LCWS 2025

Test of a partly instrumented highly compact and granular electromagnetic calorimeter in an electron beam of 1 to 6 GeV

A. Irles on behalf the ECAL-P group of LUXE

***AITANA group at IFIC – CSIC/UV**

AITANA | IFIC Institut de Física Corpuscular | Universitat de València | CSIC Consejo Superior de Investigaciones Científicas | Excelencia Severo Ochoa

Financiado por la Unión Europea NextGenerationEU | Ministerio de Ciencia, Innovación y Universidades | Agencia Estatal de Investigación | Ayuda CEX2023-001292-S financiada por MCIU/AEI | Plan de Recuperación, Transformación y Resiliencia | Generalitat Valenciana Conselleria de Educación, Universidades y Empleo | GVANEXT Fondos Next Generation en la Comunitat Valenciana | Universitat de València Departament de Física Atòmica, Molecular i Nuclear | LC inducienca | ineustar Spanish Science Industries | ASFAE | CPAN Ingenio 2010

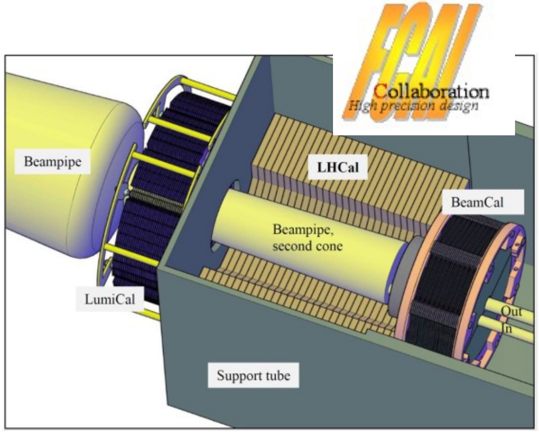
The team

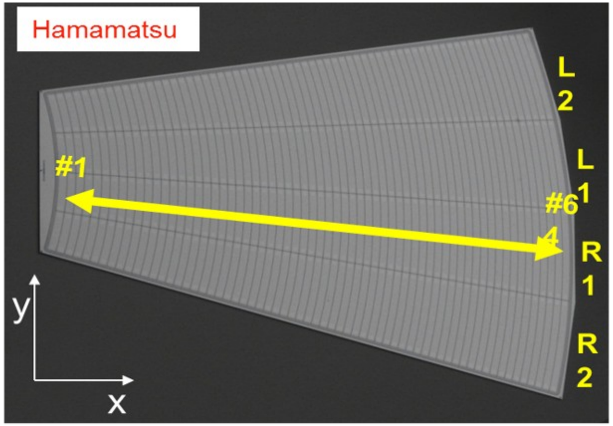
Sentence about project (Veta! - to be done)

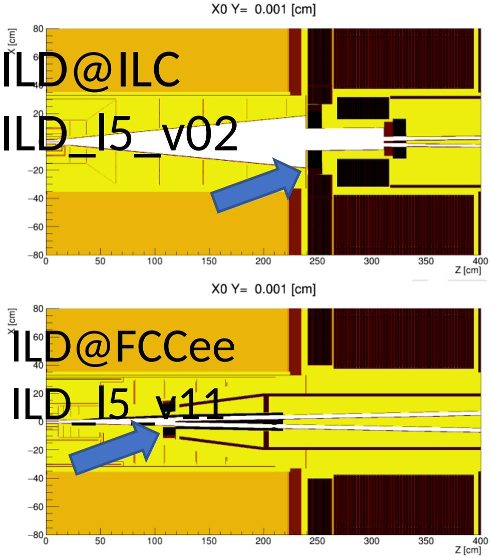
Forward Calorimetry (extreme compactness)

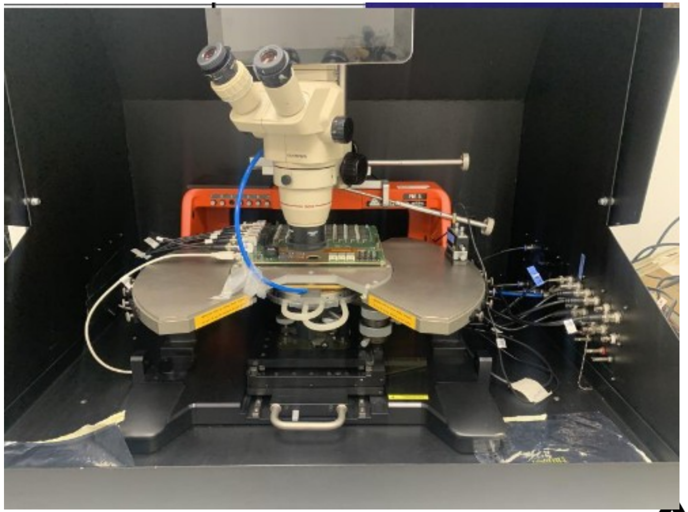
- ▷ LumiCal for precise luminosity measurement (Counting Bhabhas)
- ▷ BeamCal for fast luminosity measurement (using beamstrahlung)

- ▷ 1 X0 absorber thickness per layer, 20 (30) layers in ILC (CLIC)
  - Minimal Molière radius
- ▷ Optimal geometries for FCC being studied









Forward Calorimetry (extreme compactness)

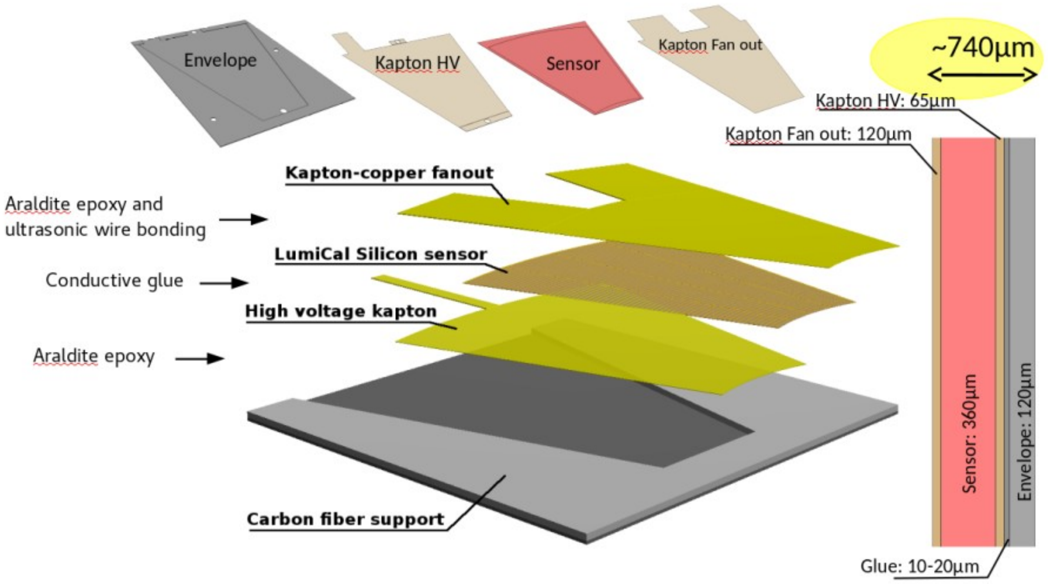


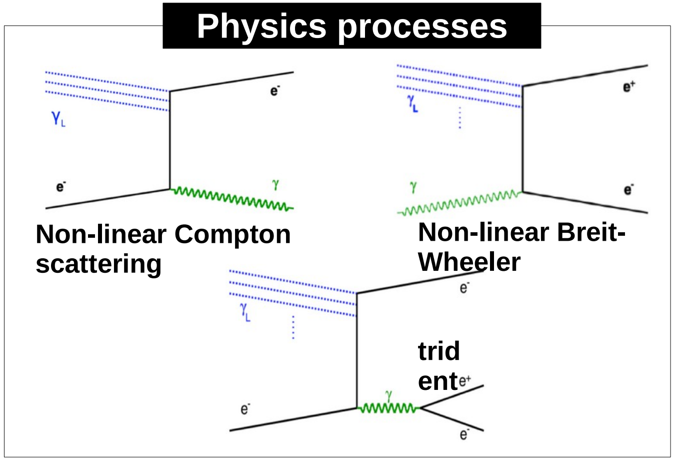
Figure 5.13. Structure of a sensitive layer of the LumiCAL calorimeter.

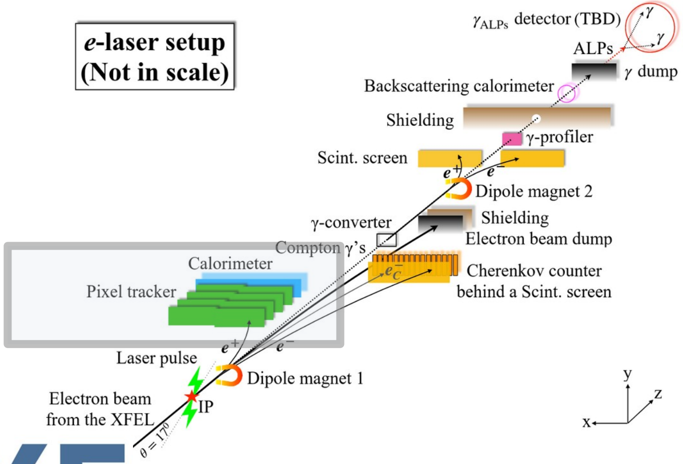
Forward region (LUMICAL) design for ILD

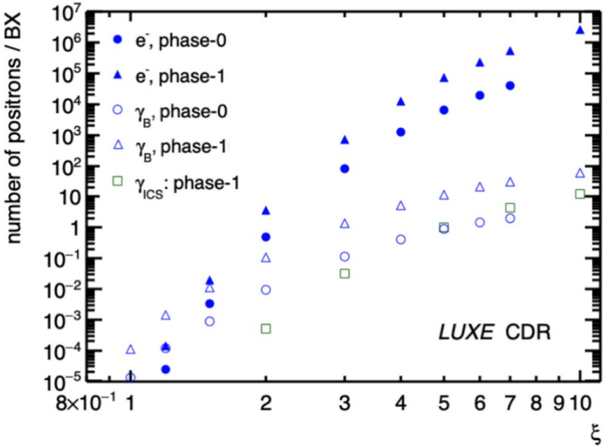
- ▷ Ultra thin layers <1mm for minimal Molière Radius
- ▷ Not embedded electronics
- ▷ Higher radiation levels than barrel.

Positron ECAL for LUXE

- ▷ LUXE: Experiment based at **DESY-XFEL**
- ▷ **Strong EM field**: 30-350TW **laser** & 16.5 GeV **e- beam**
- ▷ e- / laser interaction mode and γ /laser interaction mode
- ▷ Vast range of multiplicities per beam bunch depending on the mode of operation
  - up to 10^6 e+e- pairs per BX
  - Physics-driven detector technologies at each location





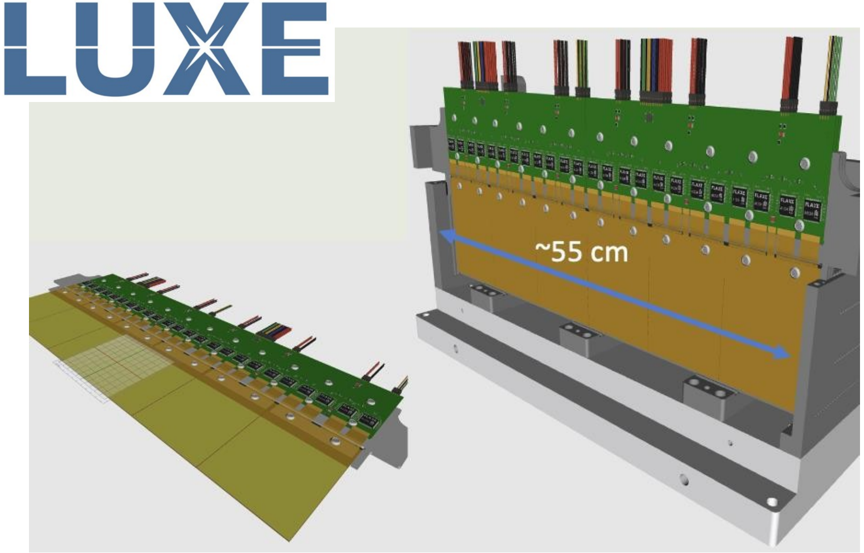


LUXE TDR: Eur.Phys.J.ST (2024)

ECALp design

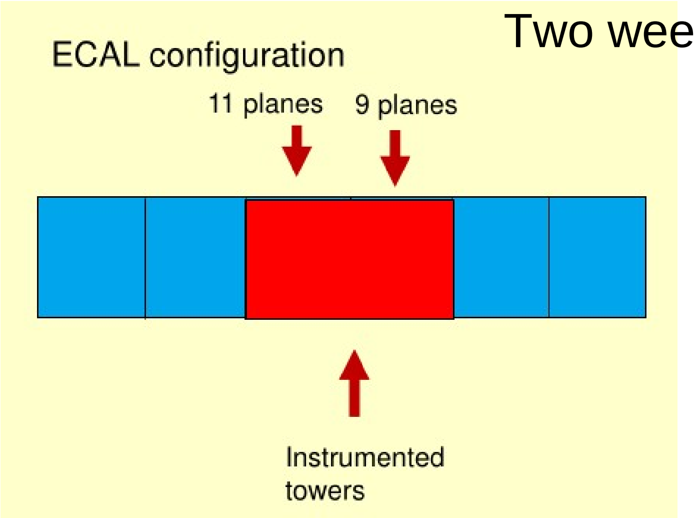
- Highly **compact and modular calorimeter** to **minimize** the **Molière radius**. Design based on the concept considered by the FCAL collaboration for compact calorimeters for luminosity measurement at future Higgs factories. Based on thin silicon sensors developed previously for CALICE (16×16 pads 5.5×5.5 mm²).

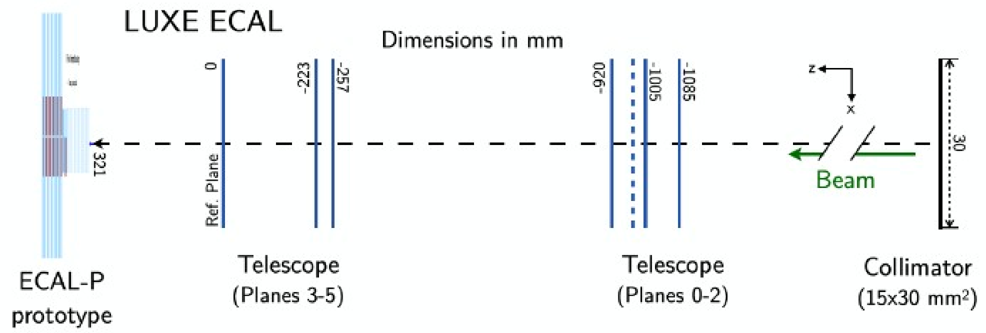
- Silicon – tungsten planes
- Six sensors per plane (~55cm)
- 20 active planes (21 W plates)
- Distance between tungsten plates : 1mm
- Front End Boards above the sensors : readout and HV
- Dedicated electronics (FLAXE) developed for LUXE
- **Test beam with single sensors (Si, GaAs) in 2022**
  - Eur.Phys.J.C 85 (2025) 6, 684
- **Test beam with 20 sensors in June 2025**
  - Discussed today



ECALp Beam test setup

Two weeks of beam test at DESY – around 250M triggers (TLU)





▷ **Tracker mode**

▷ Initial runs with 3 layers

- **Area Scan** but mostly debugging

▷ **Ful stack**, with 11 layers

- ~10 M at two positions (3 GeV)
- **Area scan** with ~1 M per position (5GeV, **35** positions)

▷ **Calorimeter mode**

▷ **Position scan**, 11X0 & 9X0 (5GeV)

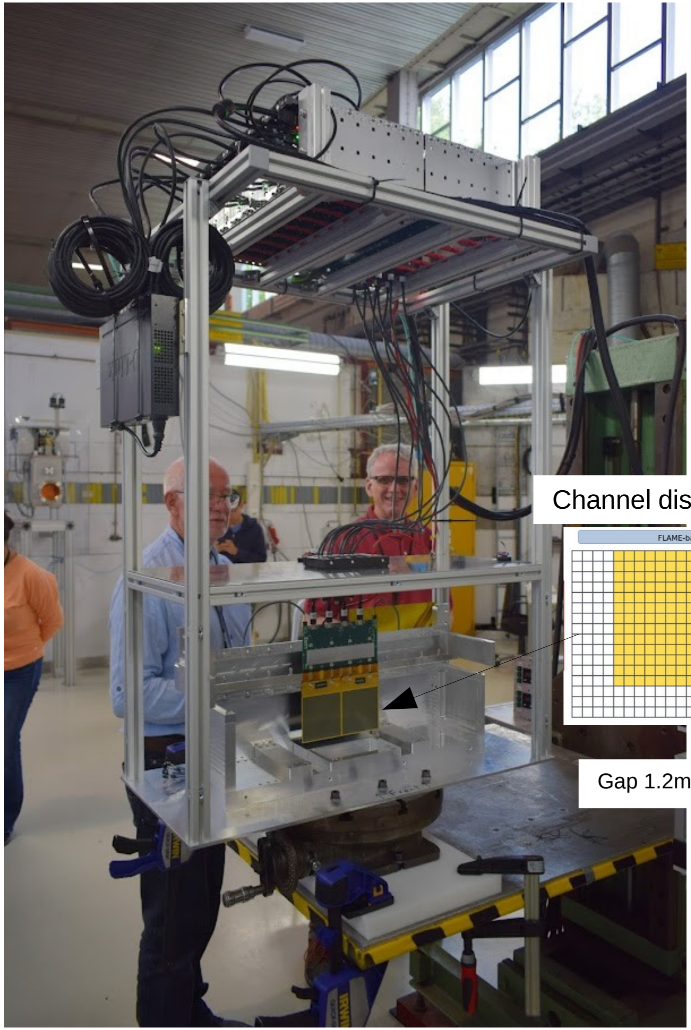
▷ **Angular scan** – energies and incidence angles matching LUXE scenarios

- Performance study with real gaps between sensors

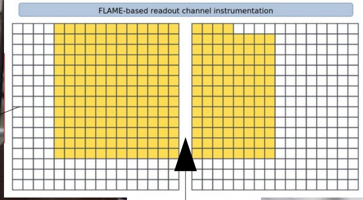
▷ **Energy scan** from 1-5.6GeV in two positions

▷ **Depth scan** 11 X0, 15 X0, 18 X0, 21 X0

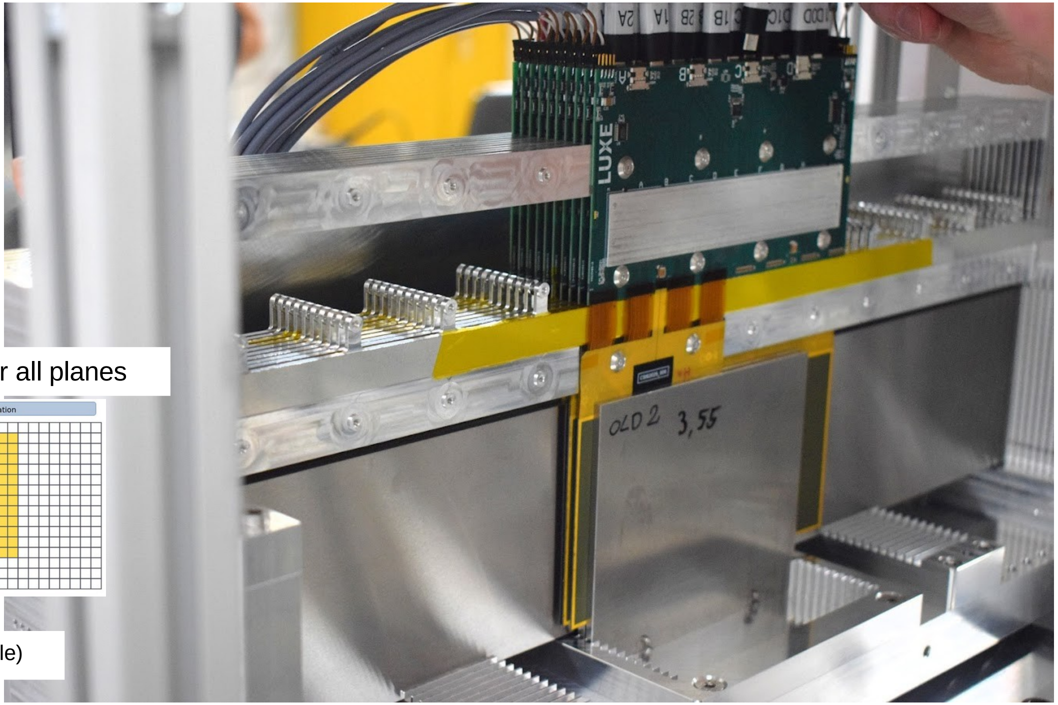
ECALp Beam test setup



Channel distribution for all planes

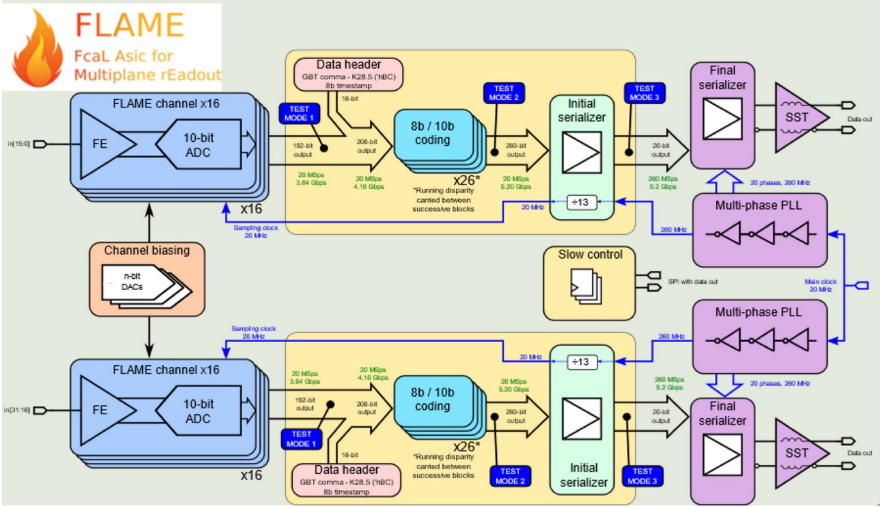


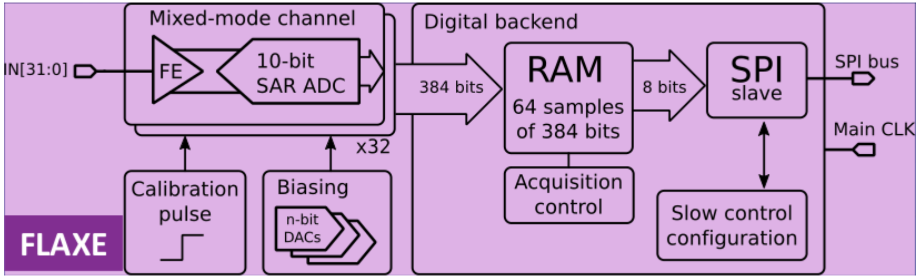
Gap 1.2mm (not to scale)



