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Momentum resolution improvement technique for the STAR-SVT

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Abstract

A technique for improving the momentum resolution for low momentum charged particles in silicon vertex trackers is presented. The particle momenta are determined from the measured dE/dx in each layer of silicon by comparing with the Landau dE/dx distribution which in the $1/\beta^2$ region has a large slope and is sufficiently narrow to give a better momentum resolution than that obtained by the standard helix fit method. Simulation results for the SVT in STAR show an improvement of almost a factor of 2 in momentum resolution for particle momenta between 60 and 200 MeV/c compared to that obtained by a helix fit that considers only multiple Coulomb scattering (MCS) effects.

1 Introduction

Recent results [1] have shown that the STAR-SVT momentum resolution in the low p_T region ($p_T < 300$ MeV/c) is rather poor. This occurs because a significant amount of MCS takes place for low momentum particles in the silicon wafers, beryllium support structure, electronics and cabelling, and water cooling structures in the three superlayers required by the SVT. It was initially believed that this would not be a problem because the SVT tracks could be matched with those in the TPC where dp_T/p_T in the region between 200 and 300 MeV is almost one order of magnitude better [2]. On the other hand recent simulations show that TPC tracking efficiencies and SVT-TPC matching efficiencies fall sharply for momenta below 200 MeV [3]. Thus the SVT might have to act as a stand-alone tracker for this low momentum region which is of great importance for the low p_T physics goals of STAR. This situation motivated the present work to develope new methods to improve the momentum resolution capability of the SVT as a stand-alone tracker.

The main idea of the present technique is to determine the momentum of low p_T particles from the SVT dE/dx information. The resulting momentum resolution obtained in this way is determined by the width of the Landau distribution for particles of known mass. The reason for the improvement in momentum resolution compared to that from helix fits is that the typical momentum standard deviation at 100 MeV/c obtained from the dE/dx Landau distribution is around 10 MeV/c, giving an uncertainty of 10%, compared to 30% uncertainty from the helix fit method.

Momentum resolution studies for SVT tracking [1],[4] provide analytic formula [6] for $\sigma(p)/p$ as a function of the total momentum which agree well with numerical simulations. For low momenta the multiple scattering term dominates giving a momentum resolution over 30 % for momentum around 100 MeV/c (see Fig.4 in [1]).

Moreover, in the $1/\beta^2$ region for silicon the dE/dx distribution is narrow and can be fitted by a Gaussian with a small sigma. Furthermore, in the $1/\beta^2$ region the slope of dE/dx versus momentum is very steep. For $p = 100$ MeV/c the dE/dx Landau distribution for pions traversing 300 microns of Si is shown in Fig.1. The dE/dx standard deviation occuring from the 30 % truncated Landau dE/dx distribution is about 1 MeV/cm. This is demonstrated in Fig.2 where the truncated mean dE/dx (*i.e.* the layer with the largest dE/dx value is not used and the remaining two are averaged) is plotted for $p = 100$ MeV/c. We can then use the Bethe-Bloch formula to find the corresponding momentum standard deviation which is about 10 MeV/c. So we get a momentum resolution of about 10 % for pions. This is more than two times better than the helix fitted momentum determination.

2 Results and Discussion

Application of the preceding technique was performed for STAR-SVT and for momenta below 200 MeV/c. For particle momenta in this region realistic simulations (real tracking and fitting) result in a $\sigma(p)/p$ of about 25 % for fits that include a known primary vertex (for fits with three SVT space points only $\sigma(p)/p$ is about 30 %). These values are in agreement with the theoretical predictions described in the previous section. It is also well known that most of the tracked particles in this momentum region are pions (90 %−95 %) and that the particle identification information is very reliable [5]. The method used here to obtain the momentum information is summarized as follows:

- Primary tracks from 10 Au+Au events were tracked using the SVT pattern recognition package SGR.
- A helix fit was performed using standard fitting routines.
- Particle identification was performed using the fitted momentum, the truncated mean dE/dx and the SVT particle identification package SPR.
- Replacement of the fitted momentum for $0.06 < p_{fitted} < 0.2$ GeV/c by the momentum that corresponds to the mean value of the dE/dx distribution for pion tracks only.

