AGH UNIVERSITY OF SCIENCE AND TECHNOLOGY

R&D for the FCAL

Marek Idzik AGH-UST

On behalf of the FCAL Collaboration

AGH-UST Cracow, ANL Argonne, CERN Geneva, DESY Zeuthen, IFIN-HH Bukharest, INPPAN Cracow, ISS Bukharest, LAL Orsay, JINR Dubna, NCPHEP Minsk, Pontifica Universidad Catholica Santiago de Chile, SLAC Stanford, Tel Aviv University, Tohoku University Sendai, University of Colorado Boulder, UC California Santa Cruz, Vinca Belgrade

ILD meeting 2013 in Cracow, 24-26 September 2013 Cracow Poland

Outline

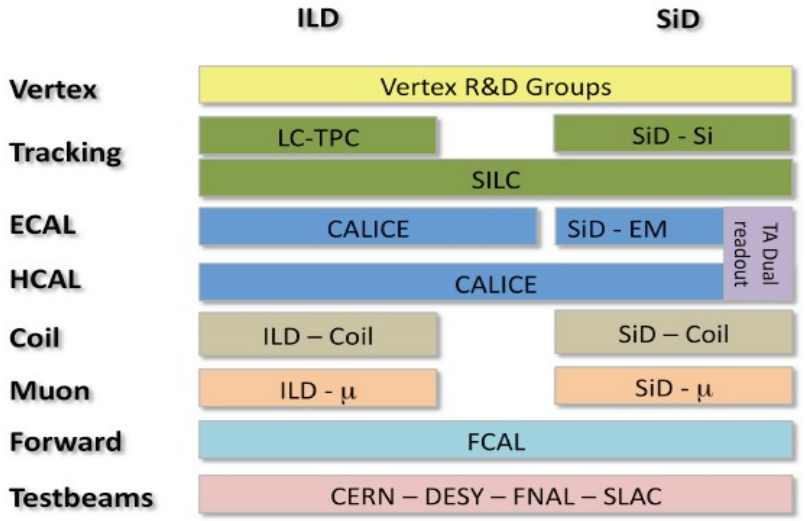
- Introduction
- Current Status
  - Subdetectors
  - Test-beam results
- FCAL R&D and future works (mostly detector oriented)
  - Near future: Mechanical frame & test-beam setup
  - Sensor R&D
  - Readout R&D
  - Laser alignment
  - MC studies: various topics of calorimeter design optimisation and physics cases are ongoing, here only an example...
- Summary & Future plans

Introduction
FCAL Mission

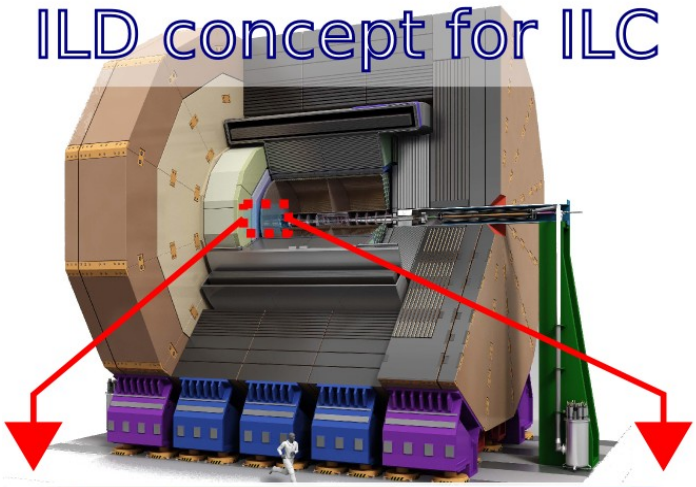
- Design of the very forward region of detectors at future linear collider
- Concept for precise and fast measurement of the luminosity
- Development, prototyping and test of the detectors
- Verification of Monte Carlo estimates of the detector performance
- Ensure that critical R&D is addressed in a timely manner

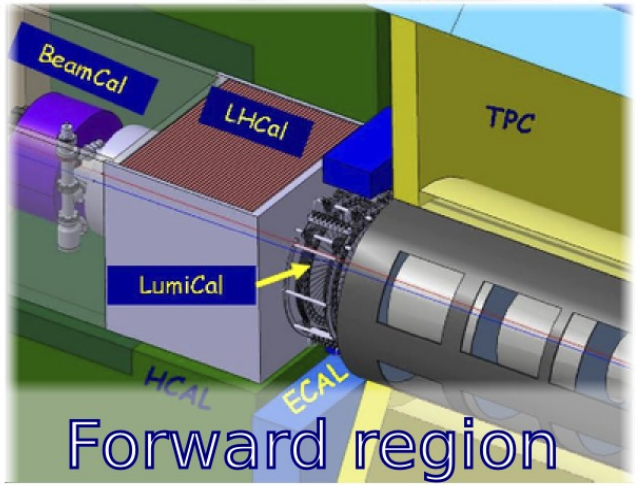
Challenges:

- High precision luminometer
- High occupancy
- High radiation tolerance
- Fast readout electronics



Introduction
Subdetectors





BeamCal (+Pair Monitor)

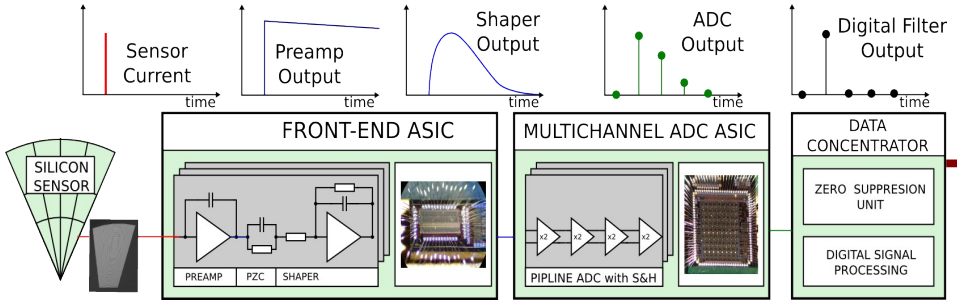
- Fast luminosity estimate (bunch-by-bunch at ILC)
- Beam parameter estimation
- Fast feedback to the machine
- Hermeticity & Low angle electron tagging

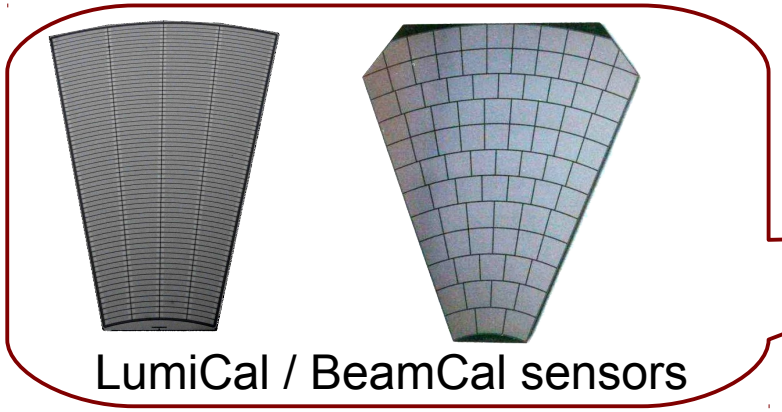
LumiCal

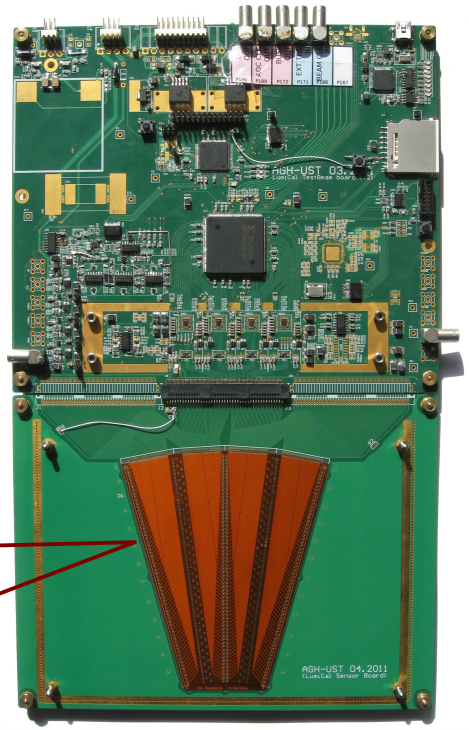
- Precise measurement of luminosity
- 10^{-3} at ILC
- Hermeticity
- Low angle physics

