STAR–Note # 152
S. Margetis , E. Paganis[1] (LBL)
February 1994

Momentum resolution studies in the SVT Part I

1 Abstract

The SVT detector in STAR can be used as a stand alone tracker [1], possibly extending the acceptance of the experiment in the low p_T region ($p_T < 300$ MeV/c). In this study the SVT angular and transverse momentum (p_T) resolution is estimated in the multiple Coulomb scattering (MCS) limit. The limited track length combined with the MCS result in a dp_T/p_T resolution of about 20 % if only SVT information is used. This combined with the small errors in the tanλ ($\equiv p_L/p_T$) and ψ (tan$\psi \equiv p_y/p_x$) shows that the p_T error dominates the overall momentum error.

2 The Procedure

Pions and Kaons were filtered out of FRITIOF RHIC events and they were tracked in a GEANT based simulation package. The SVT hits for each track was recorded and consequently fitted with fitting routines described in [3]. Most of the results in this study are extracted from fits to the three hits each track left in the SVT without using any main vertex information (3–point fit). This is certainly going to be the case for tracks originating from secondary vertices. In some cases, just for comparison, the main vertex position with its associated error [2] was used in the fit (4–point fit).

The following assumptions were made for this particular study:

- Most of the results use a detector geometry which is unrealisticaly thin (around 1 % radiation lengths for tracks of normal incidence). A comparison is also made with another hypothetical configuration which is about three times thicker.
- In the case were a low momentum track left, through spiraling, more than three hits in the SVT, only the first segment was used in the calculation.
- The position resolution of the SVT was assumed to be ideal. This is because we wanted to eliminate all contributions to resolution due to the finite position resolution of the detector.
- For the same reason we assumed ideal tracking, i.e. we used Geant information to associate hits to a track and not a pattern recognition program.

[1]Permanent address: Univ. of Texas, Austin

- Because of the uniformity of the magnetic field we adopted a track model where tracks are represented as helices. This factorizes the fitting which becomes a circle fitting in the bending (x-y) plane and a line fit on the s–z plane, where s is the track length in the bending plane.

In this study only SVT information was used, i.e. we studied the performance of the SVT as if it was the only tracker in the experiment. In reality the TPC information is going to be combined with the SVT points in some sort of integrated tracking for tracks with momentum higher than about 300 MeV/c [1], where the TPC is having a very good track reconstruction efficiency.

We estimated the resolutions quoted in this note by directly comparing the model input to the reconstructed quantities. In this case an RMS error can be extracted. During the data analysis one has to rely on the estimated errors of the fitted parameters that the fitting routine returns, which are either the standard deviations of those quantities or the full covariance matrix. In order to be able to compare the results of this simulation to the fitting errors, a gaussian fit was performed to each distribution of the simulation (which are somewhat gaussians with long tails) and a standard deviation was extracted.

In order to estimate our systematic uncertainty due to energy loss and finite tracking accuracy in GEANT, we processed events were the MCS was switched off. The deviations from the input were found to be around 2 % for the dp_T/p_T quantity. This was used as the error bar in plots with the above quantity.

3 Results and Discussion

We considered the resolution of three parameters, all of them being tracking parameters. One is the p_T, the transverse momentum, which is also the momentum in the bending plane. The magnitude of the p_T is closely connected to the total particle momentum for small pseudorapidities. The other two are angle parameters, the ψ, which defines the ratio between the two components of the transverse energy, and $\tan\lambda$, which is the ratio of the longitudinal to the transverse momentum:

$$\tan\psi = p_y/p_x$$

$$\tan\lambda = p_L/p_T$$

Angular errors are very important in modules like the TPC–SVT track matcher as well as in HBT studies.

3.1 p_T resolution

Figure 1 shows a compilation of plots about the transverse momentum resolution. In fig. 1a the correlation between the input vs the reconstructed p_T is shown. In fig. 1b the value of dp_T/p_T is shown as a function of p_T calculated for each individual track. A projection of a slice in p_T is shown in fig. 1c. The RMS values of these projections (black dots) together with the σ (open dots) of the Gaussian fits of the central parts are ploted in fig. 1d. It is probably surprising to see resolution values around 20 % for a relatively thin detector and for pions but we should keep in mind that the track length in the SVT alone is just a few centimeters (6 cm in the case of the thin and around 9 cm in the case of the thicker SVT).