ECALp readout - FLAXE

- ▷ Based on previous developments FLAME ASIC: developed for the luminosity detector at future e+e- accelerators.
  - **FLAME has been extensively tested → including in the last beam test in 2025**
- ▷ Main features
  - 32 channels
  - 10 bit ADC at 20 MHz **in each channel**
  - Analog front end in each channel. CR-RC shaper of 50 ns
  - High speed serialize
- ▷ FLAXE is similar but w/o the high speed serializer
  - Acquisition at LUXE frequency (10 Hz)
- ▷ Production failure in 2024.
  - New production in 2025-2026 (MORE INFO in the backup)





https://iopscience.iop.org/article/10.1088/1748-0221/20/01/C01026/pdf

Developments from AGH Krakow

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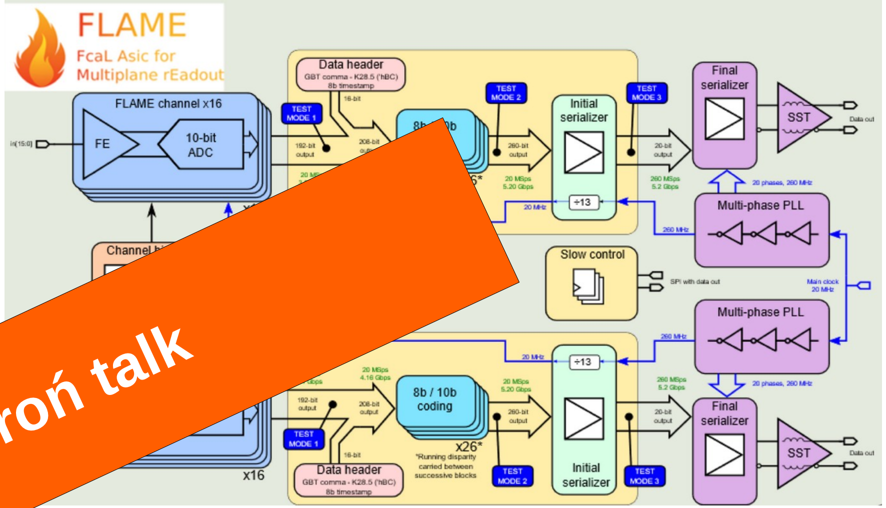
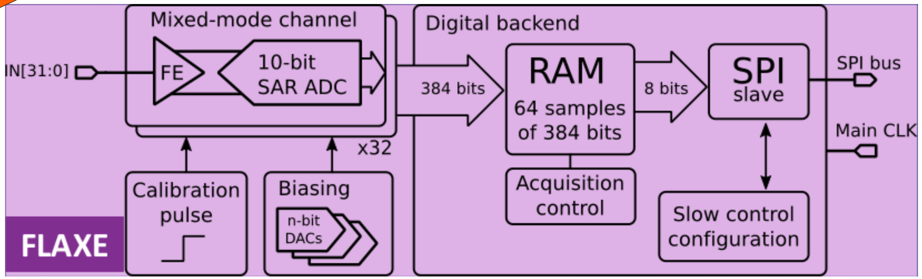
See J. Moroń talk





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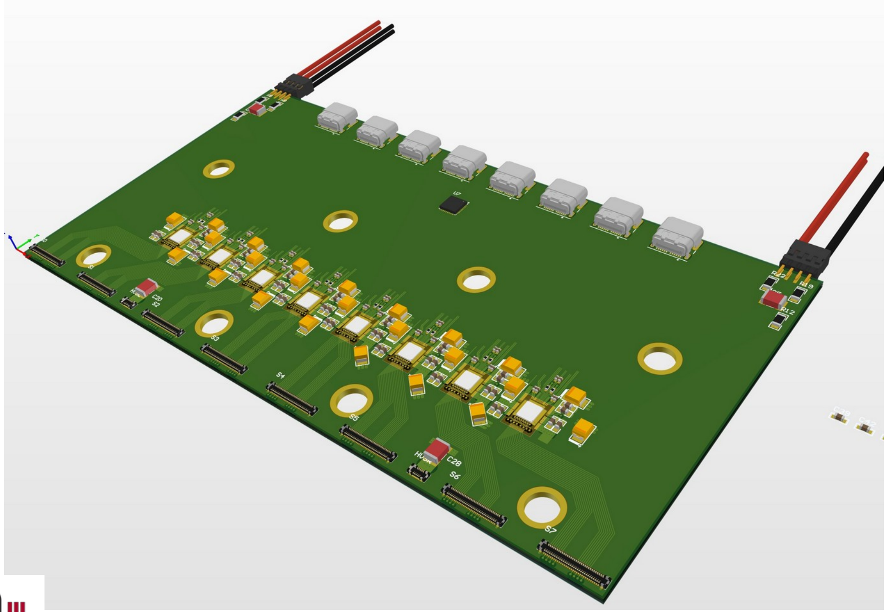
Developments from AGH Krakow

ECALp readout - FEB

▷ "Funny" mapping to enable the fabrication of a 10-11 layer prototype with 2 sensors per layer.

- With the available number of ASICS



Updated channel map

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0	1	2	3	4	5	6	7	8	9	...
15				A0	0	2	4	6	8	10	1	3	5	7	9	11	29	31	28	30					A4		
14				A4	4	6	8	10	12	14	16	18	20	22	24	26	16	18	20	22	24	26	28	30	A7		
13			A3	A4	12	14	16	18	20	22	24	26	28	30	0	2	0	2	4	6	8	10	12	14	A7		
12				A4	5	7	9	11	13	15	17	19	21	23	25	27	17	19	21	23	25	27	29	31	A7		
11			A3	A4	13	15	17	19	21	23	25	27	29	31	1	3	1	3	5	7	9	11	13	15	A7		
10			A2	A3	20	22	24	26	28	30	0	2	4	6	8	10	16	18	20	22	24	26	28	30	A6		
9			A1	A2	28	30	0	2	4	6	8	10	12	14	16	18	0	2	4	6	8	10	12	14	A6		
8			A2	A3	21	23	25	27	29	31	1	3	5	7	9	11	17	19	21	23	25	27	29	31	A6		
7			A1	A2	29	31	1	3	5	7	9	11	13	15	17	19	1	3	5	7	9	11	13	15	A6		
6				A1	4	6	8	10	12	14	16	18	20	22	24	26	16	18	20	22	24	26	28	30	A5		
5			A0	A1	12	14	16	18	20	22	24	26	28	30	0	2	0	2	4	6	8	10	12	14	A5		
4				A1	5	7	9	11	13	15	17	19	21	23	25	27	17	19	21	23	25	27	29	31	A5		
3			A0	A1	13	15	17	19	21	23	25	27	29	31	1	3	1	3	5	7	9	11	13	15	A5		
2																											
1																											
0																											

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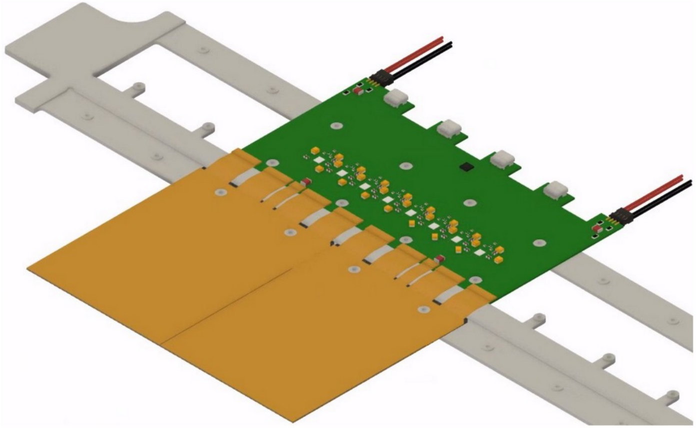
More realistic FEB



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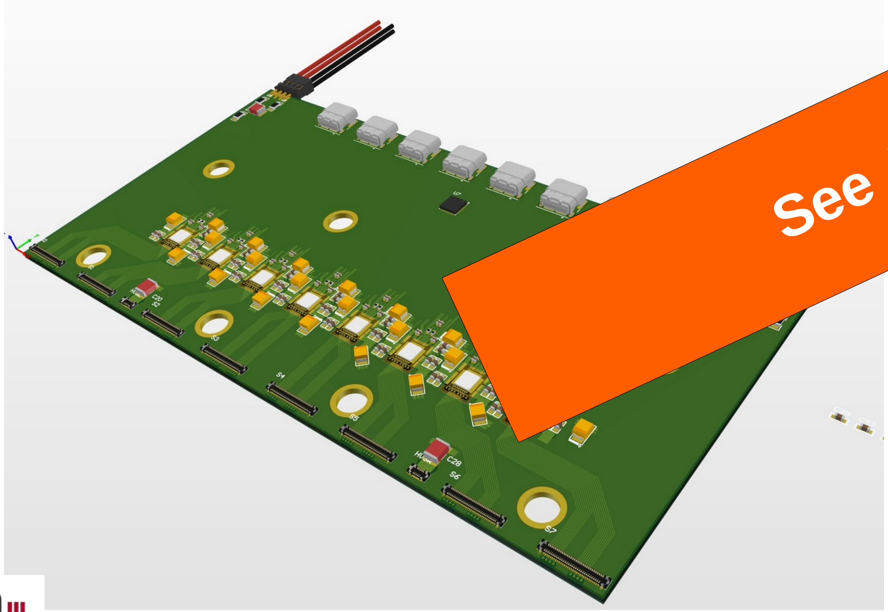
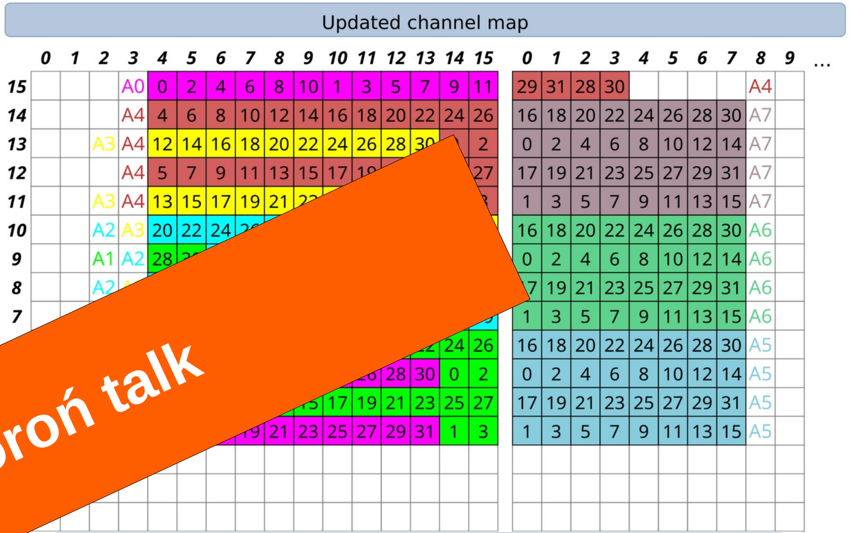
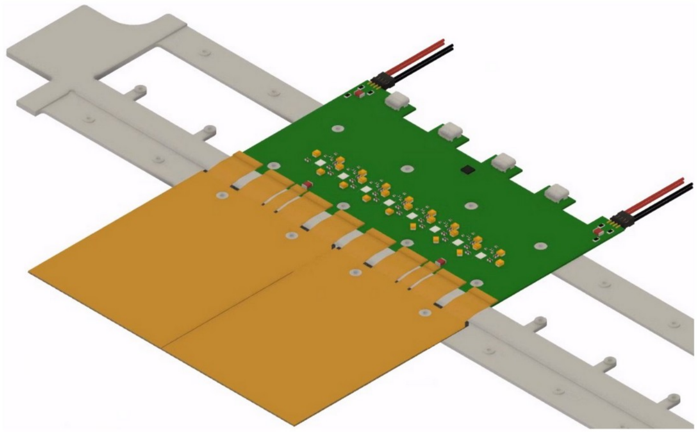






See J. Moroń talk

ECALp DAQ

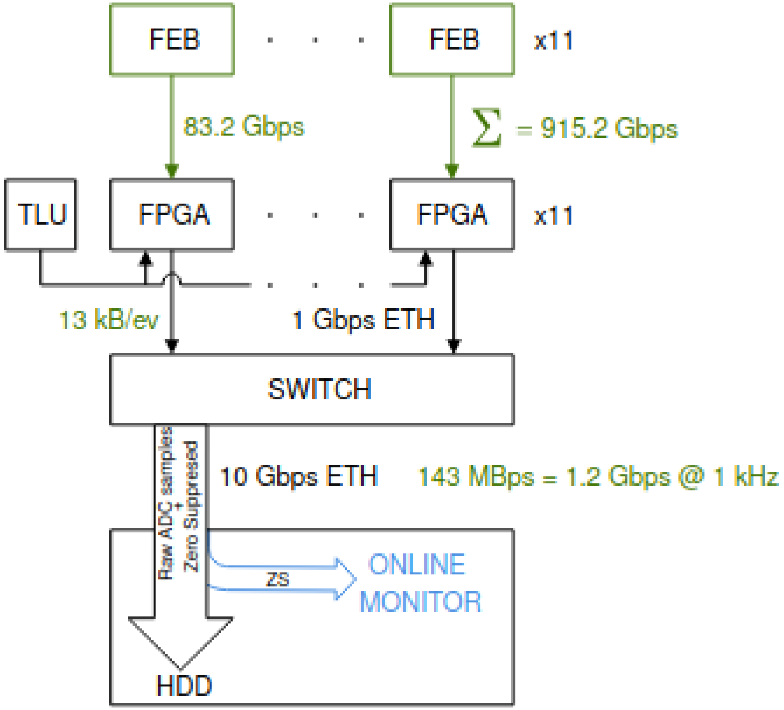
Prototype DAQ

DAQ

Two streams of data stored:

- Zero Suppressed (ZS) data
  calculated signal amplitude and arrival time for triggered channels
  crucial for on-line monitoring
- Raw ADC samples for all channels
  crucial for understanding of detector performance and proper data analysis

Raw data consumes around 250 times more storage space in comparison to ZS data.



DAQ worked without problems up to 2 kHz event rate (1830.4 Gbps)

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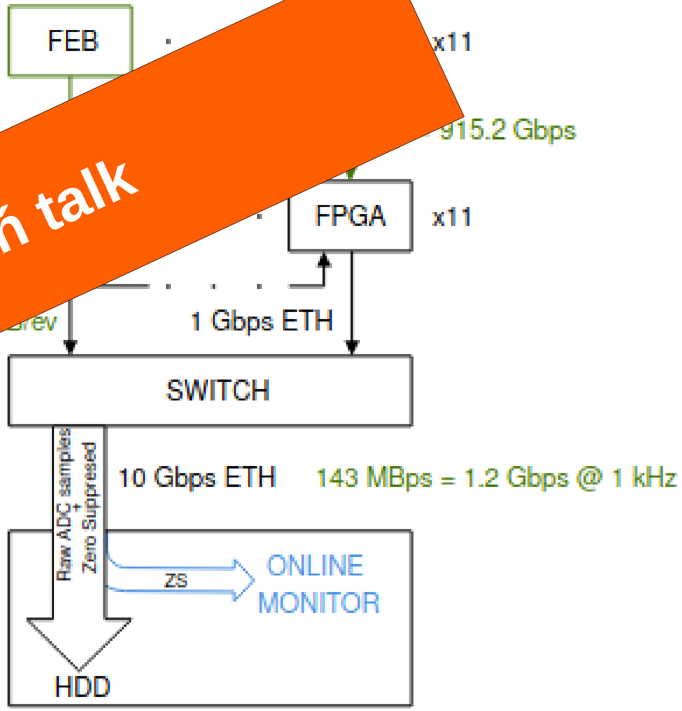

See J. Moroń talk

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ECALp Mechnical housing

▷Aluminum frame designed and manufactured at U. Warsaw

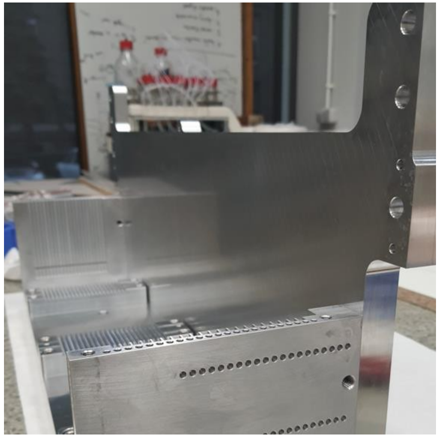
- Aluminum : bottom (30mm), backplane (20mm), combs (20mm and 10 mm)
- **Overall machining assembly ~10 um**
- Connection to the Front-End Board frame
- Technical holes for future lowering mechanics

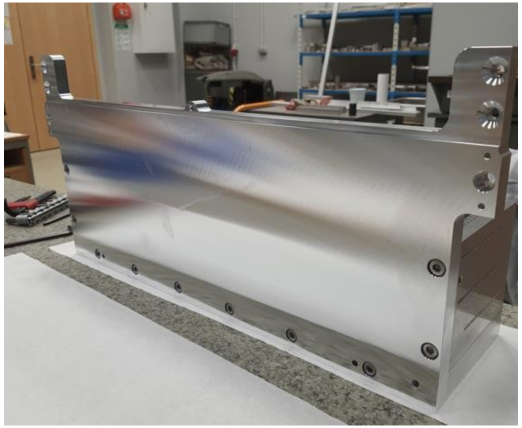
▷**Compact calorimeter for LUXE:**

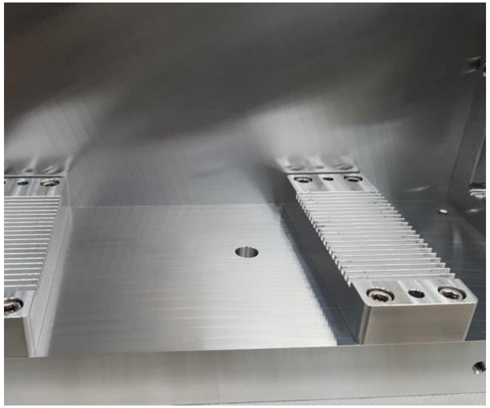
- Combs pitch : 4.5 mm (tungsten: 3.5 mm +detector: **1 mm gap**)
- Comb gaps : 3.5 + 0.08 mm (bottom combs), 3.5 + 0.08 (side combs)

▷**Prototyping phase**

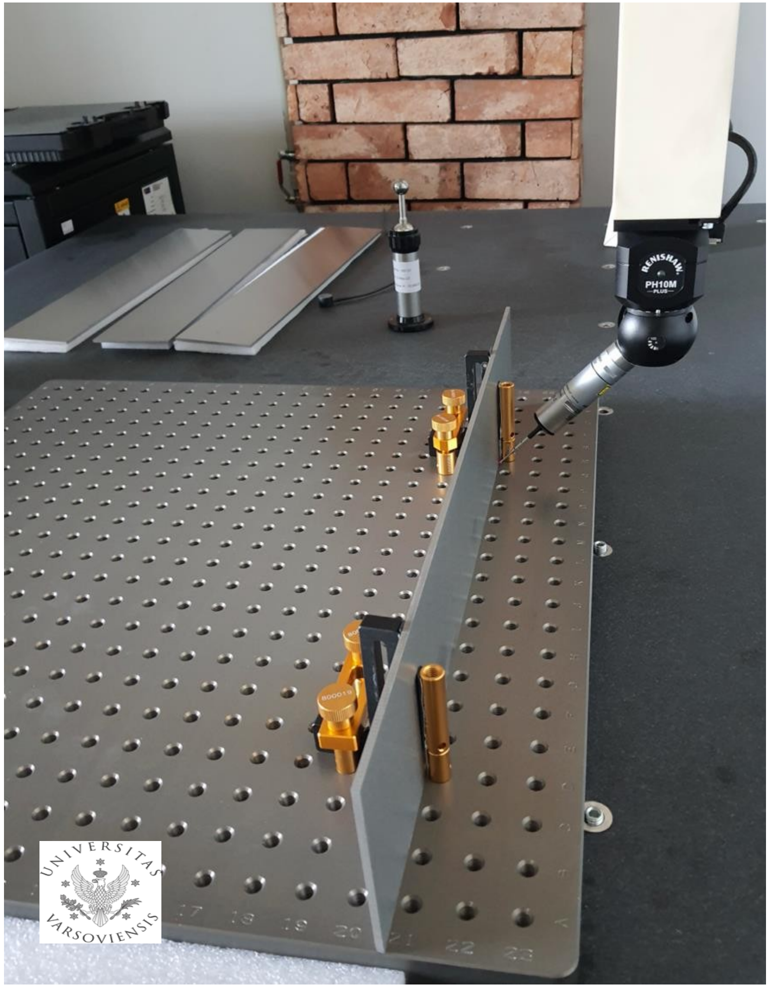
- **Gap of 1.2 mm (instead of 1mm)**







ECALp tungsten plates



▷ Long and thin tungsten plates (1X0)

- 55cm x 10xm x 0.35 cm → With requested tolerances on planarity better than 100um

▷ 9 plates purchased in 2024-2025 from three different companies (2 chinese, 1 german)

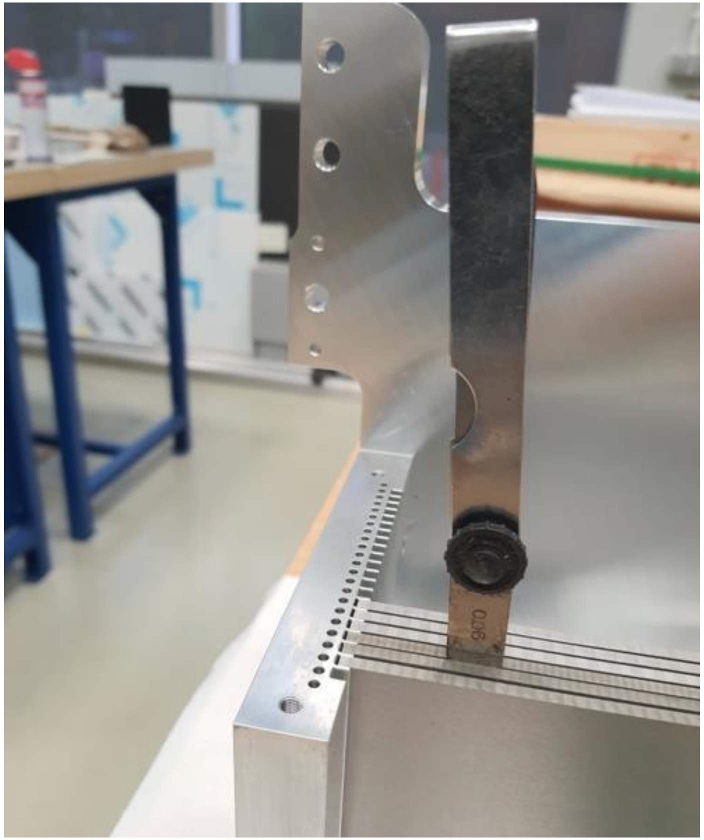
- Goal: 50um planarity

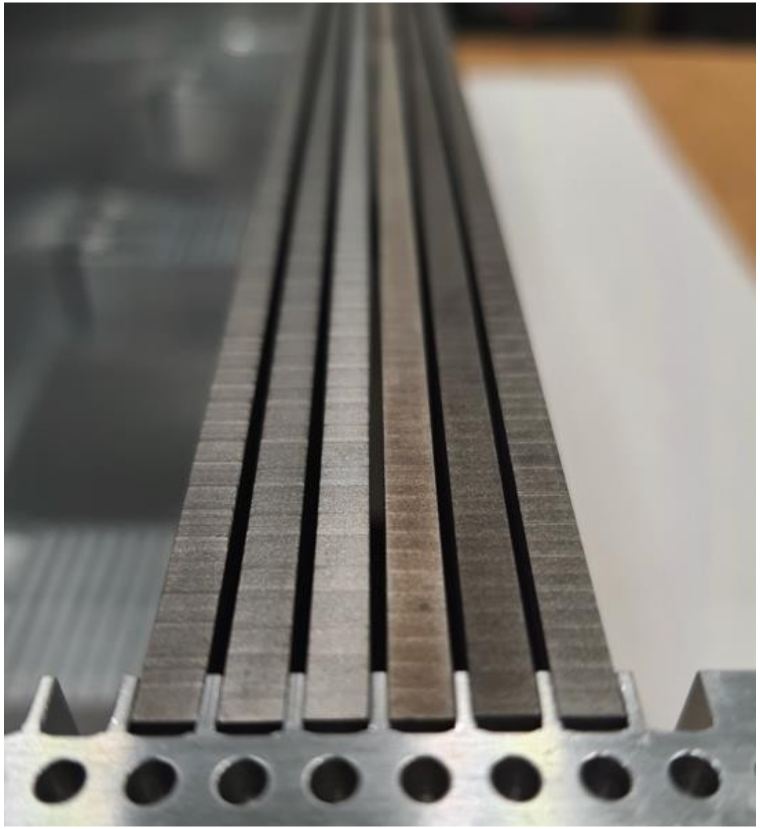
▷ **Achieved 3.55 $^{+0,0}_{-0,1}$ mm**

- Up to 150um in bending

XYZ dimensions (mm)			
Plate	X	Y	Z
X1	555.1039	100.0907	3.5593
X2	555.1047	100.0864	3.5429
X3	555.1388	100.0964	3.5407
B1	555.0785	100.0640	3.5451
B2	555.0654	100.0458	3.5547
B3	555.0637	100.0366	3.5701
Nom	555.00±0.20	100.00±0.20	3.50±0.05

