The CALICE silicon-tungsten ECAL

Present status,
with focus on activities in Japan

SiD meeting @ Tokyo
September 2014

Daniel Jeans
U. Tokyo

Many (but not all) groups researching
particle flow-based calorimeters for
linear colliders are members of

& CLIC
& others...

Groups from Japan
(all associated with ILD, rather than SiD)

- Shinshu University

- Tsukuba University

- Kyushu University

- University of Tokyo

Japanese groups working on two technologies:

silicon-tungsten ECAL

-> this talk

scintillator with MPPC readout
(mostly for ECAL, also considering application to HCAL)

-> next talk from K. Kotera

SCINTILLATOR	- Shinshu University	- Tsukuba University
SILICON	- Kyushu University	- University of Tokyo

The CALICE SiW-ECAL group has active participants from:

- France
  LLR, LAL, LPC, LPSC, LPNHE, Omega

- Japan
  Kyushu, Tokyo

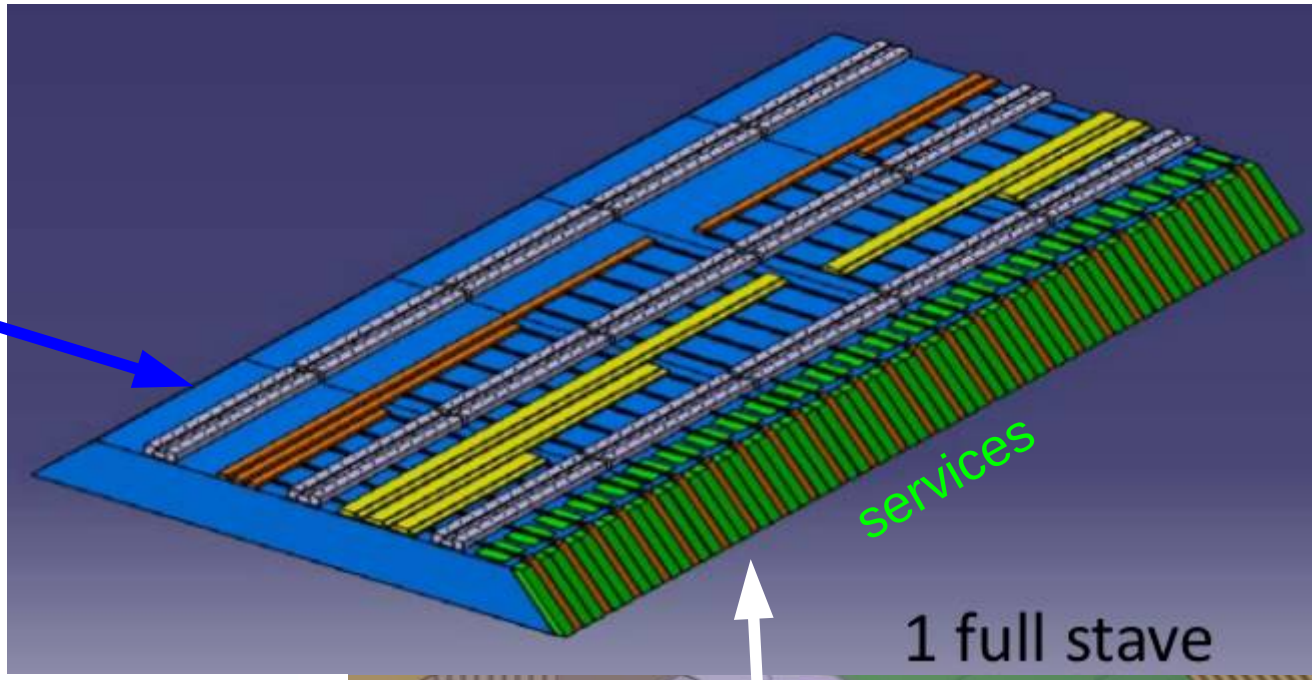
- Korea
  SKKU

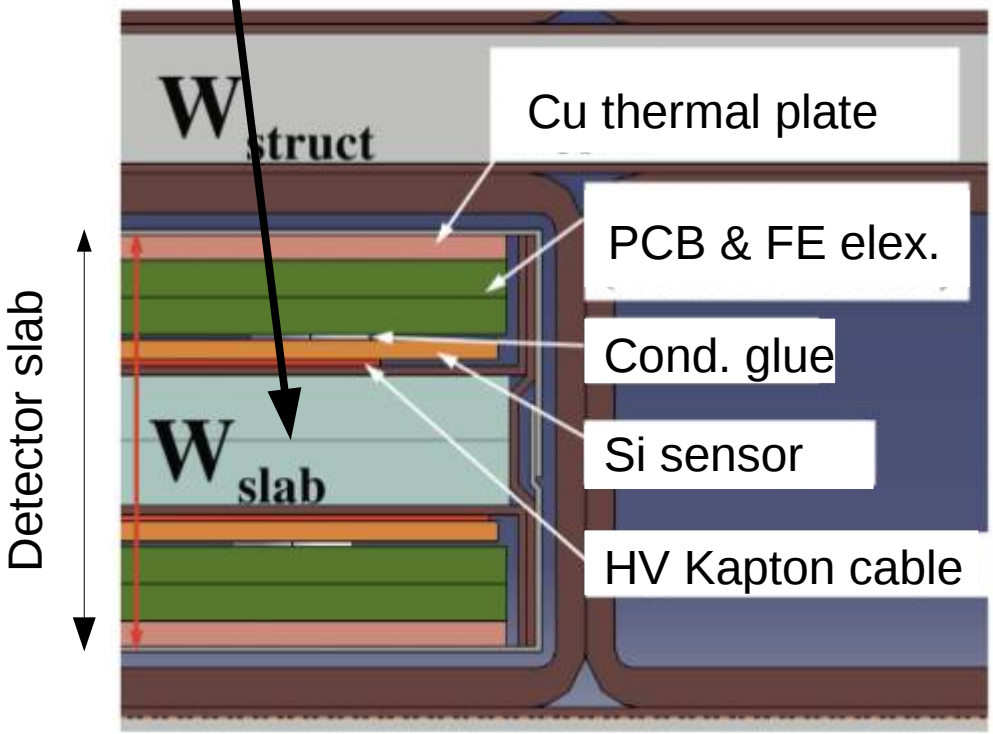
with previous (dormant?) participation from
  UK and Czech groups

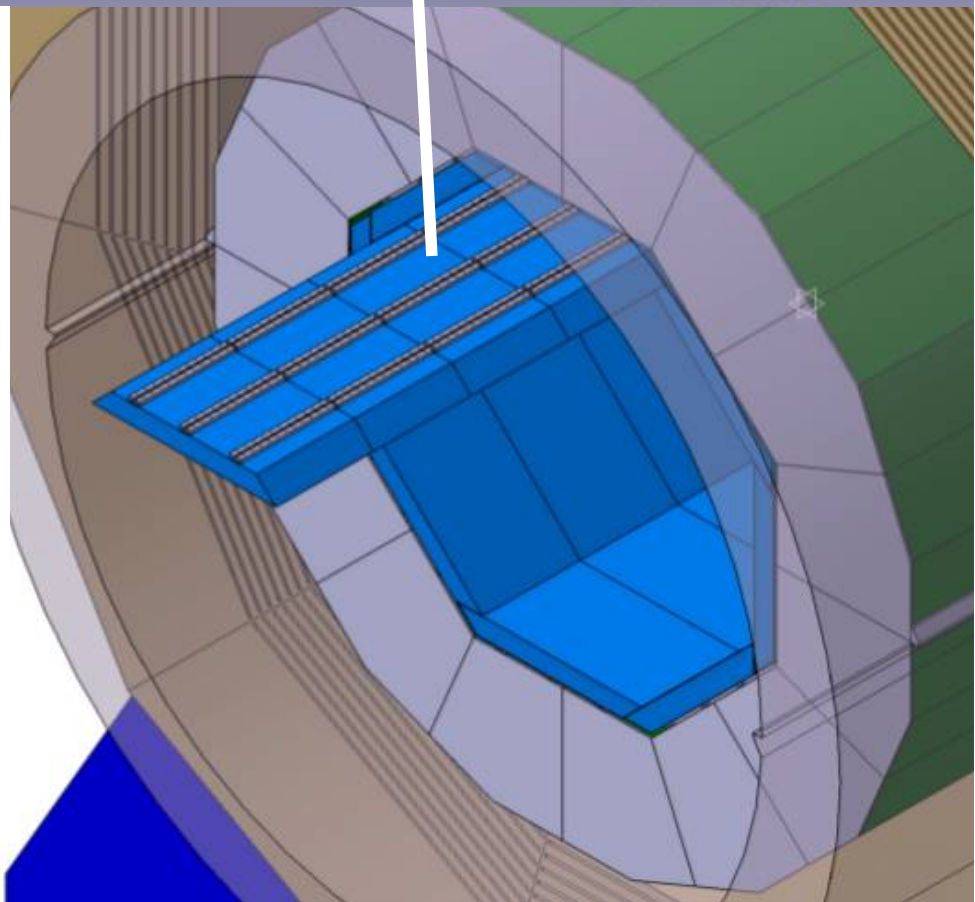
ILD Ecal structure

Carbon-fibre&W
alveolar structures

...into which
detector slabs are slid







“Physics” prototype

First prototype constructed 2006/7

30 layers, ~10k detector cells (1x1 cm^2)

retired from beam tests in 2011

after operation over 5 years in 3 laboratories (DESY, CERN, FNAL)

No aging problems identified

...other than usual problems with broken connectors

Demonstrated that technique works

but...

