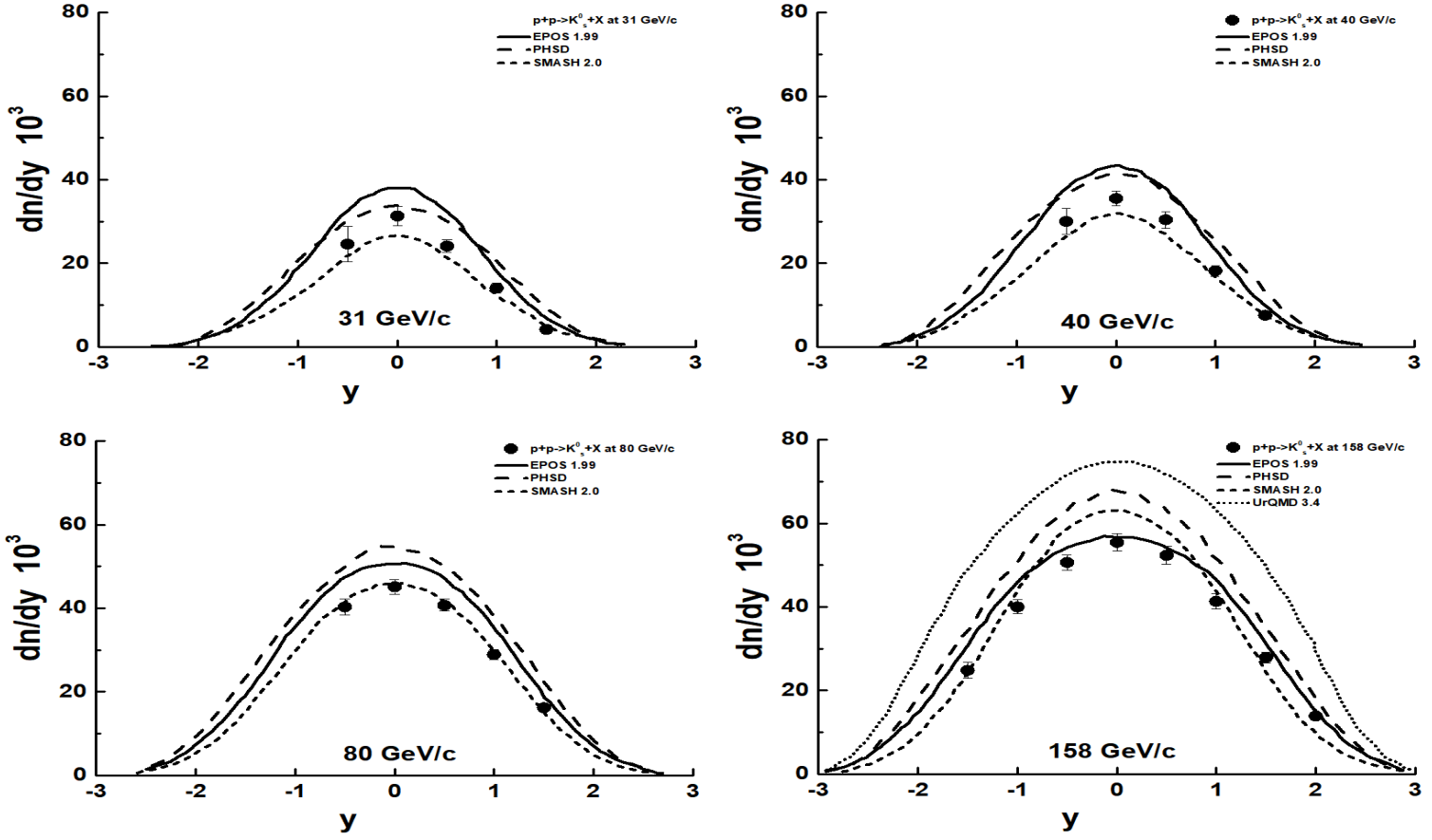
Towards understanding of $K^0_s meson production in hadronic interactions

A. Galoyan, A. Ribon, V. Uzhinsky 05.2024

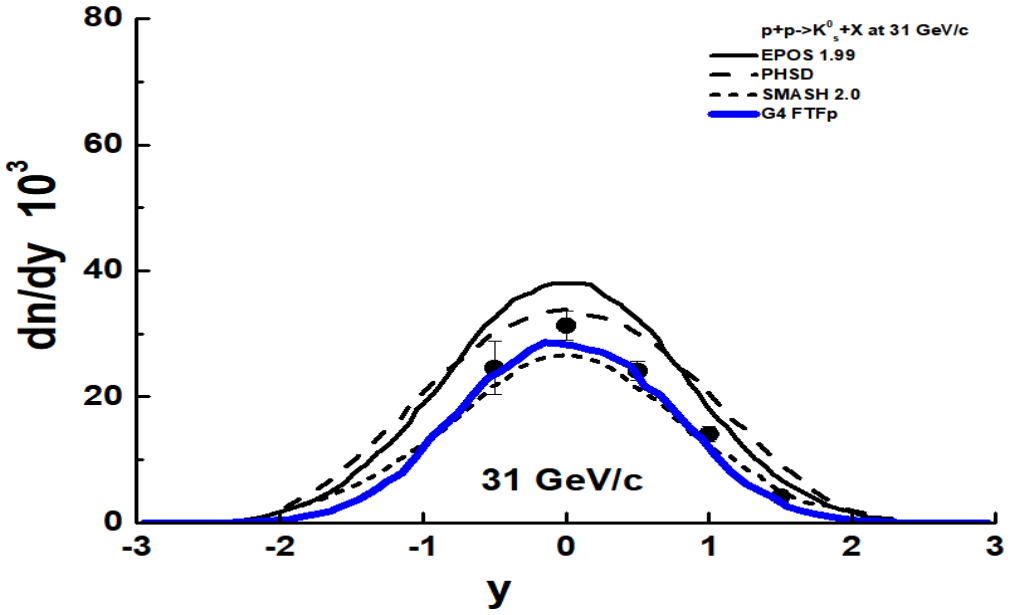
NA61/SHINE Collaboration arXiv:2402.17025v1 [hep-ex] 26 Feb 2024

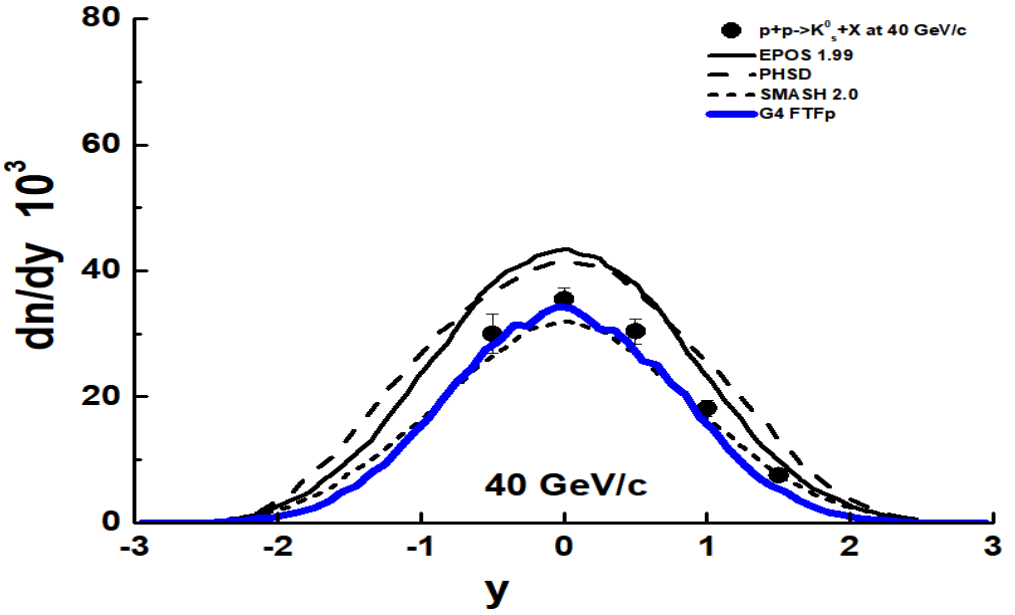
K0s meson production in inelastic p+p interactions at 31, 40 and 80 GeV/c beam momentum measured by NA61/SHINE at the CERN SPS

