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Femtoscopy study with new EPOS model

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Outline

- Motivation of the femtoscopy study with the Epos model
- Technical details of the Epos Femto package
- First results from Epos Femto package and comparison with STAR data (AuAu at 200 GeV)
- Non-femtoscopic effects in Epos
- Conclusions

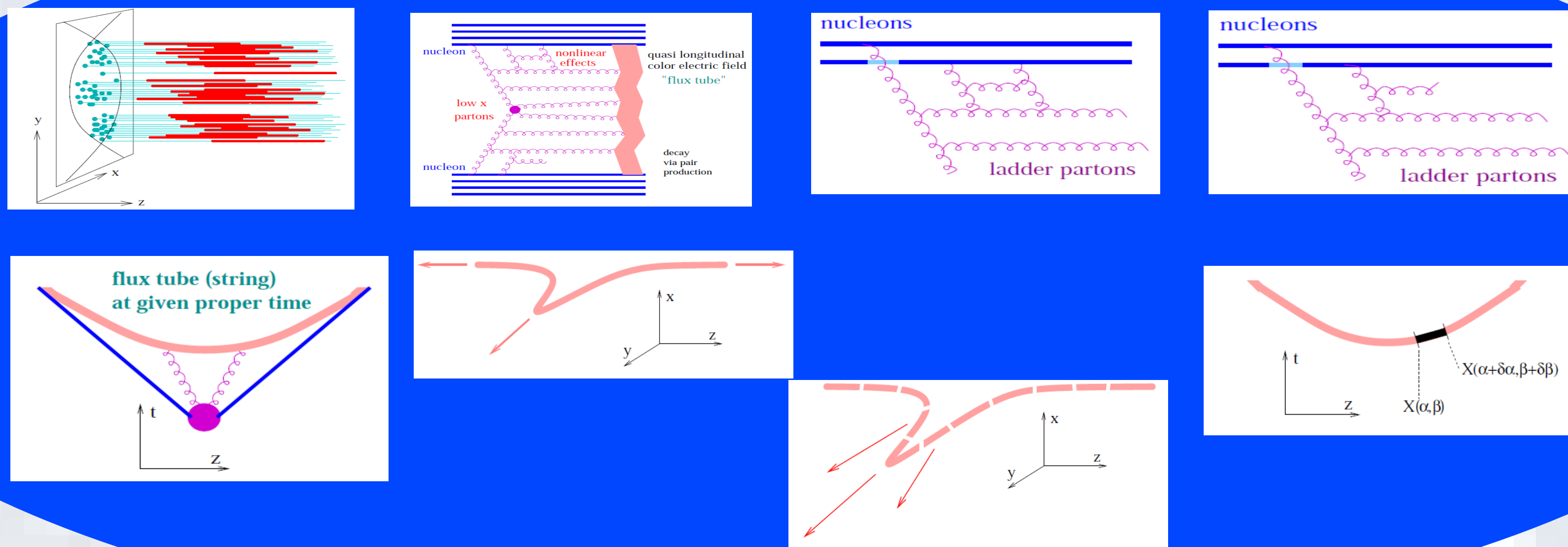
Motivation

- EPOS is not a simple MC event generator, Epos is a physical event model which includes all stages of collision (init. conditions from flux tube, EbE procedure, 3+1 hydrodynamics, realistic EoS, complete resonance table, hardonic cascade)
- EPOS provides space-time coordinates of hadrons
- Possibility to study femtoscopy with EPOS
- EPOS is very wide energy range model

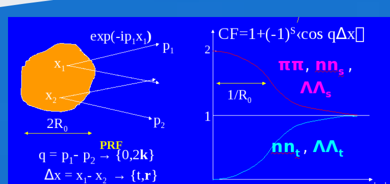
(applicability: pp, pA, AA, a tens GeV < $\sqrt{s}$ < a few TeV)

Epos and Femto

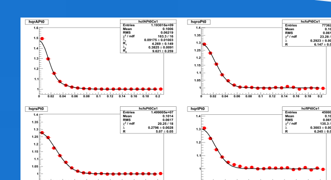
EPOS code v.2.0 [arxiv.org/abs/1004.0805]



Connection via Epos Tree



Femtoscopy analysis
1d, 3d, ππ,KK,pp,
πp,pΛ,…



Radii, k_T (m_T) dependence, centrality dependence, etc

Epos Femto Package features

- Epos Femto package is a part of Epos2 code
- Femto could be used as a stand alone code (input Epos Root Tree events)
- Femto is a C++ code based on root framework
- The correlation function is calculated with event mixing technique: $C= (dN_{real}/dQ)/(dN_{mixed}/dQ)$
- The correlation weight is provided by R.Lednicky code
- All pairs of particles which are in Lednicky's code could be studied in Epos Femto package
- It is possible to smear the momentum of the particle according to the detector response

Histograms

- Source function histograms:
  ΔR_{out}, ΔR_{side}, ΔR_{long} in LCMS

- 1D correlation function histograms:
  dN_{real}/dQ, projections: dN_{real}/dQ_{out}, dN_{real}/dQ_{side}, dN_{real}/dQ_{long}
  dN_{mix}/dQ, projections: dN_{mix}/dQ_{out}, dN_{mix}/dQ_{side}, dN_{mix}/dQ_{long}
  $CF(Q)$, projections: $CF(Q_{out})$, $CF(Q_{side})$, $CF(Q_{long})$

- 3D correlation function histograms:
  $d^3N_{real}/dQ_{out}dQ_{side}dQ_{long}$
  $d^3N_{mix}/dQ_{out}dQ_{side}dQ_{long}$
  $CF(Q_{out},Q_{side},Q_{long})$

- A few technical histograms in addition

Fit functions

- 1D fit function:

$1+\lambda \exp(-R_{inv}^2 Q_{inv}^2)$

$1+\lambda_1 \exp(-R_1^2 Q_{inv}^2)+\lambda_2 \exp(-R_2^2 Q_{inv}^2)$

$(1+\lambda \exp(-R_{inv}^2 Q_{inv}^2))*(1+\delta Q_{inv}^2)$

$(1+\lambda \exp(-R_{inv}^2 Q_{inv}^2))*(a+bQ_{inv}+cQ_{inv}^2)$

- 3D fit function:

$1+\lambda \exp(-R_{out}^2 Q_{out}^2 - R_{side}^2 Q_{side}^2 - R_{long}^2 Q_{long}^2)$

Go to the First results

http://arxiv.org/abs/1004.0805

Simulation: software and input

- EPOS 2.0, model details in http://arxiv.org/abs/1004.0805
- Compare with STAR HBT ππ in AuAu collisions at √s=200 GeV

[PHYSICAL REVIEW C 71, 044906 (2005)]

- Analysis of Epos events

~0.5 M events of AuAu collisions at 200 GeV ,
5 centrality regions: 0–5%,5–10%, 10–20%, 20–30%, 30–50%, and 50–80%

- k_T regions: 150-250,250-350,350-450,450-600 MeV/c
- STAR accepnace: $0.15<P_T<0.8$ GeV/c, $|\eta|<0.5$
- Only Q.S. weight for $\pi+\pi+$ pairs
- Fit function (3d):

$$1+\lambda \exp(-R_{out}^2 Q_{out}^2 - R_{side}^2 Q_{side}^2 - R_{long}^2 Q_{long}^2)$$

Different Epos model scenarios

We will compare three scenarios:

1.) The full scenario:
flux tube+hydro+hadronic cascade

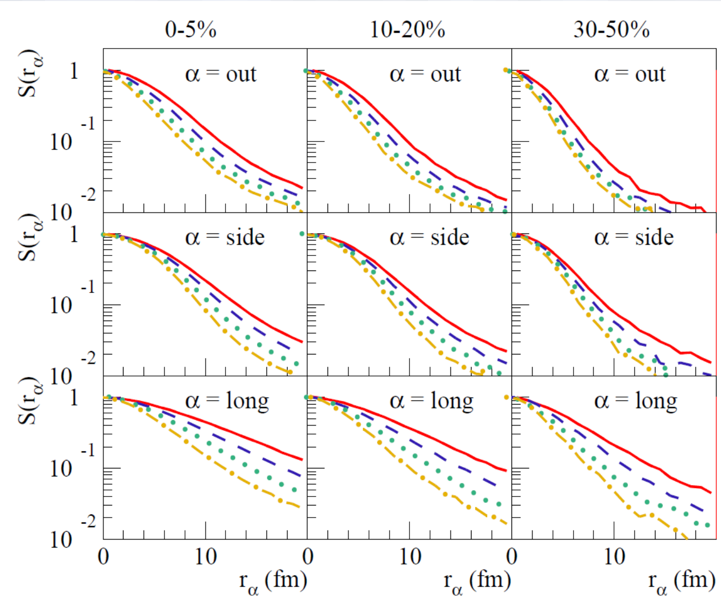
2.) The calculation without hadronic cascade:
with final freeze out at 166 MeV

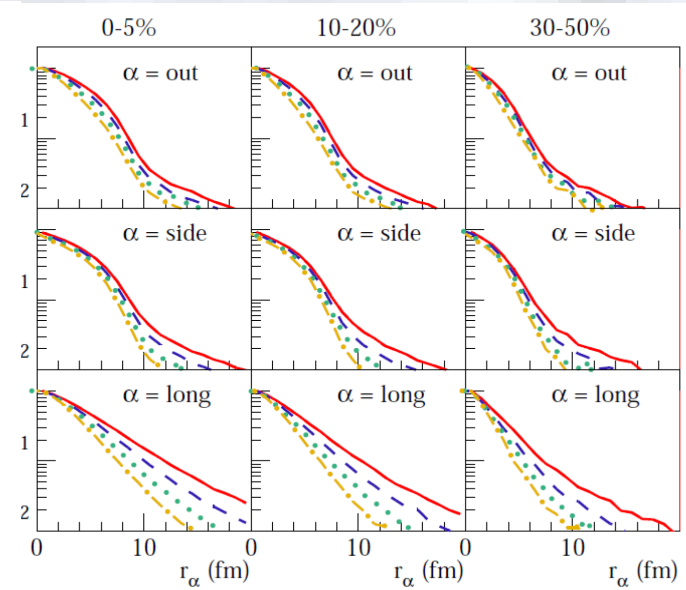
3.) The fully thermal scenario:
hydrodynamical evolution till a late freeze-out
at 130 MeV and no hadronic cascade afterwards

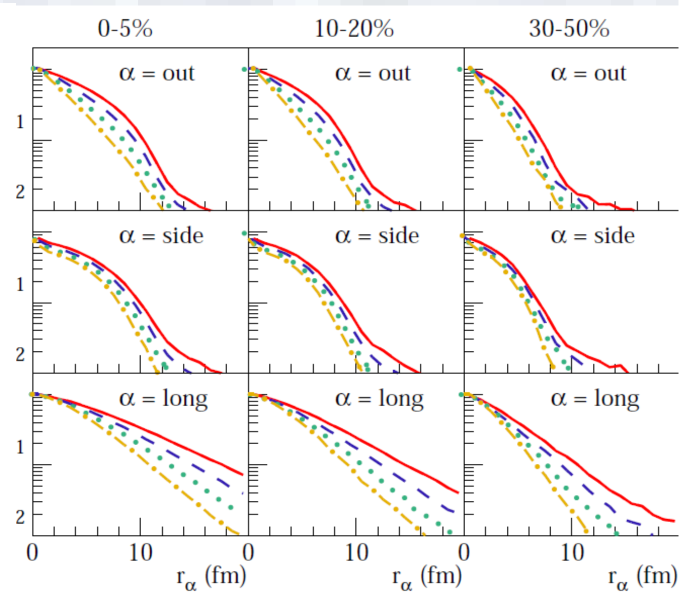
Source functions

The source functions as obtained from our simulations, for three different centralities (0-5%, 10-20%, and 30-50%), representing the distribution of the space separation of the emission points of the pairs, in LCMS. Full curves – first k_T bin, dashed – second k_T bin, and so on. The curves get narrower with increasing k_T (decreasing radii). The curves get narrower with decreasing centrality (decrease of radii with decreasing centrality).

