WARSAW UNIVERSITY OF TECHNOLOGY

Two-particle proton correlations at BES energies

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STAR ☆

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and Femtoscopy

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Outline

1) Basics of proton femtoscopy

2) Cuts used and monitors for Au+Au collisions at $\sqrt{(s_{NN})}$ = 39 GeV

3) Results from Beam Energy Scan:

     3a) Au+Au collisions at $\sqrt{(s_{NN})}$ = 39 GeV

     3b) Au+Au collisions at $\sqrt{(s_{NN})}$ = 11.5 GeV

     3c) Au+Au collisions at $\sqrt{(s_{NN})}$ = 7.7 GeV

4) Summary and conclusions

Few words about femtoscopy

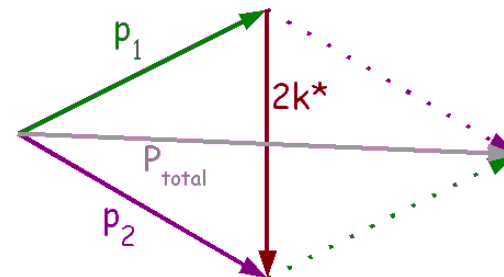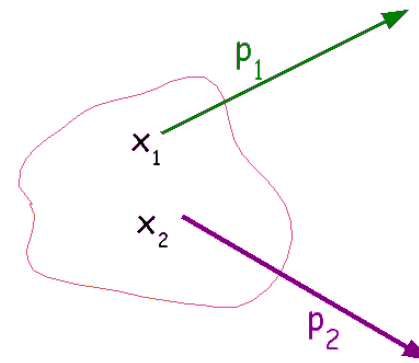## Single- and two- particle distributions

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

S(x,p) – emission function: the distribution of source density probability of finding particle with x and p
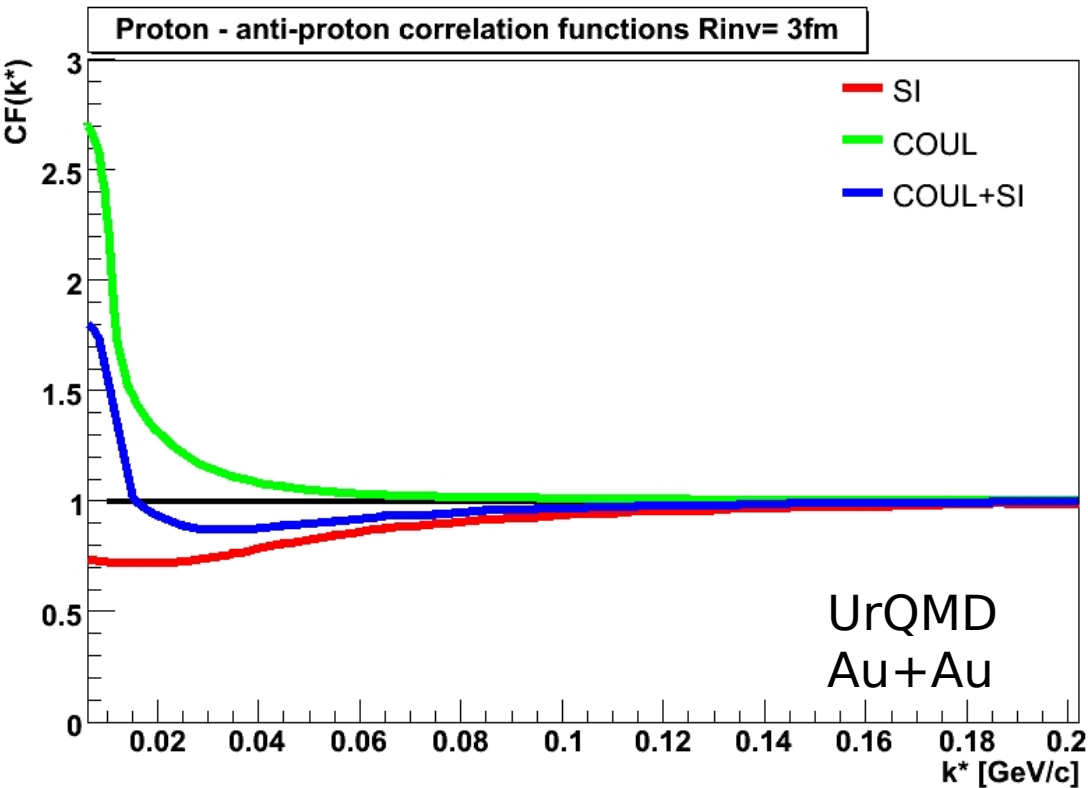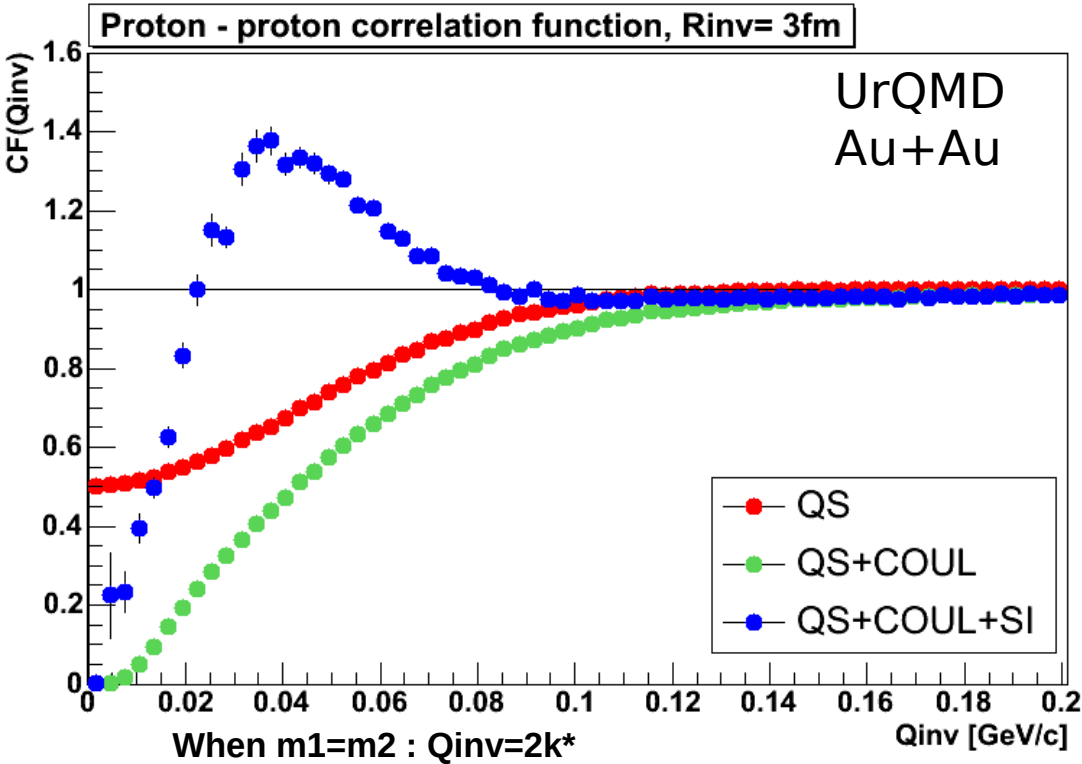
$$P_2(p_1, p_2) = E_1 E_2 \frac{dN}{d^3 p_1 d^3 p_2} = \int d^4 x_1\, S(x_1, p_1)\, d^4 x_2\, S(x_2, p_2)\, \Phi(x_2, p_2 | x_1, p_1)$$

The correlation function

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

p_1

x_1

x_2

p_2

p_1

$2k^*$

P_{total}

p_2

Proton - proton correlation function, Rinv= 3fm

UrQMD
Au+Au

- QS
- QS+COUL
- QS+COUL+SI

When m1=m2 : Qinv=2k*

Qinv [GeV/c]

Proton - anti-proton correlation functions Rinv= 3fm

- SI
- COUL
- COUL+SI

UrQMD
Au+Au

k* [GeV/c]

Proton-(anti)proton correlations

Identical baryon- baryon

- Quantum Statistics- QS

- Final State Interactions- FSI
   - Coulomb
    - Strong

Nonidentical baryon-antibaryon

- Final State Interactions- FSI
    - Coulomb
    - Strong

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Proton-(anti)proton correlations

Proton - proton correlation function, Rinv= 3fm

UrQMD
Au+Au

~1/R

When m1=m2 : Qinv=2k*

- QS
- QS+COUL
- QS+COUL+SI

Proton - anti-proton correlation functions Rinv= 3fm

- SI
- COUL
- COUL+SI

UrQMD
Au+Au

Why to do this?

We can calculate Radii using the correlation functions.