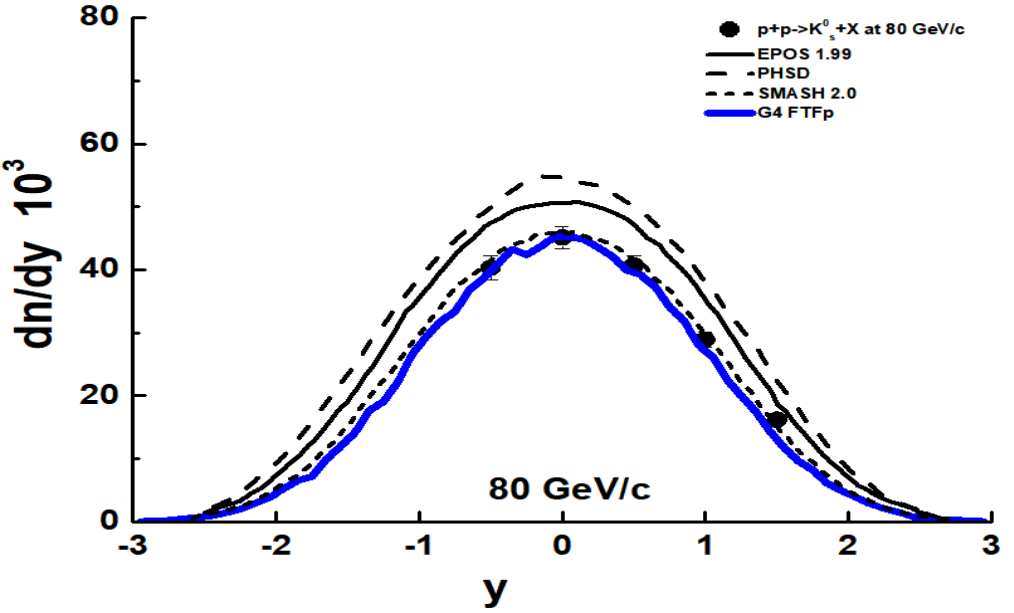


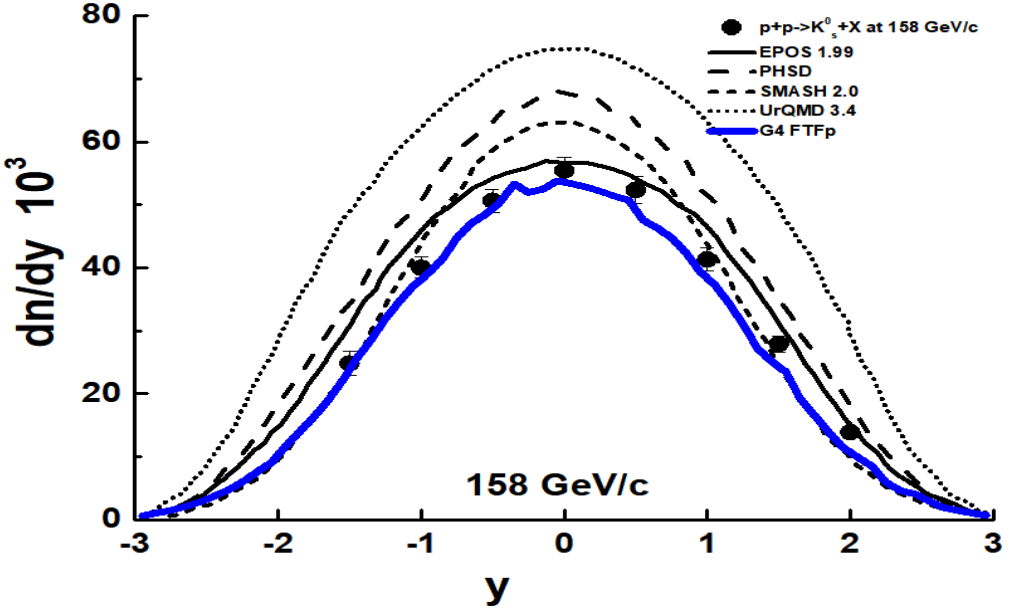
SMASH ~ O.K., EPOS O.K. at 158 GeV/c, PHSD - ???

Experimental data and models + FTF









SMASH ~ O.K., EPOS O.K. at 158 GeV/c, PHSD - ?, FTF is the best!

Study of 2-particles transverse momentum correlations of Ks0-mesons in proton-proton interactions

V.Abramov et al, Possible studies at the first stage of the NICA collider operation with polarized and unpolarized proton and deuteron beams, arXiv:2102.08477

***Phys.Part.Nucl.* 52 (2021) 6, 1044-1119** **SPD collabotation**

Spin effects in elastic scattering and hyperon production, study of multiquark correlation, dibaryon resonances, exclusive reactions, open charm and charmonia near threshold. Minimal bias interactions will be studied also at SPD. ***2-particles transverse momentum correlations of Λ –hyperons in PP and DD interactions can be studied at SPD.***

A. Galoyan, A. Ribon, V. Uzhinsky

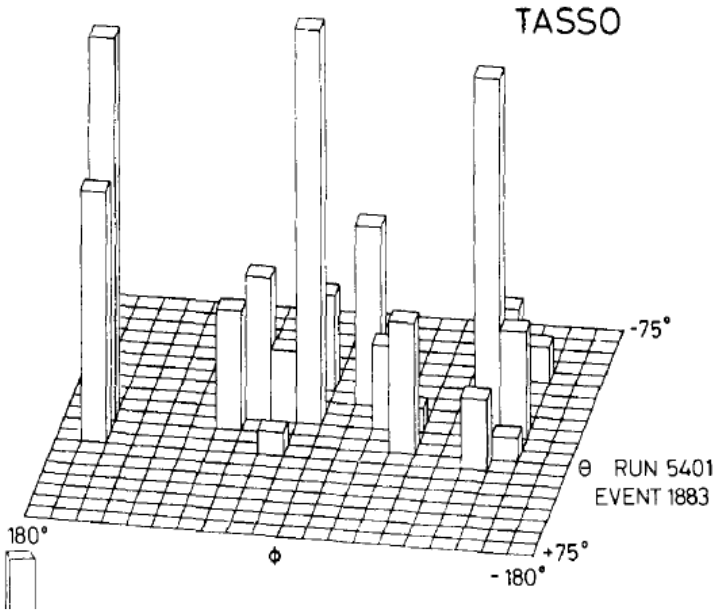
***MDPI Physics* 5 (2023) 3, 823-831**

1. The method of study of 2-particle Pt-correlations

2. 2-particle Pt correlations of Ks0-mesons in PP-interactions in Geant4/FTF model

3. The Pt correlations of in Ks0-mesons PP-interactions in Pythia model and comparison with FTF ones.

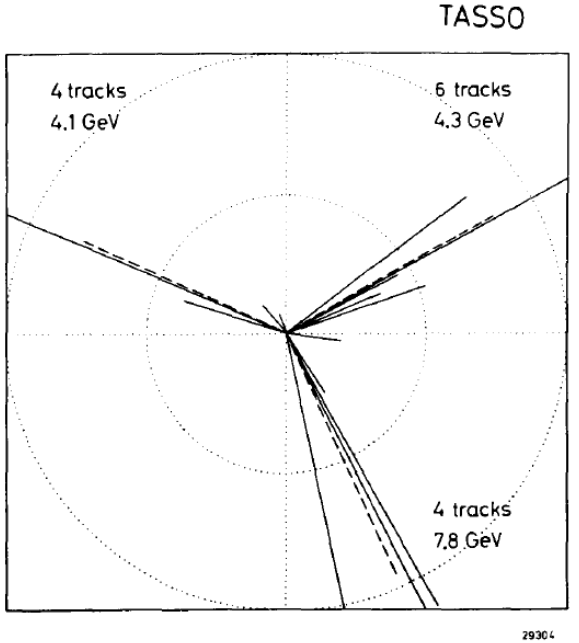
Towards Study of 2-Particle Pt Correlations

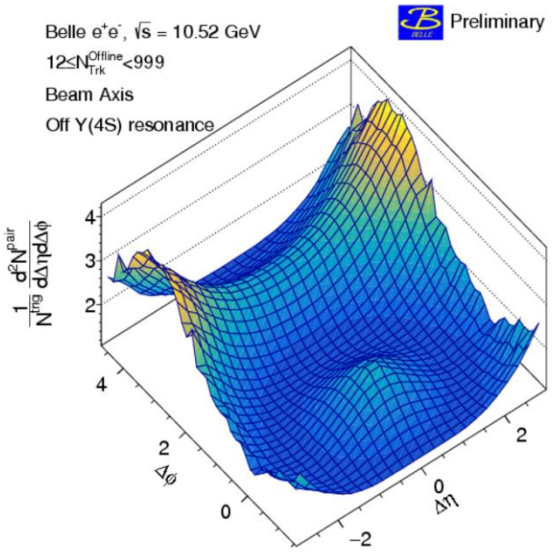


PHYSICS REPORTS 107 (1984) 59

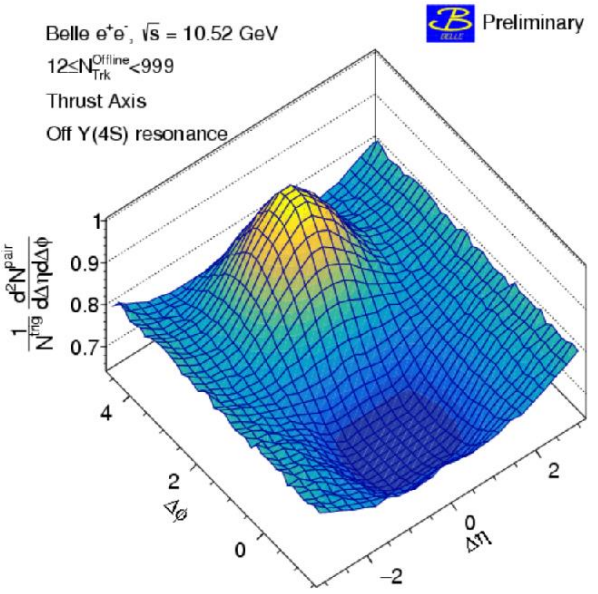
e+e- PHYSICS AT PETRA – THE FIRST FIVE YEARS,
Sau Lan WU and *DESY.*

Jets in High Energy Physics





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



What to do at lower energies when jets are not produced?

Eur. Phys. J. C (2021) 81:945

K_S^0- (Λ or anti-Λ)- hadron correlations in pp collisions at √s = 13 TeV

ALICE Collaboration

$$\frac{\mathrm{d}^2 N_{\mathrm{pair}}}{\mathrm{d}\Delta\varphi \mathrm{d}\Delta\eta}(\Delta\varphi, \Delta\eta) = \frac{1}{N_{\mathrm{trigg}}} \frac{1}{\varepsilon_{\mathrm{trigg}}} \frac{1}{\varepsilon_{\mathrm{assoc}}} \frac{\mathrm{d}^2 N_{\mathrm{pair}}^{\mathrm{raw}}}{\mathrm{d}\Delta\varphi \mathrm{d}\Delta\eta}(\Delta\varphi, \Delta\eta) \frac{1}{\varepsilon_{\mathrm{pair}}}$$

$$Y_{\Delta\varphi} = \int_{\Delta\varphi_1}^{\Delta\varphi_2} \frac{\mathrm{d}N}{\mathrm{d}\Delta\varphi} \mathrm{d}\Delta\varphi$$

