



FERMILAB



Extruded scintillator for calorimeter applications

Presented by Victor Rykalin NICADD

For Northern Illinois Center for Accelerator and Detector Development

Anna Pla-Dalmau FERMILAB



6/5/2006

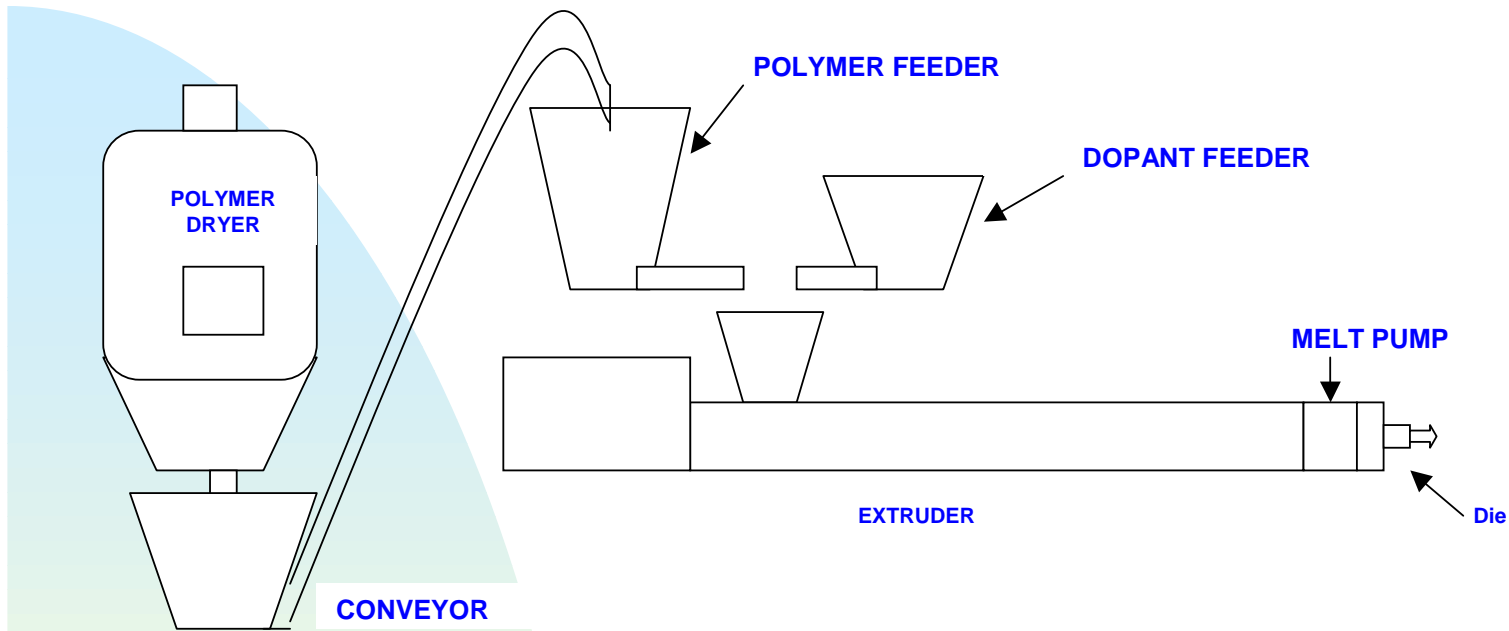


Why do we need to consider the use of extruded scintillator in calorimetry.

- **It is simple production process.**
- **It is stable during long production run.**
- **It is robust while using WLS fiber as a read out.**
- **It is cheap ! (~\$10 /kg when you order >10 T).**
- **LY of extruded scintillator is as high as KURARAY SCSN-81***
- **Mechanical tolerance is comparable to the cast scintillator .**
- **Multiple applications are pending.**
- **Coupling with Solid State Photomultiplier (SSPM: MRS, SiPM, GM-APD) comes in the natural way.**

*O.A. Grachov, T.M. Cormier, A. Pla-Dalmau, A. Bross, V. Rykalin
FNAL-CONF-04-046

FNAL-NICADD EXTRUSION FACILITY



- Line under nitrogen atmosphere:
 - Drying under nitrogen
 - Each piece of equipment is purged
- In-line continuous process:
 - Less handling of raw materials
 - Precise metering of feeders
 - Twin-screw extruder (better mixing)
 - Melt pump offers steady output
 - Control instrumentation

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ZE 40A UTS Technical

Data **Output range**
30-200kg/h

n	Screw diameter	n	44 mm
n	Screw speed	n	1200 RPM
n	Drive power	n	200 HP
n	Height	n	~1100 mm
n	Weight	n	~3500 kg
n	Lifetime	n	~40000 hours

Extruder and co-extruder



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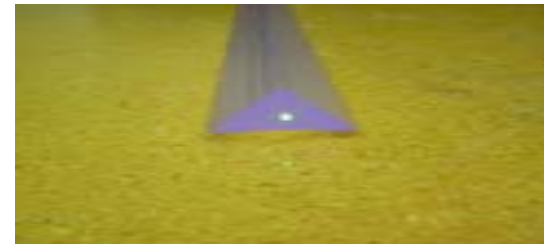
Die impact on the scintillator profile



