Status of JINR group participation in ALICE

Charged kaon femtoscopy correlations in pp collisions at sqrt(s) = 7 TeV

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Overview

ALICE experiment at LHC

JINR group participation

Correlation femtoscopy (Bose-Einstein correlations,HBT)

Motivation in HI & pp

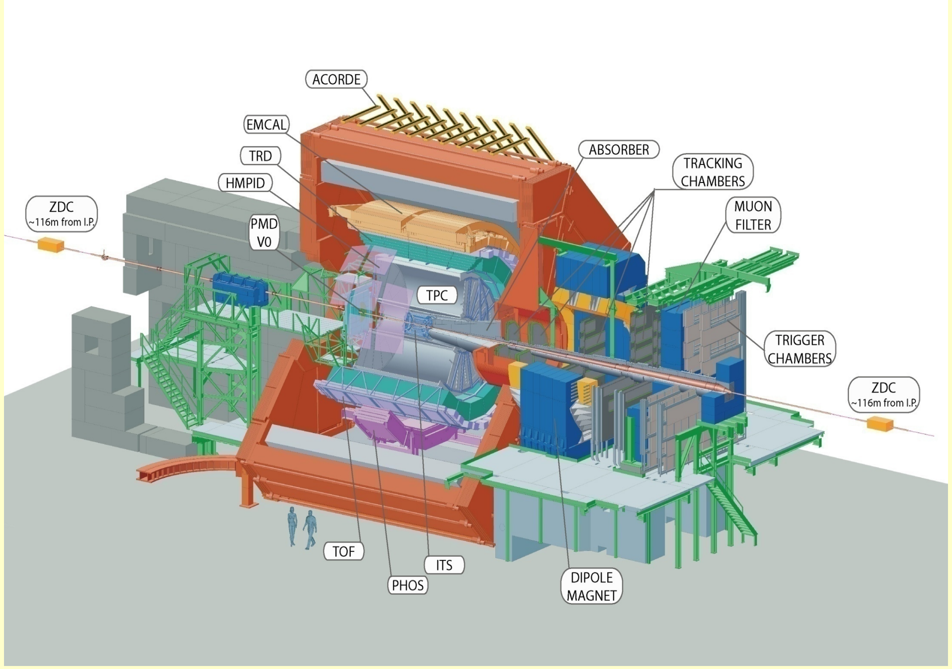
JINR group analysis :

Charged Kaon femtoscopy correlations in pp collisions at 7 TeV,

KK in PbPb collisions at 2.76 TeV (under way)

Conclusion & Plans

A Large Ion Collider Experiment (ALICE)

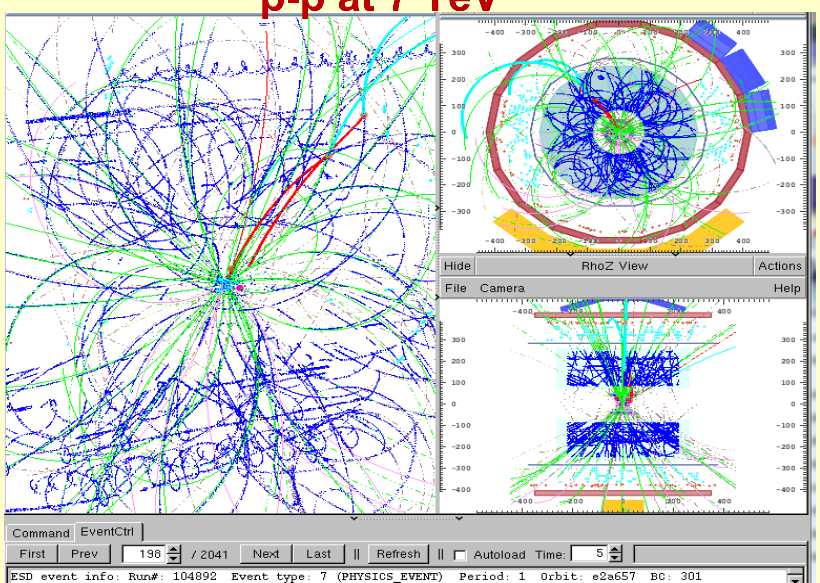


ALICE is the dedicated heavy-ion experiment at the LHC. In addition to its HI physics program, it also has a rich pp physics program benefiting from a detector with:

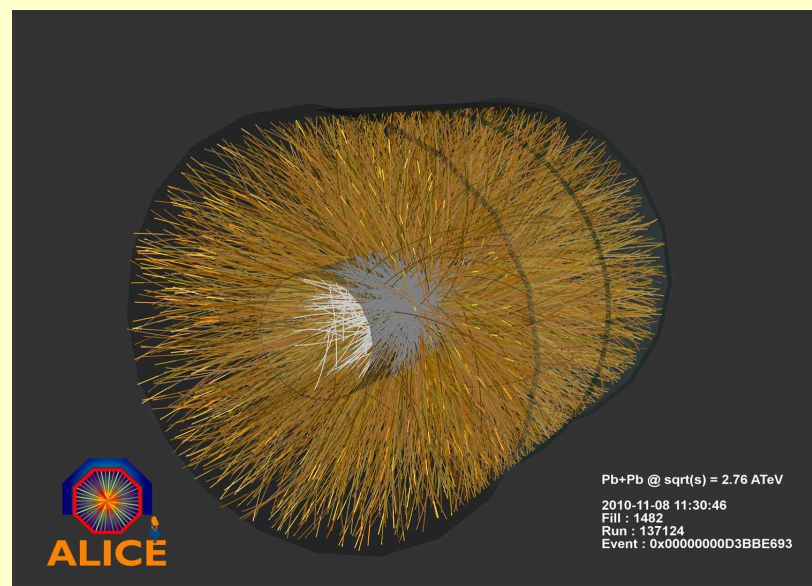
- a low momentum cut-off (p_T 50 MeV/c);
- a small material budget
- excellent particle identification (PID) by specific energy loss & time of flight & transition & Cherenkov radiation;
- good primary and secondary vertex resolution

allows for measurements of strangeness and heavy flavor with low backgrounds.

p-p at 7 TeV



Pb-Pb at 2.76 TeV



ALICE physics analysis & publications

- **17 ALICE physics publications for p-p (mostly at 7 TeV) and 6 for PbPb at 2.76 TeV per NN interactions;**
- **18 other articles for p-p and 16 for Pb-Pb are under preparation dedicated to :**
  - **Charged and neutral particle spectra,**
  - **strange and charmed particles,**
  - **two-pion Bose-Einstein correlations,**
  - **light vector mesons and baryon resonances,**
  - **elliptic and direct flows,**
  - **quarkonias,**
  - **event-by-event**

Most interest and activity of JINR group

Bose-Einstein correlations (femtoscopy correlations):

Suggestion and responsibility for an analysis of two-charged kaons Bose-Einstein correlations in pp and PbPb:

Physics of resonances:

Participation in the analysis of meson production in p-p and Pb-Pb collisions.