- external electronics
- lots of cables
- no power-pulsing

“Technological” prototype

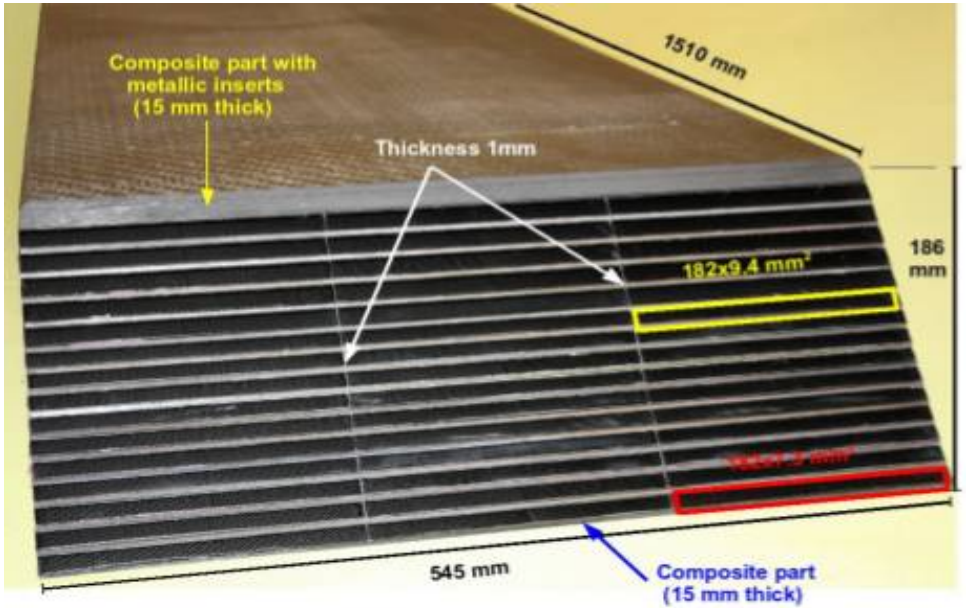
Realistic mechanics

Modular, scalable, design:
Active Sensor Unit

Embedded Front-end electronics
Power pulsing

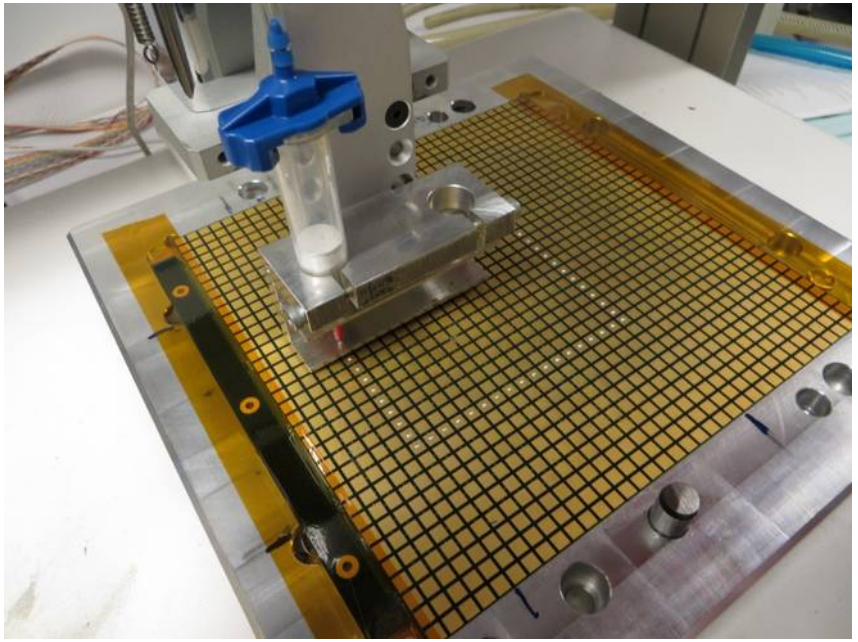
Improved sensor design

Assembly techniques

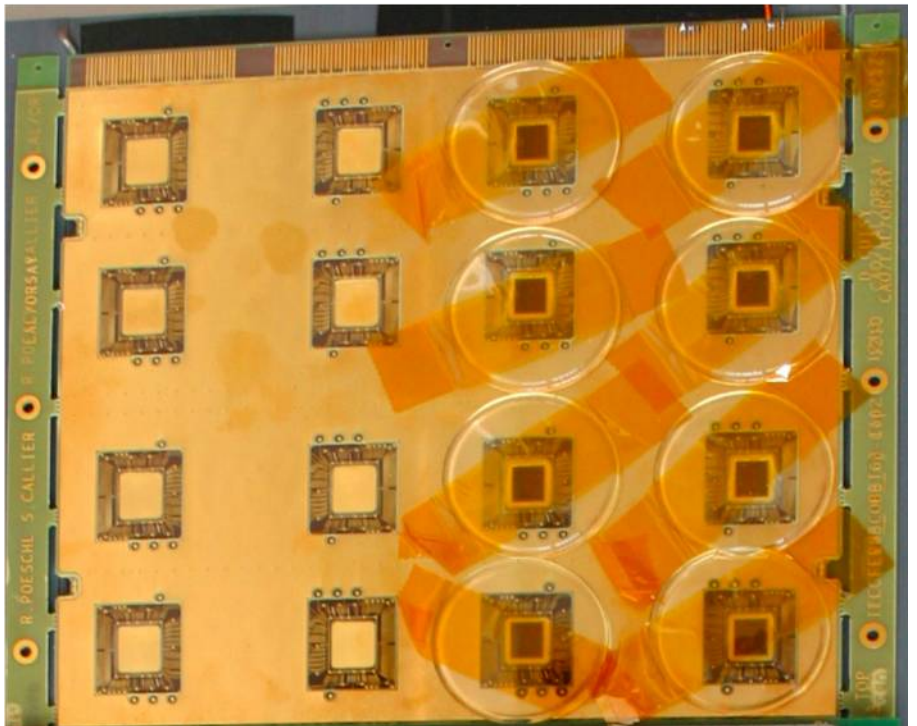


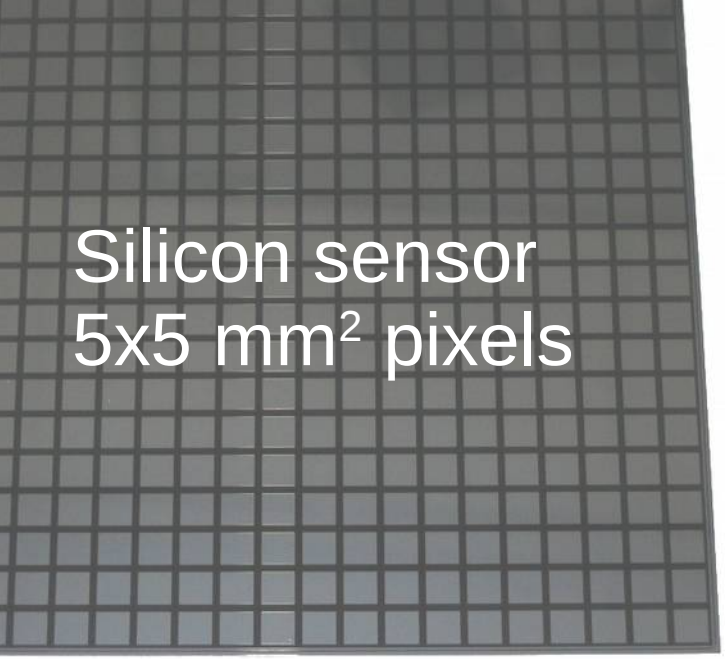
Mechanical structure @ LLR

Gluing robot @ LPNHE



PCB with ASICs @ LAL & Omega





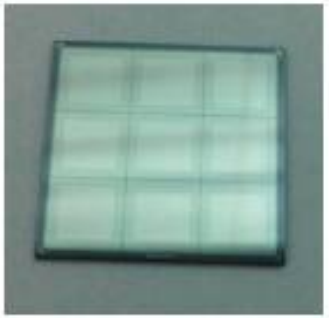
Silicon sensor development

in close association with Hamamatsu Photonics KK

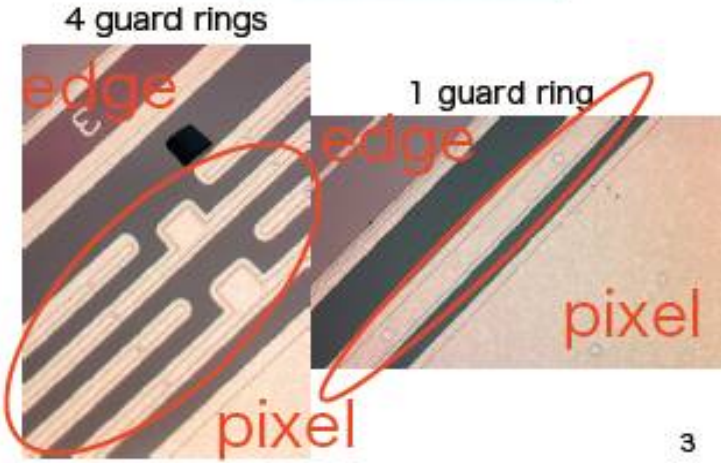
Different designs of guard rings around sensor edge

