Onset of Neutral Strange Particle Reconstruction Including the SSD

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Abstract

Results of neutral strange particle reconstruction are presented. STAR capabilities for measuring strangeness in Au+Au collisions are compared according to the configuration of the vertex detector, namely, whether the Silicon Strip Detector (SSD) is taken into account in the simulations or excluded.

1 What the SSD provides in STAR

1.1 Brief description of the SSD

The Silicon Strip Detector will be installed in the region between the SVT and the TPC with the aim to improve the STAR central tracking capabilities and hence the physics observable measurements.

The SSD barrel will surround the SVT at a radius of 23 cm from the interaction point. It will be equipped by double-sided detectors characterized by a small stereo angle (35 mrad) and positioned on 20 fiber carbon ladders (at the rate of 16 modules per ladder). The pseudo-rapidity domain covered by the SSD ranges from η =-1.2 to η =+1.2. The detailed description of the SSD can be found in its Technical Proposal [1].

1.2 Improvements of the STAR central tracking performances

Since the SSD provides the vertex detector an additional space-point, the tracking performances were expected to be enhanced in the mid-rapidity region covered by STAR. It has been already developped in the SSD Technical Proposal and summarized in section 2.1.

More specifically, the SSD is a key detector for the track reconstruction of particles with low transverse momentum ($p_t \lesssim 0.5$ GeV/c). It will allow an enhancement of the SVT performances at low p_t , which is a crucial point : the vertex detector is indeed the only apparatus able to give informations since particles do not reach the TPC.

This improvement in the low p_t domain can be alloted to several reasons inherent to the SSD:

- the SVT hardware efficiency is extended : the SVT detector geometry induces about 6 % of dead zones per layer and the SSD arrangement is such that part of these inactive areas is significantly recovered. Furthermore, the track reconstruction of secondary particles produced between the first and second layers becomes feasible.
- the capabilities of particle identification are improved due to the additional dE/dx measurement provided by the SSD. A rough estimation leads to the fact that by using the mean truncated method, the width of the normalized dE/dx distribution decreases from σ=0.12 to σ=0.10.
- momentum resolution is improved from 18% to 14%.

The improvement of the tracking performances will be described more quantitatively in section 2, but nevertheless one can already highlight the various domains of physics which will benefit from the SSD informations.

1.3 Improvements in physics observables

Consequently to the reasons listed above, the short-lived particle detection yields are increased. This particular point will be demonstrated later on by results of simulations performed on K_s^0 and Λ and by estimations done for Ξ.

Consequences are obvious also for HBT studies. Neutral kaon interferometry is improved and Λ-Λ correlations may become feasible but for the time being, still need further investigations.

The number of non-identical particle pairs will be enhanced and finally, it will be possible to obtain correlation measurements for particles with low transverse momentum (and even for pions on an event-by-event basis) as well as to look for space-time asymmetries in emission of particles with low p_t by using unlike-particle correlations.

Particle correlation studies have been reported in [2], discussing notably results obtained by taking into account the SSD or not in the simulations.

We can also mention that the complete configuration of the vertex detector offers better conditions for the search of exotic forms of strange matter. Estimations are presented in [1].

2 Simulation and reconstruction

In order to evaluate the influence of the SSD on STAR global reconstruction abilities, Hijing Au+Au events have been generated and passed thru GSTAR before entering in the reconstruction chain.

2.1 Two track finders for two vertex detector configurations

After GSTAR, the tracking procedure is then different depending on the vertex detector configuration (see Figure 1).

- If the SSD is excluded, the current chain (segment-to-segment track finder) is used meaning that separated tracking procedures in the SVT (STK module) and in the TPC (TPT module) are performed before applying the SVM module allowing matches between SVT segments and TPC tracks.
- If the SSD is taken into account, a new track finder algorithm (segment-to-space-point tracking) has been developed with the aim to take full advantages of the SSD (EST module). Starting by the TPC tracks, the method can be splitted as follow :
  - 5 passes are done with various conditions requiring different hit segment sizes (at least one hit in each layer, at least one hit in each layer with extended searching area, at least one hit in three different layers, at least one hit in two different layers and finally at least one hit in the SSD)
  - in each pass, 7 iterations over different p_t threshold are applied starting from the highest p_t tracks.
  - for each iteration, several procedures are followed : the TPC tracks are projected on the SSD; (SSD hit)+(TPC track) associations are looked for according geometrical criteria; a track refitting is performed with the new hit included. These three first steps are repeated for the SVT layers.

