WARSAW UNIVERSITY OF TECHNOLOGY

Proton femtoscopy in BES

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XII Polish Workshop on Relativistic Heavy-Ion Collisions

Kielce, Poland

4-6th November 2016

Outline

1) Motivation and 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:

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

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

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

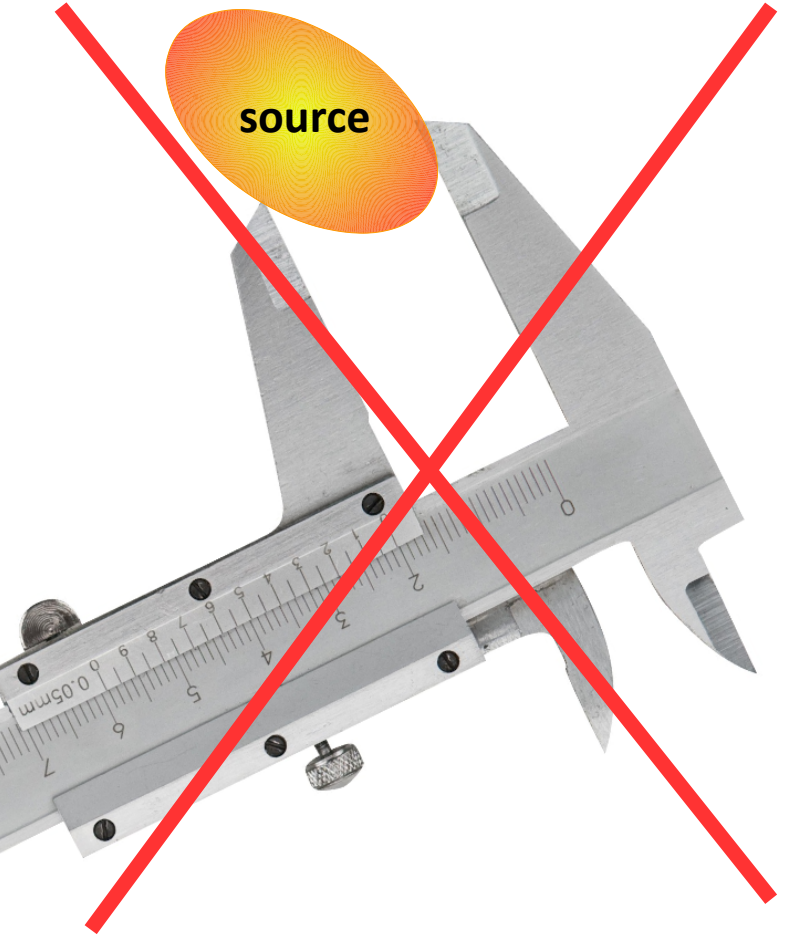
4) Summary and conclusions

Motivation

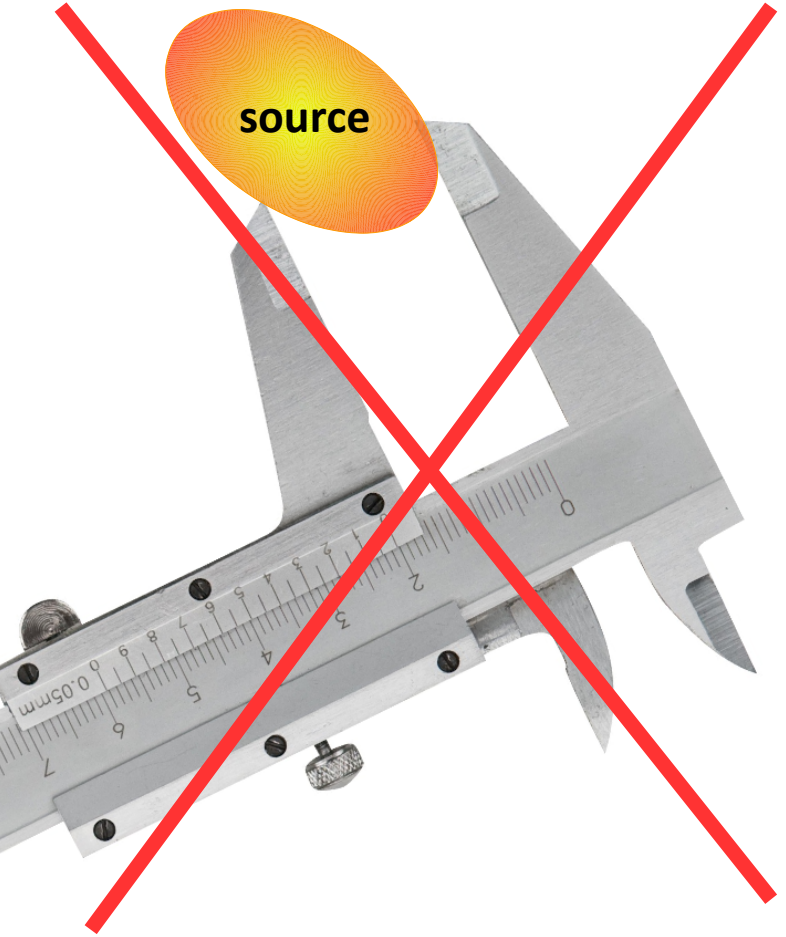
- if we extract the source radii from baryon-baryon correlations **we will be able to compare those with the radii already obtained from meson-meson and meson-baryon correlations** - such comparison will provide us with complementary information about the source characteristics

- the knowledge about interactions between two baryons, two antibaryons and between baryons and antibaryons, **when compiled, will give us a more differential view on properties of nuclear matter**