1. full scenario 2. without hadronic cascade 3. fully thermal scenario





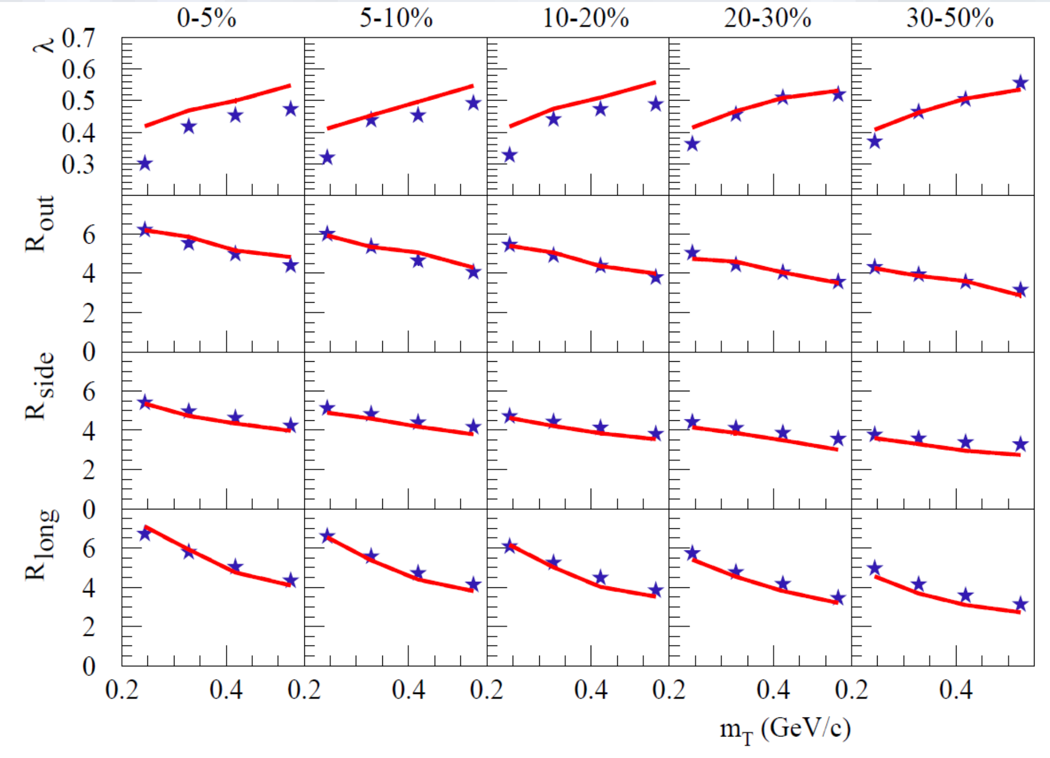


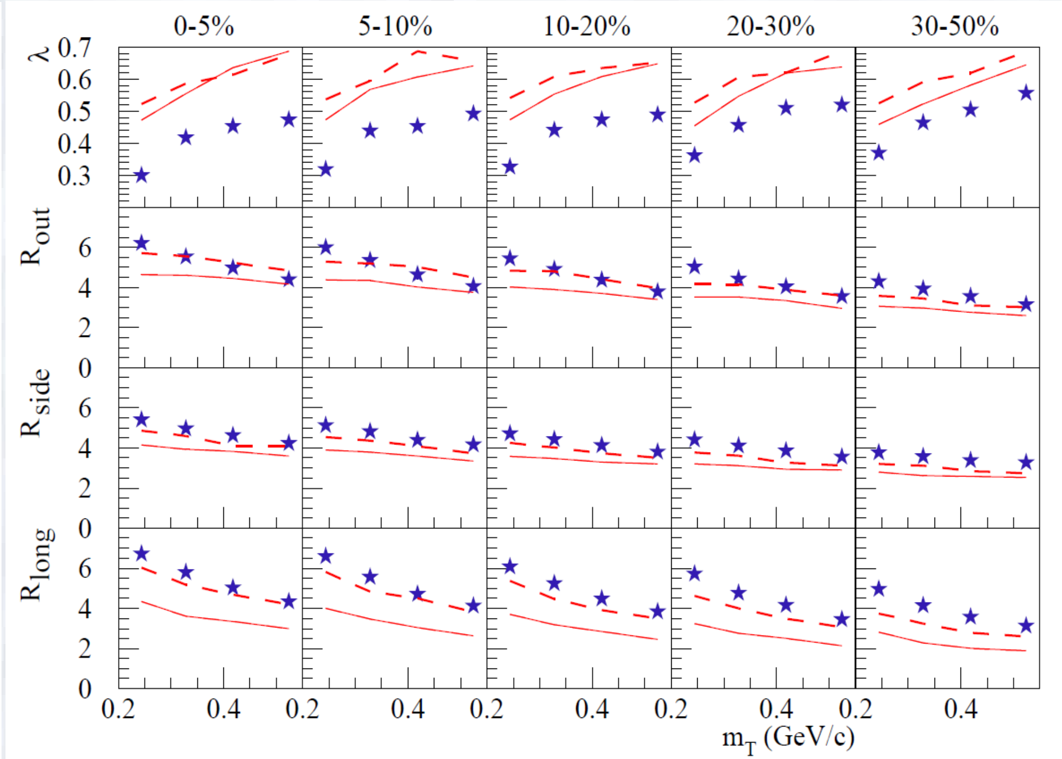
The fitting procedure based on the hypothesis that the source function Gaussians and it does not sensitive to the non-Gaussian tails.

One can expect similar results for scenario 1 and 3.

Femtoscopic radii (differnt scenarios)

R_{out}, R_{side}, and R_{long} as a function of m_T for different centralities (0-5% most central, 5-10% most central, and so on). The star sybols are the data of STAR.
Left: Thick full line - full calculation, hydro&cascade (scenario 1).
Right: Thin full line - the calculations are done without hadronic cascade (scenario 2).
Dashed lines - with a hydrodynamic evolution through the hadronic phase with freeze-out at 130 MeV (scenario 3).



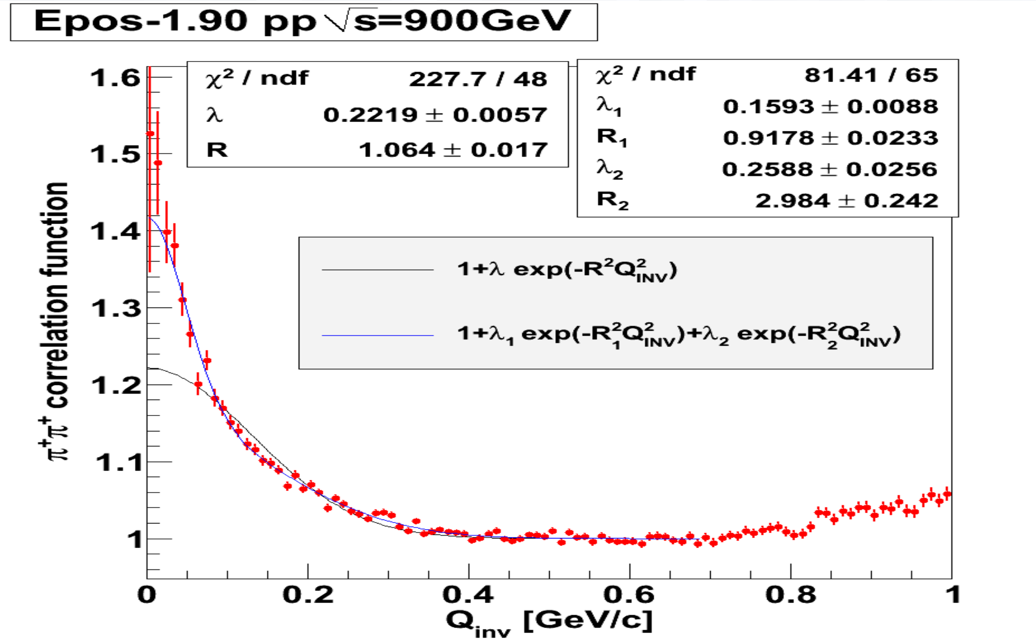


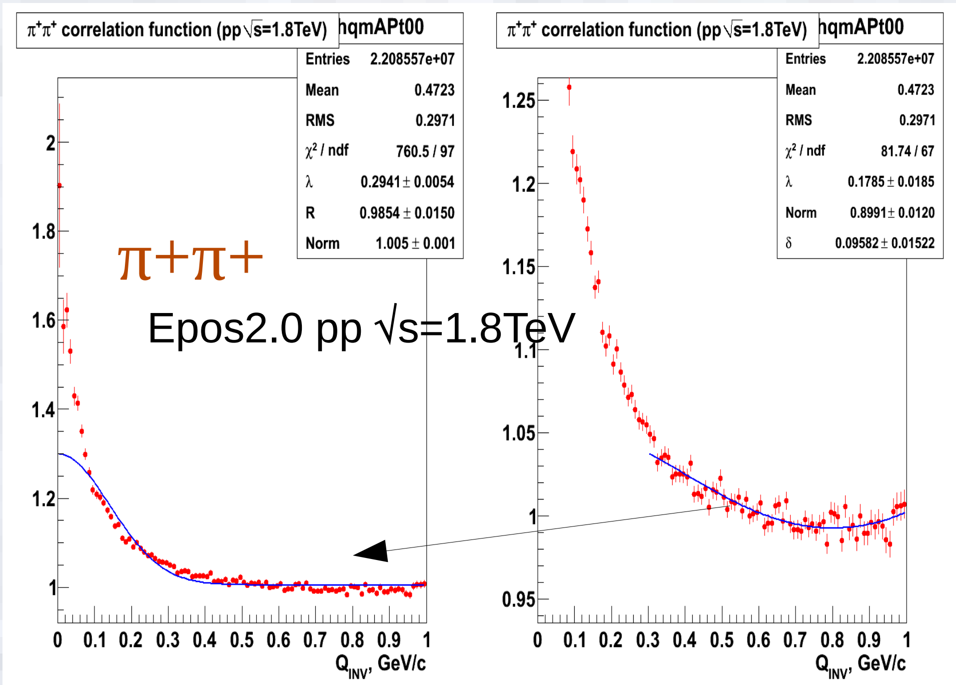
Scenario 1, scenario 3, and the data are similar.
It could be better to compare the shape of CF, not only radii

Non-femtoscopic effects...

Long range correlation

These correlations (so-called "long-range correlations "— LRC) arise mainly from momentum conservation for real events, which is not a requirement for mixed pairs. LRC cause a smooth increase of CF with q, which reflects the fact that due to momentum conservation the probability of two particles emitted in the same direction is smaller than that of two particles emitted in opposite directions. Empirically, LRC can be parametrized as R ∝exp(b cos ψ), in which ψ is the angle between the two particles and b is a constant [A. V. Vlassov et al., Phys. At. Nucl. 58, 613 (1995)]. Practically, accounting for such a weak dependence of the correlation function on q is usually taken into account by introducing into data fit a factor (1 + const q^2)





PYTHIA 7e5 pp events √s=14 TeV

π+π+ correlation function

Cuts:

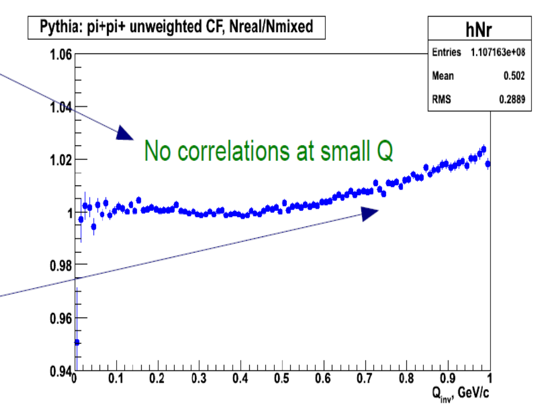
0.1 < P_T < 1.0 GeV/c

-1. < η < +1.

