Pion-kaon femtoscopy in Au+Au collisions at STAR

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Outline

- HBT (Hanbury-Brown, Twiss) interferometry
- Space-time asymmetry
- Motivation
- Data selection
- Comparison of correlation functions for $\sqrt{s_{NN}} = (130, 39, 19.6, 7.7)\,GeV$
- Comparison of asymmetry for $\sqrt{s_{NN}} = (130, 39, 19.6, 7.7)\,GeV$
- Summary

HBT interferometry (Hanbury-Brown, Twiss)

Interferometries:

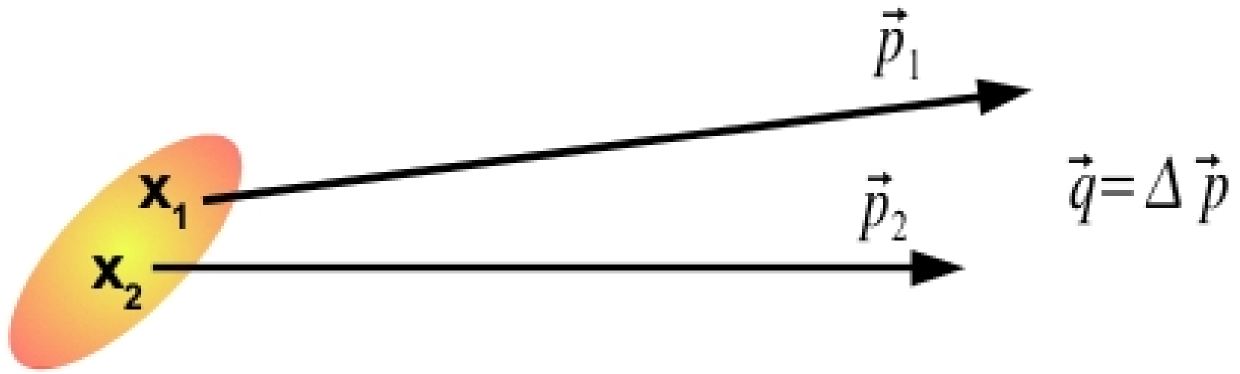
1. An interference of two waves from different sources located in space. The detector records amplitude-phase diffraction signal.

2. The interferometry of intensity occurs, when we detect two identical particles in different points in time and space (or with different energy and momentum)

Method proposed in '50 by Hanburry-Brown and Twiss.

At first was used in astronomy to measure the angular size of stars (using emission of gamma quantum) => photons interferometry of intensity

HBT

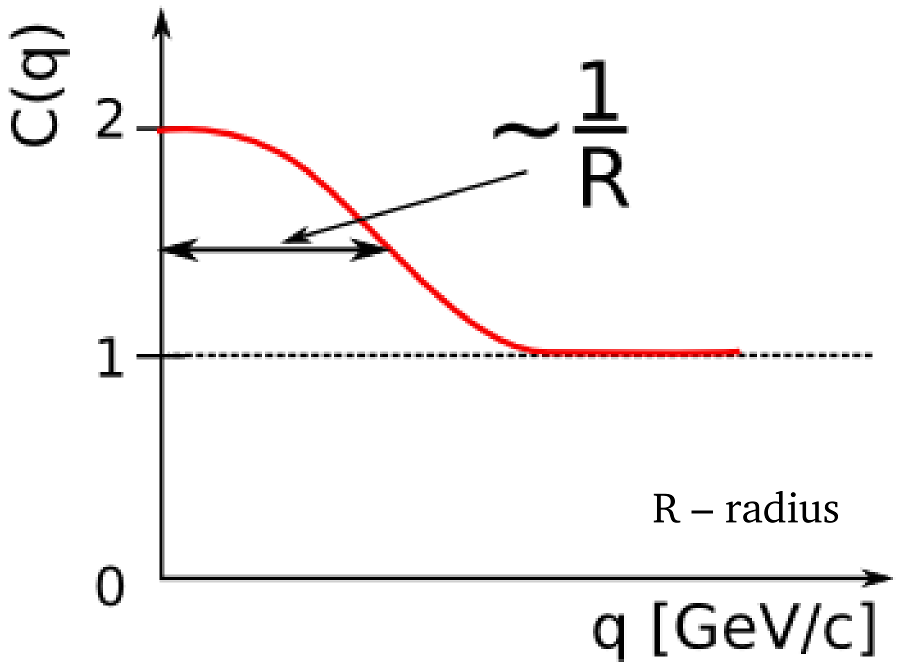


- Analyze many pairs of identical particles (p_1,x_1) and (p_2,x_2) → calculate q the difference momentum vector of those particles.

- Calculate the correlation function of pairs.

$$C(\mathbf{p}_1, \mathbf{p}_2) = \frac{P_2(\mathbf{p}_1, \mathbf{p}_2)}{P_1(\mathbf{p}_1)P_1(\mathbf{p}_2)}$$

- Calculate the source size.

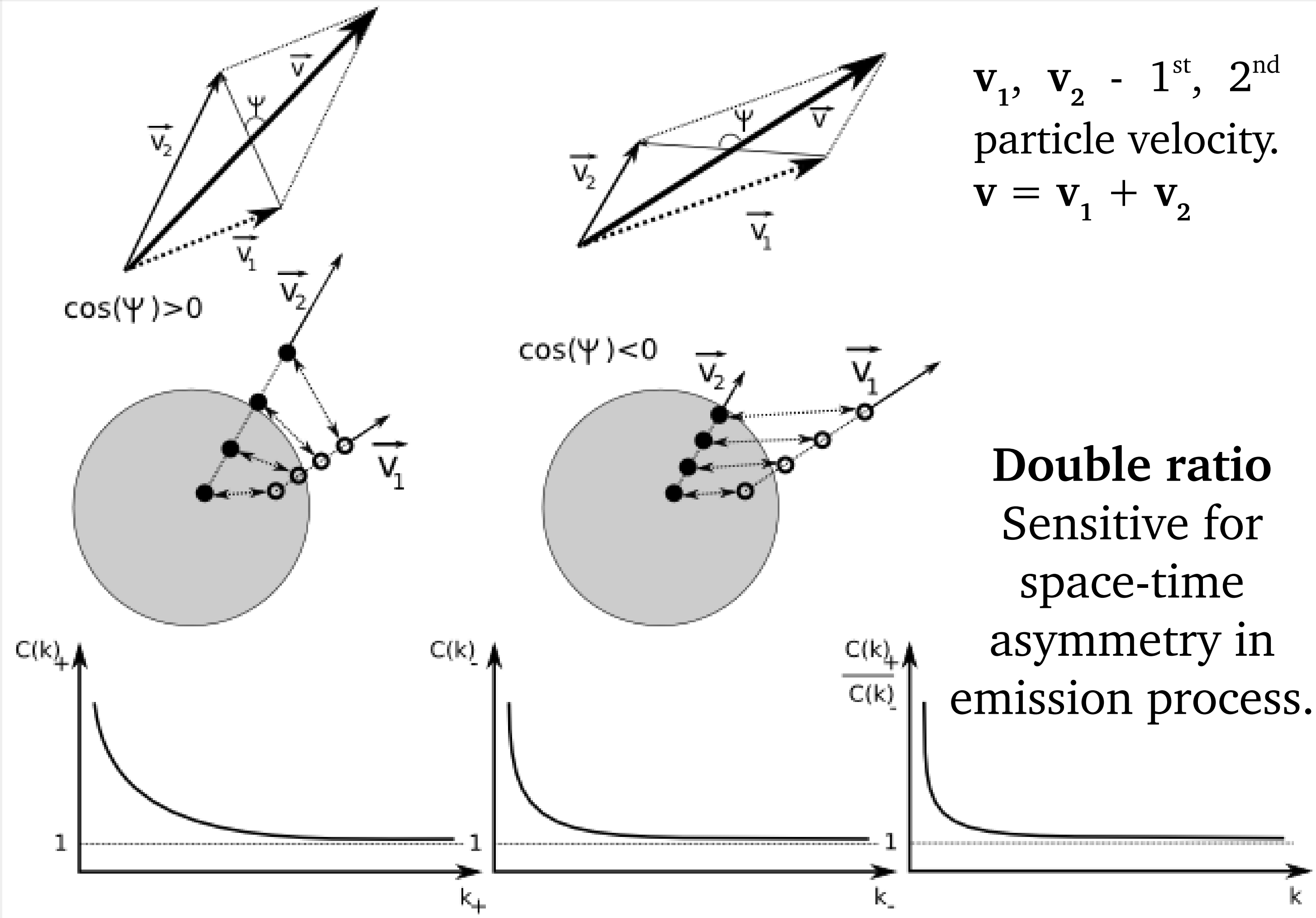


$P_2(\mathbf{p}_1, \mathbf{p}_2)$ – the probability of observing two particles with momentum p_1, and p_2 at the same time and the same place.
$P_1(\mathbf{p}_1)$, $P_1(\mathbf{p}_2)$ – the probability of observing two particles with momentum p_1, and p_2 separately.

Space-time asymmetry

cos(Ψ)>0
Catching up
Long time of effective interaction. Strong correlation.

cos(Ψ)<0
Run away
Short time of effective interaction. Weak correlation.

