DESY Beam Test of a EM Calorimeter Prototype with Extruded Scintillator Strips

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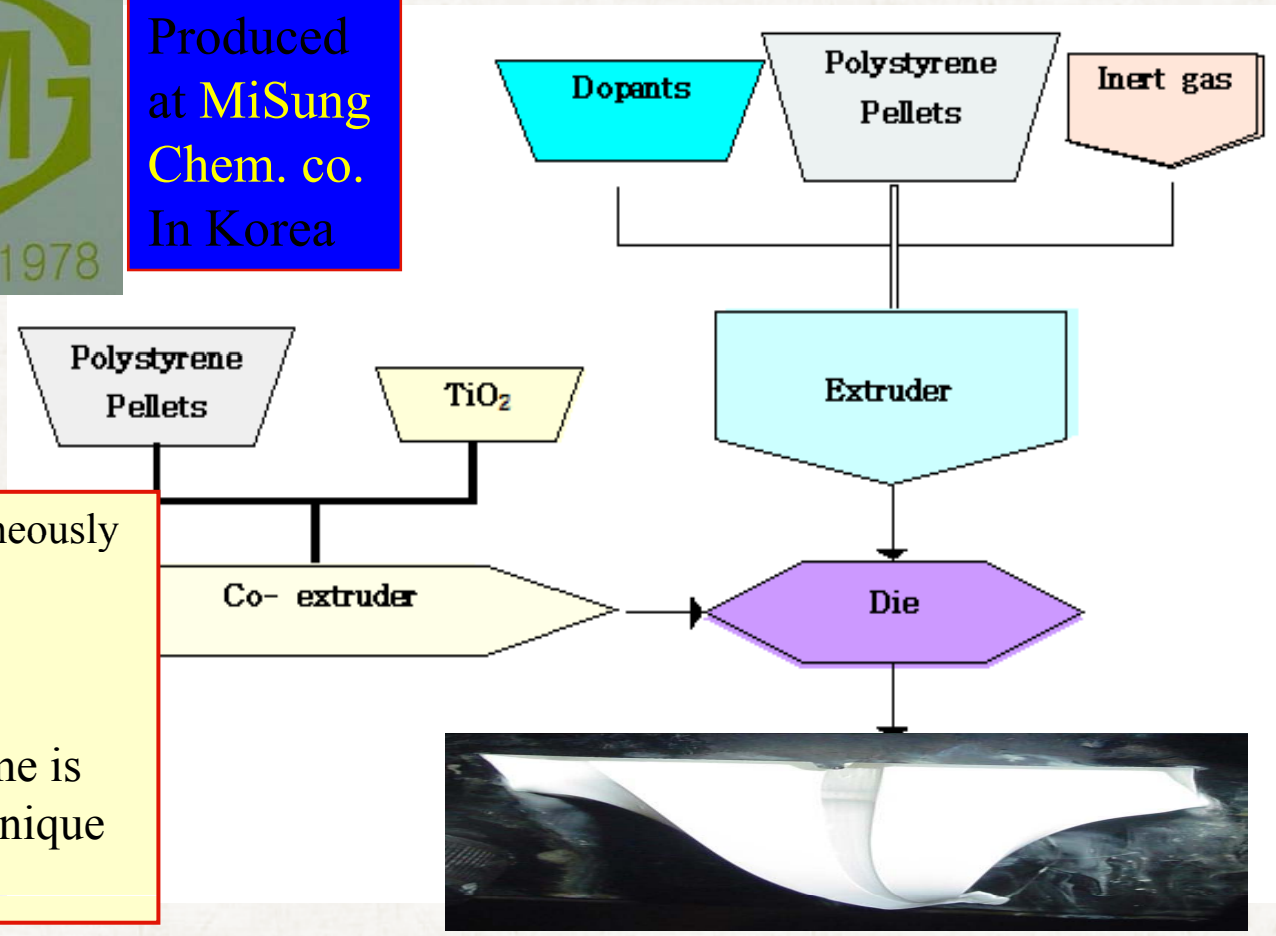
CAST Plastic Scintillator

- Probably the most commonly used organic scintillator in nuclear & high energy physics so far
- The plate used to be cut, polished, light reflector added etc..as wished.
- Recent demand of calorimetry tend to be with a fine cell (size of $1 \sim 4\ cm^2$)
  - Cast scintillator requires lots of procedures for final module and cost more
    ex) $40/kg-$60/kg (2000)
    $80/kg (2004)
    $100/kg (2005)
    $200/kg (2006)
  - Machining of the raw sheets (+ $200/kg)
  - → significantly add to the final detector cost & time

We may need a resaonable method to produce scintillator in terms of manufacturing processes and even cost → Extrusion Technique

Extruded Scintillator

Produced at MiSung Chem. co. In Korea



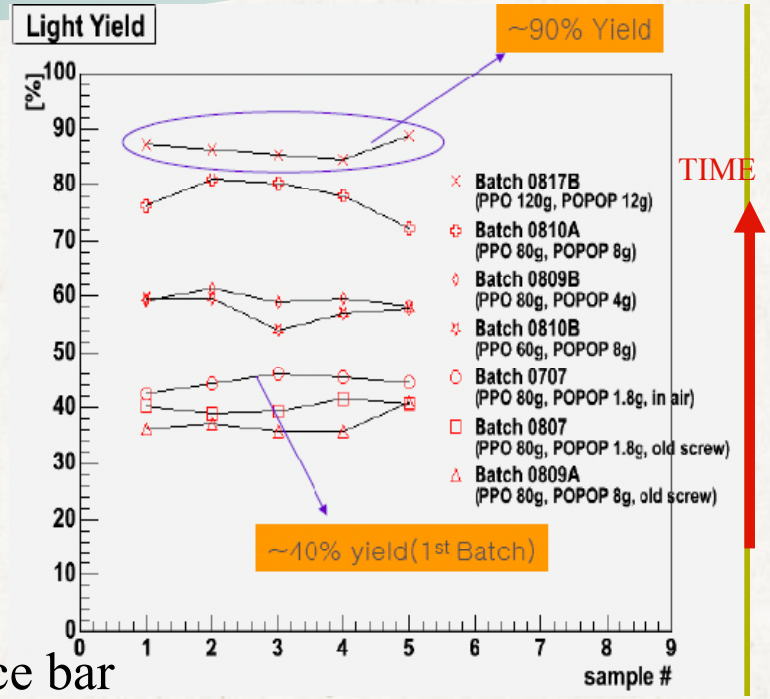
- Light Reflector comes simultaneously
- reduce lots of procedures
- rather cheap
- As long as a fine cell scheme is concerned → Extrusion technique may be more reliable

History

- 2004-2005
  - R&D of dopants (primary & secondary)
  - R&D of groove (length, depth & shape)
  - R&D of Light yield
  - Design optimization (length, width, Thickness)
- 2006
  - R & D of ECAL strip scintillator
  - Production of strips for ECAL prototype
- 2007
  - DESY Test beam studies of the ECAL test module

Early R & D

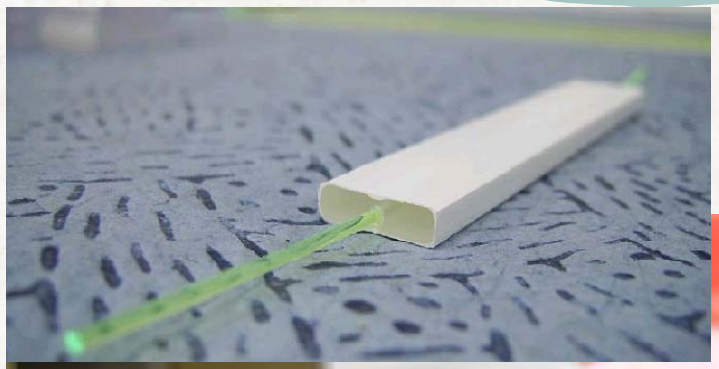
- Start with MINOS strip(bar) produced (4cm(width)X1cm(thickness)
  - → The mechanical process has been established

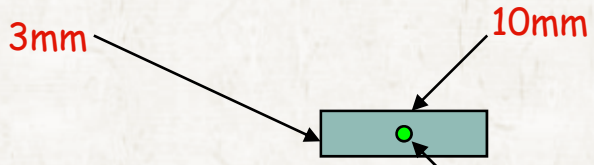


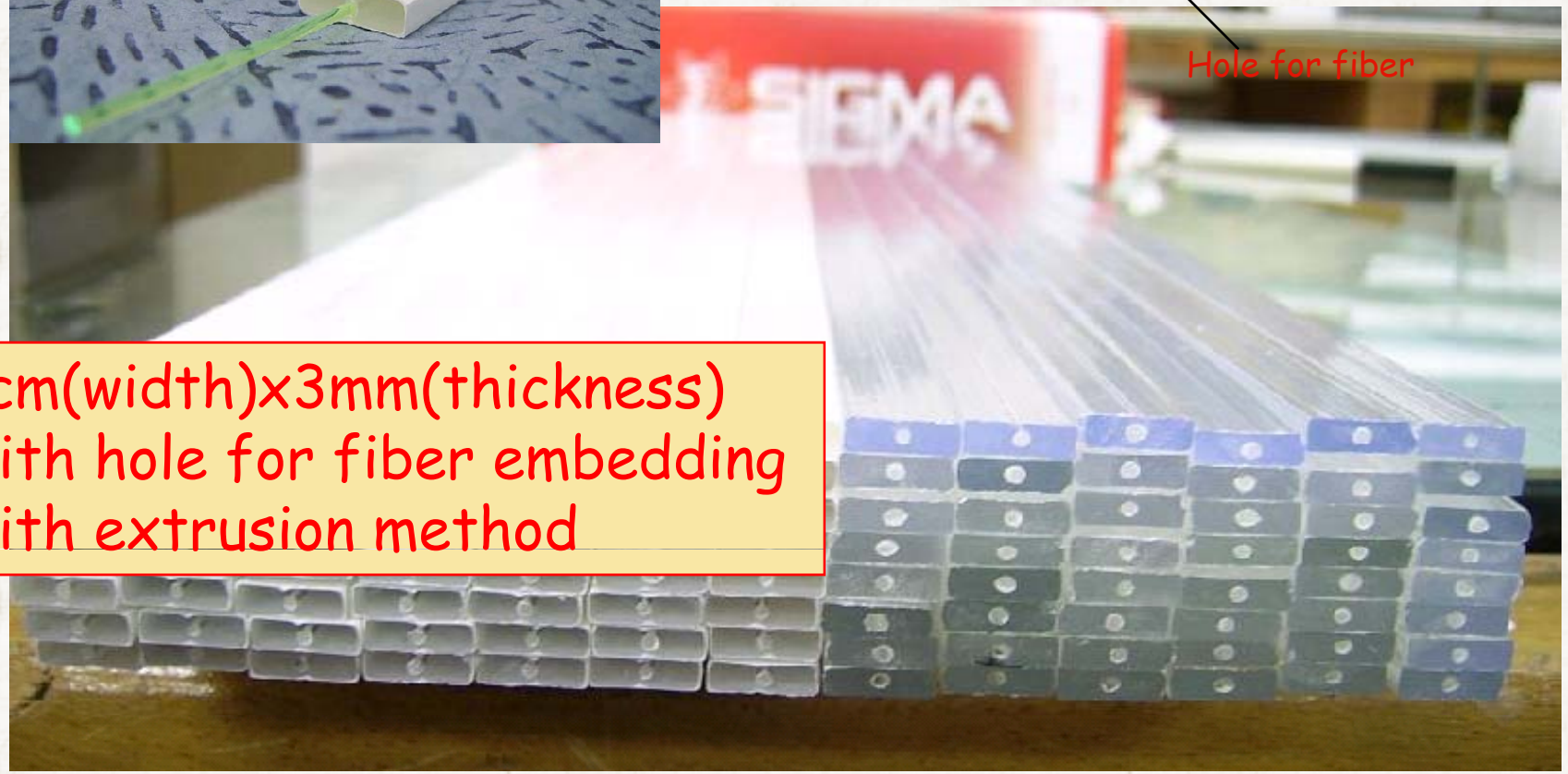
  - → Light yield comparable with MINOS reference bar
  - → proper ratio of polystyrene:PPO:POPOP

