Measuring $K^0_S K^{\pm}$ interactions using Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV

ALICE Collaboration

arXiv:1705.04929v1

Data & Selection

-- ALICE experiment

-- 22×10^6 Pb-Pb collision events with 0-10% centrality class taken in 2011 (LHC RUN-I)

-- Quality of charged tracks reconstruction, PID, TOF, , ,

-- K^0_s selection

$K^0_s \to \pi^+\pi^-$ detected in the TPC and TOF

$P_T(\pi^+/\pi^-) > 0.15$ GeV/c, good tracks ($N_\sigma<3$)

Closest distance to the $K^0_s < 0.3$cm

$0.480<$ Invariant Mass ($m_{\pi\pi}$)<0.515 GeV/c^2

-- $K^\pm$ selection

$K^\pm$ detected in the TPC and TOF

1.5GeV/c > $P_T(K^\pm)$ > 0.15 GeV/c, good tracks ($N_\sigma<1$~3, depends on P_T)

Closest distance to the beam direction (< 3.2cm), transverse (<2.4cm)

[From $3.1] Experimental Correlation Functions

$$C(k^*) = A(k^*)/B(k^*)$$

A(k*) : the measured distribution of pairs from the same event

B(k*) : the reference distribution of pairs from mixed events

k* : magnitude of the momentum of each of the particles in the pair rest frame

$$k^* = \sqrt{\frac{(s - m_{K^0}^2 - m_{K^\pm}^2)^2 - 4m_{K^0}^2 m_{K^\pm}^2}{4s}}$$

$$s = m_{K^0}^2 + m_{K^\pm}^2 + 2E_{K^0}E_{K^\pm} - 2\vec{p}_{K^0} \cdot \vec{p}_{K^\pm}$$

2 Theory and Phenomenology Basics

2.1 Formalism

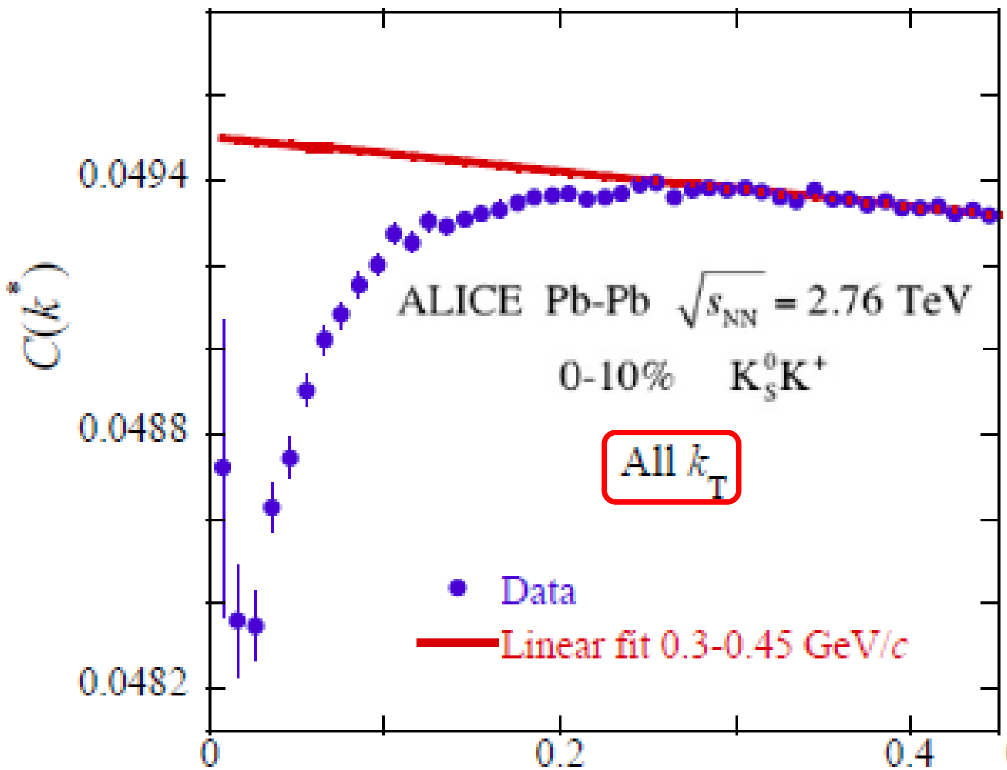
Two-particle correlation functions are constructed as the ratio of the measured two-particle inclusive and single-particle inclusive spectra,

$$C^{ab}(\mathbf{P},\mathbf{q}) = \frac{dN^{ab}/(d^3p_a d^3p_b)}{(dN^a/d^3p_a)(dN^b/d^3p_b)}, \quad (1)$$

$$P \equiv p_a + p_b, \quad q^\mu = \frac{(p_a - p_b)^\mu}{2} - \frac{(p_a - p_b)\cdot P}{2P^2} P^\mu .$$

