Tourniquet Section 01
Date : 18/11/2024

R&D Collisioneurs e^+e^-

Bilan 2019-2024

Vincent Boudry

Composition actuelle de l’équipe & Évolution récente

- 2 permanents :
  - **Vincent Boudry** (CR)
  - **Ursula Bassler** (DR, ≥ 01/09/24)
- 2 émérites
  - **Henri Videau**,
  - **Jean-Claude Brient** (≥ 20/05/22)
- 2 contributeurs (équipe CMS)
  - **Roberto Salerno** (DR)
  - **Claude Charlot** (DR)

- 1 thèse soutenues :
  - **Jonas Kunath** (en 2022 avec dir : J.C. Brient)
    Les *branchements du Higgs en e+e−*,

    (travail en tant que R&D Data Scientist/Climate Risk Modeller at Descartes Underwriting)
- 1 postdoc :
  - **Fabricio Jimenez** 11/2019–10/2022
    (sur RP, IPP Junior)
    Analyse données & Simulation Beam Tests SiW-ECAL, Machine Learning on Higgs/PFA

Activités dans l'Équipe

Coopérations en cours (locales, nationales, internationales)

- **CALICE → DRD6** : prototypes & analyses d'un SiW-ECAL
  - **MP DRD6 SiW-ECAL** en cours de discussion – IN2P3
    ↔ DRD6 MoU en cours de finalisation
  - **LUXE** collaboration : application du proto SiW-ECAL à QED non-lin
- **ILD :** Concept de Détecteur pour Higgs / EW / top factories
  - Adaptation pour Collisionneur Circulaire ;
    mise à niveau electronique, services, etc.
- **MP FCC** (FR) & **ILC** (FR, EU, Global) & **CEPC** (CN)
  - Stratégie EU & FR (ESPPU)

- **IN2P3**: IJClab, LPNHE, Omega, IP2I, (LPSC)
- **International**: CALICE/DRD6 + ILD + AIDA-2020/Innova,
  - EU : DESY, MPP Munich, U. Mainz, CERN, Tau
  - Japon: KEK, U. Kyushu, U. Tokyo
  - Chine: IHEP

Organisations d'écoles, de workshops, conférences, .. (2019–2024)

- École de Gif 2019 (50 ans) - Questions ouvertes en physique des particules ~ 55 pers, co-org : LLR, CPhT, IRFU
- rECFA meeting (Paris, 2021) ~ 60 pers.
- Meeting semestriel CALICE (l'Ecole polytechnique + IJClab, 2022) ~ 50 Pers.
- ECFA WS HET (Paris, 2024) ~ 200 pers. Coorg + Public Event + Interviews Participants

Réponses aux appels à projets (ANR, ERC, Labex, Idex, etc)

- FP7 AIDAinnova (Innovative Pilot on Detector Technology at Accelerator): démarrage avril 2021 → mars 2025
- 1 an PD (2022) IPP-X extension pour F. Jiménez.
- FCPPL et FJPPL (×2)
- ANR-DPG Calo5D (2022, port IJClab+U.Mainz) . *Exploitation du temps dans les calorimètres UG.*: → 2–3 ans de CDD HN (2025–déb. 27)
- ANR T-Calo (2022, port : IP2PI) : *Exploitation du temps dans les calorimètres UG* → 3 ans de CDD (2025–fin 27)

Particle Flow based detectors for Higgs/EW/top factories

Full Reconstruction of single particles

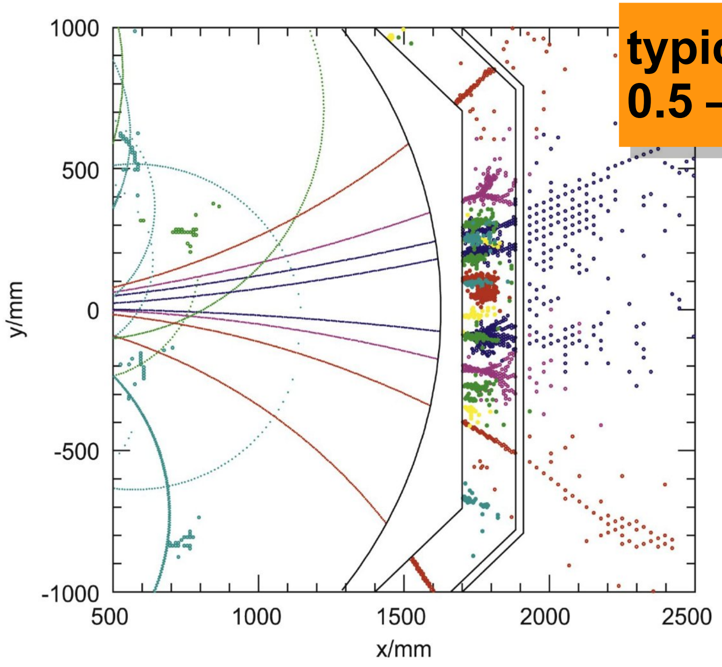
- Charged almost exclusively from trackers
  - Cluster removal by spatial matching *only* (idealy)
- Neutrals only from calorimeters

Particle Flow Algorithms :

- Jets = 65% charged (Tracks) + 25% γ (ECAL) + 10% h^0 (E+HCAL)
- TPC $\delta p/p \sim 5 \cdot 10^{-5}$; VTX $\sigma_{x,y,z} \sim 10$ μm

+ timing

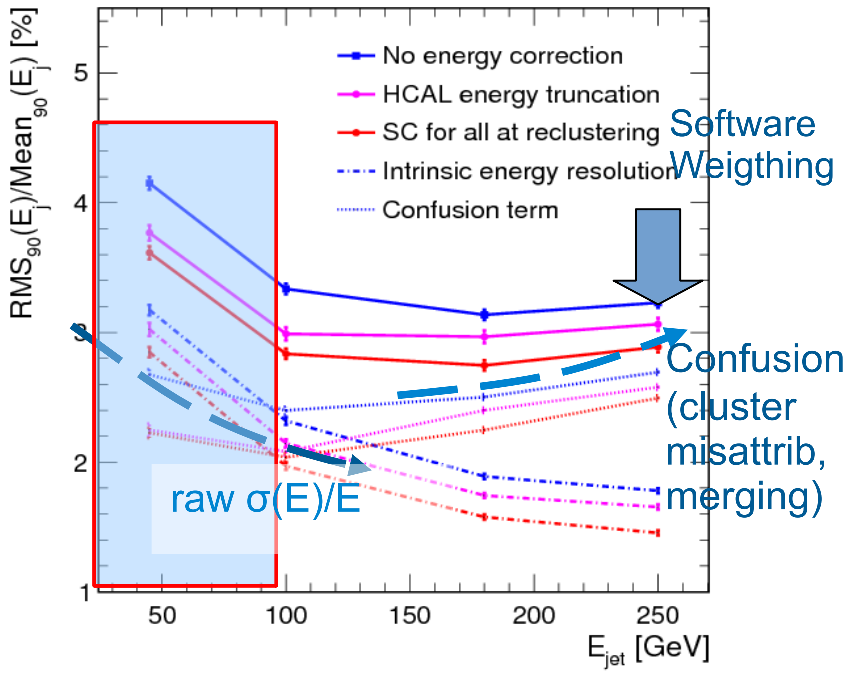
H. Videau and J. C. Brient, "Calorimetry optimised for jets," (CALOR 2002)