Few words about femtoscopy

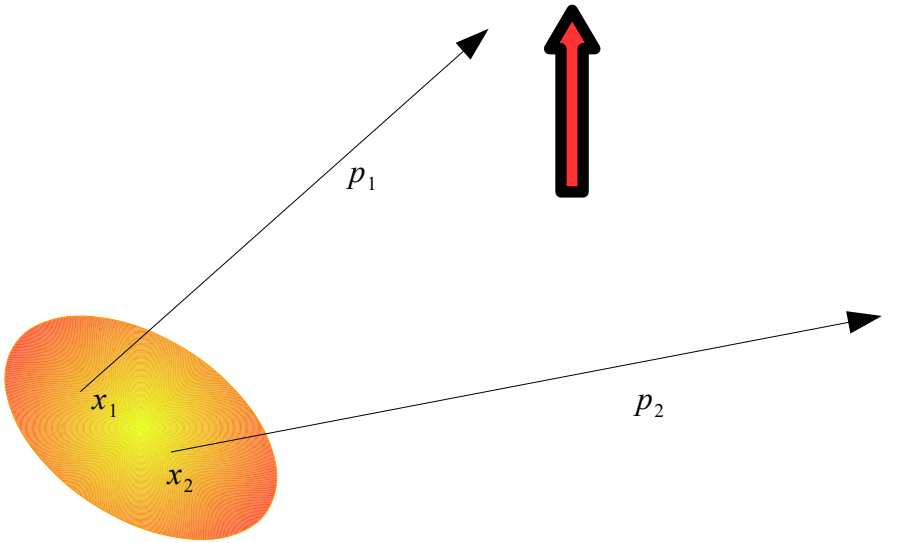


Few words about femtoscopy



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

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

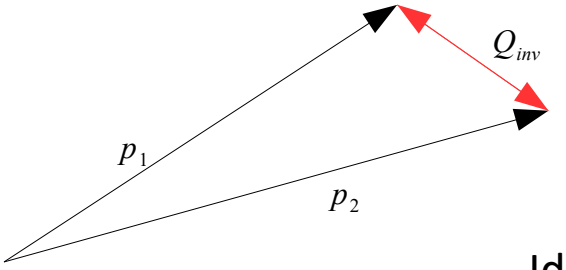
Few words about femtoscopy

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}

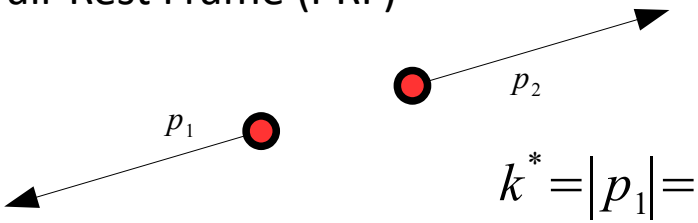
In Longitudinal Co-Moving System (LCMS)



Identical baryons

k^*

In Pair Rest Frame (PRF)



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

Non-identical 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)

Non-identical baryon-antibaryon

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

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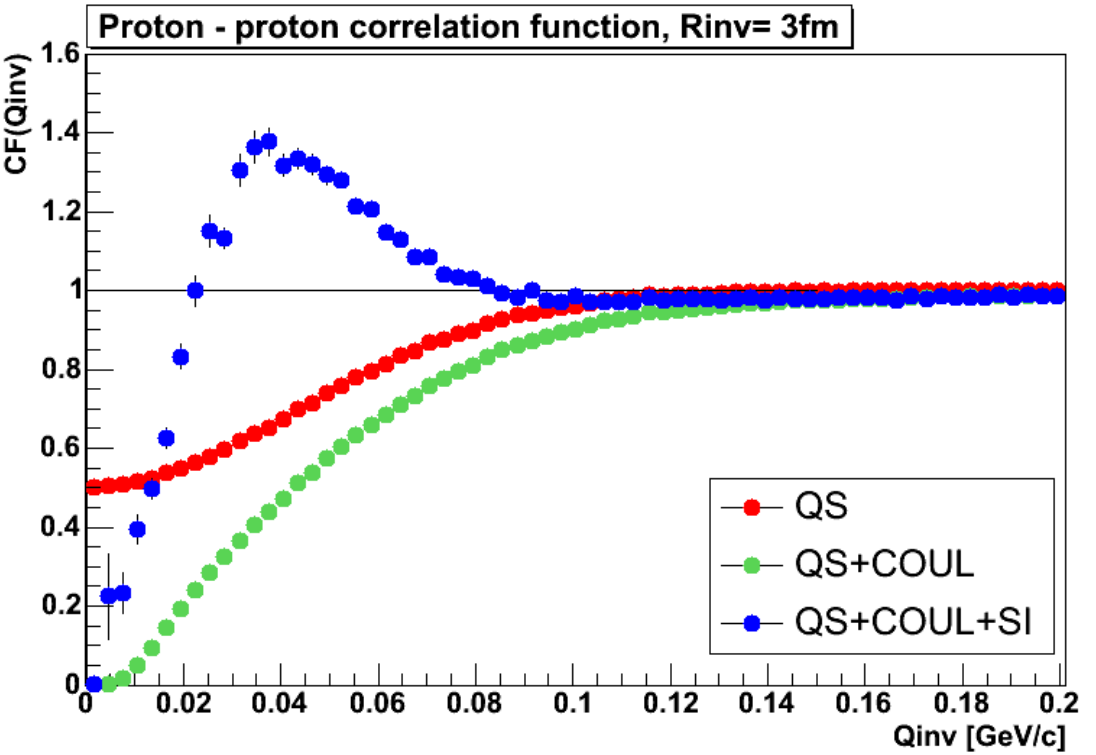

