Recent STAR results of pion-proton femtoscopy

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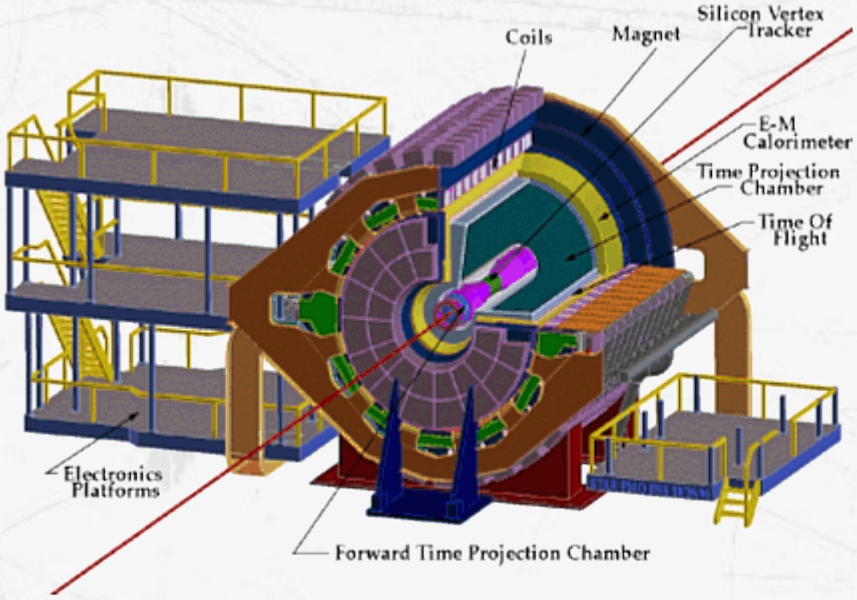
for the STAR Collaboration

V Workshop on Particle Correlations and Femtoscopy

Outline

- Physics motivation
  - size and asymmetry measurement
- Data analysis
  - data selection
  - purity correction
  - fit procedure
- Experimental results
  - correlation functions
  - fit results
- Model results
- Conclusions



FSI as an origin of asymmetry

$$CF = A_C(k^*)\left[1 + 2\underbrace{\langle r^*(1+\cos\theta^*)\rangle}_{\text{integrated over space}}/a_c + \ldots\right]$$

Gamov factor

Source of the asymmetry

Bohr radius for $\pi^- p$ $a_c = \pm 222$fm

In pion-proton system only coulomb interaction plays significant role.

k*- momentum of the first particle in PRF*

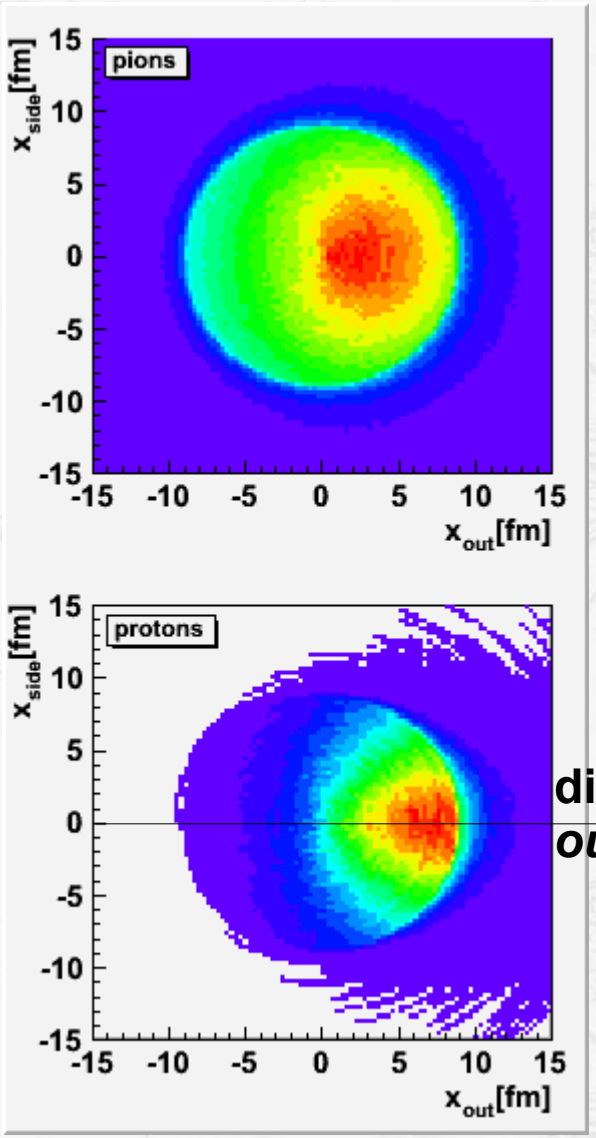
r* - separation between emission points*

