Forward Instrumentation of ILC and CLIC detectors

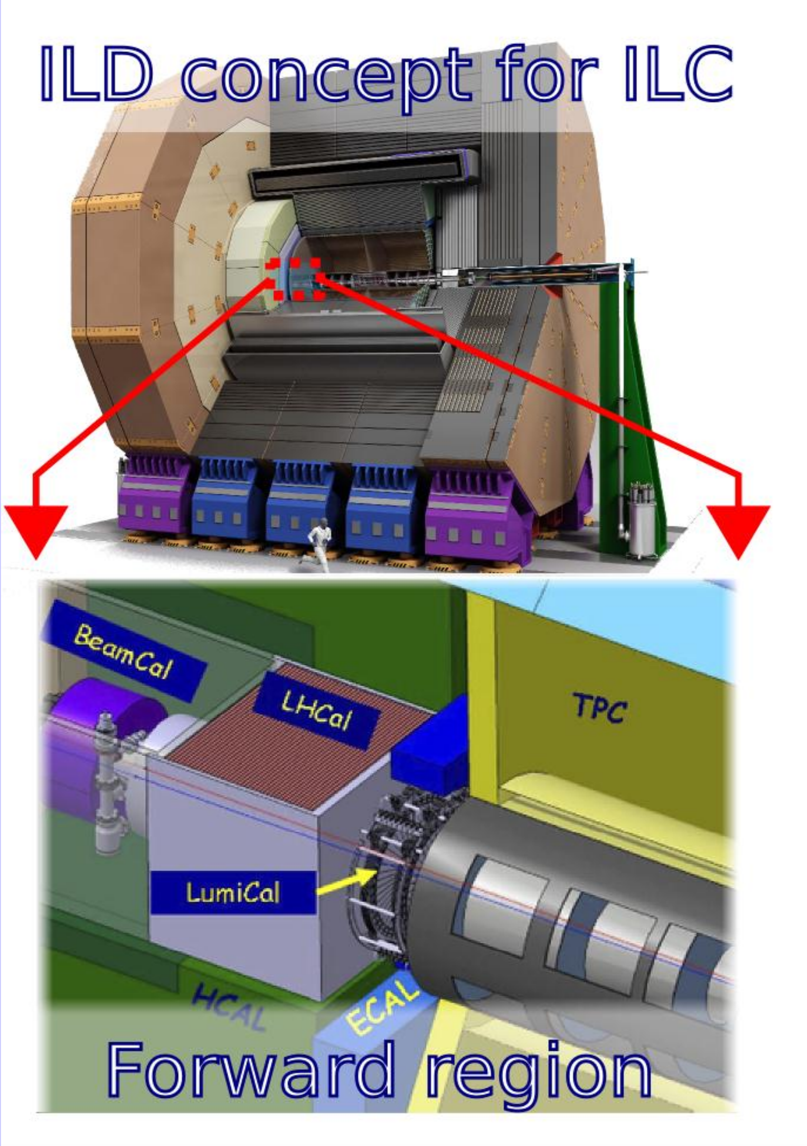
Wolfgang Lohmann,

BTU and DESY

On behalf of the FCAL collaboration

Labs involved: Argonne, Vinca Inst, Belgrade, Bukharest IFIN-HH & ISS, CERN, Univ. of Colorado, Cracow AGH-UST, Cracow IFJ-PAN, JINR Dubna, Royal Holloway, NCPHEP Minsk, Santa Cruz, Stanford University, SLAC , Tuhoku Univ., Tel Aviv Univ., DESY (Z.)

Very Forward Instrumentation- Example ILD



LumiCal

- precise luminosity measurement, 10^{-3} at ILC , 10^{-2} at 3 TeV

BeamCal (and Pair Monitor)

- hermeticity (electron detection at low polar angles),
- assisting beam tuning (fast feedback of BeamCal and pair monitor data to machine)

Challenges:

- radiation hardness (BeamCal),
- high precision (LumiCal) and
- fast readout (both)

Detector Design Studies, 500 GeV

Design studies, background, systematic effects for 500 GeV advanced

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Forward instrumentation for ILC detectors

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Design studies, background, systematic effects, readout electronic for 500 GeV advanced

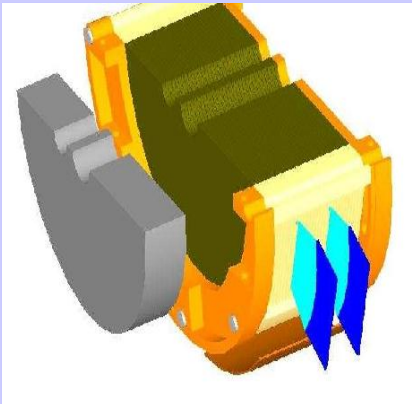
Systematics of luminosity measurement at 500GeV

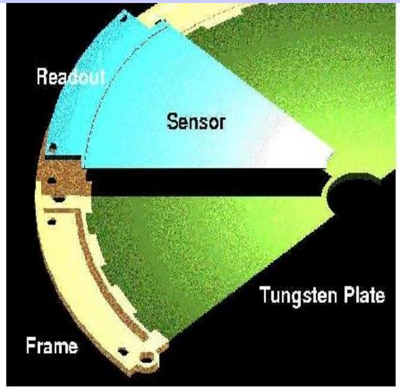
Source	Value	Uncertainty	Luminosity Uncertainty
σ_θ	2.2×10^{-2} [mrad]	100%	1.6×10^{-4}
Δ_θ	3.2×10^{-3} [mrad]	100%	1.6×10^{-4}
a_{res}	0.21	15%	10^{-4}
luminosity spectrum			10^{-3}
bunch sizes σ_x, σ_z,	655 nm, 300 μm	5%	1.5×10^{-3}
two photon events	2.3×10^{-3}	40%	0.9×10^{-3}
energy scale	400 MeV	100%	10^{-3}
polarisation, e^-, e^+	0.8, 0.6	0.0025	1.9×10^{-4}
total uncertainty			2.3×10^{-3}

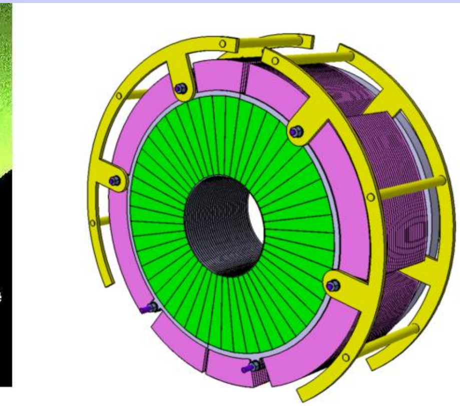
* 100%= Upper limit – the size of effect is taken as uncertainty

