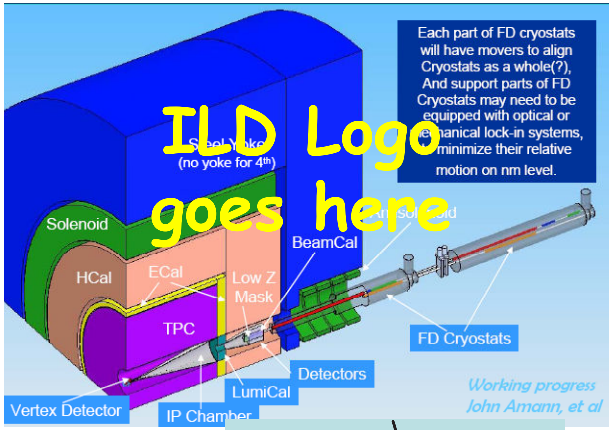
# ILC—>TPC Alignment in ILD LOI

**FYI – here are a few of "my" logos…**




ILD Logo goes here

Worldwide Study of the Physics and Detectors for Future Linear $e^+ e^-$ Colliders

Calorimeter for ILC

mpi halbleiterlabor

Max-Planck-Institut für Physik (Werner-Heisenberg-Institut)


Ron Settles


LCTPC meeting 21-22Sept2009

**IDAG: How does your alignment guarantee this?**



## 1.2 ILD DETECTOR PERFORMANCE

### 1.2.1 ILD Tracking Performance

The tracking system envisaged for ILD consists of three subsystems each capable of standalone tracking VTX, FTD and the TPC. These are augmented by three auxiliary tracking systems the SIT, SET and ETD, which provide additional high resolution measurement points. The momentum resolution goal[3] is

$$\sigma_{1/p_T} \approx 2 \times 10^{-5}\,\mathrm{GeV}^{-1},$$

and that for impact parameter resolution is

$$\sigma_{r\phi} = 5\,\mu\mathrm{m} \oplus \frac{10}{\mathrm{p(GeV)}\sin^{3/2}\theta}\,\mu\mathrm{m}.$$

#### 1.2.1.1 Coverage and Material Budget

Figure 1.2-2a shows, as a function of polar angle, $\theta$, the average number of reconstructed hits associated with simulated 100 GeV muons. The TPC provides full coverage down to $\theta = 37°$. Beyond this the number of measurement points decreases. The last measurement point provided by the TPC corresponds to $\theta \approx 10°$. The central inner tracking system, consisting of the six layer VTX and the two layer SIT, provides eight precise measurements down to $\theta = 26°$. The innermost and middle double layer of the VTX extend the coverage down to $\theta \sim 16°$. The FTD provides up to a maximum of five measurement points for tracks at small polar angles. The SET and ETD provide a single high precision measurement point with large lever arm outside of the TPC volume down to a $\theta \sim 10°$. The different tracking system contributions to the detector material budget, including support structures, is shown in Figure 1.2-2b.

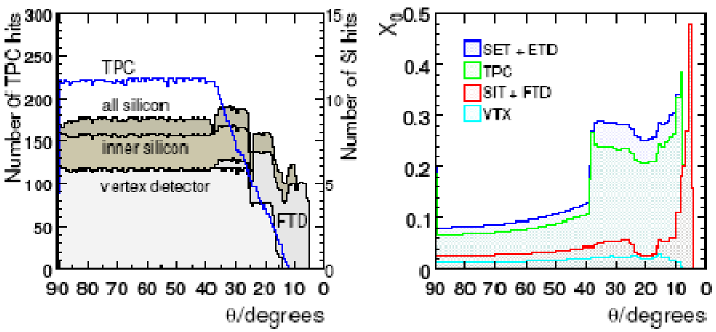



FIGURE 1.2-2. a) Average number of hits for simulated charged particle tracks as a function of polar angle. b) Average total radiation length of the material in the tracking detectors as a function of polar angle.

