Pion-Kaon Femtoscopy in 200 GeV Collisions in STAR at RHIC

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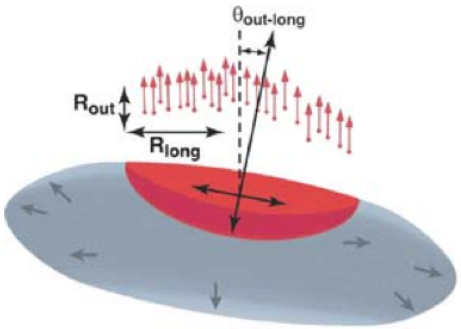
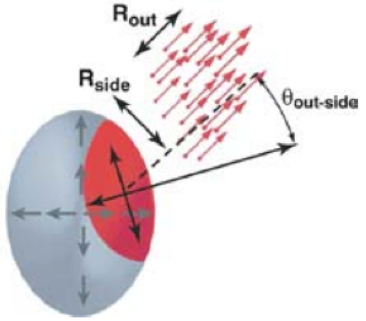
Outline

- Motivation: Non-identical particle correlation probe emitting asymmetry
- Observables: Double Ratio and Spherical Harmonics Decomposition (SHD)
- Data Set & Preliminary Results
- Summary & Outlook

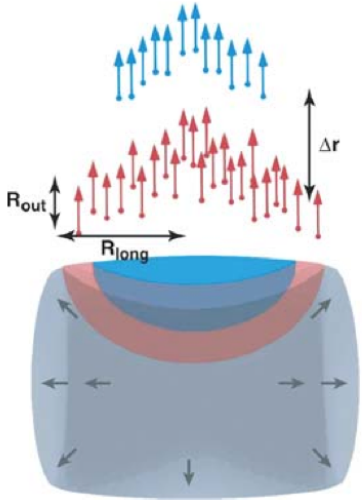
Motivation

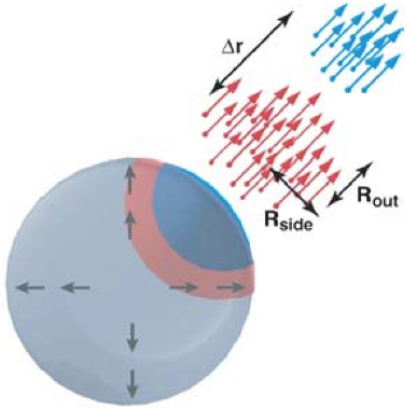
- Identical particle femtoscopy measures size and shape of homogeneity region, plus collective flow





- Non-identical particle femtoscopy probes emission asymmetry, sensitive to collective flow.
  - **kaons are emitted closer to the edge of a flowing source than pions**





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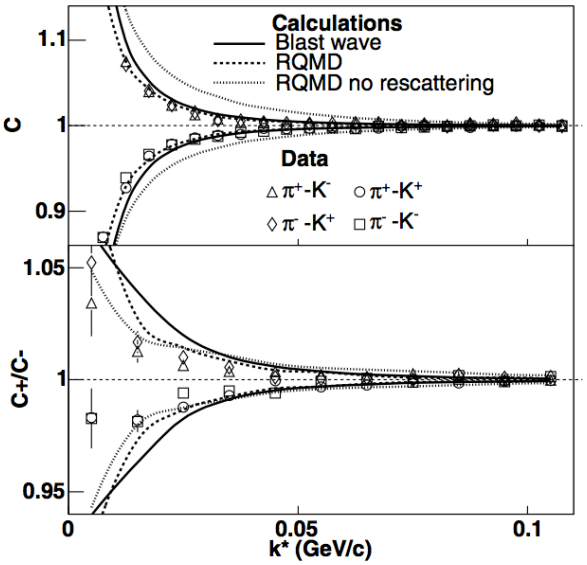
Motivation

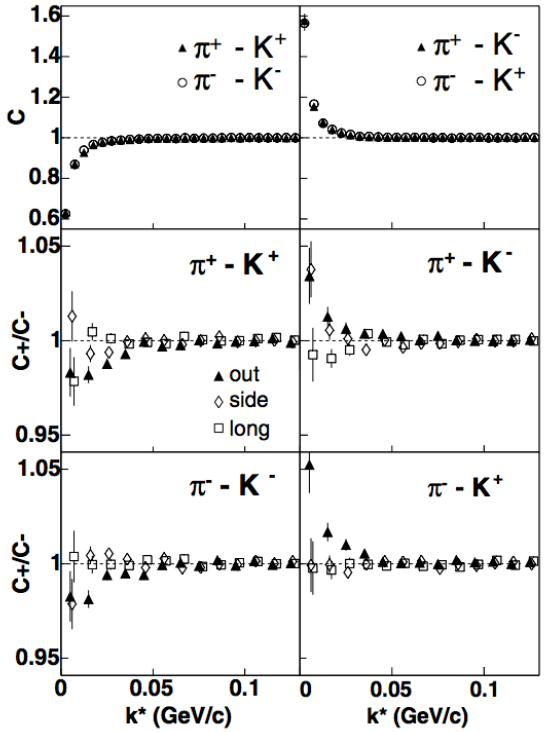
- Results from STAR pion-kaon correlation have shown that strong radial flow is built in central Au+Au collisions.

