STAR–Note # 72
S. Margetis, W. Wilson, W. Christie, G. Odyniec
June 1992

Strangeness in STAR – an Update

1 Introduction

This note is an update on the most recent developments on simulations concerning the reconstruction of strange particles in STAR's central tracking detectors (SVT and TPC). The motivation of these simulations can be found in [1–3] and the references therein.

For central Au + Au events, the most challenging events we expect, the overall track reconstruction efficiency (which includes both finding and accurate track parameter determination) is a very critical parameter in the strangeness program.

Recently, a TPC pad response program (FaST_SIMULATOR)[5] was included in the simulation chain, and more realistic detector parameters (i.e. spatial resolution, geometry) were implemented. The impact of these changes on the strangeness program and some information concerning the simulation chain is addressed in this note,.

2 The simulation chain

We give below an update on the structure of the simulation chain. We will first briefly discuss the structure of the chain which produced the preliminary results reported in [2] and [4].

- Events generated by **FRITIOF** were tracked in **GEANT**. The SVT was represented as 3 cylindrical layers of 300 μm of silicon, 50 cm long ($|\eta| \leq 2$), at a radial distance of 5, 8 and 11 cm. The beam pipe was assumed to be 1 mm of Be. The position of the vertex was fixed in GEANT (no diamond).
- The hits produced by GEANT were then preprocessed by a routine and only tracks that reached the TPC were considered. This is equal to a low p_T cut of about 40 MeV/c. At the same time the position resolution of the detectors was used to smear the hit coordinates. The SVT was assumed to have 25 μm sigma and the TPC 250 μm. The assumed momentum resolution dp/p was 0% for the K^0_S and Λ program [2] and 1.1% for the Ξ^- program [4]. In the latter case some finite angular resolution was also imposed in every track[1], although this was a small effect. Another characteristic of this set of tracks was the absence of information concerning the goodness of the track (χ^2, or covariant matrix) since GEANT momentum information was used and not fitted hits.

[1]Two SVT hits (after smearing with the SVT position resolution) were used to calculate the two angles of the helix.

- The reconstruction routines assumed 100% efficiency in determining the PID of the particles (dE/dx, TOF)[2]. Also 100% track reconstruction efficiency in the TPC and matching efficiency between the TPC and SVT hits was assumed.

- In the V_0 program a pre–selection of tracks was performed based on their impact parameter from the main vertex. This was not the case with the Ξ^- program since a similar cut had the same effect.

We list below the recent developments in the simulation chain:

- The TPC and also the SVT geometry are close to the proposed arrangement, and, especially for the SVT, support structures and dead areas are incorporated.

- The TPC parameters have been updated and a TPC pad response program interfaces GEANT to the pattern–recognition routines [5].

- Since we only use tracks which are found and fitted by the pattern recognition programs the TPC track reconstruction efficiency and resolution is automatically folded into the simulation.

Fig. 1 shows the flow chart of the simulation chain. The matching routine, the SVT simulator and SVT tracking are still under development [6]. A couple of simple routines replaced the matcher (assuming 100% matching efficiency) and the SVT simulator (only an overall position resolution of 25 μm was applied to the SVT hits). When combining the TPC and the SVT information, the tracks were refitted with the SVT hits.

3 The reconstruction chain

We describe below the main steps of the reconstruction algorithm:

- For any *pair* of tracks in an event a routine checks for a common vertex. This is done by checking the distance between them at the point of the closest approach. If the 3-D distance (r_C) between the tracks at that point is greater than a certain value the pair is rejected.

- The next check is the distance (r_D) between the secondary vertex and the main vertex (the main vertex position assumed to be known with infinite accuracy). The decay vertex has to be beyond a certain distance. This avoids the very large number of random crossings close to the main vertex.

- Then an invariant mass analysis is performed which returns the mass and the three momentum components of the parent particle.

[2]These PID ambiguities can be resolved with techniques which are based on the different decay kinematics between i.e. K^0_S's and Λ's.

