Meeting about ILD Magnet Issues
CEA, Saclay
29.07.2008, 10:30-16:15

Minutes

Present: F. Kircher (CEA), O. Delferrière (CEA), C. Clerc (LLR), M. Joré (LAL), K. Sinram (DESY), K. Buesser (DESY)

1 General Remarks

The purpose of the meeting was to have a first-hand discussion about the properties of the magnet for ILD. The calculation of the magnetic forces is an important ingredient in the engineering design of the yoke. The calculations of the magnetic fields is also needed to fulfil the requirements of the tracking system on the field homogeneities.

The discussion was prepared by a list of questions, which K. Sinram has been circulated to the meeting participants a couple of days ago. These minutes will follow the questions on the lists which deviate sometimes from the chronological course of the meeting.

The most important outcomes of the meeting was the agreement on a common set of parameters for the coil (c.f. 2.1.4) and the discussion on whether the detector could be moved in push-pull operation with the cold coil. There are concerns by F. Kircher (c.f. 2.5.6), that this could not be done, at least not often in routine operations. More studies and eventually also R&D efforts are needed to clear that point.This problem is crucial, as it might be a real show-stopper for the push-pull idea!

2 List of Questions (‚Sinram-List')

2.1 CHOICE OF FIELD CONFIGURATION AND PARAMETERS

2.1.1 What are the existing 3D- and 2 D calculations for a LDC-type detector?

At Saclay 2D simulations are being performed using Opera-2D. 3D simulations are under preparation. O. Delferrière has performed many 2D simulations to study the influence of the detailed iron geometry on the field shaping and on stray fields.

At DESY EMStudio (successor of MAFIA) ist used for the field calculations which will be used as input to yoke force calculations using ANSYS.

Simulations of the magnetic fields have also been done at KEK.

The most advanced field simulations are the ones performed by O. Delferrière and C. Clerc for the LDC-V5 version. The field homogeneities in the coil without any field-shaping devices is in the order of ΔB ~ 20mm (for def. see 2.1.4), which is large compared to the requirements stated in section 2.1.4. Adding a field shaping plate (FSP) of 10 cm thickness on every side of the solenoid and increasing the half length of coil from 3.3 to 3.5m reduces ΔB to ~ 5.5mm. Increasing the thickness of the FSP to 20cm on each size would yield ~3.2mm, which is still larger than the requirements discussed in 2.1.4. The outer radius of the FSP could stretch out to the inner radius of the coil. The simulations show however a weak dependence on the radius with an optimal value of 1.5m. Therefore the FSP might be smaller than the coil and needs to be surrounded by a ring of non-magnetic steel.

O. Delferrière did detailed simulations of the stray fields. With realistic assumptions of the gaps between the endcaps and the barrel he found out, that the iron thickness might need to be increased to 3m.

The stray fields in longitudal direction however require a total iron thickness of 3m for the endcap if one sticks to the requirement of having less than 200G stray field at 10m in z-direction. A revision of this requirement should be initiated as the 3m thick iron reduces the space available for an opening of the endcap yoke on the beam position. The area is anyhow shielded by the yoke and the pacman and should not be accessible during normal operations.

2.1.2 Which are the parameter sets used?

The parameters used at Saclay were r_i=3.4m, r_o=3.75m, l=7.0m, B=4.0T. At DESY slightly different parameters have been used. The participants of the meeting agree after some discussion on the following set of parameters for the coil:

r_{in} = 3.4 m
r_{out} = 3.75 m
l = 7.35 m
B = 4T

This parameter set for the coil will now be called *ILD_L3_Saclay*. It was the common understanding, that the parameters for the engineering study need to be realistic, but don’t need to exaclty reproduce the parameters used for the physics studies at ILD. As the detector optimisation studies are still ongoing until spring 2009, we need to agree on a set of parameters to continue the engineering studies. Moderate adjustments of the parameters could then easily be performed when the optimisation studies have converged.

The parameters above would accommodate an FSP of 10cm thickness. If more is needed, an increase of the coil length might be needed.

The segmentation of the yoke is defined by the needs for a tail catcher and a muon system. In the endcap there will be five tail-catcher layers, each with an thickness of 3cm, with 10cm of steel in-between each layers. The outer part of the endcap will be divided in four slices with 3cm slits in-between.

The geometry of the barrel yoke is similar, with the exepction that just 4 tail-catcher layers are foreseen.