Rectangle, with or without hole to host 1.2 mm WLS fiber



Triangle, with or without hole to host 1.2 or 1.5 mm WLS fiber



Rectangle, with 10 holes, or without them, to host 1.2 mm WLS fibers

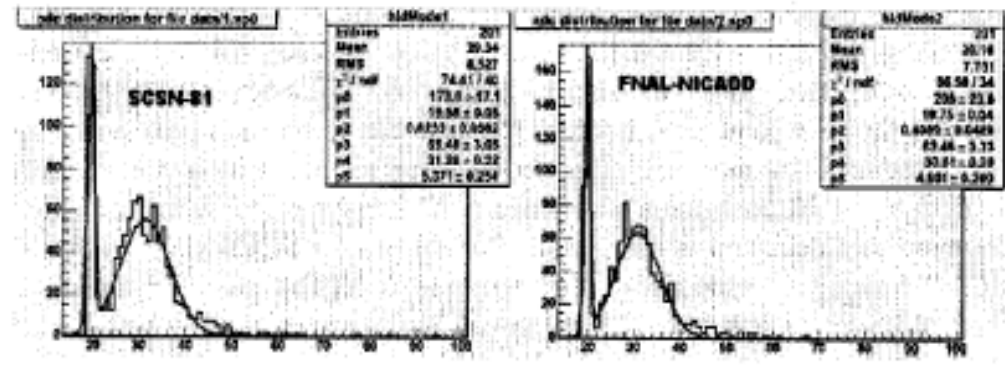
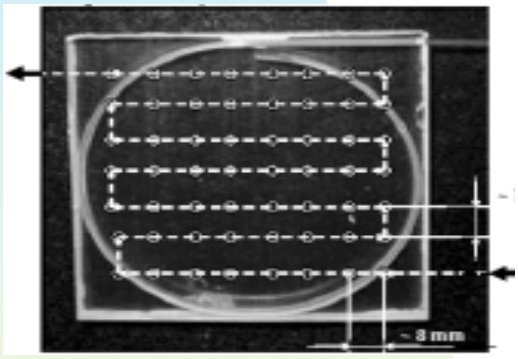
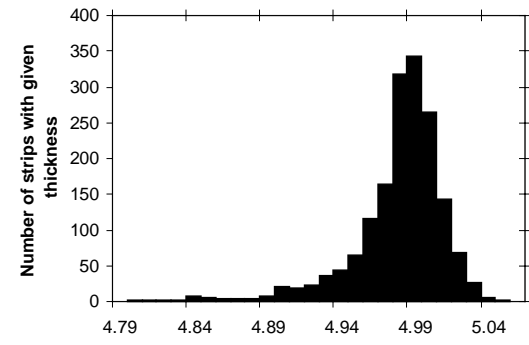


