Optimization of ILD ECAL with 'hybrid' design etc.

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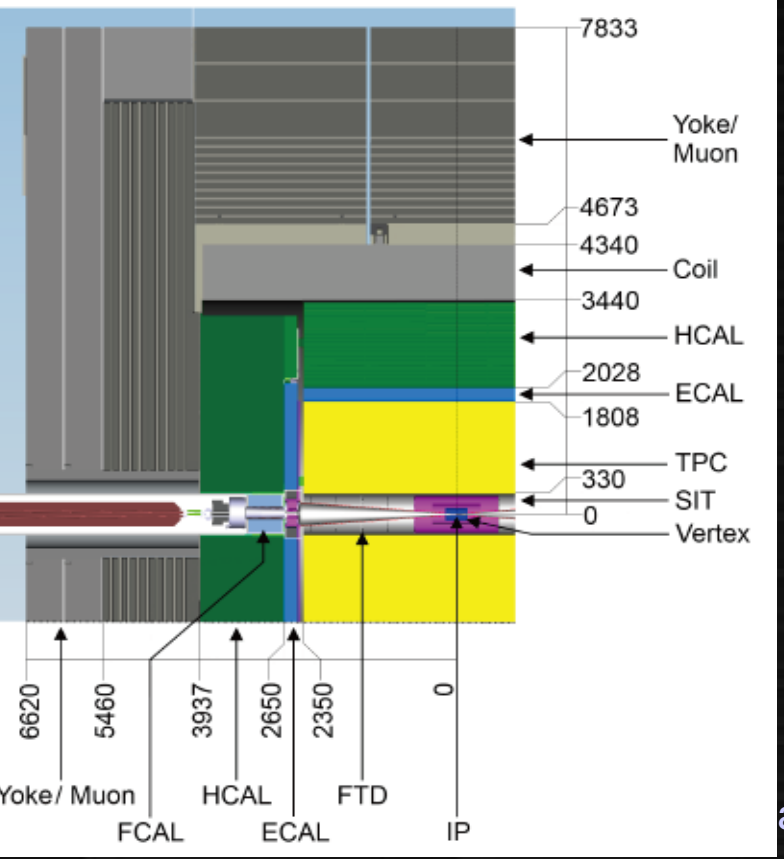
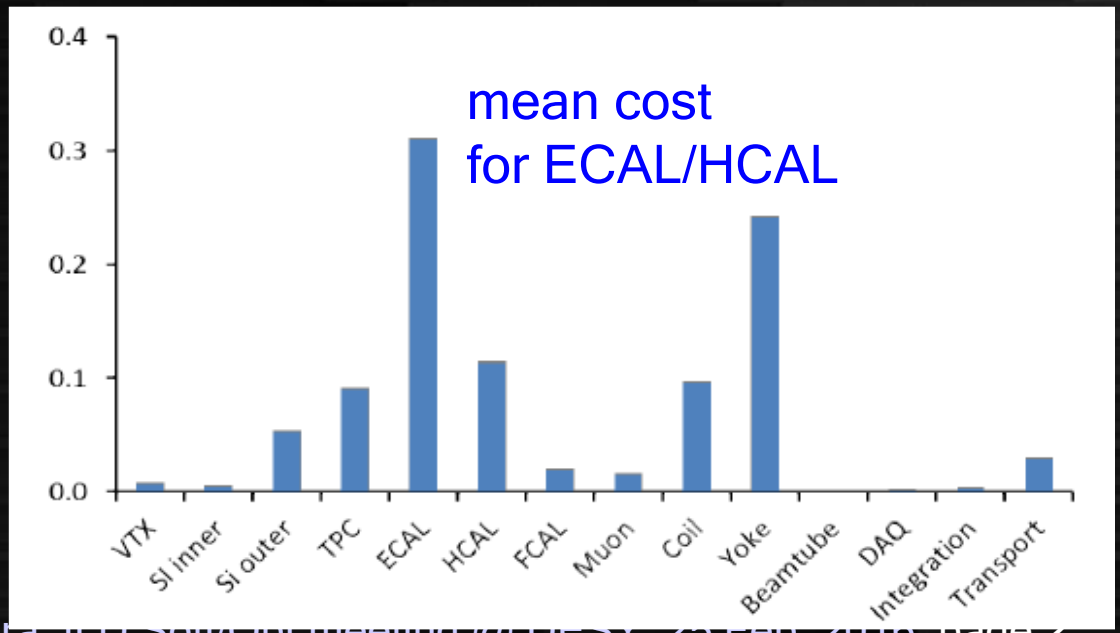
ILD & ECAL

r_{ECAL} = 1808 mm (SiD: 1265 mm)

