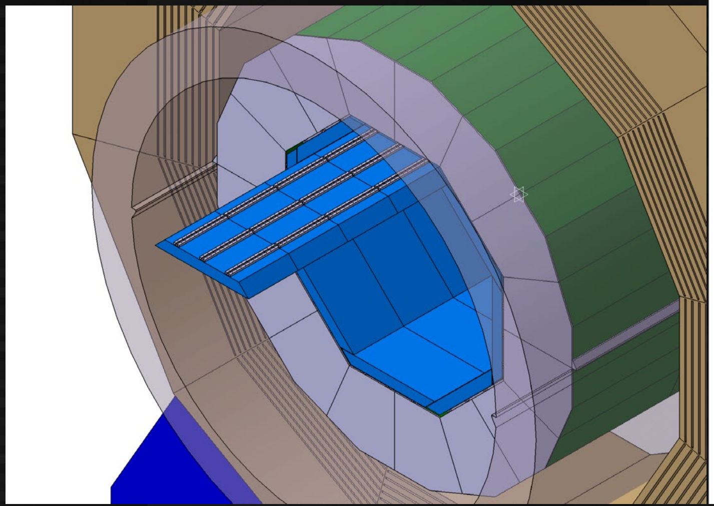
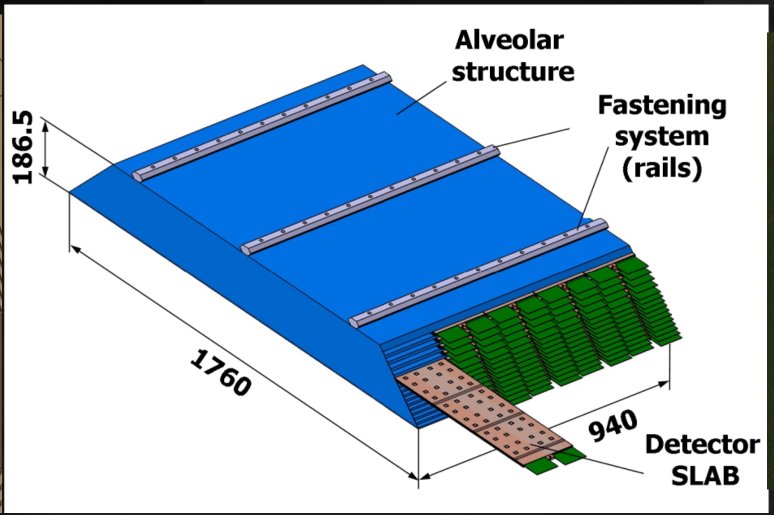
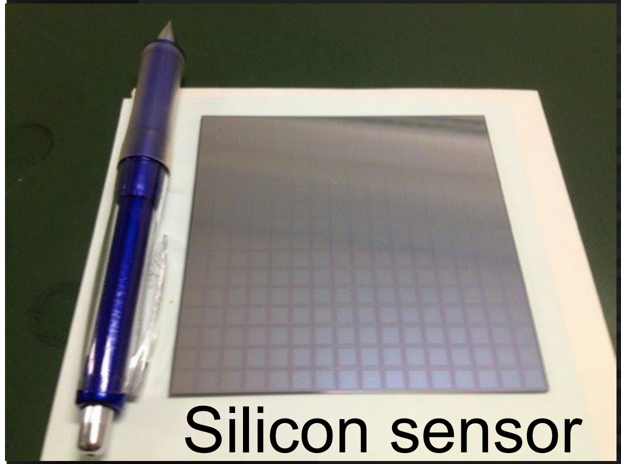
HEP_07: SiW ECAL

T. Suehara (Kyushu University)
on behalf of SiW-ECAL group

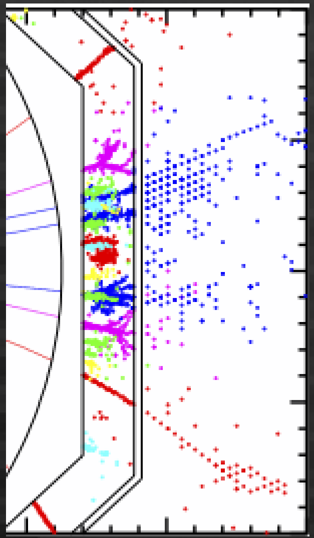
ILD SiW-ECAL: Overview





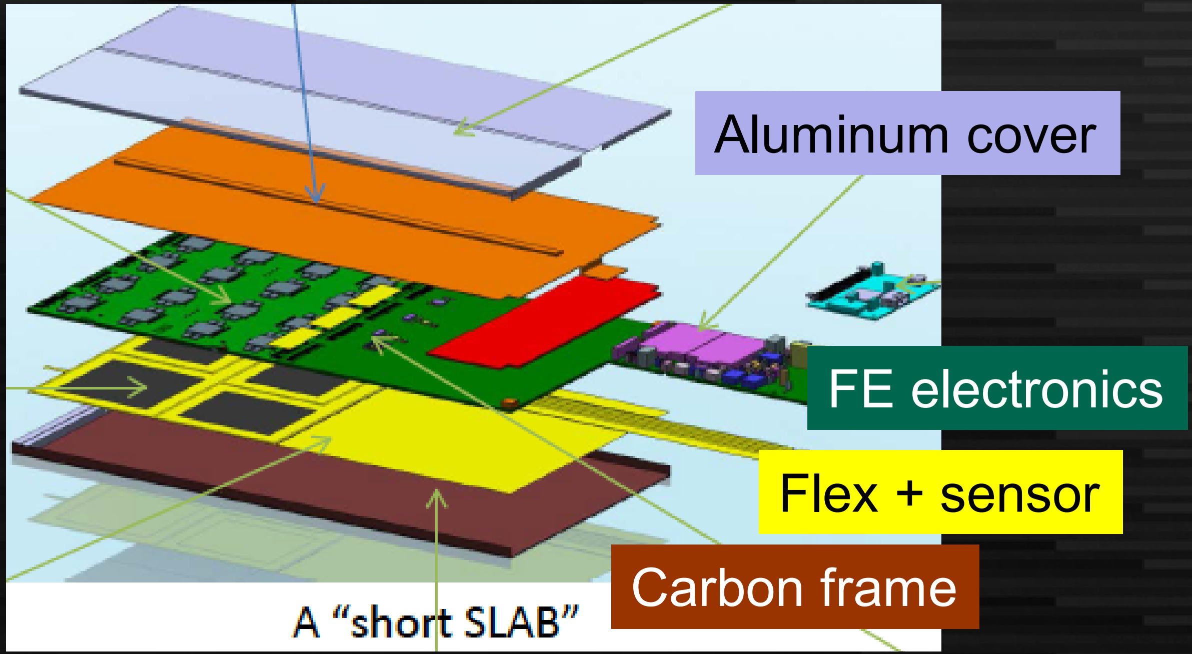


Silicon sensor



Particle flow

ILD: one of two ILC detector concepts
ILD ECAL: 20-30 layers of sandwich calorimeter with tungsten absorber and 5x5 mm - segmented silicon diodes (~ 10^8 channels in total)
PCB with ASICs (SKIROC2) embedded