UrQMD Au+Au; $R_{inv} = 3\,\mathrm{fm}$

Proton correlations

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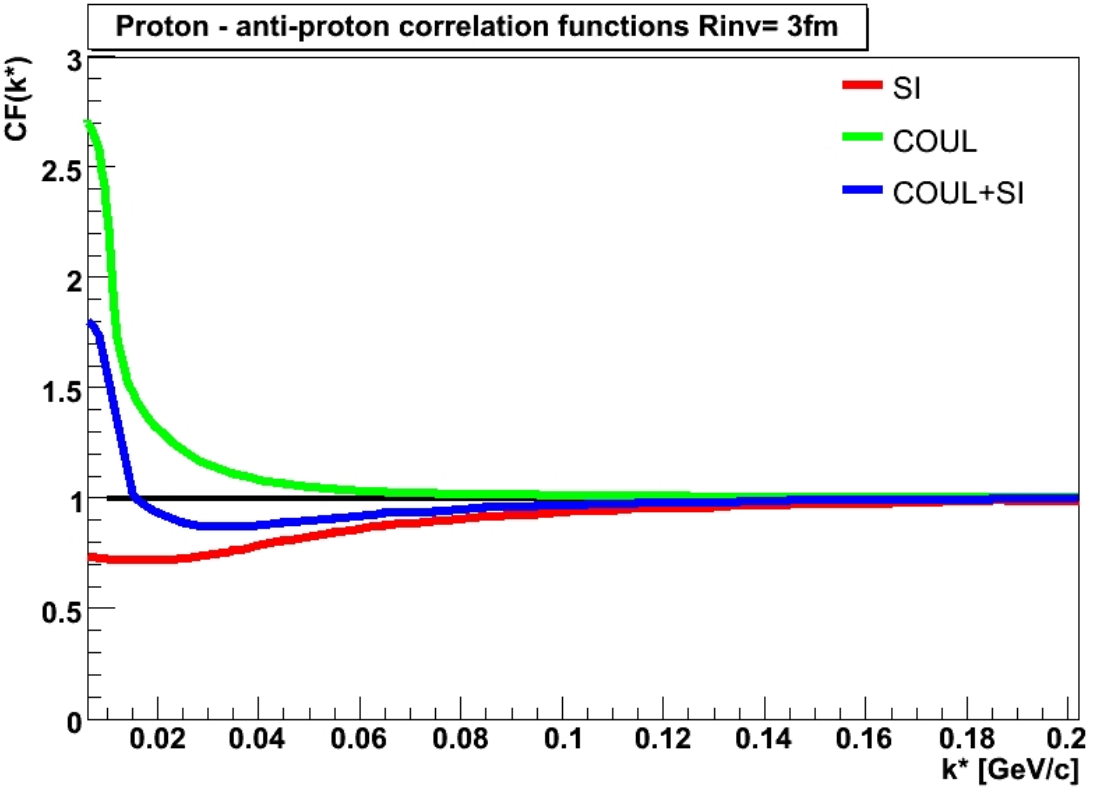

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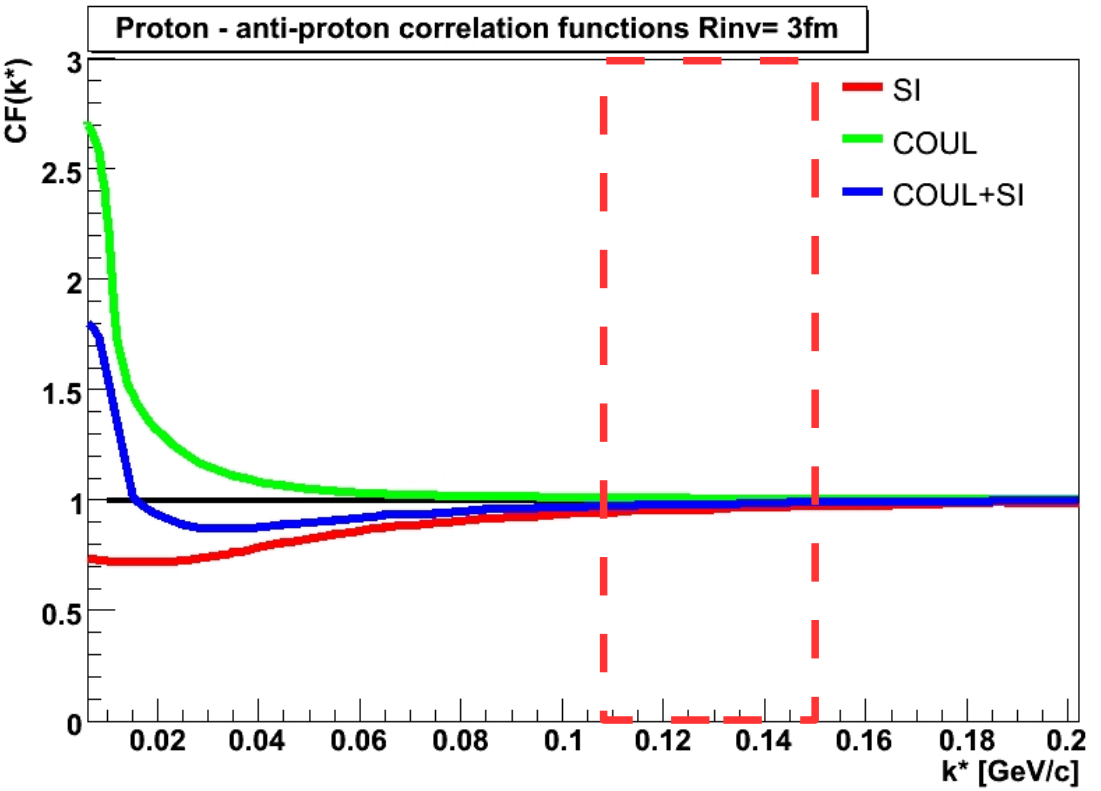
  - Strong Interaction (SI)

