Presentation

SiW Ecal Compact Digital Electronics: implementation & performance in test beam

Pöschl, R. (CNRS-LAL) *et al*
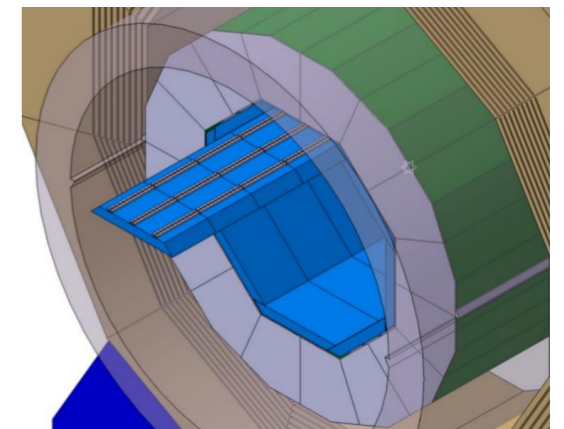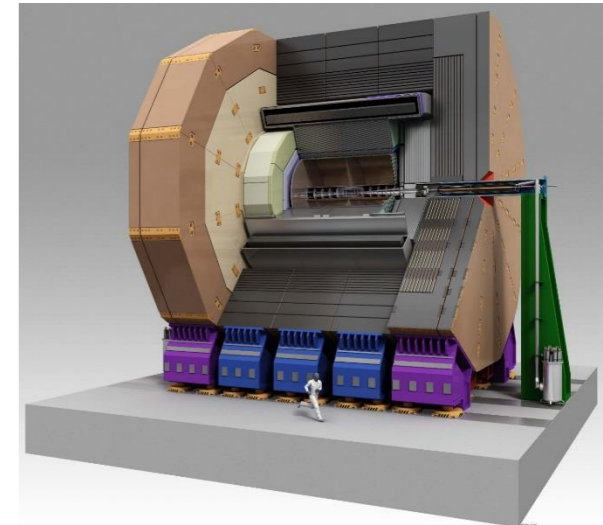
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SiW Ecal Compact Digital Electronics: implementation & performance in test beam

D.Breton, J.Jeglot, J.Maalmi, P.Rusquart, A.Saussac (SERDI ,LAL)

A.Thiebault, J.Bonis, D.Douillet, A. Gallas, C.Bourgeois (SDTM, LAL)

A.Irles, R.Pöschl, D.Zerwas (LAL)

On behalf of the groups working on the CALICE SiW ECAL

Introduction

- Description/ status of the new SiW Ecal compact digital electronics
  - SL-Board + Kapton interface
  - CORE module : Control and Readout

- Implementation in last test beam : June 24th – July 7th 2019
  - Physics results will be presented in next talk
- Poster presented at Twepp 2019 :
  « New compact readout electronics for SiW Ecal »
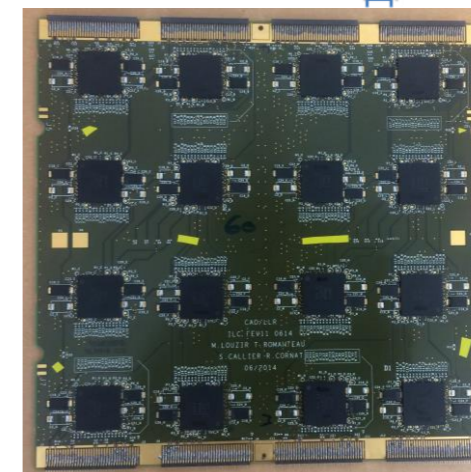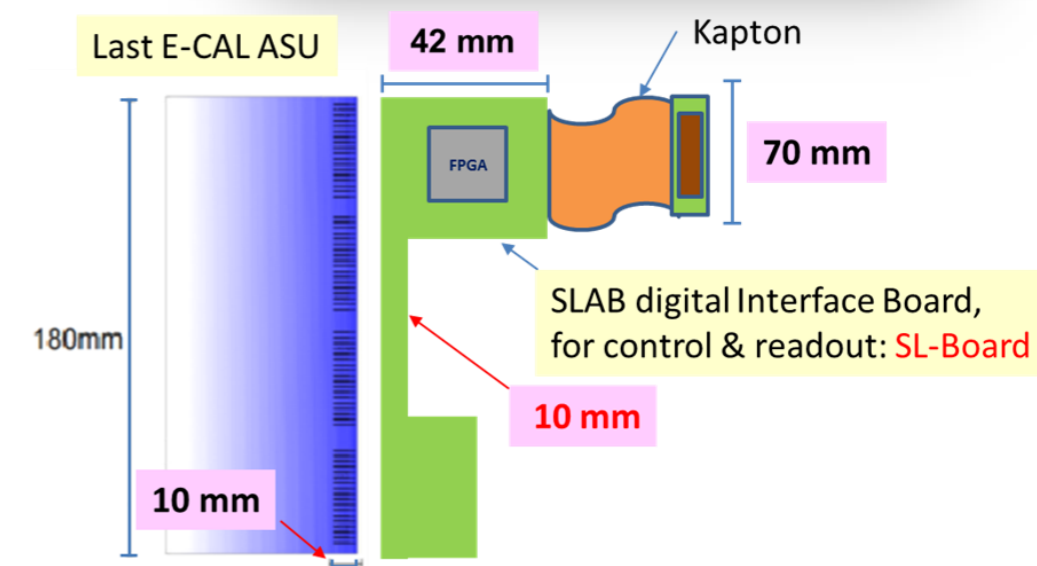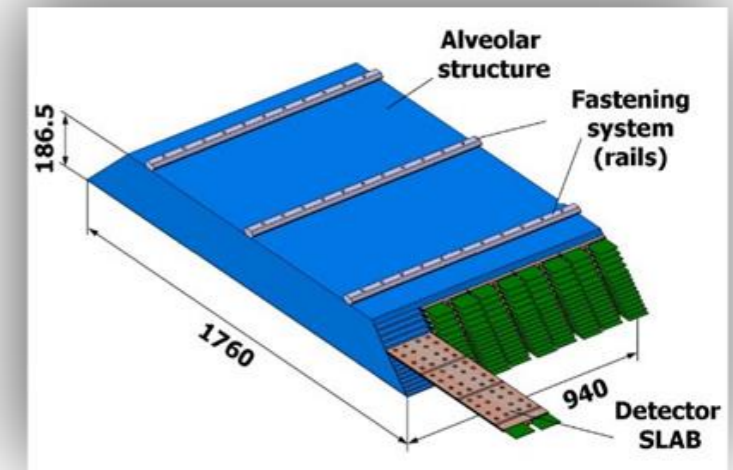- Future plans

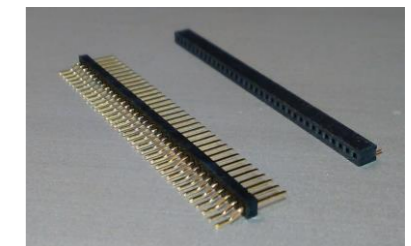## Spatial constraints for the Active Sensor Units (ASUs)

- Very limited space **between layers (depending on the total number of layers)**.

- Two protoype versions have been realized with different SKIROC packaging and thickness:
  - BGA option : PCB + components*(1,2 mm)* + connectors = **~ 3,2 mm**
  - COB (Chip On Board) option : PCB and ASICs **= 1,2 mm** + connectors = **~2,3 mm**

Constraints for the Slab Interface Board (SL-Board)

- The SL-board will be installed between ECAL and HCAL, separated by only 67 mm
- L-shape because of the cooling system
- Maximum Height : **6 to 12 mm depending on the location**
- Control & Readout electronics at the extremity of the Slab
- Signal integrity over a Slab : up to 15 interconnected ASUs
- Very low power consumption (~ 150 mA/ Slab) : needs to run in **power pulsing mode**

Alveolar structure
Fastening system (rails)
186.5
1760
940 Detector SLAB

Last E-CAL ASU
42 mm
Kapton
FPGA
70 mm
180mm
SLAB digital Interface Board, for control & readout: SL-Board
10 mm
10 mm

ASU: FEV 11, with Skiroc BGA option, and the gradconn connectors

Gradconn connectors (1,5 mm high)