Correlation function:
tells us source size

"Double ratio:"
tells us source asymmetry



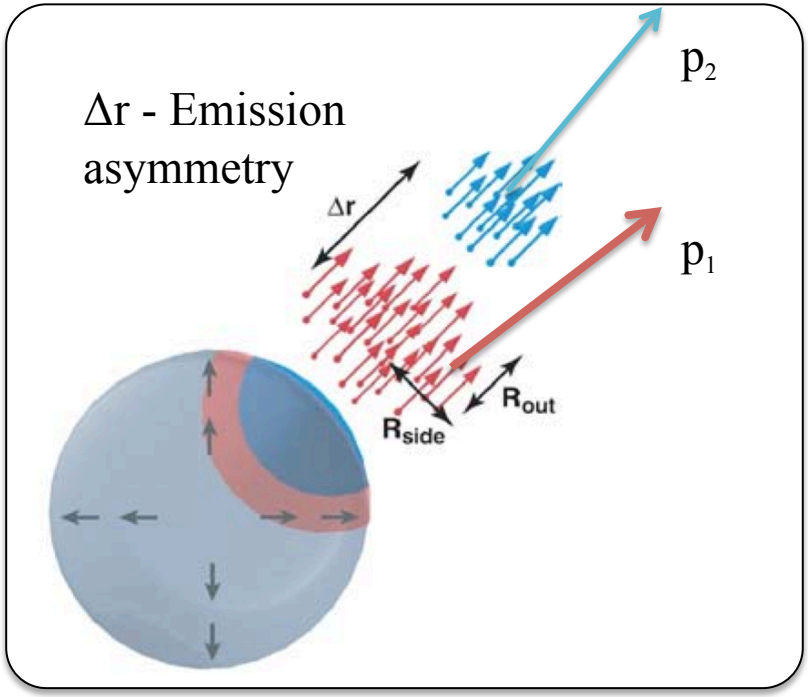
STAR, PRL, 91 (2003) 262301
Au+Au@130 GeV



Our goals:

- Improved measurement in Au+Au, using upgraded STAR PID capabilities
- Look for same signal in p+p collisions: can we see flow in p+p at RHIC??

Correlation Function (CF) – Double Ratio

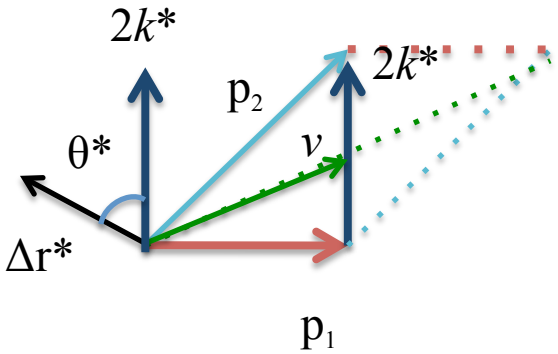


k* - momentum of the first particle (pion in our case) in pair rest frame, half of the relative momentum.

$$C(k^*) = \frac{N(k^*)}{D(k^*)}$$

constructed from the same event

constructed from the different events



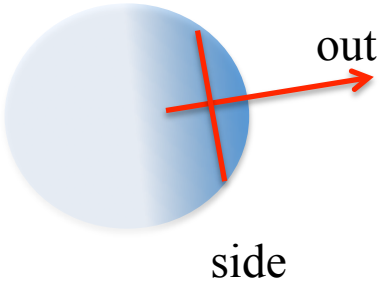
C+, "+" means sign(k*•v) is positive;
C-, "-" means sign(k*•v) is negative.
C+/C- is sensitive to Δr

Δr* - space separation between two particles in pair rest frame.

Correlation is **stronger when cosθ*<0** and **weaker when cosθ*>0**

CF – Spherical Harmonics Decomposition (SHD)

$$C(\vec{k^*}) = \sqrt{4\pi}\sum_{lm} C_{lm}(\vec{k^*})Y_{lm}(\theta,\phi)$$



$$Y_0^0 = \frac{1}{2}\sqrt{\frac{1}{\pi}}$$

C_0^0 - Overall size, similar to C(k*)

$$Y_1^0 = \frac{1}{2}\sqrt{\frac{3}{\pi}}\cos\theta$$

C_1^0 – related to long direction.
Midrapidity – should be zero due to symmetry

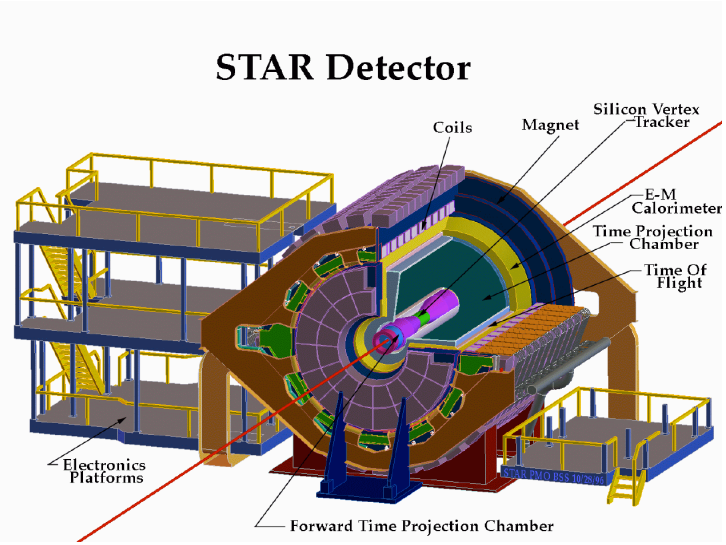
$$Y_1^1 = \frac{1}{2}\sqrt{\frac{3}{2\pi}}(\cos\phi\sin\theta + i\sin\phi\sin\theta)$$

