GOETHE UNIVERSITÄT FRANKFURT AM MAIN

H-QM Helmholtz Research School Quark Matter Studies

Femtoscopy at High m_T in Heavy-Ion Collisions with ALICE

ALICE

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for the ALICE collaboration
Hot Quarks 2012

Outline

- Introduction
- Particle selection
- Results
  - Correlation functions
  - Radii

Femtoscopic QGP observables

- Extract radii of the particle emitting source
- m_T dependence of femtoscopic radii puts constraints on model parameters:
  - Time scales
  - Temperature
  - Viscosity in QGP
  - Pre-flow (RHIC)
  - Order of phase transition
  - ...
- We measure it, you fit it! :)

Investigated systems

system	m_T ($k_T \rightarrow 0$)	correlation: quantum statistics	correlation: Coulomb	correlation: strong
• Standard				
• $\pi^{\pm}\pi^{\pm}$	0.14 GeV/c^2	x	x	(x)
• High m_T				
• $K^{\pm}K^{\pm}$	0.49 GeV/c^2	x	x	(x)
• $K^0_sK^0_s$	0.50 GeV/c^2	x		x
• pp	0.94 GeV/c^2	x	x	x
• $p\Lambda$	1.03 GeV/c^2			x

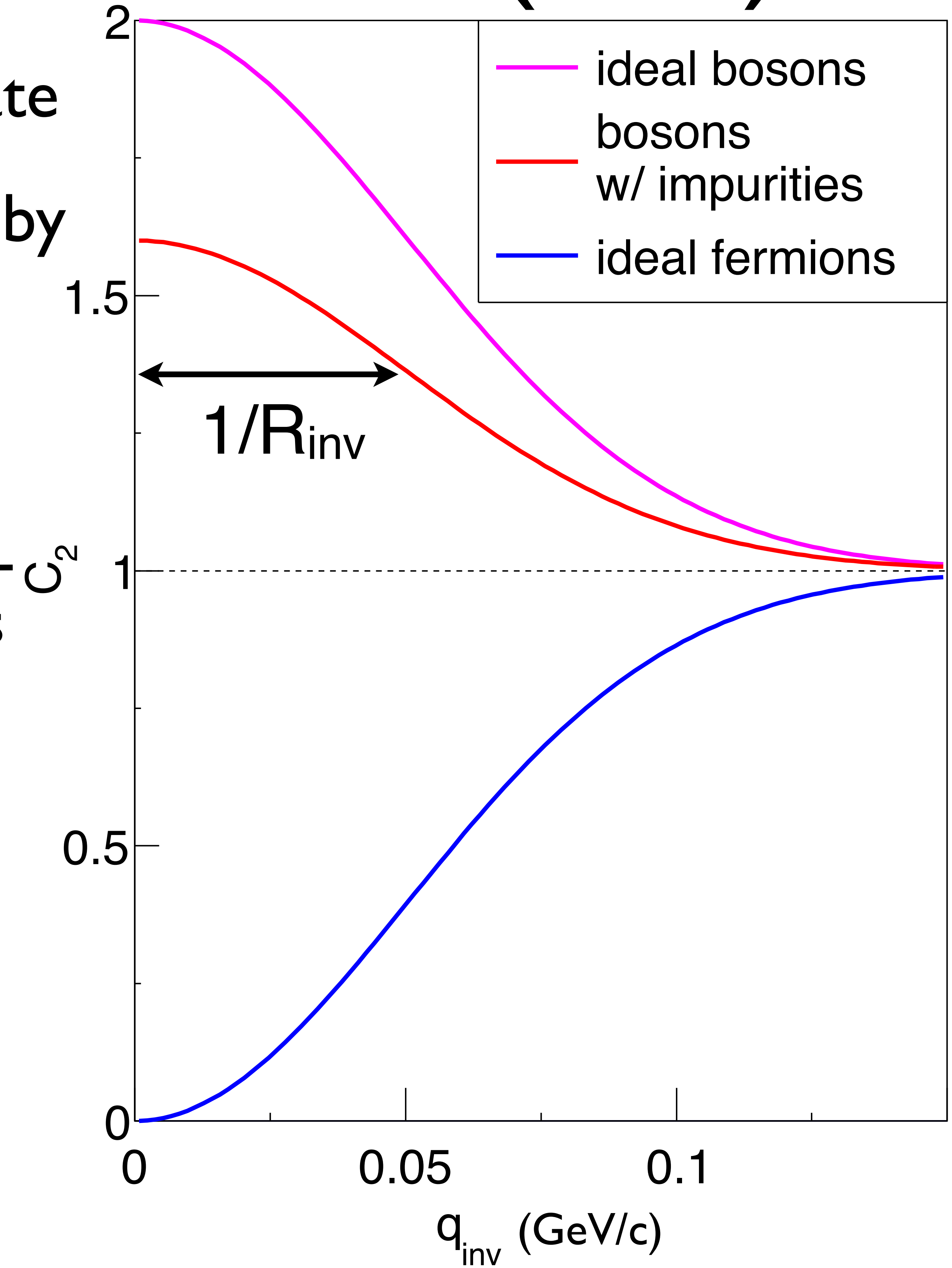
Quantum statistics (QS)

- Bosons tend to occupy same state
- Divide two-particle distribution by product of single particle distribution

$$C_2(q_{inv}) = \frac{S(q_{inv})}{B(q_{inv})} = \frac{\text{real events}}{\text{mixed events}}$$

$$q_{inv} = |\vec{p_1} - \vec{p_2}| \text{ (pair rest frame)}$$

- C_2 carries information of spatial extent of source

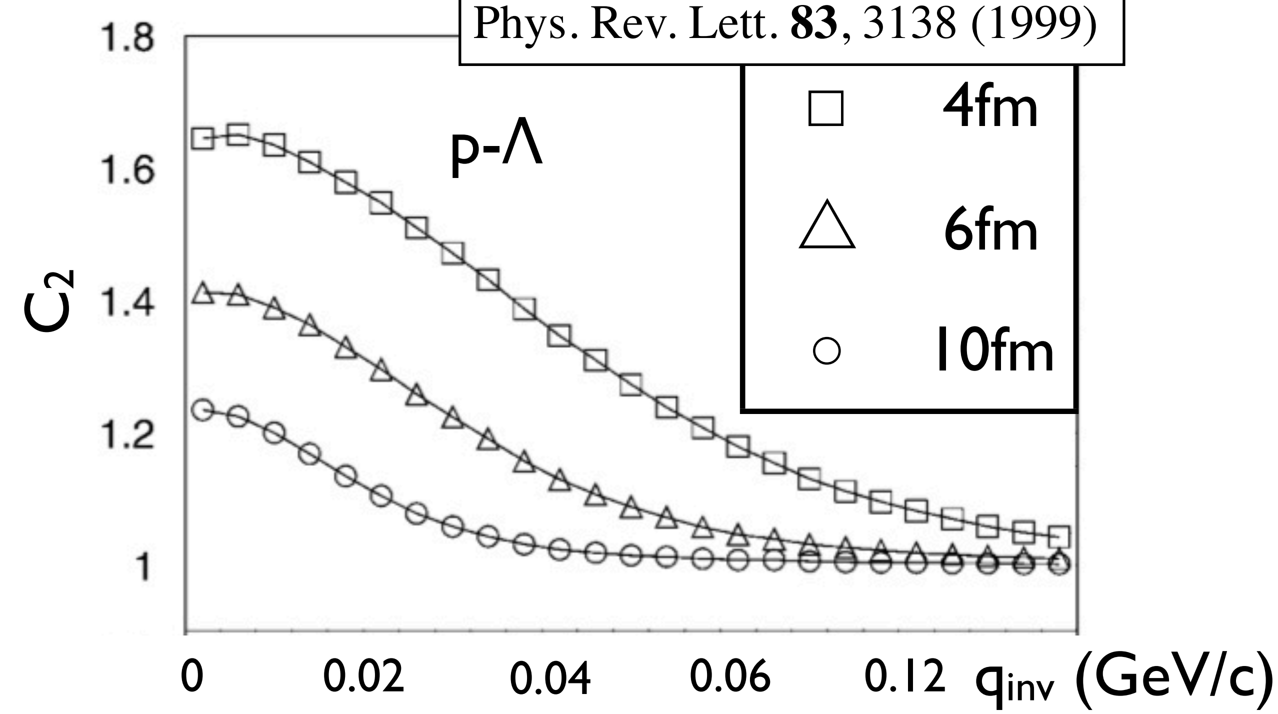


Final state interaction (FSI)

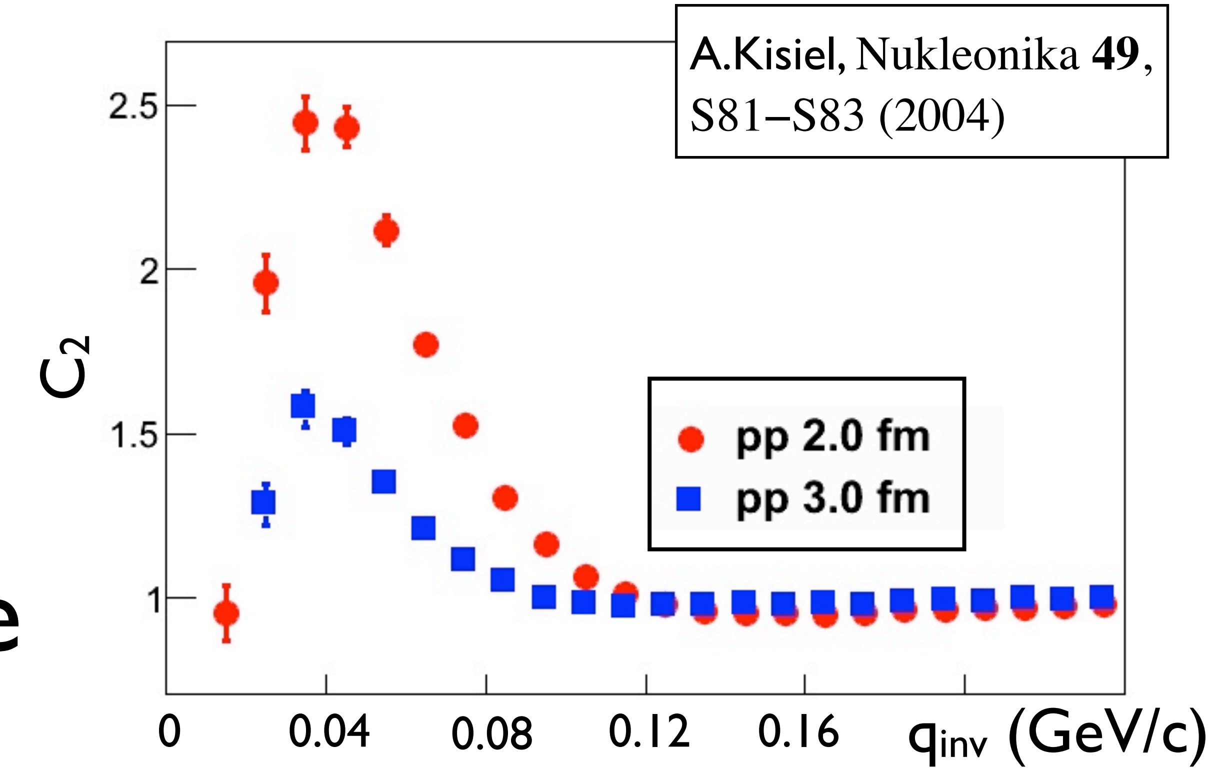
- Interaction parameters need to be known
- Model allows to extract source size