Excellent PFA power
but expensive ECAL & Yoke*
*Yoke requirement from B leak



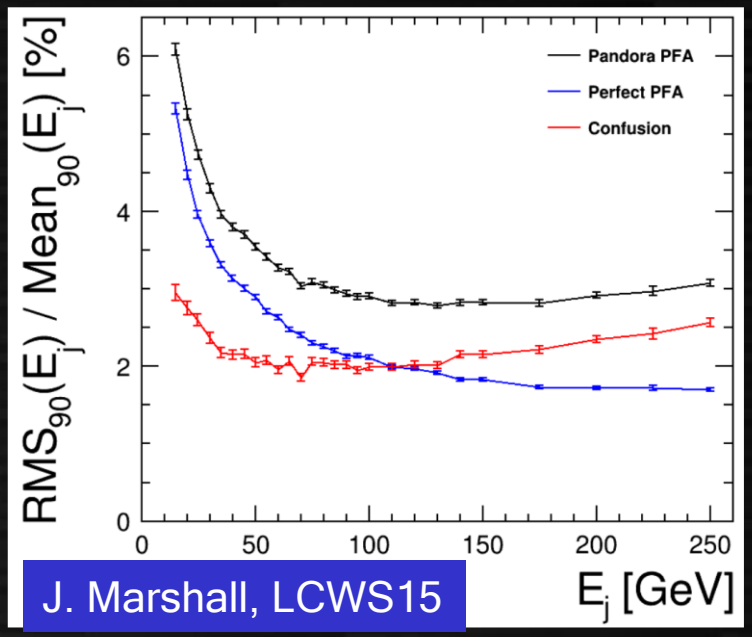
ILD cost in DBD: 391.8 MILCU in total



Cost reduction parameters

- ECAL inner radius
  - Reduce cost on both ECAL and Yoke
  - Affect particle separation
  - Affect tracker resolution
- ECAL depth (number of sensitive layers)
  - Reduce cost on mainly ECAL
  - Affect single particle resolution
- Granularity
  - Reduce cost on ECAL electronics (and SiPM in ScECAL)
  - Affect particle separation
- Si or Sc sensitive layer, or hybrid
  - Calibration and stability

Jet energy resolution



J. Marshall, LCWS15

Low energy jets → single particle
High energy jets → confusion

Dijet mass (W/Z/H) is mainly affected by the jet with worse resolution

250-500: mainly concern lower
>500: higher energy more important

	<70 GeV	70-150 GeV	>150 GeV
Photon δE	*	-	-
Hadron δE	***	**	*
confusion	*	**	***

Cost reduction comparison

	Cost (ECAL)	Photon E	K0 E	Confusion
DBD (Si Only)	+36%			
R=1650, N=30	+15%			X
R=1500, N=30	-5%			XX
R=1800, N=26	+14%	X	X	
R=1800, N=22	0%	XX	XX	
R=1650, N=26	0%	X	X	X
R=1450, N=22	-35%	XX	XX	XX
Hybrid, N=15+15	0%			x
Sc Only, N=30	-35%			xxx
Hybrid N=10+25	-1%		+?	xx

For smaller R, same aspect ratio is assumed
For smaller R, cost of Yoke and tracker perf. affected

Medium ECAL (around DBD cost)