The choice of a new strategy has been motivated by the fact that the segment-to-segment tracker leads to poor results with the (SVT+SSD) configuration (i.e. low tracking efficiency and a high number of fake tracks), and particularly for secondary particles. This method indeed does not anticipate the track bending due to the magnetic field and hence is unable to predict correctly a track projection on the SSD wafers.

A STAR note dedicated to more technical aspects of the new tracker is at the present time under preparation. One can nevertheless summarized here the principal particularities and results.

Three main features characterize the chain involving the EST module :

- no distinction has to be made between primary and secondary particles since no information on the primary vertex are needed.
- any lower limit is set on the number of hits required to form a track segment while the current tracker needs at least 3 hits located in different SVT super-layers.
- consequently to previous item, segments of tracks limited to the outermost layers can be treated. That means that even tracks related to particles decaying between the first and the second layers of the SVT can be reconstructed which was totally impossible with the current track finder.

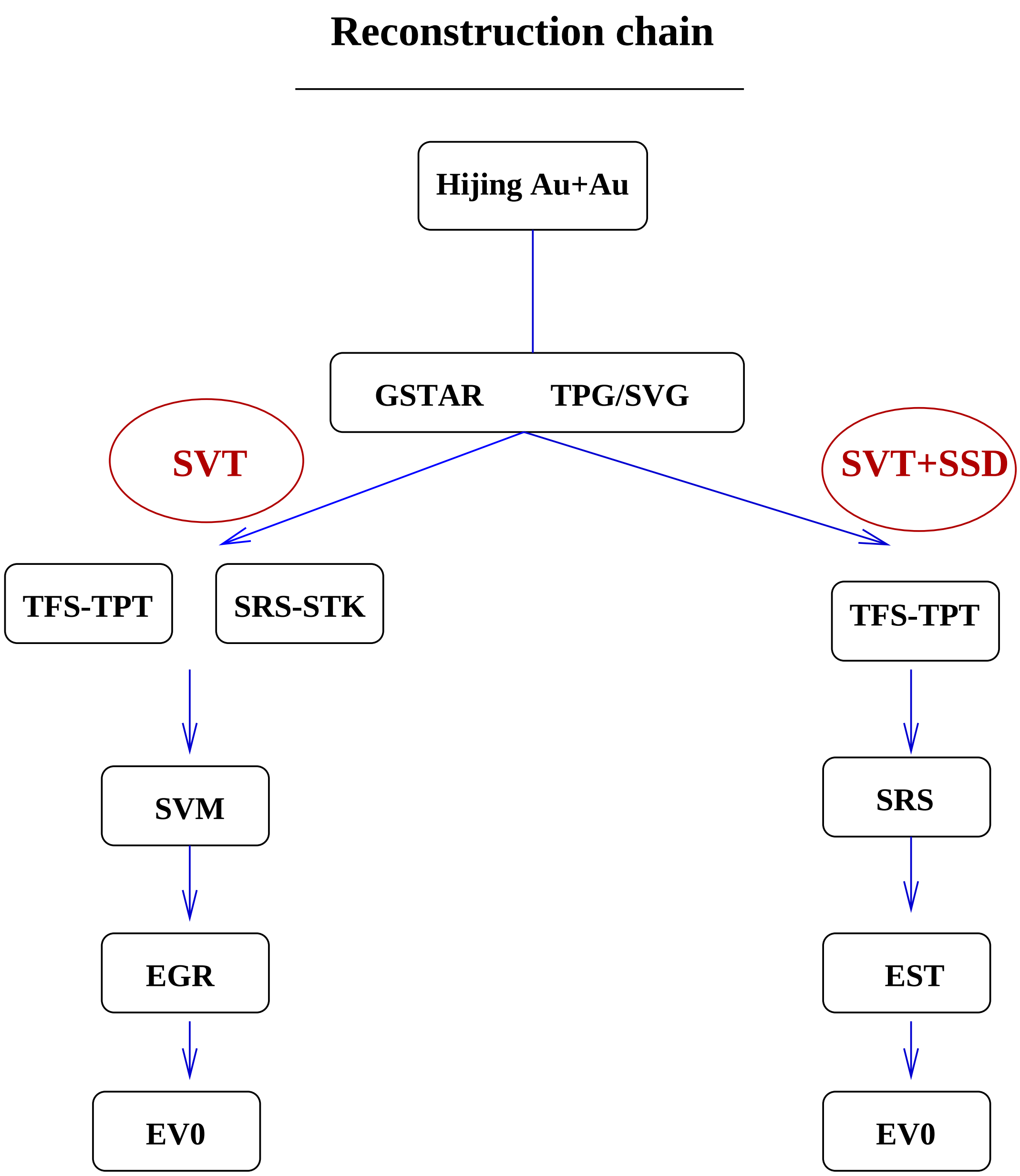

Figure 1: Analysis chains used with the SVT+TPC (left part) or SVT+SSD+TPC (right part) configurations.

