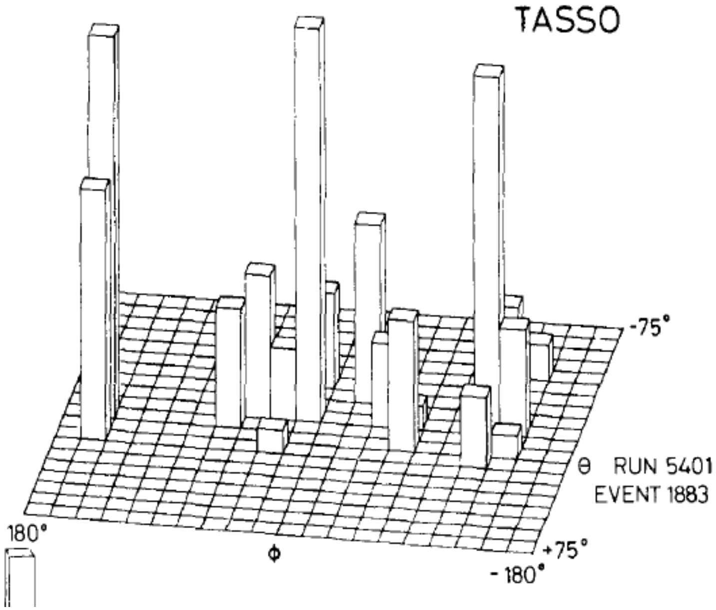
Towards Study of 2-Particle Pt Correlations

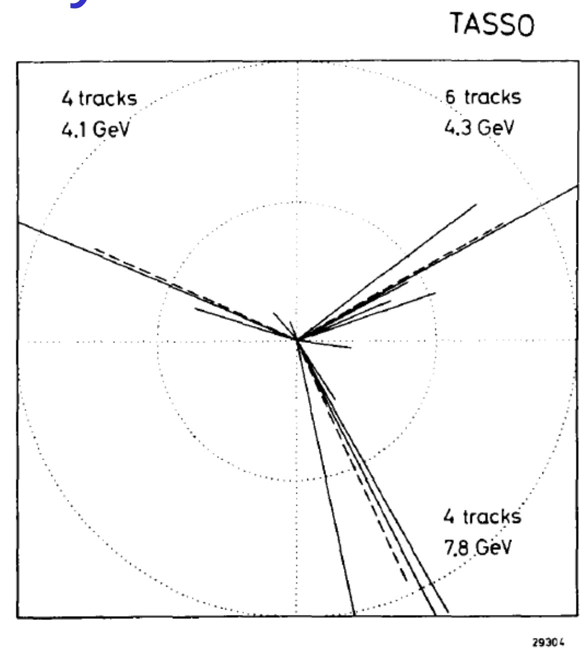
A. Galoyan and V. Uzhinsky



PHYSICS REPORTS 107 (1984) 59

e+e- PHYSICS AT PETRA – THE FIRST FIVE YEARS,
Sau Lan WU and *DESY.*

Jets in High Energy Physics



$$D(P_{T,jet}, z) = \frac{1}{N_{jet}} \frac{dN_{ch}(P_{T,jet}, z)}{dz}$$

$$z = P_{T,track} \cdot cos(\Delta R)/P_{T,jet}$$

$$\Delta R = \sqrt{(\phi_{jet} - \phi_{track})^2 + (\eta_{jet} - \eta_{track})^2}$$

P_T, η and *phi* represent transverse momentum, pdeudo-rapidity, and azimuthal angle, respectively.

Fragmentation function

$$D(P_{T,jet}, P_{T,track}) = \frac{1}{N_{jet}} \frac{dN_{ch}(P_{T,jet}, P_{T,track})}{dP_{T,track}}$$

It is the well-known procedure!

Example

19 Aug. 2020 arXiv:2008.08631 [nucl-exp]

Measurement of semi-inclusive jet fragmentation functions in Au+Au collisions at Sqrt(SNN) = 200 GeV in STAR, Saehanseul Oh (for the STAR Collaboration)

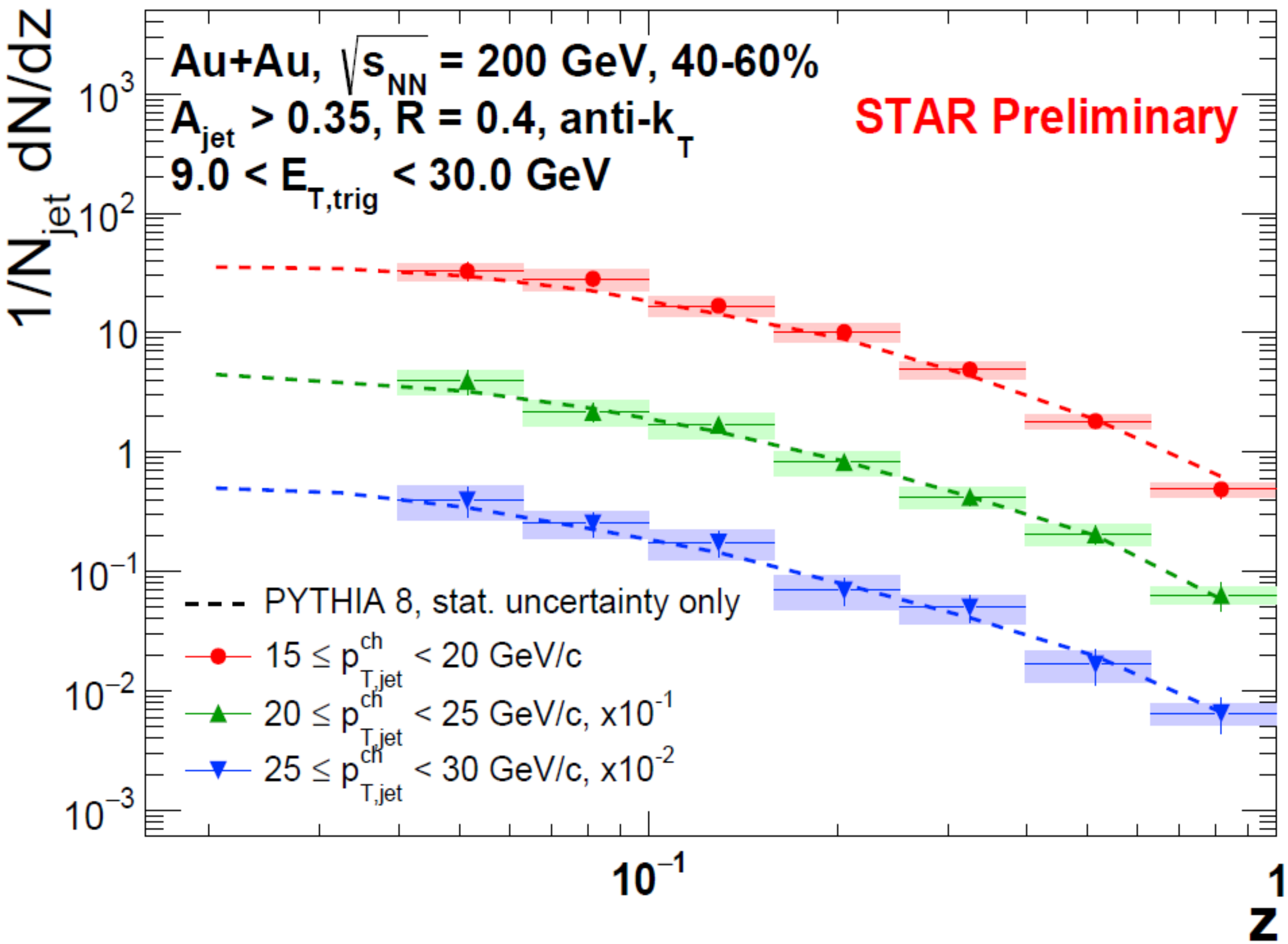


Figure 1: Semi-inclusive jet fragmentation functions measured in 40–60% Au+Au collisions for three pT;jet ranges (closed markers), compared to those calculated by PYTHIA 8 for pp collisions (dashed lines). Measured distributions are corrected for detector effects and uncorrelated background effects.

In-medium modifications of fragmentation functions have been previously reported by LHC collaborations for inclusive jet populations [4, 5].

[4] M. Aaboud *et al.*, "Measurement of jet fragmentation in Pb+Pb and pp collisions at sqrt(sNN) = 2:76 TeV with the ATLAS detector at the LHC", Eur. Phys. J. C **77**, no.6, 379 (2017).

[5] S. Chatrchyan *et al.*, "Measurement of jet fragmentation into charged particles in pp and PbPb collisions at sqrt(sNN)= 2:76 TeV", JHEP **10**, 087 (2012).

Other exp. method – azimuthal correlations

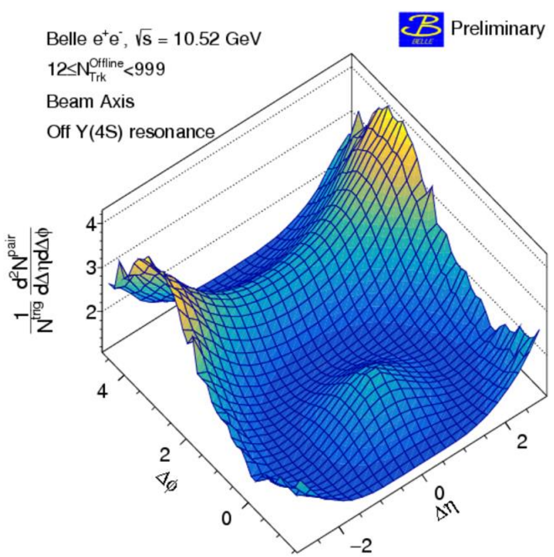
11 Aug. 2020 2008.04187 [hep-exp]

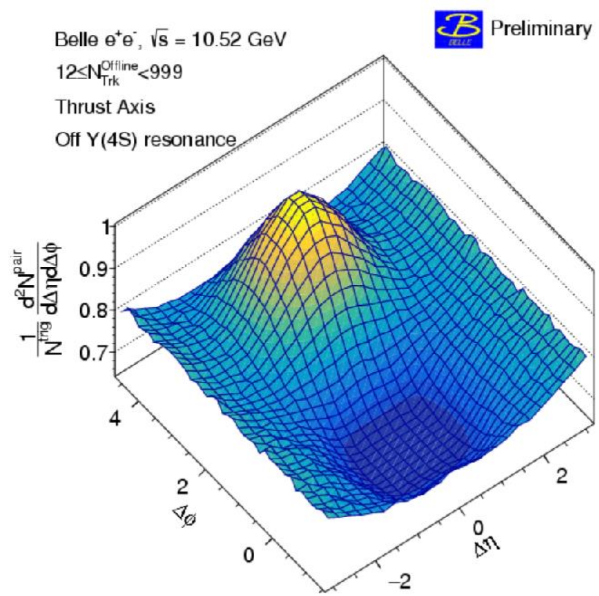
Measurement of two-particle correlations in hadronic e+e− collisions at Belle, A. Abdesselam et.al.