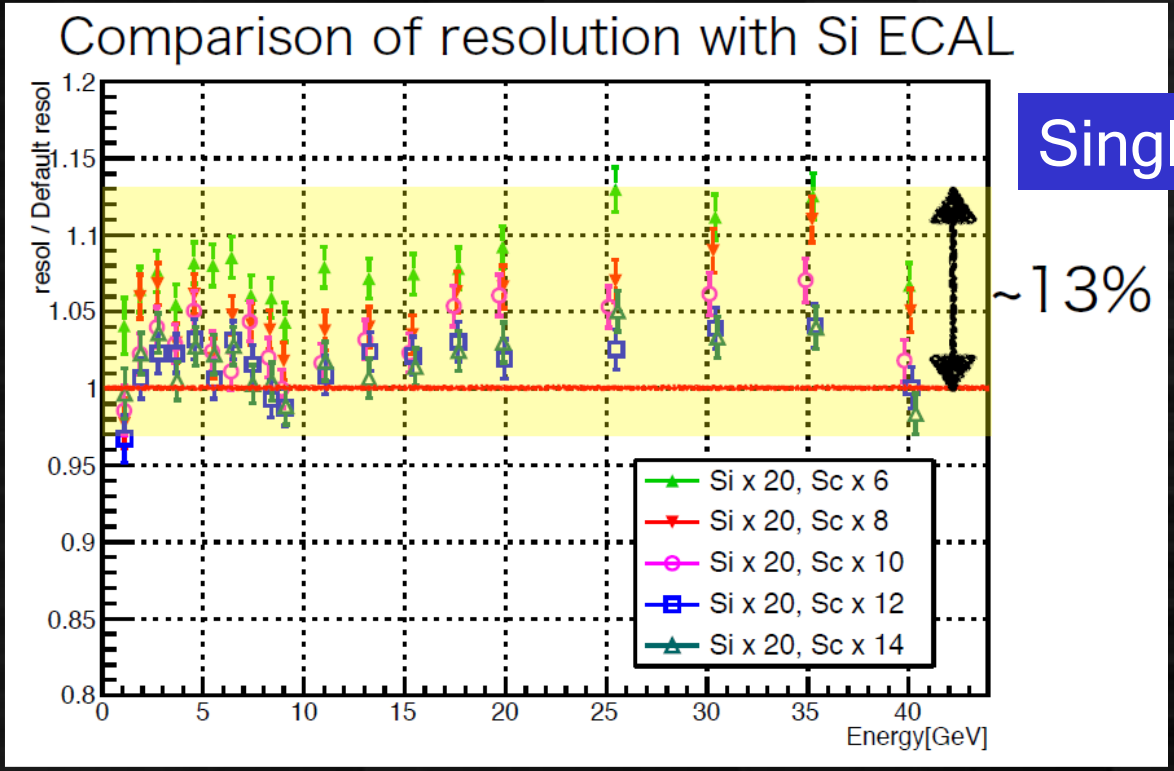
Cheap ECAL

Consideration

- For “medium cost” ECAL:
  - “Small” detector
    - Radius or number of layers?
    - Single particle resolution and confusion should be considered separately
  - “Hybrid” detector with keeping size
    - Granularity (inner vs. outer)
    - Possibility to improve single particle resolution by more Sc layers
- For “lower cost” ECAL:
  - “Very small” vs “Sc only”
  - …or small hybrid? (not in this talk)

Hybrid (1) more layers in outer Sc?

Energy resolution of neutral hadrons → important in low E jets



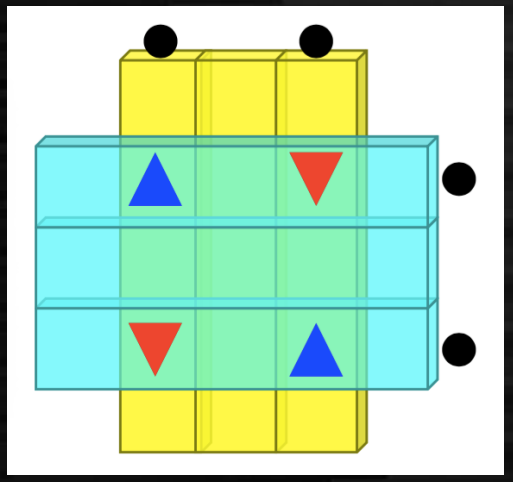
~ 5 % difference in 20+10 & 20+12?

Si-Sc difference: should be investigated: calibration??

