Scintillator-ECAL for the ILD detector

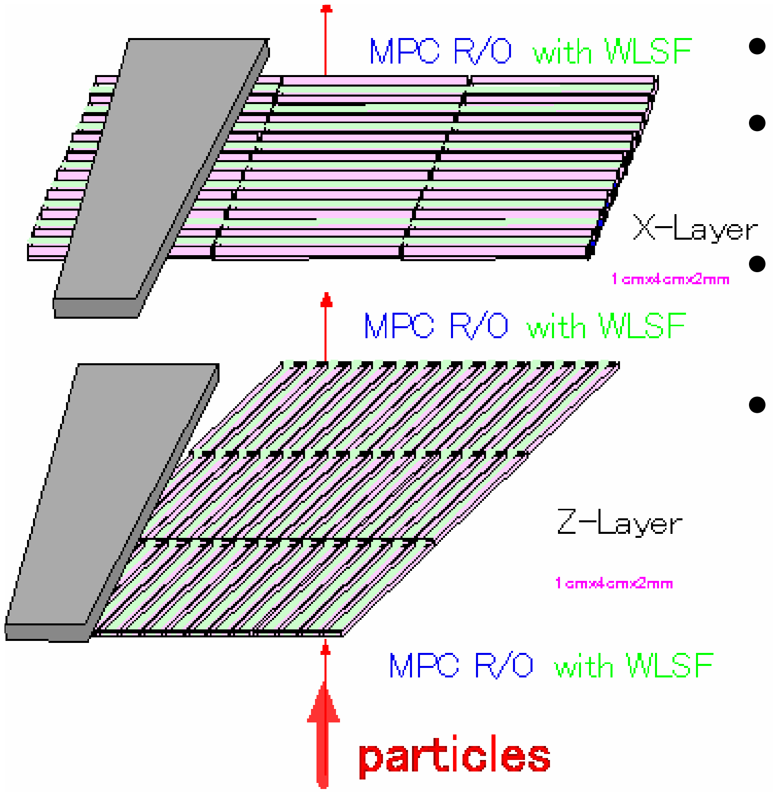
Jan-14-16 ILD workshop @ Zeuthen

S. Uozumi for the SCECAL group

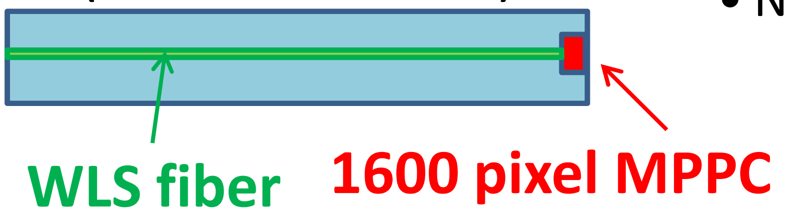
(KNU, Kobe, Niigata, Shinshu, Tokyo, Tsukuba)

1. Introduction
2. Photon Sensor R&D
3. ECAL prototype and Beam Test @ DESY
4. Extruded scintillator R&D and Beam Test @ KEK
5. FNAL Beam Test Plan
6. Summary

The Scintillator-Tungsten ECAL



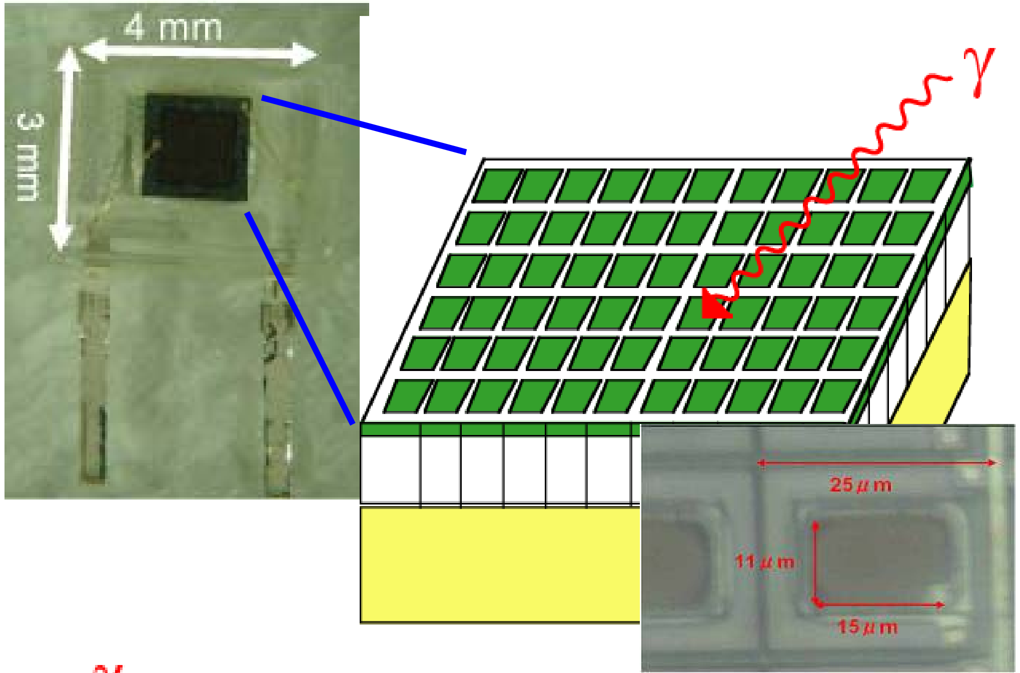
Scintillator strip
(4.5 x 1 x 0.3 cm)



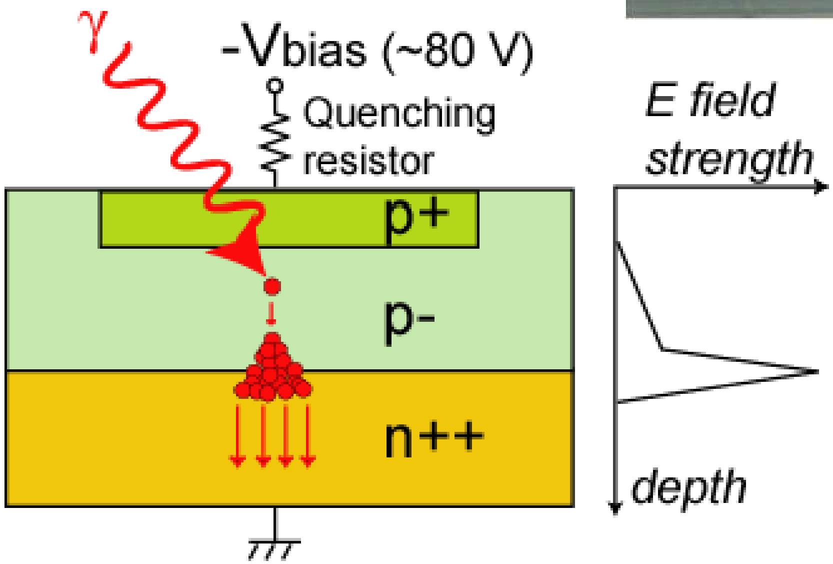
- A PFA calorimeter designed for the GLD detector.
- Sandwich structure with Scintillator(2mm)-Tungsten(3mm) layers.
- Adopt well-understood plastic scintillator technique.
- Scintillator stirp structure (1 x 4.5 cm)
  - Aiming to reduce number of readout channels while keeping granularity of 1 x 1 cm.
  - Utilize extruded scintillator technique to reduce production cost.
  - Strip clustering is a key issue. (->Daniel's talk)
- Full MPPC (Multi-Pixel Photon Counter) readout.
- Number of readout ~ 10 M channels

The Multi Pixel Photon Counter (MPPC)

- A Geiger-mode avalanche photo-diode with multi-pixel structure -



- Belongs to Pixelated Photon Detector family (same as SiPM)
- Manufactured by Hamamatsu Photonics.
- High Gain (10^5~10^6)
- Good Photon Detection Efficiency (~15% with 1600 pixel)
- Compact (package size ~ a few mm)
- Low Cost
- Insensitive to magnetic field
- Dark noise exists (~100 kHz)
- Input vs output is non-linear



We are developing and studying the 1600-pixel (or more) MPPC with Hamamatsu for the Scintillator-ECAL readout.

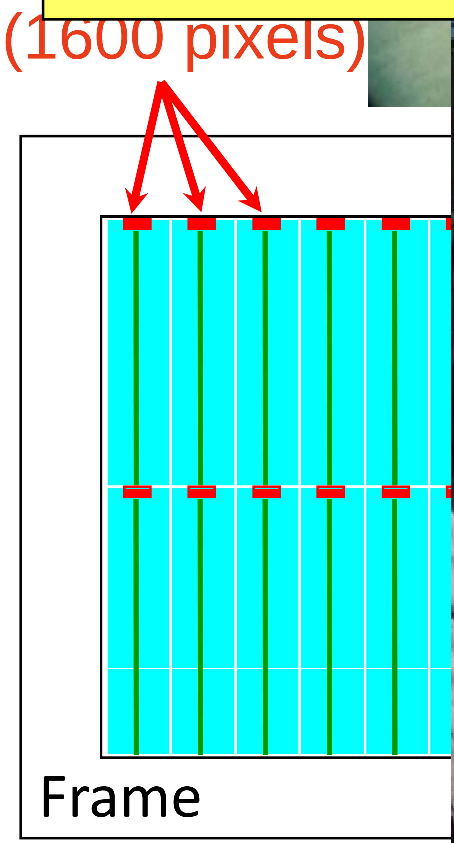
R&D Status of the 1600 pixel MPPC

	Performance	status
Gain	10^5~10^6	OK
Photon Detection Eff.	~0.2 for 1600 pix. MPPC	OK
Dark Noise Rate	~ 100 kHz	OK
Photon counting	Great	OK
Bias voltage	~ 70 V	OK
Size	Compact	OK
Dynamic range	**Determined by # of pixels and recovery time**	underway
Cost	Expected to be < $10	Negotiating
Long-term Stability	Unknown	To be checked
Robustness	Unknown, presumably good	underway
Radiation hardness	Concerned	underway
B field	Expected to be Insensitive	Looks OK (by TPC group)
Timing resolution	Expected to be 0.1~1 ns	To be checked

