Silicon tracker alignment;

ILD alignment task force

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Alignment

Finding the set of constants that relates the local measurement (in units of strip number) to the global detector reference frame

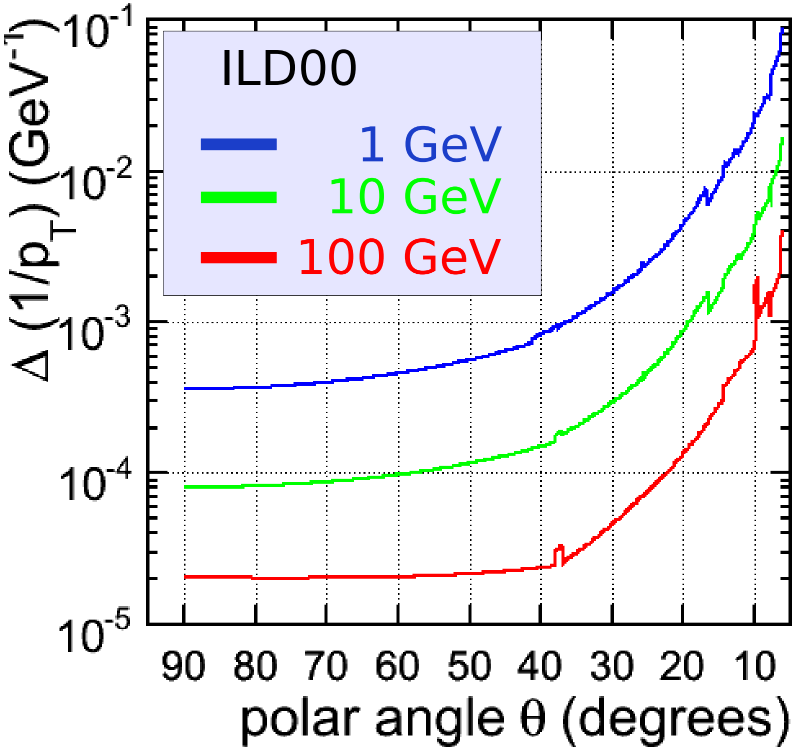
To achieve this, all detector elements must be aligned to better than their intrinsic resolution

<< 2.8 μm in VXD

<< 7 μm in silicon

<< 50 μm in TPC

A "degenerate" problem is the determination of the the magnetic field map



Mounting precision

The precision with which detector structures are mounted:

Sensor:

Thickness: 5 %

Flatness: +/- 200 μm (ATLAS SCT spec.)

actual wafers much flatter when unstressed)

Segmentation: precise

Module:

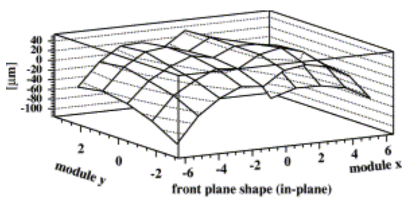
In-plane sensor-sensor alignment 5 μm (ATLAS spec.)

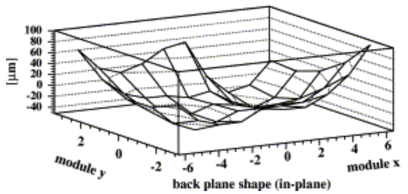
Front-to-back alignment 10 μm (ATLAS spec.)

~100 μm (CMS)

Flatness: 100 μm

Note: placing a wafer with 5 μm precision is trivial,
keeping it in that position while the glue cures (24 hours)
Is a bit harder





(L. Eklund, the ATLAS semi-conductor tracker

Module mounting uses precise (short-range) stages and microscopes, recognition of fiducial marks. Note: not even the lowest level is aligned to ILC requirements

