Very forward calorimeters at ILC/ILD

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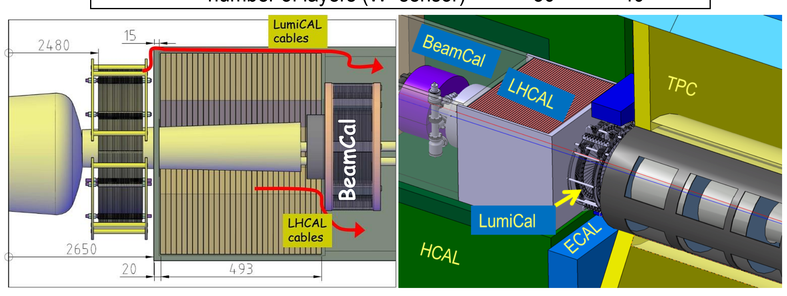
[on behalf of ILD and FCAL Collaborations]

Forward region of the ILD detector

Two specialized calorimeters foreseen:
- **LumiCal** - *precise luminosity measurement;*
- **BeamCal** - *fast luminosity estimate and beam parameters control.*

Both calorimeters improve the hermeticity of the main detector at very small polar angles.

	Parameters	ILD	CLICdet
LumiCal	geometrical acceptance [mrad]	31-77	38-110
	fiducial acceptance [mrad]	41-67	44-80
	z (from IP) [mm]	2480	2539
	number of layers (W+Si)	30	40
BeamCal	geometrical acceptance [mrad]	5-40	10-40
	z (from IP) [mm]	3200	3181
	number of layers (W+sensor)	30	40

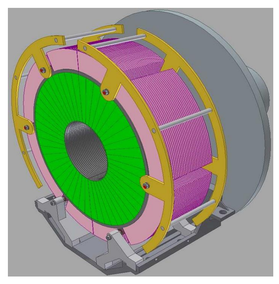


ILD forward region

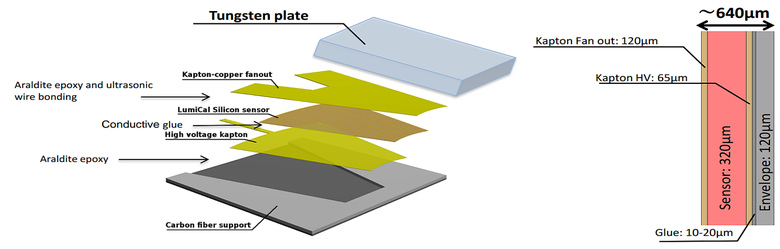
LumiCal prototype

LumiCal - a Si-W electromagnetic sandwich calorimeter designed to measure the integrated luminosity with a precision better then 10^{-3} for ILC and 10^{-2} for CLIC

Si-sensor prototype (produced by Hamamatsu):
- 6-inch wafer;
- 320 μm thickness;
- 4 azimuthal sectors in one tile, each 7.5 degrees;
- radial segmentation – 64 pads, 1.8 mm pitch;
- 12 tiles makes full azimuthal coverage.



LumiCal

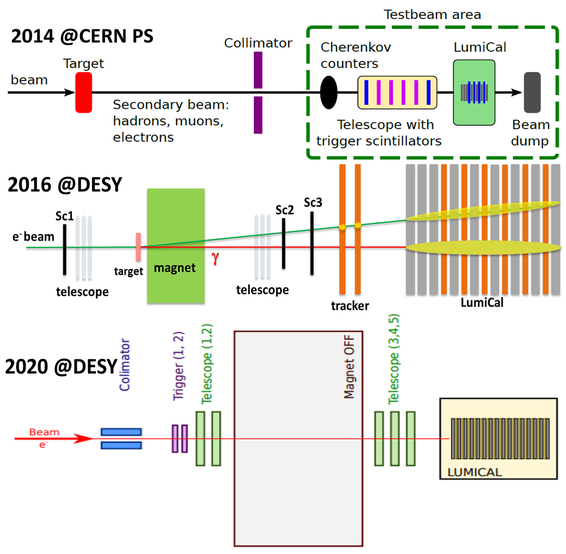


Thin LumiCal module

Test beam campaigns

- Several test-beam campaigns, 2014-2020
- Started with 4 fully equiped LumiCal planes with **APV25** readout
- Last campaign (2020) - 15 LumiCal planes, new **FLAME** readout tested.

Goals:
- Tests and demonstration of multi-plane operation of the forward detector prototype;
- Study of the electromagnetic shower in a precise and well known structure and compare with MC simulations;
- Measurement of Molière radius;
- Study of e-/γ identification using bremsstrahlung;
- Energy and spatial resolution studies;
- Polar angle bias study

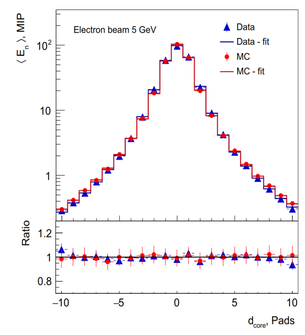


FLAME - **F**ca**L** **A**sic for **M**ultiplane r**E**adout - a new complete readout electronic developed for LumiCal, integrating full on board functionality. 32 mix-mode channels (FE & 10bit ADC).
- Variable gain from 4fC (1 MIP) to 200pC (shower core).
- Sampling rate of up to 50MHz.
- Ultra low power (< 2mW/ch).
- Fast serializer & driver (up to 8 Gbps).
- 4 FLAME controlled by single FPGA.

