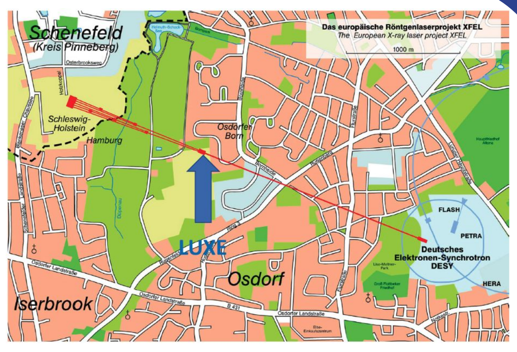
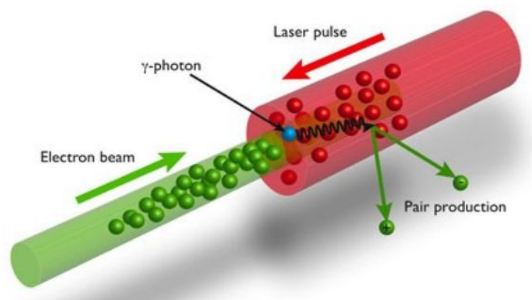
Design, prototyping and test of a Highly Compact and Granular Electromagnetic Calorimeter for the LUXE experiment

Melissa Almanza Soto on behalf of the LUXE ECAL-P Group
Instituto de Física Corpuscular (CSIC/Universidad de Valencia)

① LUXE

The Laser Und XFEL Experiment (**LUXE**) will **study the behavior of Quantum Electrodynamics in the strong-field regime**

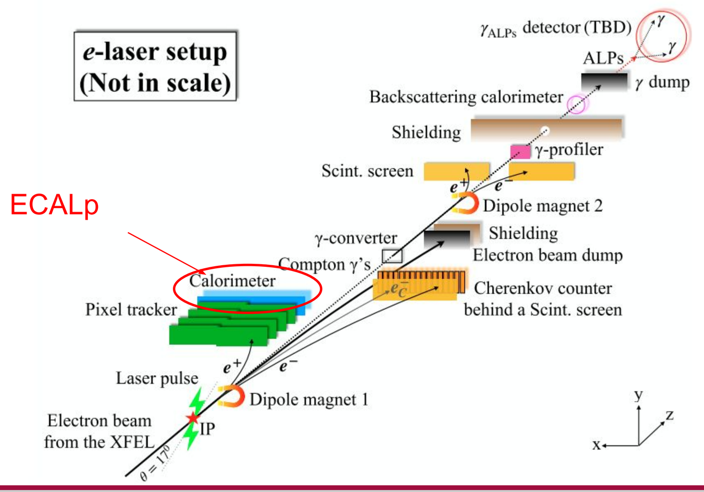




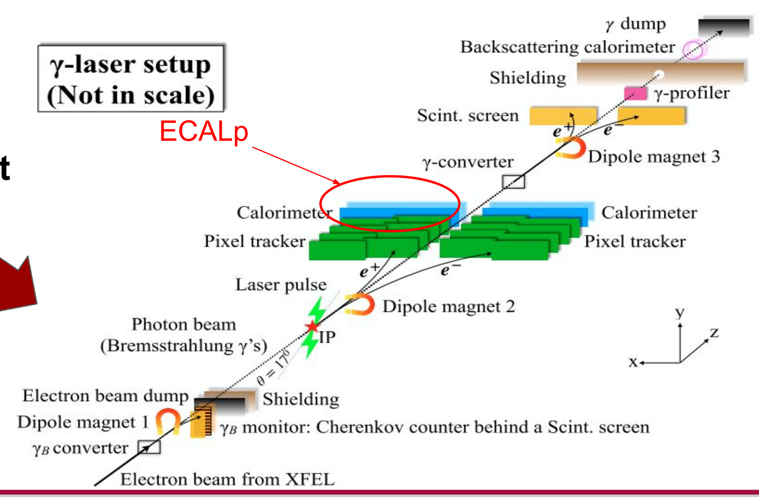
High-energy electron beam + **High-power laser** = **Non-linear and non-perturbative QED regime**

The 16.5 GeV electron beam from the European XFEL will collide with a high-intensity laser to reach and surpass the critical field strength (Schwinger limit) $E_{cr} = m_e^2c^3/(e\hbar) = 1.32 \times 10^{18}$ **V/m** in the electron's reference frame.

	Phase-0	40 TW
	Phase-1	350 TW



Two experiment modes



Electron-Laser Mode	**γ-Laser Mode**
Beam electrons will interact directly with the laser pulse.	High energy electrons converted into a photon beam which will interact with the laser pulse.

