WARSAW UNIVERSITY OF TECHNOLOGY

Proton-proton, proton-antiproton and antiproton-antiproton correlations

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For the STAR collaboration

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Netherlands
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Outline and motivation

1) Motivation and basics of proton femtoscopy

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

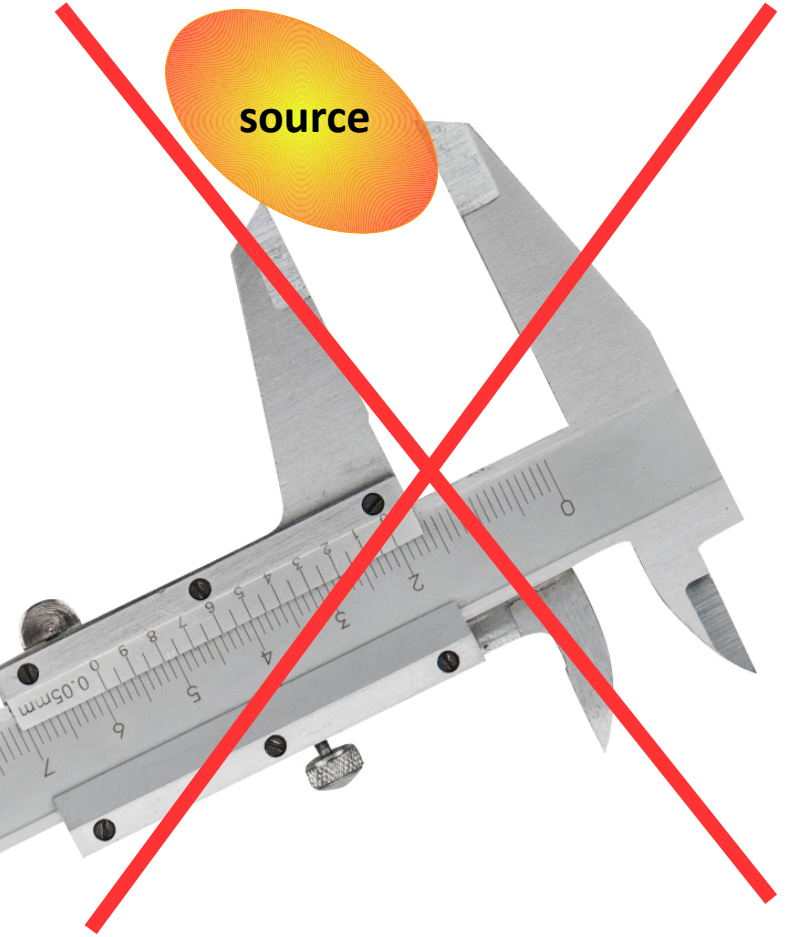
3) Results from Beam Energy Scan:

Au+Au collisions at $\sqrt{s_{NN}}$ = 39, 11.5 and 7.7 GeV

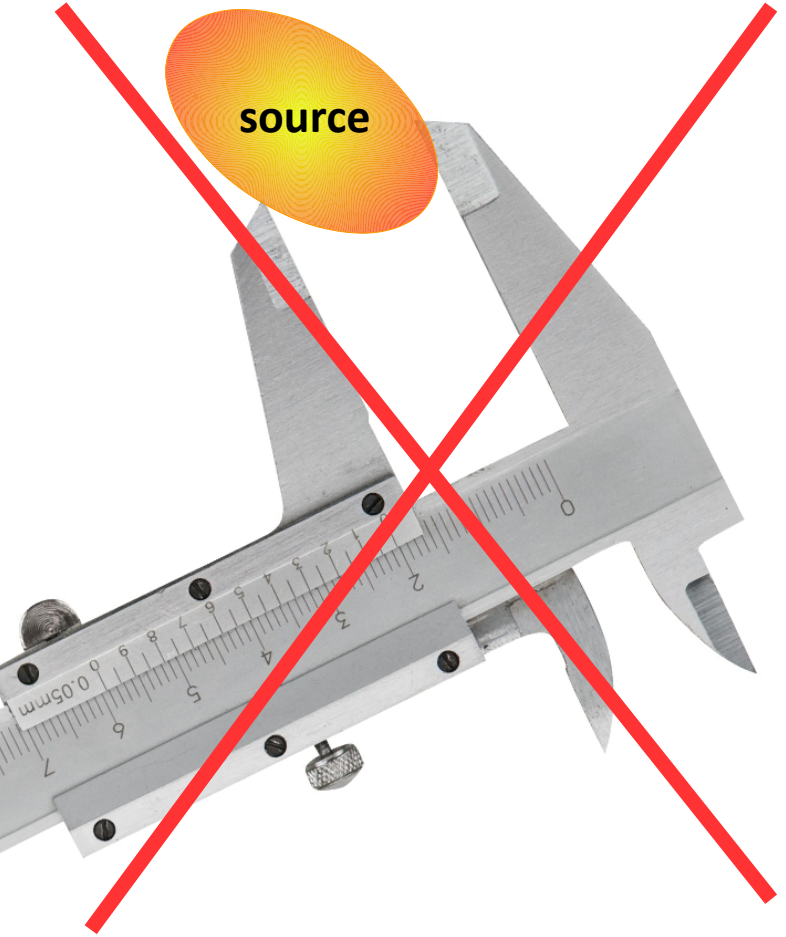
4) Summary and conclusions

if we extract the source radii from baryon-baryon correlations we will be able to compare those with the radii already obtained from meson-meson and meson-baryon correlations - such comparison will provide us with complementary information about the source characteristics