ECALp tungsten plates - 2024

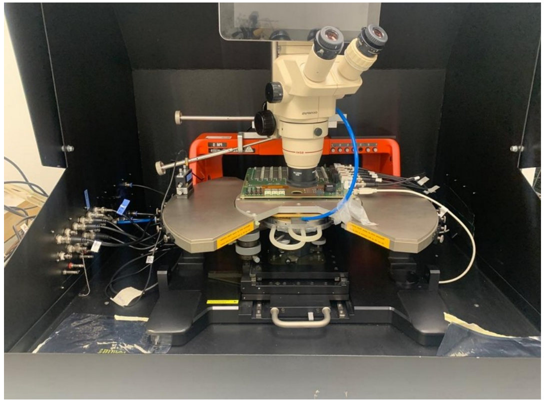


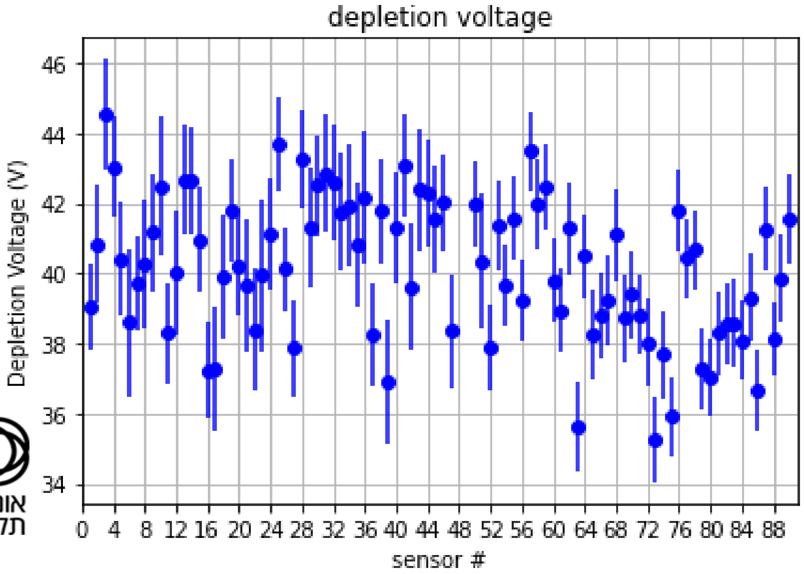


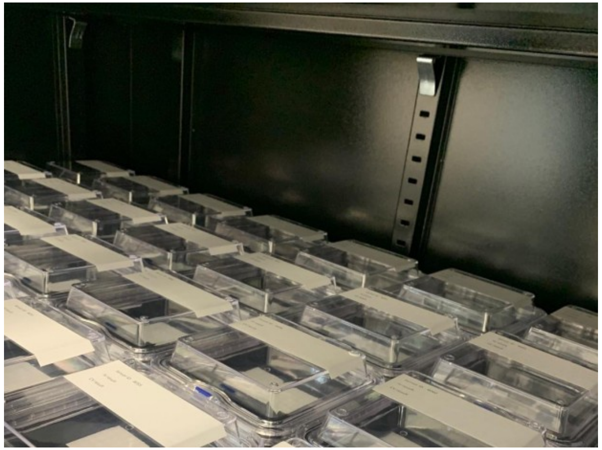
ECALp CSIS – sensors

▷ 110 sensors purchased to Hamamtsu

- 16x16 pads of 5.52 x 5.52 mm²
- 320 um thickness
- 90 tested and fully characterized by **Tel Aviv University**
- 20 used in Test Beam at DESY 2025







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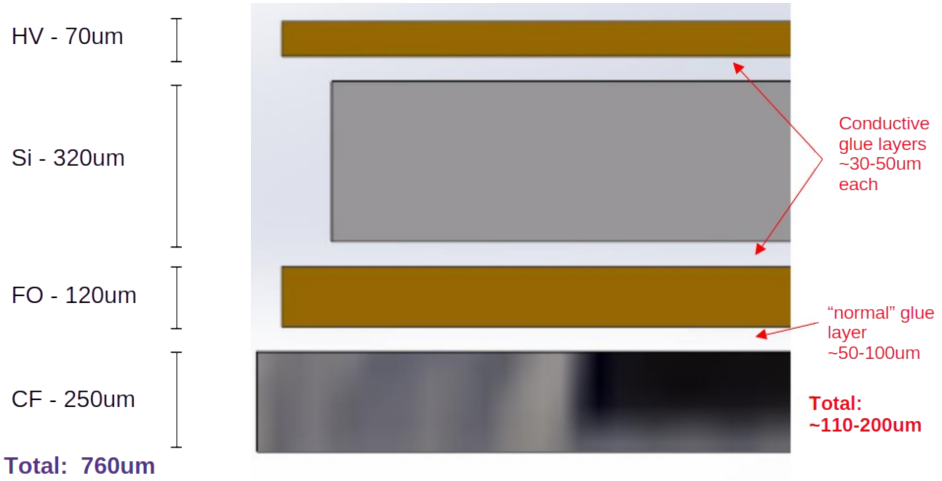
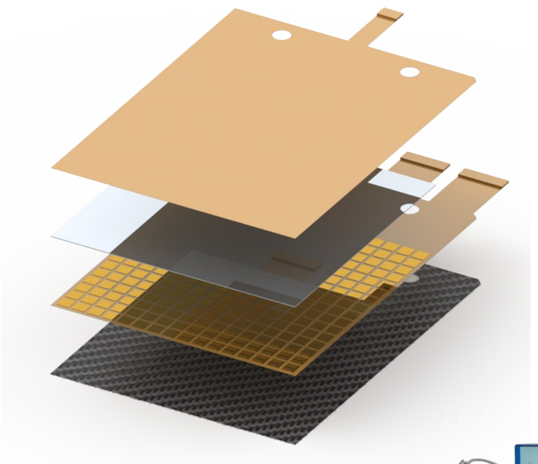
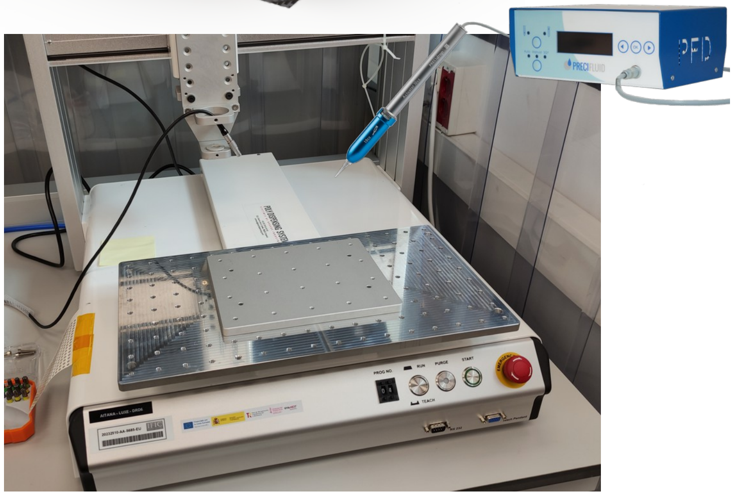
ECALp Compact Silicon Sandwich - CSIS

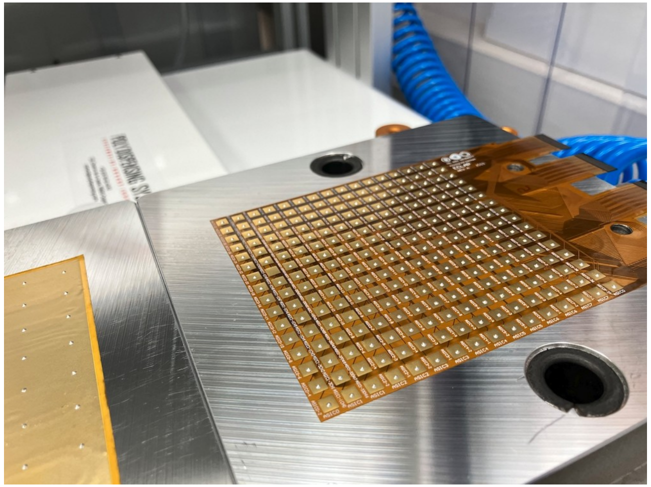
- ▷ CSIS = entity of Carbon fiber support, signal fanout, silicon sensor, HV delivery kapton
- ▷ Designed to match the **tight mechanical** precision requirements from the mechanical housing (physics driven)
  - Thickness bellow 1mm (relaxed to 1.2 mm for the testbeam 2025)
  - Precision in the lateral separation between sensors to be better than 100 um (relaxed to 200um for beam test 2025)

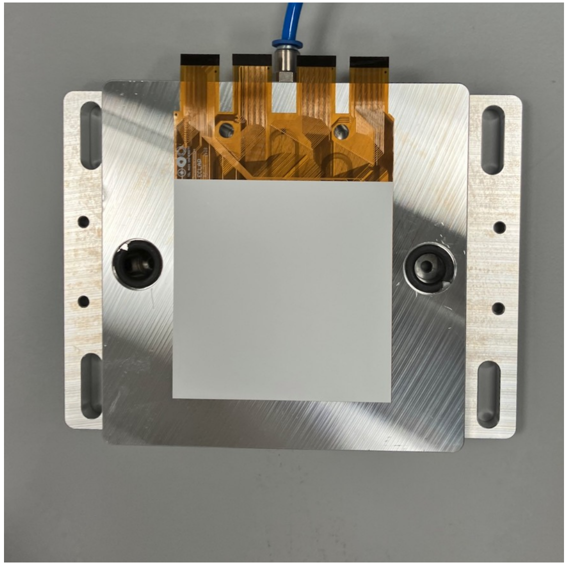


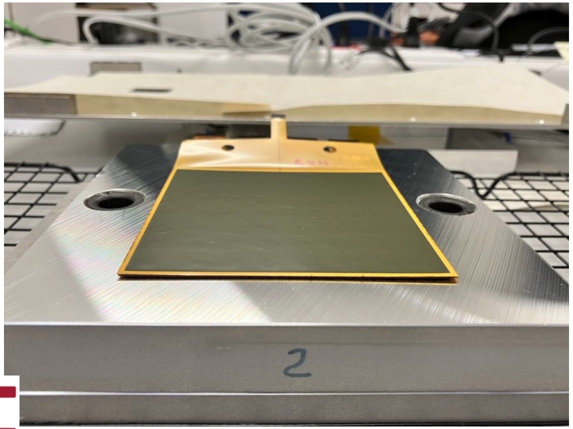


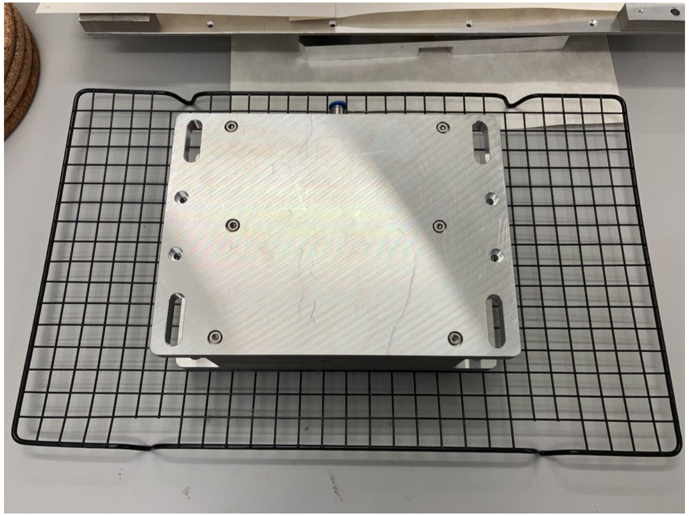


ECALp CSIS Assembly







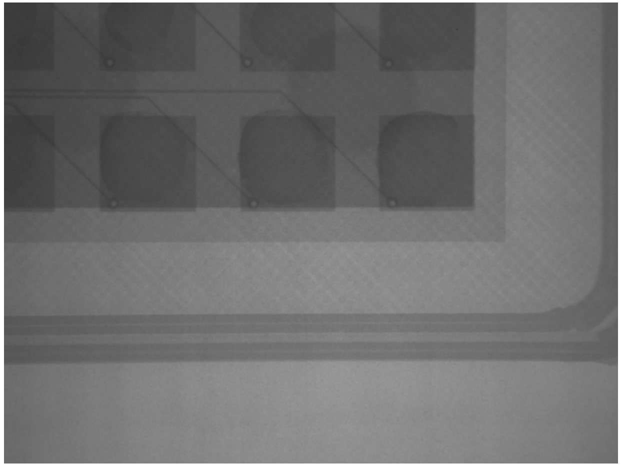


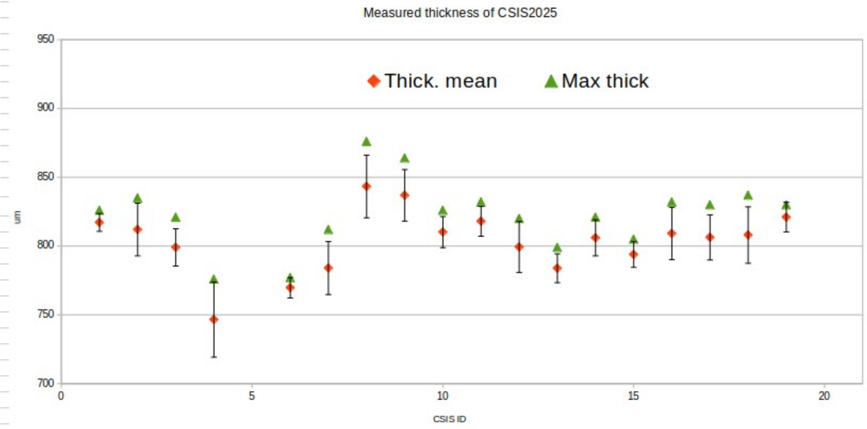
ECALp CSIS validation

X-ray inspection of glue dots.

CMM measurements: All bellow 900um

Electrical in probe station: All operative





2025_001	DOWSIL+H20E
2025_002	DOWSIL+H20E
2025_003	DOWSIL+H20E
2025_004	3MDST+H20E
2025_005	3MDST+H20E
2025_006	3MDST+H20E
2025_007	3MDST+MG9410
2025_008	DOWSIL+MG9410
2025_009	DOWSIL+MG9410
2025_010	DOWSIL+H20E
2025_011	DOWSIL+H20E
2025_012	DOWSIL+H20E
2025_013	DOWSIL+H20E
2025_014	DOWSIL+H20E
2025_015	DOWSIL+H20E
2025_016	DOWSIL+H20E
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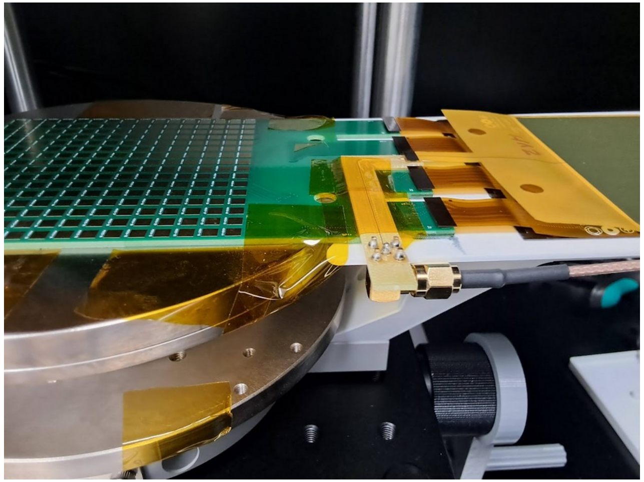
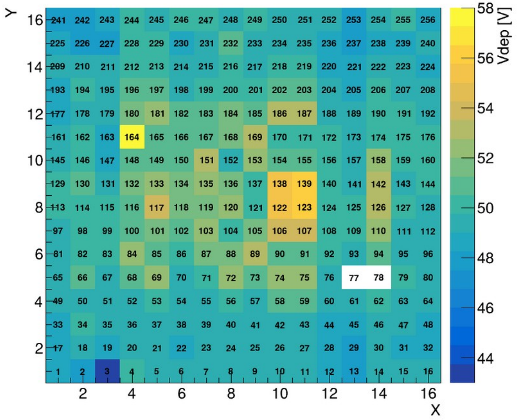
2025_019	DOWSIL+H20E
2025_020	DOWSIL+H20E





Data !

First:

▷ Understanding the data

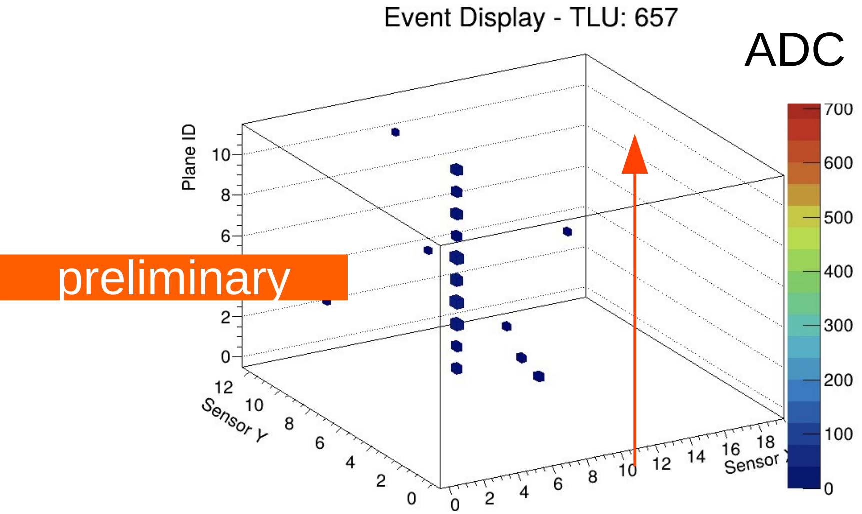
Analysis goals

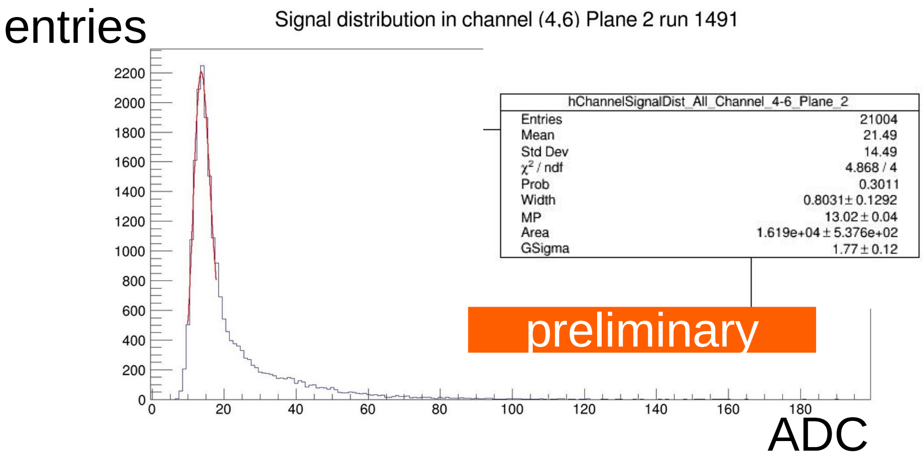
▷ Main topics we want to study:

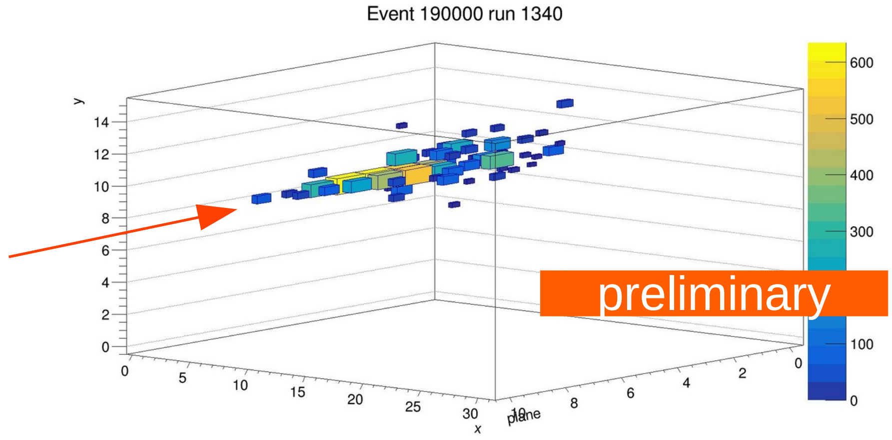
- energy resolution, linearity (challenging with 11 X0, but should still be possible)
- Longitudinal and transverse EM shower profiles
- impact of incident angle on shower development and calorimeter response
- impact of inter-sensor gap on the calorimeter response
- position and direction reconstruction

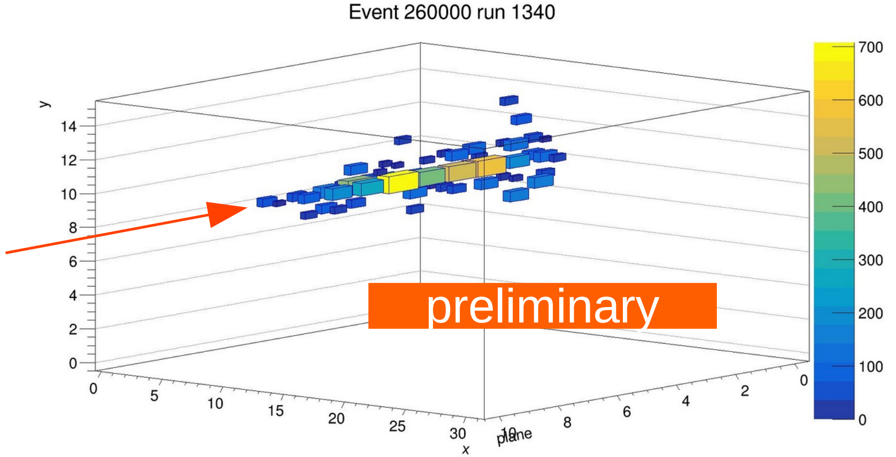
▷ With proper modeling of calorimeter performance in Monte Carlo

