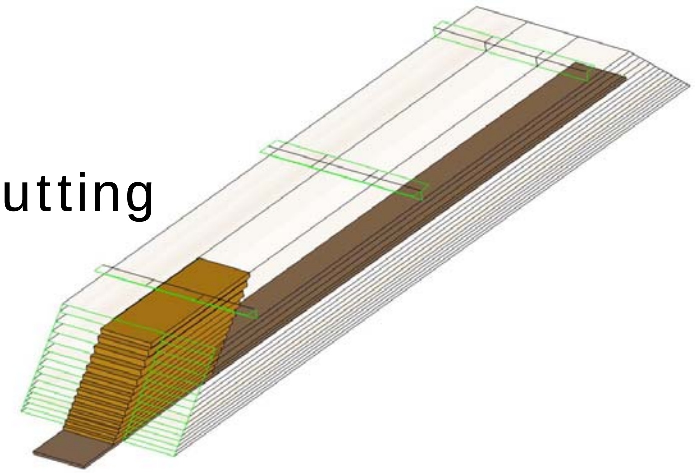
ECAL EUDET MODULE progress & perspective

EUDET annual meeting, oct, 18st, Munich

Calorimeter for ILC

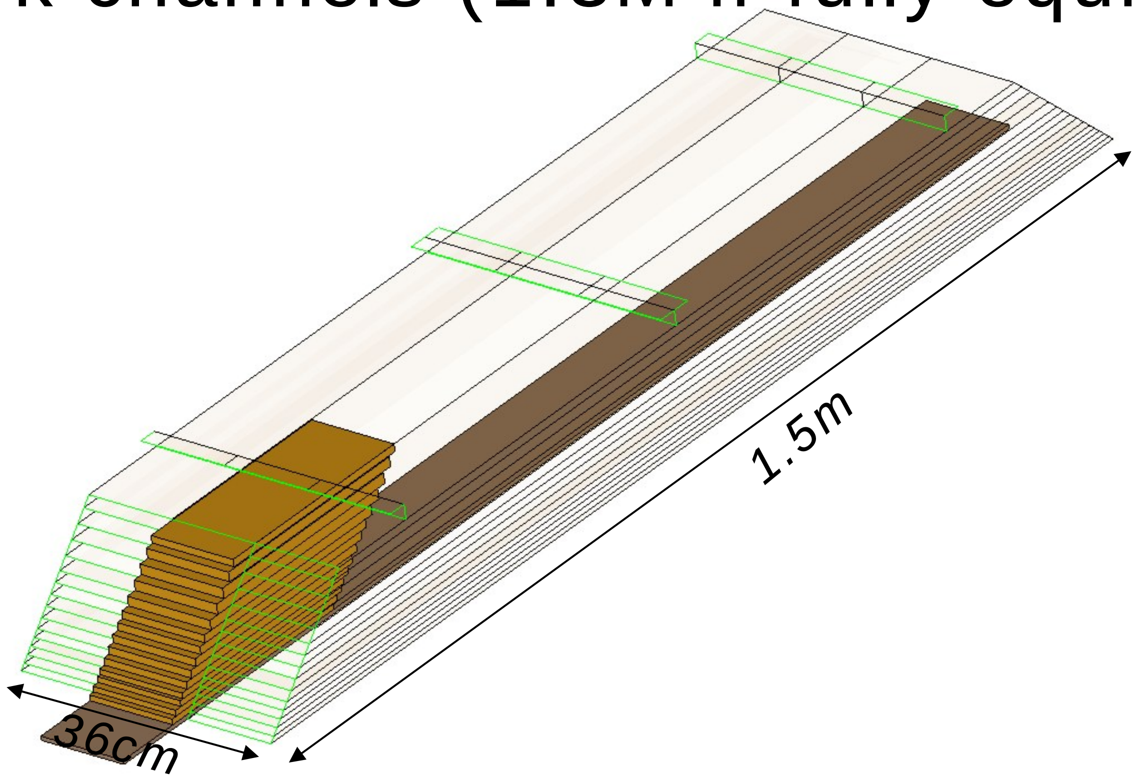
Goal of the program

- Mechanic
  - Validate a full length structure
  - Validate fastening
  - Validate thermal calculation
- Silicon sensor
  - Validate physical behaviour
  - Validate costing and production feasibility
- Electronic
  - Validate front-end ASIC
    - Ultra low comsumption
    - System on chip
    - Daisy chaining and data outputting



EUDET module overview

- Full length structure
- 500kg radiator
- 40k channels (1.3M if fully equipped)