Different raw material quality – i.e. resistivity
(with view to large-scale production)

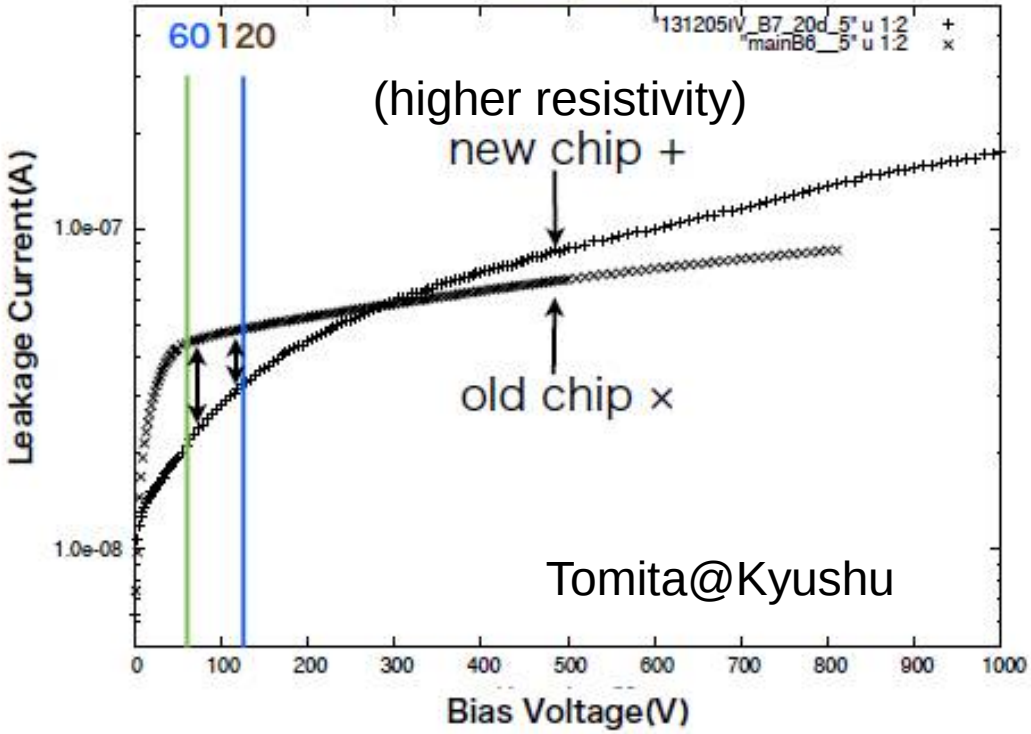
Discussions on cost of large-scale production
raw wafer size, sensor thickness, ...



"baby" sensor
to test guard
ring designs



The leakage current at 120 V is 31nA (old : 48nA),
at 60 V is 21nA.