Should separate layer effect and other effect (Si-Sc)

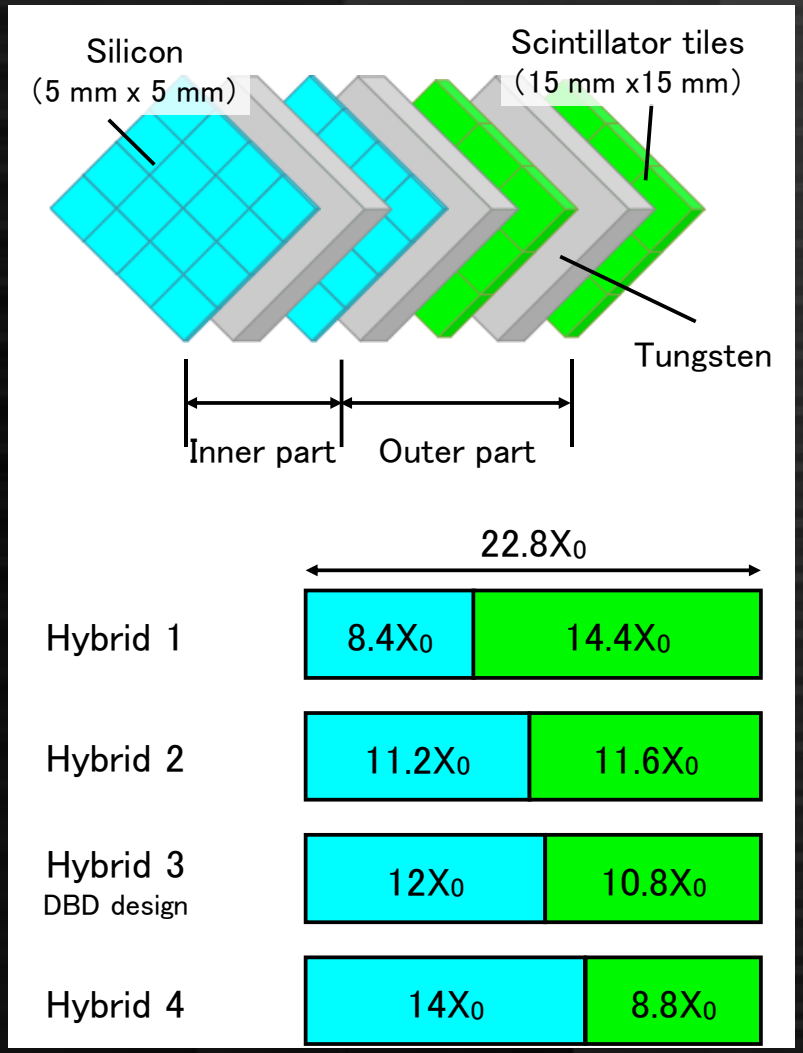
Hybrid (2) tile vs strip?

- Possible setup
  - 5 x 45 mm^2, 15 x 15 mm^2, 10 x 22.5 mm^2
  - Bigger cells – seems no meaning (PCB dominates)
- Low occupancy
  (<= 1 hit in 45 x 45 mm for 5x45 mm strip)
  - Strip has better position resolution
- High occupancy
  - Ghost occurs
    (right figure: 2 hits going to 4)
  - Tiles may be better
    (maybe shifted tiles help)