Triangle with co-extruded TiO₂ coating

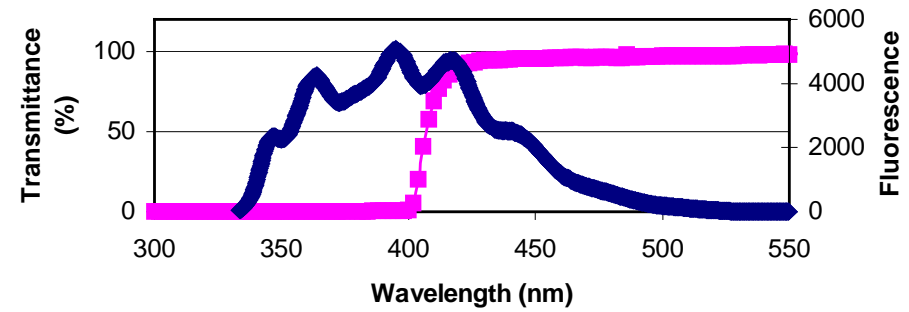


Parameters of extruded and co-extruded scintillator

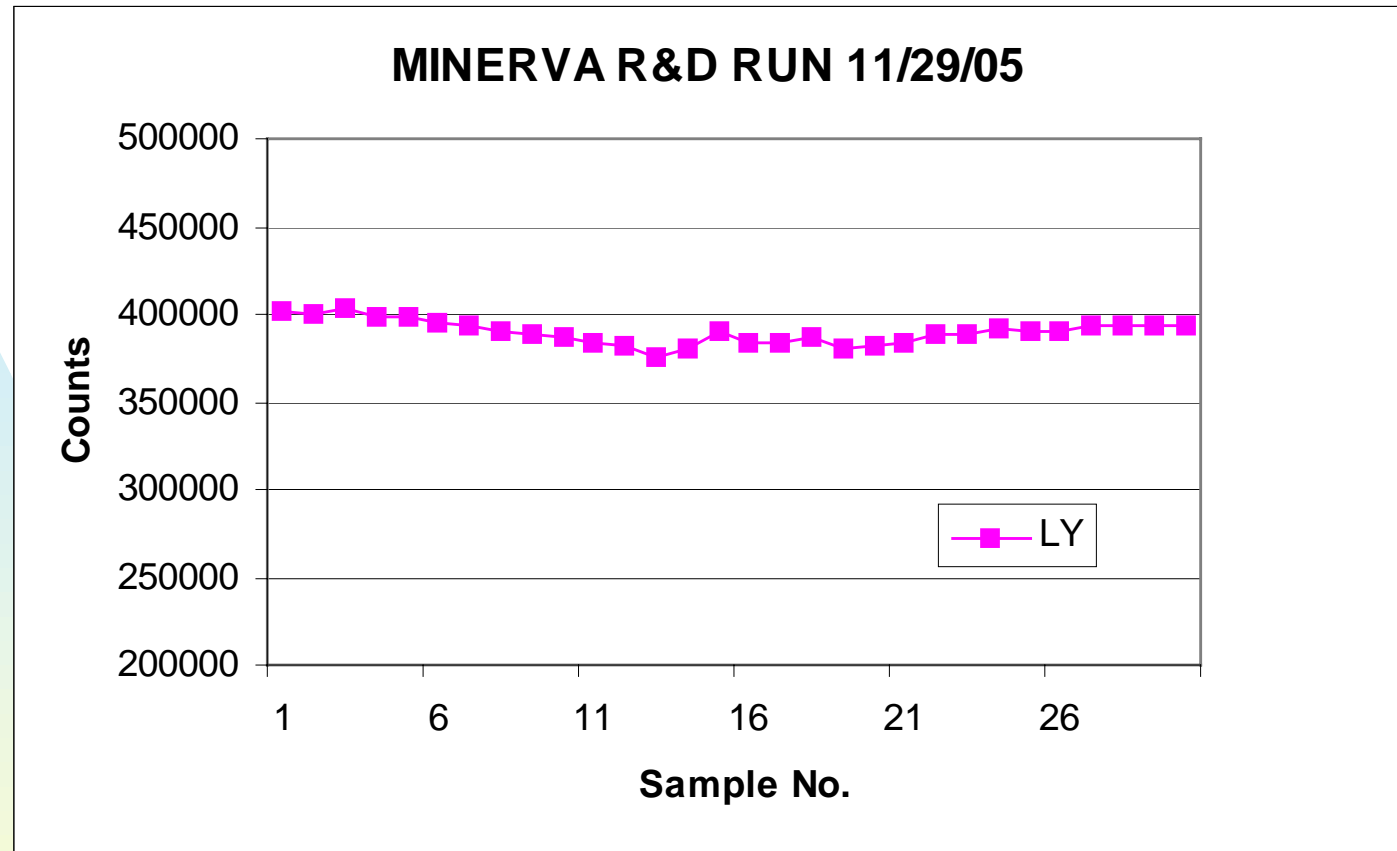
- Thickness:** $\sigma \sim 0.6\%$ (Over 300 m)
- Width :** $\sigma \sim 0.2\%$ (Over 300 m)
- LY non-uniformity** $\sigma \sim 2.2\%$ (10*10 cm²)
- Light Yield** **66% of BC408**
~100% of Kuraray SCSN-81



