Detector & more closeout

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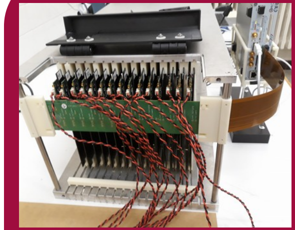
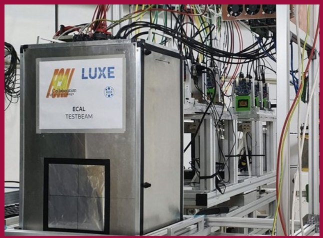
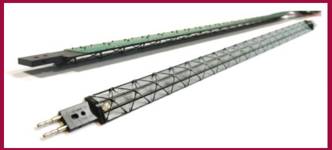


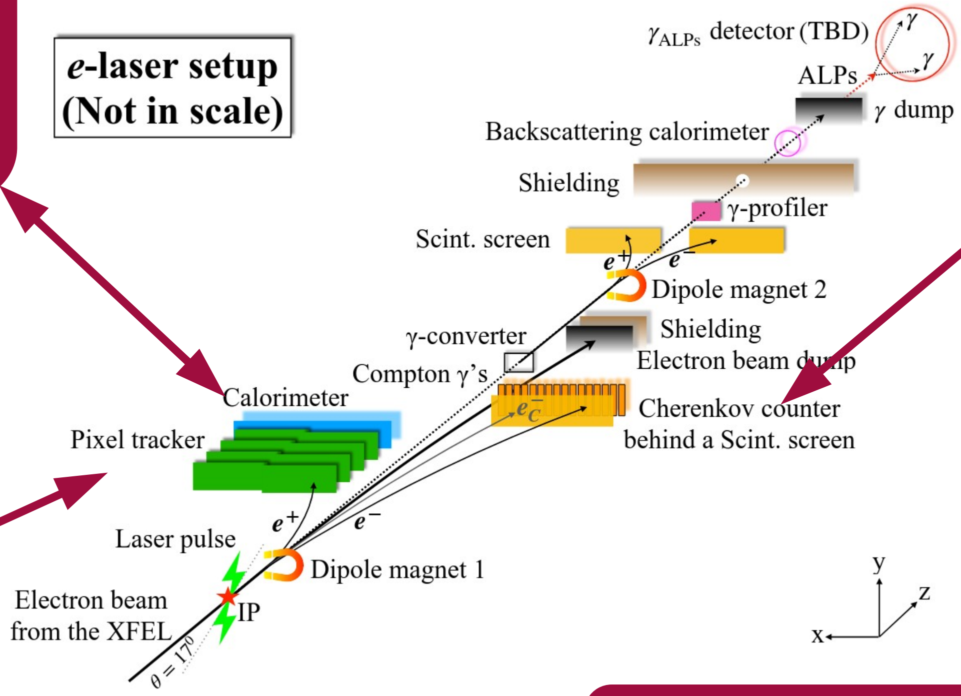


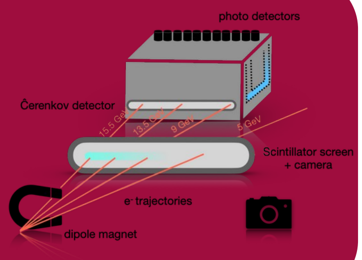
CALICE -type calorimeter

FCAL-type calorimeter



ALPIDE sensors (ALICE)





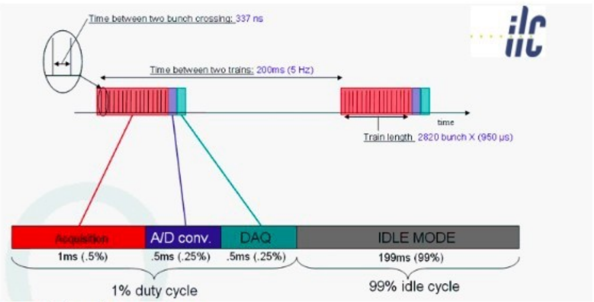
ILC polarimeter

Near future applications for FC detector protoypes: LUXE, EBES, Lohengrin, etc

Overview of detector concepts

Detector concepts ILC-CLIC (Jinlong Zhang)

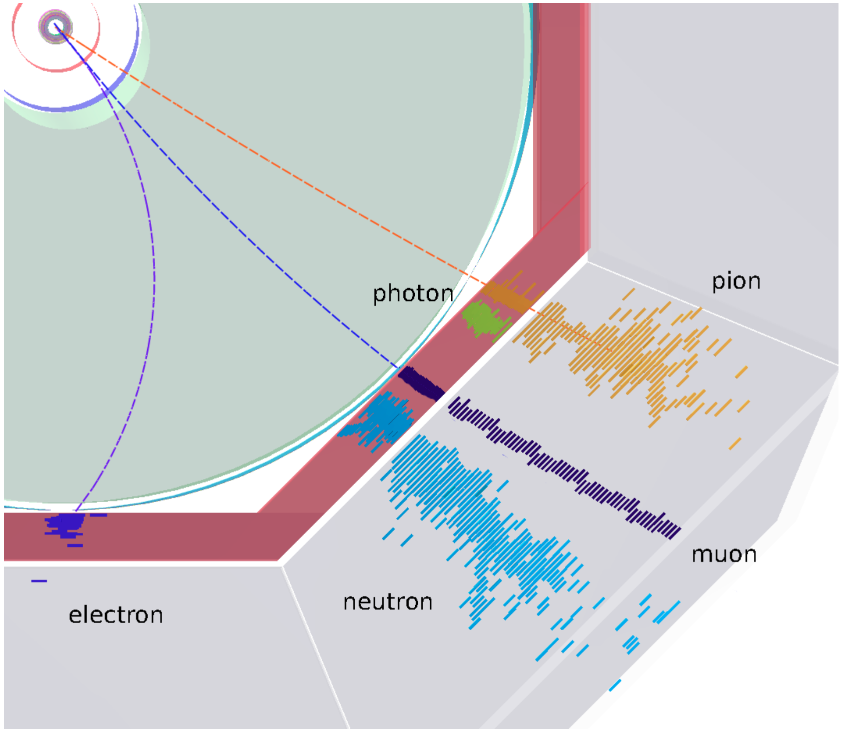
Detector Requirements		⟷ Physics Studies
Impact parameter resolution $\sigma(d_0) < 5 \oplus 10 / (p[\mathrm{GeV}] \sin^{3/2}\theta)\ \mu m$	~ LHC / 2	$H \rightarrow bb, cc, \tau\tau$
Transverse momentum resolution $\sigma(1/p_T) = 2 \times 10^{-5}\ \mathrm{GeV}^{-1} \oplus 1 \times 10^{-3} / (p_T \sin^{1/2}\theta)$	~ LHC / 10	Total $\sigma(e+e- \rightarrow ZH)$
Jet energy resolution 3-4% (around E_{jet} ~100 GeV)	~ LHC / 2	$Z/W/H \rightarrow jj$; $H \rightarrow$ invisible
Hermeticity $\theta_{min} = 5$ mrad	~ LHC / 3	$H \rightarrow$ invisible; BSM



N.B. Final numbers may vary

- Electronics switched on during > ~1ms of ILC bunch train and data acquisition
- Bias currents shut down between bunch trains

Mastering of technology is essential for operation ofILC detectors



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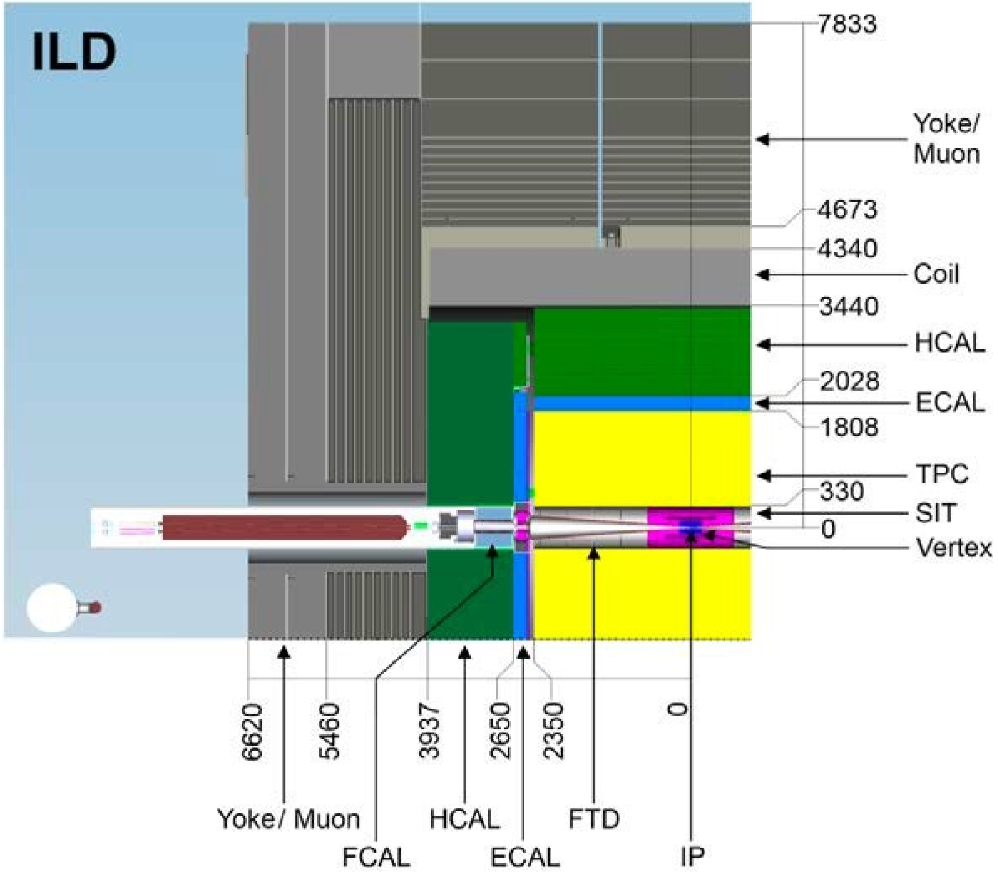
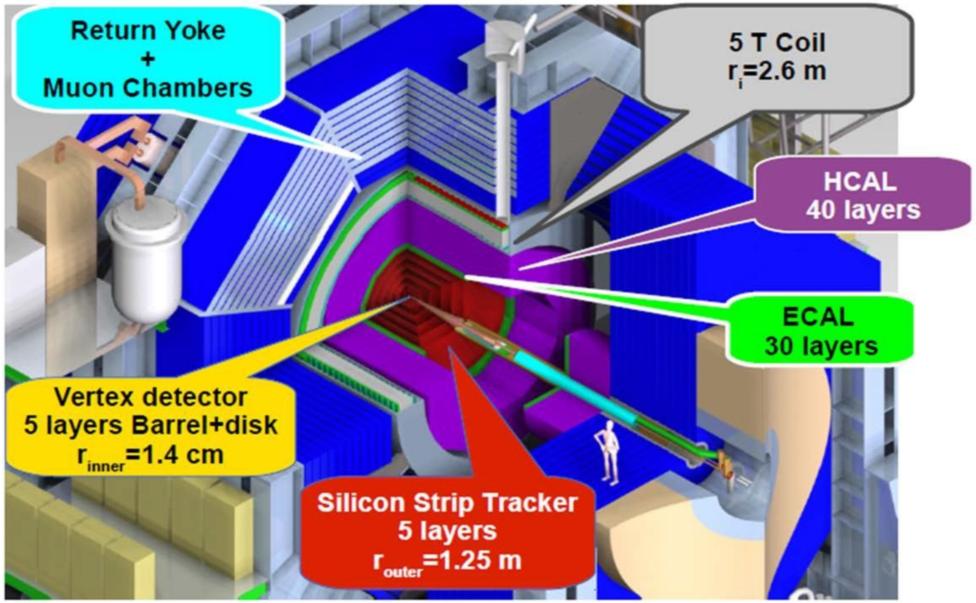
Detector concepts ILC-CLIC (Jinlong Zhang)