R. Lednicky and V. L. Lyuboshits, Sov. J. Nucl. Phys. **35**, 770 (1982)

- Correlation functions sensitive in height and shape

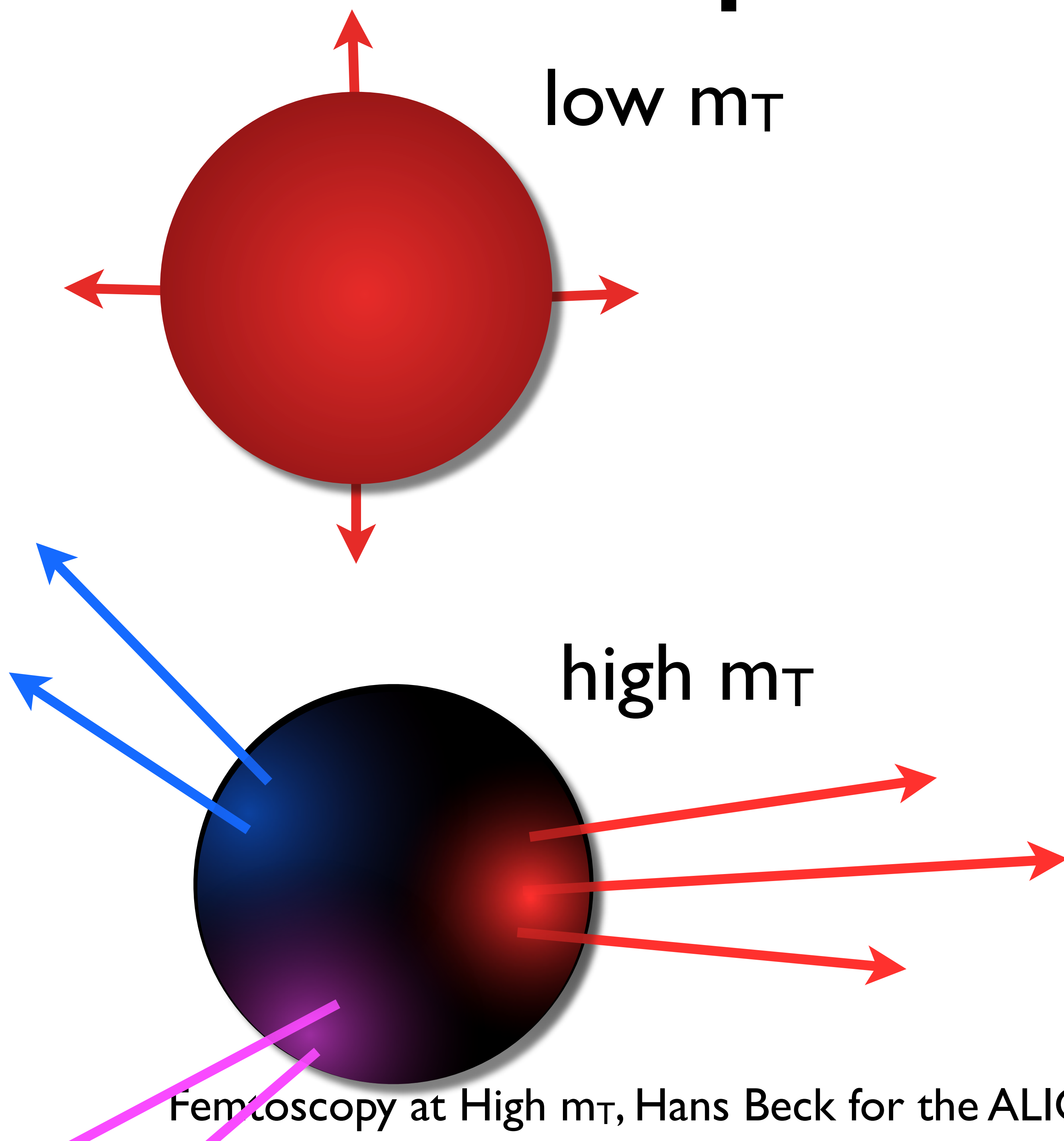


F. Wang and S. Pratt, Phys. Rev. Lett. **83**, 3138 (1999)



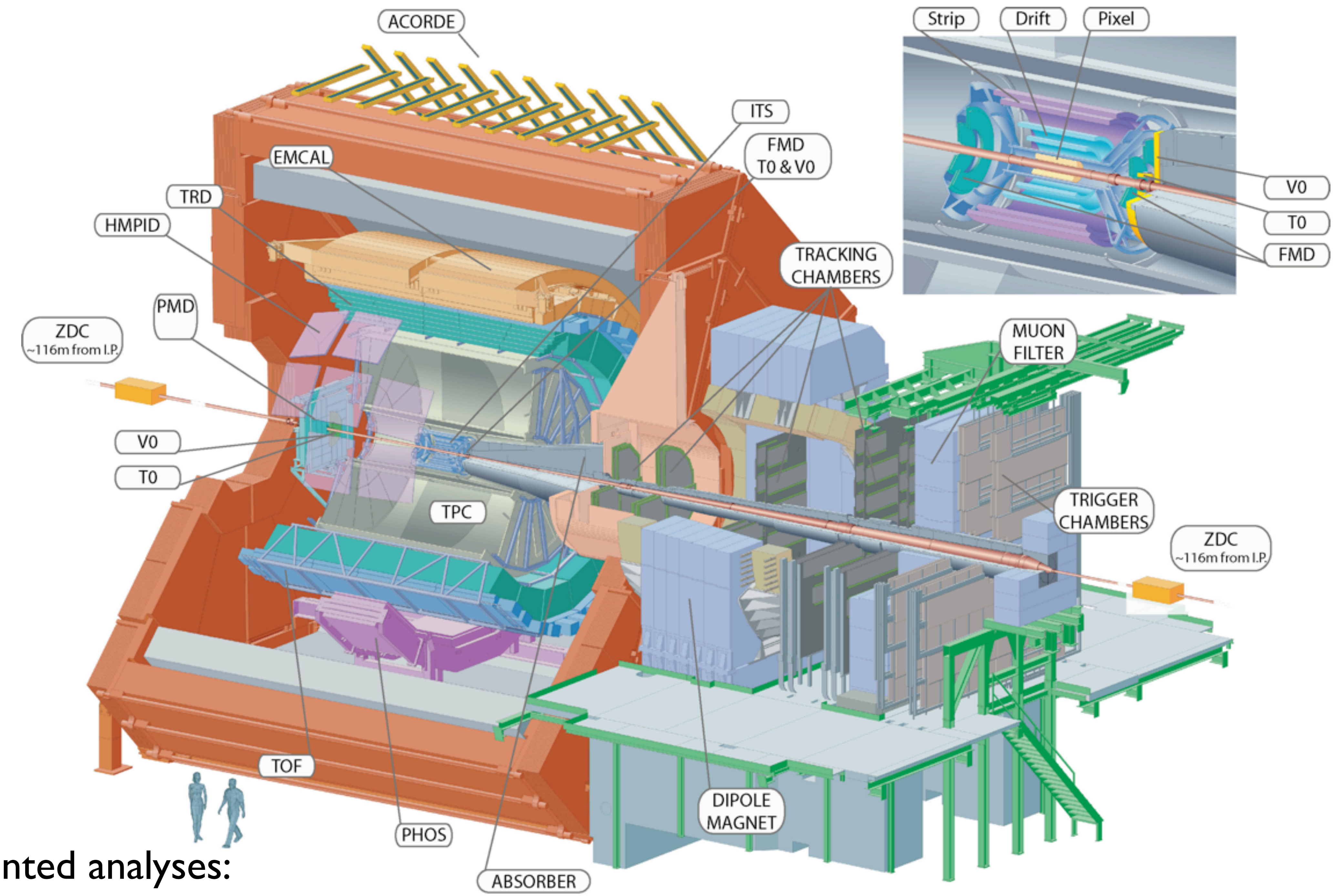
A.Kisiel, Nukleonika **49**, S81–S83 (2004)

Transverse mass dependence



- Expanding medium
- Region of homogeneity smaller than the full source
- Apparent source size decreases with m_T
- Probes dynamics of source

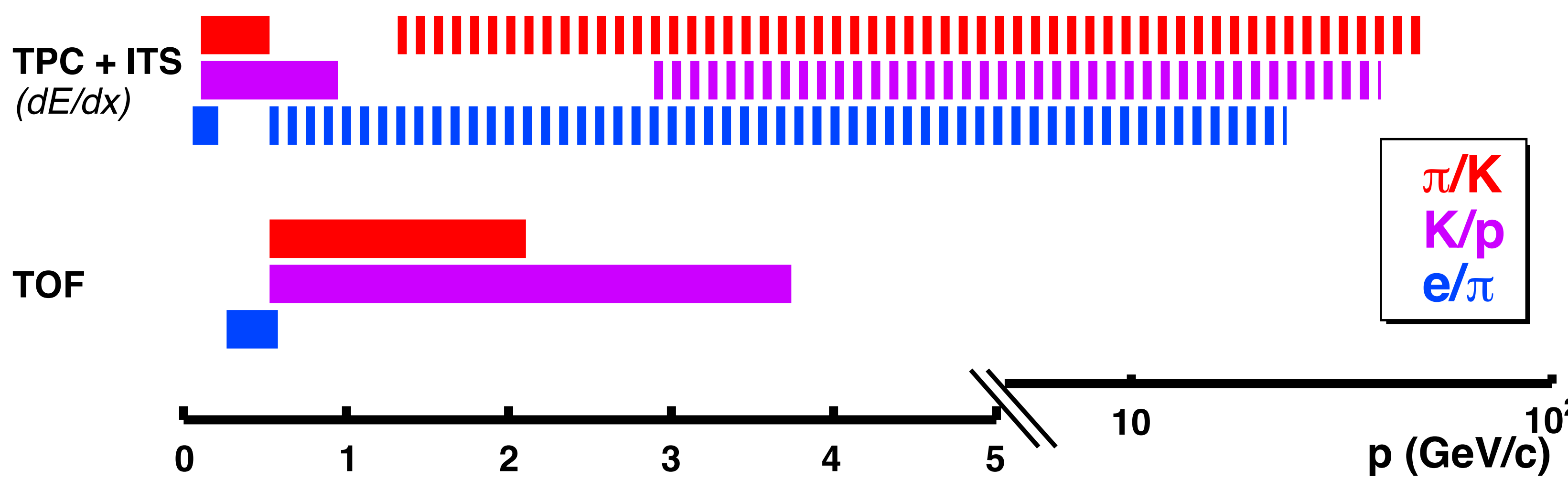
ALICE



In presented analyses:

Trigger, Centrality	Tracking	PID
VZERO, T0, ZDC, ITS	ITS, TPC, TRD	TPC, TOF

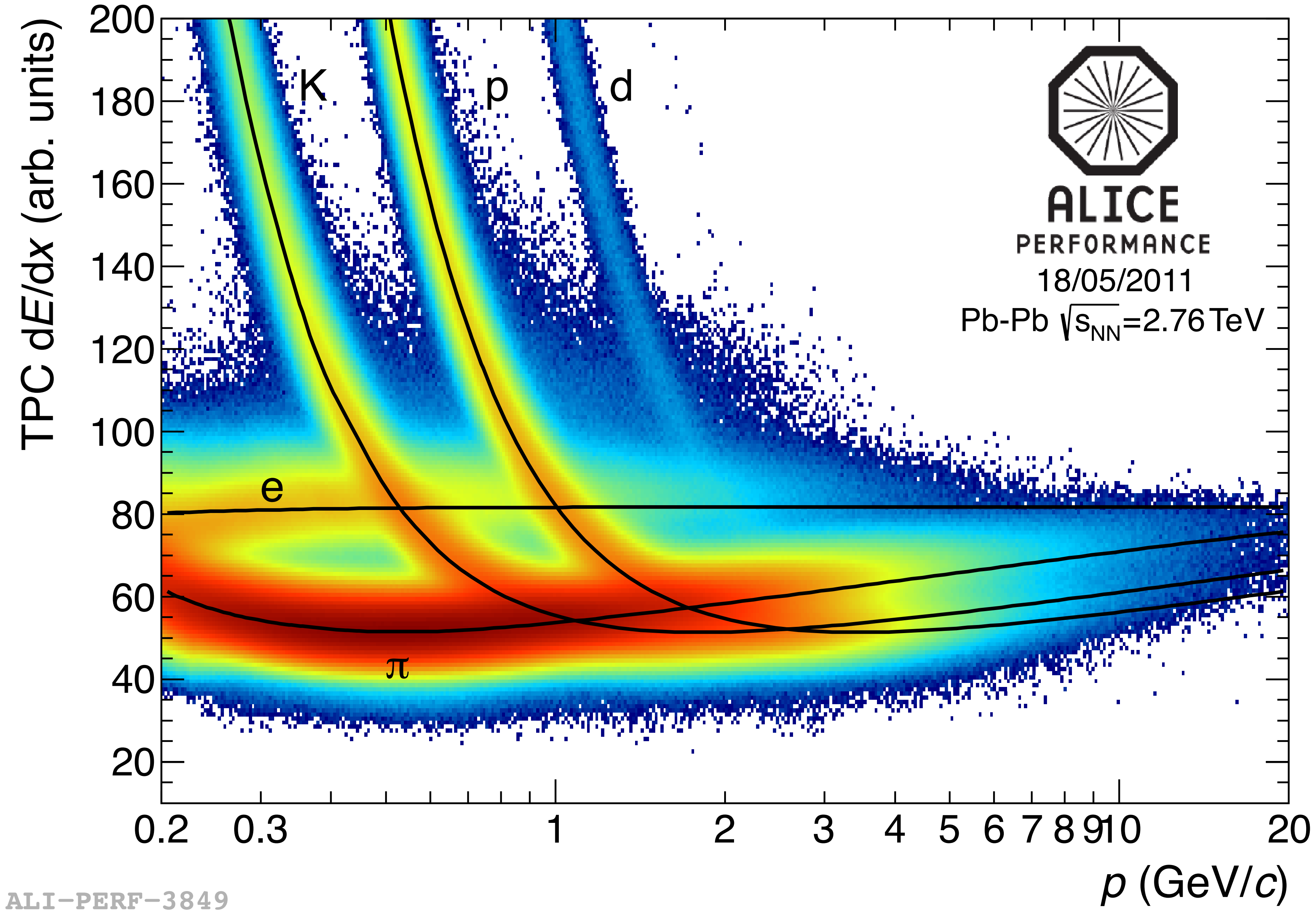
Proton selection



- Different PID technique depending on momentum

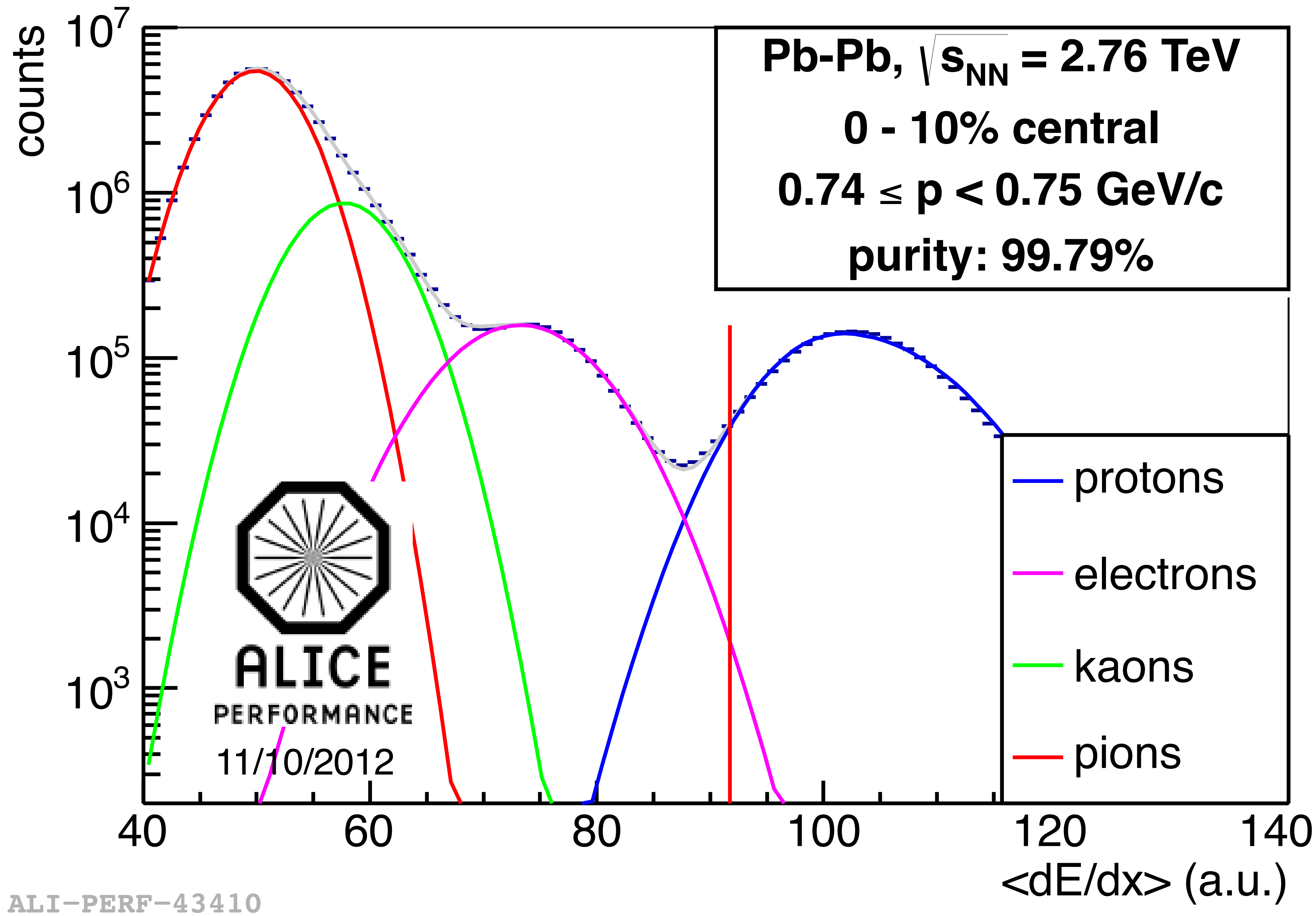
momentum	detector
$p < 0.75$ GeV/c	TPC
$0.75 \leq p < 1.0$ GeV/c	TPC & TOF
$1.0 \leq p < 3.25$ GeV/c	TOF

p selection: TPC



- Upper & lower Bethe Bloch parametrized cut
- Clear separation up to p = 0.75 GeV/c
- Kaons selected similarly