The “ridge signal”, is a phenomenon widely observed in high multiplicity proton-proton, proton-ion and deutron-ion collisions, which is not yet fully understood.

$$\frac{1}{N_{\rm trig}}\frac{d^2N^{\rm pair}}{d\Delta\eta d\Delta\phi} = B(0,0)\times\frac{S(\Delta\eta,\Delta\phi)}{B(\Delta\eta,\Delta\phi)},$$

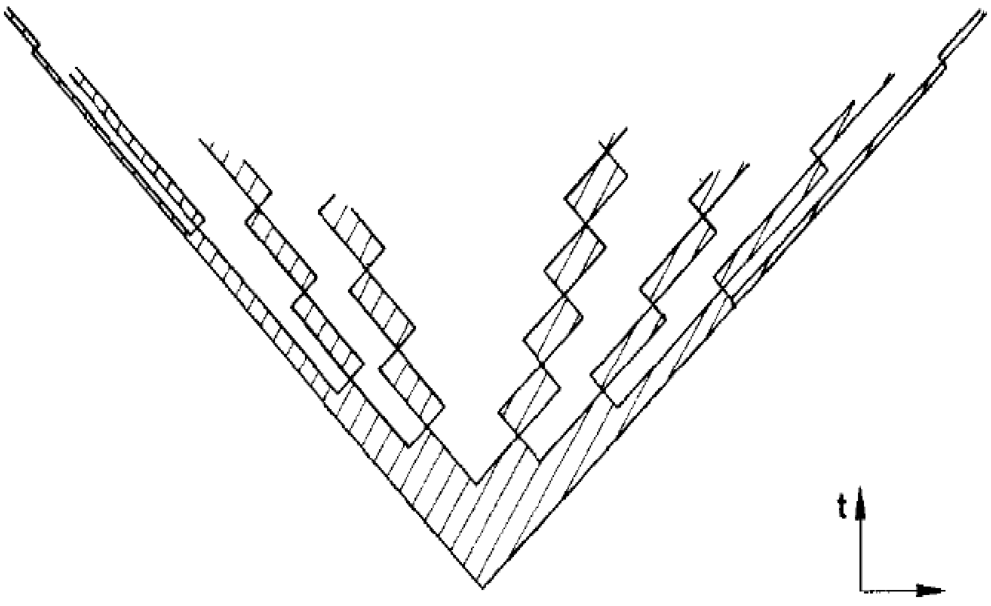
$$S(\Delta\eta,\Delta\phi) = \frac{1}{N_{\rm trig}}\frac{d^2N^{\rm same}}{d\Delta\eta d\Delta\phi},\quad B(\Delta\eta,\Delta\phi) = \frac{1}{N_{\rm trig}}\frac{d^2N^{\rm mix}}{d\Delta\eta d\Delta\phi},$$





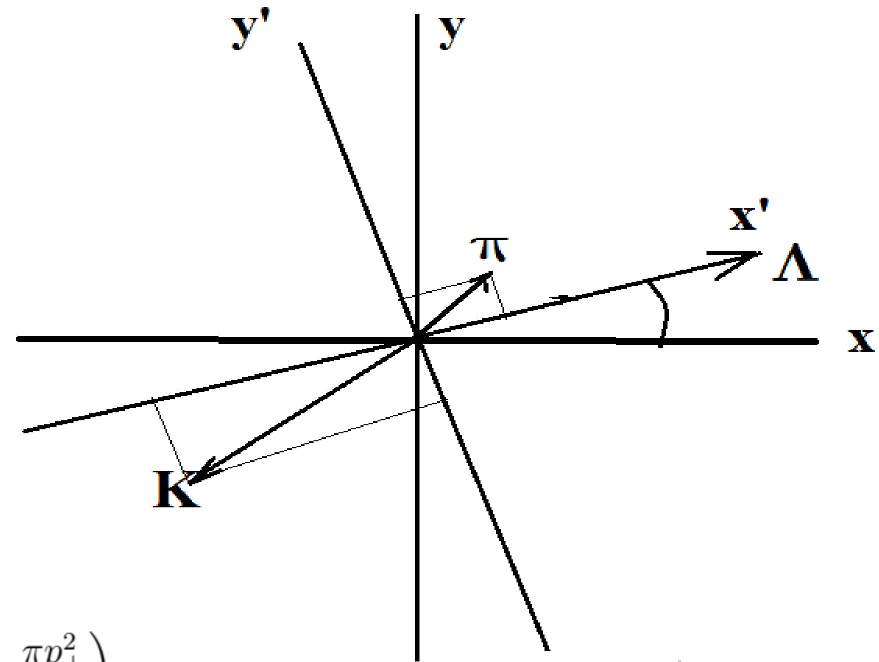
Two-particle correlation functions for beam (left) and thrust (right) axis analyses with offline multiplicity $N_{\rm offline\ Trk} \geq 12$.

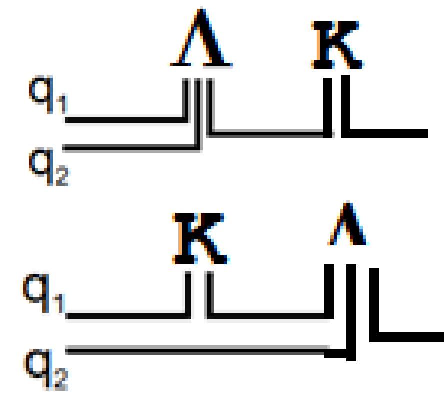
What to do if there is No Jet? Main idea



The Schwinger model

$$\exp\left(-\frac{\pi m_\perp^2}{\kappa}\right) = \exp\left(-\frac{\pi m^2}{\kappa}\right)\exp\left(-\frac{\pi p_\perp^2}{\kappa}\right)$$



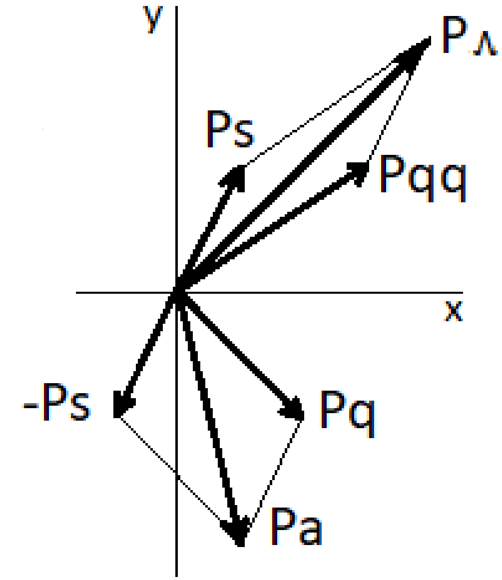


2-Particle Pt Correlations

$$C(\vec{P}_{T,triger}, \vec{P}_{T,track}) = \frac{1}{N_{triger}} \frac{dN_{triger,\ track}}{d^2P_{T,triger} d^2P_{T,track}}$$

4 independent variables: $\vec{P}_{T,triger}$ and $\vec{P}_{T,track}$.

Azimuthal symmetry – 1 variable: $\vec{P}_{T,triger} \rightarrow |\vec{P}_{T,triger}|$ plus $P_{x',track}$ and $P_{y',track}$



The Schwinger model

$$W = \left[\frac{1}{\pi\ \sigma_1}\ e^{-(\vec{P}_T^{qq})^2/\sigma_1 T}\right]\ \left[\frac{1}{\pi\ \sigma_2}\ e^{-(\vec{P}_T^{s})^2/\sigma_2}\right]\ \left[\frac{1}{\pi\ \sigma_2}\ e^{-(\vec{P}_T^{q})^2/\sigma_2}\right]$$

$$W(\vec{P}_T^{tr}, \vec{P}_T^{as}) = \int W\ \delta(\vec{P}_T^{tr} - \vec{P}_T^{qq} - \vec{P}_T^{s})\delta(\vec{P}_T^{as} + \vec{P}_T^{s} - \vec{P}_T^{q})\ d^2P_T^{qq}\ d^2P_T^{s}\ d^2P_T^{q}$$

$$\propto \exp(-(\vec{P}_T^{tr})^2/\sigma_1) - (\vec{P}_T^{as})^2/\sigma_2 + \frac{\sigma_1\ \sigma_2}{2\sigma_1 + \sigma_2}(\vec{P}_T^{tr}/\sigma_1 - \vec{P}_T^{as}/\sigma_2)^2).$$