LUXE opens the possibility to study:

- The interaction of real photons with electrons and photons at field strengths where the coupling to charges becomes non-perturbative
- Strong-field QED processes to design a sensitive search of new particles BSM that couple to photons

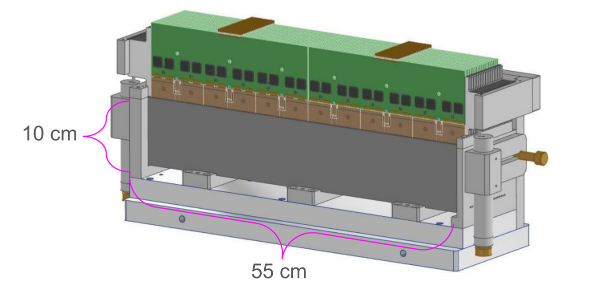
② The Positron Electromagnetic Calorimeter for LUXE

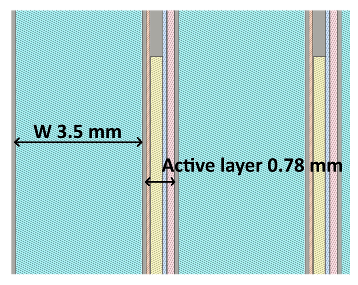
The expected positron rates at LUXE = **10^{-4} to 10^{7}** per bunch crossing.

Challenges:
- EM shower overlap at high multiplicity
- Low multiplicity showers immersed background

Proposed solution:
- Compact sampling calorimeter
- Small Molière radius
- High granularity

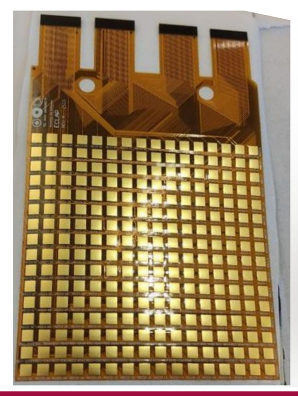
ECAL-P design:
- 21 layers of 3.5 mm tungsten (R_M=9.3mm) for absorber
- Active layers including sensors and readout less than 1 mm in thickness.

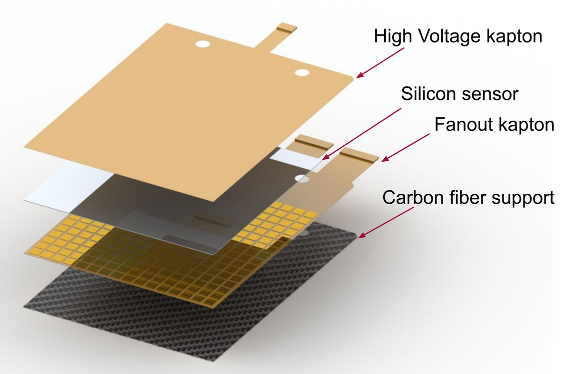




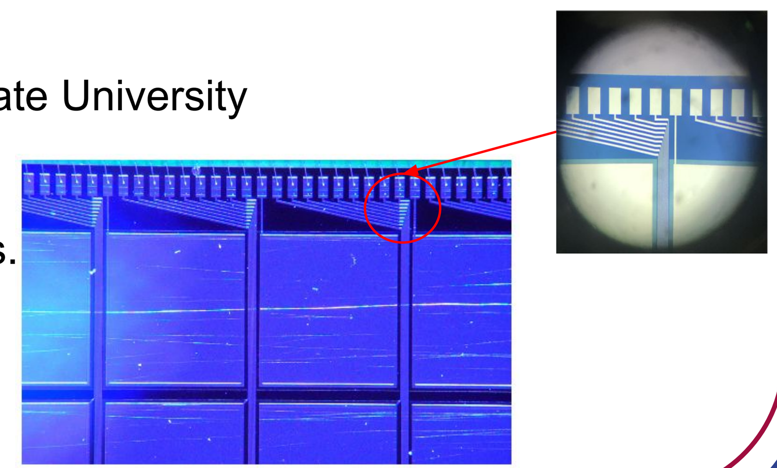
Proposed materials for the sensitive layers: **Silicon** and **Gallium Arsenide (GaAs)**

Silicon sensors:
- Manufactured by Hamamatsu
- 320 µm thick, 5.5 × 5.5 mm^2 pad
- Small gap of 10 µm between pads
- Fanout: Flex PCB with copper traces connected to the sensor pads with conductive glue.



