Flow and non-identical two-particle correlations

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This talk includes the work of many students:

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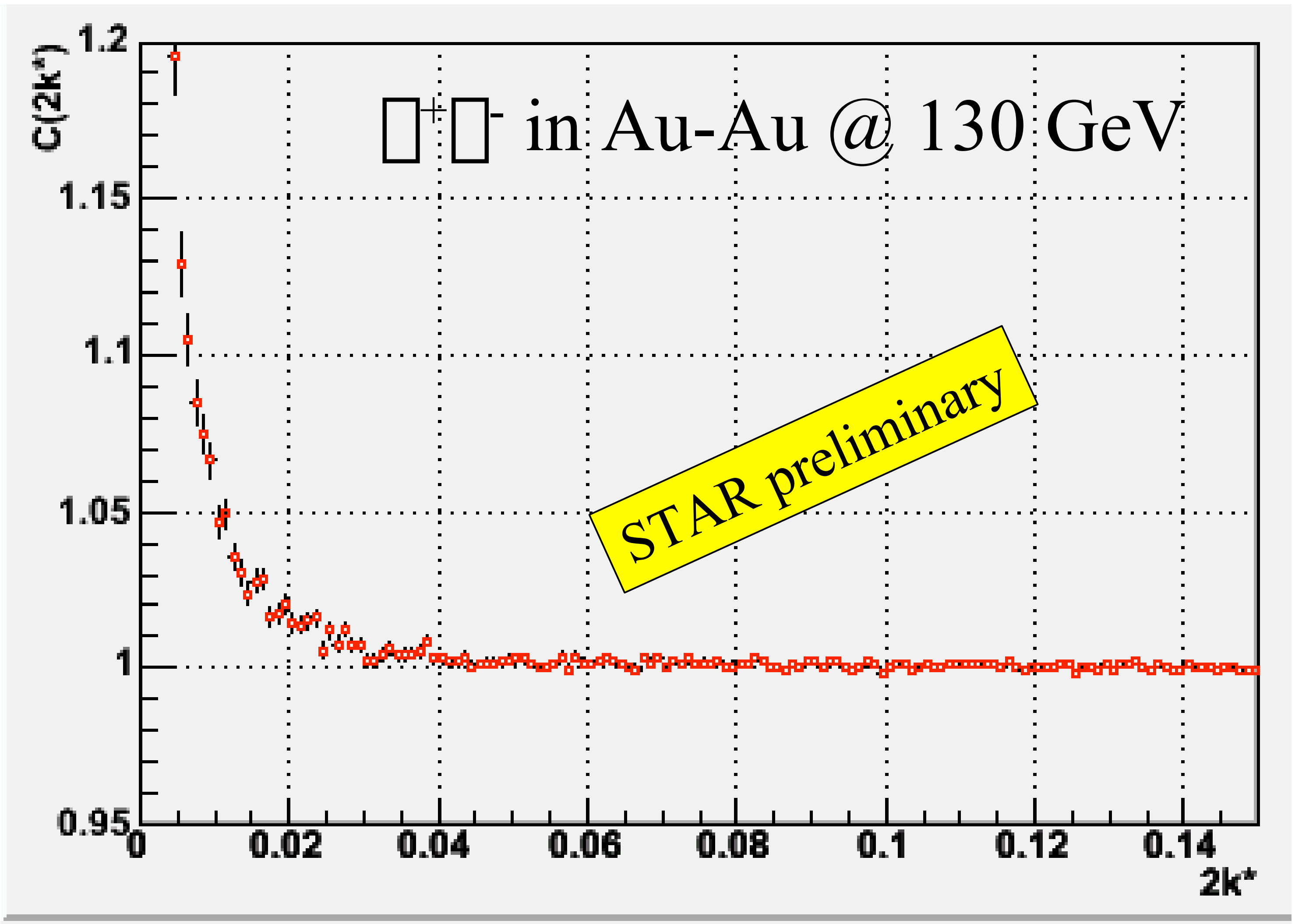
G. Renault (Subatech)

H. Gos, M. Janik, A. Kisiel, P. Swarwas (Warsaw U. of Tech.)

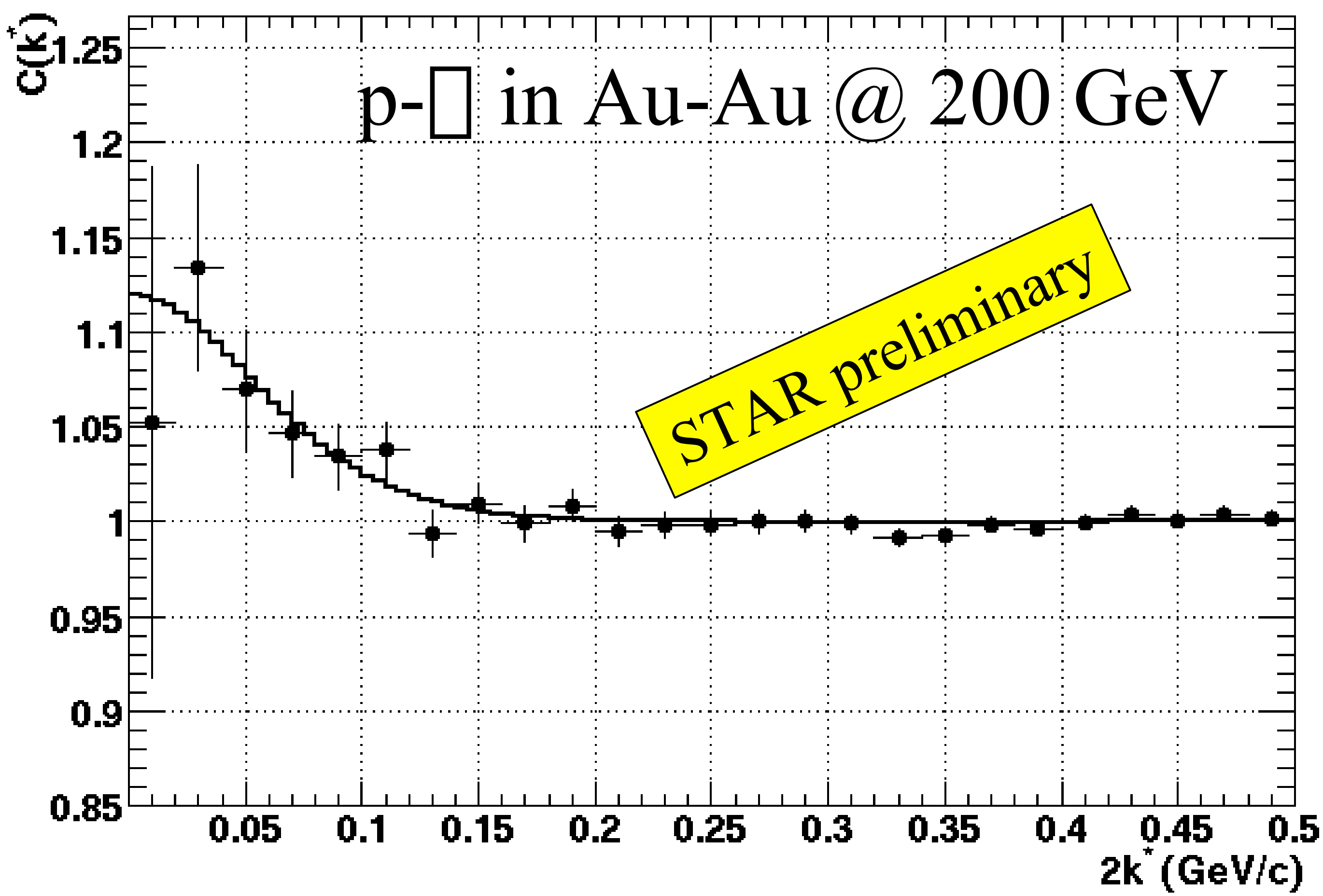
Outline

- Extracting space-time information from non-id correlation
- How flow shifts sources of different particle species
- Flow models/parameterization vs STAR data
- Outlook

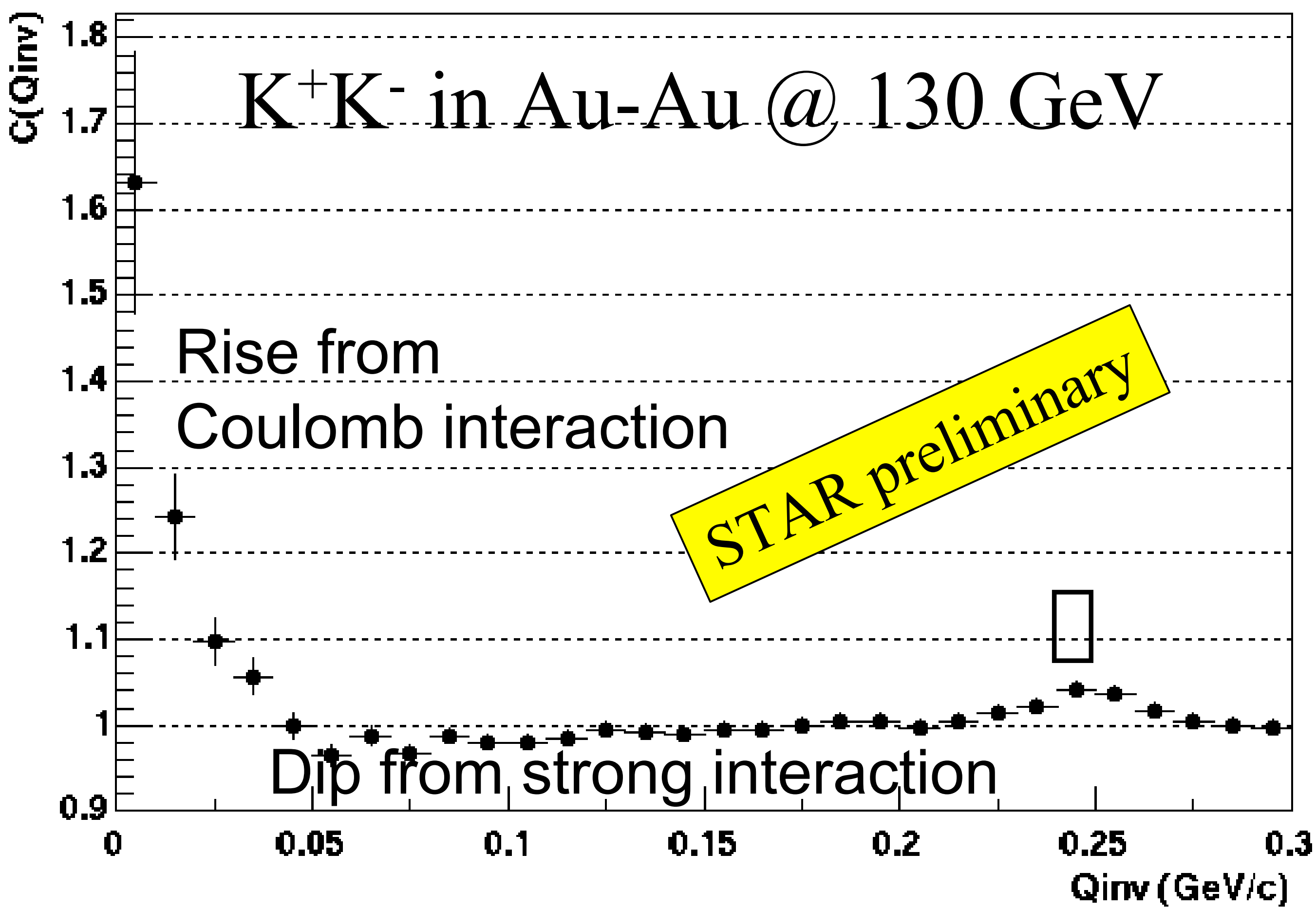
Effect of final state interactions
(i) Coulomb dominates