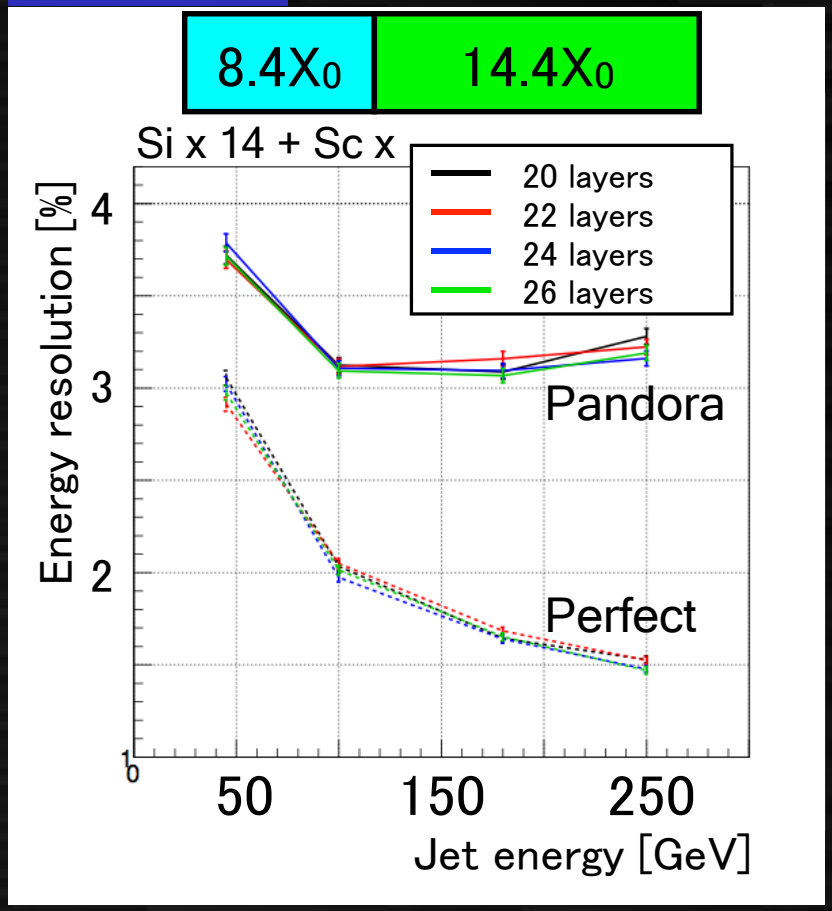
Hybrid (3) layer structure

- Innermost layers
  - Shower start position should be important → silicon?
  - Some new ideas
- Middle layers
  - Silicon or alternating Si/Sc
  - More layers important for single particle resolution
- Outer layers
  - Sc fitted?
  - Requirement of granularity should be revisited
- Boundary to HCAL should also be reconsidered

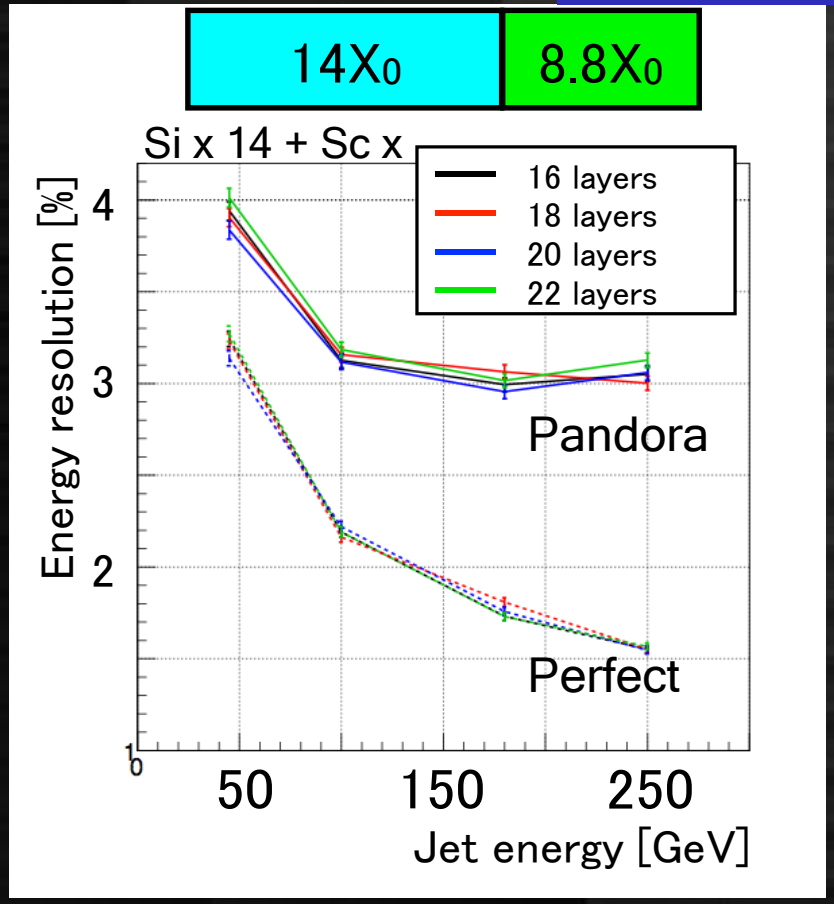


A study (1)

