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http://triton.itep.ru/ions/nantes2017.html

Kaon femtoscopy with EPOS3 model

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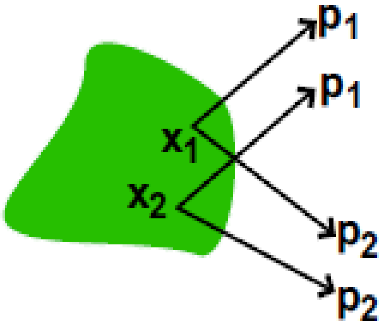
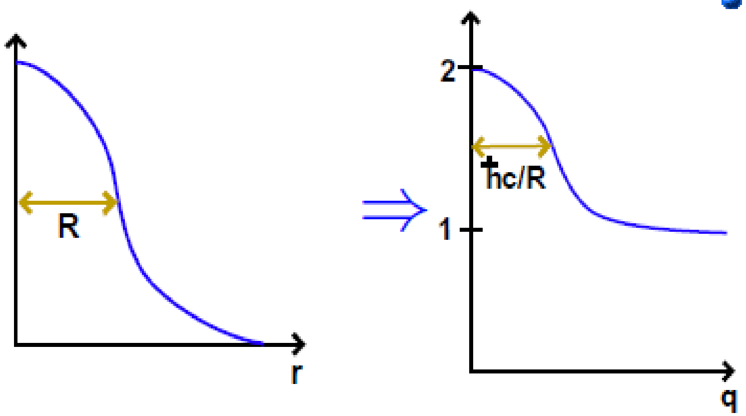
Outline

- Introduction
- Motivation of kaon femtoscopy study in ion collisions
- EPOS3 with 1d CF $K^{\pm}K^{\pm}$ in p-Pb
- EPOS3 with 1d CF $K^{\pm}K^{\pm}$ in Pb-Pb collisions
- EPOS3 with 3d CF $K^{\pm}K^{\pm}$ in Pb-Pb collisions
- Conclusions

Introduction



- Correlation femtoscopy is the direct tool to measure R, cτ ~ fm
  Based on Bose-Einstein or Fermi-Dirac symmetric properties and Final State Interactions



- Correlation function: $C(q)=\frac{N_2(p_1,p_2)}{N_1(p_1)\cdot N_2(p_1)}, C(\infty)=1$

$$C(q)=\frac{S(q)}{B(q)}, q=p_1-p_2$$

S(q) – pairs from same event
B(q) – pairs from different event

- Parametrization: $C(q_{inv})=1+\lambda\exp(-R^2 q_{inv}^2)$

R Gaussian radius in Pair Rest Frame **(PRF)**
λ correlation strength parameter

3-dimensional: R_{side} transverse size, R_{long} time of freeze-out, R_{out} / R_{side} emis. duration.

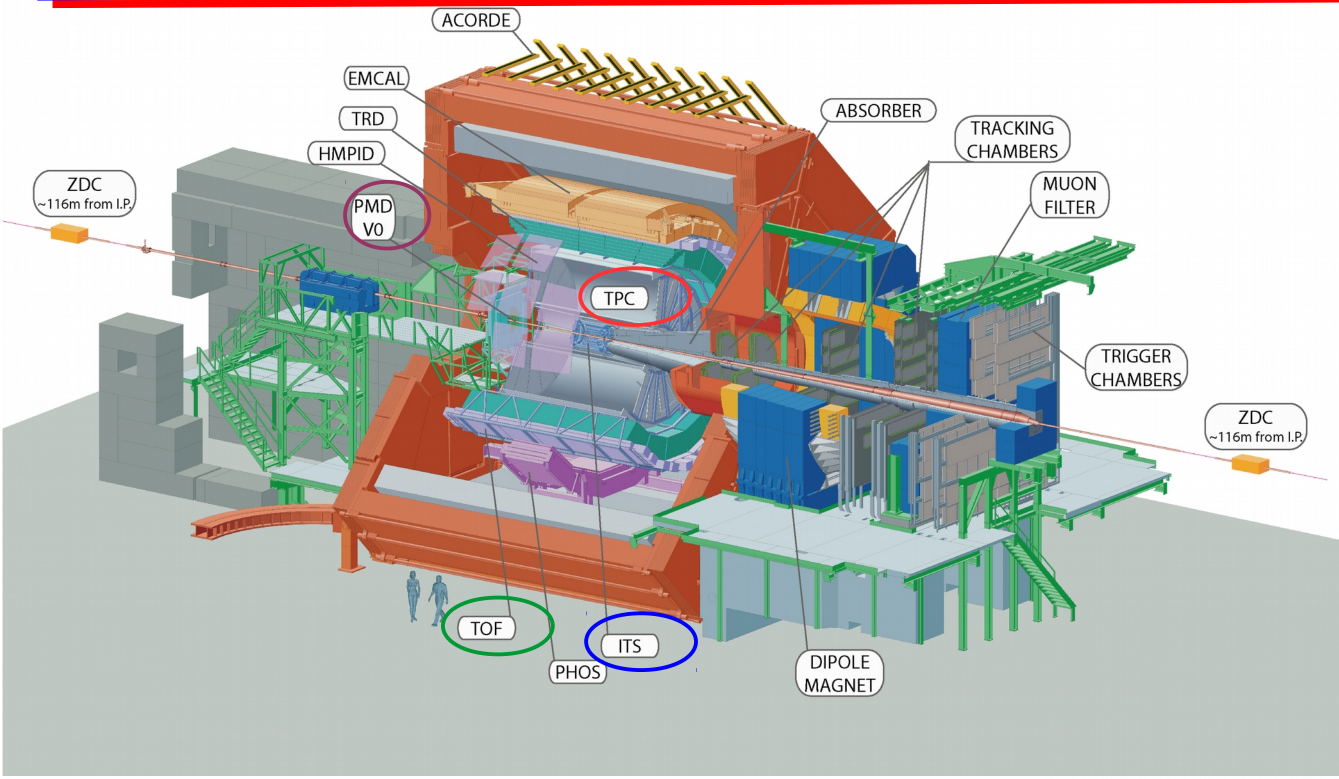
$$C(q_{out},q_{side},q_{long})=1+\lambda\exp(-R_{out}^2 q_{out}^2-R_{side}^2 q_{side}^2-R_{long}^2 q_{long}^2)$$

Identical kaon: Motivation

- Check of EPOS3* predictions in comparison with data on kaon femtoscopy
- Momentum correlations (due to QS and FSI) → space-time characteristic of production process
  - $K^{\pm}K^{\pm}$: QS+Coulomb FSI (strong FSI is negligible)
  - $K^0_sK^0_s$: QS+Strong FSI
  - Cross-check $K^{\pm}K^{\pm}$ and $K^0_sK^0_s$ (diff. physics and diff. method)
- **K** less influenced by resonance decays than **π** → clearer signal
- Study of collective dynamics (**K** together with **π** and **p**):
- m_T dependence of correlation radii (collective flow)

*K. Werner, B. Guiot, Iu. Karpenko, T. Pierog, Phys.Rev. C89 (2014) 6, 064903

ALICE at LHC

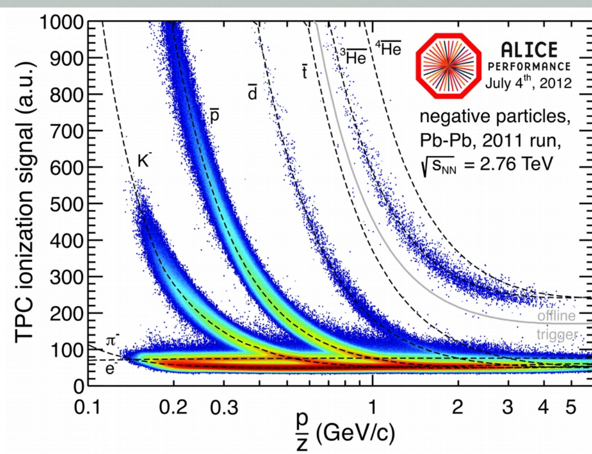


Tracking and vertex
- Time Projection Camber (TPC) & Inner Tracking System (ITS)