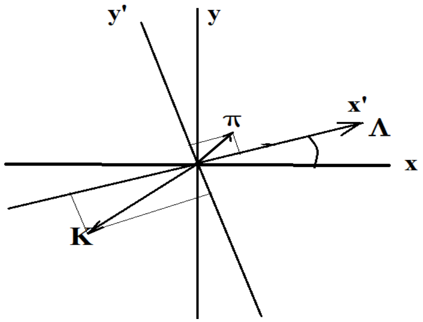
$$W(\vec{P}_T^{tr}, \vec{P}_T^{as}) \propto \exp\left(-\frac{\sigma_1 + \sigma_2}{\sigma_2(2\sigma_1 + \sigma_2)}\left[P_{T,L}^{as} + \frac{\sigma_2}{\sigma_1 + \sigma_2}P_T^{tr}\right]^2 - \frac{\sigma_1 + \sigma_2}{\sigma_2(2\sigma_1 + \sigma_2)}(P_{T,T}^{as})^2\right)$$

$$< P_x^{as} >= -\frac{\sigma_2}{\sigma_1 + \sigma_2}P_T^{tr},$$

$$< (P_y^{as})^2 >= \frac{2\sigma_1 + \sigma_2}{\sigma_1 + \sigma_2} \cdot \sigma_2.$$

1) $\sigma_1 = 0, \quad < P_y^2 >= \sigma_2, \quad < P_x >= -P^{tr}$
2) $\sigma_1 = \sigma_2, \quad < P_y^2 >= \frac{3}{2}\sigma_2, \quad < P_x >= -\frac{1}{2}P^{tr}$
3) $\sigma_2 \simeq 0, \quad < P_y^2 >\simeq 0, \quad < P_x >\simeq 0$

Pt-Correlation: calculation method



1. We calculated 1000000 PbarP-events at Plab=5 and 15 GeV/c using FTF generator in PandaRoot

2. We selected events with Λ –hyperons, and calculated

$$\mathrm{Cos}(\varphi\_\Lambda) = Px\_\Lambda \,/\, Pt\_\Lambda$$
$$\mathrm{Sin}(\varphi\_\Lambda) = Py\_\Lambda \,/\, Pt\_\Lambda$$

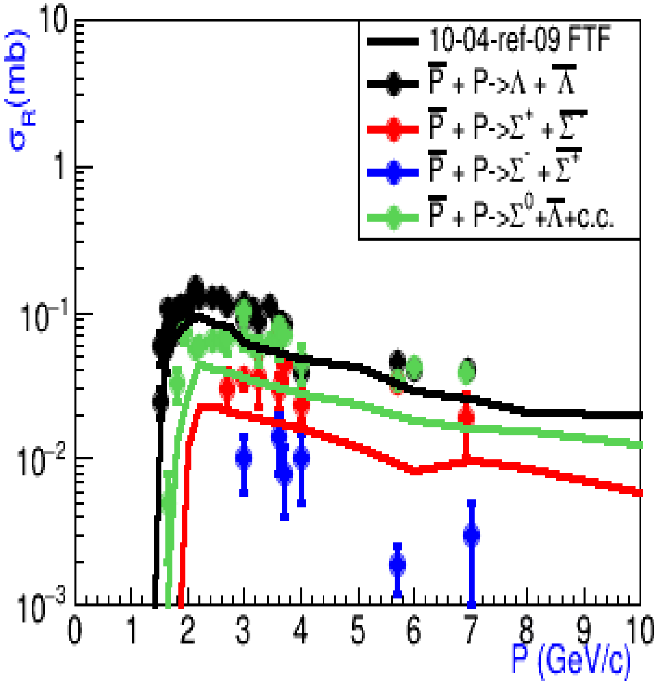
3. For these events we transformed Px and Py momenta of particles associated with Λ –hyperon in the new rotated coordinate system.

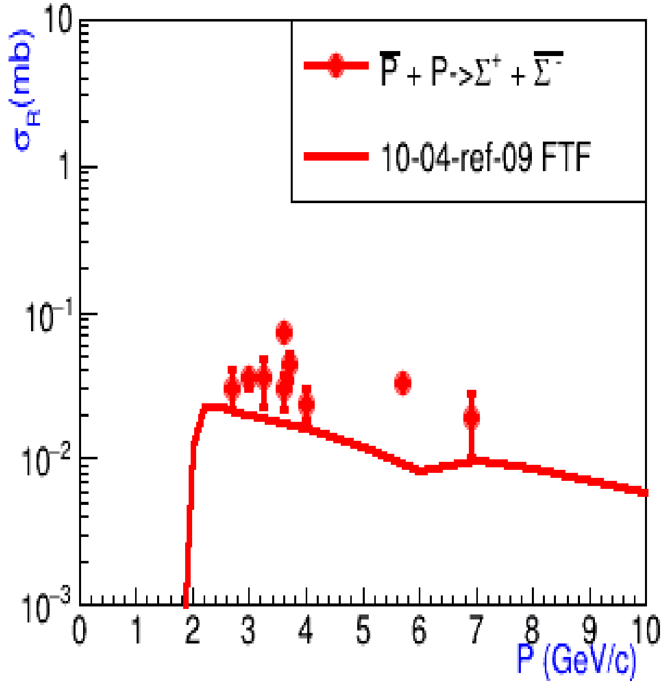
$$Px' = Px * \mathrm{Cos}(\varphi\_\Lambda) + Py * \mathrm{Sin}(\varphi\_\Lambda)$$
$$Py' = - Px * \mathrm{Sin}(\varphi\_\Lambda) + Py * \mathrm{Cos}(\varphi\_\Lambda)$$

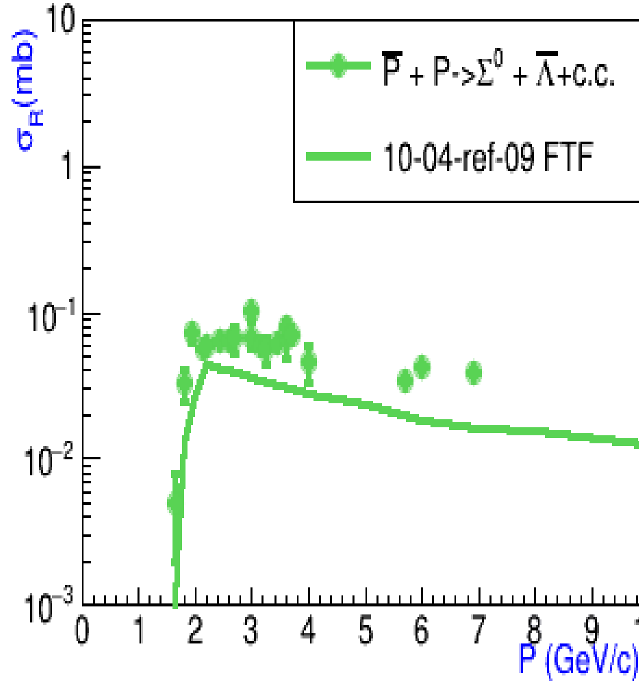
(It is obviously, that for Λ –hyperon Px'=Pt; Py'=0)

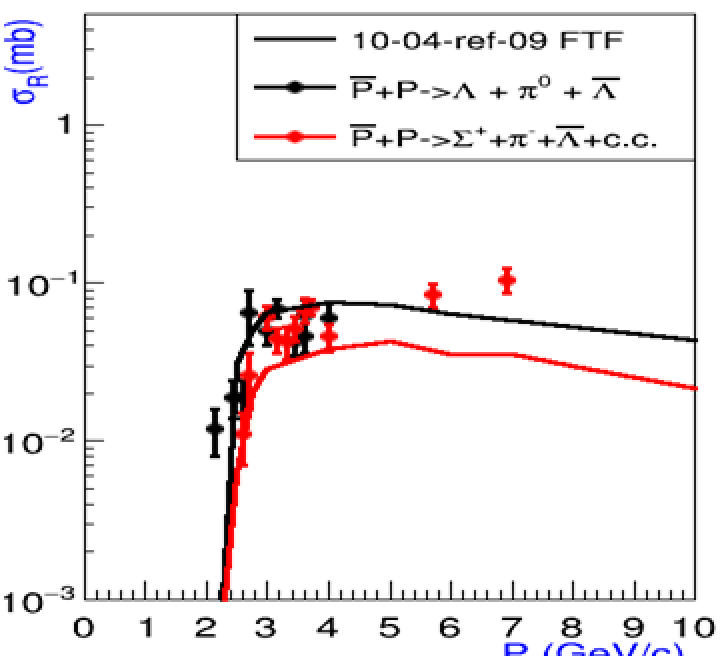
4. We performed analysis of transformed Px' and Py'^{2} of particles produced with Λ –hyperons.

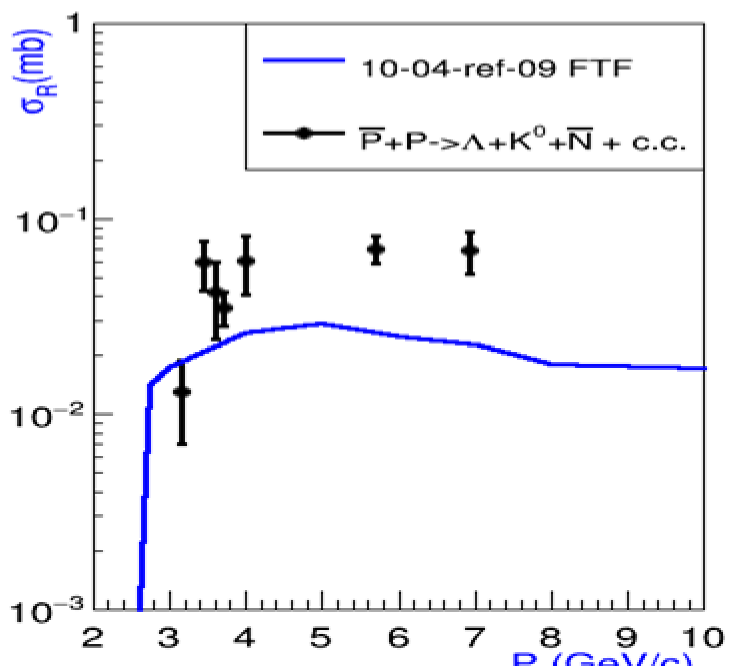
Validation of FTF for Λ production in PbarP events