CF=Real/Mixed

Energy and Momentum Conservation-Induced Correlations:

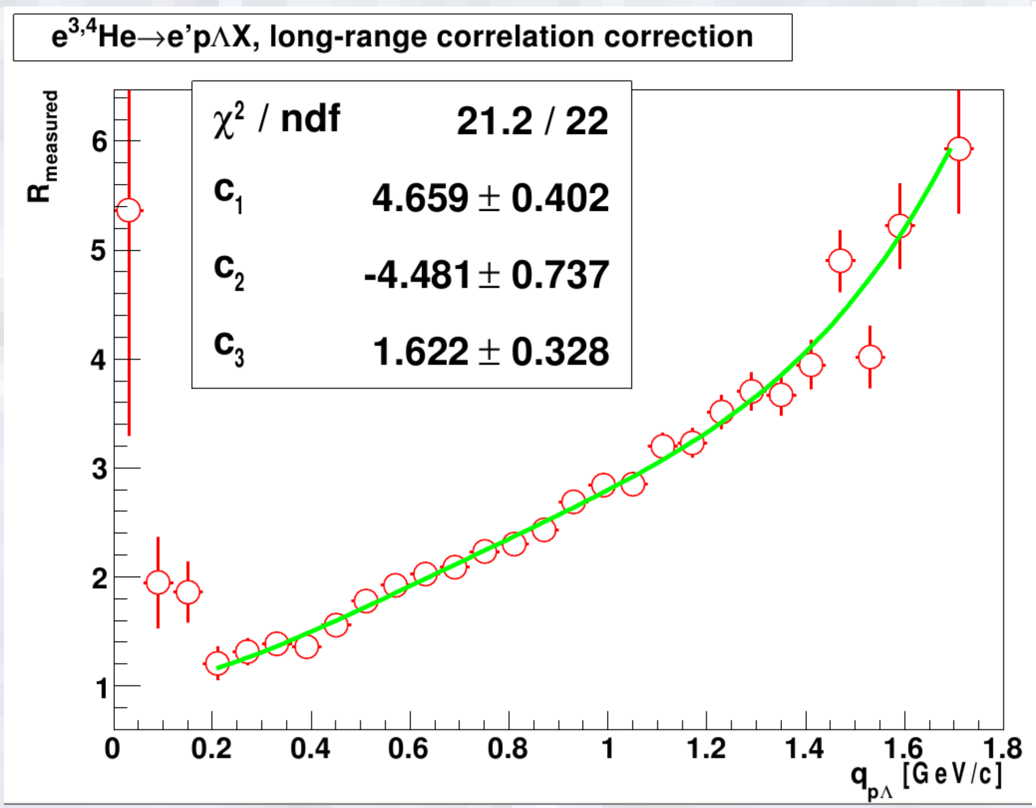
Due to energy-momentum conservation probability of two particle emitted at same direction is smaller than in opposite direction

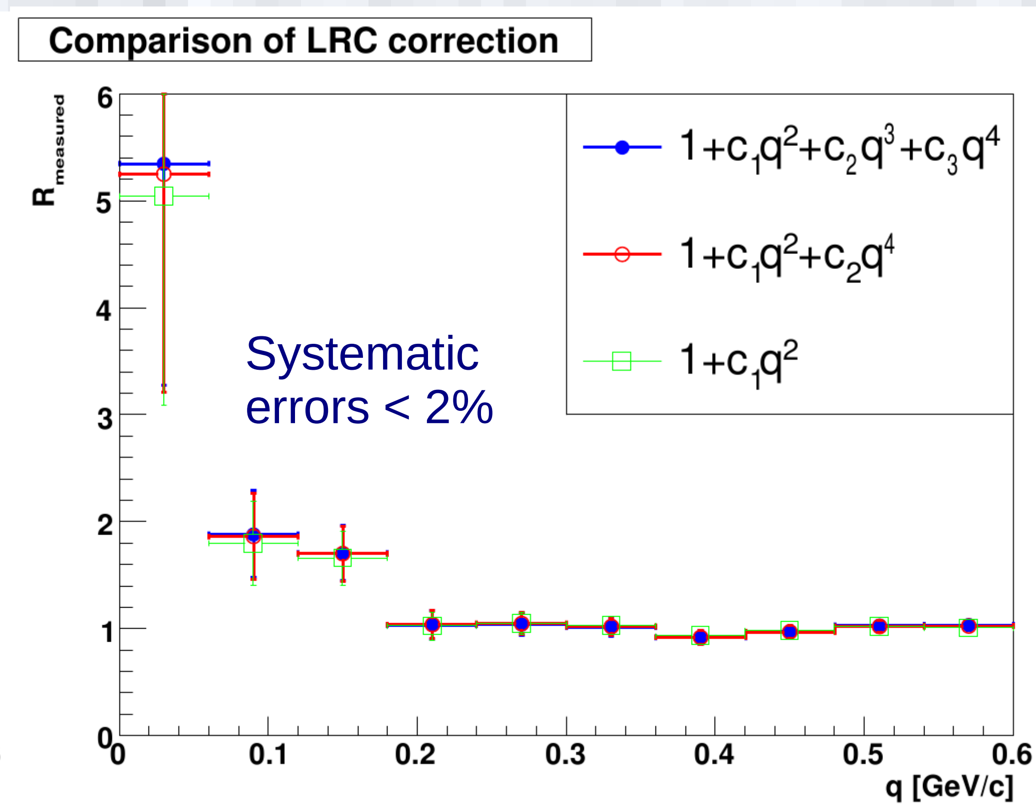


CEBAF data

Source-Size Measurements in the $e^3He(^4He) \rightarrow e'p\Lambda X$ Reaction

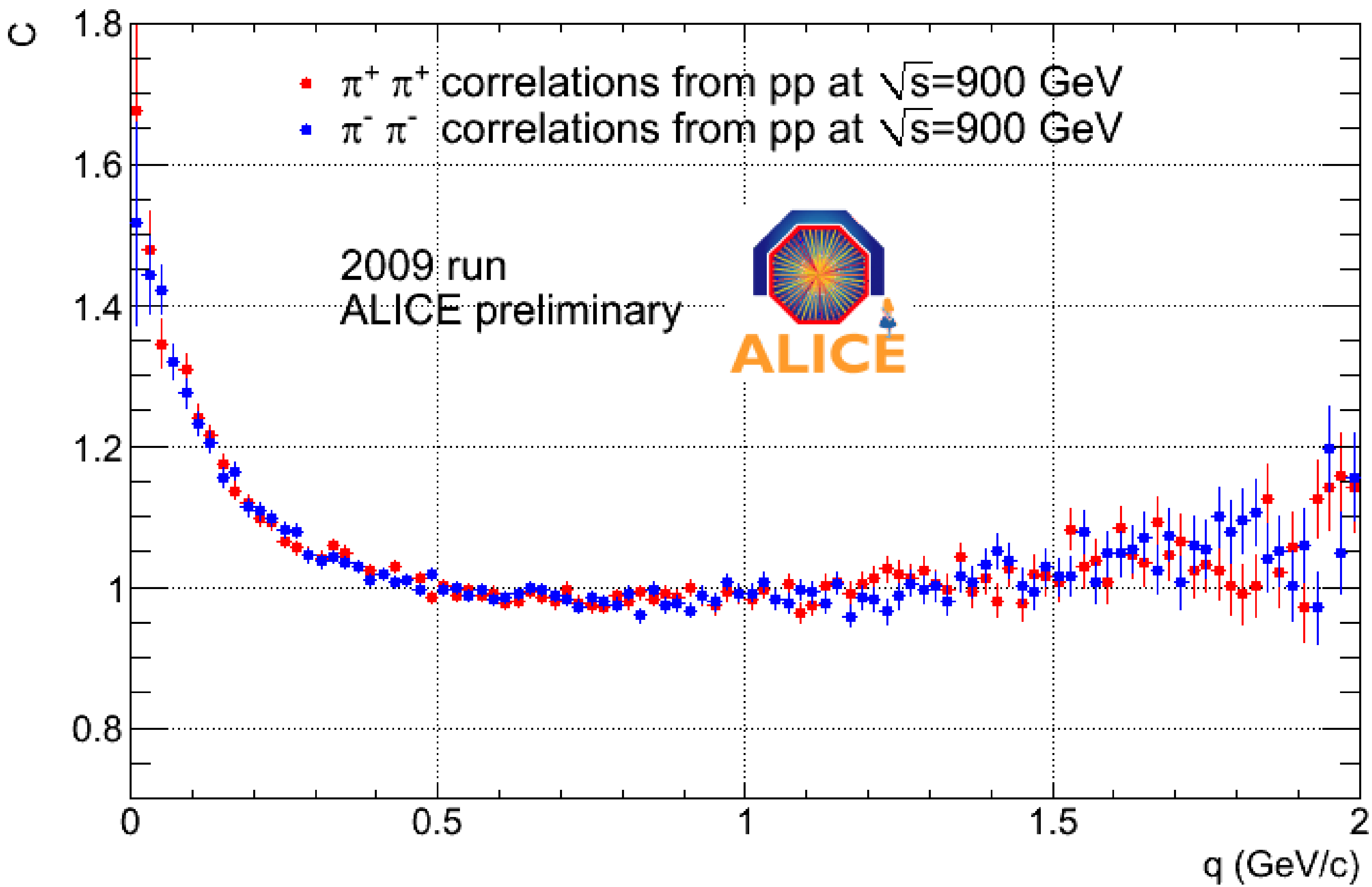
[Physics of Atomic Nuclei, 2009, Vol. 72, No. 4, pp. 668–674.]





LRC in ALICE

Dariusz Miskowiec, Particle correlations in ALICE, Physics at the LHC, Hamburg, 10-Jun-2010



Non-femtoscpic effects with EPOS

- ππ correlation in pp at $\sqrt{s}$=900GeV Epos 2.05 model calculation
- k_T intervals [100,250],[250,400],[400-550],[550-700],[700-1000] MeV/c
- High multiplicity $dN_{ch}/d\eta(0)=12.9$
- Full correlation function with mixing procedure (femto and non-femto):

  $CF = [dN_{real}/dq_{inv} *W(r,p)] / [dN_{mixed}/dq_{inv}]$

- Pure femtoscopic correlation function (femto):

