

# Scintillation ECAL R&D Status

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# Scintillator ECAL: Institutes



- Strip unit
- MPPC
- EBU



- Strip unit
- EBU



**University of Tsukuba**

- MPPC
- Simulation



- Hybrid



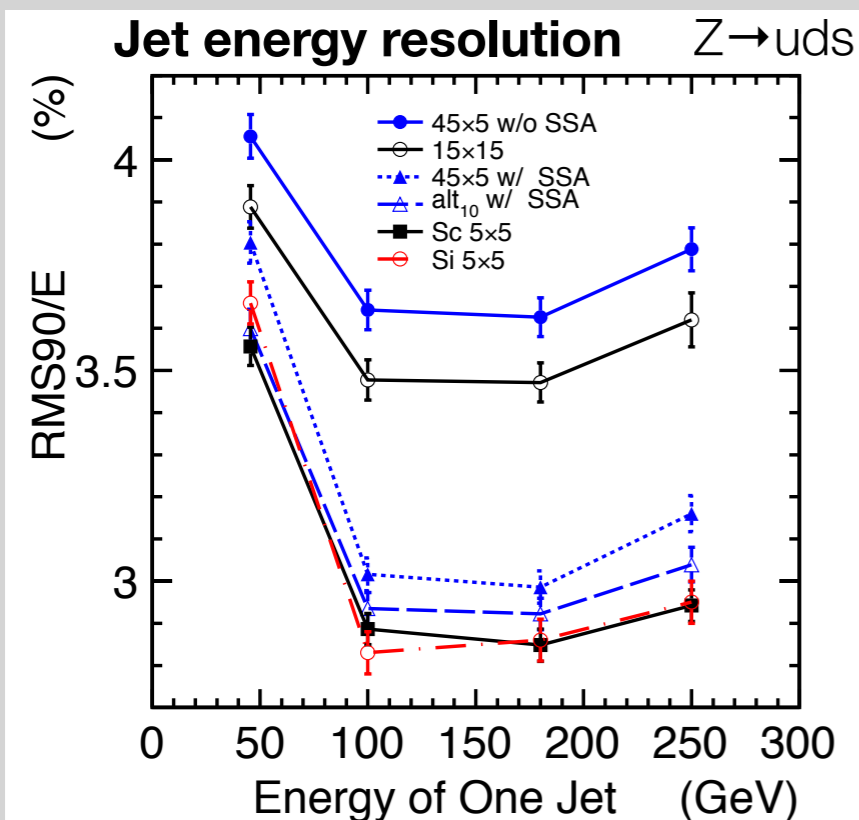
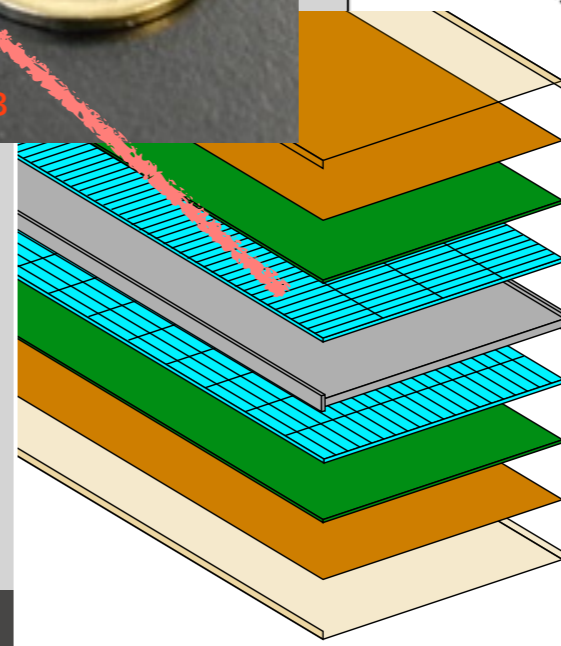
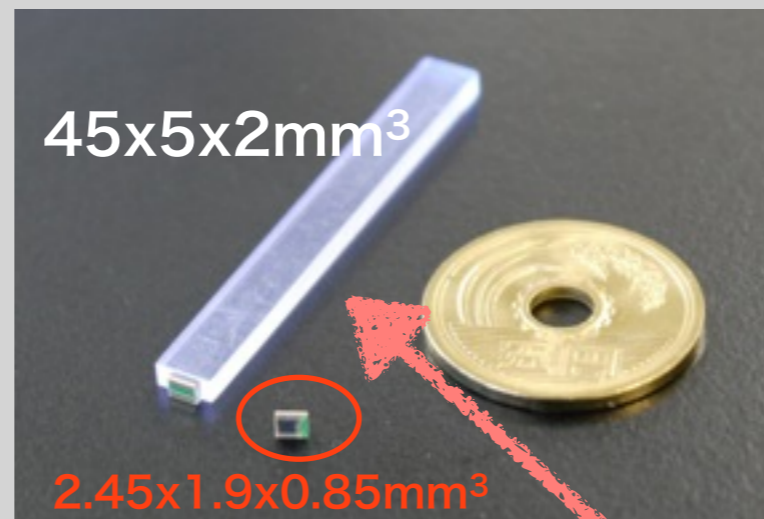
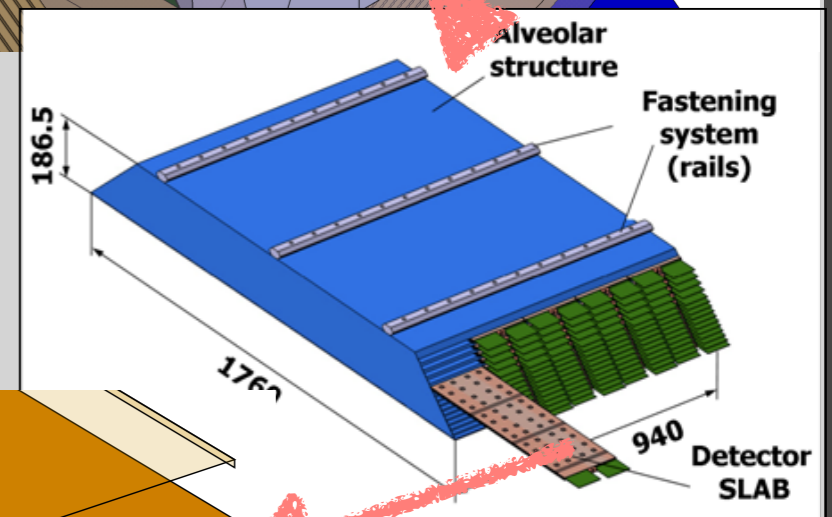
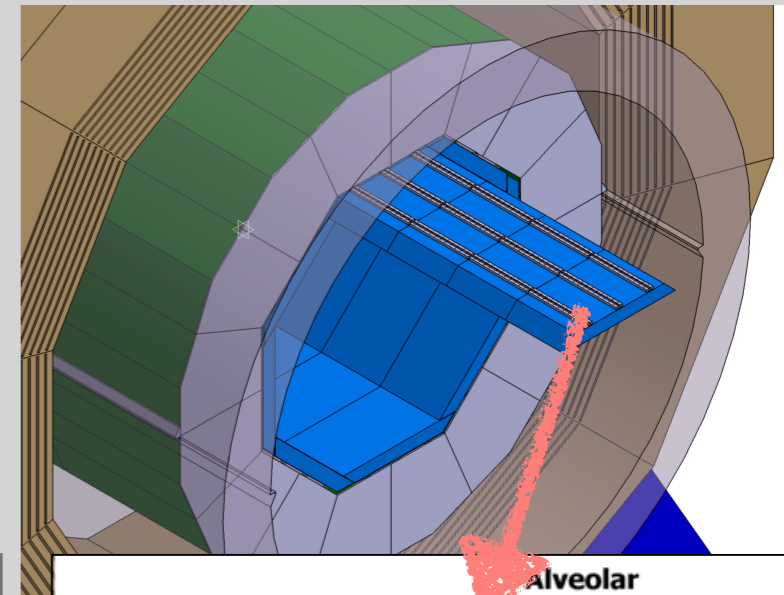
- Simulation



- Strip

# Scintillator ECAL in a Nutshell

- Based on **scintillator strips readout by SiPM (MPPC)**
- Virtual segmentation ( $\sim 5 \times 5 \text{mm}^2$ ) with strips in x-y configuration
- Reduced number of readout channels :  $10^8 \rightarrow 10^7$
- Reconstruction with **Strip Splitting Algorithm (SSA)**
- **Performance comparable to pure  $5 \times 5 \text{mm}^2$  pixel**
- Timing resolution < **1ns**
- **Low cost**



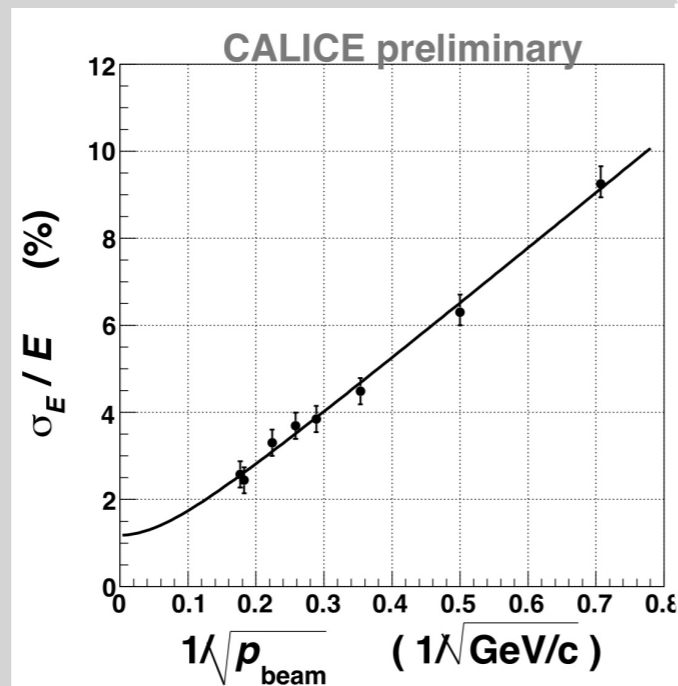
# ScECAL R&D: Brief History

## • Physics Prototype

- Scintillator strip (45×10×3mm) readout by WLS fibre+MPPC
- Demonstrated good performance (energy resolution and linearity) using 2-32GeV electron at Fermilab