2009/09/22

INTERNATIONAL LARGE DETECTOR

LETTER OF INTENT

## Aligning the ILD Tracker:
## Status Report and Answers to IDAG

The ILD concept group

The ILD tracker alignment task force:
T. Behnke, R. De Masi, M. Fernandez, D. Gamba, D. Imbault, T. Matsuda, P. Mereu, D. Peterson, Y. Sugimoto, A. Savoy-Navarro, R. Settles, J. Timmermans, M. Vos, M. Winter, H. Yamamoto

June, 2009

…which contains the information from an internal TPC Note:
“file: 20090612-Answers-to-IDAG-Alignment-questions-TPC
Dan Peterson and Ron Settles      date: 20090612”

***<u>What is the plan for aligning your tracking system?</u>***

file: 20090612-Answers-to-IDAG-Alignment-questions-TPC
Dan Peterson and Ron Settles      date: 20090612

***What is the plan for aligning your tracking system?***

There are two levels of alignment that are necessary for the tracking system. In the first, "internal alignment", components of the separate subdetectors, VTX, SIT, TPC, SET, ETD, FTD are aligned within the subdetector. In the second, "global alignment", the subdetectors are aligned with respect to each other.

Internal Alignment

The internal alignment process will begin with subdetectors that have been engineered and assembled to have internal components that are stable and measured to tolerances of ~10-20μm. The B-field, which is as important to the ultimate measurement precision as the mechanical components, will be mapped using probes to a level of $dB/B<10^{-4}$ as described in the note: LC-DET-2008-002. At this point, unambiguous preliminary tracks can be defined using TPC alone. These tracks, with only preliminary fits, are sufficient to define roads in the silicon detectors where hits can be unambiguously associated with the track. In the case of the very forward detectors, preliminary tracks will be defined in the FTD.

Components of the silicon detectors will subsequently be aligned internally using fits to the hits defined by the preliminary tracks described above. We will investigate supplementing the track-based alignment with a laser system that works by creating ionization in the detector elements.

In the TPC, the internal components, i.e. the detector modules, will be manufactured to tolerances of 20μm while tolerances for placing the modules on the endplate will be about 60μm. The internal TPC alignment process must provide the final required precision for both the mechanical alignment and the magnetic field measurement. Achieving these goals will require iteration. As mechanical distortions and magnetic field distortions can lead to similar track distortions, supplementary alignment systems will be used to resolve the ambiguities. We plan to use a laser system and, possibly, coatings on the cathode, both of which create lines of ionization in the chamber gas.

The required number of clean tracks will come from 10/pb at the Z-peak after a long maintenance (e.g., winter) shutdown and 1/pb after push-pull. (A data set of 1/pb at the Z-peak will provide 30000 Z's and takes ~ 1 day at $10^{31}$ or ~ 3 hours at $10^{32}/cm^2s^2$).

Global Alignment

A preliminary global alignment of the subdetectors, using a survey-reference network, can achieve a precision of ~0.2mm, similar to that achieved at CMS.
For the track-based global alignment, hits will be selected as in the internal alignment. Fits of the tracks using all available detectors provide the momentum and hit residuals. In the global alignment stage, parameters that define the overall position in space of the sub-detectors will be varied to produce correct momentum of $Z\rightarrow\mu\mu$ events and minimize

# -TPC internal alignment

All issues are covered in the LOI and are valid

--`5%' criterion correct (ie decrease in mom.res.
due to misalignments not more than 5%,
which means 20-30micron for the TPC)
--All E-field effects covered in the
TPC section of LOI
--All B-field effects are covered in LC-DET-2008-002
by Werner Wiedenmann and RS
--Double-antiDID is a future option
to have an additional tool if needed (being studied)

# -Tracking subdetectors

Overall strategy as written

-Subdetectors fabricated/measured to 10-20micron internal or better
-Subdetectors measured to 0.1-0.2mm external or better
-Bfield mapped to ~1-3G accuracy (LC-DET-2008-002)
-Each subdetectors first aligned internally using tracks from Z or $\sqrt{s}$ data
-In 2nd pass, subdetectors aligned wrt each other using same data
-Iterate until correct momentum is attained

From our internal TPC Note: "We will investigate supplementing the track-based alignment with a laser system that works by creating ionization in the detector elements."

# -TPC/Tracking subdetectors

Toy MC study by Dan of how well subdetector positions must be known wrt one another and fulfill the 5% criterion overall:

- -- coherent displacement of the VTX, 2.8 $\mu$m;
- -- coherent displacement of the SIT, 3.5 $\mu$m;
- -- coherent displacement of the SET, 6 $\mu$m; and
- -- coherent displacement of the TPC, 3.6 $\mu$m.

