VFS Integration Status

ILD integration Meeting

DESY Hamburg, 11–12 February 2019

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Update of Interface Control Document

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  Pair Monitor
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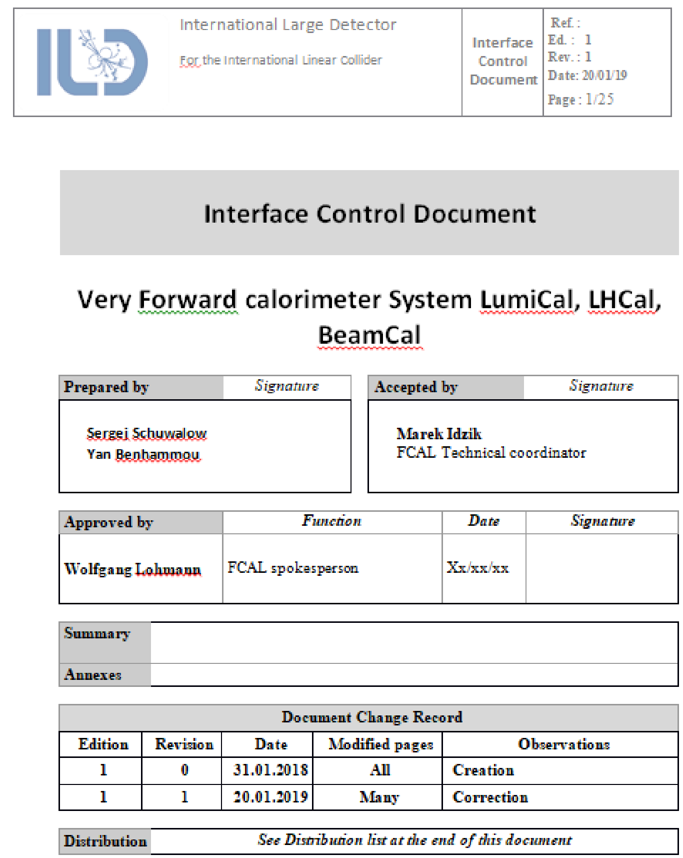

International Large Detector For the International Linear Collider	Interface Control Document	Ref. : Ed. : 1 Rev. : 1 Date: 20/01/19 Page : 1/25	

Interface Control Document

Very Forward calorimeter System LumiCal, LHCal, BeamCal

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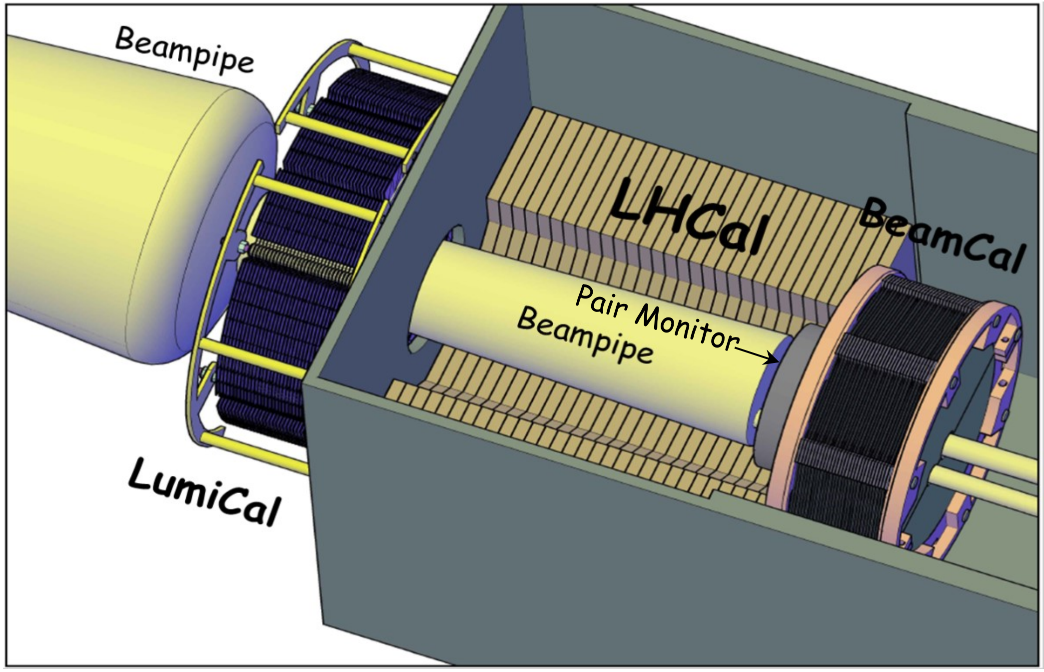
Summary	
Annexes	

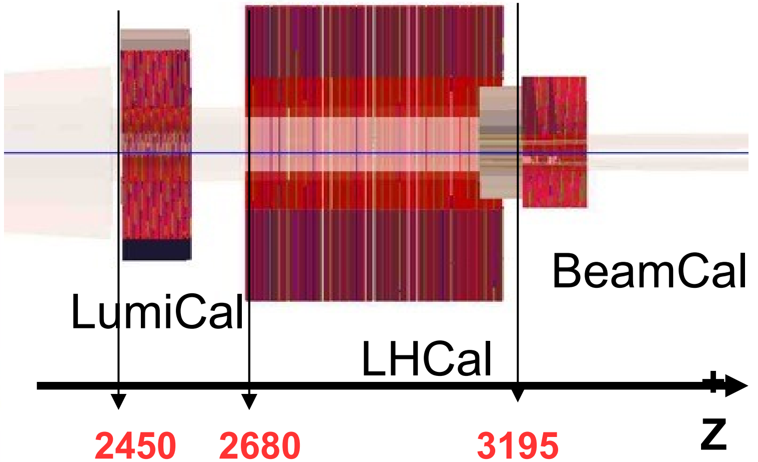
Document Change Record				
Edition	Revision	Date	Modified pages	Observations
1	0	31.01.2018	All	Creation
1	1	20.01.2019	Many	Correction