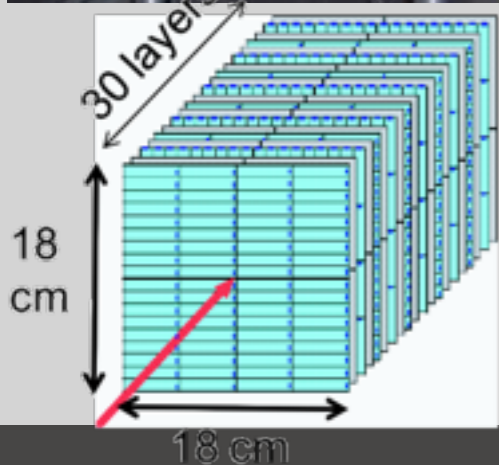


2-32GeV electron @ Fermilab



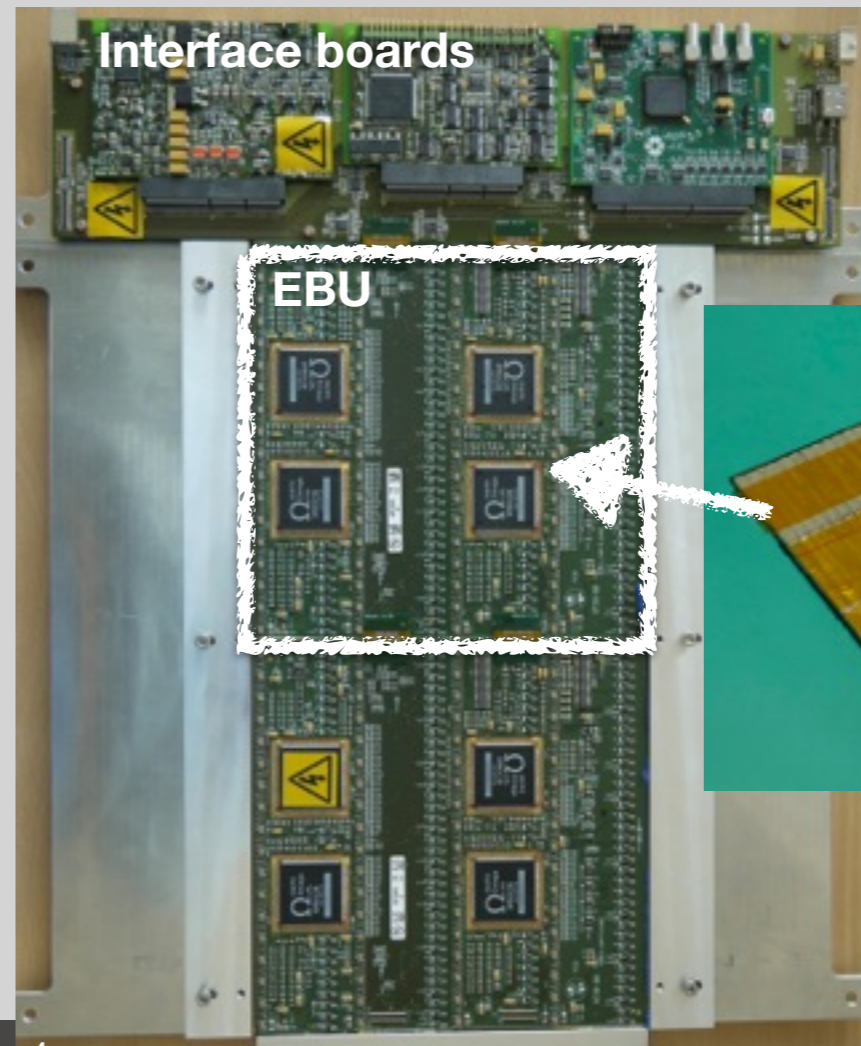
$$\frac{\sigma}{E} = \frac{(12.9 \pm 0.1 \pm 0.4)}{\sqrt{E}} \oplus (1.2 \pm 0.1^{+0.4}_{-1.2})\%$$

Non-linearity < ±2%

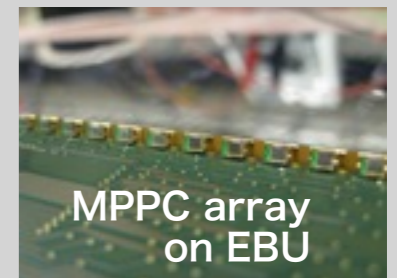


## • Technological Prototype

- Scintillator strip (45×5×2mm) readout by MPPC
- Strips are assembled on PCB with integrated readout electronics ("EBU")