Five Au+Au Hijing events have been processed to evaluate quantitatively the performances of the tracking methods and conclusions are the following :

a) The EST module allows to reach track reconstruction efficiencies of 80 % and 60 % for the primary and secondary particles, respectively.

b) It is possible to quantify the gain due to the SSD by considering the number of reconstructed tracks.

_ For the primary particles, the (SVT+SSD)+TPC configuration allows to reconstruct ∼1300 primary tracks, which represents a gain of about 20 % compared to the number of tracks reconstructed with only the SVT and TPC. These results have been obtained independently of the track finder algorithm.

_ Concerning now secondary particles, the (SVT+SSD) configurations leads to ∼200 secondary tracks, hence leading to an increase by a factor of 4 compared to the SVT+TPC configuration. This factor is deduced from a comparison between results obtained with the SVT+TPC and the current method and those provided by the mew algorithm with the (SVT+SSD)+TPC.

Once tracks are reconstructed, the search and identification of vertices are done applying the standard combinatorial method, namely with the EV0 module.

2.2 K_s^0 and Λ reconstruction

Let us consider now the specific cases of K_s^0 and Λ particles.

2.2.1 K_s^0 and Λ acceptance

600 Hijing Au+Au events have been processed in GSTAR/G2T. One event contains an averaged number of about 110 K_s^0 and 70 Λ.

Neutral strange particle acceptances have been studied for both SVT+TPC and (SVT+SSD)+TPC. Criteria, applied on both daughter tracks, are the following :

For the (SVT+TPC) setup :

- at least 5 hits in the TPC
- at least 3 hits in the SVT (this condition is a prerequisite for the segment-to-segment track finder)

For the (SVT+SSD+TPC) setup :

- at least 5 hits in the TPC
- at least 1 hit in the SVT+SSD (only one hit is required for associating a TPC track if the segment-to-space-point track finder is used).

Acceptance distributions as a function of the transverse momentum have been obtained requiring $|y|<1.7$. This condition is set only with the aim to have distributions directly comparable to those obtained in previous studies relative to the SVT+TPC acceptance [3].

On figures 2 (related to K_s^0) and 3 (to Λ), it appears clearly that the acceptance is enhanced if the SSD is included, and this trend is even more pronounced for Λ due to the fact that the $c\tau$ of Λ is about three time greater than in the case of K_s^0.