The width of the Quantum Statistics part in correlation functions is inversely proportional to the Radius of the "source" size.
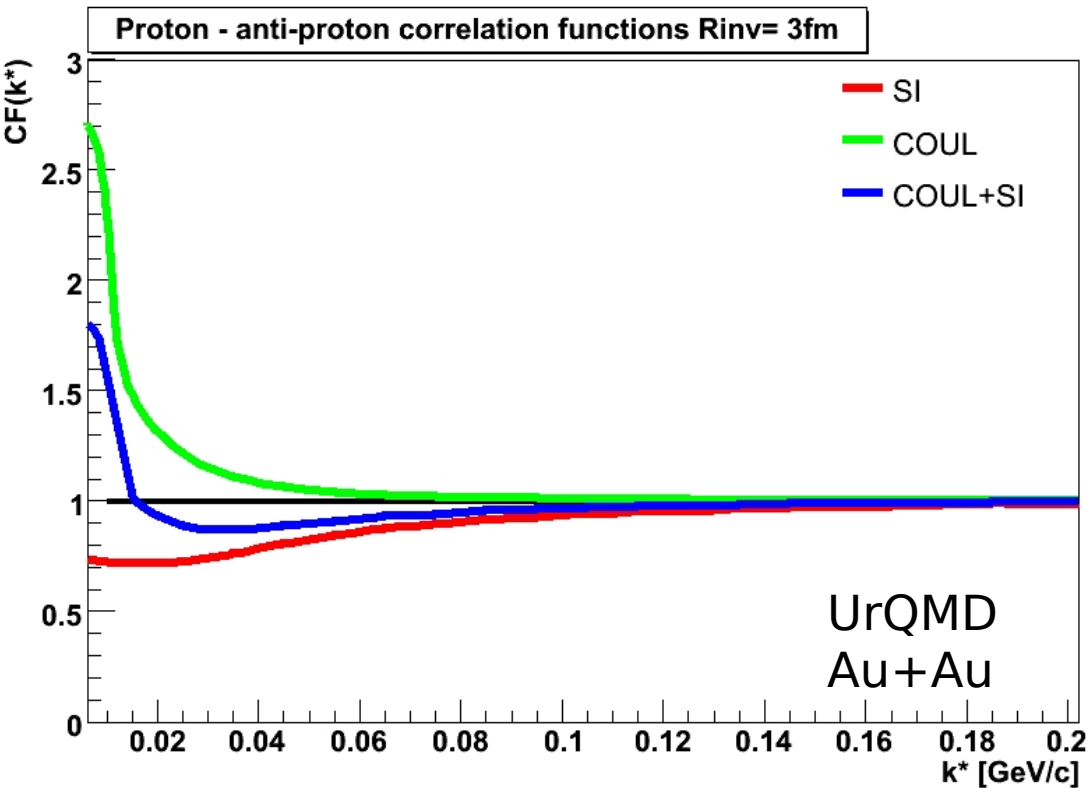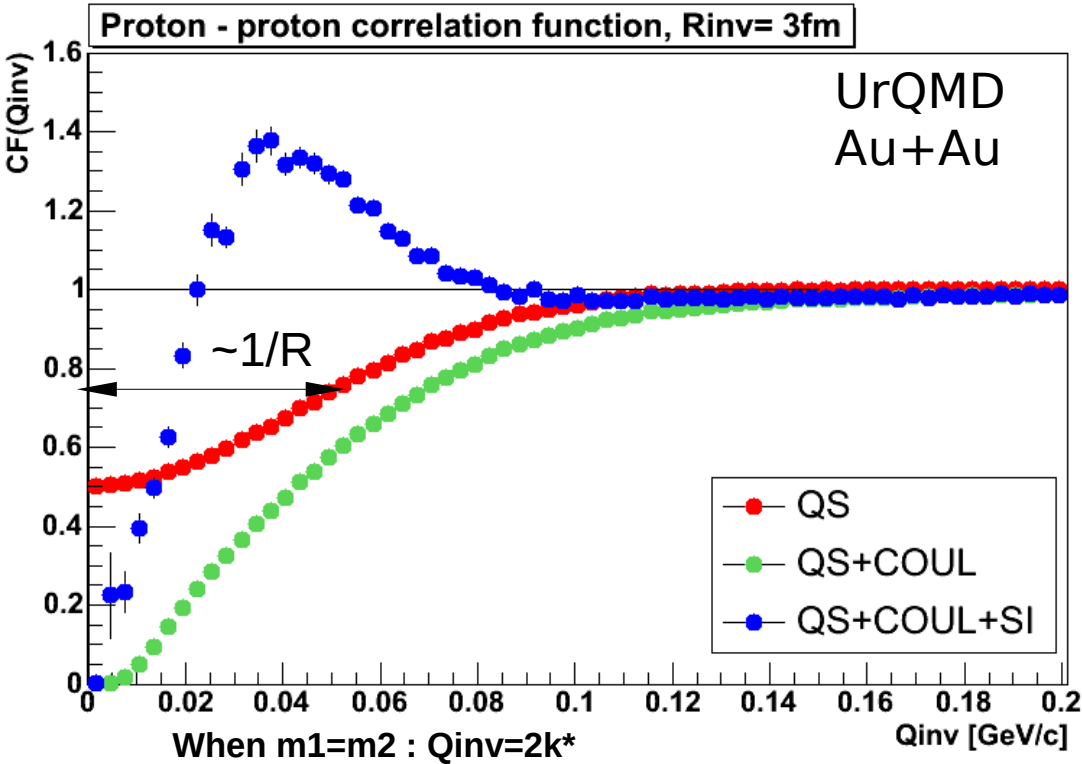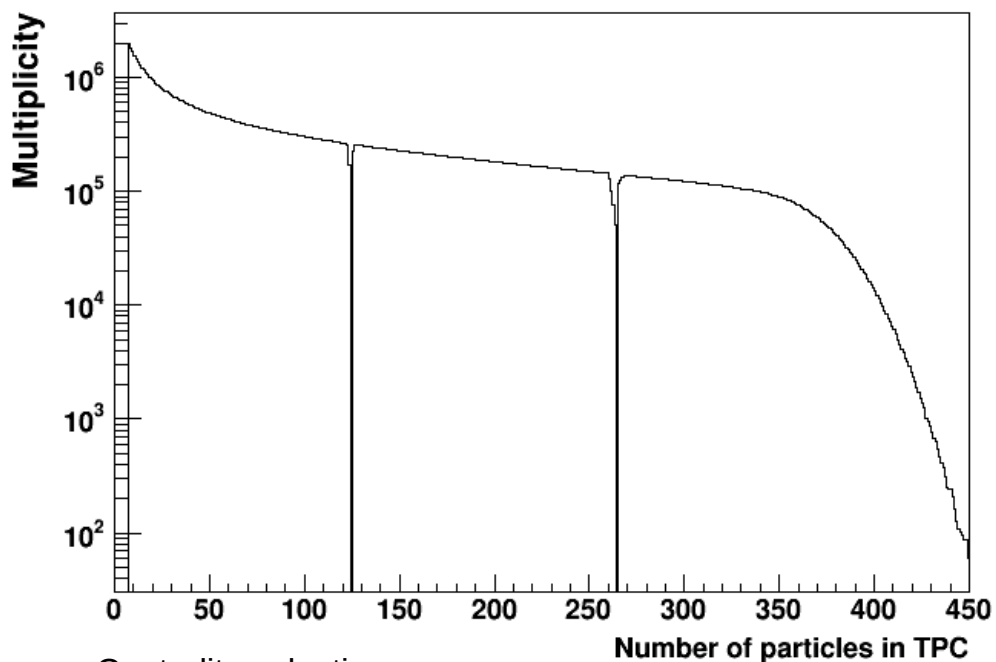
Cuts used

Cut	Range/value
Momentum (p)	$0.4 < p < 3.0$ [GeV/c]
Transverse momentum (p_T)	$0.4 < p_T < 2.5$ [GeV/c]
Pseudorapidity (η)	$-0.5 < \eta < 0.5$
Distance of closest approach (DCA)	DCA < 1 [cm]
Mass window	$0.76 < m < 1.03$ [GeV/c^2]
N σ	$-3.0 < N < 3.0$
Z vertex: - 7.7 GeV - 11.5 GeV - 39 GeV	[cm] $-70 < z < 70$ $-50 < z < 50$ $-30 < z < 30$