Hybrid 1

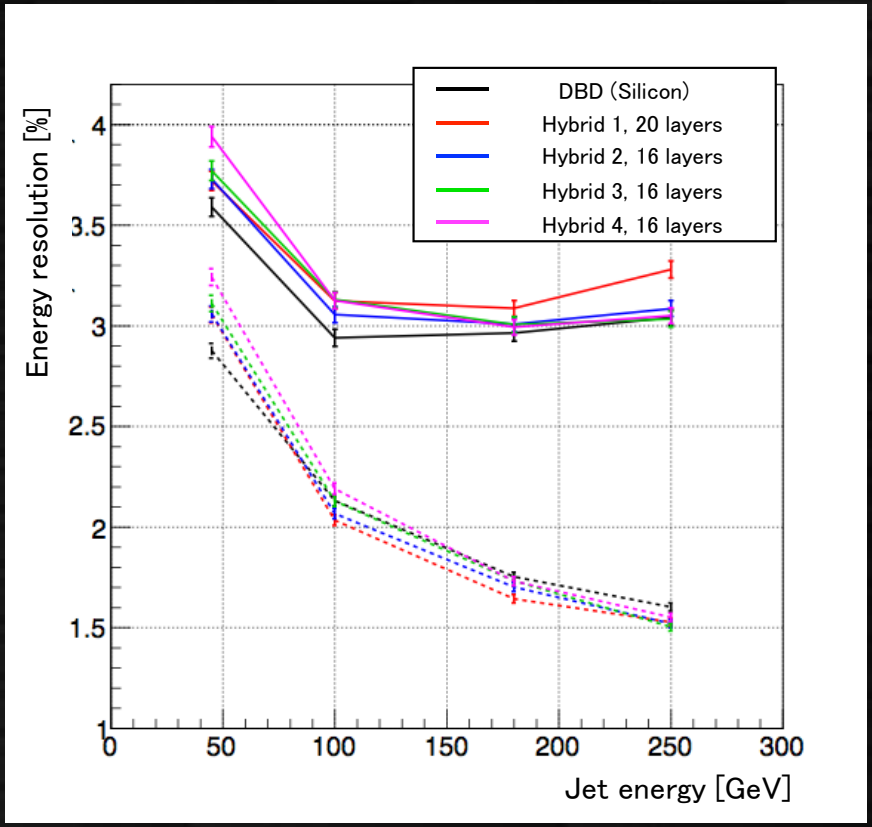


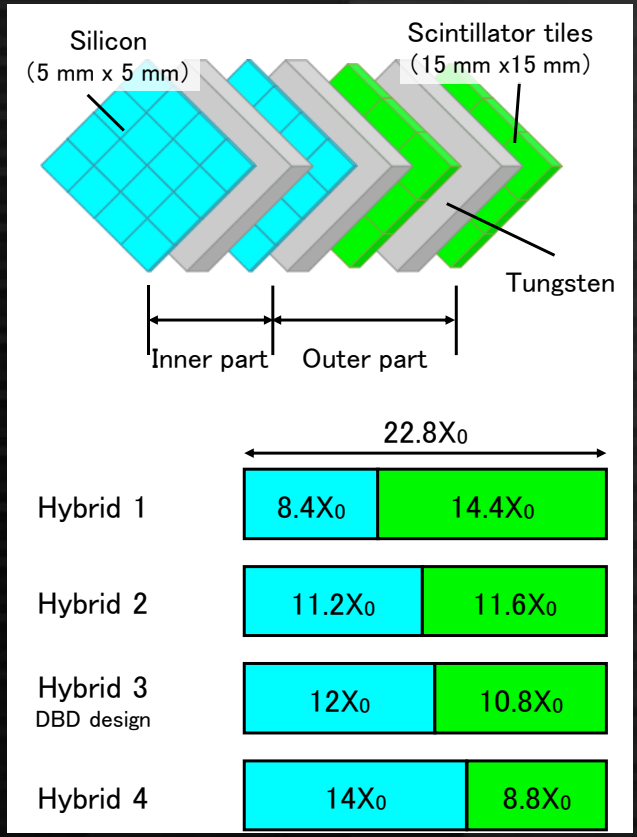
Hybrid 4



- Resolution on perfectPFA better in “hybrid 1”
- Confusion worse in “hybrid 1” in > 100 GeV
- No big difference on layers so far → why??

