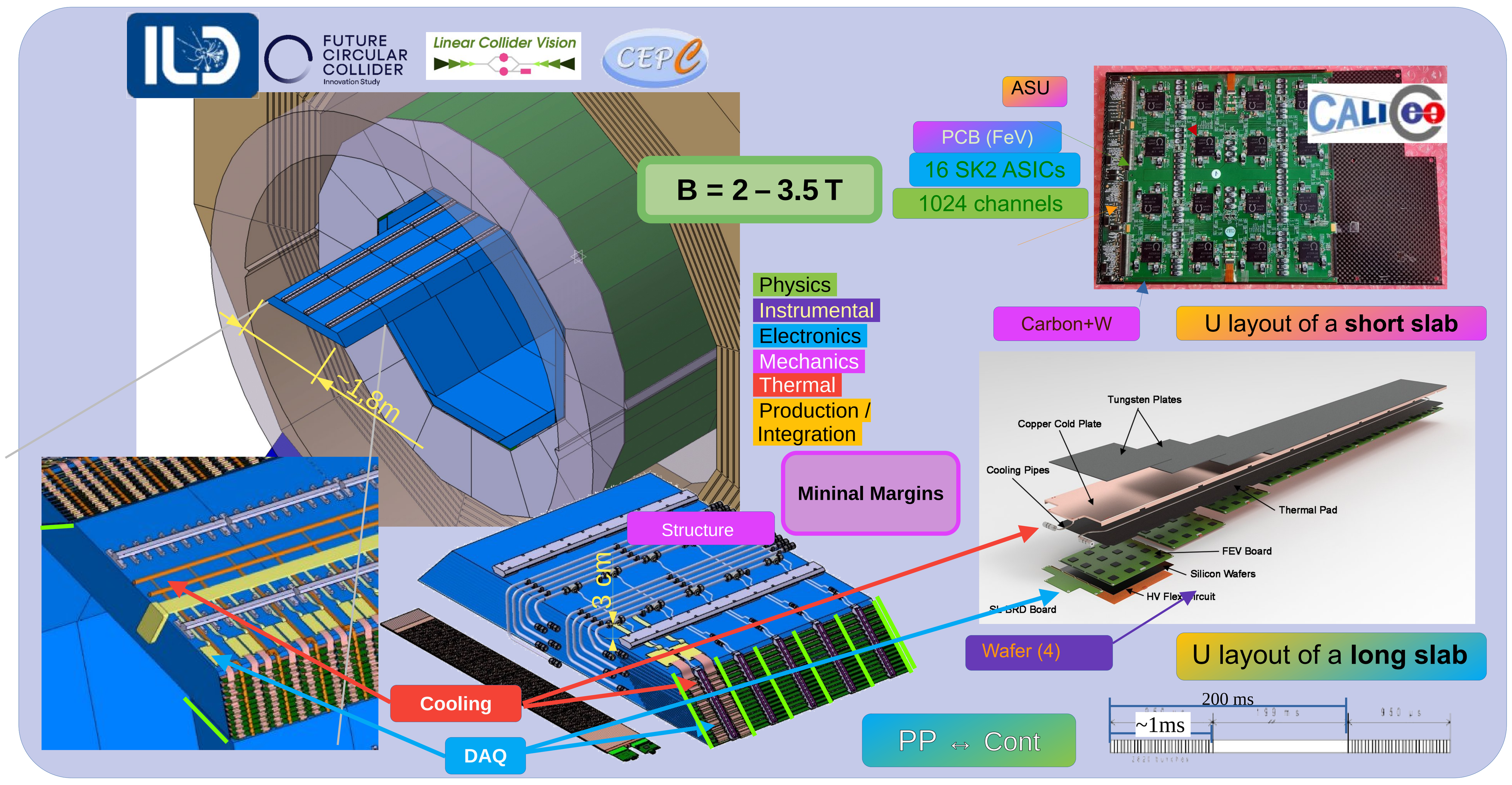
A Silicon-Tungsten Electromagnetic Calorimeter for Future Higgs Factories

A Recept for Particle Flow

How to get a ≤ 3% on Jet Energy Resolution ?

