Warsaw University of Technology

ZIMÁNYI SCHOOL'19
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Introduction to the correction of residual contamination of proton and antiproton correlations using Therminator 2 model

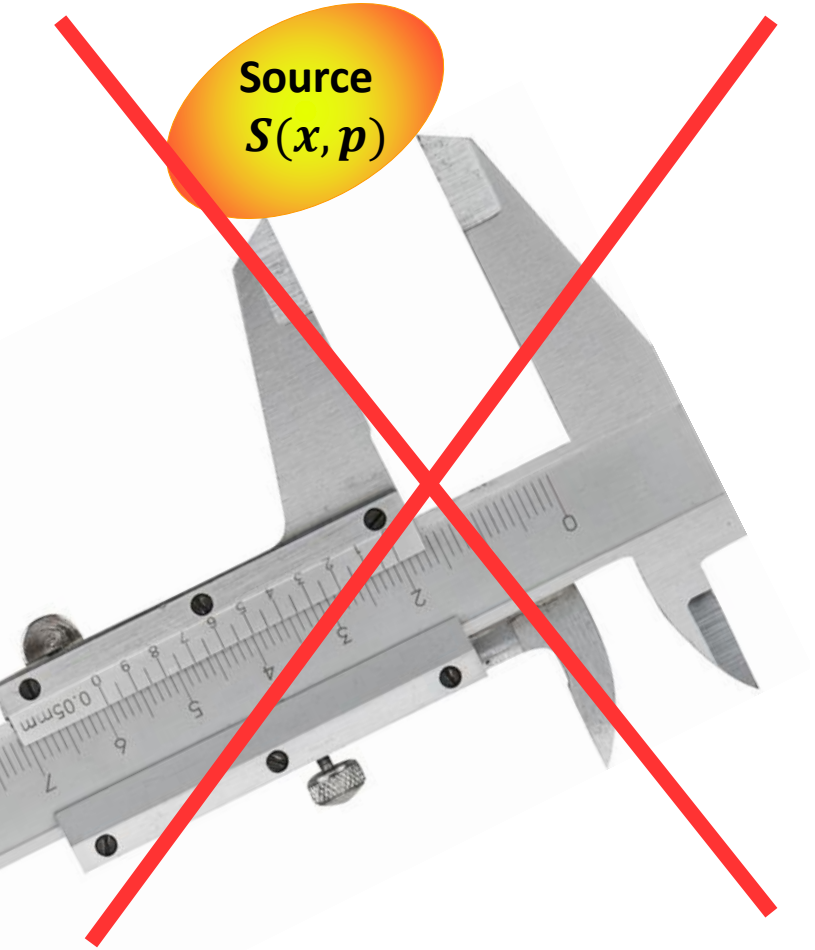
Sebastian Siejka

Warsaw University of Technology
Faculty of Physics

Outline

1) Femtoscopy
2) Types of correlation functions
3) Current status of analysis
4) Residual contamination
5) Residual correction

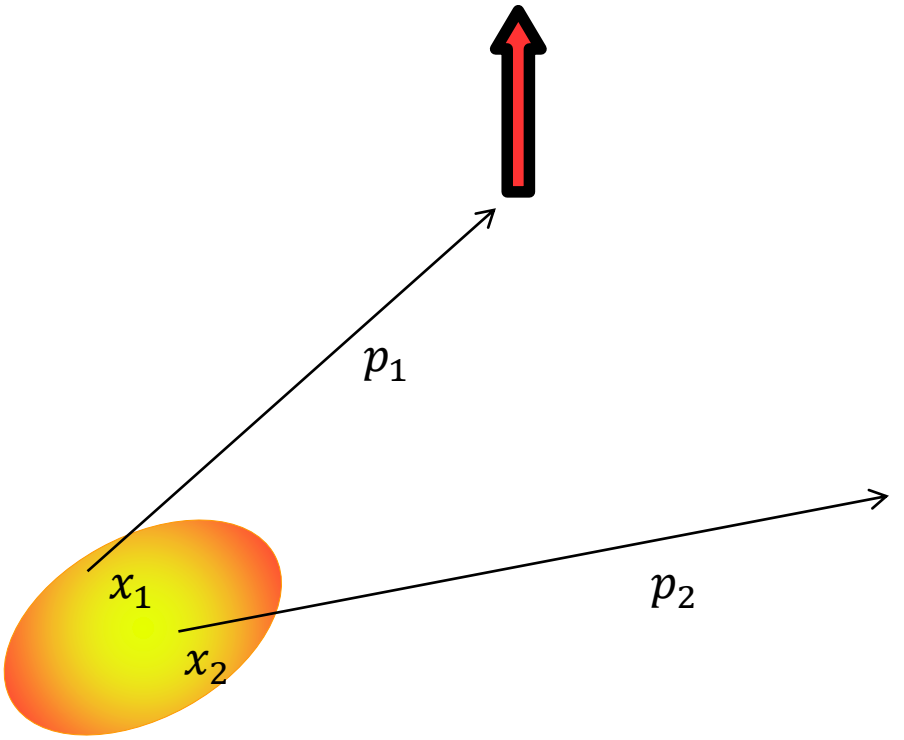
Femtoscopy



Femtoscopy

Correlation function

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



Femtoscopy

Single-particle distribution

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

Correlation function

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

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

Two-particle distribution

$$P_2(p_1,p_2) = E_1E_2\frac{dN}{d^3p_1d^3p_2} = \int d^4\, x_1S(x_1,p_1)d^4x_2S(x_2,p_2)\Phi(x_2,p_2 \mid x_1,p_1)$$

Φ – pair mutual interaction

Correlation function shows echo of emission function as seen through pair mutual interaction.

Types of Correlation Functions

Identical particle combination

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

Non-identical particle combination

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

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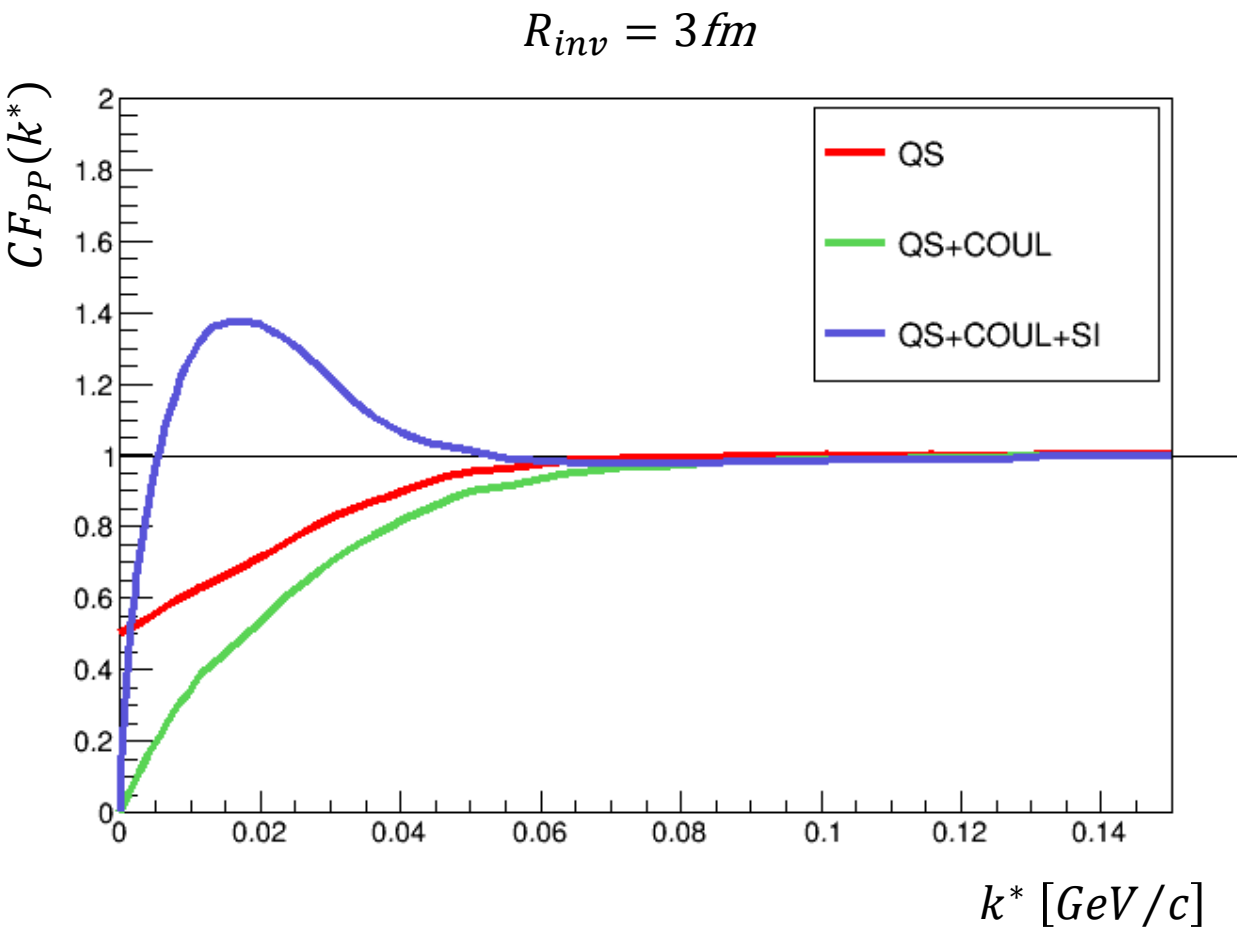