Effect of final state interactions
(ii) Only strong interaction

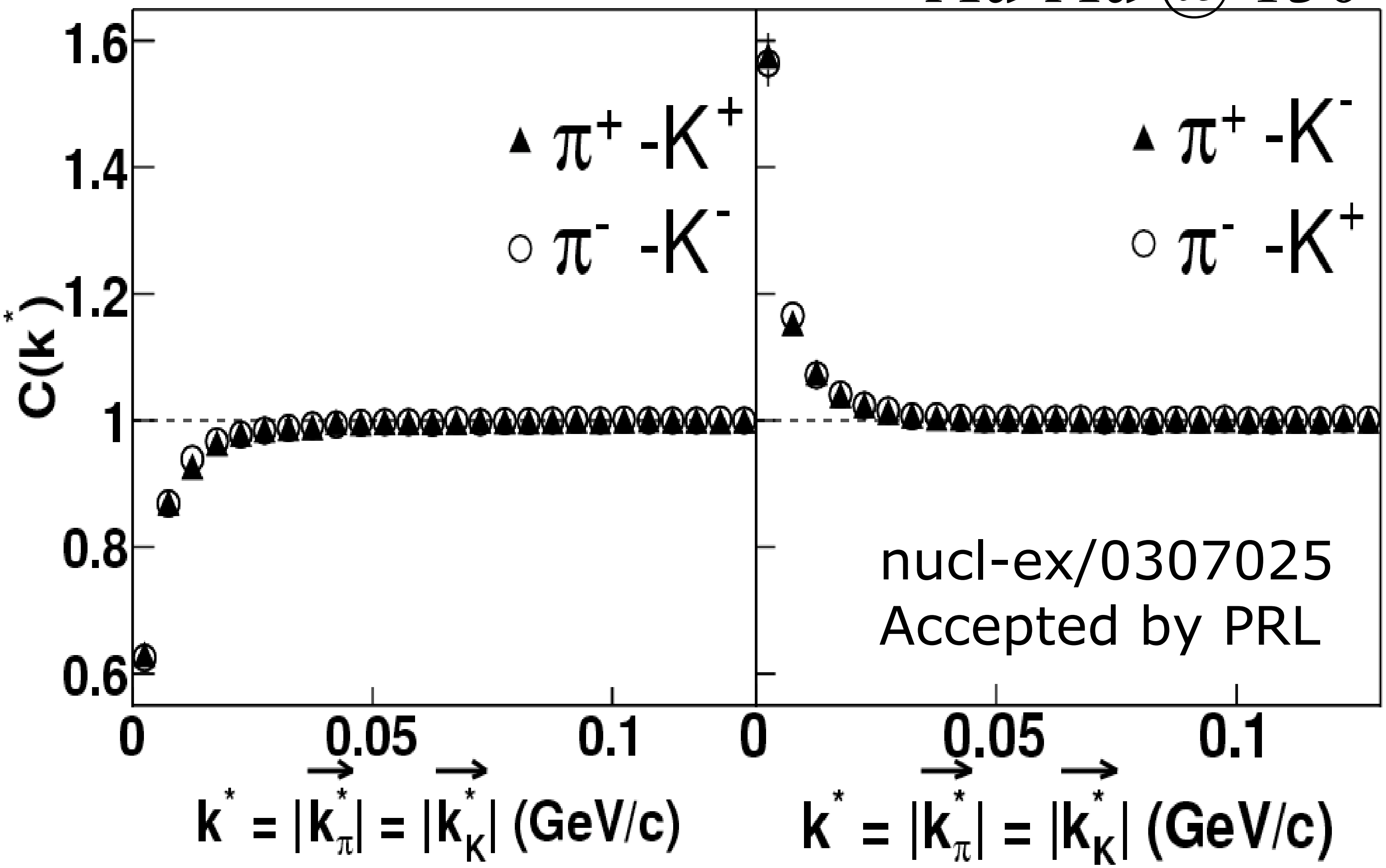


Effect of final state interactions
(iii) Coulomb and Strong combined

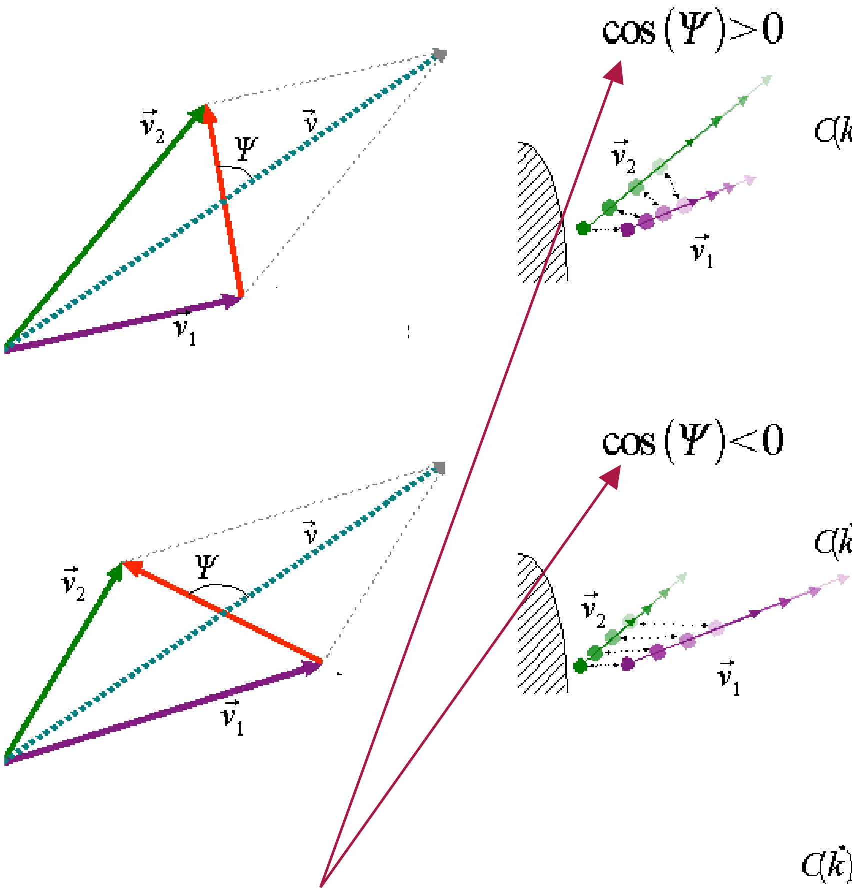


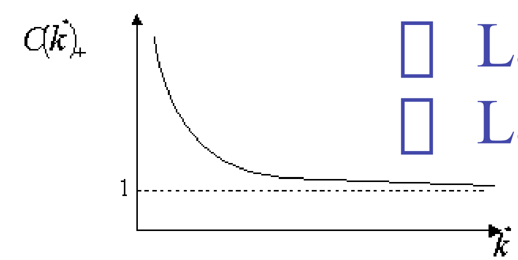
-K correlation functions Dominated by Coulomb

Au-Au @ 130 GeV



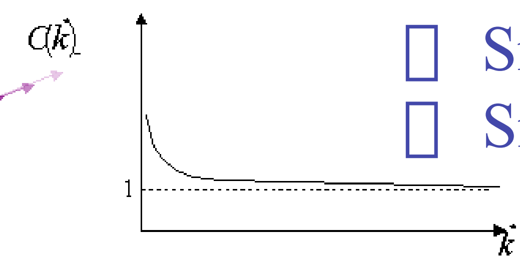
Probing the space-time emission asymmetry





