The Forward Calorimetry Integration in ILD.

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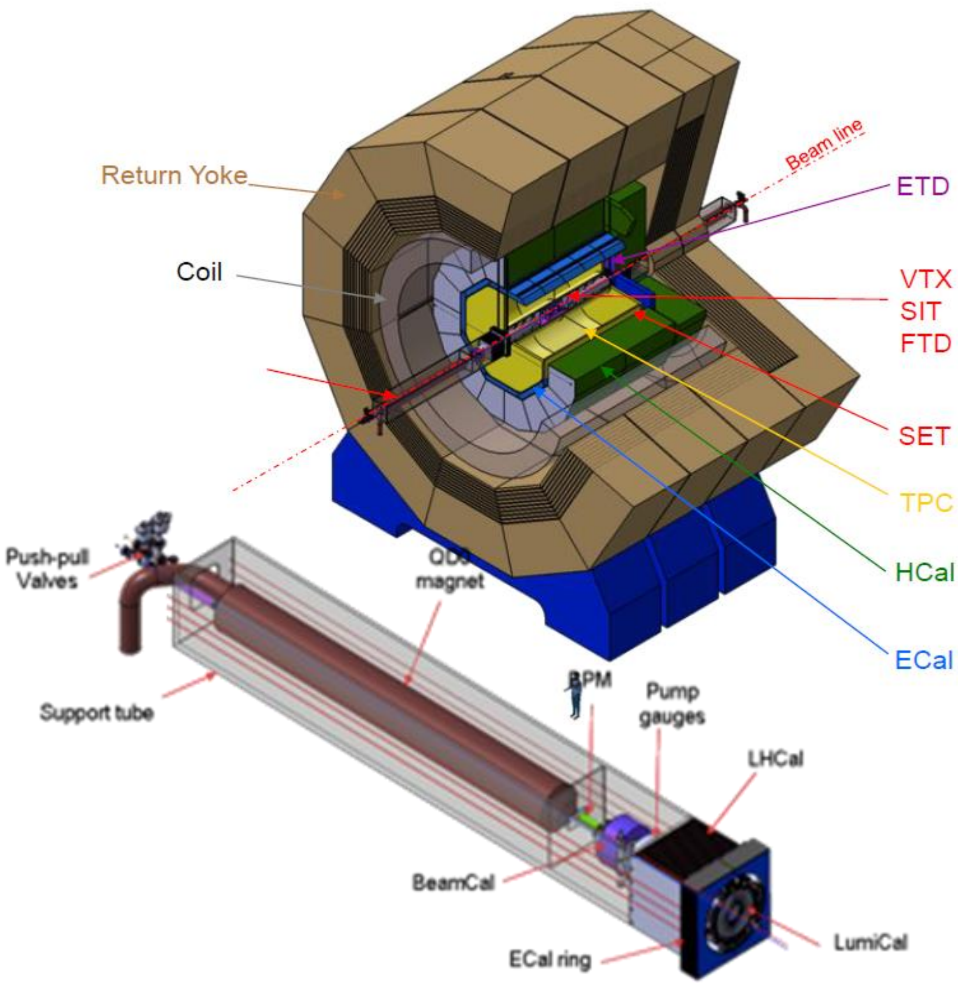
FCAL Collaboration
High precision design

Challenges of Forward Region

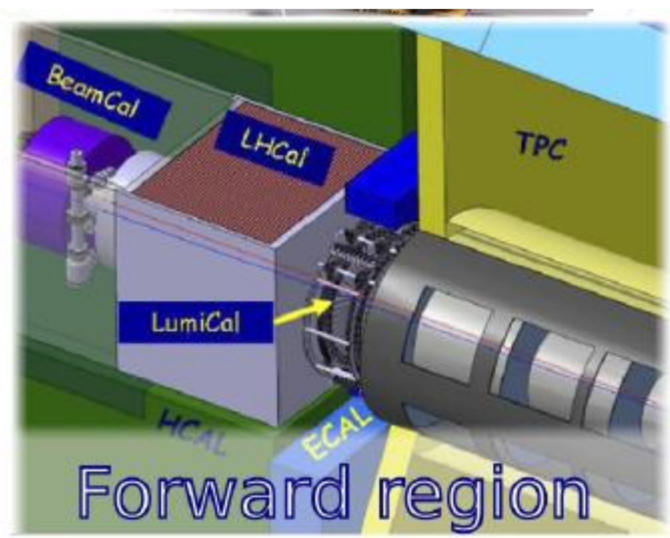


LumiCal

precise luminosity measurement
(10^{-3} at 500 GeV @ ILC, 10^{-2} at 3 TeV @ CLIC)

