# FEASIBILITY STUDIES OF FEMTOSCOPIC MEASUREMENTS IN MPD

DANIEL WIELANEK

NICA DAY 2019

# OUTLINE

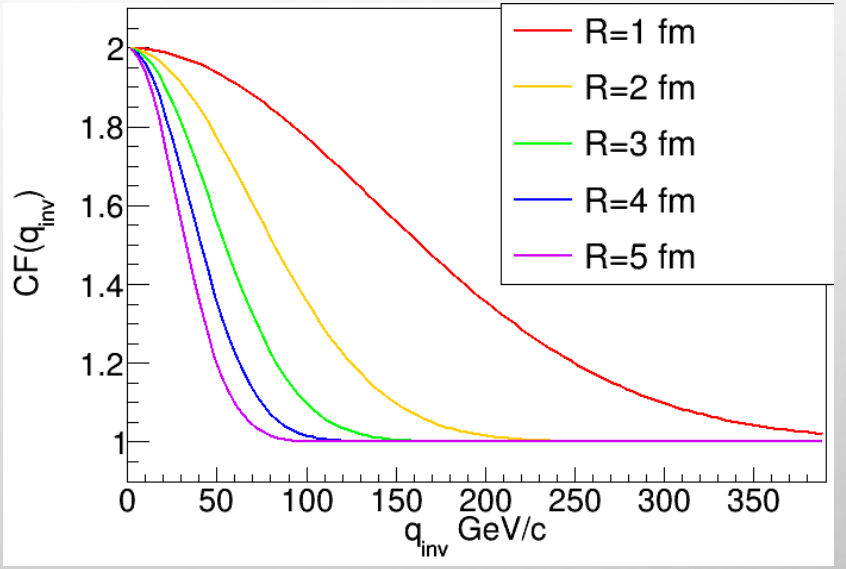
- MOTIVATION
- ANALYSIS
  - SOFTWARE
  - DATA SELECTION
  - RESULTS
- SUMMARY

# MOTIVATION

- ACCESS TO INFORMATION ABOUT SPATIOTEMPORAL STRUCTURE OF THE EVENT

$$CF(q) = \frac{N(q)}{D(q)}$$

$$q = p_1 - p_2$$



# SOFTWARE

- URQMD 3.4 FOR SIMULATION OF MC-DATA
- MPDROOT (MAY 2018 VERSION) FOR SIMULATION OF DETECTOR RESPONSE
- NICAFEMTO
  - CALCULATION OF CF
  - FITTING CF

# DATA

- 3.6 M AU+AU EVENTS
- ENERGY: $\sqrt{s_{NN}} = 11\ GeV$
- CENTRALITY 0-5% (IMPACT PARAMETER <3.5 FM)

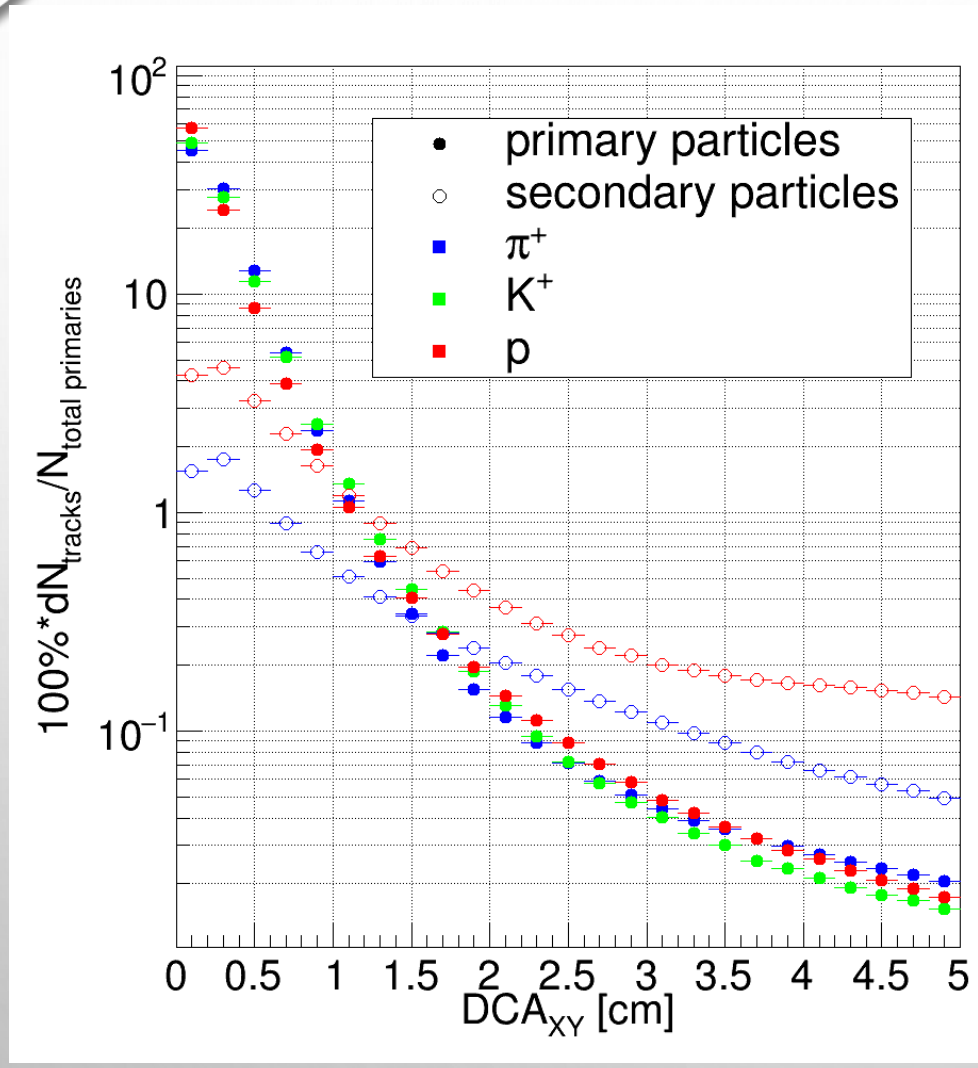
# DATA

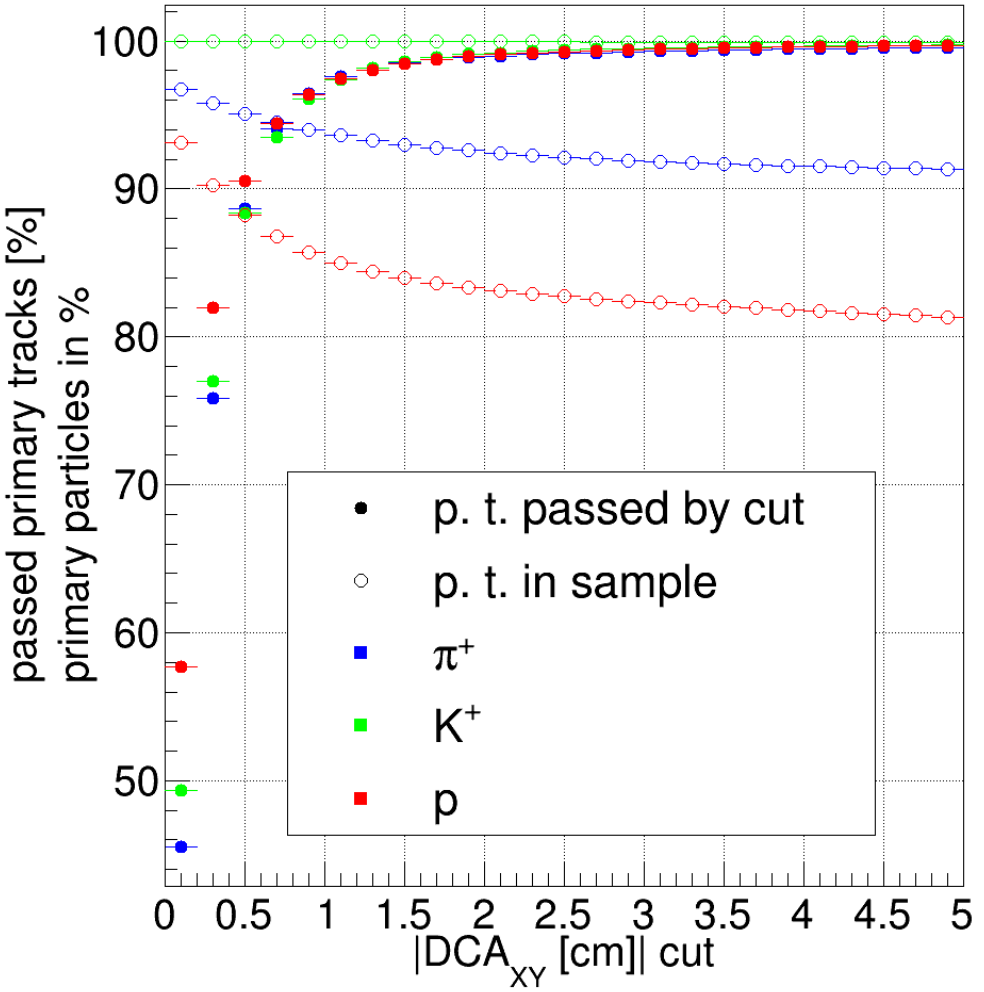
- SIMULATED WITH STANDARD MACROS
- COLLISION POSITION FIXED AT (0,0,0)

