Two - proton femtoscopy at STAR

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Outline

1) STAR complex @ RHIC

2) Basics of proton femtoscopy

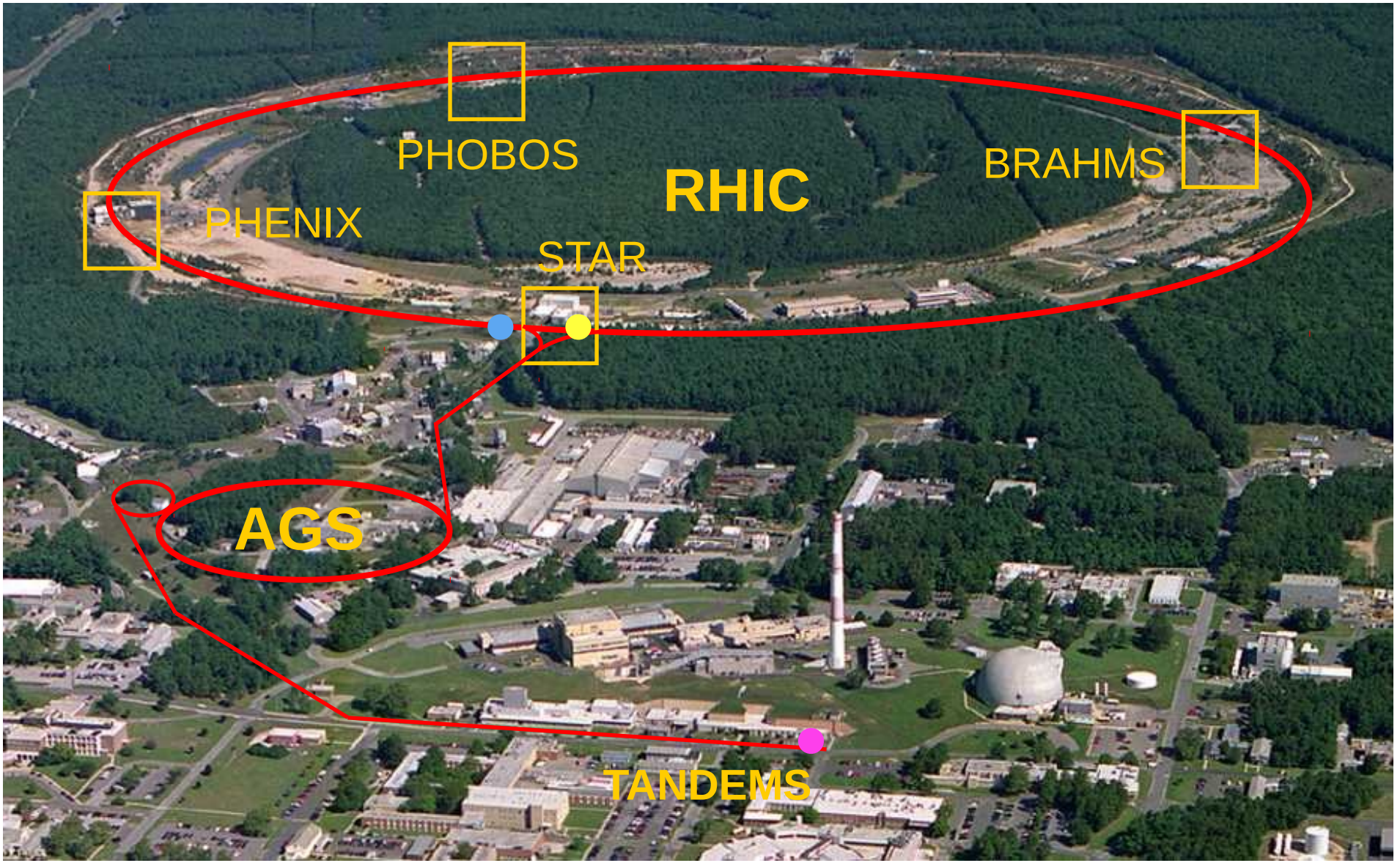
3) Results from lower energies

4) Results from Beam Energy Scan (BES) and higher energies:

$\sqrt{s_{NN}}$ = 7.7 GeV, 11.5 GeV, 39 GeV, 62.4 GeV, 200 GeV

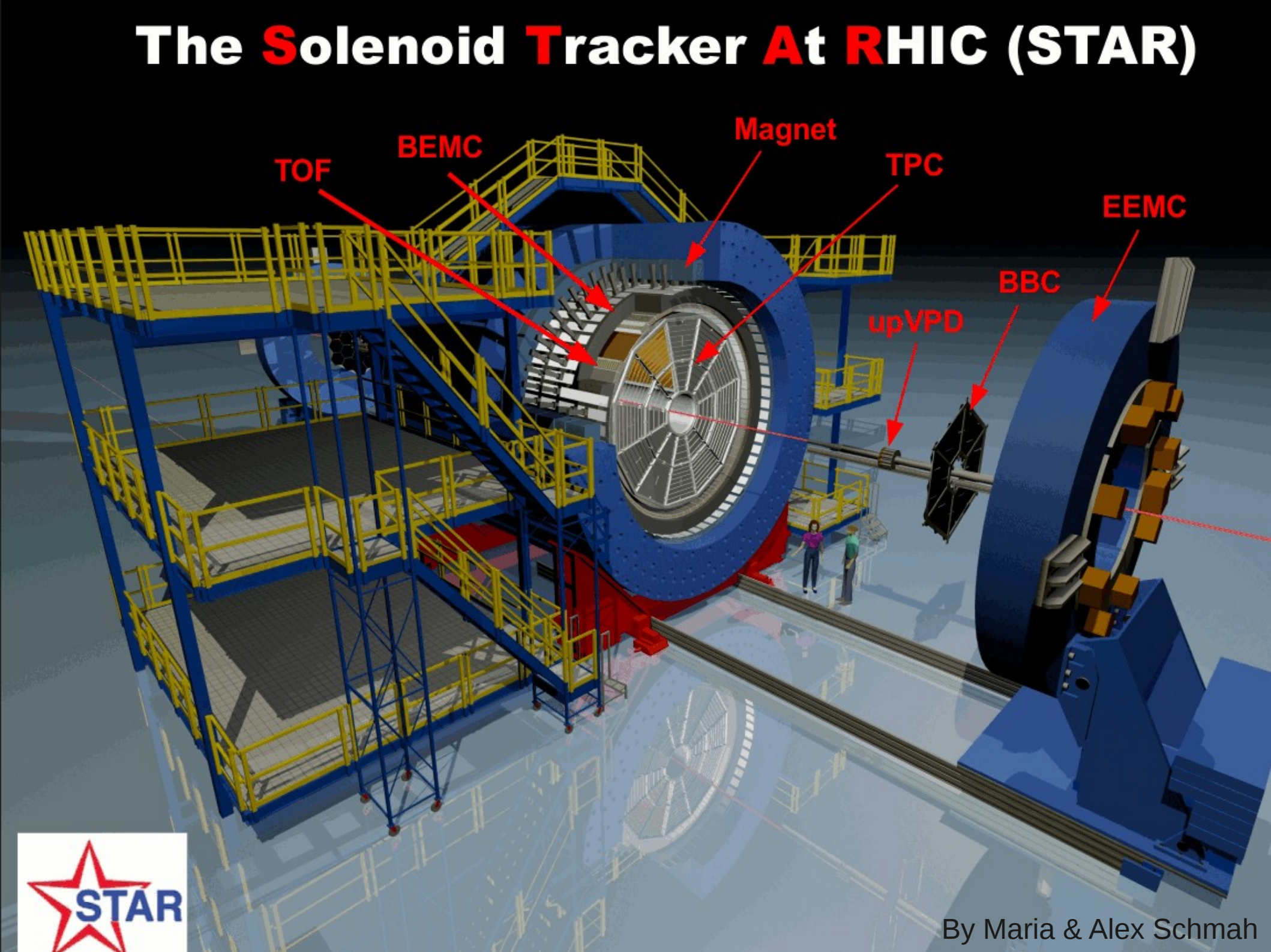
5) Summary and conclusions

1) **R**elativistic **H**eavy **I**on **C**ollider (RHIC)
Brookhaven National Laboratory (BNL), New York



- 2 concentric rings of 1740 superconducting magnets
- 3.8 km circumference

The Solenoid Tracker At RHIC (STAR)



By Maria & Alex Schmah

2) Few words about femtoscopy

Single- and two- particle distributions

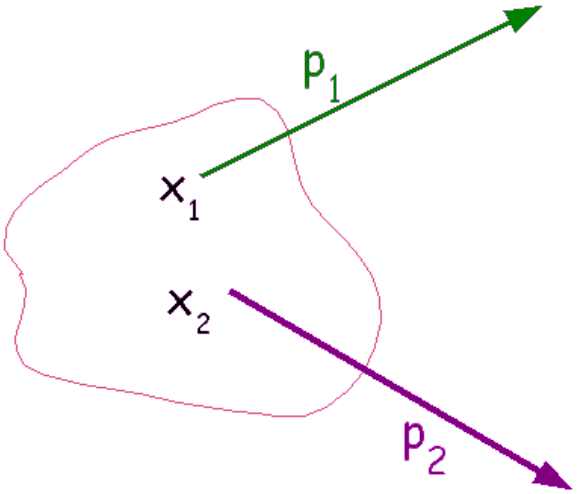
$$P_1(p) = E\frac{dN}{d^3p} = \int d^4x\, S(x,p)$$

S(x,p) – emission function: the distribution of source density probability of finding particle with x and p