ILD & SiD

- ▶ SiD meeting on wednesday

  https://indico.slac.stanford.edu/event/7467/sessions/515/#20230517

	Welcome	53/3-3004 - Havasu, SLAC	Andrew White et al.	16:45 - 16:50
17:00	Higgs Factory Detector R&D	53/3-3004 - Havasu, SLAC	Jim Brau	16:50 - 17:10
	SiD & PiD	53/3-3004 - Havasu, SLAC	Marcel Stanitzki	17:10 - 17:25
18:00	Discussion	53/3-3004 - Havasu, SLAC		17:25 - 18:10
	Adjourn for Dinner	53/3-3004 - Havasu, SLAC		18:10 - 18:15

- ▶ ILD meeting on wednesday

  https://indico.slac.stanford.edu/event/7467/sessions/514/#20230517

WEDNESDAY, MAY 17

		Speaker		
9:00 PM → 9:20 PM	ILD: Status and Plans	Kiyotomo Kawagoe (Kyushu University)	ILD-status-LCWS20...	20m
9:20 PM → 9:40 PM	Technical plans and opportunities at ILD	Mary-Cruz Fouz Iglesias (CIEMAT - Centro de Investigaciones Energéticas Medioambientales y Tec. (ES))	ILD_TC_LCWS2023...	20m
9:40 PM → 10:00 PM	Status of ILD/ ILC software and simulation	Daniel Jeans	lcws23-ild-software...	20m
10:00 PM → 10:20 PM	Status of ILD analyses	Aleksander Filip Zarnecki (University of Warsaw)	lcws2023_2023051...	20m
10:20 PM → 10:30 PM	Discussion			10m

- ▶ Plus a talk: ILD status and plans
  - T. Behnke

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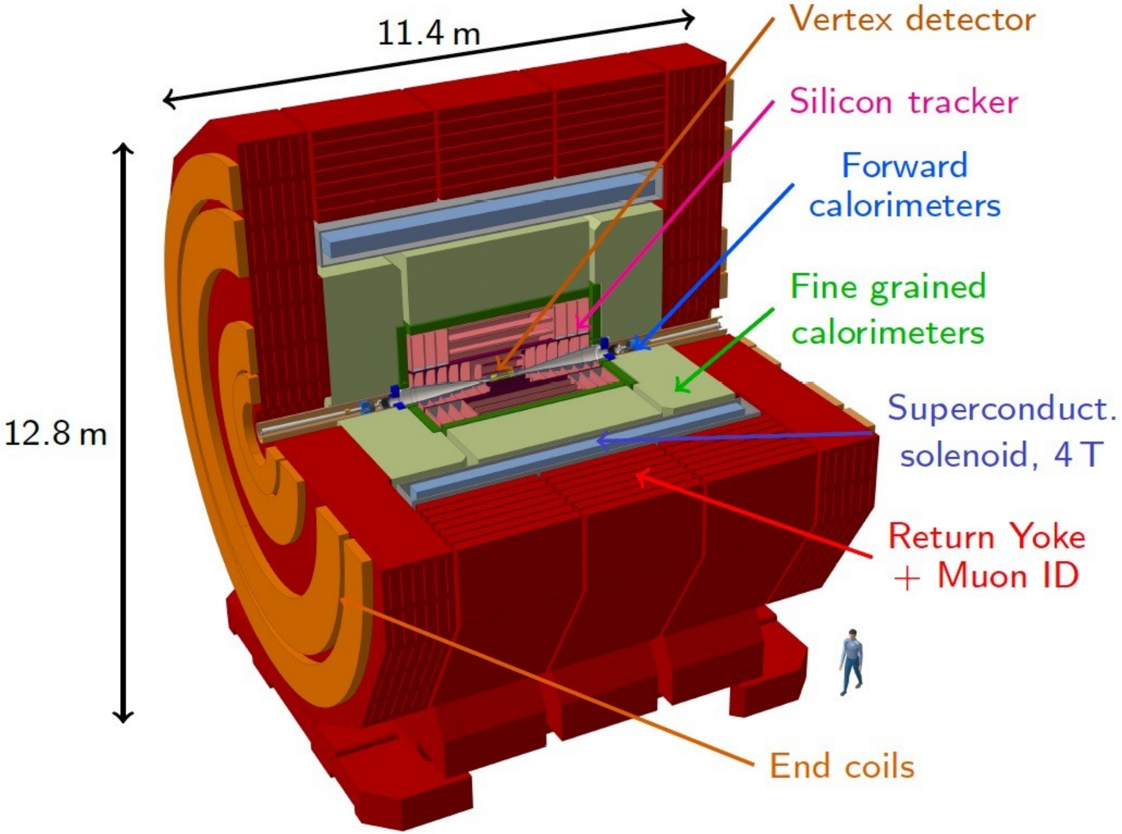
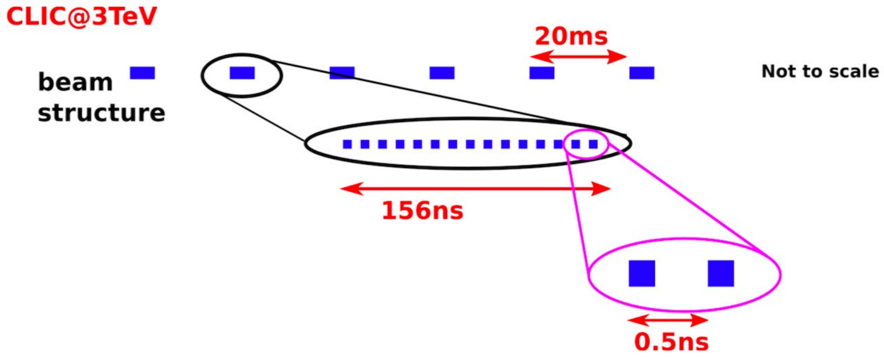
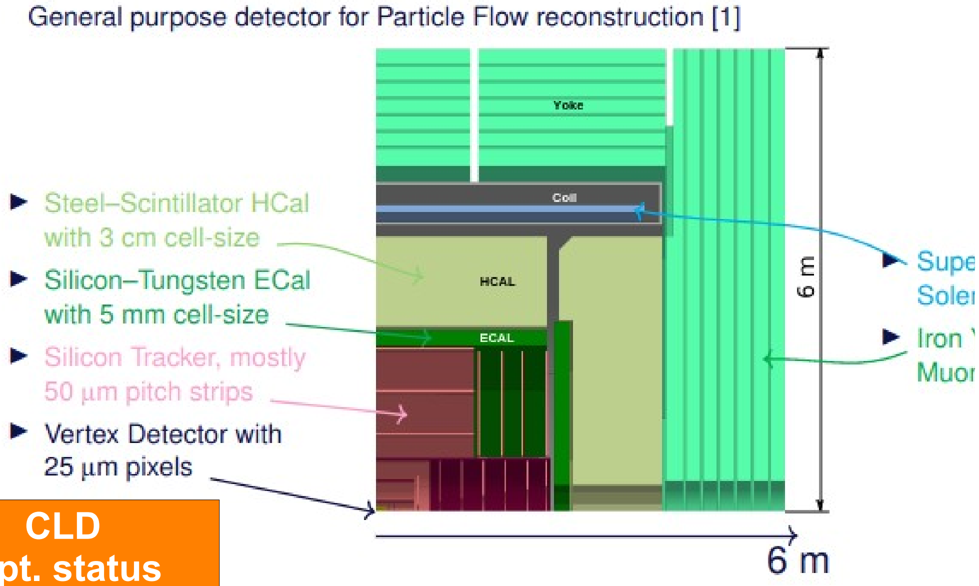
Detector concepts ILC-CLIC (Jinlong Zhang)