Global Architecture Scheme

~ 2 x 15 slabs

Gbit UDP/USB/Optical Fibre

Control & Readout Kapton

Control PC

CORE-MOTHER

CORE-Daughter

CORE-Daughter

SL-BRD

ASU /WAFER

ASU /WAFER

ASU /WAFER

Other utility I/Os

External clock

Data : 40 /80 Mbits/s

HV Kapton
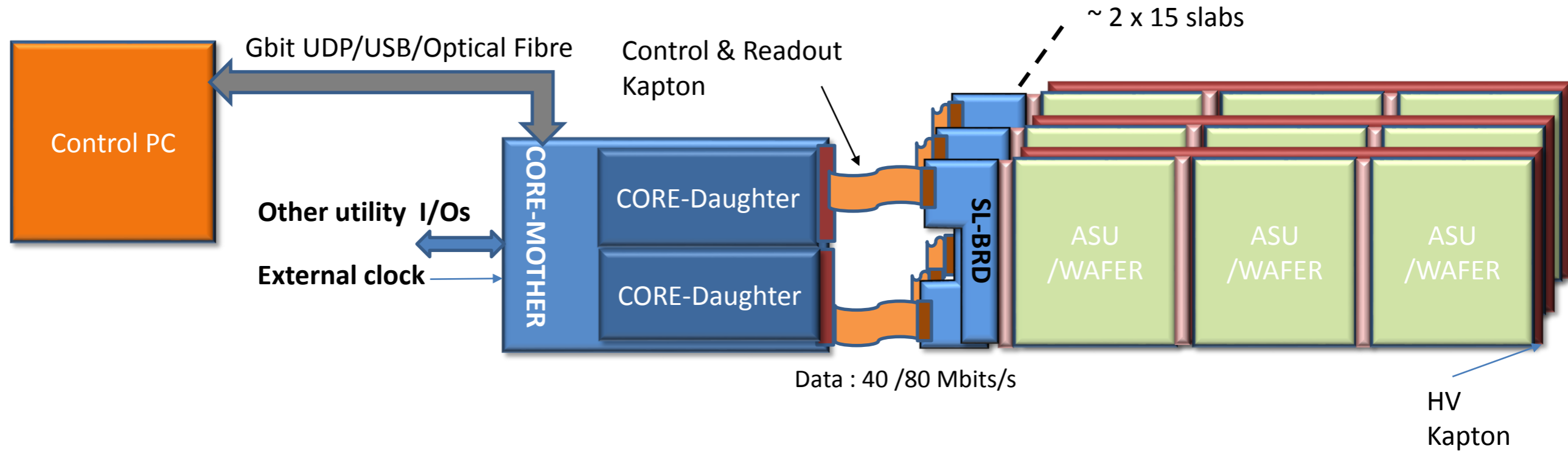
CORE *Module/Mother/Daughter* : Control and Readout
SL-BRD : Interface board to Slab

External clock and Utility I/Os : possibility to be synchronised with other systems!

The SL-Board

The **SL-Board** is the sole interface for the **~10,000 channels of a slab :**

- It delivers the **regulated power supplies,** including **High Voltage**, **controls** the SKIROC ASICs, and **perfoms the full data readout**.
- It is connected to the CORE-Kapton via an internal **kapton layer** and a 40-pin connector.
- It is based on a **MAX10 from ALTERA**, which is a mix of CPLD and FPGA.
- It includes an ADC which will be used to monitor the pulsed power supply.
- Very size **limited:** 18 cm in width, 10 to 42 mm in length.
- Its **own power** consumption is **< 1W**
- It can also be an **autonomous system** with direct computer access for testing and characterization purposes (using the **FTDI USB module**).
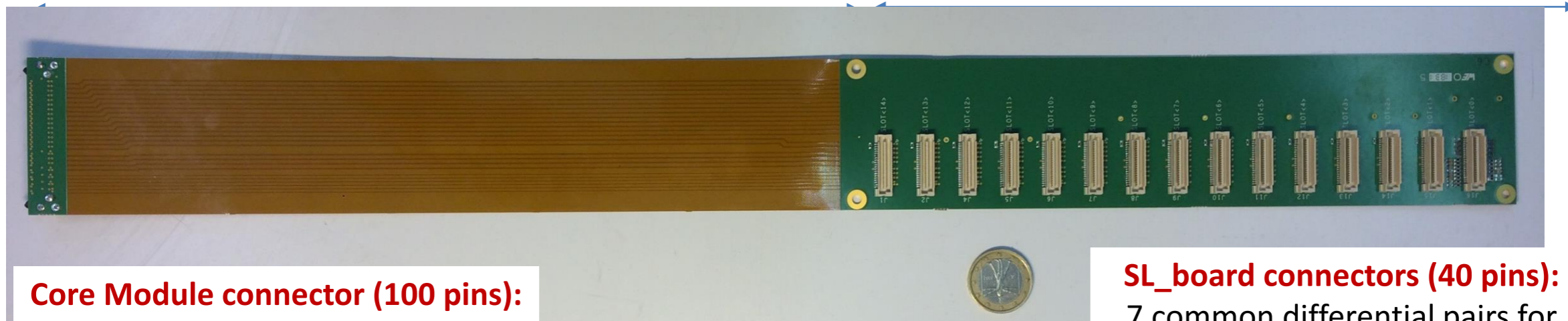
The SL Board Core-Link (Core-kapton)
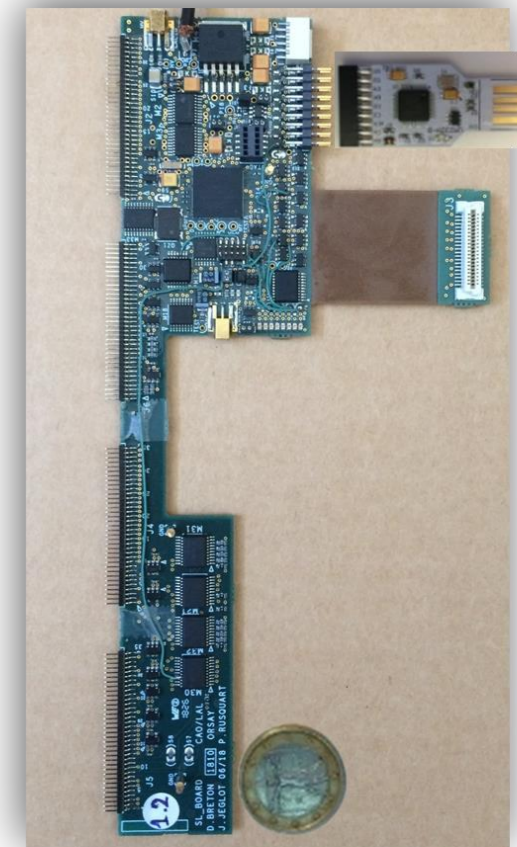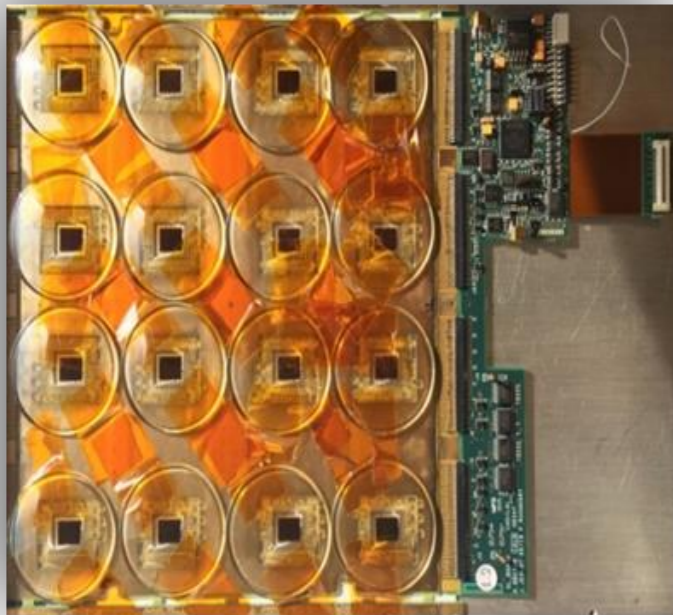
CORE side — Flexible kapton — Total length ~40 cm — Slab side (~22cm, rigid, pitch of 15mm)