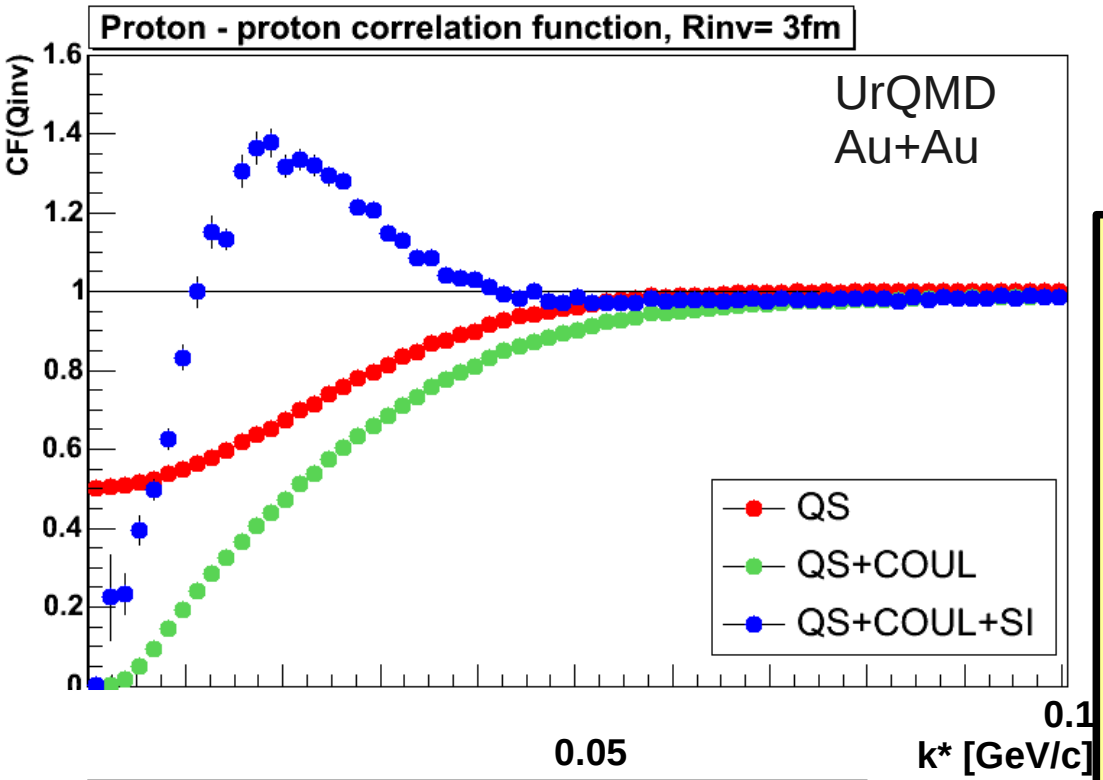
$$P_2(p_1,p_2) = E_1E_2\frac{dN}{d^3p_1 d^3p_2} = \int d^4x_1 S(x_1,p_1) d^4x_2 S(x_2,p_2)\Phi(x_2,p_2|x_1,p_1)$$

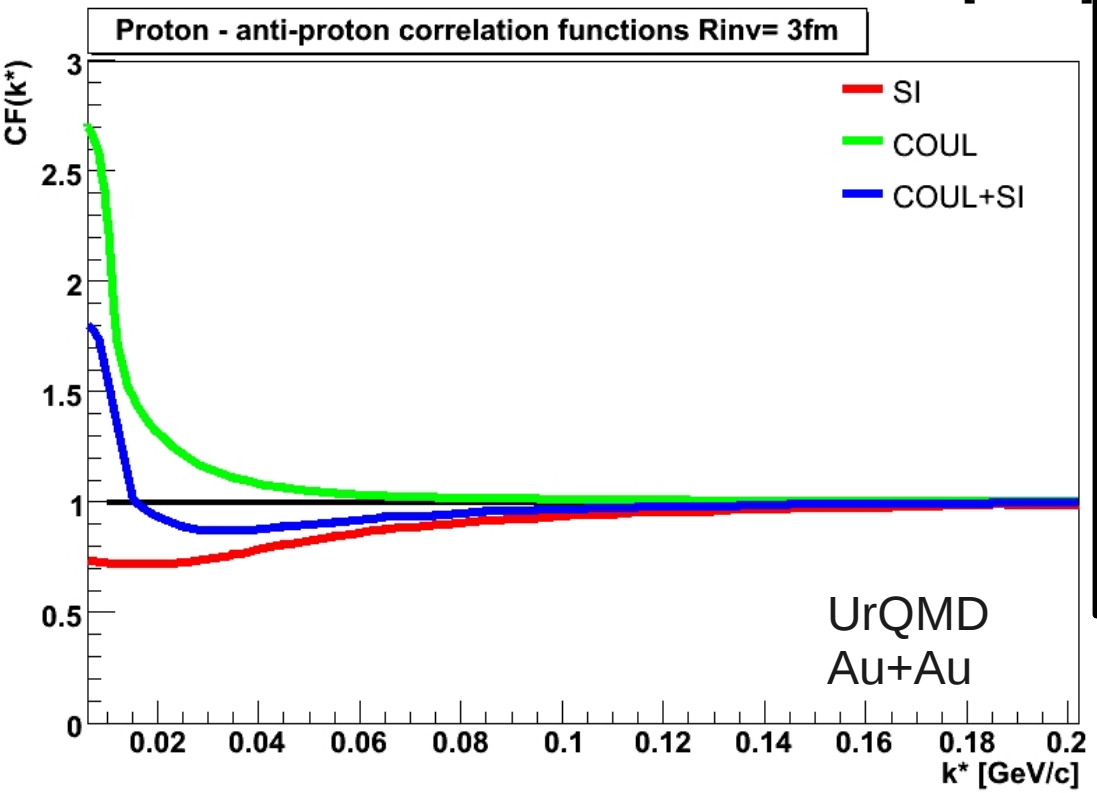
The correlation function

$$C(p_1,p_2) = \frac{P_2(p_1,p_2)}{P_1(p_1)P_1(p_2)}$$



Proton- (anti)proton correlations





Identical baryon- baryon

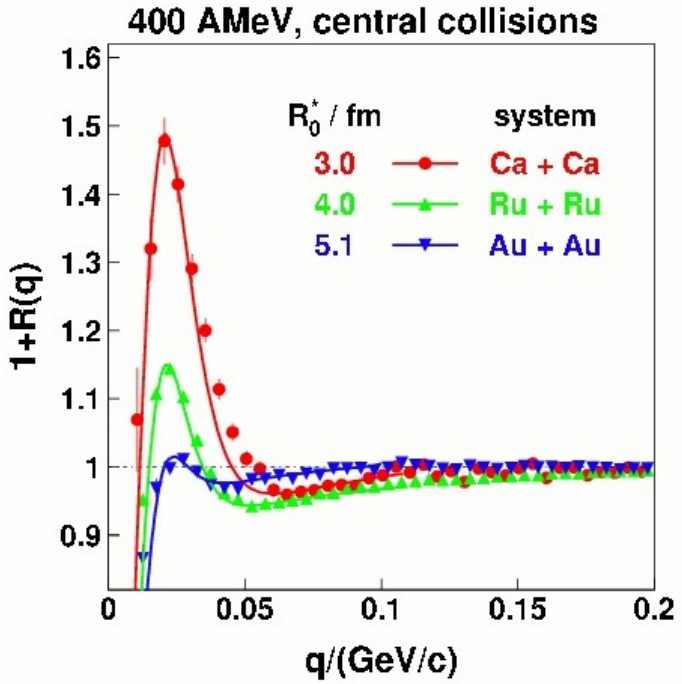
- Quantum Statistics- **QS**

- Final State Interactions- **FSI**
  - **Coulomb**
  - **Strong**

Nonidentical baryon- (anti)baryon

- Final State Interactions- **FSI**
  - **Coulomb**
  - **Strong**

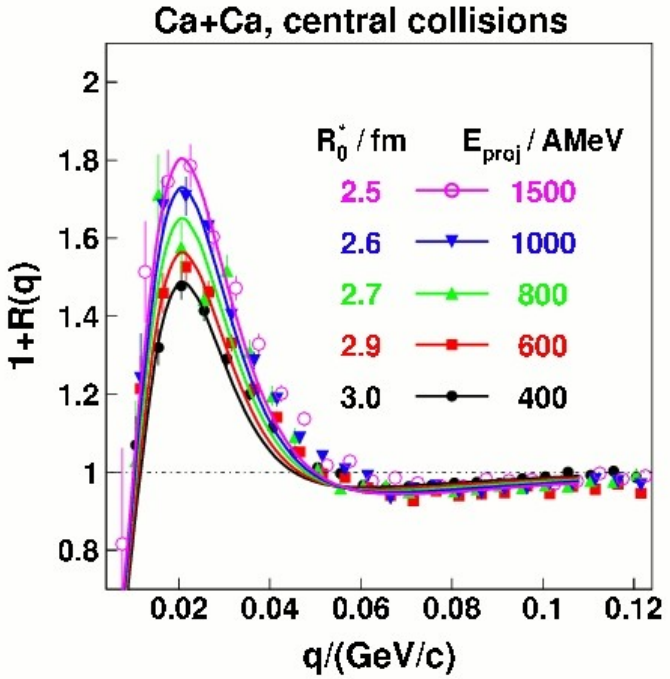
3) Results of p-p correlations from lower energies