# -What is needed next by LCTPC?

**A "task force" to start work on these tools for the Large Prototype data:**

-- B-field corrections to 30 micron level.

-- ditto for E-field

-- SIT/SET alignment to 3 micron level.

**1st side remark on performance in backgrounds:**



assumed for ILD, 150 BXs of beam-related background correspond to a voxel occupancy of approximately 0.05 % (the TPC voxel size is taken to be 1 mm in the $\phi$ direction, 6 mm in $r$ and 5 mm in $z$).

Figure 1.2-5 shows the TPC hits for a single $t\bar{t}$ event at $\sqrt{s} = 500$ GeV overlayed with 150 BXs of pair-background hits. On average there are 265,000 background hits in the TPC, compared to the average number of signal hits of 23100 (8630 from charged particles with $p_T$ >1 GeV). Even with this level of background, the tracks from the $t\bar{t}$ event are clearly visible in the $r\phi$ view. A significant fraction of the background hits in the TPC arise from low energy electrons/positrons from photon conversions. These low energy particles form small radius helices parallel to the $z$ axis, clearly visible as lines in the $rz$ view. These "micro-curlers" deposit charge on a small number of TPC pads over a large number of BXs. Specific pattern recognition software has been written to identify and remove these hits prior to track reconstruction. (Whilst not explicitly studied, similar cuts are expected to remove a significant fraction of hits from beam halo muons.) Figure 1.2-6 shows the TPC hits after removing hits from micro-curlers. Whilst not perfect, the cuts remove approximately 99 % of the background hits and only 3 % of hits from the primary interation and the majority of these are from low $p_T$ tracks. Less than 1 % of hits from tracks with $p_T$ >1 GeV originating from the $t\bar{t}$ event are removed.

This level of background hits proves no problem for the track-finding pattern recognition software, as can be seen from Figure 1.2-7. Even when the background level is increased by a factor of three over the nominal background no degradation of TPC track finding efficiency is observed for the 100 events simulated. This study demonstrates the robustness of TPC tracking in the ILC background environment.

These conclusions are supported by an earlier study based on a detector concept with $B = 3.0$ T, a TPC radius of 1.9 m and TPC readout cells of $3 \times 10\,\mathrm{mm}^2$. This earlier study used a uniform distribution of background hits in the TPC volume, but included a very detailed simulation of the digitised detector response and full pattern recognition is performed in both time and space. The TPC reconstruction efficiency as a function of the noise occupancy is presented in Section ??; there is essentially no loss of efficiency for 1 %

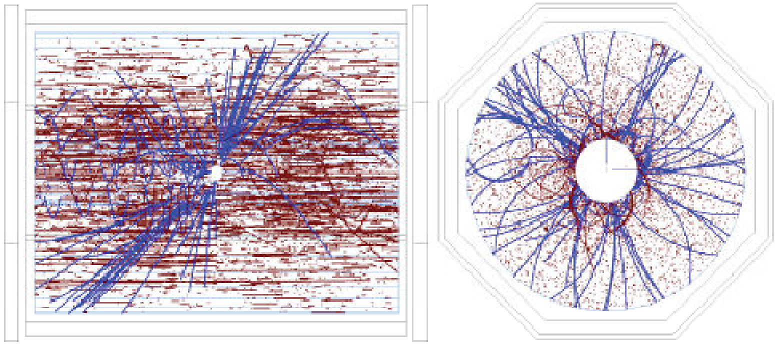


FIGURE 1.2-5. The $rz$ and $r\phi$ views of the TPC hits from a 500 GeV $t\bar{t}$ event (blue) with 150 BXs of beam background (red) overlayed.



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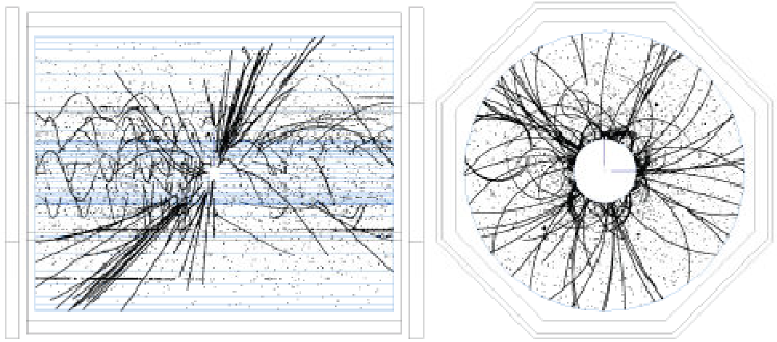

FIGURE 1.2-6. The same event as the previous figure, with the micro-curler removal algorithm applied. This is the input to the TPC track finding algorithm.