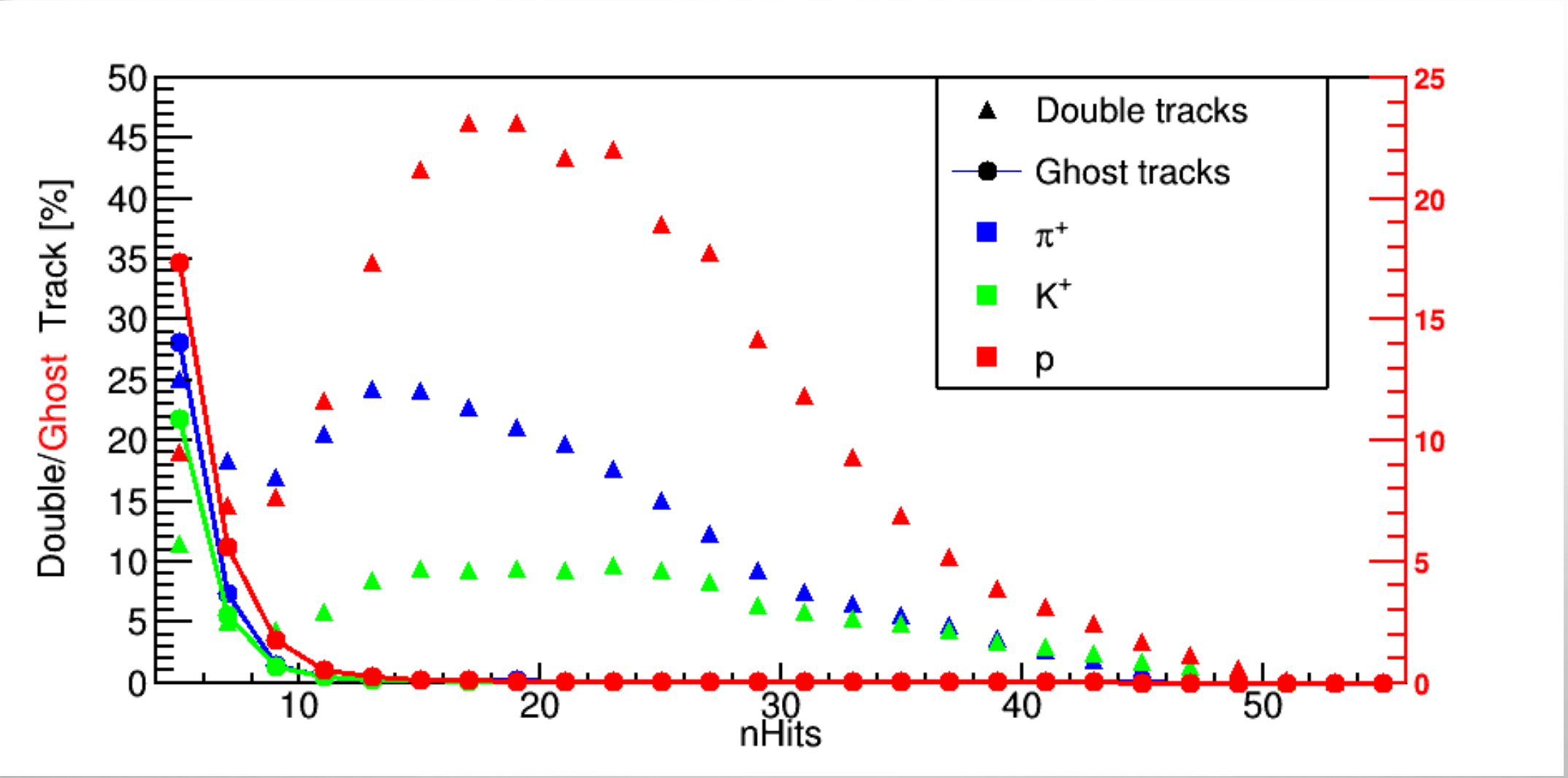
# DATA SELECTION

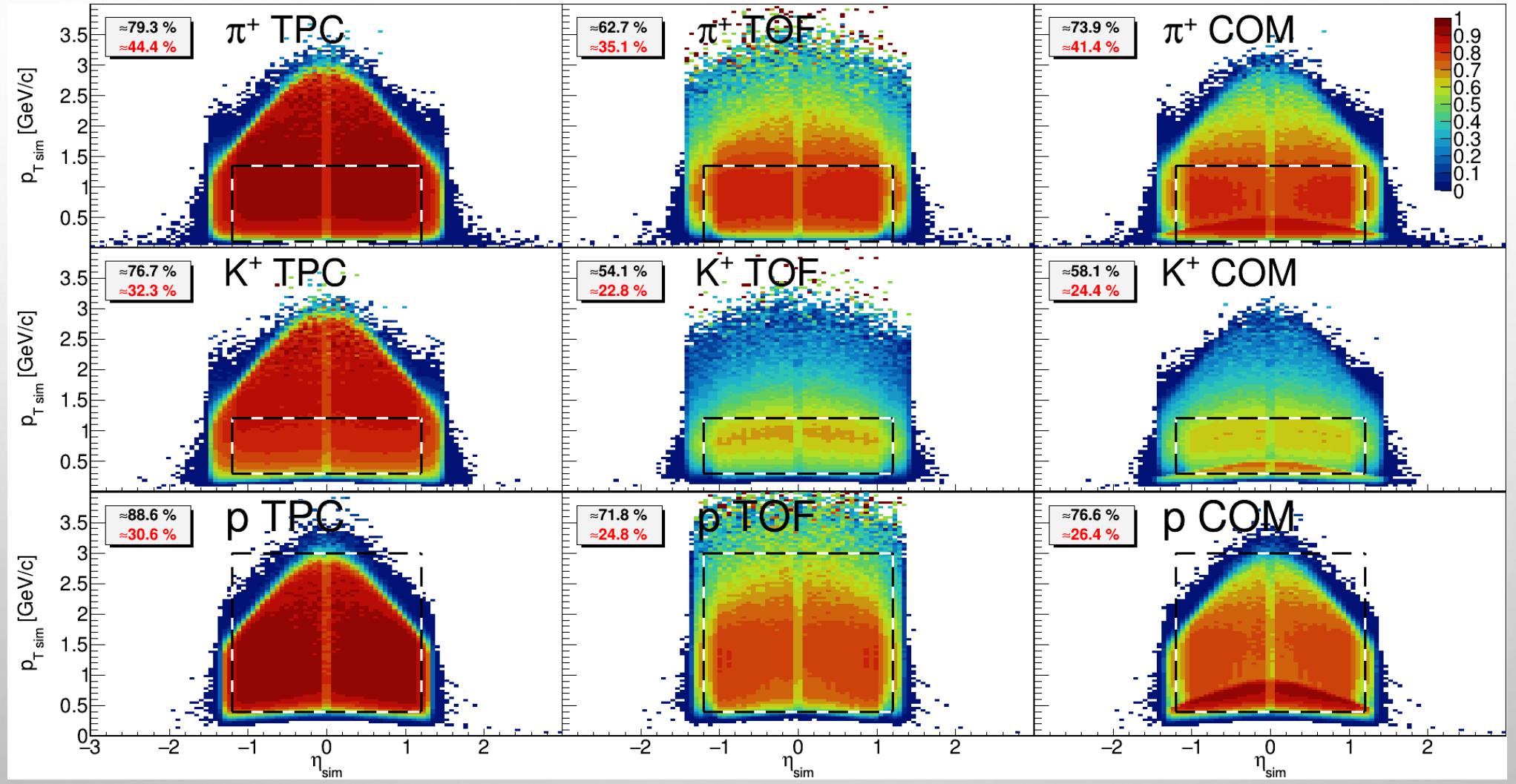
- I FOCUSED ON $\pi^+\pi^+$ CORRELATIONS, THEREFORE I SHOULD SELECT
  - PRIMARY PIONS
  - RELATIVELY WELL RECONSTRUCTED

