Perfomance Studies for a magnet tracker with a reduced set of Outer Tracker superlayers

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1 Aim

The main purpose of the magnet tracker is to connect the track segments of the pattern tracker and vertex detector and to provide momentum and vertex information for V^0's decaying in the magnet.

The detailed design of the chambers that were planned to be put inside the magnet showed that the superlayer MC07 conflicts with the High–p_t chambers due to the space need of the chambers.

The superlayer MC05 is difficult to mount in the center of the yoke and there is hardly space for prepamplifiers, cabeling etc.

As the pattern recognition chambers provide a good initial track definition, the information of the last magnet tracker superlayer MC09 might not improve the track parameters much. Since the magnet field strength at its position is already low, it would also hardly improve the momentum resolution.

This investigation tries to give some answers to the question of how far the removal of these magnet chambers lead to a loss in efficiency.

2 Geometries

The study was done on seven different geometries. As a starting point, the standard hbgeant geometry 04-01 was modified to contain only 3 stereo layers in MC01 as this modification was already decided. This was taken as full geometry, denoted by "*all MCxx*". Further modification were:

Geometry	**denoted by**
without MC07	no MC07
without MC09	no MC09
without MC07 and MC07	no MC07 MC09
without MC05, MC07 and MC09	no MC7 MC9 MC9
without MC03, MC05, MC07 and MC09	no MC3579
with only MC01, MC05, and MC08	no MC234679

the last one mainly as extreme example for comparison and the *no MC3579* geometry to get a better feeling for the effect of subsequent removals of planes.

3 Simulation

The strategy to answer the question was twofold:

1. Samples of 600 B interactions and corresponding minimum bias interactions were generated for the geometries *all MCxx* , *no MC07* , *no MC09* and *no MC07 MC09* to be mixed at a fixed ratio

(no poisson distribution) of 1:4. For these samples the μ reconstruction efficiency was calculated. To save time, only 1 missing hit (fault) in a row was tolerated, resulting in reduced track finding effiencies which are only useful for relative comparison. The definition for tracks being properly reconstructed was based on the fraction of properly reconstructed hits. Reference tracks were defined as MC tracks with at least 7 hits in the magnet superlayers, not counting hits in MC07 and MC09, and a z value of the first hit lower than 450 cm (center of magnet).

The reconstruction efficiency was defined as the rate of the reference tracks that were reconstructed by Ranger 4.6 with a (preliminary) magnet tracking for non-homogeneous field.

As this definition of the reference tracks and hence the efficiency can not completely be generalized to other geometries, these efficiencies were only calculated for those four geometries mentioned above, resulting in the following numbers:

Geometry	**Efficiency**[1]
all MCxx	(88.75 ± 2.04) %
no MC07	(86.23 ± 2.19) %
no MC09	(87.50 ± 2.10) %
no MC07 MC09	(87.30 ± 2.13) %

As the different geometries were respected at the level of event generation — giving different random numbers for different geometries — the statistical errors are uncorrelated.

2. In order to optain a geometry–independend measure, and in addition take also the quality of a reconstructed track into account, a second study was done.

   As one of the most delicate tasks of the tracking system is the reconstruction of the K_S^0 — having lower momenta than the J/Ψ and thus being more critical — this was chosen as topic of investigation.

   This identification is done by reconstructing the invariant mass from the $\pi^+\pi^-$ produced in a K_S^0 decay, therefore its distribution is a realistic measurement for the quality of the $\pi^\pm$ track reconstruction.

   In this study the reconstruction was done as before, this time allowing 2 missing hits in a row to get a more realistic result. The pions were related to a Kaon by MC information, their track parameters were propagated to the z position of the MC vertex. No vertex reconstruction or fitting was used[2].

   For all K_S^0 that decayed into two charged pions, for which any related tracks where "found", the invariant mass was calculated, even if a "found" track had only one segment outside the magnet, e.g. for geometrical reasons. For those $\pi^\pm$ MC tracks which had more than one related reconstructed track, the reconstructed parameters of the track with the highest quality value $\#\text{hits} - \chi^2$ were taken, #hits meaning the number of reconstructed hits and the χ^2 taken from the Ranger track fit without iteration.