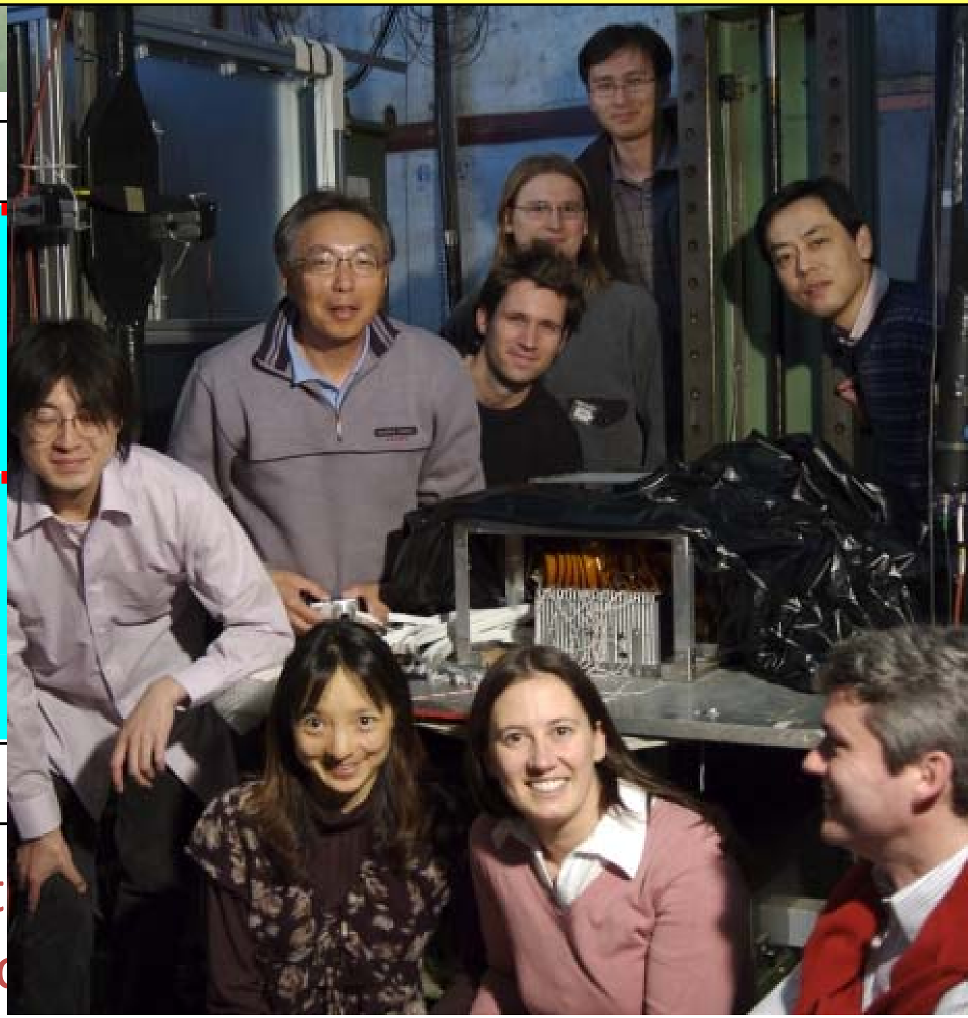
Scintillator-ECAL prototype and Beam Test @ DESY in Mar 2008

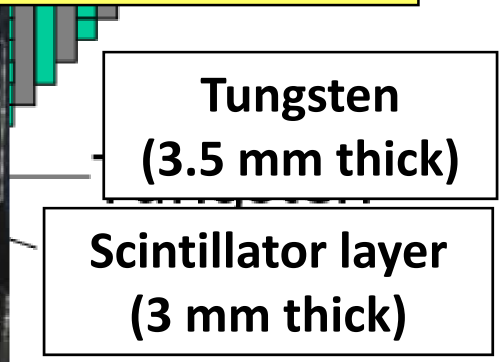
- Check performance of EM calorimeter with scintillator-strips and MPPC using 1-6 GeV positron beams.
- Trial of massive use of the MPPC.
  (Those 2 things are world's first trial !)
- Test direct readout and extruded scintillator strips.

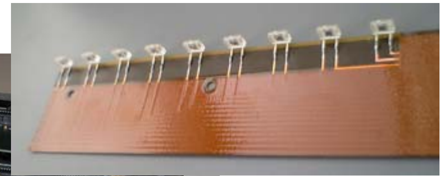
In 2007 Spring beam test has been performed at DESY using 1-6 GeV e^+ beams.
People from KNU, Kobe, Shinshu, Tokyo with great help from DESY people

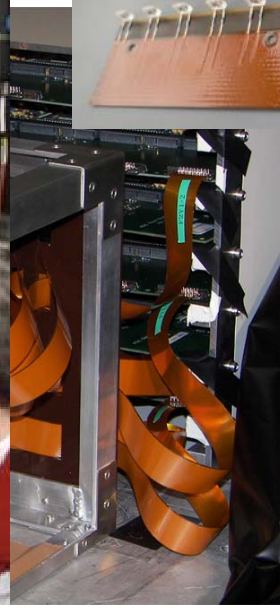


Scintillator st
(1 x 4.5 x 0.3 c

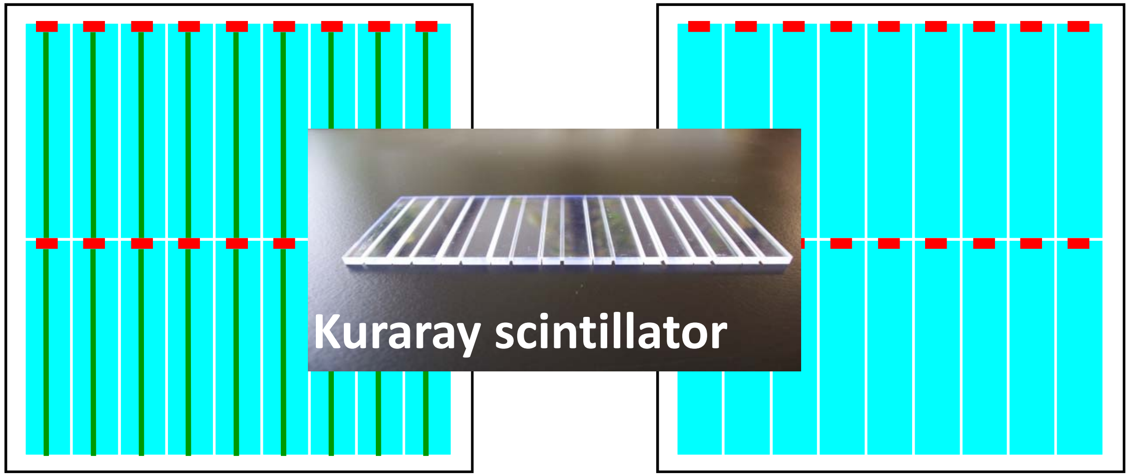








3 Types of Modules

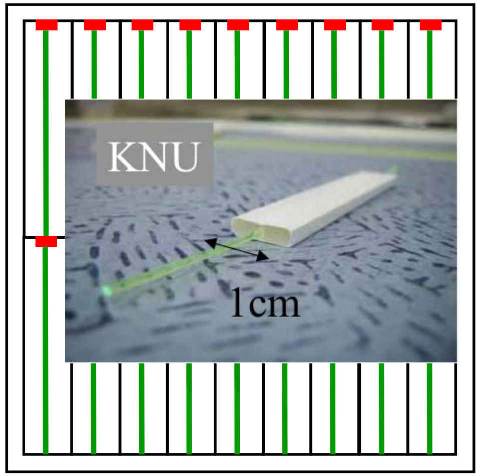


① **WLSF readout**

13 layers

② **Direct readout**

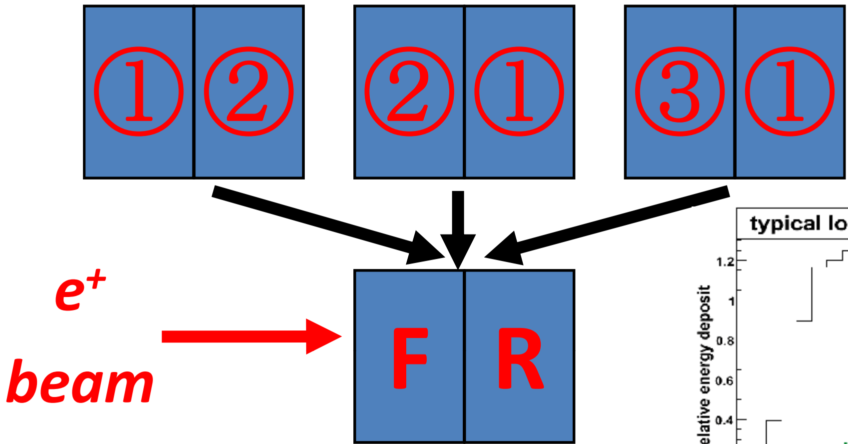
13 layers



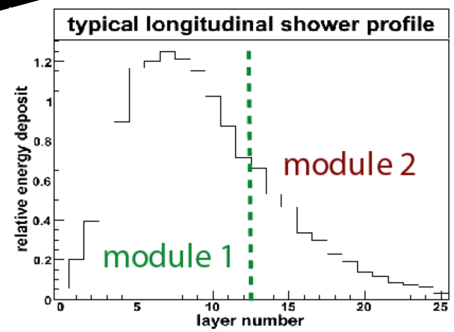
③ **WLSF readout**

by extrusion technique

13 layers

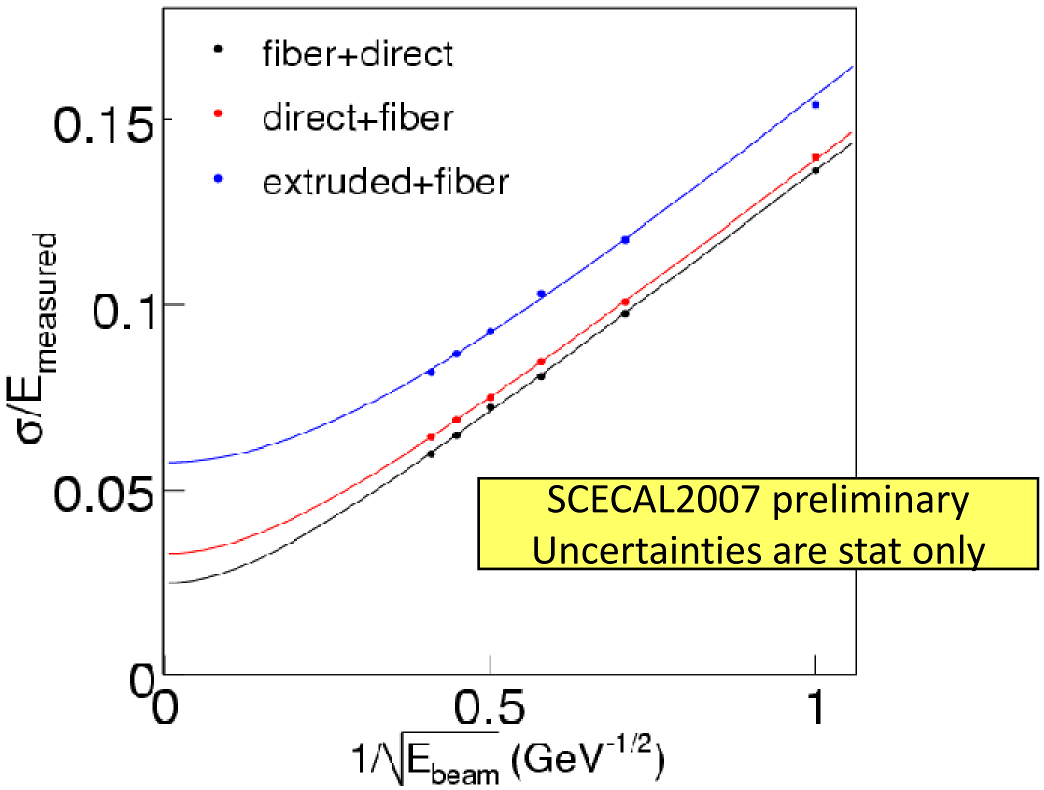


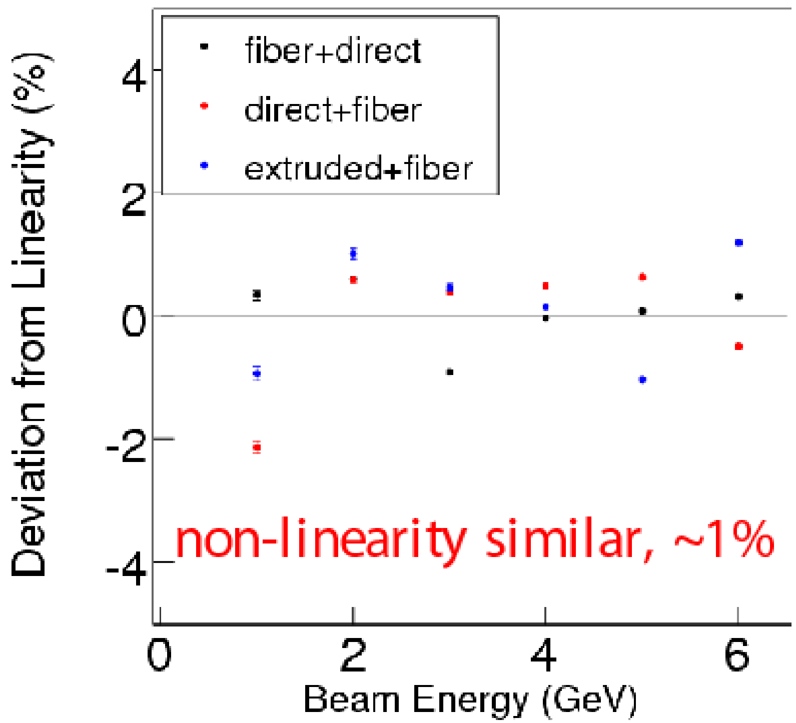
13 + 13 layers



- **For** ① and ②,well-known Kuraray scintillator is used.
- Extruded scintillator for ③ is very important for cost reduction.