Distribution	*See Distribution list at the end of this document*

General Description of Very Forward System

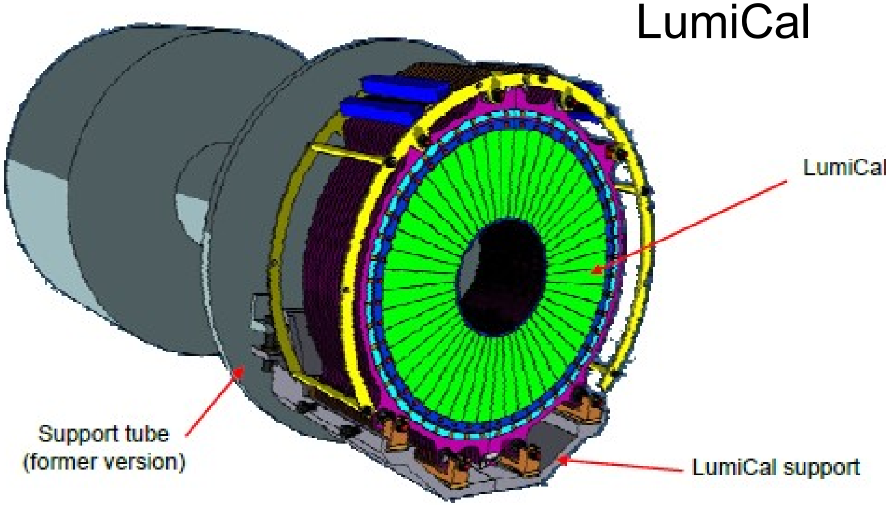
The instrumentation of the very forward region comprises several subdetectors, placed symmetrically on both sides of the interaction point at a distance of 2.5-3.5 m. At small polar angles, adjacent to the beam-pipe, the Pair Monitor and BeamCal measure remnants of beamstrahlung to assist beam tuning. BeamCal will also measure high energy single electrons. LumiCal, at larger polar angles, will be the luminometer of the experiment using Bhabha scattering as the gauge process. LHCal is needed to provide hermeticity of the detector and facilitates particle ID and energy measurement at low polar angles.

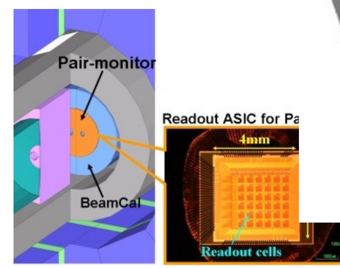




Forward Detectors

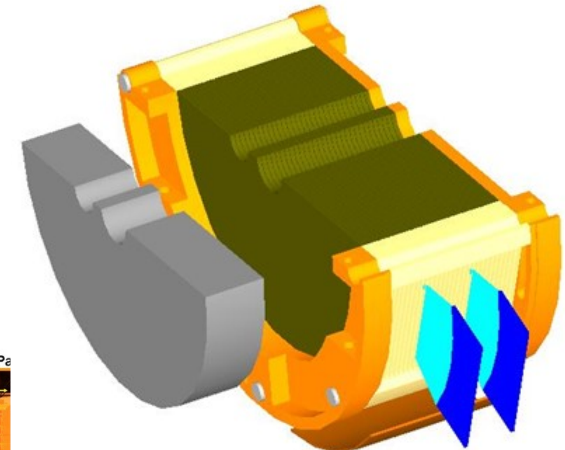
LumiCal



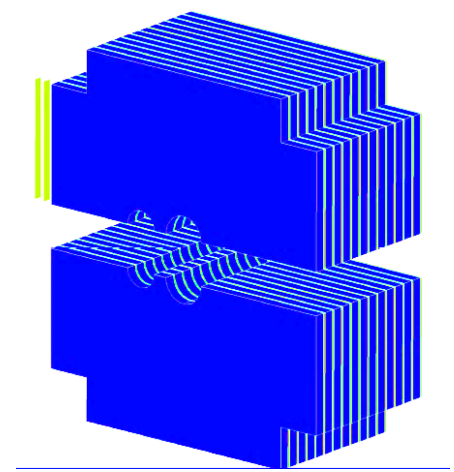


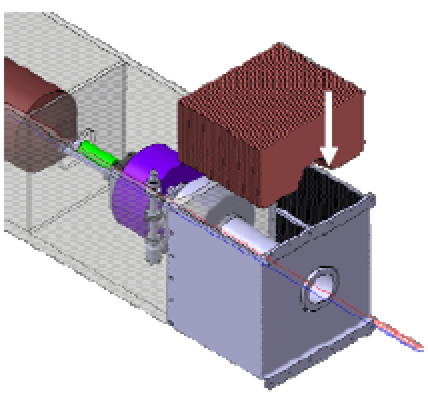
Pair monitor

BeamCal

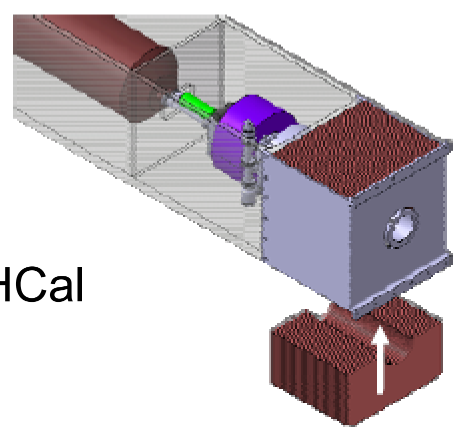


BeamCal (sapphire)





LHCal



FCAL detector designs in future e+e- linear accelerators

- **LumiCal :**
  - Electromagnetic sampling calorimeter
  - layers of 3.5 mm thick tungsten plates with 1 mm gap for silicon sensors (30 for ILC, 40 for CLIC)
- **LHCal :**
  - Sampling calorimeter (silicon pad sensors)
  - 29 layers of 16mm thickness. Absorber : tungsten alloy
- **BeamCal:**
  - Sampling calorimeter based on tungsten plates (30 layers for ILC, 40 layers for CLIC)
  - Due to large dose, rad hard pad sensors (GaAs, Radiation Hard Silicon, Sapphire, Diamond)

VFS components: BeamCal

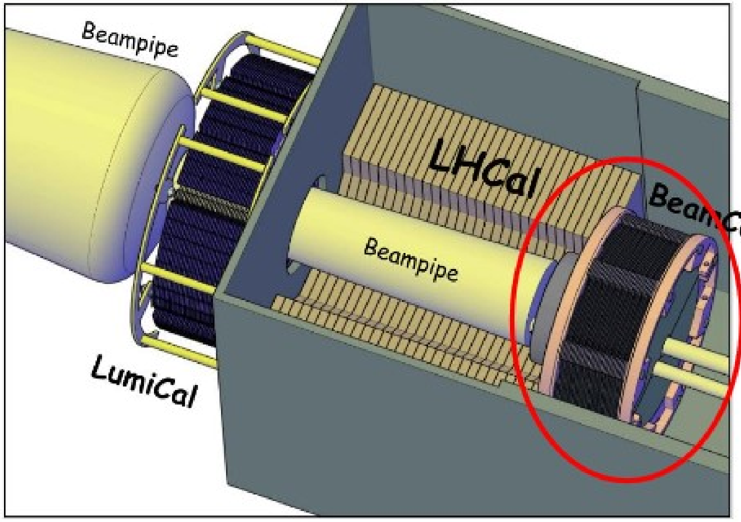
- **BeamCal** is an electromagnetic sandwich calorimeter that uses tungsten as absorber. It serves three major purposes:
- Improving the hermeticity of the ILC detector by providing electron and photon identification down to polar angles of a few mrad. This is a specially challenging task due to the vast amount of deposited energy from the electron-positron pairs originating from beamstrahlung.
- Reducing the backscattering from pairs into the inner ILC detector part and protecting the final magnet of the beam delivery system.
- Assisting beam diagnostics. A fast luminosity signal will be provided by BeamCal. The detailed analysis of the shape of the energy deposition from pairs hitting the BeamCal grants access to parameters of the colliding beams.