The solid line is an analytical prediction of a formula taken from ref. [4] for a 1 % radiation length detector and 6 cm transverse track length. We observe that it reproduces very well the features of the simulation points.

Table 1 holds the values of the points in fig. 1d. It also shows the RMS values in the case of kaons instead of pions. We see that for low momenta the more severe MCS of the heavier (slower) kaons leads to an extra degradation of the resolution by about 10 %, which decreases as we go up in momentum.

p_T range (GeV/c)	0.0–0.2	0.2–0.4	0.4–0.6	0.6–0.8	0.8–1.0	1.0-1.5
RMS (%) pions	25	21	21	21	20	22
kaons	36	29	25	23	23	23
σ (%) pions	20	17	17	16	16	17

Table 1: Transverse momentum resolution in the thin SVT. Both the RMS and the σ values for pions and the RMS values for kaons are shown.

We did not observe a big difference between the results of the 3 and 4–point fits although there is a significant increase in the track length. This might be due the presence of the beam pipe between the vertex and the detector which counterweights the increase in the track length.

3.2 ψ resolution

Figure 2 shows resolution plots related to the azimuthal angle ψ of the transverse momentum vector. It is reasonable to say that the error on ψ should be independent of ψ in an almost cylindrical detector. Figure 1a is the scatter plot of this relation and it shows that indeed there is no correlation between the two.

p_T range (GeV/c)	0.0–0.2	0.2–0.4	0.4–0.8	0.8–∞
RMS pions	.0188	.0088	.0051	.0025
σ pions	.0178	.0079	.0042	.0022

Table 2: ψ resolution as a function of the track p_T in radians.

On the other hand there should be a rather strong correlation between the error in the p_T and the error in ψ, i.e. the better one determines the curvature of the circle the better it determines the emission angle too. This is shown in fig. 2b which should also be compared with the fig. 1d. Also Table 2 shows the RMS values and the σ of this dependence. We observe that the higher the momentum, the smaller the error in ψ (and in p_T).

The average error was extracted by projecting the histogram in fig. 2a. The $< RMS >$ value as well as the $< \sigma >$ are noted in fig. 2d. We observe that it is less than 1 % on the average.

3.3 tanλ resolution

Figure 3 refers to the resolution in the tanλ. The correlation plot between input and reconstructed quantities is shown in fig. 3a. We see that the quantities are very nicely correlated, i.e. the width of the distribution is very narrow. We intuitively expect to observe a correlation between the error and the tanλ itself since for large (or very small) values the particles have to traverse effectively larger lengths in Silicon. This is not the case with gaseous detectors like the TPC. The effect is shown in fig. 3b and 3d were we observe that tracks which traverse the SVT layers almost normal to the surface exhibit less spreading.

tanλ range	-2 – -1	-1 – -0.5	-0.5 – 0.	0. – 0.5	0.5 – 1	1 – 2
RMS 3–points	.0115	.0089	.0063	.0066	.0082	.0117
4–points	.0083	.0058	.0035	.0037	.0054	.0082
σ 3–points	.0048	.0035	.0024	.0025	.003	.0052

Table 3: Pion tanλ resolution in the thin SVT. Also the RMS values for the fits with and without the vertex are shown.

We also observed a similar to the ψ strong correlation between the tanλ and p_T which is usually not expected. Since our study refers to MCS effects, the severe scattering of low momentum tracks is definitely affecting strongly also tanλ.

The values in fig. 3d were calculated by making vertical slices in fig. 3b and fitting the central part of the projections. Table 3 contains the values plotted in fig. 3d. One of the projections is shown in fig. 3c. The average error seems to be less than 1 % also in this case.

Table 3 also compares the RMS values for the 3 and 4–point fits. In this case the addition of the extra point (the main vertex) significantly improves the resolution.

