STAR Note #**69**
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Some considerations about the SVT geometry.

1 Introduction

In this note we describe the criteria used and the resultant geometry for the STAR–SVT detector [1]. We will concentrate first on a three layer detector system and briefly give some thoughts on a four layer detector geometry.

In a three layer system our two main criteria are:

- Give as precise a value as possible of the impact parameter (point of closest approach to primary vertex), which improves the momentum resolution for a track and is valuable in determining whether or not a given track comes from the primary vertex.
- Maximizing the ability to match hits in the SVT with the tracks in the TPC.

2 General information/input.

At present, the RHIC beam pipe has a radius of 4 cm. We assume that due to the technical difficulties and possible radiation damage to the silicon drift detectors (SDD) that all layers of the SVT will be outside of the beam pipe. This thus sets a lower limit on the radius of the 1^{st} SVT layer.

The TPC field cage is at a radius of 50 cm. This sets an upper limit for the radius of the outer layer of the SVT.

Due to the multiple Coulomb scattering (MCS) consideration it is important to keep in mind the momentum spectrum for the particles one expects to observe at RHIC. Shown in Fig. 1 are momentum spectra for a single Au+Au central event, produced using the FRITIOF event generator. In all the plots in Fig. 1 a cut has been applied that $|p| \leq 2$ GeV/c. Fig. 1a and b show the momentum for all charged particles, without and with the cut $|\eta| \leq 1$. Fig. 1c and d show the same spectra for the charged pions. Table 1 lists the number (and %) of charged pions ($|\eta| < 1$) below various momentum cutoffs.

Fig. 2 shows the MCS angle (in space) versus pion momentum for 300μm of silicon. When we consider the efficiency with which one can match SVT points to tracks, the two most important parameters are the smearing or uncertainty of the SVT hits due to MCS, and the track density on the SVT layers. Fig. 3a, b and c show the number of hits/cm^2 versus position along the SVT cylinders, for all charged particles (including secondaries), for SVT cylinders at 5, 8 and 11 cm, for a central Au+Au event [2].