- One very good measure $\sigma(p_T)/p_T \approx 2\cdot10^{-5} p_T(\mathrm{GeV}/c)$ of tracks (65%)
- Stretch them to the calorimeters
- Carefully remove their contributions from calos clusters.
- Use the rest to mount your collection of neutral objects (25 % γ's, 10 % h^0)
- Mix the tracks and neutral to get the best jet composition
- Spice with PiD
- Adjust the seasonning according to you favourite analysis
  - RMS90, Gaussian



Calorimetry Cookware:

- An hermetic detector
- A moderate Energy Resolution
- A (very) Good granularity
- High Sensitivity (mips)
- Option: Good timing ?

Challenges

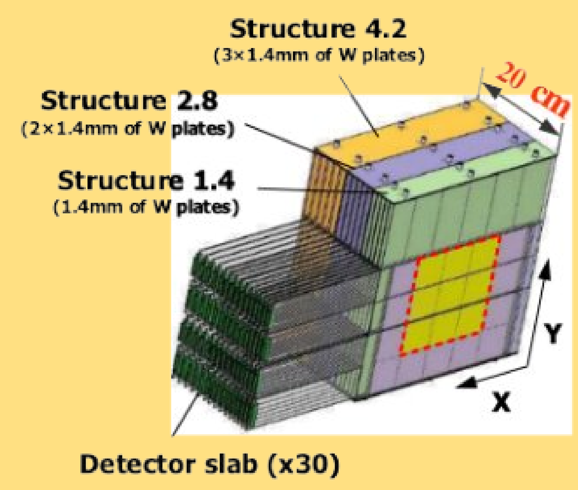
High density of channels
→ Multiplexing
→ Embedded Electronics
→ Low Power
→ Integration

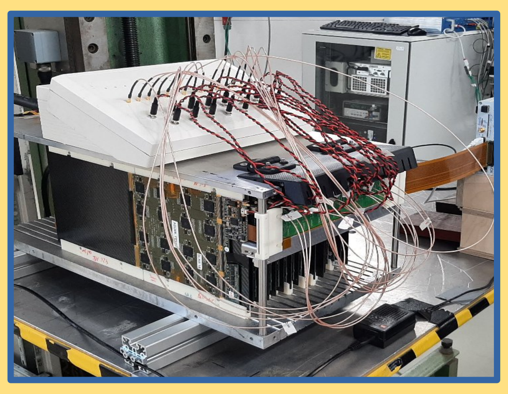
Compactness
→ min. of low density mat.
→ Tungsten
→ Compact design
→ services (Cooling, DAQ)

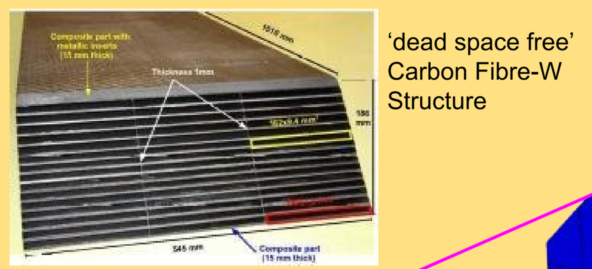
Good Tracking:
→ minimal discontinuities (gaps, dead mat.)
→ in-ECAL
→ ECAL–HCAL