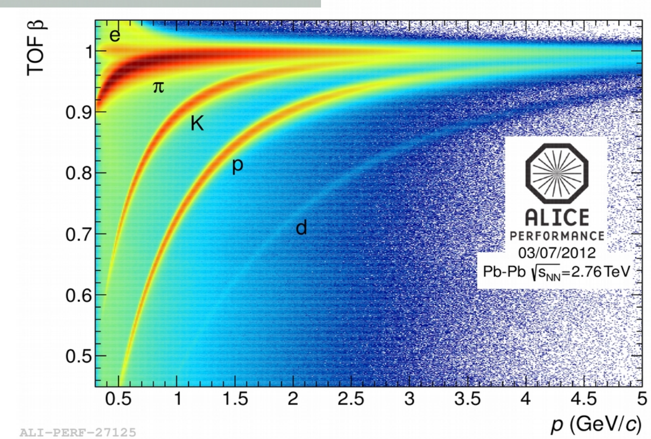
Particle Identification
- TPC and Time of Flight

Centrality determination
- V0

PID TPC:



PID TOF:



Identical kaon femtoscopy with EPOS3 in p-Pb at $\sqrt{s_{NN}}$=5.02 TeV

- Data: Charged KK femtoscopic correlations in p–Pb collisions at $\sqrt{s_{NN}}$ =5.02 TeV with ALICE at the LHC (XII WPCF 2017, E.Rogochaya)
- Bins k_T: 0.2-0.5, 0.5-1.0 GeV/c; cent:0-20,20-40,40-90%
- EPOS ver.3.111*, p-Pb at $\sqrt{s_{NN}}$=5.02 TeV
- select K+K+(K-K-) $|\eta|<0.8$, $0.14<p_T<1.5$ GeV/c (same as in the data)
- Same bins on k_T and centrality
- UrQMD is ON

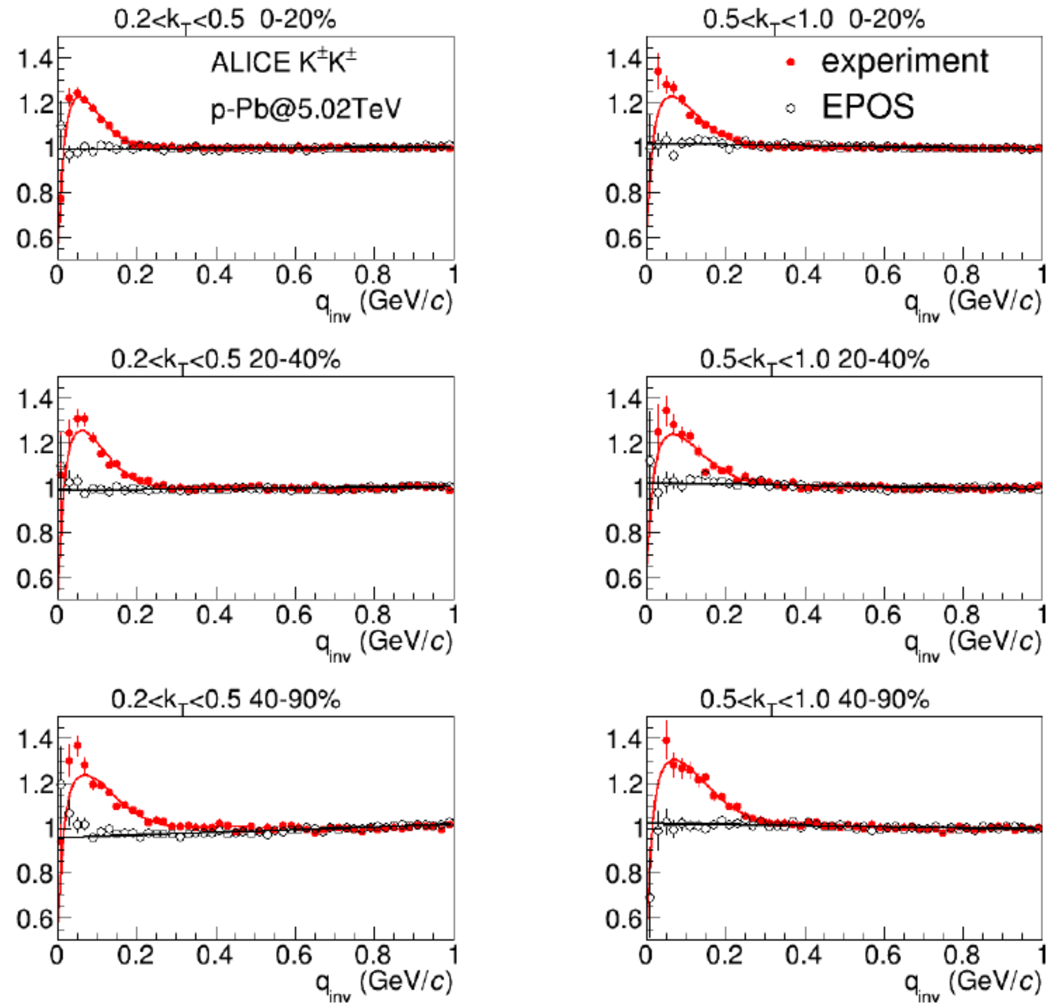
* p-Pb at 5.02 TeV (about 17e6) events generated on ITEP cluster

Data: KK in p-Pb at $\sqrt{s_{NN}}$=5.02 TeV, ALICE(E.Rogochaya,XII WPCF)

Correlation function is fitted by the Bowler-Sinyukov formula:

$$C(q_{\rm inv}) = \left((1-\lambda) + \lambda K(q_{\rm inv})\left(1 + e^{-R^2_{\rm inv} q^2_{\rm inv}}\right)\right) P(q_{\rm inv})$$

$K = C(\mathrm{QS}+\mathrm{Coulomb})/C(\mathrm{QS})$,
$C(\mathrm{QS})$ - theoretical CF calculated with pure quantum statistic weights (wave function squared),
$C(\mathrm{QS}+\mathrm{Coulomb})$ - quantum statistic + Coulomb weights,
Coulomb source size r^*=1.5 fm
P - baseline (non-femto effects)