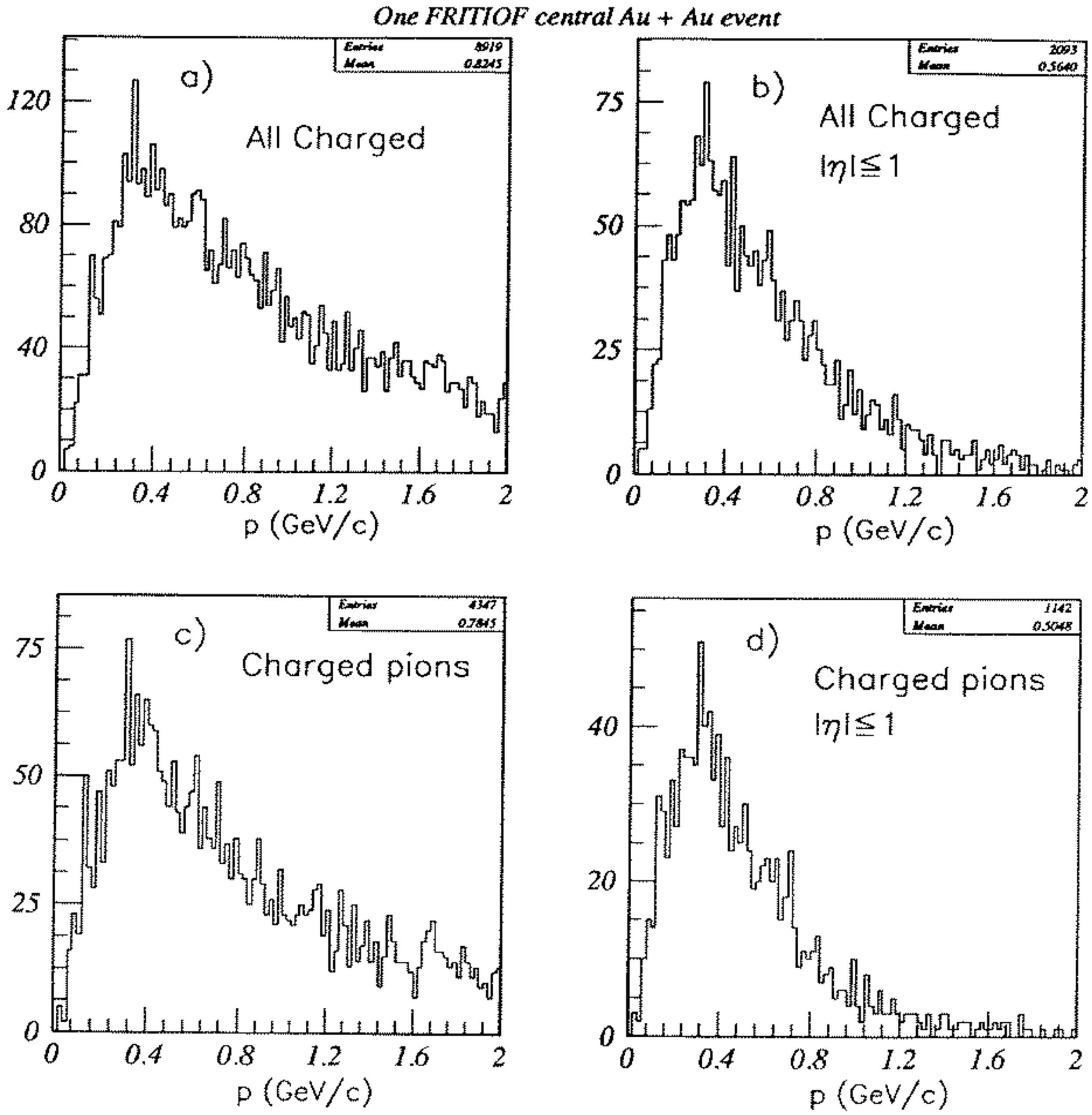

Figure 1: Momentum spectra of all charged particles or charged pions in 4π, and $|\eta| \leq 1$, for a central Au+Au Fritiof event.

Particle momentum (MeV)	# of particles (%)
0–50	4 (0.4%)
0–100	30 (2.6%)
0–150	91 (8.0%)
0–200	160 (14.0%)

Table 1: Charged pion density ($|\eta| < 1$) for different ranges of momentum.

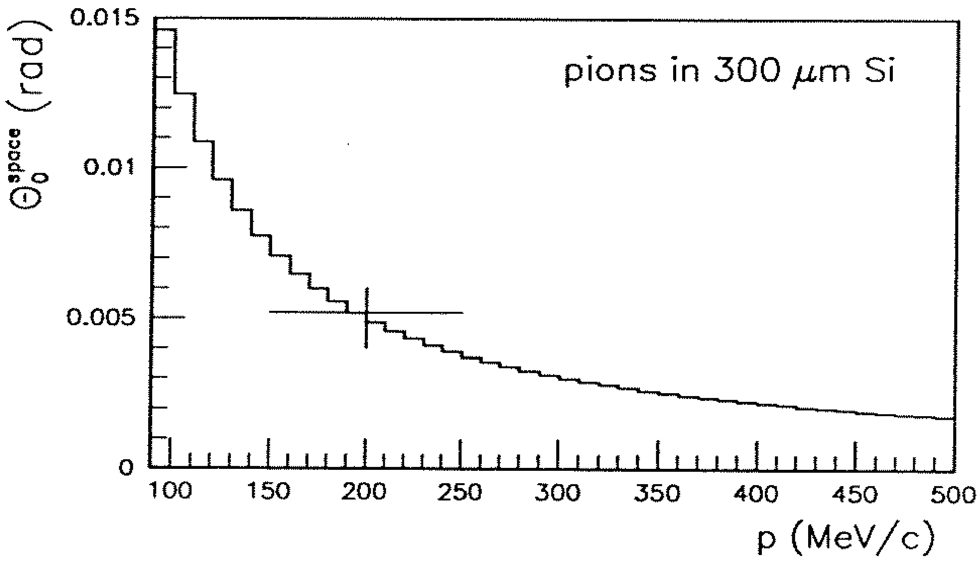

Figure 2: MCS angle as function of pion momentum in 300 μm Si.