1% PPO + 0.03% POPOP

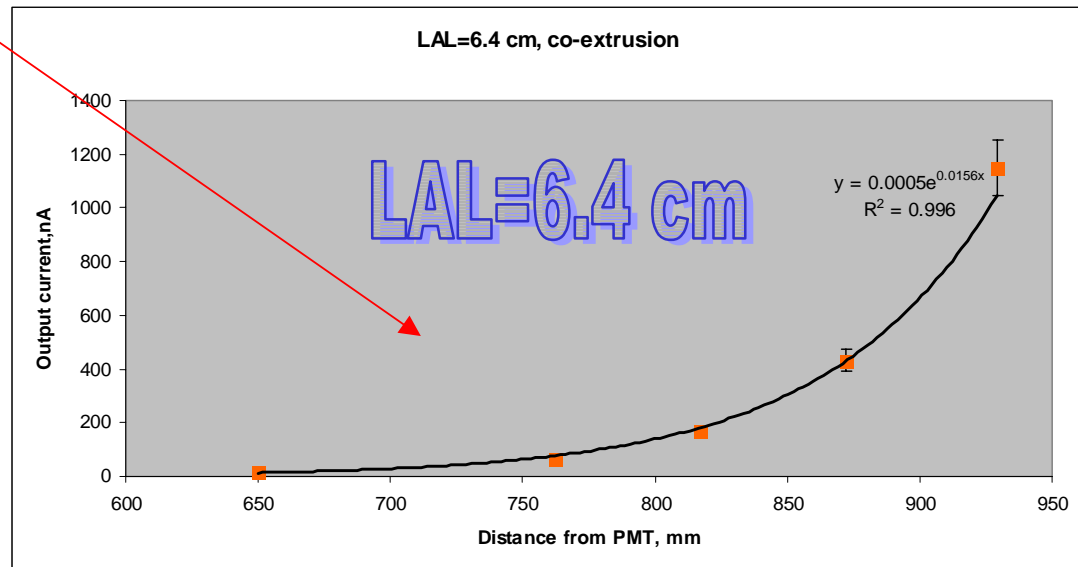
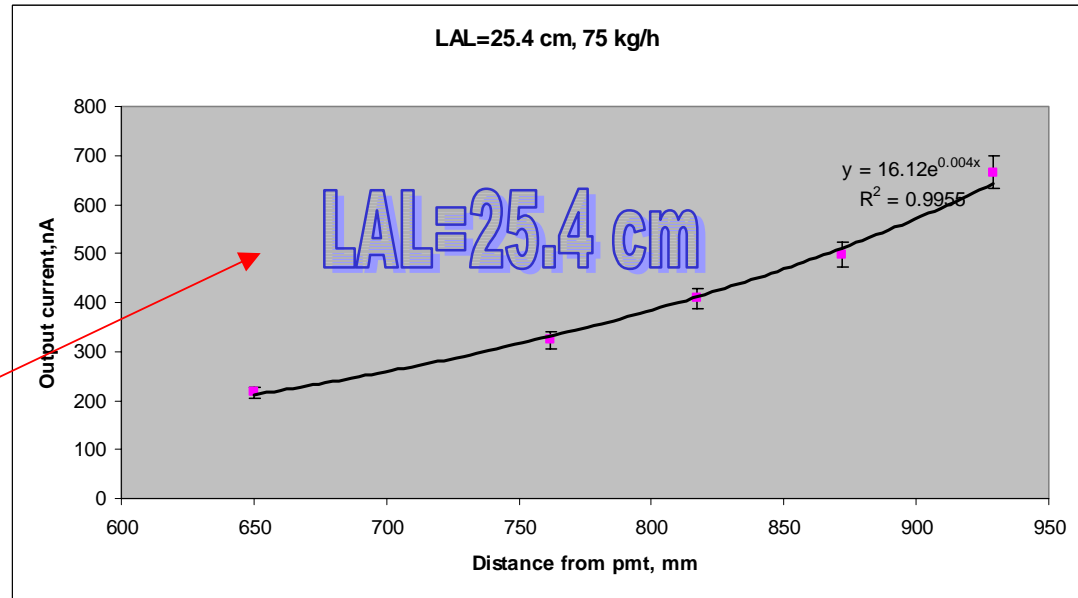


LY nonuniformity over 30 samples



ABOUT A 5% VARIATION ! Over 200 m of extrusion

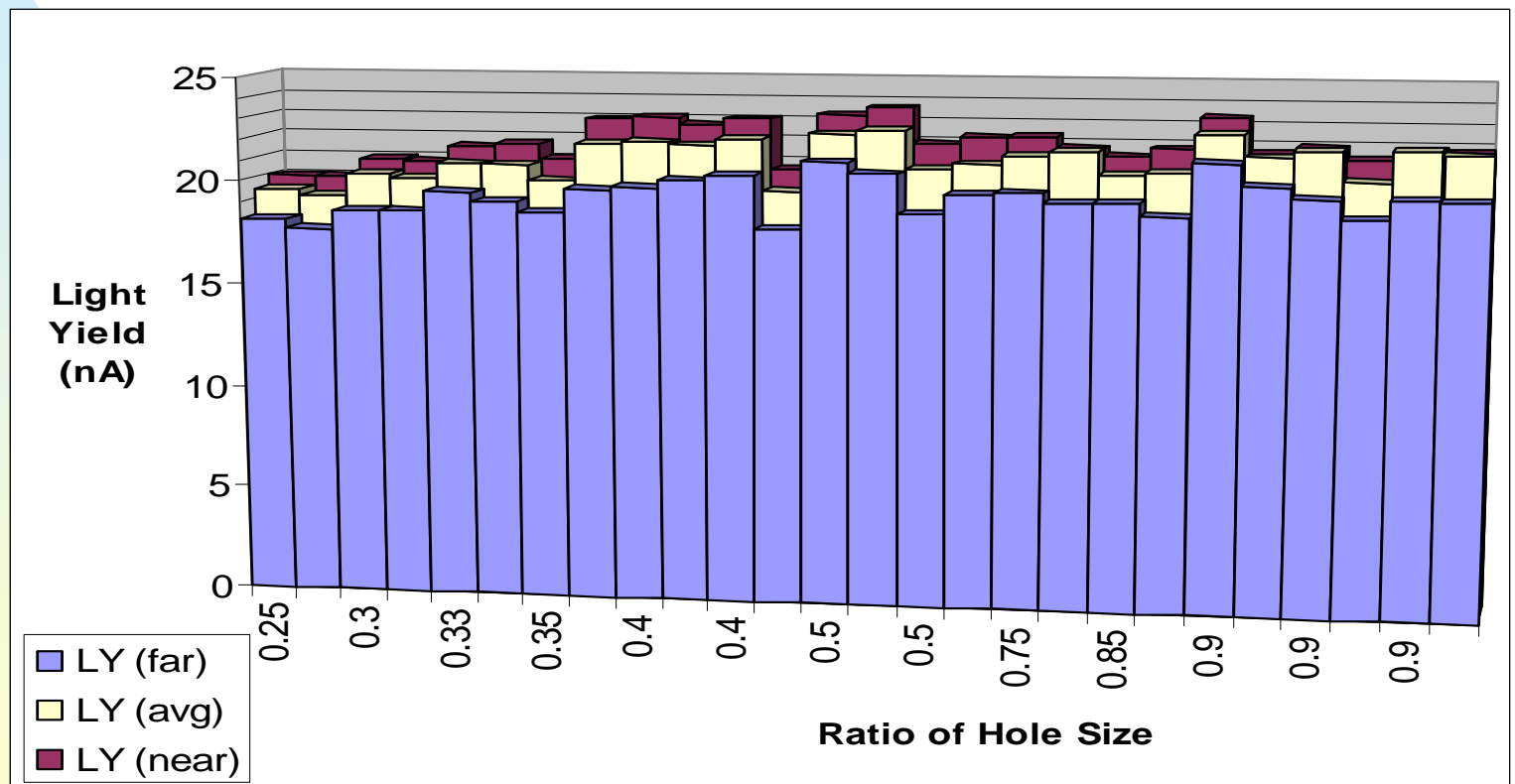
Impact of co-extrusion on Light Attenuation Length