❶ **EPOS*baseline**

*K. Werner, B. Guiot, Iu. Karpenko, T. Pierog Phys.Rev. C89 (2014) 6, 064903

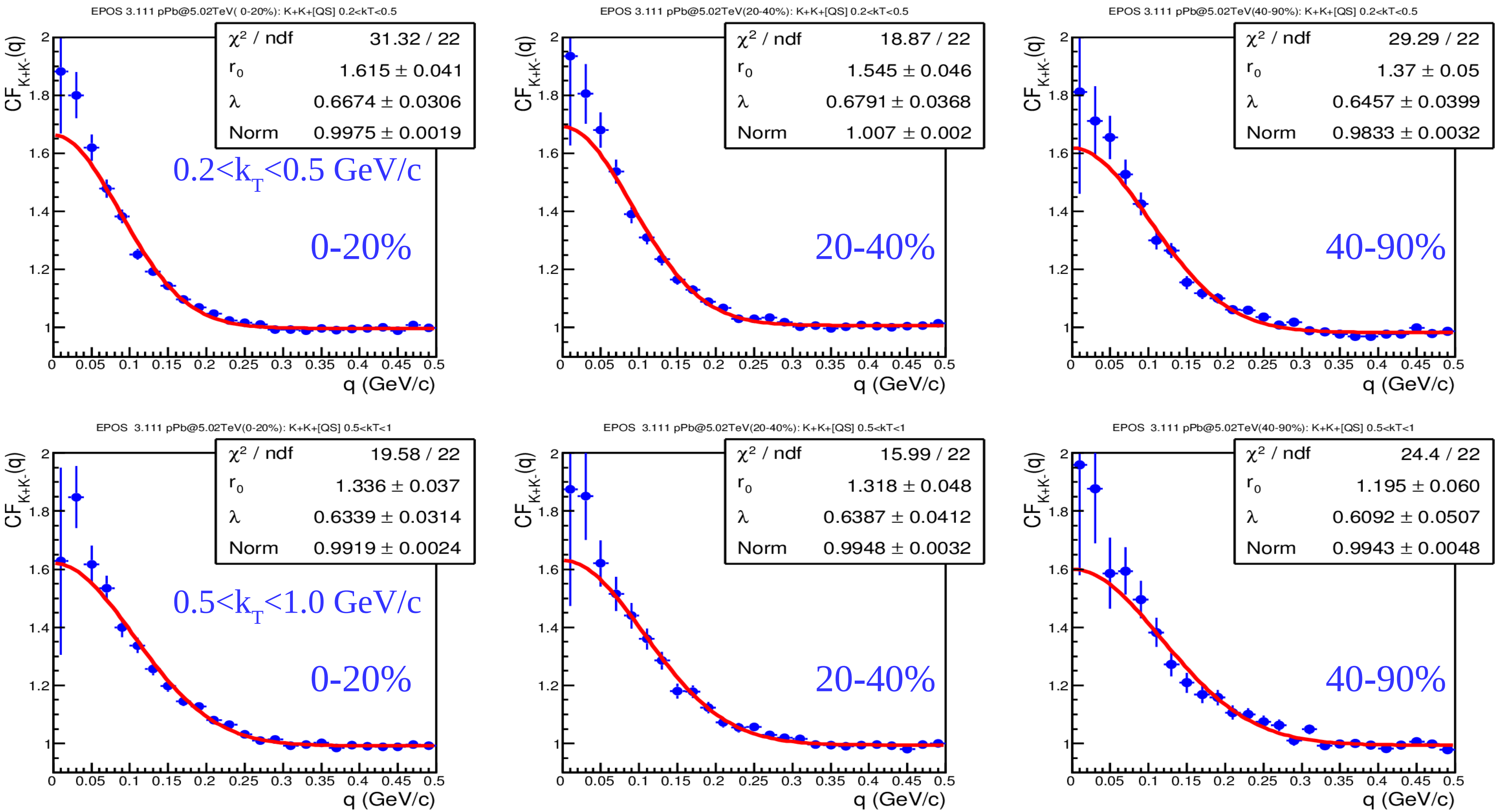
fitted by $P(q_{\rm inv}) = 1 + a q_{\rm inv}$

in $0.0 < q_{\rm inv} < 1.0$ GeV/c

❷ $P(q_{\rm inv})$ used to fit CF in $0.0 < q_{\rm inv} < 0.5$ GeV/c

https://indico.cern.ch/event/539093/contributions/2570701/attachments/1474530/2284014/Rogochaya_WPCF2017.pdf

EPOS3: KK in p-Pb at $\sqrt{s_{NN}}$=5.02 TeV

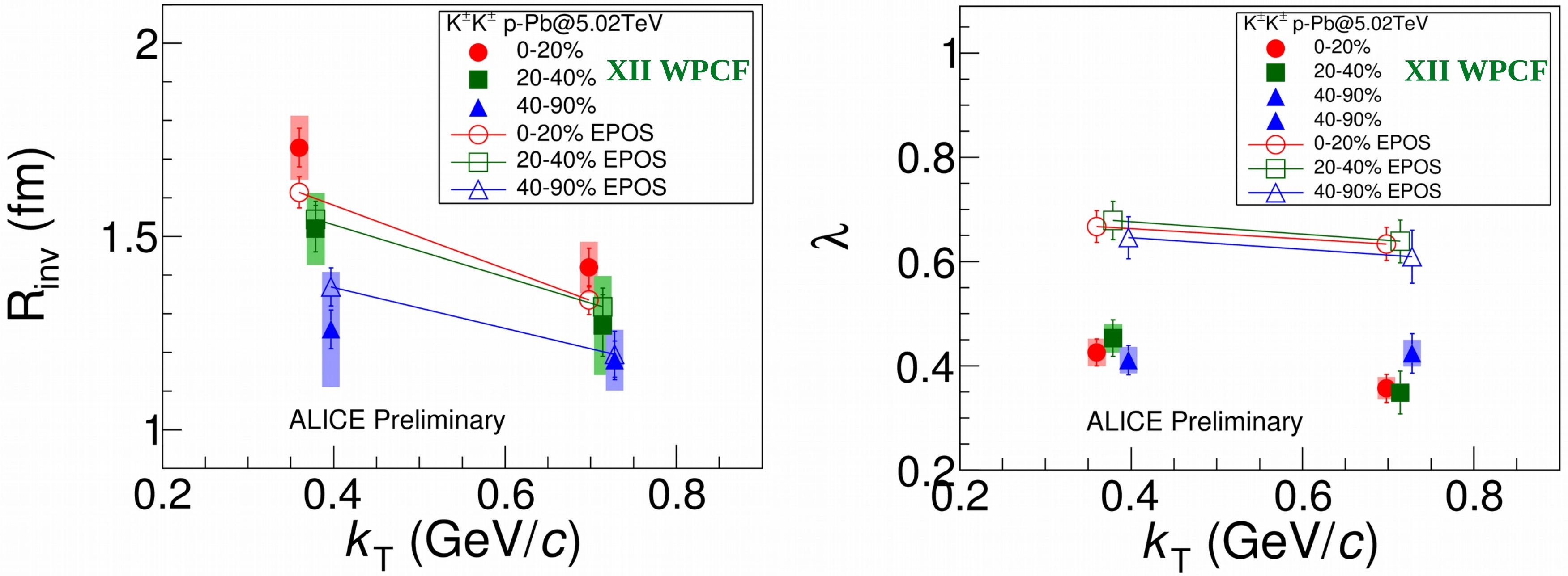


- CF_{EPOS} is pure QS weight. Fit: $C(q_{inv}) = 1 + \lambda \exp(-R^2 q_{inv}^2)$
- Good description

EPOS3 and ALICE data*: R and λ for p-Pb 5.02TeV

***E.Rogochaya,XII WPCF**

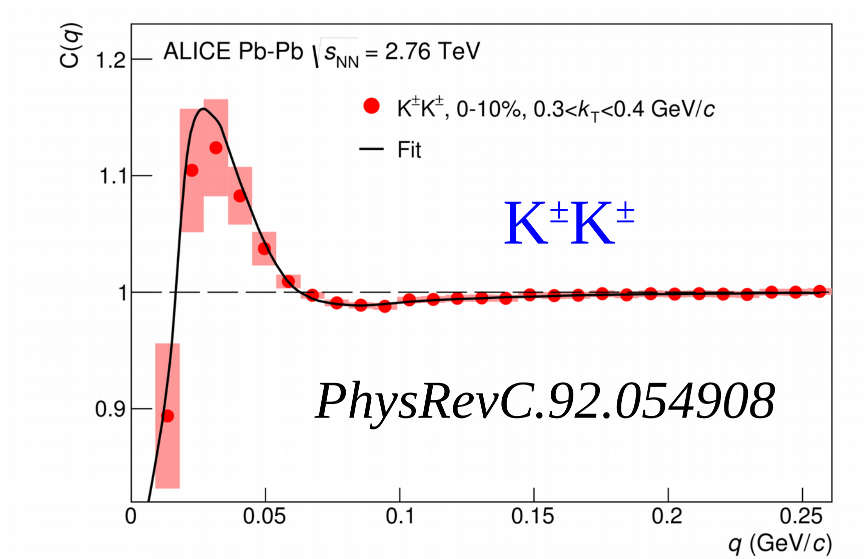
https://indico.cern.ch/event/539093/contributions/2570701/attachments/1474530/2284014/Rogochaya_WPCF2017.pdf



- Radii: good agreement of EPOS3 predictions with the data
- Lambdas: the data are systematically less than the EPOS3 (possible non-Gaussian shape of CF in data?)

