission points

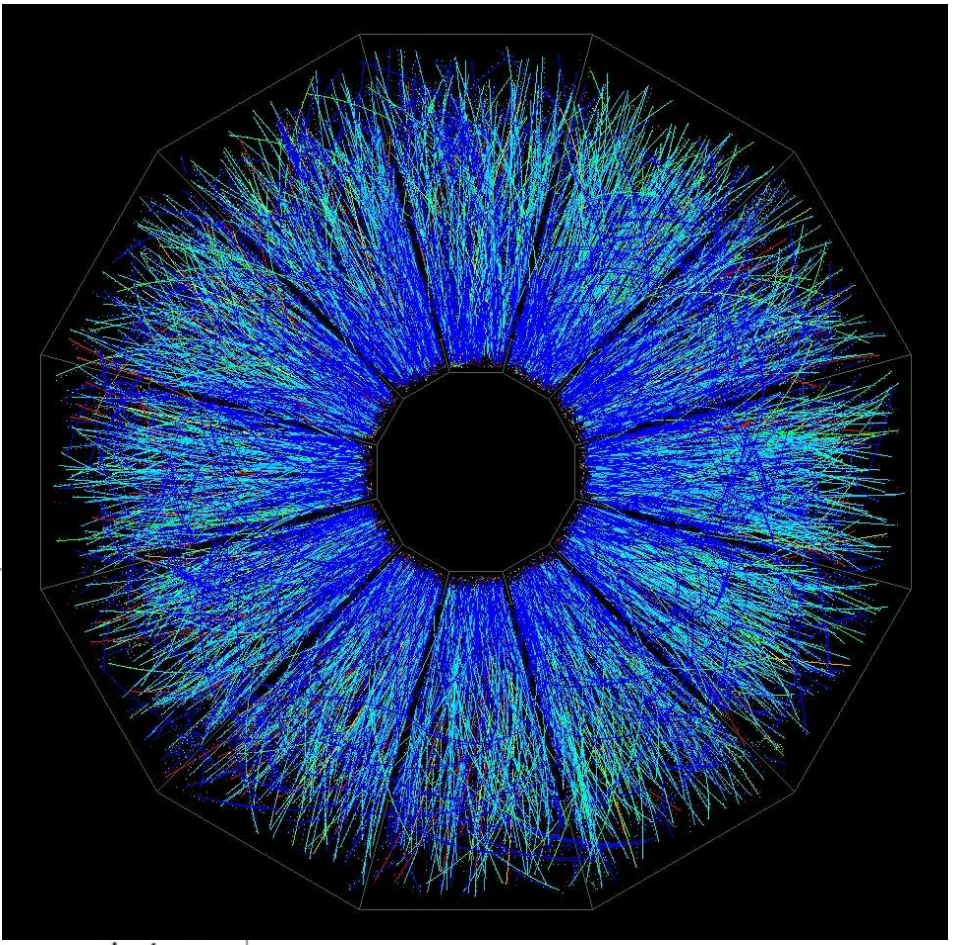
Spatial shifts (Δr)

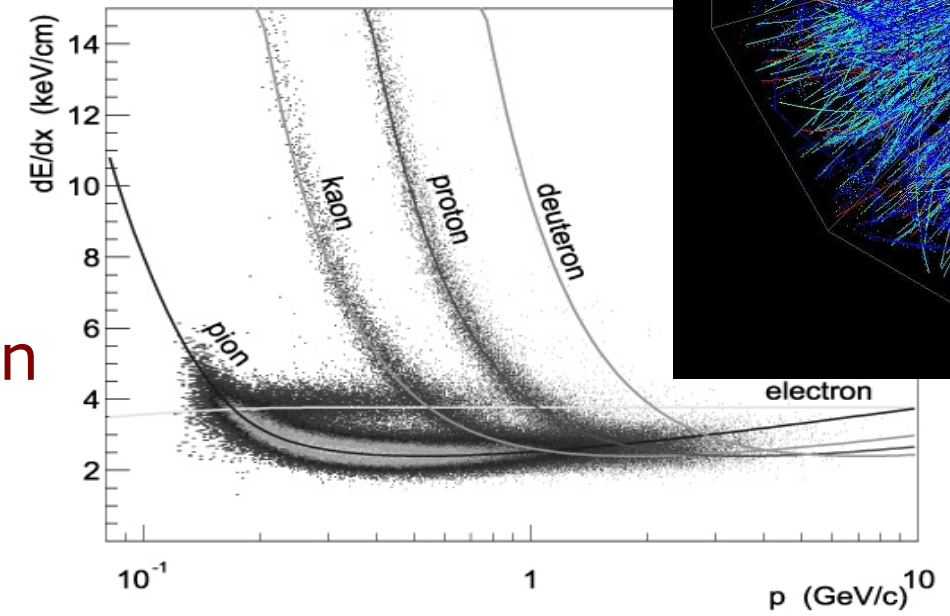


Particle momentum

Non-identical particle correlations at STAR

- We present data from Year1 – 130 AGeV
- Central events – 13% of total cross-section
- Mid-rapidity particles from the TPC (|y| < 0.5)
- Particles identified by the dE/dx information