Sensor testing stations at Kyushu and Tokyo

Electrical characterisation

IR laser injection system

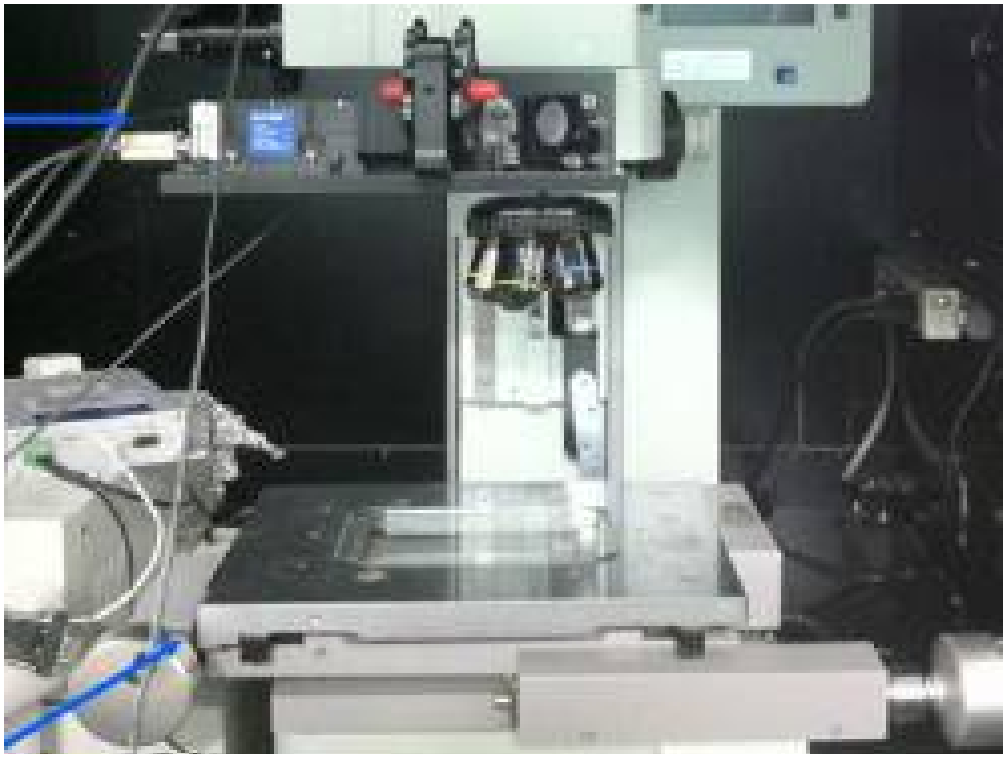
Testing with cosmics and sources

Several studies in progress

Comparison of sensor designs

Radiation hardness

Laser system @ Kyushu



Technical prototype

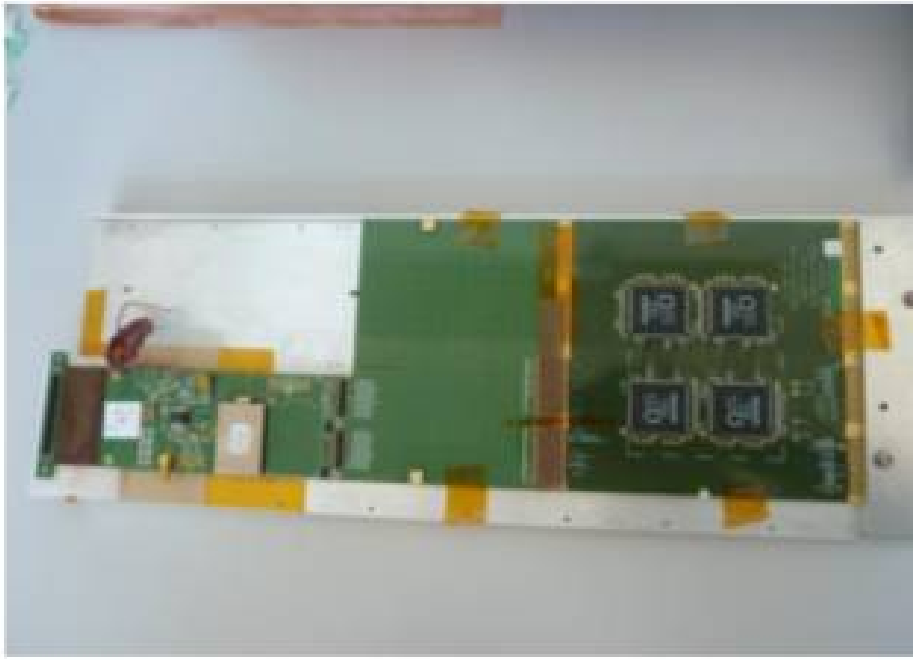
Several small layers

constructed
and
tested in cosmics and
electron beams

Develop assembly techniques

Debug design, operation

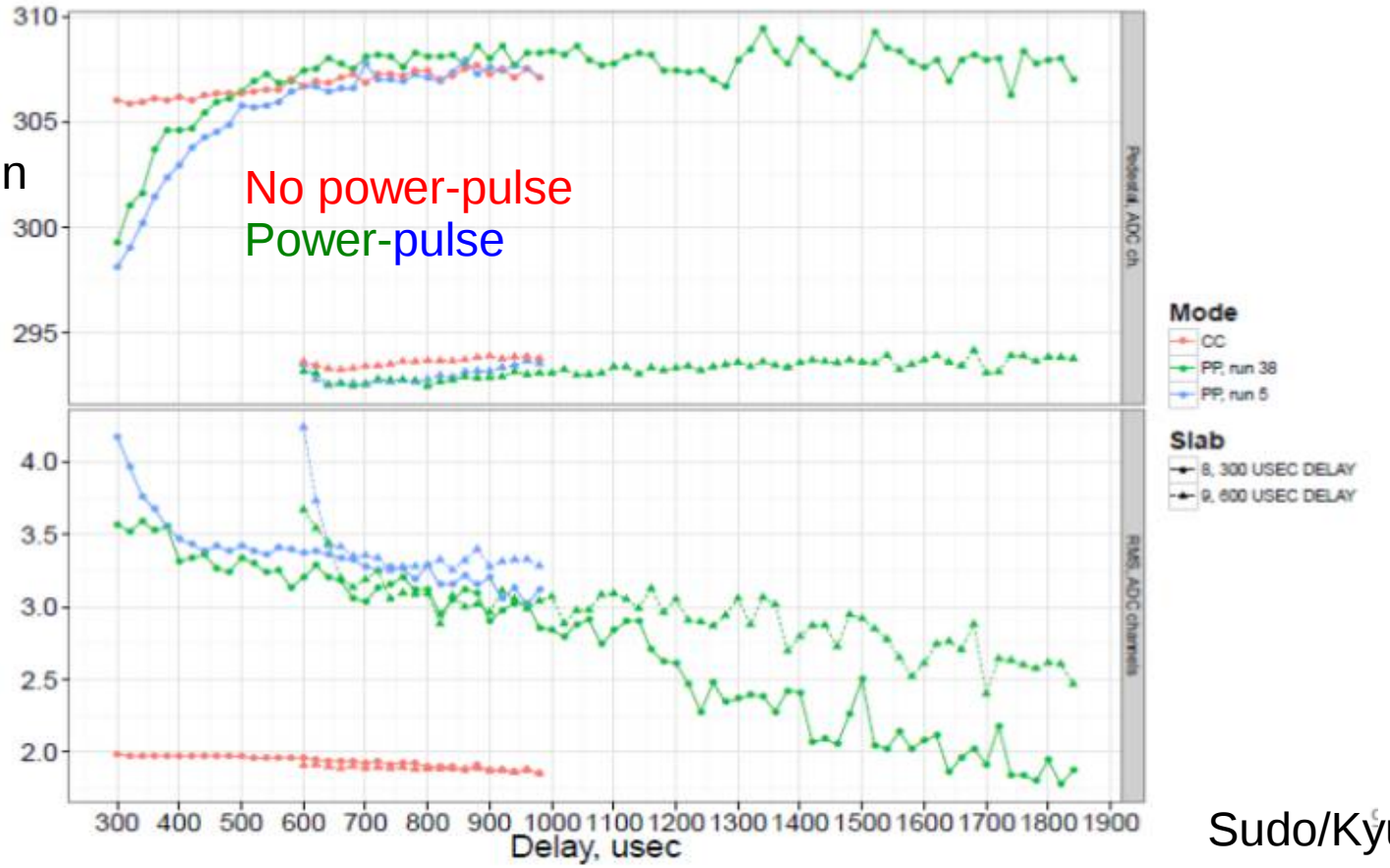
Also preparing long detector slabs



Power pulsing tests of detector slab

SKIROC2

Pedestal position [ADC]



Pedestal width [ADC]

Sudo/Kyushu

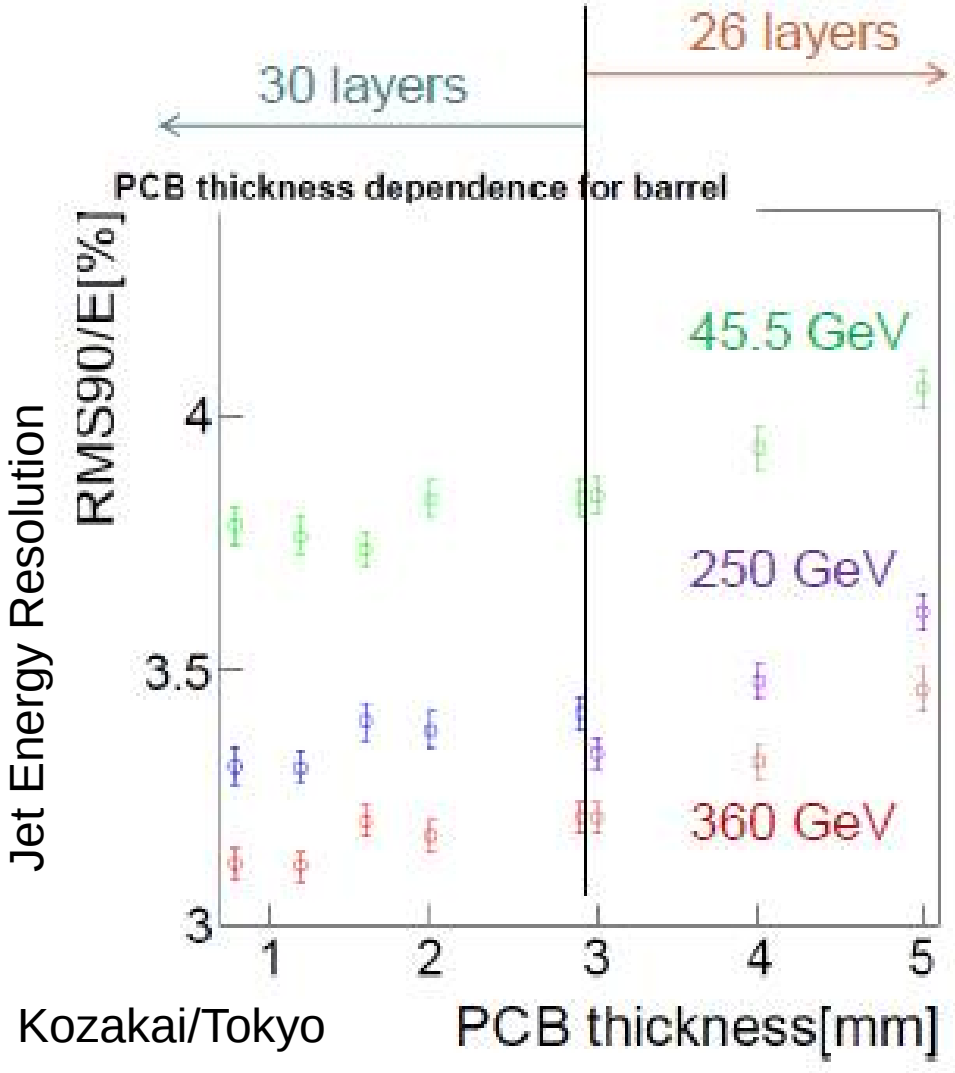
500 1000 1500 µsec

Time after power-on

Technical optimisation studies

e.g. what is effect of PCB thickness on Jet Energy Resolution?

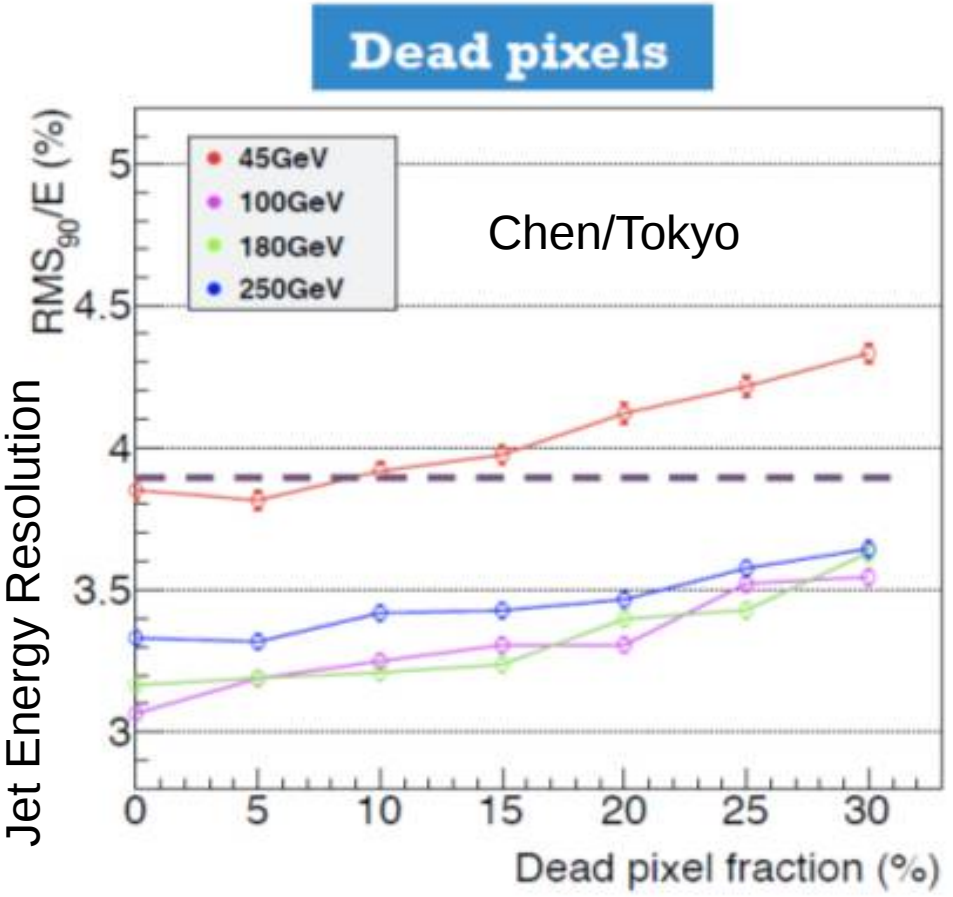
Thicker PCB gives larger EM showers; Is final performance degraded?