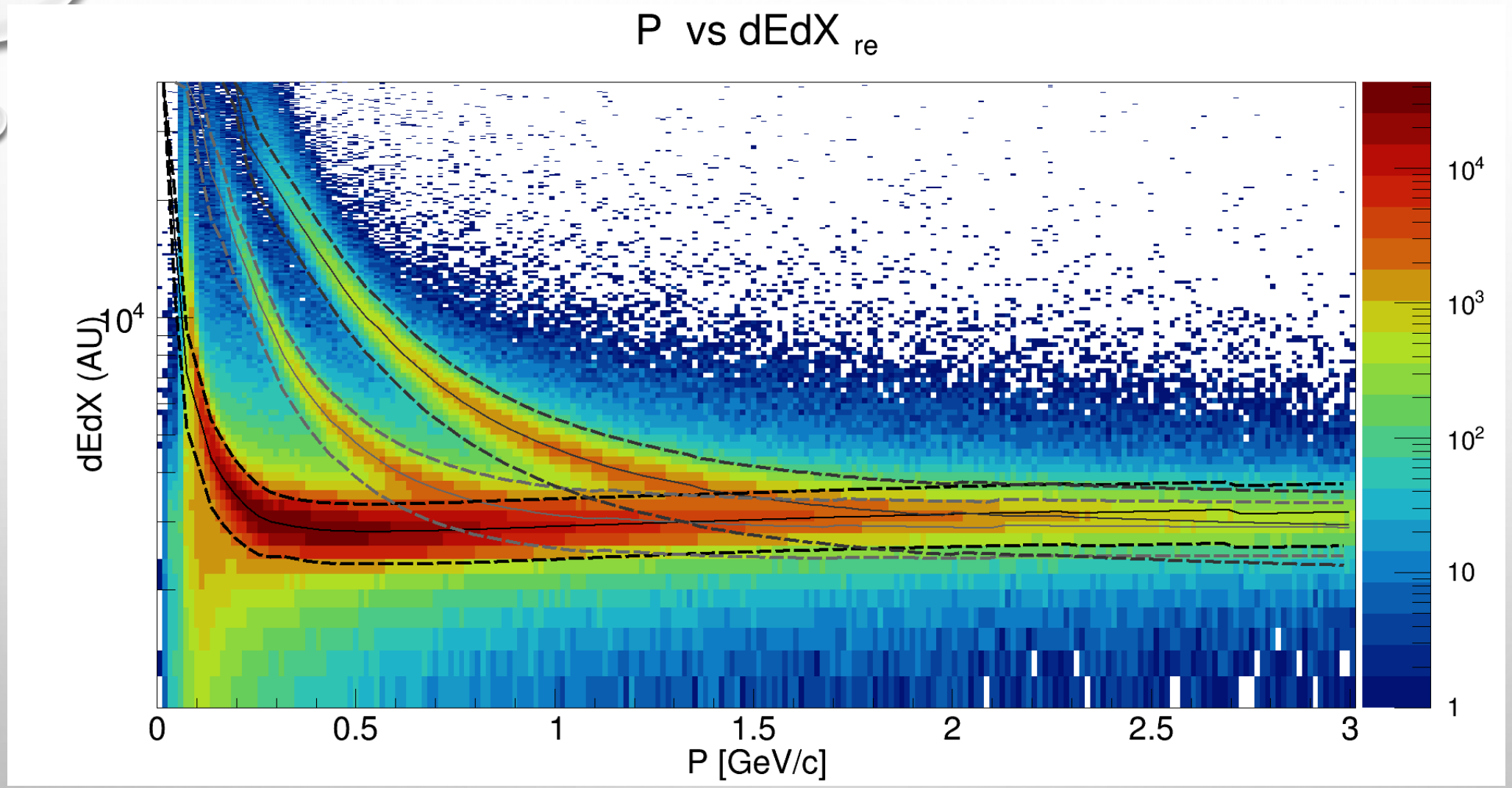
# TRACK CUTS

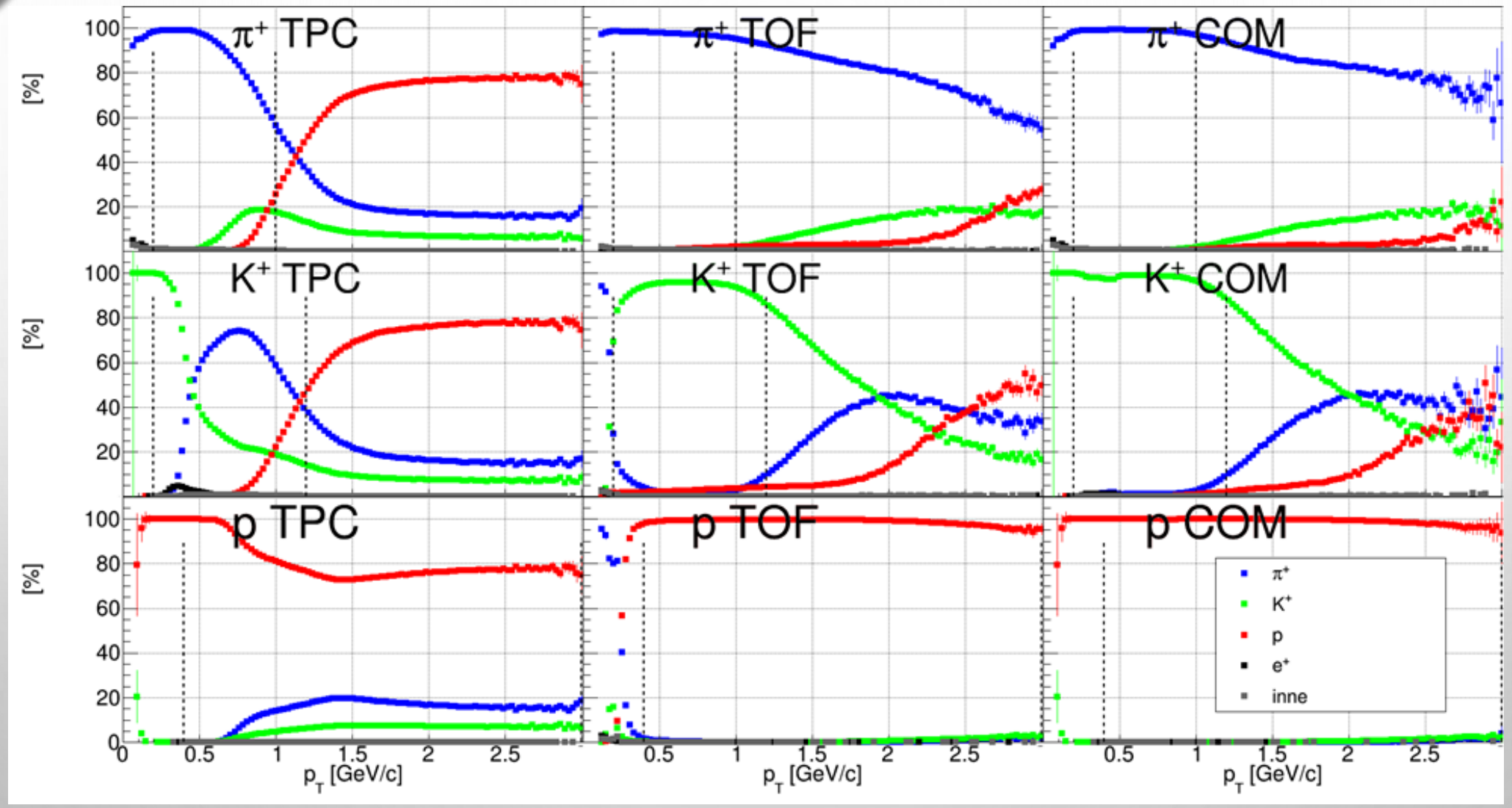

primary particles
secondary particles
π+
K+
p
100%*dN_tracks/N_total primaries
DCA_XY [cm]


p. t. passed by cut
p. t. in sample
π+
K+
p
passed primary tracks [%]
primary particles in %
|DCA_XY [cm]| cut


Double tracks
Ghost tracks
π+
K+
p
Double/Ghost Track [%]
nHits
0
5
10
15
20
25
30
35
40
45
50
10
20
30
40
50
0
5
10
15
20
25


≈79.3 %
≈44.4 %
π+ TPC
≈62.7 %
≈35.1 %
π+ TOF
≈73.9 %
≈41.4 %
π+ COM
≈76.7 %
≈32.3 %
K+ TPC
≈54.1 %
≈22.8 %
K+ TOF
≈58.1 %
≈24.4 %
K+ COM
≈88.6 %
≈30.6 %
p TPC
≈71.8 %
≈24.8 %
p TOF
≈76.6 %
≈26.4 %
p COM
p_T sim [GeV/c]
η_sim


P vs dEdX re
dEdX (AU)
$10^4$
0
0.5
1
1.5
2
2.5
3
P [GeV/c]
$10^4$
$10^3$
$10^2$
10
1


π+ TPC
π+ TOF
π+ COM
K+ TPC
K+ TOF
K+ COM
p TPC
p TOF
p COM
[%]
100
80
60
40
20
0
0.5
1
1.5
2
2.5
pT [GeV/c]
π+
K+
p
e+
inne