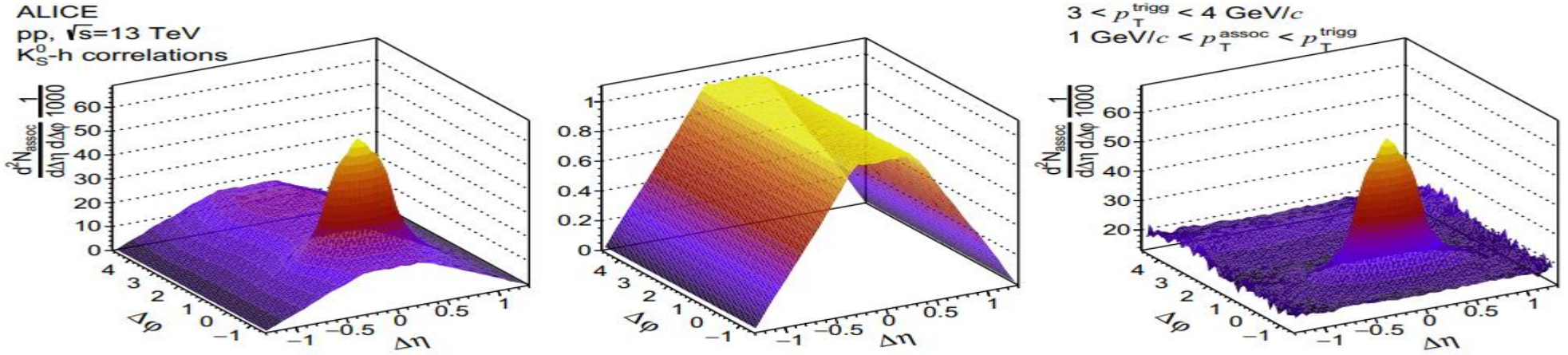
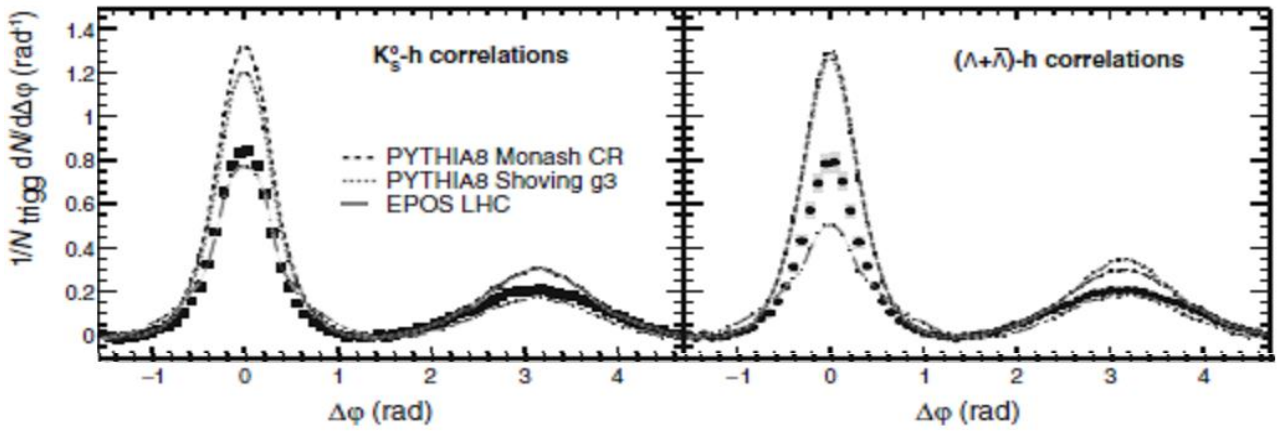
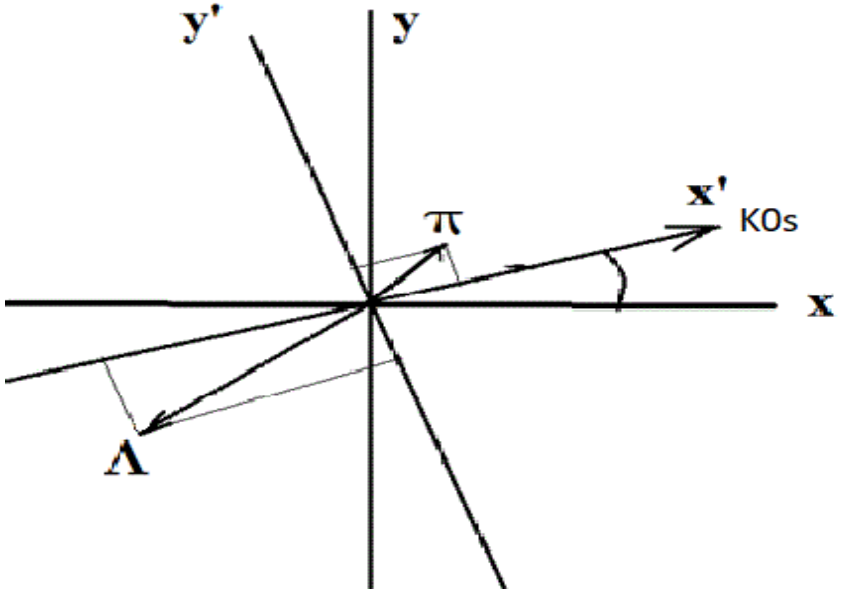


Fig. 1 An example of the raw same-event (left), mixed-event (middle) and final (mixed-event scaled, right) two-dimensional correlation function for K_S^0-hadrons. The correlation functions were scaled with 1/1000 for better visibility. The plateau in the left and middle plot is caused by non-equal selection in η of the trigger and associated particle



Exp. data on K_S^0-and (Λ anti-Λ) - hadron correlations were compared with predictions of Pythia, EPOS models.

2-Particle Pt Correlations



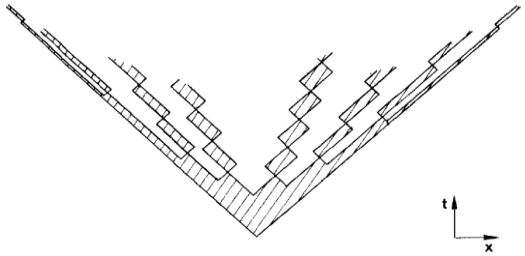
$$C(\vec{P}_{T,triger}, \vec{P}_{T,track}) = \frac{1}{N_{triger}} \frac{dN_{triger,\ track}}{d^2P_{T,triger} d^2P_{T,track}}$$

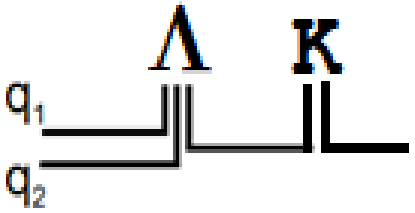
4 independent variables: $\vec{P}_{T,triger}$ and $\vec{P}_{T,track}$.

There are 3 independent variables with accounting the azimuthal symmetry – $|P_{T,triger}|$, $P_{x,track}$ and $P_{y,\ track}$

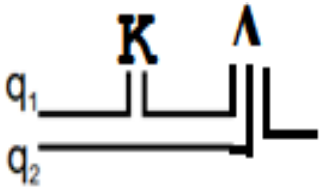
$$\exp\left(-\frac{\pi m_\perp^2}{\kappa}\right) = \exp\left(-\frac{\pi m^2}{\kappa}\right) \exp\left(-\frac{\pi p_\perp^2}{\kappa}\right)$$

The correlations are connected with Shwinger mechanism of particle production





$$\vec{P}_{T,\Lambda} = \vec{P}_{T,qq} + \vec{P}_{T,S}, \qquad \vec{P}_{T,K} = -\vec{P}_{T,\bar{S}} + \vec{P}_{T,q}$$

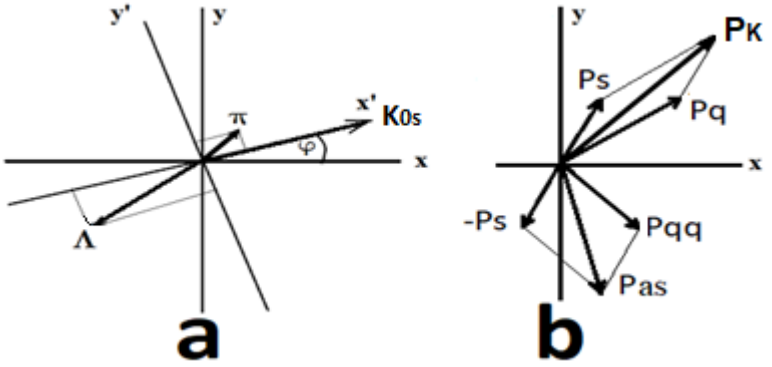


$$\vec{P}_{T,\Lambda} \cdot \vec{P}_{T,K} = -\vec{P}_{T,qq} \cdot \vec{P}_{T,\bar{S}} + \vec{P}_{T,qq} \cdot \vec{P}_{T,q} - |\vec{P}_{T,S}|^2 + \vec{P}_{T,S} \cdot \vec{P}_{T,q}$$

$$< \vec{P}_{T,\Lambda} \cdot \vec{P}_{T,K} > = \quad 0 \qquad 0 \qquad -|\vec{P}_{T,S}|^2 \qquad 0$$

Method of study 2 particle's Pt-correlations

1. We calculated 1000000 proton-proton interactions at √S=10 GeV using FTF and Pythia generators in SPDRoot version 4.1.6.1



2. We selected events with production of Ks0-mesons, and calculated:

$Cos(\varphi\_K0s) = Px\_K0s / Pt\_K0s$

$Sin(\varphi\_K0s) = Py\_K0s / Pt\_K0s$

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

$Px' = Px * Cos(\varphi\_K0s) + Py * Sin(\varphi\_K0s)$

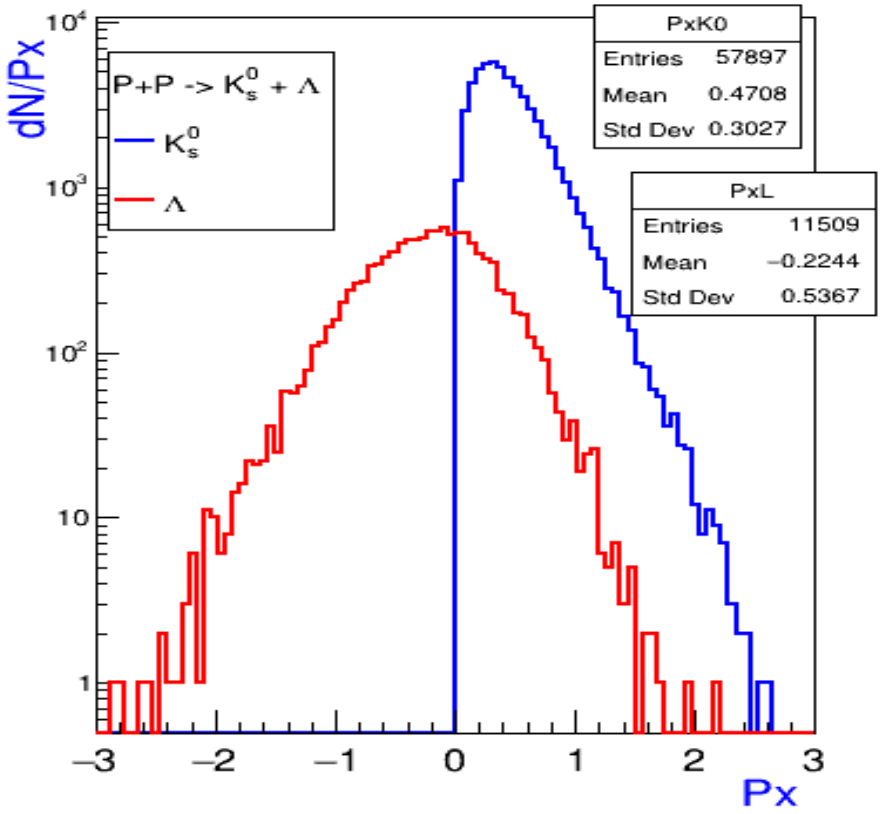
$Py' = - Px * Sin(\varphi\_K0s) + Py * Cos(\varphi\_K0s)$