FCAL Detector R&D Status
Prototype subdetectors

- Readout module (LumiCal) for 32 channels
- LumiCal sensors
- BeamCal sensors

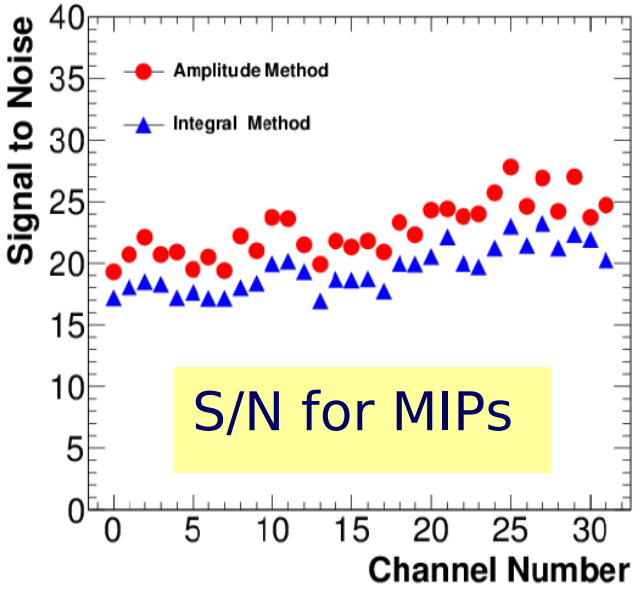






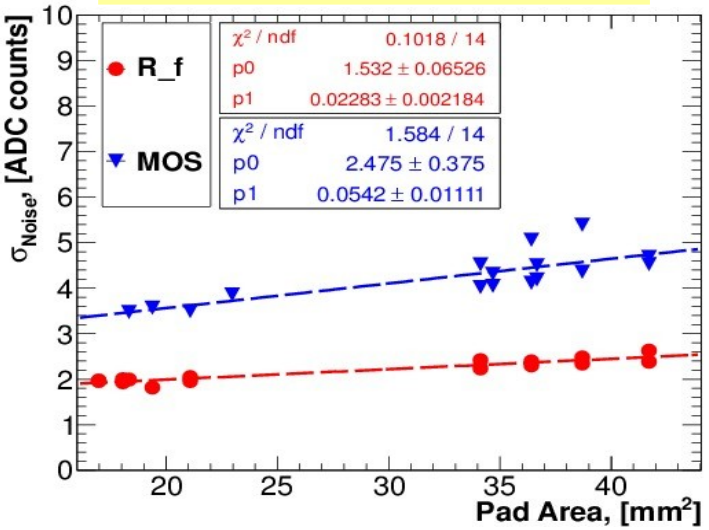
Few succesful test-beams were run in recent years

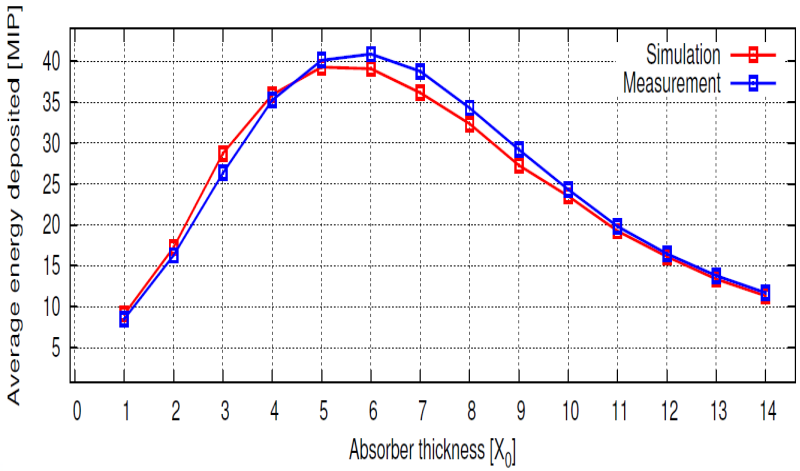
Beam-test result examples
S/N, noise, shower profile



S/N for MIPs

Noise vs. pad area

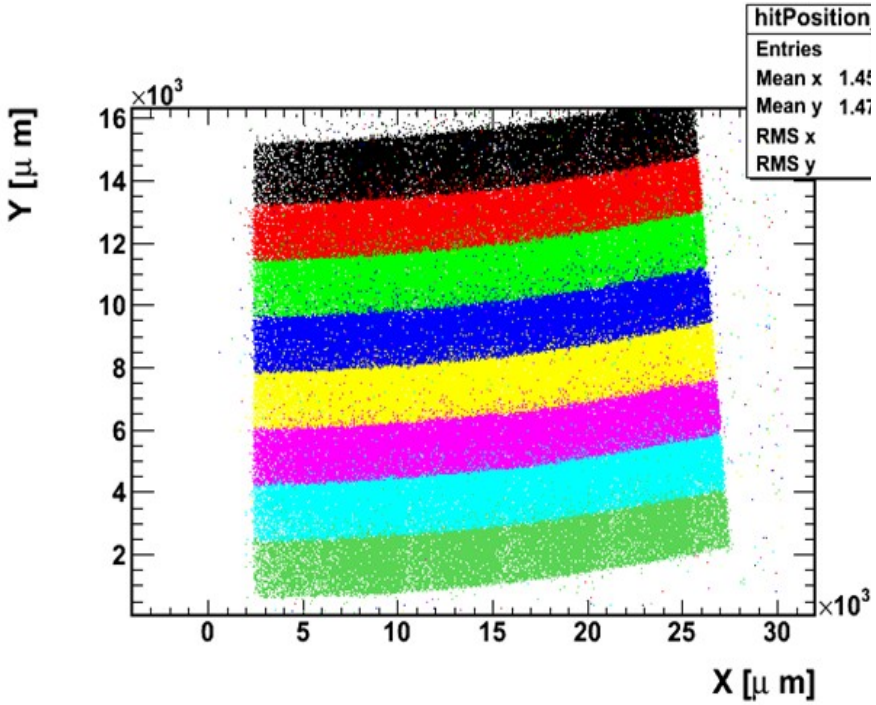




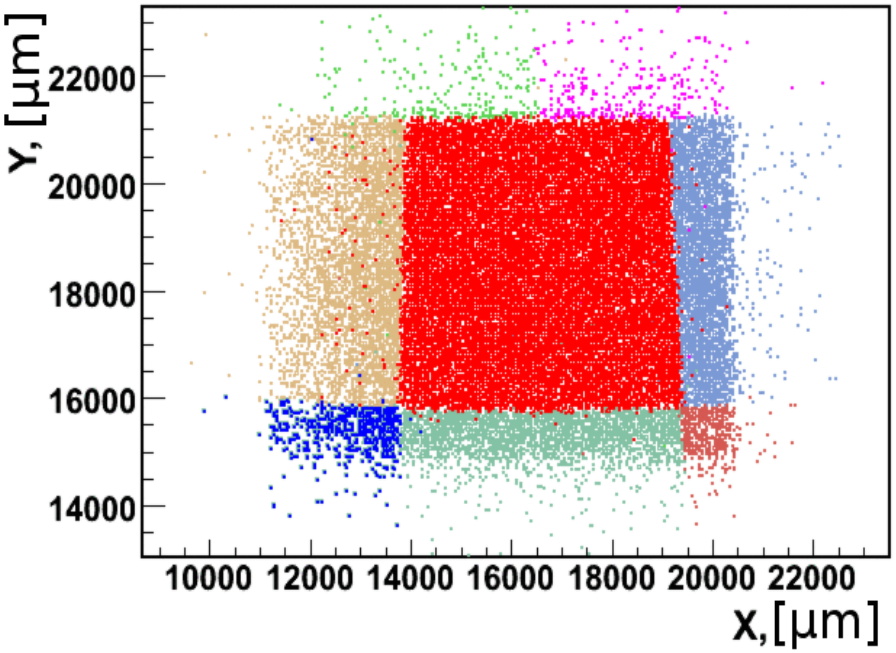
Shower profile measurements with n X0 tungsten blocks in front of the sensors