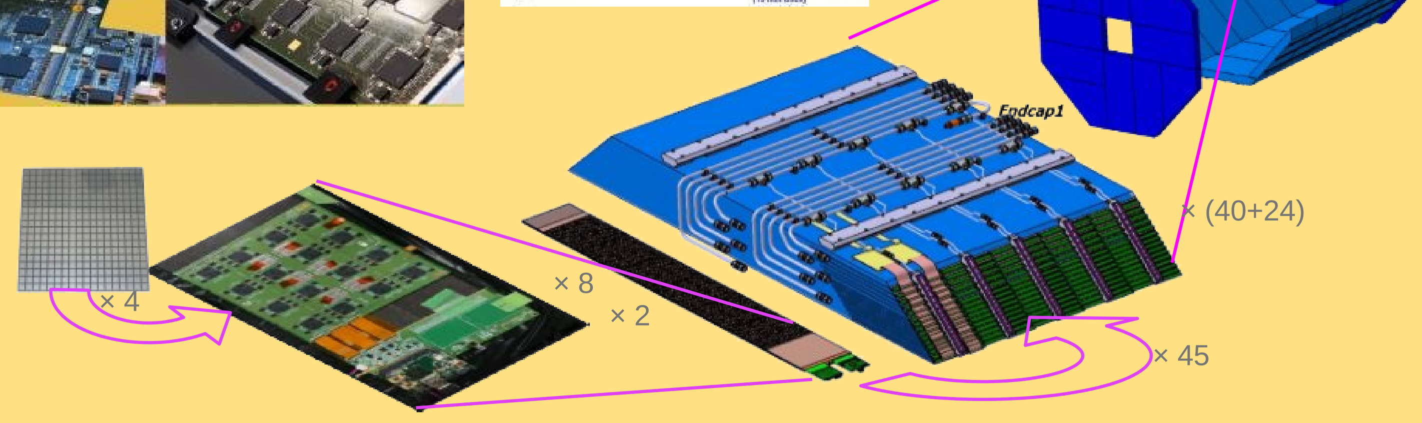
Stability:
→ Silicon as a sensor

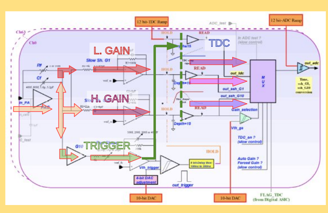
Not a challenge:
Radiations

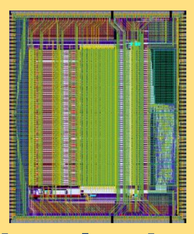


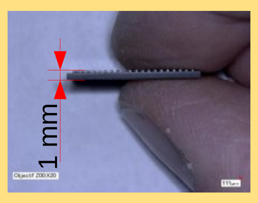












Physical (2005–11)

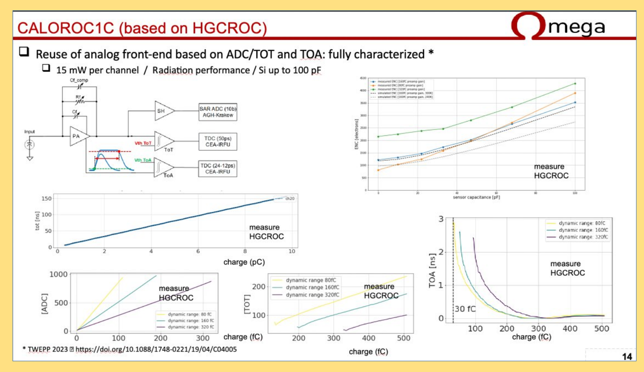
- 1×1 cm² on 500µm 6×6 cm² Pad glued on PCB Floating GR
- × 30 layers (10k chan).
- External readout
- Proof of principe

Technological (now)

- Embedded electronics
  - Power-Pulsed, Auto-Trig, delayed RO
  - S/N = (MPV/σ_{Noise}) ≥ ~12 (trig)
- Compatible w/ 8+ modules-slab
- 5×5 mm² on 320–650m 9×9 cm² × 26–30 layers
  - 8k (slab) ~ 30k (calo) channels

Pilote ➡ Full Detector

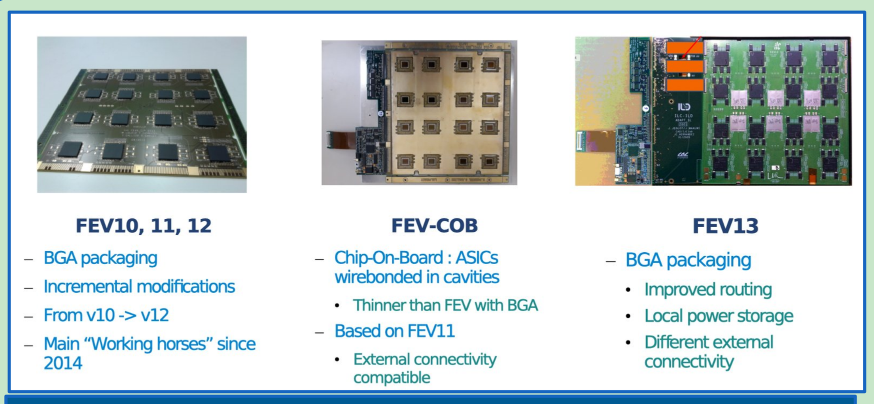
- 1M ➡ 70M channels
- On 725 µm 12×12 cm² (8'') Wafers?
- Pre-industrial building
- Full integration (⊃ cooling)
- **Final ASIC**