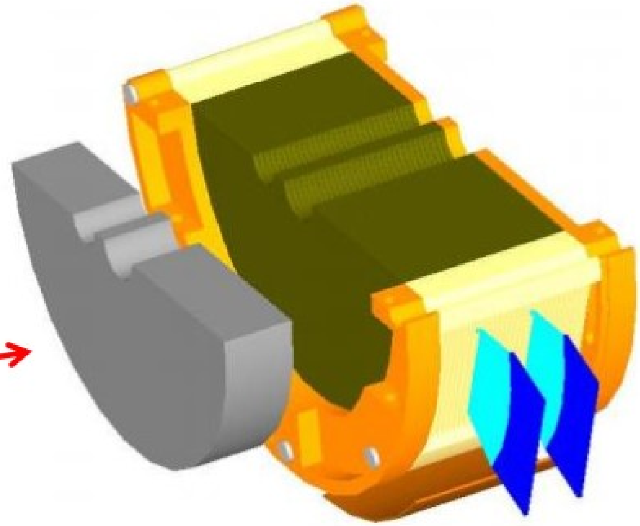
The sensors of the BeamCal must be very radiation hard. The technologies under investigation are:

- - GaAs (baseline)
- - radiation hard silicon
- - single crystal sapphire
- - polycrystalline CVD diamond (Chemical Vapor Deposition)
- - single crystal CVD diamond

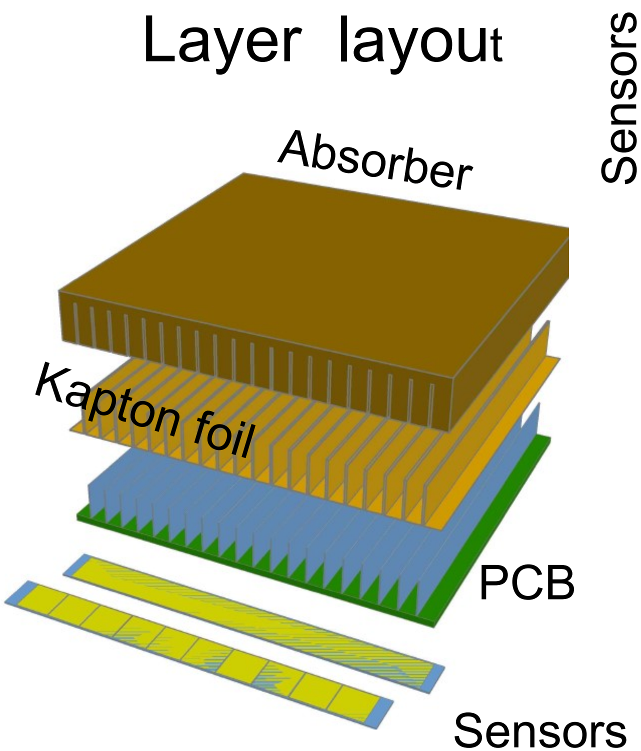
BeamCal Design

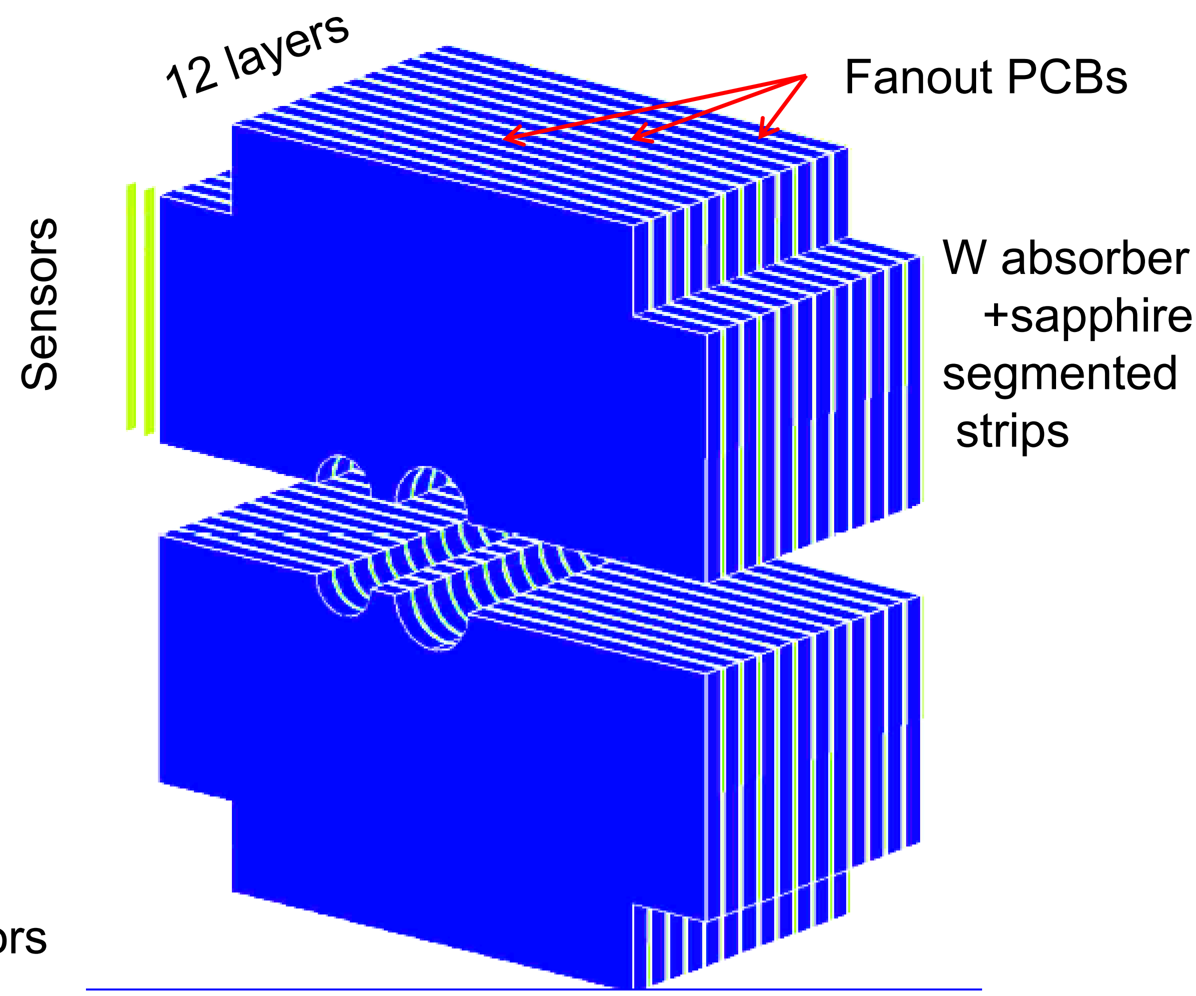
- Sampling **?**-W calorimeter
  - Sapphire, CVD diamond and GaAs are possible candidates
- 30 **precise** layers at ILC (40 at CLIC), one radiation length each
- 5–45 mrad at ILC (15–38 mrad at CLIC)
- High radiation tolerance
- Fast bx-by-bx readout



