SUMMARY OF WG3 SESSIONS AND PLANS

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4 SESSIONS - 21 TALKS

Many interesting things and very difficult to summarize in ~20´
This talk represents "my view" and "my interpretations"
Sorry to the speakers for the bias and any possible error/misinterpretation

Thanks to all the speakers for the very nice presentations

Wednesday 9 October 2024

Parallel - WG3 - Amphi Farabeuf (11:00 - 13:00)

-Conveners: Felix Sefkow; Giovanni Marchiori; Mary-Cruz Fouz

time	title	presenter
11:00	Design, performance and future prospects of vertex detectors at the FCC-ee	ILG, Armin PALLA, Fabrizio
		BESSON, auguste
11:24	CMOS R&D targeting a vertex detector for Higgs factories	GAO, Yanyan
11:48	Large area low-power Monolithic CMOS Tracking Detectors for FCC-ee	APRESYAN, Artur
12:12	Development of precision tracking detectors at Fermilab	DANNHEIM, Dominik
12:36	The H2M project: Porting the functionality of a hybrid readout chip into a monolithic 65 nm CMOS imaging process	

Parallel - WG3 - Amphi Farabeuf (14:15 - 16:15)

-Conveners: Giovanni Marchiori; Felix Sefkow; Mary-Cruz Fouz

time	title	presenter
14:15	Beamstrahlung backgrounds in ILD at linear (ILC) and circular (FCCee) colliders	JEANS, Daniel
14:39	Performance of a Pixel Time Projection Chamber	KLUIT, Peter
15:03	A straw tracker for FCC-ee	GUAN, Liang
15:27	Advancing Particle Identification in Helium-Based Drift Chambers: A Cluster Counting Technique Study through Beam Tests	ELMETENAWEE, Walaa Mohamed Abdelaziz
15:51	The ARC compact RICH detector: reconstruction and performance	PEZZULO, Serena

Thursday 10 October 2024

Parallel - WG3 - Amphi Farabeuf (11:00 - 13:00)

-Conveners: Giovanni Marchiori; Felix Sefkow; Mary-Cruz Fouz

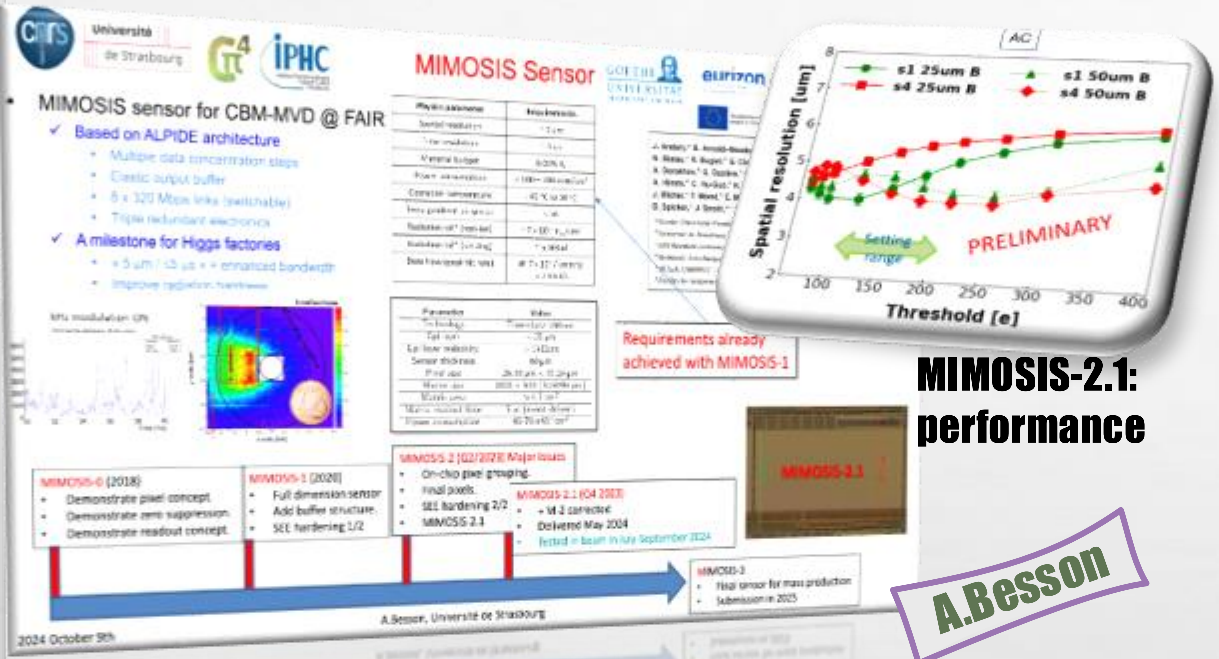
time	title	presenter
11:00	R&D on Noble Liquid Calorimeter for Future Collider Experiments	DJAMA, Fares
11:18	Design and performance of the calorimeter system for ALLEGRO FCC-ee detector concept	MLYNARIKOVA, Michaela
11:36	Estimation of the fluxes in ILD calorimeters at FCC-ee	BOUDRY, Vincent
11:54	Challenges ahead of the ILD SiW-ECAL	IRLES, Adrian POESCHL, Roman BOUDRY, Vincent
		TURRA, Ruggero
12:12	Dual-Readout Fibre-Sampling Calorimeter for next lepton collider	ZHANG, Yang
12:36	Particle Flow Algorithm for Long Crystal Bar ECAL	

Parallel - WG3 - Amphi Farabeuf (14:15 - 16:15)

-Conveners: Giovanni Marchiori; Felix Sefkow; Mary-Cruz Fouz

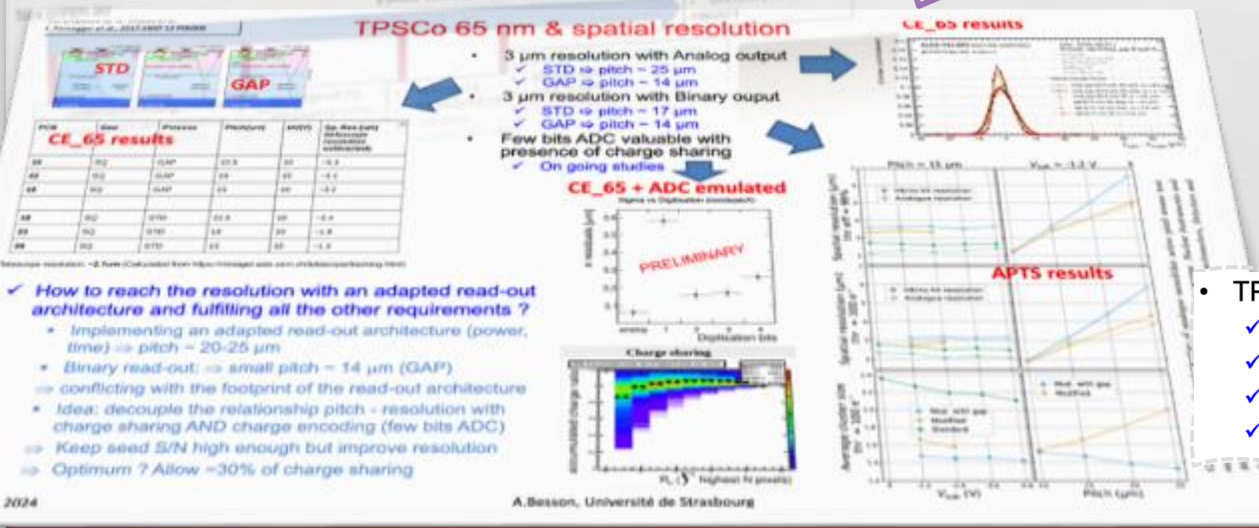
time	title	presenter
14:15	GRAiNITA a new type of calorimeter	SCHUNE, Marie-Hélène
14:39	μ-RWELL muon system and pre-shower for FCC-ee	FARINELLI, Riccardo
15:03	Preshower simulation of IDEA detector	NITIKA, Nitika
15:27	Towards an asymmetric detector at HALHF	LAUDRAIN, Antoine
15:51	Embedded FPGAs for Data Processing in Future e+e- Detectors	GONSKI, Julia GONSKI, Julia Lynne

VERTEX DETECTORS – CMOS TECHNOLOGIES. SOME R&D ACTIVITIES & DETECTOR DESIGNS



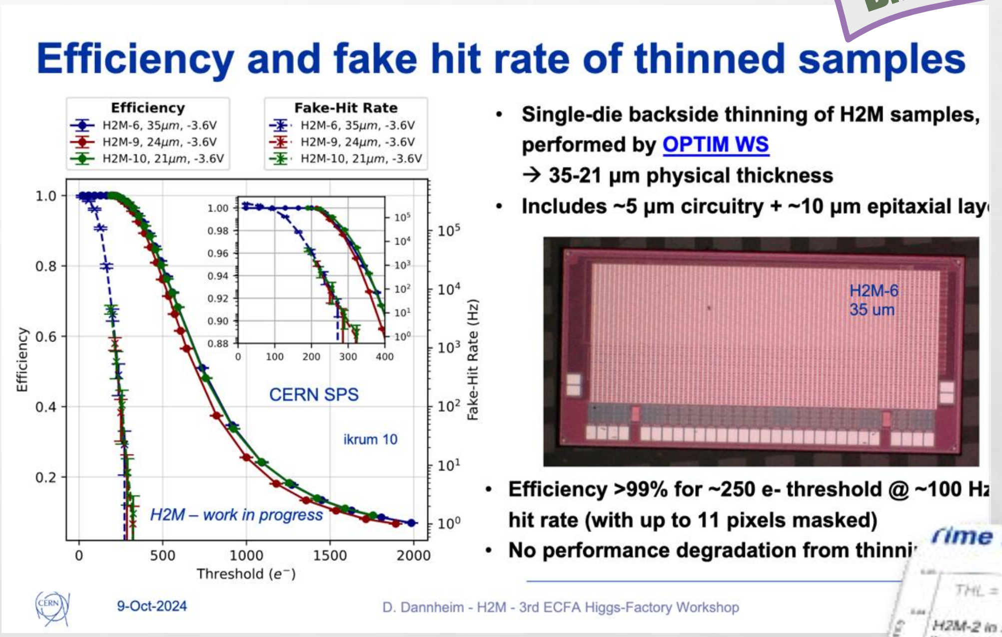
MIMOSIS-2.1: performance

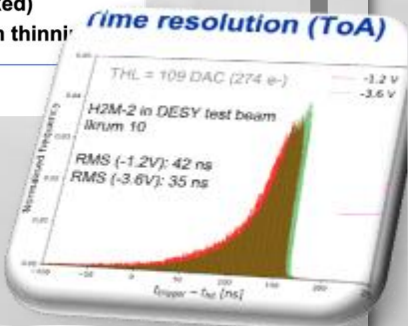
A.Besson



H2M (Hybrid-to-Monolithic) 65 nm CMOS

D.Dannheim

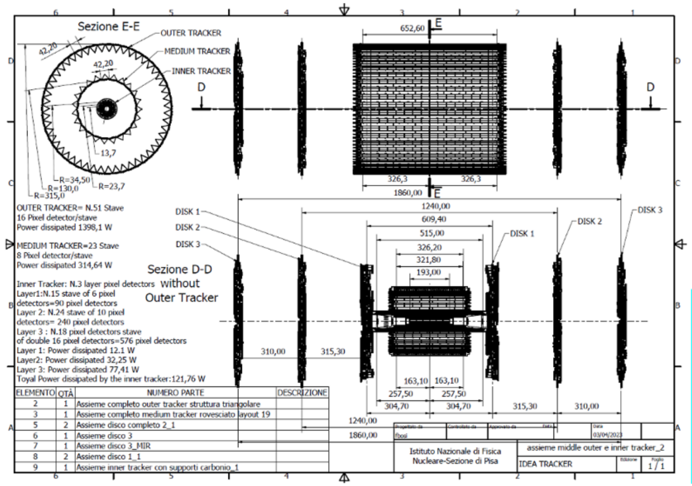




- TPSCo 65 nm
  - ✓ CE65 family (MLR1/ER1) ⇒ Exploration of resolution / charge sharing / charge encoding emulation
  - ✓ SPARC prototype ⇒ first asynchronous architecture to be submitted in ER2
  - ✓ OCTOPUS LoI in DRD3 ⇒ R&D program targeting fine resolution for Higgs factory VTX
  - ✓ Other EoIs (tracker, etc.) ⇒ synergies to be exploited

VERTEX DETECTORS – CMOS TECHNOLOGIES SOME R&D ACTIVITIES & DETECTOR DESIGNS

(IDEA and ALLEGRO) Vertex detector layout



Outer vertex tracker:
ATLASPix3 based

Modules of $50 \times 150\ \mu m^2$ pixel size

- Intermediate barrel at 13 cm radius
- Outer barrel at 34.5 cm radius
- 3 disks per side