+ proper event selection

Analysis Au+Au collisions @ 39 GeV

Multiplicity monitor

Centrality selection
based on MC
Glauber calculation

Total: 101 M events

63 M events – centrality 30-80%

26 M events – centrality 10-30%

13 M events – centrality   0-10%
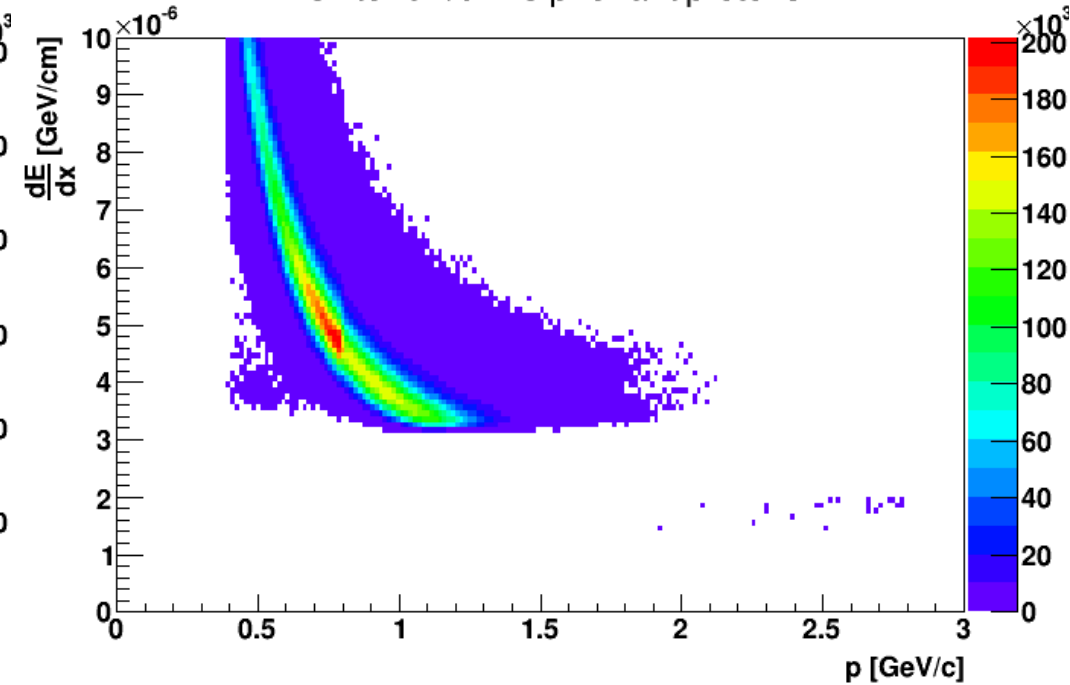
Z vertex monitor
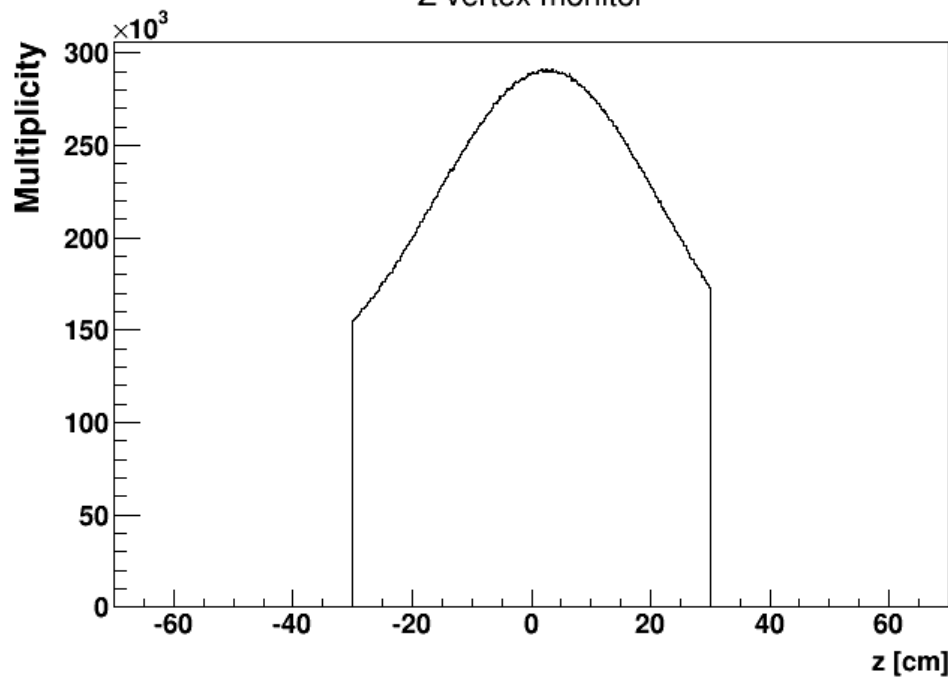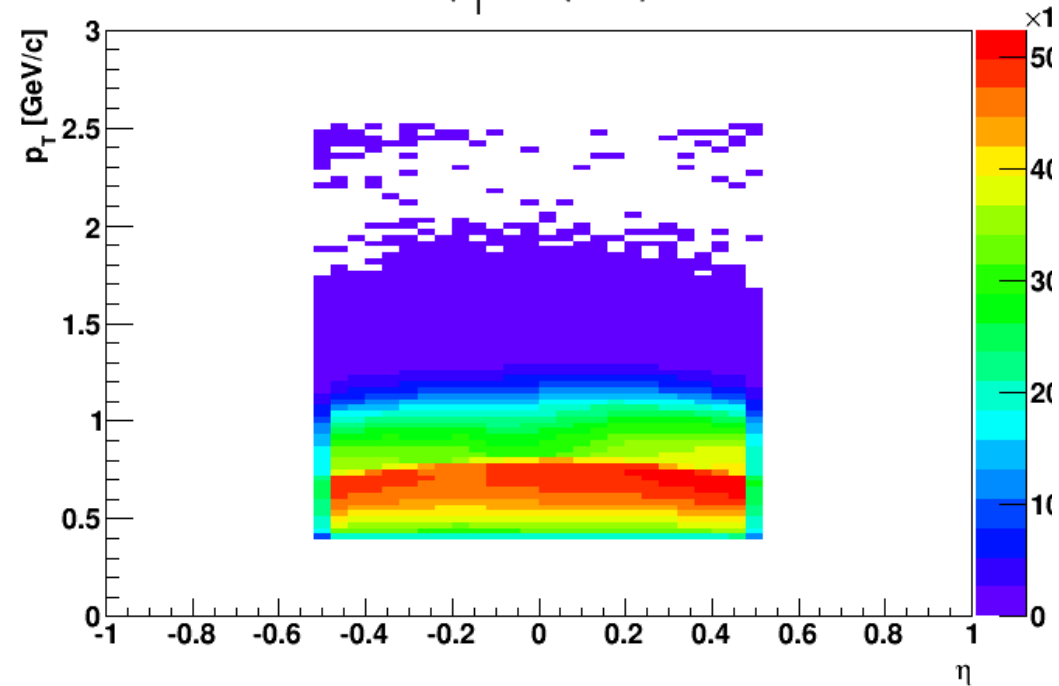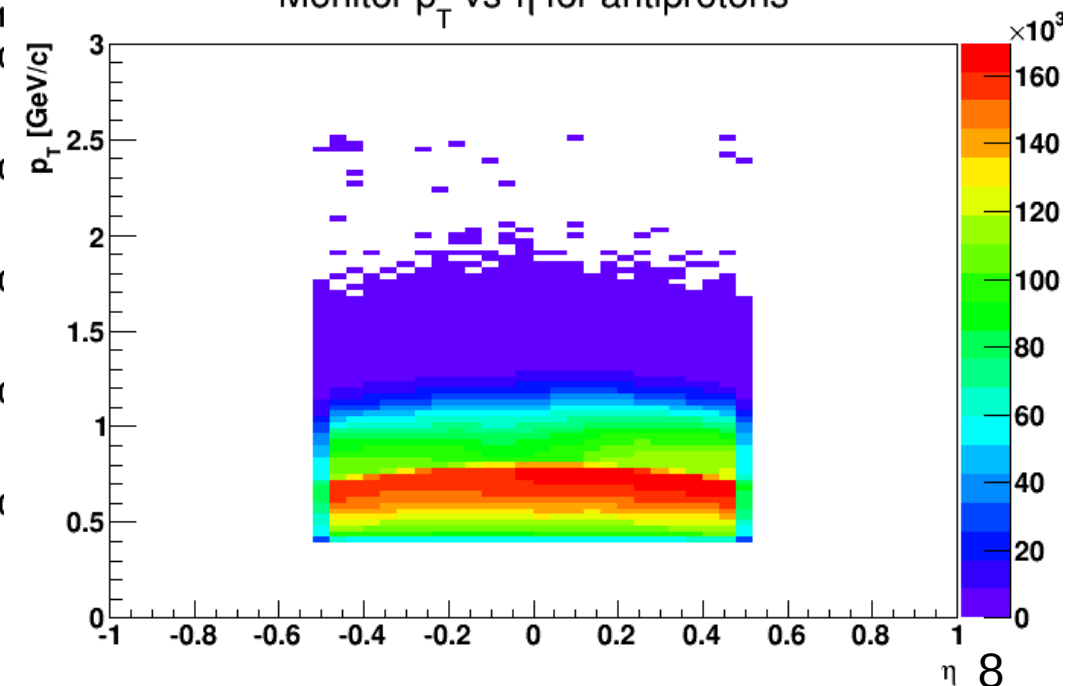
Analysis Au+Au collisions @ 39 GeV

Monitor dE/dx vs p for protons
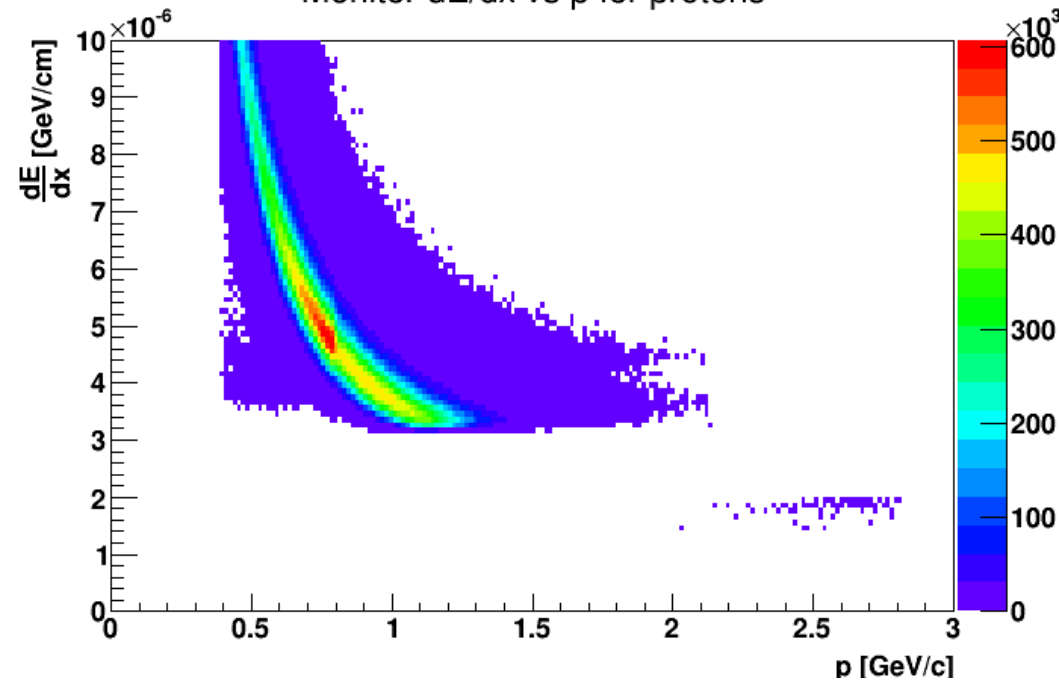
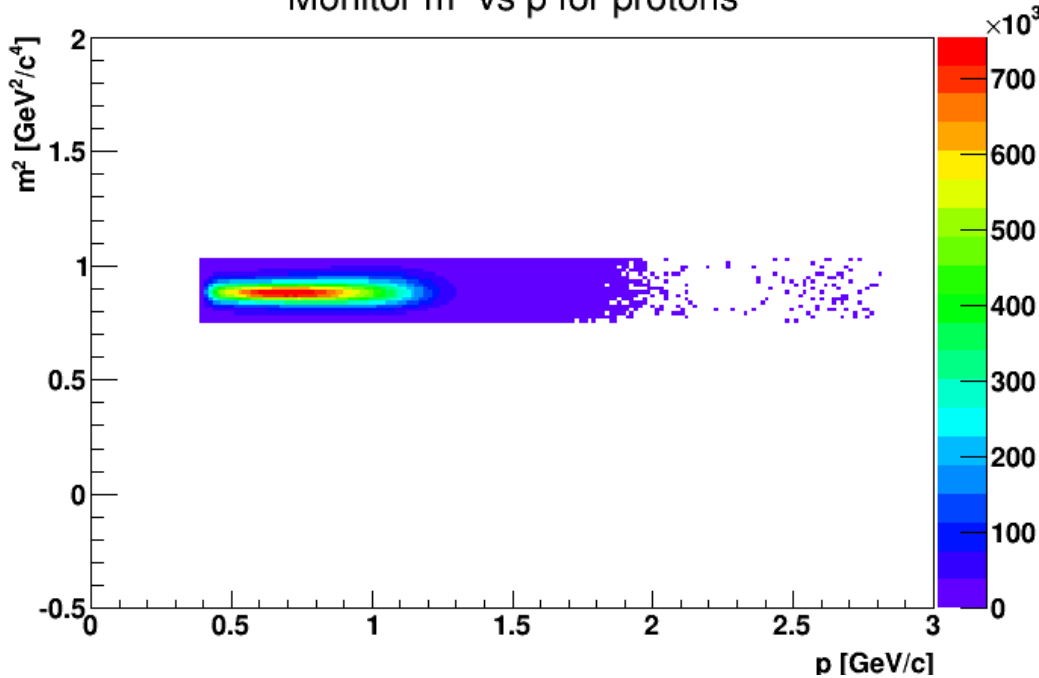Monitor dE/dx vs p for antiprotons