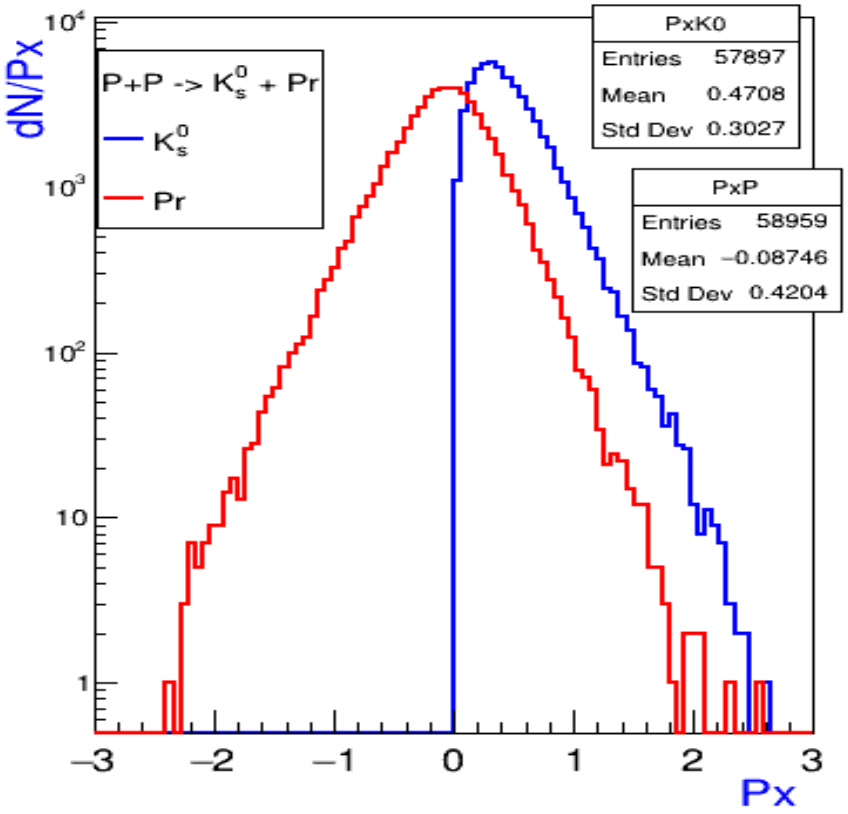
(It is obviously, that for K0s $Px'=Pt$; $Py'=0$)

4. We performed analysis of transformed Px' and Py'^2 of particles produced with K0s - mesons.

Comparison of Px' of Λ-hyperons and protons associated with K^0_s - mesons in PP- events calculated by **FTF**

<Px'_ K^0_s > = 470.8 MeV/c, N_ K^0_s = 57897



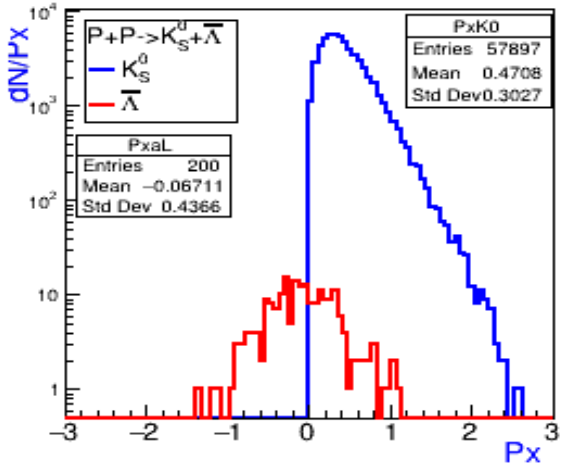


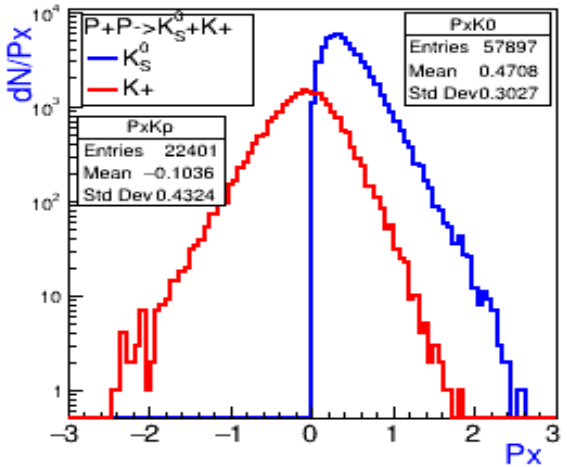
<Px'_Λ > = - 224 MeV/c, N_ Λ = 11509

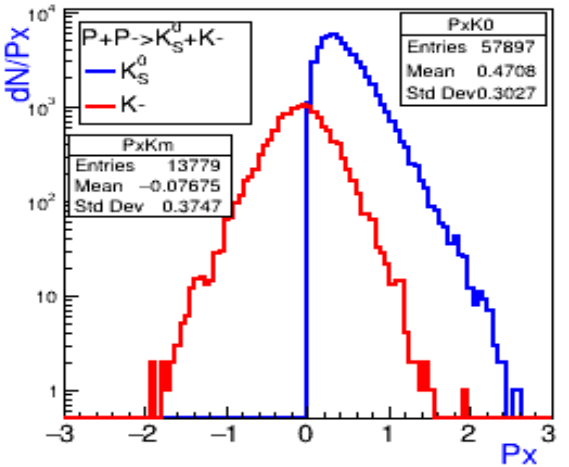
<Px'_Pr> = - 87.5 MeV/c, N_Pr = 58959

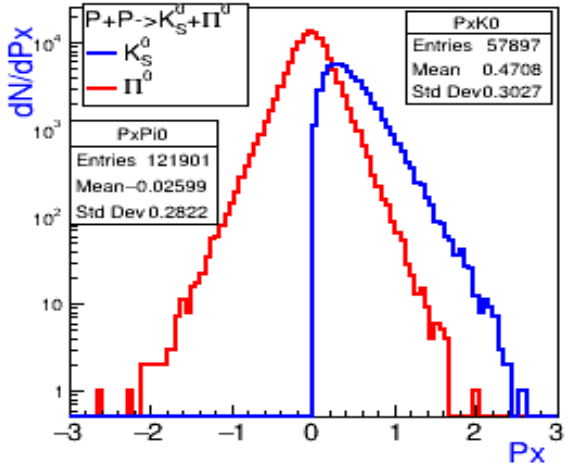
Px' of particles associated with K^0_s – meson in PP-events calculated by **FTF** generator

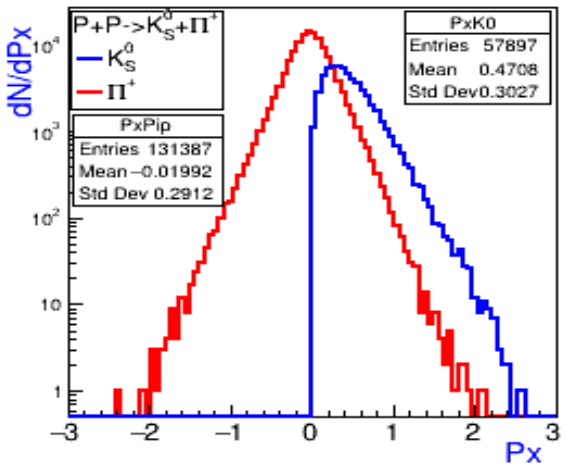
<Px' K^0_s > = 470.8 MeV/c

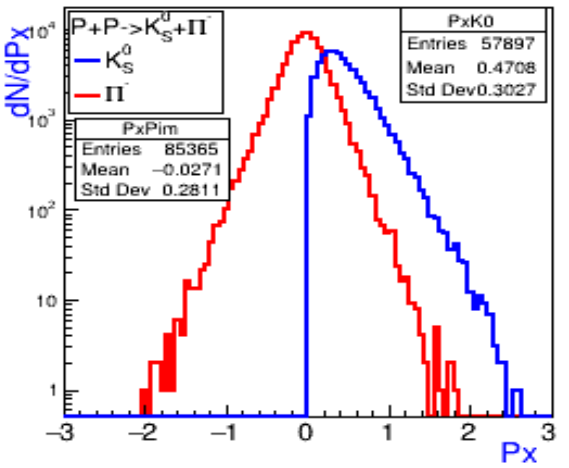








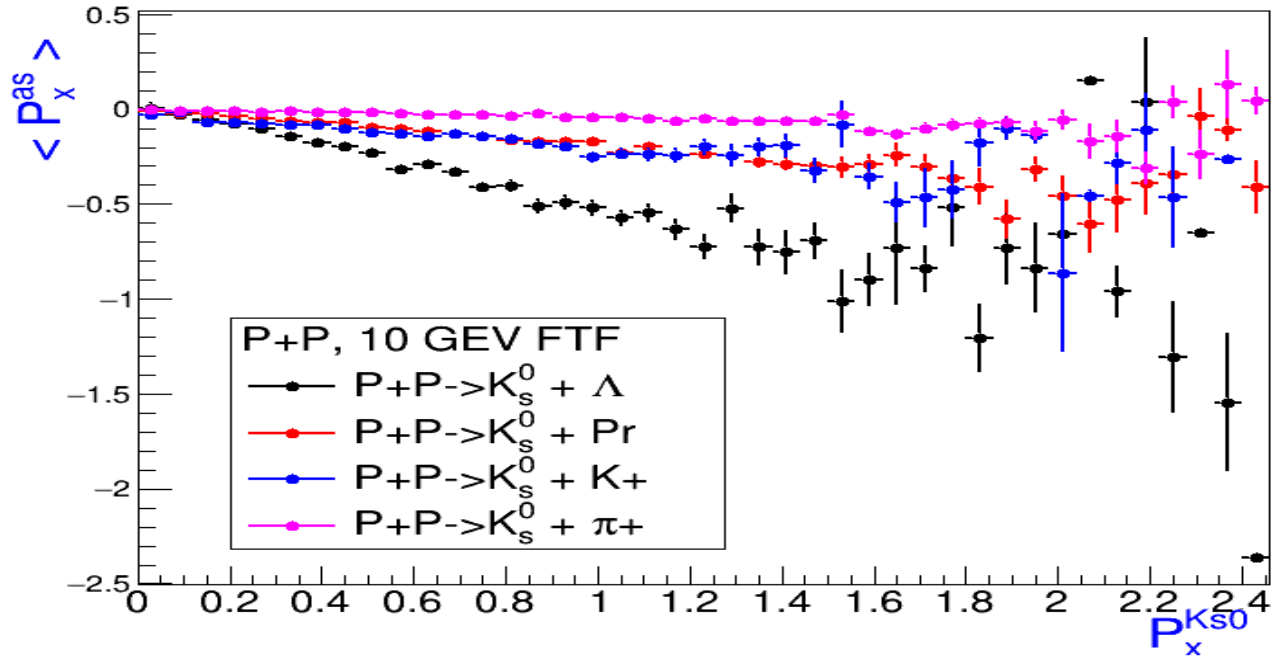




<Px'_Λbar> = -67.1 MeV/c , **<Px'_K+>=-103.6 MeV/c**, <Px'_K- > = -78.8 MeV/c

<Px'_π0> = -26 MeV/c, <Px'_π+>=-20 MeV/c, <Px'_π- > = -27 MeV/c

Correlations of mean Px' of Λ-hyperons, K+, protons and π- mesons with K^0_s – meson Px' in PP-events calculated by **FTF** and **PyTHIA**