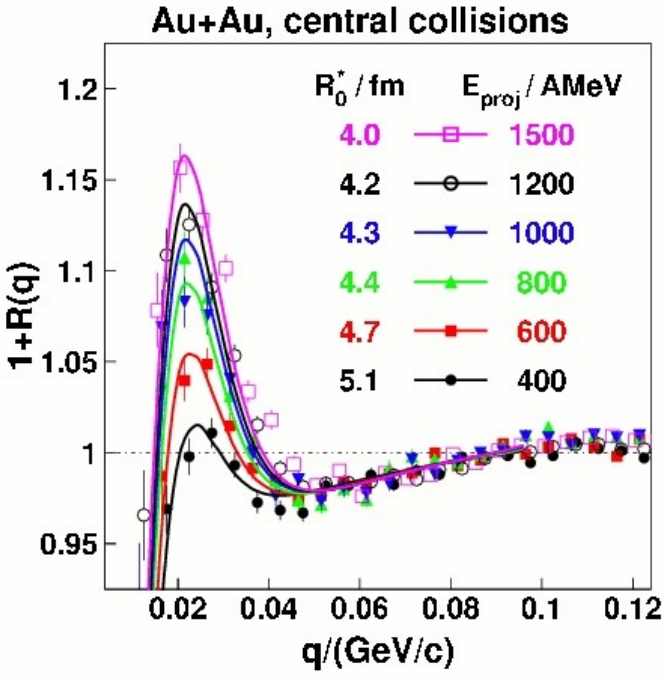


SIS → AGS/SPS → RHIC

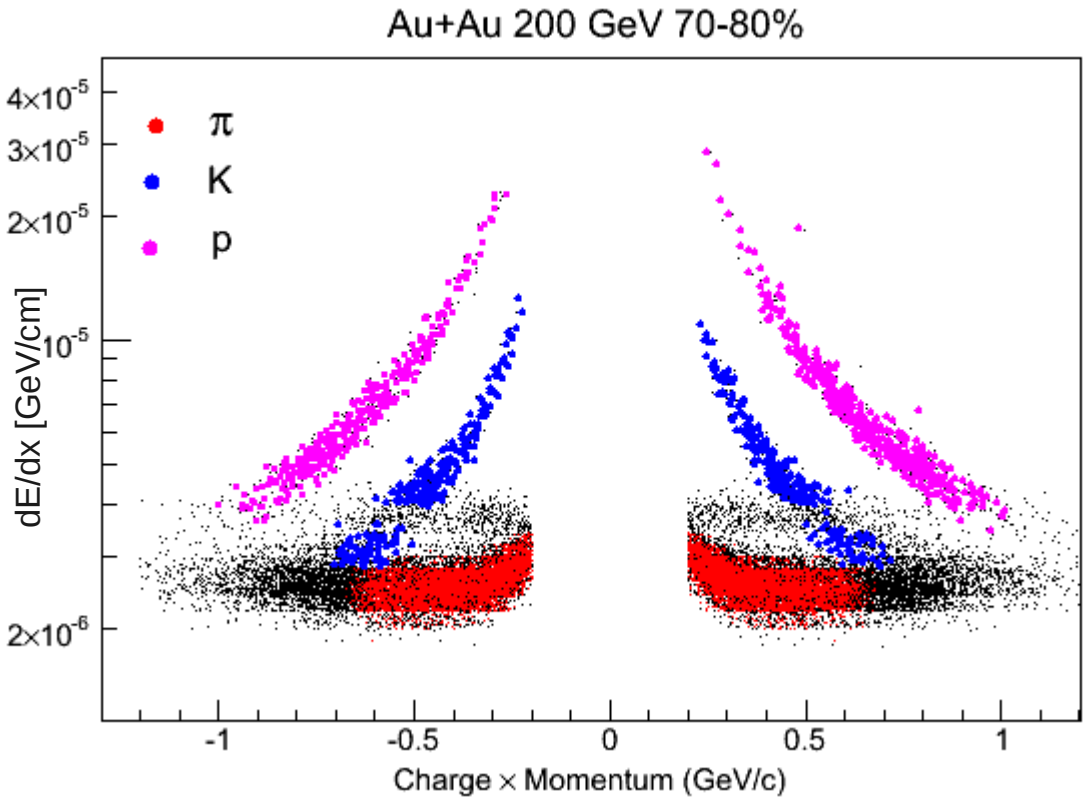
Eur.Phys.J.A23, 271-278 (2005)

FOPI Collaboration (SIS)





4) Analysed data, particle Identification - PID



$$\frac{-dE}{dx} = \frac{4\pi}{m_e c^2}\frac{nz^2}{\beta^2}\frac{e^2}{4\pi\varepsilon_0}\left[\ln\frac{2m_e c^2\beta^2}{I(1-\beta^2)} - \beta^2\right]$$

E- energy
x- distance
β=v/c (v- particle velocity,
c- speed of light)
m_e - electron mass
z- particle charge
n – density of e- inside medium
$n=N_A Z\rho/A$
N_A- Avogadro's number
A, Z- atomic and mass numbers
ρ – medium density
I- ionization potential

Analysed data:

$\sqrt{s_{NN}}$ = 7.7 GeV: 3.0 M
$\sqrt{s_{NN}}$ = 11.5 GeV: 10 M
$\sqrt{s_{NN}}$ = 39 GeV: 8.5
$\sqrt{s_{NN}}$ = 62.4 GeV: 5 M
$\sqrt{s_{NN}}$ = 200 GeV: 11 M

3 centrality classes (the percentage of the total hadronic cross-section of the collision):

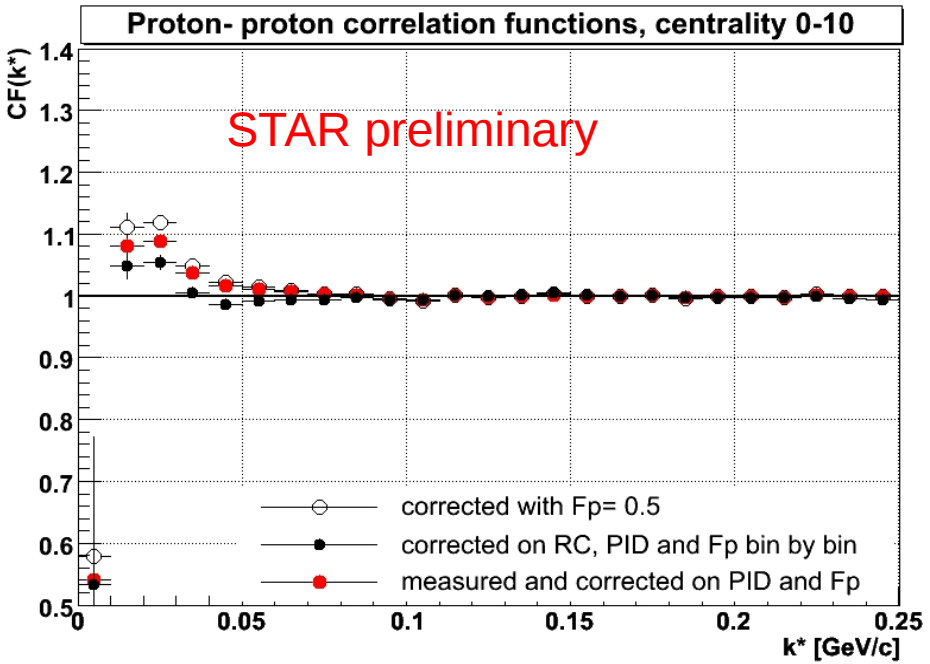
0-10%
10-30%
30-80%

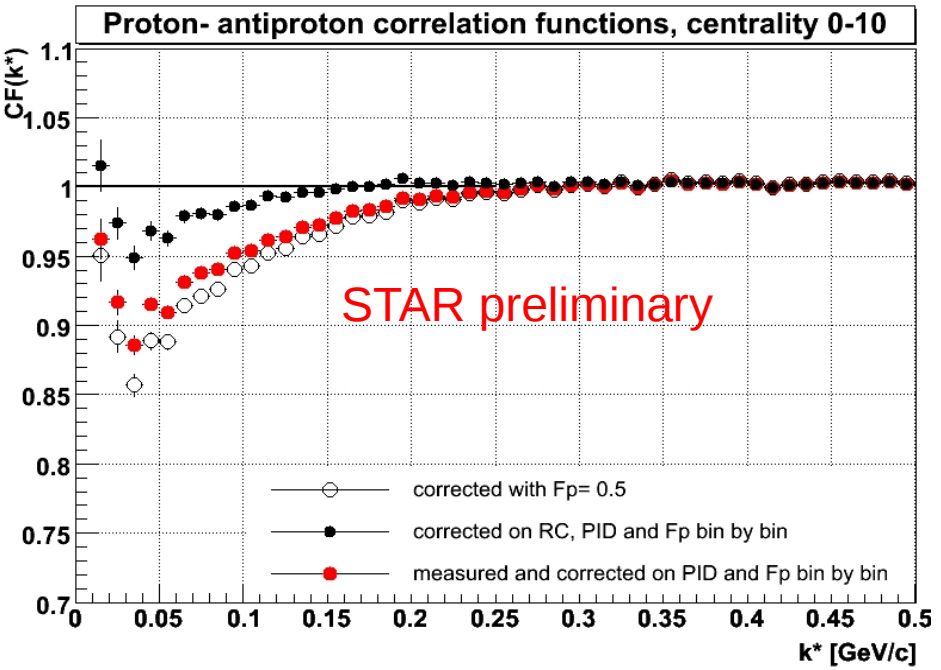
Selected protons and antiprotons:

p in [0.4, 0.9] GeV/c
p_T in [0.4, 0.8] GeV/c
rapidity y in [-0.5, 0.5]

An importance of applied corrections

Au+ Au @ 200 GeV



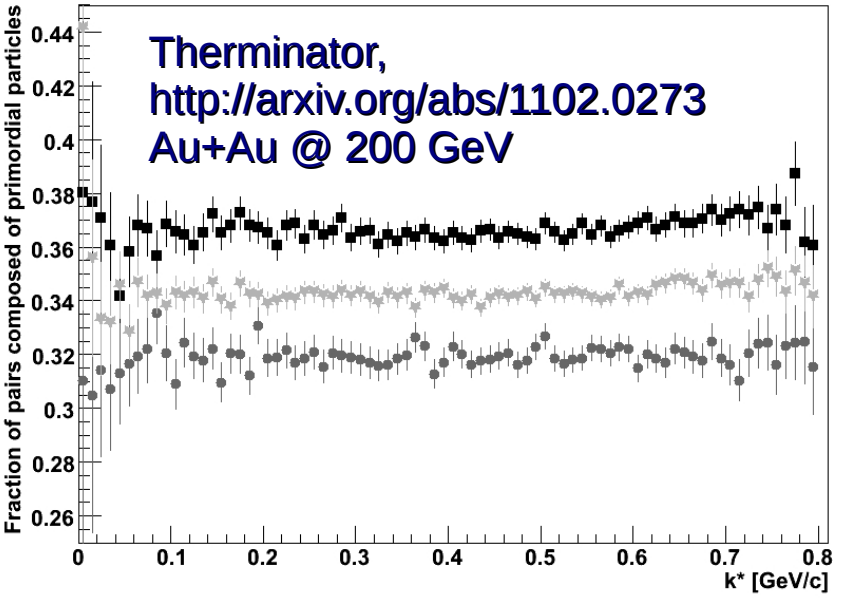


○: Fp= 0.5 assumes that 50% particles is primordial ones (pair purity = 0.25)