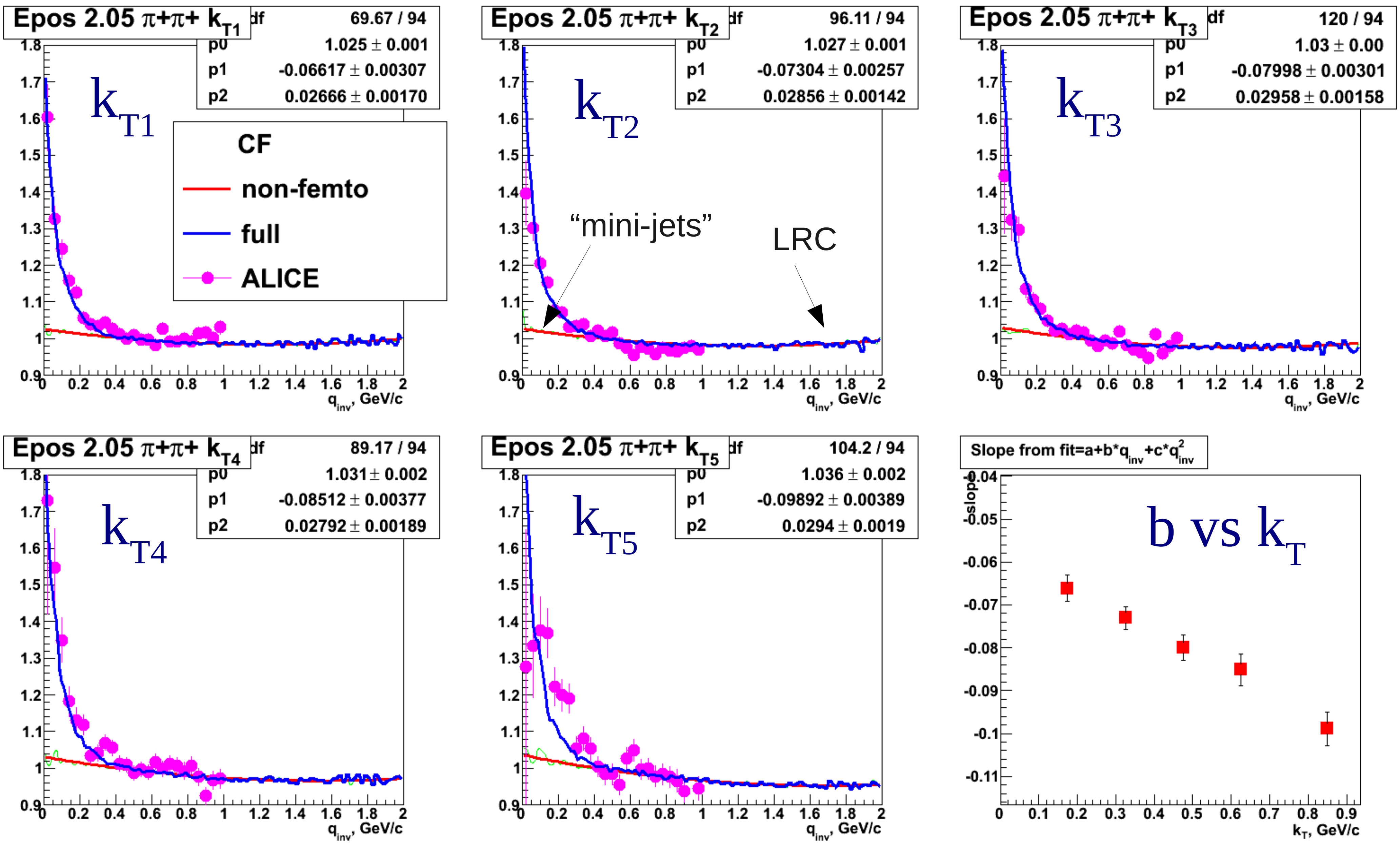
  $CF= [dN_{real}/dq_{inv} *W(r,p)] / [dN_{real}/dq_{inv}]$, where W is pure femtoscopic weight from Lednicky's code (QS only)

- Pure Epos correlation function (non-femto):

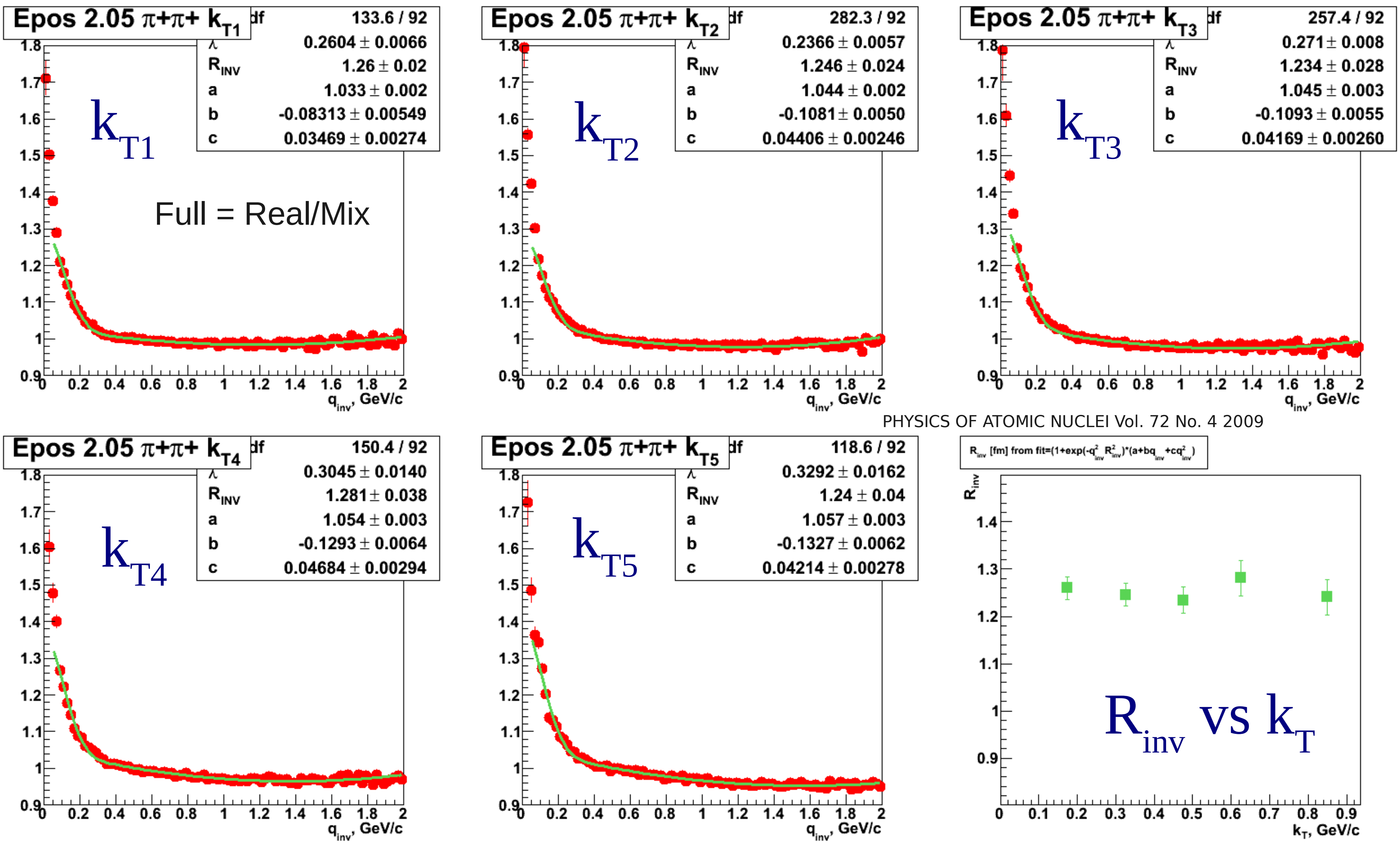
  $CF = [dN_{real}/dq_{inv}] / [dN_{mixed}/dq_{inv}]$

Epos non-femto: $a+bq_{inv}+cq_{inv}^2$

Points are ALICE ππ correlation in pp$\sqrt{S}$=900GeV data [arXiv:1007.0516v1 hep-ex]