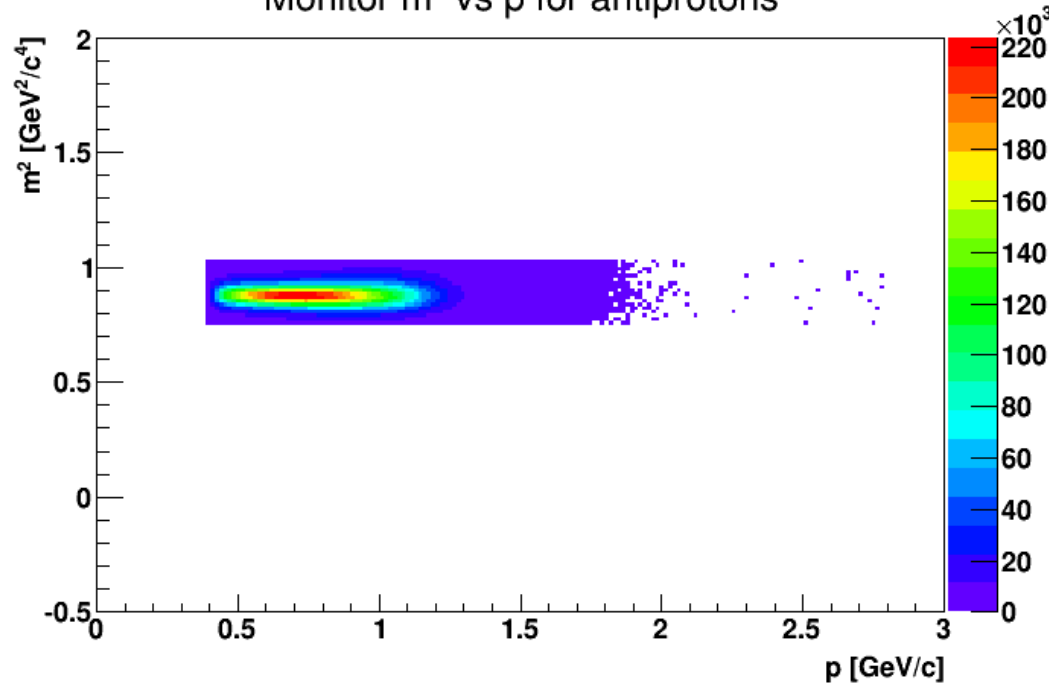Monitor p_T vs η for protons

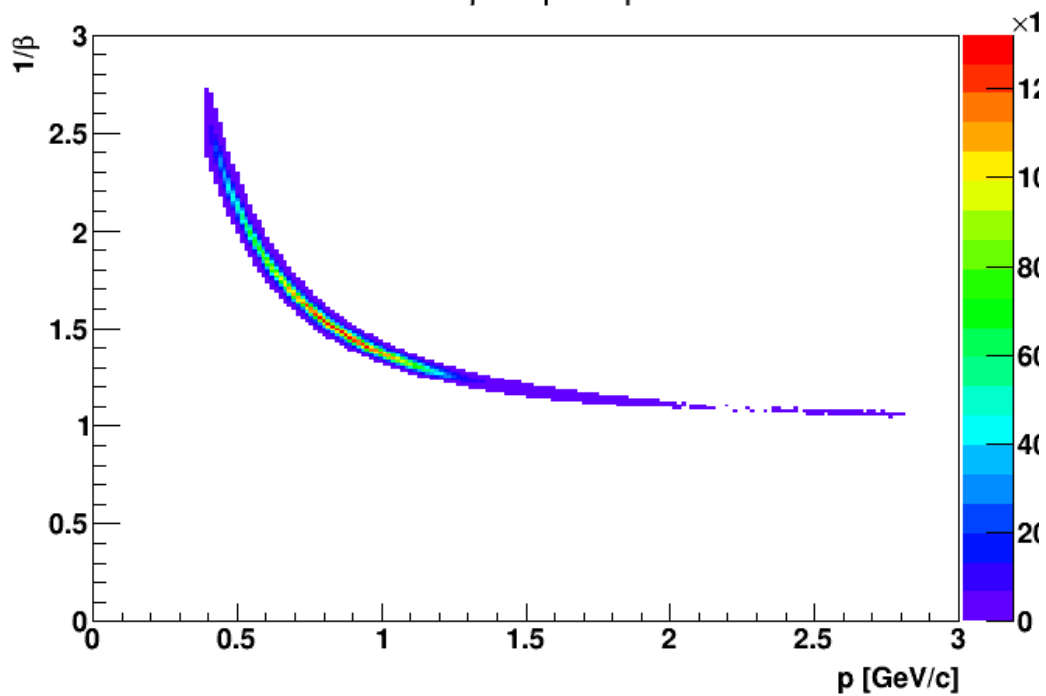Monitor p_T vs η for antiprotons

Analysis Au+Au collisions @ 39 GeV

Monitor m^2 vs p for protons
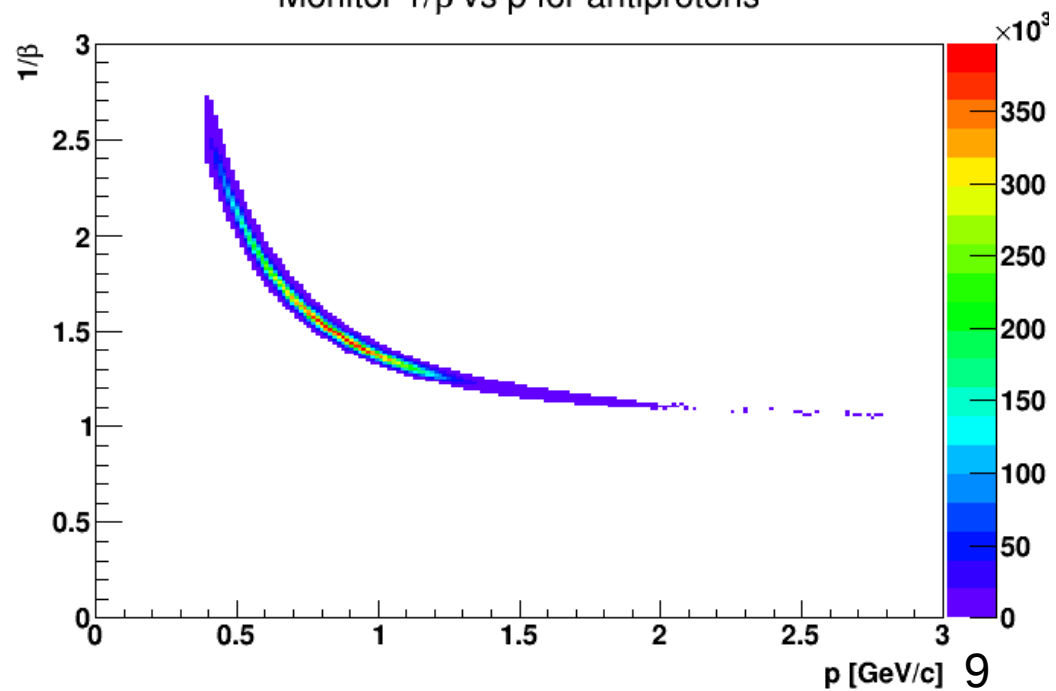
Monitor m^2 vs p for antiprotons