   To save cpu time, this simulation was not done with full B interactions. Instead a sample of 5000 single K_S^0 for each geometry was generated, approximating the momentum spectra from B decays (cf. fig. 1). 10 of those single Kaons were mixed with 4 minimum bias interactions, thus in 500 events (per geometry) over 5000 K_S^0 decays — including those from the minimum bias interactions — with occupancies comparable to those in a $1B + 4$ minbias event were available.

   For efficiency estimates, all K_S^0 with a reconstructed invariant mass within a ± 20 MeV window around the nominal K_S^0 mass value were considered to be properly reconstructed.

[1] with 2 tolerated faults, Ranger in its current state finds in the standard geometry ~ 92 % of the muons from the golden B decay

[2] At the time of the study, no vertex fitting routine for the inhomogeneous magnetic field was available

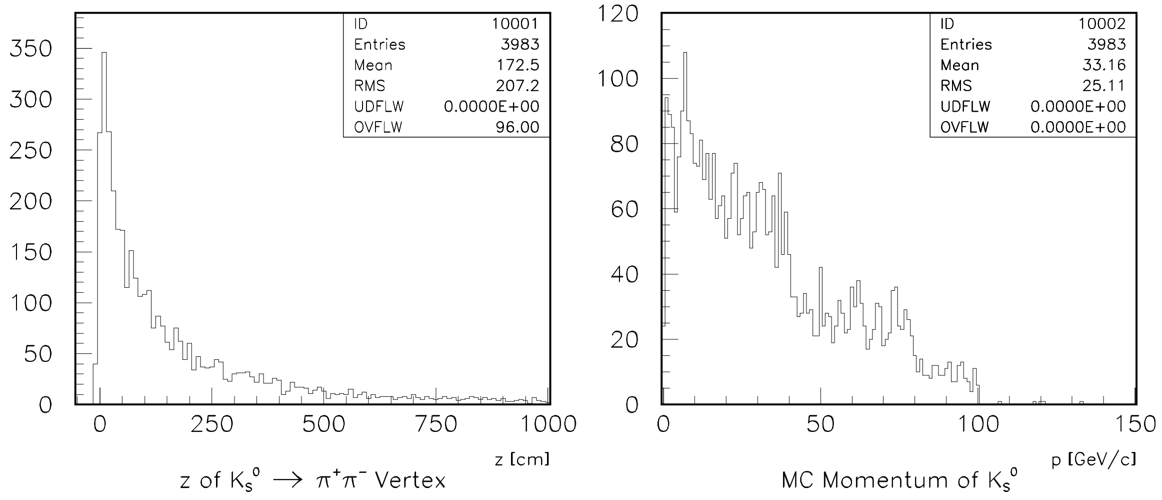

Figure 1: Distribution of the MC K_S^0 decay vertex z value and the MC K_S^0 momentum used in the second method for one of the samples. Including the values of the individually generated K_S^0 as well as those from the minimum bias interactions.

As the artificial K_S^0 generation does not reproduce the kinematics of those produced in B interactions exactly, the geometrical acceptance might differ slightly. Therefore the number of reconstructed K_S^0 was related to the number of all calculated invariant masses, thus reducing the sample to K_S^0 's which have at least been reconstructed in the pattern tracker and therefore giving a "Relative Efficiency" containing some geometry factors. Therefore these efficiency numbers serve only for relative comparison within this note and should not be related to any number outside this study.

