FCAL Activities in AIDA -
LumiCal Alignment System
Status report

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On behalf of FCAL Collaboration

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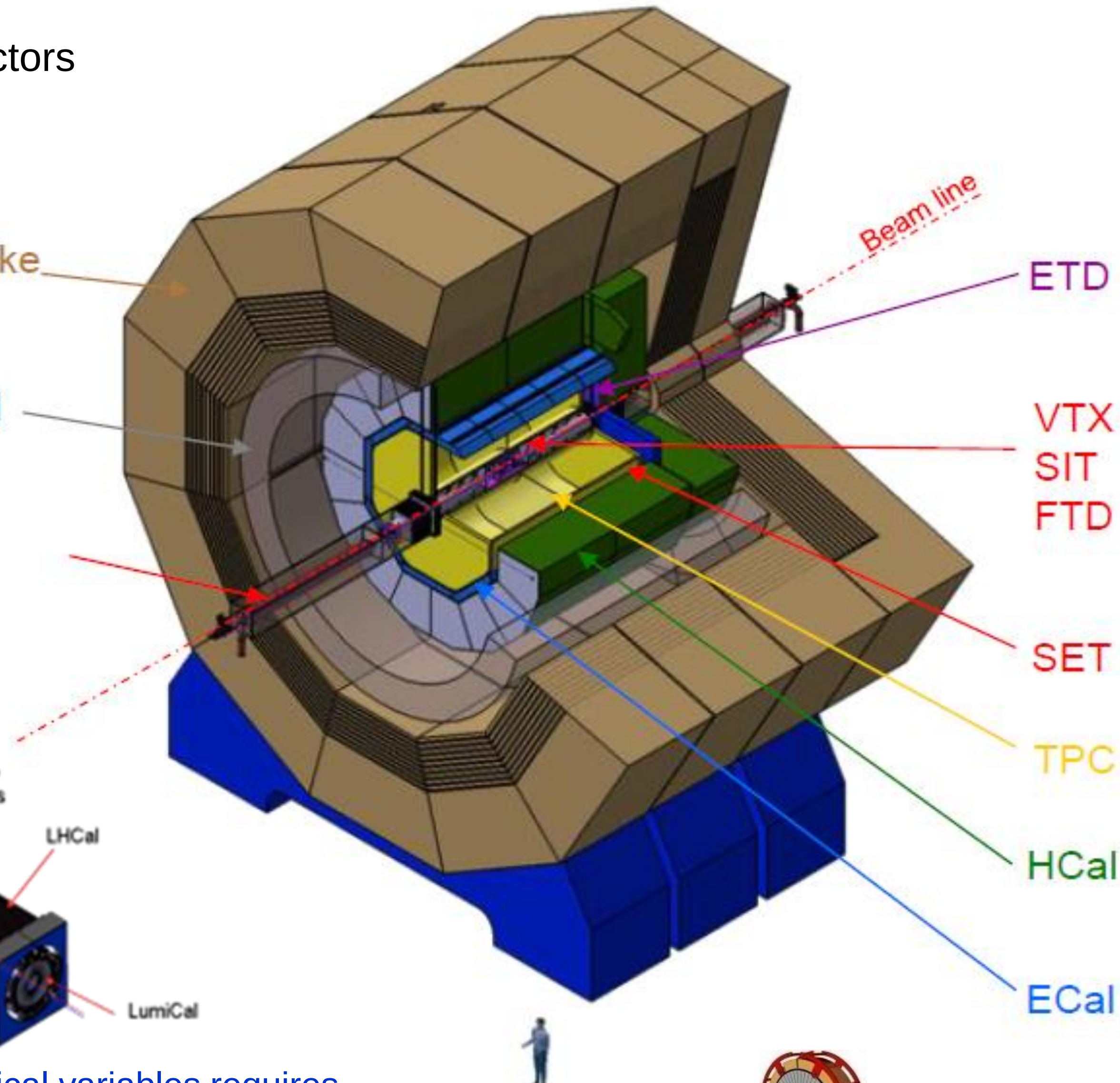
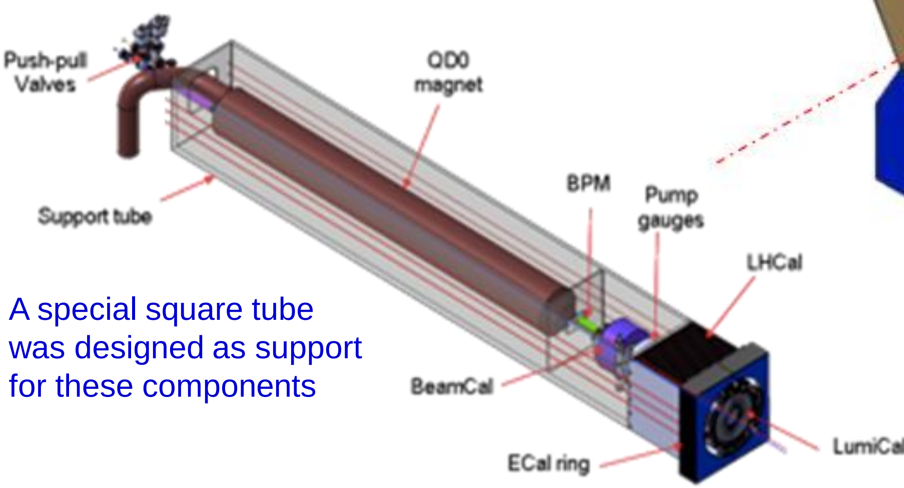
ILD and LumiCal