typical size : 0.5 – 3 cm

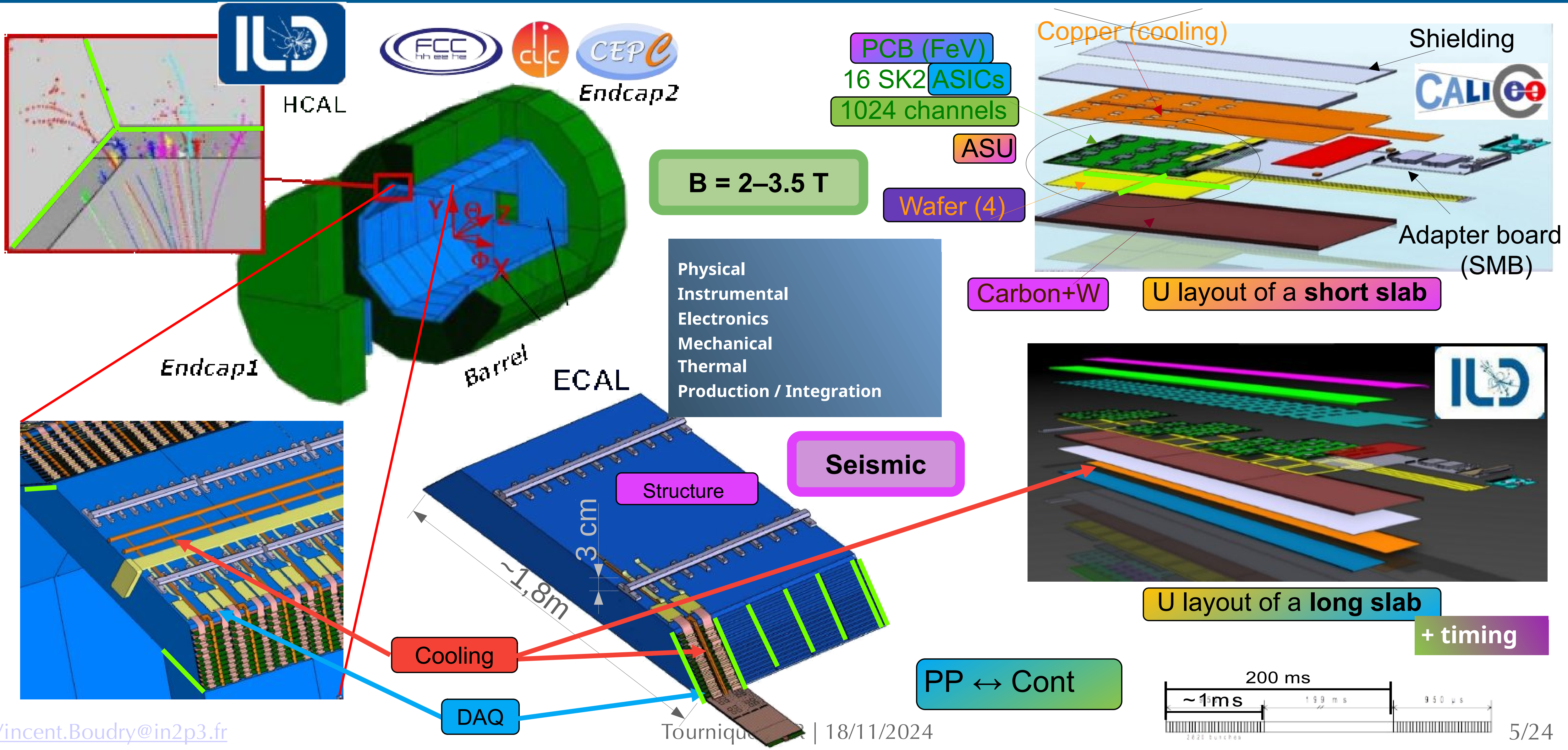
Optimisation from M. Thomson

Pandora PFA: EPJ C77 (2017) 10, 698

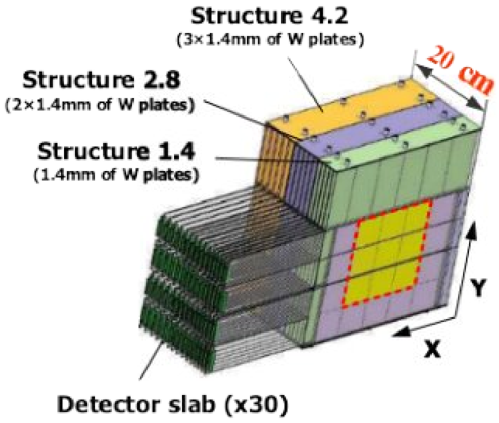


Low E jets ⇒ where PFA brings most

ILD SiW-ECAL: Modularity & Transversal Constraints

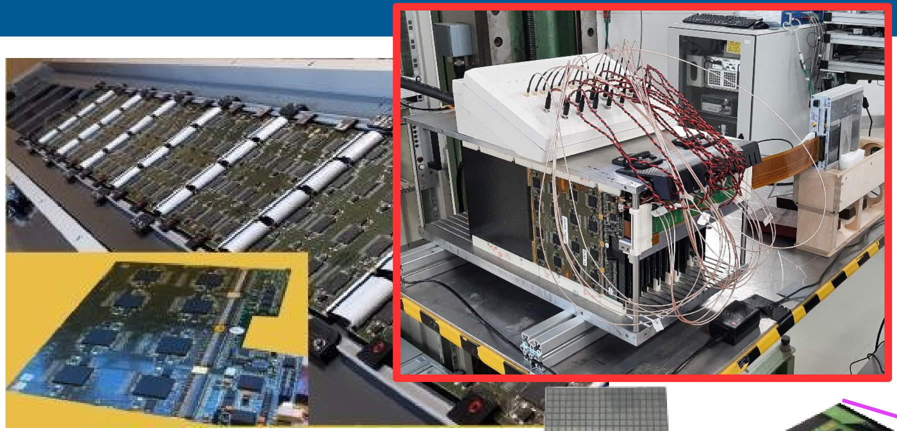


Timeline of SiW-ECAL Prototypes



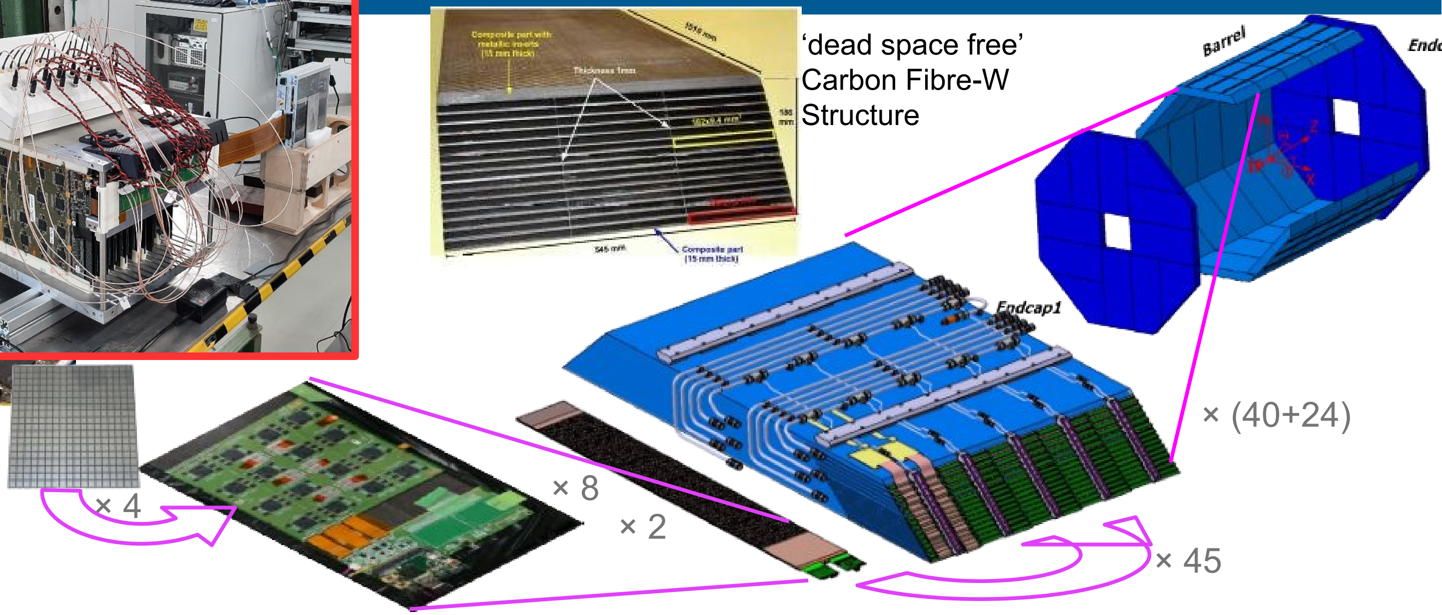
Physical (2005-11)

- 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 725µm 12×12 cm² 8'' Wafers ?
- Pre-industrial building
- Full integration (⊃ cooling)
- Final ASIC

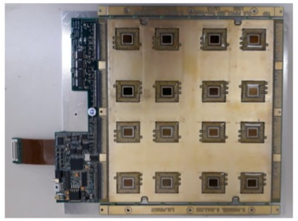
We are here

'Almost' ready for an ILC

Technological Prototype: Beam Test at DESY & CERN (2022)

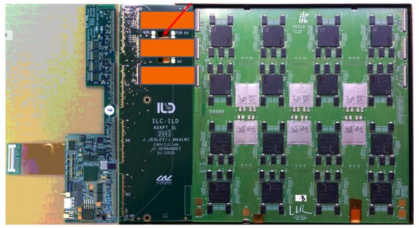
FEV10, 11, 12

- BGA packaging
- Incremental modifications
- From v10 -> v12
- Main "Working horses" since 2014



FEV-COB

- Chip-On-Board : ASICs wirebonded in cavities
  - Thinner than FEV with BGA
- Based on FEV11
  - External connectivity compatible

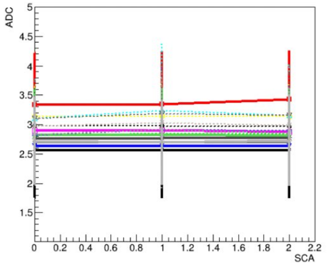


FEV13

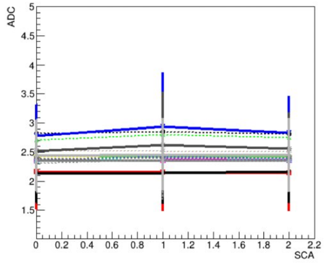
- BGA packaging
  - Improved routing
  - Local power storage
  - Different external connectivity

Pedestal widths, 1st memory cells, per asic

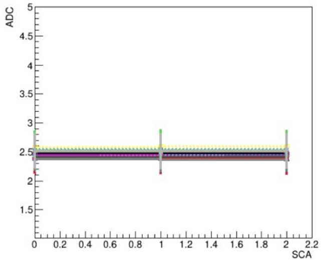
COB



FEV12

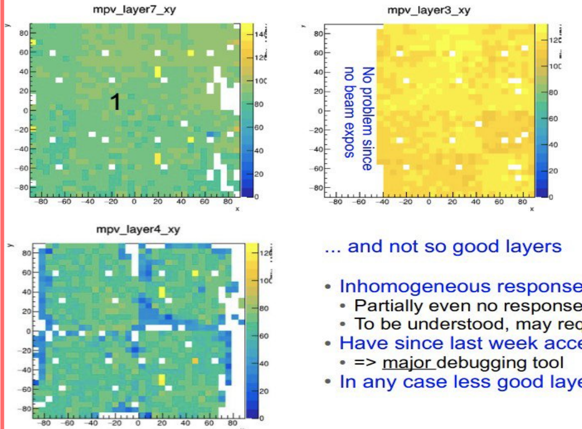


FEV13



- (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

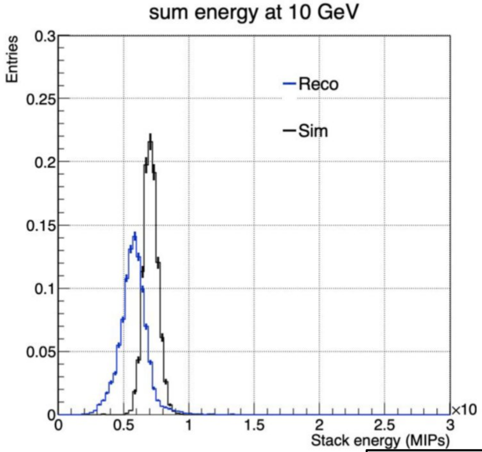
Adrian Irles



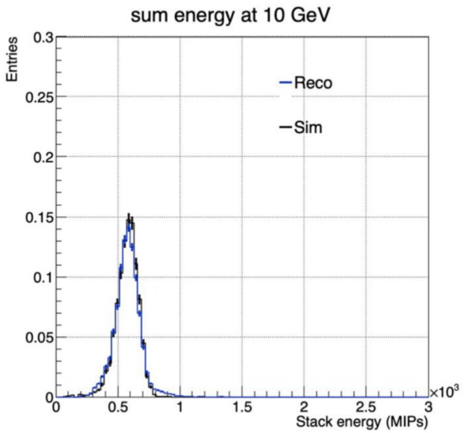
- We have good layers …
  - Homogeneous response to MIPs over layer surface
  - Here white cells are masked cells due to PCB routing
    - Understood and will be corrected

… and not so good layers

- Inhomogeneous response to MIPs
  - Partially even no response at all, in particular at the wafer boundaries
  - To be understood, may require dedicated aging studies
- Have since last week access to the different stages of the ASICs
  - => major debugging tool
- In any case less good layers will be replaced in coming months



Masking
Beam profiling
+
Digitzation



Yuichi Okugawa (PhD in Feb.