The distribution of the reconstructed $\pi^+\pi^-$ mass spectra for all investigated geometries can be seen in fig. 2, the values for resolution and efficiencies in fig. 3 and the following table:

Geometry	**K_S^0 Mass Resolution**	**Rel. Efficiency**
all MCxx	(9.44 ± 0.26) MeV	(66.58 ± 0.99) %
no MC07	(8.74 ± 0.29) MeV	(62.25 ± 1.02) %
no MC09	(9.63 ± 0.28) MeV	(69.34 ± 0.97) %
no MC07 MC09	(9.74 ± 0.29) MeV	(62.79 ± 1.03) %
no M5 MC7 MC9	(9.12 ± 0.26) MeV	(61.14 ± 1.04) %
no MC3579	(9.83 ± 0.33) MeV	(59.91 ± 1.04) %
no MC234679	(11.75 ± 0.76) MeV	(24.93 ± 0.95) %

4 Conclusion & Remarks

We understand the results in the following way:

- Removing MC09 from a detector with all magnet superlayers or all but MC07 seems not to lead to noticeable loss in efficiency.

  This can be understood since MC09 hardly improves the momentum and the other 4 track parameters are sufficiently precise.

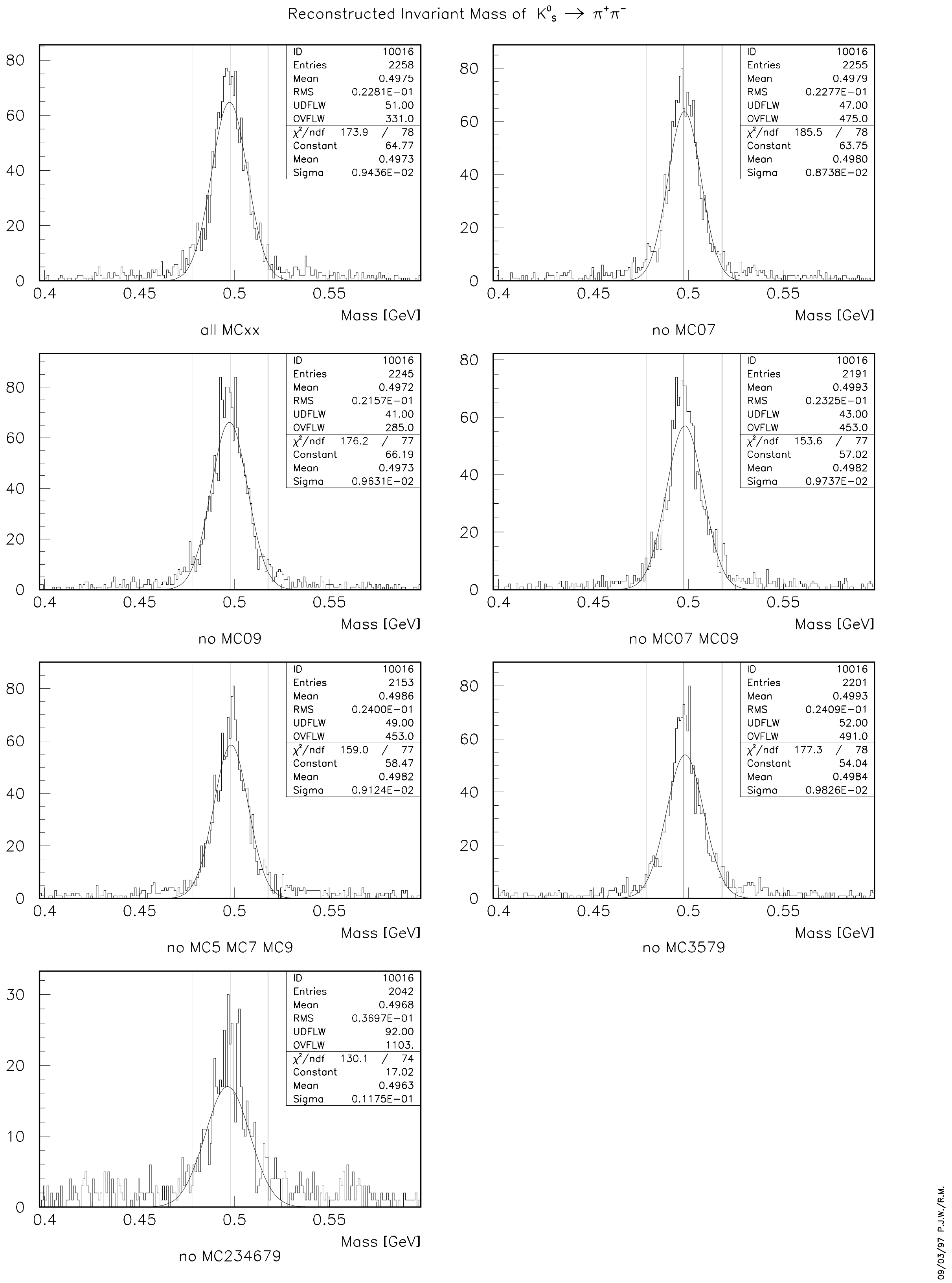

Figure 2: Distribution of the reconstructed K_S^0 mass for different geometries. The nominal K_S^0 mass and the $\pm 20\,\mathrm{MeV}$ window for efficiency studies are indicated by vertical lines

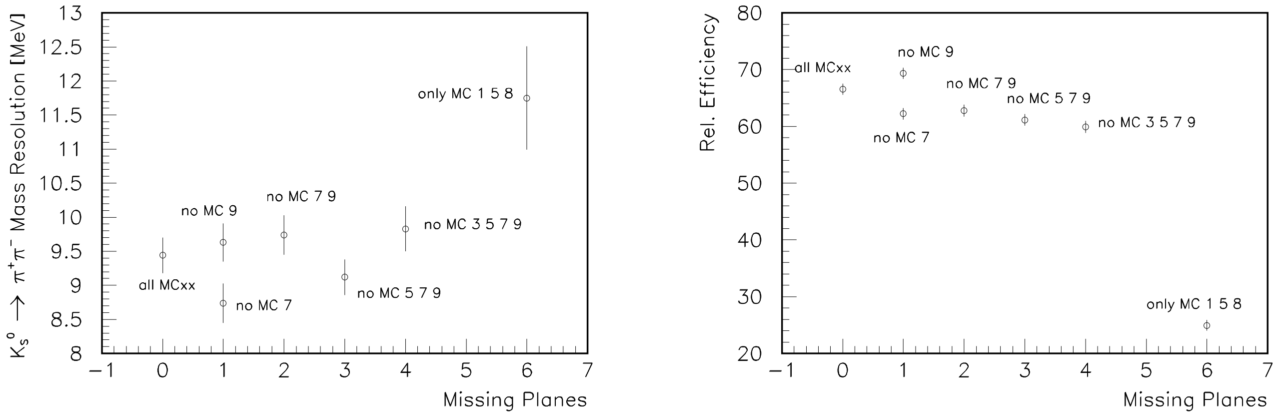

Figure 3: The values of the resolutions (left) and rel. efficiencies (right) of the K_S^0 reconstruction for the different geometries, plottet against the number of missing superlayers

- The removal of MC07 leads to a loss of about 4 ± 1.5 % in efficiency.
- Further removal of MC05 and MC03 costs additional ~ 1.5 % efficiency each.
- The extreme example *no MC234679* gives inacceptable results.

  The big drop in efficiency compared to even the worst one of the other examples might be explained by the fact that this is the only geometry having more than one superlayer in a row removed, thus having the largest gaps between two superlayers.
- The study was done on K_S^0 and related $\pi^{\pm}$ identified by MC information, therefore conclusions about background are not drawn here.
- The mean resolution of the reconstructed mass will of course be better, when the hits in the silicon vertex detector are added. However in scenarios where the magnet tracker cannot reconstruct the $\pi^+\pi^-$ mass, proper matching with the vertex detector segment is doubtful.
- As these distributions are the first masses reconstructed with the full main tracker pattern recognition, the resolutions and efficiencies should not be taken as final numbers.

5 Inner Tracker

It has to be noted, that the geometry of the Inner Tracker was not adapted to the changes of the Outer Tracker but left unchanged. A clear statement about the Inner Tracker geometry can not be made *on the basis of this investigation.* However it is obvious that the Inner Tracker planes have to be placed near the Outer Tracker planes. Other constellations will lead to an increase in the geometrical loss. To compensate for that simply by increasing the area of the planes would mean an increase in material.