Finally, for reference we list in Table 2 some of the components of interest, along with their material type, thickness in radiation lengths, and the MCS angle ($\theta_0^{space} = \sqrt{2}\,\theta_0$) for a 200 MeV/c charged pion.

3 Geometry for three layer SVT

The radius for the innermost SVT layer should be as close as possible to the RHIC beam pipe. This gives one a space point which has the smallest uncertainty due to MCS, and minimizes the distance over which one must project one's helix, which maximizes the single track impact parameter resolution (see Fig. 7). With the present RHIC beam pipe (radius of 4 cm) this leads to a radius for SVT layer 1 of 5 cm.

Moving on to the outermost layer of the SVT, our primary criteria here is to maximize the matching efficiency of hits on this layer with helices projected back from the TPC. Quantitatively, we want the number of SVT hits within the 3σ area of uncertainty (due to MCS) for a 200 MeV/c pion track projected back to SVT3 to be $\approx$1. Fig. 4 illustrates the geometry one should have in mind.

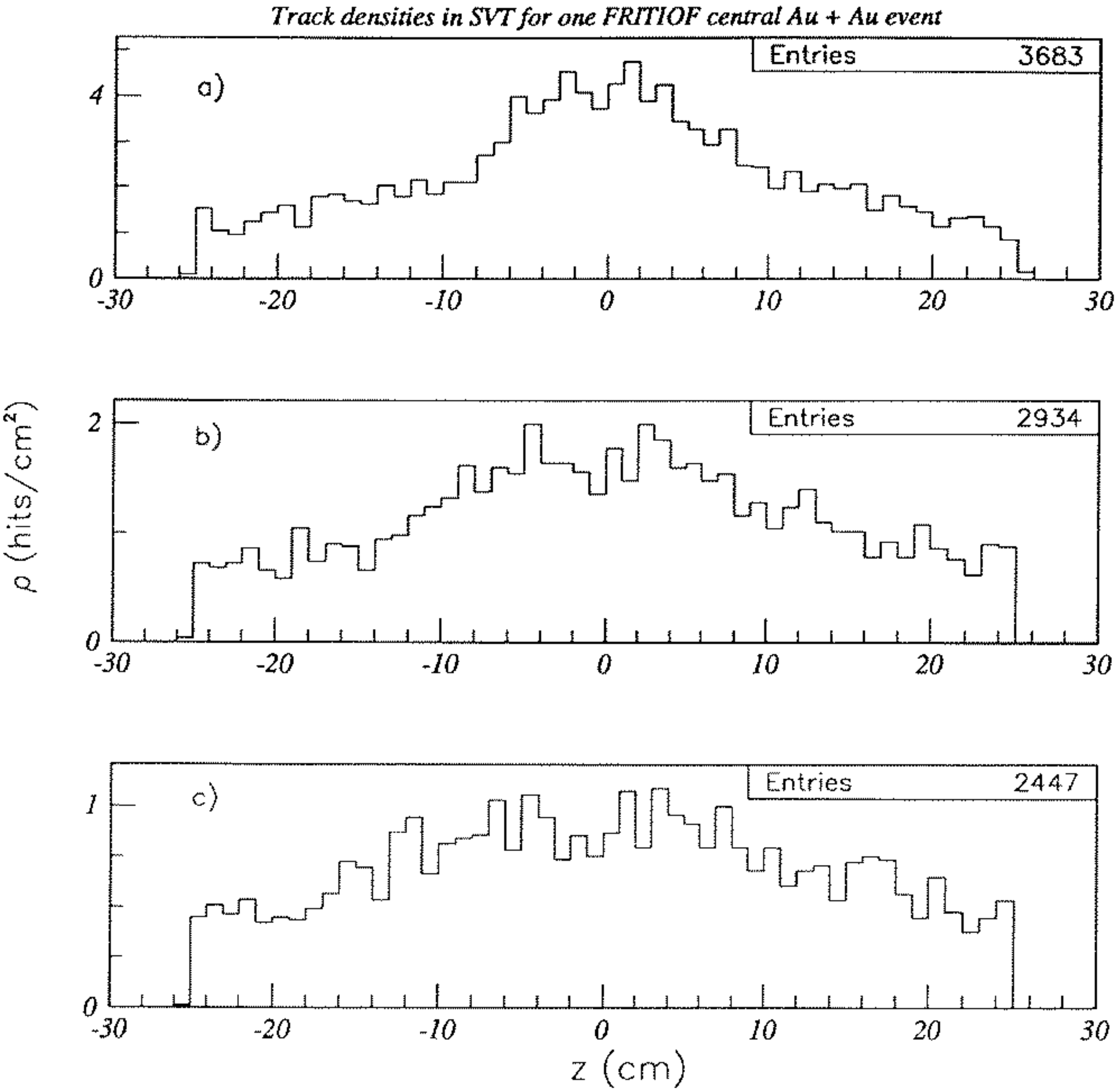

Figure 3: Track densities (in hits/cm^2) in the different SVT layers: a) 5 cm; b) 8 cm and c) 11 cm.