Few words about femtoscopy

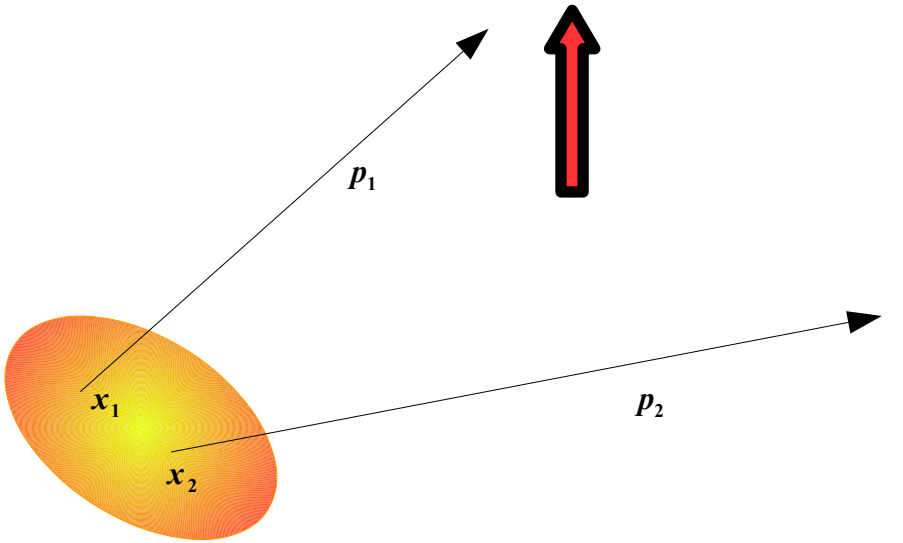


Few words about femtoscopy



The correlation function

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



Few words about femtoscopy

Two-particle distribution

$$P_2(p_1, p_2) = E_1 E_2 \frac{dN}{d^3 p_1 d^3 p_2} = \int d^4 x_1 S(x_1, p_1) d^4 x_2 S(x_2, p_2) \Phi(x_2, p_2 | x_1, p_1)$$

The correlation function

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

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

Single-particle distribution

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

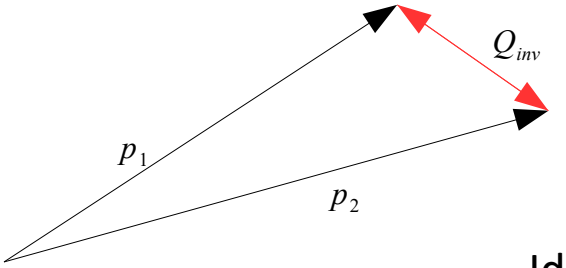
Few words about femtoscopy

The correlation function

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

Q_{inv}

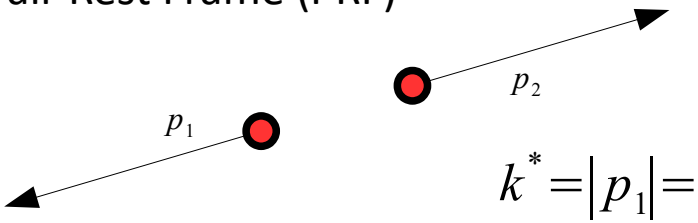
In Longitudinal Co-Moving System (LCMS)



Identical baryons

k^*

In Pair Rest Frame (PRF)



$k^* = |p_1| = |p_2|$

Nonidentical baryons

$Q_{inv} = 2k^*$

for $m_1 = m_2$

Proton correlations

Identical baryon-baryon

- Quantum Statistics (QS)
- Final State Interactions:
  - Coulomb Interaction (COUL)
  - Strong Interaction (SI)