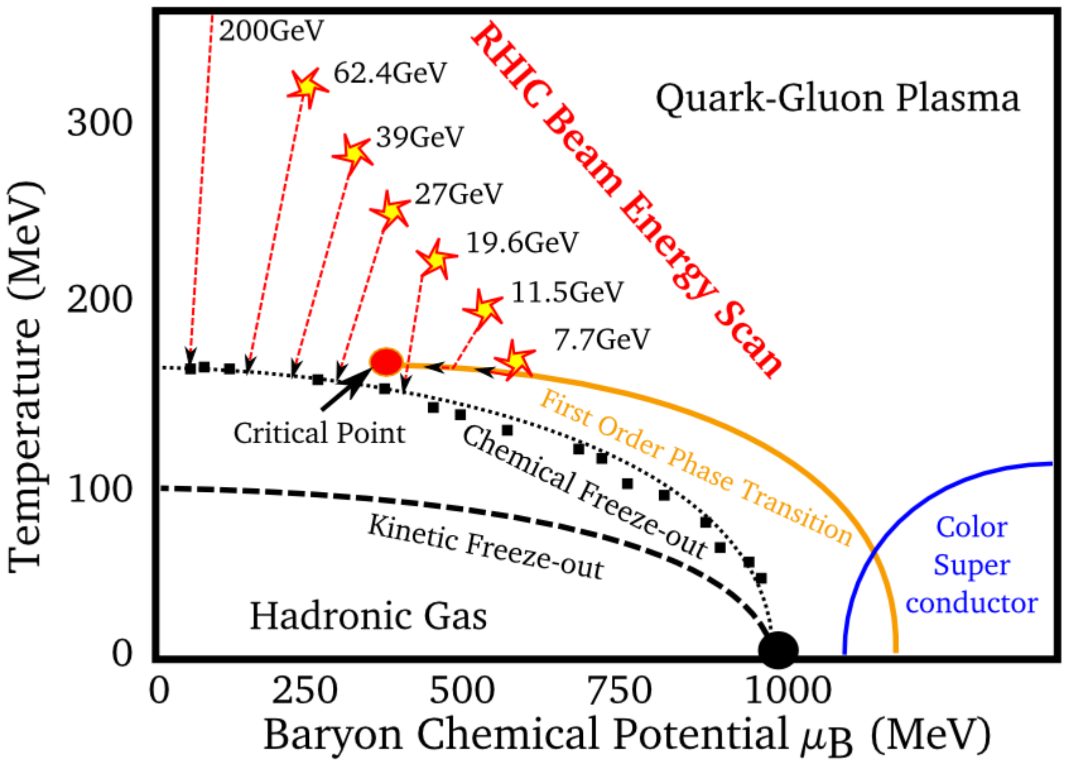


$\mathbf{v}_1$, $\mathbf{v}_2$ - 1st, 2nd particle velocity.
$\mathbf{v} = \mathbf{v}_1 + \mathbf{v}_2$

Double ratio
Sensitive for space-time asymmetry in emission process.

k* - the magnitude of the three-momentum of the particles in the pair rest frame.

Motivation



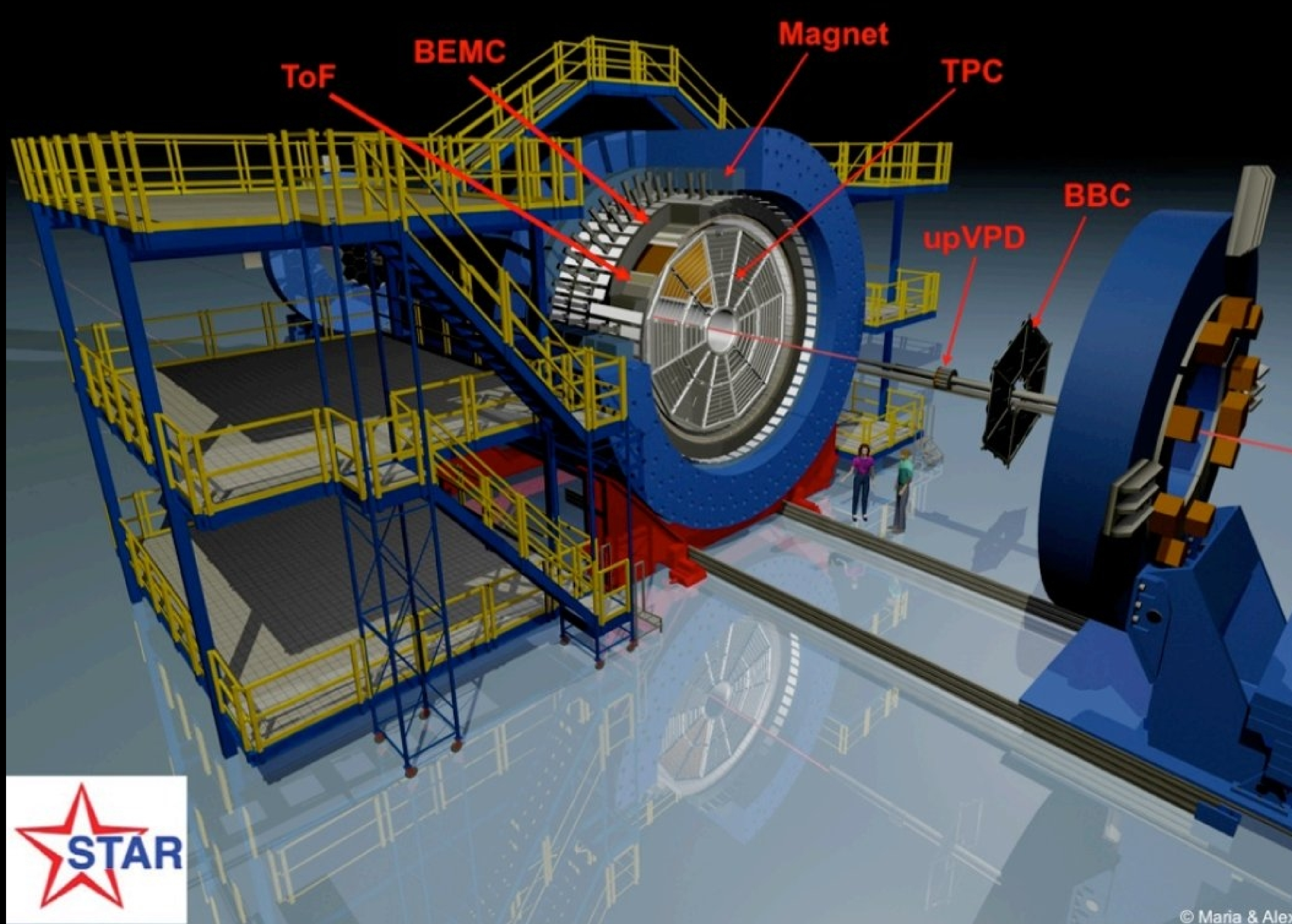
Analyze all Beam Energy Scan (BES) energies and find answers:

If or how pion-kaon source changes with energy?

If or how pion-kaon asymmetry in emission process looks for all BES energies?

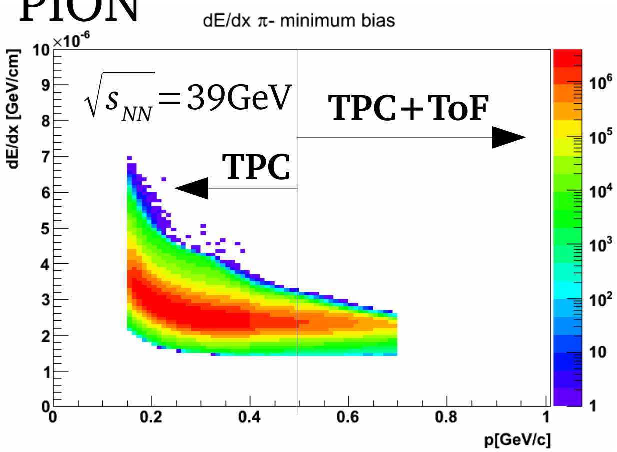
If or how the flow affects the pion-kaon system, consisting of particles of different masses?

The Solenoidal Tracker At RHIC (STAR)

