

04/11/2024



NUCLÉAIRE
& PARTICULES



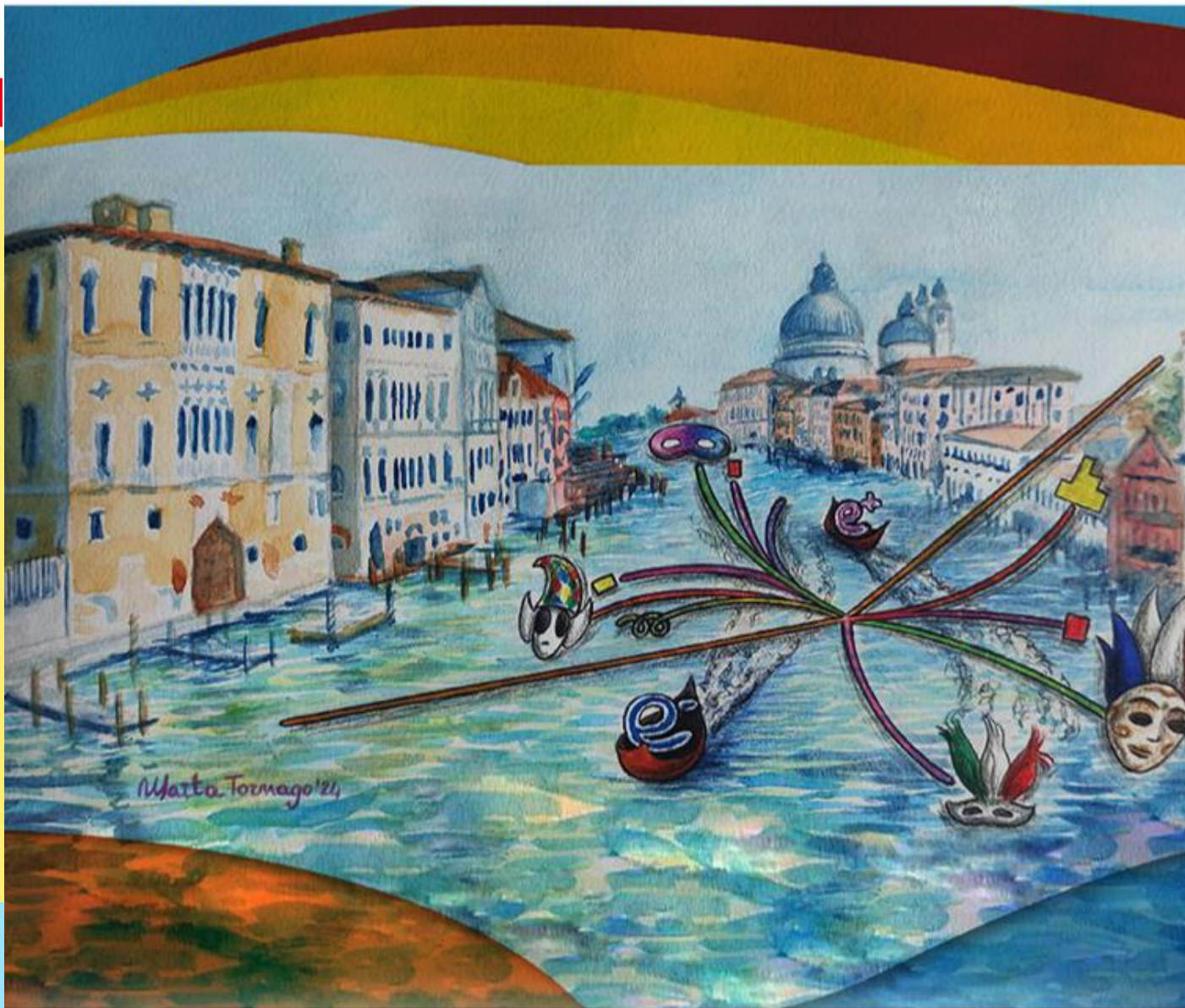
Overview of the FCC project in France

Gregorio Bernardi

+Roy Aleksan(IRFU), Giovanni Marchiori (APC) Fares Djama (CPPM),
Nicolas Morange (IJCLab), Suzanne Gascon-Shotkin (IP2I), Ziad El Bitar (IPHC)
Marco Delmastro (LAPP), Vincent Boudry (LLR), Stéphane Monteil (LPC),
Luc Poggioli (LPNHE), Jean-Baptiste De Vivie (LPSC), Catherine Biscarat (L2IT)

2ND "FCC ITALY & FRANCE WORKSHOP"

VENICE, PALAZZO FRANCHETTI - NOVEMBER 4 - 6, 2024



FCC activities in France

- Will concentrate on PED activities, mainly Detector and Physics
- Accelerator activities will be covered by Manuela
- In France, ILD effort is also present, so more diverse situation than in Italy
- At this workshop we will investigate possible collaborations with Italian colleagues following new developments on our side

FCC-PED goals (overall and in France)

- Contribute to the Final version of the FCC Feasibility study, in order to contribute to the ESPPU, towards the recommendation of moving forward with FCC
- Contribute to DRD's, and produce EoI's for FCC subdetectors.
- Join EoI's for FCC Detector concepts
- Contribute to the ECFA report of future e+e- colliders (physics, detectors)
- Contribute to the National Strategy, and to National FCC EoI's

Contributions to ECFA panels: HET factory study

- Based on the recommendations of the [ESPP Update], ECFA has organised a series of workshops on physics studies, experiment design and detector technologies towards a future electron-positron Higgs/EW/Top factory.

The aim is to bring together the efforts of various e^+e^- projects, to share challenges and expertise, to explore synergies and to respond coherently to this high-priority strategy item.

HET Factory Workshops:

- First: 2022 @ DESY (GE);
- Second: 2023 @ Paestum (IT);
- Third : 2024 @ Paris, October 9-11

Current goal: write up in an ECFA White Paper (or CERN Yellow Report) for March 2025 based on the submitted contributions (Editors: A. Robson and C. Leonidopoulos)

Task for FCC-France

- Submit physics and detectors contributions.