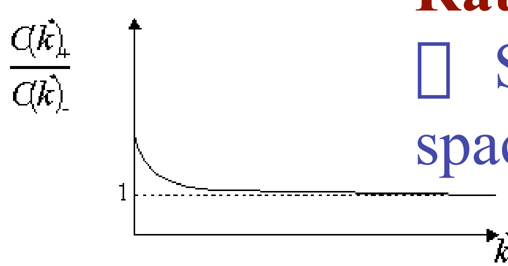
Catching up

- Large interaction time
- Large correlation



Moving away

- Small interaction time
- Small correlation



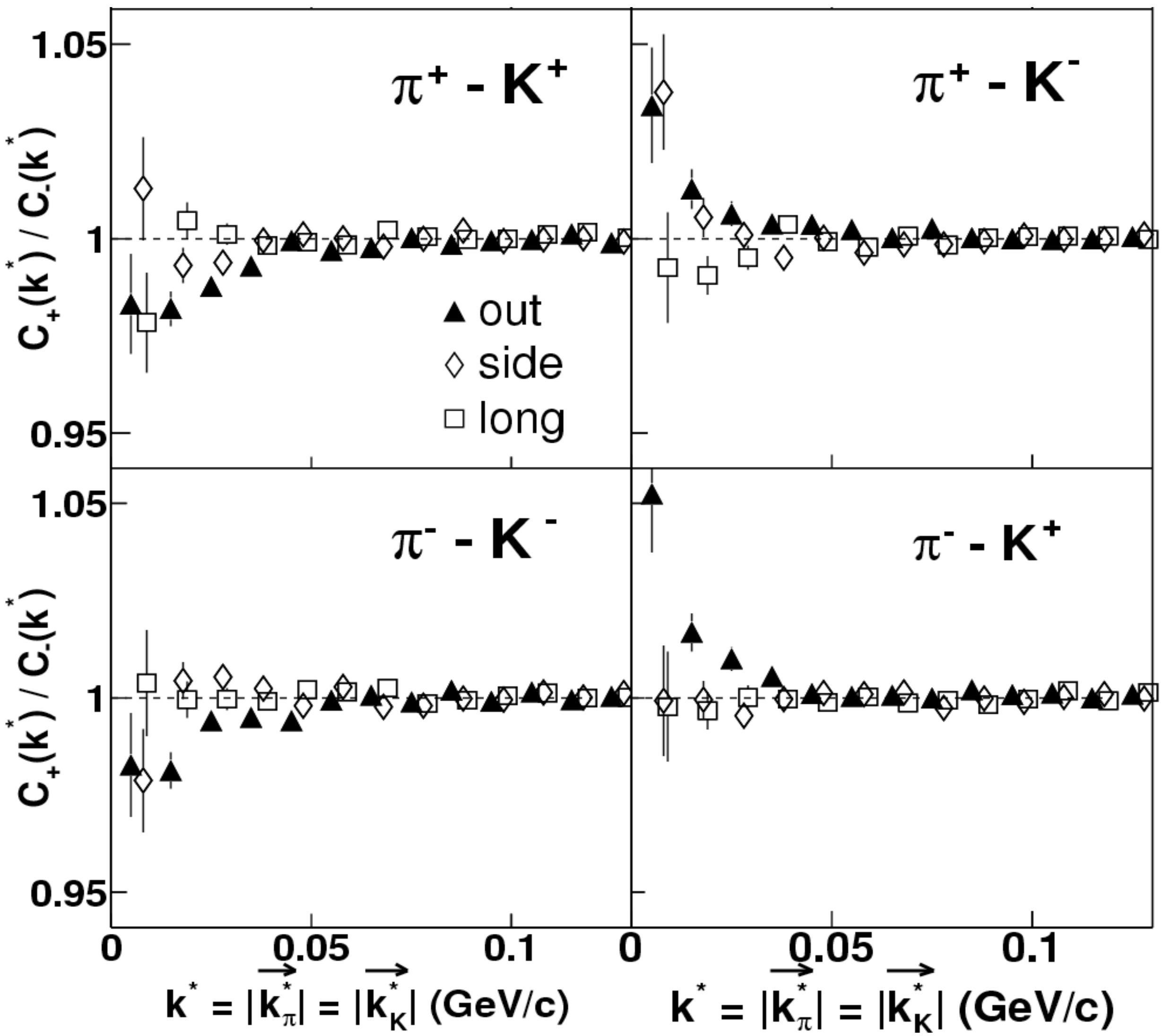
Ratio

- Sensitive to the space-time asymmetry

Kinematics selection

R.Lednicky, V. Lyuboshitz, B. Erazmus, D. Nouais, Phys.Lett. B 373 (1996) 30.

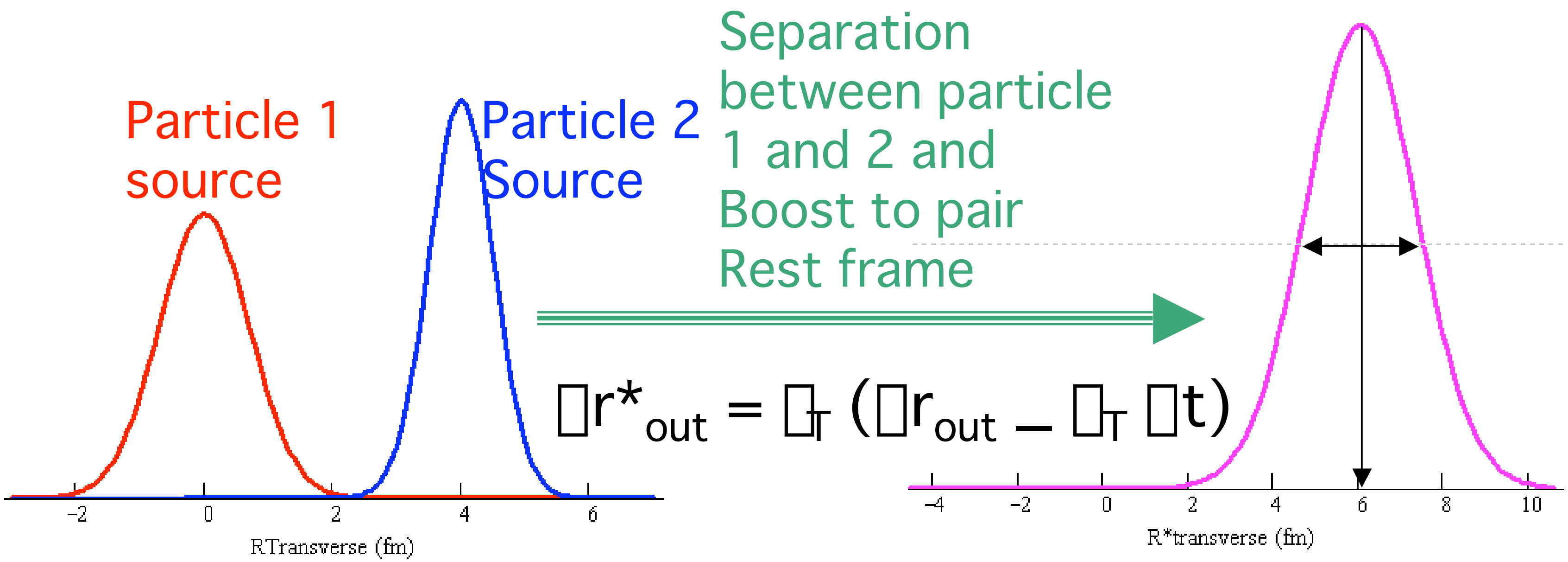
π-K double ratios



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

Au-Au @ 130 GeV

Getting more quantitative by fitting the correlation functions



$$\Delta r^*_{out} = \gamma_T (\Delta r_{out} - \beta_T \Delta t)$$

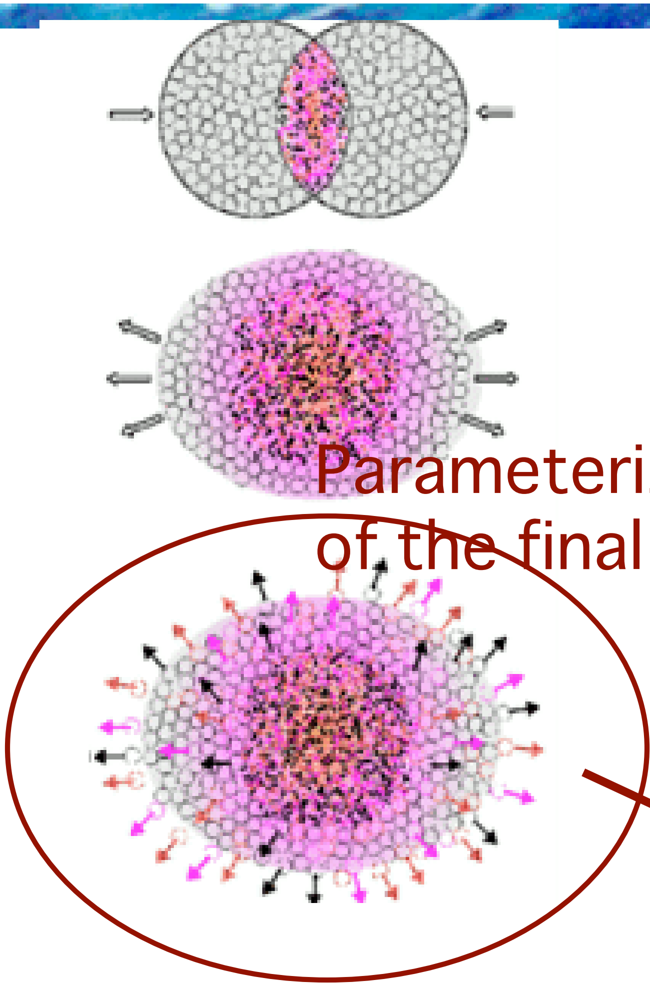
- Take momentum from reconstruted pairs
- Caculate CFs using code from R.Lednicky et al.
- Add position according to a 3D Gaussian in the pair rest frame
  - Parameters: σ and <Δr_{out}>

Fit results

pair	σ (fm)	Δr^*_{out} (fm)	χ^2 / dof
$\pi^+ - K^+$	12.2 ± 0.6	-6.3 ± 1.2	$25.8/26$
$\pi^- - K^-$	12.2 ± 0.7	-5.7 ± 1.2	$23.6/26$
$\pi^+ - K^-$	13.5 ± 0.8	-5.3 ± 1.2	$41.9/26$
$\pi^- - K^+$	12.7 ± 0.6	-4.6 ± 1.0	$43.1/26$

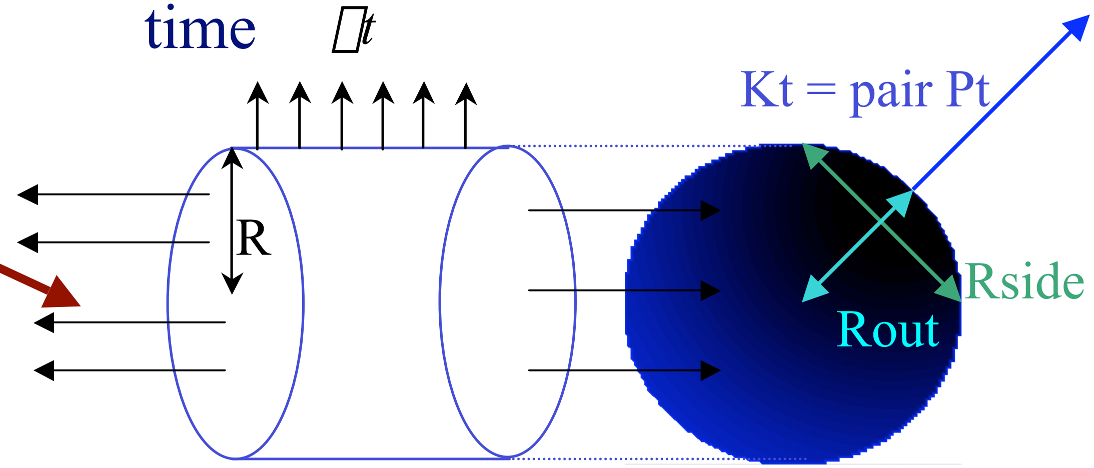
- Systematic errors
  - Uncertainty on purity
  - Uncertainty in correlation calculation
  - Gaussian source assumption
- More fit results (4 CFs average)
  - $\langle r^*_{\square} - r^*_{\square} \rangle = -5.6 \pm 0.6^{+1.9}_{-1.3}$ fm
    - 130 GeV, to be published in PRL
  - $\langle r^*_{\square} - r^*_{p} \rangle = -6.3 \pm 0.6 \pm 2$ fm
    - 130 GeV, still preliminary
  - $\langle r^*_{\square} - r^*_{p} \rangle = 0.9 \pm 0.7 \pm 2$ fm
    - 200 GeV, still preliminary

