Warsaw University of Technology

Faculty of Physics

MDC wires effect on measured like-sign pion correlation function in AgAg collisions at $\sqrt{s_{NN}} = 2.55$ GeV

Anna Kodym

Outline

Motivation

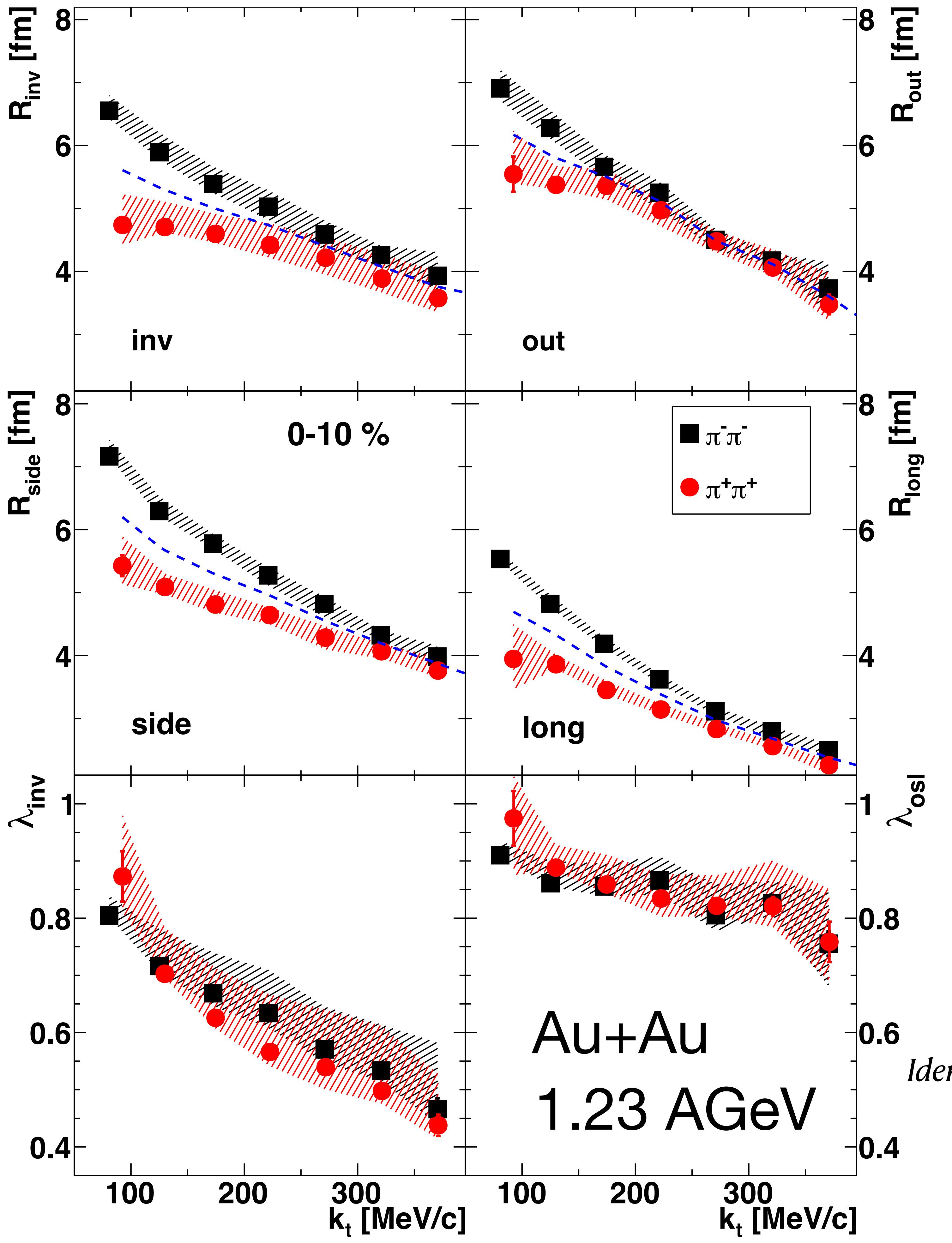
Base Femtoscopy

Data Analysis

Wire Analysis

Current Status

Motivation

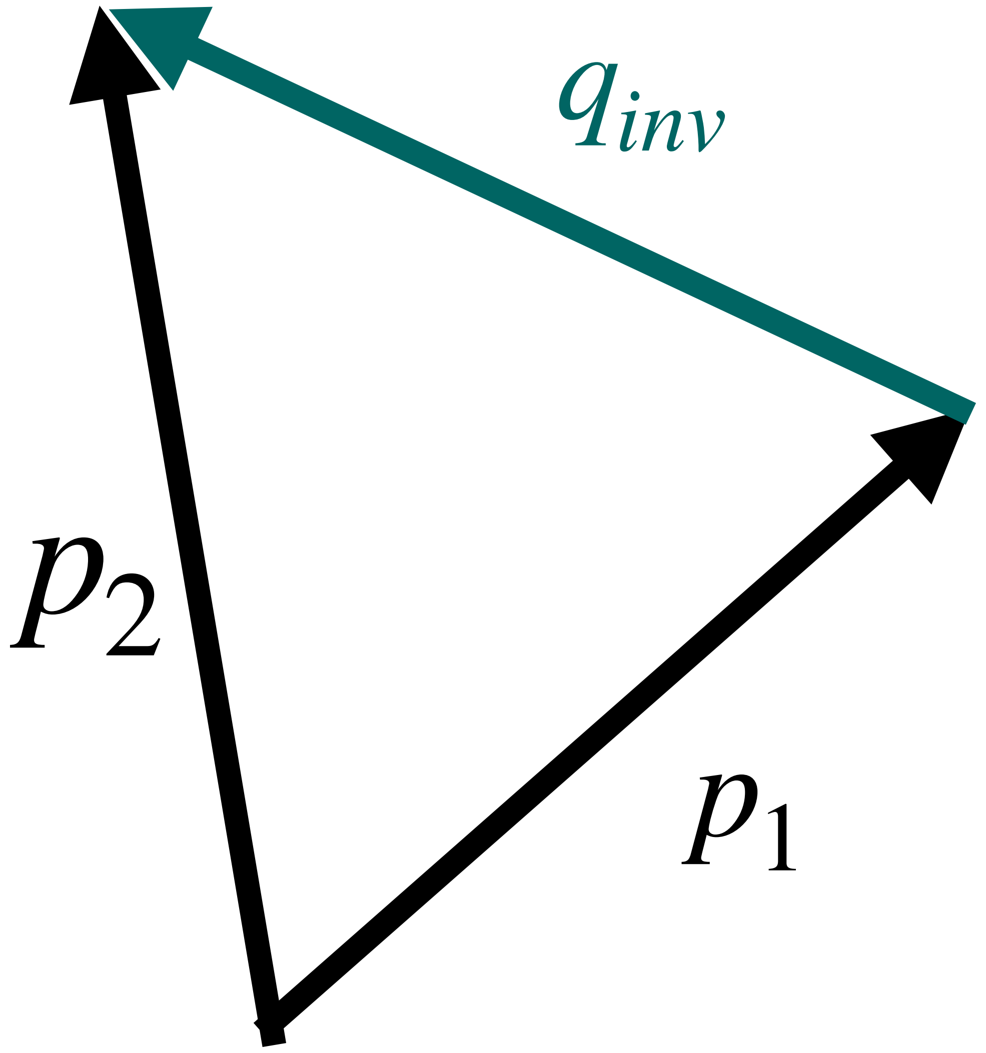


Removal of detector effects from measured data

See pion **correlations** change with charge and Coulomb asymmetry

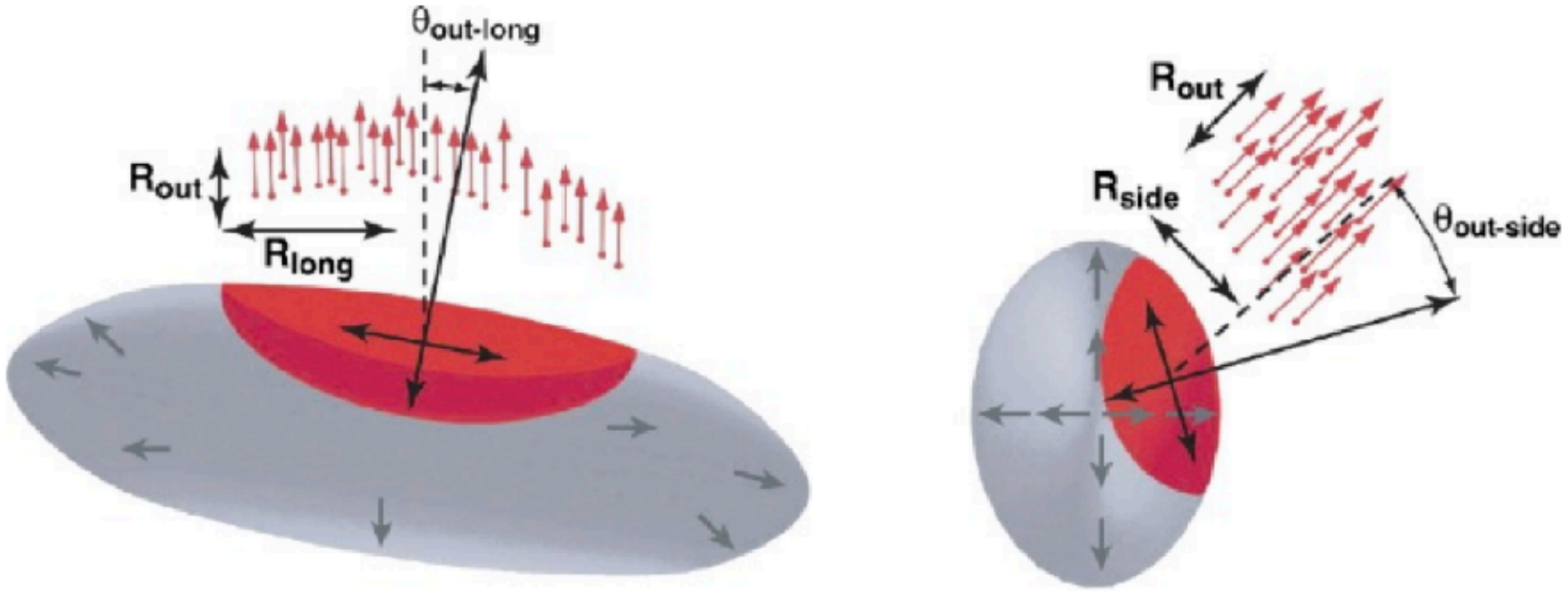
Source:
Identical pion intensity interferometry in central Au+Au collisions at 1.23 AGeV, Phys. Lett. B 795 (2019) 446
Eur. Phys. J. A 56, 140 (2020)

Femtoscopy



Identical particles

Metod that lets us learn about particles source
space-time properties



Lisa MA, et al. 2005.
Annu. Rev. Nucl. Part. Sci. 55:357–402

LCMS - **L**ongitudinal **C**o-**M**oving **S**ystem, total momentum along beam axis equals zero

$$\overrightarrow{p_{1,L}} = -\overrightarrow{p_{2,L}}$$

Base information

Source function:

- Spatial map of the particle source at freeze out

Wave function:

- Description of relative state of particle pair
- Quantum mechanics and final state interactions

Correlation function:

- Ratio: probability of observing particle pair / probability of observing two individual particles
- Carries information about source