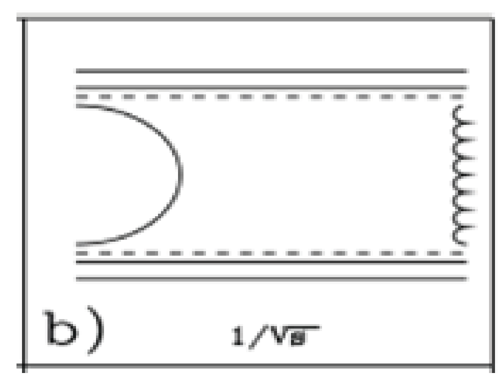








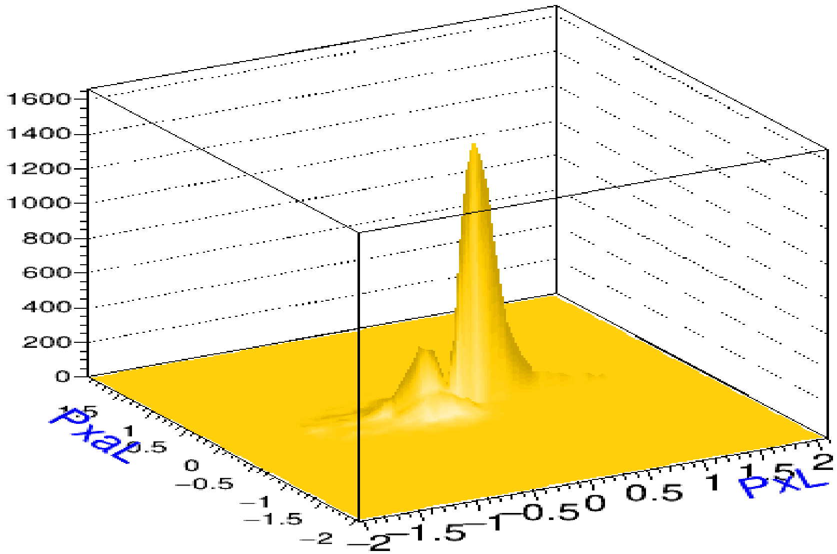


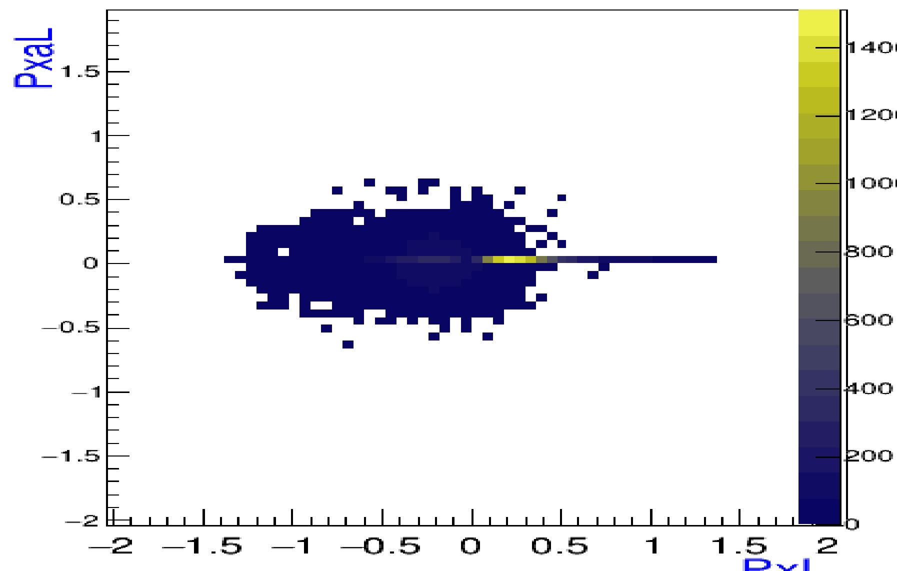


Pt-Correlations of Λ and Λbar : results

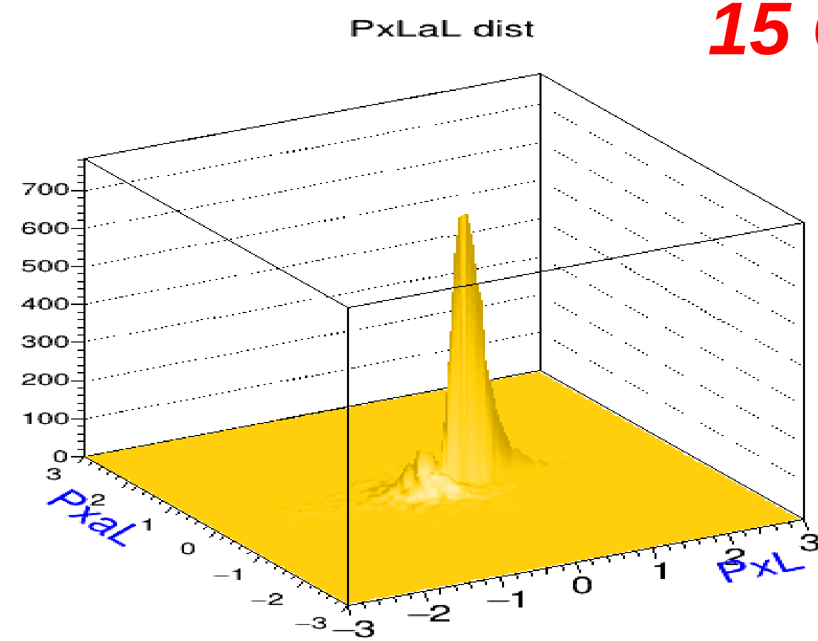
Comparison of P_T' of Λ-bar hyperons associated with Λ hyperon in PbarP- events calculated by FTF model

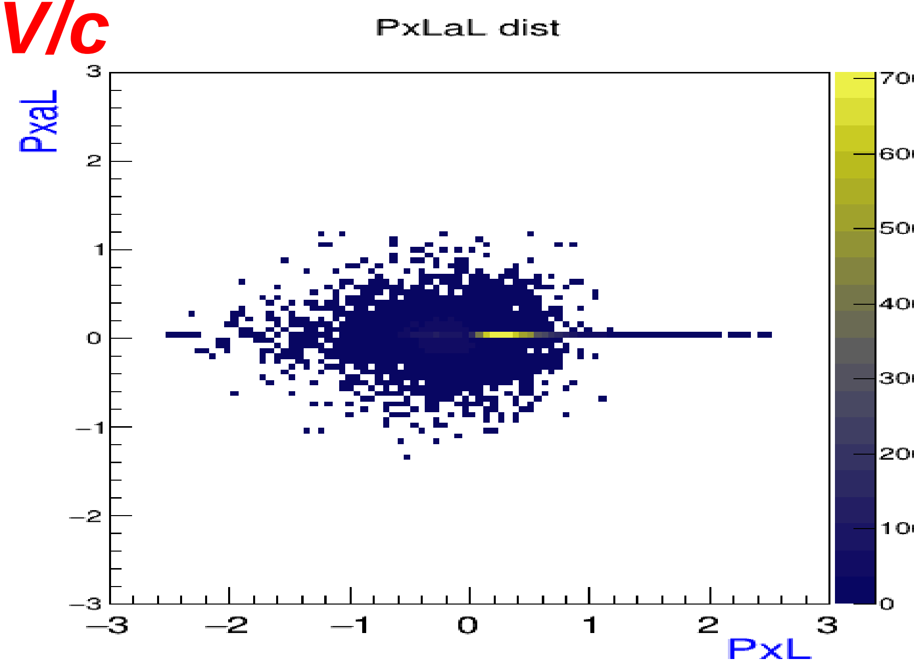
5 GeV/c





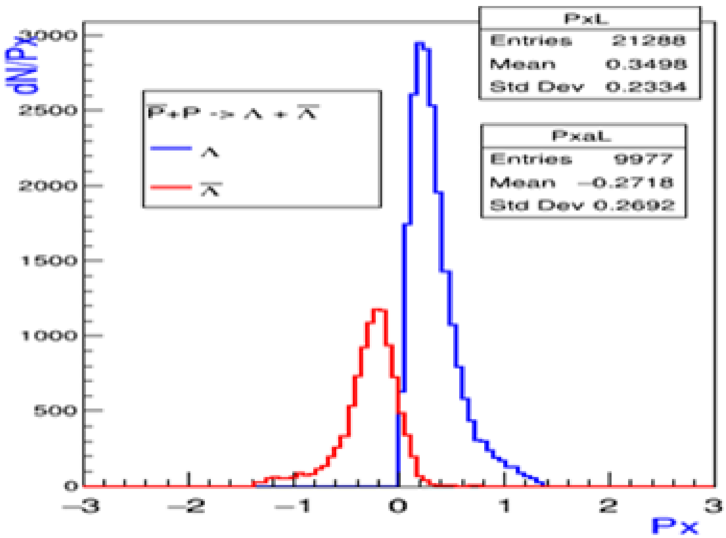
15 GeV/c

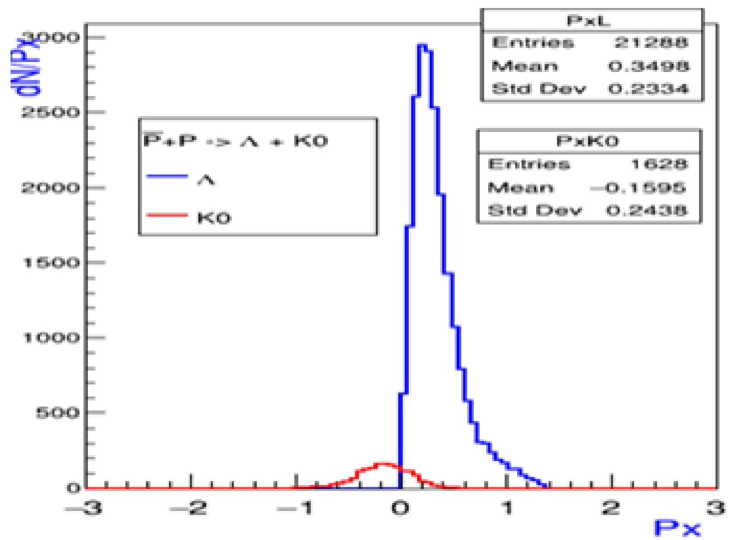




Comparison of Px' of Λ-bar hyperons and K0-mesons associated with Λ hyperon in PbarP- events

