

FCAL Needs and Capability



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On behalf of the FCAL collaboration



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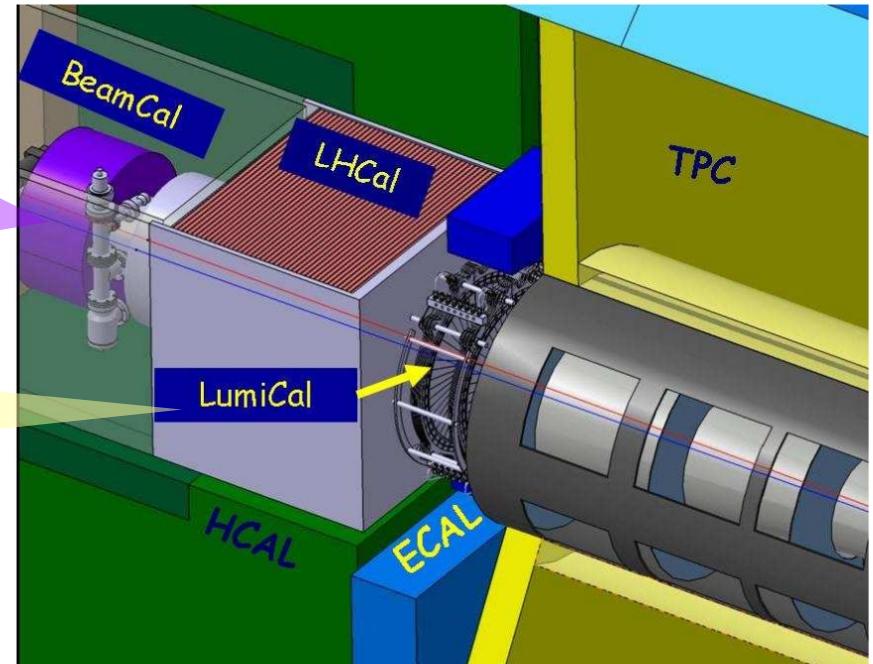
Overview

- Instrumentation of the forward regions in linear collider experiments
- FCAL beam-test infrastructure:
 - LumiCal module and beam test infrastructure;
 - Typical beam-test setup.
- LumiCal readout
- BeamCal R&D
- Summary

FCAL Detectors at LC

Goals:

- Instant luminosity measurement;
- Provide information for beam tuning;
- Precise integrated luminosity measurement;
- Extend a calorimetric coverage to small polar angles. Important for physics analysis.



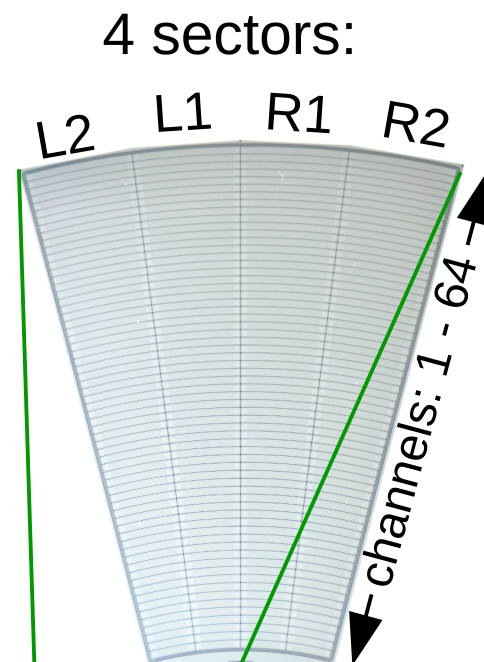
LumiCal: two tungsten-silicon calorimeters placed symmetrically on both sides of the interaction point at a distance of ~ 2.5 m.

Each calorimeter consists of 30 (ILC), 40 (CLIC) layers of 3.5 mm thick tungsten plates 1 mm apart interleaved with silicon sensors.