Nonidentical baryon-antibaryon

- Final State Interactions:
  - Coulomb Interaction (COUL)
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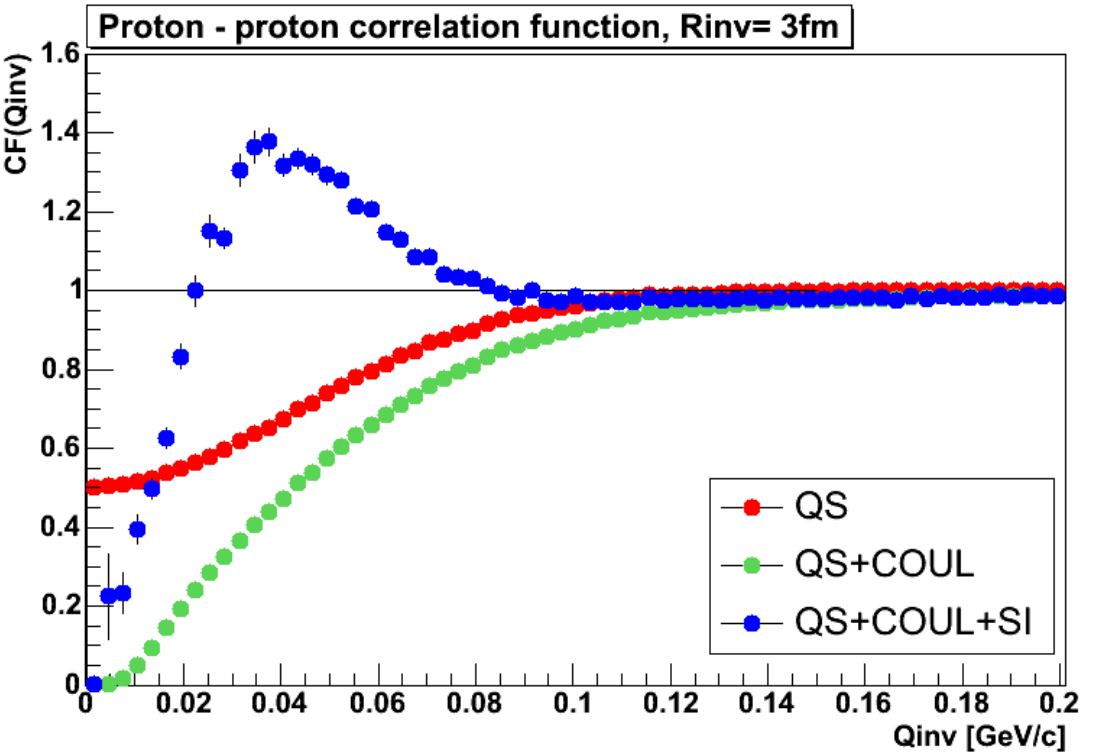

UrQMD Au+Au; $R_{inv} = 3\,\mathrm{fm}$

Relativistic Hadron-Hadron Collisions in the Ultra-Relativistic Quantum Molecular Dynamics Model
J. Phys. G: Nucl. Part. Phys. 25 (1999) 1859-1896

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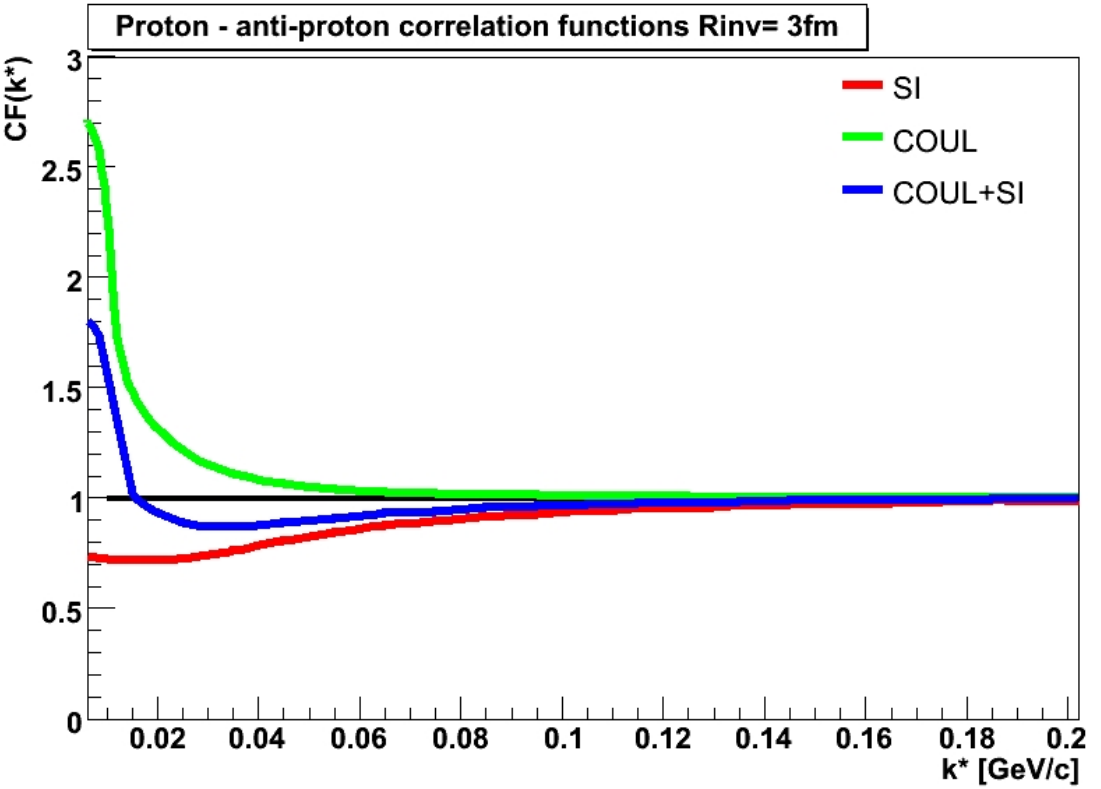