- After making sure, R & D to produce fine strip scintillator for Tile/W calorimeter ,

Extruded fine scintillator strips





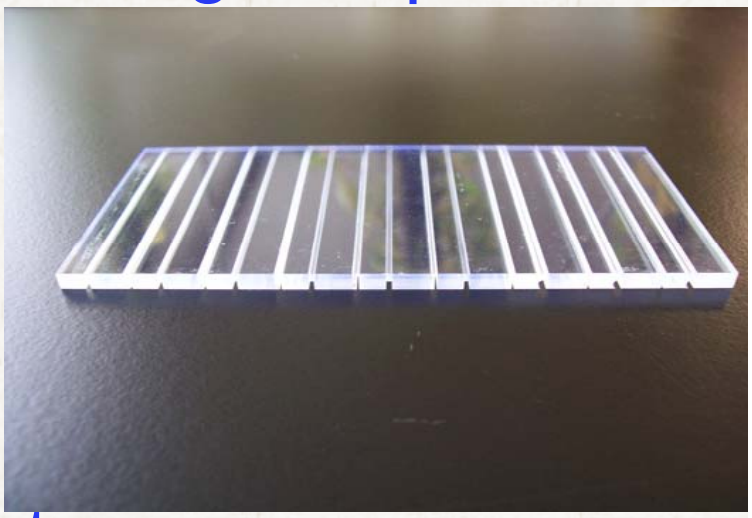


1cm(width)x3mm(thickness)
with hole for fiber embedding
with extrusion method

scintillators

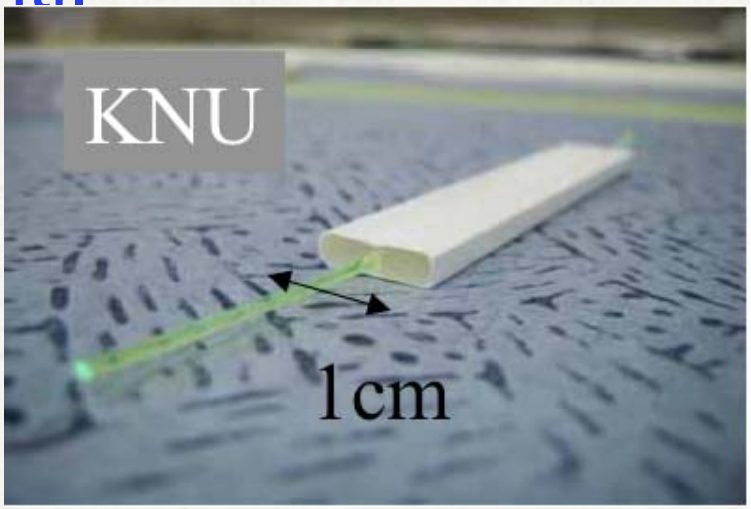
Kuraray plastic scintillator SCS : Mega strip

made from a plate
grooves for WLSF and strip isolation

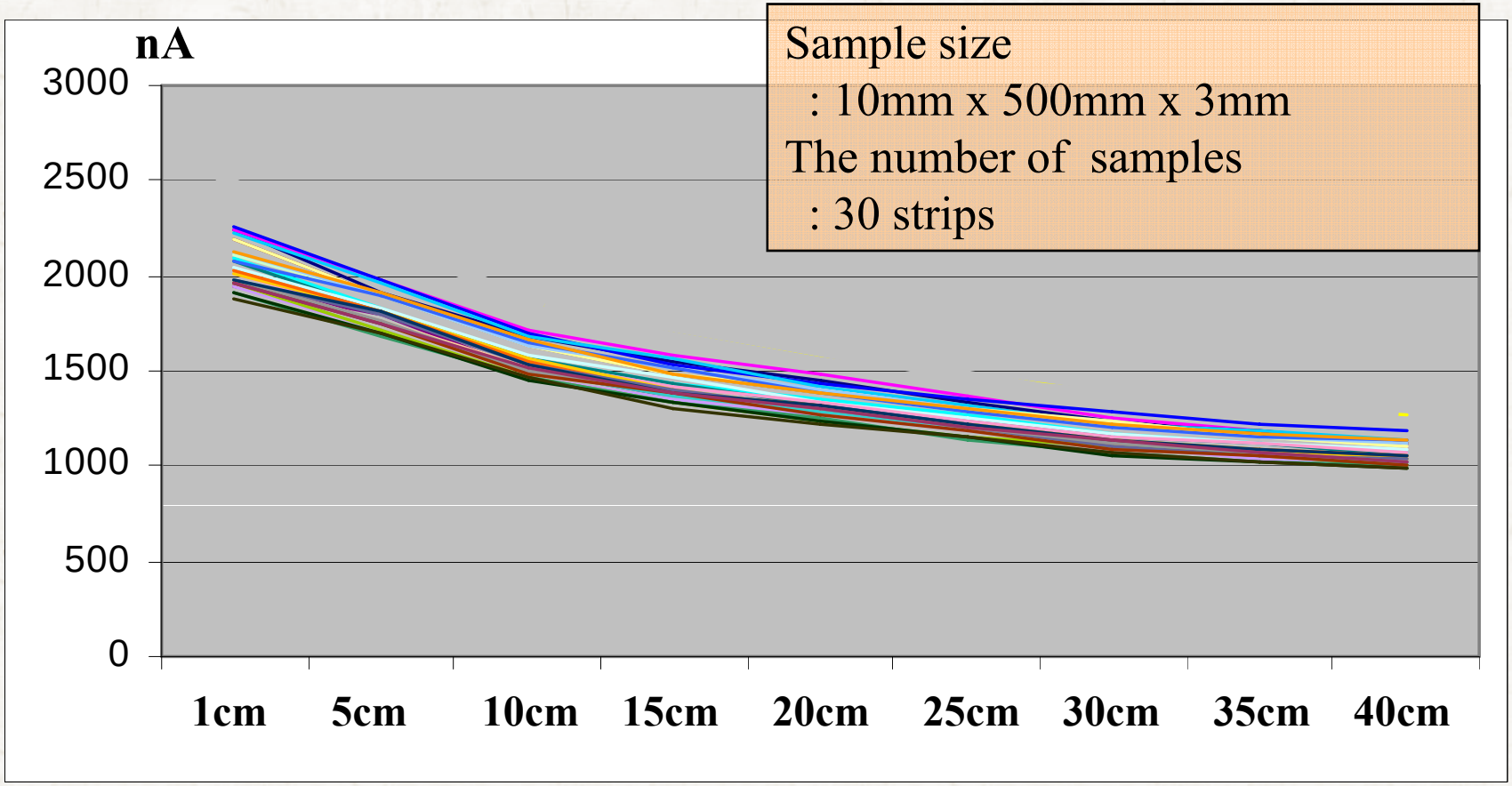


Kyungpook N. U : extruded scinti.