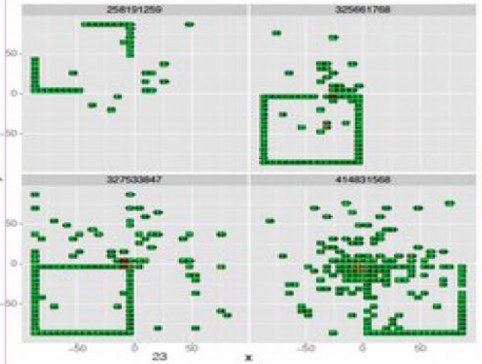
Achievements in FY2018

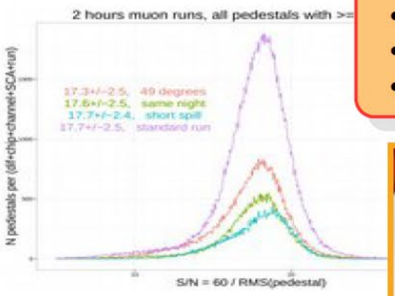
- Two test beams at DESY and CERN SPS
  - Analysis on 2017 test beam submitted to NIMA
- New tech. prototype (FEV13/SMBv5) designed in LLR/Kyushu and assembled in Kyushu
  - With new 650 μm silicon sensors
- Redesigning ECAL structure for cost optimization and adopting thicker/bigger silicon sensors
- Analysis on physics performance of ILC/ILD for tau final states
  - Higgs CP analysis published in PRD
  - $e^+e^- \rightarrow \tau^+\tau^-$ for detector optimization

Beam-test 2015–2018

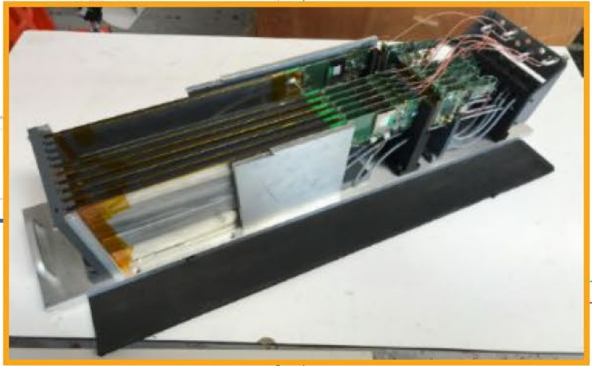
CERN 2015

"Naked FEV11"





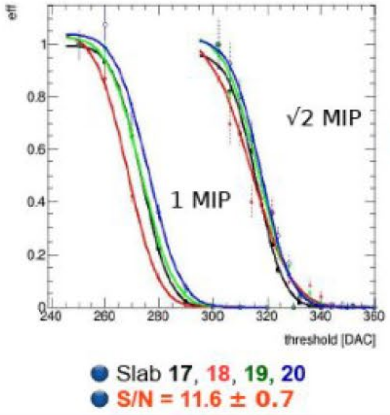
S/N_{ADC} = 16–17
(MIP – ped) / σ_{ped}
Defaults cataract :
- Negative signals
- re-triggers
- ~ high thr.
- sq events / 10

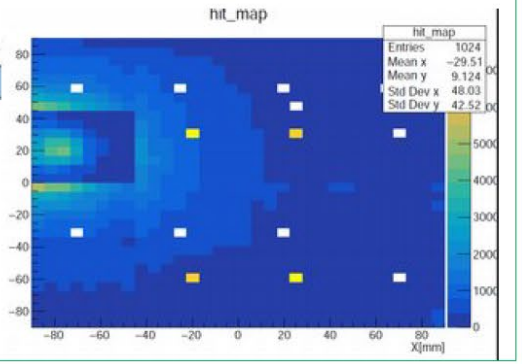


DESY 2018

7 FEV11 + 1 FEV13(650μm)

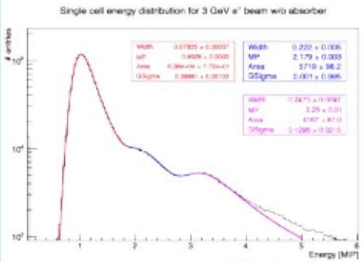
S/N_{Trig} ~ 11.6.±0.7
Trigger → ~1/3 mip (est.)
First comm. of FEV13

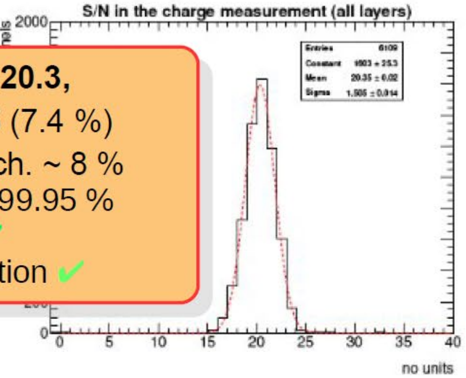


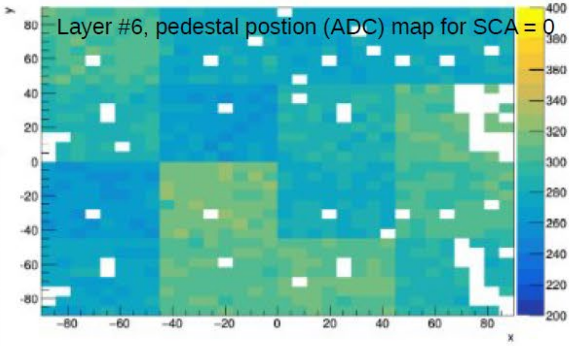


DESY 2017

7 FEV11





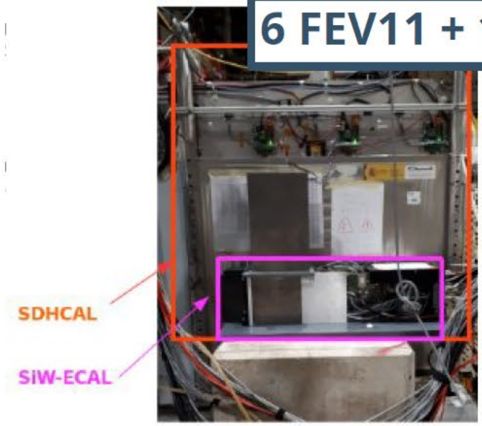


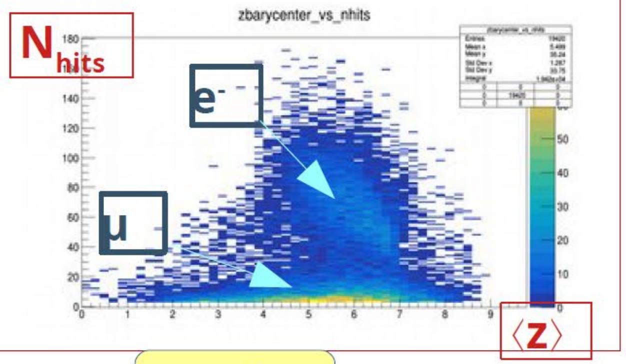
S/N_{ADC} = 20.3,
$\sigma_{S/N}$ = 1.5 (7.4 %)
masked ch. ~ 8 %
Hit eff. ~ 99.95 %
0°, 45° ✔
1T operation ✔

CERN 2018

Masked ch (FEV11) ~ 4 %

6 FEV11 + 1(4) FEV13(320 & 650μm) + 24X_0 W





Paper on TB 2017 DESY

Beam test performance of the highly granular SiW-ECAL technological prototype for the ILC.

