LUMINOMETERS FOR FUTURE LINEAR COLLIDER EXPERIMENTS

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[on behalf of the FCAL Collaboration]

Abstract:

The FCAL collaboration develops the technologies of compact and fast calorimeters to measure the luminosity of Linear Collider collisions both with high precision using small angle Bhabha scattering, and bunch-by-bunch using beamstrahlung pairs. Beside the luminosity measurement, the capability of detecting high energy electrons at low angles is important for many search experiments.

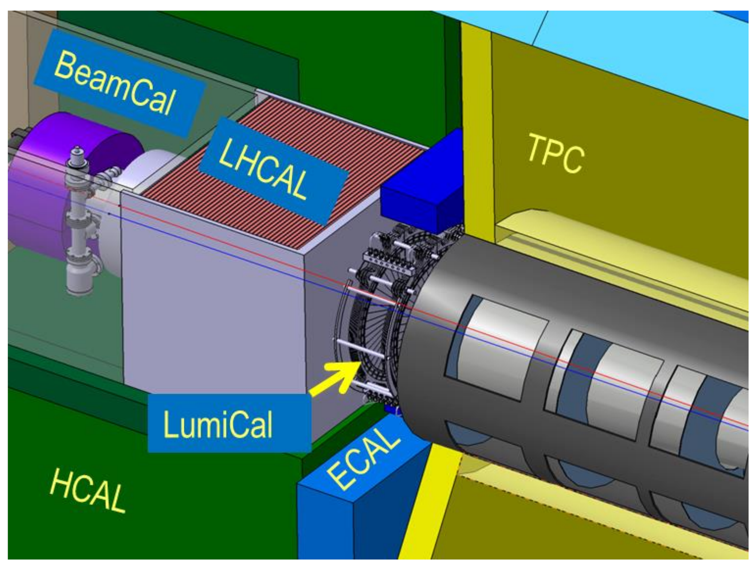
A small Moliere radius facilitates the measurement of Bhabha events in the presence of background and allows the detection of single high energy electrons on top of the widely spread background of beamstrahlung.

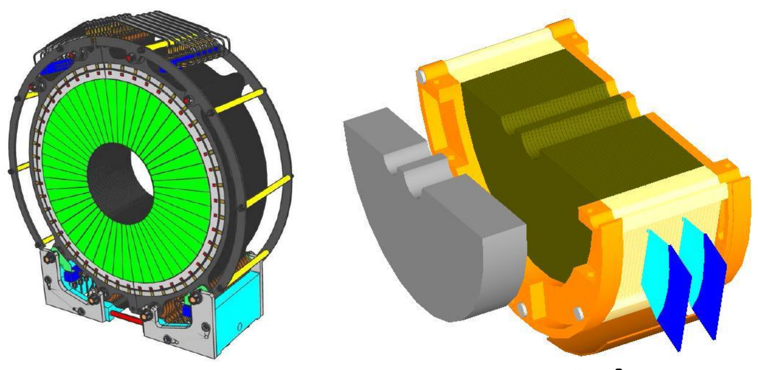
A multi-plane prototype of a compact, precision luminometer was studied in an electron beam at DESY with momentum around 5 GeV. The results for the longitudinal and the transverse shower profiles are compared with Geant4 simulations of the setup and used to determine the effective Moliere radius of the prototype, which approaches the technological limit.

A dedicated multi-channel ultra-low power readout ASIC is under development in 130nm CMOS, comprising an analogue front-end and fast 10-bit ADC in each channel, followed by fast serialization and data transmission. In addition, an ASIC with a dual readout scheme for BeamCal allowing for a fast feedback to the accelerator and simultaneous data taking and calibration is under development.

The talk will give a summary of results on design optimisation, beam-tests, sensor radiation damage studies, and the status of the readout ASICs.