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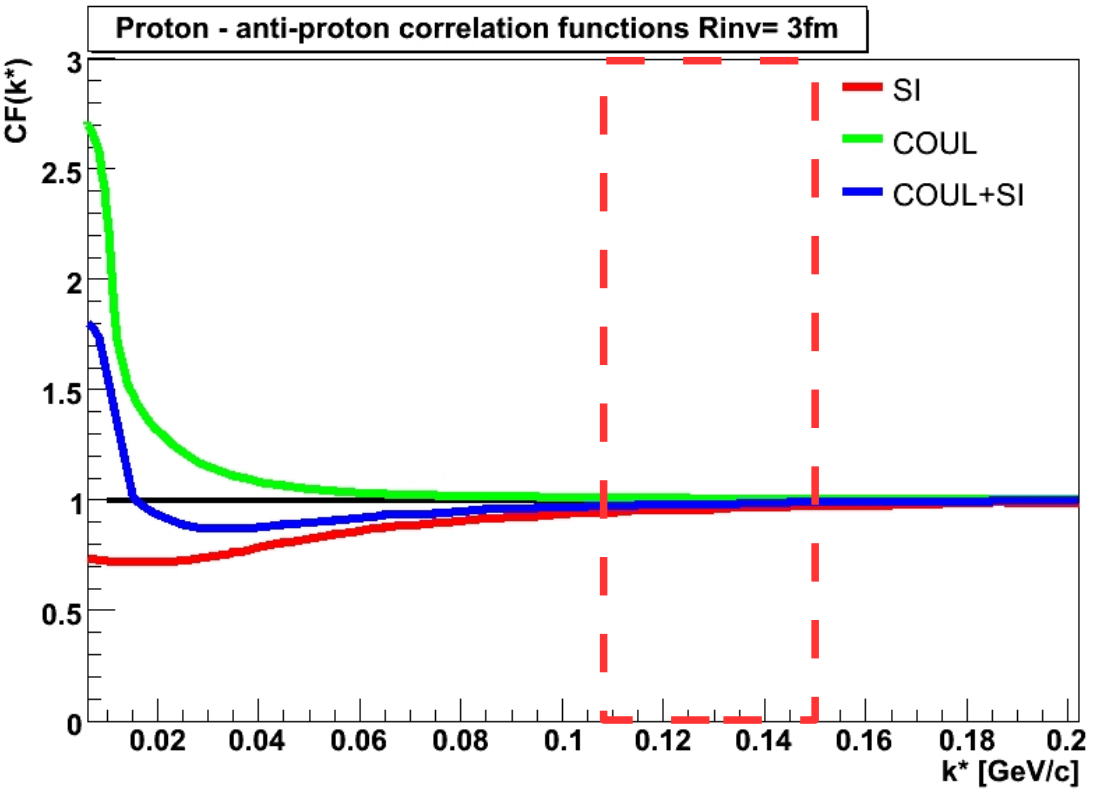
$k^* \approx 130\,\mathrm{MeV}/c$



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Nonidentical baryon-antibaryon

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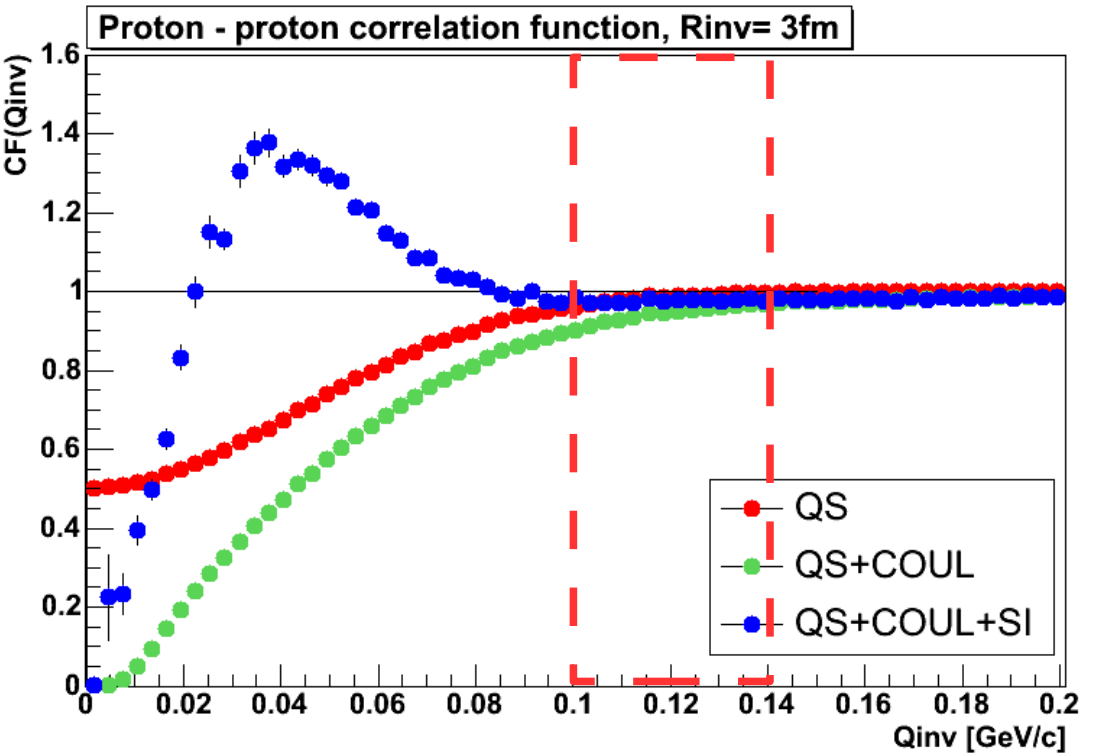
  - Strong Interaction (SI)