Interface boards



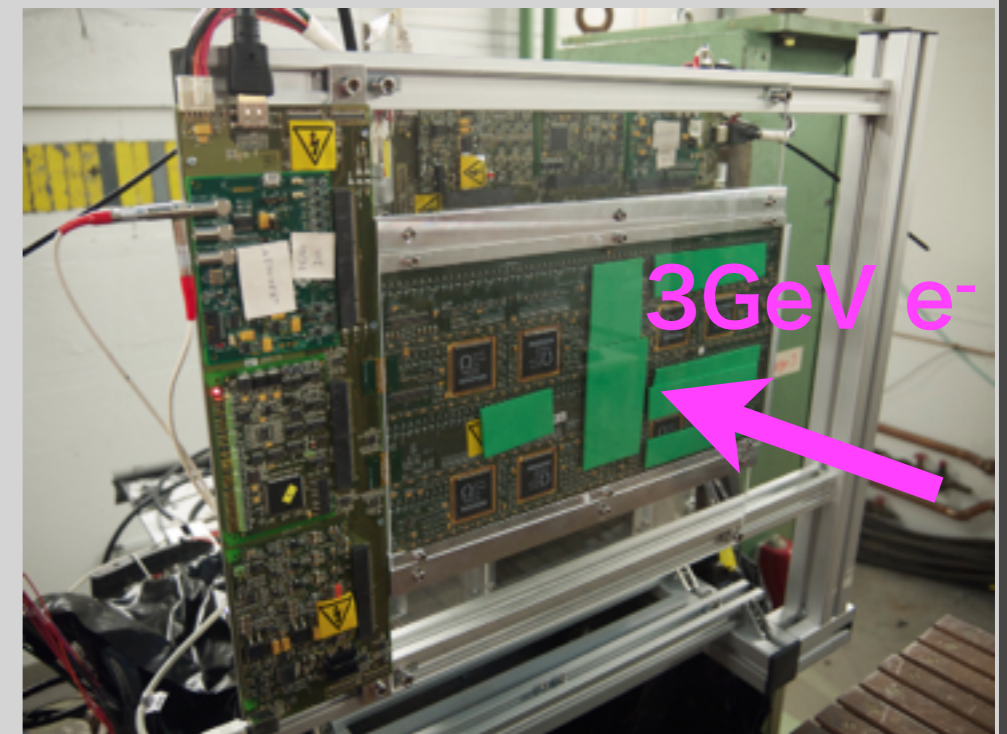
MPPC array on EBU



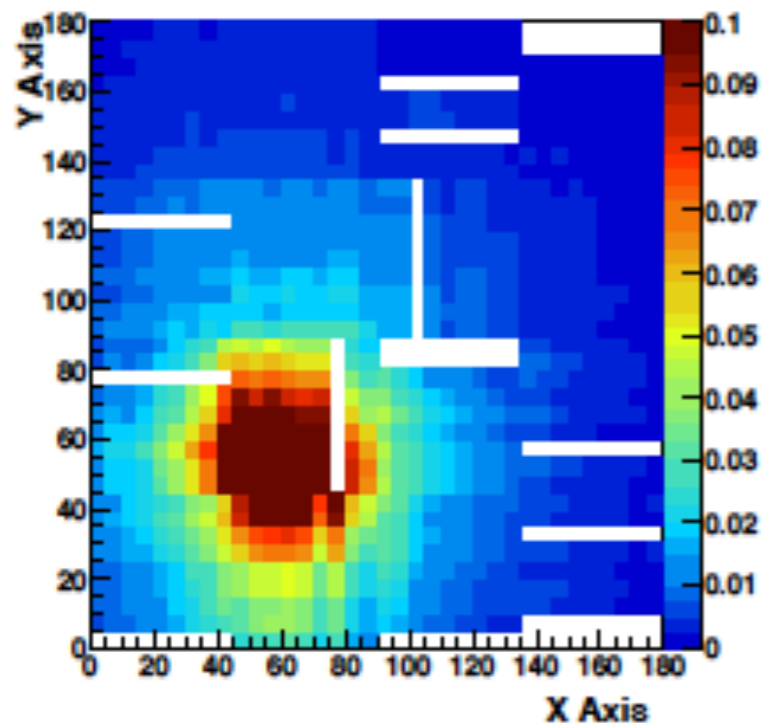
Strip assembly (144 strips) for EBU

# Test Beam at DESY in 2012/2013

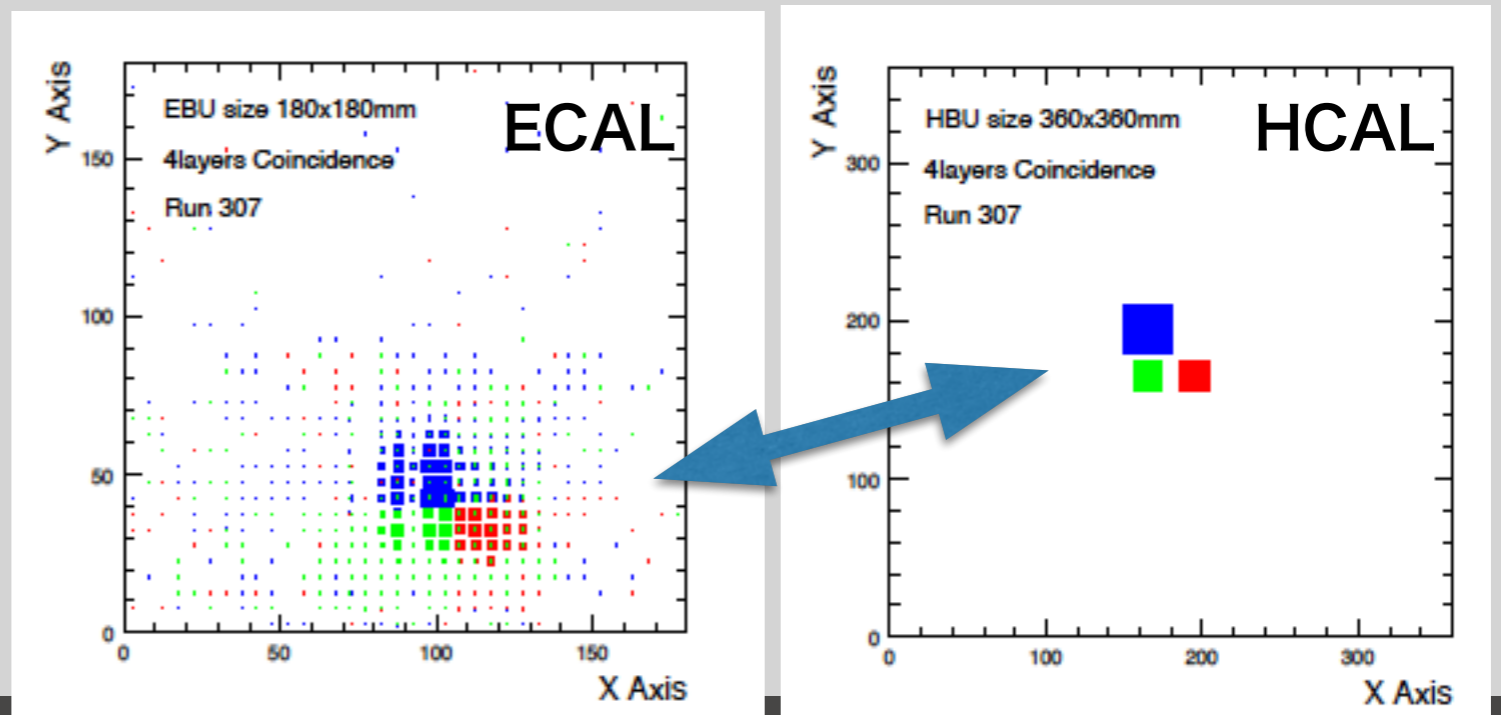
- Technological prototype tested at DESY test beam
- Two EBU layers in x-y configuration
  - 144 strips/EBU readout by 4 ASICs (SPIROC2b)
  - Bias control for individual channels
  - TDC
  - Power-pulsing capability (not yet demonstrated)



Pseudo-shower generated in W-absorber

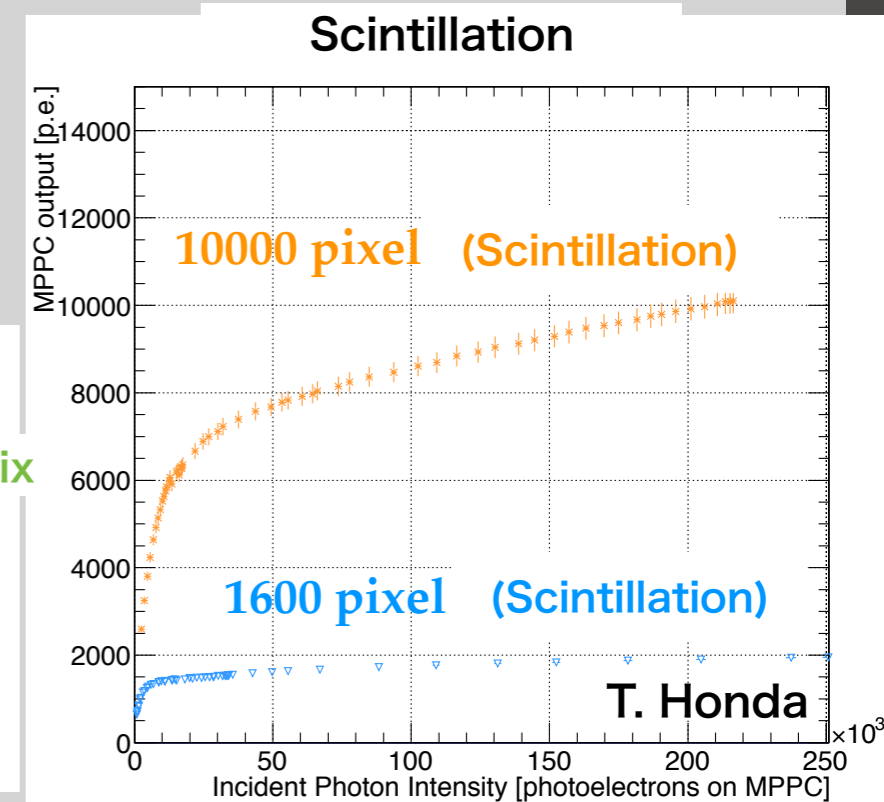
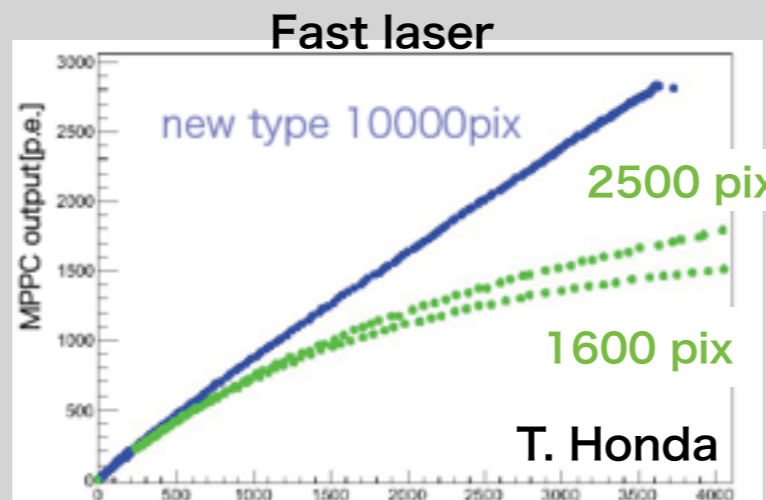


Combined measurement with ECAL and AHCAL



# Photosensor

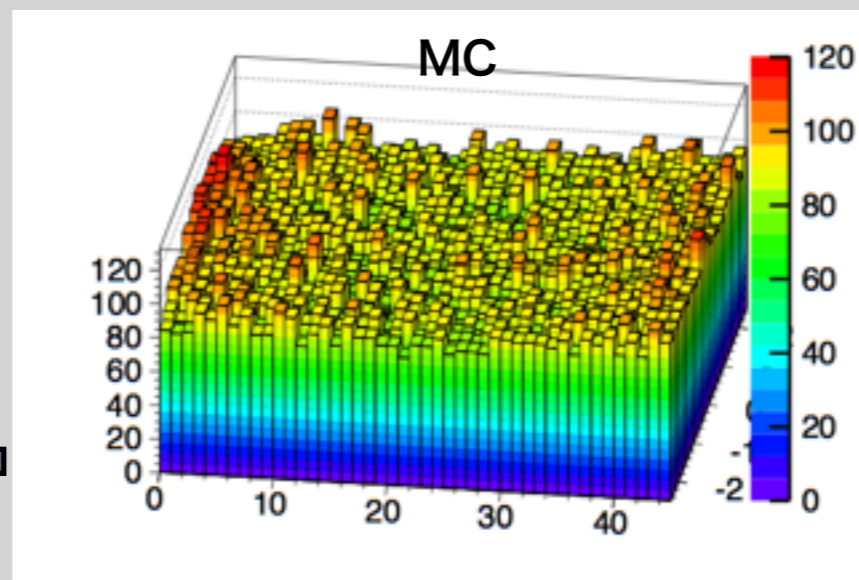
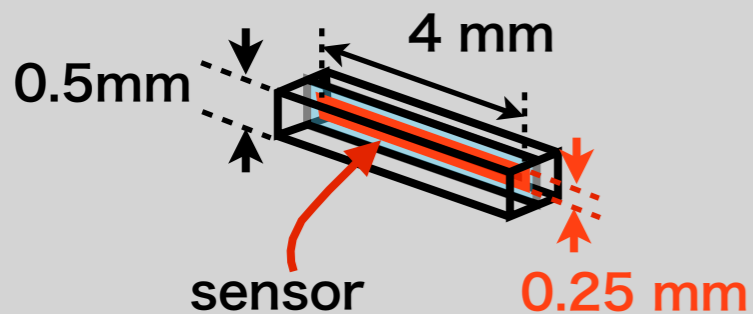
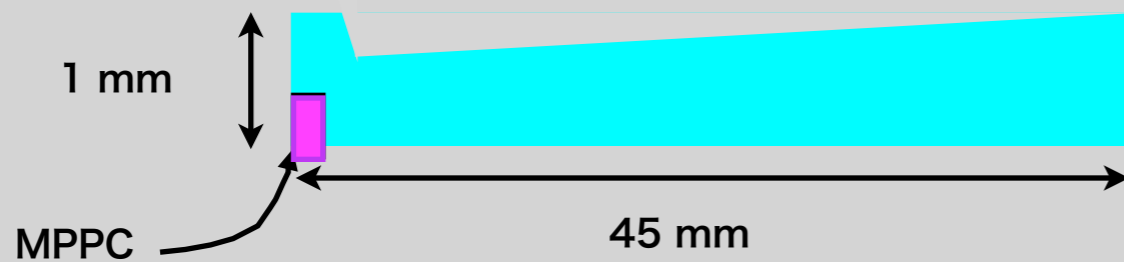
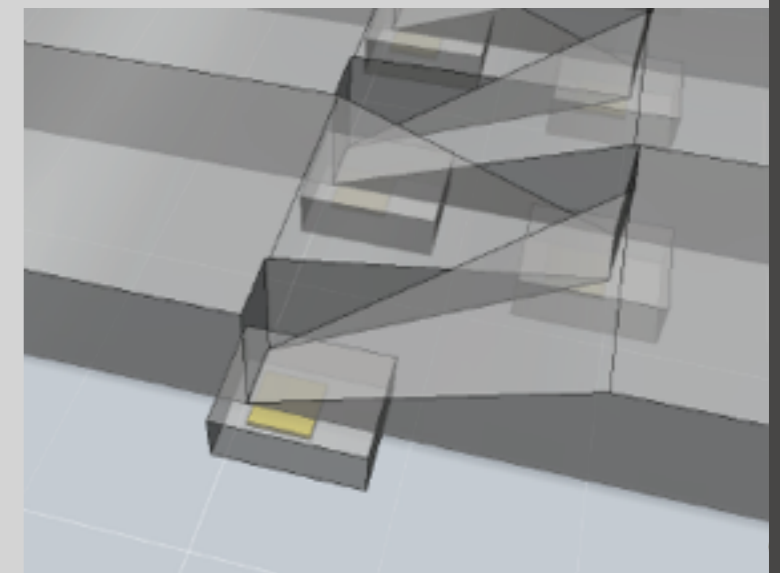
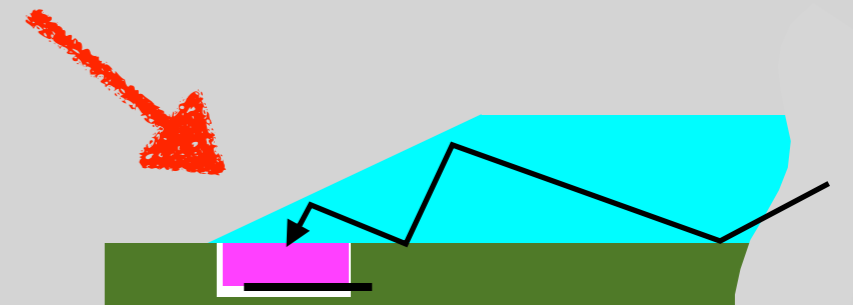
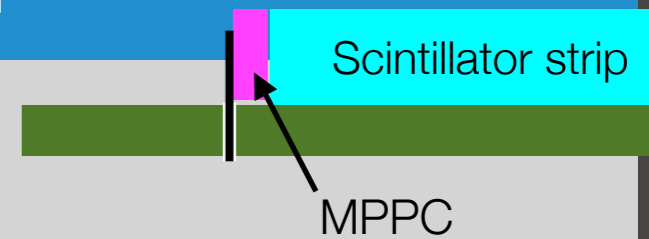
- Requirements for ScECAL photosensor
  - Compact
  - High gain/PDE
  - Low dark count rate
  - Wide dynamic range to cover up to Bhabha event ( $\approx 30k$  p.e.)
  - Low cost
- Current best candidate: **Hamamatsu MPPC** (active area:  $1 \times 1 \text{ mm}^2$ )
- Recent progress for Hamamatsu MPPC
  - Lower dark count rate  $< 100 \text{ kHz/mm}^2$
  - Lower after-pulse rate
  - Improved active area coverage by using metal quench resistor
  - Lower cross-talk rate (not yet applied to 10k-pix MPPC)
- **10k-pix MPPC is now being tested.**
  - Showed much wider dynamic range
  - Drawback: lower gain/PDE



