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Magnet parameters and the momentum resolution

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The aim of this paper is to study how the momentum resolution depends on magnet parameters of the CMS or a CMS-like detector. It is an extension of the work presented in CMS TN/92-12 and in CMS TN/93-62. The later one is devoted to study behaviour of the barrel part of the detector whereas here we consider also forward region. We examined variation of the magnetic field value, the coil radius and the aspect ratio, possibility of adding forward toroids and implications for the choice of the inner tracker technique.

The goal of the first part of this paper is to answer the question about performance of the CMS detector with reduced magnetic field, given by LHCC referees. The second part is a contribution to the work of the "Group of Six" (GoS) appointed by CMS and L3P collaborations in order to explore a possibility to design a detector acceptable for both collaborations.

1 Reduction of the magnetic field in CMS

We have studied a possibility of reduction of the magnetic field from 4 T to 3.5 T or 3 T. Since the radius of the coil has been fixed, the overall magnetic flux is reduced. Therefore the return yoke is thinner by 20 cm and 40 cm respectively in order to keep the iron saturated. Other dimensions of the detector are unchanged (Fig. 1 and 2).

Comparison of momentum resolution for the three values of the magnetic field is presented in Fig 3. As expected, dp/p increases proportionally to the field value except for low momentum and high rapidity region. In this region multiple scattering plays a dominant role. Hence reduction of the bending power is compensated by smaller multiple scattering in the thinner yoke.

2 Detectors studies by GoS

In the discussion with L3P, CMS proposed a detector similar to this presented in the LOI but with tracker radius R_e enlarged from 1.3 to 1.7 m. Coil parameters are the same as described in the LOI.

Silicon Tracker is also the same, but MSGCs are enlarged and redistributed proportionally to fill the inner tracker cavity. All other radial dimensions are enlarged by 40 cm and longitudinal ones by 80 cm. This version, called "CMS a", is a result of optimization procedure described in CMS TN/93-62. In order to improve the performance of the detector a small modification has been done (see Fig. 4). Coil radius has been changed from 3 to 3.4 m to accommodate the whole HCAL inside. Magnetic field has been then reduced from 4 to 3.5 T to keep the flux constant and thus avoid modification of the muon system. Length of the coil has been increased in order to keep constant aspect ratio. Hereafter we call this version "CMS c".

L3P considered further increment of R_e up to 2.3 m (Fig. 5).

3 Inner tracker technique

In case of R_e=2.3 m detector proportional enlarging of the MSGCs is no longer possible due to high cost. Thus one has to consider replacing some MSGCs by another technique like Straw Drift Tubes. Two extreme possibilities has been examined. One is a la CMS solution but outermost MSGC superlayer in the barrel is replaced by Straw Tubes. We call this version "L3P c". The second solution, a la L3P, is essentially an inner tracker proposed in the L3P LOI scaled proportionally down. It has two superlayers of Straw Tubes in the barrel, 2x2 superlayers of MSGCs in the forward region and no Silicon Detector. We denote it "L3P s". Presumably the "L3P c" version is too expensive and the "L3P s" is too coarse but they give reasonable lower and upper limits.

Momentum resolution of the two versions as a function of η is compared in Fig. 7. For the lowest momenta the resolution is dominated by multiple scattering, hence L3P like version having much less material is better in this region. However to achieve good resolution at higher momenta, more precise CMS like tracking is required. Thus hereafter we consider the CMS like tracking only.

4 Coil aspect ratio and forward toroids

Originally the R_e=2.3 m detector has been proposed with the same length as the CMS LOI version. That case one can expect degradation of the resolution in the forward region related to the coil aspect ratio. This can be improved by making the coil longer to restore the original CMS aspect ratio. To distinguish these two versions we denote the short one "L3P b" (Fig. 5) and leave the name "L3P c" (Fig. 6) for the long one.

Another possibility to improve performance of the detector in the forward region is to add toroidal magnets. We examined a possibility of reusing the existing L3 magnet of 1.8 Tm and building a new one having as much as 6 Tm. The two versions we call "L3P t" and "L3P T" respectively. The comparison is presented in Fig. 8. An improvement due to toroids is marginal whereas making the coil longer improve the resolution remarkably.

5 Comparison of various solenoids

Among various L3P proposals we selected "L3P c" as the best one. We compare it with "CMS c" and CMS LOI version. The result is presented in Fig. 9. Since all the three detectors are equipped with high granularity trackers the momentum resolution is better for larger radii. However to draw a proper conclusion one has to balance the improvement with increment of the overall cost.

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