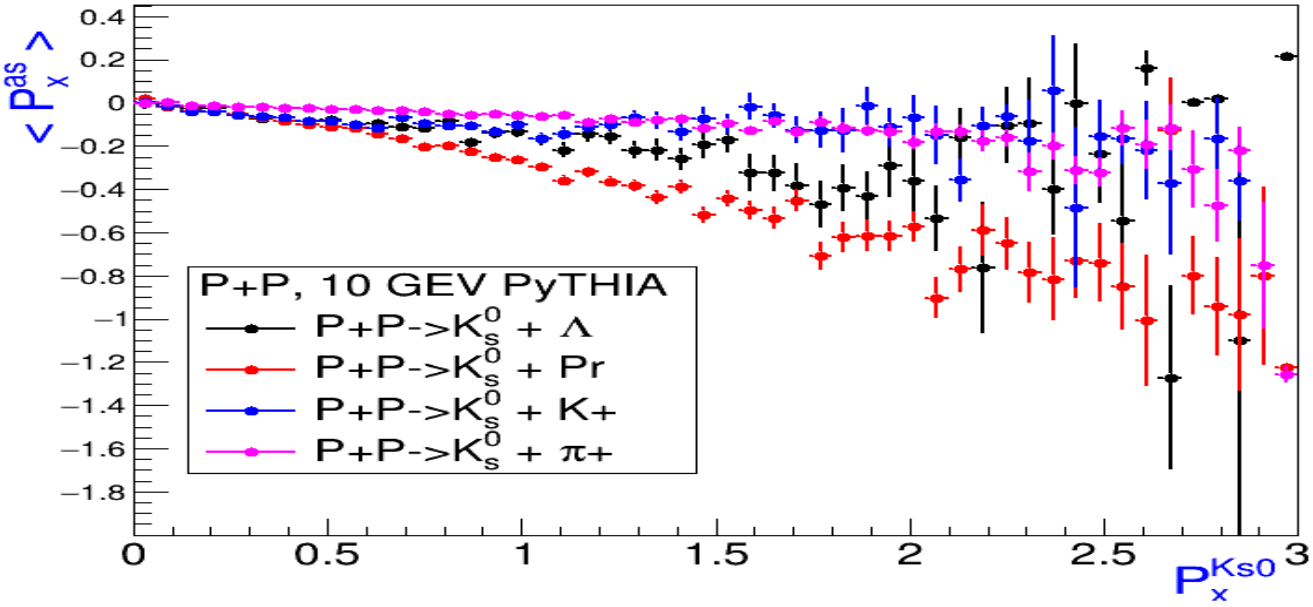
FTF

<Px'_Λ >= -224 MeV/c

<Px'_K+>=-103.6 MeV/c

<Px'Pr>= -87.5 MeV/c

<Px'_π+>= -20 MeV/c



PyTHIA

<Px'_Pr > = -128 MeV/c

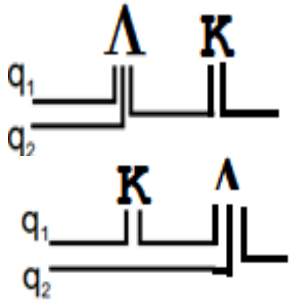
<Px'_Λ> = -87.8 MeV/c

<Px'_K+> = -74.8 MeV/c

<Px'_π+> = - 31 MeV/c

Comparison of correlations of mean Px' of Λ hyperons, protons, K-mesons and π-mesons with K^0_s – meson Px' in events calculated by **PYTHIA** and **FTF**

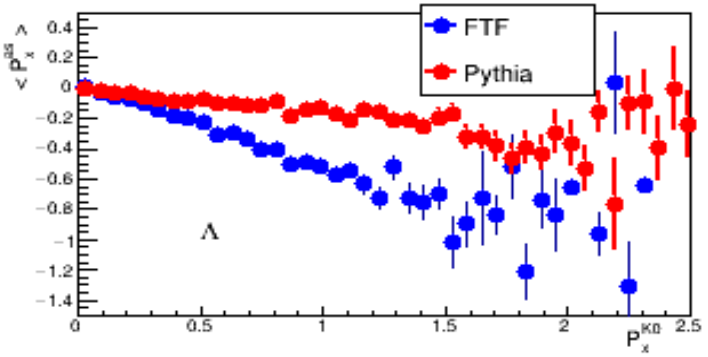
FTF

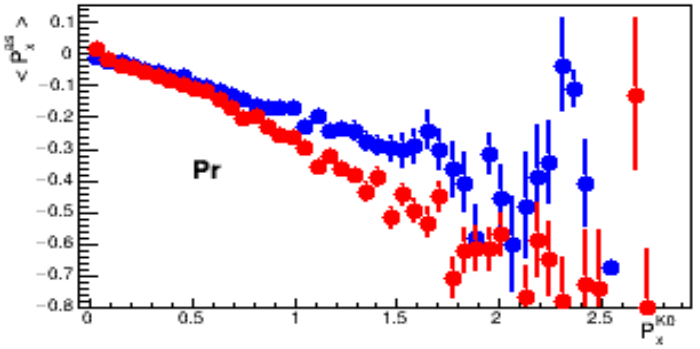


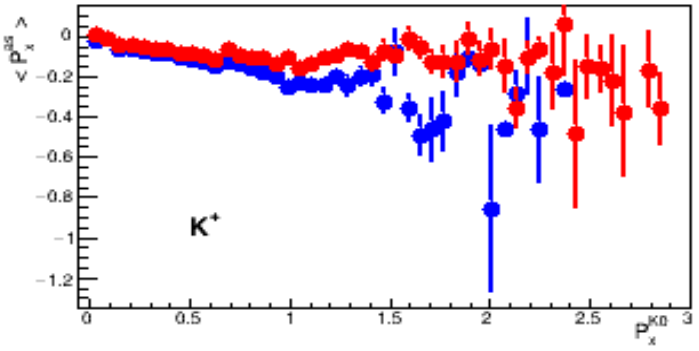
PyTHIA

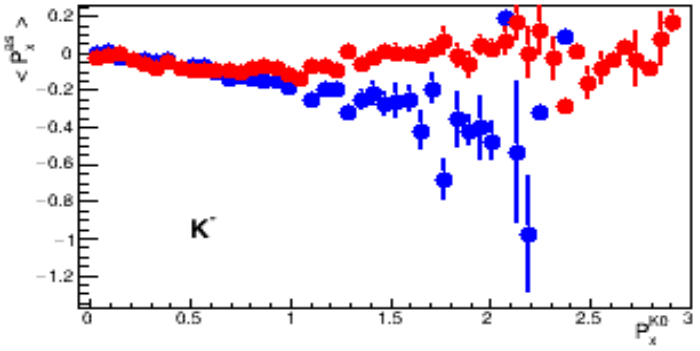
Beam reamnant fragmentation

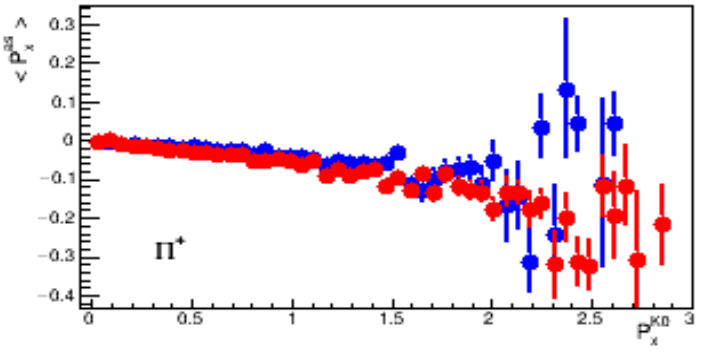
Where is truth?