ZS online data – promising prospects









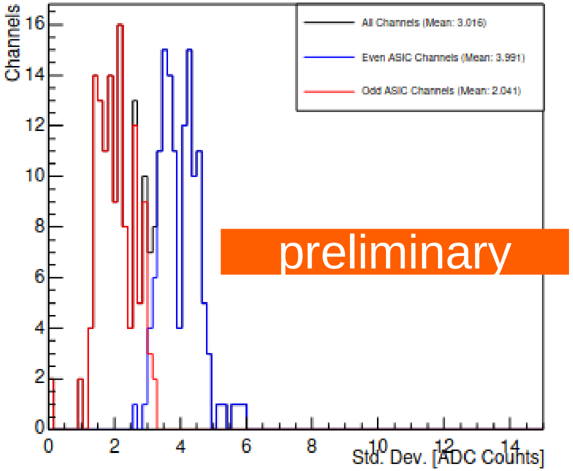
5 GeV showers

Reprocessing data & MIP calibration

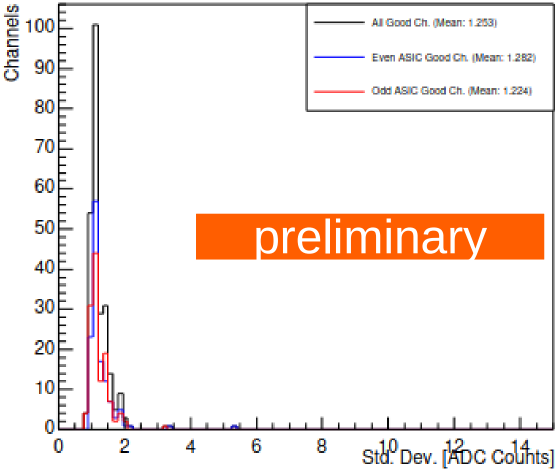
Noise patterns – PCB routing dependent

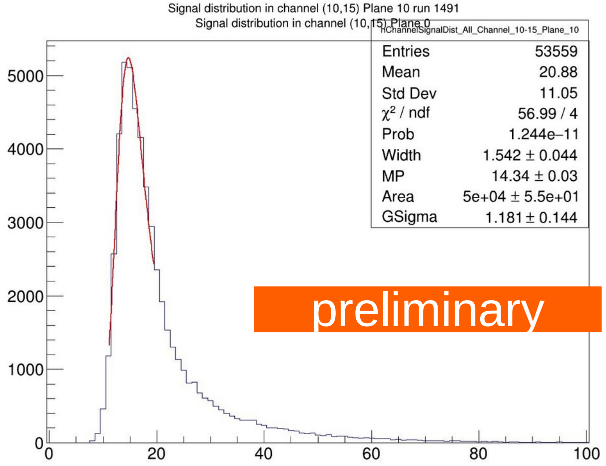
- Can be reduced significantly by Common Mode Subtraction (See J. Moroń's talk)
- Signal over Noise (at MIP) around 12.5 after corrections

Before CMS



After CMS

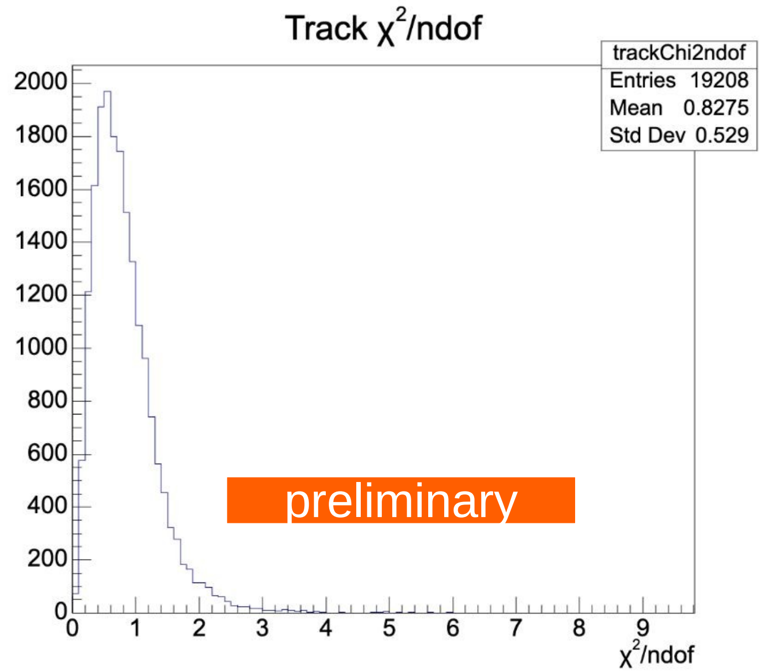


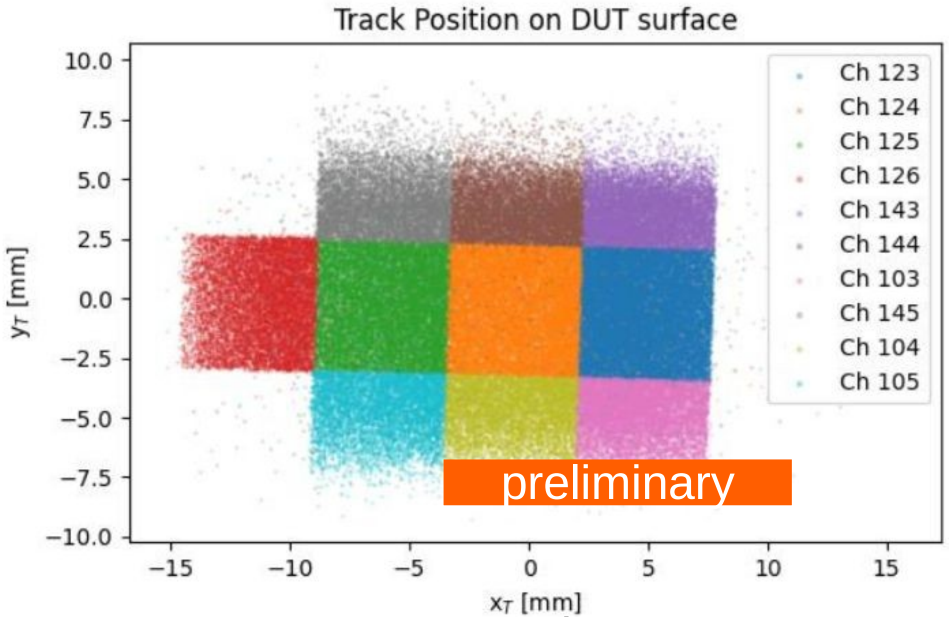


Telescope and DUT alignment

Noise patterns – PCB routing dependent

- ▷Prototype and telescope data properly synchronized (up to telescope readout errors)
- ▷Telescope alignment successful (good track quality). Expected precision on ECAL face ~ 50μm.

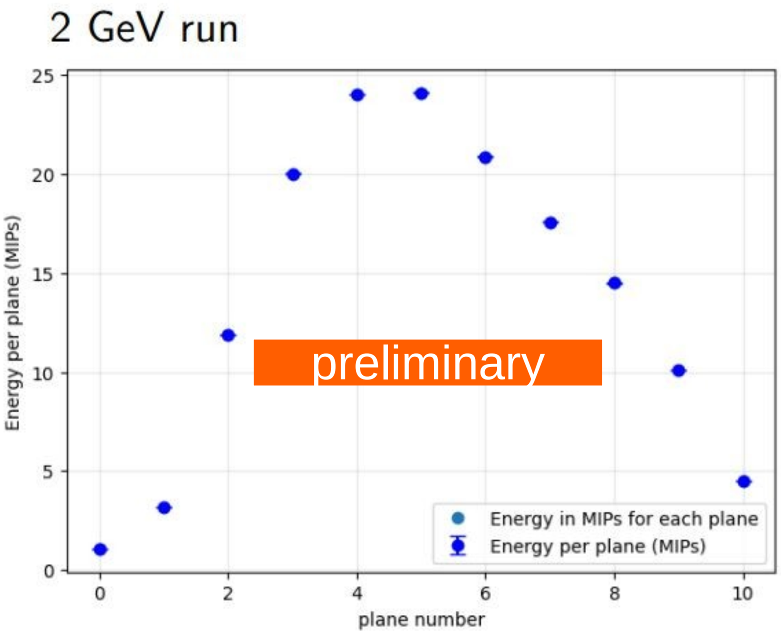


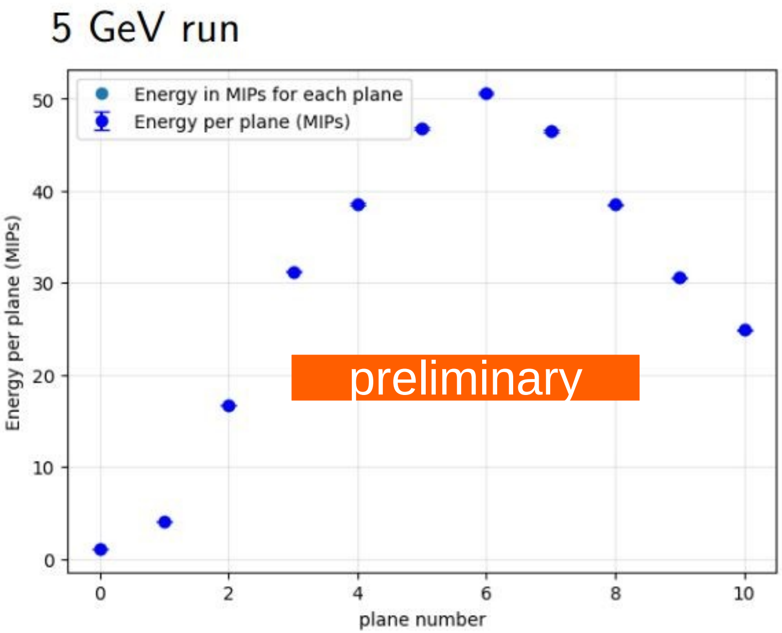


Hough
Transform

Calorimeter data

Longitudinal shower profile for two example runs (very preliminary)





Slide on simulation !!

AGH

UNIVERSITY OF WARSAW

TEL AVIV UNIVERSITY

DESY.

INSTITUTE OF SPACE SCIENCE INFLPR SUBSIDIARY

IFIC

The measurements leading to these results have been performed at the Test Beam Facility at DESY Hamburg (Germany), a member of the Helmholtz Association (HGF)

Back-up slides

Challenges – proposed solutions

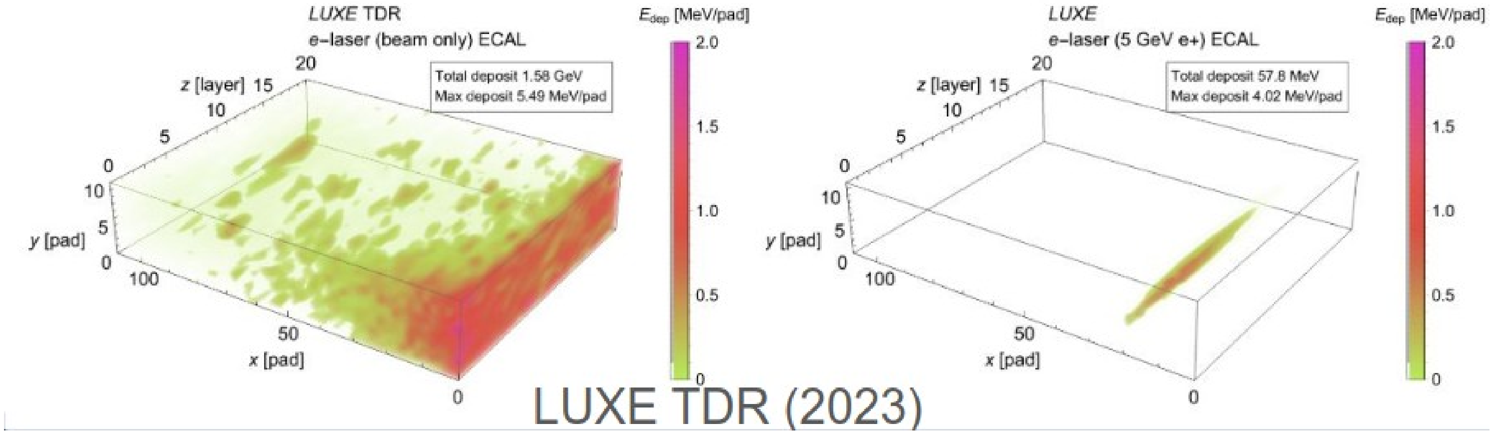
▷ (main) **Challenges**

- Two modes with expected number of positrons varying from 10^{-4} to 10^{7} per laser pulse

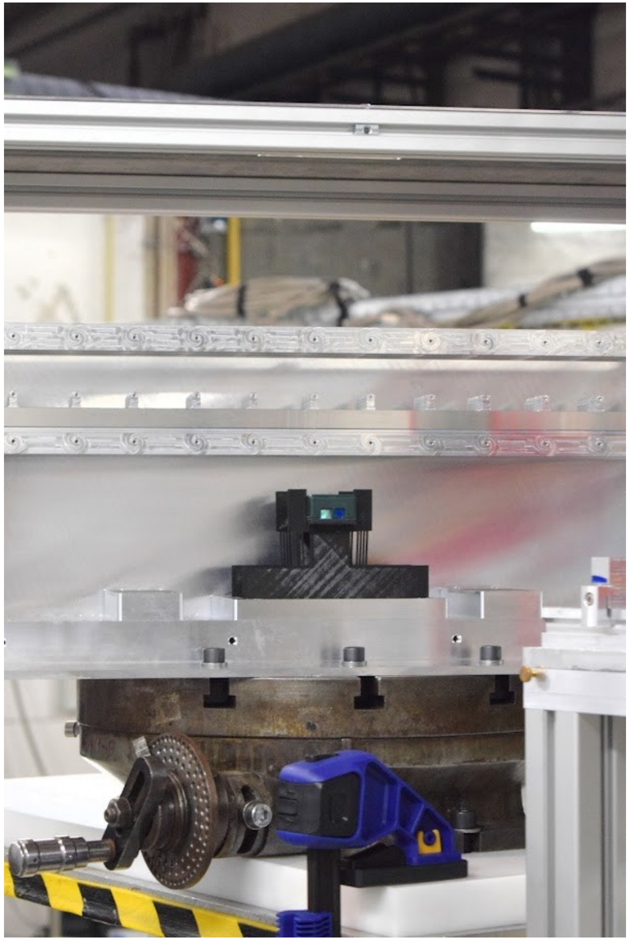
▷ Two running modes planned for positron calorimeter, for low and high intensity:

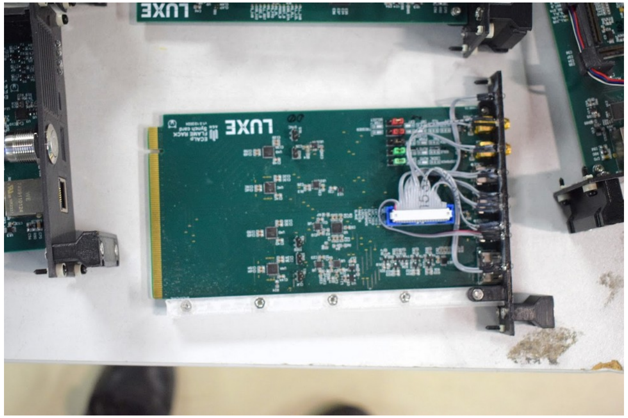
- at low intensity showers need to be identified in a widely spread background
- at high intensity shower will overlap ⇒ only total flux reconstruction possible

For both modes, precision depends on the transverse shower size !