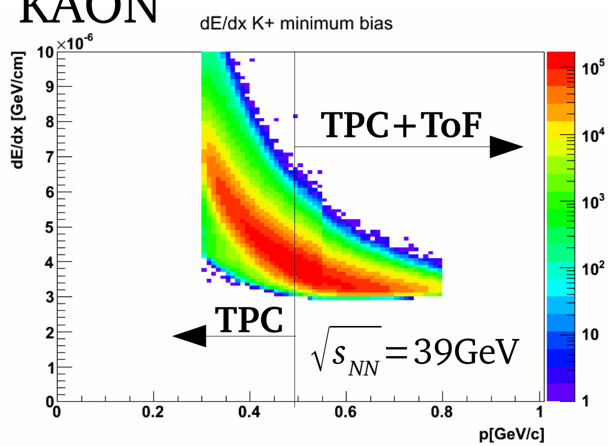


Data selection

PION

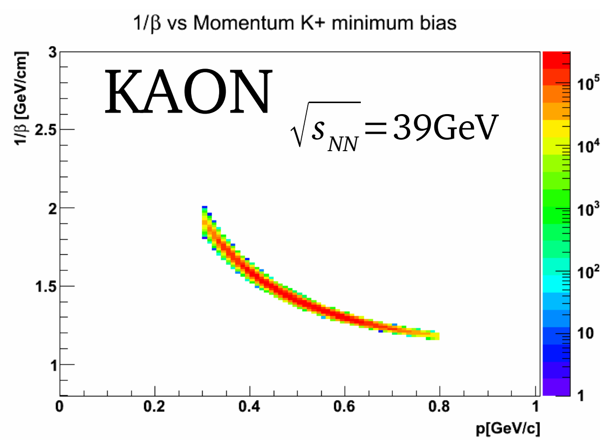


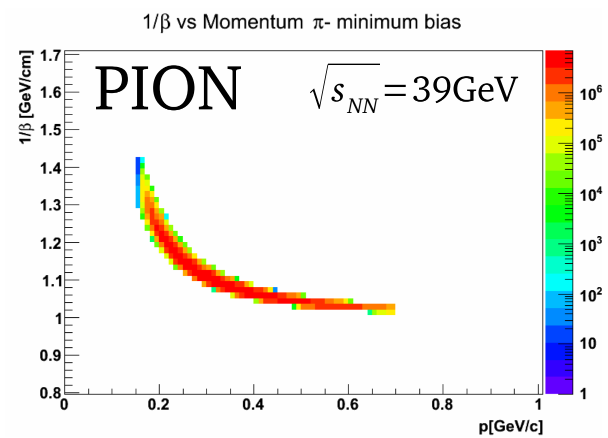
KAON



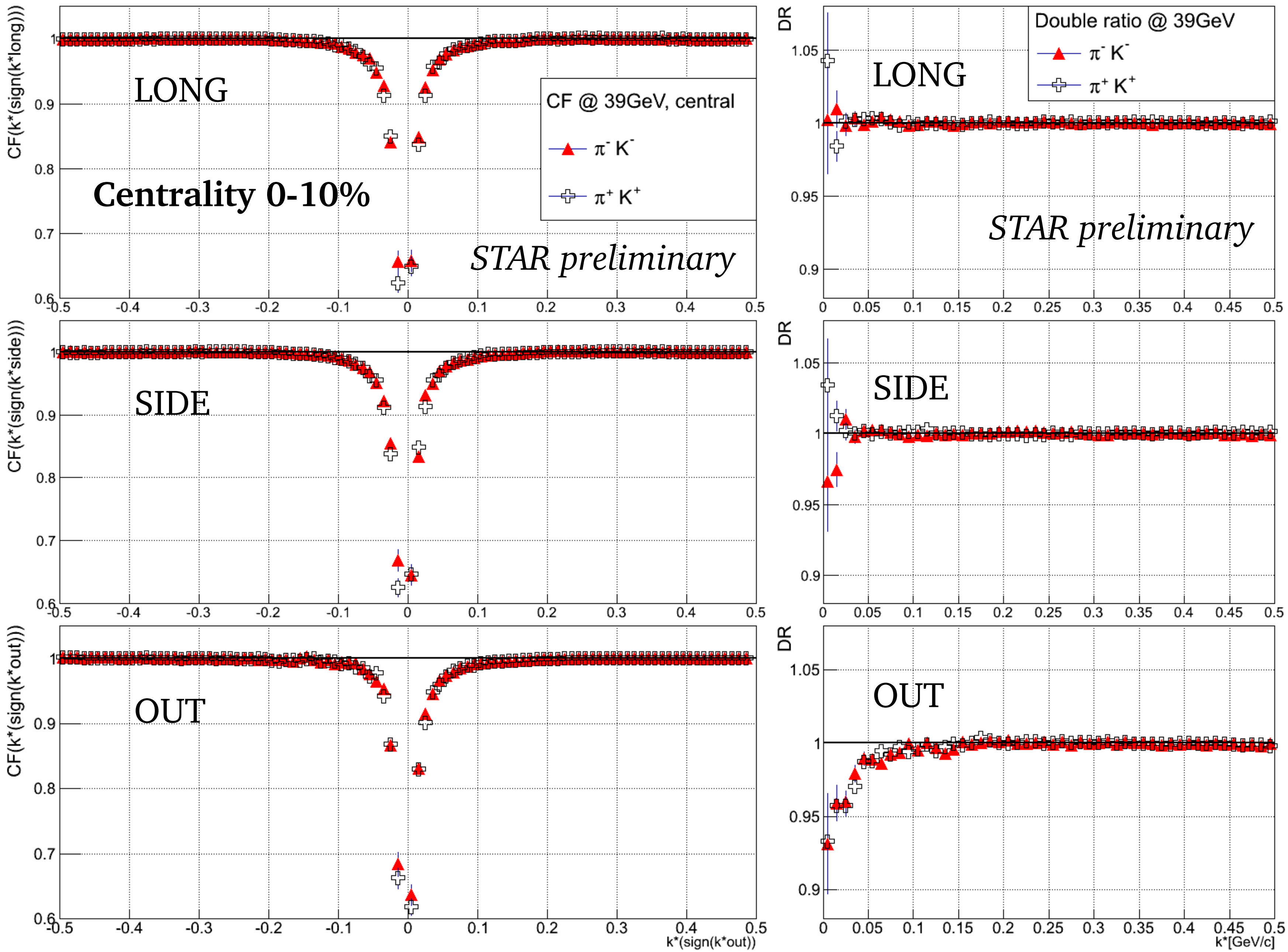
$\sqrt{s_{NN}}$	7.7 GeV	19.6 GeV	39 GeV	130 GeV
analyzed	4.1 mln events	17.5 mln events	91.2 mln events	0,32 mln events
π transverse momentum	[0.1, 1.2] GeV/c	[0.1, 1.2] GeV/c	[0.15, 0.7] GeV/c	[0.08, 0.25] GeV/c
K transverse momentum	[0.1, 1.2] GeV/c	[0.1, 1.2] GeV/c	[0.3, 0.8] GeV/c	[0.4, 0.7] GeV/c
N σ for π and K	< 3.0	< 3.0	< 3.0	< 3.0
π m^2	[0.0176, 0.022] GeV^2/c^4	[0.0176, 0.022] GeV^2/c^4	[0.017, 0.026] GeV^2/c^4	----
K m^2	[0.23, 0.26] GeV^2/c^4	[0.23, 0.26] GeV^2/c^4	[0.22, 0.27] GeV^2/c^4	----
$\lvert\eta\rvert$	< 0.5	< 0.5	< 0.5	< 0.5
DCA	< 3cm	< 3cm	< 3cm	< 3cm

