Pion-Kaon Femtoscopy at $\sqrt{s_{NN}}$ = 200 GeV Collisions in STAR at RHIC

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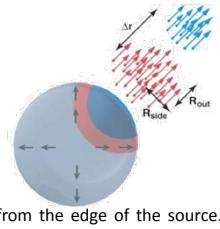
Abstract

Correlations between non-identical particles at low relative momentum in the center of mass encode unique information on the space-time structure of the emitting system. In addition to size of the homogeneity region, analysis of correlation functions in the three-dimensional k* space can reveal a space-time offset of one particle species (e.g. kaons) with respect to another (e.g. pions). Early results from STAR at $\sqrt{s_{NN}}$ = 130 GeV showed such an asymmetry, which was consistent with collective radial flow. This early analysis was hampered by the limited particle identification capabilities of the STAR Time Projection Chamber, as well as from marginal statistics and photon conversion due to a significant material budget close to the beam. In year 2010 and year 2011, STAR had accumulated more than one billion minimum bias events at $\sqrt{s_{NN}}$ = 200 GeV Au+Au collisions with full Time of Flight detector in operation, which enables detailed non-identical femtoscopy measurements. We present new measurements of pion-kaon correlations in the more sensitive spherical harmonic decomposition representation at $\sqrt{s_{NN}}$ = 200 GeV collisions from these data sets with a lower material budget and much higher statistics. The analysis greatly benefits when information from the STAR Time of Flight detector is used to extend particle identification capabilities. Centrality dependence of pion-kaon femtoscopy in Au+Au collisions will be presented for the first time. Finally, we present a first similar analysis of p+p collisions at $\sqrt{s}$ = 200 GeV.

Motivation

Non-identical particle femtoscopy probes not only the size of the emitting system, but also the emission asymmetries between particles of different masses, which are intimately related to the collective behavior of matter.



Heavy particles are preferentially emitted from the edge of the source. Two particle correlations measure the size and average separation of the two sources.

$\vec{k}^*$ – momentum of the 1st in pair rest frame

$$\underbrace{R(\vec{k}^*) = \frac{A(\vec{k}^*)}{B(\vec{k}^*)} - 1}_{\text{measured}} = \int d^3r \underbrace{S(\vec{r})}_{\text{wanted}} \underbrace{|\Psi(\vec{r},\vec{k}^*)|^2}_{\text{known}}$$

$\vec{r}$ – pair separation in the pair rest frame

Sensitive Quantities

Spherical harmonic moments of the correlation function

$$R_{l,m}(|\vec{k}^*|) \equiv \int d\Omega R(\vec{k}^*) Y_{l,m}(\Omega)$$

$R_{0,0}(|\vec{k}^*|)$ -sensitive to size

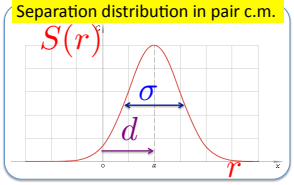
$\mathrm{Re}(R_{1,1}(|\vec{k}^*|))$ -sensitive to the offset

Source Parameterization

$$S(\vec{r}) \propto e^{-(\vec{r}-\vec{d})^2/2\sigma^2}$$

$\vec{d}$ = offset, points in direction of motion

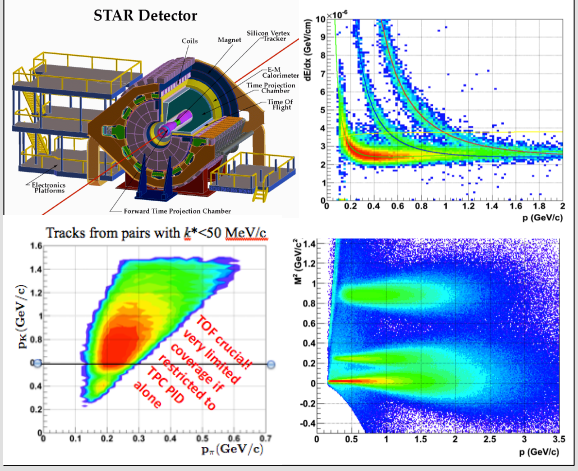
Separation distribution in pair c.m.



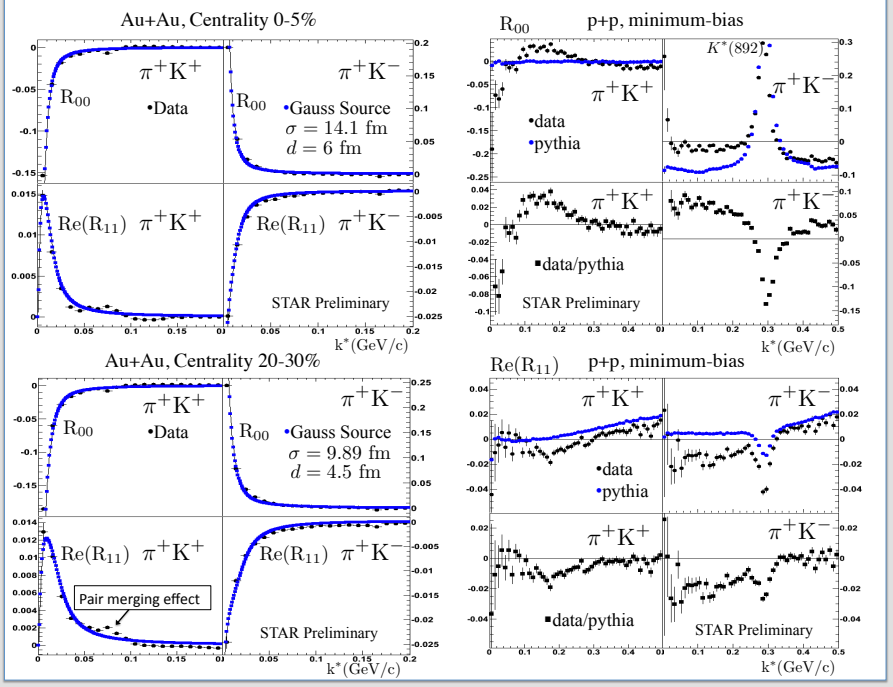
Pion and Kaon Identification

For momenta greater than 0.6 GeV/c, pions and kaons are only identified by Time-of-Flight(ToF).
For momentum smaller than 0.6 GeV/c, the particle are preferentially identified by ToF.

If there is no ToF information for this particle, pions and kaons are identified by requiring the measured energy loss within 2 standard deviation from the expected dEdx band.



Results



Summary

Clear source asymmetry signal in Au+Au collisions
- offset is roughly half of the source size
- geometric substructure qualitatively consistent with flow-dominated source[1]
- ~consistent w/ published results from central collisions at 130 GeV
- Reasonable centrality dependence of source size and offset.

[1] Retiere and Lisa, Phys.Rev. C70 (2004) 044907

Similar analysis performed in p+p collisions at 200 GeV
- Asymmetry signal present in correlation function…
- … but non-femtoscopic correlations are important in p+p collisions
- Pythia qualitatively reproduces large-k* behavior of R(k*)
- Work presently underway to identify additional **femtoscopic** (e.g. energy-momentum conservation) correlations in the data

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The STAR Collaboration: http://drupal.star.bnl.gov/STAR/presentations

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