BeamCal (and Pair Monitor)

- low polar angle electron tagging
- beam tuning and beam diagnostics
- fast feedback using special futures of the ASICs

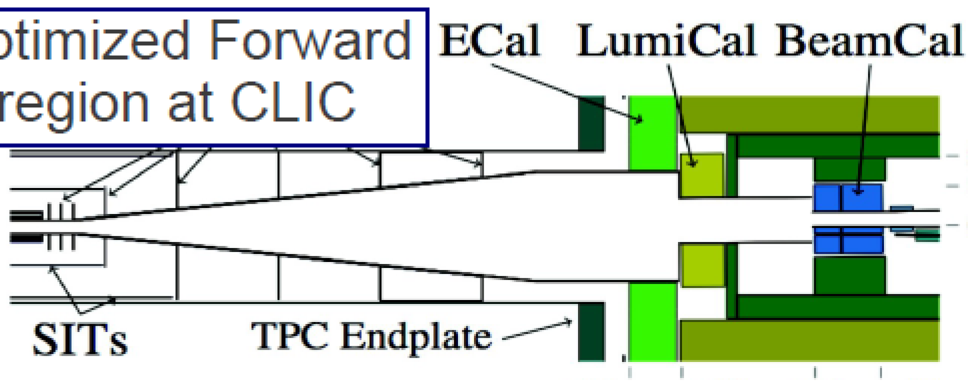


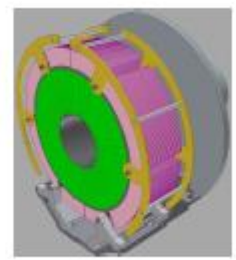
Challenges:
- high precision (LumiCal),
- radiation hardness (BeamCal),
- very fast read-out (both)

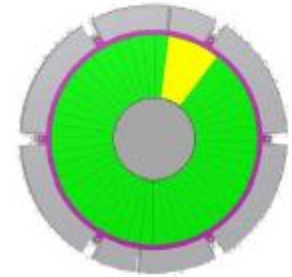
Detectors design

		Unit	ILC	CLIC_ILD
LumiCal	geometrical acceptance	mrad	31-77	38-110
LumiCal	fiducial acceptance	mrad	41-67	44-80
LumiCal	z(start)		2450	2654
LumiCal	number of layers(W+Si)		30	40
LumiCal	number of channels		~180k	~250k
BeamCal	geometrical acceptance	mm	5-40	10-40
BeamCal	z(start)		3600	3281
BeamCal	number of layers(W+Sensor)	mm	30	40
BeamCal	graphite layer thickness		100	100
BeamCal	number of channels		~62k	~84k