Centrality definition:
central: 0-10%
minimum bias: 0-80%

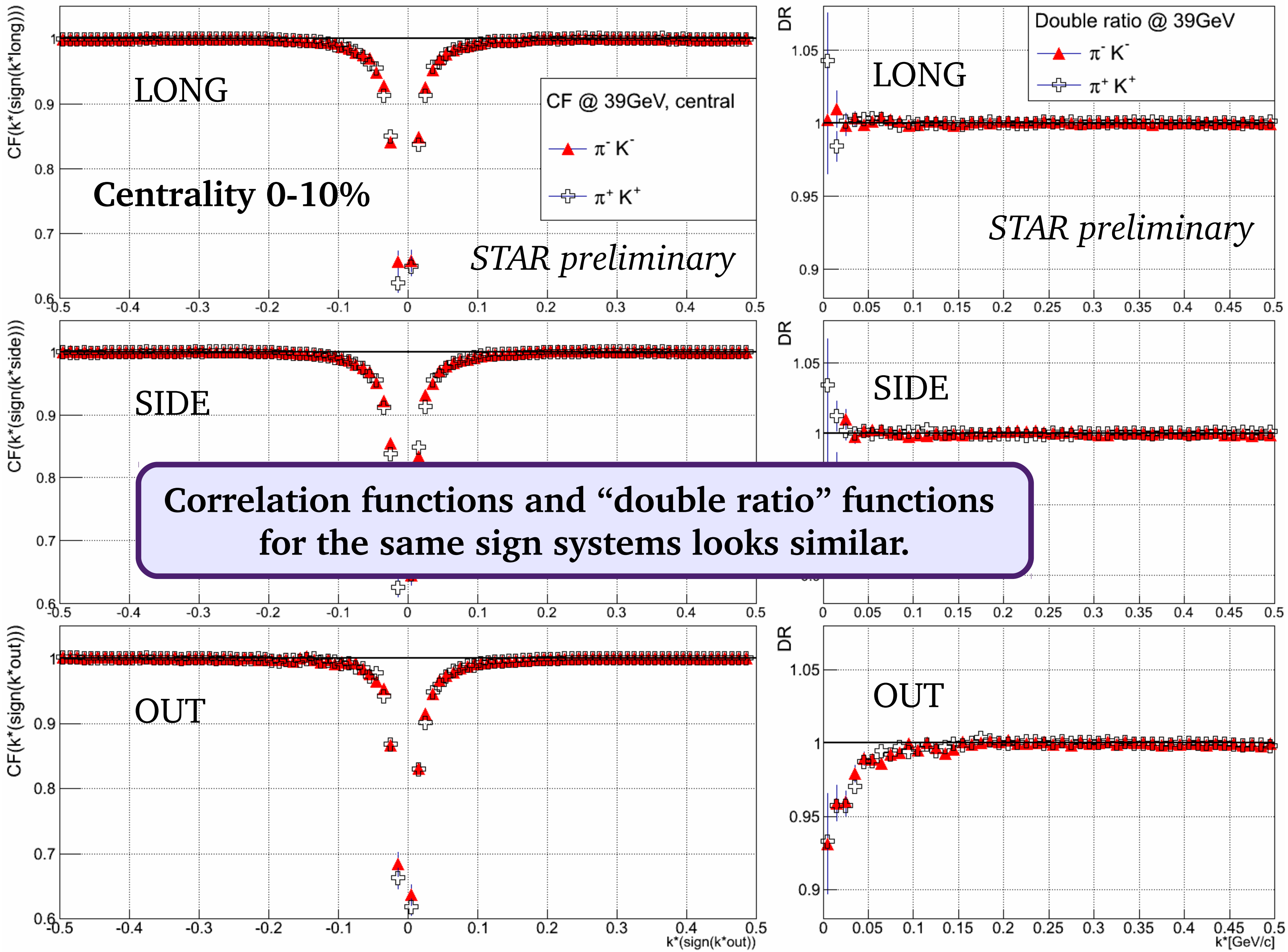




CF & DR for π- K- and π+ K+

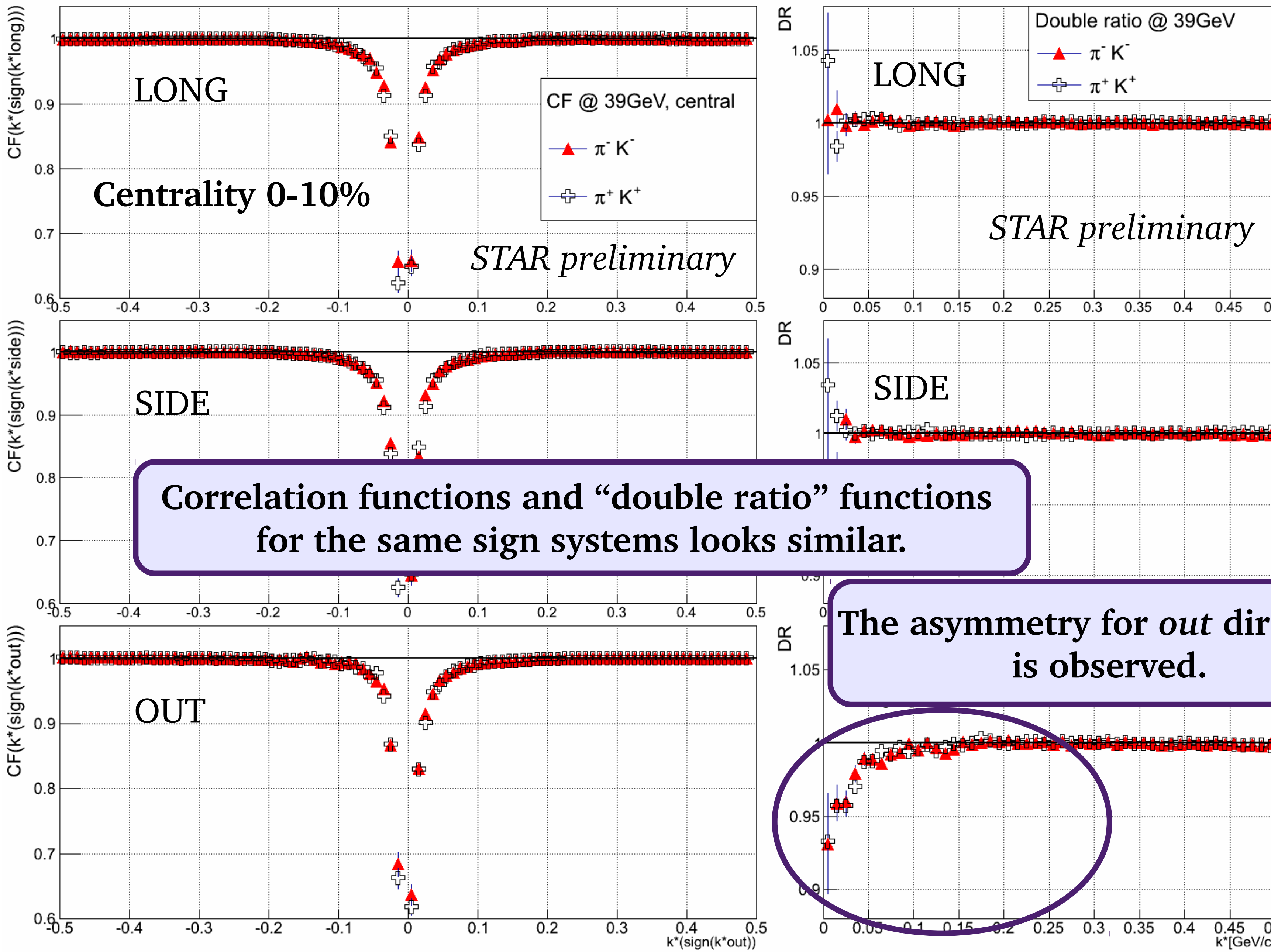


CF & DR for π- K- and π+ K+



Correlation functions and "double ratio" functions for the same sign systems looks similar.

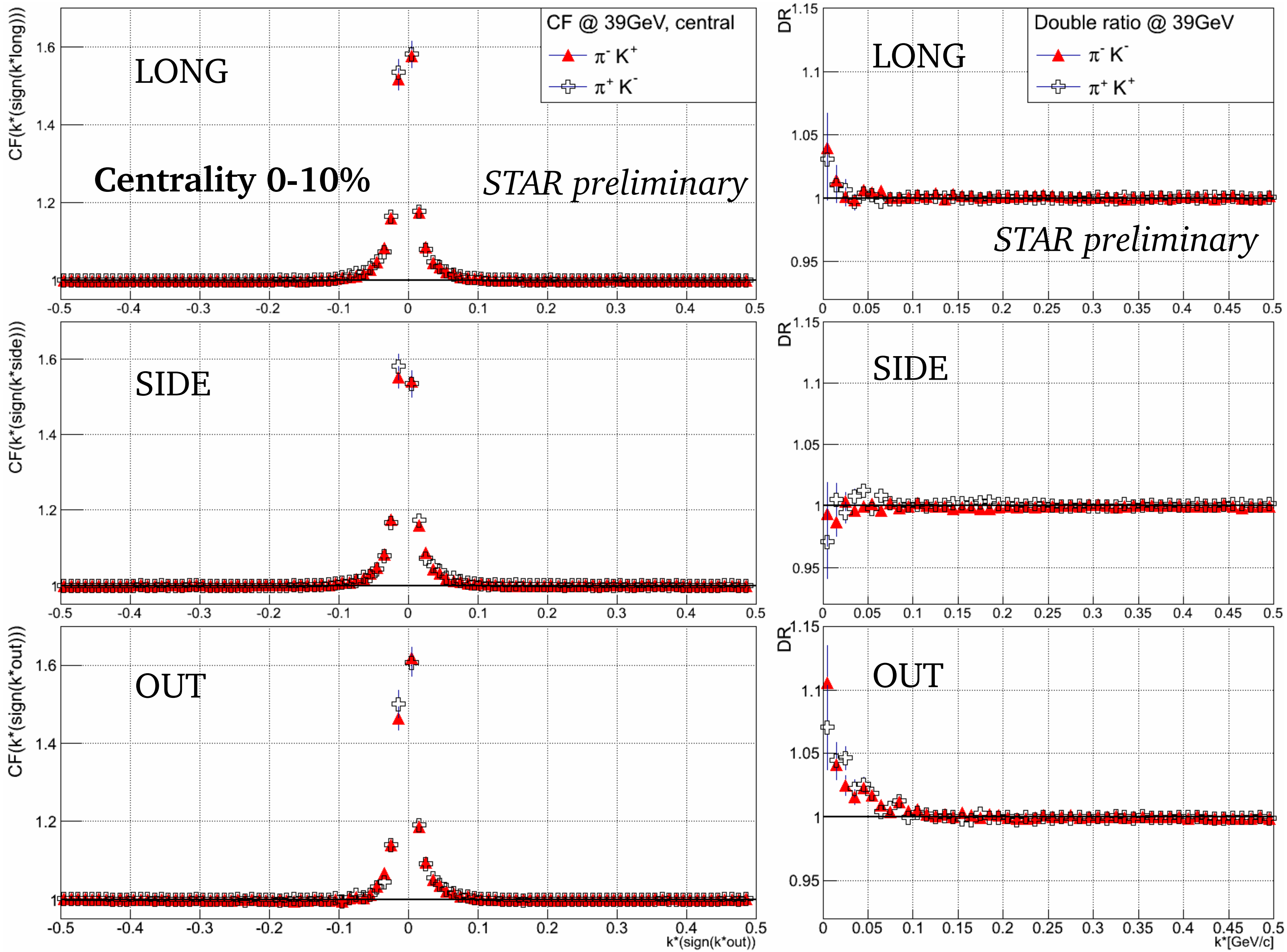
CF & DR for π- K- and π+ K+



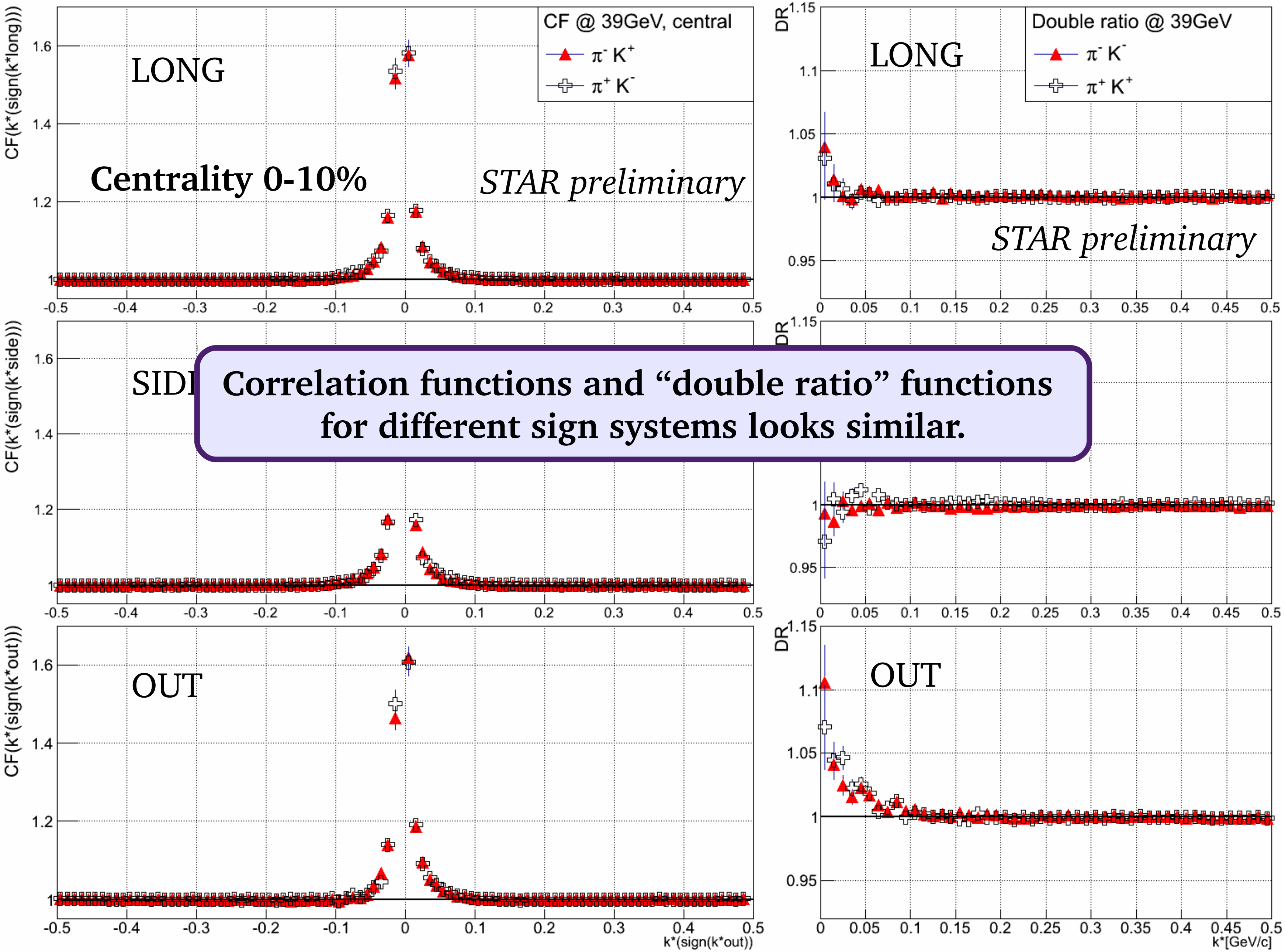
Correlation functions and "double ratio" functions for the same sign systems looks similar.