Core Module connector (100 pins):
7 common differential pairs for sensitive signals, *30 individual pairs* for control and readout, 14 common lines, GND
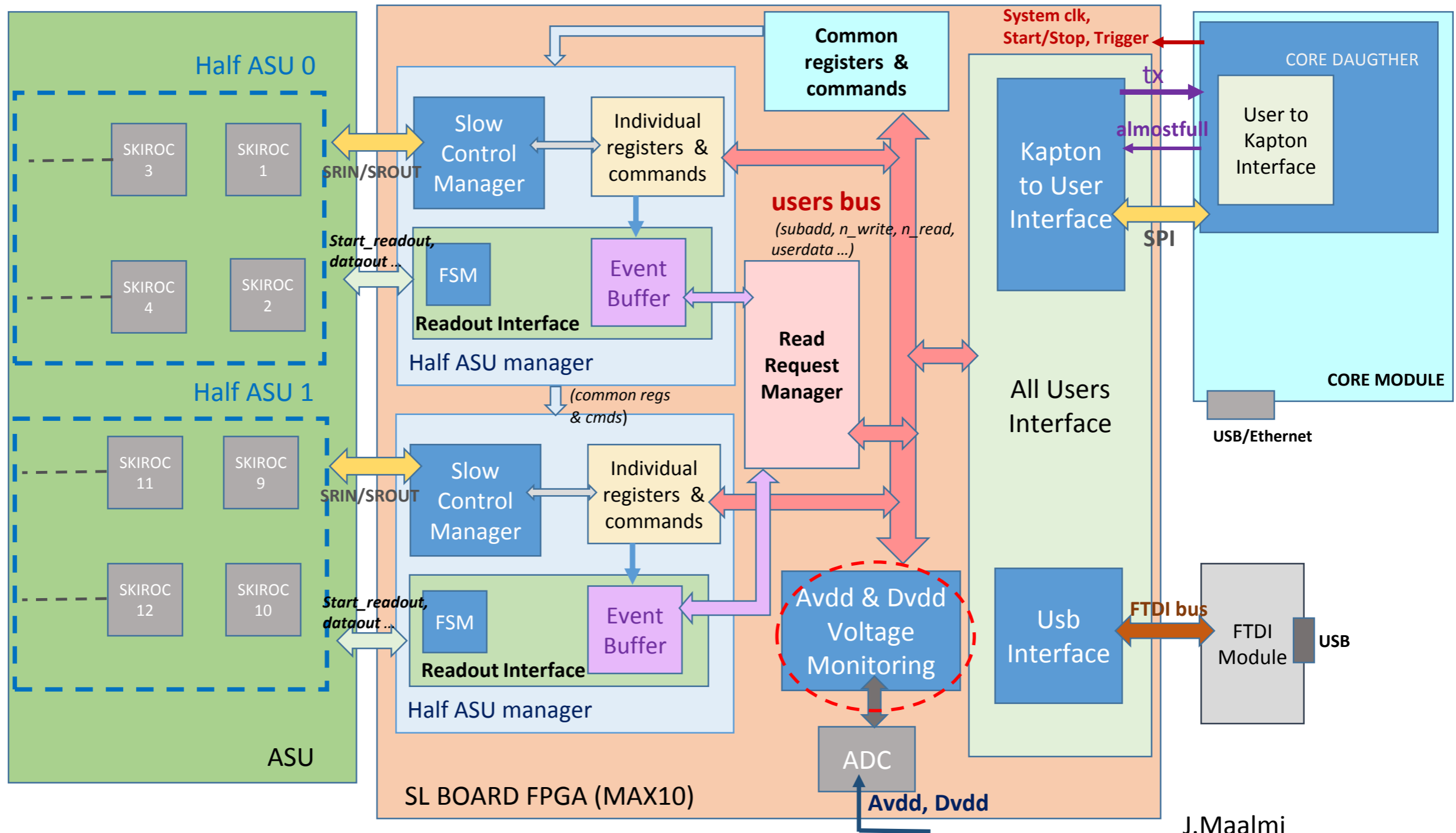
SL_board connectors (40 pins):
7 common differential pairs for sensitive signals, *1 individual pair* for control and readout, 14 common lines, GND

- The **CORE kapton** measures 40 cm. It is the **interface** between the CORE Daughter and the SL-Board. It permits driving and reading out **up to 15 slabs**.
- It transmits all the **clocks and fast signals**, and houses the control and readout links.
- It handles the **synchronisation** of the **15 slabs**.
- The Kapton Interface makes use of **asynchronous serial transmissions** in order to greatly simplify the synchronization of the numerous control and data links.
- The speed of the slow control and the individual readout links is : **40 Mbits/s**
- Reminder : readout link of the ASUs **: 2 x 5 MBits/s**