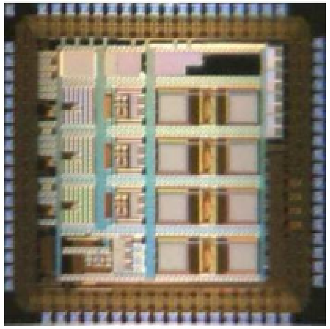


BeamCal – sapphire based design

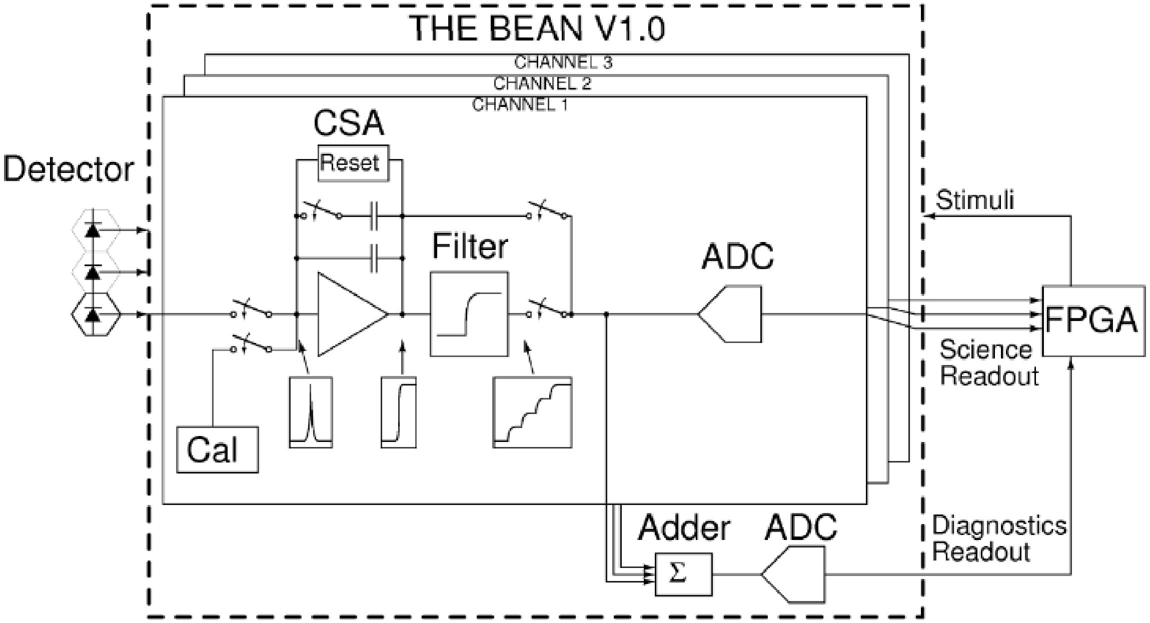




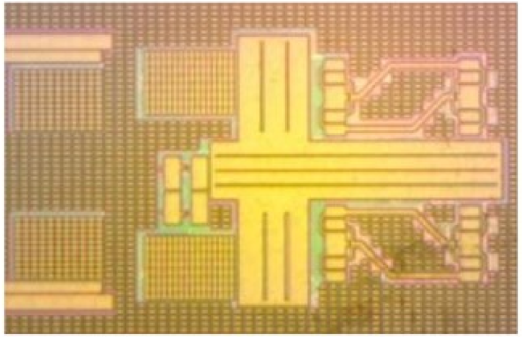
BeamCal Readout: BEAN V1

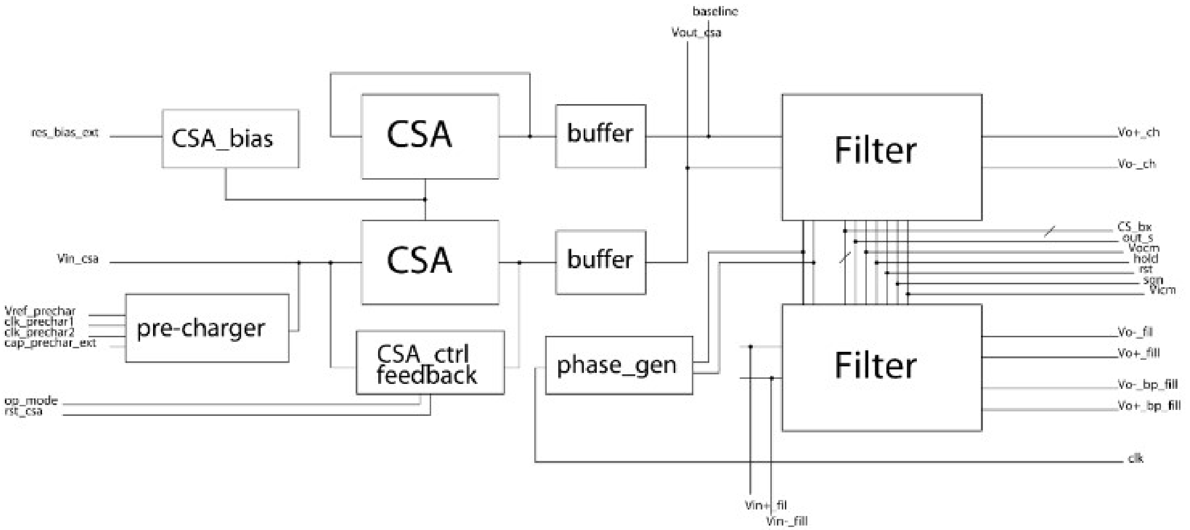


DOI: [10.1109/TNS.2012.2194308](https://doi.org/10.1109/TNS.2012.2194308)



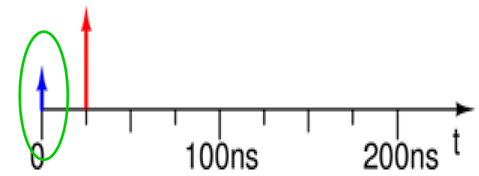
BEAN V2: Arbitrary weighting function generation