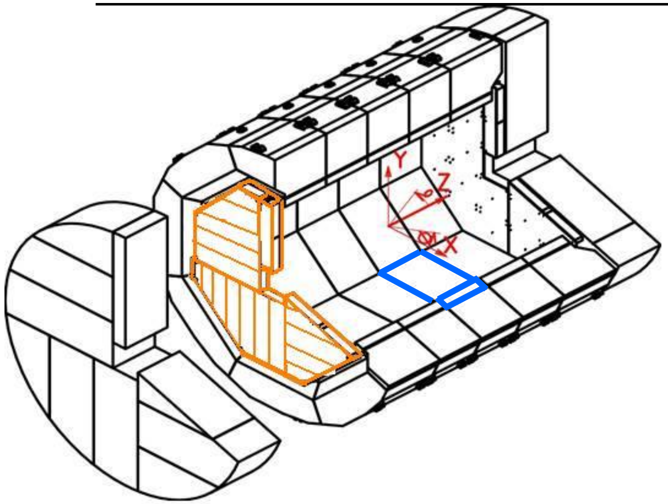
Mechanical R&D

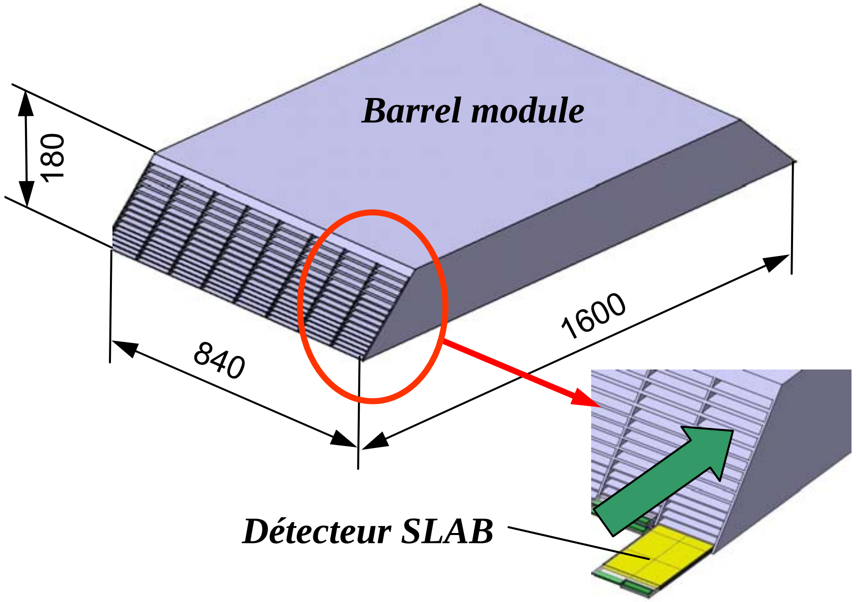
On behalf of Marc Anduze &Denis Grondin

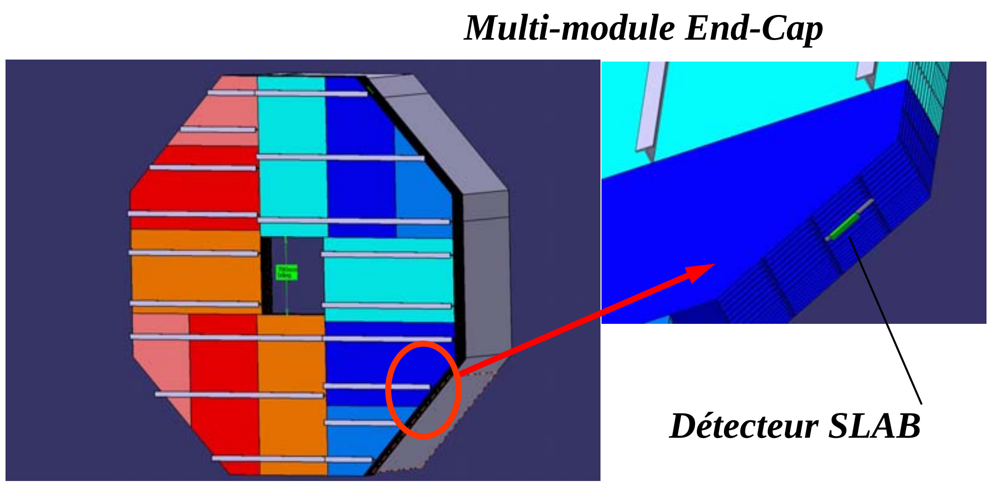
LLR/LPSC

ECAL for LDC- Global presentation

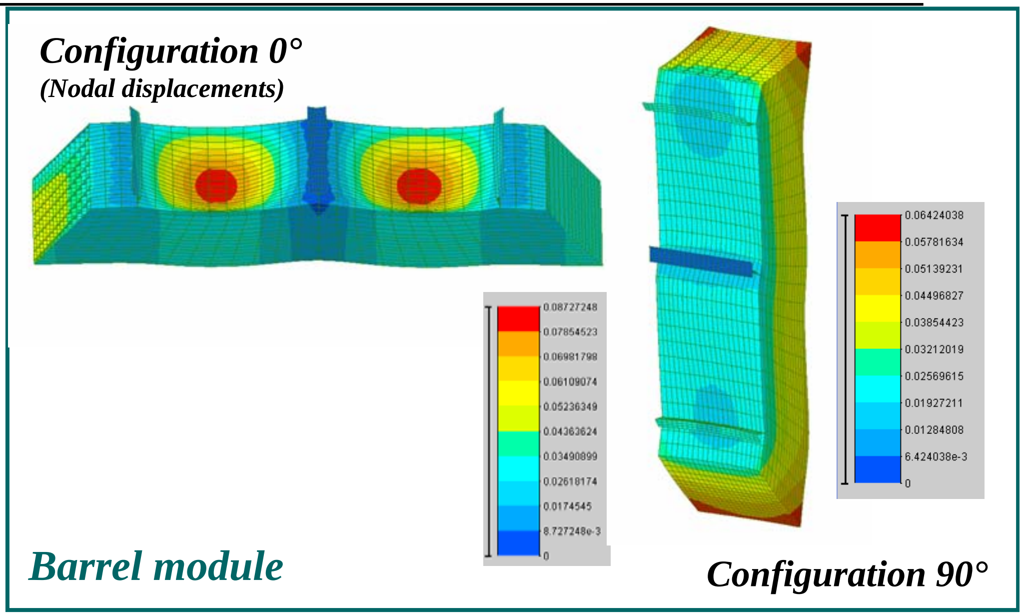
- W/Si calorimeter (24 X_0 with 29 W layers)
  Weight full ECAL: ~ 112 T (80 barrel+32 End-Cap)
- Barrel : 40 identical trapezoidal modules
- End-Cap : constituted of 12 modules (3 types)
- ECAL module : alveolar structure - carbone fibers compound including half of W plates (fixed on HCAL End-Cap with rails)
  ⇨ Minimization of dead zones
- Detection elements (detector slab) in each alveolar case (Si+W), FE chips integrated, pad size : 5×5 mm^2







ECAL - Alveolar structure design

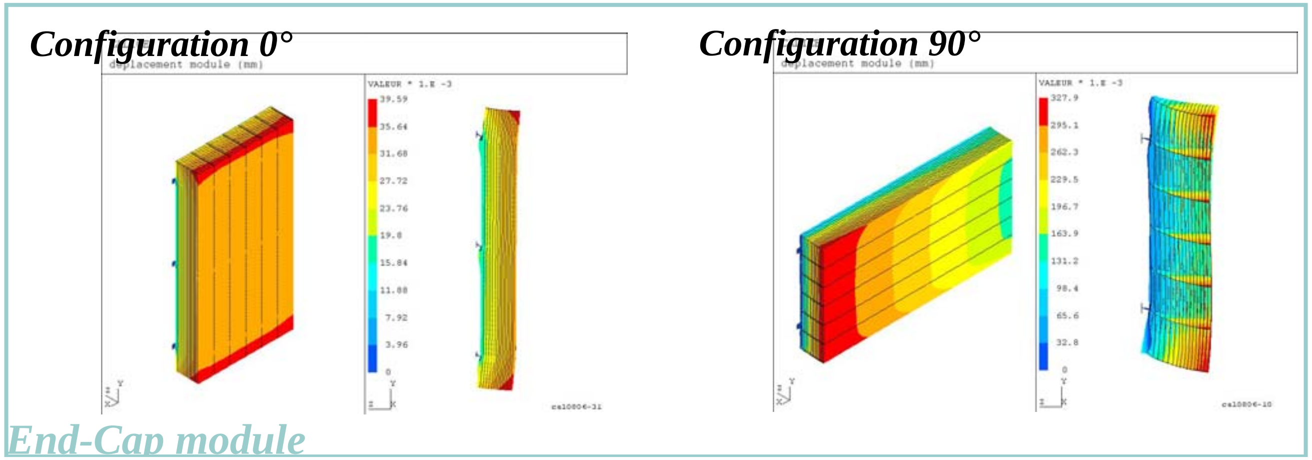


Linear Analysis

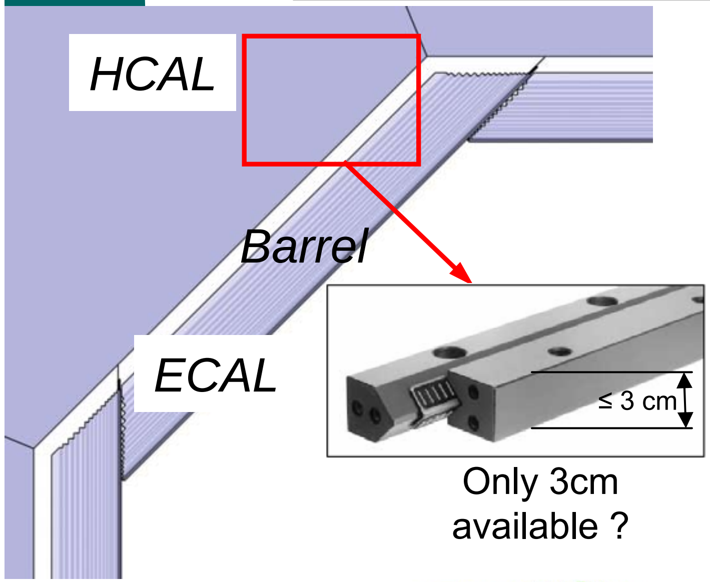
- Global simulations : global displacements and localization of high stress zone for different solutions (definition of dimensions)
- Local simulations : more precise simulations and study of different local parameters to design each part of theses structures

Main ISSUES :

- Dead zones : thickness of main composite sheets
- Fastening system : choice of fasteners (metal inserts, rails…)
- Thermal cooling (active or passive ?)
- Connectors ?



ECAL/HCAL - Interface



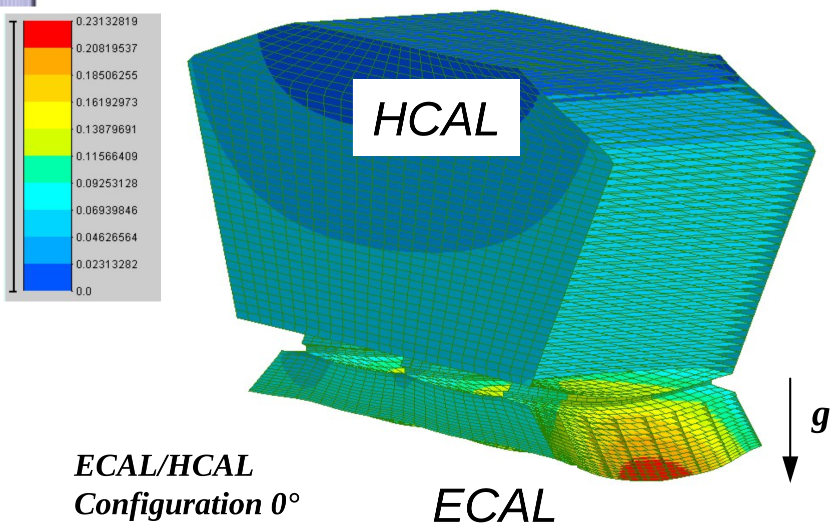
Only 3cm available ?