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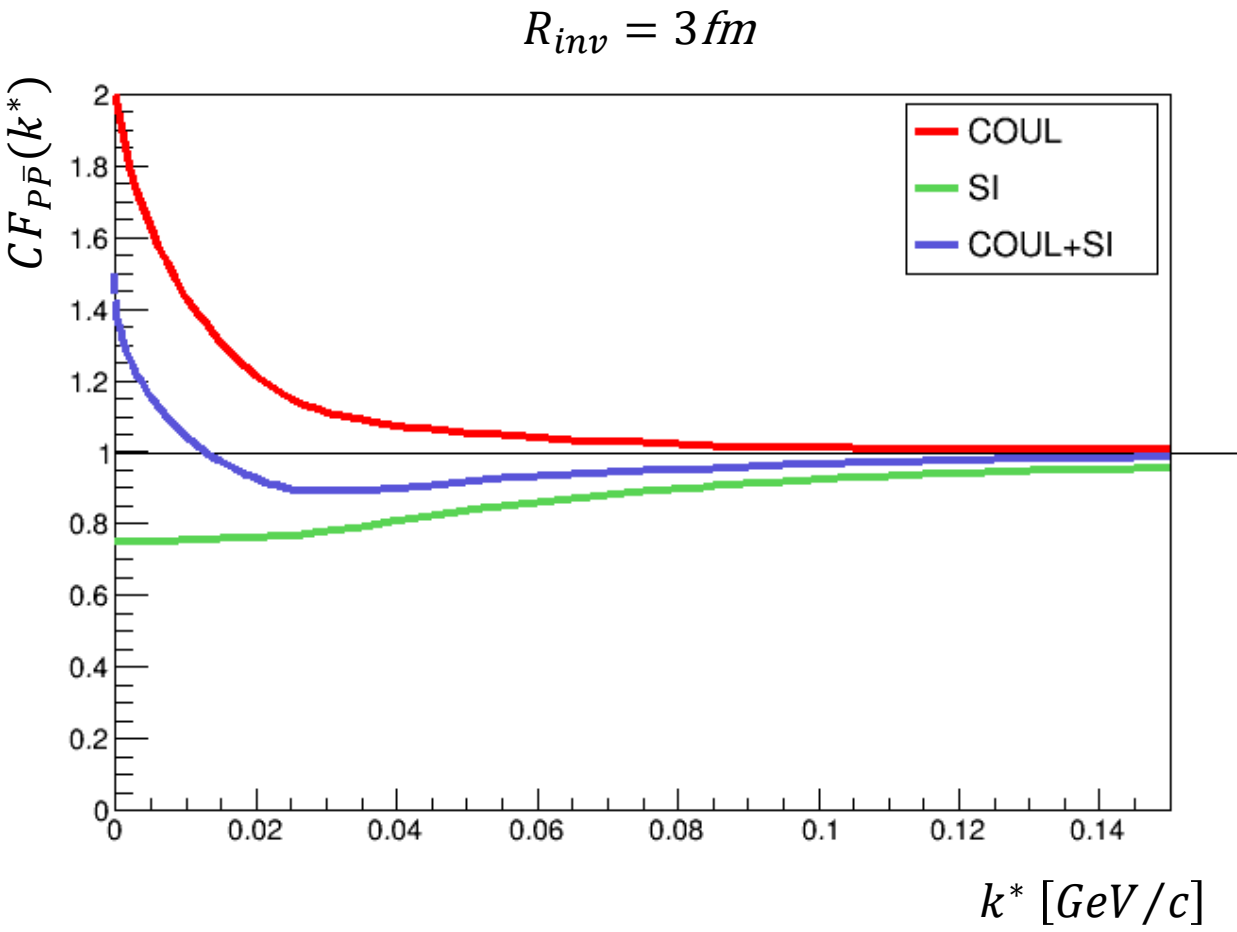
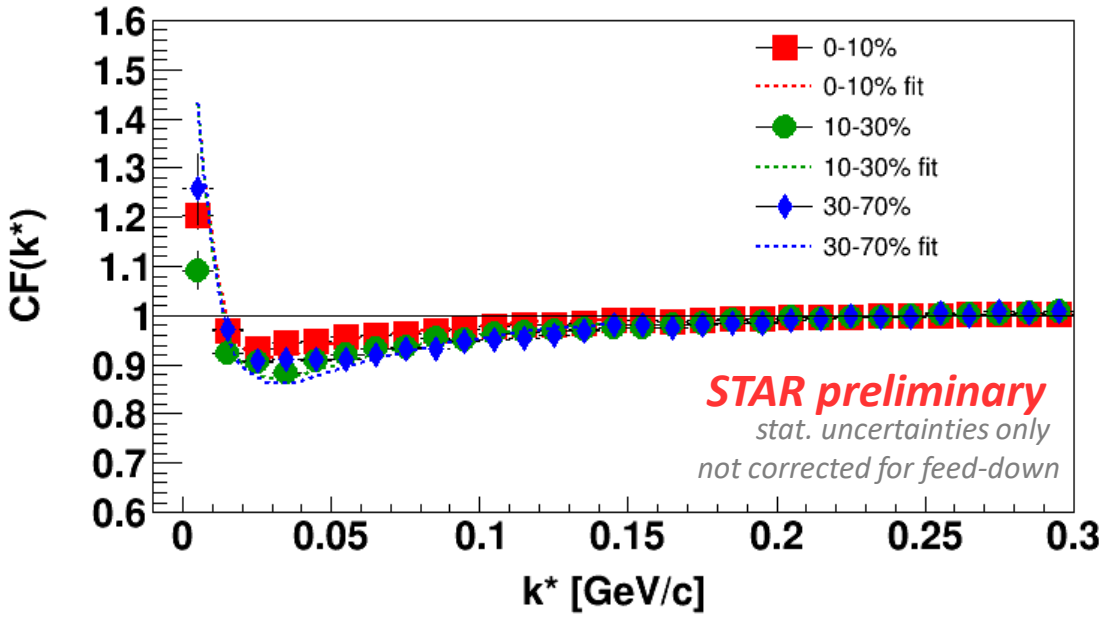


Current status of analysis

$p - \bar{p}$ @ Au+Au 39 GeV



Clear centrality dependence

$\boldsymbol{R(0–10\%) > R(10–30\%) > R(30–70\%)}$

centrality	R_{inv} $p - \bar{p}$ [fm]
0-10%	$\mathbf{3.39} \pm 0.12 \pm 0.14$
10-30%	$\mathbf{2.69} \pm 0.10 \pm 0.12$
30-70%	$\mathbf{2.56} \pm 0.09 \pm 0.12$

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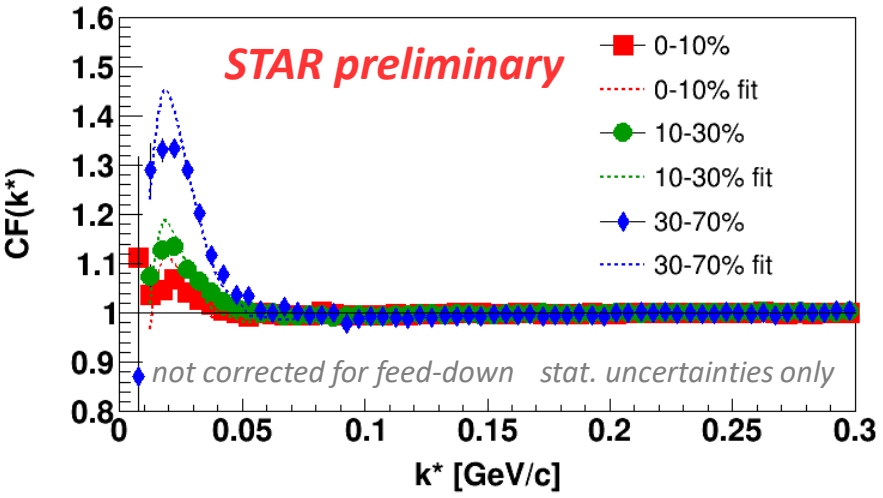
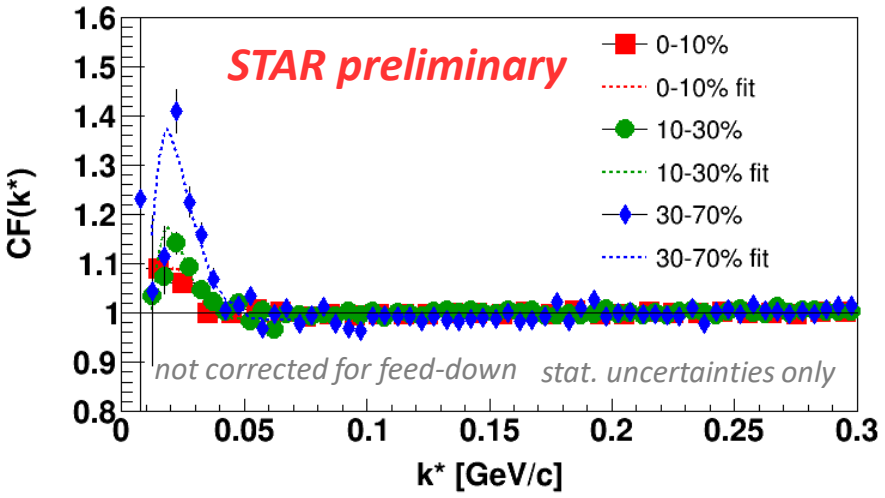
Current status of analysis

$p - p$ @ Au+Au 39 GeV



$\bar{p} - \bar{p}$ @ Au+Au 39 GeV



centrality	R_{inv} $p - p$ [fm]	R_{inv} $\bar{p} - \bar{p}$ [fm]
0-10%	$\mathbf{4.00} \pm 0.15 \pm 0.02$	$\mathbf{3.83} \pm 0.20 \pm 0.03$
10-30%	$\mathbf{3.61} \pm 0.13 \pm 0.17$	$\mathbf{3.68} \pm 0.15 \pm 0.11$
30-70%	$\mathbf{2.72} \pm 0.07 \pm 0.07$	$\mathbf{2.95} \pm 0.11 \pm 0.08$

No significant difference between $p - p$ and $\bar{p} - \bar{p}$ correlation functions.

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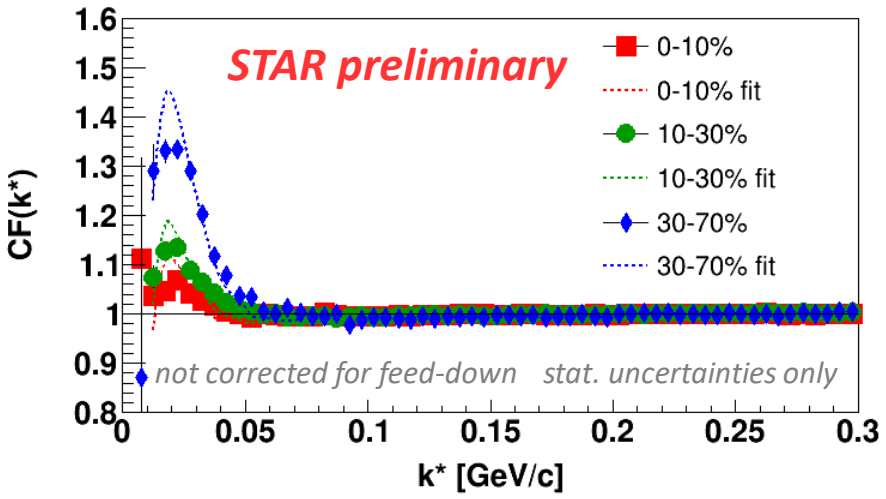
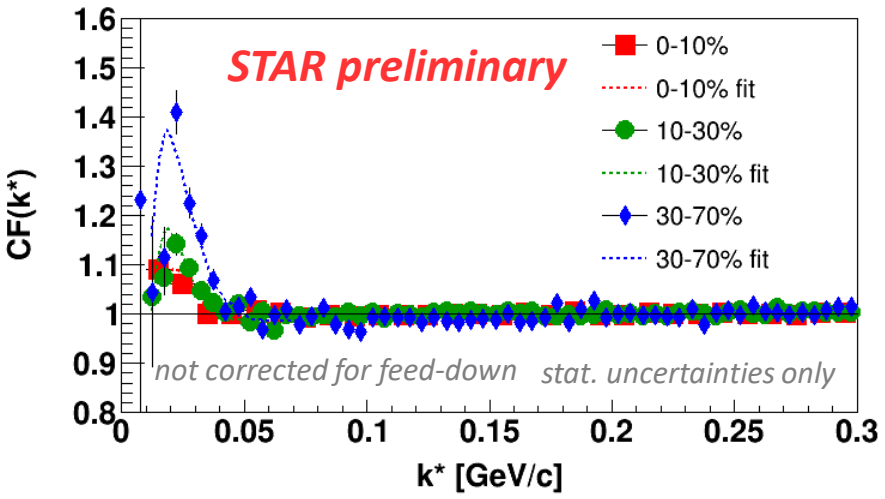
Current status of analysis