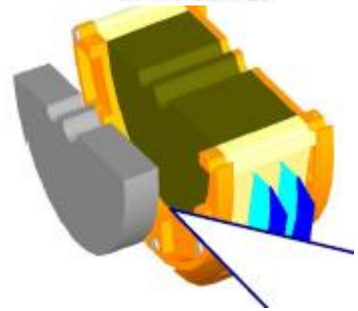
Optimized Forward region at CLIC

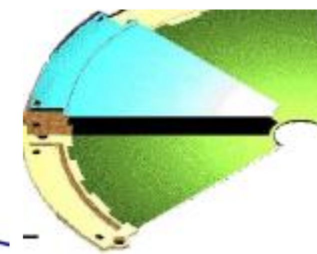






Mechanical structure of the LumiCal





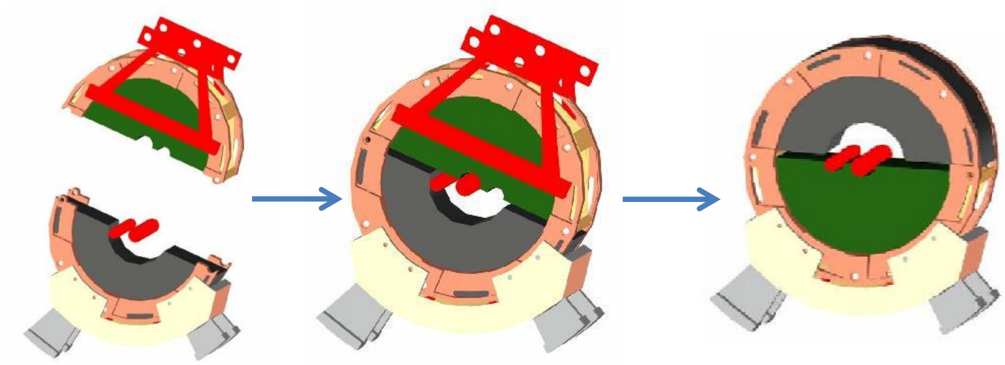
Pair Monitor

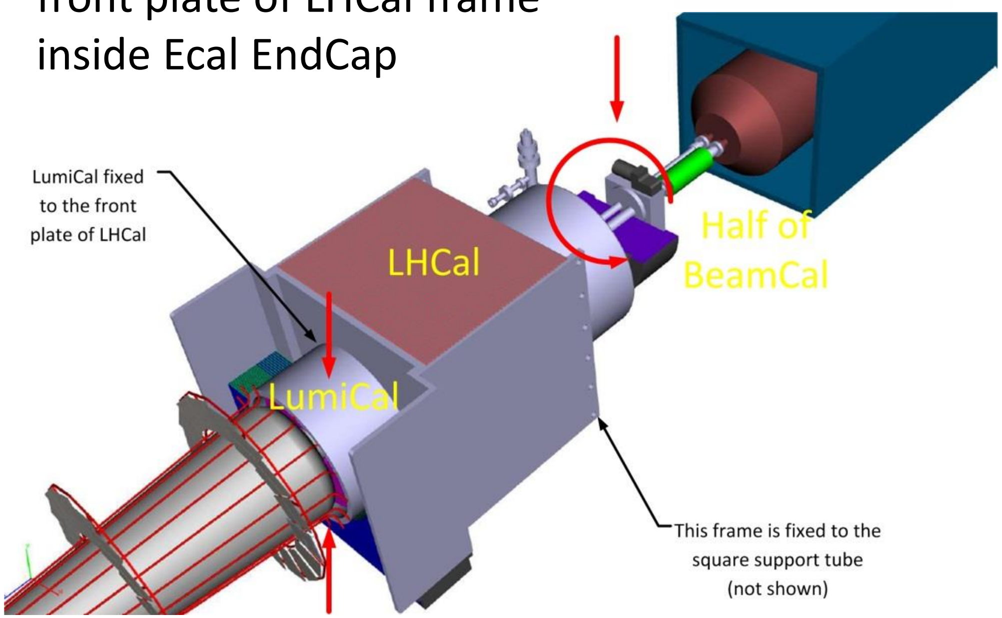
- detector radius 10cm
- pixel size 400x400 μm2
- total number of pixels ~ 200k

Integration and montage in ILD

LumiCal

Half barrels will be inserted from top and bottom and fixed to the front plate of LHCal frame inside Ecal EndCap



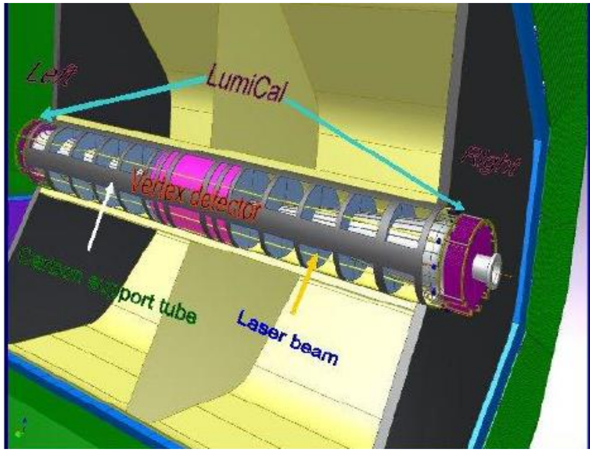


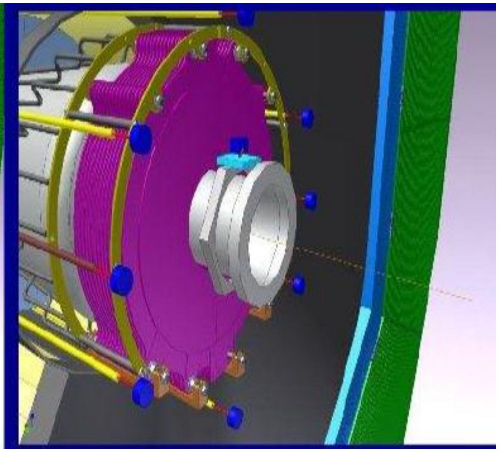
BeamCal

Half barrels will be inserted from top. The bottom part will be rotated 180 degrees under the in- and out- going beam pipes.