Fastening system ECAL/HCAL is fundamental for mechanical and thermal calculations (barrel and End-Caps):

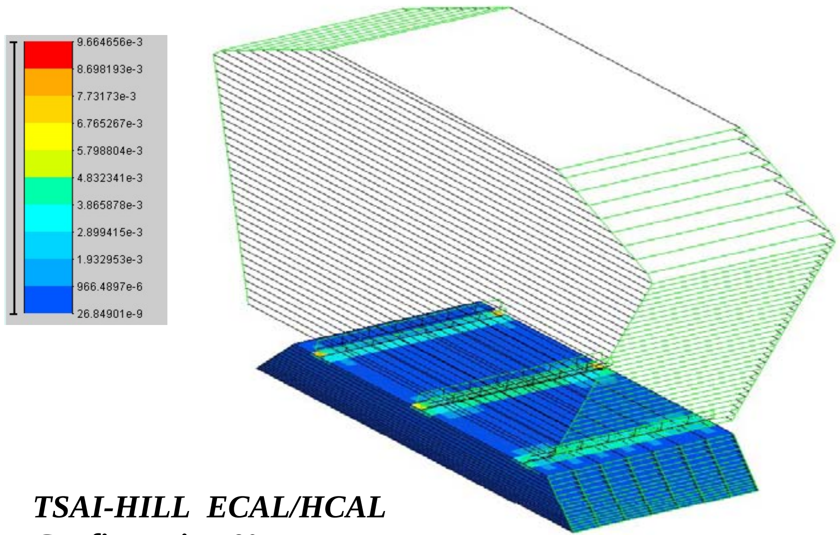
- choice of fasteners : rails directly inside composite

or metal inserts ?

- Connections set path in gap between ECAL and HCAL (via a panel for cabling interface ?)
- Rails are 1 way for positioning system (gravity support) but a second complementary system may be added for fast interchange of modules… recommendation ?
- Whole End-Cap (ECAL+HCAL) assembly behavior

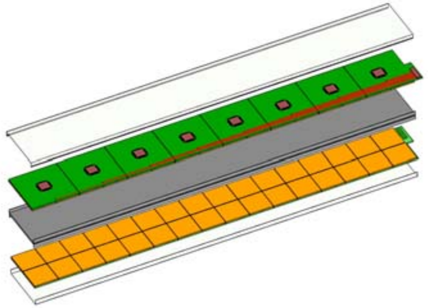


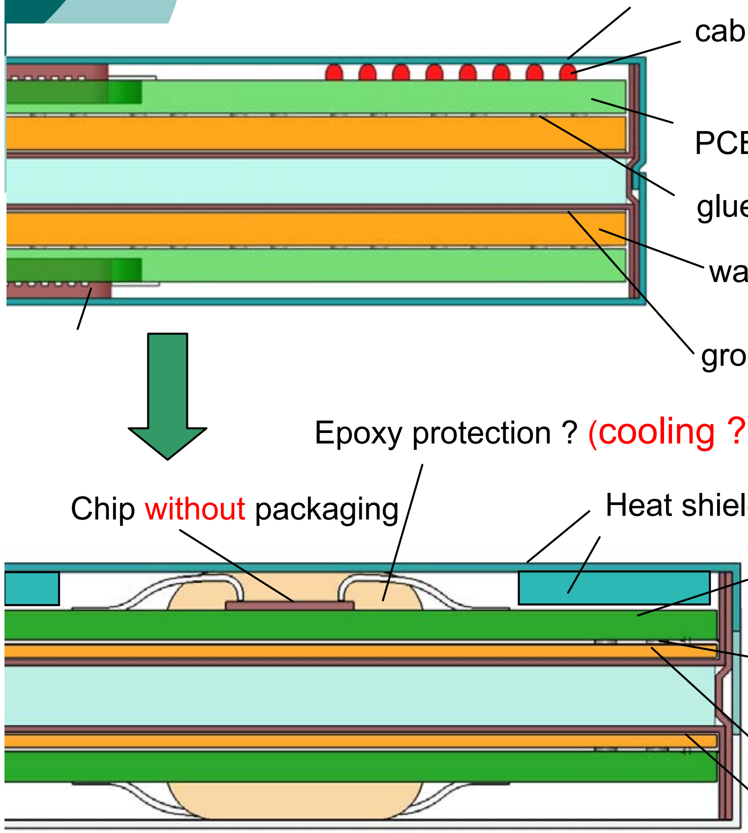
ECAL/HCAL Configuration 0°



TSAI-HILL ECAL/HCAL Configuration 0°

ECAL - Detector slab





Main ISSUES :

Front End chips inside :

⇨ Thermal dissipation (cooling ?)

⇨ Chip behaviour in an electron shower (tests with a thin PCB in October 2006)

- Long structure :

⇨ Design and fabrication problems (composite with segmentation of W plates, mechanical behaviour …)

⇨ Segmentation of PCB (design of an interconnection)

- Diminution of the pads size

⇨ Increases of the number of channels (thermal cooling ?)

⇨ Size of glue dots

ECAL - Thermal analysis

Thermal sources:

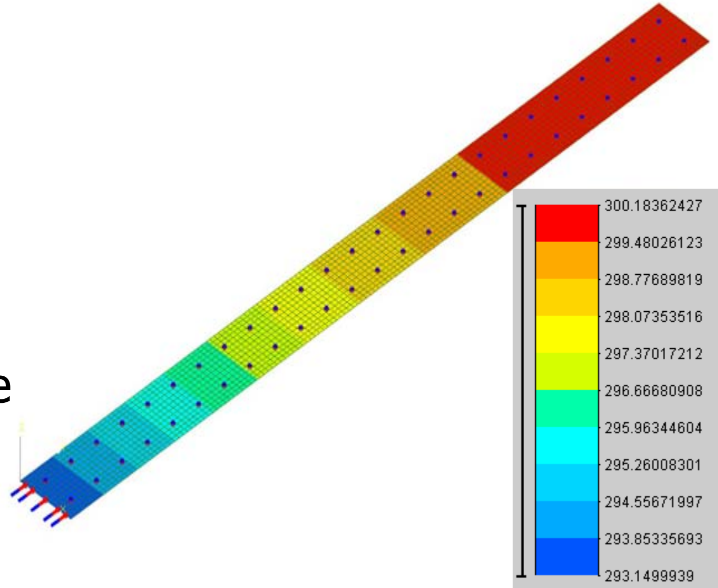
Pad size	Chan/ wafers	Ch/chip	Chip/wafer	Chip size mm^2	Chan/barrel	Chan/ End-cap
$5*5\ mm^2$	144	72	2	15x15	60.4 M	21.8 M

⇨ CALICE ECAL: ~ 82.2 M of channels

Assuming that the chip power is 25 μW/channel
total power to dissipate will be : 2055 W

⇨ external cooling OK

inside each slab :
necessity of cooling system but active or passive ?
Ex: Pessimist simulation of heat conduction just by the heat shield : $\lambda = 400$ W/m/K (copper) ; $S = 124*0{,}4\ mm^2$
$L = 1{,}55$ m ; $\Phi = 50*\ \Phi_{chip} = 0{,}18$ W

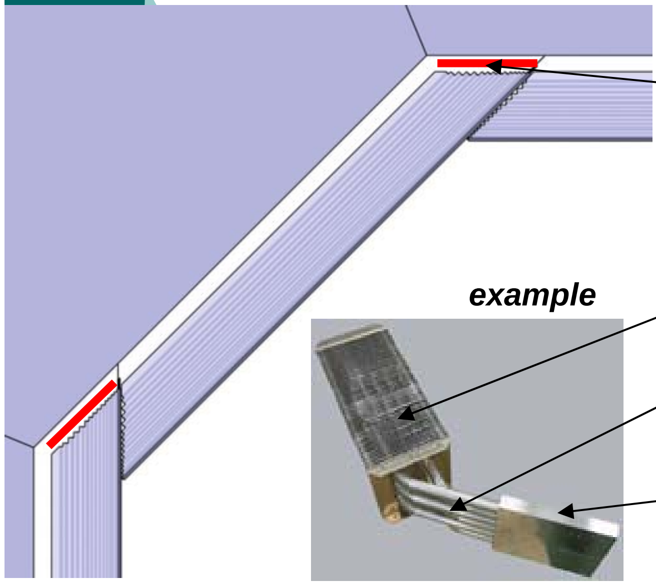


We can estimate the temperature difference along the slab layer around 7°C and without contribution of all material from slab (PCB, tungsten, carbon fibers…)

⇨ passive cooling OK ?

ECAL - Cooling technology

- External cooling location: for each module, on the front end, by pipes running in the space between ECAL and HCAL. Unfortunately, in the same space we will find all the slab's output/input.