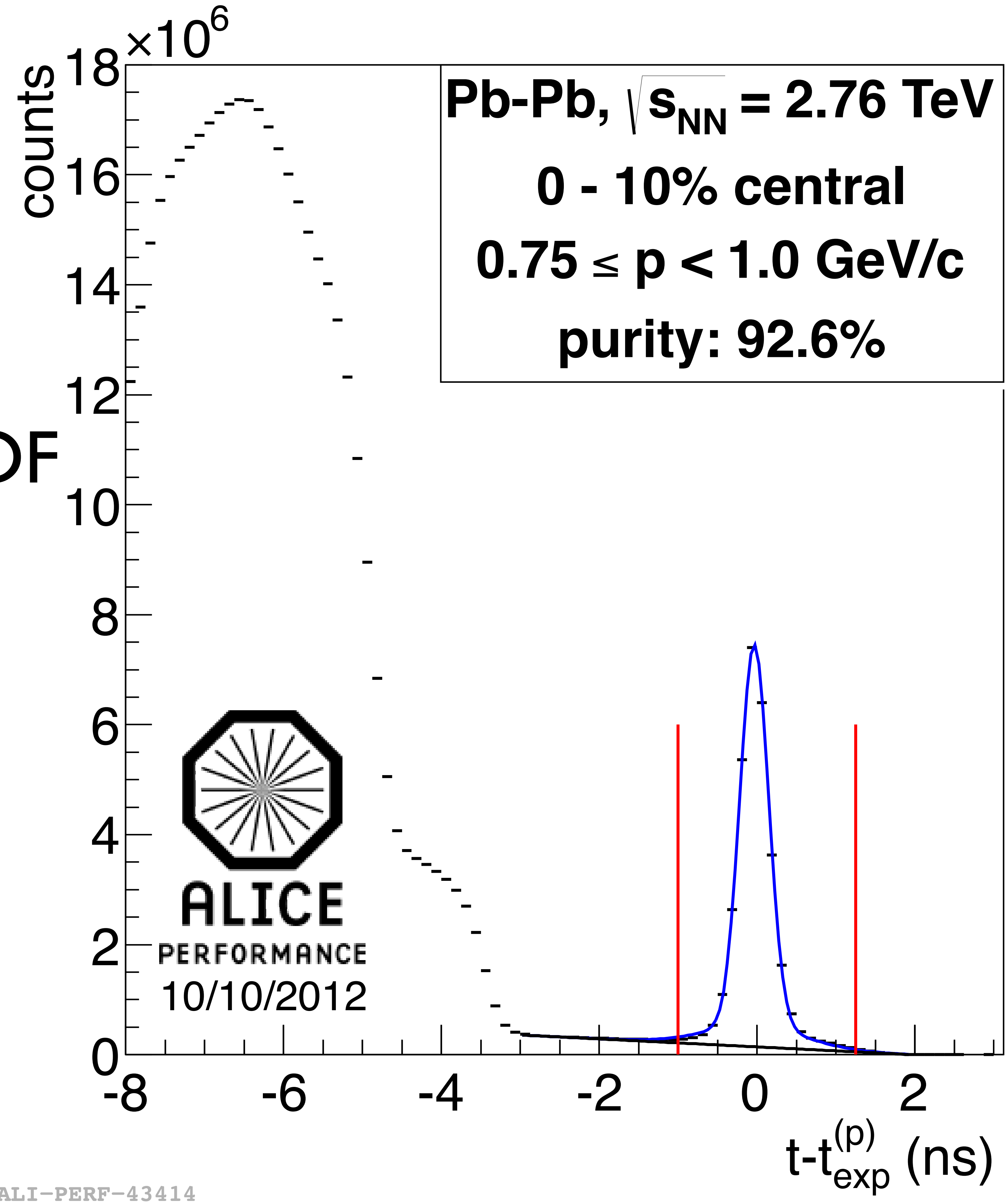
p selection: TPC



- Excellent TPC performance
- High purity obtained
- Nearly no signal loss

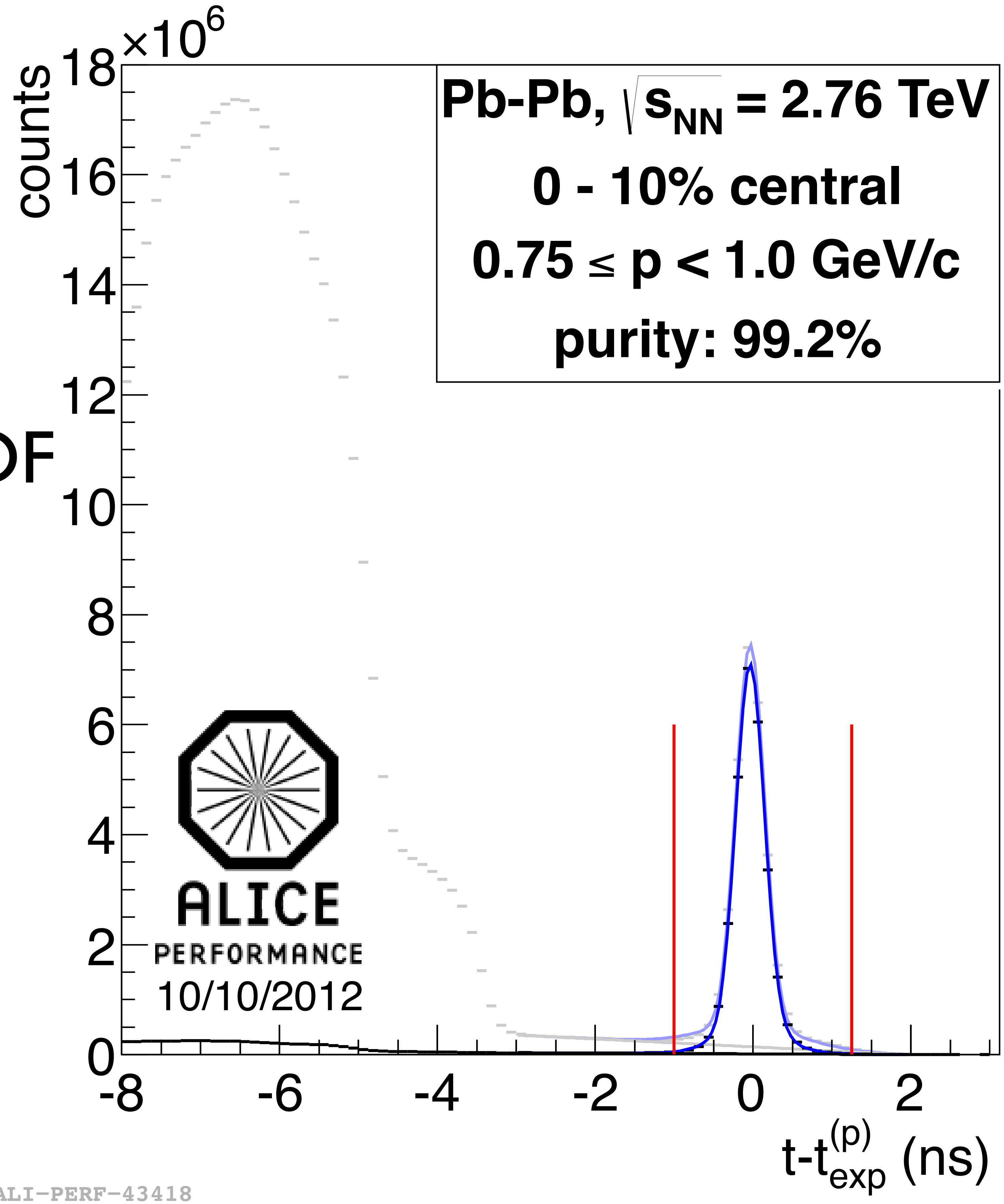
p selection: TPC & TOF

- $0.75 \leq p < 1.0$ GeV/c
- Low momentum for TOF
- Mismatch issue (mainly pions)



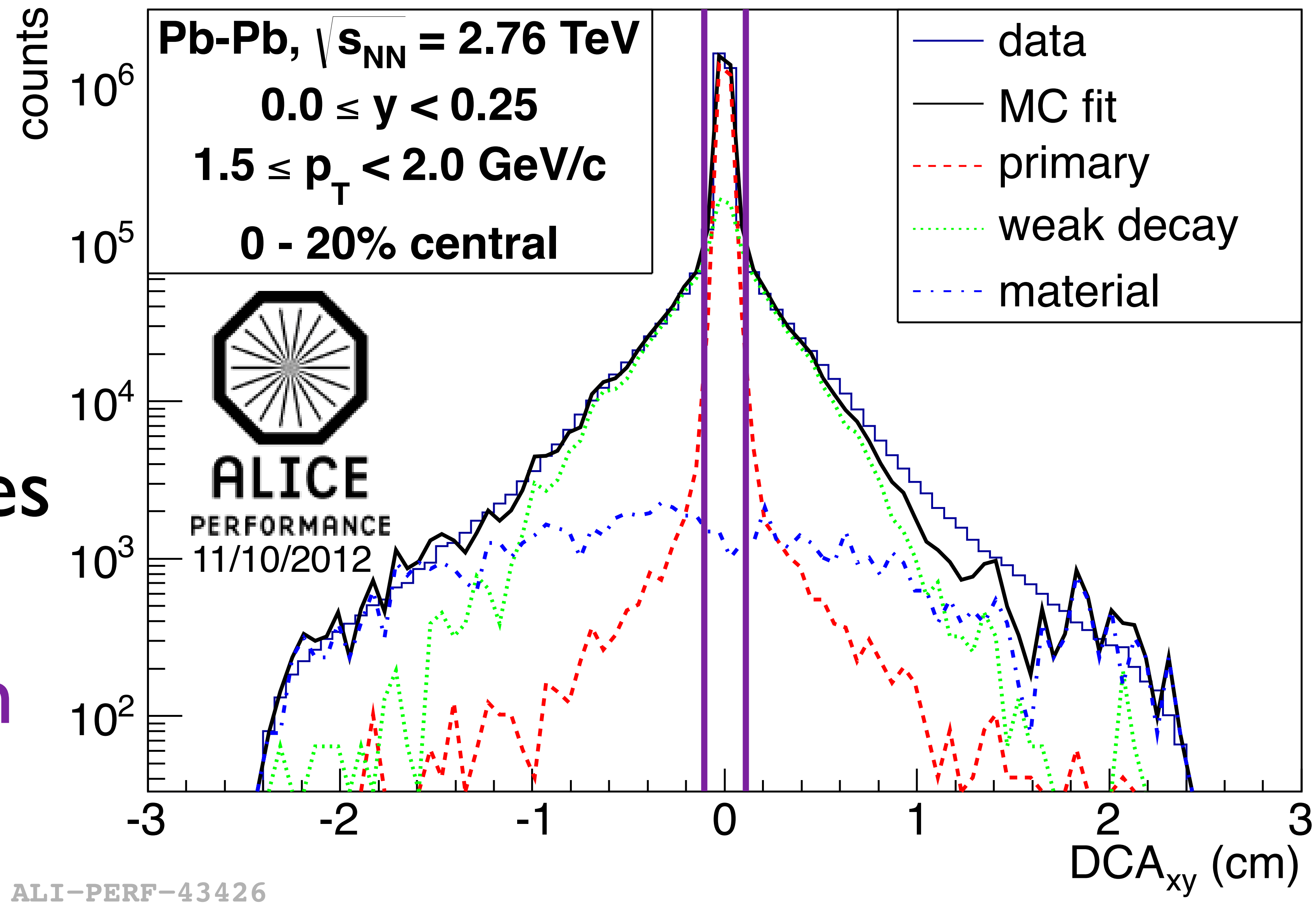
p selection: TPC & TOF

- $0.75 \leq p < 1.0$ GeV/c
- Low momentum for TOF
- Mismatch issue (mainly pions)
- Mild dE/dx pre-selection helps
- No signal loss by dE/dx cut
- No signal loss by TOF cut
- Increased purity



Feed-down into protons

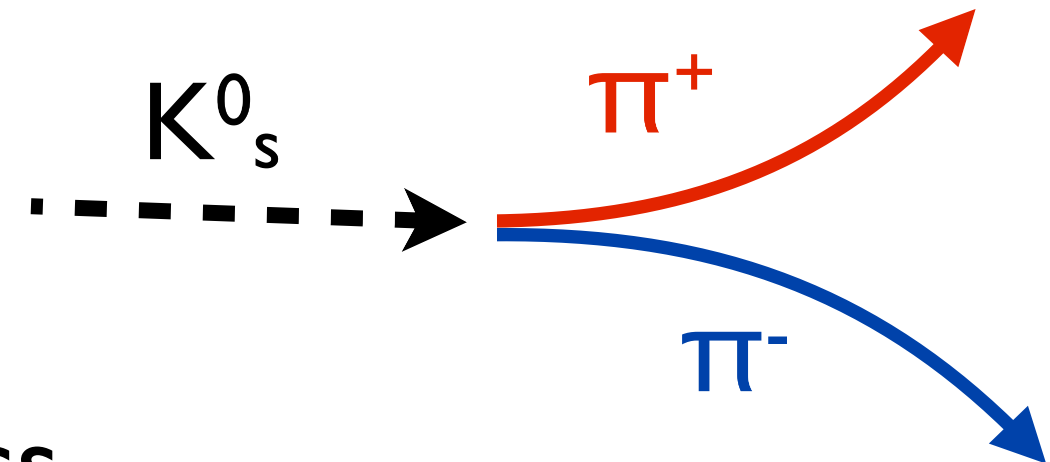
- Select primary protons
- Take only particles with $|DCA_{xy}| \leq 0.1$cm