3rd ECFA workshop on e⁺e⁻ Higgs, Top & ElectroWeak Factories

9–11 October 2024

Sorbonne Université, Campus des Cordeliers, Paris



International Advisory Committee

- Patricia Cordeiro Nunes (IST/LP)
- Debes Choudhury (IN2P3)
- Magyara Domokos (CERN)
- Arnoud Ferrarri (STFC)
- Juan Foster (Valencia)
- Ekmel Gurses (TUBITAK)
- Jorgen D'Hondt (VUB)
- Christophe Grosjean (CEA)
- Patrick Janot (CEA)
- Hani Khan (CERN)
- Christos Leontiadopoulos (Edinburgh)
- Carlos Martinez Rivera (WZL)
- Joachim Albrecht (CEA)
- Alessandro Nischi (INFN)
- Adam Robinson (Glasgow)
- Frank Simon (KIT)
- Paris Spharopoulos (CERN, Chateaubriant)
- Steinar Stenlund (CERN)
- Roberto Tenchini (INFN)
- Guy Wilkinson (Oxford)
- Andrea Wolter (Luzern)

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- Gaëlle Boudoul (IP2I Lyon, ACP)
- Vincent Bouvier (ILL, Palaiseau)
- Paul Colas (IP2I, CEA/Saclay)
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- Jean-Baptiste De Vivie (IPSC, Grenoble)
- Fabrice Dujardin (CPPM, Marseille)
- Zoltan Borzanyi (IPHC, Strasbourg)
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<https://indico.in2p3.fr/e/ecfa2024>



Science et Société: le projet FCC, le Futur Collisionneur Circulaire de particules élémentaires du CERN

8 octobre 2024
Campus des Cordeliers, Paris, Metro Odeon
Fuseau horaire Europe/Paris

Entrer le texte à rechercher

- Accueil
- Ordre du jour
- Inscription
- Contact

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Séminaire d'information sur la faisabilité du FCC, le Futur Collisionneur Circulaire au CERN.

Lors de la dernière stratégie européenne pour le futur de la physique des particules élémentaires, le CERN a reçu le mandat, par ses États membres, d'étudier la faisabilité d'un futur collisionneur circulaire ou FCC. Le FCC serait un collisionneur de particules de nouvelle génération installé dans un tunnel souterrain de 91 km qui serait creusé en profondeur sous les départements de l'Ain et de la Haute-Savoie en France, ainsi que le canton de Genève, en Suisse. Le FCC succéderait au Grand Collisionneur de Hadrons (LHC) dont le programme de recherche s'achèvera au début des années 2040.

+ ECR workshop on 8/1 (afternoon)

French Institute Interests per Physics topic

- **In Higgs Physics:**

- Expected Measurements of the Higgs Boson Mass and ZH Production Cross Sections at FCC-ee
- Study of the Higgs boson couplings to Heavy quarks at FCC-ee
- Perspectives in measurement of the Higgs boson width via the $ZH/H \rightarrow ZZ^*$ cross section measurements
- Measurement of the HWW coupling in the channel $ee \rightarrow H\nu\nu$, $H \rightarrow WW$ hadronic
- Prospects for the Higgs boson self-coupling indirect measurement at FCC-ee, from the 240 and 365 GeV runs

- **In Electroweak, QCD, Top and Heavy Flavour Physics:**

- Prospects for QCD and Lund Jet Plane studies at FCC-ee
- Measuring A_{FB}^b and R_b with exclusive b-hadron decays at FCC-ee
- Study of rare decays of heavy-flavoured particles and corresponding detector requirements at FCC-ee
- Study of the prospects for CKM profile (V_{cb} , CKM angles, mixing-induced phases from tree & penguin@FCCee)

- **In Physics beyond the Standard Model, Theory and Phenomenology:**

- Search for Heavy Neutral Lepton at FCC-ee, and comparisons between Fast and Full Simulation
- Search for Axion-Like Particles decaying into a pair of gluons at FCC-ee
- Timing-based mass measurement of exotic long-lived particles at the FCC-ee
- Search for new light (pseudo-)scalar particles at FCC-ee
- **Theoretical studies:** precision electroweak physics tests, top quark physics, couplings and width of the Higgs boson, extensions to the scalar sector, flavour physics, composite particles, baryogenesis.

- **Contributions made to the FCC software, both in fast and detailed simulations:**

- The FCC Software for PED studies
- Tracking Resolution Studies with CLD Detector
- CaloFlux: A Tool to Estimate Fluxes in Calorimeters at Colliders

French Institute Interests per DRD topic, for FCC-ee Subdetectors

- **Tracking**
 - TPC IRFU;
 - MCMOS CPPM, IPHC, IP2I, LPNHE;
 - DCH IJCLab, Ganil, LPSC

- **Timing Layers**
 - MicroMegas IRFU,
 - MCMOS IPHC, IP2I, CPPM,
 - Optical CPPM, IP2I

- **Liquid Argon calorimetry**
 - ECAL APC, CPPM, IJCLAB, LPNHE, LAPP
 - electronics Omega

- **Sampling calorimetry with fully embedded electronics**
 - ECAL/SiW (calice) IJCLab, LLR, LPNHE;
 - HCAL IP2I,
 - electronics Omega

- **Optical calorimetry**
 - ECAL GRAiNita IJCLAB, LPC-CF,
 - Crystals IP2I

- **Muon hodoscope/tagger**
 - Micromegas IRFU,
 - (RPC experience at IP2I but no specific project)