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



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

Proton correlations

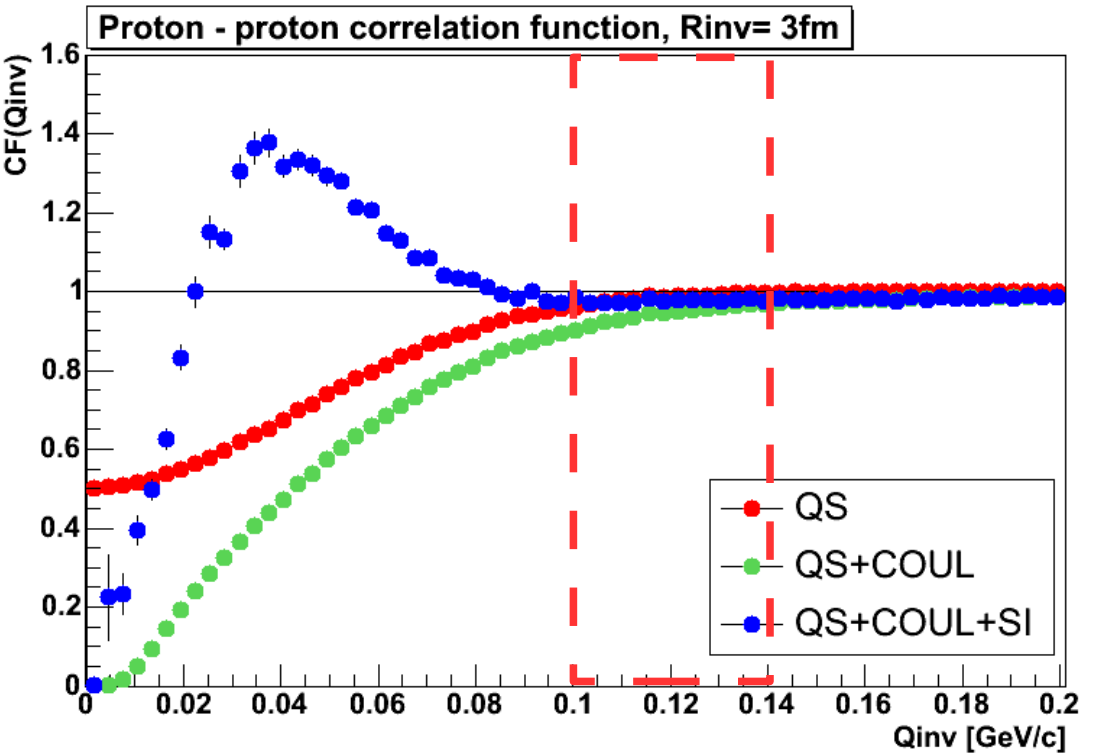
Identical baryon-baryon

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

Non-identical baryon-antibaryon

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

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



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

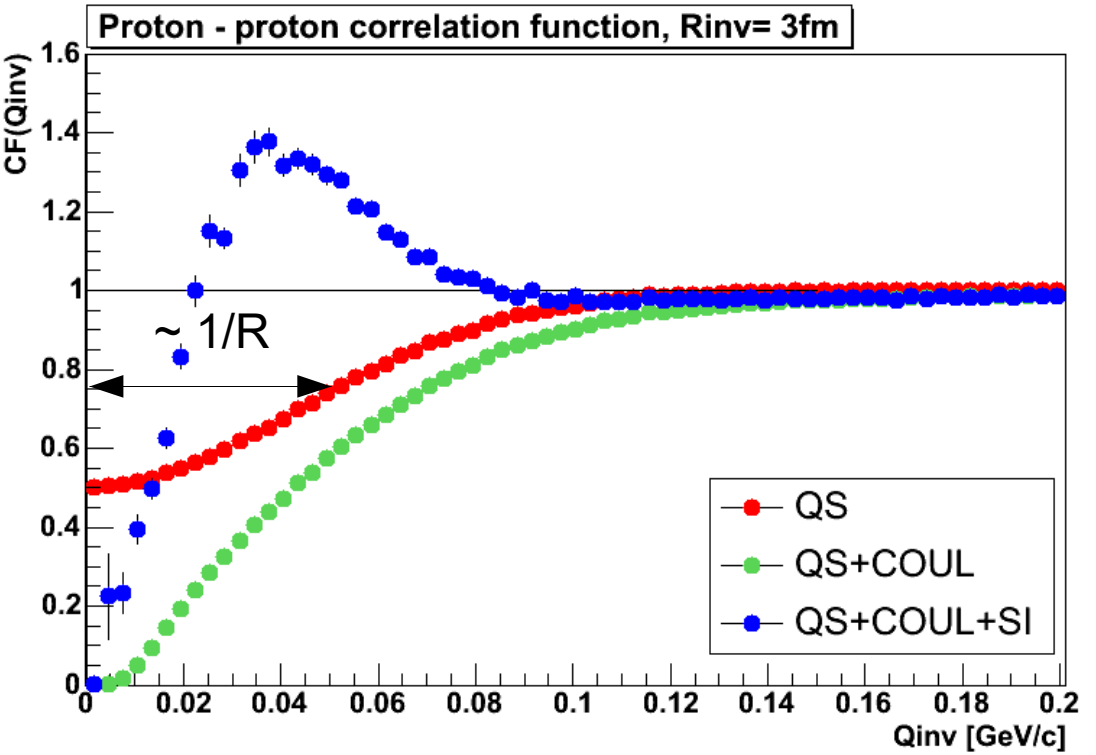
Proton correlations

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.