Beam-test result examples
Position reconstruction

Impact point reconstruction using
the beam telescope
For LumiCal sensor



Impact point reconstruction using
the beam telescope
For BeamCal sensor



Current status
FCAL Deliveries (so far)

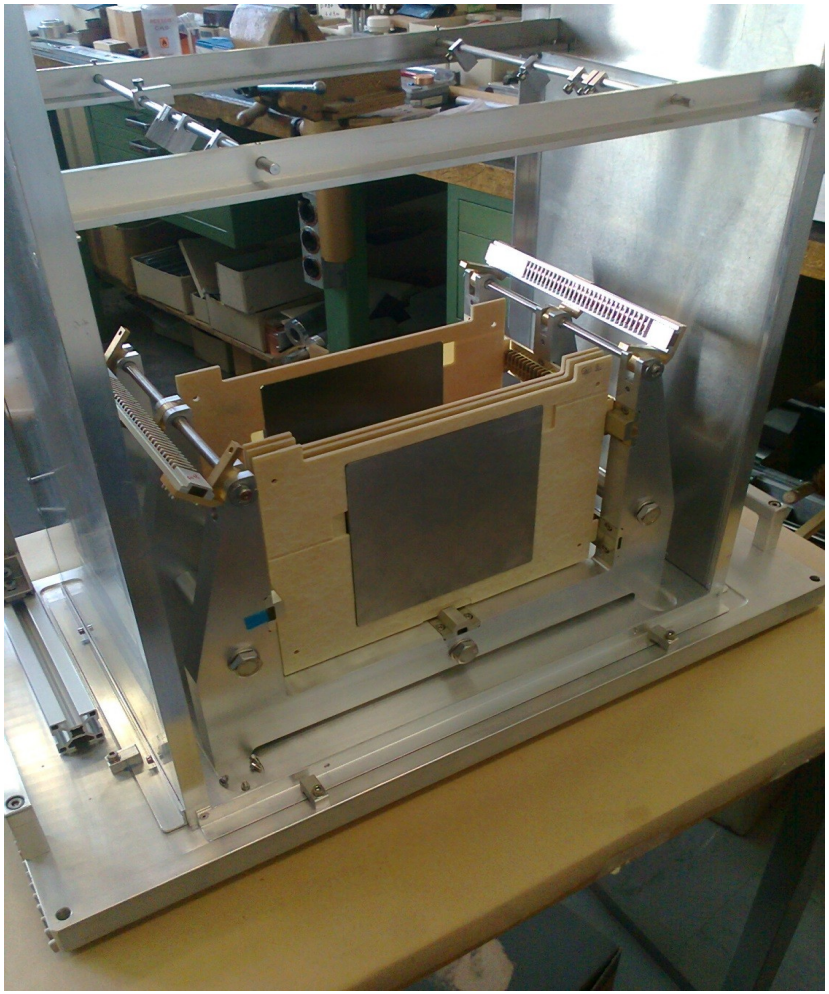
- Designs of the very forward region for ILC and CLIC detectors
- Monte Carlo estimates of the expected performance of a Luminometer for precise luminosity measurement
- Feasibility of fast luminosity measurement, beam parameter determination and electron tagging with BeamCal and Pair Monitor
- Successful development of sensors and dedicated ASICs
- Successful prototyping of major detector components and validation on test-beams
- Unique contributions to the ILC RDR, the CLIC CDR, the ILC TDR and to the detector concepts ILD and SiD

The review by 'European Detector R&D' committee in June 2013 stated that: *"The linear collider community and the funding agencies should strongly support this activity as it is a key issue for precision measurements"*

FCAL R&D at CERN – Near future

Flexible mechanical frame with tungsten plates

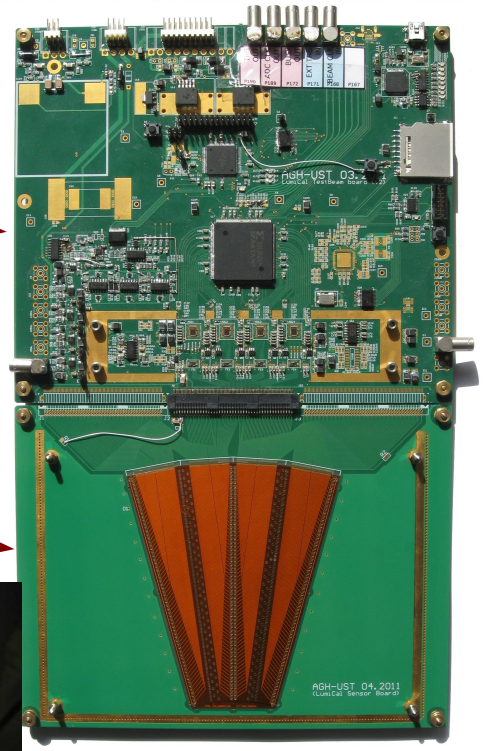
AIDA milestone

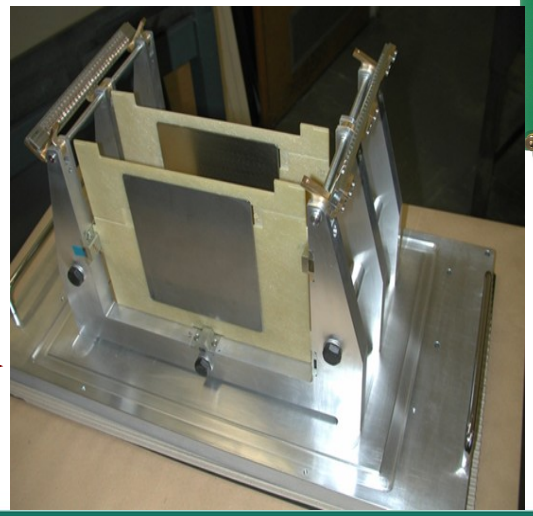


- Mechanical frame has been built
- 11 tungsten plates obtained from Plansee and MGSanders (AGH-UST, CERN, INP PAN)
  - Plansee plates much better and almost within specifications
- Works ongoing on integration and cabling of prototype detectors

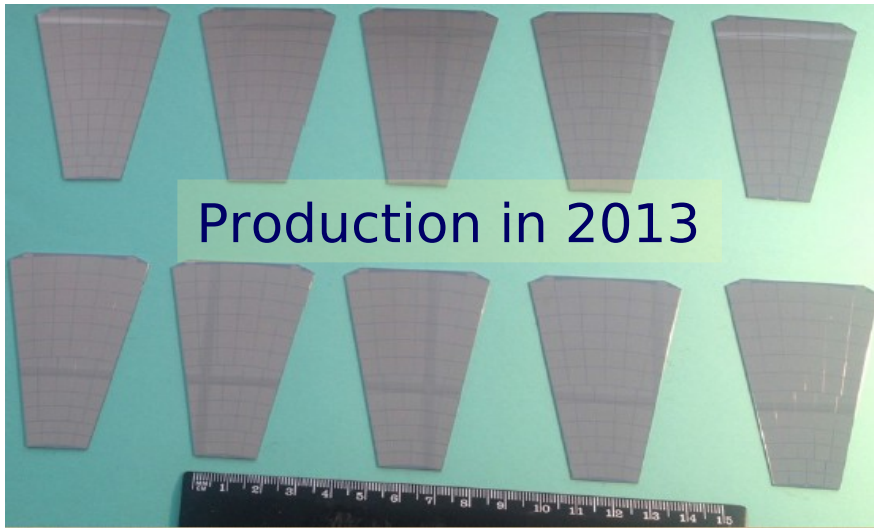
FCAL activities for testbeams – Near future
Mechanical frame with sub-detector modules