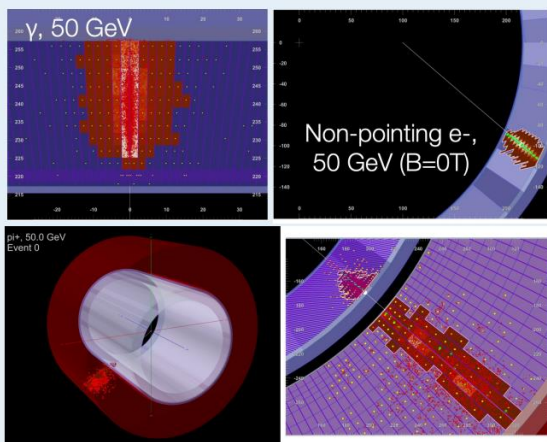
APC	Paris
CPPM	Marseille
IJC Lab	Orsay
IPHC	Strasbourg
IP2I	Lyon
LAPP	Annecy
LLR	Polytechnique
LPC	Clermont-Ferrand
LPNHE	Paris
LPSC	Grenoble
IRFU	Saclay

Some Results in 2024: APC (Paris)

ALLEGRO Calorimeter Performance studies → & Software developments

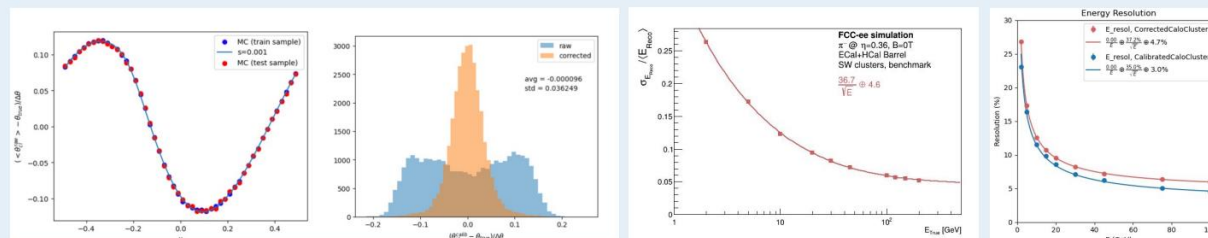
Clustering performance

- Topo and sliding-window clustering algorithms re-designed based on the new calorimeter segmentation
- Nice event display tool was developed
- Enabled clustering with ECal + HCal combination

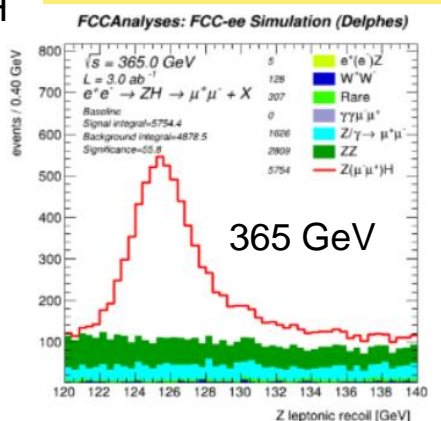
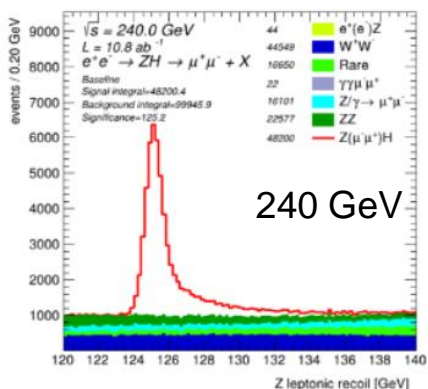


Resolution correction and calibration

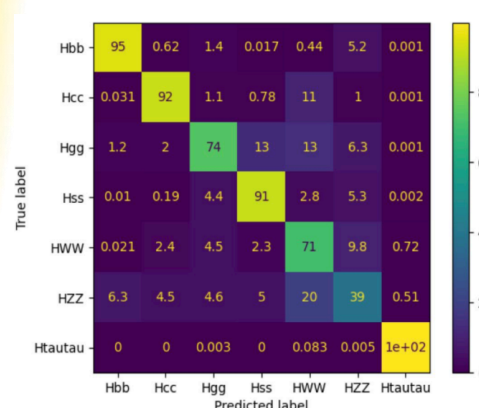
- S-curve is observed in θ resolution due to the finite cell size that will lead to a bias of measurement to the center of cell
- A “common” detector effect:
 - We have observed that curve before in the ATLAS detector
- Corrected by re-defining the barycenter calculation
 - Use $\log E_{\text{cell}}$ weights:
- Energy resolution to single pion with combined reconstruction in ECal and HCal barrels, calibration with benchmark method in red, with MVA in blue



Higgs Physics Studies: Recoil Mass for mass & ZH



Hadronic Higgs decays @ FCC-ee (quark Yukawa and gluon couplings)



√s=240 GeV only

Final state	$\delta\sigma\text{BR}/\sigma\text{BR}$ Z(l)H(jj) %	$\delta\sigma\text{BR}/\sigma\text{BR}$ Z(vv)H(jj) %	$\delta\sigma\text{BR}/\sigma\text{BR}$ Z(qq)H(jj) %	BR(SM)
H→bb	0.7	0.4	0.3	58 %
H→cc	4.1	2.2	3.3	2.9 %
H→gg	2.2	1.1	3.1	8.6 %
H→ss	230	150	440	0.024 %
H→WW→had	1.8	1.1	8.7	10 %

σ_{ZH} is measured in a model independent way with 0.6% accuracy at 240 GeV, 1.5% at 365 GeV opening the way to precise Higgs couplings measurements

10.8/ab at $\sqrt{s}=240$ GeV : $\delta\sigma\text{BR}/\sigma\text{BR} = 0.22\%$ (bb), 1.7% (cc), 0.9% (gg), 120% (ss), 1.1% (WW)
3/ab at $\sqrt{s}=365$ GeV : expect reduction of $\delta\text{BR}/\text{BR}$ by ~10% in combination with 240 GeV