ILC & CLIC

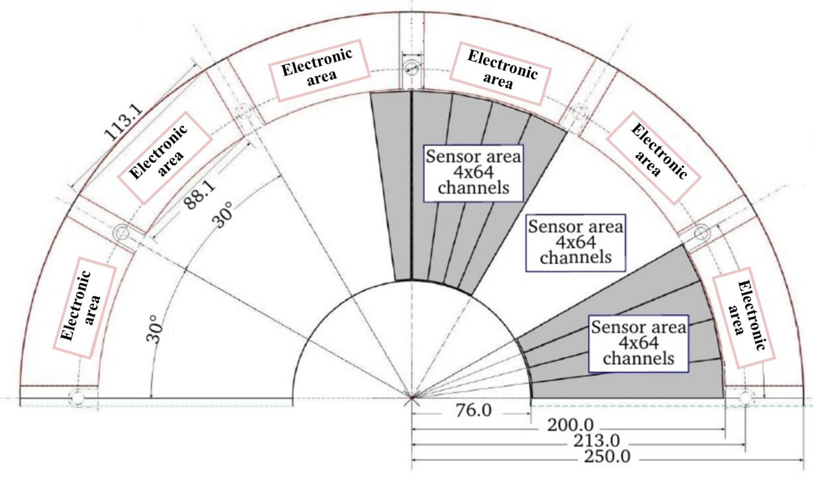




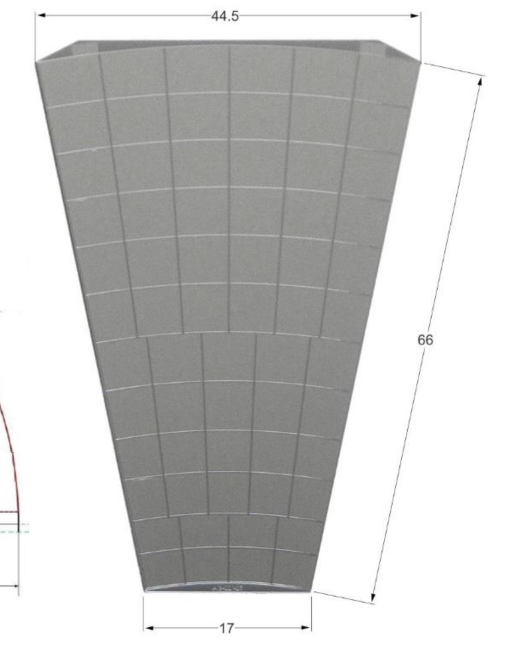
LumiCal **BeamCal**

Two special calorimeters are foreseen in the very forward region of future Linear Collider detectors: Luminosity Calorimeter (**LumiCal**) for precision luminosity measurements and an instrumented absorber for beam-beam background pairs (**BeamCal**) that can also tag high-energy electrons. Both calorimeters extend the detector coverage to low polar angles, important e.g. for new particle searches with missing energy signature.

	Parameters	ILC (ILD)	CLIC_ILD
LumiCal	geometrical acceptance [mrad]	31 - 77	38 - 110
	fiducial acceptance [mrad]	41 - 67	44 - 80
	number of layers (W + Si)	30	40
BeamCal	geometrical acceptance [mrad]	5 - 40	10 - 40
	z (start) [mm]	3600	3281
	number of layers (W + sensor)	30	40



LumiCal - Si sensor half-plane schematic.



