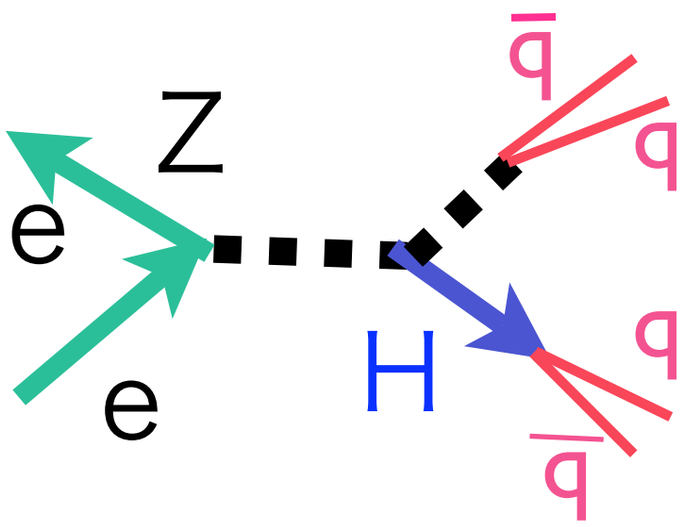
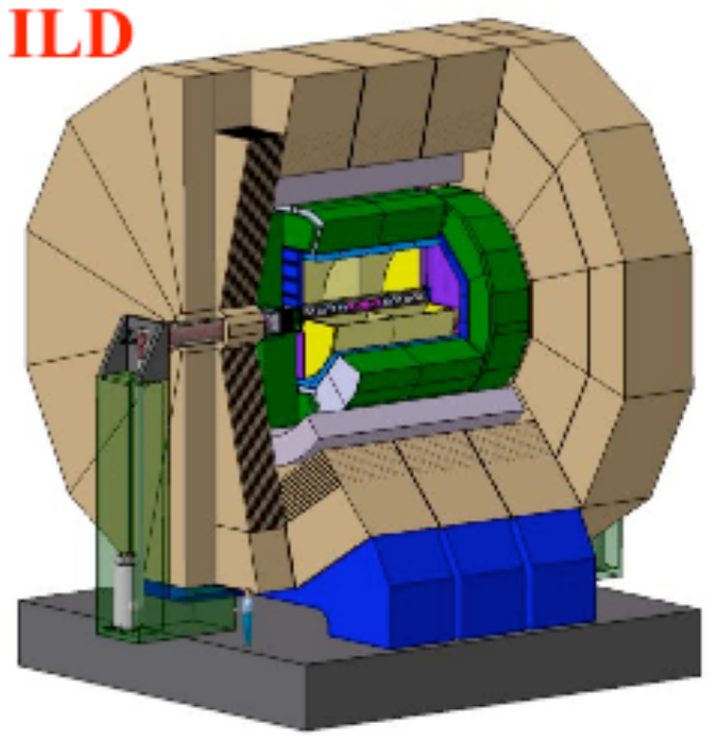
ILC calorimeterの技術開発

by S. Numazawa



竹下徹
(信州大)

目的と測定器への要求
アイデアと実モデル
技術開発の現状と結果
近未来



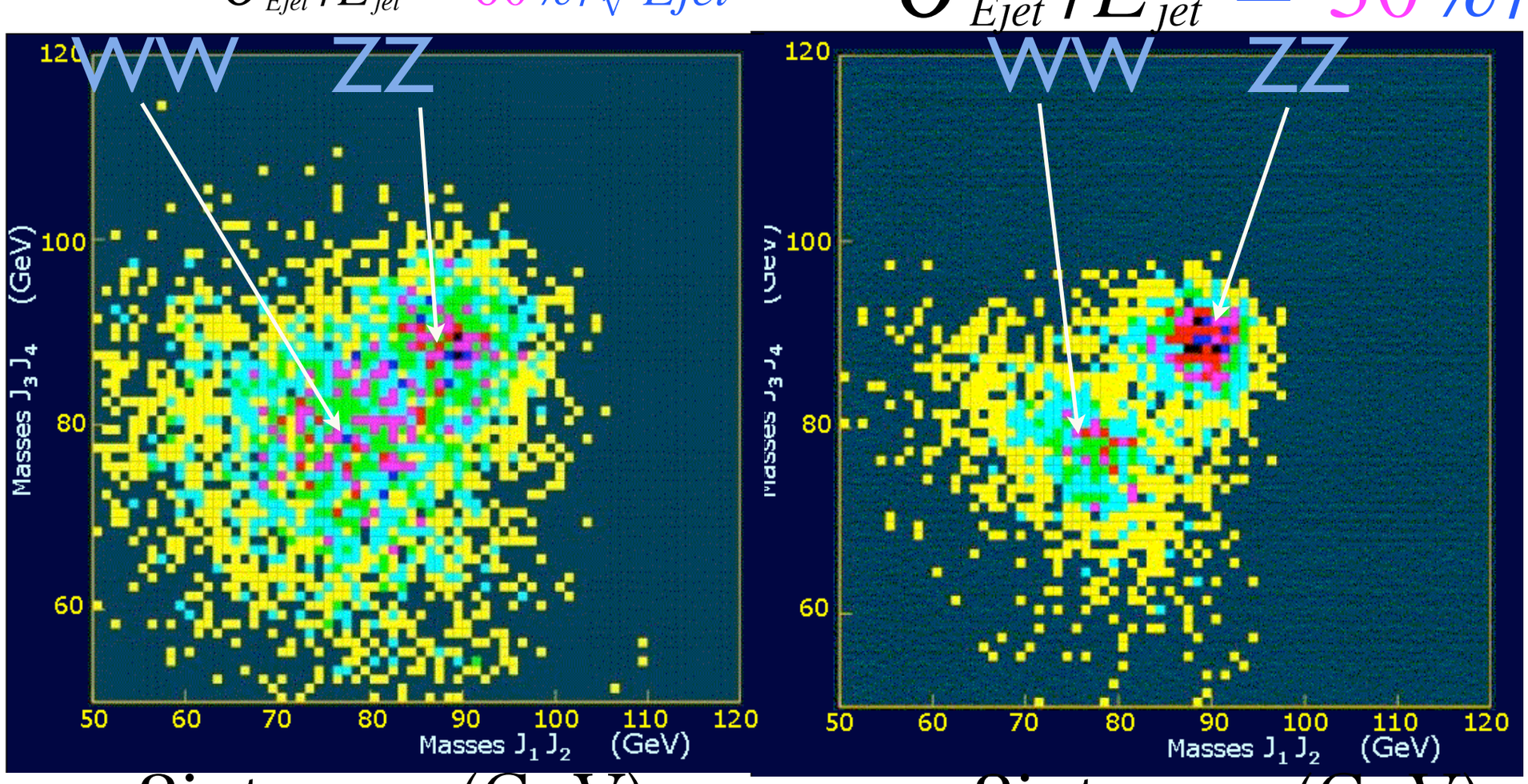
CALICE
Calorimeter for ILC

物理の要求

- jet 事象中でW/Zを質量再構成し、同定する
- jet エネルギー分解能 ~ a few GeV ~ W/Z 幅
- PFA : Jet energy　再構成手法

$$e^+e^- \to \nu\bar{\nu}WW/\nu\bar{\nu}ZZ \to qq'qq' \to 4jets$$

$$\sigma_{Ejet}/E_{jet} = 60\%/\sqrt{Ejet} \qquad \sigma_{Ejet}/E_{jet} = 30\%/\sqrt{Ejet}$$



2jet-mass(GeV)　　2jet-mass(GeV)

JCBrient

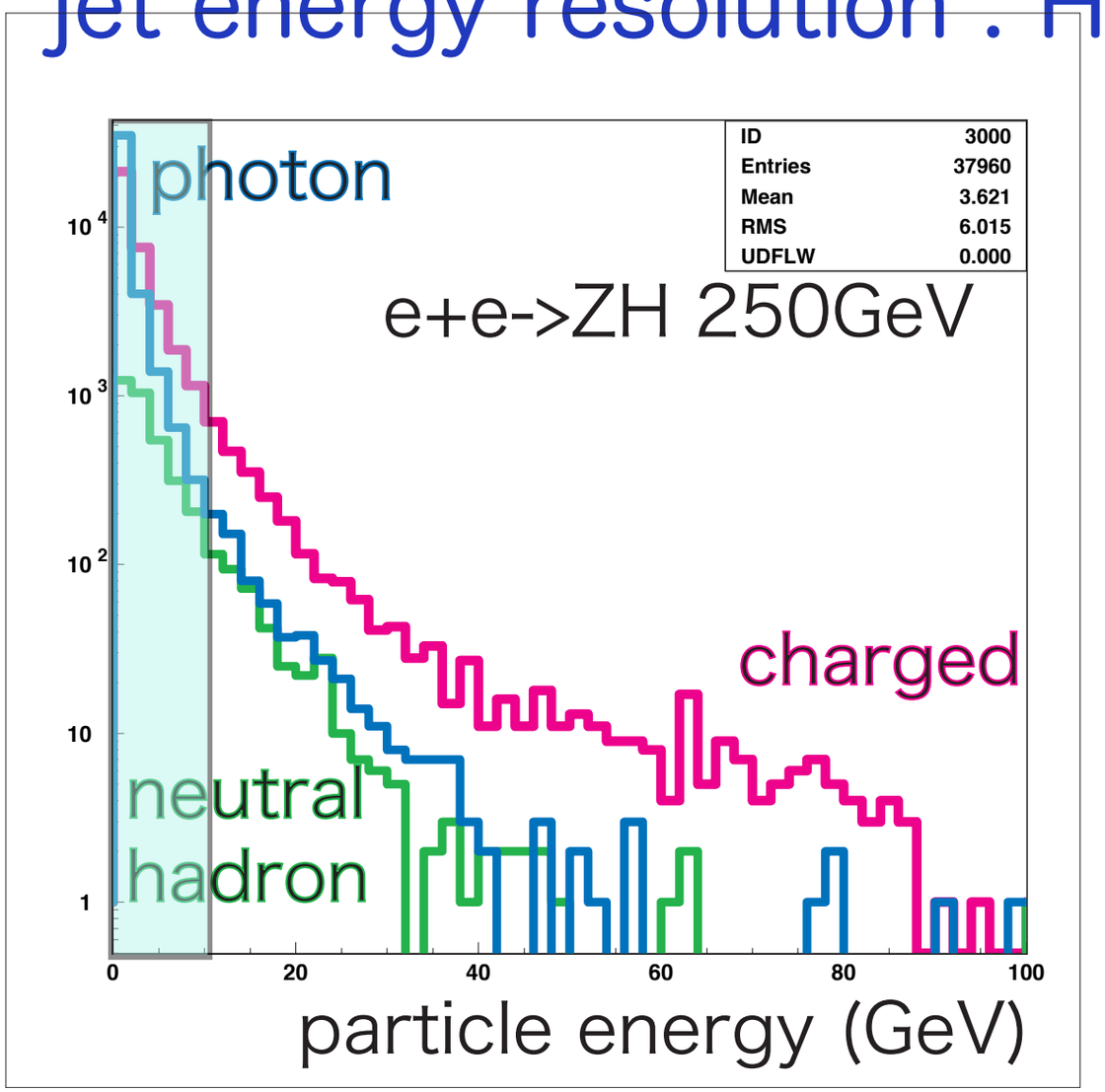
PFA:いい所取り

- 荷電粒子: pion,Kaon: Tracker :60% of Ejet
- 中性：光子: ECAL :30% of Ejet
- 中性: ハドロンKo,n: HCAL: 10% of Ejet
- jet energy resolution : HCAL

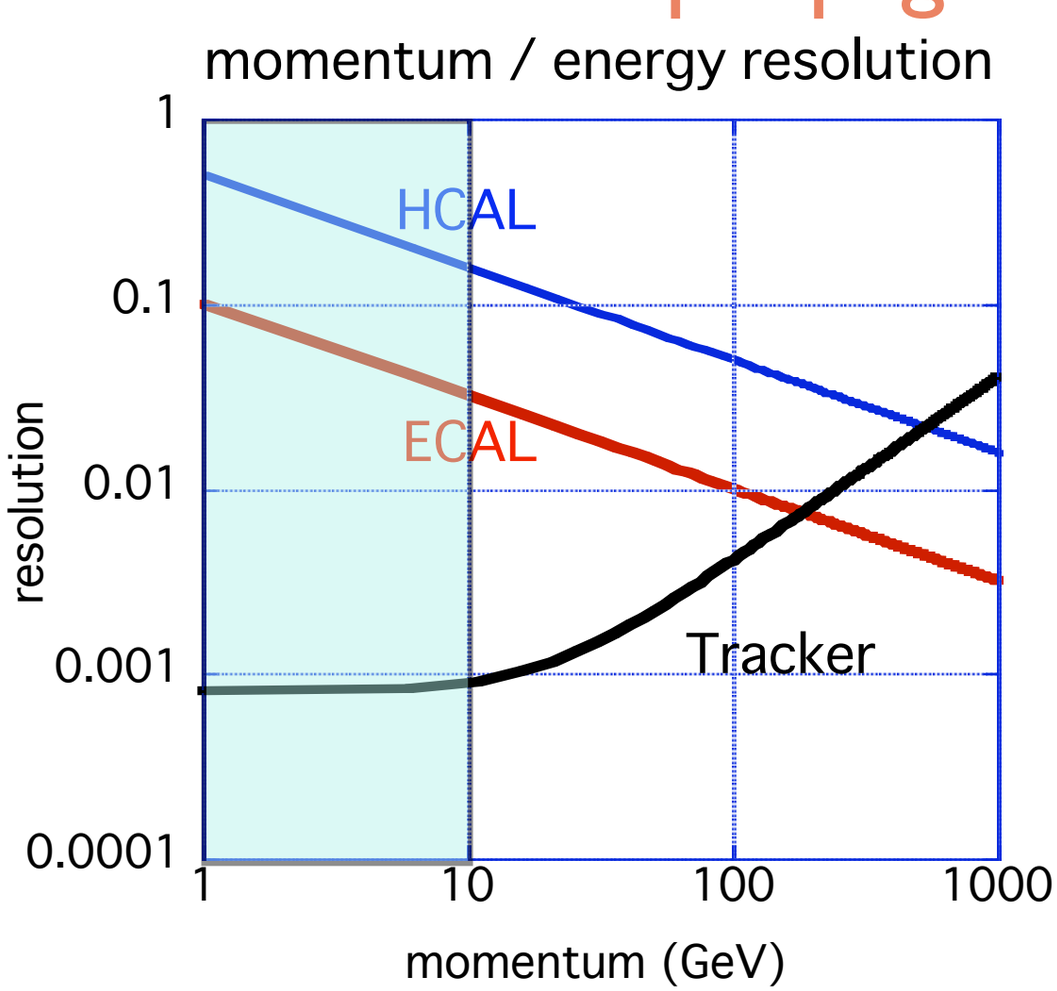
0.001@10GeV

0.05@10GeV

0.2@10GeV



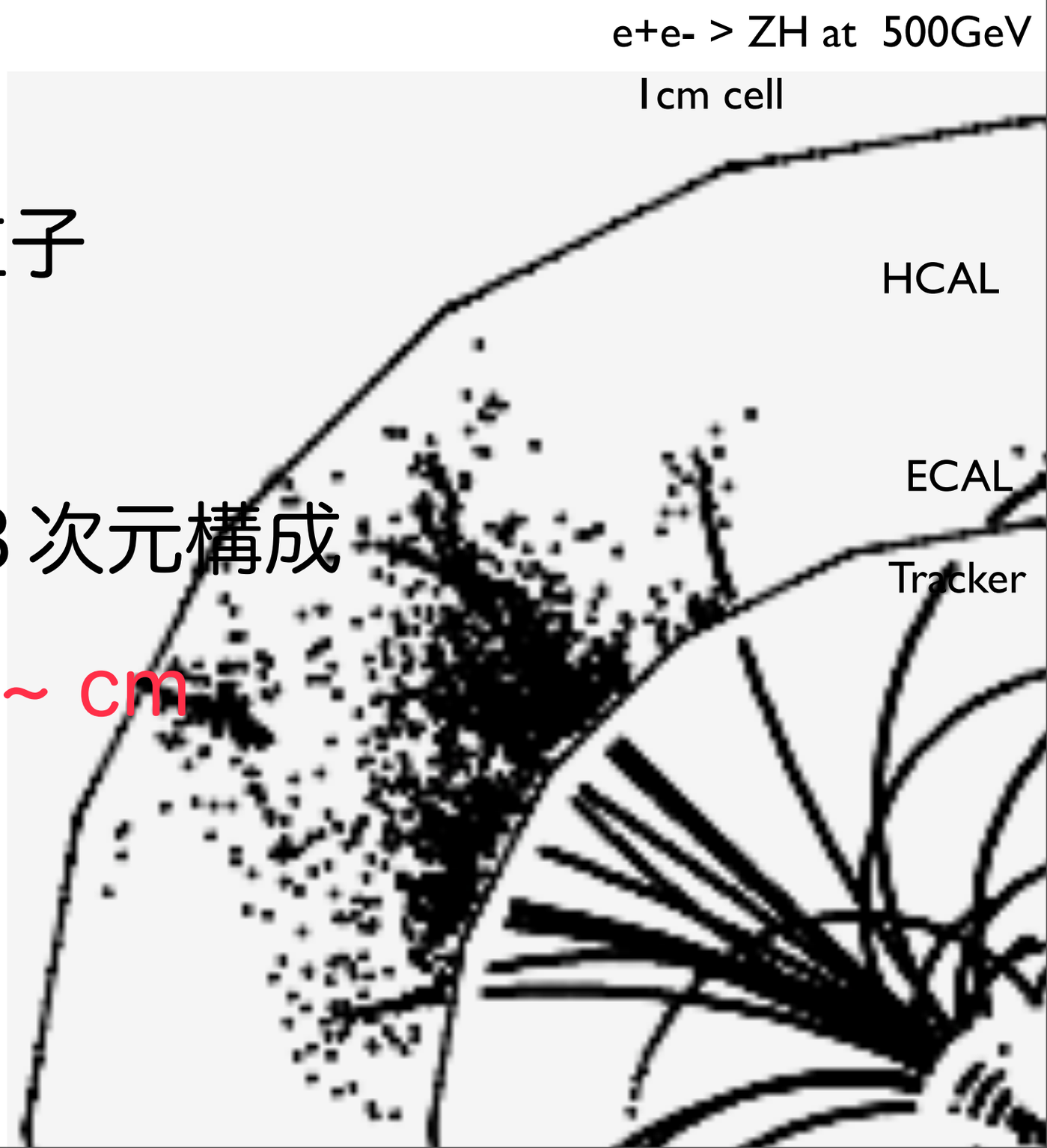
error propagation



問題点

- カロリメータ中でのシャワーの重なり

- 分離の必要
- 電磁シャワーと荷電粒子
- 中性ハドロンの特定
- シャワーの広がりを３次元構成
  - fine segmentation ~ cm
  - 横方向＆奥行き
- ソフトウエアー重要



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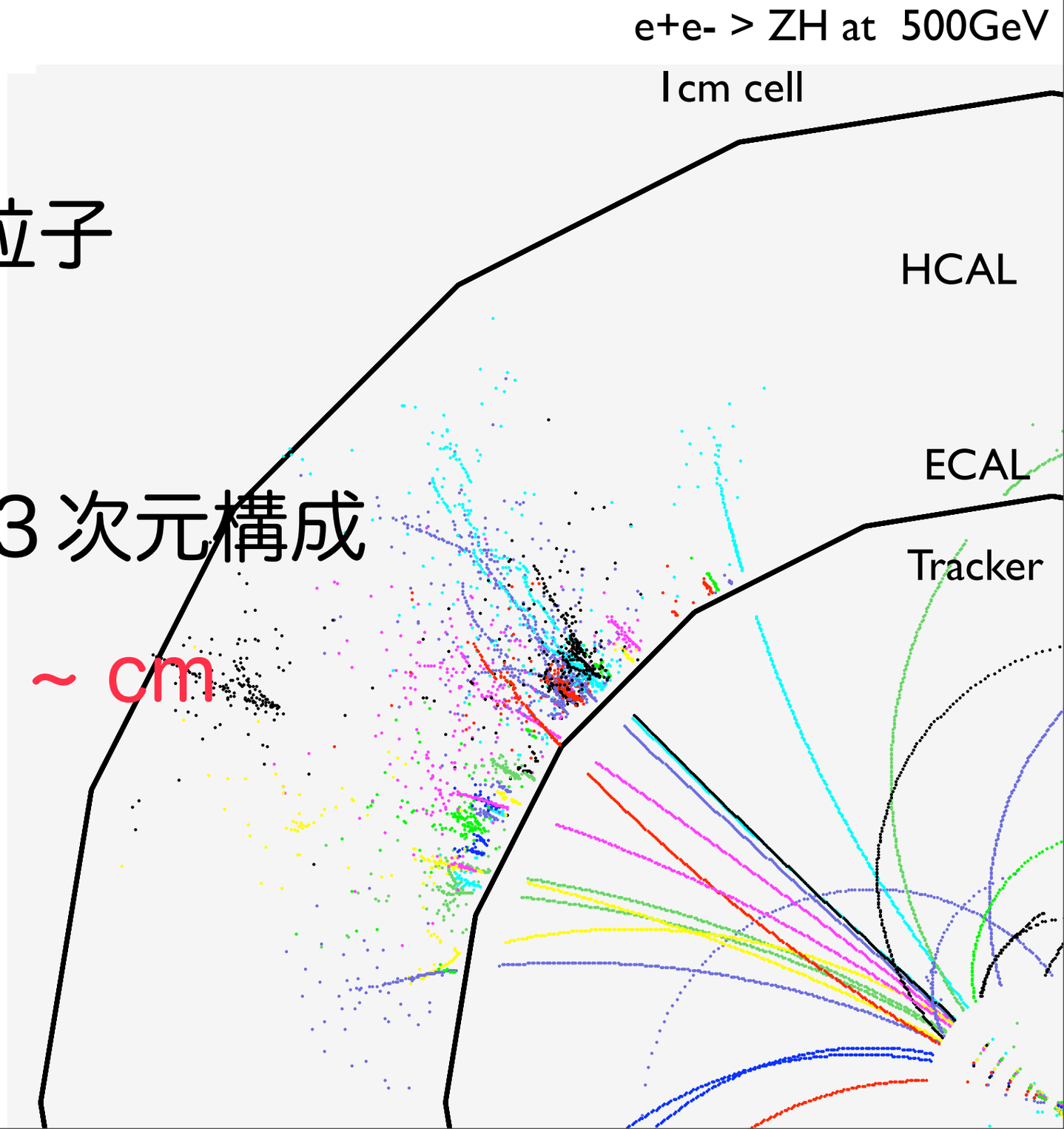
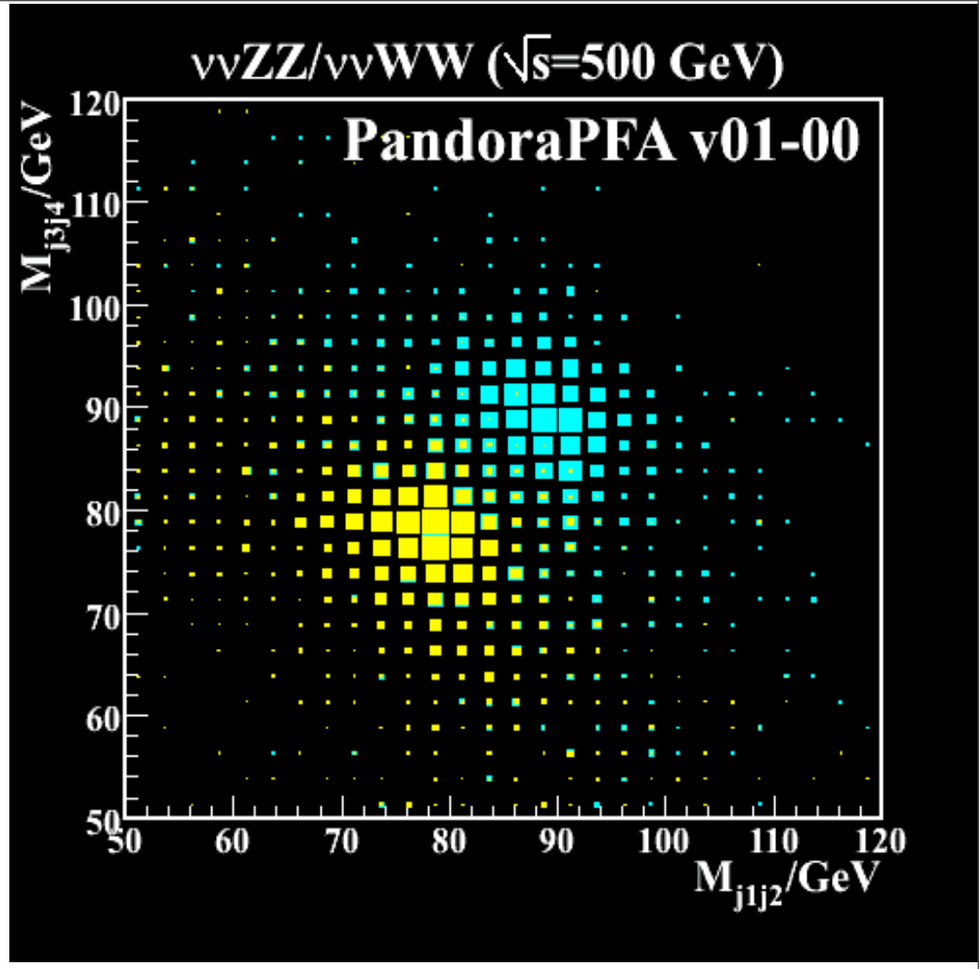
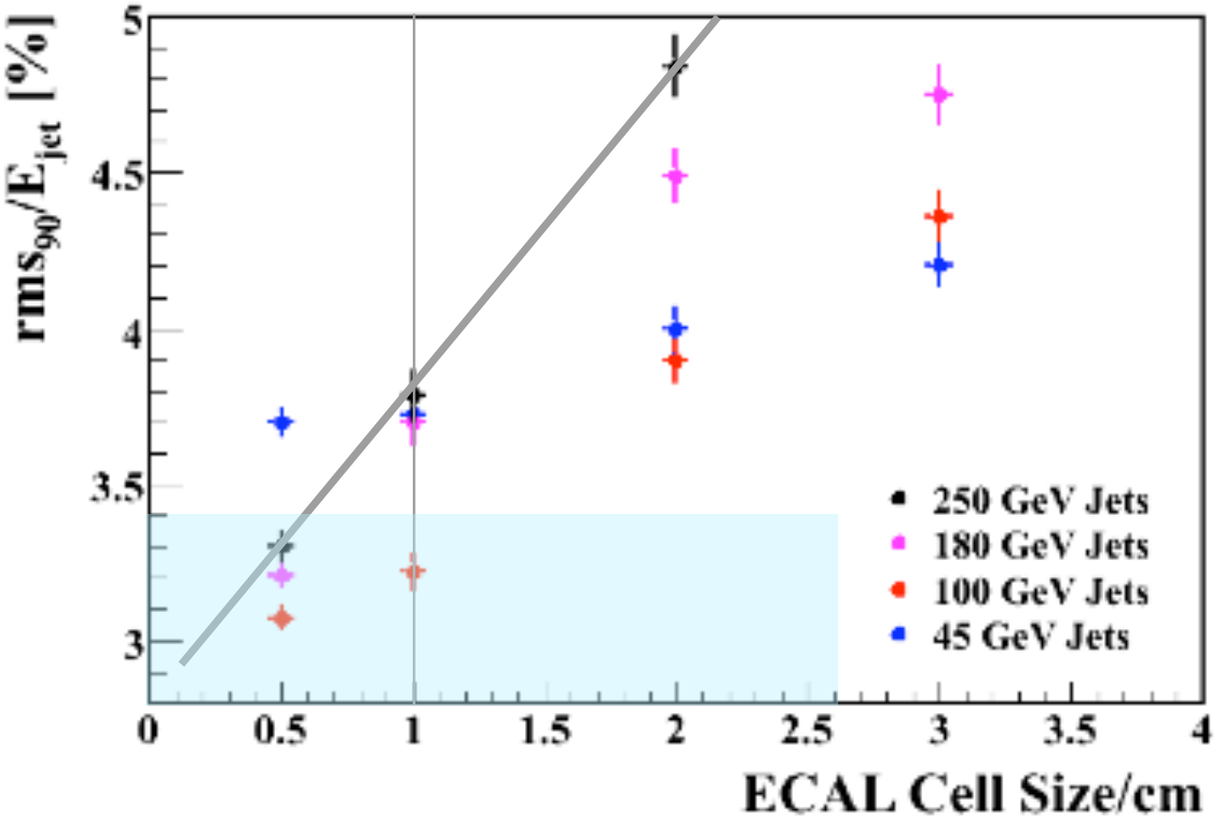