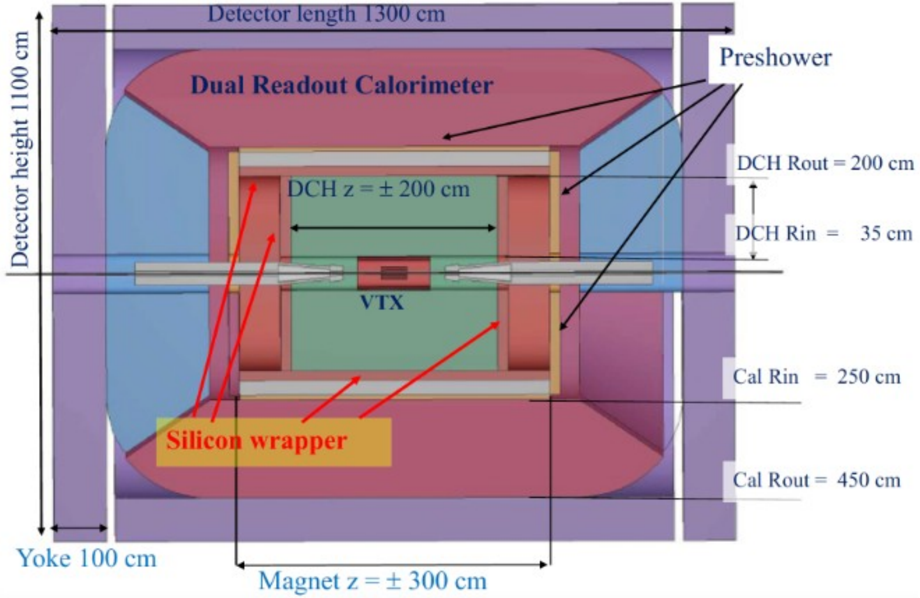




CC concepts: FCC



CLD
opt. status
L. Reichenbach

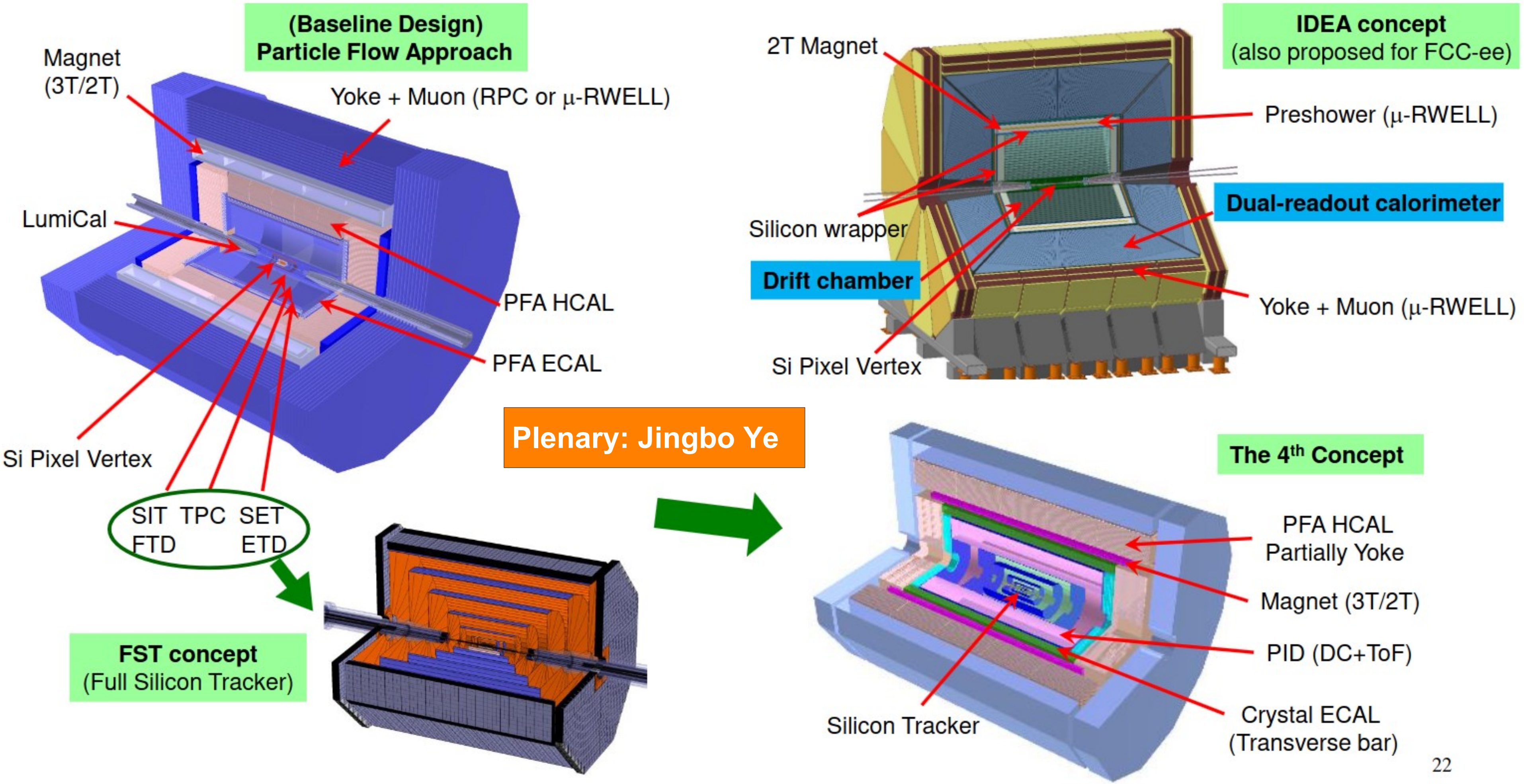


Schematic layout of the IDEA detector concept for FCC-ee [2]

Status of simulation: Full simulation in Geant4
Goal now: Full simulation in native Key4hep!

IDEA
full simulation
A. Ilg

CC concepts: CepC



Further optimizations of the concepts

Some of the most mentioned R&D topics in this meeting

- Precise timing
  - For PID (10-50ps)
  - For improved tracking (ns)
  - For Calorimetry PF ?
- Highly integrated sensors: MAPS
  - Not only for tracking
- Different PID approaches
- Smart sensors/ASICs
- Better and modern software frameworks
  - Simulation
  - Reconstruction
  - analysis

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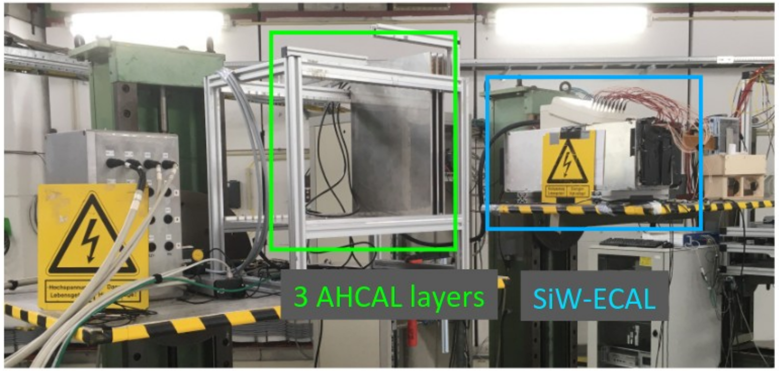
calorimetry

SiW-ECAL (R. Poeschl & A. I.)

SiW-ECAL + AHCAL DAQ test @ DESY in March 2022

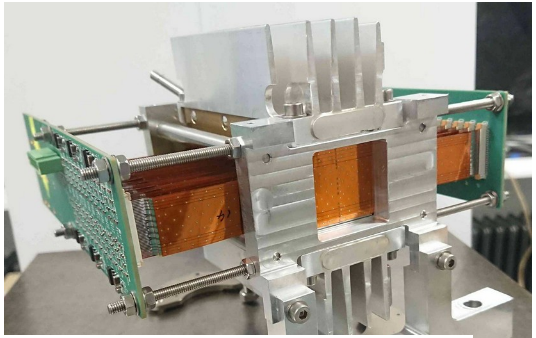


15360 + 22000 (full analogue) readout cells

- Two beam tests campaigns in 2021 and 2022
  - ... partially in combination with CALICE AHCAL
  - Data analysis is still ongoing
  - See also Adrian's talk on Chip-On-board PCBs
- CALICE SiW ECAL is about to reply to conclusions from 2021/22 beam test campaigns
- Understanding and remedying of observed sensor delamination
  - Independent of application in future projects
  - One study ongoing with underfill agent and epoxy with better mechanical properties
  - Further solutions will have to be studied and evaluated
  - Need a conclusion this year in order to move on
- New PCB designed and meanwhile manufactured
  - Basis for revised 15 layers stack => Gearing up for next beam test campaign in 2024
  - Will be important step towards readiness for linear collider detector construction
- Precious feedback from LHC Upgrades for future steps
  - System integration, timing, active cooling

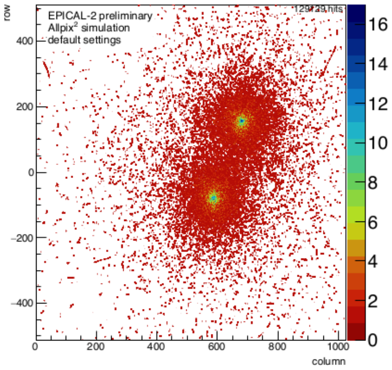
Chip-On-Board PCB:
Ultra-thin 1.2mm
Naked ASICs wirebonded.
Cavities (~250um) for the ASICs

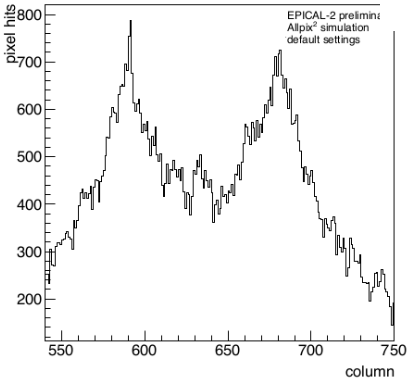
ultra-high granularity CMOS ECAL (N. Watson)

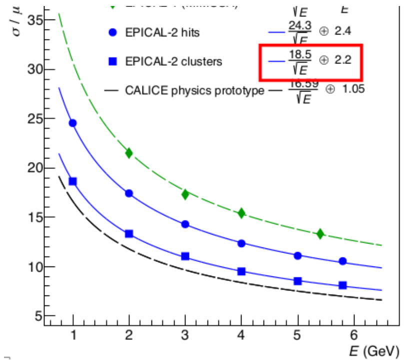


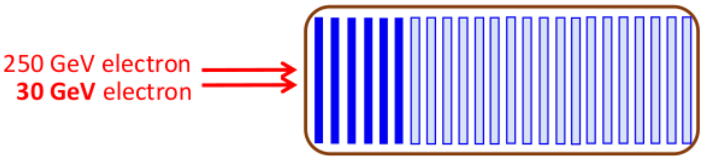
24 layers, each
- 3 mm W / 2 ALPIDE CMOS
- 3 x 3 cm^2 active
- 1M (29.24 x 26.88 μm^2) pixels
- ultra-thin flex cables (LTU Kharkiv)
- compact design: expect $R_M \approx 11$ mm

- **Si-W calorimetry can give excellent PFA performance**
  - Potential for reconfigurable technology: outer tracker/preshower/ECAL
    - I.Kopsalis et al, NIM A1038 (2022) 166955
    - P.P.Allport et al, Sensors 2022, 22(18) 6848
- Affordable Si-W calorimeters, sensors ~ CHF/cm^2 (active areas > 10^7cm^2)
  - Potentially achievable with CMOS MAPS
- Power needs study, CMOS estimates range ~50-100mW/cm^2 (no pulsing)
- Prototype demonstrating concept of digital ECAL, in same CMOS line as CERN et al, can deliver radiation hardness to > 10^{15}neq/cm^2
- **Digital EM calorimetry, high potential esp. for future e^+e^-**
  - Ultra-high granularity can benefit physics as well as cost (boosted decays)
  - Calorimetric performance demonstrated
  - Existing data with EPICAL-2 up to 80 GeV / SPS (analysis in progress)
  - Enhance with optimised sensor development
  - ECFA DRD proposal and interested in collaborate widely ☺

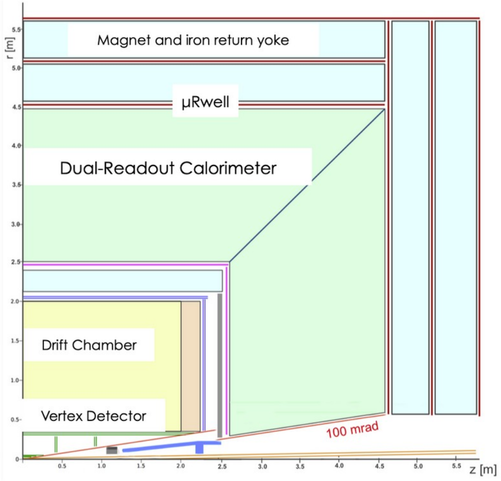


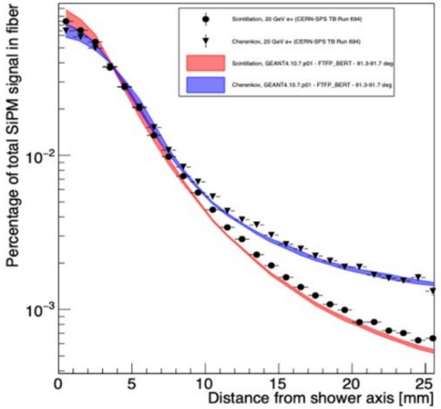


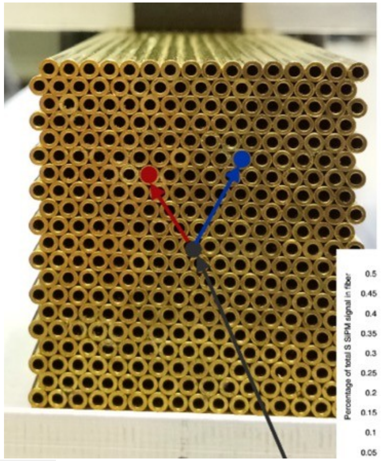


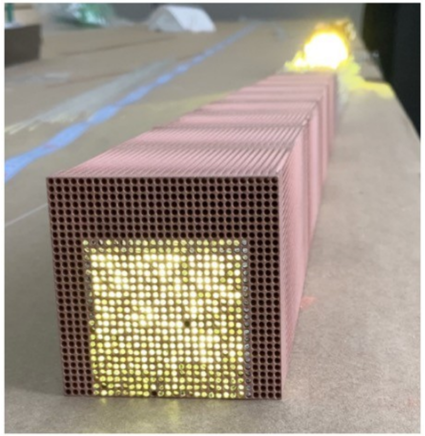


Dual RD (S. Kunori)