Mounting precision

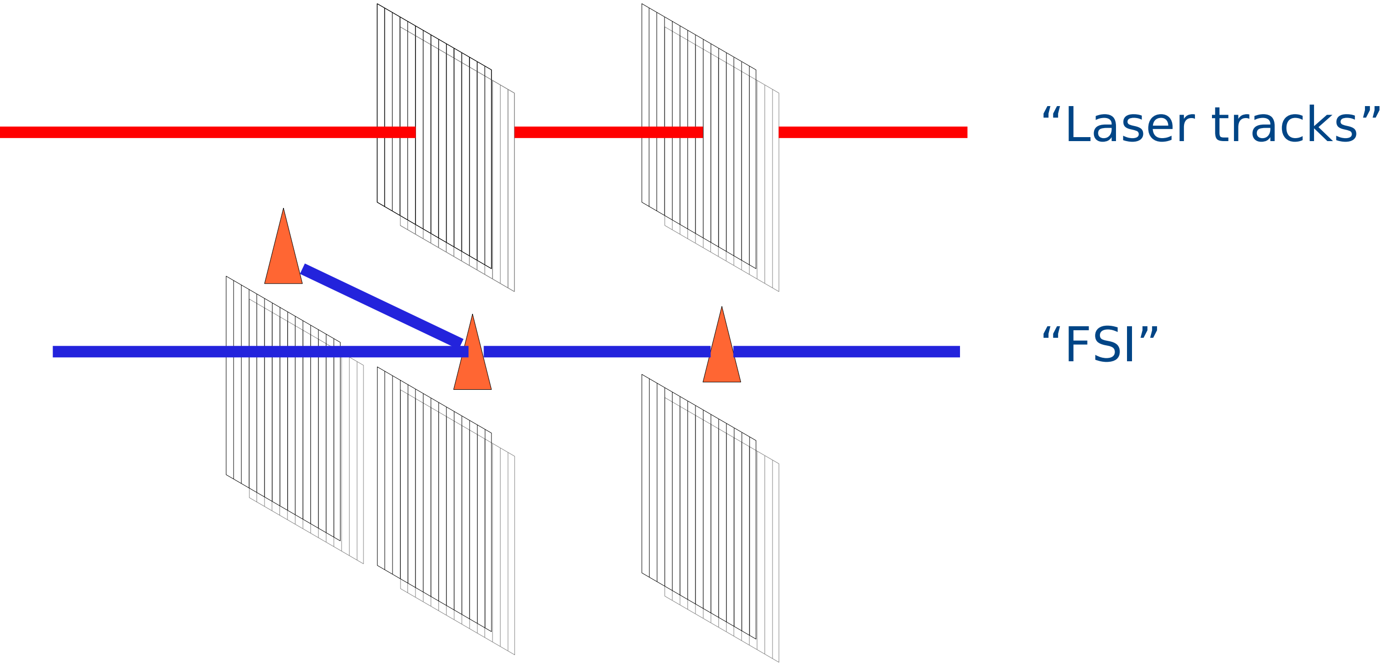
Ladder:screw modules on precision mounting pin, 10s of μm (CMS TOB)

Survey of cylinders: 500 μm (CMS TIB)

The bottom line: a hierarchy of decreasing precision for larger structures (ve
good precision over large volume = expensive machines)

www.mitutoyo.com

Hardware alignment system



Two approaches on the market offer little additional material in tracking volume and fast response

- Laser tracks (AMS/CMS)
  ILD group from IFCA Santander (I. Vila)
  Constrains the “important” positions
  Directly relates to the local coordinate system
- Frequency Scanning Interferometry (ATLAS)
  ILC group from Michigan (K. Riles)
  Constrains complex grid of distances between “jewels”
  Transfer of position from jewel to sensor

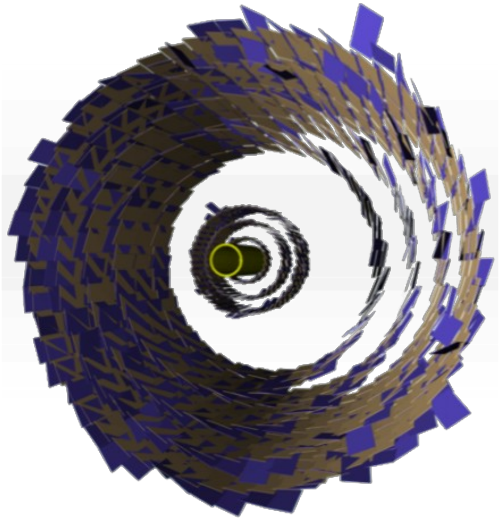
Track-based alignment

Track-based alignment

Start from initial engineering constraints
+ FSI / laser alignment system

Construct residuals in all subdetectors for a sample of tracks from collisions, cosmics, beam halo