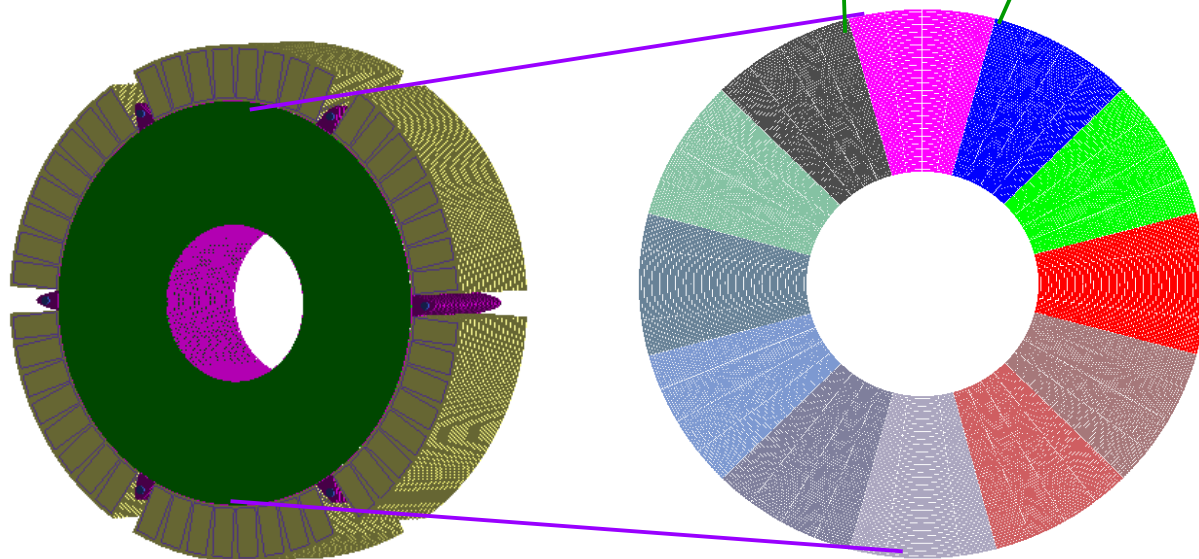
BeamCal: similar construction, with tungsten absorber but radiation hard sensors (GaAs, CVD diamond).