$p - p$ @ Au+Au 39 GeV



$\bar{p} - \bar{p}$ @ Au+Au 39 GeV



centrality	R_{inv} $p - p$ [fm]	R_{inv} $\bar{p} - \bar{p}$ [fm]	R_{inv} $p - \bar{p}$ [fm]
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No significant difference between $p - p$ and $\bar{p} - \bar{p}$ correlation functions.

Radii from $p - p$ and $\bar{p} - \bar{p}$ systems differ from radii from $p - \bar{p}$ system –> residual correlations contaminate correlation functions.

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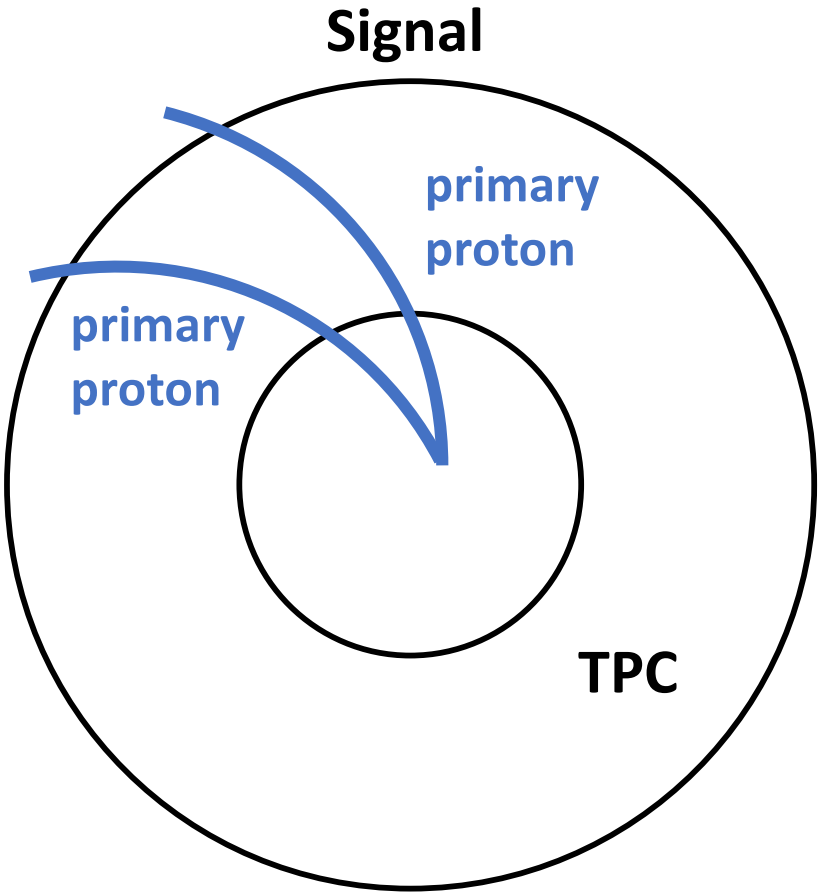
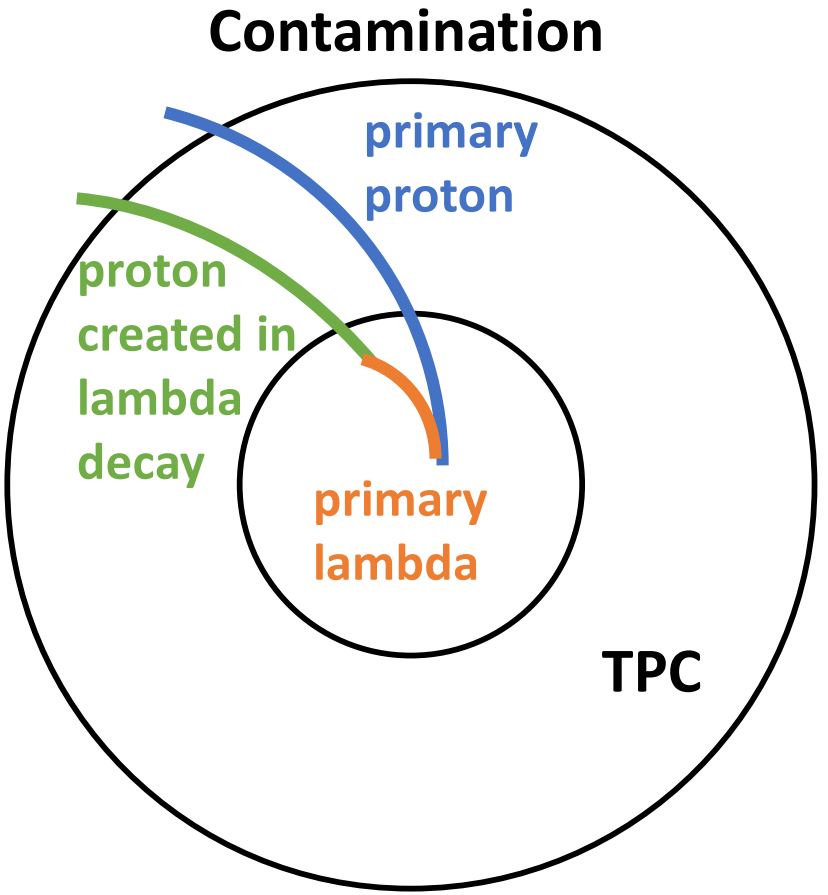
Residual contamination



Correlation between two protons is measured



Correlation between proton and lambda contaminates data

F. Wang **Phys.Rev. C60 (1999) 067901**
A. Kisiel, H. Zbroszczyk and M. Szymański **Phys.Rev. C89 (2014) no.5, 054916**
H. Gos **Eur.Phys.J. C49 (2007) 75-80**
M. Szymański **Nucl.Phys. A 904-905 (2013) 447c-450c**

THERMAL HEAVY-ION GENERATOR II

- Based on Monte Carlo methods
- Capable of generating collisions of relativistic heavy ions at various energies (RHIC, LHC)
- Implements thermal models of particle production with single freeze-out

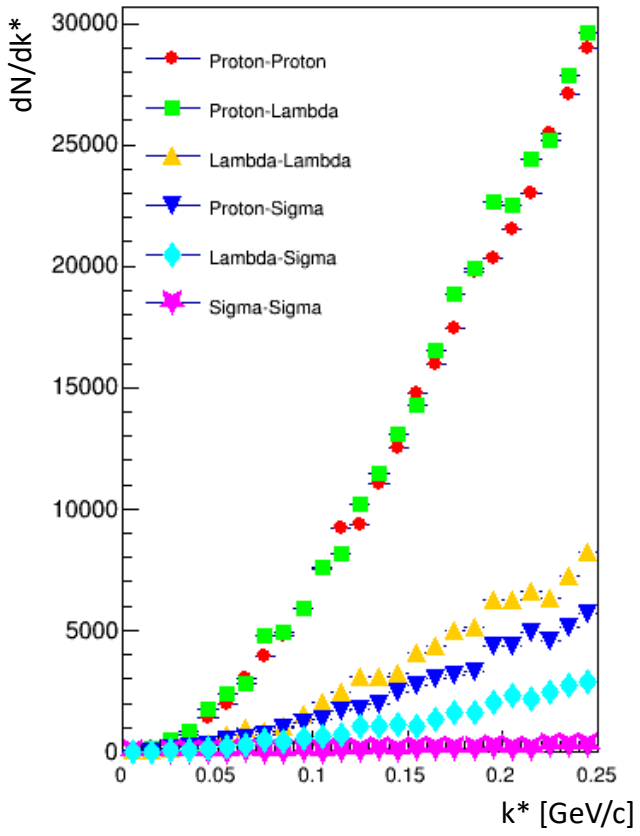
A. Kisiel, M. Chojnacki, W. Broniowski and W. Florkowski
„THERMINATOR 2: THERMal heavy-IoN generator 2”
Comput.Phys.Commun. 183.3 (2012) 746-773

Residual contamination – model results

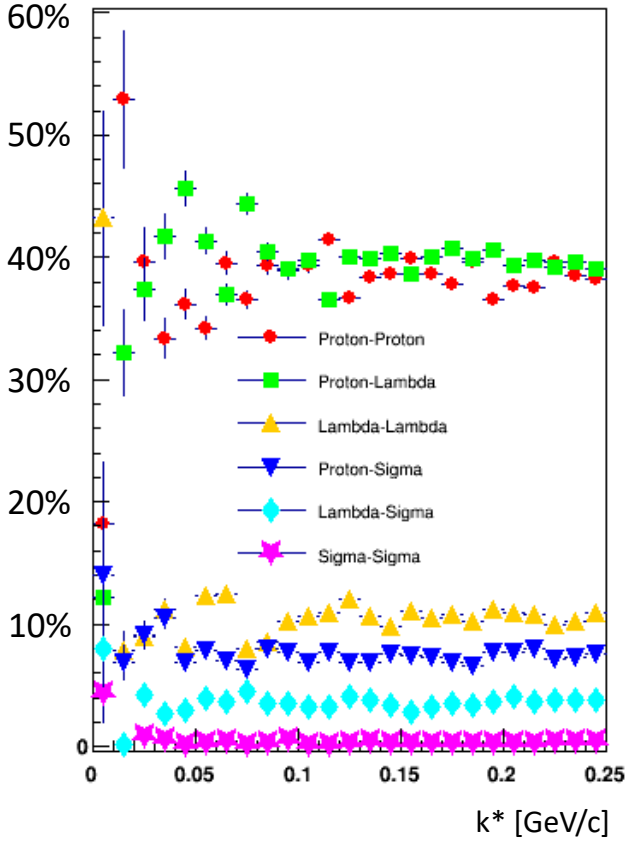
$$CF_{measured} = \sum_i CF_i \cdot f_i$$

