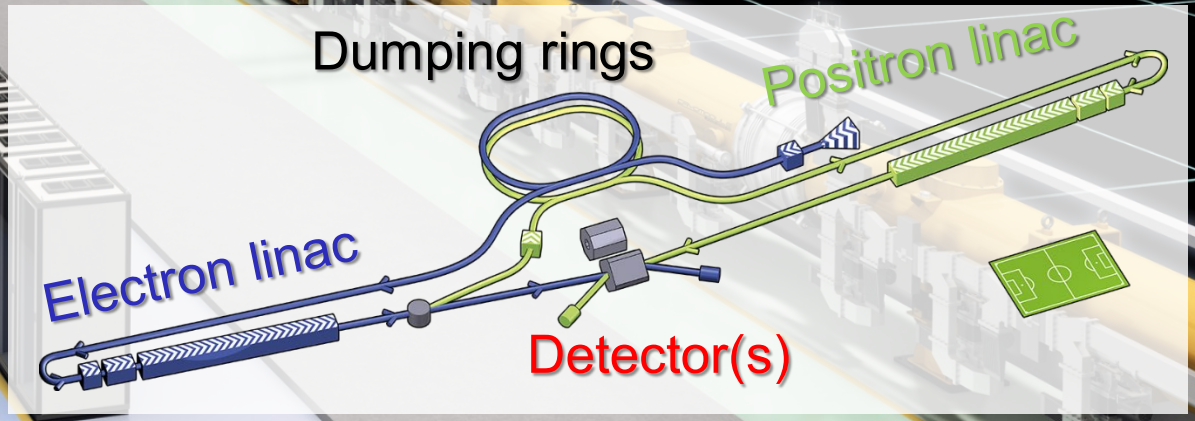
Overview of CALICE/ILD SiW-ECAL

Taikan Suehara
(Kyushu University)

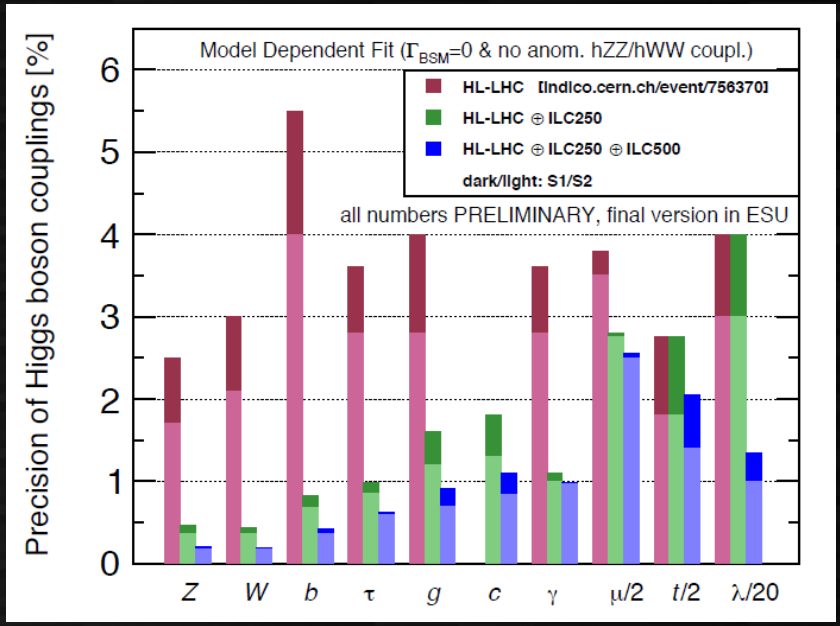
International Linear Collider (ILC)

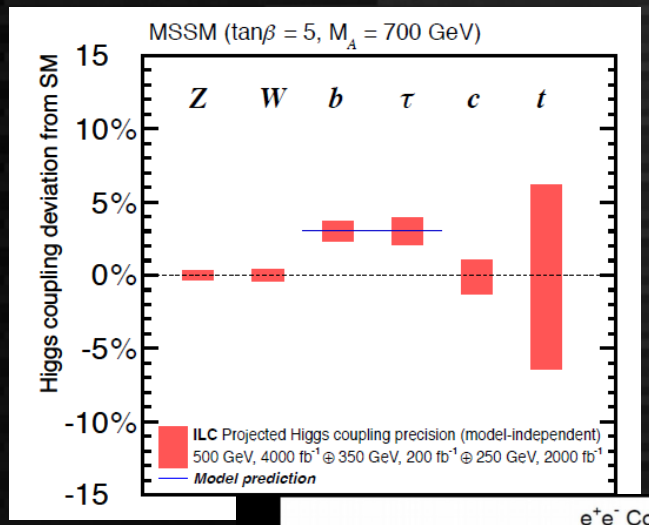
Linear accelerator of 20 km
w/ superconducting cavities
e^+e^- collision at $\sqrt{s}$ = 250 GeV
(upgrade: -50 km, -1 TeV)



Rey.Hori

ILC Project: Physics



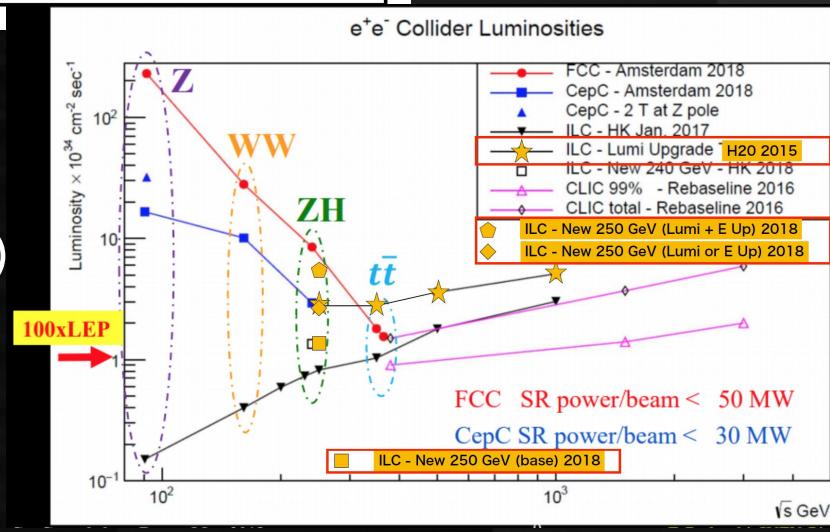


Deviations in Higgs couplings with TeV BSMs fingerprinting possible

0.5-2% precision of most of Higgs couplings with 2 ab^{-1} (in ~ 10 operation years)

Main target: precision Higgs study for a probe to new physics

Also a probe to BSM physics with direct search (soft final states, monophoton, …) & precision EW measurements



Similar luminosity to FCCee with energy upgradability

ILC Project: The Situation

- 2004 Superconducting technology chosen
  → ILC project started by combining several projects
- 2007 Reference Design Report
- 2013 ILC TDR and detector DBD report
- 2013 Japanese site selection → Tohoku
- 2008- Big supports from politics, economics, locals etc.
  - Federation of diet members for ILC from 2008 (> 100 members)
  - Advanced Accelerator Association (executives of big companies)
  - A lot more

Murayama, Koshiba, Evans | PM Abe

- 2019 (A kind of) Expression of Interest from government
  - To be considered in European Strategy 2020-
- ~2022 International agreement on construction foreseen?

Statement on March 7 (yesterday)

- MEXT official (Mr. Isogai) (private translation)
  - Final decision on hosting the project is not possible at this point
  - Need more discussions in Japanese academic field (SCJ)
  - Watching European situation (EPPSU)
  - MEXT is keeping the interest to ILC project and continue international exchange of opinions.
- While the statement does not seem enthusiastic, it shows that the government decided to go forward to a new step with the "expression of interest" above.
  - This is the first official statement the government has ever issued for ILC
  - Initiate discussion with France and Germany in addition to US
  - KEK will initiate the discussion of the cost sharing model
  - Will try to push ILC on the European strategy as well as SCJ master plan.