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

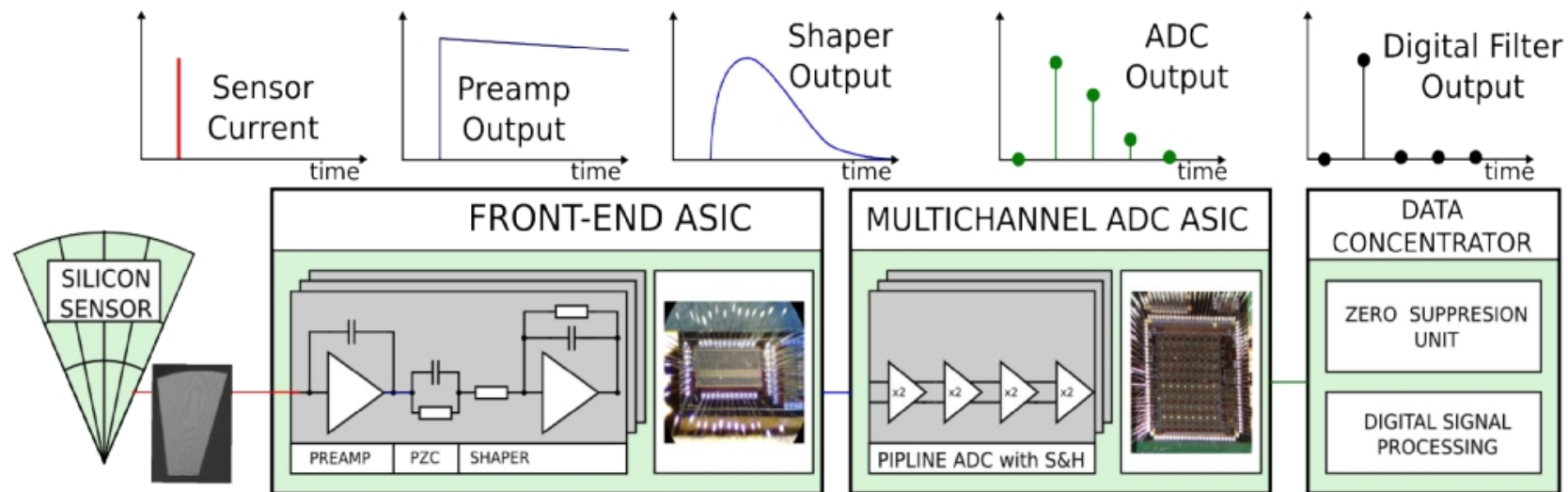


Total number of
LumiCal
channels: 184320



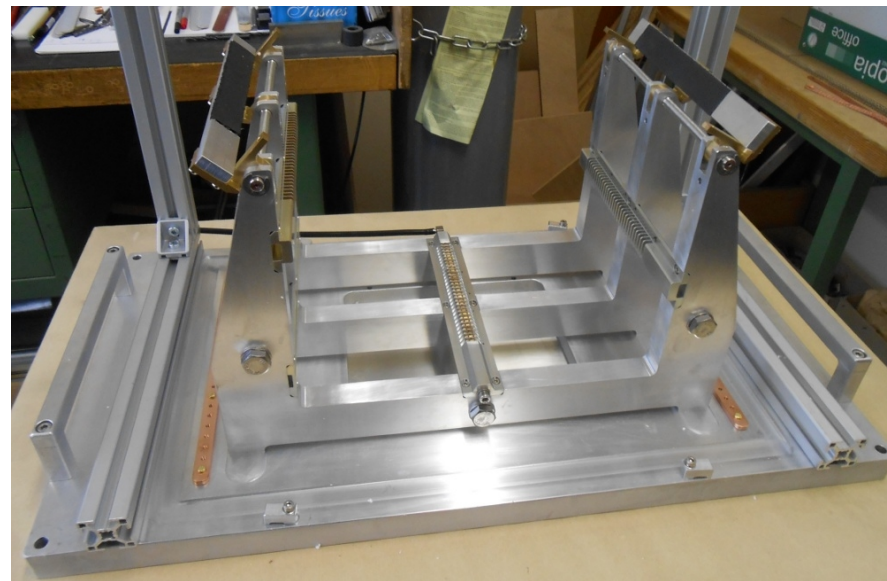
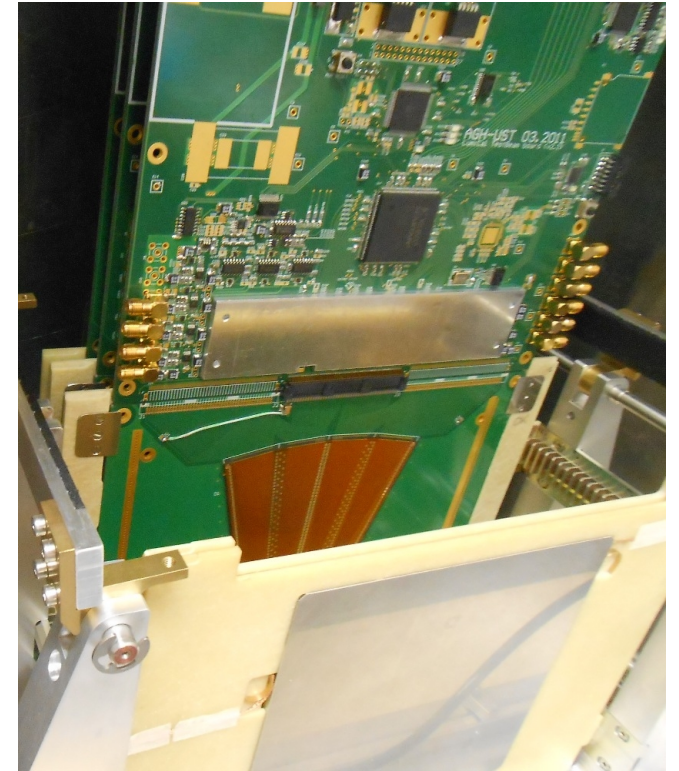
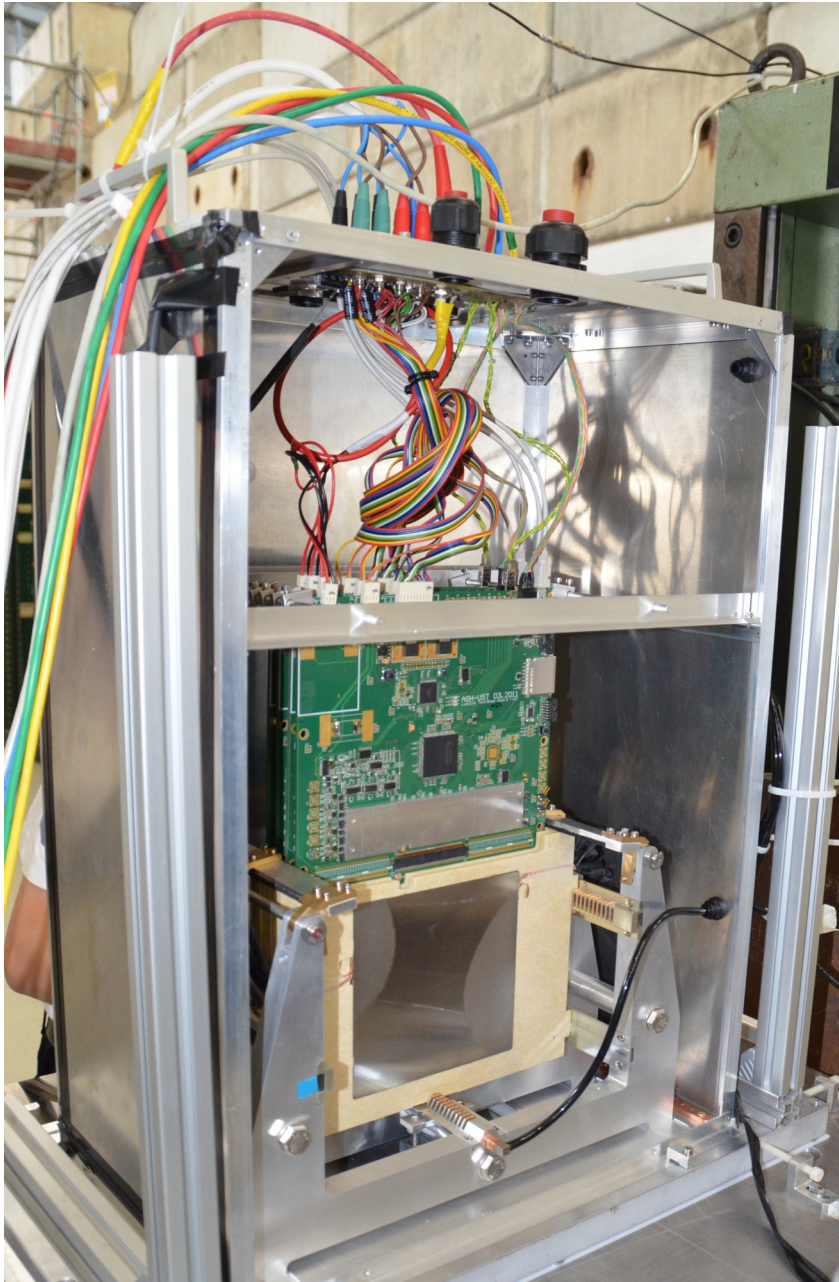
LumiCal Readout Electronics