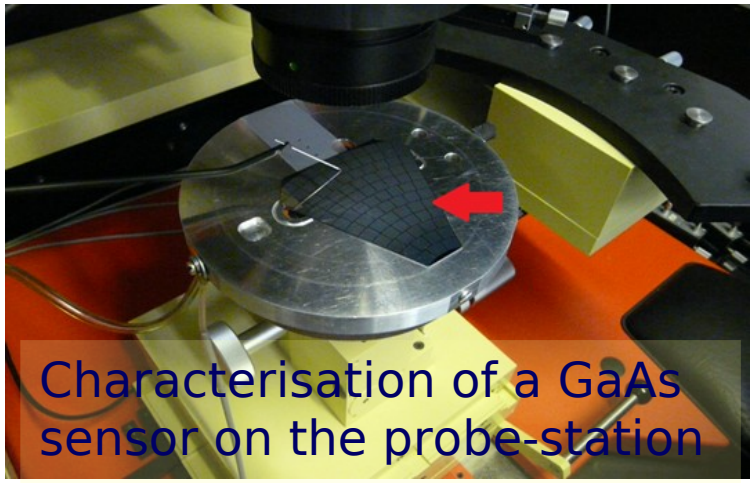
- FCAL detector components:
  - Recently we have assembled more LumiCal readout boards so there are 4 completed (which are also used for BeamCal readout)
  - LumiCal: 40 sensor tiles produced, 2 boards ready
  - BeamCal: almost 30 sensor tiles produced, 2 boards ready
- Previous test-beams done with single detector modules and row (not well flattened, composition not known precisely) tungsten material
- For future test-beam we plan to use the flexible mechanical frame with tungsten plates and all detector modules



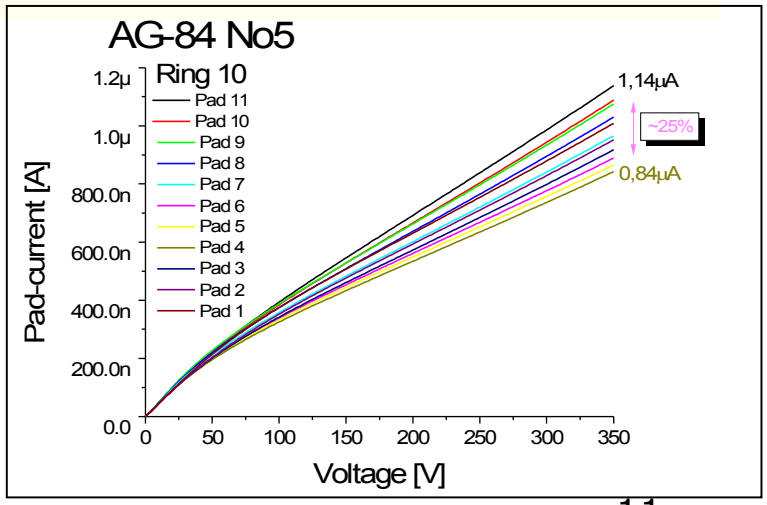


BeamCal Sensor R&D
DESY-JINR collaboration on GaAs sensors





- Test of the guard ring
- Measurement of leakage current for each pad
- Set criteria for later use in the prototype calorimeter

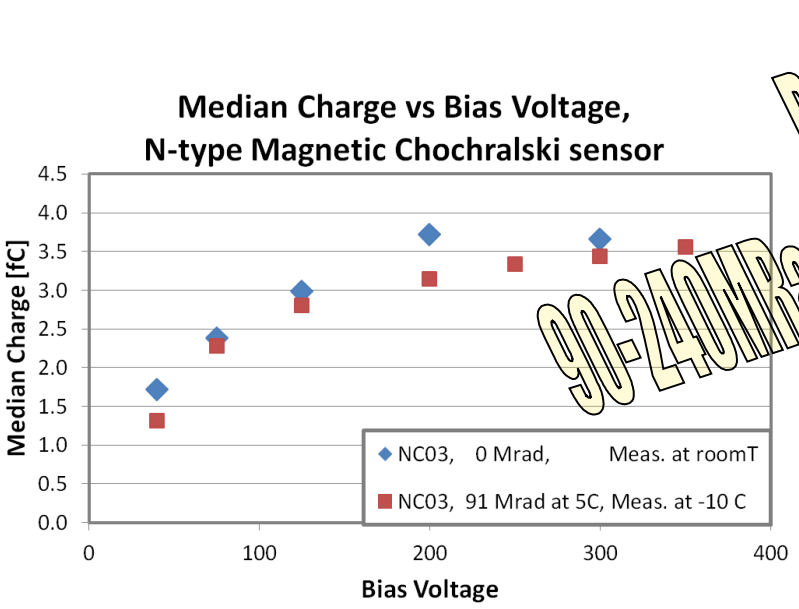


The aim is to produce good sensors for 30 BeamCal layers

Sensor R&D – new activity
Irradiations of prototypes at UC Santa Cruz & SLAC

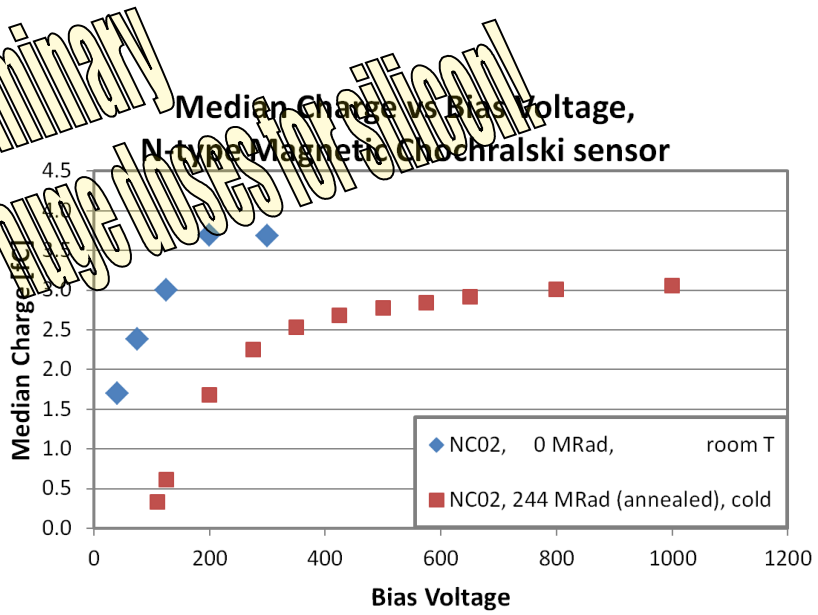
Extension of radiation hardness studies to silicon using a realistic particle composition (tungsten pre-radiator)

- 4-10 GeV electron beam
- 21mm of tungsten
- N-type Magnetic Czochralski silicon strip sensors at (-10 - 5) ^{0}C



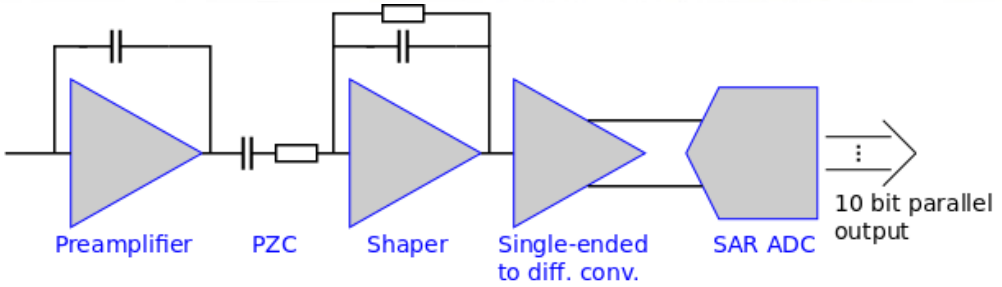
Preliminary

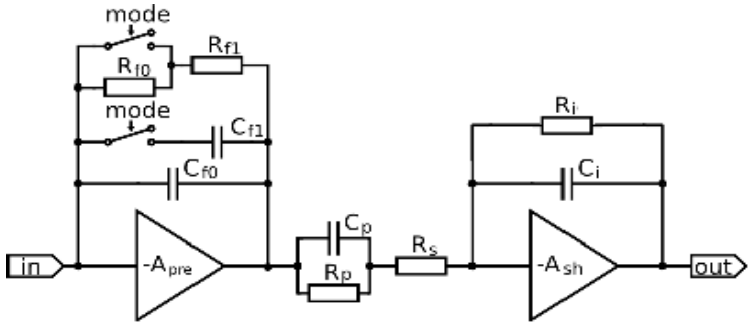
90-240MRads - huge doses for silicon!