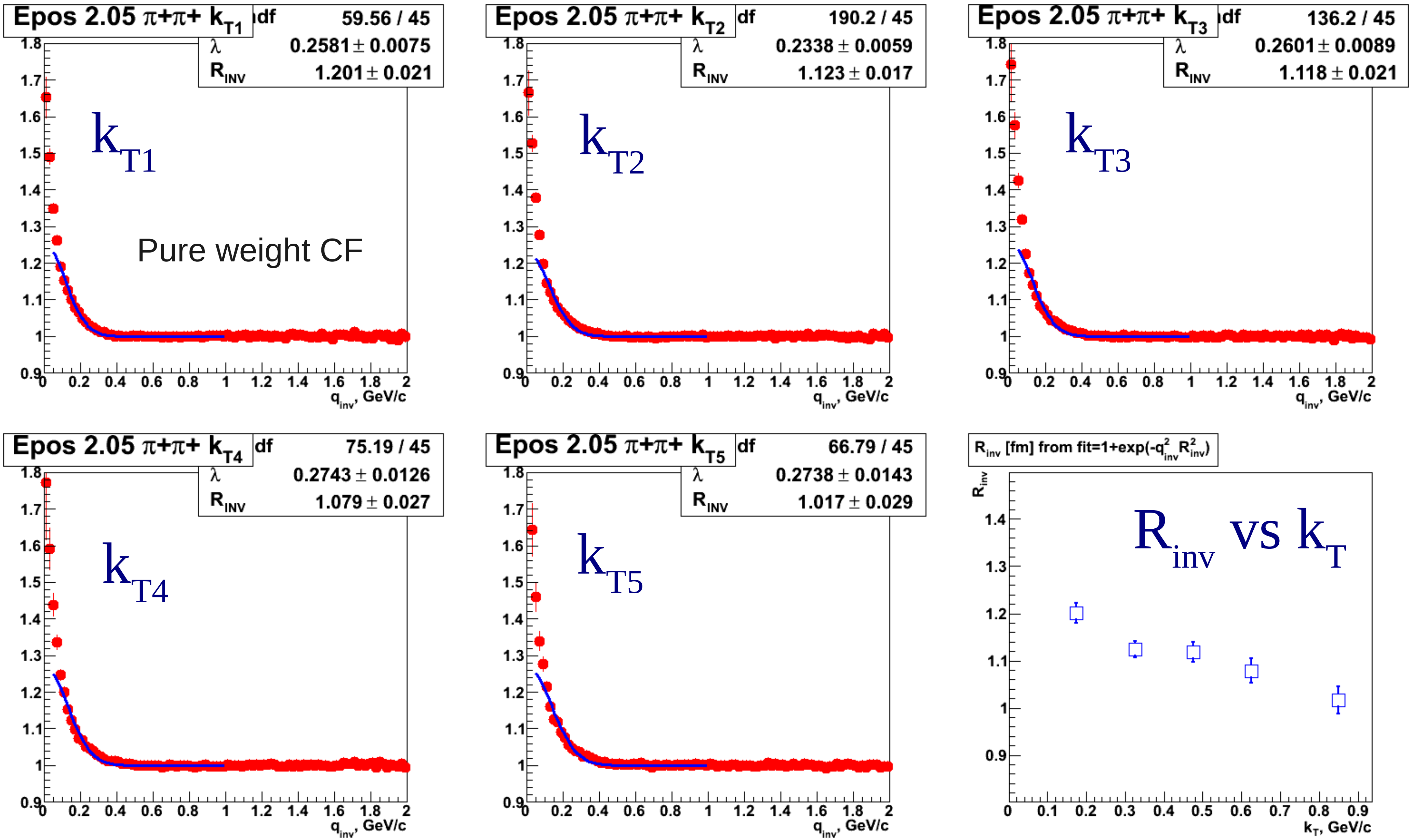


Epos full: $(1+\lambda\exp(-R^2q^2))(a+bq+cq^2)$

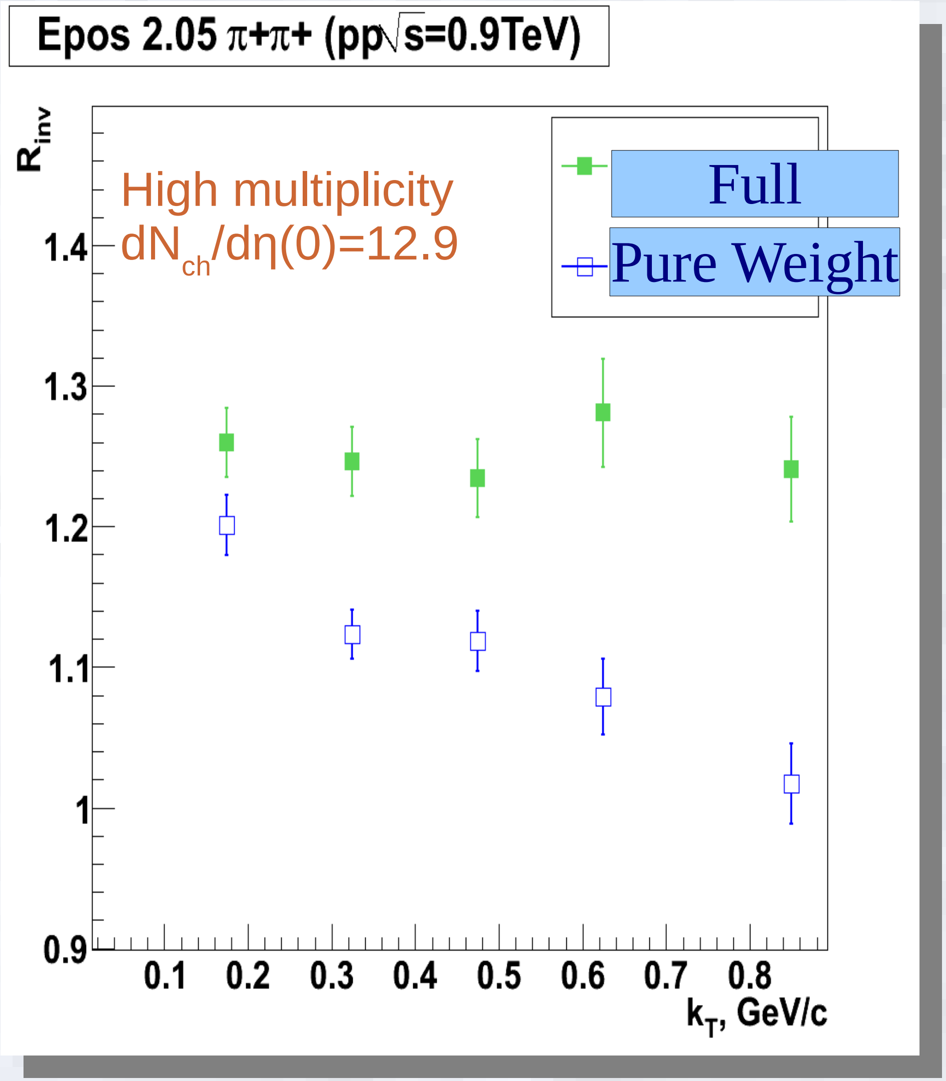


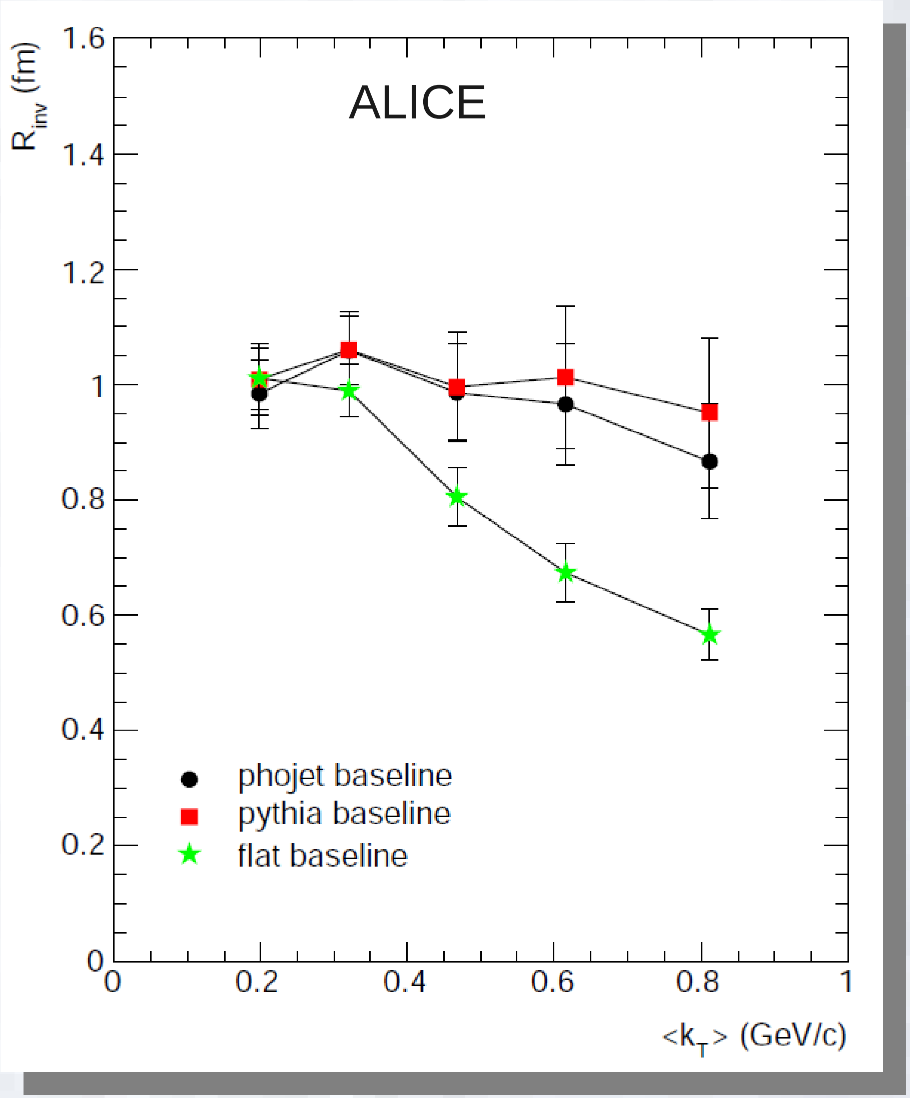
PHYSICS OF ATOMIC NUCLEI Vol. 72 No. 4 2009