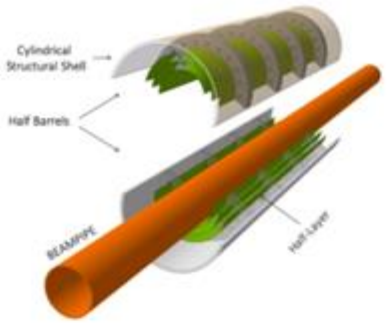
Inner Vertex detector:
ARCADIA based

Modules of $25 \times 25\ \mu m^2$ pixel size

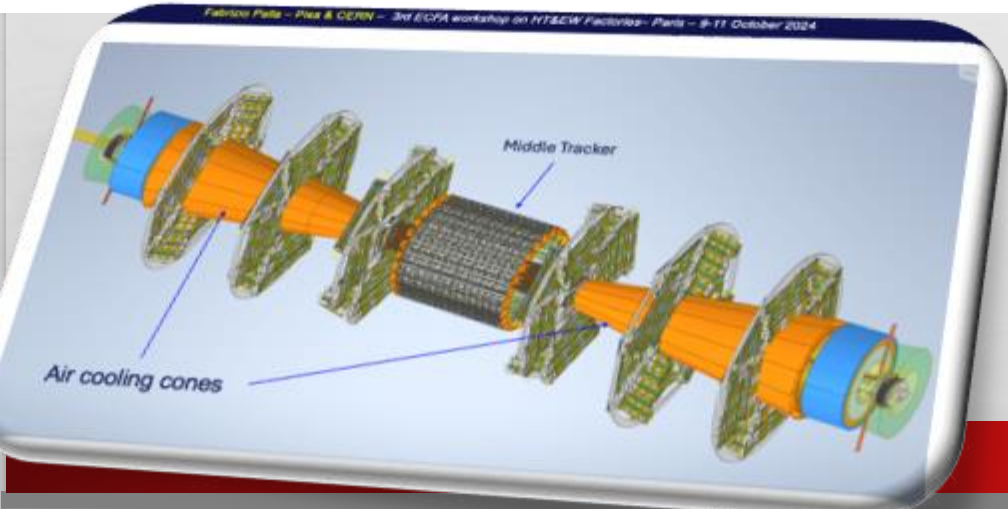
3 barrel layers at
- 13.7, 23.7 and 34/35.6 mm radius

F.Palla

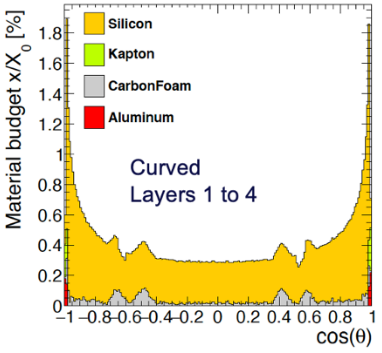
Fabrizio Palla – Pisa & CERN – 3rd ECFA workshop on HT&EW Factories– Paris – 9-11 October 2024

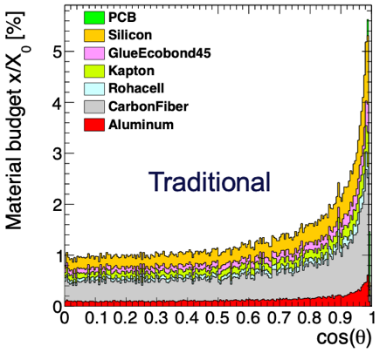


Lightweight layout using an ALICE ITS3 inspired design



Material budget inner vertex

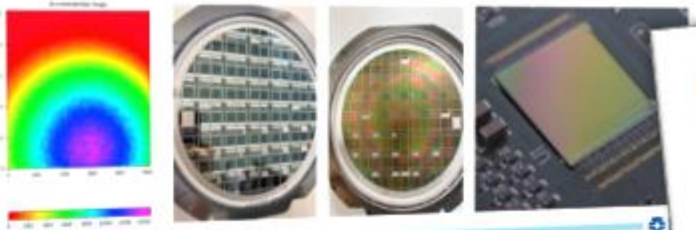




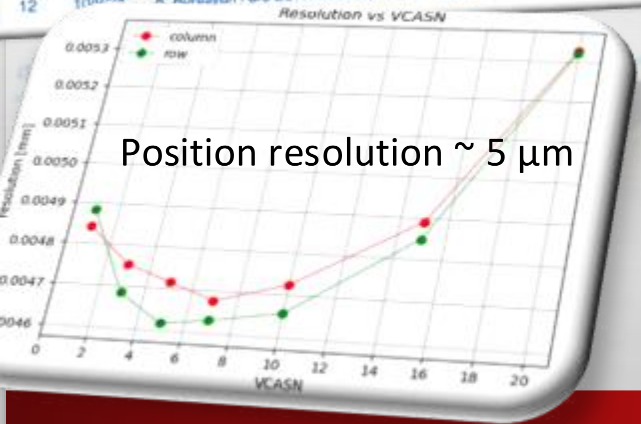
TRACKING DETECTORS: SILICON BASED

ARCADIA DMAPs sensors

- Sensor design and fabrication platform on LF11is technology
  - Full-chip FDMAPS for Future Lepton Colliders and Space Instruments
  - Scalable architecture with very low-power: 10 mW/cm²
- Technology demonstrators
  - Main demonstrator (512 x 512 pixels) 25x25 µm² pixels
  - Several other demonstrators produced: pixel and strip test structures down to 10 µm pitch, small-scale demonstrator for fast timing, etc



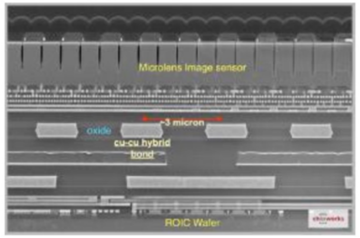
12 10/9/24 A. Apresyan I 3rd ECFA workshop on e+e- Higgs, EWK and Top Factories



A.Apresyan

3D-integrated sensors project

- Development of low-power, highly granular detectors in ($\vec{x}$, t)
  - Required to achieve breakthroughs across HEP, NP, BES, and FES
  - Adoption of 3D-integration has been cost-prohibitive in academia
- Supported by DOE "Accelerated Innovation in Emerging Technologies"
  - Joint development effort of SLAC, FNAL and LLNL teams
  - Partner with industry leaders to implement new technologies
  - Design goal is to achieve position resolution ~5 µm, timing ~ 5-10 ps



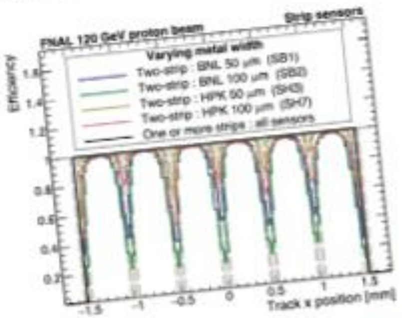
Section of the Sony Exmor camera chip showing the hybrid bond interface

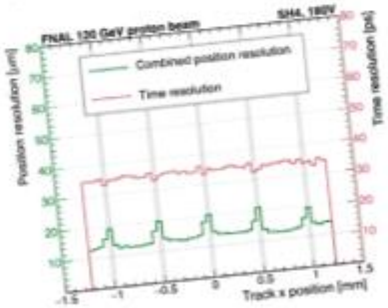
Fermilab

syan I 3rd ECFA workshop on e+e- Higgs, EWK and Top Factories

Long AC-LGAD strip sensors performance

- Position reconstruction
  - Achieve 15-20 µm resolution in 10mm strips, 500 µm pitch
- Excellent time resolution
  - Achieve 30-35 ps for 10 mm strips





Fermilab

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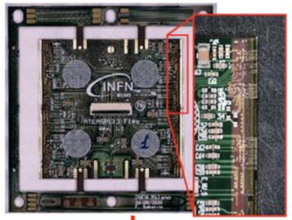
TRACKING DETECTORS: SILICON BASED

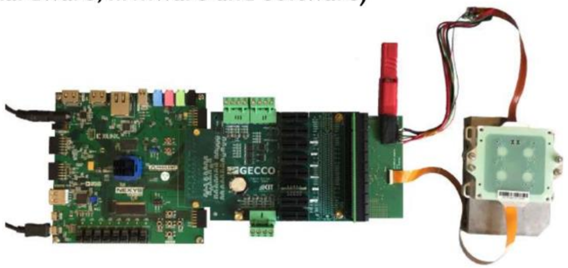
FCC-ee requires an order of magnitude larger in area than the state-of-the-art MAPS track. (IDEA outer tracker ~90m^2)
These need to be addressed during R&D together with sensor designs

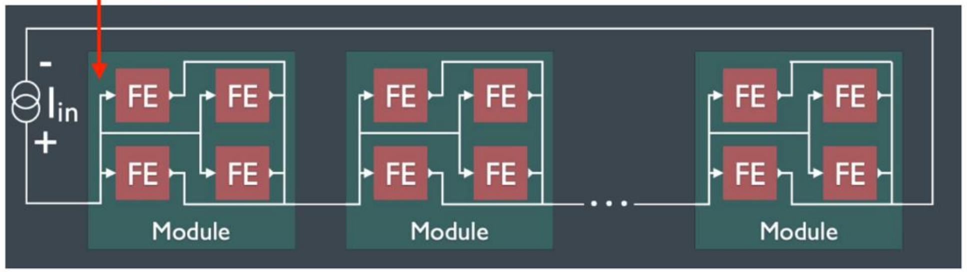
Y.Gao

Quad module and Serial Powering (SP) Chain

- ATLAS ITk pixel detector inspired quad module and SP chain is being developed using ATLAPix3 for data aggregation and power distributions
  - 4 modules within a quad share data, and bias
  - Dedicated changes in flex, readout (hardware, firmware and software)







J. Chan, ATL-ITK-SLIDE-2022-674

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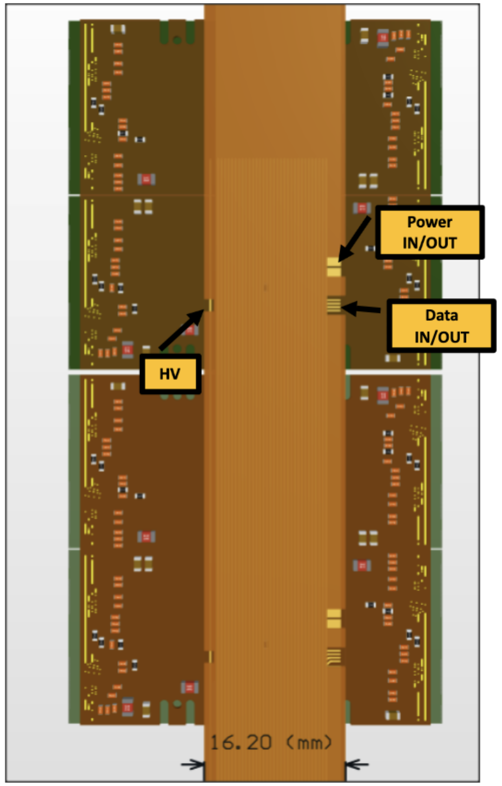
Quad-module → Stave electrical bus considerations

- Distribution of power and data along the stave
  - reducing power dissipation on the distribution lines
  - minimise the number of connections
- Read-out units
  - Multi-chip modules (example 2x2 quad modules)
    - Or large stitched detectors
  - Bias in parallel all sensors in a module
- Serial powering chain supplied by constant current
  - All biases are generated internally by SLDO and on-chip regulators
  - Chip-to-chip data transmissions: local data aggregation on module (not on APix3)
  - clock data recovery (not on APix3)
- Reduce material by developing PCB with Al as conductor