Energy Resolution, Linearity

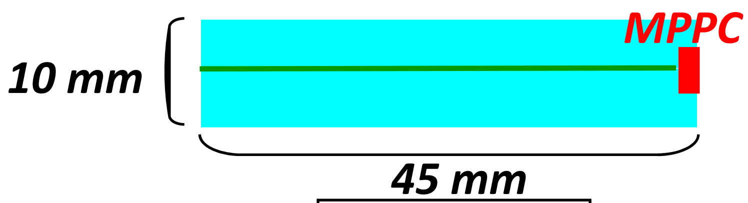


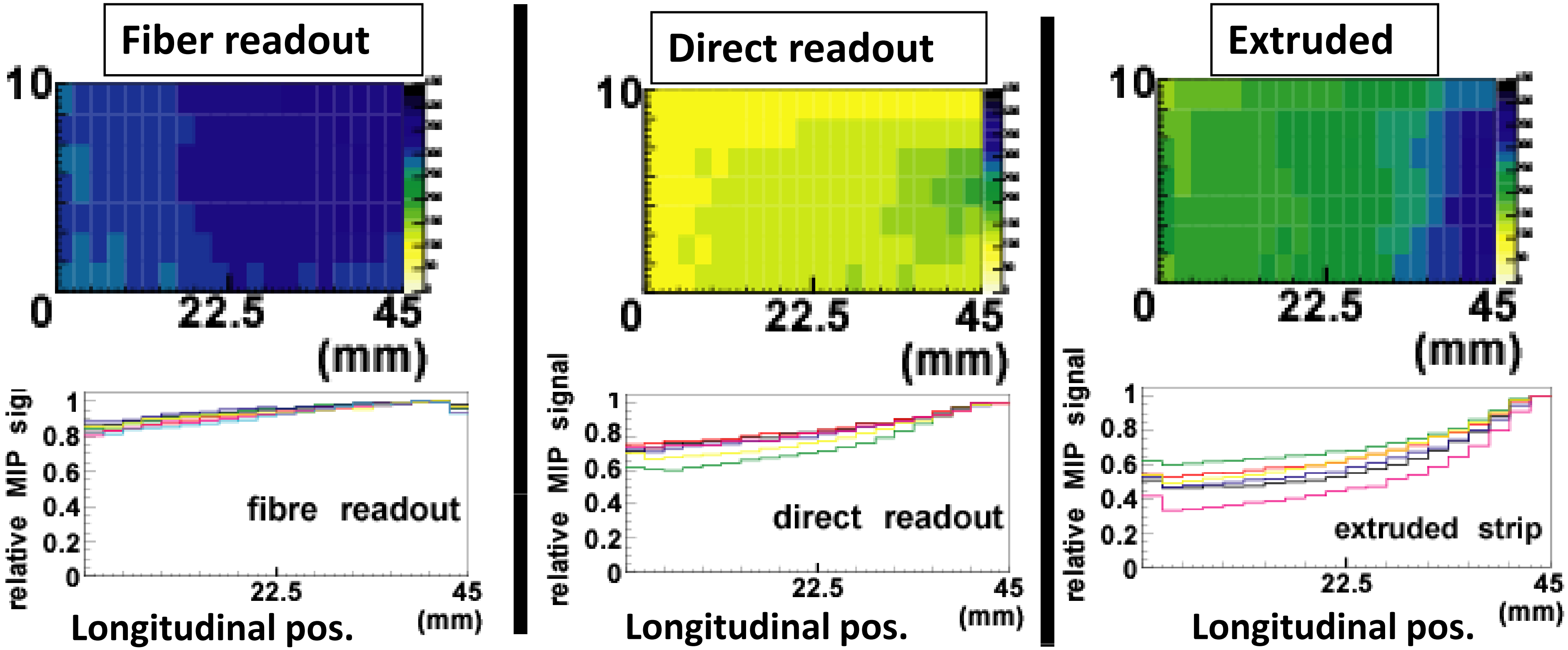


- Energy resolution ~ $13\%/\sqrt{E} \oplus 2.5\%$ with fiber+direct config, almost consistent with expectation.
- Significant constant term with extruded + fiber config due to strip response non-uniformity.
- Deviation from linearity < 2%, even without saturation correction of the MPPC response.

Uniformity of MIP Response inside Strip

MIP data is taken without tungsten absorbers.

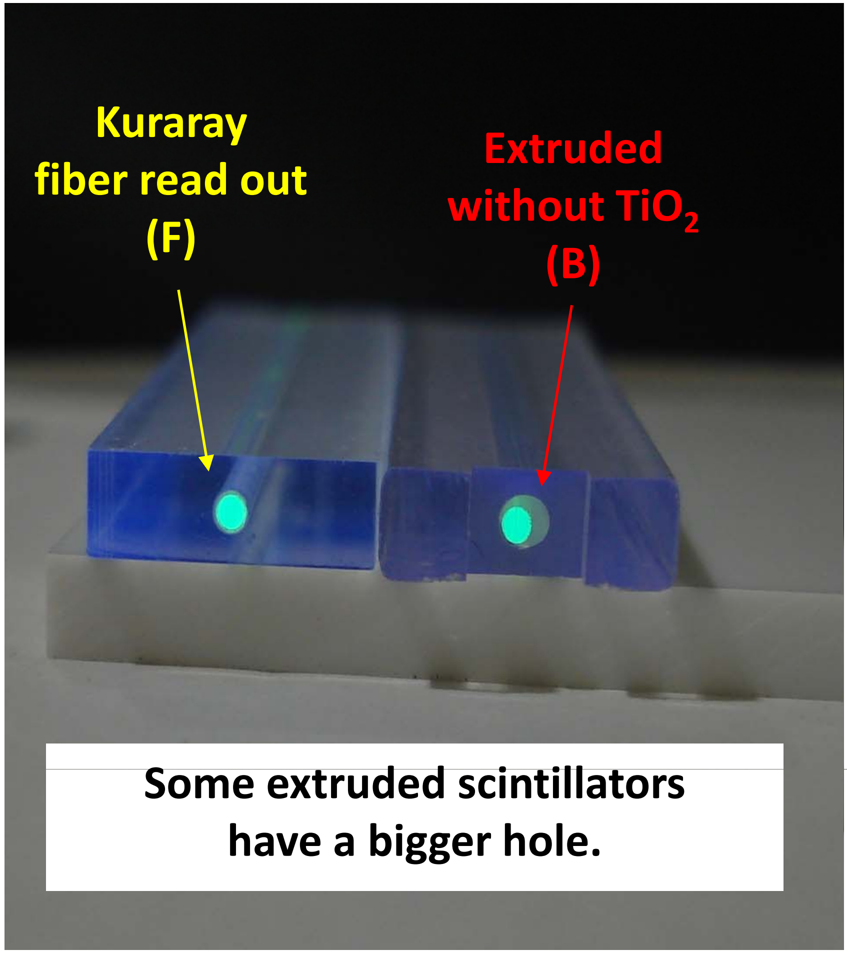


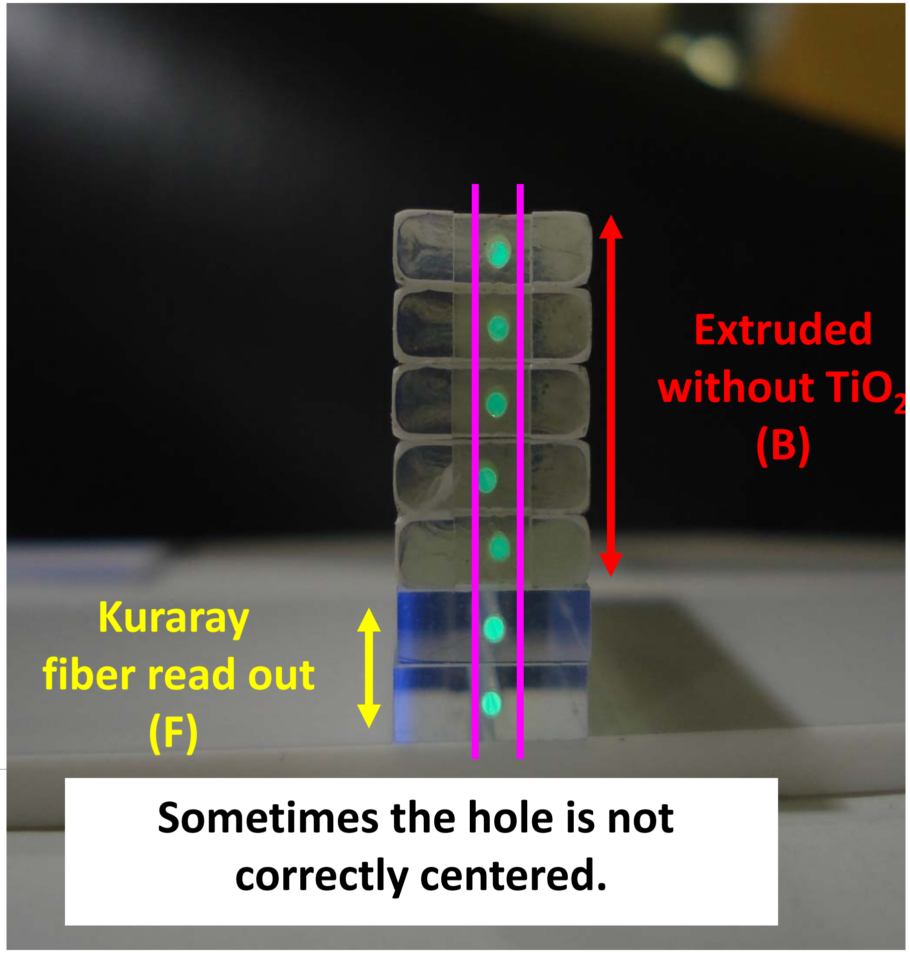


- Kuraray fiber readout strip shows the best uniformity.
- Direct readout strip is a little worse than fiber readout.
- Extruded shows significant non-uniformity (50% light attenuation at strip edge).