Monitor $1/\beta$ vs p for protons
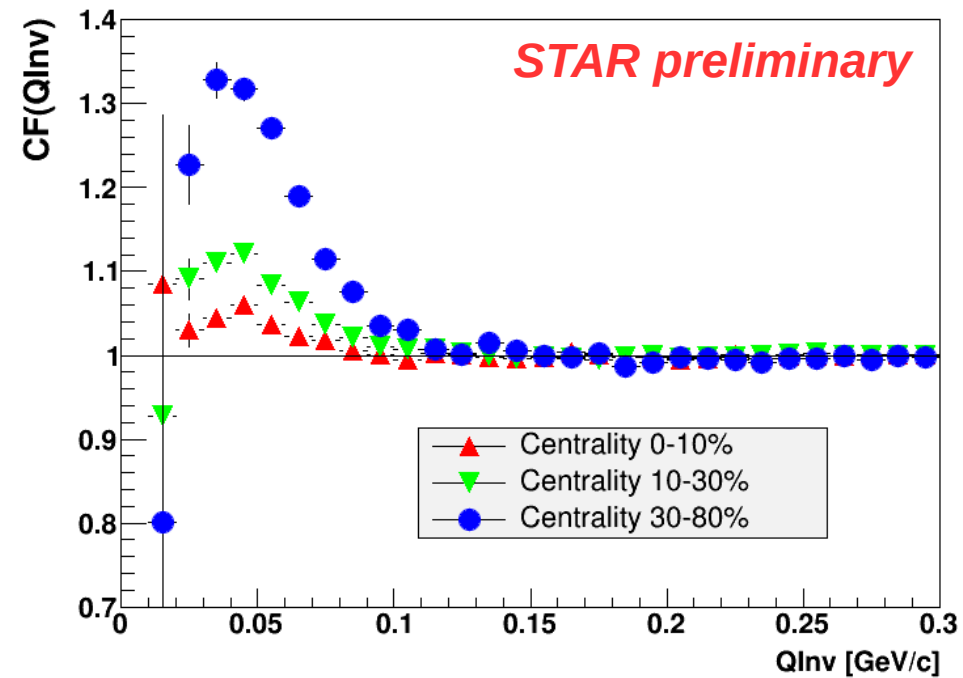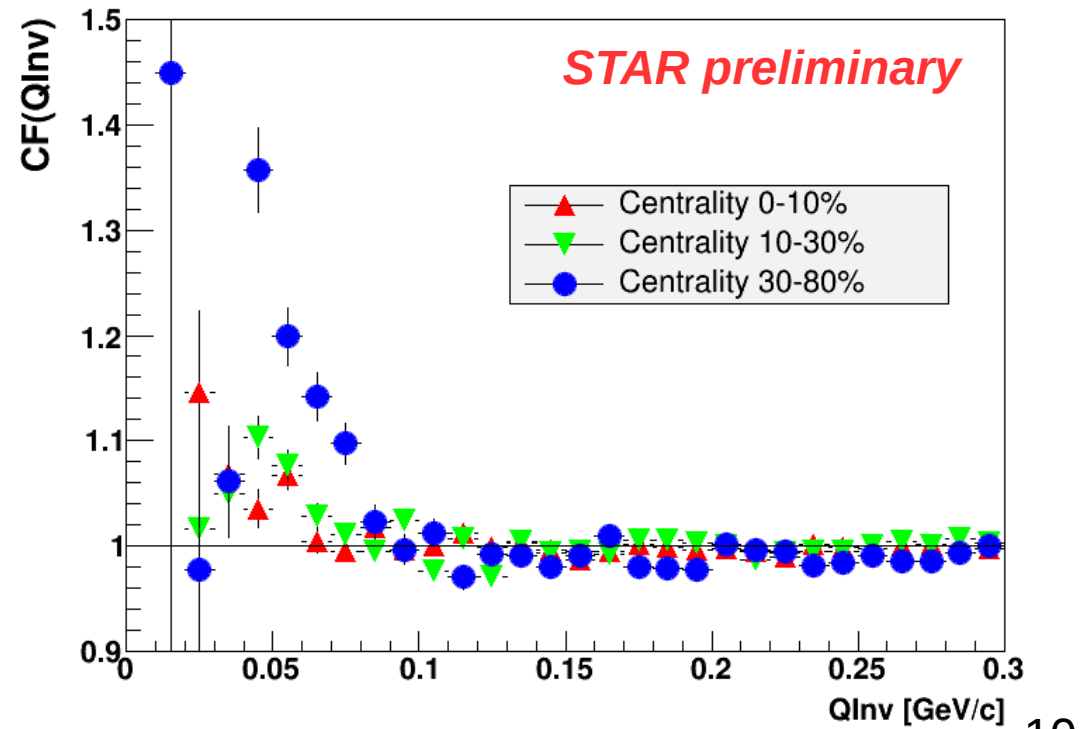
Monitor $1/\beta$ vs p for antiprotons

Analysis Au+Au collisions @ 39 GeV

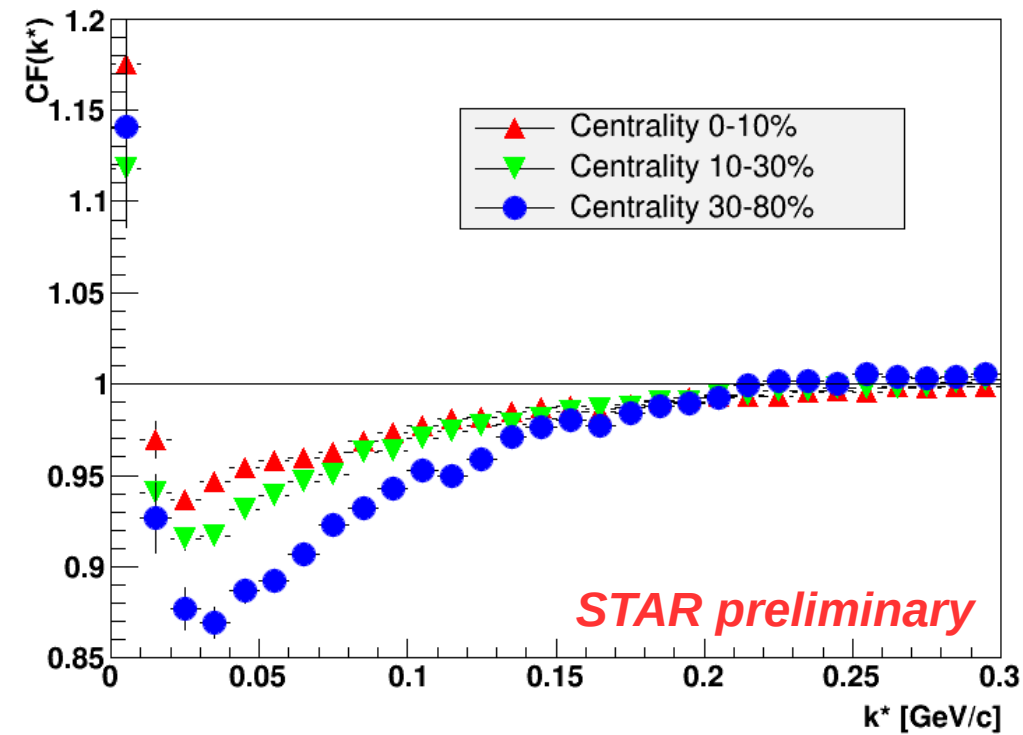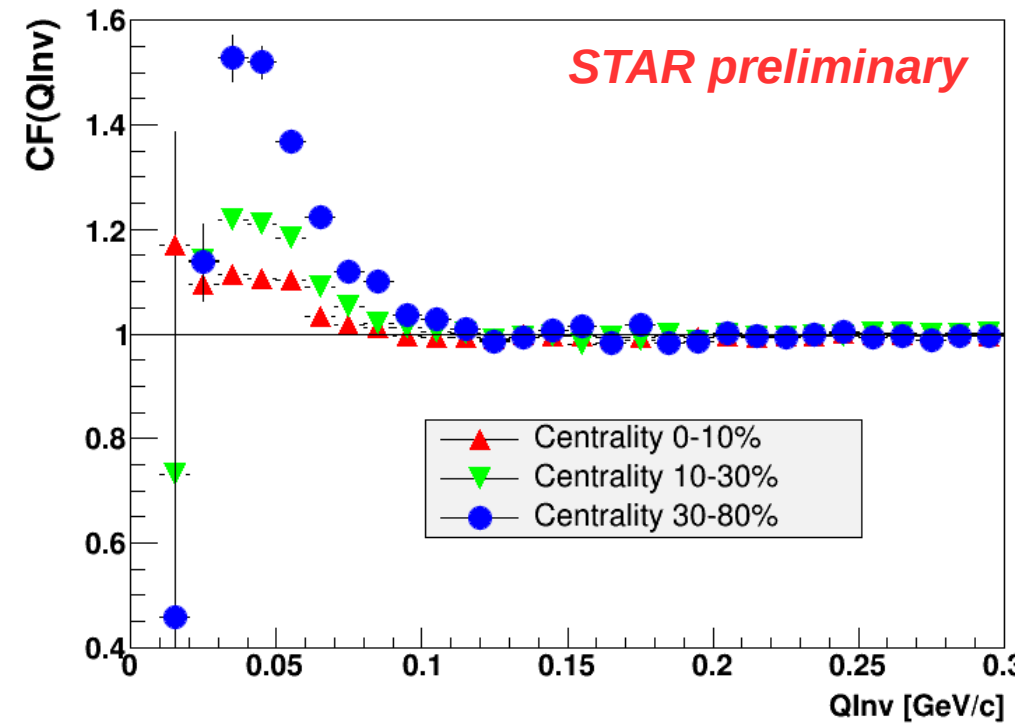Measured correlation functions are shown

Clear centrality dependence

Proton-Proton CFs

STAR preliminary

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

Proton-Antiproton CFs

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

STAR preliminary

Antiproton-Antiproton CFs

STAR preliminary

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

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Analysis Au+Au collisions @ 11.5 GeV