CALICE Collaboration

https://twiki.cern.ch/twiki/bin/view/CALICE/WebHome

The CALICE Collaboration

336 physicists/engineers from 57 institutes and 17 countries coming from the 4 regions (Africa, America, Asia and Europe)

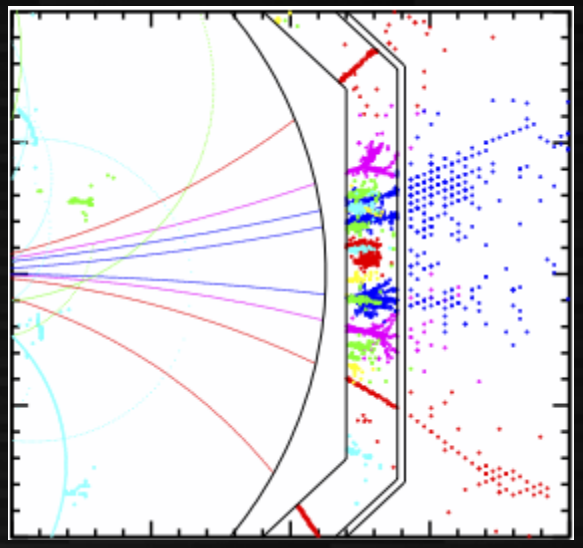
Projects: Particle Flow (PFA) Calorimeter

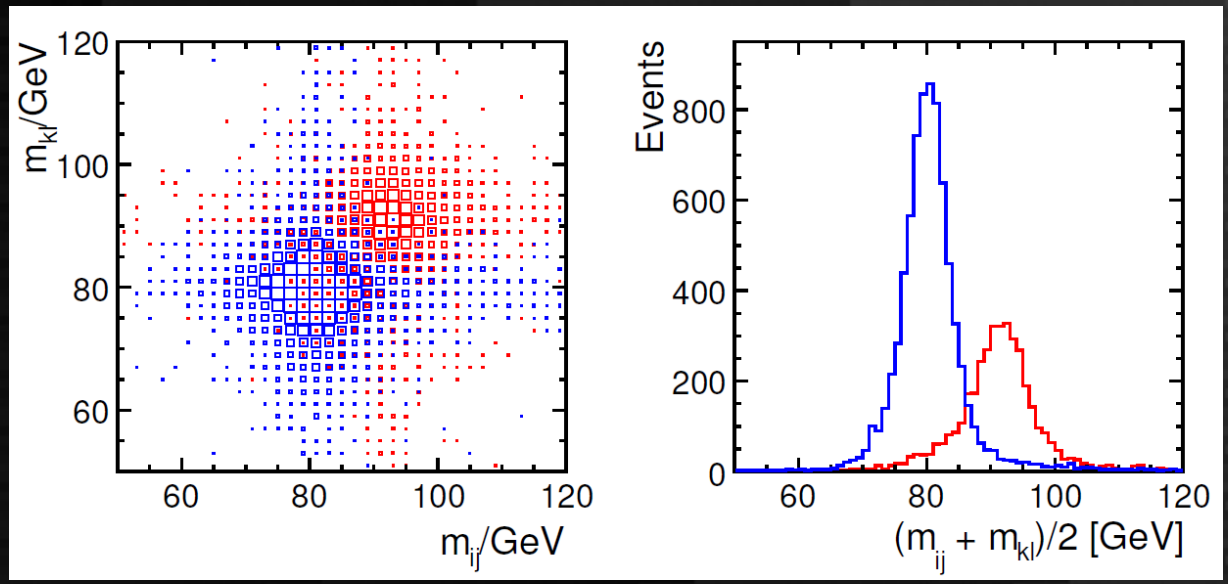
- Silicon-Tungsten ECAL
- Scintillator-Tungsten ECAL
- MAPS ECAL
- Analog HCAL (Scintillator)
- Semi-Digital HCAL (Glass RPC)
- Digital HCAL (mostly terminated)

Purpose

- Interface to test beam
- Collaboration on readout
  - ROC series by OMEGA
  - Detector Interface
  - Clock/spill distribution
- Collaboration meetings
  - Next: Utrecht, 10-12 April

Particle Flow Algorithm





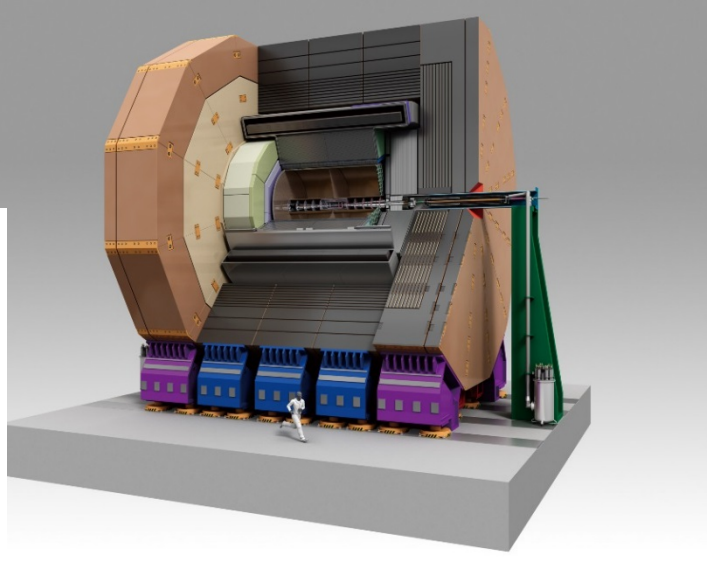
Particle flow:
separate each particle inside a jet to eliminate clusters of charged particles

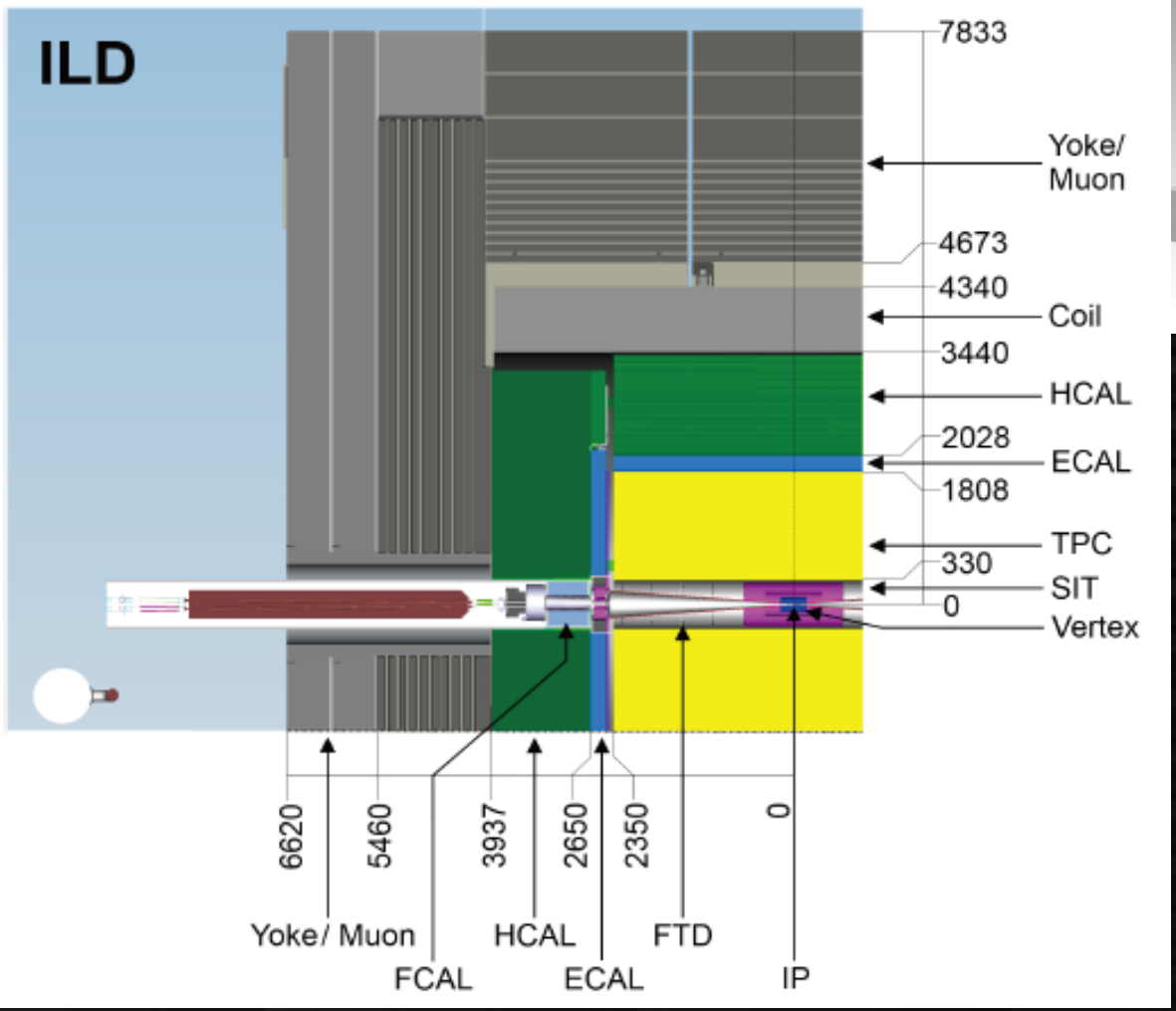
Hadronic WW/ZZ separation

Finely-granular calorimeter is critical for PFA

$E_{jet}(PFA) = E_{tr}$ (60%) + E_{γ} (30%) + E_{nh} (10%)
$E_{jet}(non\text{-}PFA) = E_{\gamma}$ (30%) + E_{h} (70%)