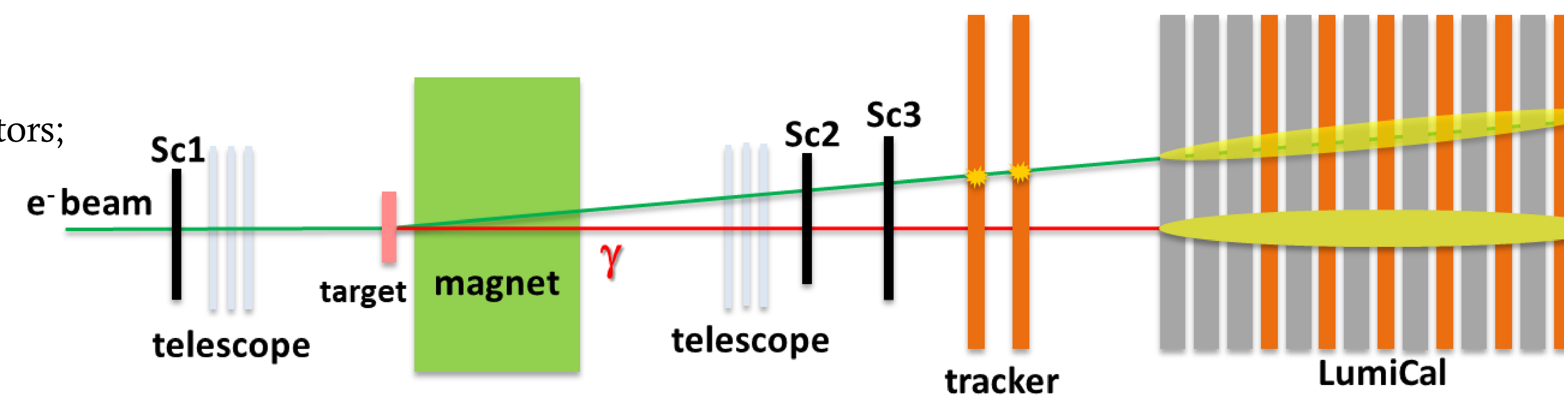
BeamCal - GaAs sensor prototype

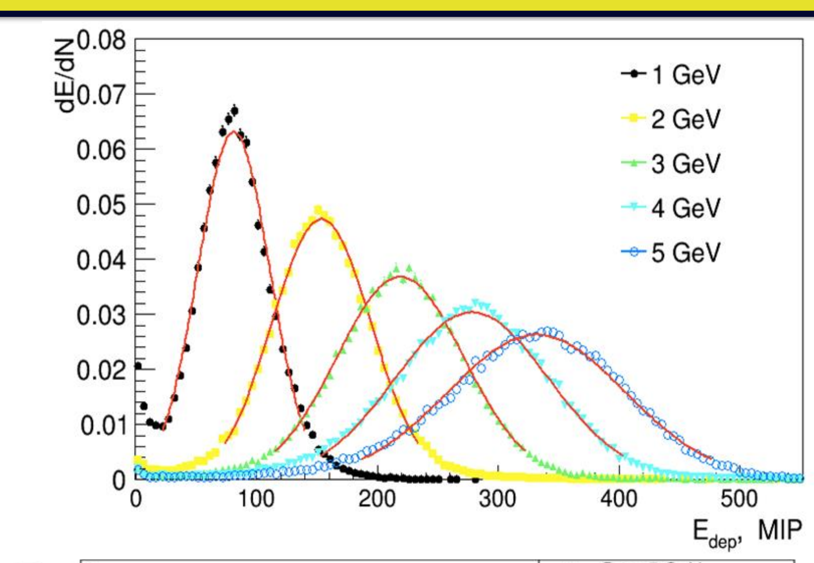
LumiCal and **BeamCal** are designed as cylindrical sensor-tungsten sandwich electromagnetic calorimeters. Each layer is segmented radially and azimuthally into pads. Front-end ASICs are positioned at the outer radius of the calorimeters. **LumiCal** is positioned in a circular hole of the end-cap electromagnetic calorimeter ECAL. **BeamCal** is placed just in front of the final focus quadrupole. The similarity between **LumiCal** and **BeamCal** designs implies that the technology developed for one can be used also for the other.

TEST BEAM SET-UP & RESULTS

Test beam infrastructure @ DESY-II:

- **Electron** beam **1 - 5 GeV energy**;
- **Dipole magnet** 1–13 kGs for e/γ separation;
- **EUDET telescope** based on MIMOSA detectors;
- **DAQ** framework provided:
  - EUDAQ (software);
  - Trigger Logic Unit (hardware);
  - Very good **user support.**