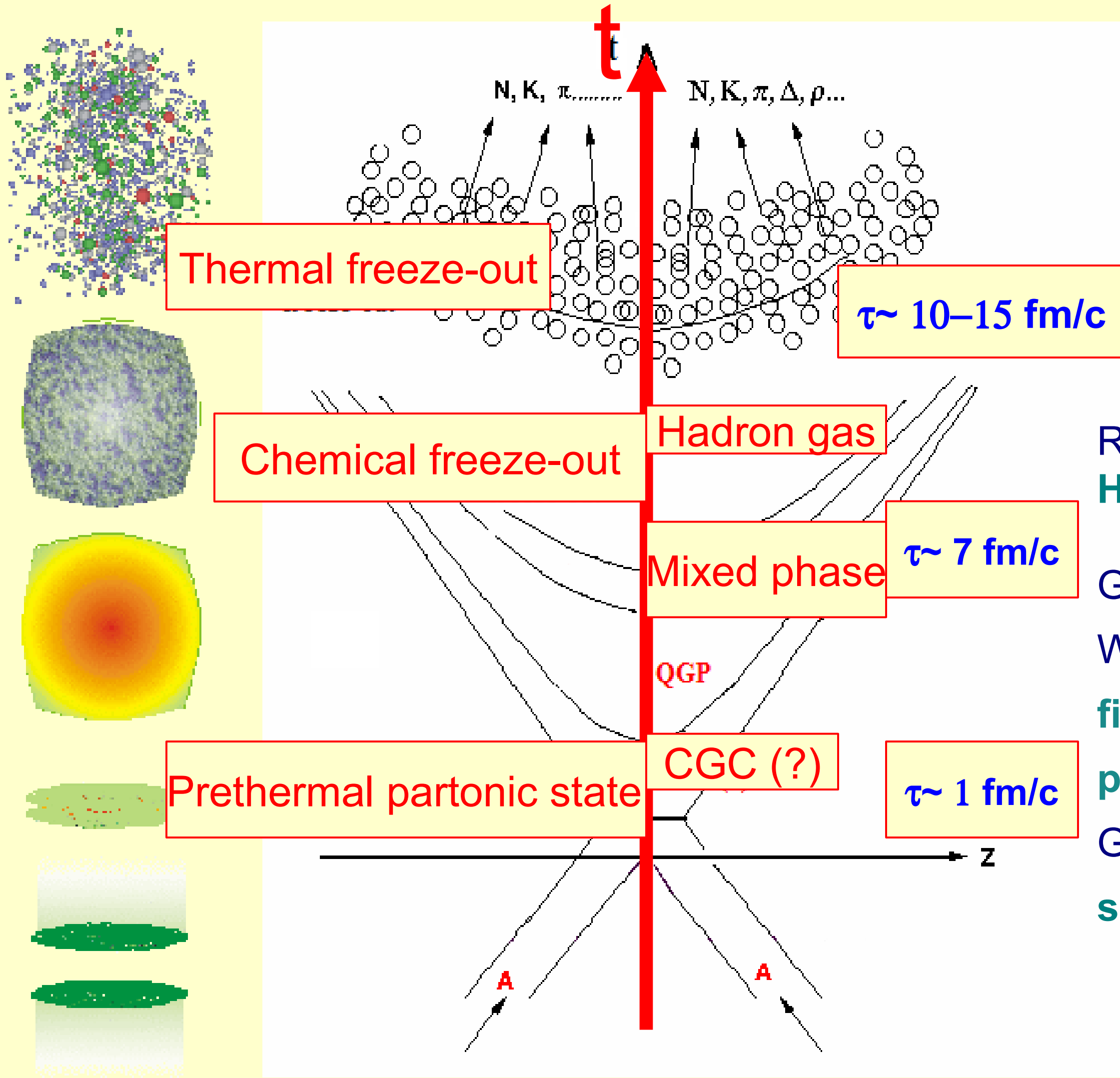
Quarkonia physics:

Participation in the analysis of $J/\psi \to \mu\mu$ in p-p and Pb-Pb collisions.

Updating of the analysis software.

GRID and PROOF computing and software activity.

Evolution of matter in HI collisions



Correlation femtoscopy : measurement of space-time characteristics R, $c\tau$ ~fm of particle production using particle correlations due to the effects of QS and FSI

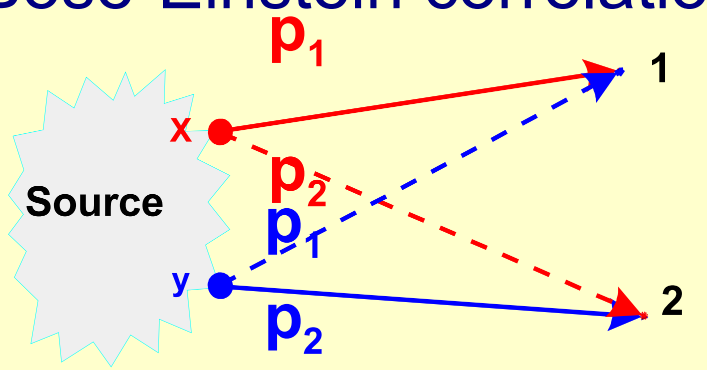
R. Hanbury-Brown and R.Q. Twiss (1956)- **HBT effect in astronomy**

G. Goldhaber, S. Goldhaber, W-Y Lee, A. Pais (1960) **firstly shown BE correlation of identical pions in ap-p collisions**

G.I. Kopylov and M.I. Podgoretsky (71-75) **settled basics of correlation femtoscopy**

Correlation femtoscopy: Quantum Statistics

Bose-Einstein correlations



2-particles correlation function:

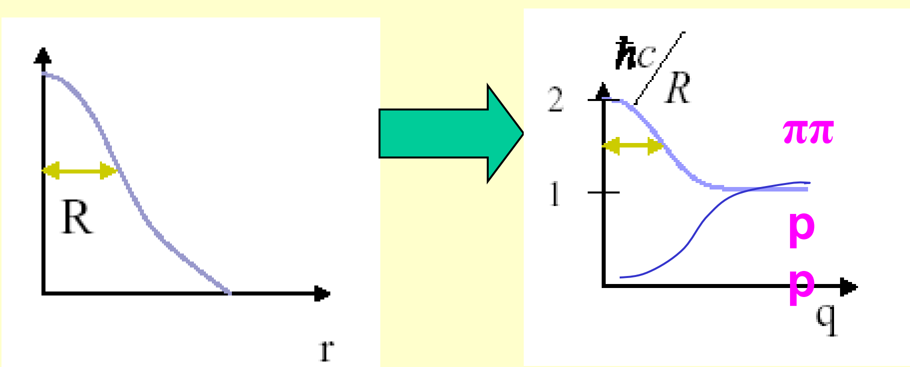
$$C(q)=\frac{N_2(p_1,p_2)}{N_1(p_1)N_2(p_2)}$$

$$C(\infty)=1$$

$$q=(-(p_1-p_2)^2)^{1/2}$$

Experimentally:

$$C(q)=\frac{S(q)}{B(q)}$$



S(q) -distribution of pair momentum difference of particles from the same events

B(q) -reference distribution, build by mixing particles from different events

Commonly used parametrizations: $C(q)=1+\lambda\exp(-R^2q^2)$

λ – Strength of correlations

R - effective size of emission region

Out: direction of the mean transverse momentum of the pair

Side: orthogonal to out

Long: beam direction

$$CF=1+\lambda\exp(-R_o^2q_o^2-R_s^2q_s^2-R_l^2q_l^2)$$

JINR analysis: Kaon femtoscopy motivation

- Study of mt-dependence of correlation radii. In heavy ions collisions at RHIC was observed $m_T(KK) > m_T(\pi\pi)$, $R(KK) < R(\pi\pi)$ – indication on effects of hydrodynamic expansion