Kozakai/Tokyo

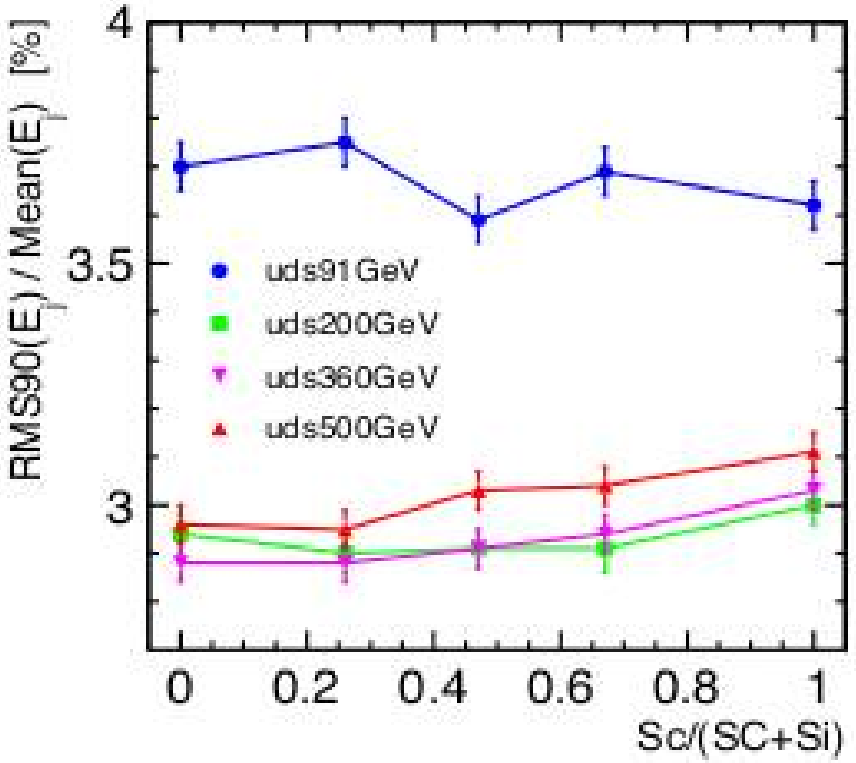
What fraction of “dead” detector cells is acceptable?

Input for sensor quality specifications

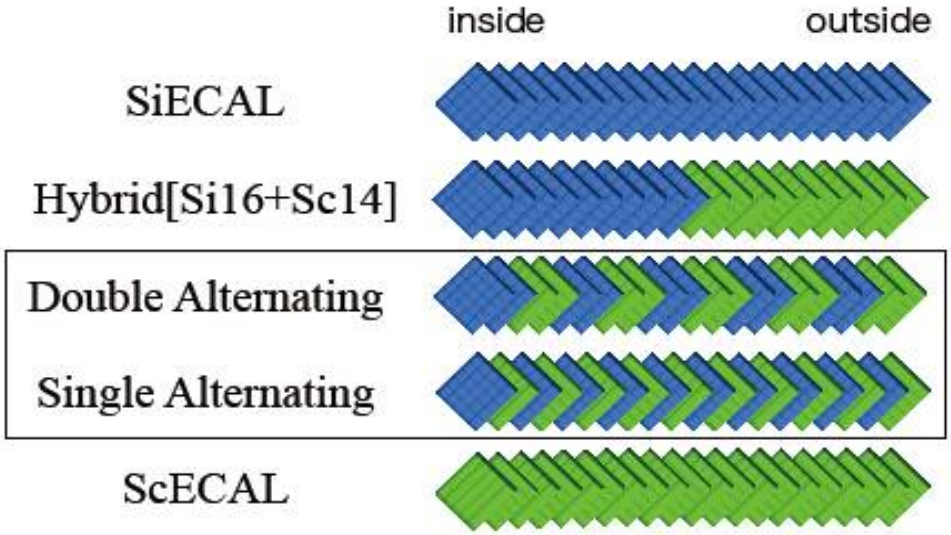


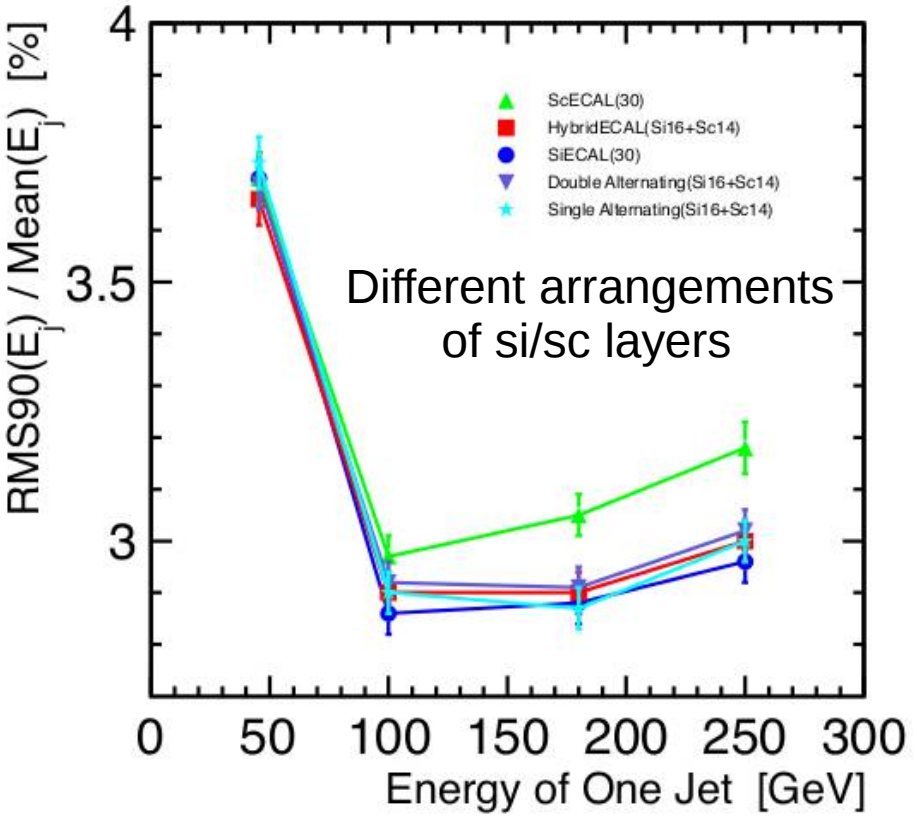
Hybrid ECAL studies

Would a mixture of silicon and scintillator layers work?



fraction of scintillator layers





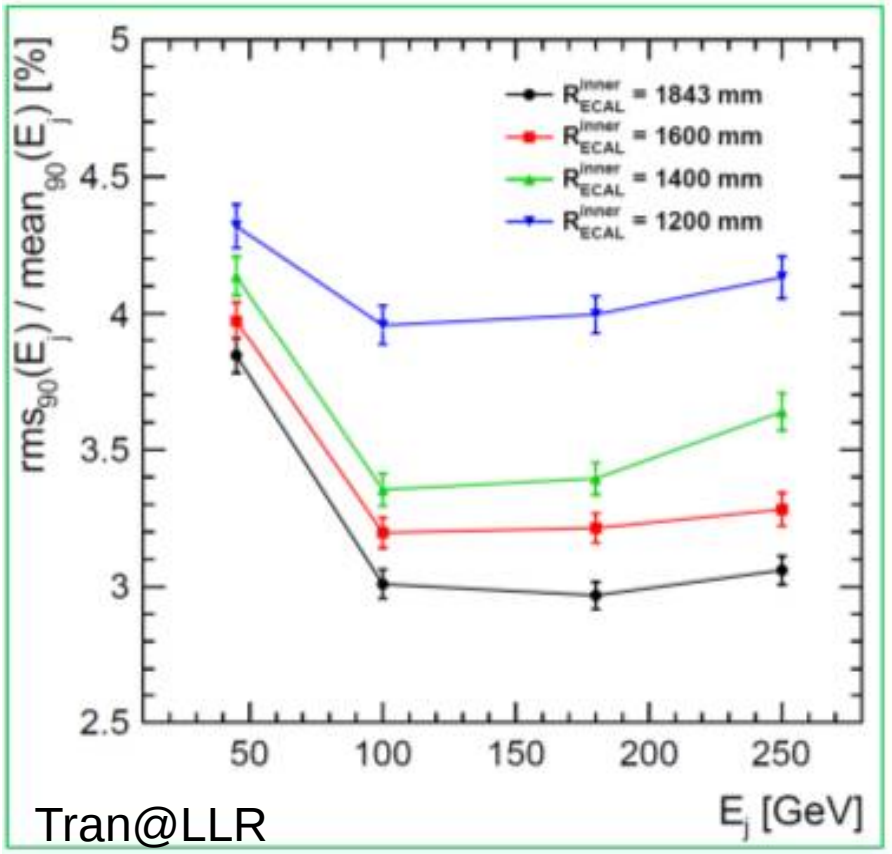
Also technical work on combined operation of silicon/scintillator layers