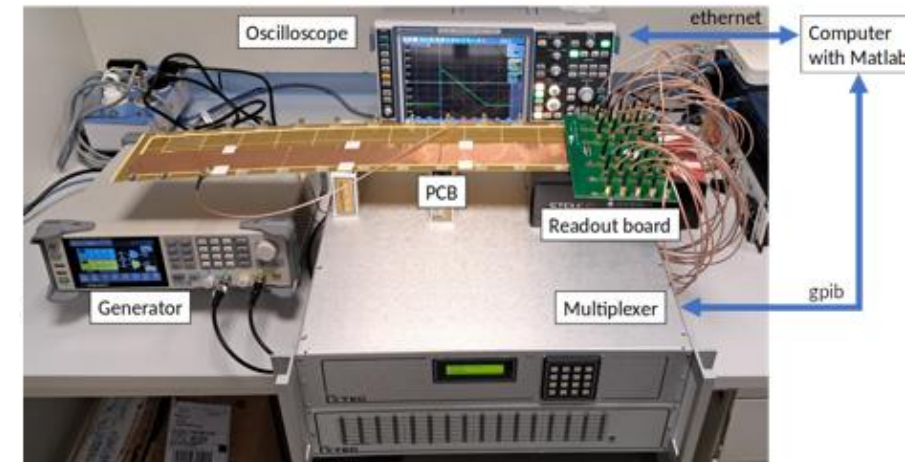
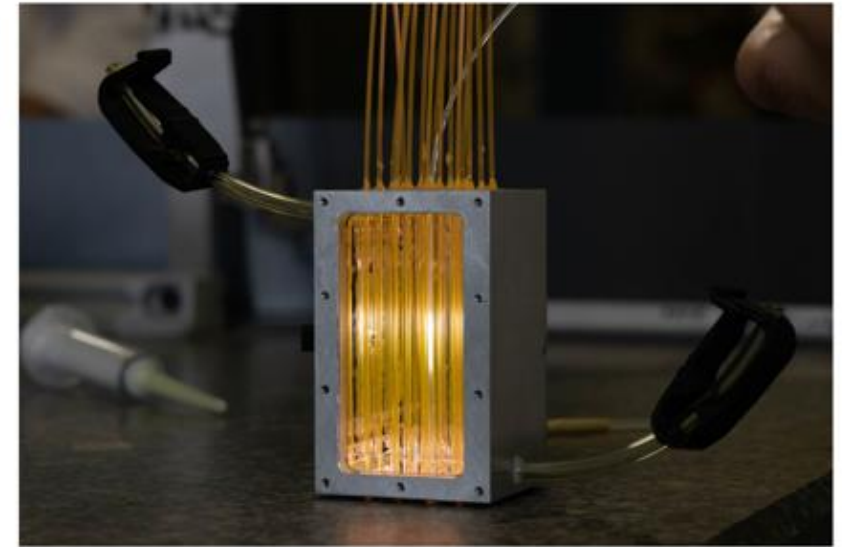
Some Results in 2024: IJC Lab (Orsay)

GRAiNITA

- Innovative concept for high resolution EM Calorimetry
- JINST Publication
- Testbeam (in parasitic mode of an LHCb Upgrade TB)
 - Data staking successful. Efficiencies and uniformity measured

Allegro Ecal

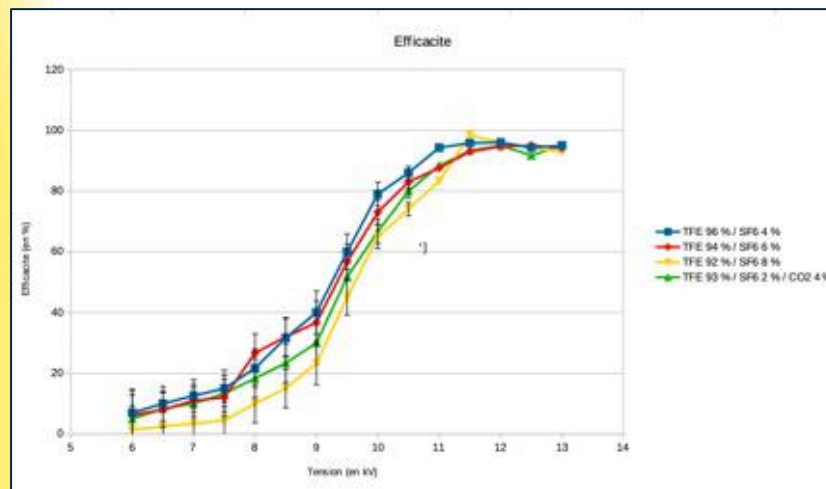
- Electrode Design
 - New prototype, 3 towers with 15 cells/tower
 - Measurement/understanding subtle effects
 - Joint work with CERN to optimize the design
- Simulation
 - Joint collaboration with APC on photon ID
- Coordination Allegro



Some Results in 2024 : IP2I Lyon

• T-SDHCAL & T-MRPC:

- RPC construction with 4 'gaps' (1m²) in 'fishing lines' (new mounting technique, $\epsilon > 95\%$)

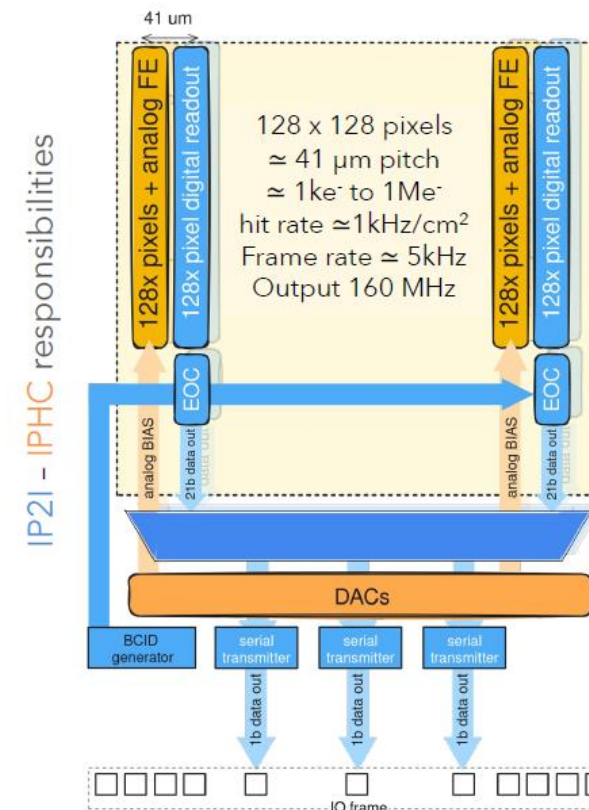


- Inclusion in the key4hep software of a processor "Marlin" providing SDHCAL Calibration/PandoraPFA and APRIL PFA.