$i_{identical}$: $p-p, p-\Lambda, \Lambda-\Lambda, p-\Sigma, \Sigma-\Sigma, \Lambda-\Sigma$ [6]
$i_{nonidentical}$: $p-\bar{p}, p-\bar{\Lambda}, p-\bar{\Sigma}, \Lambda-\bar{p}, \Lambda-\bar{\Lambda}, \Lambda-\bar{\Sigma}, \Sigma-\bar{p}, \Sigma-\bar{\Lambda}, \Sigma-\bar{\Sigma}$ [9]
f – fraction

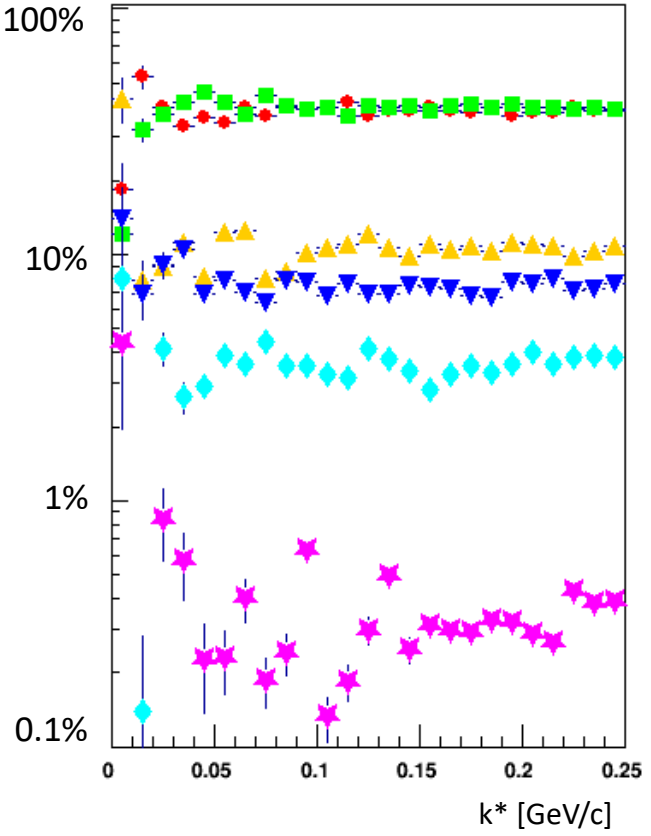
Number of pairs at given k*



Fractions at given k*



Fractions at given k* (log scale)



39GeV data, based on Therminator II model

Residual contamination – model results

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$i_{identical}$: $p-p, p-\Lambda, \Lambda-\Lambda, p-\Sigma, \Sigma-\Sigma, \Lambda-\Sigma$ [6]
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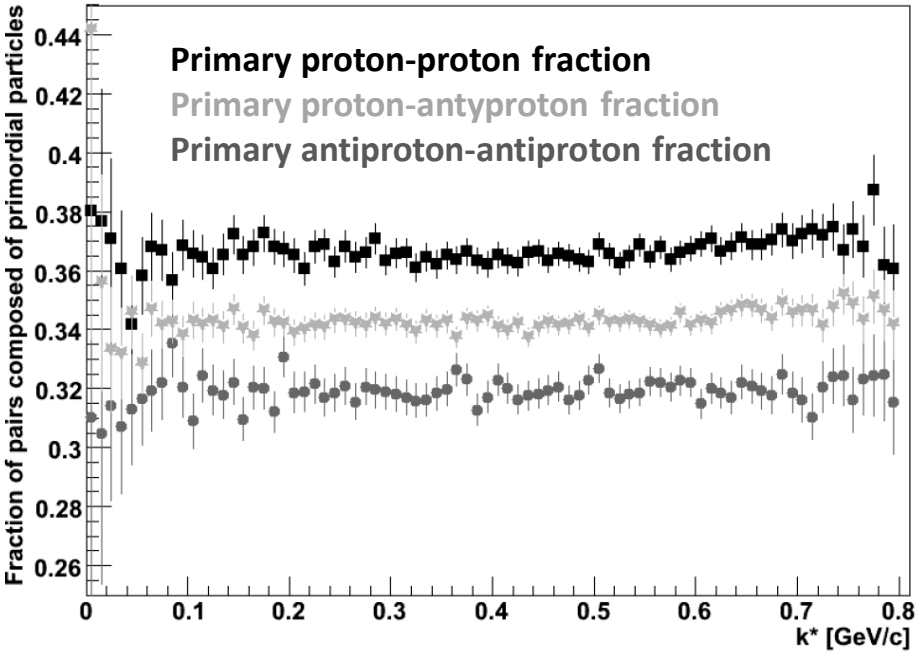
f – fraction

Primary fractions	39 GeV	200 GeV
proton-proton	38%	37%
proton-antiproton	34%	34%
antiproton-antiproton	28%	32%

39 GeV: Data from Therminator II



Data from 200GeV analysis

H. Zbroszczyk „Studies of Baryon-Baryon Correlations in Relativistic NuclearCollisions Registered at the STAR Experiment”

Residual correction

$$CF_{measured} = \sum_i CF_i \cdot f_i$$

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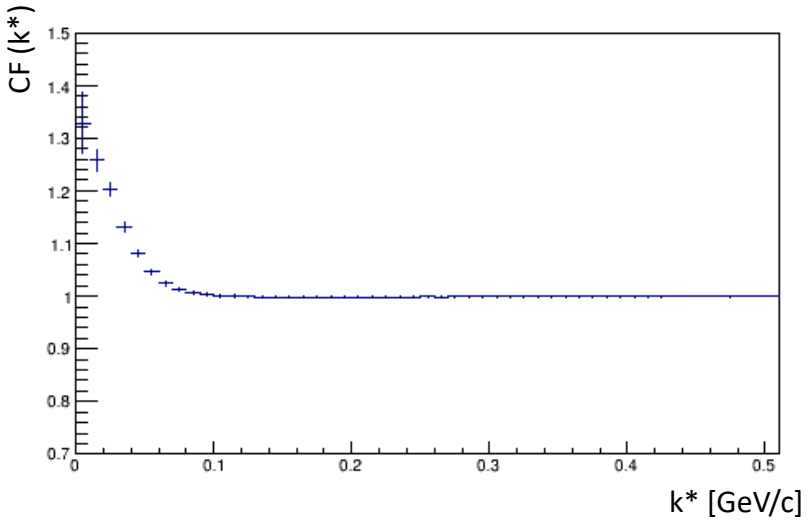
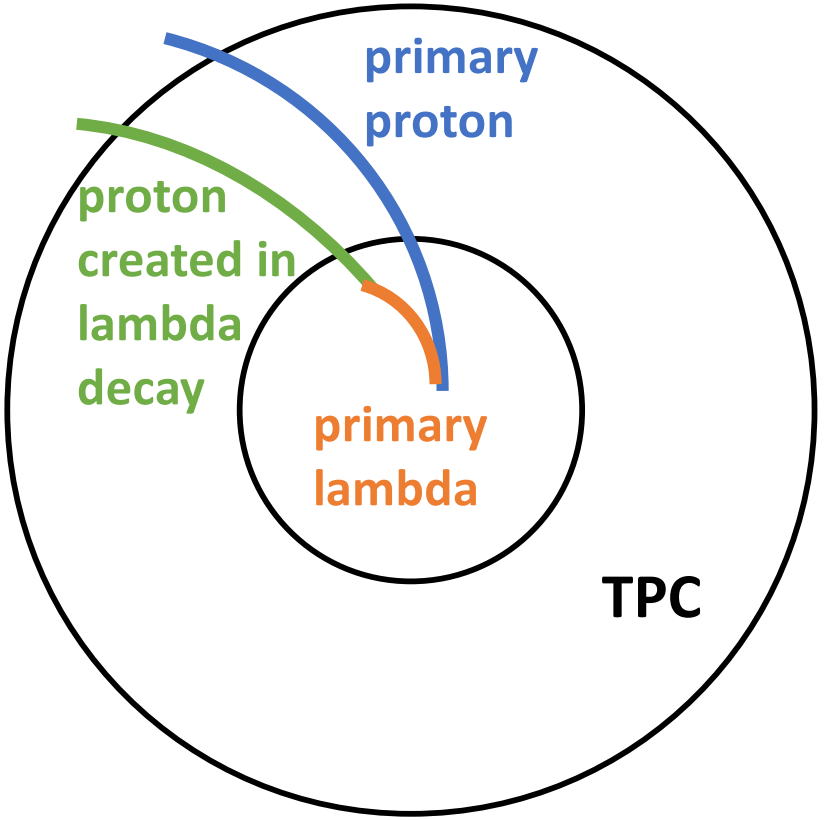
f – fraction

Proton-Lambda CF





No femtoscopic information in model data!

Femtoscopic effects are added separately, after the simulation.

Example: Lednicky Model

Lednicky, Richard & Lyuboshits, V.L.
Effect of the final-state interaction on pairing correlations of particles with small relative momenta.
Sov. J. Nucl. Phys. (1982) 35:5.