Identical kaon femtoscopy with EPOS3 in Pb-Pb at $\sqrt{s_{NN}}$=2.76 TeV

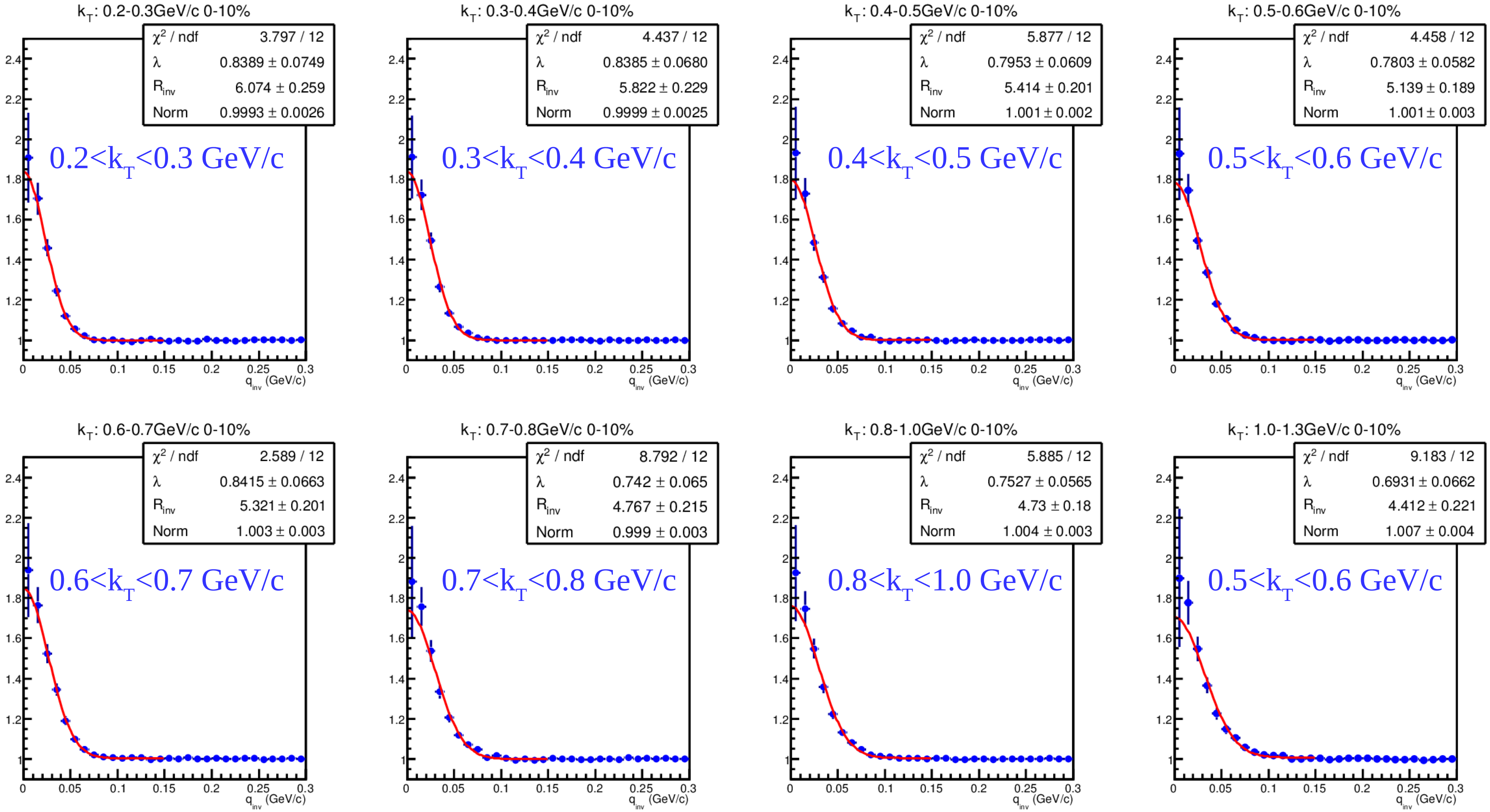
- Data from ALICE paper: *PhysRevC.92.054908*
- Bins 8 kT: 0.2-0.3, 0.3-0.4, 0.5-0.6, 0.6-0.7, 0.8-1.0, 1.0-1.3 GeV/c;
- 3 cent:0-10,10-30,30-50%
- EPOS3: Ver.3.107*, PbPb at $\sqrt{s_{NN}}$=2.76 TeV
- UrQMD is ON (6.3e+5 minimum bias events)
  UrQMD is OFF (1.8e+5 minimum bias events)
- select K+K+(K-K-) |η|<0.8, 0.14<p_T<1.5 GeV/c (same as in the data)
- Same bins + 50-100%



* *The authors/speaker acknowledge Christina Markert and Anders Knospe and the Texas Advanced Computing Center (TACC) at the University of Texas at Austin for providing computing resources that have contributed to the research results reported within this paper/talk. URL: http://www.tacc.utexas.edu.*

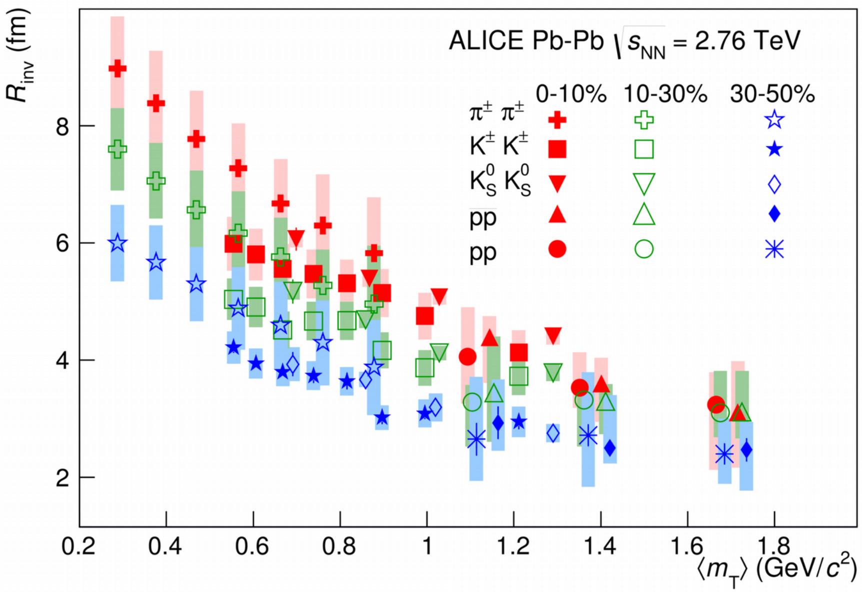
$$C(q) = N[1-\lambda+\lambda K(q)(1+\exp(-R_{inv}^2 q^2))]$$