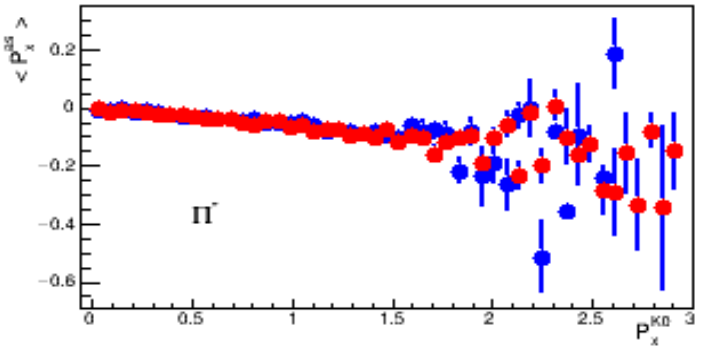




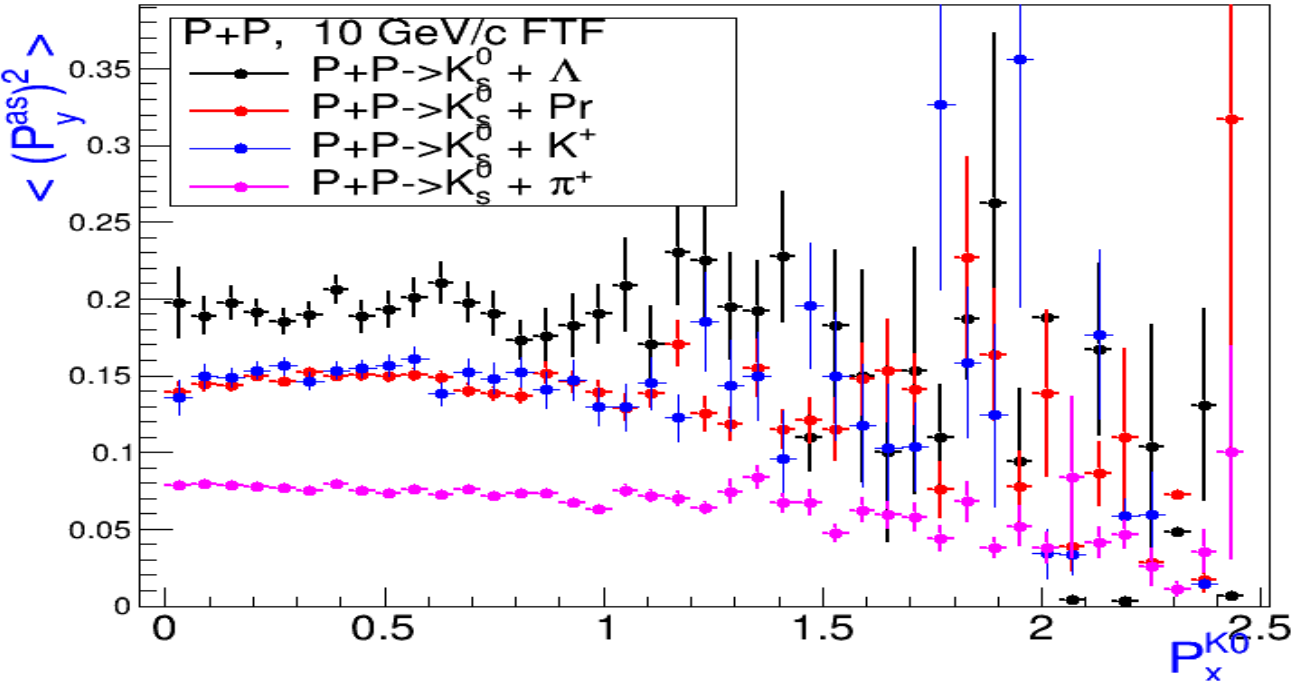








Correlations of mean Py'^2 of Λ- hyperons, protons K and π mesons with K^0_s – meson Px' in PP-events calculated by **FTF and PyTHIA**



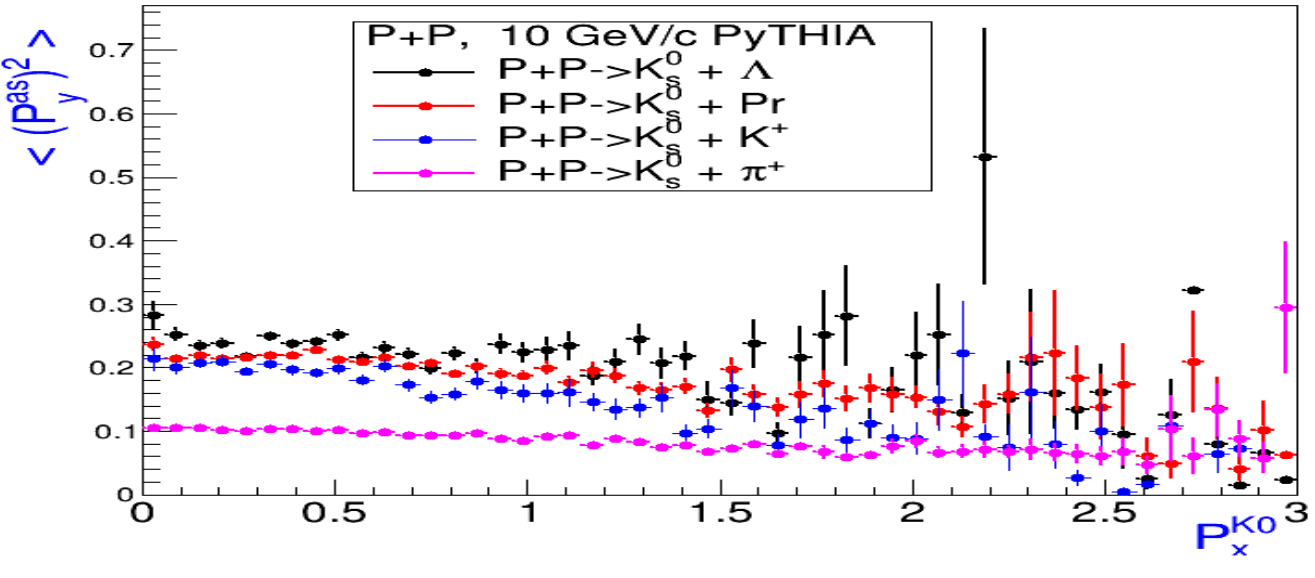
FTF

<Py'² Λ>= 193 (MeV/c)²

< Py'² K+>= 151 (MeV/c)²

<Py'² Pr>= 147(MeV/c)²

< Py'² π+>= 75 (MeV/c)²



PyTHIA

<Py'² Λ>= 232 (MeV/c)²

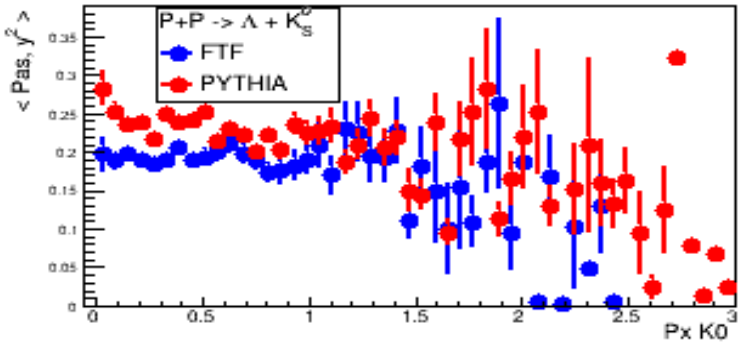
< Py'² Pr>= 211 (MeV/c)²

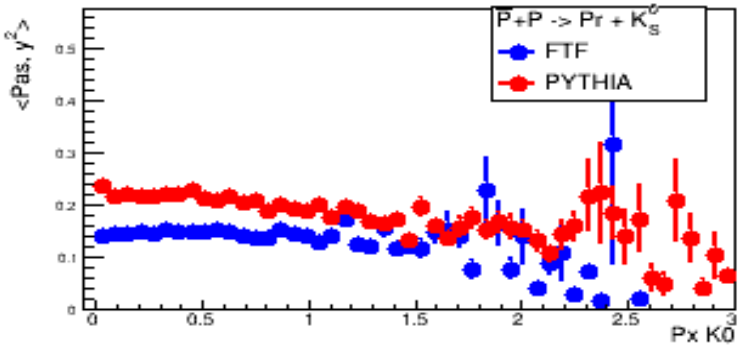
<Py'² K+>= 188 (MeV/c)²

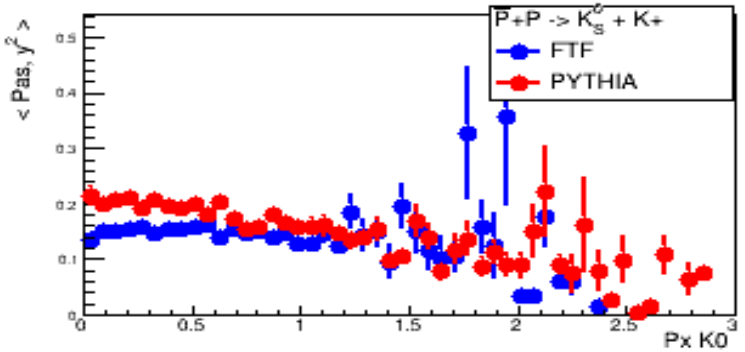
< Py'² π+>= 98 (MeV/c)²

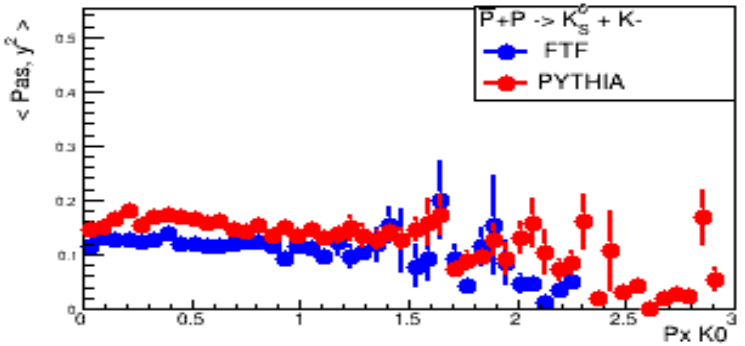
Comparison of correlations of mean Py'^2 of Λ hyperons, protons, K- and π-mesons with K^0_s – meson Px' in events calculated by FTF and PYTHIA

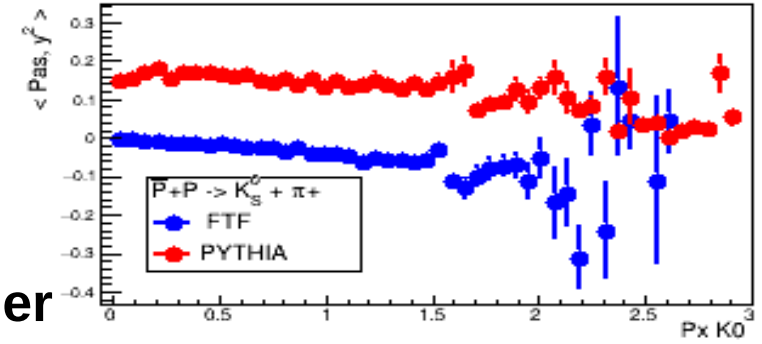
Mt scaling

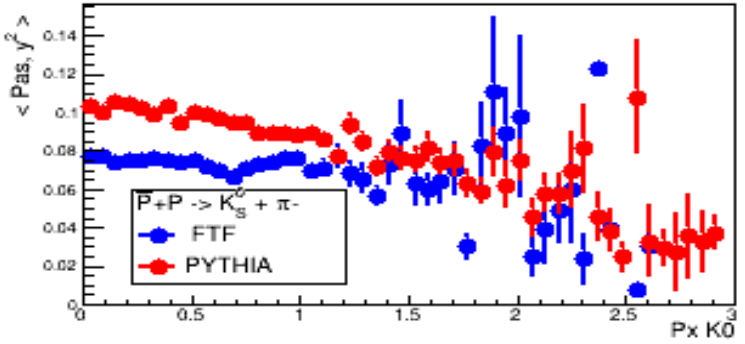












Nadine Fischer
Torbjörn Sjöstrand
Thermodynamical String Fragmentation
JHEP 1701 (2017) 140

Table of Numbers and mean values of Px' and Py'^2 of particles associated with K^0_s – meson in PP-events at $\sqrt{S}$ = 10 GeV

Gene-rator	K^0_s	Λ	K+	K-	Λbar	Proton	π+	π-	π0
FTF	N 57897	N 11509	N 22401	N 13779	N 200	N 58959	N 131387	N 85365	N 121901
Pythia	N 78850	N 28219	N 29466	N 20857	N 573	N 74571	N 201812	N 129411	N 182025
FTF	<Px> 471	<Px> -224	<Px> -104	<Px> -77	<Px> -67	<Px> -87	<Px> -30	<Px> -27	<Px> -26
Pythia	<Px> 523	<Px> -88	<Px> -75	<Px> -63	<Px> -77	<Px> -128	<Px> -31	<Px> -33	<Px> -34
FTF	$<Py^2>$ 0	$<Py^2>$ 193	$<Py^2>$ 151	$<Py^2>$ 122	$<Py^2>$ 202	$<Py^2>$ 147	$<Py^2>$ 75	$<Py^2>$ 73	$<Py^2>$ 72
Pythia	$<Py^2>$ 0	$<Py^2>$ 232	$<Py^2>$ 188	$<Py^2>$ 158	$<Py^2>$ 222	$<Py^2>$ 211	$<Py^2>$ 98	$<Py^2>$ 97	$<Py^2>$ 91

Summary

1. We observe strong 2-particle Pt correlations between K^0_s mesons and strange particles in PP interactions according to Geant4 FTF model.