“Femtoscopy in Relativistic heavy Ion Collosions : Two Decades of Progress”
M. A. Lisa et.al, arXiv:nucl-ex/0505014v2

Fig. 1: Examples of raw $K^0_S K^+$ correlation functions



feature of the femtoscopic correlation function: the suppression due to the strong final-state interactions for small k^*. In the higher k^* region, the effects of the a_0 appear to not be present and thus could be used as a reference, i.e. "baseline", for the a_0-based model fitted to $C(k^*)$ in order to extract the source parameters. Also shown in the figure are linear fits to the baseline for large k^*. The effects on $C(k^*)$ by

[From $3.2] Experimental Correlation Functions

・ The $K^0_sK^{\pm}$ correlation functions were fit with functions that include a parameterization which incorporates strong FSI.

・It was assumed that the FSI arises in the $K^0_sK^{\pm}$ channels due to the near-threshold resonance, a_0(980).

・The parameterization was introduced by R.Lednicky and is based on the model by R. Ledniky and V. L. Lyuboshitz.

$$f(k^*) = \frac{\gamma_{a_0 \to K\overline{K}}}{m_{a_0}^2 - s - i(\gamma_{a_0 \to K\overline{K}} k^* + \gamma_{a_0 \to \pi\eta} k_{\pi\eta})}$$

: s-wave $K^0K^-(\overline{K}^0K^+)$ scattering amplitude from a_0 resonance

Reference	m_{a_0}	$\gamma_{a_0 K\bar{K}}$	$\gamma_{a_0 \pi\eta}$
Martin [7]	0.974	0.333	0.222
Antonelli [8]	0.985	0.4038	0.3711
Achasov1 [9]	0.992	0.5555	0.4401
Achasov2 [9]	1.003	0.8365	0.4580

$$C(k^*) = 1 + \lambda\alpha \left[\frac{1}{2} \left| \frac{f(k^*)}{R} \right|^2 + \frac{2\mathscr{R} f(k^*)}{\sqrt{\pi} R} F_1(2k^*R) - \frac{\mathscr{I} f(k^*)}{R} F_2(2k^*R) \right],$$

just factors ($\lambda\alpha$)

$$F_1(z) \equiv \int_0^z dx \frac{e^{x^2 - z^2}}{z}; \qquad F_2(z) \equiv \frac{1 - e^{-z^2}}{z}.$$

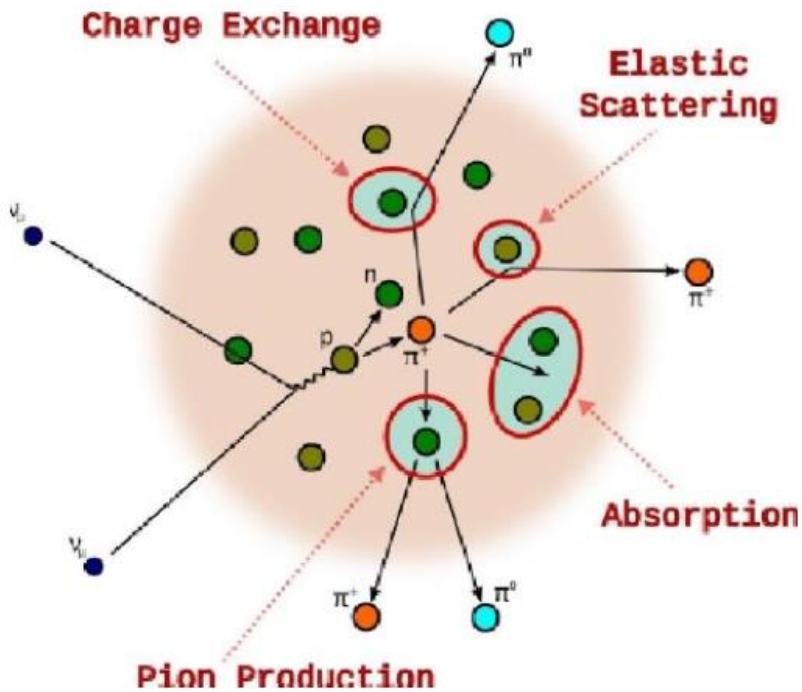
*** Give up to follow these equation this this time …..**

Meaning is that if the size of the system (distance between the particles) ***R*** is small, the correlation is enhanced.