Precision LumiCal alignment

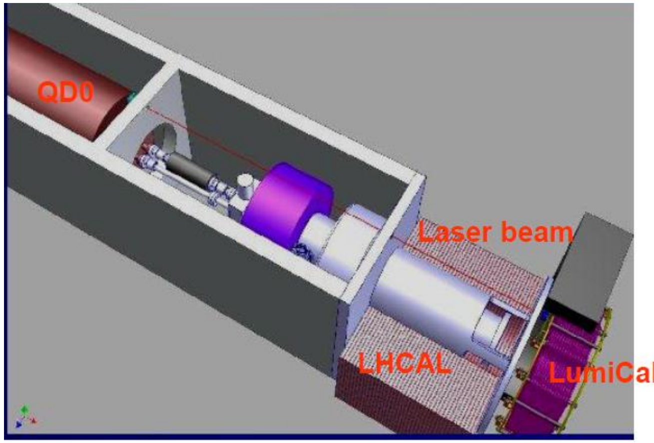
High accuracy in luminosity measurements at ILC/CLIC ($\Delta L/L \sim 10^{-3} / 10^{-2}$) require precisely measurement of the luminosity detector displacements:
less than 500 μm in X,Y directions , 1 mm in Z direction and
a few microns for internal silicon sensor layers





Good reference points for position measurement of LumiCal can be:

- QD0 magnet
- Beam Position Monitors
- also beam pipe



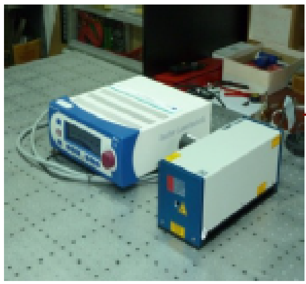
The measurements of absolute distance between Left and Right LumiCal calorimeters

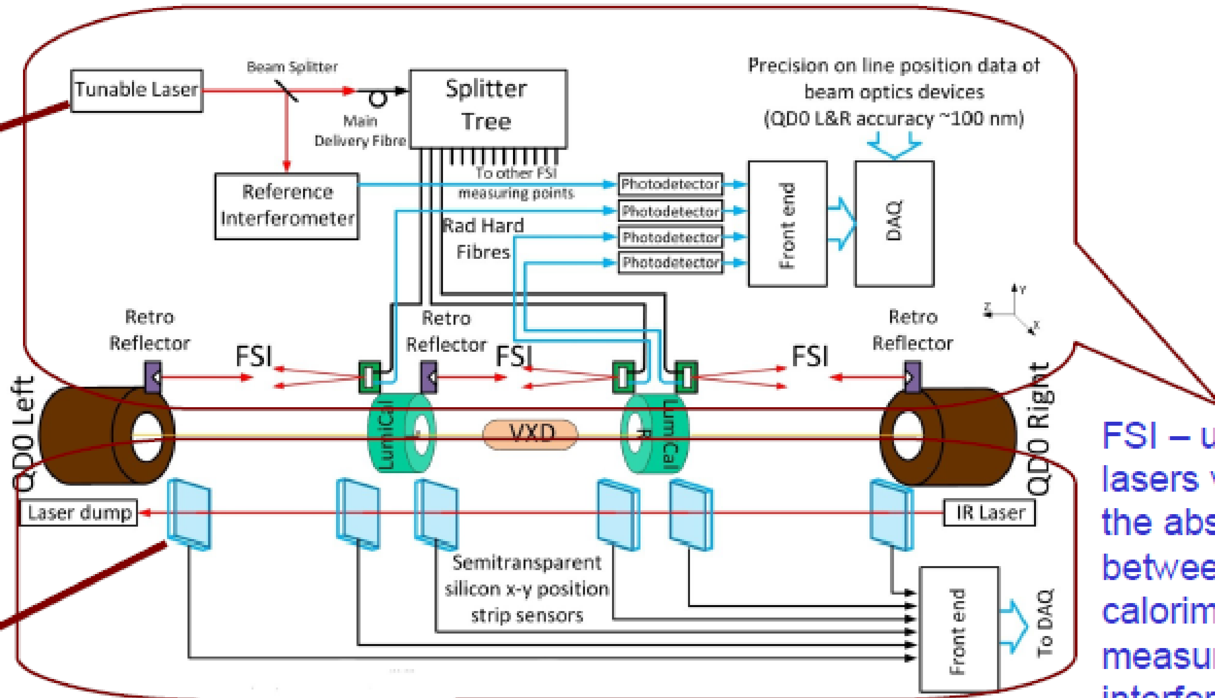
The measurements of the relative distances to QD0 in X,Y and Z directions

