TCHoU DPPD workshop 2022

DEVELOPMENT OF FOCAL-E ELECTRONICS PROTOTYPE IN ALICE

Presented by: Abderrahmane GHIMOUZ

On the behalf of FoCal team

22/03/2022

Personal Introduction

Abderrahmane GHIMOUZ

筑波大学
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ALICE

CERN

UGA Université Grenoble Alpes

GRENOBLE INP UGA

LPSC GRENOBLE | MODANE

DIAMRAS IC

PostDoc

Ph. D. degree

-Microelectronics

UGA Université Grenoble Alpes

GRENOBLE INP UGA

USTHB

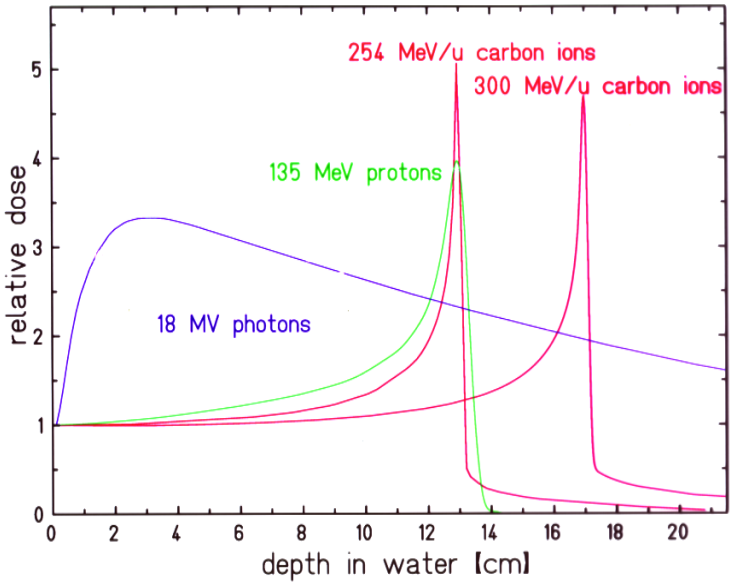
Master degree

- Instrumentation Engineering

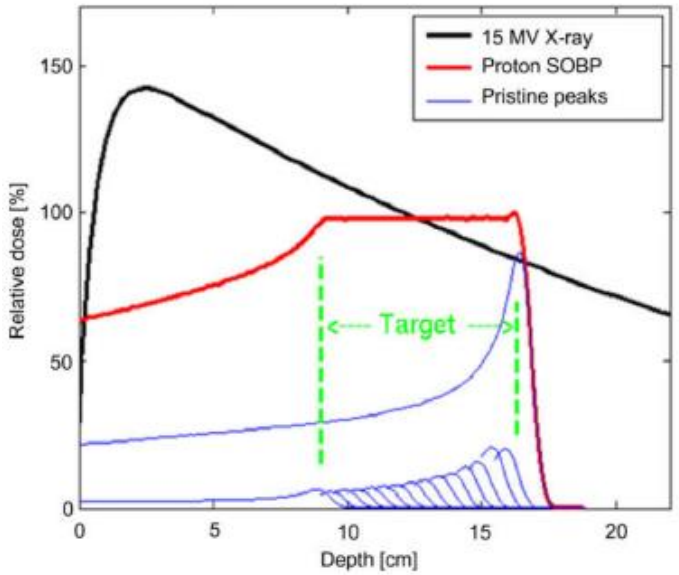
- Microelectronics

P.h .D work and results

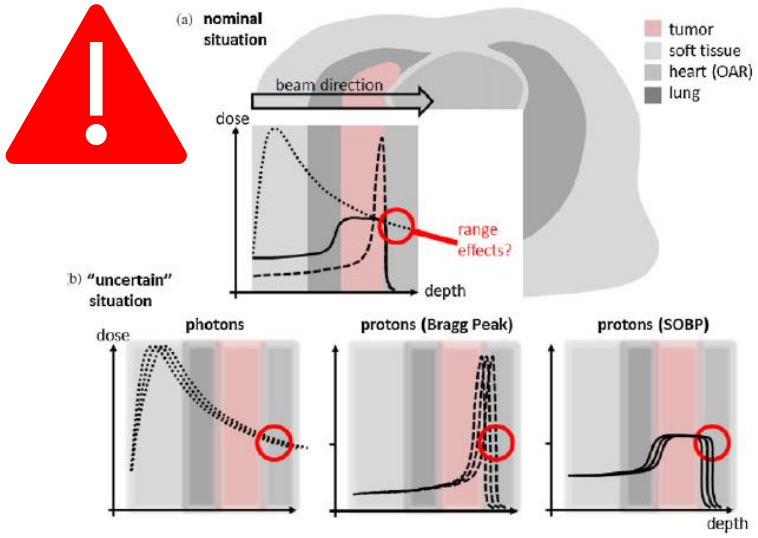
Case of study: Hadrontherapy



The position of the Bragg peak can be controlled



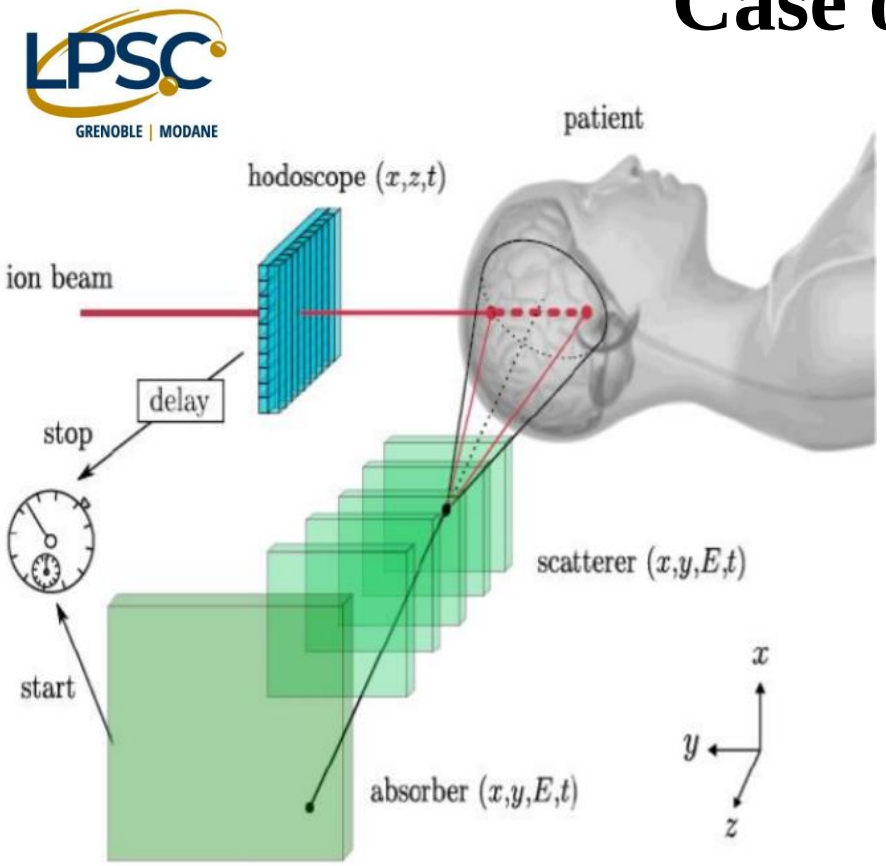
The use of the spread-out Bragg peak

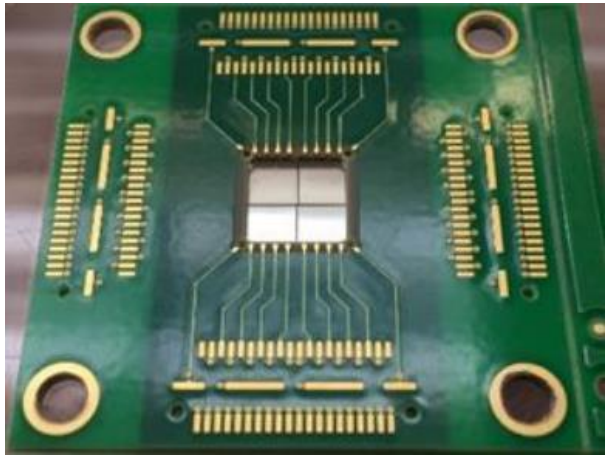


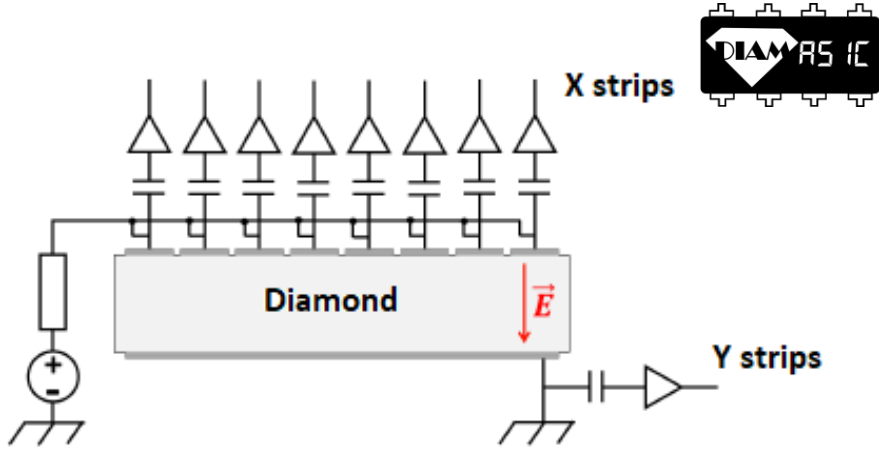
The impact of uncertainties on the dose deposit