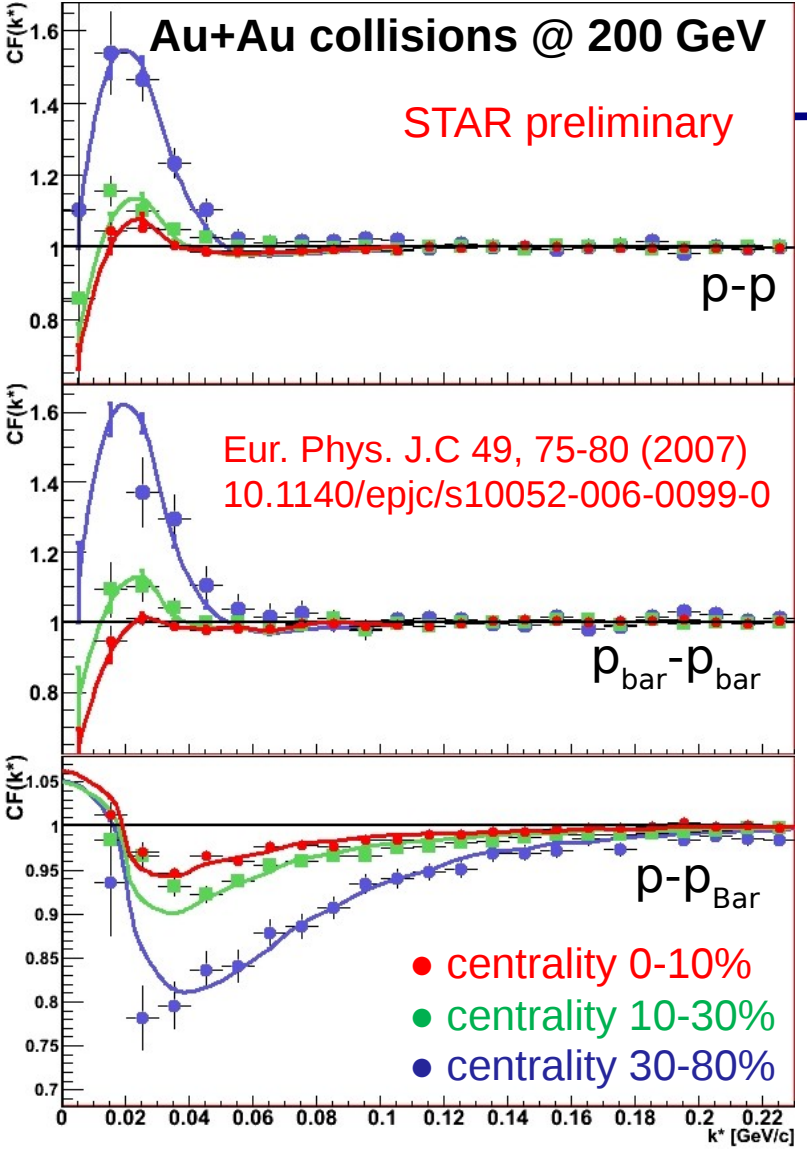
●: purity correction done precisly (accurate Fp and PID taken into account)

●: precise purity correction and Residual Correlation taken into account

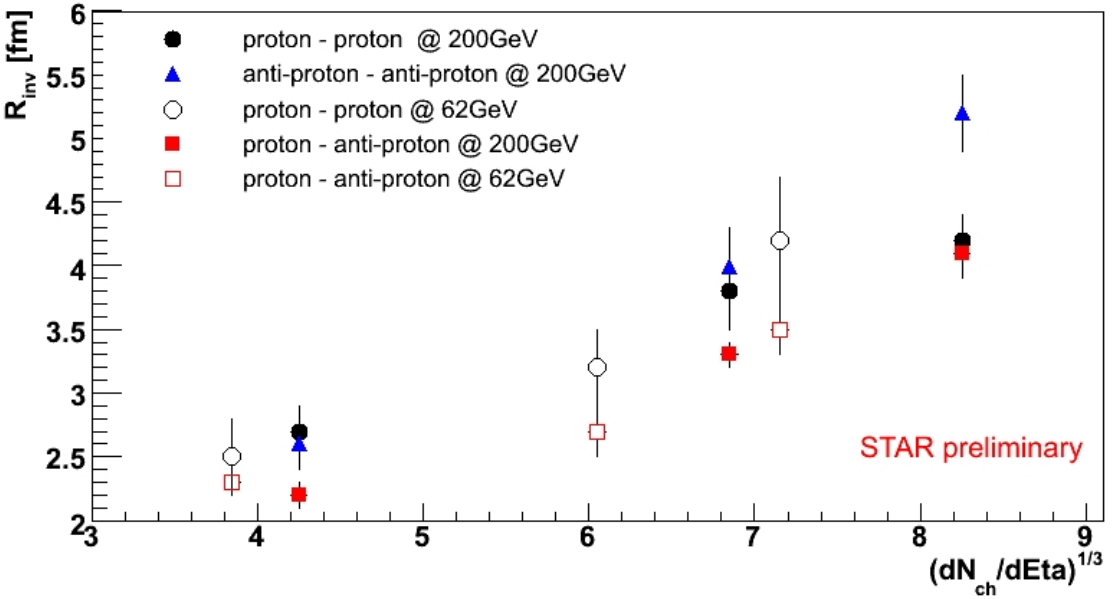
The impact of Residual Correlations is indicated by the differences between ● and ● symbols



Proton femtoscopy @200GeV



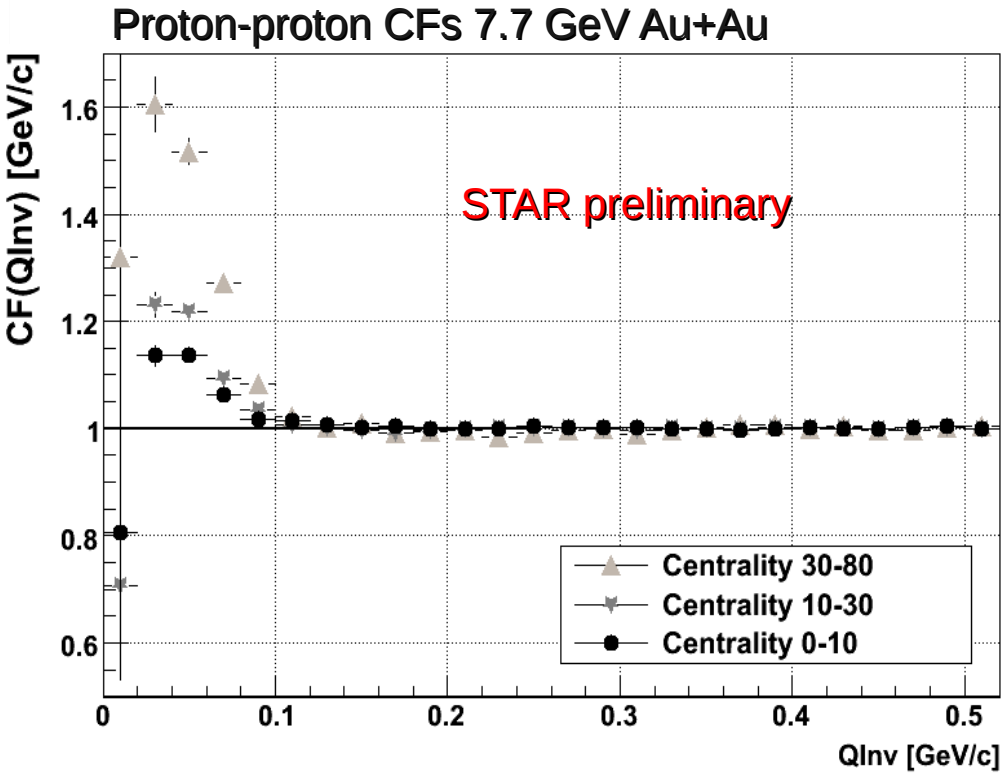
- 10 millions of minimum-bias data analyzed
- Applied corrections: purity, resolution smearing, residual correlations
- Centrality dependence is shown
- Gaussian source distribution assumed (the same source size in each direction)
- Agreement of experimental data and fits is very good



For the first time:

- The analysis of two-baryon correlations for all proton and antiproton systems (in the same experimental conditions)
- The sizes of antiproton emission region measured
- Data corrected for the residual correlations

Results from BES program: @ 7.7 GeV

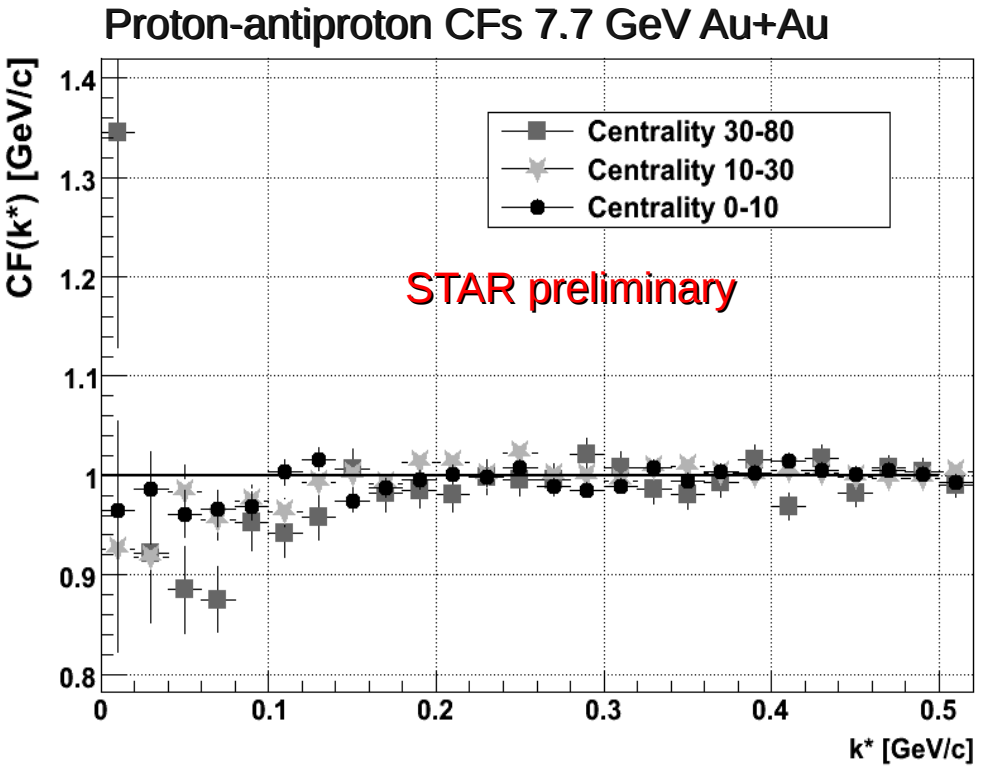


Centrality dependence very clear:

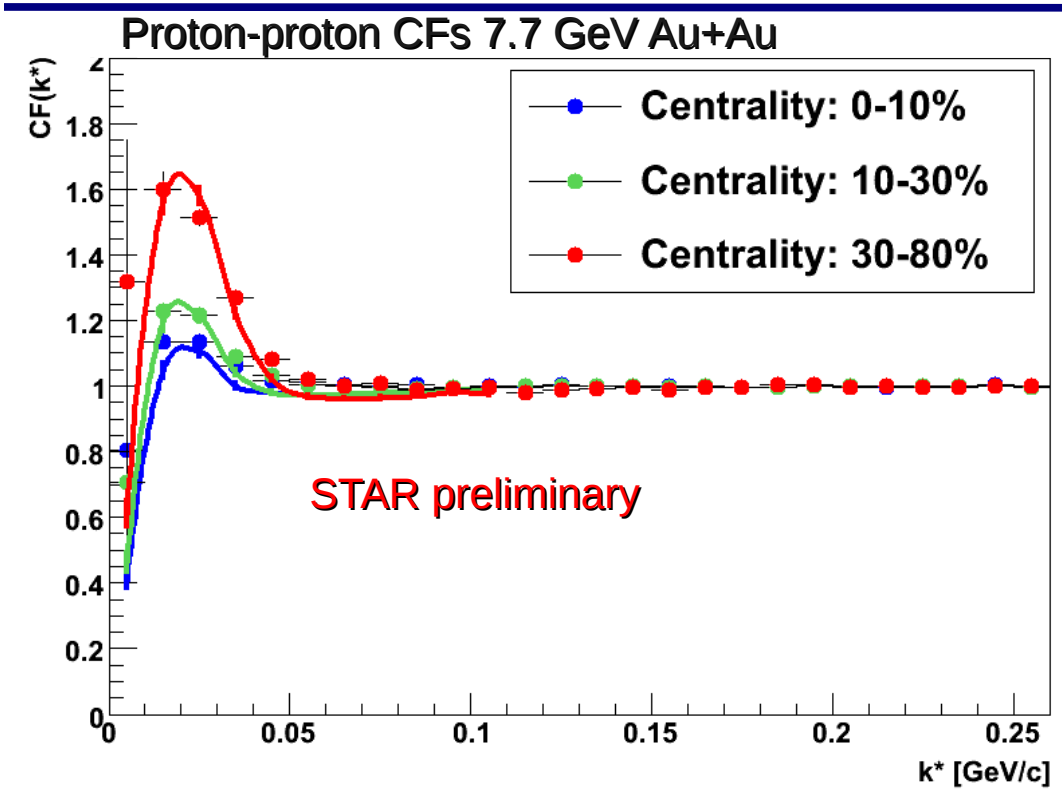
the correlation effect is the strongest

for the most peripheral collisions

Reference multiplicity:
Central (0-10%) > 155
Mid-central (10-30%) - 73 - 154
Peripheral (30-80 %) - 5 - 72

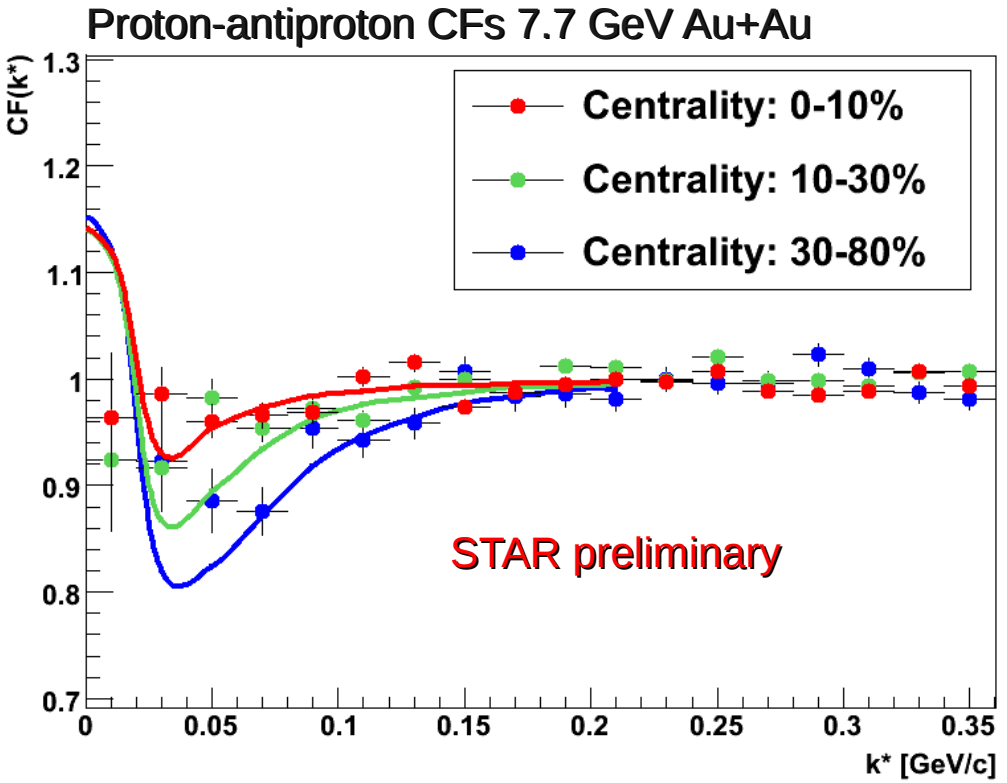


Results from BES program: @ 7.7 GeV - fits



Fits to p-p + pbar-pbar:
Central: 4.15 ± 0.43 fm
Mid-central: 3.62 ± 0.21 fm
Peripheral: 2.74 ± 0.32 fm
Fits to p-pbar:
Central: 3.98 ± 0.23 fm
Mid-central: 2.92 ± 0,41 fm
Peripheral: 2.21 ± 0.43 fm

only statistical error

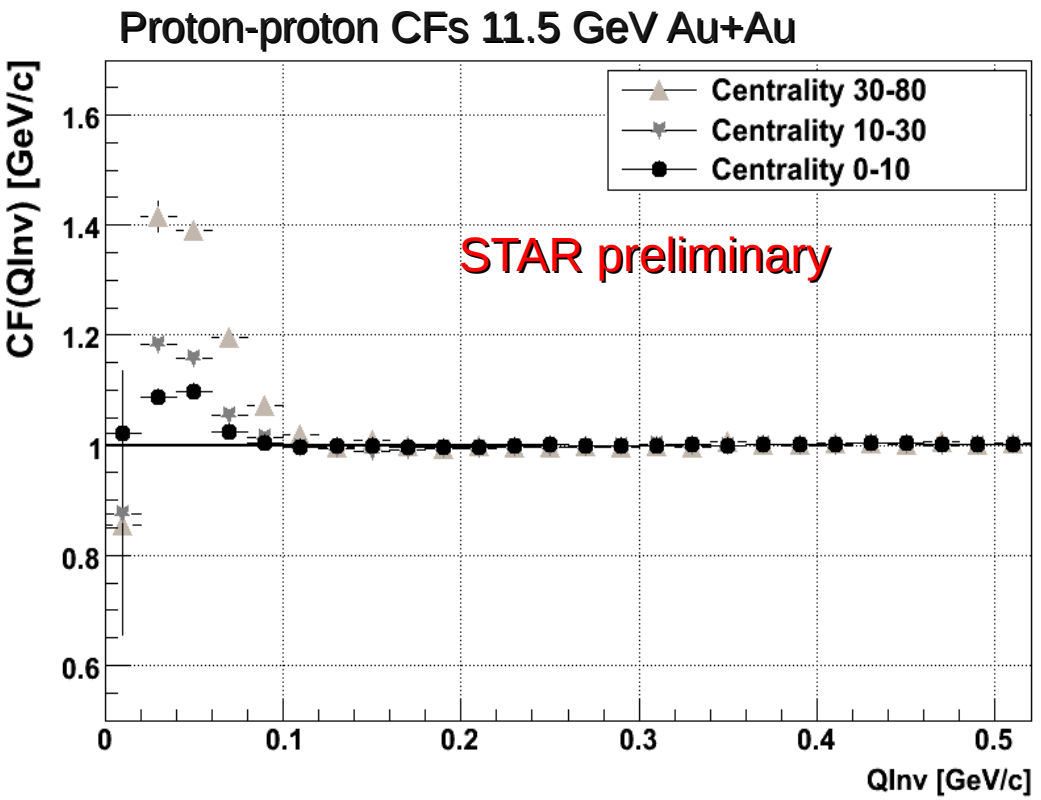


The fitting formula based on wave functions:
includes:
QS + FSI (identical systems)
FSI (nonidentical systems)

Discrepancies between estimated source sizes within the same collision centrality indicate an importance of applying significant corrections: purity and Residual Correlations

Estimations from purity and Residual Correlations for BES are ongoing!