5 GeV/c





N_Λ = 21288

<Px'_Λ>= 350 MeV/c

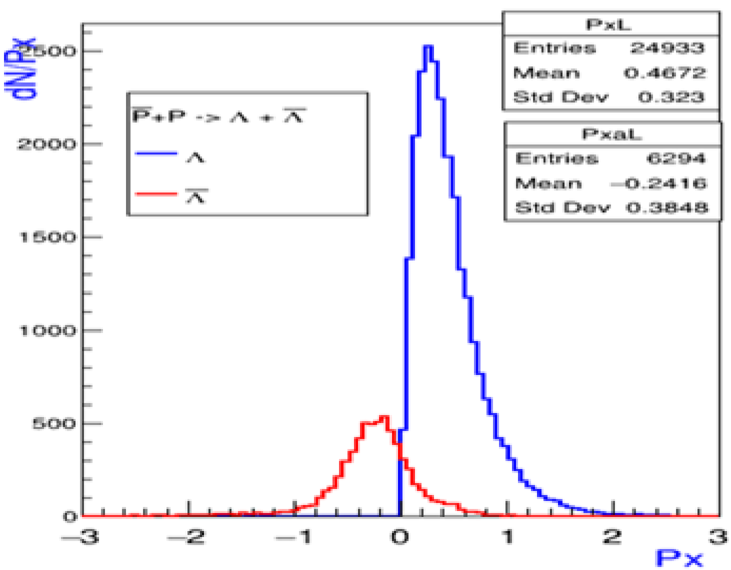
N_Λ bar=9977

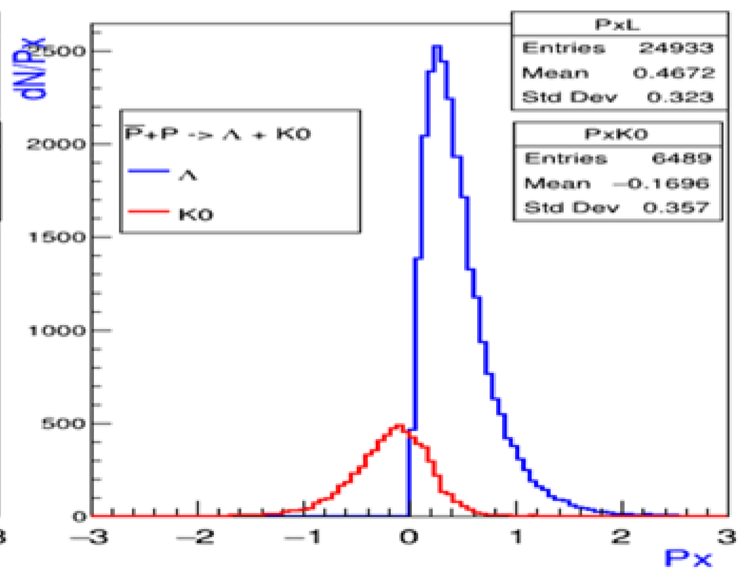
<Px'_Λbar>= -272MeV/c

N_K0=1628

<Px'_K0>= -160 MeV/c

15 GeV/c





N_Λ = 24933

<Px'_Λ>= 467 MeV/c,

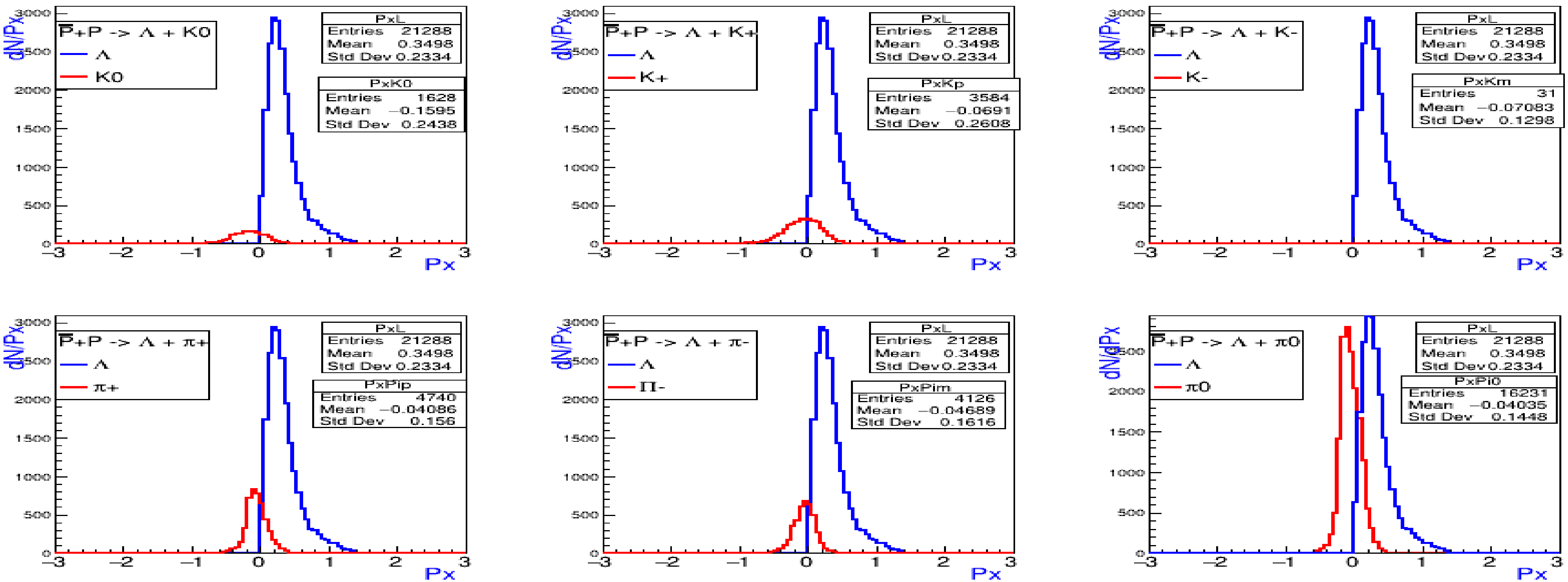
N_Λ bar=6294

<Px'_Λbar>= -242 MeV/c

N_K0=6489

<Px'_K0>= -170 MeV/c

Px' of particles associated with Λ hyperons in PbarP-events calculated by FTF at 5 GeV/c



Plab=5 GeV/c **<Px'_Λ> = 350 MeV/c**

<Px'_K0> = -160 MeV/c , <Px'_K+>=-69 MeV/c, <Px'_K- > = -71 MeV/c

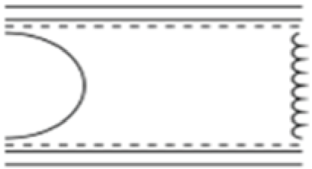
<Px'_π+> = -41 MeV/c, <Px'_π->=-47 MeV/c <Px'_π0 > = -40 MeV/c

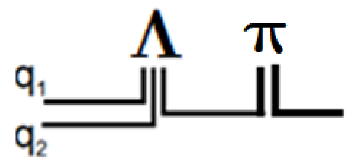
Plab=15 GeV/c **<Px'_Λ> = 467 MeV/c**

<Px'_K0> = -170 MeV/c , <Px'_K+>=-111 MeV/c, <Px'_K- > = -118 MeV/c

<Px'_π+> = -61 MeV/c, <Px'_π->=-65 MeV/c <Px'_π0 > = -42 MeV/c

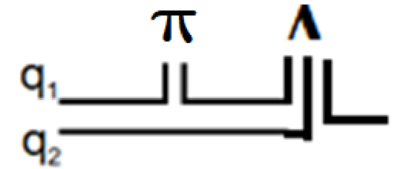
Correlations of mean Px' of Λ-bar hyperons, K and π mesons with Λ hyperon Px' in PbarP-events calculated by FTF