component	material	thickness ($\%X_0$)	θ_0^{space} (10^{-3} rad) (for 200 MeV/c pions)
Beam pipe	Beryllium	0.28	4.9
SDD	Silicon	0.32	5.2
TPC gas vessel	Carbon	0.50	6.6
TPC field cage	Composite	0.75	8.2

Table 2: Material in the track path.

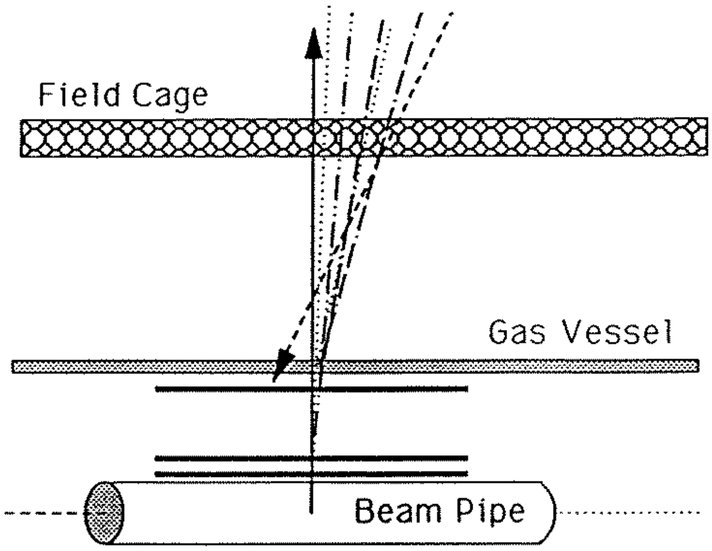

Figure 4: The layout of the SVT–TPC tracking complex.

For a 200 MeV/c pion the MCS angle in the TPC field cage is 8.2 mrad[1]. Assuming normal incidence, the 3σ area of uncertainty for the projected track at SVT3 is given by:

$$3\sigma\,\text{search area} = \pi \cdot [(distance \cdot \theta_0^{space}) \cdot 3]^2 = 0.0019 \cdot (50 - R_{SVT3})^2$$

where R_{SVT3} is the radius of SVT3 in cm and $(50 - R_{SVT3})$ is the distance over which one projects the track.

The track density (hits/cm^2) for SVT3, as a function of R_{SVT3}, can be calculated by scaling the value for an SVT layer with a radius of 11 cm, given in Fig. 3c (max. $\approx$ 0.83 hits/cm^2). The scaling goes as:

$$\frac{R_{SVT3}^2}{11^2} = \frac{0.83}{\rho_{SVT3}} \Rightarrow \rho_{SVT3} = \frac{11^2 \cdot 0.83}{R_{SVT3}^2} \cdot \frac{\text{hits}}{\text{cm}^2}$$

[1]If one places the gas vessel as close as possible to SVT3, the projected uncertainty due to MCS in the gas vessel is negligible, due to the short distance.