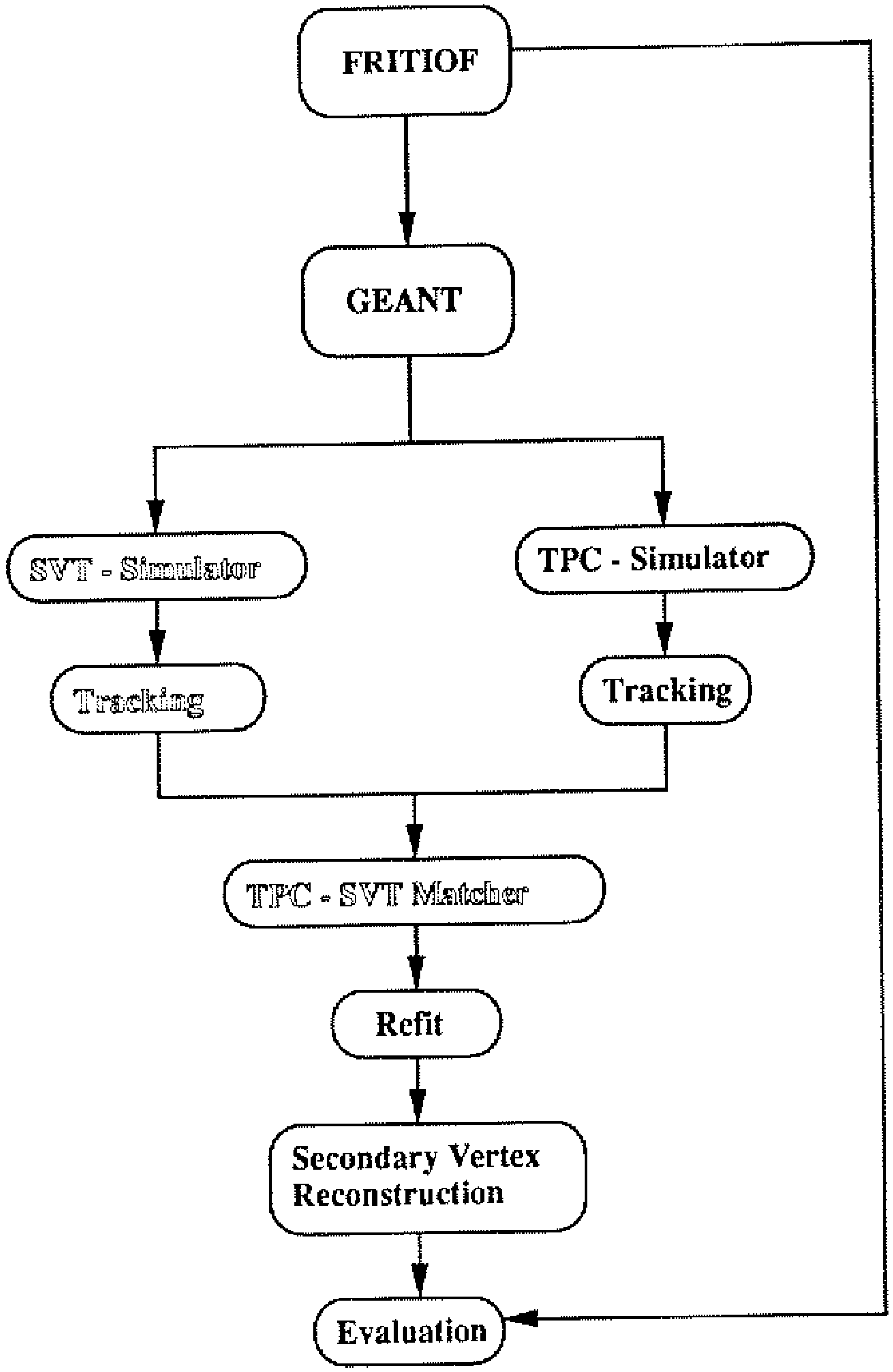

Figure 1: A simplified diagram of the simulation chain for flavor physics.

- A final test is then performed by requiring the parent particle to emanate from the main vertex. The impact parameter (r_{min}) of the parent has to be less than a cut value.

The following table is a compilation of the different test cut values used in this analysis.

Cut (cm)	K^0_S	Λ	$\overline{\Lambda}$
r_C	0.15	0.20	0.20
r_D	1.00	1.50	2.50
r_{min}	0.15	0.20	0.15

Table 1: The space cuts in the analysis program.