The asymmetry for *out* direction is observed.

CF & DR for π- K+ and π+ K-

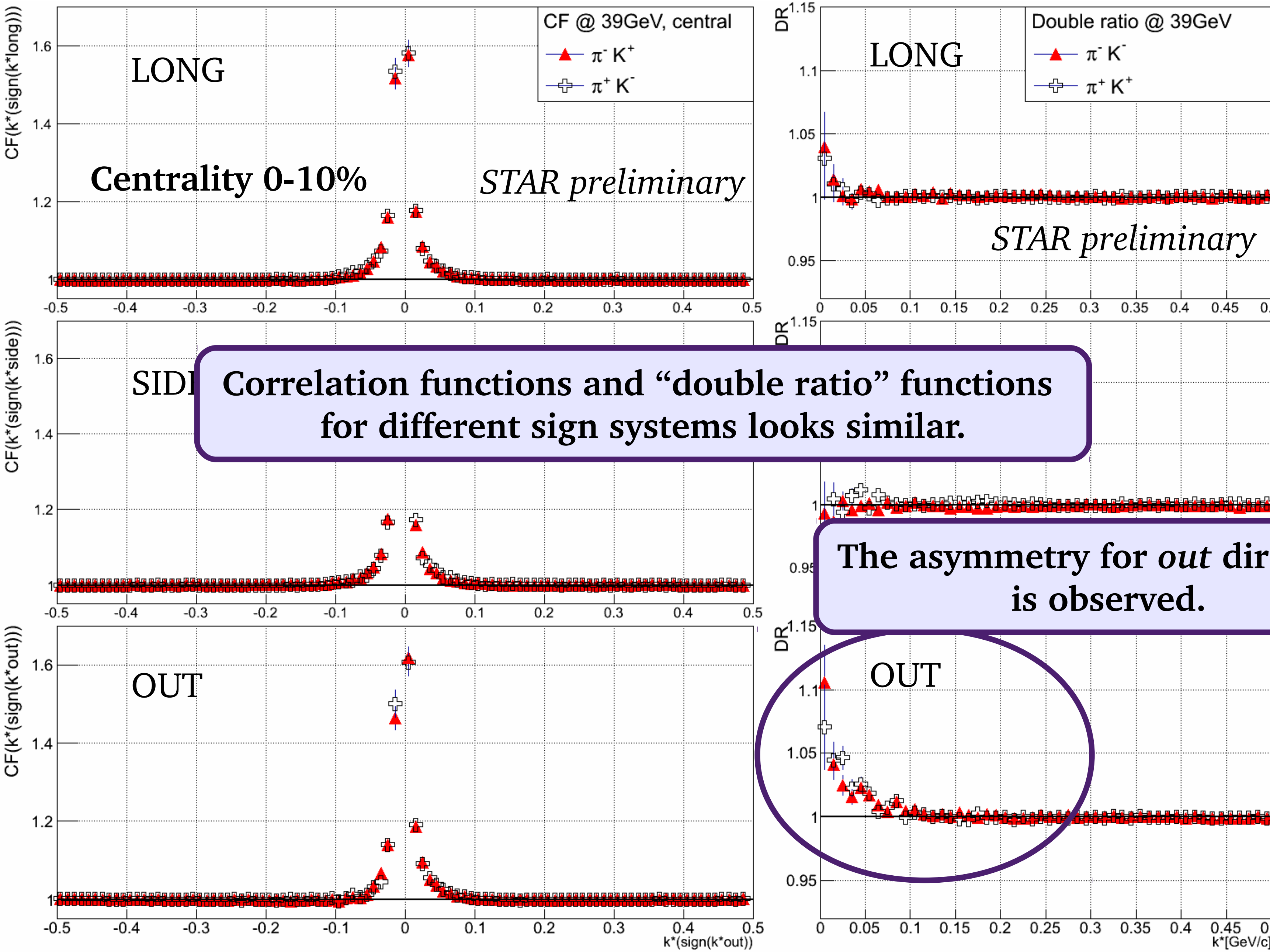


CF & DR for π- K+ and π+ K-



Correlation functions and "double ratio" functions for different sign systems looks similar.

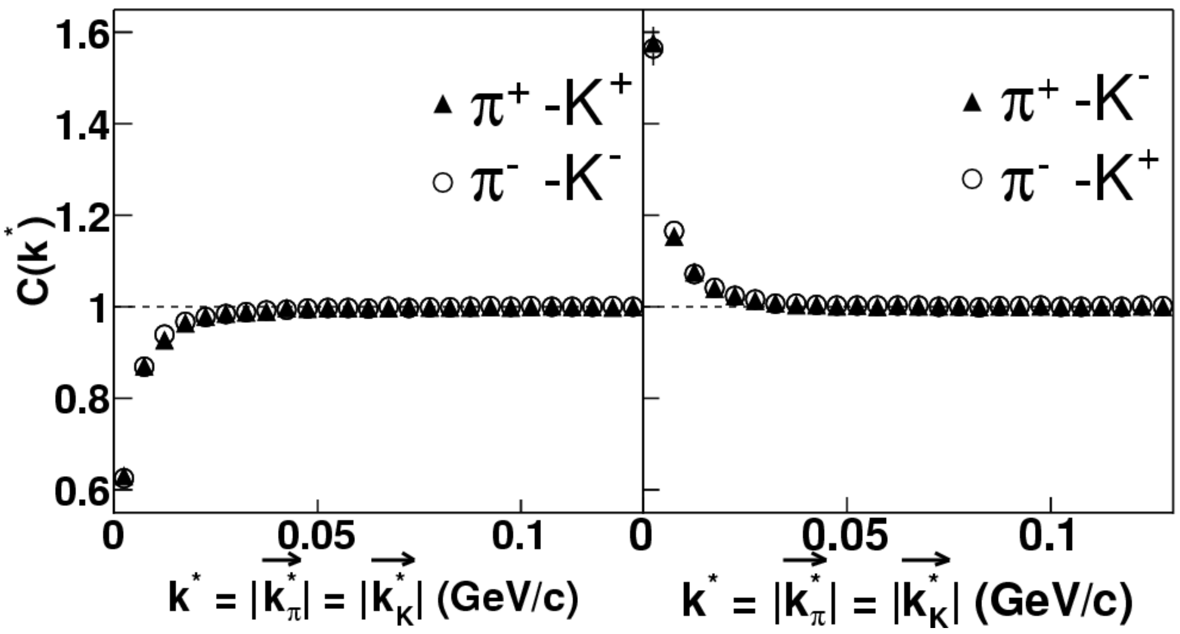
CF & DR for π- K+ and π+ K-



Correlation functions and "double ratio" functions for different sign systems looks similar.

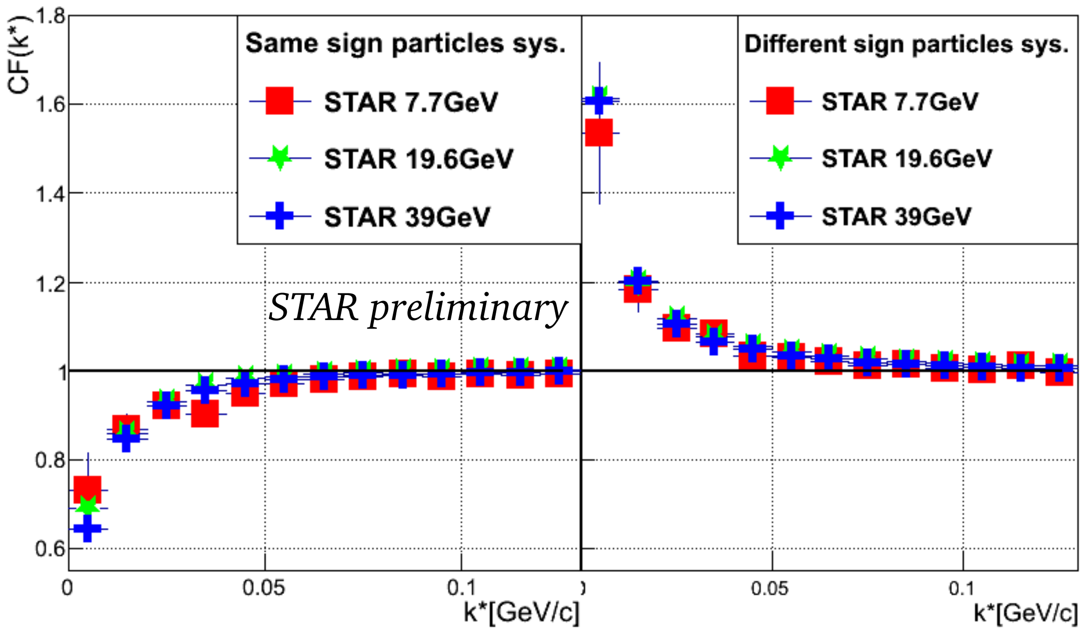
The asymmetry for *out* direction is observed.