- Nearly all heat generated by the chips will go to slab's front-end. Then, some cooling option can be foreseen:
  - •Thermal conductors (heat shield) can be added in the slab to carry heat more efficiently along the slab direction.
  - •Thermal cooling inside : by the way of heat pipes connected to cooling fans deported ; increase the thickness of slab.

- **<u>Interest</u>:** thermal conductivity of heat pipe > 1000 times copper's one.
  Heat pipes could "displace" the heat source in a busy place without energy source, without maintenance, at low cost. Heat pipe is only a means of transport for energy. (heat transfer is achieved thanks to a displacement of fluid)

EUDET Module - Presentation

Concept : to be the most representative of the final detector module :

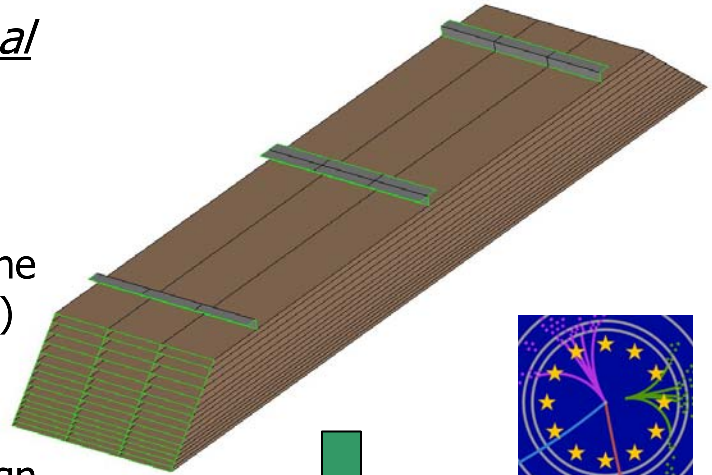
- A alveolar composite/tungsten structure with :

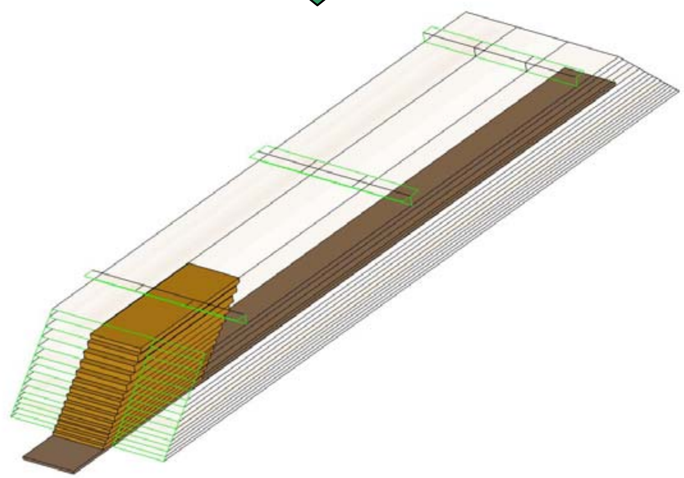
  - same radiator sampling
  - 3 columns of cells to have representative cells in the middle of the structure (with thin composite sheets)
  - Identical global dimensions (1.5m long) and shape (trapezoidal)
  - fastening system ECAL/HCAL (included in the design of composite structure)

- 15 Detector slabs with FE chips integrated

  - 1 long and complete slab (L=1.5m)
  - 14 short slabs to obtain a complete tower of detection (typ. L=30 cm?) and

  design of compact outlet.





R&D – EUDET module (2006-2007)

- *Long Type H structures* :

  - Design and fabrication of the long mould – (end of 2006)
  - Fabrication of validation model (1-3 samples)

- *module EUDET* :

  - 1.5 m long ; ≈ 500 Kg
  - real radiator sampling : 20 layers with 2.1 mm thick
    9 layers with 4.2 mm thick

- Design (mechanical and thermal simulations) of the module
- Optimization of composite sheets : studies of main parameters (thickness, shape ...)
- Fastening system on HCAL : design and destructive tests too
- Design and fabrication of the mould with an industrial expertise (DDL consultants)
- Transport tools
- Fabrication of the structure (end 2007)
- Mechanical support for beam test in 2008

R&D – Scope of work

Mechanical and thermal simulations :

Linear Analysis

- Global simulations :
  - weight configuration: Barrel and End-Caps static study with external load (HCAL, LumiCAL …)
  - Nodal displacements: weakness of system mainly located on fastening points of modules hung on HCAL.
- Local simulations : more precise simulations and study of different local parameters to design correctly each part of this structure (thickness of main composite sheets, choice of fasteners …)

Tests :

- Destructives tests to check local simulations
- Fastening systems and interface integration on composite structure
- Production specifications and moulds for long alveolar structure (Eudet)

Medium-term perspectives :

-

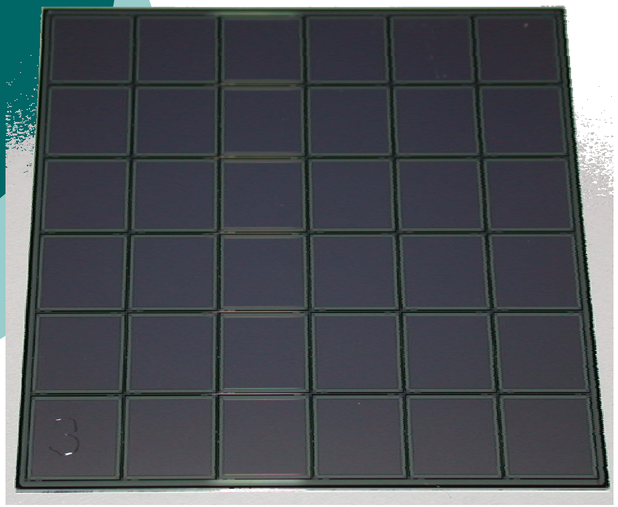
- New calculation performed on each of module structures
- Finite Element Model of a HCAL/ECAL to estimate the overall deflection,
- Work to be done on the fastening systems (rails, facilitated insertion of modules)
-Thermal analysis and technology: design and test of heat pipes – connection to slab
-Other cooling fluids (air, forced convection,…) to be studied if necessary.

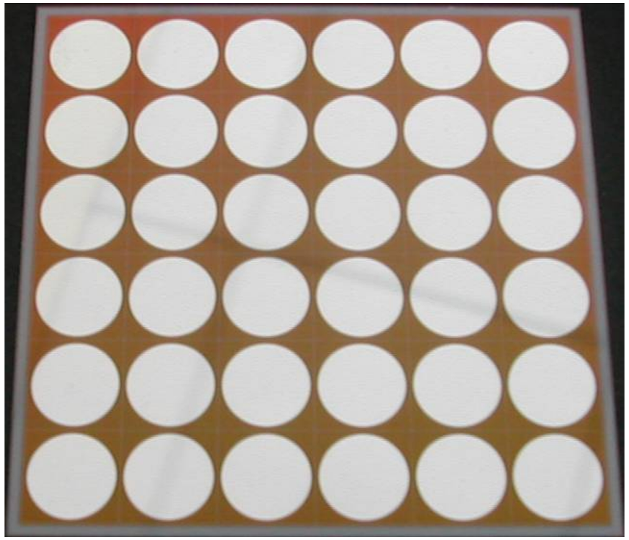
Silicon detector R&D

On behalf of Jean-Charles Vanel

LLR

Starting point : the physic prototype





- Several producer
  - To manage production risks
    - Russia
    - Czech Republic
    - Korea
    - Brazil
    - India
    - Contact with Hamamatsu

Final detector : Cost driven

Parameters change

	CALICE Physic prototype	EUDET Module
Thickness	525µm	300µm
Pad size	$1*1cm^2$	$5*5mm^2$
MIP in electron	42000	24000
Pad capacitance	21pF	9.2pF
Full depletion	~150V	~75V