K. Kawagoe[a], Y. Miura[a], I. Sekiya[a], T. Suehara[a], T. Yoshioka[a], S. Bilokin[b,*], J. Bonis[b], P. Cornebise[b], A. Gallas[b], A. Irles[b,**], R. Pöschl[b], F. Richard[b], A. Thiebault[b], D. Zerwas[b], M. Anduze[c], V. Balagura[c], V. Boudry[c], J-C. Brient[c], E. Edy[c], G. Fayolle[c], M. Frotin[c], F. Gastaldi[c], R. Guillaumat[c], A. Lobanov[c], M. Louzir[c], F. Magniette[c], J. Nanni[c], M. Rubio-Roy[c,*], K. Shpak[c], H. Videau[c], D. Yu[c,d], S. Callier[e], F. Dulucq[e], Ch. de la Taille[e], N. Seguin-Moreau[e], J.E. Augustin[f], R. Cornat[f], J. David[f], P. Ghislain[f], D. Lacour[f], L. Lavergne[f,*], J.M. Parraud[f], J. S. Chai[g], D. Jeans[h]

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Abstract

The technological prototype of the CALICE highly granular silicon-tungsten electromagnetic calorimeter (SiW-ECAL) tested in beam at DESY in 2017. In this test the setup comprised seven layers of 1024 channels and a size of 18×18 cm^2 each. This article presents key performance results in terms of signal over noise ratios at different levels of the readout chain and a study of the uniformity of the detector response.

Keywords: Calorimeter methods, calorimeters, Si and pad detectors

arXiv: 1902.00110

Under review in NIMA

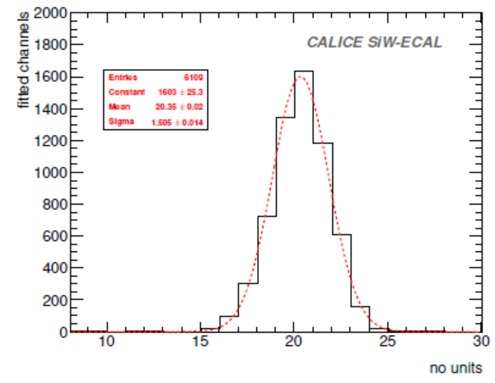


Figure 7: Distribution of the $(S/N)_{charge}$ for all calibrated channels.

S/N ratio of around 20 is obtained for most of channels

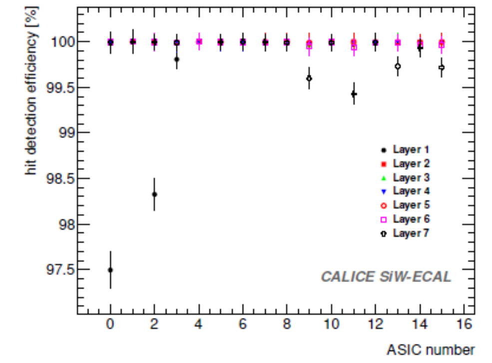


Figure 8: MIP detection efficiency in high purity samples of tracks of MIP-like acting particles for all layers. The average for all readout channels in each ASICs is shown. The error bars correspond to the standard deviation of the efficiency distribution of all channels in th ASIC.

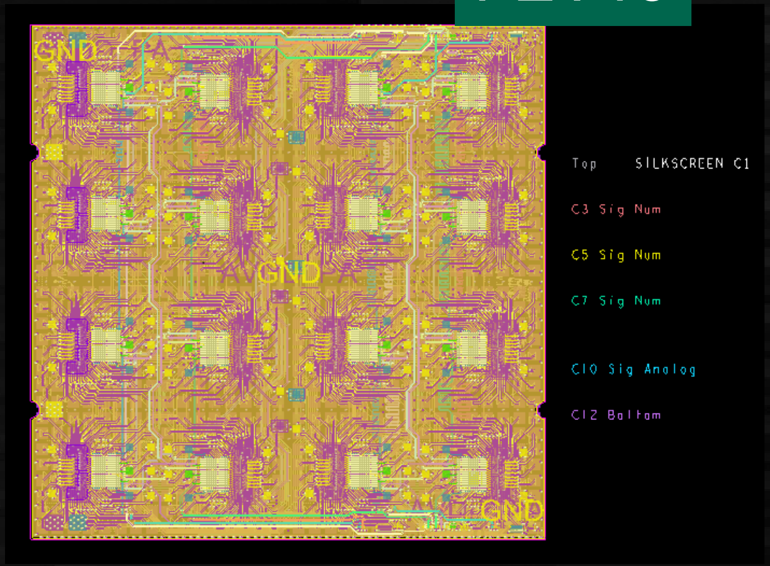
Good detection efficiency is observed with penetrating MIPs

Major changes for the 2018 prototype (FEV13)

Designed and produced in LLR/Kyushu collaboration

- ASIC: SKIROC2 → SKIROC2A
  - Individual threshold control
  - Improvements on TDC
- Dedicated power plane for AVDD_PA
  - Power layers: 2→3
  - Total layers: 10→12
- Smaller SMB footprint
- Connection by 0.4mm-pitch flex cables
  - Two candidates, footprint compatible
- Power pulsing capacitor on FEV
  - 0.4 mm thickness, 40 mF x 6