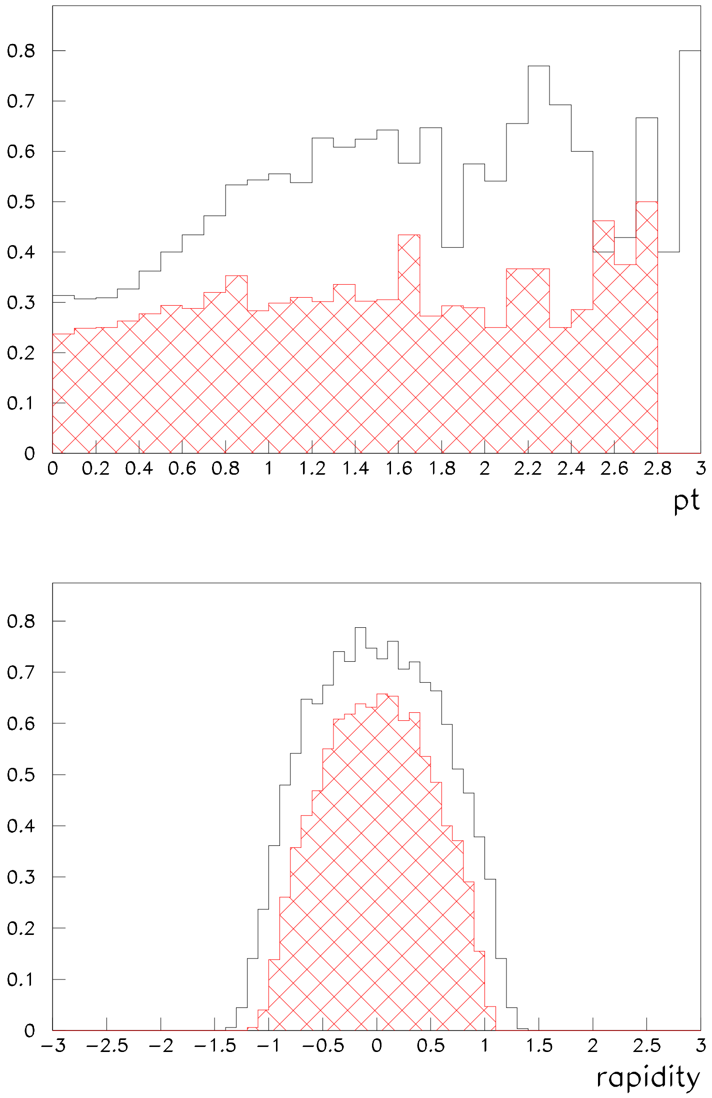

Figure 2: K^0_s acceptance distributions represented as a function of the transverse momentum (upper part) and the rapidity (lower part). The solid histogram corresponds to simulations realized with the SVT and TPC detectors while the other one is related to simulations

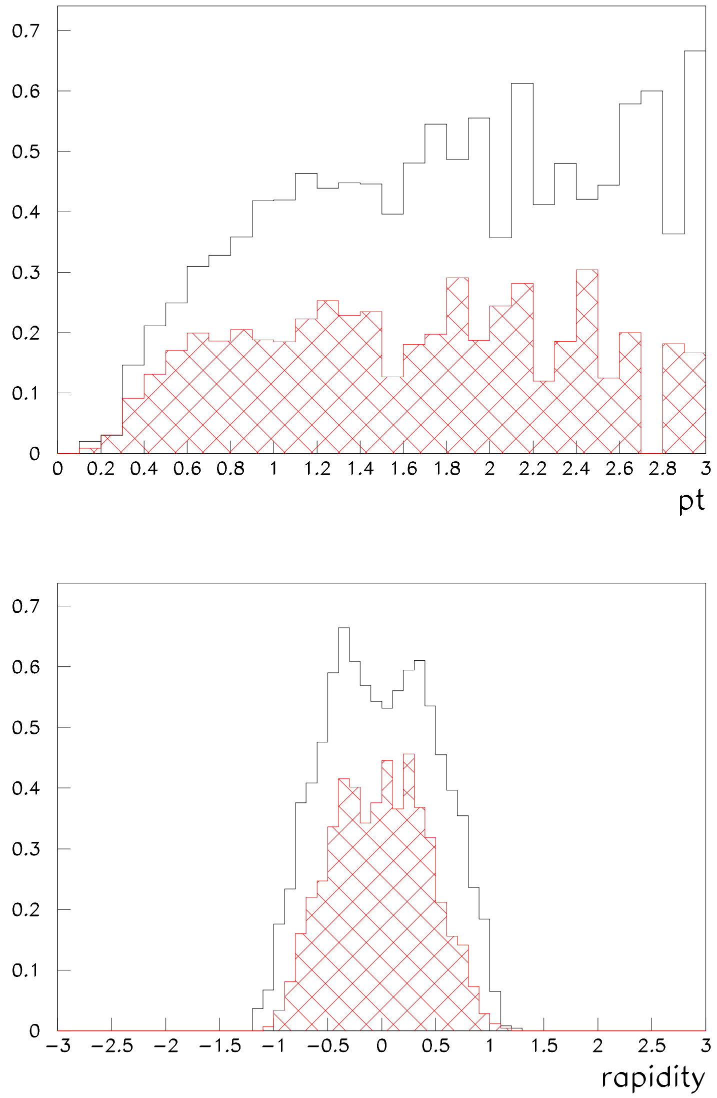

Figure 3: Same as figure 2 but for Λ particles.

2.2.2 Vertex reconstruction via EV0

Several criteria are useful for identifying vertices, such as : *dca*[1], the distance of closest approach between the two decay products; *dlen*, the distance between the primary and the secondary vertices; *dcav0*, an impact parameter-like of the reconstructed vertex from the primary one. The search is also restricted to a reduced range in mass depending on the particle species.

First, wide cuts are applied on these parameters and they are defined with identical values for kaons and lambdas, except the mass cuts (it has been done similarly to other studies [4, 5]). The aim of this step is to surround the searching areas and hence to reduce as much as possible the sizes of the various tables involved as well as the CPU.

The chosen values for EV0 parameters are the following :

$$dca<0.8,\ dlen>0.6 \text{ and } dcav0<0.3$$

Additional cuts are then applied on the *dcap and dcan* parameters related to the distance of closest approach between the primary vertex and the positive and negative decay daughters, respectively. By setting a lower limit on these parameters, one assure that candidate daughters do not point to the primary vertex and thus are really secondary tracks.