EPOS3: Identical kaon correlation function 0-10%



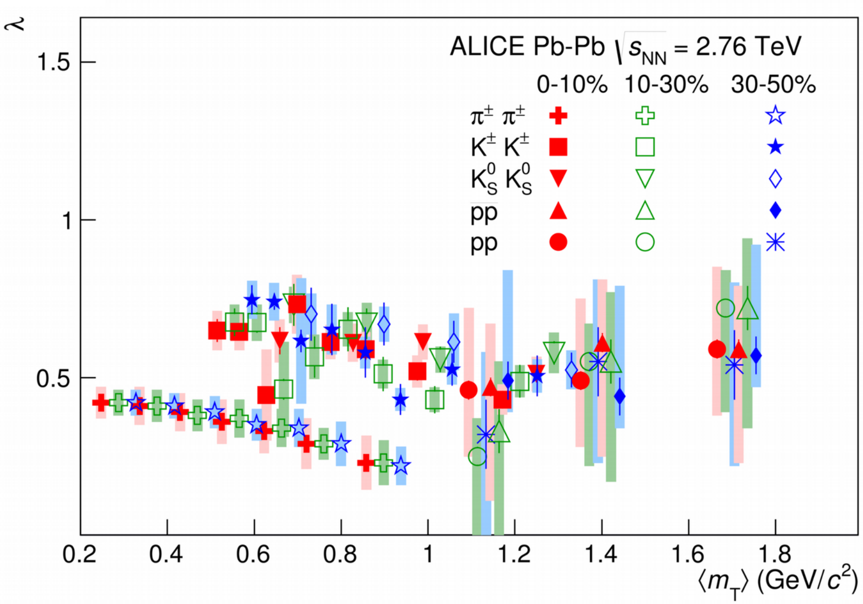
- CF_{EPOS} is pure QS weight. Fit: $C(q_{inv}) = 1 + \lambda \exp(-R^2 q_{inv}^2)$
- Good description

$K^{\pm}K^{\pm}$ and $K^0_sK^0_s$ in Pb-Pb at $\sqrt{s_{NN}}$=2.76 TeV: R and λ param.



Results from PhysRevC.92.054908

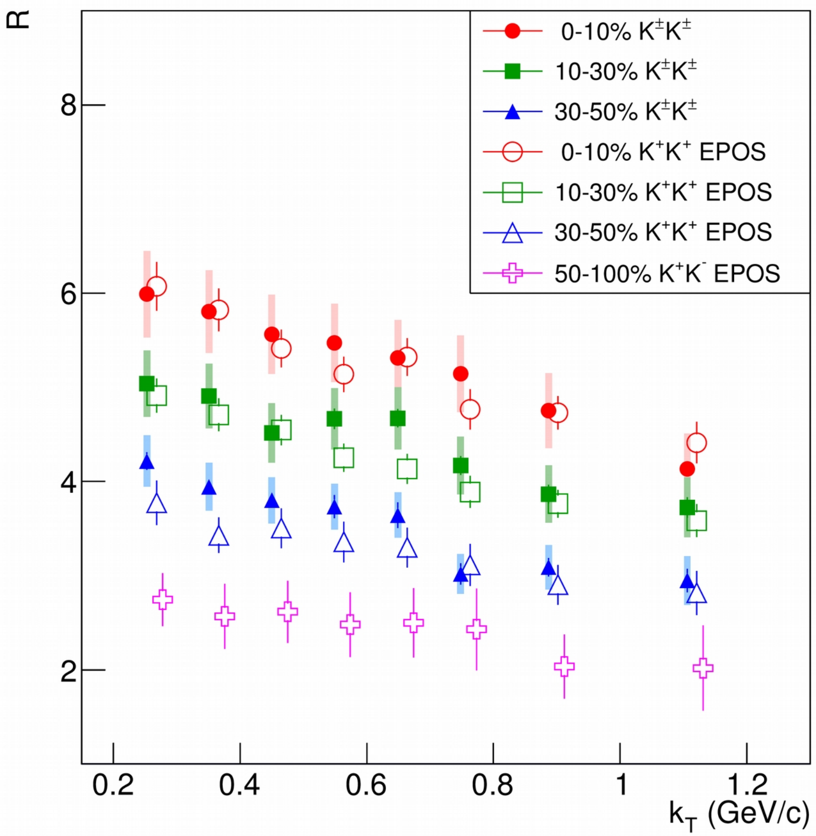
- R and λ for $\pi^{\pm}\pi^{\pm}$,$K^{\pm}K^{\pm}$,$K^0_sK^0_s$, pp and $\overline{pp}$ vs m_T for several centralities
- R for overlapping m_T consistent
- $R_{\pi} > R_K$ due to pion Lorentz factor
- m_T dependence → collective flow
- Centrality dependence

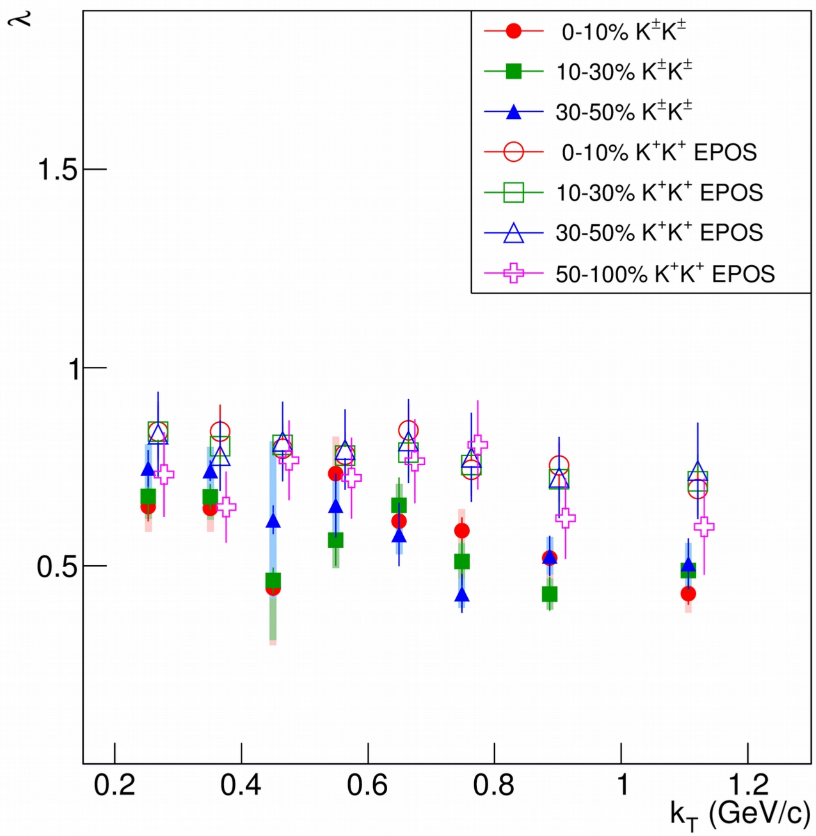


- All λ lie mostly in 0.3-0.7 due to long-lived resonances, non-Gaussian shape.
- No significant centrality dependence
- λ_{π} are lower than λ_K due to the stronger influence of resonances