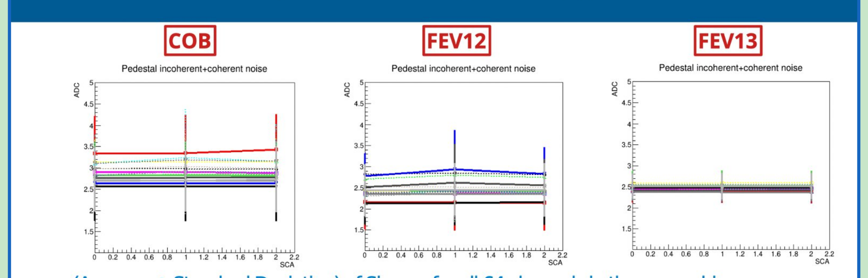
We are here

For a CC — For a LC

'Almost ready' for LC
To be revisited for CC



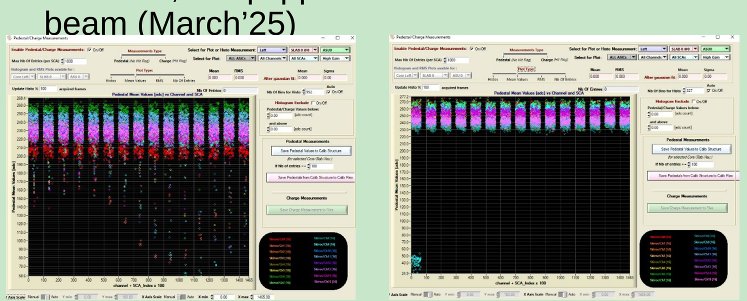
Pedestal widths, 1st memory cells, per asic



- (Average ± Standard Deviation) of Sigmas for all 64 channels in the same chip
- Latest PCBs, with optimized routing of power distribution shows better behavior
- Slightly larger spread on COB due to a near lack of decoupling capacitors

'Ultimate' LC version
Improvements:
- Power distributions
  - Local LV power regulation: LDO's
  - Local HV filtering & Supply
- Signal distribution (buffering), data paths
- Monitoring (single ID, temp, probe analogue line)
- ASIC shielding/routing

Status:
- Noise uniformity dramatically improved (ex: outliers in thr. / 20)
- version 2.1 produced
- 4 cabled, 2 equipped with sensors and tested in beam (March'25)



Revisiting gluing Silicon – PCB (IFIC, IJClab, DMLAB)

PCB metrology
- Bef. & After curing & soldering

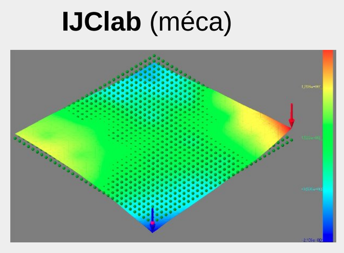
Glue formula & preparation

Gluing methods
- Robot
- Stencil

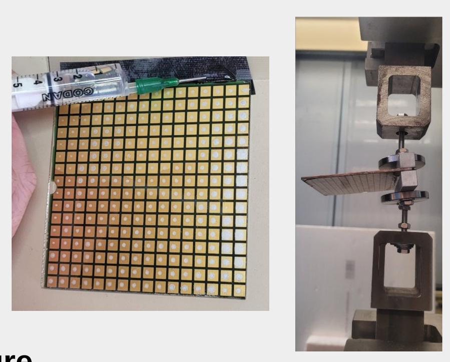
Reenforcement
- Filling glue
- Adhesive films