LumiCal - one of the FCAL detectors placed in forward region of ILD

Forward components: beside calorimeters also QD0 magnets, pipe and BPM's

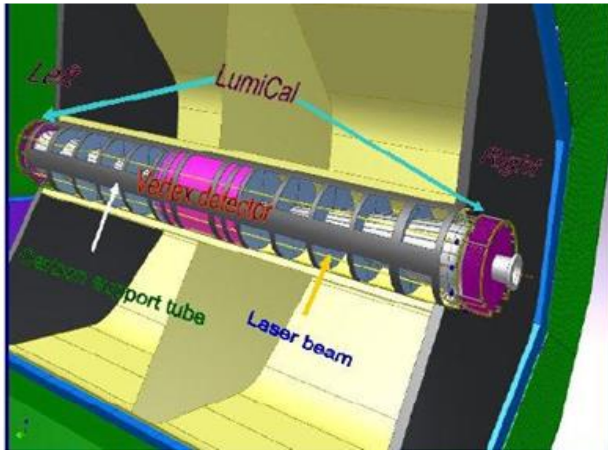


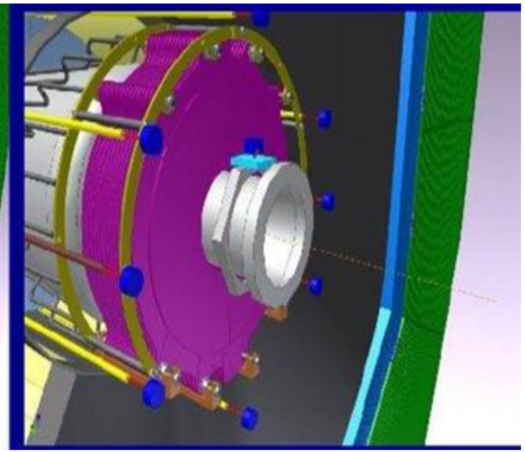


A special square tube was designed as support for these components

High precision measurement of the physical variables requires building an laser alignment system(s) (LAS) for components of ILD also for LumiCal

Mechanical aspects of LumiCal alignment





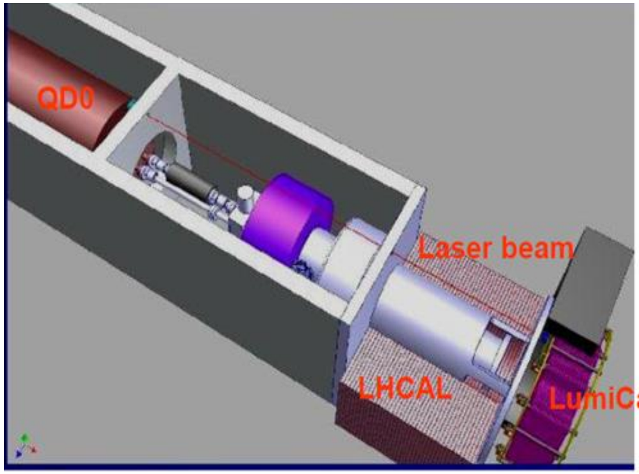
The good reference frame:
- QD0 magnets
- Beam Position Monitors
- Beam pipe

due to knowledge
of their precise positions

In the frame of the alignment will be performed measurements of absolute distance between the left and right calorimeters and their relative positions with respect to selected reference system

Necessary optical elements need to installed in the LumiCal environment: lasers, beam splitters fibers, retroreflectors, position sensitive sensors, carbon pipe for laser beams

As example : QD0 magnet



An important task in MDI studies:
define available free space for elements
of LAS system in the forward region

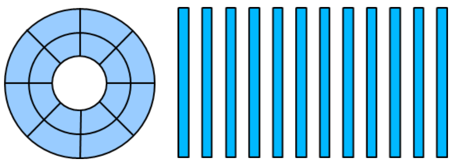
Alignment LumiCal - requirements

The precise measurements of the LumiCal displacements are necessary for a high accuracy in the measur. of luminosity: ILC/CLIC ($\Delta L/L \approx 2\,\Delta\theta / \theta_{min} \sim 10^{-3}/10^{-2}$) . The size of $\Delta\theta$ depends on uncertainties of LumiCal Z position and inner radius R (X, Y)

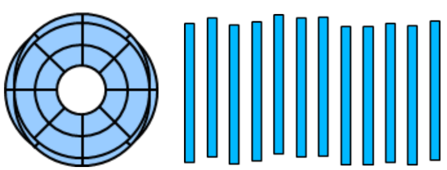
Monte Carlo studies
(~10^{8} events – BHLUMI gen., ILC500, ILC1000, Giga Z, CLIC3TeV)