Femtoscopy

Two-particle wave function - *assumed*

For pion pairs: **Coulomb force** as strong interaction is negligible

Correlation function - *measured*

experiment

$$C(q,r) = \int S(r)\,|\psi(q,r)|^2\,d^3r = \frac{Sgnl(q)}{Bckg(q)}$$

Koonin-Pratt equation

Source function - *determined*

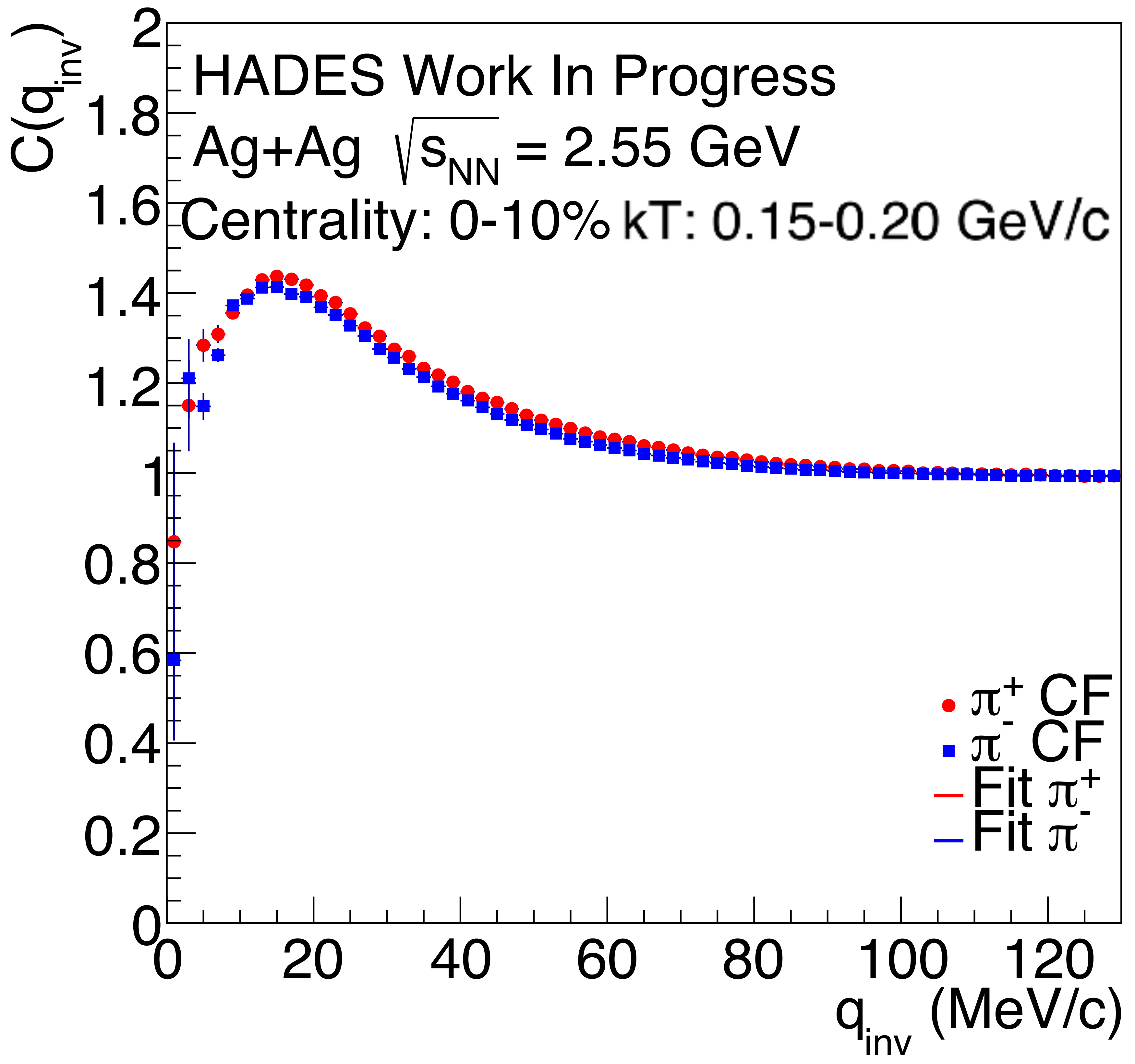
effect of analysis

Sgnl(q) → Pairs from same event

Bckg(q) → Pairs from different but similar events

Correlations functions

$$k_T = \frac{\sqrt{(p_{x1}+p_{x2})^2 + (p_{y1}+p_{y2})^2}}{2}$$



Correlations functions

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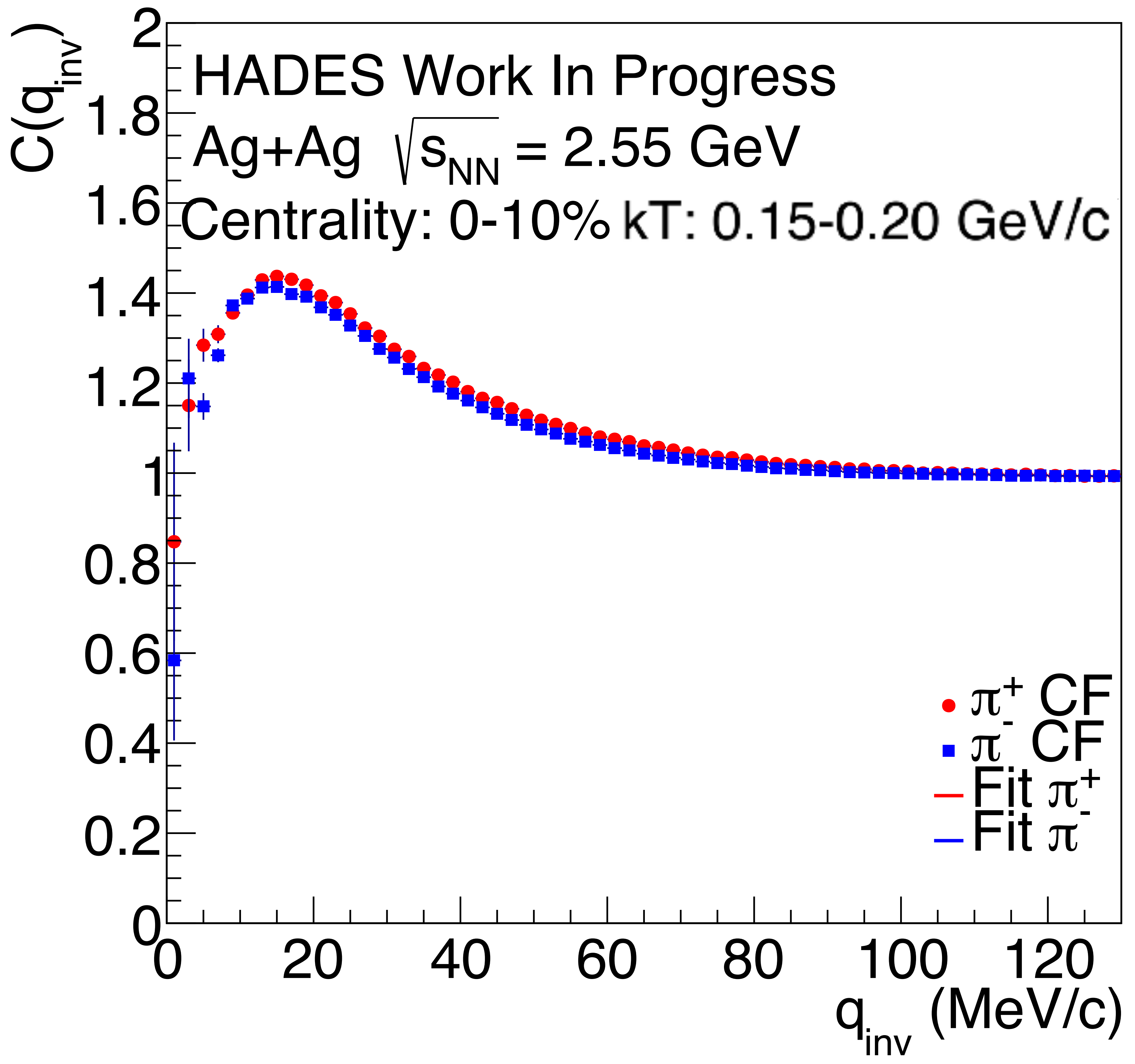
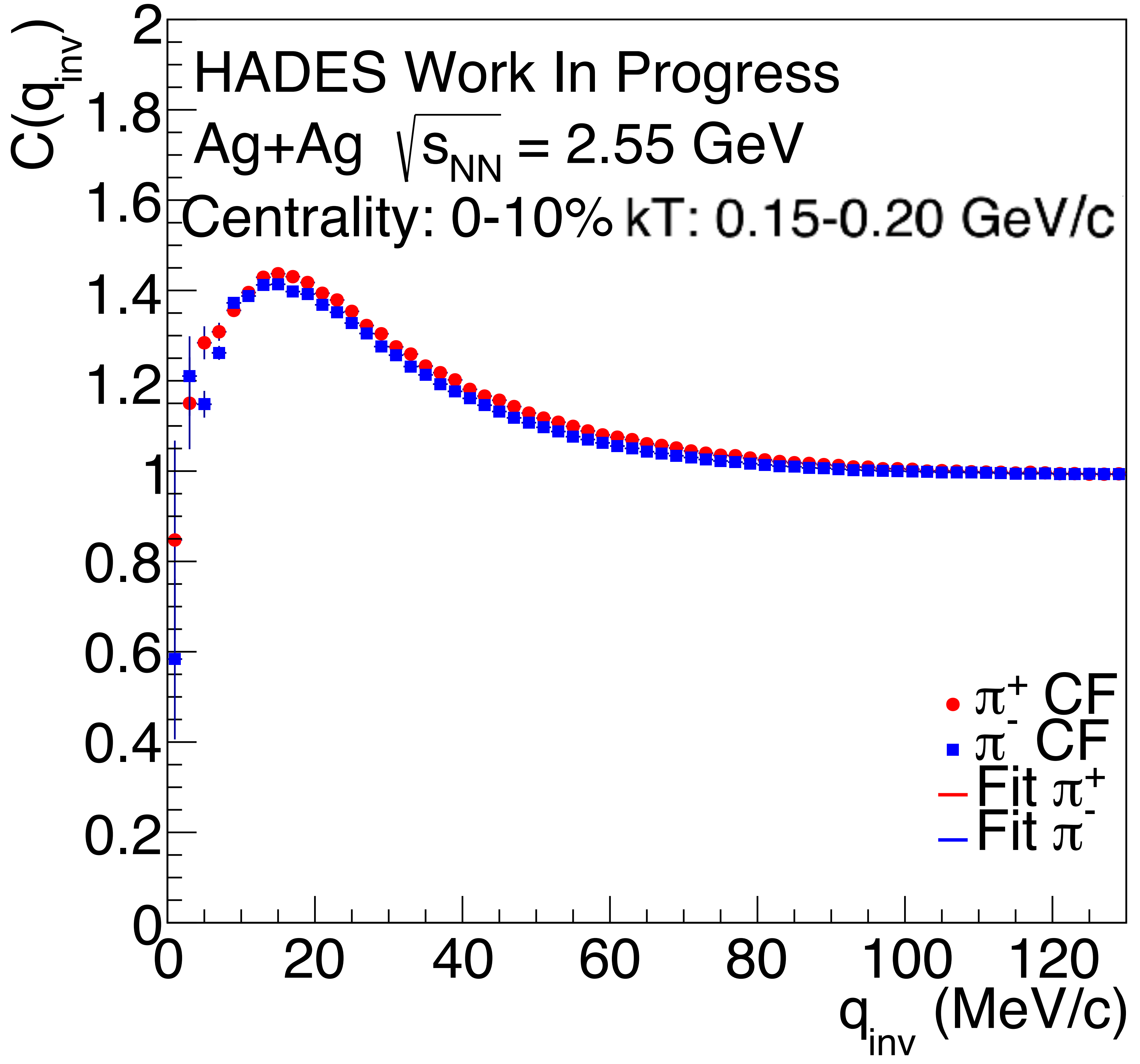


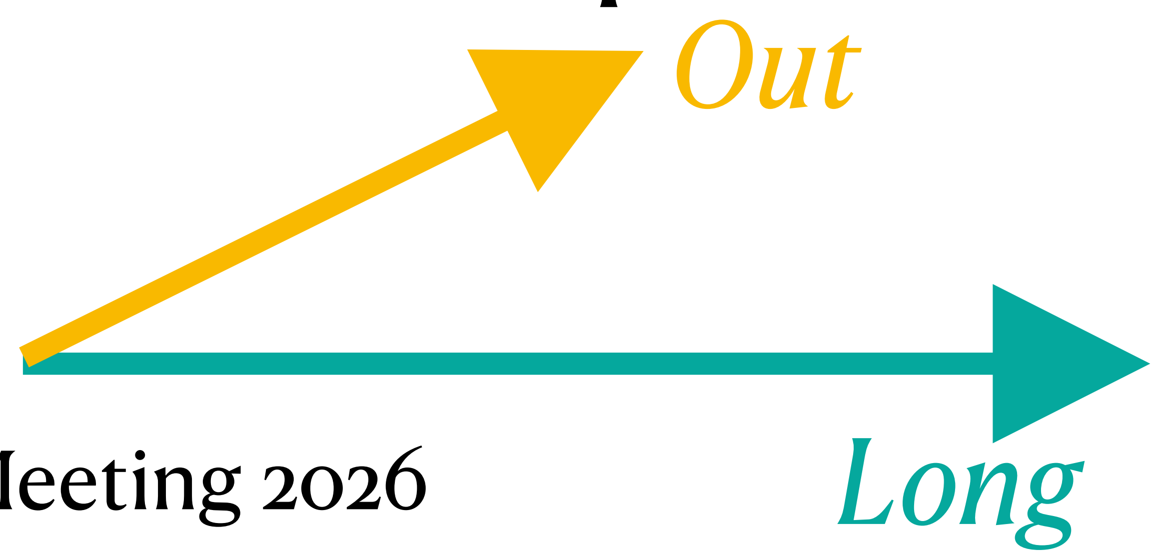
Long → Long direction is in beam direction