A study (2)





- Currently DBD gives better – include non-desired difference
- Hybrid 2-3 reasonable in this plots
- ~20% reduction of costs from DBD

What to investigate

- Separate Si-Sc and granularity/layer effect
  - Maybe all-silicon study desired
    (multiple pixel sizes / strip silicon etc.)
  - Want to see improvements by more layers
- Investigate Si-Sc difference in detail
- Pandora optimization
- More optimization
  - Three (inner-middle-outer) layer configurations
  - Alternating Si-Sc
  - Strip vs tile, strip length, shifted tile, shifted strip etc.
- Software compensation in ECAL
- ECAL-HCAL total optimization

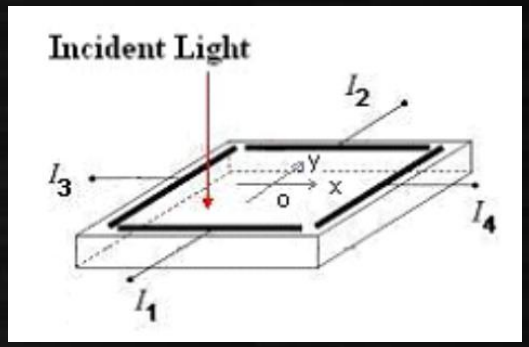
Plan

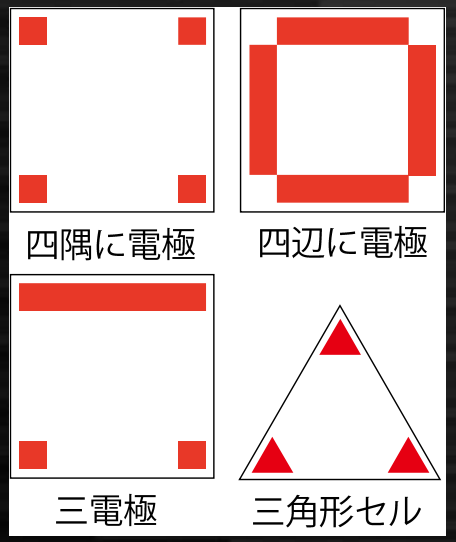
- I will succeed the students' work to conclude within a half year (which I have time to work)
- By Mokka
  - Investigating Si-Sc difference
  - Tuning strip algorithm
  - Software compensation in ECAL (+ HCAL)
- By DD4hep version if available…
  - Study on dependence of various params
  - Establishing "reference hybrid detector" with reasonable performance and ~DBD cost

Additional: innermost layers

- Possibility to introduce “extremely granular” layers in innermost part (up to 2-3 X_0)
  - Target position resolution of track/gamma
    - For precise gamma studies (H→$\gamma\gamma$, tau etc.)
    - May improve JER by precise shower-start finding
  - Technologies
    - Silicon strips with similar channel density (maybe possible to substitute SET)
    - Position sensitive silicon detector (multiple electrodes in one cell for charge sharing)
    - MAPS

New idea - position sensitive det.

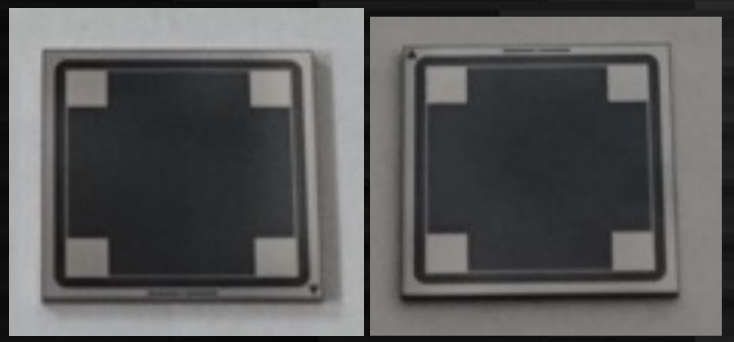




ideas on electrodes

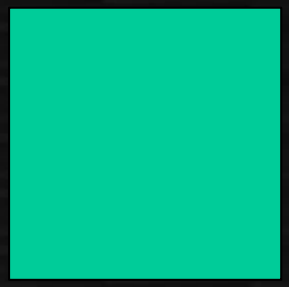
Position sensitive detector (PSD) popular in laser measurement (produced by Hamamatsu)
Application on heavy-ion exists

Divide signal into several electrodes
→ less S/N expected
No much difference on electronics
For “precision shower start finder” to be used in inner layers of ECAL

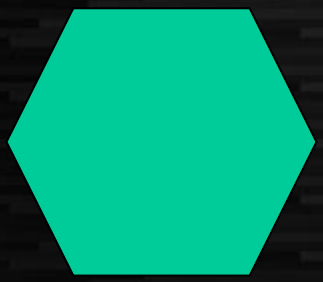


First PSD sample in Kyushu
meshed (left) and unmeshed
8 mm one side, 1 mm electrodes