$k^* \approx 60\,\mathrm{MeV}/c$



UrQMD Au+Au; $R_{inv} = 3\,\mathrm{fm}$

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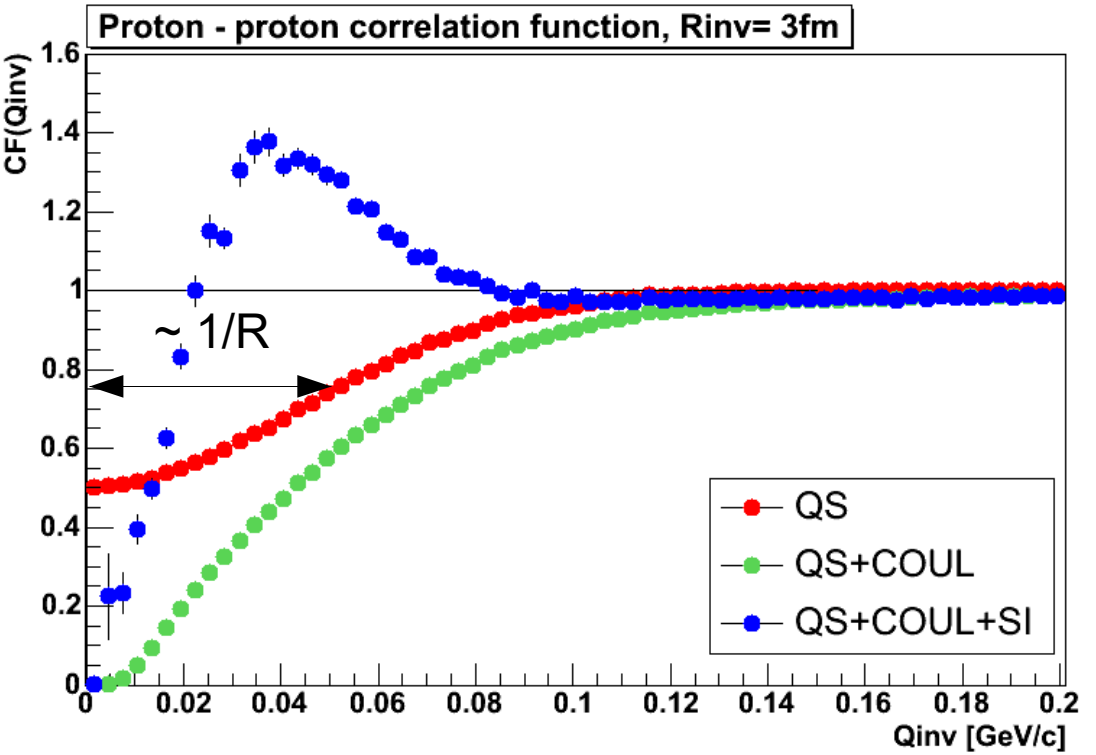
Proton correlations

Why 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.

The radii can be qualitatively compared using the height and the width of the pike in identical baryon-baryon correlation functions.



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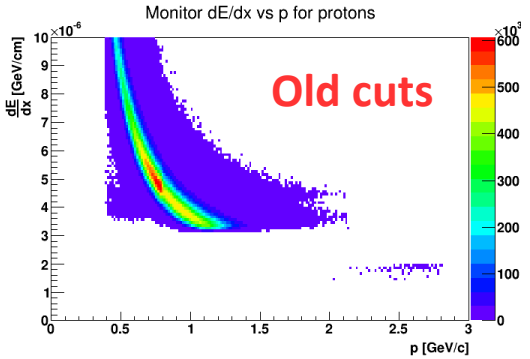
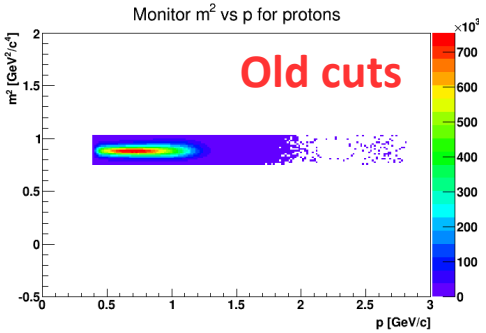
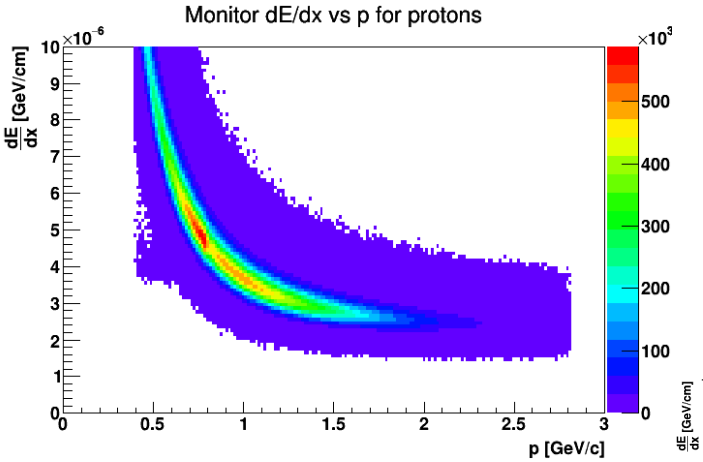
Data selection