39GeV data, based on Therminator II model

Residual correction

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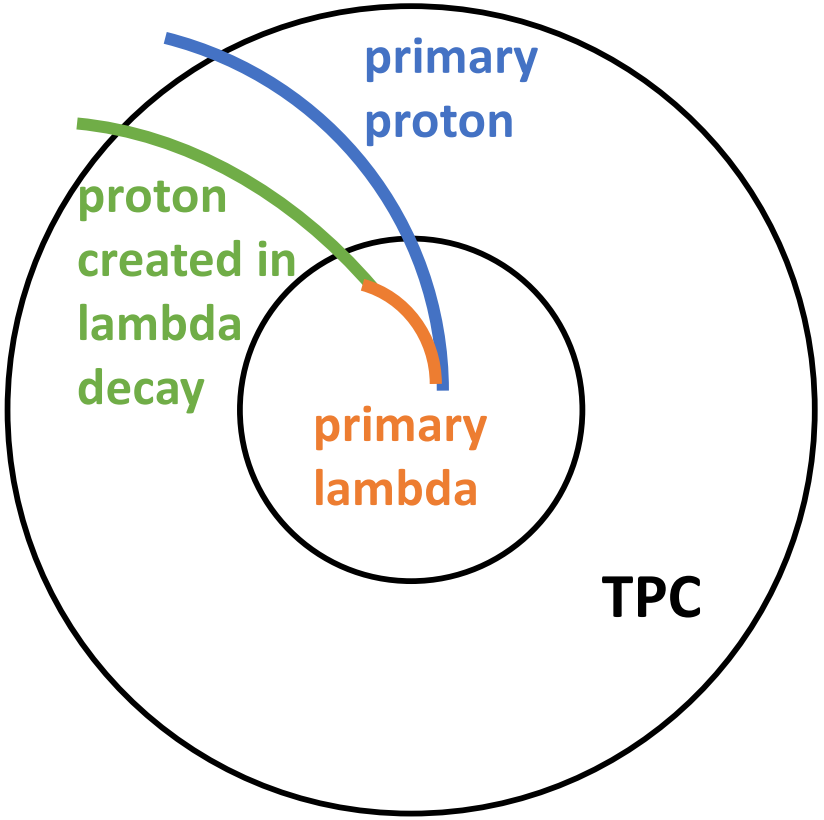
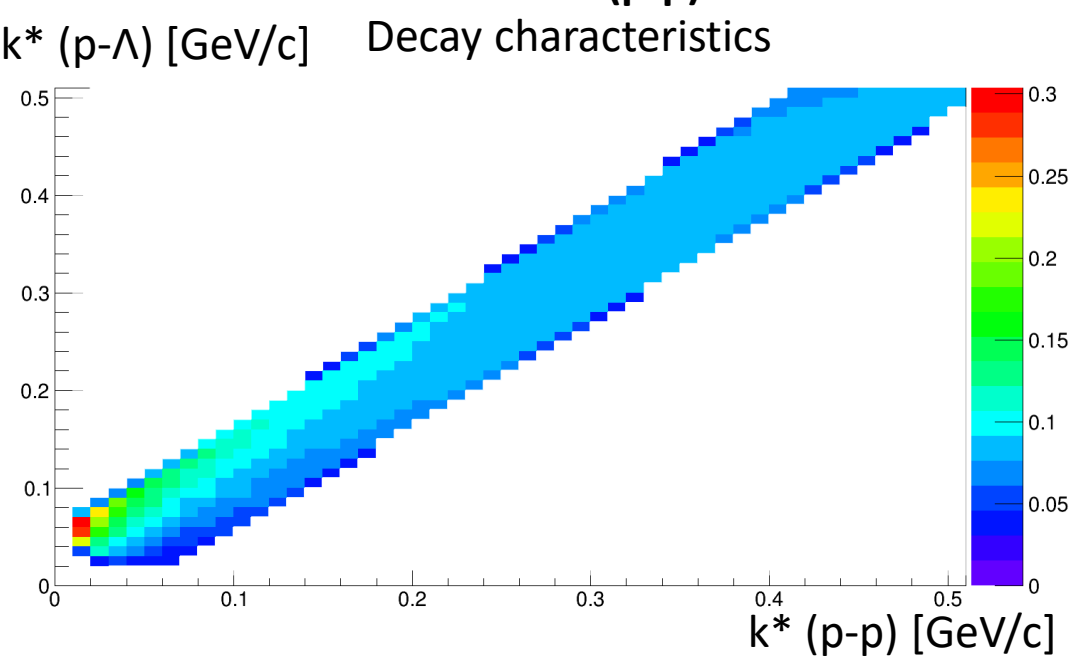


k* measured between Proton and Lambda characteristics are normalized for k* (p-p)



k* measured between Proton and Proton

39GeV data, based on Therminator II model

Residual correction

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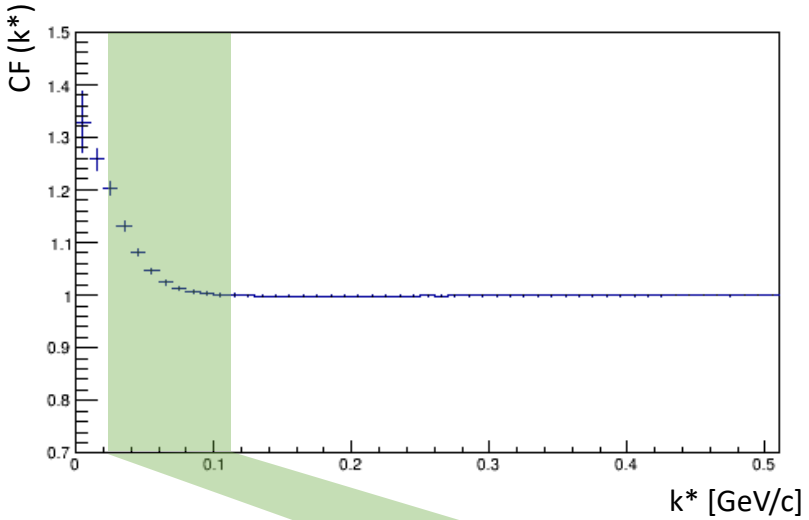
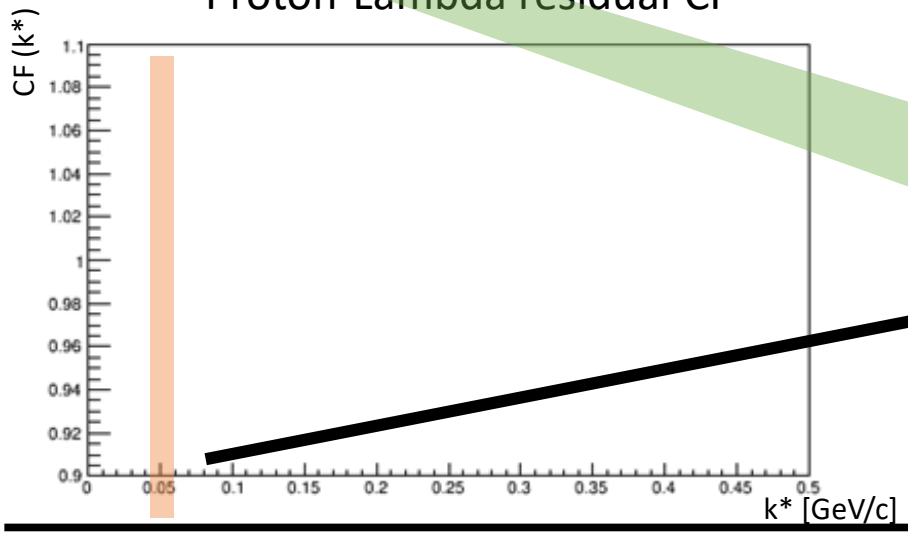
f – fraction

Proton-Lambda CF

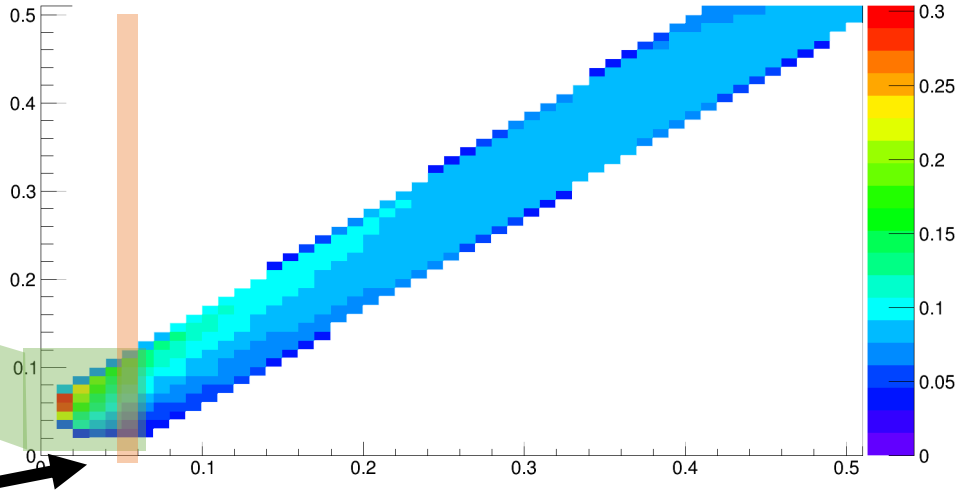


Proton-Lambda residual CF



k* (p-Λ) [GeV/c]

Decay characteristics



39GeV data, based on Therminator II model

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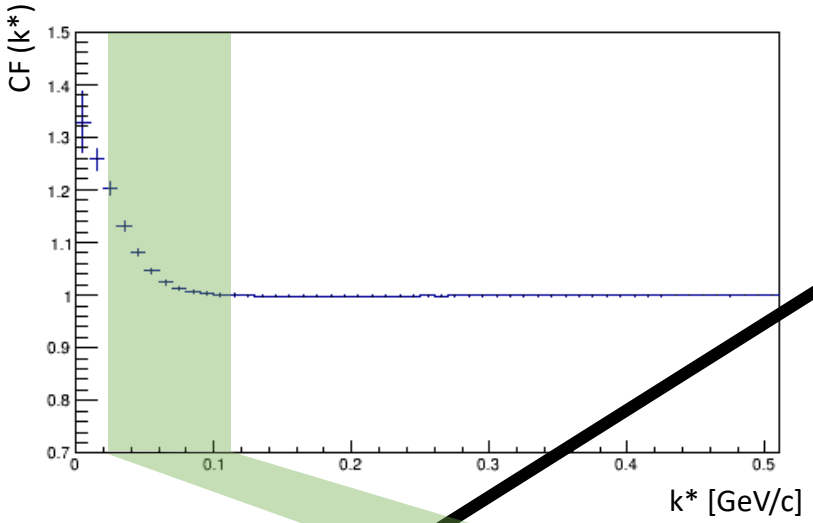
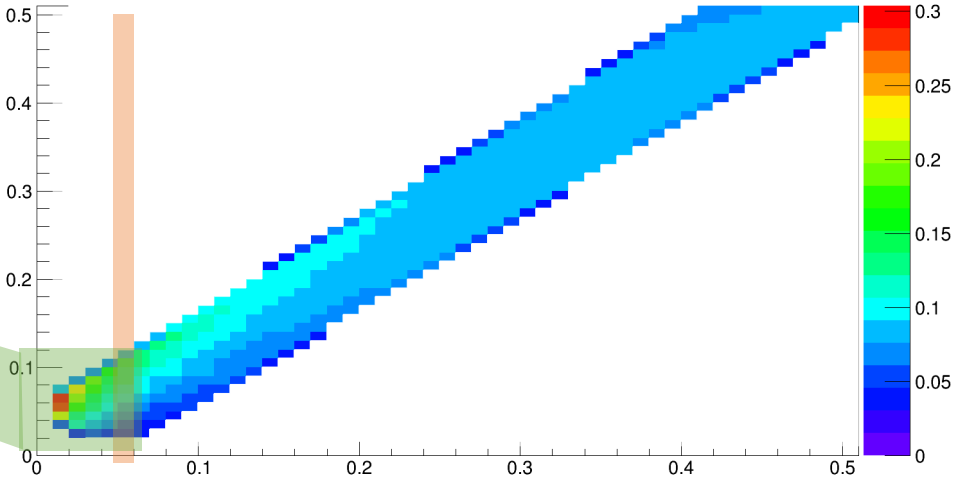
Proton-Lambda CF