Compare to a flow baseline: Blast wave parameterization



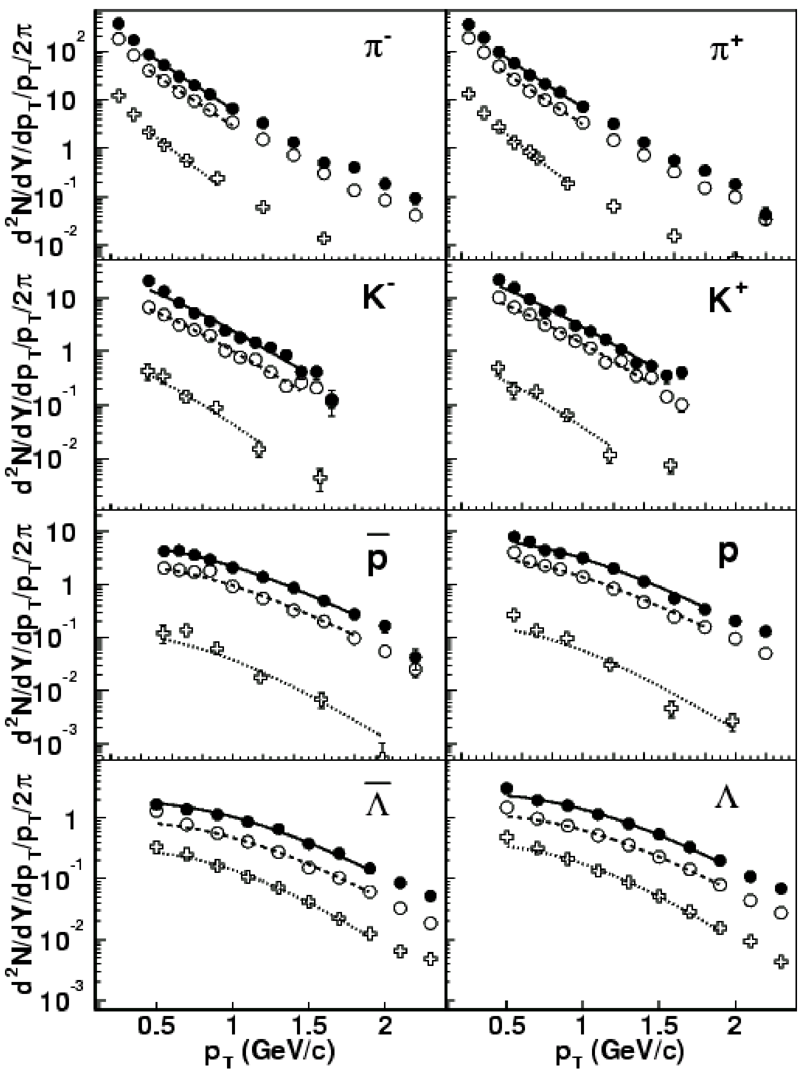
Parameterization of the final state

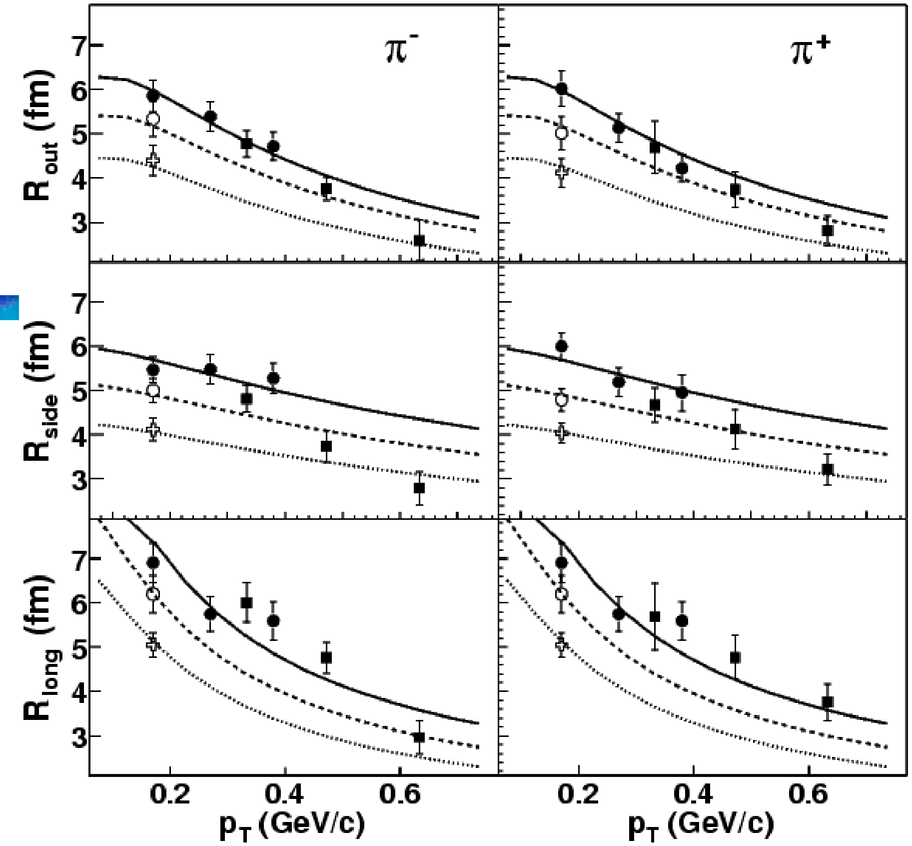
- Hydro-inspired parameterization
  - Boost invariant longitudinal flow
  - Transverse flow
    - Linear rapidity profile
    - Azymuthal oscilation in non-central
  - Tunable system size, shape and life time Δt



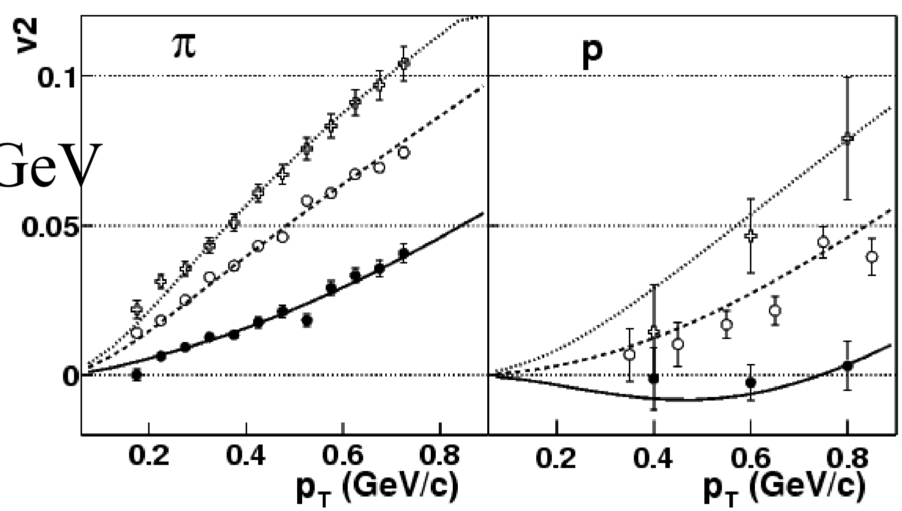
Inspired by E.Schnedermann, J. Sollfrank, and U. Heins, PRC 48 (2002) 2462