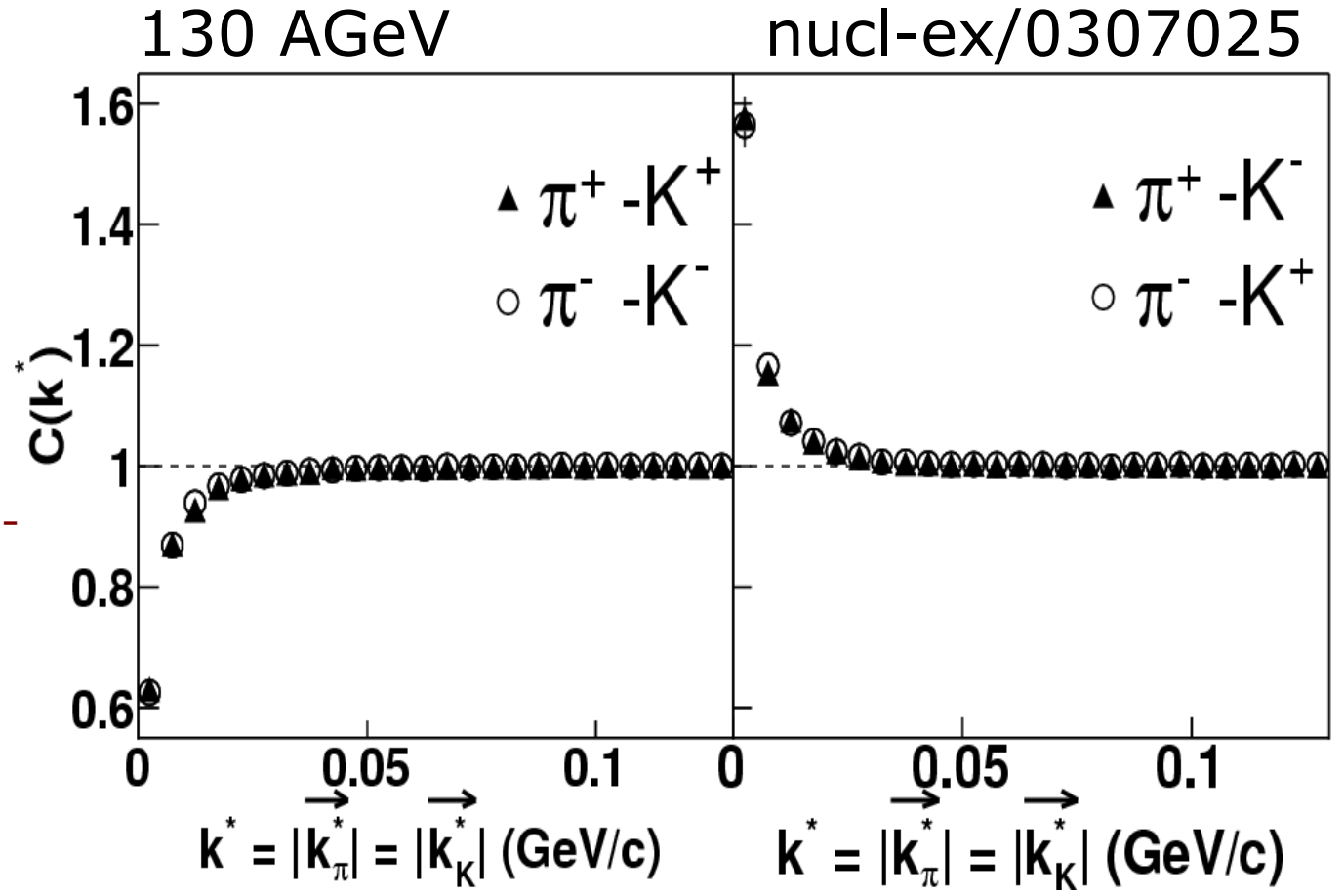


Technical Issues

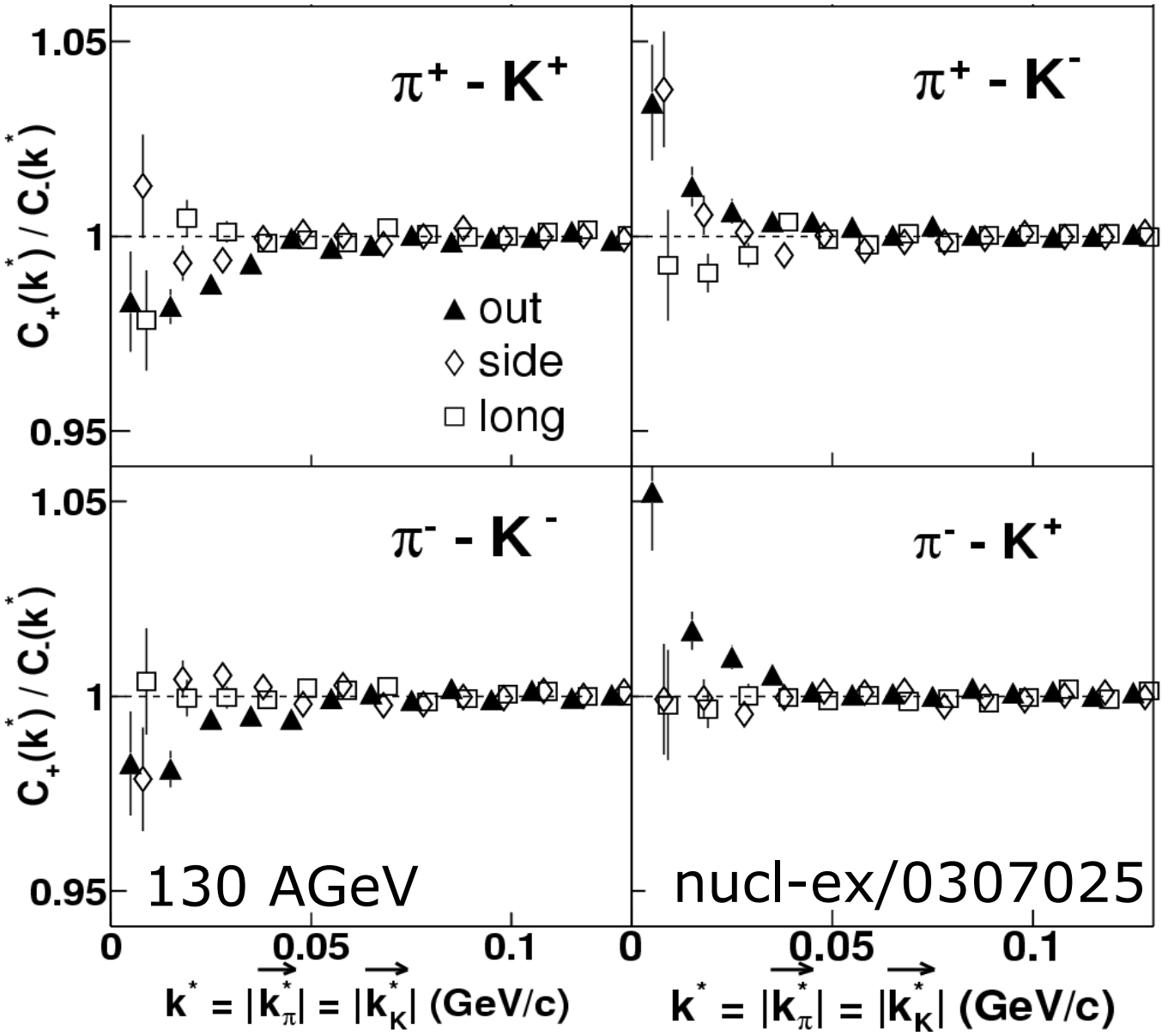
- Particle purity must be carefully studied
- We use dE/dx PID probability
  - Pair cuts: π-K or π-P pair probability > 0.6
  - Removal of correlated pairs from γ decay: probability of e^+e^- < 0.01
- Detector issues corrections
  - Two-track effects:
    - elimination of tracks with possible shared hits in the TPC
  - Particle purity
    - PID probability for kaons
    - PID probabilty + estimation of weak decay products for pions
  - Momentum resolution

Correlation functions

- The correlation functions are dominated by Coulomb – identical for the same charge combinations
- The agreement within the charge combination points to a very similar K^+ and K^- emission mechanism



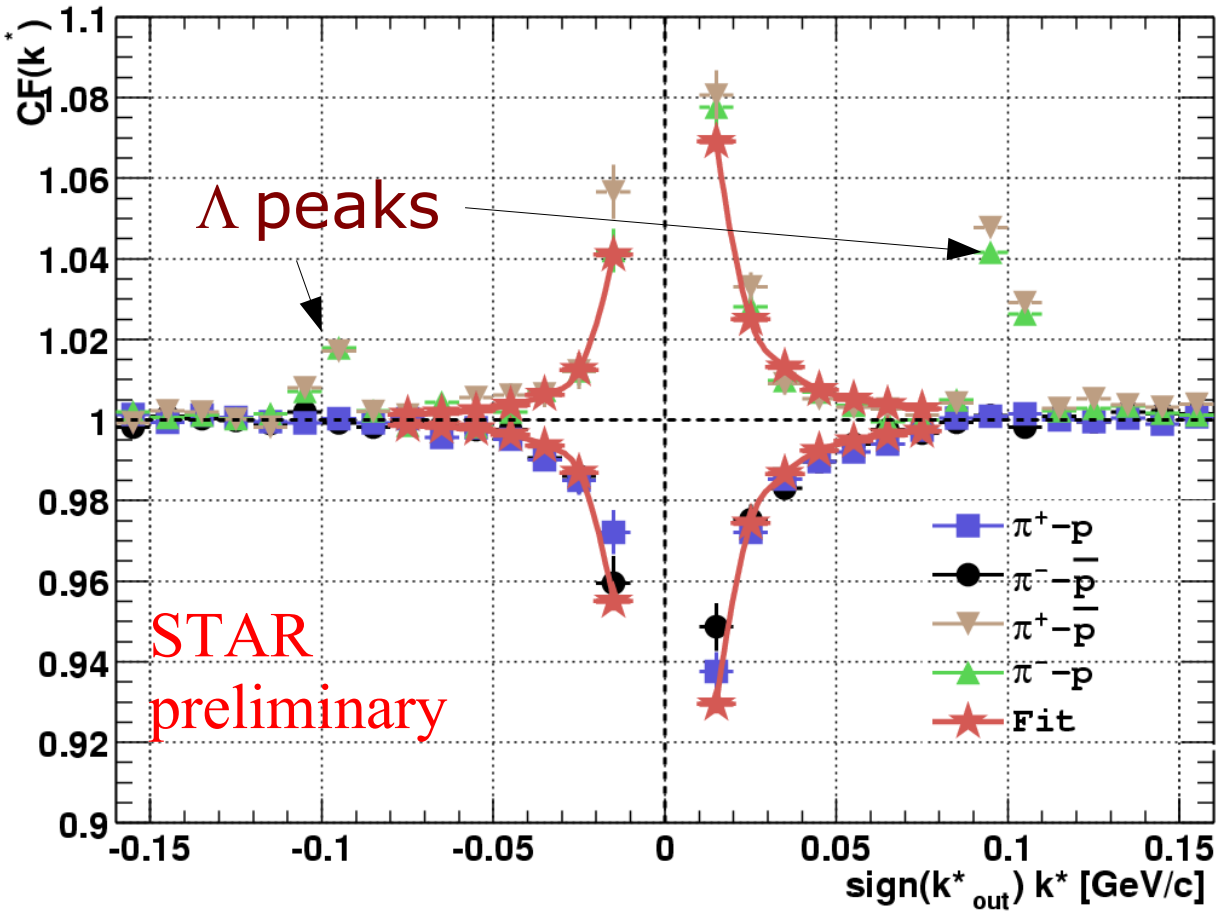
Double ratios



- Clear deviation from unity for Out – sign of asymmetry
- Side and Long – flat as expected (cross-check)

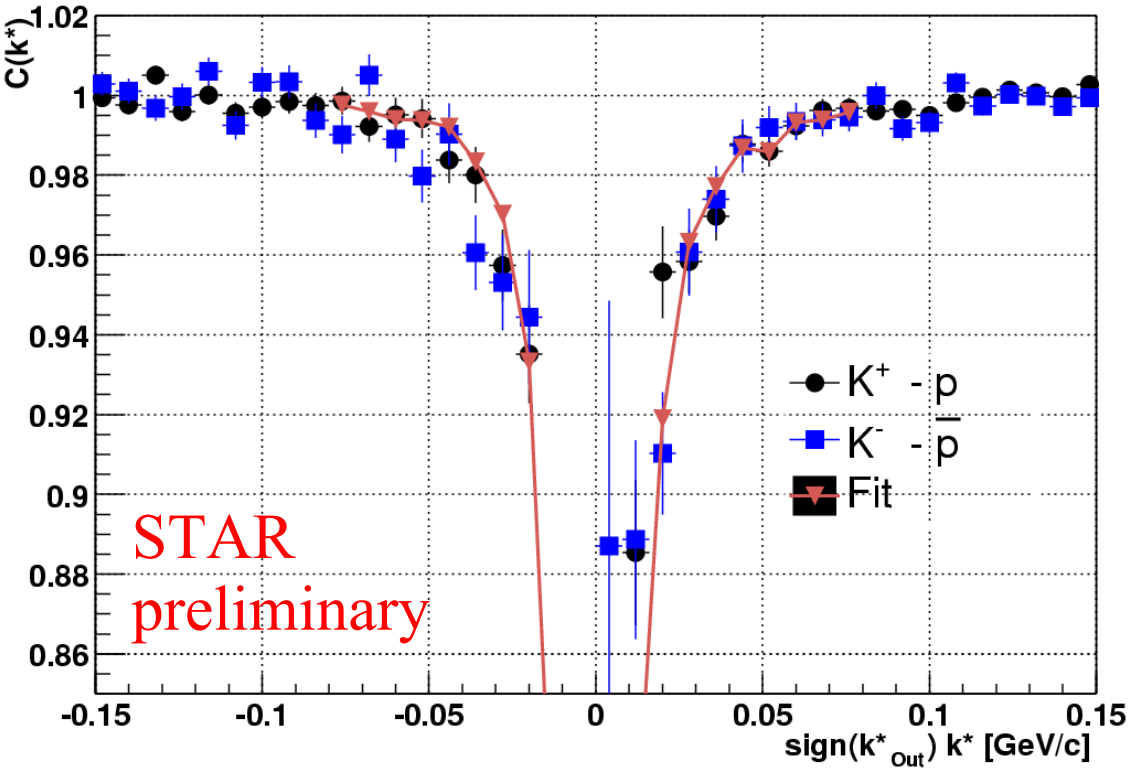
Results for Pion-Proton

- Similar preliminary analysis done for pion-proton
- We observe Lambda peaks at $k^* \sim m_{inv}$ of Λ
- Good agreement for identical and non-identical charge combinations