HDMI from CCC

Guiding/receiving signals to/from slabs
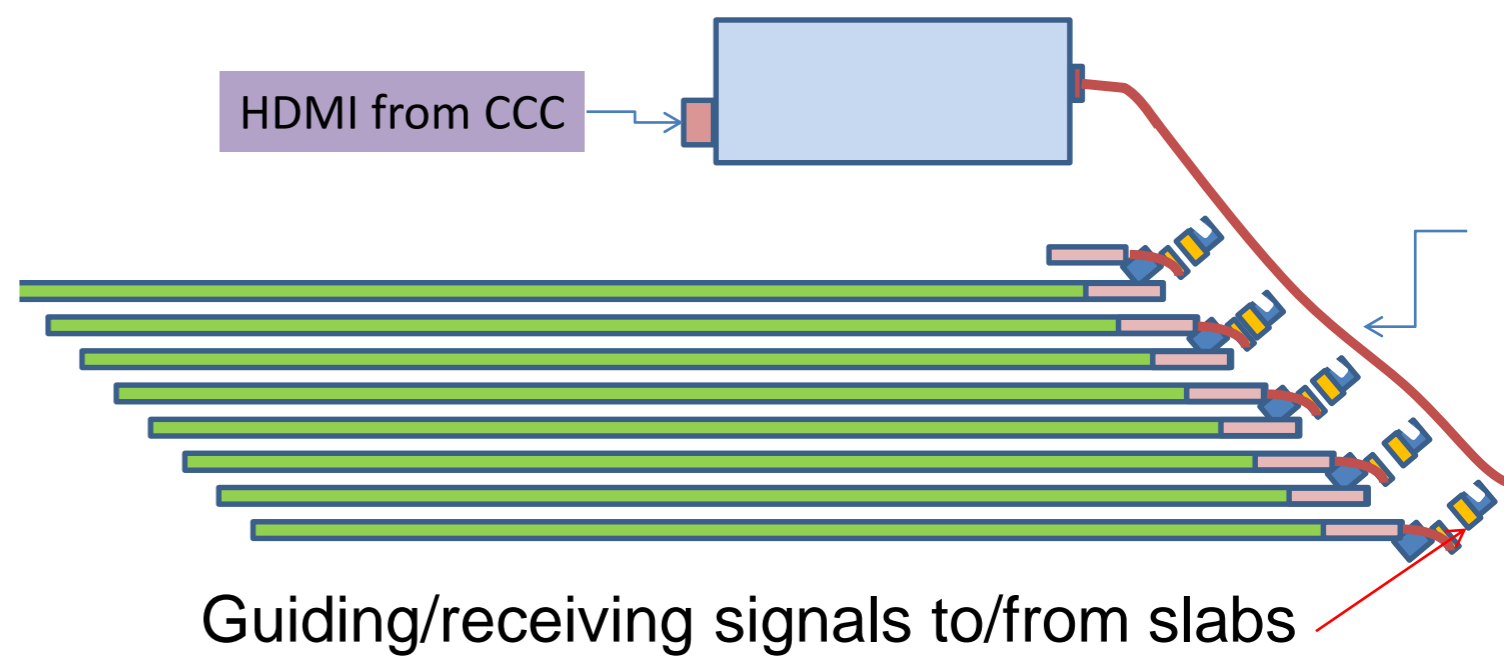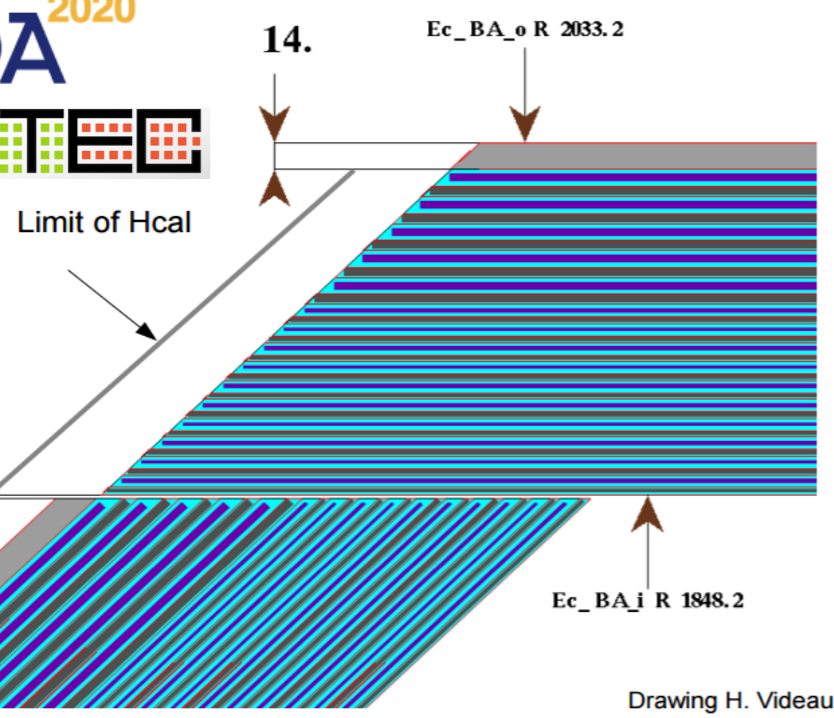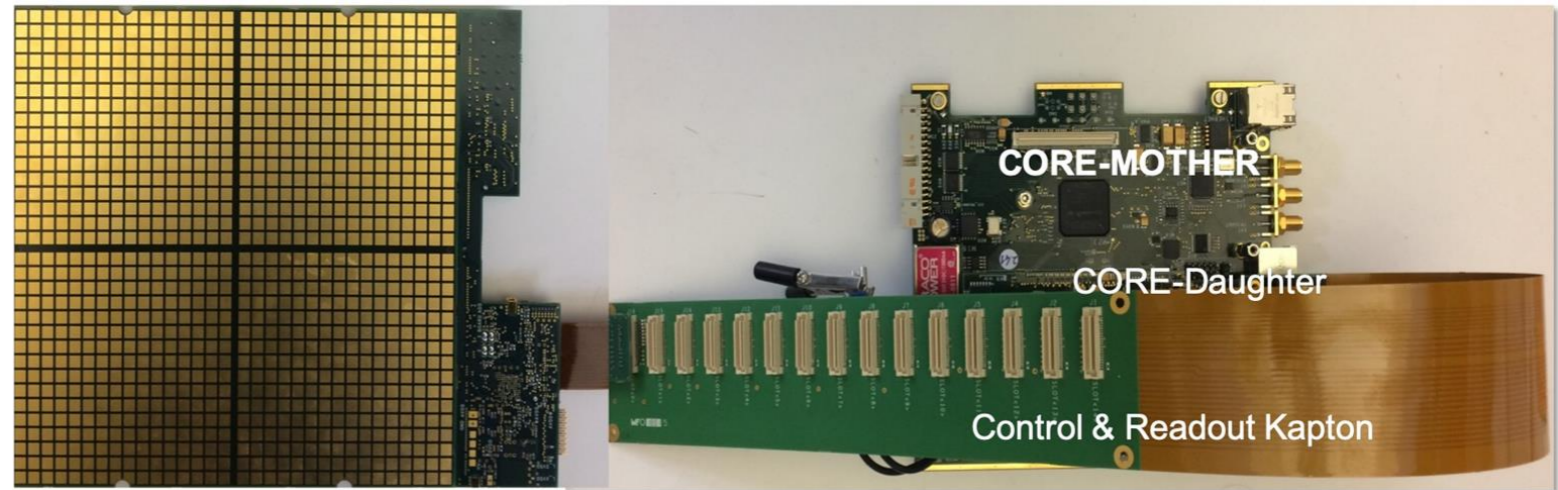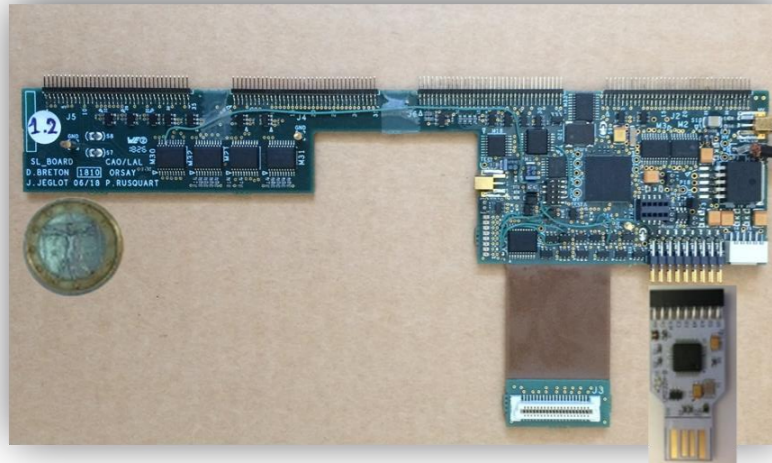
Approximately 6cm between Ecal and Hcal

SL Board Firmware diagram:

The CORE Module

The CORE Mother:

- The **Control and Readout Motherboard** have been developed for housing up to 2 **Mezzanines**: it permits separating the **acquisition** part from the specific front end part.
- **External** input and output signals permit **synchronising** or interfacing the module with other systems.
- The CORE mother sends common clocks and fast signals to the Core Daughters to keep the **system synchronised**
- The control and readout is possible through **USB(2.0)**, **UDP or Optical link** (Ethernet over optical)
- The CORE module **power consumption** is **5 W**

The CORE mother

The CORE module

The CORE Daughter:

- The **CORE Daughter** is based on a Cyclone IV FPGA. It is the interface between the CORE motherboard and the Kapton which permits driving and reading out **up to 15 slabs**.
- It buffers all the clocks and fast signals, and deals with the control and readout links through the Kapton Interface.
- It houses the second level of **event buffers** (derandomizers)**.**
- Ctrl & Readout link between CORE Daughter and CORE Mother : **60 MBytes/s** if USB**, and 125 Mbytes/s if UDP.**