Fit with blast wave parameterization

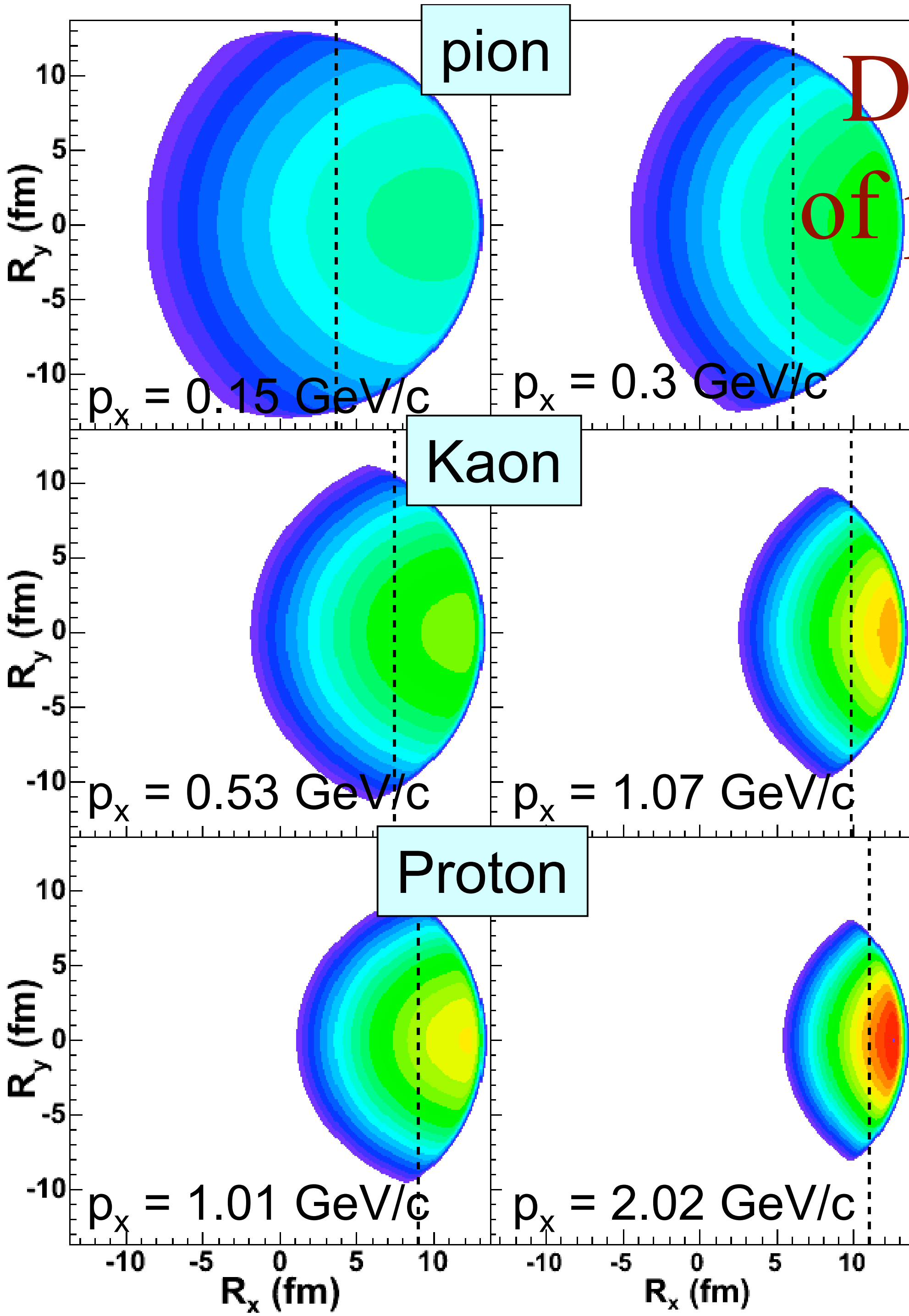




Fit to
Au-Au
@ 130GeV



Distribution emission of points in Blast-Wave



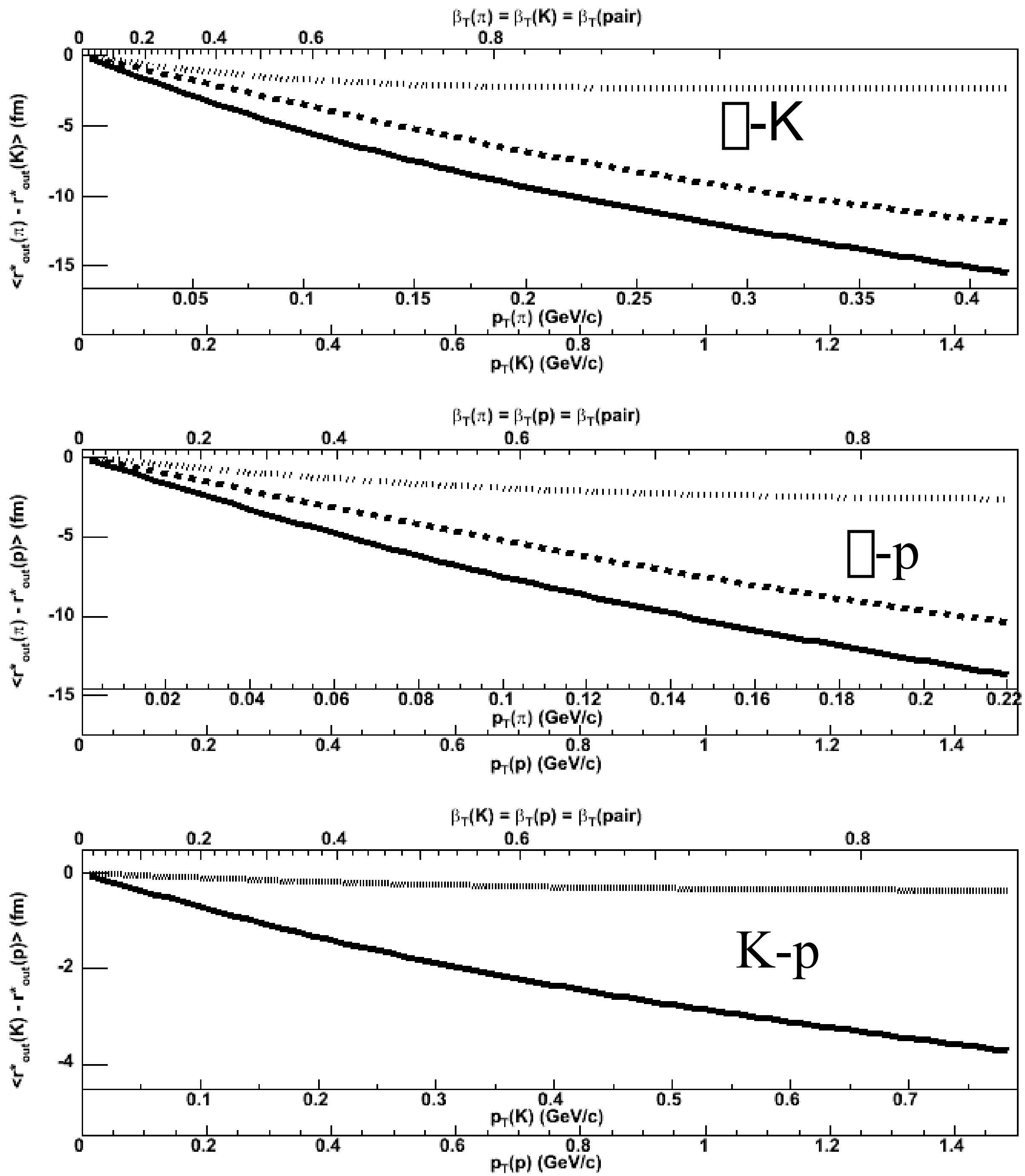
Distribution of emission points at a given emission momentum.

Particles are correlated when their velocities are similar.
Keep velocity constant:
- Left, $□_x$ = 0.73c, $□_y$ = 0
- Right, $□_x$ = 0.91c, $□_y$ = 0

Dash lines: average emission Radius.
□ $\langle R_x(□)\rangle < \langle r_x(K)\rangle < \langle R_x(p)\rangle$

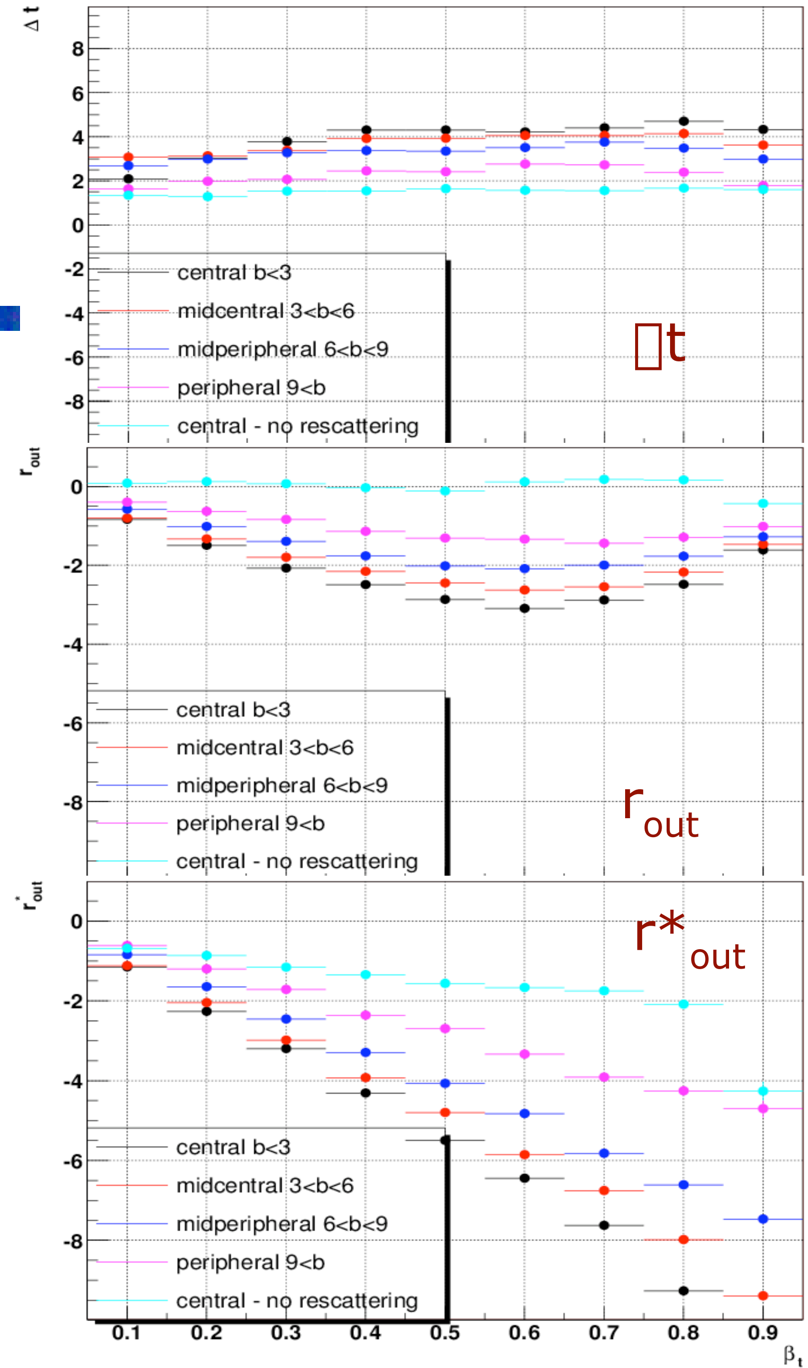
Shifts from Blast wave

- Parameters from best fit to central Au-Au @ 130 GeV
  - No tuning
- Legend
  - Dot = -□□□t
  - Dash = □□r_{out}
  - Plain = □r^*_{out}