Design of LAS system

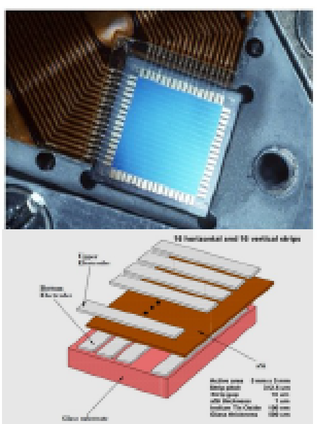
The proposed laser alignmet system for LumiCal combines two components:

- infra-red laser beam and semi-transparent position sensitive detectors (PSDs) - already available
- tunable laser(s) working within Frequency Scanning Interferometry (FSI) system - in preparation





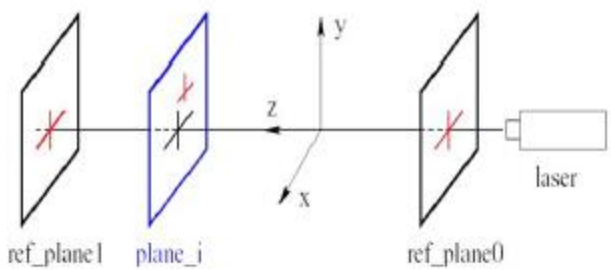
FSI – using tunable lasers will measure the absolute distance between LumiCal calorimeters by measurement of interferometer optical path differences (counting the fringes)



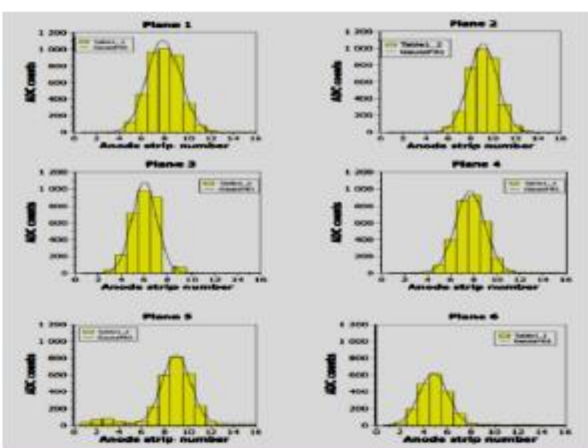
Semi-transparent sensors : LumiCal displacements of the internal Si layers and detectors relative positions

Semi-transparent sensors PSD

Laboratory setup : 6 PSD sensors

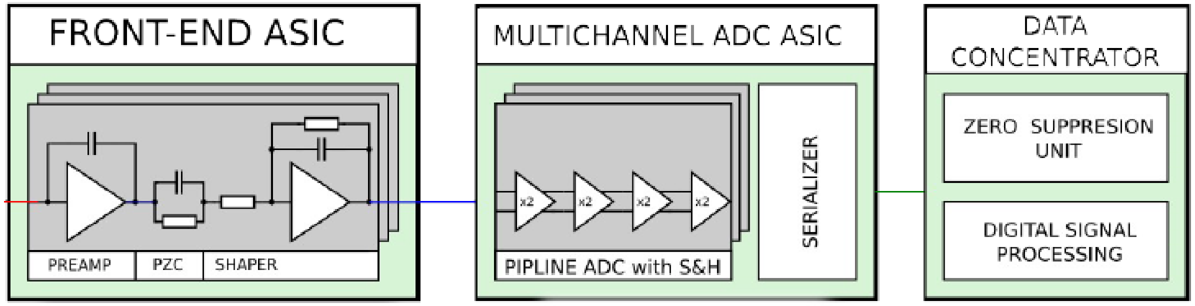


Laser beam-profile signals from anode of sensors measured along beam line



LAB prototype system with optical movable 2D table.
It allows studies of sensor behaviour, laser beam and calculation of displacements.
Expected accuracy: few microns