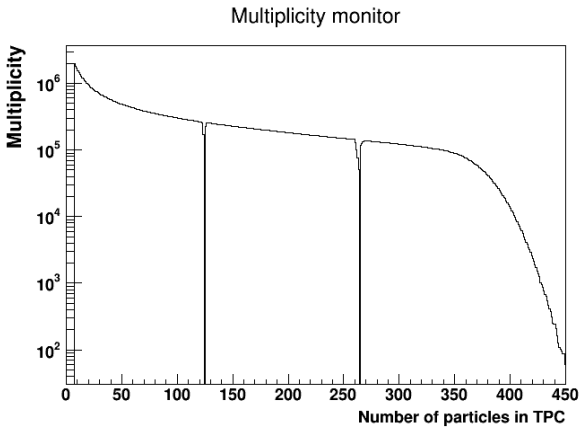
The Radii can be qualitatively compared by comparing the height of the peak in identical baryon-baryon correlation functions, because it also is inversely dependent on Radius of the „source” size.



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

Data selection

Example monitors for Au+Au collisions at $\sqrt{s_{NN}}$ = 39 GeV



Total: 101 M events

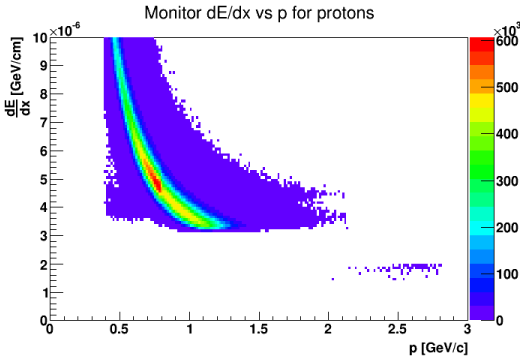
63 M events – centrality 30-80%

26 M events – centrality 10-30%

13 M events – centrality 0-10%

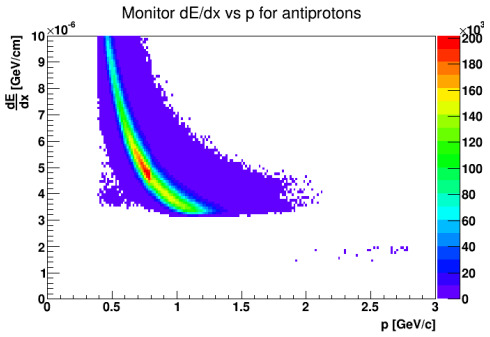
Cut	Range/value
Momentum (p)	0.4 < p < 3.0 [GeV/c]
Mass^2 window	0.76 < m < 1.03 [GeV^2/c^4]
N σ	-3.0 < N < 3.0
Z vertex: - 7.7 GeV - 11.5 GeV - 39 GeV	[cm] -70 < z < 70 -50 < z < 50 -30 < z < 30

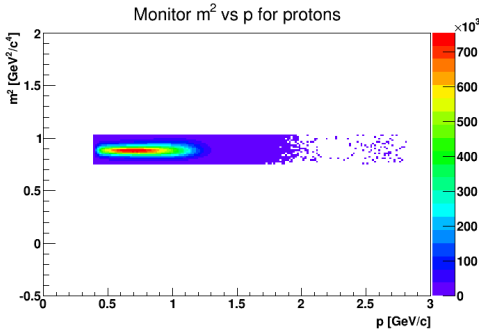
Centrality selection based on MC Glauber calculation