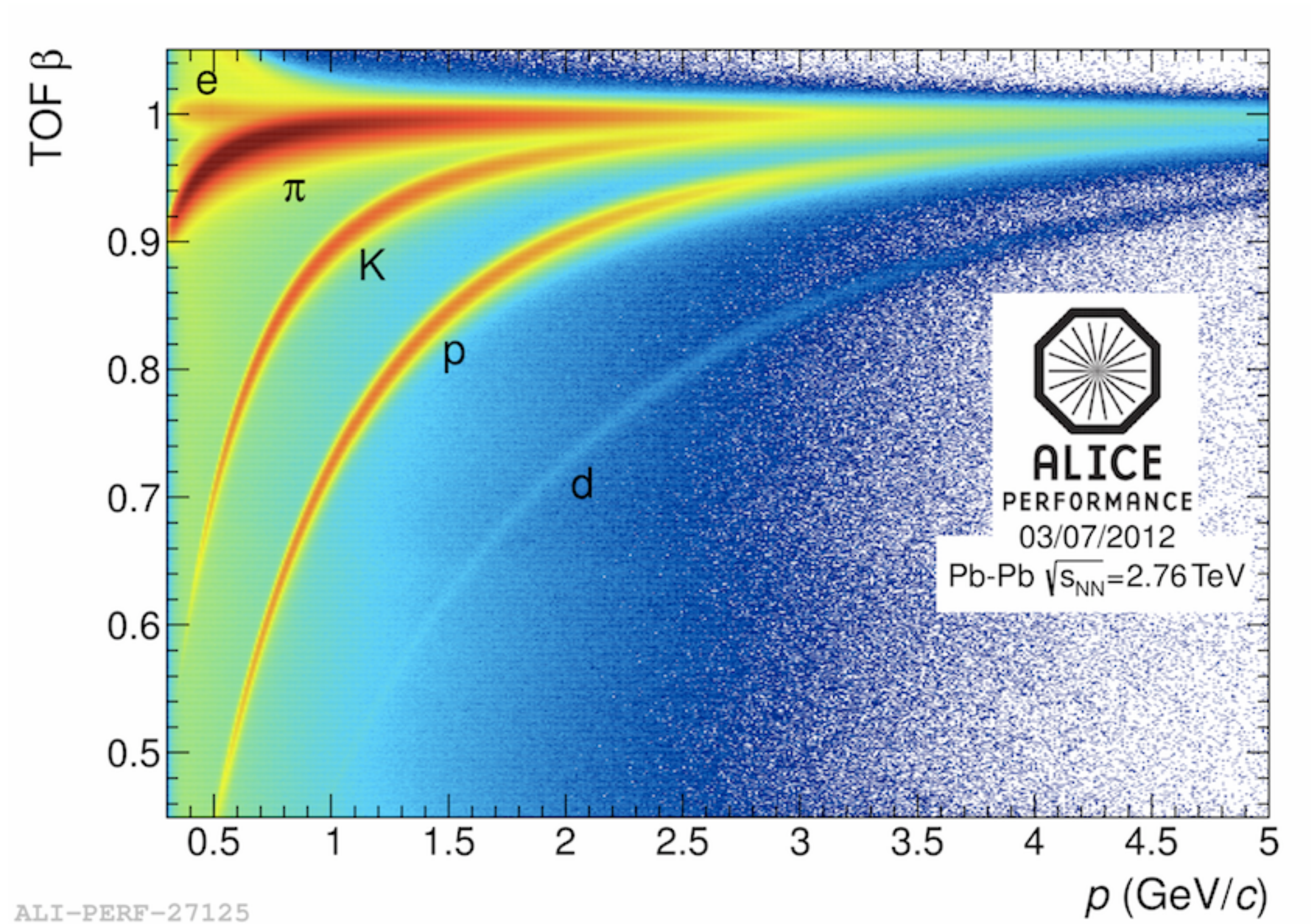
- Enhances correlation signal
- Allows to determine contamination

Kaon PID

- K^0_s reconstructed via their charged decay
  - Identified via invariant mass



- $K^{\pm}$ using TPC & TOF
  - p_T up to 1.5 GeV/c

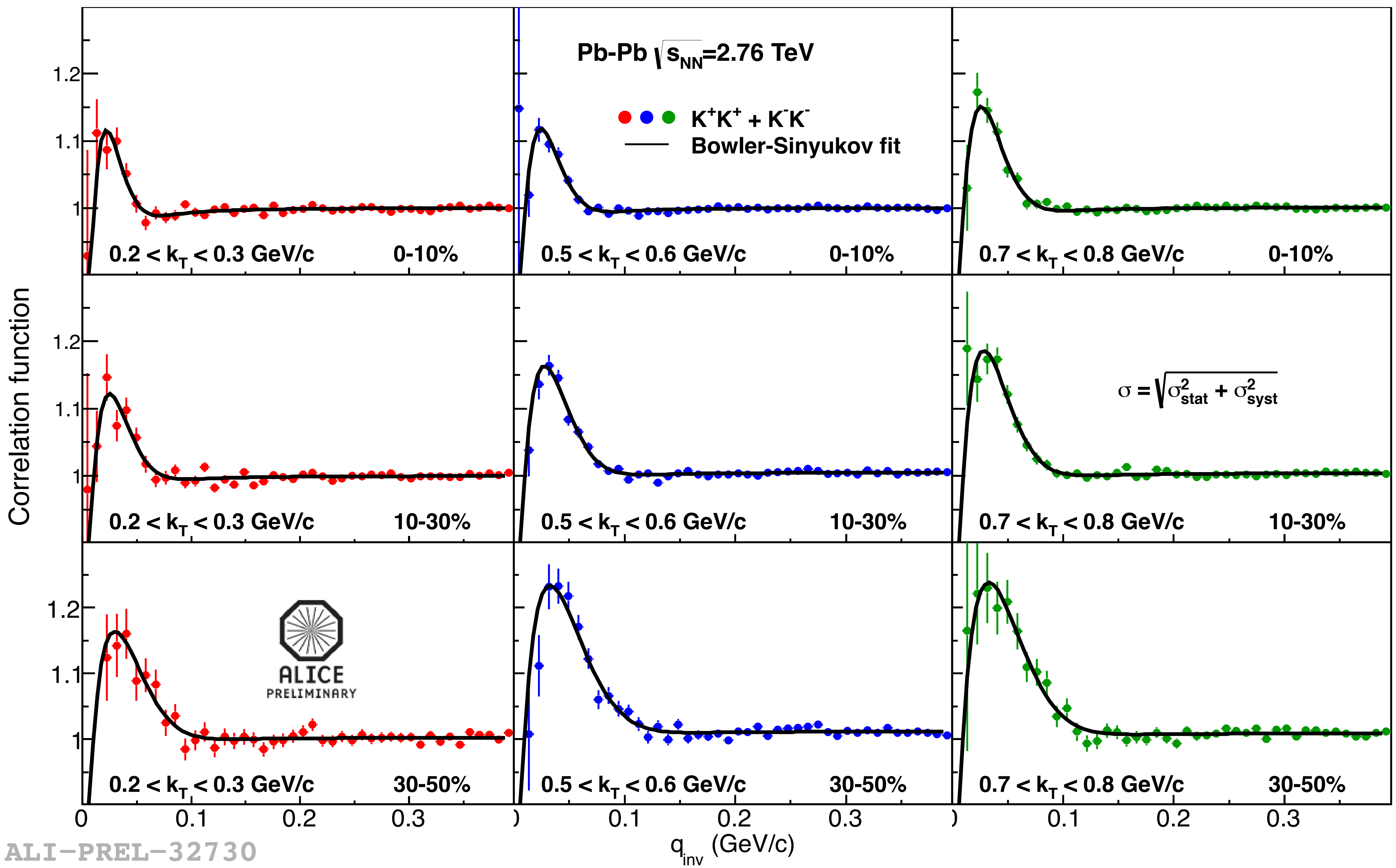


Results

$K^{\pm}K^{\pm}$

- Bowler-Sinyukov fit for Coulomb treatment[1,2]

$$C(q_{inv}) = 1 - \lambda + \lambda K(q_{inv})\left(1 + \exp\left(-R_{inv}^2 q_{inv}^2\right)\right)$$



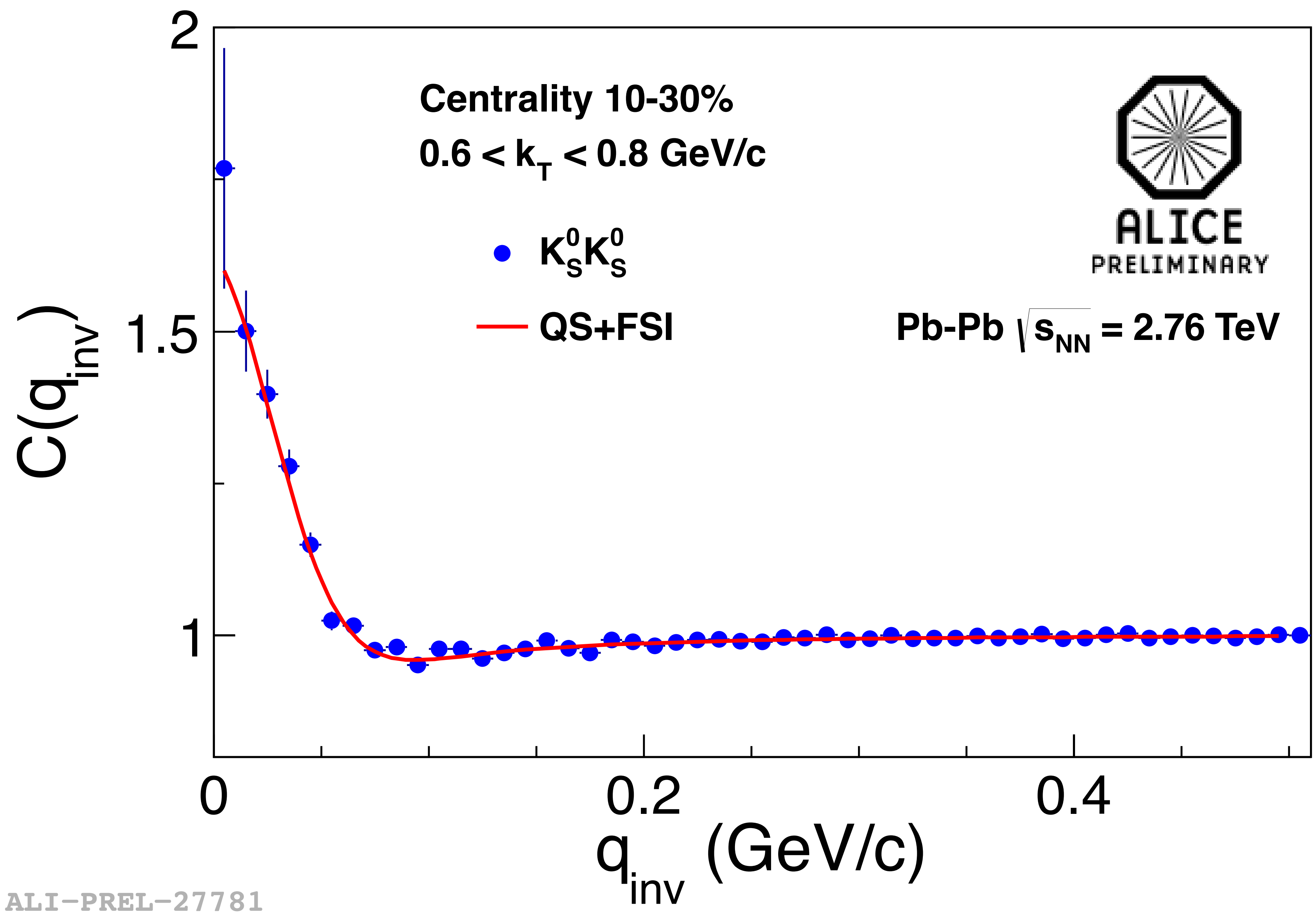
- Clear k_T dependence visible

[1] M.G. Bowler, Phys. Lett. B270, 69 (1991)
[2] Yu. Sinyukov et al, Phys. Lett.B432, 248 (1998)

$K^0_s K^0_s$

- Attractive strong FSI and QS fitted

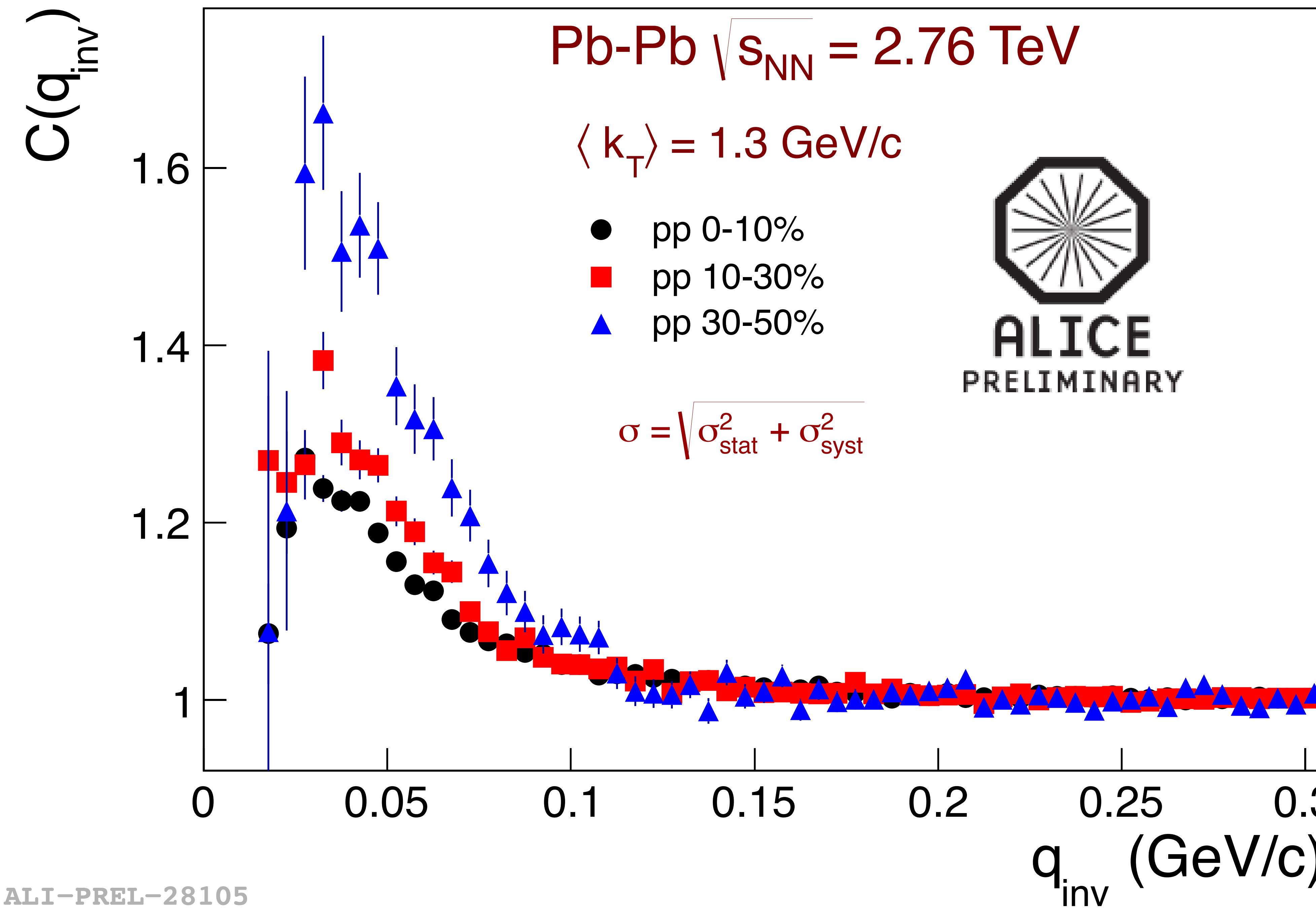
R. Lednicky and V. L. Lyuboshits, Sov. J. Nucl. Phys. **35**, 770 (1982)