Example plots showing data that passed selection criteria for Au+Au collisions at $\sqrt{s_{NN}}$ = 39 GeV

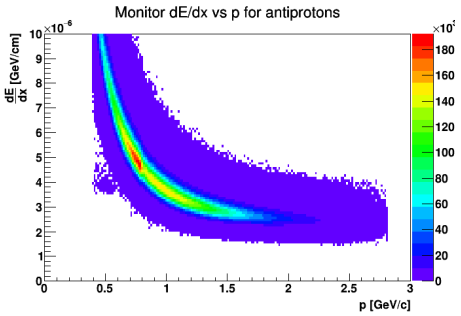


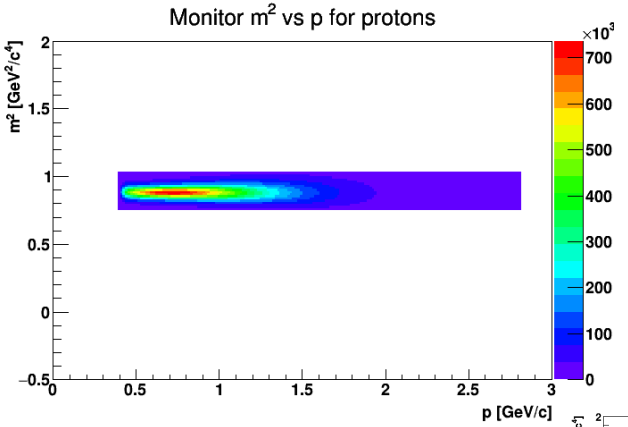


Cut	Range/value
Momentum (p)	0.4 < p < 3.0 [GeV/c]
Mass window	0.76 < m < 1.03 [GeV/c^2]
N σ	-3.0 < N < 3.0
Z vertex: - 7.7 GeV - 11.5 GeV - 39 GeV	[cm] -70 < z < 70 -50 < z < 50 -30 < z < 30

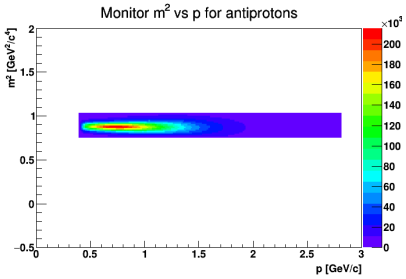


below p=0.8 GeV/c information from TPC is sufficient for particle identification





above p=0.8 GeV/c we need combined information from TPC and ToF in order to properly identify particles