P.h .D work and results

Case of study: Hadrontherapy





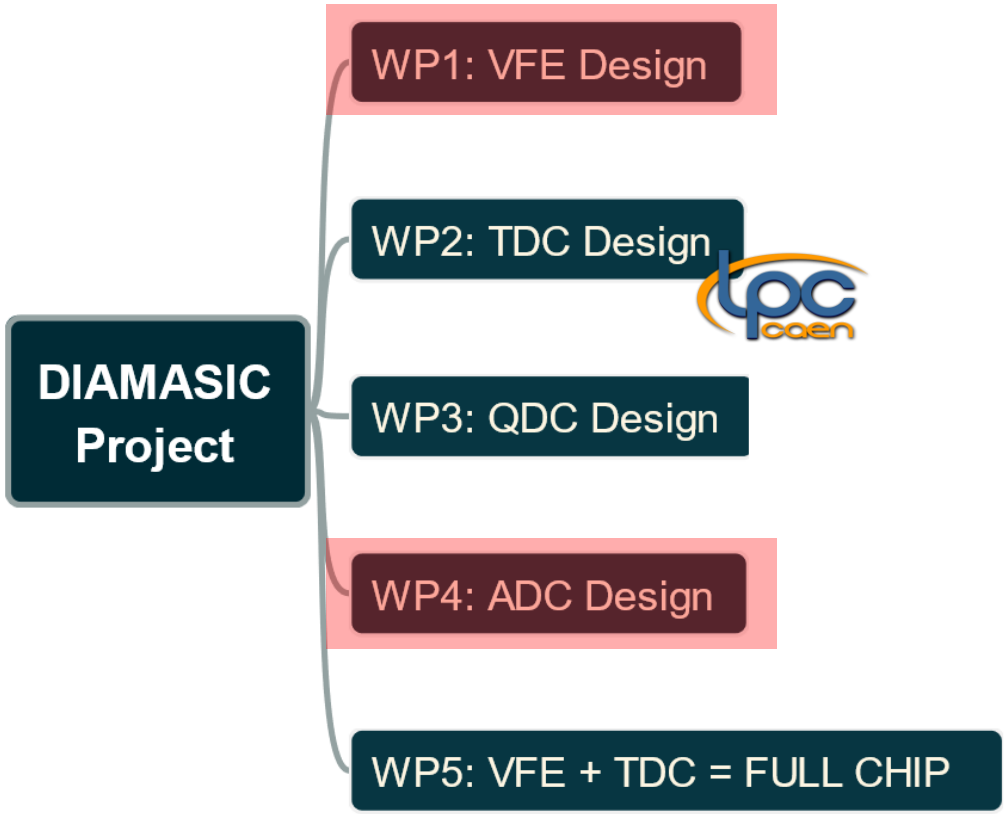


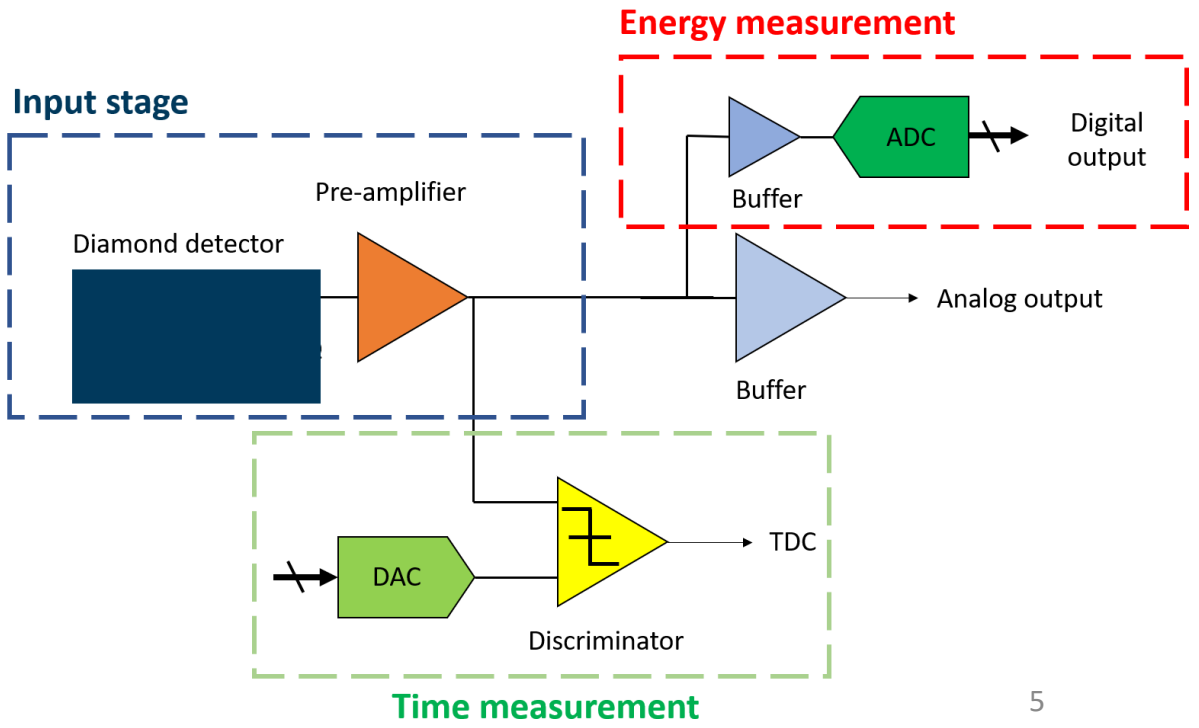
The demonstrator must meet the following specifications:

- **A temporal resolution less than 100 ps;**
- **An overall count rate that can reach the 100 MHz;**
- **A very high resistance to radiation;**
- **A very wide dynamic range (a single 250 MeV proton to 60 MeV proton packets);**

P.h .D work and results

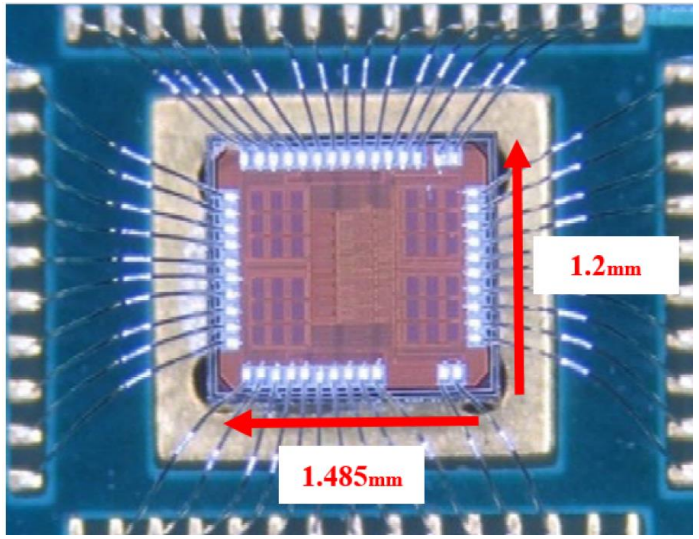
Subject: **Design of a continuous time Delta-Sigma modulator for energy measurement using diamond detectors**