4 The RHIC environment

The multiplicities at RHIC will be a challenge for every current detector technique. About half of the 8000 produced particles in a central Au+Au event are seen by the central set of tracking detectors which are located around mid-rapidity. Therefore, for strange particles which are less numerous, the combinatorial background is suspected to be high. Table 2 gives the FRITIOF data rates for the particles we are interested in, together with some decay parameters. The pion multiplicity is given as a reference. In a collider experiment there is no significant Lorentz boost around mid-rapidity (if any). Therefore:

- The mean momentum of most of the decay particles is well below 1 GeV (Figures 2 and 3).
- Multiple Coulomb scattering (MCS) is not negligible.
- Most of the strange particles decay very close to the main vertex (Figures 4a and b).

These simple facts, combined with the very high track density around the main vertex, result in very stringent requirements concerning the track by track impact parameter resolution (extrapolation accuracy).

Consider the V_0 particles as an example with mean life times between 3 and 8 cm. Figures 4a, b show the distribution of the decay distance from the vertex for a set of K^0_S and Λ particles in STAR's acceptance. It is obvious that in order to recover a sizeable fraction of the signal one has to resolve secondary vertices which are very

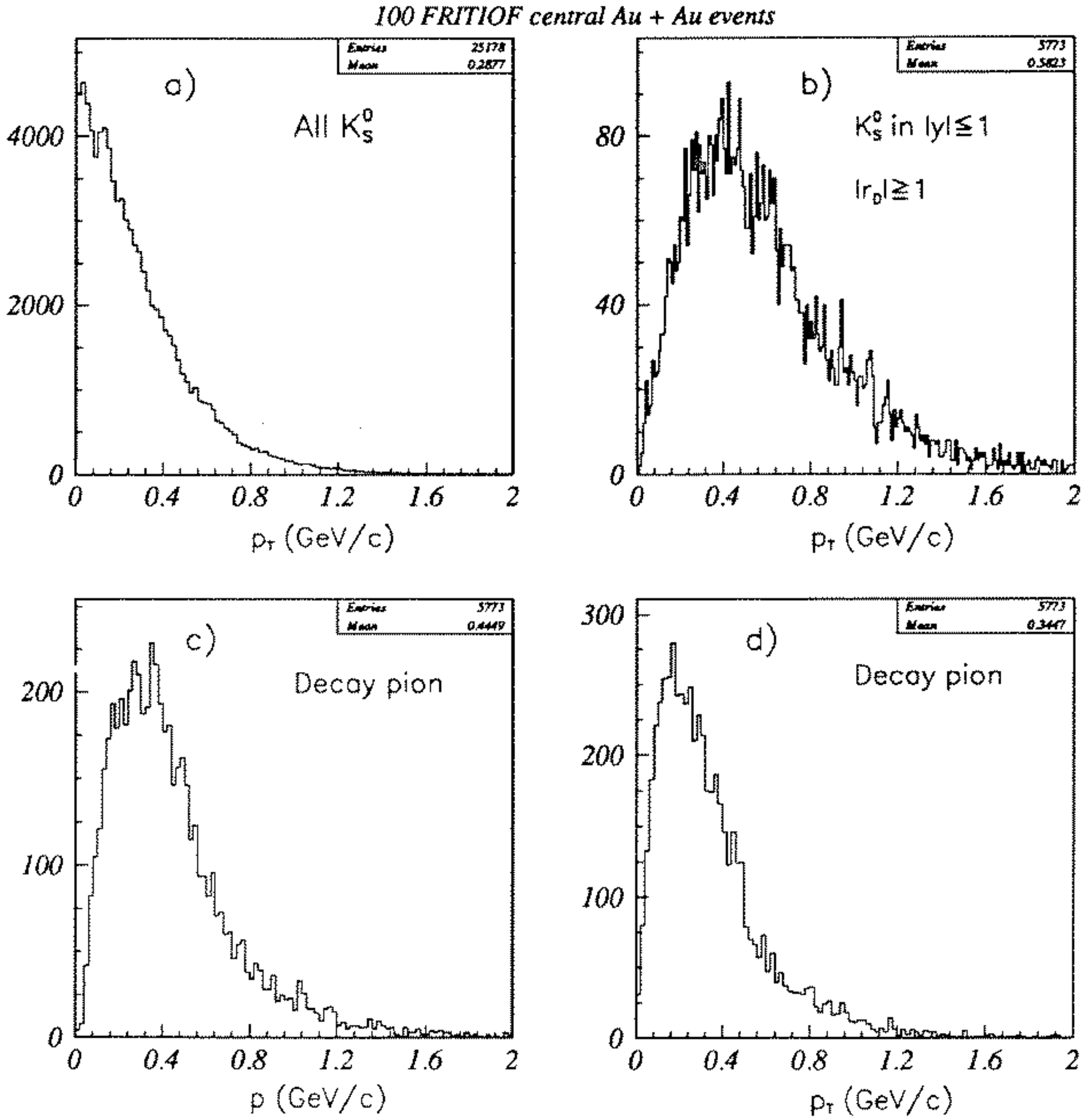

Figure 2: Decay characteristics of K_S^0. In a) the 4π p_T spectrum; in b) the p_T spectrum for K_S^0 with $|y| \leq 1$ and decay length more than 1 cm. The decay pion spectra in c) and d) come from the K_S^0 's in b).