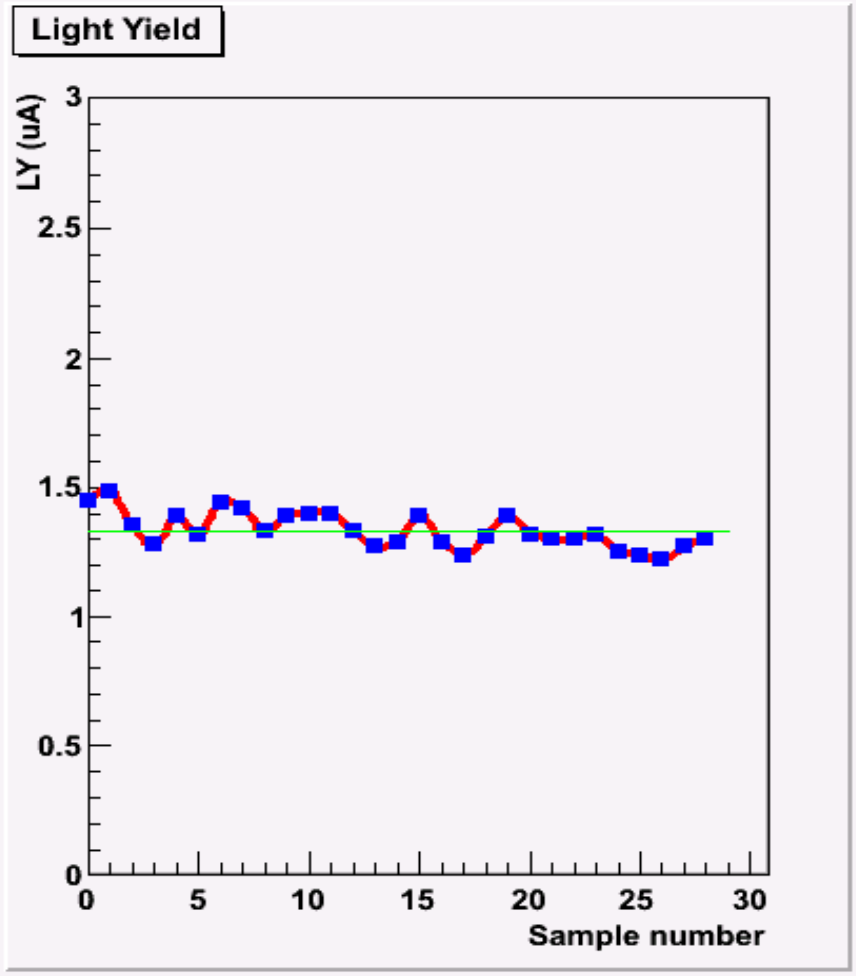
a hole
outer shield by TiO2

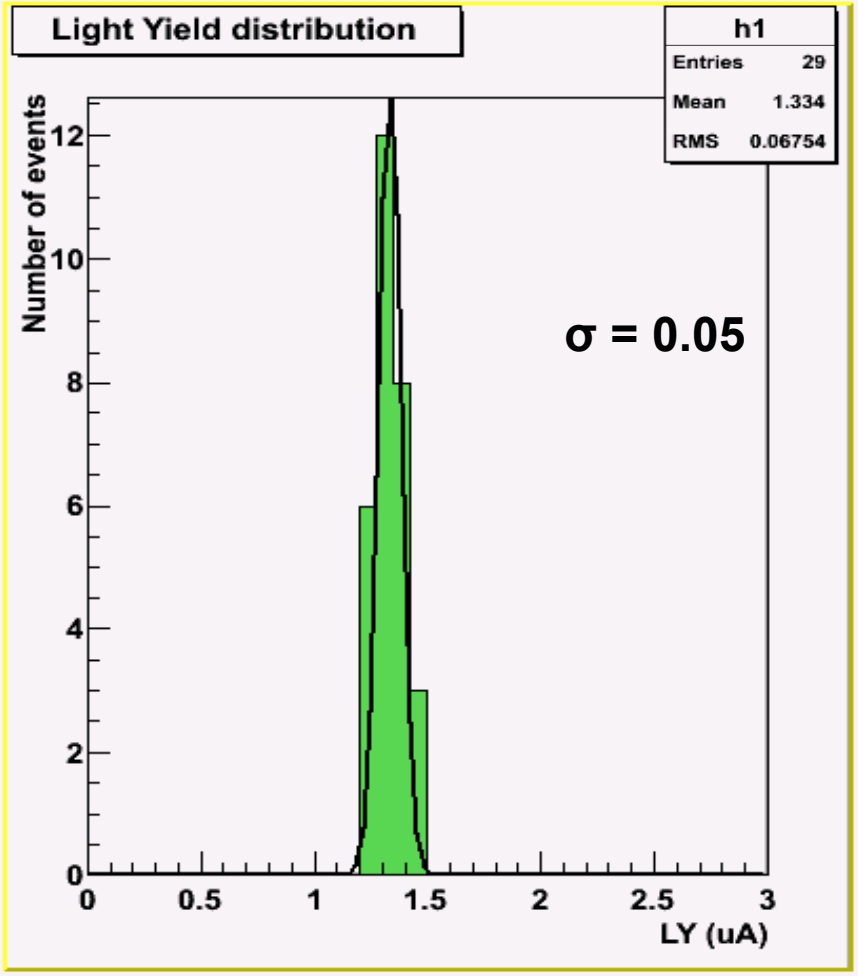


Light Yield along position for each strips

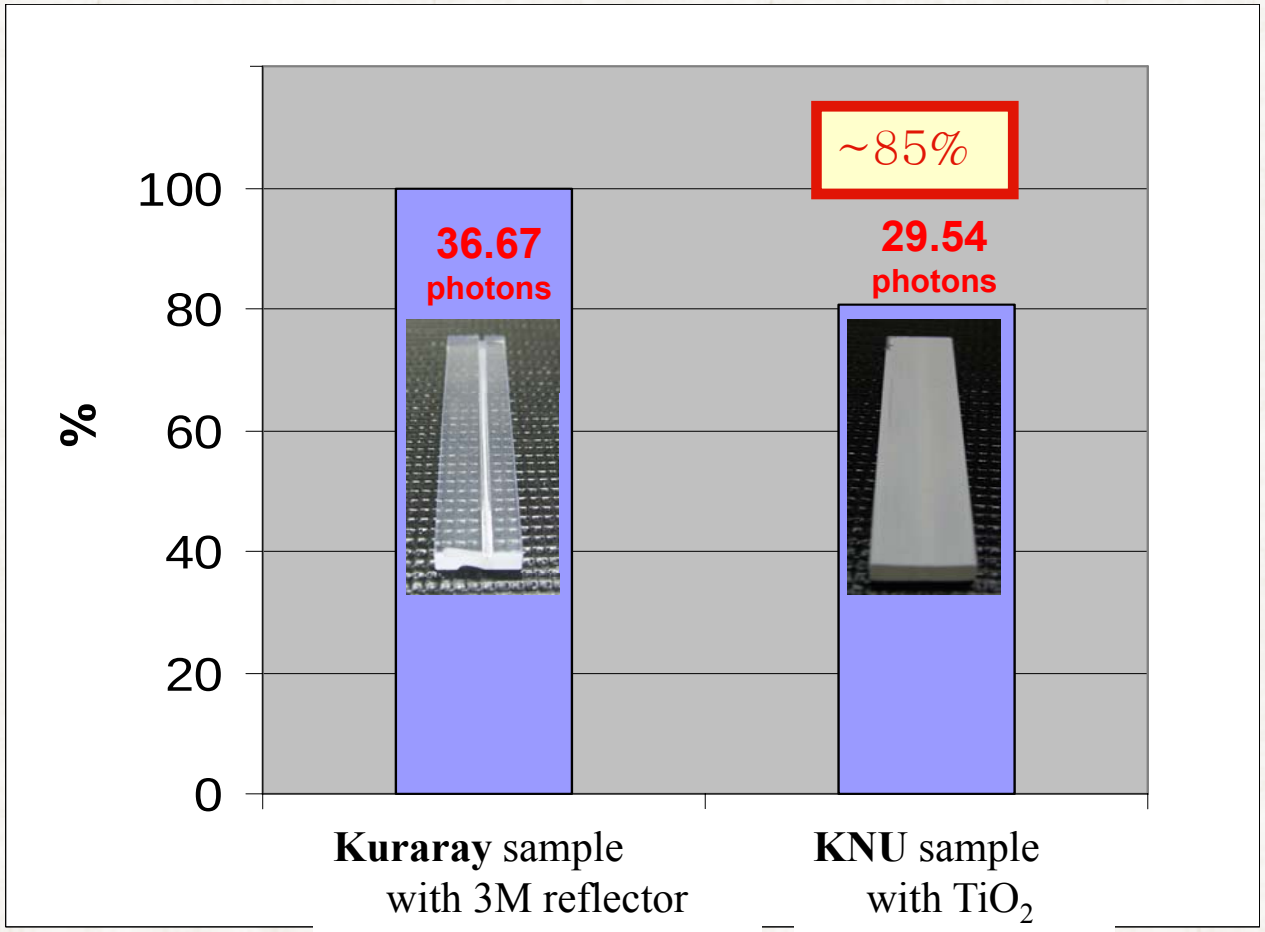


Light Yield Uniformity for all strips

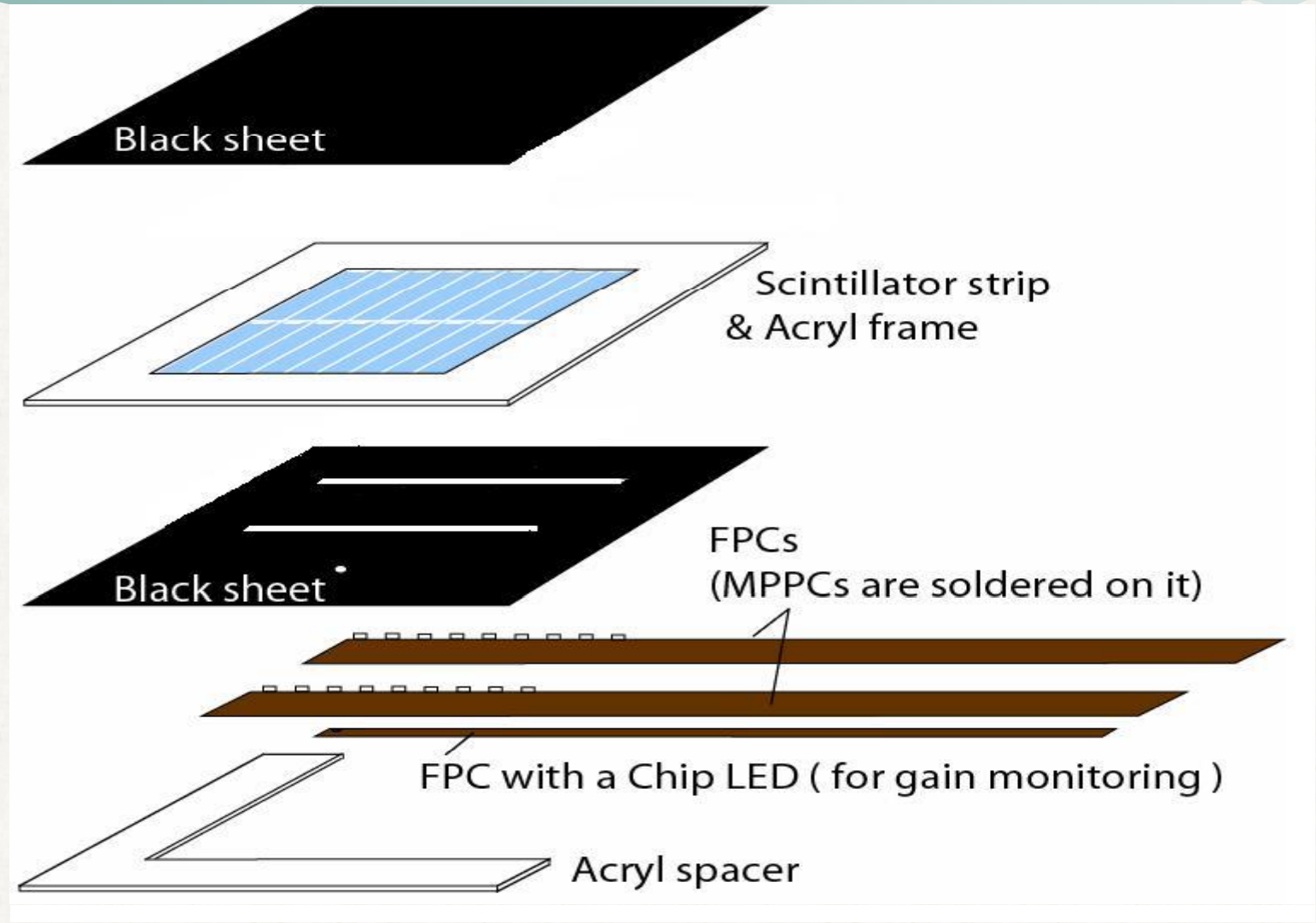




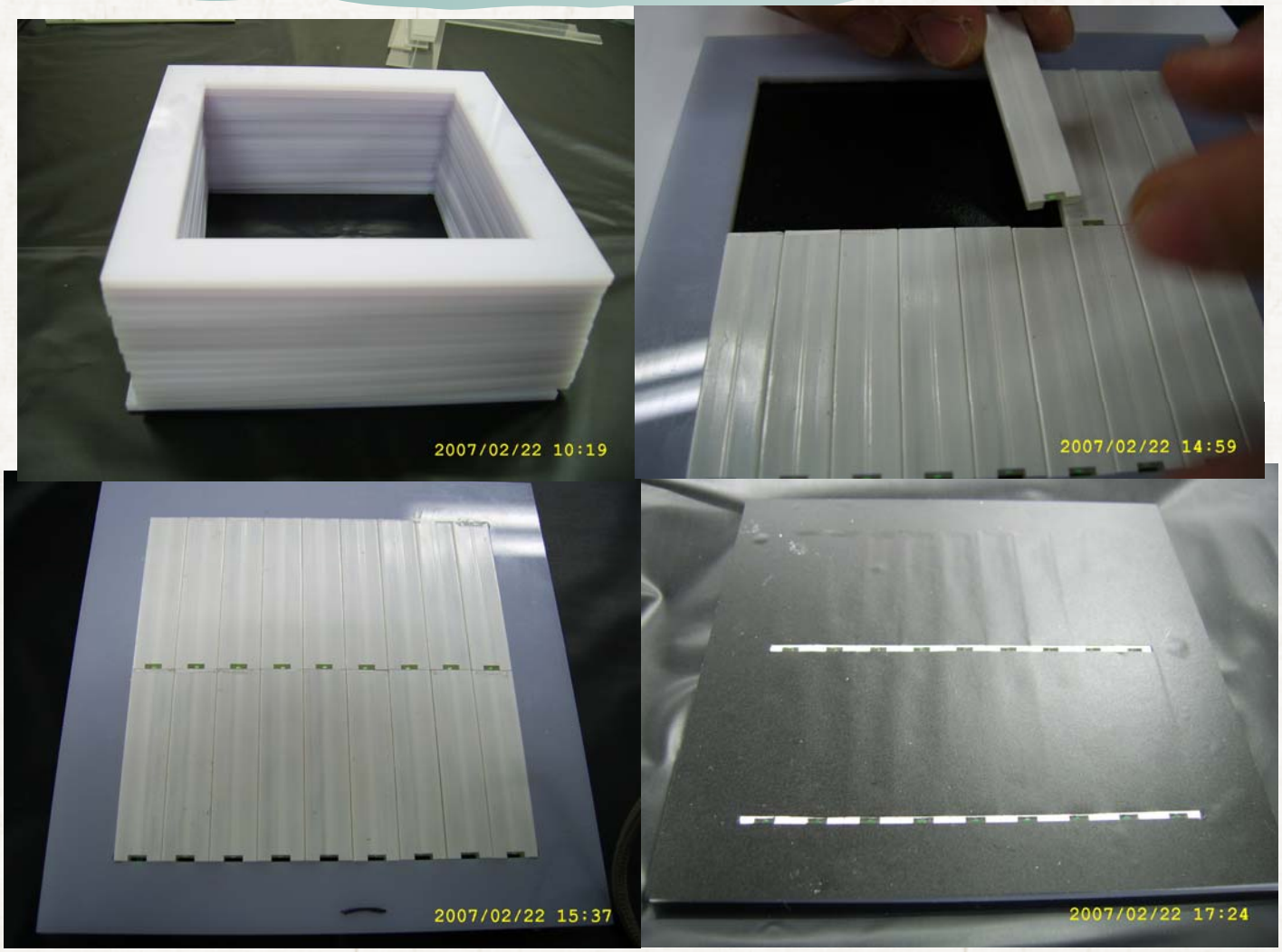
Light Yield Comparison



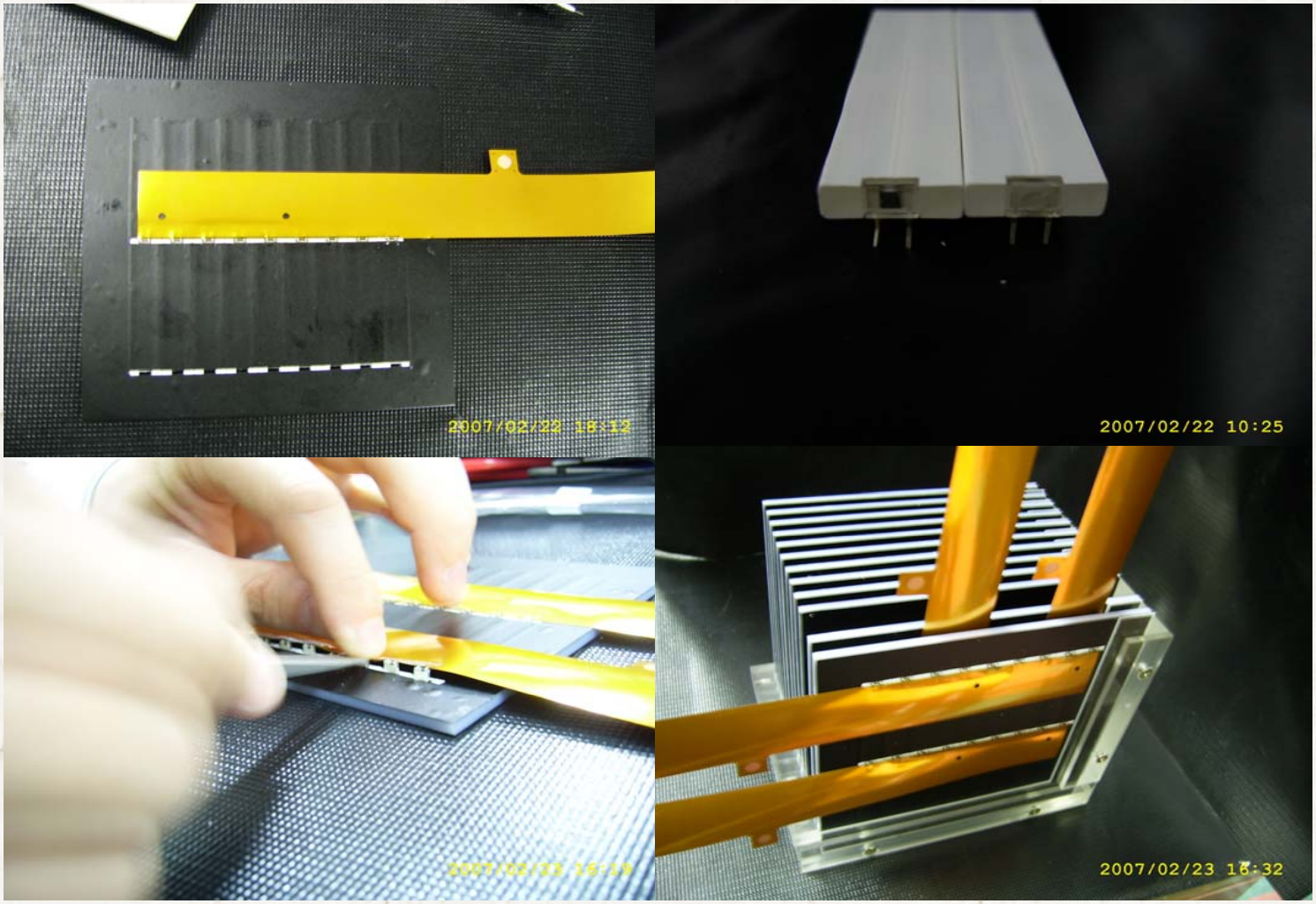
Assembly of a layer