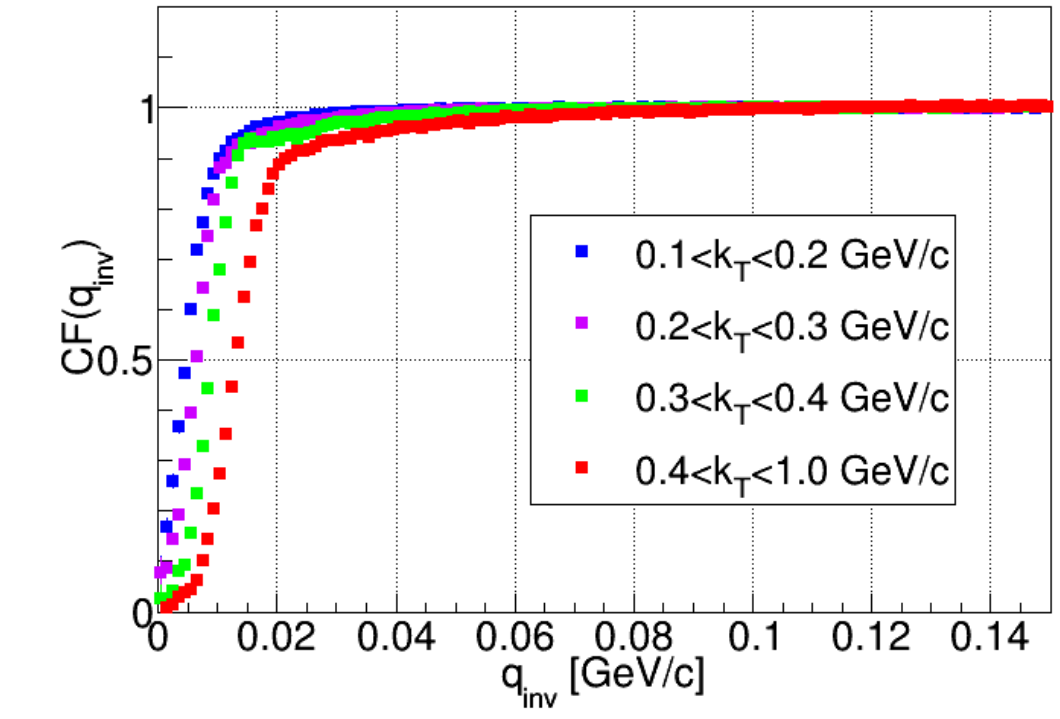
# DATA SELECTION

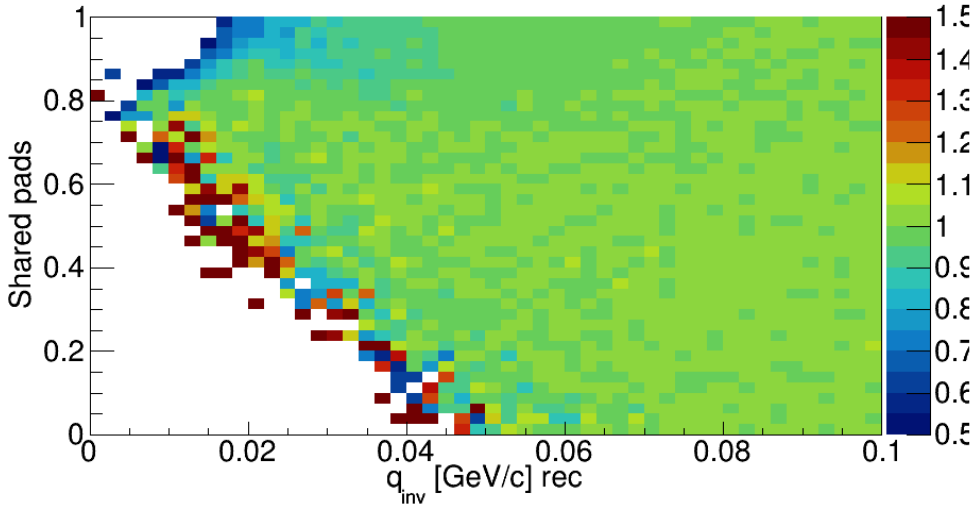
- TRACK CUTS
  - $DCA_{XY} < 1.25$ CM
  - $|DCA_Z| < 0.75$ CM
  - NHITS>29
  - $|\eta| < 1.2$
  - |PION N-SIGMA| <2
  - $0.3 < M^2 < 0.15$ GEV$^2$/C$^4$ IF P>0.5 GEV/C

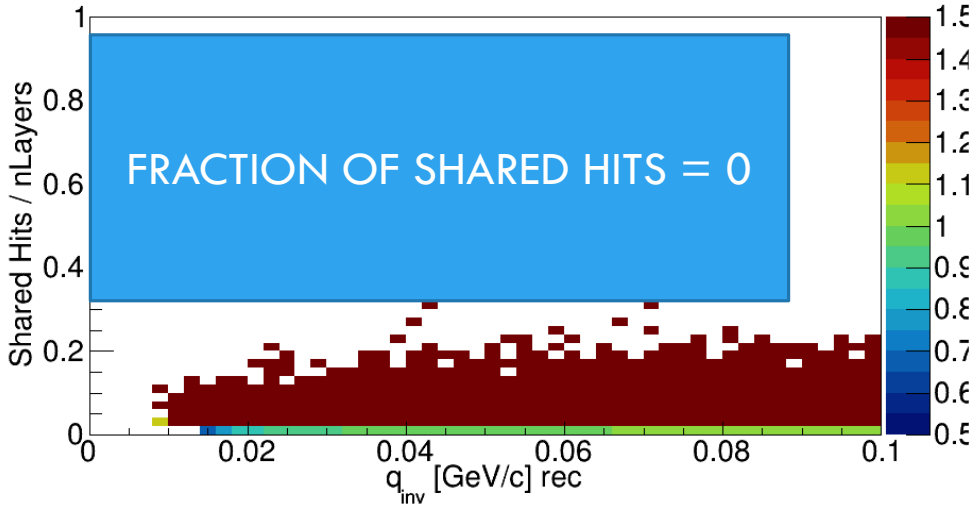
# CORRELATION FUNCTION

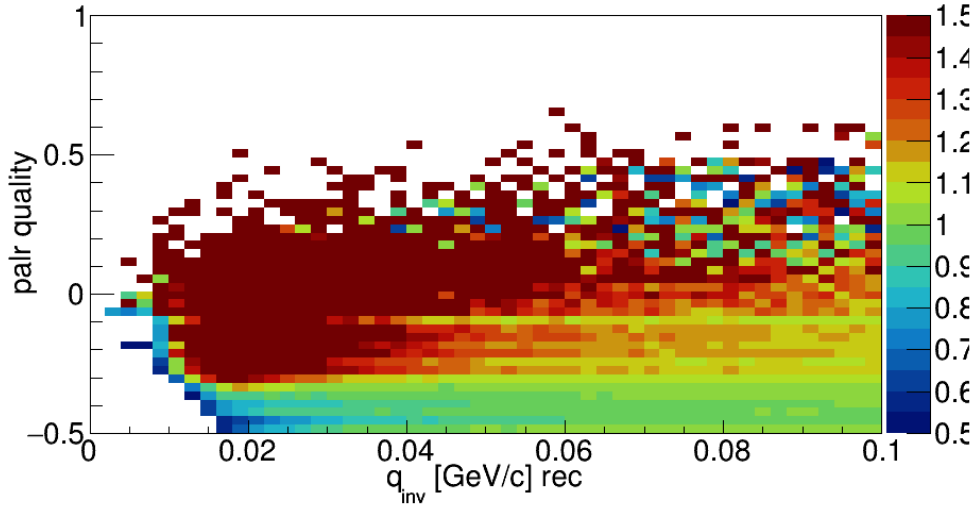
- „RAW FUNCTION” – NO FEMTOSCOPIC WEIGHTS, NO TWO-PARTICLE CUTS:
  - CF=1 – EXPECTED
  - CF<1 – MERGING (RECONSTRUCTION OF A PAIR AS A SINGLE PARTICLE )
  - CF>1 – SPLITTING (RECONSTRUCTION OF A PARTICLE AS A PAIR OF THE PARTICLES )