ILD / ECAL optimisation

with an eye on cost control

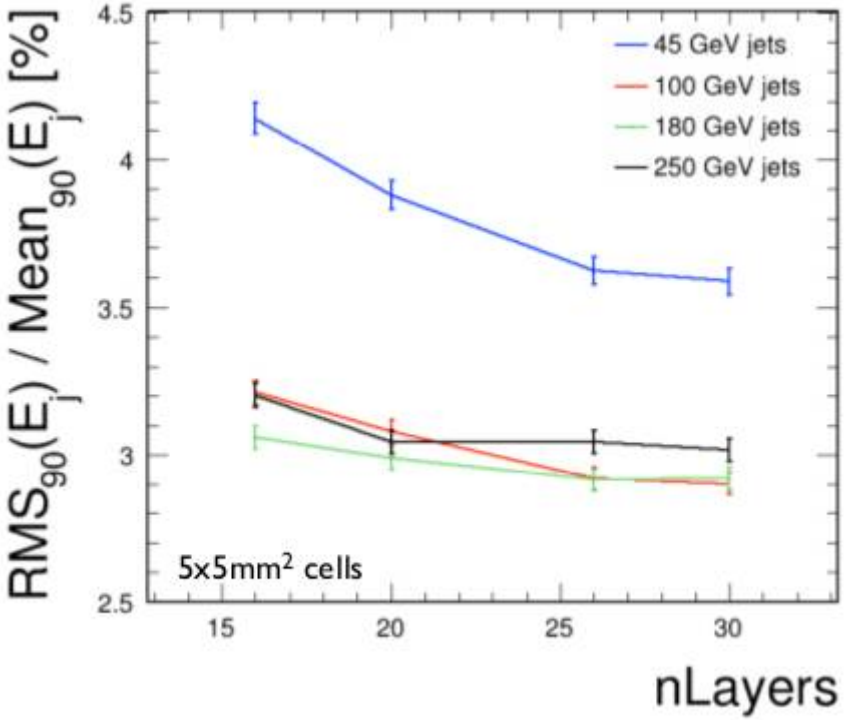
Several studies of effect of reducing ECAL size & cost

ECAL inner radius



Tran@LLR

Number of ECAL layers



Marshall@Cambridge

At least for jet energy measurement, indications that both number of layers and inner radius can be reduced with relatively mild performance degradations

Summary

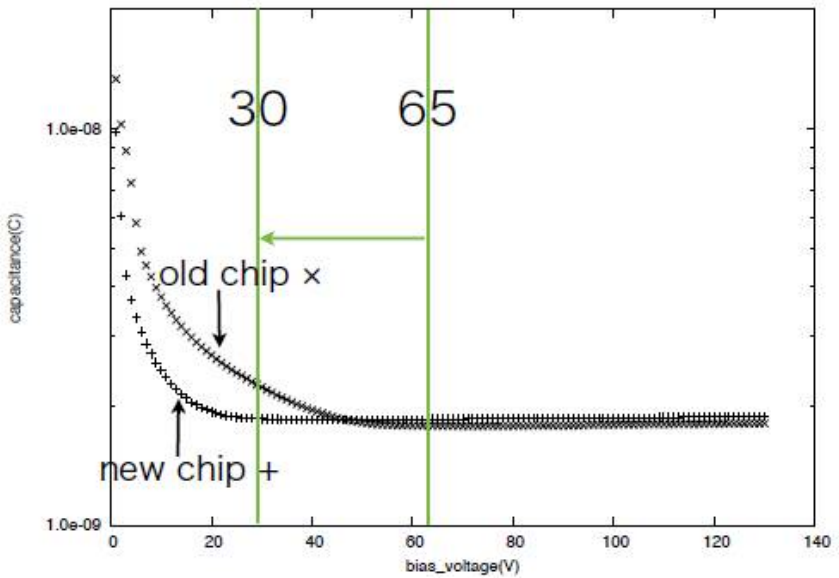
CALICE Si-W ECAL is in pretty good shape
- Basic technologies are there...but still plenty to do before a TDR

Japanese groups (Kyushu & Tokyo) have been active members of the CALICE silicon-ECAL group for a number of years

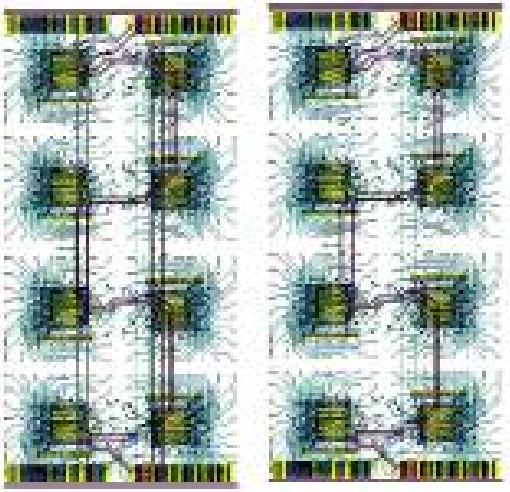
We are working mostly on:

- R&D of silicon sensors
  - profiting from proximity to Hamamatsu
- Analysis of test beam data
- Simulation studies for detector optimisation
- Data acquisition,
  - at present particularly for Hybrid ECAL