Epos pure weight: $(1+\lambda\exp(-R^2q^2))$

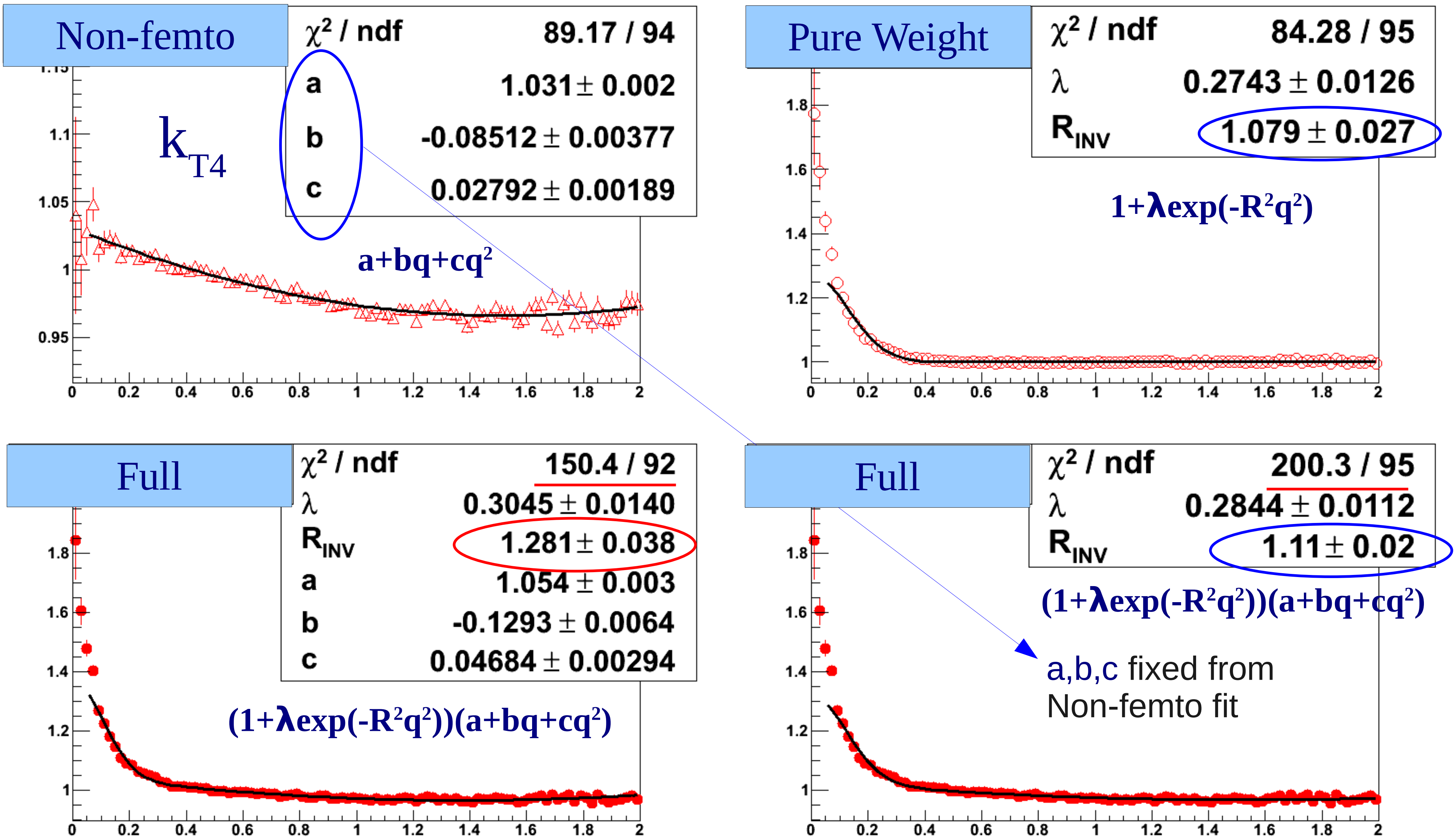


R_{inv} pure and full



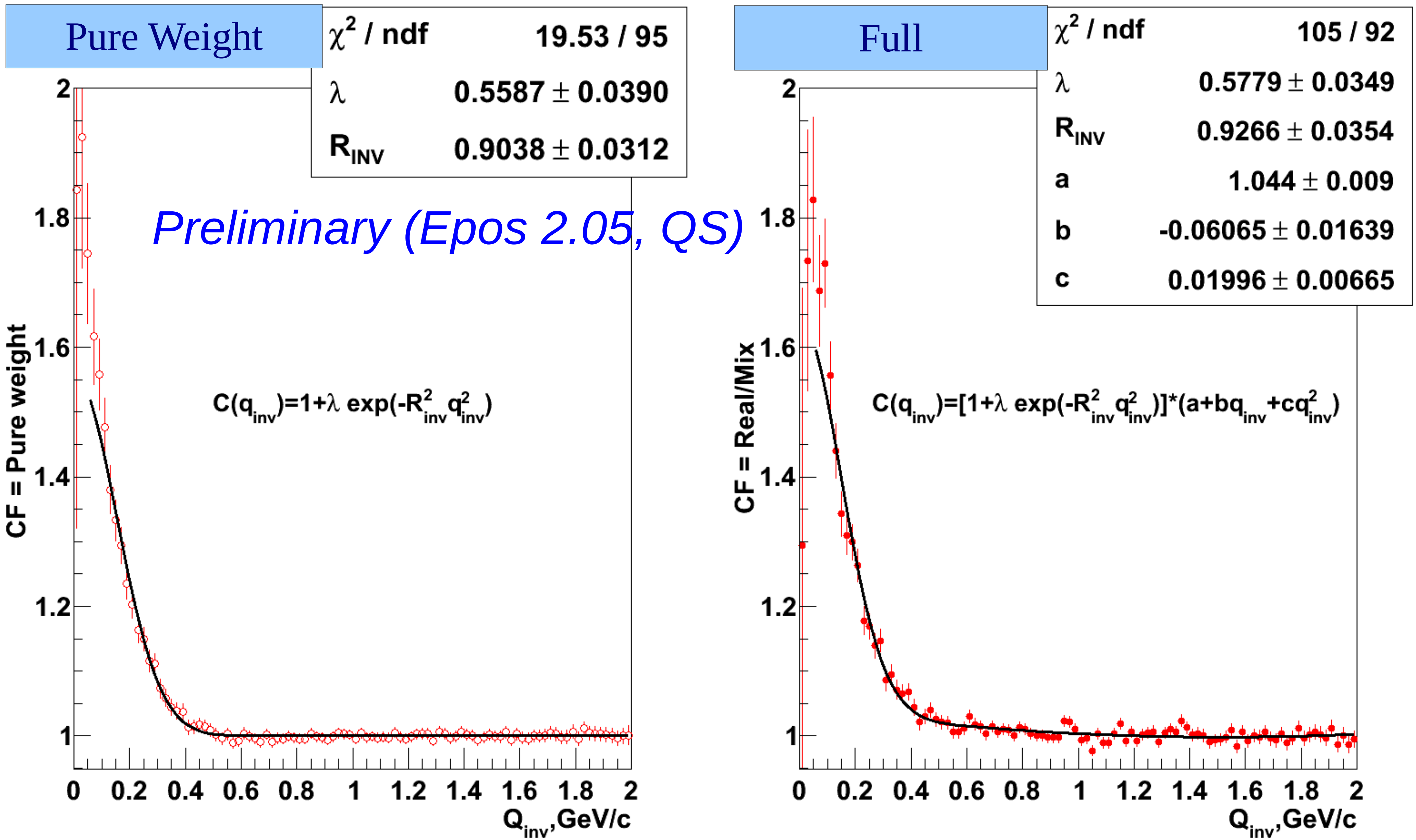


Epos: non-femto, pure, real/mix

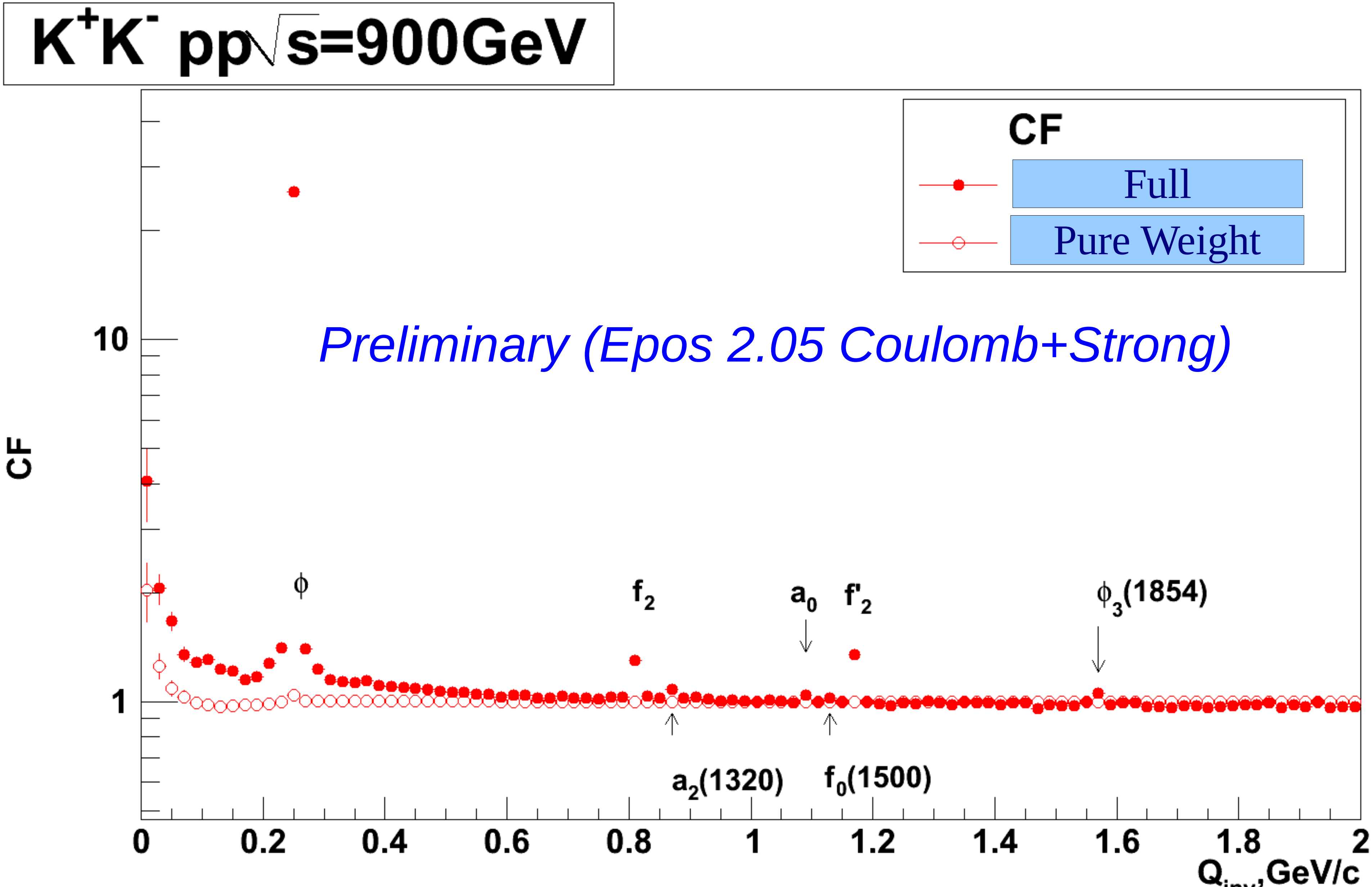


KK in Epos 2.05 (Preliminary)

Epos 2.05 K+K+ pp √s=900GeV



Epos 2.05 K+K- pp √s=900GeV

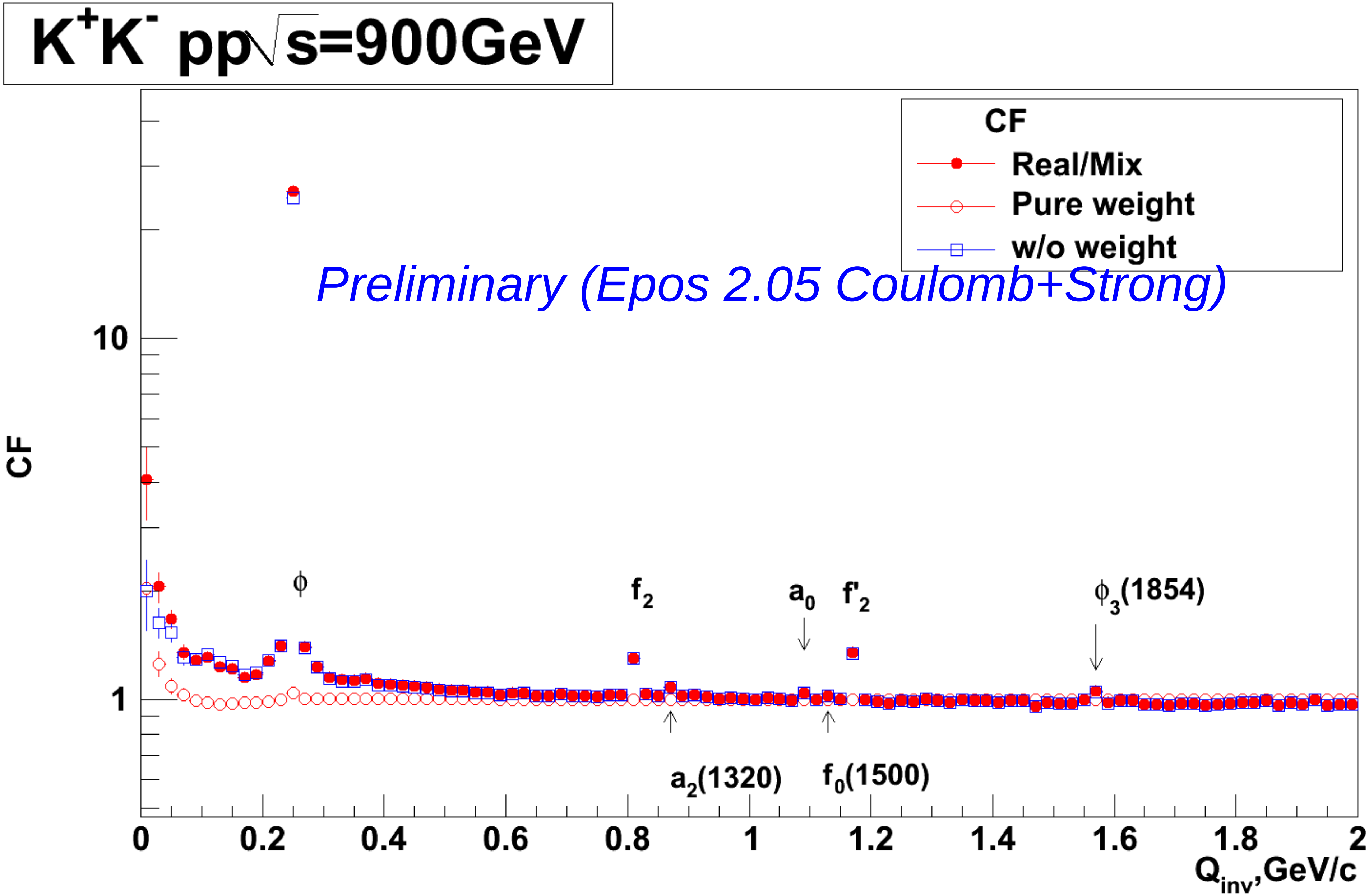


Conclusion

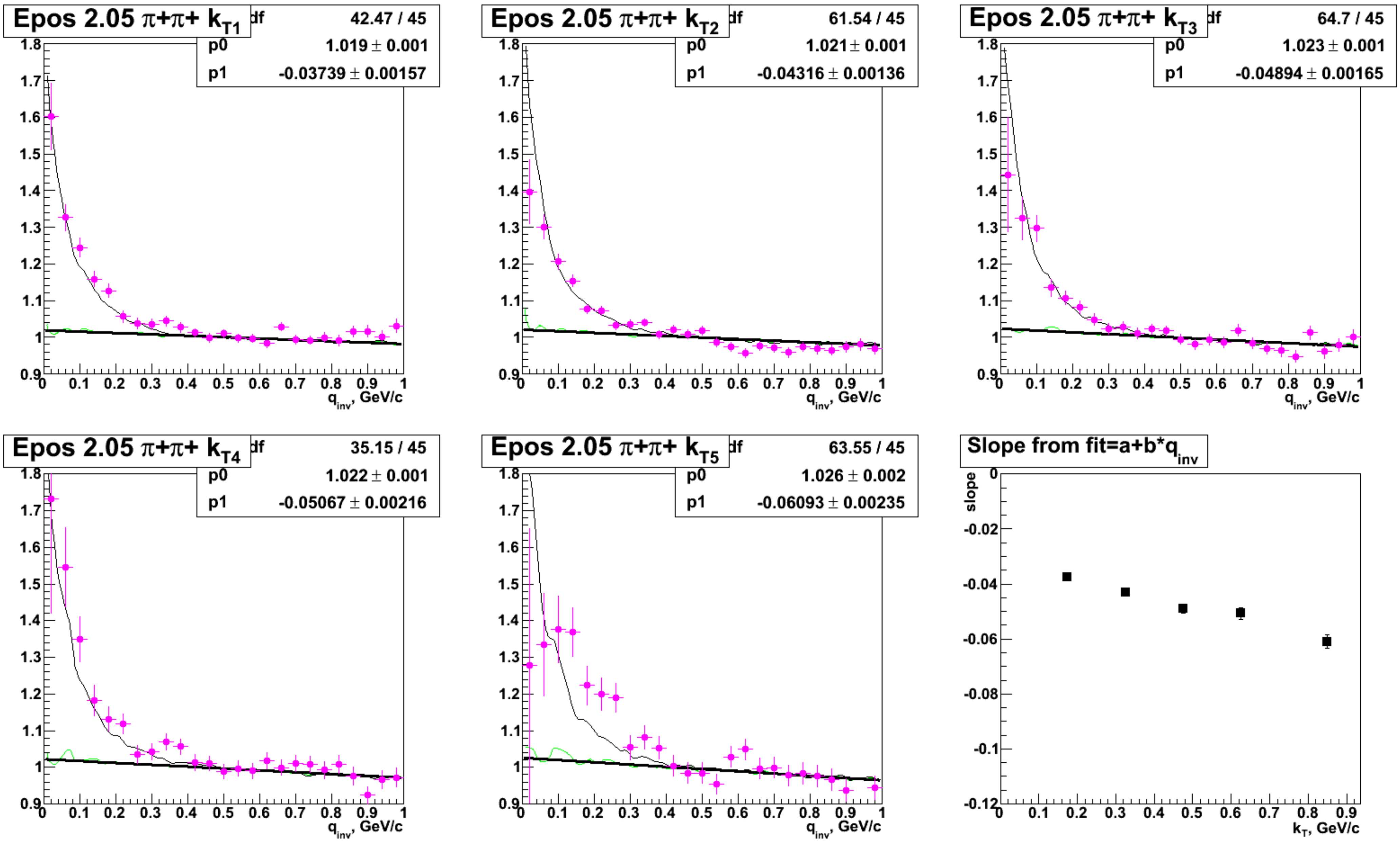
1. The Epos Femto package exists and works
2. STAR HBT pipi data was described with new Epos2+Femto
3. New studies (pp collisions at LHC energies) with Epos Femto are in progress
4. Non-femtoscopic effects could be very important in case of low multiplicity, e.g. pp collisions

Thank you for your attention!