valuable cross-checks for artifacts, non-physics correlations

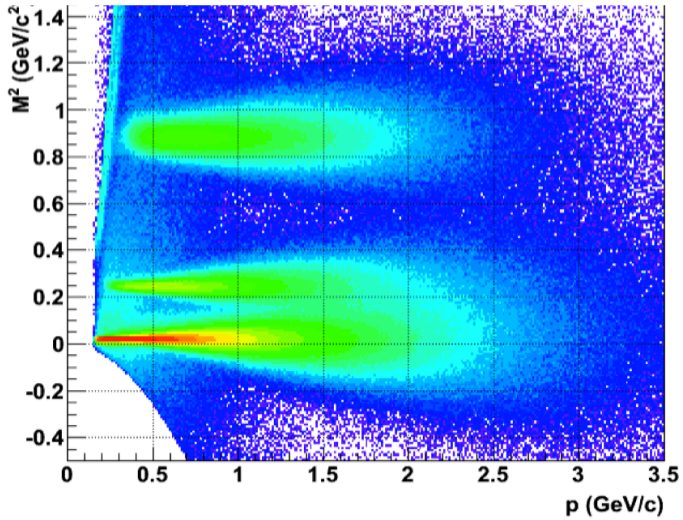
Re(C_1^1) – related to out direction, asymmetry,

Im(C_1^1) – related to side direction, should be zero due to symmetry

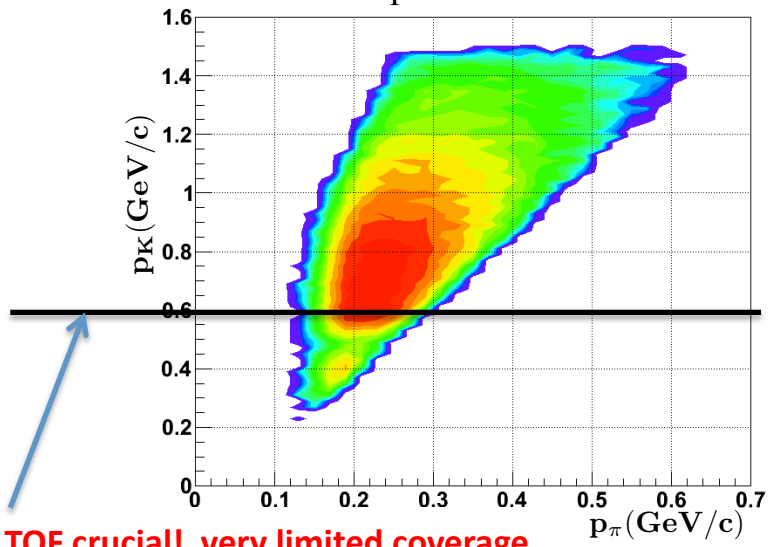
STAR



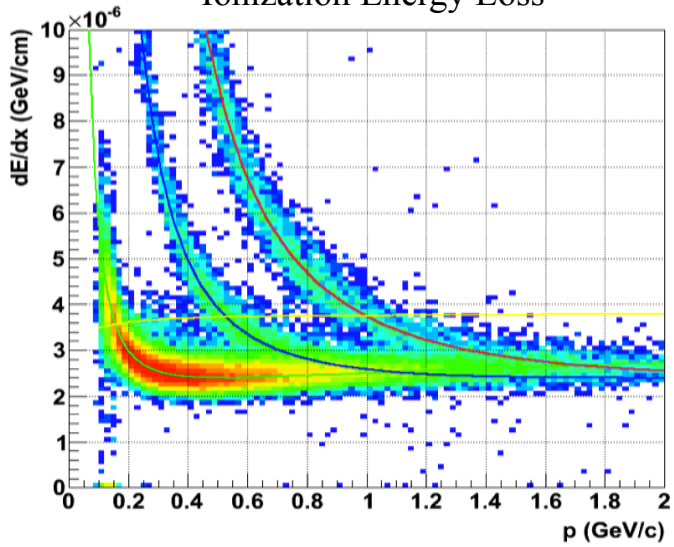
m^2 from Time Of Flight (TOF)