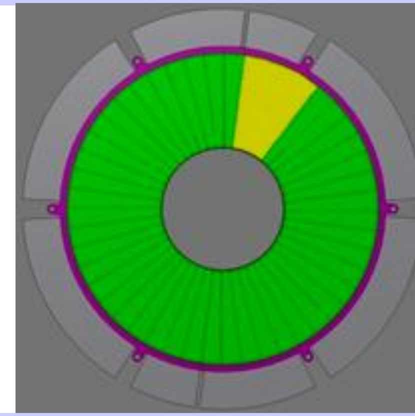
- Cylindrical sensor-tungsten sandwich calorimeter
- Small Moliere radius
- Finely segments
- FE ASICs positioned at the outer radius

Calorimeter, general structure



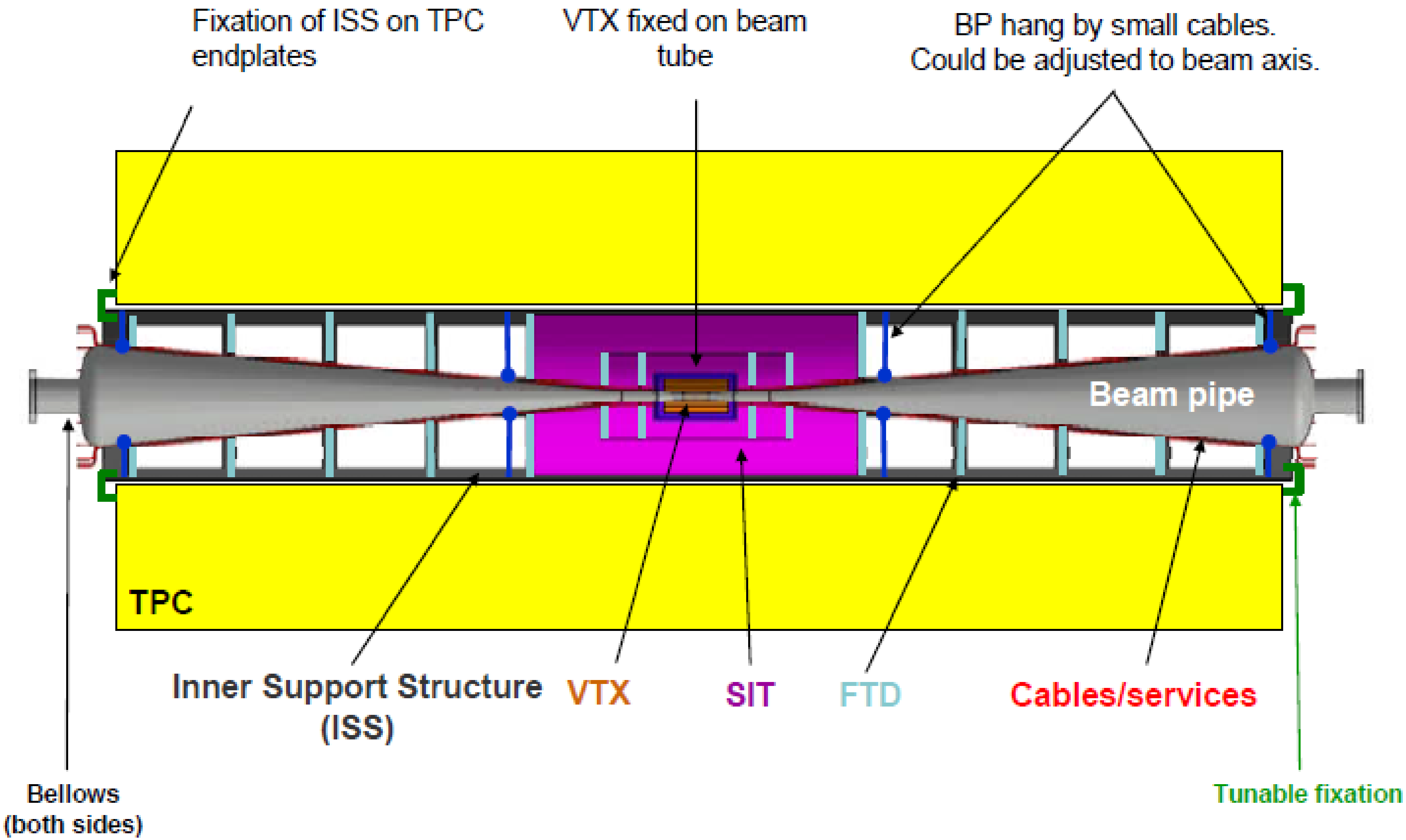




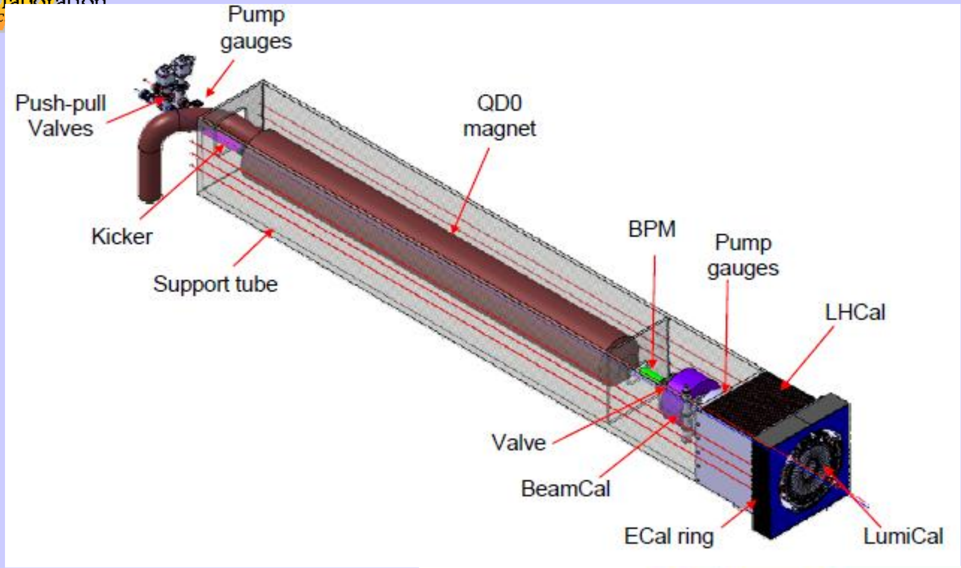


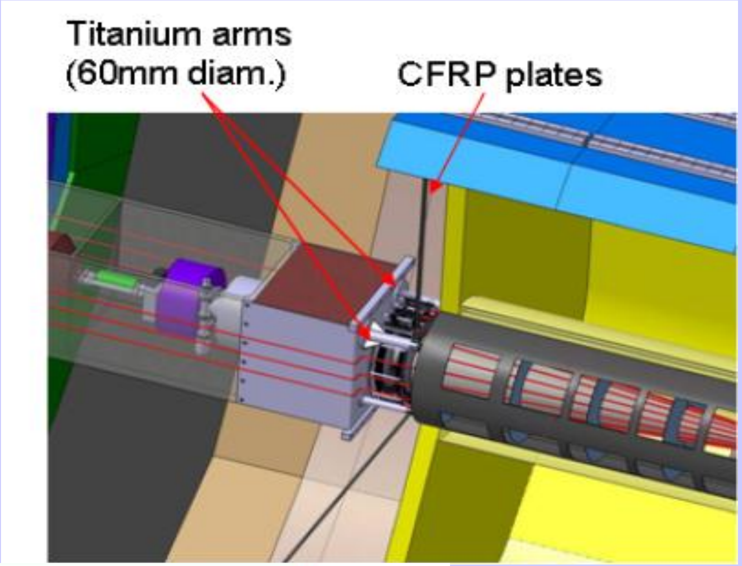
- Tungsten thickness 1 X_0, 30 layers
- BeamCal sensors GaAs, 500 μm thick
- LumiCal sensors silicon, 320 μm thick
- FE ASICs positioned at the outer radius
- BeamCal angular coverage 5.8 – 43.5 mrad
- LumiCal coverage 31 – 78 mrad