The results are shown in Fig.4 where a $\sigma(p)/p$ around 12 % is obtained. This should be compared with the results shown in Fig.3 for exactly the same tracks using only the helix fits to determine momentum.

The technique described above is obviously useful for Silicon trackers which by their nature (at least three Silicon layers are required) have a radiation length high enough for a certain momentum region, to generate a momentum resolution lower than that given from the dE/dx information. In particular for heavy ion experiments where low p_T physics is important (HBT studies, secondary particle reconstruction etc.) like the STAR detector at RHIC, it is necessary to determine the particle momentum as accurately as possible for the lowest possible momentum regions. The method proposed in this note can improve the momentum determination in the SVT by more than a factor of 2.

3 Acknowledgements

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References

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[2] STAR–CDR, PUB–5347.

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[4] C. Pruneau et al.; STAR note # 162, May 1994.

[5] E. Paganis, S. Margetis; STAR note # 126, September 1993.

[6] 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.

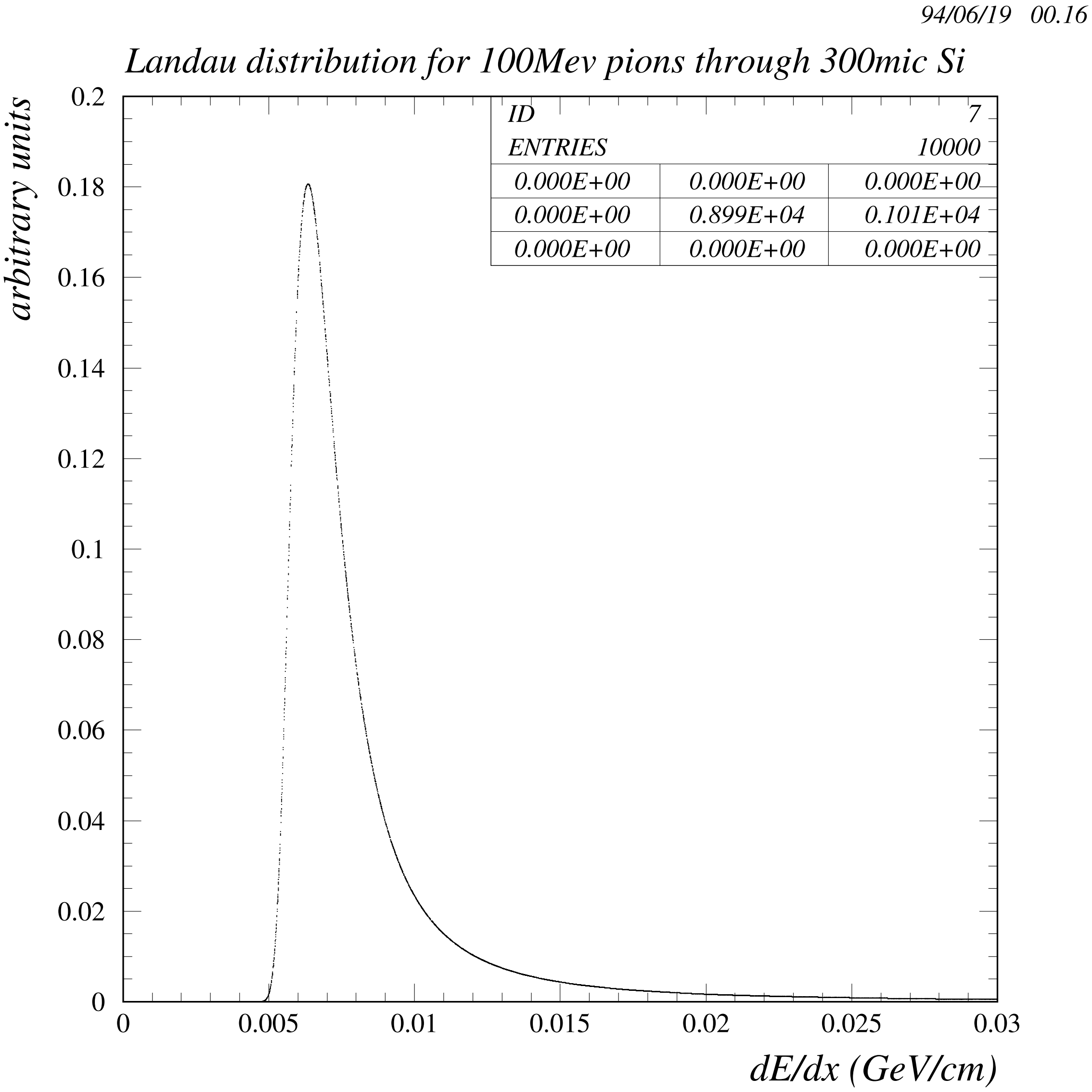

Figure 1: dE/dx Landau distribution for 100 MeV/c pions.

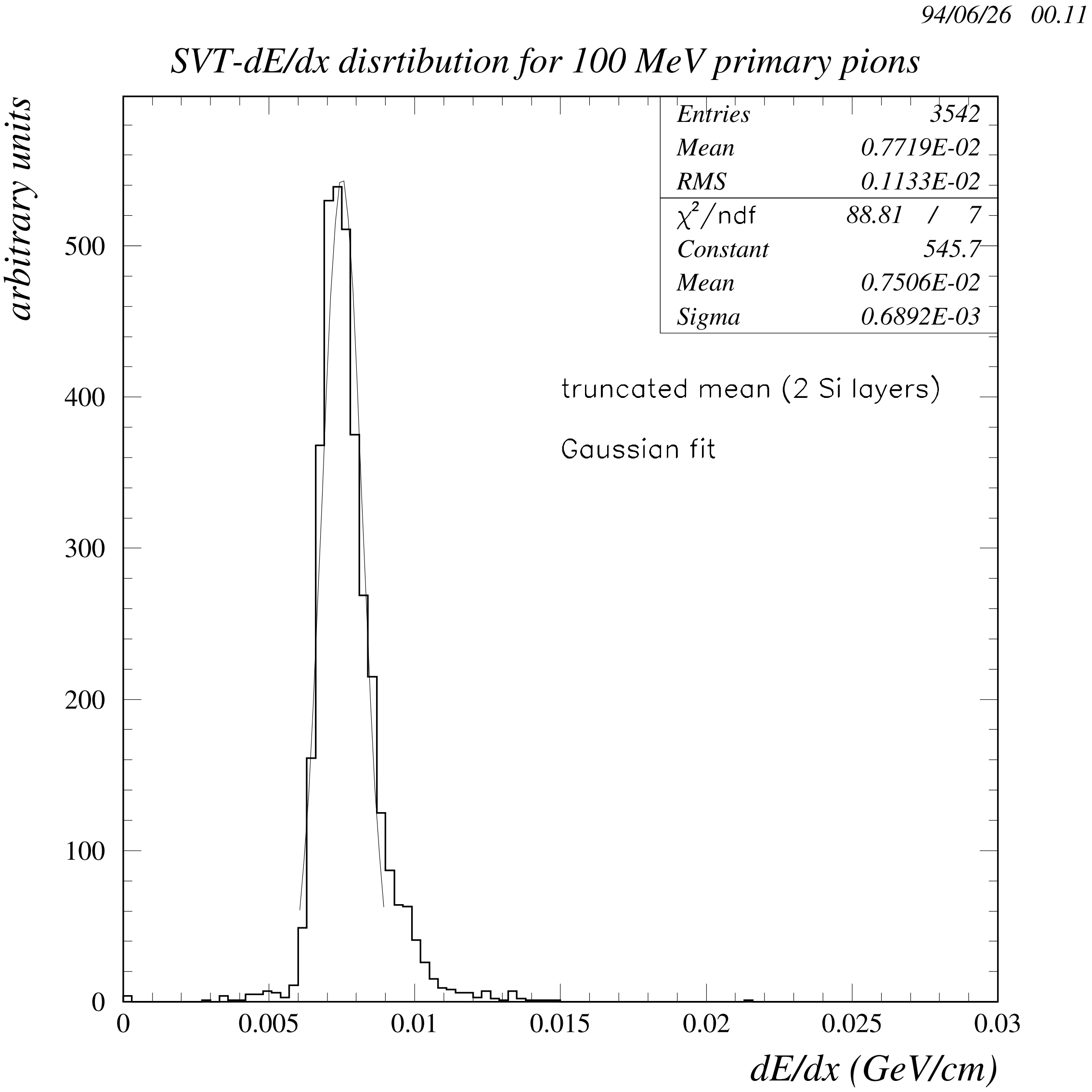

Figure 2: SVT-dE/dx truncated mean distribution for 100 MeV/c pions.