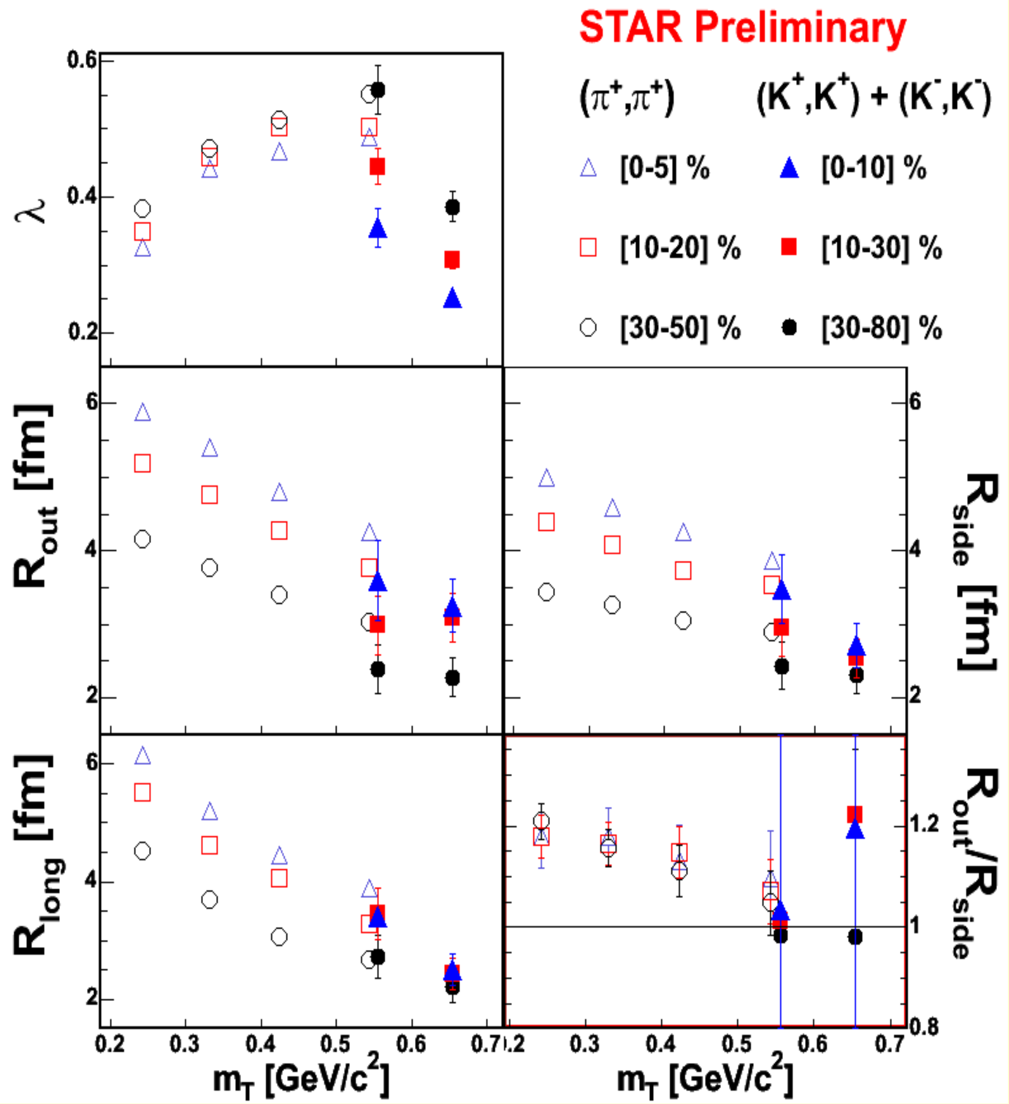
- KK suffer less from the resonance contributions then ππ -> more clear signal

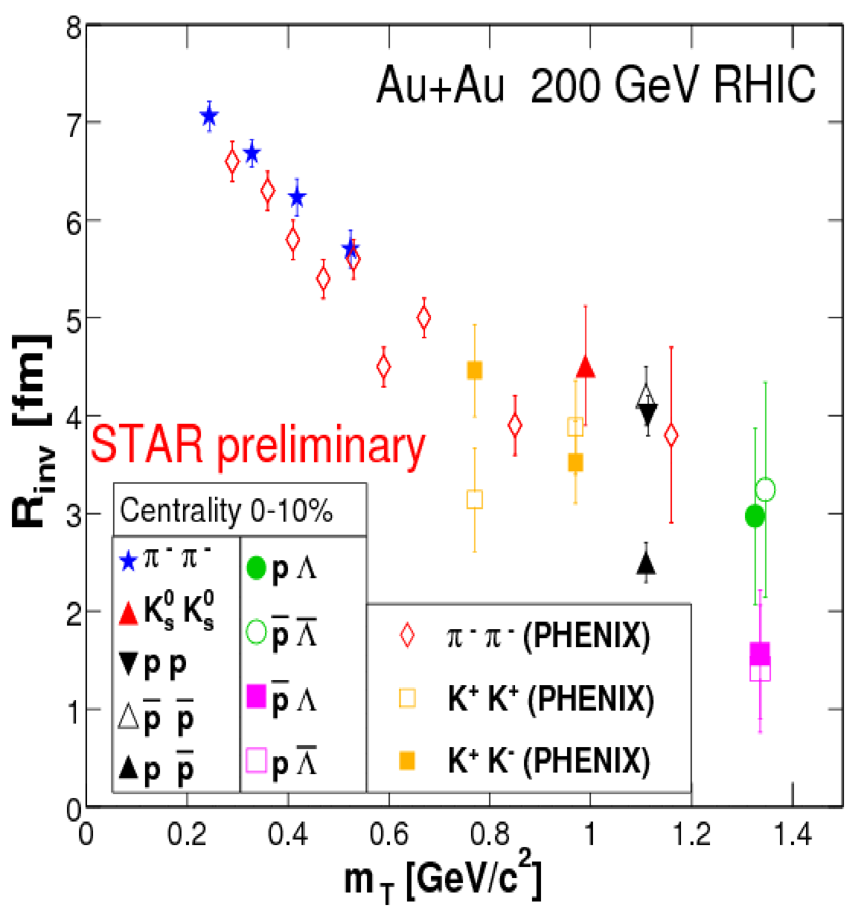
- Strong FSI leads to coupling of K+K- ->φ, dependence of the magnitude of the peak on the source size -> additional information about space-time source sizes and asymmetries

- Residual correlations of φφ can be seen from KK CF

- Strangeness distillation mechanism could lead to strong temporal emission asymmetries between K+ and K-. It is possible to determine the difference between emission times and positions of K+ and K- e. g. D.Ardouin et al. Phys.Lett.B446, 191 (1999)

KK at RHIC: Au+Au $\sqrt{s_{NN}}$=200 GeV





- an approximately "universal" m_T dependence is usually attributed to collective flow

- KK one dimensional radius 3-5 fm

We studied the charged KK femtoscopy correlations in 7 TeV pp collisions from the ALICE date 2010.
Preparation of the article is under way.

Results were shown on QM2011, Annecy & "LHC on the March", Protvino Nov2011

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KK correlations in pp
Motivation & main problems

- Perform the first measurements of the charged kaon source size in pp collisions by Bose-Einstein correlations (femtoscopy)

- Look for collective behavior by studying the source size dependence on the particle transverse momentum and mass

-Using charged KK & $K^0_s K^0_s$ increases available k_T range

Problems: stronger Coulomb FSI & smaller purity of the charged KK make the correlation peak less pronounced then in $\pi\pi$ and $K^0_s K^0_s$ cases so the relative role of the non-femtoscopic background increases. Baseline determination is main problem of KK analysis.

Details of Analysis

General analysis conditions:

- 3 bins in uncorrected charged particle multiplicity :

$M<11$, $11<M<22$, $M>23$

- 4 bins in k_T **(0.2-0.35) (0.35-0.5) (0.5-0.7) (0.7-1.0)** GeV/c.

All LHC10bcd and MB trigger LHC10e ~300 mln events

Fit by :

(1) $CF=N(1-\lambda+\lambda K_{coul}(1+\exp(-R^2Q_{inv}^2)))\ \{1 + a\,Q_{inv} + bQ_{inv}^2\}$

(2) $CF=N(1-\lambda+\lambda K_{coul}(1+\exp(-R^2Q_{inv}^2)))\ \mathrm{sqrt}\{1 + a\,Q_{inv}^2 + bQ_{inv}^4\}$

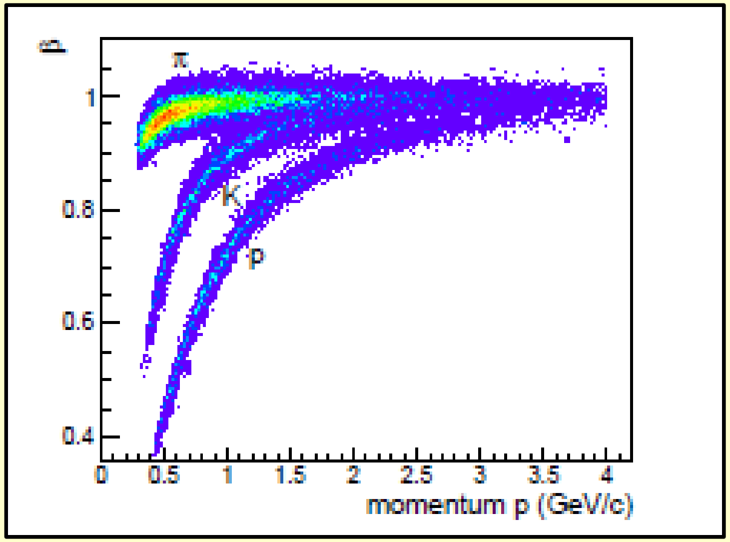
(3) $CF=N(1-\lambda+\lambda K_{coul}(1+\exp(-R^2Q_{inv}^2)))b\ (1+\exp(-aQ_{inv}^2)$