Results on the relative LY with fibers (no optical glue)



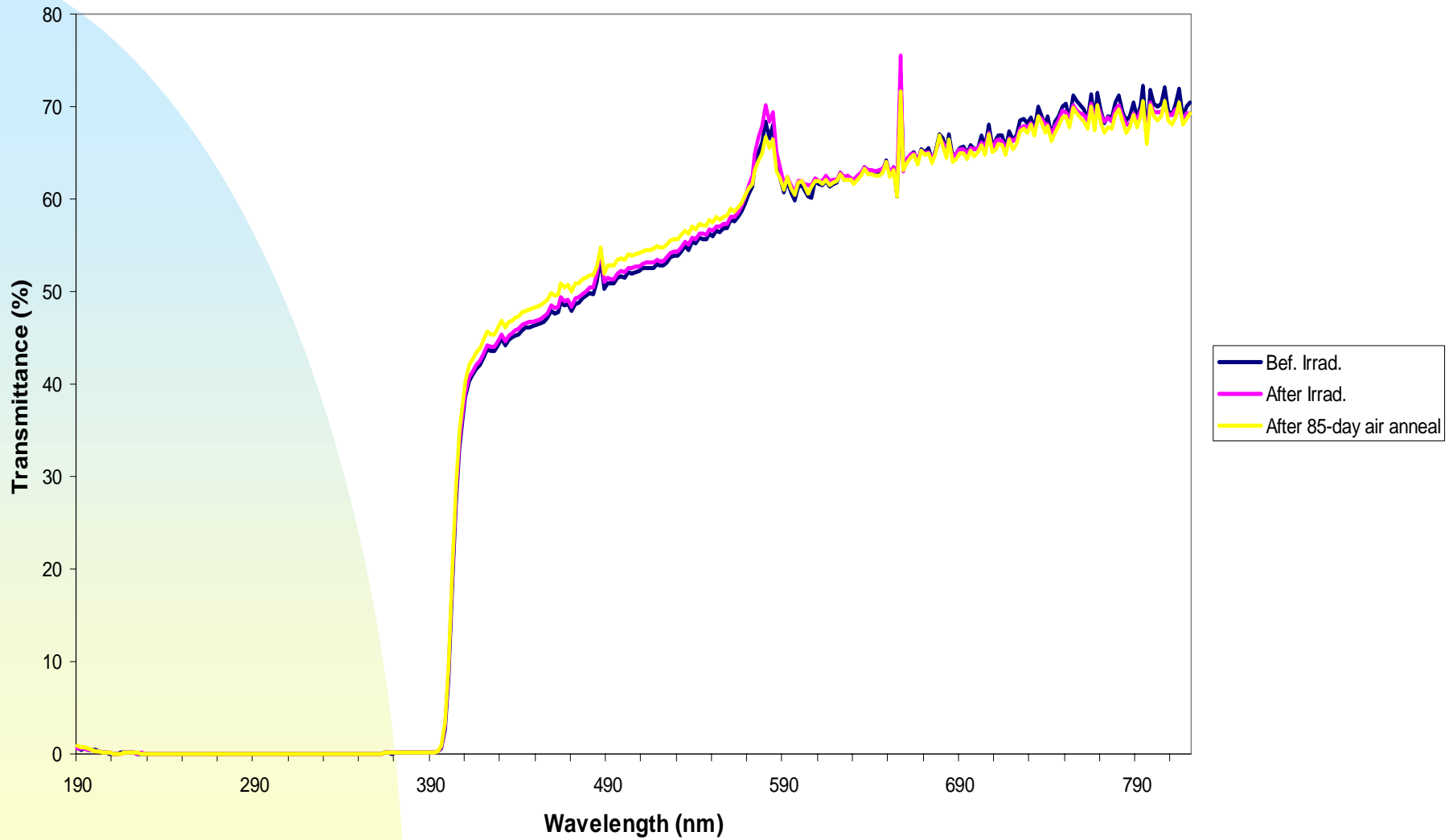
$$\text{Ratio of diameters} = \frac{d_{\text{fiber}}}{d_{\text{hole}}}$$



There is no significant impact on LY !