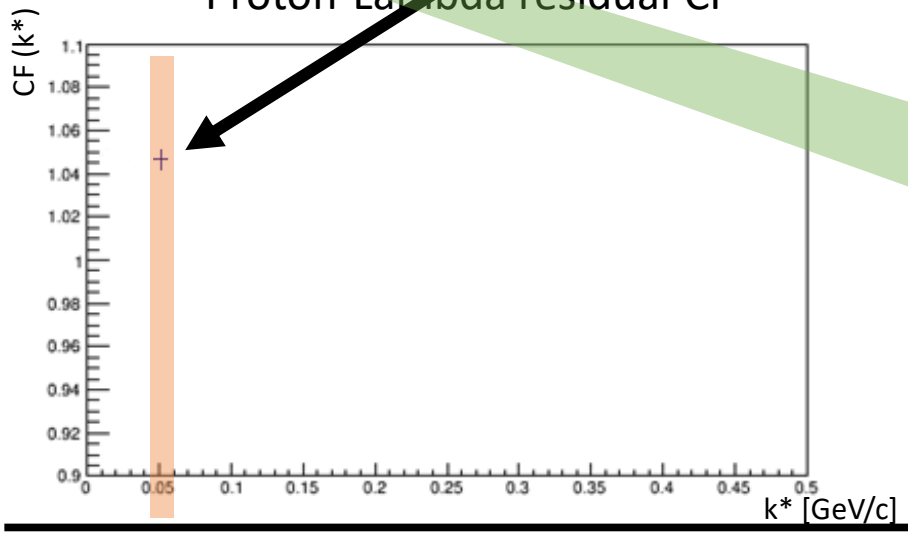
$$\boldsymbol{CF\left(k^*_{p-p}\right) = \sum_{k^*_{p-\Lambda}} CF\left(k^*_{p-\Lambda}\right) \times weight}$$

k* (p-Λ) [GeV/c]

Decay characteristics



Proton-Lambda residual CF



39GeV data, based on Therminator II model

Residual correction

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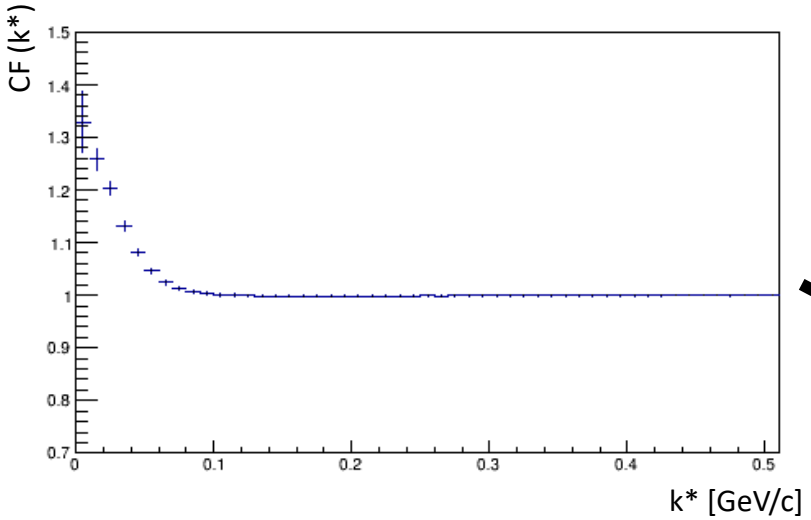
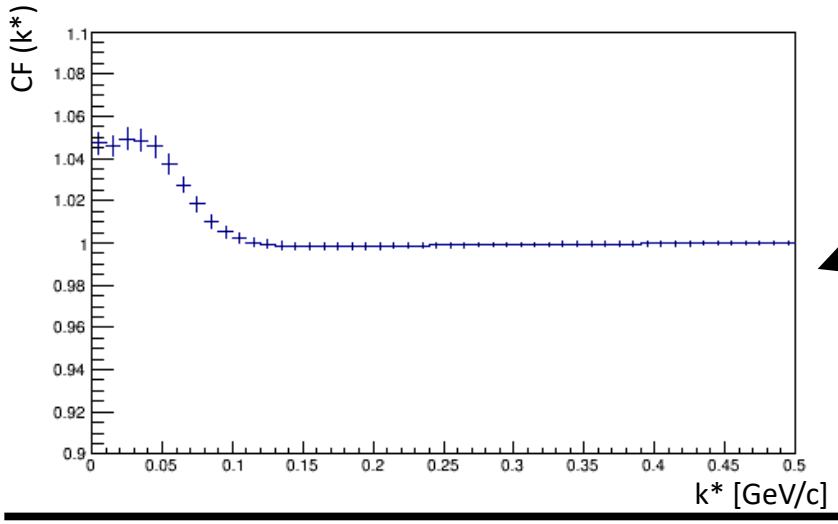
f – fraction