The CORE daughter

Software Development Status: Main Panel for Acquisition:
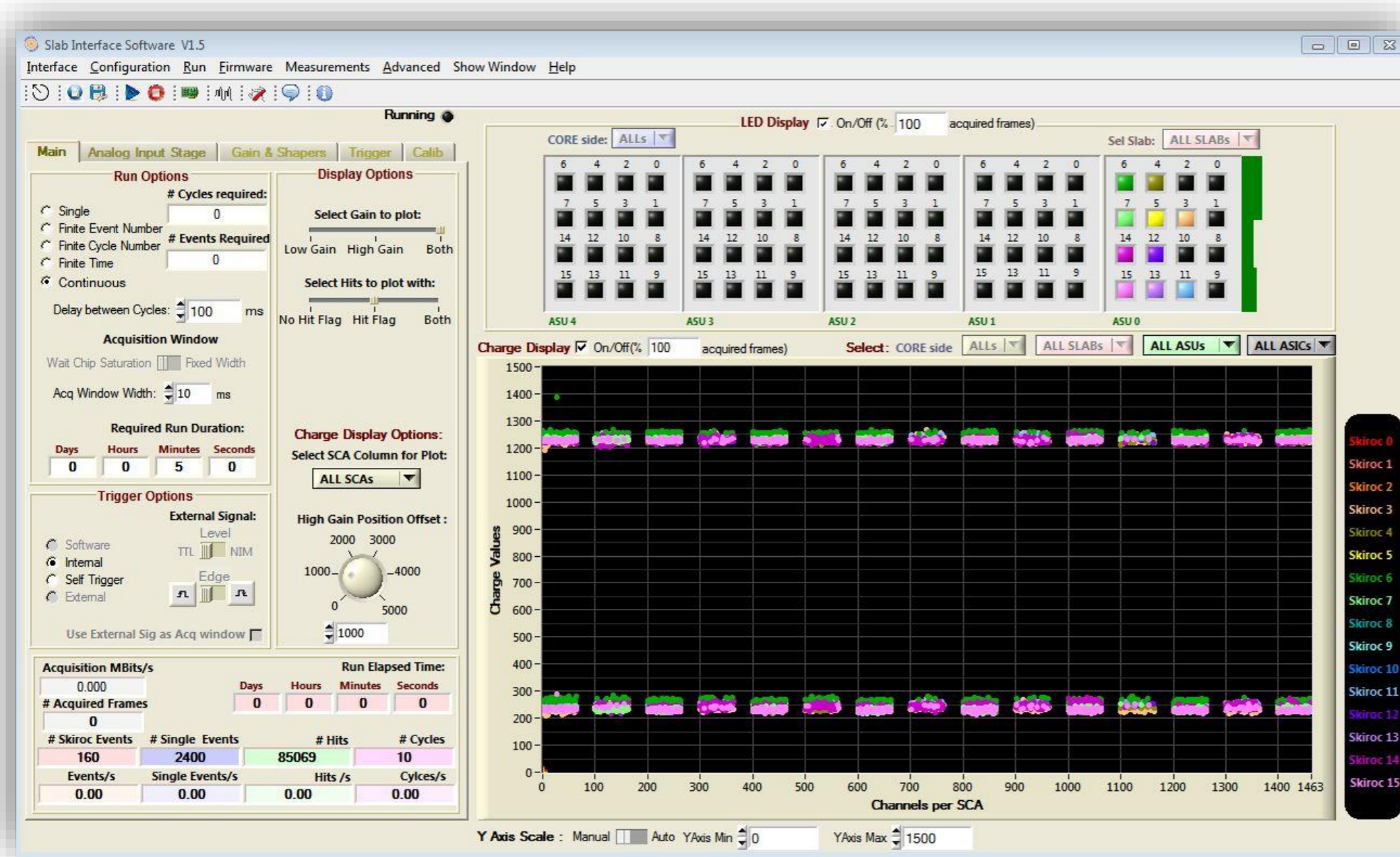
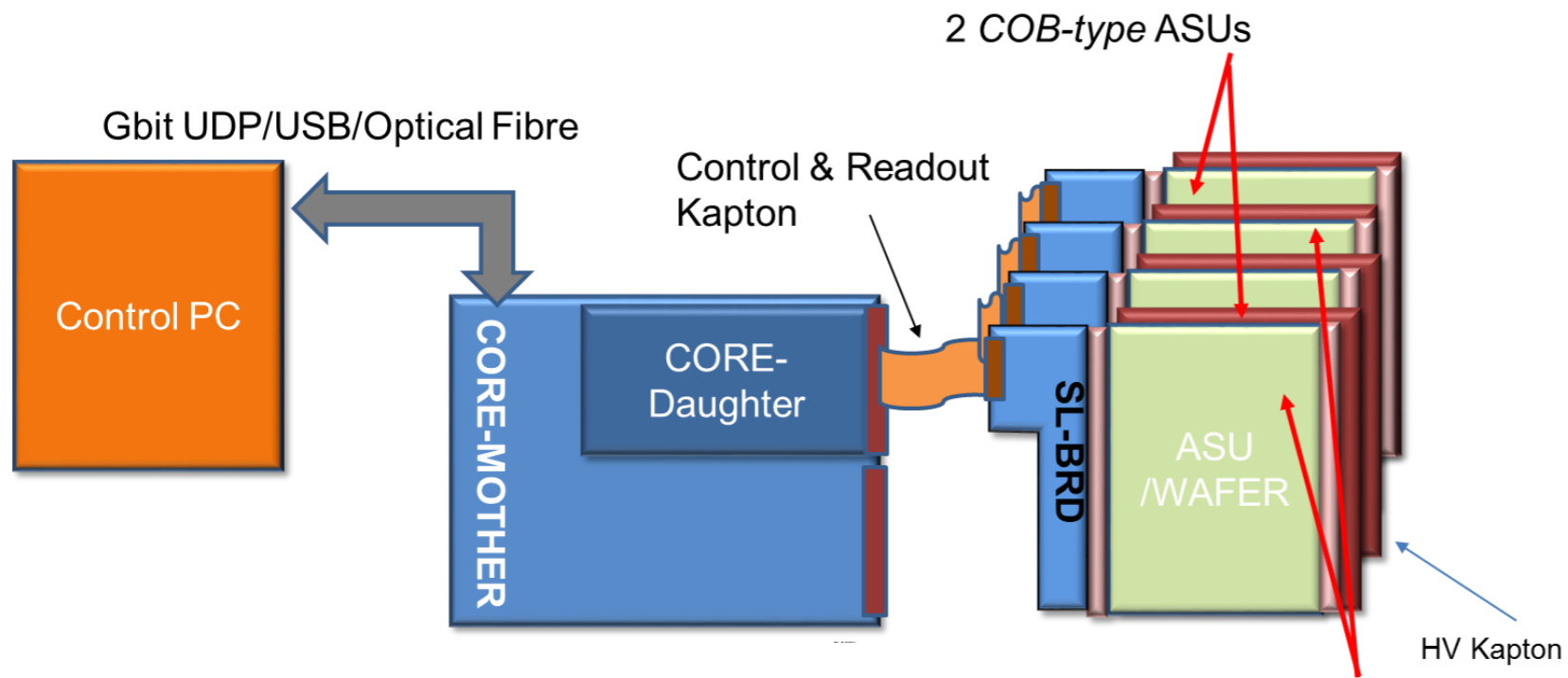Remaining work to perform: pedestal measurements, online charge histogramming etc...

- ➤ The Software can handle the communication through FTDI connector **or** through **CORE Module**.
- ➤ It handles the **whole detector module**:
  - ▪ **Two sides with 15 SLABs each.**
  - ▪ **Each slab with up to 5 ASUs.**
- ➤ It written in **C** under **Labwindows CVI**
- ➤ Advanced measurements can be performed Online such as threshold scans...
- ➤ The C-functions that handles the communication (readout and configuration) can be used as a a library with any other program that handles C-langage.

Slow Control

- ➢ All the hardware components are detected automatically : **Number of daughter boards**, **number of SL Boards** connected to each daughter board, and also the **number of ASUs** on each slab using **slow control readout**.
- ➢ **Slow Control**:
  - ▪ All necessary slow control **parameters** can be programmed through the Software
  - ▪ Slow control configuration is checked by writing twice the same values to the SKIROC shift regiser and reading back the pushed value on the SROUT signal.
- ➢ Control and data Readout with **direct connection** to the SL Board via FTDI module or through the **CORE module**.