ILD-PFA

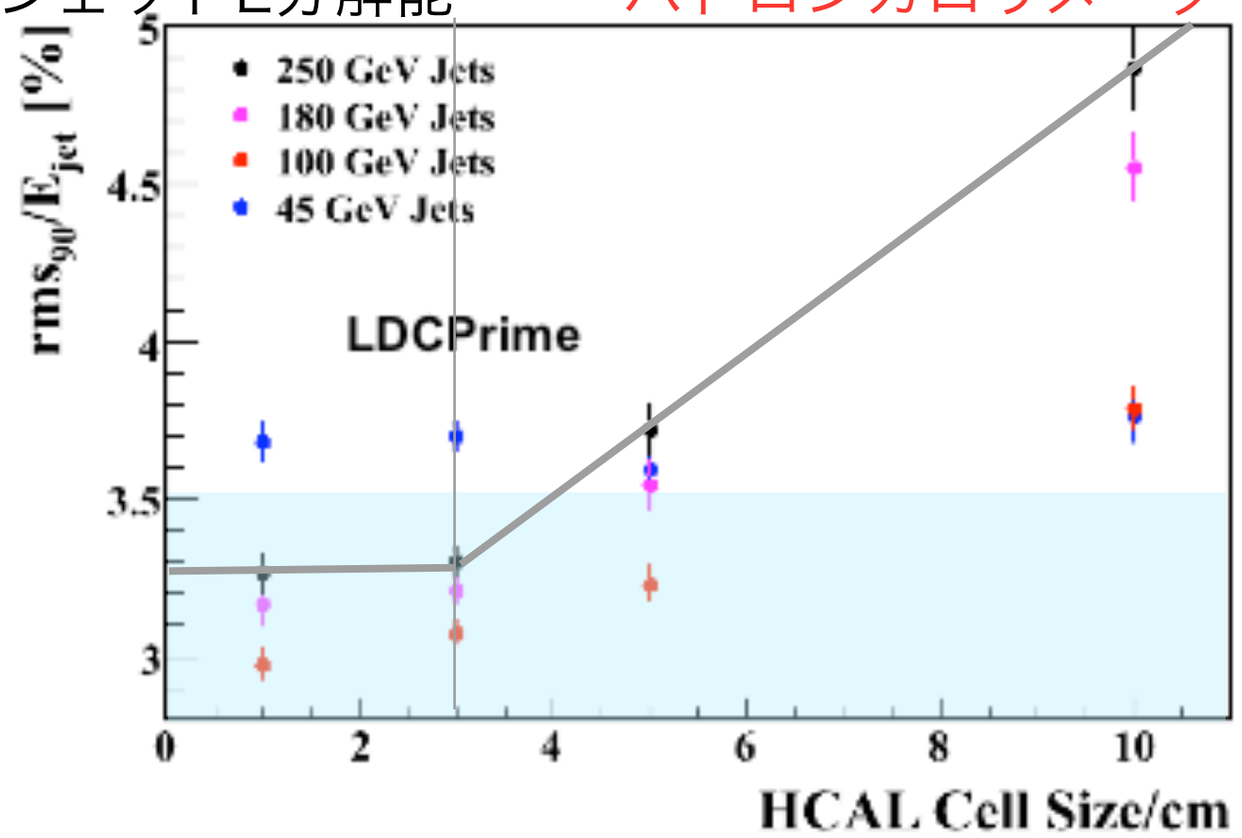
- ソフトウエアー M.Thomson
- 電磁カロリメータ~ 5mm
- ハドロンカロリメータ~３cm



ジェットE分解能 電磁カロリメータ



ジェットE分解能 ハドロンカロリメータ



測定器アイデア

	ILD	SiD	
ECAL with tungsten	silicon(仏:EP,Orsay)	silicon (米:Oregon,SLAC)	CALICE
	scintillator(日韓 神戸信州筑波東京, Kyungpook)		
HCAL with steel	analog scinti.(独露: DESY,Heidelberg,ITEP)	RPC(仏: Lyon 米:ANL)/GEM (米:Texas)/ microMegas (仏:Annecy,Grenoble)	
	digital MPGD		
non PFA non segmented	dual read out(米)	scintillation & Cerenkov	

CALICE

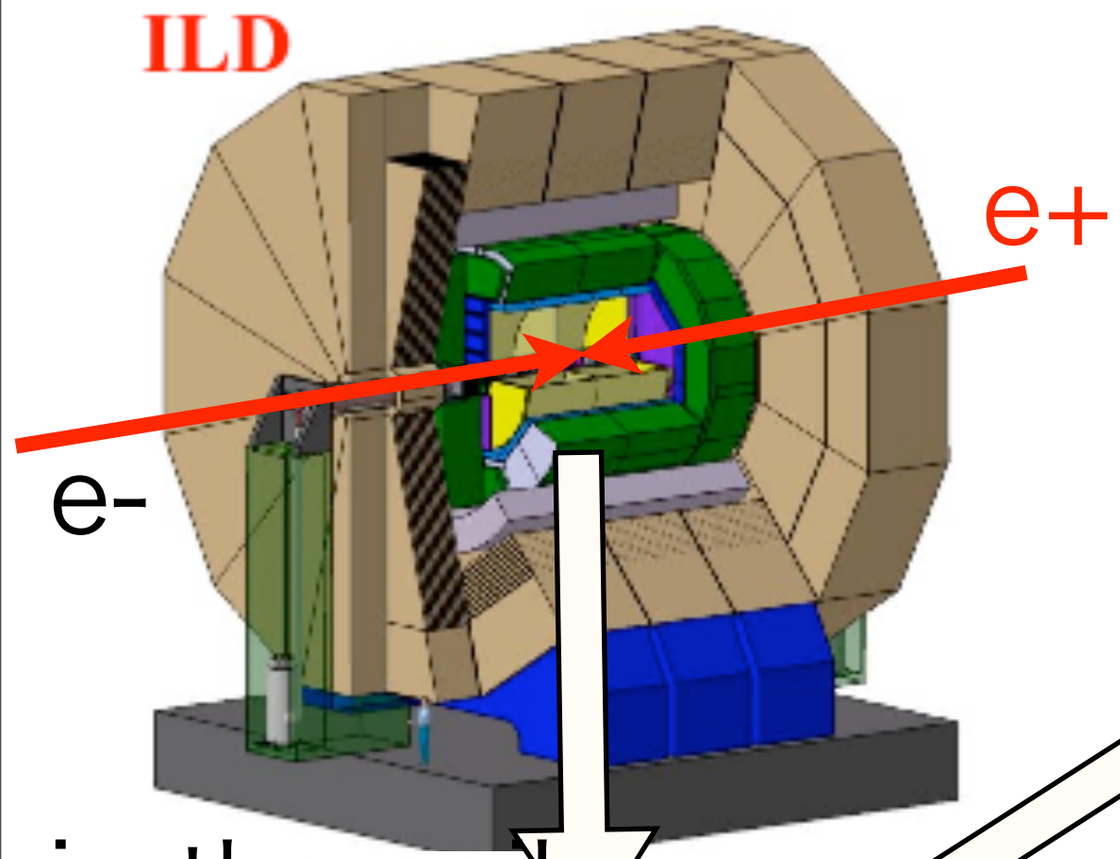
CAlorimeter for the LInear Collider Experiment

281 physicists/engineers from 47 institutes and 12 countries

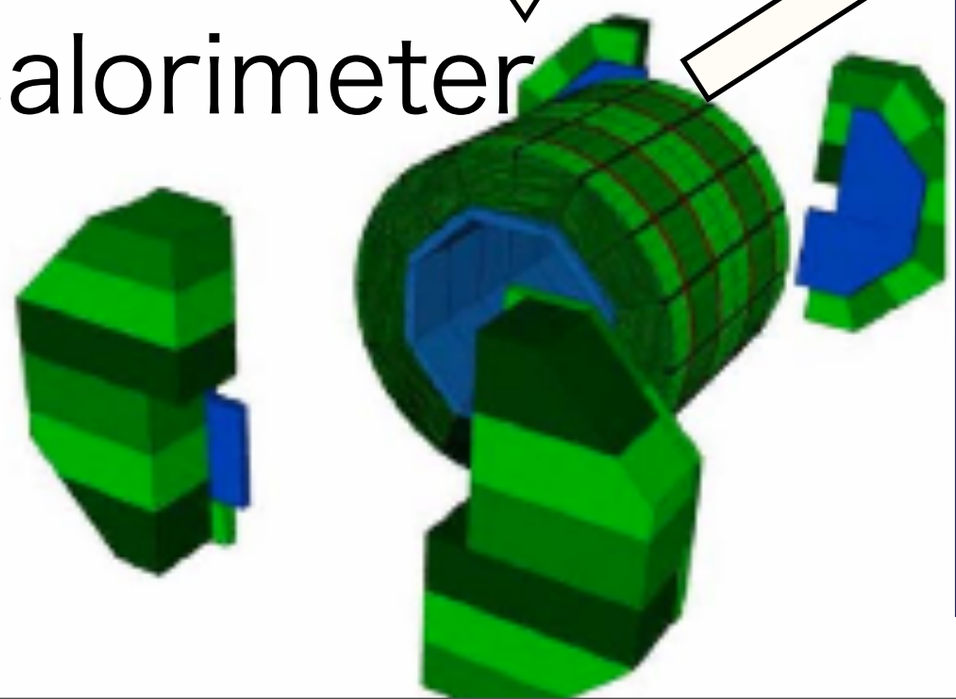
- CALICE meeting at Lyon 2009

神戸信州筑波

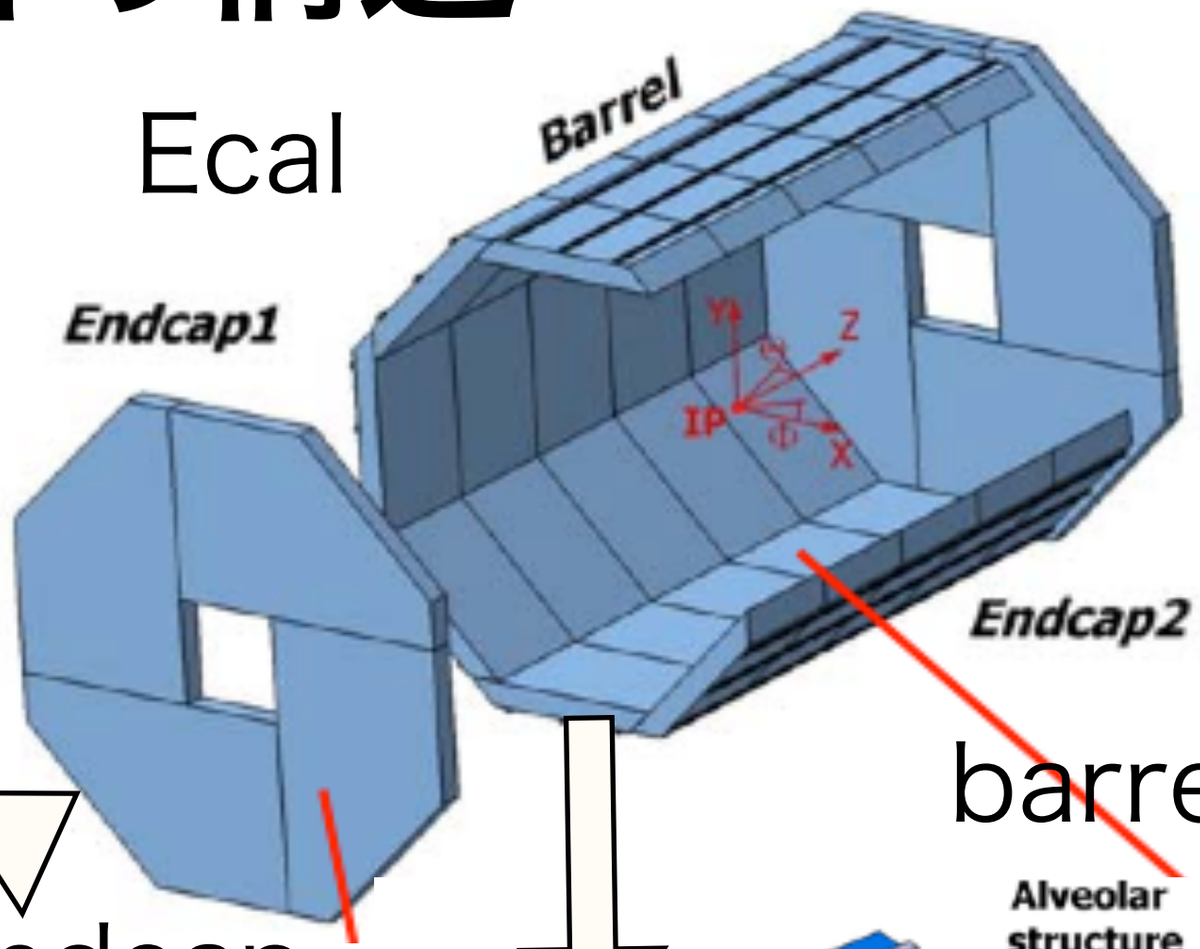
測定器の構造



in the coil
calorimeter

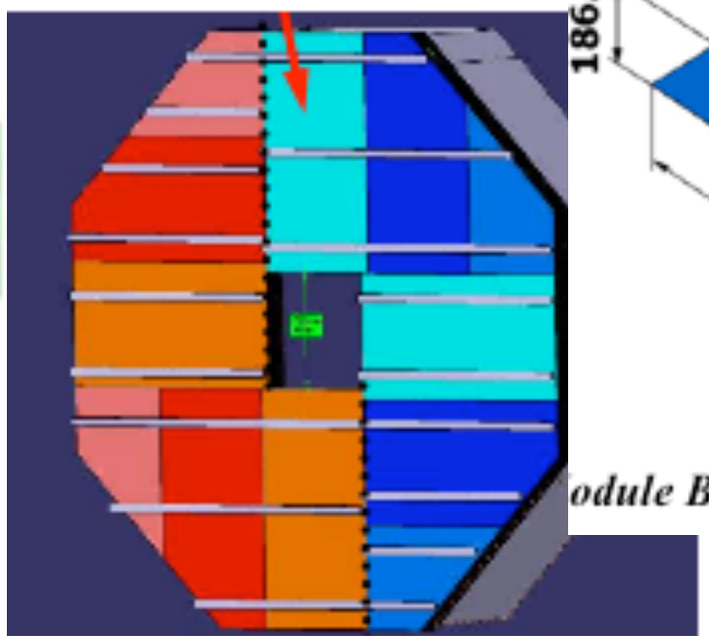


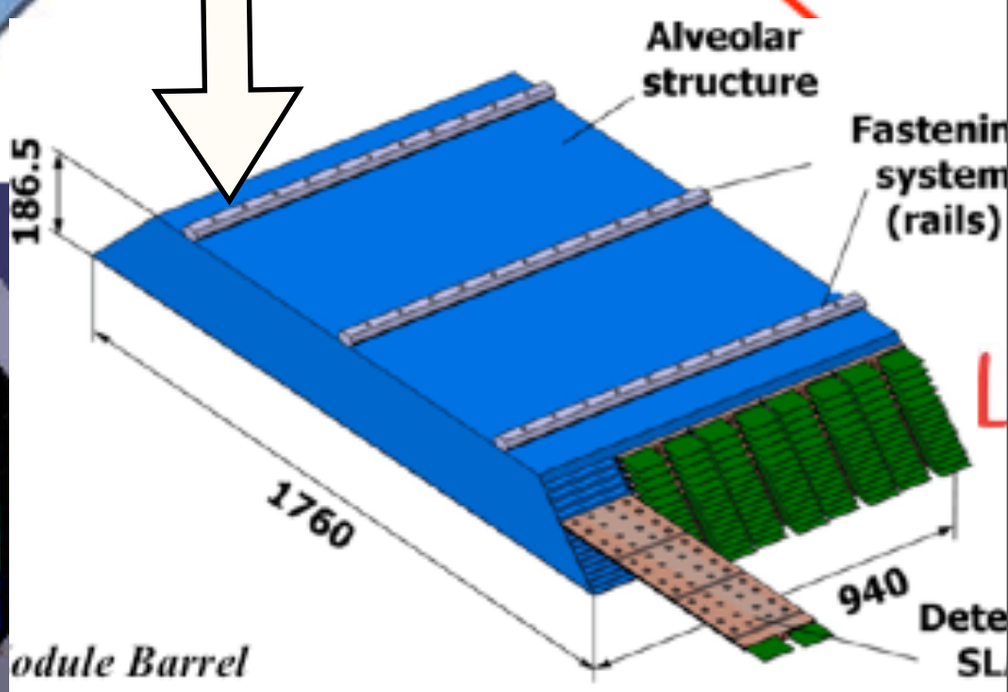
Ecal



barrel

endcap

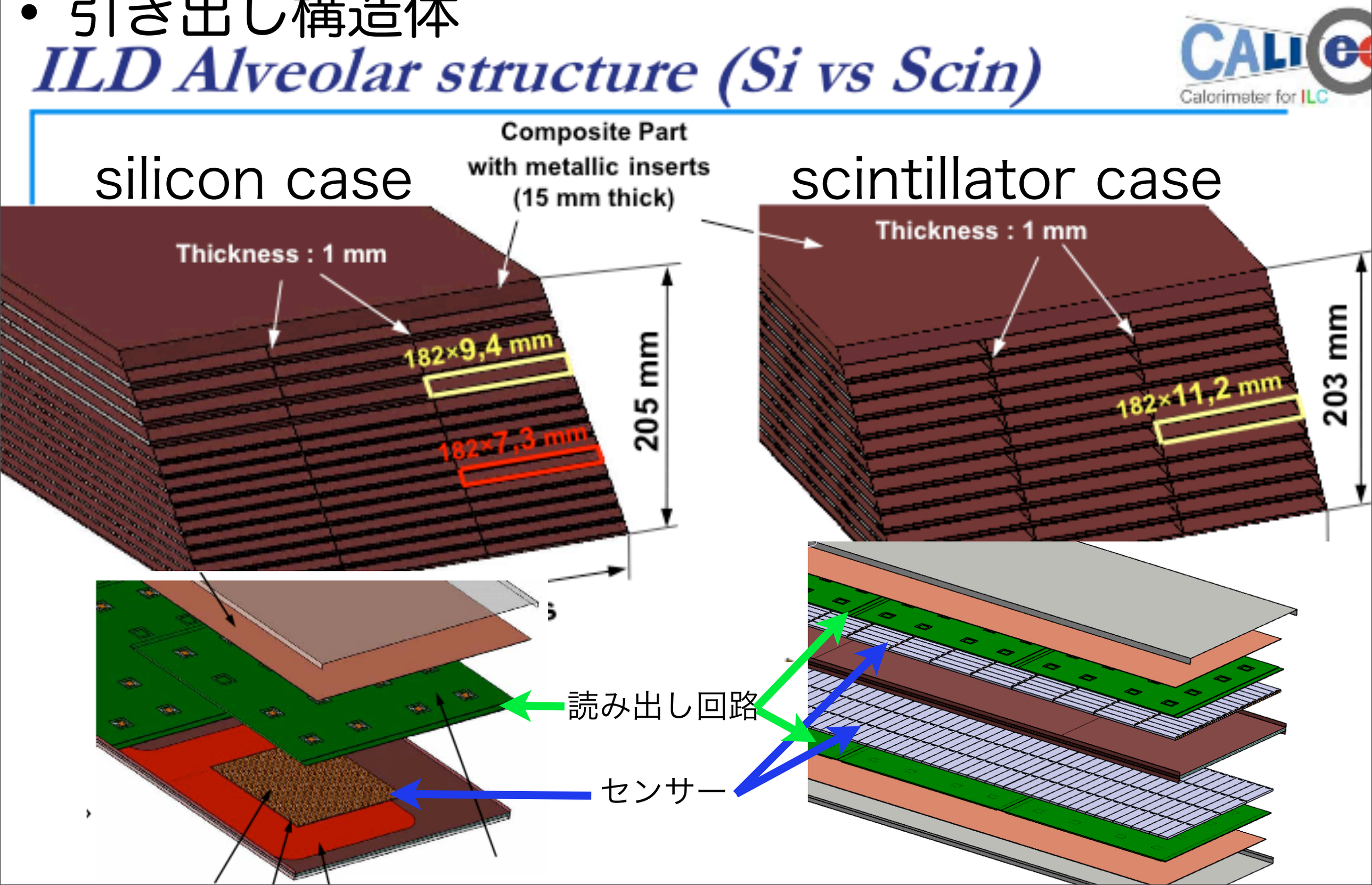




引き出し構造

ECAL 構造

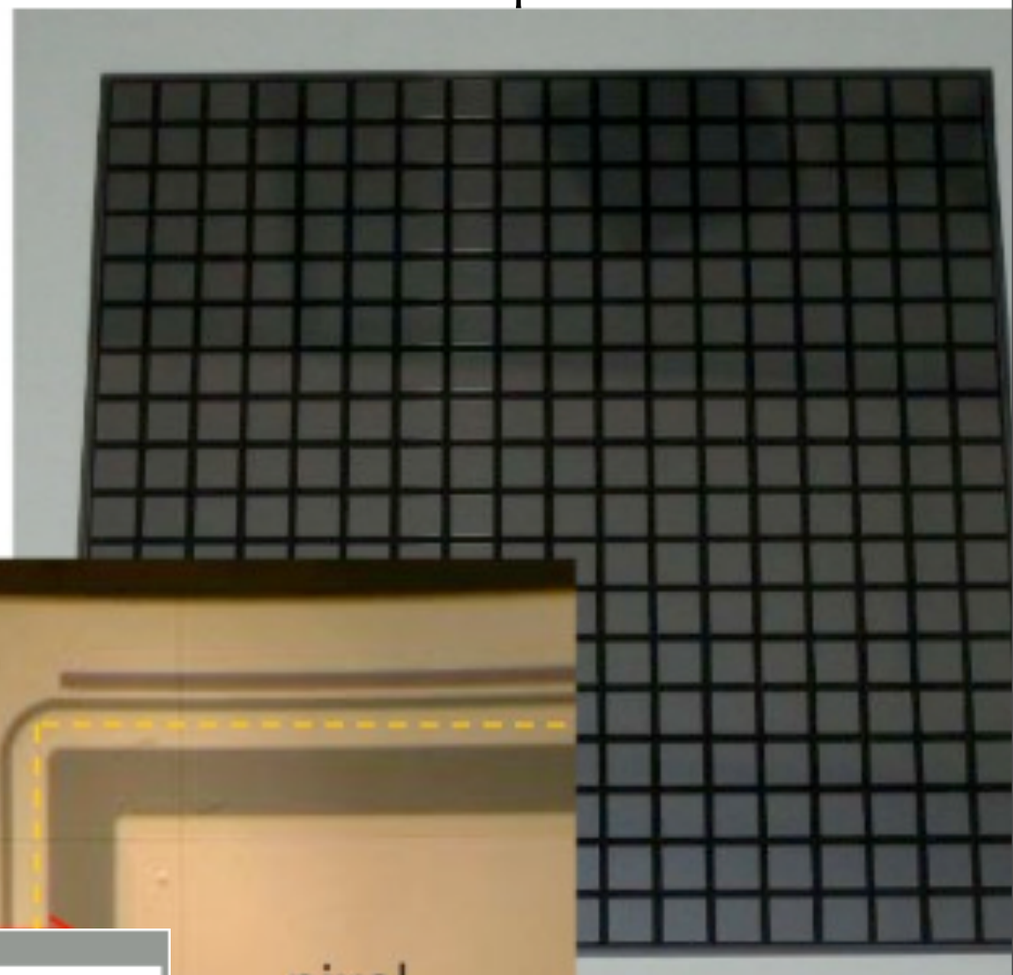
- 引き出し構造体



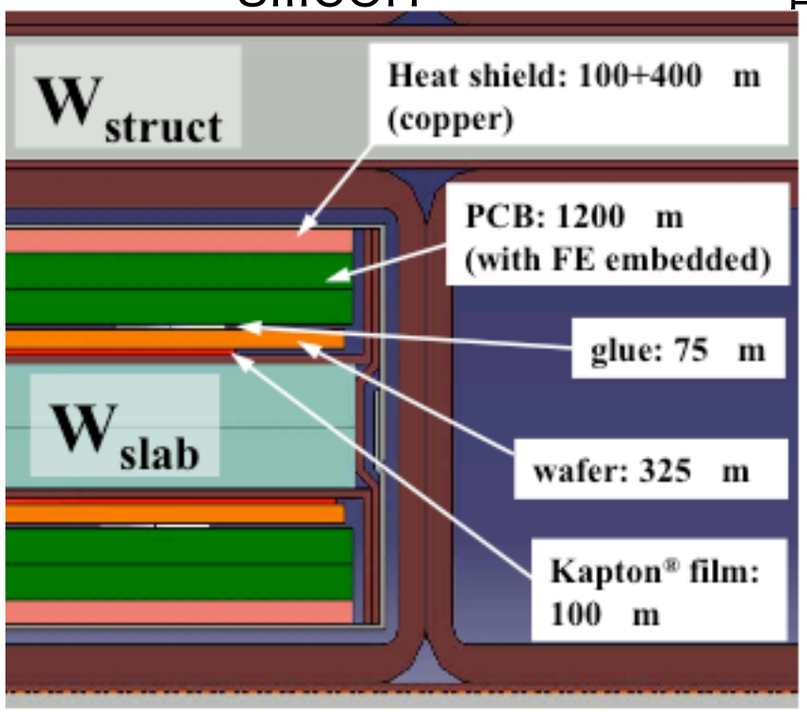
ECAL

- silicon pixel ~5mm x 5mm
  100Mch
- scinti. strip 5mm x 40mm
  10Mch

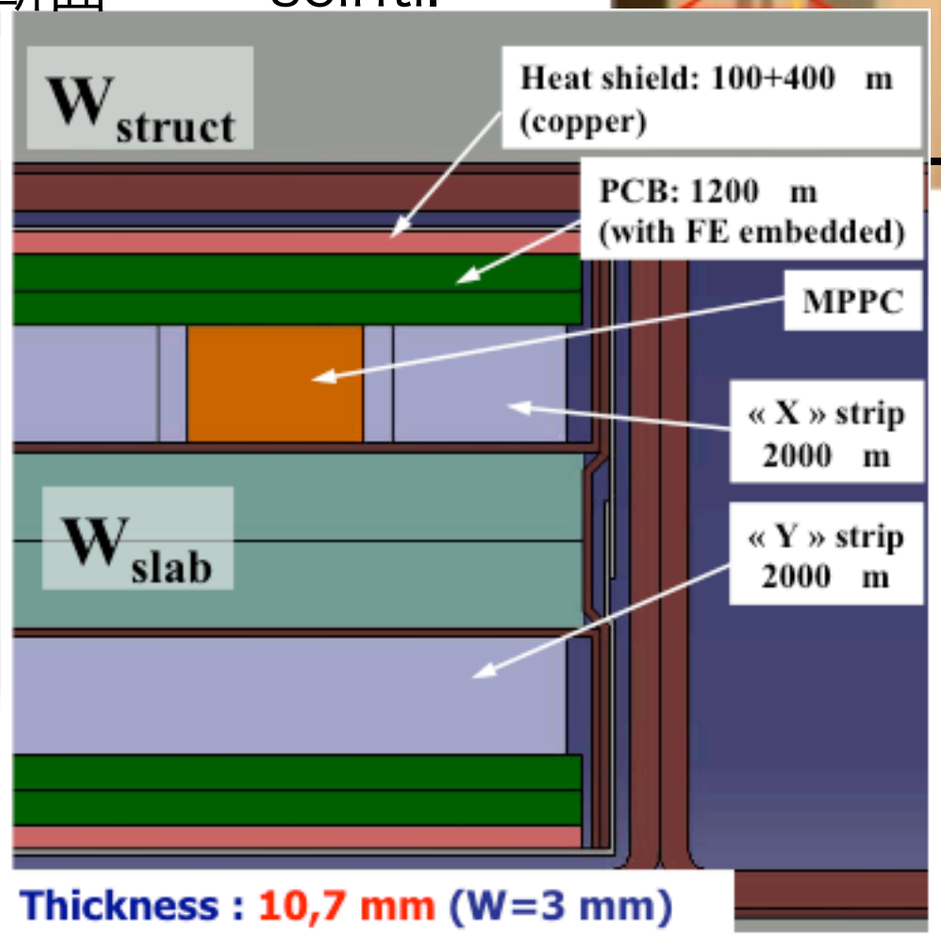
silicon pixels



silicon 断面 scinti.