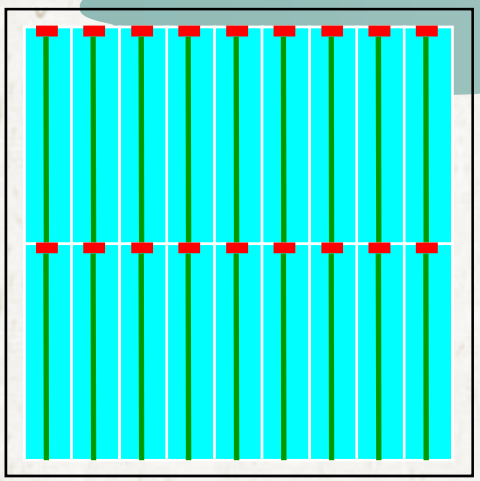
Fabrication of Module



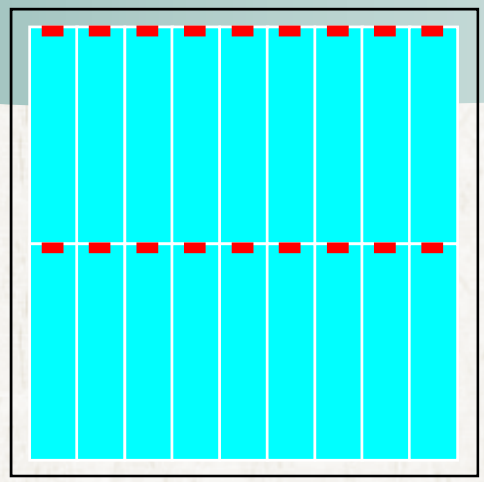
Fabrication with FPCB



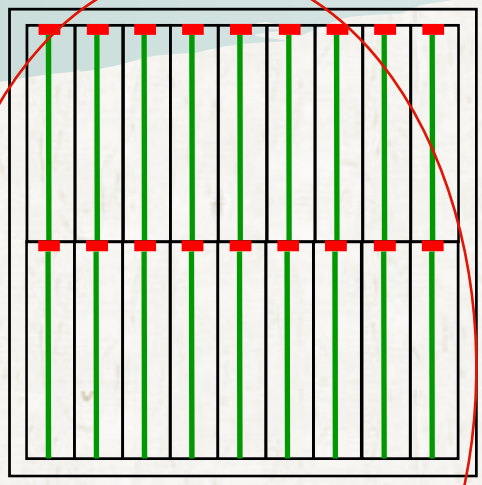
3 Types of Modules tested



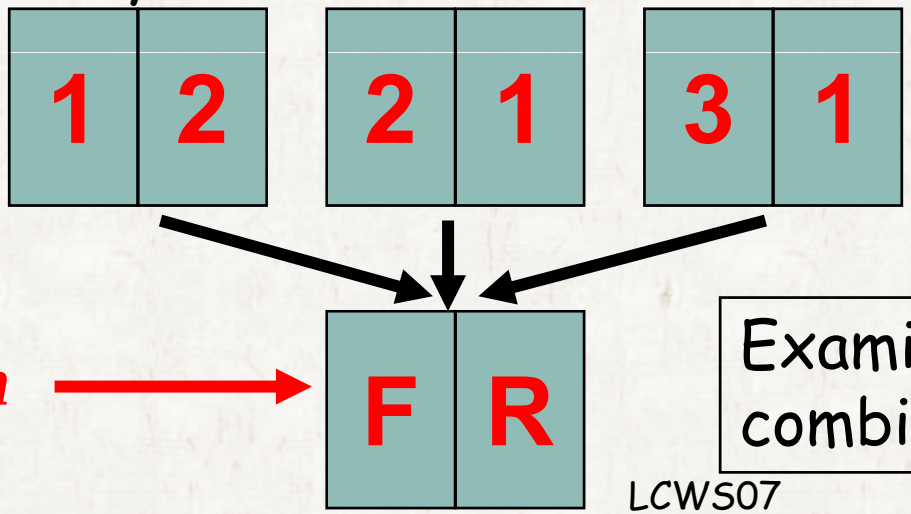
1. Mega-strips, WLSF readout, 13 layers



2. Mega-strips, Direct readout, 13 layers



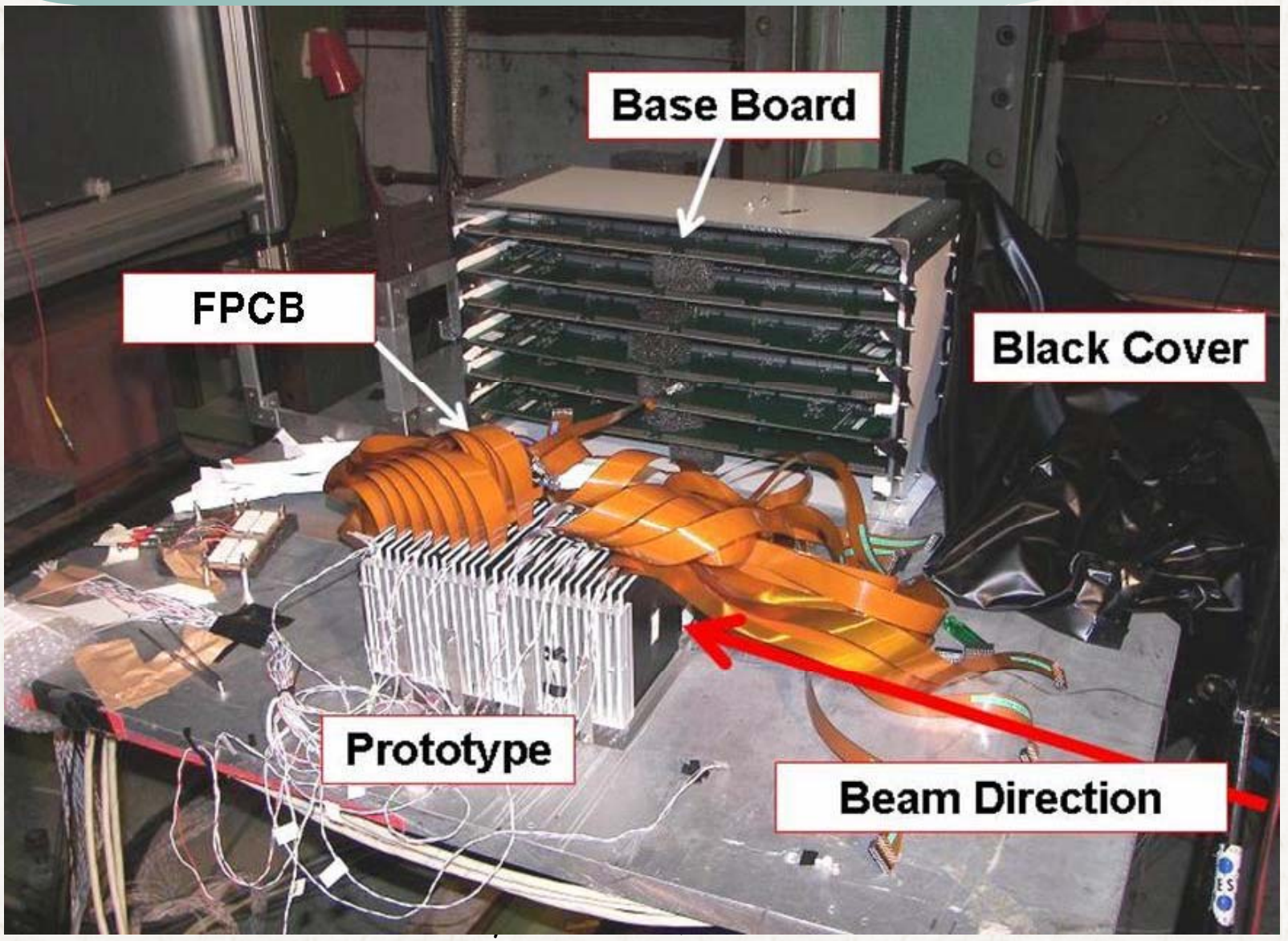
3. Extruded strips covered by TiO_2, WLSF readout, 13 layers (KNU)