2 *COB-type* ASUs

Gbit UDP/USB/Optical Fibre

Control & Readout Kapton

Control PC

CORE-MOTHER

CORE-Daughter

SL-BRD

ASU /WAFER
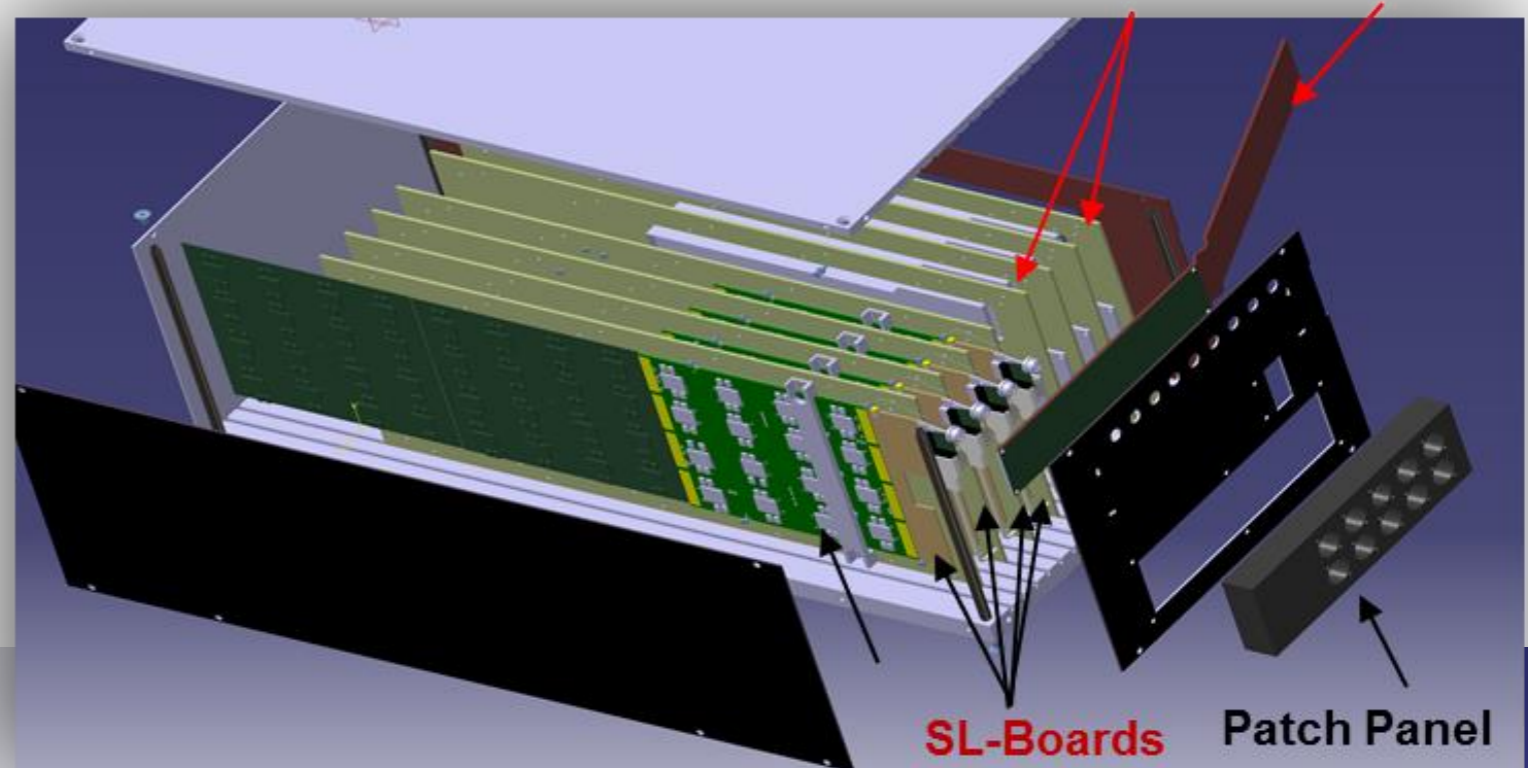
HV Kapton

2 *BGA-type* ASUs

CORE *Module/Mother/Daughter* : Control and Readout
SL-BOARD : Interface board to Slab

- **Cycles** and **acquisition windows** are programmable and generated by the CORE Module.
- All ASUs run **synchronously**.
- Possibility to check **buffer overflow**

Free Slots for *Kyushu* boards

CORE KAPTON

SL-Boards

Patch Panel
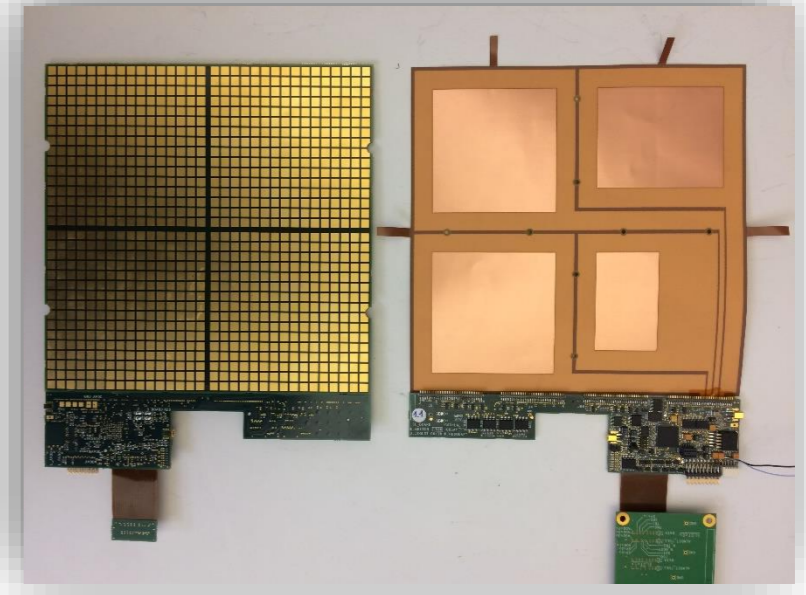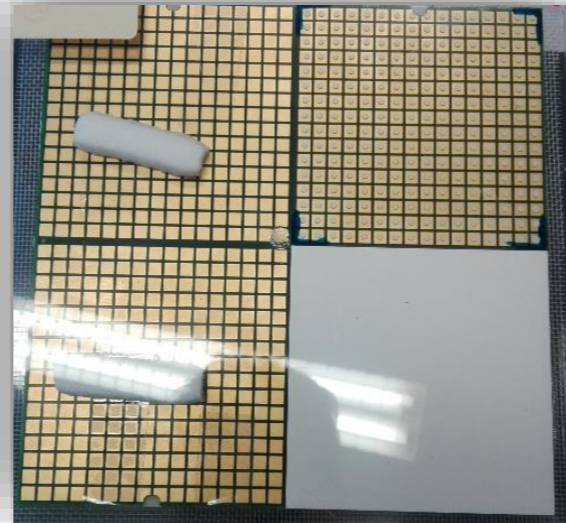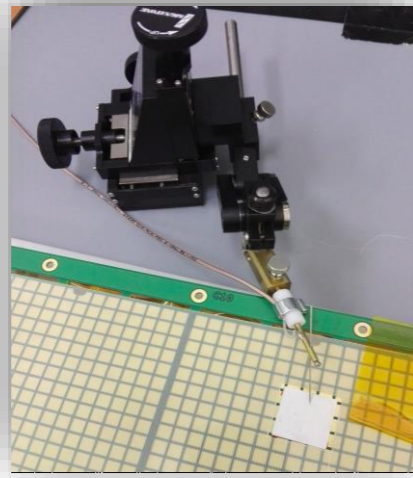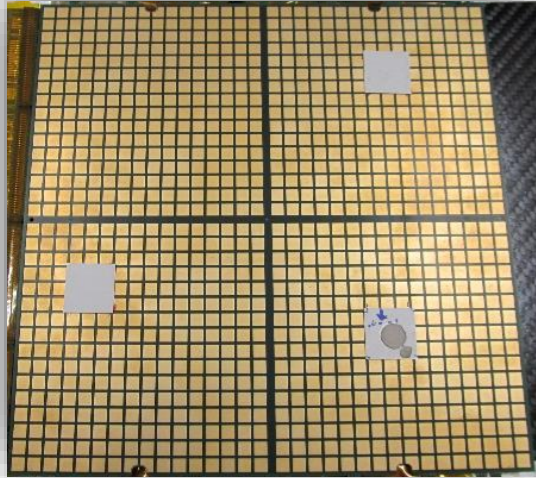
Test of 3 baby wafers

HV via Probe (150Volts)

Wafer gluing (500um) made at LPNHE

Mounting of HV Kapton

* A particular thank you to Remi Cornat and Patrick Ghislain from LPNHE for the development of the wafer-ASU assembly of both ASU types

SL-board + ASU on support

- Number of Layers in the prototype box: **4 Layers** running with SL-Board DAQ, and **5 Layers** with DIF DAQ.

- 4 Layers with SL-Board/Core Module DAQ :
  - 2 ASUs (*COB option*) with **500um Si wafers**
  - 2 ASUs (*FEV12, BGA option*) with **500um Si wafers**

- 5 Layers with DIF DAQ (SMBv5):
  - 4 ASUs (FEV13) equipped with **650 um Si Wafers**
  - 1 ASU (FEV13) with **320um Si Wafer**.
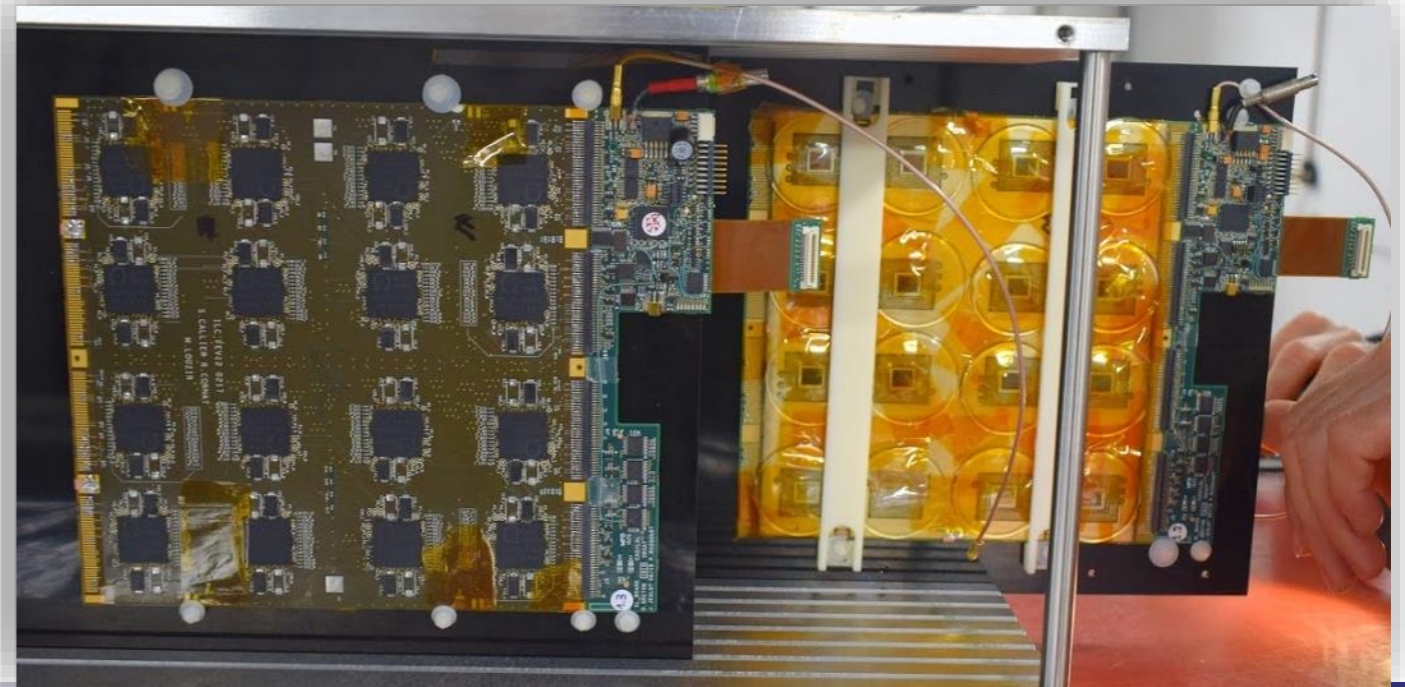
- The **Front End** ASICs used are **SKIROC** version **2a**.