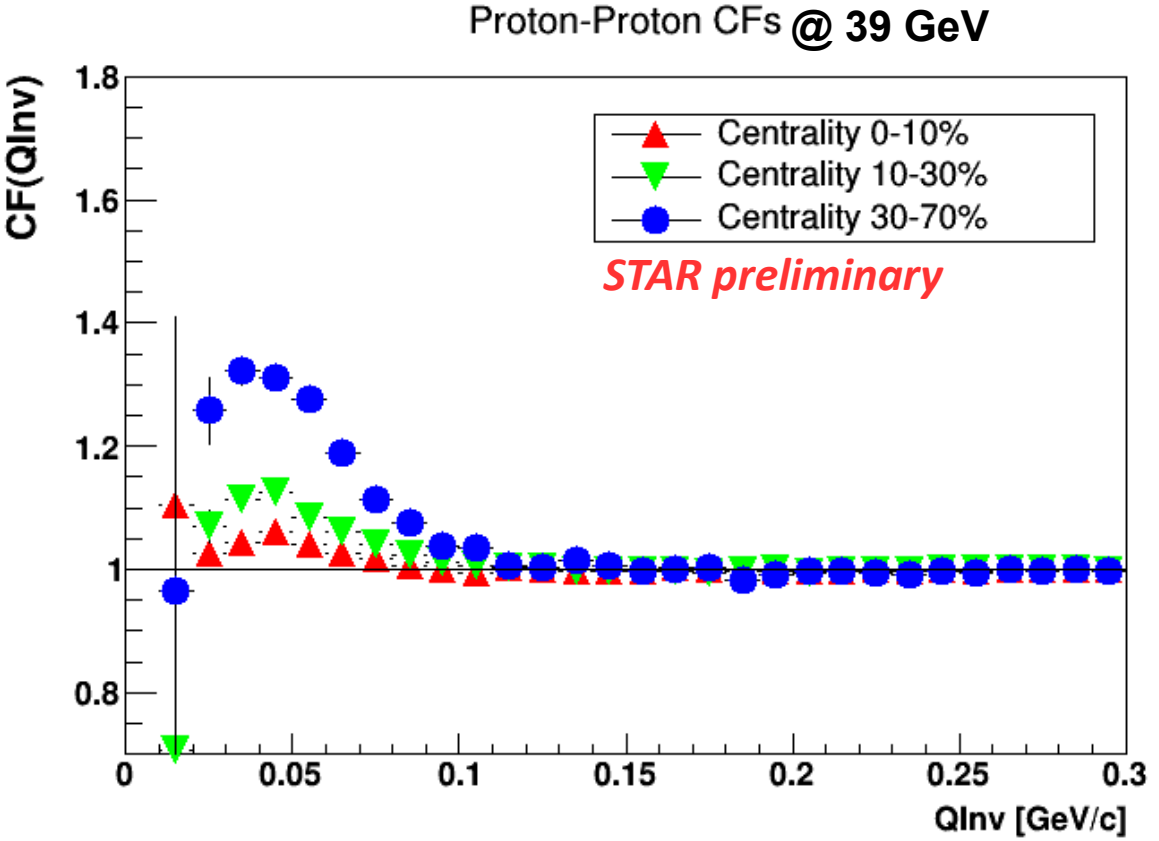


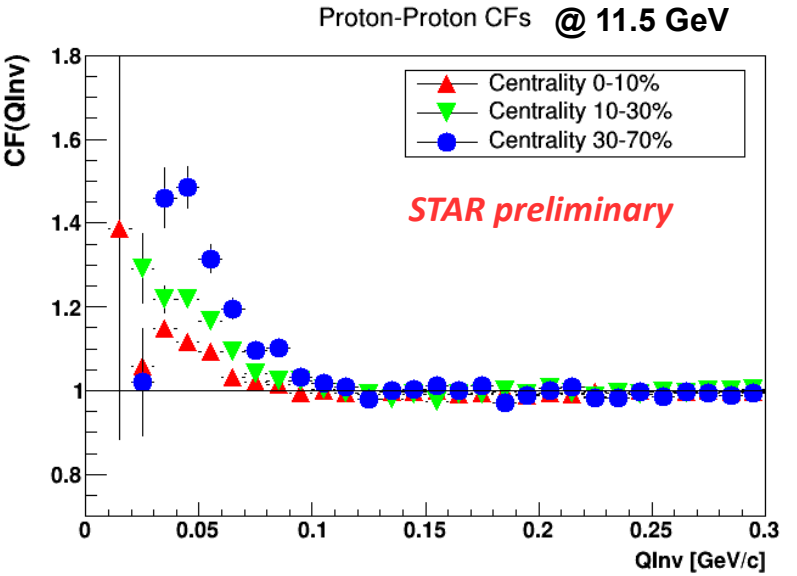
Analysis Au+Au collisions @ 39 GeV, 11.5 GeV and 7.7 GeV

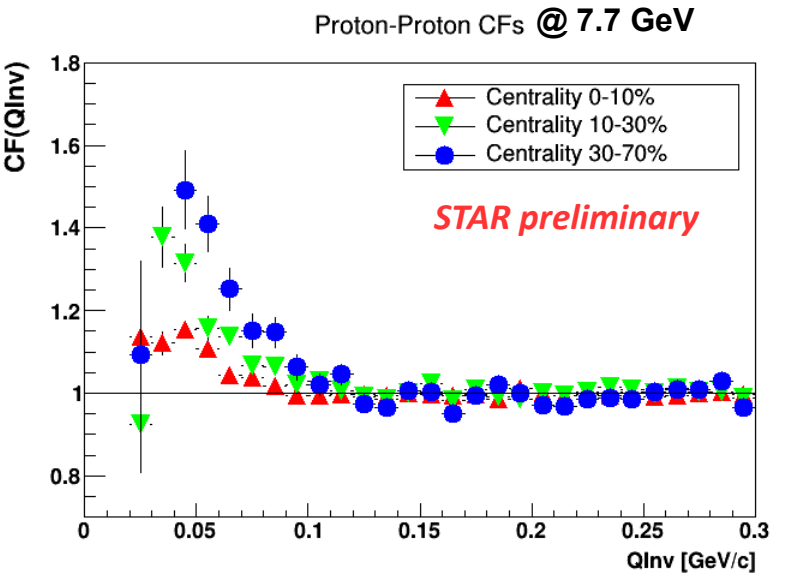
Measured correlation functions are shown