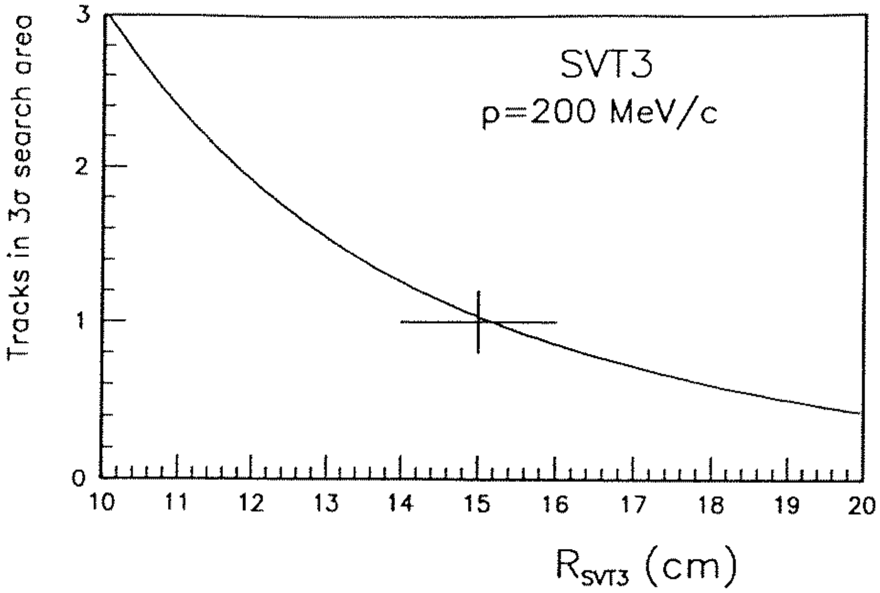

Figure 5: Number of hits in a 3σ search area.

Fig. 5 shows the number of hits in a 3σ search area (for the projected 200 MeV/c pion track) versus R_{SVT3}. We can solve for the solution which meets our criteria of 1 hit/(3σ search area) by setting the product of the track density (ρ_{SVT3}) times the 3σ search area, equal to 1:

$$3\sigma \cdot \rho_{SVT3} = 1 \Rightarrow 0.19 \cdot \frac{(50 - R_{SVT3})^2}{R^2_{SVT3}} = 1 \Rightarrow \rho_{SVT3} = 15 \text{ cm}$$

From matching efforts already carried out, it has been seen that one has very good efficiency in matching the high p_T ($p_T > 200$ MeV/c) tracks. We understand this as being due to the lower MCS for the higher momentum tracks and hence the smaller search area one must use. If one matches and removes the hits in the SVT due to the high momentum tracks first, the hit density, and hence matching, should get much easier for the low momentum tracks. This may allow us to reduce the radius and hence the cost of layer 3.

This brings us to the intermediate layer, SVT2. This third layer is necessary for redundancy, and to allow for the stand alone SVT tracking of low p_T particles from the primary vertex. The considerations for this layer are the error in the hit at SVT2 due to the projected MCS angle due to SVT1, the matching efficiency for the projected track from the hit on SVT3, and the cost.

The uncertainty in the hit position (in one dimension) in SVT2, resulting from the MCS angle due to SVT1, is plotted versus the radial separation of SVT1 and SVT2 for four different momenta, in Fig. 6. Using the criteria that the uncertainty due to MCS for the hit on SVT2 should be *at least* as large as the intrinsic position resolution of the detector, and using what we feel is a conservative value of 50 μm for the intrinsic resolution of the detector, one sees from the plot that the *minimum* separation between SVT1 and SVT2 should be about 2 cm.