# Strip-MPPPC Unit Design

- Further optimisation of design of scintillator strip-MPPPC unit
  - Bottom-side readout at wedge-shaped strip end
  - Yet another design

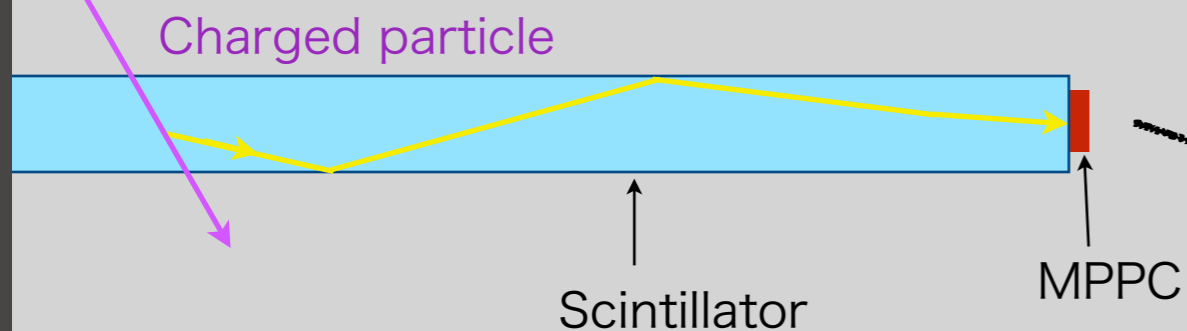
Baseline design



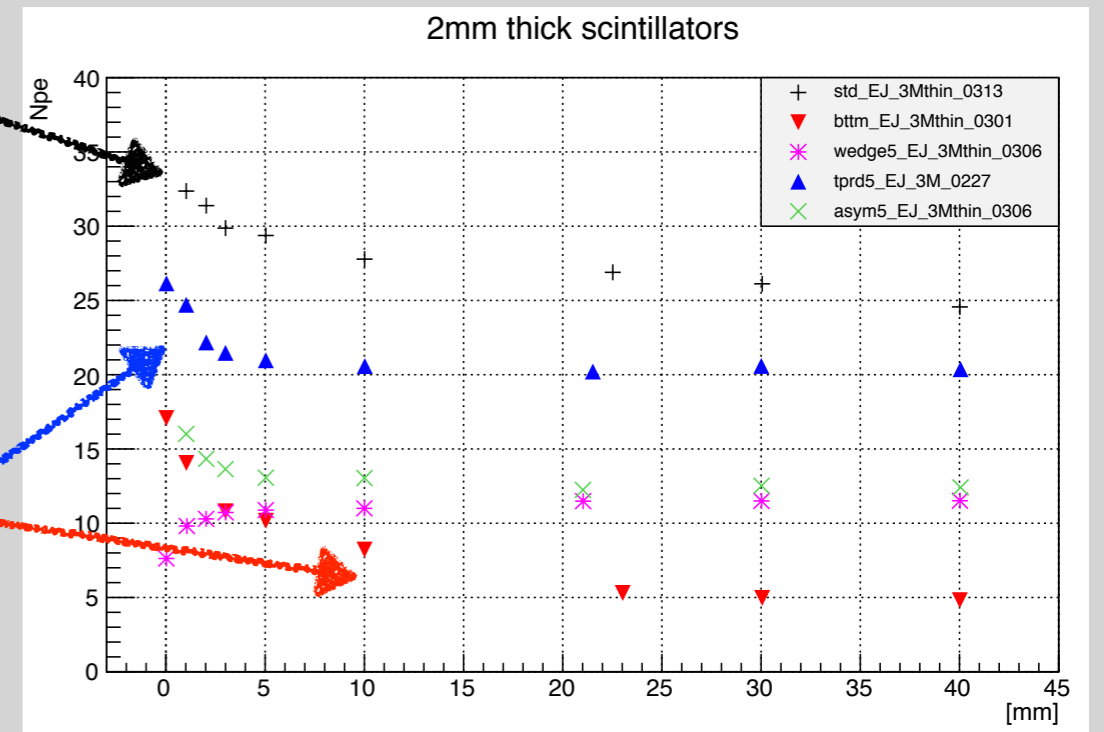
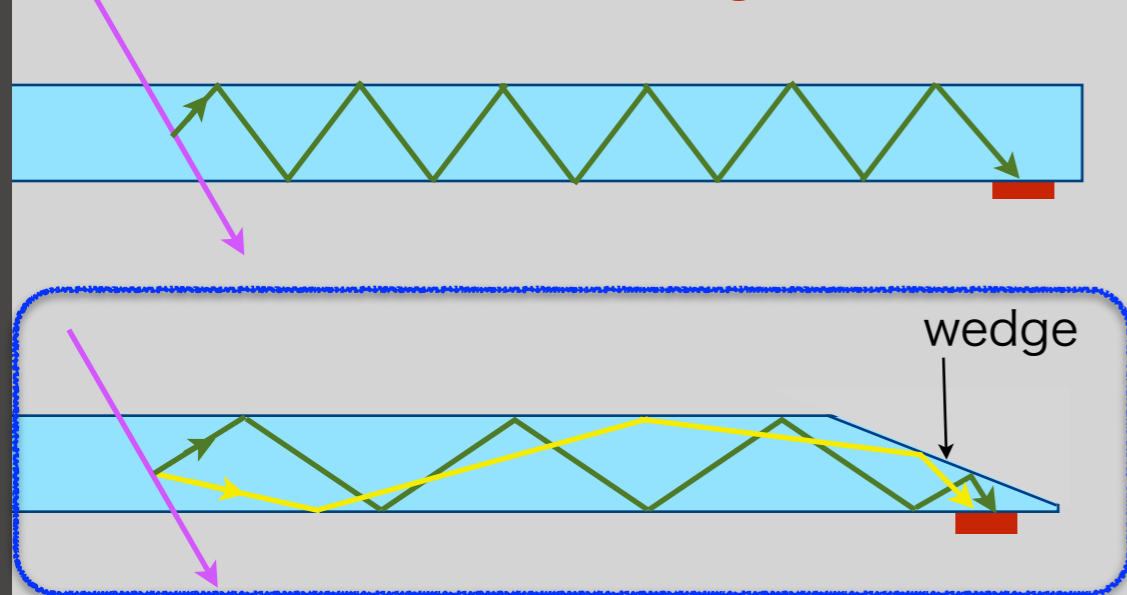
# Bottom-side MPPC Readout

- **Bottom-side readout with wedge-shaped strip end**
  - No dead area due to MPPC package
  - Reasonably high light yield
  - Good uniformity
  - Readout by surface-mount MPPC embedded in PCB