NB: For the endcaps, the designers at LLR/LAL proposed to concentrate the muon chambers in a first half of the endcap, and to keep a second (outer) part free of muons chambers, for stiffness reasons, and to allow splitting. The the distribution and numbers of chambers have to be checked regarding the numbers of λ.

The total thickness of the iron depends on the requirements of the stray fields and might be increased to 3m of iron everywhere.

2.1.3 Which tools (Ansys, EM-Studio?)

See 2.1.1 above.

2.1.4 Which criteria have to be fulfilled for the solenoidal field, what is the definition for a "good field"?

The most common measure of the field quality is the following integral:

$$\Delta B = \int_{z}^{z_{max}} (B_r/B_z)\, dz$$

The most stringent requirements for the field quality most probably come from the TPC. A final answer from the LC-TPC collaboration on the needs for the field homogeneity has not been given yet. A recent LC-Note[1] summarises the state of the discussion. Therefore the precision of the field map is more important than the classical requirement ΔB < 2mm which has been followed, e.g. at LEP. However it is stated that as a potential DID or Anti-DID field will dilute ΔB to about 20 mm, it might still be advisable to follow the '2mm requirement' for the solenoid coil.

2.1.5 Are there calculations for different central fields (3 T/ 3.5 T/ 4 T)?

All simulations have been performed for a 4T field. As this is the most challenging case it was decided to stick with this field strength for the time being.

2.1.6 Are the fields in the slits of the iron yoke crucial for the detector elements (Muon chambers/tail catcher) ?

This needs to be studied. It should be doable on a short timescale as the simulation tools are at hand.

2.2 MAGNETIC ANALYSIS

2.2.1 Is there a favourable dimensional ratio (length/radius) for the coil?

This probably exists, but the current ILD design is far away from that optimum.

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[1] R. Settles, W. Wiedenmann, ‚The Linear Collider TPC: Revised Magnetic-field Requirements', Draft LC-DET-2008-XXX

2.2.2 How does the length of the solenoid influence the field quality?

The longer, the better.

2.2.3 How does an increasing radius of the solenoid influence the field quality for a fixed length?

It probably decreases.

2.2.4 Is there a strong reason to go for steel with special magnetic properties (high permeability/low coercive force)?

A requirement for special steel magnetic properties will most probably not arise from the requirements on the field homogeneity (with exception to e.g. the FSP). This could be verified easily by changing the magnetic properties of the iron used in the simulations.

The remnant fields however will be affected by the magnetic properties. Here it is especially important to avoid inhomogeneities in the magnetic steel properties. These will e.g. arise from treatment (cutting, welding) of the steel.

2.2.5 How strong are the remanent fields in the yoke iron and the resulting forces using soft magnetic steel or steel grades with better mechanical properties (higher allowable stresses)

The remnant fields have been measured at CMS and were found to be in the order of 500G. This should not impose problems.

2.3 COIL

The outline for the coil was given in the LDC DOD and is in principle still valid. The parameters need to be adapted for the new ‘Saclay’ parameter set.
The coil will be divided in five modules, the central three each of ¼ of the total length, the outer two each of 1/8 of the total length. So for the ‘Saclay’ parameters, the central parts have a length of 1.85m, while the outer two parts are 0.9m long each.

2.3.1 How many layers, number of turns are foreseen for the coil?

- Coil with correction currents:
  - central modules, 1.6 m long each, 4 layers, 70 turns/layer, I = 17.9 kA
  - 2 external modules, 1.17 m long each, 4 layers, 44 turns/layer, I = 17.9 + 29. 0 = 46.9 kA in the 2 central layers, 17.9 kA in the two others

- Coil without correction current (will be more accurate after Olivier’s calculations):
  - 3 modules, about 2.4 m each, 4 layers, about 100 turns/layer, I around 20 kA

2.3.2 Are correction coils necessary to eventually improve the field quality?

Yes: the magnetic nose has been forbidden and the FSP is not sufficient to reduce ΔB to few mm

2.3.3 What are the operating currents for 3 T/ 3.5 T/ 4 T?

For 4T: around 20 kA for the main current and 30 kA for the correction current. These currents are roughly proportional to the field

2.3.4 What is the ramp-up and ramp-down time?

About 4h.

2.3.5 What is the cool-down and warm-up time?

About 1 month for each operation (rate about 0.5 K/h).

2.4 VACUUM TANK

The following questions have been discussed, but no answers could be given from the present persons. The CMS vacuum tank has been designed and constructed by CERN, so we should try to get some information from there.