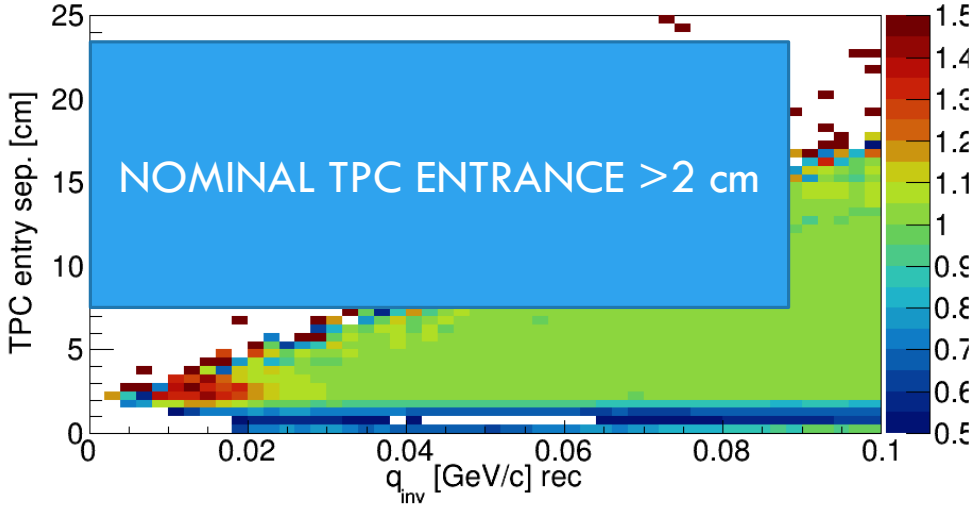
# „RAW” CORRELATION FUNCTION



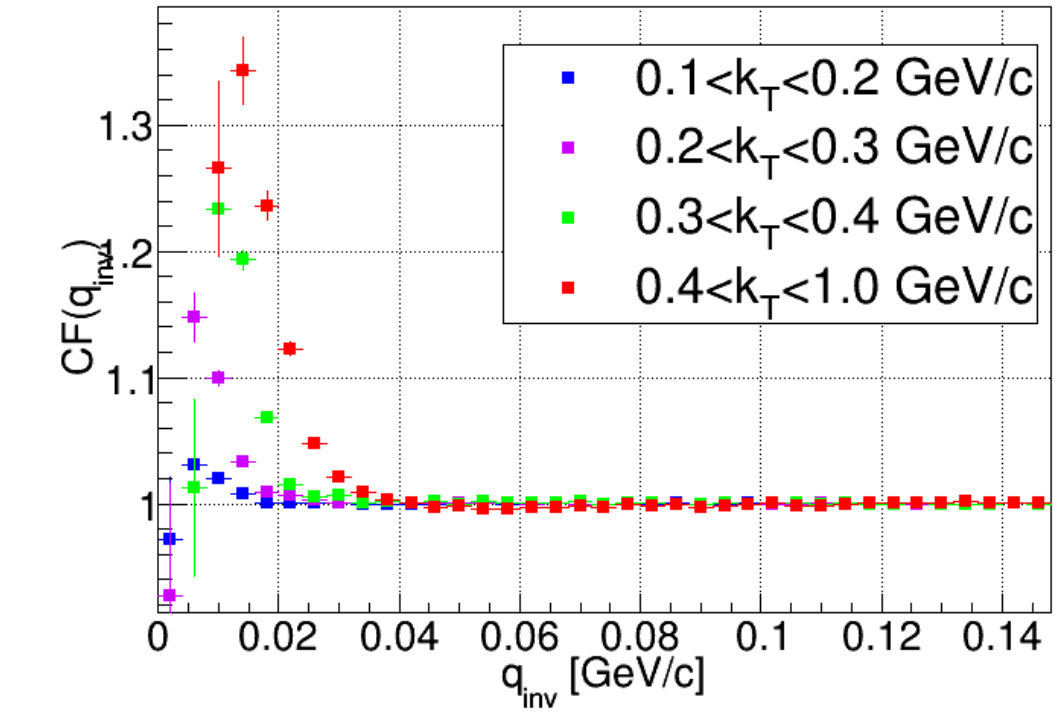

Shared pads
$q_{inv}$ [GeV/c] rec


Shared Hits / nLayers
FRACTION OF SHARED HITS = 0
$q_{inv}$ [GeV/c] rec


palr quality
$q_{inv}$ [GeV/c] rec


TPC entry sep. [cm]
NOMINAL TPC ENTRANCE >2 cm
$q_{inv}$ [GeV/c] rec

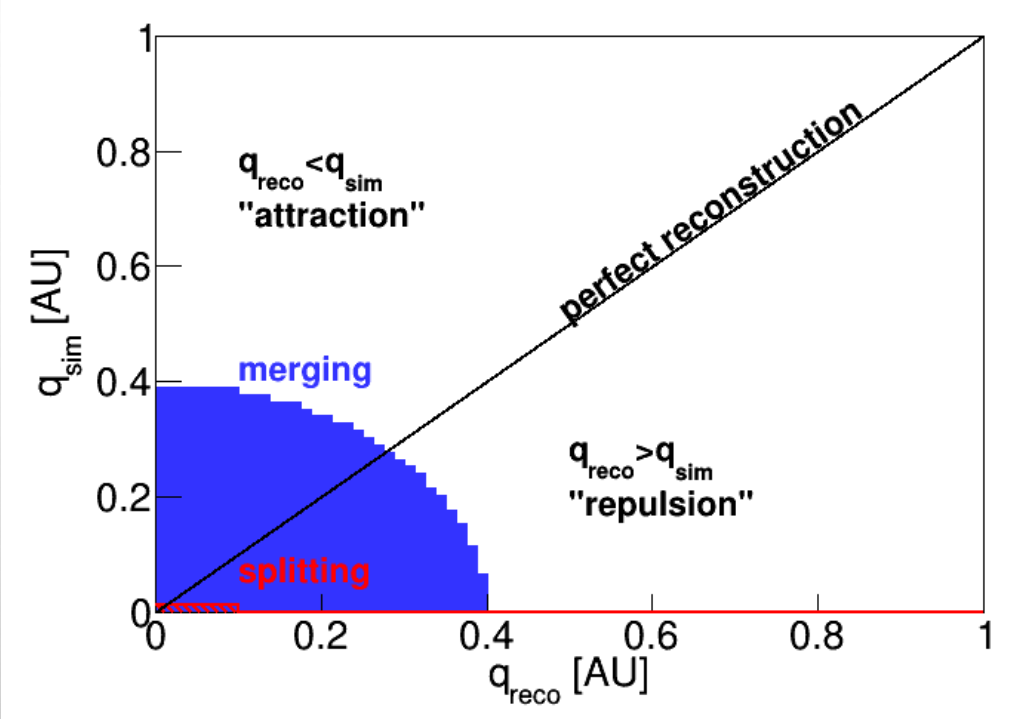
# „SECOND" CORRELATION FUNCTION



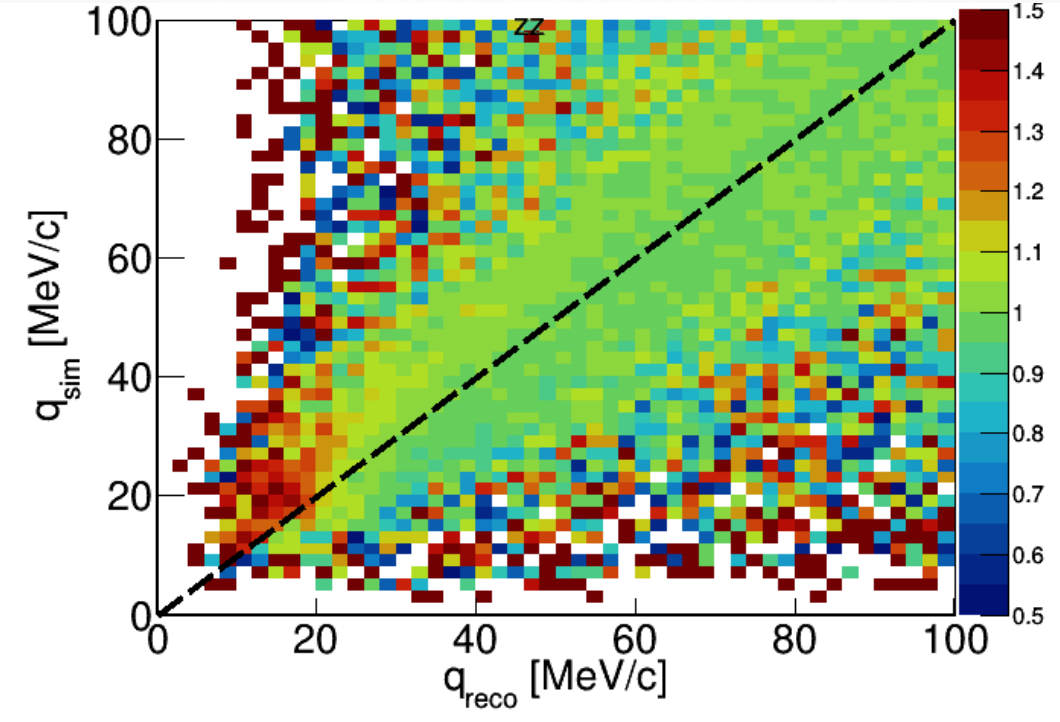
# „SECOND" CORRELATION FUNCTION

- „PSEUDOSPLITTING PROBLEM"
  - ALL STANDARD ANTI-SPLITTING CUTS DO NOT WORK
  - REMOVING TRACKS WITH THE SAME MC PARENT DOES NOT HELP