- **Two weeks** of testbeam.

- First **individual runs**, then **common runs** of the 9 Layers using a **common external signal as Start/Stop** of the acquisition window of the Front End ASICs.

- Tungsten plates added during the second week between the 9 Layers.

- Results will be shown in next talk

4 layers, SL-board DAQ (LAL)   5 layers, DIF DAQ (Kyushu)

Intermediate slots for Tungsten plates

Future plans
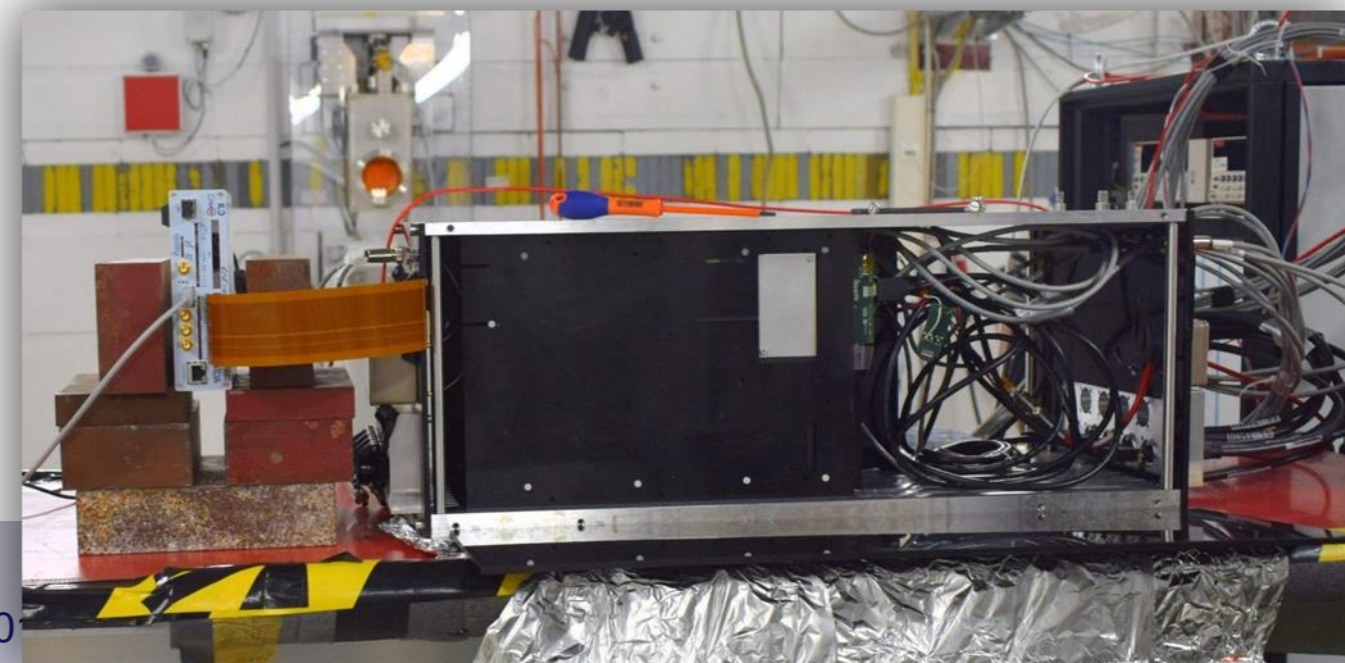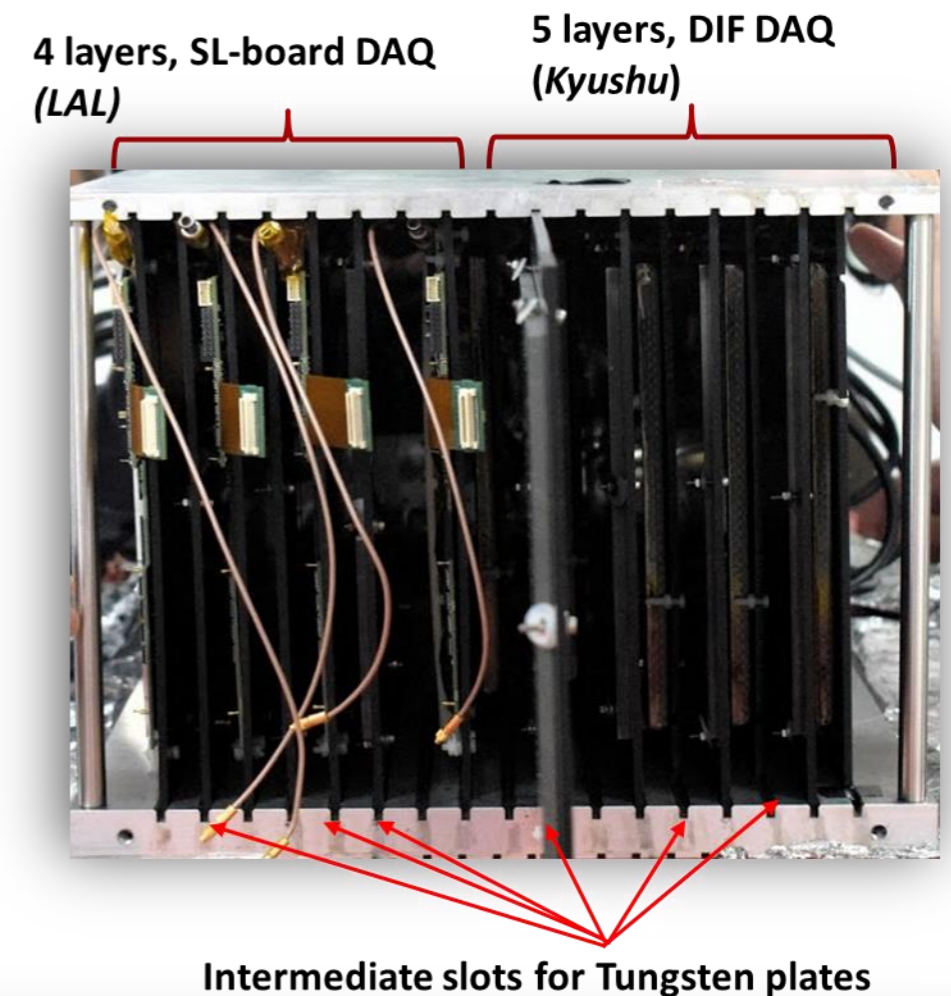
- **Firmware :**

  ➢ Some improvements to be done in the Firmware after some bugs seen during the test beam
  ➢ **JTAG adaptor board** under design in order to **program** the SL Boards firmware through the CORE Module.

