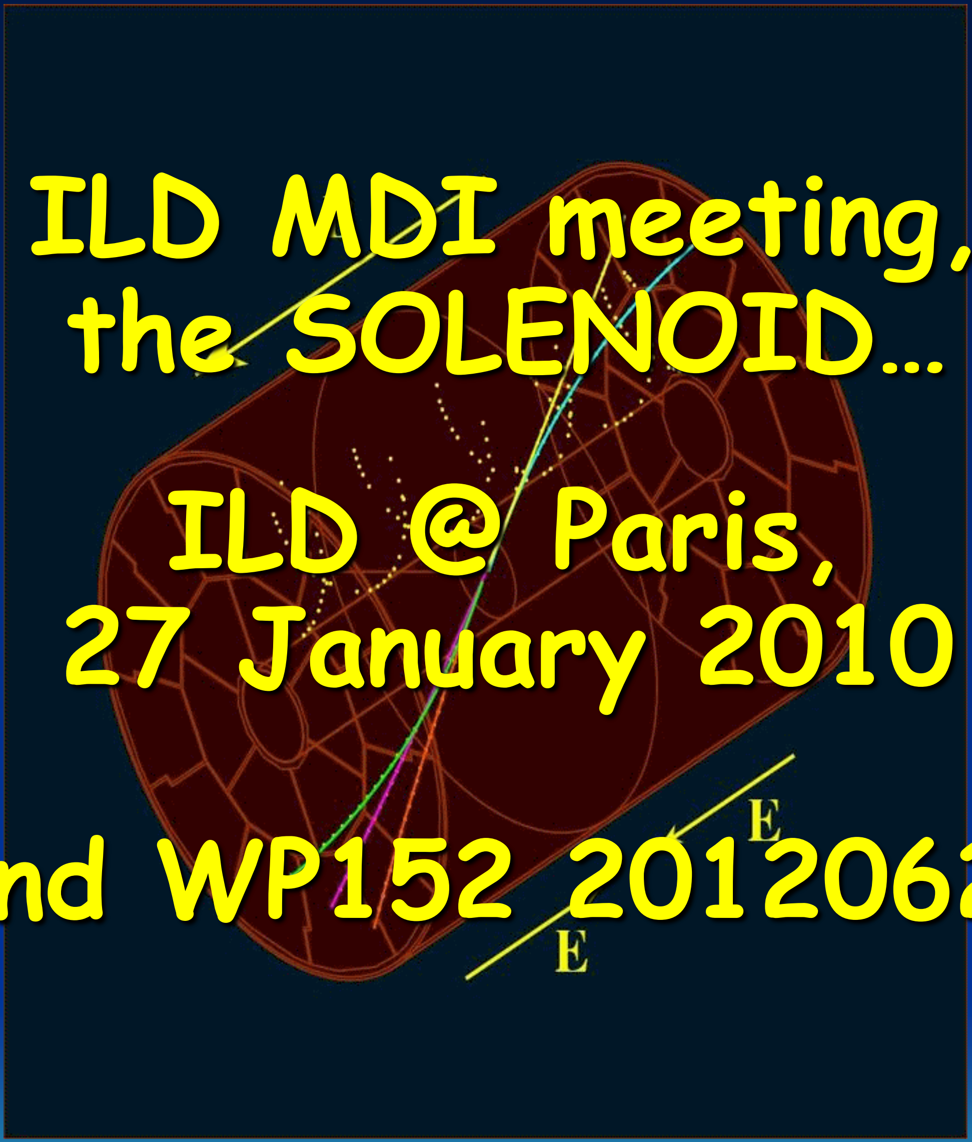
ILD MDI meeting, the SOLENOID…

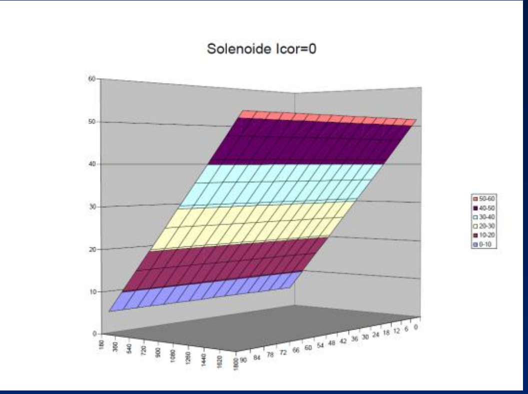
ILD @ Paris, 27 January 2010

and WP152 20120621

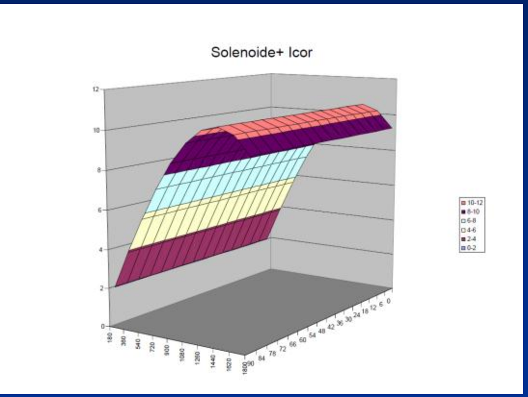


Ron Settles MPI-Munich

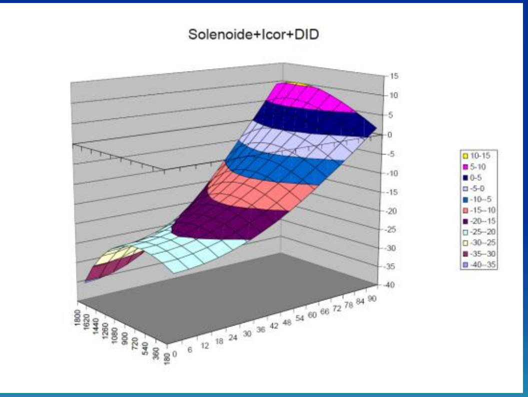
Options for the ILD solenoid…



Bare magnet,
∫Br/Bz dz ≤ ~ 54mm

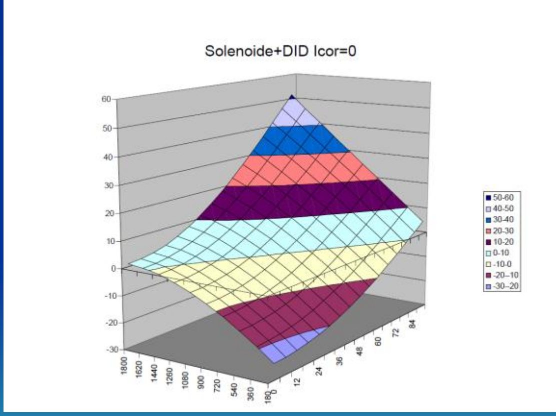


Correction coils,
∫ ≤ ~ 10mm



Add antiDID,
∫ ≤ ~ 35mm

With andiDID but no correction,
∫ ≤ ~ 50mm



Since 35mm (with corrector windings) and 50mm (without) is not a big difference, the big question was: "Do we need the corrector windings?" At the Paris meeting, ILD decided the answer was **"NO"!**

- So ILD decided in Jan 2010 not to have corrector coils, but this was not realized by a lot of the community.
- I was asked to write an LC-NOTE to document this fact…

final version 20111212
LC-DET-2011-002
http://www-flc.desy.de/lcnotes
ILC-NOTE-2011-061
http://ilcdoc.linearcollider.org
LCD-NOTE-2011-039
http://lcd.web.cern.ch/LCD/Documents/Documents.html

LCTPC and the Magnetic Field for ILD: Update 2010

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Abstract

This note is a further development of the ideas presented in Refs. [1][2][3][4]. The recent issue is that the LCTPC [5] collaboration in conjunction with the ILD [6] has decided not to specify a limit on the uniformity of the magnetic field. The reason is that large gradients will result from the anti-DID (Detector Integrated Dipole)[7][8], which will be implemented to reduce backgrounds in the detector. Since now a uniformity-limit will not be defined, the corrector windings in the solenoid can be eliminated. This decision had not been published as LCNote in 2010 and will be documented here.[2] The TPC for CLIC is also addressed.