Proton-Proton CFs

STAR preliminary

Measured correlation functions are shown

Clear centrality dependence

Proton-Antiproton CFs

STAR preliminary

Antiproton-Antiproton CFs

not available due to low statistics

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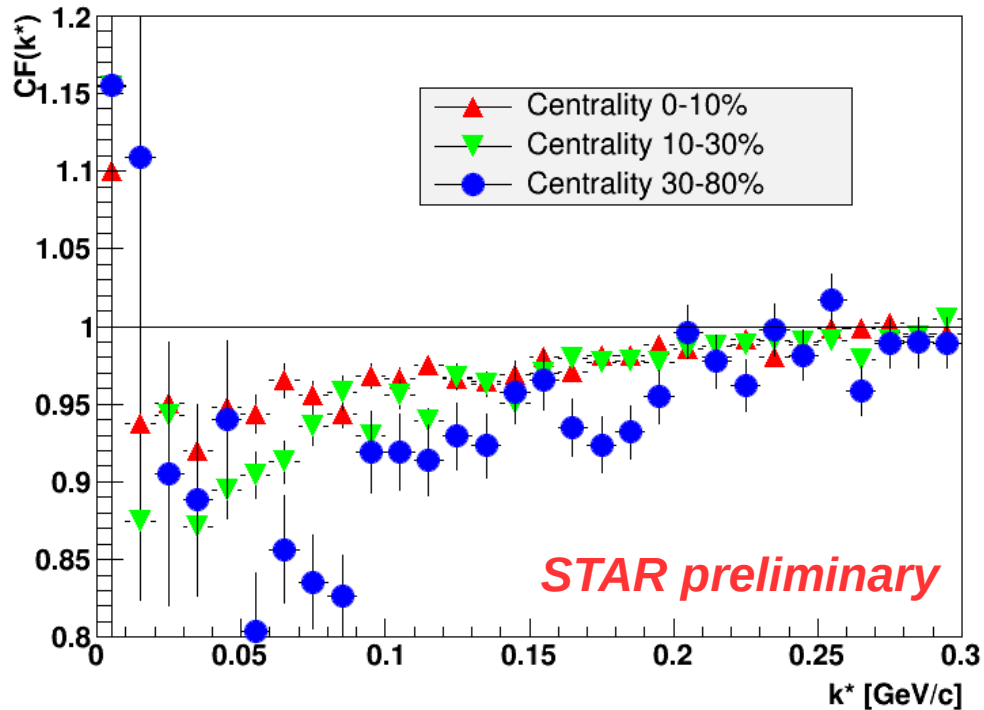
Analysis Au+Au collisions @ 7.7 GeV

Proton-Proton CFs

Measured correlation functions are shown

Clear centrality dependence

STAR preliminary

Centrality 0-10%
Centrality 10-30%
Centrality 30-80%
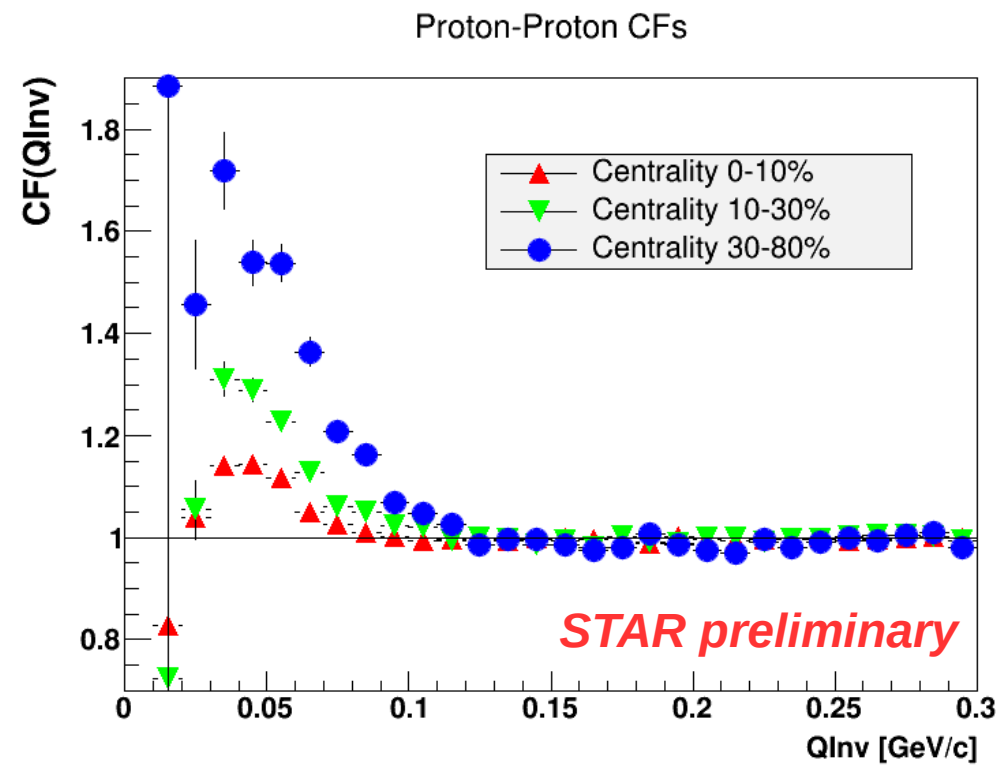
Proton-Antiproton CFs

not available due to low statistics

Antiproton-Antiproton CFs

not available due to low statistics

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Analysis Au+Au collisions MB comparison

Antiproton-Antiproton pairs have been added to Proton-Proton pairs in order to have Identical Baryon CFs with increased statistics

Measured correlation functions are shown

Clear energy dependence

Identical Baryon CFs

7 GeV
11 GeV
39 GeV

STAR preliminary

Proton-Antiproton CFs

11 GeV
39 GeV

STAR preliminary

Plots are Minimum Bias
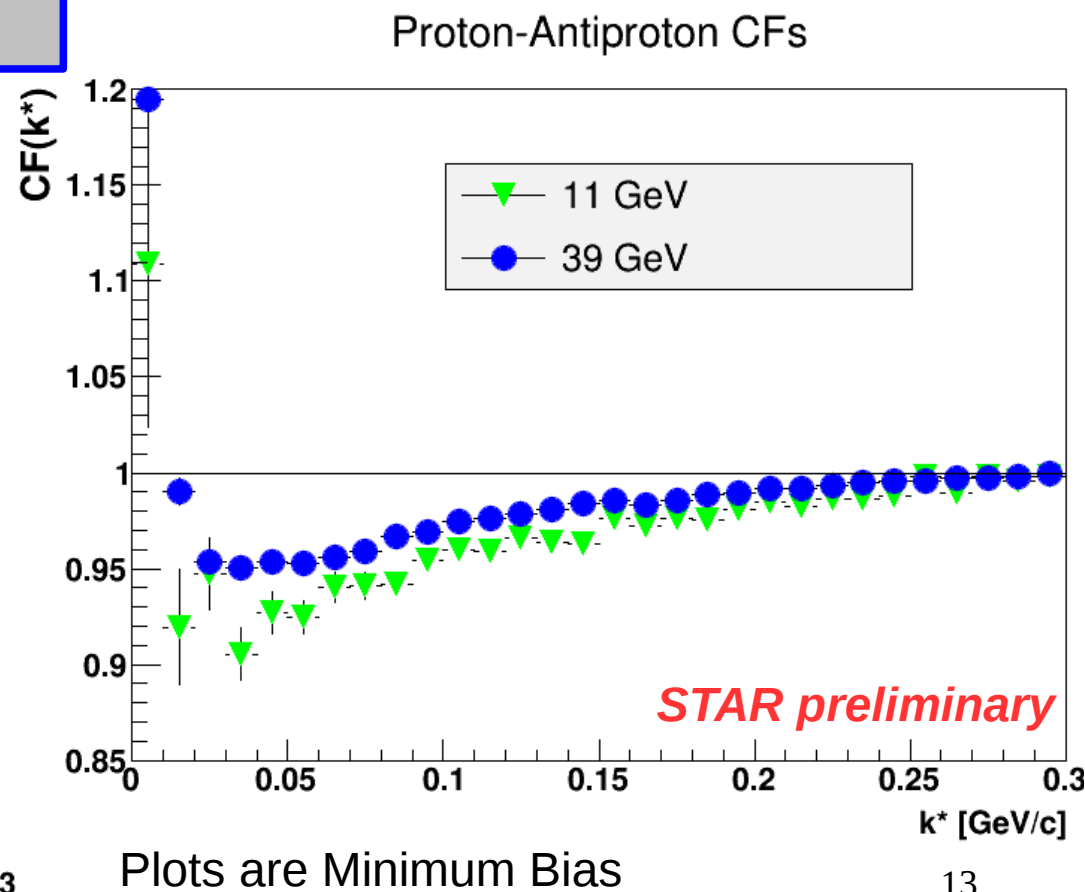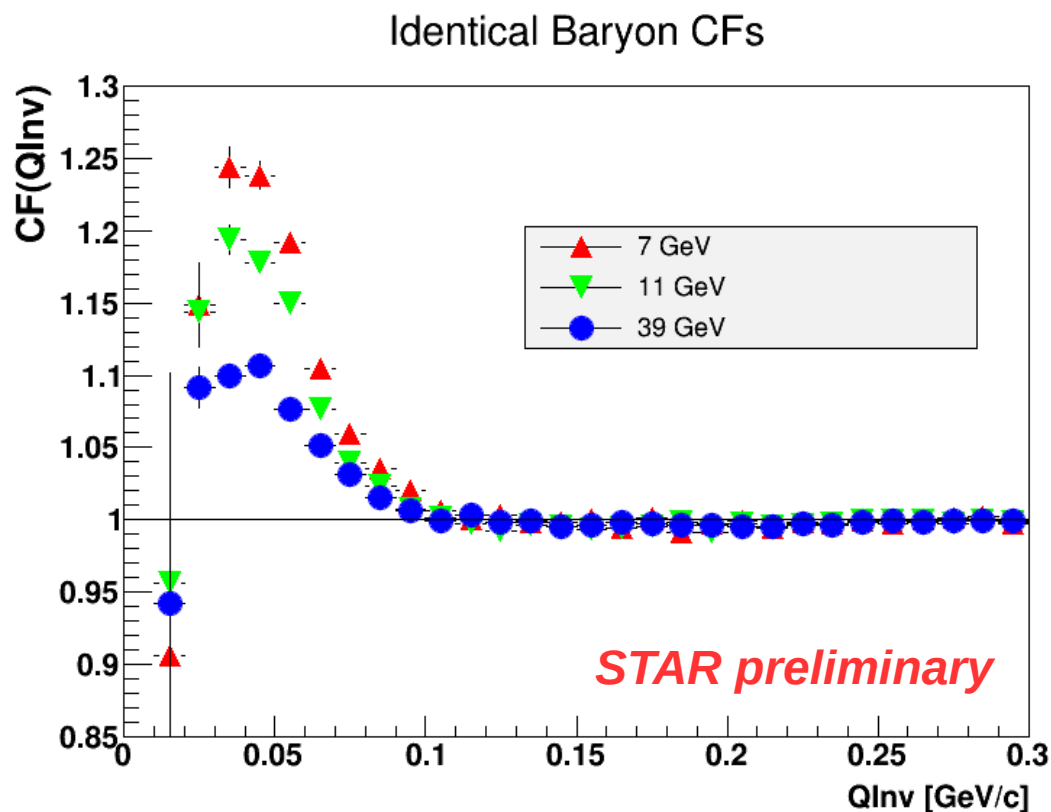
Summary & Conclusions