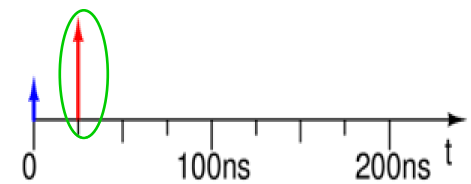




BeamCal dual readout

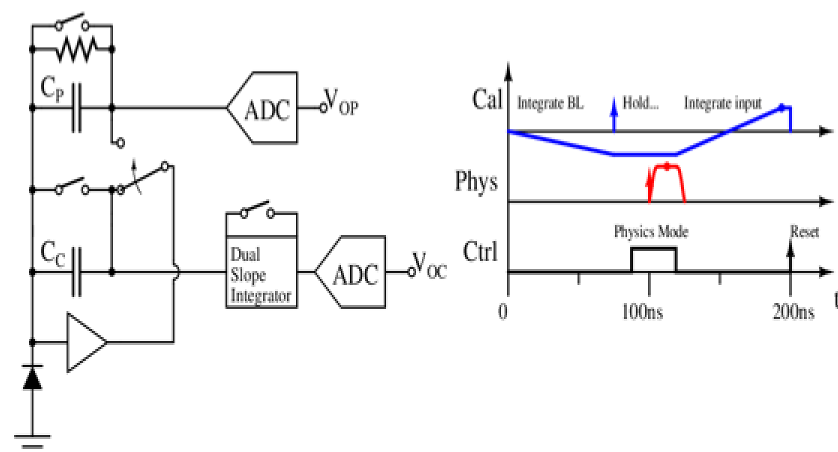
- Firstly, BeamCal is hit by beam halo (muons)
  - MIP deposition, low noise electronics
  - Clean environment
  - Good for calibration
- ~25ns later, BeamCal is hit by collision products
  - Large deposit energy
  - Physics readout





Dual slope integrator for calibration signal

1. Integrate baseline (negative gain)
2. Calibration halo signal is deposited and held
3. Switch to physics mode, process and digitize Vop
4. Then integrate calibration signal and digitize Voc

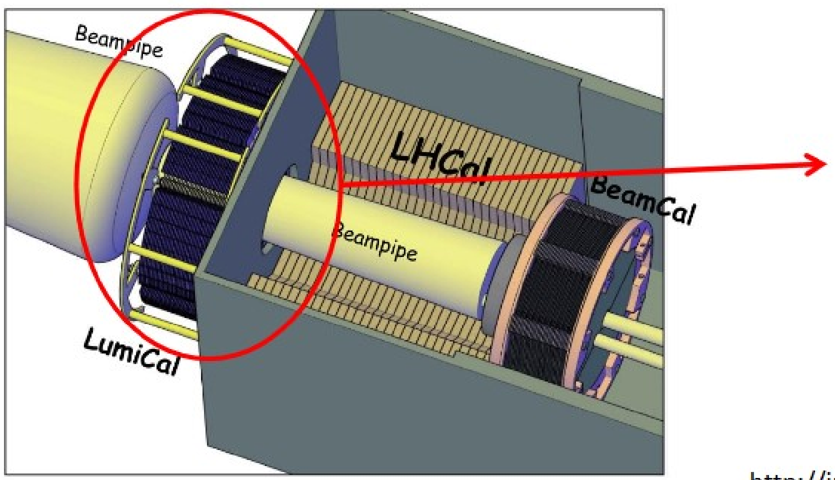


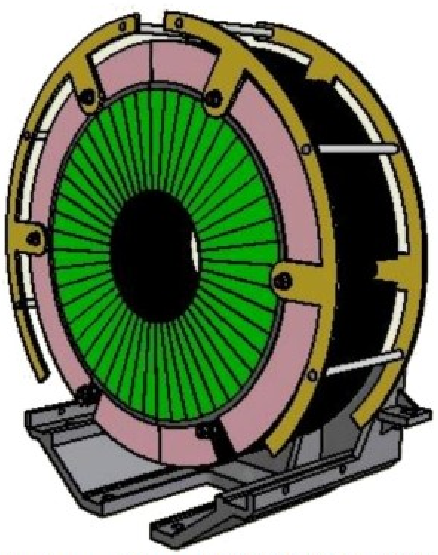
VFS components: LumiCal

- **LumiCal** serves three major purposes:
- Measuring the rate of Bhabha events at low angles. The well known Bhabha scattering cross section will allow the precise determination of the luminosity of the ILC. Achieving the desired precision of better than 10^{-3} is a challenge.
- Reducing background by acting as a mask.
- Improving the hermeticity of the ILC detector by providing electron and photon identification down to polar angles of a few mrad.
- The technology of a Si-W sandwich calorimeter is a baseline option for the LumiCal.

LumiCal

- Sampling (sandwich) Si-W calorimeter
- 30 **precise** layers at ILC (40 at CLIC), one radiation length each
- 42–67 mrad at ILC (38–110 mrad at CLIC)
- **Compactness** for ~1cm Molière radius

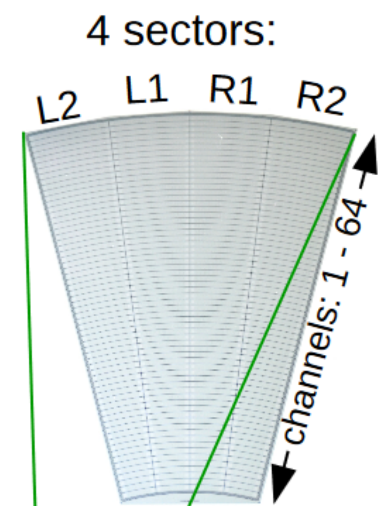




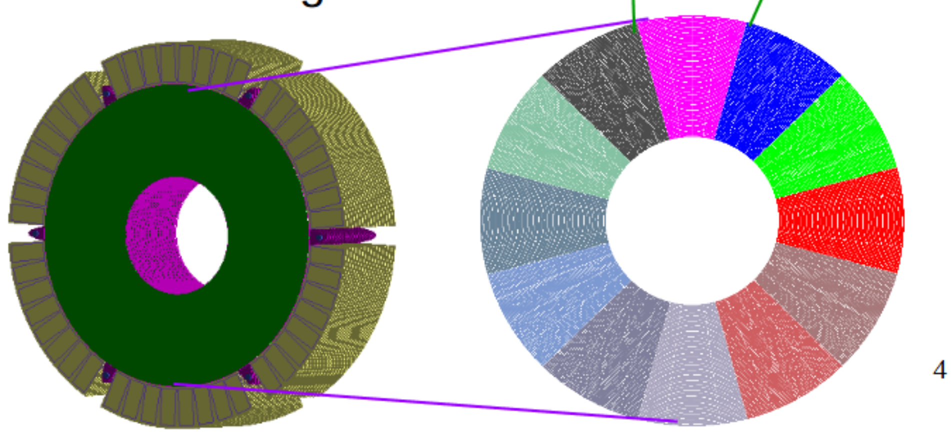
http://inspirehep.net/record/1386724/files/v46p1297.pdf