3.4 Thick vs thin detector

Figure 4 shows the momentum resolution for two detector thicknesses; one being three layers of Silicon with some beryllium support structures, the other being the same plus some extra material due to water cooling and FEE. The extra material is responsible for the more than 10 % degradation in p_T resolution. The dashed line is from ref. [4] for 4 % radiation length and 9 cm transverse track length.

4 Acknowledgement

The authors would like to thank M. Bloomer for providing the functions for the analytical calculations.

References

[1] STAR–CDR, PUB–5347.
D. Prindle; STAR note # 153
J. Bielecki; STAR note # 131
C. Pruneau; STAR note # 145

[2] S. Margetis et al.; STAR note # 89, December 1992,

[3] S. Margetis et al.; STAR note # 127, September 1993,
M. Hansroul et al.;'Fast circle fit with the conformal mapping method',
NIM A270(1988)498.

[4] R. Bock, H. Grote, D. Notz and M. Regler, (ed. by M. Regler).
Data Analysis Techniques in High Energy Physics Experiments.
Cambridge Univ. Press, Cambridge (UK), 1990.

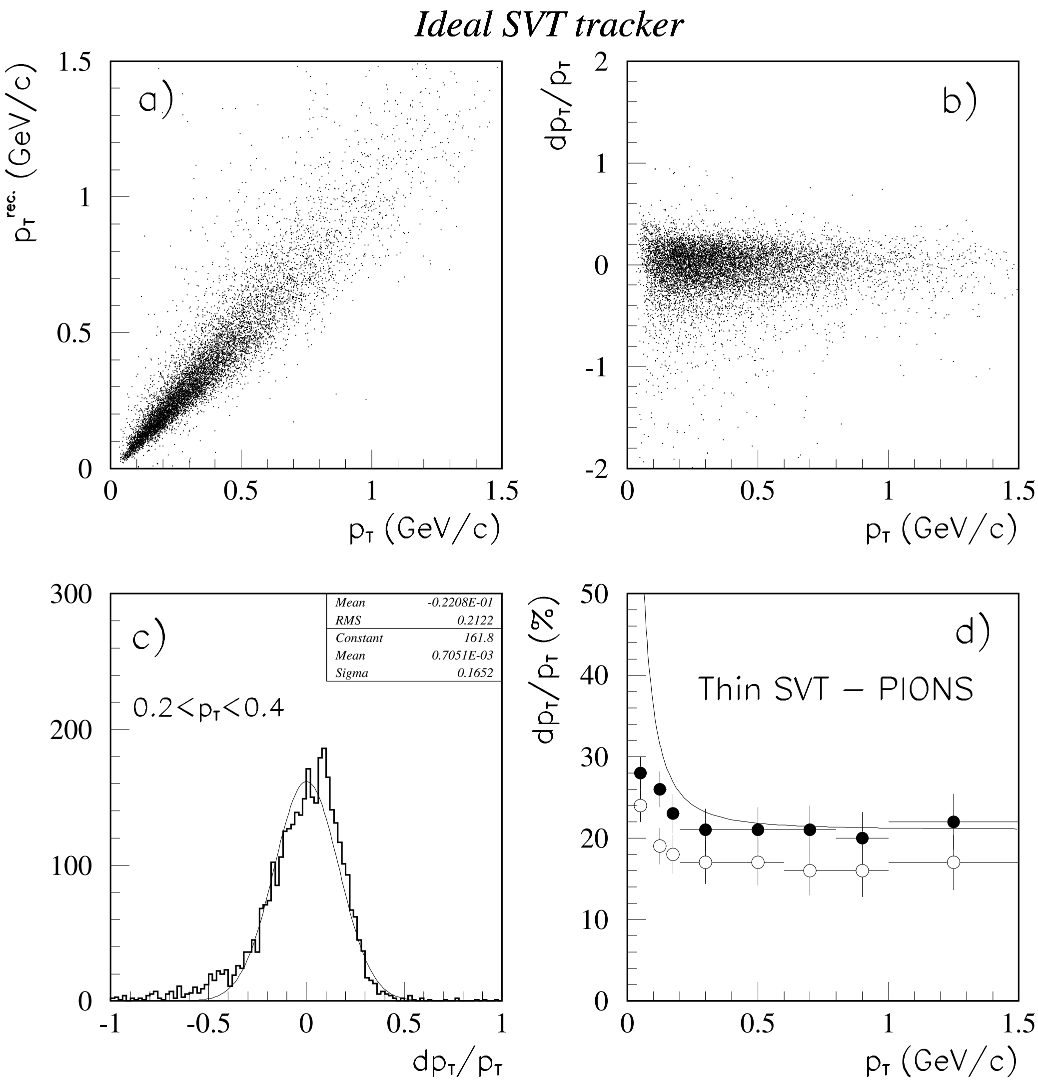

Figure 1: Transverse momentum resolution.