Minimize χ^2

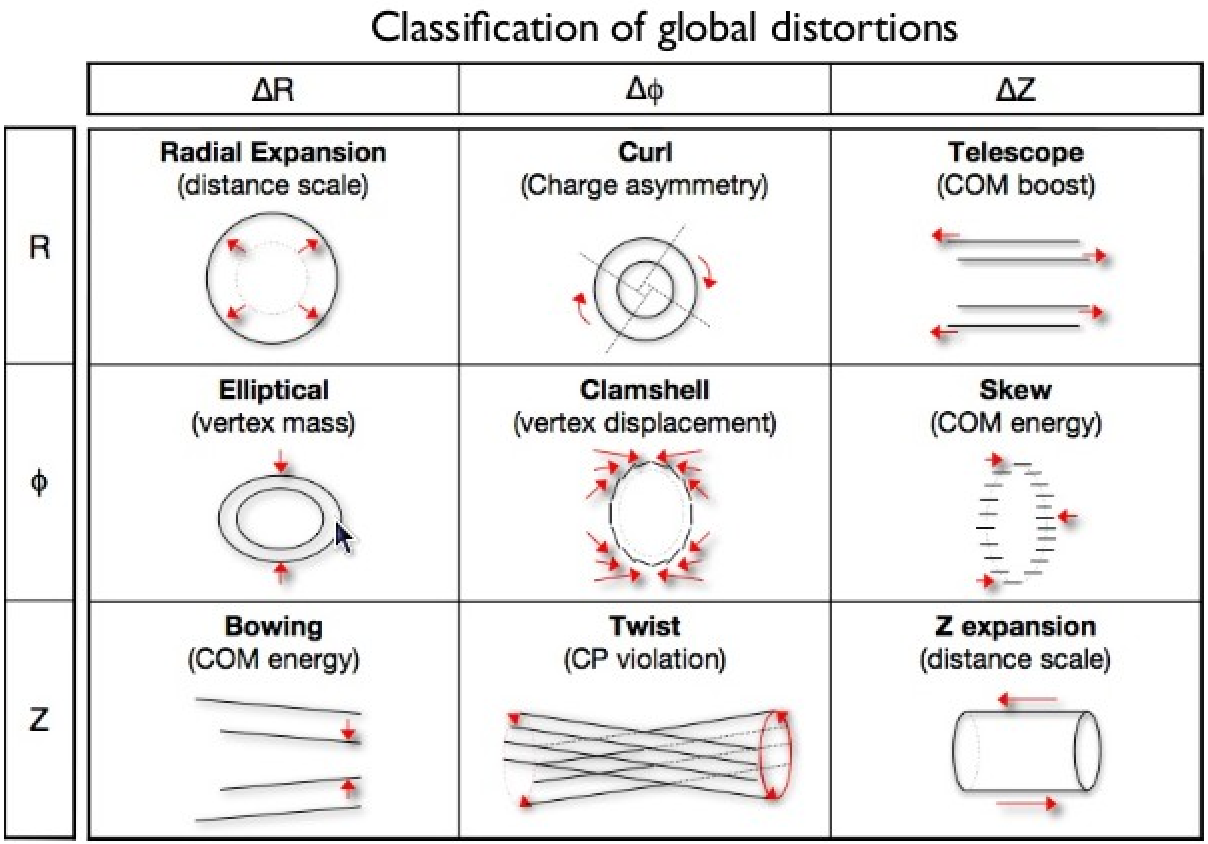


To be performed on different levels

Sub-detectors O (100) DOF
Layers O (1000) DOF
Single wafer O(100.000) DOF

Track-based alignment

Strong constraints on overlapping modules.
Tracks connect modules in different layers (only few well-defined combinations of modules)
Still quite some freedom for movements.



Non-IP tracks, resonances with known mass and laser or FSI lines help to resolve some of these

Time

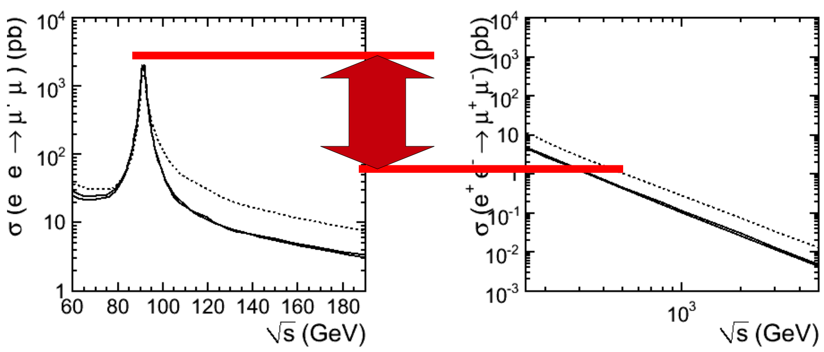
Align once – valid for ever? Each month?