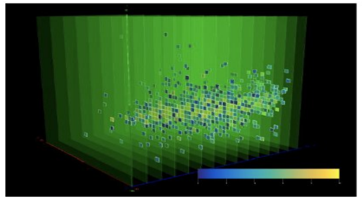


Fig. Simulation e- 100 GeV

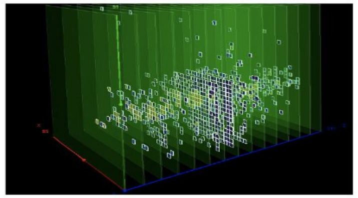
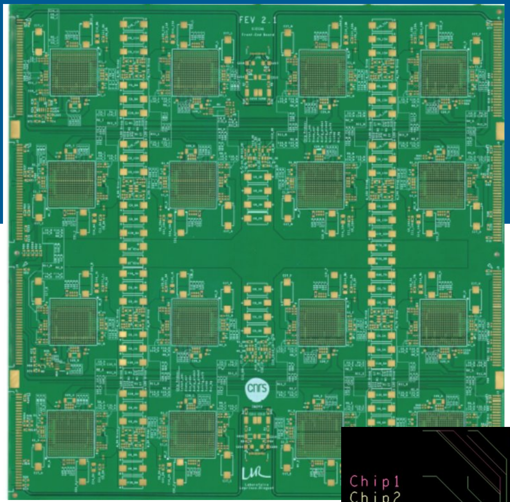
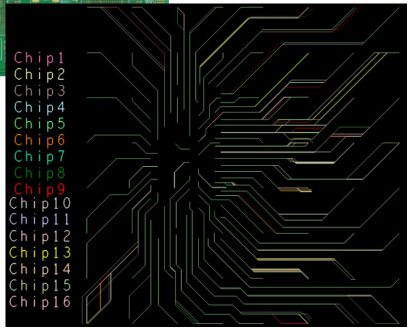


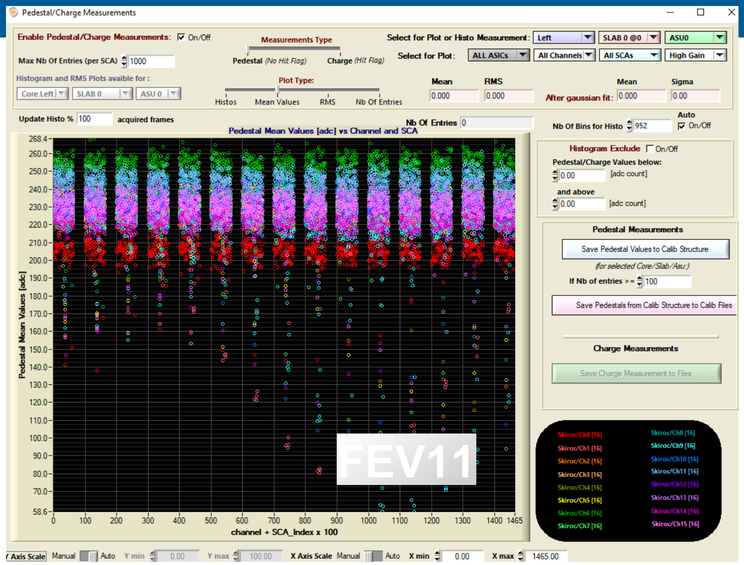
Fig. Reconstructed e- 100 GeV

New FE boards

LLR: J. Nanni + R. Guillaumat
IJClab: D. Breton







Pedestal measurements vs. Ch# + Mem#×100)

SIngle channel → the fault on the ASIC/packaging

Improvements:

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

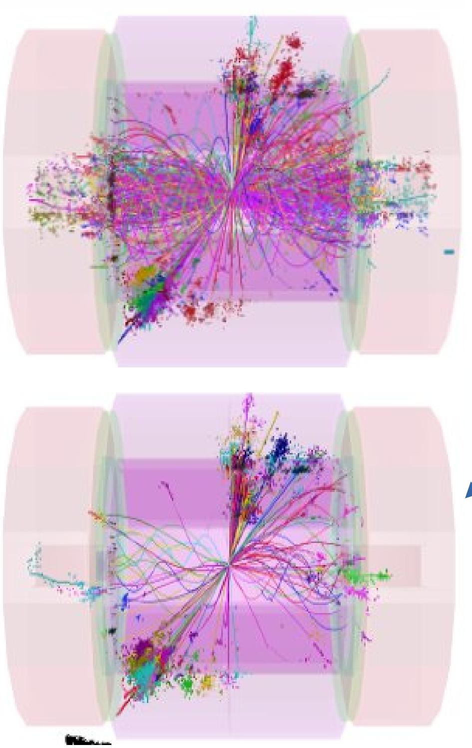
Status:

- version 2.1 produced, … in metrology
  - before cabling, 2nd metrology, gluing, …
  - All material available : ASICs being tested
- Preparing 2 equipped boards (IFIC, Valencia)
  → BT in DESY March 2025

Timing in Calorimeters: 0.1–1 ns range

1 cm/c = 30 ps

Cleaning of Events

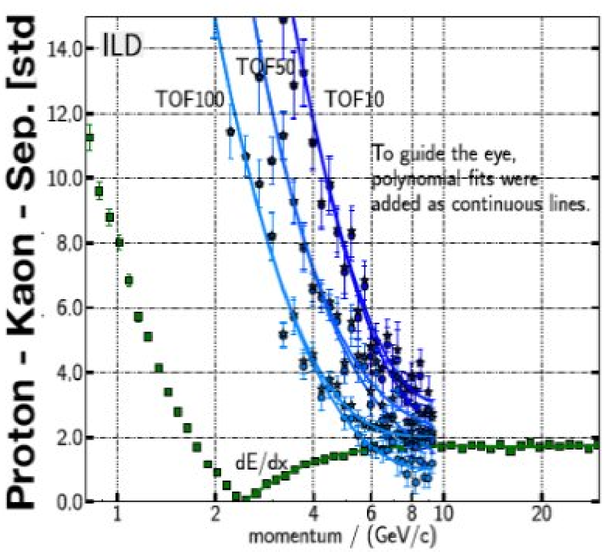


time cut

[CLIC CDR: 1202.5940]
adapted from L. Emberger

Particle ID by Time-of-Flight

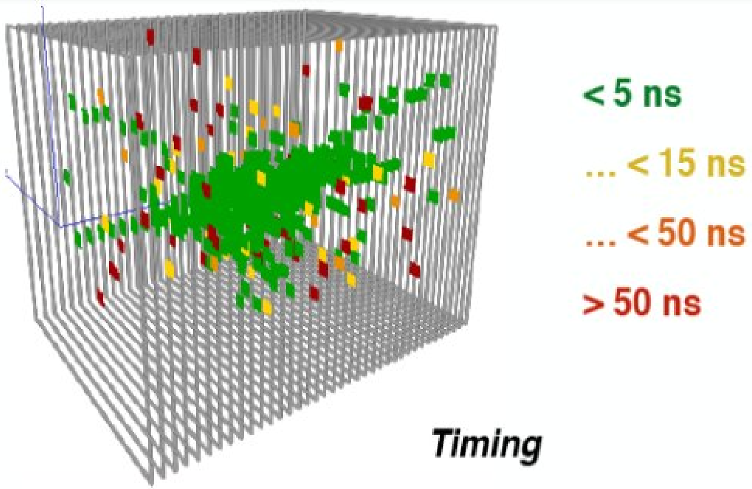
– Complementary to dE/dx
  - here with 100 ps on 10 ECAL hits



S. Dharani, U. Einhaus, J. List

Ease Particle Flow:

– Identify primers in showers
– Help against confusion
  better separation of showers
– Cleaning of late neutrons & back scattering.

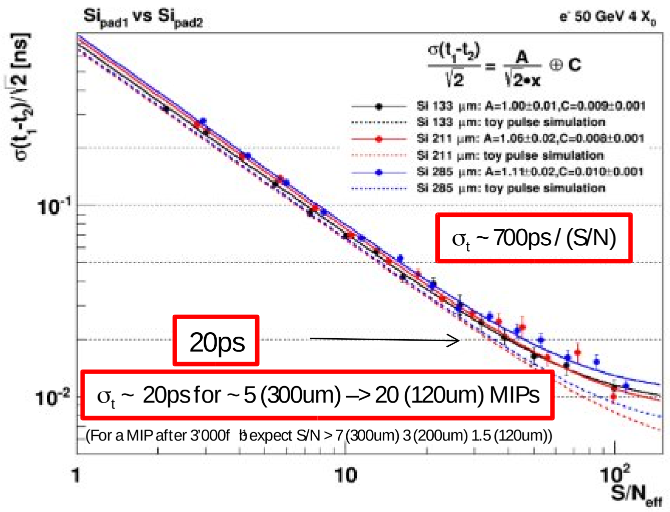


Ch. Graf

Calorimeter Timing Studies

2015 CMS HGCAL CERN timing test beam

– Time resolution vs S/N ratio



Transparent cells => no timing
Solid cells = > timing information ~50ps

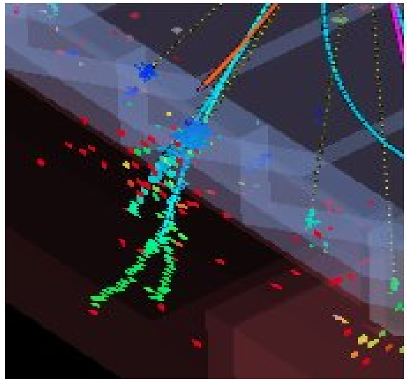
2024: Funding for
2 programs in FR & DE :

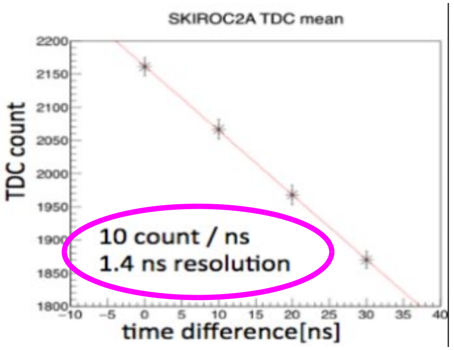
T-Calo & Calo5D
→ full chain of Sim.
→ Phys. Perf.