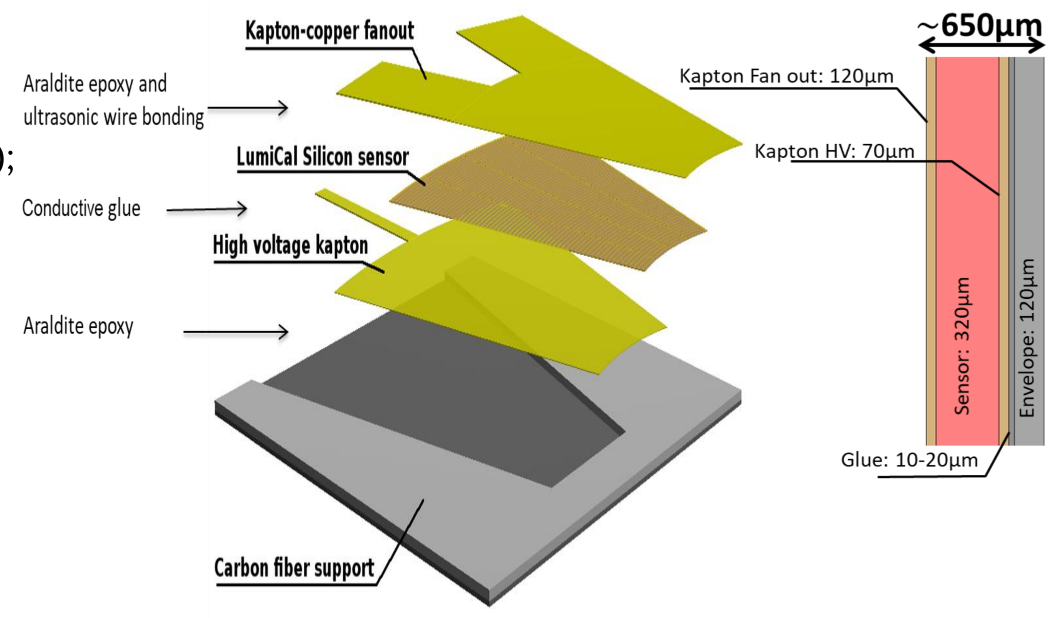


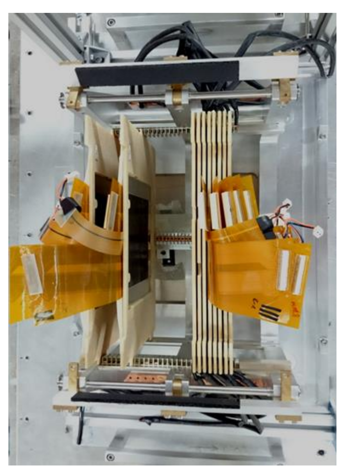


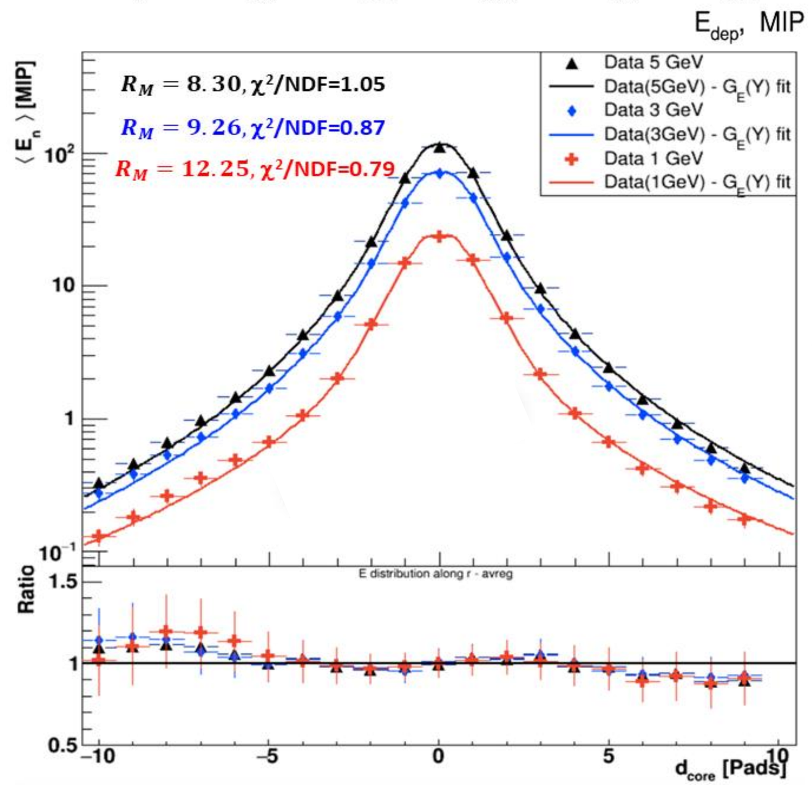
Energy deposited distribution in LumiCal prototype for different beam energy

DUT (LumiCal multi-layer prototype):

- First **sub-millimeter LumiCal** detector module (**~650 μm**);
- 8 Si sensors (**320 μm** thick) with **256 equipped channels**;
- 2 Si sensors used as a tracker;
- FEB: **APV-25 hybrid chip** based;
- **Si sensors** always separated by **one absorber layer**;
- **3.5 mm** thick tungsten absorber layer.