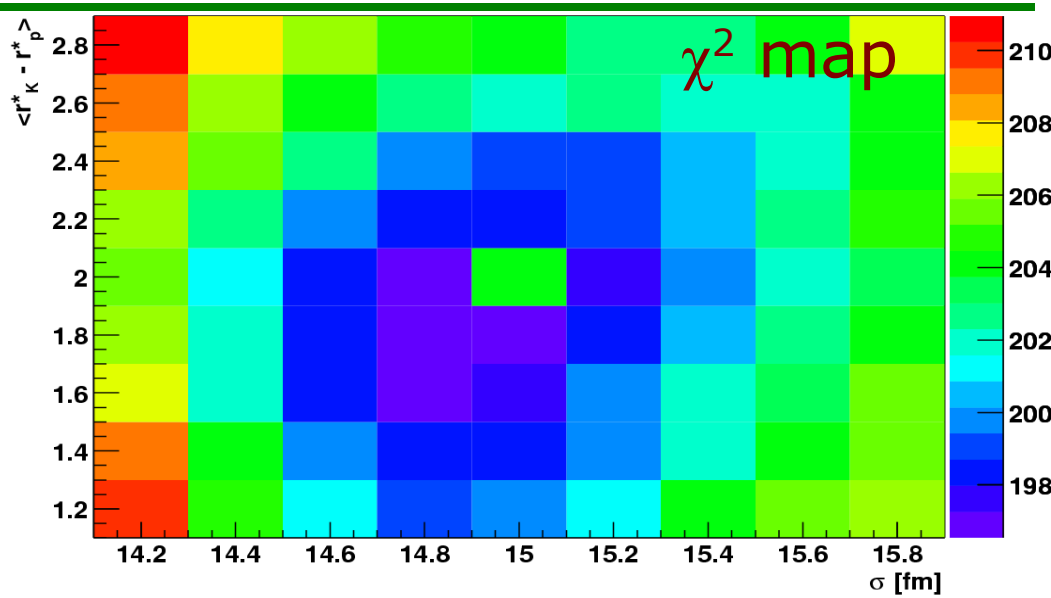
Preliminary results for Kaon-Proton

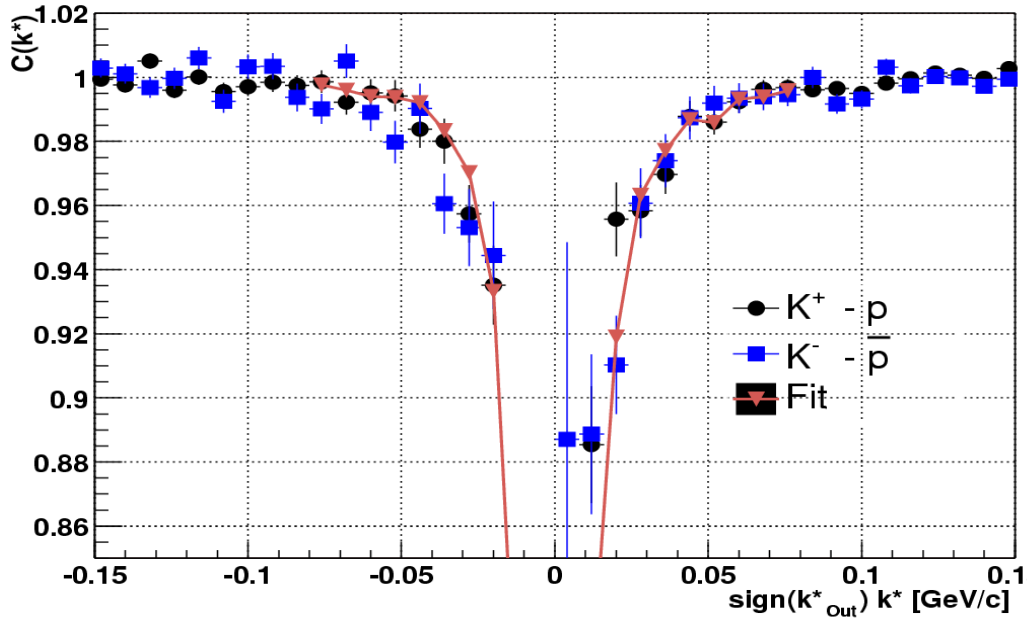
- Using data from Year2 (200 AGeV) – sufficient statistics
- No corrections for purity and/or momentum resolution done
- No error estimation yet – fit indicates theoretical expectations



Fitting procedure

- No analytic form of correlation function
- Need to generate correlation functions using experimental momentum distributions, Monte-Carlo methods and Lednicky's pair weights
- Best fit parameters are taken at the minimum χ^2 value





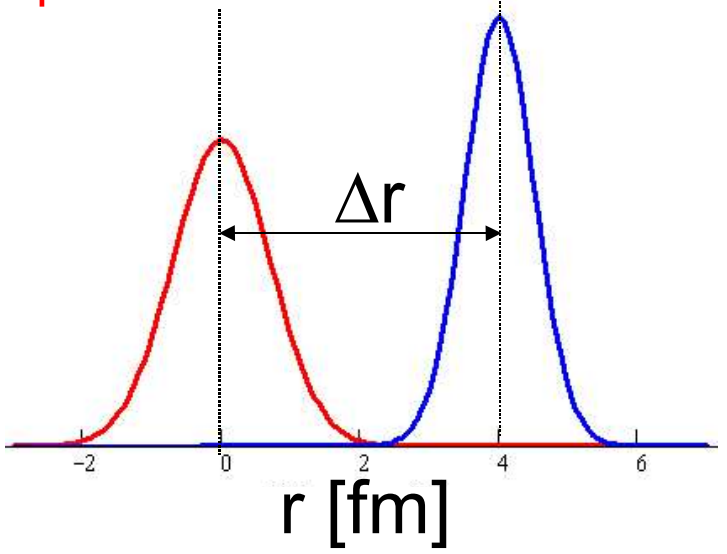
Modeling the emission asymmetry

- Need models producing strong transverse radial flow:
  - Blast-wave as a baseline
  - RQMD
  - UrQMD
  - T. Humanic's rescattering model
- What do we measure and how to compare it to the models?
- Is our fitting method working? And if yes, what does it tell us?
- Need to disentangle flow and time shift

1D relativistic view
What can be probed?

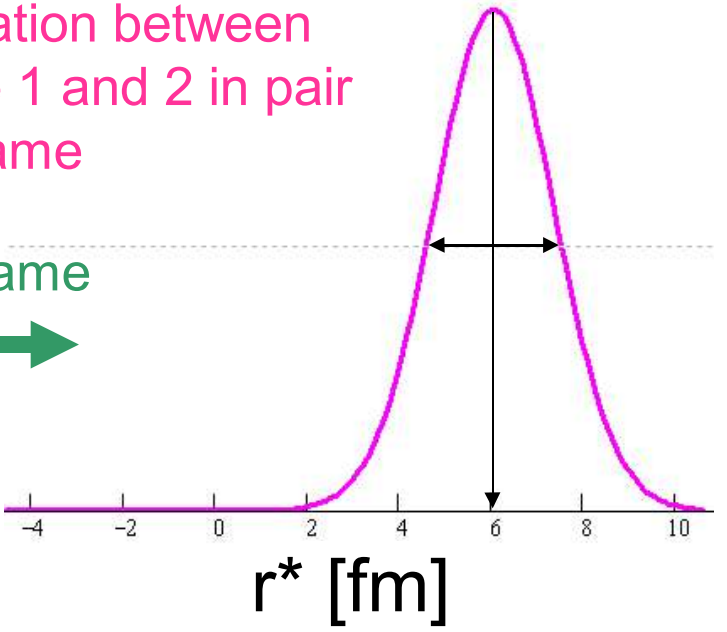
Source of particle 1

Source of particle 2



Boost to pair rest frame

Separation between source 1 and 2 in pair rest frame



$\Delta r^* = \gamma_{pair} (\Delta r - \beta_{pair} \Delta t)$

Δr^* separation in pair rest frame

Function of $\gamma_{pair}(\beta_{pair})$ which depend on the pair acceptance

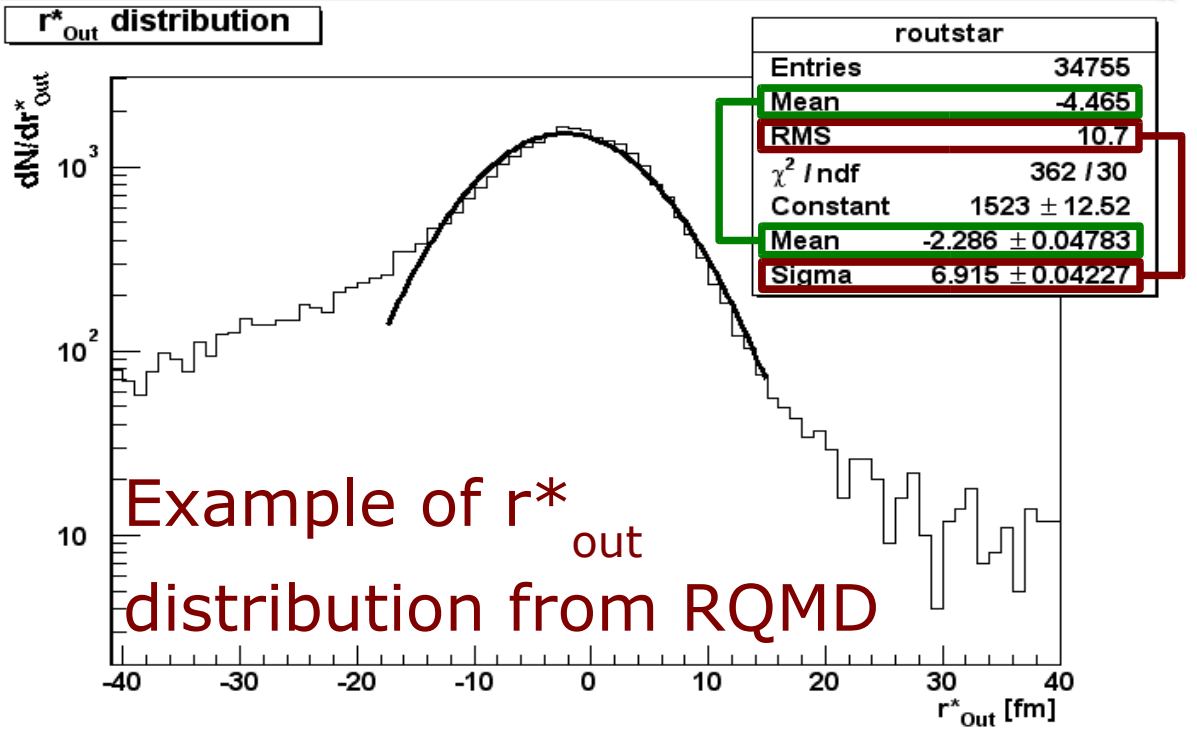
2 parameters
- Mean shift ($<\Delta r^*>$)
- Sigma (σ_{r^*})

Fitting and quantitative comparisons

- Fits assume gaussian source in PRF
- r^*_{out} distributions have non-gaussian tails
- Use the same fitting procedure for models and data - correlation functions constructed with "Lednicky's weights"

nucl-ex/0307025

	σ (fm)	$\langle \Delta r^*_{out} \rangle$ (fm)	χ^2 / dof
Data	$12.5 \pm 0.4^{+2.2}_{-3}$	$-5.6 \pm 0.6^{+1.9}_{-1.3}$	134.5/110
RQMD	11.8 ± 0.4	-8.0 ± 0.6	205/54
RQMD no rescattering	5.8 ± 0.1	-2.0 ± 0.3	940/54
BWP	9.9 ± 0.1	-6.9 ± 0.3	1020/118



Example of r^*_{out} distribution from RQMD

Do we see time shifts, spatial shifts, or both?