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

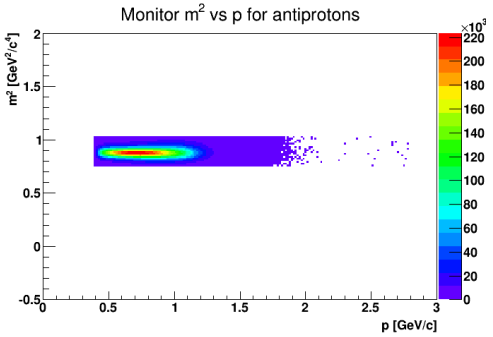
TPC





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

ToF

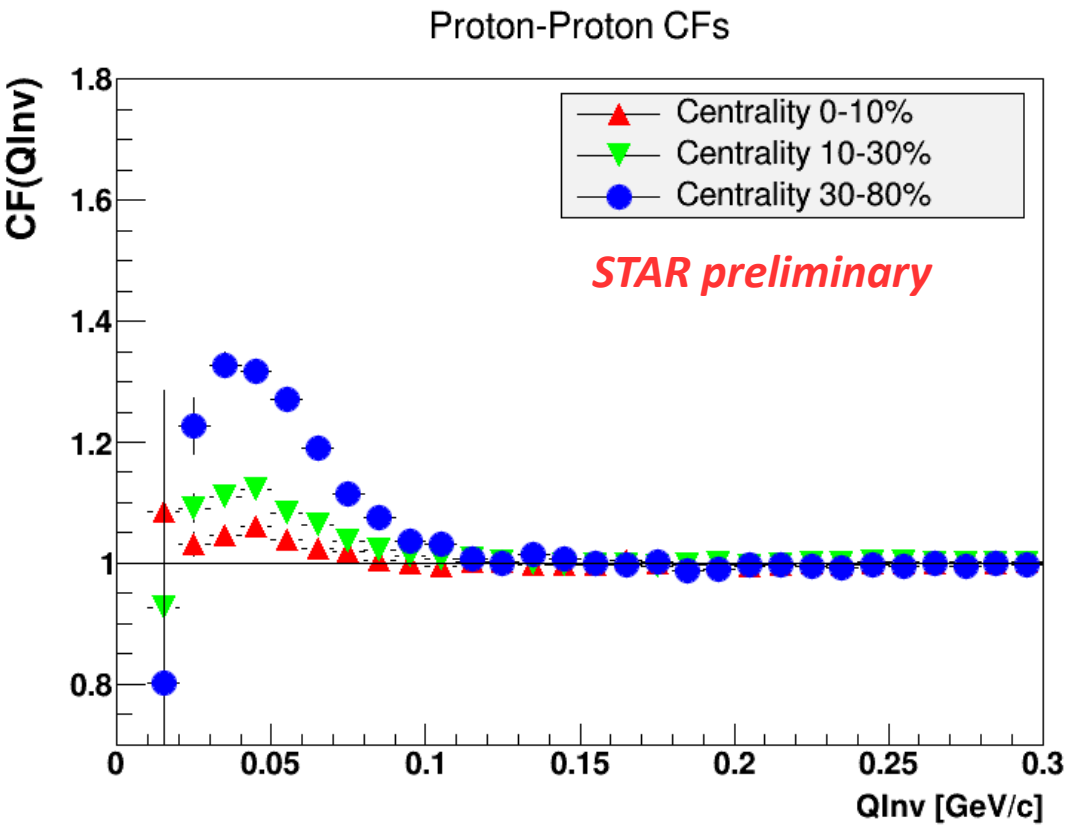


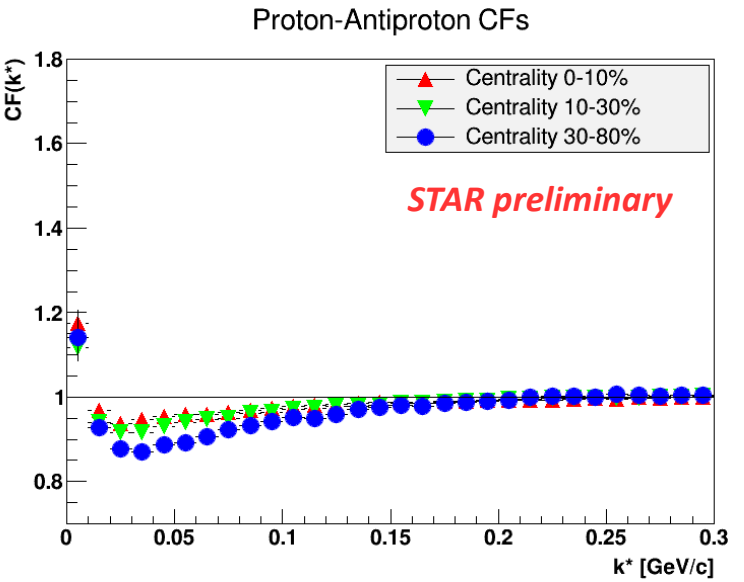
Analysis Au+Au collisions @ 39 GeV

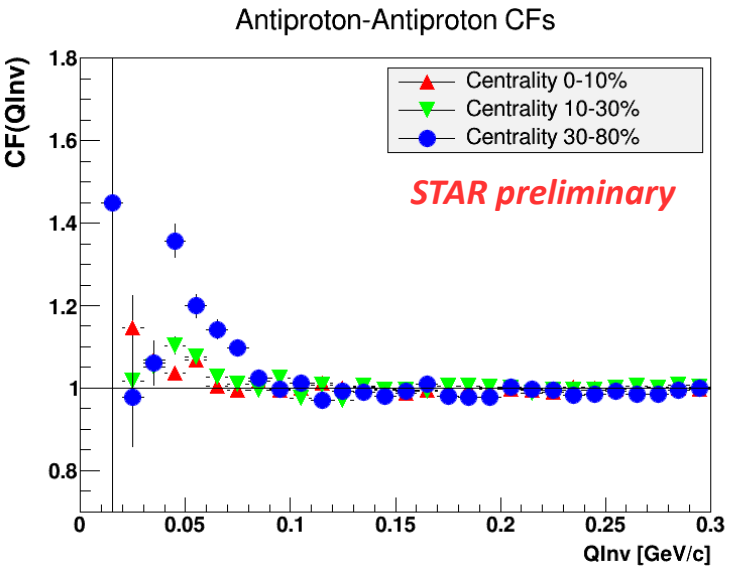
Measured correlation functions are shown