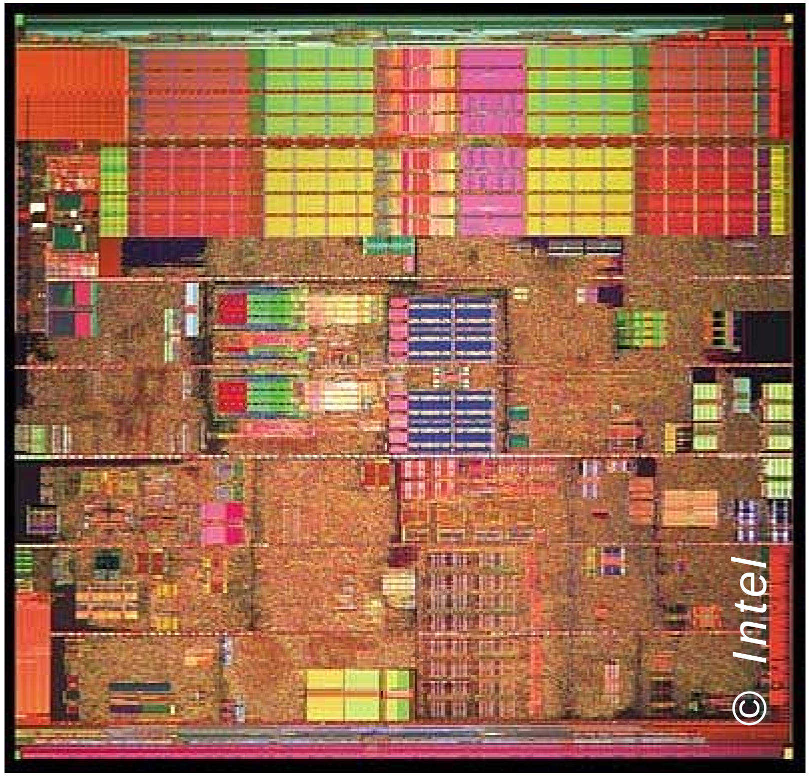
- *Still under study : Guard ring issues, leakage current*
- *Many data provided by test beams to be analyzed*
- *ECAL physic prototype analysis crucial for good detector optimization*

Electronic R&D

ILC_PHY5

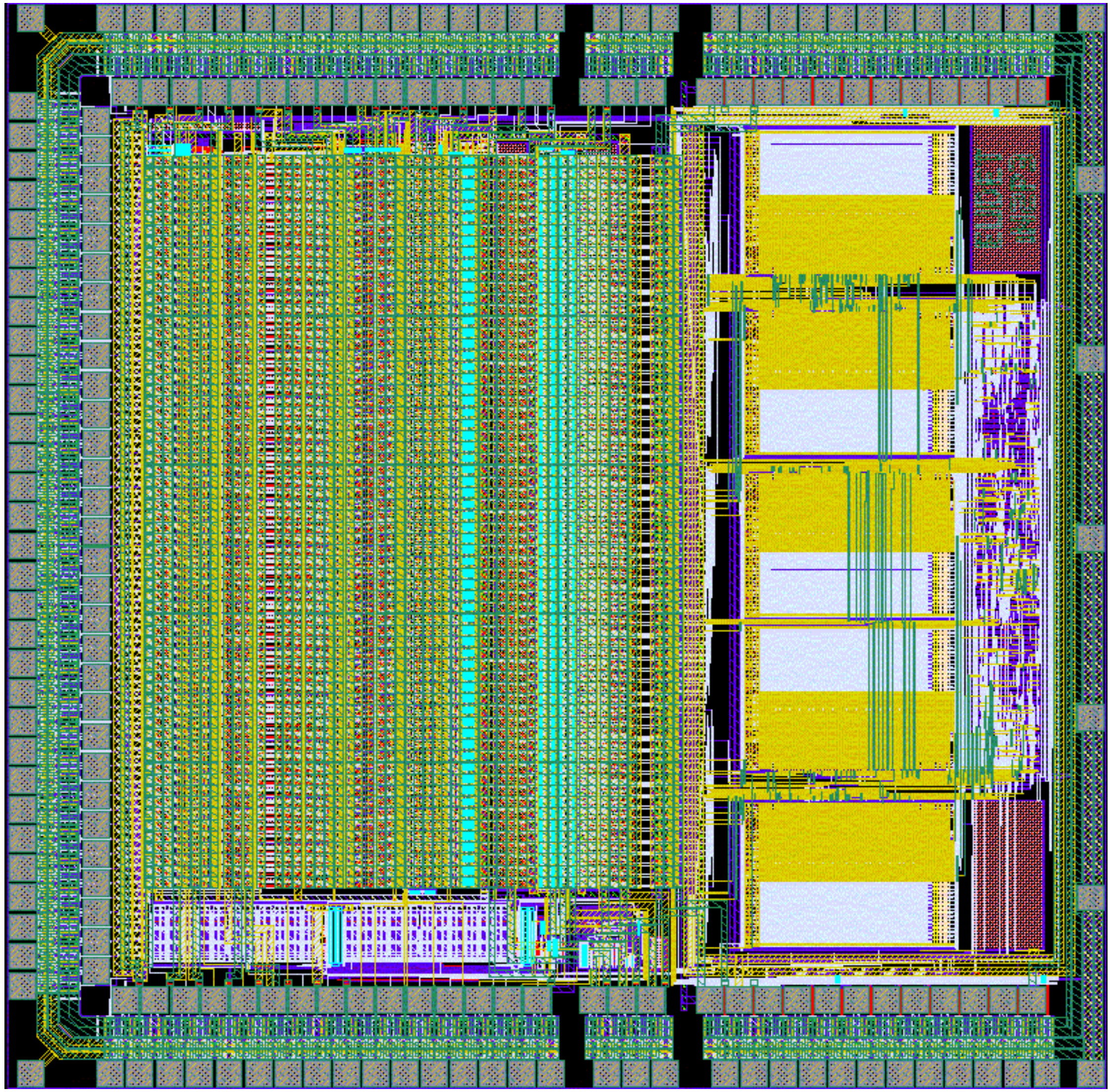
In behalf of :

LPC/LAL/LLR/UCL

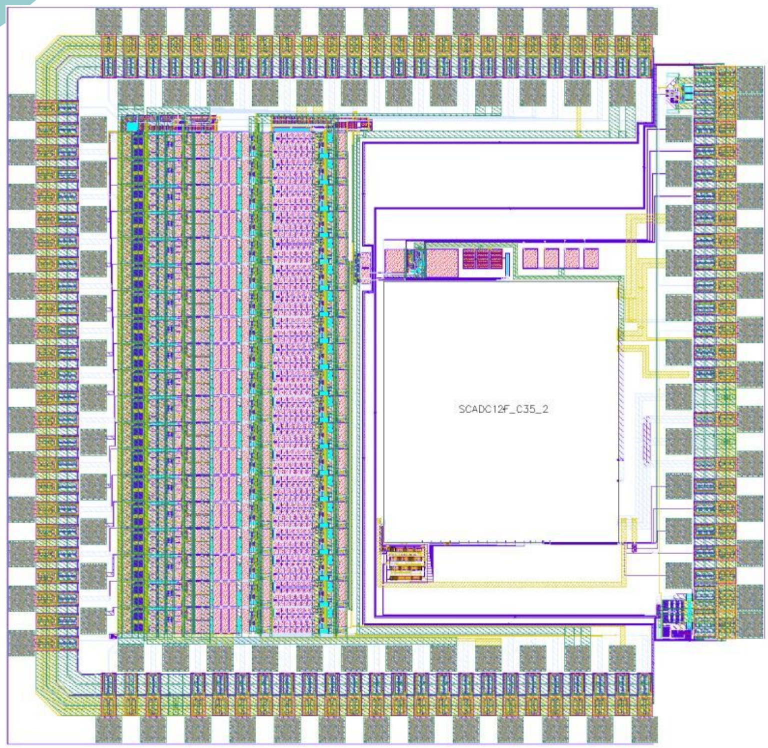


System on Chip design

HaRD_ROC (2006)



ILC_PHY4 (2005)