→ **Standardized procedure**

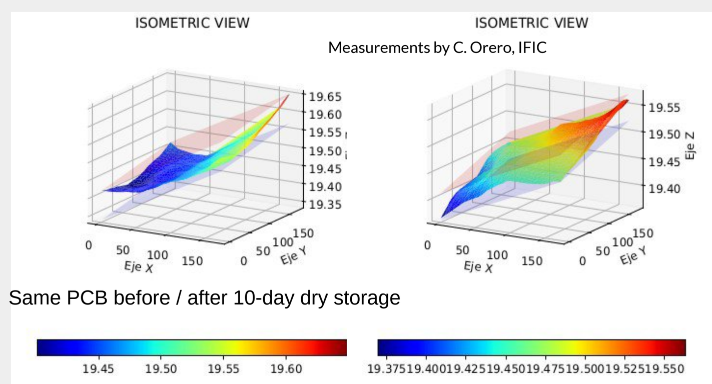
IJClab (méca)



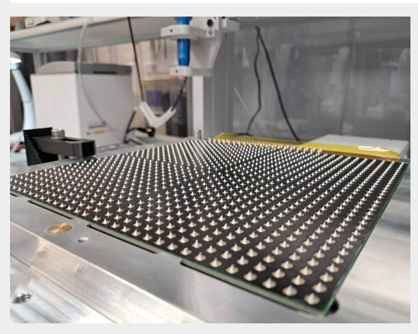
Conductive glue + filling (~invisible) on a glass plate



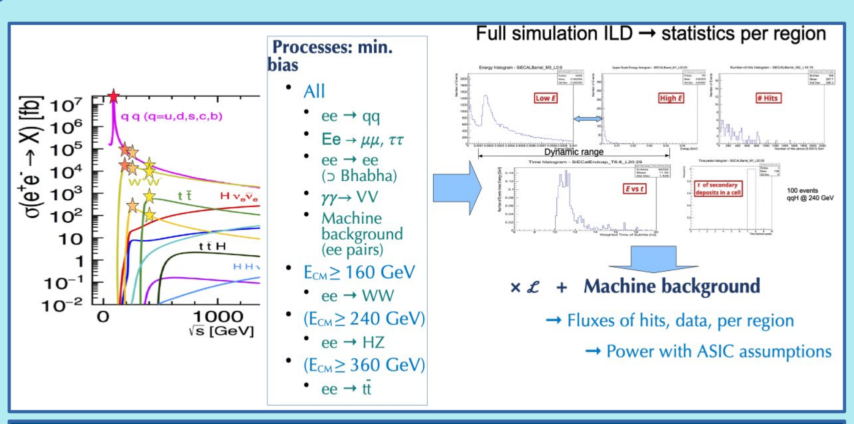
IFIC (optical)