- *Magnet ramp leads to O(mm) displacement of large iron structures*
- *Ground movement?*
- *Thermal excursions: (night/day), pulsed powering*

Position of detector as a whole will vary. What about internal degrees of freedom? Some monitoring (and correction) tools are required.

Track-based alignment is too slow to correct for fast movements:

$$\boldsymbol{\sigma(e^+e^- \rightarrow \mu^+ \mu^-)_{pT\,(\mu)\,>\,10\ GeV/c} \sim 440\ fb}$$



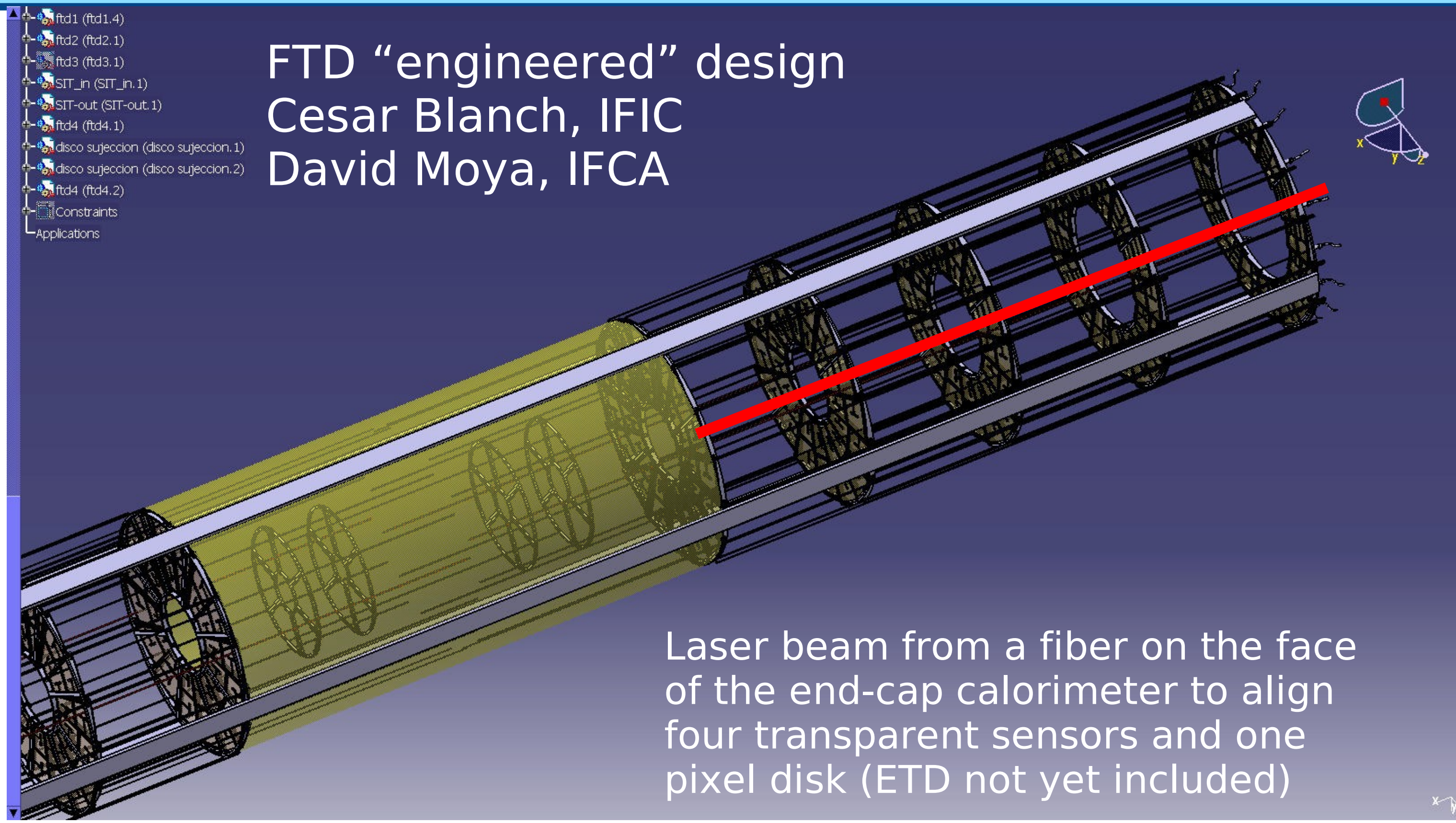
Factor 1000 from "mini Giga-Z"