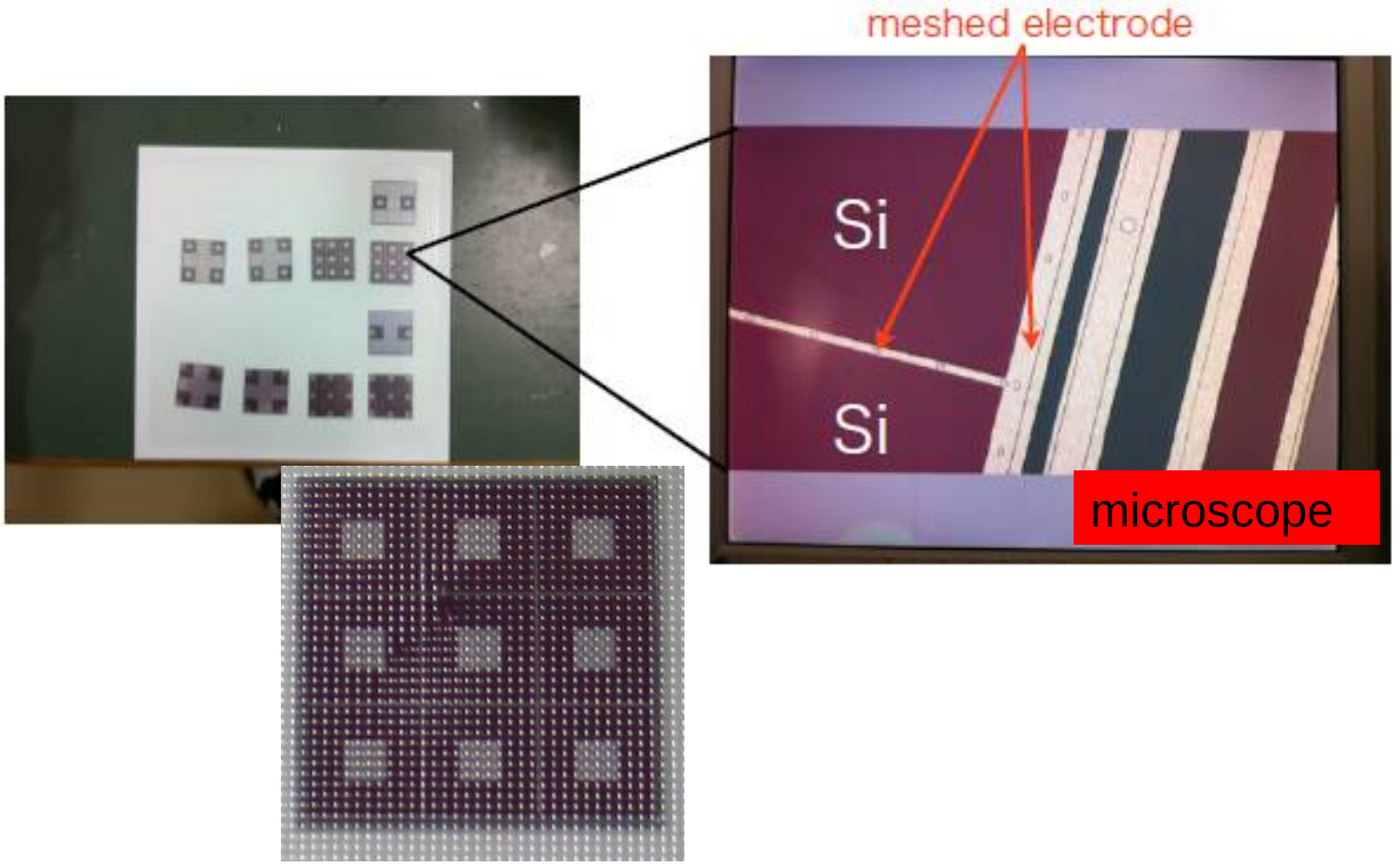
Backup

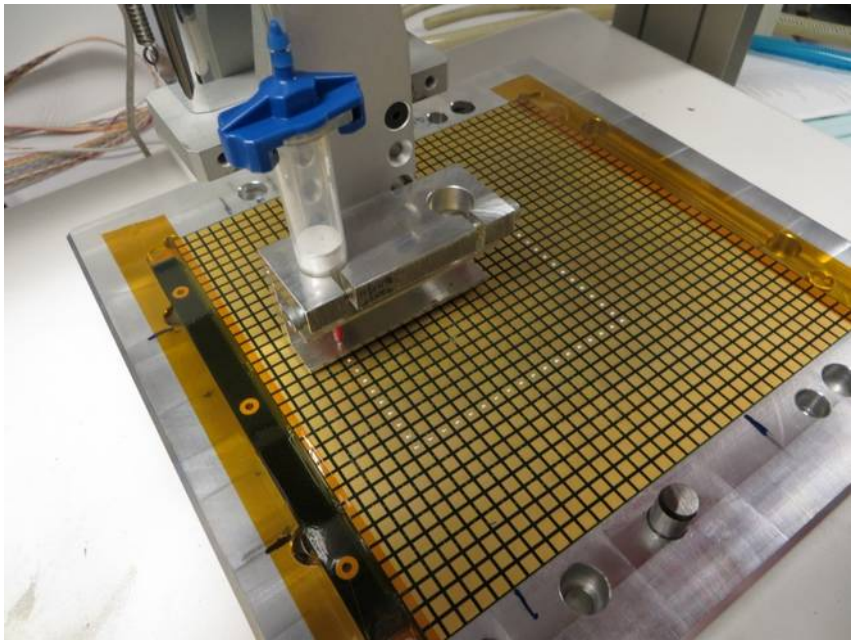

30
65
1.0e-08
1.0e-09
capacitance(C)
old chip ×
new chip +
0
20
40
60
80
100
120
140
bias_voltage(V)