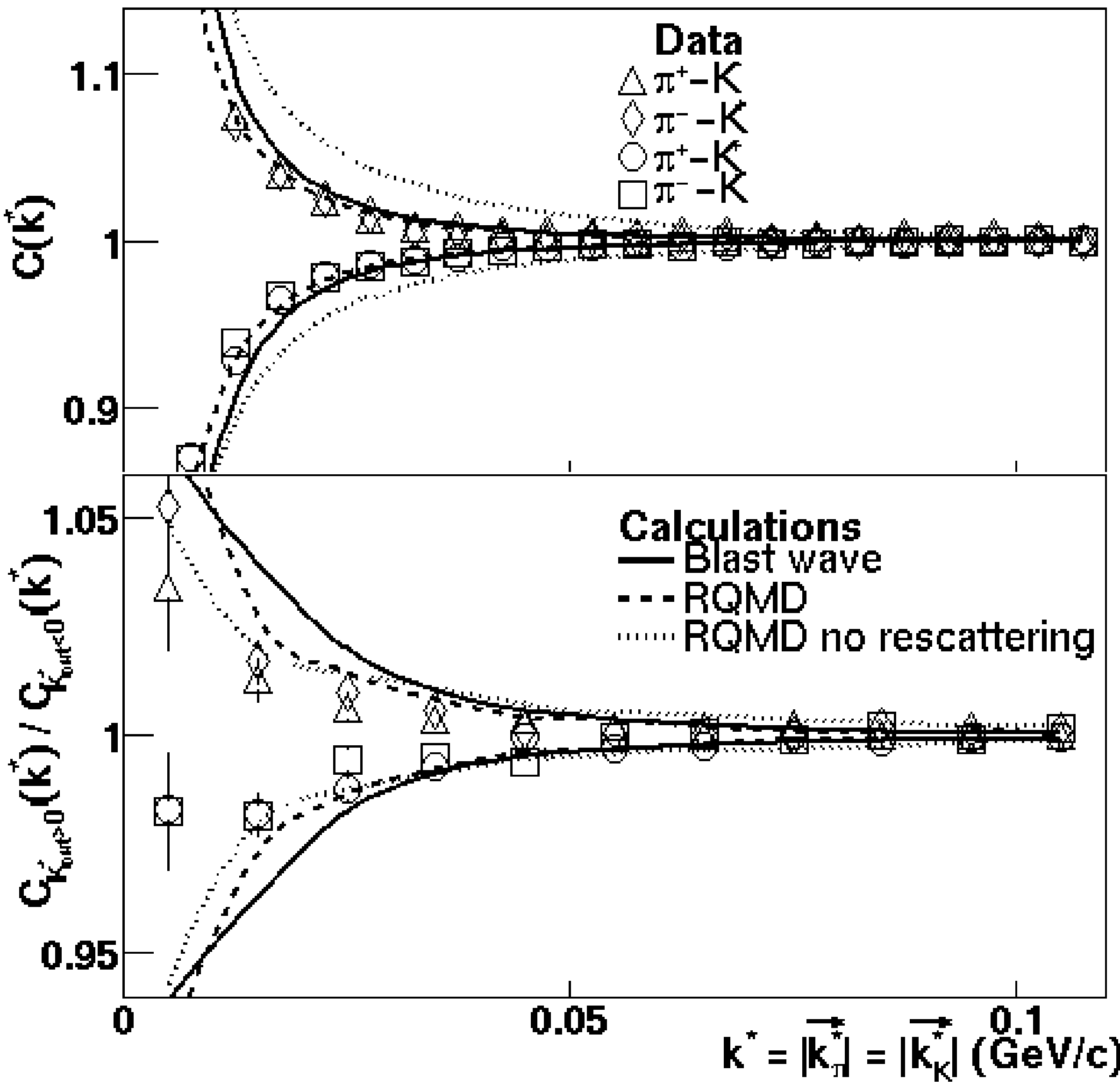


More time shift from resonances

- Use RQMD as a gauge
  - Similar spatial shift as in the BWP
    - Turns off when rescattering is turned off
  - Time shift
    - Similar to BWP
    - + effect of resonances



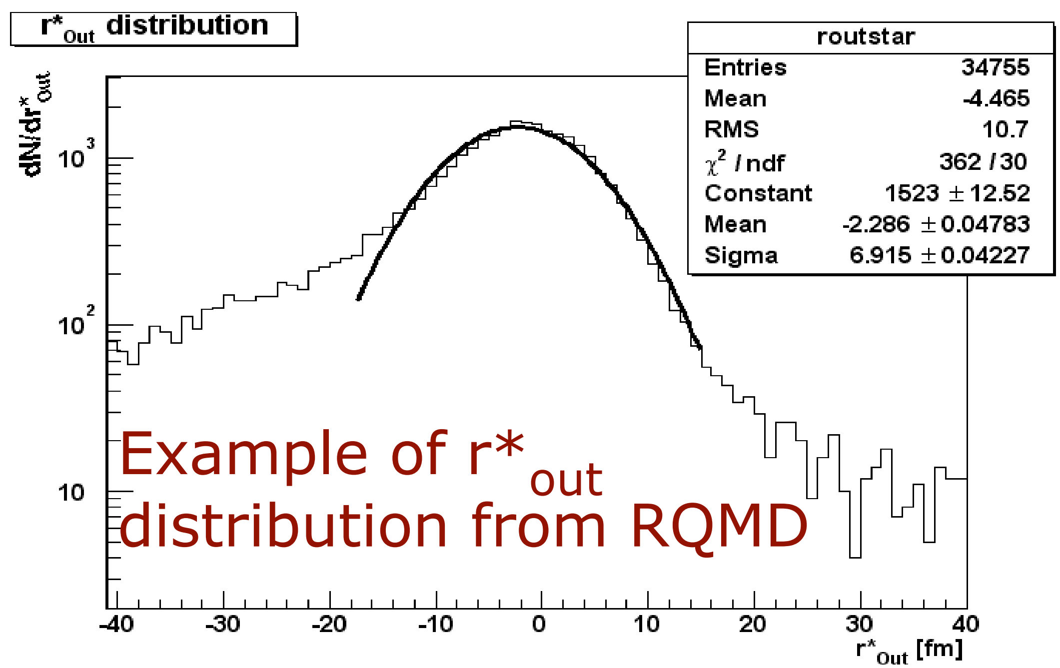
STAR data and models



Fitting and quantitative comparisons

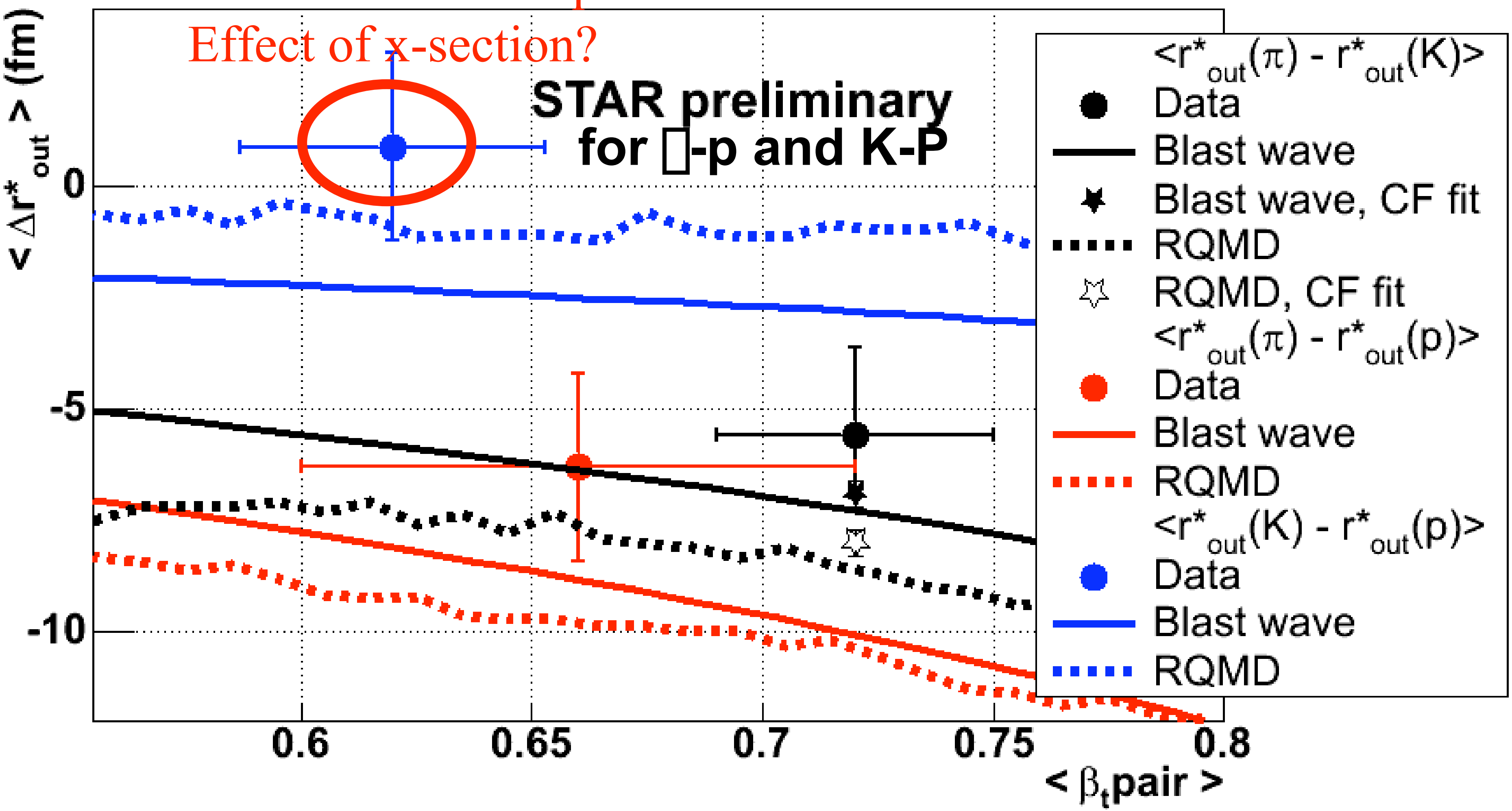
- Source is not Gaussian in model
  - Ambiguity when comparing spatial distribution directly
- Data statistics too low to study whether or not the source is Gaussian

	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	$1020/118$



Summary plot

Late freeze-out of p?
Effect of x-section?