- Existing readout was developed in AGH-UST Cracow.
- It is a 32-channel readout system based on 8-channel front-end and 10 bit ADC ASICs developed in AMS 0.35 μm .
- It has been used in test-beams in recent years.



- 8 channel front-end (preamp, shaper $T_{\text{peak}} \sim 60 \text{ ns}$, $\sim 9 \text{ mW/channel}$, configurable gain);
- 8 channel pipeline ADC, $T_{\text{smp}} \leq 25 \text{ MS/s}$, $\sim 1.2 \text{ mW/MHz}$;
- FPGA based data concentrator and further readout.

FCAL test beam infrastructure



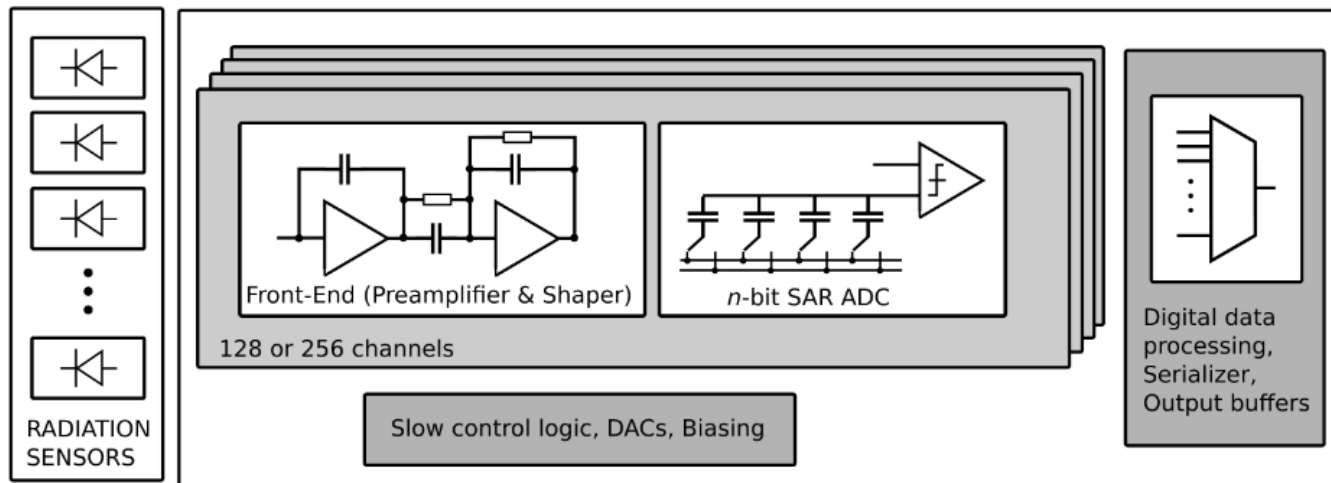
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DAQ Used for Beam-tests

- The main issue in DAQ for the last beam test was the synchronization between the events in the FCAL DAQ and MIMOSA Telescope DAQ used by Aarhus university group.
- For that an AUX device was built, based on CAEN v1495 I/O module to match between TLU number (FCAL) to hardware frame number of MIMOSA.
- For the 32 connected channels
- at 20 MHz signal sampling rate,
- and digitized with 10-bit resolution
- the raw data stream is about 6.4 Gbps.



Future LumiCal Electronics Development



- New 10-bit SAR ADC ASIC has been designed, produced and tested. Excellent performance, 40 MS/s, power consumption <1 mW.
- In 2015 plan to submit an ~8-channel CMOS 130 nm chip containing front-end, ADC, serialization, all biasing and digital control.
- New multichannel ASICs will comprise all readout functionalities to minimize number of external components – to enable construction of highly COMPACT calorimeter. The readout module should be small and <4.5mm thick (presently ~1 cm).