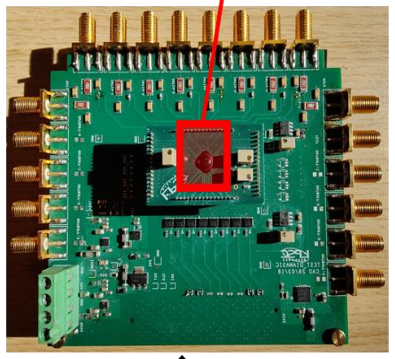


P.h .D work and results

Results for the time measurement system



Pulse generator A81110 Keysight



The ASIC

WaveCatcher

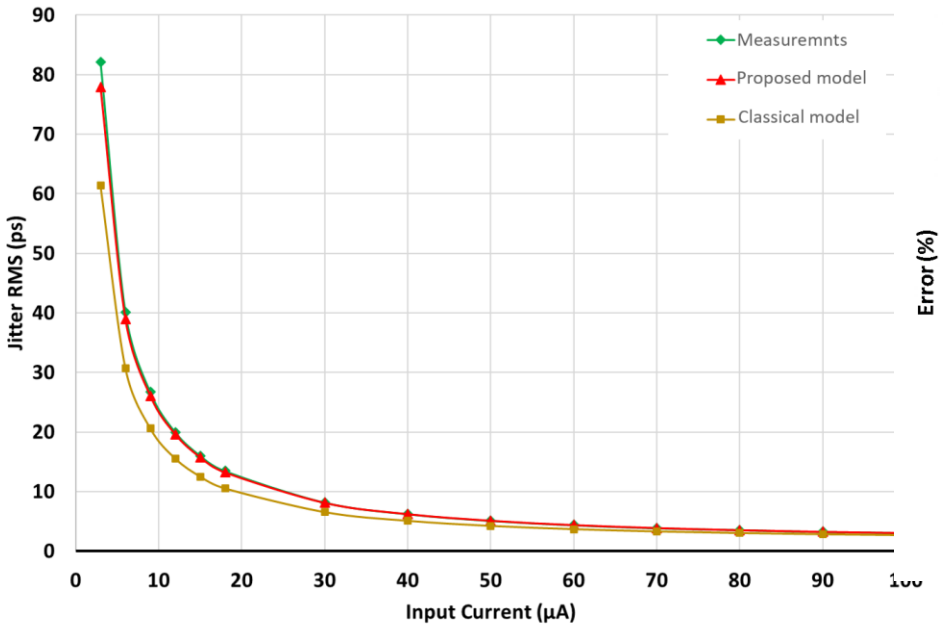
Plotting results

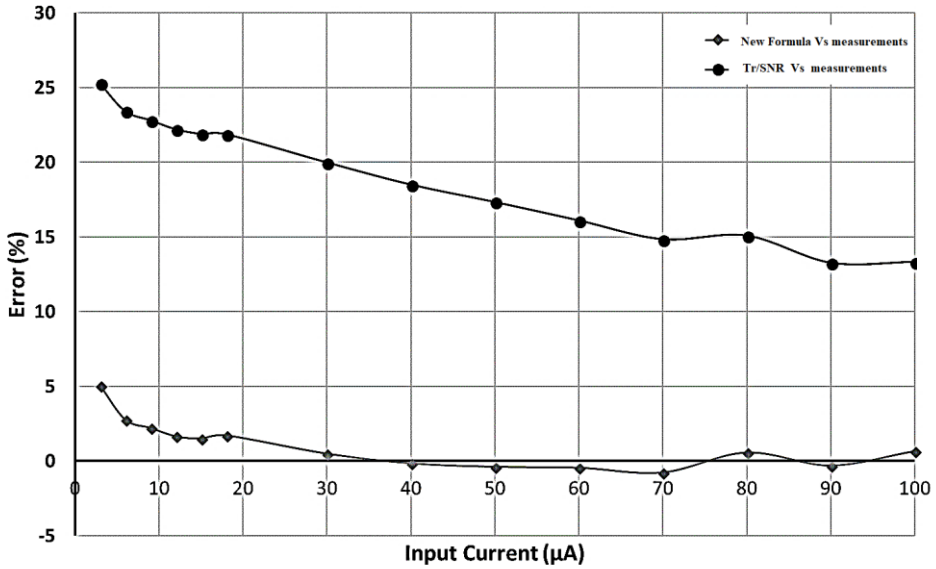
Slow control

Developed 8 channels ASIC and its testing setup

P.h .D work and results

Results for the time measurement system





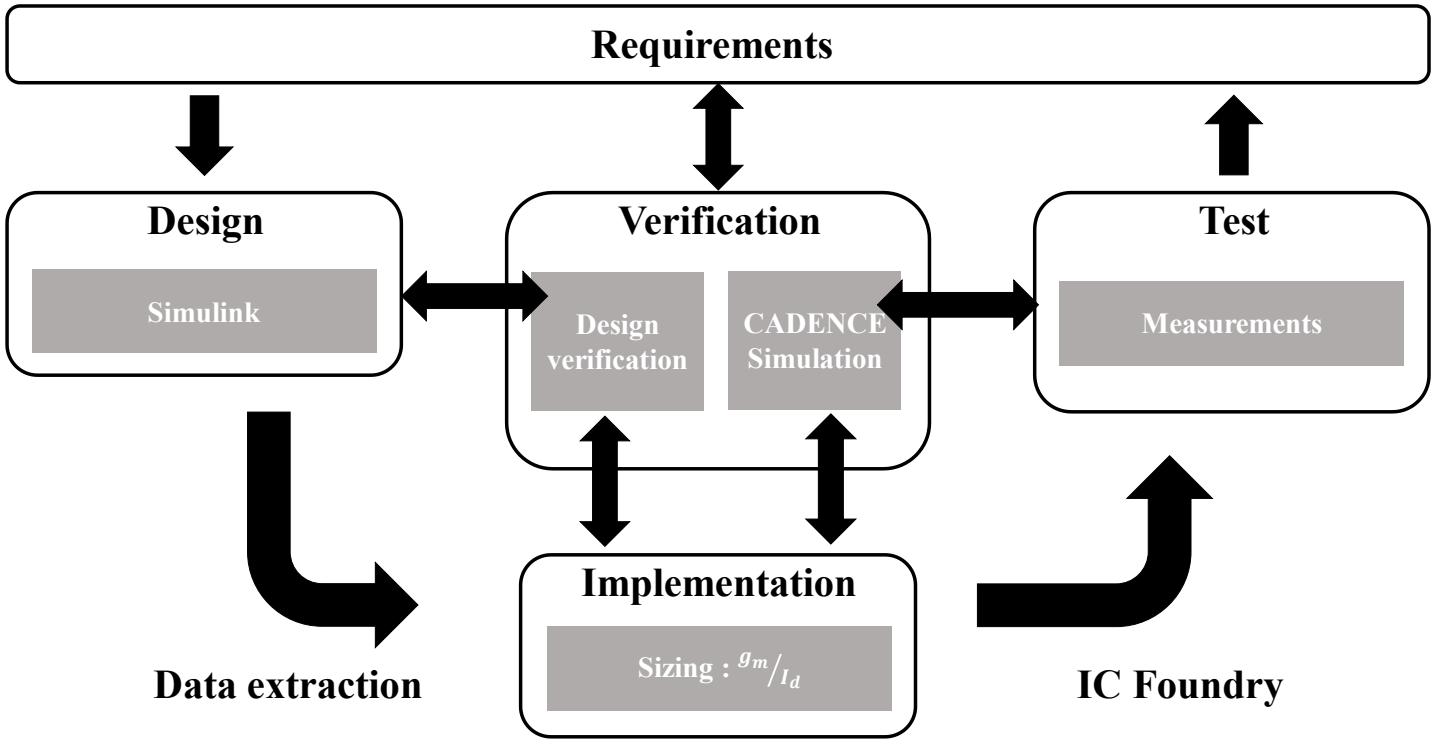
Parameters	values
TIA gain (dBΩ)	66.55 (2125 V/A)
DC input impedance (Ω)	20.78
TIA BW (f_{-3dB} MHZ)	562.74
i_n ($pA/\sqrt{Hz}$)	13.62
Power consumption @1.2V (mW)	2.54

Precision of the proposed model

Performance of the TIA

P.h .D work and results

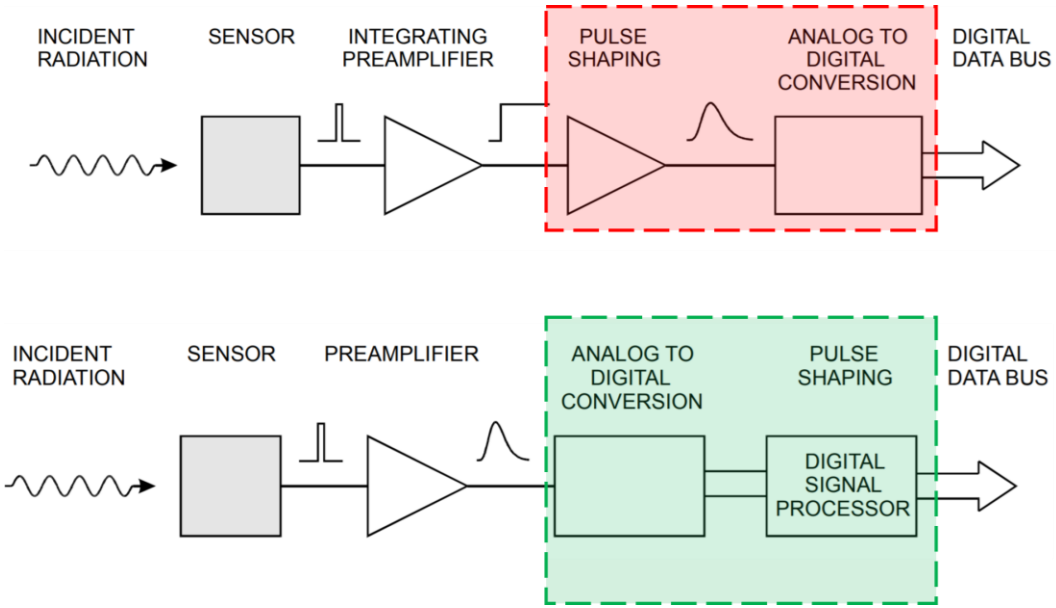
Results for the energy measurement system (ADC)

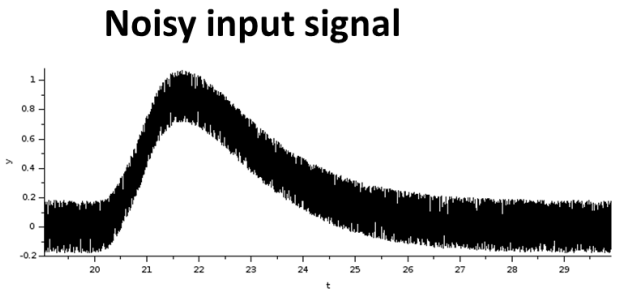


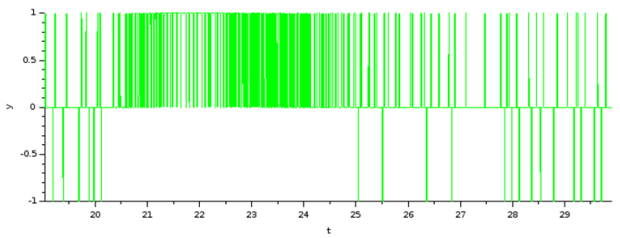
Exploring the use of the model based design approach