EPOS3 and ALICE data: R and λ for PbPb 2.76TeV

$K^{\pm}K^{\pm}$ are from ALICE paper: Phys. Rev. C 92 (2015) 054908

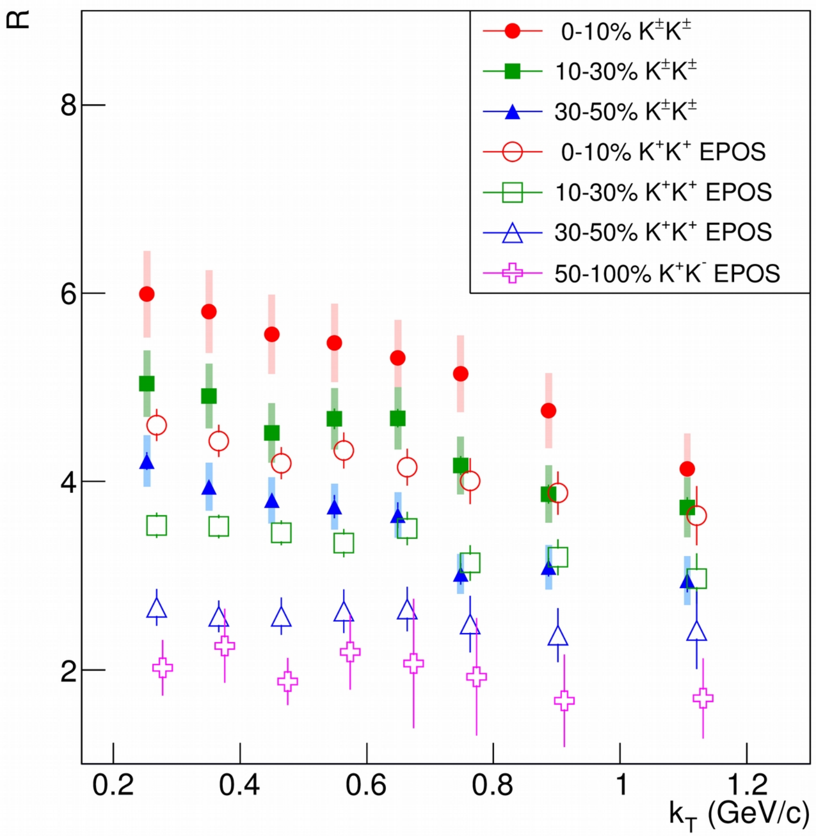


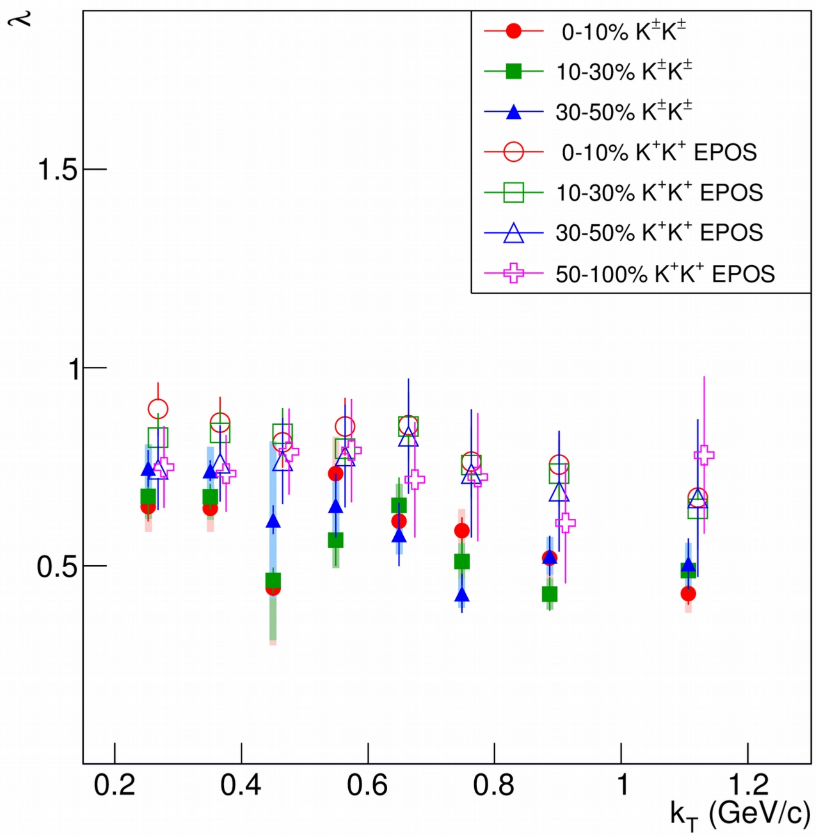


- Radii: excellent agreement of EPOS3 predictions with the data
- Lambdas: the data are very close to the EPOS3

EPOS3(w/o UrQMD) and ALICE data: R and λ for PbPb 2.76TeV

K±K± are from ALICE paper: Phys. Rev. C 92 (2015) 054908





- Radii from EPOS3 w/o hadron cascade are significantly smaller than the data
- Lambdas: become slightly larger than they were with cascade
- Hadron cascade is very important to describe the data!