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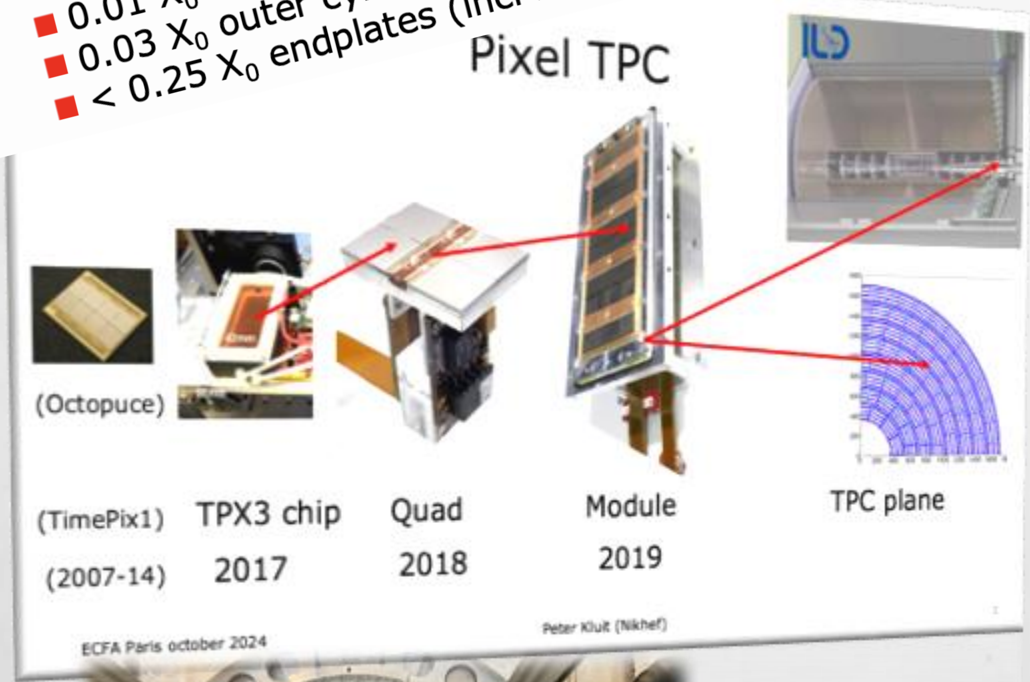
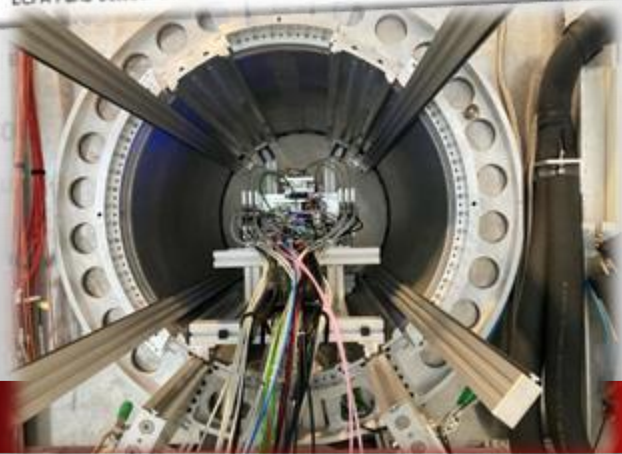
TRACKING DETECTORS - TPC

Material budget is
- 0.01 X_0 TPC gas
- 0.01 X_0 inner cylinder
- 0.03 X_0 outer cylinder
- < 0.25 X_0 endplates (incl readout)





Test beam 2021
9 quad modules

P.Kluit

DESY testbeam Module Analysis

Nikhef — UNIVERSITÄT BONN

dEdx Performance extrapolated to the ILD detector

Test beam B = 1 T
p=5,6 GeV/c

electron resolution 2.9(3.6)%
for method 2 (1)

1 m track 60% and coverage

ILD detector

rInner = 329 rOuter = 1770 mm

electron resolution = 2.5(3.0)%
at $\theta=\pi/2$ for method 2 (1)

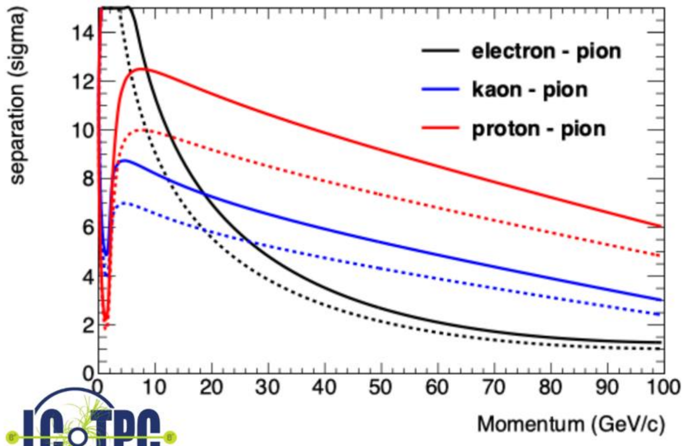
Assume Pixel TPC performance at
B = 1 T at p = 5,6 GeV/c

LC TPC — ILD

DESY testbeam Module Analysis

Nikhef — UNIVERSITÄT BONN

Pixel TPC dEdx performance



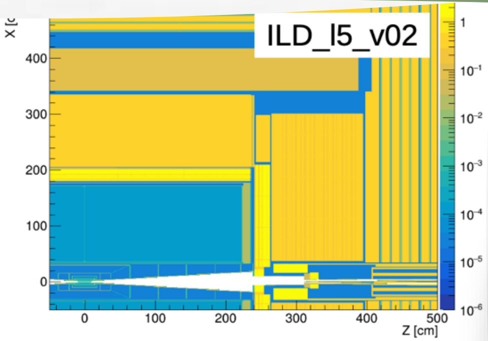
- The expected pion-kaon separation for momenta in the range of 2.5-45 GeV/c at cos θ = 0 is more than 5.5(4.5)σ for the two resolution scenarios.
- At a momentum of 100 GeV/c the separation is still 3.0(2.0)σ.
- Protons can be separated from pions for momenta in the range of 2.5-100 GeV/c with more than 6.0(4.8)σ.

LC TPC — ILD

BEAMSTRAHLUNG BACKGROUNDS IN ILD AT LINEAR (ILC) AND CIRCULAR (FCCee) COLLIDERS

new models of ILD for FCCee

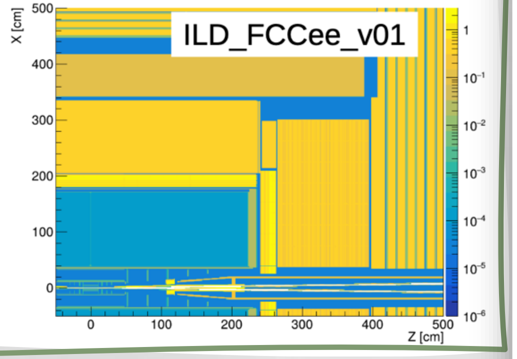
Work In Progress
with V. Schwan



common MDI: MDI_o1_v00

vertex, inner tracker adapted from CLD_o1_v07

remainder from ILD



Very different MDI region

New model for ILD @ FCCee

D. Jeans

Z pole much more demanding & continuous beams (no gating possible)
Important to understand the distortion effects due to ion back fluxes

compare to ALICE-TPC

ALICE TPC upgrade TDR: CERN-LHCC-2013-020

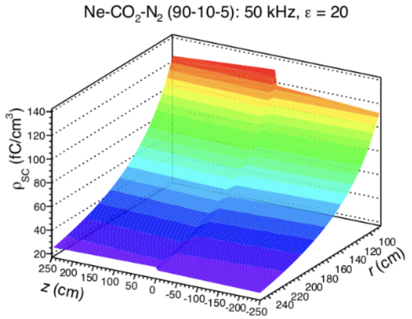
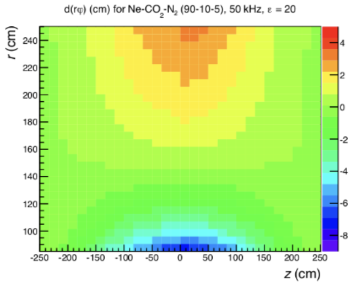


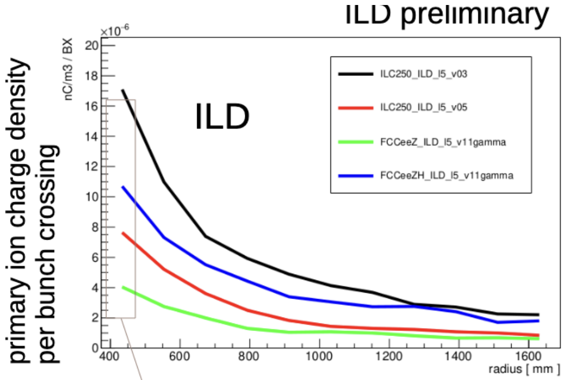
Figure 7.7: Average space charge density for Ne-CO_2-N_2 (90-10-5), R_{int} = 50 kHz and ε = 20.

assumed ion back flow factor ε: 20 secondary ions / primary

20~120 fC/cm³ → cm-level distortions



r-phi distortion [cm]



maximum steady state space-charge ~
max space-charge/BX * BX freq * max drift time * 50%

	max (single BX)	BX freq	max (steady state)
FCCee91	4e-6 nC/m³	30M	26 nC/m³
FCC240	1e-5 nC/m³	800k	2 nC/m³
ILC250 (v5)	8e-6 nC/m³	6.6k	0.01 nC/m³
ALICE		50k	120 nC/m³ with IBF=20

primary ions only: IBF=0

TPC at FCCee91 with IBF of 3~5
→ similar space-charge as at ALICE
O(1~10) cm max distortions
consistent with our "first-principles" estimate

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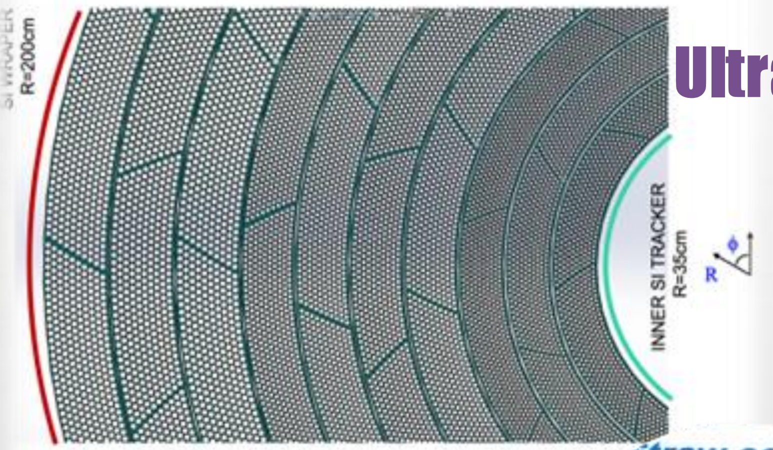
TRAKING DETECTORS - STRAW

A strawman layout of the straw outer tracker



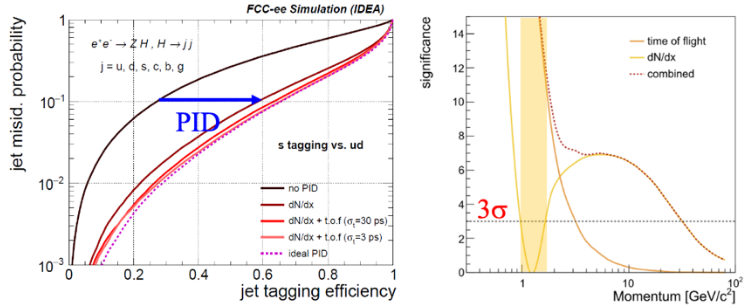
- 10 multi-layers
- 10 straw layers for each mulit-layer
- 10 -15 mm diameter str
- O(100k) tubes

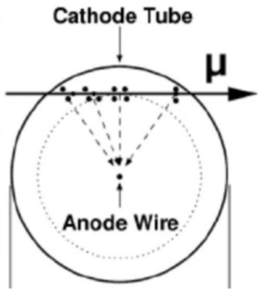
Ultra-light weight straw tracker

Particle Identification Capability

- Essential for flavor physics and bring significant benefits for other areas
  - Flavor physics measurements: $B^0_s \rightarrow D^{\pm}_s K^{\mp}$, $B \rightarrow K^* \nu\nu$, $B_s \rightarrow \phi\nu\nu$, …
  - s-quark jet identification → K identification ($H \rightarrow ss$, V_{ts}, V_{bs}, $H \rightarrow bs$, …)
- The straw tracker could provide PID at low momentum range based on d*E*/dx or d*N*/dx measurements, similar as the Drift Chamber (DCH).
- Induced current signal and timing properties are expected to be similar to DCH's.