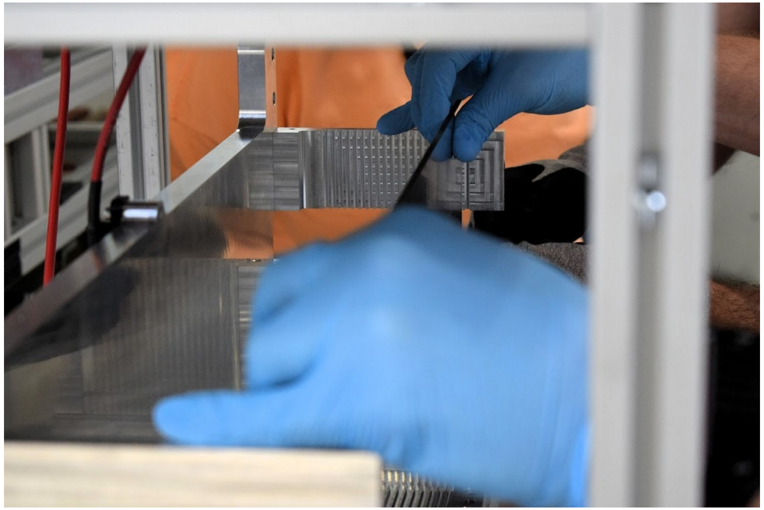


Beam test fun

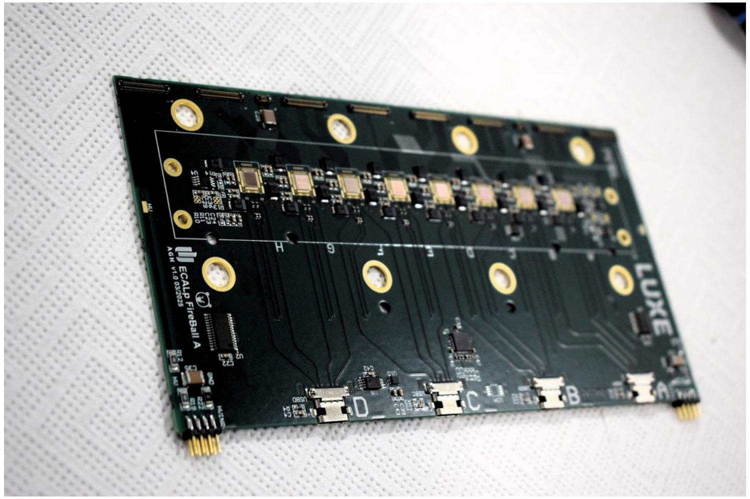


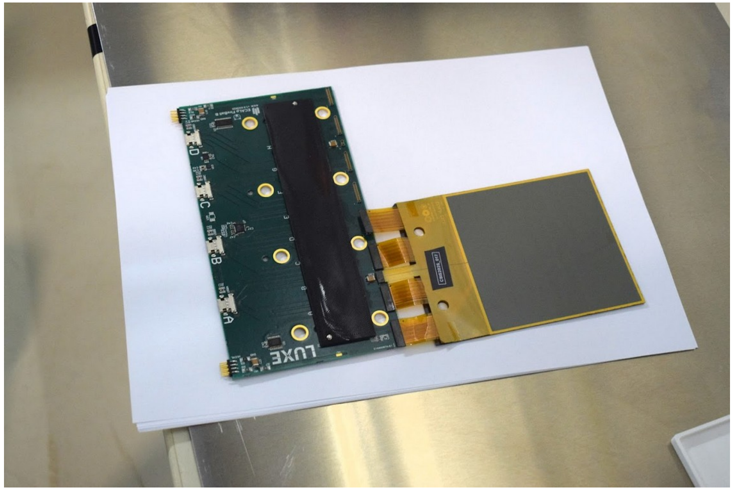


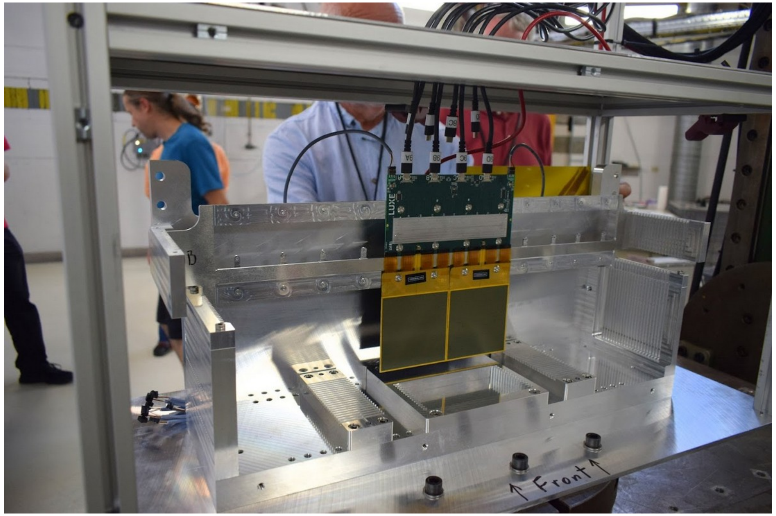
Beam test fun

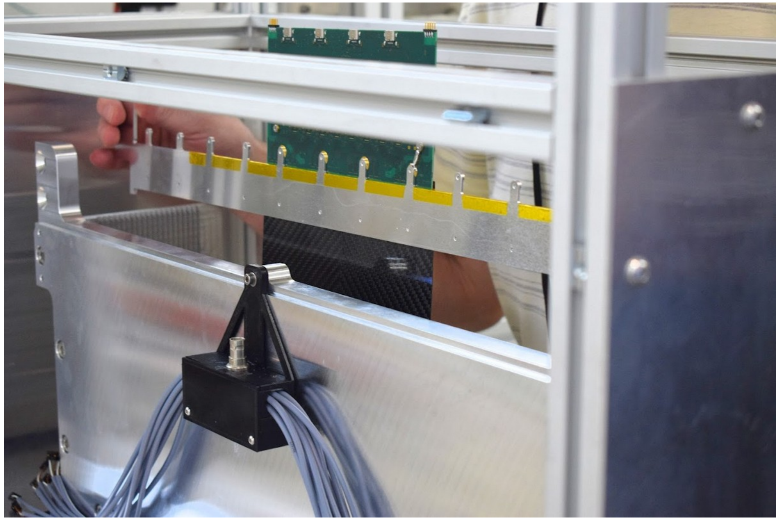




Beam test fun

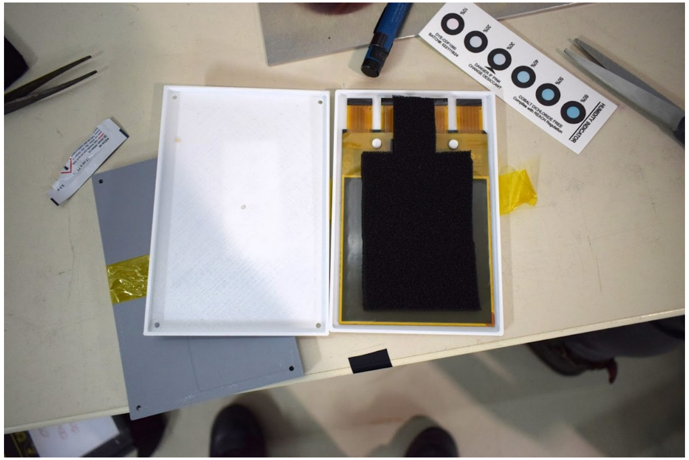


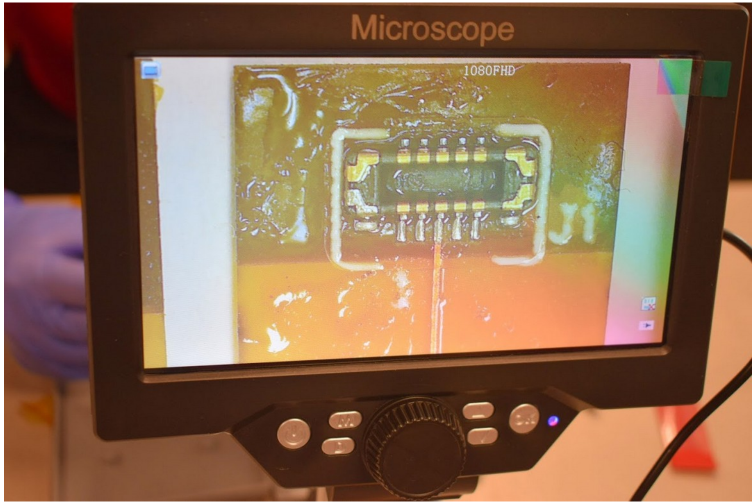


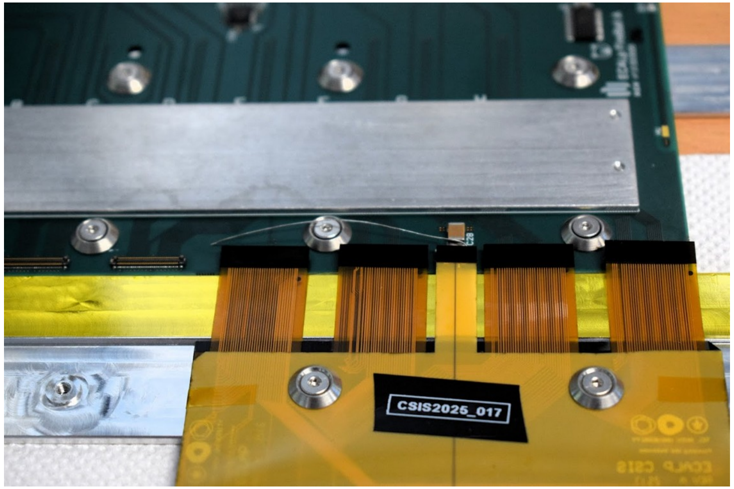


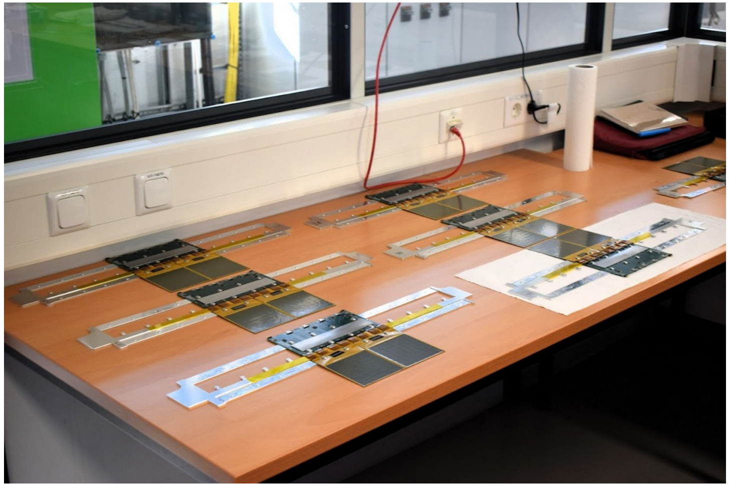


Beam test fun

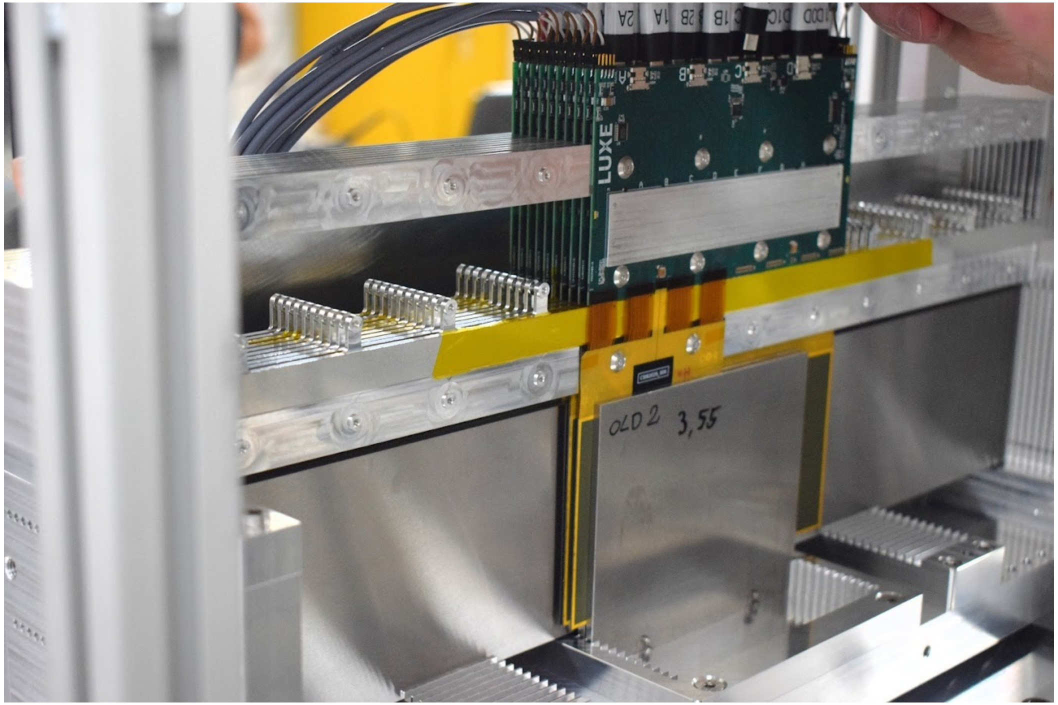






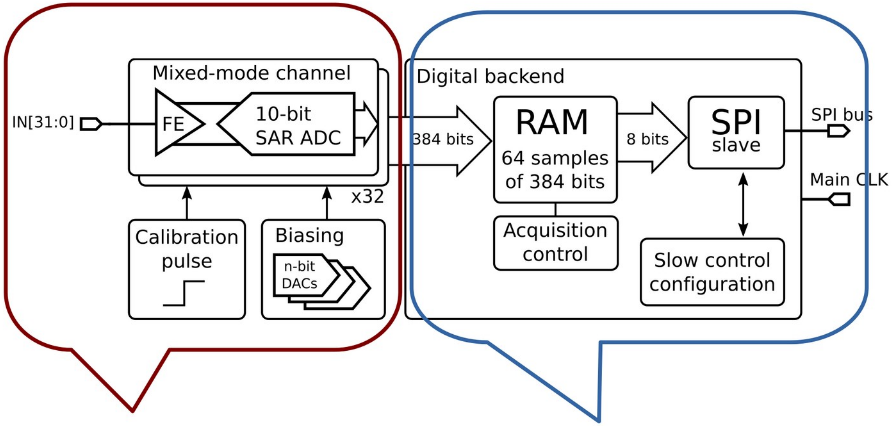


Beam test fun



FLAXE

FLAXE architecture

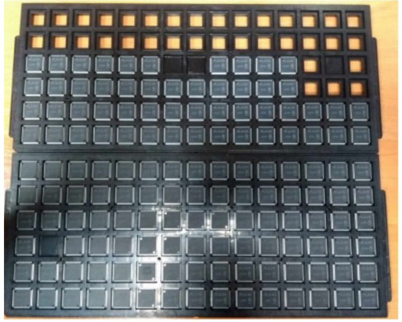


Copied from FLAME

New “simple” slow readout with memory

FLAXE – Qualification tests

Out of ~1000 fabricated chips, 142 were packaged and tested



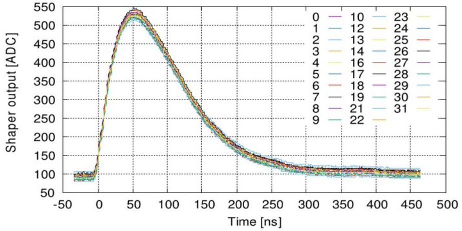
Test	Good	Acceptable	Bad	Failed
Overall ASIC yield	0 [0%]	6 [4.2%]	5 [3.5%]	131 [92.3%]
Supply shorts	92 [64.8%]	0 [0%]	0 [0%]	50 [35.2%]
Power consumption in sleep mode	7 [7.6%]	9 [9.8%]	30 [32.6%]	46 [50%]
Power consumption in always on	6 [12.8%]	9 [19.1%]	25 [53.2%]	7 [14.9%]
SPI SC register default read	33 [35.9%]	10 [10.9%]	46 [50%]	3 [3.3%]
SPI SC register write	10 [10.9%]	16 [17.4%]	21 [22.8%]	45 [48.9%]
Datapath RAM error map	0 [0%]	18 [38.3%]	3 [6.4%]	26 [55.3%]
Datapath RAM input sample	41 [87.2%]	3 [6.4%]	2 [4.3%]	1 [2.1%]
Biasing DAC’s	17 [36.2%]	15 [31.9%]	1 [2.1%]	14 [29.8%]
Channel data readability	5 [10.6%]	12 [25.5%]	4 [8.5%]	26 [55.3%]
Channel trimDAC	0 [0%]	19 [90.5%]	1 [4.8%]	1 [4.8%]
FE response and pulse shape	0 [0%]	7 [33.3%]	4 [19%]	10 [47.6%]
FE gain	0 [0%]	7 [33.3%]	4 [19%]	10 [47.6%]

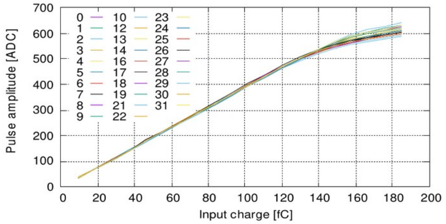
Our conclusion is that there was a production failure

FLAXE

FLAXE – Tests
6 chips got "acceptable" status

Chip Number	No. of working channels	No. of correct trimDAC's	No. of correct shapes	No. of correct gains
25	19	20	11	16
32	26	25	25	26
76	22	23	19	20
84	27	28	16	27
136	30	30	28	29
139	27	27	25	26





Performance of working channels in very good agreement with simulations

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Topical Workshop on Electronics for Particle Physics
University of Glasgow, Scotland, U.K.
30 September–4 October 2024

FLAXE, a SoC readout ASIC for electromagnetic calorimeter at LUXE experiment

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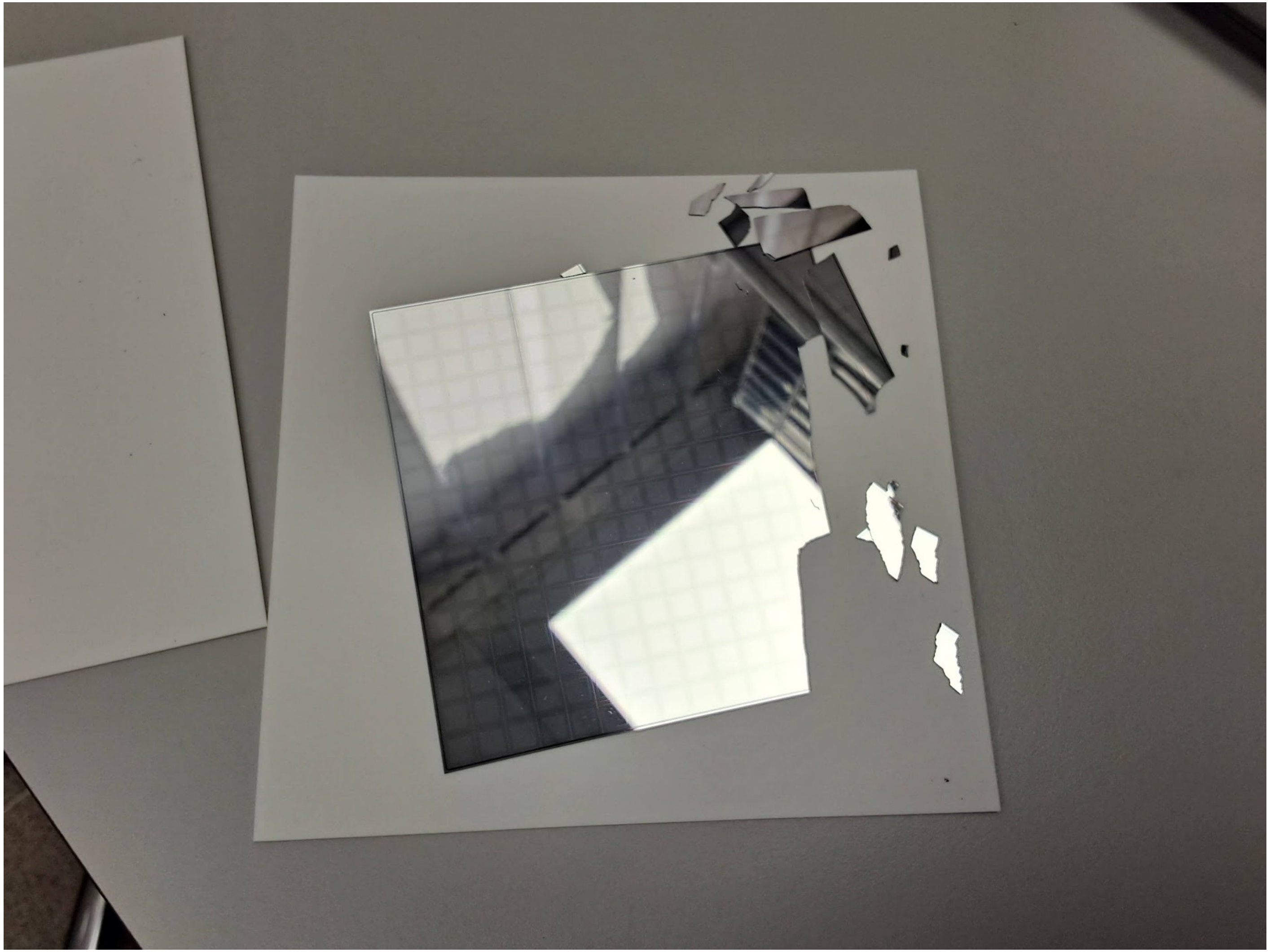
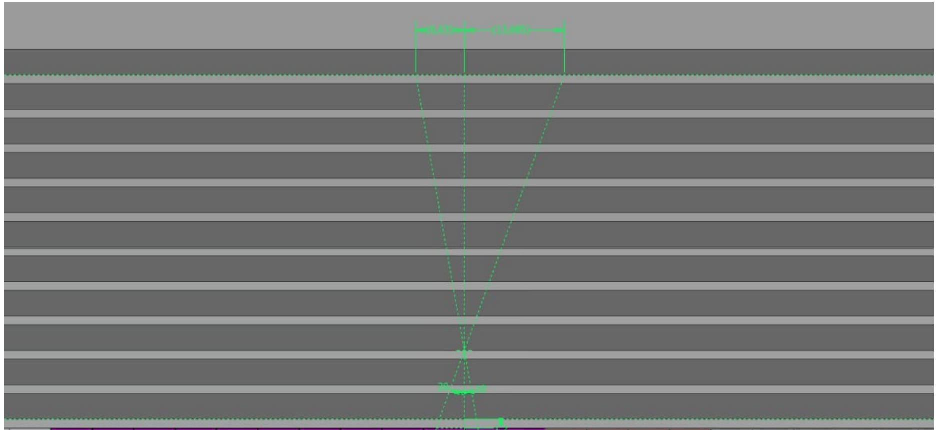
Abstract: The design and qualification results of a System on Chip (SoC) Application-Specific Integrated Circuit (ASIC), called FLAXE, fabricated in 130 nm CMOS technology are presented. FLAXE is a readout ASIC designed for ECAL-p, a compact electromagnetic calorimeter being a part of a detector system for Laser Und XFEL Experiment (LUXE) proposed at DESY, Hamburg, as an extension to the European X-ray Free Electron Laser (XFEL) facility. ECAL-p is a sampling calorimeter with a very compact design targeting small Molière radius, comprising 16 (up to 20) layers composed of 3.5 mm (1 X_0) thick tungsten absorber plates interspersed with silicon sensors. Sensor signal is read and shaped by the analogue readout channel, comprising a Charge Sensitive Amplifier (CSA) and a fully differential CR-RC shaper with 50 ns peaking time, which output is digitized in each channel by a 10-bit Successive Approximation Register (SAR) Analog-to-Digital Converter (ADC). Data from ADC are collected into the ASIC internal memory and read out by the Data Acquisition (DAQ) system between Bunch Crossings (BXs). Around 1000 ASICs have been fabricated and a first batch of 142 ASICs has been packaged and tested. The results of the qualification procedure.

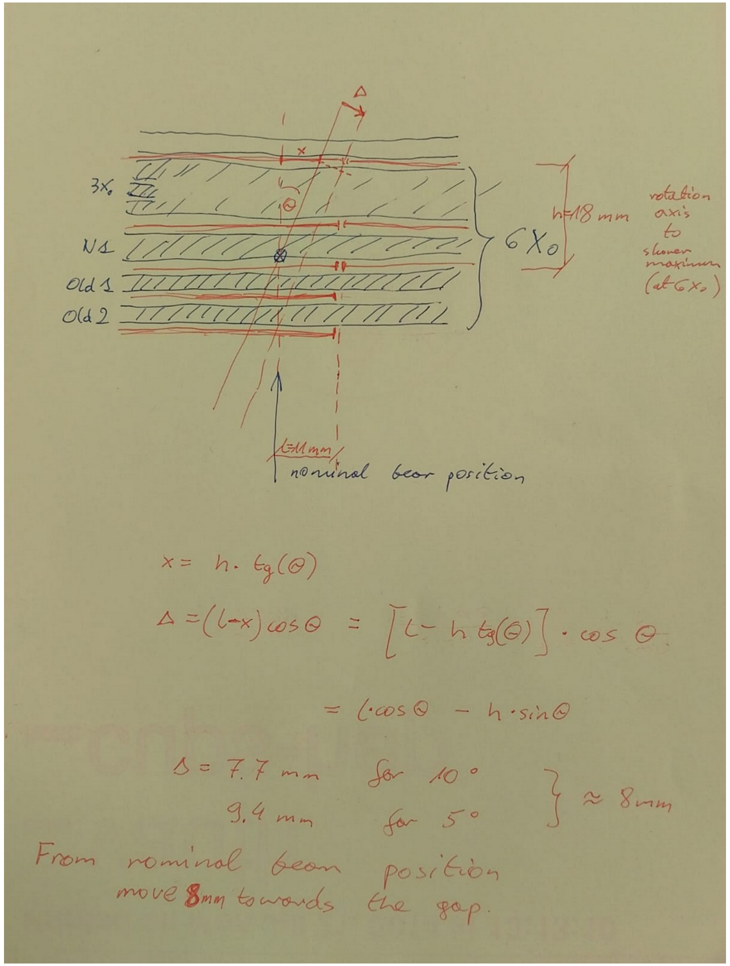
2025 JINST 20 C01026



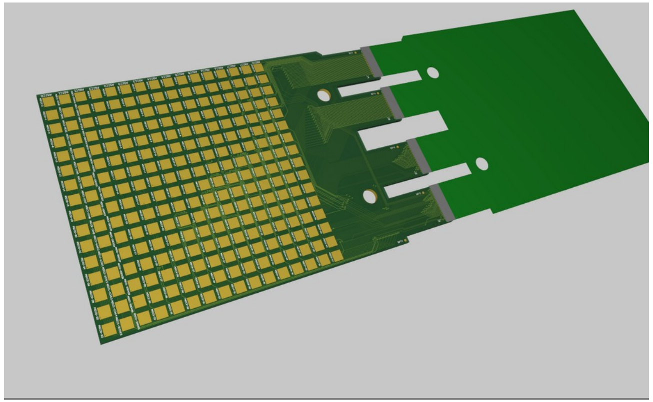
Beam test setup

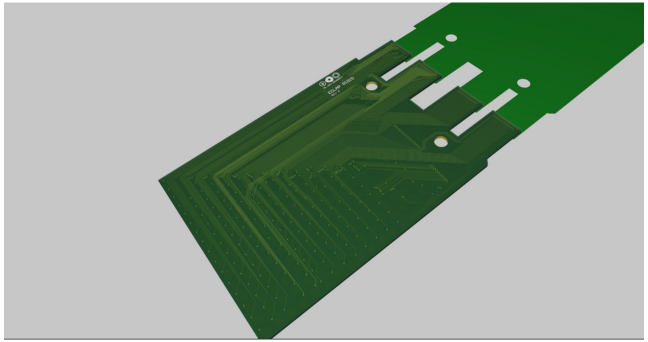


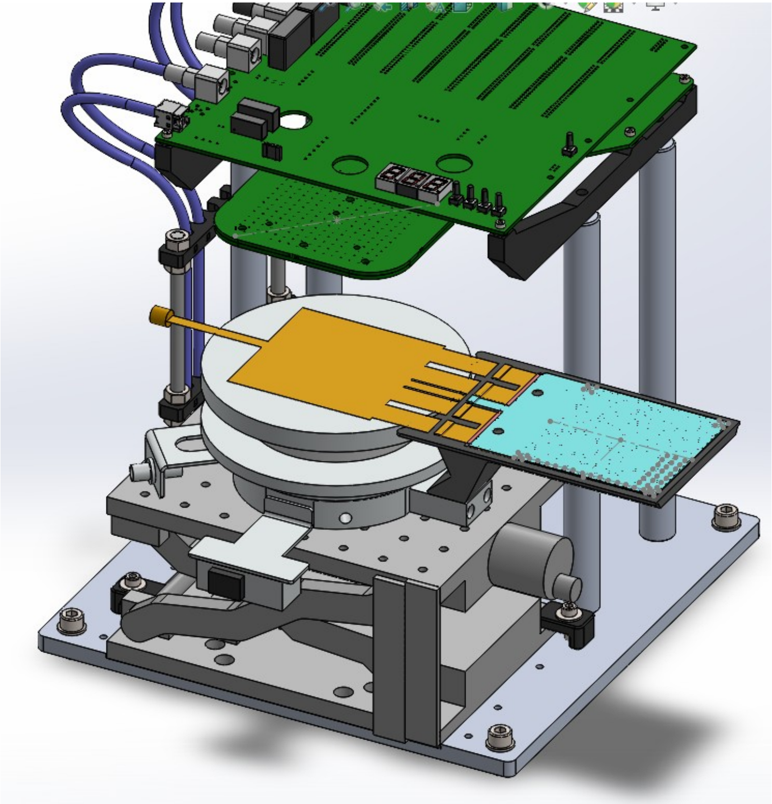
A0	0	2	4	6	8	10	1	3	5	7	9	11	29	31	28	30					A4
A4	4	6	8	10	12	14	16	18	20	22	24	26	16	18	20	22	24	26	28	30	A7
A4	12	14	16	18	20	22	24	26	28	30	0	2	0	2	4	6	8	10	12	14	A7
A4	5	7	9	11	13	15	17	19	21	23	25	27	17	19	21	23	25	27	29	31	A7



Testing the connectivity







9410

MG Chemicals

1-Part Epoxy, Electrically Conductive Adhesive, High T_g

9410 is a 1-part electrically conductive epoxy adhesive that can be stored at room temperature. It bonds well to a wide variety of substrates, and offers strong chemical resistance.

9410 is designed for semi-conductor flip chip packaging as well as die attach for small chips, LEDs and diodes. It provides excellent EMI/RFI shielding and is very effective at filling in seams between metal plates. It can be readily used in manual, pneumatic and robotic dispensing processes.

Features and Benefits

- Creates strong permanent electrical connections
- No mixing required
- Low cure temperature of 90 °C
- Room temperature storage (≤22 °C)
- Suitable for automated dispensing

Available Packaging

Cat. No.	Packaging	Net Vol.	Net Wt.
9410-3ML	Syringe	3 mL	7.00 g
9410-30ML	Cartridge	30 mL	70.0 g
9410-180ML	Cartridge	180 mL	378 g

Contact Information

MG Chemicals, 1210 Corporate Drive
Burlington, Ontario, Canada L7L 5R6

Email: support@mgchemicals.com

Phone: North America: +(1)800-340-0772
International: +(1) 905-331-1396
Europe: +(44)1663 362888

Cured Properties

Resistivity	1.8×10^{-3} Ω·cm
Hardness	70 D
Compressive Strength	26 N/mm²
Lap Shear (stainless steel)	2.6 N/mm²
(aluminum)	2.8 N/mm²
Glass Transition Temperature (T_g)	96 ˚C
CTE Prior T_g	42 ppm/˚C
CTE After T_g	150 ppm/˚C
Thermal Conductivity @ 25 ˚C	1.1 W/(m·K)
Service Temperature Range	-65–145 ˚C

Uncured Properties

Viscosity @ 25 ˚C	Thixotropic paste
Thixotropic Index @ 25 ˚C	3
Density	2.3 g/mL

EPOXY TECHNOLOGY

EPO-TEK® H20E

Technical Data Sheet
For Reference Only
Electrically Conductive, Silver Epoxy

Date:	November 2019	
Rev:	XVII	
No. of Components:	Two	
Mix Ratio by Weight:	1 : 1	
Specific Gravity:	Part A: 2.03	Part B: 3.07 Syringe: 2.67
Pot Life:	2.5 Days	
Shelf Life- Bulk:	One year at room temperature	
Shelf Life- Syringe:	One year at -40°C	

Recommended Cure: 150°C / 1 Hour

Minimum Alternative Cure(s):
May not achieve performance properties below
150°C / 5 Minutes
120°C / 15 Minutes
80°C / 3 Hours

NOTES:
- Container(s) should be kept closed when not in use.
- Filled systems should be stirred thoroughly before mixing and prior to use.
- Performance properties (rheology, conductivity, others) of the product may vary from those stated on the data sheet when bi-pak/syringe packaging or post-processing of any kind is performed. Epoxy's warranties shall not apply to any products that have been reprocessed or repackaged from Epoxy's delivered status/container into any other containers of any kind, including but not limited to syringes, bi-paks, cartridges, pouches, tubes, capsules, films or other packages.