-Use PYTHIA(PERUGIA2011) to model baseline:

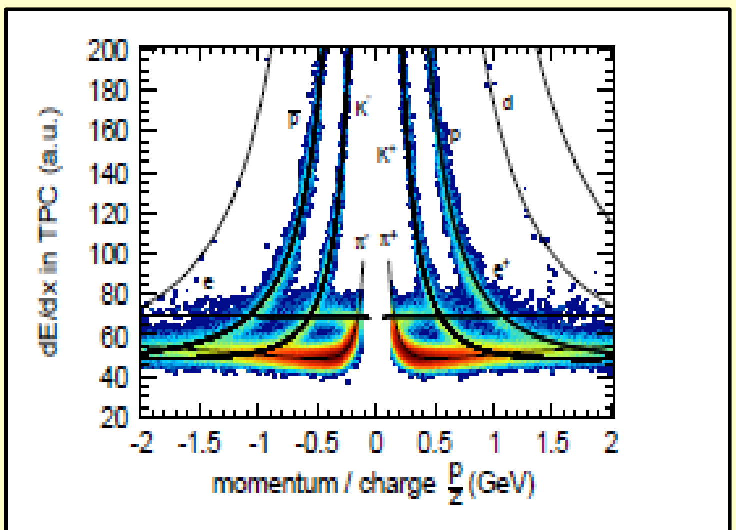
Make baseline fit with **(1) $\{1 + a\,Q_{inv} + bQ_{inv}^2\}$; (2) $\mathrm{sqrt}\{1 + a\,Q_{inv}^2 + bQ_{inv}^4\}$; (3) Gaussian** to extract parameters a,b for fitting $CF(Q_{inv})$

Charged kaon identification pp @ 7 TeV

TOF momentum versus velocity

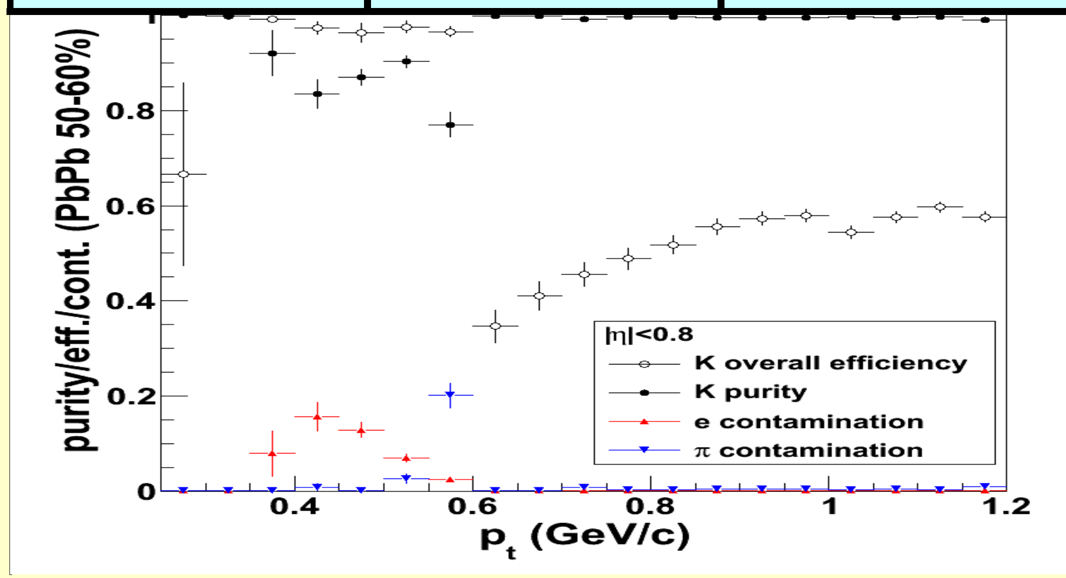


TPC dEdx versus momentum



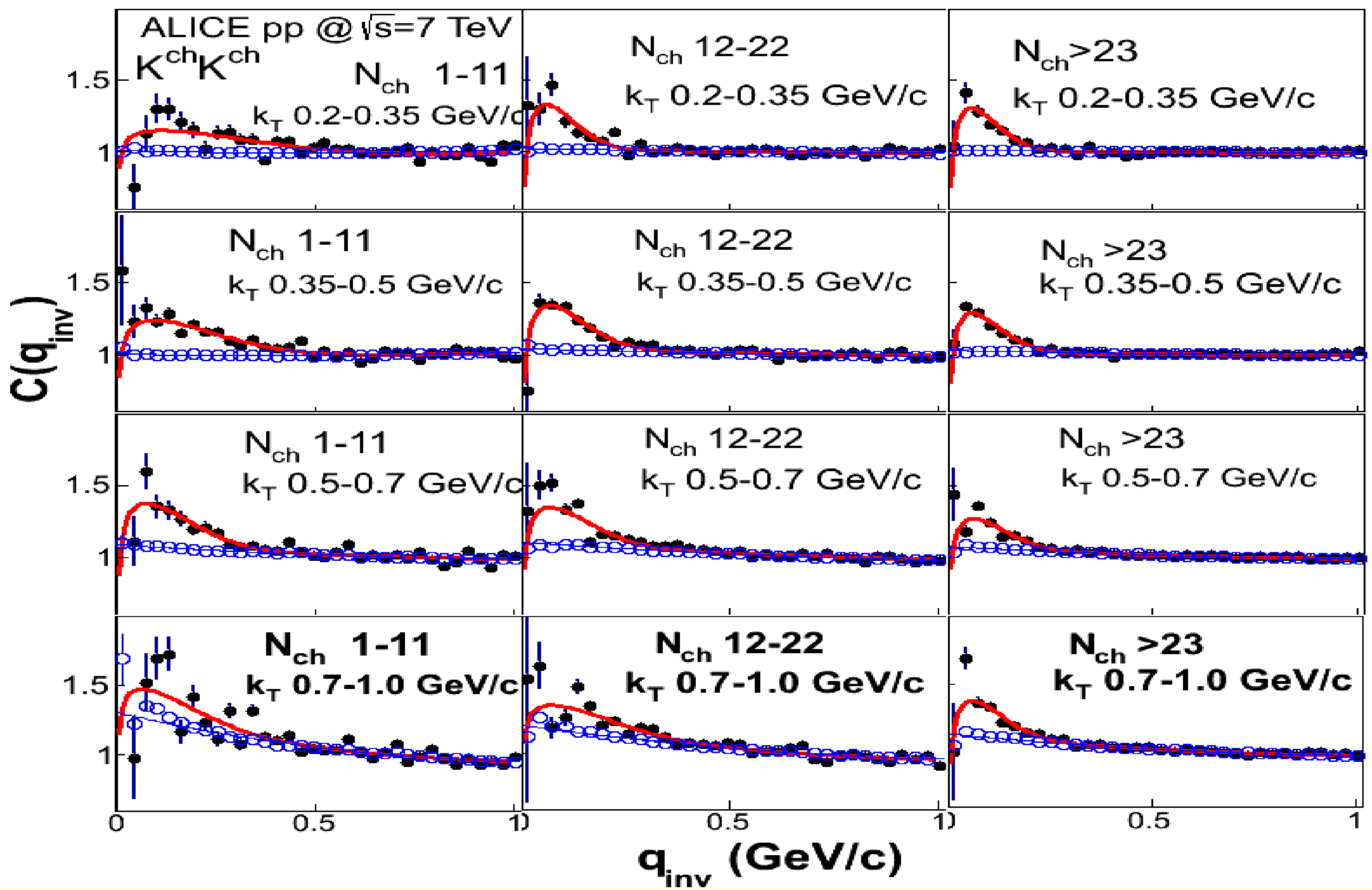
Kaons selection cuts

cut	TOF PID not available Nσ	TOF PID is available Nσ
Kaon Nσ	**TPC signal** **P<0.350 GeV/c** **1.0** **350<P<600 MeV** **2.0**	**TPC signal** **always 5.0** **TOF signal** **P<1.5 GeV/c** **3.0** **p>1.5 GeV/c** **2.0**