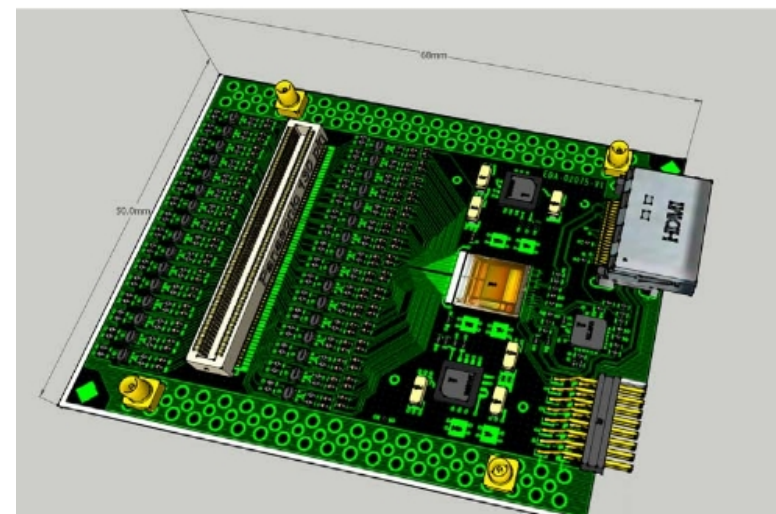
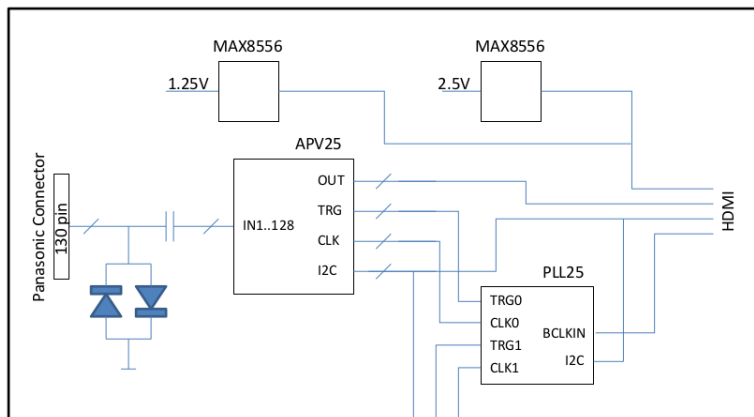
Future LumiCal Electronics Development

- A thin (<4.5 mm) readout board needs to be built.
 - Readout will collect and process the digital data from the ASICs and will transmit it to an external DAQ system.
 - The idea is to have a FPGA chip as a core processing unit of the readout board, similarly as it was done in the existing readout.
 - The design has not yet started but will be done in collaboration between TAU, DESY, IFJPAN, and AGH-UST.
- For the 20-layers LumiCal prototype with one sensor in the layer at 40 MHz sampling rate with 10 bit resolution the data stream would be about 1000 Gbps.
 - CM noise correction and Zero Suppression implemented in firmware can significantly reduce it, but for the beam-test it is important to collect all signals for offline study.

Test with SRS and APV 25

Front-end chip APV25:

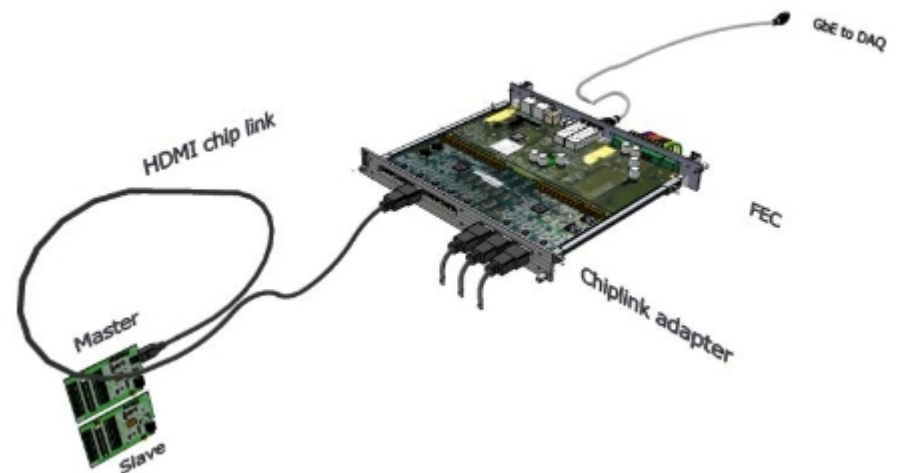
- Designed for CMS silicon microstrip detectors;
- 128 channels;
- Shaping time (min): 50 ns;
- Range: 125 keV;
- Supports both signal polarity;
- Sampling rate 40 MHz;
- Radiation hard;
- Available at CERN stock.