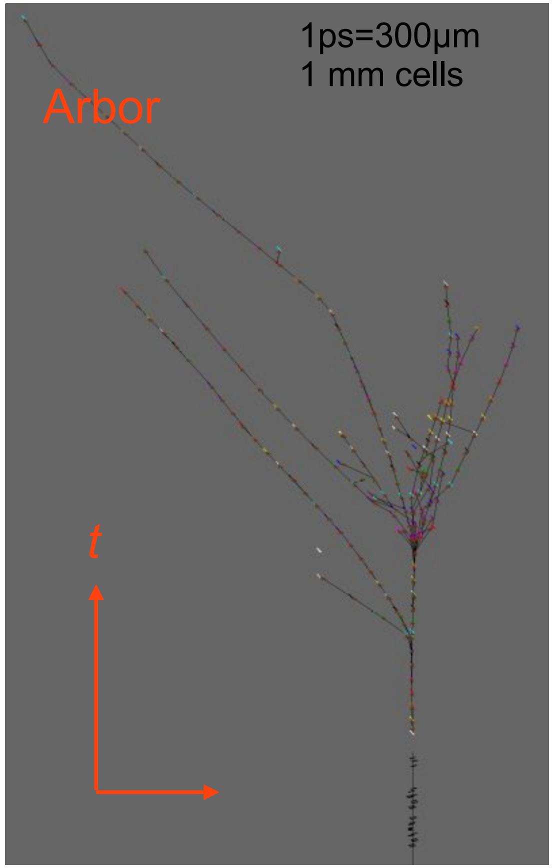
2 PostDoc recruited

Work just started…

Option 1) **Bulk Timing**







Option 2) **Dedicated layers with fast sensors (LGADs, MAPs, …)**

Linear → Circular Collider's Conditions

Linear (ILC, HL-ILC…)

- 250 GeV (ZH), 365 GeV (tt), 500 GeV (ZHH) + [1000 GeV], $\mathcal{L}$ ~ cst.
- Power pulsing : 5 [10–15]Hz × 1 [2] ms   Power ~ $\mathcal{L}$.

More diverse et stringent conditions:

- 90GeV × 10^7 fb × $5 \cdot 10^{36}$ cm^{-2} s^{-1} (qq × 20,000 ILC @ 250)
- 150 GeV (WW) + 250 GeV (ZH)+ 365 GeV (tt)
  ~10^4 fb × $5 \cdot 10^{35}$ cm^{-2} s^{-1} (qq × 5–10 ILC @ 250)

From Pulsed to Continuous operation

- Power = cst + convertion+RO × local rates (P_{Conv}+P_{RO} ~ 40% P_{ACQ})
- ASIC, Power/Cooling, DAQ, *Granularity, Precisions (E, t),* New ideas…

HL-ILC:

- $\mathcal{L}$ × 4 (6)
- $N_{bunches}$ × 2 : τ_{Train} : 1 → 2 ms
- f_{rep} ×2 (3): 5 → 15 Hz

Dominated by ACQ time:
P(~25µW/ch) × 6

HL-CLIC:

- $\mathcal{L}$ × 2
- $N_{bunches}$ → : τ_{Train} : 176 ns
- f_{rep} ×2 : 50 → 100 Hz

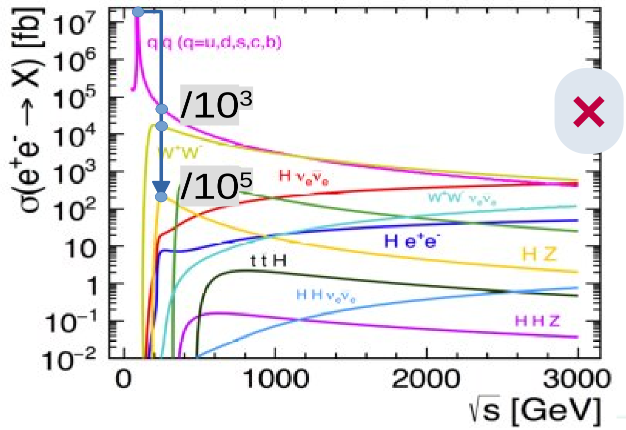
Dominated by Set-up & Conversion time: P (~82µW/ch) ×2

FCC-ee parameters		Z	W⁺W⁻	ZH	ttbar
√s	GeV	91.2	160	240	350-365
Luminosity / IP	10^{34} cm^{-2} s^{-1}	230	28	8.5	1.7
Bunch spacing	ns	19.6	163	994	3000
"Physics" cross section	pb	35,000	10	0.2	0.5
Total cross section (Z)	pb	40,000	30	10	8
Event rate	Hz	92,000	8.4	1	0.1
"Pile up" parameter [µ]	10^{-6}	1,800	1	1	1

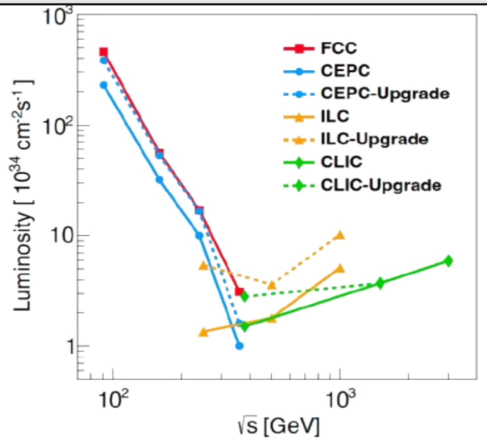
Experimentally, Z pole most challenging

- Extremely large statistics
- Physics event rates up to 100 kHz
- Bunch spacing at 20 ns
  - "Continuous" beams, no bunch trains, no power pulsing
- No pileup, no underlying event …
  - …well, pileup of 2 x 10^{-3} at Z pole

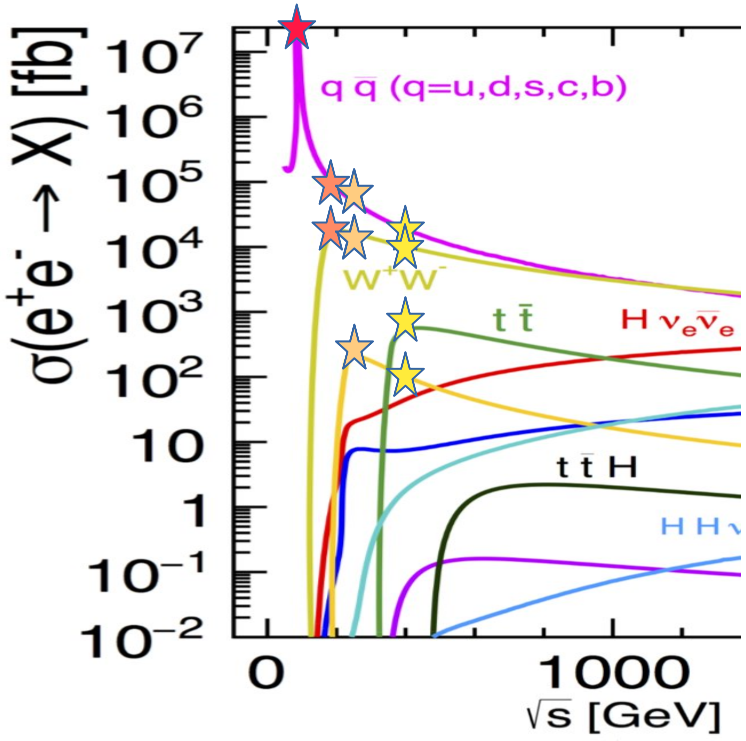
https://indico.cern.ch/event/1064327/contributions/4893208/
Mogens Dam @ FCC Week, 10/06/2022



Status of the CEPC, October 2022 J. Guimarães da Costa



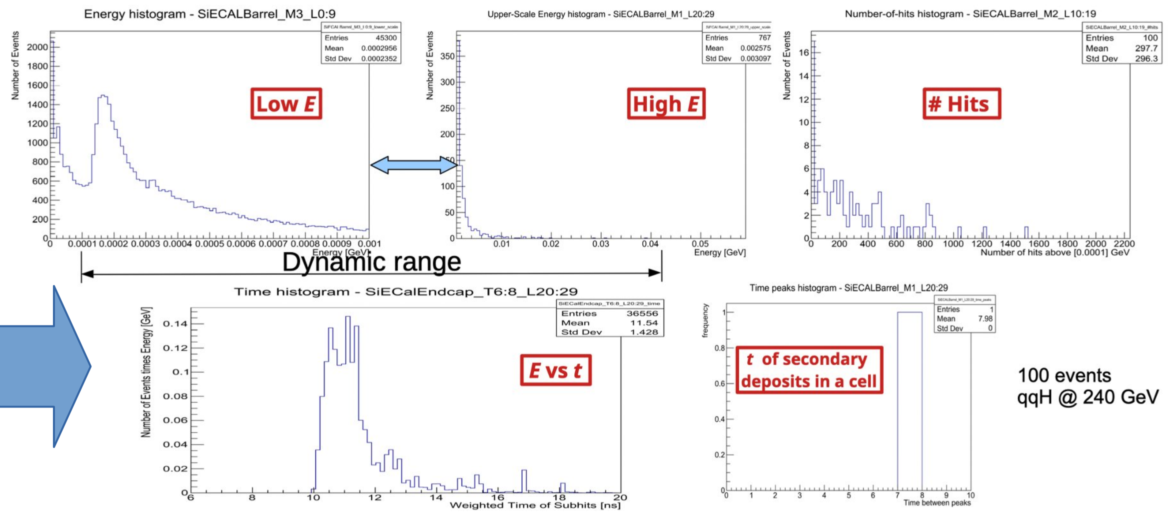
Fluxes in calorimeters



Processes: min. bias

- All
  - ee → qq
  - Ee → $\mu\mu$, $\tau\tau$
  - ee → ee (⊃ Bhabha)
  - → VV
  - Machine background (ee pairs)
- $E_{CM} \geq 160$ GeV
  - ee → WW
- ($E_{CM} \geq 240$ GeV)
  - ee → HZ
- ($E_{CM} \geq 360$ GeV)
  - ee → tt