LumiCal Sensor and Assembly

- Silicon sensor
- thickness 320 µm
- DC coupled with read-out electronics
- p+ implants in n-type bulk
- 64 radial pads, pitch 1.8 mm
- 4 azimuthal sectors in one tile, each 7.5°
- 12 tiles makes full azimuthal coverage



Total number of LumiCal channels: 184320

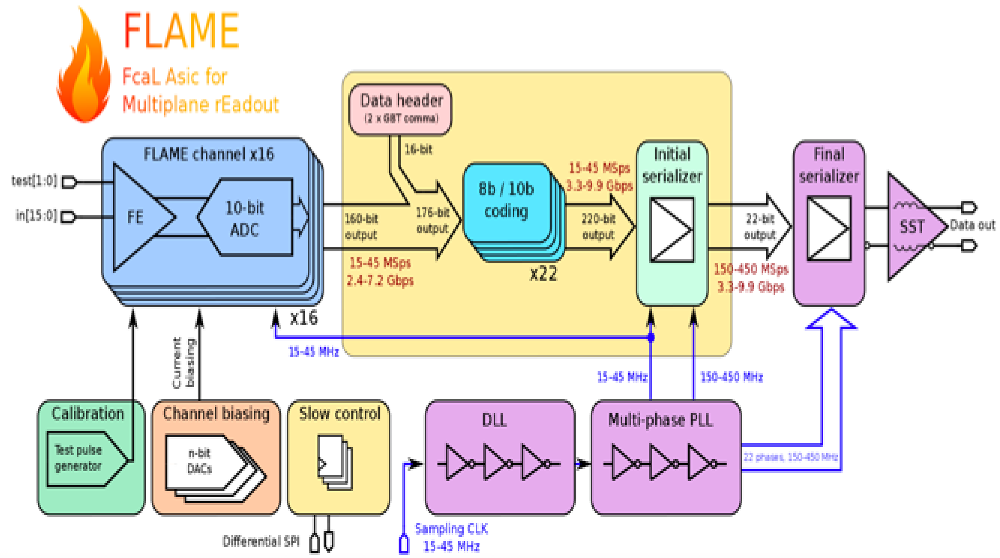


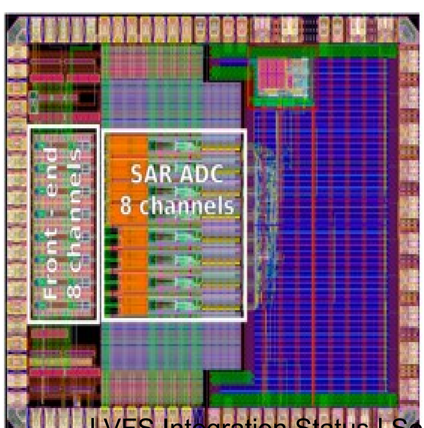
New readout : FLAME

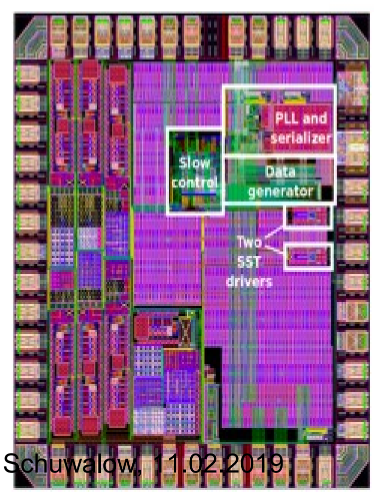
JINST 10 (2015) P11012
JINST 10 (2015) P12015

- FLAME: project of 16-channel readout ASIC in CMOS 130nm, front-end&ADC in each channel, fast serialization and data transmission, all functionalities in a single ASIC

- FLAME prototype :
  - Prototype 8-channel FE+ADC ASIC
  - Prototype serializer ASIC



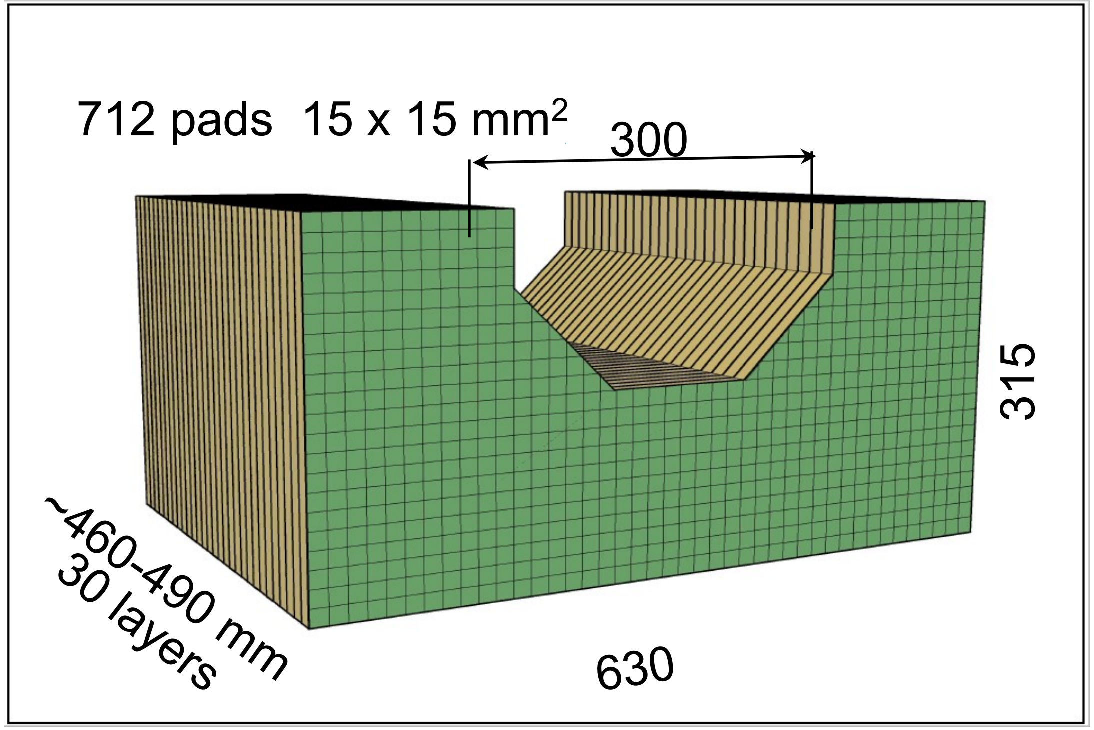




First tests are encouraging : FE ok, ADC ok, basic functionality of serializer are ok