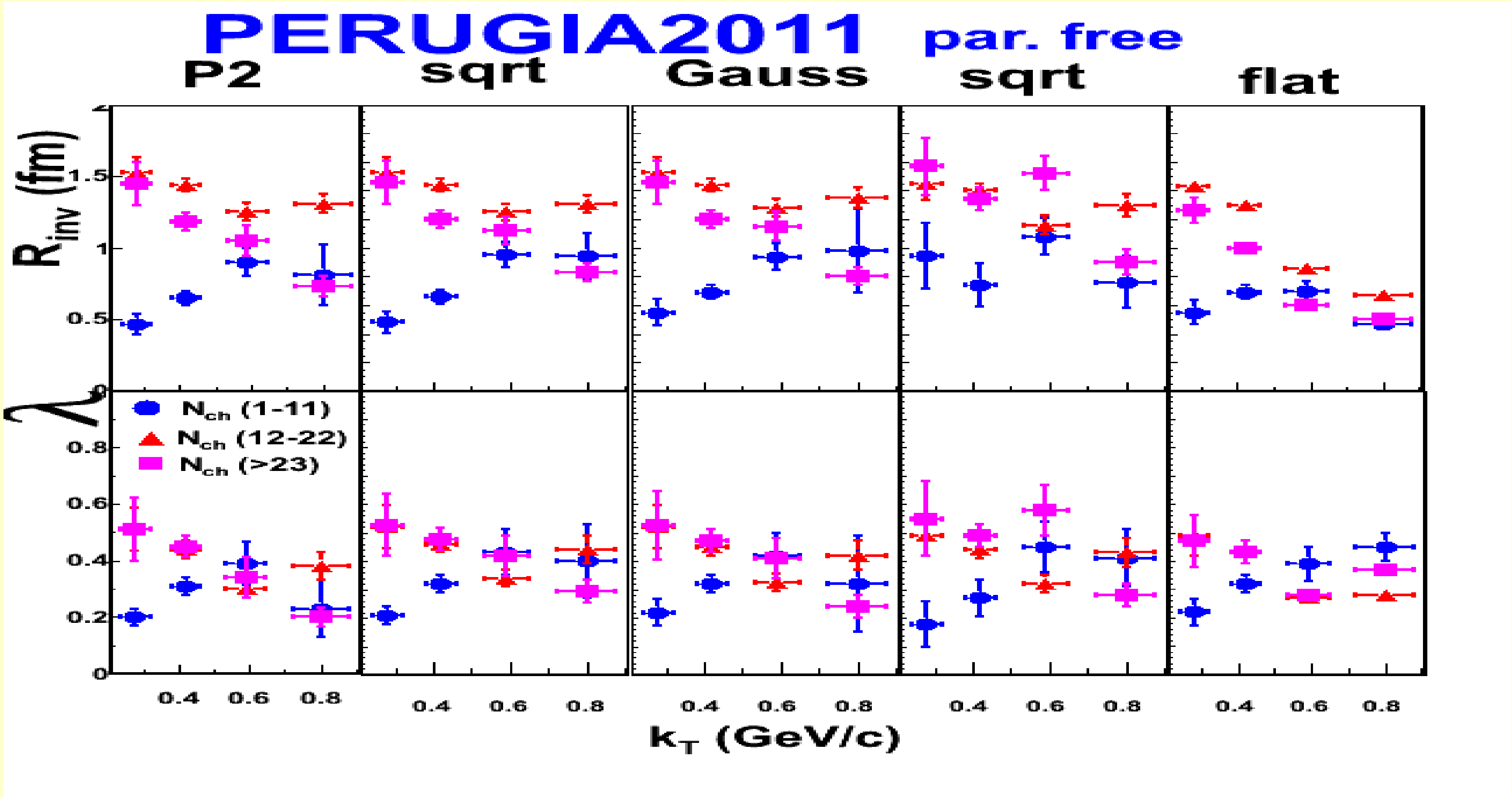
KK CFs fitted by Gaussian * PERUGIA2011 baseline fitted with with $\{1 + a\,Q_{inv} + bQ_{inv}^2\}$

Figure from the article



Ideal description of long range correlations by PERUGIA2011, small hi2/ndf~ (2-3)

Comparison of different fitting strategies



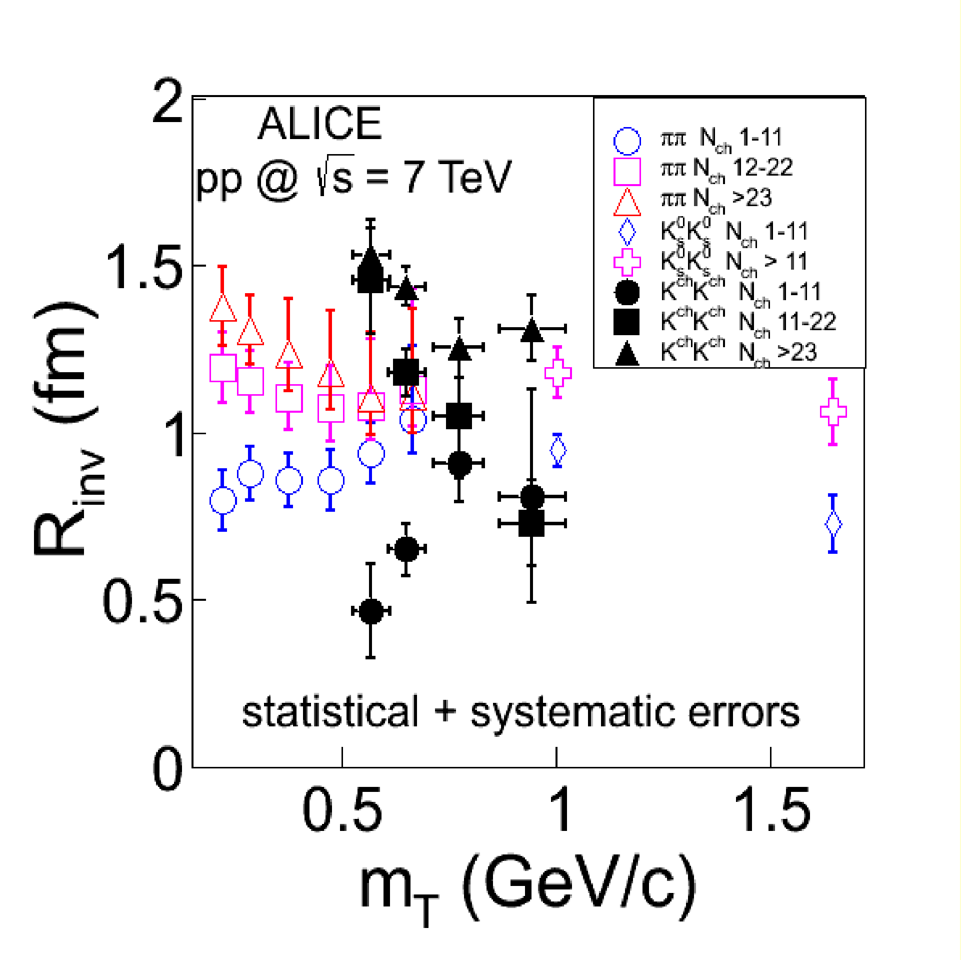
blue M0(1-11), **rosy M1(12-22)**, **red (23-140)**

- R_{inv} increase with multiplicity;
- R_{inv} decrease with $\mathbf{k_T}$ for M1, M2

- R_{inv} obtained with different baseline fits are very close now ! Systematic errors due to different fitting procedure are <5%

Charged KK versus $K^0_s K^0_s$ and $\pi\pi$ (Gaussian*PERUGIA)

Figure for the article



- radii increase with multiplicity

- radii decrease with kT at large multiplicities (M1(11-22),M2(>22)) similarly to HI

- at small multiplicity (M0 (1-11)) behaviour of kaon radii is different, similarly to pion ones

- breaking of mt scaling $R_K > R_\pi$

(attempt of interpretaion A. Kisiel, [arXiv:1012.1517 [nucl-th]]) in pp collisions flow of short lived resonances plays an important role differently for pions and kaons; T. J. Humanic, J. Phys. G 38, 124058 (2011) [arXiv:1107.0084 [hep-ex]].