Transmittance before and after irradiation, 5 Mrad, ^{60}Co

FNAL/NICADD SCINTILLATOR



Radiation hardness

FNAL-NICADD extruded scintillator, 18 samples of 2*2 cm², Irradiation in air and annealing in air during 85 days, 9 KGy/h).

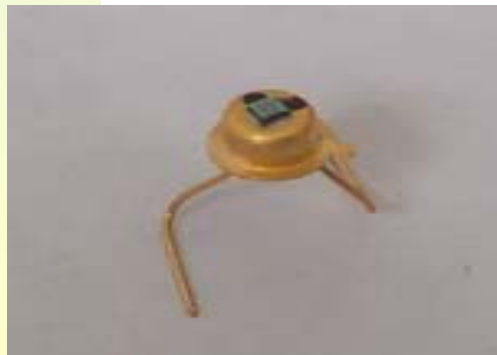


Dose absorbed γ , ⁶⁰ Co	Before Irradiation (ADC counts)	After irradiation and anneal (ADC counts)	Light yield loss
0.5 Mrad (5KGy)	264±8.6	266±7.7	
1 Mrad (10KGy)	273±5.8	261±7.1	~ 5 ±2 %

Coupling of extruded scintillator with co-extruded hole and SSPM comes in a natural way!

General introduction to SSPM

- Spectral response range 420-800 nm
- Peak sensitivity wavelength 630 nm (SSPM CPTA)
- ϵ (500 nm) $\sim 25\% \cdot (0.4-0.6) = 12-15\%$
- Operating voltage 28-65 Volts
- Dark current $\sim 2 \mu\text{A}$
- Capacitance $\sim 25 \text{ pF}$
- Gain $\sim (0.5-2) \cdot 10^6$
- Good single electron separation
- Time response $\sim 1-2 \text{ ns}$
- Time resolution $< 300 \text{ ps}$