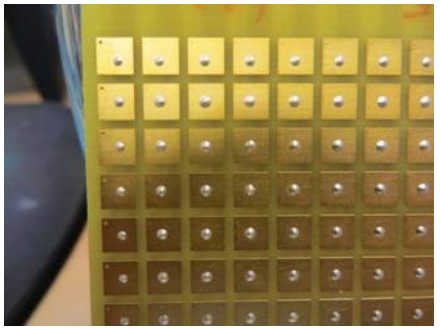
Mechanical model, no chips

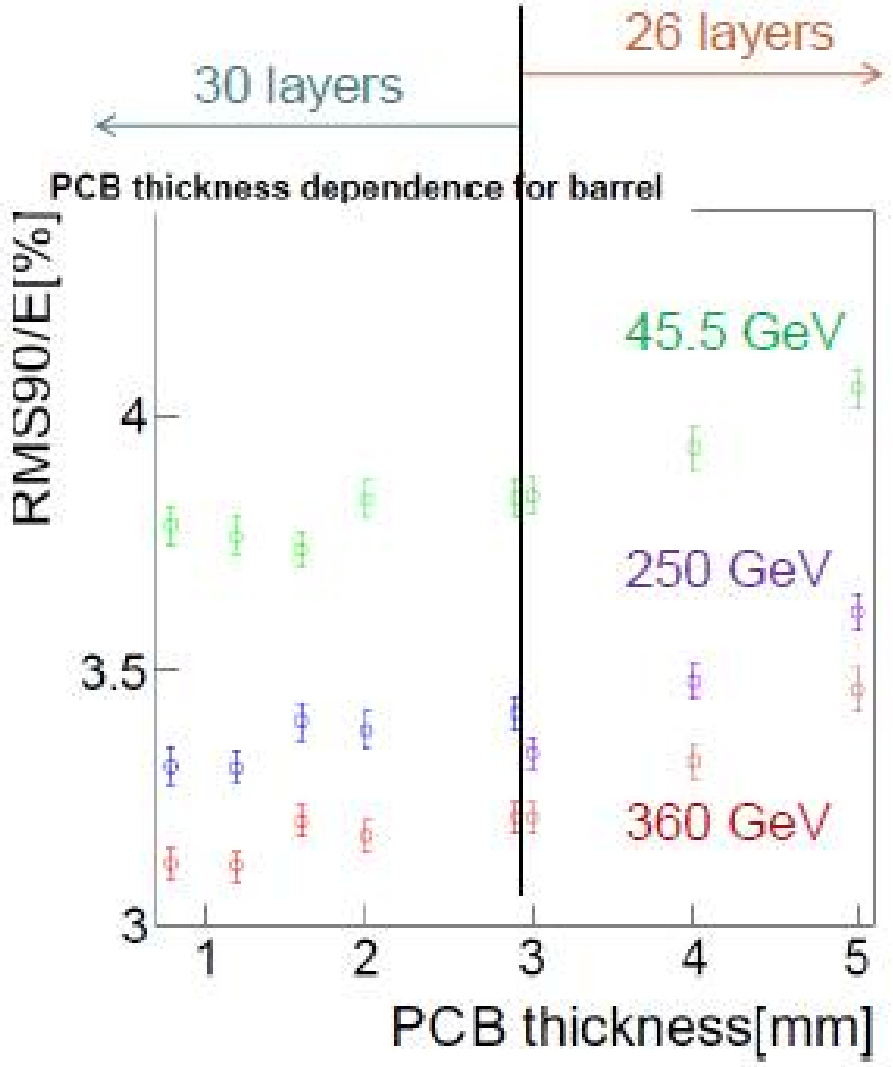


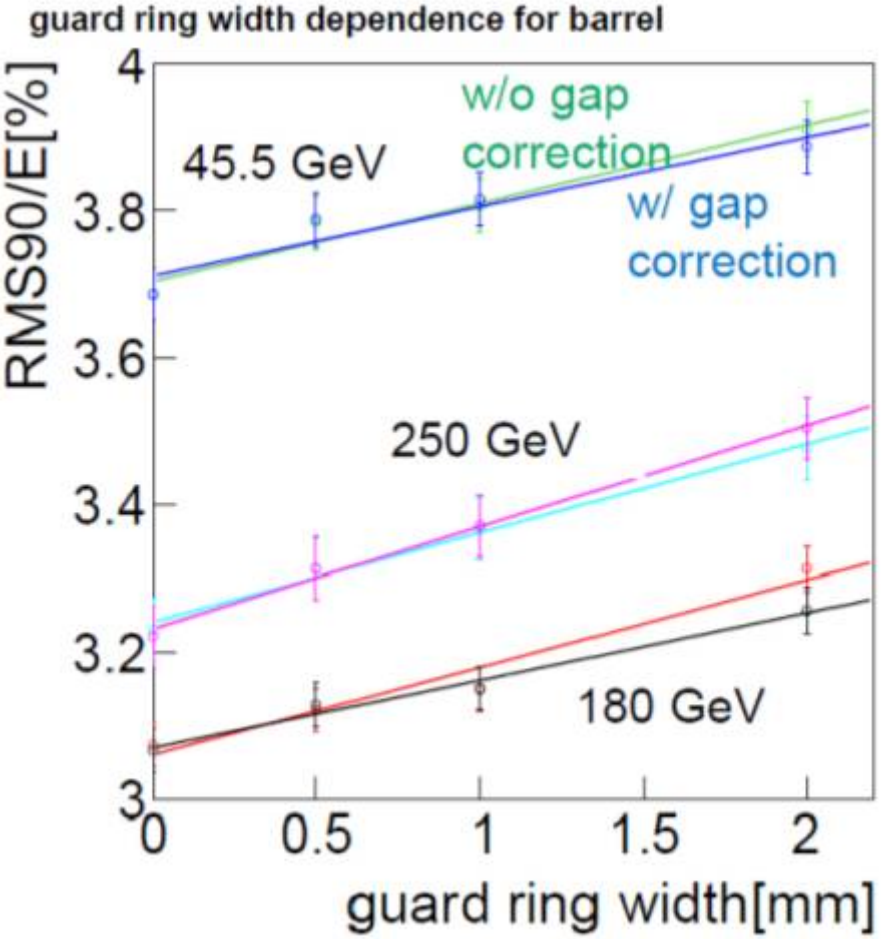
Straight and snake lines

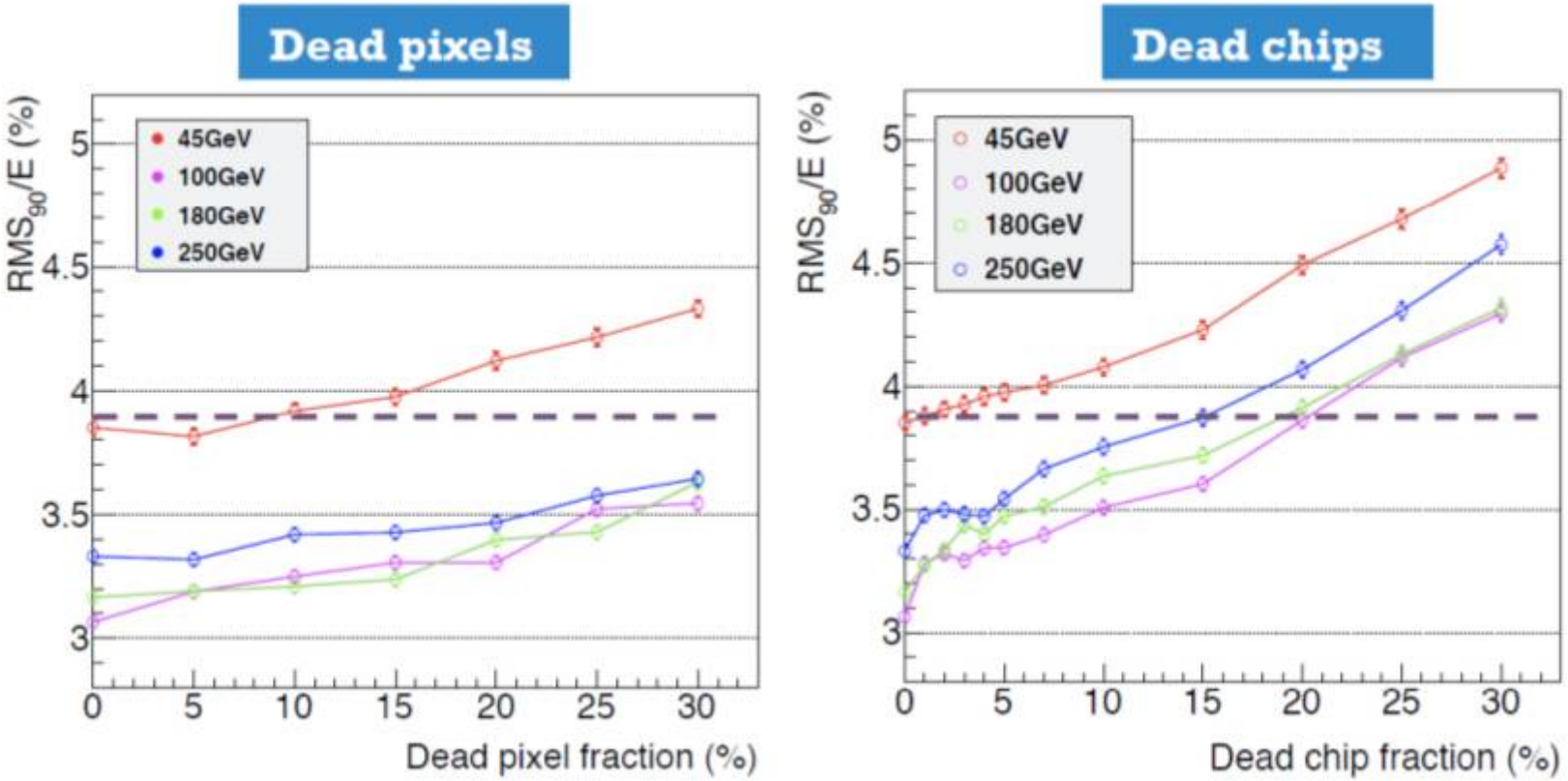

meshed electrode
Si
Si
microscope

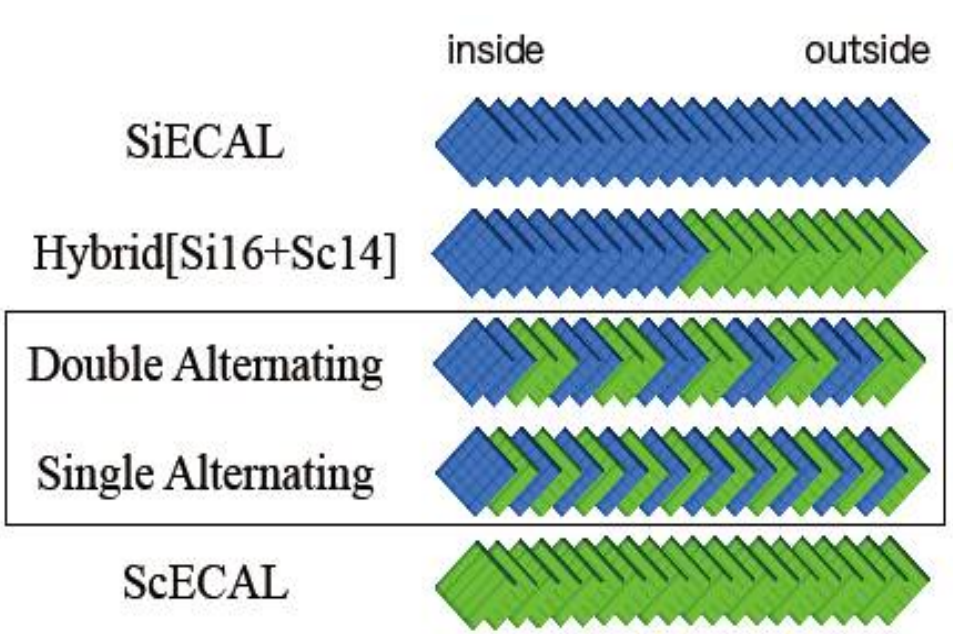


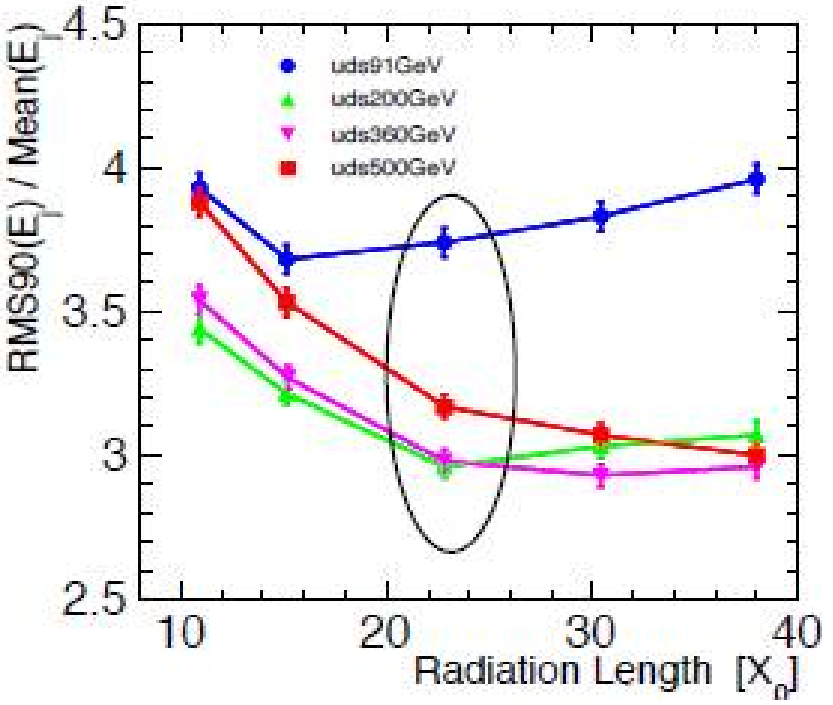



30 layers
26 layers
PCB thickness dependence for barrel
RMS90/E[%]
45.5 GeV
250 GeV
360 GeV
4
3.5
3
1
2
3
4
5
PCB thickness[mm]

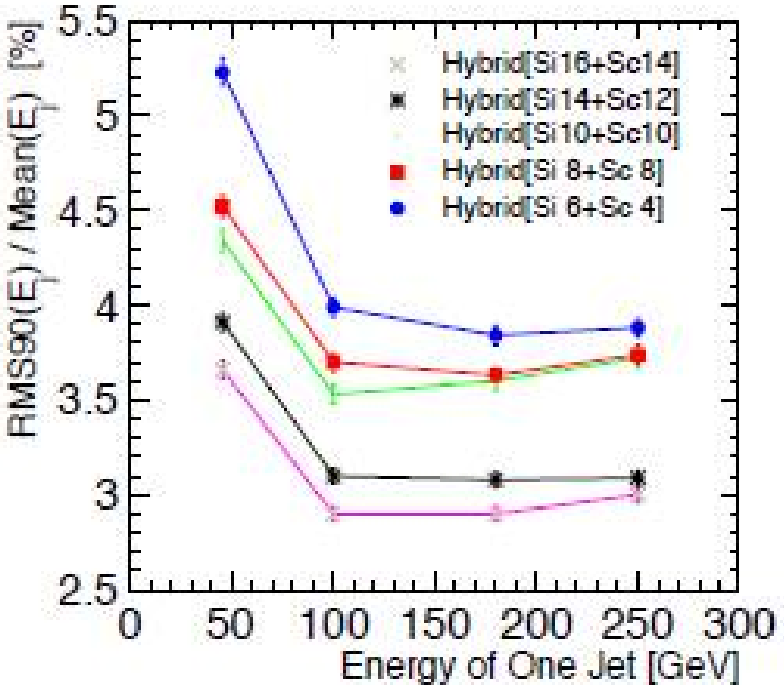

guard ring width dependence for barrel
RMS90/E[%]
w/o gap correction
w/ gap correction
45.5 GeV
250 GeV
180 GeV
4
3.8
3.6
3.4
3.2
3
0
0.5
1
1.5
2
guard ring width[mm]


Dead pixels
RMS90/E (%)
45GeV
100GeV
180GeV
250GeV
5
4.5
4
3.5
3
0
5
10
15
20
25
30
Dead pixel fraction (%)
Dead chips
RMS90/E (%)
45GeV
100GeV
180GeV
250GeV
5
4.5
4
3.5
3
0
5
10
15
20
25
30
Dead chip fraction (%)





Hybrid [Si16+Sc14]



10layers

16layers

20layers

26layers

30layers