Comparison between Kuraray and extruded scintillator strips

Extruded scintillators have some problems.

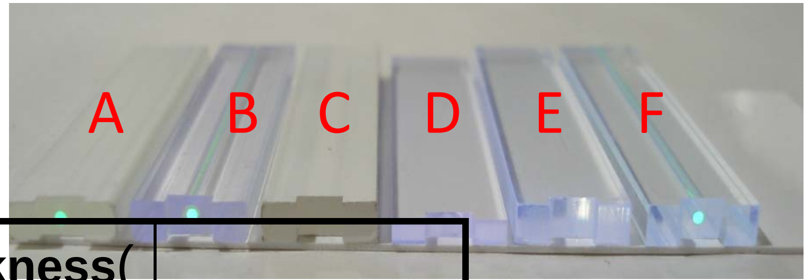




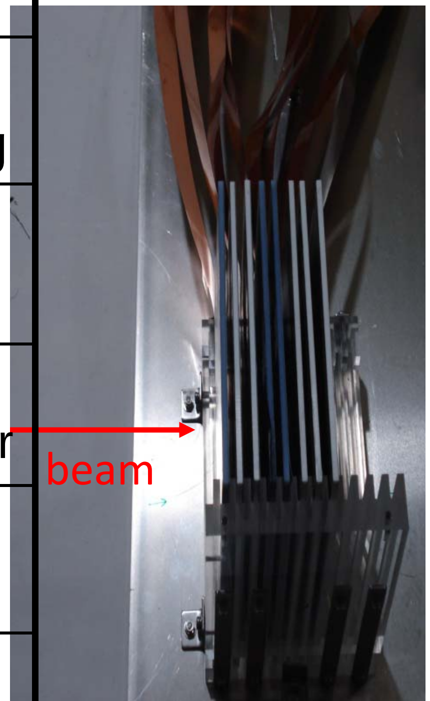
Extruded scintillator R&D and KEK Beam Test (Nov 2007)

- Extruded scintillator R&D is very important for cost reduction of scintillator production.
- However first prototype showed large response non-uniformity at the DESY beam test.
- Need to perform deeper study of improved extruded scintillator strips by 2D scanning with MIPs (3 GeV electrons).
  - Evaluate light yield , position dependence , strip-by-strip variation
  - What factor affect to those performance?
    - Optical matching between fiber and MPPC
    - Cover material
    - Attenuation length of scintillator
- Compare various extruded scintillator strips with Kuraray strips.

Tested Scintillator Strips



	Scintillator	Read-out	Cover	**Thickness**(mm)	
A1	Extruded	Fiber	TiO_2 (white)	3	No fiber
A2					good positioning
B1			**Reflector film**		big hole For fiber
B2					matched hole for fiber
C1		Direct	TiO_2 (white)		
D	Kuraray	Direct	**Reflector film**	2	
E				3	**Megastrip structure**
F		Fiber			



Response for MIP

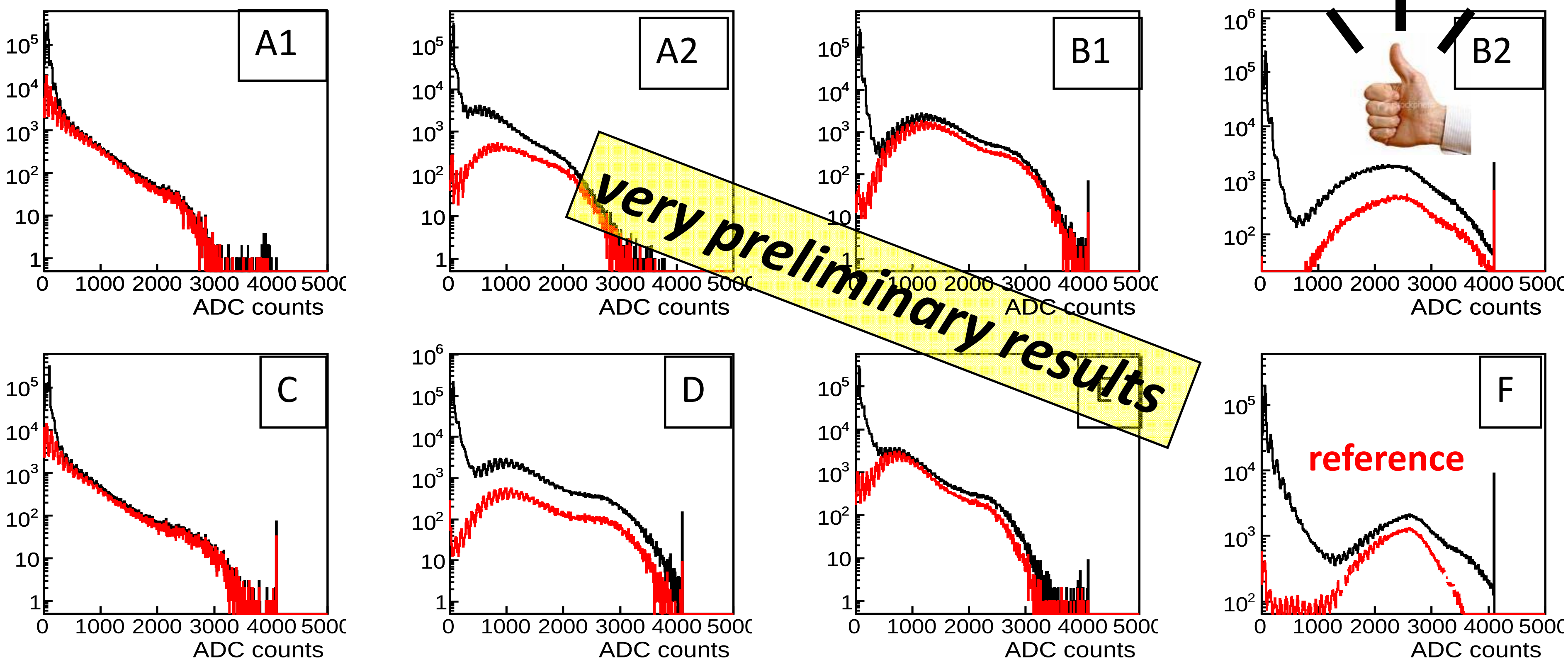
Black … all collected events
Red … selected MIP events

Extruded, TiO_2
Fiber readout
but no fiber

Extruded, TiO_2
Fiber readout

Extruded, reflector
Fiber readout
large hole

Extruded, reflector
Fiber readout
Matched hole



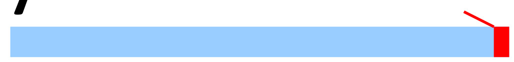
Extruded, TiO_2
Direct readout

Kuraray 2 mm
reflector
Direct readout

Kuraray 3 mm
reflector
Direct readout

Kuraray 3 mm
reflector
Fiber readout

Longitudinal Response Uniformity

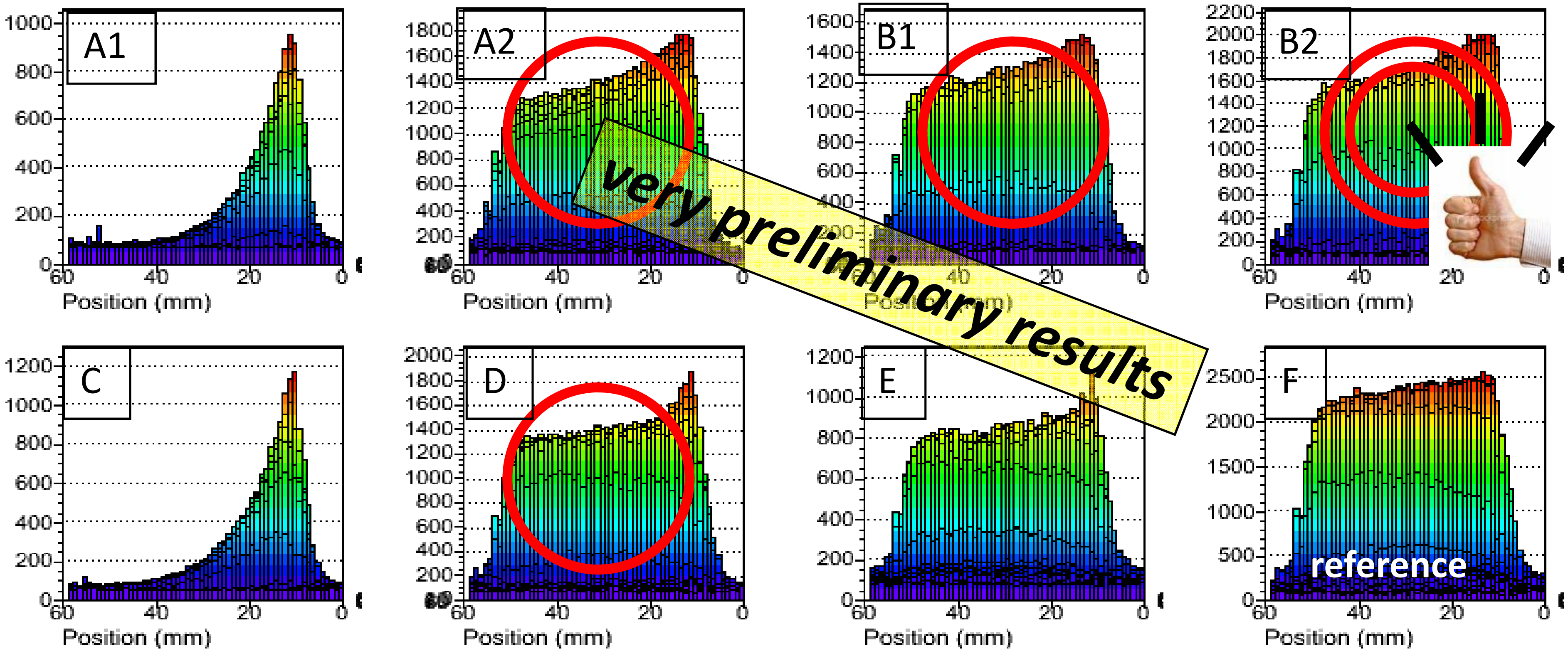


Extruded, TiO_2
Fiber readout
but no fiber

Extruded, TiO_2
Fiber readout

Extruded, reflector
Fiber readout
large hole

Extruded, reflector
Fiber readout
Matched hole



Extruded, TiO_2
Direct readout

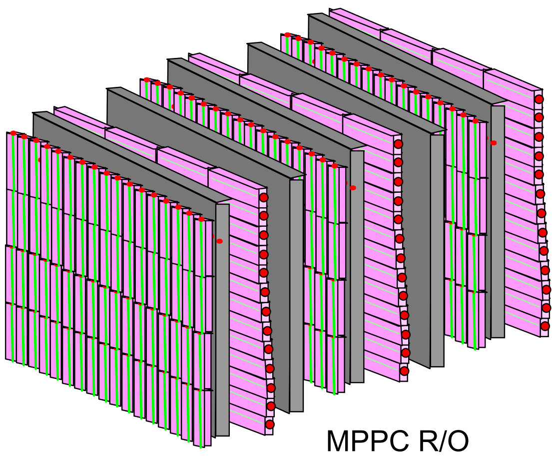
Kuraray 2 mm
reflector
Direct readout

Kuraray 3 mm
reflector
Direct readout

Kuraray 3 mm
reflector
Fiber readout

Future plan : The FNAL beam test in Aug 2008

- Establish the Scintillator-strip ECAL
  - Test linearity of the full-MPPC readout calorimeter with high energy beam.
  - Evaluate all the necessary performances using various beams (π,K,e,μ….) with wider energy range
  - Make the SCECAL ready for the engineering design
- Combined test with the Analog HCAL
- Test π^0 -> 2γ reconstruction
- Measure hadron shower to test simulation model
  - Compare the result with various models
  - Precise hadron simulation will help study of PFA



- The 2nd prototype will be 4 times larger than the DESY BT module.
  (20 x 20 cm, ~30 layers)
- Fully adopt the extruded scintillators.
- Expect > 2000 readout channels.