Thickness of slabs :
6,8 mm (W=2,1 mm)
8,9 mm (W=4,2 mm)



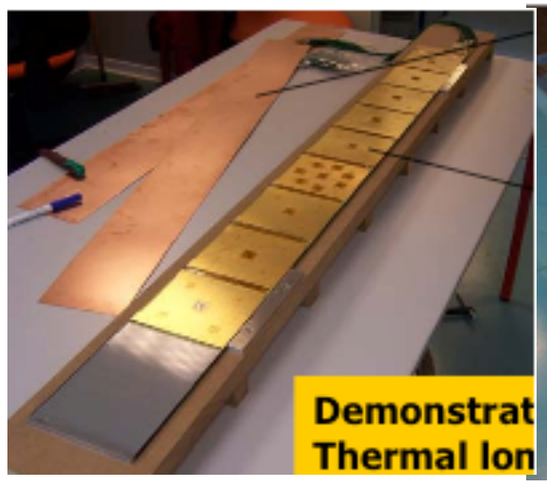
Thickness : 10,7 mm (W=3 mm)

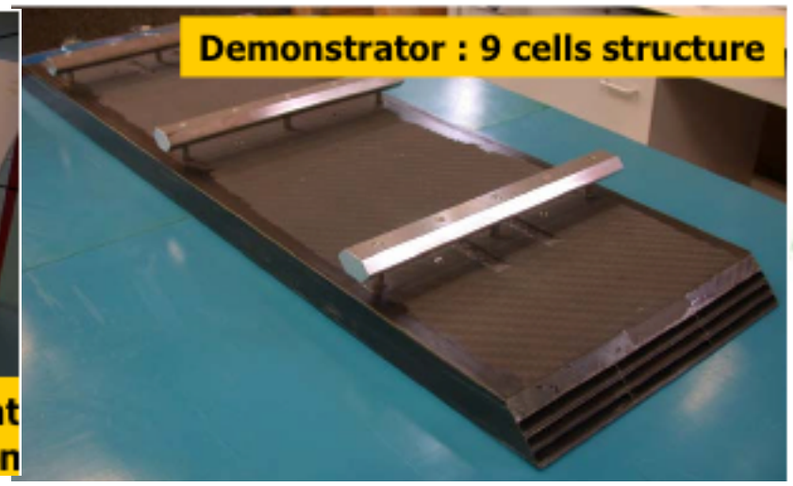
scintillator strip

silicon Ecal R&D

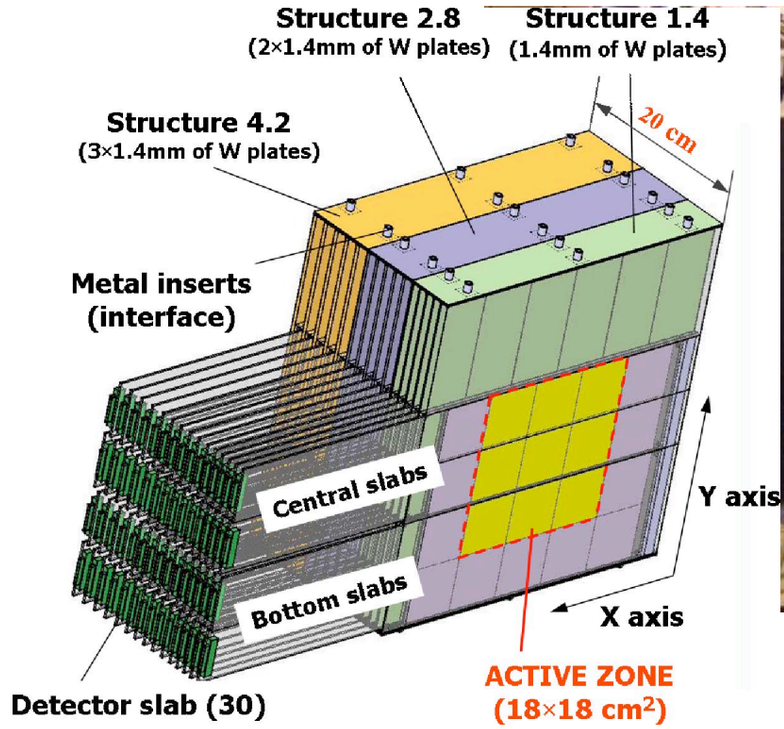
- small prototype
  proof of principle 2005~2009
- 読み出しasic
  SKYROCK
- large prototype
  elex. in layers 2010　power pulsing
- realistic structure
  module 0

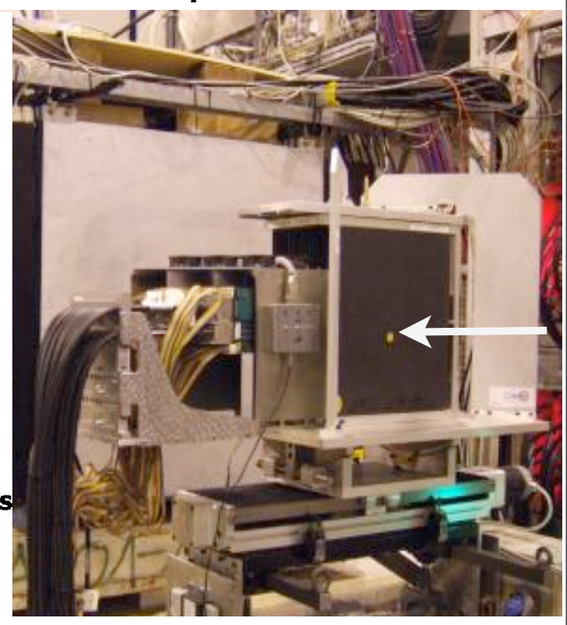
power pulsing test　tungsten + carbon



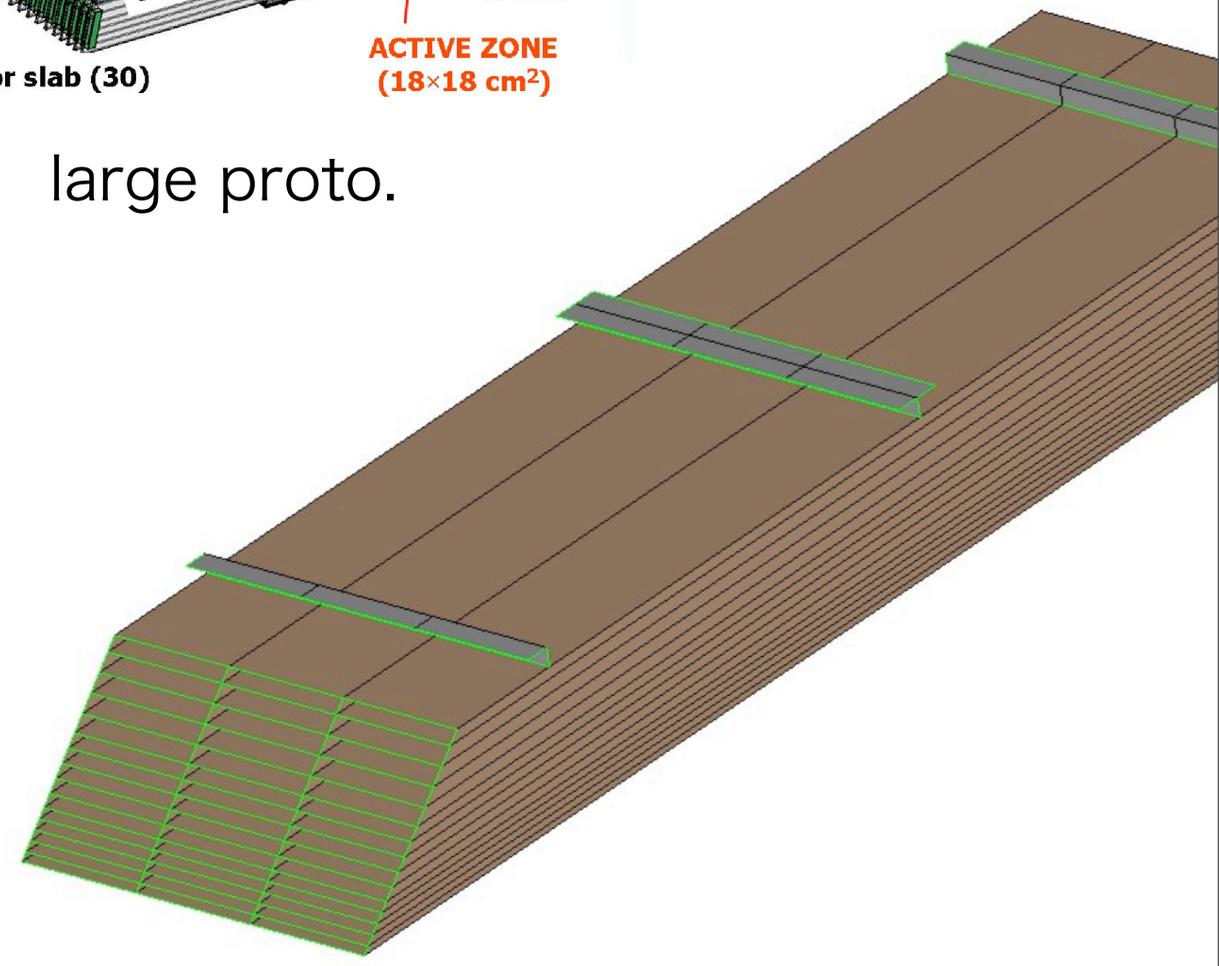


small proto.





large proto.



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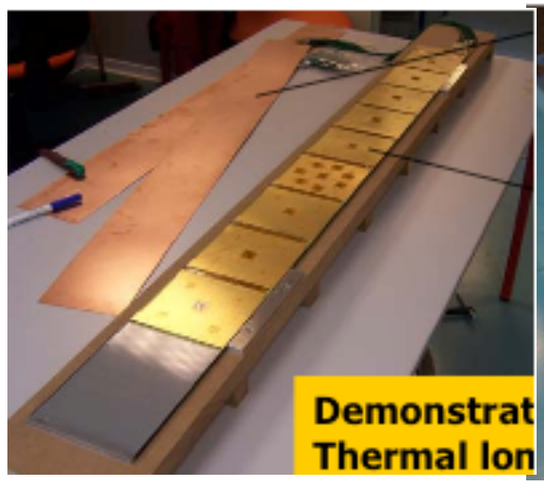
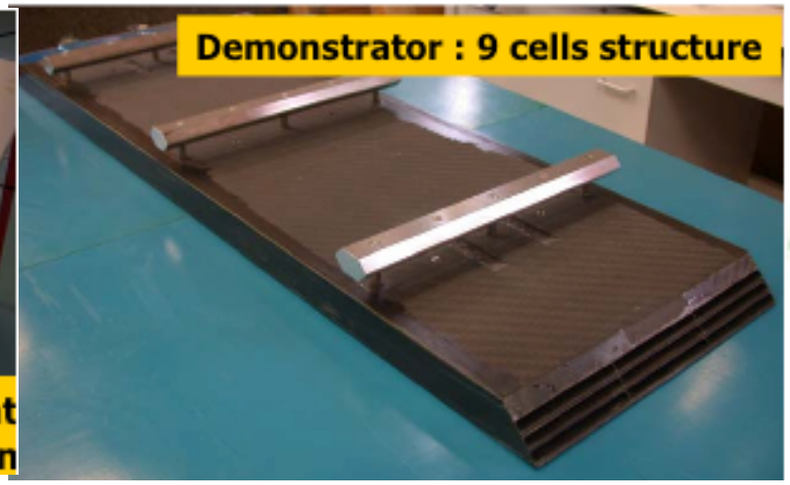
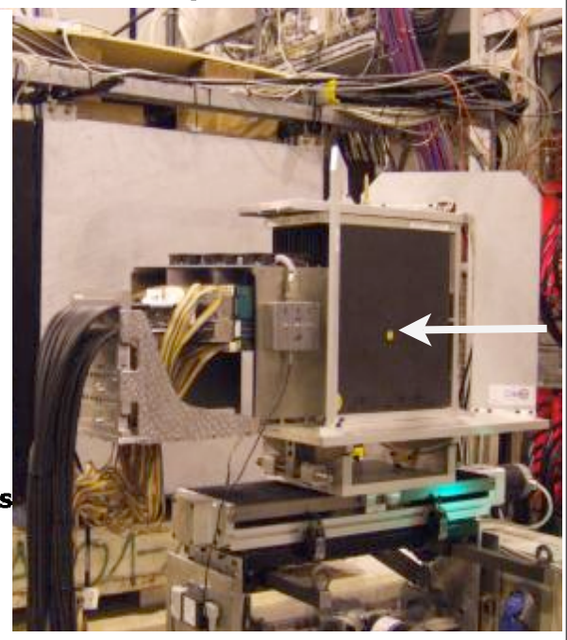
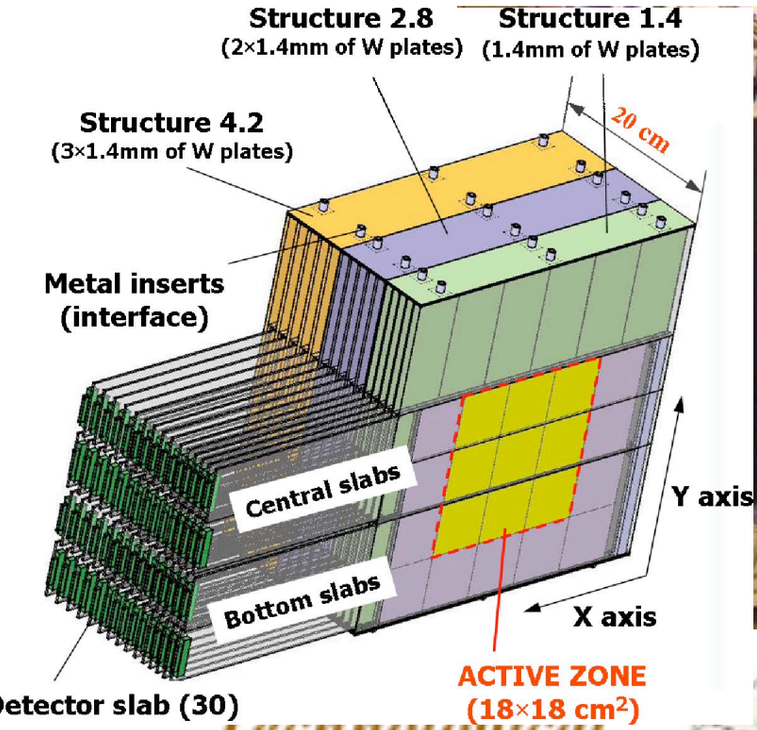


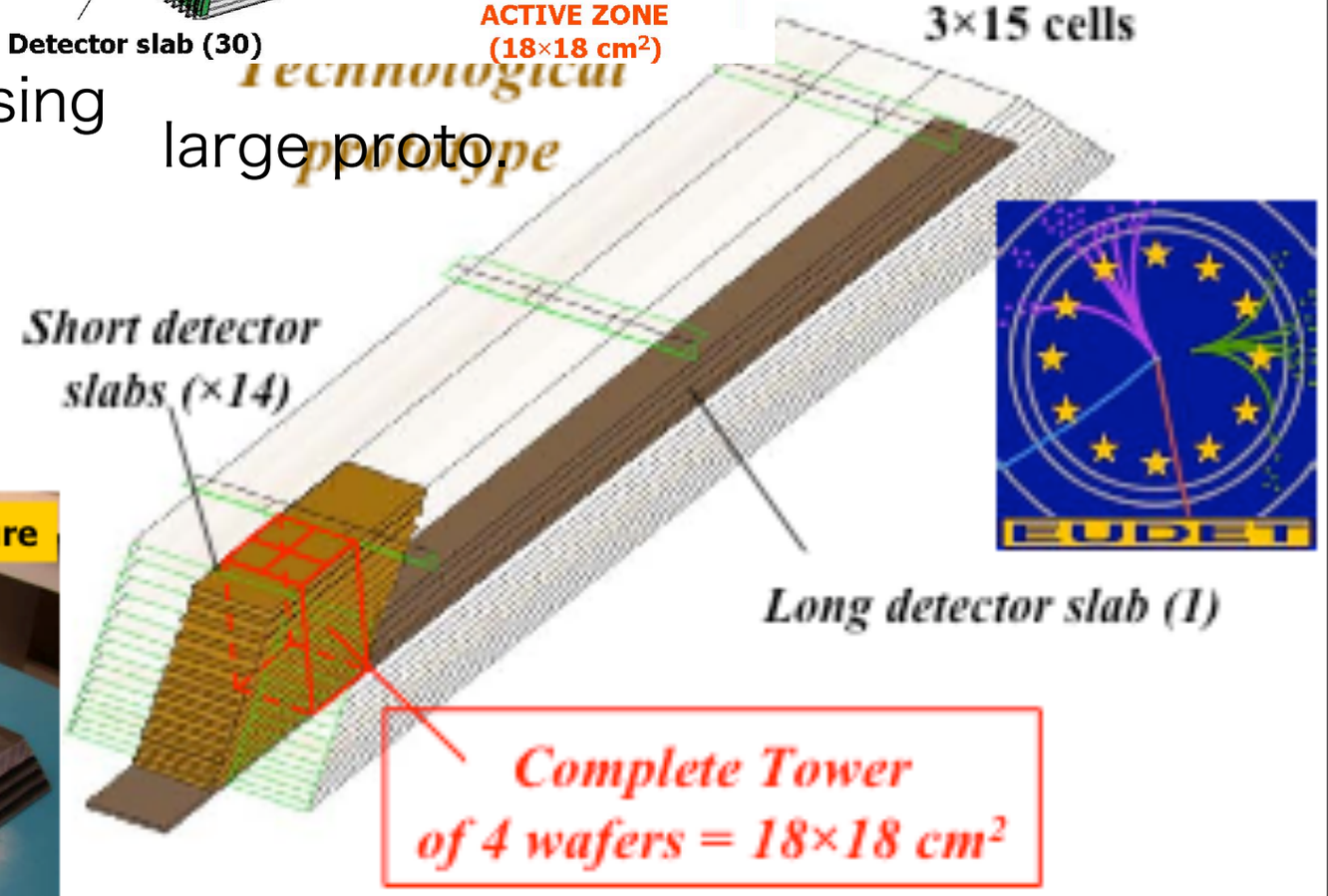


small proto.





large proto.

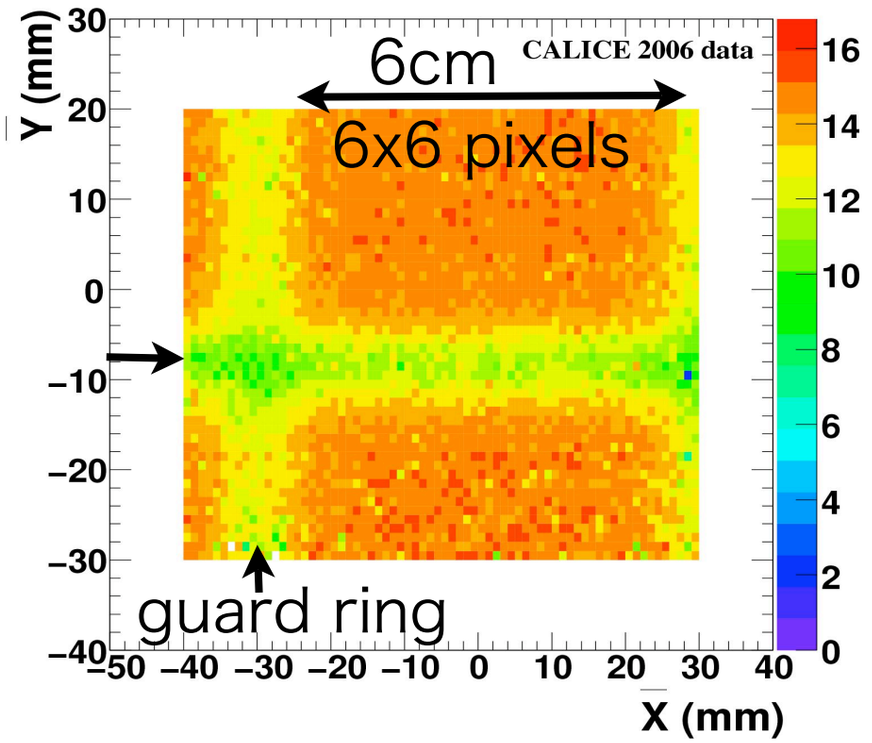


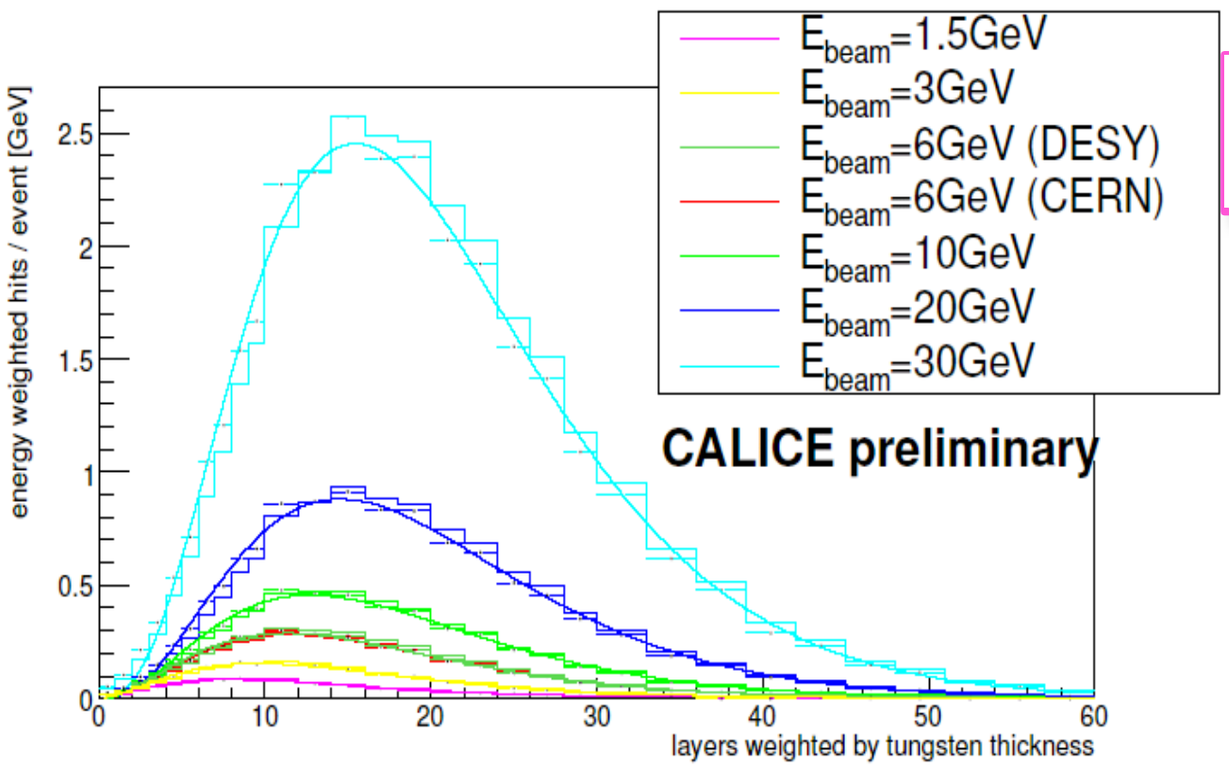
silicon Ecal results

- small prototype
- 18 x 18 cm^2 x 30 layers
- 9720ch 読み出しエレキは外

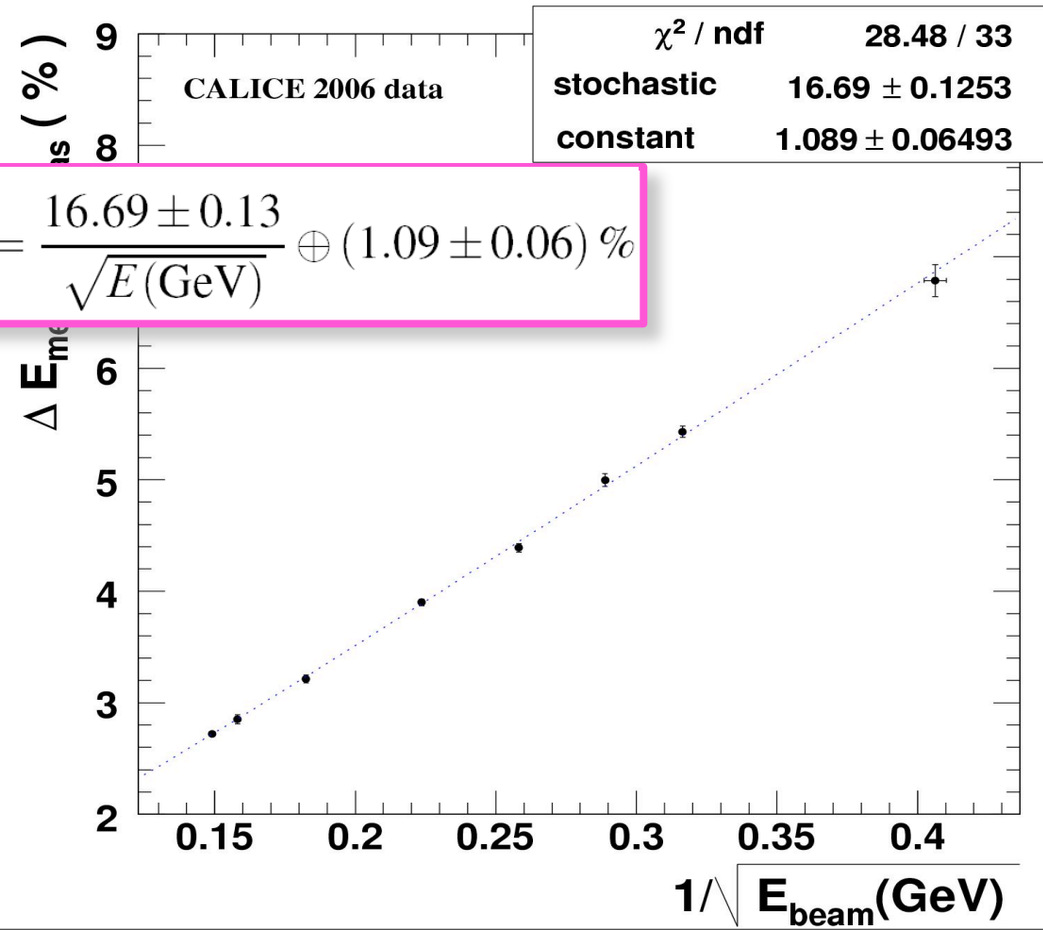
1cm x1cm pixel　　SKYROC

- tungsten absorber 2, 4mm





$$\frac{\Delta E_{\mathrm{meas}}}{E_{\mathrm{meas}}} = \frac{16.69 \pm 0.13}{\sqrt{E(\mathrm{GeV})}} \oplus (1.09 \pm 0.06)\,\%$$



scintillator Ecal

- 小型&中型 proto.