FEV13



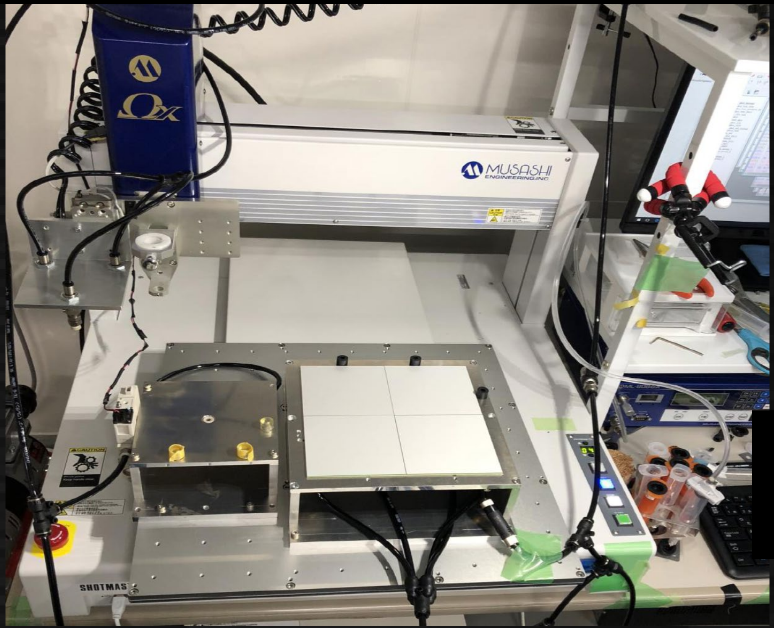
Micro-coaxial cable by KEL

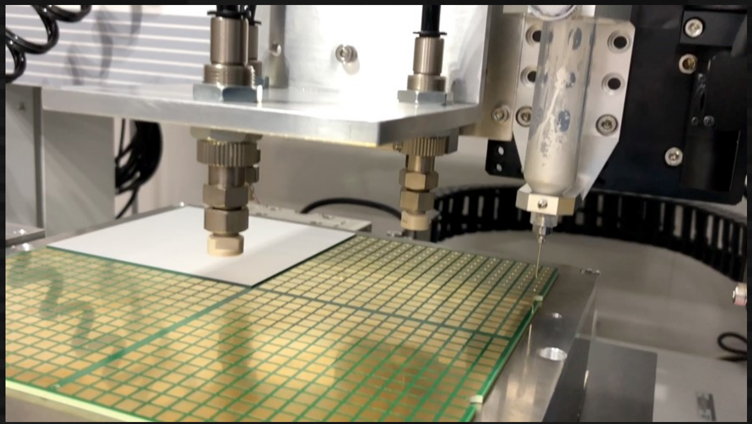
Flexible cable with Panasonic connector

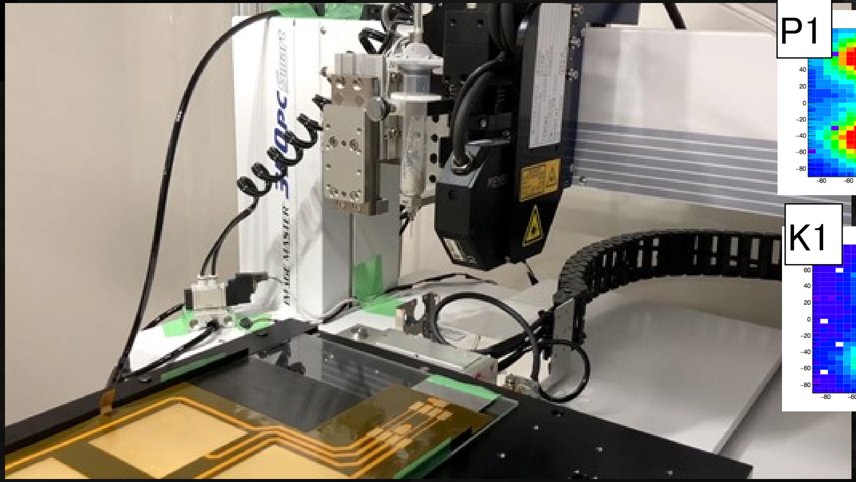
Thin capacitor used to provide power pulsing current

Assembly of FEV13 (in Kyushu)

Glue dispenser & sensor pick up

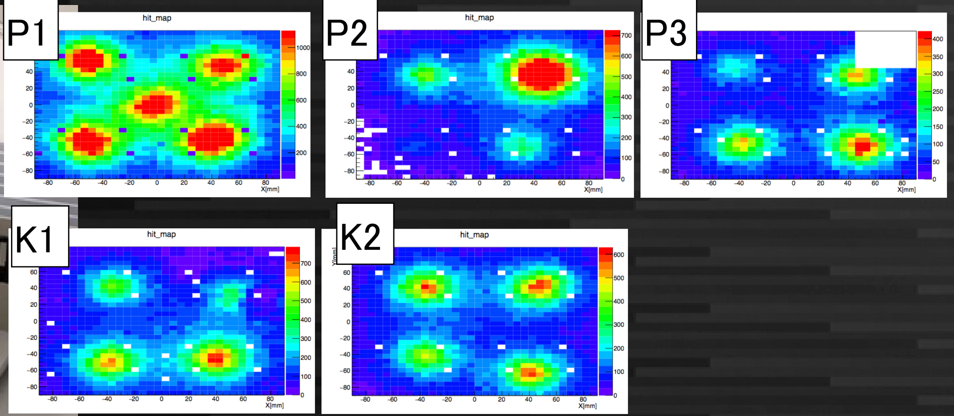




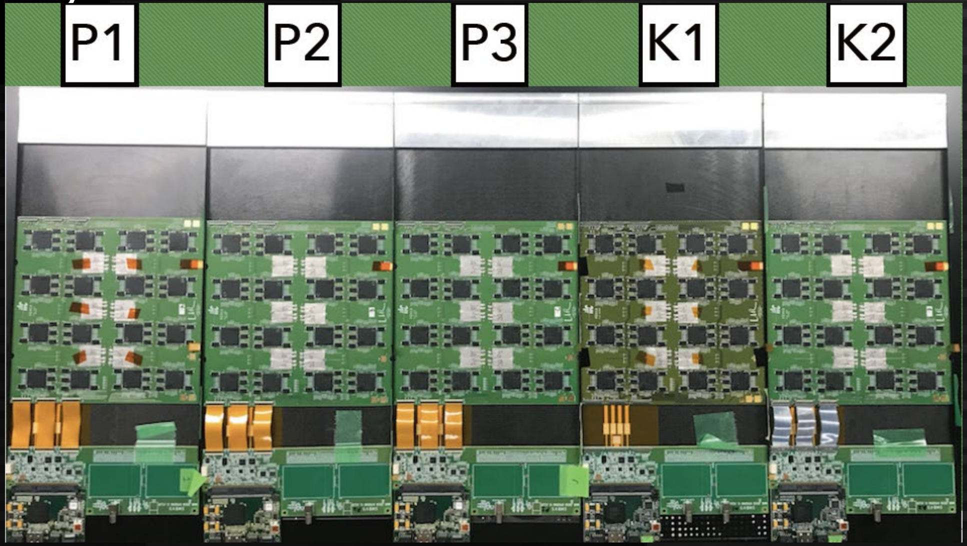


Gluing flex to PCB/sensor assembly
with automatic alignment

Conductive glue
(E4110-LV, silver-epoxy)