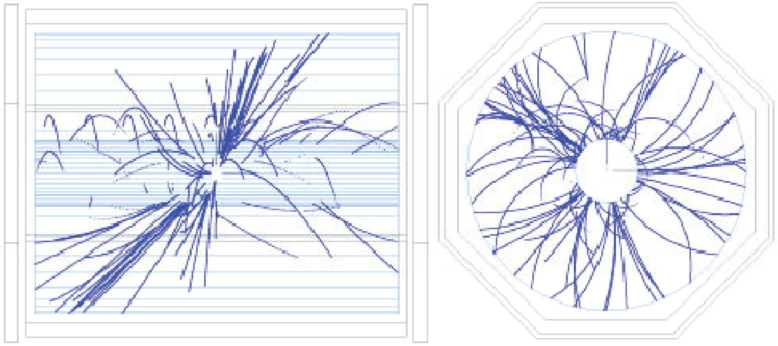

FIGURE 1.2-7. The same event as the previous plot, now showing the reconstructed TPC tracks.

occupancy (uniformly distributed through the TPC). It should be noted that this level of occupancy is twice the nominal occupancy at the TPC inner radius and about fifty times the typical total occupancy in the TPC.

#### 1.2.2.2 Background in the Vertex Detector

The impact of background in the vertex detector (VTX) depends on the assumptions made for the Silicon read-out time. If one were to assume single BX time-stamping capability in the vertex detector, the anticipated background level is negligible. However, it is anticipated that the readout of the Silicon pixel ladders will integrate over many BXs. For the studies presented here, it is assumed that vertex detector readout integrates over 83 and 333 BXs for the inner two and outer four layers respectively. For the silicon strip-based SIT detector, single BX time-stamping is assumed. Hence the background hits which are superimposed on the physics event correspond to 1 BX in the SIT, 150 BXs in the TPC and 83/333 BXs in

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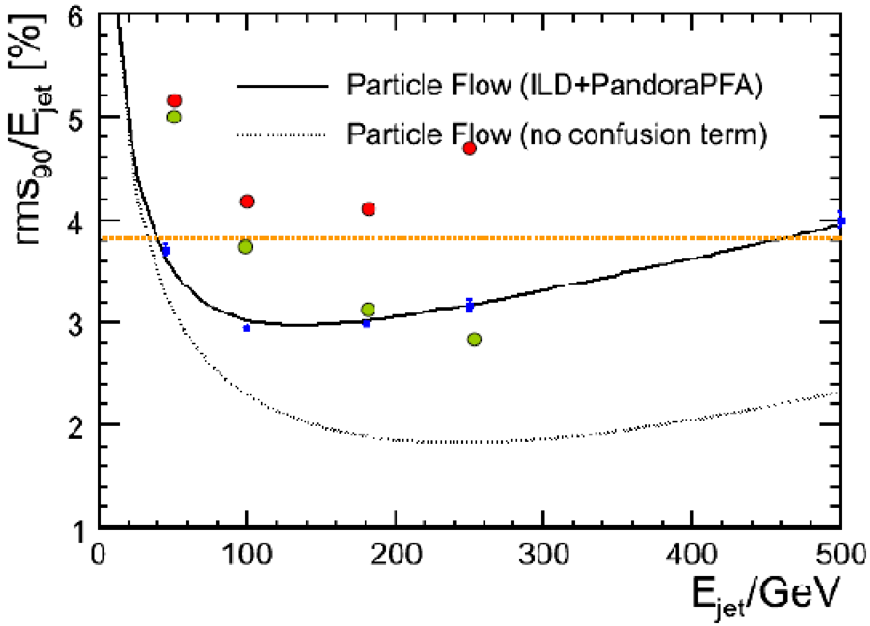
# 2nd side remark (post-LOI after TILC09):

## Jet Energy Comparison

• SiD • 4th (Gaussian not $rms_{90}$ – but tails) (Different simulation)




- SiD/ILD ~ 1.35 - 1.55
- 4th/ILD ~ 1.3 - 0.9