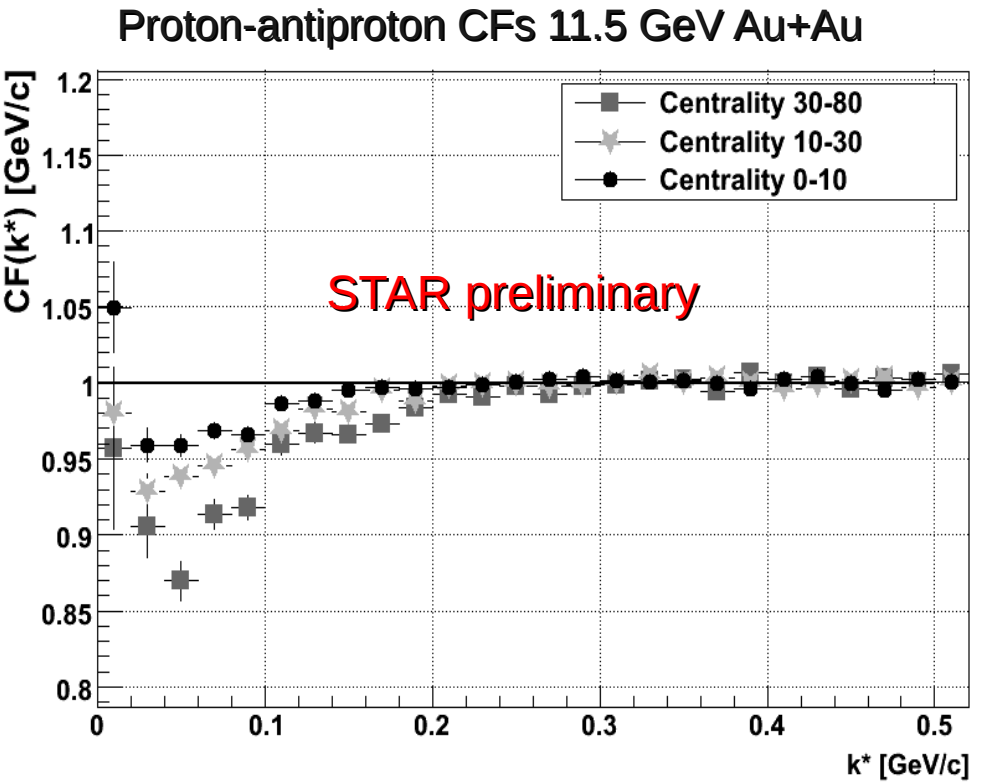
Results from BES program: @ 11.5 GeV



Centrality dependence very clear:

the correlation effect is the strongest

for the most peripheral collisions



Reference multiplicity:

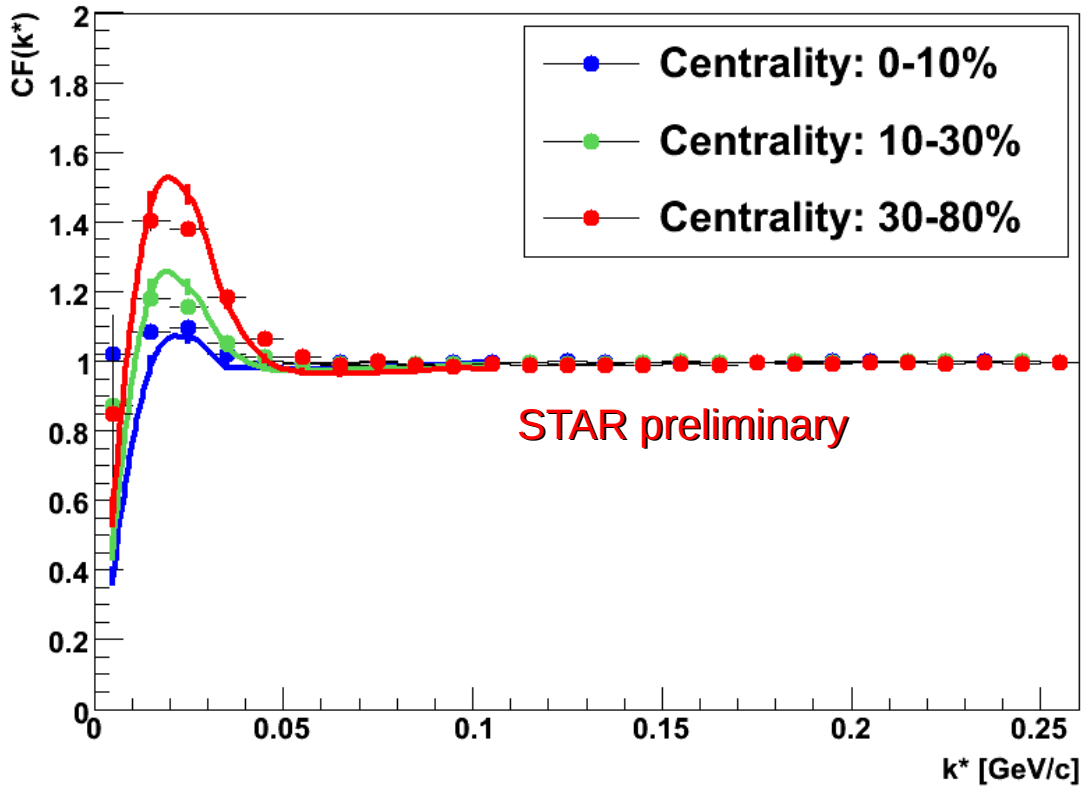
Central (0-10%) > 185

Mid-central (10-30%) - 87 - 184

Peripheral (30-80 %) - 6 - 86

Results from BES program: @ 11.5 GeV - fits

Proton-proton CFs 11.5 GeV Au+Au

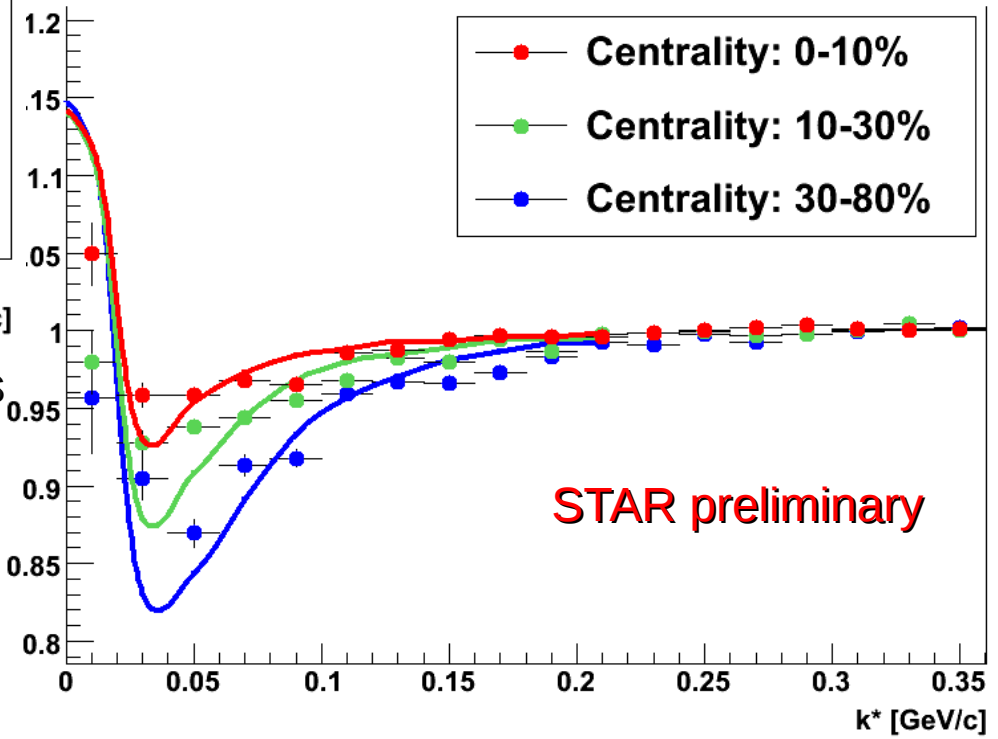


Fits to p-p + pbar-pbar:
Central: 4.51 ± 0.23 fm
Mid-central: 3.62 ± 0.11 fm
Peripheral: 2.92 ± 0.13 fm

Fits to p-pbar:
Central: 3.98 ± 0.13 fm
Mid-central: 3.09 ± 0.25 fm
Peripheral: 2.39 ± 0.34 fm

only statistical error

Proton-antiproton CFs 11.5 GeV Au+Au

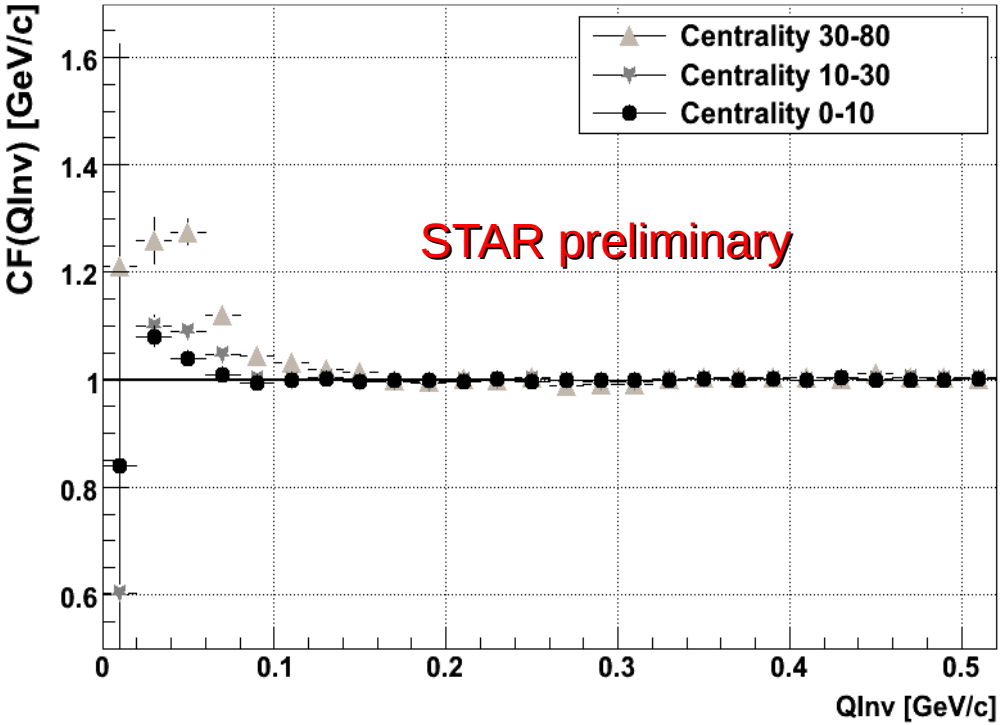


Discrepancies between estimated source sizes within the same collision centrality indicate an importance of applying significant corrections: purity and Residual Correlations

Estimations from purity and Residual Correlations for BES are ongoing!