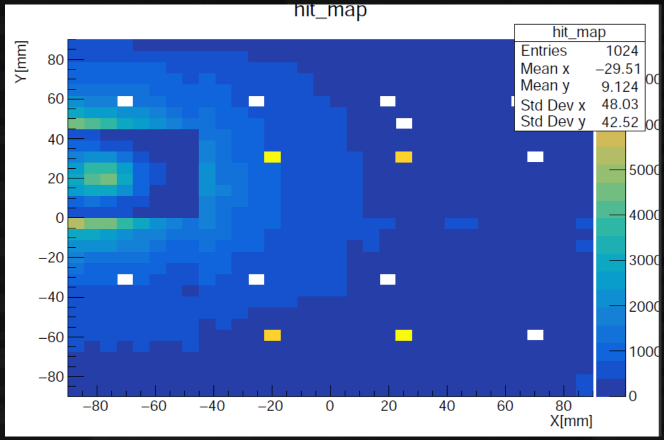


Test with radiation source

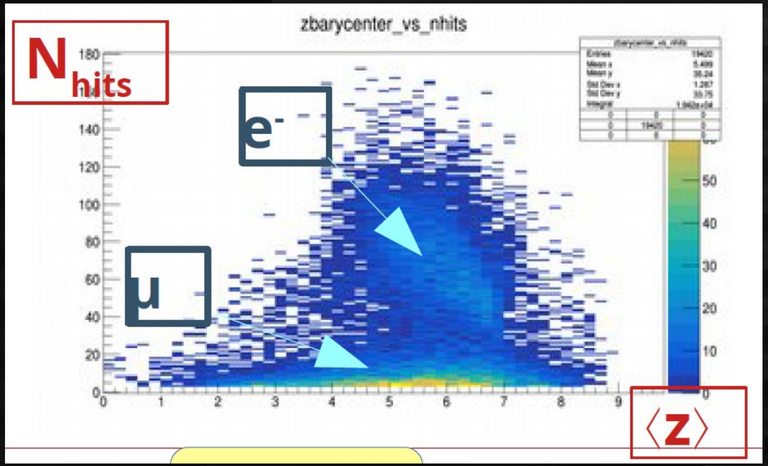


5 assembled slabs, Sep. 2018

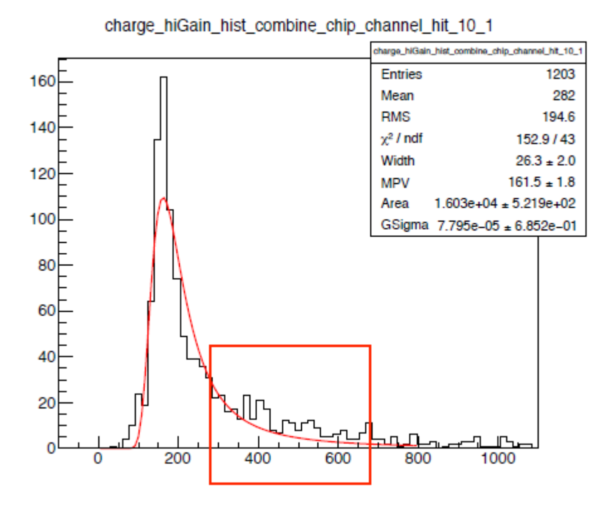
Quick look of results at test beams



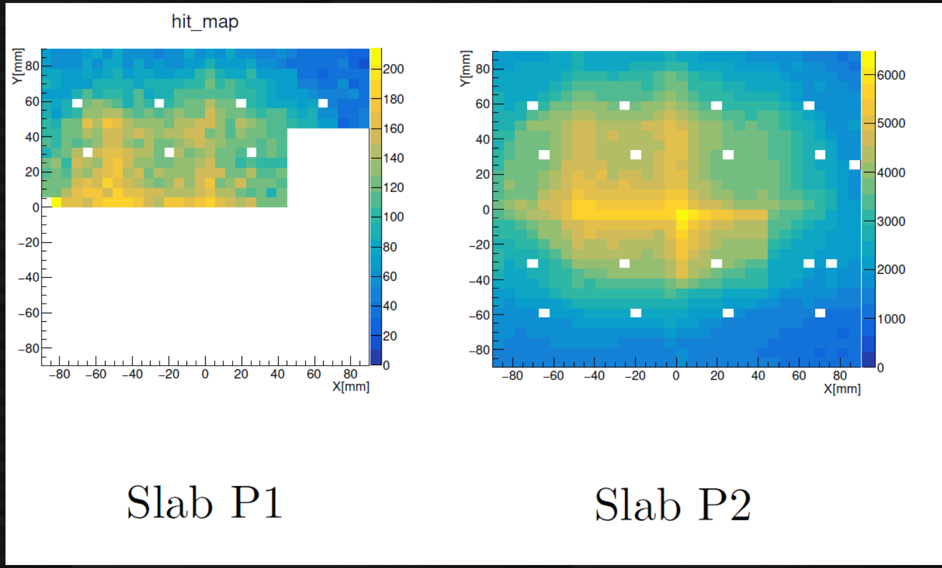
Hit map of FEV13 at DESY



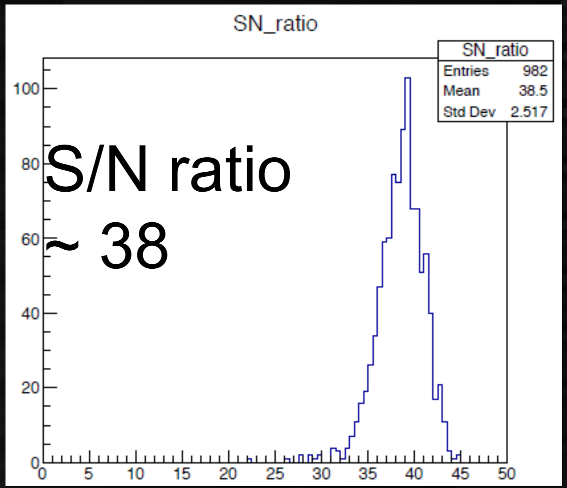
Difference on # hits for e/μ ID



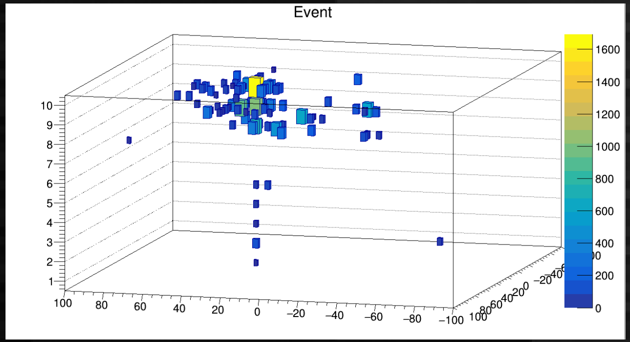
MIP peak with 650 μm sensors
2.5 times higher than 320 μm



Hit map of FEV13 at CERN: some part is not responding due to HV connection



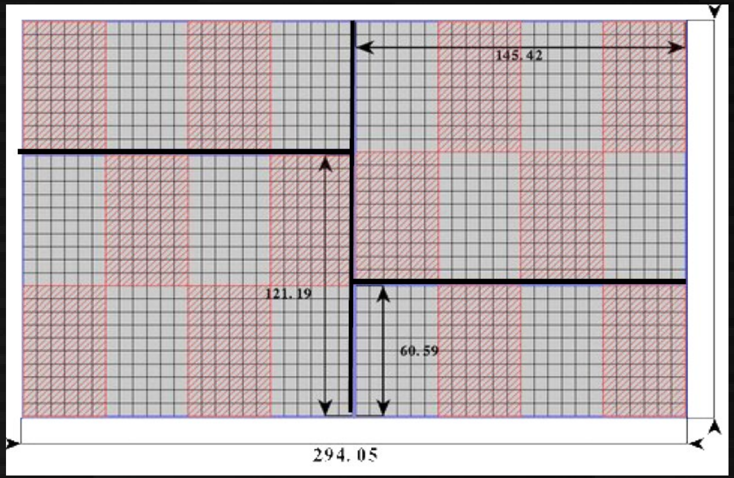
S/N ratio is ~ 2 times higher
Mainly due to bigger MIP signal