## Baseline design



## Bottom side readout design



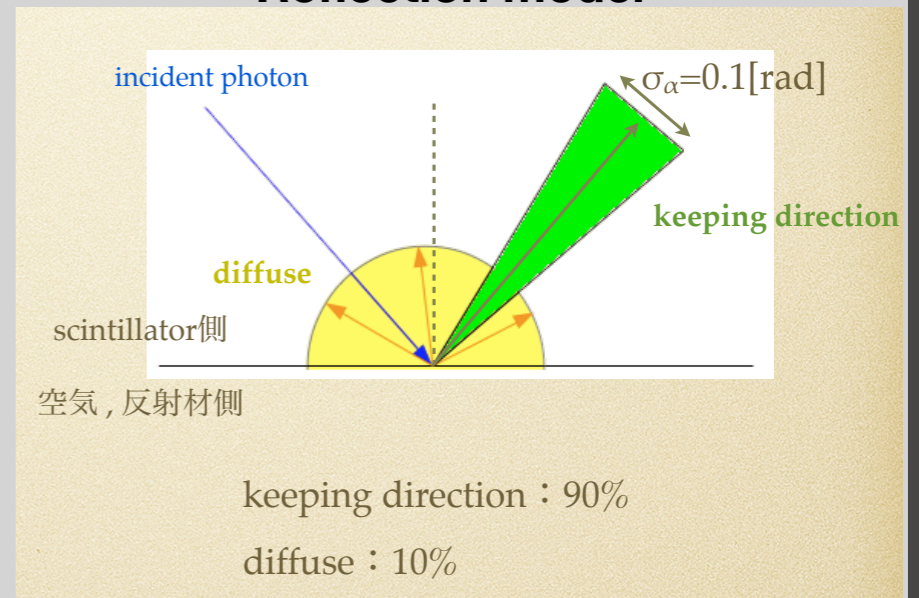
S. Ieki



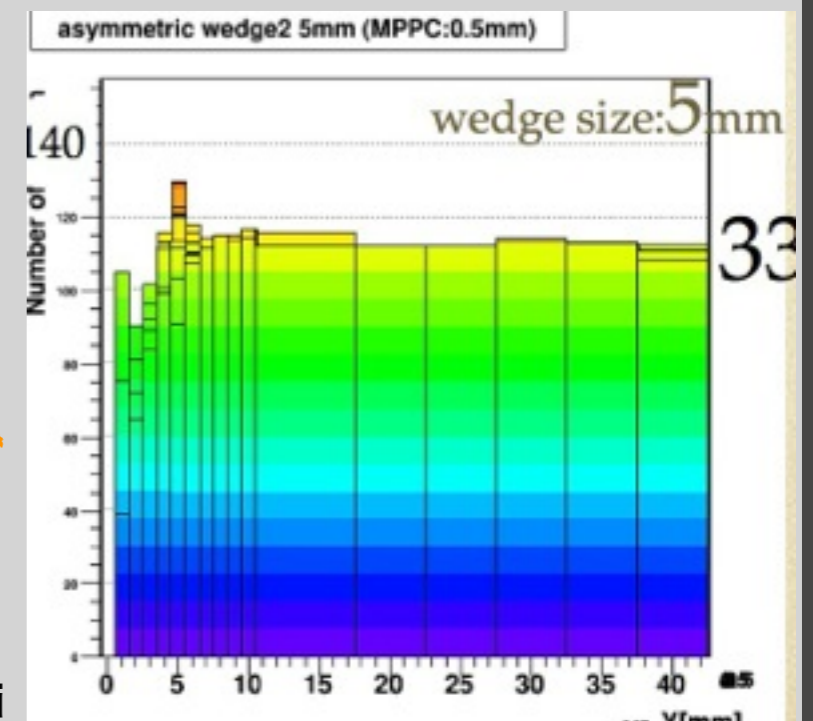
# Scintillation Photon Simulation

- A Geant4-based simulation tool for scintillation photon tracking in strip unit is under development for optimisation study.
- Parameters to be tuned
  - Light yield
  - Attenuation length
  - Reflection model at surface
  - ...
- Optimal parameters roughly reproduces the measurement.

## Reflection model



## Simulation result



|  | # of p.e.(PDE:0.3)      | Uniformity |
|--|-------------------------|------------|
| wedge                 | 24(MPPC position:1.0mm) | good       |
| tapered wedge         | 27(MPPC position:1.5mm) | good       |
| single_side tapered   | 25(MPPC position:1.5mm) | not good   |
| single_side tapered2  | 33(MPPC position:0.5mm) | very good  |

T. Tsuzuki

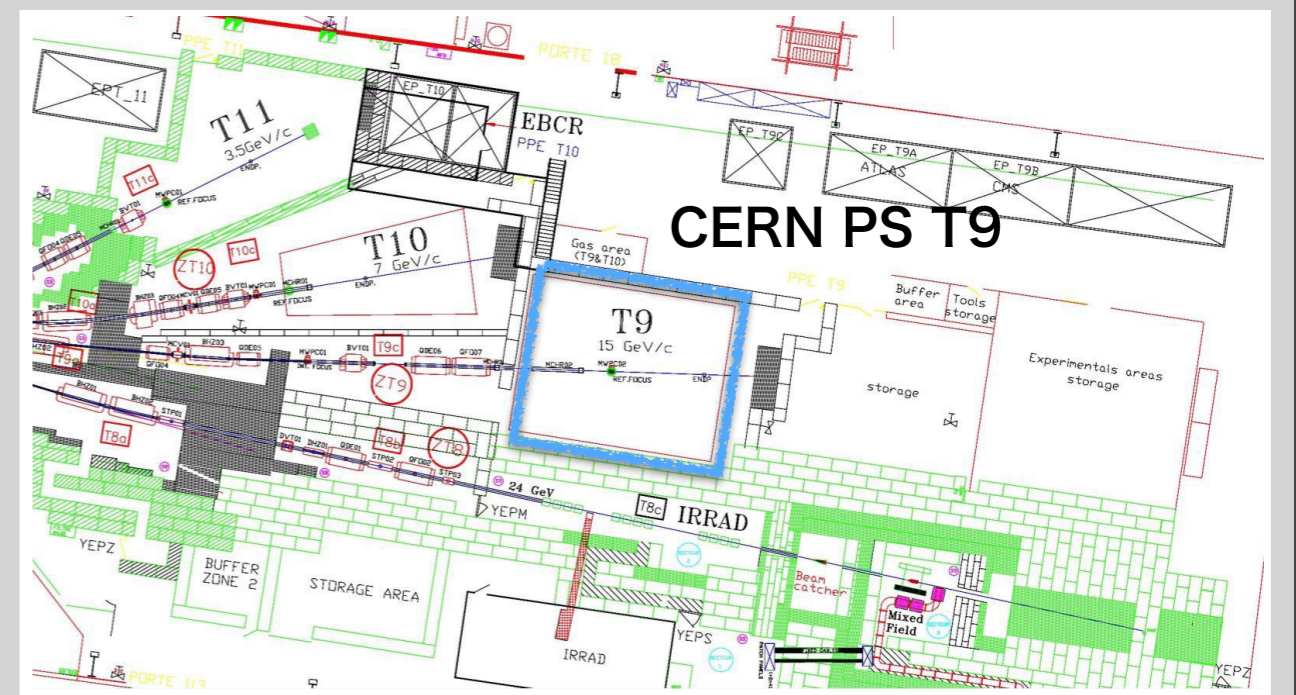
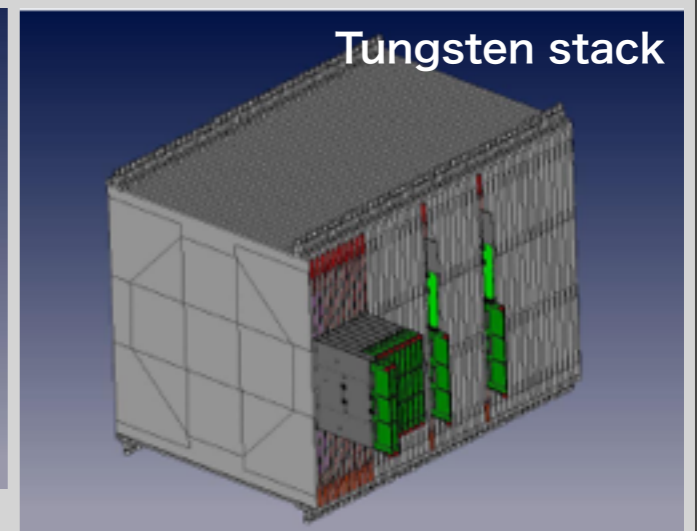
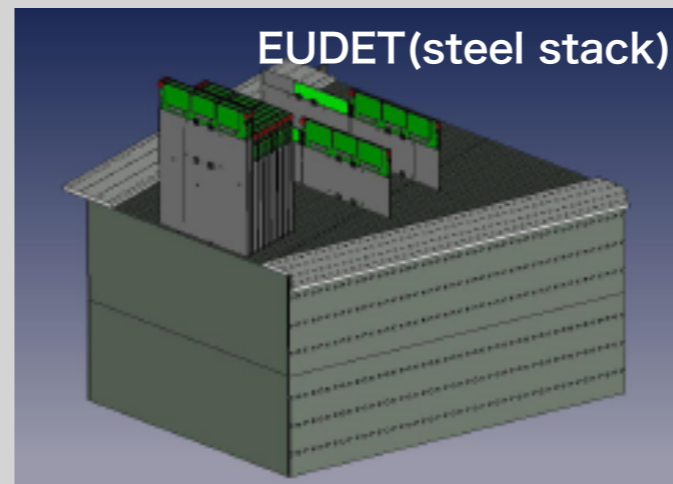
# CERN Test Beam 2014

- Joint test beam experiment of AHCAL and ScECAL at CERN PS

- 1st period: 8-22 Oct. 2014
  - EUDET steel stack
- 2nd period: 26 Nov. - 8 Dec. 2014
  - Tungsten stack