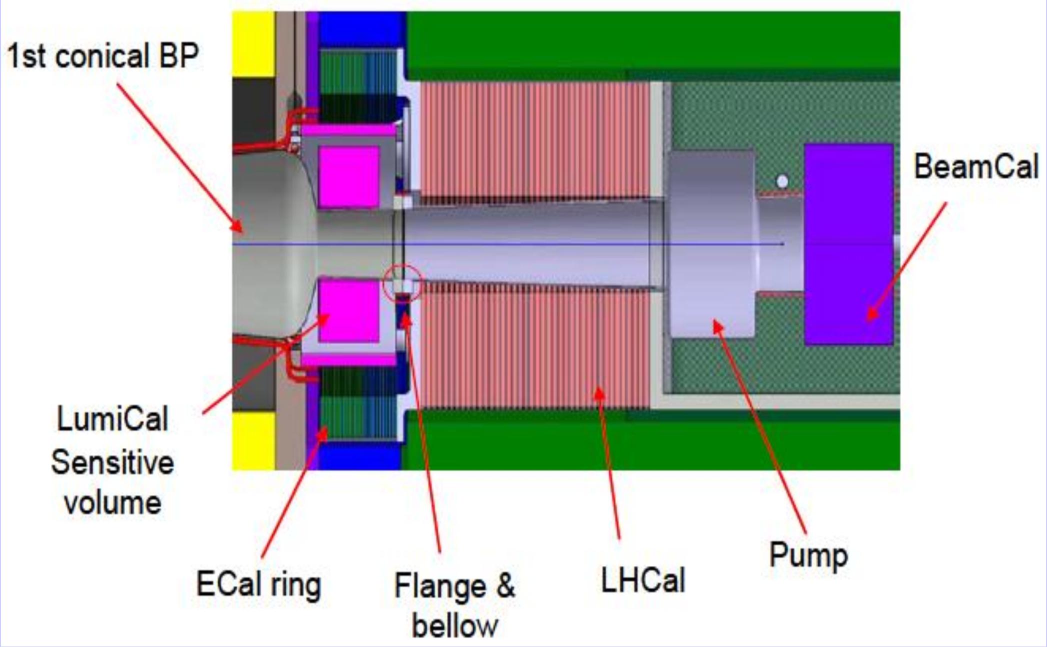
Vorward Region Design, ILD



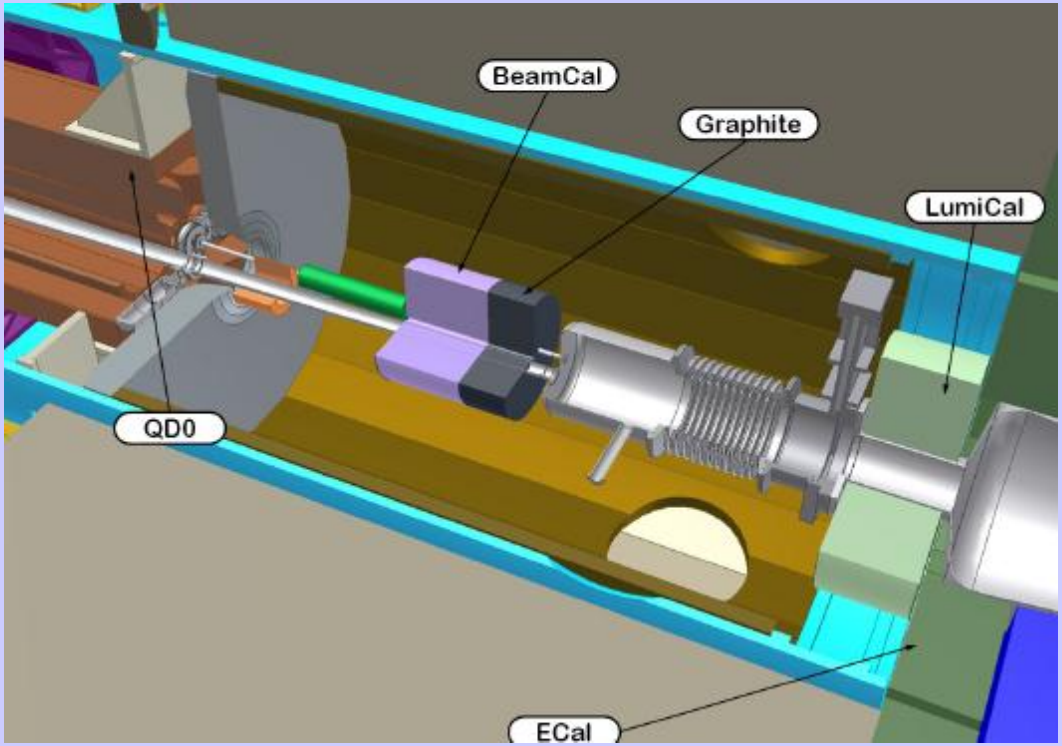
Vorward Region Design, ILD

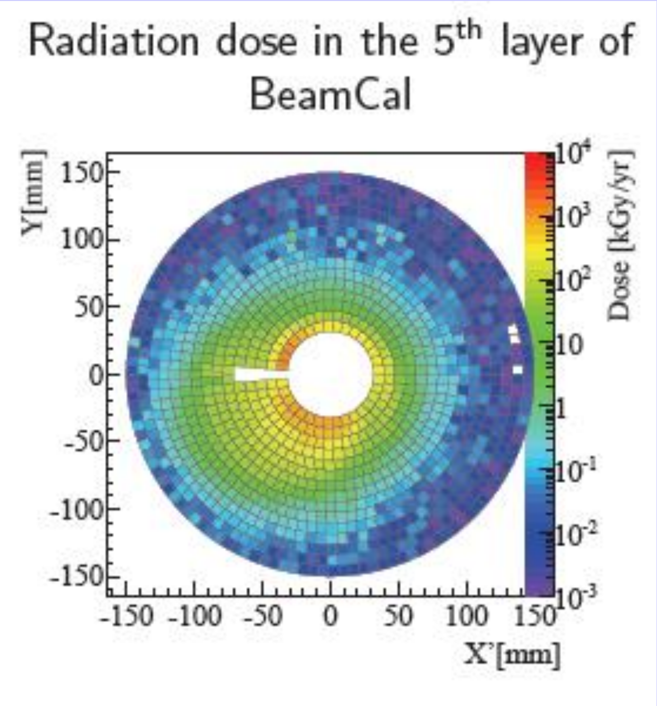






Design of the forward region of a CLIC detector



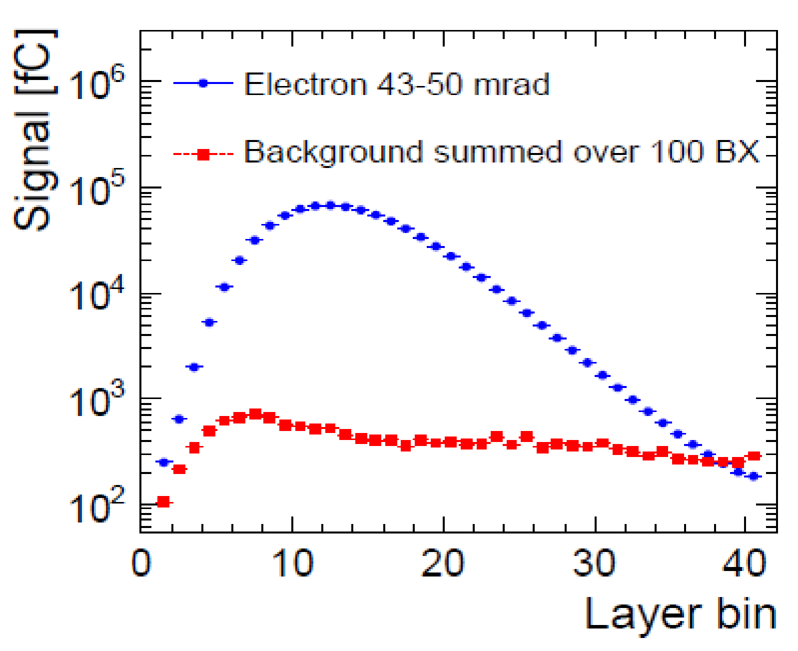


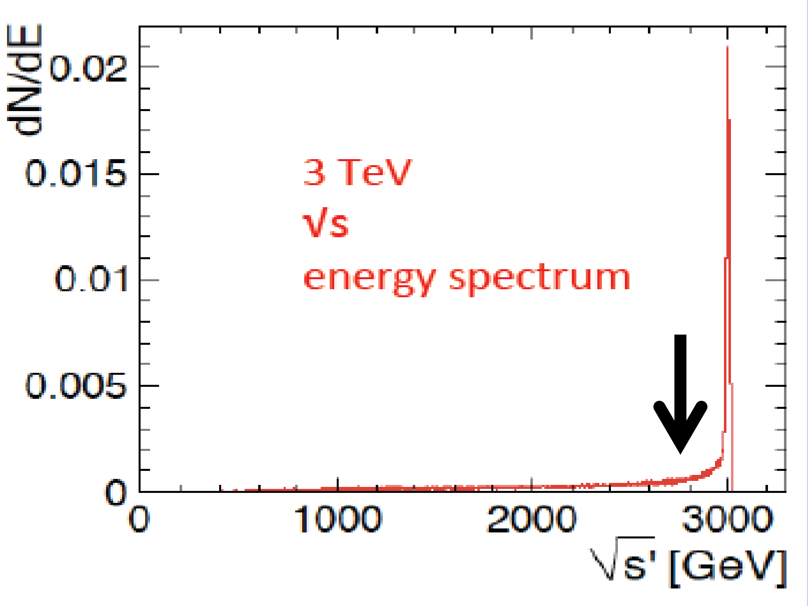
Crossing angle 20 mrad

- BeamCal angular coverage 10 – 40 mrad
- LumiCal coverage 38 - 110 mrad
- 40 X_0 depth
- Optimised to minimise backscattered particles

CLIC challenges:

- Two-photon background in LumiCal (occupancy)
- Read-out speed (.5 ns between BX)
- Luminosity spectrum