ILD detector

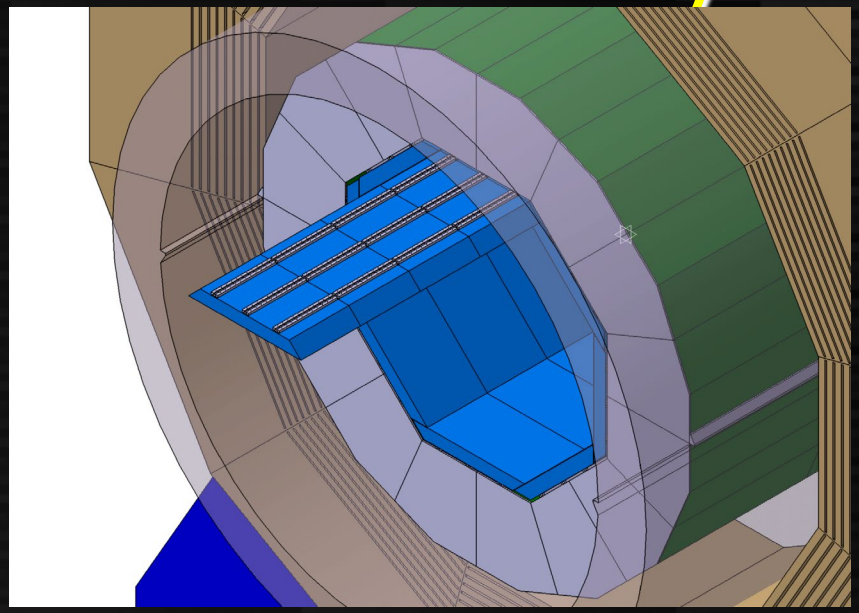


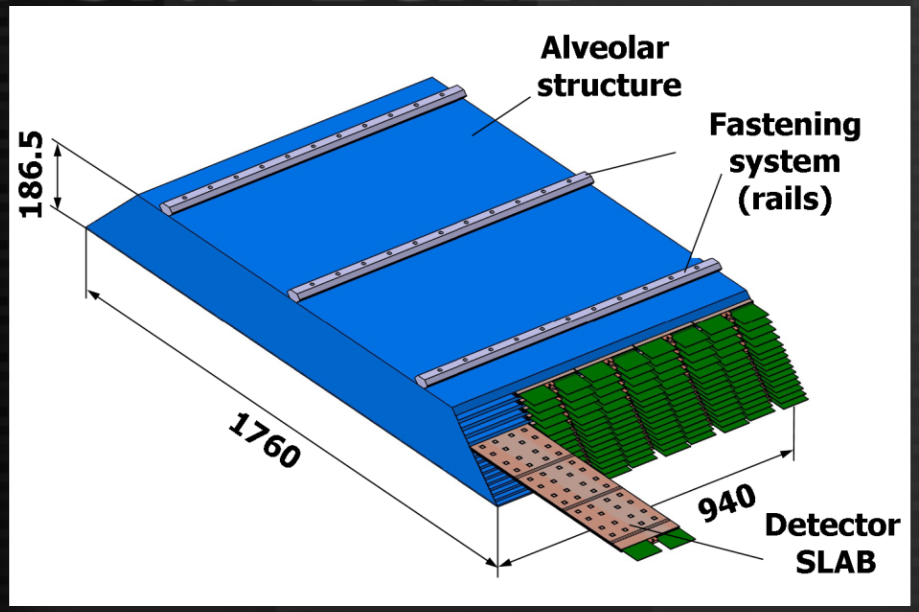


One of two ILC detectors

- Pixel vertex detector
- Silicon tracking (SIT/SET/ETD/FTD)
- Gas TPC
- ECAL/HCAL/FCAL
- SC Coil (3.5 Tesla)
- Muon detector inside iron yoke

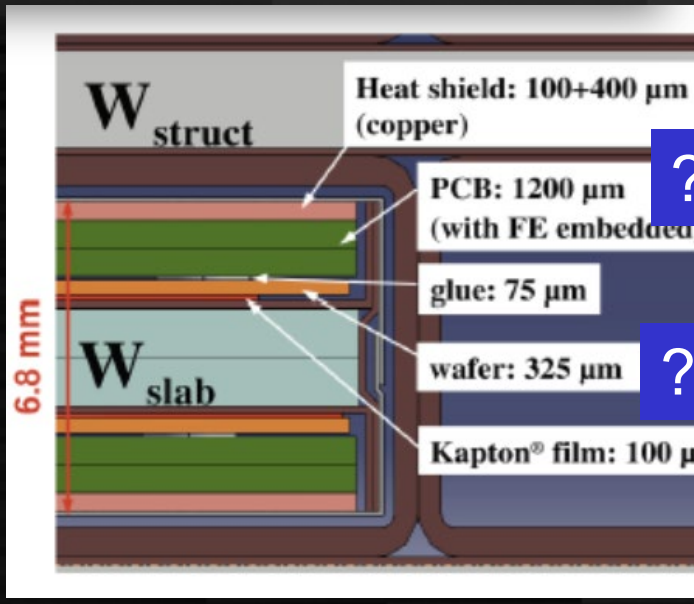
CALICE/ILD SiW-ECAL



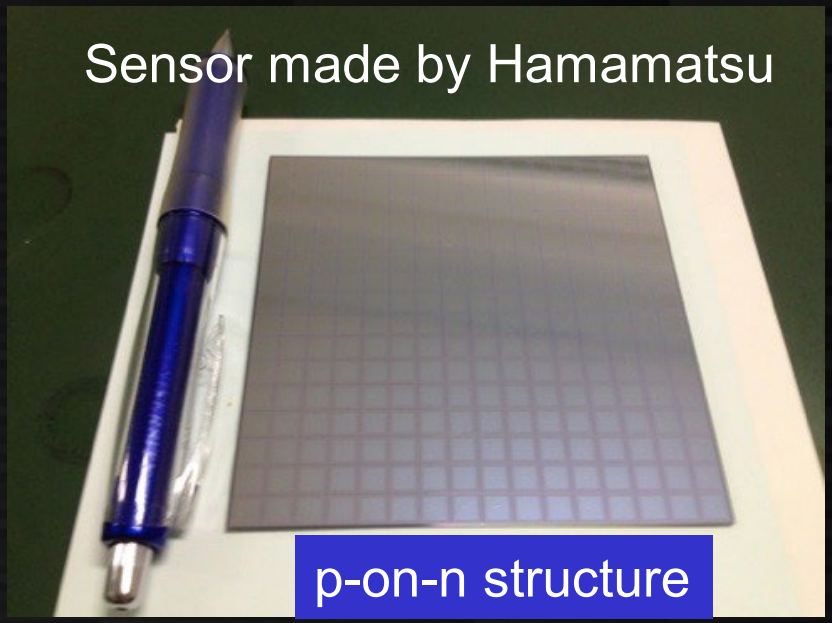


20-30 layers of sandwich calorimeter
with tungsten absorber
and 5x5 mm - segmented silicon diodes
(~ 10^8 channels in total)
PCB with ASICs embedded
Other options:

- Scintillator strip (5 x 45 mm, alternating)
- MAPS (50 μm pixel, digital readout)