Extra Slides

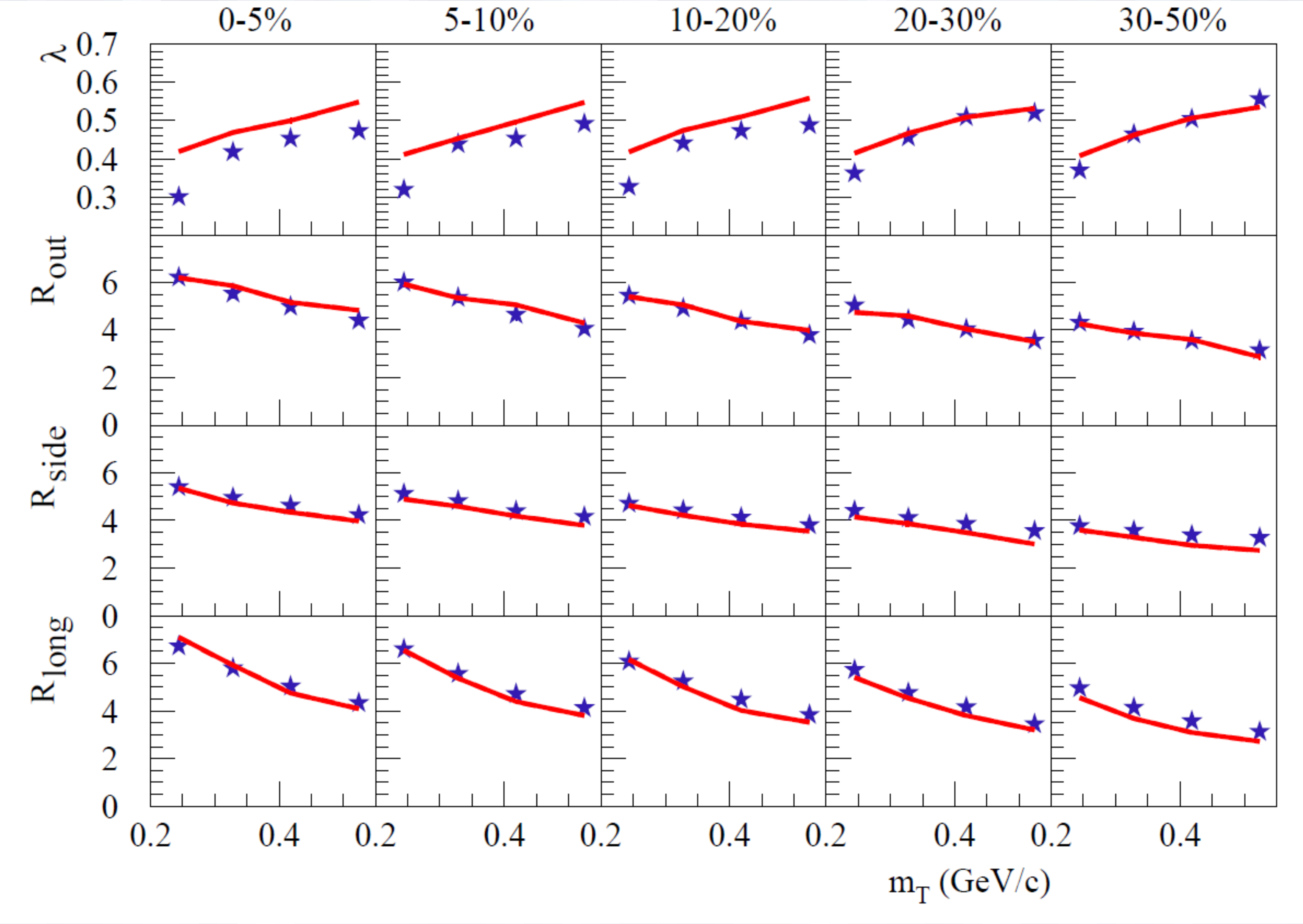

K^+K^- pp$\sqrt{s}$=900GeV
CF
Real/Mix
Pure weight
w/o weight
Preliminary (Epos 2.05 Coulomb+Strong)
10
1
CF
ϕ
f_2
a_0
f'_2
$\phi_3(1854)$
$a_2(1320)$
$f_0(1500)$
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Q_{inv},GeV/c

$a+bq_{inv}$ in $\pi^+\pi^+$ CF



Femtoscopic radii (full calculation)

Rout, Rside, and Rlong as a function of m_T for different centralities (0-5% most central, 5-10% most central, and so on). The full lines are the full calculations (including hadronic cascade), the stars data of STAR

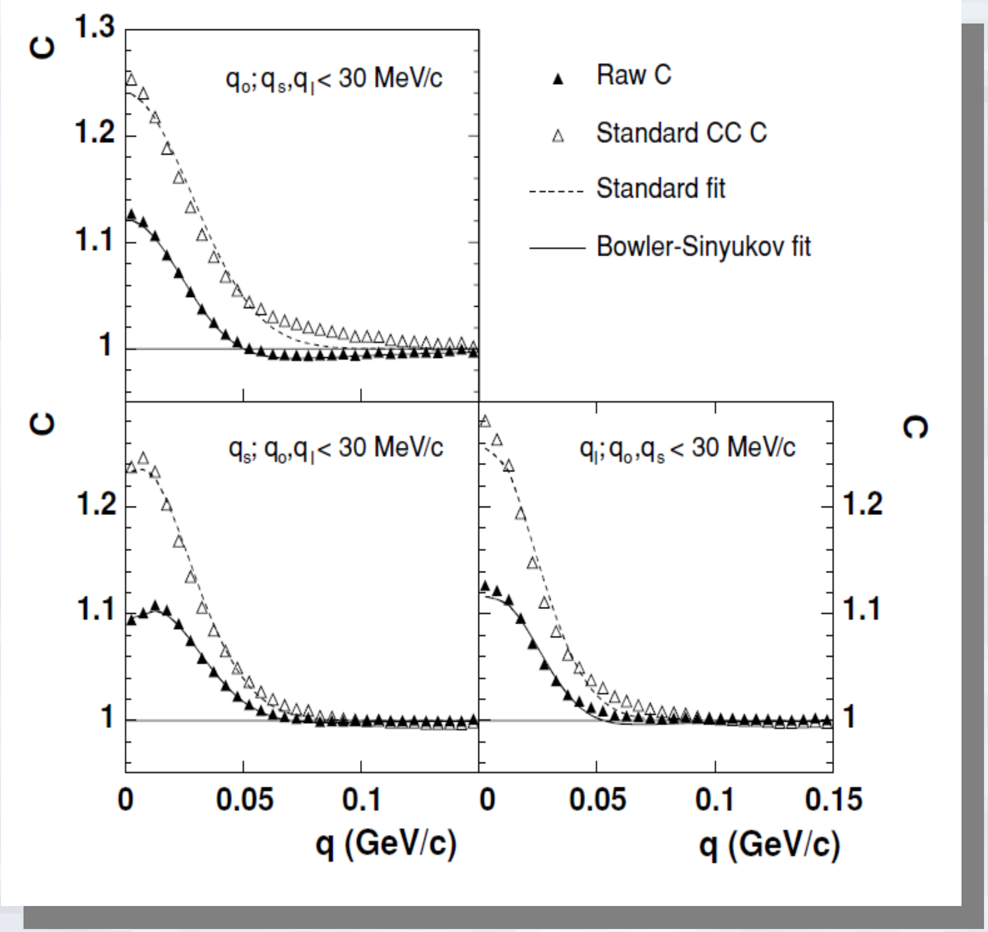


STAR experimental results

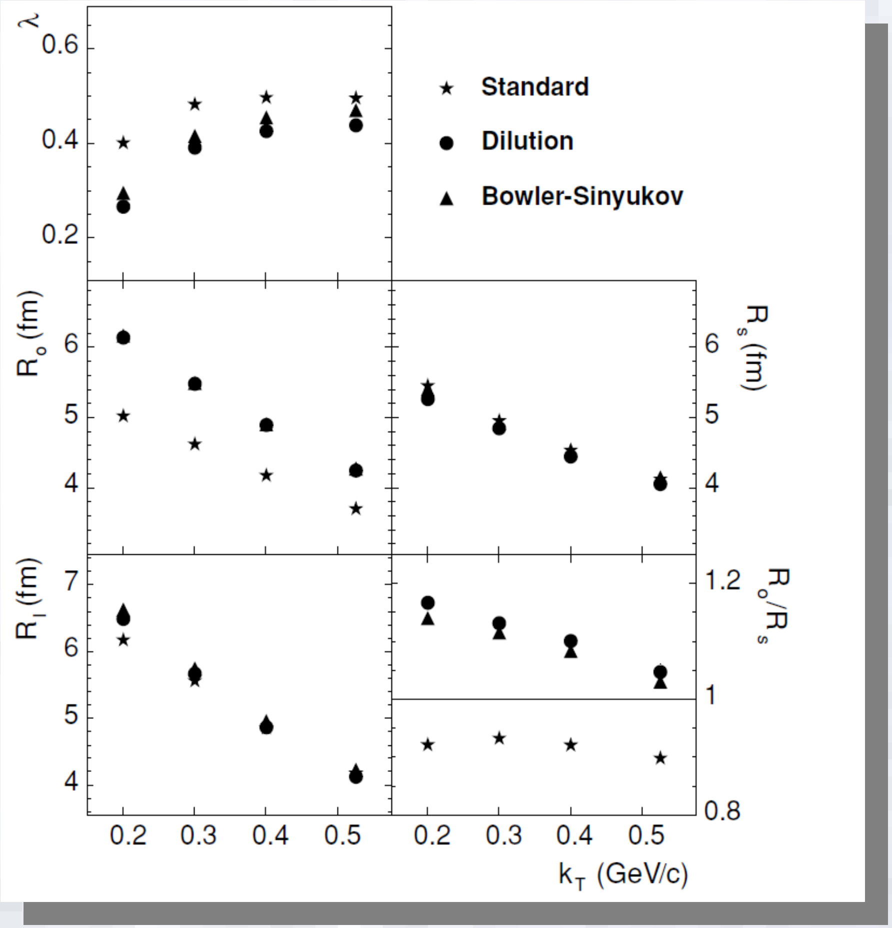
RHIC-STAR: ππ femtoscopy for Au+Au $_{NN}$=200GeV

[PHYSICAL REVIEW C 71, 044906 (2005)]