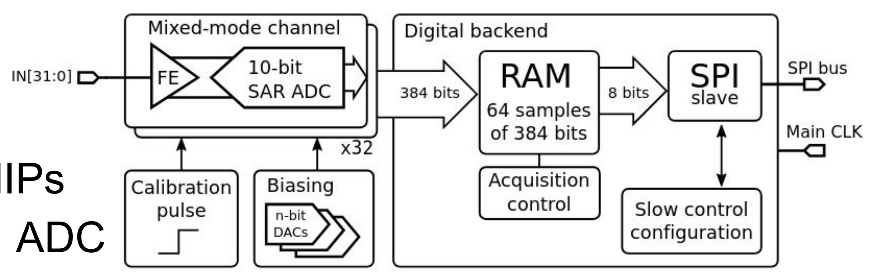


GaAs sensors:
- Produced by National Research Tomsk State University
- Pad area of 4.7 × 4.7 mm^2
- 0.3 mm gap between pads
- Fanout Al traces in the gaps between pads.
- Sensor thickness of 500 µm.
- Tolerate higher radiation dose than silicon.



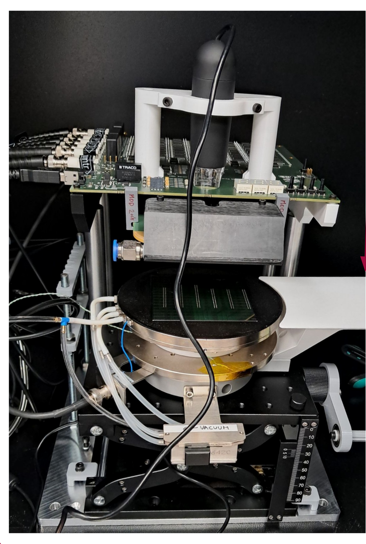
③ FLAXE Readout ASIC

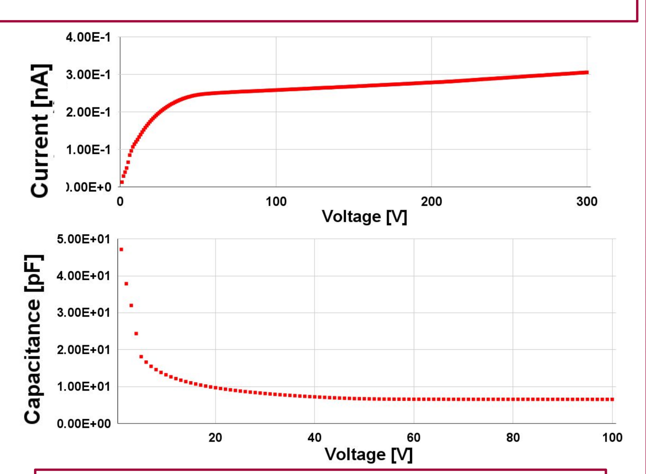
- 32-channel ASIC in CMOS 130nm
- CR-RC shaping T_{peak} ~ 50ns
- Switched gain: 1 MIP and up to ~1250 MIPs
- On-chip DAQ collecting 64 consecutive ADC samples from all 32 channels
- Design based on the tested FLAME ASIC by FCAL Collaboration with redesigned digital back-end and minor changes to the analogue front-end