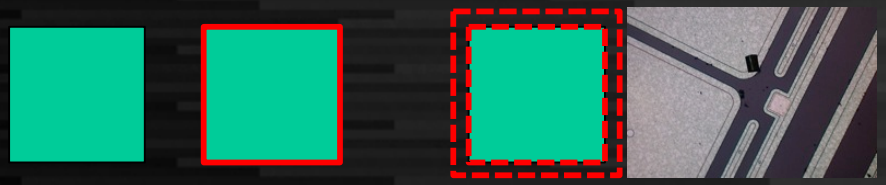


SiW-ECAL: sensor



5.5 mm x 256 pixels, 9 x 9 cm / sensor

(Floating) guard ring (GR) structures



0 GR 1 GR Split GR (2/4 GR)

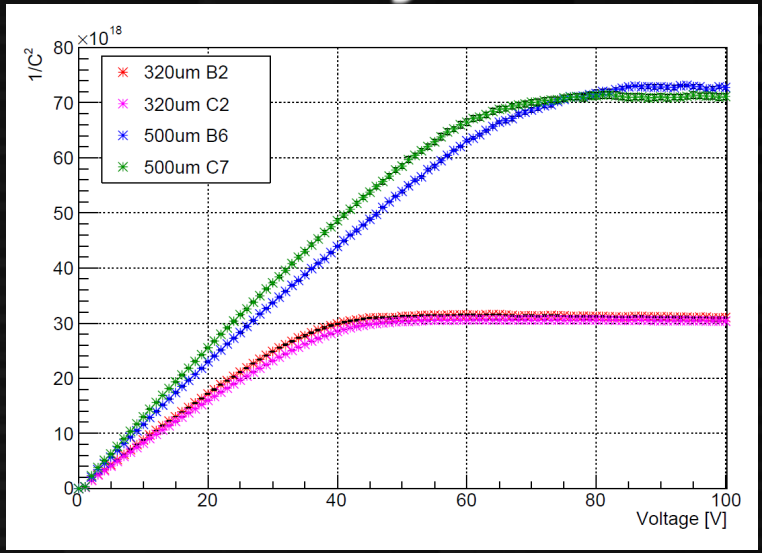
- Floating GR causes ring crosstalk
- No GR / split GR avoid crosstalk
- No GR has least dead area
- Breakdown voltage high enough

→ adopt 0 GR structure

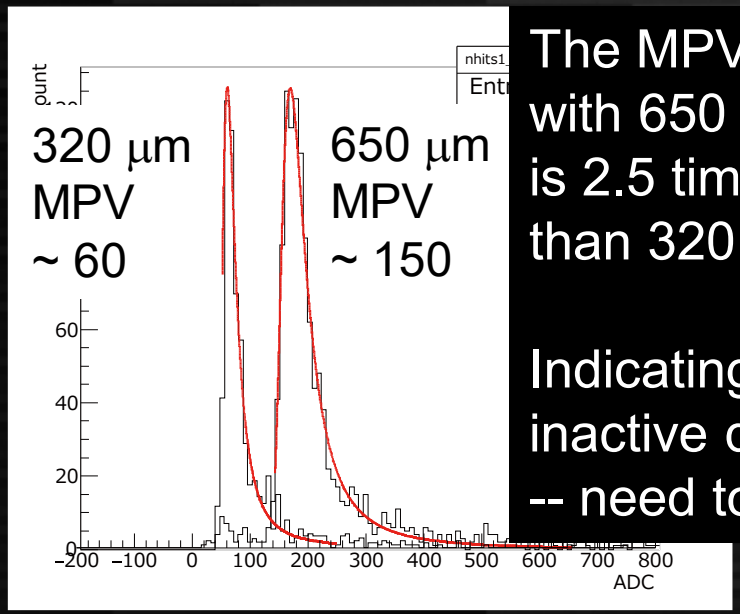
Prod. date	Thickness	Guard rings	Edge cut	Qty.J	Qty.F
2013/10/30	320 μm	0 GR	B (0.5 mm)	14	
2015/7/23	320 μm	1 GR	C (0.35 mm)	5	
2015/8/5	500 μm	1 GR	C (0.35 mm)	5	
2017/1/16	500 μm	0 GR	B (0.5 mm)	2	~20
2018/5/9	650 μm	0 GR	B (0.5 mm)	24	

Samples with more variation in hand for small test sensors (4x4, 3x3 pixels)

Study on sensor characteristics

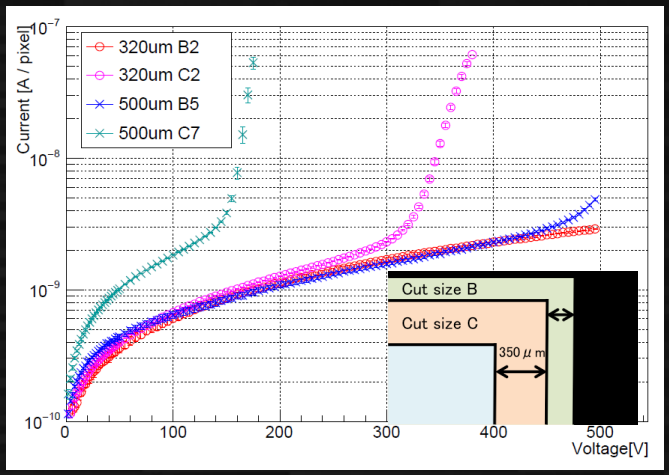


V_{FD} ~ 40 V (320 μm),
70 V (500 μm), 110 V (650 μm)

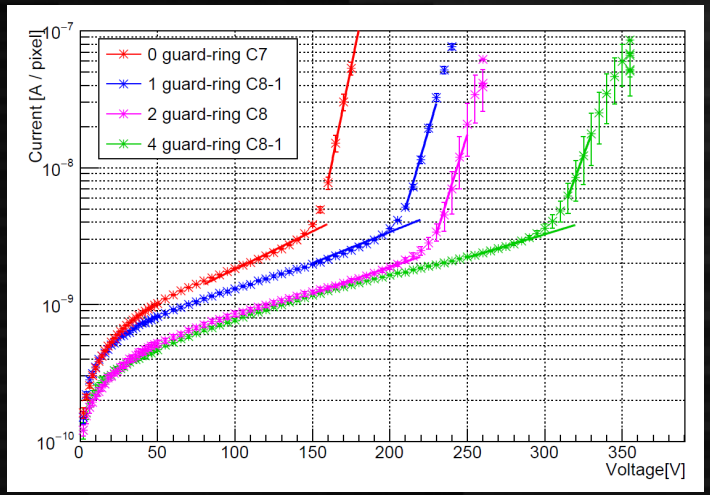


The MPV amplitude with 650 μm sensor is 2.5 times higher than 320 μm sensor

Indicating rather thick inactive depth
-- need to be confirmed

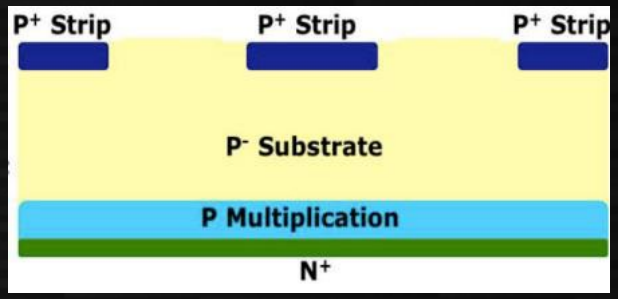


Leakage current
← Dependence
on edge cut
C = 0.35 mm
B = 0.50 mm
→ Dependence
on guard rings

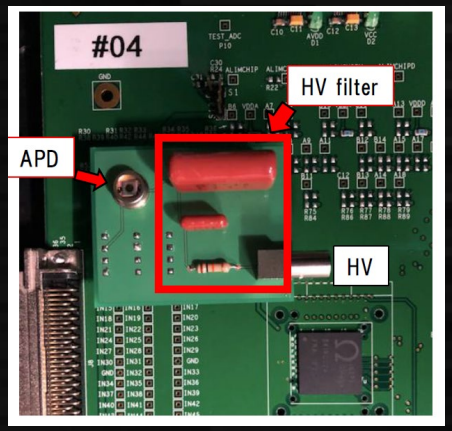


New sensor developments

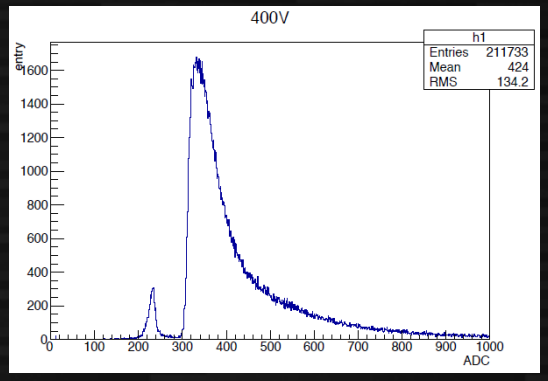
LGAD for timing detector



Inverse LGAD: better for gain flatness



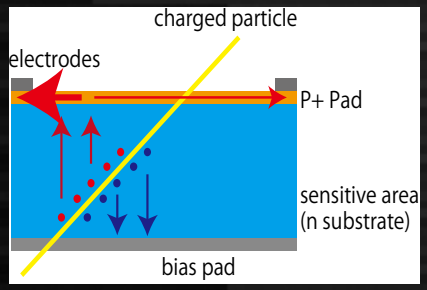
Testing inverse APD with SKIROC2 testboard