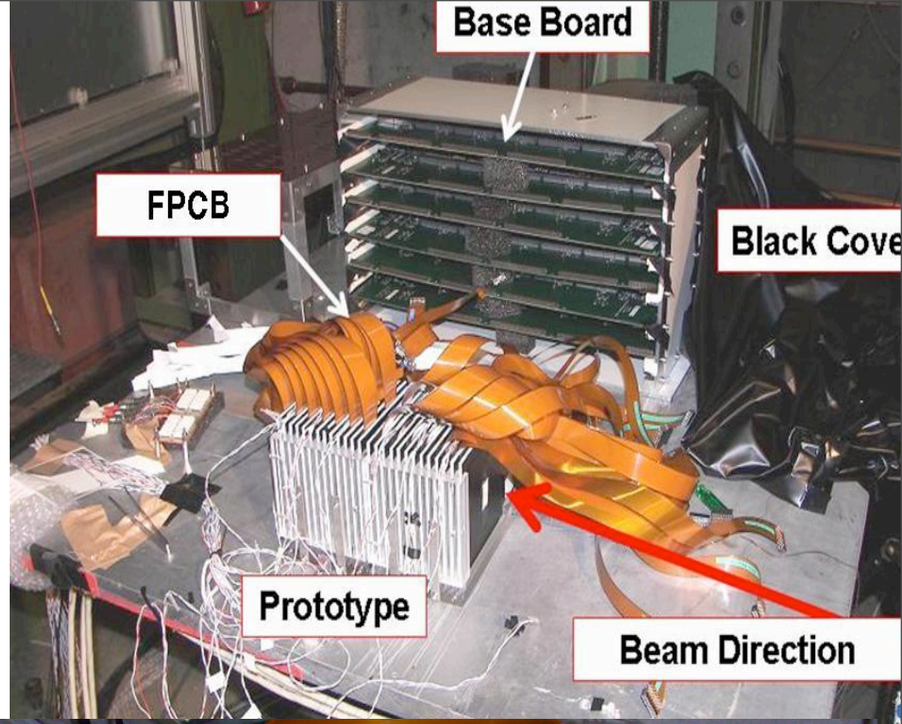
proof of principle 2007~2009　elex. out side

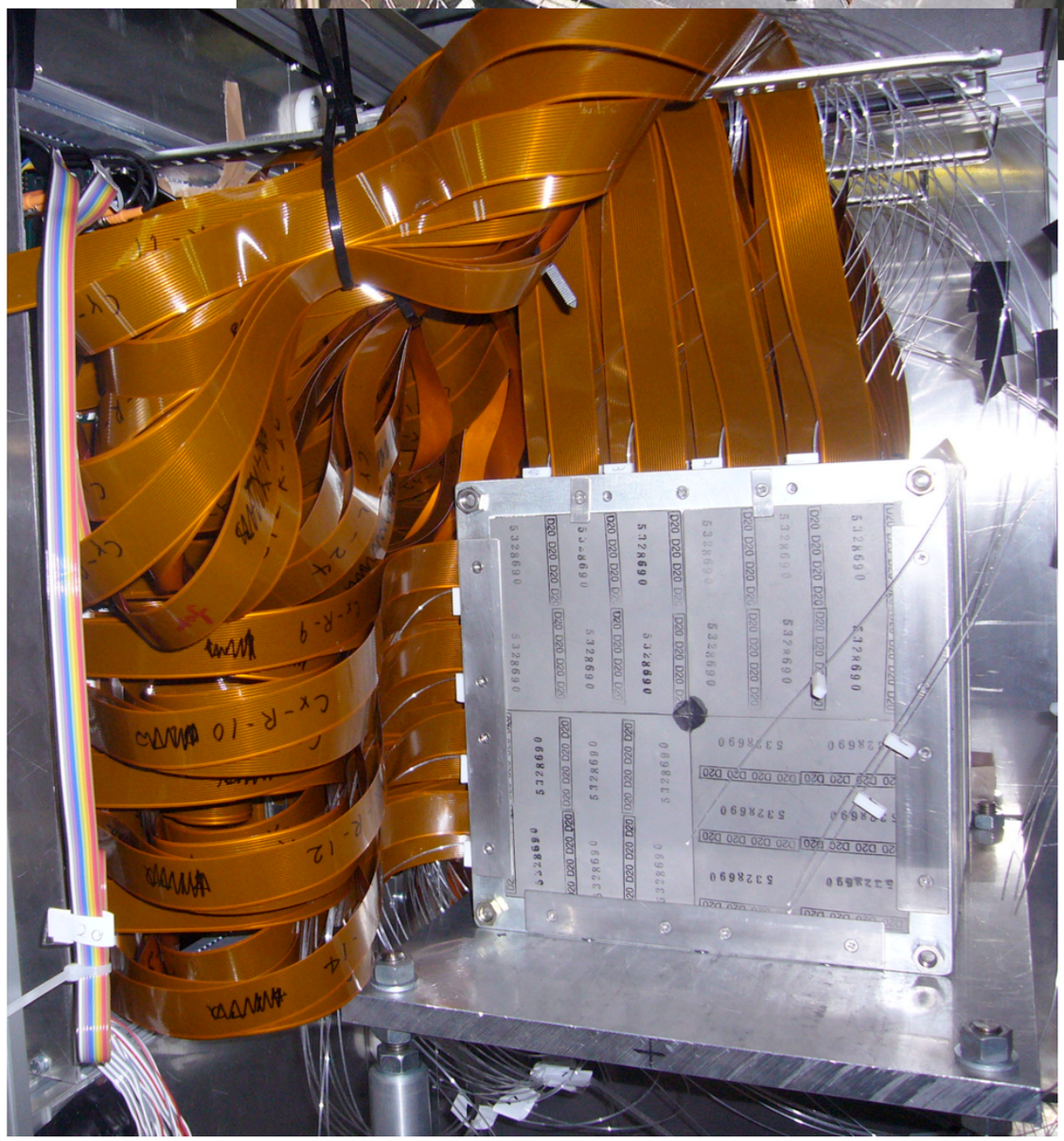
9x9: 2007~ 18x18 :2008~9

468 ch ~ 2160 ch

- シンチレーター：韓国

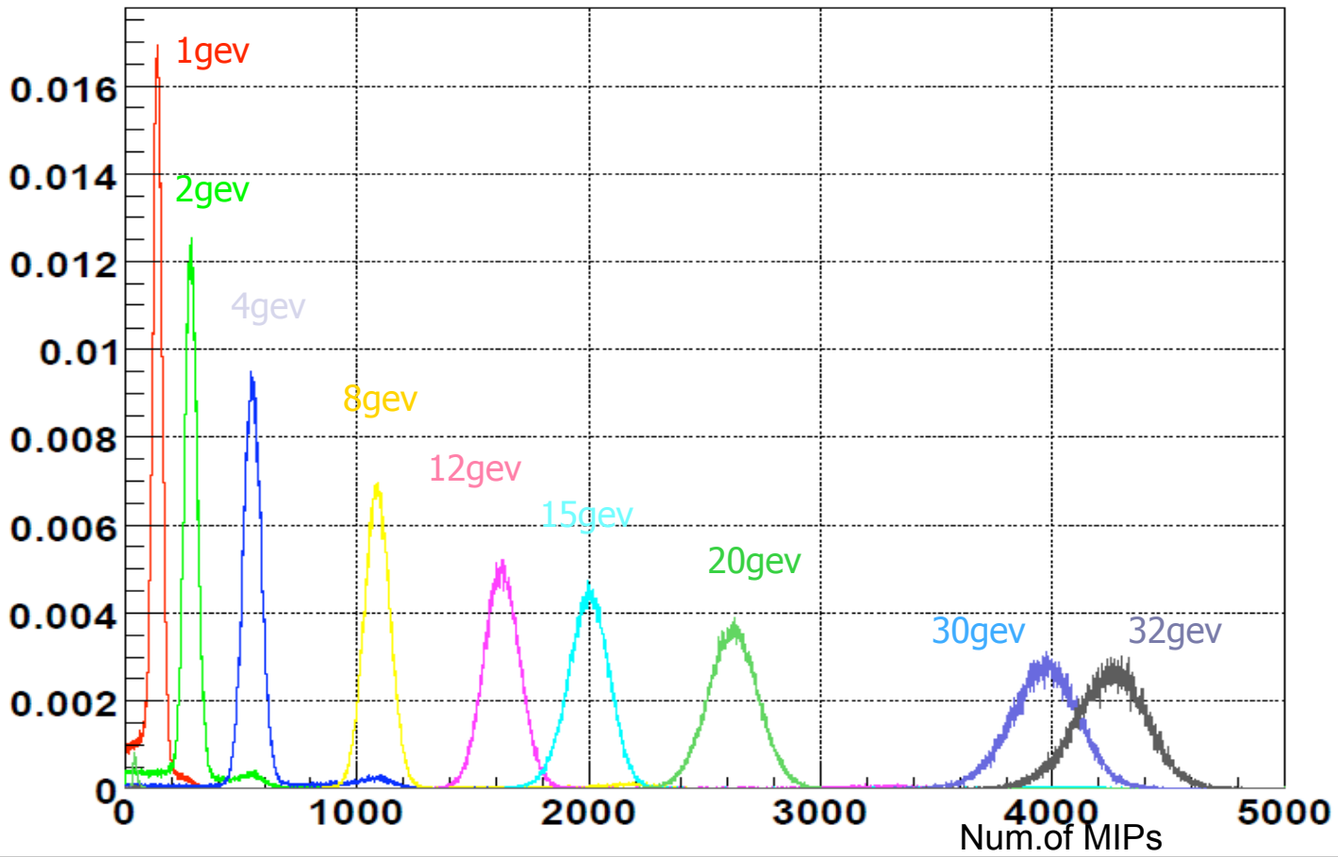
extruded





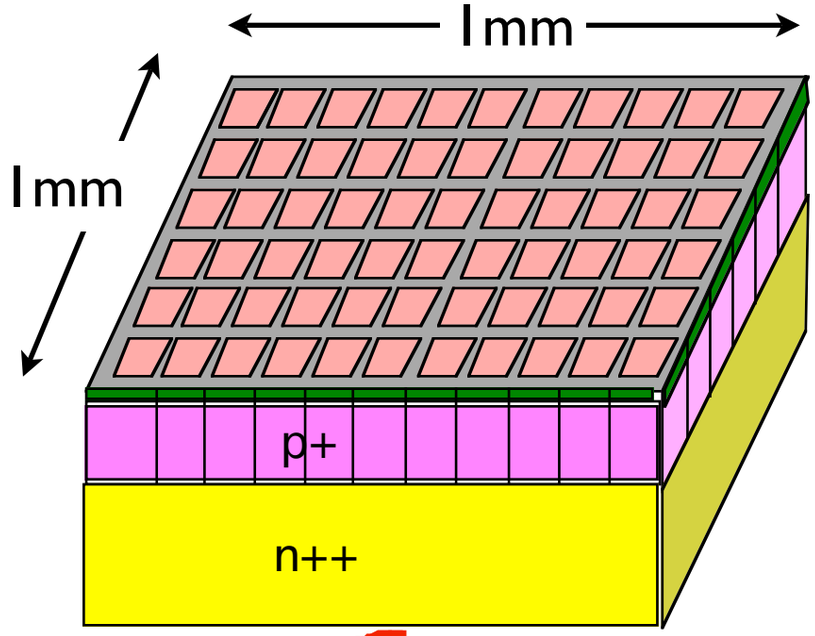
- large proto.

elex. in layers 2011

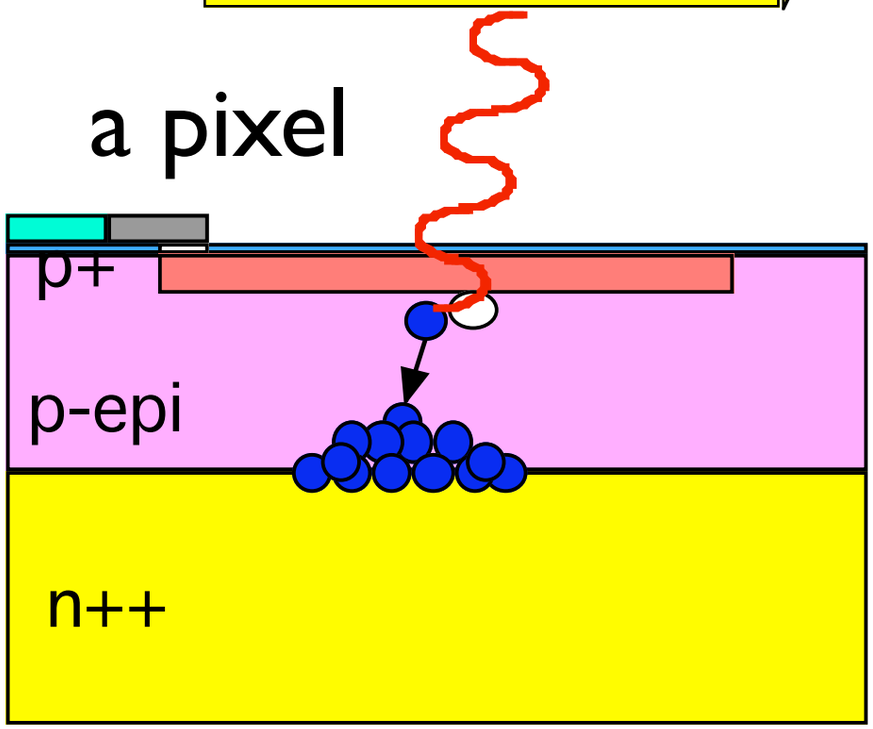


scintillator Ecal sensor

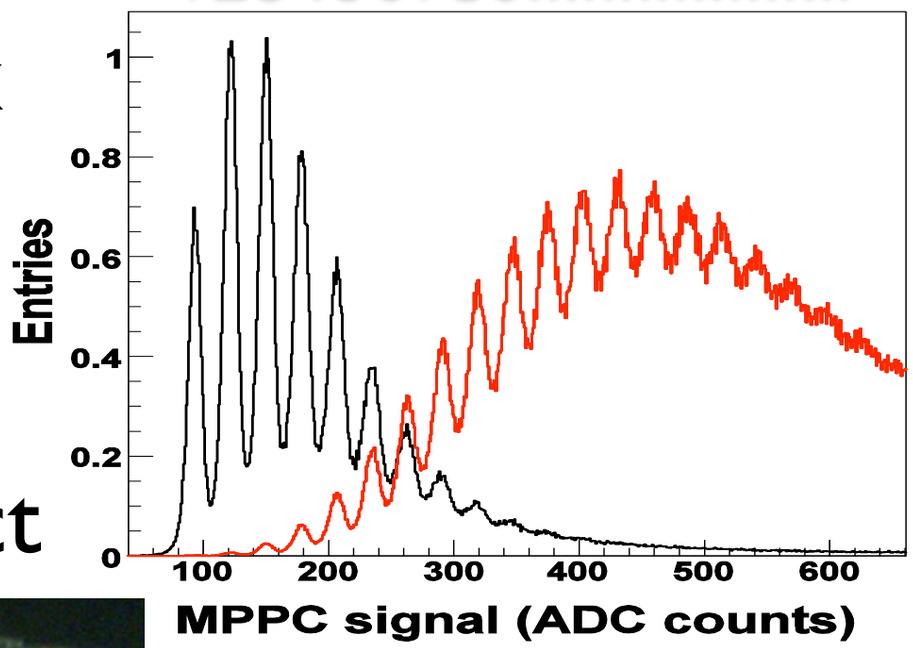
日本・超小型（半導体）光センサー：MPPC



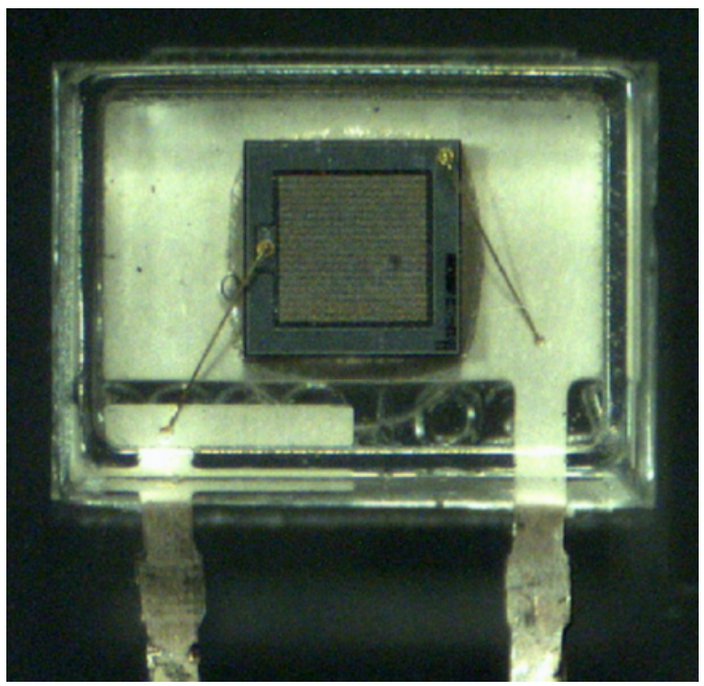
a pixel



# of p. e.
= # of pix



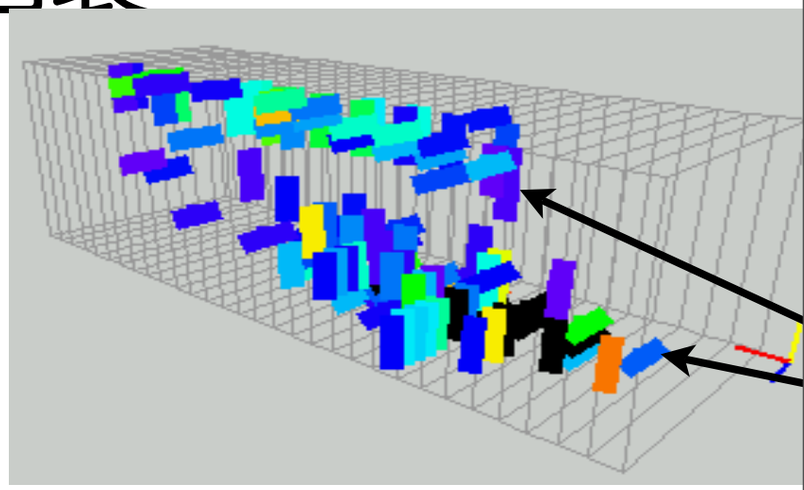
MPPC pict



high gain ~ $10^{5\sim6}$
blue sensitive
low Voltage ~<100V
small ~1mm^2
insensitive to mag.