Clear centrality dependence

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







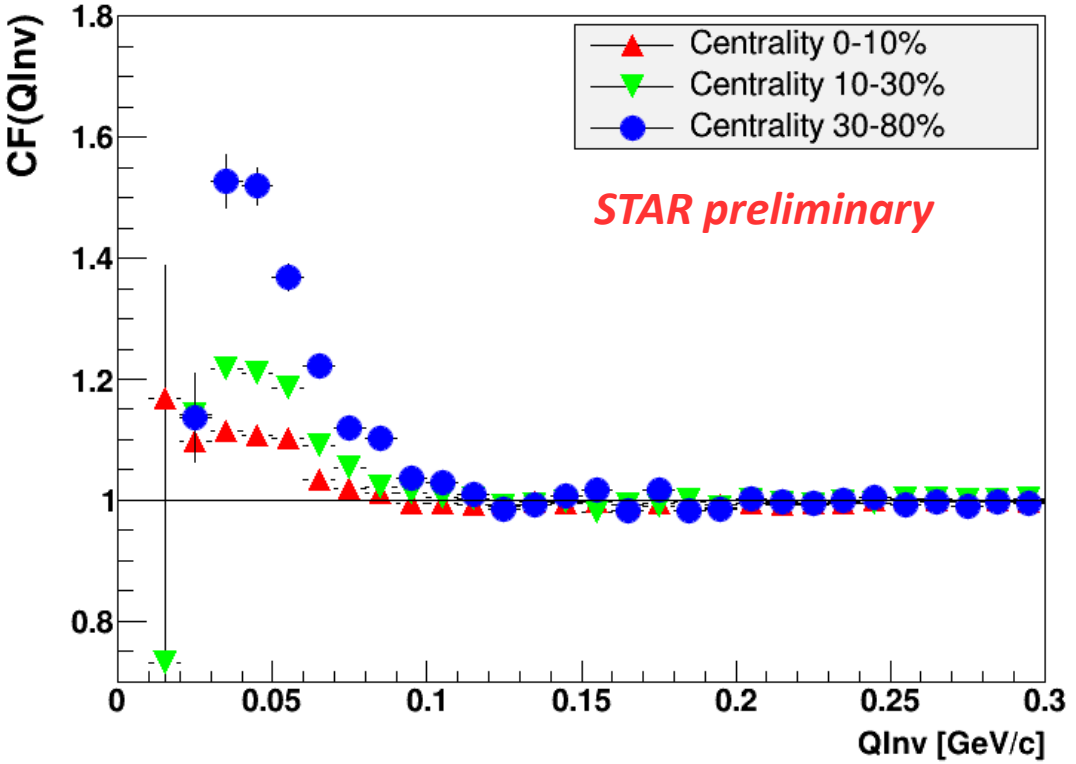
Analysis Au+Au collisions @ 11.5 GeV

Measured correlation functions are shown

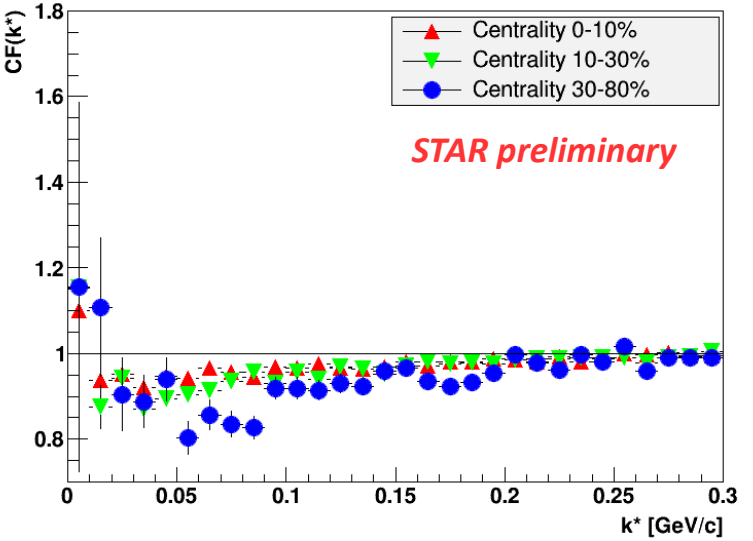
Clear centrality dependence

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

Proton-Proton CFs



Proton-Antiproton CFs



Antiproton-Antiproton CFs

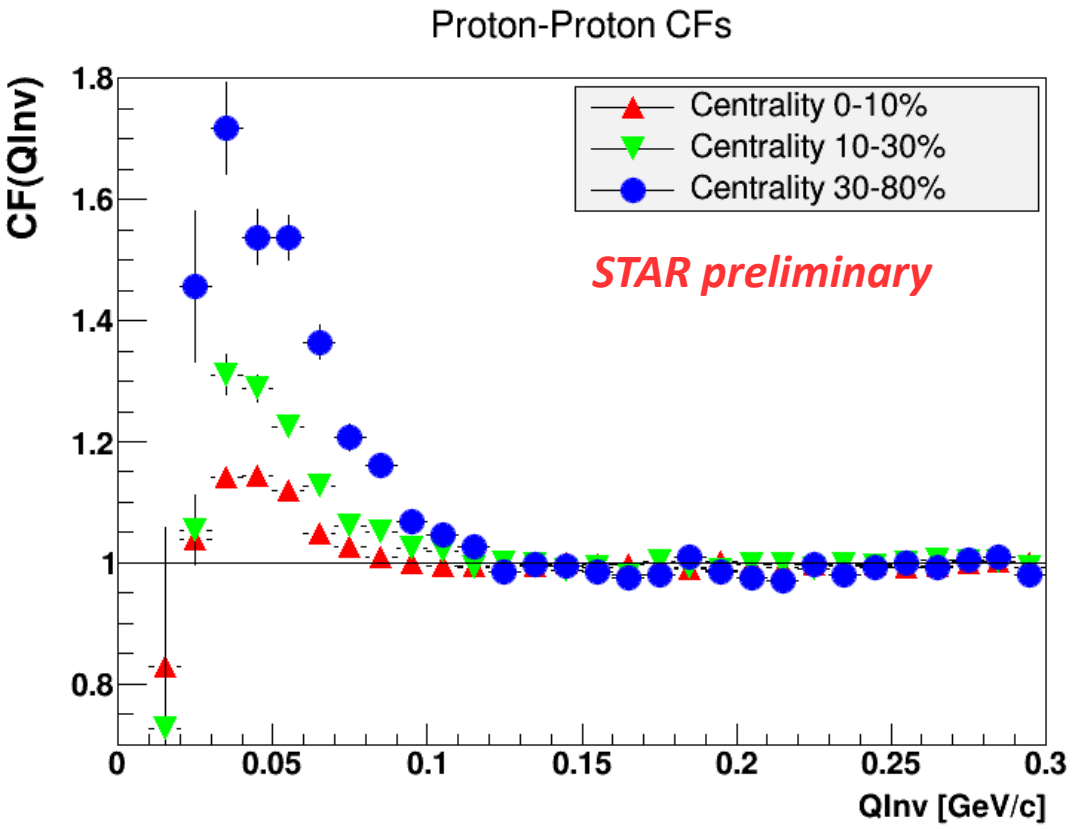
not available due to low statistics

Analysis Au+Au collisions @ 7.7 GeV

Measured correlation functions are shown

Clear centrality dependence

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



Proton-Antiproton CFs

not available due to low statistics

Antiproton-Antiproton CFs

not available due to low statistics

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