2. Event generators – Pythia and Geant4 FTF give different predictions for these correlations. FTF model predicts stronger correlations between strange particles than Pythia model.

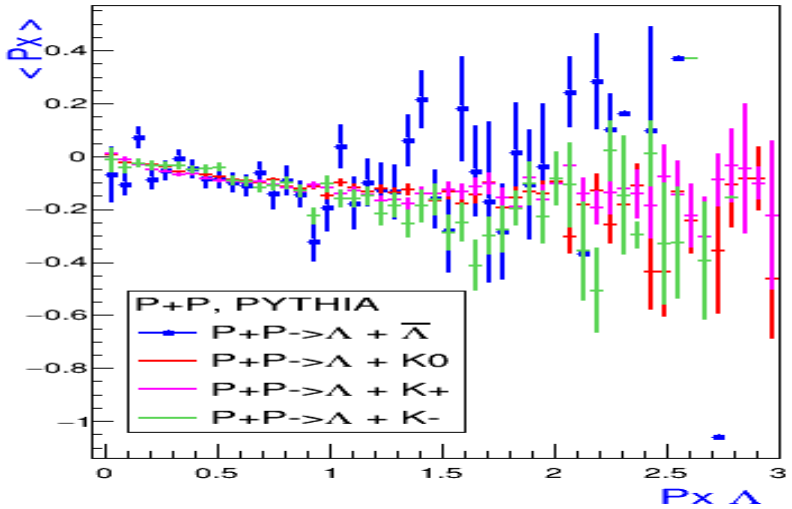
3. According to Pythia generator, 2-particle Pt correlations between K^0_s mesons and protons stronger than in FTF generator.

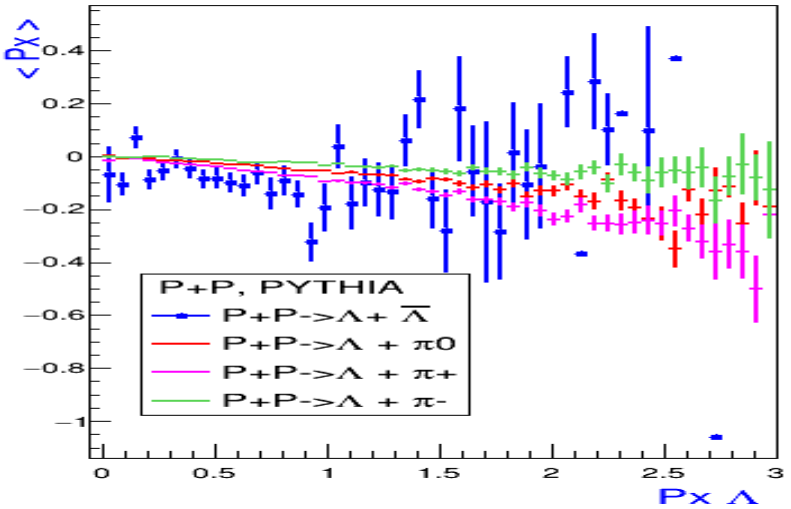
4. FTF predicts lower values of mean Py'^2 of associated particles with K^0_s mesons than PyTHIA generator.

5. The Pt correlations are connected with main assumptions of various string models used in Pythia and Geant4 FTF .

Study of correlations allows tuning and calibration of the main simulation generators -- Pythia and Geant4 in high energy physics!

Correlations of mean Px', Py'^{2} of Λ-bar hyperons, K and π mesons with Λ hyperon Px' in PP-events calculated by PYTHIA





aLY%Lam

Mt scaling

Nadine Fischer and Torbjörn Sjöstrand

Thermodynamical String Fragmenta-tion

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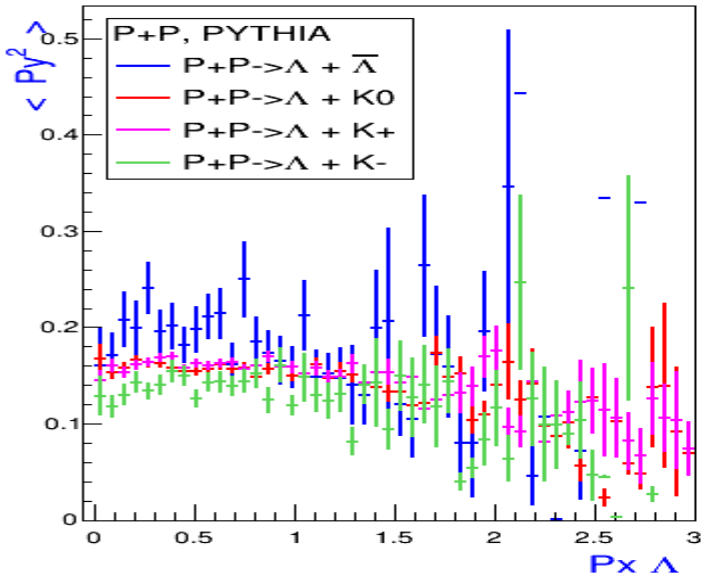
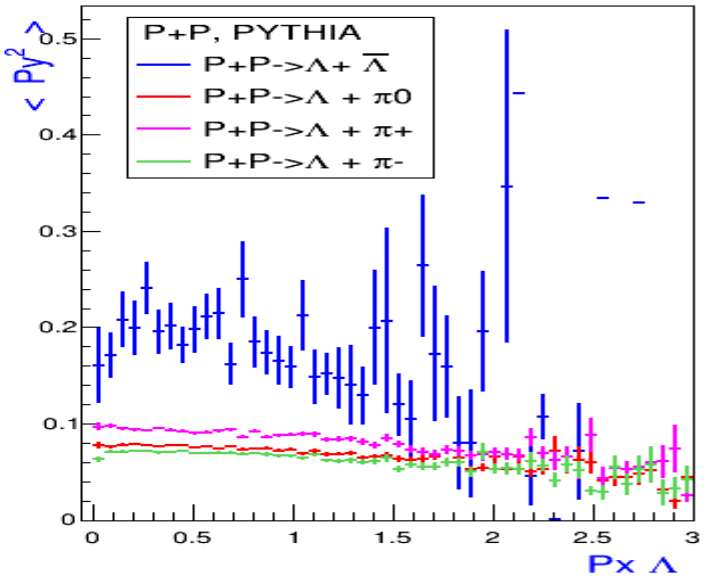
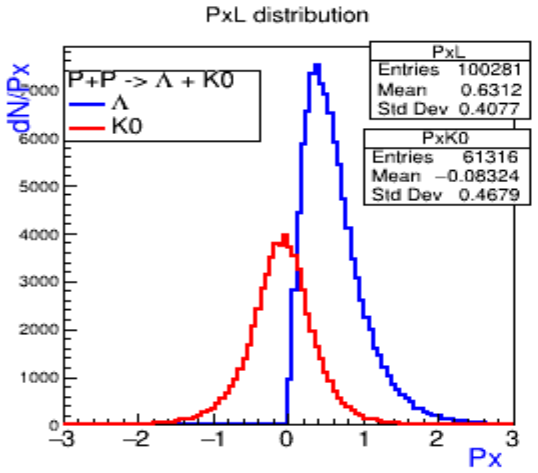


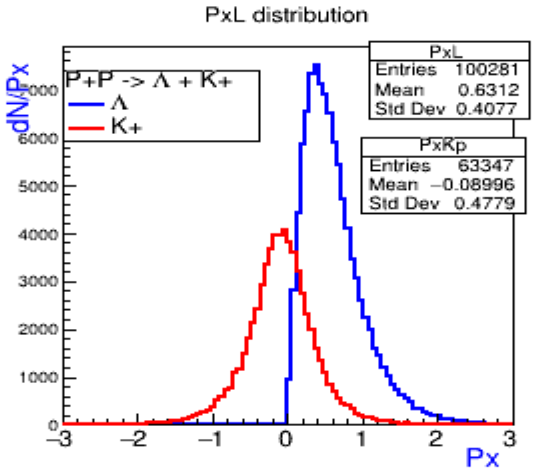


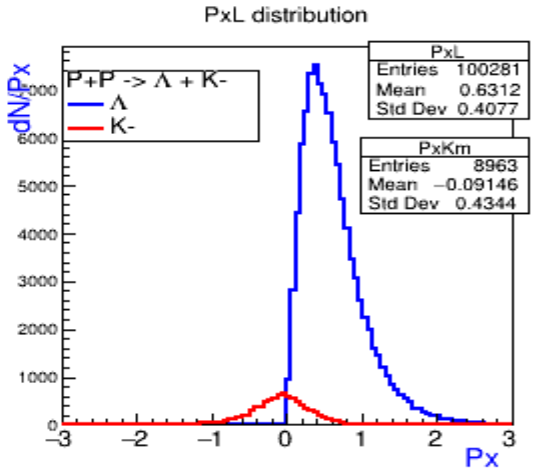
<Py'^{2} Λbar> = 193 (MeV/c)^2 <Py'^{2} K0> = 156 (MeV/c)^2 <Py'^{2} π0> = 74 (MeV/c)^2