LumiCal det. simul.– example with a possible deformation of the inner layers of silicon sensors

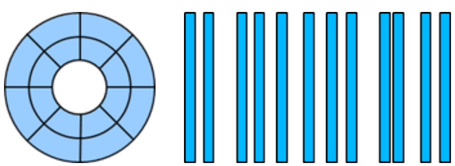
Estimation of the displacement measurements accuracy:
- a few hundred μm in X, Y directions
- about 100 μm in Z direction
- a few tens for internal sensor layers
  but ~ 4 μm for inner radius for Giga Z data



normall



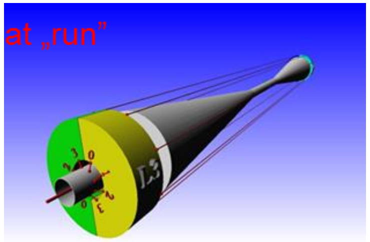
X,Y deformation

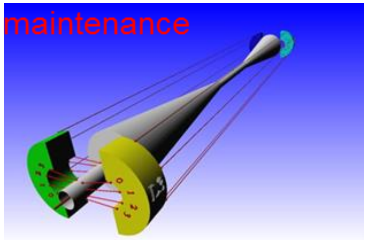


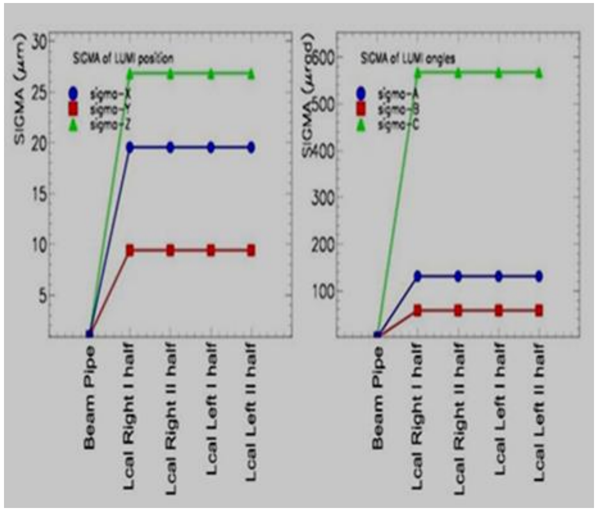
Z deformation

Deformations:
gravitational sag, temperature

The SIMULGEO program - to check if the interferometric method of position measurement can be applied here







- 6 laser beams between both LumiCal's
- 8 laser beams from each Lumical to the beam pipe (X,Y)
- Laser beams for x,y not perpendicular to beam pipe axis – possible a rotation of LumiCal

The design of the LAS system

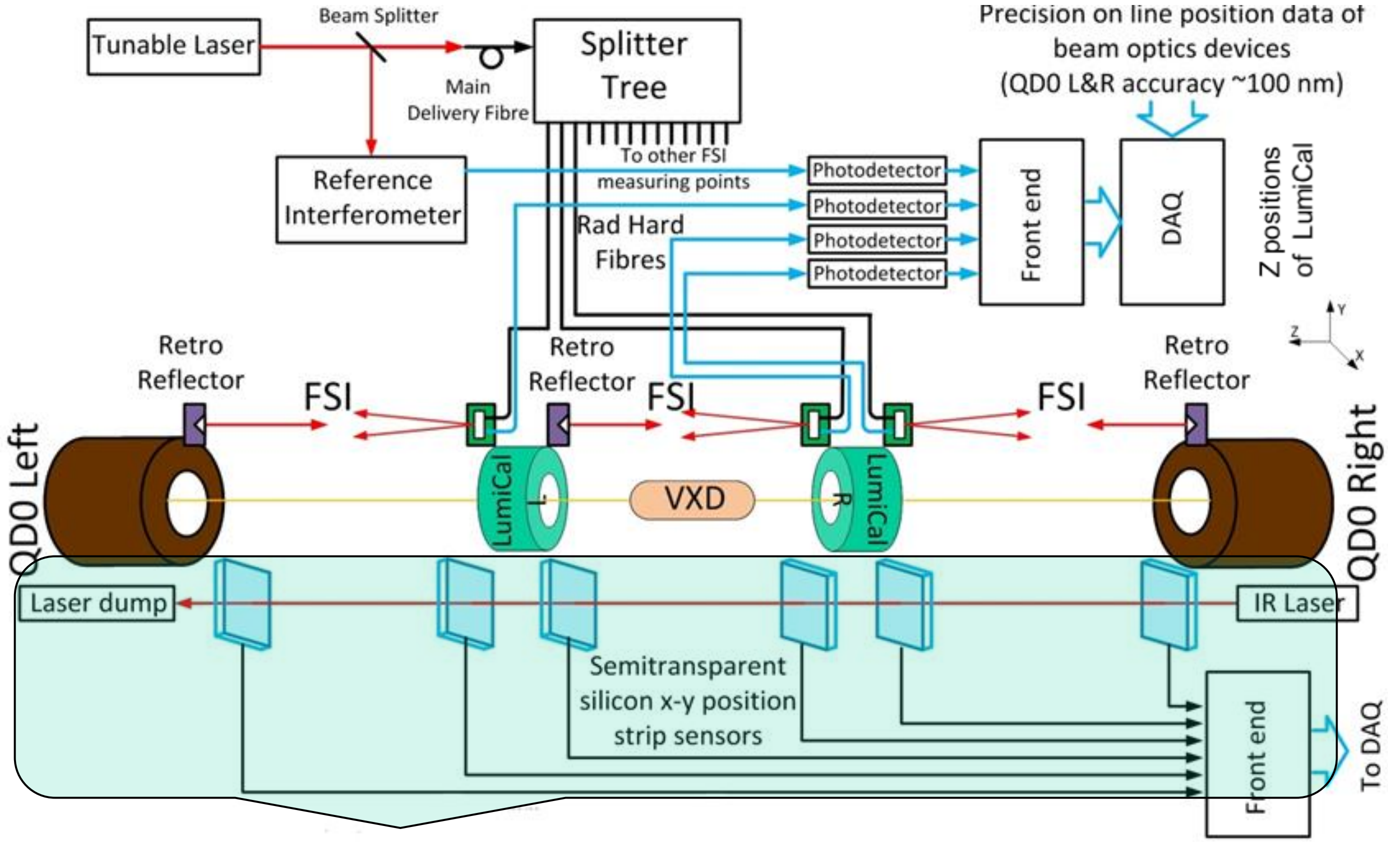
The alignmen system may include two components:

- IR laser + PSD system:

infra-red laser beam and semi-transparent position sensitive detectors

- FSI system:

tunable laser(s), beam splitters, isolator, Fabry-Perot interferometer, retroreflectors, fibers, collimators, photodetectors, lens

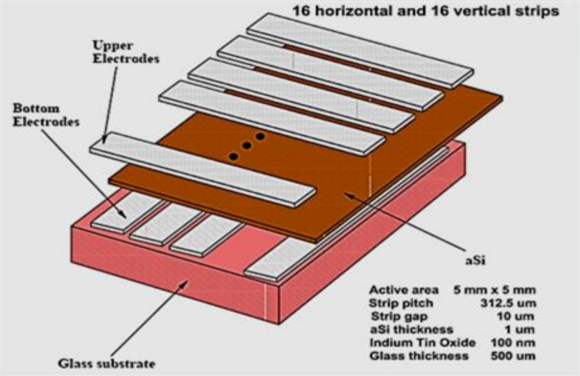


FSI - Frequency Scanned Interferometry):

The absolute distance measurements between LumiCal's

IR Laser + PSD

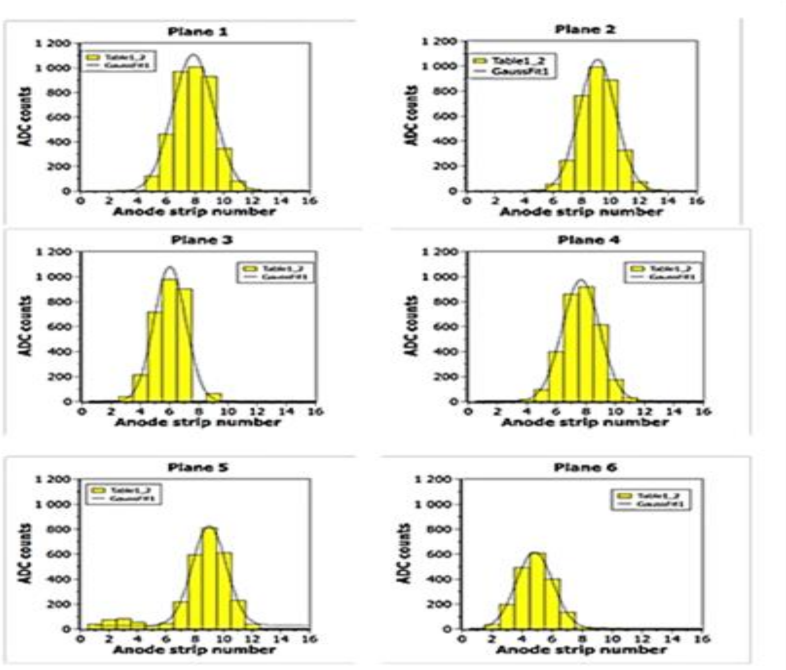
Relative positions of LumiCal's and displacments of the internal Si layers