Correlations functions

$$k_T = \frac{\sqrt{(p_{x1}+p_{x2})^2+(p_{y1}+p_{y2})^2}}{2}$$



Out direction is the same as pair transverse momentum



Long direction is in beam direction

Correlations functions

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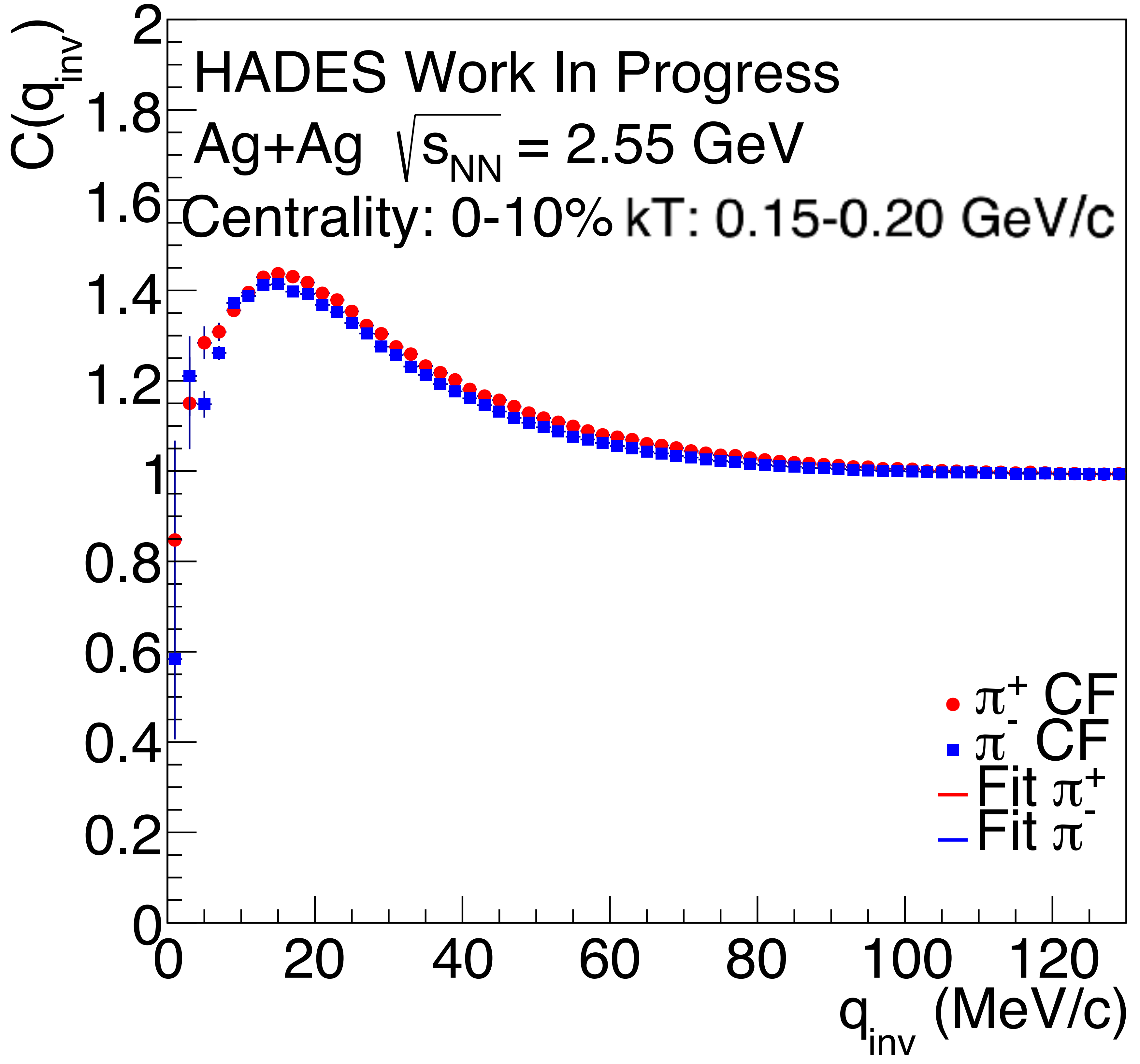
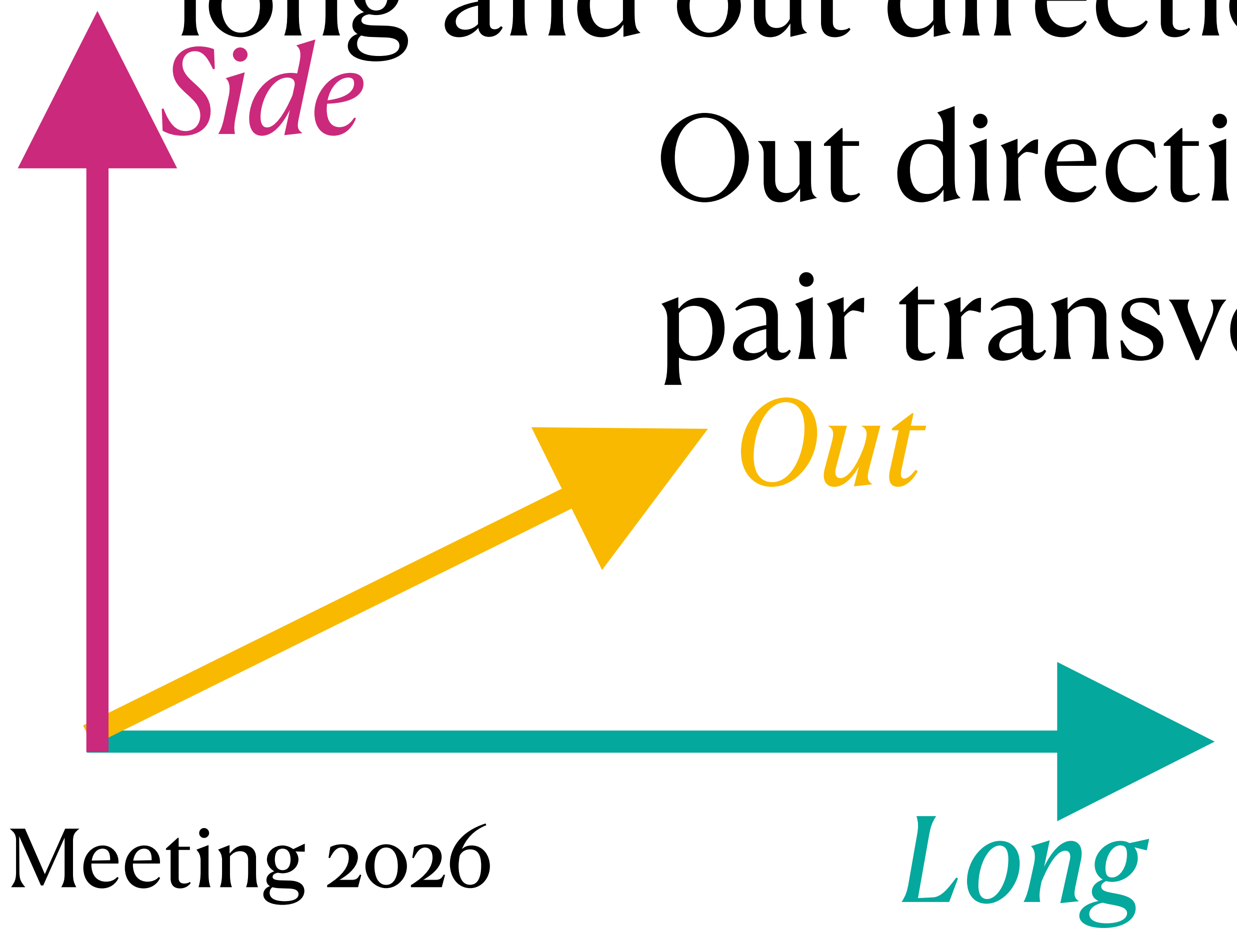