$r^* = x_1 - x_2$

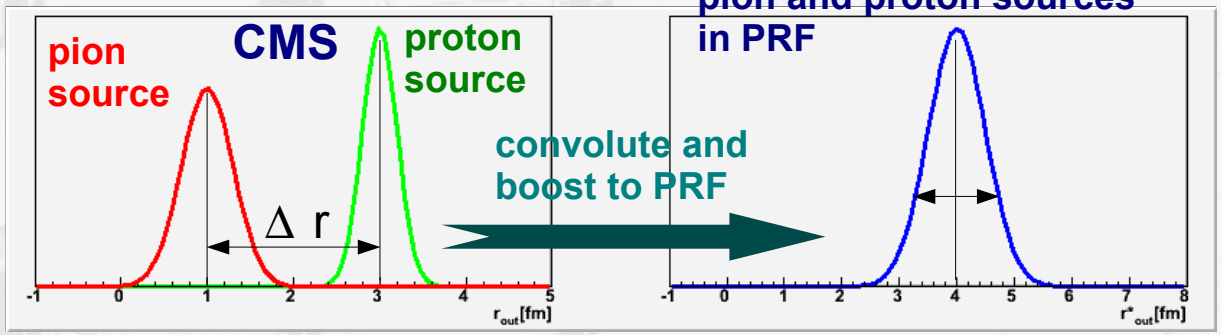
θ^* - angle between *k** and *r** vectors

Correlation is stronger when $\cos\theta^* < 0$ – *k and *r** are anti-aligned and weaker when $\cos\theta^* > 0$ – *k** and *r** are aligned.**

Observed asymmetry



direction of a pair
out



$$\sigma_{\pi p} = \sqrt{\sigma_\pi^2 + \sigma_p^2}$$

two particle width

single particle widths

Observed separation in PRF comes from

- **space asymmetry (flow)**

and from

- **emission time difference**

$$\langle r^* \rangle = \langle \gamma_T (\Delta r - \beta_T \Delta t) \rangle$$

Phys.Lett.B373 (1996) 30

Decomposition and interpretation of the correlation function in spherical harmonics

distribution of correlated pairs

distribution of uncorrelated pairs

$$T(\vec{k}^*) = C(\vec{k}^*) \cdot M(\vec{k}^*)$$

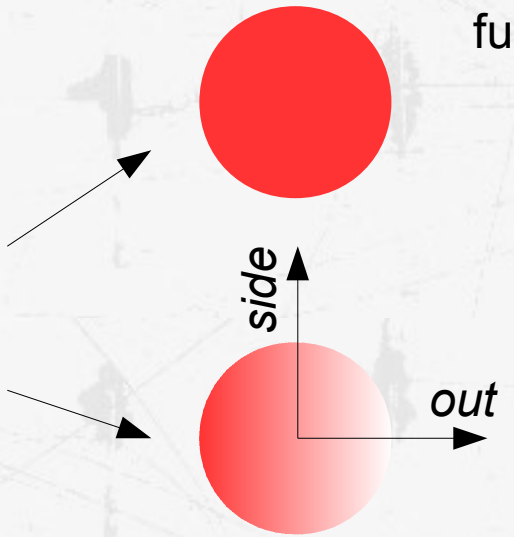
correlation function

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

Symmetry:

- Calculated function is integrated over reaction plane angle thus all imaginary elements vanish.
- Symmetric mid-rapidity region → odd (*l*+*m*) real components of the function vanish

- C^0_0 functions give information about overall size and the real
- Re C^1_1 component gives information about asymmetry.



Phys.Rev.C78:064903,2008
arXiv:0901.3527v1 [nucl-th]

Data selection

Au+Au $\sqrt{s_{NN}}$=200GeV

Events:

- central (0-10%)
- semi-central (10-30%)
- mid-central (30-50%)
- z-vertex position ±30cm

Single track level cuts (π,p)

- dE/dx
- $p_T(\pi) \in$<0.1,0.6>
- $p_T(p) \in$<0.4,1.25>
- $y \in$<-0.7,0.7>

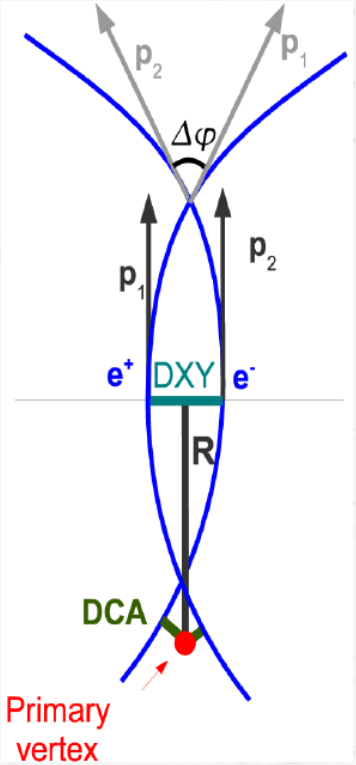
Pair level cuts:

pairs with merged hits of tracks

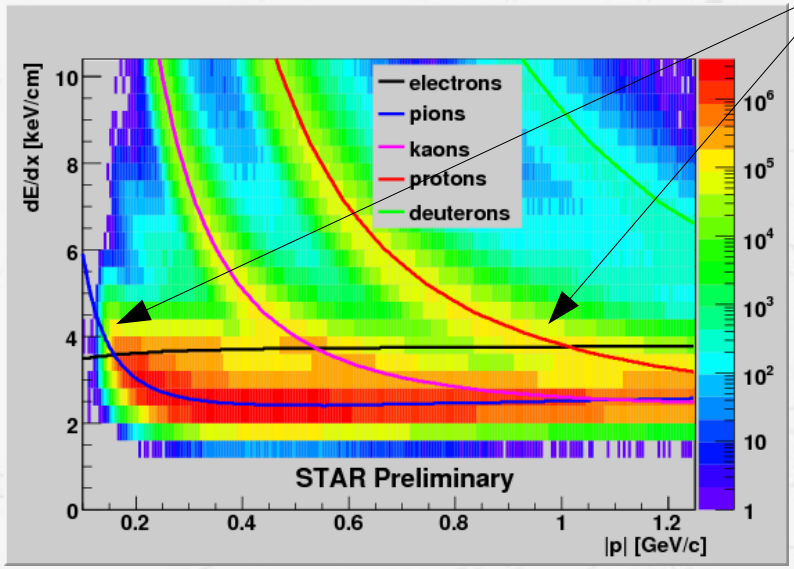
pairs with split tracks

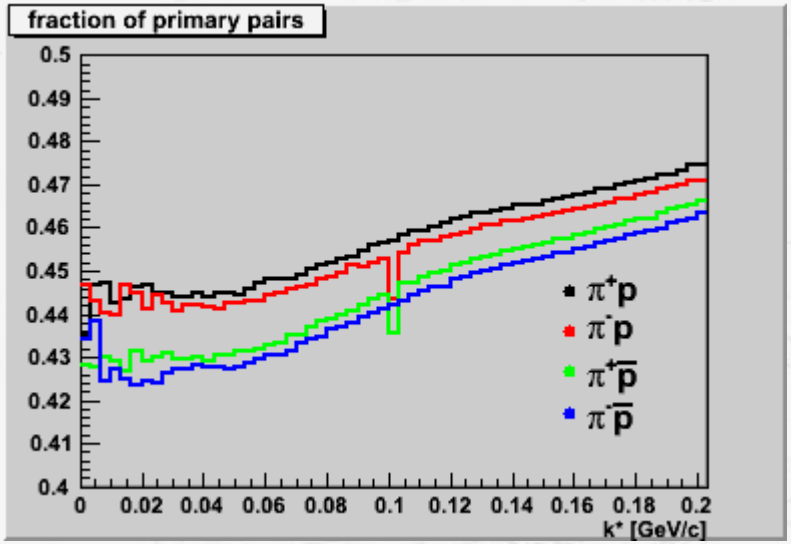
electron-positron pairs from gamma conversion (advanced topological cut)

non π -p pairs based on pair probability



Data analysis





Low relative momentum in PRF corresponds to close relative velocities in CMS.
E.g. pion with p_T=0.1GeV/c has a close velocity proton with p_T=0.67GeV/c. Pion p_T=0.15GeV/c corresponds to proton p_T=1GeV/c. In these regions pions and protons are crossing the electron line.

$$C_{\text{Real}} = C_{\text{Exp}} \cdot C_{\text{Purity}}^{-1}$$

C_{Purity} – two particle distribution weighted with experimental PID probability and fraction of primary pairs

mixed pairs are constructed only from events with similar characteristics:

- z-vertex position 15 bins
- multiplicity 6 bins
- event mean p_T 3 bins

Total 270 bins

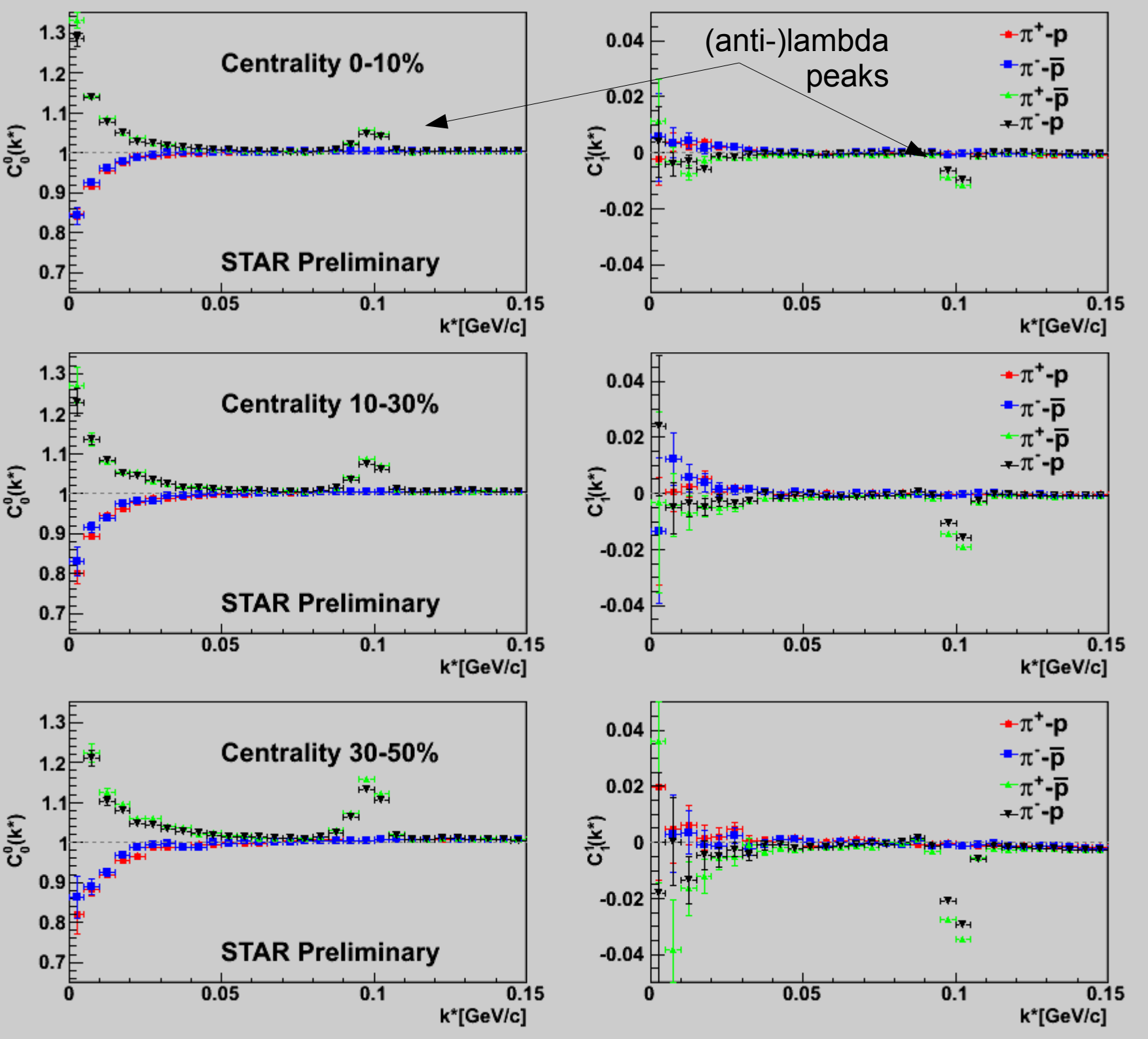
Fit procedure

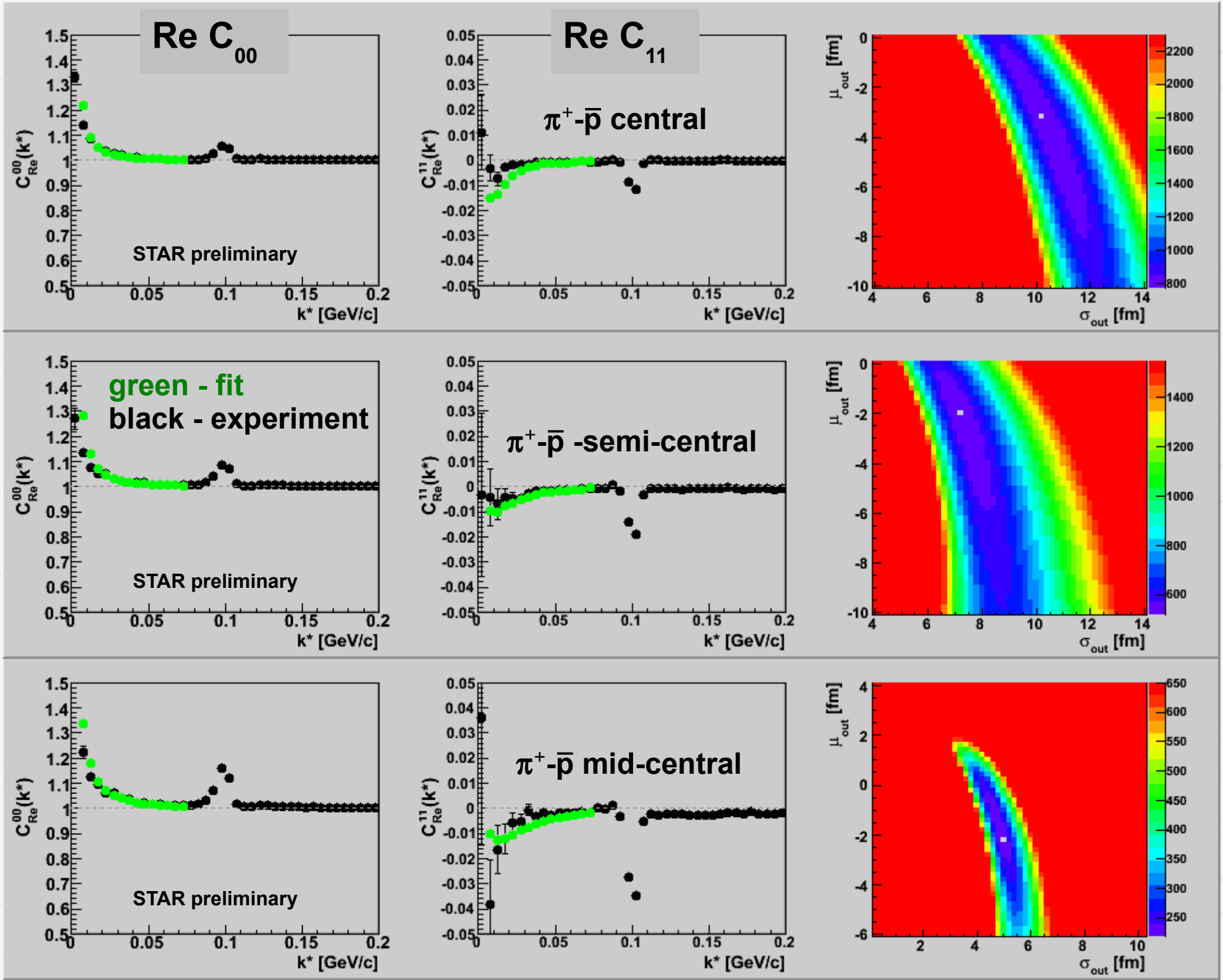
- spatial Gaussian emission function

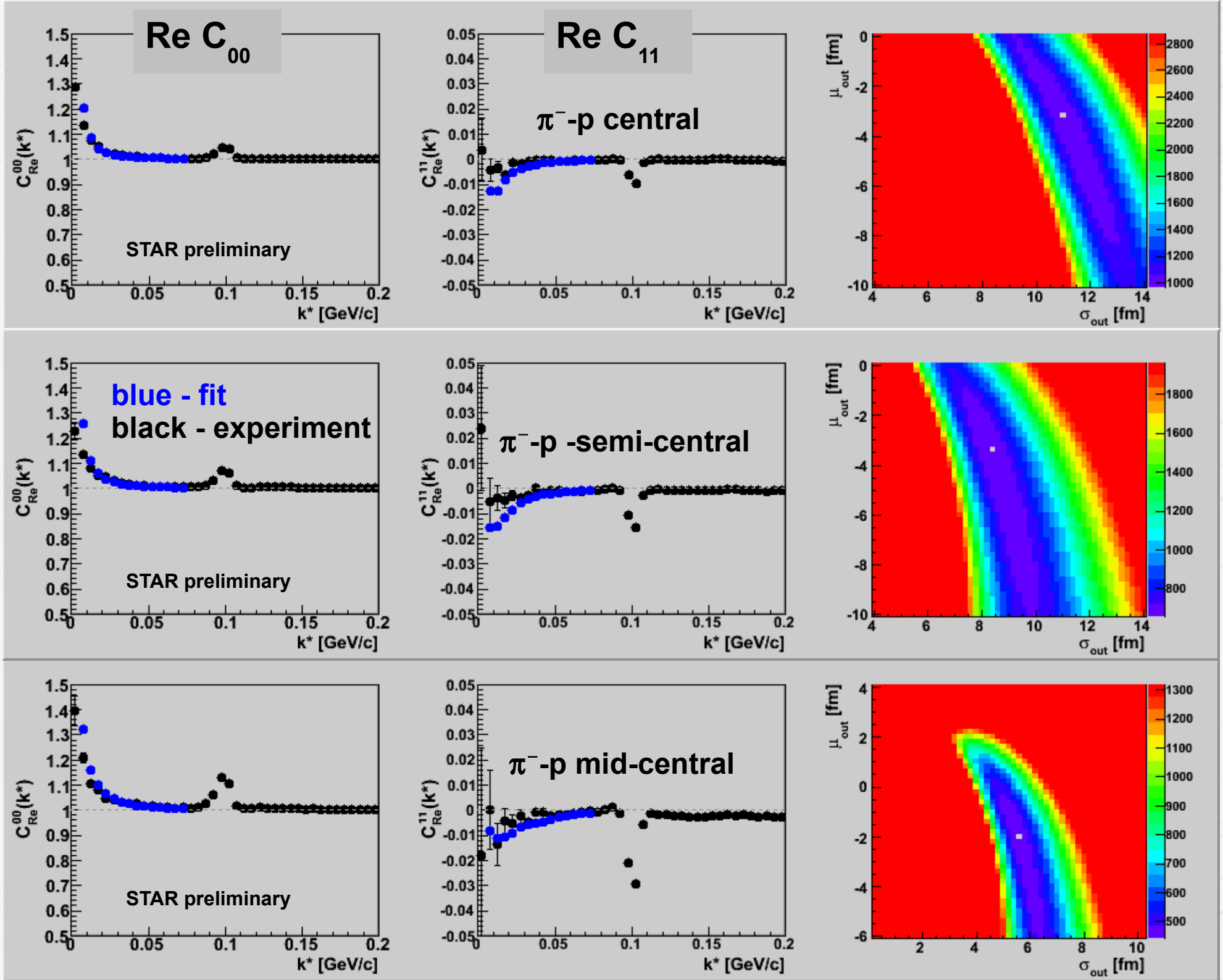
$$S(\vec{r}) \approx \exp\left(\frac{-\left(r_{out}-\mu_{out}\right)^2 + r_{side}^2 + r_{long}^2}{2R^2}\right)$$

- generated emission points + experimental momenta of the pairs
- momentum resolution correction
- Lednicky's weights (squared wave function of a pair)
- χ^2 minimization