• CMOS monolithic/GRAM: 1st circuit 'DoTIIX' (IP2I+IPHC),

technology TJ180nm for ions measurements, Foundry submission foreseen

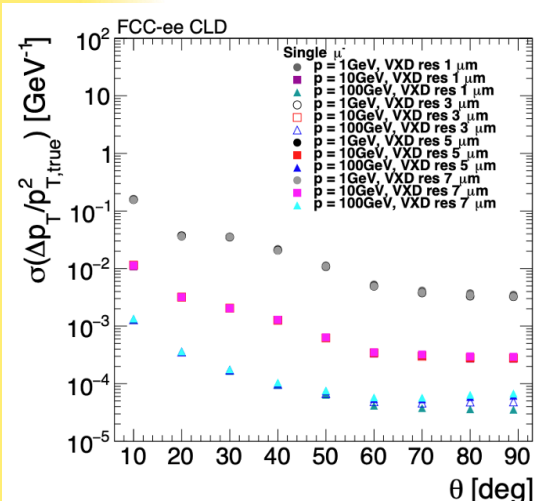
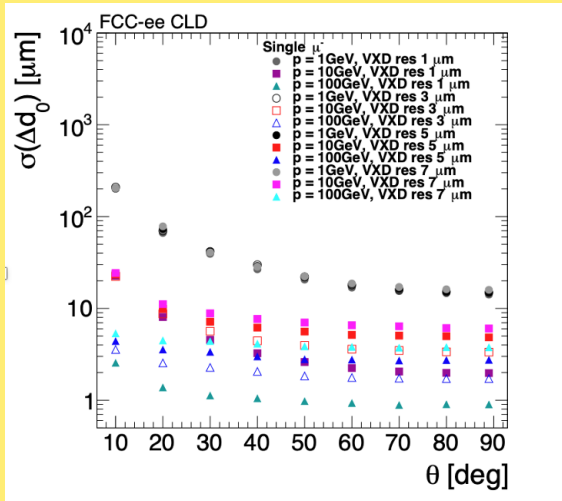
by end of 2024. Evolution to TPSCo 65nm in 2025



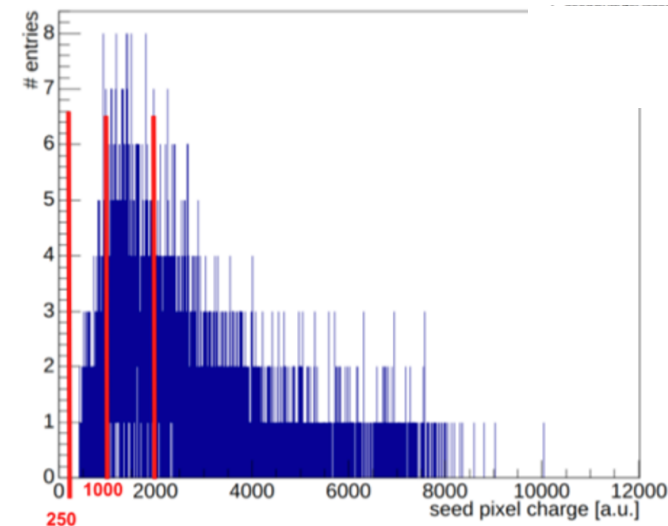
Some Results in 2024 : IPHC (Strasbourg)

Vertex Detector Performance at CLD : FullSim

- Relation Hit resolution and tracks:

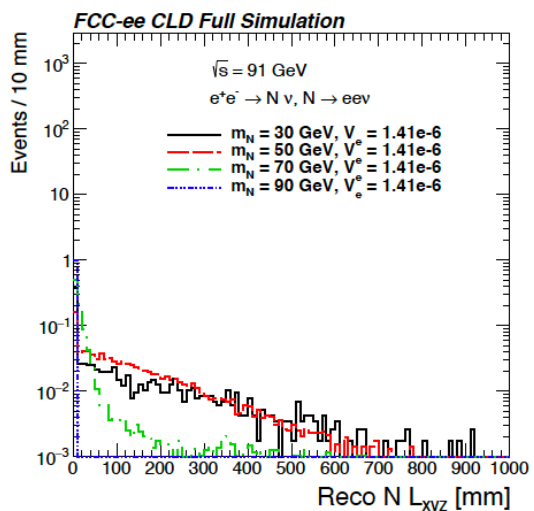


- Digitisation of the sensors signal (CMOS)