Luminosity	10^{32} cm^{-2}s^{-1}		$2*10^{33}$ cm^{-2}s^{-1}		
Time Int. Luminosity	few weeks 100 pb^{-1}	6 months 1 fb^{-1}	1 day	few weeks 1 fb^{-1}	one year 10 fb^{-1}
$W^\pm \rightarrow \mu^\pm \nu$	700K	7M	100K	7M	70M
$Z^0 \rightarrow \mu^+\mu^-$	100K	1M	20K	1M	10M

Compare rates at the LHC

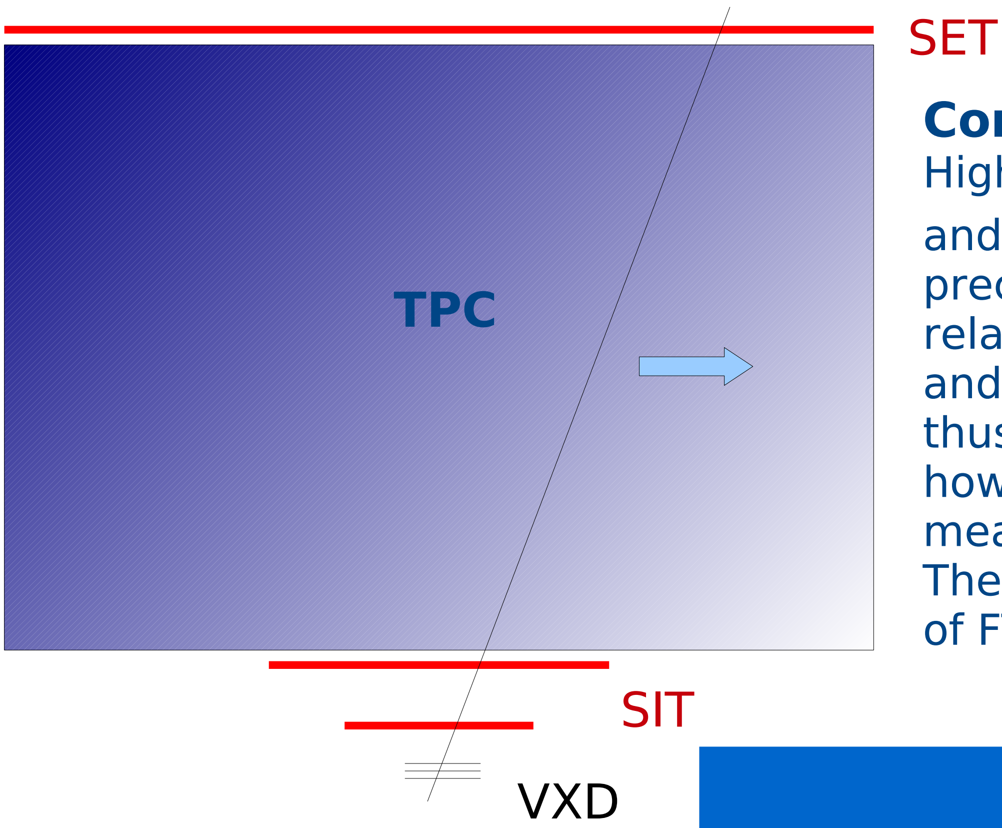
$\sigma\,(pp \rightarrow \mu^+ \mu^-)_{pT\,(\mu)\,>\,10\ GeV/c} \sim 1000$ pb

Time



Similarly, VXD and SIT (and TPC field cage) could be connected

Silicon-to-TPC



Connection silicon-to-TPC.

High p_T tracks reconstructed in VXD, SIT and SET can be used to predict pretty precise space points in the TPC volume. A relation between silicon measurements and the time coordenate of the TPC can thus be established. This requires, however, a rather accurate z-measurement on SIT and SET.

The same is true for the r-measurement of FTD and ETD.

	VXD	VXD +SIT	VXD +SET
σ(z) @ 50 cm	35	16	28
σ(z) @ 100 cm	77	39	30
σ(z) @ 118 cm	118	50	39