Projection of 3-d correlation function

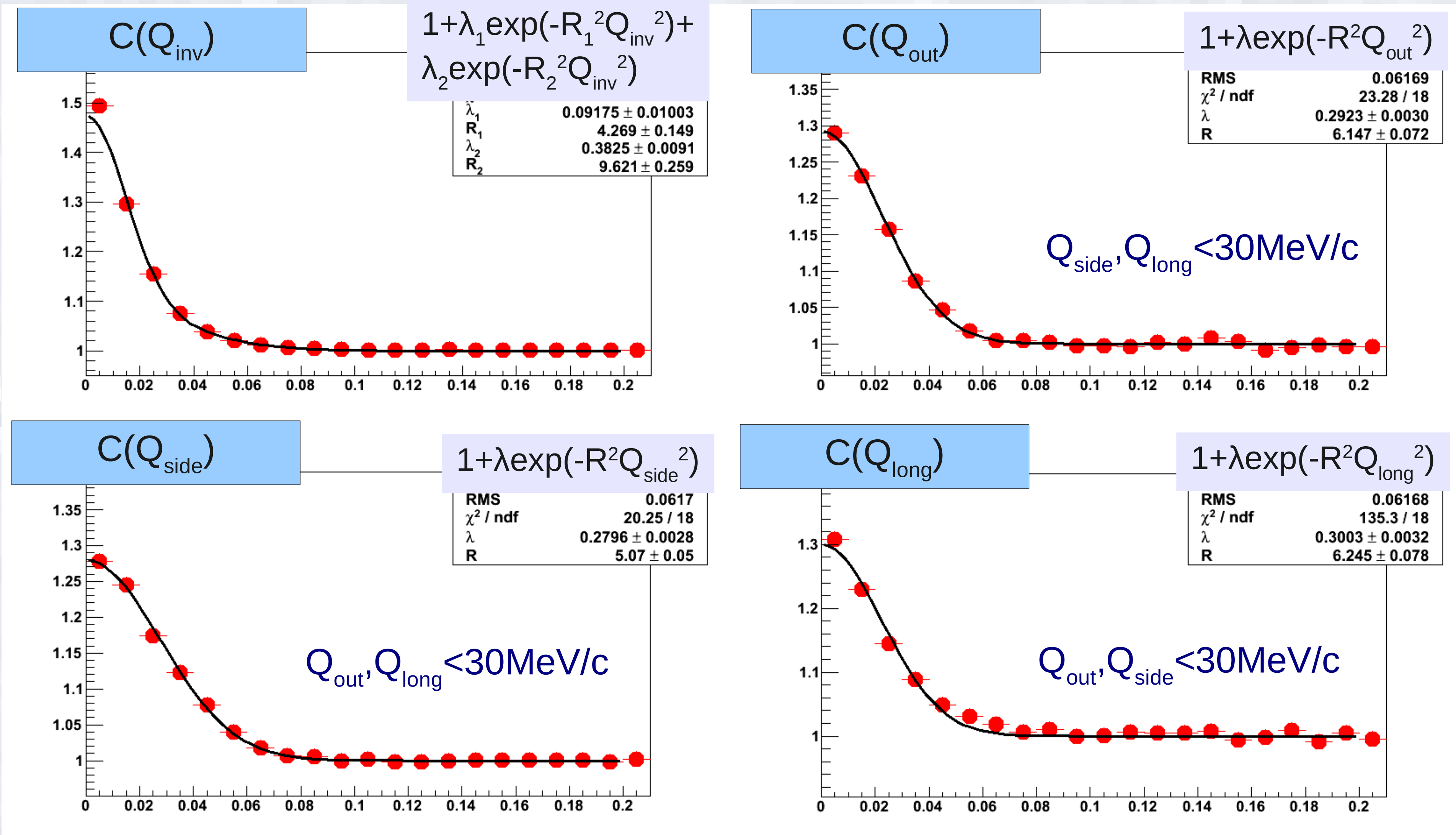


3-d fit results (3 variants of Coulomb)



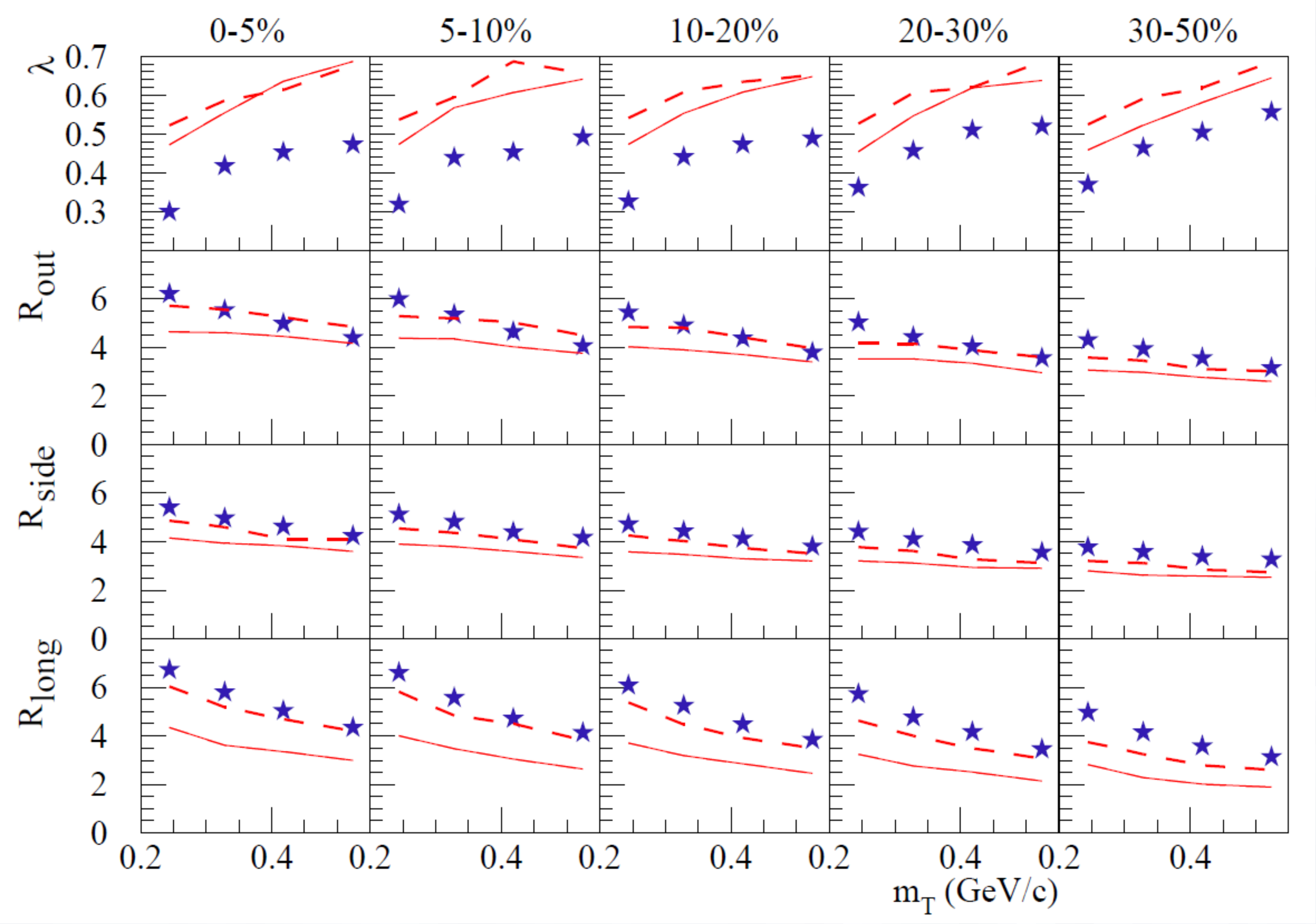
Femto package: 1d CF

Example of 1d pi+pi+ correlation function
for central events

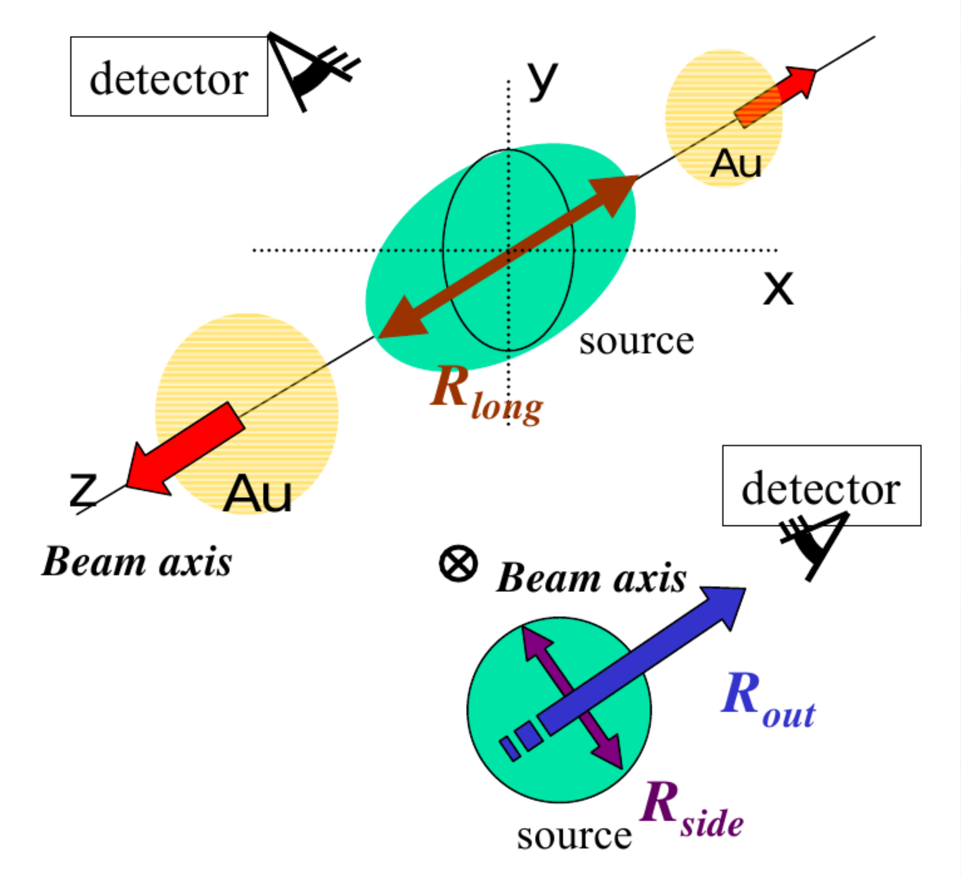


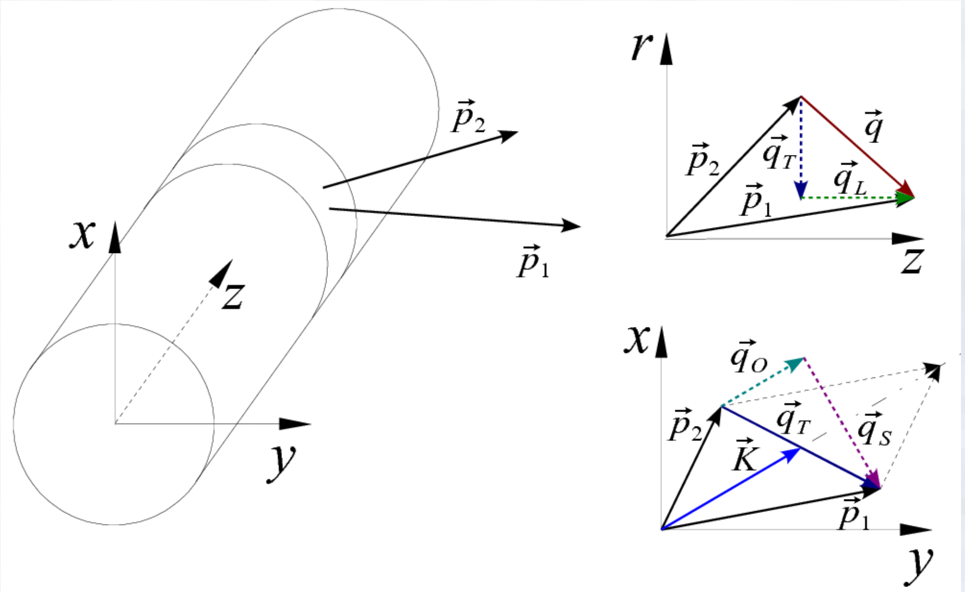
Femtoscopic radii (other scenarios)

Full line the calculations are done without hadronic cascade (scenario 2).
Dashed lines with a hydrodynamic evolution through the hadronic phase with freeze-out at 130 MeV (scenario 3).



Longitudinally CoMoving Sysytem





Source function, etc.

$$C(\mathbf{P},\mathbf{q}) = \int d^3r' \, S(\mathbf{P},\mathbf{r}') \, |\Psi(\mathbf{q}',\mathbf{r}')|^2$$

$$C(\mathbf{P},\mathbf{q}) = 1 + \lambda \exp\left(-R_{\mathrm{out}}^2 \, q_{\mathrm{out}}^2 - R_{\mathrm{side}}^2 \, q_{\mathrm{side}}^2 - R_{\mathrm{long}}^2 \, q_{\mathrm{long}}^2\right)$$

$$k_T = \frac{1}{2}\left(|\vec{p}_T(\mathrm{pion}\,1) + \vec{p}_T(\mathrm{pion}\,2)|\right)$$