Readout R&D in IBM CMOS 130 nm
Development of LumiCal readout at AGH-UST
AIDA milestone

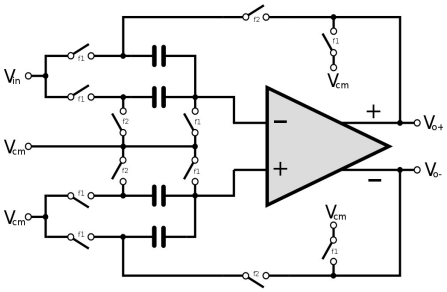
New readout in 130 nm has very similar architecture to existing one in 0.35um but should consume much less power and be radiation resistant





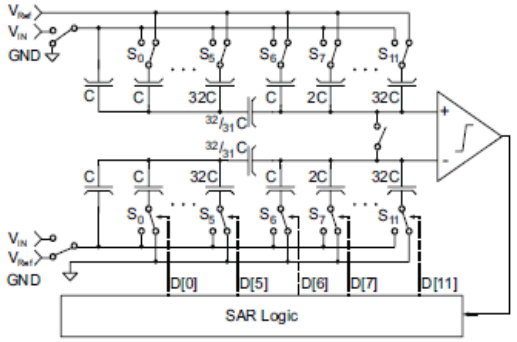
Front-end specs:

- Cdet ≈ 5 ÷ 50pF
- 1st order shaper (Tpeak ≈ 50 ns)
- Variable gain, two modes:
  - calibration: MIP sensitivity
  - physics: Q_{in} up to ~6 pC
- Power pulsing implemented
- Peak power cons. ~1.5 mW/channel



Single-to-Diff specs:

- Max freq. > 40MHz
- Power pulsing
- Peak power ~ 0.5mW

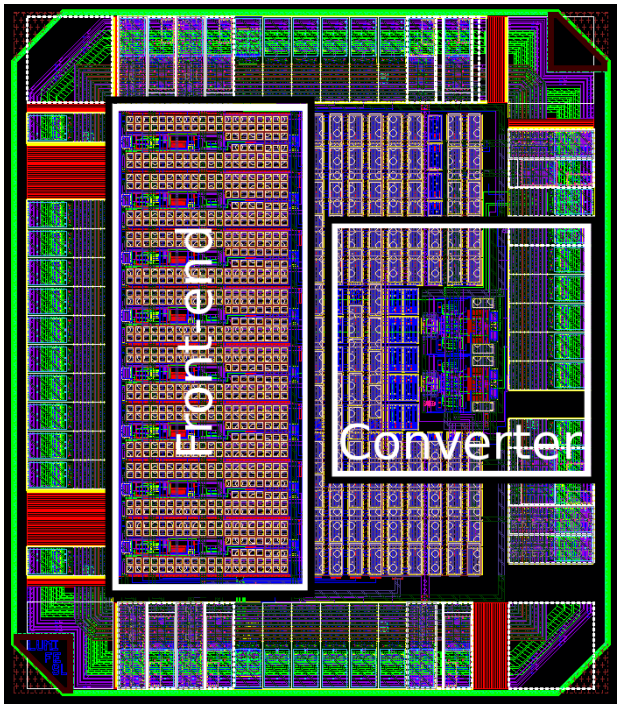


ADC specs:

- 10-bit resolution
- Architecture: SAR ADC with segmented/split DAC
- Max frequency > 40 MHz
- Power pulsing
- Peak power 1-2 mW @40MHz

Readout R&D in IBM CMOS 130 nm
Development of LumiCal readout at AGH-UST
AIDA milestone

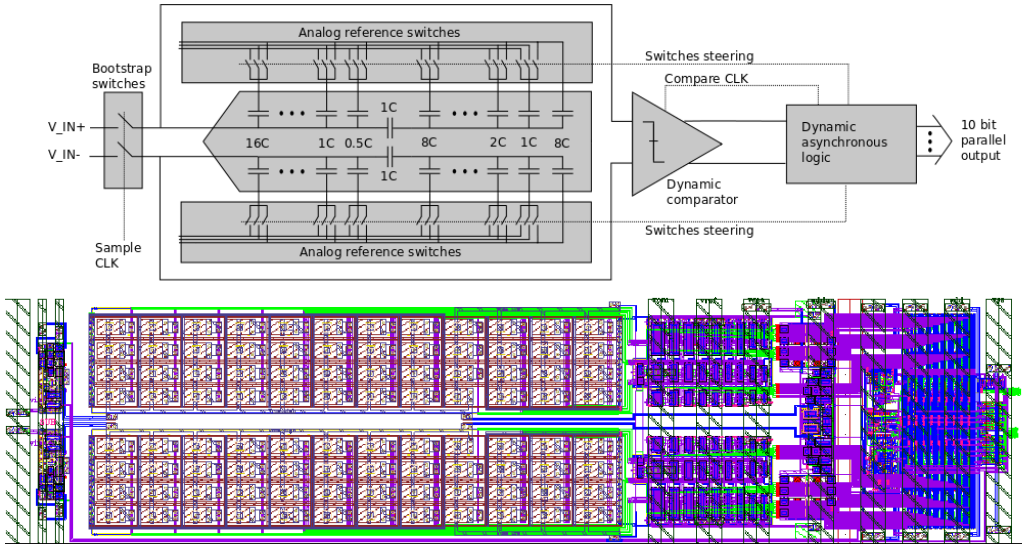
Front-end and Single-to-Diff conv.



Few channels ASIC designed and submitted in February 2013

We are just starting the tests, first signals seen 2 days ago...

10-bit SAR ADC

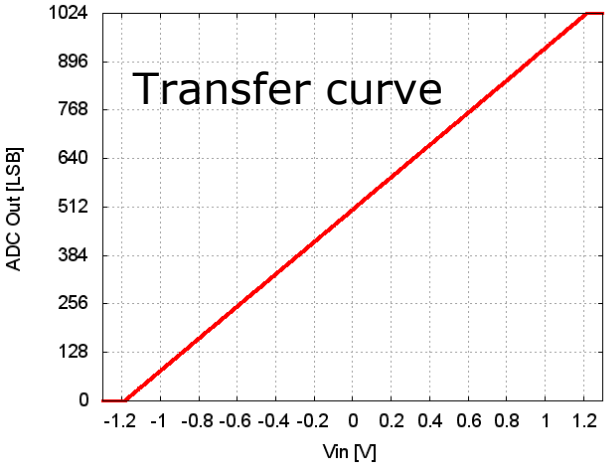


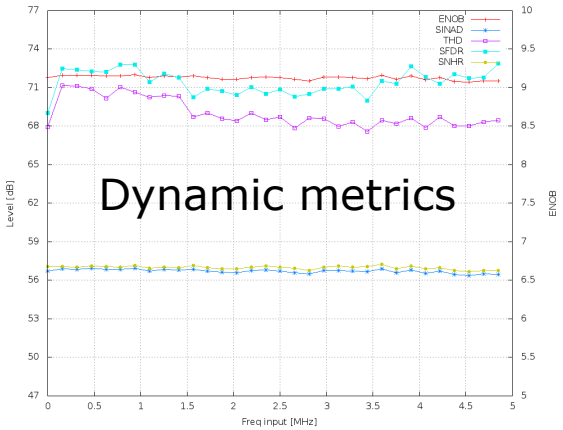
600um x 146um

Designed and fabricated in 2012

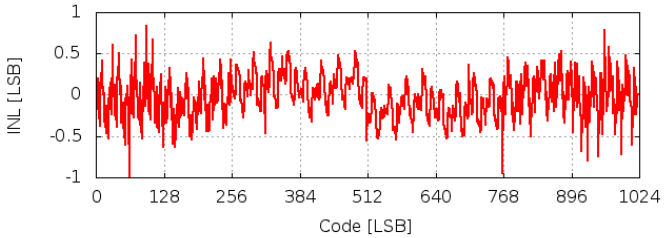
Tests in advanced stage (next slide)