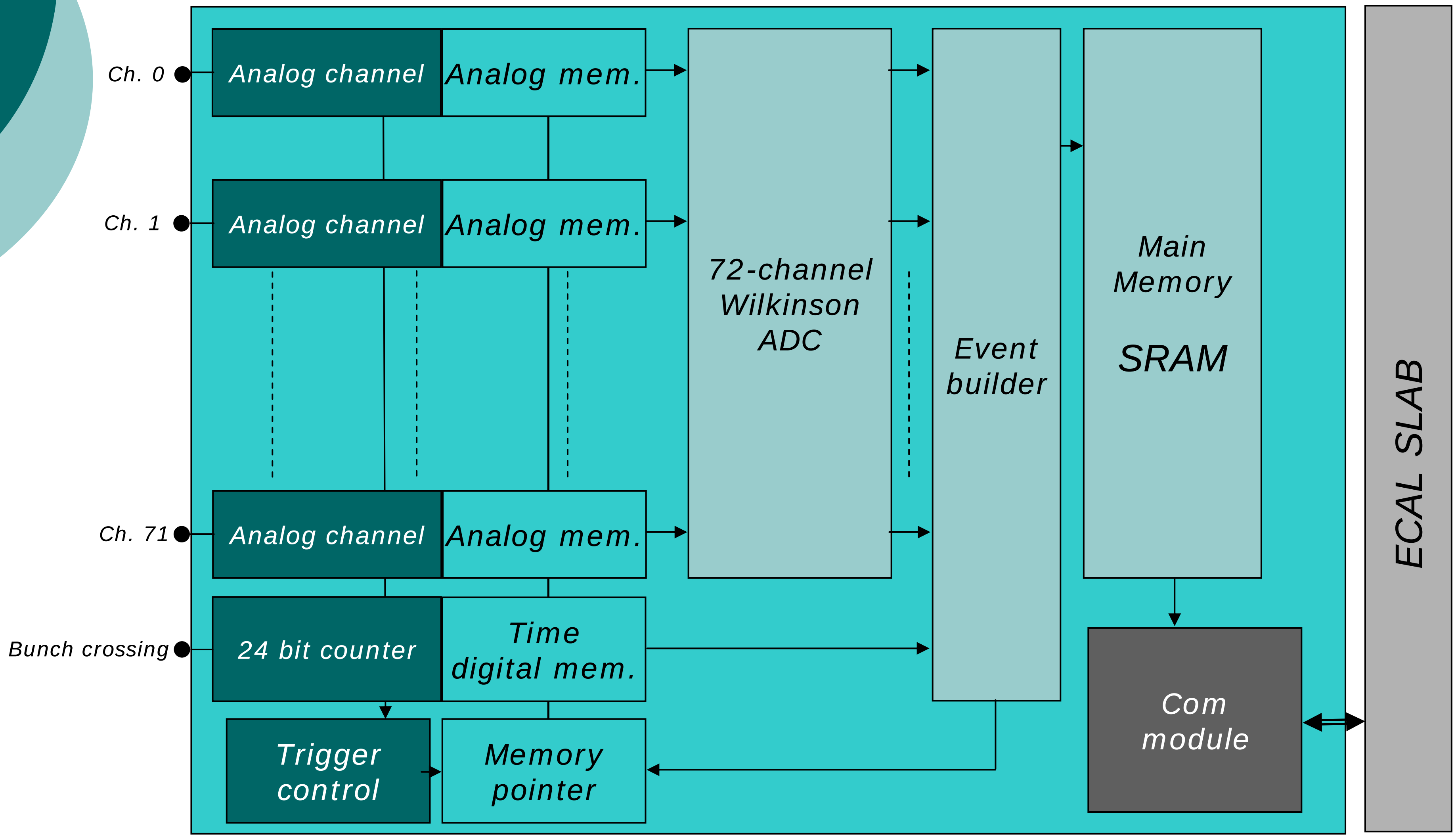
Requirements for FEE

- Designed for 5*5 mm² pads
- 72 channels (first proto 36 ch.)
- Detector AC/DC coupled
- Auto-trigger
- 2 gains / 12 bit ADC → 2000 MIP
  - Energy resolution :4.89 GeV (cf JCB)
- 24 bits Bunch Crossing ID
- Internal SRAM with data formatting
- Output & control with daisy-chain

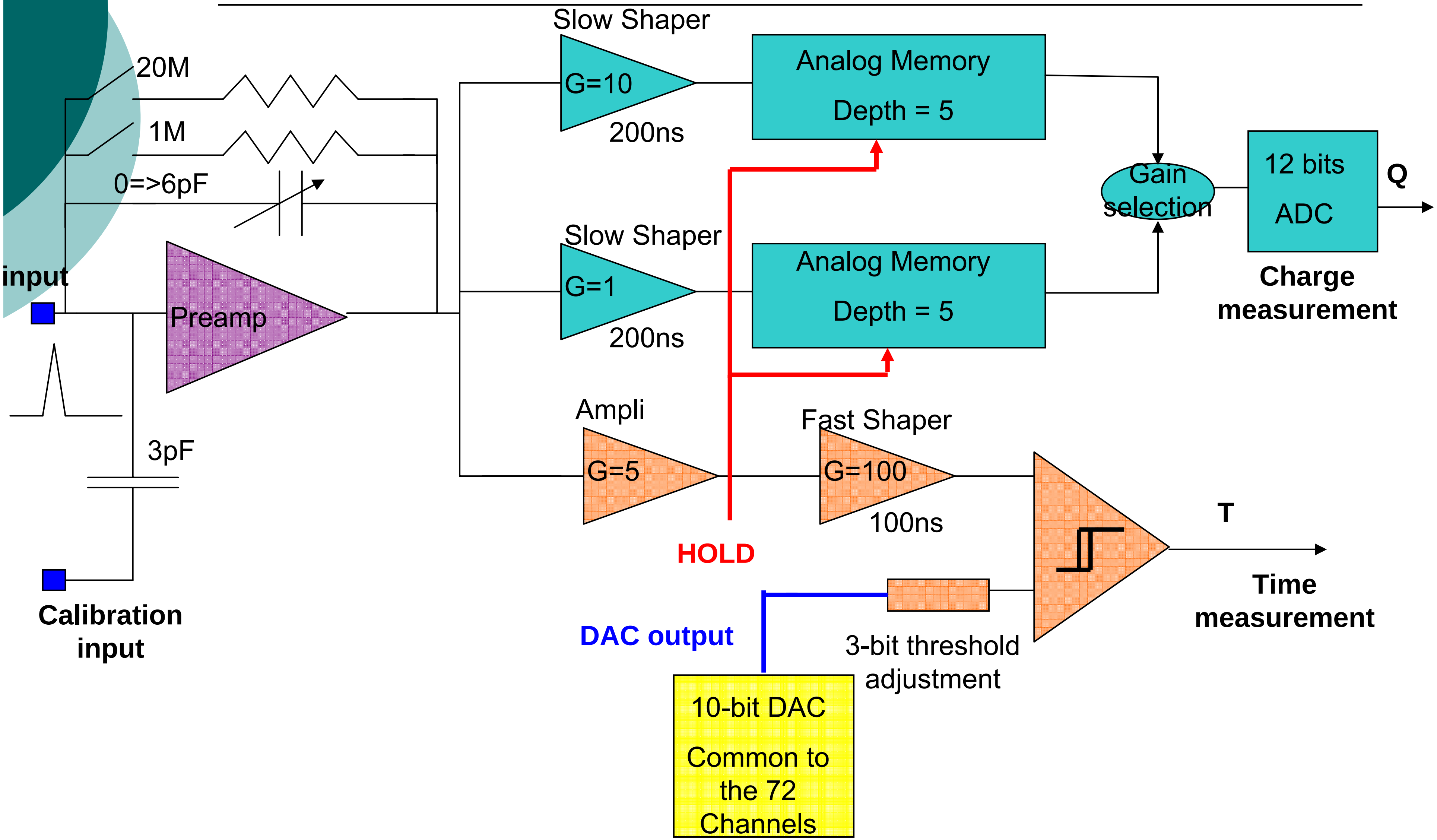
Requirements for ILC_PHY5 (contd)

- Power pulsing
  - Programmable stage by stage
- Calibration injection capacitance
- Embedded bandgap for references
- Embedded DAC for trig threshold
- Compatible with physic proto DAQ
  - Serial analogue output
  - External “force trigger”
- Probe bus for debug