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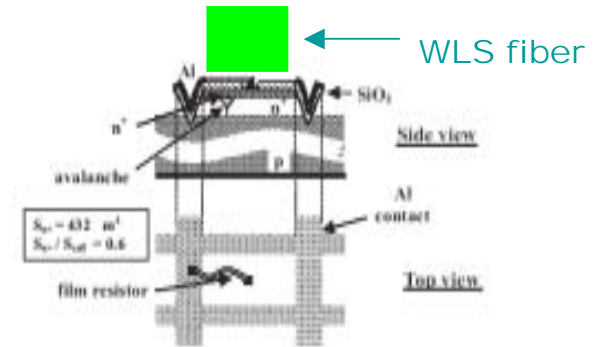
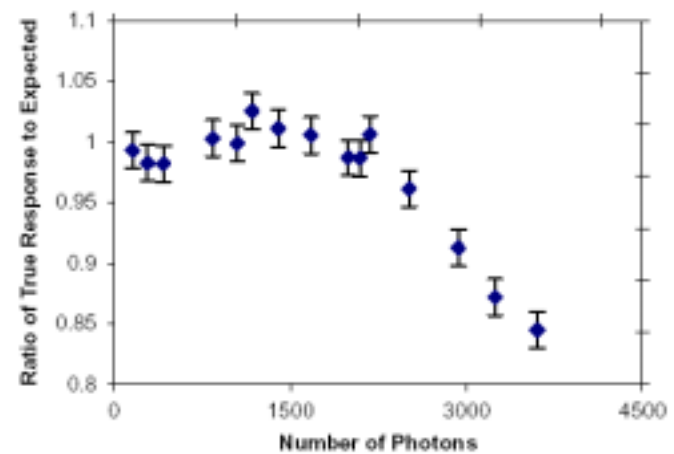
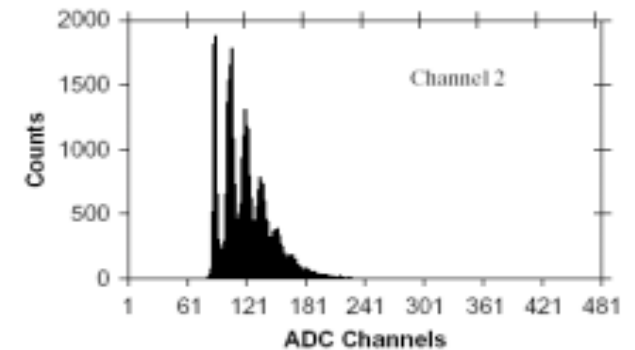
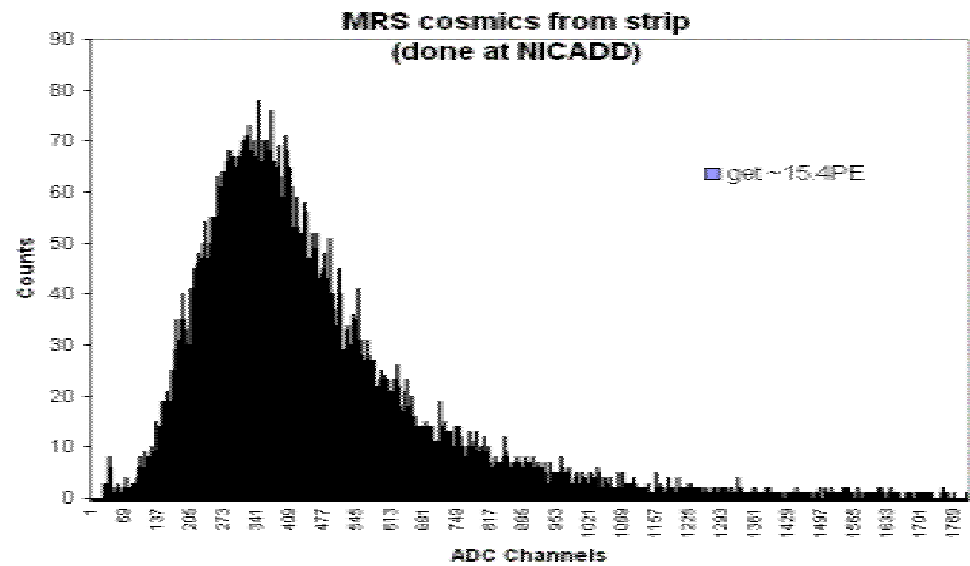
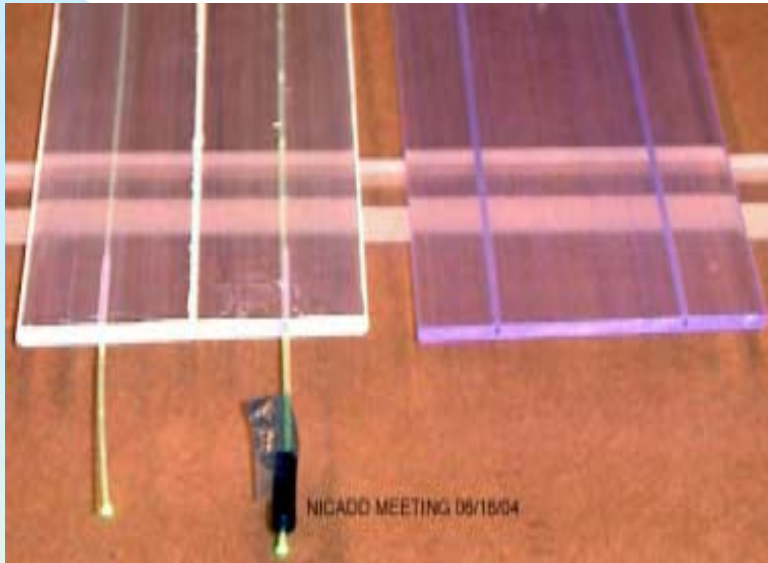


Figure 1. Schematic view of one MRS APD_μ-cell.



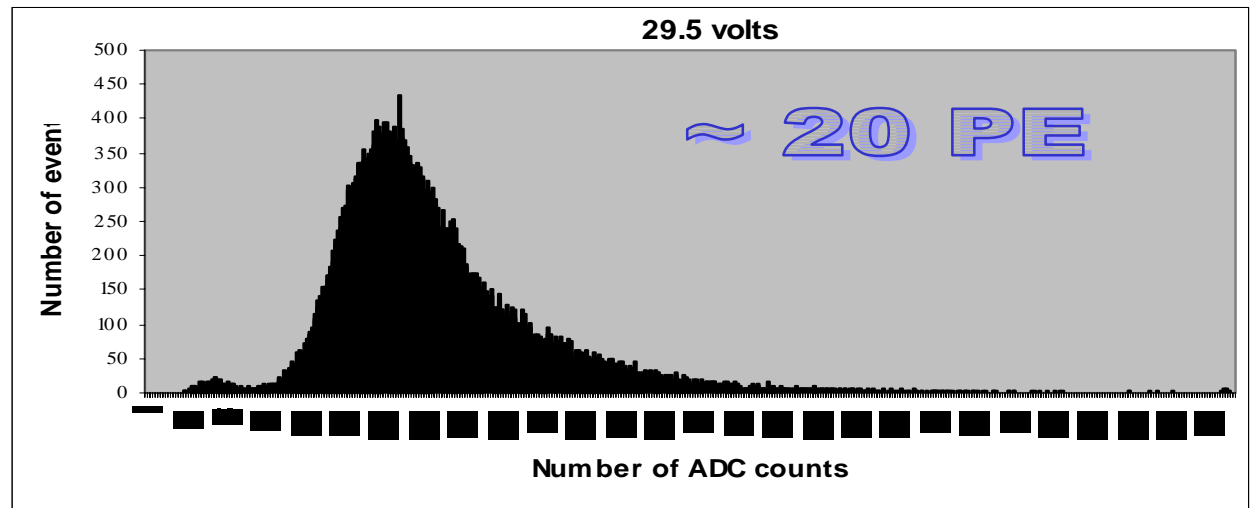
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Light output SSPM (CPTA)