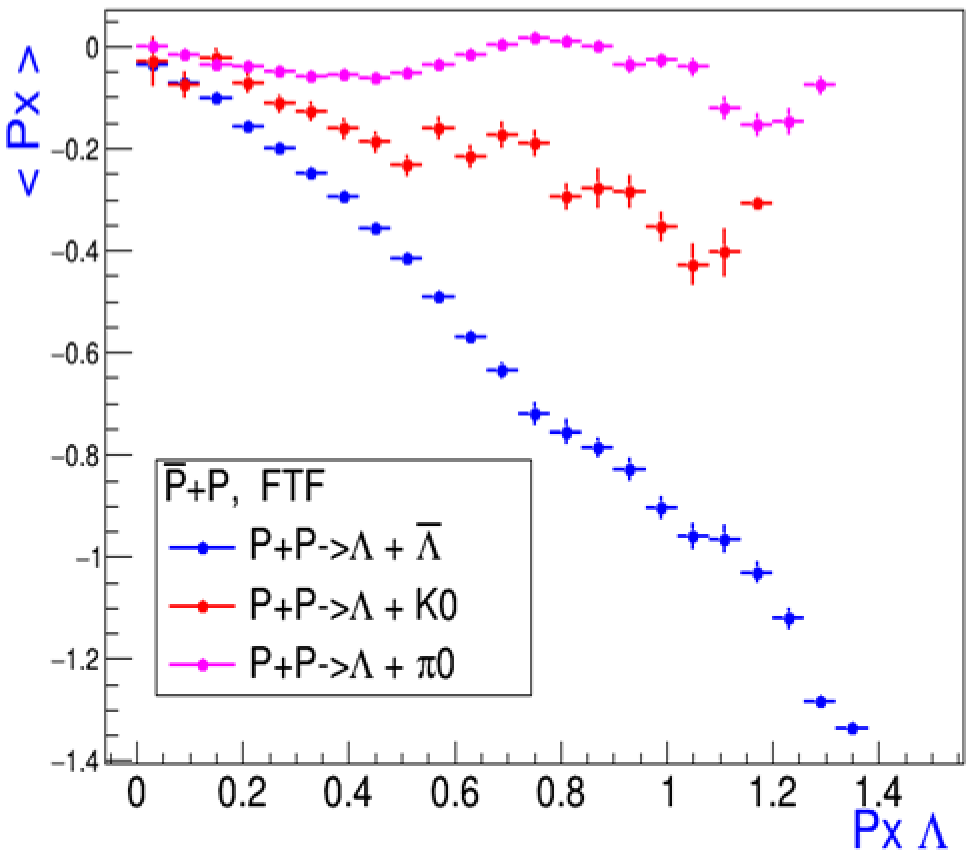


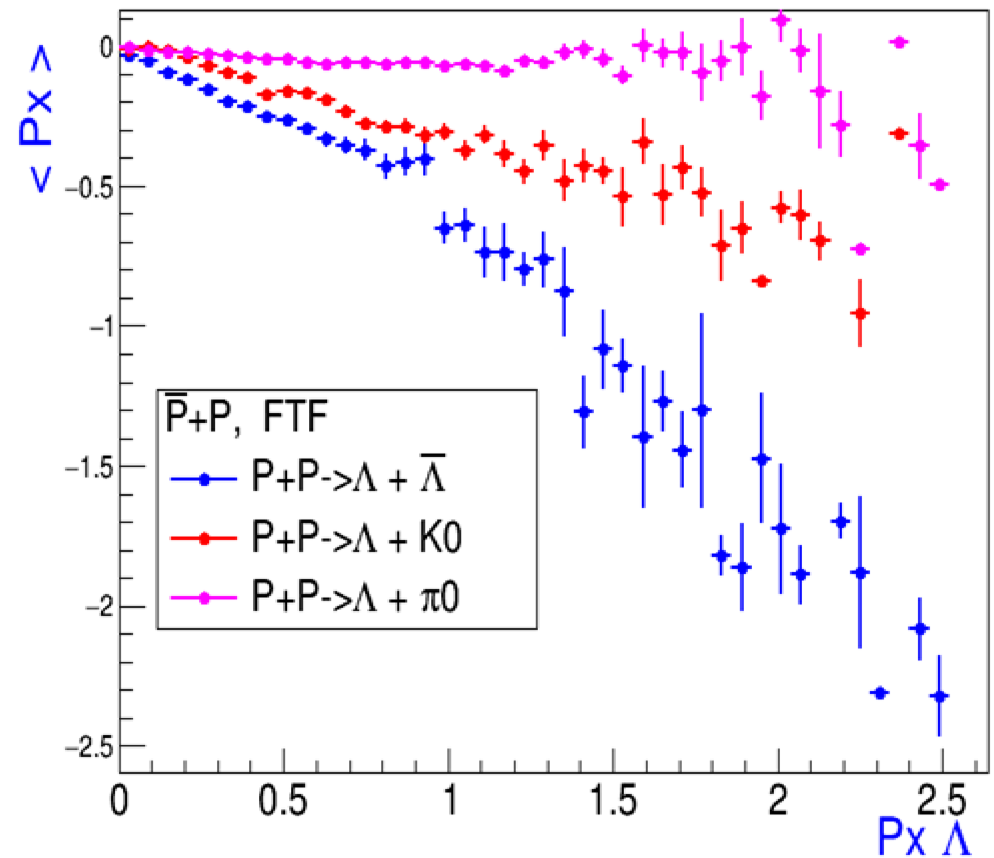


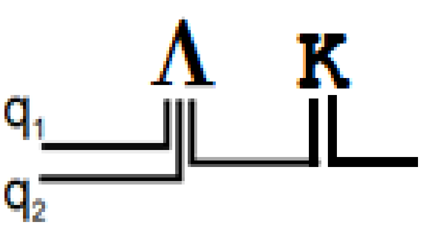
5 GeV/c

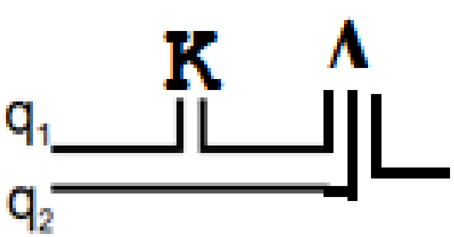
15 GeV/c









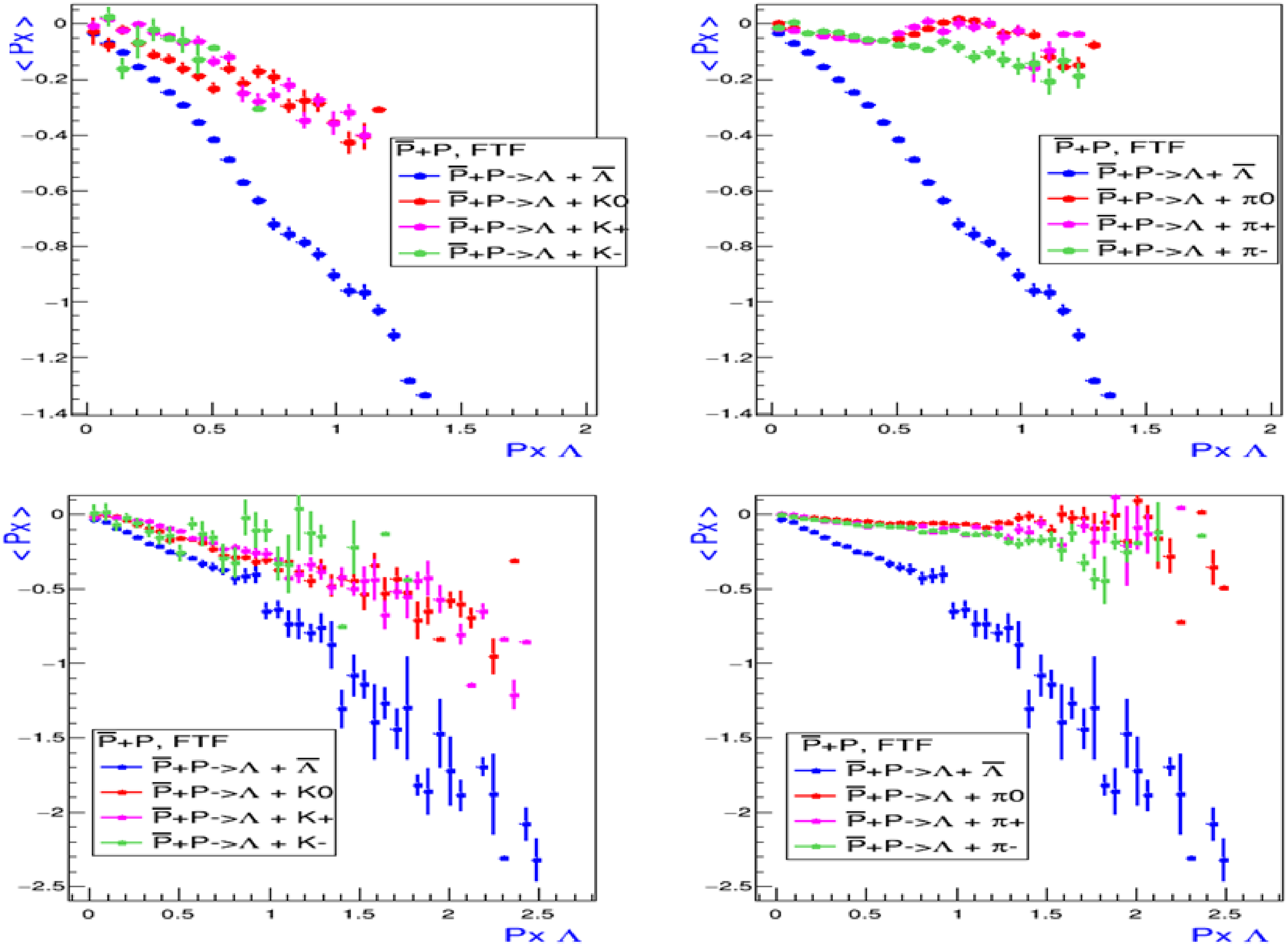


1) $\sigma_1 = 0, \quad < P_y^2 >= \sigma_2, \quad < P_x >= -P^{tr}$

2) $\sigma_1 = \sigma_2, \quad < P_y^2 >= \frac{3}{2}\sigma_2, \quad < P_x >= -\frac{1}{2}P^{tr}$

3) $\sigma_1 \simeq 0, \quad < P_y^2 >\simeq 0, \quad < P_x >\simeq 0$

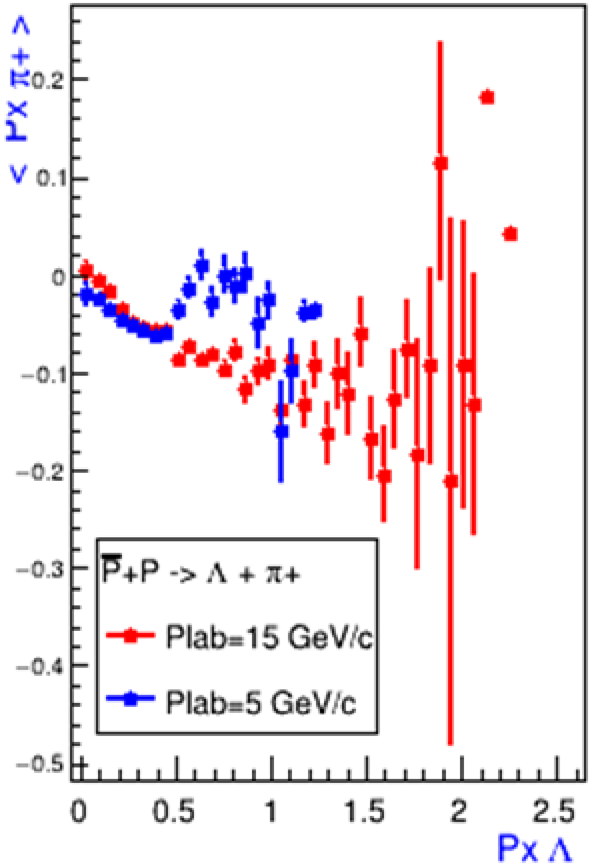
Correlations of mean Px' of Λ-bar hyperons, K and π mesons with Λ hyperon Px' in PbarP-events calculated by FTF