Comparison of Au+Au data for $\sqrt{s_{NN}}=(130, 39, 19.6, 7.7)\,GeV$



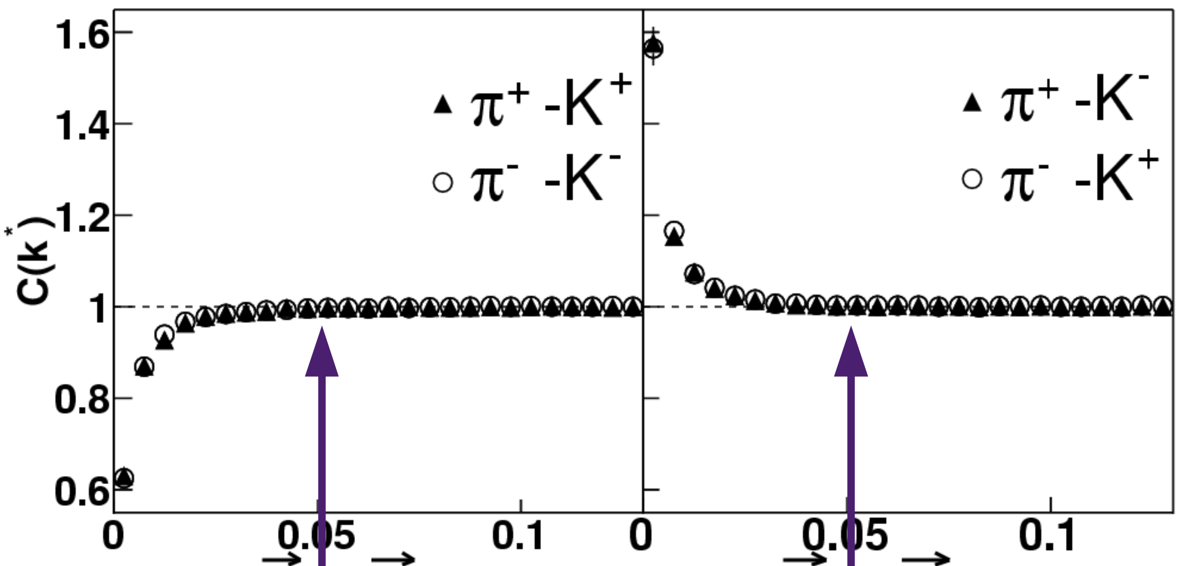
Au+Au collision at $\sqrt{s_{NN}}=130GeV$ (central)

Phys. Rev. Lett. 91 (2003) 262302



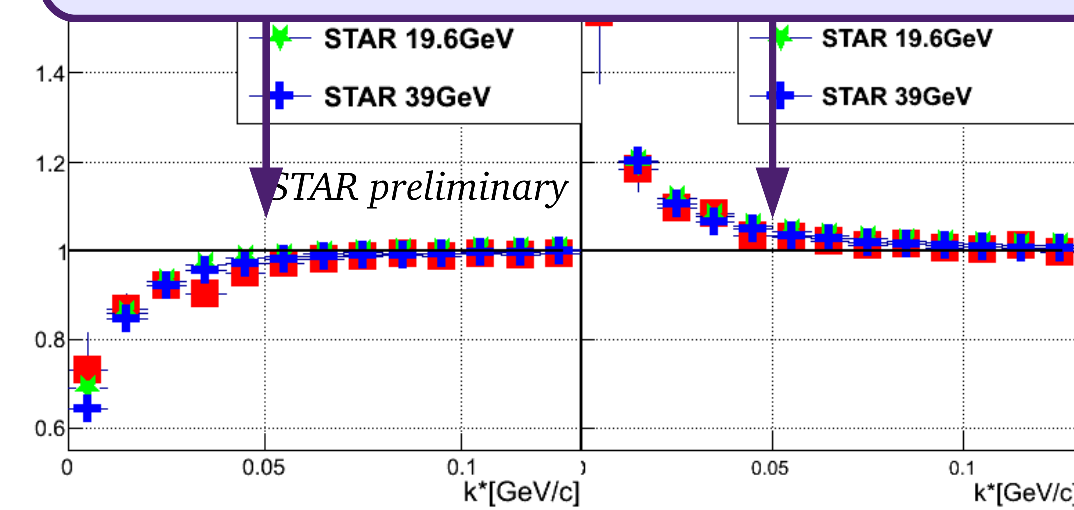
Au+Au collision at $\sqrt{s_{NN}}=(39, 19.6, 7.7)\,GeV$ (minimum bias)

Comparison of Au+Au data for $\sqrt{s_{NN}} = (130, 39, 19.6, 7.7)\,GeV$



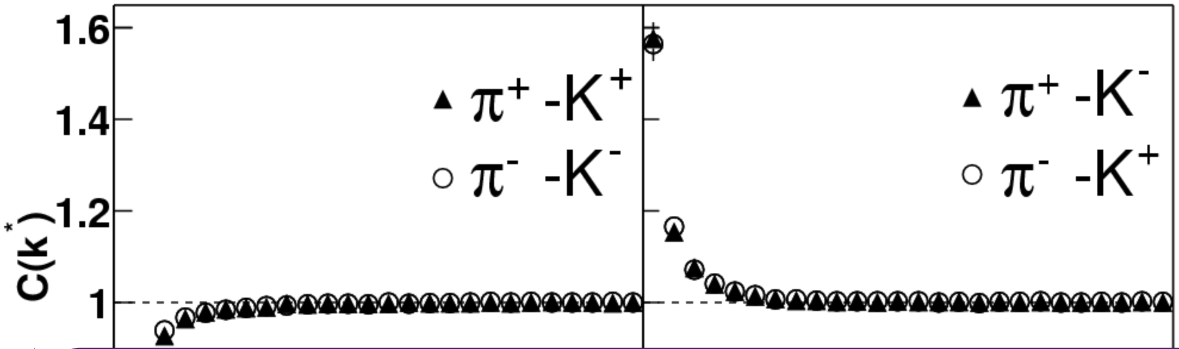
Au+Au collision at $\sqrt{s_{NN}} = 130\text{GeV}$ (central)

Correlation function for $\sqrt{s_{NN}} = 130\text{GeV}$ is narrower than CF for $\sqrt{s_{NN}} = (39, 19.6, 7.7)\,GeV$, so the source size for $\sqrt{s_{NN}} = 130\text{GeV}$ is bigger.



Au+Au collision at $\sqrt{s_{NN}} = (39, 19.6, 7.7)\,GeV$ (minimum bias)

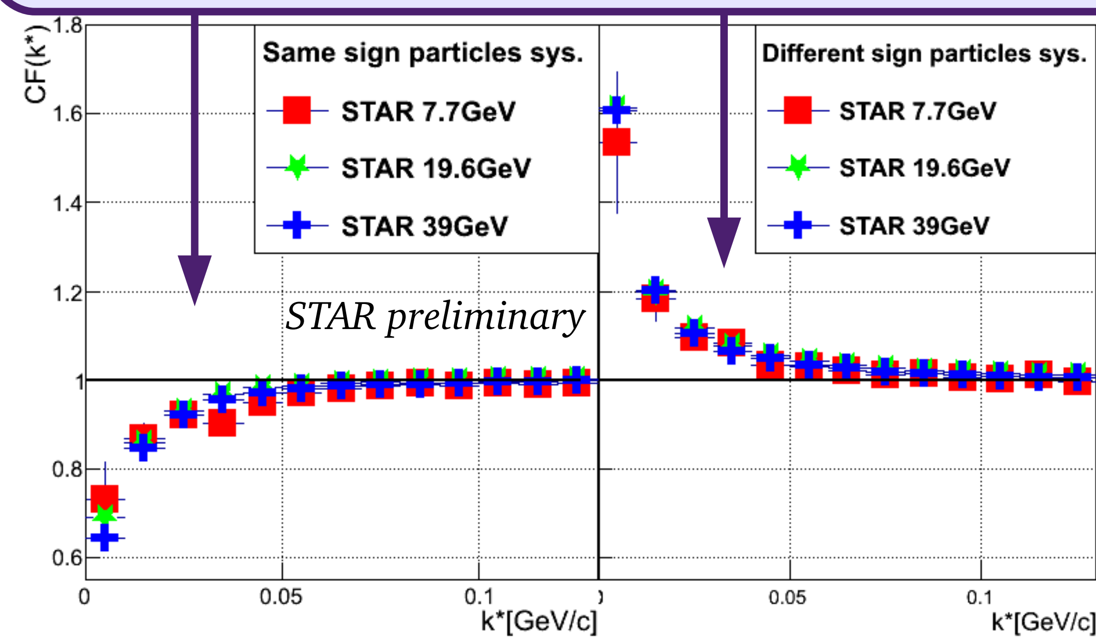
Comparison of Au+Au data for $\sqrt{s_{NN}}=(130, 39, 19.6, 7.7)\,GeV$



Au+Au collision at $\sqrt{s_{NN}}=130GeV$ (central)

Trends of correlation functions for all energies are the same.

The correlation functions for $\sqrt{s_{NN}}=(39, 19.6, 7.7)\,GeV$ looks the same within error bars.

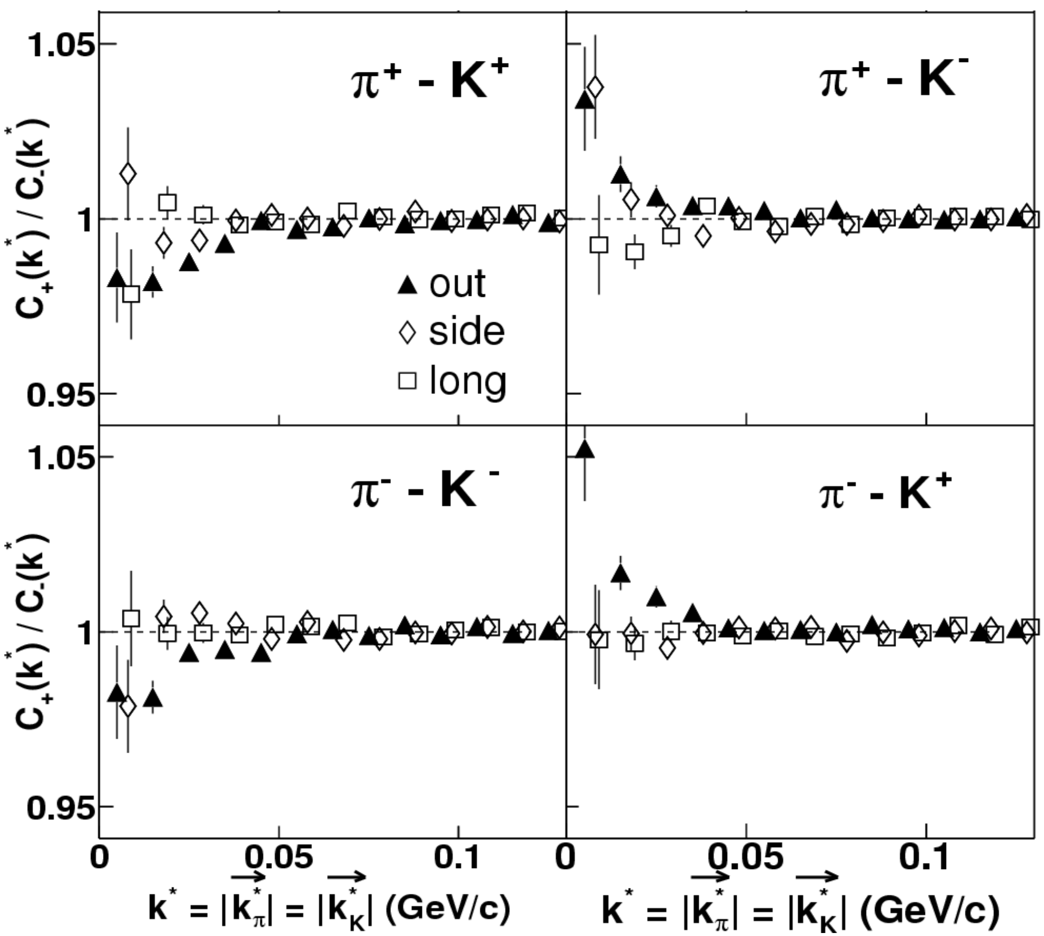


Au+Au collision at $\sqrt{s_{NN}}=(39, 19.6, 7.7)\,GeV$ (minimum bias)