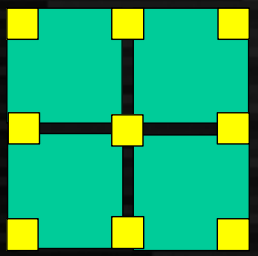
Successfully obtained ^{90}Sr signal
A few 10 μm active thickness estimated

Performance comparison between inverse and reach-through type under preparation SKIROC2CMS (with the same testboard) will be used for timing study

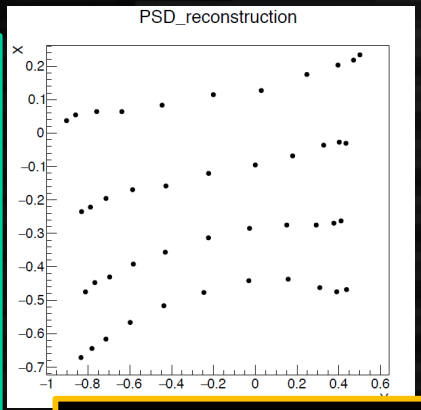
PSD for position detector



charge sharing for better position determination



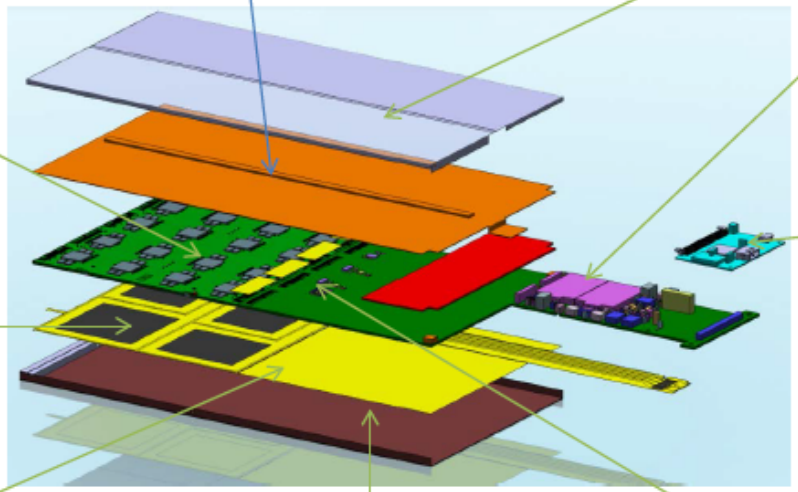
Neighbor channels combined to reduce readout channels



Laser test with high resistivity gives good dynamic range

Detailed study ongoing

Technological Prototype



Coper sheet for cooling

Cover (EMI shielding)

Power pulsing circuitry (400 mF)

PCB 1024 chn. 16x **SKIROC2**

Detector Interface (DIF)

Si PIN diodes

Front-end, DAQ, TFC Not shown

HV kapton

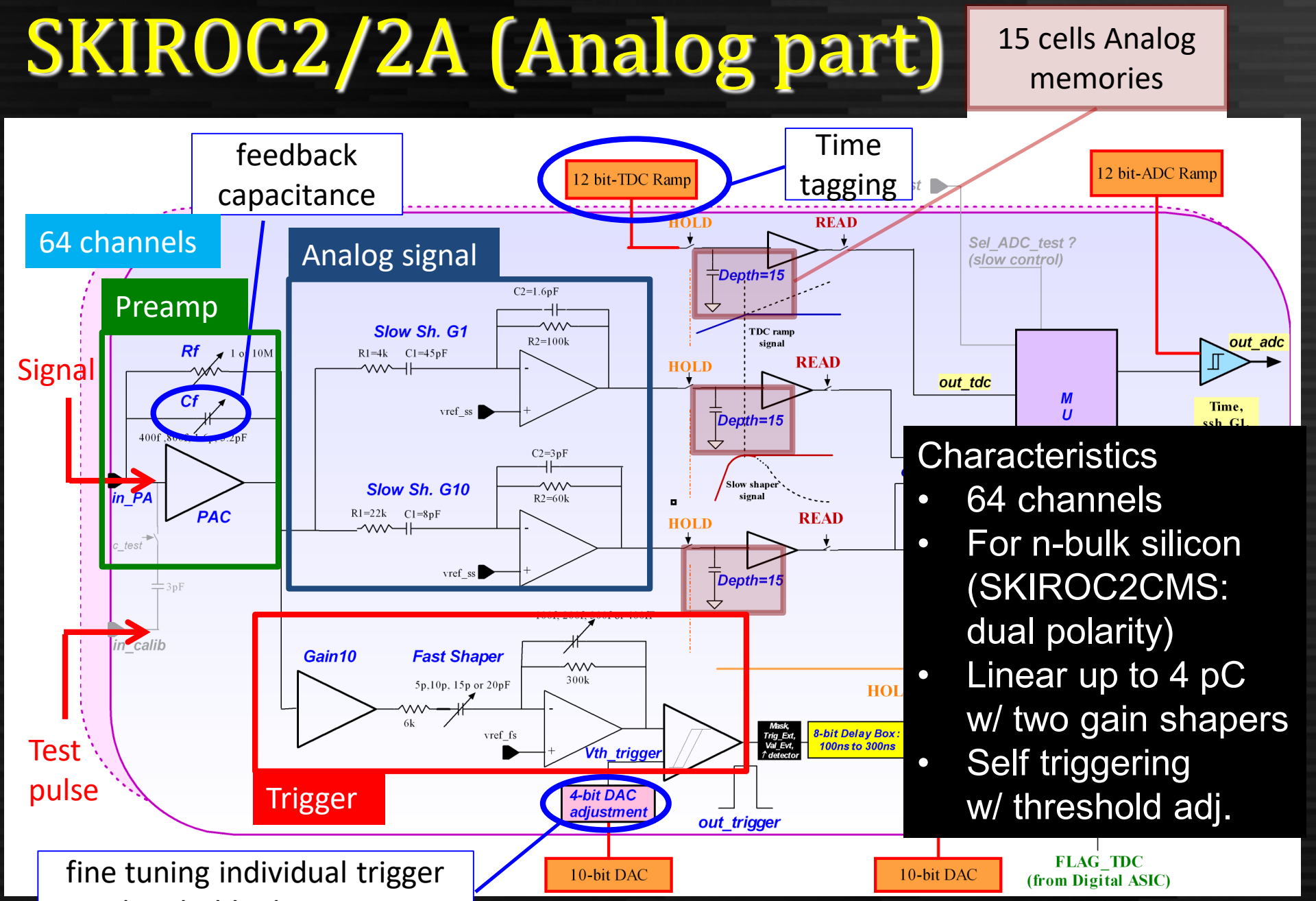
A "short SLAB"

FCC Interconnects

Stiffener, Absorber Carbon fiber + W

Single layer, 'U' stiffener

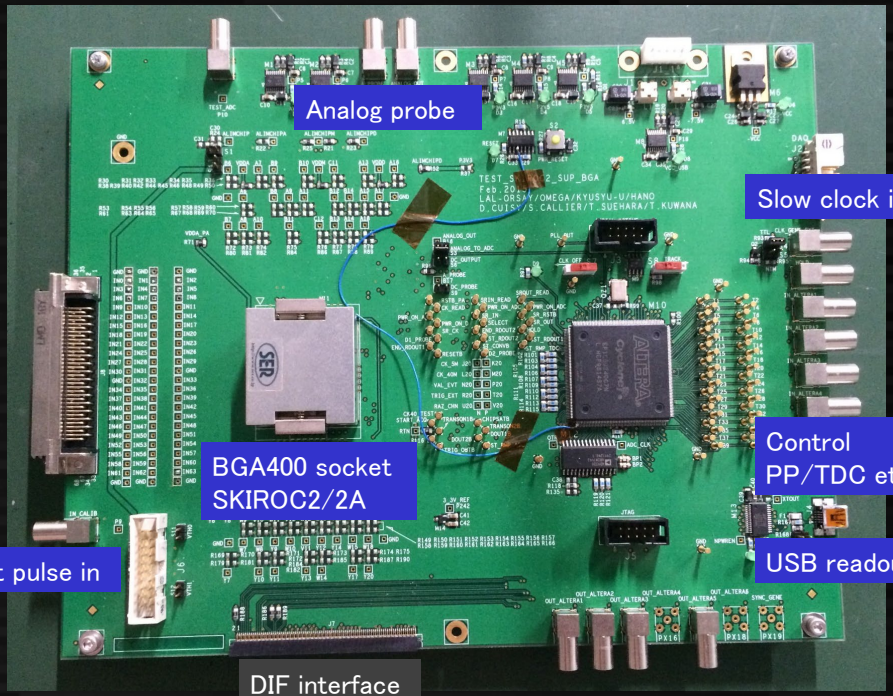
SKIROC2/2A (Analog part)