Tracks from pair with k^*<50 MeV/c



Ionization Energy Loss



TOF crucial! very limited coverage if restricted to TPC PID alone

Data Set

~180M 200 GeV Au+Au collisions from RHIC Run10

- collision vertex within 30 cm of TPC center
- 0-5% centrality

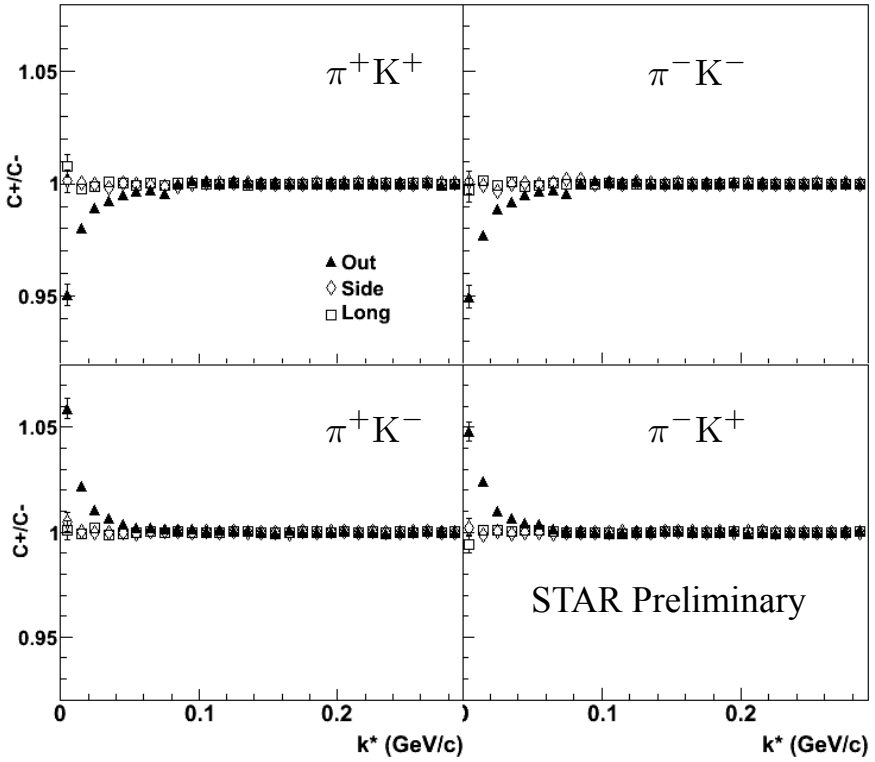
~300 M 200 GeV p+p collisions from RHIC Run9

- collision vertex within 50 cm of TPC center
- minimum bias trigger

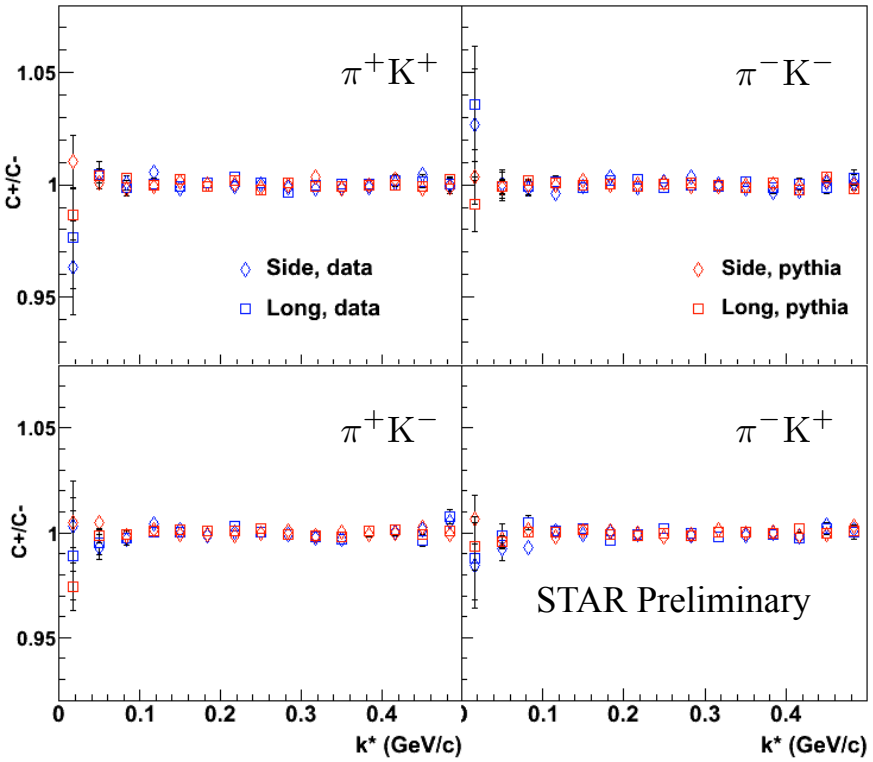
- Standard STAR and STAR-HBT cuts applied
- PID by combining TOF and TPC information: p_T = 0.15-1.5 GeV/c