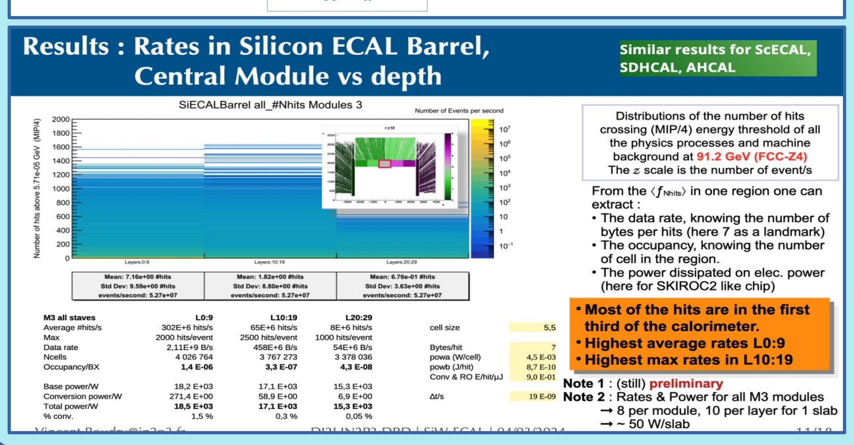


Same PCB before / after 10-day dry storage



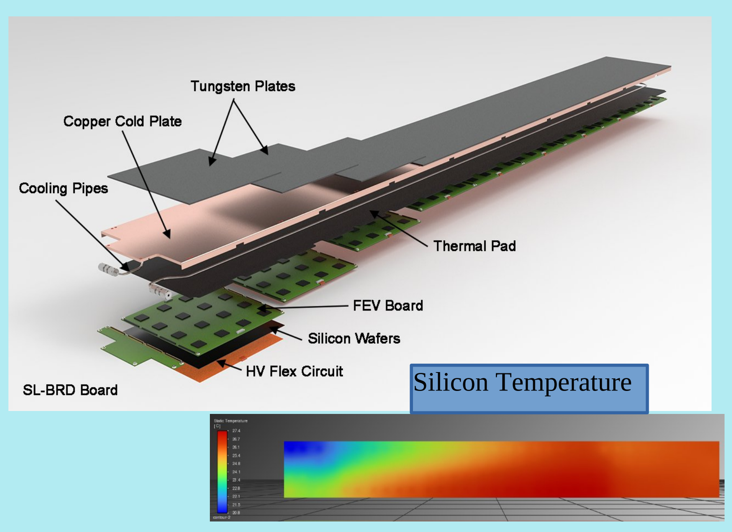
Punctured adhesive film (**DMLab**)
+
conductive glue dots



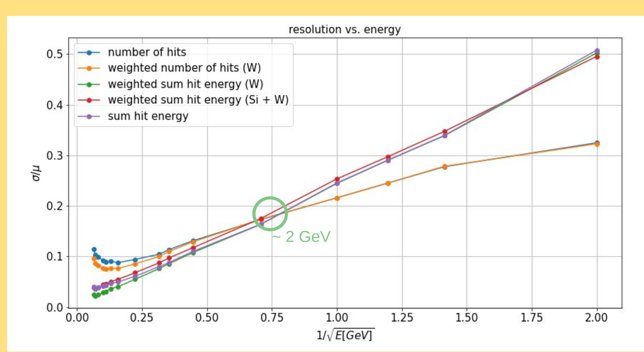


Adaptation to FCC-ee

- **Rates (physics + machine Background)**
- **Continuous operation**
  - **No more power-pulsing**
  - **Active cooling**



- **New Electronics (AMS130 → TSMC 130/65)**

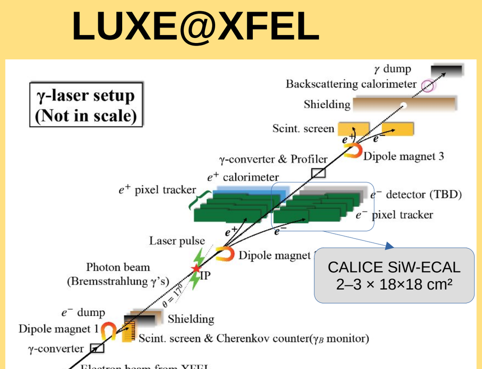


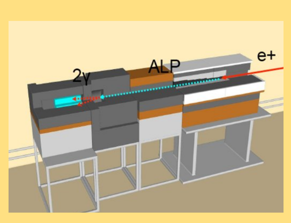
Re-optimisation paths:

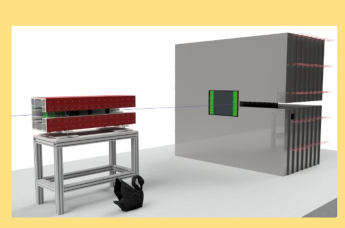
Addition of dedicated timing / position layers
Using the (semi)-digital approach
Using 725 µm sensors
Go '5D' : (x, y, z, t, E)
- Event clean-up (e.g. from beam-background)
- ToF / PID
- Natural order in particle tracking
- Other effect, yet to be discovered…

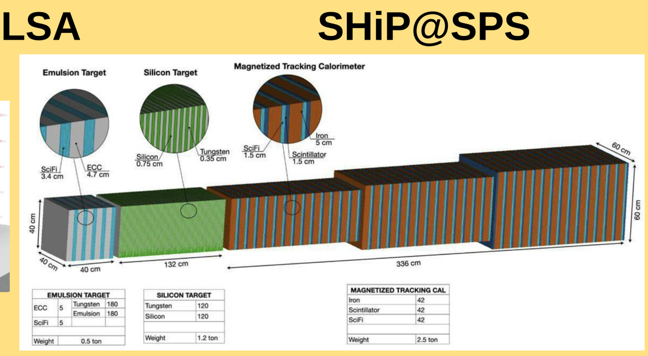
Direct Applications:

LUXE@XFEL — EBES@KEK — Lohengrin@ELSA — SHiP@SPS









with current Electronics — with new Electronics

CALICE — DRD6-Calo — ILD

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