Will hear from the next talk many details and progress already made with dN/dx





09-10-2024 Liang Guan (lguan@cern.ch) 12

Straw construction technologies

Winding

- Production speed: 1 m/min
- Maximal length: 5.5 m
- Diameters: 2,4,6,10,20 mm
- Wall thickness: 15+ um

Example: Mu2e
- two layers 6 µm-thick Mylar, max length: 1.2 m
- 23k straws

Ultrasonic welding

- Production speed: 1 m/min
- Maximal length: 5.5 m
- Diameters: 5,10,20 mm
- Wall thickness: 15, 20, 36, 50 um

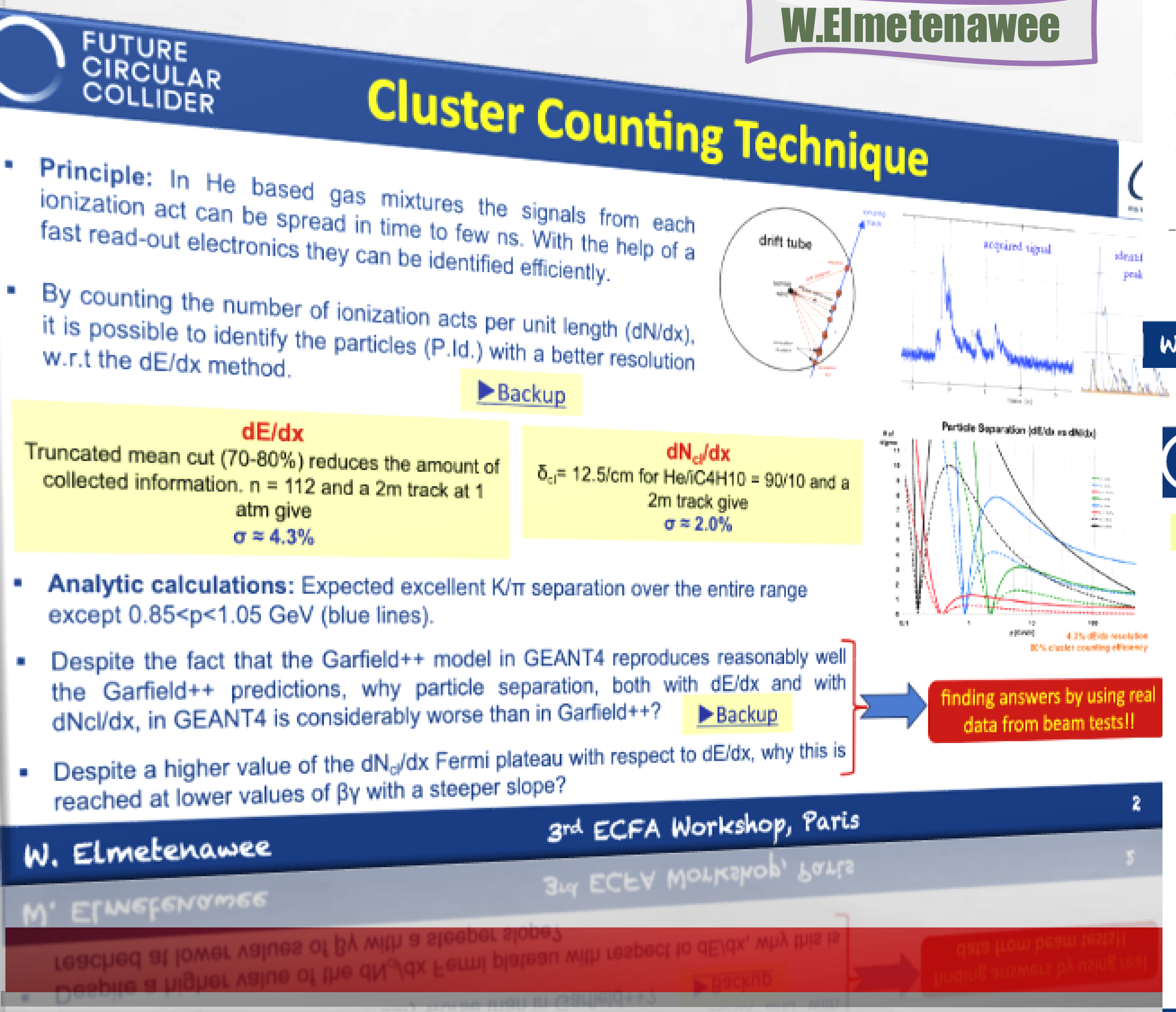
Example: DUNE
- 19 µm-thick Mylar film, max length: 3.83 m
- 200k+ straws

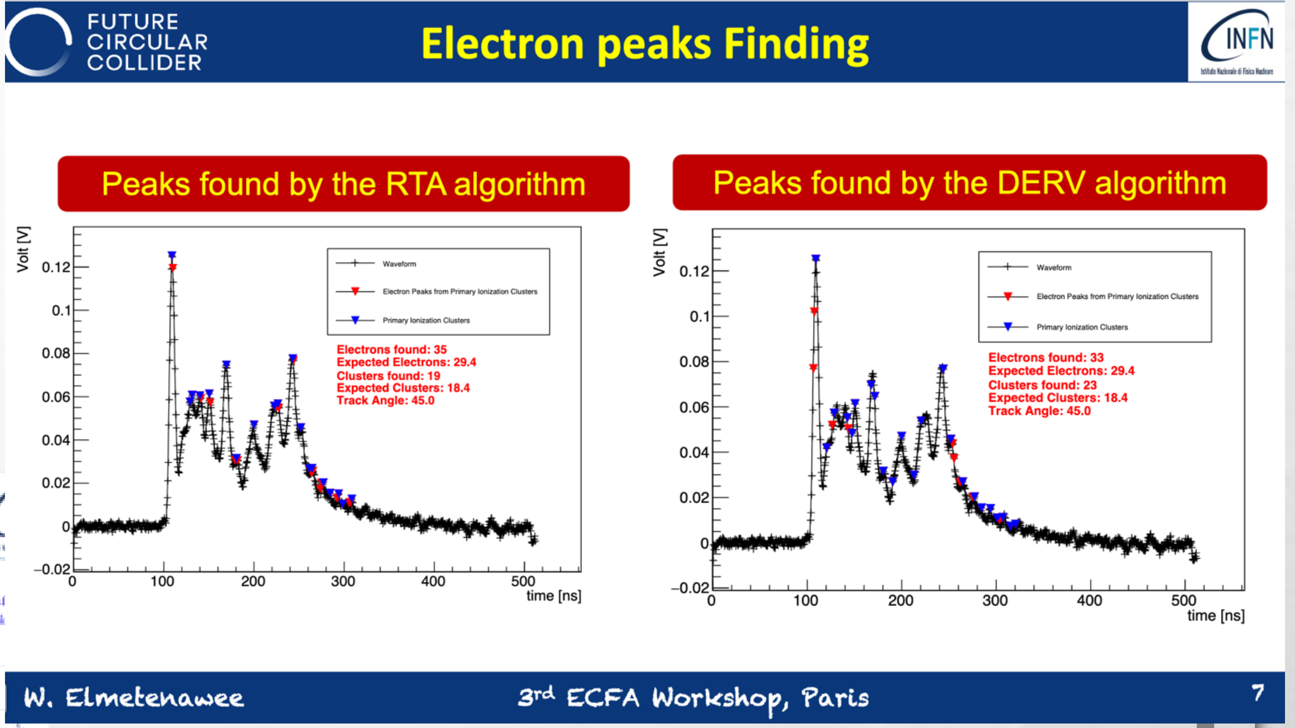
09-10-2024 Liang Guan (lguan@cern.ch)

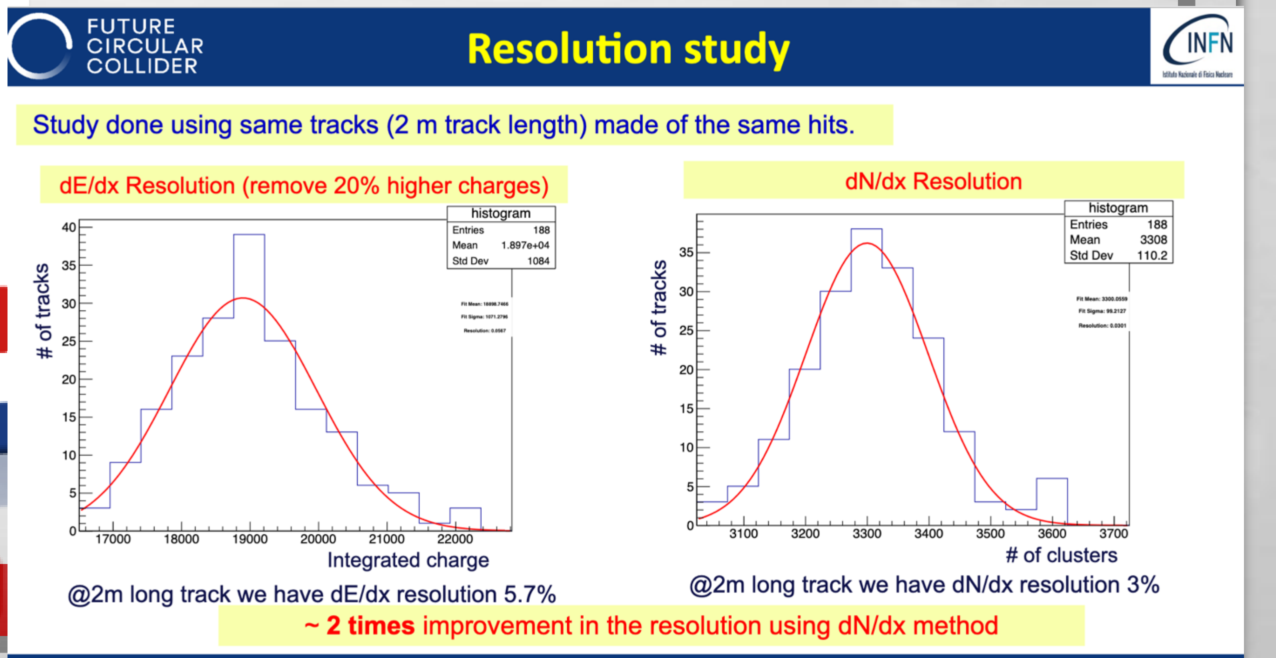
L.Guan

ADVANCING PID IN He DT. CLUSTER COUNTING TECHNIQUE

W.Elmetenawee





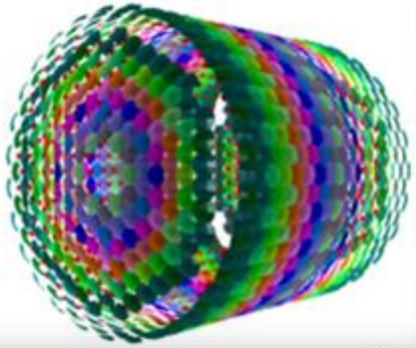


THE ARC COMPACT RICH DETECTOR – PID-ADAPTED TO CLD

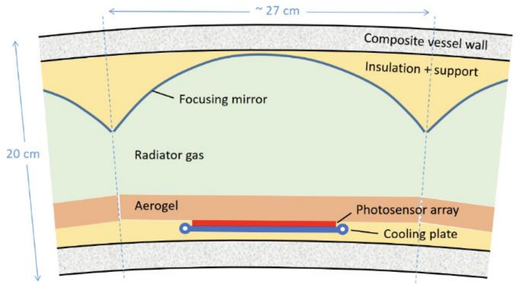
The ARC concept

ARC (**A**rray of **R**ich **C**ells) is a proposed RICH detector for the FCC (or another Higgs factory)

- First presented by R. Forty at FCC week 2021
- Lightweight and compact solution for PID
- Specifically adapted for the CLD experiment, occupying 10% of the tracker volume:
  - Dimensions: 20 cm radial depth, 2.1 m radius, 4.4 m length
  - Material budget targeted below $0.1X_0$
- Cellular in design, with each cell functioning as an independent RICH detector cell



ARC single cell geometry

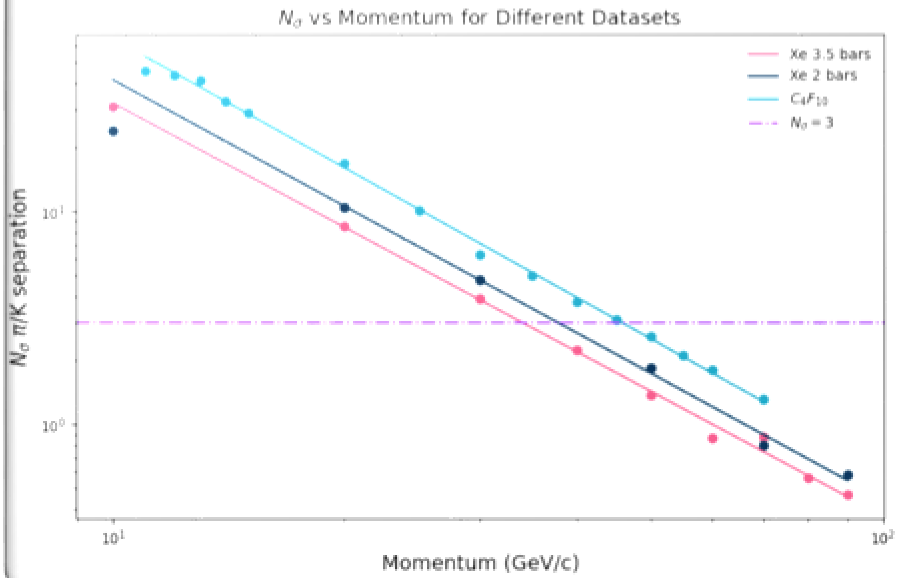


- Two radiators: C_4F_{10} (or a more eco-friendly alternative) + **Aerogel** (for low **p** tracks)
- Spherical focusing mirror
- Photosensor array: most suitable candidates are Silicon Photomultipliers (SiPMs) arrays with cooling plates
- Aerogel also as thermal insulator between SiPM array and gas radiator

Goal: Construct prototype of single cell in 3 years (fostered by DRD4 Collaboration)

S. Pezzulo

π/K separation - Xe



Radiator	Max p [GeV/c]
C_4F_{10} @ 1 bar	45
Xe @ 2 bar	38
Xe @ 3.5 bar	33

Xenon could be suitable, but must be pressurized to achieve sufficient photon yield
→ the vessel needs to be reinforced

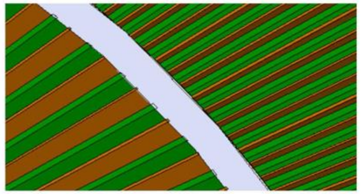
NOBLE LIQUID CALORIMETER
ALLEGRO

Farès Djama

The concept is being adapted for the endcap.