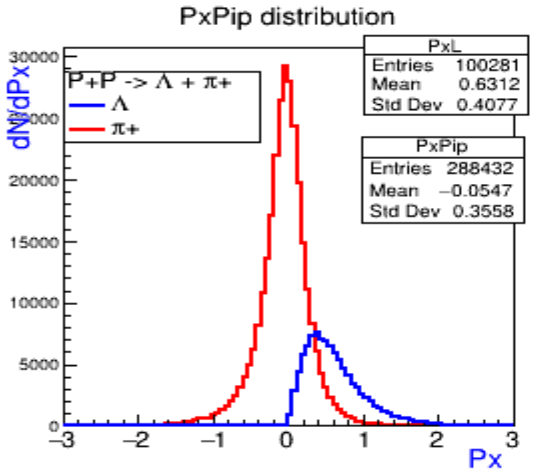
Px' of particles associated with Λ hyperons in PP- events calculated by **Pythia**

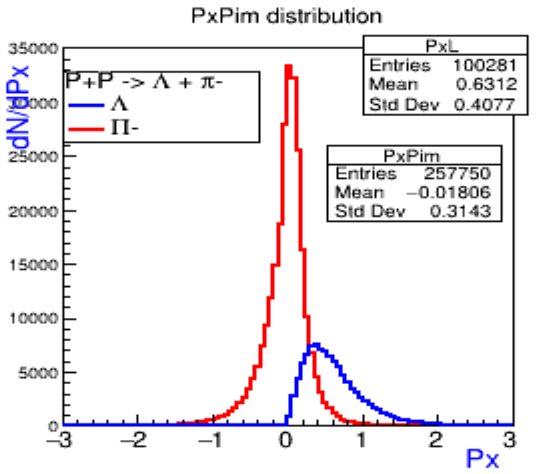
We calculated 1000000 PP-events at √S=10 GeV using Pythia in SPDRoot

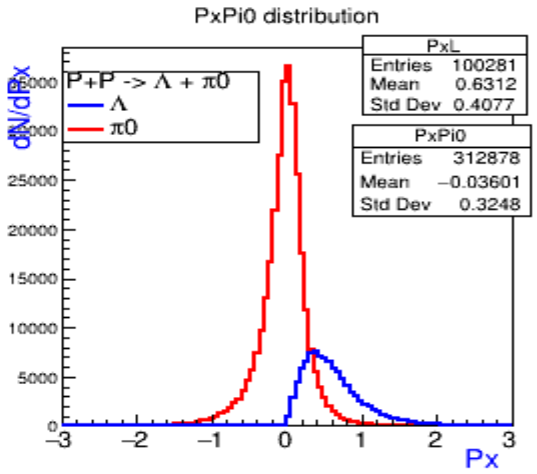










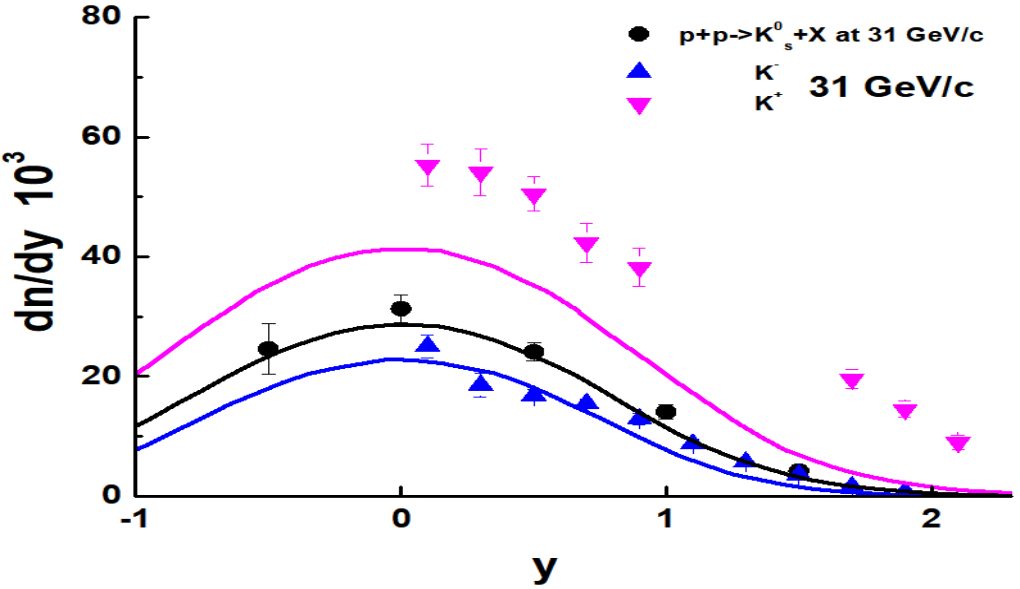


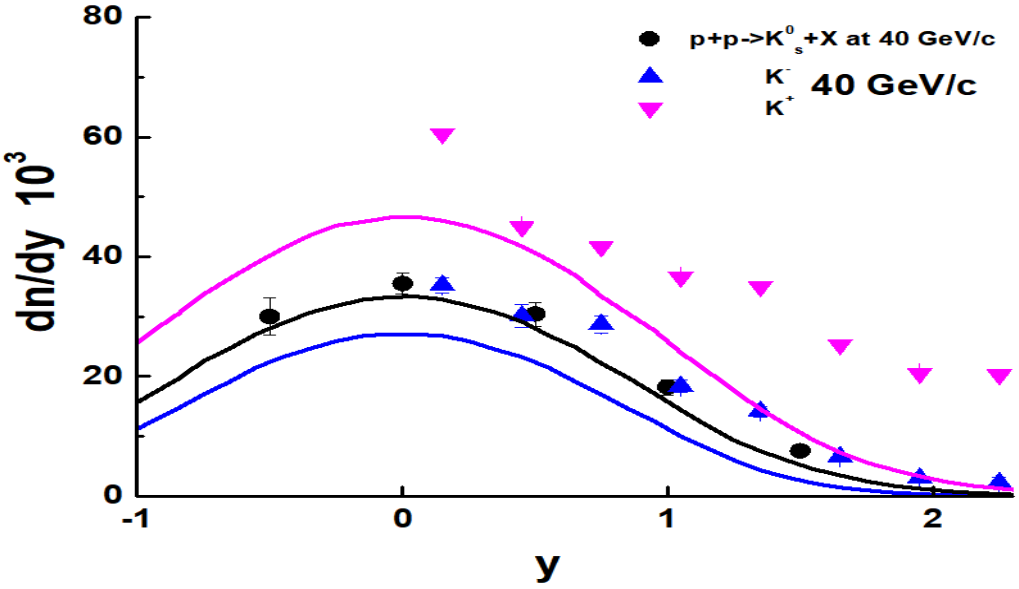
<Px'_Λ> = 613 MeV/c, N_Λ=100281; <Px'_Λbar>=-80 MeV/c, N_Λbar=2731

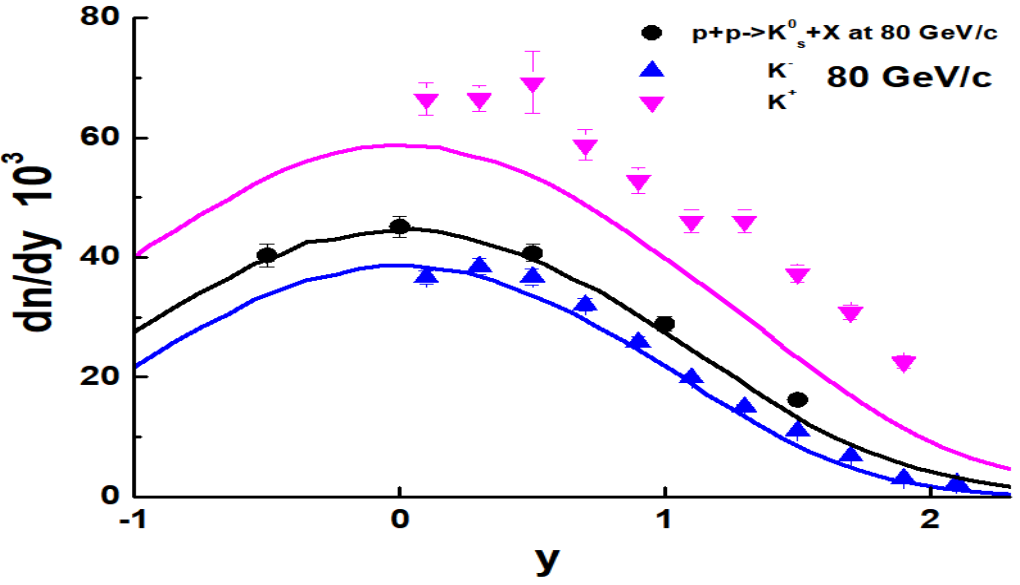
<Px'_K0> = -83 MeV/c, <Px'_K+>=-90 MeV/c, <Px'_K- > = -91 MeV/c

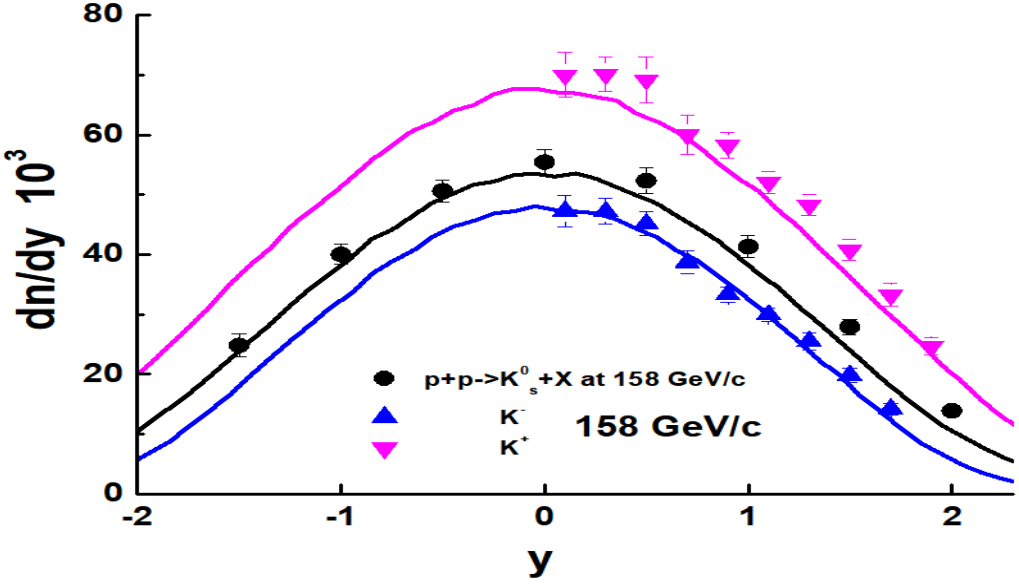
<Px'_π0> = -36 MeV/c, <Px'_π+>=-55 MeV/c, <Px'_π- > = -18 MeV/c

K+, K- and K0s in FTF model









All O.K. with K0s. K- ~ O.K. There is exp. problem with K+!