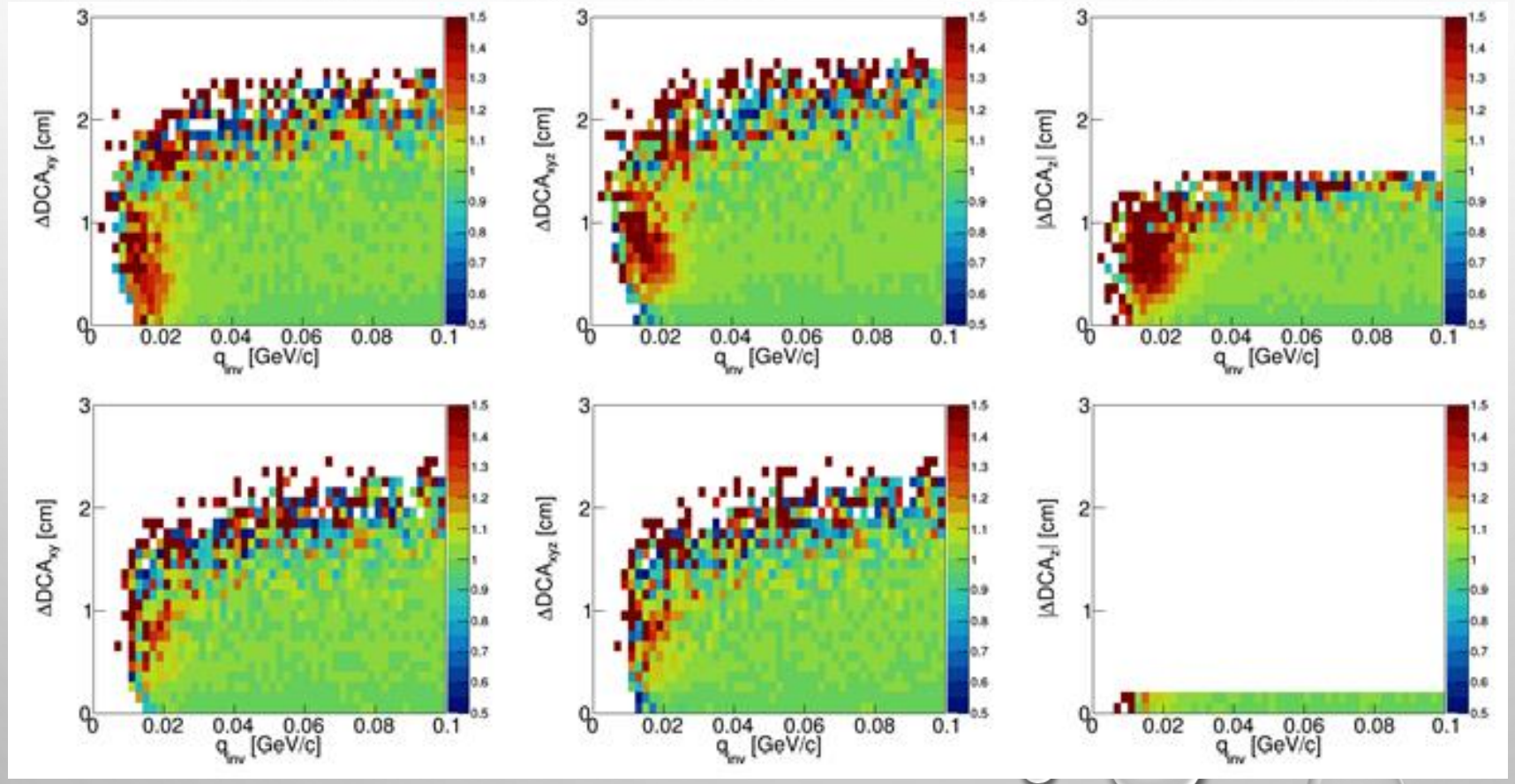
# „SECOND" CORRELATION FUNCTION



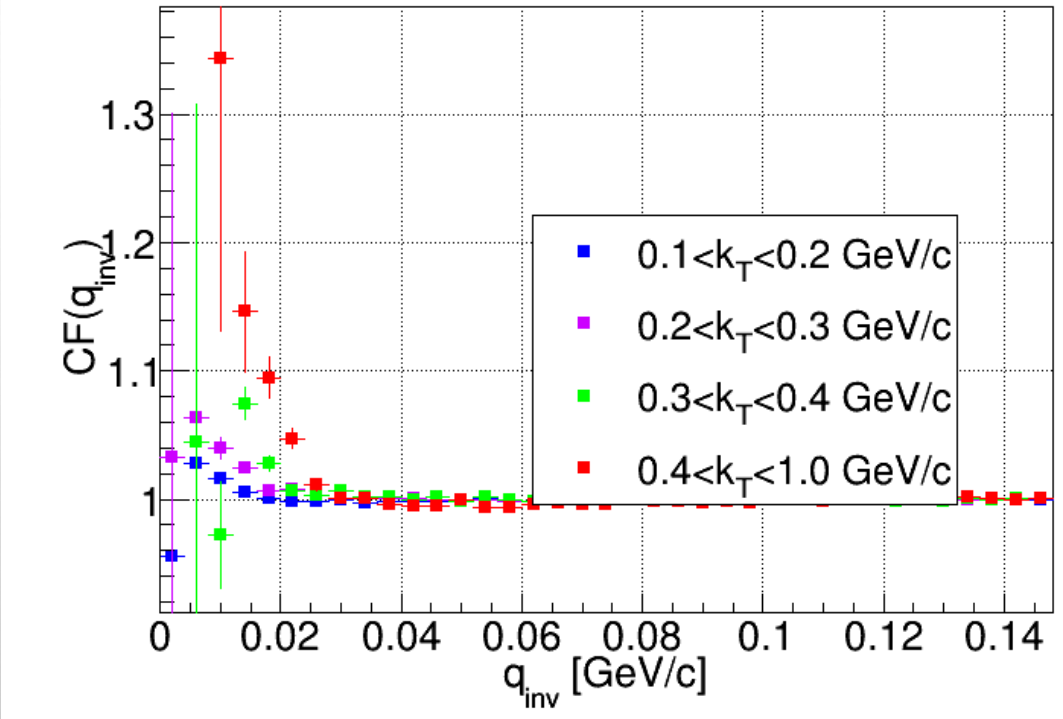
# „SECOND" CORRELATION FUNCTION



# „SECOND" CORRELATION FUNCTION



# „FINAL” CF


1.3
1.2
1.1
1
CF(q_inv)
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
q_inv [GeV/c]
0.1<k_T<0.2 GeV/c
0.2<k_T<0.3 GeV/c
0.3<k_T<0.4 GeV/c
0.4<k_T<1.0 GeV/c

# 1-D CORRELATION FUNCTION

# SIMULATION PARAMETERS

- INCOHERENCE FACTOR ($\lambda$) SET TO 0.5
- RADII TAKEN FROM STAR DATA ($\sqrt{s_{NN}} = 11.5\ GeV$ )
- 3D GAUSSIAN IN LCMS ASSUMED

# FITTING

- 1D GAUSSIAN SOURCE ASSUMED
- MOMENTUM SMEARING TAKEN INTO ACCOUNT ($C_{gaussian}(q,r) \rightarrow C_{smeared}(q,R)$)
- FITTING FUNCTION:

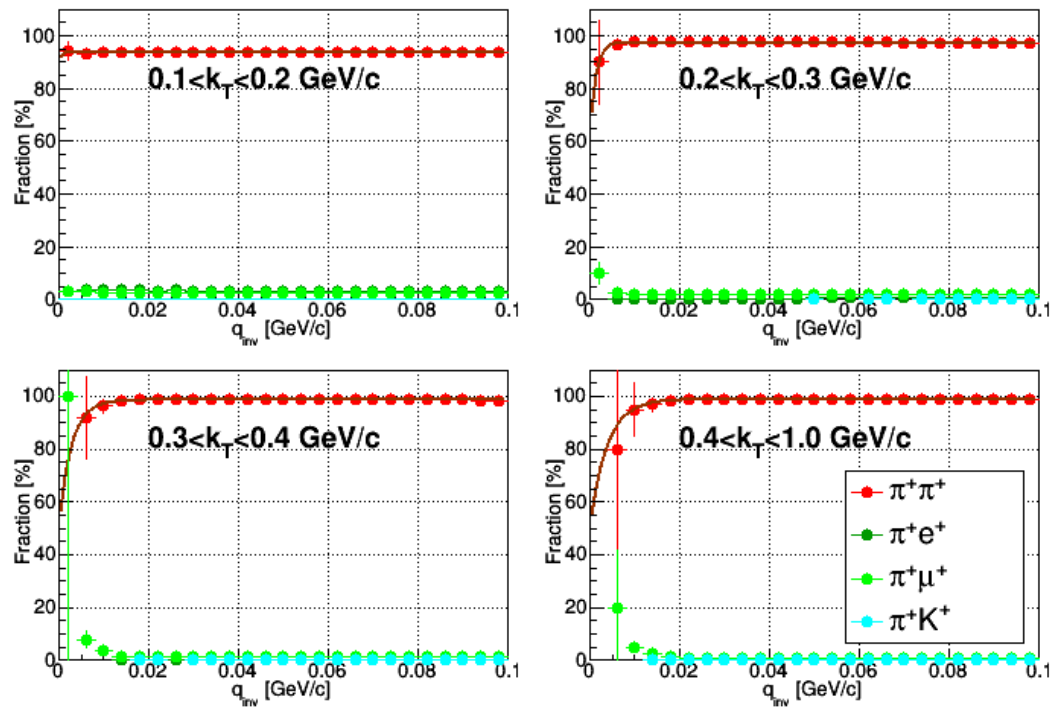
$$C(q,r) = NC_{BCKG}(q)\{\lambda\left[(C_{smeared}(q,R) - 1)C_{purity}(q)\right] + 1\}$$

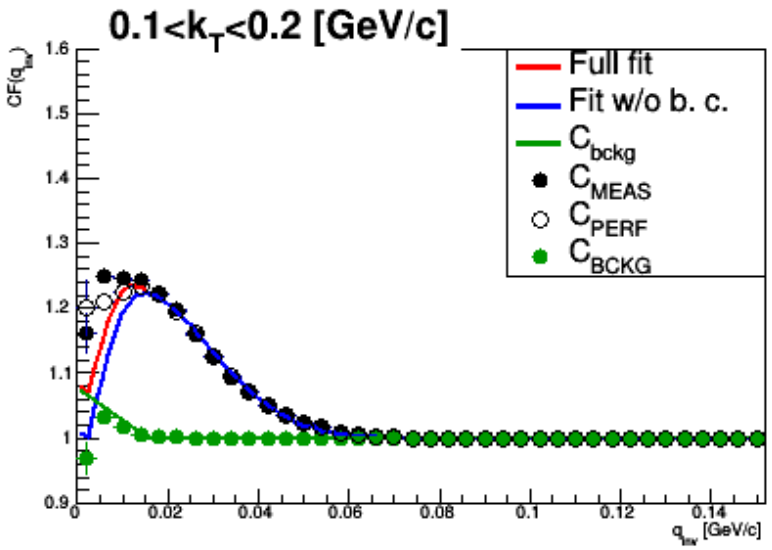
# FITTING

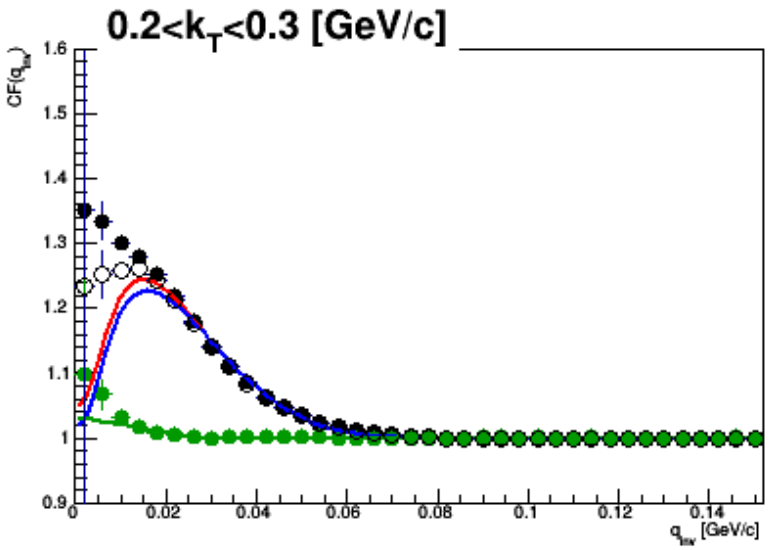
- THE „PSEUDOSPLITTING" WAS PARAMETRIZED BY A LINEAR FUNCTION
  - $C_{BCKG}(q) = 1 + a + bq$ IF $aq > 0$
  - $C_{BCKG}(q) = 1$IF $a + bq < 0$