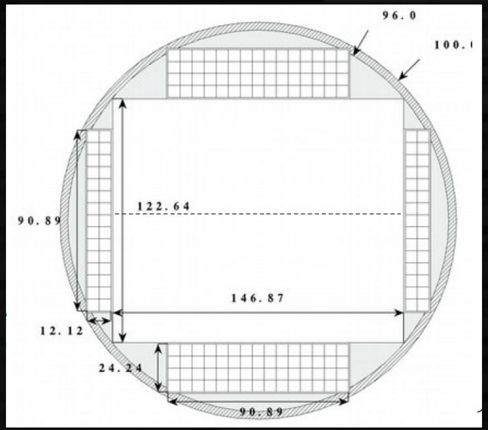
A pion event showing a track

Structure studies and optimization

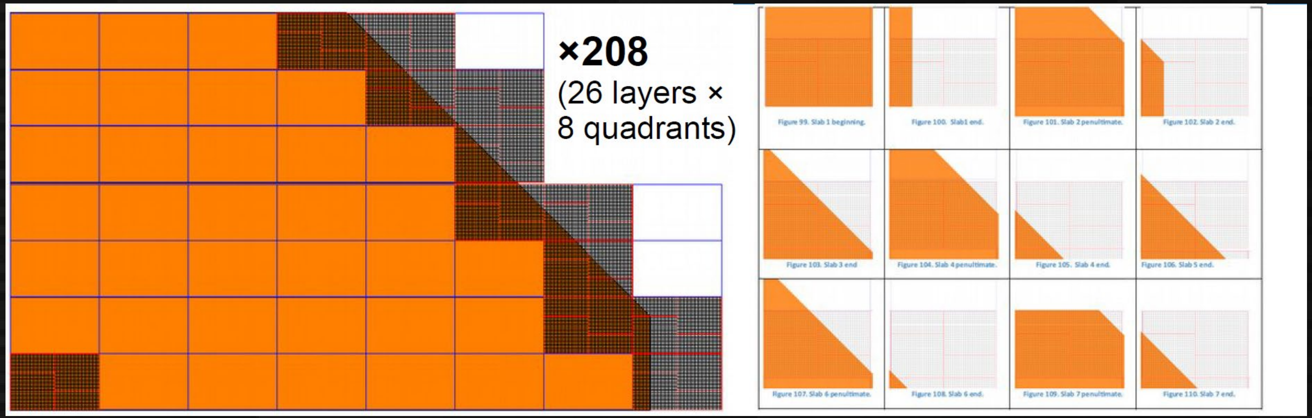
Optimization with 8-inch wafers



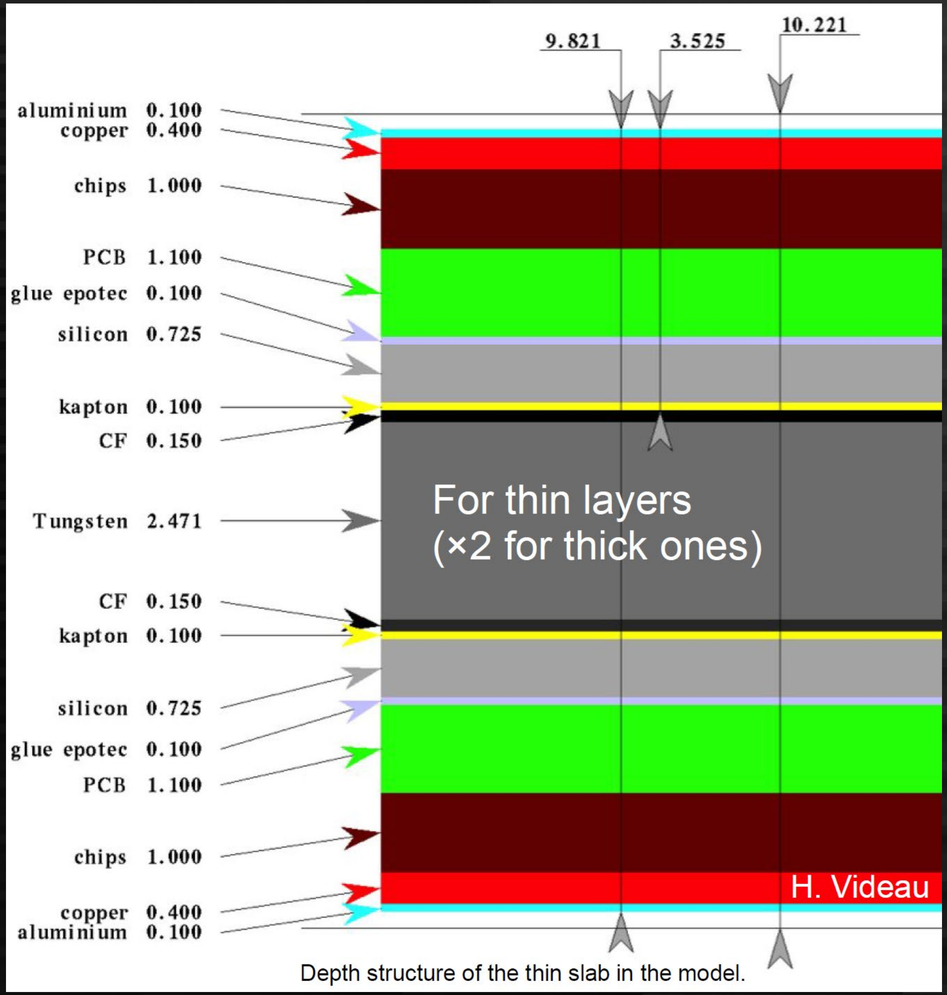
Compatible geometry with half tiles



Maximal usage of Si with smaller tiles



Edge of the ECAL with various sensor shapes



Revisiting thickness structures with 30 and 26 layer (for smaller detector) specifications

study of high energy tau reconstruction at ILC

$e^+ e^- \to \tau^+ \tau^-$ at 500 GeV,
full simulation, realistic reconstruction

main aims:

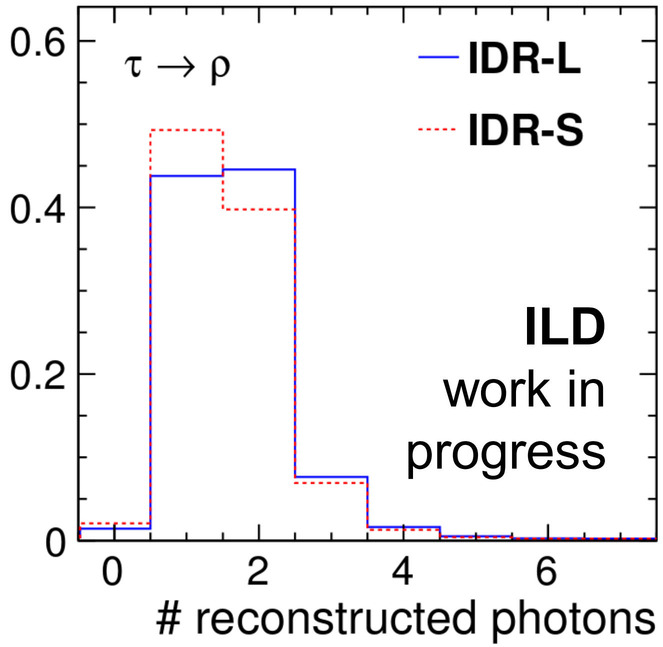
extract tau polarisation (hadronic decays)
→ strong handle to spin-dependent effects in
2-fermion processes

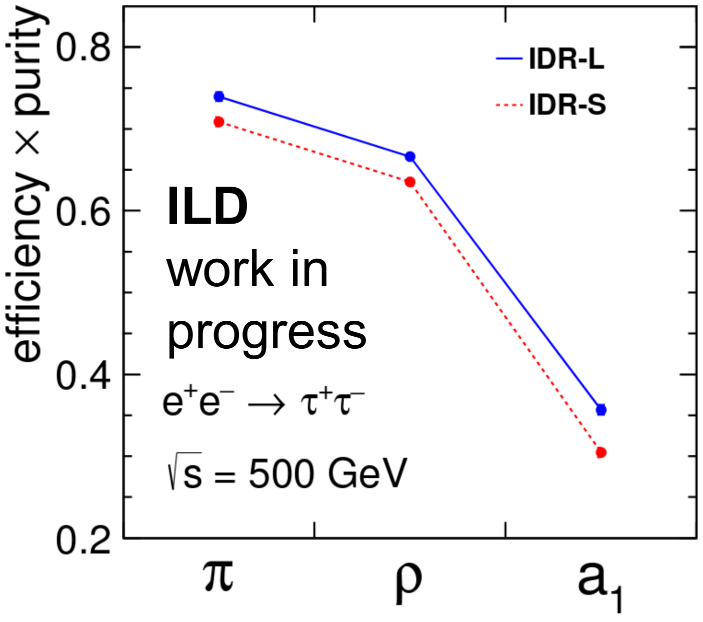
compare larger/smaller detector models

key points:

identification of hadronic tau decay modes
→ π^0 identification and energy measurement
→ *key role for high granularity ECAL*

some small differences between detector models
in ability to distinguish decay modes





measurement of CP properties in
$H \rightarrow \tau^+ \tau^-$

Phys.Rev. D98 (2018) no.1, 013007

Ψ_{CP} is mixing angle between even and odd CP components

CP of $\tau^+ \tau^-$ pair from H decay is reflected in correlations between τ spins

High granularity ECAL of ILD crucial in identification of tau leptons and estimation of their spin orientation

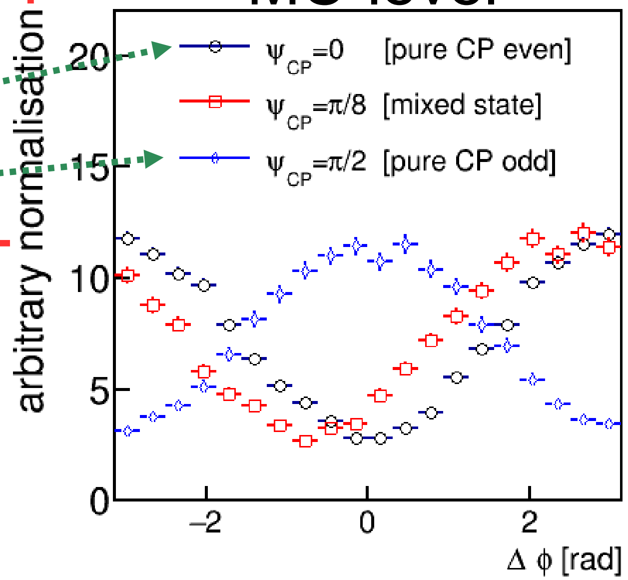
Full simulation and reconstruction study in ILD at ILC-250, assuming 2 ab^{-1}
→ sensitivity on Ψ_{CP} at the level of ~4.3°

h is a spin 0 state:

$| f \; f > = |\uparrow\downarrow> + e^{2i\,\psi_{CP}} |\downarrow\uparrow>$

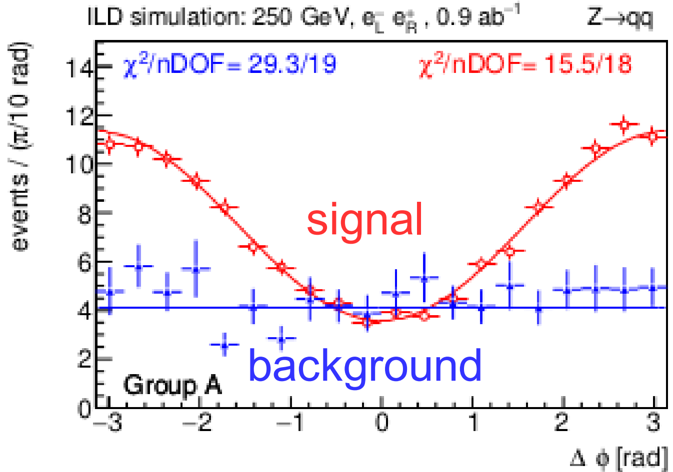
[ψ_{CP} = 0 CP even,
π/2 CP odd]

MC-level



$\tau^+ \tau^-$ spin correlation

full simulation & reconstruction



Plans in FY2019

- Test beam in DESY in June-July 2019
  - Optimization of FEV13 support structure
  - New FE electronics (SL-board) developed in LAL
- Production of new prototype towards module-0 if ILC gets clearer green signal
  - 8-inch wafers
  - A pair of long slabs (1.5 m long) with ILD-design tungsten structure
- Finish analysis on test beam 2018
  - Long slabs, FEV13, …

Working hypotheses

① The ILC is decided this year

– We still have 3–4 years of R&D before launching the production

ILD assembly timeline for Hybrid option (CMS style assembly))

2017		2019	2020	2021	2022	2023	2024	2025	2026	2027
Sub-detector		Y-3	Y-2	Y-1	Y1	Y2	Y3	Y4	Y5	Y6
ECAL (Barrel)	R&D	TDR			Construction off site				Ass. On site	Install
ECAL (End cap)	R&D	TDR			Construction off site			Ass. On site	Install	
HCAL (Barrel)	R&D	TDR			Construction off site				Ass. On site	Install
HCAL (End cap)	R&D	TDR			Construction off site			Ass. On site	Install	

adapted from 2014 ressource survey

– The organisation
  - should switch from “loose R&D” to **project mode**,
  - “ILD-like” steps-up in 2020 as main organisation (view of IN2P3)
    – CALICE to publish legacy papers for references

– Decision on staging scheme ≤ end 2020 ?