- Very good agreement with charged kaons

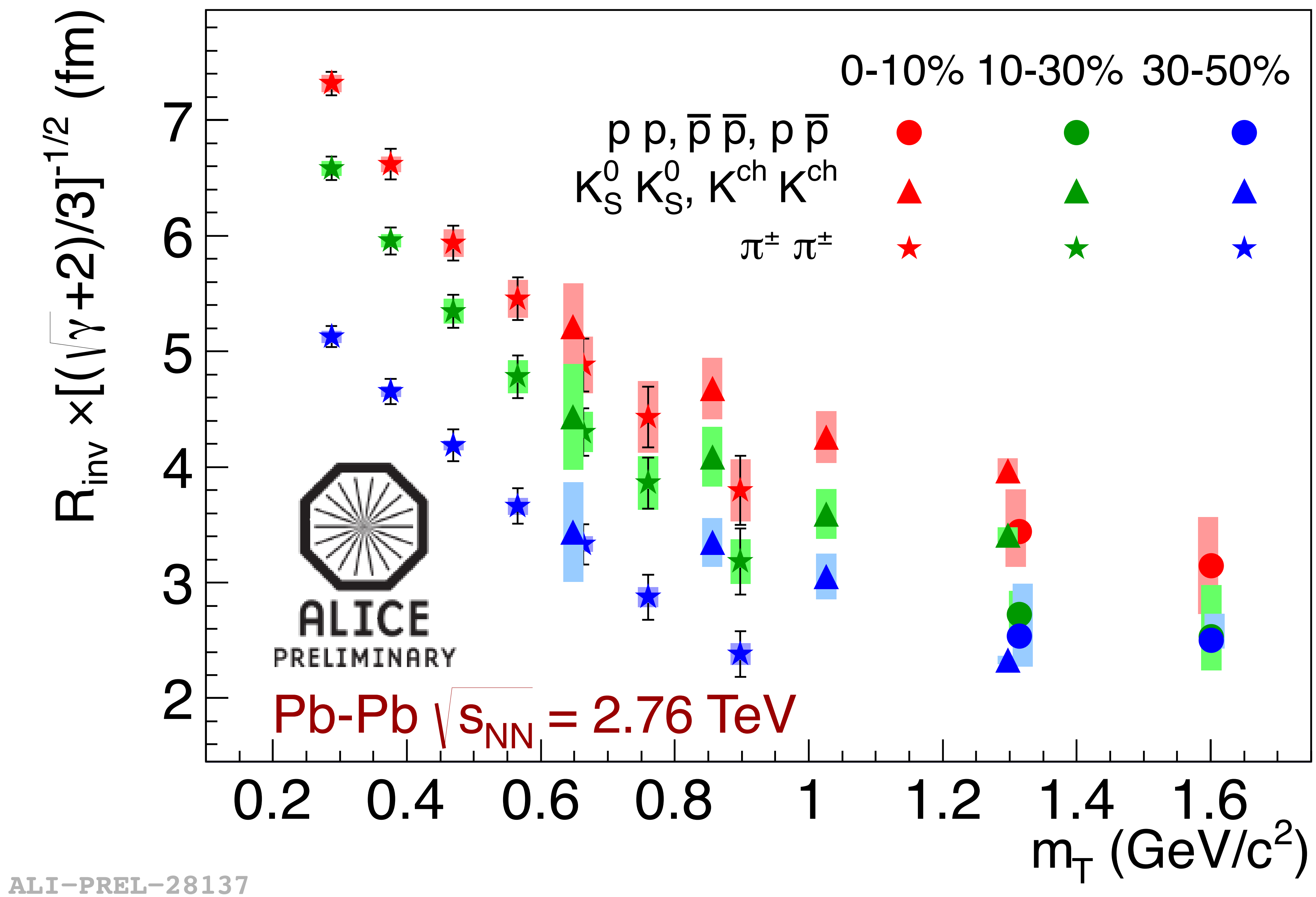
pp

- Differential in centrality and k_T



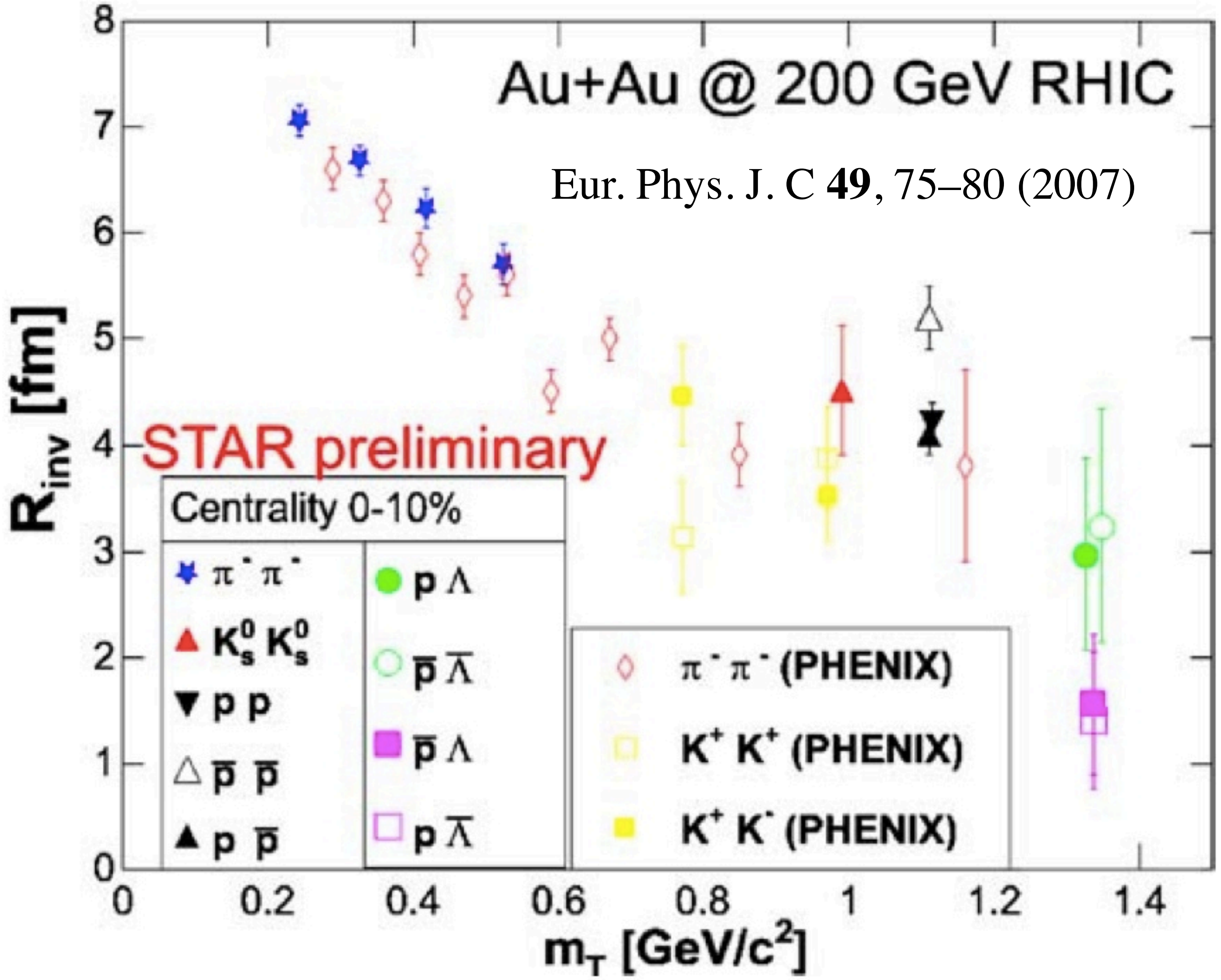
- Strong centrality dependence observed

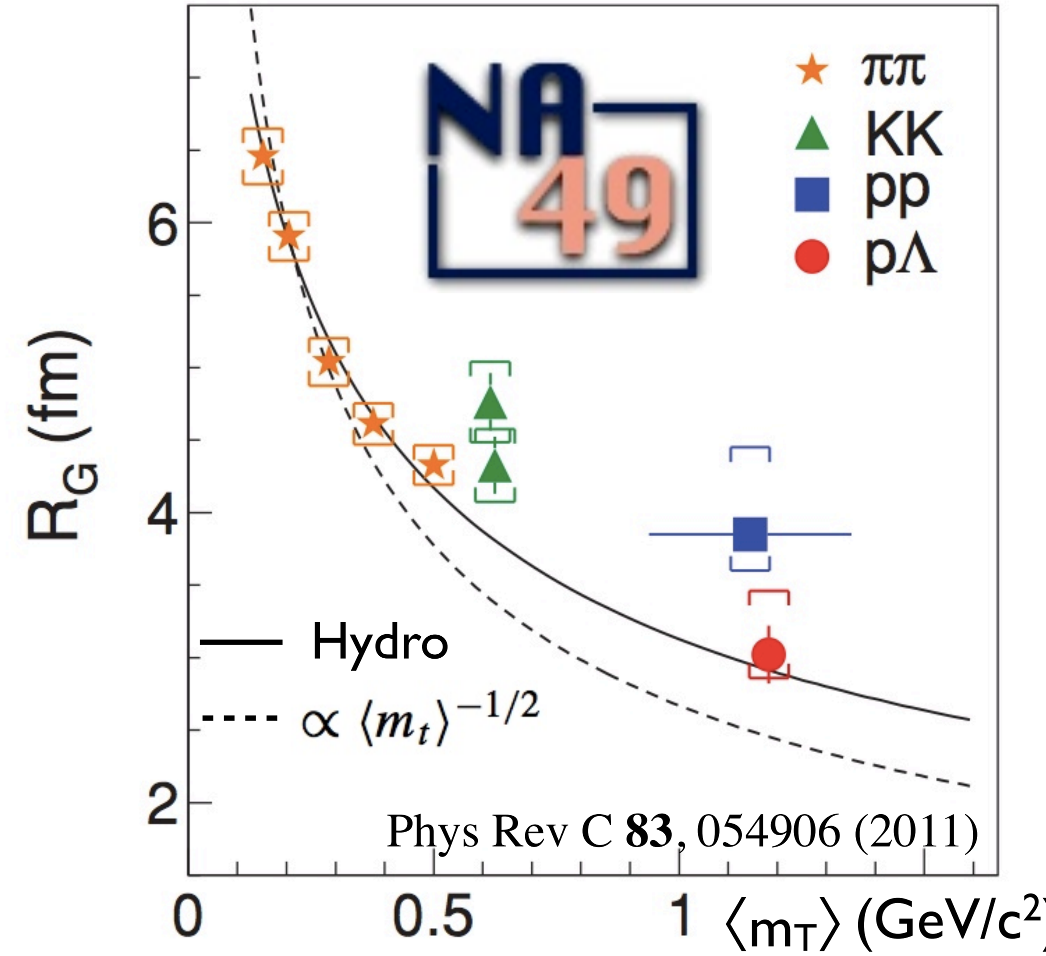
Radii at high m_T



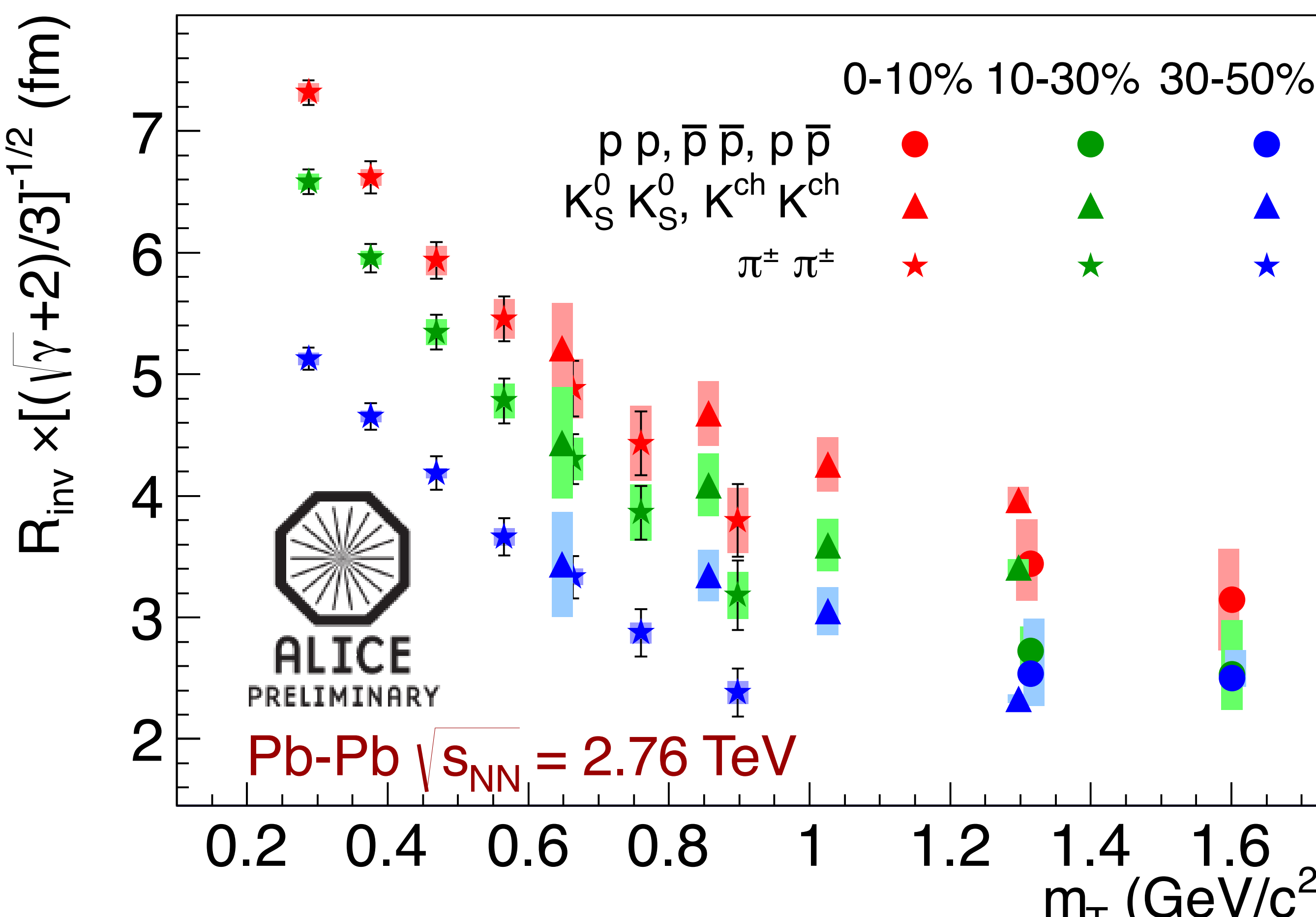
- Approximate m_T scaling
- Kaons and protons double m_T reach