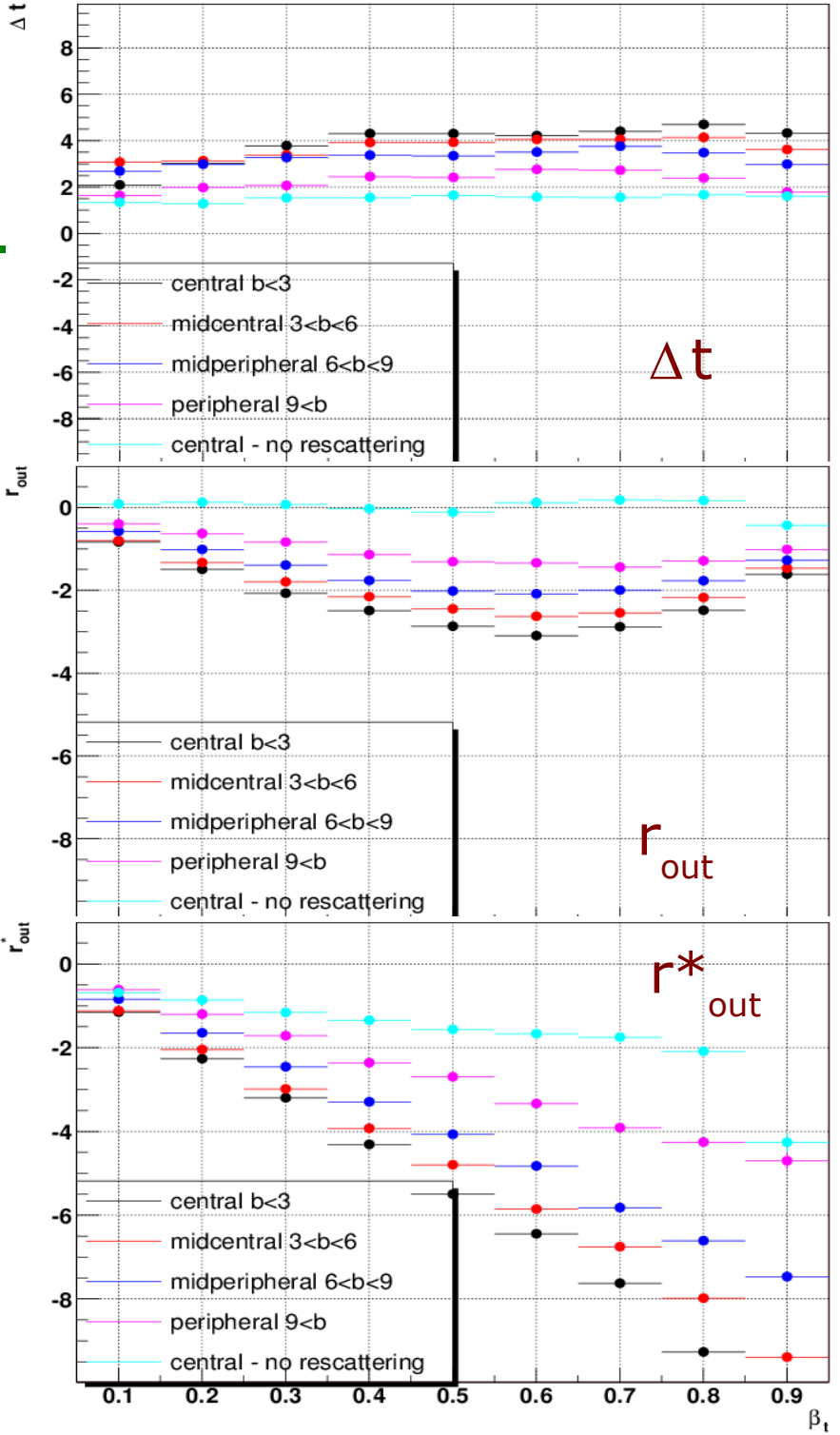
The general formula:

$$\Delta r^* = \gamma_{pair} (\Delta r - \beta_{pair} \Delta t)$$

r_{out} is a measure of flow

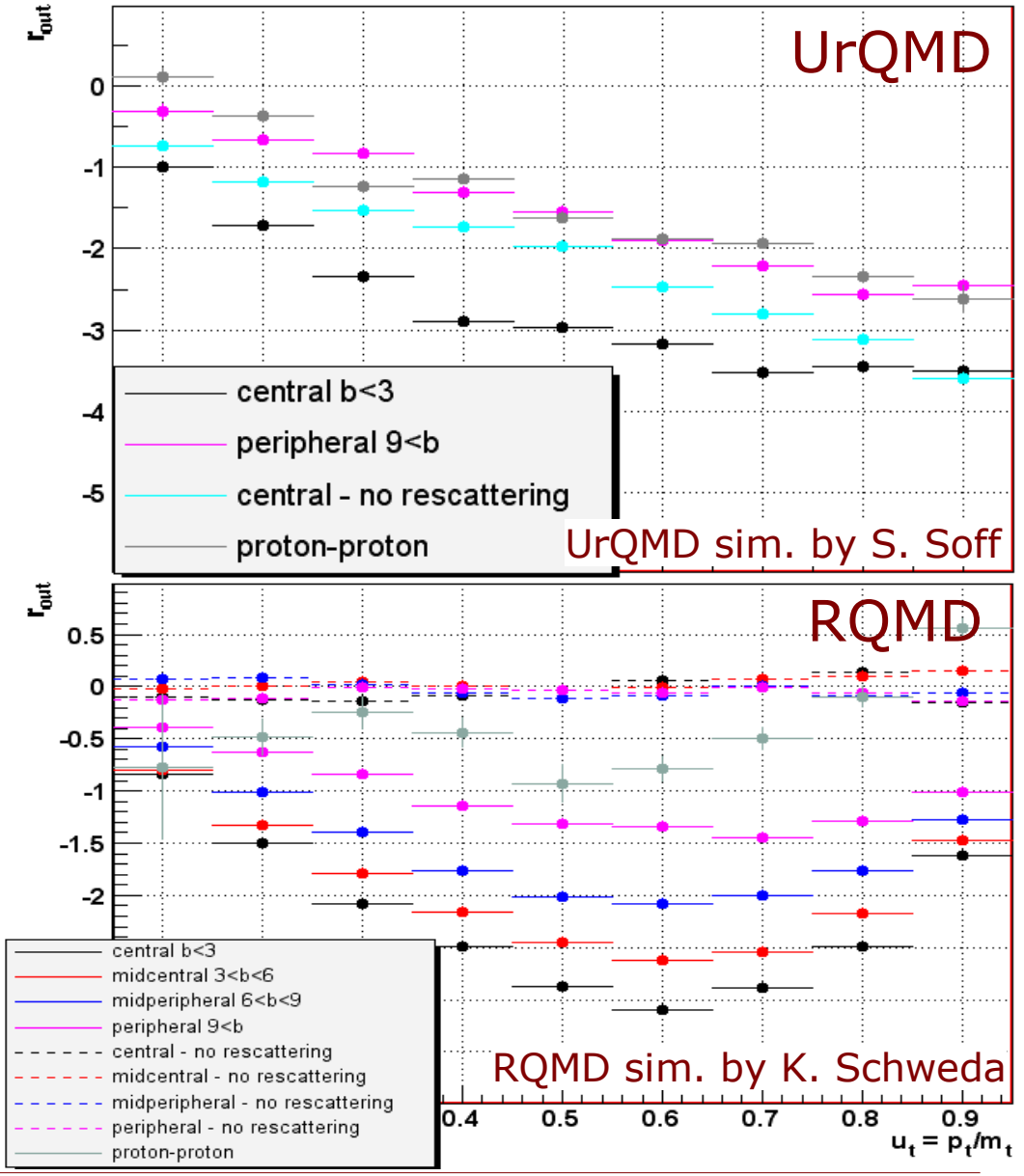
Turning off rescattering shuts down flow and decreases time shifts

We measure r^*_{out}, which combines time shifts and spatial shifts (from space-momentum ϕ correlations)