Double Ratio

Au+Au@200 GeV



p+p@200 GeV

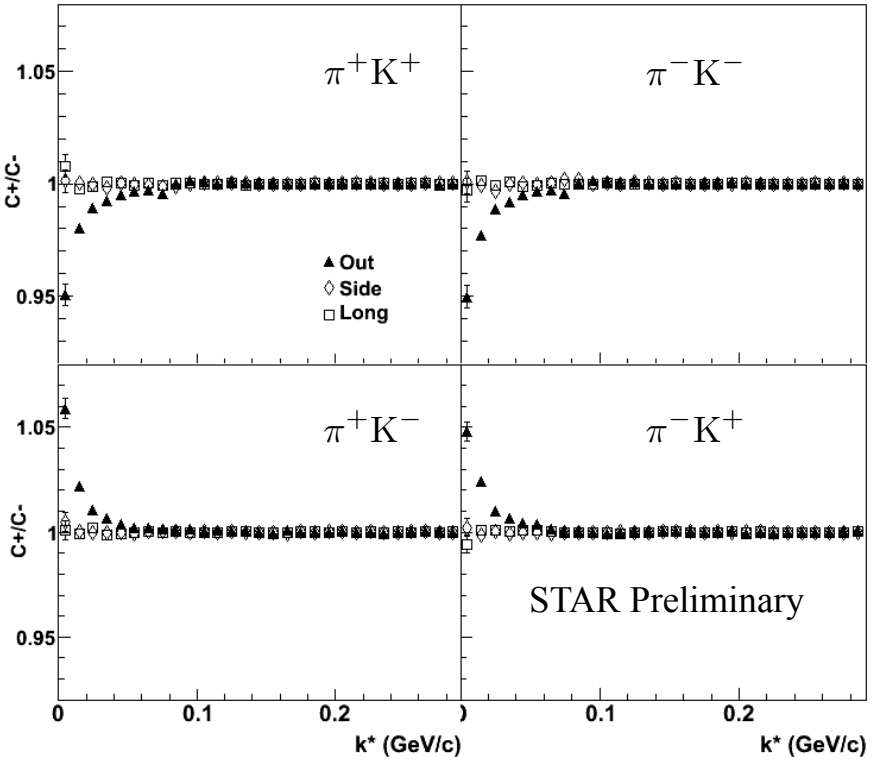


- ✓ double ratio for side, long consistent with 1
  - sensitive to merging/splitting/artifacts

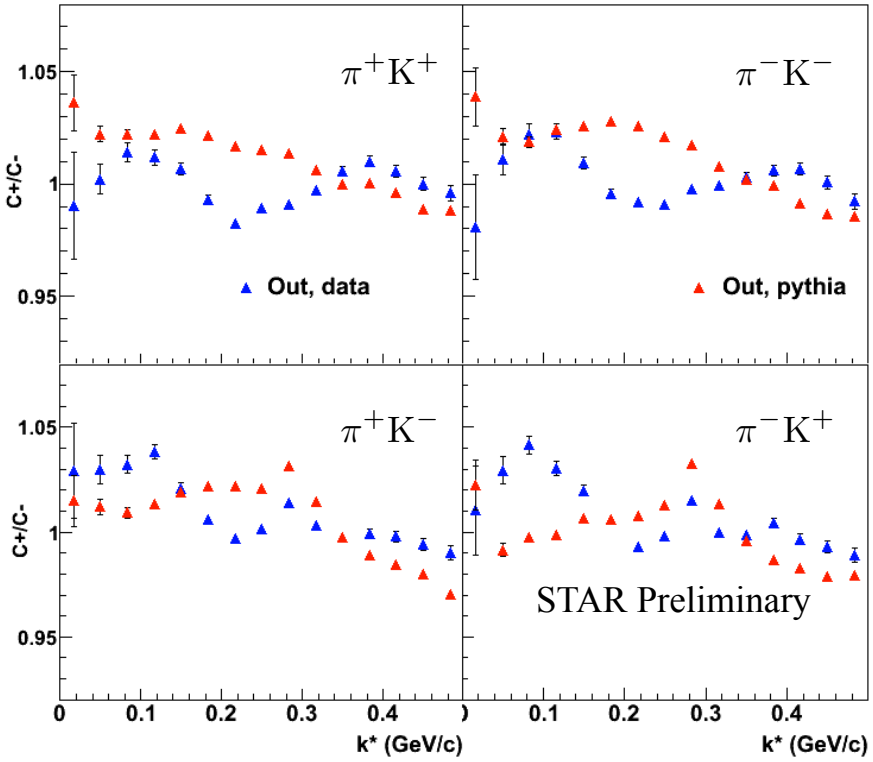
- ✓ double ratio for side, long consistent with 1

Double Ratio

Au+Au@200 GeV



p+p@200 GeV

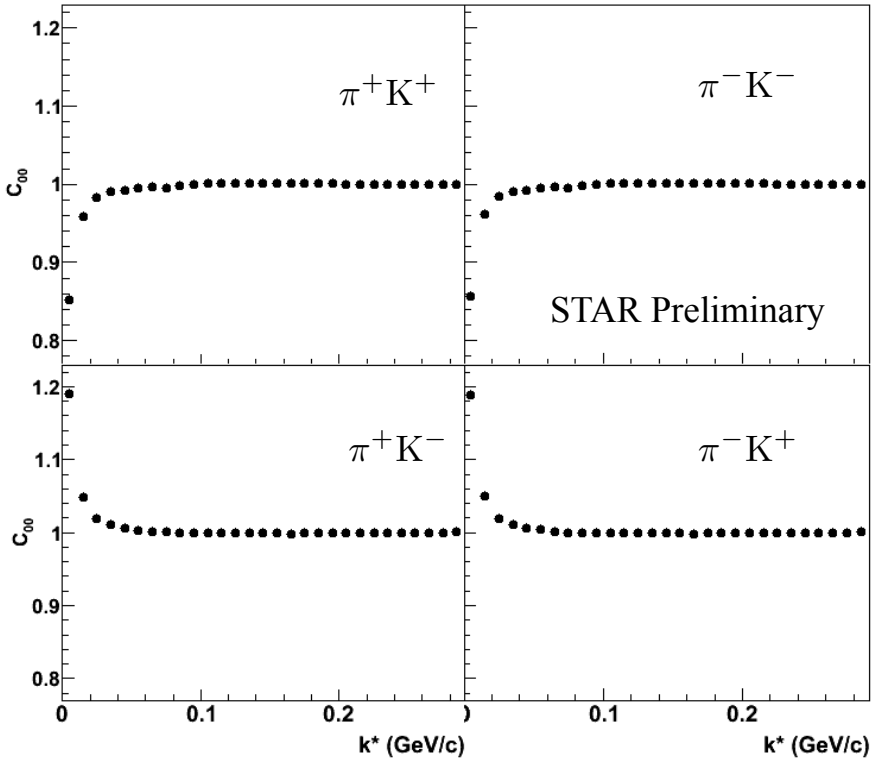


- ✓ double ratio for side, long consistent with 1
  - sensitive to merging/splitting/artifacts
- ✓ Double ratio in out is consistent with STAR published result at 130 GeV
  - reflects flow-induced emission asymmetry