General block scheme

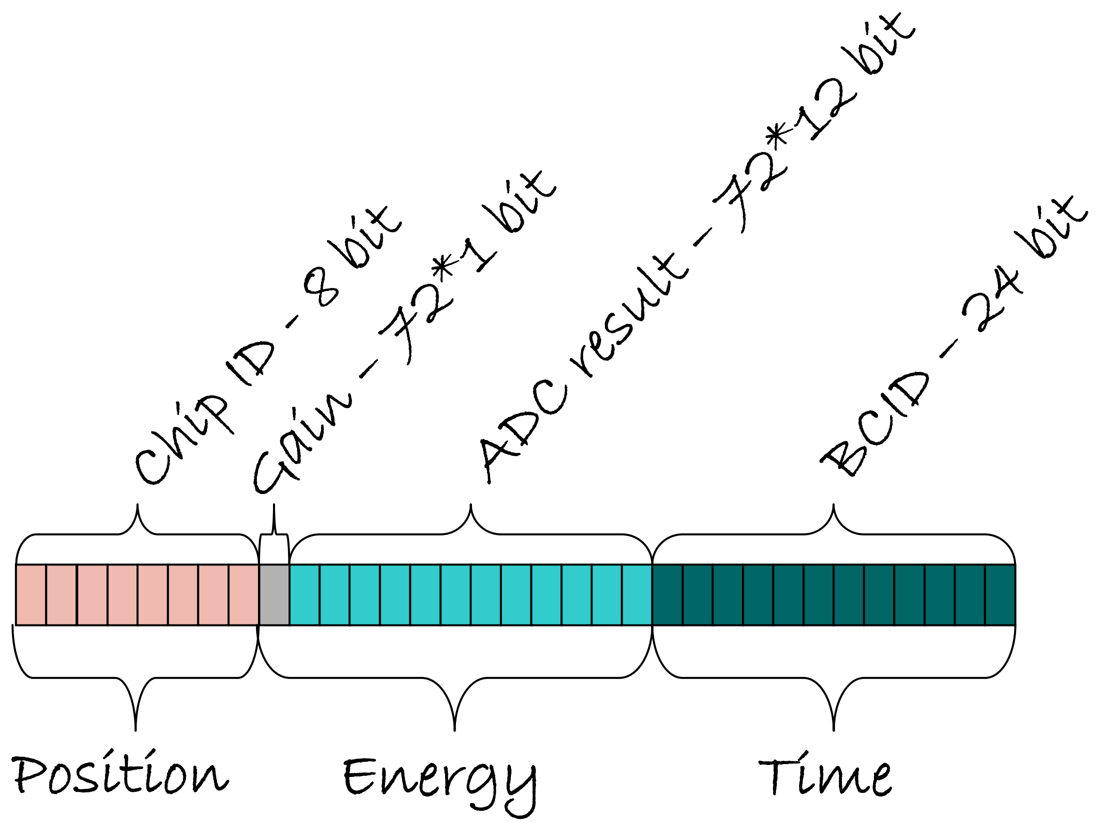


One channel



Slow Shaper
G=10
200ns
Analog Memory
Depth = 5
20M
1M
0=>6pF
Slow Shaper
G=1
200ns
Analog Memory
Depth = 5
Gain selection
12 bits
ADC
Q
Charge measurement
input
Preamp
3pF
Calibration input
Ampli
G=5
Fast Shaper
G=100
100ns
HOLD
T
Time measurement
DAC output
3-bit threshold adjustment
10-bit DAC
Common to the 72 Channels

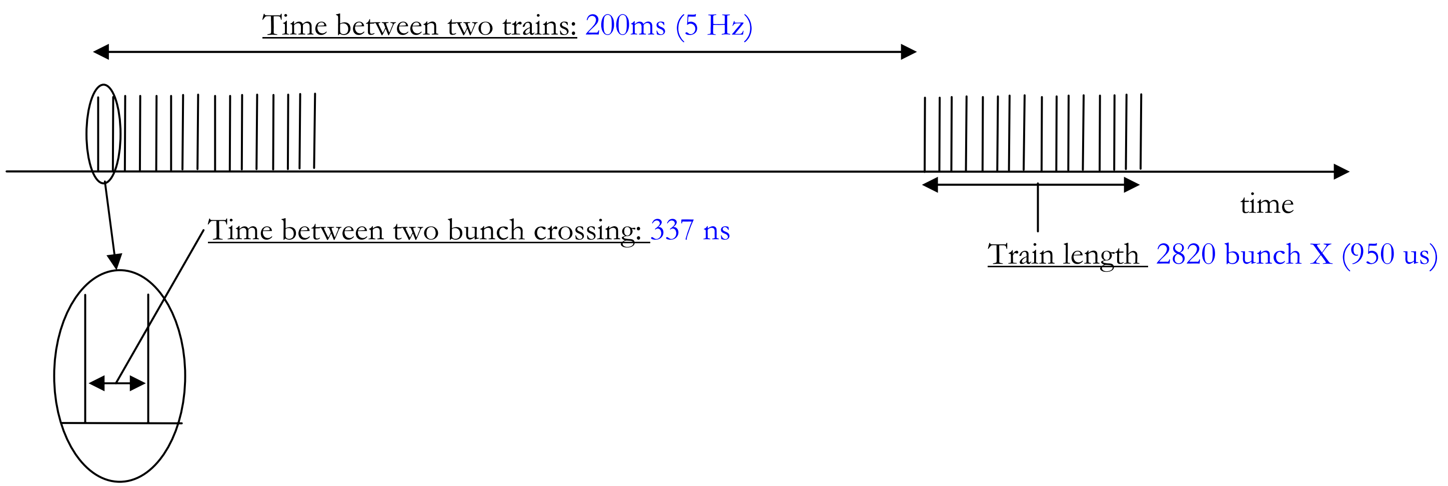
One ILC_PHY5 event

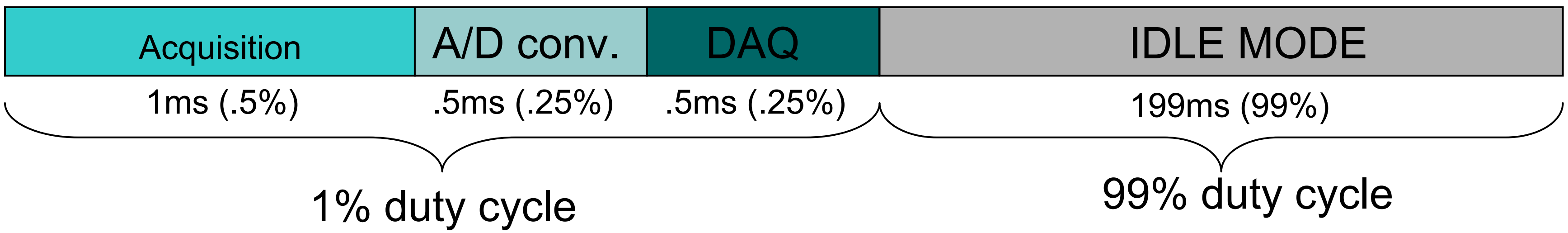


→ 968 bits / chip event

- Depht is 5 because of room on silicon

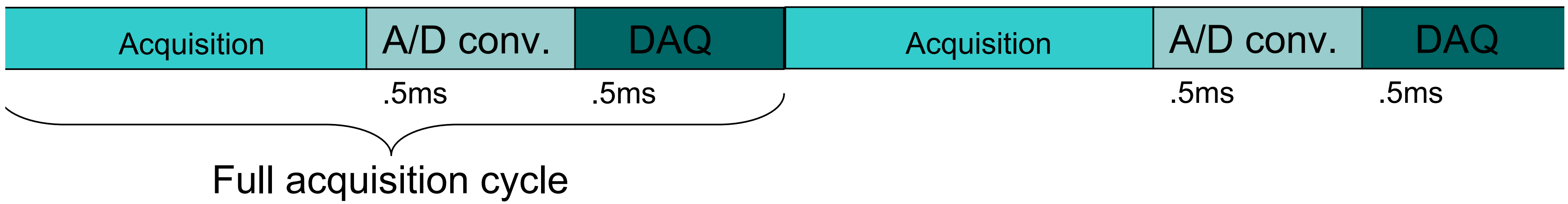
Time considerations





And for test beam …

When spill :



When no spill :

IDLE MODE

Duty factor = duty factor of the spill structure

Consumption

- The goal is 25µW/ch. (with Power Pulsing)
- The analogue part consumption :

  is 2.3mW/Ch. Without Power Pulsing

  ie 11.5µW with 99.5% Power Pulsing
- The ADC part comsumtion :