Results from BES program: @ 39 GeV

Proton-proton CFs 39 GeV Au+Au



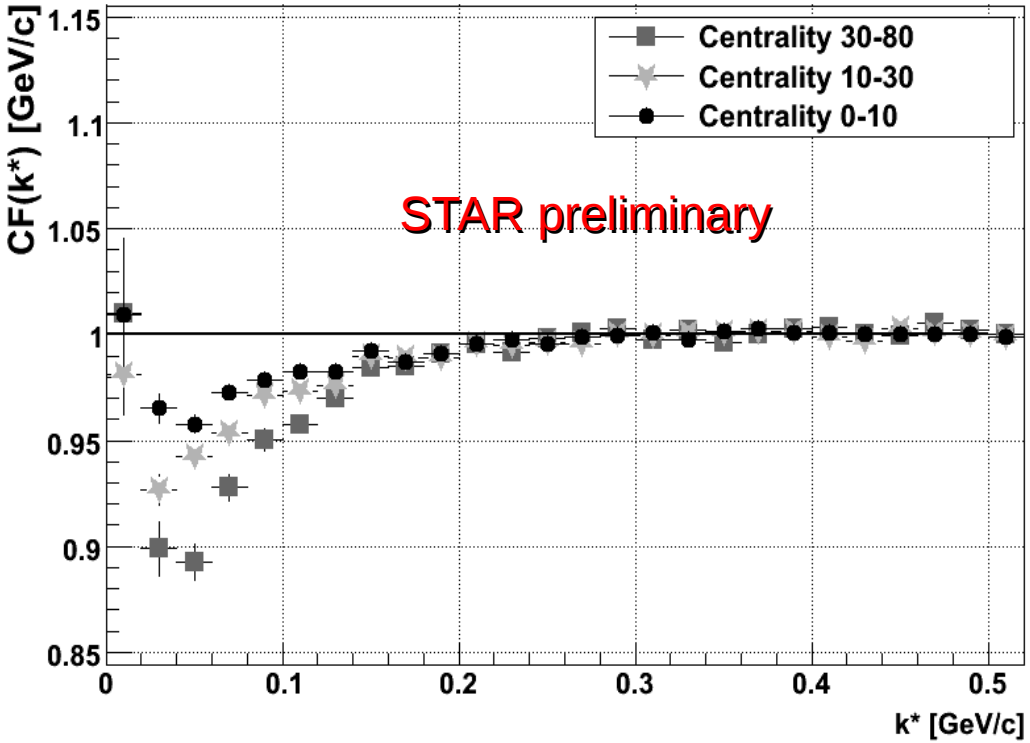
Reference multiplicity:
Central (0-10%) > 266
Mid-central (10-30%) - 125 - 265
Peripheral (30-80 %) - 8 - 125

Centrality dependence very clear:

the correlation effect is the strongest

for the most peripheral collisions

Proton-antiproton CFs 39 GeV Au+Au

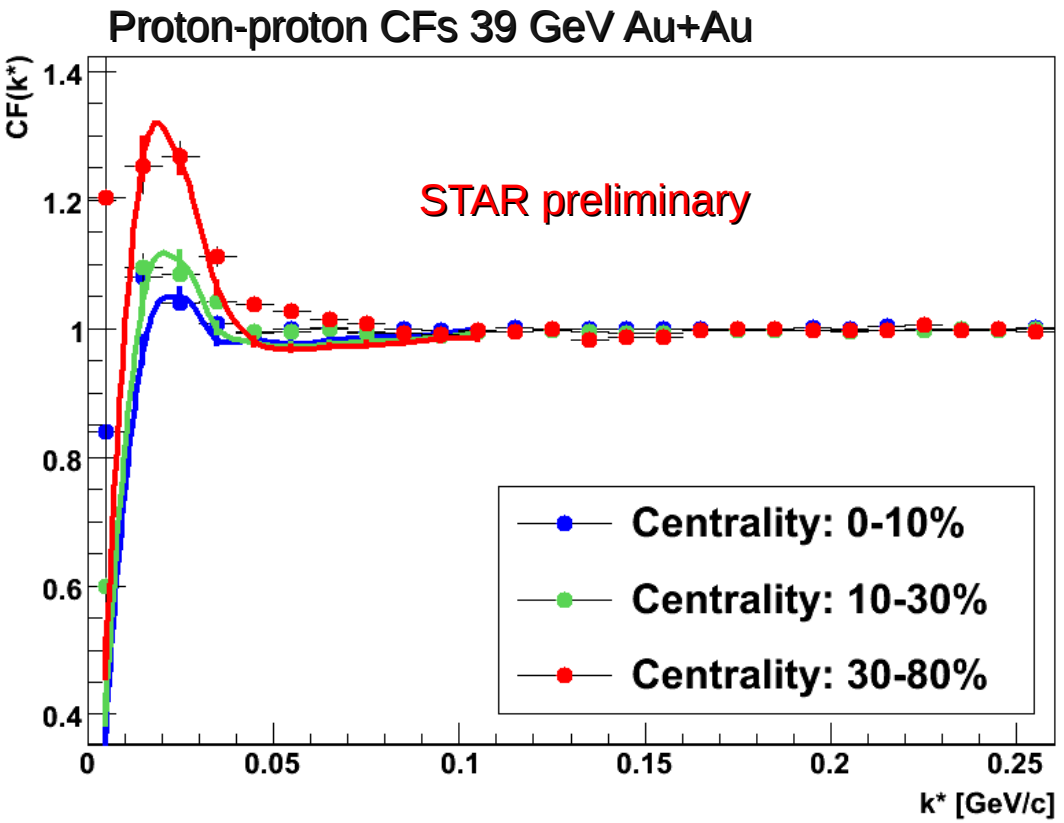


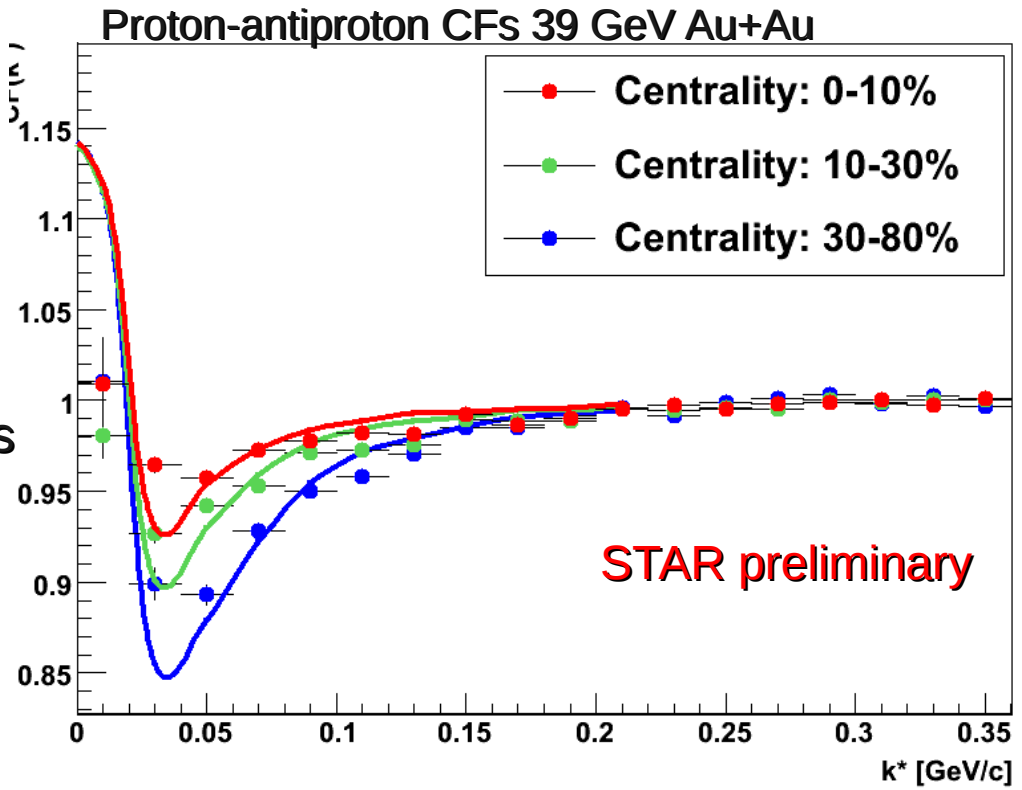
Results from BES program: @ 39 GeV - fits

Fits to p-p + pbar-pbar:
Central: 4.68 ± 0.16 fm
Mid-central: 4.15 ± 0.27 fm
Peripheral: 3.45 ± 0.34 fm

Fits to p-pbar:
Central: 3.98 ± 0.24 fm
Mid-central: 3.45 ± 0.36 fm
Peripheral: 2.75 ± 0.29 fm

only statistical error





Discrepancies between estimated source sizes within the same collision centrality indicate an importance of applying significant corrections: purity and Residual Correlations

Estimations from purity and Residual Correlations for BES are ongoing!