Clear centrality dependence

$$R_{p-p}(0-10\%) > R_{p-p}(10-30\%) > R_{p-p}(30-70\%)$$







Analysis Au+Au collisions - comparison of plots for different energies

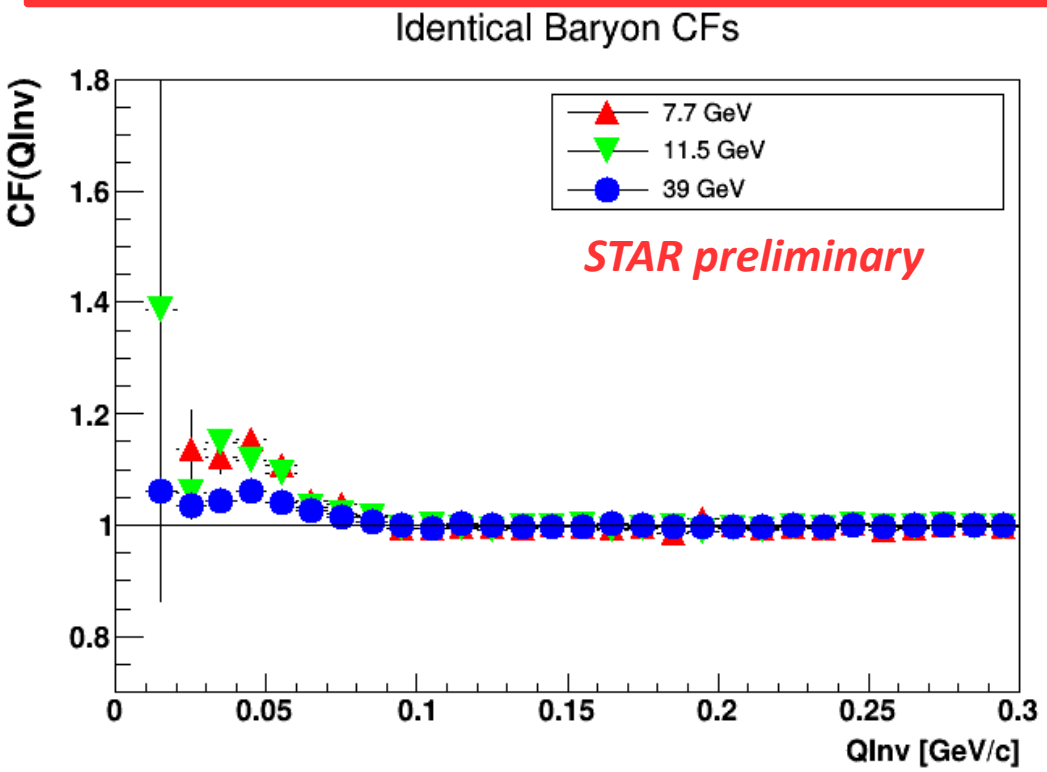
Measured correlation functions are shown

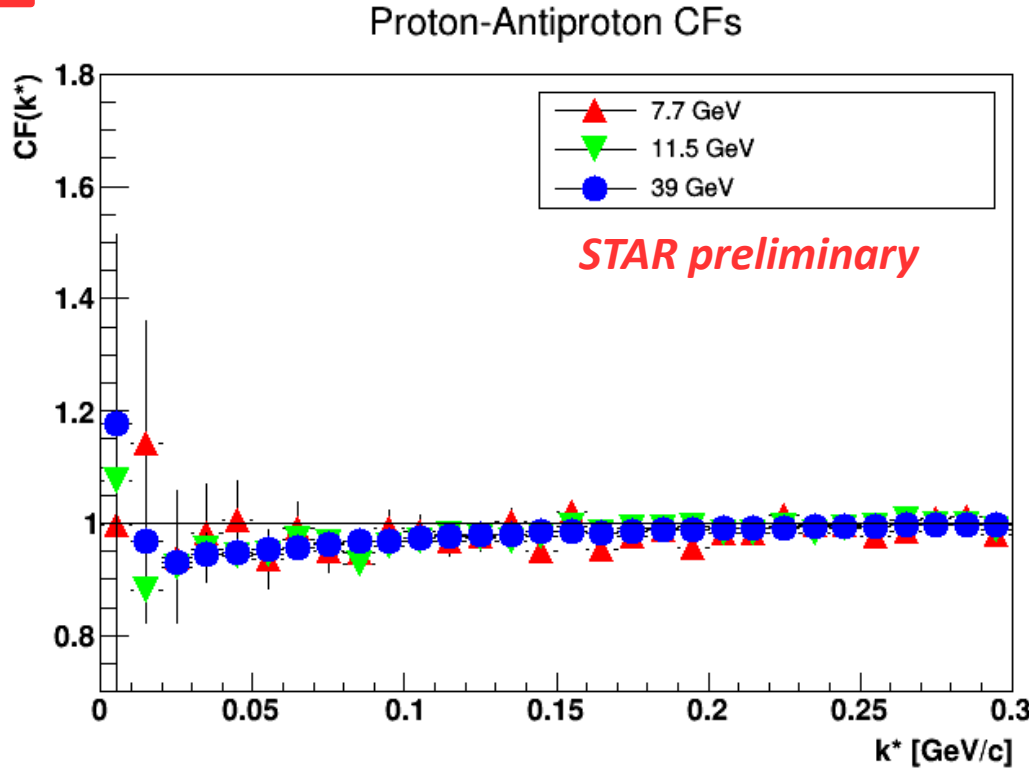
Energy dependence

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

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

Plots are 0-10% centrality





Summary

- **data analysed: 7.7 GeV, 11.5 GeV, 39 GeV**
- **selection criteria updated to provide better particle identification**
- **(anti)proton femtoscopy sensitive to Quantum Statistic Effects and Final State Interactions**

  => different strong interaction influence due to annihilation processes for Identical Baryon CFs and Non-identical Baryon CFs
- **proton - proton, antiproton - antiproton and proton - antiproton systems checked**

  => the range of correlations different for identical and non-identical particle combinations
- **the results allow for qualitative source size observation:**

  radii increase with centrality at fixed $\sqrt{s_{NN}}$

$$R_{p-p}(0-10\%) > R_{p-p}(10-30\%) > R_{p-p}(30-70\%)$$

  radii increase with $\sqrt{s_{NN}}$ at fixed centrality

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

Thank you for your attention