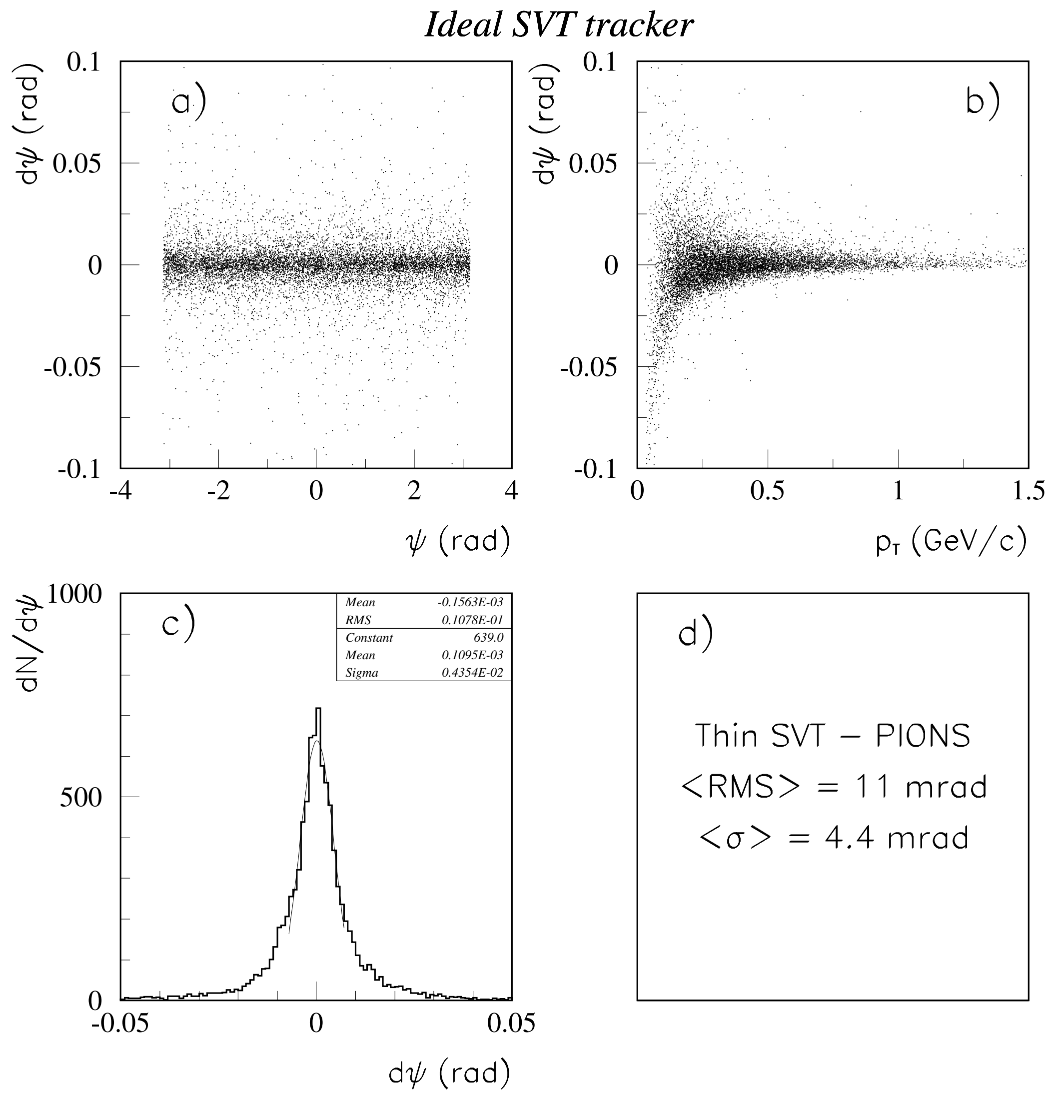

Figure 2: Resolution of the angle ψ, i.e. the bending plane angle.

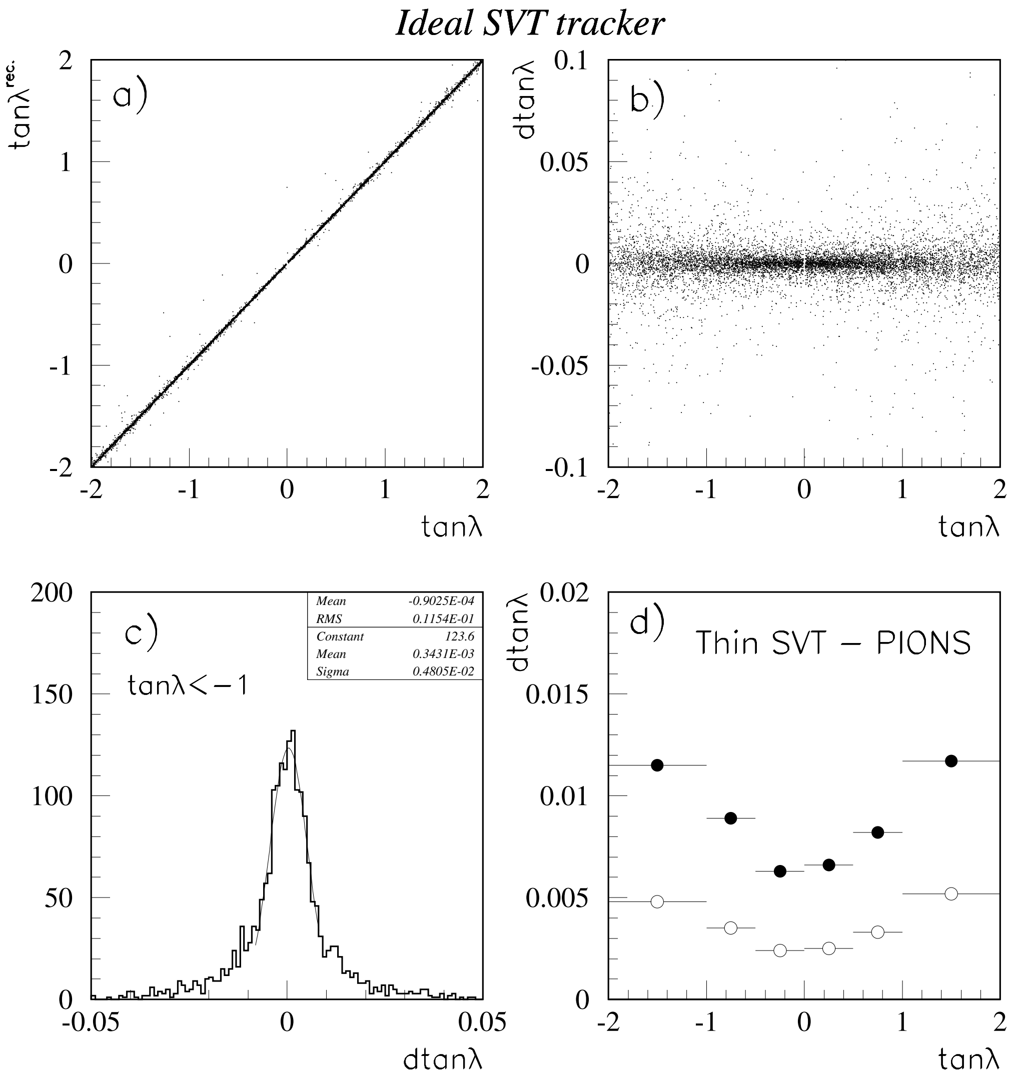

Figure 3: Resolution of the $\tan\lambda$, i.e. the ratio between the longitudinal to the transverse momentum.