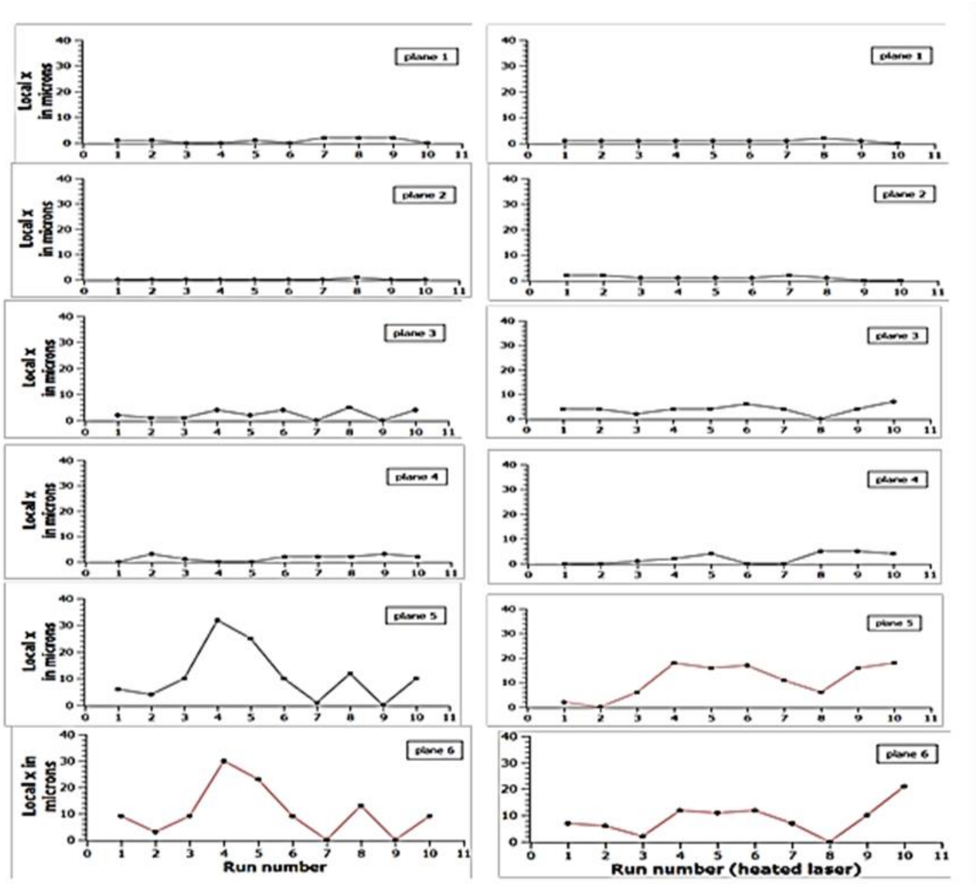


Position Sensitive Detectors

Laser beam position measurements

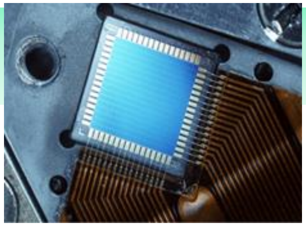
Light transmission: above 85% for λ > 780 nm





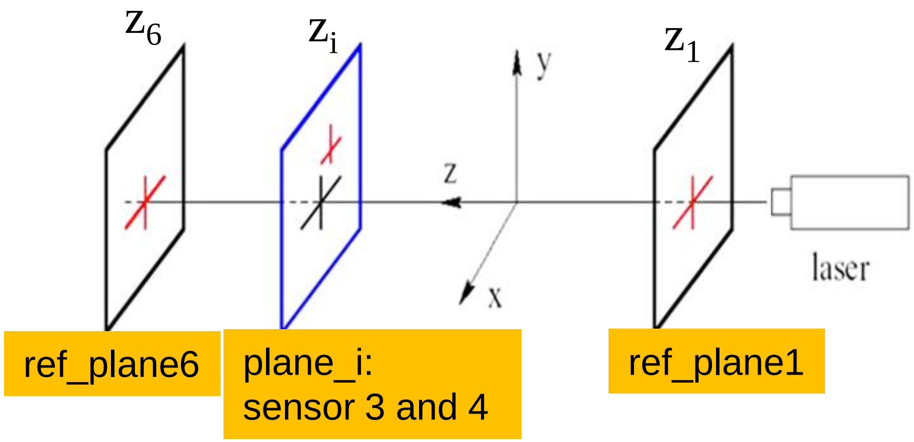
An example: beam profile signals from the X-strips along the moving beam. The available aperture for laser beam is 5 x 5 mm^2 for sensor. The mean positions **mx_i** were obtained from a Gaussian fit to observed signals

Fluctuations increasing with distance along the laser beam. They can be related to: laser instability with an increase of beam diameter and noise of the sensor. Data from laser working since hours show smaller fluctuations