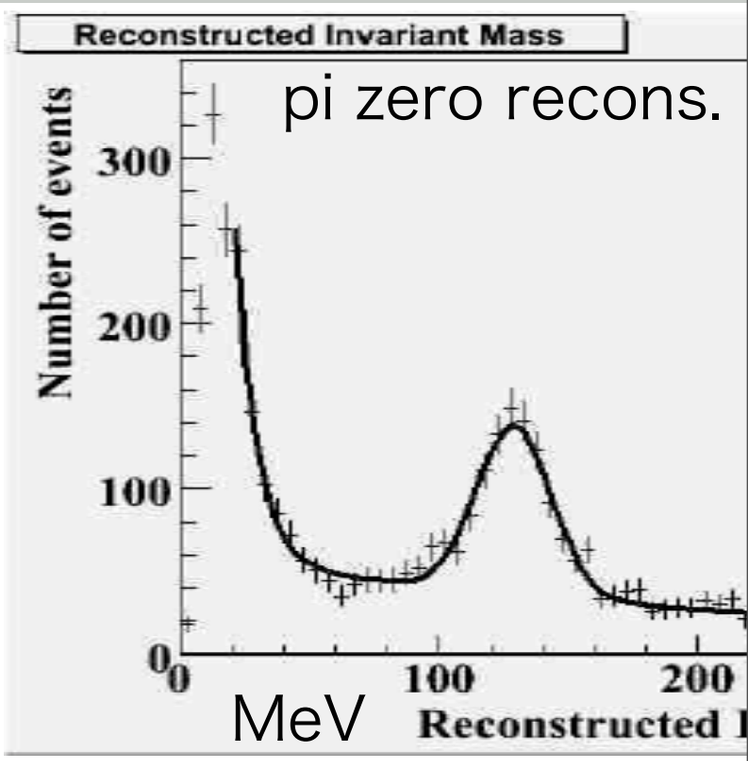
scint. Ecal results

- 小型：シンチレータ選択：韓国製
- 中型：高エネルギー性能



linearity

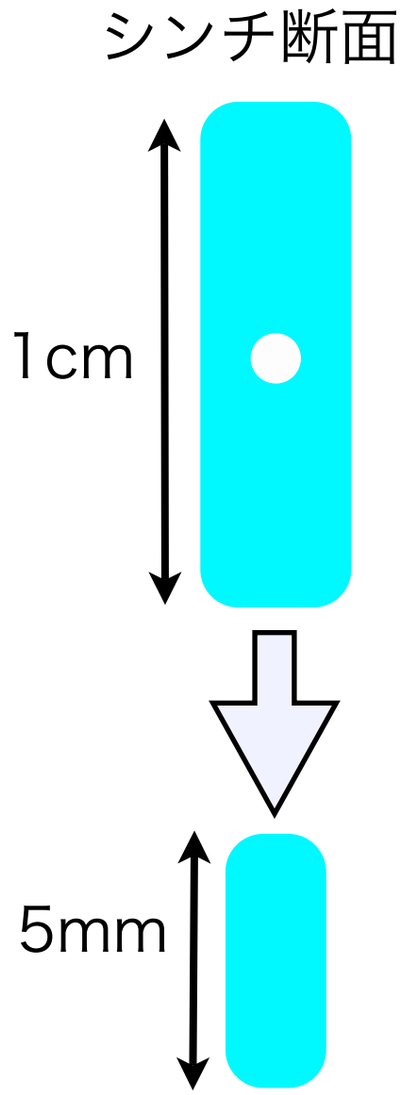
resolution



invariant mass

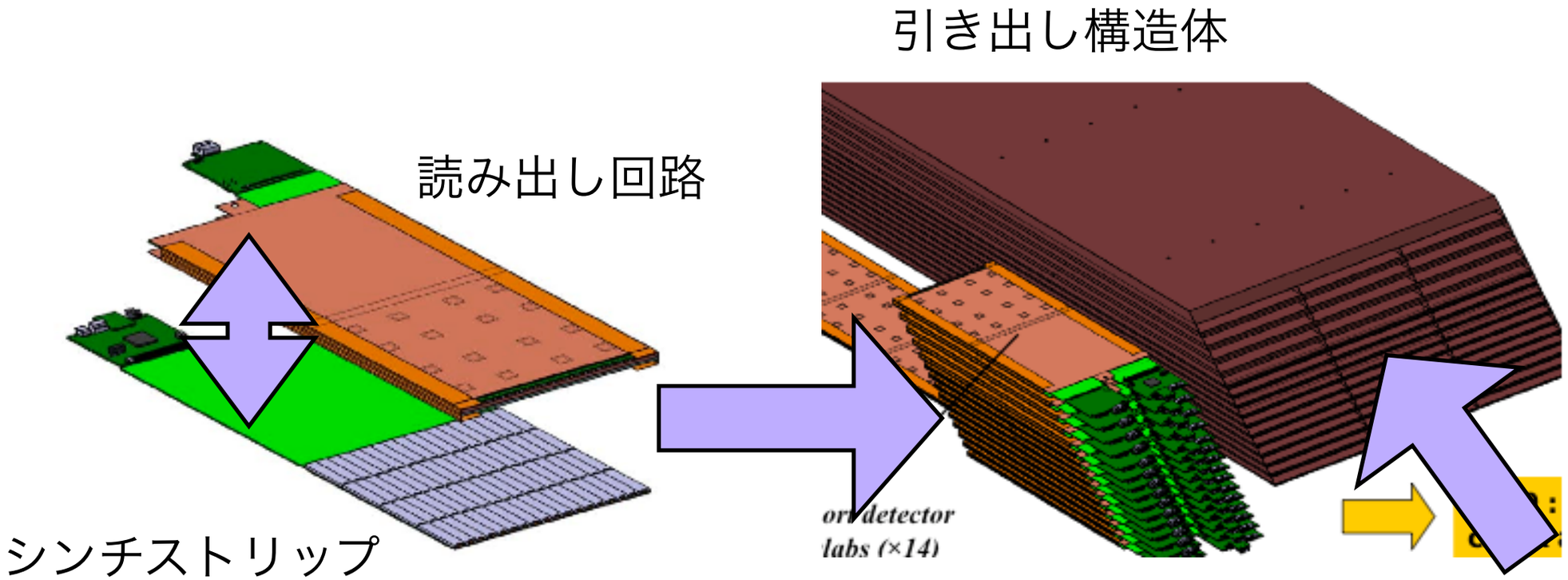
ECAL near future

- 引き出し構造体 の一部に挿入しテスト
- MPPC改善：多ピクセル化 20μm
- 5mm 幅シンチレータの製作とテスト



韓国　extrusion

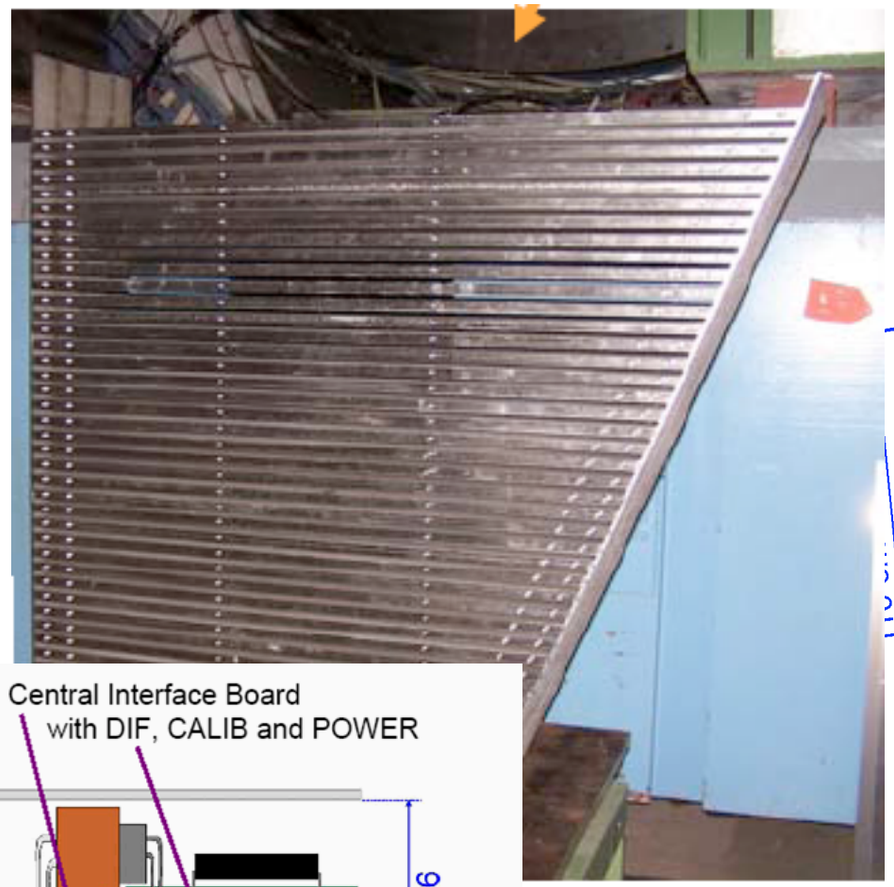
- ストリップ　ソフトウエアの改善

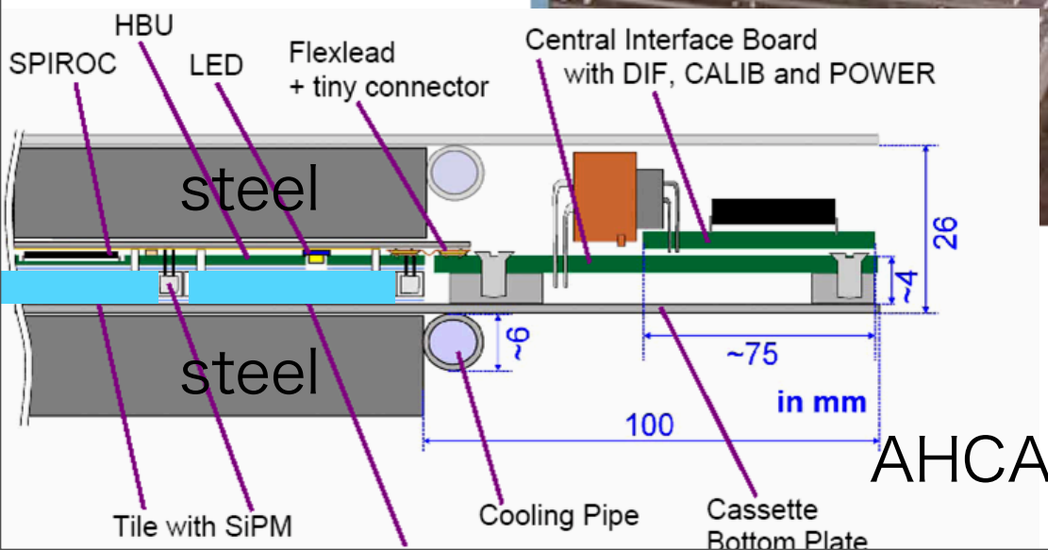


HCAL

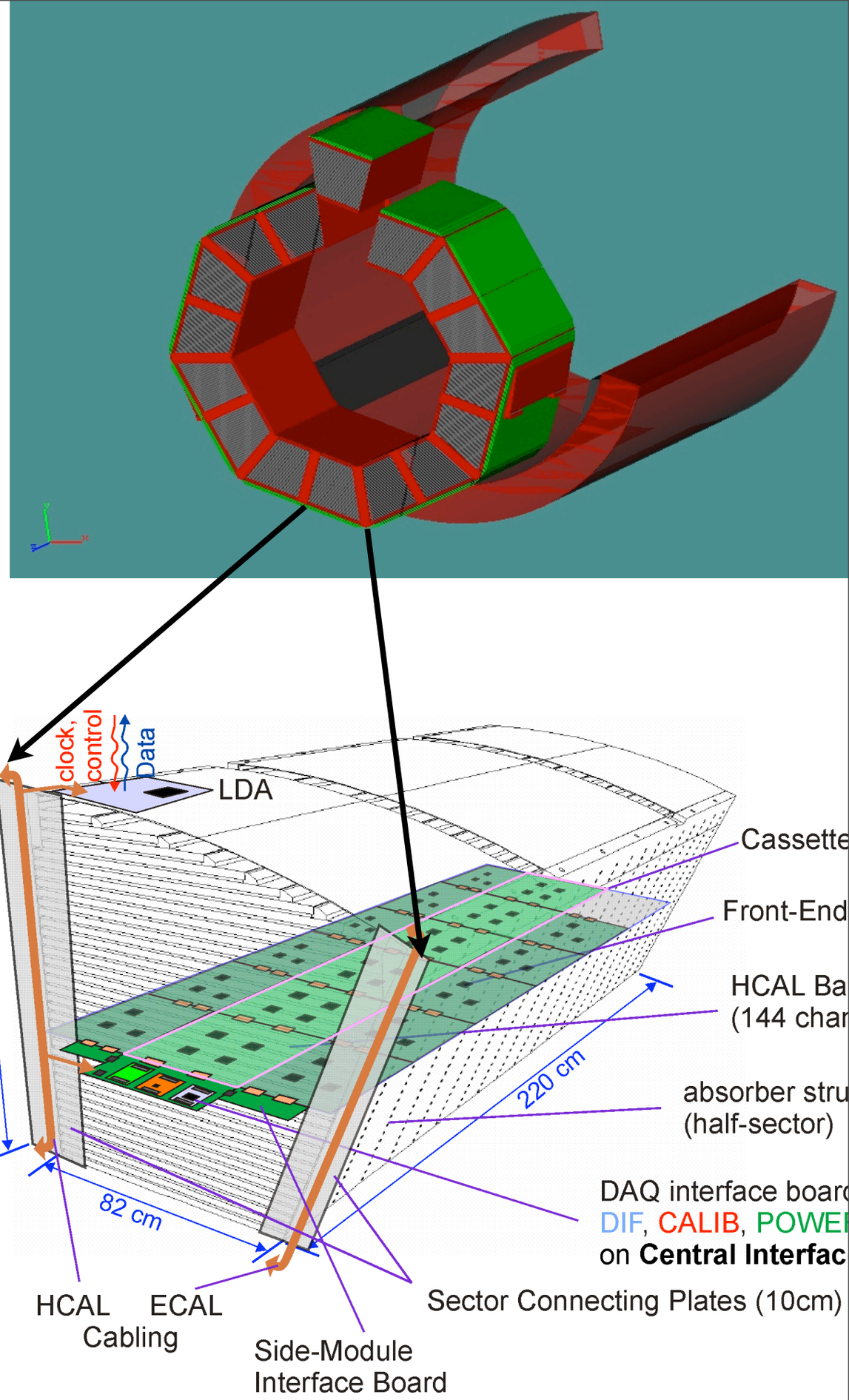
- analog scintillator 3cm
  7Mch
- digital (RPC/MPGD) 1cm
  70Mch

スライス
モデル



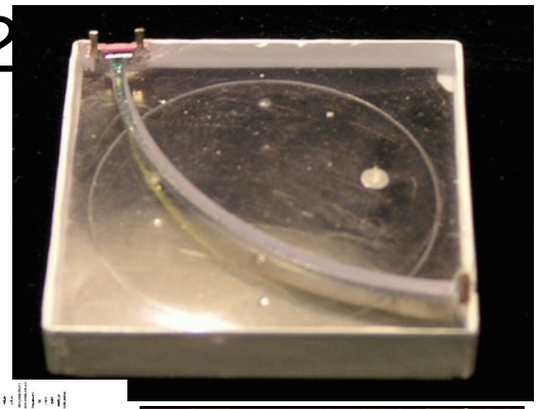


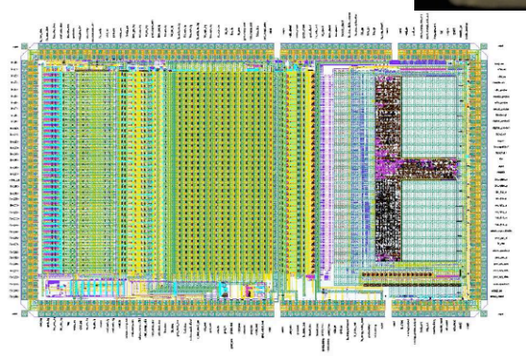
AHCAL断面

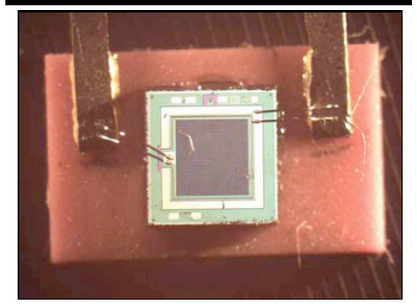


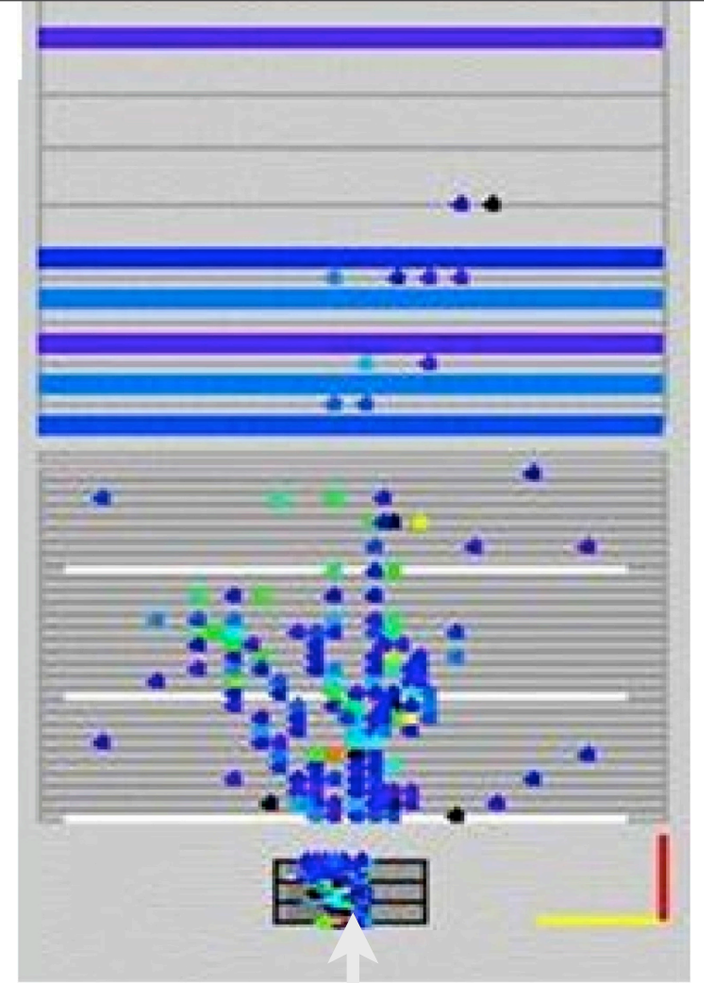
Analog HCal

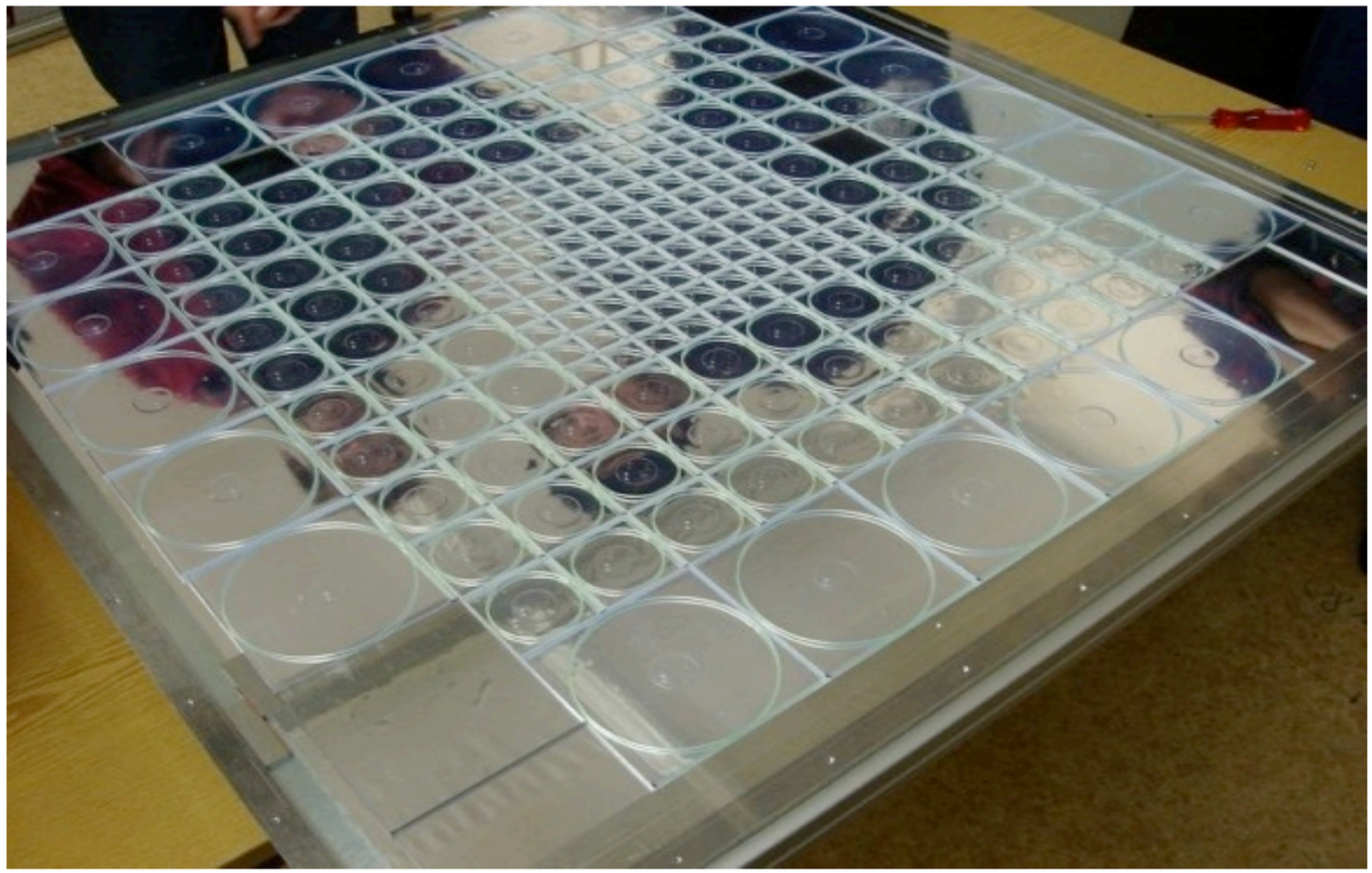
- scintillator tile 3x3cm²
  1mx1mx1m 38層
- SiPM(露) 読み出し
- シンチ(露)
- SPIROC(仏)

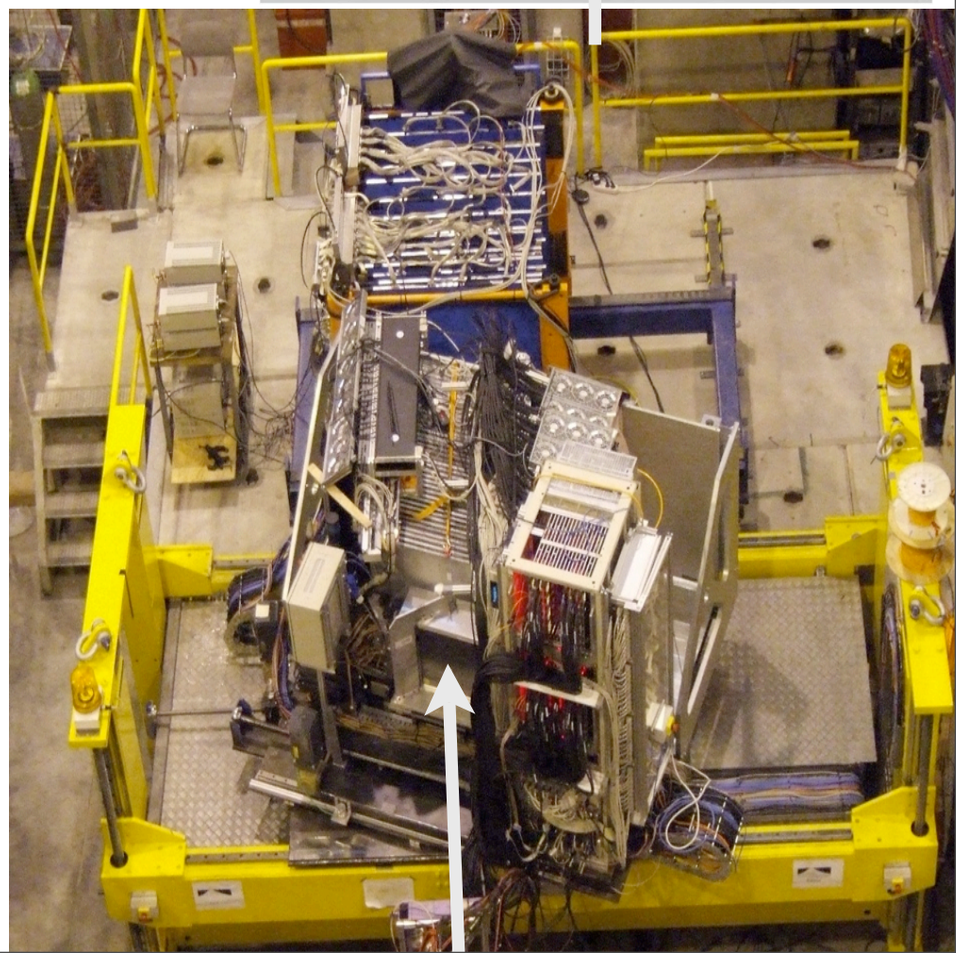






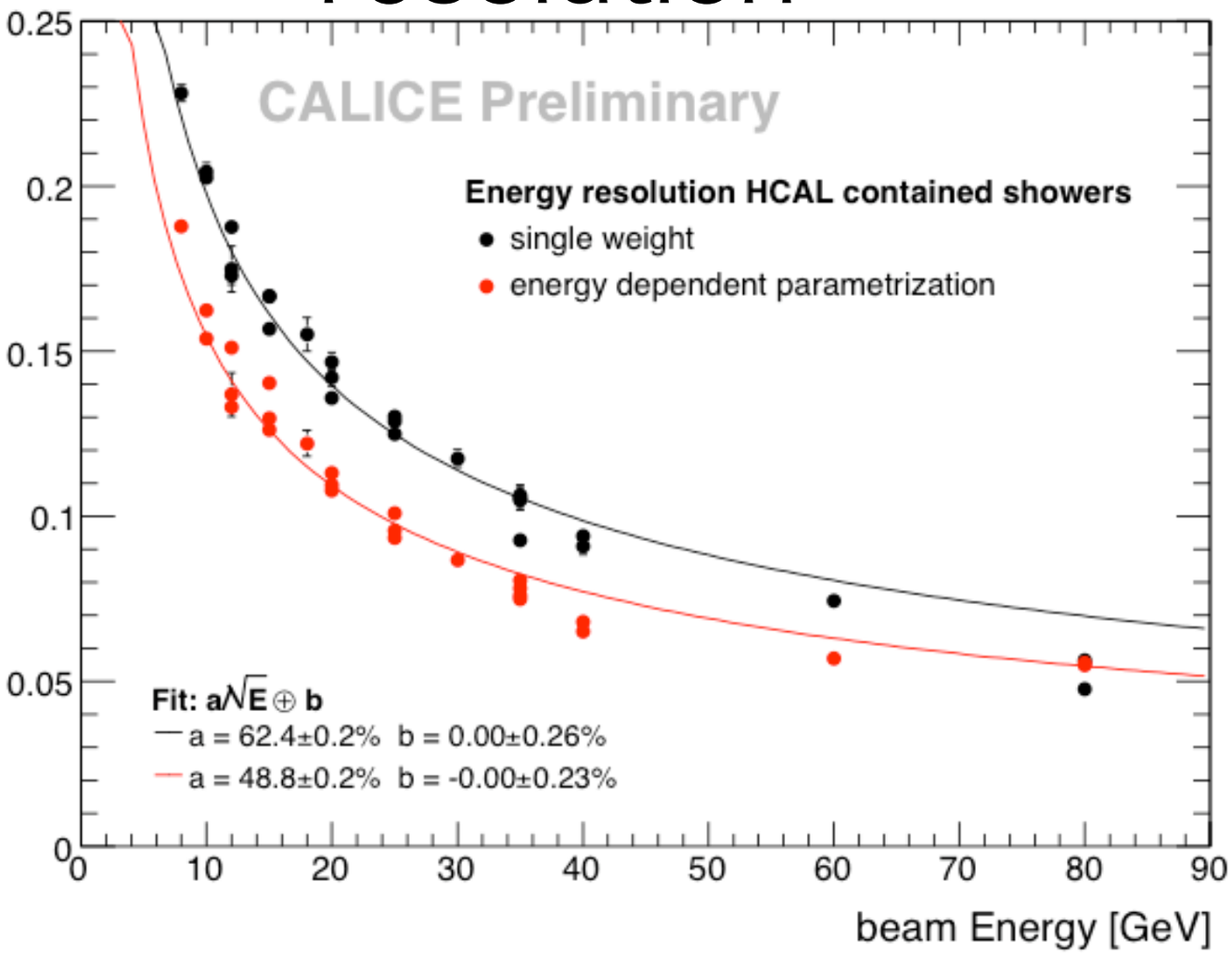




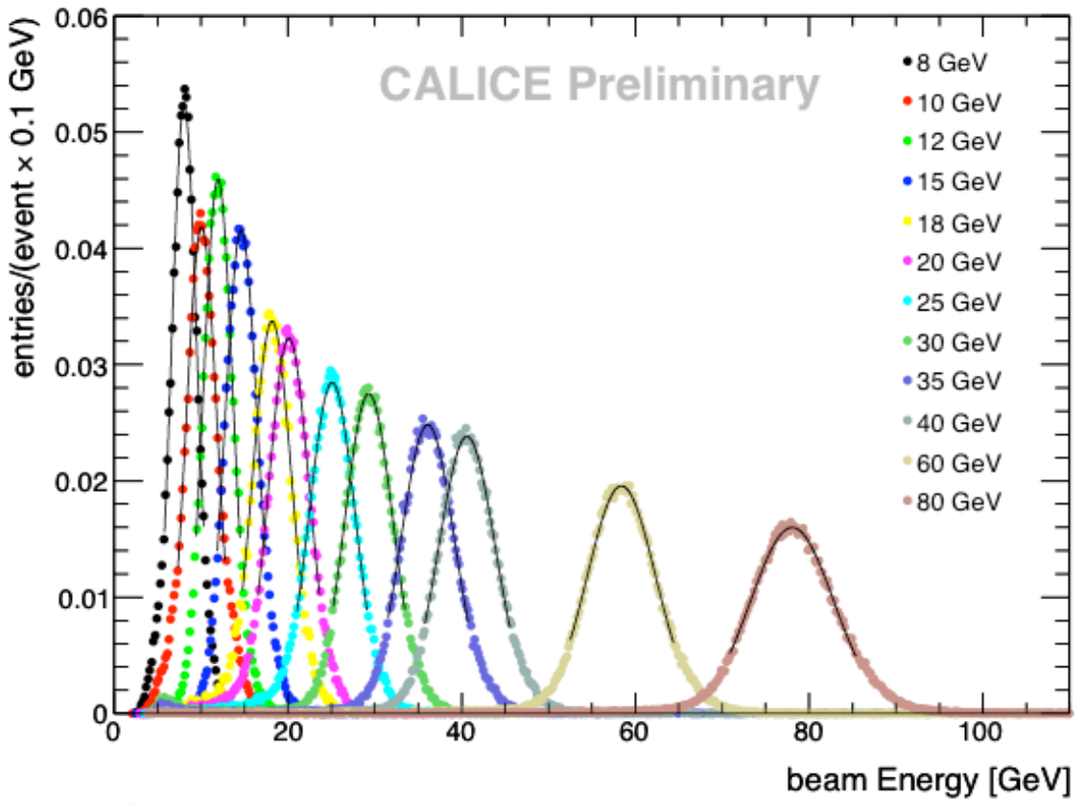


AHCal results

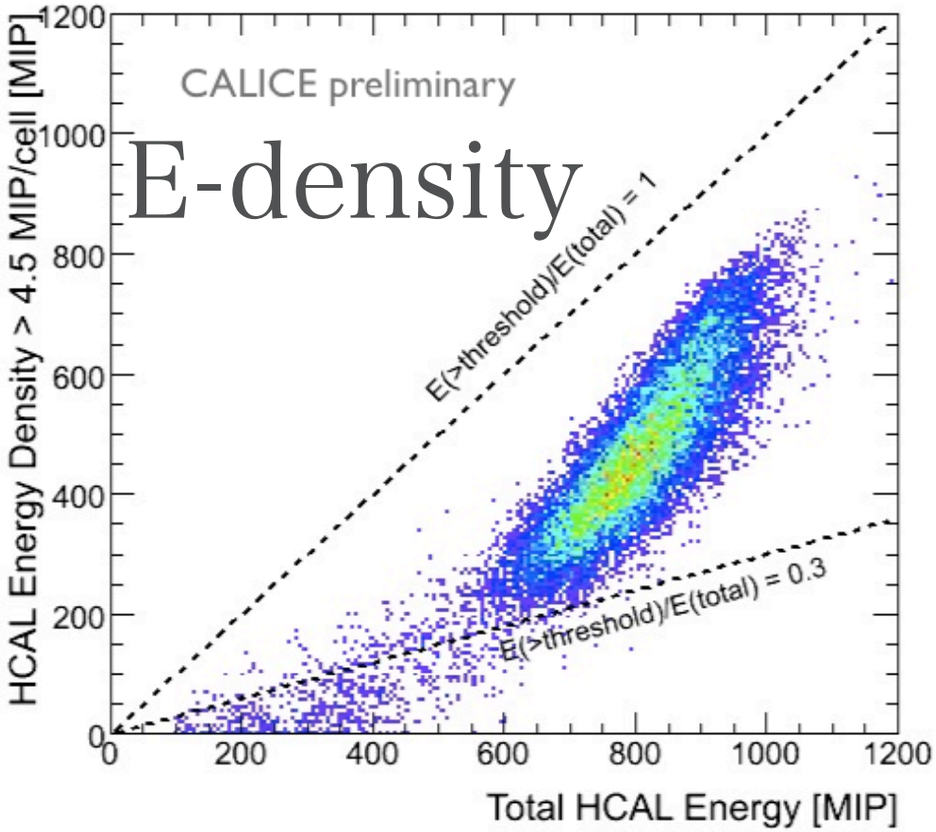
resolution



49%/sqrt(E) with E-dens.