Side is perpendicular to long and out direction

Out direction is the same as pair transverse momentum

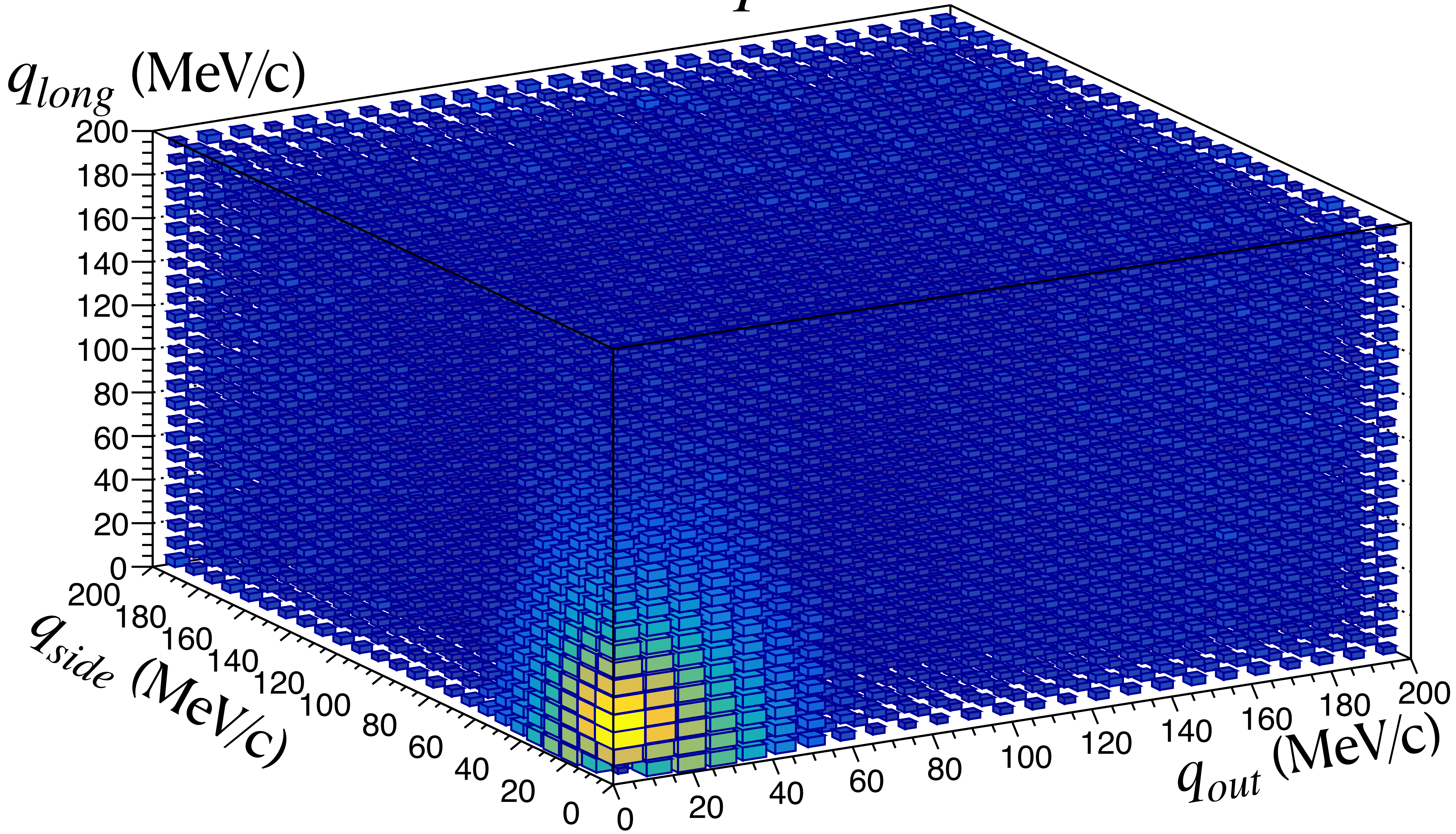
Long direction is in beam direction

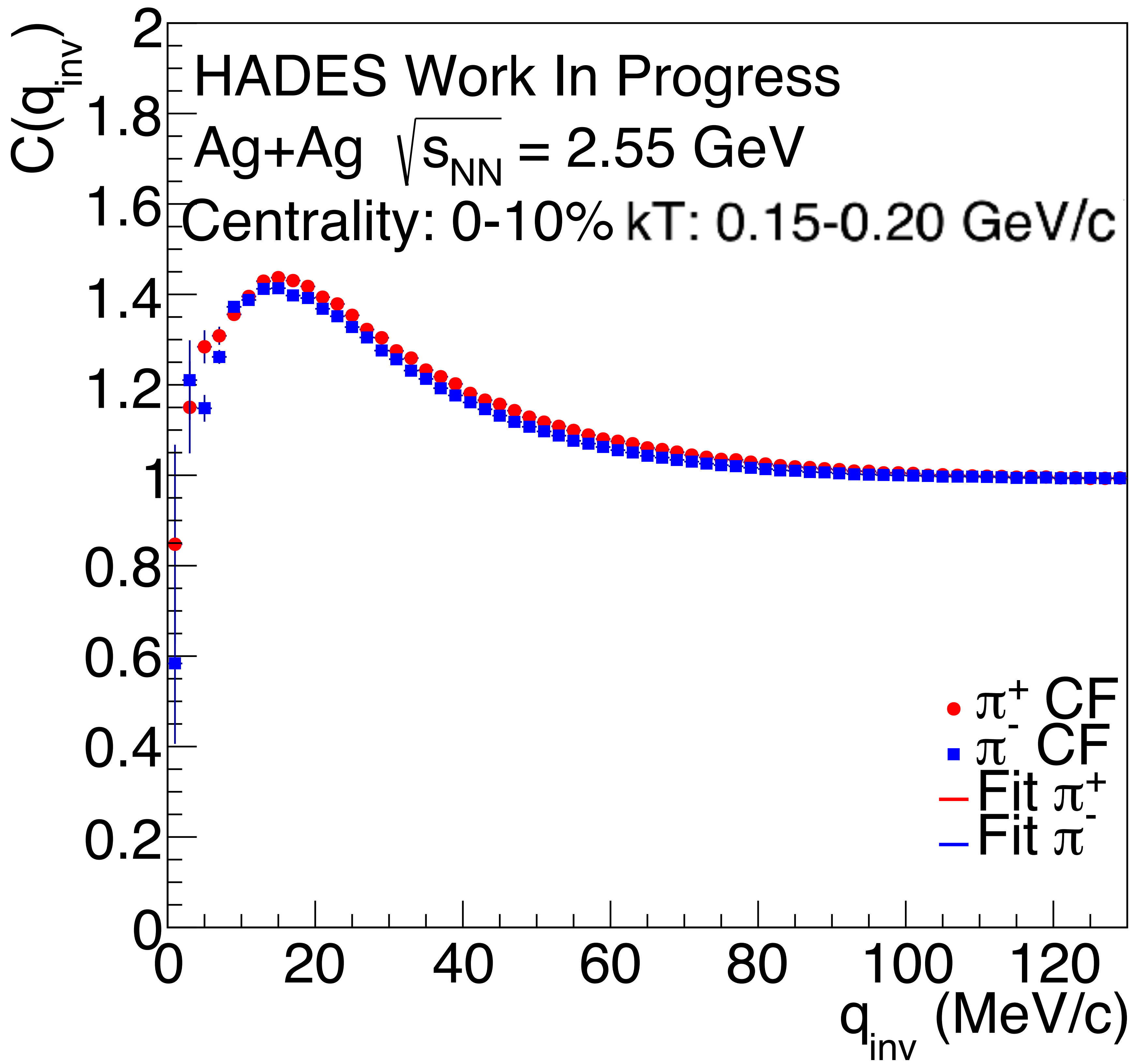


Correlations functions

$$k_T = \frac{\sqrt{(p_{x1}+p_{x2})^2 + (p_{y1}+p_{y2})^2}}{2}$$

$\pi^+\pi^+$ cen=0-10% k_T = 0.15-0.20 GeV/c





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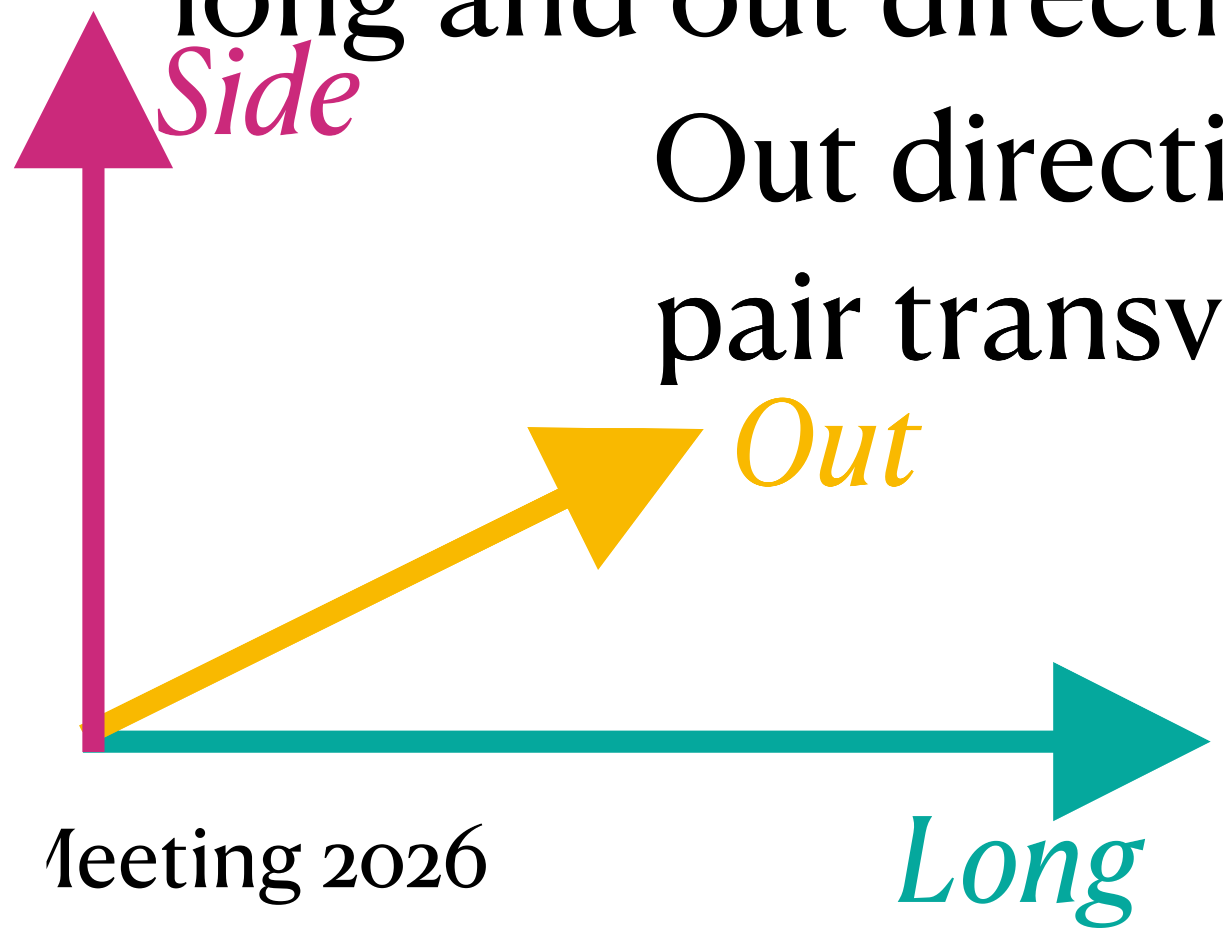
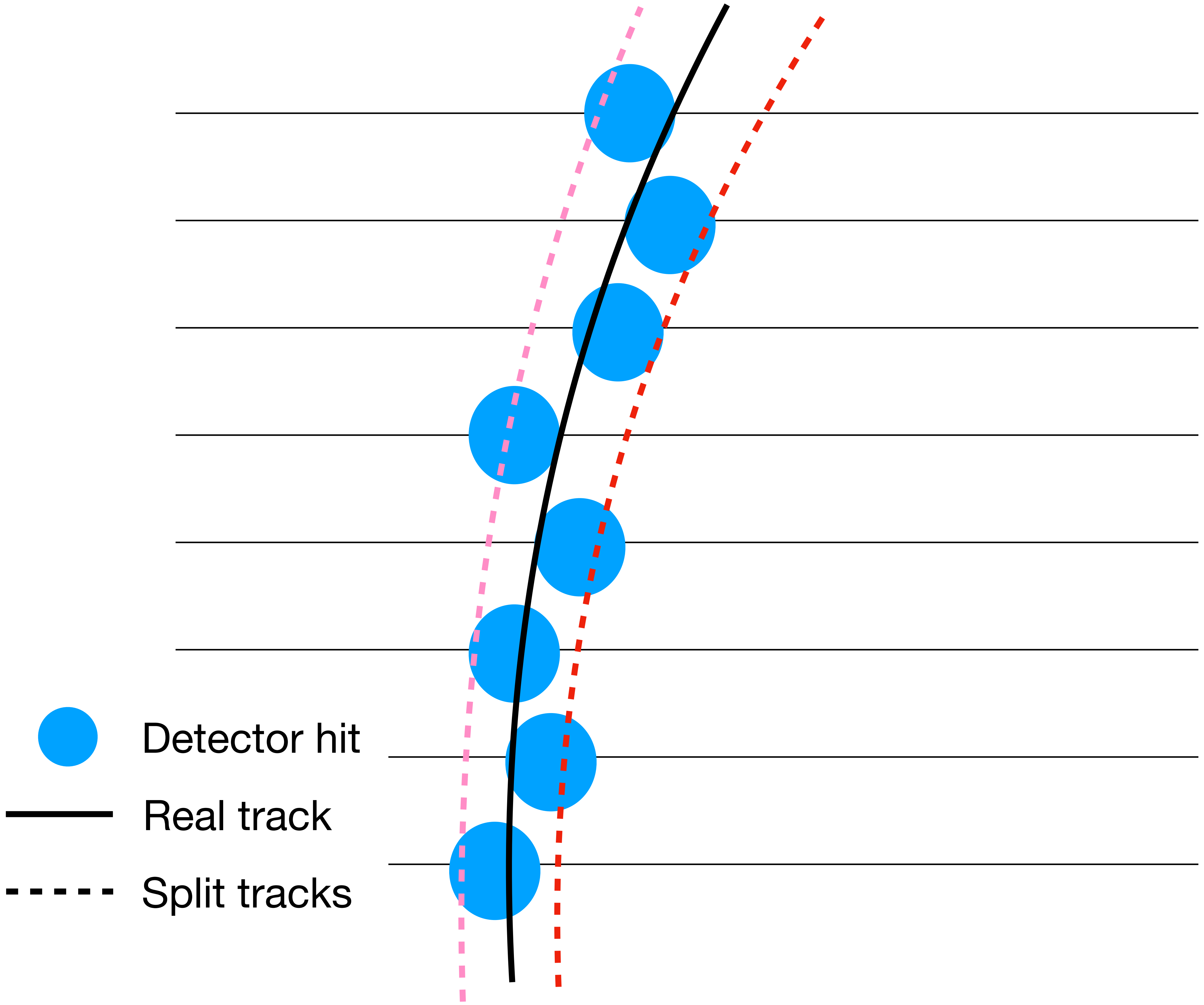
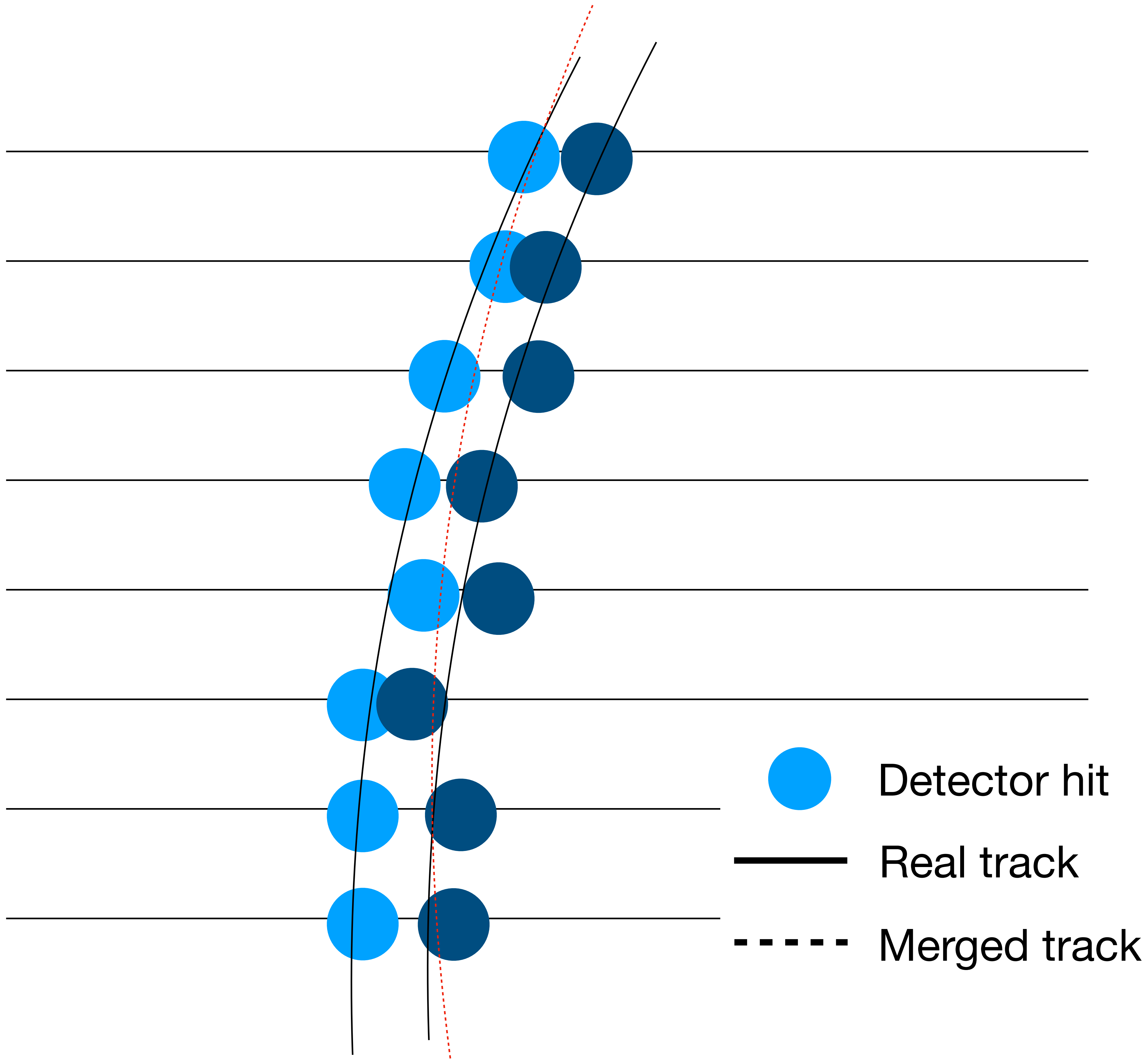


Detector Effects

Splitting:



Merging:



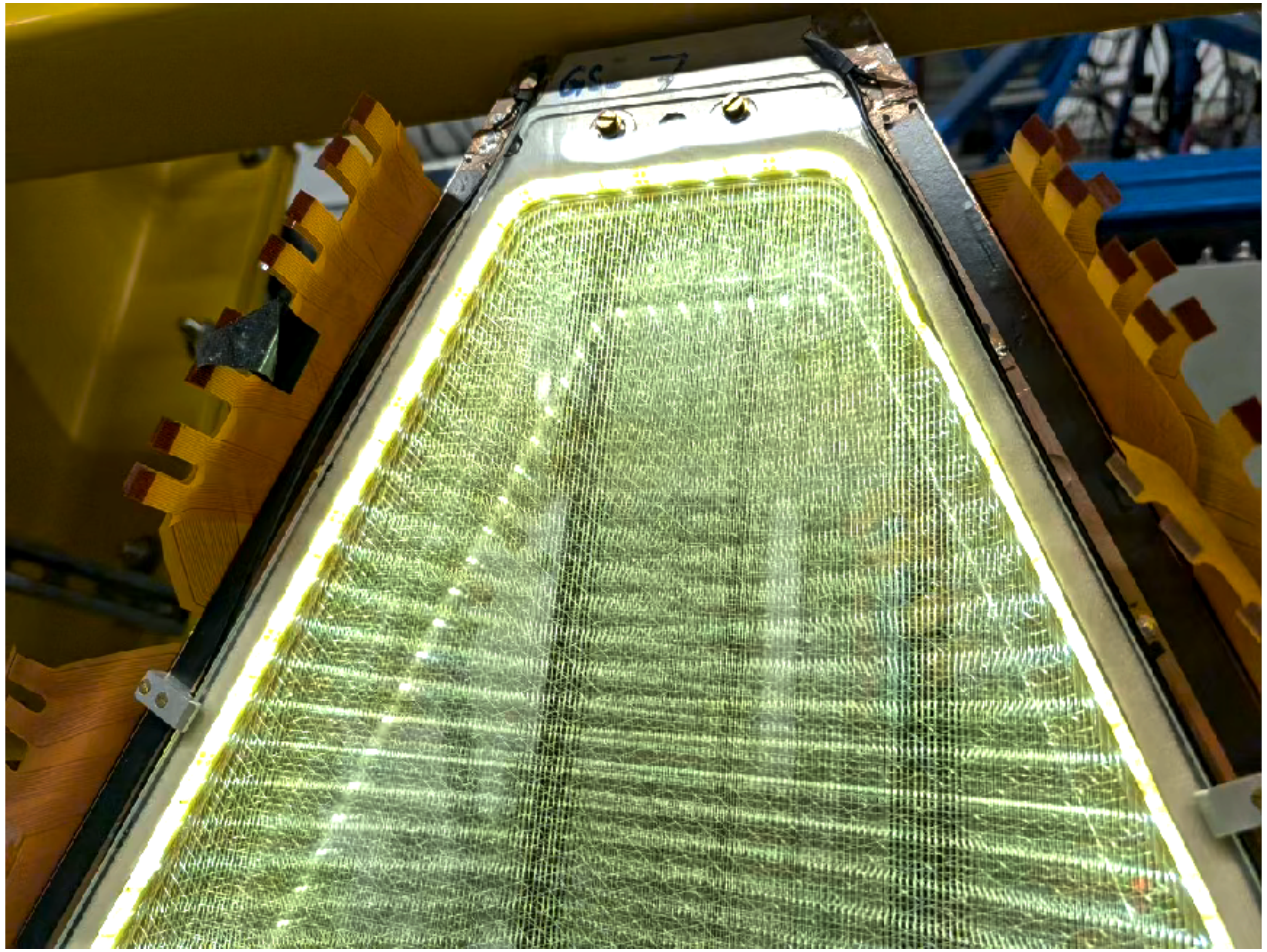
Detector cut

Using **M**ultiwire **D**rift **C**hambers (**MDC**) detector

Used value:

Distance between hit wires

Default **separation** distance is set on 2 wires



Source: *https://hades.gsi.de/node/43*

Data analysis parametrization

Bowler-Sinyukov approach:

- Takes **Coulomb** interactions into account **instead of subtracting** them
- **Well suited** for **like-sign** pion pairs
- For **1D** case:

$$C(q_{inv}) = (1 - \lambda_{inv}) + \lambda_{inv} K_C(q_{inv}, R_{inv}) e^{-(q_{inv} R_{inv})^2}$$