The precise knowledge of the spectrum shape and the energy scale of the calorimeter are essential for the precision of the luminosity measurement!

Dedicated meeting at the FCAL workshop May 2012

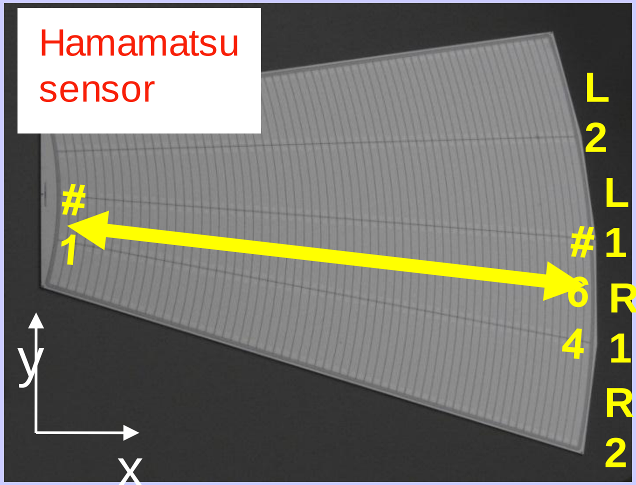
CLIC CDR

CLIC CONCEPTUAL DESIGN REPORT

VOL. 2:
PHYSICS AND DETECTORS AT CLIC

Sensor prototypes

LumiCal

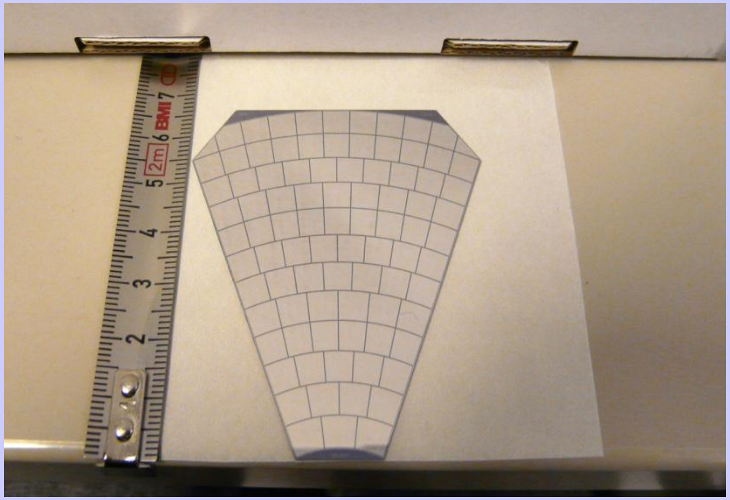


p in n, strip pitch 2.2 mm

40 pieces, joint effort

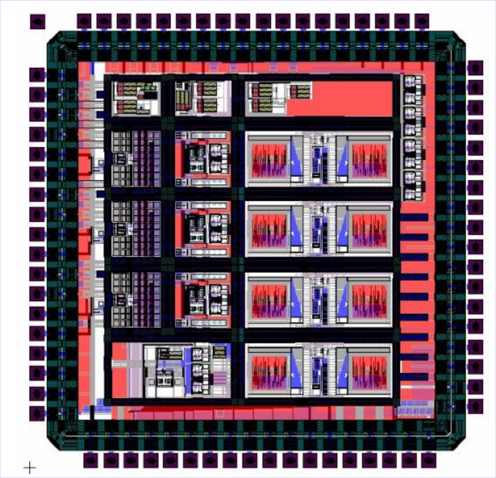
IFJ PAN Cracow, DESY, TAU

BeamCal



Compensated GaAs several pieces,

Institute in Tomsk, DESY-JINR collaboration (BMBF supported)