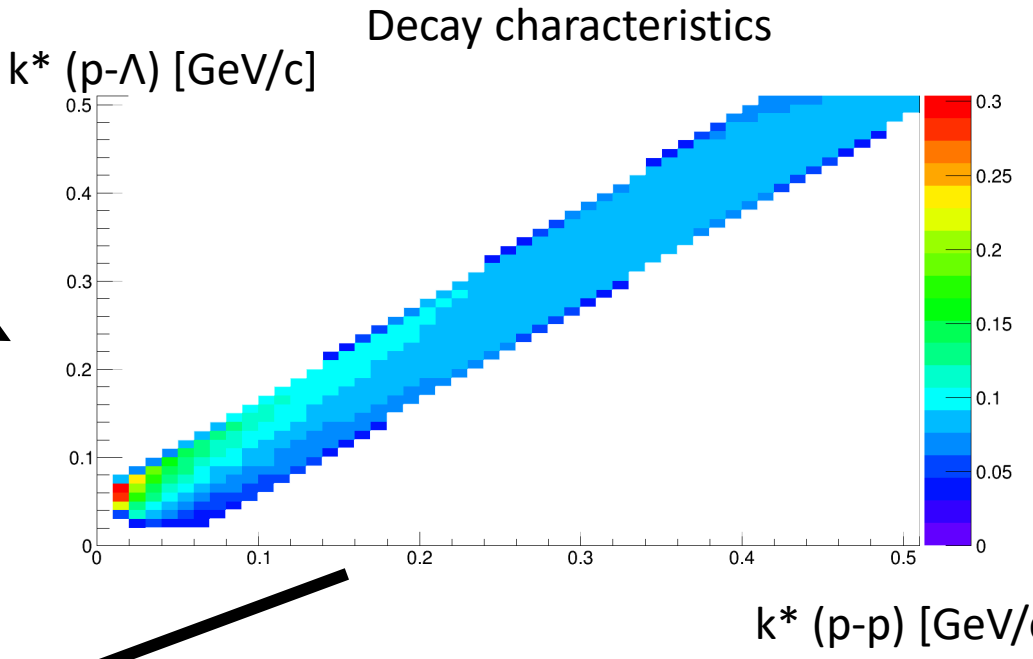
Proton-Lambda CF



Proton-Lambda residual CF



Decay characteristics

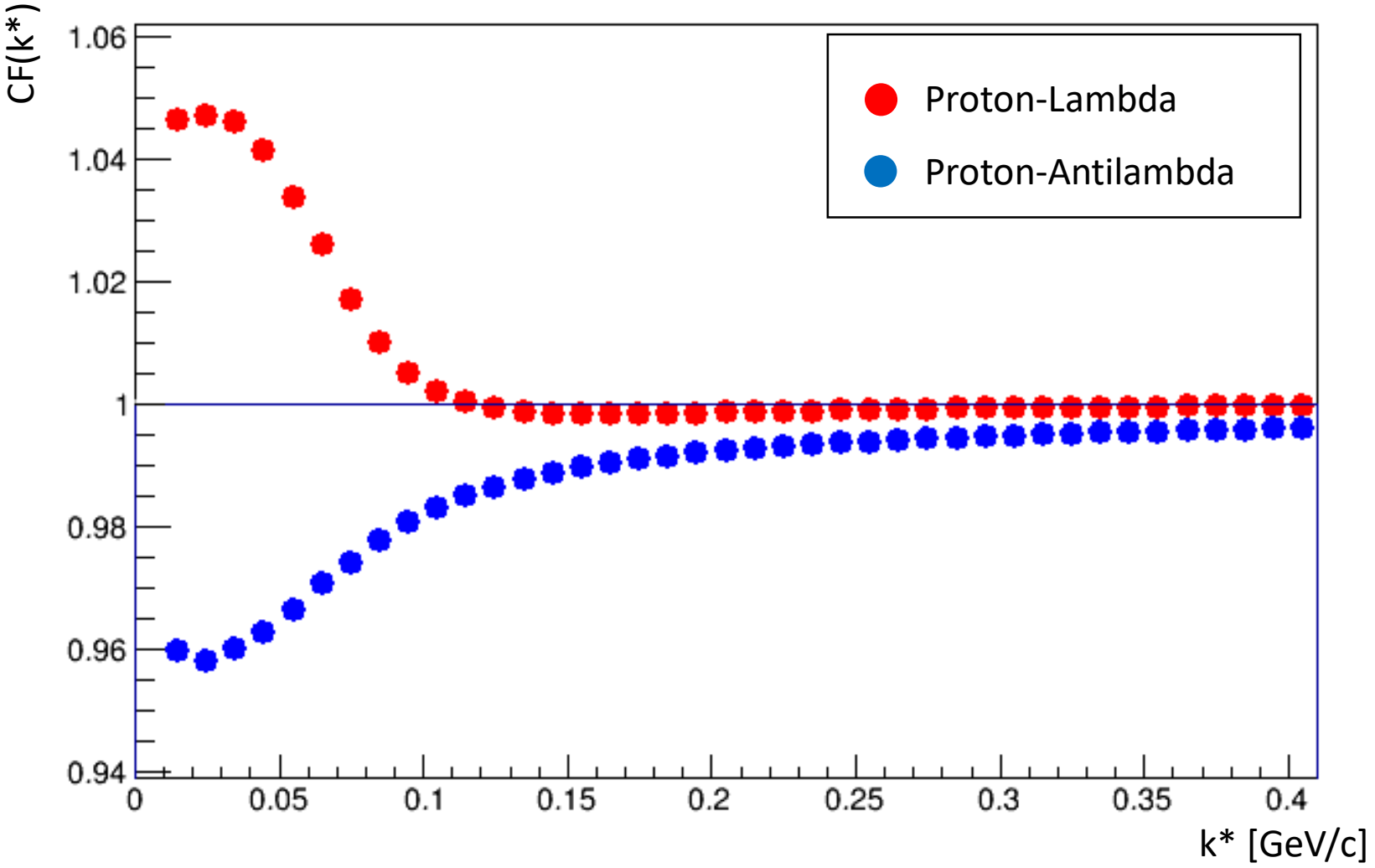


$$CF(k^*_{p-p}) = \sum_{k^*_{p-\Lambda}} CF(k^*_{p-\Lambda}) \times weight$$

39GeV data, based on Therminator II model

Residual correction – model results

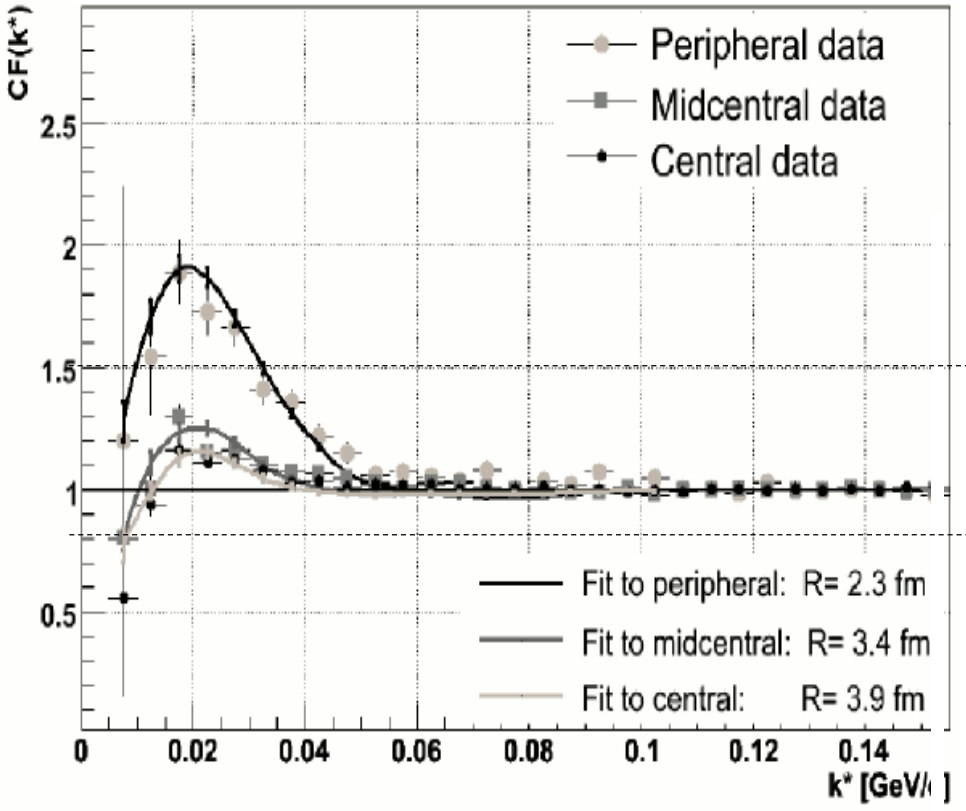
Residual correlations in Proton-Proton system for central Au+Au collisions @ 39GeV



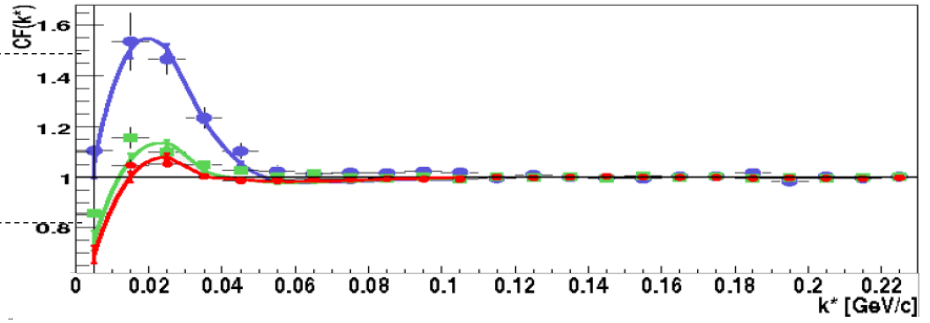
Residual correction – example from 200GeV analysis

$p - p$ @ Au+Au 200 GeV

Before corrections



After corrections



Centrality	R_{p-p} before	R_{p-p} after
central	3.89 ± 0.16 fm	4.51 ± 0.26 fm
mid-central	3.41 ± 0.15 fm	3.82 ± 0.20 fm
peripheral	2.31 ± 0.18 fm	2.71 ± 0.24 fm

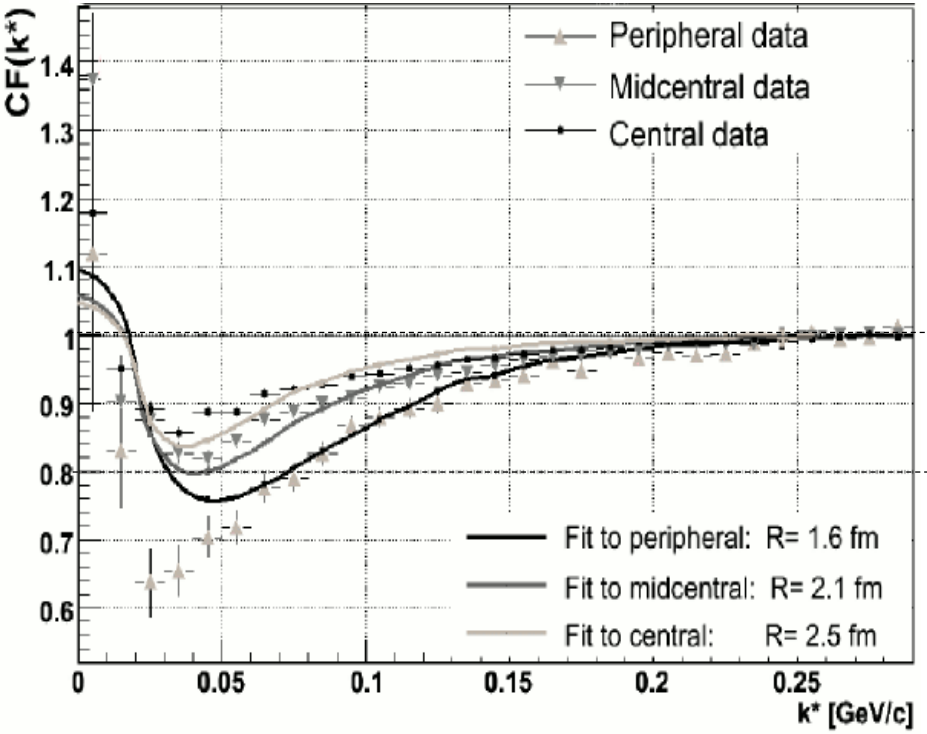
Data from 200GeV analysis

H. Zbroszczyk „Studies of Baryon-Baryon Correlations in Relativistic NuclearCollisions Registered at the STAR Experiment”

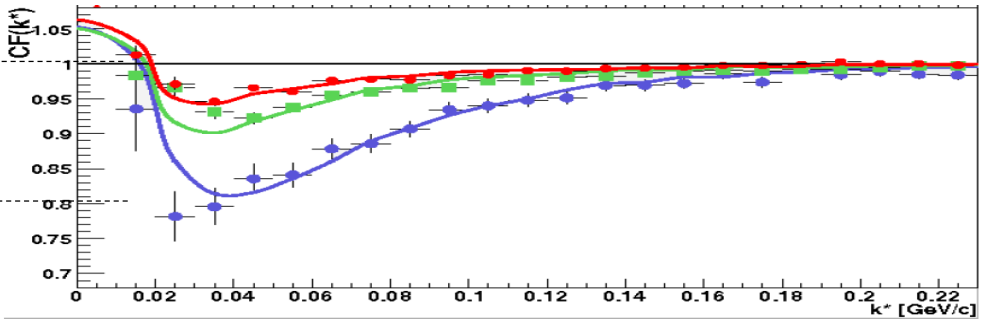
Residual correction – example from 200GeV analysis

$p - \bar{p}$ @ Au+Au 200 GeV

Before corrections



After corrections



Centrality	$R_{p-\bar{p}}$ before	$R_{p-\bar{p}}$ after
central	2.48 ± 0.14 fm	4.08 ± 0.19 fm
mid-central	2.14 ± 0.15 fm	3.27 ± 0.23 fm
peripheral	1.62 ± 0.14 fm	2.22 ± 0.25 fm

Data from 200GeV analysis

H. Zbroszczyk „Studies of Baryon-Baryon Correlations in Relativistic NuclearCollisions Registered at the STAR Experiment”