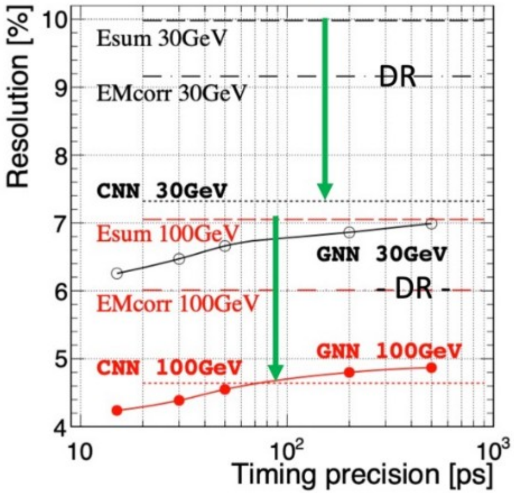




dE/dx (ionization) Calorimeter (*1)

20x20x20 mm^3 cube
Cu (17) +Si (3)

CNN: 0-5 ns 1 image/cube
GNN: 0-10 ns 8 images/cube (1st image: 15 ps)

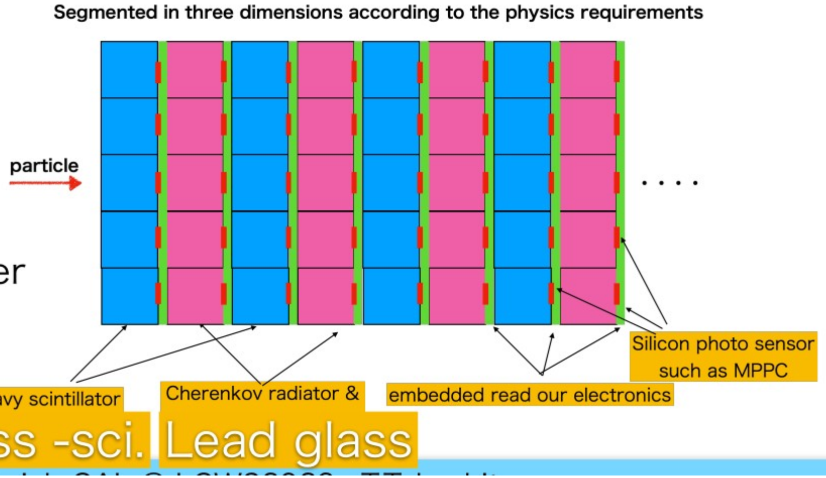


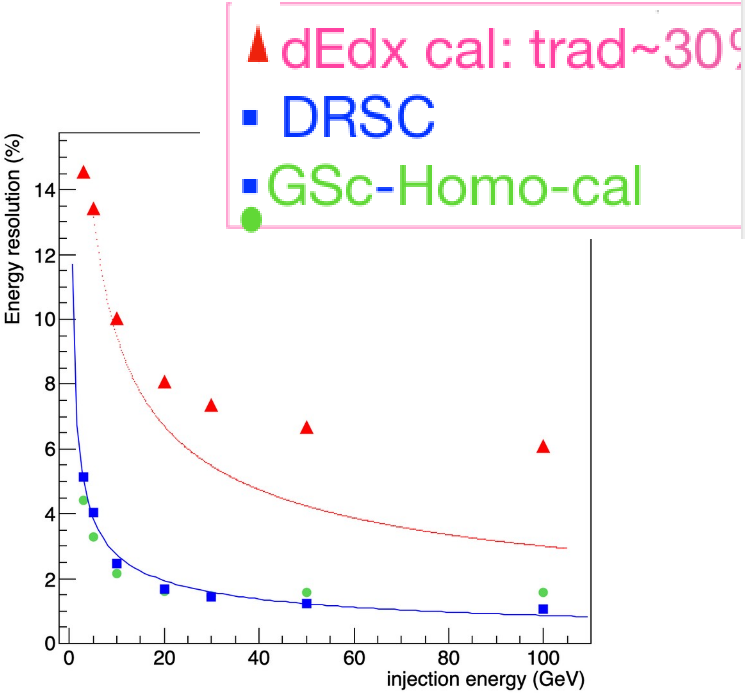
NN trained with pi+ works well for electrons/photons and jets.

Sandwich Dual RD (T. Takeshita)

a new idea :DRSC

- separate Cherenkov radiator and Scintillation material with sandwich style (TL, active absorber, ED)
- with highly granular option for PFA
- DRSC
  Double
  Readout
  Sandwich
  Calorimeter





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PFA Calo designs: lineal vs circular (R. Poeschl)

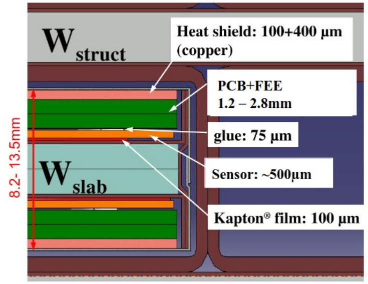
- Choice of collider option has considerable influence on calorimeter deseign

- Current (ILD) Calorimeter design seems to be well suited for all Linear Collider Options
  - Very short bunch train separation (CLIC) may comprimise compromise cpacotir recharging for Local power storage

- The break comes when considering circulaar colliders
  - Smaller magnetic field
    - ==> Larger inner Ecal radius
  - Continous operation
    - ==> No power pulsing
    - Different data acquisition architecture
    - Different (more?) services
  - Smaller granularity (lateral (not shown) and longitudinal
  - Barrel/endcap may become critical
    - Watch closely with detailed simulation!
  - What to optimise for Z-pole, HZ?

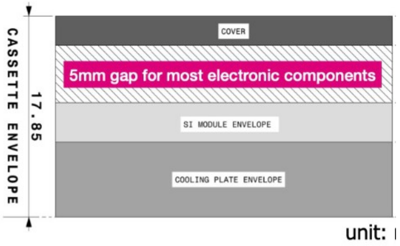
- Conclusions for ILC can be ported to other LC options
- Circular machines require a full blown optimisation study (partially done for CEPC)

ILD SiECAL



- **Two** layers within 13mm max.
- Including one absorber layer
  - 2.1mm or 4.2mm W
- 500um for heat evacuation

CMS HGCAL
N. Strobbe, CALOR 2022



- One layer within ~18mm
  - w/o absorber
  - 6mm for cooling

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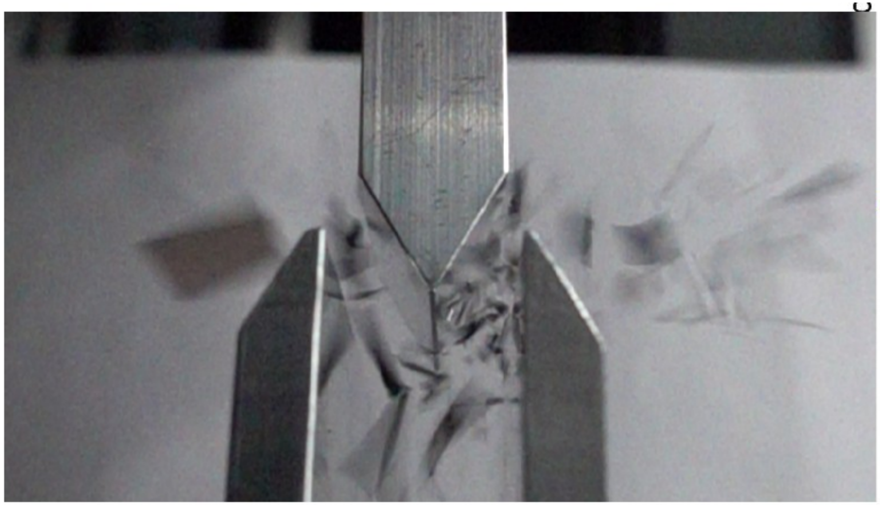
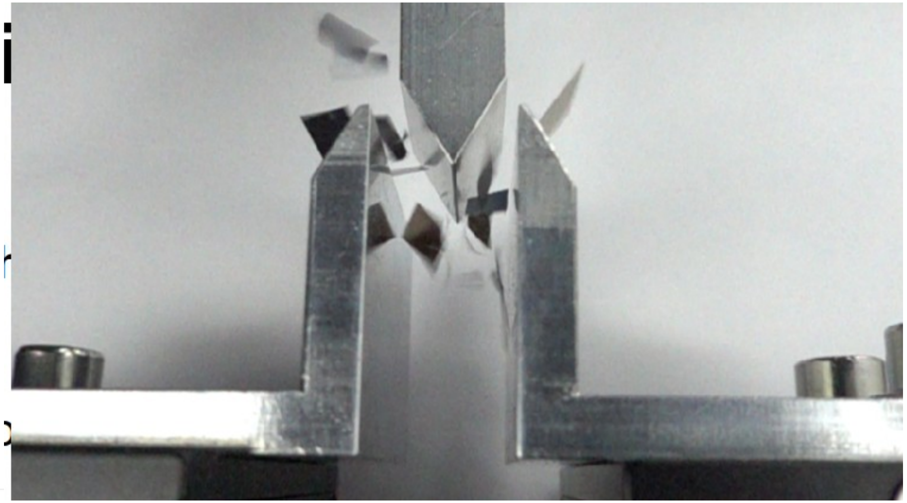
Tracking & PID

MAPS, ITS3 (M. Mager, M. Vassilev)





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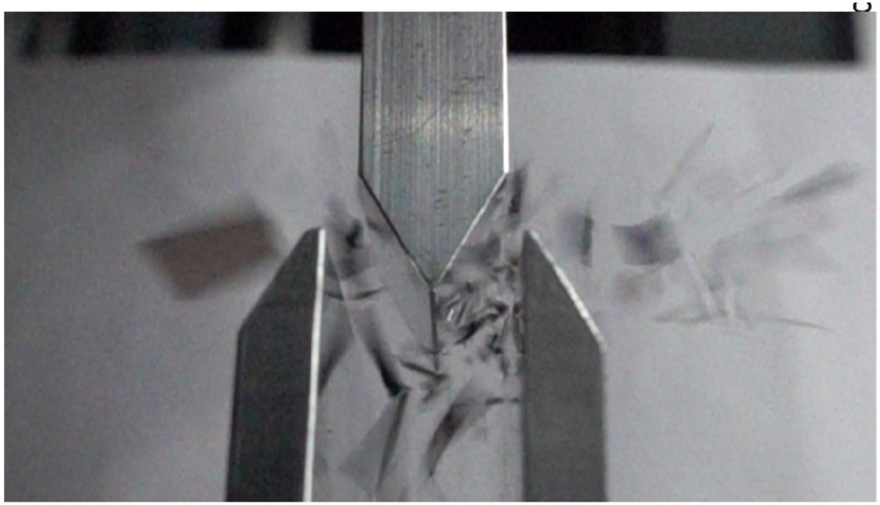
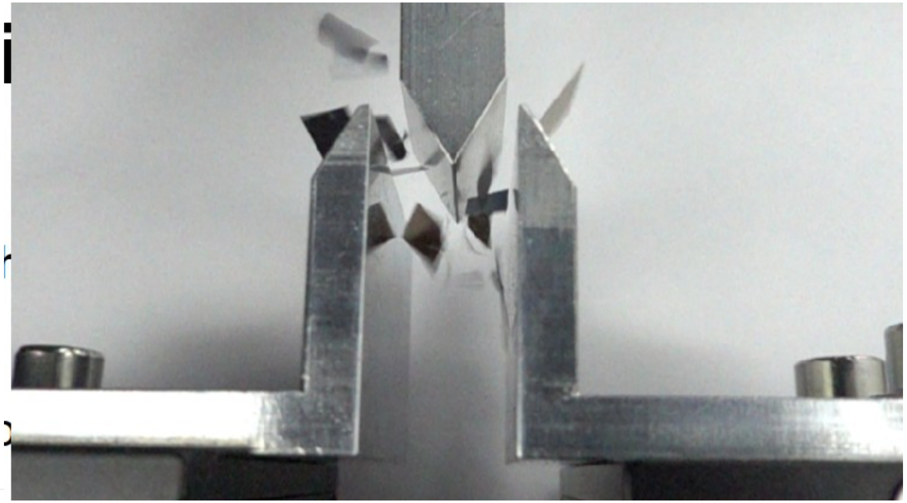
MAPS, ITS3 (M. Mager, M. Vassilev)