Full simulation ILD → statistics per region



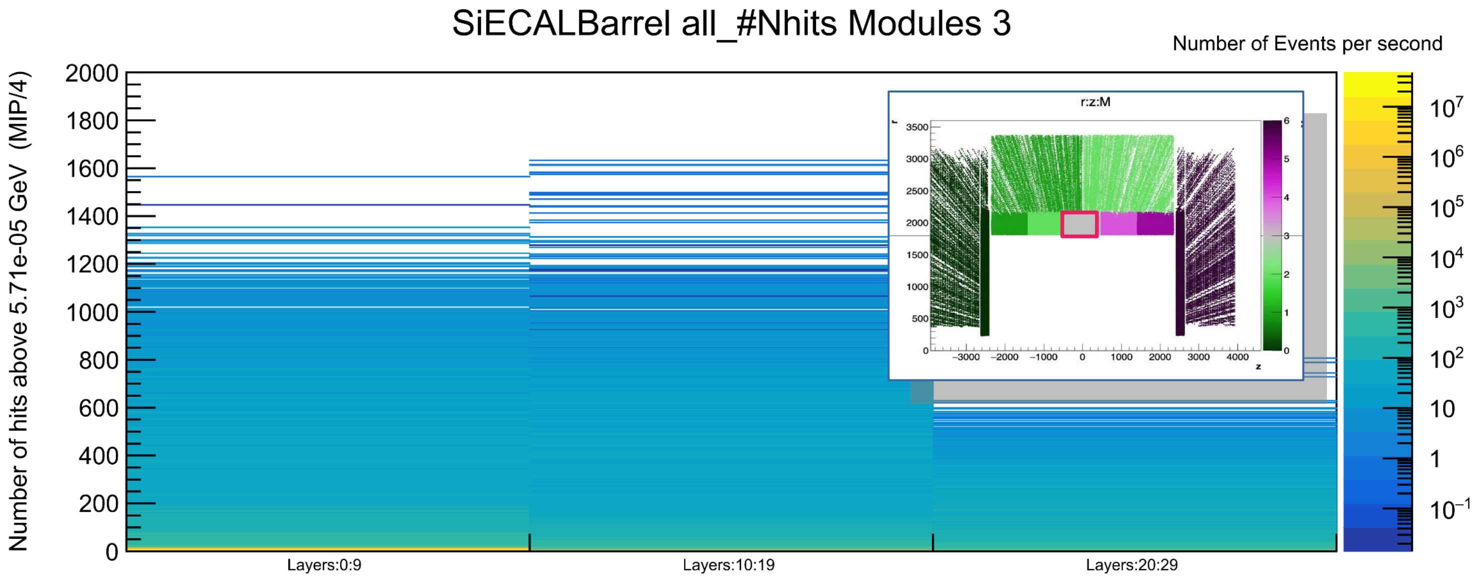
× $\mathcal{L}$ + **Machine background**

→ Fluxes of hits, data, per region

→ Power with ASIC assumptions

Results : Rates in Silicon ECAL Barrel, Central Module vs depth

Similar results for ScECAL, SDHCAL, AHCAL



Layers:0:9	Layers:10:19	Layers:20:29
Mean: 7.16e+00 #hits	Mean: 1.82e+00 #hits	Mean: 6.76e-01 #hits
Std Dev: 9.59e+00 #hits	Std Dev: 8.80e+00 #hits	Std Dev: 3.63e+00 #hits
events/second: 5.27e+07	events/second: 5.27e+07	events/second: 5.27e+07

Distributions of the number of hits crossing (MIP/4) energy threshold of all the physics processes and machine background at **91.2 GeV (FCC-Z4)**
The z scale is the number of event/s

From the $\langle f_{\text{Nhits}} \rangle$ in one region one can extract :

- The data rate, knowing the number of bytes per hits (here 7 as a landmark)
- The occupancy, knowing the number of cell in the region.
- The power dissipated on elec. power (here for SKIROC2 like chip)

M3 all staves	**L0:9**	**L10:19**	**L20:29**
Average #hits/s	302E+6 hits/s	65E+6 hits/s	8E+6 hits/s
Max	2000 hits/event	2500 hits/event	1000 hits/event
Data rate	2,11E+9 B/s	458E+6 B/s	54E+6 B/s
Ncells	4 026 764	3 767 273	3 378 036
Occupancy/BX	**1,4 E-06**	**3,3 E-07**	**4,3 E-08**
Base power/W	18,2 E+03	17,1 E+03	15,3 E+03
Conversion power/W	271,4 E+00	58,9 E+00	6,9 E+00
Total power/W	**18,5 E+03**	**17,1 E+03**	**15,3 E+03**
% conv.	1,5 %	0,3 %	0,05 %

cell size	5,5
Bytes/hit	7
powa (W/cell)	4,5 E-03
powb (J/hit)	8,7 E-10
Conv & RO E/hit/µJ	9,0 E-01
Δt/s	19 E-09

- **Most of the hits are in the first third of the calorimeter.**
- **Highest average rates L0:9**
- **Highest max rates in L10:19**

Note 1 : (still) **preliminary**
Note 2 : Rates & Power for all M3 modules
→ 8 per module, 10 per layer for 1 slab
→ ~ 50 W/slab

ECAL adaptation : flat water cooling, preliminary thermal studies

© Oscar Ferreira @ LLR

Uniform solutions:

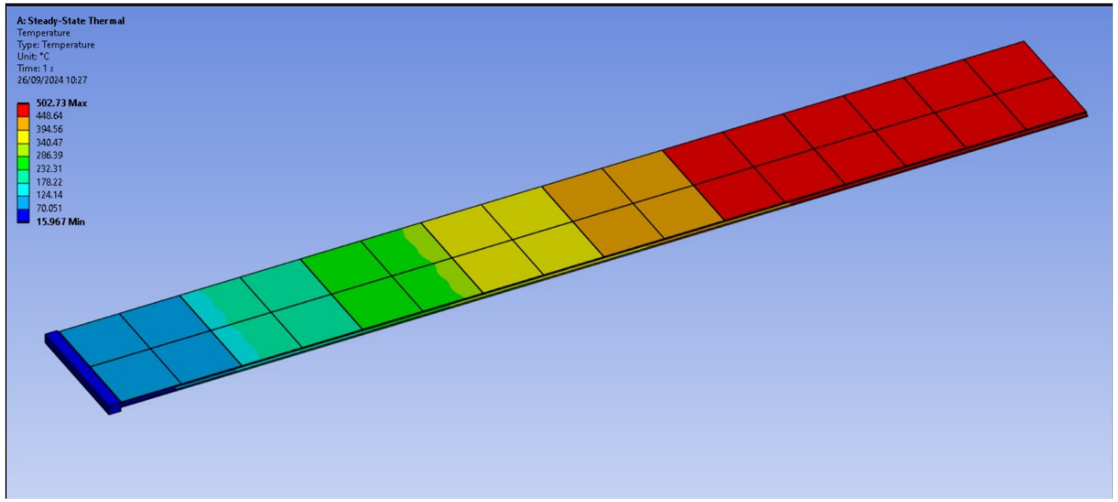
“Standart Slab”:

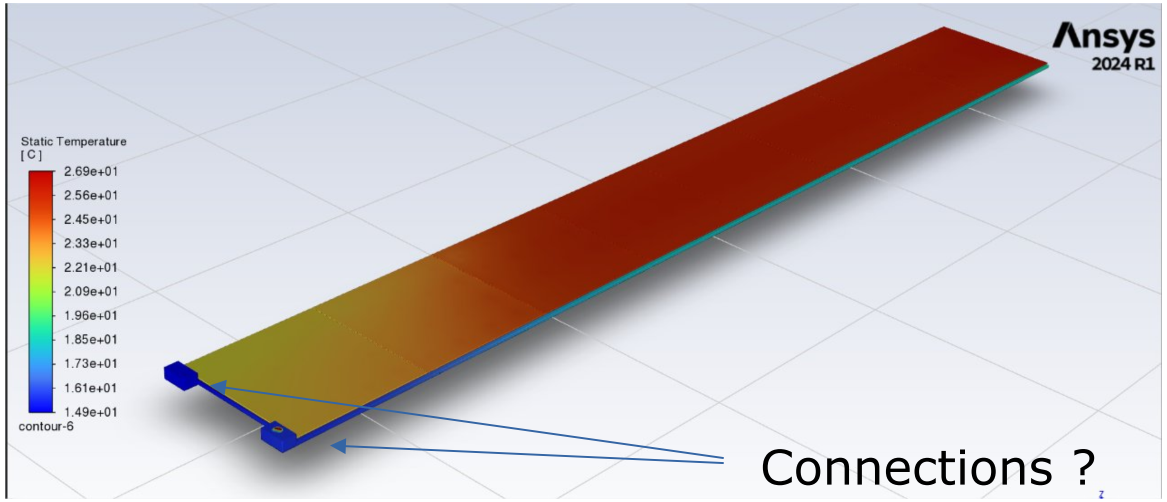
- 8 ASU (1440mm), 8192 ch / 128 ASICs
- 100 W

Passive cooling: Cu of 2mm (W, C ignored)

Adiabatic, but for heat bridge at the end

ΔT = 500°C on Wafer surface at *t* = ∞





“Standart Slab”:

- 8 ASU (1440mm), 8192 ch / 128 ASICs
- 128 W (1W/ASIC ~16 mW /ch)

Active cooling:

- Hollowed Cu of 4mm, with 1ℓ/min of water @ 15°C

Adiabatic, but for heat bridge at the end

ΔT = 12°C on Wafer surface at *t* = ∞

Conclusions

SiW-ECAL technological prototypes

- **2022:** Heterogeneous 15 layers
  - 1st full calorimeter working [DESY22, CERN22]
    - Shower seen, Detailled simulation ready
    - Analysis on-going ➞ resolutions, …
  - Numerous emerging issues
    - gluing, HV filtering at high energy
- **2024 2025-26:** Uniform 15 layers
  - ➞ New VFE boards
    - Cleaner PS & Clock distributions; more uniform
  - Gluing being revisited
  - Material available.
  - To be tested in 2025

    ➞ Provide reference sample for GEANT4

    ➞ With funding ➞ "full" LUXE

SiW-ECAL design for HET factories

- **2023–25**: Power budget & performances to be re visited
  - Occupancy, power, data fluxes (on-going)

    ➞ Granularity; Passive or Active cooling

    ➞ new ASIC attributes
  - 2025–27: PFA & Timing & Physics performances

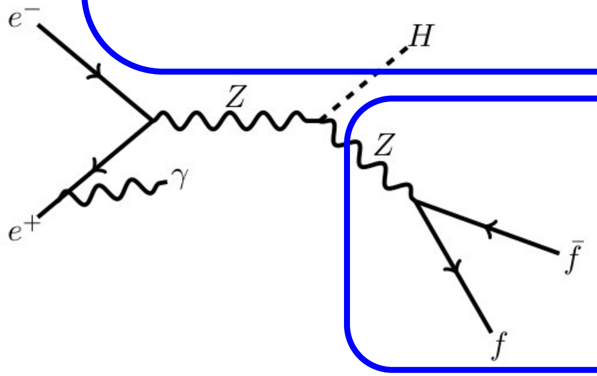
2025–27 : Blue-print for a SiW-ECAL detector for the next ee collider