Other Ongoing / Remaining Jobs

- Strip Clustering – excellent work is underway by Daniel Jeans.
- Further study and development of MPPC is extensively ongoing.

  (more dynamic range, radiation hardness, etc…)
- Engineering design – no man-power available

  for now
- Detector calibration using pions in QCD jet events

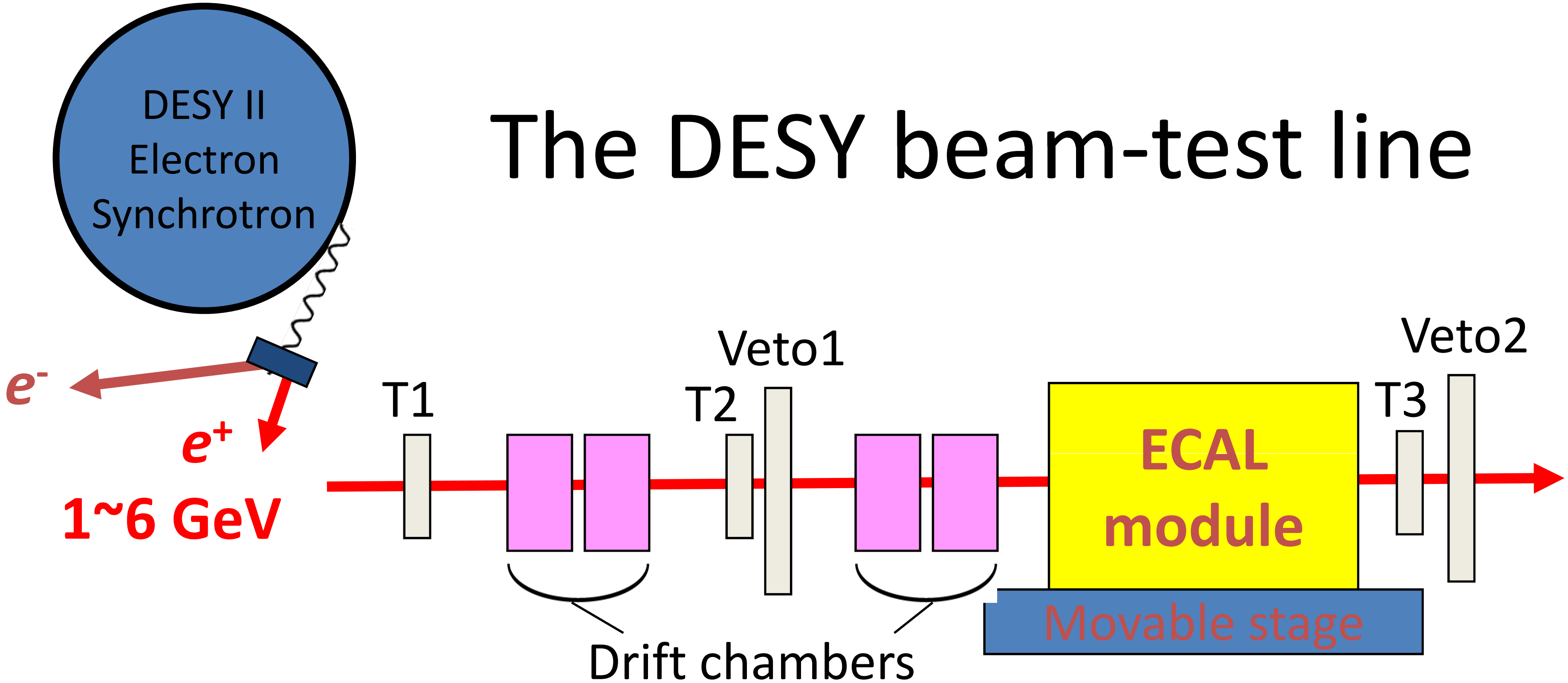
  - simulation study ongoing.

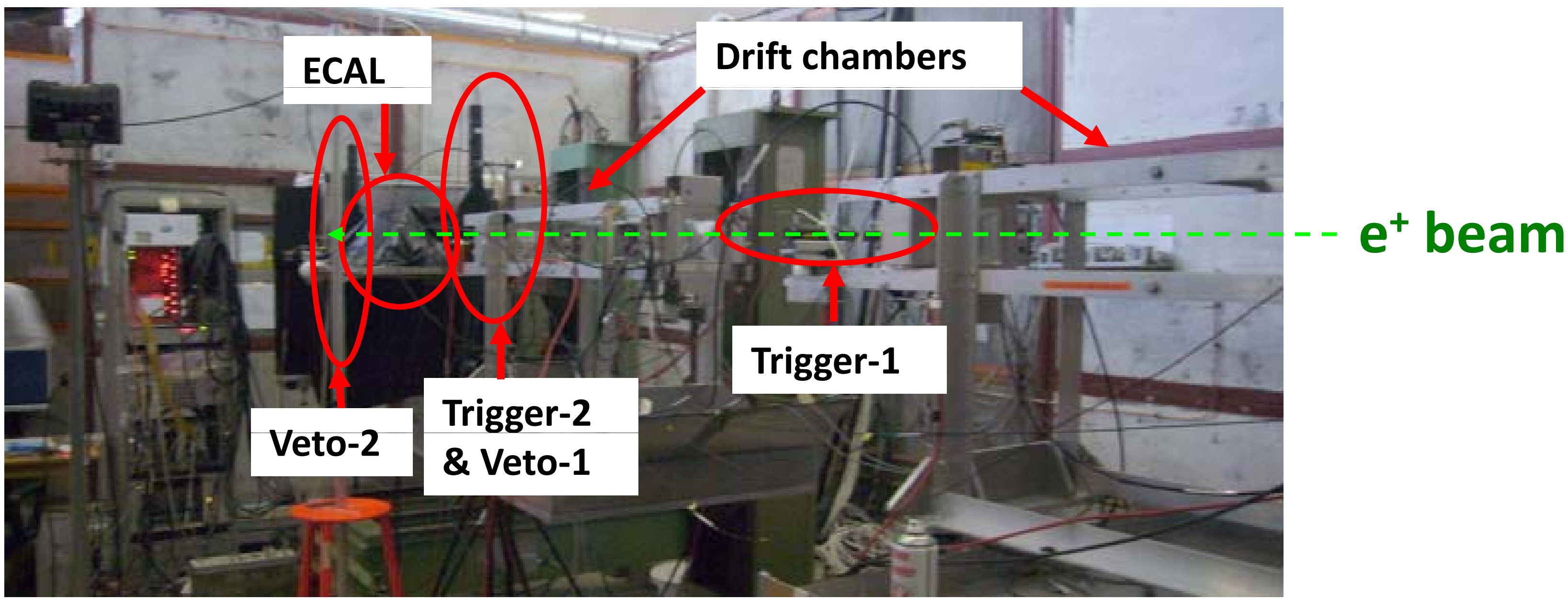
Summary

- Study of the scintillator-ECAL is steadily ongoing.
- R&D of the photon sensor is underway collaborating with Hamamatsu.
- Current 1600-pixel MPPC sample already shows almost satisfactory performance.
- We have proven that scintillator-strip calorimeter with full MPPC readout works.
- Study of the extruded scintillator production is ongoing in Korea.
- From results of the KEK beam test, we understand how to improve the performance of extruded scintillators.
- The Scintillator-ECAL technology will be established and all tested at the next FNAL beam test in this year.
- There are still some concerns, however almost of them can be solved.
  - Dynamic range – MPPC improvement ongoing.
  - Granularity – up to 1 x 1 cm possible
  - Strip clustering – work ongoing.
  - Cost – extrusion method will reduce scintillator cost. MPPC cost is another key issue.
  - Detector calibration – will use MIPs in jets, study ongoing.
- The SCECAL has great possibility as the ILD EM calorimeter !