- The basic idea: any B-inhomogeniety can be corrected if the B-field is known exactly, i.e., mapped well enough. We just have to invest sufficient effort in measuring it…

3 Magnetic Field Accuracy, Ref. [2]

In this note, the discussion will be based on the ideas presented in Ref. [2].

To achieve the required tracking performance, as formulated in [2], systematic effects in the TPC track reconstruction should be corrected to an accuracy of about $\sigma_0 \simeq 30\ \mu$m. The 30 μm was somewhat arbitrary and will be re-examined in Sec. 5.

The relevant equations in [2] for the field map were the following. The main requirement proposed was that the uncertainty in the field map be smaller than σ_0:

$$\delta(\Delta r\varphi) = \frac{(\omega\tau)^2}{1+(\omega\tau)^2}\,\delta\left(\int_z^{z_{max}}\left(\frac{B_\varphi}{B_z}+\frac{1}{\omega\tau}\frac{B_r}{B_z}\right)dz\right) < \sigma_0. \qquad (1)$$

The total uncertainty in the $\Delta(r\varphi)$-displacement correction, due to both B_r and B_φ components which are statistically-independent measurements, is from Eq. 1,

$$\sigma_{\Delta r\varphi_i} = \frac{1}{\sqrt{N_i}}\frac{z_i}{B_z}\sqrt{\sigma^2_{B_\varphi}+\frac{1}{\omega^2\tau^2}\sigma^2_{B_r}}, \qquad (2)$$

where $\Delta z = z_i/N_i$, Δz is the step in z taken by the B-field-measuring apparatus and N_i is the number of points measured up to point z_i ($i = 0$ for zero drift).