We started study of charged KK femtoscopy correlations in 2.76 TeV PbPb collisions from the ALICE data 2010 (7 mln events in this analysis); data 2011(80 mln will be analised)

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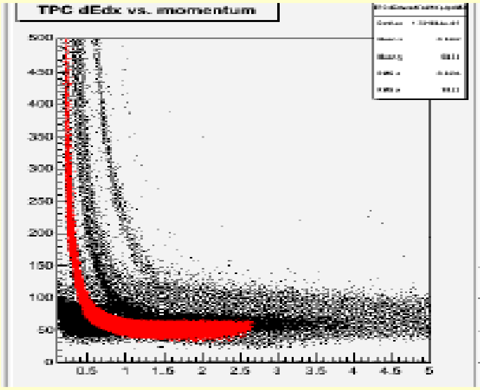
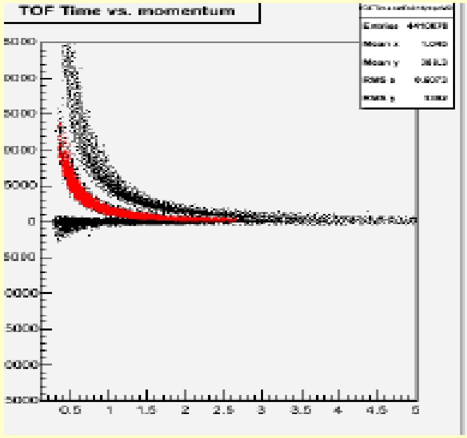
KK analysis in PbPb: first results