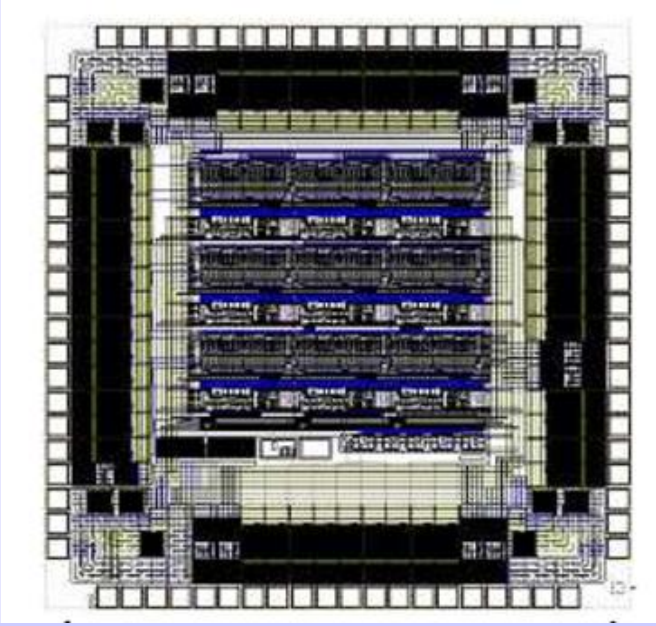
SLAC-Stanford chip (BeamCal)

- Prototypes in 180-nm TSMC process
- Charge sensitive preamplifier (CSA)
- Analog adder to provide fast feedback
- ADC : 10-bit SAR ADC
- Preparation for beam-test foreseen
- (A. Abusleme visits Desy for two weeks)

Pair Monitor readout (Tohuku Univ.)

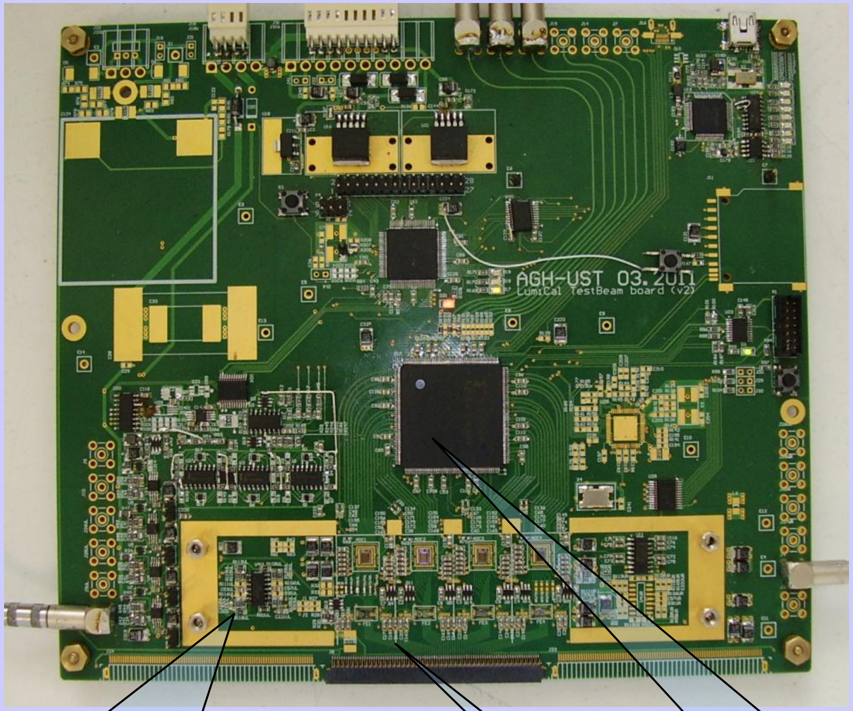
- Silicon On Insulator (SOI) technology – first
The sensor and readout electronics are integrated in the SOI substrate. (monolithic)

- SOI 0.2 μm CMOS process
noise : 260 e^- (+130 e^-/pF) excepted signal : 20000 e



AGH-UST Cracow Readout board, 32 channels

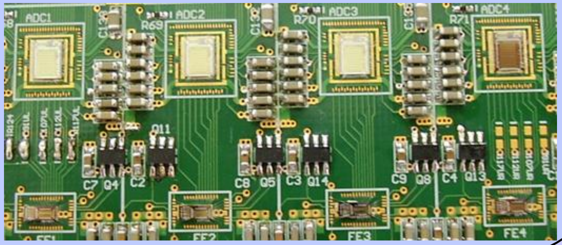
- AMS 350 nm
- 20 Ms/s ADC
- External and self trigger
- Internal or 'beam' clock
- Data transfer via USB
- Power pulsing
- Handshaking with Trigger Logic Unit (TLU)
- Used in several beam-test ventures