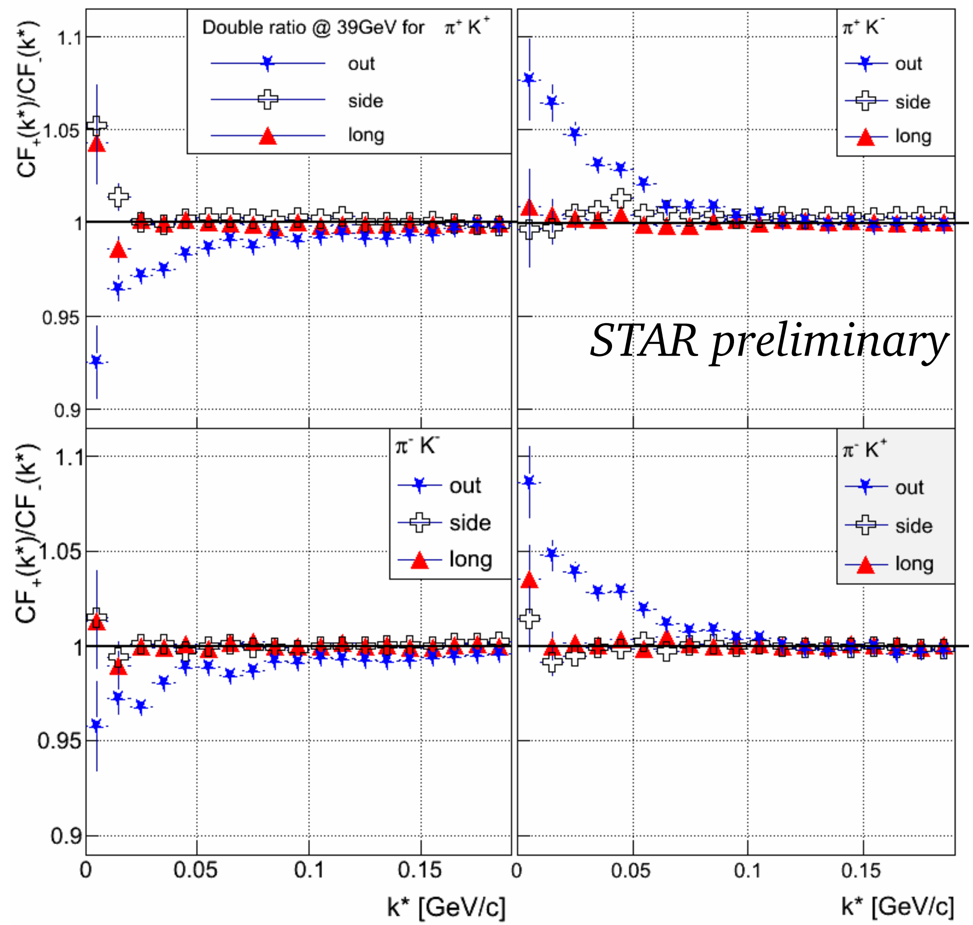
Comparison of Au+Au data for $\sqrt{s_{NN}} = 130\text{GeV}$ and $\sqrt{s_{NN}} = 39\text{GeV}$

Au+Au collision at $\sqrt{s_{NN}} = 130\text{GeV}$ (central)

Phys. Rev. Lett. 91 (2003) 262302



Au+Au collision at $\sqrt{s_{NN}} = 39\text{GeV}$ (central)

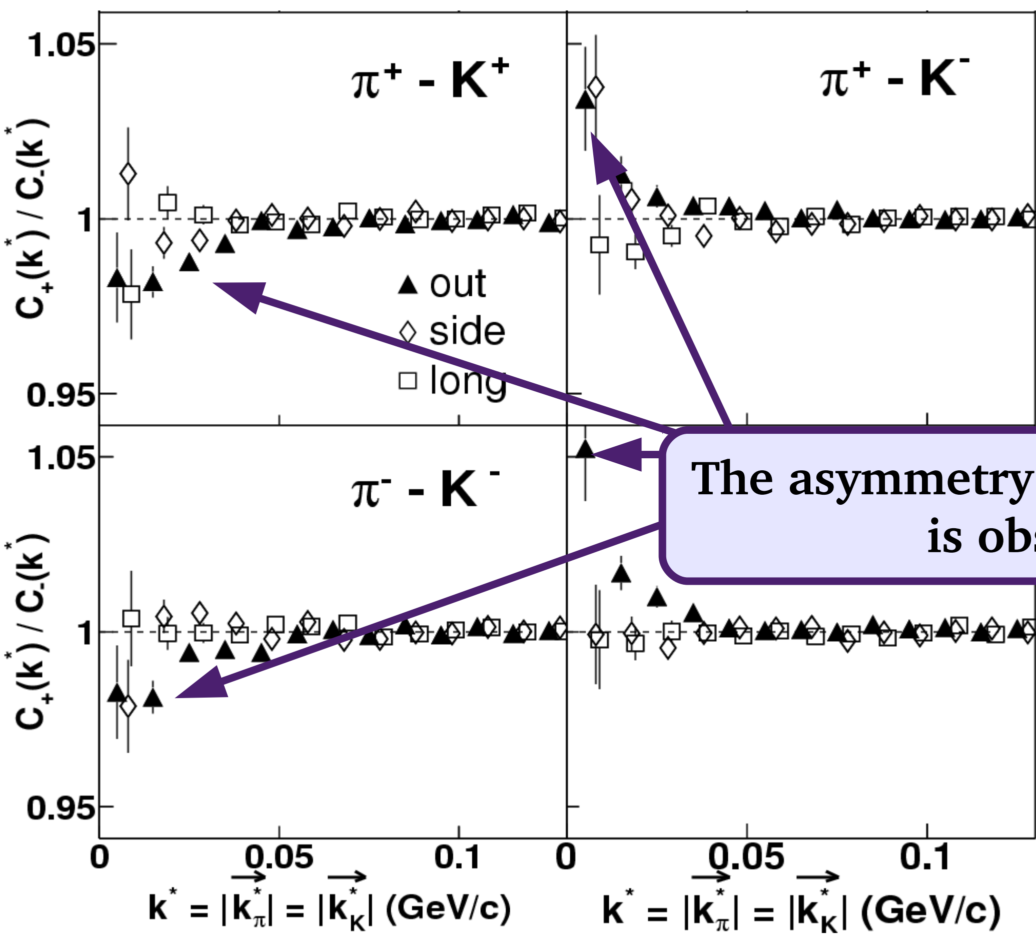


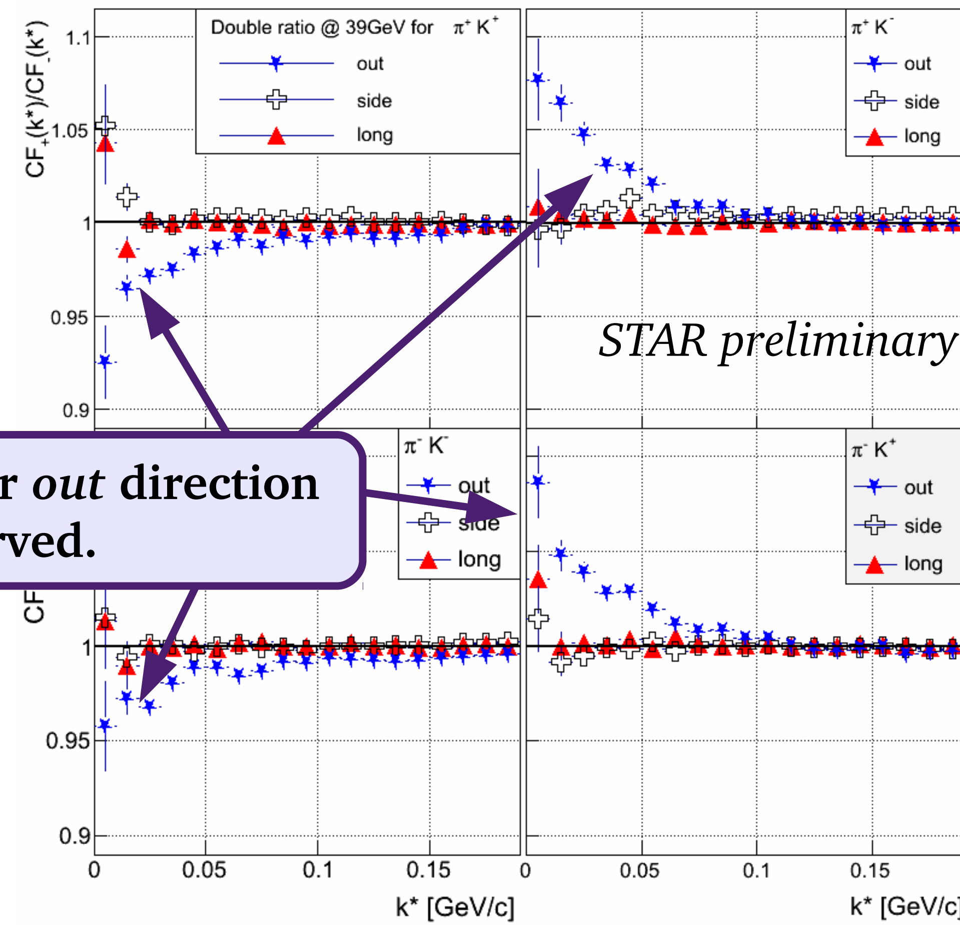
Comparison of Au+Au data for $\sqrt{s_{NN}}=130GeV$ and $\sqrt{s_{NN}}=39GeV$