For neutral kaons, the same value is taken for *dcap and dcan* but for lambda's, since the secondary particles have quite different masses, linear combinations of the two parameters have been optimized to define searching areas. It allows to reduce considerably the background without any significant loss of vertices correctly reconstructed.

2.2.3 Results

171 Hijing Au+Au events have been processed thru the whole chain to perform this analysis leading to a comfortable statistics. Results are presented on figure 4 for K_s^0.

Whatever the vertex detector configuration is, the same quite high signal over noise ratio has been considered (around 5) to allow a direct comparison between the (SVT+TPC) and (SVT+SSD+TPC) capabilities.

The conclusion is that the inclusion of the SSD allows to enhance the number of reconstructed K_s^0 per event (2.75 compared to 6.62). The same analysis has been done for Λ (figure 5). The (SVT+SSD) allows to reconstruct 0.63 Λ compared to 0.2 obtained with the SVT alone.

The numbers of K_s^0 or Λ reconstructed per event look small but one has to remember that they correspond to a quite high signal over noise ratio. When this latter is taken smaller, it becomes possible to reconstruct at least one Λ per event if and only if the SSD is included (see figure 6).

On figures 7 and 8 are presented the same analyses as before but in this case, the TPC tracks leaving any hits in the SVT or SSD and leading to vertices are removed

[1] *dca* is a 2-dimensional distance. Analyses have to be reconsidered by taking into account the new 3-dimensional criterion.

in order to check their influence. One can notice that by removing these tracks, the shape and yield of the background are considerably changing. The change is not the same in both cases (SVT or SVT+SSD) but it is not so trivial to find a simple explanation, or in other words, to understand the role of the combinatorial. However it is certain, that the fact that the number of reconstructed secondary particles is greater with EST than with the other track finder, enters in the argumentation.

For neutral kaons, one can reach a S/N ratio of about 11 with a similar number of K_s^0 per event as in the first analysis. For Λ, numbers vary by a factor of 2.

One should keep in mind that about 30% of the reconstructed Λ come from decay of other strange particles like Σ^0, Ξ^0 and Ξ^-. However, since the Ξ decay farther from the primary vertex, it should be possible to reduce their contribution to the Λ peak.

3 Conclusion and outlook

The significant contribution of the SSD to the neutral strange particle reconstruction has been demonstatred. These studies have to be considered like preliminary ones, in terms of statistics or optimization of EV0 cuts.

Simulations have been performed for K_s^0 and Λ and have to be continued for Ξ and Ω. Starting from a given number of those particles in 4π (5 for Ξ and 0.05 for Ω), estimations have been already done and reported in Table 1.

Particle	4π (Hijing)	> 9 TPC hits	Reconstr. TPC+SVT	Reconstr. in TPC+SSD+SVT
Ξ	5	0.3	0.003	0.01-0.02
Ω	0.05	0.003	3.10^{-5}	

Table 1: Estimated rate per event for Ξ and Ω predicted by Hijing and rates of reconstruction in STAR for the TPC alone, TPC+SVT and TPC+SSD+SVT (Presented by P. Jones at the STAR Collaboration Meeting, February 99)

References

[1] *Proposal for a Silicon Strip Detector for STAR (SSD)*
Can be found temporarily in :
http://www-subatech.in2p3.fr/~hadrons/doc/star_tp.ps

[2] B. Erazmus *et al.*, STAR Note # 370

[3] See results shown on the Strange Working Group Web pages :
http://www.rhic.bnl.gov/STAR/html/strange_l/strange.html