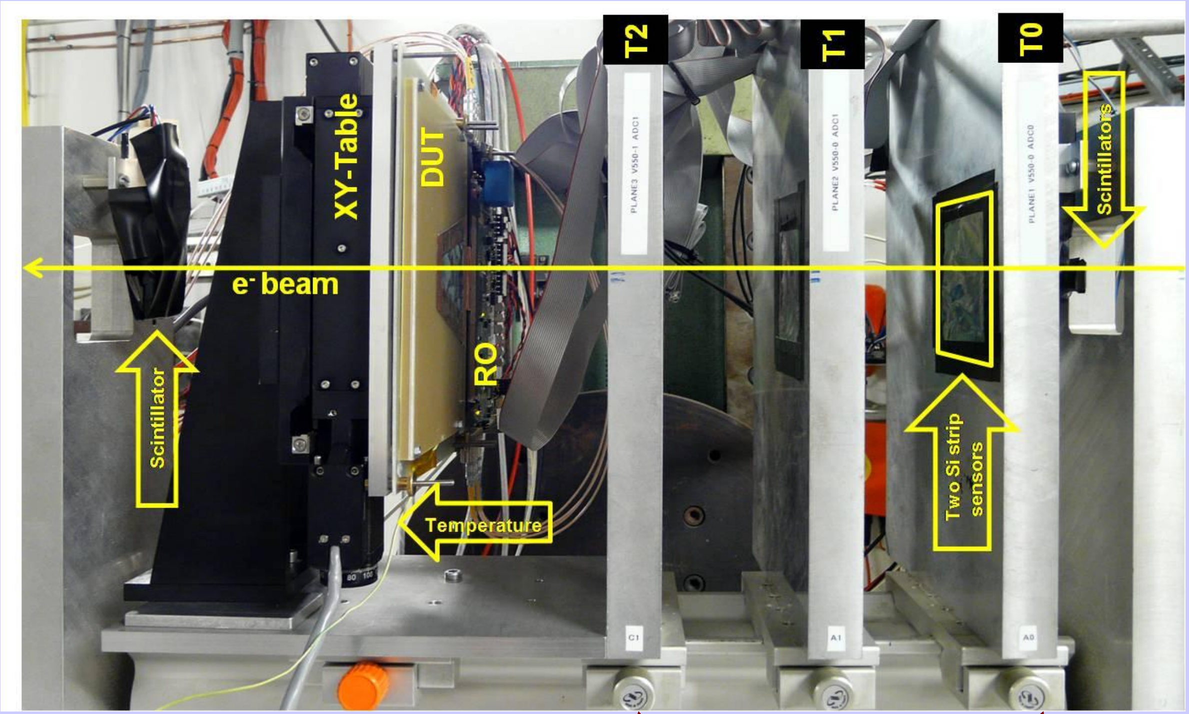
Data concentrator
Xilinx Spartan 3E

sensor
connector

4 pairs of front-end+ADC ASICs

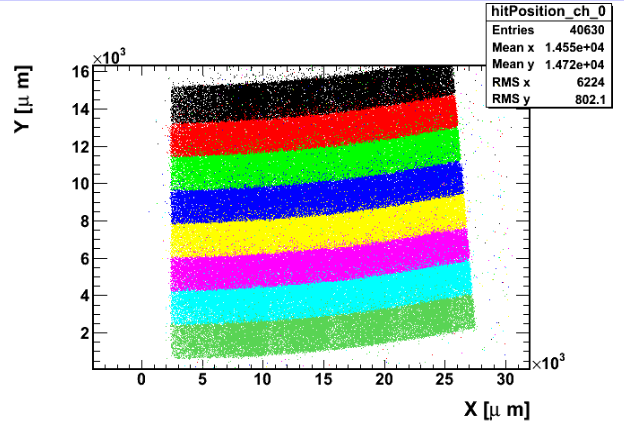


Beam-Test

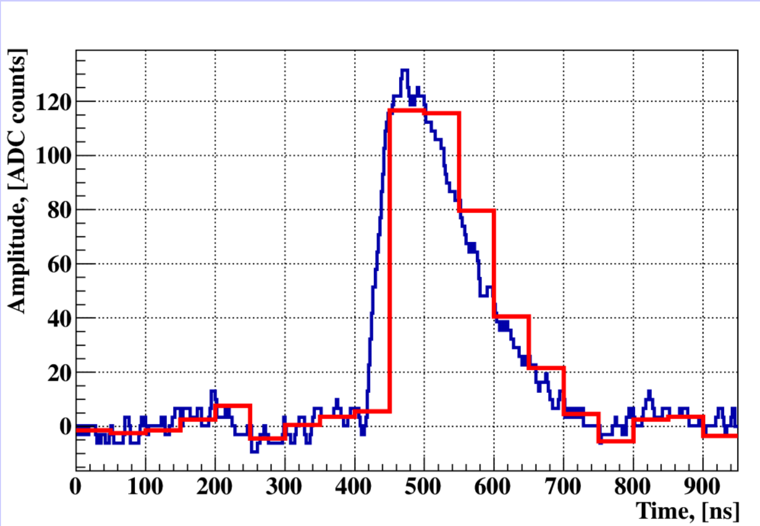


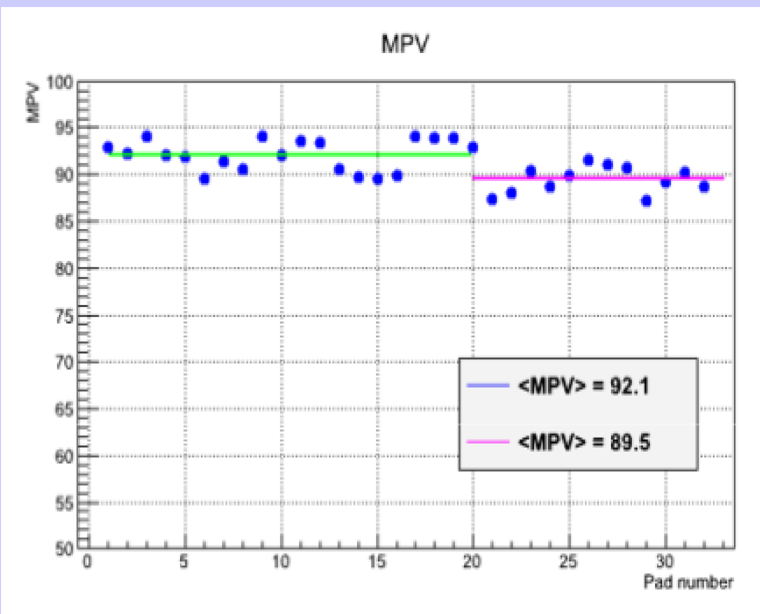
- 50×10^6 trigger
- different areas of the sensor
- different FE settings (feedback in the FE ASICs)
- data with FE and external ADC

Silicon strip planes



Beam-Test





Example signal:

Signal digitized with ADC ASIC (red) and external ADC (blue)

Preliminary results:

S/N ~ 25 (RC feedback)
~ 17 (FET feedback)

homogeneity of response (uncalibrated)

Analysis still ongoing, Results will be part of the DBD

Preparation of a prototype Calorimeter:

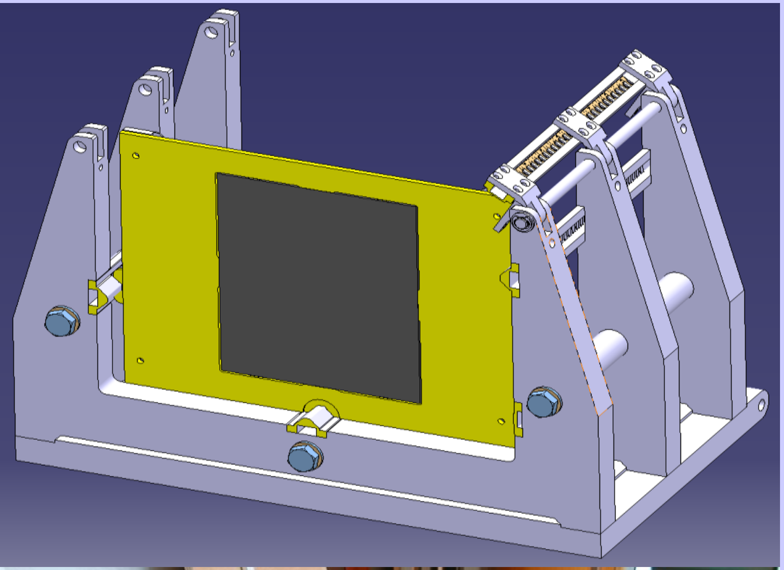
- Flexible, high precision tungsten structure,
- FE ASICs in 130 nm technology
- Position control devices
- Fully assembled sensor planes, covering ≥ 30^0
- Power pulsing