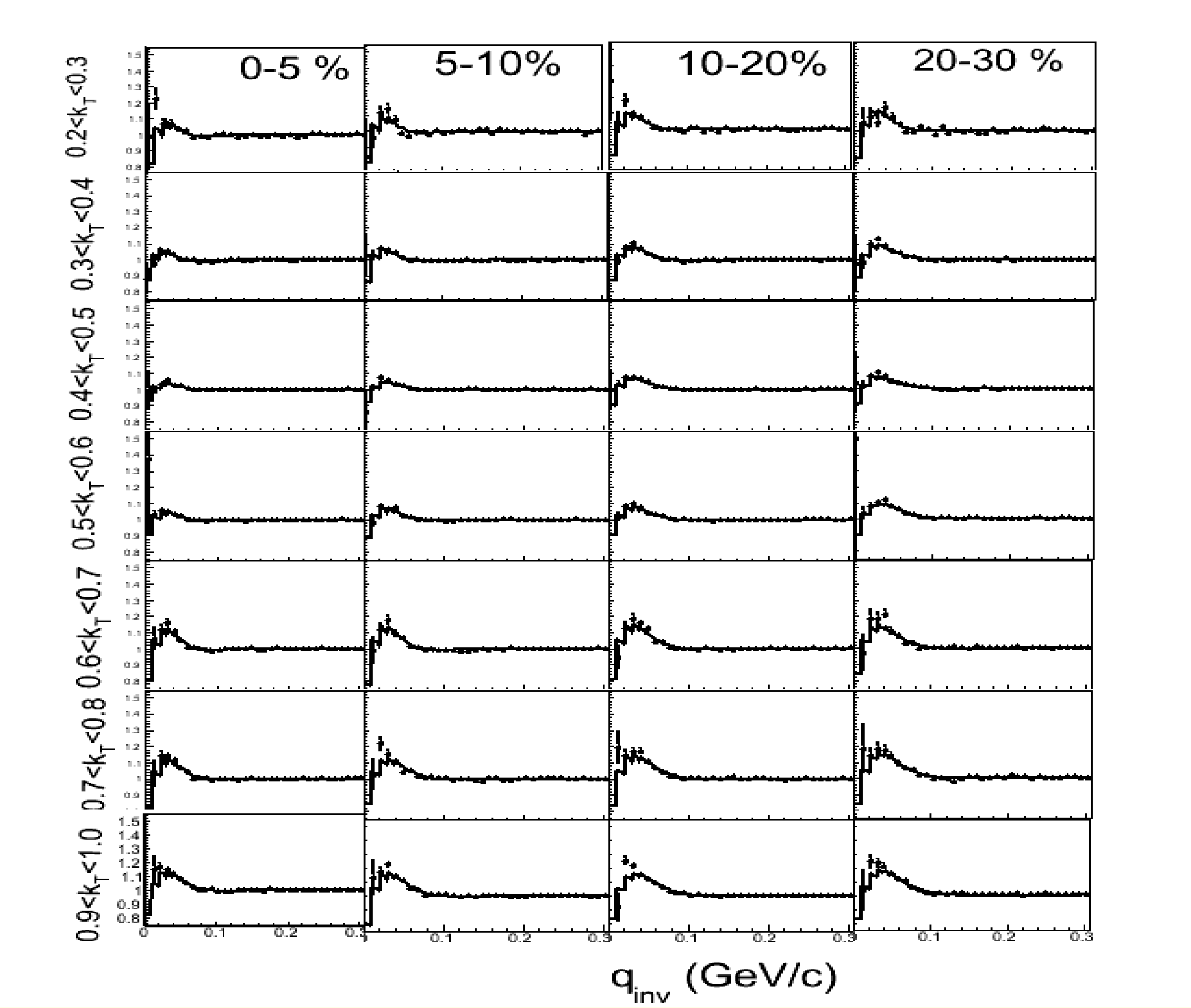
TPC dEdx



TOF p & time



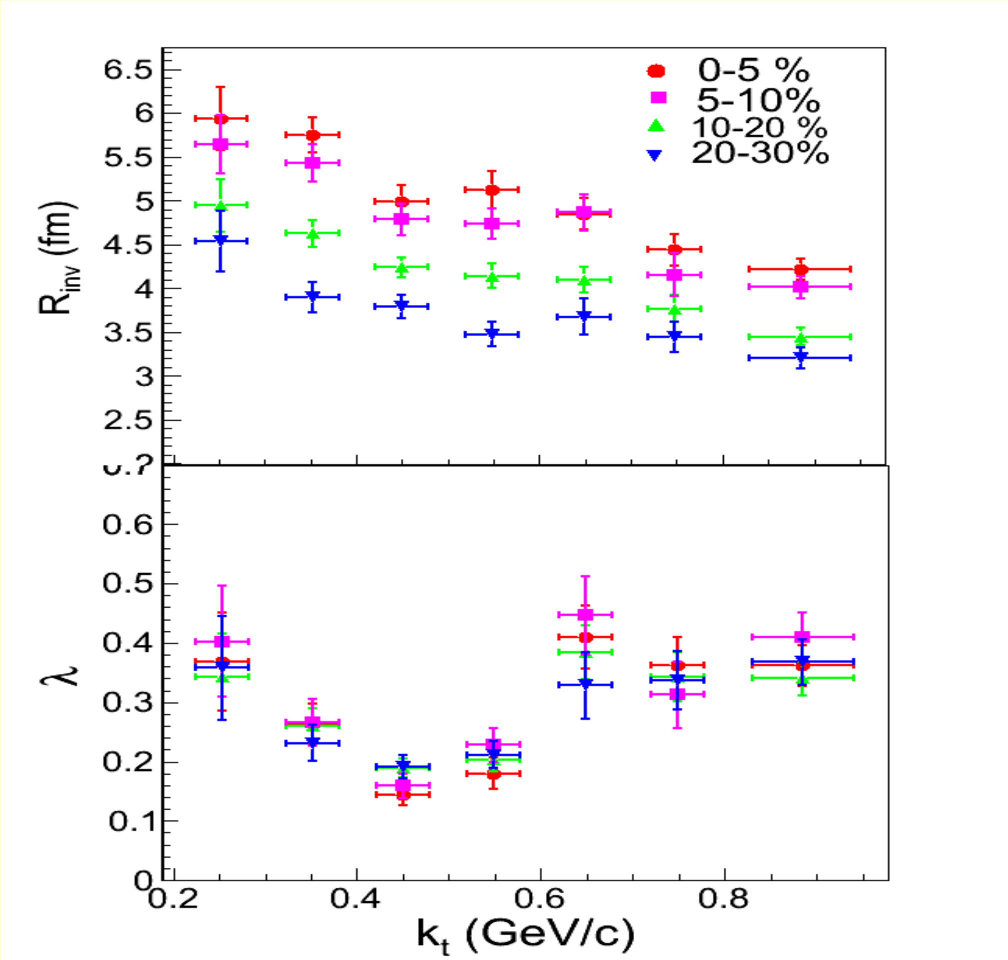
Correlation functions



Fit with $CF = N(1-\lambda+\lambda\, K_{cou1}(1+\exp(-R^2 Q_{inv}^2)))$ r=5 fm

KK analysis in PbPb: first results

k_T dependence of radii



Kaon radii decrease with kT , increase with multiplicity similarly to RHIC HI data; study of mT dependence for different centralities is under way.

Conclusions & Plans

- In pp and PbPb radii increase with multiplicity

- In pp radii decrease with kT at large multiplicities (M1(11-22), M2(>22)) similarly to PbPb

- At small multiplicity (M0 (1-11)) behaviour of kaon radii in pp is different, similarly to pion ones

- In pp breaking of mt-scaling.

These peculiarities deserve further experimental and theoretical studies

Plans:

- Prepare the article "Charged kaon femtoscopy correlations in pp collisions at sqrt(s) = 7 TeV"

- Continue analysis of KK in PbPb at 2.76 TeV

Additional slides

Charged KK (Gaussian* P2 PERUGIA2011)

ALICE

Table for the article

Table 1: $K^{ch}K^{ch}$ source parameters vs. k_T for $\sqrt{s}$=7 TeV pp collisions. Statistical and systematic errors are listed.

k_T range (GeV/c)	N_{ch}	$< k_T >$ (GeV/c)	$dN_{ch}/d\eta$	λ	R_{inv} (fm)
0.20-0.35	1-11	0.28 ± 0.04	3.2	0.20 ± 0.04 ± 0.03	0.47 ± 0.07 ± 0.12
0.35-0.50	1-11	0.42 ± 0.05	3.2	0.31 ± 0.03 ± 0.02	0.65 ± 0.05 ± 0.06
0.50-0.70	1-11	0.59 ± 0.06	3.2	0.39 ± 0.08 ± 0.03	0.91 ± 0.10 ± 0.06
0.07-1.00	1-11	0.80 ± 0.08	3.2	0.23 ± 0.10 ± 0.20	0.81 ± 0.21 ± 0.24
0.20-0.35	12-22	0.28 ± 0.04	8.9	0.51 ± 0.12 ± 0.03	1.45 ± 0.15 ± 0.02
0.35-0.50	12-22	0.42 ± 0.05	8.9	0.46 ± 0.04 ± 0.04	1.18 ± 0.06 ± 0.03
0.50-0.70	12-22	0.59 ± 0.06	8.9	0.34 ± 0.07 ± 0.10	1.05 ± 0.12 ± 0.14
0.70-1.00	12-22	0.80 ± 0.08	8.9	0.21 ± 0.04 ± 0.10	0.73 ± 0.07 ± 0.10
0.20-0.35	>23	0.28 ± 0.04	15.3	0.51 ± 0.08 ± 0.03	1.53 ± 0.10 ± 0.02
0.35-0.50	>23	0.42 ± 0.05	15.3	0.44 ± 0.03 ± 0.04	1.44 ± 0.04 ± 0.03
0.50-0.70	>23	0.59 ± 0.06	15.3	0.30 ± 0.03 ± 0.04	1.25 ± 0.06 ± 0.06
0.70-1.00	>23	0.80 ± 0.08	15.3	0.37 ± 0.05 ± 0.06	1.31 ± 0.08 ± 0.08

Statistical & systematic errors are shown;
(statistical + systematical errors were summarized quadratically)

Details of Analysis pp

Event selection:

- Only events with minimum bias trigger were selected.
- Reconstructed vertex must be within 10 cm of the center of the TPC along the beam direction.
- At least one particle must be reconstructed and identified as a kaon.

Single track cuts:

- $|\eta| < 1.0$ & $0.15 < p_T < 1.2$ GeV/c.
- Only well reconstructed tracks are accepted: at least 70 out of maximum 159 points in the TPC.
- Distance of particle trajectory to the primary vertex. in the transverse plane < 0.2 cm and in the beam direction < 0.25 cm.

Double track cuts:

- pairs which share more than 5% of clusters in the TPC were removed - anti-splitting cut;
- pairs that are separated by less than 3 cm at the entrance of the TPC were removed – anti-merging cut.

Pair cuts were applied in exactly the same way for same (signal) and mixed (background) pairs.

Details of Analysis PbPb

Event selection:

- Only events with minimum bias trigger were selected.
- Reconstructed vertex must be within 8 cm of the center of the TPC along the beam direction.
- At least one particle must be reconstructed and identified as a kaon.

Single track cuts:

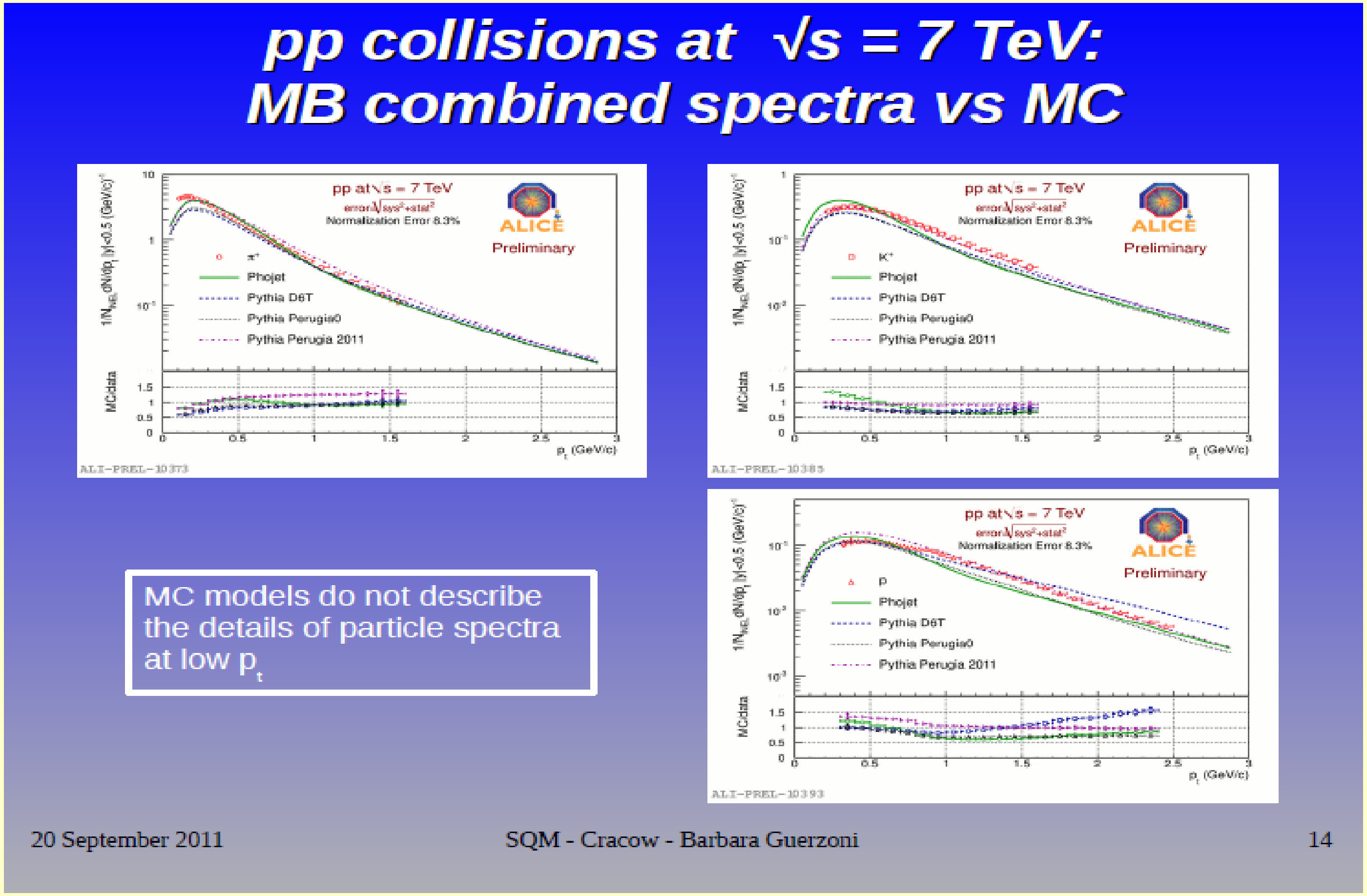
- $|\eta| < 0.8$ & $0.14 < p_T < 2.0$ GeV/c.
- TPC inner tracks
  Maximum TPC ChiNdof = 4