Product Description: EPO-TEK® H20E is a two component, 100% solids silver-filled epoxy system designed specifically for chip bonding in microelectronic and optoelectronic applications. It is also used extensively for thermal management applications due to its high thermal conductivity. It has proven itself to be extremely reliable over many years of service and is still the conductive adhesive of choice for new applications. Also available in a single component frozen syringe.

Typical Properties: Cure condition: 150°C / 1 Hour Different batches, conditions & applications yield differing results.
Data below is not guaranteed. To be used as a guide only, not as a specification. * denotes test on lot acceptance basis

PHYSICAL PROPERTIES:				
* Color (before cure):		Part A: Silver	Part B: Silver	
* Consistency:		Smooth thixotropic paste		
* Viscosity (23°C) @ 100 rpm:		2,200 - 3,200	cPs	
Thixotropic Index:		4.6		
* Glass Transition Temp:		≥ 80	°C	(Dynamic Cure: 20-200°C/ISO 25 Min; Ramp -10-200°C @20°C/Min)
Coefficient of Thermal Expansion (CTE):				
	Below Tg:	31	$\times 10^{-6}$ in/in°C	
	Above Tg:	158	$\times 10^{-6}$ in/in°C	
Shore D Hardness:		75		
Lap Shear @ 23°C:		1,475	psi	
Die Shear @ 23°C:		≥ 10	Kg	3,556 psi
Degradation Temp:		425	°C	
Weight Loss:				
	@ 200°C:	0.59	%	
	@ 250°C:	1.09	%	
	@ 300°C:	1.67	%	
Suggested Operating Temperature:		< 300	°C (Intermittent)	
Storage Modulus:		808,700	psi	
Ion Content	Cl^-:	73 ppm	Na^+:	2 ppm
	NH_4^+:	98 ppm	K^+:	3 ppm
* Particle Size:		≤ 45	microns	

ELECTRICAL AND THERMAL PROPERTIES:		
Thermal Conductivity:	2.5	W/mK *based on standard method: Laser Flash*
Thermal Conductivity:	29	W/mK *based on Thermal Resistance Data: $R = L \times K^{-1} \times A^{-1}$)*
Thermal Resistance (Junction to Case):		TO-18 package with nickel-gold metallized 20 x 20 mil chips and bonded with H20E (2mils thick) *EPO-TEK® H20E*: 6.7 to 7.0°C/W *Solder:* 4.0 to 5.0°C/W
* Volume Resistivity @ 23°C:	≤ 0.0004	Ohm-cm

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14 FORTUNE DRIVE, BILLERICA, MA 01821 (978) 667-3805, FAX (978) 663-9782
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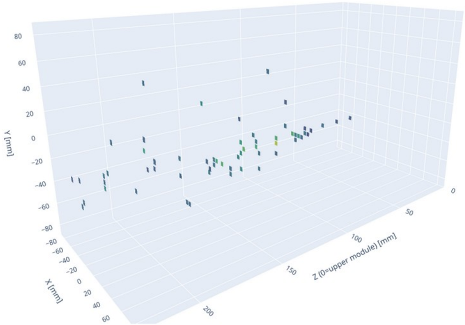
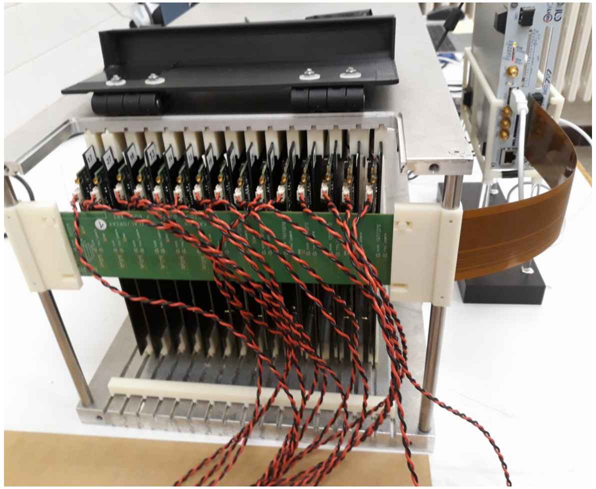
SiW-ECAL CALICE prototype (current version)

SiW-ECAL
- **15 layers 18×18 cm²**
- 0.5×0.5 cm² Si cells
- 2.8+5.6 mm W (21 X_0)
- 100 kg, 0.4×0.4×80 cm³
- **15k channels**





In process to be rebuilt + upgraded + extended + "compacted"

Since 2020

DRD6 – high granular silicon ECALs

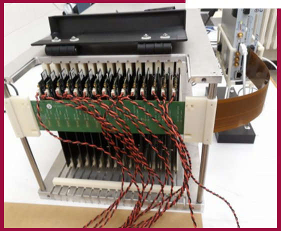
Barrel ECAL:
Similar design in:

(linear collider)
CLICdetector, ILD, SiD

(circular collider)
CLD, ILD, CepC

Electron Calo for LUXE

LUXE



CALICE -type calorimeter

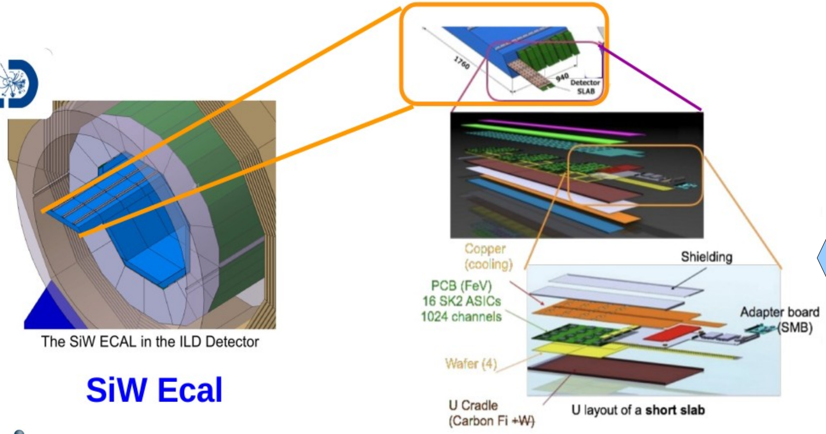
FCAL-type calorimeter

Froward LumiCAL:
Similar design in:

(linear collider)
CLICdetector, ILD, SiD

(circular collider – with adaptations)
ILD, CEPC,..

Positron Calo for LUXE

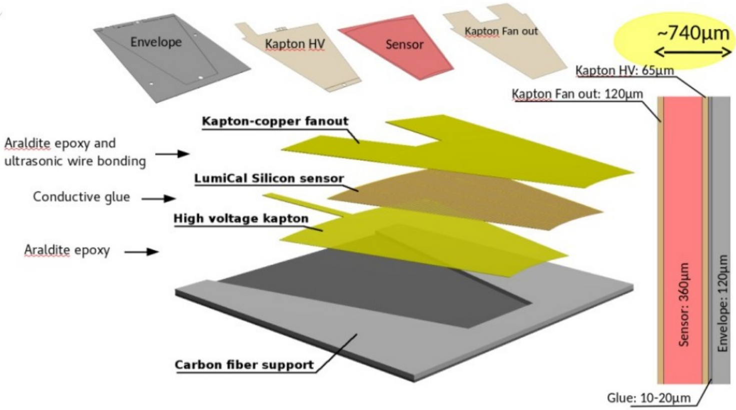


The SiW ECAL in the ILD Detector

SiW Ecal

R&D on sensor hybridization

IFIC
INSTITUT DE FÍSICA CORPUSCULAR



High granular & compact silicon calorimetry

▷ Explain the concept (silicon for granulairty and large area surface, tungsten for narrow showers)

▷ Examples:

- Siwecal
- Fcal
- Focal and cmos detector

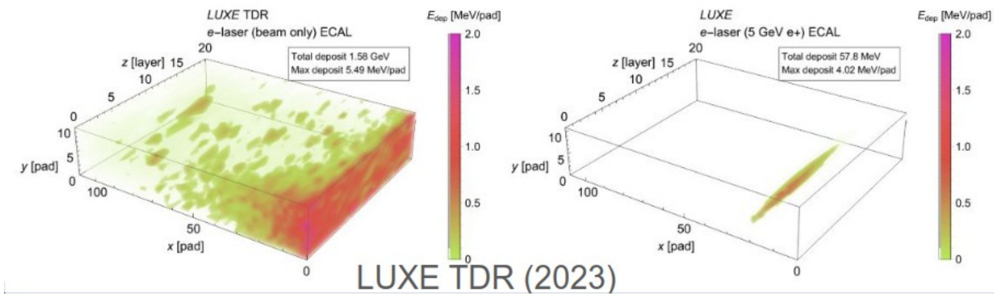
▷ Focus here on the applications for future colliders (including HL-LHC)

▷ 1 slide – no need to focus on details just mention that these concepts exist since long

Challenges – proposed solutions

▷ (main) **Challenges**

- Two modes with expected number of positrons varying from 10^{-4} 10^{7}
- EM shower overlap at high multiplicity
- Low multiplicity showers immersed in low energy widely spread background



LUXE TDR (2023)

▷ **Solutions**

- Compact sampling calorimeter
- Small Molière radius
- High granularity

▷ **ECALe** design is oriented to maximize the integration

- Fully embedded electronics (as for Particle Flow barrel ECALs in future Higgs Factories)

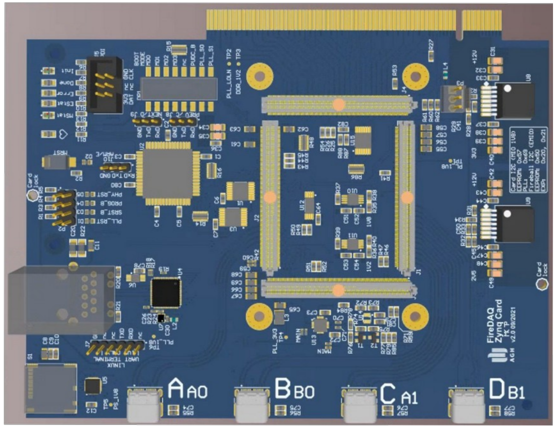
▷ **ECALp** design is oriented to maximize the compactness

- Minimal dead material between absorber plates and silicon sensors (as for luminometers in future Higgs Factories)

ECALp readout – FPGA & Synch

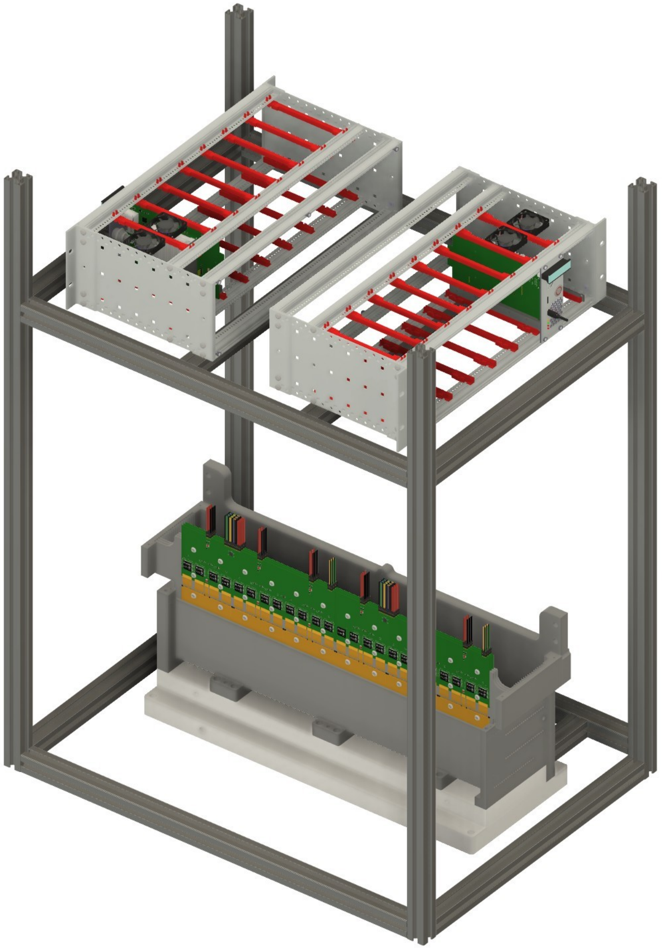
▷ Commercial Trenz TE0808 FPGA modules were used FLAME (we kept same design)

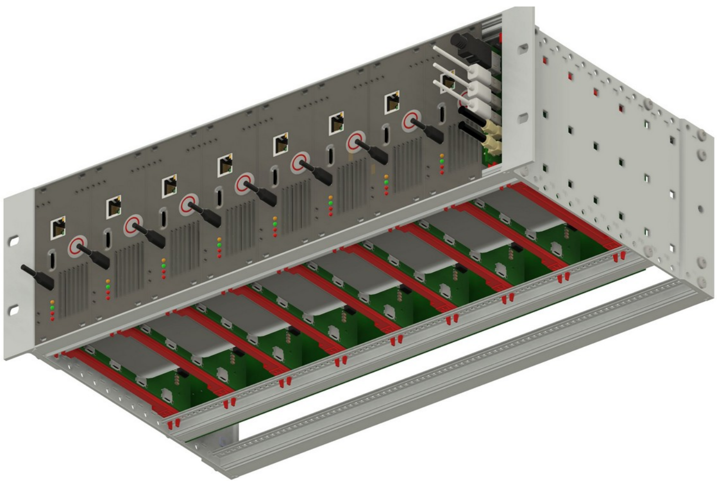
- Baseboard was based on custom made solution for FCAL. Required optimization of power suply control (simplification) and synchronization