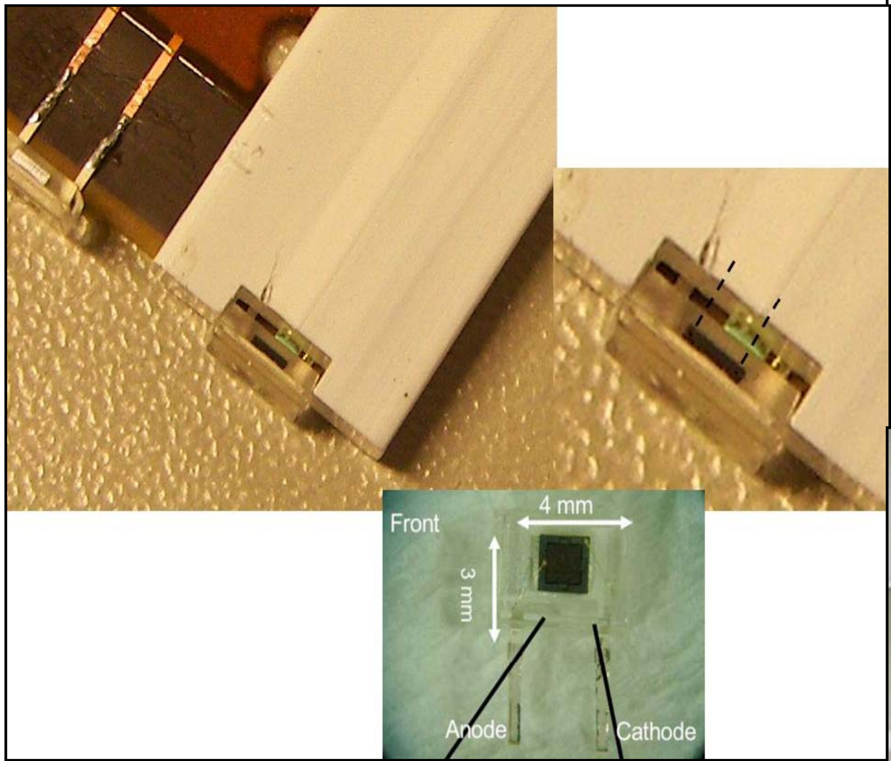
Backups

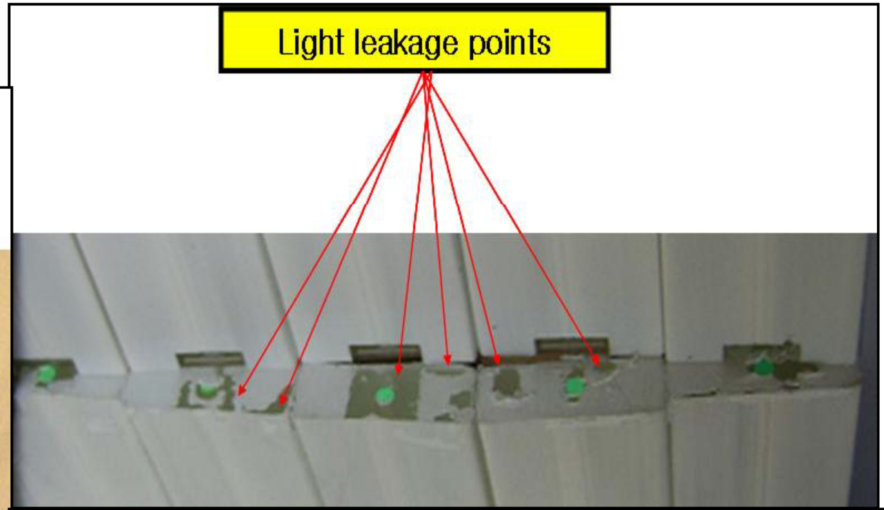
The DESY beam-test line

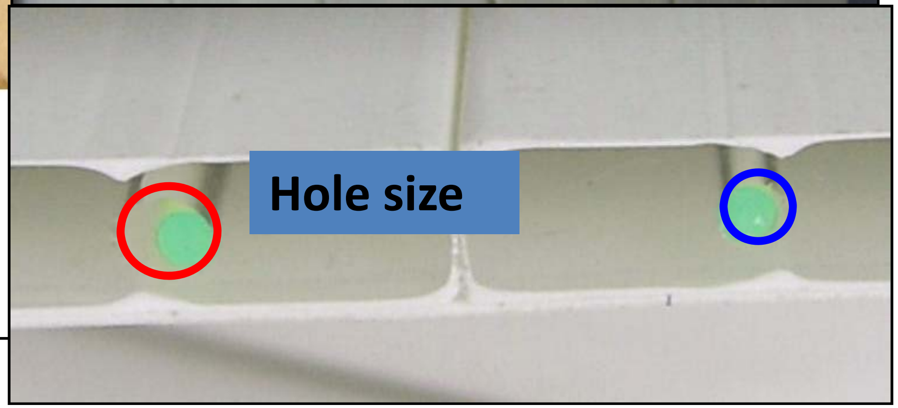




What was happening with the extruded scintillator ?



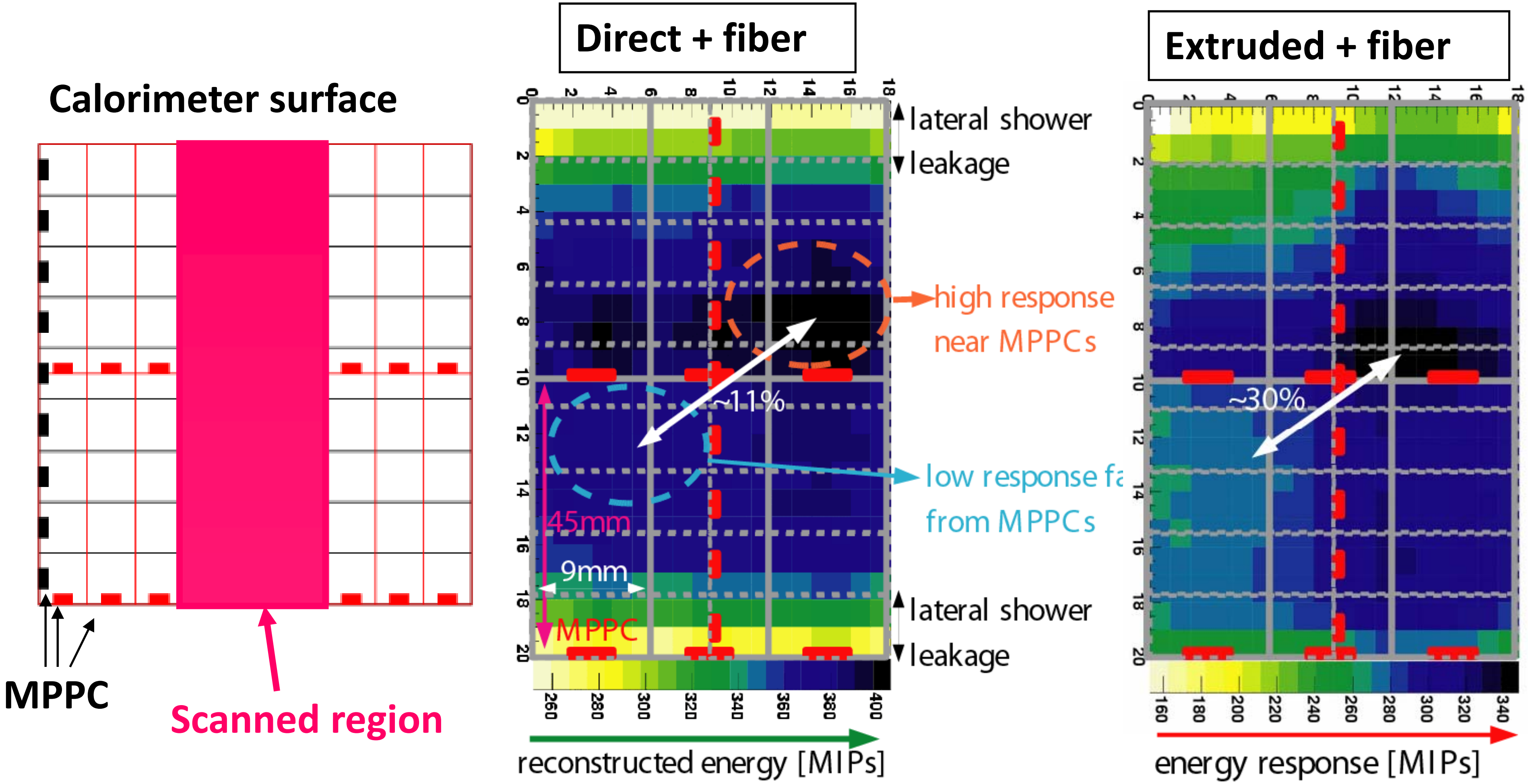




- Some problems were found.
- Production of improved version will be done soon and its performance will be checked at KEK beam test in next month.

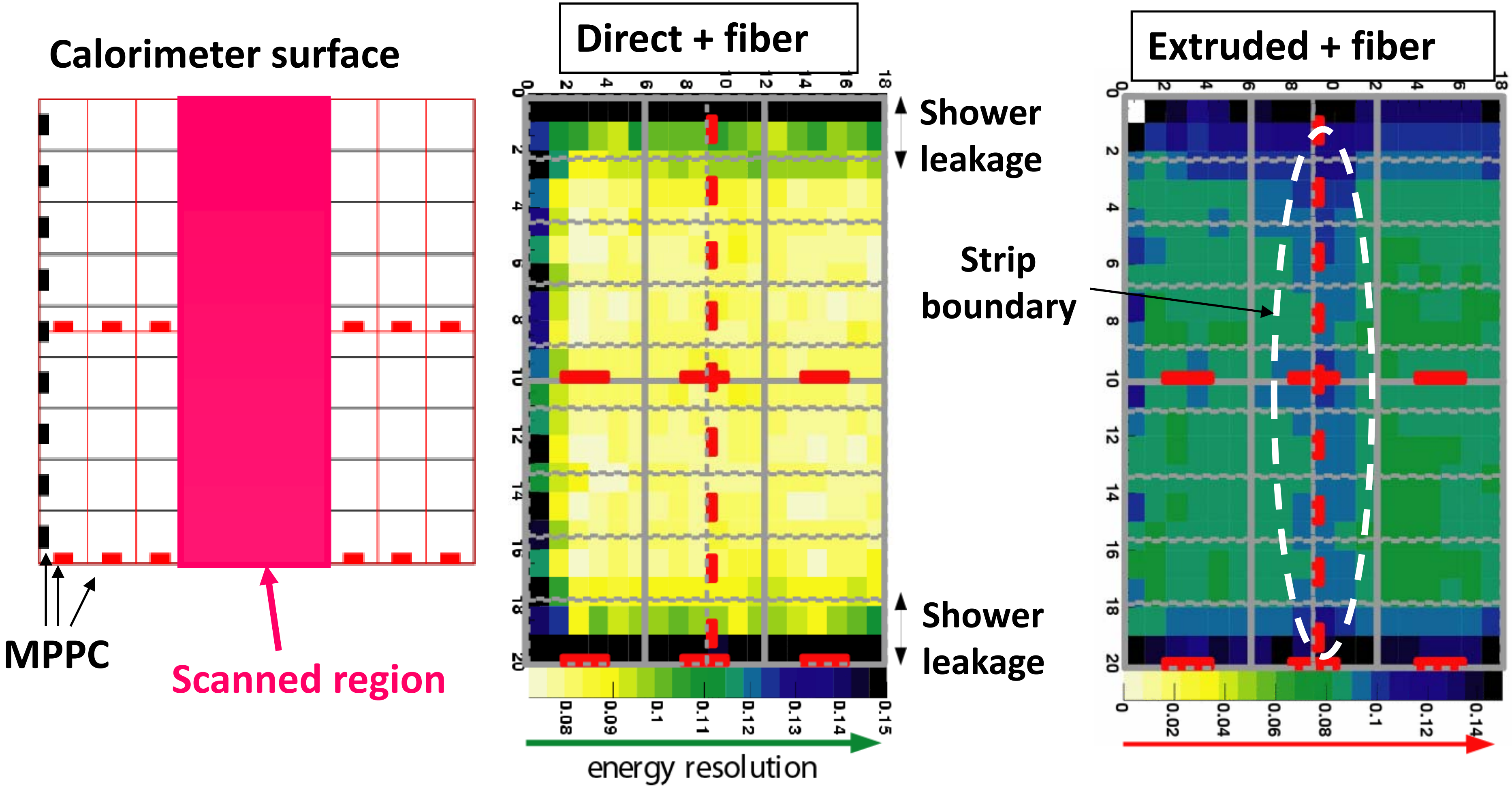
Position Dependence : Response to EM Shower

(taken with 3 GeV positron beam)



- ~ 11 % of peak-to-peak-variation with direct+fiber config.
- ~ 30 % variation with extruded + fiber config
  due to strip non-uniformity.

Position Dependence : Energy resolution (taken with 3 GeV positron beam)



- Just a small variation is observed in almost of region.
- Extruded+fiber config shows a little worse resolution around strip boundary.