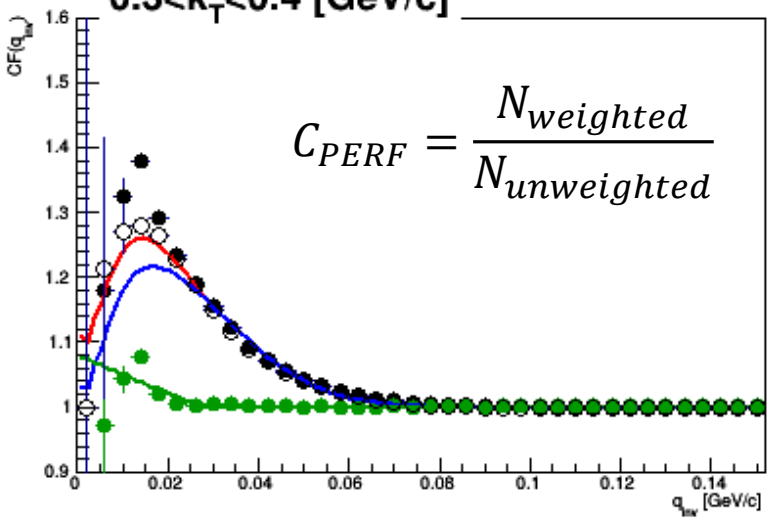
# PURITY STUDY

$C_{purity}$(q)=C-B*exp(-qA)

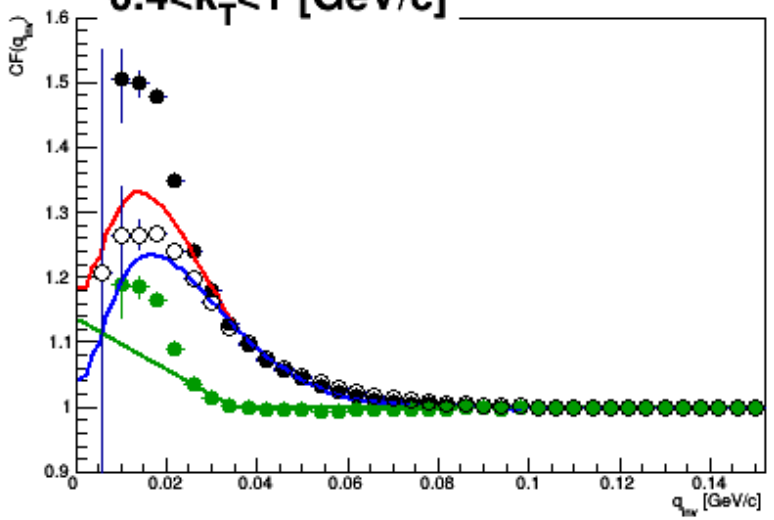





$$C_{PERF} = \frac{N_{weighted}}{N_{unweighted}}$$



# RESULTS

- STASTIC UNCERTAINTY WAS NEIGLIGIBLE
- THE SYSTEMATIC UNCERTAINTY:
  - 6.2-19.3 % FOR RADII (DEPENDS ON $K_T$)
  - 46.9-63.3 % FOR LAMBDA (DEPENDS ON $K_T$)
- MAIN SOURCES OF UNCERTAINTY:
  - FITTING RANGE
  - BACKGROUND CORRECTION FUNCTION

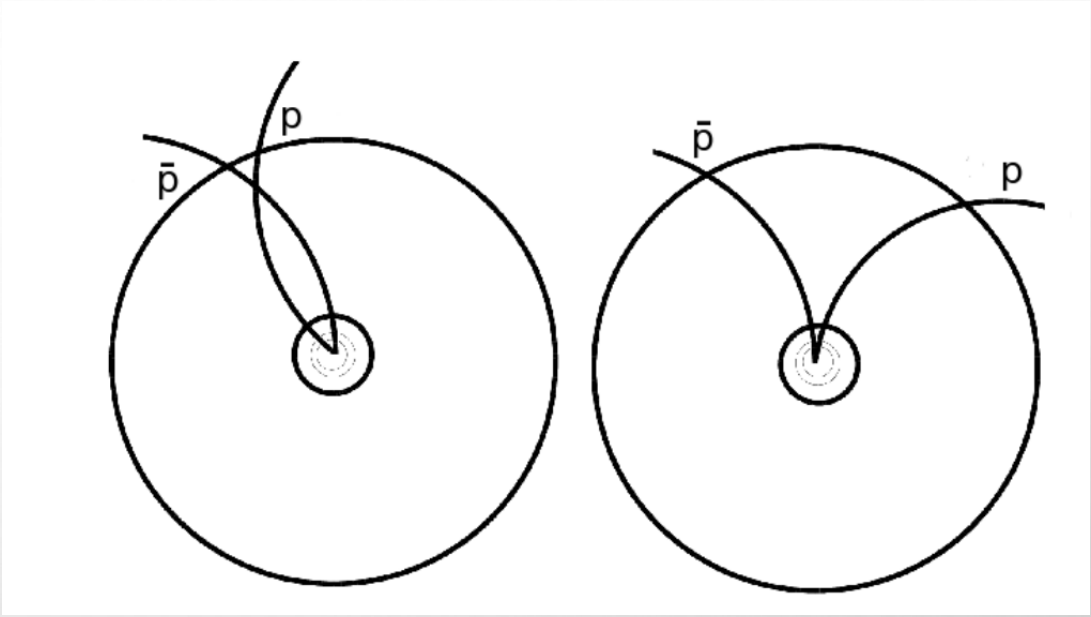
# 3-D CORRELATION FUNCTIONS

# 3D STUDIES

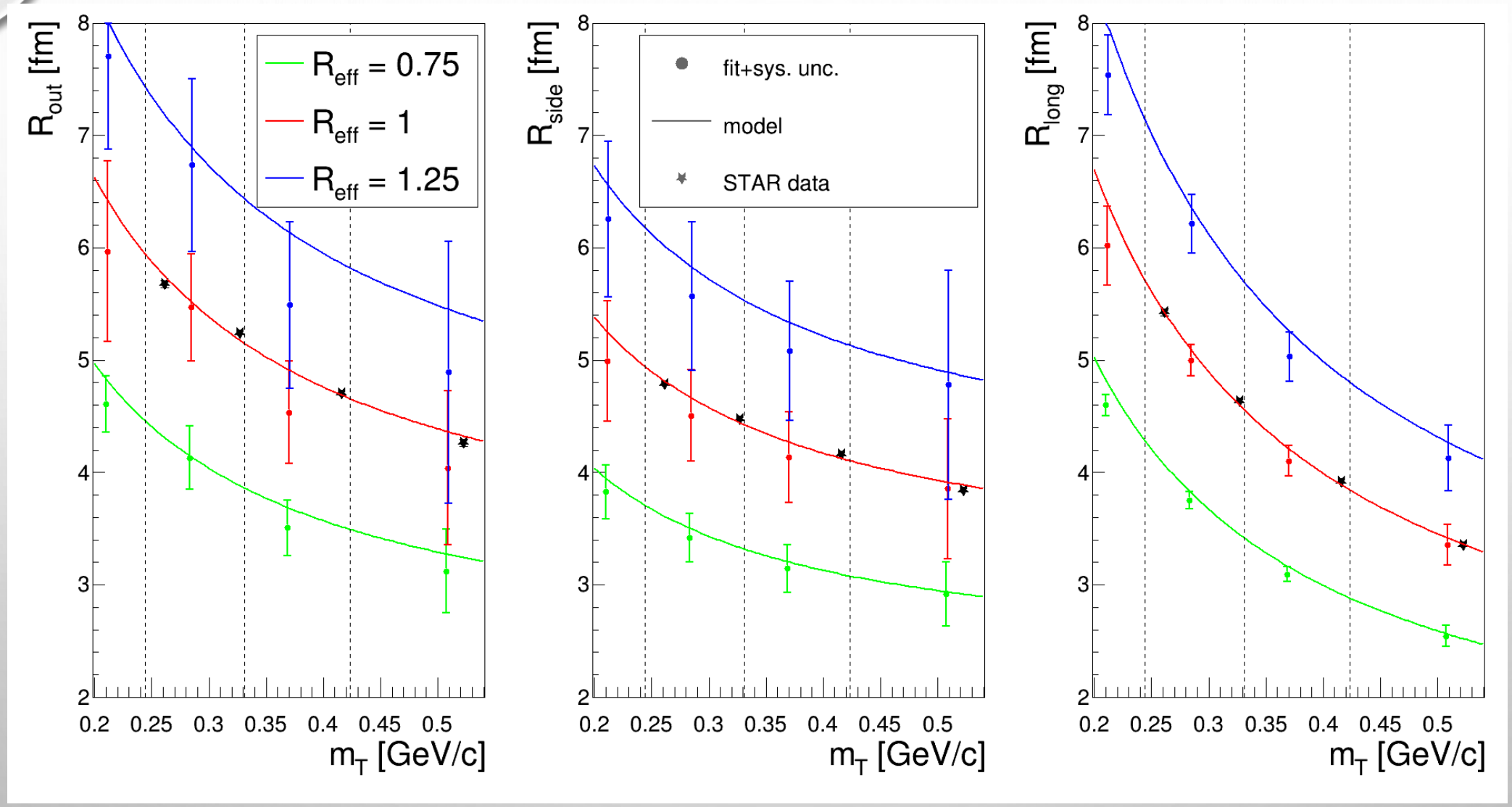
- THE SAME CUTS WERE APPLIED ON THE SAME DATA
- MAIN DIFFERENCES IN FITTING PROCEDURE:
  - DUE TO COMPUTING RESOURCES MOMENTUM RESOLUTION CORRECTION WAS NOT APPLIED – ONLY SYSTEMATIC UNCERTAINTY WAS ESTIMATED( AS A DIFFERENCE BETWEEN DATA FITTED WITH AND WITHOUT SMEARED MOMENTUM)
  - BOWLER-SINYUKOV USED (INSTEAD OF FUNCTION DIRECTLY FROM LEDNICKY'S CODE)
  - BACKGROUND FUNCTION DESCRIBED NUMERICALLY (CALCULATED FROM $\pi^-\pi^-$ PAIRS)