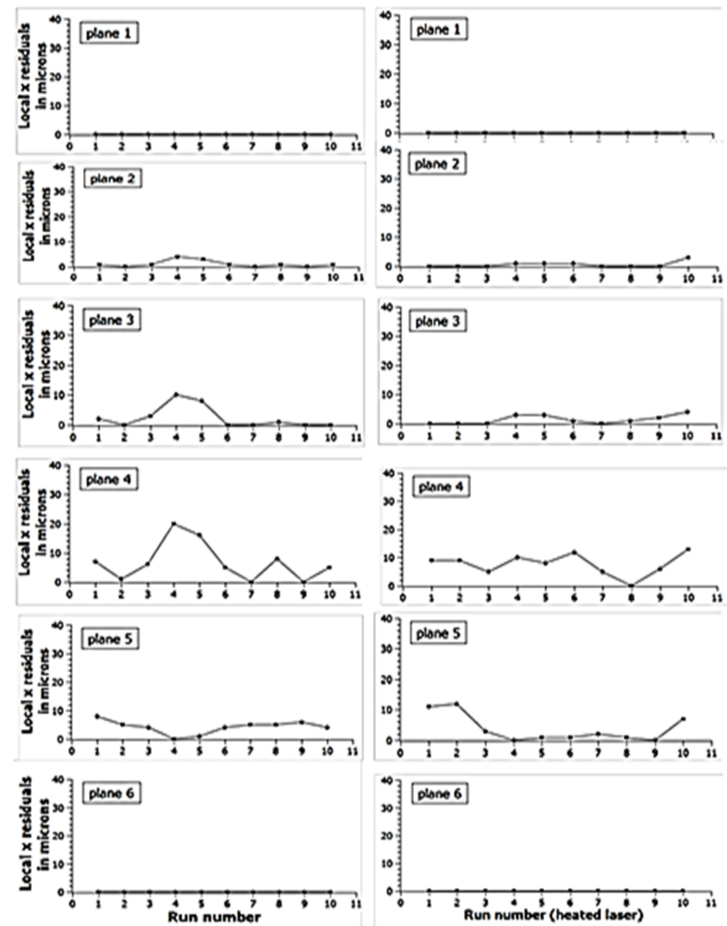


Position measurement

The method of using a residual approach



Used residuals for analysis beam pos.data – reduction of fluctuations



The mean position of sensors 1 and 6, **mx, my** define the reference straight line.

The expected position of the beam at sensor plane i :

$$\Delta x_i = mx_1 \frac{z_6 - z_i}{z_6 - z_1} + mx_6 \frac{z_i - z_1}{z_6 - z_1}$$

$$\Delta y_i = my_1 \frac{z_6 - z_i}{z_6 - z_1} + my_6 \frac{z_i - z_1}{z_6 - z_1}$$

Residuals:

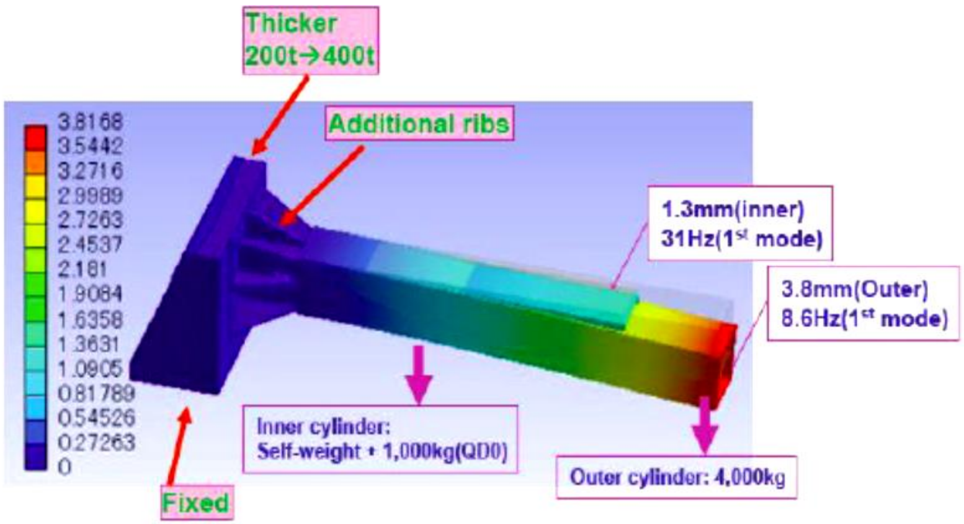
$Rx_i = \Delta x_i - mx_i$

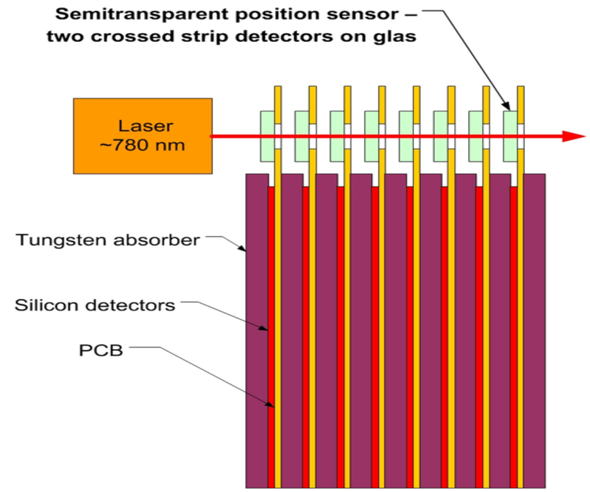
$Ry_i = \Delta y_i - my_i$

Further development at AIDA2 ?

This would require the replacement of the PSD system by a new one (as existing was received from the Oxford University after several years working in the ZEUS exp. – lack of warranty that it will work in future). Is it would be possible to get a help from people (group from Spain) involved with LAS for CMS and EUDET project (M. Fernandez et al.) ?