Frontend board (hybrid) with APV25 chip

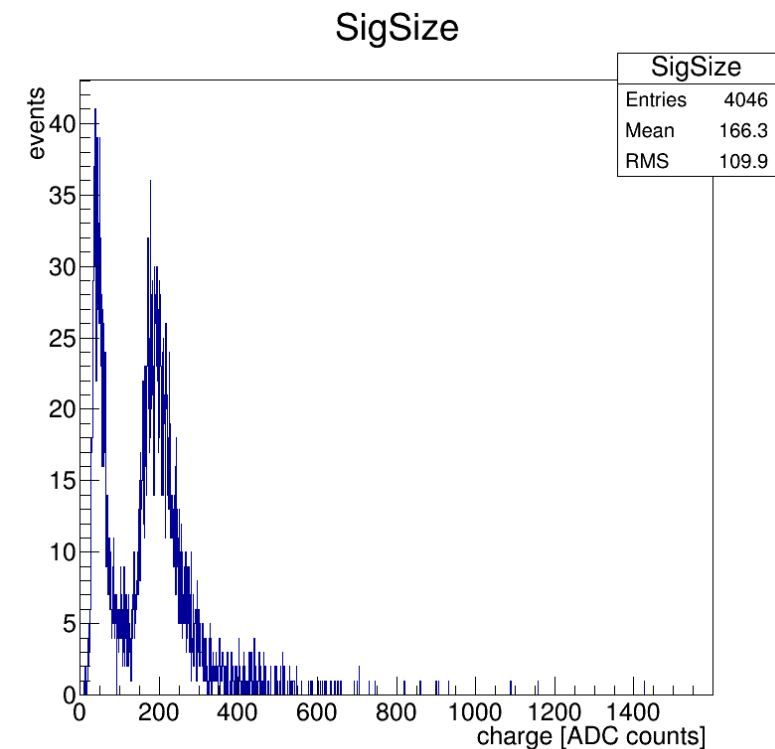
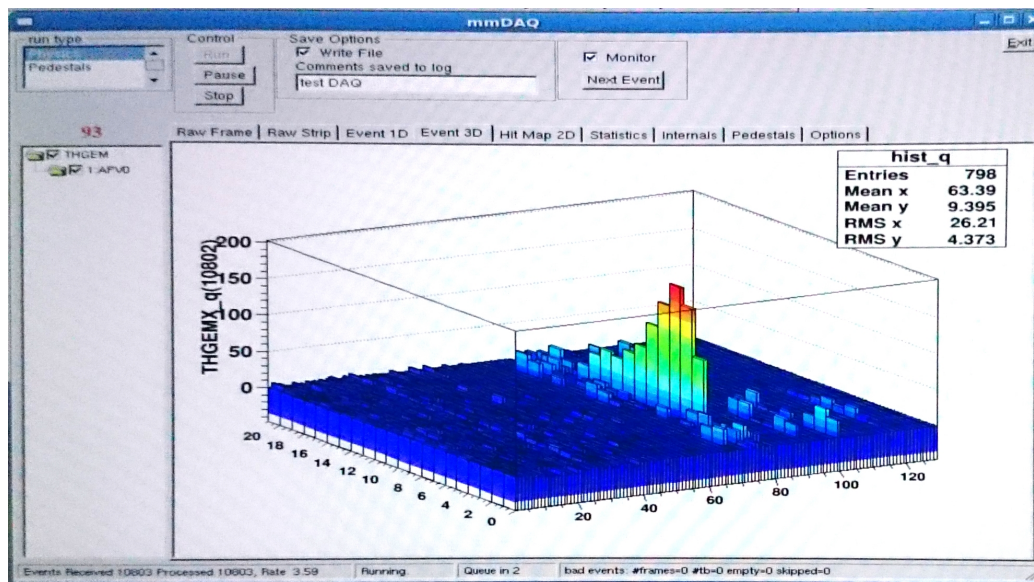
SRS System

- Common chip link interface allowing to choose a readout chip
 - Scalability from a small to a large system based on a common readout backend
 - Integration of commercial standards for a minimum of custom hardware
 - Default availability of a robust and well supported data acquisition package
 - Possibility for different readout architectures and trigger schemes
 - Open platform invites users for development of SRS hardware and firmware
-
- Supports the system construction up to 10M channels;
 - Small test systems with a low number of channels (minimum 1 chip, max 2048 channels on 16 chips) can be implemented as desktop system, connected via Ethernet to a PC with standard Online and Offline Analysis software;
 - Available at CERN stock;
 - DATE DAQ and ROOT for analysis.



LumiCal Module Performance with APV25

- mmDAQ was used: DAQ system developed for Micromegas ATLAS detector;
- Ru106 source and trigger from a scintillator;
- Typically LumiCal sensor is directly coupled with the FE chip;
- Decoupling capacitors were removed from original APV25 FE board;
- Though both versions worked well.