➡ planning for a pilote module @ T_0 collider-8y -5y (1 Mch, 1/60th of real detector)

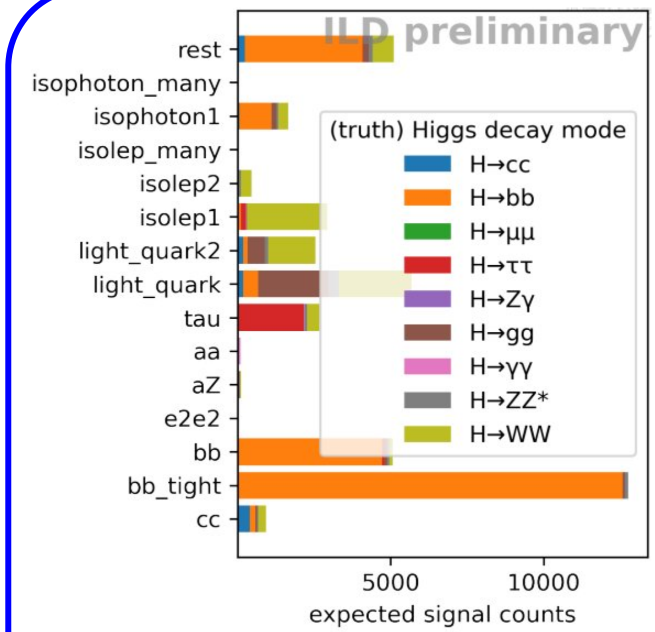
semi-industrial, quality, ASICs, …

Plenty of instrumental work & beam data analysis

(All) Higgs Branching Ratios at ILD250

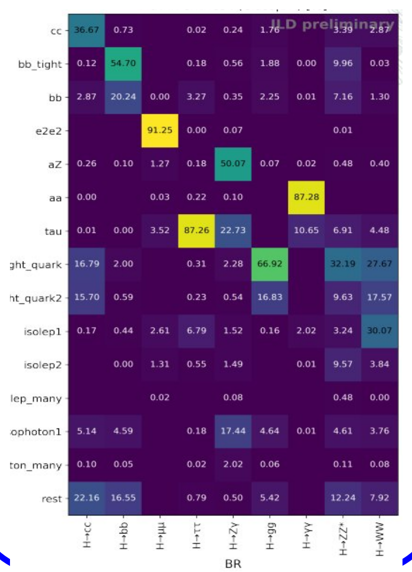


1. Event selection



2. Sample creation

3. BR fit



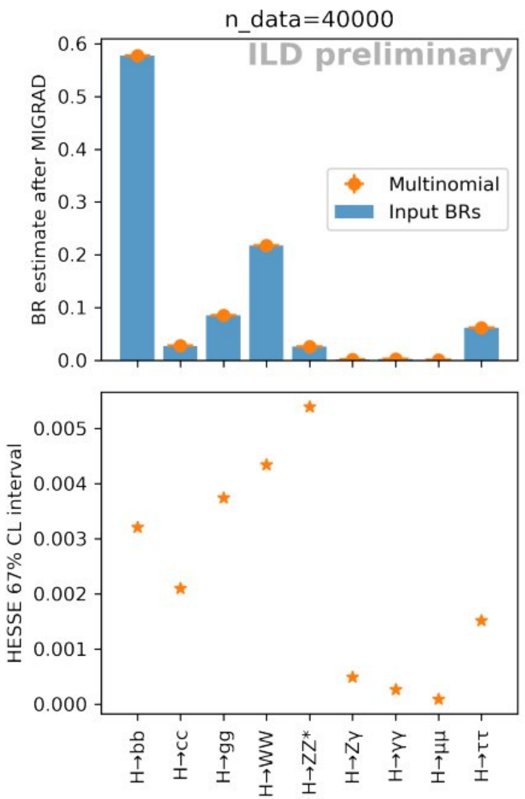
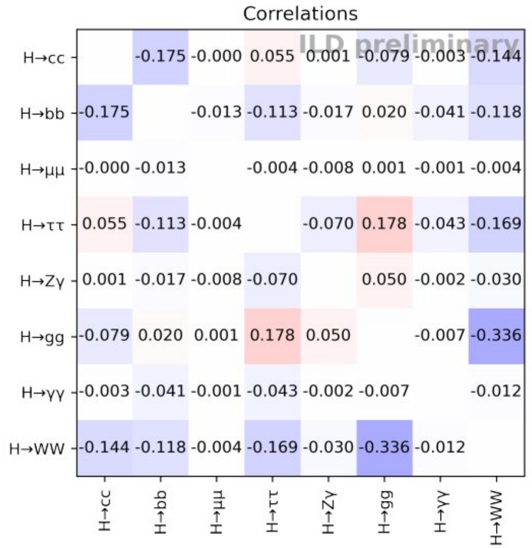
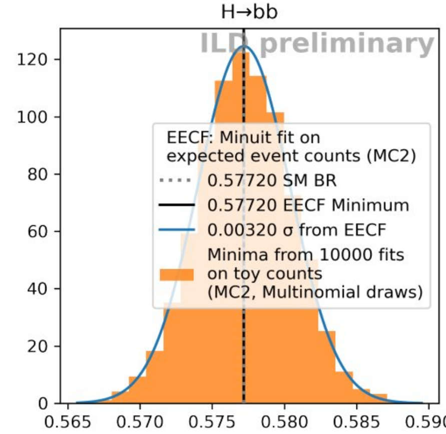


TABLE – Results of a fit on the expected event counts. In %. ILD preliminary.

	SM BR	minimum	σ
$H \to cc$	2.718	2.733	0.210
$H \to bb$	57.720	57.743	0.321
$H \to \mu\mu$	0.030	0.030	0.009
$H \to \tau\tau$	6.198	6.207	0.152
$H \to Z\gamma$	0.170	0.176	0.050
$H \to gg$	8.550	8.499	0.374
$H \to \gamma\gamma$	0.242	0.243	0.027
$H \to WW$	21.756	21.761	0.434
$H \to ZZ^*$	2.616	2.608	0.539



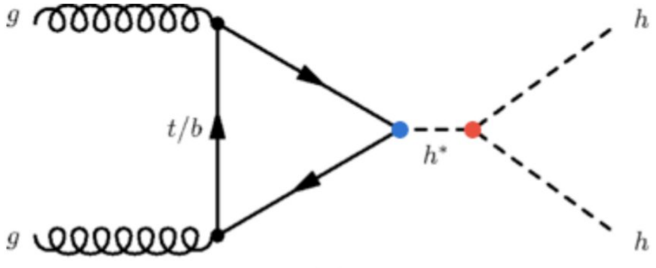


Thèse Jonas Kunath (LLR)
PANIC2021 (2022) ,
EPS-HEP2021
LCWS 20

Improving the sensitivity of λ_{HHH} measurement by exploiting the kinematical properties at the FCC-hh

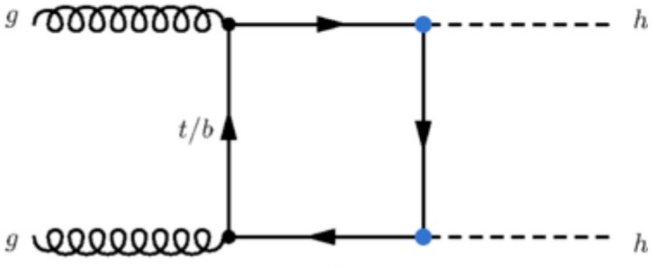
Gluon-gluon fusion Higgs boson pair production @ LO, dominant at 100 TeV

"Triangle" amplitude $\mathcal{M}_{\triangleright} \propto y_t \lambda_{hhh}$

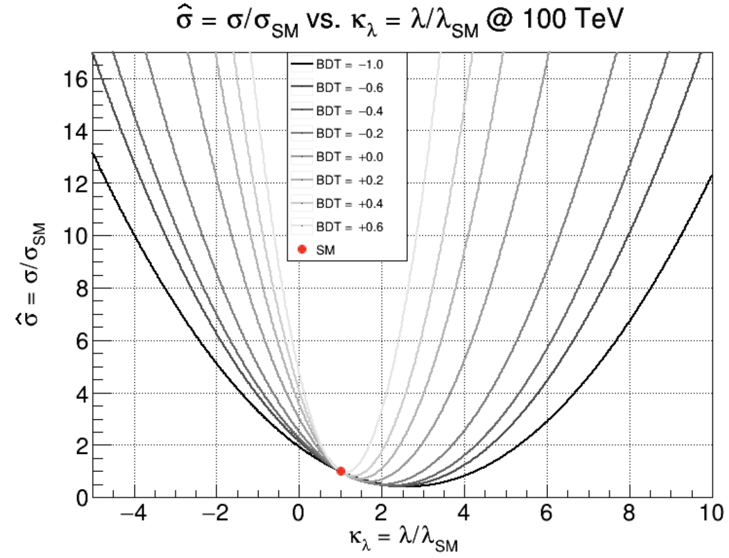


(a)

"Box" amplitude $\mathcal{M}_{\square} \propto y_t^2$



(b)

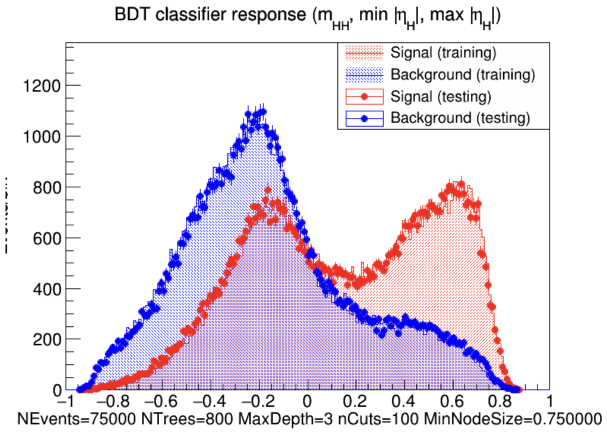


Sensibilité au $\kappa_t \equiv y_t / y_t^{SM}$ et $\kappa_\lambda \equiv \lambda_{hhh} / \lambda_{hhh}^{SM}$

Amélioration de la sensibilité via cinématique hh

Étude générateur (MadGraph5_aMC @NLO) + BDT(6 var.):

- Couverture optimale: $|\eta| \leq 5$
- Maximizing $\triangleright$ contributions / all sdf



Next:

- Dedicated decay channel: $bb\gamma\gamma$
- FastSim for detector effects (DELPHES)

Bastien Voirin
M2 internship (2024)
avec C. Charlot.