- For **3D** case

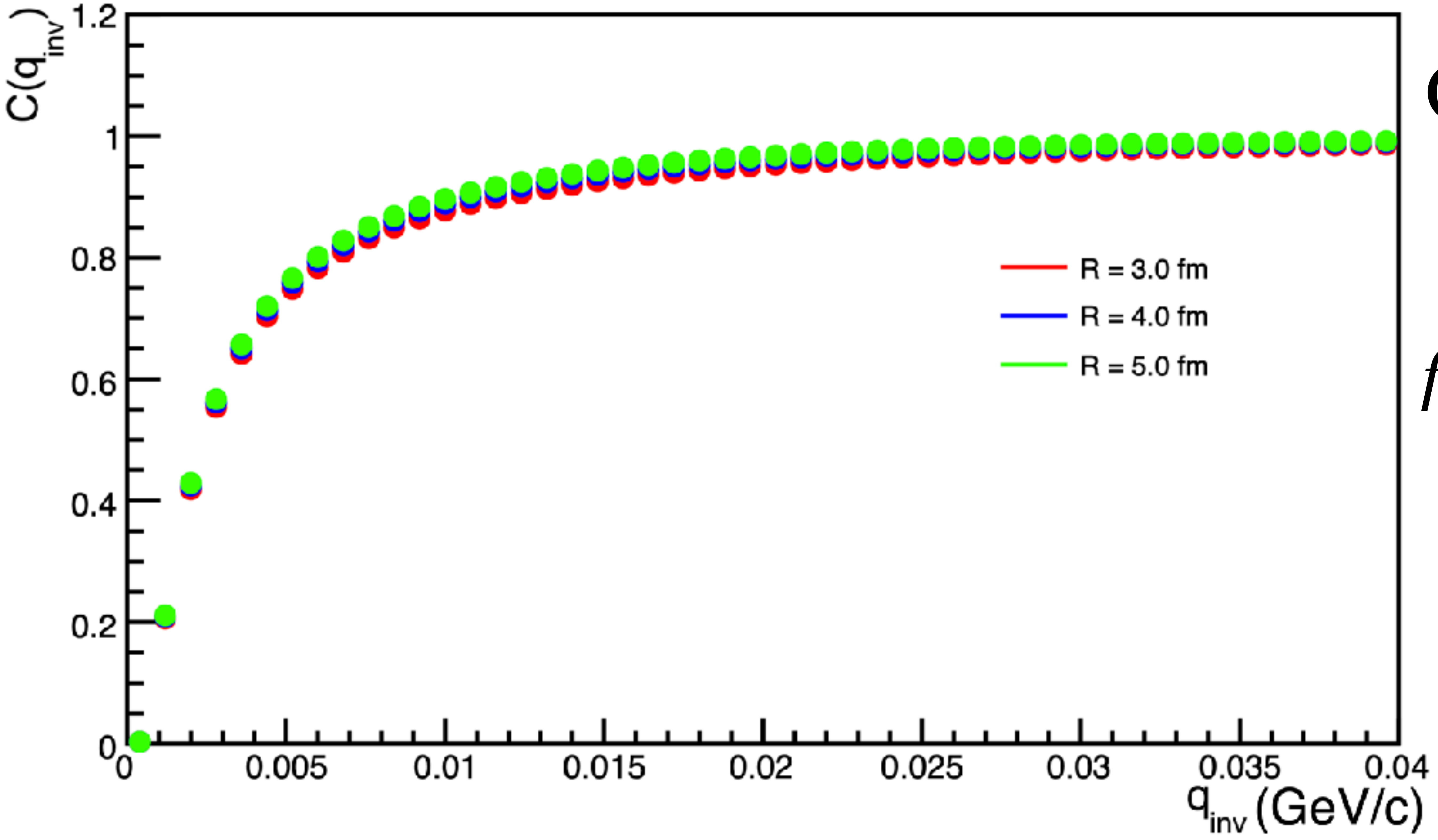
$$C(q_{out}, q_{side}, q_{long}) = (1 - \lambda_{osl}) + \lambda_{osl} K_C(q, R_{inv}) (1 + e^{-(q_{out}R_{out})^2 - (q_{side}R_{side})^2 - (q_{long}R_{long})^2})$$

Where K_C is simulated **Coulomb** function

Coulomb force

Included in Bowler-Sinyukov formula

Default radius value 5 fm



Generated using **HAL** software

HAL *- **H**eavy Ion **A**nalysis **L**ibraries, written by Daniel Wielanek, framework for analysis of the collisions of heavy ions*

https://wielanek.fizyka.pw.edu.pl/127.0.0.1_2222/wielanek/index.php/hal-framework.html

Almost **no difference** between different radii

Data selection

$$k_T = \frac{\sqrt{(p_{x1}+p_{x2})^2+(p_{y1}+p_{y2})^2}}{2}$$

Track selection:

β **- momentum** criteria with 2σ values

Pair selection:

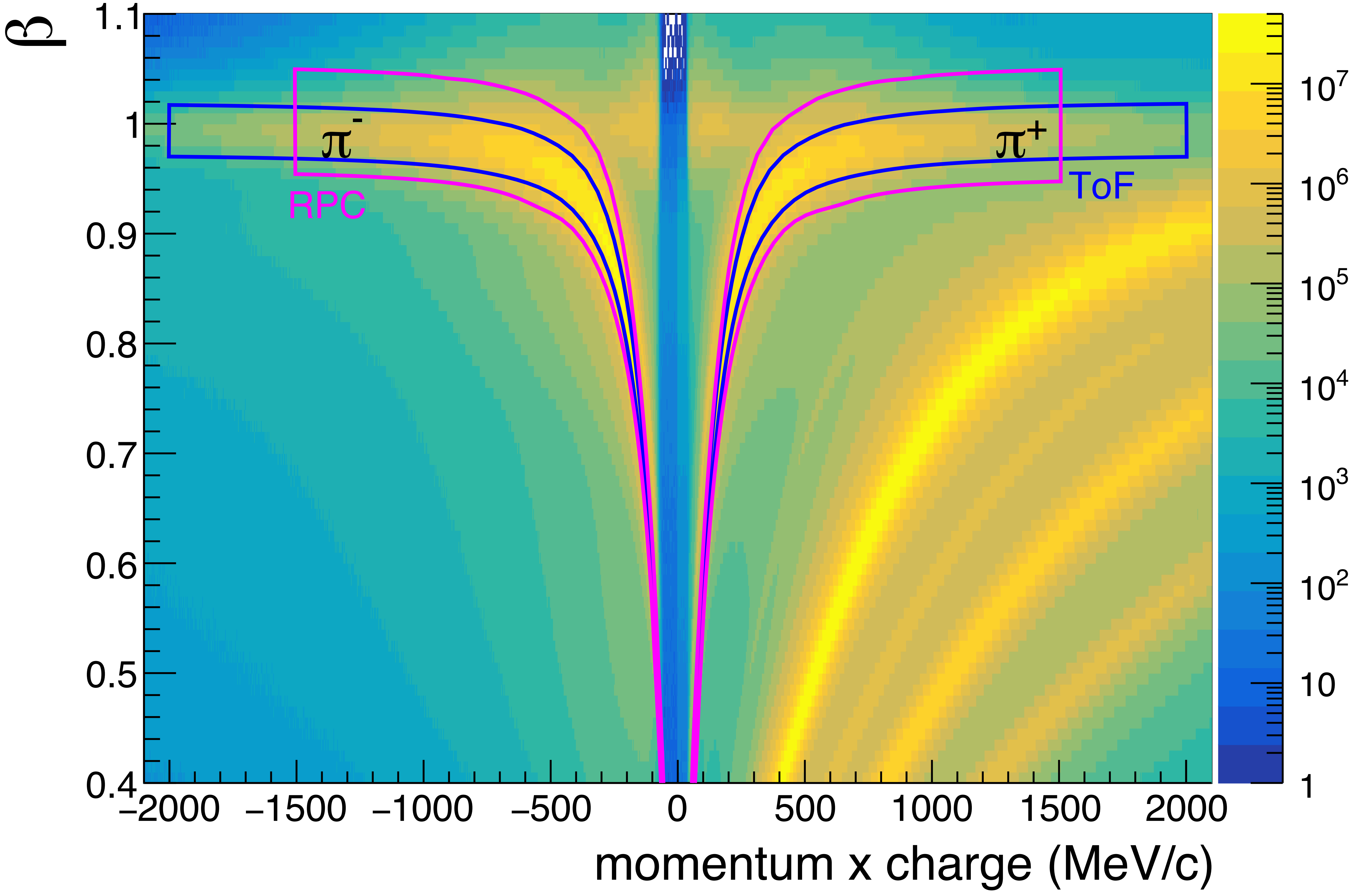
Detector cut: closest wire 2

k_T: 0.15-0.2, 0.2-0.25, 0.25-0.3, 0.3-0.35, 0.35-0.4, 0.4-0.45 GeV/c

Events selection:

Centrality classes:

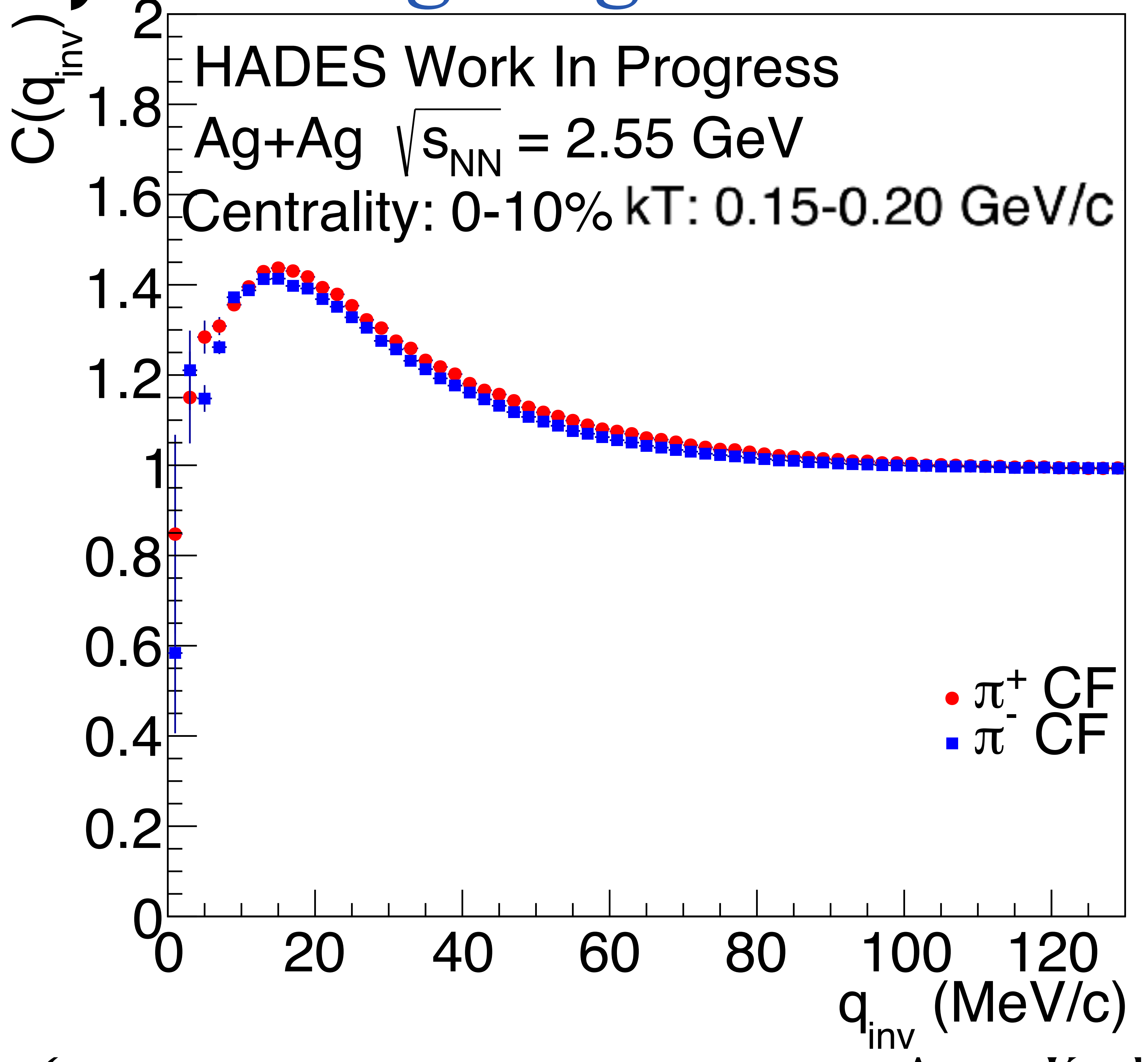
0-10%, 10-20%, 20-30%, 30-40%



Data analysis

Data:

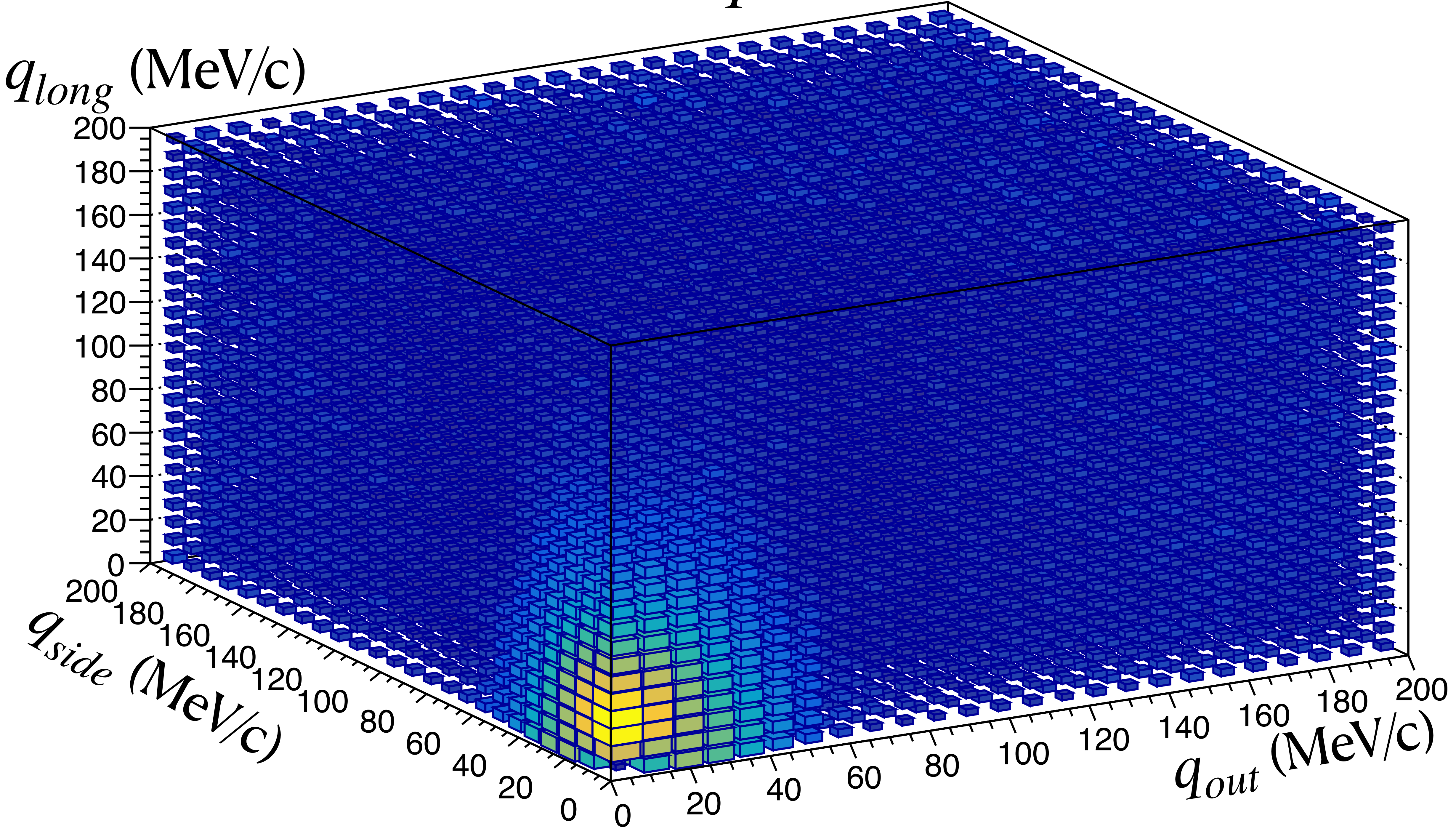
- **Energy**: $\sqrt{s_{NN}}$ = 2.55 GeV (1.58 AGeV)
- **System**: Ag + Ag collision



Analysis methods and parametrization:

- **1D** femtoscopy
- **3D** femtoscopy
- **Bowler-Sinyukov** approach

$\pi^+\pi^+$ cen=0-10% k_T = 0.15-0.20 GeV/c

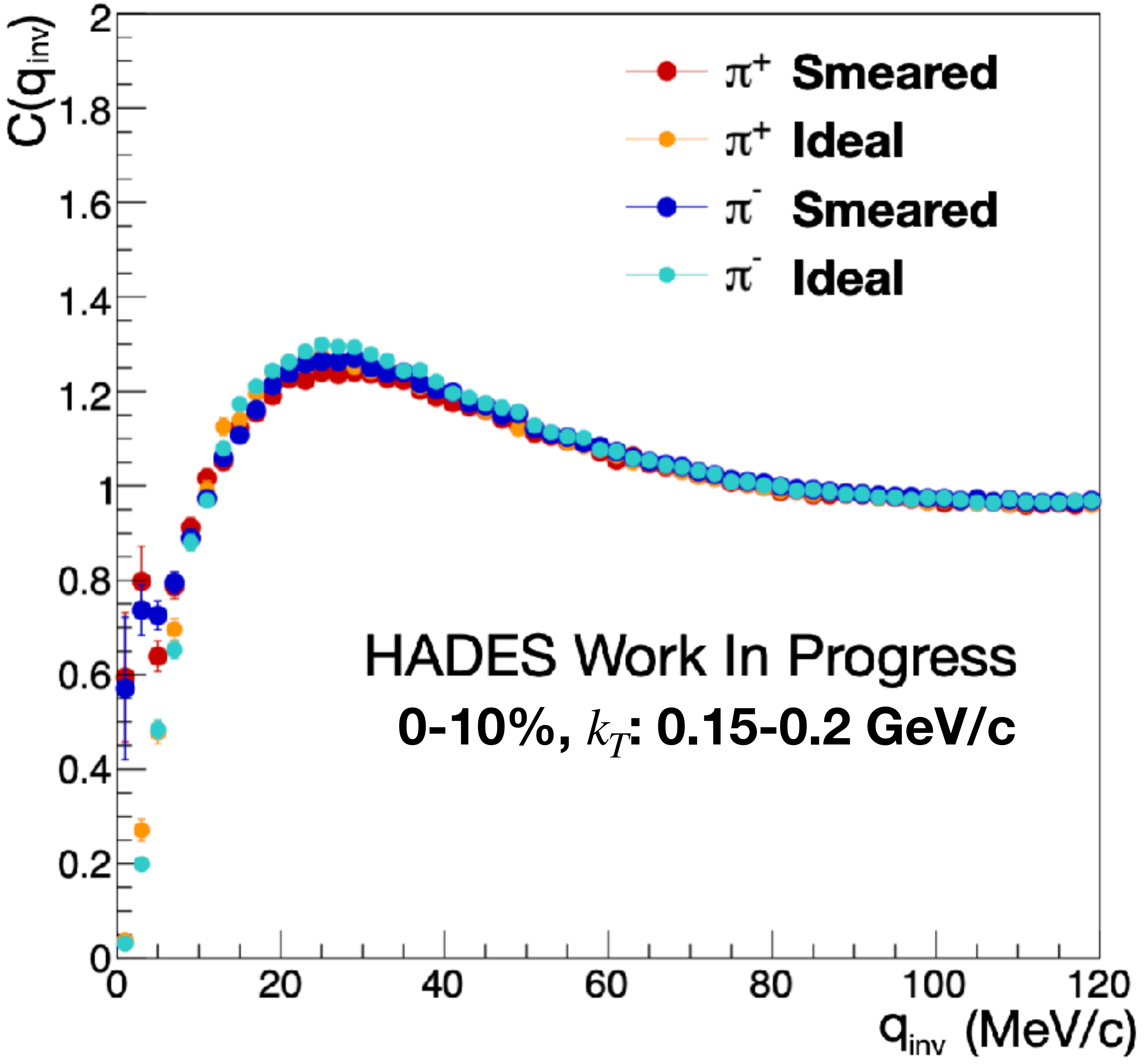


Momentum resolution correction

Done for both 1D and 3D analysis

Biggest influence for low q

Similar for π^+ and π^-

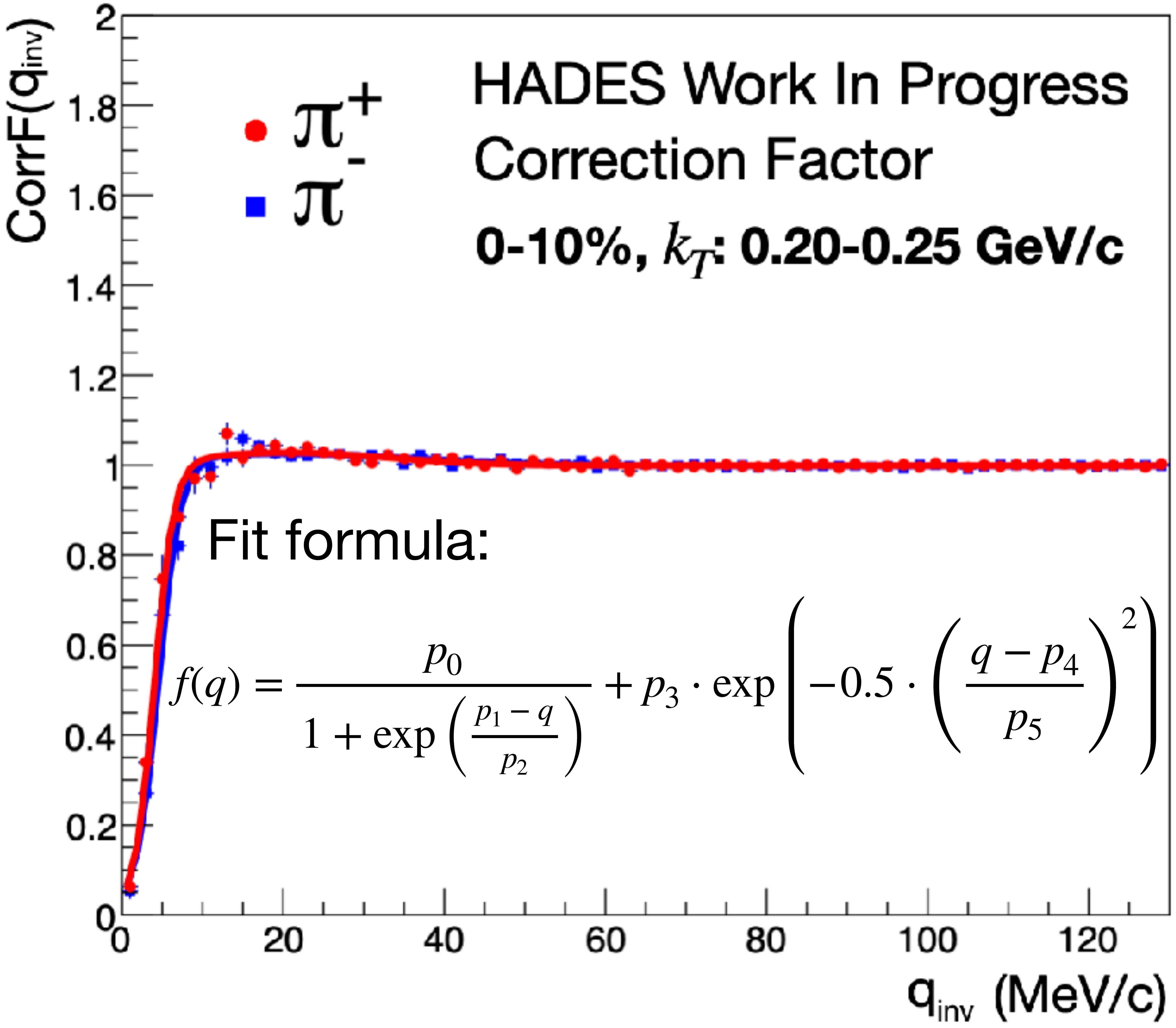


Momentum resolution correction

Calculated difference in θ, ϕ and **p**

Ideal function smeared by differences

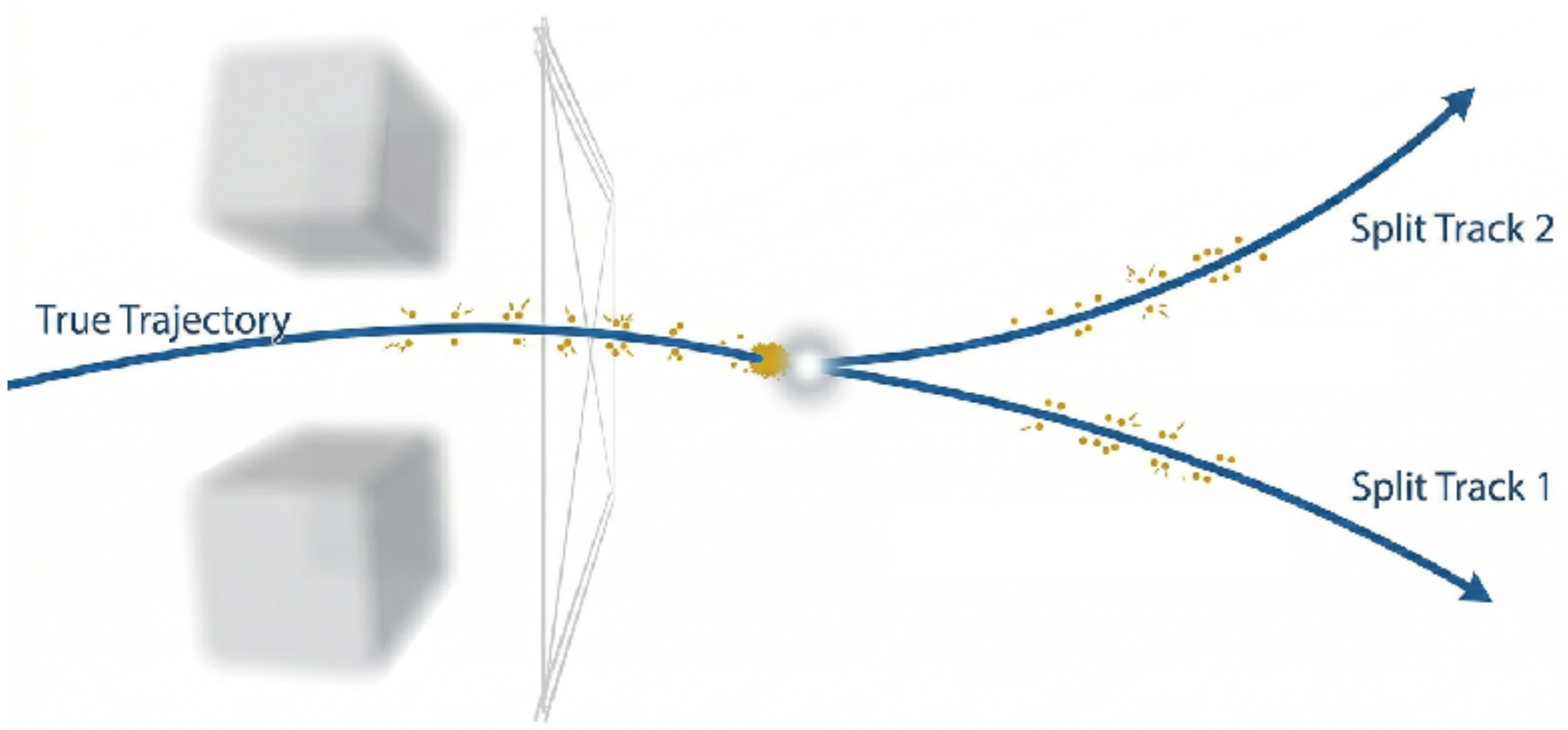
Ideal **divided** by smeared -> **correction factor**



Wire analysis

Why do this?

Splitting and strong merging



Wire analysis

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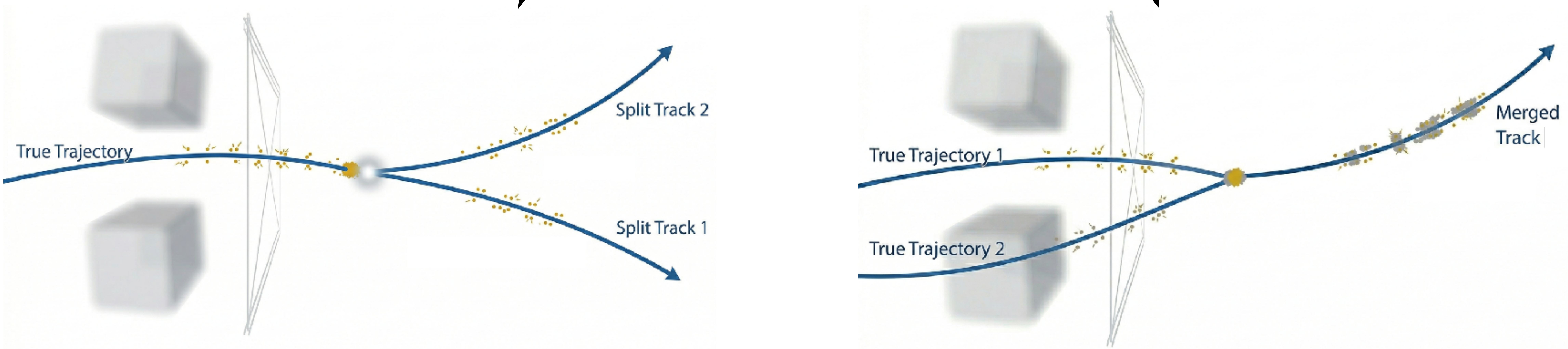


Wire analysis

Wire and opening angle cut — why different?