Summary

- Data analysed: 7.7 GeV, 11.5 GeV, 39 GeV, 200 GeV
- 1D correlation studies done
- (p-p + pbar-pbar) and p-pbar systems checked
- estimation of purity and Residual Correlations done for 200 GeV
- strong contamination of Residual Correlations is seen as discrepancies between estimated from correlation functions of identical and nonidentical particle combinations source sizes within the same collision centrality

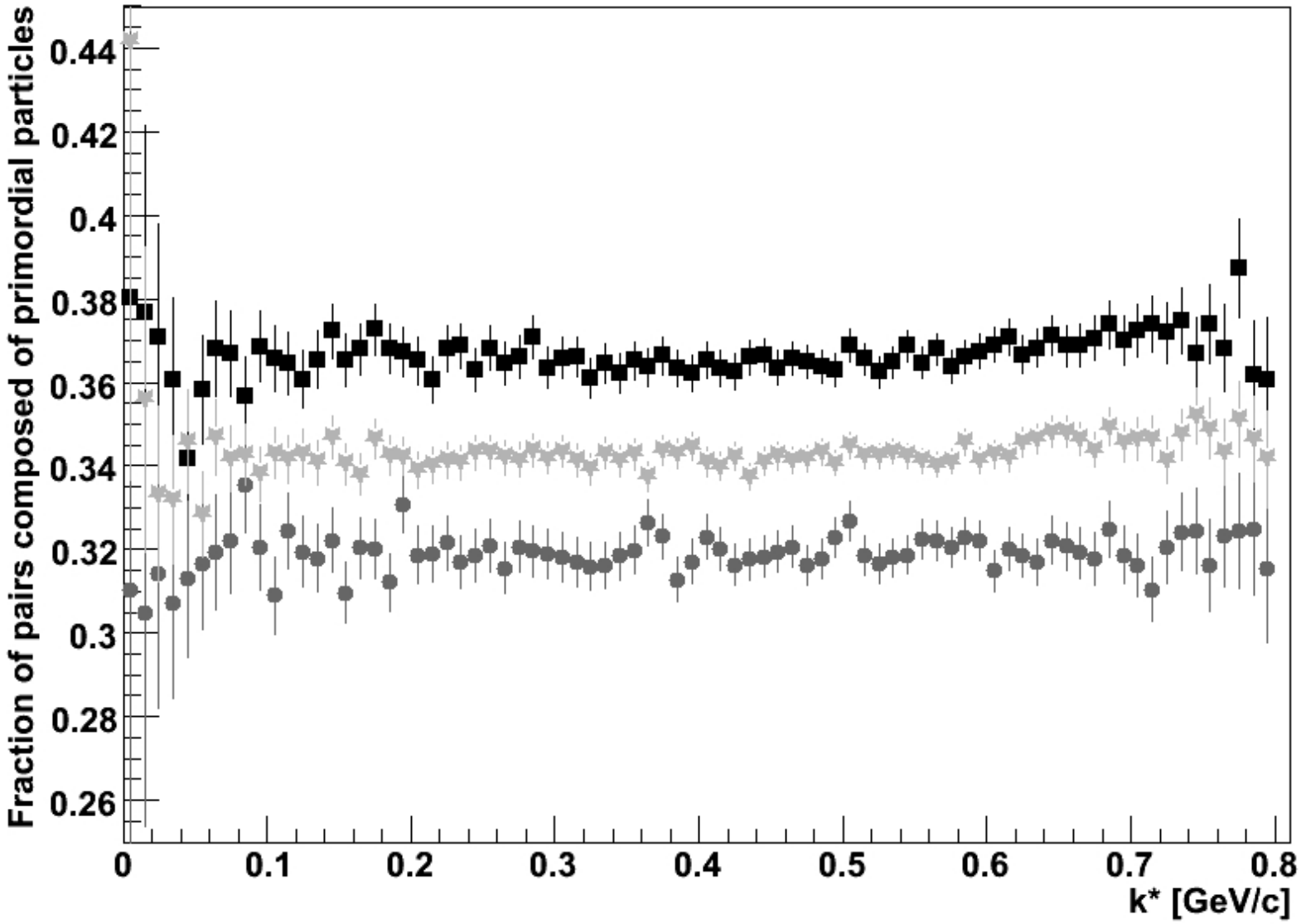
- The effect of purity correction and Residual Correlations has to be taken into account

Plans:

- To estimate Residual Correlations for BES data

The fraction of proton-proton pairs

$$F_{p-p}(k_{star}) = \frac{f_{p-p}(k_{star})}{\sum_{i,j=\,p,\Lambda,\Sigma} f_{i,j}(k_{star})}$$

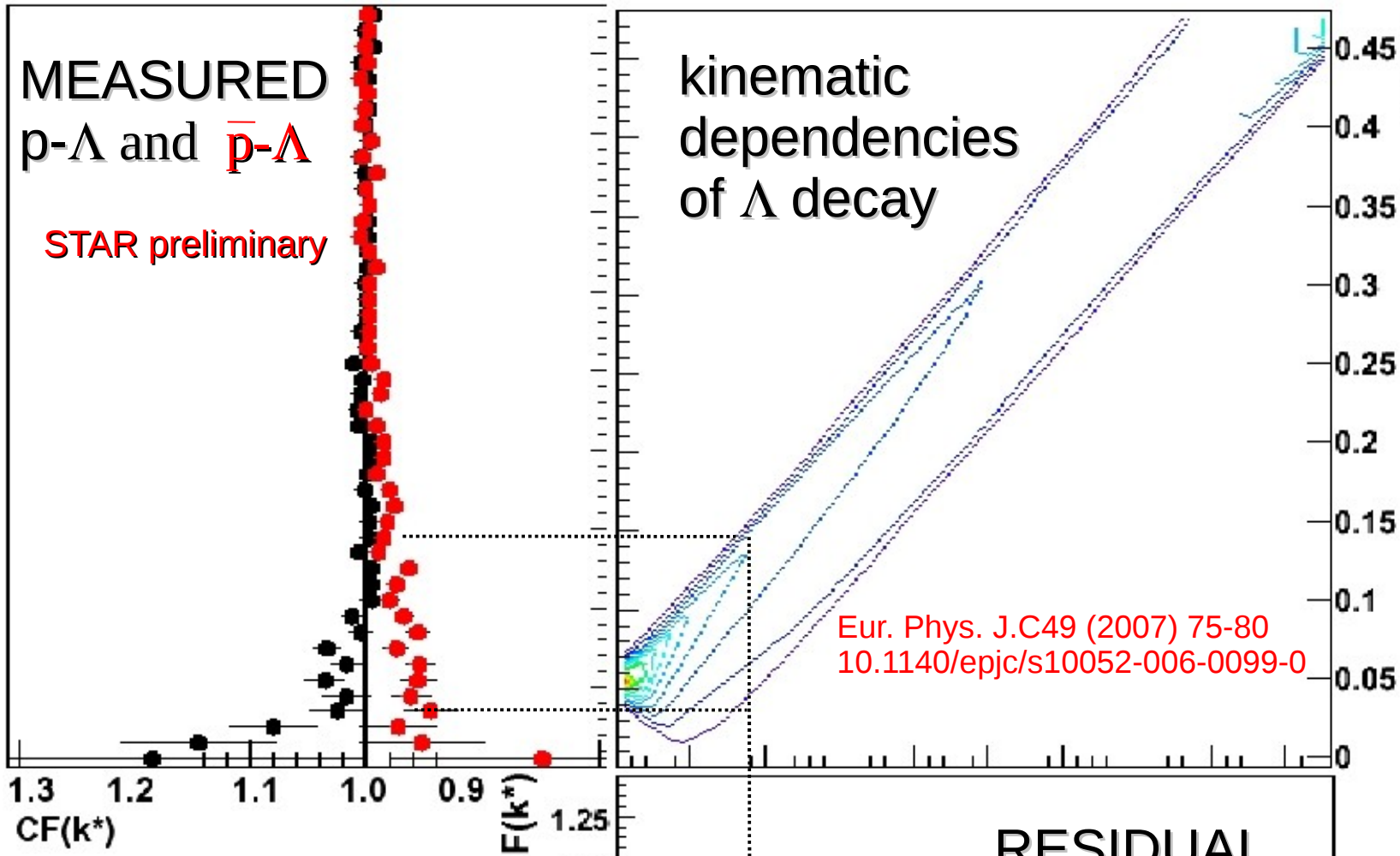


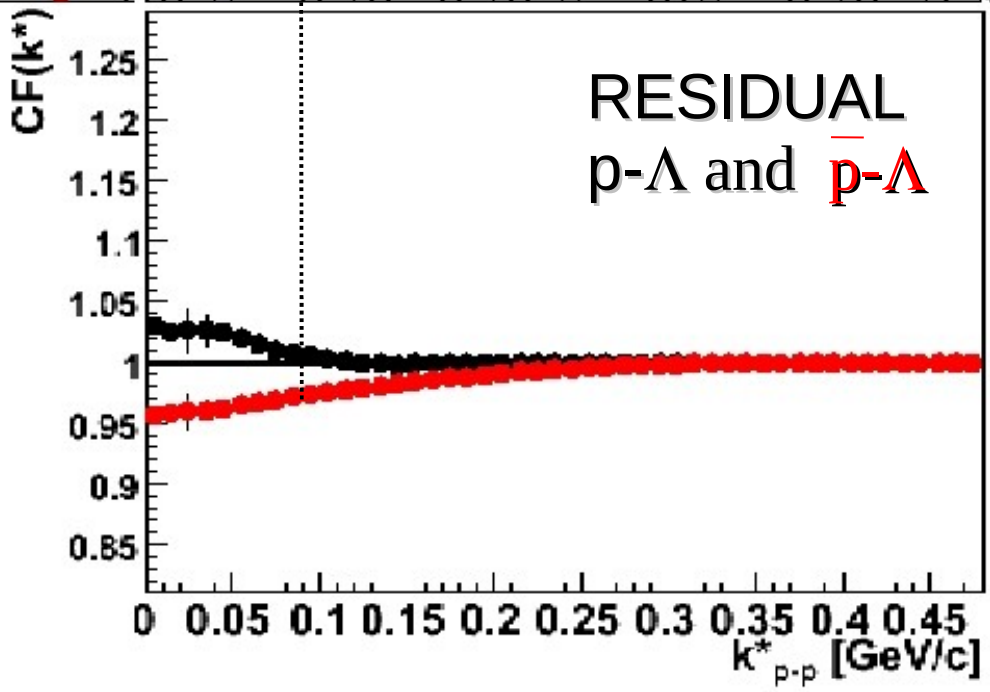
Therminator,
Au+Au @ 200 GeV

p-p: ~ 37%

p-$\bar{p}$: ~ 34%

$\bar{p}$-$\bar{p}$: ~ 32%





The estimation of p-Λ residual correlation

$$\sum_{k^{star}_{p-\Lambda}} CF^{meas}_{p-\Lambda}(k^{star}_{p-\Lambda}) W(k^{star}_{p-p}, k^{star}_{p-\Lambda})$$