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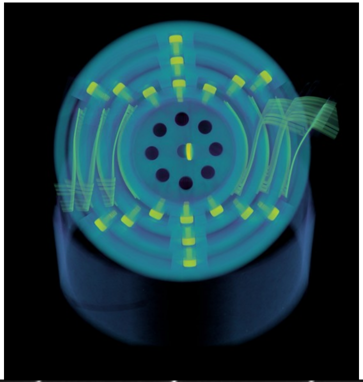
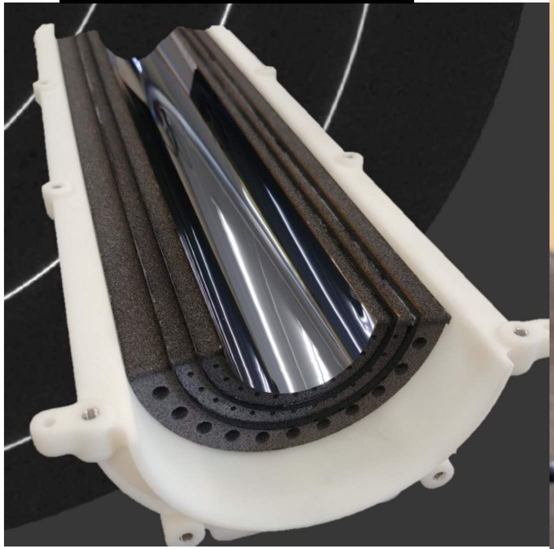
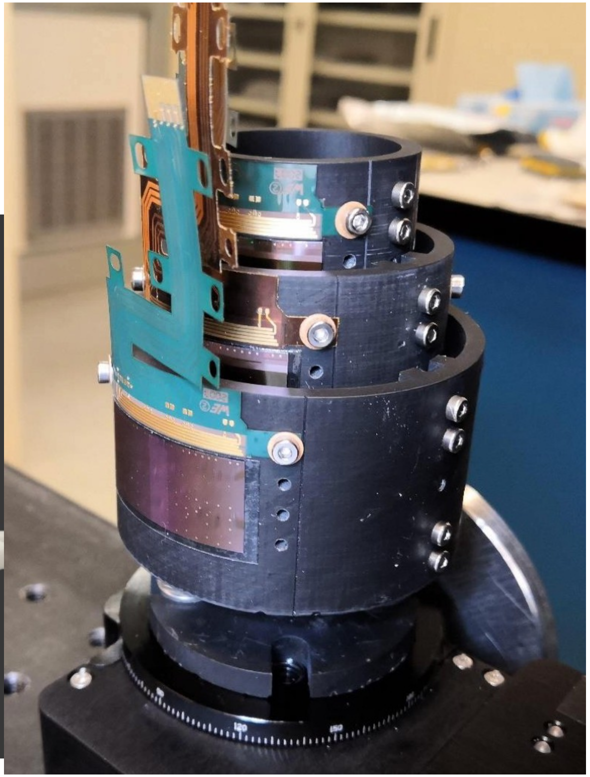
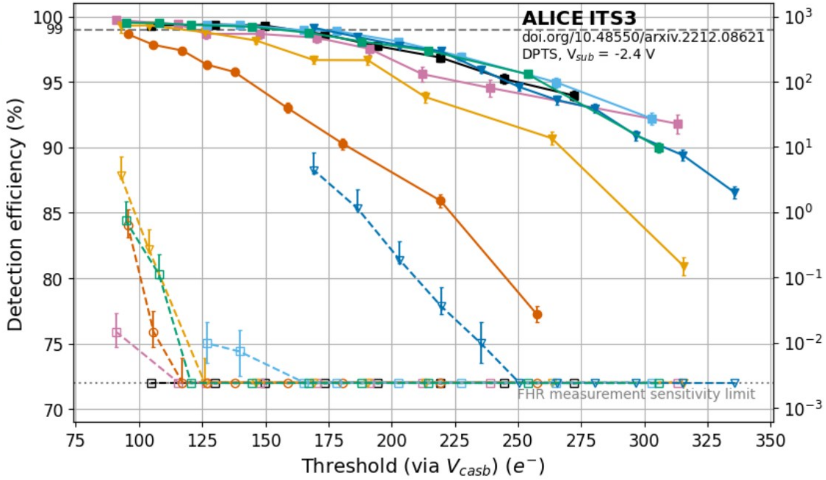
MAPS, ITS3 (M. Mager, M. Vassilev)

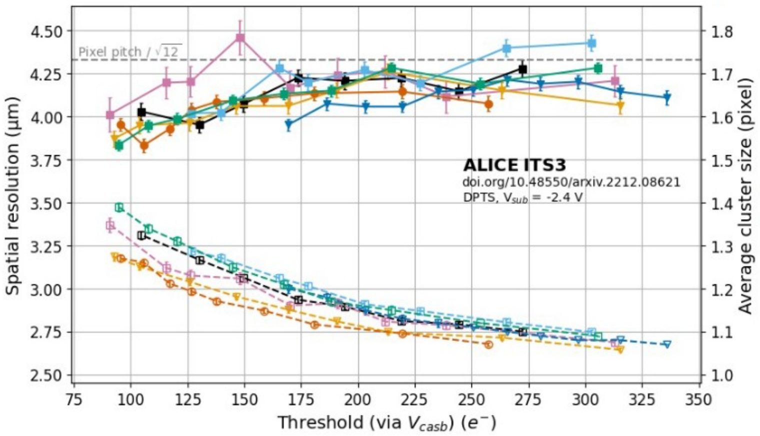






Digital pixel test chip ("DPTS")

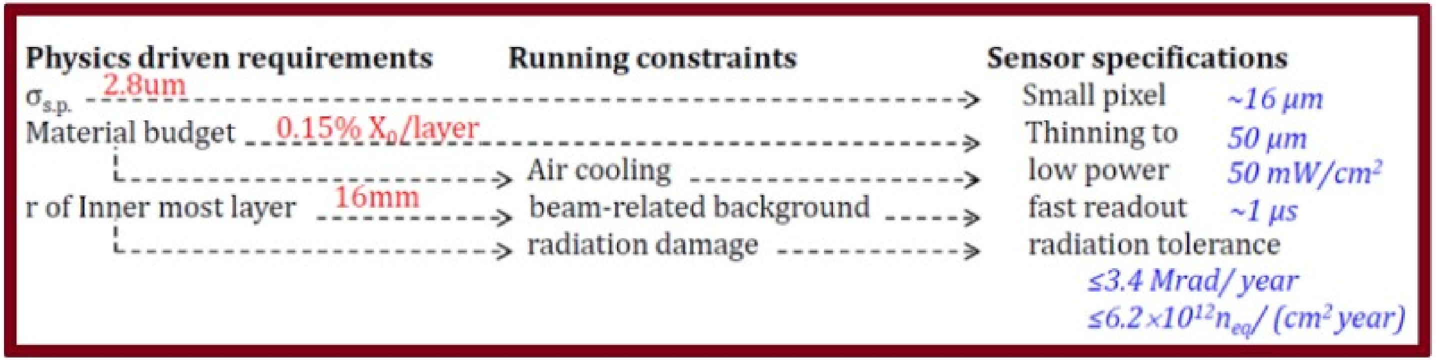




MAPS, ITS3 (M. Mager, M. Vassilev)

ALICE
5 μm
0.05 % X_o/layer

18 mm



ALICE
15 μm
<50 μm
20 mW / cm^2
–

1 Mrad
10^{13} 1 MeV n_{eq}/cm^2

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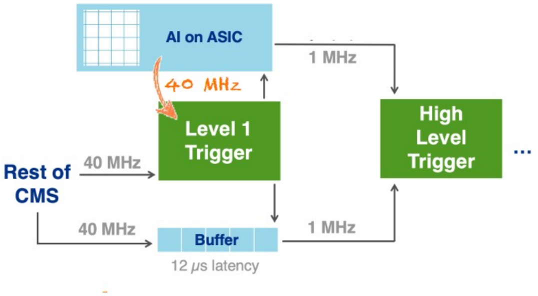
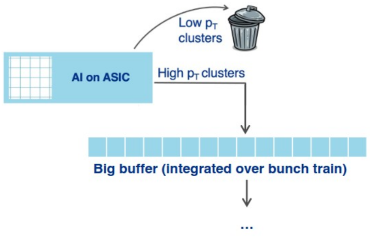
MAPS: novel ideas (J. Dickinson)

Pixel readout chain: our futuristic CMS detector

- Detector is an array of **4N** pixels
  - **50 x 12.5** μm pitch
  - 100 μm thick sensor
- **Pixel data is passed to L1 trigger at 40 MHz**
- Passed to HLT at 1 MHz

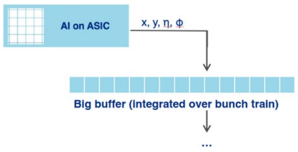




e^+e^- collisions: on-ASIC filtering

e^+e^- collisions: on-ASIC featurization

e^+e^- collisions with on-ASIC data reduction



Smart pixels: summary

- AI on-chip has great potential to **reduce data rates to manageable levels**
  - First implementation of the p_T filtering looks very promising!
  - Feature extraction for x, y, α, β underway
- Plan to leverage **emerging technologies** to improve energy efficiency, accuracy
- Co-design with focus on preserving **information that is useful for physics**
  - For e^+e^- this reaches all the way down to accelerator level
  - Smart pixels would provide **more flexibility** in experimental design at linear e^+e^- machines

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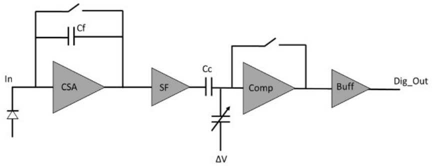
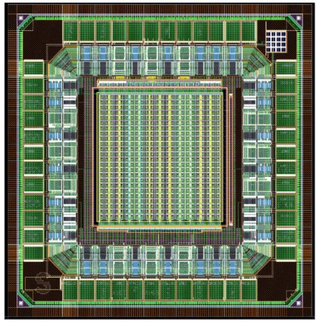
MAPS for Large Area Sensors with timing ~1ns (A. Habib)

NAPA_p1: NAnosecond Pixel for large Area sensors – Prototype 1

- Design in Tower Semiconductor 65 nm imaging technology, capitalizing on the CERN WP1.2 efforts over a decade of sensor optimization.
- The prototype design submitted with a total area 5 mm x 5 mm and a pixel of 25 µm × 25 µm, to serve as a baseline for sensor and pixel performance.