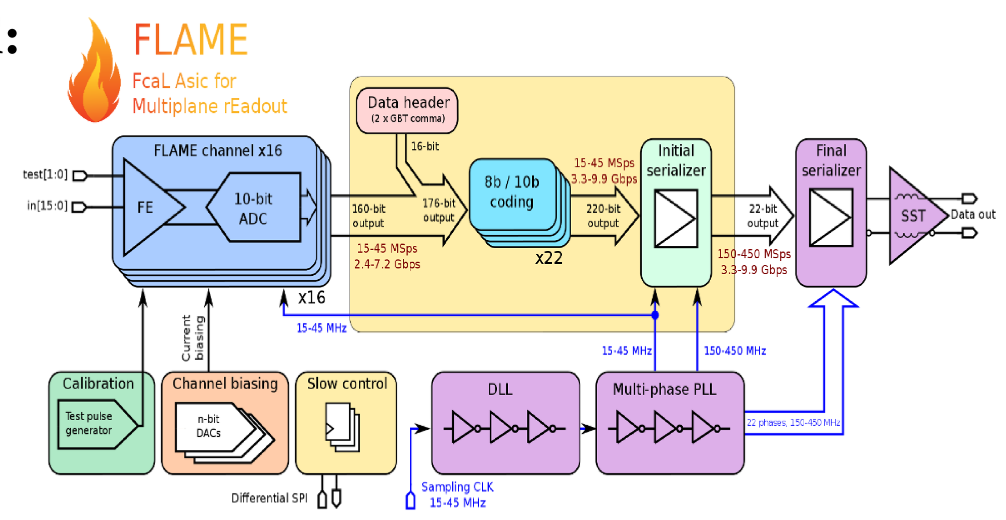


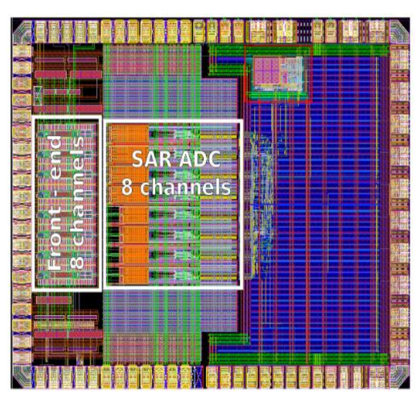


Average transverse shower profile as a function of d_{core} in units of pads, for different beam energy. The ratio between data and the fitted functions.

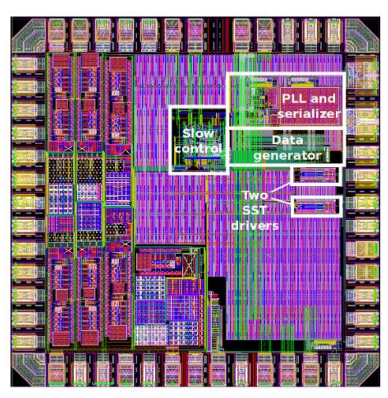
FLAME - new readout ASIC for LumiCal:

- **FLAME** is a **System on Chip (SoC)** solution;
- **130 nm CMOS** technology;
- **Variable gain** front-end:
  - **High gain** – for MIP sensitivity
  - **Low gain** – for shower deposition
- Internal calibration and pedestal trimDAC;
- 10-bit SAR ADC per channel;
- Ultra low power consumption;

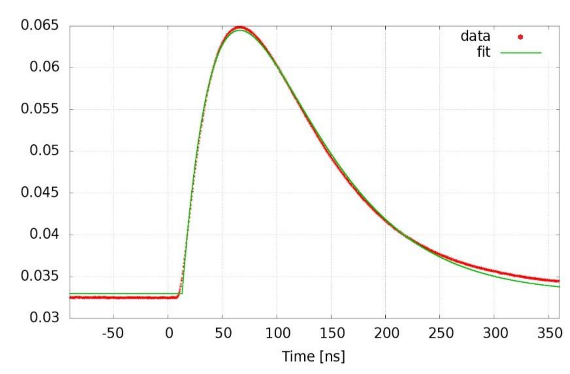




Prototype 8-channel FE+ADC ASIC



Prototype serializer ASIC



Front-end response for MIP

Conclusions & Future Work

- First sub-millimeter **LumiCal** detector prototype was tested with 5 GeV electrons energy at DESY, data taken in test beam were processed using various algorithms to investigate shower development and effective Moliere radius. The effective Moliere radius was determined to ~8.3±0.1mm, this value is close to the technological limit;
- The results of $R_M(E)$ dependence show slight dependence on energy which could be attributed to the fact that for higher energies smaller fraction of the shower is deposited in calorimeter with only 6 working layers;
- **FLAME** chip is just being submitted;
- BeamCal sensor based on GaAs gave relatively good charge collection efficiency and a new sapphire based prototype is under investigation;
- A new test beam at DESY-II in 2019 with a new compact **LumiCal** prototype using up to 20 sub-millimetre layers in order to investigate the performances of the **LumiCal** prototype ;

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