Organisation-fonctionnement du groupe

Coordinateur équipe : VB

- **SiW-ECAL CALICE / DRD6**
  - VB : Speakers Bureau, Coord. SiW-ECAL
  - VB : Réorg. CALICE S → DRD6, MP IN2P3
  - J. Nanni : Tech. Coord. Électronique.
  - Analyse optimisations resolution avec etudiants
- **ILD**
  - Exec Team : H. Videau (< 04/2021), JCB (≥04/2021)
  - Tech Board & Contact SIW-ECAL : VB
- **MP FCC** : R. Salerno (interim : VB)
  - Analyses : R. Salerno, C. Charlot, JC Brient
- **PFA / Timing Studies** : H. Videau, JC Brient, VB

Dans le laboratoire :

- Groupe électronique :
  - Conception PCB (FEV2) : J. Nanni (Coordinateur) + R. Guillaumat
  - Lien avec Ωmega (CALICE/DRD6 – ANR)
- Groupe mécanique :
  - Étude d'un cooling actif pour circulaire : O. Ferreira (≥2024)

Enseignements :

- ***Master 2 HEP*** IPP-Eth Zurich:
  J.C. Brient, Détecteurs (36 h)
- **École des Mines** (Paris) :
  V. Boudry : Cosmologie (16 h)
- **École de Gif**
  V. Boudry : Responsable (≥2021)

Communication :

Fête de la Science : J.C. Brient, C. Charlot

Public Event avec table ronde : V. Boudry
Science et Société: le FCC, Futur Collisionneur Circulaire de particules élémentaires du CERN:

ECFA HET WS : Interviews (S. Pieyre, VB)

Expertise :

Revue EuroFusion Facilities (2023) : V. Boudry

Production scientifique

Publications significatives/emblématiques de l’équipe dans revues à comité de lecture (2019-2024) :

- K. Hassouna and V. Boudry, **CaloFlux: a tool to estimate fluxes in calorimeters at colliders**, JINST 19, (2024) T10009
- H. Abramowicz et al., **Technical Design Report for the LUXE experiment**, Eur. Phys. J. ST 233, (2024) 1709.
- W. Abdallah et al., **CEPC Technical Design Report: Accelerator,** Radiat. Detect. Technol. Methods 8, (2024) 1
- Y. Che, V. Boudry, H. Videau, M. He and M. Ruan, **Cluster time measurement with CEPC calorimeter**, Eur. Phys. J. C 83, (2023) 93.
- V. Boudry, **New results of the technological prototype of the CALICE highly granular silicon tungsten calorimeter**, **PM2021 (Elba)** NIMA 1051, (2023) 168185.
- CALICE Collaboration, V. Boudry, “**Implementation of large imaging calorimeters**,” PoS **ICHEP2020** (2021) 823.
- D. Yu, et al. “**The measurement of the H $\rightarrow \tau\tau$ signal strength in the future e+e− Higgs factories**,” Eur. Phys. J. C 80 no. 1, (2020) 7.
- ILD Concept Group, F. Magniette et al., “**ILD silicon tungsten electromagnetic calorimeter first full scale electronic prototype,**” **VCI2019**, NIMA958 (2020) 162732, arXiv:1909.04329 [physics.ins-det].
- K. Kawagoe et al., “**Beam test performance of the highly granular SiW-ECAL technological prototype for the ILC**”, Nucl. Instrum. Meth. A 950 (2020) 162969, arXiv:1902.00110 [physics.ins-det]

Publications récentes de conférence à forte contribution de l'équipe (revue, proceeding,..) :

- V. Boudry for the CALICE collaboration, ‘’**CALICE, a legacy**’’, presentation at **CALOR’2024.**
- S. V. Chekanov and others, **Precision timing for collider-experiment-based calorimetry**, (2022). Contribution au SNOWMASS P5
- A. Aryshev and others, **The International Linear Collider: Report to Snowmass 2021**, (2022).
- J. Kunath, F. J. Morales, J.-C. Brient and V. Boudry, **A Combined Fit to the Higgs Branching Ratios at ILD**, in **LCWS2021**.
- ILD Concept Group, H. Abramowicz et al., “**International Large Detector: Interim Design Report**,” arXiv:2003.01116 [physics.ins-det].
- J. Kunath and J.-C. Brient, “**Inclusive Higgsstrahlung cross section measurements with the new reference sample method**,” in **LCWS’2020.** arXiv:2002.06371 [hep-ex].

Projet scientifique, anticipation

CALICE/DRD6

- Contribution ESPPU
- Capitalisation sur
  - le matériel existant → prototype uniforme : BT 2025 et 2026
    - Possibilité d'utilisation dans LUXE (XFEL), EBES (KEK), Lohengrin (ELSA)
  - Les données existantes, <u>si manpower analyse</u>
    - Modèle GEANT4
- Préparation de la prochaine génération ASICS CALOROC → CC, cooling

Timing:

- Mise en place ANRs (2 CDD ~ 36m en place janv. 2025)
- Ajout timing dans le PFA "classique" et ML (↔ IJClab, IP2I)
- Étude des performances physique (Higgs, EW ↔ IJClab, IP2I, DESY, Mainz, KIT)

Concepts ILD:

- Contribution ESPPU
- Mise à niveau → solution pour le FCC
  - Estim. besoins : data, power, cooling
  - Solution cooling

FCC:

- Contribution FCC feasibility study (Sub-Detecteur & Concepts)
- Analyses FCC-hh (↔ HL-LHC)
- Analyses Precision Z-poles (syst.)

Auto analyse du groupe

Points forts:

- Expertise reconnue :
  - Particle Flow,
  - Concepts,
  - Détecteurs (→ HGCAL)
- Expertise Technique intégration (Méca, Électronique)

Points faibles:

- Manque de personnes / Surcharge
  → Perte d'opportunités :
    - Collab HGCAL : ASICs, Timing, ML
- Manque de moyens
  - MP → Délais

Opportunités:

- Proposition d'une solution «clé en main » SiW-ECAL ILD-CC
- Avec solution innovante (5D)

Risques:

- Disparition de l'expertise (fin éméritats)
- Référent instru ~ unique
- Non-prise en compte par les tutelles
  - 0 recrutement IN2P3 sur 12 dern. années.

BESOINS:

- Renforcement ↗ pressant de +1 permanent en instrumentation & analyse.
  - V. Balagura (2019 → LHCb), retraite de J.C. Brient (2022)

Annexes

BT DESY-2017

- 8 couches

Reconstruction profile en énergie / espace

- Prise en compte dead cells

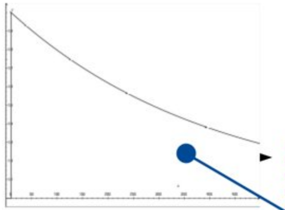
Digitization

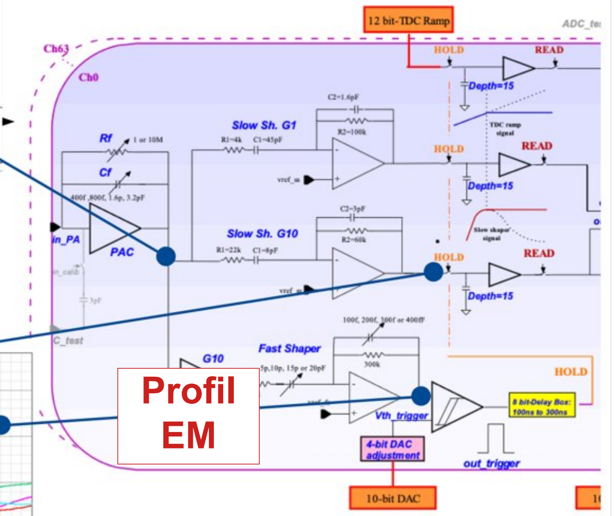
- resolution en E, t

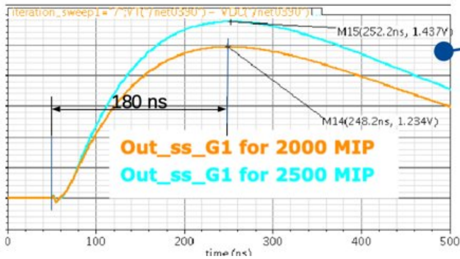
En contact CERN (HGCAL): ML pour la reconstruct

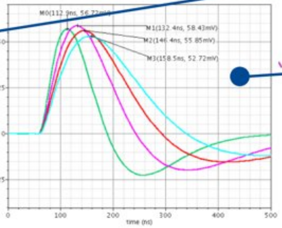
Signal path in each channel:

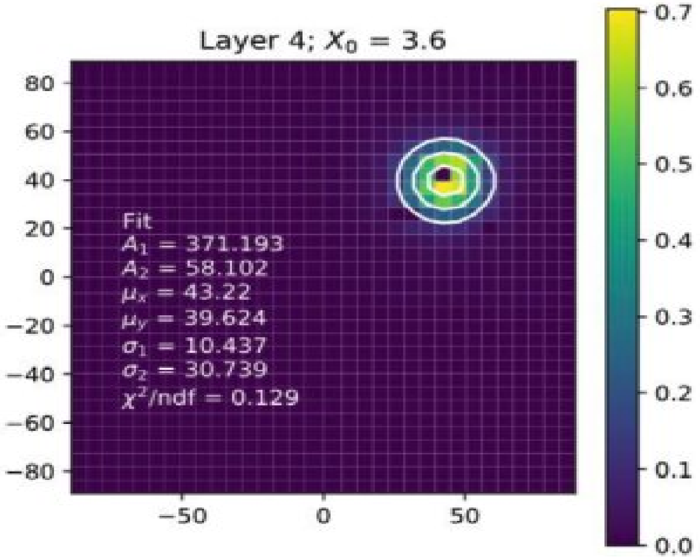
- 1 pre-Amp =
  - integrator with $\tau_i \sim 0.4$–$32\ \mu s$
- Fast Shaper
  - CR-RC$^{(1\sim2)}$ with τ_i and $\tau_d \sim 30$–120 ns
- Slow Shapers
  - CR-RC$^{(1\sim2)}$ with τ_i and $\tau_d = 180$ ns