- (anti)proton femtoscopy sensitive to Quantum Statistic Effects and

    Final State Interactions

- Different strong interaction due to annihilation processes

- **Data analysed: 7.7 GeV, 11.5 GeV, 39 GeV**

- proton - proton, antiproton - antiproton and proton - antiproton systems checked

    → The range of correlations different for identical and nonidentical

        particle combinations

- The results allow for qualitative source sizes observation:

Radii increase with $\sqrt{(s_{NN})}$ at fixed centrality

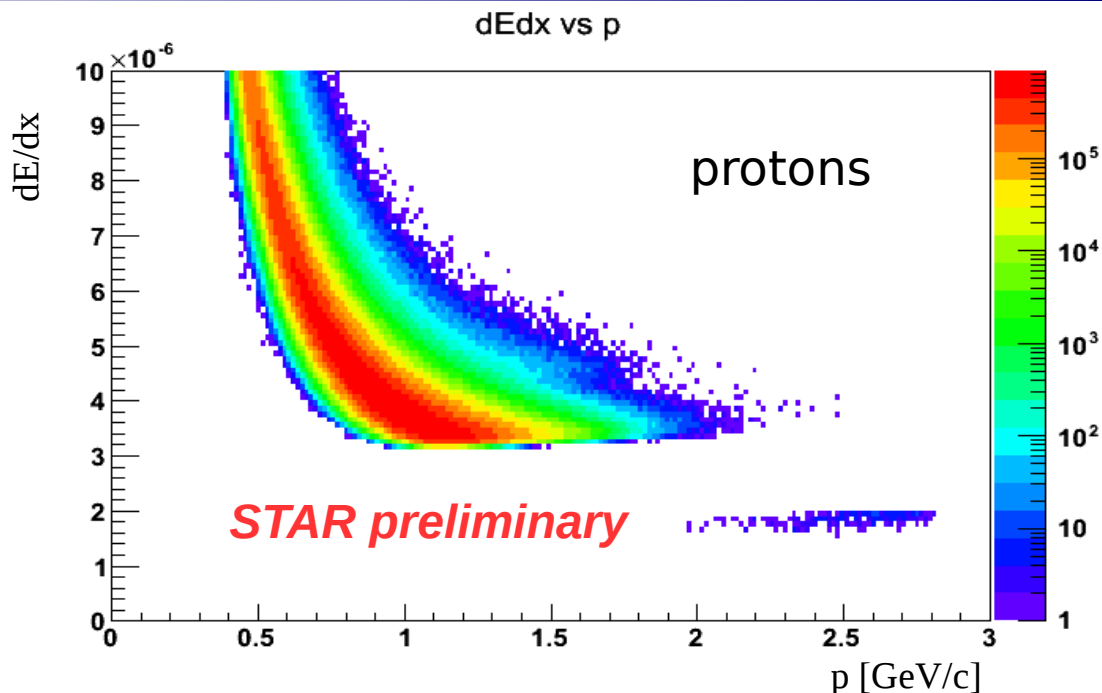$$R_{p-p}(39\,GeV) > R_{p-p}(11.5\,GeV) > R_{p-p}(7.7\,GeV)$$

Radii increase with centrality at fixed $\sqrt{(s_{NN})}$

$$R_{p-p}(0-10) > R_{p-p}(10-30) > R_{p-p}(30-80)$$

Thank You for Your attention!

BACKUP

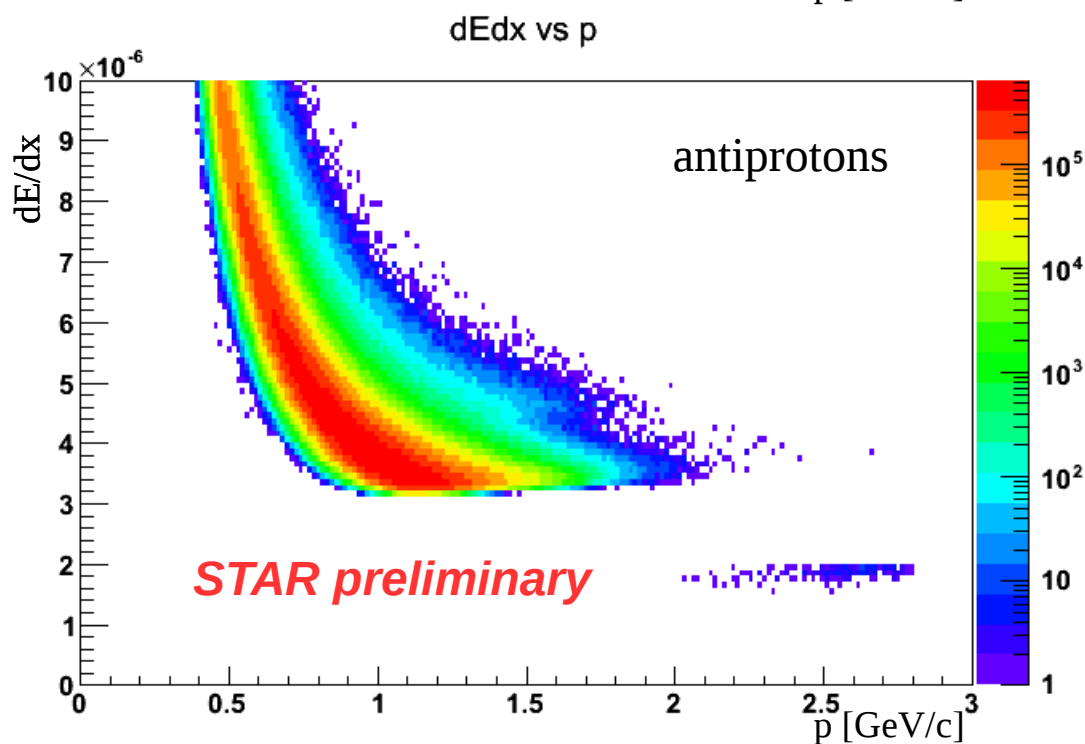# Analysis Au+Au collisions @ 200 GeV

dEdx vs p — protons

STAR preliminary

dEdx vs p — antiprotons

STAR preliminary

Total: 210 mln events
126 mln events - centrality 30 – 80%
  57 mln events – centrality 10- 30%
  27 mln events – centrality   0 -10%

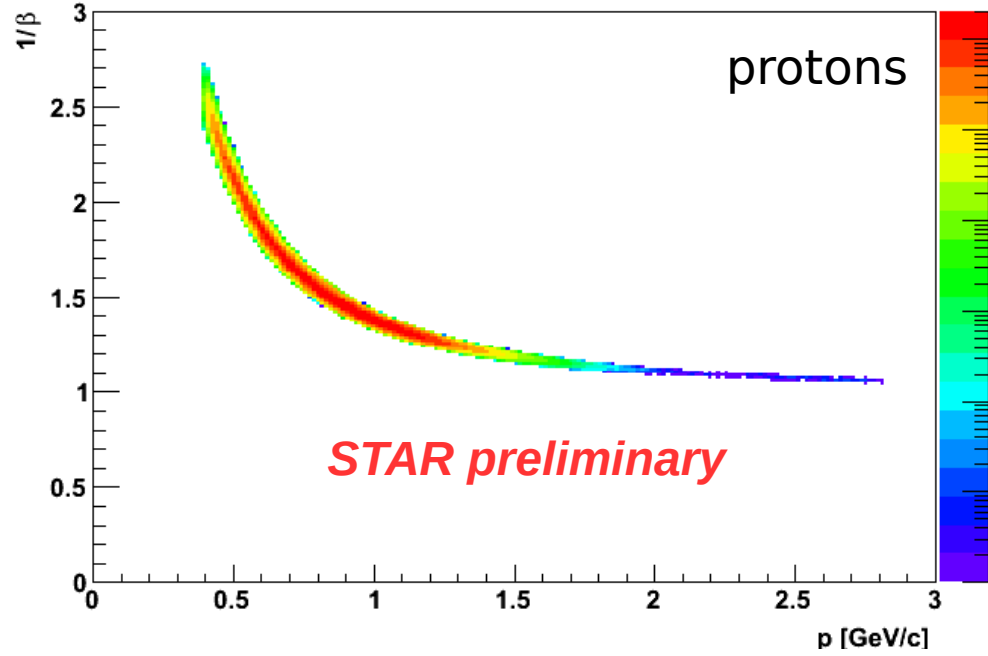$p \in [0.4, 3.0]$ GeV/c
$pT \in [0.4, 2.5]$ GeV/c
$|\eta| < 0.5$
Nhits $\in [15, 50]$
DCA <1cm
Nσ p < 3.0
Nσ π, K > 3.0
$m^2 \in [0.76, 1.03]$