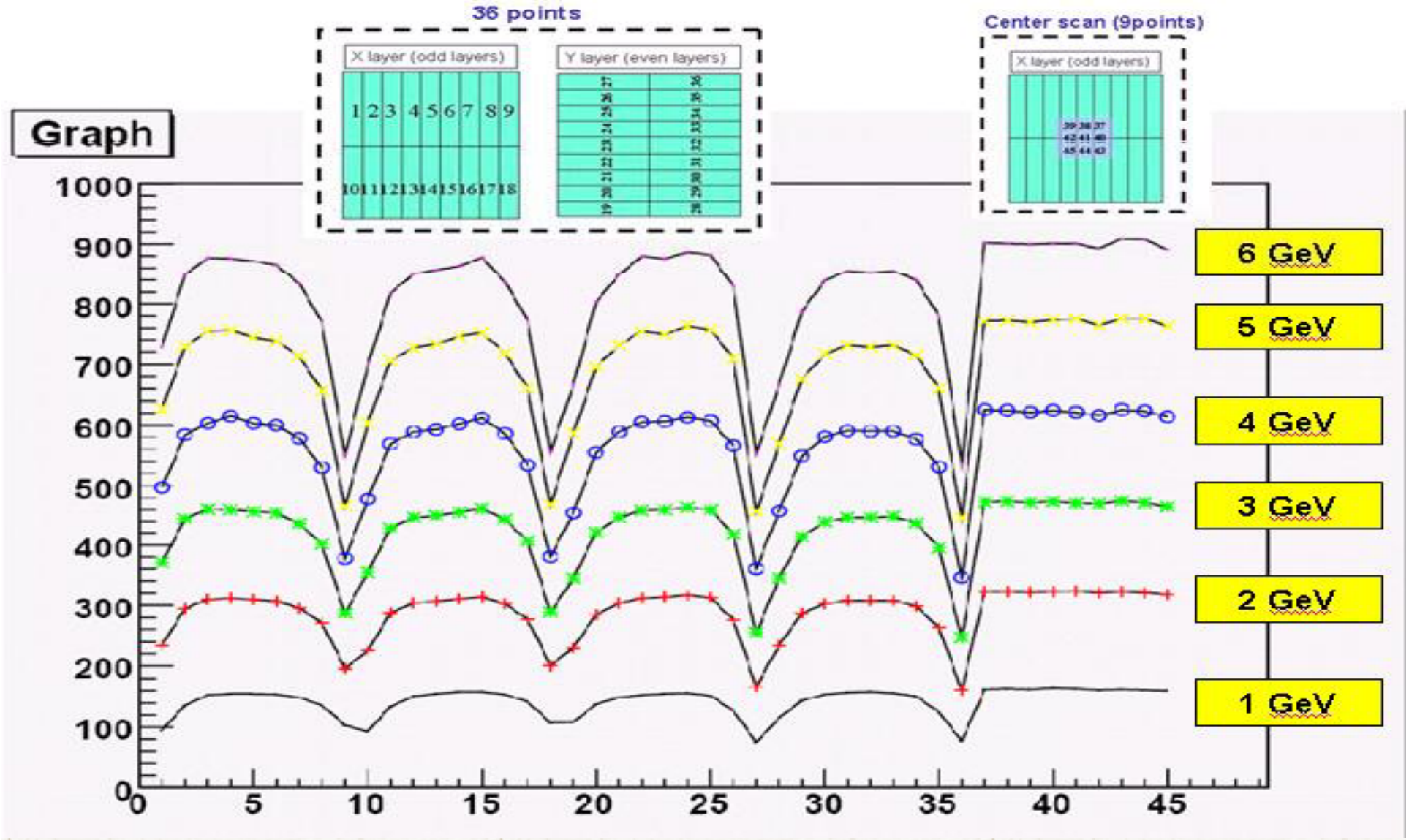
13 + 13 layers

Examined 3 different combinations of the modules.