LHC, SPS & RHIC





- Approximate m_T scaling in R_{inv}
- 3D radii under investigation in ALICE



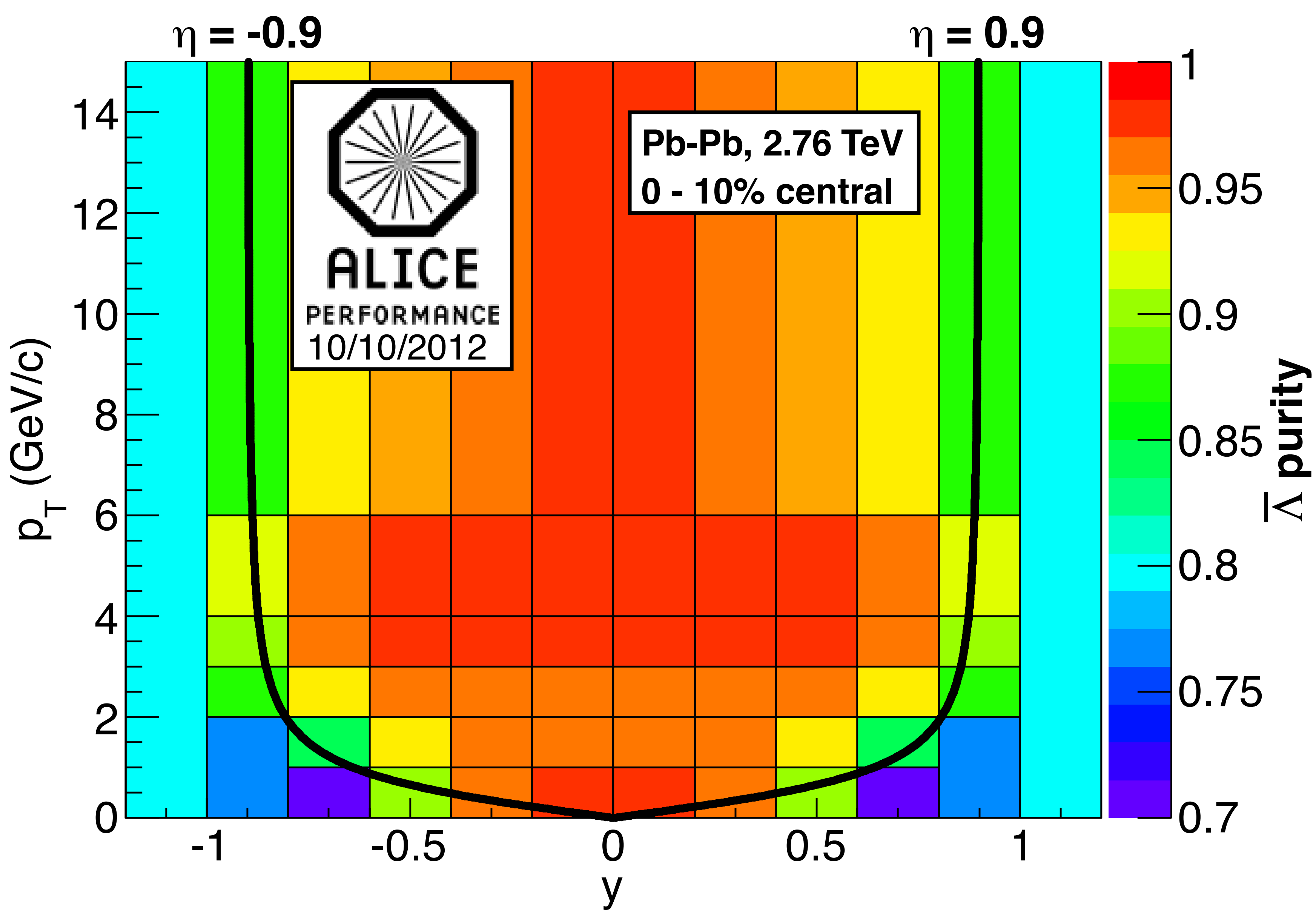
Outlook

- $p\Lambda$ & $\bar{p}\bar{\Lambda}$ correlations reached highest m_T at SPS and RHIC

- Studies ongoing in ALICE

- Λ cuts maximize significance

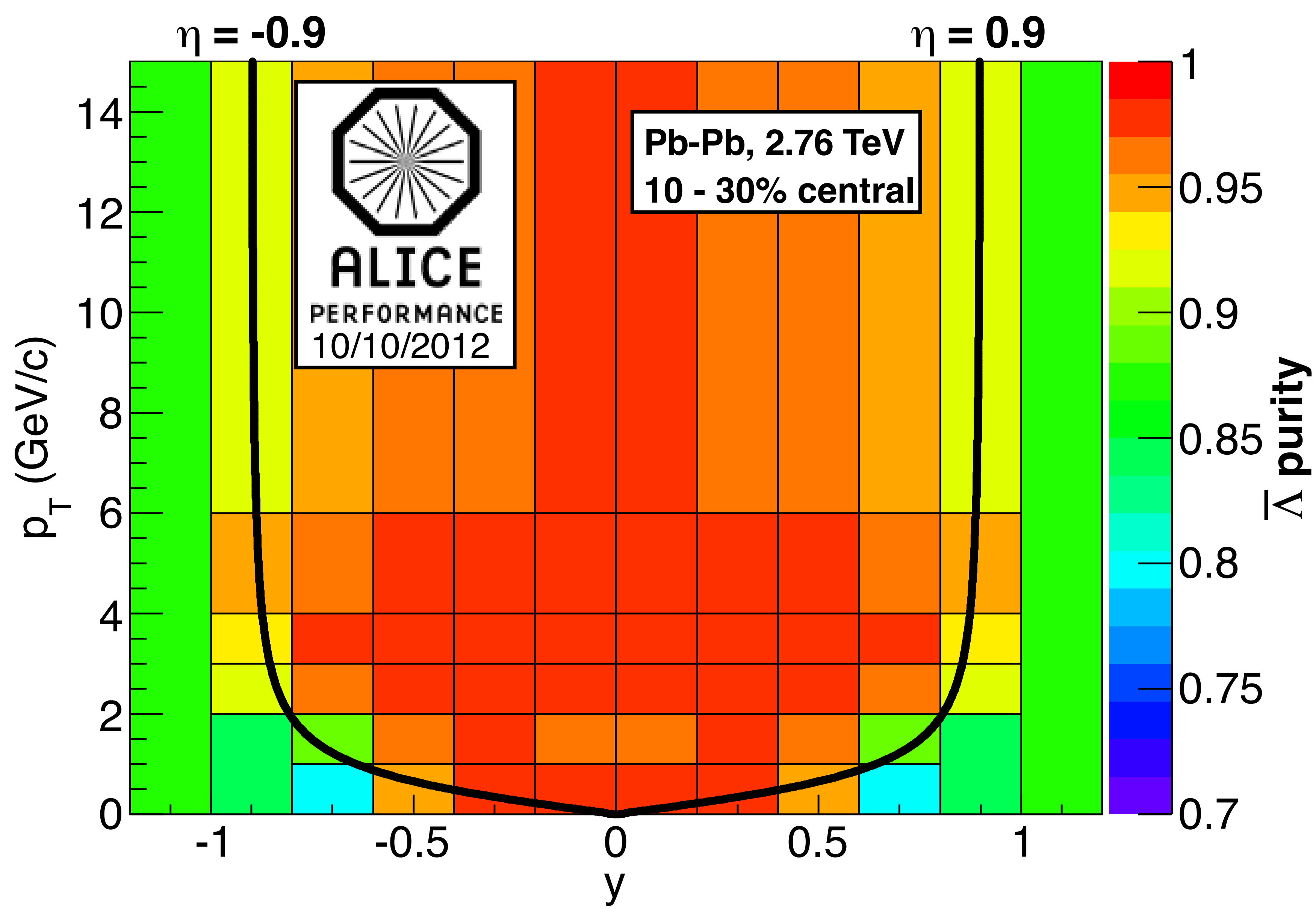
- High purity sample obtained



Outlook

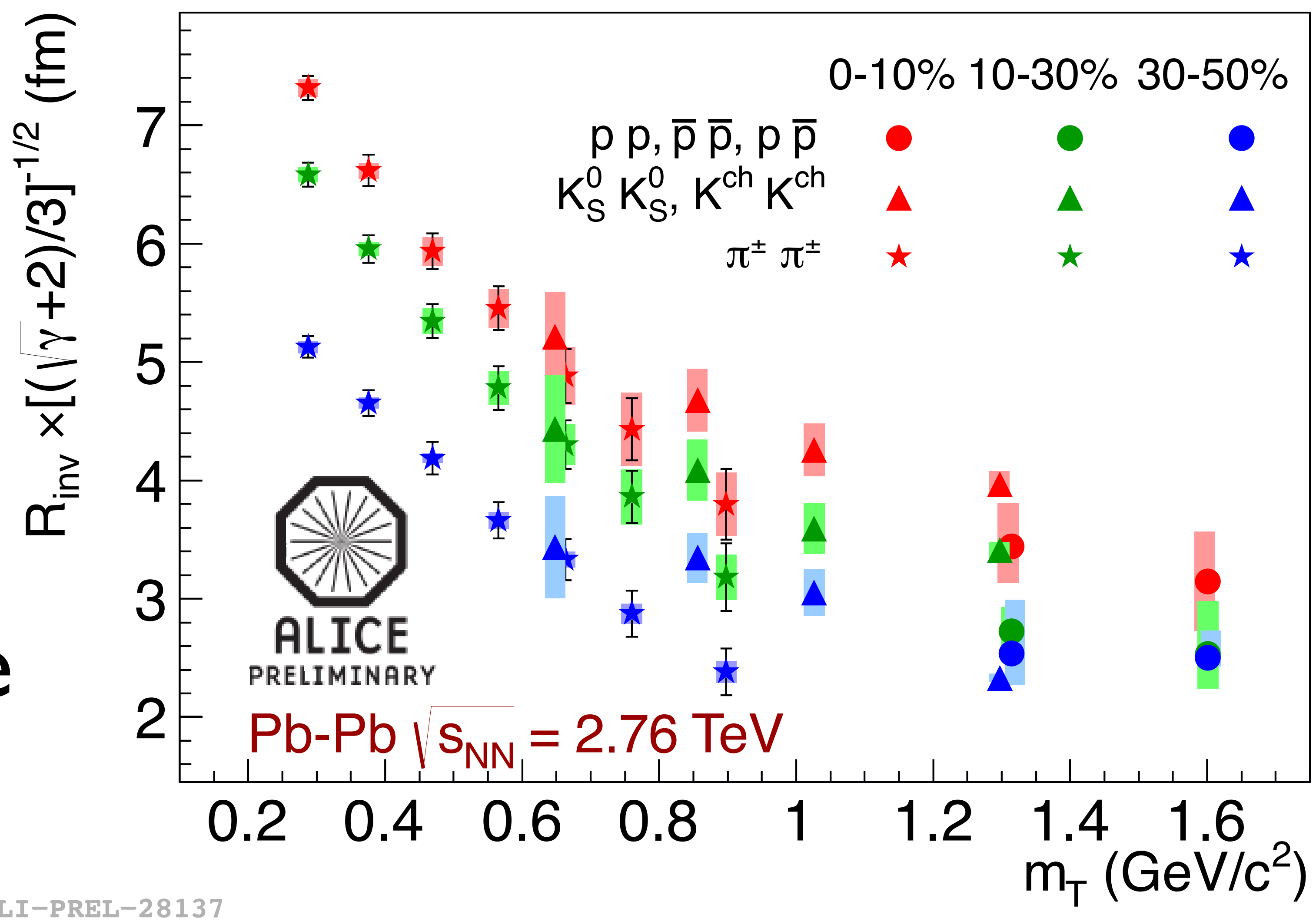
- $p\Lambda$ & $\bar{p}\bar{\Lambda}$ correlations reached highest m_T at SPS and RHIC
- Studies ongoing in ALICE

- Λ cuts maximize significance
- High purity sample obtained
- Nice evolution with centrality



Summary

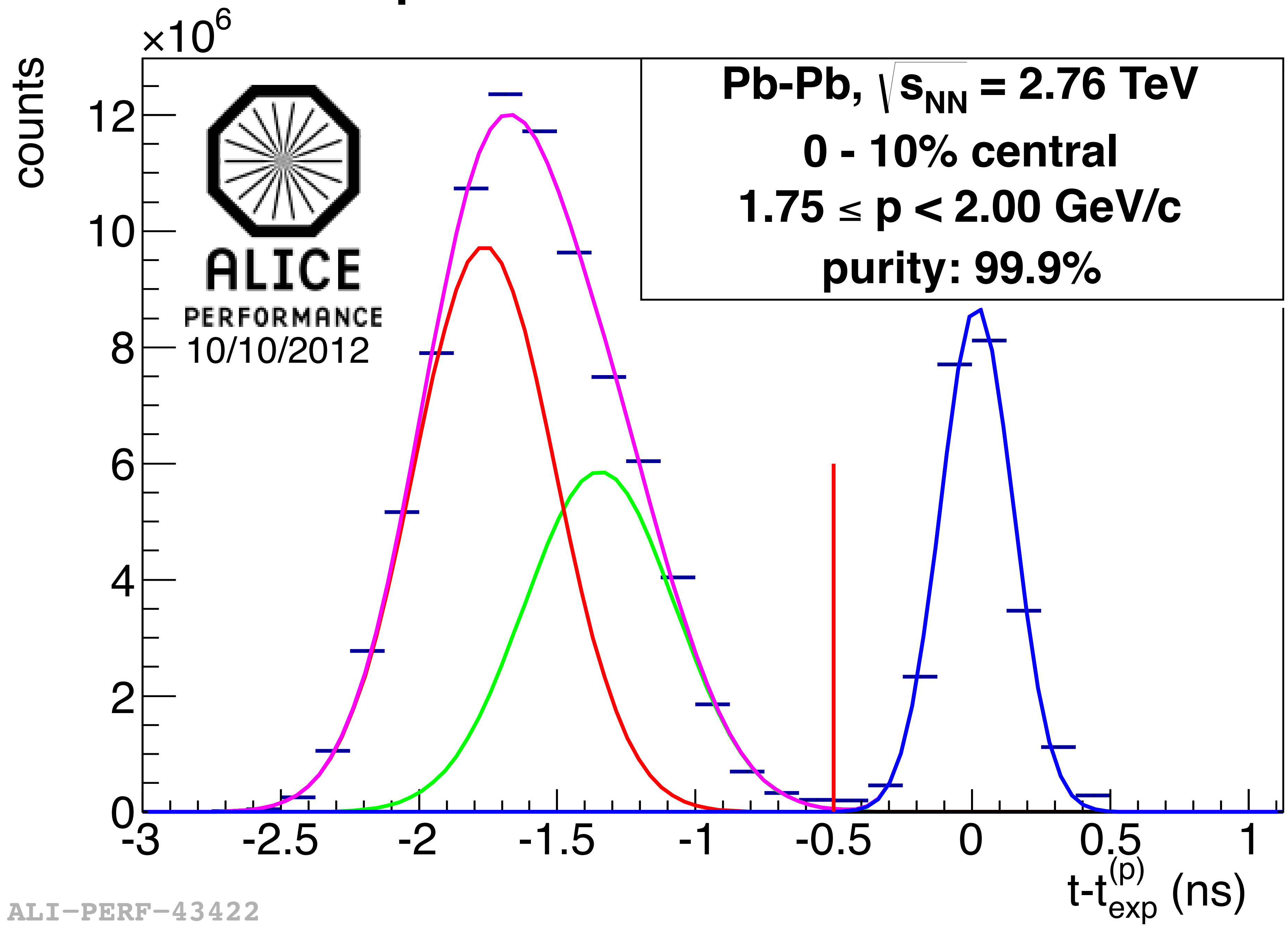
- ALICE provides an excellent environment for high purity and high statistics Femtoscopy
- Radii for various systems at high m_T have been extracted