Opening angle cut — cone-shaped area removed behind particle

Wire — cylinder-shaped area removed behind and before particle

Implementation:

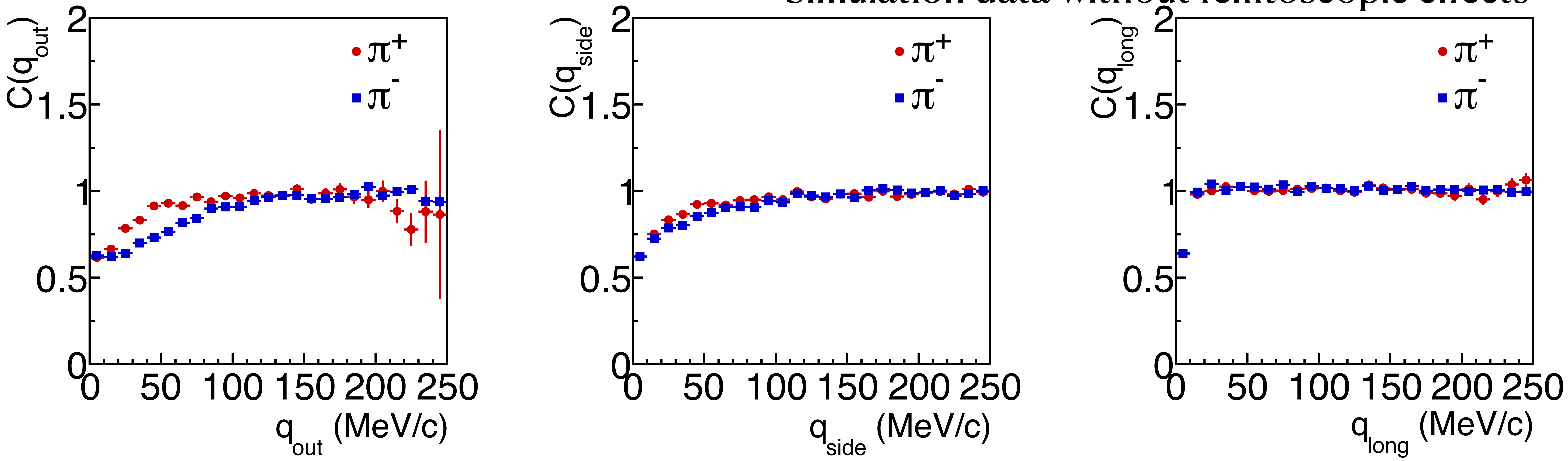
Unfortunately no wire data in dsts

Using Hydra algorithm **HParticleMetaMatcher** instead (needs hydra7.2)

Wire analysis

Merging and splitting - influence on correlation function

Centrality: 0-10% k_T: 0.2-0.25 GeV/c
Simulation data without femtoscopic effects



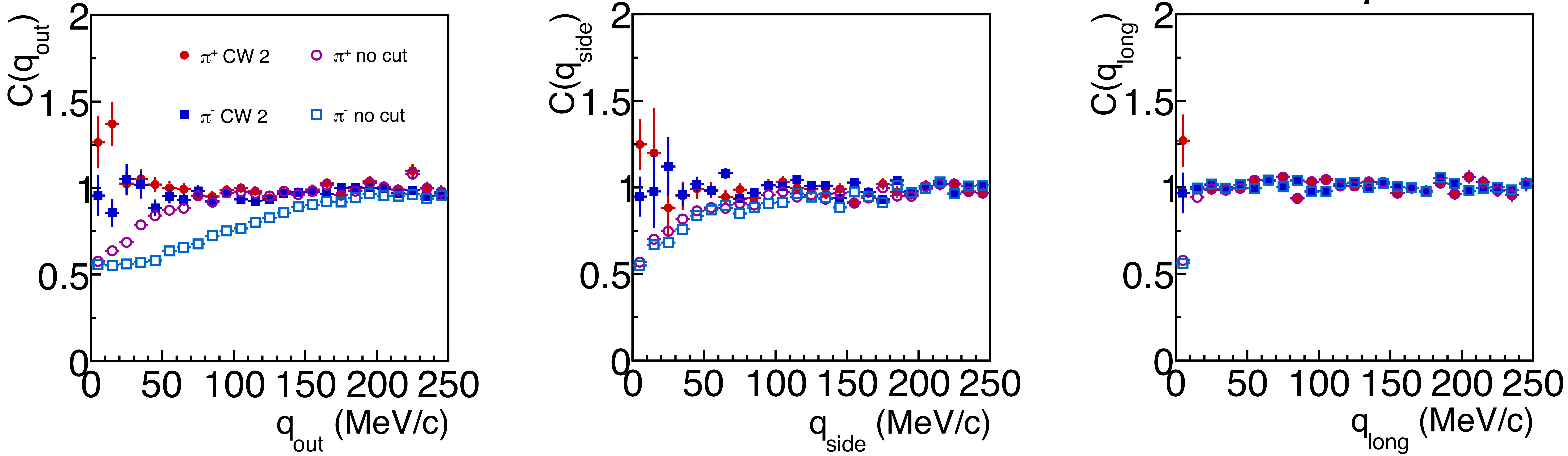
Wire analysis

Almost no detector effects (in simulation)

Great improvement

Higher statistical uncertainties — amount of data from experiment will help

Centrality: 0-10% k_T: 0.2-0.25 GeV/c
Simulation data without femtoscopic effects



Wire analysis - data comparison

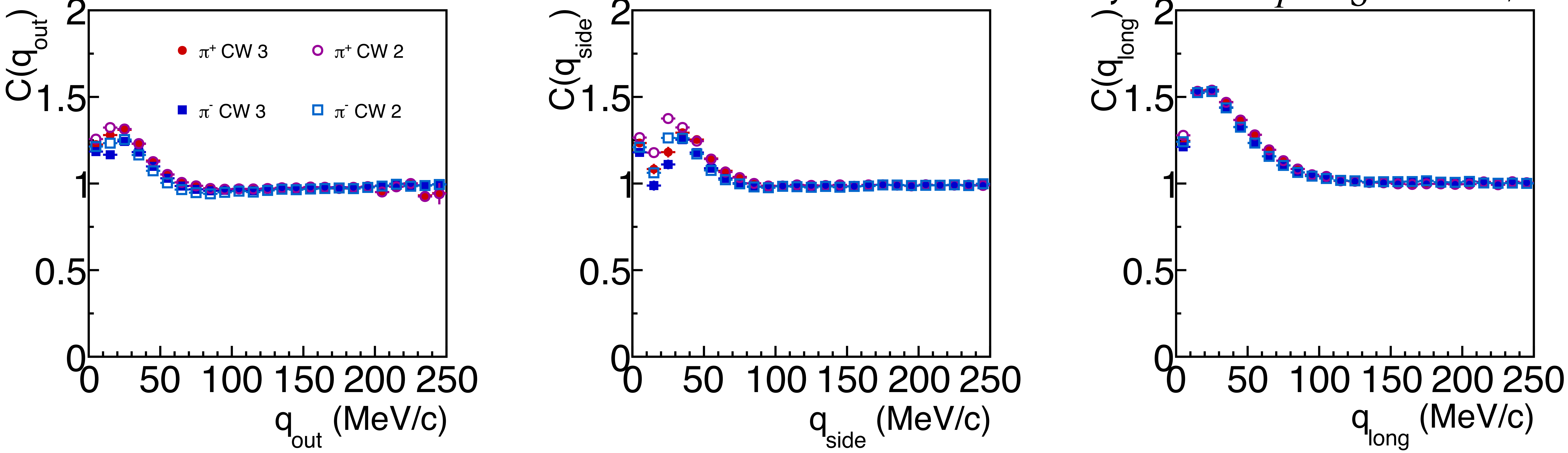
Comparison between closest wires distance: 2 and 3