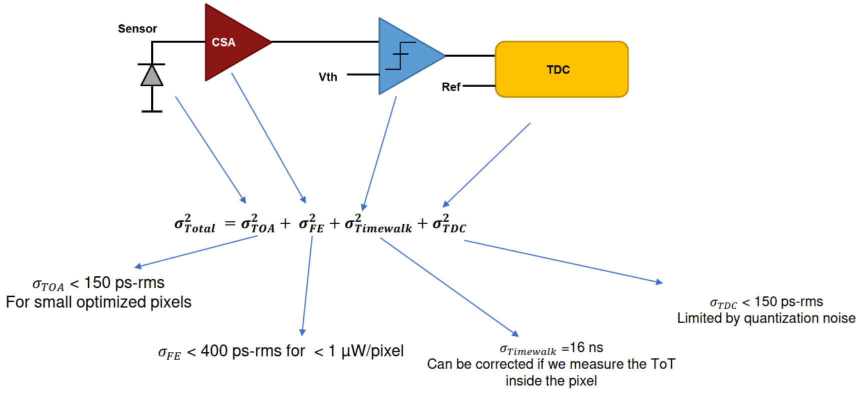




Layout of MAPS SLAC prototype for WP1.2 shared submission

Pixel key elements

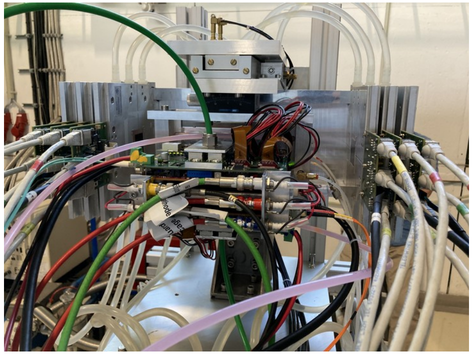
- Charge Sensitive Amplifier (CSA) with a synchronous reset, which can be powered down during inactive time
- A comparator with auto-zero technique, removing the need for per-pixel threshold calibration

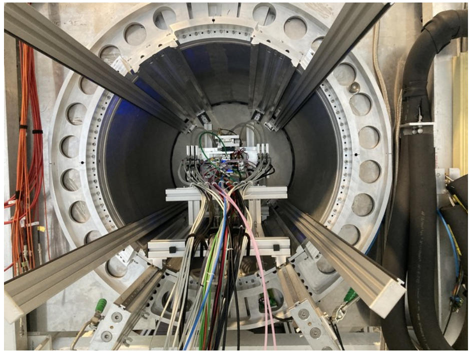


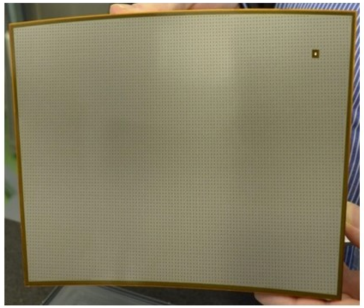
SLAC

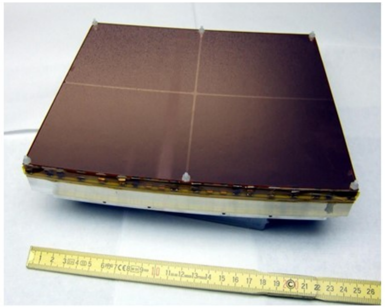
Assuming time walk is fully corrected ➔ σ_{Total}~500 ps-rms with reasonable pixel power consumption, going lower will cost increasingly more power, not compatible with large area sensors. Accounting for residual time Walk after correction, and other non-idealities, it is reasonable to aim for 1 ns-rms time resolution

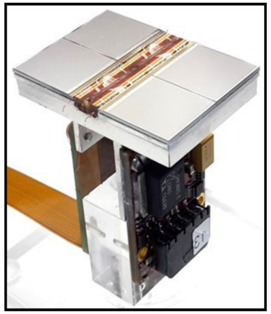
TPC (LC-TPC collab, P. Kluit)











Micromegas GEM GridPix

Sic-->

- A single chip GridPix detector was reliably operated in a test beam in 2017
- A Quad detector was designed and the results from the 2018 test beam shown
- An 8-Quad module has been designed with guard wires
- Preliminary 2021 test beam results are excelllent

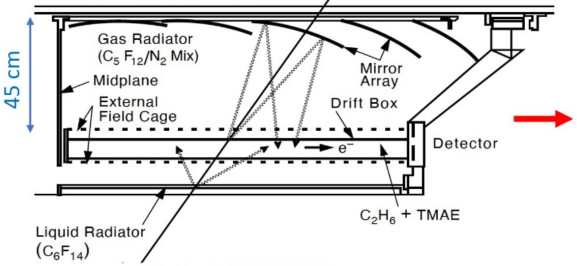
▶ A pixel TPC has become a realistic viable option for experiments

Gaseous compact RICH (J. Va'vra)

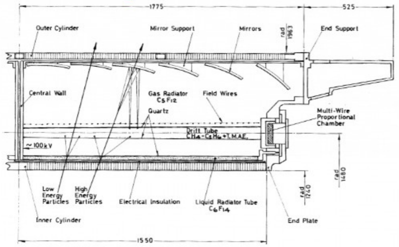
- ▶ pi/K separation of 4.6s is possible at 50 GeV/c & 5 T,
  - if tracking direction error will be ~ 0.1 mrad.
- ▶ the focusing effect error is larger than the magnetic smearing error for momenta larger than 20 GeV/c.

- ▶ Next:
  - Introduce a realistic SiPM noise to verify that timing cuts work.
- ▶ Down the road challenges:
  - Optimize optical design of the entire system considering all tracks.
  - MC simulation of the entire system

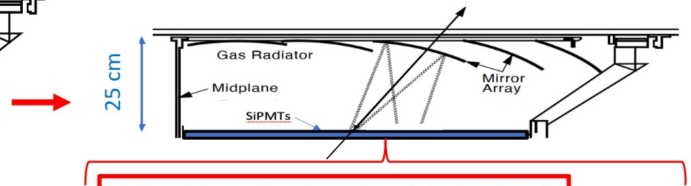
SLD CRID:



Delphi RICH:



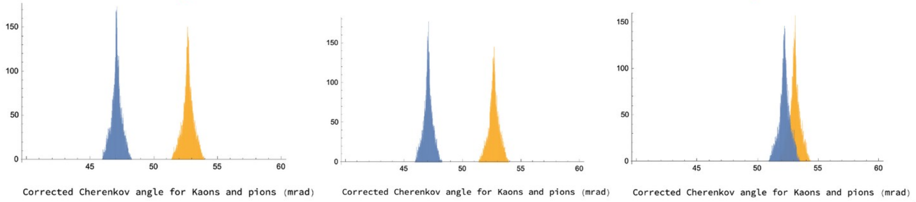
Our proposed RICH:



- C_4F_{10} at 1 bar (boiling point -1.9 C at 1 bar)
- Beryllium mirrors with reflective coating
- Low mass carbon-composite structure
- Timing will be used to cut SiPM noise
- SiPM detector will run at +2-3°C

PID for $\theta_{dip} = 40°$

Typical rms error (pion) ~ 0.43 mrad per single hit



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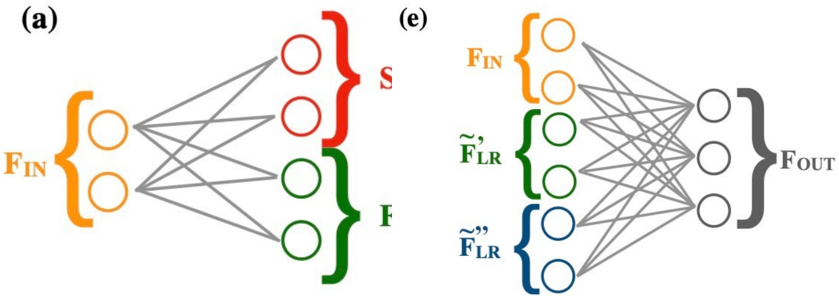
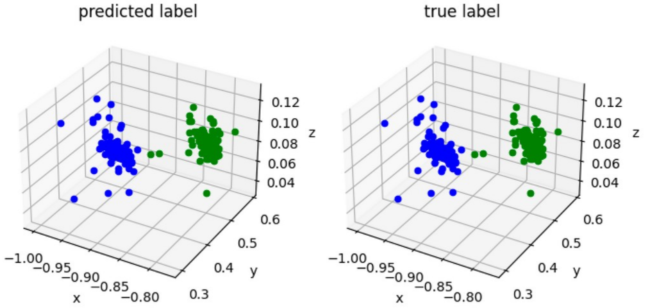
tools

High Level Reco with DNN (T. Suehara)

- Calorimeter clustering with GravNet/Object condensation (S. Tsumura)
  - Deep Learning application to PFA
  - Calorimeter clustering





- b/c tagging with Graph Attention Network (T. Onoe)

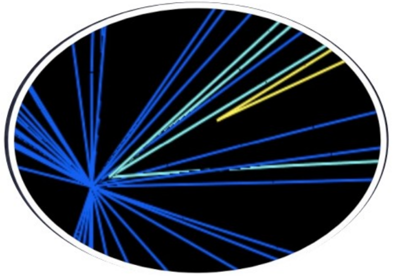


Fig. Event display of Monte-Carlo simulation

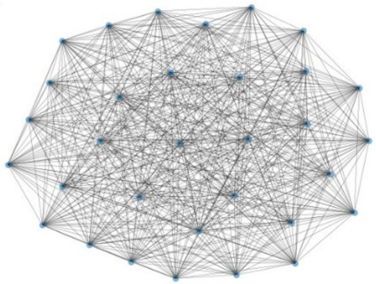
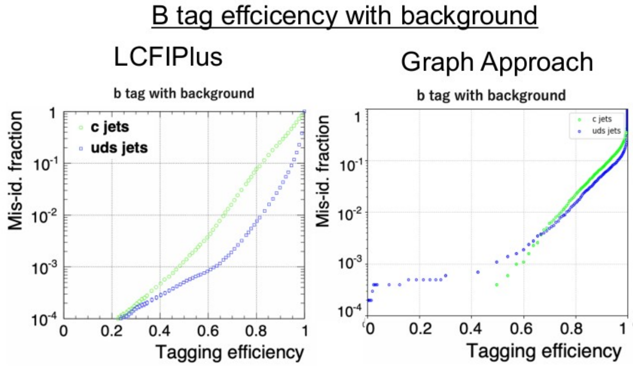