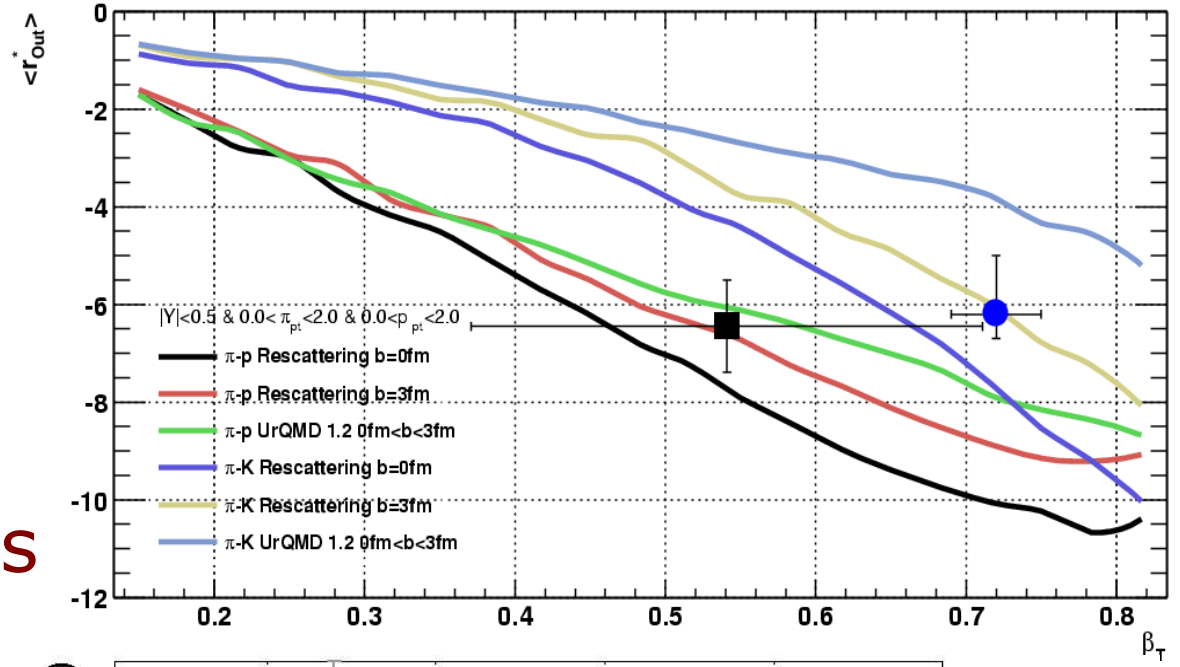
Rescattering models

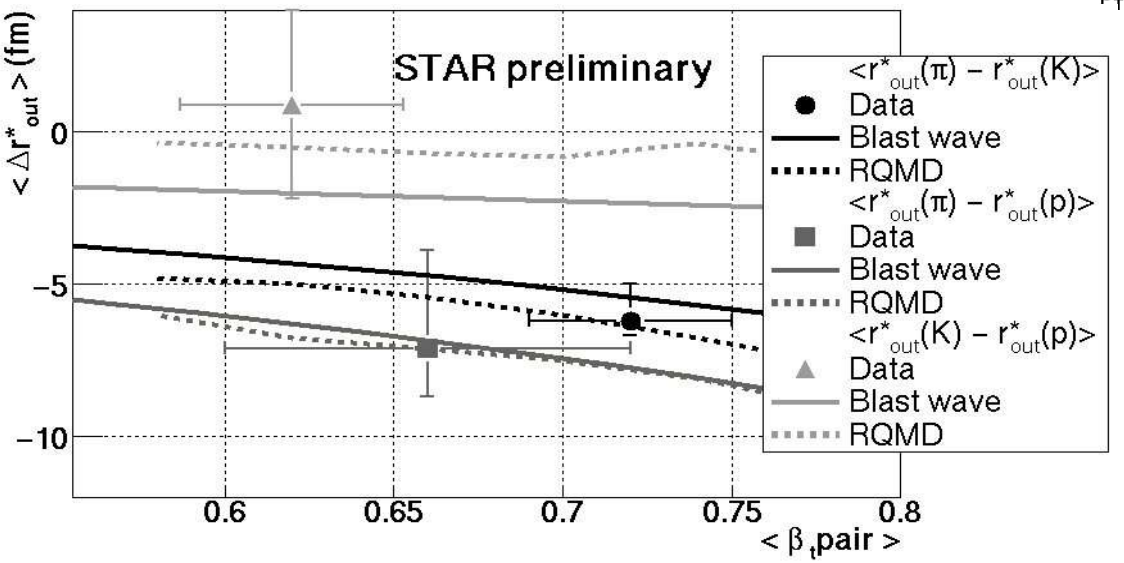
- Both models produce significant flow
- Flow intensity scales with centrality
- RMQD w/o rescattering produced no flow
- pp collisions produce space-momentum correlations – jets?



Comparing models to data

- Rescattering models and blast-wave are able to reproduce the data
- Blast wave parameters constrained by other measurements from STAR
- In all models flow is required to reproduce the data

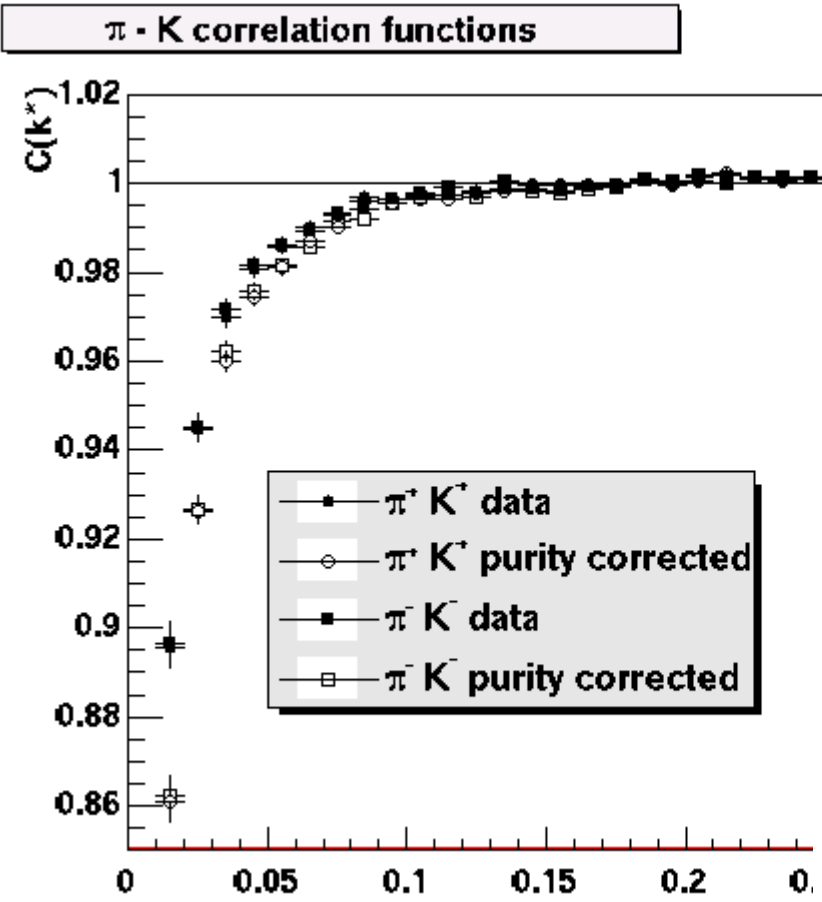




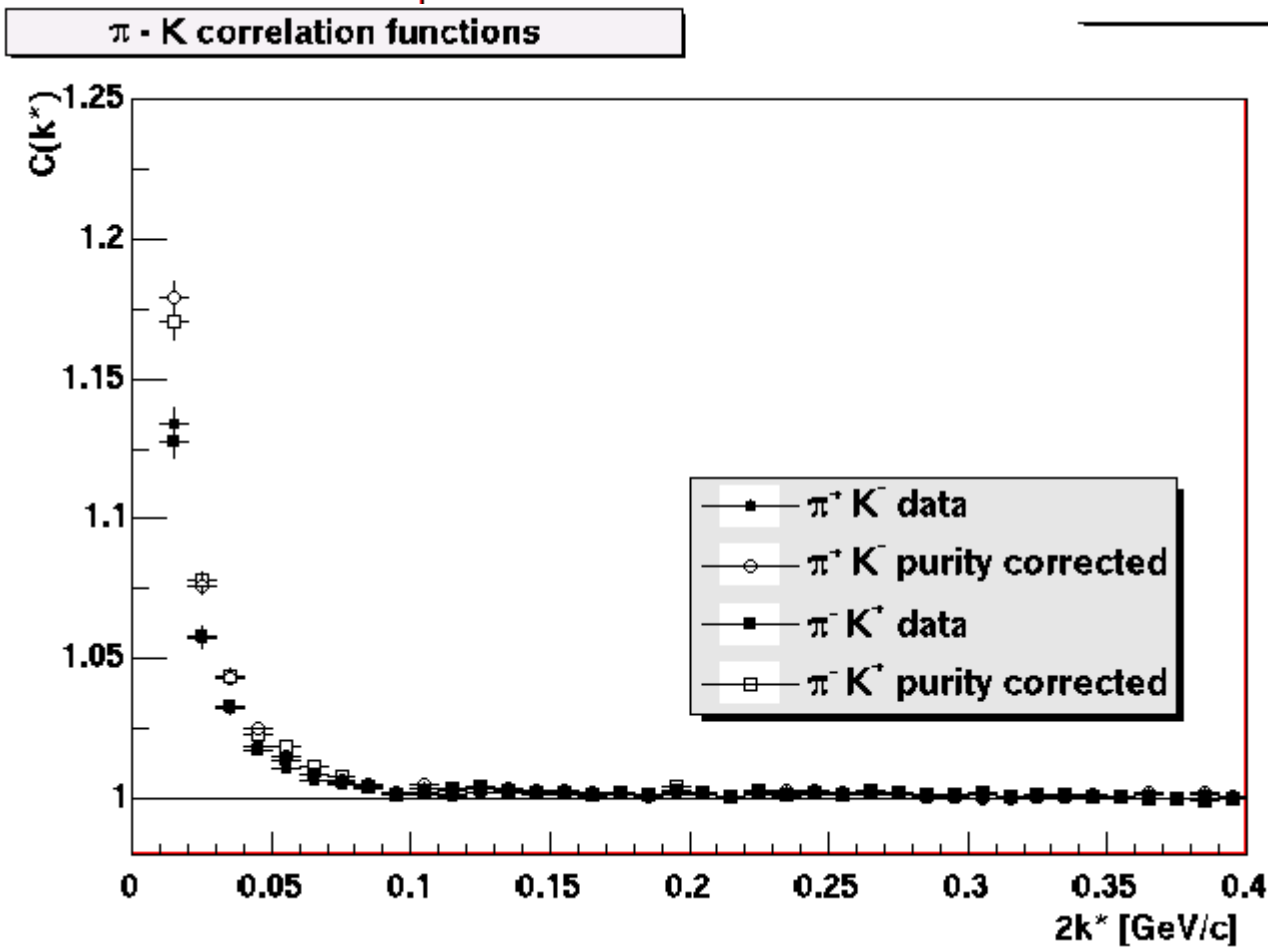
Summary and outlook

- Non-identical particle correlations give qualitatively new information: emission asymmetries, and an independent measurement of space-momentum correlations (transverse radial flow)
- Emission asymmetry was observed at STAR for pion-kaon and pion-proton pairs
- Rescattering models and blast-wave are consistent with the data, because they produce radial flow
- More systems (e.g. Proton-Lambda, Pion-Cascade), more statistics, higher collision energy data coming