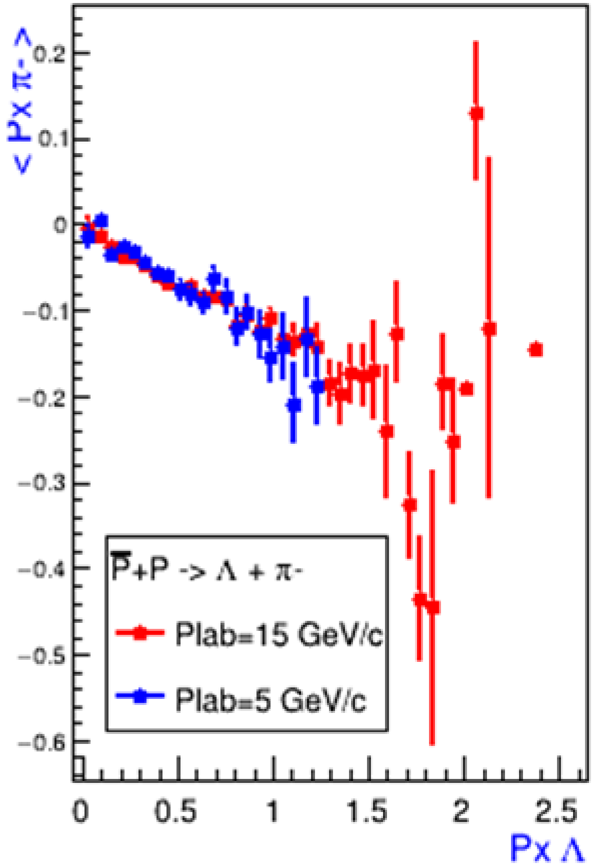


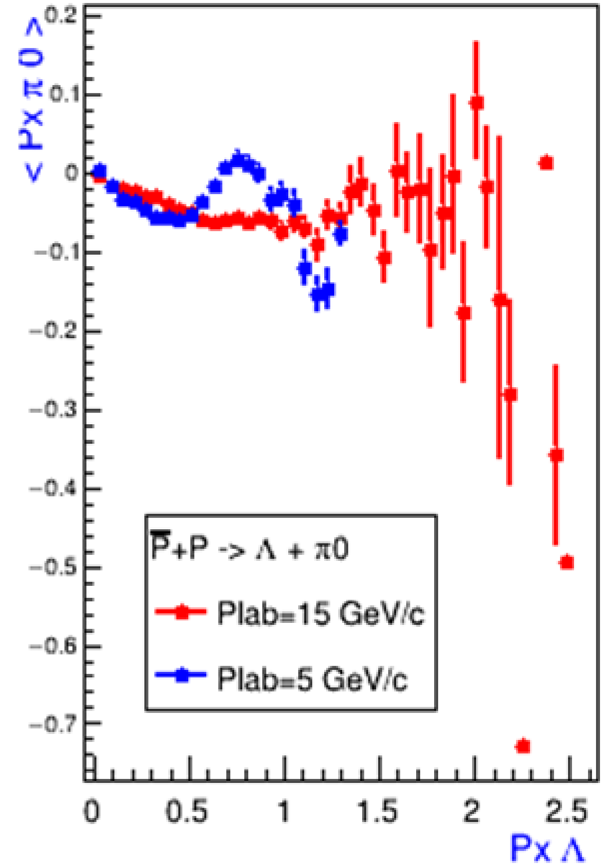
5 GeV/c

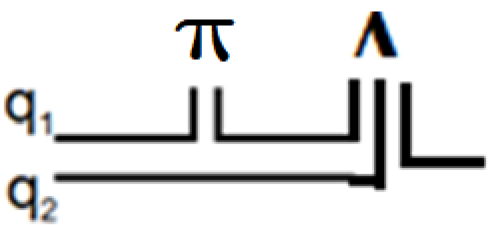
15 GeV/c

Comparison of correlations of mean Px' of Λ-bar hyperons and π-mesons with Λ hyperon Px' in PbarP events at 5 and 15 GeV/c



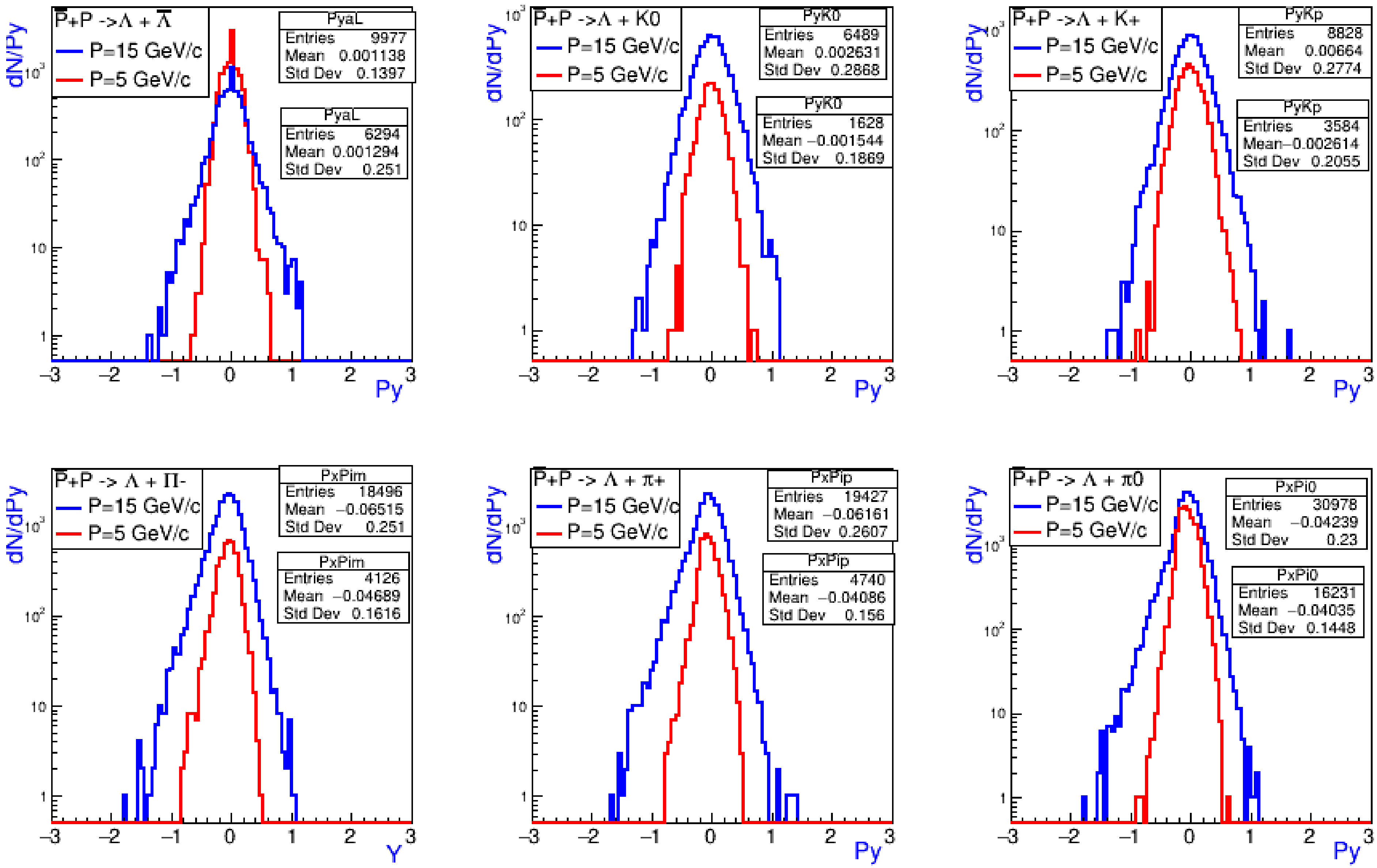






Comparison of Py' distributions of Λ-bar hyperons, K and π mesons in PbarP-events at 5 and 15 GeV/c calculated by FTF

5 GeV/c ***15 GeV/c***



Correlations of mean Py'^{2} of Λ-bar hyperons, K and π mesons with Λ hyperon Px' in PbarP-events at **5** and **15** GeV/c