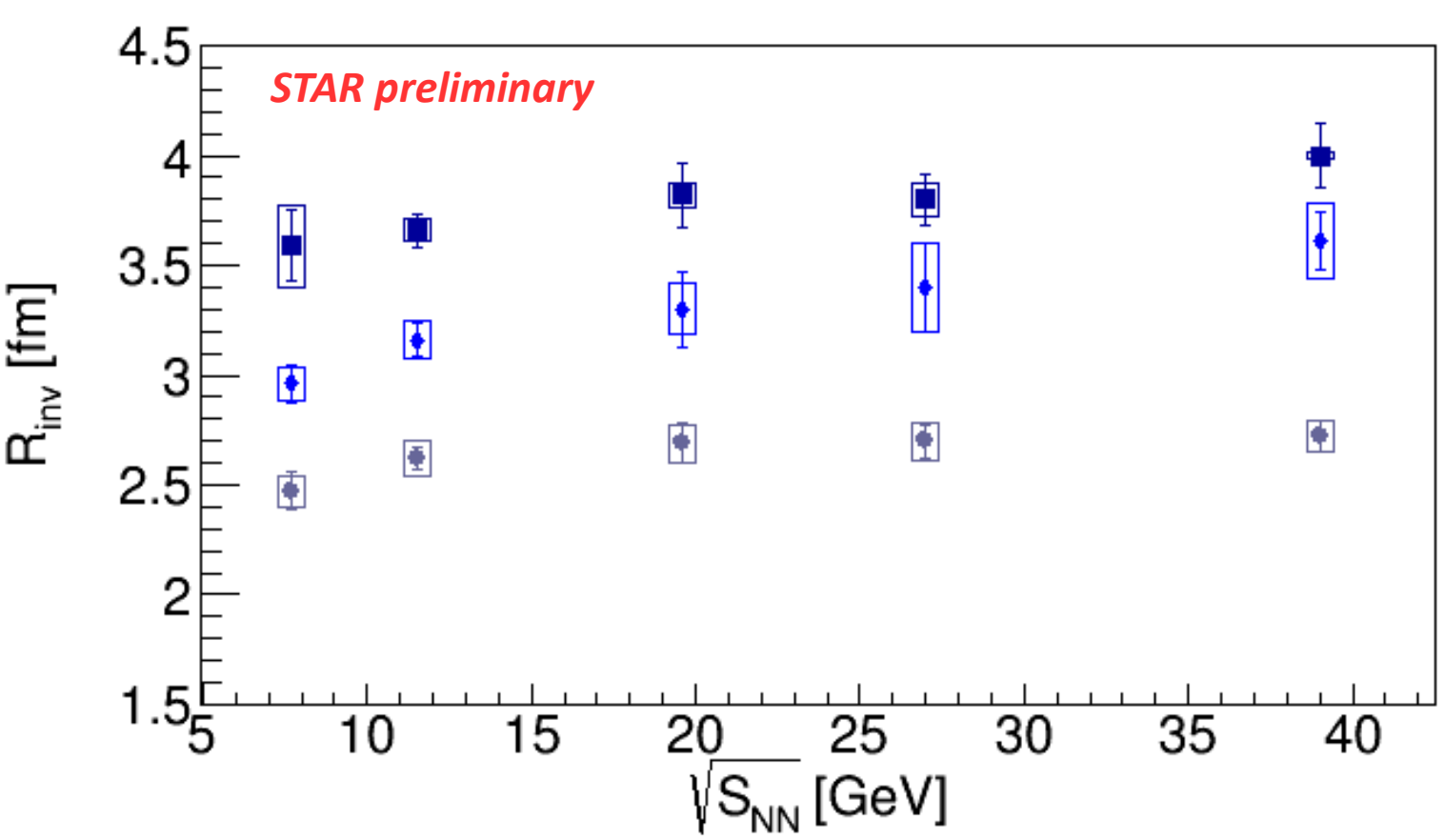
Summary

- Experimental data is contaminated by particles from weak decays
- Therminator II simulation suggests significant residual contamination in 39 GeV
- Different impact of residual correction on identical and non-identical systems
- Applying residual correction is necessary to obtain meaningful results

Thank you for your attention

BACKUP - Current status of analysis

R_{inv} dependence



$p-p$

0-10%

10-30%

30-70%

Feed-down correction may decrease significance of centrality dependence.

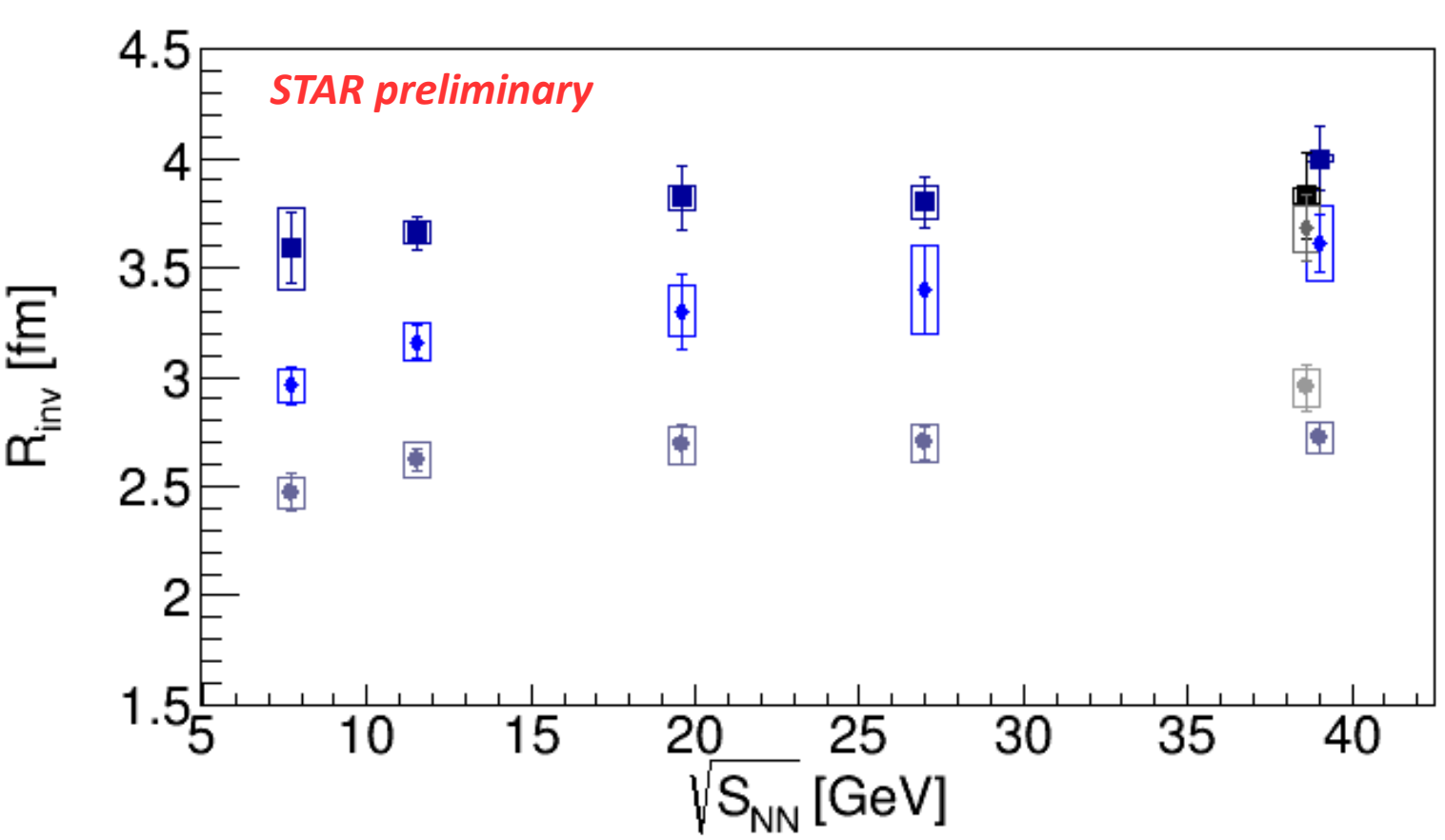
Significant centrality dependence.

$\sqrt{s_{NN}}$ dependence weak for all centralities.

QM 2018

BACKUP - Current status of analysis

R_{inv} dependence



$p - p$

$\bar{p} - \bar{p}$

0-10%

10-30%

30-70%

No significant difference between $p - p$ and $\bar{p} - \bar{p}$ correlation functions at $\sqrt{s_{NN}}$ = 39 GeV

Feed-down correction may decrease significance of centrality dependence.

Significant centrality dependence.

$\sqrt{s_{NN}}$ dependence weak for all centralities.

QM 2018

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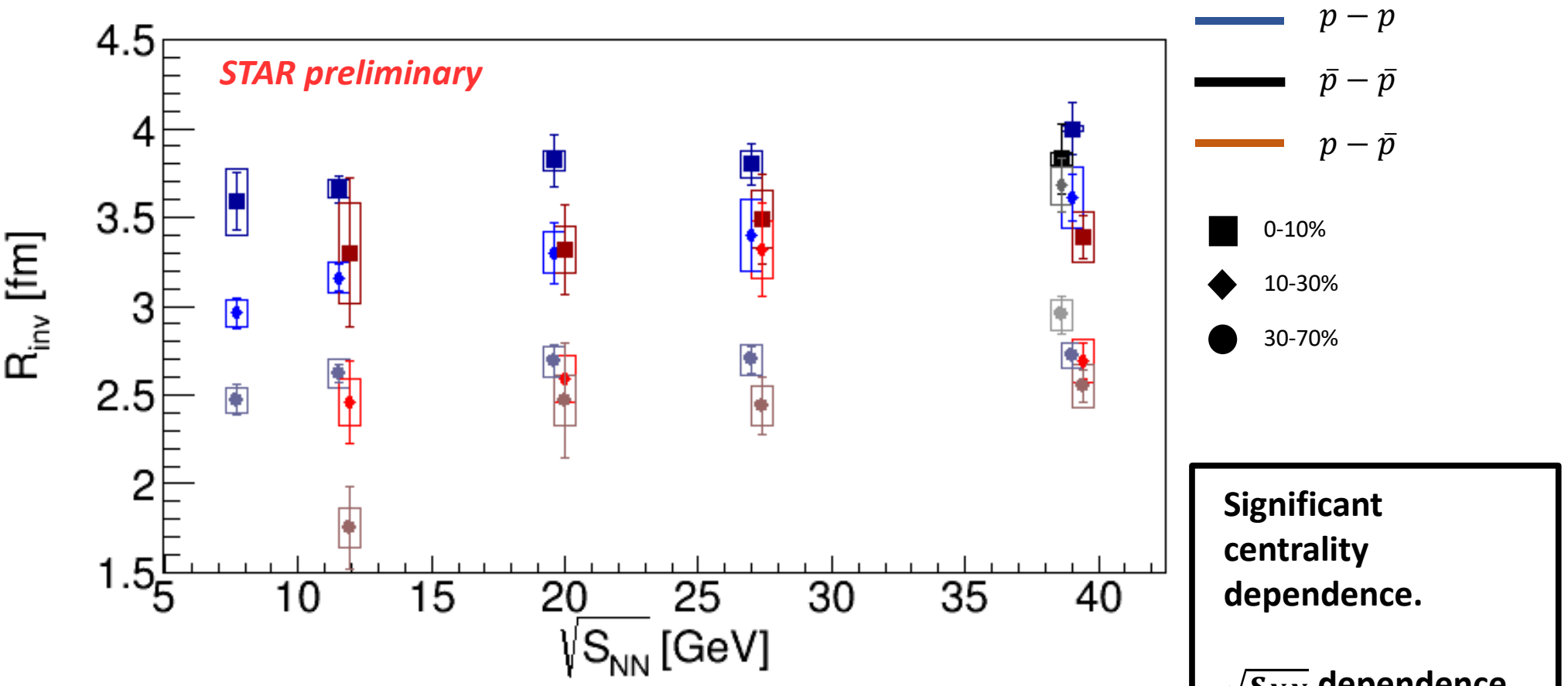

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