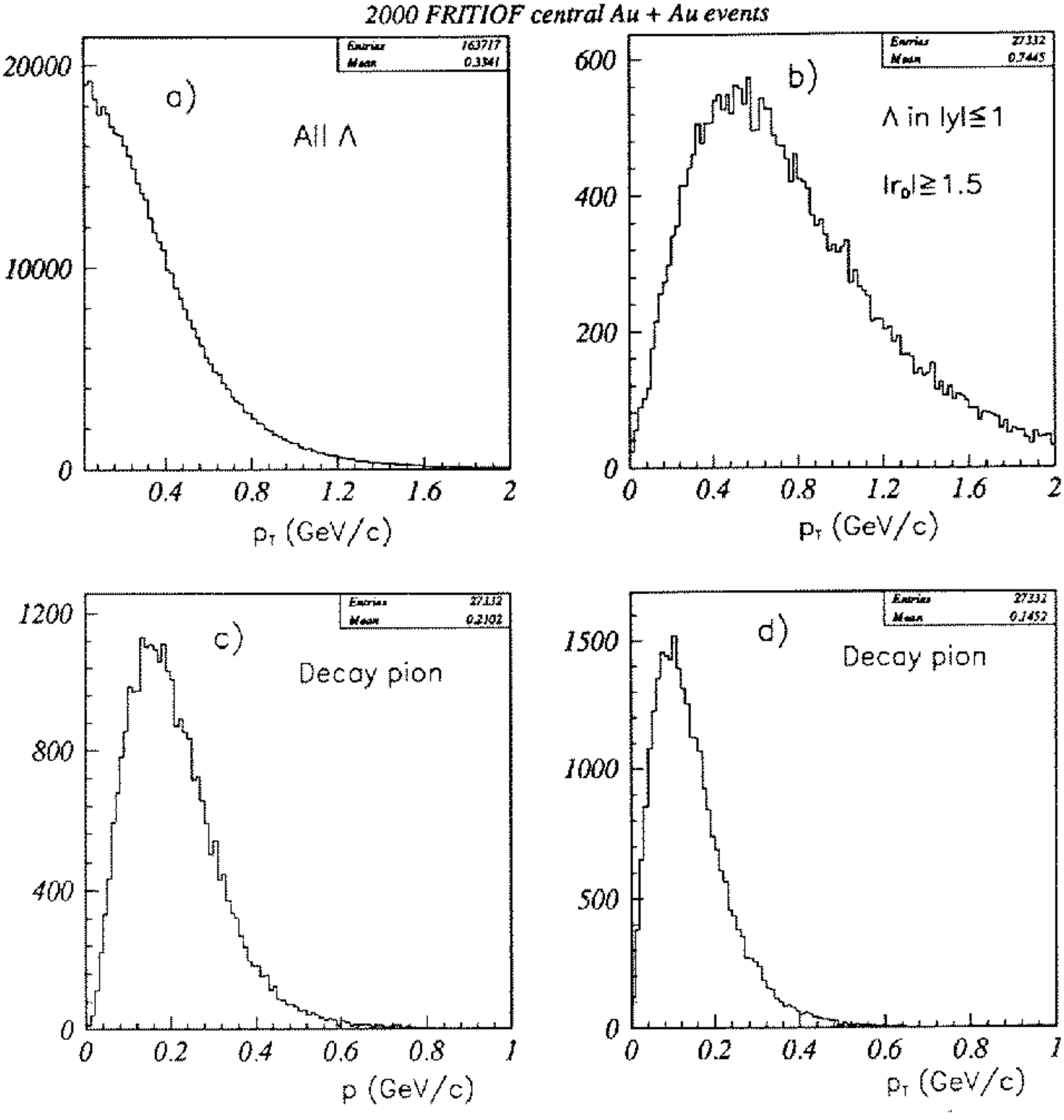

Figure 3: Decay characteristics of Λ 's. In a) the 4π p_T spectrum; in b) the p_T spectrum for Λ 's with $|y| \leq 1$ and decay length more than 1.5 cm. The decay pion spectra in c) and d) come from the Λ 's in b).