Hexagonal sensors

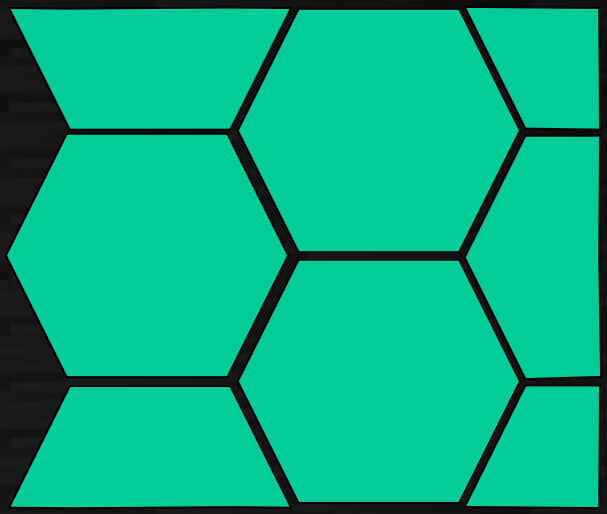


Square
Max. 9.8x9.8 cm^2
Area = 96.04 cm^2

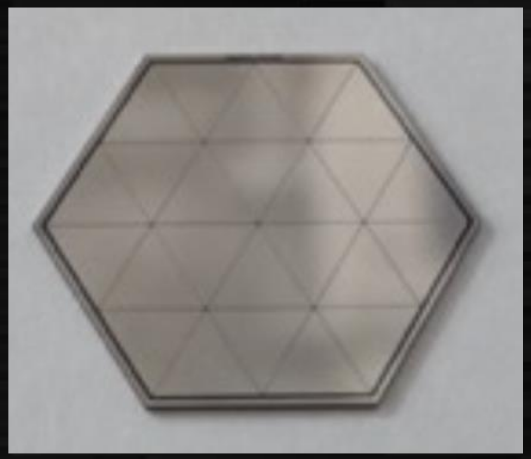


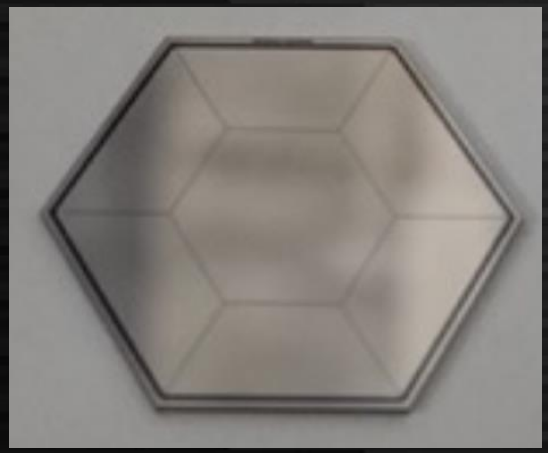
Hexagon
Max. 6.9 cm each edge
Area = 123.69 cm^2
(28.8% larger than square)

28.8% more area per wafer → 22.4% less wafers needed



Preliminary idea
of “Slab for hexagon”





The first “baby” sample in Kyushu
8 mm each side

Summary

- Hybrid is a cost-effective implementation of ILD-ECAL
  - hybrid with r = 1800 mm roughly comparable to all-silicon ECAL with r = 1650 mm
- Various things need to be addressed
  - PFA performance (software tuning)
  - Reasonable layer structure
- Some new ideas exist for further study

Backup: DBD cost

SiECAL		ScECAL	
Item	Cost [kILCU]	Item	Cost [kILCU]
Tungsten	16310	Tungsten + carbon parts	18500
Carbon fiber structure	2130	Module realisation	1700
Silicon sensors	75000	Scintillators	1030
Readout ASIC	16500	Photo Detectors	10200
Readout Board	21000	Readout ASIC	2500
Materials	1300	Readout Board	25000
Cables, connectors	2220	Readout System	6200
Tooling	9300	Cables, connectors	1000
Assembly	13500	Power supplies	4100
Integration	500	Tooling	3800
Sum SiECAL	157760	Sum ScECAL	74000