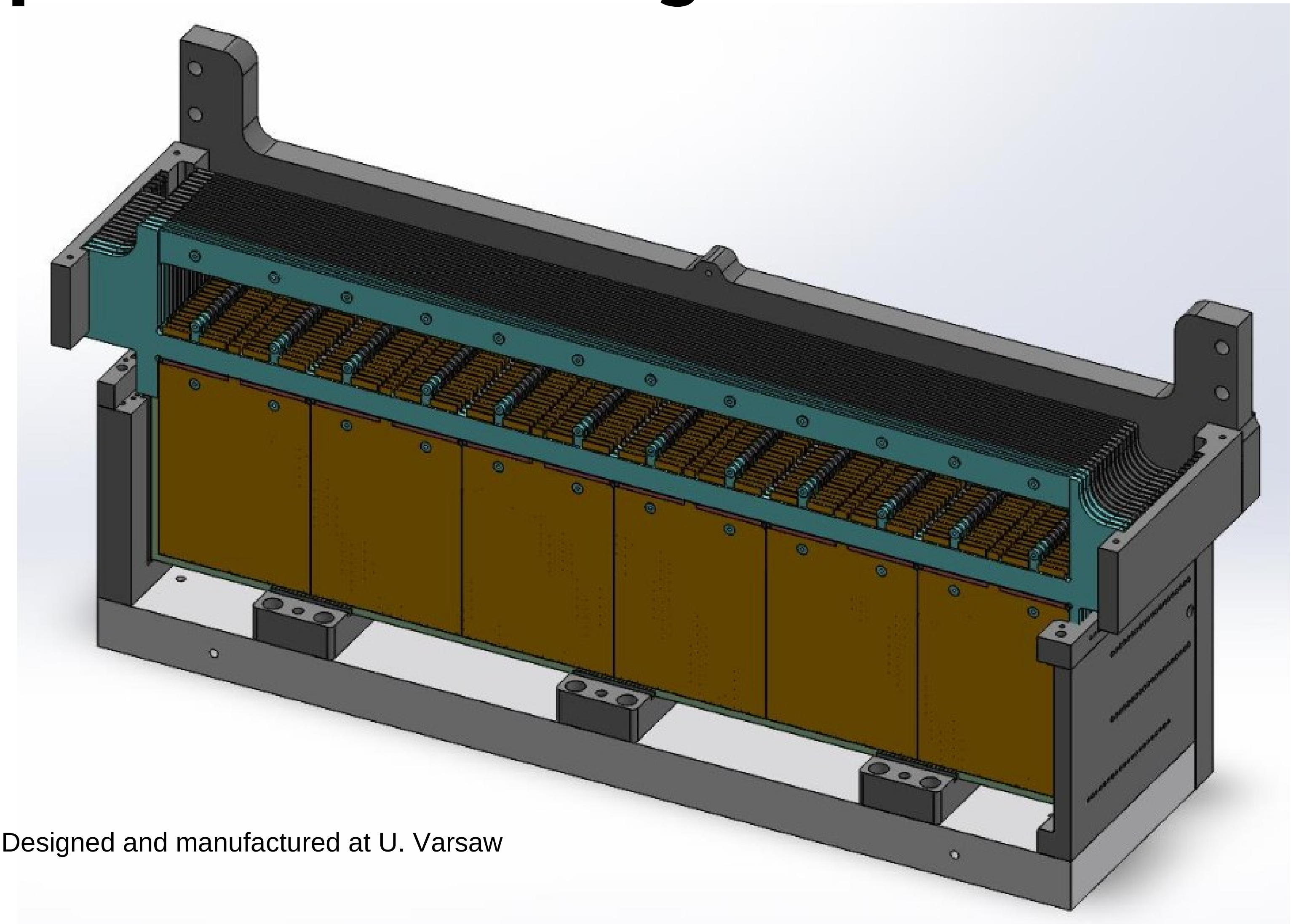
AGH

ECALp Mechnical housing



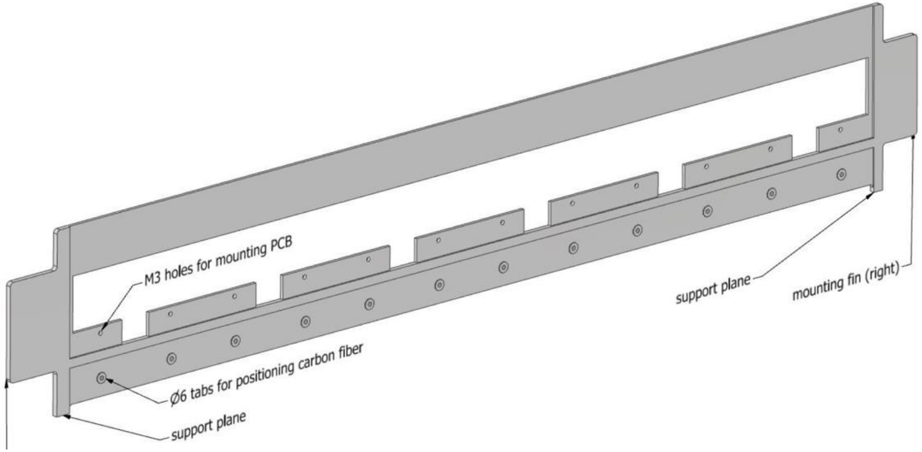


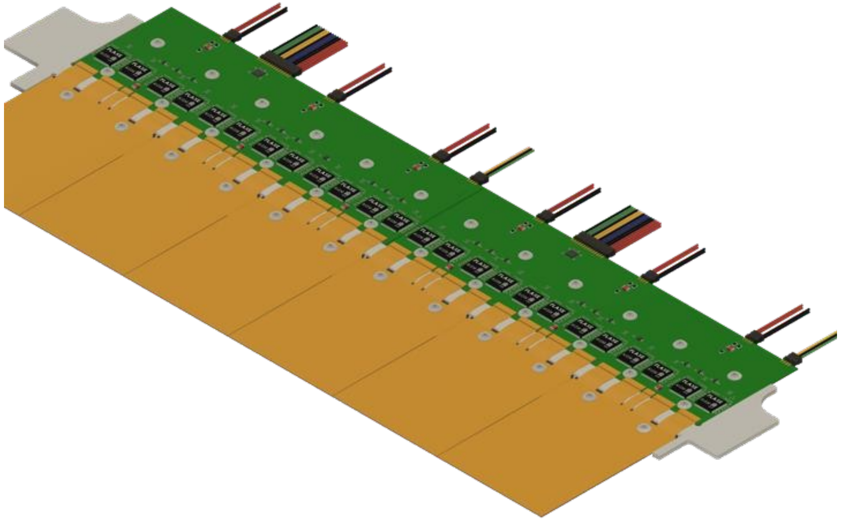
ECALp Mechnical housing



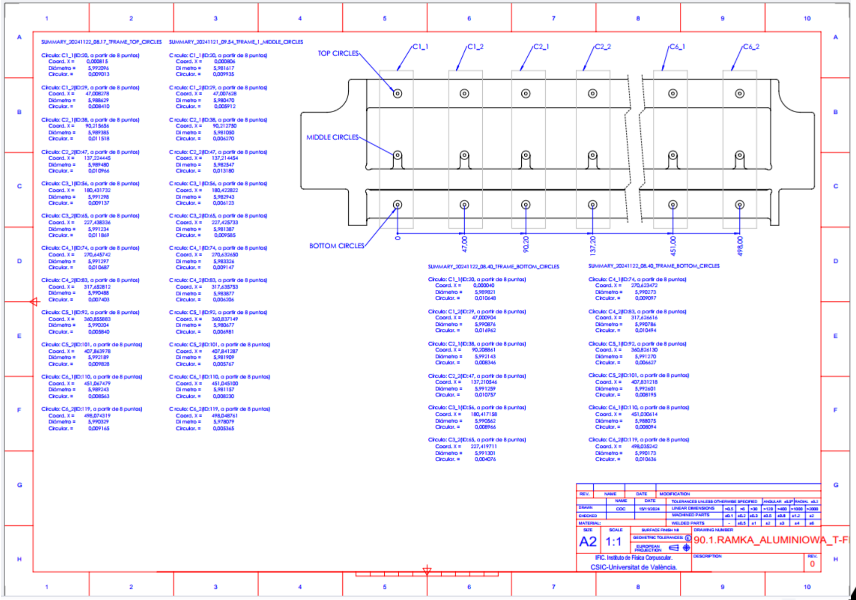
Designed and manufactured at U. Varsaw

ECALp Mechnical housing

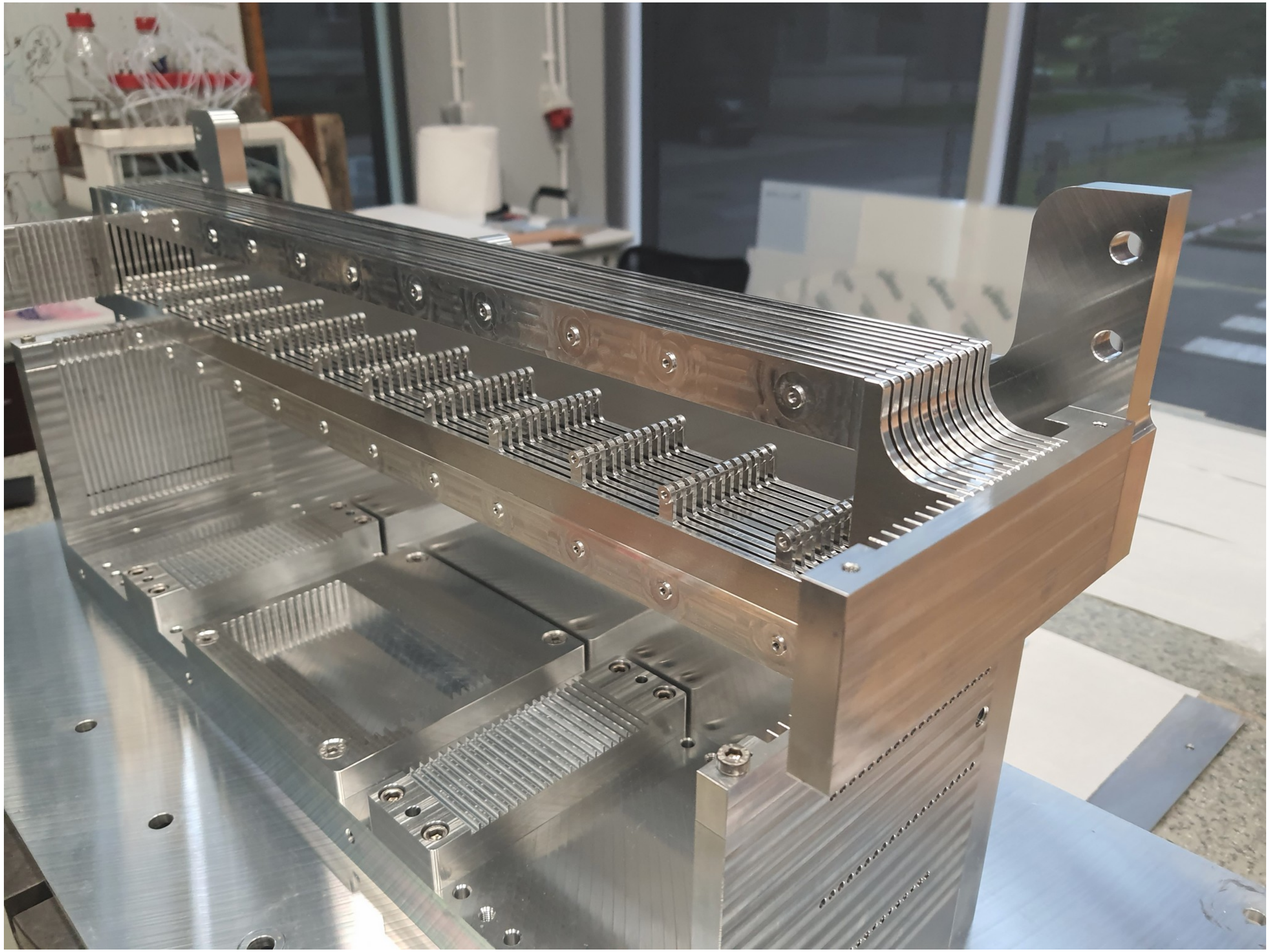




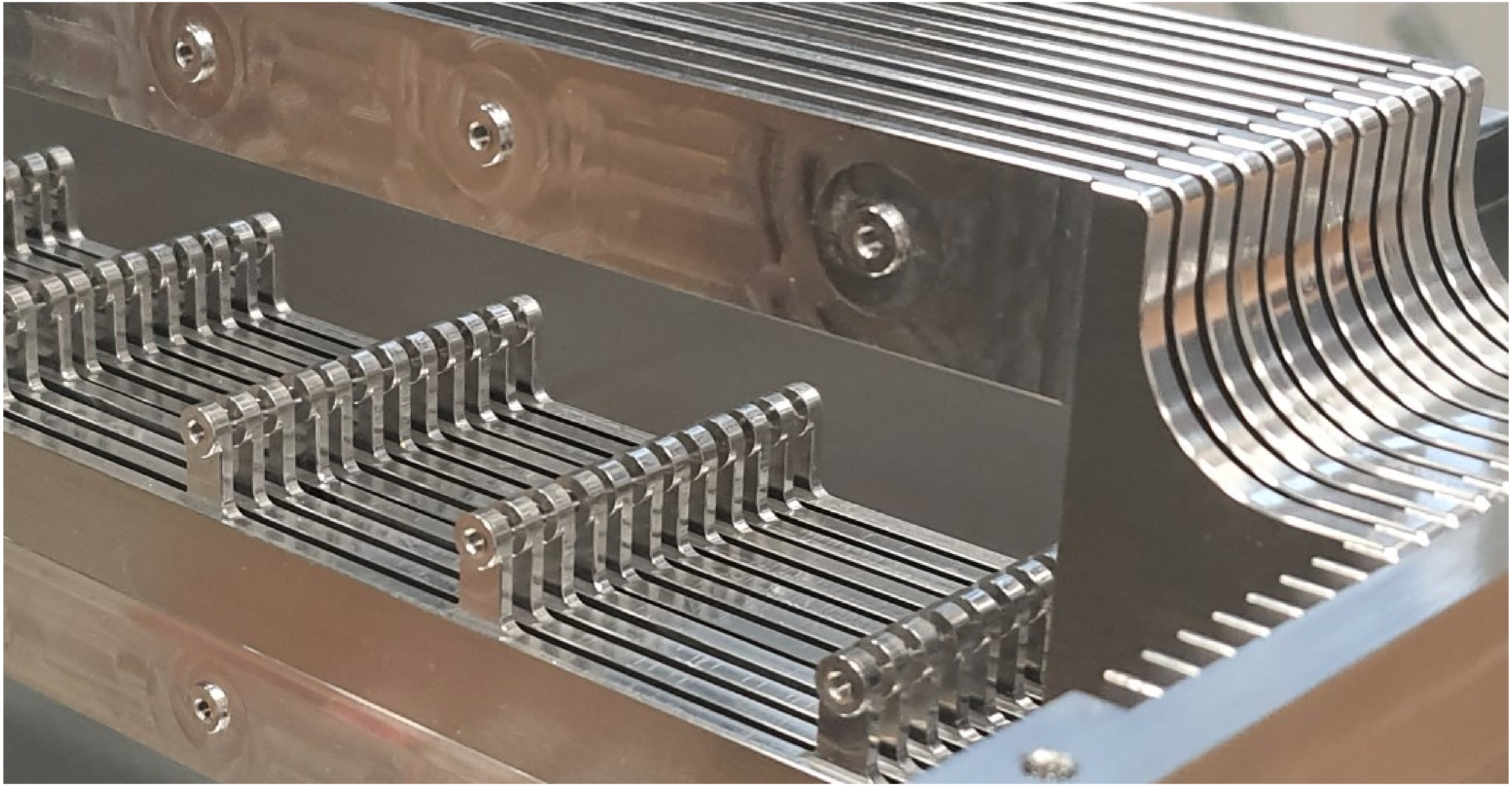
- T-Frames
  - The sensors are hanging from it
  - The FEB is supported by it.
- The sensors position in the detector is defined wrt the Ø6mm tabs
  - 10um precision seek and reached!



ECALp Mechnical housing



ECALp Mechnical housing

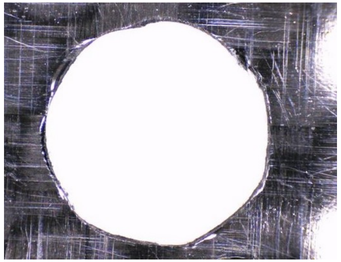


ECALp tungsten plates – 2025 (and from the past)

- New purchase to german company
  - 6 plates with 55cm x 10xm x 0.355 cm dimensions
  - Arrived directly to DESY the day of the beam test start.
- In addition, we took 6 "old FCAL" plates which were also 1X0 thick but different size
  - They were cut to fit in front of the detector
  - A new comb designed and manufactured

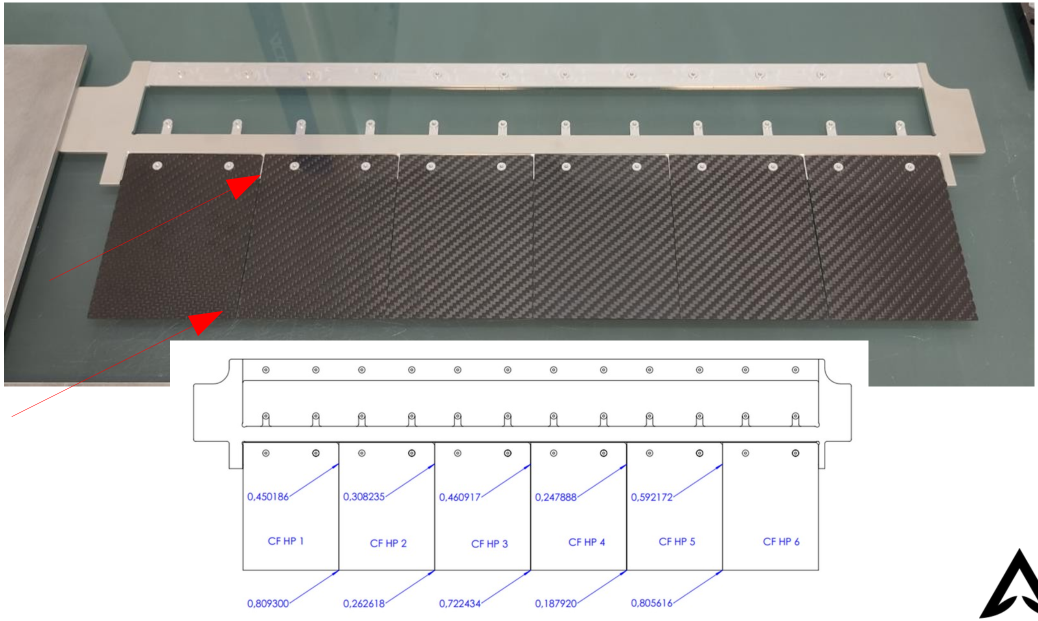
ECALp Compact Silicon Sandwich - CSIS

- ▷ Carbon-fibber sheet, 250um thick
  - Manufactured by a small Spanish company (ClipCarbono): good thickness but with improvable machining results
  - Machined by a French company (Workshape)
  - Overall size slightly bellow specs (obtained 89.7-89.8mm !)
- ▷ Si Sensors – 320um (not measured after production)
- ▷ Kaptons (measured after production)
  - 120um (fanout)
  - 70um (HV)



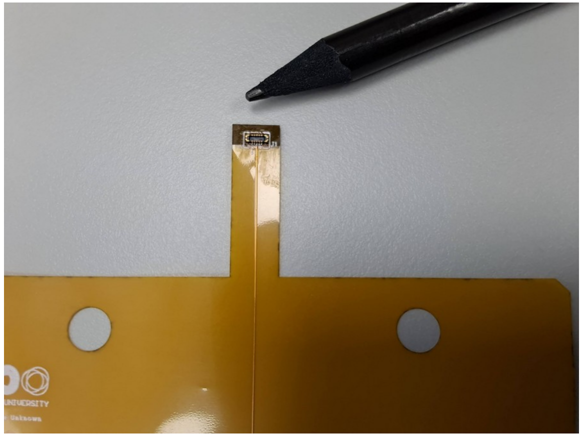
ClipCarbono

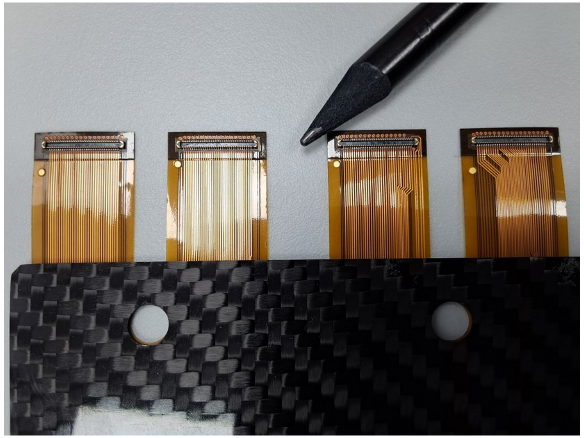
Workshape

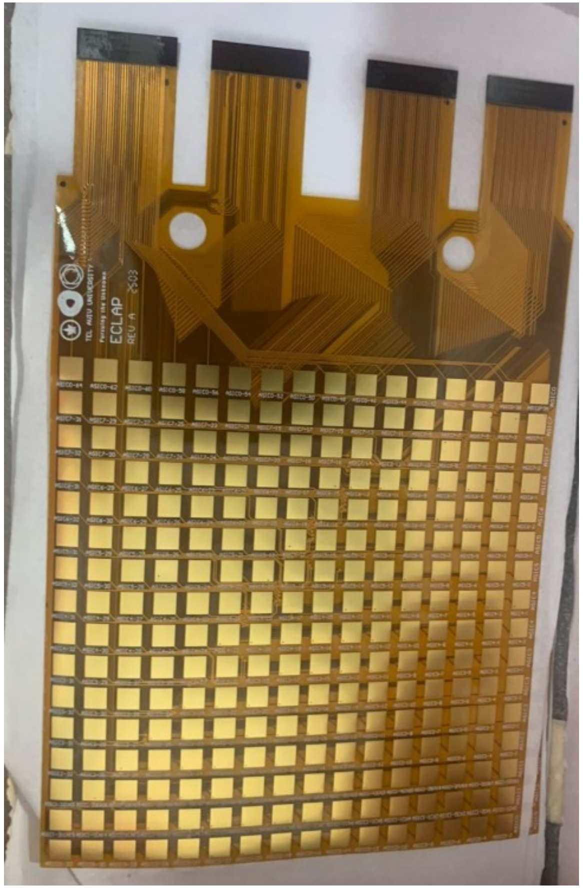


ECALp Compact Silicon Sandwich - Kaptons

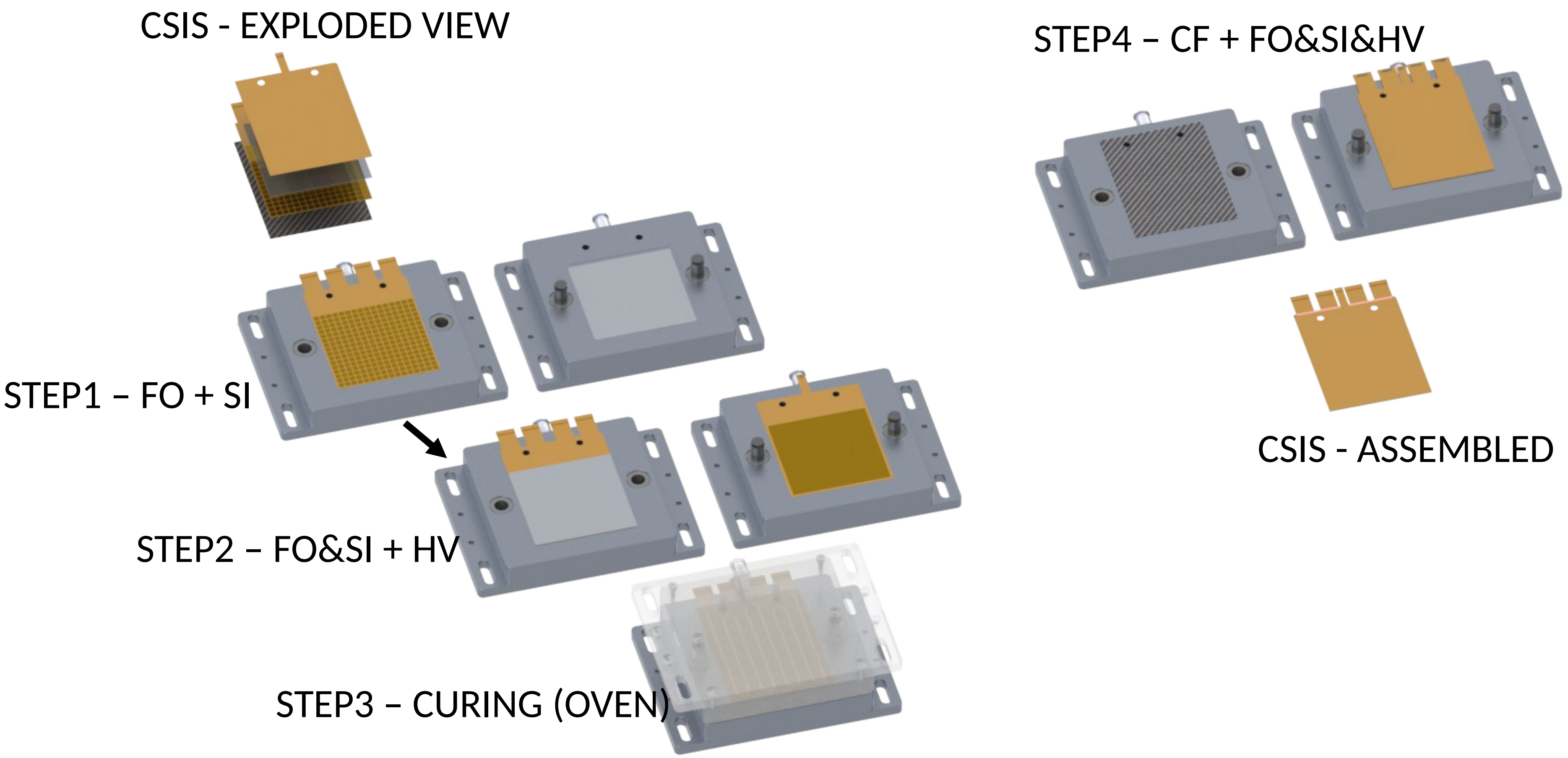
- Designed and produced by Tel Aviv U.





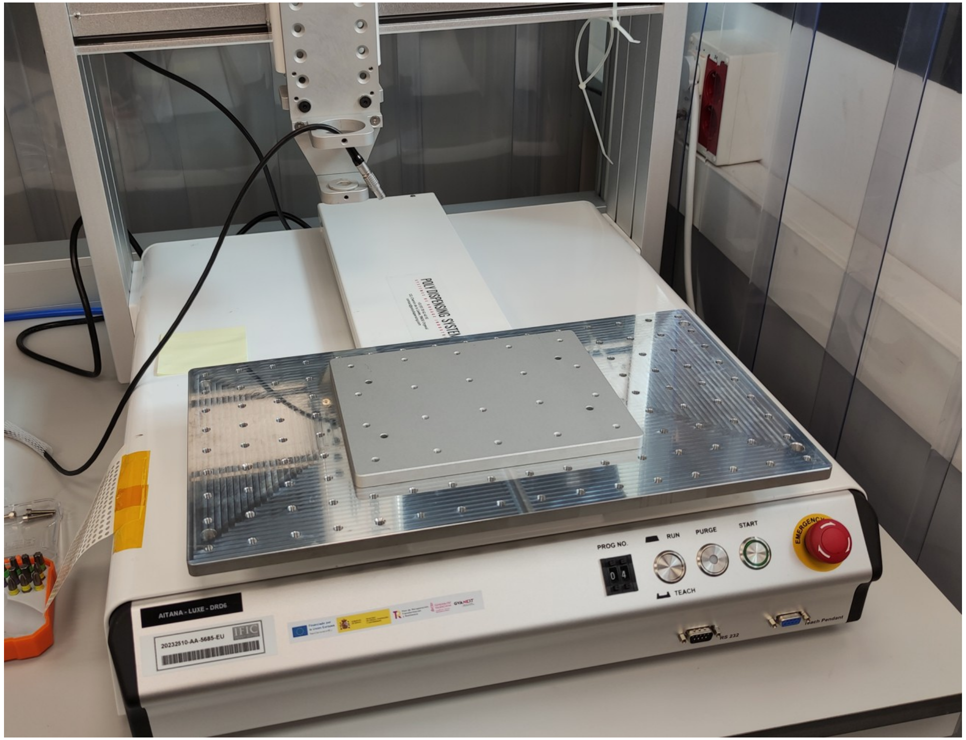


ECALp CSIS Assembly



ECALp CSIS Assembly

Glue mixing tooling



3d programmable robot - PDS400

ECALp CSIS Assembly

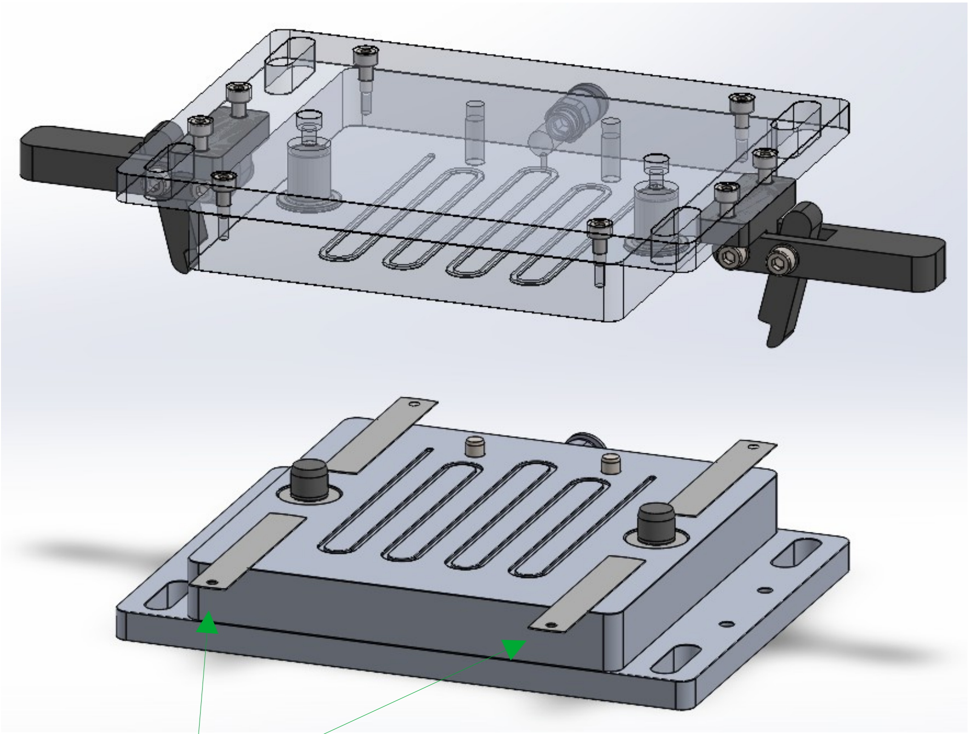
Glue preparation (of small doses!) is an crafting work – mastered by the full group now.

▷ Two types of glue tested (datasheets in the backup)

- H20E – from EPOTEK (Standard recommended solution for hybrid micro-electronics)
- TDS-9410 – from MG-Chemicals. Mono component solution, cheaper, less performant… but enough for us?