Purity correction

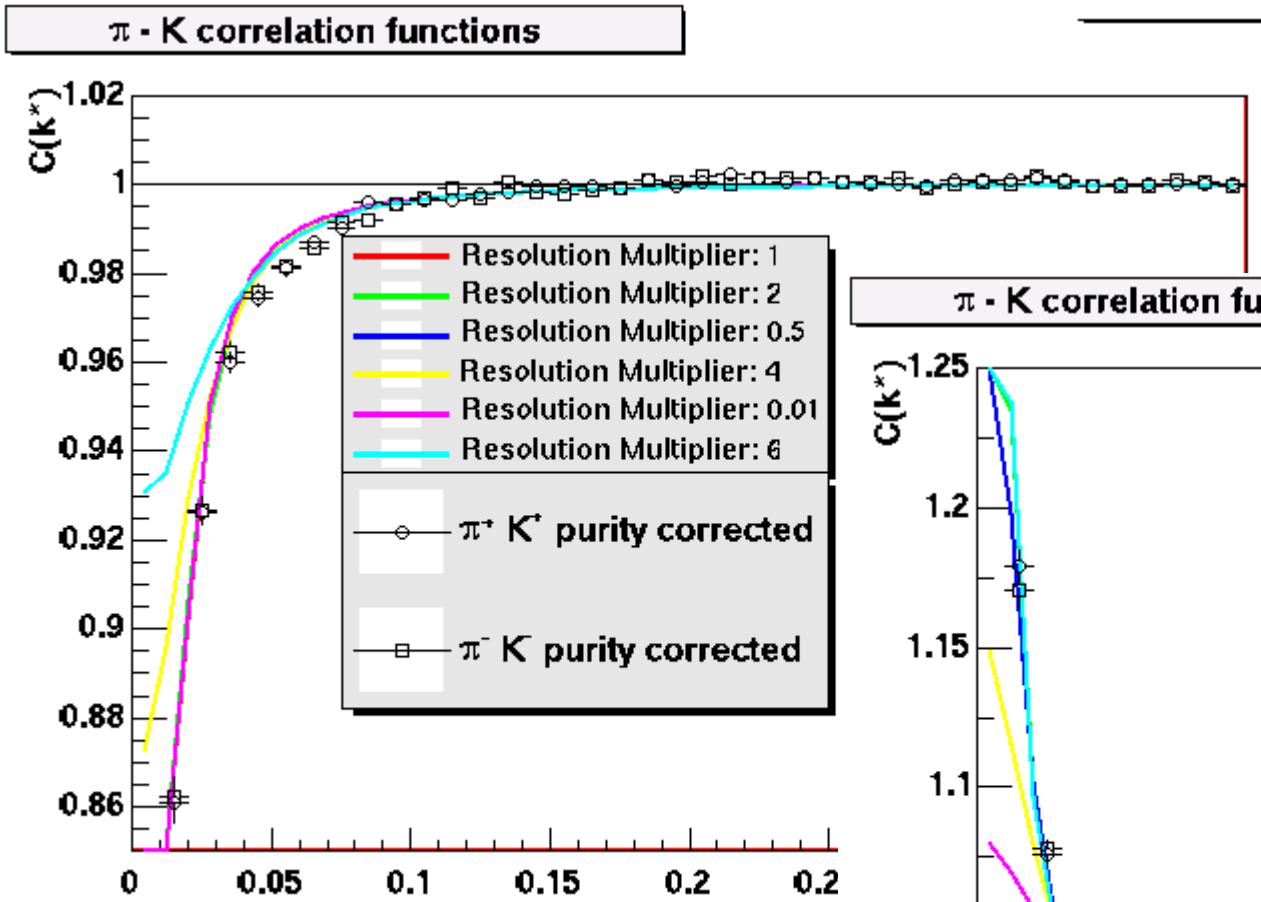


Average pair purity = **0.75**

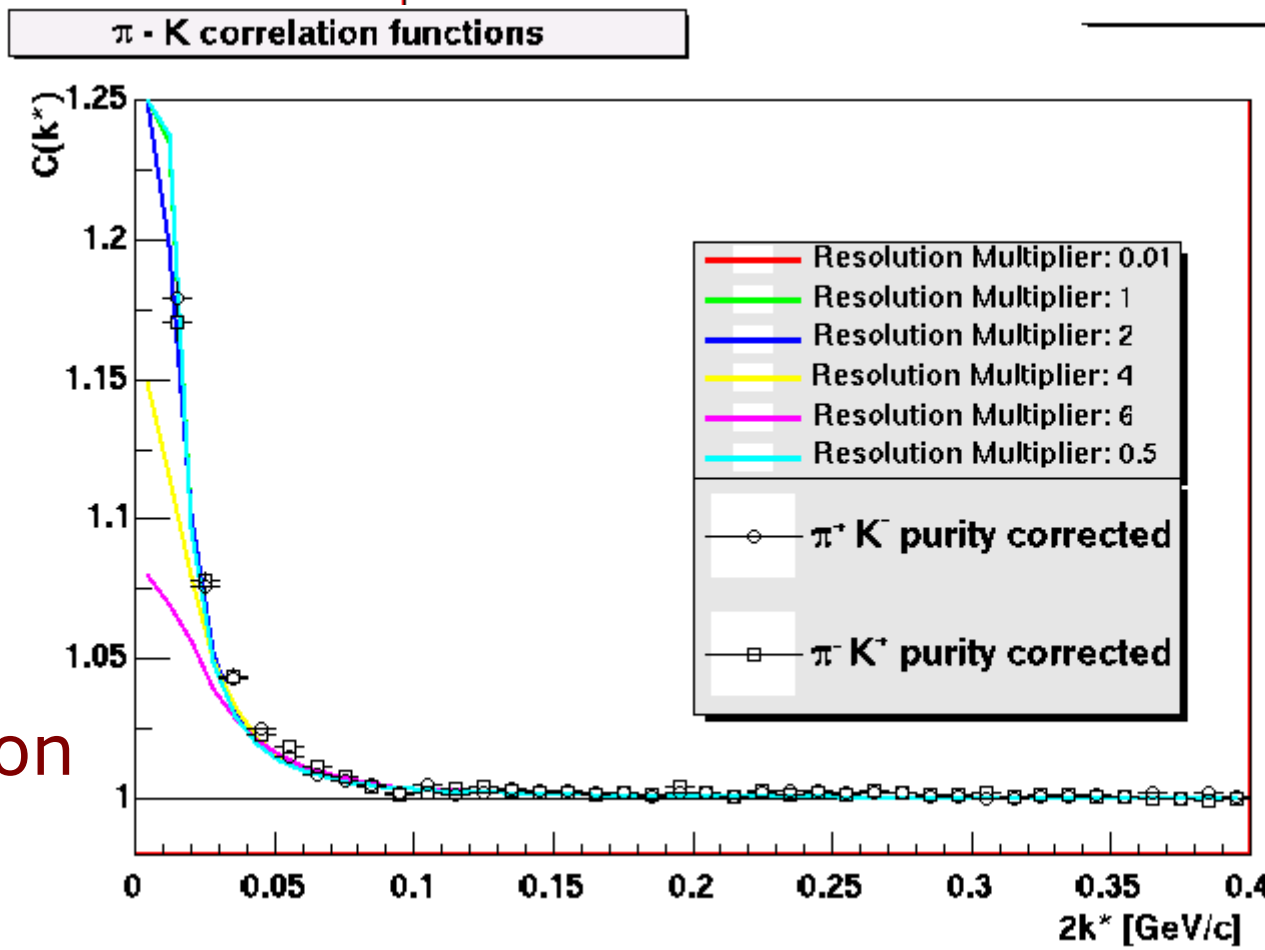


$$C_{corrected} = \frac{C_{measured} - (1 - P) * 1.0}{P}$$

Momentum resolution

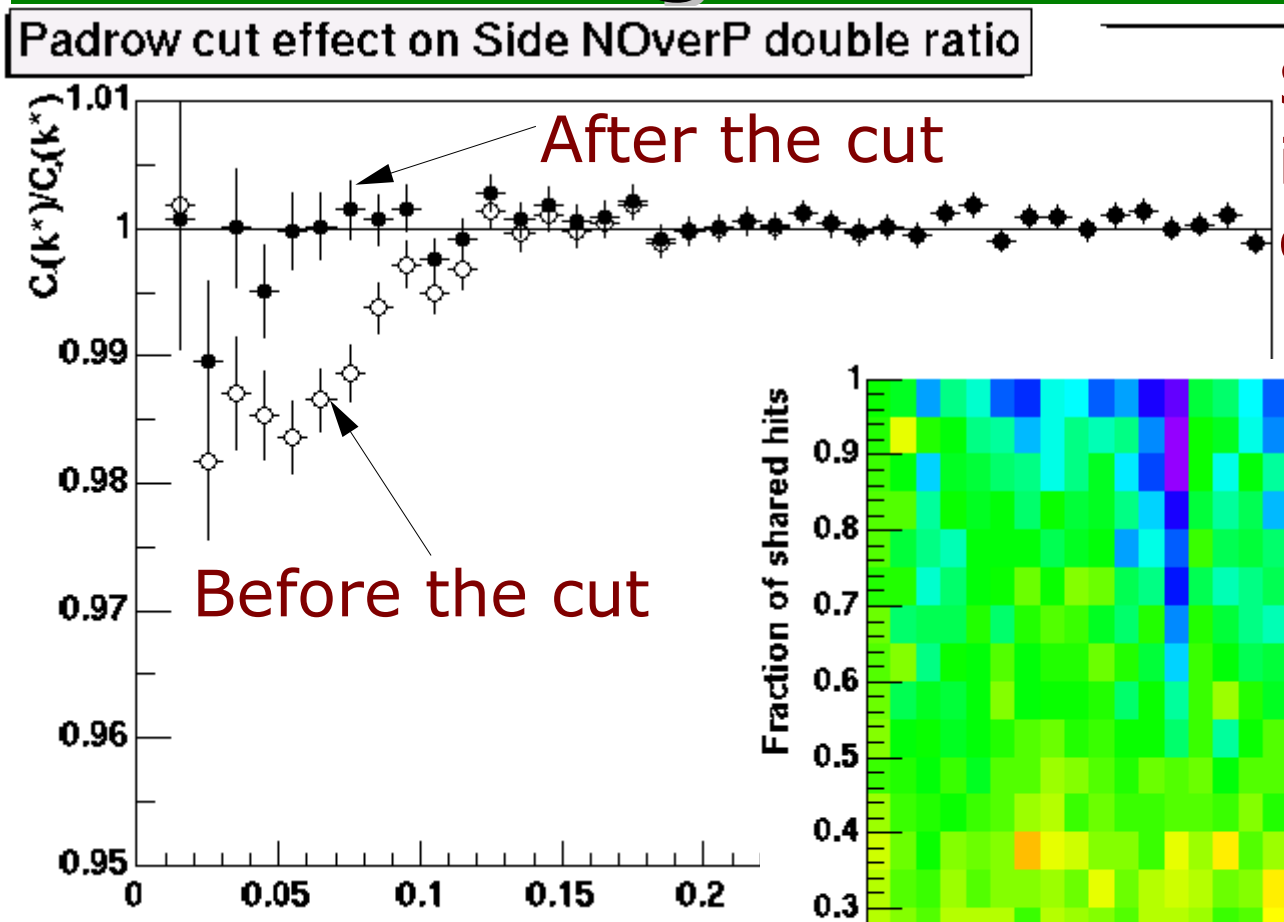


Momentum smearing and low p_T shift