Identical kaon femtoscopy with EPOS3 in Pb-Pb at $\sqrt{s_{NN}}$=2.76 TeV

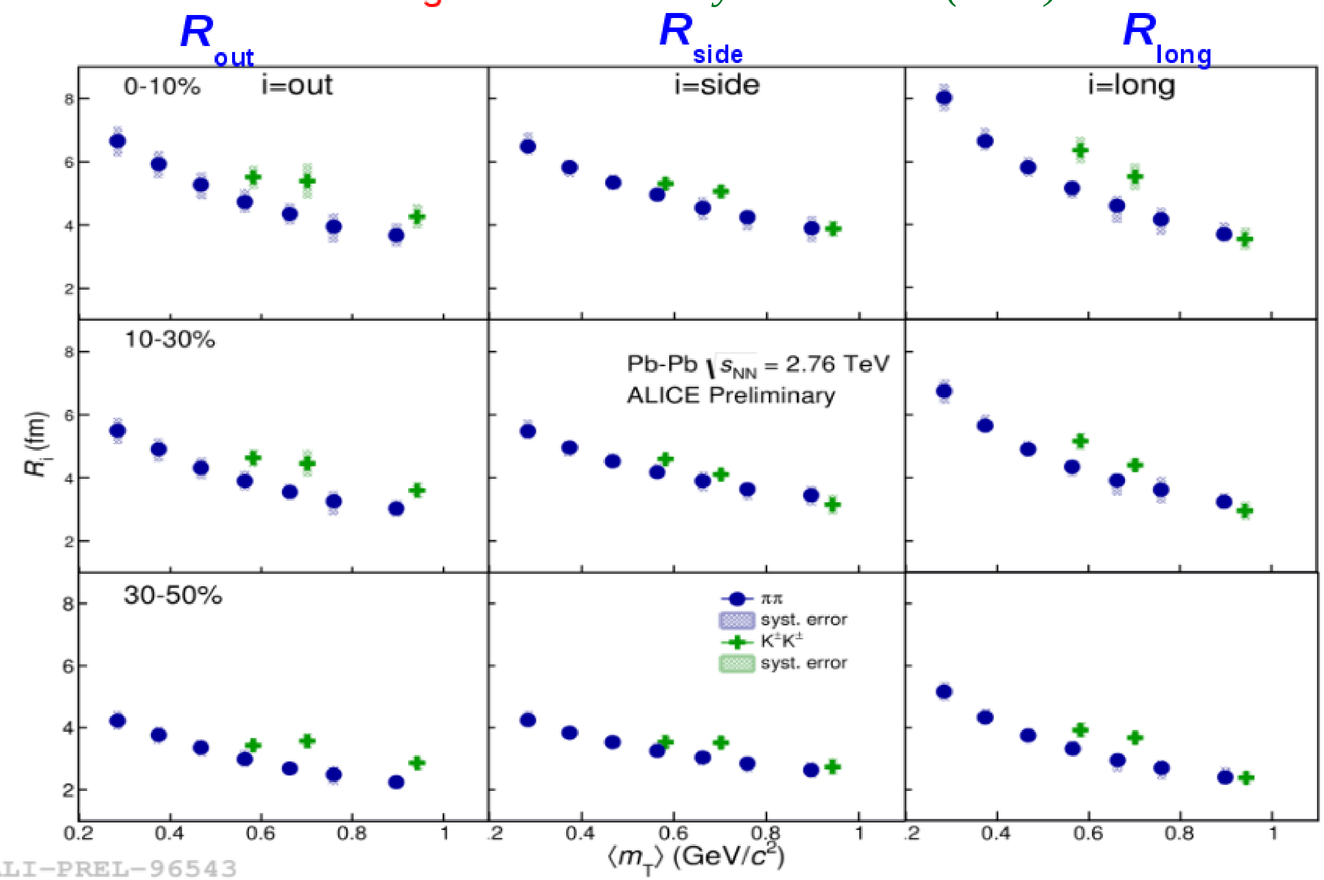
3D kaon correlations

- Data: ALICE 3d kaon (L.Malinina QM'2015)
- Bins 3 kT: 0.2-0.4, 0.4-0.6, 0.6-1.3 GeV/c;
- 3 cent:0-10,10-30,30-50%
- EPOS3: Ver.3.107*, PbPb at $\sqrt{s_{NN}}$=2.76 TeV
- UrQMD is ON (6.3e+5 minimum bias events)
  UrQMD is OFF (1.8e+5 minimum bias events)
- select K+K+(K-K-) $|\eta|<0.8$, $0.14<p_T<1.5$ GeV/c (same as in the data)
- Same kT and centrality bins

** The authors/speaker acknowledge Christina Markert and Anders Knospe and the Texas Advanced Computing Center (TACC) at the University of Texas at Austin for providing computing resources that have contributed to the research results reported within this paper/talk. URL: http://www.tacc.utexas.edu.*

3D $K^{\pm}K^{\pm}$ & ππ radii versus m_T

Pion results from ArXiv.org:1507.06842 *Phys. Rev. C 93 (2016) 024905*



- R_{side} shows approximate m_T scaling;
- R_{out}, R_{long} of K are larger than those of π → m_T scaling is broken;
- This difference increases for more central collisions;
- The effect is more important for R_{long}

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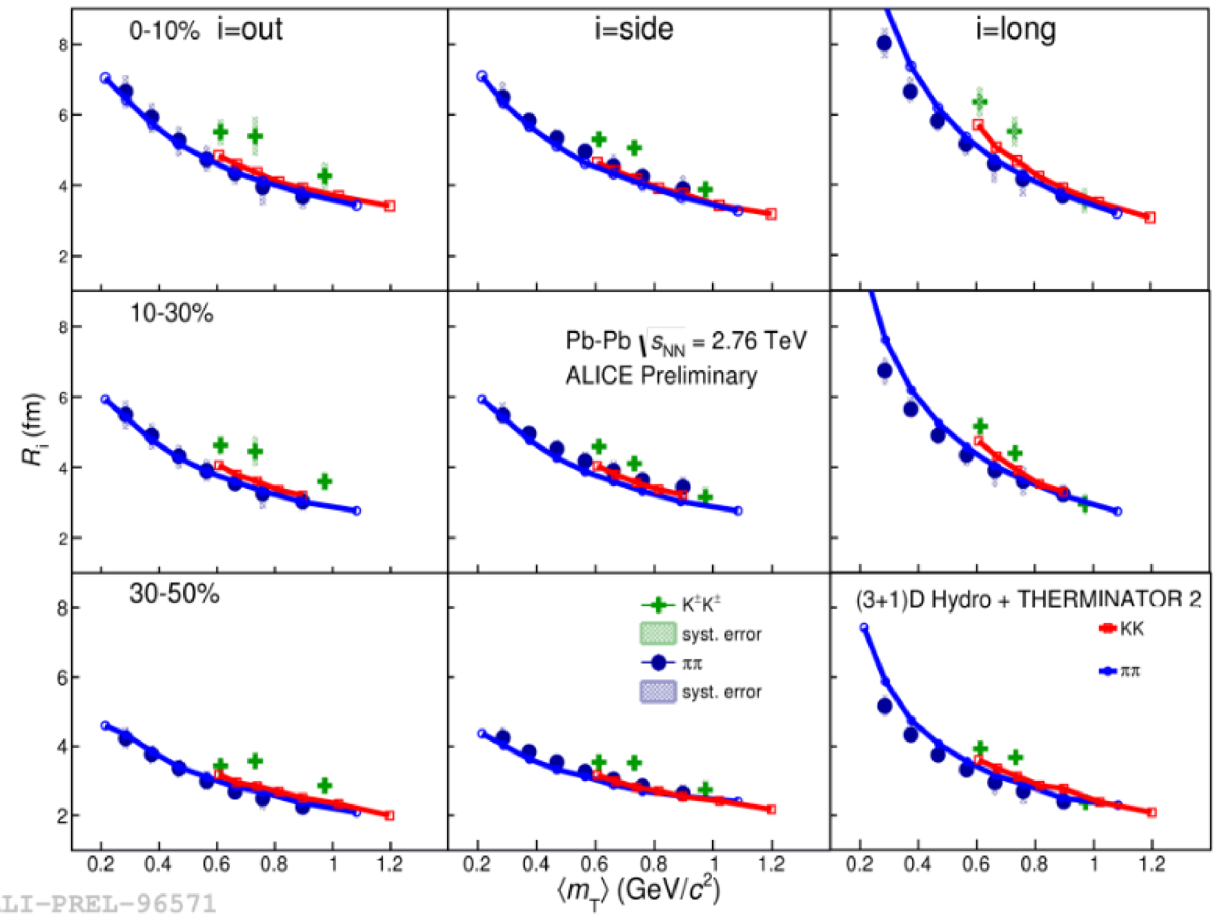
Comparison with (3+1)D Hydro+THERMINATOR2