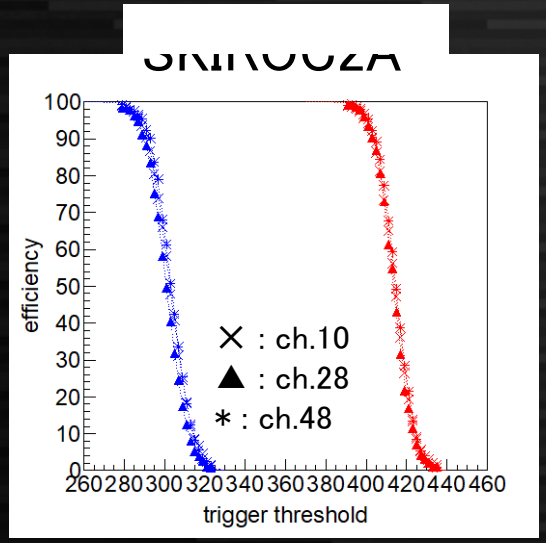
Characteristics

- 64 channels
- For n-bulk silicon (SKIROC2CMS: dual polarity)
- Linear up to 4 pC w/ two gain shapers
- Self triggering w/ threshold adj.

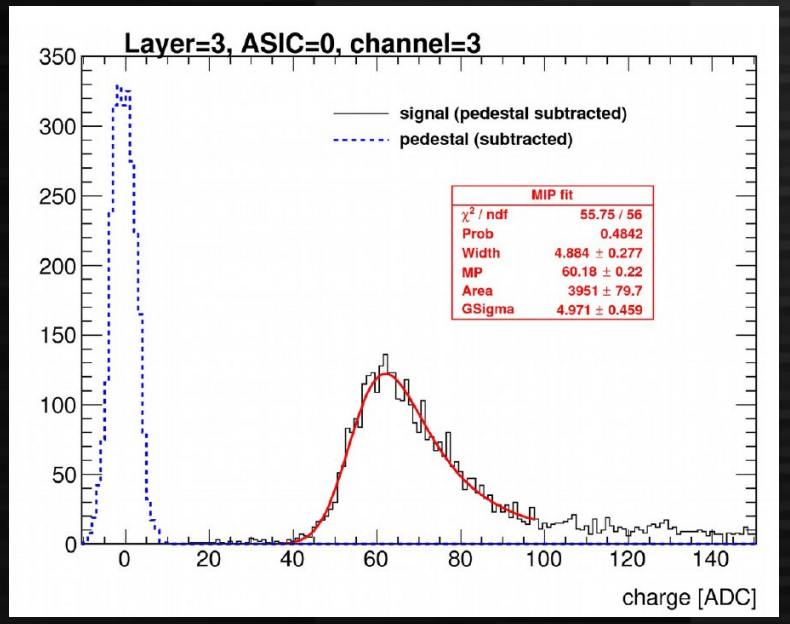
SKIROC2/2A/CMS studies



Testboard for SKIROC2 series
(sensor adapter under preparation)