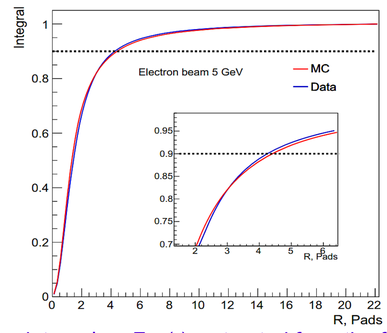
Results - transverse shower

- Shower parametrisation in radial direction: $F_E(r) = A_C e^{-\left(\frac{r}{R_C}\right)^2} + A_T \frac{2r^{\alpha} R_T^2}{(r^2 + R_T^2)^2}$

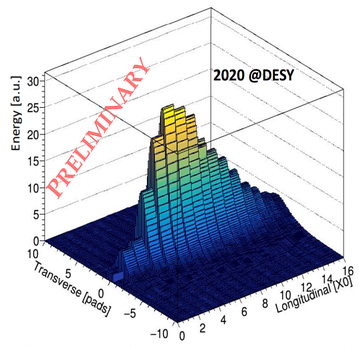
- The Molière radius, R_M, can be found from: $0.9 = \frac{\int_0^{2\pi} d\varphi \int_0^{R_M} F_E(r) r dr}{\int_0^{2\pi} d\varphi \int_0^{\infty} F_E(r) r dr}$



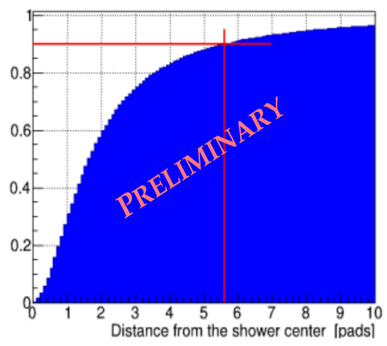
The transverse shower profile $\langle E_n \rangle$, as a function of d_{core} in units of pads.



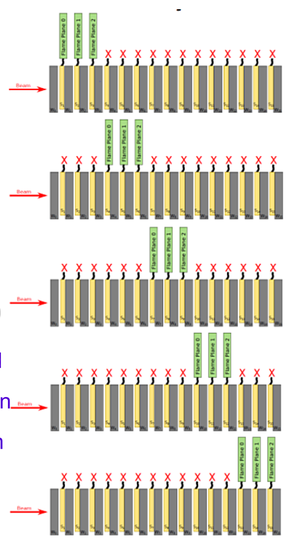
The integral on F_E (r), extracted from the fit, as a function of the radius, R, in units of pads (1,8mm)



A lego plot of the transverse profile for each layer from the test-beam data

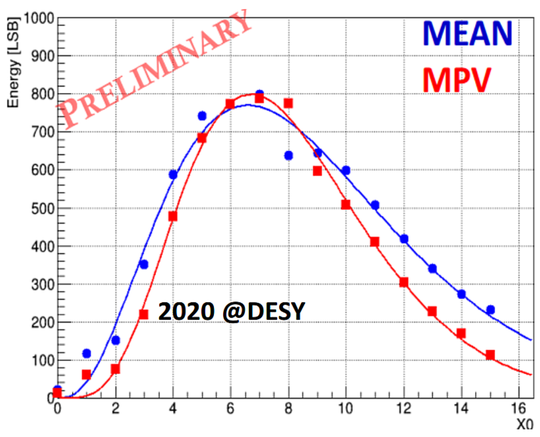


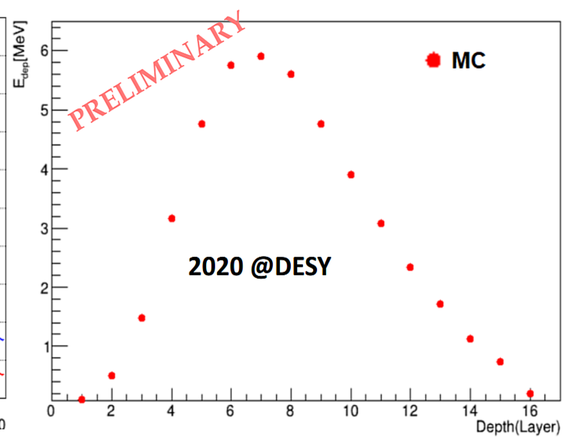
The integral on F_E (r), that was extracted from the fit, as a function of the distance in units of pads (1,8mm) for 5 GeV e⁻ beam



The effective Molière radius has been estimated to be **10.1 mm (5.6 pads)**

Results - longitudinal shower





Conclusions and future steps

- Major components developed by FCAL Collaboration foresees ILD detector to be realized at ILC.
- The FCAL collaboration continues the detector R&D and forward region design optimisation.
- Thin LumiCal module with submillimeter thickness was developed and produced. Its geometry meets requirements of LumiCal conceptual design.
- Dedicated FLAME readout ASIC together with FPGA back-end were developed and tested in the beam for the first time.
- Results from the test of the compact calorimeter prototype are promising.
- Analysis of data and MC from the full compact calorimeter prototype test-beam is ongoing.
- Technologies developed in FCAL are applied in other experiments, e.g.CMS, XFEL and considered for LUXE at DESY.

First ECFA Workshop on e+e- Higgs/EW/Top factories
October 5 – 7, 2022
DESY, Hamburg