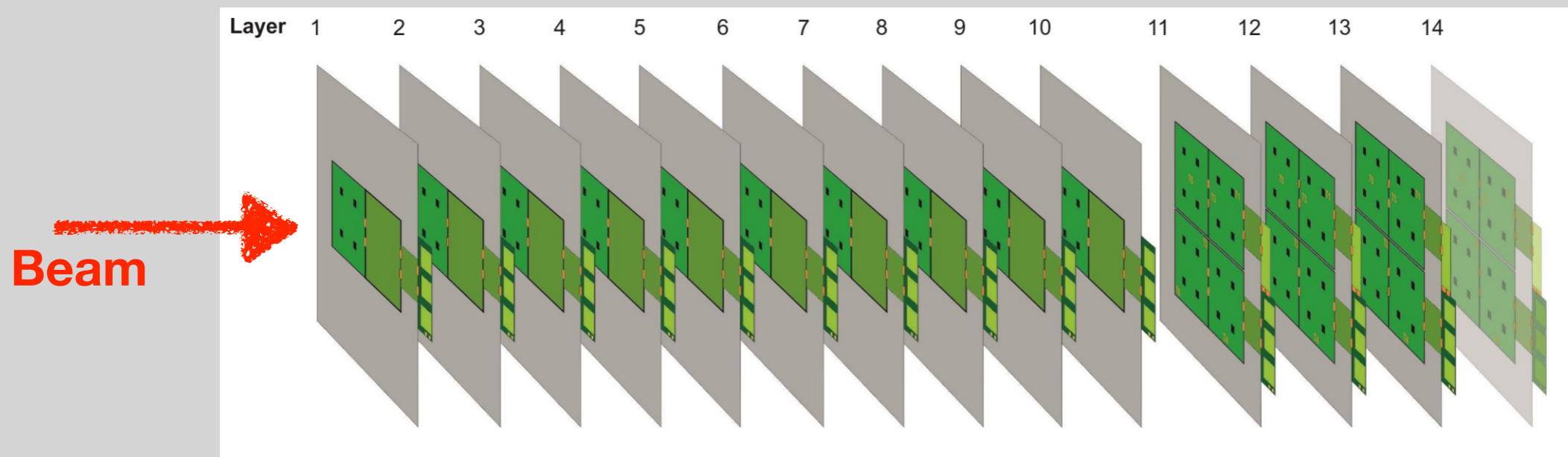
- Purpose from ScECAL viewpoint

- Shower start finder for AHCAL layers
- Test three EBU layers incl. two new ones.
  - 2× standard strip-MPPC unit + 1× bottom-side readout
- Test 10k pix MPPC
- Test some mass-production conscious assembly procedures



# CERN Test Beam 2014

- Configuration of EBU/HBU layers



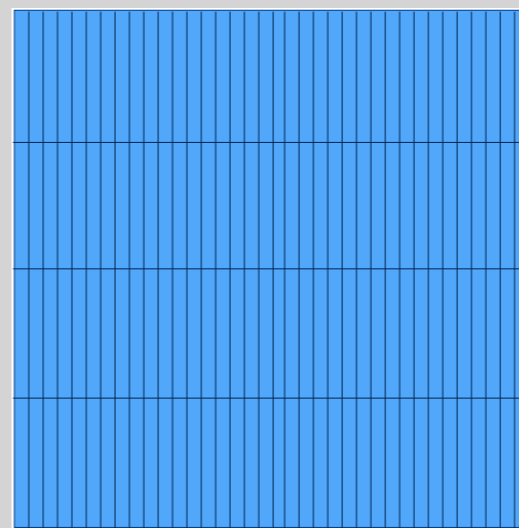
## Layers

- |                                      |                      |
|--------------------------------------|----------------------|
| 1. EBU vertical(bottom-side readout) | 8. HBU2 X            |
| 2. EBU horizontal (baseline readout) | 9. HBU2 13           |
| 3. EBU vertical (baseline readout)   | 10. HBU2 14          |
| 4. SM HBU(NIU) or HBU2 IX            | 11. 4 x HBU2 Ketek   |
| 5. HBU2 VIII                         | 12. 4 x HBU3 Ketek   |
| 6. HBU2 VII                          | 13. 4 x HBU3 SensL   |
| 7. HBU2 VI                           | 14. 4 x HBU3 (spare) |

# 2nd/3rd EBU

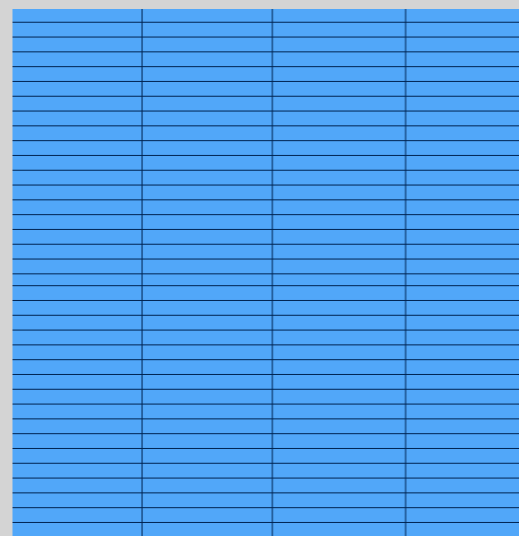
- **EBU with baseline readout method**
- MPPC
  - 2nd EBU: **1.6k-pix + 10k-pix**
  - 3rd EBU: **1.6k-pix**
    - 1.6k-pix: S10362-11-025p
    - 10k-pix: S12571-010p
- Scintillator: **Kuraray SCSN38** (2mm thick)
- Reflector: **Kimoto Ref-white**
- Light yield: **~15 p.e. (Sr-90)**