④ Silicon sensors characterization

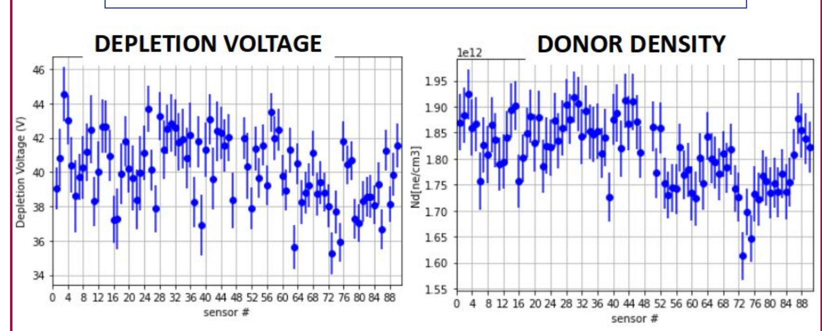
Probe stations used to test sensors





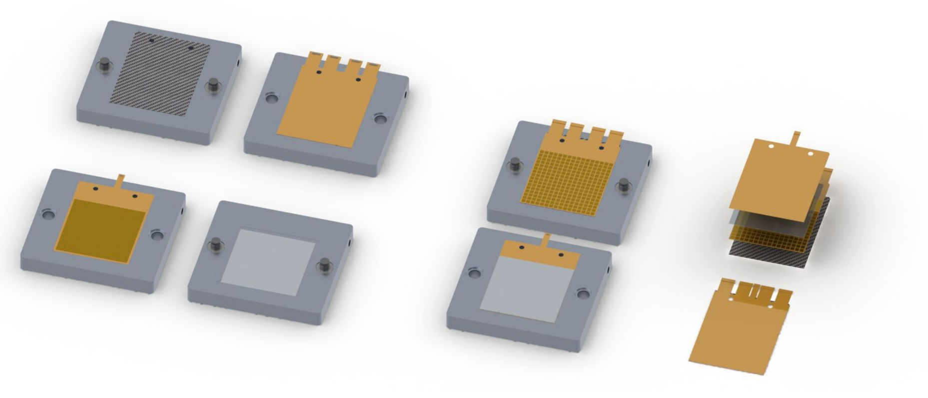
CV and IV tests for each pad

90 sensors tested and passed specifications

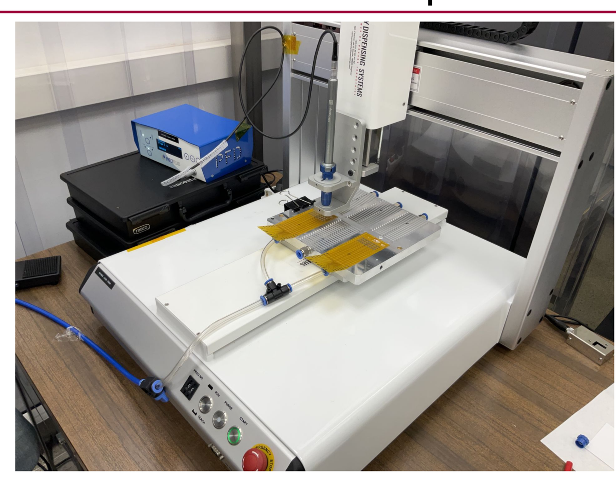


⑤ Active planes assembly

Aspiration jigs designed to achieve precision in gluing of all 4 layers of a sensor plane



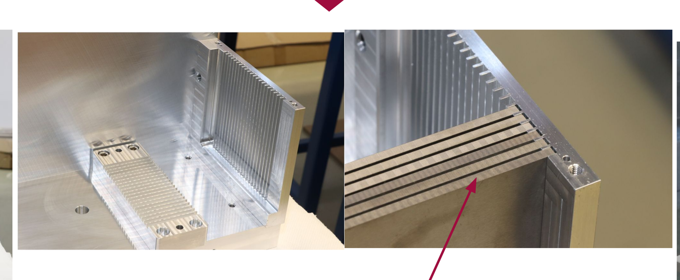
Gluing robot depositing conductive glue dots on each pad



⑥ Mechanics prototyping

Machining of aluminum frame for calorimeter

Precision machined combs for tungsten planes placing

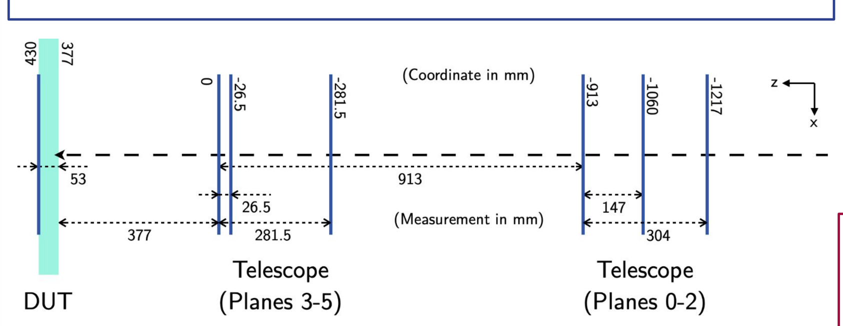


TFrame design for alignment of sensor planes and FE electronics boards on top of ECAL-P