VFS components: LHCal

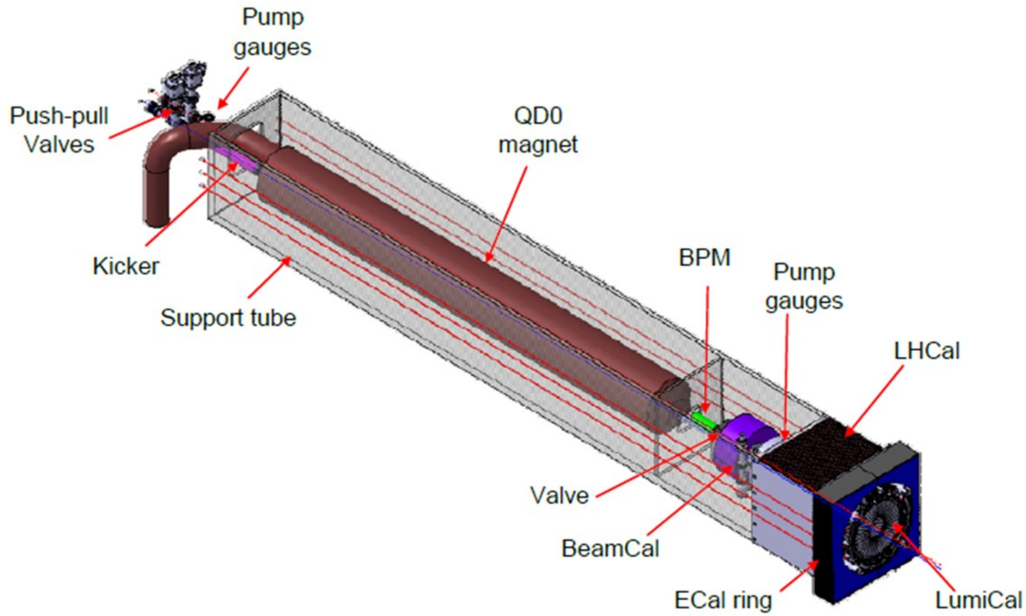
- **LHCal** is a hadronic sampling calorimeter that uses tungsten alloy as absorber.
- Sensors are silicon pad planes. This calorimeter provides particle identification and energy measurement at low polar angles, extending rapidity coverage of ILD endcup calorimeters. Detailed design of LHCal is not yet available, simple model of it is included in Monte Carlo simulations for the performance studies and optimization.



LHCal Layout (bottom half)

General interface description

All components of the very forward system are mounted on the supporting rectangular beam. The support beam will be a square 670 x 670 mm^2 structure of stainless steel plates 30 mm thick, partly open on its top. It will be aligned in a millimeter range to the beams axes. The fine adjustment of the forward calorimeters (except LHCal) and of the QD0 magnet mounted there will be obtained by movers integrated between components and the support tube. For stability reasons the tube is sustained on each side: 1) outside the detector using a pillar and 2) inside the detector with two vertical tension rods attached on the coil cryostat.



For reduced L* the design of support tube is slightly modified: wall thicknesses at the LHCal location are reduced to 15 mm, front plate 15 mm thick now starts at z=2650 mm and has round cutout 100 mm radius around the beampipe. LumiCal and ECAL-ring detectors are attached to the front plate, which also serves as a very first absorber plate of LHCal detector.

ECal-rings are parts of end cup electromagnetic calorimeter and made of two halves (modules), see Figure 3 and Figure 4 and description in ECAL interface document.

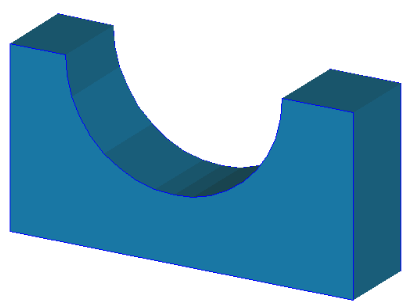


Figure 3 ECal ring module.

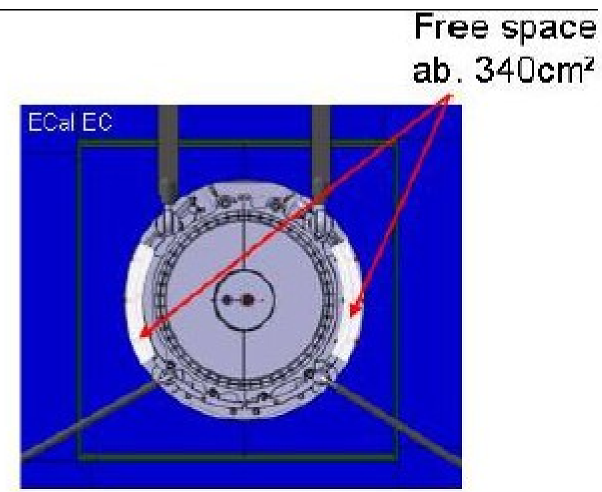


Figure 4 ECal ring and LumiCal

Mechanical interface

1. **Coordinate system**

- The coordinate system for the VFS is the general coordinate system of ILD as described in the ILD C&R. For each component additional local coordinate system is often used. The origin of local coordinate system is typically at the crossing of the nominal position of outgoing beam axis and front (looking from IP) surface of the first calorimeter absorber. Z axis is along the outgoing beam axis, the X axis is horizontal and the Y is vertical, with the direction the same as for the Y axis of general ILD coordinate system.

1. **Mechanical concept**

- General description of detector elements.

  The subdetector ensembles are shown in the previous section for one arm. Full set consists of two identical LumiCal detectors and two pairs of mirror-symmetrical LHCal and BeamCal detectors. Each of six detectors is made out of two halves with individual set of cooling pipes, power cables, fast and slow control links and data transmission optical fibers. Thus in total minimum 12 separate connection sets and routing paths should be specified.

Positioning and alignment constraints

For every subsystem:

- Positioning constraints: position of a subsystem vrt another one
  LHCal is attached to the supporting beam and cannot be moved or positioned independently, **BeamCal** has adjustable support for initial positioning with respect to the beampipe. **LumiCal** has the most sophisticated adjustment system including optical sensors and piezoelectric movers. Laser alignment system for this detector is under investigation. Critical is the distance between LumiCal's at +Z and –Z sides (direct view for laser beam?)
- Alignment constraints: absolute/or relative alignment precision for a system from another AND requested precision for the verification of this alignment.