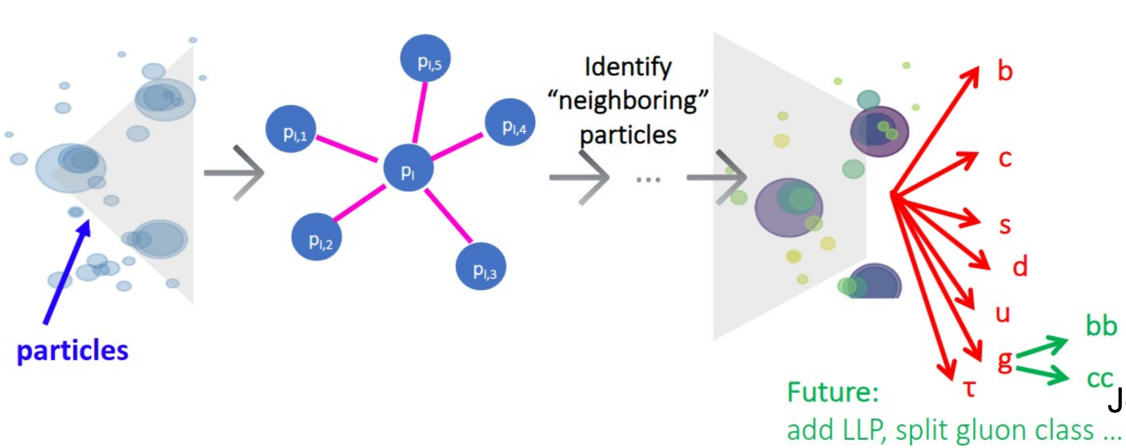
Fig. example of a jet as a graph

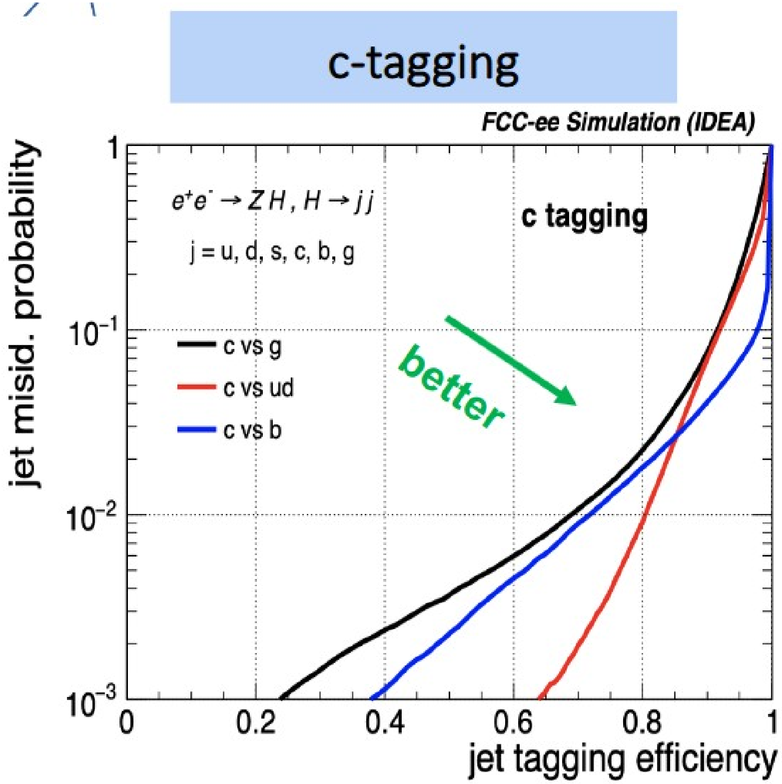


Jet flavor identification (FCCee, L. Gouskos)

Scope of this work:
General framework for developing flavor tagging algorithms for future colliders [eg., e^+e^-]

- Fast detector simulation
  - Understand detector requirements/ optimize design
    - eg., vertexing and PID capabilities of the FCCee detectors
- Develop a versatile flavor tagger
  - identify different particle species
    - Results shown for FCC-ee & IDEA detector





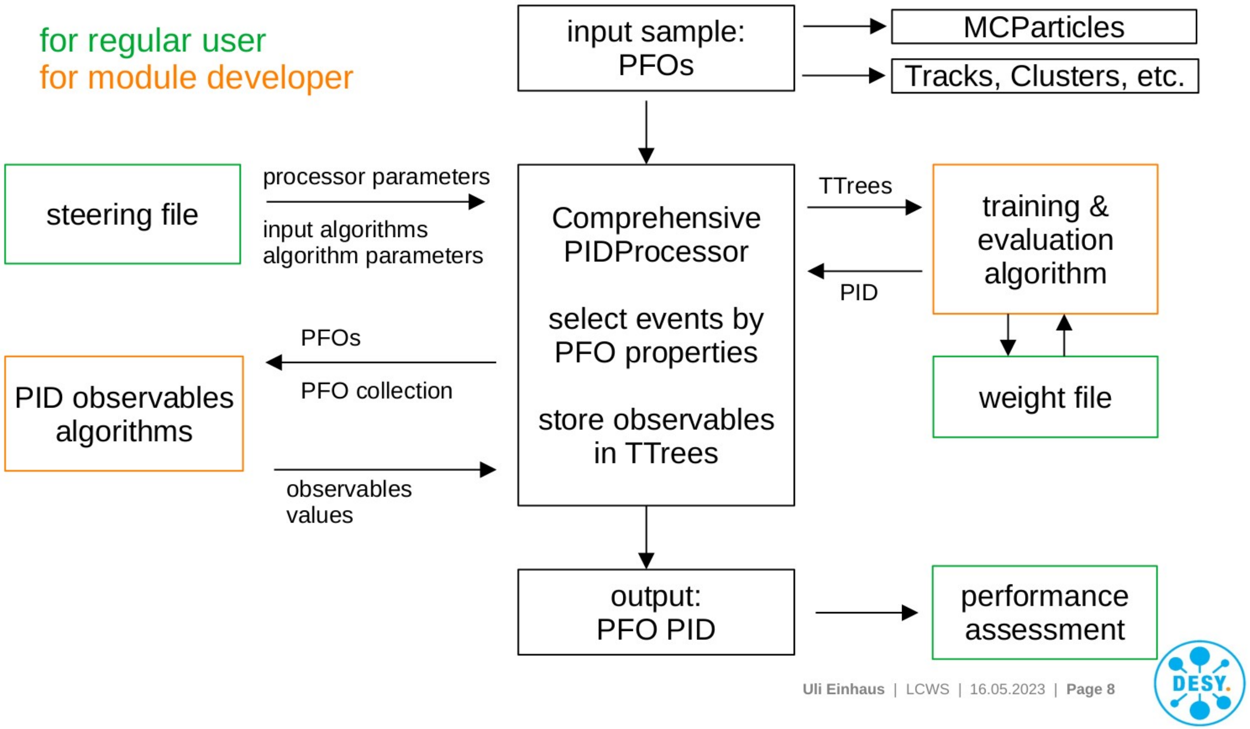
Jet representation: Particle cloud

Particle cloud represented as a graph

Hierarchical learning approach: local à global structures

Particle ID Framework for FC (U. Einhaus)

Common platform for future e+e- Higgs factories
- Allow for
– combining and comparing PID techonologies
– assessing on full detector level with robust performance quantities
– easy-to-use retraining and flexible adaptation
- First performance indicators already comparable to state-of-the-art
- Application to ongoing ILD physics analyses under discussion



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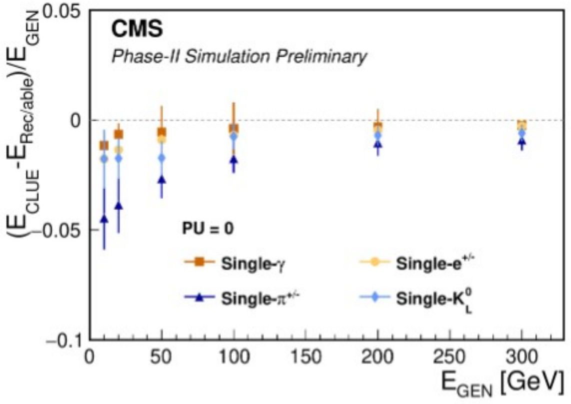
K4CLUE (E. Brondolin)

● CLUE (CLUstering of Energy) is a fast density-based clustering algorithm for the next generation of sampling calorimeter with high granularity in HEP

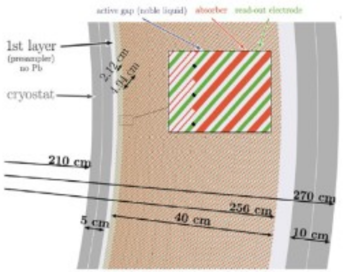


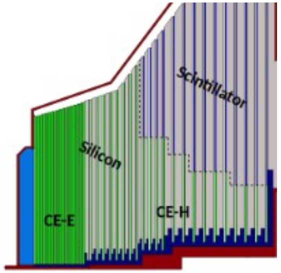
Conclusions

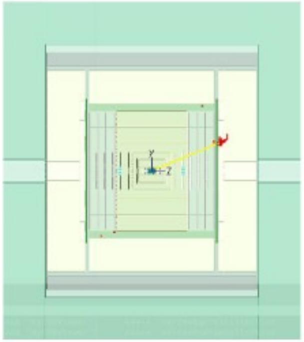
- k4Clue package (v01-00) has improved upon the standalone CLUE
  - Run on the full detector (barrel & endcap)
  - Adapted for different types of calorimeters
- Analysis on three different future calorimeters has demonstrated the good performance for single gamma events
  - Good performance even in the presence of noise
  - Compared favorably to other baseline algorithms

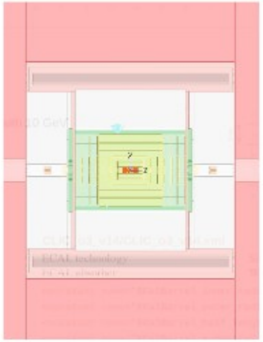
This work highlights the adaptability and versatility of the CLUE algorithm for a wide range of experiments and detectors, as well as its potential for future high-energy physics experiments beyond CMS

  - Improvements from k4clue also under discussion to use the developments also in CMS (Phase-2 barrel region)









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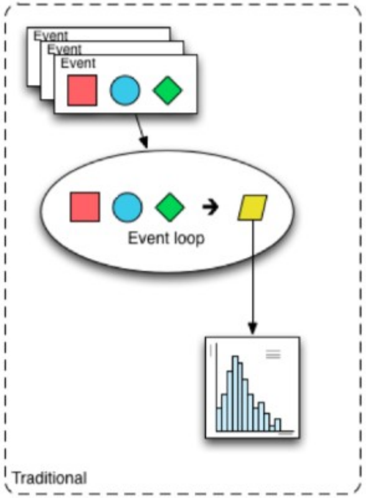
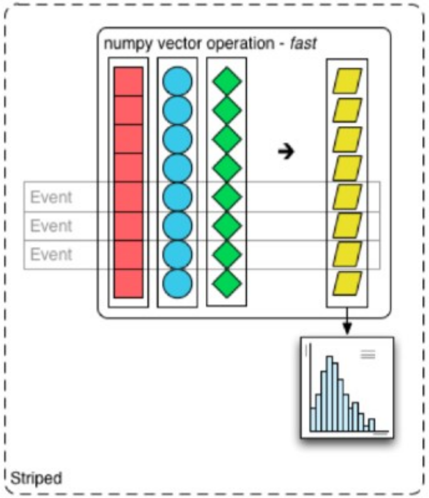
Columnar Analysis for LC using Coffea (L. Gray)

Coffea is

- A package in the scientific python ecosystem
  - `$ pip install coffea`
- A user interface for columnar analysis
  - With missing pieces of the stack filled in
- A minimum viable product
  - We are data analyzers too #dogfooding
- A really strong glue

- Going strong for five years
  - Many published analyses now





Other: detector integration, assembly…

"My logisticians are a humorless lot… they know if my campaign fails, they are the first ones I will slay."