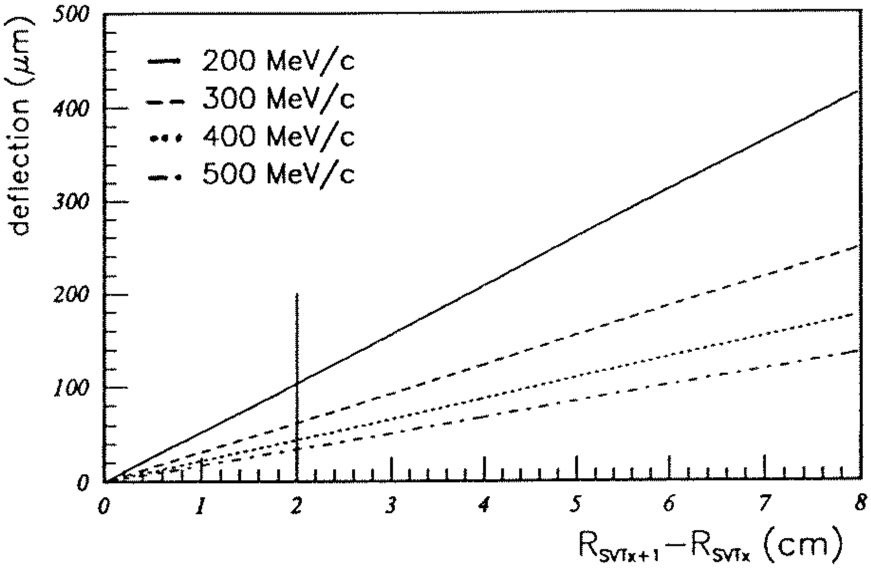

Figure 6: Inter–layer separation versus the MCS deflection.

We now consider the matching efficiency with a track which has been projected from the TPC and matched with a hit in SVT3. As a very conservative estimate for the error in the angle of the track at SVT3 we will take the 8.2 mrad due to the MCS at the TPC field cage for our 200 Mev/c pion. This is equivalent to assuming that the addition of the hit in SVT3 does nothing to improve the angle of the track (which is certainly NOT the case). If one were to project to a radius of 7 cm (5 cm for SVT1 plus minimum value of 2 cm from preceeding MCS argument), the 3σ search area would be $\pi[(15-7)\cdot(8.2\cdot10^{-3})\cdot3]^2 = 0.12$ cm^2. Scaling the peak hit density from 8 cm (Fig. 3b) to 7 cm one finds $\rho_{7cm} = 2$ hits/cm^2. Using the two values above one calculates that the number of hits in a 3σ search area on SVT2 ($R = 7$ cm) is

$$\rho\cdot(3\sigma \text{ search area}) = 0.24\,\frac{\text{hits}}{3\sigma \text{ search area}}$$

From this we conclude that the matching from SVT3 to SVT2 will not pose a problem, regardless of where we place SVT2. This brings us to our final consideration for SVT2, which is cost. Requiring that the uncertainty in the hit position due to MCS be greater or equal to the intrinsic detector resolution places SVT2 at a minimum radius of 7 cm. We've argued that once one has matched a TPC track to a hit in SVT3, matching with SVT2 will not be a problem, regardless of the radius of SVT2. Therefore, as the cost increases with the radius, we propose that SVT2 be placed at a radius of 7 cm. Due to mechanical considerations one will likely find that the radius of SVT2 may have to be slightly larger than 7 cm.

Our final configuration, due to the considerations addressed in this note, is thus:

SVT layer	Radius	Comments
1	5 cm	or as close to beam pipe as possible
2	7 cm	or at least 2 cm out from SVT1
3	15 cm	

4 Other considerations

In the preceeding arguments we've tried to justify and optimize the SVT geometry for a system whose primary goal is to match SVT hits with TPC tracks, and allow stand alone tracking of low p_T, primary tracks. We wish to stress that there are other considerations. Our arguments are most valid for the case in which one wants to match SVT hits to TPC tracks. When it comes to doing stand alone SVT tracking of low p_T tracks (using primary vertex as one point in fit), the optimum geometry will depend on what procedure one uses to do the tracking, i.e. track from the outside–in, inside–out, etc. Fig 7 summarizes many of the different aspects of the problem.

We also have not discussed the possible fourth layer of the SVT, which is necessary of one wishes to do stand alone SVT tracking for secondaries. Extrapolating from the calculations which we've presented, if one had a fourth layer our first guess is that one would place it at a radius of 9 cm.

To really optimize the SVT geometry we feel it is crucial to do the detailed simulations of the proposed geometries, and work at optimizing both the matching code for the TPC tracks, and the stand alone tracking code for the SVT. It is through this process of actually working on these codes that further insights may be gained on what the optimum SVT geometry is. To speed and simplify this process we believe it would be very beneficial to have all the necessary software modules (TPC tracking, TPC+SVT matching, Stand alone tracking, Decay particle reconstruction, etc.) in some sort of an analysis shell.