[4] S. Margetis *et al.*, STAR Note # 72.
W.K. Wilson, STAR Note # 233

[5] S. Margetis, STAR Note # 367

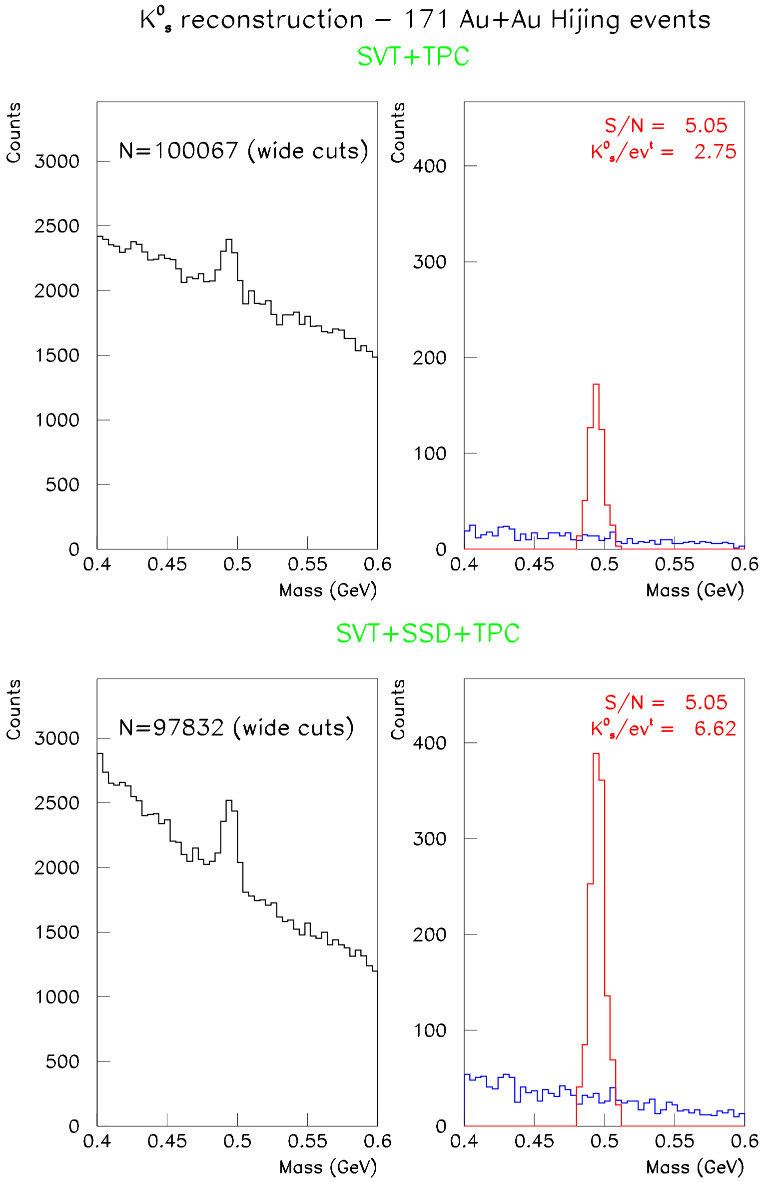

Figure 4: Distributions of K^0_s invariant mass obtained after processing 171 Hijing Au+Au events. The upper parts present results with the SVT+TPC configuration while the lower ones are including the SSD. On the right, distributions are obtained by applying wide cuts and on the left, with more severe cuts (see text) one can extract, for a given signal over noise ratio, a number of strange particles per event. Values are given on the figures.