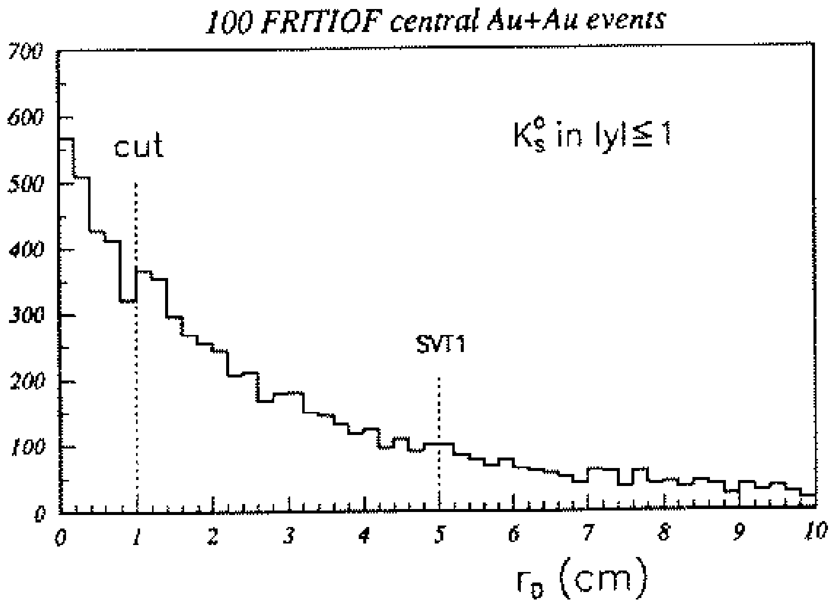

Figure 4: Decay distance from the vertex for K^0_S particles.

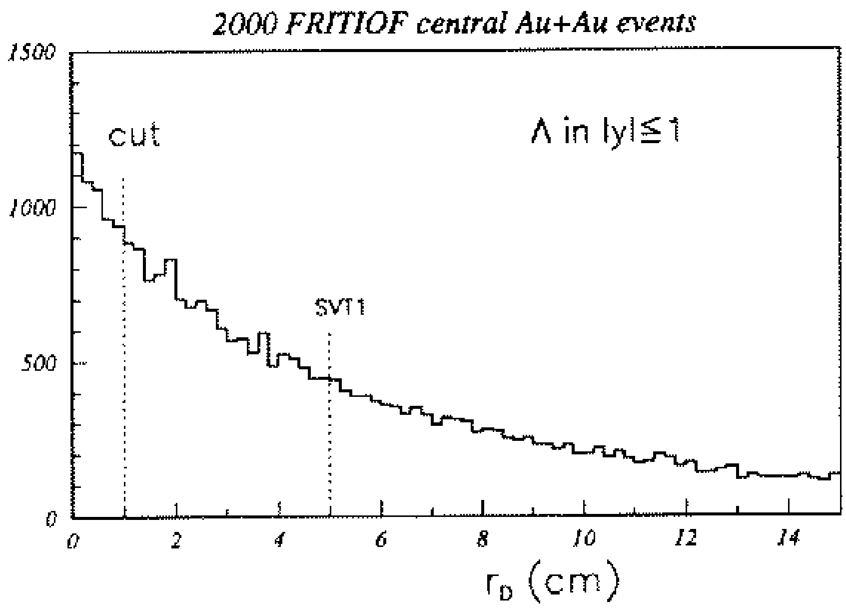

Figure 5: Decay distance from the vertex for Λ's.