- **Software:**
  ➢ Online measurements with the Software: charge histograms …
  ➢ Pedestal Calibrations
  ➢ …

- **Hardware**
  ➢ SL Board V2 → see next slides
  ➢ **Power pulsing mode** : → see next slides

- **Mechanics:**
  ➢ Improvement of the prototype box: modification of the front panel for giving a better access to all connectors of the SL Boards.

- **Preparation of the next test beam (March 2020 ?):**
  - More layers
  - Calibration of Noisy channels
  - Tests with muons
  - More calibrations before test beam
  - **Full synchronisation** with Layers from Kyushu: same clock, sync signals …

Going from SL_Board V1 to V2

Experience from beam test permitted **upgrading the design** of the SL_Board:

- All useless circuitry has been removed and the rest optimized
- Kapton length will be raised from **40** to **60 mm** (this will **ease the plugging to the kapton**)
- The main input plugs are moved next to the kapton (HV and calibration pulse in MMCX)
- The connector for the FTDI USB module is changed and moved => takes less space, easier to handle
- A **switch** will permit encoding the **slot number**

- Adding of :
  - a **DAC for SKIROC ADC calibration**
  - a **flash EEPROM** for permanent information storage

- The FPGA will produce **pulses** for **autonomous functional calibration of both gains**
- The **HV will be made available on the SL_Board** to ASU connectors (both sides)

- **Design is almost finished** => still need to make a decision on the low voltage power supply connector type (moving to a **more robust** through-hole 2-point connector ?)
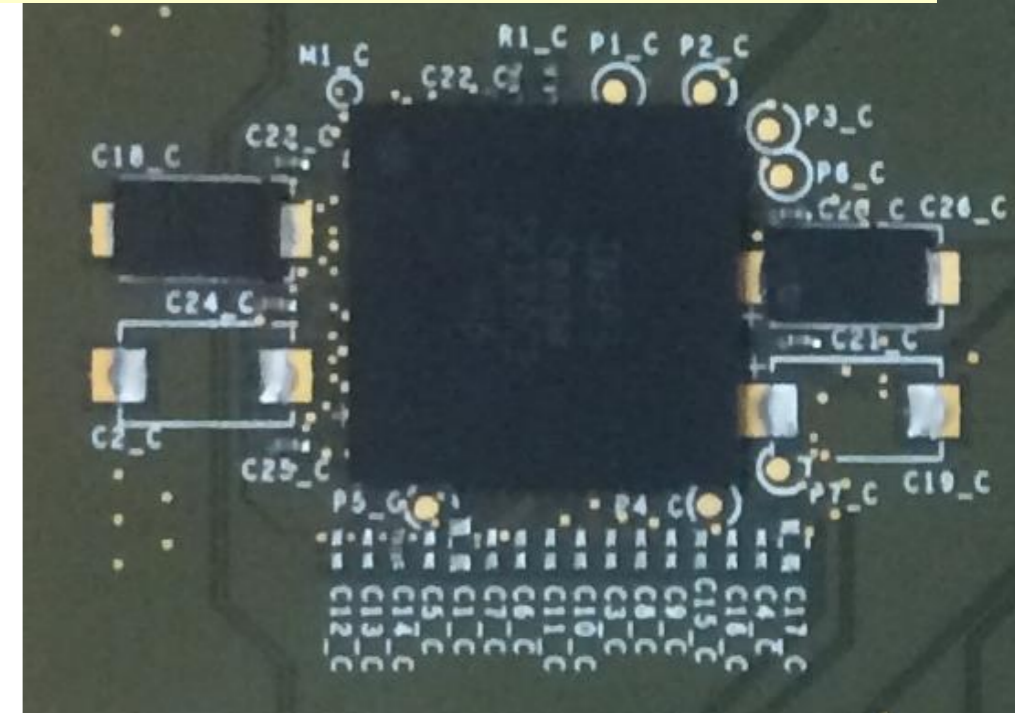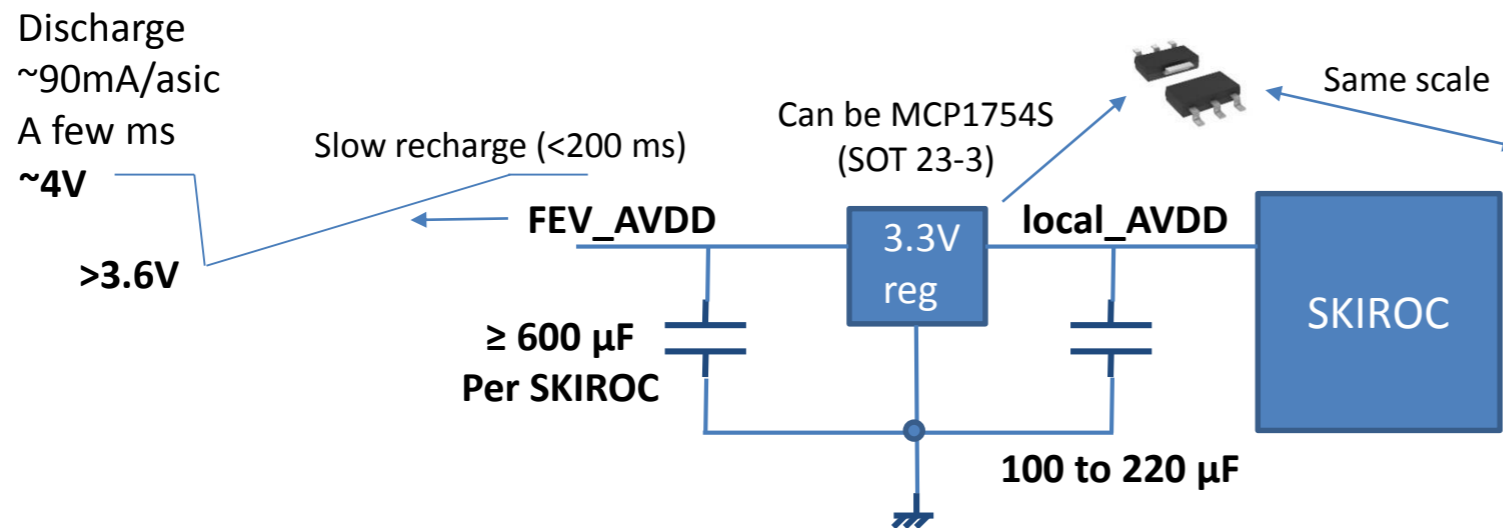
Working on the power pulsing
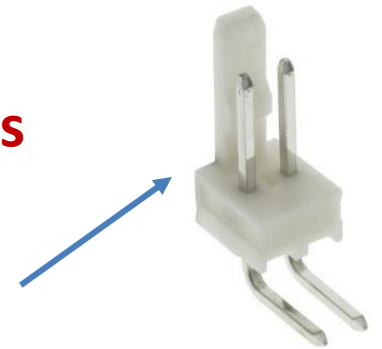
Two remarks:
1) High-value flat capacitors actually have a poor **ESR** (**order of Ohms**) => not adapted to high currents
2) It is better that **the AVDD of the SKIROC chips does not vary** during the power pulsing

⇒ two actions:
1) Put **enough lower-value capacitors** with very **good ESR (~ tens of mOhms)** to store the charge
2) AND add an **individual regulator** for producing each SKIROC's AVDD locally

Discharge
~90mA/asic
A few ms
~4V

Slow recharge (<200 ms)

>3.6V

Can be MCP1754S
(SOT 23-3)

Same scale

FEV_AVDD

3.3V
reg

local_AVDD

SKIROC

≥ 600 µF
Per SKIROC

100 to 220 µF

Example of Discharge/Recharge Cycle for one SKIROC block:
- Current of 90 mA during 2.5 ms in 600 µF => ΔV ~ 0.4V
- Total FEV capacitance ~ 15 000 µF
- Reload current can be as low as 15 mA/ASU

There are already 4 slots for decoupling capacitors around the SKIROC chips. More can be added if required (space is available).

There is **no more effect of the variations of AVDD on the SKIROC chips**
The only constraint is to **keep AVDD > 3.6 V.**
The higher the capacitance, the lower the variations => look for the optimum
(~1000 µF ?)…

Conclusion

➢ The new compact digital electronics for the control & readout of the SiW Ecal is functional

➢ It worked very nicely during the test beam in June: results will be presented in the next talk

➢ A lot of experience learned from this test beam: improvements will be realized for the next one in March.

➢ Improved version of the SL Board is almost ready

➢ We are currently studying a new version of the FEV in order to work on the optimization of the power pulsing mode.

➢ Remark: Compact design may lead to spin-offs beyond LC Detectors