P.h .D work and results

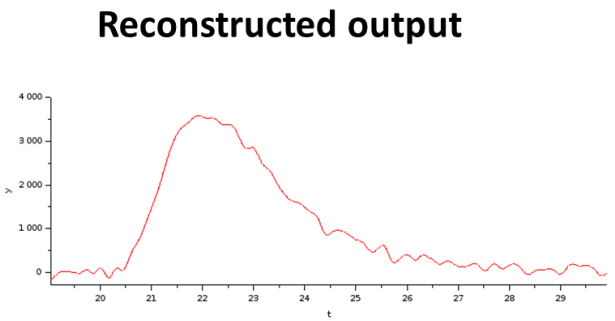
Results for the energy measurement system (ADC)







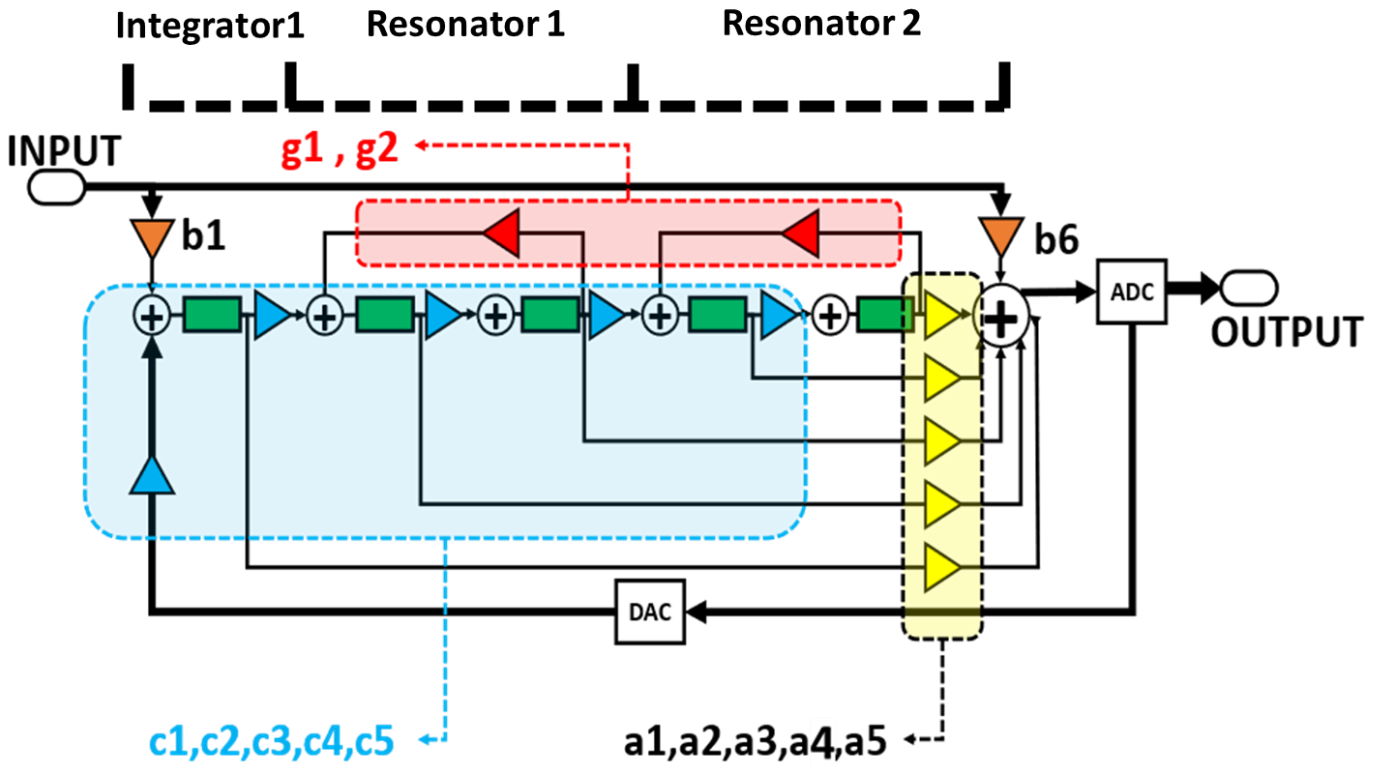
Digital filter



Doing analog-to-digital conversion as early as possible

P.h .D work and results

Results for the energy measurement system (ADC)



- ✓ CT
- ✓ Single loop
- ✓ High order loop filter
- ✓ Mixed feedforward-feedback

"Cascaded Resonators Feedforward" or CRFF topology

P.h .D work and results

Results for the energy measurement system (ADC)

Parameter	Achieved
Technology	CMOS 130 nm
Architecture	5^{th} order CT LP CRFF $\Delta\Sigma$
Sampling frequency	160 MHz
Signal bandwidth	10 MHz
MSA voltage	$-3.5\ dBFS/1.2\ V_{p-p}$ (differential)
SNR	51.4 dB
ENOB at MSA	8.3 $bits$
DR	56 dB
Power supply	1.2 V
Power consumption	39.43 mW

Block	power consumption details (mW)	Total (mW)
Loop filter	5×4.4	22
Summing block	1×14	14
Loop ADC	7×0.47	3.3
feedback DAC	1×0.04	0.04
	TOTAL	**39,34**

Simulated modulator performance

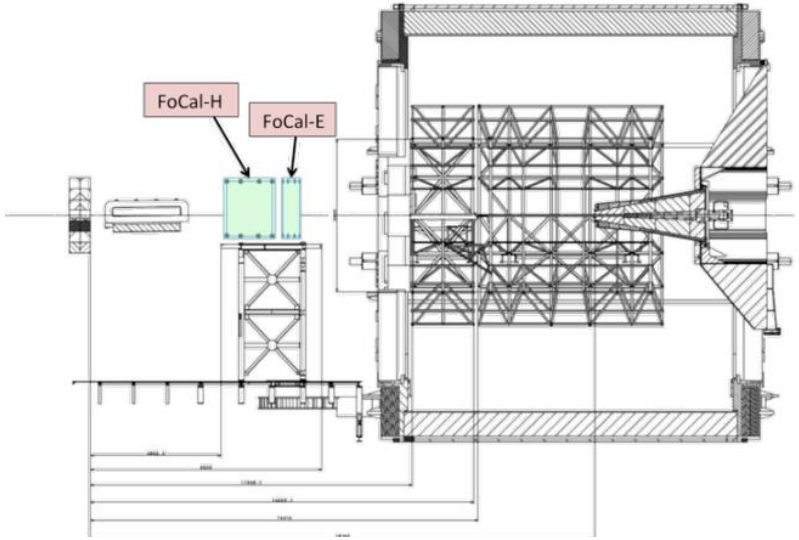
Power consumption estimation

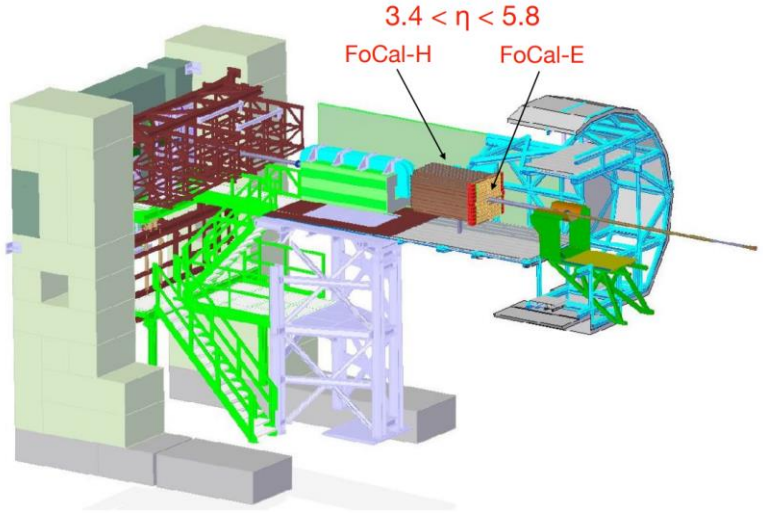
P.h .D work and results

List of publications:

- [1] Abderrahmane Ghimouz et al. “A Preamplifier-discriminator circuit based on a Common Gate Feedforward TIA for fast time measurements using diamond detectors.” In: 2018 25th IEEE International Conference on Electronics, Circuits and Systems (ICECS). 2018, pp. 281–284. DOI: 10.1109/ICECS.2018.8617950.
- [2] Abderrahmane Ghimouz, et al. “Systematic high-level design of a fifth order Continuous-Time CRFF Delta Sigma ADC.” In: 2021 IEEE 12th Latin America Symposium on Circuits and System (LASCAS). 2021, pp. 1–4. DOI: 10.1109/LASCAS51355.2021.9459156.
- [3] Abderrahmane Ghimouz, et al. “Designing Opamp amplifiers for a 5th order CT CRFF DS ADC using Model-based design paradigm and gm/ID methodology.” In: International Conference on Analog VLSI Circuits 2021.
- [4] Abderrahmane Ghimouz et al. “A multichannel front-end electronics ASIC for high-accuracy time measurements using diamond detectors.” In: International Conference on Analog VLSI Circuits 2021.
- [5] Abderrahmane Ghimouz, et al. “New Design Approach of Front-End Electronics for high Accuracy Time Measurement Systems.” In: 2021 28th IEEE International Conference on Electronics, Circuits and Systems (ICECS). 2021, pp. 1-4, DOI: 10.1109/ICECS53924.2021.9665533.
- [6] Abderrahmane Ghimouz, et al. “DIAMASIC: A multichannel front-end electronics for high accuracy time measurements for diamond detectors.” In: TWEPP 2021 Topical Workshop on Electronics for Particle Physics. 2021

FoCal Project



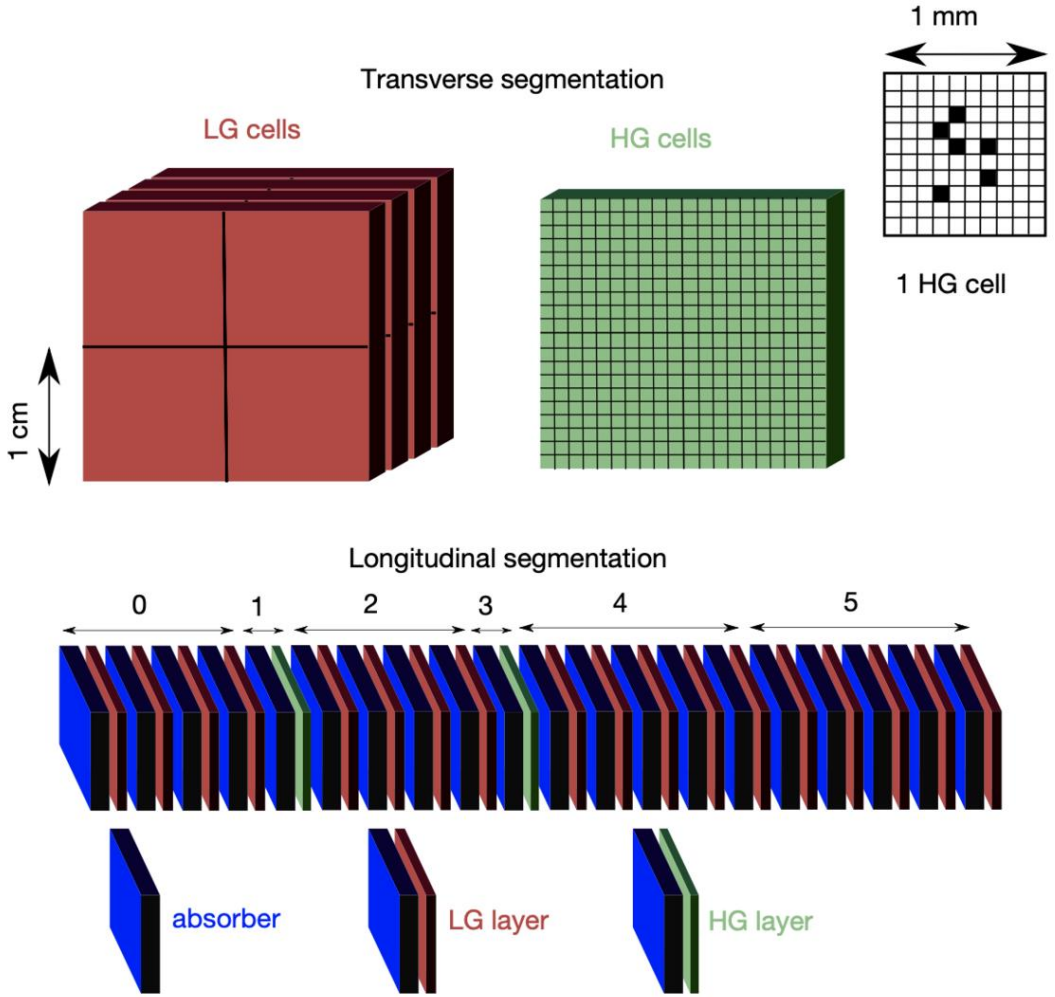


Main physics goal: **Nucleus structure at small -x**

System composition:

- **FoCal-E**: high-granularity Si-W sampling sandwich calorimeter for photons and π^0
- **FoCal-H**: conventional metal-scintillator sampling calorimeter for photon isolation and jets

FoCal–E Detector



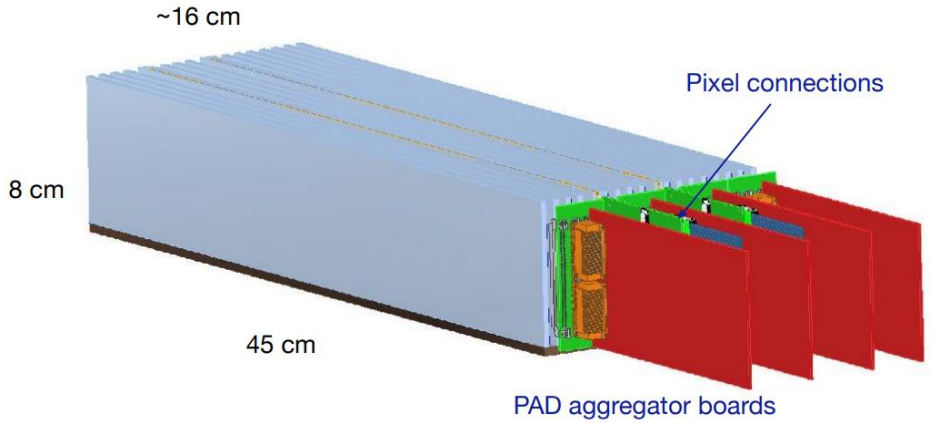
System design: Two readout granularities

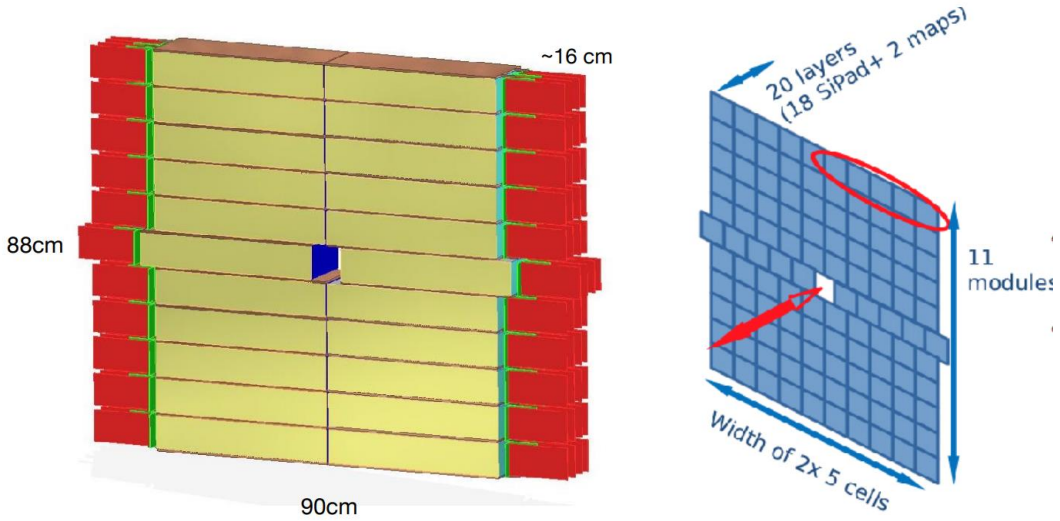
- **PAD (LG) layers:** granularity 1x1 cm2, analog readout
- **PIXEL (HG) layers:** 30x30 µm2 digital readout (ALIPIDE)

Challenge:

- **Separate** γ/π^0 at high energy

FoCal–E Detector





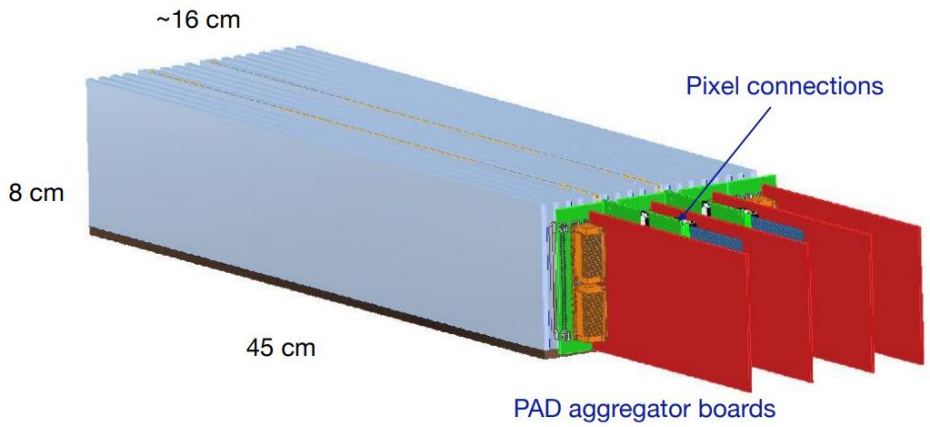
Each module:

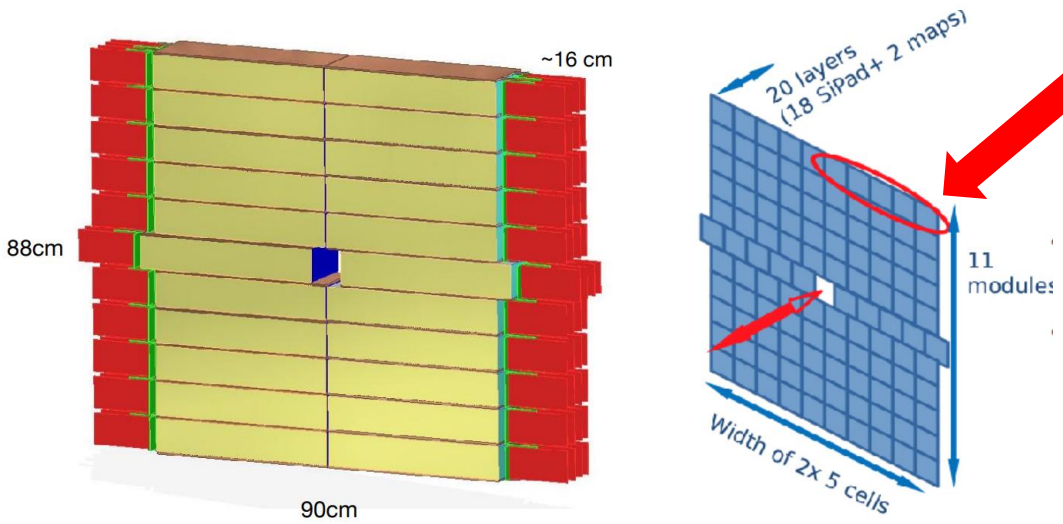
- **18 PAD (LG) layers with 5 aggregators boards**
- **2 PIXEL (HG) layers with individual readout**

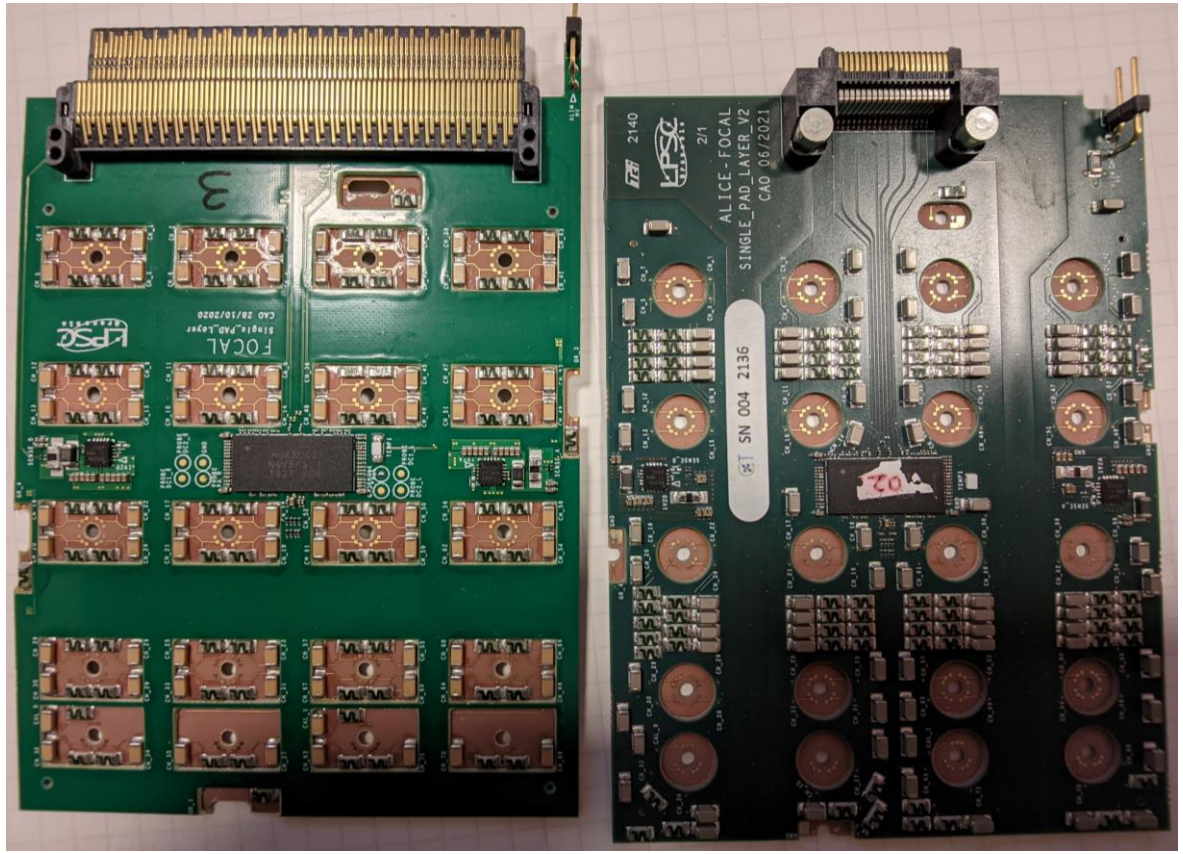
Final structure:

- **22 Modules**

FoCal–E Detector

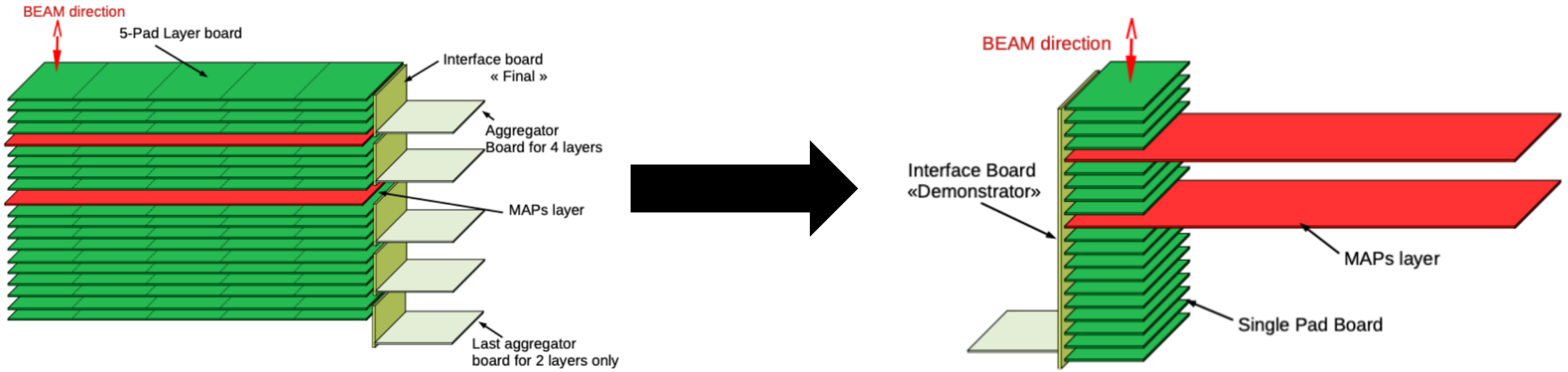






Single E-PAD board: V1 and V2

FoCal–E Demostrator



Final module:

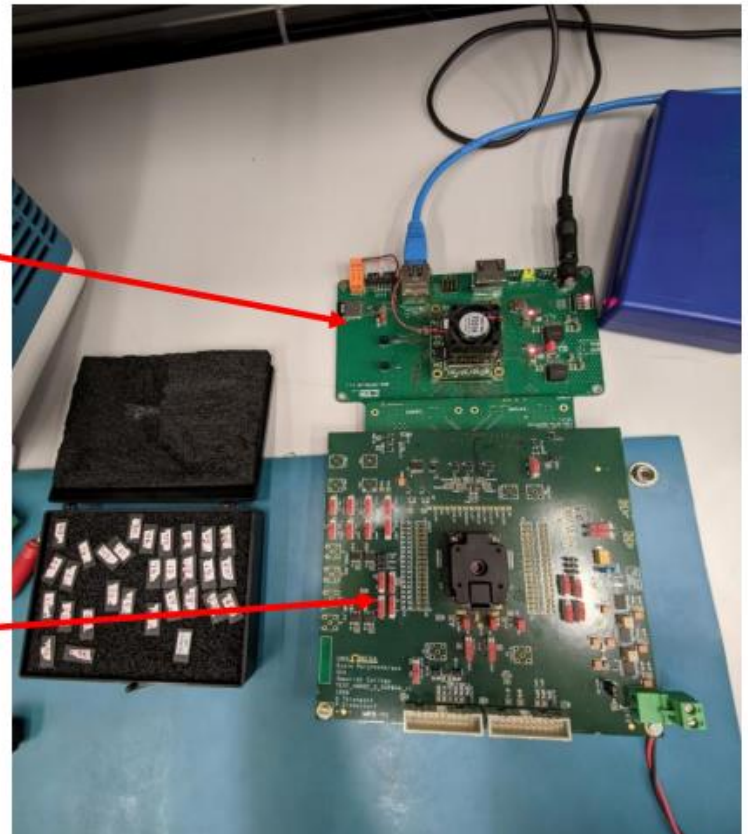
- 18 5-pad layer boards (90 HGCROC with 6480 channels)
- 5 Aggregator board