Power dissipation of LumiCal & BeamCal readout



8 channel Front-End ASIC
- Preamp. + PZC + CR-RC
- $T_{peak} \approx 60$ ns
- C_{det} up to 100pF
- Switched gain: ~2fC <Qin<10 pC
- Event rate up to 3 MHz

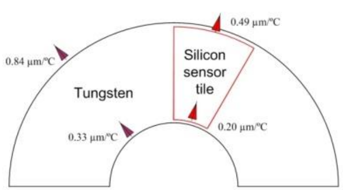
8 channel 10-bit ADC ASIC
- 1.5 bit pipeline architecture
- Digital serializer
- F_{max} 25 Ms/s (9.7 ENOB)
- Power: ~1.2mW/chan/MHz
- Power pulsing embedded

Power dissipation
- Front end electronics will be the major source of heat in the LumiCal.
- Thanks to the power cycling during brakes (199 ms) between trains (5 Hz, 1 ms) the dissipated power in one LumiCal will be around 30 W.
- We overestimate 60 W per detector which gives ~2 W per sensor plane.

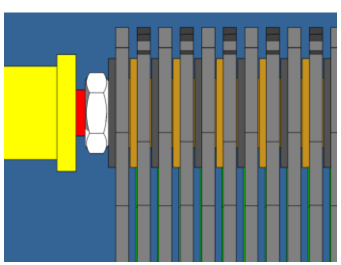
Power consumption
- At 40MS/s ~ 1 mW
- Power scaling ~ **25 uW/channel/MHz**
- In AMS0.35um it was 1 mW/channel/MHz
- With power pulsing (1% duty cycle) **~0.25 uW/channel/MHz**

Thermal expansion

The most important parameter for luminosity measurement is the inner radius of LumiCal silicon sensors. This parameter should be known and stable with the accuracy better than 4 μm.



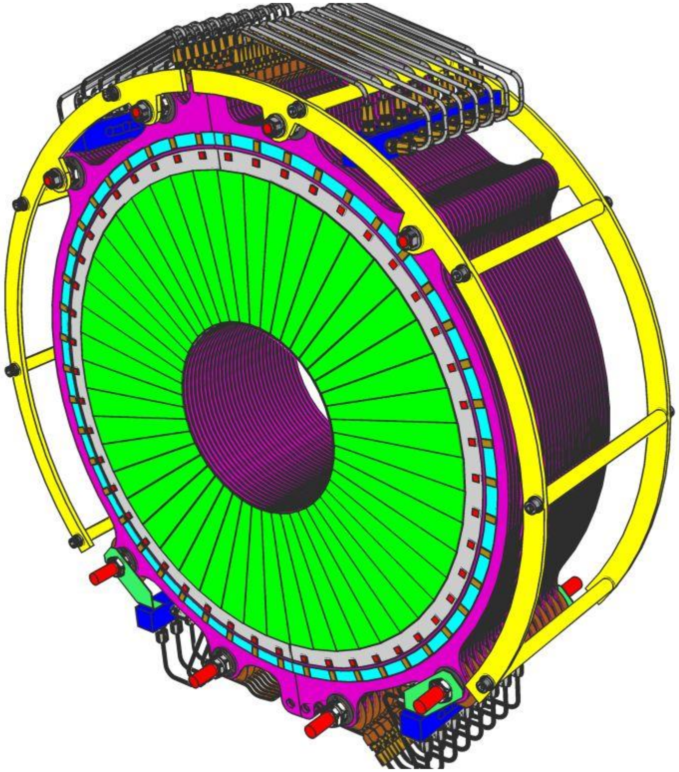
- The silicon sensors are glued on the tungsten absorber with Kapton E foil insulation. Tungsten has a small coefficient of thermal expansion α (CTE = 4.3 x 10^{-6} K).
- The inner radius of LumiCal absorber (76 mm) will expand thermally by 0.33 μm/ºC.
- The outer active radius (195.2 mm) will change by + 0.84 μm/ºC.
- Silicon has coefficient of thermal expansion α (2.5 x 10^{-6} K) ~2 times smaller than tungsten. We can roughly estimate that the inner radius of LumiCal will expand less than 0.5 μm/º C.