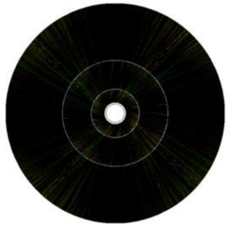
Adaptation for Endcap

- 420 mm < R < 2750 mm
- Turbine implementation of the technique on the endcap: hermeticity, homogenous in ϕ, readout from the rear.
- But it has a major issue: Gap widening range is too large.
- Mitigation is being worked out:
  - 3 nested wheels.
  - But still sampling fraction varying a lot.
  - Solution to be evaluated: Variable absorber thickness.

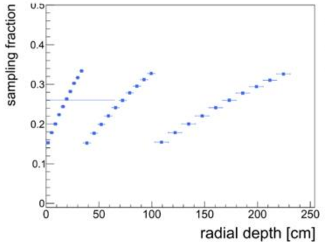


Zoom between 2 nested wheels

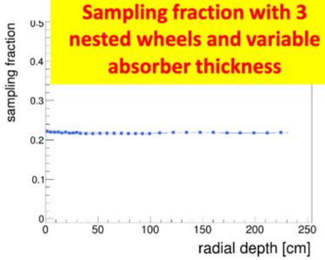
Simple turbine



3 nested wheels



Sampling fraction with 3 nested wheels

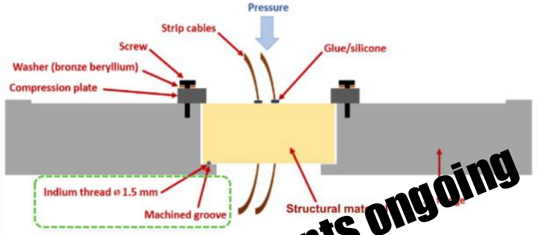


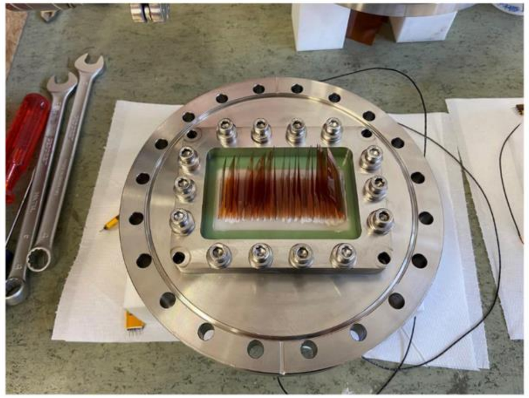
Sampling fraction with 3 nested wheels and variable absorber thickness

Mechanics developments ongoing

Cryostat and Feedthroughs

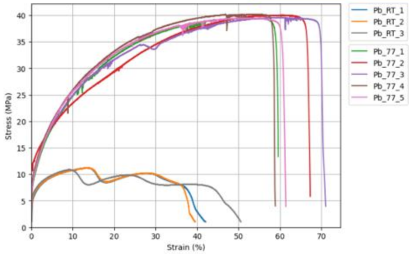
- Developping a very light cryostat made with carbon fiber including a full carbon composite honeycomb.
- Channel density in the feedthroughs will be 5 time larger than in ATLAS.
- Developping a connectorless feedthrough:
  - 3D printed epoxy resine structure with slits for strip cables, glued to the flange.
  - Passed leak and pressure tests at room and liquid nitrogene temperatures.



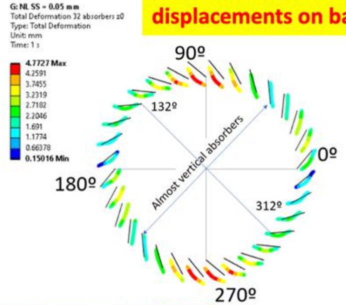


Barrel Structure

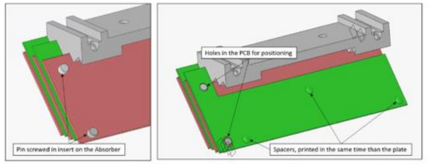
Lead strength test

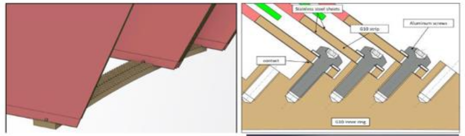


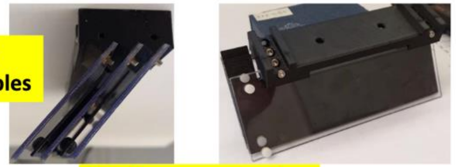
Simulation of absorber displacements on barrel



Full scale 3D printed samples







Fixation on outer rings

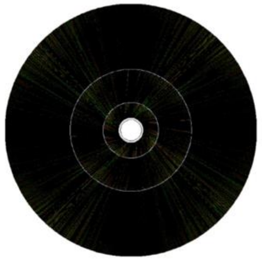
Fixation on inner rings

ALLEGRO FCC-ee DETECTOR - SIMULATION

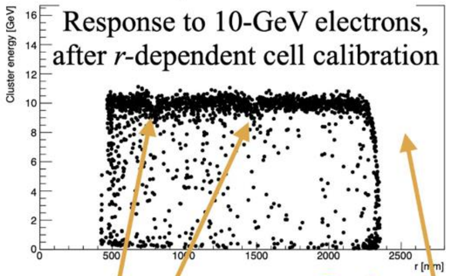
A lot of progress towards the full detector simulation of ALLEGRO

ECal endcap simulation

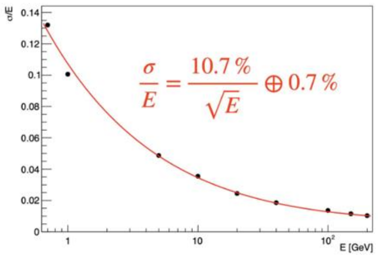
- One consideration is the variation of the gap with radius
  - It means that response is very different at the inner and outer radii (42 cm and 275 cm)
- To mitigate this, the detector can be subdivided into a set of nested wheels
- Tapering the absorbers to be thicker with increasing *r* may be necessary



LAr + tapered Pb absorbers



Resolution similar to barrel ECal



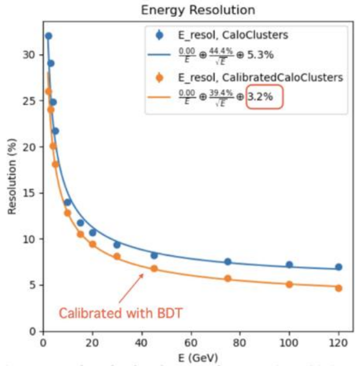
Transitions between wheels

Region shadowed by barrel ECal

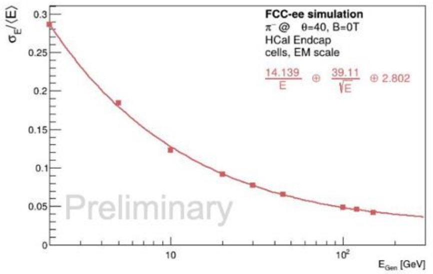
M. Mlynarikova

HCal barrel and endcap simulation

- Barrel: Implemented MVA calibration of cluster energy, using boosted decision tree (BDT), compared to cell-based approximate calibration using 100 GeV π^-
  - Inputs: total cluster energy $E_{cluster}$ and energy per layer → $E_i/E_{cluster}$
  - Regression target: $E_{true}/E_{cluster}$
  - Constant term decreased from 5.3% to 3.2%, energy response $(E_{cluster}-E_{true})/E_{true}$ → within 1-2%

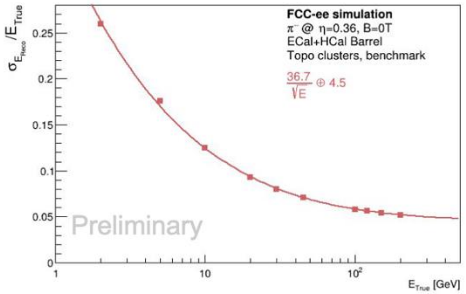


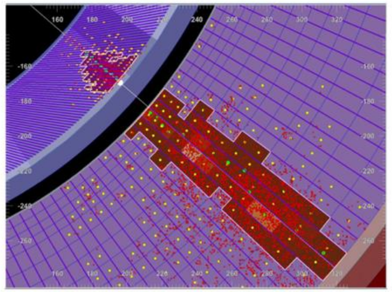
- Endcap: Implemented the detector geometry, cells readout and sliding window clustering algorithm
  - Topological clustering implementation on the way
- Next: Include HCal in the particle flow

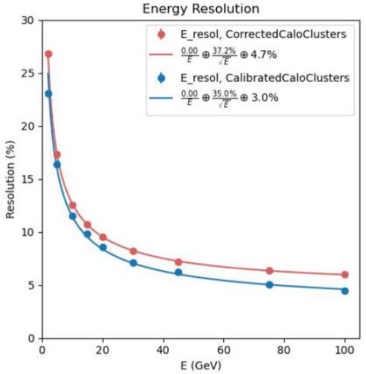


ECal+HCal barrel combined simulation

- The goal is to combine ECal and HCal calorimeter information (and later add tracker and do particle flow)
- Topological clustering implemented in the barrel region, sliding window algorithm available as well
- Cluster energy calibration done with a BDT (similar to HCal)

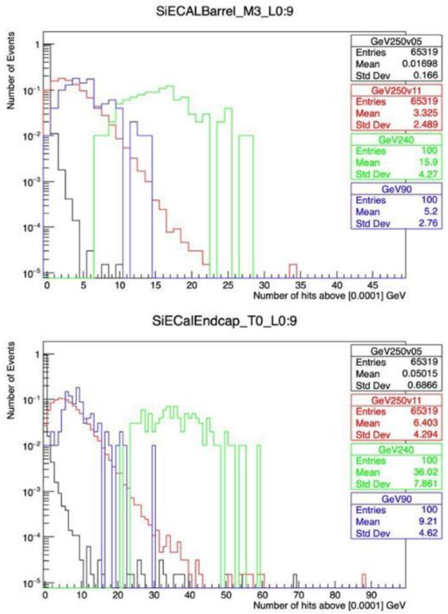






FLUXES ILD CALORIMETERS AT FCCee

Machine backgrounds for ILC/FCC tracking configurations



ILC@250GeV/ILD_l5_v05/ :	65319 BX
ILC@250GeV/ILD_l5_v11gamma/ :	65319 BX
FCCee@240GeV/ILD_l5_v11gamma/ :	100 BX
FCCee@90GeV/ILD_l5_v11gamma/ :	100 BX

		⟨Nhit⟩/BX	
Config		Barrel M3 L0:9	EndCap T0 L0:9
ILC @ 250 GeV	ILD_l5_v05	0,0170	0,0500
ILC @ 250 GeV	ILD_l5_v11γ	3,33	6,40
FCCee @ 240 GeV	ILD_l5_v11γ	15,9	36,0
FCCee @ 90 GeV	ILD_l5_v11γ	5,2	9,21

⟨Nhits⟩, per BX

- Barrel and Endcaps ~ same behaviour
- Much higher numbers in
  - 240 GeV (FCC config)~ 4 × 90 GeV
  - 250 v11 ~ 100× 250 v5

Distribution of hit energ

- No difference

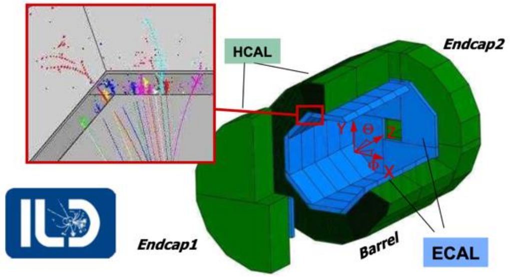
SiECALBarrel_M3_L0:9

V.Boudry

Rationale for HG calorimeters: ILD as an example

ILD high granularity calorimeters

- Designed for ILC
  - Power pulsing, low occupancy
- Marginally adapted for CLIC and CLD
  - Physics : number of layers
- Adapted for CEPC
  - Lower granularity, …
- Needs strong adaptation for EW physics and continuous operation
  - Rates, Heat, Electronics



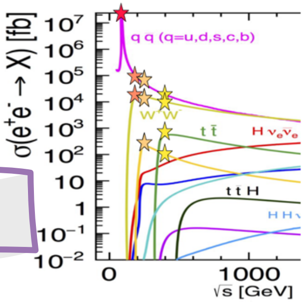
ECAL: 30 layers
- SiW-ECAL": Si cells 0.5 × 0.5 cm²
- ScECAL: Scint strips 0.5 × 5.0 cm²