Generally, FSI means that hadrons re-scatter while propagating through the nuclear medium, can change its status during the re-scattering.

Reminder: the basic picture is impulse approximation

As a consequence, final state interactions effects must be included:



T. Golan

Pions...

- can be absorbed
- can be scattered elastically
- (if energetically enough) can produce new pions
- can exchange electic charge with nucleons

A similar picture can be drawn for nucleons.

The meaning of final state interactions can be confusing.

however, there are people who use the term FSI with different meaning

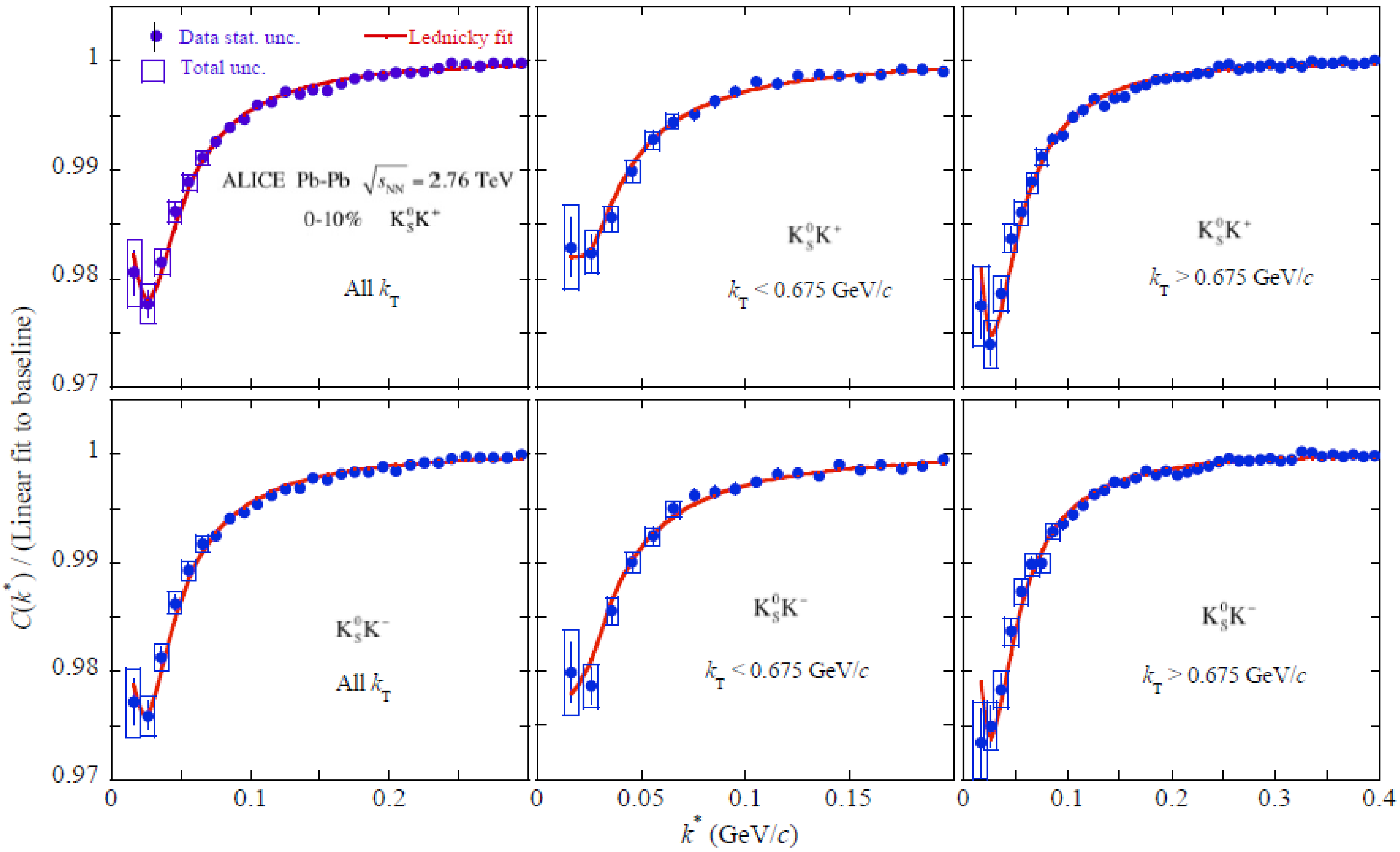


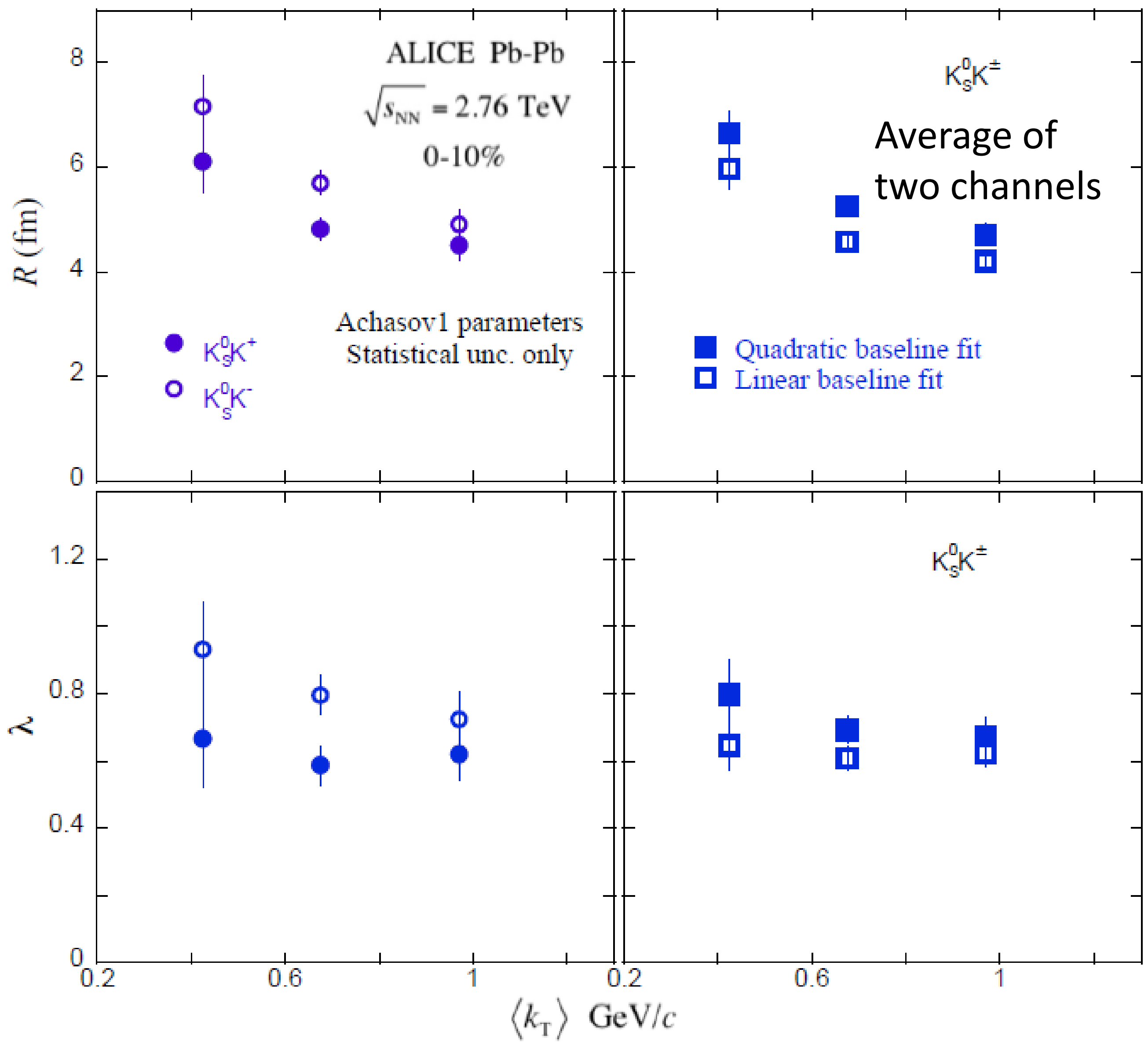
Fig. 2: Examples of $K^0_SK^+$ and $K^0_SK^-$ correlation functions divided by linear fits to the baseline with the Lednicky parameterization using the Achasov2 [9] parameters. Statistical (lines) and the linear sum of statistical and systematic uncertainties (boxes) are shown.