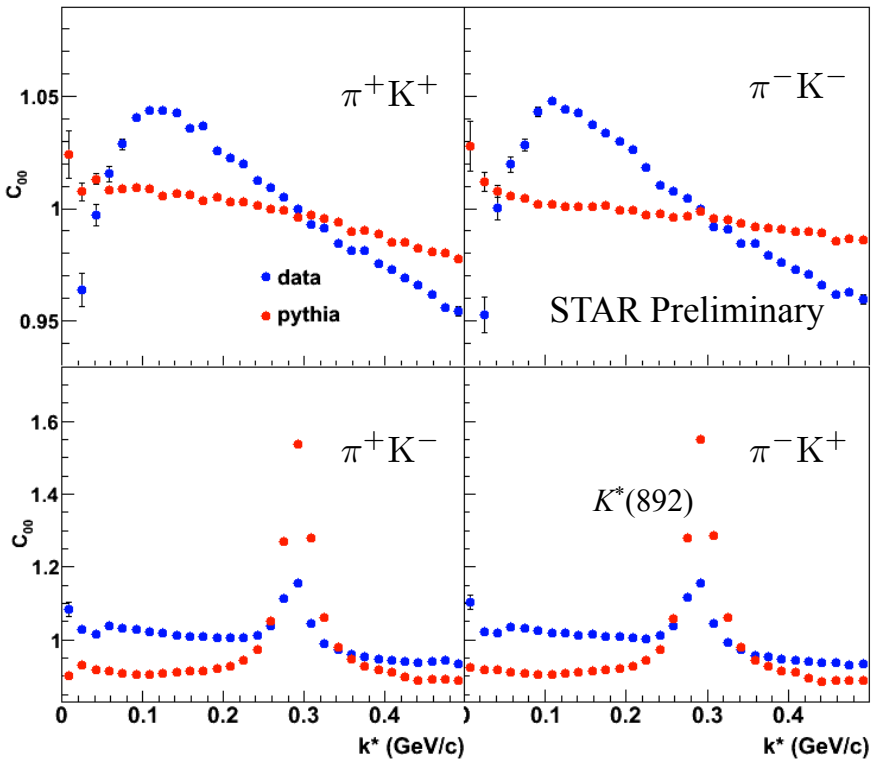
- ✓ double ratio for side, long consistent with 1
- ✓ non-trivial structure in out
  - both in data and PYTHIA
  - under study: not sufficiently understood to extract femtoscopic information

SHD representation: C_{00} (overall size)

Au+Au@200 GeV



p+p@200 GeV

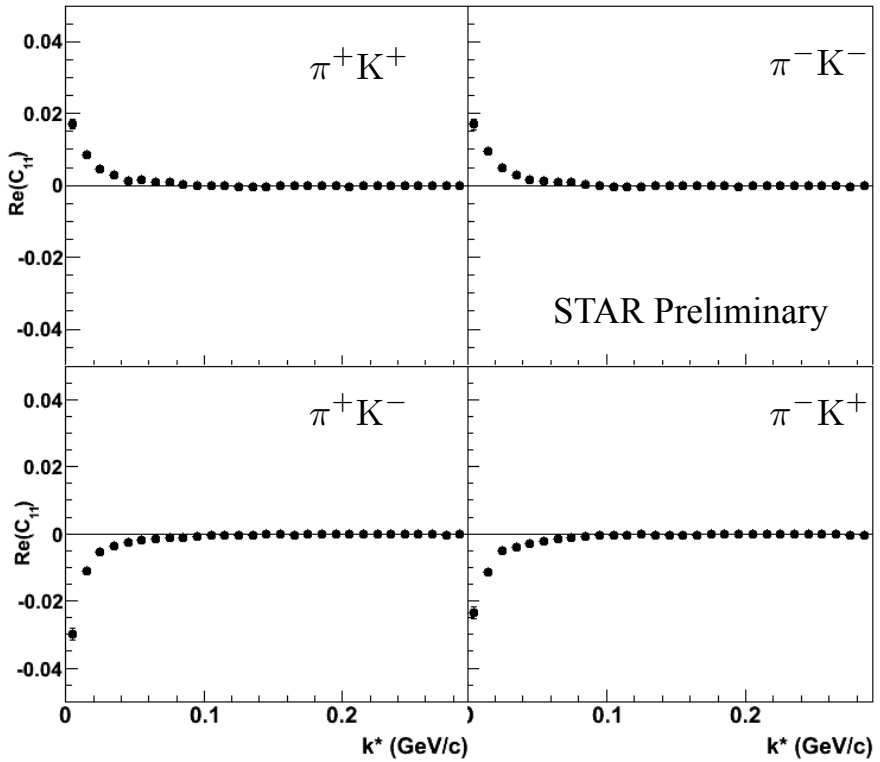


- ✓ low-k* suppression (enhancement) for like-sign (unlike-sign) pairs
- ✓ scale of correlation ~ 6 fm source