MC simulations have proved that inaccuracy in distances among tungsten plates and silicon sensors along the LumiCal axis less than 50 μm has negligible influence to the luminosity measurement.

- The length of LumiCal is ~135 mm and will expand + 2.41 μm/ºC.
- This distances between two silicon sensors will change in *z* less than 0.1 μm/ºC.

LumiCal temperature stabilization



- It is foreseen to use the water as a temperature stabilization medium for the LumiCal.
- Thermal insulation of the LumiCal to prevent temperature changes is necessary.
- Assume the temperature change of ±2 ºC which seems to be a save estimation.
- The thermal expansion of LumiCal silicon sensors inner radius will be smaller than ~2 µm (<4 µm).
- The water flow of ~0.5 l/min. per plane will take heat off with 0.1 ºC temperature increase. The total water flow in one LumiCal will be less than ~5 l/min.

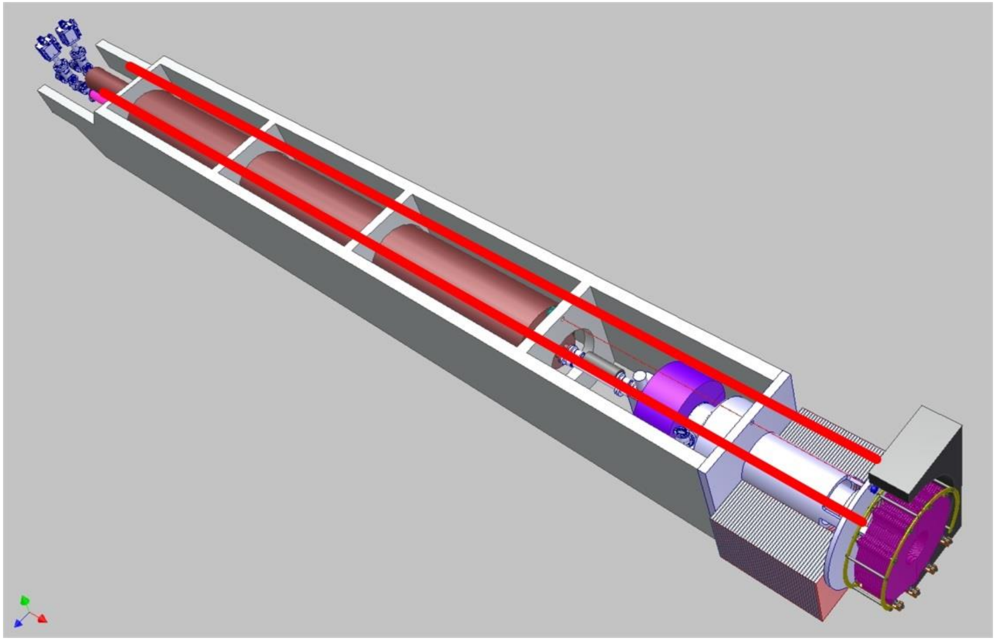
Cabling and services

LumiCal:
- Signal cables TP or FO ~10 cm²
- Power cables, ground ~5 cm²
- Water pipes ~5 cm²