Infrastructure common with others:

- Data acquisition
- Tracking in front of the calorimeter

Participating Institutes: AGH-UST (Cracow), CERN, DESY (Zeuthen), IFJPAN (Cracow), TAU (Tel Aviv), (IFIN, VINCA Associated)

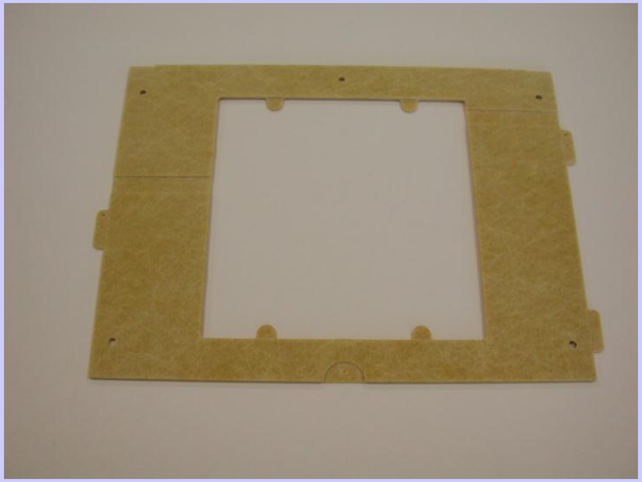
Mechanical structure



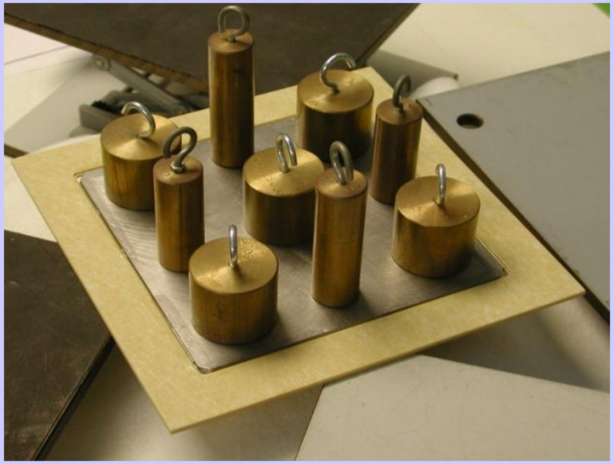
- 30 Tungsten absorber plates, $1X_0$
- sensor gap 0.5, 1 and 2 mm
- precision 50 μm
- flexibe, easy exchange of sensor layers

Designed and manufactured by CERN , Physics department,
Detector technology group