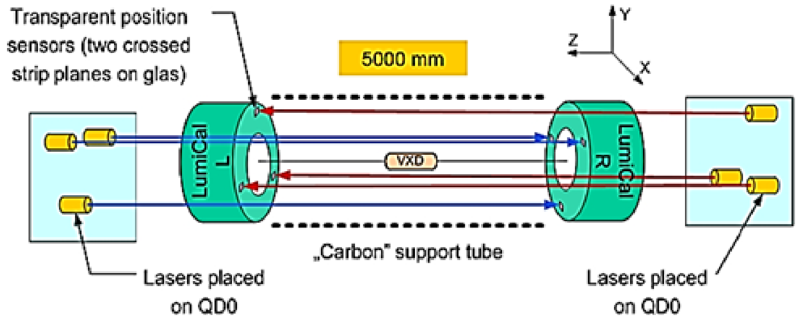
The measurement of the displacements on short and long distances





Precision X, Y measurement of silicon sensors position

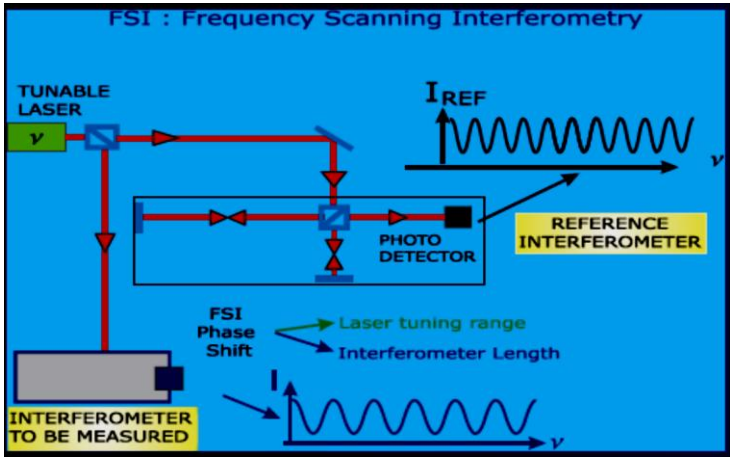
The laser beams at a distance about 5 m.
In reality problem with space for some tubes containing laser beams, glued to support carbon tube



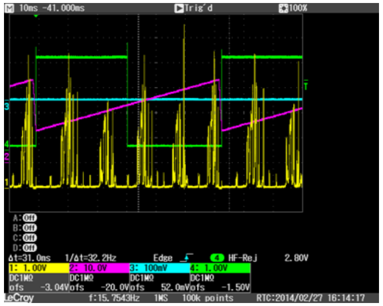
Local DAQ of PSD sensors would be a part of the DAQ system of LumiCal

Alignment based on FSI - status

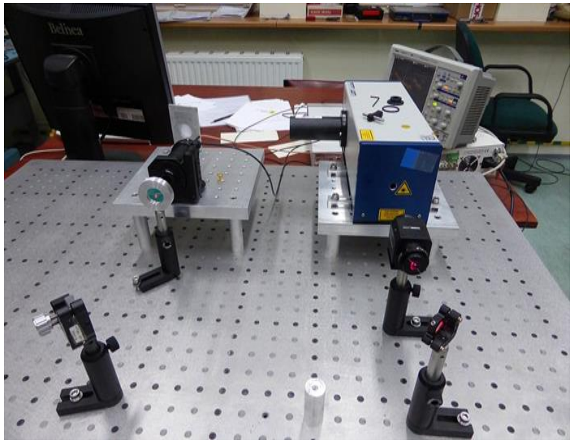
FSI technique enables remote, multiple, simultaneous and precide distance measurements, on small-micrometer level. It uses tunable lasers for measurement of interferometer optical path differences (counting the number of fringes) and provides an absolute distance measurements



The main optical elements for FSI prototype were collected – DAQ card will come soon



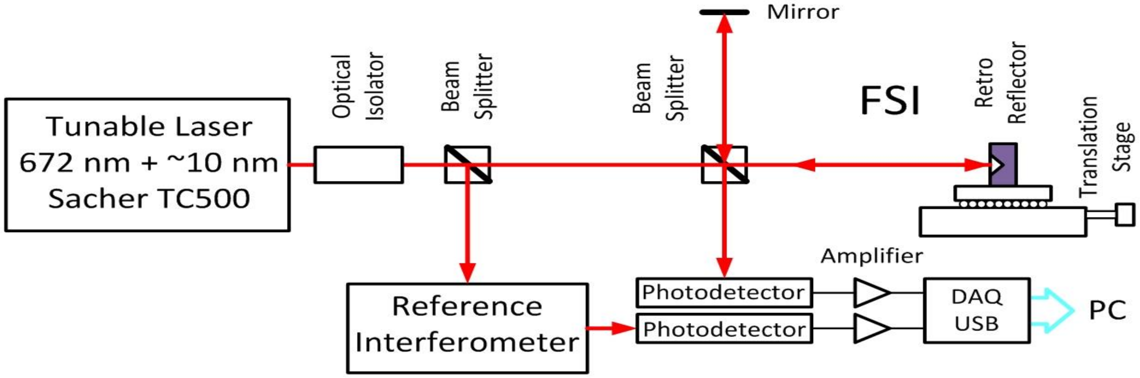
Observed signals from FB using simple laser diode