Prototype Module

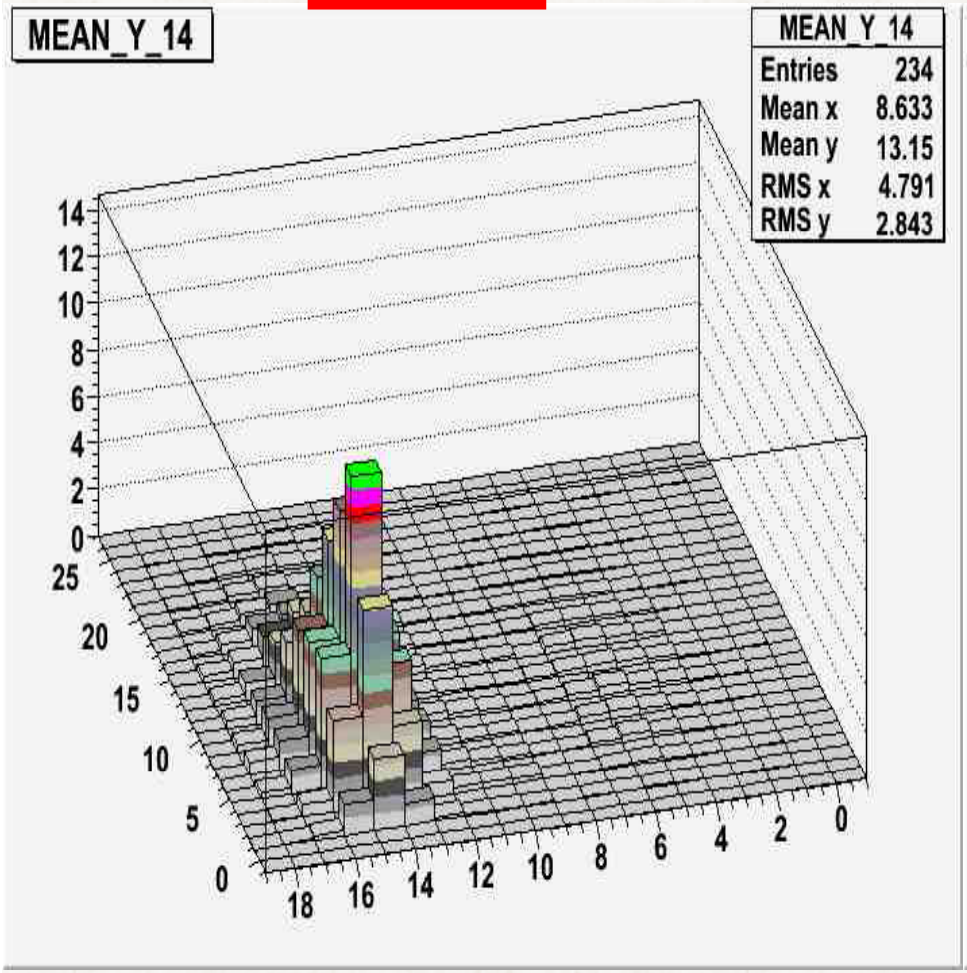


Position scans at 1,2,3,4,5,6 GeV

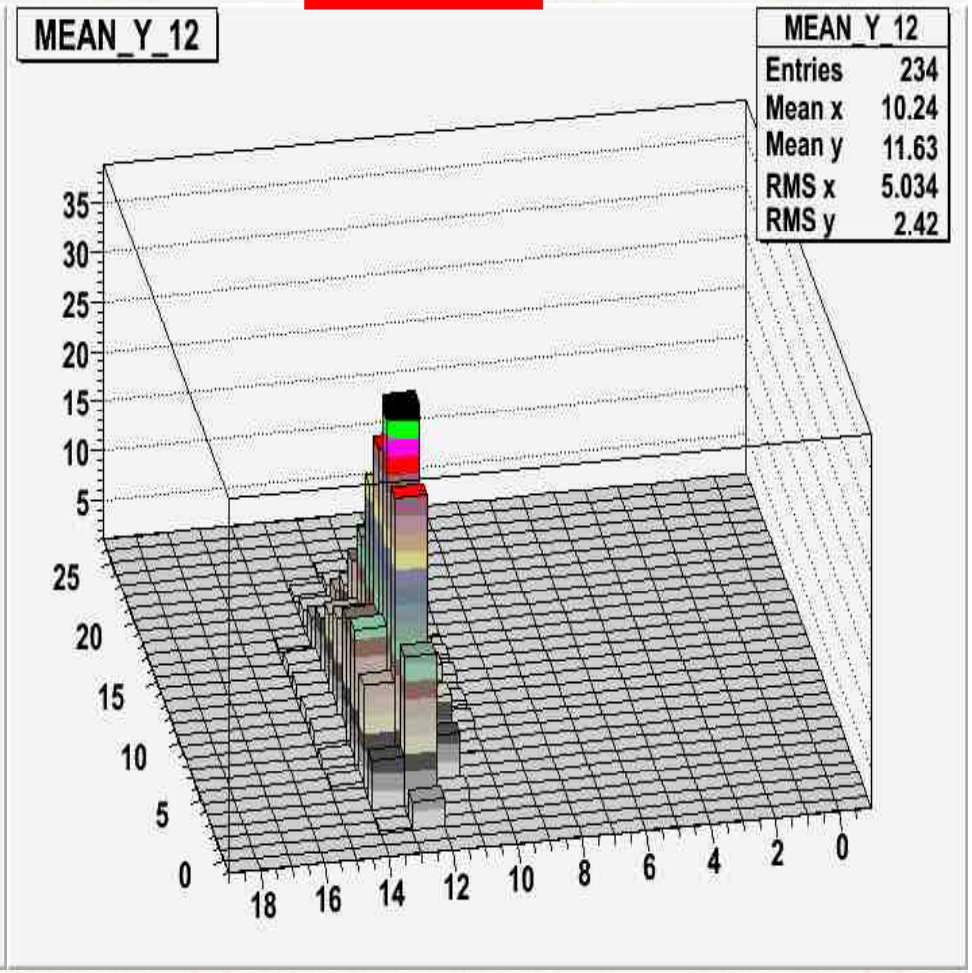


Shower profile at 1 & 6 GeV

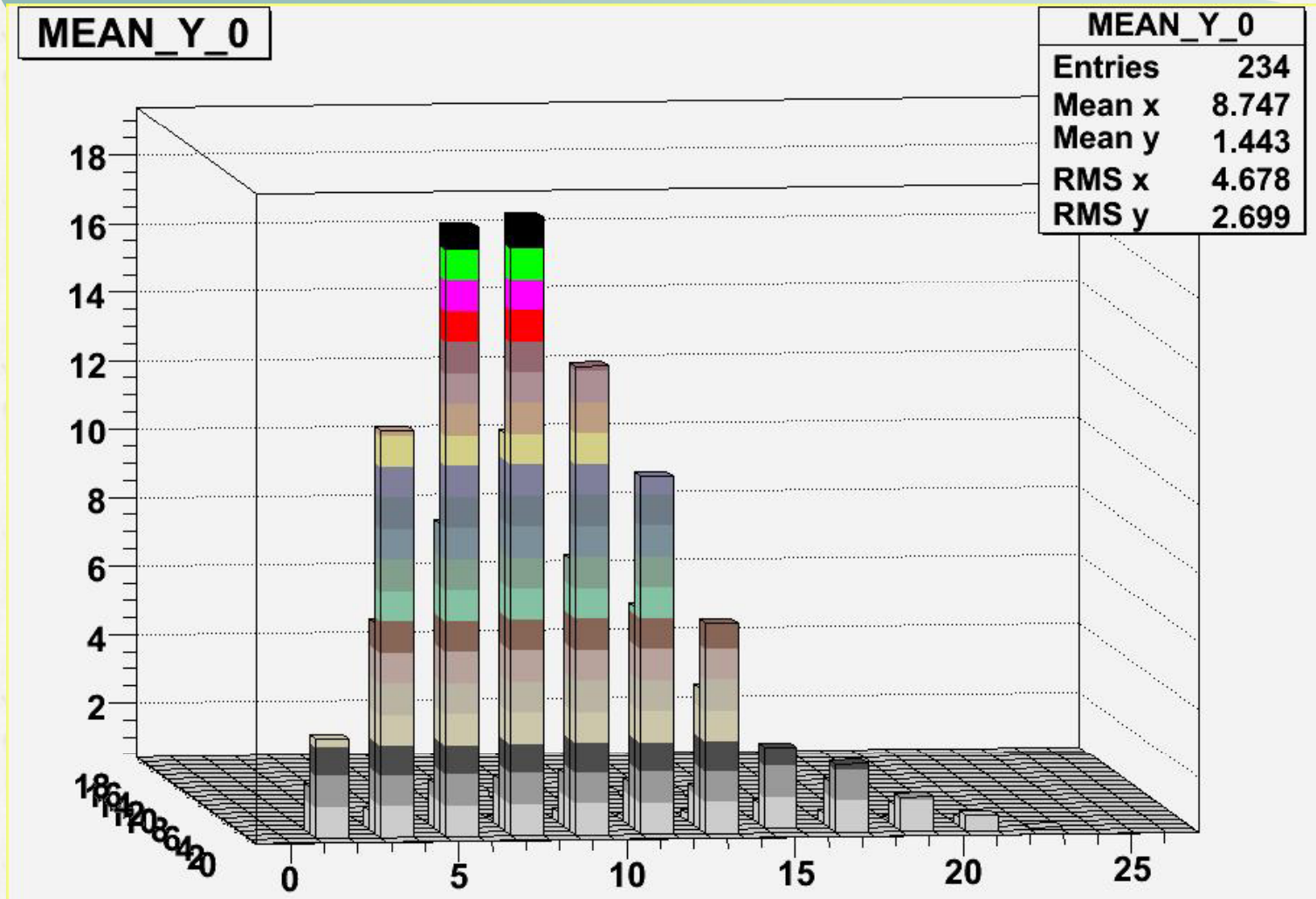
1 GeV



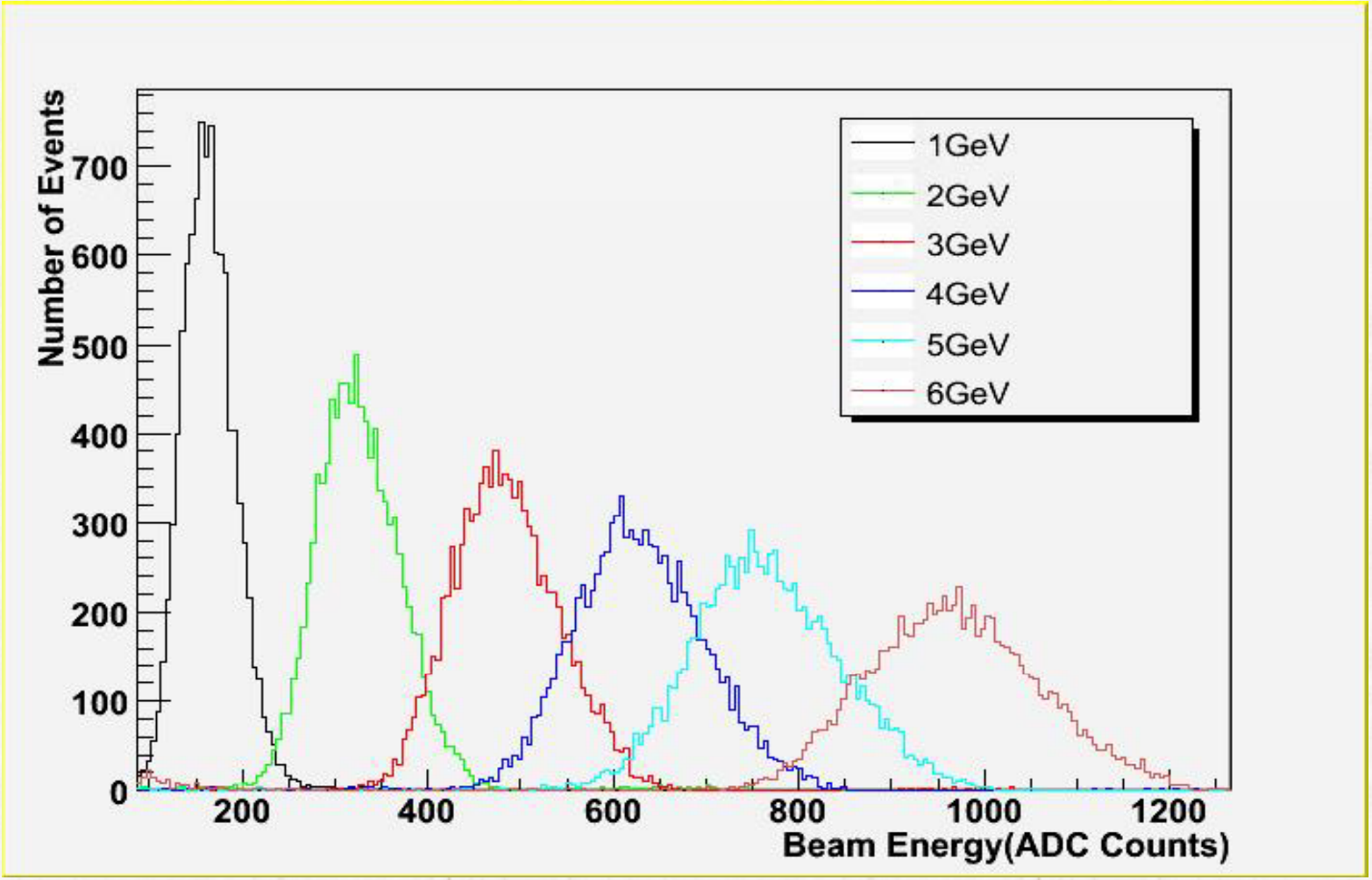
6 GeV



Shower profile in depth



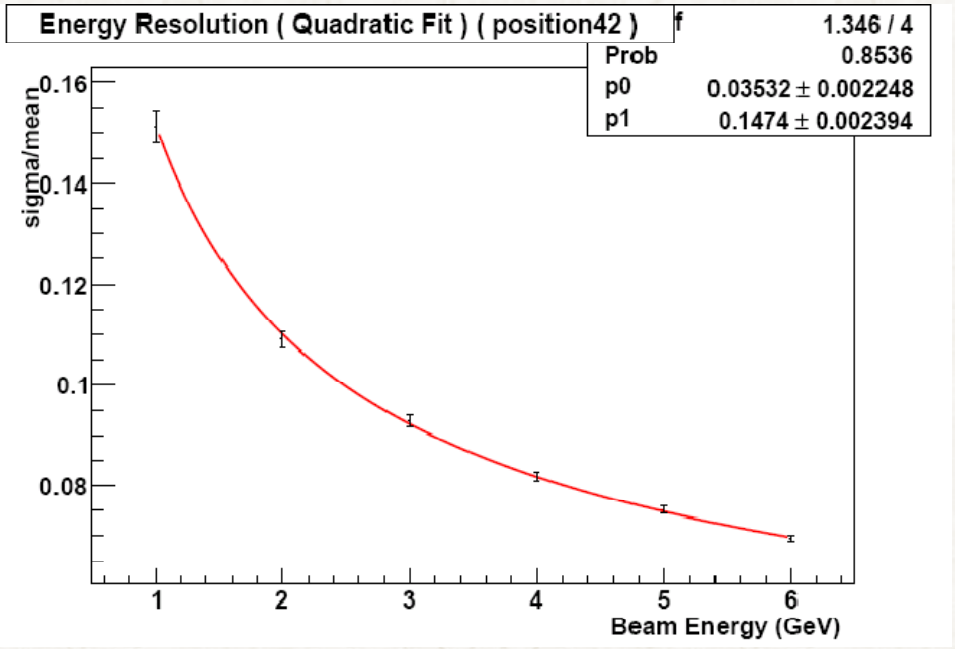
Beam Energy Profile

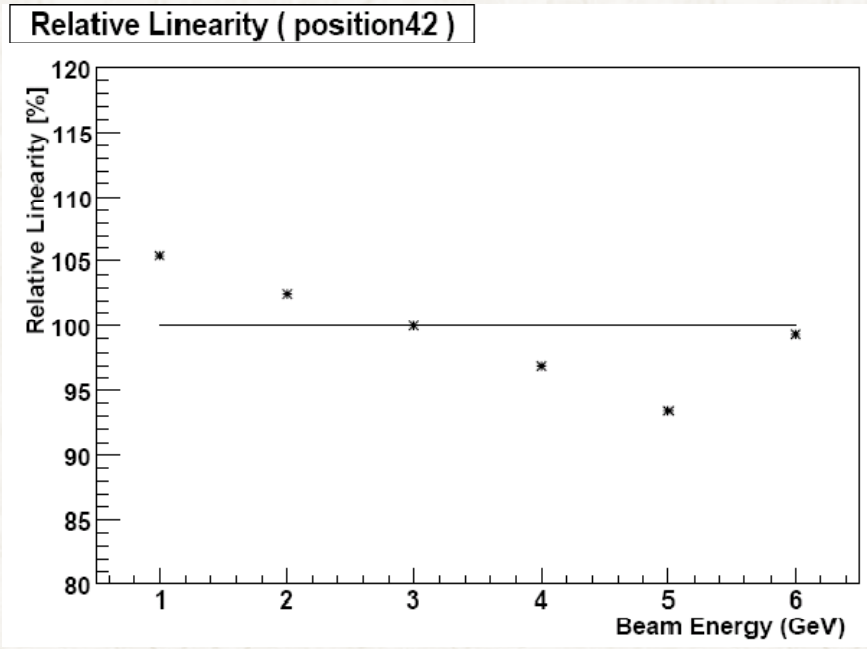


Energy Resolution and Linearity(preliminary)

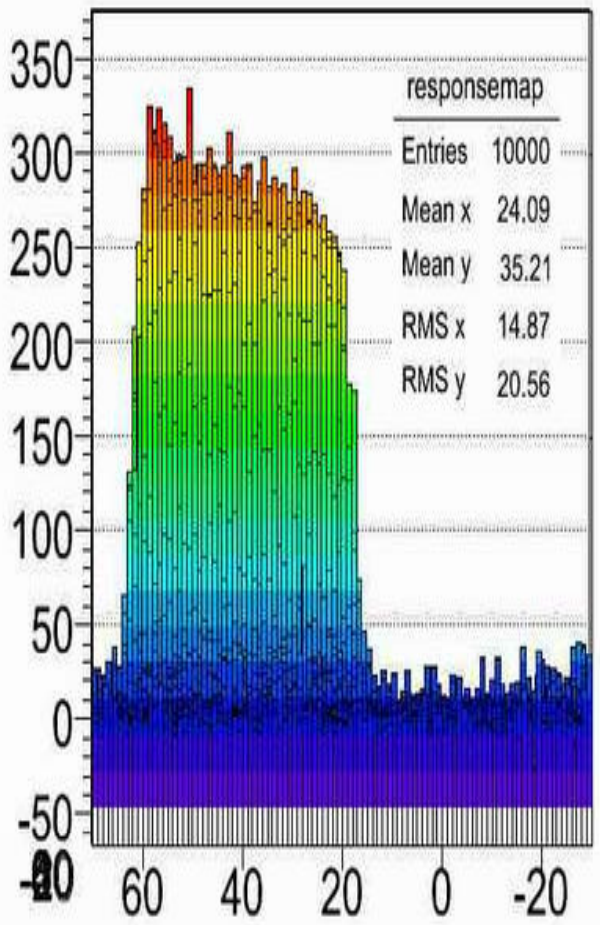
14.7%/√E ⊕ **3.5%**

- Linear term is about to be expected
- Constant term is rather high
- Linearity is ~ 5% level