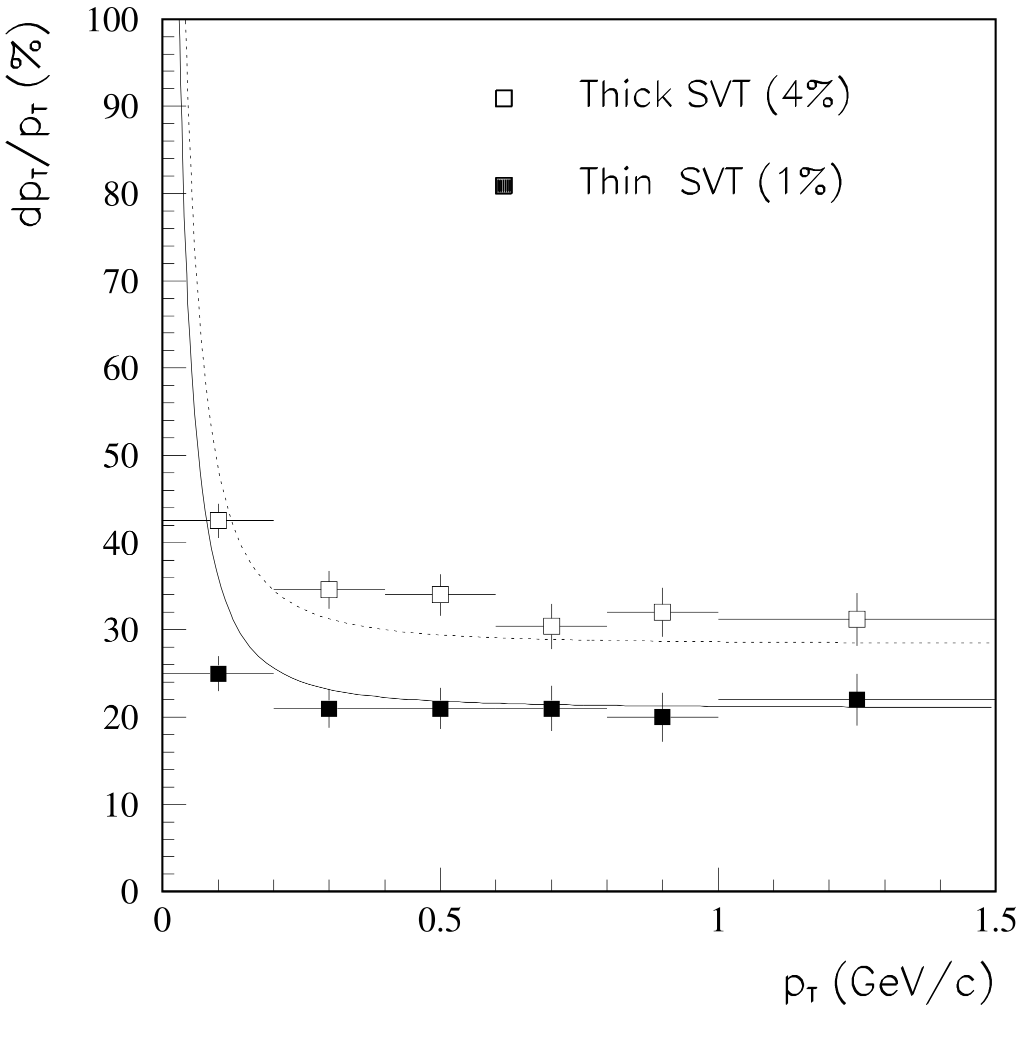

Figure 4: Comparing the effect of the detector thickness on the transverse momentum resolution. See also text.