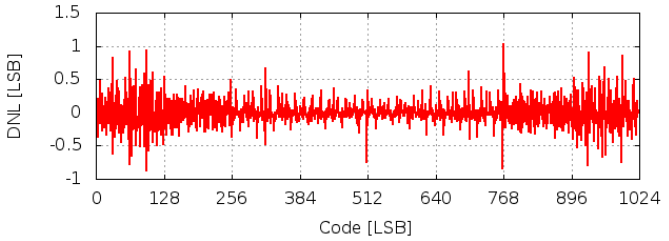
Readout R&D in IBM CMOS 130 nm
10-bit SAR ADC measurement results
AIDA milestone





INL/DNL measurements





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)

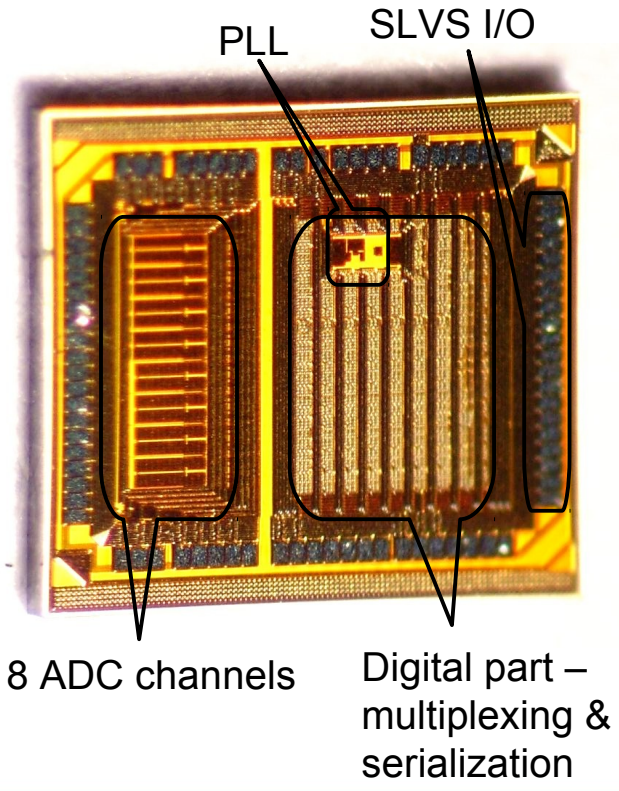
  ~0.25 uW/channel/MHz

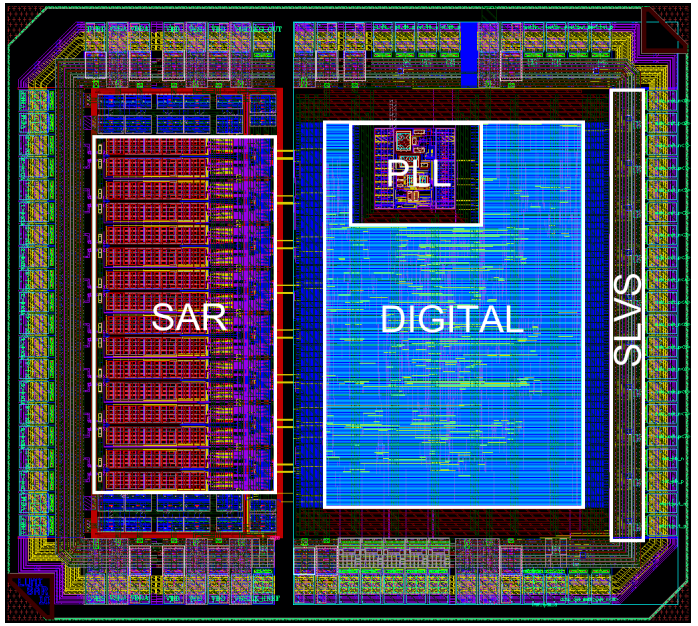
- ADC is fully functional, has ENOB~9.2 and consumes very low power
- Linearity can be further improved...

Readout R&D in IBM CMOS 130 nm
Multichannel SAR ADC with data serialization
AIDA milestone

Specifications :

- 8 channels of 10-bit SAR ADC
- Layout with 146um ADC pitch
- Max. sampling frequency 40 MHz
- Multimode digital multiplexer/serializer:
  - Serial mode: one link per all channels
  - Parallel mode: one link per channel
  - Test mode: single channnel output
- PLL for data serialization
- High speed SLVS interface (>1GHz)
- Power pulsing

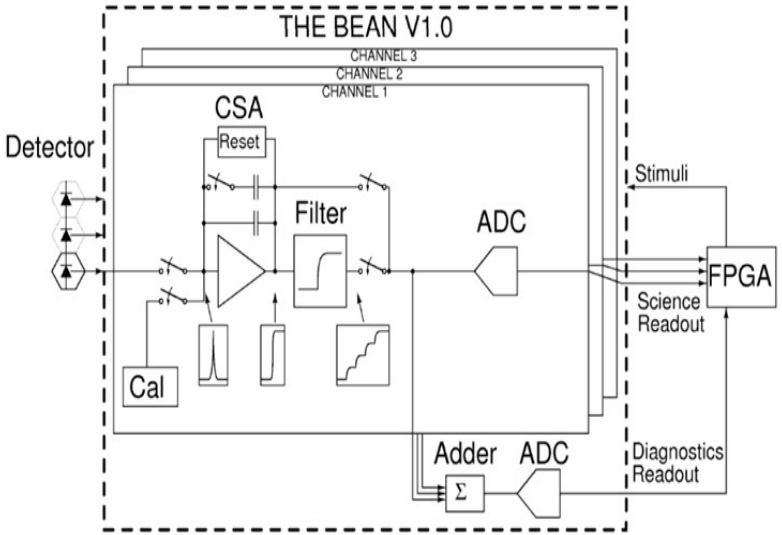




2200um x 2000um

Tests will start soon...

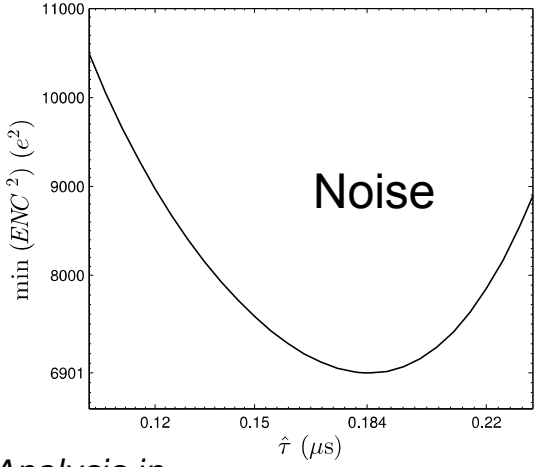
Readout R&D at PUC Chile
BeamCal detector Readout ASIC