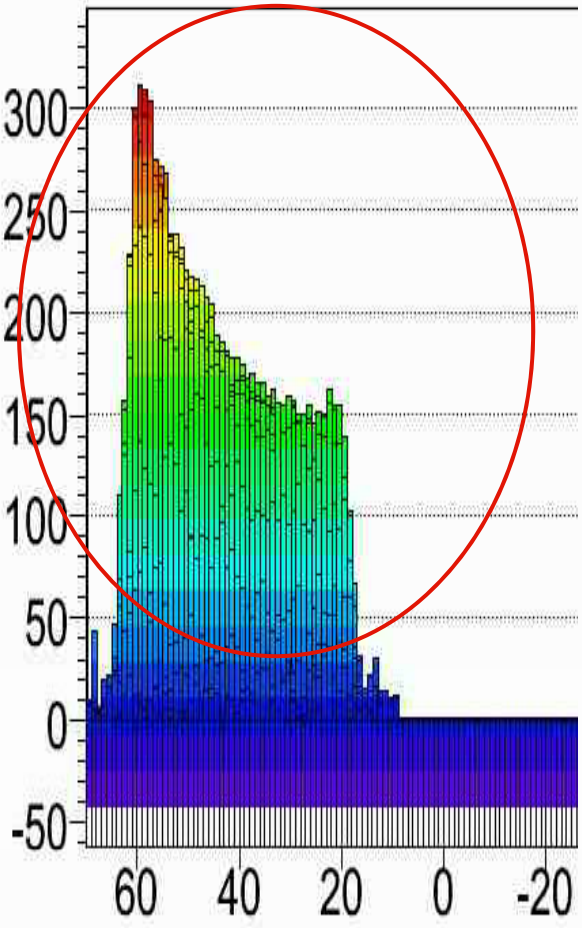




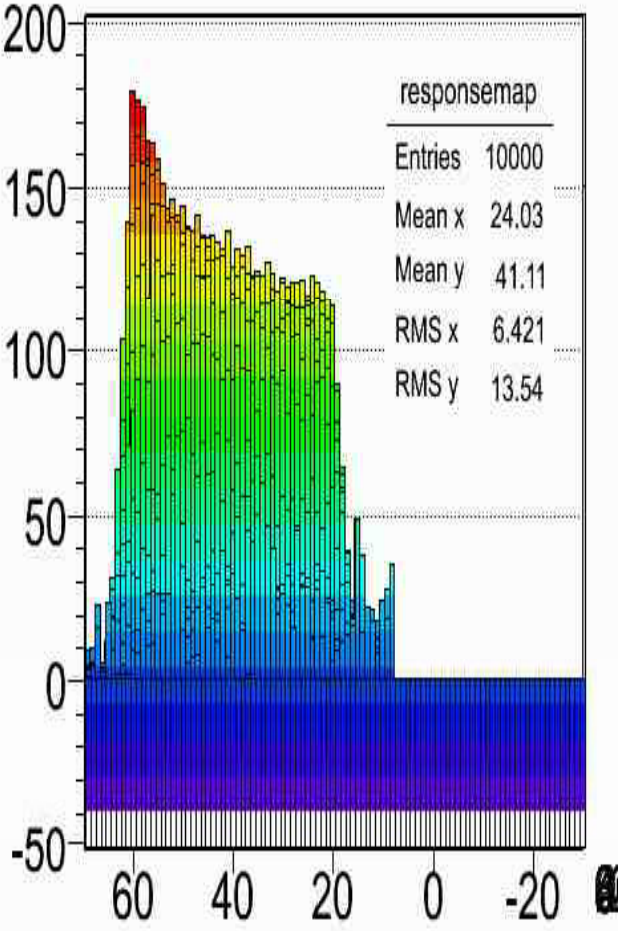
Response along the strip



Kuraray strip w/ fiber



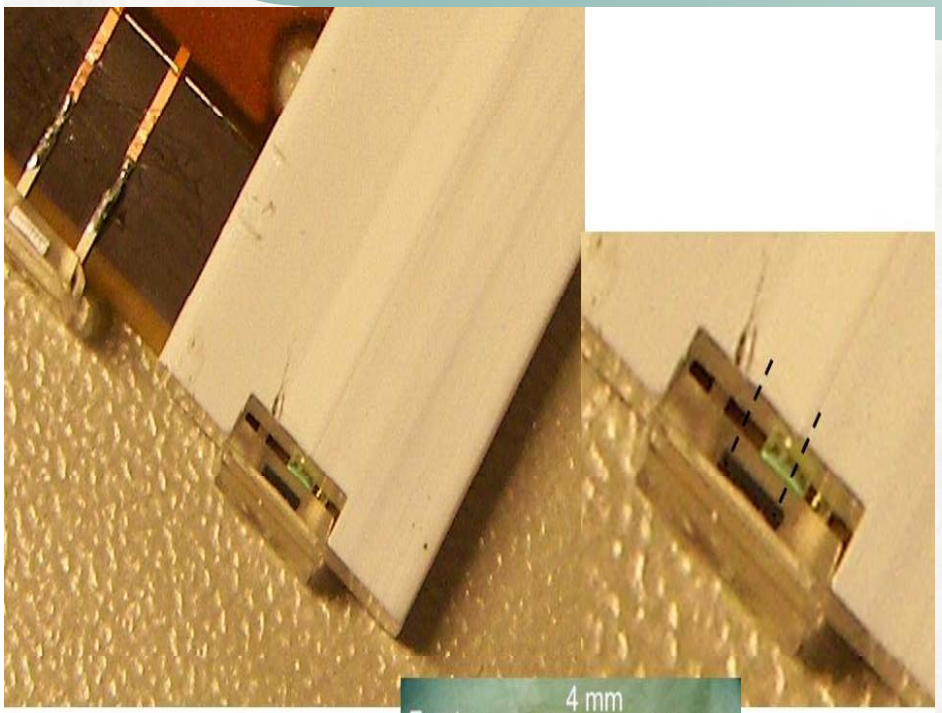
KNU strip w/ fiber

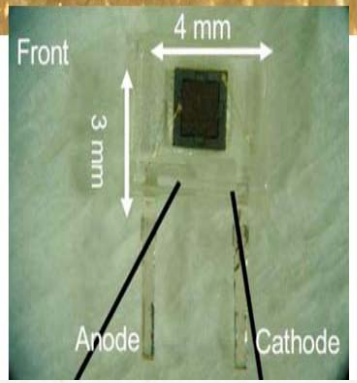


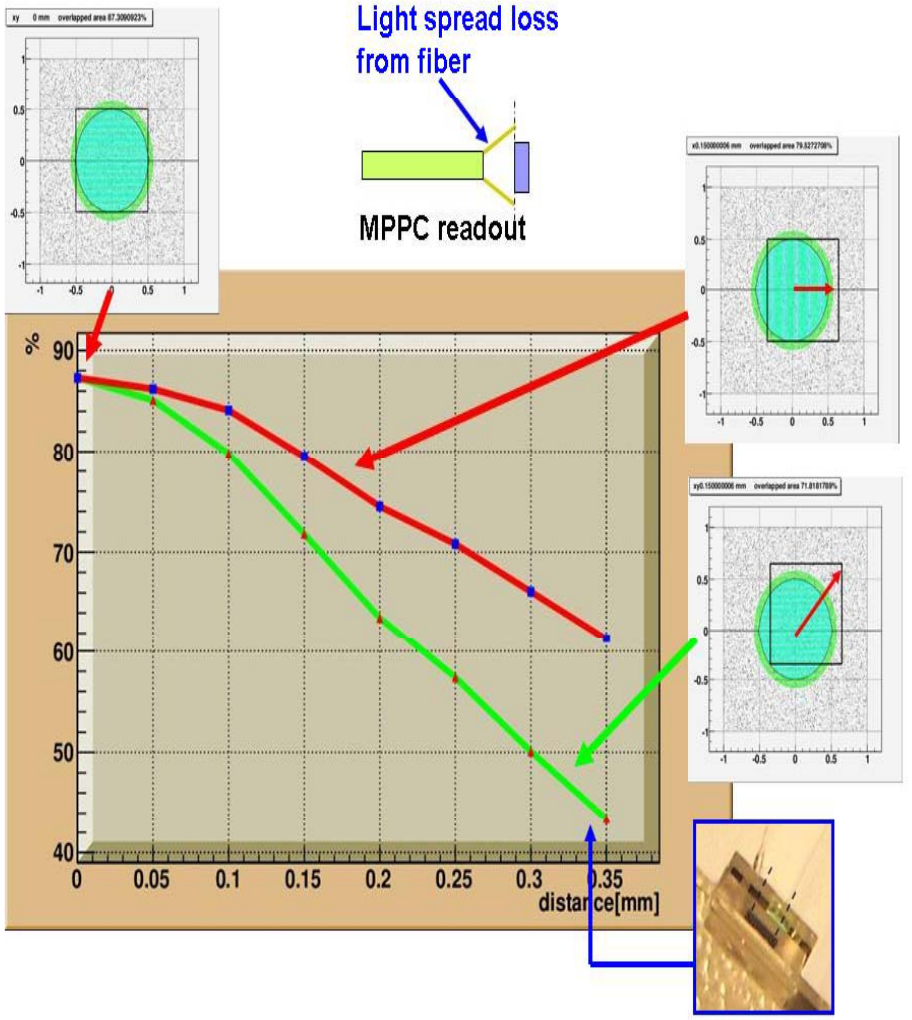
Kuraray strip w/o fiber

Hole size comparison (from different batch)

Matching problem of MPPC & fiber







Lesson from the Beam Test

- Based on preliminary results
- high cost with cast scintillator
  - More plausible with extruded strips (?)
- However, extruded strips need more R&D
  - Fiber sitting problem, reflector on edge etc..

  → these might be resolved.

R & D List for the future

- Embedded WLS fiber to the strips
  - to minimize mismatch between WLS fiber and MPPC active area
  - Temperature concerned → need investigations
  - consider this option → die under making
- If succeed, WLS fiber will be produced as well
- MEGA tile concept
- Quality Control scheme on production.
- Try next beam test at FNAL after resolving

Summary

- First results show would-be-promise with extruded scintillator
- Of course, More R & D required
- See what happen Next Test Beam at FNAL

Backup

Summary and plan

- ✓ First results show would-be-promise with extruded scintillator
- ✓ Of course, More R & D required
- ✓See what happen at the next Beam Test