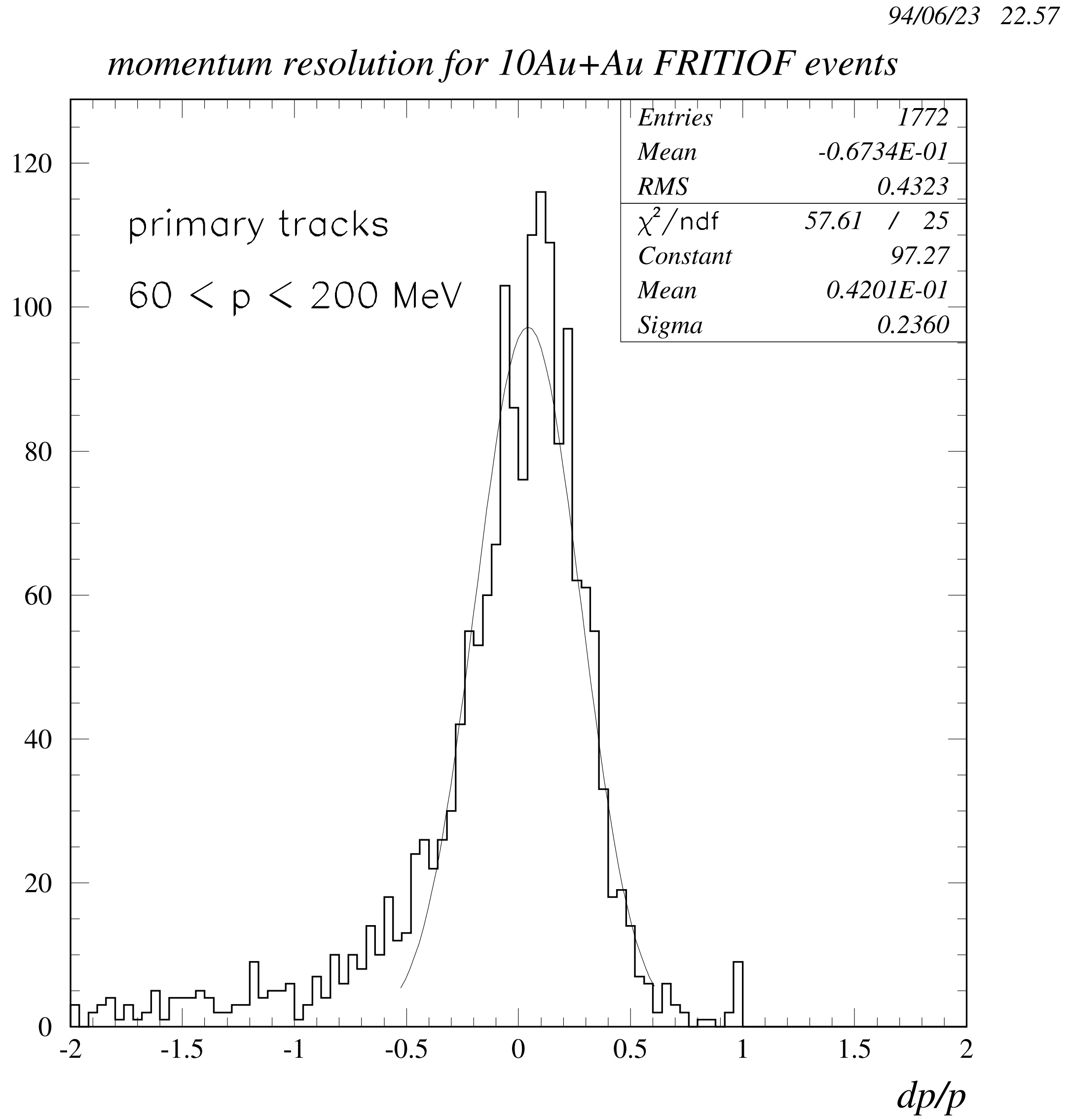

Figure 3: Momentum resolution for the STAR-SVT.