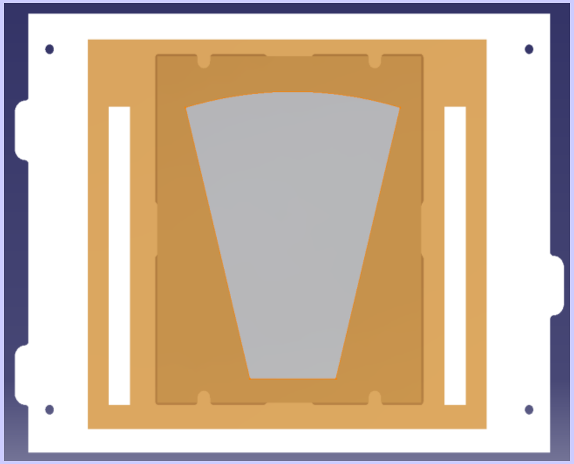
Mechanical Frame



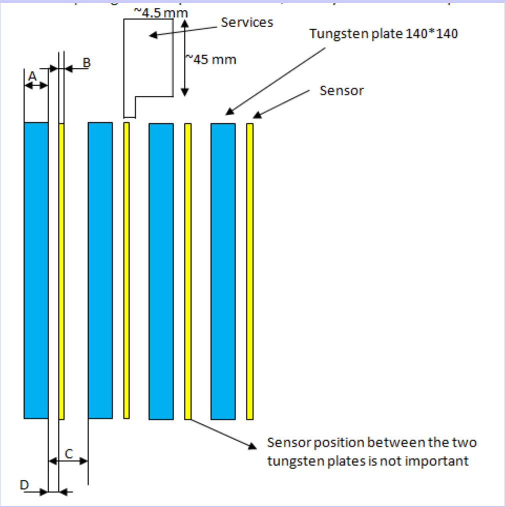
First machined permaglass frame

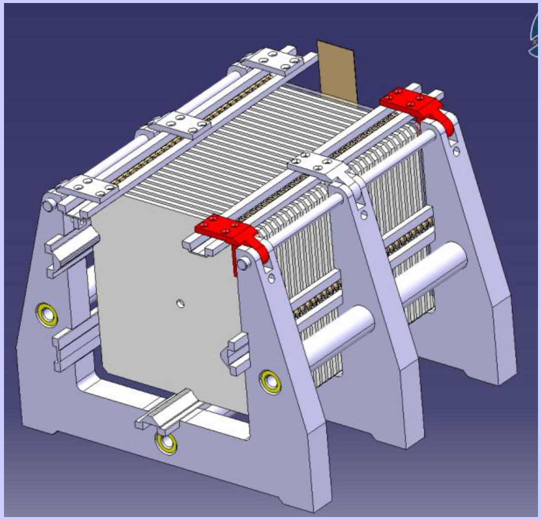


tungsten absorber plate inserted



Sensor plane

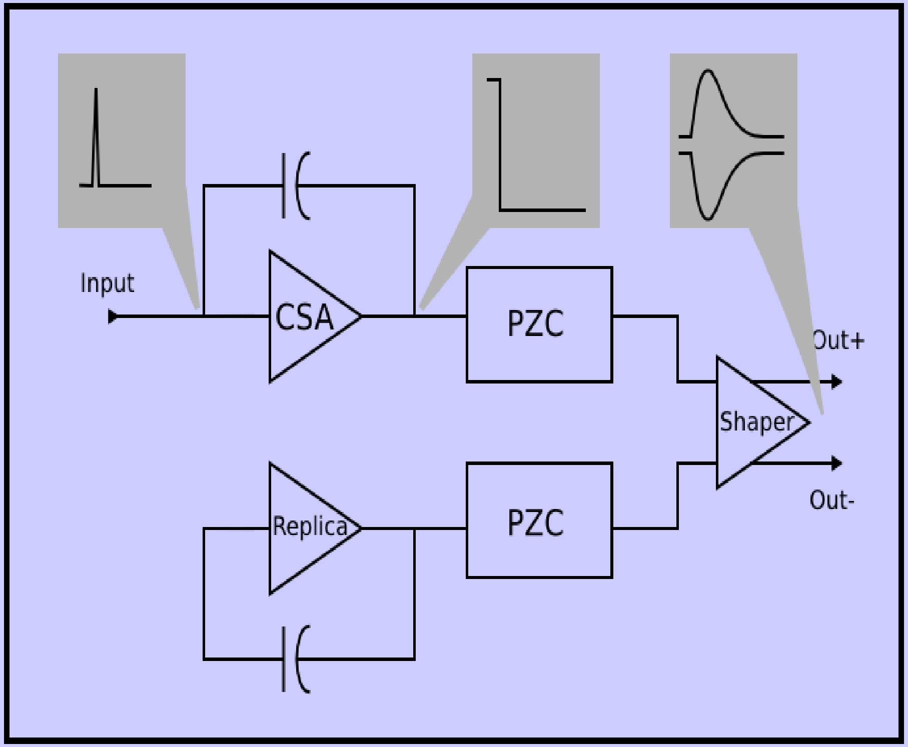




New ASIC prototypes

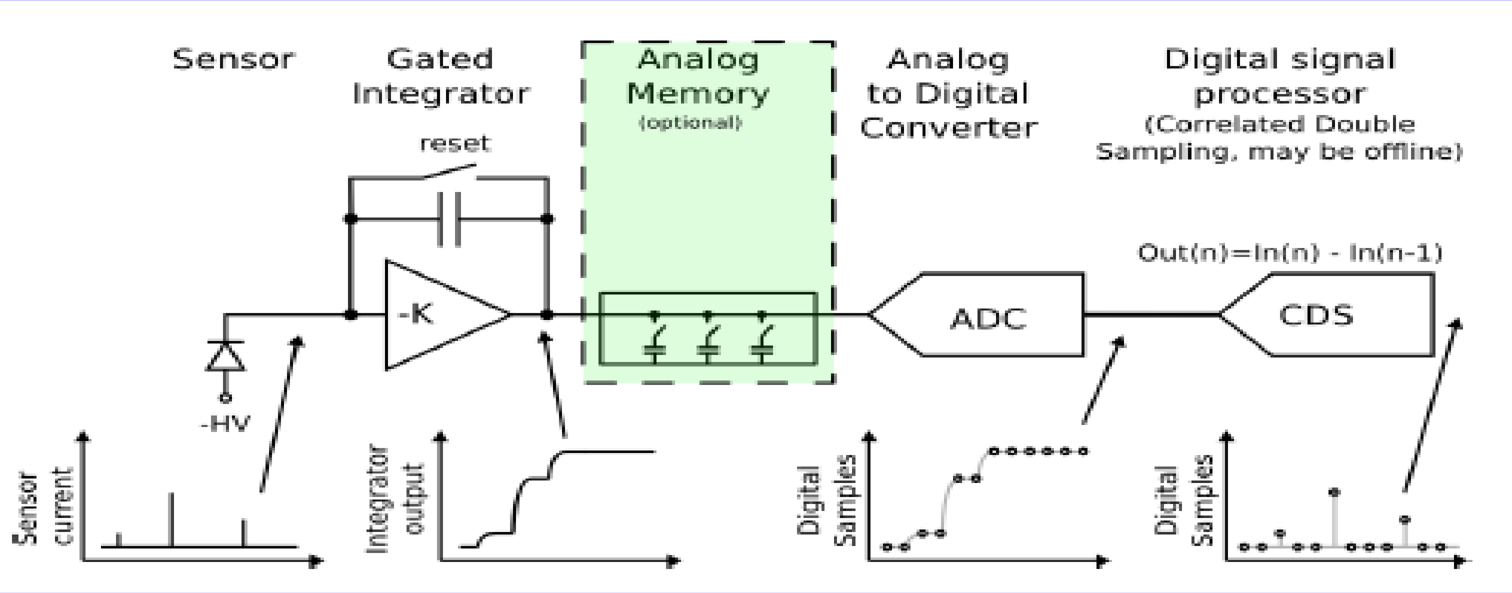
Future ASICs will be designed and produced in 130 nm IBM technology (AGH-UST Cracow)
faster, lower power consumption, radiation hard

- 10 bit SAR ADC (submitted
- in February 2012)
  - 1-2 mW at 40 Ms/s
  - 150 µm pitch
- new FE ASIC, improved ADC (submission in May)
  - Charge sensitive, PZC
  - Gain 0.15mV/fC and 15 mV/fC (switchable)
  - Peaking time 25-100 ns variable
  - 2 mW/channel
- Multichannel version in 2013



CLIC Electronics (proposal)

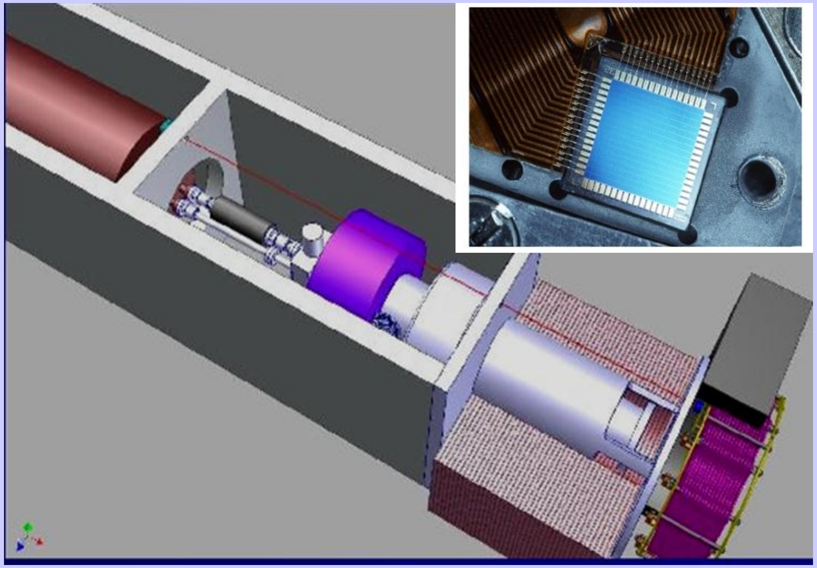
Triggerless time and amplitude reconstruction using asynchronous deconvolution or a gated integrator



With a peaking time of 60 ns and S/N = 20 a time resolution Of < 2ns was obtained (simulation and test with dedicated hardware.

More detailed physics background simulations needed!

Laser Alignment and DAQ



Alignment Concept (INPAS Cracow)

- Reference for position monitoring QD0
- Laser beams and sensors between QD0 and LumiCal

- Laser beams between both LumiCal

DAQ (INP and TAU)

- Follows the ILD standard (Calice, LCTPC)
- 4 Detector Interface units are ordered
- 1 Link Data Aggregator under test
- Concept not yet finished

Irradiation Studies (Plan)

Radiation Damage Study Facility (Santa Cruz)

will allow performing radiation hardness studies under more realistic conditions, e.g. considering also the hadronic component in electromagnetic showers;