particle	#/event	mass (GeV)	dominant decay mode (%)	$c\tau$ (cm)
π^-	2200	0.1396		
K^0_S	230	0.4977	$\pi^+\pi^-$ (68.6)	2.7
Λ	60	1.1156	$p\pi^-$ (64.1)	7.9
$\overline{\Lambda}$	35	1.1156	$\overline{p}\pi^+$ (64.1)	7.9
Ξ^-	3–4	1.3213	$\Lambda\pi^-$ (100.)	4.9
$\overline{\Xi}^-$	3	1.3213	$\overline{\Lambda}\pi^+$ (100.)	4.9

Table 2: FRITIOF (4π) predictions for the average central Au+Au event. The negative pion multiplicity is given as a reference.

close to the main vertex (a couple of centimeters). The hit density (ρ) in the first layer of the SVT (5 cm from the beam) for a central Au+Au event would be about 4 hits/cm^2 [7]. It scales as $\rho_{r2} = (r_1^2/r_2^2)\rho_{r1}$ and at a distance of e.g. 1 cm from the main vertex the mean distance between tracks ($< dr >= 1/\sqrt{\rho}$) is about 1 millimeter. The impact parameter resolution has to be comparable to this number.

Let us see how this compares with the abilities of the two detectors, the SVT and the TPC. Since the SVT is located much closer to the main vertex, it already has a big advantage over the TPC which has to extrapolate every track over a distance of about 0.5 meter. The SVT has to extrapolate to distances up to its inner–layer distance which is 2–5 cm. Assuming correct matching of hits that belong to the same track, we have a conservative estimate for the impact parameter resolution of the SVT which is 100 μm. Resolving secondary vertices is therefore not a problem with the SVT.

For just the TPC, on the other hand, a small error in the determination of the momentum of a track in the TPC is going to be dramatically magnified by the time the track is extrapolated to the vertex. By also taking into account the effect of MCS, is seems very hard to achieve the millimeter accuracy required[3].

5 Results–Discussion

In this section we present results for a sample of 10 central Au+Au events.

Figure 5a shows the invariant mass spectrum of all K^0_S candidates. The cuts used are listed in Table 1. The cuts were optimized in such a way that they maximize the signal to background ratio. The algorithm allows a track to participate in many candidates. We observe a large combinatorial background around the threshold ($2m_\pi = 279.1$ MeV), which drops quickly as the mass increases, and around the

[3]Compare also with Fig. 4.C.3.13 in CDR (track impact parameter distribution with TPC).