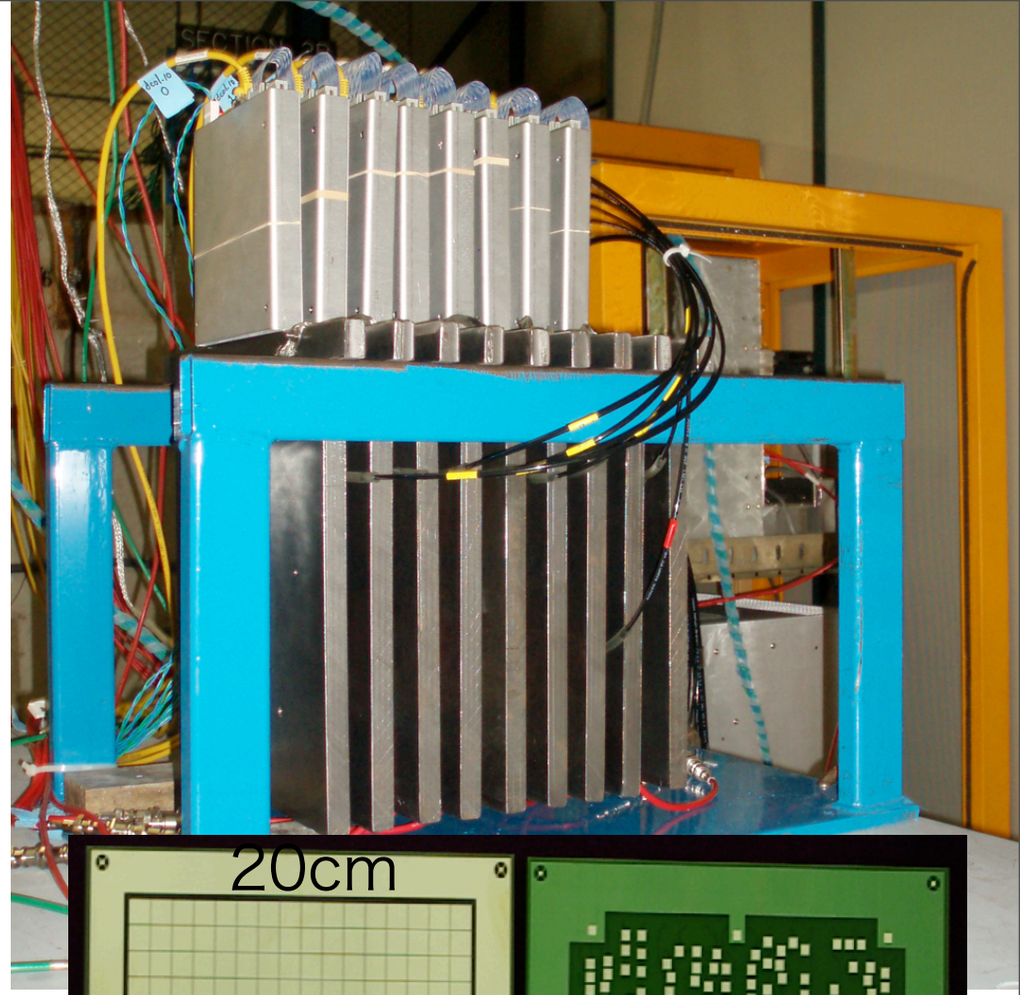
E-density



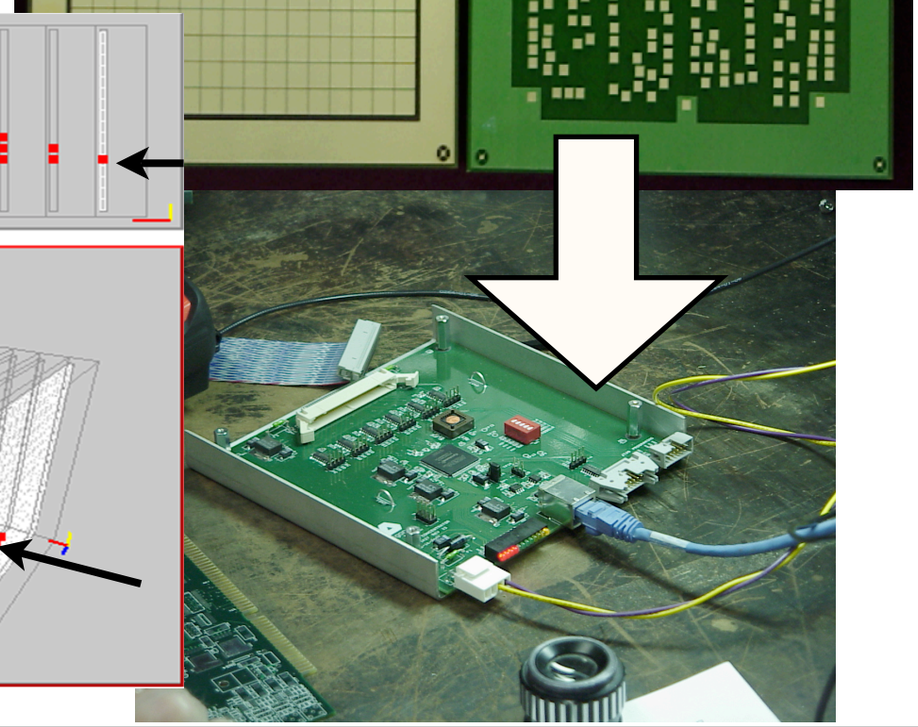
Digital HCal

- 1cm x 1cm pad 読み出し
- on / off digital
- 読み出しエレキは層中

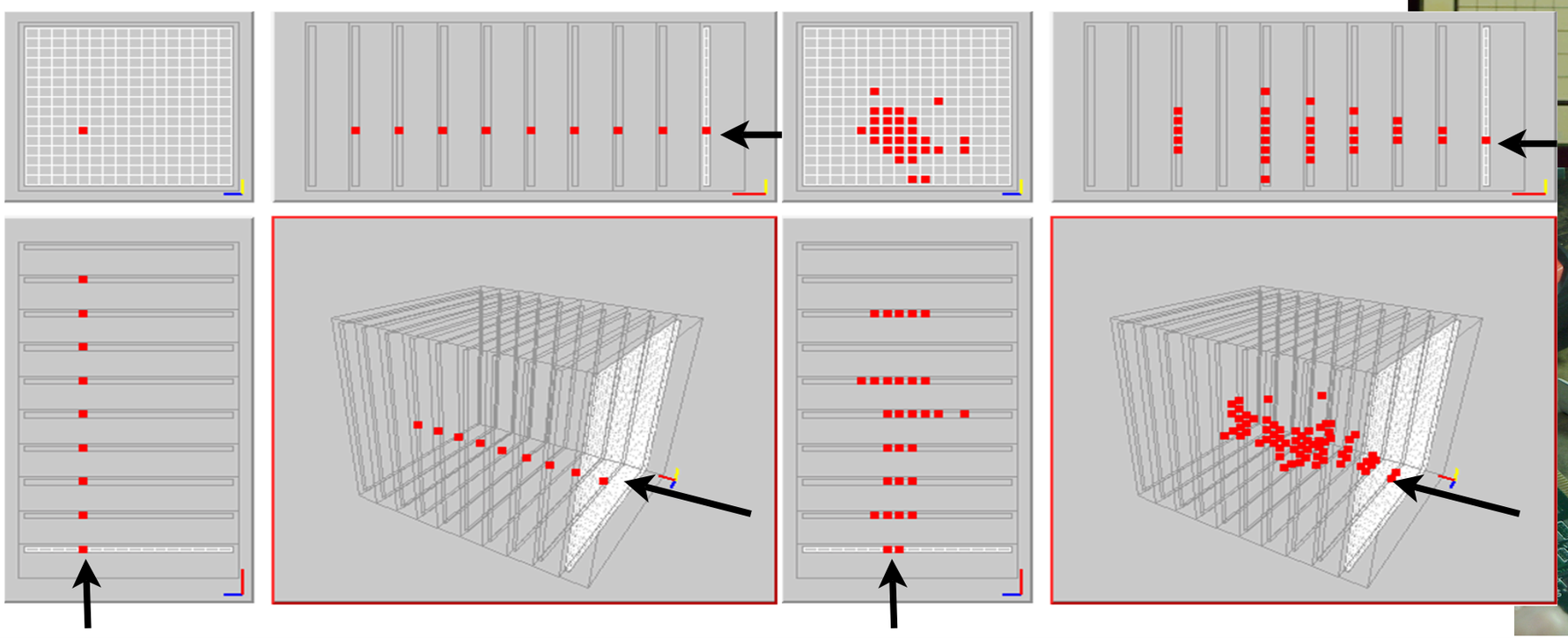
RPC



- 小型　20x20 cm^2



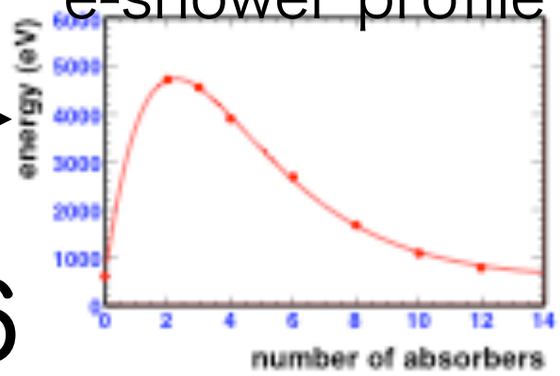
muon　　electron

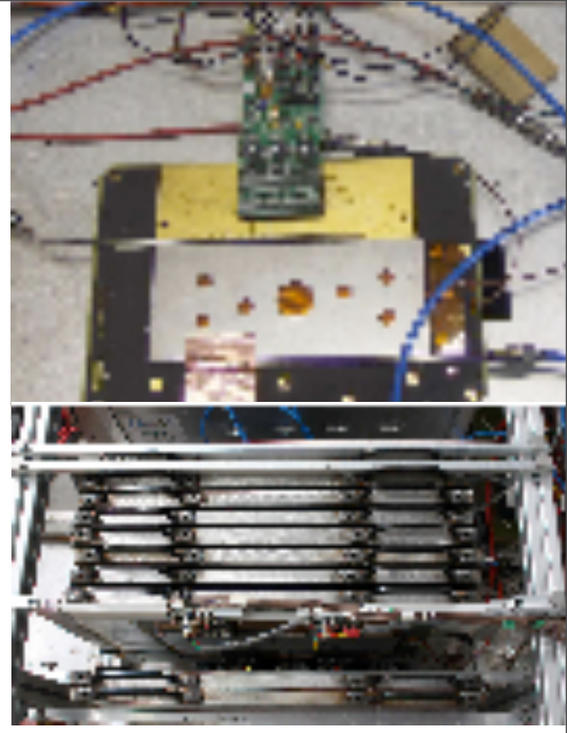


DHCal results

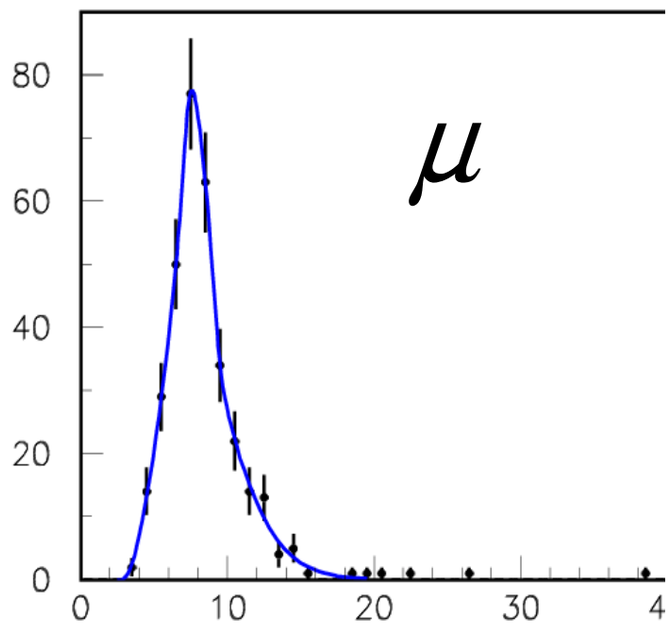
- RPC/mMegas
- 小型　proto. 20x20/16x6
- 大型　2010年

e-shower profile

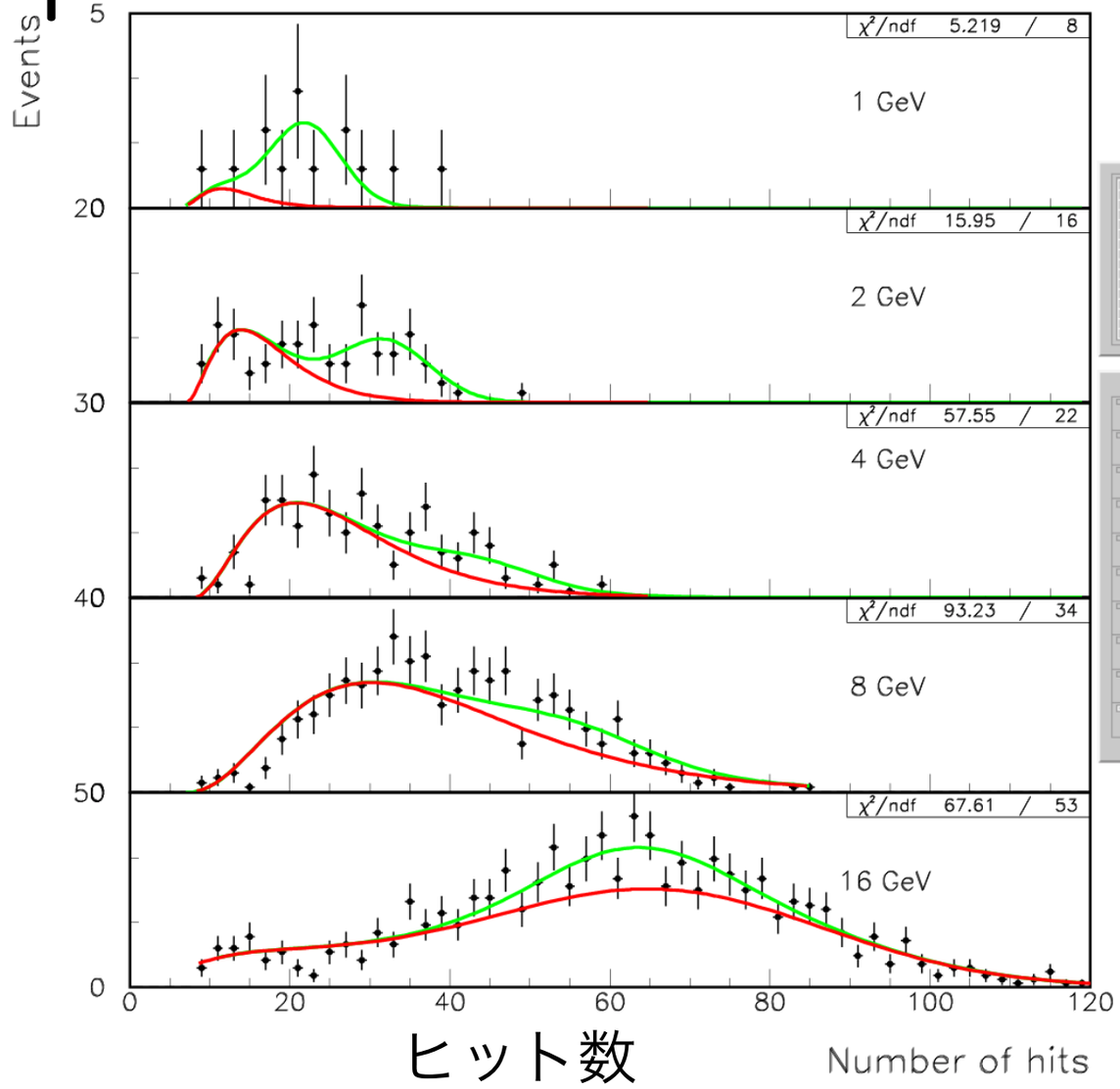


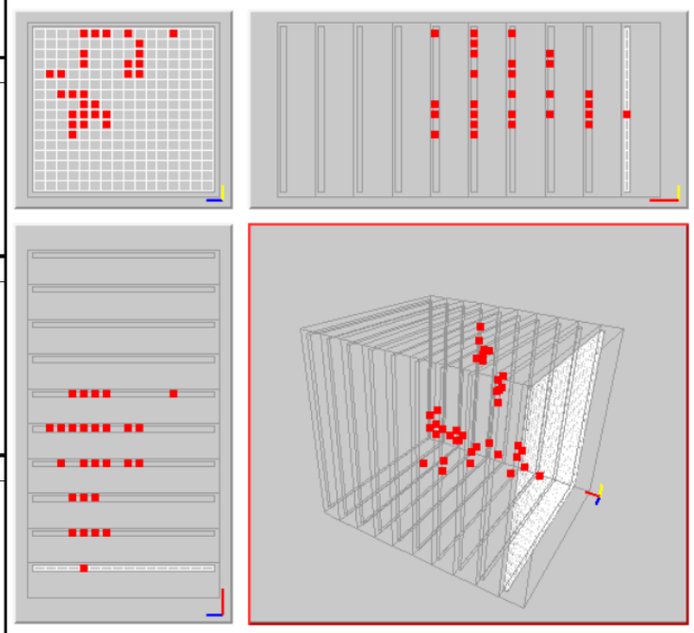


mMegas



RPC

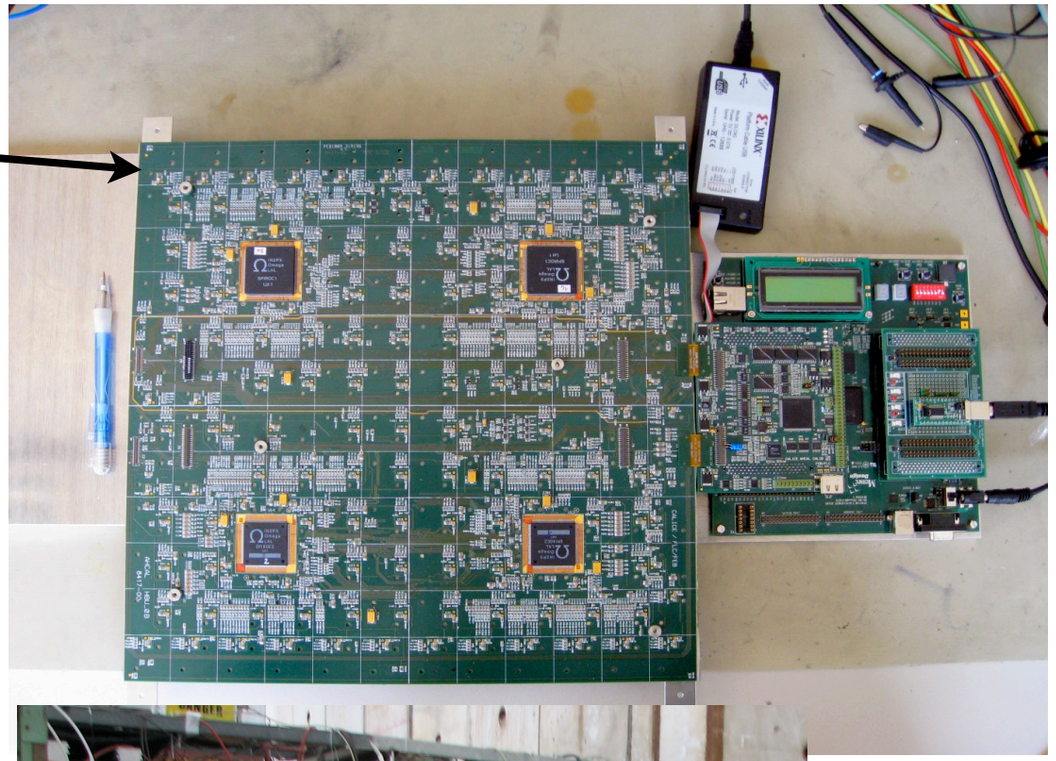




π

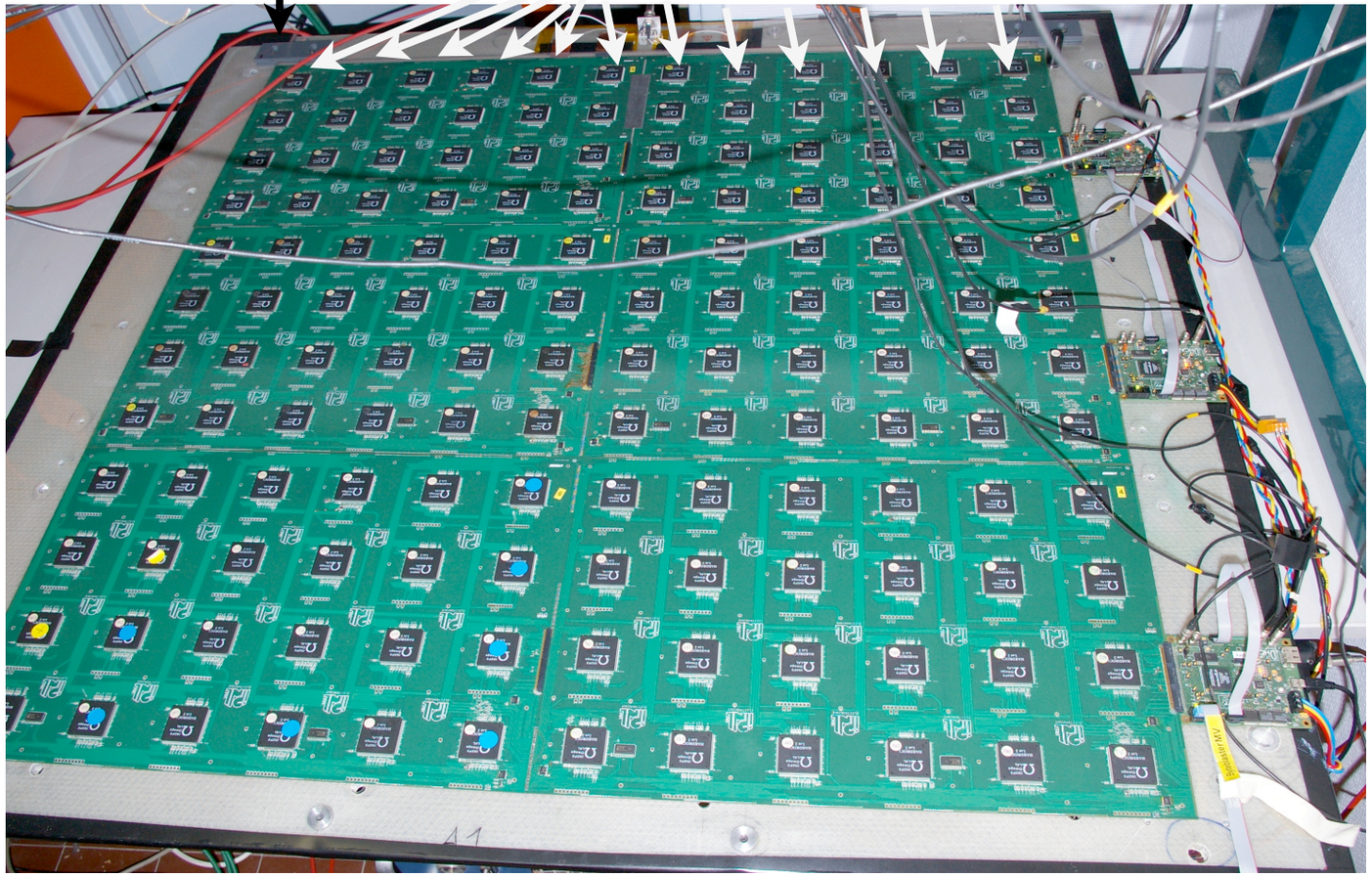
HCAL future plan

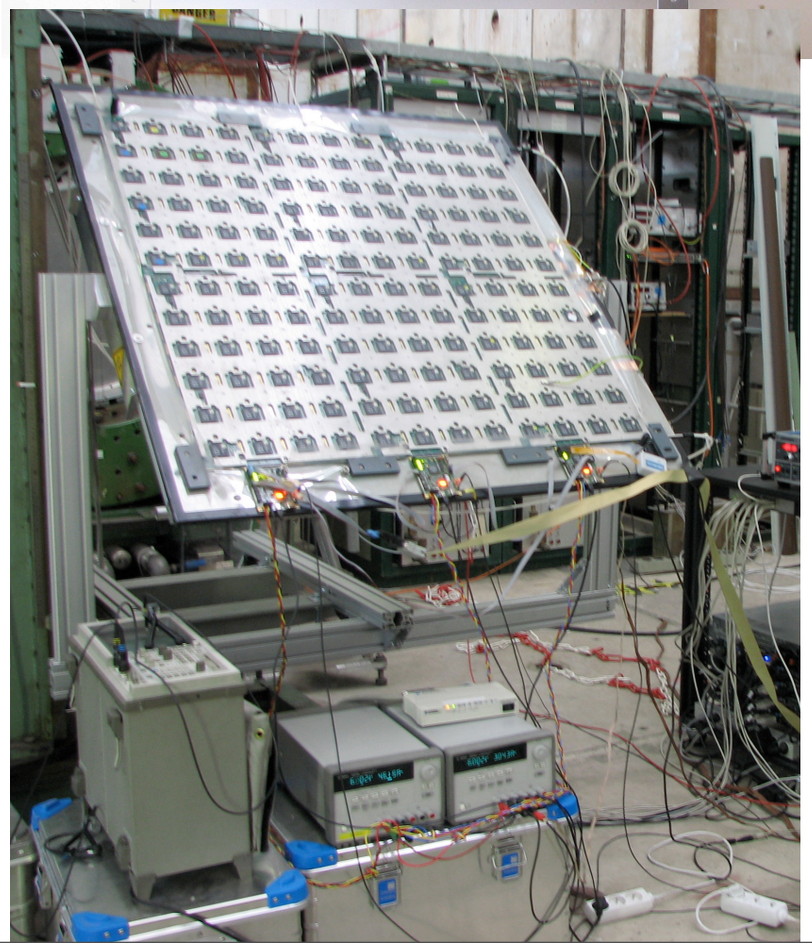
- AHCal for realistic proto.
  3cm x 3cm analog
- DHcal：原理検証段階　読出し層中
  1cm x1cm digital