Backup

p Selection: TOF

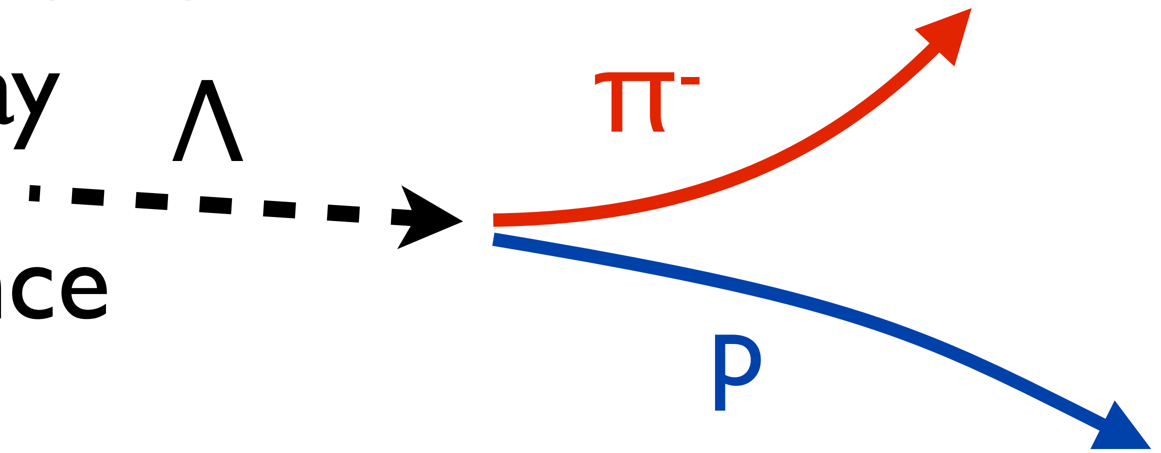
- Protons well separated

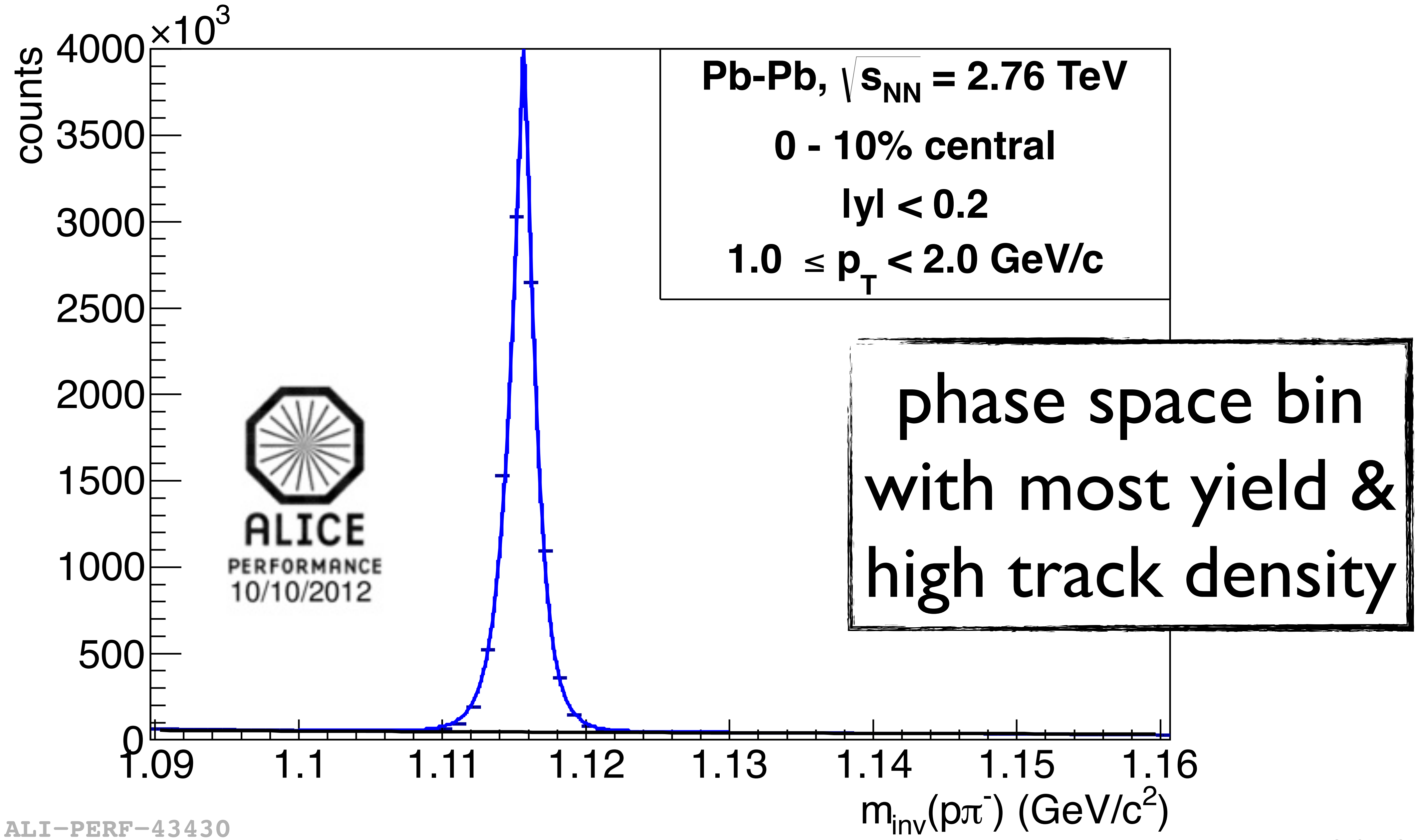


- Proton purity above 99% everywhere

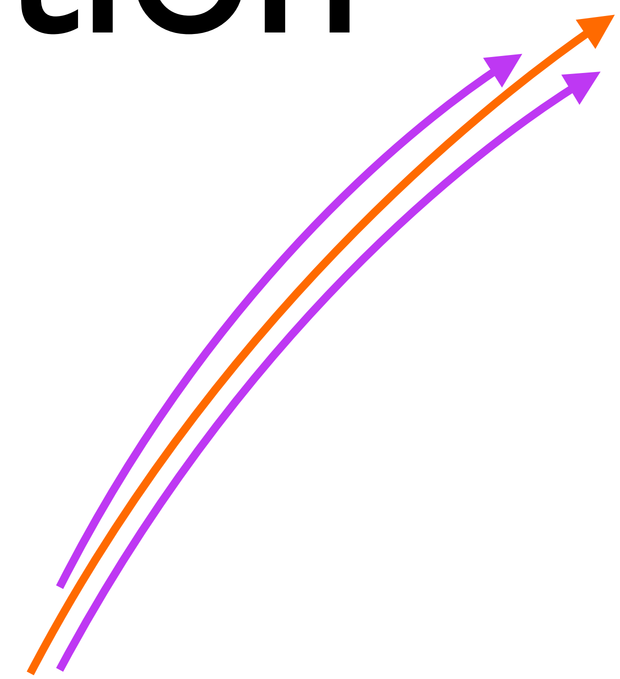
Λ selection

- Reconstructed via charged decay
- Analysis cuts optimize significance
- Identified via invariant mass

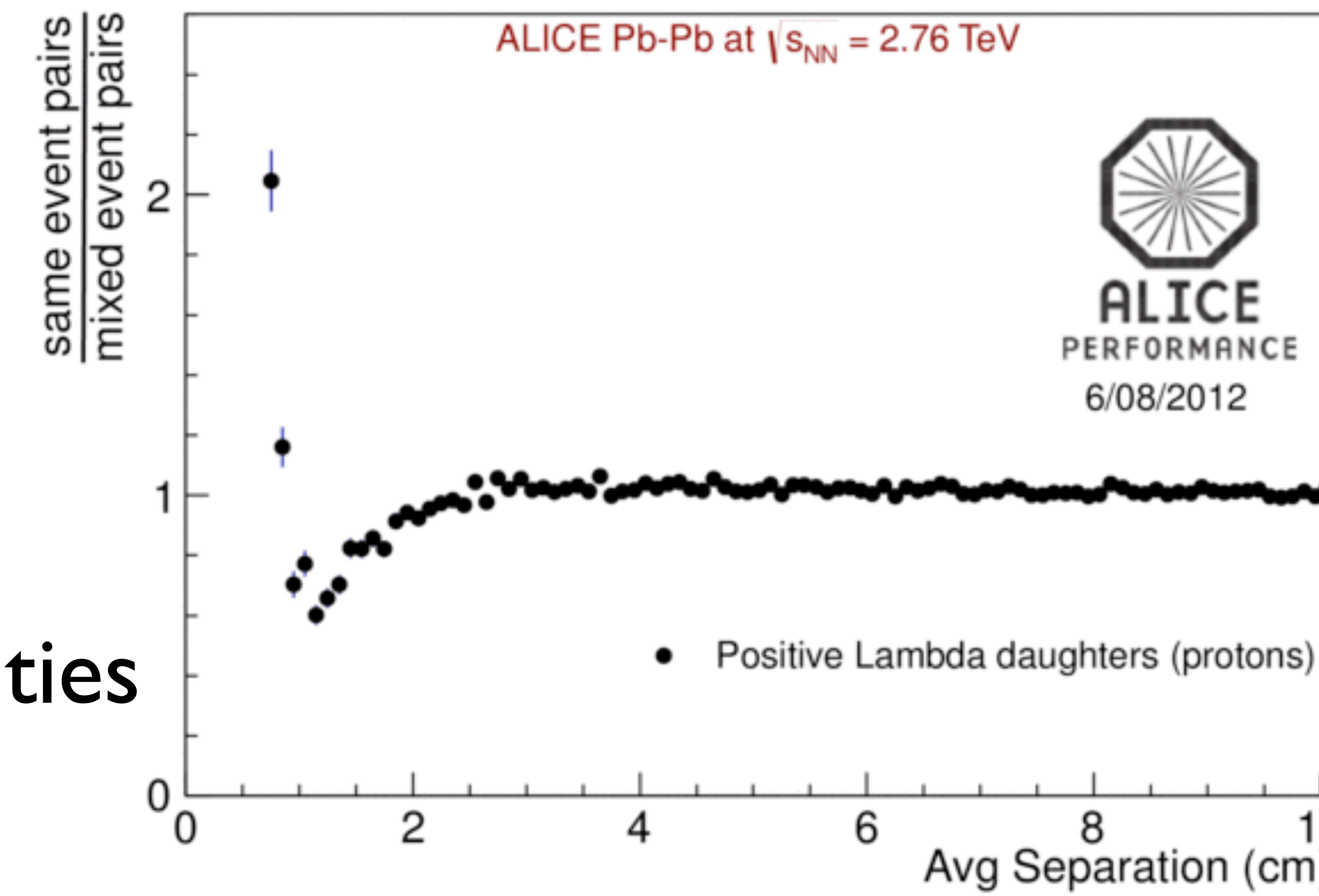




Two-track resolution



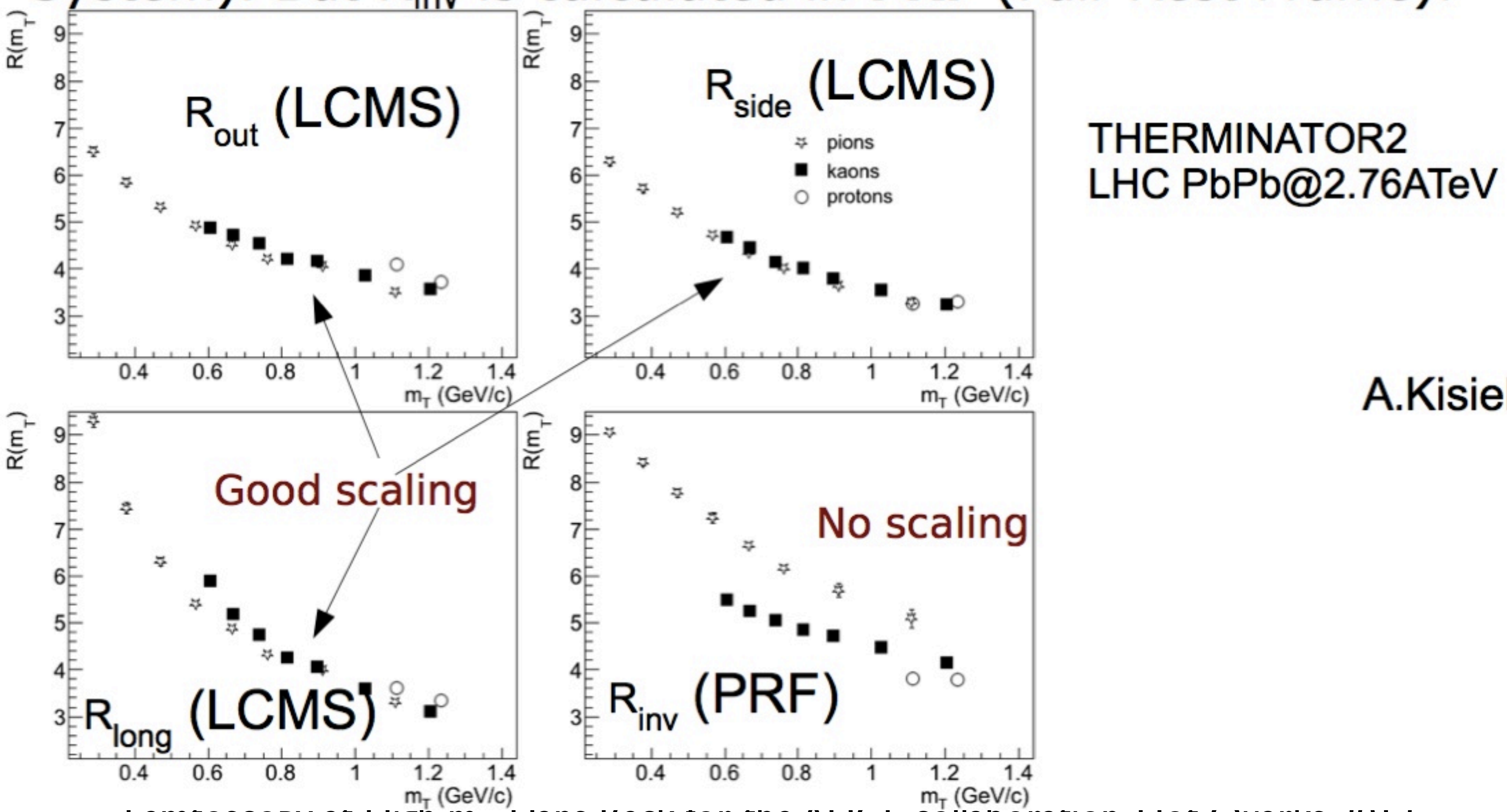
- 2 close tracks get merged to 1 track
- 1 track splits in 2 tracks
- Close pairs have similar momentum
- Not present in mixed events
- Would affect correlation function
- Cut on non-uniformities at small distances