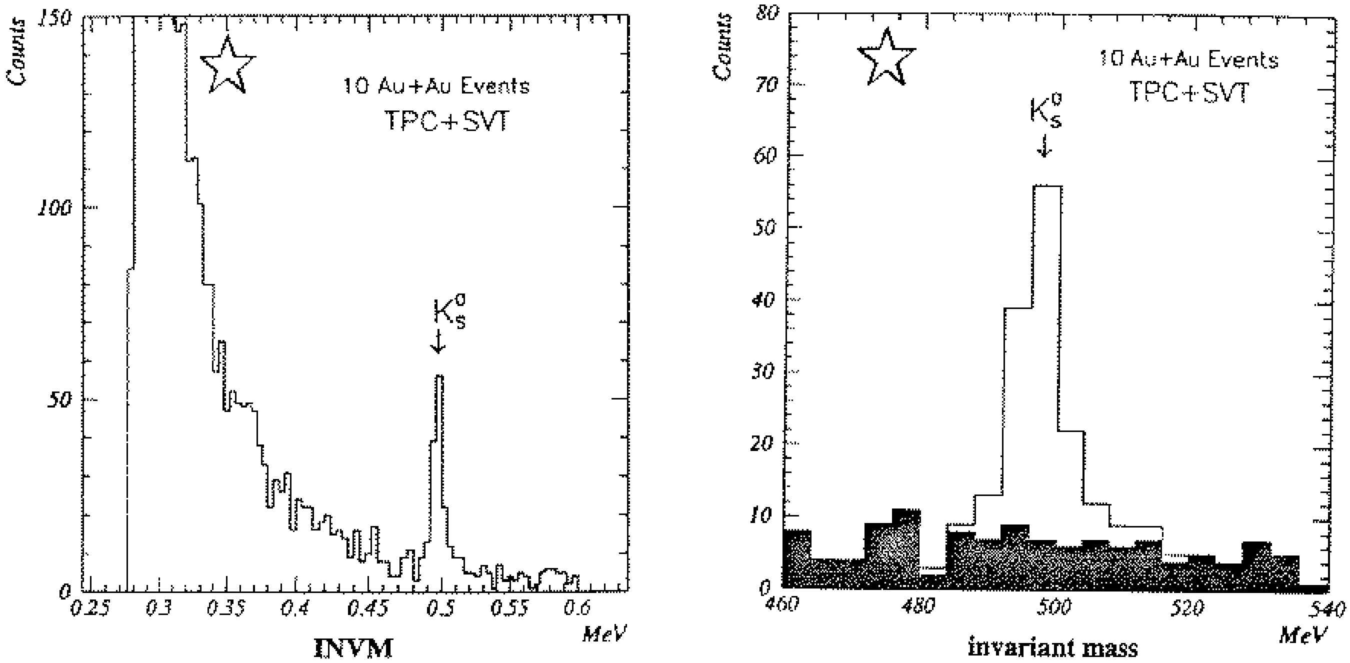

Figure 6: Invariant mass distribution for K^0_S.

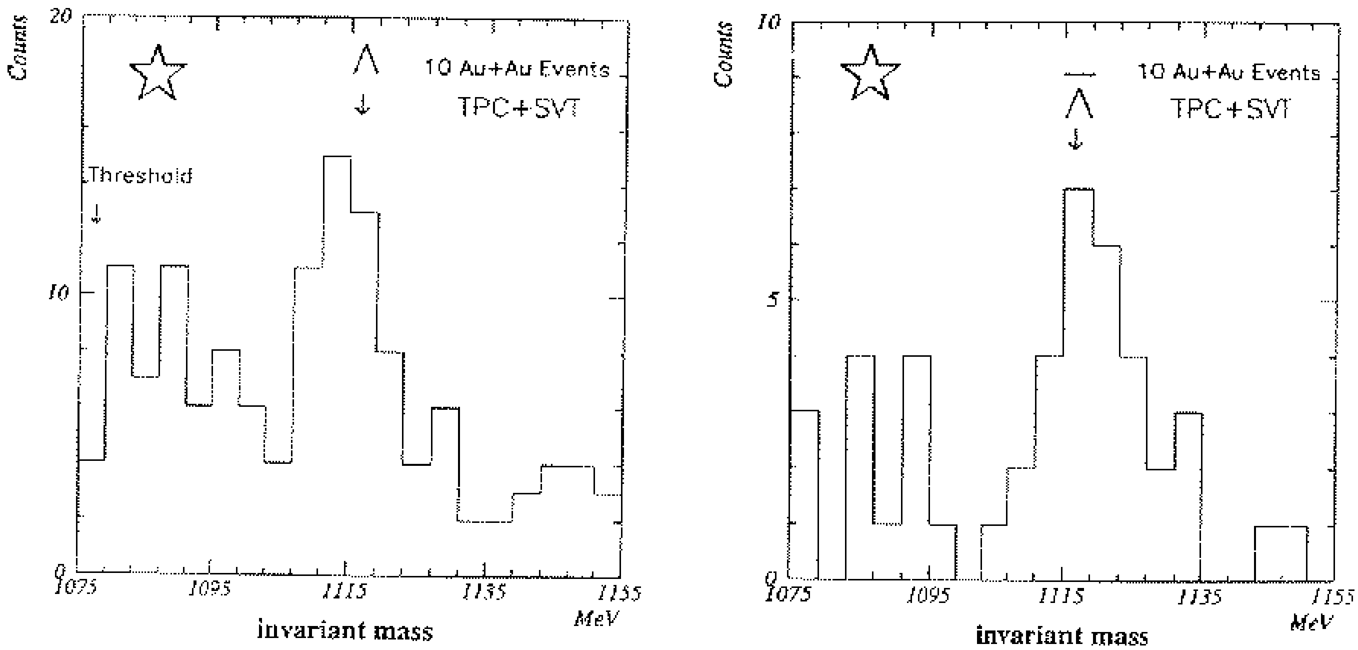

Figure 7: Invariant mass distribution for Λ 's and $\overline{\Lambda}$'s.