  is 3.7mW/Ch. Without Power Pulsing

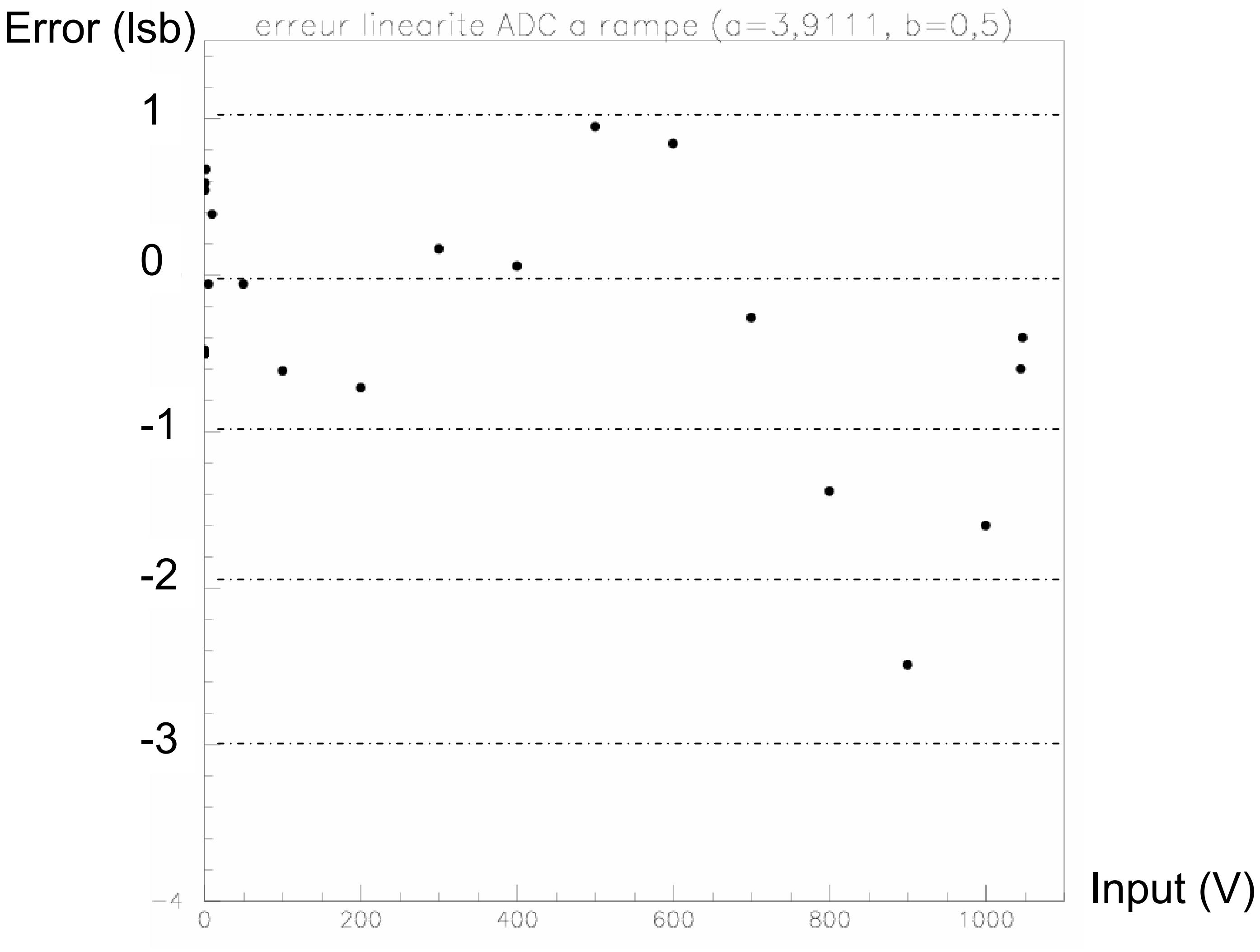
  Ie 9.25µW/Ch. With 99.75% Power Pulsing
- Need to estimate digital part consumption

→ So far, on track

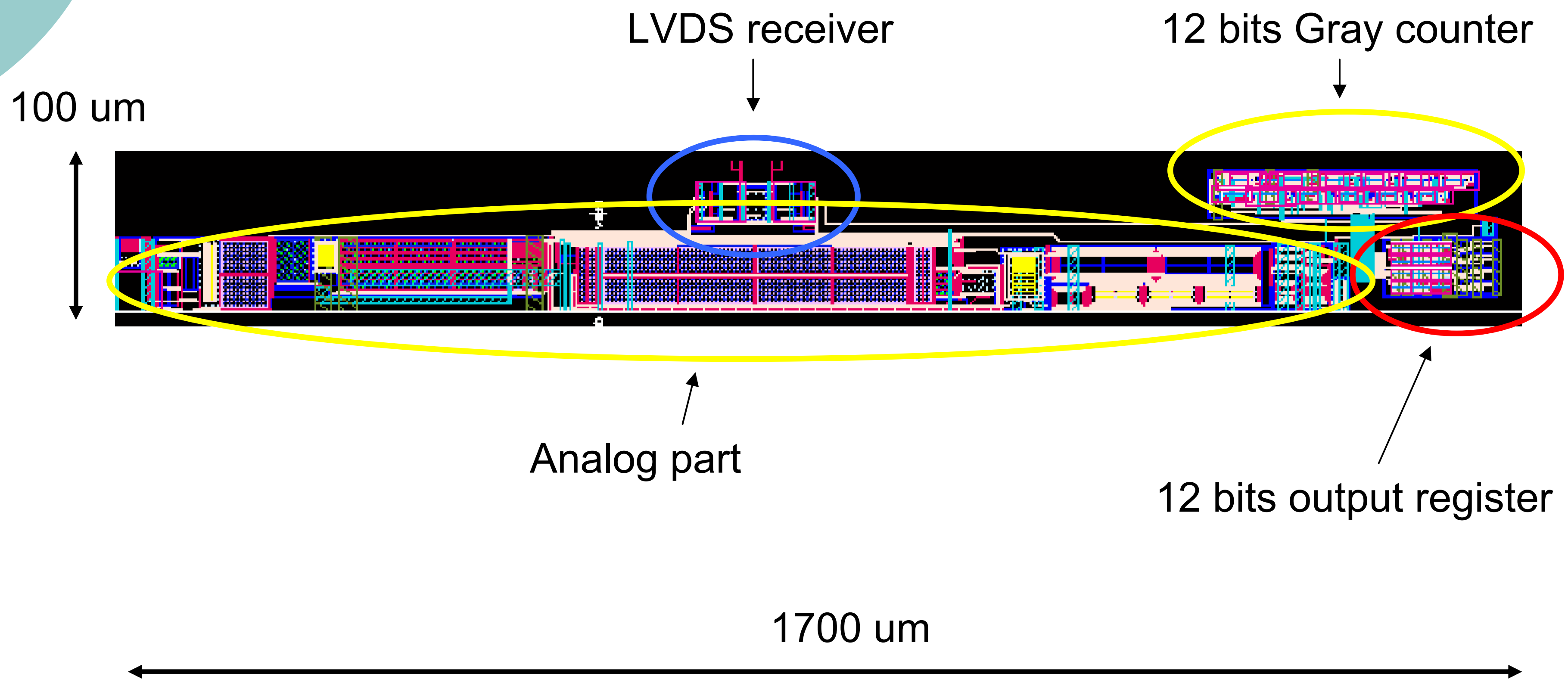
Wilkinson ADC description

- Main characteristics
  - Technology ams BiCMOS SiGe 0.35
  - Fully differential structure (MC to MD input stage)
  - 1V input dynamic range
  - 12 bits output Gray code
  - Counting frequency: 50MHz → 82µs conversion time
  - Power supply: 3.5V (analog) and 2.5V (digital)
  - Power consumption < 3mW
- Circuit (1 channel) submitted in september

Linearity error (simulation)



Ramp ADC: layout (1 channel)



ILC_PHY5 schedule

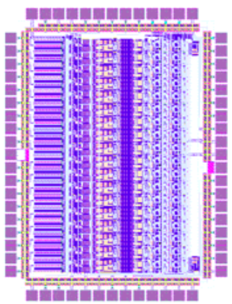
- Analogue blocks :
  - Designed
  - Simulated
  - Layouted
- Digital blocks :
  - HaRD-ROC & MAROC2 as a starting point
  - Many modifications to be done
- Wilkinson ADC : submitted (1 ch)
- Submission : November 24

Conclusion

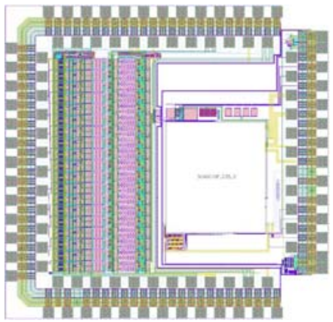
- Work is going on
- Complexity increases quickly

- Collaboration is very efficient and fruitful. It shall achieve the outstanding expectations within the very tight schedule

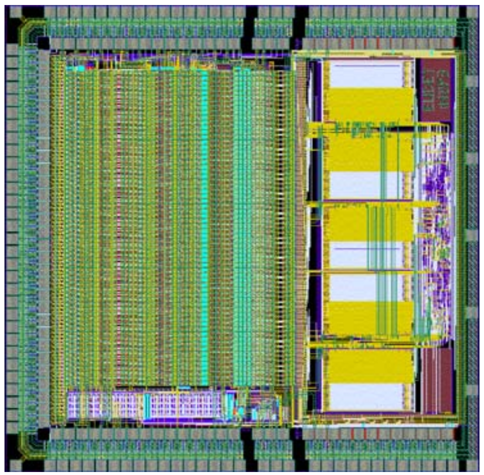
FLC_PHY3 (2003)



ILC_PHY4 (2005)



HaRD_ROC (2006)



ILC_PHY5 (2006)