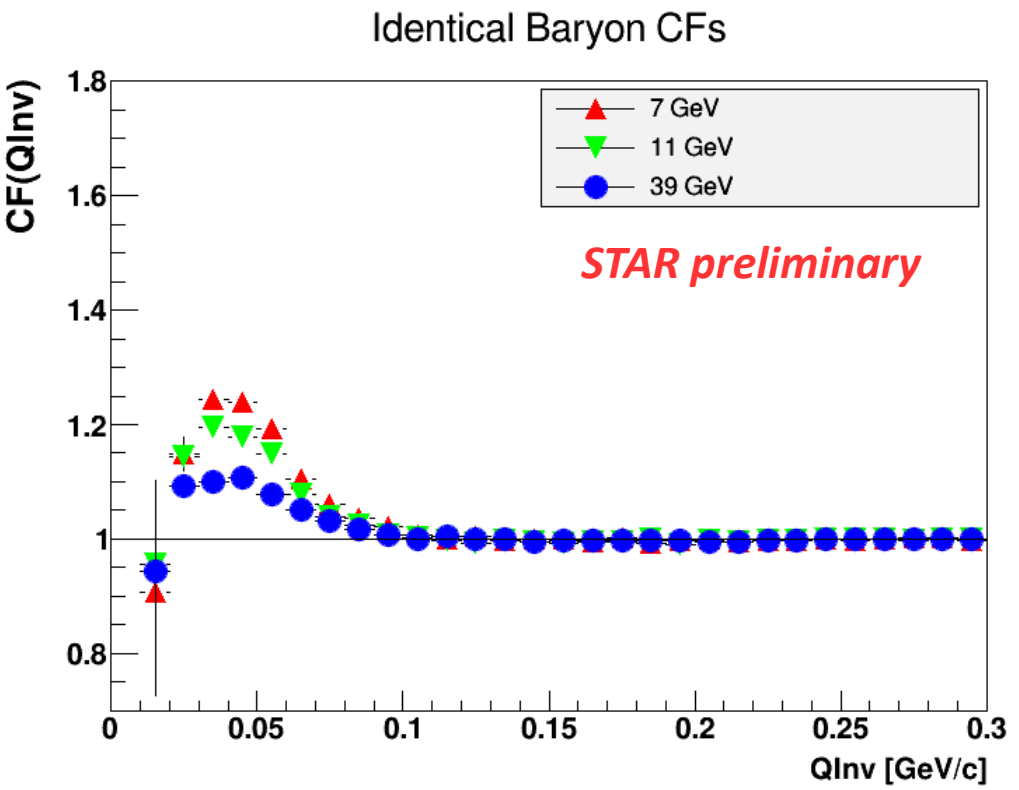
Measured correlation functions are shown

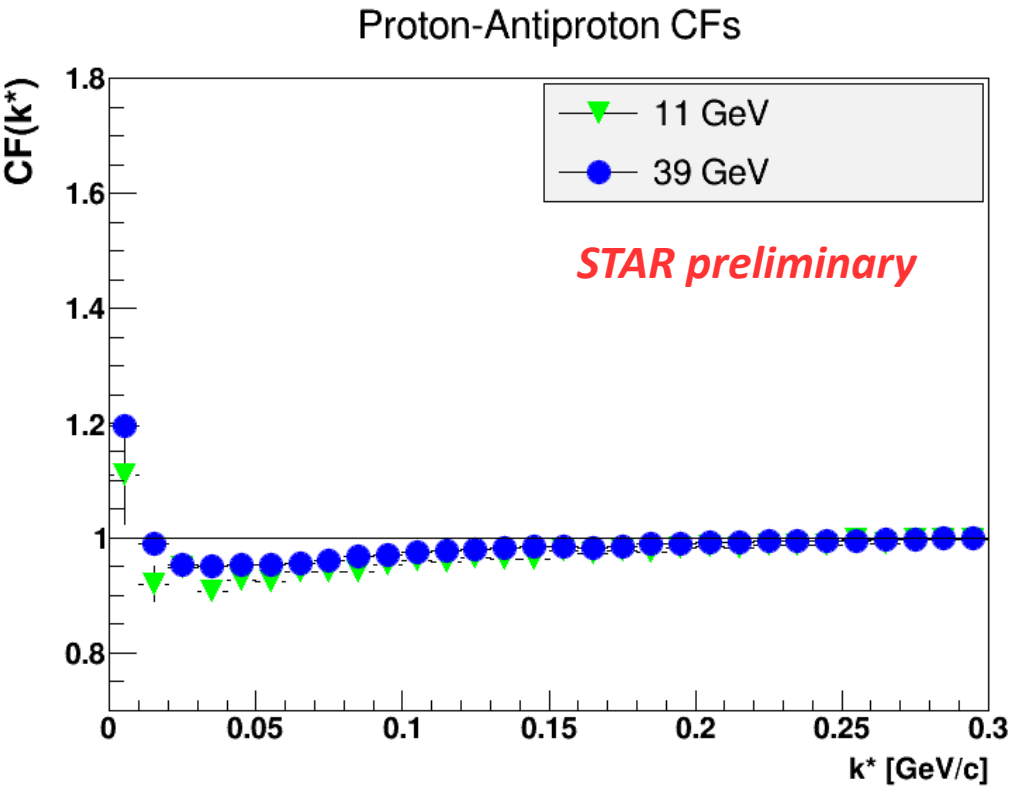
Clear energy dependence

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

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

Plots are 0-80% centrality





Summary

- **(anti)proton femtoscopy sensitive to Quantum Statistic Effects and Final State Interactions**
- **different strong interaction influence 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 non-identical particle combinations

- **the results allow for qualitative source sizes observation:**

  a) radii increase with √(s_{NN}) at fixed centrality

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

  b) radii increase with centrality at fixed √(s_{NN})

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

Thank you for your attention