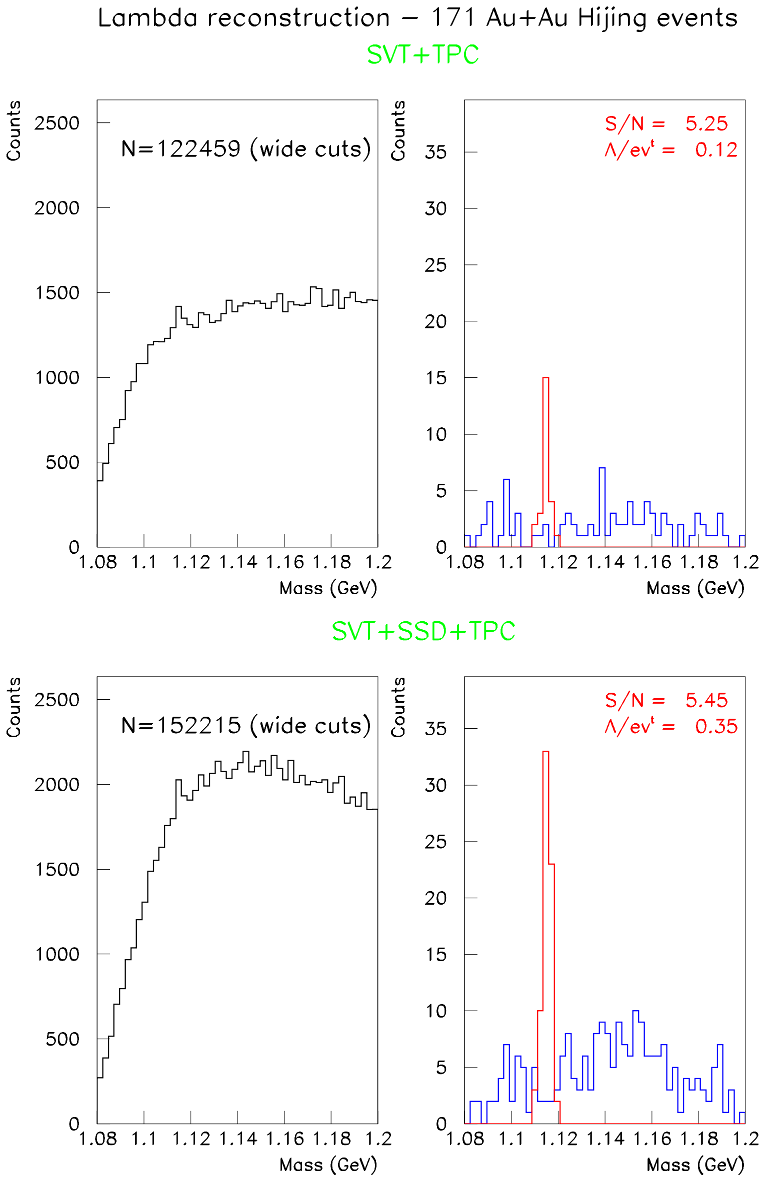

Figure 5: Same analysis as figure 4 but for Λ particles.

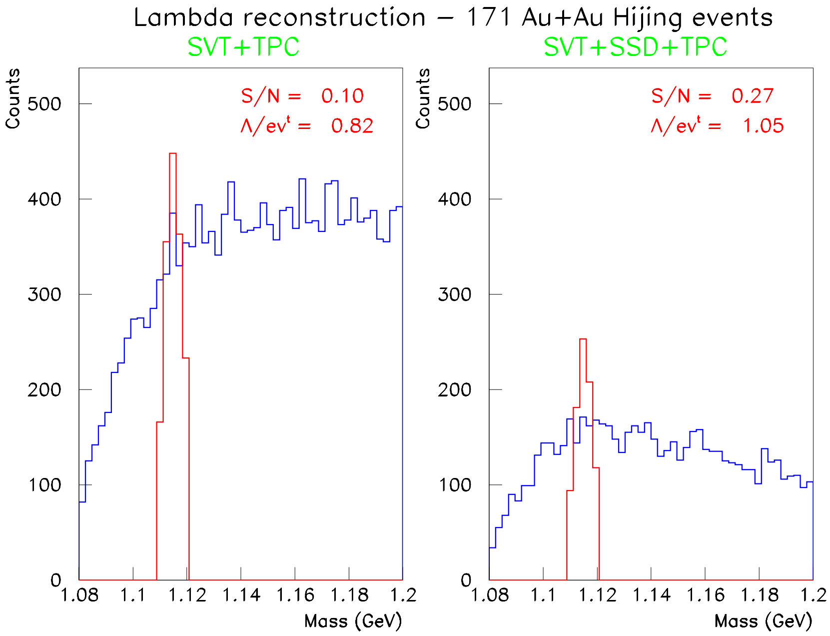

Figure 6: Same analysis as figure 5 but in this case, the signal over noise ratio has been reduced in order to enhance the number of Λ reconstructed per event.