Longitudinal EBU, 2nd layer

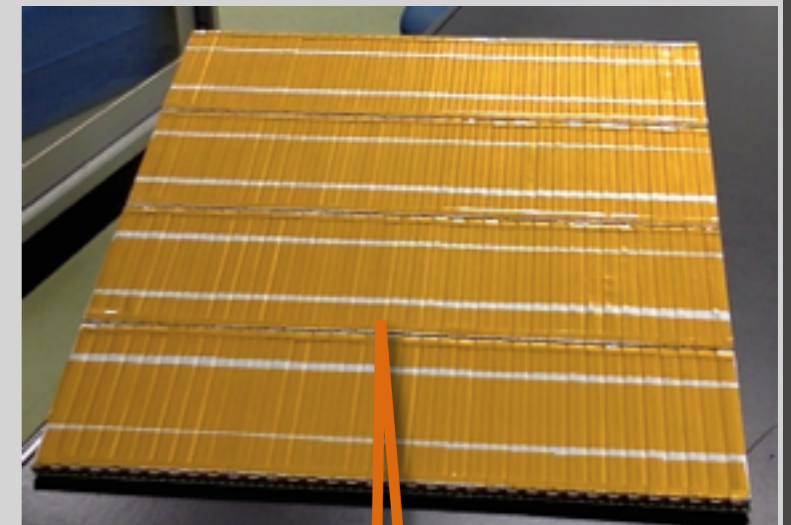


18cm

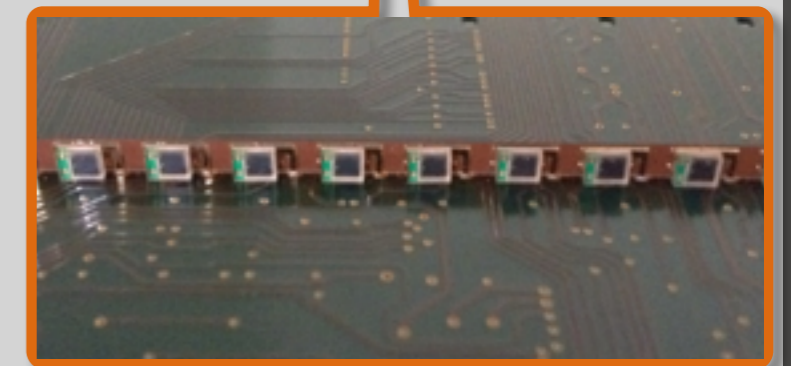
Transverse EBU, 3rd layer



EBU + MPPC + Scintillator

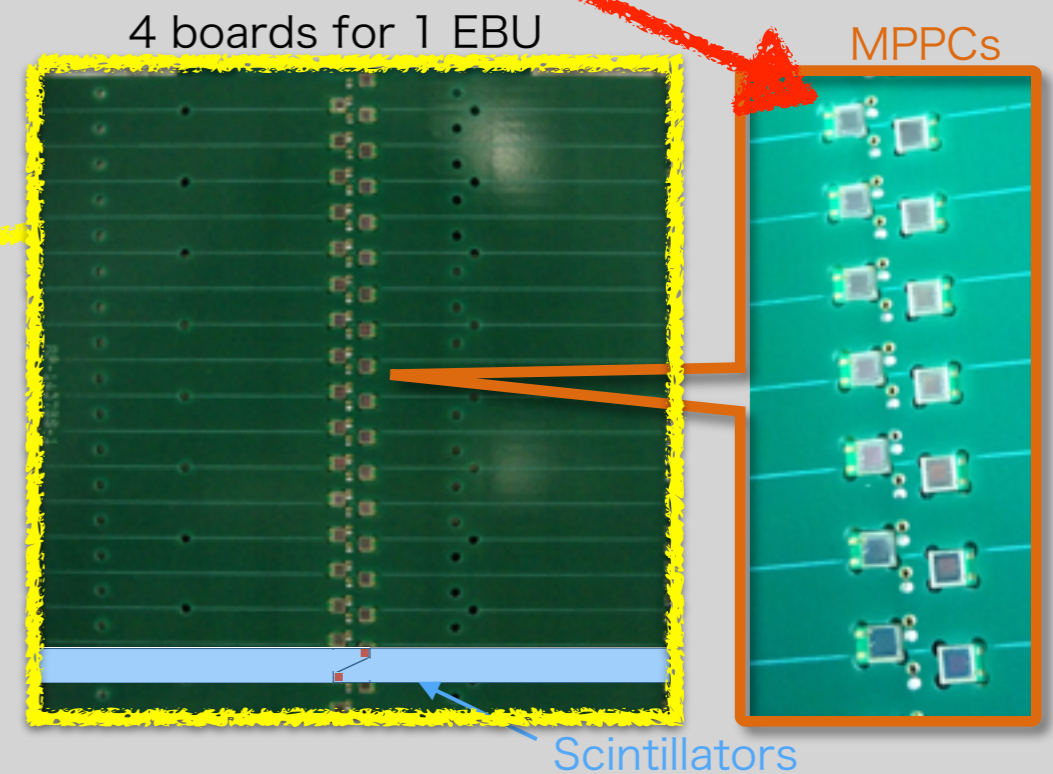
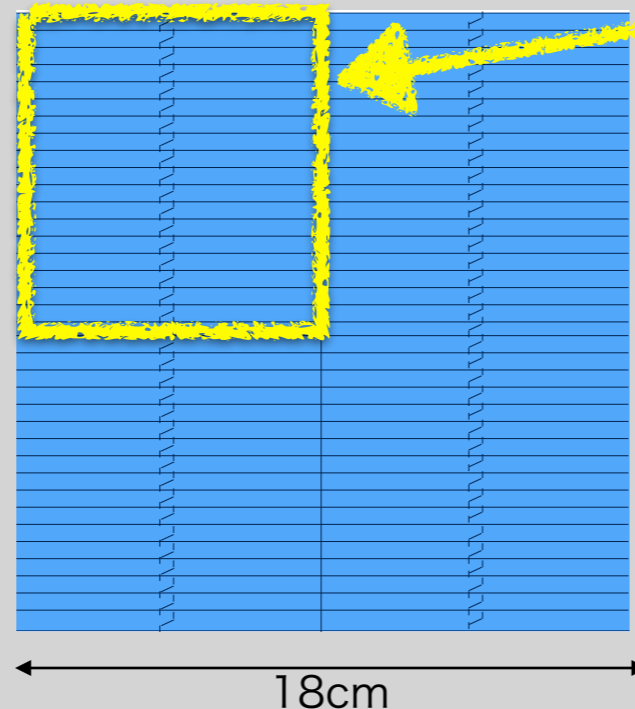
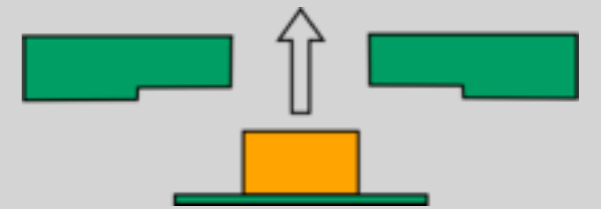
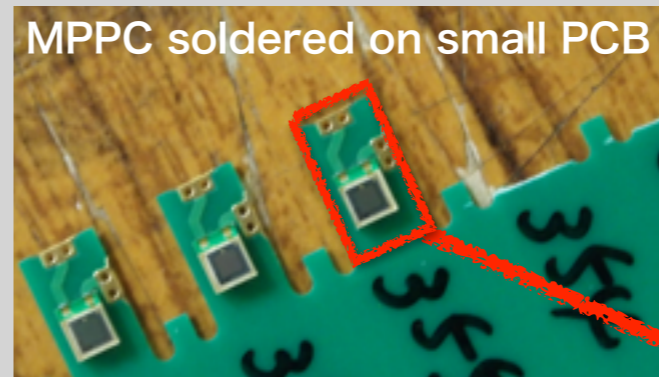


MPPCs

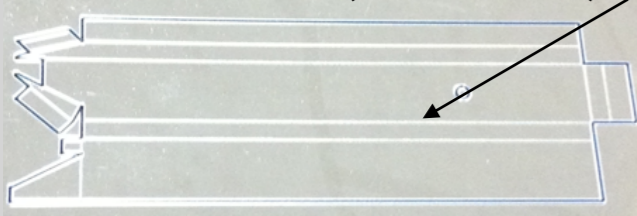


# 1st EBU

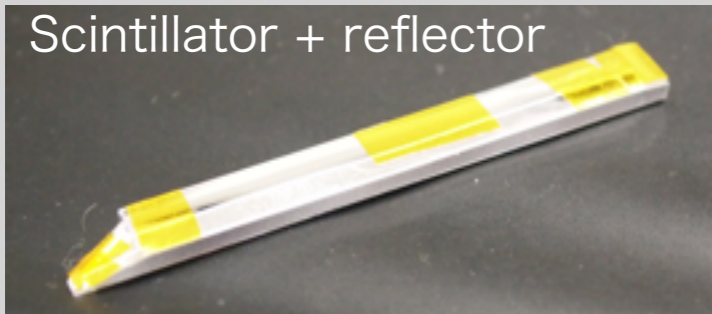
- **EBU with bottom-side readout method**
- MPPC: 10k-pix (S12571-010p)
- Scintillator: **Eljen EJ-204** (1.8mm thick)
- Reflector: **3M ESR**
- **Secondary PCB where surface-mount MPPC is embedded.**
  - Temporary solution just to use existing EBU
  - MPPC will be embedded directly into EBU in the real detector.
- Light yield: **~11p.e. (Sr-90)**



Reflector (laser cut) half-cut



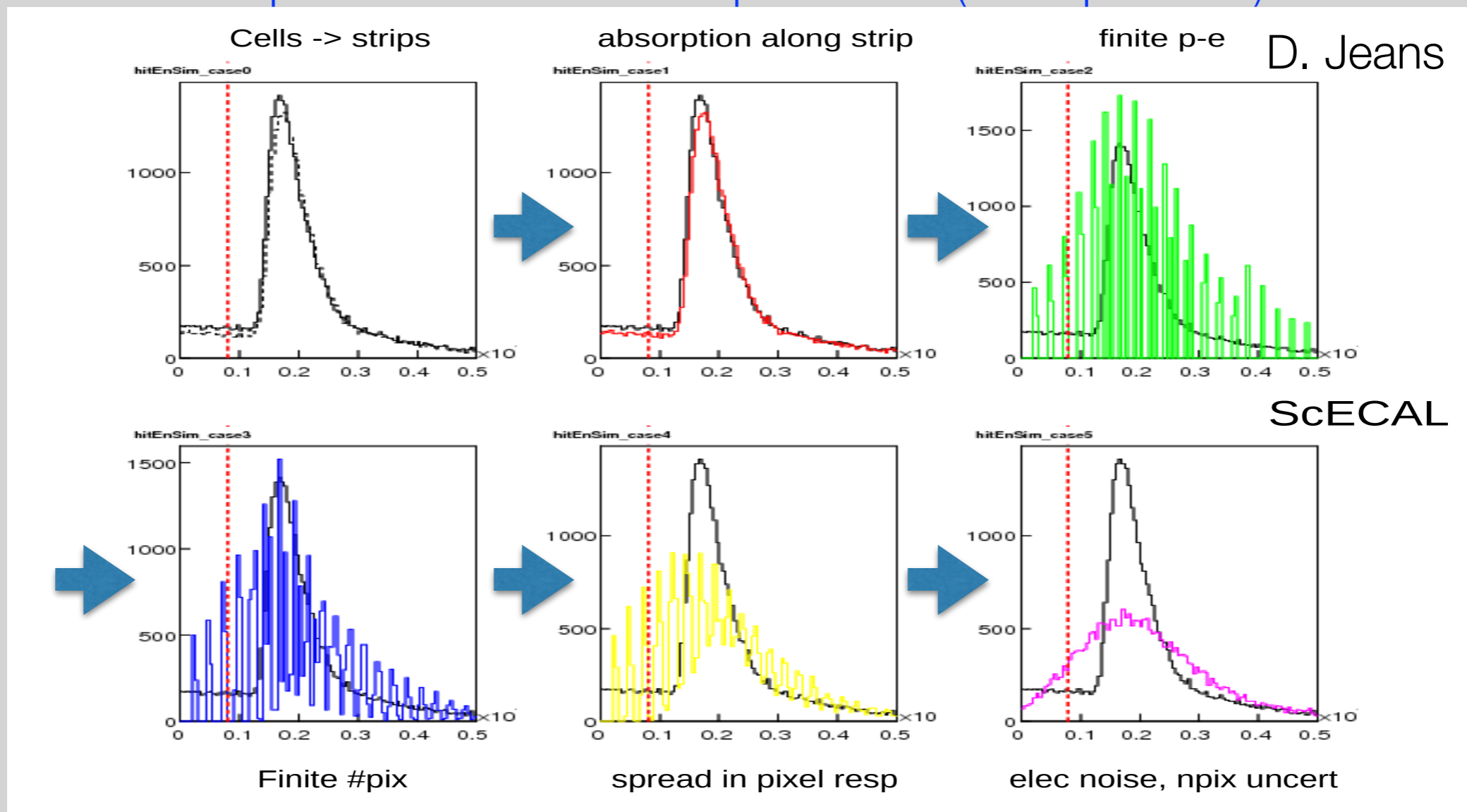
Scintillator + reflector



# Realistic Simulation

- Realistic simulation of ScECAL for reliable performance study
  - N.B. only energy deposit in DBD study
- Response parameters still to be optimised.
- Effect on the performance is being evaluated.