10–100M channels

HCAL: 48 layers
- AHCAL: scint. cells 3 × 3 cm²
- SDHCAL: RPC cells 1 × 1 cm²

10–70M channels

Selected modes



Processes: min. bias
- All
  - ee → qq
  - ee → $\mu\mu$, $\tau\tau$
  - ee → ee (⊃ Bhabha)
  - $\gamma\gamma$→ VV
  - Machine background (ee pairs)
- E_{CM} ≥ 160 GeV
  - ee → WW
- (E_{CM} ≥ 240 GeV)
  - ee → HZ
- (E_{CM} ≥ 360 GeV)
  - ee → tt

Config	#IP	E_{Beam}	#BX	$\mathcal{L}$ [10^{34}/cm²/s]	ΔT [μs]	Freq[Hz]	√s [GeV]
FCC-Z2	2	45,6	12000	180,0	0,025		91,2
FCC-Z4	4	45,6	15880	140,0	0,019		91,2
FCC-W	4	81,3	688	21,4	0,442		162,5
FCC-ZH	4	120,0	260	6,9	1,169		240,0
FCC-tt	4	182,5	40	1,2	7,600		365,0
ILC250 [1]	1	125,0	1312	1,4	0,554	5,0	250,0
ILC500	1	250,0	1312	1,8	0,554	5,0	500,0
ILC1000	1	500,0	2450	4,9	0,366	5,0	1000,0
CLIC380	1	160,0				10,0	380,0
ILC-GZ	1	45,6				5,0	91,2
ILC250-HL	1	125,0	2625	2,7	0,366	5,0	250,0
CEPC							
C^3							
⋮							

ILC from: P. Bambade et al., The International Linear Collider: A Global Project, arXiv:1903.01629 [Hep-Ex, Physics:Hep-Ph, Physics:Physics]. (2019).
FCC from: Tor Raubenheimer, FCC Week June 2023

Done

Flux determinations

- Simulated detector-level data for main physics processes and machine background at 91.2 GeV and 240 GeV.
  - Simulated detector-level data for all physics processes but not machine background at 162.5 GeV and 365 GeV.
- Generated primary, secondary 1D and 2D histograms in 11 systems of ECAL and HCAL of the ILD calorimeters
- Merged different processes and background and got collective histograms.

Conclusions or the ECAL:

- The power is ≥90% driven by the continuous component even in the endcaps sections for SKIROC2 ASICs in CC
- Machine background / BX much higher in the FCC-ee config.

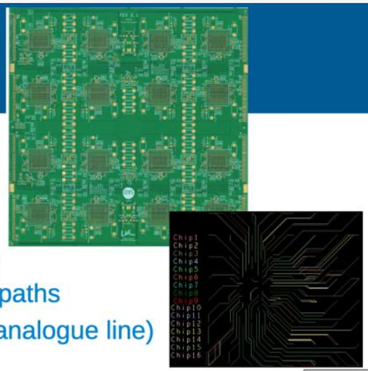
Occupancy and Bandwidth requirements for highly granular calorimeters at FCCee

ILD SIW-ECAL CHALLENGES
(TECHNOLOGY & FCCee CONDITIONS

Cooling studies
(Relevant for FCC – not power pulsing as in ILC)
Developments on new FE boards
Hybridization studies
(issues with PCB flatness and gluing being study)
Use of timing studies (timing everywhere or dedicated layers)
PID from TOF (complementary to dE/dx)
PFA improvements.

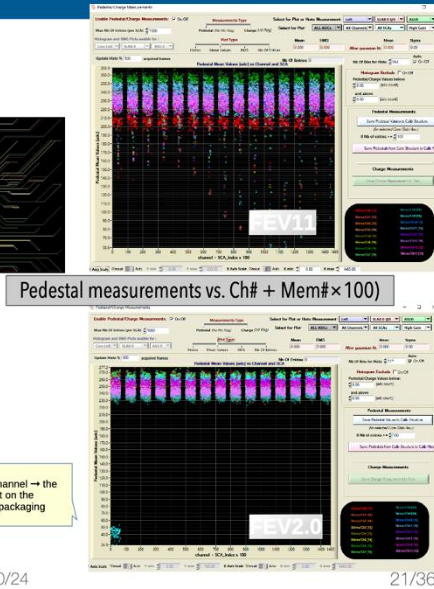
V.Boudry

New FE boards



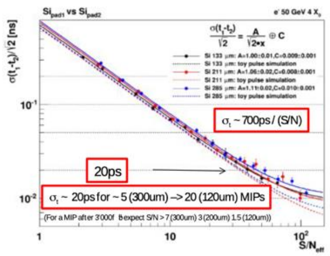
Improvements:
- Power distributions
  - Local power regulation: LDO's
  - Local High Voltage filtering & Supply
- Signal distribution (buffering), data paths
- Monitoring (single ID, temp, probe analogue line)
- ASIC shielding/routing

Status:
- pre-version 2.0 tested, minor corrections needed
  - Noise uniformity dramatically improved (ex: outliers in thr. / 20 !)
- version 2.1 produced, … in metrology
  - before cabling, 2nd metrology, gluing, …
  - All material available : ASICs being tested



Calorimeter Timing Studies

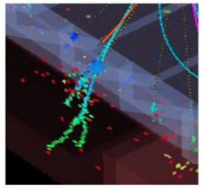
2015 CMS HGCAL CERN timing test beam
- Time resolution vs S/N ratio

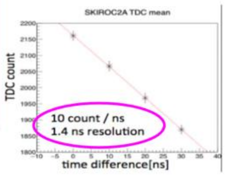


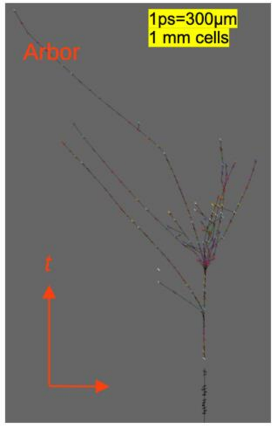
Funding for 2 programs in FR & DE : **T-Calo & Calo5D** → full chain of Sim. → Phys. Perf.

Work just started

Option 1) Bulk Timing





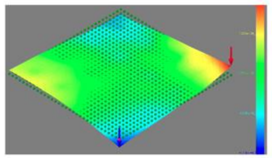


Option 2) Dedicated layers with fast sensors (LGADs, MAPs, …)

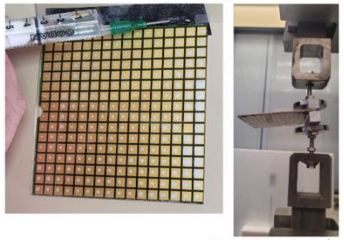
Hybridization studies :
How to assemble silicon sensors & PCB ?

Revisiting gluing (IFIC, IJClab, DMLAB)
- PCB metrology
  - Bef. & After curing & soldering
- Glue formula & preparation
- Gluing methods
  - Robot
  - Stencil
- Reenforcement
  - Filling glue
  - Adhesive films

IJClab (méca)

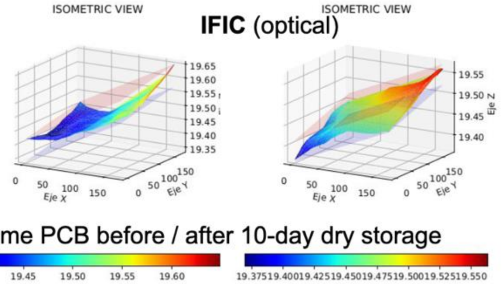


Conductive glue + filling (~invisible) on a glass plate



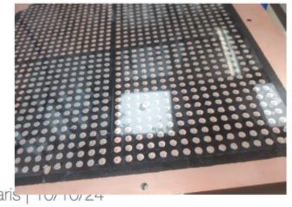
Flatness of PCB

IFIC (optical)



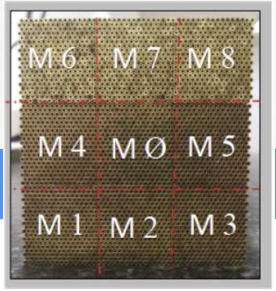
Same PCB before / after 10-day dry storage

Measurements by C. Orero, IFIC



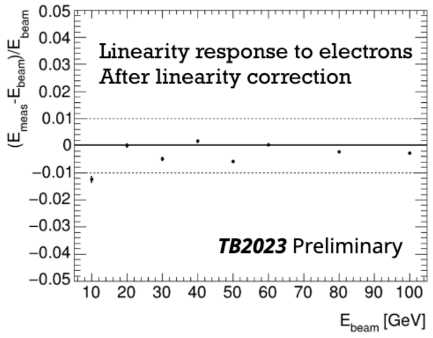
Puncturated adhesive film and condutive glue dots

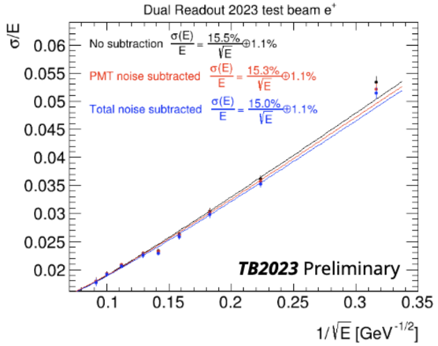
DUAL READOUT CALORIMETER



Developments of different prototypes:

- **Bucatini prototype – Several test beams (2021, 2023)**
- **Hidra – for hadronic shower containment**
- **Drago prototype – Test beam 2024v(analysis ongoing)**
  Hidra prototype instrumented only with PMTs





- Good linearity over the whole energy range
- Promising resolution, in agreement with simulations.
  - Difference in the constant term mostly due to spread in beam energy
  - Working on a better understanding of the noise

Dual readout 10/10/2024 11 / 17

HiDRa construction

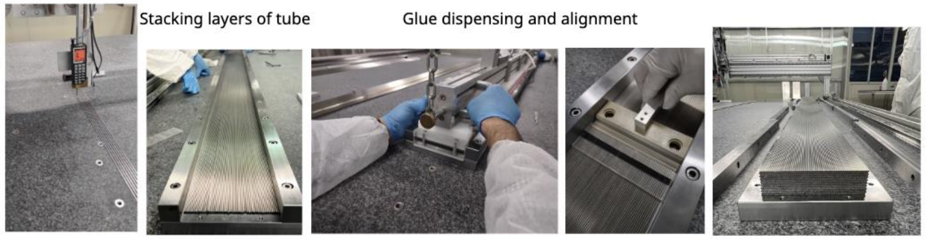
With HiDRa we are investigating an assembly procedure

Tube selection: thickness, straightness, length, internal diameter

Stacking layers of tube

Glue dispensing and alignment

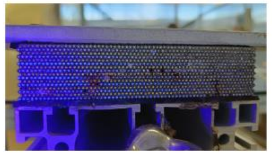
Mini-module

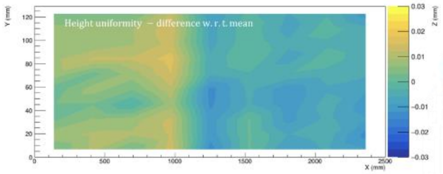


Semi-automatic system for planarity measurement

O (10 μm) precision on mini-module height

Fiber loaded





R. Turra

Drago prototype

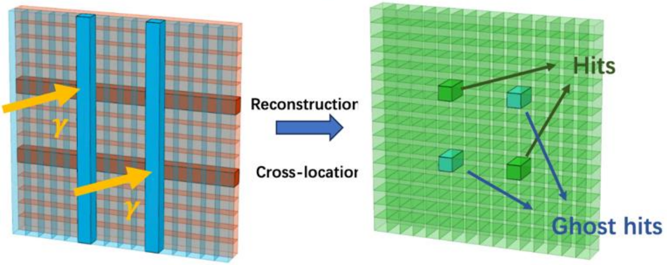
- HiDRa prototype instrumented only with PMTs
- 36 minimodules, organised in 12 rows, 3 columns each (∼50% HiDRa)

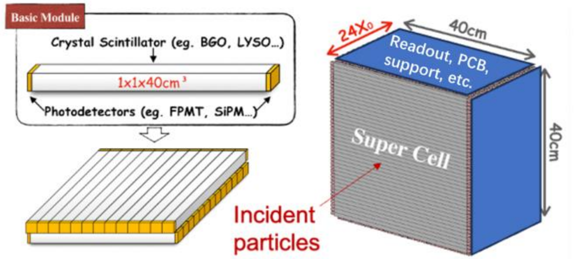
CRYSTAL ECAL

CyberPFA: CrYstal Bar ECAL Reconstruction in CEPC

Homogeneous ECAL

- **New concept of crystal ECAL: orthogonal arranged crystal bars.**
  - Double-end readout with SiPM (Q, T).
  - Cross-location by bars.
  - Less readout channels, lower cost.
  - New challenge: multi-particle ambiguity.