Au+Au collision at $\sqrt{s_{NN}}=130GeV$ (central)

Au+Au collision at $\sqrt{s_{NN}}=39GeV$ (central)

Phys. Rev. Lett. 91 (2003) 262302

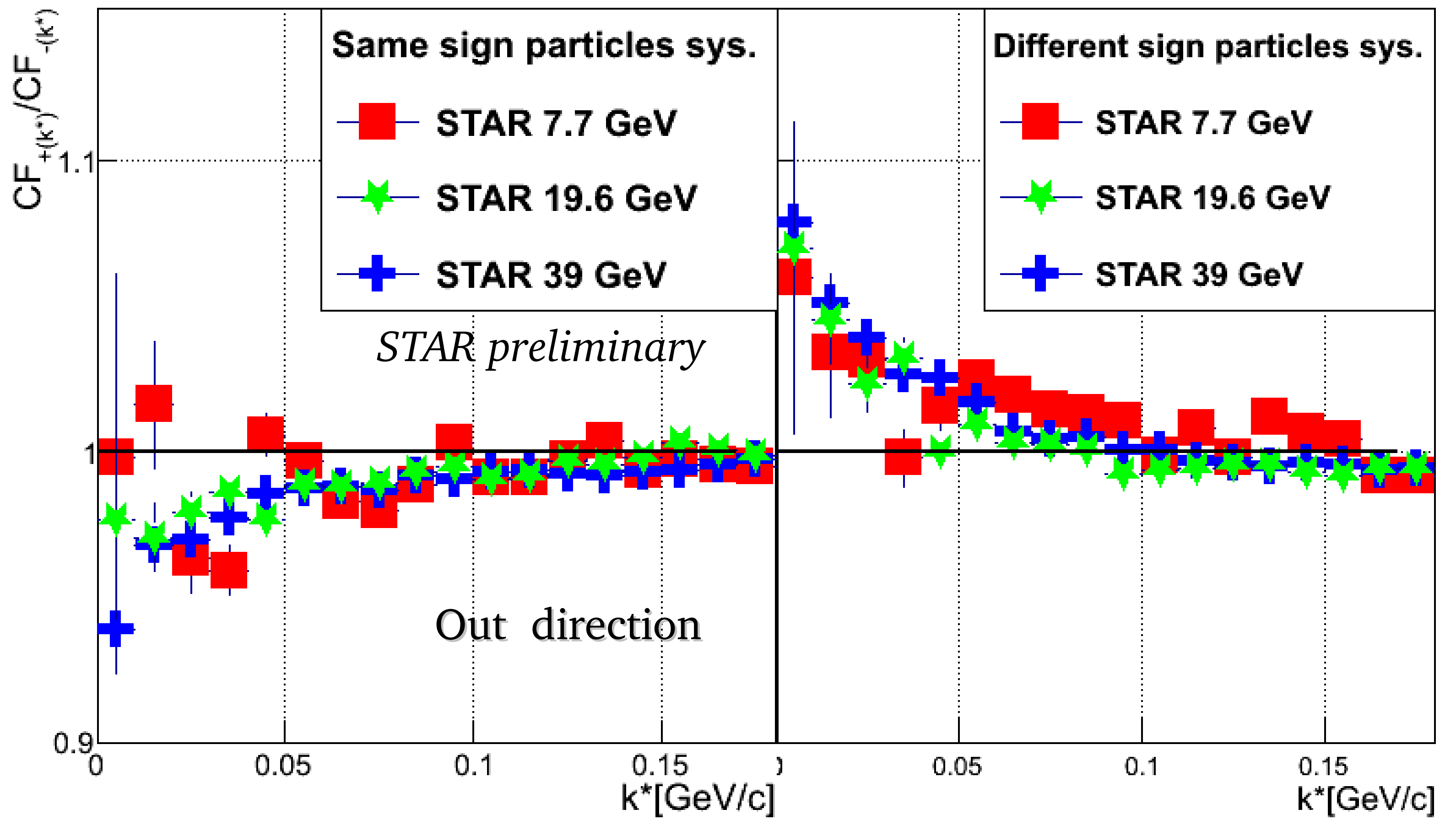




The asymmetry for *out* direction is observed.

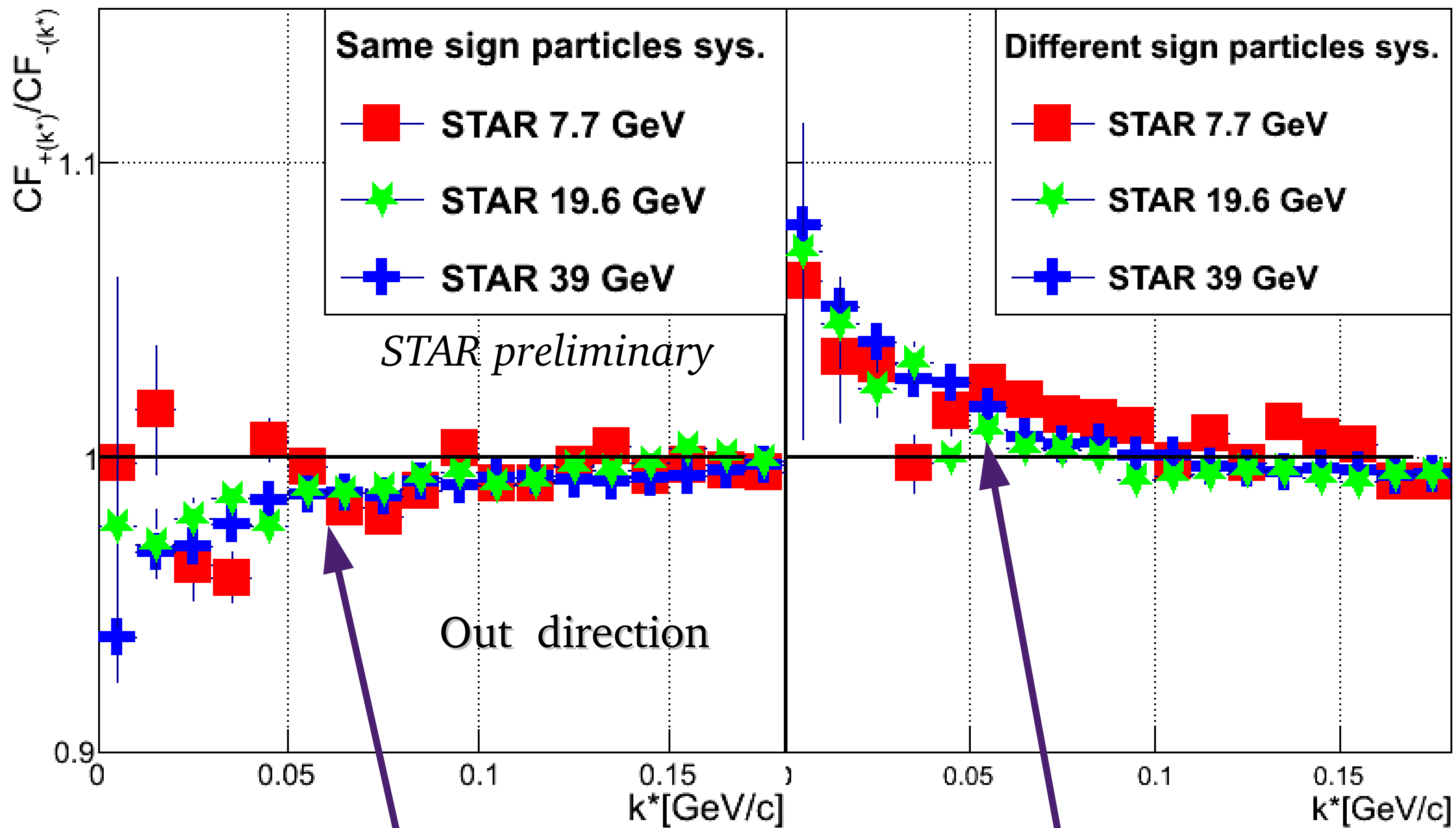
Comparison of Au+Au data for $\sqrt{s_{NN}} = (39, 19.6, 7.7)\, GeV$

Minimum bias data.



Comparison of Au+Au data for $\sqrt{s_{NN}}=(39, 19.6, 7.7)\,GeV$

Minimum bias data.



We observe the same tendency in asymmetry for all energies.

Summary

- Correlation functions and “double ratio” functions for minimum bias Au+Au collisions at $\sqrt{s_{NN}}=(39, 19.6, 7.7)GeV$ are calculated.

- Trends of correlation functions and “double ratio” functions for Au+Au collisions at $\sqrt{s_{NN}}=(130, 39, 19.6, 7.7)GeV$ are the same – results are consistent.

- Source size is bigger in Au+Au collisions at $\sqrt{s_{NN}}=130\mathrm{GeV}$ than at $\sqrt{s_{NN}}=(39, 19.6, 7.7)GeV$.

- Due to limited statistics we can only say, that source size in Au+Au collision at $\sqrt{s_{NN}}=7.7\mathrm{GeV}$ and $\sqrt{s_{NN}}=19.6\mathrm{GeV}$ are close to source size in Au+Au collision at $\sqrt{s_{NN}}=39\mathrm{GeV}$.

- Pions are emitted closer to the system's center or/and later than kaons in systems created in collisions for $\sqrt{s_{NN}}=(130, 39, 19.6, 7.7)GeV$.

Thank you for your attention!