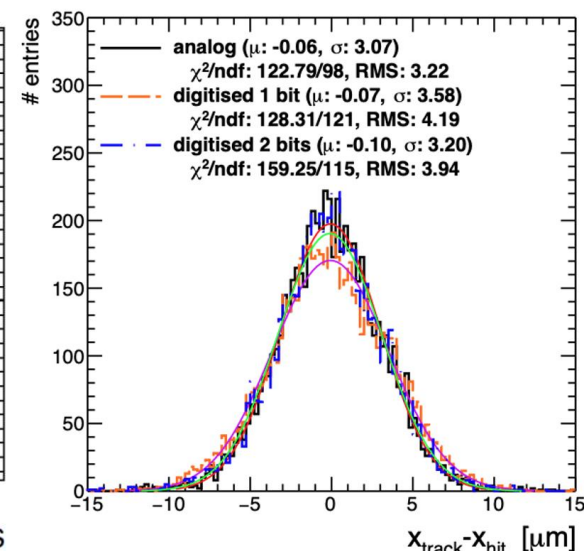
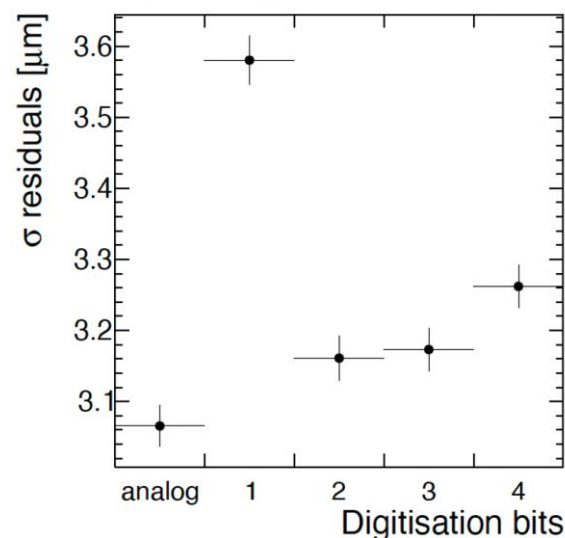


HNL and ALPs :

- Phenomenology
- Generation,
- FullSim
- Reconstruction



Sigma vs Digitisation (residualsX)



Some Results in 2024 : LAPP (Annecy)

En cours

✓ Simulation détecteur ALLEGRO

- Simulation cross-talk et bruit ECAL
- Optimization des geometries des electrodes ALLEGRO pour reconstruction optimale gerbes electromagnetique et identification particules

✓ Physique du Higgs au FCC-ee

- Mesure de $VH/H \rightarrow ZZ^*$ dans les canaux $4l+w$ et $4l+jj$, pour la mesure de la largeur du Higgs

À venir (2025)

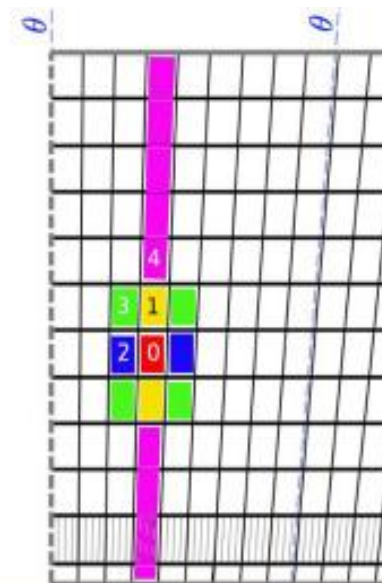
✓ Simulation détecteur ALLEGRO

- R&T calorimétrie; EoI ALLEGRO ECAL

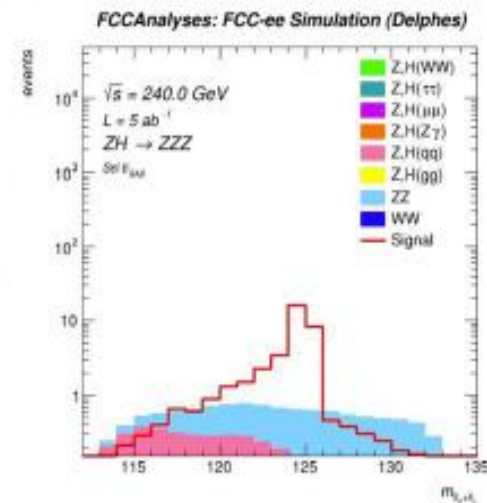
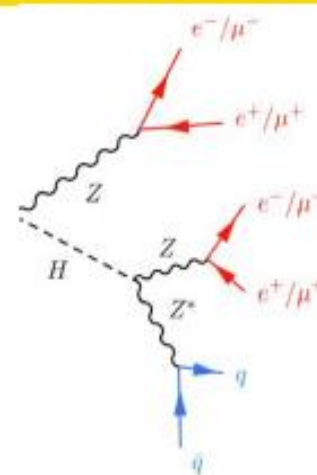
✓ Contributions au FS et au rapport ECFA

- Physique du Higgs au FCC-ee

Variable discriminant dans l'analyse $VH/H \rightarrow ZZ^* \rightarrow lljj$



Des mesures du cross-talk sur le prototype d'electrode à l'emulation dans la simulation



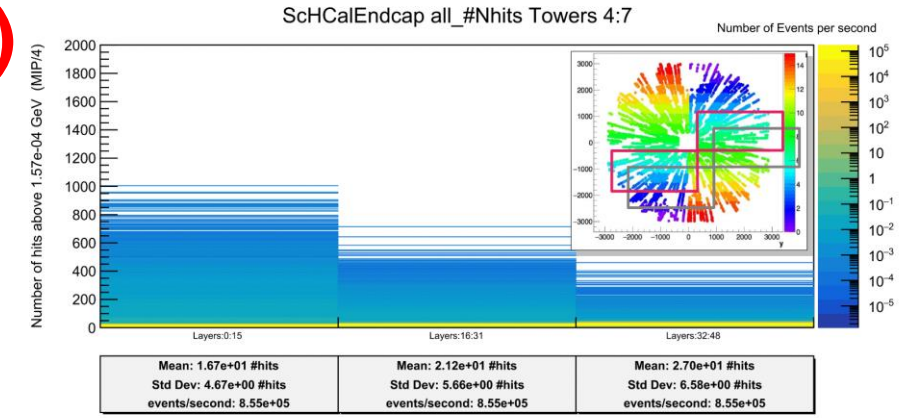
Some Results in 2024 : LLR (Polytechnique)

- CaloFlux: evaluation tool of the data flow, occupancy and heat dissipation in calorimeters → JINST
 - à partir de simulations détaillées d'évènements minimum-bias et de bruit de fond machine. Résultats → Meeting ECFA

- Preparation of ILD-CC : SiW-ECAL @ FCC (cooling)
 - contributions to ESPPu : FCC, ILD-CC ; SiW-ECAL