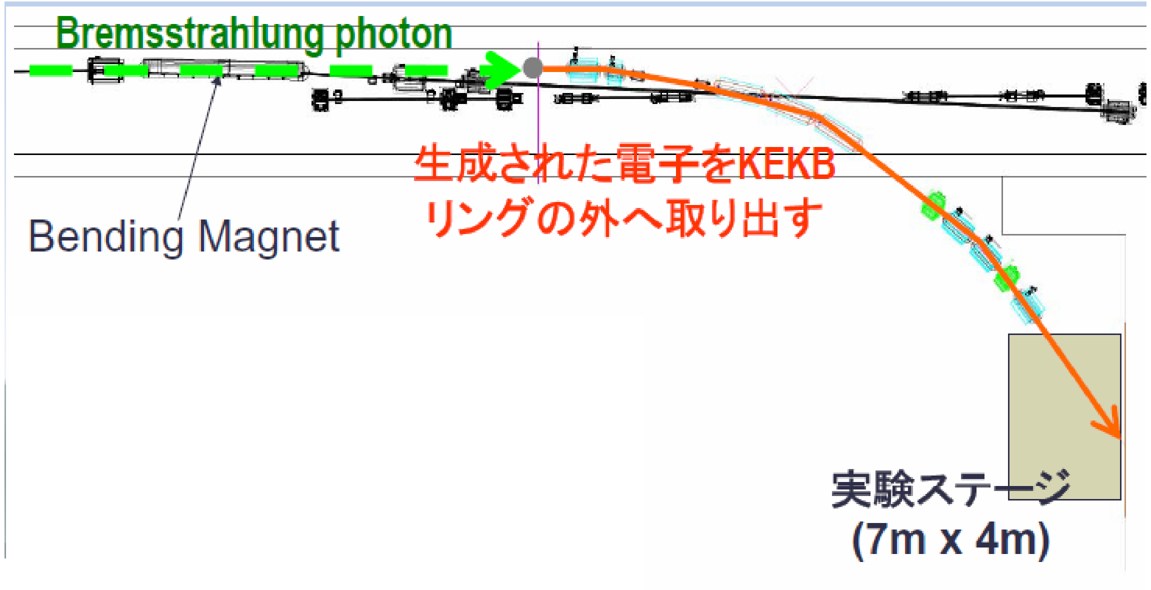
Schedule & people

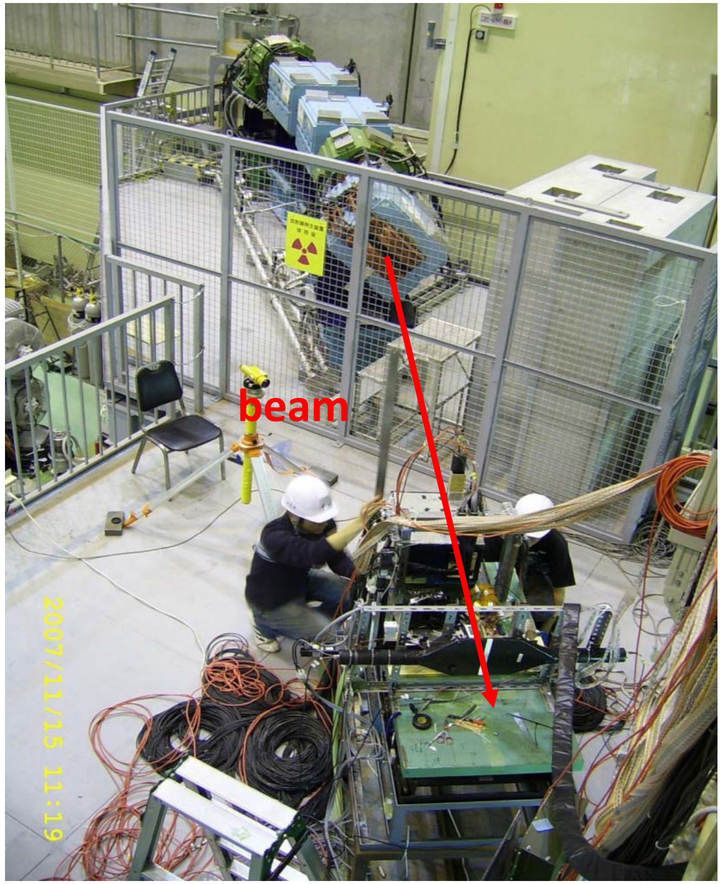
Nov 16th : kick-off meeting
17th ~ 21th : Setup
22th ~ 29th : Data taking
(including 4 days of beamtime extension)
29th : withdrawal

People

D. Kong (KNU)
K. Kawagoe (Kobe)
D. Jeans (kobe)
T. Kaneko (Kobe)
H. Ikeda (Kobe)
K. Ueyama (Kobe)
T. Takeshita (shinshu)
S. Uozumi (shinshu)
M. Nishiyama (Shinshu)
Y. Sudo (Tsukuba)
T. Ikuno (Tsukuba)
H. Yamazaki (Tsukuba)
Y. Takahashi (Tsukuba)

KEK Fuji beam line

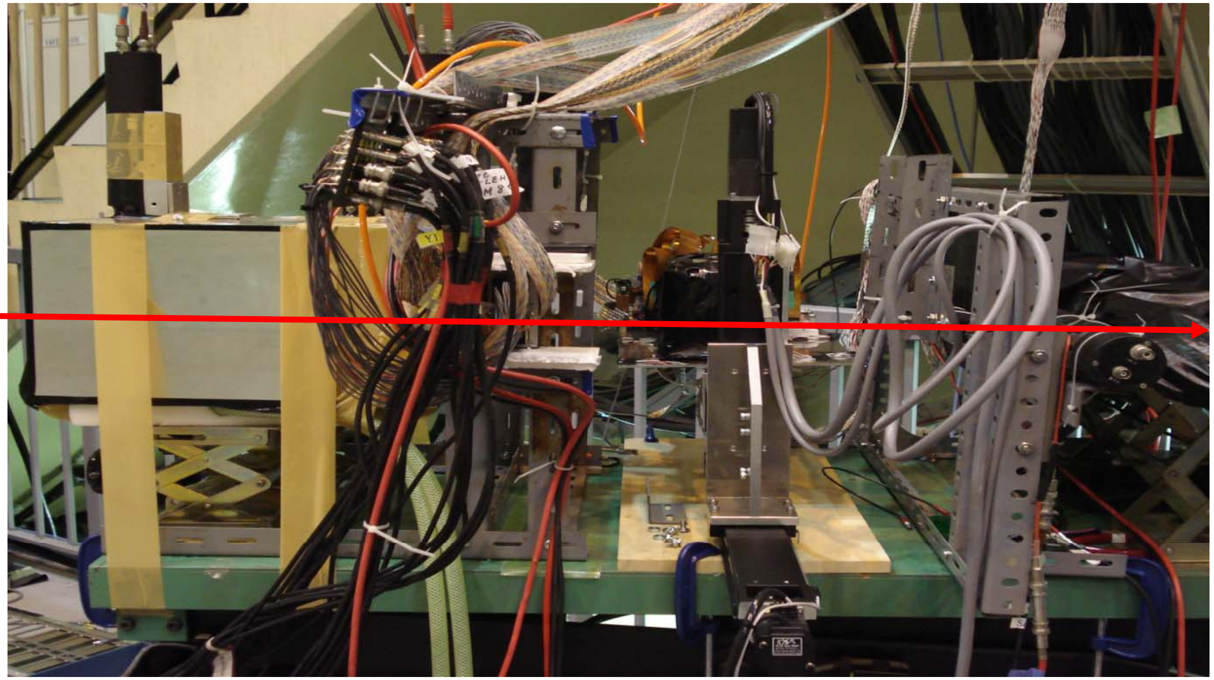




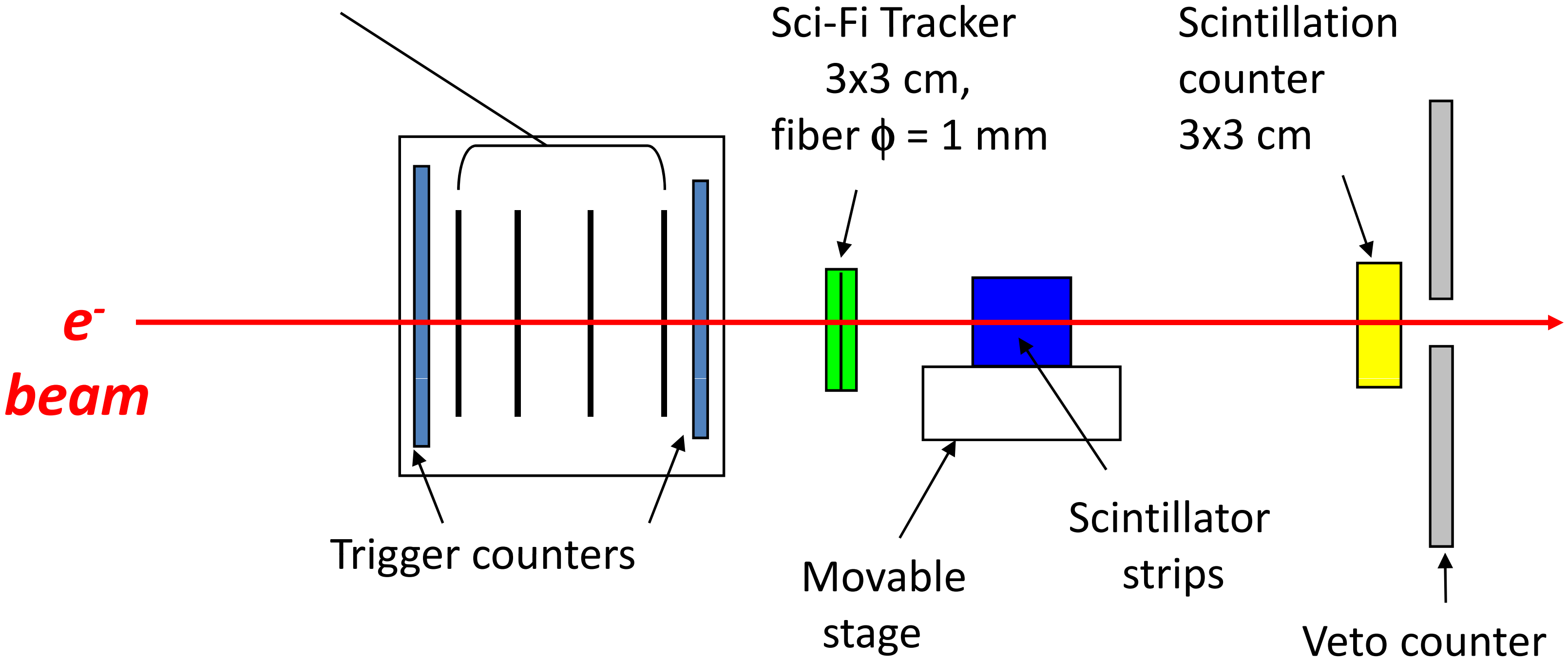
- Electron beam line in Fuji experiment hall
- Make use of bremsstrahlung photons from KEKB ring
- Beam energy : 3 GeV (can not be changed for now)
- Beam spot size: ~ 3 x 4 cm
- Rate: 15Hz @ 3 GeV
- Temperature in the beamline is perfectly stabilized.