# 3D STUDIES

- STATISTIC UNCERTAINTY NEGLIGIBLE (<0.3%)
- TOTAL SYSTEMATIC UNCERTAINTY OF RADII
  - 14-17% FOR „OUT”
  - 11-15% FOR „SIDE”
  - 5 – 6% FOR „LONG”
  - 22-24% FOR „LAMBDA”




- MAIN SOURCE OF UNCERTAINTIES: TWO PARTICLE CUTS, COWBOY-SAILOR CUT, BOWLER-SINYUKOV PROCEDURE, MOMENTUM RESOLUTION CORRECTION


$R_{out}$ [fm]
$R_{side}$ [fm]
$R_{long}$ [fm]
$R_{eff}$ = 0.75
$R_{eff}$ = 1
$R_{eff}$ = 1.25
fit+sys. unc.
model
STAR data
$m_T$ [GeV/c]
2
3
4
5
6
7
8
0.2
0.25
0.3
0.35
0.4
0.45
0.5

# SUMMARY

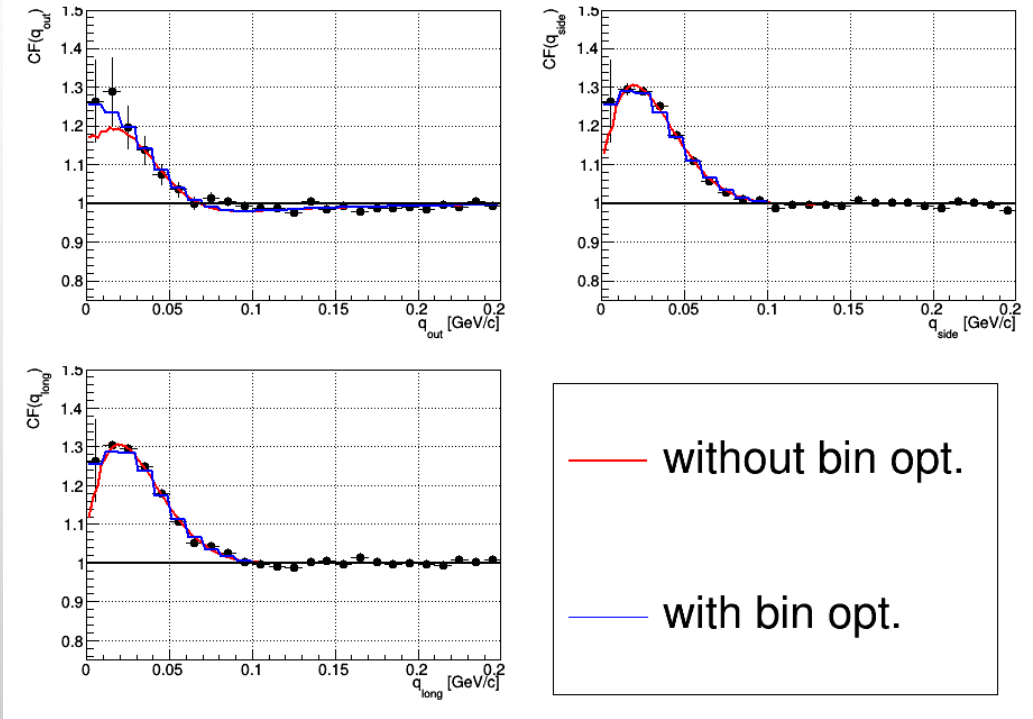
- STUDIES OF PION CORRELATION IN ONE AND THREE DIMENSIONS WERE PERFORMED
- THE „PSEUDOSPLITTING” EFFECT WAS OBSERVED (BUT NOT EXPLAINED!)
- BASIC TOOLS FOR FITTING WERE DEVELOPED AND TESTED
- SYSTEMATIC UNCERTAINTIES WERE ESTIMATED

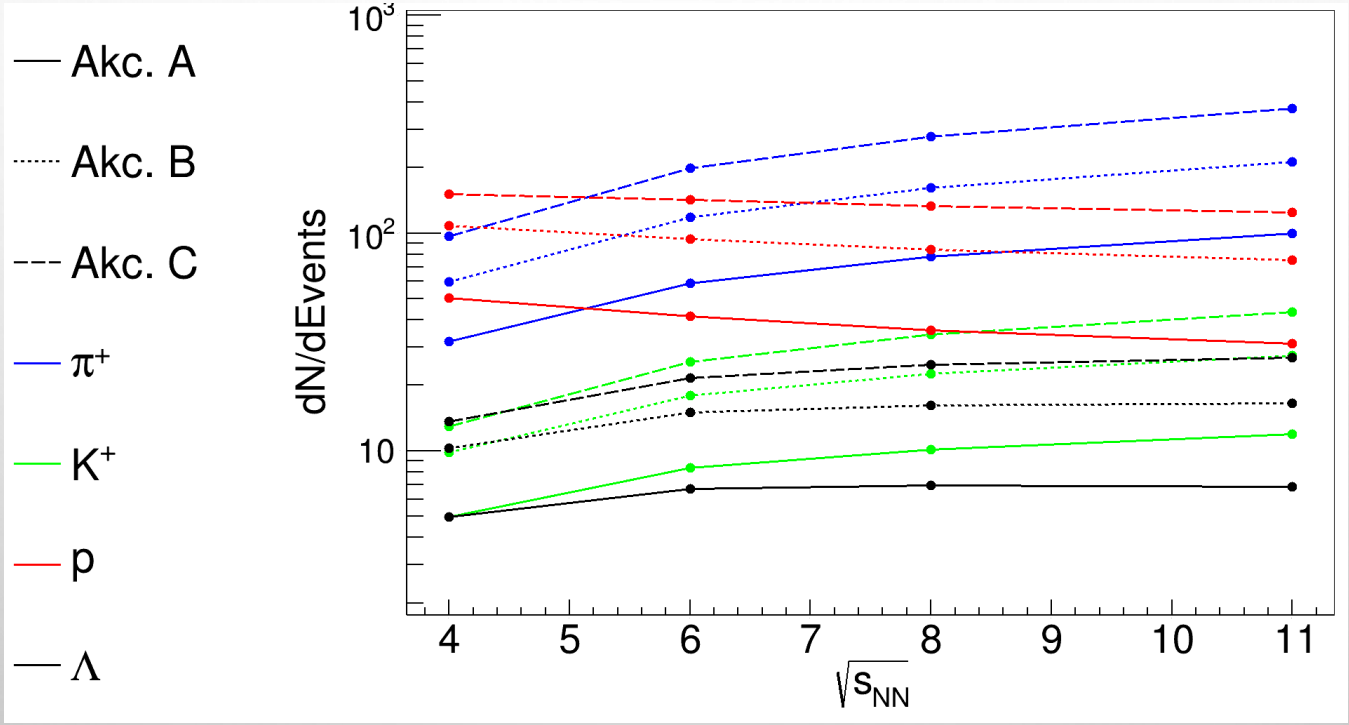
# PLANS FOR THE FUTURE

- GENERATION OF DATA WITH NEWER SOFTWARE
- IMPROVEMENTS IN FITTING PROCEDURES (ESPECIALLY FOR 3D CF)
- STUDY OF KAONS AND PROTONS (REQUIRE MUCH MORE STATISTICS)

# THANK YOU FOR YOUR ATTENTION

# BACKUP SLIDES




Akc. A
Akc. B
Akc. C
π+
K+
p
Λ
dN/dEvents
10³
10²
10
4
5
6
7
8
9
10
11
√sNN