読み出しasic

RPC





カロリメータまとめ

- PFA に主導されたカロリメータ　開発
- 特徴：小さな測定単位
- 電磁シャワー：silicon / scinti.　~5mm
- hadronシャワー：scinti. / digital MPGD
  3cm / 1cm
- 2012年準備完了予定

測定器全体のまとめ１

- 目標：2012年中に 詳細設計書を書く
- 現状

VTX : FPCCD / CMOS / DEPFET

TPC : GEM / microMEGAS

ECAL : silicon / scinti. strip

HCAL : scinti. analog / MPGD digital

共通:精力的なビームテストが進行中

測定器全体のまとめ2

- 目標：2012年中に 詳細設計書を書く
- 今後の課題

共通: 回路のpower pulsingとintegration

VTX：測定器と回路の開発、低物質量化

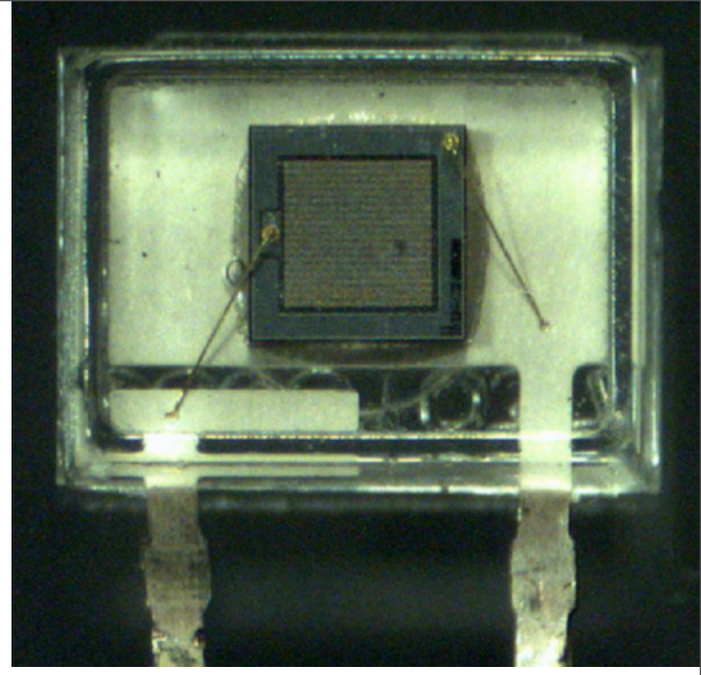
TPC：表面実装読出しとイオンゲート

ECAL：silicon 価格 / strip clustering

HCAL：SiPM量産 / 1m^{3}プロトタイプ製作

analog / digital

MPPC

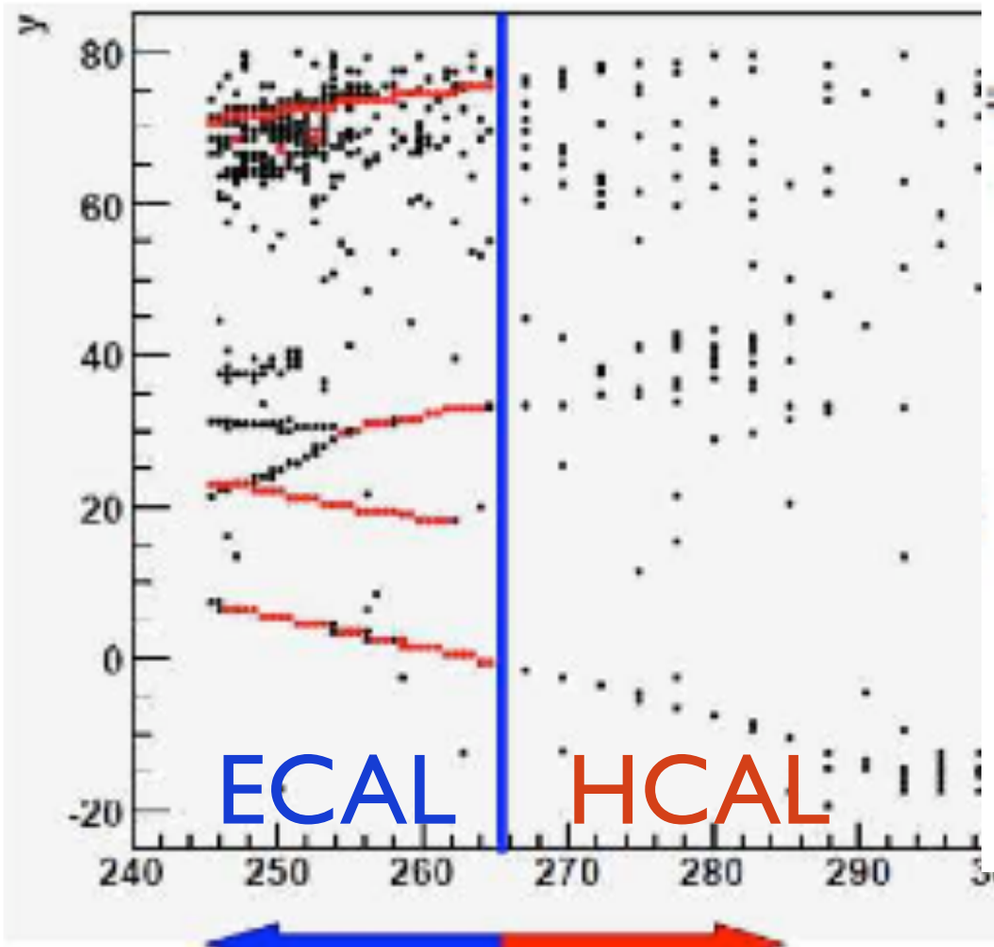


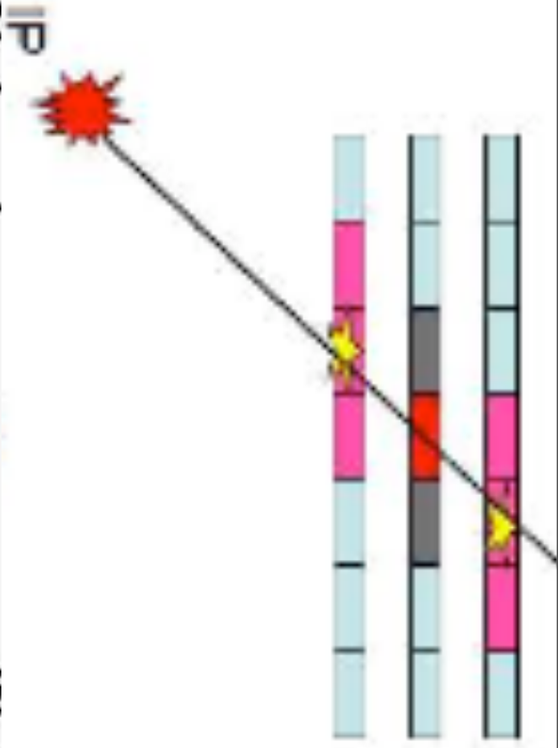
- KEK 測定器開発室
- 京都大(ニュートリノ)と一緒に開発
- 名古屋大（Belle-II チェレンコフ）
- 製造：浜松ホトニクス社
- PET ....

reserves

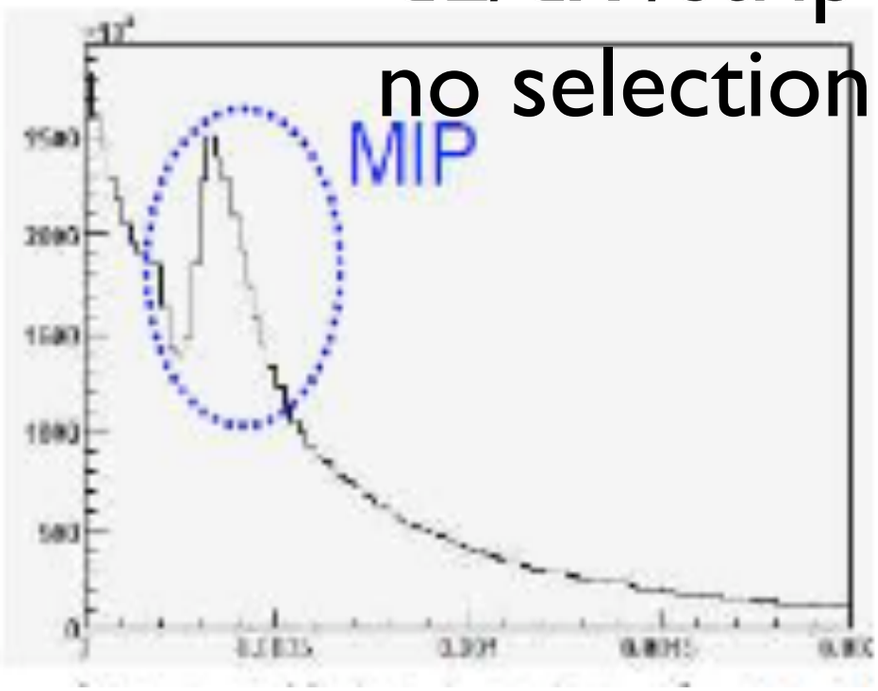
calibration(1)

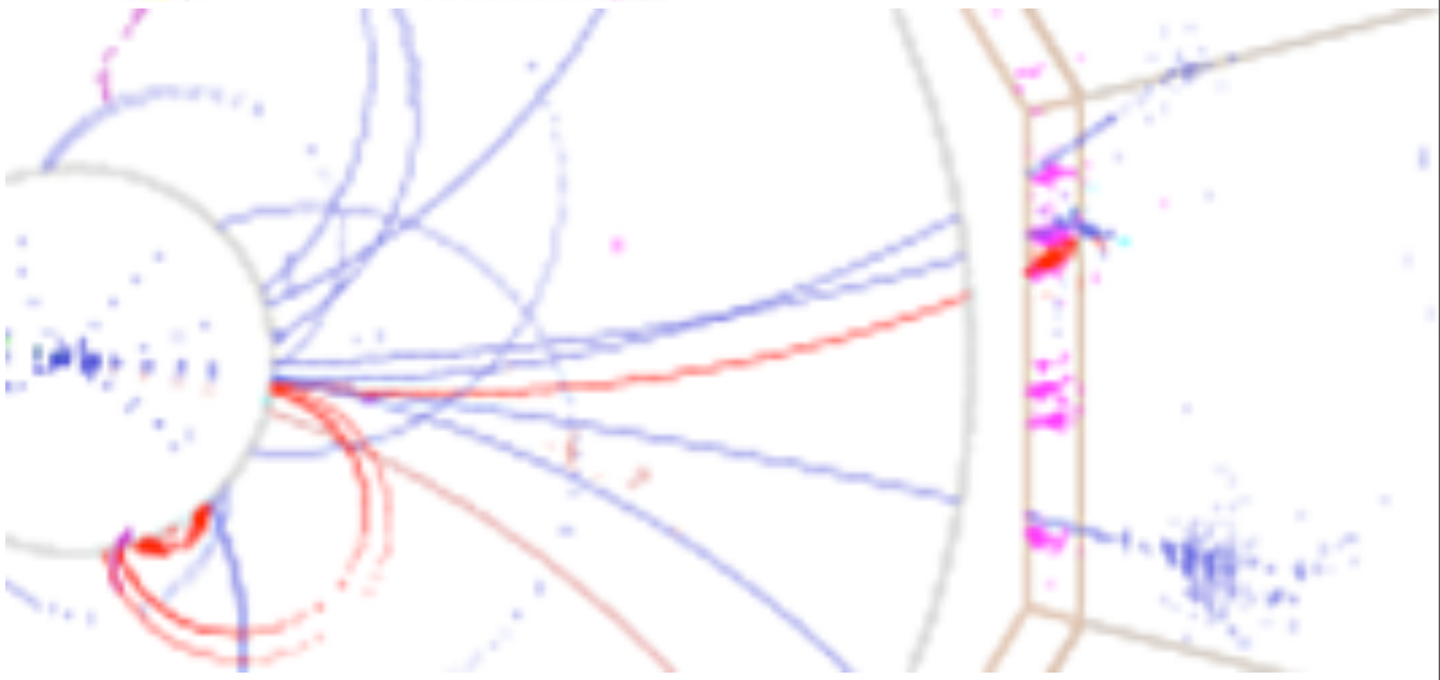
- in situ calibration
- other than CRs
- by hadronic MIP
- tracks in jets





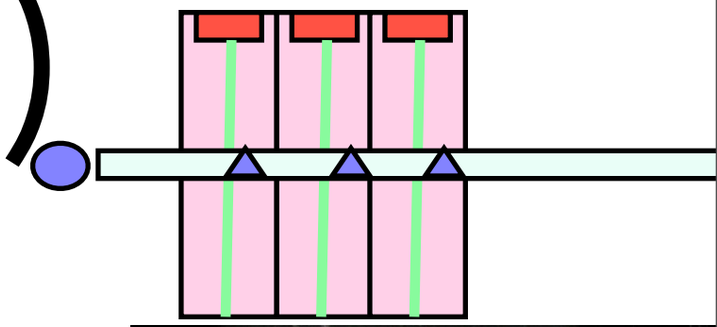
dE/dx /strip
no selection



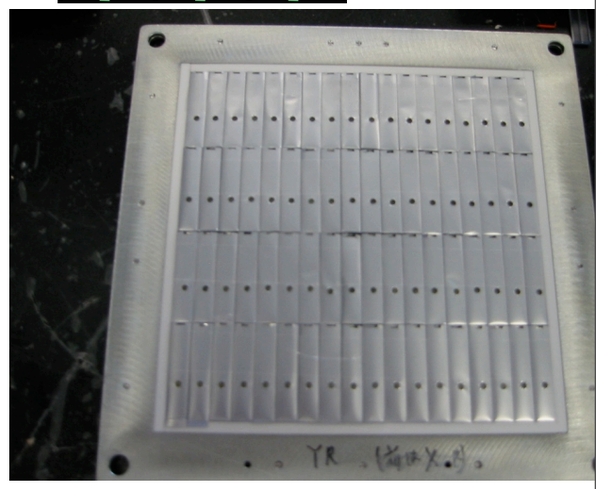


calibration(2)

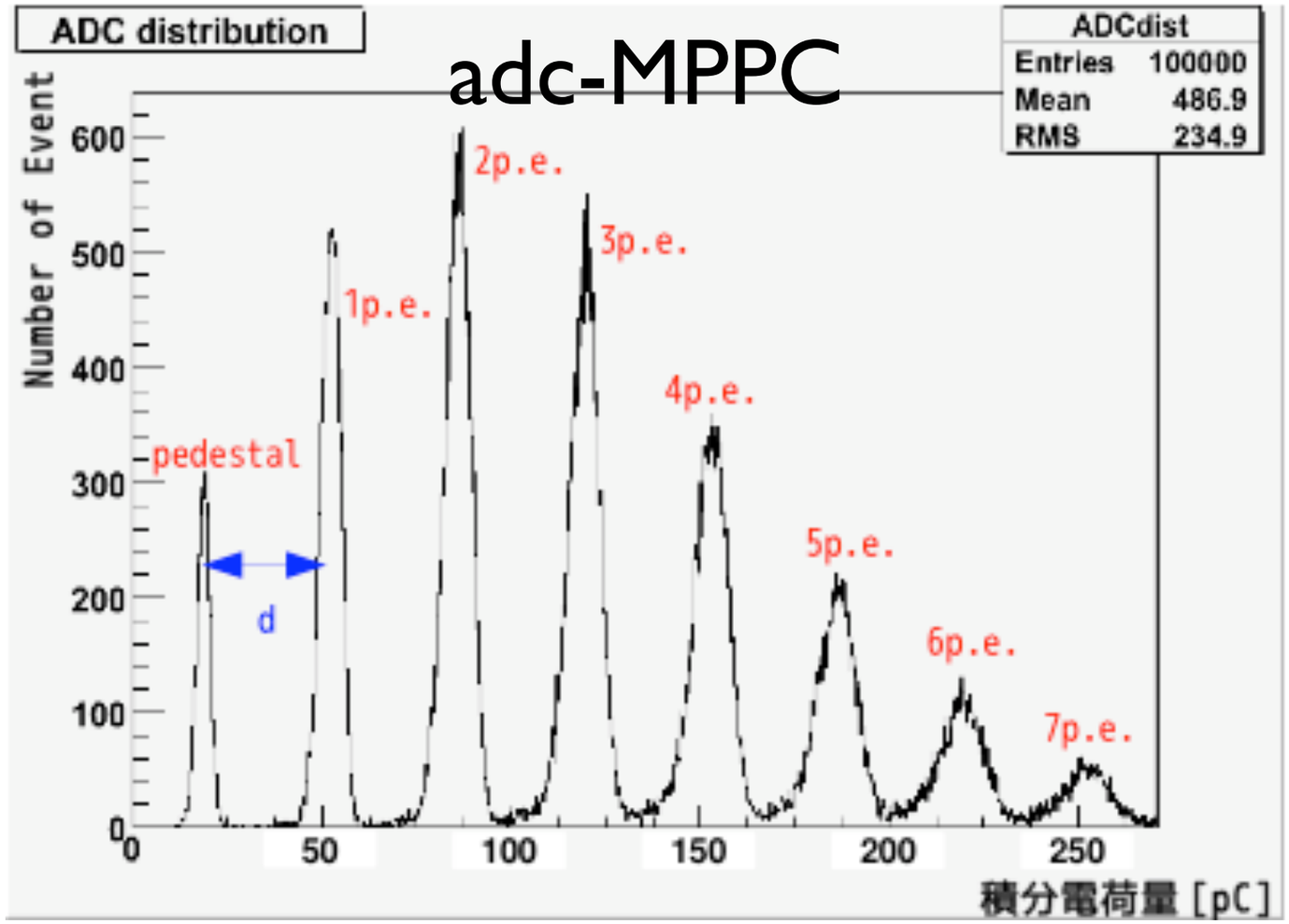
- scintillator monitoring

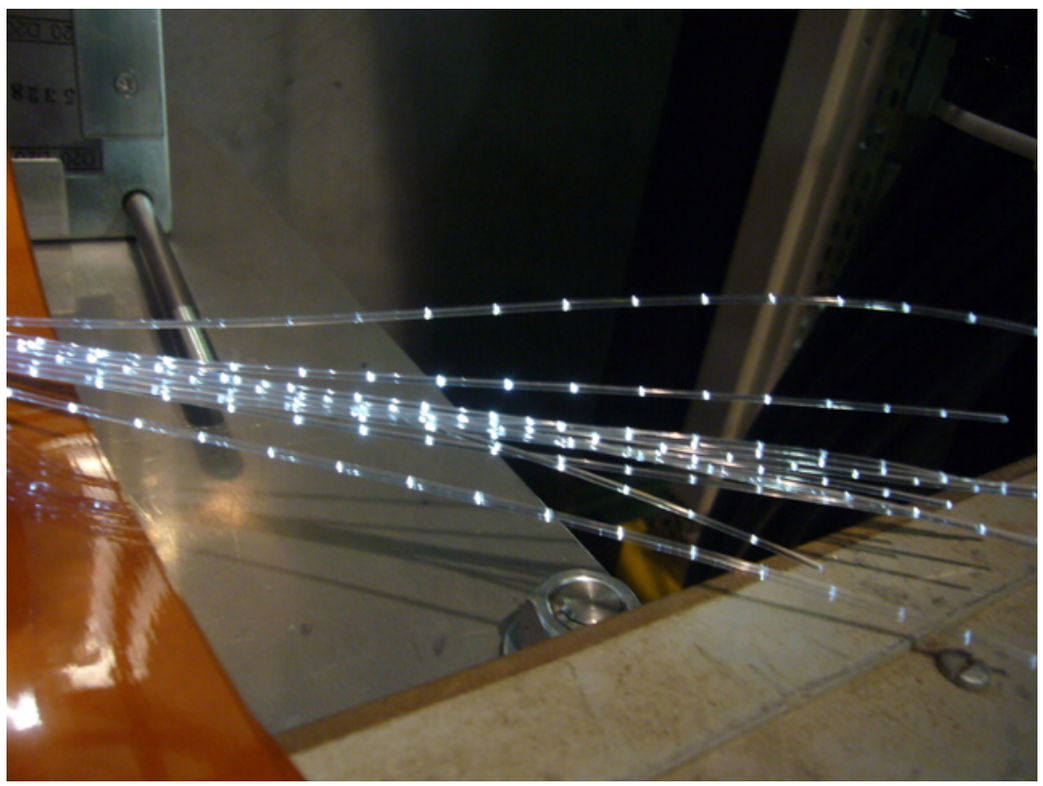


- auto-calibration of MPPC gain at p.e.
- monitoring system of whole system
- LED lights distribution through clear fiber
- with notches