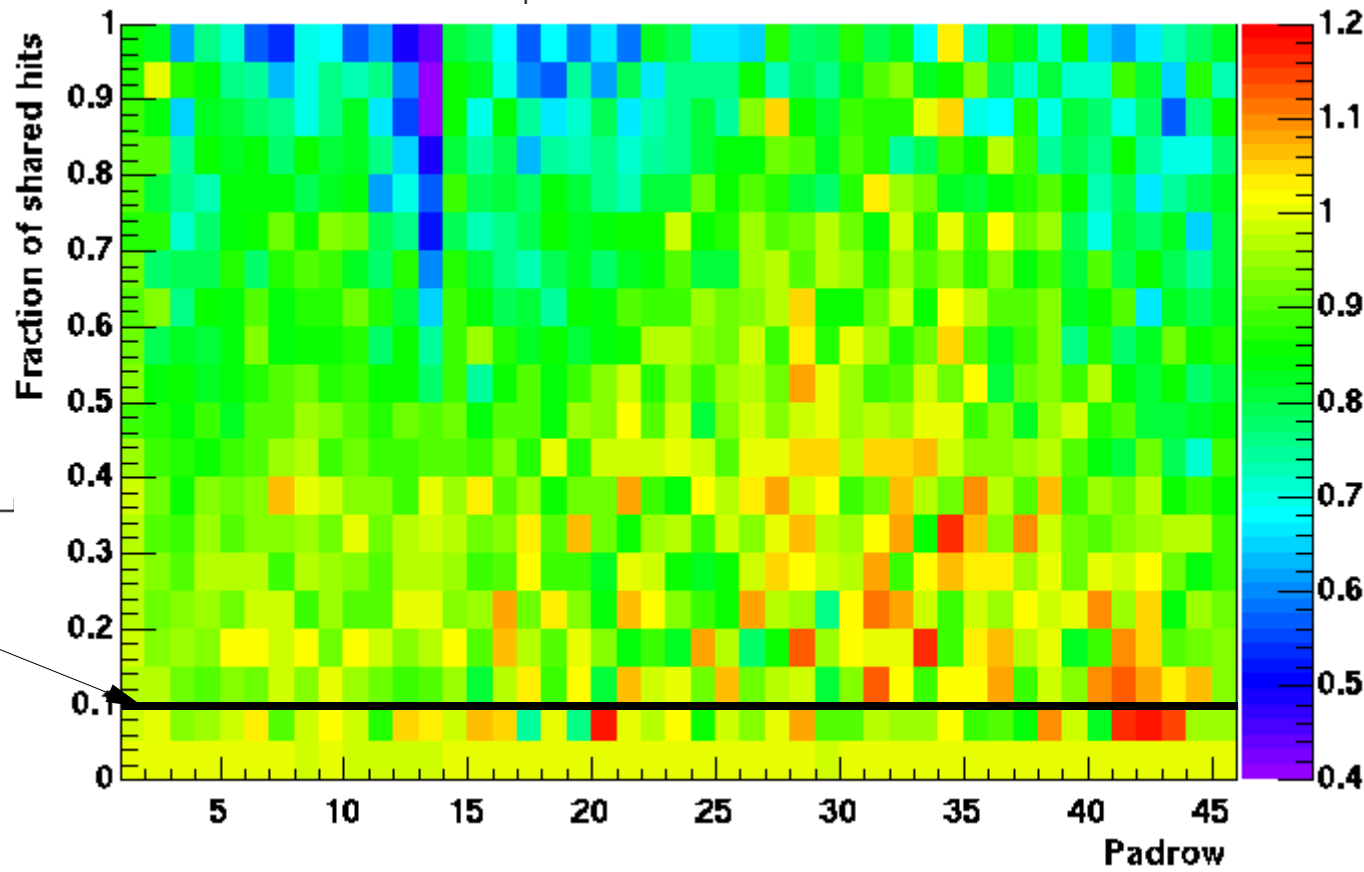


No change until resolution 4x worse than STAR

Hit sharing cut effect on Side ratio

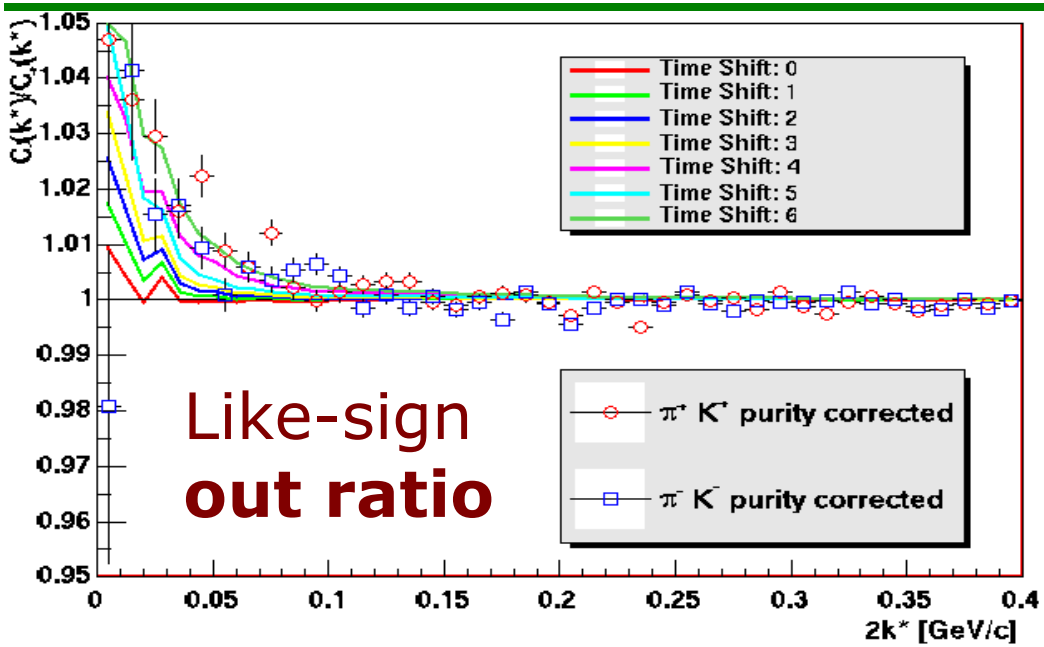


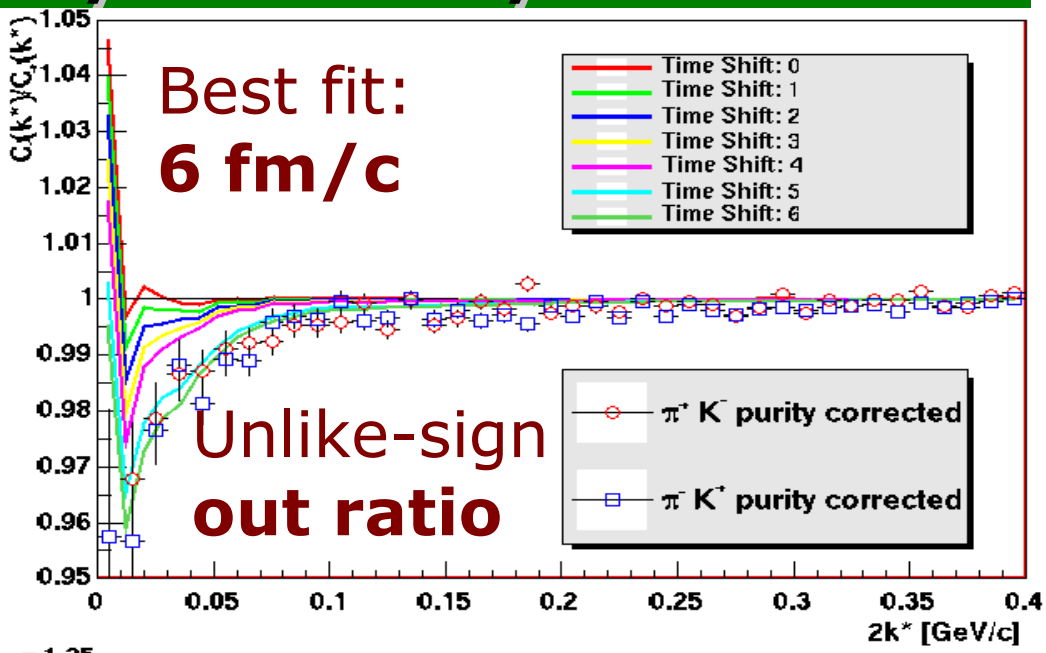
Should be at 1.0 as there is no physics effect that can cause the asymmetry