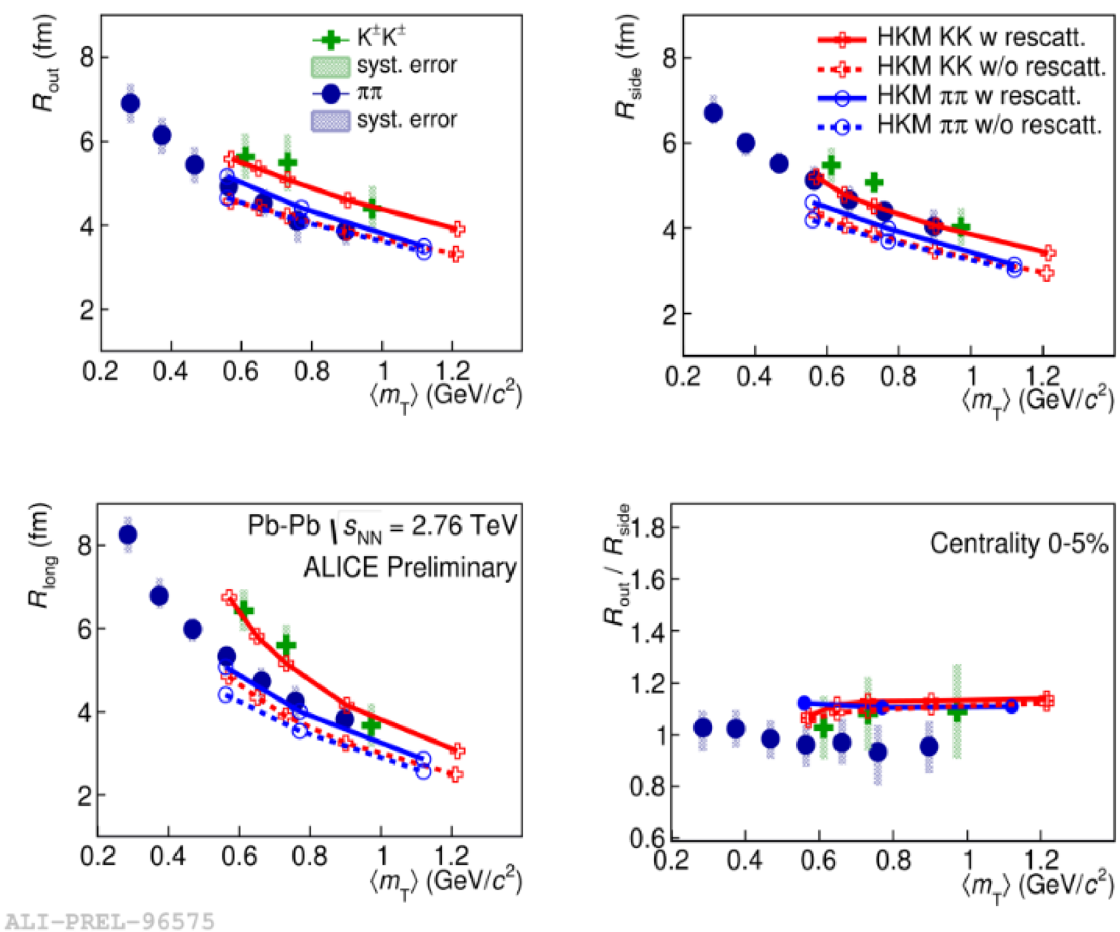
R_{out} R_{side} R_{long}



- Model (A. Kisiel, M. Galazyn, P. Bozek, Phys.Rev. C90 (2014) 064914) includes hydrodynamics and resonances decays
- Good description of pion radii vs. m_T
- Underestimation of kaon radii

- Model demonstrates approximate $R \sim m_T^a$ scaling for π & K, with "**a**" being different for R_{out}, R_{side}, R_{long} (A. Kisiel, M. Galazyn, P. Bozek, Phys.Rev. C90 (2014) 064914)

Comparison with HKM for 0-5% centrality



- HKM model with re-scatterings (M. Shapoval, P. Braun-Munzinger, Iu.A. Karpenko, Yu.M. Sinyukov, Nucl.Phys. A 929 (2014) 1.) describes well ALICE π & K data.
- HKM model w/o re-scatterings demonstrates approximate m_T scaling for π & K, but does not describe ALICE π & K data
- The observed deviation from m_T scaling is explained in (M. Shapoval, P. Braun-Munzinger, Iu.A. Karpenko, Yu.M. Sinyukov, Nucl.Phys. A 929 (2014) by essential transverse flow & re-scattering phase.
- HKM model slightly underestimates R_{side} → overestimates R_{out}/R_{side} ratio for π

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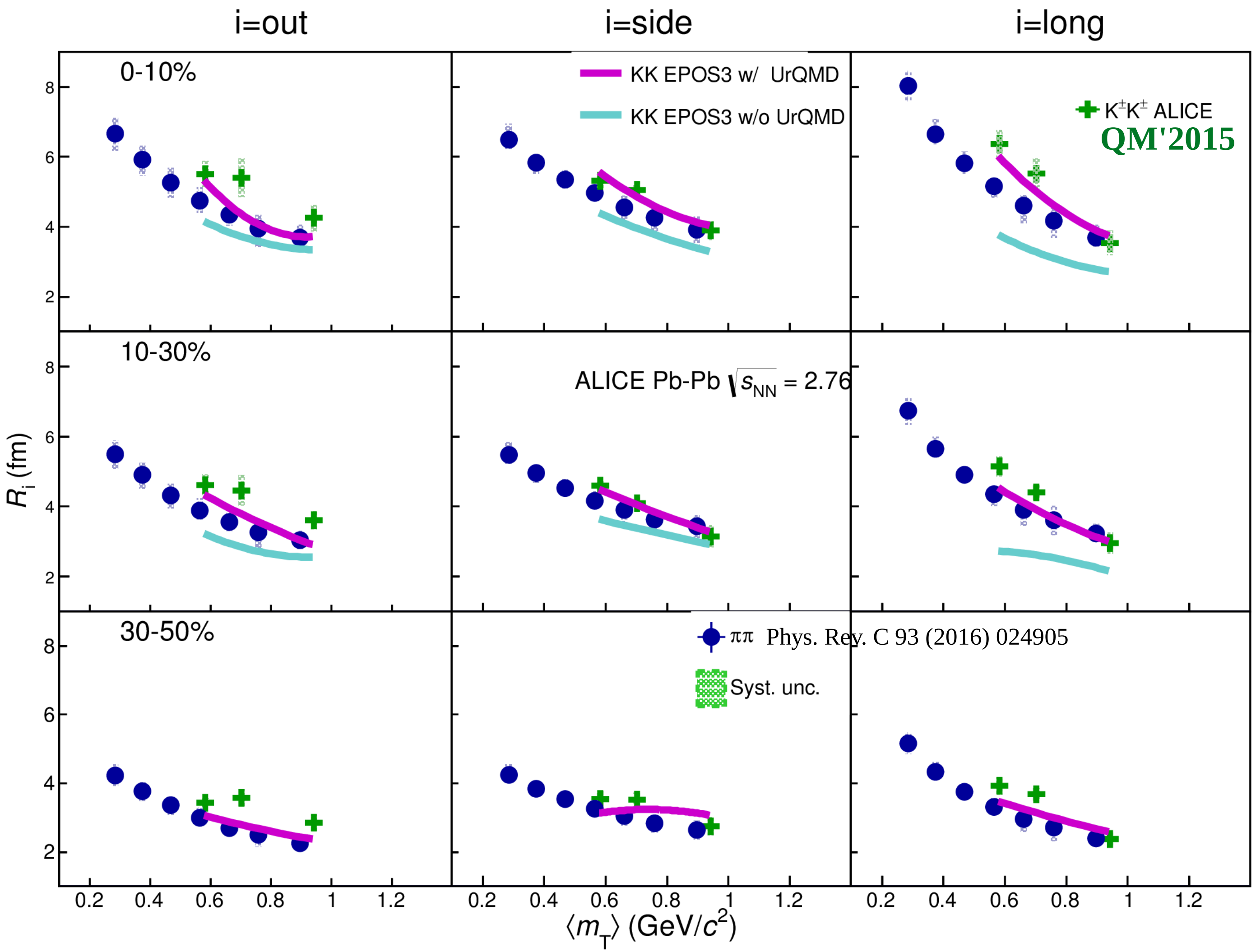
EPOS3 and data(QM'2015) radii from 3d fit of KK CF



- Radii: good agreement of EPOS3 predictions with the data except out direction
- Hadron cascade is very important for 0-10 and 10-30% centrality
- Too small statistics for 30-50% (w/o UrQMD not available)

Conclusions and plans

- Charged kaon correlation functions simulated with EPOS3 model for collisions p-Pb@5.02 TeV and PbPb@2.76 TeV were presented
- Good agreement of EPOS3 predictions for radii in p-Pb@5.02TeV with the data
- Lambda for p-Pb data are systematically less than the EPOS3 (possible non-Gaussian shape in data)
- Radii for PbPb@2.76: excellent agreement of EPOS3 predictions with the data
- Lambdas PbPb@2.76: the data are very close to the EPOS3
- Radii from EPOS3 for PbPb@2.76 w/o hadron cascade are significantly smaller than the data
- Lambdas from EPOS3 for PbPb@2.76 w/o hadron cascade: are slightly larger than experimental ones
- 3d radii: good agreement of EPOS3 predictions for side and long direction, out direction slightly smaller than in the data
- m_T dependence with EPOS3 is in good agreement with data
- Hadron cascade is very important to describe the data!

- We are planing to continue this study in close cooperation with K.Werner
- We'd like to look at the 3d pion correlation functions

Thank you for your attention!!!