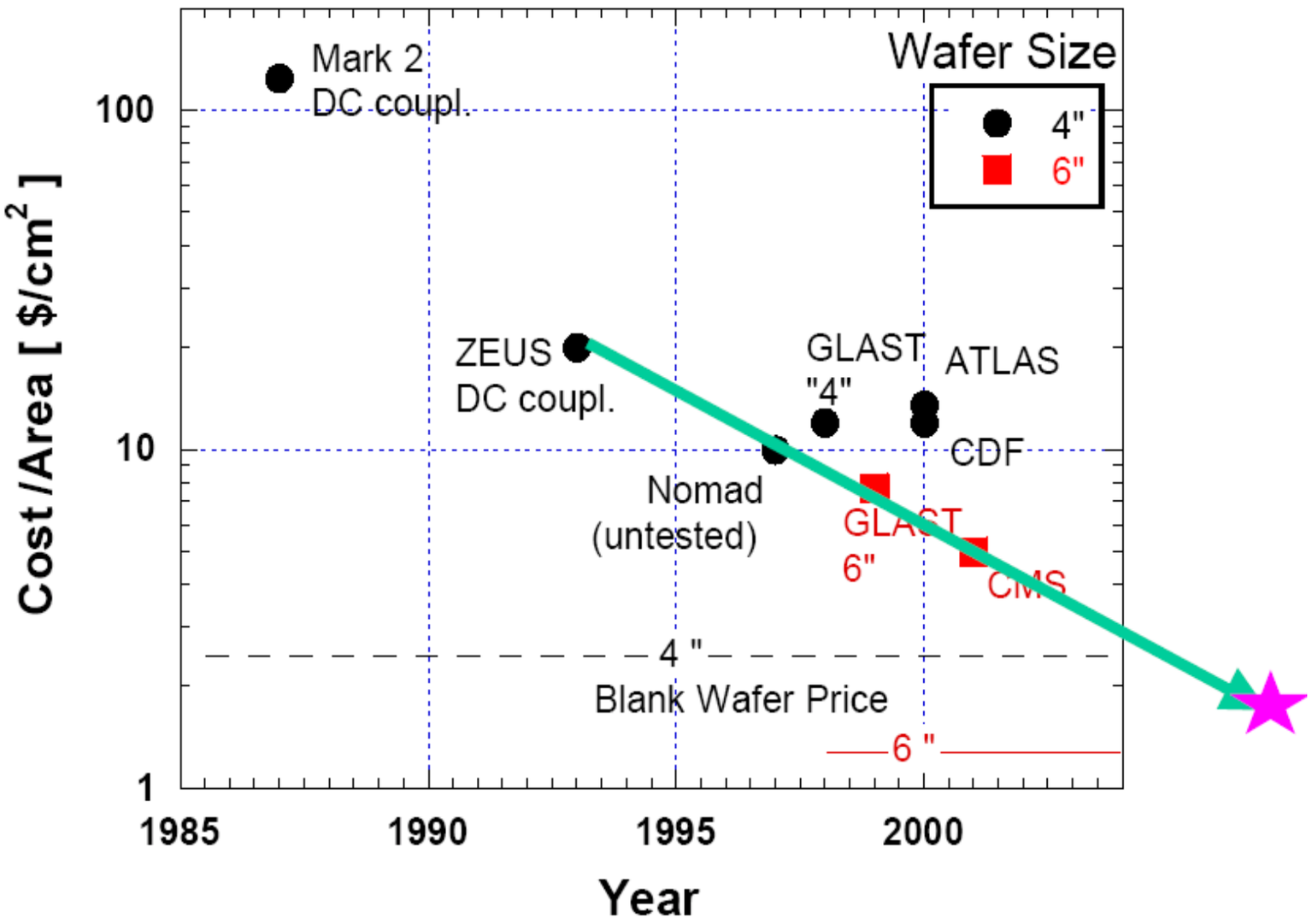
adc-MPPC



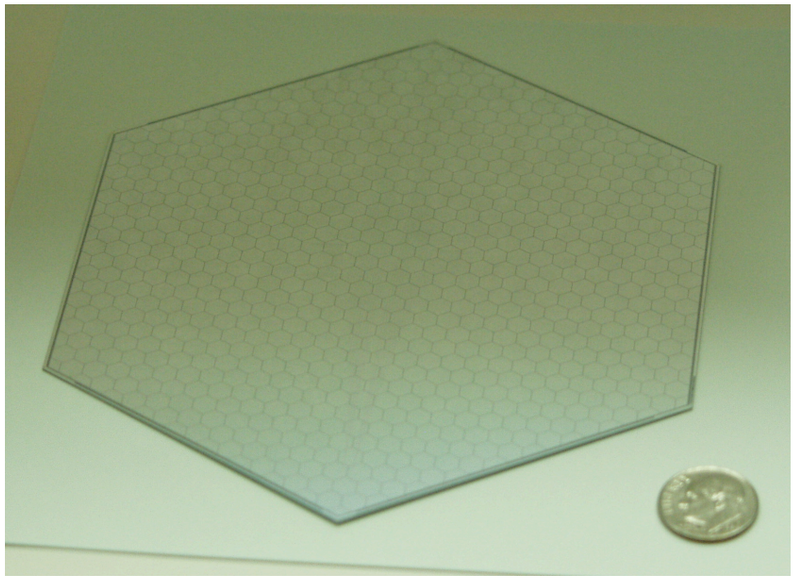


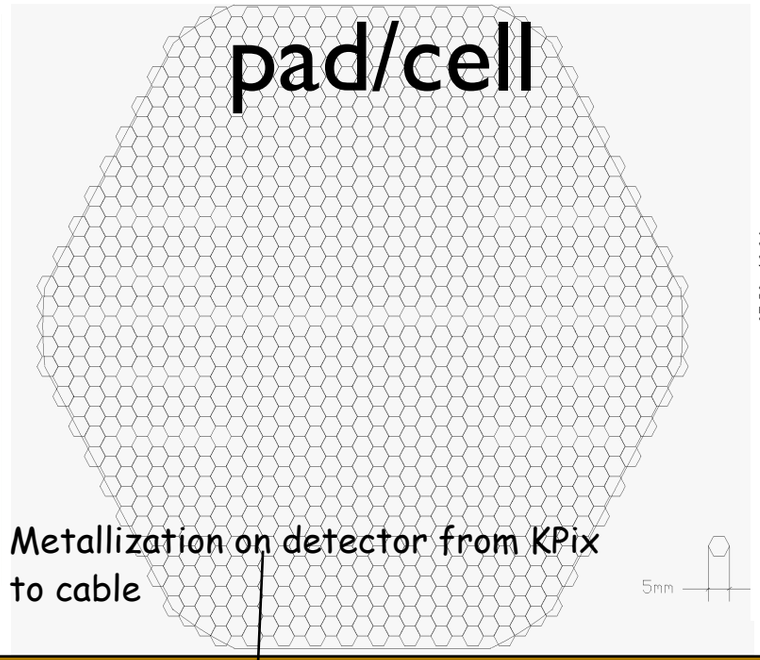
current problems

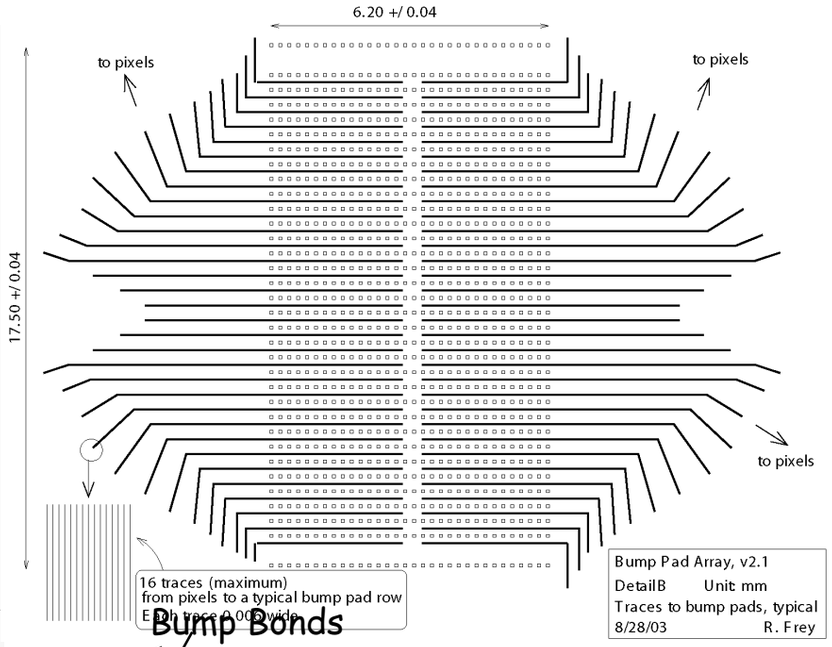
- silicon : cost issue
- scintillator : saturation of MPPC



ECAL in US-SiD



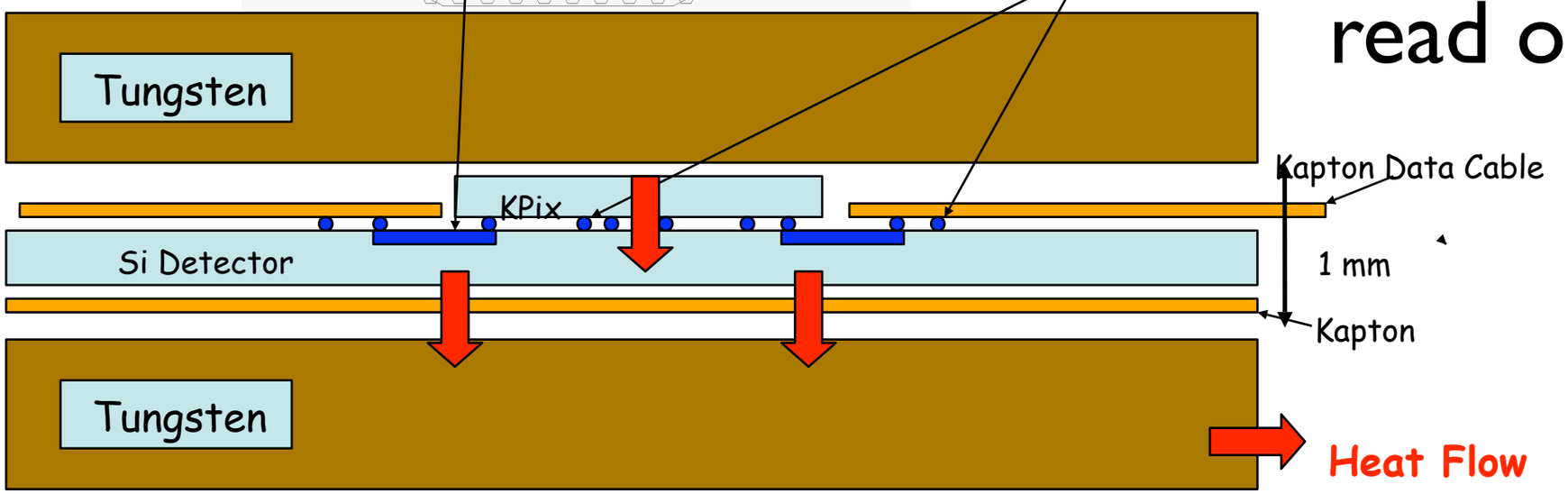




Silicon

read out

bump bond

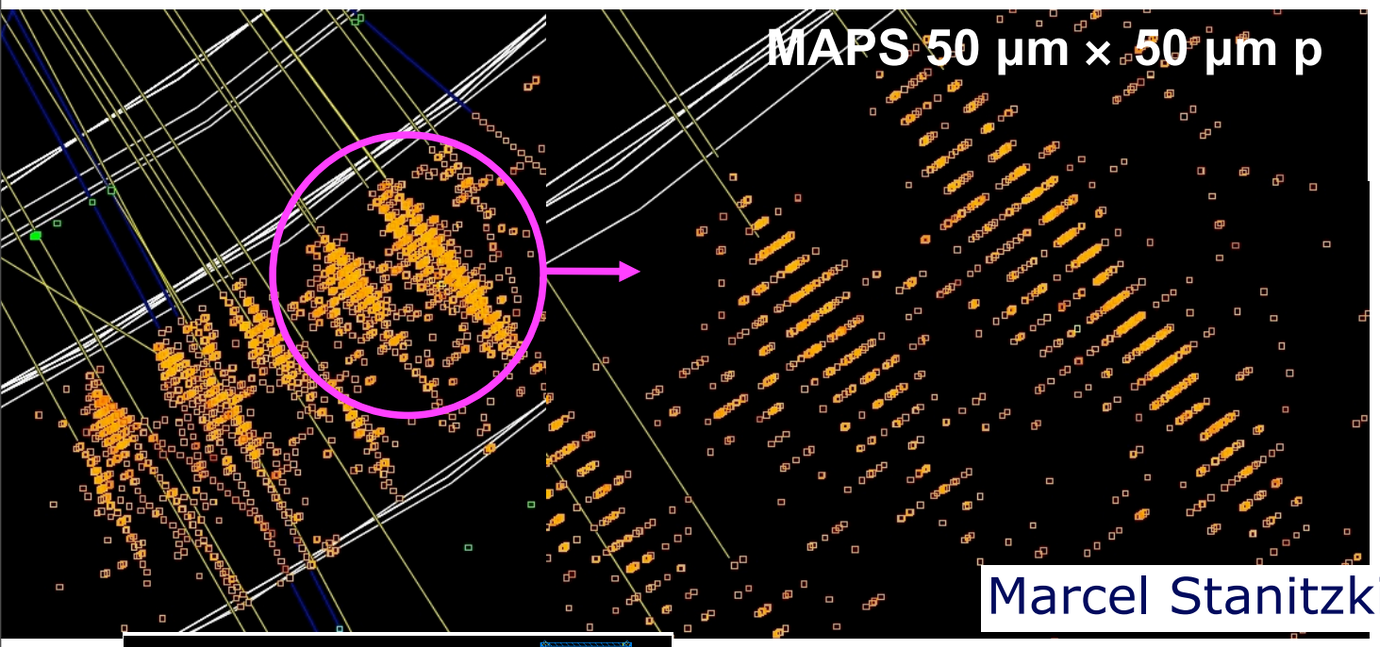


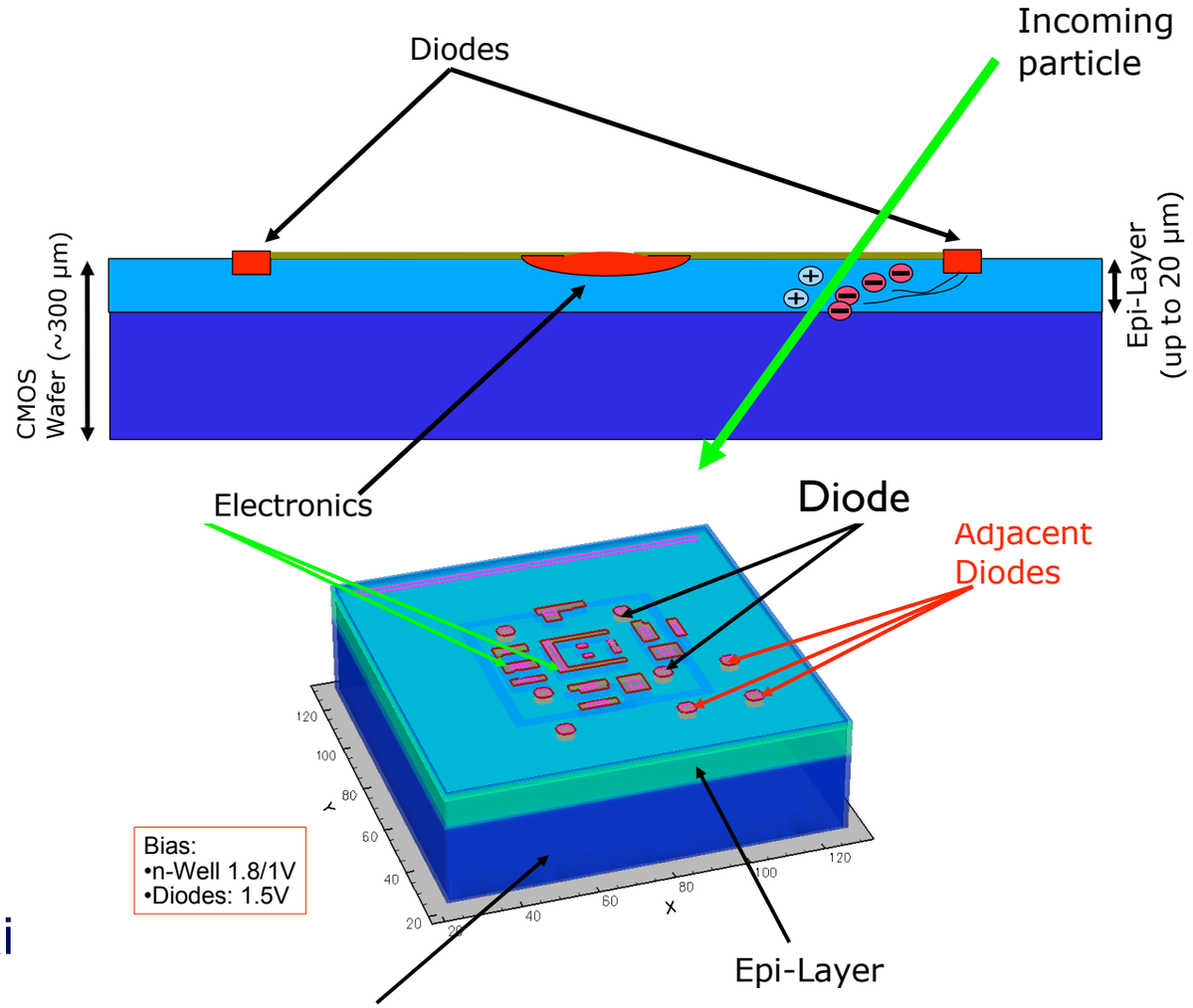
M Breidenbach

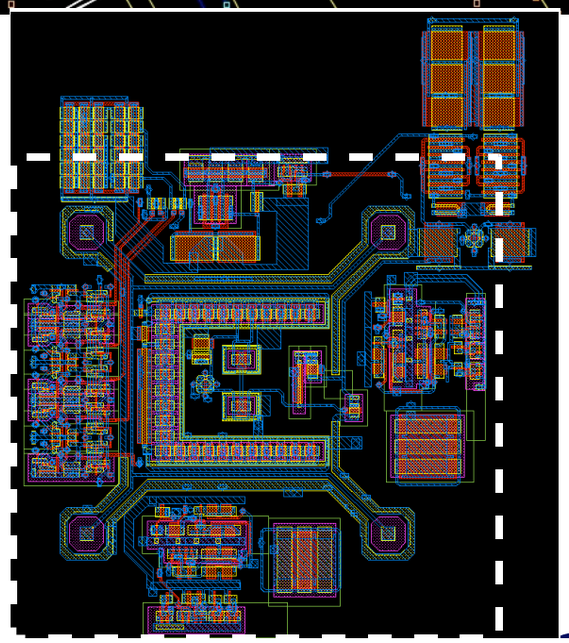
read out electronics Kpix problem

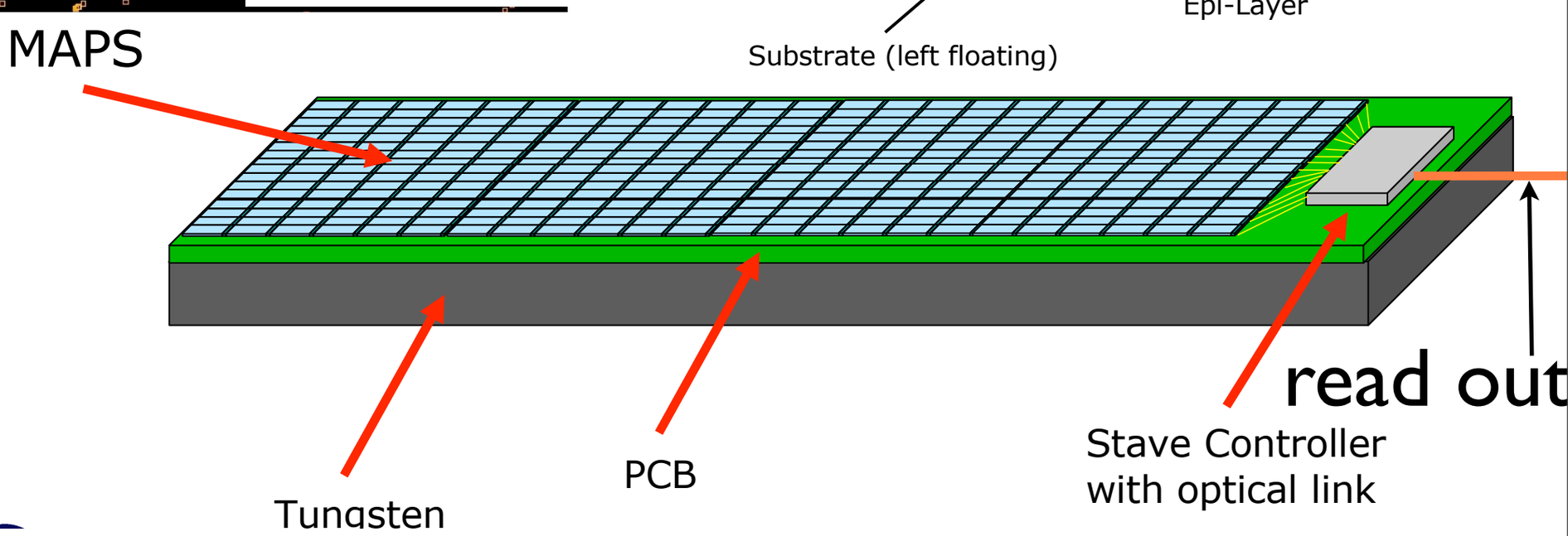
ECAL digital MAPS

Monolithic Active Pixel Sensor
Integrated Sensor and Readout
50μm^2 pixel with digital readout





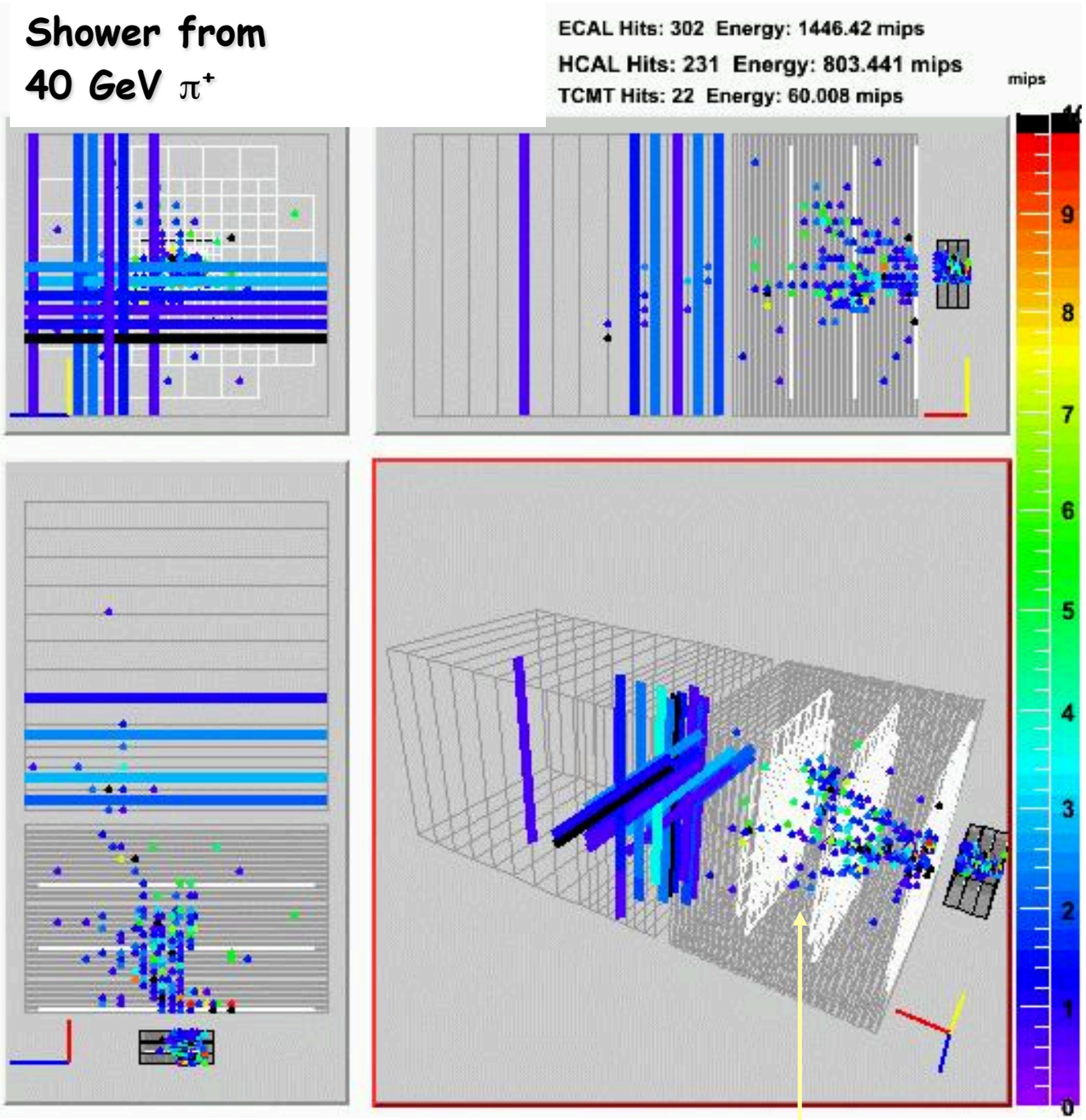




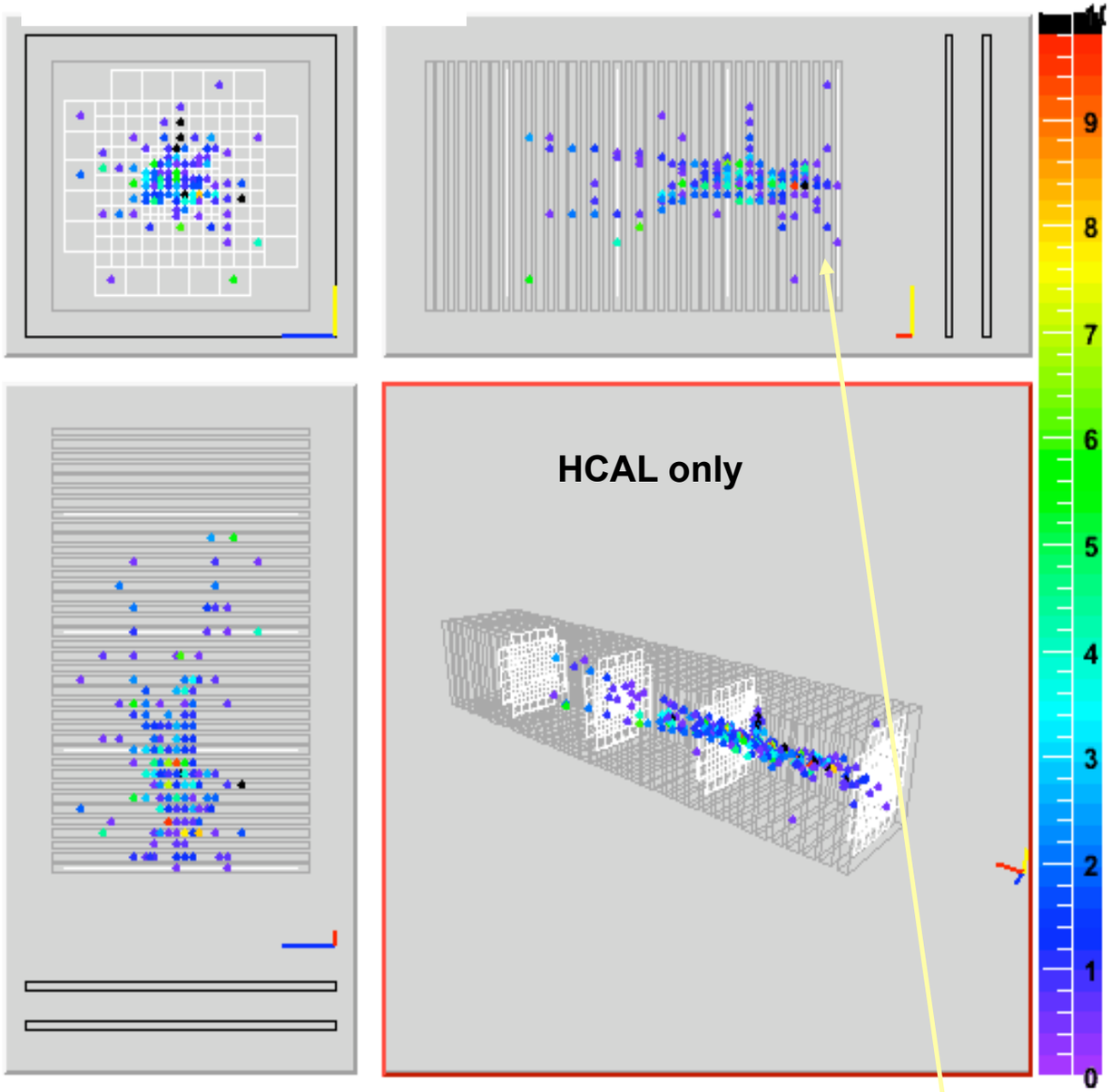
Event display

CALICE combined BT

Shower from
40 GeV π^+



20 GeV π^+



Clear structure visible in hadronic shower

Back-scattered particle