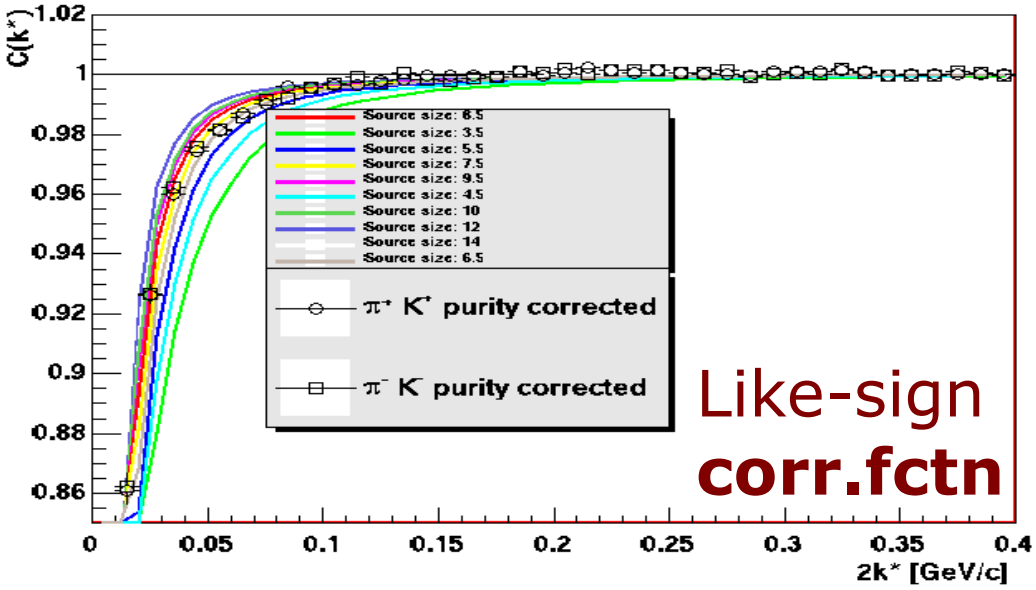


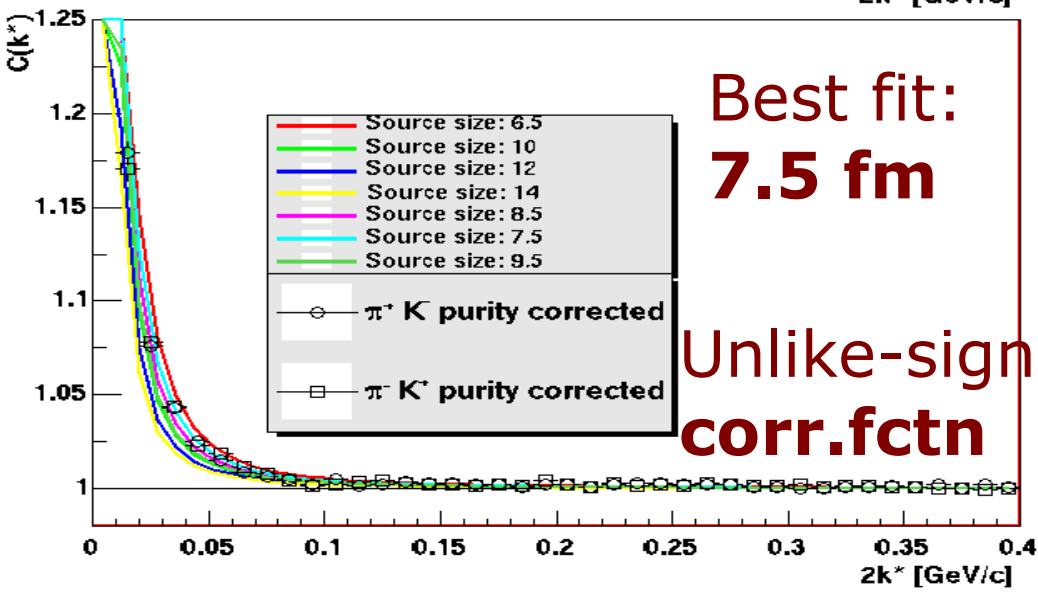
Maximum number of shared hits between two tracks = 10%

Static source - time shift can be the cause for asymmetry



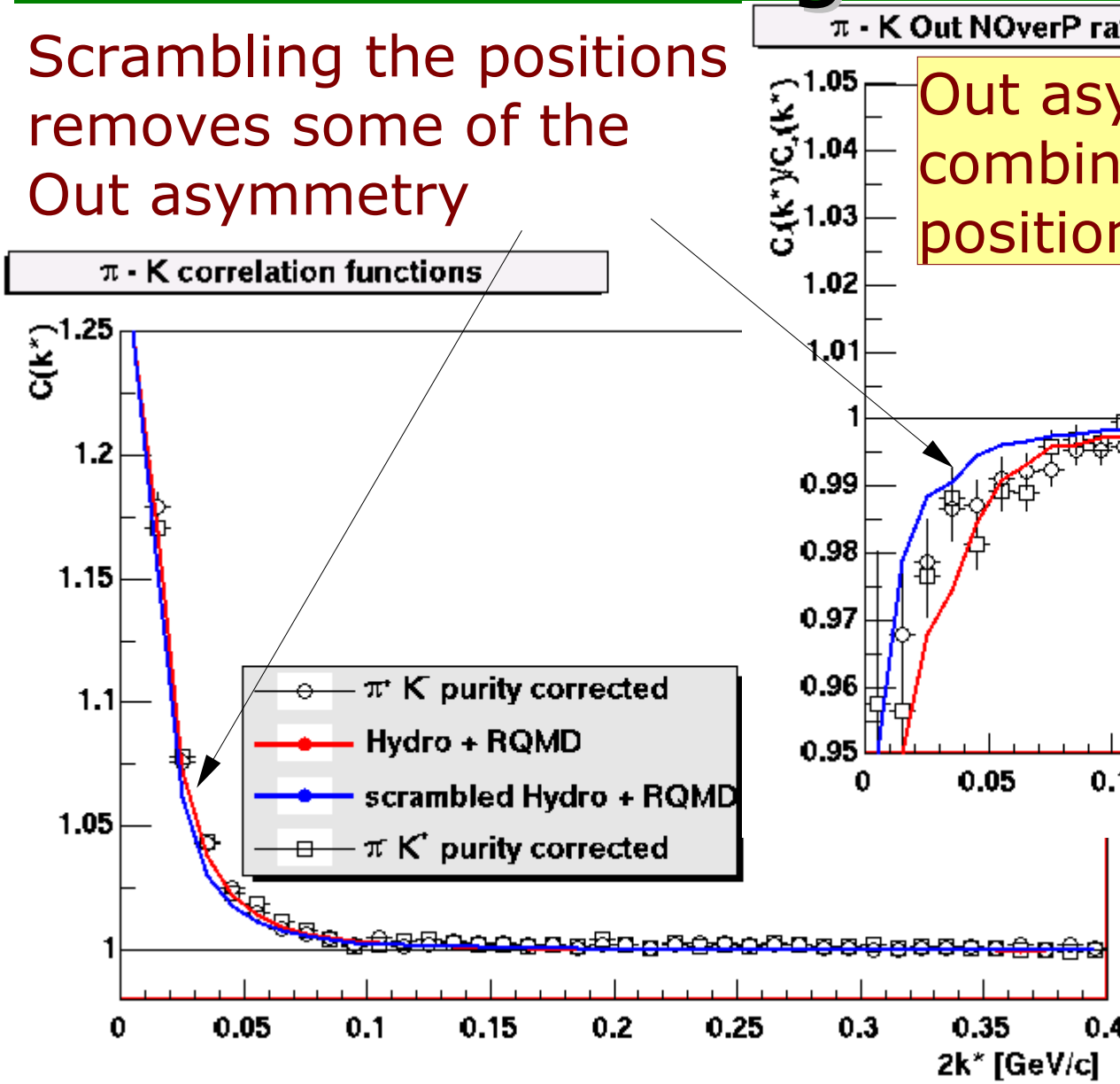


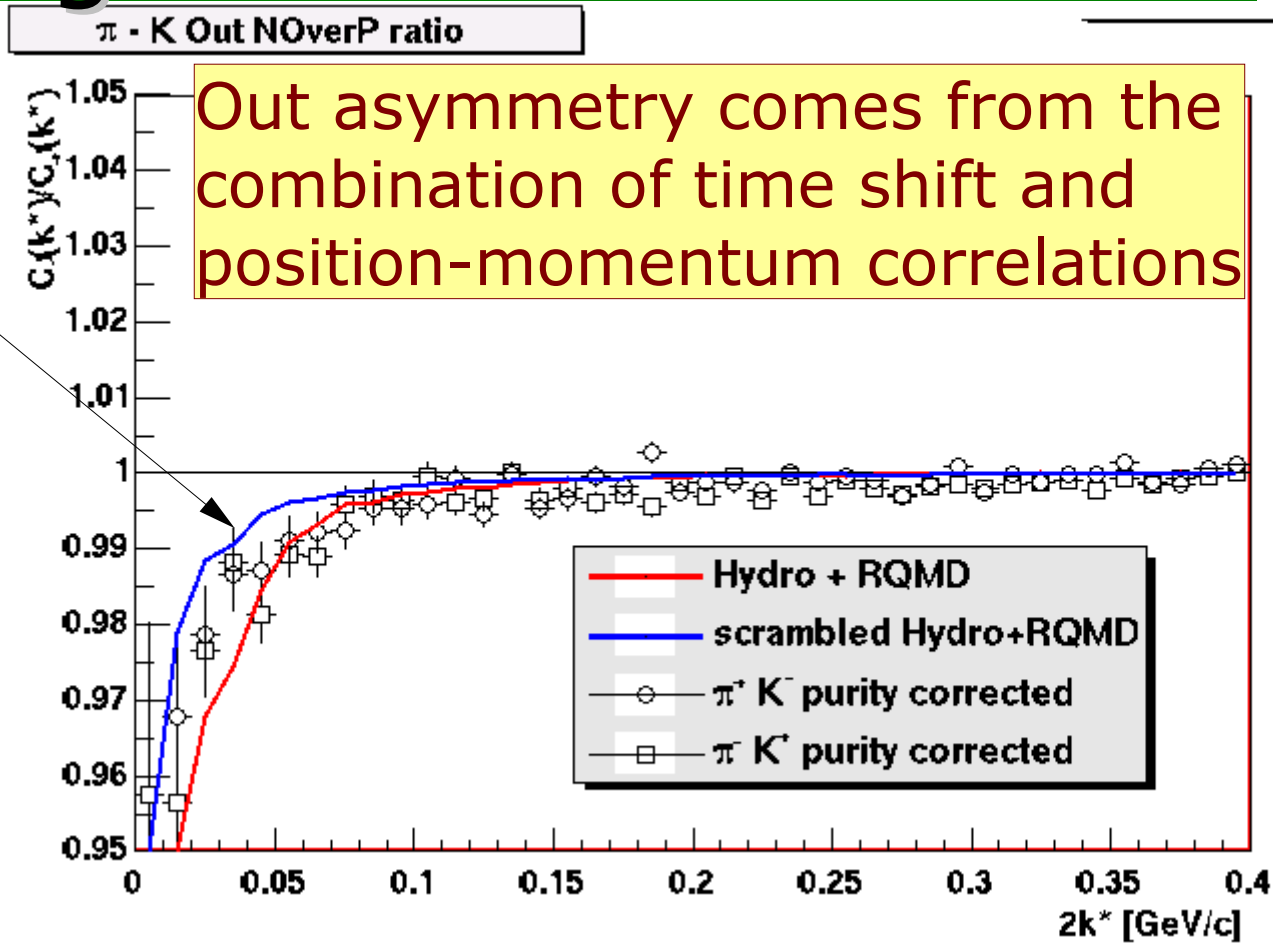




Hydro + RQMD pure and scrambled can we disentangle time shift and flow

Scrambling the positions removes some of the Out asymmetry





Out asymmetry comes from the combination of time shift and position-momentum correlations

phi scrambling does not remove all momentum-position correlation

Hydro inspired parametrization - radial flow produces asymmetry