Test with VMM and VMM2

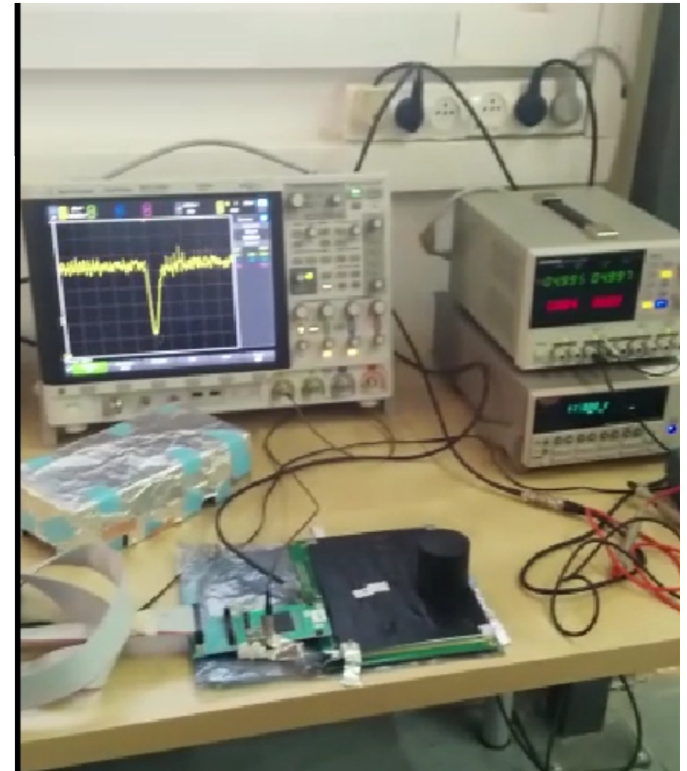
The VMM1/2 chips were designed for upgrade of ATLAS muon system which consists of two new small wheels (NSW) based on MICROME GAS (Micromesh Gaseous Structure) and Thin Gap Chamber (TGC) detectors.

VMM1:

- Dual Polarity (does not seem working);
- Adjustable Gain (0.5 – 9.0 mV/fC);
- Adjustable peaking Time (25-200 ns);
- Address in Real Time (Fast OR in effect)
- Prompt digitized (6-bit) Amplitude, Time-over-threshold, time-to-peak (TGC Trigger)

VMM2:

- Dual Polarity
- Includes 10-bit digitizers for amplitude and timing (200 ns);
- Includes a 6-bit Amplitude digitizer at ~40 ns conversion time;

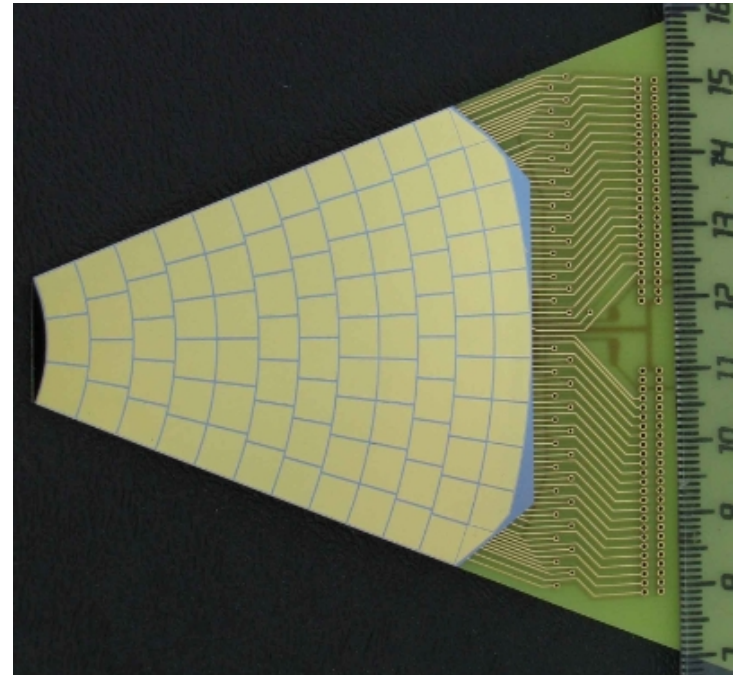


Both can be coupled with SRS System

BeamCal

BeamCal Sensor:

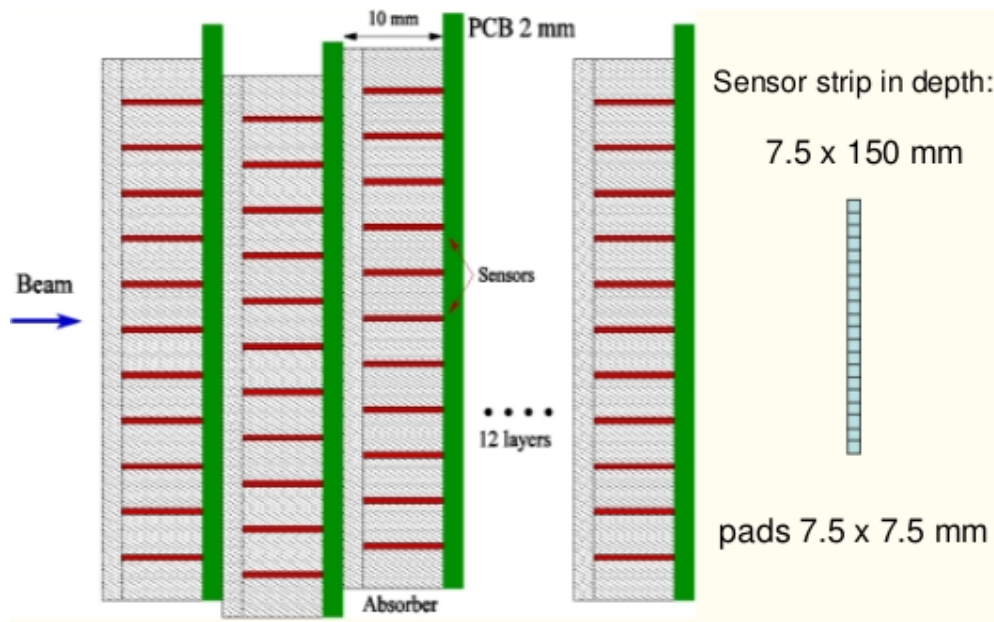
- compensated GaAs sensors
- 500 μm thick
- 30 sensors available
- DESY, JINR collaboration