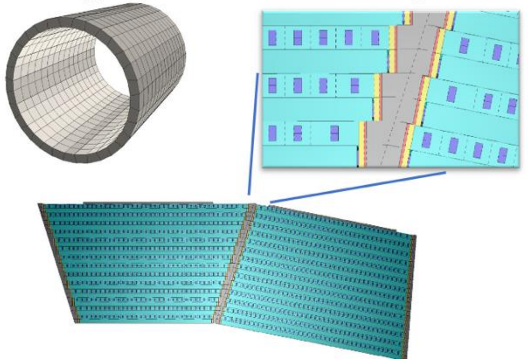
Software task:
* Clustering
* Pattern recognition.
+ Overlap: energy splitting.

Y. Zhang

Detector Simulation

CEPC

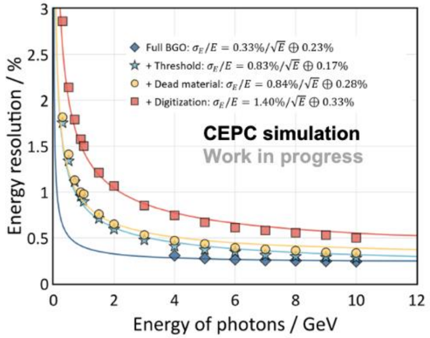
A realistic detector description implemented in CEPCSW with DD4HEP
- Inner R = 1830 mm, depth 300 mm (24 X_0), 28 layers.
- $1 \times 1 \times \sim 40\ cm^3$ BGO bars with ESR wrapping
- 32-side polygon, invert trapezoid modules.
- Dead material between modules:
  - SiPM, PCB, FE and BE electronic boards (~3 mm)
  - Copper plate cooling (1 mm)
  - Carbon fiber supporting (5 mm/side)
- An energy correction for the crack leakage.



Digitization model: from beam test
- Crystal scintillation: 100 p.e./MIP (single end detected)
- SiPM gain calibration: 1 p.e. = 5 ADC, with noise
- Electronics: 12 bits ADC with precision 0.2%, 3 gain modes
- Threshold: 0.1 MIP.

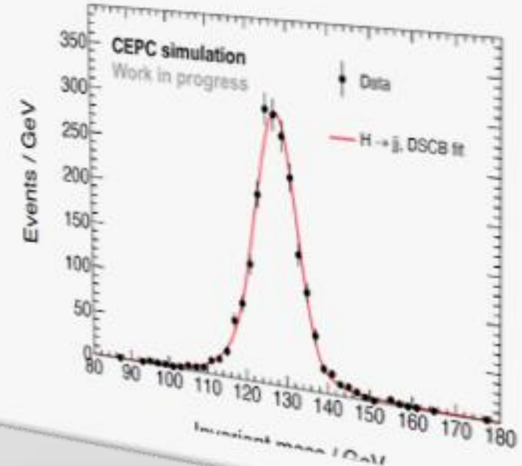
Energy resolution with full digi: $\sigma_E/E = 1.4\%/\sqrt{E} \oplus 0.3\%$ (in module center)

Geant4 hits: Energy deposition → Crystal-SiPM: detected photons → SiPM: p.e. to ADC → ASIC: ADC in Gain modes → ADC digits



Physics performance: $H \to gg$

- Physics process: $ee \to ZH \to \nu\nu gg$ in $\sqrt{s} = 240$ GeV
  - Full reconstruction in CEPC detector: Silicon + TPC tracker, crystal ECAL, glass tile HCAL.



$m_{jj} = 127.3$ GeV, $\sigma(m_{jj}) = 5.23$ GeV
Boson mass resolution (BMR) 4.11%.
With truth track: BMR 3.73%.

Main challenges: overlapping & ambiguity
(Several algorithms under development)

GRAiNITA STATUS

GRAiNITA concept (2019)

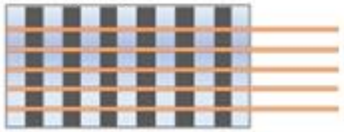
Inspired by LiquidO technique for neutrino detector
(A. Cabrera et al. LiquidO Commun Phys 4, 273 (2021))

Typical sampling calorimeters:
$\frac{\sigma_E}{E} \sim \frac{10\% - 15\%}{\sqrt{E}}$

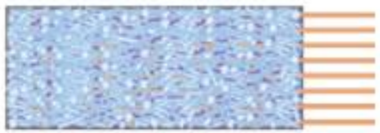
Crystal calorimeters :
$\frac{\sigma_E}{E} \sim \frac{1\% - 2\%}{\sqrt{E}}$

Requirements:
- fine sampling
- scintillation light locally contained

Shashlyk-type calorimeter



GRAiNITA



3rd ECFA workshop, 9-11 October 2024

M-H. Schune

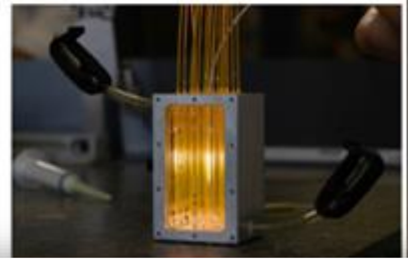
Where are we ?

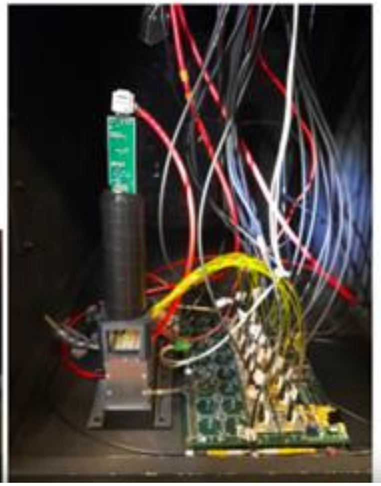
Small (2 x 2 x 5.5 cm³) prototype filled with ZnWO4 grains + water or Heavy Liquid (EGL or LST_fastloat (d=2.8)) and 16 WLS fibers read out by SiPM and a Wave-Catcher

Depolished fiber in the center to allow for green light injection

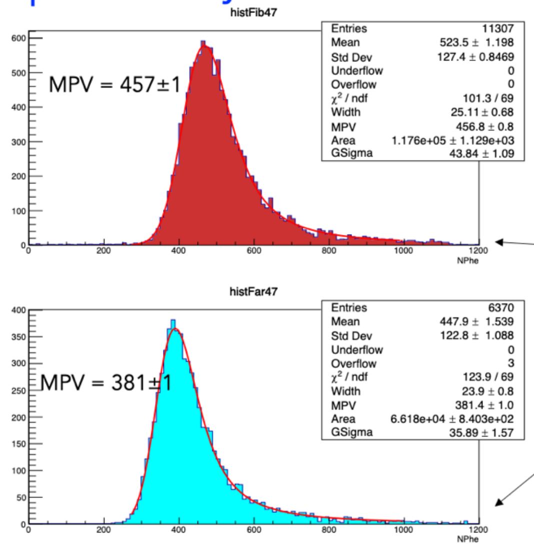
	$ZnWO_4$
Effective Z	61
Density (g/cm^3)	7.87
Refractive index	2.0 - 2.3
Light yield (photons/MeV)	~ 9000
Peak emission wavelength (nm)	480
Decay time (μs)	20
Radiation length (cm)	1.20
Molière radius (cm)	1.98

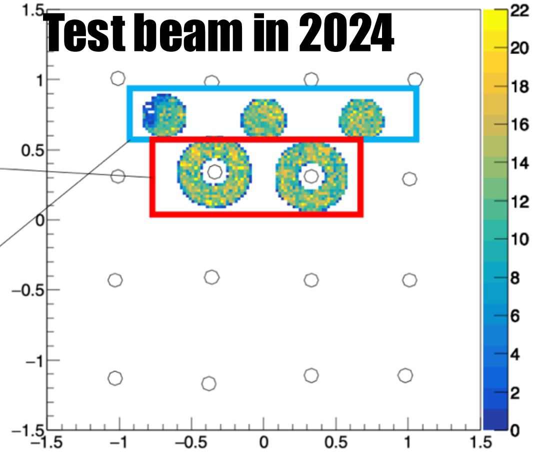
built in 2023





preliminary look





~±9% variation
Simplified simulation(*) indicates that $\frac{\sigma_E}{E} \sim$ 1% should be at reach

(*) $1 + 0.07\cos\left(\frac{2\pi X}{7\ mm}\right) + 0.07\cos\left(\frac{2\pi Y}{7\ mm}\right)$

μ-RWELL: MUON AND PRESHOWER FOR IDEA FCCee

Pre-shower High resolution after the magnet

G. Bencivenni et al., 2015 JINST 10 P02008

Optimizations studies:
- Resistivity, Strip pitch, 2D readout layout

ASIC developments – TIGER
- Test beam performed

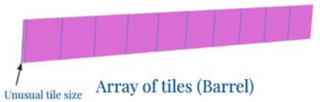
Preshower (detailed geometry)

For the detailed version of the preshower with μ-RWELL tiles, the specifications to be achieved :

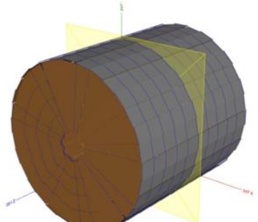
- Active area: 50 × 50 cm²
- Pitch between readout strips: 400 μm
- A readout system 2D (CartesianGridXY), for each individual chamber.
- Space Resolution < 100 μm
- 1.3 million channels

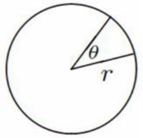
Simulations ongoing

```
                         <!-- Barrel -->
<constant name = "psBarrelFirstLayerRadius"        value = "2420*mm"/>     <!-- 1st Barrel microRWELL detector inner radius-->
<constant name = "psBarrelLength"                  value = "4900*mm"/>     <!--Barrel detector length,in description of detctor we always us
                         <!-- Endcap -->
<constant name = "psEndcapFirstLayerZOffset"       value = "2400*mm"/>     <!-- 1st Endcap microRWELL detector inner ZOffset -->
<constant name = "psEndcapLayersInnerRadius"       value = "390*mm"/>      <!--Endcap detector inner radius, its start point of thicknesses of detector material -->
<constant name = "psEndcapLayersOuterRadius"       value = "2420*mm"/>     <!--Endcap detector outer radius, its end point of thicknesses of detector material -->
<!-- End of Pre-shower Parameters-->
```



Array of tiles (Barrel)

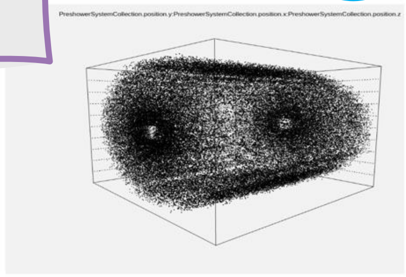


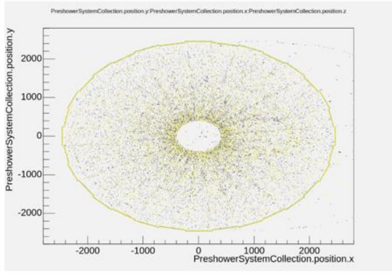


n=2π/θ

https://fcc-ee-detector-full-sim.docs.cern.ch/IDEA/ 6

N. Nitika

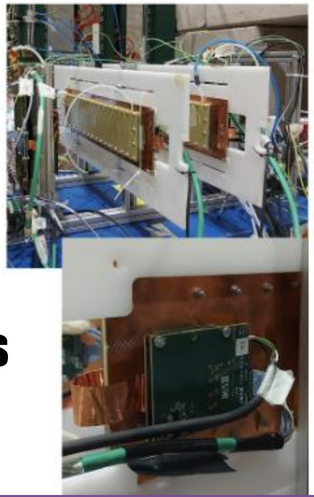




Simulation of 100k events hits of muons, appeared from preshower chambers readout system having 32 sides. 10

μRWELL and TIGER electronics

R. Farinelli

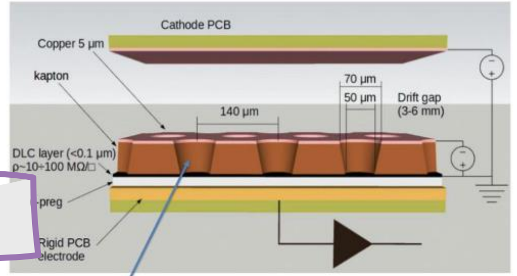


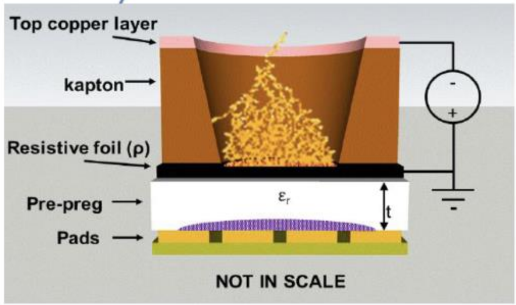
Detector under test:
- 4 μRWELL w/ 40 cm strip length
  1D strip pitch of 0.4/0.8/1.2/1.6 mm

Readout under test:
- TIGER FEE
- GEMROC FPGA

Goals of the testbeam:
- Define the state of art of μRWELL+TIGER for IDEA Muon system optimization studies
- Compare the APV-25 performance studies with TIGER
- Performance in Ar:CO2 and Ar:CO2:CF4 comparison
- Collect data to compare experimental measurement and simulation

Measurements:
- Gain scan to evaluate the amplification/saturation/performance
- Drift scan to evaluate the signal collection
- Threshold scan to optimize S/N





The μ-RWELL is composed of only **two elements**:

- **μ-RWELL_PCB** = amplification-stage ⊕ resistive stage ⊕ readout PCB
- **cathode** defining the gas gap

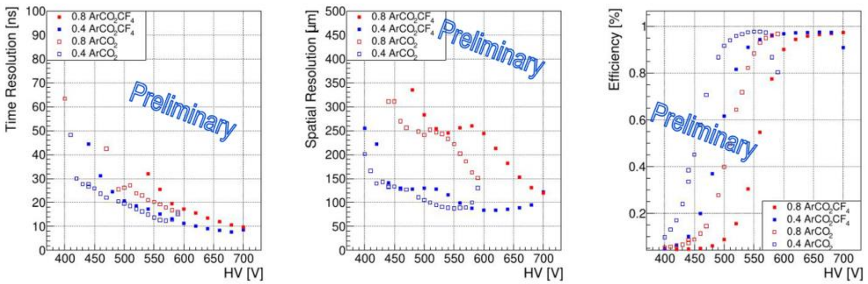
Results without CF4 gas

The gas mixtures based on CF4 are suitable for a fast electron diffusion but they are not classified as eco-gases.