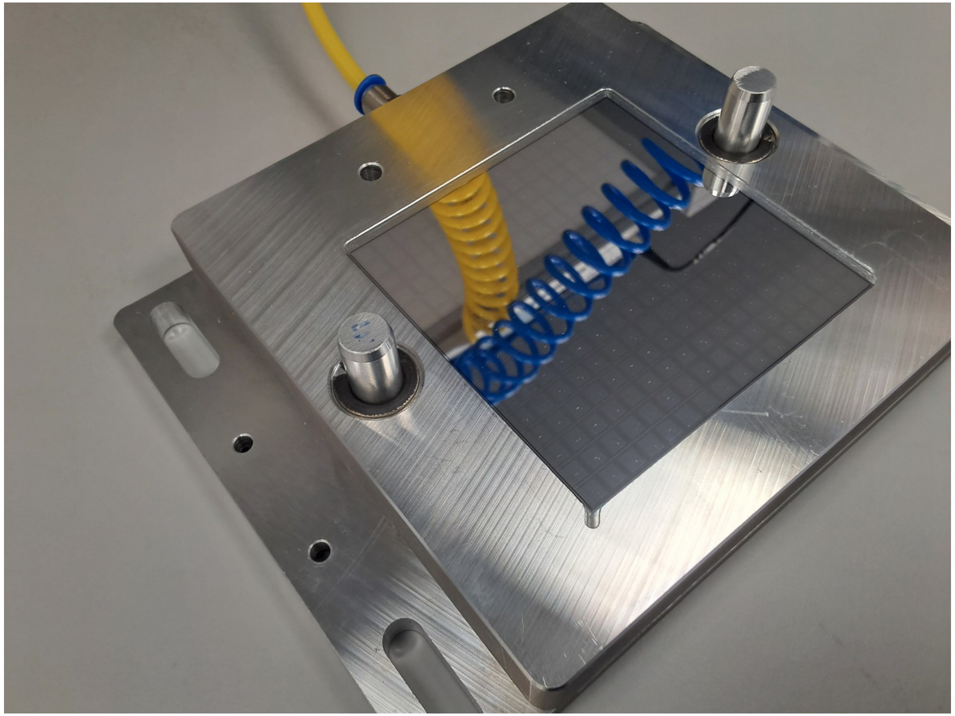
ECALp CSIS Assembly

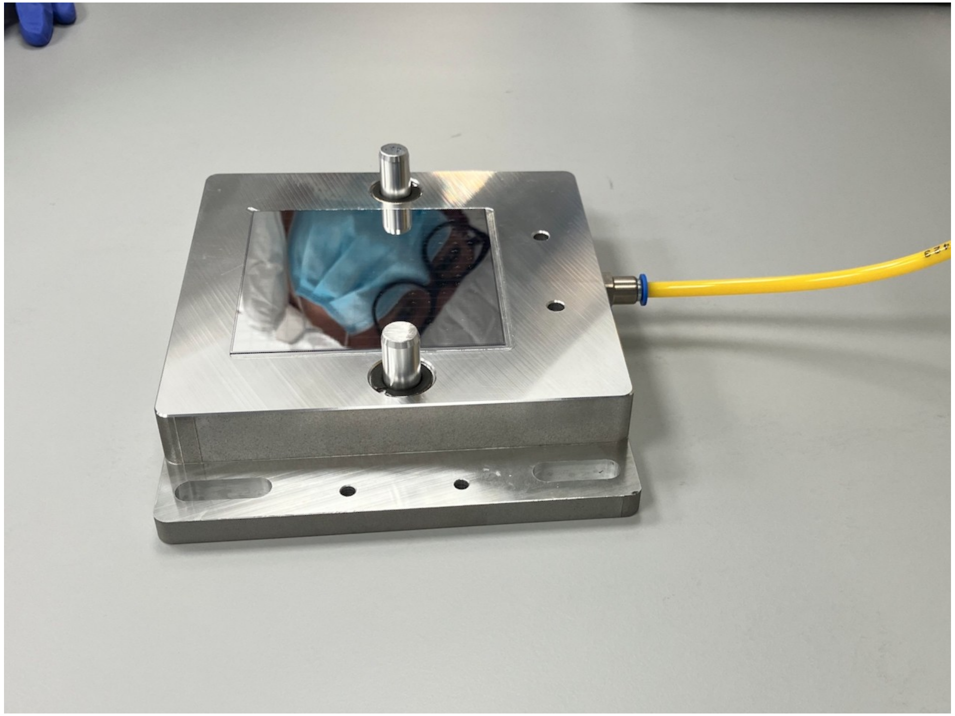
▷ Jigs and tooling manufactured at IFIC



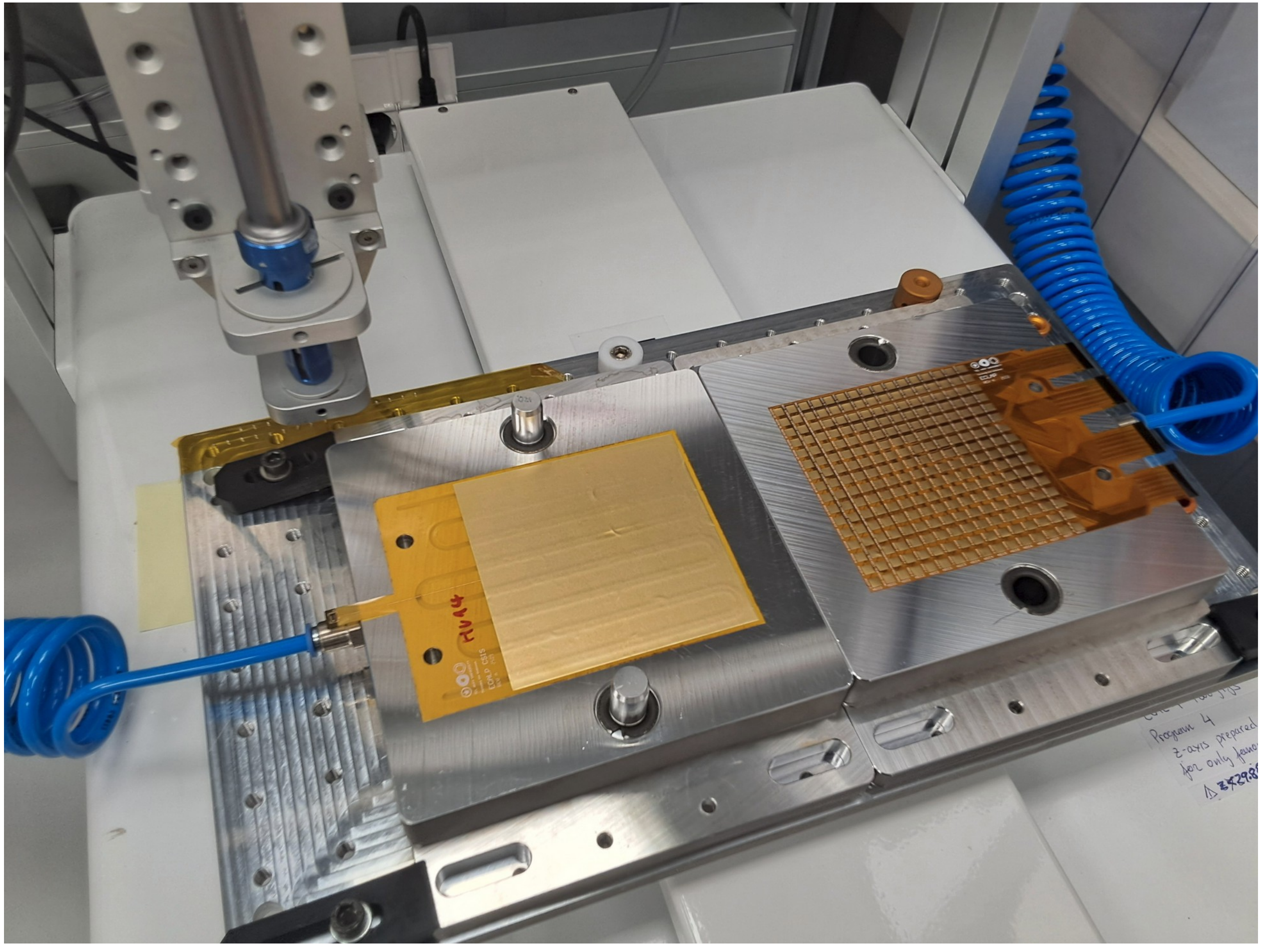
No feeler gauges used for current production → only the weight of the jigs

ECALp CSIS Assembly

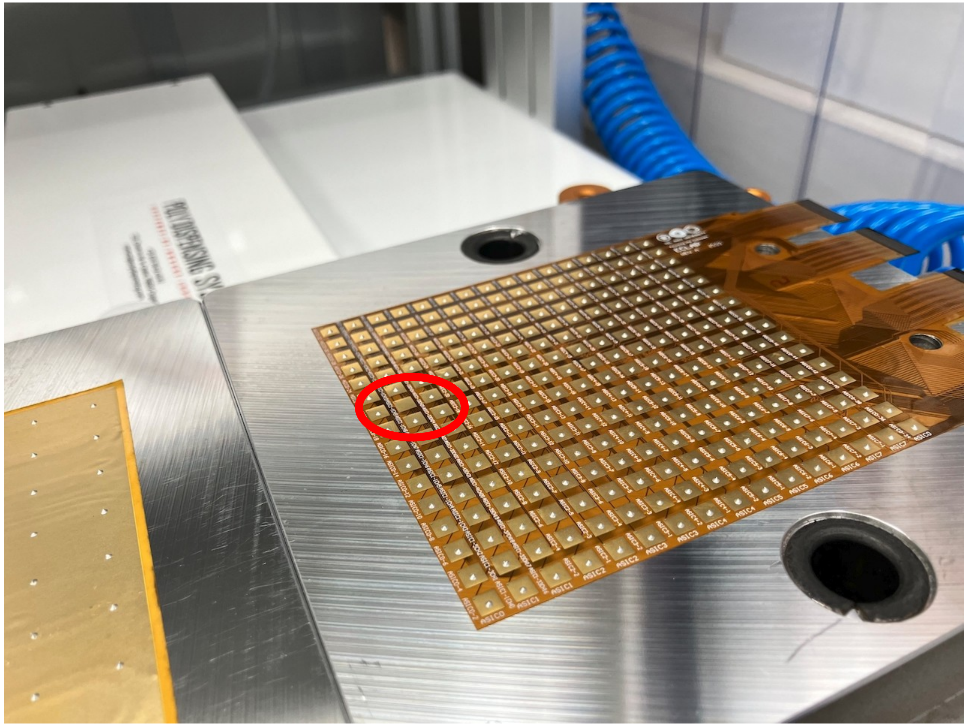


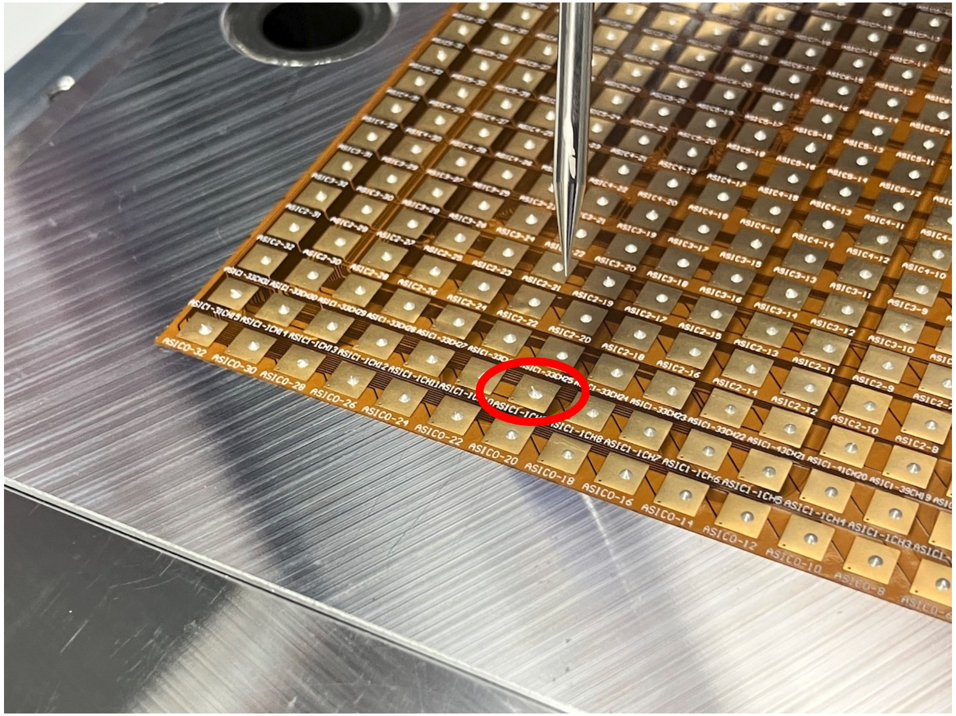


ECALp CSIS Assembly



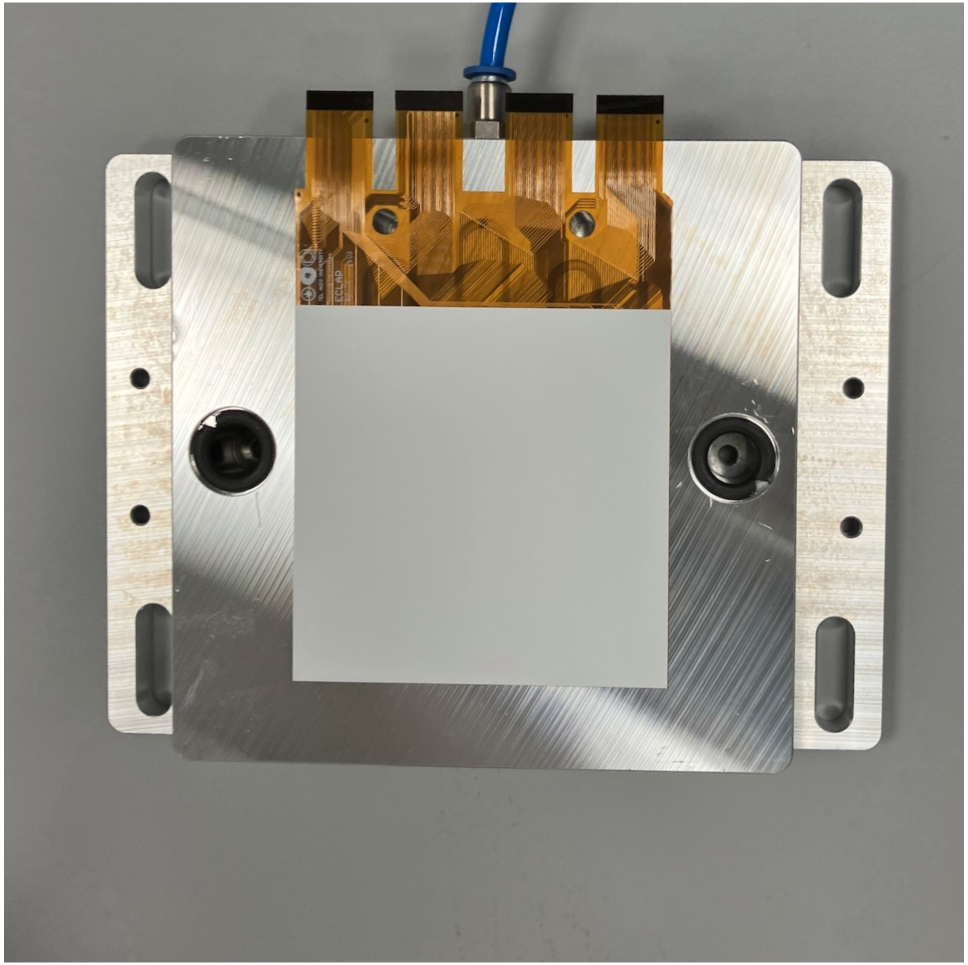
ECALp CSIS Assembly

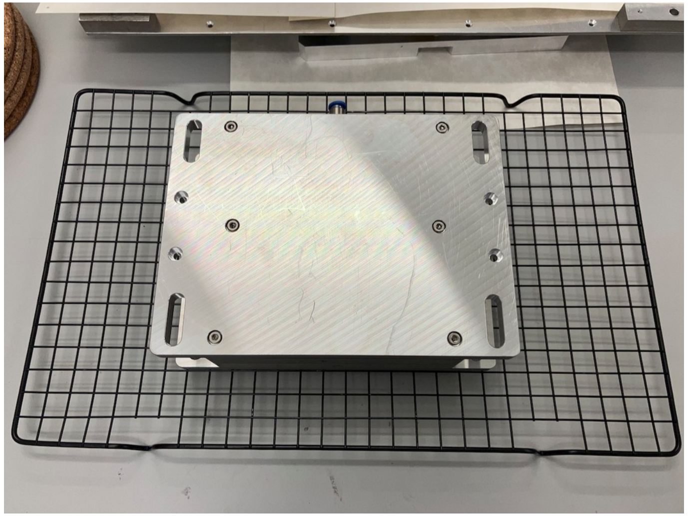


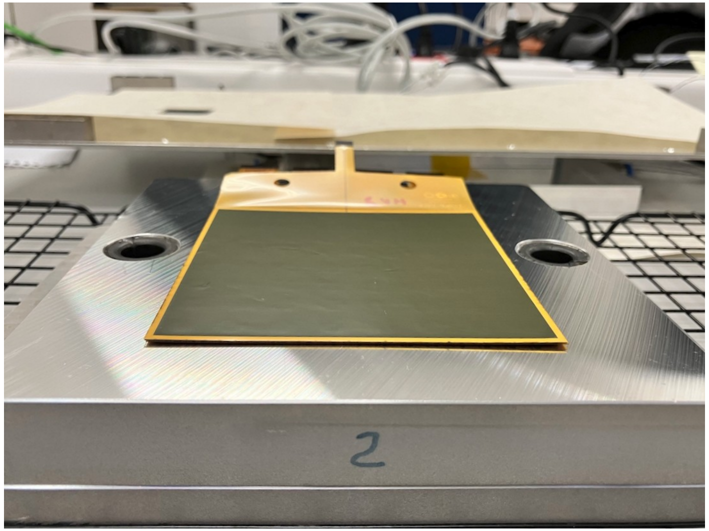


- We deposited more than 2112 glue dots → only 4 were missing.
  - Manually corrected with a needle and profiting from capillarity effects to deposit.

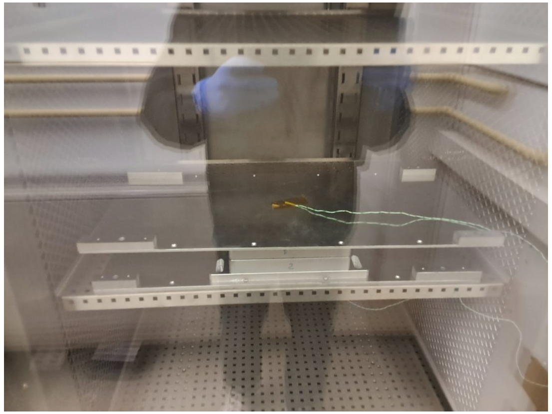
ECALp CSIS Assembly

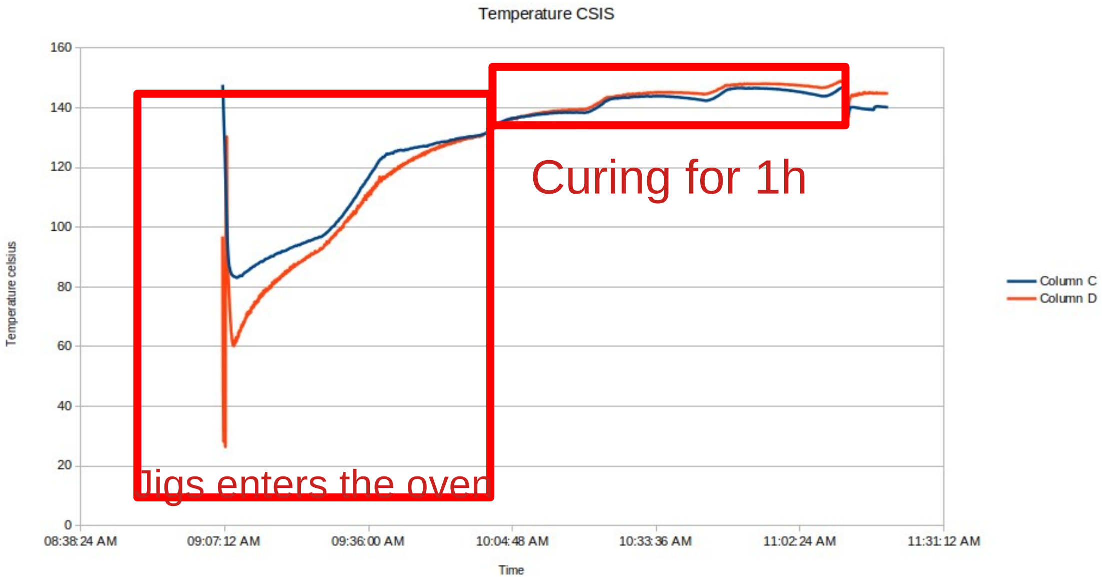




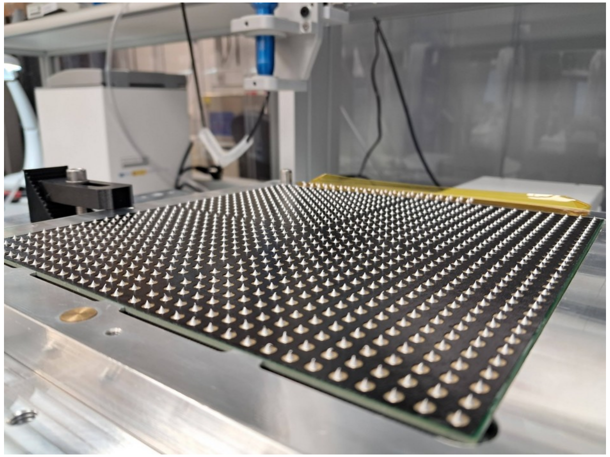


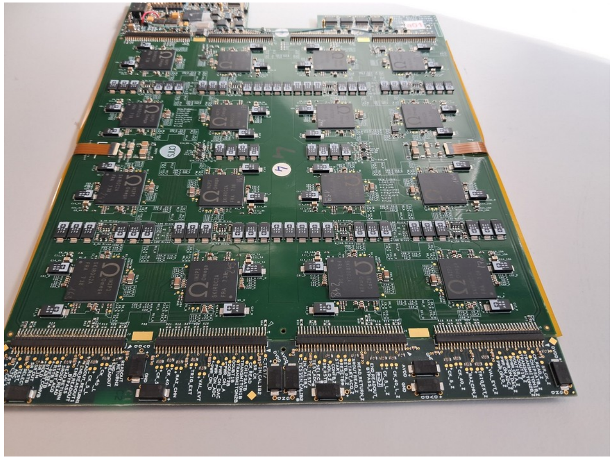
ECALp CSIS Assembly & storage





TARDIS-Lab for LUXE ECAL(s) module assembly



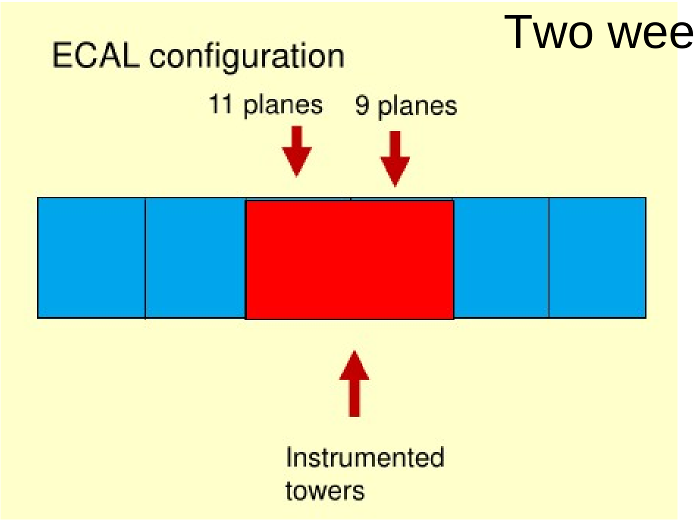


- ▷ The hybridization process is done in the new clean room (ISO4-5) of IFIC (TARDIS-Lab*)
  - For sensor characterization
  - Module assembly
  - Module characterization
- ▷ Same technologies used for ECALp and ECALe.
  - First two modules with upgraded Front-End-Board electronics (FEV2.1) of ECALe were assembled at IFIC in March
  - Tested at DESY in March too.

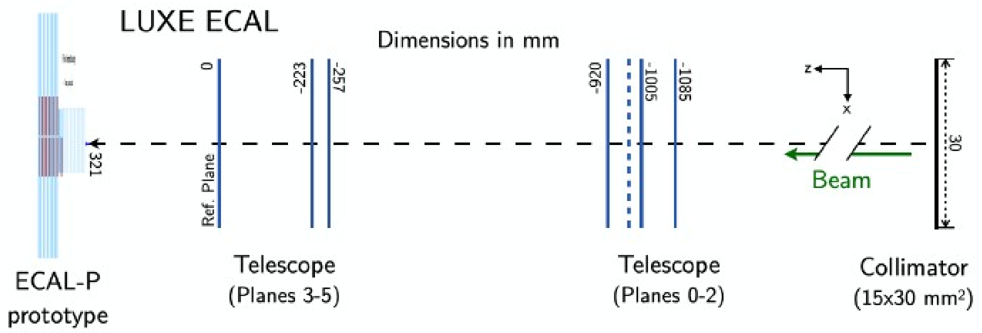
TARDIS-Lab

((because it is larger on the inside)

ECALp Beam test setup



Two weeks of beam test at DESY – around 250M triggers (TLU)



▷**Tracker mode**

▷Initial runs with 3 layers

- **Area Scan** but mostly debugging

▷**Ful stack**, with 11 layers

- ~10 M at two positions (3 GeV)
- **Area scan** with ~1 M per position (5GeV, **35** positions)

▷**Calorimeter mode**

▷**Position scan**, 11X0 & 9X0 (5GeV)

▷**Angular scan** – energies and incidence angles matching LUXE scenarios

- Performance study with real gaps between sensors

▷**Energy scan** from 1-5.6GeV in two positions

▷**Depth scan** 11 X0, 15 X0, 18 X0, 21 X0