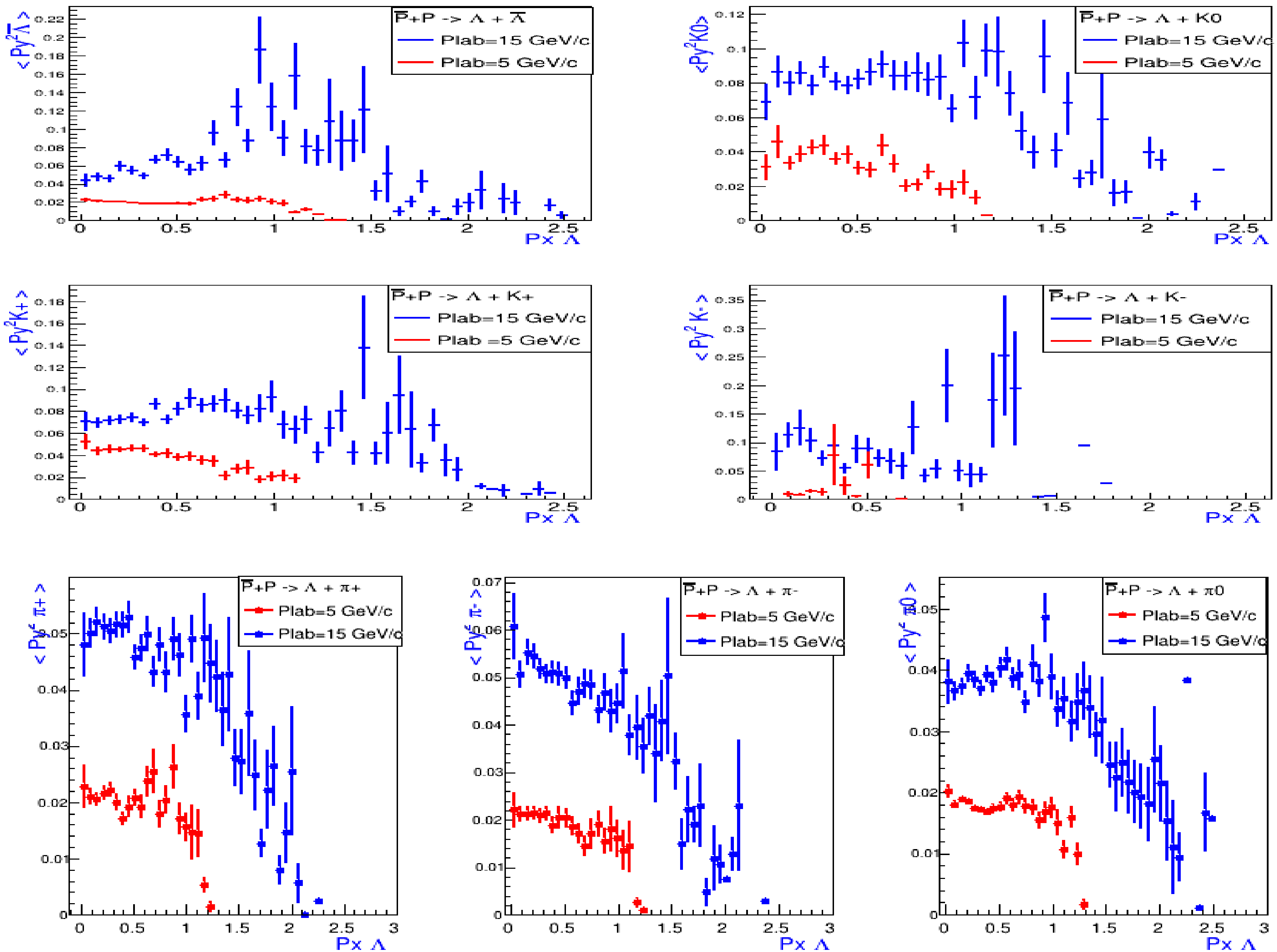


Table of Numbers and Mean values of Px’ and Py’^{2} of Λ-hyperons and particles associated with Λ-hyperon in PbarP-events

Plab GeV/c	Λ	Λbar	K+	K-	K0	π+	π-	π0
5	N 21288	N 9977	N 3584	N 31	N 1628	N 4740	N 4126	N 16231
15	N 24933	N 6294	N 8828	N 661	N 6489	N 19427	N 18496	N 30978
5	<Px> 350	<Px> -272	<Px> -69	<Px> -71	<Px> -160	<Px> -41	<Px> -47	<Px> -40
15	<Px> 467	<Px> -242	<Px> -111	<Px> -118	<Px> -170	<Px> -61	<Px> -65	<Px> -42
5	<Py^2> 0	<Py^2> 20	<Py^2> 42	<Py^2> 19	<Py^2> 35	<Py^2> 20	<Py^2> 20	<Py^2> 18
15	<Py^2> 0	<Py^2> 63	<Py^2> 77	<Py^2> 87	<Py^2> 82	<Py^2> 49	<Py^2> 50	<Py^2> 38

Summary

1. We have proposed a New Method of Study of 2-Particle Pt correlations in soft interactions. The correlations are sensitive to main assumptions of string model especially used in Geant4 FTF one.

2. We calculated Pt correlations of Λ -hyperons and associated particles in PbarP interactions at 5 and 15 GeV/c in FTF model

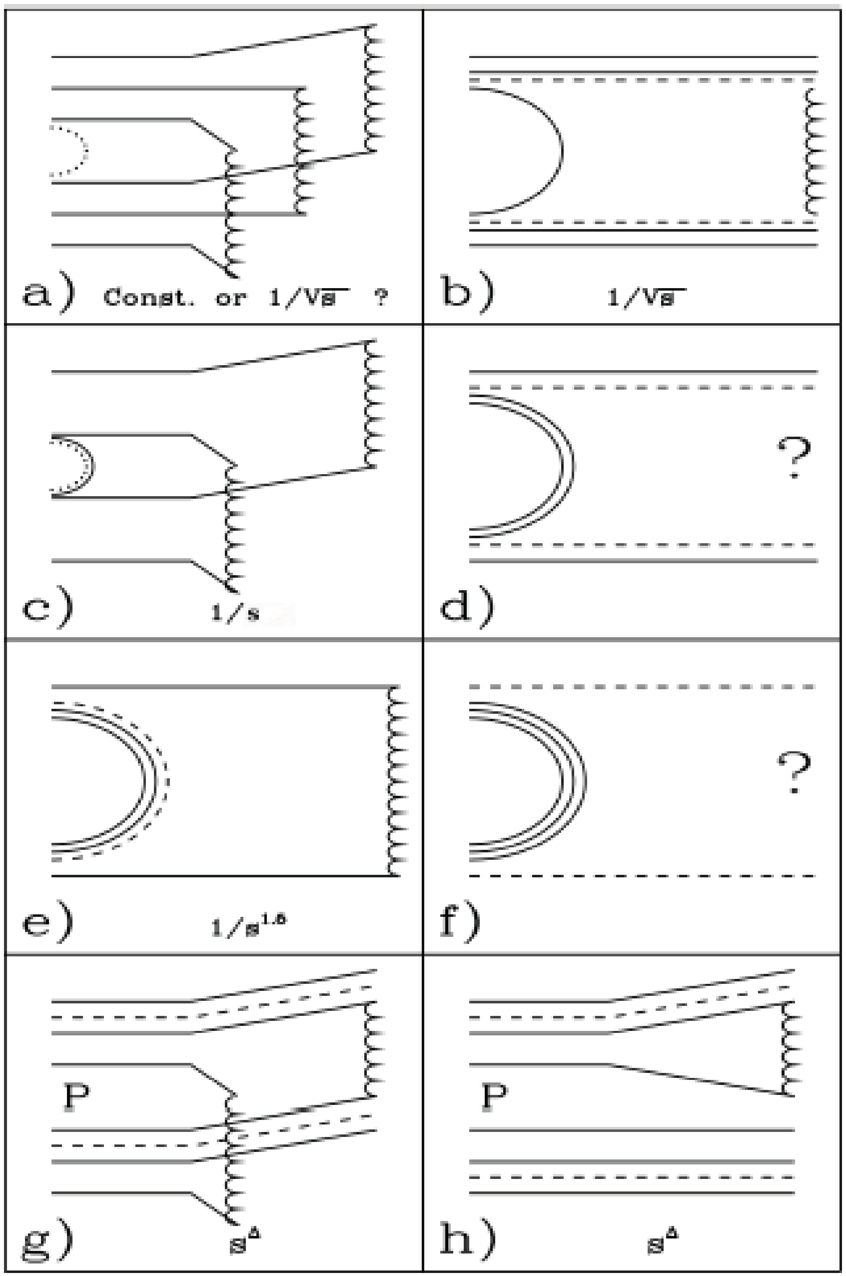
3. We observe strong 2-particle Pt correlations between anti- Λ and Λ-hyperons.

4. Pt correlations of Λ -hyperons and K-mesons are more stronger than correlations of Λ-hyperons and π-mesons.

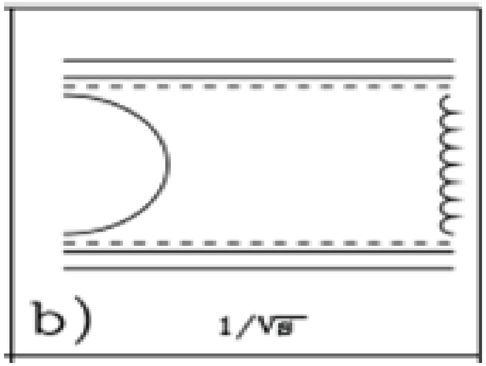
5. Pt correlations of Λ -hyperons and K-mesons increase with initial energy growth. The same is true for Pt correlations of π-mesons and Λ -hyperons.

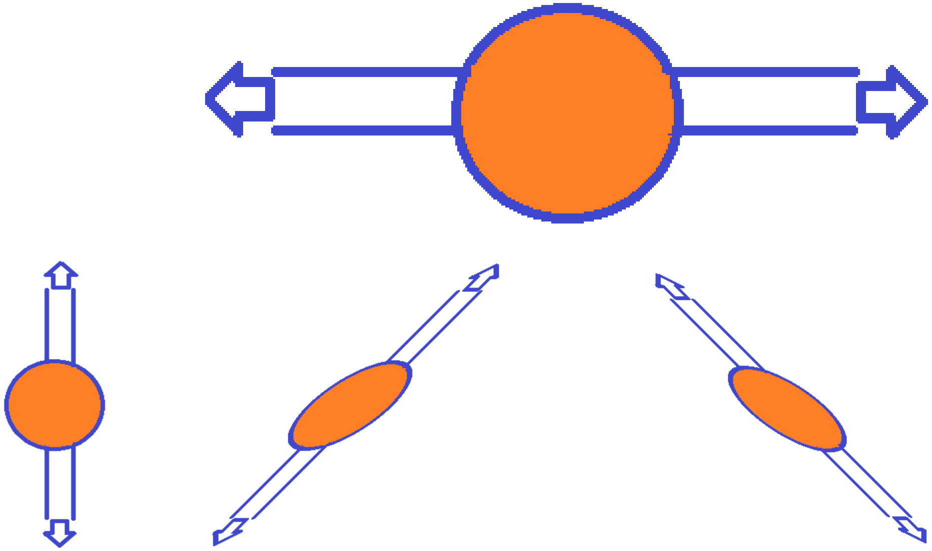
Detailed study of the Pt - correlations at PANDA will give a new look on anti-proton − proton interactions

Anti-proton proton annihilation



The question marks mean that the corresponding estimations are absent.





Randomly izotrophically rotate string!

$$Prob \propto \left(\frac{2\,M_N}{\sqrt{s}}\right)^a$$