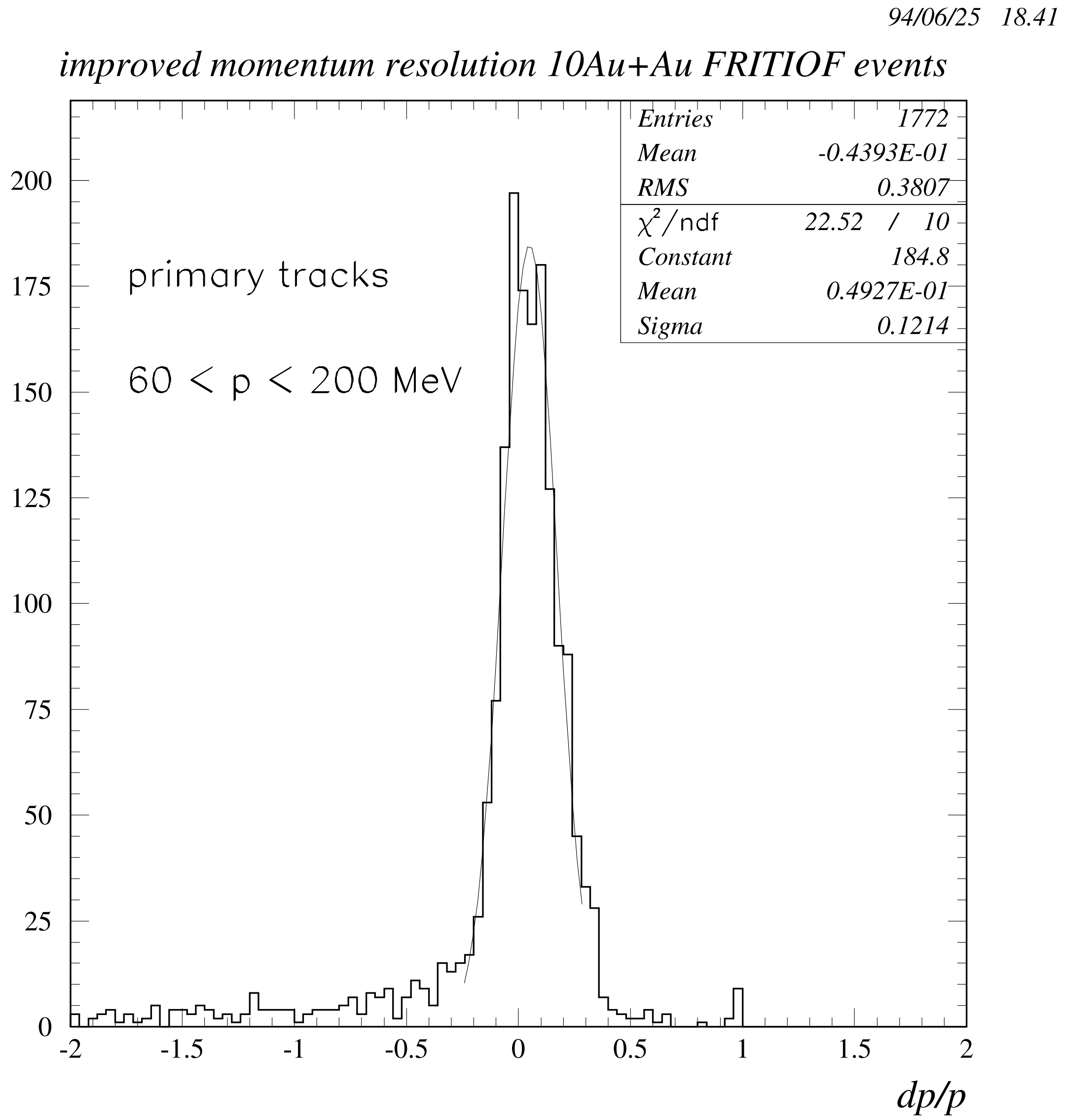

Figure 4: Momentum resolution improvement using the SVT-dE/dx information.