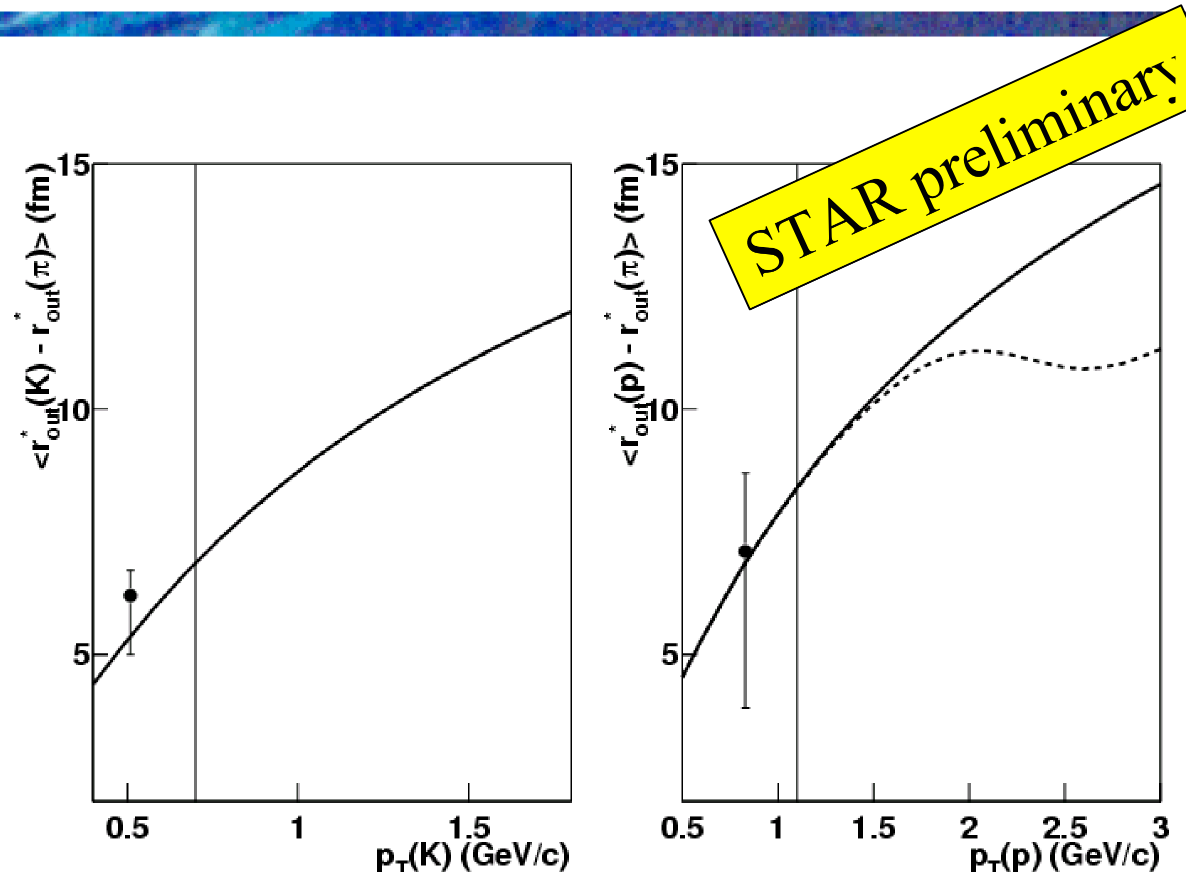


Summary

- Average emission point/time of pions, kaons and protons are shifted.
- Shift consistent with flow
  - Non-id correlation analyses offer a new way to study flow.
  - Agreement with the blast wave parameterization
    - No tuning. Parameters from fit to HBT and spectra
- RQMD: Flow + significant contribution from resonance decay
- Hints that the proton decouple late?

Outlook 1
Overcoming the systematic errors

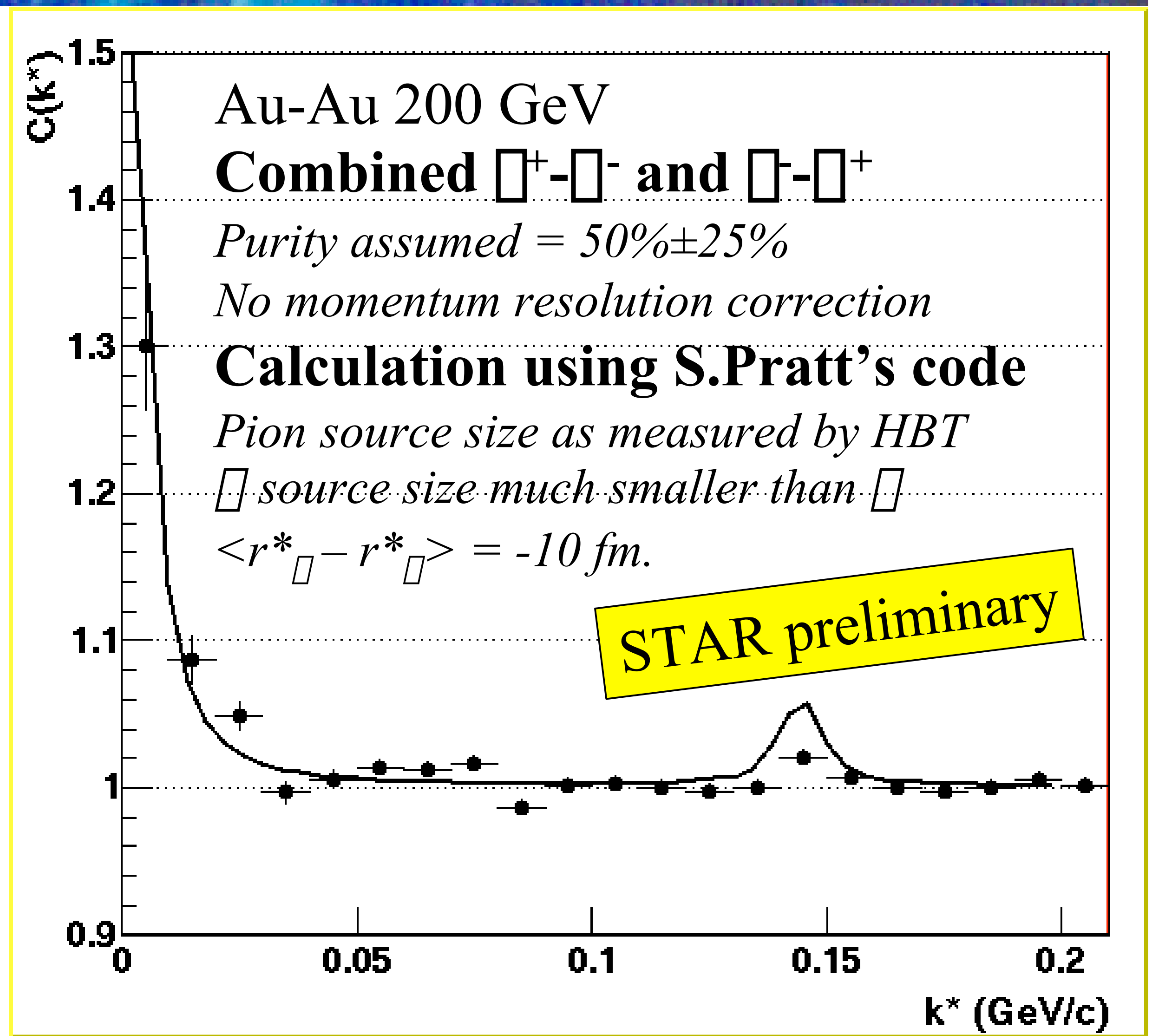
- Systematic errors
  - Purity estimation
  - Source shape
  - Correlation function calculations
    - Uncertainties on scattering length, …
- Errors vary little with p
  - Point to point errors would be small



Points: preliminary STAR data
Plain line: Blast wave calculation
Dash line: BW + prompt emission of p

Outlook 2
□-□ correlation and collectivity

- Source size and shift from □⁻-□⁻ and □⁺-□⁺
  - Coulomb only
- Do □ flow as □?
- Investigate strong interaction in unlike-sign
  - Input onto cross-sections?



Outlook 3
A lot can be done

	□$^{\pm}$	$K^{\pm}$	K^0_s	$p^{\pm}$	□	□$^{\pm}$	□$^{\pm}$	$D^{\pm}$
□$^{\pm}$	Y1-4							
$K^{\pm}$	Y1-4	Y1-4						
K^0_s	int. ?	int. ?	Y2-4					
$p^{\pm}$	Y1-4	Y2-4	int. ?	Y2-4				
□	int. ?	int. ?	no stat	Y2-4	Y4			
□$^{\pm}$	Y2-4	Y4?	no stat	Y4?	no stat	no stat		
□$^{\pm}$	Y4?	no stat	no stat	no stat	no stat	no stat	no stat	
$D^{\pm}$	Y7?	no stat	no stat	no stat	no stat	no stat	no stat	no stat

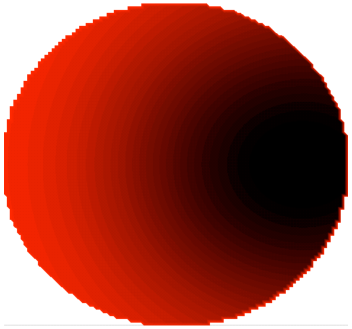
Hope other RHIC experiments join in

Y1 (2000) = 0.5M central @ 130GeV, Y2 = 2M central @ 200 GeV, Y4 = 50M+ min-bias @ 200 GeV