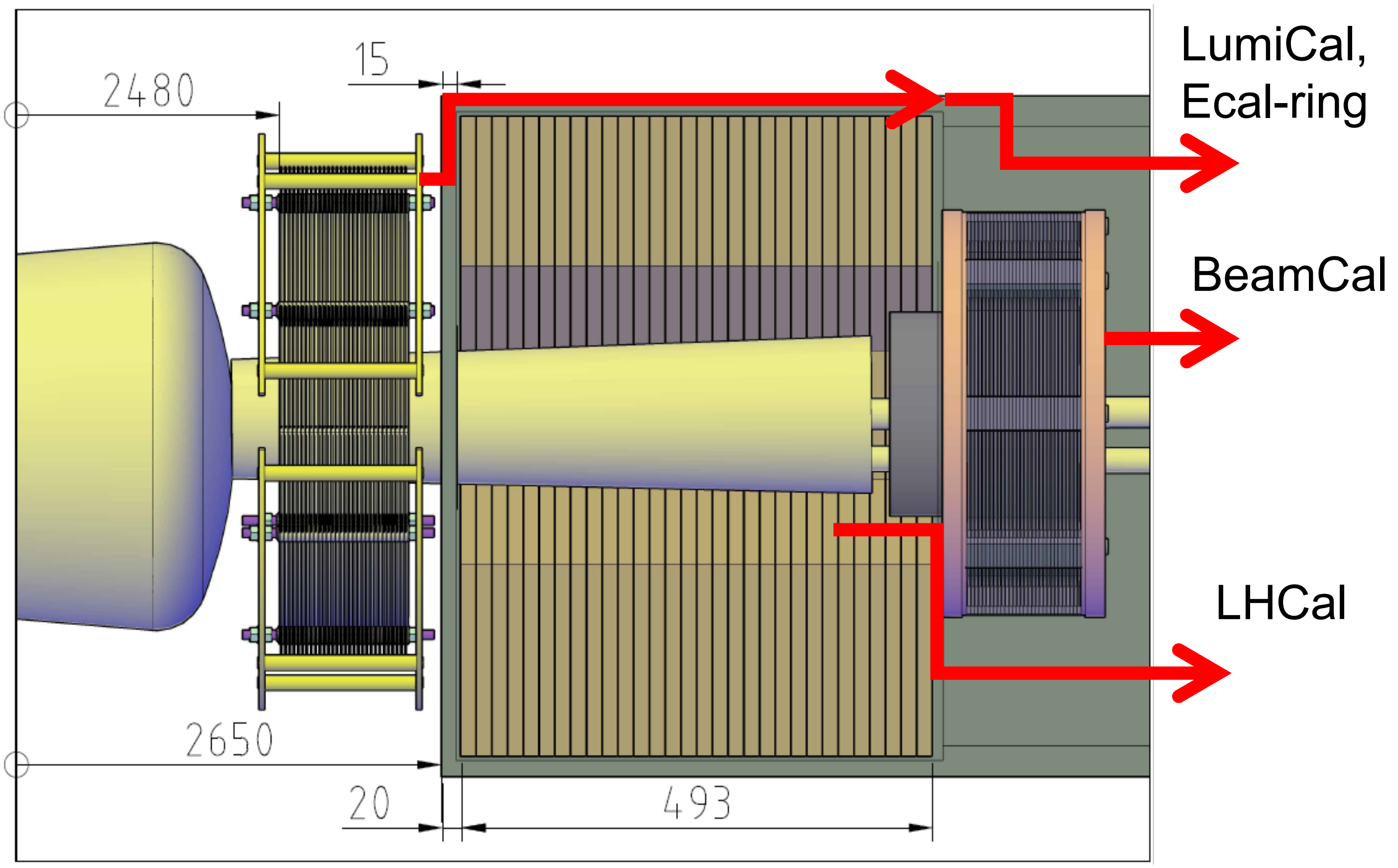
Electrical interface

All cables and cooling pipes from VFS components will be guided inside the support beam and attached to the pillars. The critical path is the outer part of the support beam, where machine elements like QD0, BPM and vacuum pumps will be located.

Detailed routing of the cables should be communicated with the Central Design and Integration group (not yet done).

- Power (the type of power [regulated, unregulated, heating-, number of lines for each type):
  Exact parameters are not known yet. VFS will need low voltage lines (high current, two polarities), high voltage for sensor bias (low power, up to 1 kV for some BeamCal sensor options). Power pulsing is foreseen for the LV.
- Remote control: control type (relays, digital ...), the number of each type of control:
  Control of piezoelectric movers, laser alignment system, number of control channels to be defined.
- Insulation:
  According to safety rules, halogen free insulation.
- Other interfaces: clock, other instruments, ...
  Further interfaces are the clock distribution and transmission of fast control commands. Optical links are preferable to avoid ground loops. Data transmission to the DAQ will be done via optical links.

Cabling and cooling pipes paths



Gas system interface

- The VFS is cooled with water, no gas system is foreseen.
- In case, if BeamCal sensors will be made out of radiation hard silicon,

  BeamCal CO_2 cooling will be needed (approx -20°C).

Liquid system interface

The cooling pipes are made from copper. For all VFS components the cooling scheme is similar: heat exchange is done at the outer detector mechanical structure which in turn has thermal connection to the absorber stack and readout electronics. For LHCal absorber stack itself is cooled.

- Pressure

  The system will be leakless (water underpressure) – similar to other systems (ILD standard?).

  Flow to be specified (~ 4 kW VFS total heat power for removal)

  Water temperature input/output: 18°C / 23°C (maximal) – similar to surrounding detectors.

- Purity constraints of the fluid

  Distilled water.

DAQ requirements

- Number of readout channels, data structure, rate:
- LumiCal - 180 k (2 x 90 k) readout channels, readout every BX, 10-bit resolution, zero suppression, ~ 3% occupancy.
- LHCal - 90 k (2 x 45 k) readout channels, self triggering, data transmission between bunch trains, 12-bit resolution, zero suppression, ~5 % occupancy
- BeamCal – 30 k (2 x 15 k) readout channels , readout every BX, 10-bit resolution, ~ 50% occupancy. In addition, 16-channel analog sum of depositions and 10-bit digitization for fast luminosity tuning (possibility of DAQ readout for off-line control).

Expected mean rate ~ 1 Gbit/s / link (12 optical links)

Cavern equipment

- All numbers are preliminary
- All VFS detectors (LumiCal, BeamCal, LHCal) are put together.
- Two separate sets of equipment for -Z and +Z sides, 2 racks on the platform.

	Sub-detector name	VFS	
P_FE	Power consumption of Front-end Electronics	4	kW
Q_PC	Heat loss in Power Cables	< 1	kW
e	Efficiency of low voltage power supply	80%	
P_BE	AC Power input to Back-end Electronics	< 1	kW
P_CS	Electric power to drive Cooling System	1	kW
	Type of cooling water for cooling system	Chilled water	
P_LV	AC Power input to Low Voltage power supply	6,25	kW
Q_LV	Heat loss in Low Voltage power supply	< ,25	kW
Q_BE	Heat loss in Back-end Electronics	< 1	kW
Q_CS	Heat to be extracted from cooling system	5	kW

Rooms

- Assembly area 100 m^2 ISO 7 temperature stabilized, crane 10 t

  Test lab with water and nitrogen supplies, sources (Sr^{90})

  Access to bonding facility

  Cable workshop common with other subsystems

- Storage: we also need something, not much, but there are usually crates, instruments, spares, materials to be used for assembly which have to be kept somewhere nearby (~20 m^2 is sufficient)

- Office space is also necessary. lets assume there are 20 people present, 5 offices for 4 people each, or 10 for two is a good ansatz

Thank you