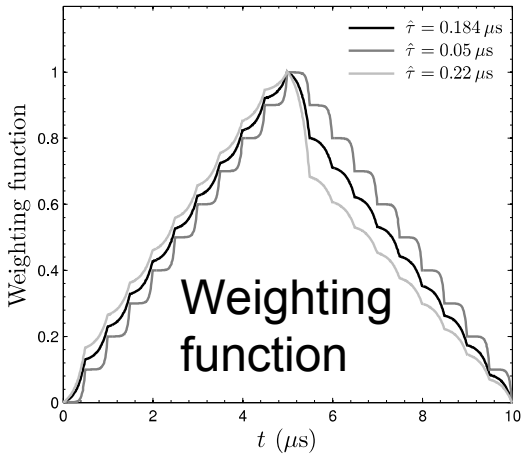


- 180 nm TSMC technology
- BEAN readout ASIC R&D:
  - Front-end: noise analysis for discrete systems in progress
  - Prototype of 10-bit SAR ADC designed and under test

Front-end studies:

Z-domain processing allows configurable filters: with arbitrary weighting functions and optimized parameters

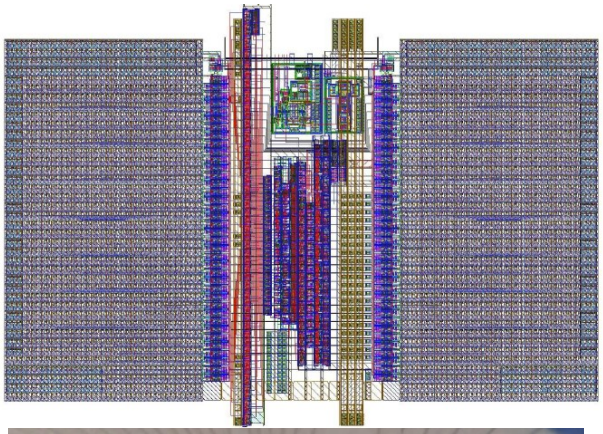


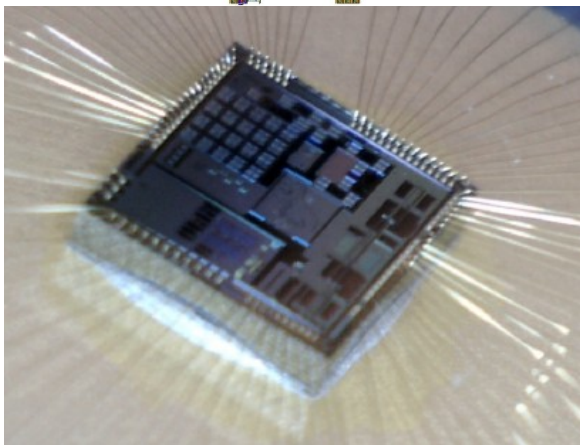


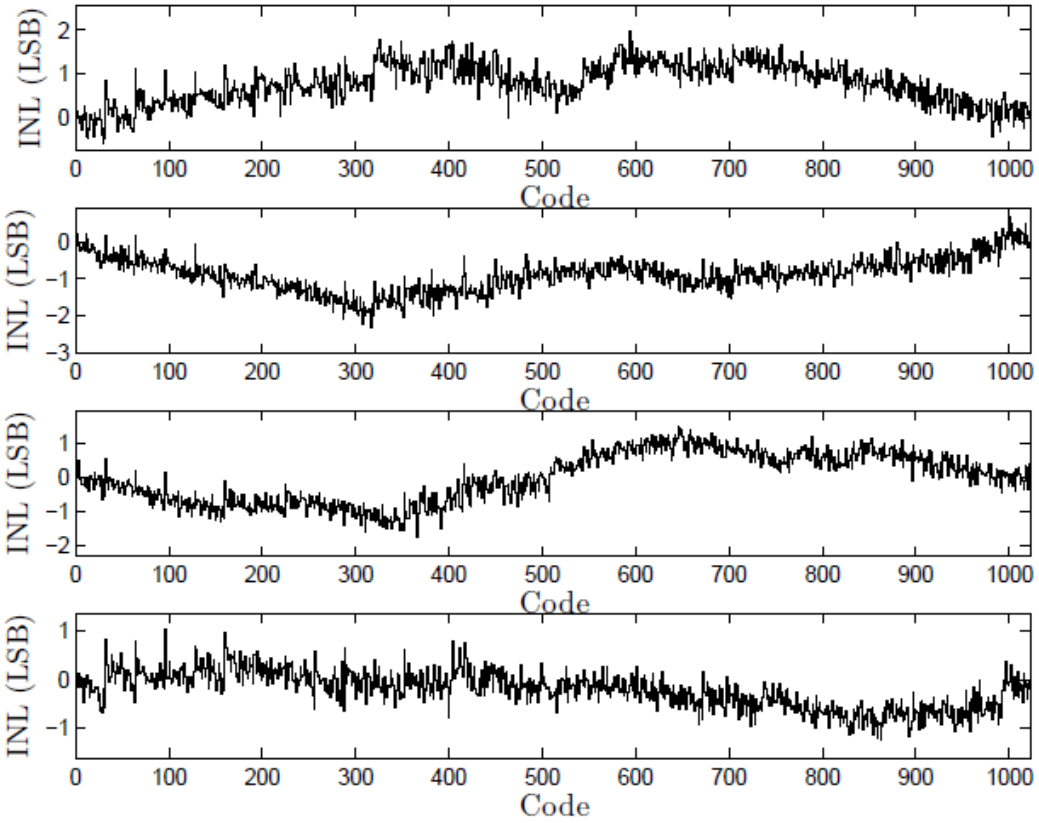
[D. Avila, E. Alvarez, A. Abusleme, *"Noise Analysis in Pulse processing Discrete Time Filters"*, accepted IEEE TNS]

Readout R&D at PUC Chile
10-bit SAR ADC

ADC uses systematic process mismatch to correct nonlinearity

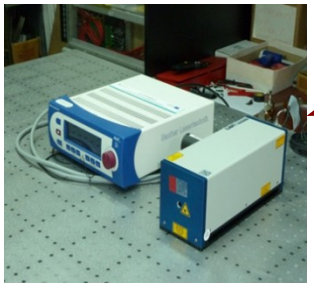


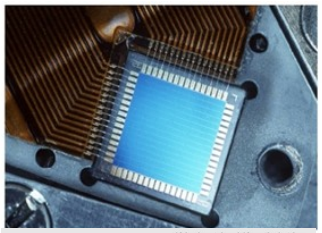


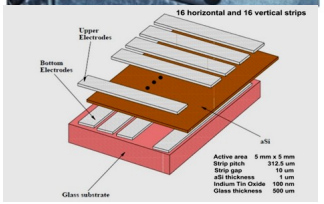


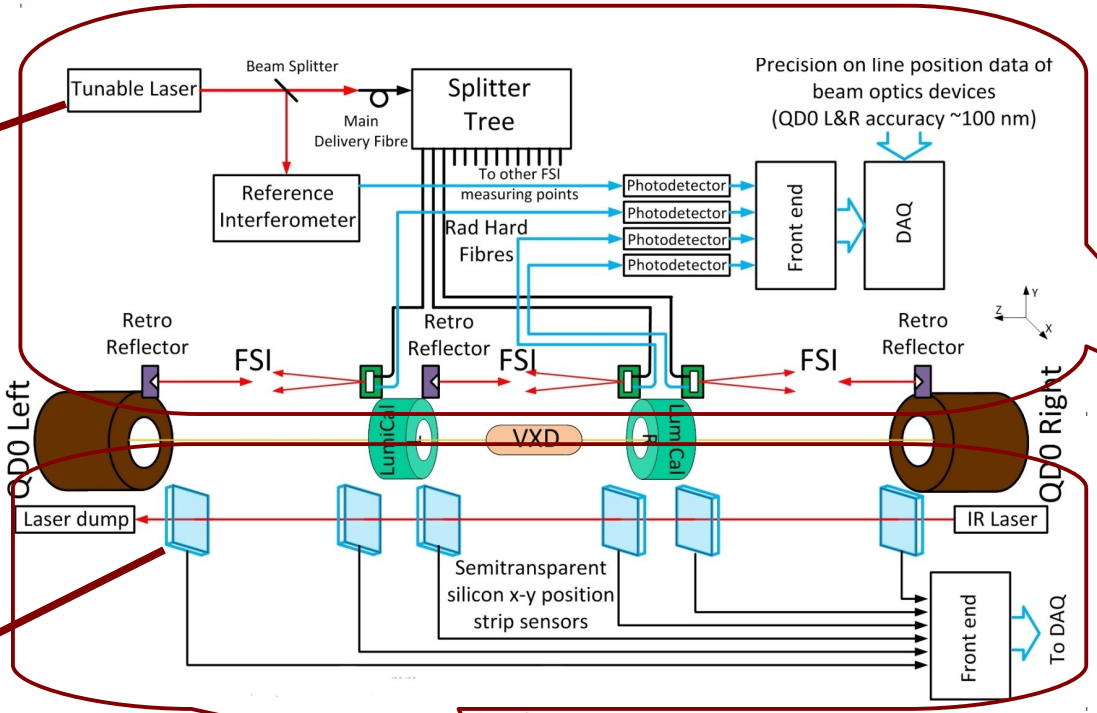
Laser alignment R&D at INP PAN
LumiCal Laser Alignement System (LAS)