↔ MP DRD6 SiW-ECAL ; ANRs timing in calorimeters : T-Calo / Calo5D

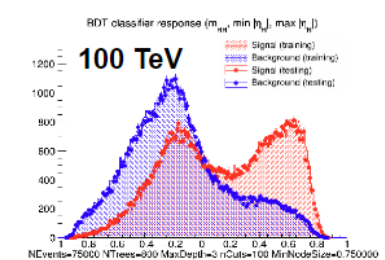
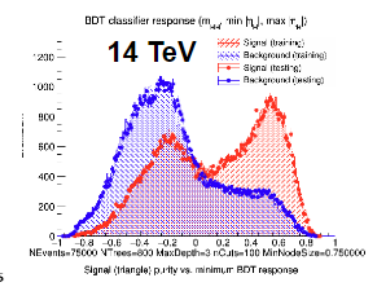
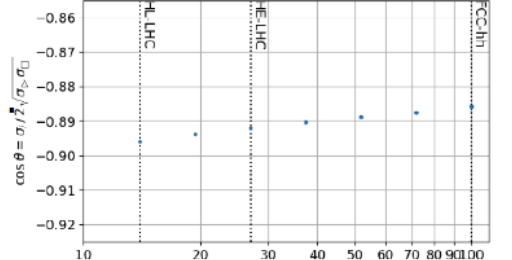
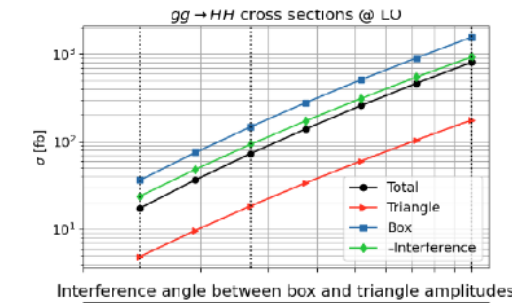
- Sensitivity Study to the triple Higgs coupling at HL-LHC and FCC-hh



Average	14E+6 hits/s	18E+6 hits/s	23E+6 hits/s
MaxNhits	1000 Nhits/event	600 Nhits/event	400 Nhits/event
for 6B/hits	86E+6 B/s	109E+6 B/s	139E+6 B/s
Est. Ncells	278 756	278 756	278 756
Occupancy/BX	1,0E-06	1,3E-06	1,7E-06
cell size	30		

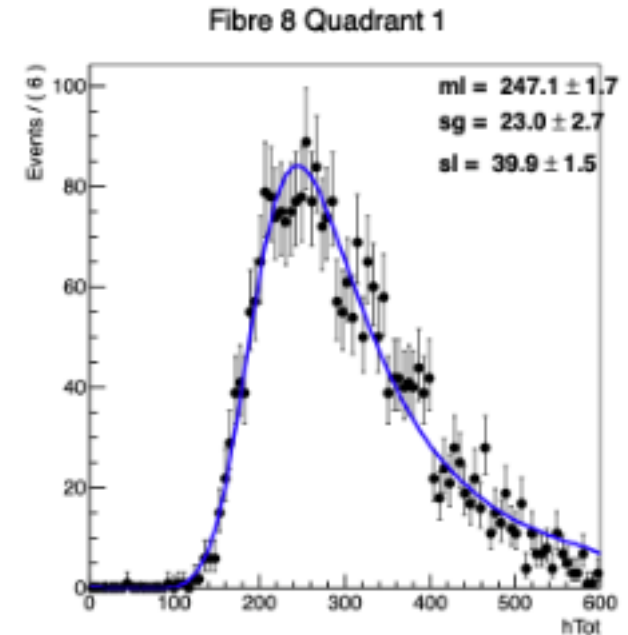
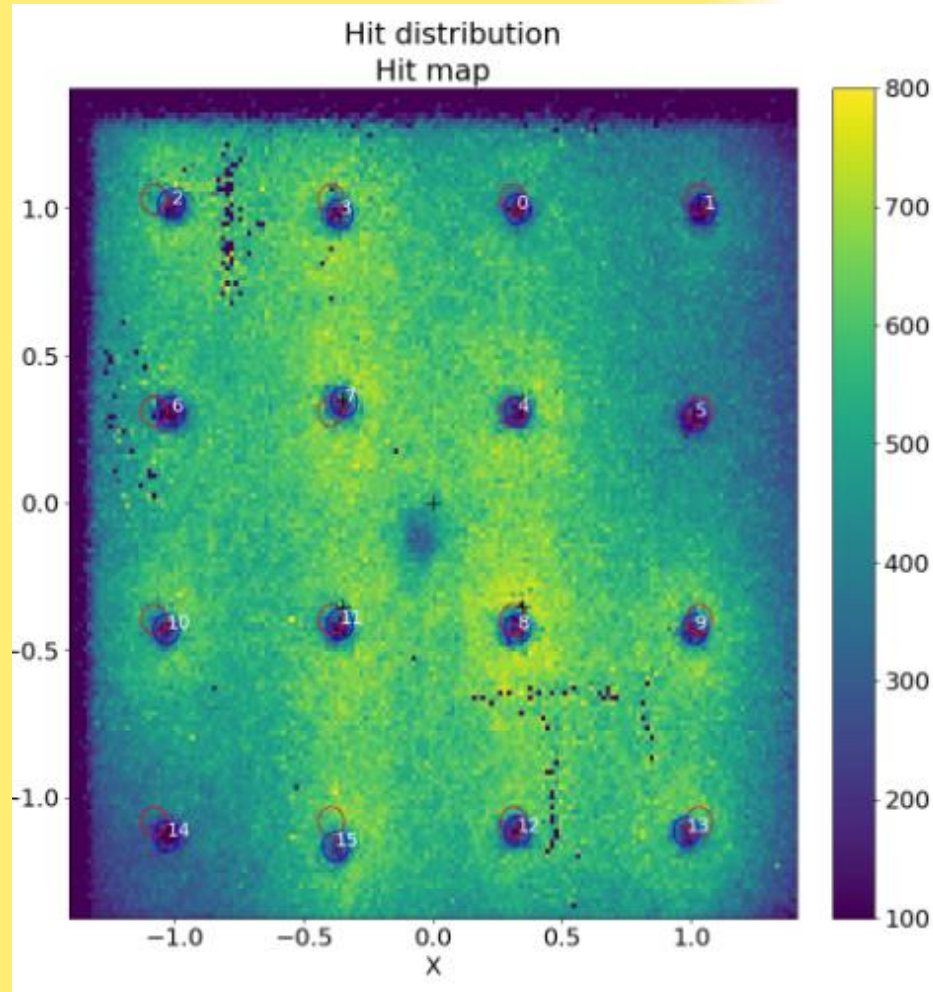
Note 1 : Very preliminary
Note 2 : Rates for all tower 4:7 modules → /4 per module, /16 per layer