Nukleonika 49;Suppl 2:s81-s83


Centrality 0-10%
STAR Preliminary
Centrality 10-30%
STAR Preliminary
Centrality 30-50%
STAR Preliminary
(anti-)lambda peaks
π^+-p
π^--$\bar{p}$
π^+-$\bar{p}$
π^--p
$C_0^0(k^*)$
$C_1^1(k^*)$
k*[GeV/c]


Re C00
Re C11
π+-p̄ central
green - fit
black - experiment
π+-p̄ -semi-central
π+-p̄ mid-central
STAR preliminary
k* [GeV/c]
σout [fm]
rout [fm]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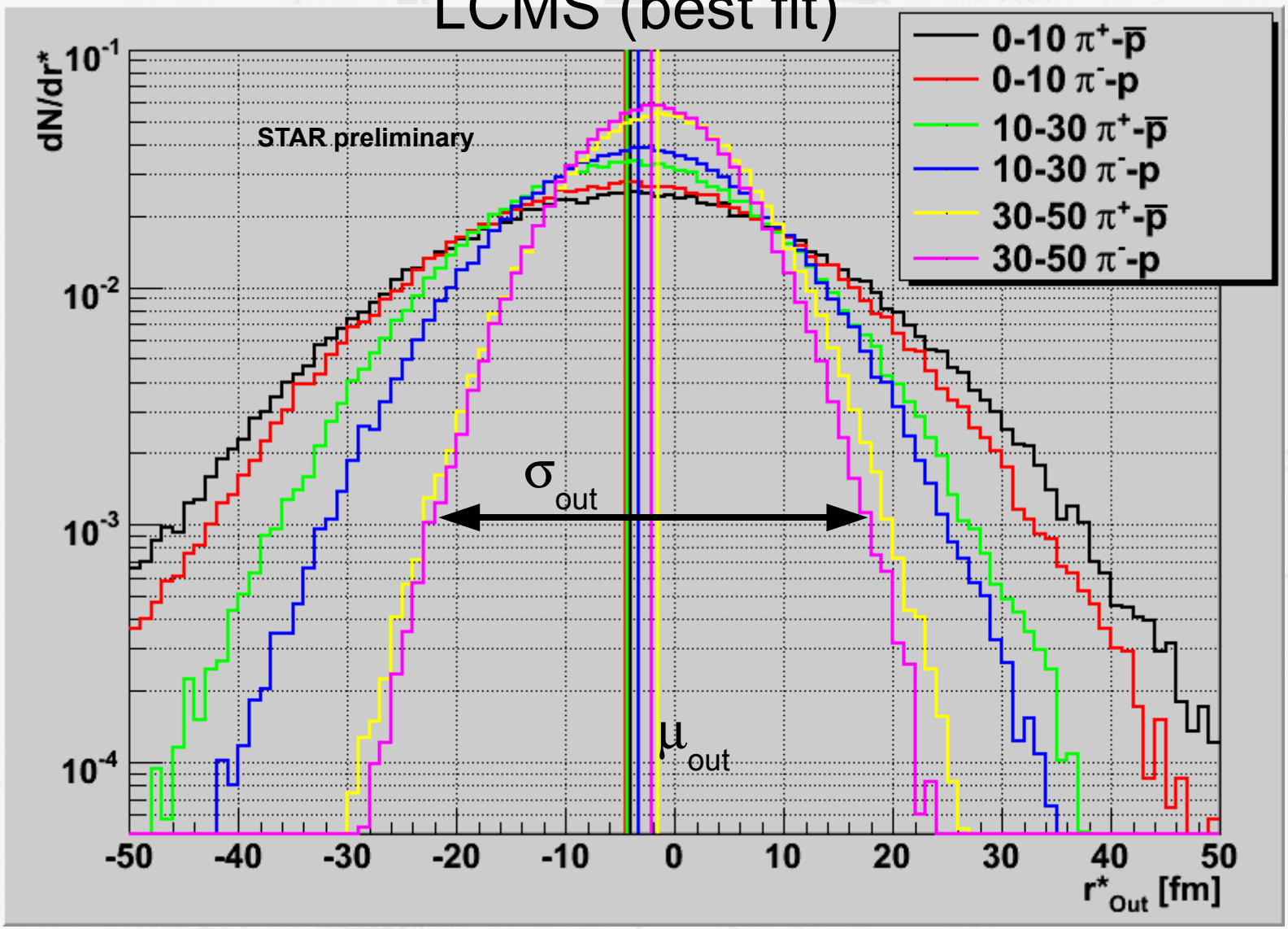
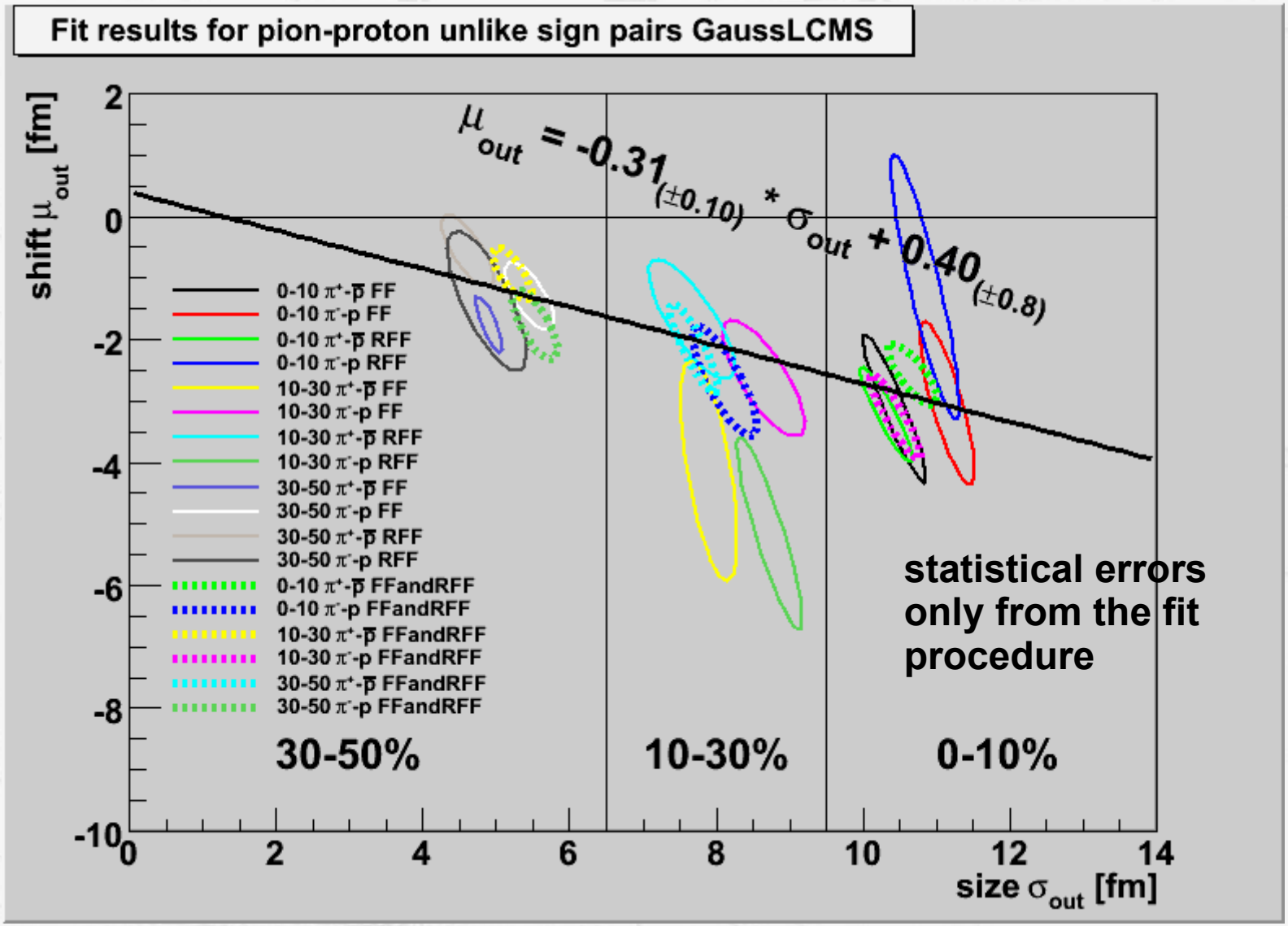
Gaussian two particle distribution of pion-proton source in LCMS (best fit)