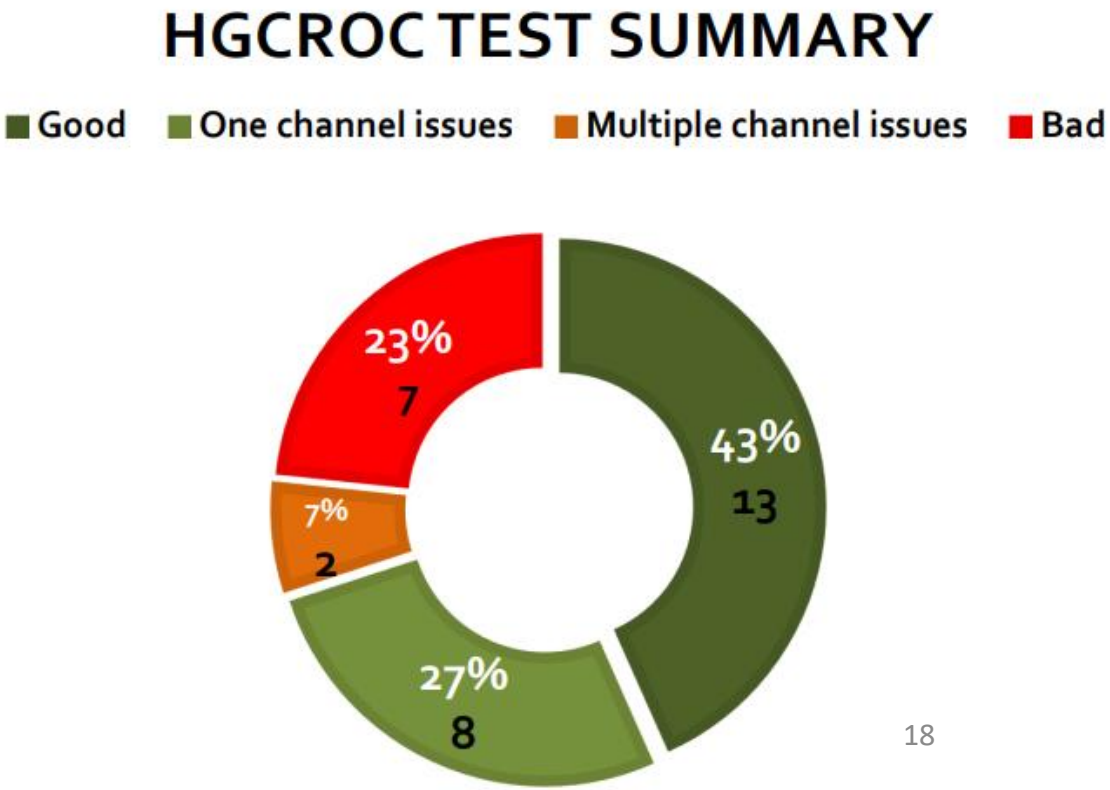
Demonstrator module:

- 18 single pad board (18 HGCROC with 1296 channels)
- 1 Aggregator board

FoCal–E my contribution

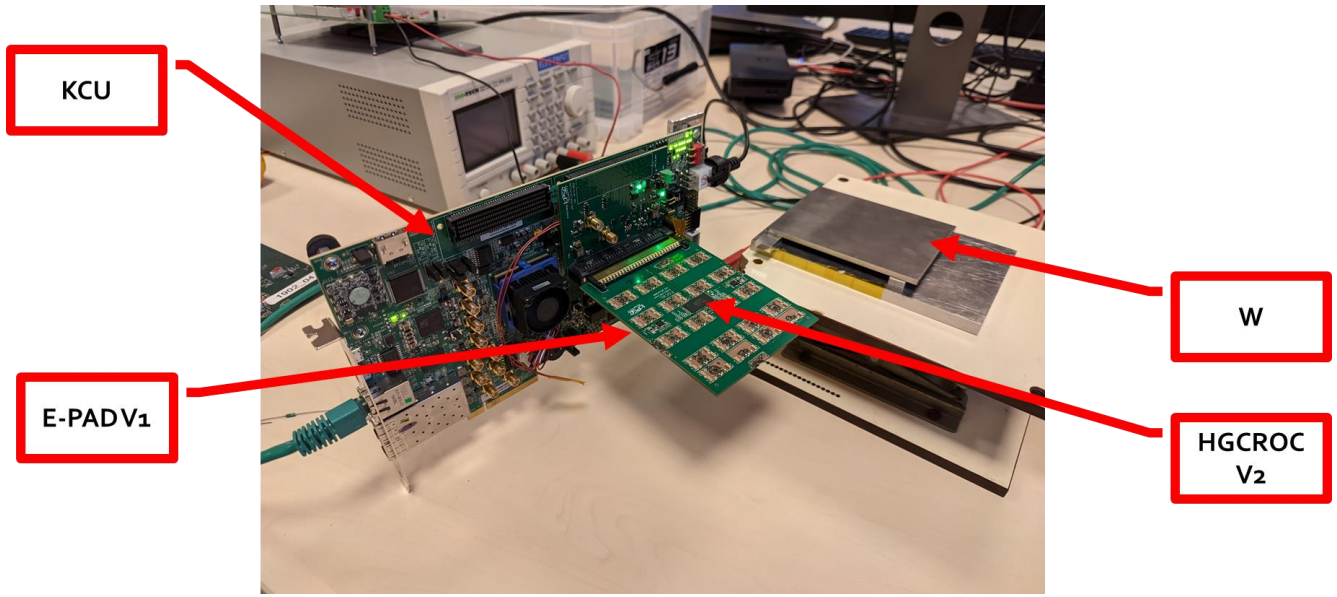
PHASE 1: Selection of the good HGCROC circuits

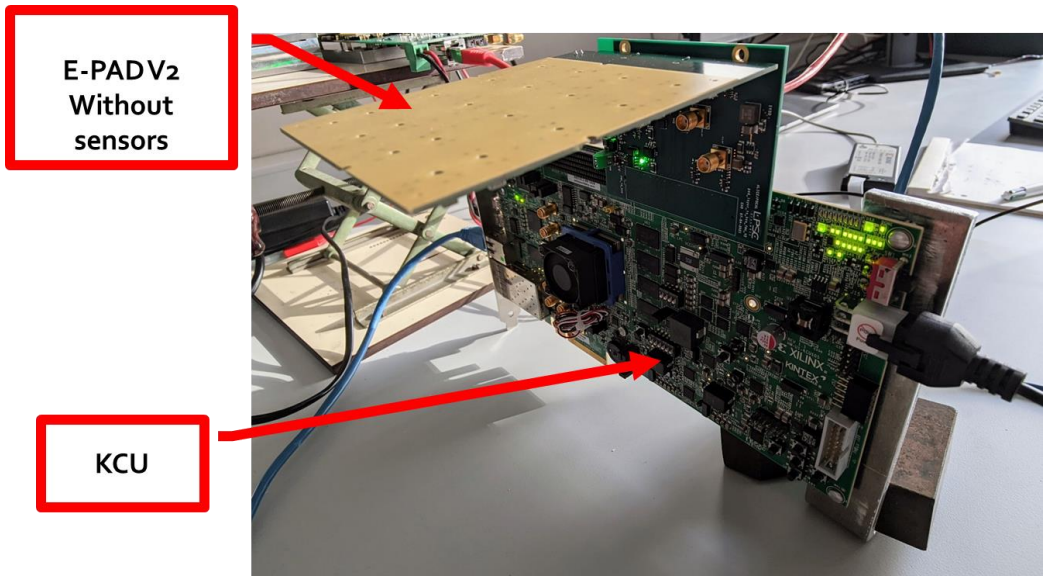




FoCal–E my contribution

PHASE 2: Characterizing E-PAD V1 and V2

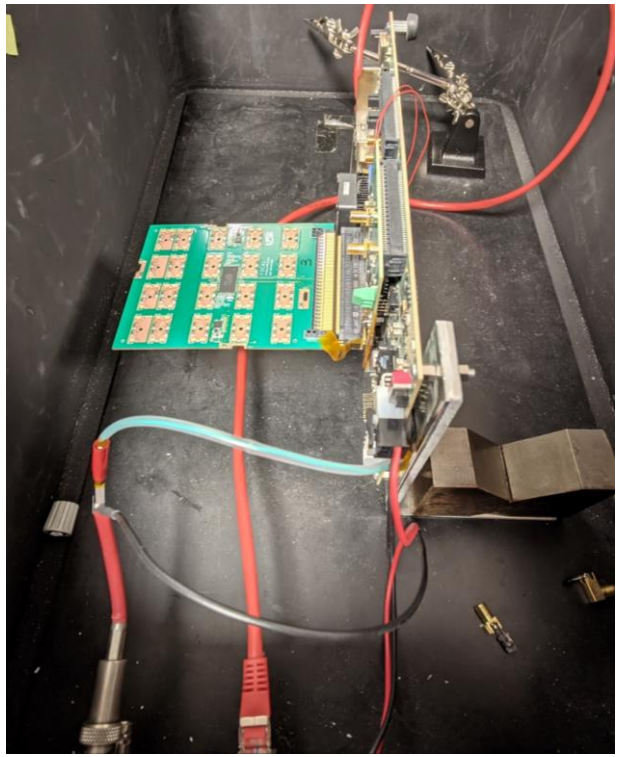




Evaluating the parameters of the ADC, ToA and ToT and the noise associated to them