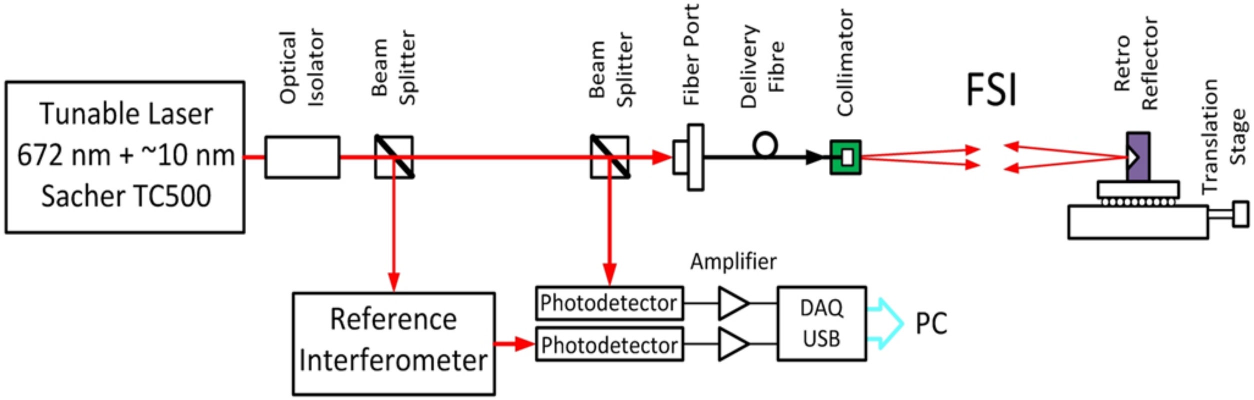
A problem which was encountered while testing the Fabry-Perot interferometer. All tests indicated the incorrect behavior of the tunable laser and it was sent to the manufacturer for inspection.

The steps towards the final FSI prototype

1. The single laser beam in air from tunable laser
   - no optical fibers retroreflector on translation stage

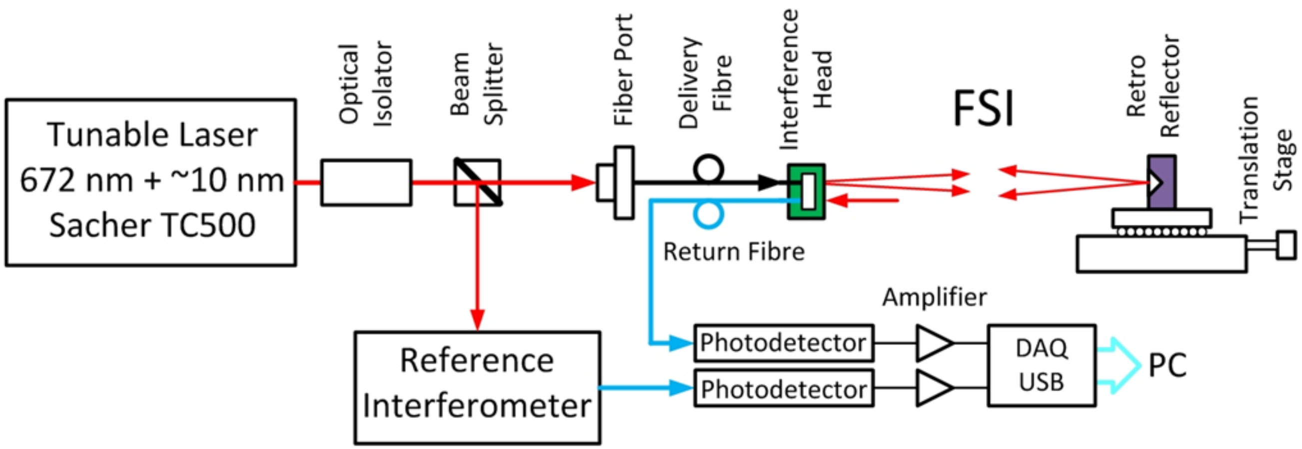


2. Laser beam coupled into a single-mode optical fiber with fiber coupler-colimator, AIDA2



The steps towards the final FSI prototype (cd)

3. Interference head and forward and return fibers, AIDA2



4. Tests of the complete FSI system -
(in laboratory and at test beam), AIDA 2

Summary

● The accuracy received in preliminary measurements of the beam position was less than 20 micrometers, using the layout of 6 semi-transparent sensors. An improvement of the conditions of measurement (like thermal insulation) will lead to a smaller value.

● For beam test measurements and further development of the prototype a new complete system (PSD with readout and DAQ) seems to be necessary. Question is if this will be possible?
Another option which can provide the measurement of transverse displacements is optical system RASNIK (Red Alignment System NIKHEF)

● FSI elements which recently were collected allow to build a simple prototype. The FSI studies will be continued after finished some tests performed by the producer for tunable laser.

● Several steps are planned during such studies, leading towards the final prototype. This will be continued inside the AIDA2 project.