2.4.1 What are the dimensions of the vacuum tank (thickness inner shell, thickness outer shell, end flanges) used in the calculations?

2.4.2 What are the loads acting on the vacuum tank?

2.4.3 Where are the optimal positions for rails welded to the inner vacuum tank shell to hold the barrel hadronic calorimeter?

2.5 BARREL YOKE

2.5.1 Which geometry of the barrel yoke was used in the magnetic analysis of the solenoid magnet?

The geometries were close to the ones defined in 2.1.2. All future simulations will be done with the 'Saclay Parameter Set'.

2.5.2 How sensitive is the field quality to details (total iron thickness, number of layers, thickness of individual layers) in the barrel yoke design?

This needs to be checked in detail. Most probably the field quality inside the coil is not very much affected by the geometrical details in the yoke. The total thickness of the iron counts.

2.5.3 What are the magnetic forces acting on the individual elements of the barrel yoke?

The simulation of the forces are pending at DESY. As the currents and field of the coil are very similar to CMS, the forces – as documented in the CMS magnet TDR – should be similar.

2.5.4 What is the impact of the gaps between the 3 barrel rings?

The gaps should have no effect on the field quality, but they influence the stray fields outside!

2.5.5 Are there field disturbances within the solenoid volume due to local asymmetries in the barrel yoke (cut outs for the cryogenic and the vacuum and current lead chimneys)?

The local asymmetries (e.g. chimneys) are tiny local disturbances and will not influence the field quality inside the solenoid.

2.5.6 Is it possible to power the magnet during push-pull to insure rigidity between the 3 barrel rings and the closed endcaps? What infrastructures are needed (moving helium supply) for such an operation?

No! (F. Kircher). Francois was very worried that the magnet should be moved powered-down but still cold. He is concerned that vibrations during the movement of the magnet might destroy the support structures inside the coil. As example he mentioned tests, which have been done with Titanium structures – the support structures inside the coil are made of Titanium – in cold and warm conditions. For some Ti alloy (Ti 6Al 4V ELI), the notch ratio is below 1 at cryogenics temperature, which means that a crack inside the support will propagate. Fracture toughness tests have confirmed the different behaviour of this material at cryogenics temperature with Ti 5Al 2.5 Sn ELI for example (the one used in CMS, but quite difficult to get nowadays).
Further mechanical calculations and studies are needed to clarify that problem!

NB: If this is true, the concept of push-pull is not viable anymore, as the warm-up resp. cool-down times are in the order of one month!

2.6 ENDCAP YOKE

If not stated otherwise, the answers to the relevant questions in section 2.5 apply here too.

2.6.1 Which geometry of the endcap yokes was used in the magnetic analysis of the solenoid magnet?

2.6.2 How sensitive is the field quality to details (total iron thickness, number of layers, thickness of individual layers) in the endcap yoke design?

2.6.3 Is there a substantially difference in the field quality between flat endcaps and endcaps with field shaping noses for a fixed solenoid geometry?

Yes! The CEA simulations show that a field shaping plate (FSP) might be needed (c.f. 2.1.1).

2.6.4 What are the magnetic forces acting on the individual elements of the endcap yokes?

2.6.5 What makes the difference between a round and a squared hole in the encap yoke?

No difference expected.

2.6.6 How does the field in the endcap hole interferes with the QD0-field? Is there an effect on the beams?

The QD0 magnets are surrounded by an anti-solenoid, which shields the main coil effects. So no major effects are expected.

2.6.7 How wide is the gap between barrel yoke and endcap to overcome the attracting forces due to remanent fields to separate the endcap from the barrel in z-direction?

The CMS experience shows that 5mm are needed.

2.6.8 Is it possible to cycle the magnet to reduce the remanent magnetisation of the iron to reduce this gap? How long would that take?

F. Kircher would advise to not cycle the magnet. First of all the remnant fields are low (500G), so that it is not needed. Then, the cycling would take too long, as the power-up/down time of the magnet is about 4h. And finally, the stresses on the coil components are big and should be avoided.

2.7 TOOLS

2.7.1 Which tools for magnetic force calculations (ANSYS, EMStudio)?

CEA uses Opera-2D and Opera-3D for the field calculations. The forces are calculated with the CEA made code CAST3M.
At DESY the fields are calculated using EMStudio, the forces are calculated in ANSYS.

2.7.2 Influence of mesh sizes on results?

It is important to use very fine meshs. Also the mesh size needs to be much bigger than the magnet itself. The meshs used reach more than 30m outside the magnet.