- Distance of particle trajectory to the primary vertex.
  in the transverse plane < 0.2 cm and in the beam direction < 0.15 cm.

Double track cuts:

SetShareQualityMax(1.0)
SetShareFractionMax(0.05)
SetPhiStarDifferenceMinimum(0.017)
SetEtaDifferenceMinimum(0.015)
SetMagneticFieldSign(-1)

PERUGIA 2011



Neither PYTHIA(PERUGIA0) nor PHOJET described kaon spectra; new PERUGIA2011 is created and seems to describe the kaon spectra much better then previous PYTHIA tunes e.g. PERUGIA0

Estimation of systematic errors

- **systematic errors from baseline functional form** (1-10 %)

- **systematic errors related to the choice of the fit range** **(2 − 15%)**

  Q_{inv} (0.0-1.0) GeV/c was used, (0.0-1.5) GeV/c , (0.0-0.8) GeV/c for the test;

  study of double tracks effects influence: (0.03-1.0); (0.06-1.0) GeV/c

- **Coulomb function influence**: (2-4 %) at first, the radius of the spherical source was taken equal to 1 fm, then the radii were calculated and for each correlation function the argument of Coulomb function was varied within ±3R (where R is the total systematic error).

- **PID contaminations** The contaminations in the kaon sample of the other particles were estimated by the Monte Carlo simulation:

$p_T < 0.35$ GeV/c and $0.6 < p_T < 1.2$ GeV/c all contaminations are negligible,

$0.35 < p_T < 0.5$ the contamination comes mainly from **e** ~15%, π 2− 3%,

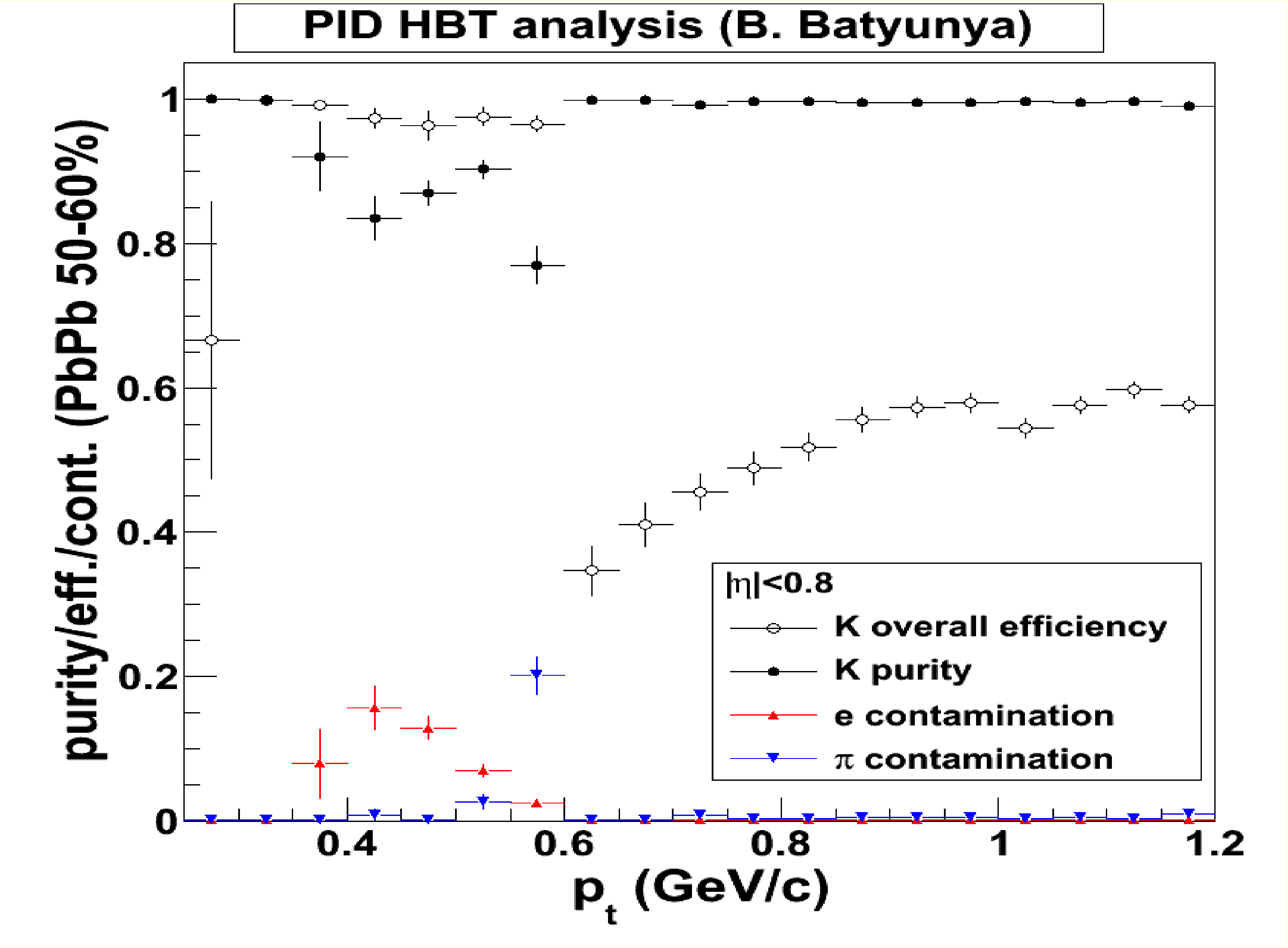
$0.5 < p_T < 0.6$ GeV/c π ~ 10%, **e** ~ 5% .

probability of taking the **ee** pair instead of **KK** pair at $0.35 < p_T < 0.5$ GeV/c, where the contamination is maximal, is still very low **2%**;

probability of taking **eK** for **KK** is **12%**, but such contaminations decrease only the strength of correlations and do not change the shape of the correlation function.

purity of kaon pairs is higher than 95% at $pT < 0.35$ GeV/c and $0.6 < pT < 1.2$ GeV/c, and about 72% at $0.35 < pT < 0.6$ GeV/c.

Purity calculation by F. Noferini



The analysis JINR group :

11 physicists including 2 PhD and

1 graduate student

(the group leader is Boris Batyunya)

COMPUTING

- 30,000 cores
- 70 computer centres (1T0, 5T1, 64T2)
- America, Europe, Africa and Asia
- Stable and smooth operation 24 x 7
- Operated according to the Computing Model