Alternative to CF4 are needed. Here the performance of a μRWELL with Ar:CO2 (70/30) is compared with Ar:CO2:CF4 (45:15:40)

A shift in the working point of about 50-100V is observed due to different ratio of Argon but similar results are achieved.

The most important measurement here is the time resolution where a good value of 10 ns is reached with ArCO2



TOWARDS AN ASYMMETRIC DETECTOR FOR HALHF

A detector for HALHF starting from the ILD design – extended ILD (e-ILD)

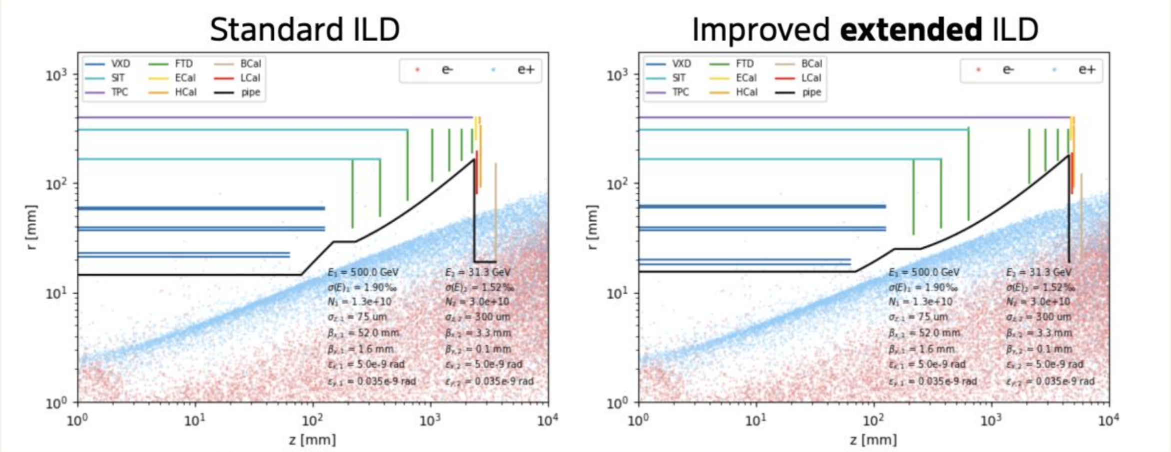
Studies on Beam backgrounds

The backgrounds constrain the available space for the detector.

A. Laudrain

Beam-strahlung: optimising the detector config

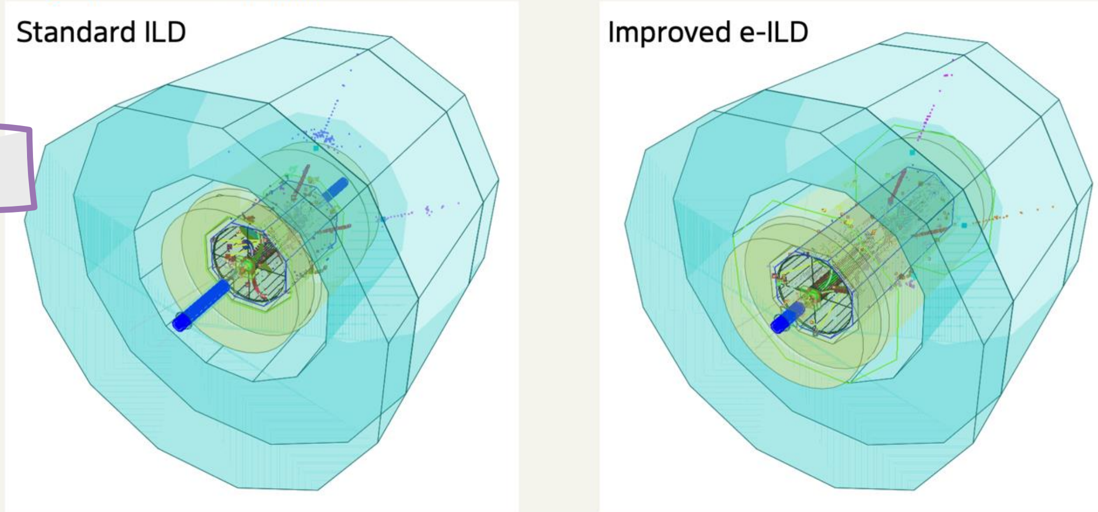
- Minimum clearance between beam pipe and backgrounds = 5 mm.
- TPC length doubled: 2350 mm → 4700 mm.
- FTD positions rescaled accordingly.
- VXD extended as much as possible without hitting the beam pipe.



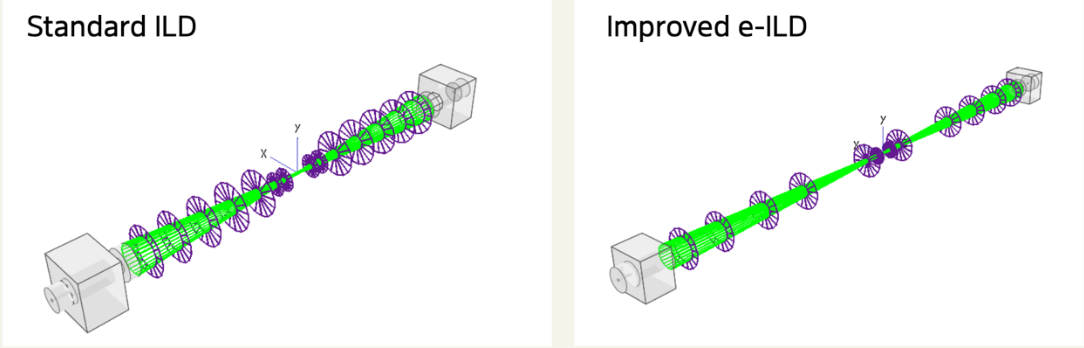
DESY. | Antoine Laudrain (he/him) | ECFA HET 2024 — 10.10.2024 — Towards an asymmetric detector for HALHF

Towards a Geant4 implementation

Single (non-boosted) Z(μμ)H event



DESY. | Antoine Laudrain (he/him) | ECFA HET 2024 — 10.10.2024 — Towards an asymmetric detector for HALHF



DESY. | Antoine Laudrain (he/him) | ECFA HET 2024 — 10.10.2024 — Towards an asymmetric detector for HALHF

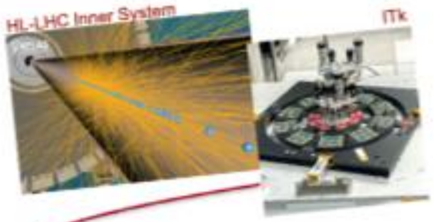
EMBEDDED FPGAS FOR MACHINE LEARNING IN FUTURE e+e- DETECTORS

J. Gonski

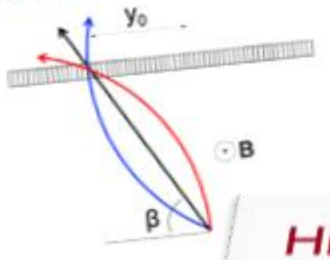
ML in Silicon Front-End Readout

SLAC

- Future silicon pixel detectors will present exceptional challenges
  - Close to beamline = high occupancies/radiation
  - Very high granularity (25 μm) pixel pitch
  - Little room for services/cooling → minimize material budget & power density
- ML at the front-end to reduce off-detector data rate
  - HET factory: reduce cabling, increase granularity
  - Exascale (10^{15} bytes/sec) data rates anticipated at FCChh
- "Smart pixel" collaboration: study AI/ML to filter high p_T from pileup tracks (< 2 GeV) at source using pattern of deposited charge



"Smart Pixel" Pileup Track Filtering



Proof-of-Concept eFPGA Tapeouts

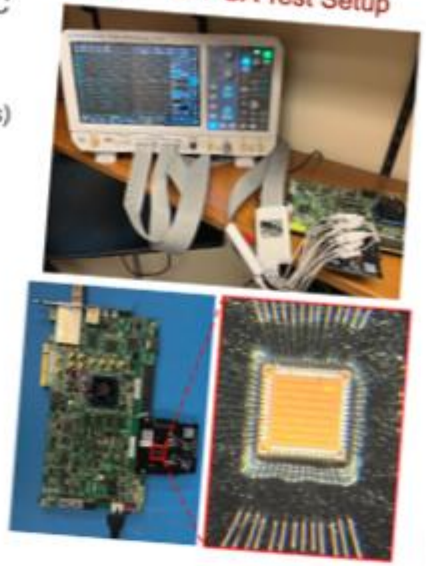
[2404.17701]

SLAC

- SLAC designed prototype eFPGAs with FABulous and taped out in 130nm & 28nm CMOS on TSMC MPW
  - Area: 1 mm²
  - Very small logical capacity (< 500 look-up tables)
- Physics performance: classify pileup from signal tracks
  - Model: boosted decision tree with depth 5, 440 LUTs and quantized to `ap_fixed<28,19>`
  - Configured to eFPGA and read back with 100% accuracy with respect to simulated expectation and quantized software result

→Proof-of-concept for open-source design tools for eFPGAs ✓

28nm eFPGA Test Setup



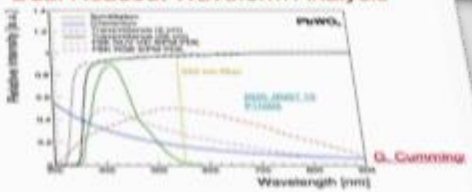
Higgs Factory Applications

SLAC

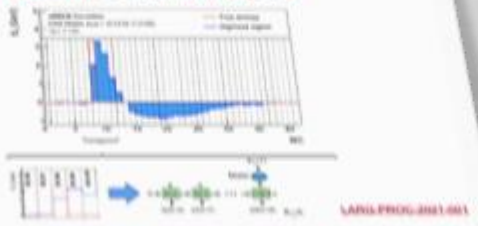
- Reconfigurability of eFPGAs enables generic ML methodologies: applicable to wide variety of datasets & subsystems
  - **Dual readout calorimetry**: ML to extract Cherenkov C and scintillation S photon yields from single waveform
  - **High granularity calorimetry**: ML for pattern recognition of hits → showers & energy regression
  - **Liquid argon**: ML to extract energy and timing from time-domain waveform

→**Get in touch if interested!**

Dual Readout Waveform Analysis



LAr Waveform Analysis



10 October 2024 J. Gonski 10

PLANS ON ECFA REPORT – UNDER DISCUSSION NOW

Overlaps with strategy inputs of:

- **Detector concepts**
- **DRDs**

Nevertheless some information must be included (~20 pages for everything)

It will include

- **Summary of the experimental conditions for the experiments**
- **Short discussion on the detector evolution from linear to circular**
- **DRDs short term plans related to Higgs factories**

It will be prepared togheter with our (=WG3) contacts from concepts groups & DRDs

SUMMARY

Many results presented with very interesting discussions after the presentations

Lot of advances in the last years (new ideas, designs, tests, simulations…)

Several talks showing the efforts of the ILD to adapt the ILC detector version to FCCee
(and even some studies for HALHF)

If you are not yet involved on detector developments

Select your preferred technology and join us

- To contribute with your ideas and work to present developments
- Proposing any new detector which could improve the performance of the future collider experiments

Thanks to all the speakers for the very nice presentations