K^0_S mass (Fig. 5b) is at the level of a few counts(shaded histogram). The width of the reconstructed signal is ≈ 4 MeV which is due to the systematic resolutions of the detectors. About 15 K^0_S are reconstructed in every central Au+Au event out of about 40–50 potentially reconstructible (Fig. 2b). The difference is mainly due to the branching ratio (68.6%) and the limited tracking efficiency of the TPC for soft pions (Fig.2c, d). It seems that a sample of a few hundred central Au+Au events will be sufficient for an estimation of the production cross section of K^0_S.

It was found that we cover $\pm$ 1 unit of rapidity around mid–rapidity. This is because the probability that one of the decay particles escapes the STAR acceptance is very high for high rapidity K^0_S 's[4]. We also observed that K^0_S with transverse momentum below 500 MeV are hardly reconstructed. This is because most of them decay within the cut–volume around the vertex, and also because of the particular decay kinematics (slow secondaries, large decay angles etc.).

A first attempt to reconstruct K^0_S particle with the TPC information only (by ignoring the SVT hits) was not successful (see Fig. 8). It is possible that a larger sample of events might allow for some better optimization of the cut parameters.

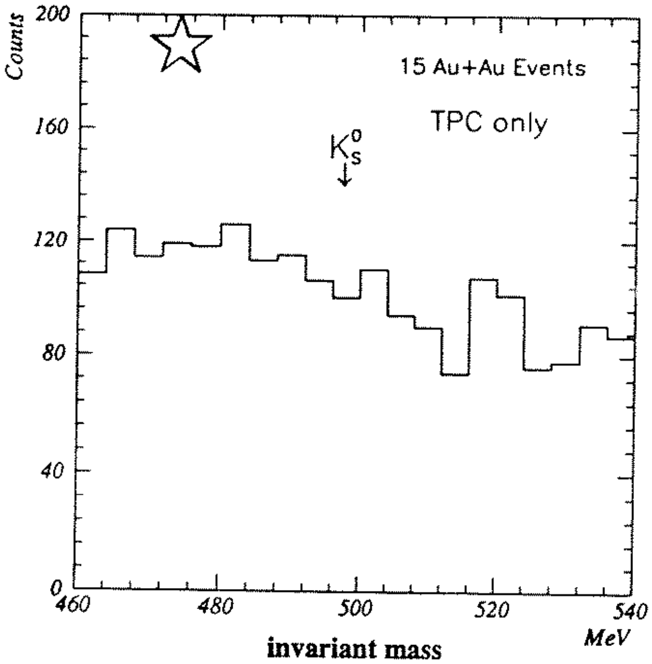

Figure 8: Invariant mass distribution for K^0_S particles with the TPC.

The invariant mass distribution for Λ's is shown in Fig. 6. and for $\overline{\Lambda}$'s in Fig. 7. A factor of ten is needed in statistics in order to have a picture comparable to the K^0_S one. The width of the reconstructed signals is ≈ 2.5 MeV in both cases. We observe that the width of the K^0_S distribution is almost double the width for the Λ 's. This is because K^0_S is a relatively light particle and the sigma of the invariant mass scales, among other things, as 1/(inv.mass).

[4]This "edge" effect has a definite impact on the minimum length of SVT required for a given rapidity coverage.

Because of the statistics we are not yet in a position to make any comments about the Ξ particles.

6 Acknowledgement

The authors would like to thank the following people for their contribution to this work. D. Cebra, P. Jones, R. Morse and I. Sakrejda.

References

[1] G. Odyniec et al., LBL–31773

[2] The STAR Coll., LBL–29651; STAR ULOI, LBL–31040

[3] D. Keane, STAR–Note #47

[4] Proceedings of STAR Coll. meeting, BNL Nov. 1991

[5] P. Jones et al., STAR–Note #33, #34, #56 ;

[6] W. Wilson, STAR–SVT Note #2–92

[7] W. Christie, STAR Note # 15