Total ~20 cm²

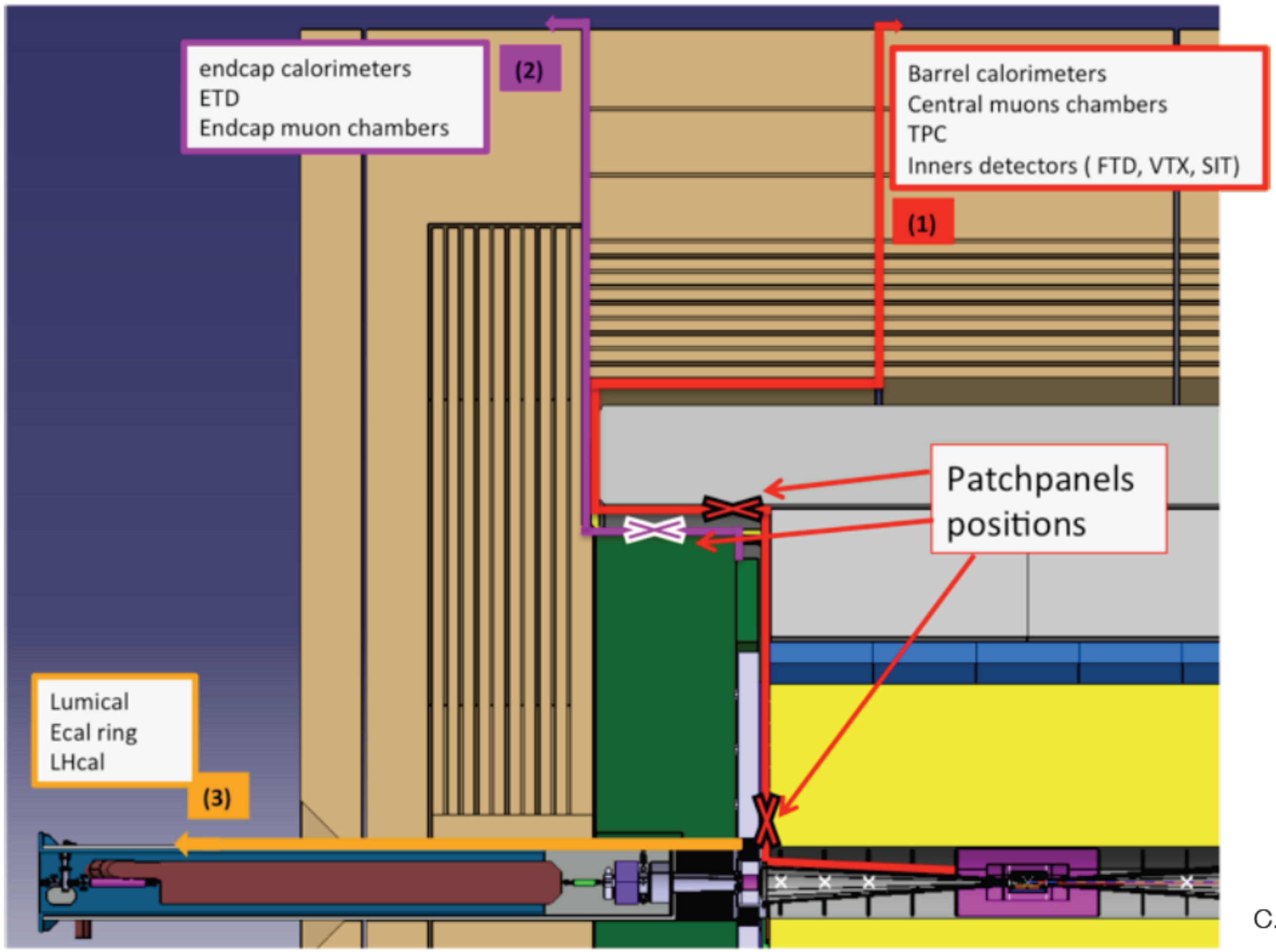
BeamCal
- Signal cables TP or FO ~10 cm²
- Power cables, ground ~5 cm²
- Water pipes ~5 cm²

Total ~20 cm²



All signal and power cables and water pipes from LumiCal and BeamCal should go inside the square support tube. The space for cables and services can be shared with other components (Vertex, FDET etc.).

Cabling and services



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The cables from inner detectors and TPC should have connectors to allow to pull out of TPC. The LumiCal and BeamCal cables should have connectors and patch panels to allow dismounted half barrels.

Next steps

- More effort on FCAL 3D model improvement (detailed mechanical design, implementation in ILD model).
- Build of FSI alignment system in laboratory similar to that used for SiD (ATLAS concept).
- Detailed cables, services path and connectors space desing.
- Design of LumiCal thermal insulation.
- Design od temperature stabilization concept.

FCAL Collaboration

Institutes involved:

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ISS, Bucharest, Romania
NCPHEP, Minsk, Belarus
Tel Aviv University, Tel Aviv, Israel
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IFIN-HH, Bucharest, Romania
JINR, Dubna, Russia
SLAC, Menlo Park, USA
Tohoku University, Sendai, Japan
Vinca,Belgrade, Serbia

CERN, Geneva, Switzerland
INP PAN, Cracow, Poland
LAL, Orsay, France
Stanford University, Stanford, USA
UC California, Santa Cruz, USA
Pontificia Universidad Católica, Chile