FoCal–E my contribution

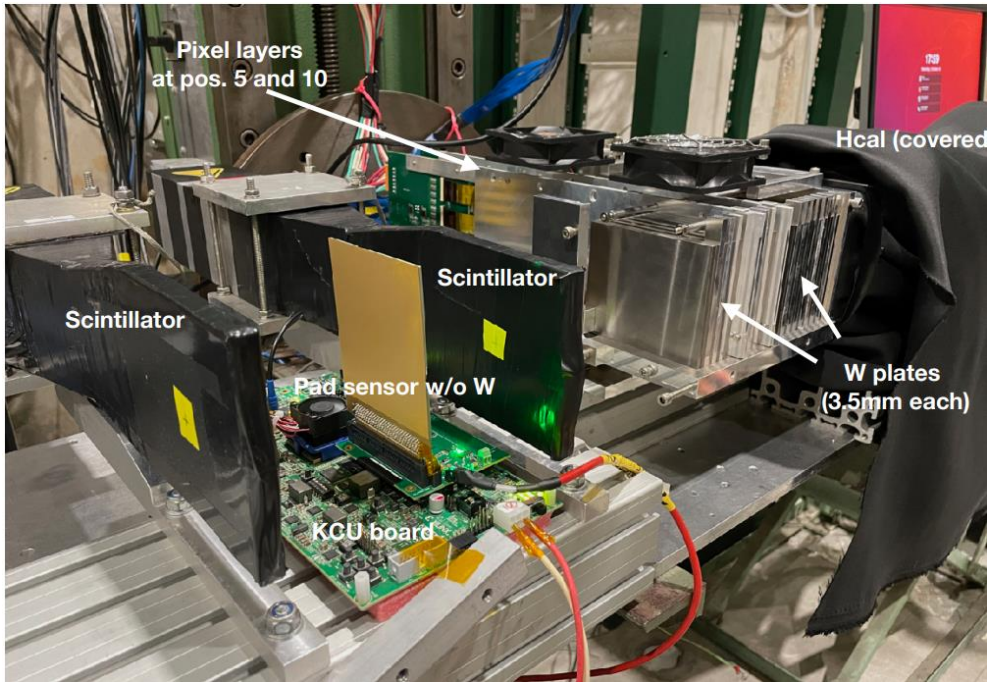
PHASE 2: Characterizing E-PAD V1 and V2



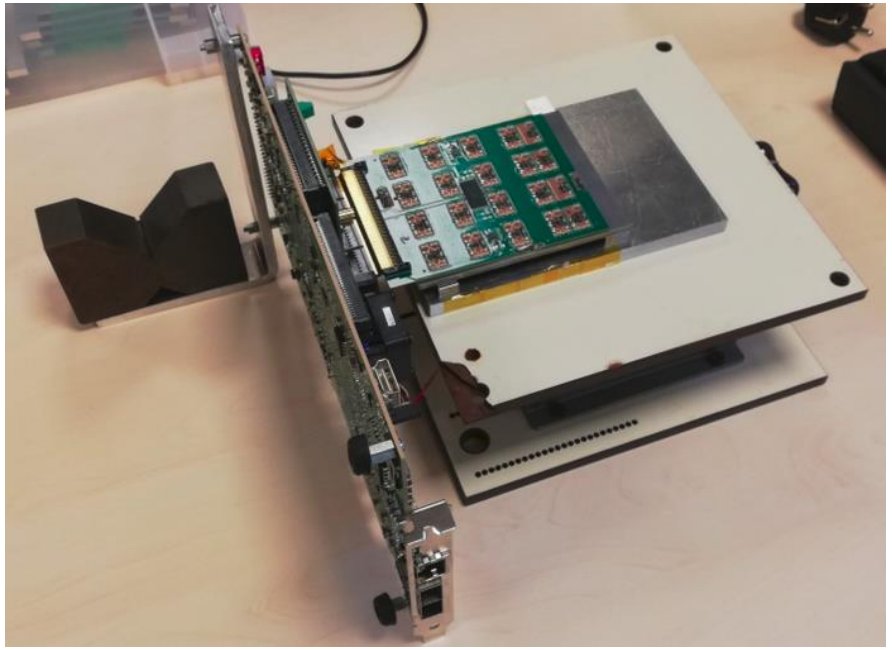
Test under HV

FoCal–E my contribution

PHASE 3: Correcting the GND issue



SPS September 2021

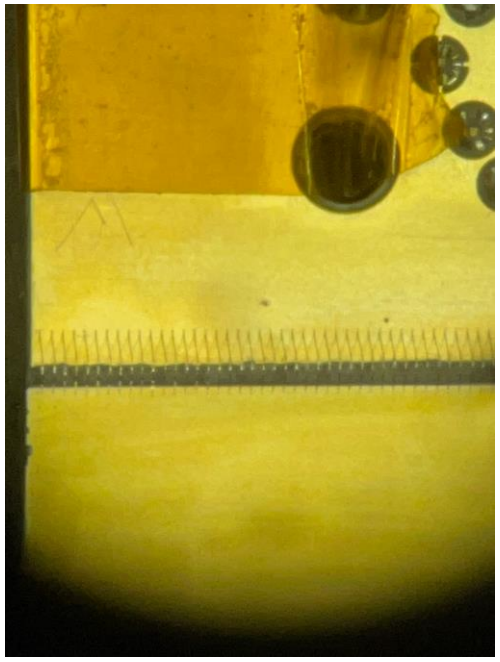


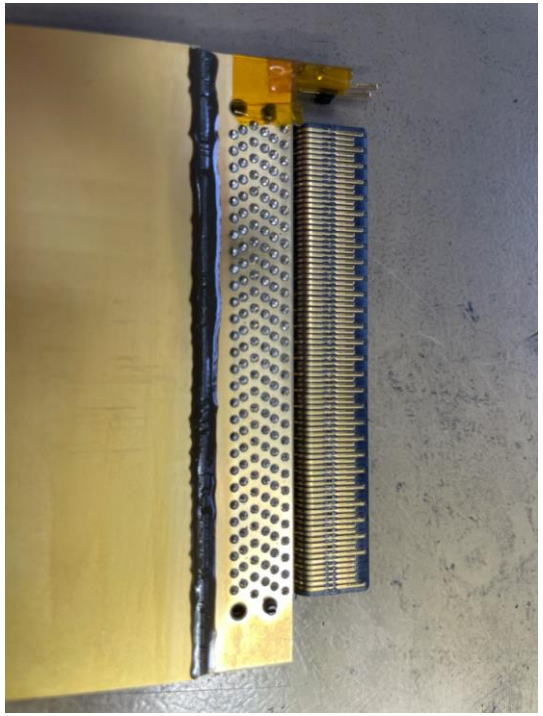
LPSC Grenoble November 2021

Reproduction of the issue in Lab

FoCal–E my contribution

PHASE 3: Correcting the GND issue

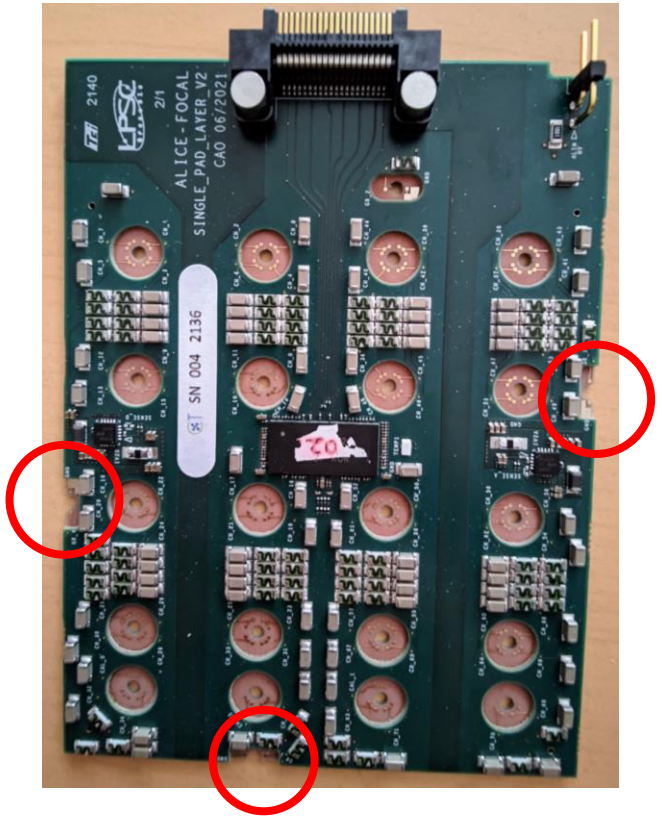




Solution for the E-PAD V1

FoCal–E my contribution

PHASE 3: Correcting the GND issue



Designing a solution for the E-PAD V2

Conclusion

- **A fully functional prototype of a demonstrator for FoCal-E is under development**
- **New calibration algorithms are optimized**
- **A cosmic test setup is build and will be used soon**
- **New beam tests of the prototype are planned (Japan, CERN)**

Conclusion

Thank you for your attention

ご清聴ありがとうございました