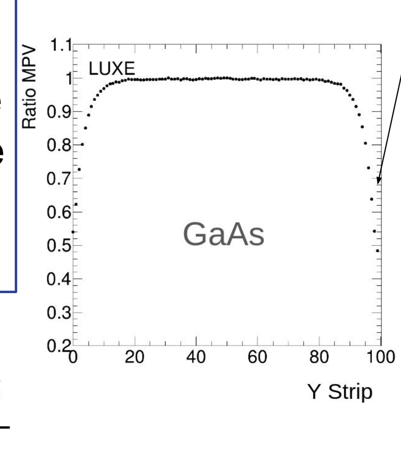
1mm gap to insert sensor planes

⑦ Sensor planes testbeam 2022 results

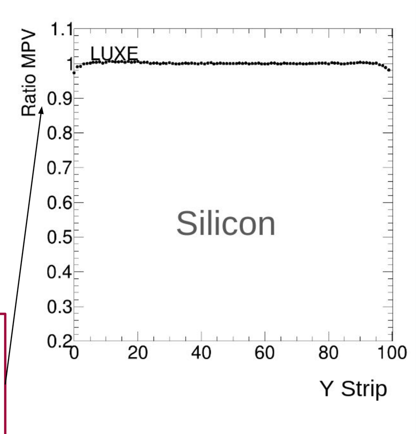
- Two 16 × 8 pad arrays of silicon sensors and two 15 × 10 pad arrays of GaAs sensors were tested in a 5 GeV electron beam at the DESY-II facility.
- Beam telescope composed of 6 Alpide sensors was used to measure the tracks of the beam electrons.
- FLAME ASICs used.



Pads are separated into thin strips



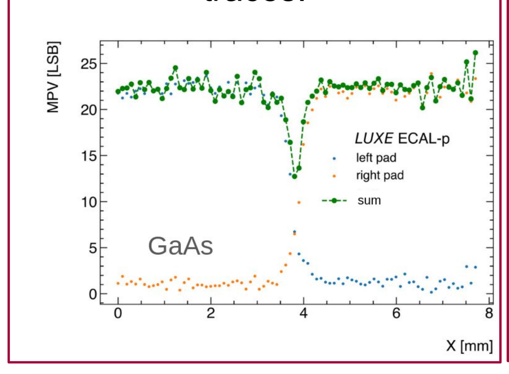
Drop amounts to 50% of the MPV of the center of the pad.



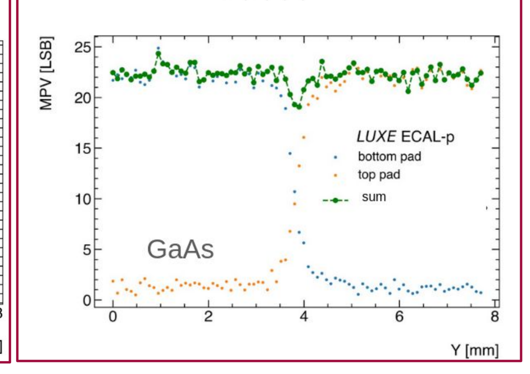
2 to 3% drop at the edges of the pad

Edge effects:
Signals from two adjacent pads added for events in which electrons enter the detector in the gap between the pads.

40% drop for electrons hitting traces.

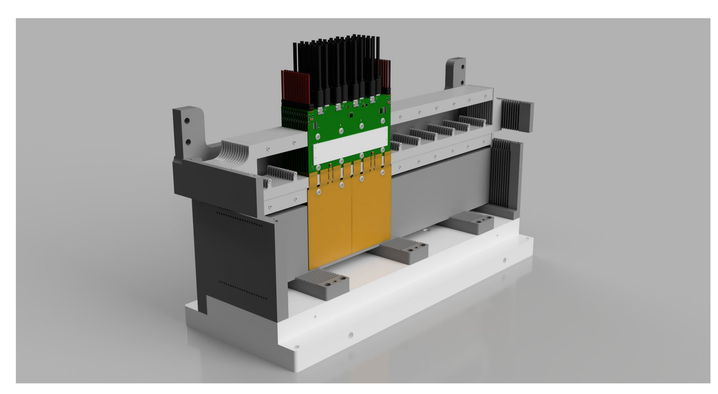


Drop 10% in gaps without traces.



This effect was not observed for the silicon sensor

⑧ Testbeam 2025



- Two towers of 11 active planes
- 10 Tungsten plates
- Beam telescope composed of 6 Alpide sensors will be used to measure the tracks of the beam electrons.
- FLAME ASICs for readout
- Calorimetry studies to be performed

Financiado por la Unión Europea NextGenerationEU
Plan de Recuperación, Transformación y Resiliencia
GENERALITAT VALENCIANA
VNIVERSITAT DE VALÈNCIA
IFIC INSTITUT DE FÍSICA CORPUSCULAR
CSIC CONSEJO SUPERIOR DE INVESTIGACIONES CIENTÍFICAS
GOBIERNO DE ESPAÑA MINISTERIO DE CIENCIA, INNOVACIÓN Y UNIVERSIDADES
AITANA LUXE