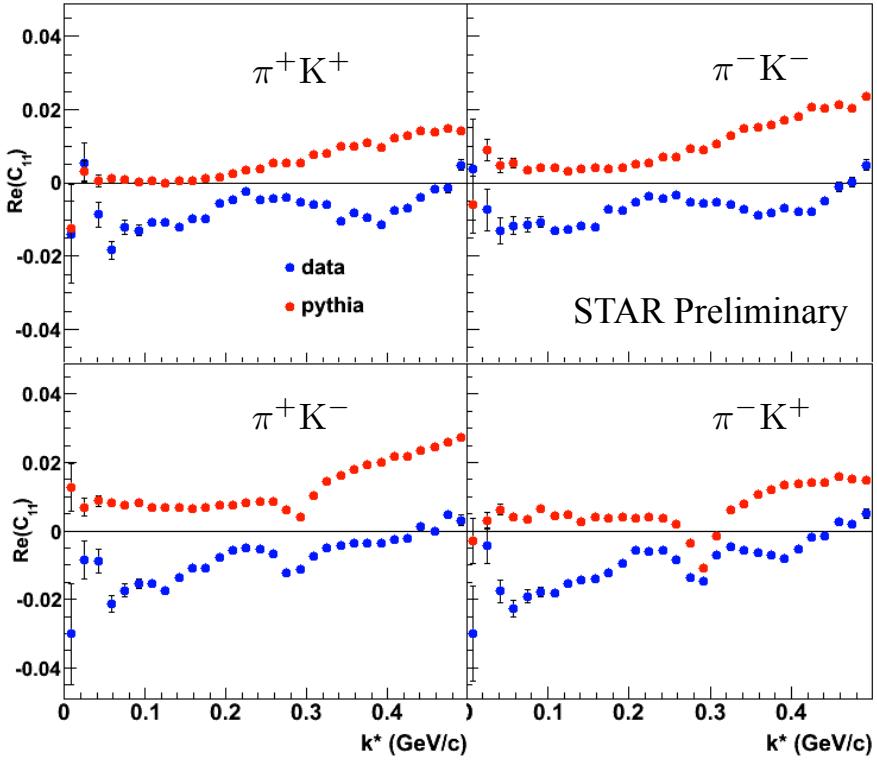
- PYTHIA and data: large-scale structure
  - similar but not identical
- low-k* suppression/enhancement in data superimposed on PYTHIA background??
- K* ➔ K+π visible (low combinatorics)

SHD representation: Re(C_{11}) (emission asymmetry)

Au+Au@200 GeV



p+p@200 GeV



- ✓ Consistent with flow-induced asymmetry
- ✓ confirmed that C10 and Im(C11) vanish
  - sensitive to merging/splitting/artifacts

- PYTHIA and data: large-scale structure
  - similar but not identical
- K* ➔ K+π visible (low combinatorics)
- structures and difference to PYTHIA under study

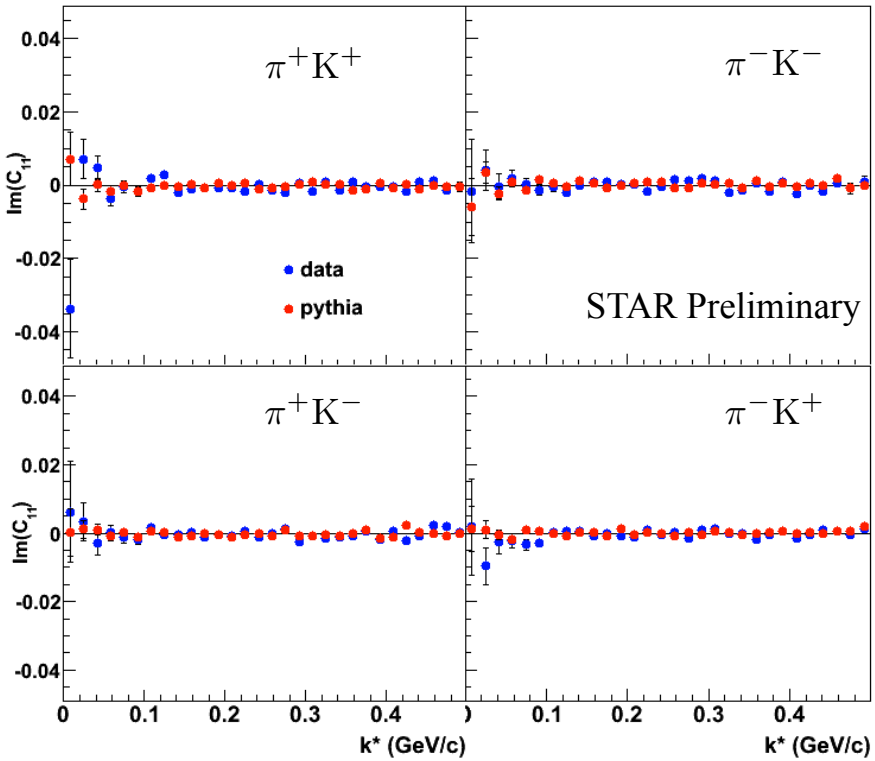
Summary and Outlook

- Pion-kaon correlations: unique opportunity to probe flow-induced geometric substructure
- STAR Time of Flight: crucial for improved, detailed study
- Preliminary 200 GeV Au+Au femtoscopic correlations consistent with published 130 GeV data
- First preliminary pion-kaon correlations in 200 GeV p+p collisions reported
  - Nontrivial non-femtoscopic structure in correlations, both in data and PYTHIA
  - Insufficiently understood to allow femtoscopic interpretation at present
  - stay tuned!
- Centrality dependence will be studied in near future.