– Alexander the Great

Summary: ILD detector assembly

Conclusions

Detector assembly has been studied in quite some detail in the past

- Check E-JADE Deliverable Report #22: https://www.e-jade.eu/publications/deliverable_reports
- Technical schedule assumes 9 years of construction, 1 year of commissioning
  - Solenoid construction is on the critical path for the detectors
    - R&D, preparation, and construction in industry requires significant funds very early
    - to some extent already in preparatory phase

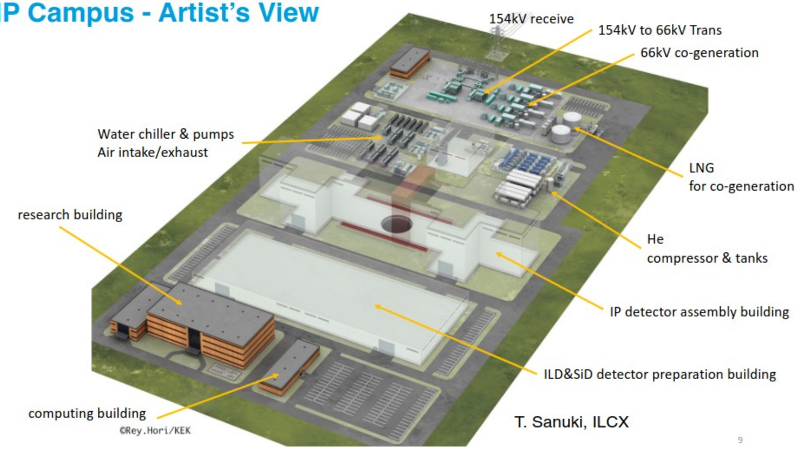
CFS and site schedules have been estimated by LCC and local experts

- Need a significant „preparatory phase“ after green light and before construction start
  - legal procedures, environmental assessment, land acquisition, etc.
    - requires already significant project funding
    - takes 4 (-6) years
- On-site assembly of detector parts can only start after Assembly Hall is ready
  - 3-4 years after construction start, 8-10 years after green light

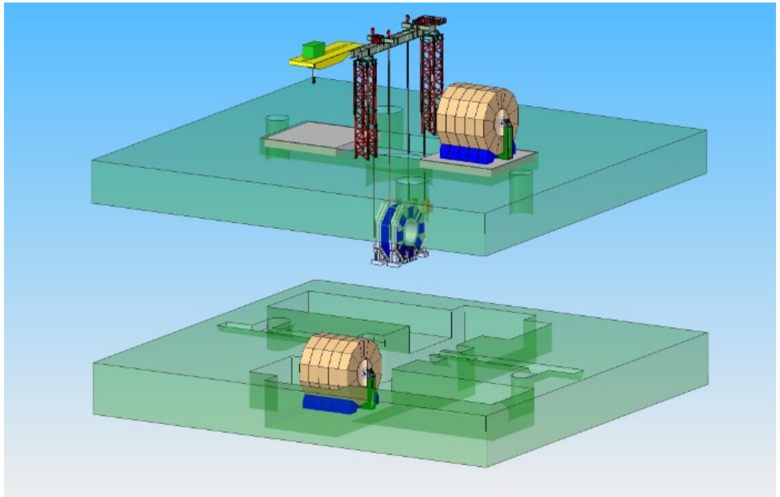
Caveats

- Need to update knowledge about status of local planning
  - Ball has been dropped 2019
- Large uncertainties in all schedules

IP Campus - Artist's View



T. Sanuki, ILCX



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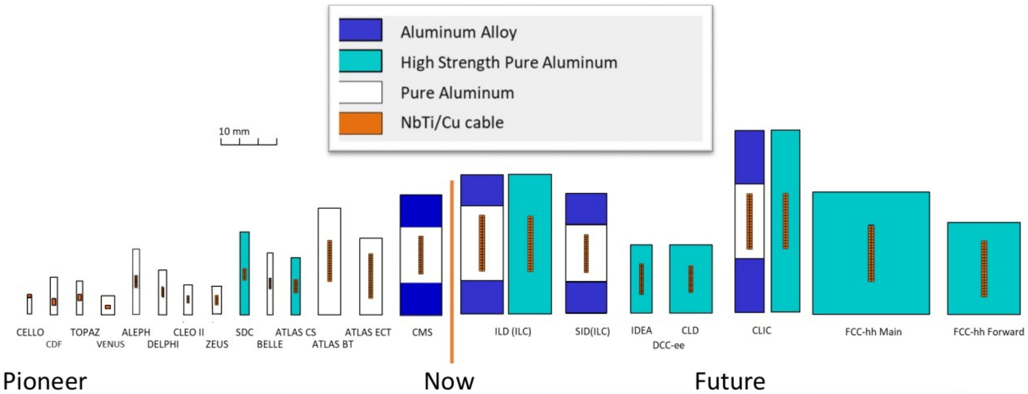
Summary: WS S/C Detector Magnets (K. Buesser)



	Experiments	Site	B	Size ID x L	Energy (MJ)	Note	Fabrication Expected
Collider	EIC-Detector	BNL	1.5~3	2.5~3.2 x 8.5	45.7	Cu only	2025 ~
	ILC-ILD	Japan	4	6.88 X 7.35	2300		2030 ~
	ILC-SiD	Japan	5	5 X 5	1400		2030 ~
	CLICdet	CERN	4	7 X 8.3	2320		2035 ~
	FCC-ee IDEA	CERN	2	4.2 X 6.0	170		2035 ~
	FCC-ee CLD	CERN	2	7.4 X 7.4	600		2035 ~
	FCC-hh	CERN	4	10 X 20	13800		2040 ~
Others	BabyAXIO	DESY	2	0.7 X 10	38	Racetrack	~2024
	AXIO	DESY	5 - 6	5 X 25	500	Toroid (Racetrack)	2024~

Status of co-extrusion in industry

Companies that performed coextrusion for the LHC detector magnets

ATLAS Conductors:

Barrel and End cap toroids:
- VAC Vacuumschmelze , Hydro aluminium (Seneffe, B) (later EAS). *Facility closed in 2014.*
- Alcatel Cable Suisse (later Nexans). *Facility dismantled (2022). Expert left company in 2016.*

No more contact or information available.

Central Solenoid: (Japan)
- Furukawa Electric Co. Ltd,
- Hitachi Cable Co. Ltd.

Ref: H. H. J. Kate, "ATLAS superconducting toroids and solenoid," in IEEE Transactions on Applied Superconductivity, vol. 15, no. 2, pp. 1267-1270, June 2005, doi: 10.1109/TASC.2005.849560.

CMS Conductor:
- Alcatel Cable Suisse (later Nexans). *Facility dismantled (2022). Expert left company in 2016.*

Ref: B. Blau et al., "The CMS conductor," in IEEE Transactions on Applied Superconductivity, vol. 12, no. 1, pp. 345-348, March 2002, doi: 10.1109/TASC.2002.1018416.

Currently no manufacturer in Europe, Japan or US availa
- PANDA is working with institutes in Russia
  - no alternative anymore

No new company identified yet.

Looking for manufacturer with coextrusion capacities:
- Continuous process,
- Semi-continuous process (short stop)
- With Rutherford cable exposed to max temperature < ~350°C for short time.
- Using typically extrusion press or Conform process.

We expect to find such companies in the high power cable market.

→ These are mostly **global corporations**, or subcontractors of them, inside international groups.

→ The **compatibility** of the production plans of these companies with our needs (and our schedules) should be considered, once potential companies are identified.

ILD installation timeline (K. Buesser)

Conclusions

There is a problem with the bread-and-butter technology of particle detector magnets

- Al-stabilized conductors are an established technology, best adapted to our requirements
  - high fields, large volumes, low material budget
- Unfortunately, industry in large parts of the world has abandoned the technology
  - there are no available production sites with a proven track record (e.g. from LHC detectors)
- Russian institutes and industry are not an option anymore
- A newcomer from China (TOLY) is doing R&D for CEPC
  - an on-going R&D process
- Ideas for R&D facility at CERN

Soldering/EB-Welding might be an alternative

- was used in the past, but has not being followed up for large detector magnets since decades

CICC might be worth to look into in more detail

- requires different magnet system design

HTS are attractive

- but the Al-stabilization is also a good idea for them

Need to push for R&D in labs together with industry to keep the timelines of future projects!

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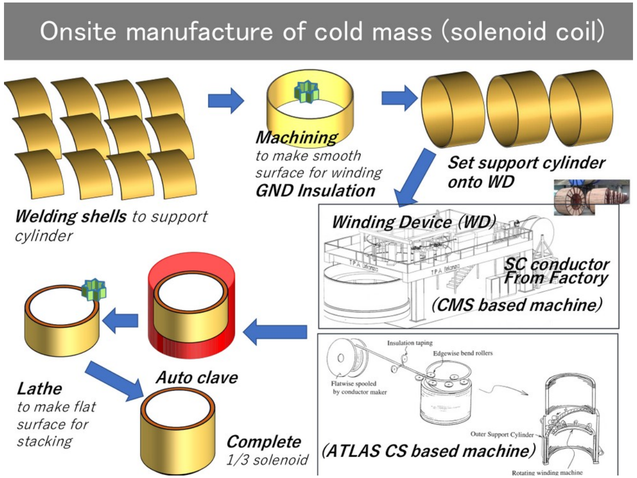
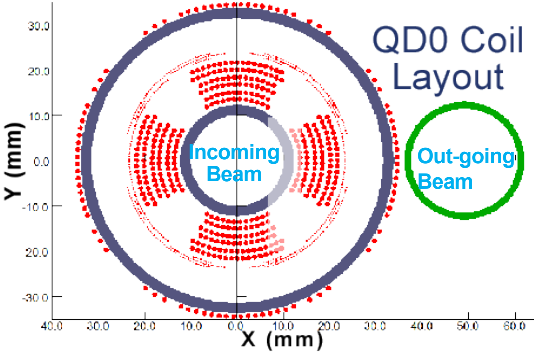
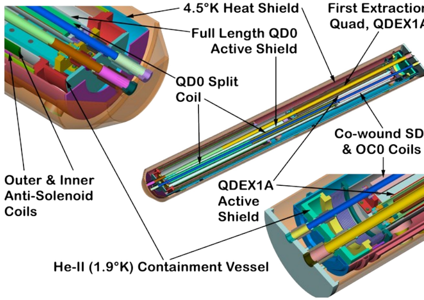
ILD solenoid magnet manufacture – Onsite winding (Y. Makida)



- Magnet manufacture procedure has been investigated with the cooperation by magnet makers, forwarding agents and local support organizations.
  - In the CMS experience, the coil modules were manufactured in the factories and were transported to the experimental site.
  - It is not impossible for ILD coil module to be transported on surface, but its cost and getting public agreement to occupy regional traffic has been promoting its onsite winding.
  - In case of onsite winding, large massive device machining the support cylinder is to be prepared. It's really costly, so we need to transport support cylinder from factories before onsite winding.
  - Anyway many technical methods, direct-internal-multilayer winding should be learned from CMS experience.

ILC-IDT WP16 prime (B. Parker)





The Final Doublet Design Optimization work package (WP'16) consists of two parts:

- Complete the vibration stability measurement R&D; i.e., use the 90% complete QD0 prototype that was left unfinished after the ILC TDR was finalized in 2014.
- Revisit the QD0 and QF1 magnetic coil and cryostat designs to take into account significant technological advances made since the ILC TDR was finalized in 2014.

In the following presentation we will argue that both WP'16 subtopics 1 and 2 have very strong synergies with other accelerator projects such as the EIC, SuperKEKB and FCC-ee and deserve funding as basic general accelerator R&D not limited to the specific requirements of ILC in Japan.


TOUTES DIRECTIONS
AUTRES DIRECTIONS

Thank you for your attention

Thanks to all speakers for the wonderful talks and studies.