Since the B_r and B_φ measurements with Hall plates are technically equivalent, the error distributions with widths σ_{B_r} and σ_{B_φ} will be about the same. Thus the B_r contribution will be damped by the $\omega\tau$ factor.

The B_r component was used define the homogeneity in the past and in Sec. 2 above. It can be seen from this equation that the B_φ is the more sensitive component, which is however zero for an ideal solenoid. B_φ is non-zero in reality due to several effects (e.g., the iron yoke) and is non-zero due to the anti-DID, as will be seen in Sec. 4. Since it turns out that the B_r and B_φ components have similar magnitudes in the final set-up (Ref. [12]), both components are used to illustrate the effects.

- The recipe: increase the number of measuring points if you need more accuracy…

$$\sigma_{\Delta r\varphi_i} = \frac{1}{\sqrt{N_i}} \frac{\sigma_{B_\varphi}}{B_z} z_i \qquad (6)$$

where each of the uncertainites δB_{φ_j} is sampled from the same Gaussian distribution of width σ_{B_φ}.

- And the Bphi component is more important than Br…

$$\sigma_{\Delta r\varphi_i} = \frac{1}{\sqrt{N_i}} \frac{z_i}{B_z} \sqrt{\sigma^2_{B_\varphi} + \frac{1}{\omega^2\tau^2}\sigma^2_{B_r}}.$$

- …we just have to invest sufficient effort in measuring it: Aleph did invest a lot of effort, but several problems remained which we must avoid but which I won't go into today (read the notes).

Hall probe measuring devices being set up in the coil.

5 Discussion

5.1 B-field Map

The list presented in on p.9 of Ref. [2] contains a set of ideas how to ensure that the B-field will be known with sufficient accuracy. The goal for attaining the required tracking performance was formulated as follows: systematic effects in the TPC track reconstruction should be corrected to an accuracy of about 30 μm. This accuracy was motivated by allowing at most for a 5% increase in the momentum error due to uncertainty in the B-field, that is, σ^2_{point}=$(100\mu m)^2$+$(30\mu m)^2$=$(105\mu m)^2$, where $\delta(\frac{1}{p})$ is proportional to σ_{point} in Gluckstern's formula[13]. This was a proposal for quantifying the field-mapping effect such that the momentum measurement was essentially unaffected.

The question now is, what happens if the gradients are large?

It should be noted that the 5% was a guide; larger values are possible as seen by the following example. Considering the maximum drift length = 2200mm, N_i = 100 at the maximum drift length (z_{100} = 2200mm, Δz=22mm) and $\sigma_{B_\varphi} = \sigma_{B_r}$ = 10 G. According to Eq. 2 the error on the $r\varphi$ measurement due to the field map will be $\sigma_{\Delta r\varphi}$ = .055 mm. The candidate gases (Fig. 4.3-5(right) on p.75 of Ref. [6]) will allow a σ_{point} of around 70 μm. In this case the overall σ^2_{point}=$(70\mu m)^2$+$55\mu m)^2$=$(89\mu m)^2$, which would satisfy the requirement in Table 4.3-5 on p.70 of [6] (i.e., σ_{point} < 100μm). Thus the 5% becomes 25% which is still allowed if the errors are added in quadrature.

One can add the errors in quadrature as long as the errors due to the mapping are "statistically" (i.e. randomly) distributed along the tracks. Larger B-field gradients and larger σ_0 are permissable along as the errors due to the corrections are statistical in nature.

5.2 Conclusions

The conclusions of the discussions in Paris[11] and in this note are:

- Higher B-field gradients will not degrade the TPC performance if the B-field Hall-probes are calibrated to 1 or 2 G, the list in on p.9 of [2] is followed, and the procedures involving laser calibration system, Z-peak calibration and Z→ $\mu\mu$ events collected during physics running at $\sqrt{s}$ are applied, and that the errors due to the corrections are added in quadrature.
- If the "1 or 2 G" in the previous bullet is not achievable, then one can compensate by increasing the number of steps during the field mapping. For the example shown above, 10 G Hall-probe accuracy, can be compensated by mapping with N_i = 100 steps. This gain is "in theory", while "in practice" systematic effects due to the measuring apparatus may limit the accuracy. The measuring apparatus must be well designed.
- For the overall ILD tracking performance, alignment with other subdetectors will also be important; the discussion is on p.74 of Ref. [6], Sec. 4.3.2.7.
- The Z→ $\mu\mu$ events will allow any remaining systematic effects in regions of large B-bield gradients to be corrected so that fluctuations due to the corrections can be added in quadrature.

My opinion? Start planning. This exercise will be an interesting engineering challenge.

Hall probe measuring devices being set up in the coil.