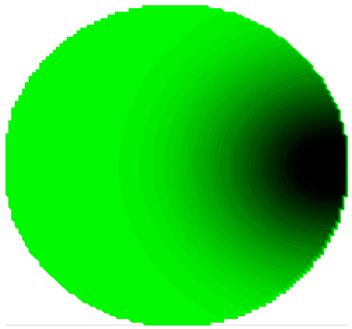
Extra slides

Transverse flow shifts average emission points

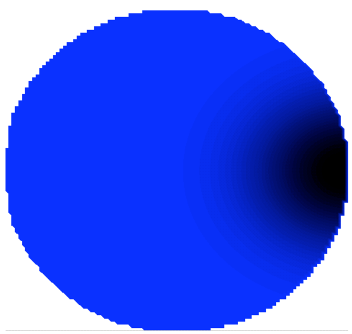
Pion
pt = 0.15 GeV/c
□t = 0.73

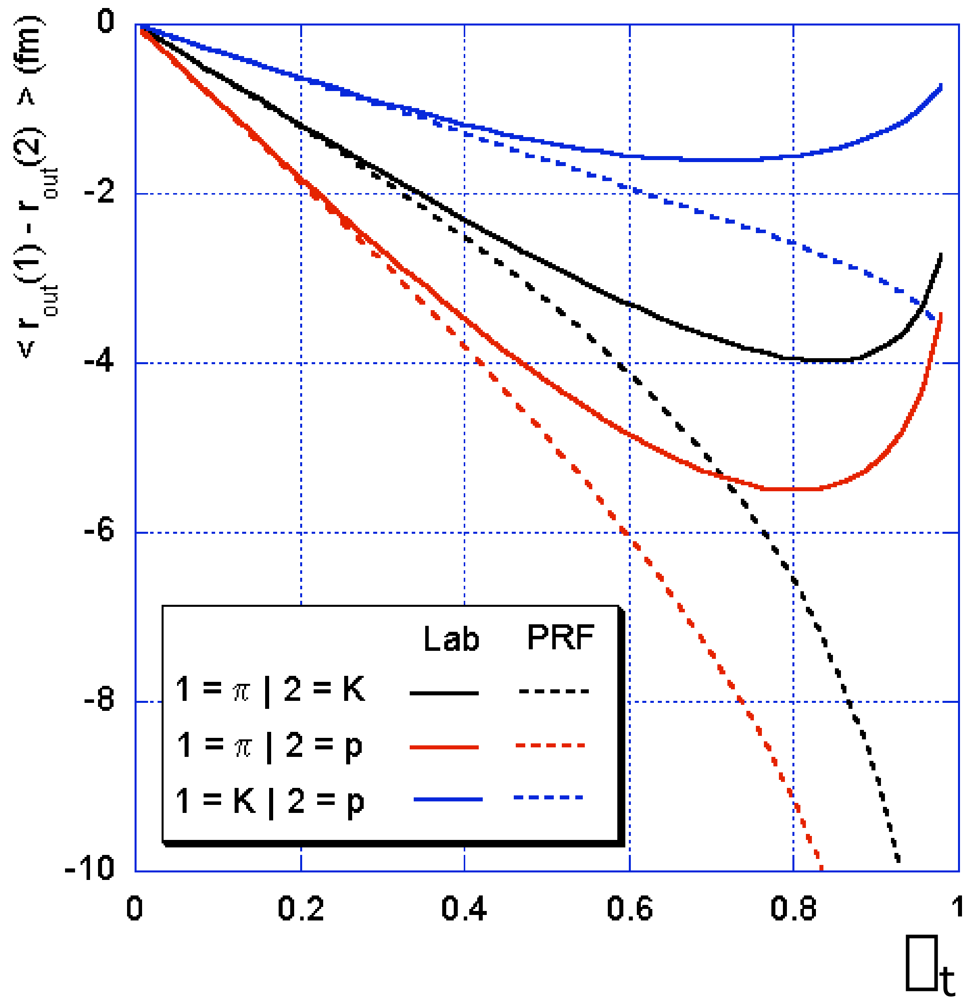


Kaon
pt = 0.5 GeV/c
□t = 0.71



Proton
pt = 1. GeV/c
□t = 0.73





Fit parameters

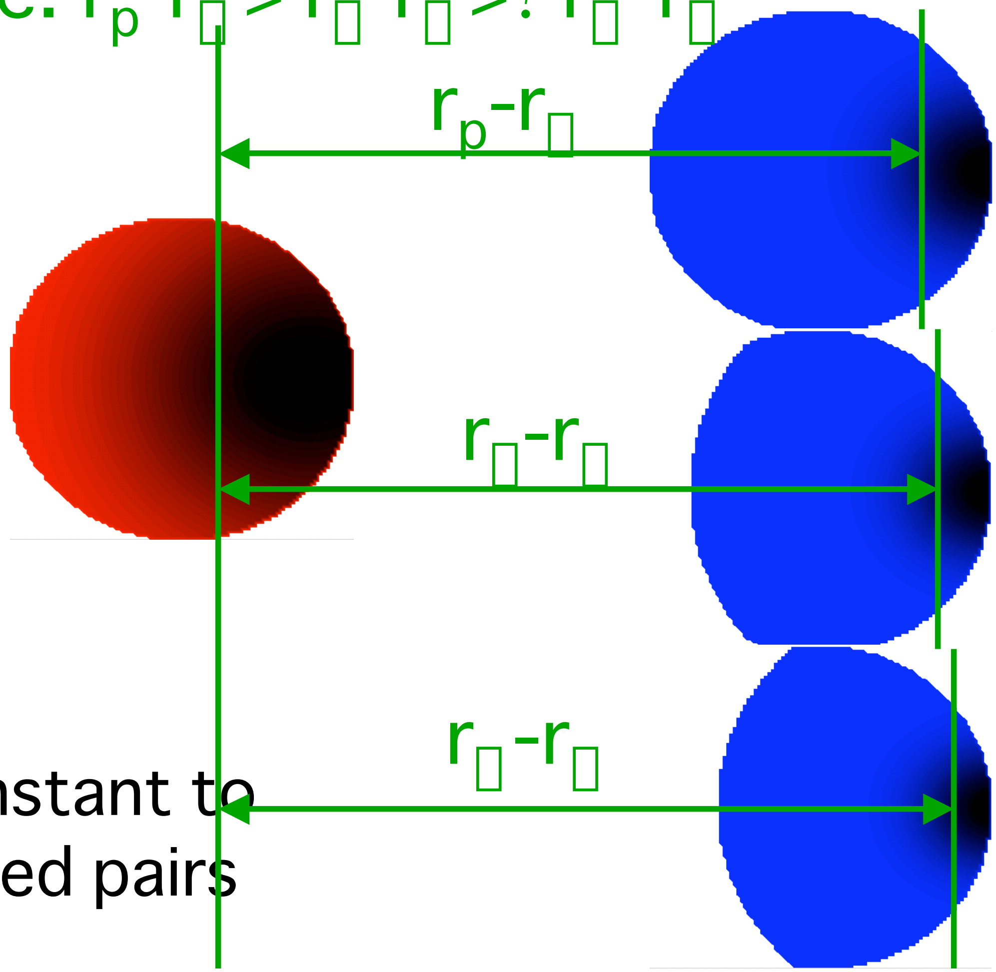
3D Blast wave analysis done with Mike Lisa (OSU)

Will increase with new Coulomb correction of pion HBT radii

	Central	Mid-central	Peripheral
data			
π, K, p spectra [?]	0-5%	15-30%	60-92%
Λ spectra [?]	0-5%	20-35%	35-75%
pion radii [29]	0-12%	20-40%	32-72%
Elliptic flow [20]	0-11%	11-45%	45-85%
χ^2/bin			
π^+ & π^- spectra	10.4/12	46.4/12	14.1/9
K^+ & K^- spectra	24.6/22	20.6/22	9.2/10
p & $\overline{p}$ spectra	10.6/18	26.3/18	28.6/12
Λ & $\overline{\Lambda}$ spectra	9.5/16	12.3/16	12.1/16
$\pi\ v_2$	13.8/12	36.1/12	8.5/12
$p\ v_2$	0.8/3	11.3/6	1.2/3
$\pi\ r_{out}$	1.8/6	0.4/2	0.4/2
$\pi\ r_{side}$	2.6/6	0.3/2	0.07/2
$\pi\ r_{long}$	6.5/6	0.003/2	0.09/2
Total	80.5/101	153.7/92	74.3/68
parameters			
T (MeV)	108 ± 3	106 ± 3	95 ± 4
ρ_0	0.88 ± 0.01	0.87 ± 0.02	0.81 ± 0.02
$\langle\beta_T\rangle$	0.53 ± 0.01	0.52 ± 0.02	0.47 ± 0.02
ρ_a	0.059 ± 0.008	0.052 ± 0.006	0.04 ± 0.01
$R_x(fm)$	12.9 ± 0.3	10.2 ± 0.5	8.00 ± 0.4
$R_y(fm)$	12.8 ± 0.3	11.8 ± 0.6	10.1 ± 0.4
$\tau(fm/c)$	8.9 ± 0.3	7.4 ± 1.2	6.5 ± 0.8
$\Delta t(fm/c)$	0.002 ± 1.4	0.8 ± 3.2	0.8 ± 1.9

Multi-strange baryon flow?
Non-id correlation as a probe

If □ and □ flow as protons: r_p-$r_□$ < $r_□$-$r_□$ < $r_□$-$r_□$
Otherwise: r_p-$r_□$ > $r_□$-$r_□$ >? $r_□$-$r_□$



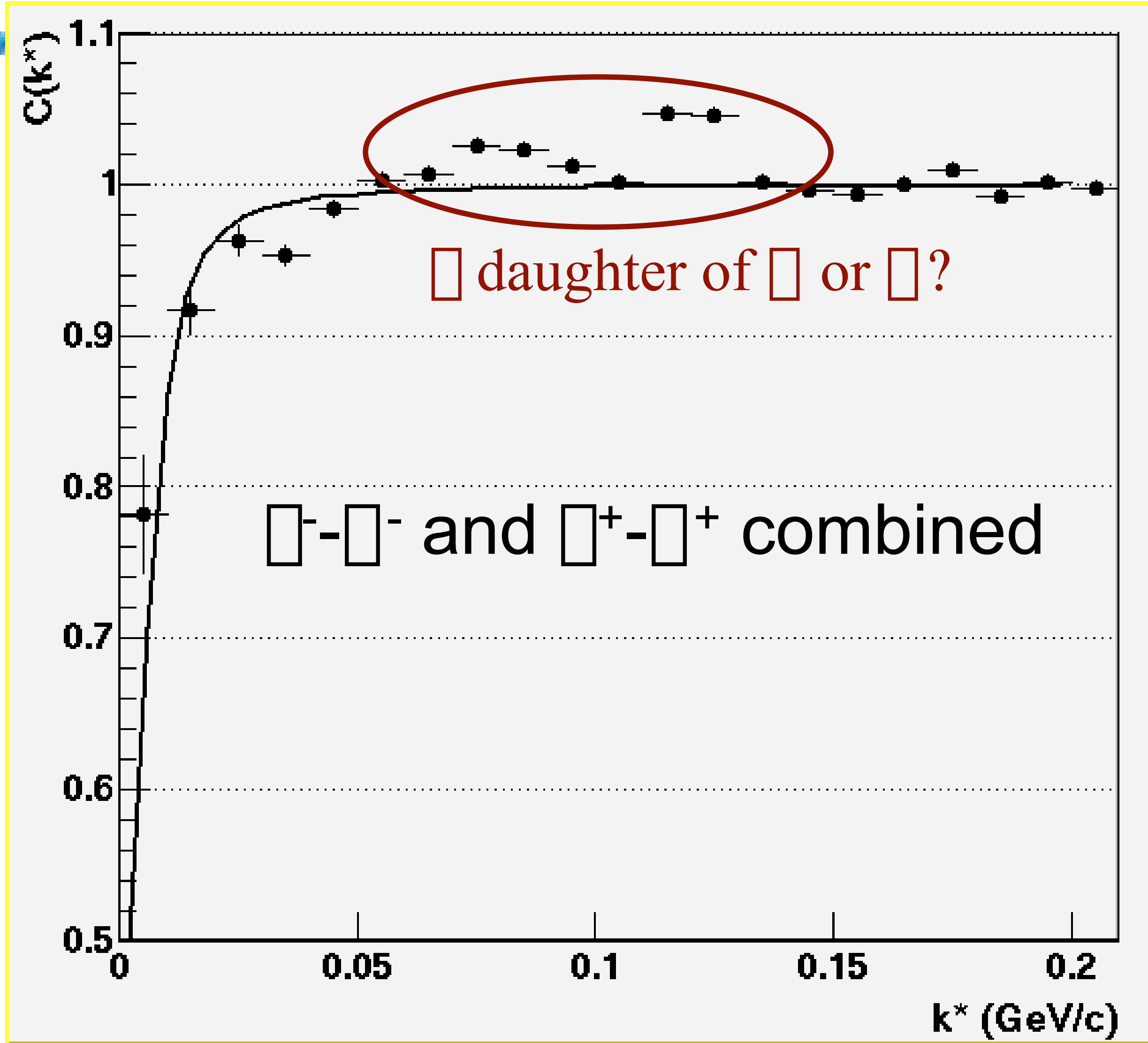
Pion
pt = 0.15 GeV/c
□t = 0.73

Proton
pt = 1. GeV/c
□t = 0.73

□□
pt = 1.4 GeV/c
□t = 0.73

□□
pt = 1.8 GeV/c
□t = 0.73

□t is kept constant to have correlated pairs


C(k*)
1.1
1
0.9
0.8
0.7
0.6
0.5
0
0.05
0.1
0.15
0.2
k* (GeV/c)
 daughter of or ?
- - - and + - + combined