ALI-PERF-28270

mT scaling of radii

- Hydrodynamics + resonances calculation (THERMINATOR2) with parameters for PbPb collisions at 2.76 ATeV, clearly predicts m_T scaling in **LCMS** (Longitudinally Co-Moving System). But R_{inv} is calculated in **PRF** (Pair Rest Frame)!



mT scaling of radii

- One can get an approximate 1D radius in LCMS with: $R_{LCMS} = \sqrt{(R_{out}^2 + R_{side}^2 + R_{long}^2)/3}$

  which should also scale
- But in PRF, we have:

$$R_{out}^{PRF} \sim \gamma R_{out}^{LCMS}$$

A.Kisiel

- The increase of R_{out} in PRF has two effects:
  - The overall radius of the system increases
  - The source becomes non-gaussian
- The interplay of the two effects can be accounted for with an approximate formula relating 1D sizes in LCMS and PRF

$$R_{PRF} \stackrel{\text{def}}{=} R_{inv} = \sqrt{(R_{out}^2 \sqrt{\gamma} + R_{side}^2 + R_{long}^2)/3}$$

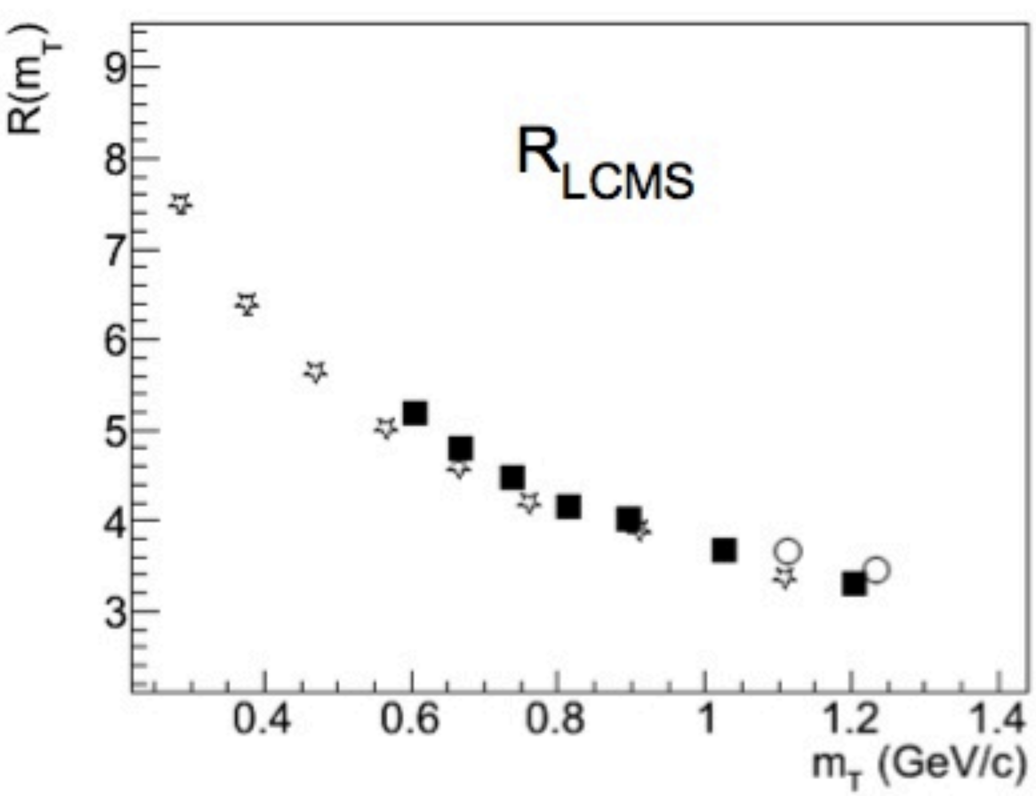
mT scaling of radii

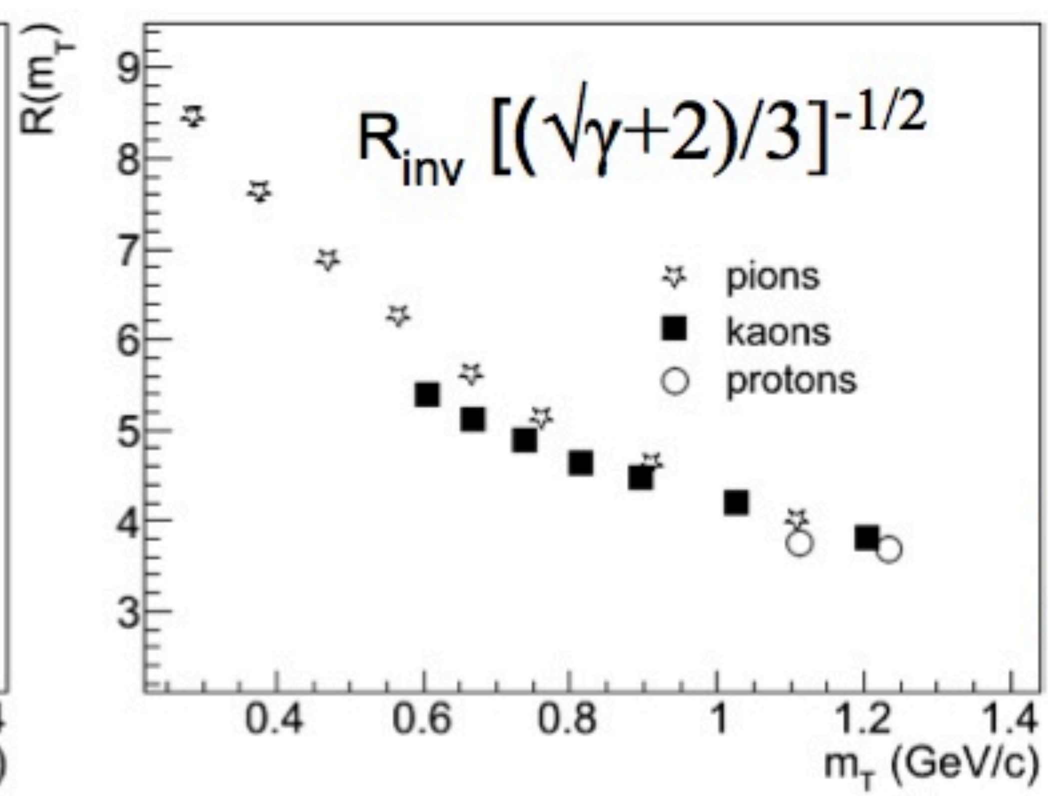
- Therefore one can recover the R_{LCMS} from R_{inv} with a simple kinematic scaling:

$$R_{LCMS} = R_{inv} \left(\frac{\sqrt{\gamma} + 2}{3} \right)^{-1/2}$$

- Please note that this is pure kinematics (not model dependent) and approximate (~10%, worse as gamma increases), but R_{inv} is an approximation in itself.

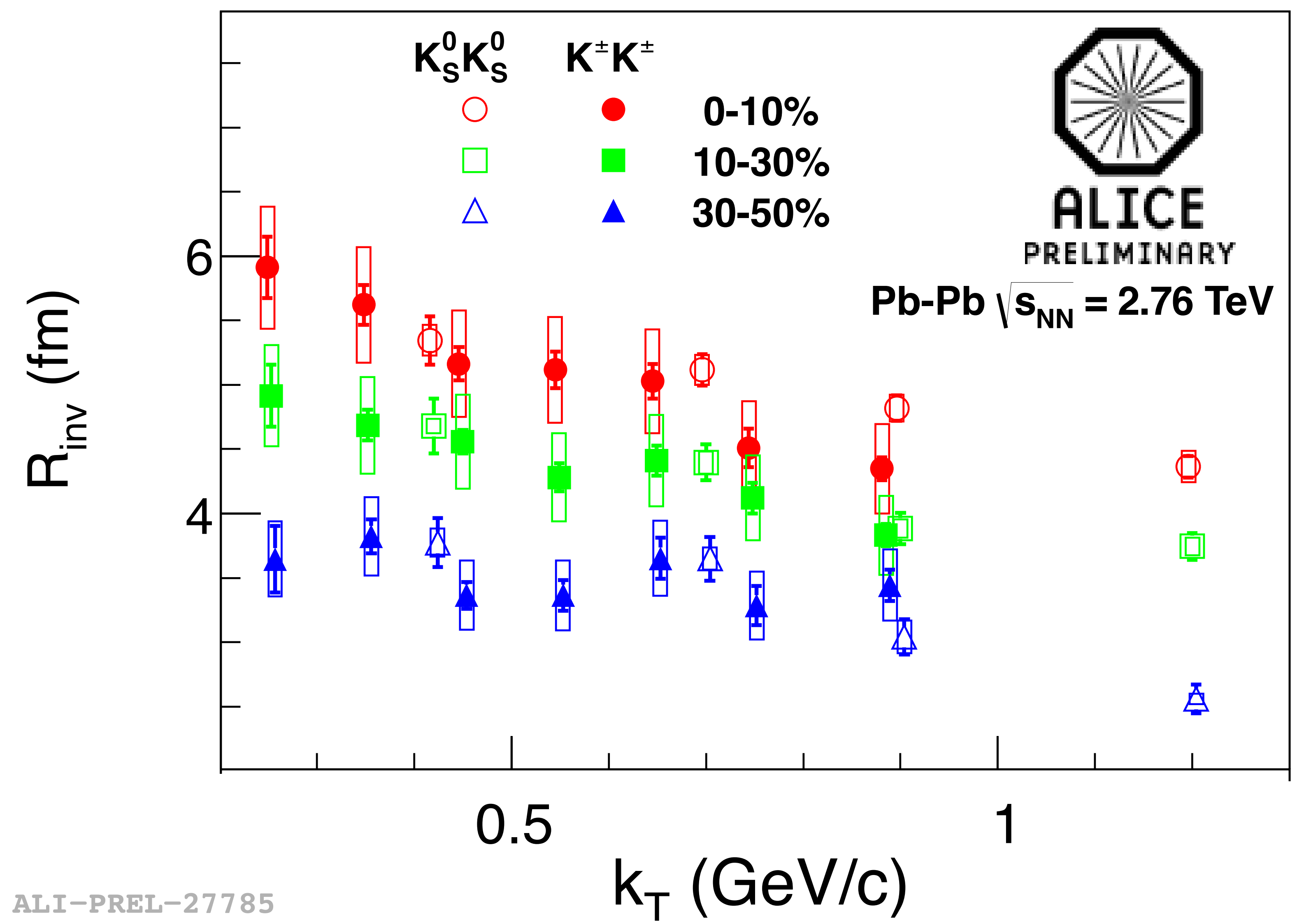
A.Kisiel



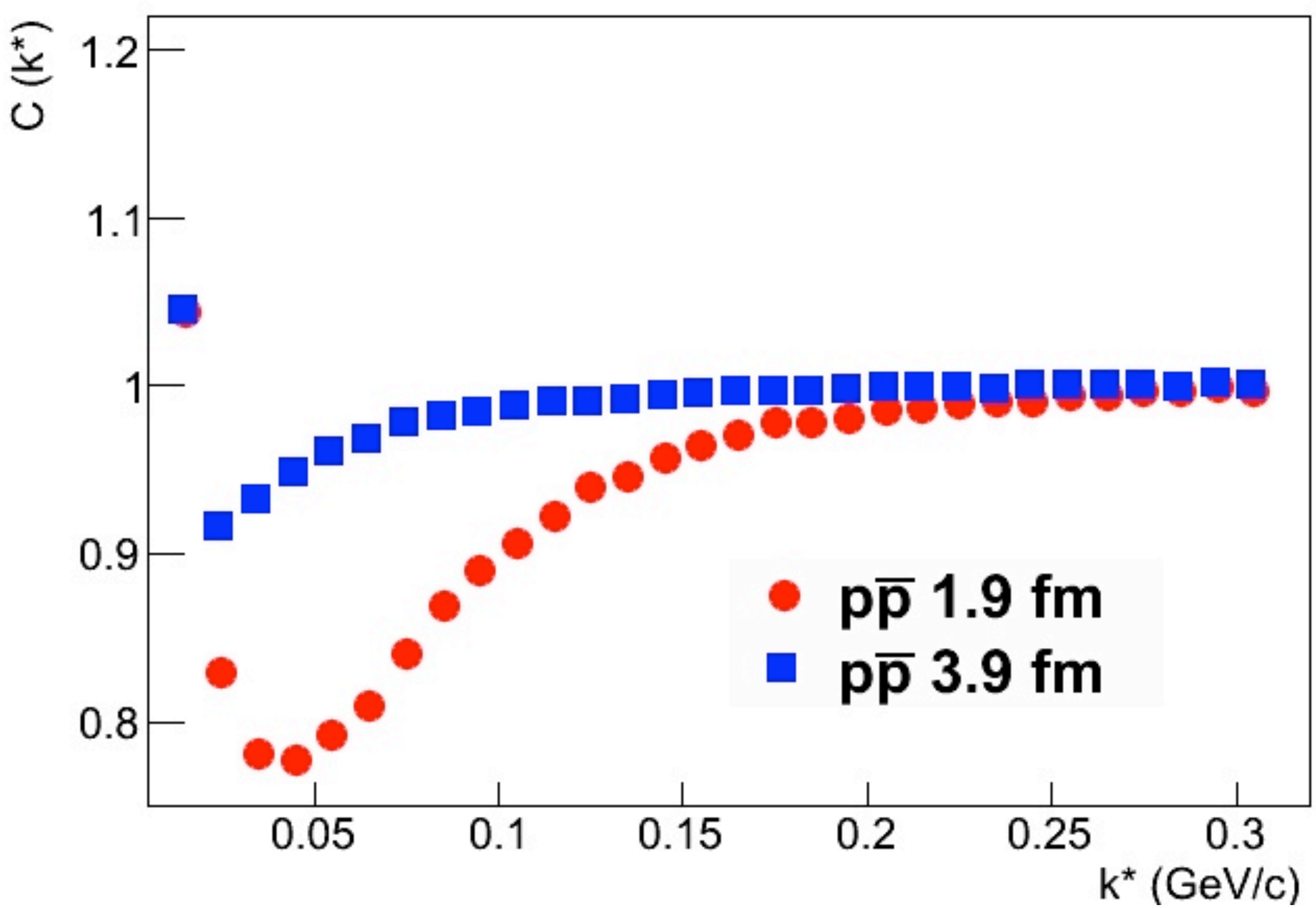


THERMINATOR2
LHC PbPb@2.76ATeV

Kaon agreement



$p\bar{p}$ FSI



p$\bar{\text{p}}$ correlation function