Fig. 3: Sample results for the R and λ parameters

Comparison

Left: K^0K^- & K^0K^+

Right: Fitting method



With results from the other K-K combination

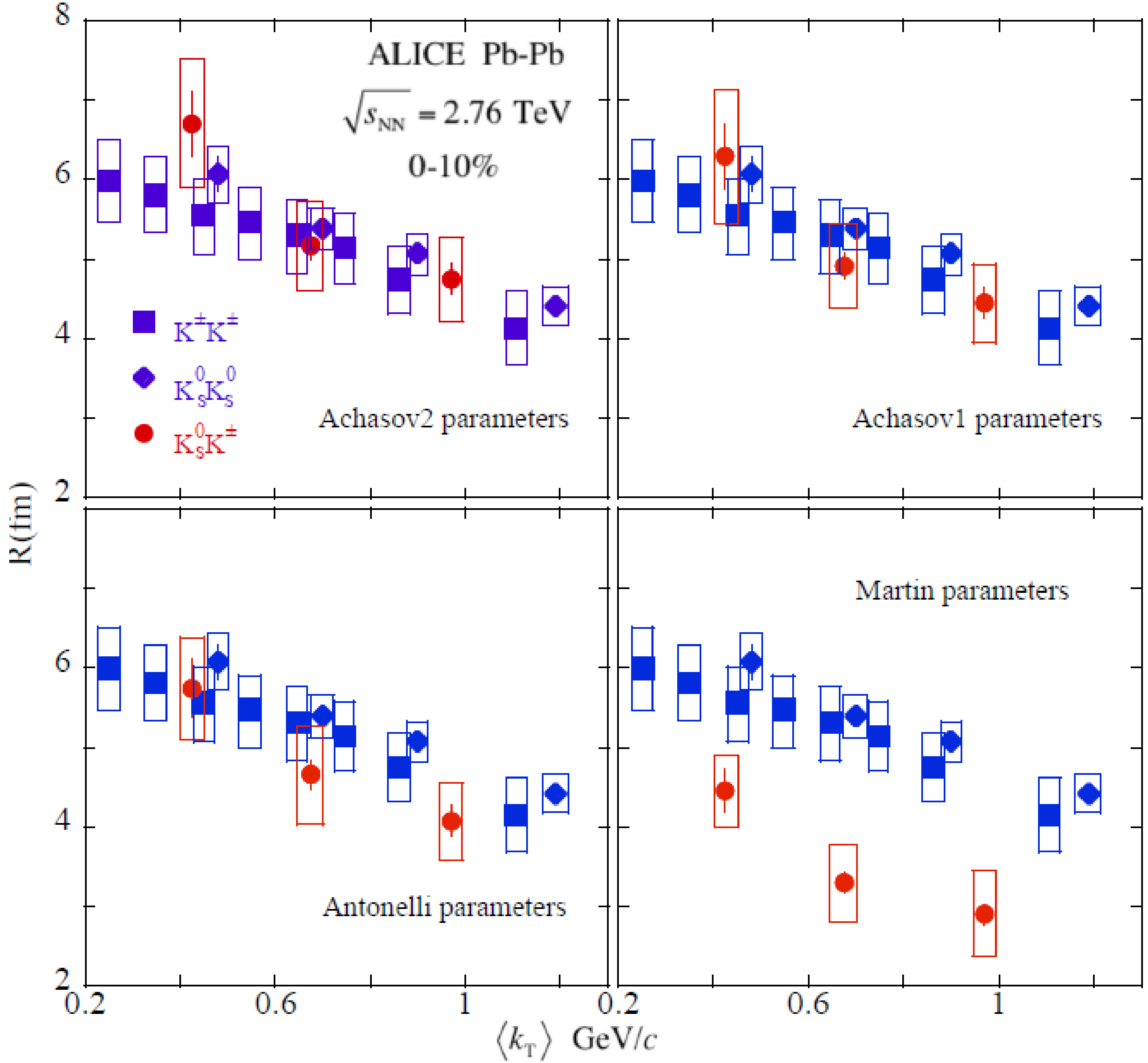
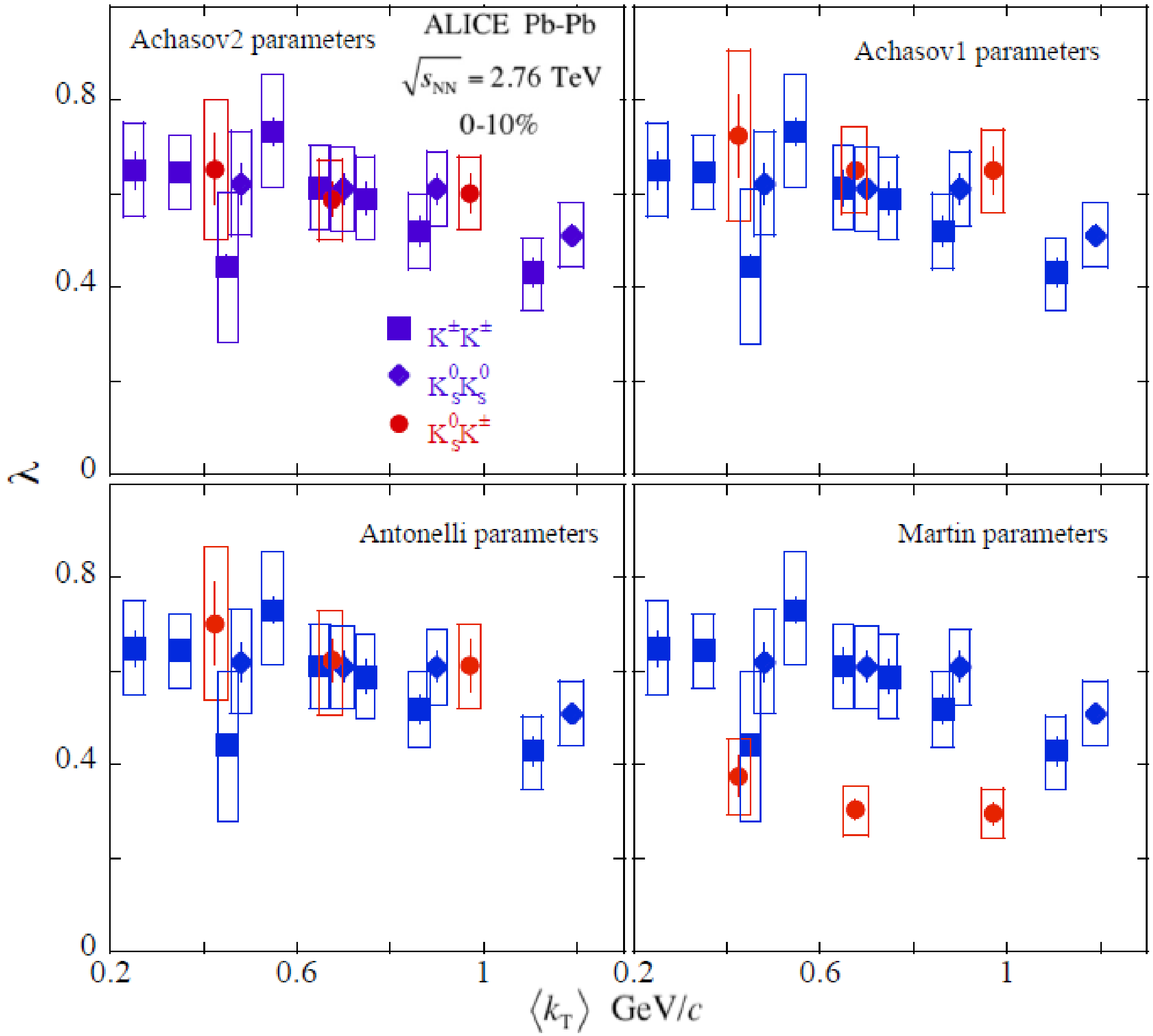


Fig. 5: Correlation strength parameter, λ



The λ value seems to be the same level from KK pairs

Discussion Point

- Distance (***R***) & coupling strength (λ) from $K^0_s K^{\pm}$ analysis shows similar value as the other KK pairs, Where KK pairs has the Coulomb interaction, and quantum statistics, and resonances.

- Distance (***R***) ~ 5 fm, and assuming width of kaon wavepacket as ~1 fm, it seems to not encourage a FSI, but free-streaming of the kaons.

- Nevertheless, the coupling strength (λ) is the same level as KK pairs. ➔ a_0 resonance can be interpreted as tetraquark state or $\bar{K}$-K molecular state.