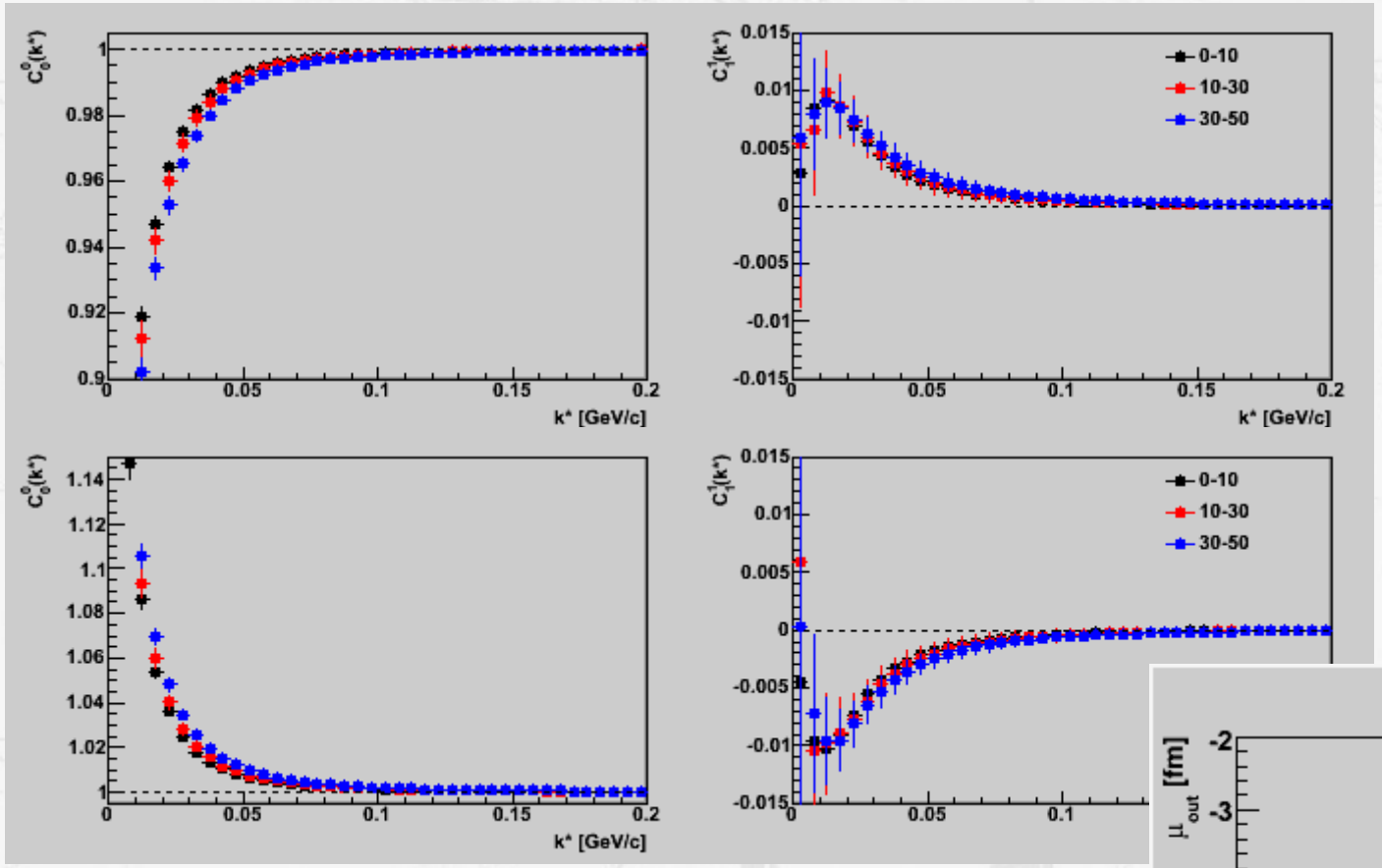


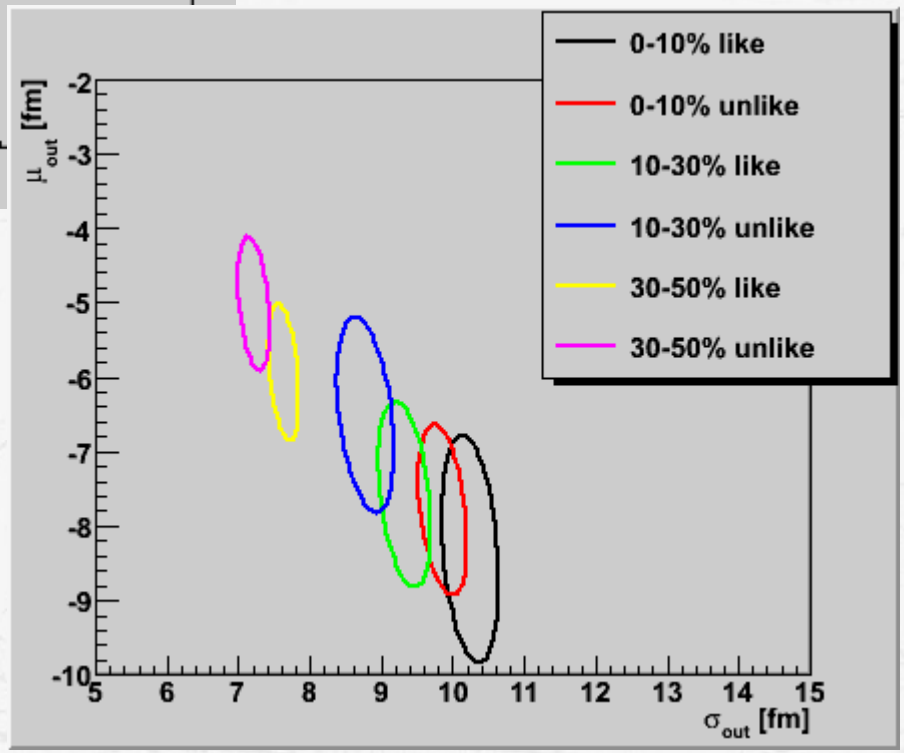
Fit results



STAR preliminary

Data simulated in Therminator





- Simulated RHIC Au+Au collision at 200AGeV
- No weak decays in the calculation
- Very small difference in calculated functions between centralities gives quite significant difference in extracted size and shift.
- Amplitude of an asymmetry higher than in experiment

Comp. Phys. Comm. 174 (2006) 669

Conclusions

- First time presented quantitative results for pion-proton system for Au+Au @ 200GeV
- Space-time asymmetry and size of the π–p source correlated and depend on centrality

$$\mu_{out} = -0.31(\pm 0.10)\cdot\sigma_{out} + 0.4(\pm 0.8)$$

- Extrapolation gives zero shift for zero size system