Default: **2 wires**

Small differences

Real data

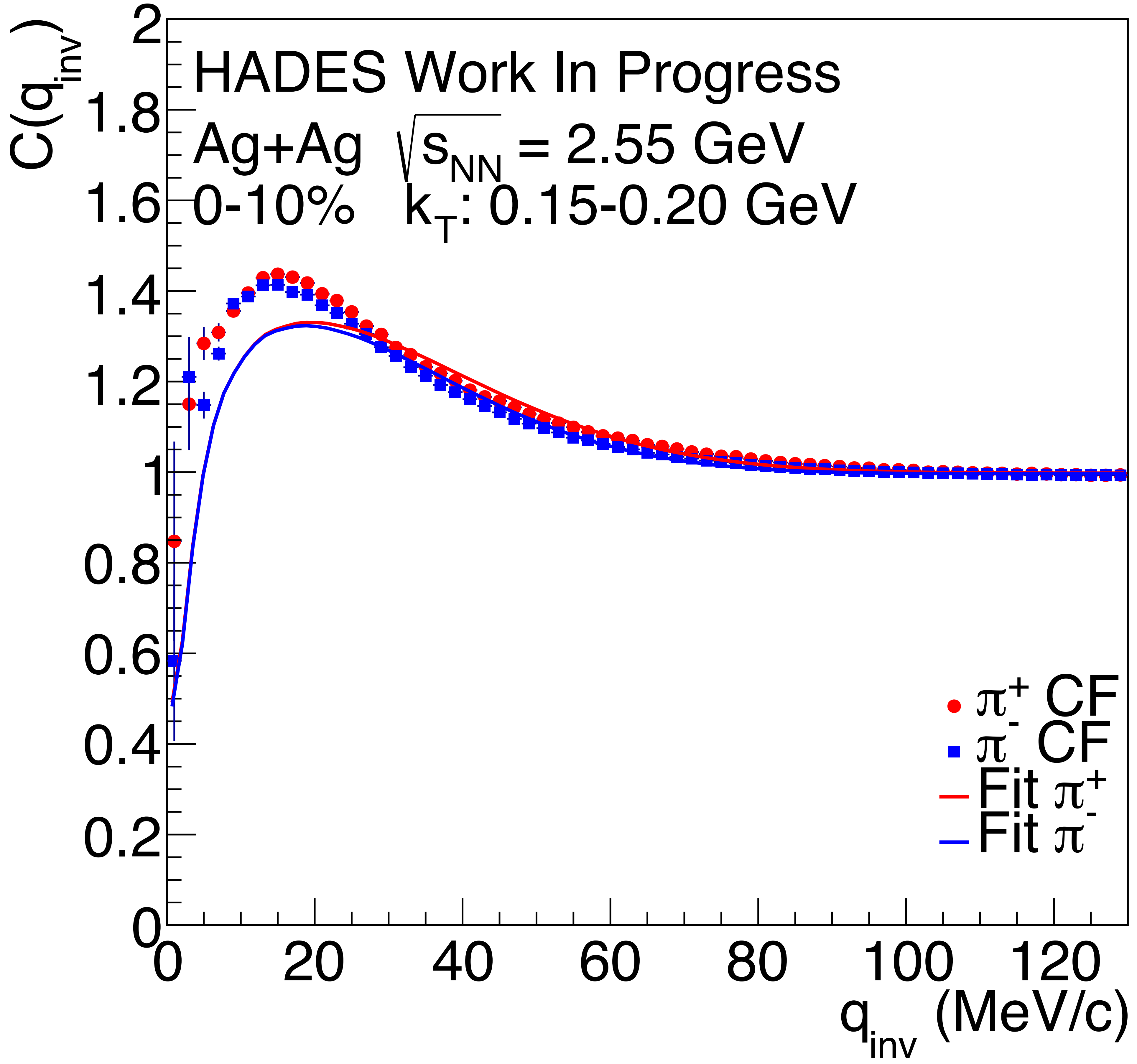
Centrality: 0-10% k_T: 0.15-0.2 GeV/c



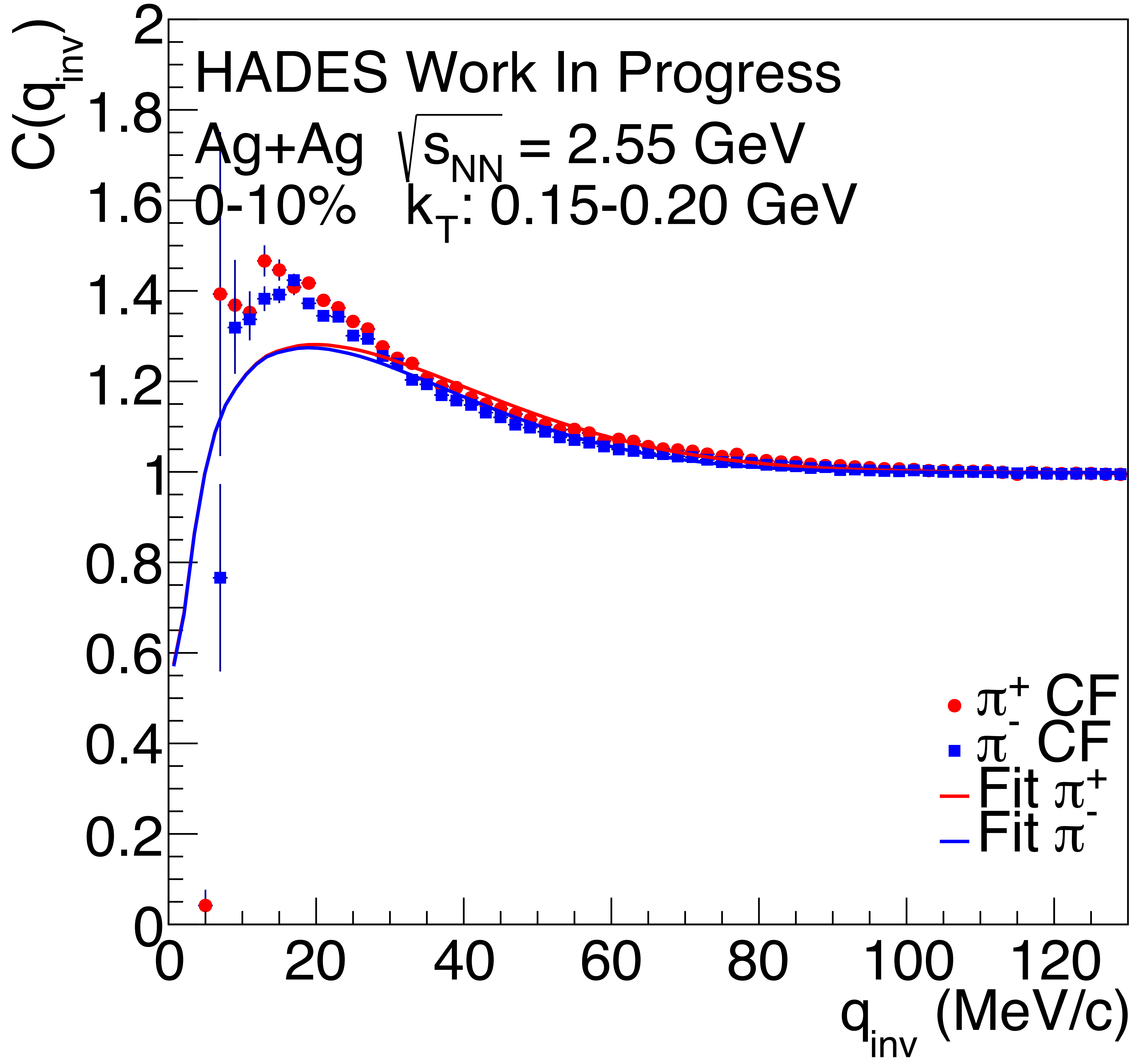
Wire analysis

To remove leftover detector effects opening angle cut (set on 2°) was added

Wires only



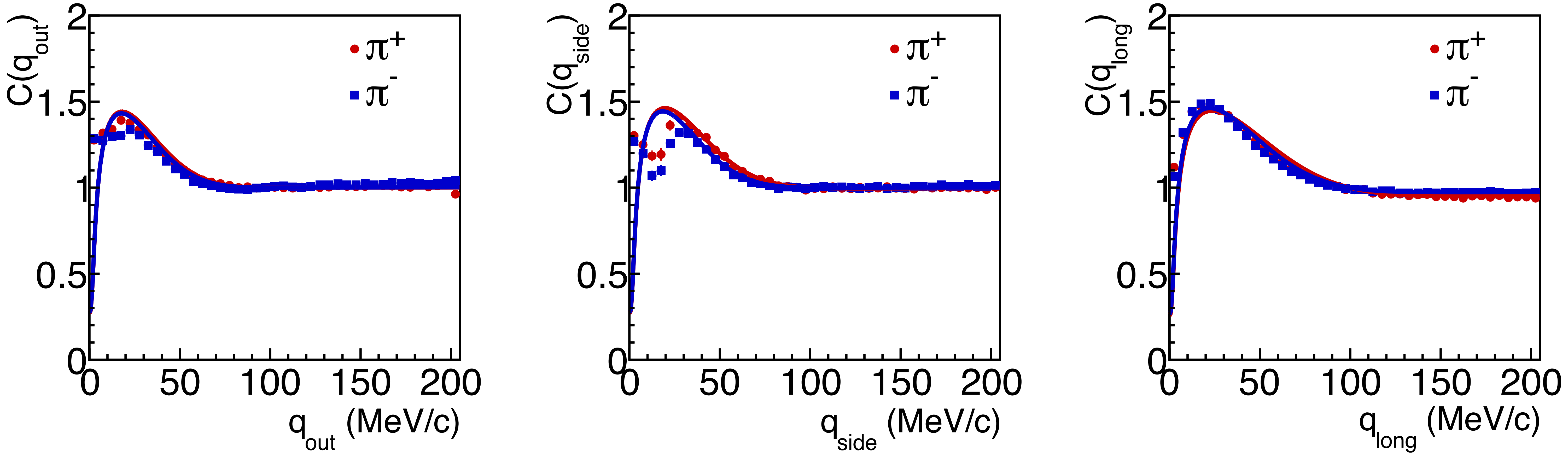
Wires + opening angle



Centrality: 0-10%

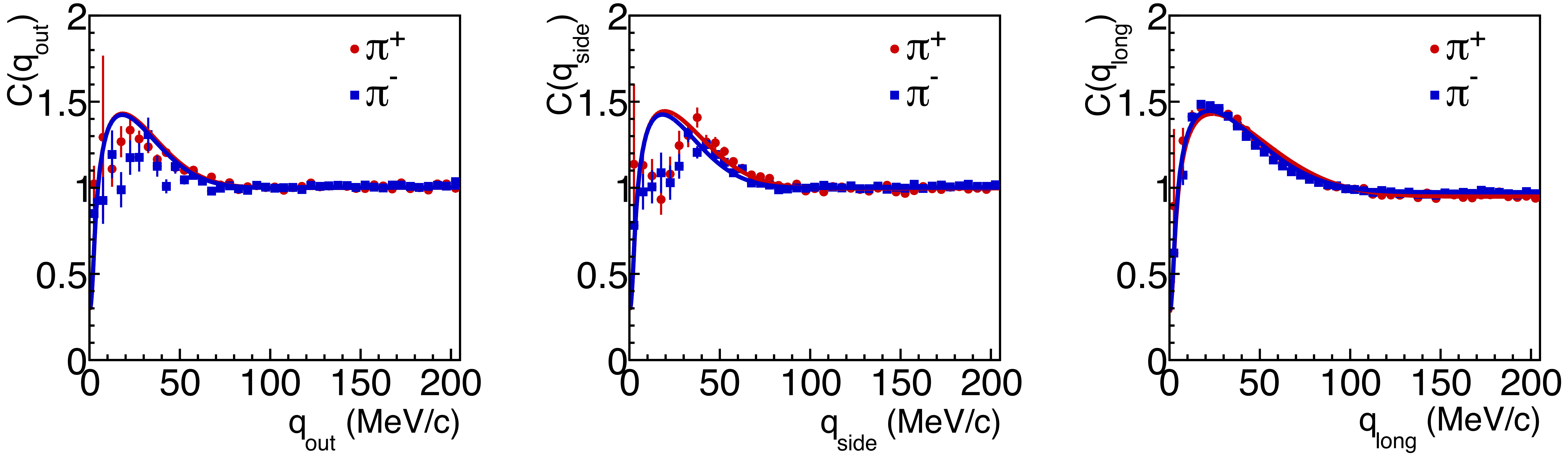
k_T:0.15-0.2 GeV/c

Wires only *(default setting)*



Addition of opening-angle cut only made statistic worse

Wires + opening angle



Problems outweigh benefits

One dimensional fits

Fitted with Bowler-Sinyukov correction:

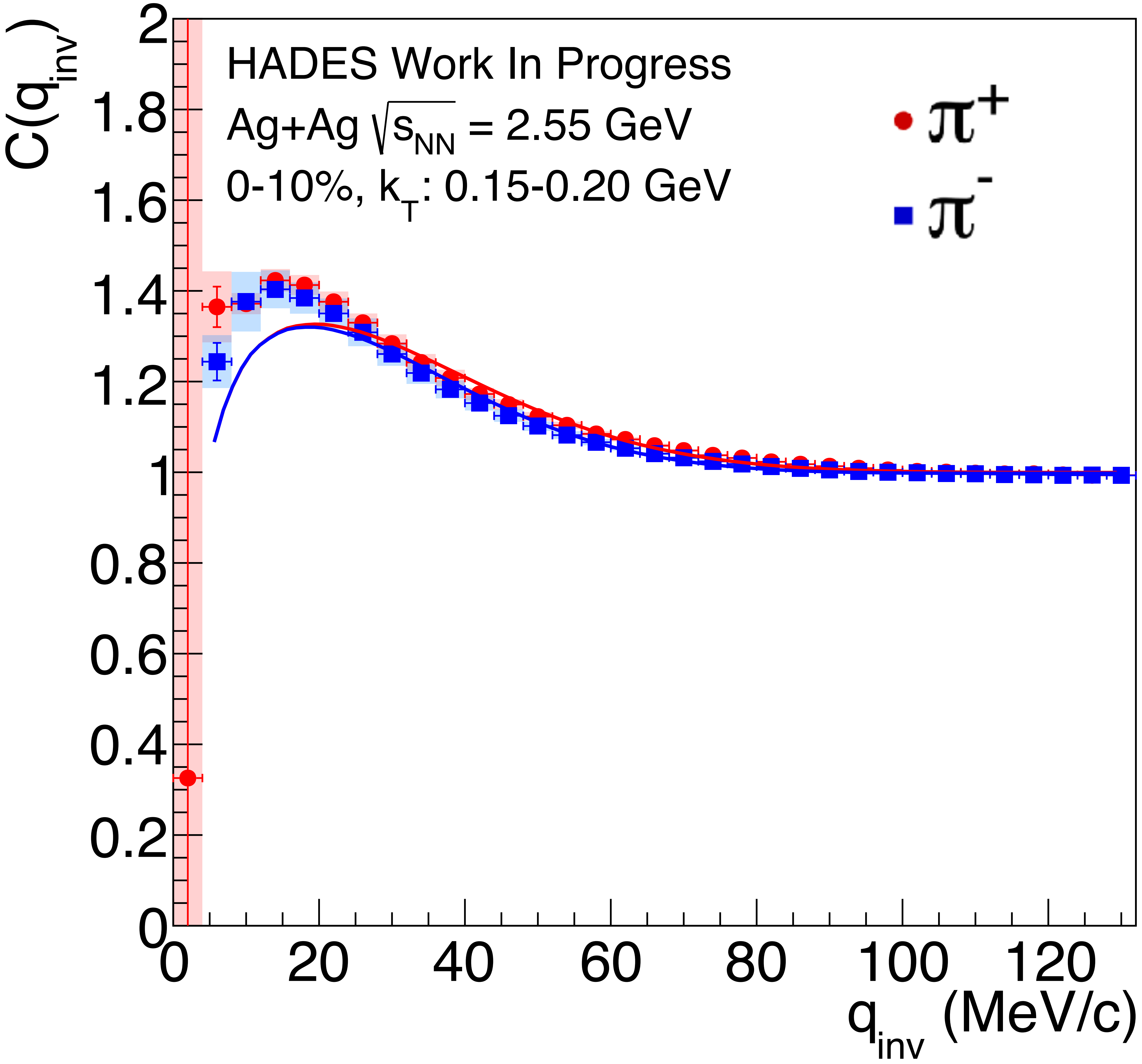
$C(q_{inv}) = (1 - \lambda_{inv}) + \lambda_{inv} K_C(q_{inv}, R_{inv}) e^{-(q_{inv} R_{inv})^2}$

where K_C is Coulomb function

Gaussian parametrization does **not** describe data well

Different radii for π^+ and π^-

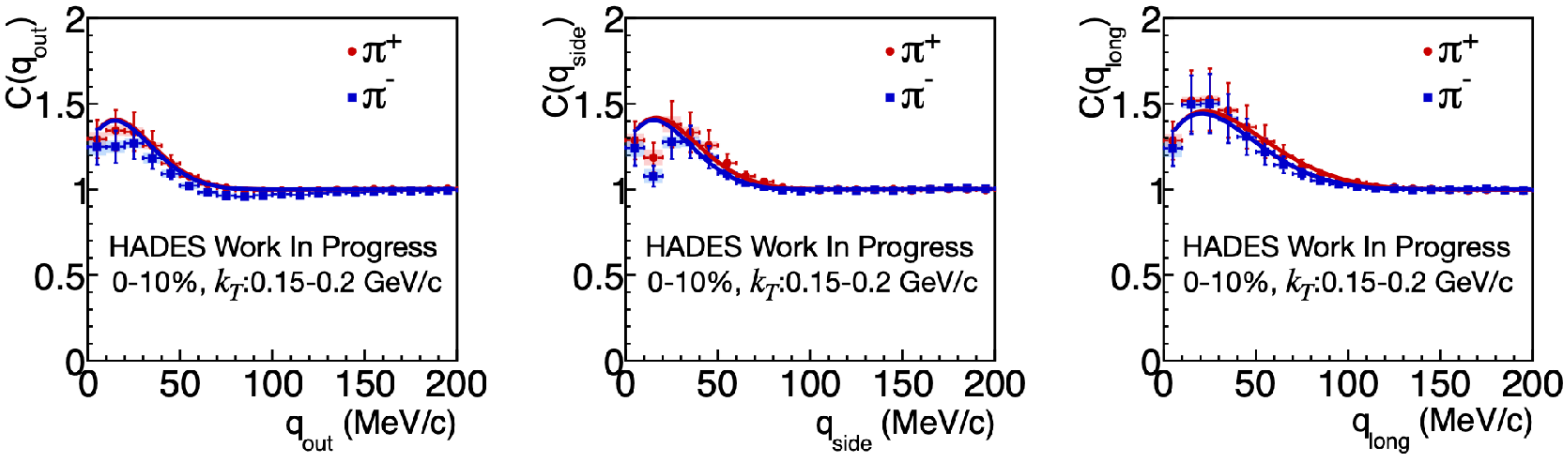
Similar λ



3D fit function

Fitted with Bowler-Sinyukov correction:

$$C(q_{out}, q_{side}, q_{long}) = (1 - \lambda_{osl}) + \lambda_{osl} K_C(q, R_{inv})(1 + e^{-(q_{out}R_{out})^2 - (q_{side}R_{side})^2 - (q_{long}R_{long})^2})$$



Similar radii for **out** and **side** direction

Long is half smaller - as expected

Better description with **gaussian** than for **1D**

Current systematic uncertainties

Taken into systematic uncertainty:

Calculated by running analysis the same way, with **one parameter changed** at a time

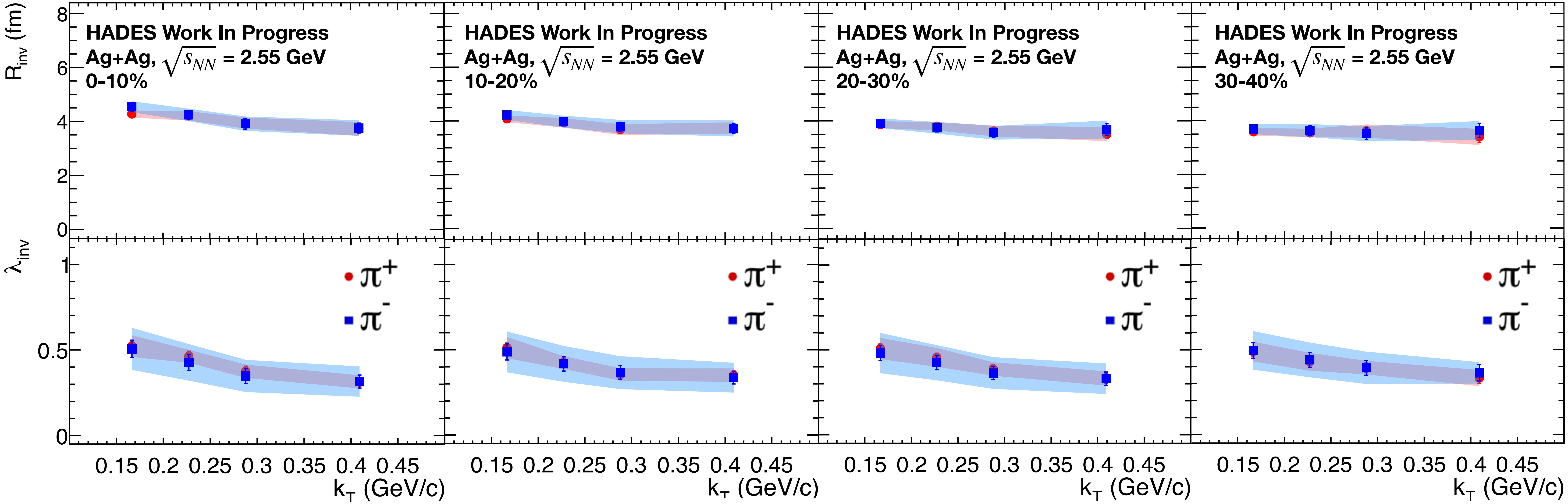
Variable	Default	Variation	Input
$\beta - p\ \sigma$	2	+- 1	34.11%
Momentum resolution	Given by function	+-10%	26.70%
Detector cut	2	+-1	39.11%

To do: only 3D detailed is left

Observables

Full finished analysis for 1D

Ongoing (**advanced**) systematic analysis for 3D



Current status and future

Status:

Including **wire's** in the analysis removes a lot of detector effects

Full 1D and 3D analysis made

1D systematic analysis **finished**

3D almost finished

Plans:

Finish **full 3D** systematic analysis (very **advanced** at this moment)

Thank you for your attention!