– Decision on 1 vs 2 experiments ≤ end 2020 ?

if 2) conservative: decide on SiW-ECAL parameters

if 1) merge SiD & ILD concepts:

– highly political → 1(2) year delay ?

② The ILC is not decided; CEPC becomes the NLO machine and $N^{1.5}$LO CLIC

– Decision within 3–4 years ? CLIC TDR in 2025 ?

– Detector R&D must foster on continous operation mode:
  - Adapted electronics and DAQ
  - Active cooling
  - ILD model must be revised (esp. cost, granularity):
    – 2 detectors for 500M$? [2019-03 CEPC Calo Topical WS]

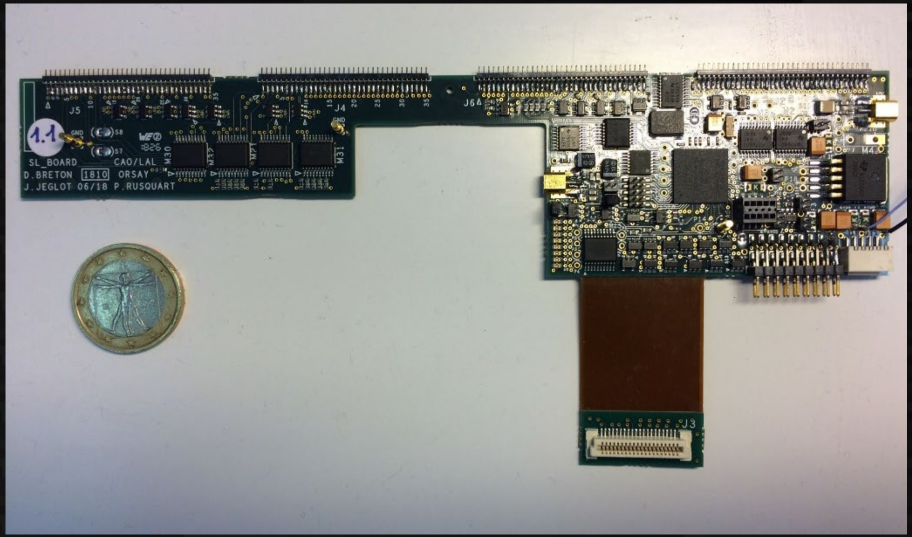
– The organisation stays R&D oriented, *à la CALICE*
  - partial evaporation of interest and support are unavoidable

③ CEPC and CLIC don’t concretise; FCC-ee as N^2LO projects

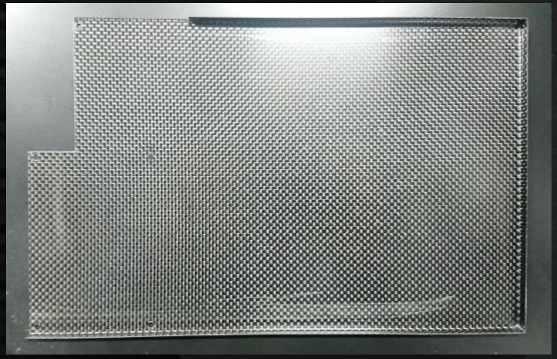
– The organisation stays R&D oriented, *à la CALICE*

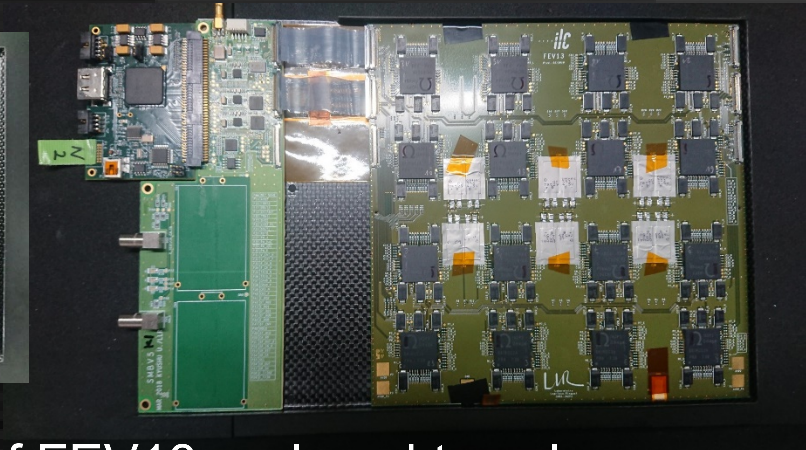
– Planning is fuzzy; same case as ② in worse...

Preparation for test beam at DESY in June-July



A new interface card (SL-board) developed in LAL, commissioning ongoing

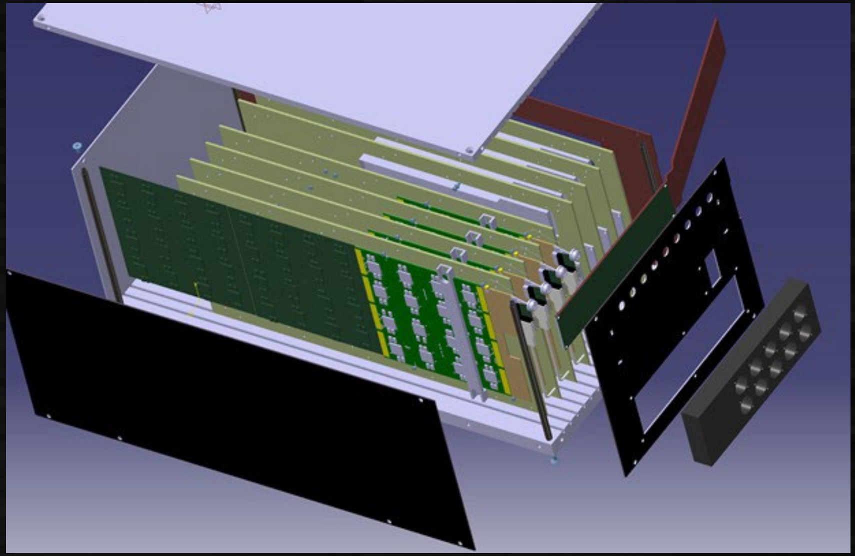




Carbon frame of FEV13 replaced to solve the HV connection issues found at the last TB

Chip-on-board version of FEV11 (with thinner board) will also be tested

See talk by Mitra Ghergherehchi (FKPPL, SKKU)



Design of slab stack to accommodate both FEV12-LAL with new interface and FEV13

Summary

- France-Japan collaboration got stronger in FY2018
  - More detailed collaboration of the slab assembly
  - Continued effort on the sensor, ASIC, test beam analysis and physics
  - Results on test beam in 2017 will soon be published
- A more test beam foreseen in DESY in June-July
  - Complete FEV13 development and commissioning of new electronics
  - Expect more manpower on analysis → quick publication in scope
- Plan after FY2020 strongly depends on project status (of ILC and other lepton colliders)