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







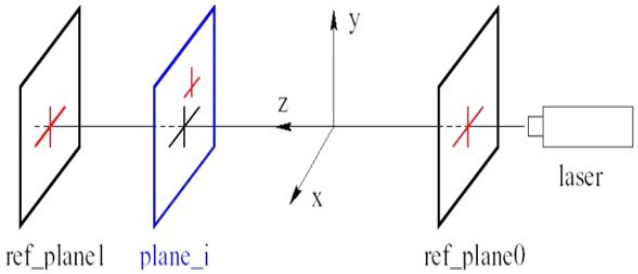


Semi-transparent sensors : LumiCal displacements of the internal Si layers and detectors relative positions

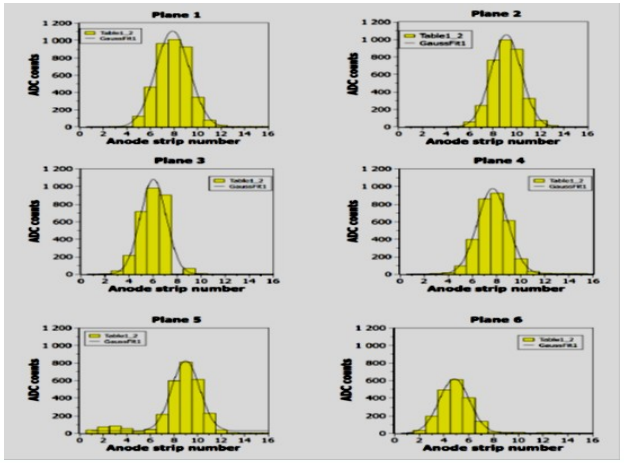
FSI – using tunable lasers will measure the absolute distance between LumiCal calorimeters by measurement of interferometer optical path differences (counting the fringes)

Laser alignment R&D at INP PAN
Semi-transparent sensors

Laboratory setup : 6 PSD sensors



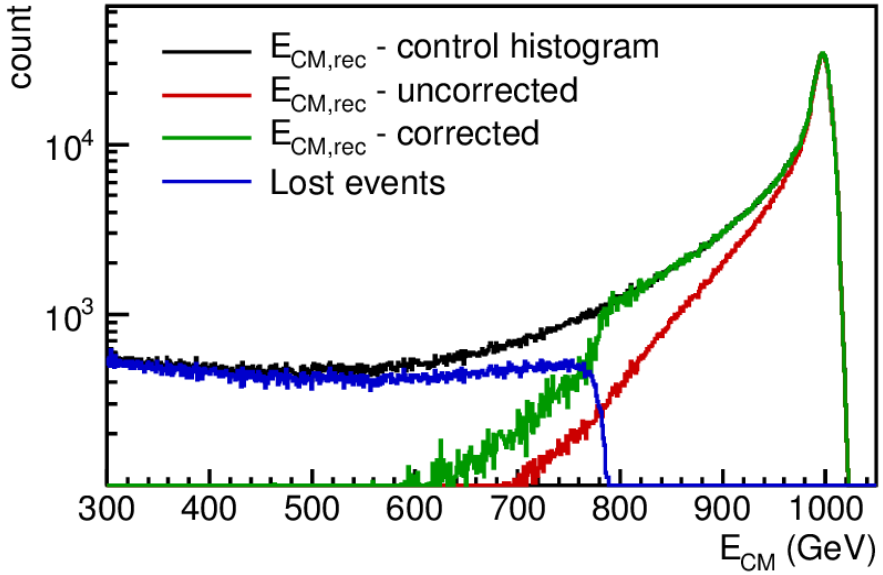
Laser beam-profile signals from anode of sensors measured along beam line

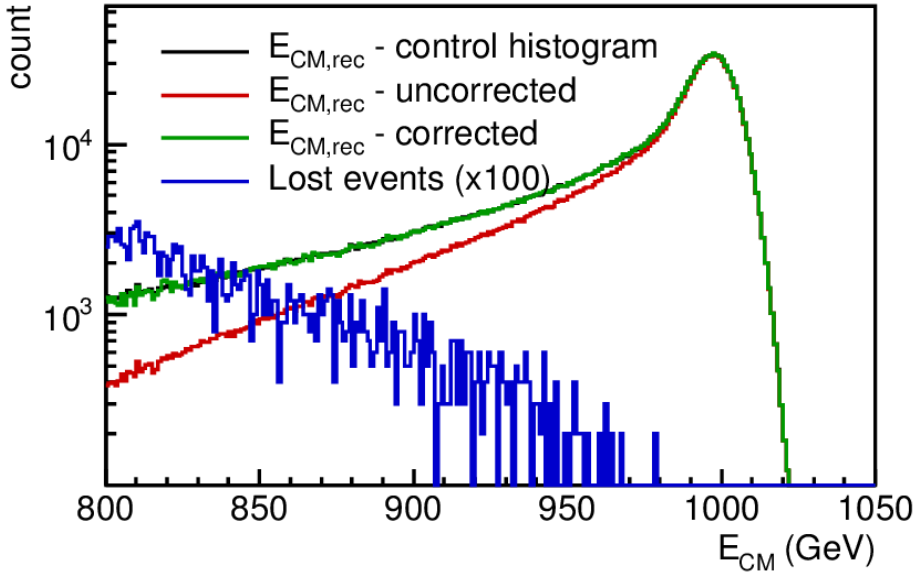


LAB prototype system with optical movable 2D table.
It allows studies of sensor behaviour, laser beam and calculation of displacements.
Expected accuracy: few microns

MC studies – example from VINCA Belgrade
Precise luminosity measurement

- Correction of the beam-beam effects by reconstruction of the velocity of the collision frame β_{coll} - precision better than 1 ‰
- Estimate and reduction of the physics background
- Total systematic uncertainty of luminosity in the forward region ~2 permille (Božović-Jelisavčić et al., JINST 8 (2013) P08012)





Influence and correction of the beam-beam effects on the luminosity measurement

Future Plans

- Complition of AIDA program (2014/2015)
  - Flexible mechanical frame with tungsten plates
  - New multichannel readout ASICs for LumiCal in IBM 130 nm
- New LumiCal readout module with new ASICs
- Prototyping of dedicated FE and ADC ASICs for BeamCal
- Development of DAQ system (TelAviv, INP PAN)
- Irradiation tests of prototype sensors for BeamCal
- MC studies to refine design and contribute to the physics program (various FCAL groups)

Organization issues

- A new LC management structure is established.
R&D collaborations need a representation
- New FCAL management:
  - Spokesperson: W. Lohmann (DESY)
  - Deputy: M. Idzik (AGH-UST)
  - IB chair: Ivanka Bozovic-Jelisavcic (VINCA)

  will strengthen the level of commitments
- In Europe FCAL got limited support up to 2015 within FP7 and GIF, needs effort
- Essential, albeit limited, support by grants from national funding agencies
- At **DESY** a new funding period starts in 2015, **support for FCAL unclear, needs strong effort**