LO cross sections vs. center-of-mass energy \sqrt{s}



Some Results in 2024 : LPC (Clermont-Ferrand)

Test beam Campaign at CERN (muons and pions) for GRAiNITA (June 2024)



Confirmation to possibly reach a stochastic term of the order of **1% / \sqrt{E}** .
Analysis in progress.

Some Results in 2024 : CPPM (Marseille), LPNHE(Paris)

CPPM

- Calorimétrie à liquide noble, dans le detector-concept Allegro:
 - Mécanique
 - Simulation, optimisation, performance
- Pixels
 - Développement de DMAPS

LPNHE

• Physics Studies

– Etudes QCD (α_s , Lund Jet Plane)

- Sensibilité potentielle à α_s au FCC-ee
- Implications sur le design du détecteur (eg calorimètre)

- Historiquement autour de l'étude de la multiplicité en #jets
- Maintenant centré autour du Lund Jet Plane (synergie avec les études dans ATLAS)

• Detector concepts

Scientific Production

APC:

- 1) ALLEGRO contribution to the Feasibility study, work in progress
- 2) FCC software contribution to the FS, work in progress
- 2) ZH cross section from Z-Leptonic decays / contribution to FS / work in progress
- 3) Hadronic Higgs decay / contribution to FS / work in progress

IPHC:

- 1) Search for HNL at FCCee, and comparisons between Fast and Full Sim, proposal F.S., work in progress.
- 2) Search for Axion-Like Particles decaying into a pair of gluons at FCC-ee, proposal to FS work in progress.
- 3) Tracking Resolution Studies with CLD Detector, proposal to the feasibility study

IP2I:

- 1) Recherches de nouveaux (pseudo-) scalaires légers contributions FCC FS/ECFA/ESPPU en préparation
- 2) Mesure du couplage HWW dans le canal $ee \rightarrow H\nu\nu$, $H \rightarrow WW$ hadronique (contributions FCC FS/ECFA/ESPPU en préparation)
- 3) Etudes théoriques: tests de physique électrofaible de précision, physique du quark top, couplages et largeur du boson de Higgs, extensions au secteur scalaire, physique du saveur, particules composites, baryogenèse (contribution ESPPU en préparation, FCC FS/ECFA?)

IJCLab:

- 1) ALLEGRO contribution to the Feasibility study, work in progress
- 2) First characterization of a novel grain calorimeter: the GRAiNITA prototype, JINST, Volume 19, April 2024

LAPP:

- 1) ALLEGRO contribution to the Feasibility study, work in progress
- 2) ZH/H \rightarrow ZZ* cross section from 4l+X final states (Higgs width measurement) / contribution to FS / work in progress

LPC:

- 1) [First characterization of a novel grain calorimeter: the GRAiNITA prototype](#), S. Barsuk et al., *JINST* 19 (2024) 04, P04008
- 2) Study of the feasibility of the observation of B_0 to $K^*(892) \tau^+\tau^-$ at FCC-eeT Miralles et al., doi 10.17181/d772d-egz40
- 3) Measuring A_{FB}^b and R_b with exclusive b-hadron decays at FCC-ee, doi 10.17181/yax2s-mvc83

LLR:

- 1) "CaloFlux: A Tool to Estimate Fluxes in Calorimeters at Colliders", accepted at JINST as tech. report.

Next 5 years / HEP Collaborations building

- EOI for subdetectors and proto-detector concepts to be submitted by March 2025
- National/Regional EOI in support of FCC for subdetectors to be submitted by March 2025 ?
- Set-up process for proto-collaborations formation in 2028-2029

The Cost Review Panel recommends to work with the scientific community, institutes, laboratories and funding agencies to ensure support and resources for **four experiments**, facilitating the exploitation of the full scientific potential offered by the large investment in the FCC-ee facility

- Completing list of tasks of the Institutes in the IFNC
- Iterate with National Contacts to gather latest information of possible funding of the HEP teams.
- Explore how the countries/institutes positions themselves on the current/future proto-detector concepts

A possible strategy for building HEP collaborations in the next five years:

- Start with EOI for subdetectors and proto-detector concepts in 2025, and their development in the following two years.
- Assuming positive recommendation to push forward by end of 2027 by the CERN council:
 - Setting up FCCC and proto-collaborations (following call for CDR); probably around proposed proto-detector concepts,
 - Find a scheme to reduce the number of proto-collaborations (merging) if more than 4 proposals
 - **Process could converge by 2030-2031**

Eol's signed by several French Institutes

- Calorimetry:

- ALLEGRO

- SiW-ECAL / - T-SDHCAL & T-MRPC

- GRAINITA

- Tracking and vertex detectors:

- Eol for a Vertex Detector at FCC-ee (FCC-SEED)

- Eol for Time of Flight layers for PID (Precision timing in a Monolithic CMOS technology)

- Detector Concepts:

- ALLEGRO

- ILD-CC

- IDEA ? Other subdetectors Eol's ? Up for discussion during this workshop