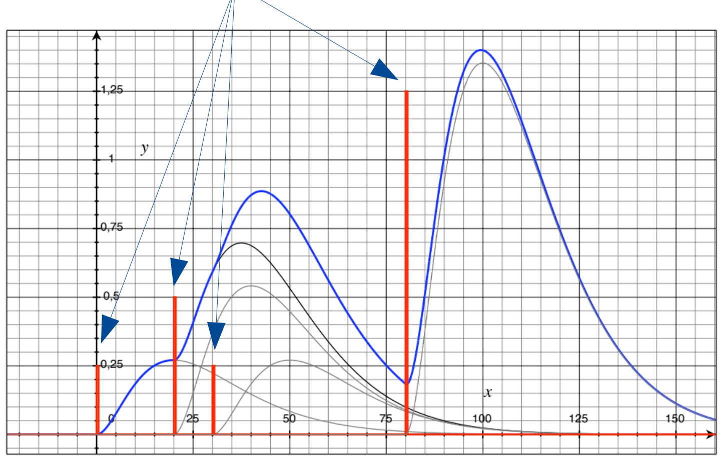






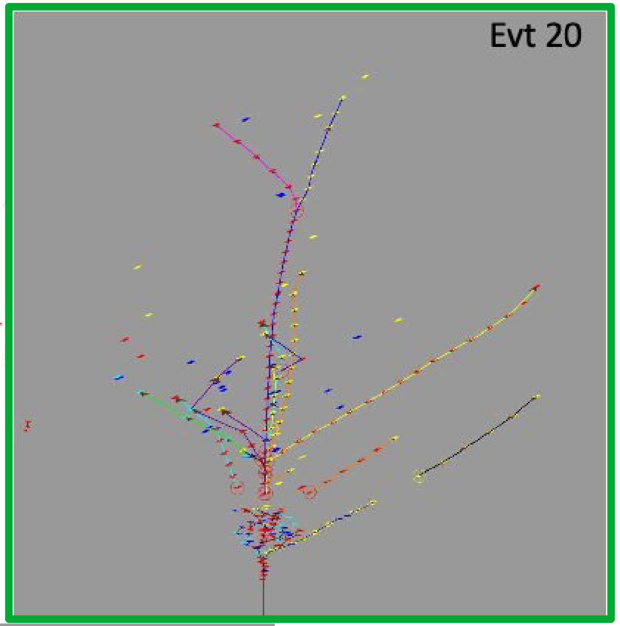
Profil fitting ⇒ corrections

Sub-Hits (in a given cell)



Example of pulse shape output of CR-(CR)² filter with a nτ=20 ns from 4 inputs, at 0, 20, 30 and 80 ns, with relative amplitudes of 1,2,1 and 5.

Shower reconstruction



It is known that the more dimensions, the easiest to reconstruct

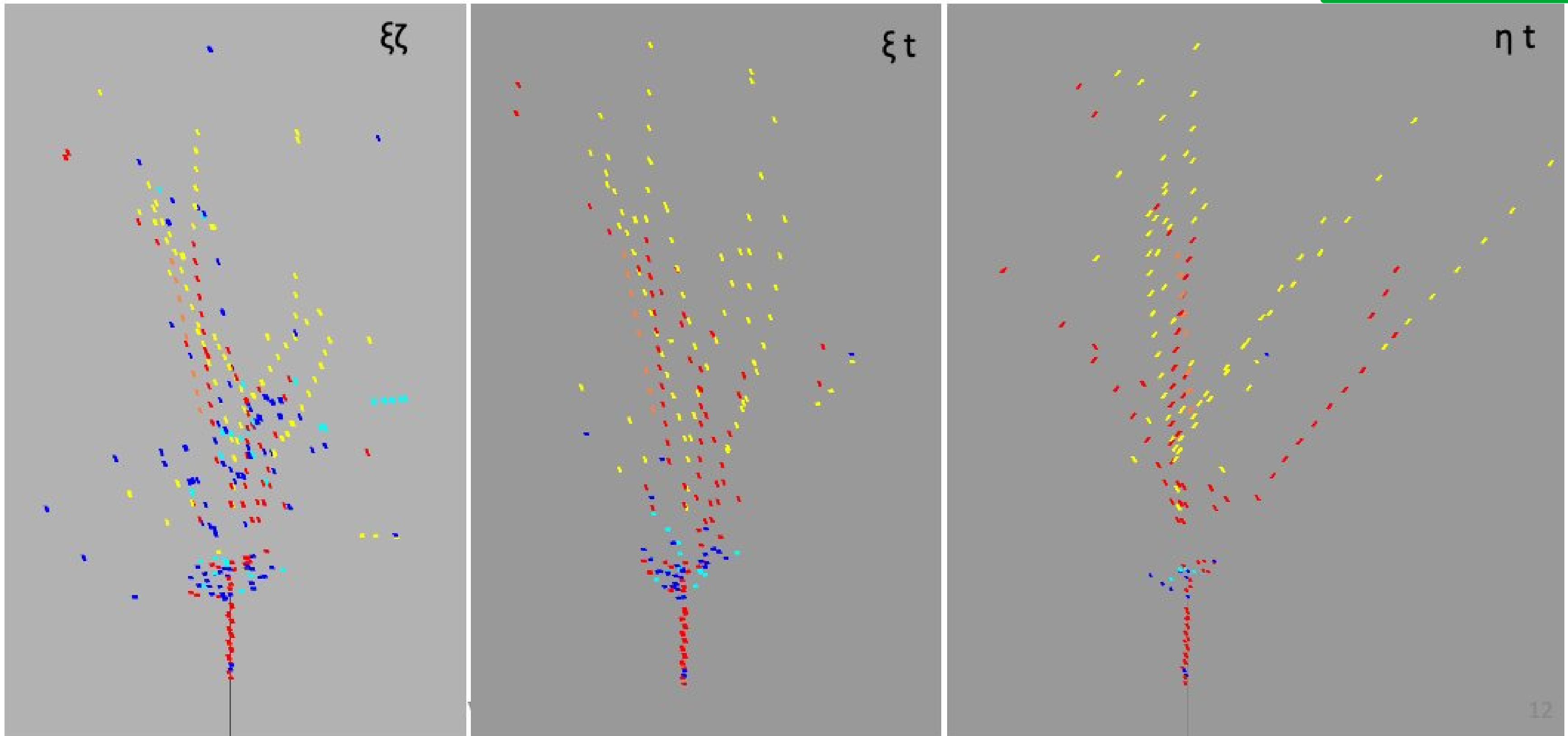
Using the time-space

To figure out the pattern of a shower developed by a charged track or a neutral
We assume that the main direction of the shower, called ζ, is
- along the flight line from interaction to the earliest hit in the Ecal (or globally) for a neutral
- along the track direction at the position of the earliest hit for a charged track

Two perpendicular coordinates, ξ and η, are chosen to optimise the match with the detector axes, mostly for visualisation.
Then t which is much correlated to ζ.

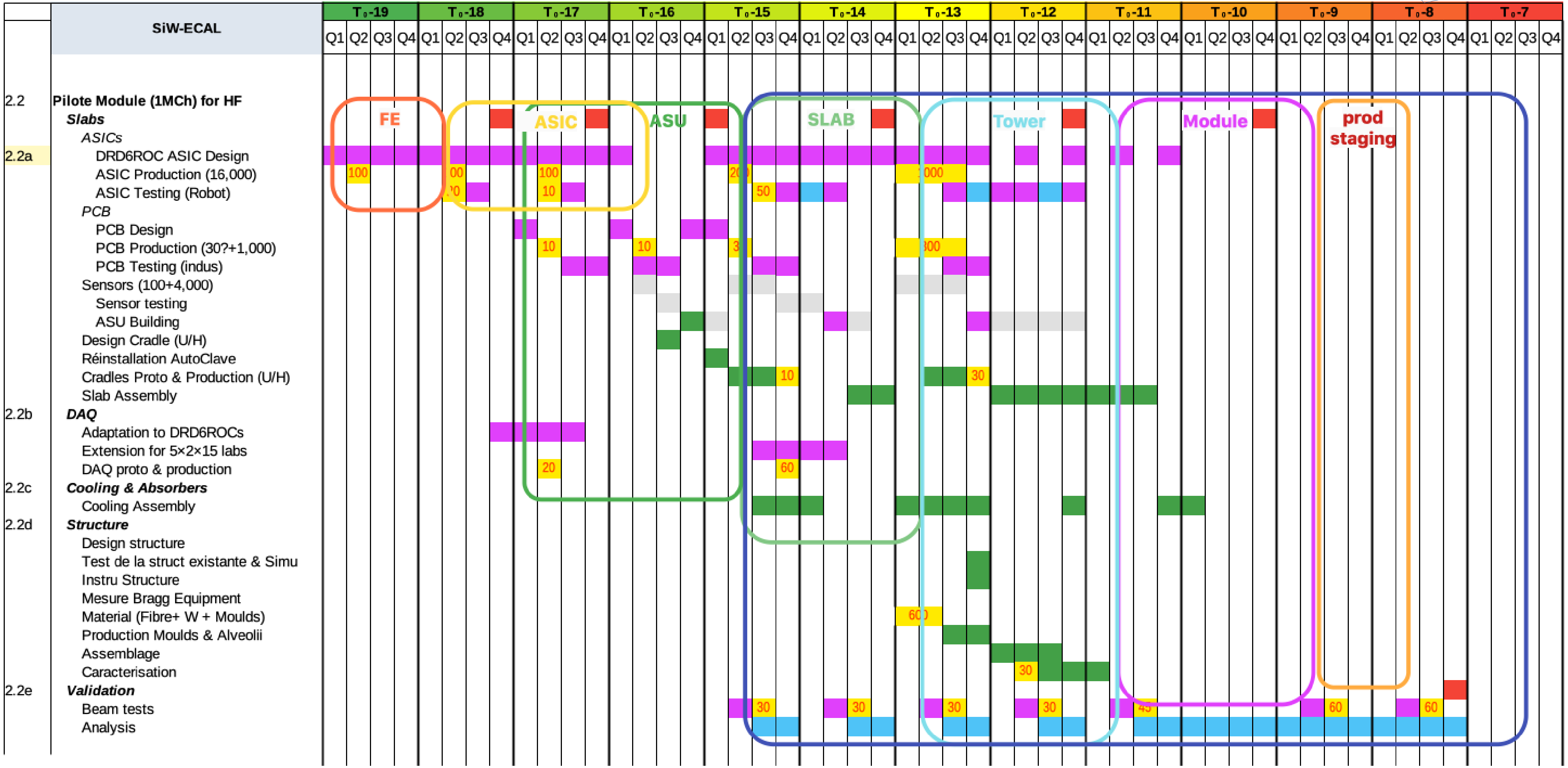
On the plots
The Ecal and the Hcal are coloured according to the nature of the touching particle
Blue electrons,
Cyan positrons,
Red pions
Salmon Kaons
Yellow protons

You see immediately the role of the β and how the protons slow down when the pions do not



Planning towards a pilot module… *just in case*

T_0-8 : production start



	T_0
FCCee	2045–48 ?
CEPC	2035 ?
ILC	2040 ?