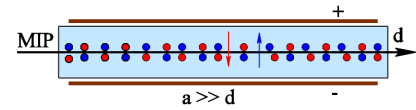
BeamCal electronics R&D in Pontificia Universidad Catolica de Chile:

- FE chip equipped with fast analog sum of several channels, to be used for the feedback to the machine.
- Existing chip (Bean V1.0): 3 charge amps, 4 x 10 bit, fully diff. SAR ADCs, 1 SC adder, 3 SC filters, etc.
- Design, fabrication and test of discrete-time signal processing filter to optimize SNR;
- Study the possibility to use nonlinear ADC to extend dynamic range.

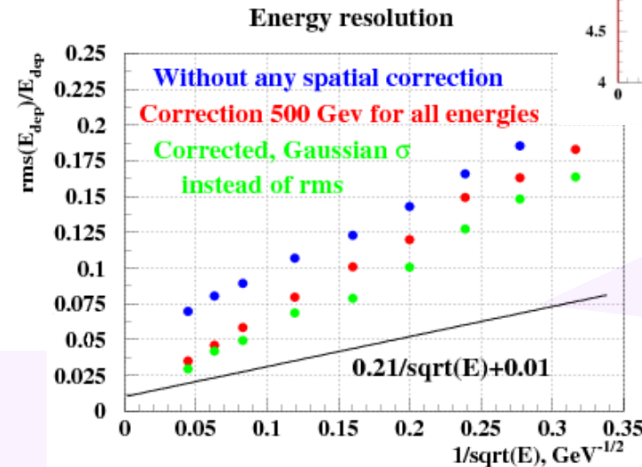
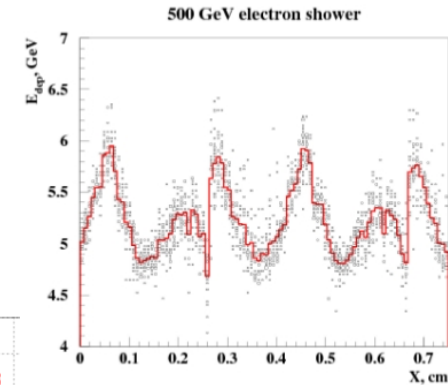
BeamCal Sapphire Calorimeter Prototype Design



Performance can be improved by optimizing design and software



$a=10\text{ mm} \Rightarrow 220\text{K e-h pairs produced}$
 $\sim 5\% \text{ CCE} \rightarrow \sim 11000 \text{ e signal, similar to}$
 $100\% \text{ efficient scCVD diamond detectors.}$



Ideal case, without BG for baseline design

- Because of low CCE ($\sim 5\%$) for sapphire the new design allows to increase the response of the sensors to the MIPs, shifting calibration signal up in the “physical” working range, thus additional calibration mode is not needed anymore.
- Longitudinal and transverse sizes for both designs are kept the same
- Number of readout channels is 12000 for baseline design and 8880 for new one
- More space for electronics between layers, fanout PCB could be made using standard multilayer technology
- New sapphire sensors are investigated. They are very cheap! Very radiation resistant! and “small signal” down point is solved by turning sensors

Summary

- So far the FCAL detectors were successfully tested with beams using EUTelescope and EUDAQ.
- Last LumiCal 4-plane beam-test was performed using two different DAQ systems: EUDAQ for LumiCal and Mimosa chip specific DAQ. Successful synchronization was achieved using auxiliary device which matched triggerID from TLU with Mimosa 26 hardware frame number.
- In future multi-plane FCAL detectors beam tests we might benefit from using DAQ capable working with different type of readout electronics and providing easy integration with a telescope.
- Physics and calibration mode of FCAL detector operation must be considered upon detector control system design.
- FCAL detectors with 184 k (LumiCal) and 12 k (BeamCal) of channels could be integrated with common DAQ system considered for LC experiments.

Thank you for attention!