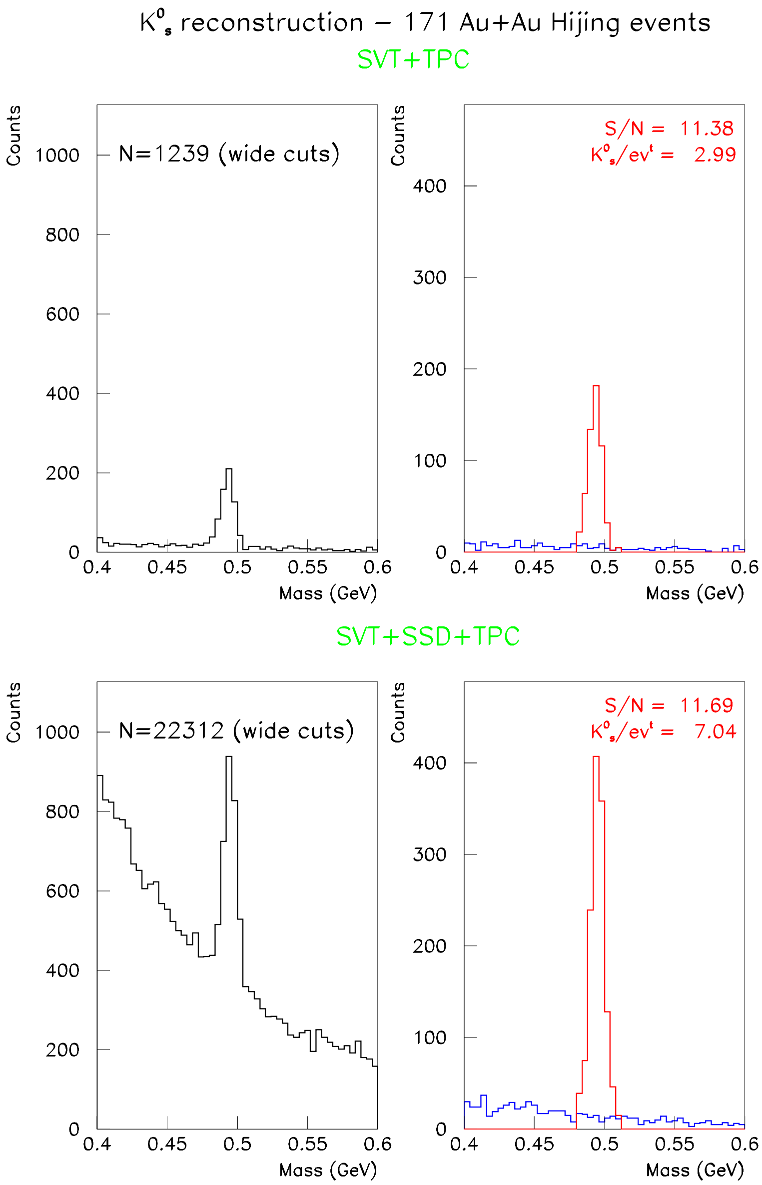

Figure 7: Same analysis as figure 4 but for this study, TPC tracks without leaving any hits in the vertex detector (in SVT or SSD layers) are removed from the analysis.

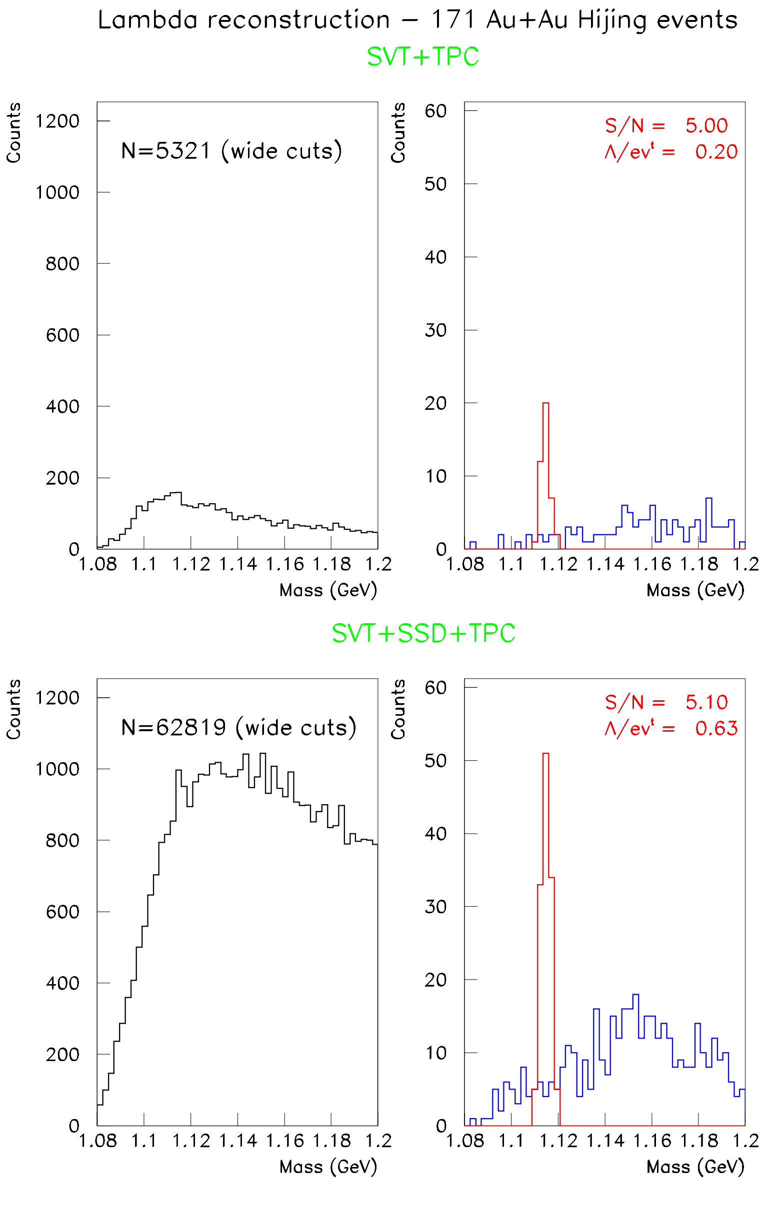

Figure 8: Same study as figure 7 but for Λ particles.