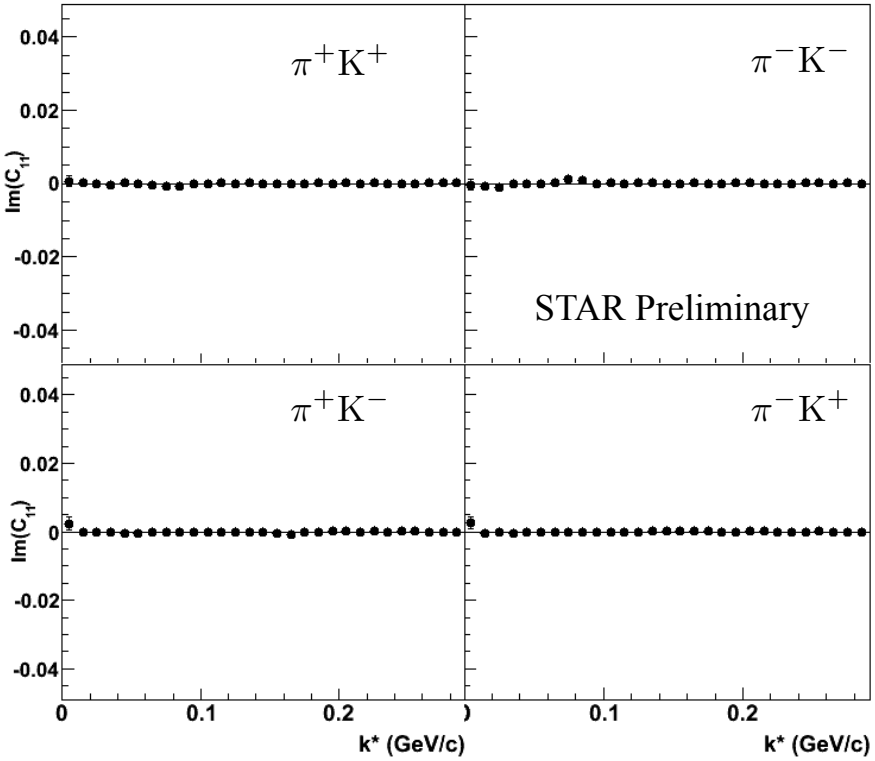
Back up

SHD – $Im(C_{11})$

p+p@200 GeV



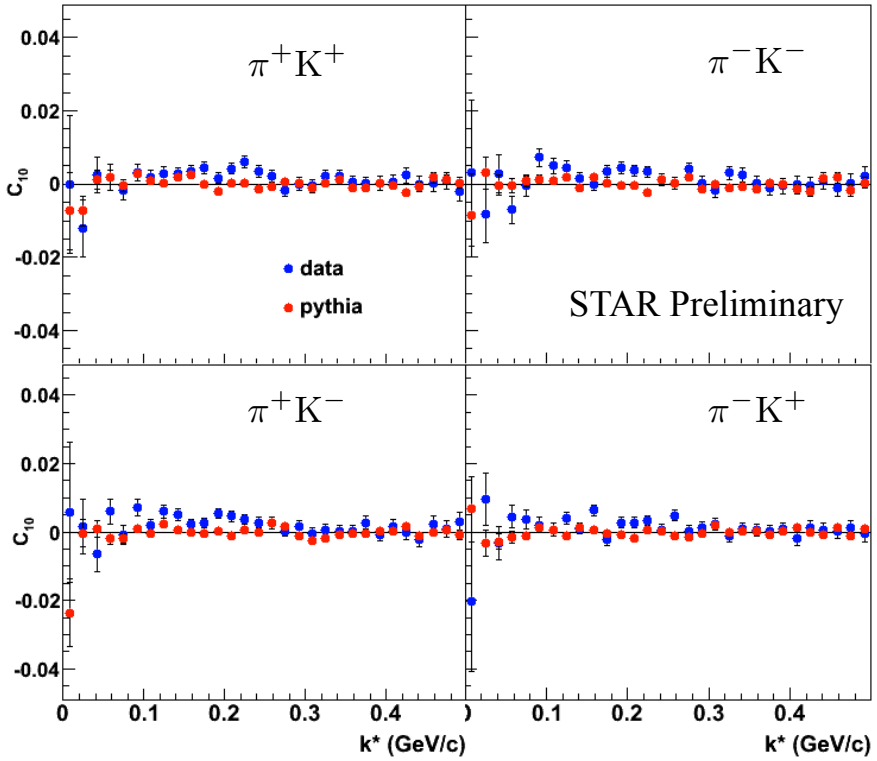
Au+Au@200 GeV



Back up

SHD – C_{10}

p+p@200 GeV



Au+Au@200 GeV