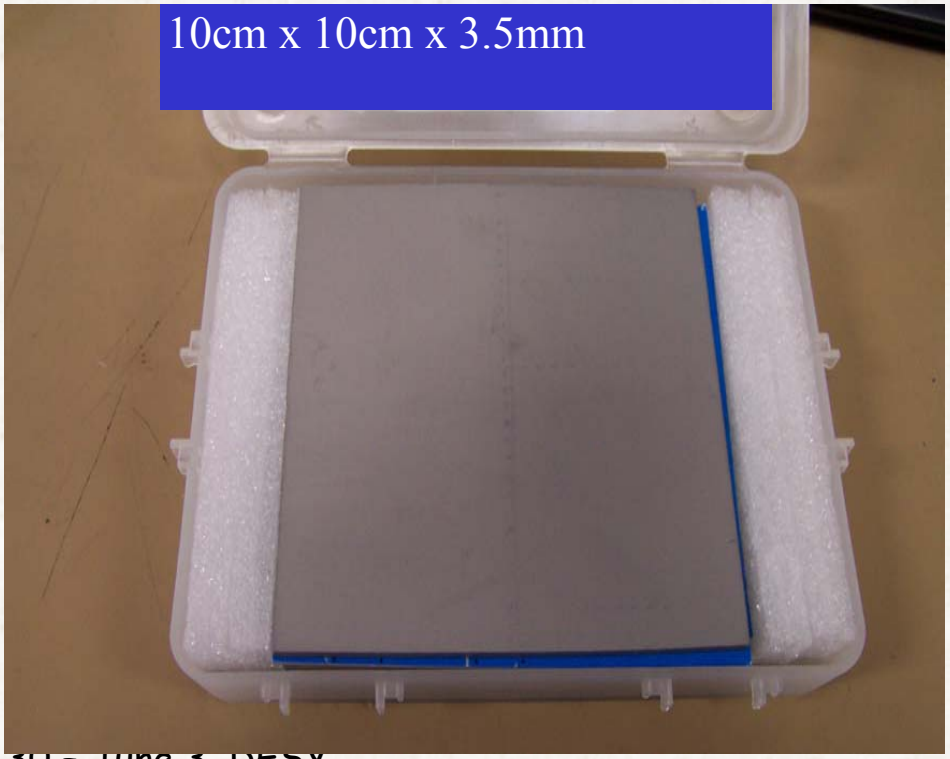
Absorber

Tungsten plate

- Taegu Tech in Korea

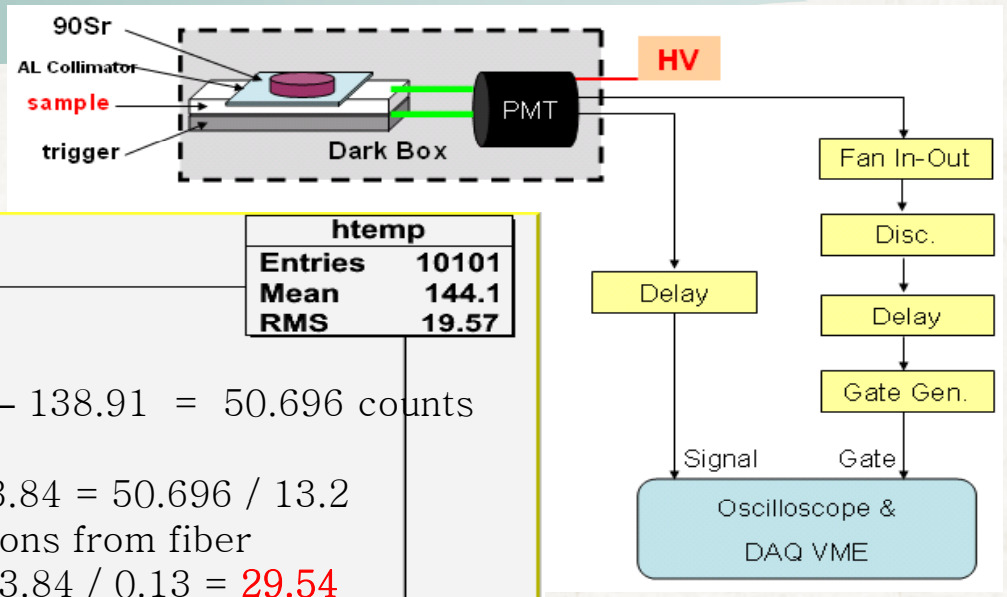
W(88%)+Co(12%)+C(0.5%) Super strong Tungsten

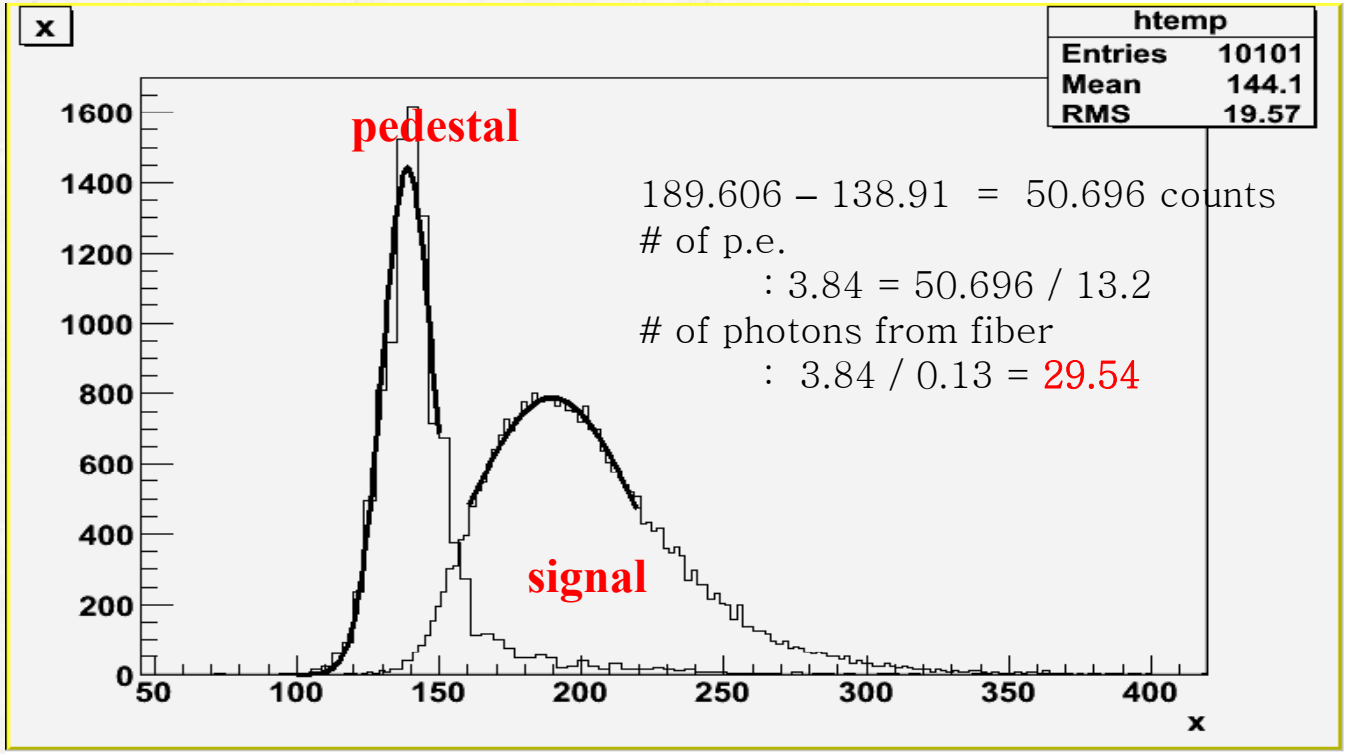
128plates
thickness = 3.522
±0.017 mm
density =14.5 g/cm³
Moliere R =10.1 mm



Measurement of absolute Light Yield

Sample : KNU tile
10mm x 50mm x 3mm





$$\#\text{ of photon from fiber} = \frac{\text{Pulse height (ADC counts)}}{\text{13.2 (ADC count / 1pe) * Q.E.}} = \sim 30 \text{ photons}$$

Energy Resolution comparison

		Energy resolution	
		Linear(%)	Constant(%)
1	Japan strips w/ fiber	14.8	0.2
2	Japan strips w/o fiber	12.4	3.2
3	Korea strips w/ fiber	13.1	4.0

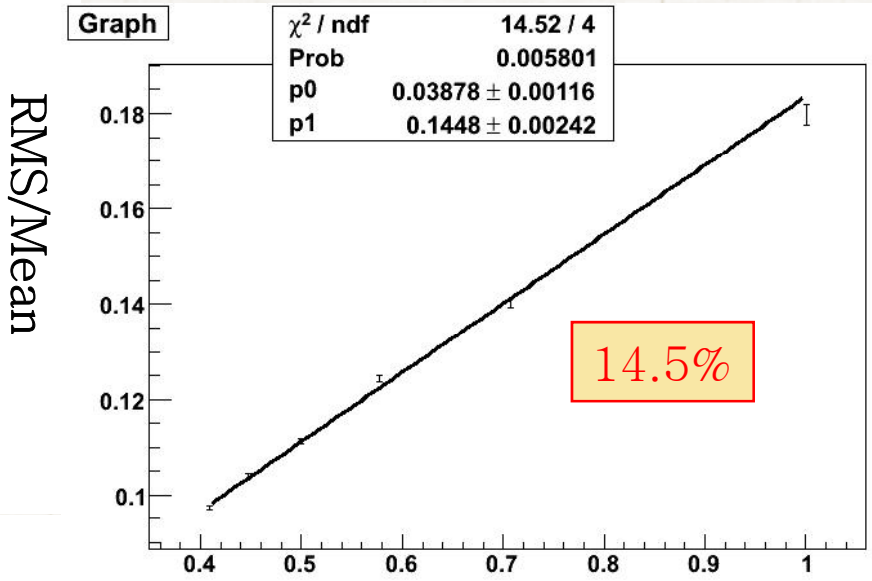
- In overall, good results : expected good results under given material configuration
- Configuration 1,2 & 3 : comparable linear term but 1 is a bit bad
- Config 2 & 3 : rather high constant term
- Configuration 2 : this option may be discarded since
  the constant term is not controllable.
- Configuration 3 : the constant term can be controlled.

- However it is preliminary and need more analysis and inspections.

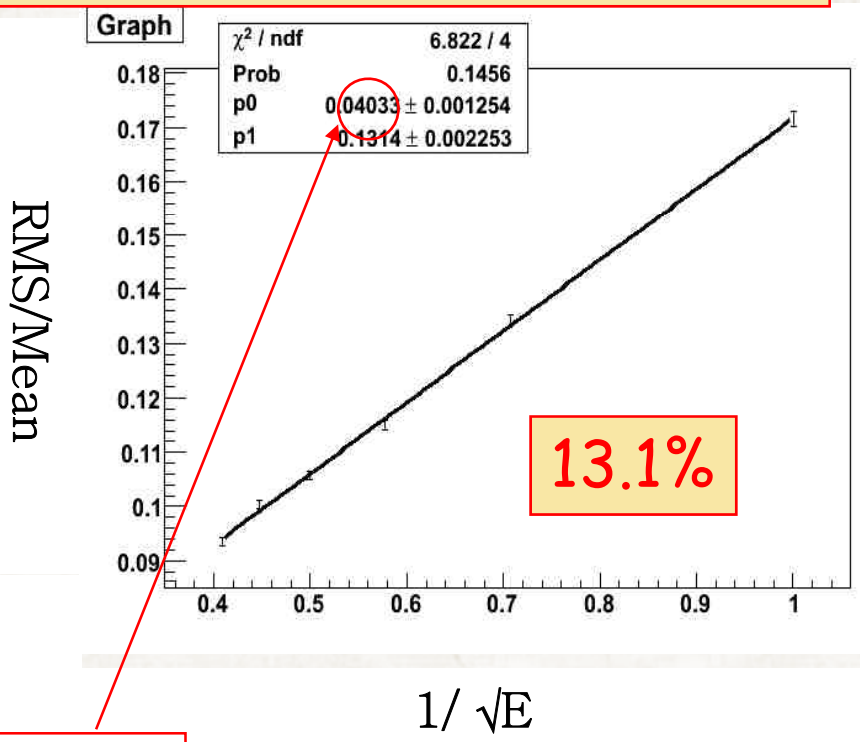
Preliminary results

- Energy Resolution of extrudedStripmodule

Raw data

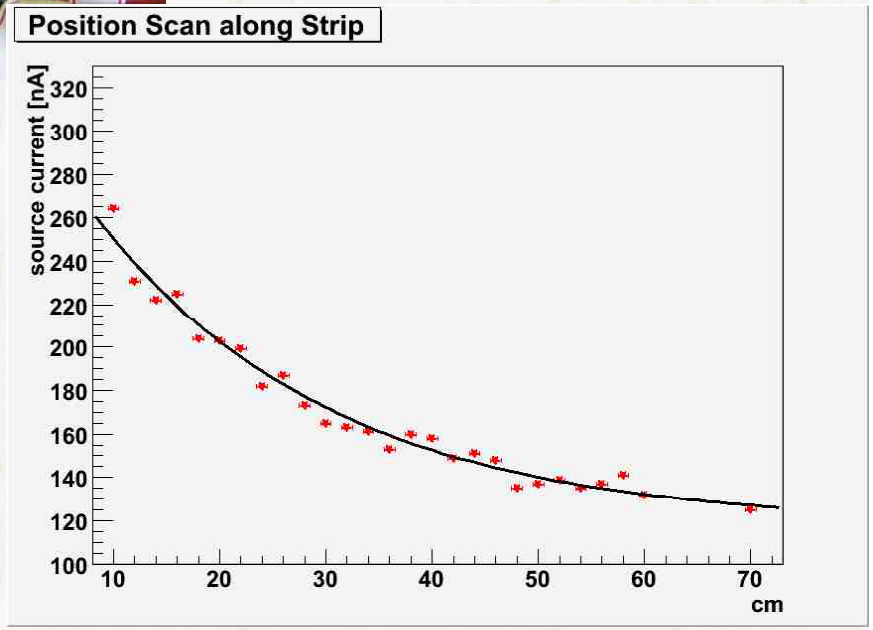


After applying correction coefficients



However, the constant term is 4% !

Position Scan



Scan with ^{90}Sr along 1 m Strip bar

Attenuation Length

Constant term

- High constant term causes problems in very high energy.
- It usually happens when the light is not uniform in strip by strip.
- After investigations, two very plausible problems found.
  - Fiber loose in hole → cause light loss
  - Light reflector in far side edge from MPPC ripped off