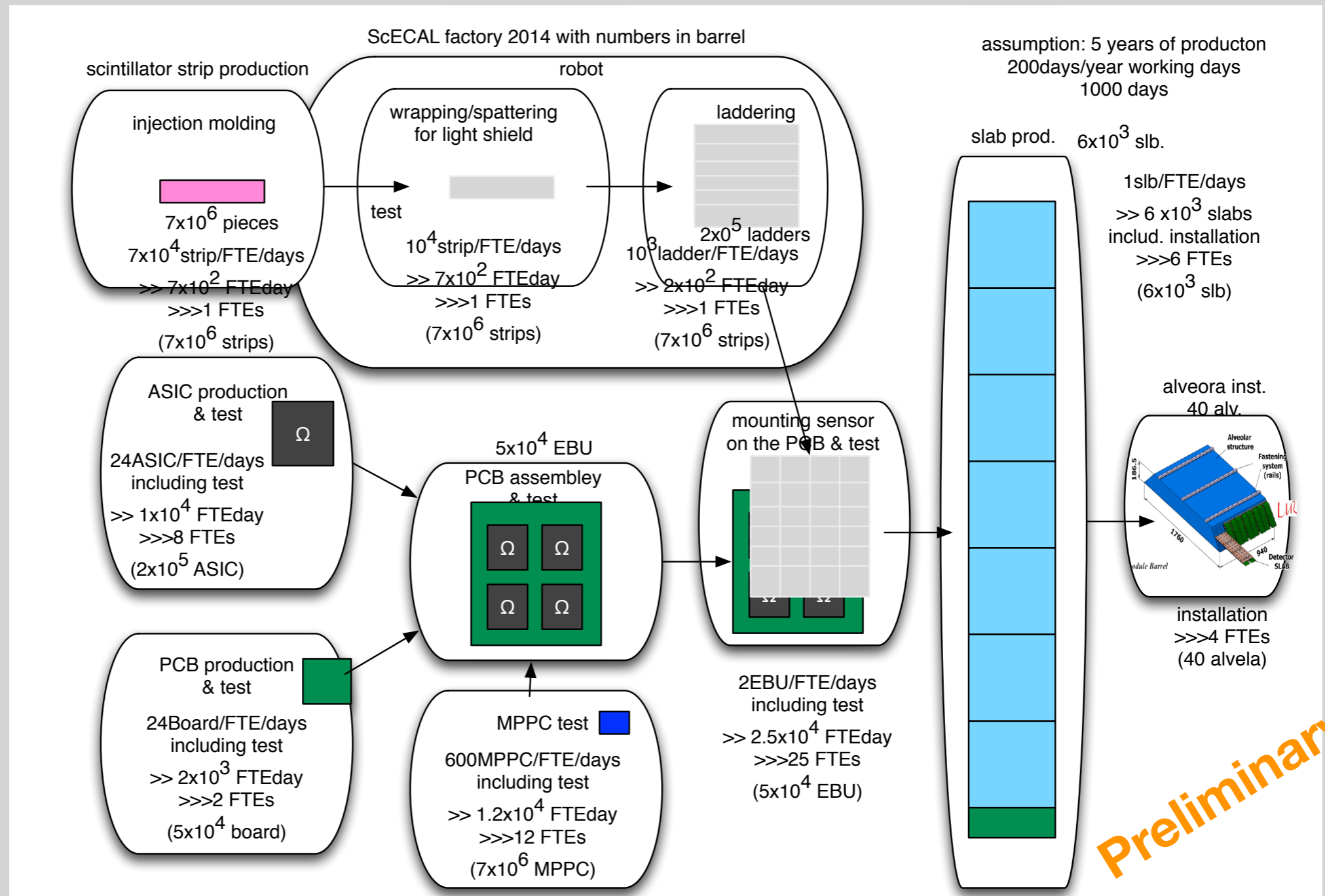
Response of scintillator strip to muon (LY=7 p.e./MIP)



# Mass Production Model

• Mass production model is now under study including estimates of

- Schedule
- Cost
- Manpower

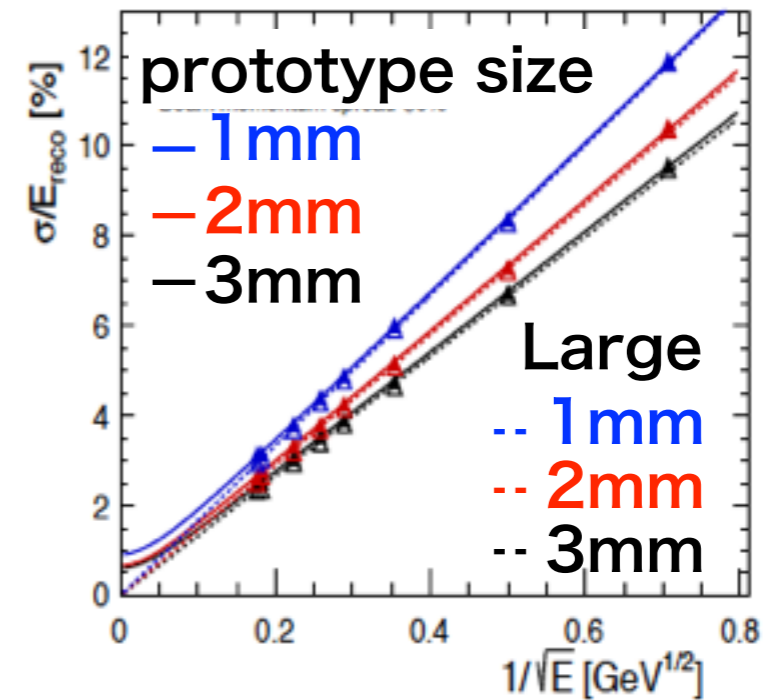
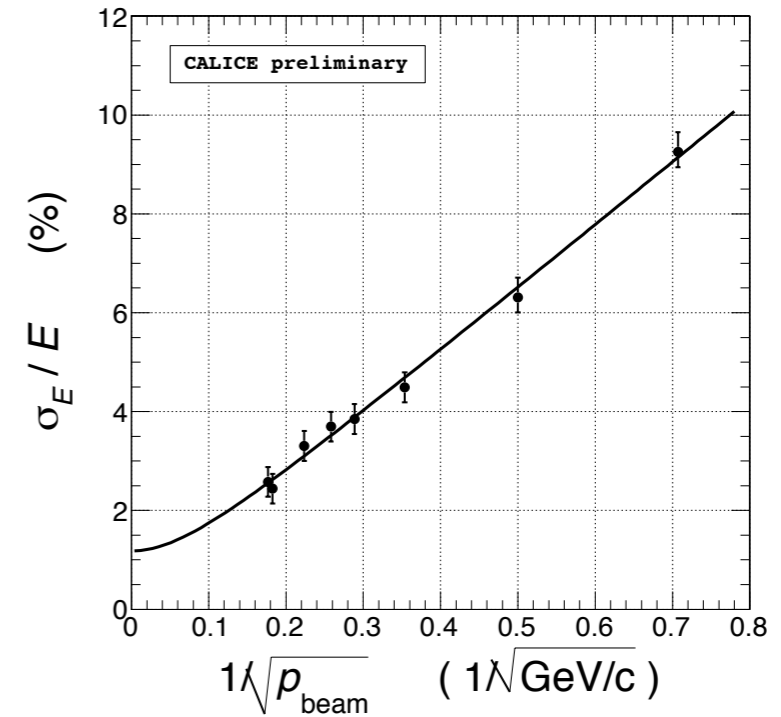
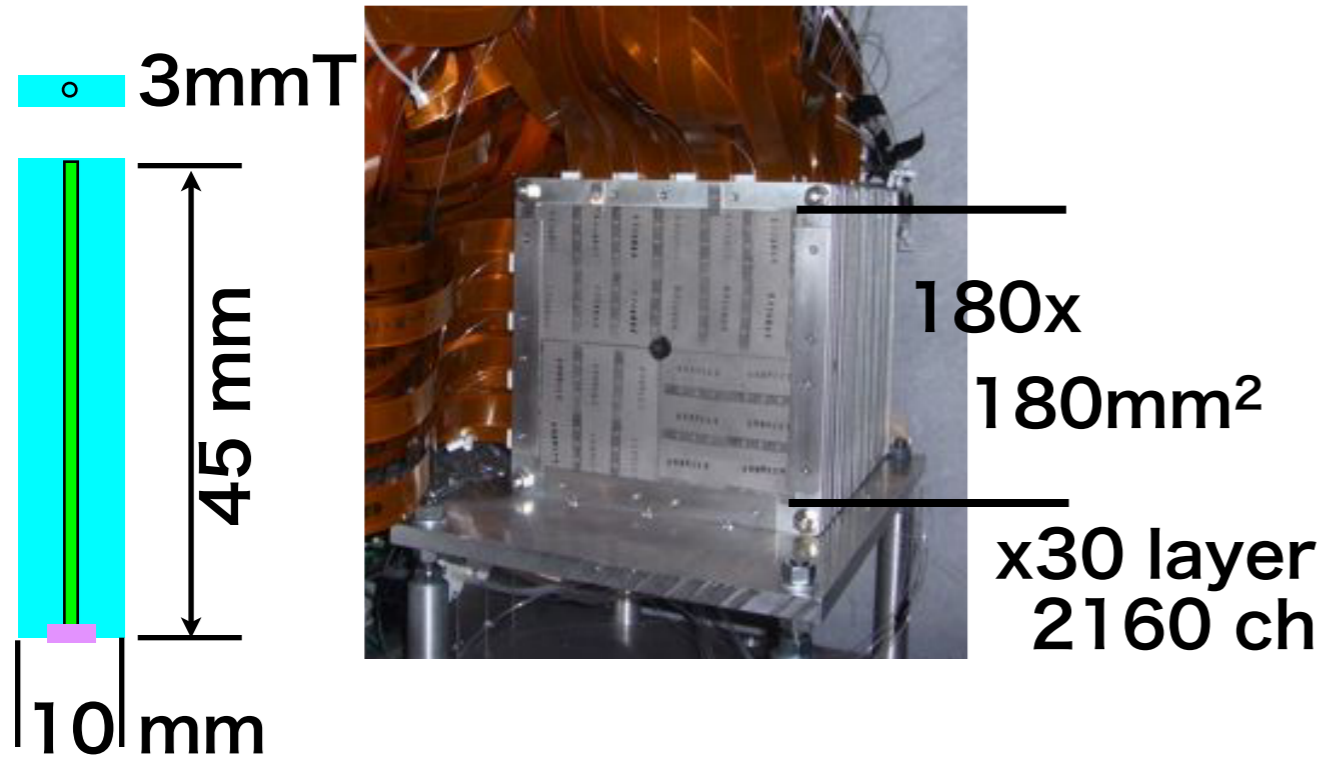


# Summary and Perspectives

- R&D on scintillator-based ECAL is in progress.
- Further optimisation studies are ongoing.
  - New 10k-pix MPPC was successfully tested and showed a much wider dynamic range.
  - New designs of strip-MPPC unit are under study.
  - Plan to test new EBUs in CERN TB in autumn 2014 (joint exp. with AHCAL)
- Simulation with more realistic detector response
- Mass production model is under study.
- We are now shifting to R&D to be ready for construction.



# 2 - 32 GeV electron (at Fermilab)



Energy resolution ( $\sigma_E/E$ )  
=  $(12.9 \pm 0.4/\sqrt{E} \oplus 1.2^{+0.4}_{-1.2})\%$

Max deviation from linear < 2%

| scint. thick | MC stochastic(%) |
|--------------|------------------|
| 3 mm         | 13.4             |
| 2 mm         | 14.6             |
| 1 mm         | 16.7             |