5 Conclusions

For a three layer SVT, with the insights we have at present, we conclude that the radii for the SVT detector layers should be 5, 7 and 15 cm.

References

[1] G. Odyniec et al., LBL–31773

[2] W. Christie, STAR Note # 15

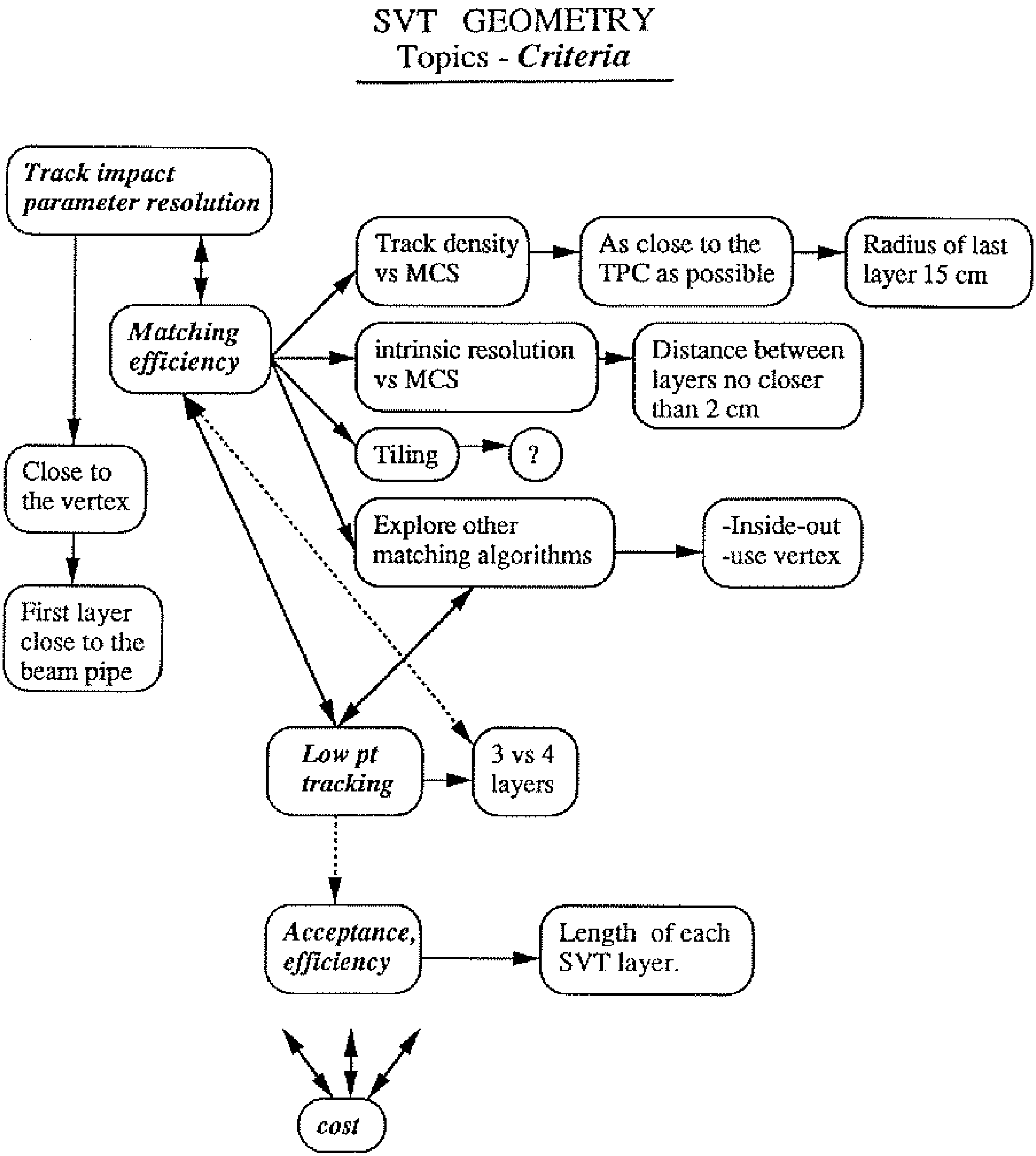

Figure 7: Different aspects of the SVT geometry problem.