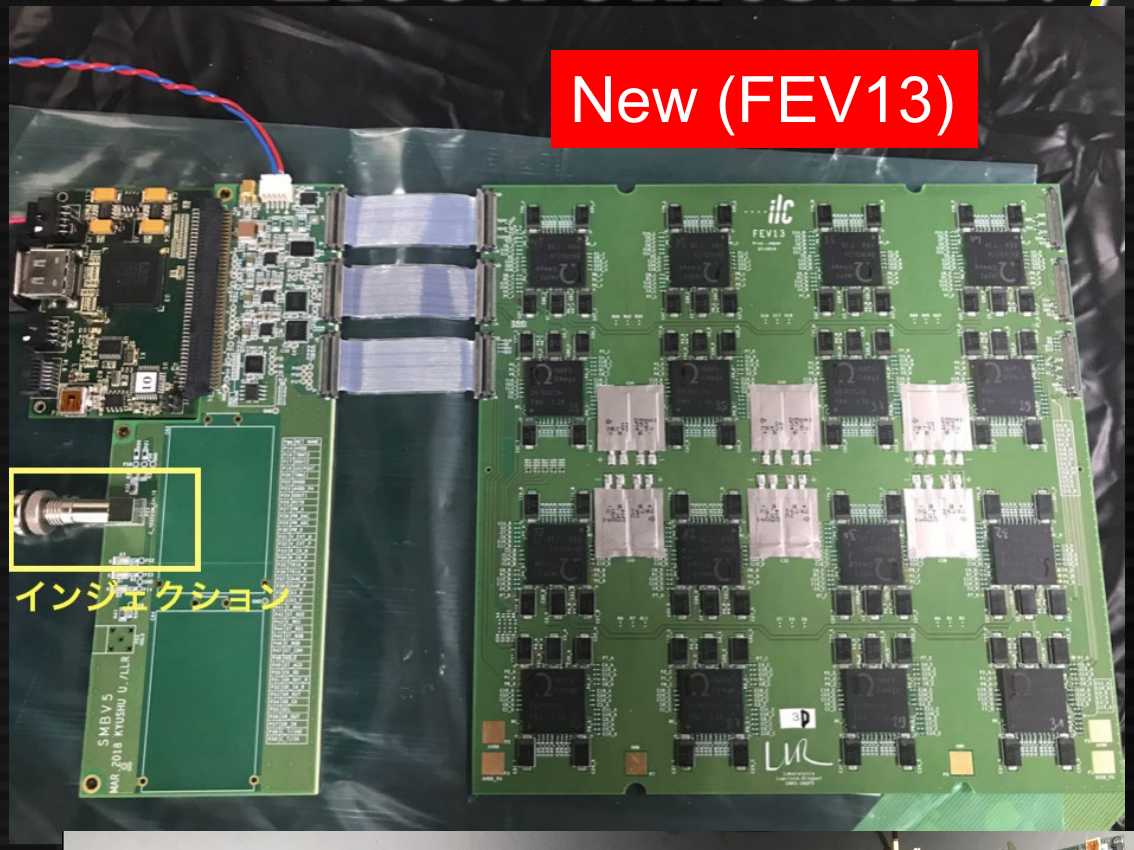


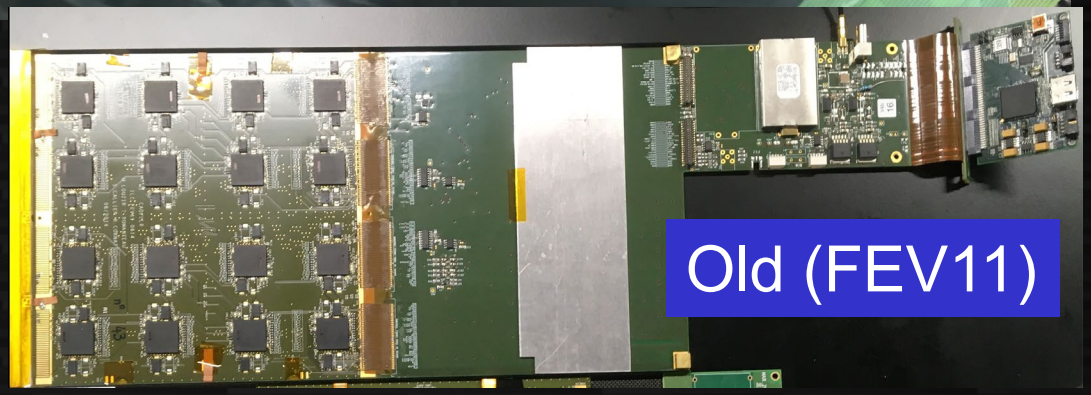
Trigger
S/N ~ 12
with
4 fC signal



S/N on slow shaper ~ 18
with 4 fC signal

Electronics: FEV/SMB/DIF

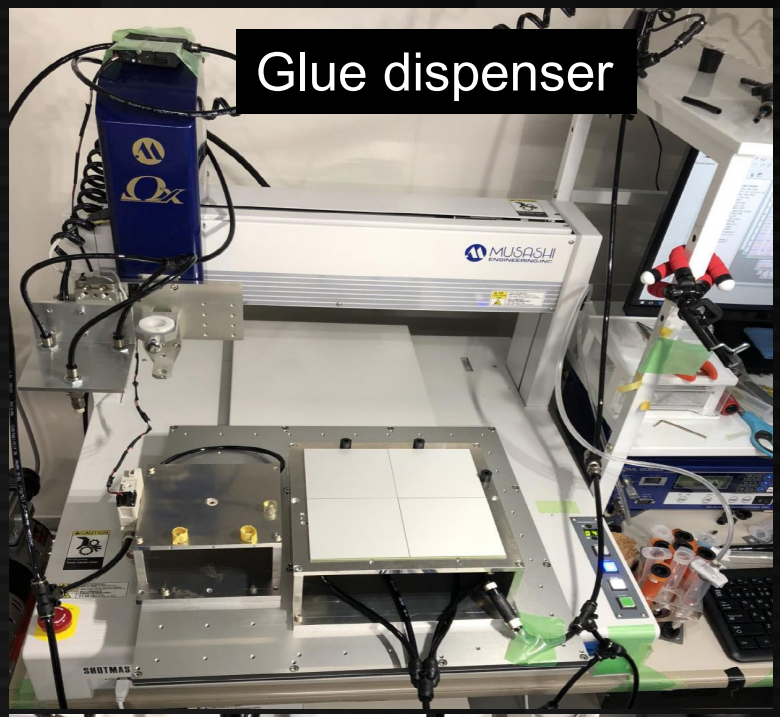


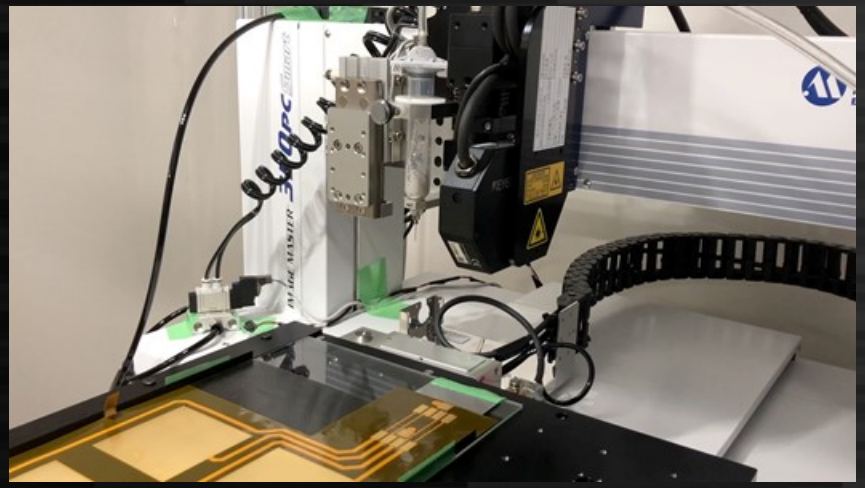


Slab assembly

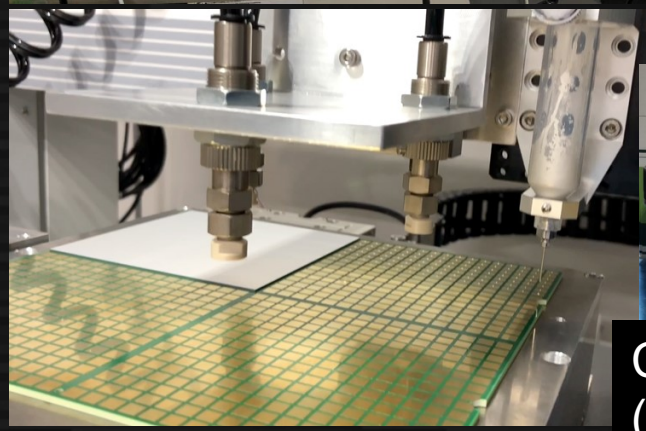
- FEV
  - 16 ASICs (256 ch)
  - 4 sensors embedded
  - Thin super-capacitors for power-switching at 5 Hz
  - 12 layers
    3 power planes of 3.3V (PA, Analog, Digital)
  - Thin flat connector/cable
- SMB
  - Regulators/repeaters
  - HV filter (CR)
- DIF
  - FPGA (Spartan3) (will be redesigned)
  - HDMI I/O

Slab Assembly (in Kyushu)

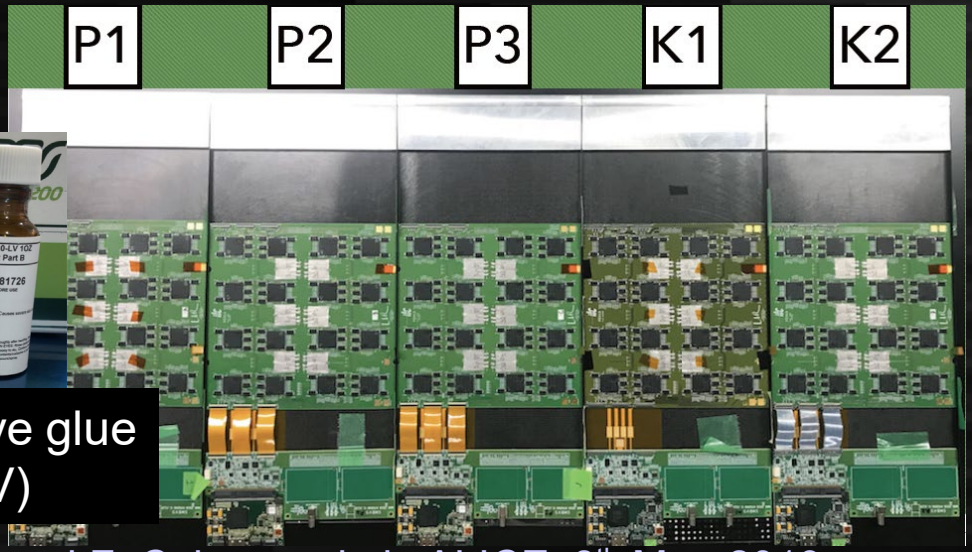




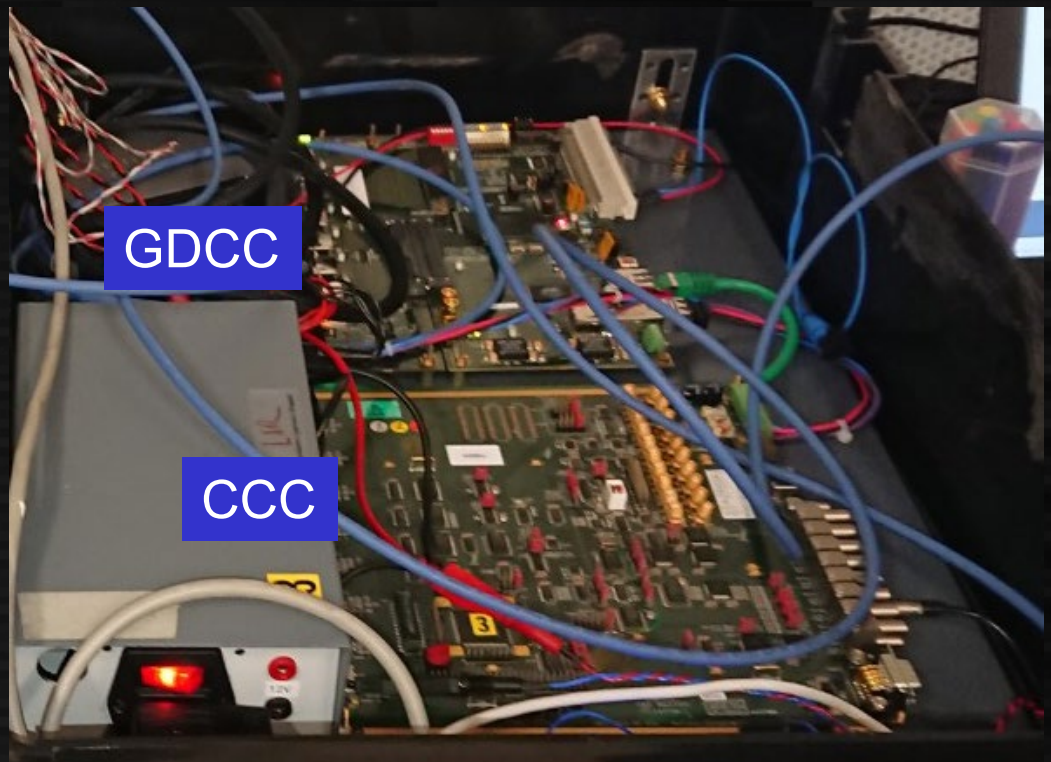
Gluing flex to PCB/sensor assembly with automatic alignment