For each particle TPC & TOF signal is required.
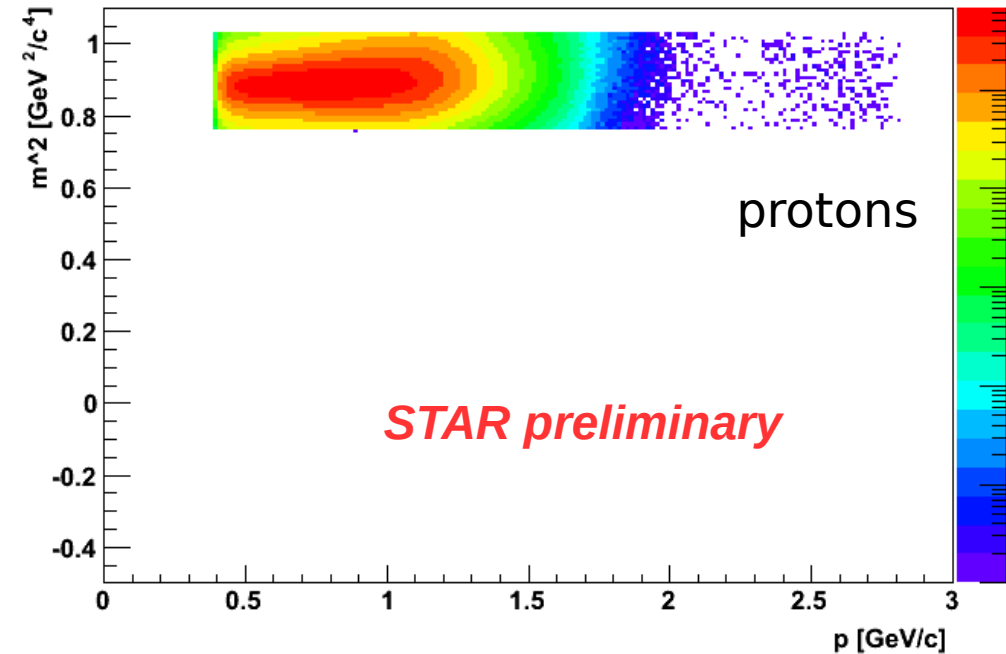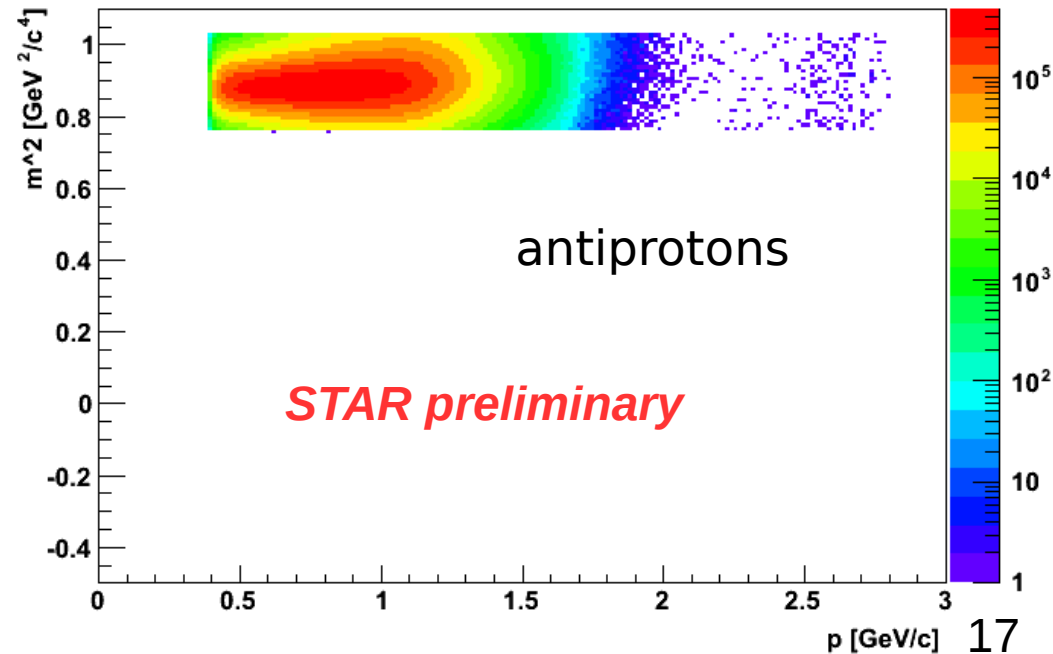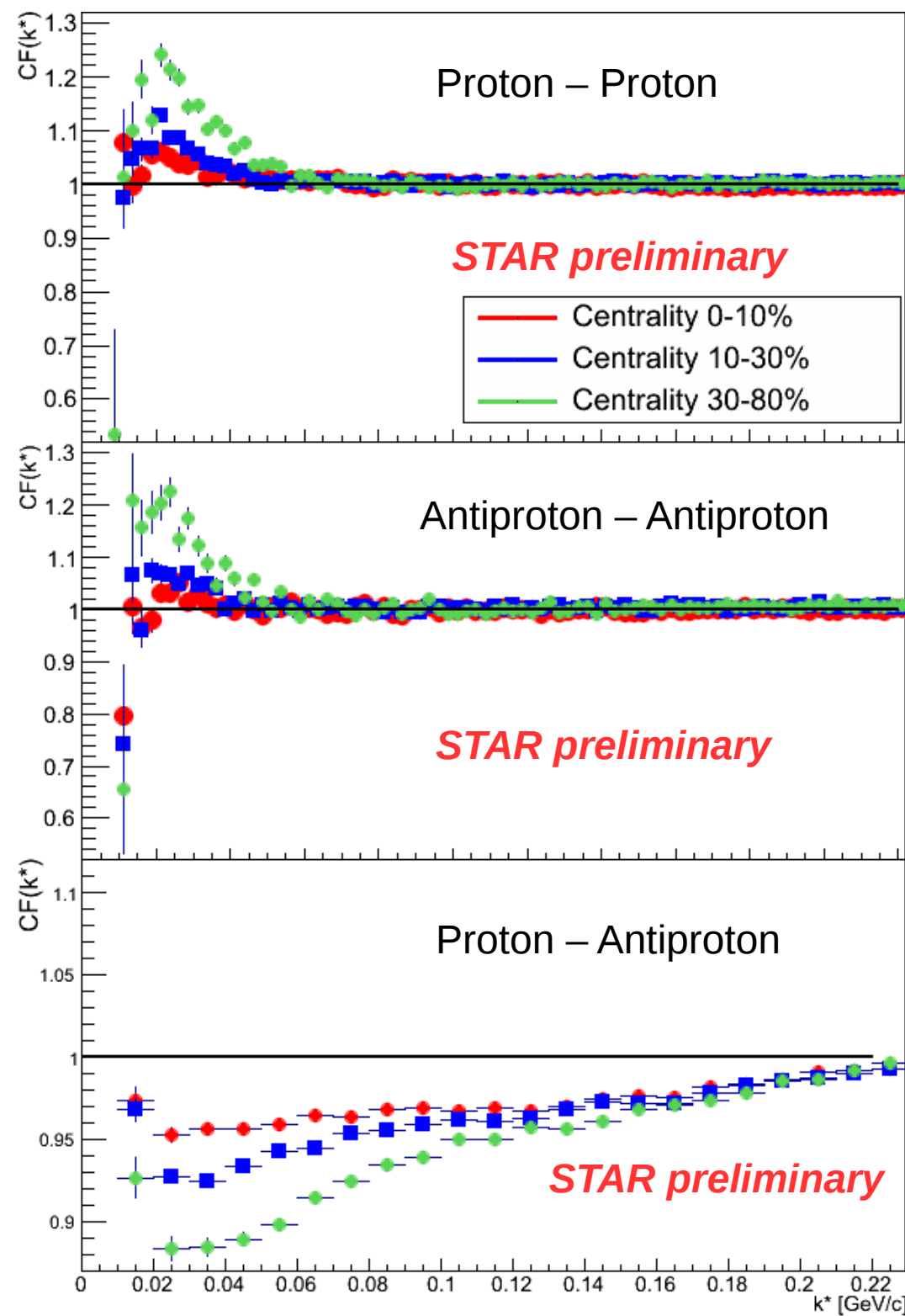
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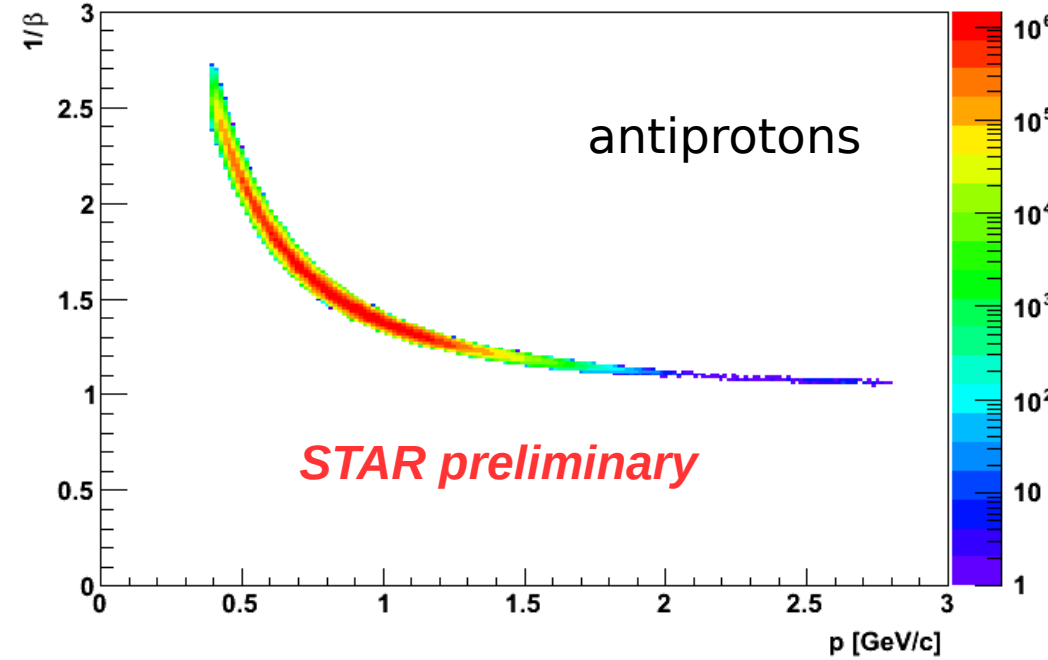
Analysis Au+Au collisions @ 200 GeV

Analysis Au+Au collisions @ 200 GeV

Measured correlation functions are shown

Clear centrality dependence