Setup

Beam
e^-



ATLAS SCT
12 cm × 6 cm
σx ~ 25 μm,
σy ~ 500 μm



Extruded scinrillator strips
(3 mm thick)

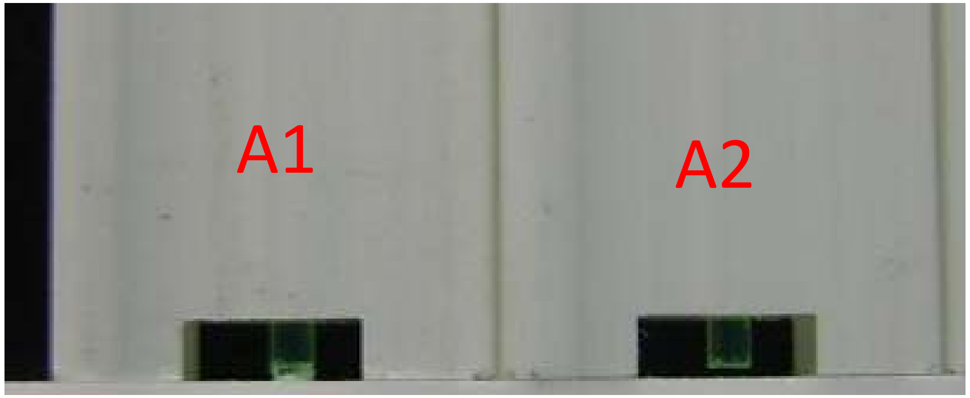
Type : A

with the fiber hole painted by TiO2

A1 : fiber-MPPC bad matching

no fiber inserted

A2 : fiber-MPPC good matching



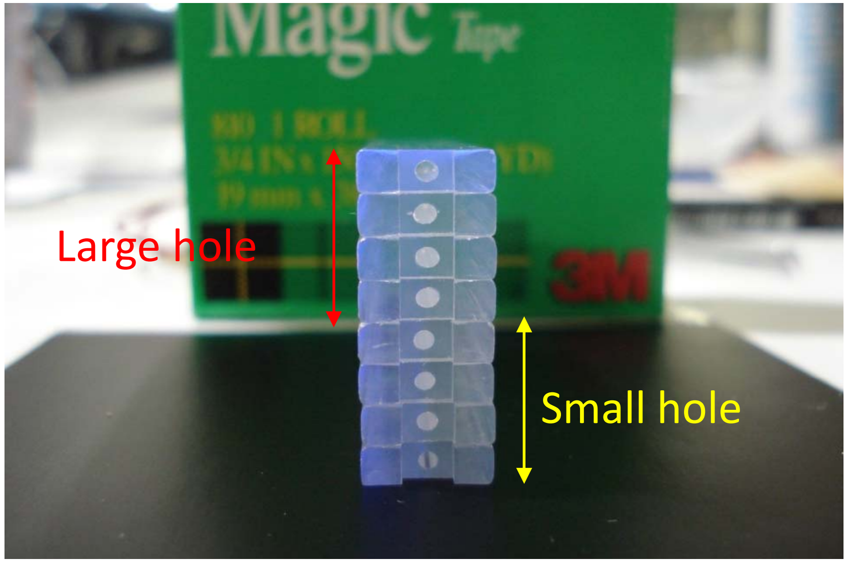
Type : B

with the fiber hole

covered with KIMOTO reflector film

B1 : large hole

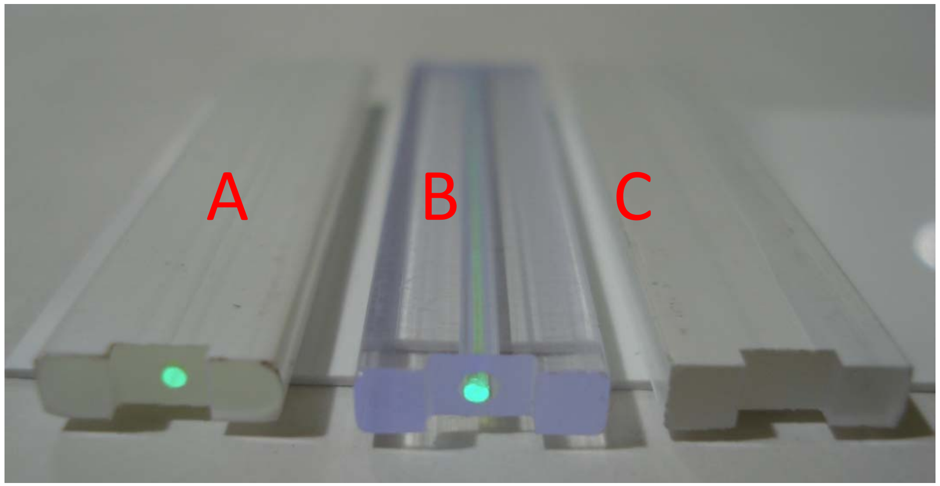
B2 : matched hole



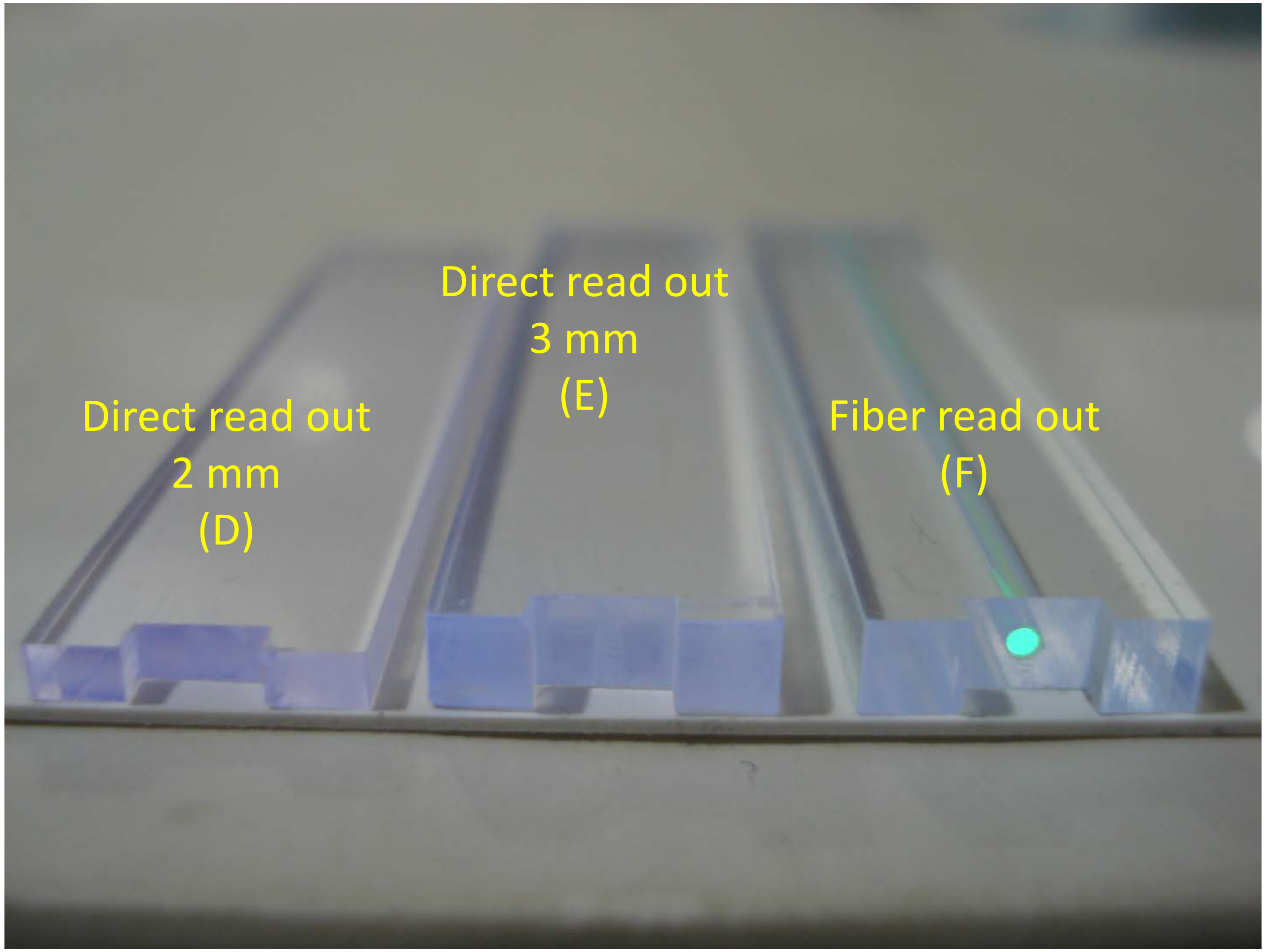
Type : C

painted by TiO_2

without the fiber hole



Kuraray Scintillators



D : Direct read out (2 mm thick)
E : Direct read out (3 mm thick)
F : Fiber read out   (3 mm thick) … REFERENCE

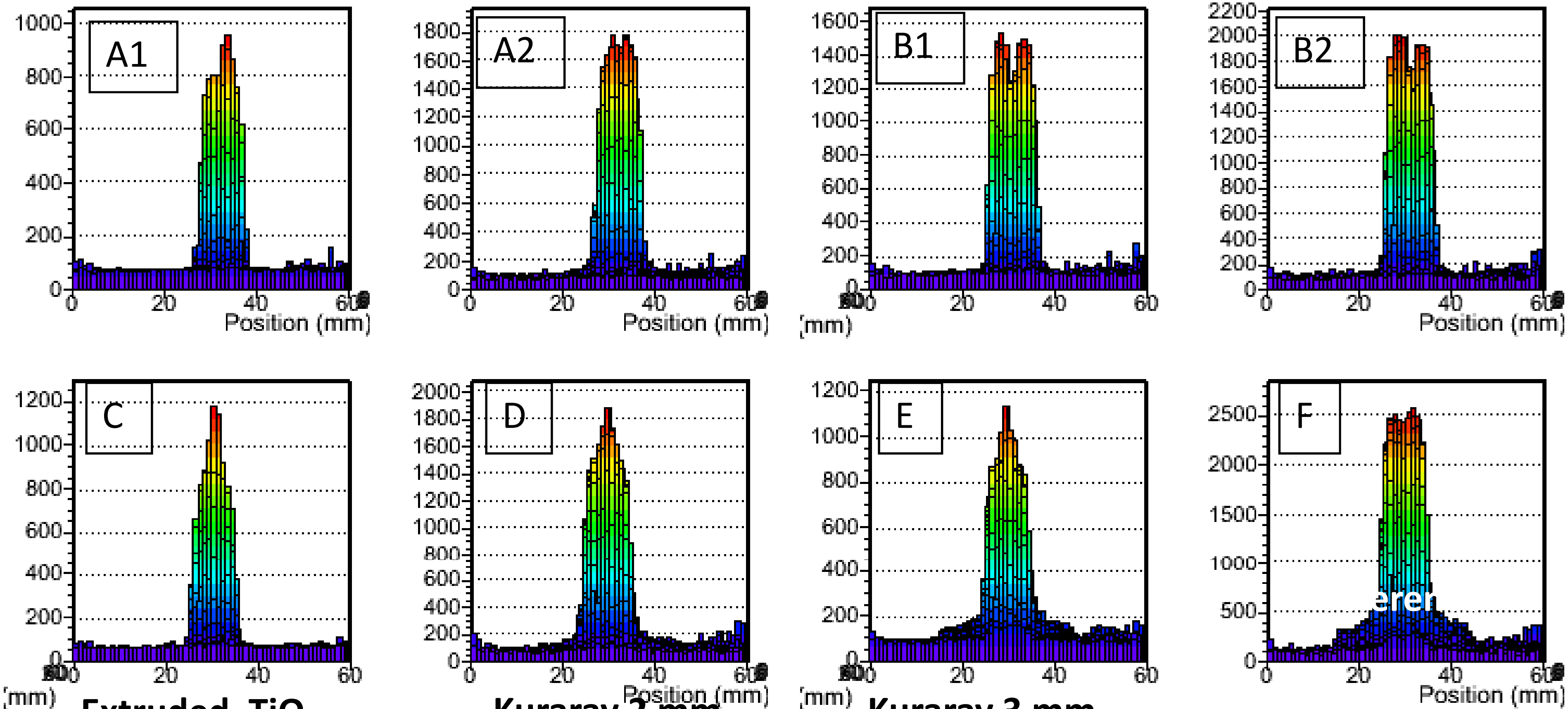
Lateral Response Uniformity

Extruded, TiO_2 Fiber readout but no fiber

Extruded, TiO_2 Fiber readout

Extruded, reflector Fiber readout large hole

Extruded, reflector Fiber readout Matched hole



Extruded, TiO_2 Direct readout

Kuraray 2 mm reflector Direct readout

Kuraray 3 mm reflector Direct readout

Kuraray 3 mm reflector Fiber readout