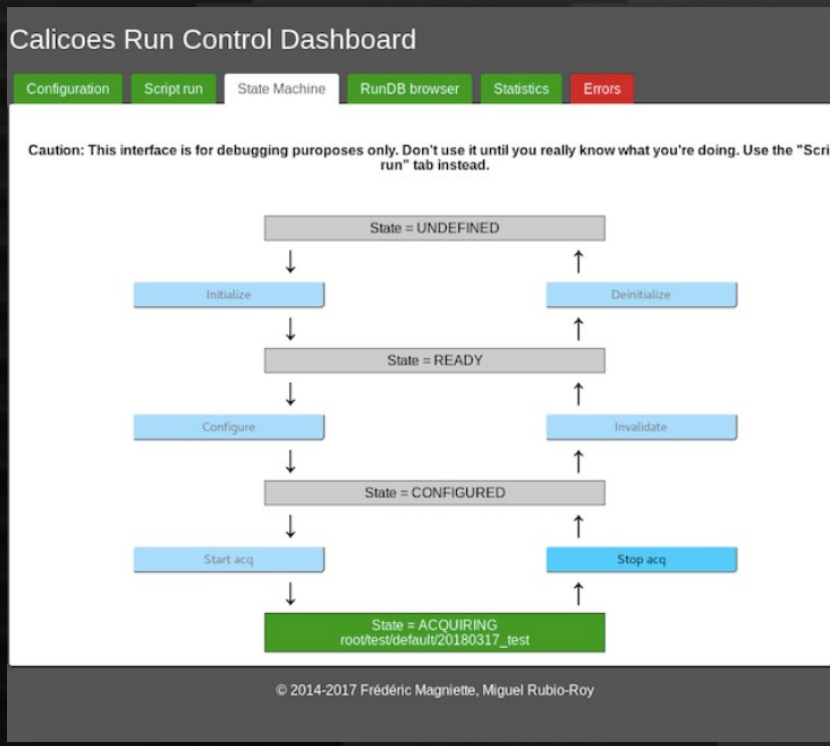


Conductive glue (E4110-LV)



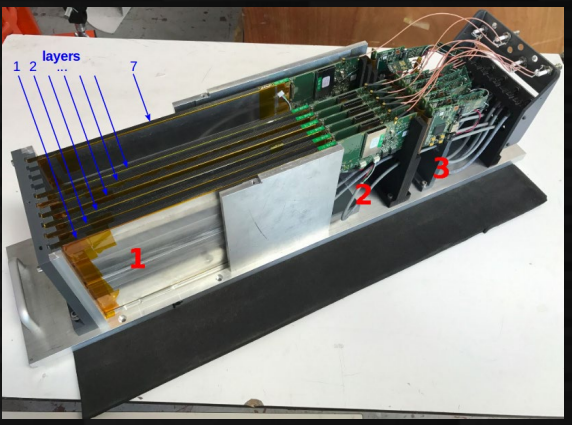
Interface cards and DAQ





- GDCC (Giga Data Concentration Card)
  - Interface to DIFs via 8 HDMI ports
  - RJ45 to PC (GbE) for data transfer (raw Ethernet protocol)
- CCC (Clock Control Card)
  - 10 HDMI IOs
  - Distribute clock (40 or 50 MHz)
  - Distribute spill via HDMI (fast command)
  - Busy treatment
- CALICOES (DAQ)
  - Configuration by XML
  - Control by GUI
  - Python script

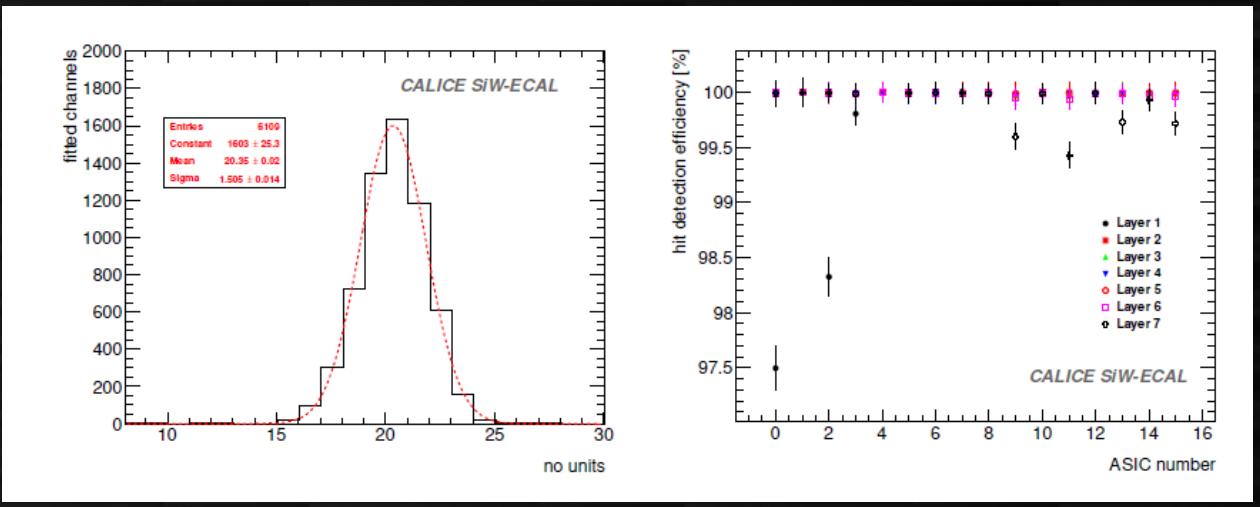
Test Beams



2017 DESY

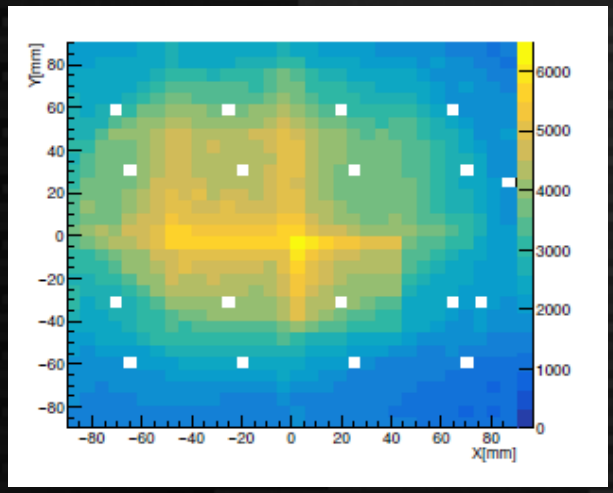
2018 DESY

2018 CERN SPS



S/N ratio (2017)

Hit efficiency (2017)



Hit map (SPS 2018)

arXiv: 1902.00110

Test beams: what we have learned

- The prototypes work reasonably good
  - Some missing channels due to the noise
  - Some issues on triggering (retriggering)
  - Acquisition rate limited by data transfer
    Need more efficient communication
  - Improvements needed for mechanical support
- Common run with HCAL partially done
  - Sometimes suffered from noise from other detectors
  - Common clock/spill/DAQ non-trivial
  - Several options, complicated (human) relations

Discussions on sensor production

- 8-inch sensors (initiated by CMS production)
  - Production in HPK possible from 2020
    - They are preparing the production line
  - Standard thickness should be 700 μm
    - Thinning possible (with additional cost)
  - Cost/area similar to 6-inch sensors
    - 2-3 EUR/cm^2 in mass production (> 100 k sensors)
  - Resistivity may be lower (means higher V_{FD})
- Alternative producers: still missing (with large qty)
- Guard rings: effective for higher V_{BD} but must be grounded (by wire etc.) 0 GR promising with low V_{FD}

OMEGA ASICs for silicon pads

- SKIROC2/2A
  - Only for n-bulk, optimized on ILC bunch structure
- SKIROC2CMS
  - Rolling buffer (no trigger selection)
  - Focused on timing resolution
  - Dual polarity
- SKIROC3
  - Final version for ILD SiW-ECAL?
  - Zero suppression
- HGCROC
  - Under development for HGCAL in CMS

Integration to bigger detectors

"Long slab" prototype

The realistic "module 0" should be prepared before the construction

- 20-30 layers of long slab (-1k sensors)
- Tungsten absorber and mechanical support, cooling
- Space-compatible adapters
- Firmware and software efficient enough to read -20 long slabs
- Cooperation with HCAL and trackers with common DAQ
- Reasonable maturity on quality control in production and test

Summary

- ILC has just been pushed forward with the statement of March 7th from MEXT.
- SiW-ECAL is a key element of ILD detector.
- Technological prototypes were fabricated and the basic functions confirmed.
- Bigger prototype towards “module 0” is now being prepared.
- Collaboration with FoCAL people is already at some level; more desired.
- ILC welcomes young people with future hope.