**5 mm extruded scintillator
thickness, extruded hole, 1.2 mm
Y11 fiber, 10 cm out of scintillator,
SSPM (CPTA) readout ~ 15 PE**

Light yield with SSPM(CPTA)
read-out, co-extruded, MINOS
type scintillator, Y11, 1.2 mm.

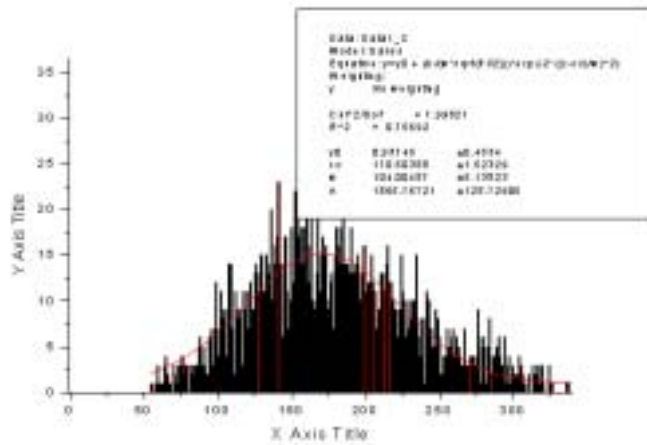


Light yield with SSPM read-out co-extruded , MINERvA rectangle type scintillator.

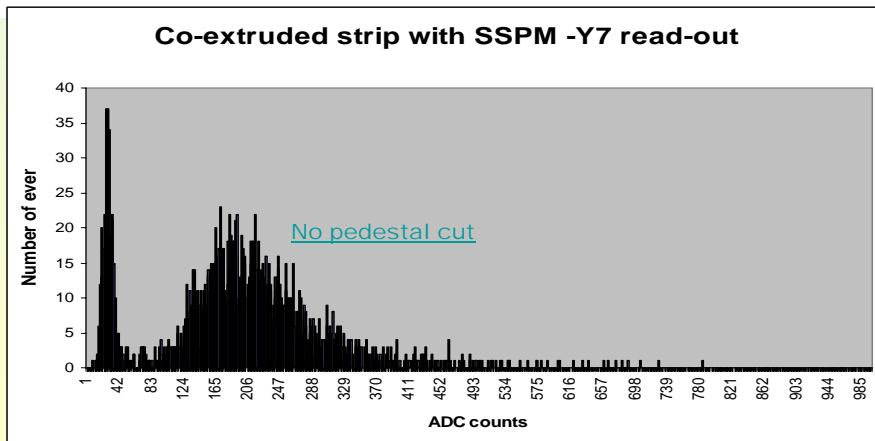
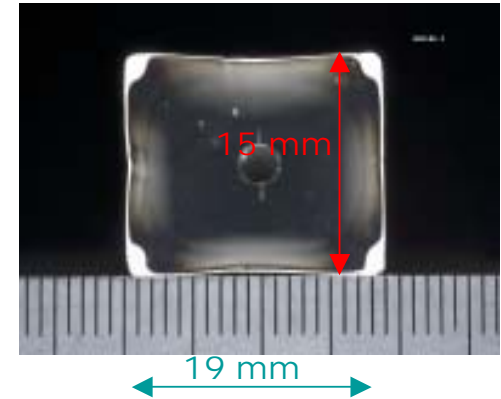
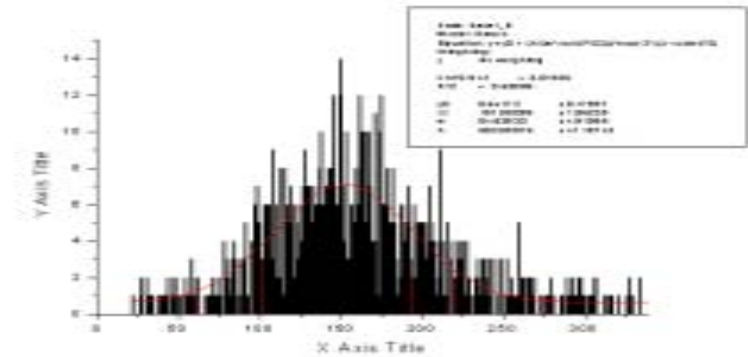
Scintillator



Y7 ,1.2 mm, no glue, no mirroring, 1PE=8 ADC counts, total ~ 21.3 PE, PED=30 ADC counts



Y11 ,1.2 mm, no glue, no mirroring, 1PE=8 ADC counts, total ~ 19 PE, PED=30 ADC counts



$Y7/Y11 = 1.12$

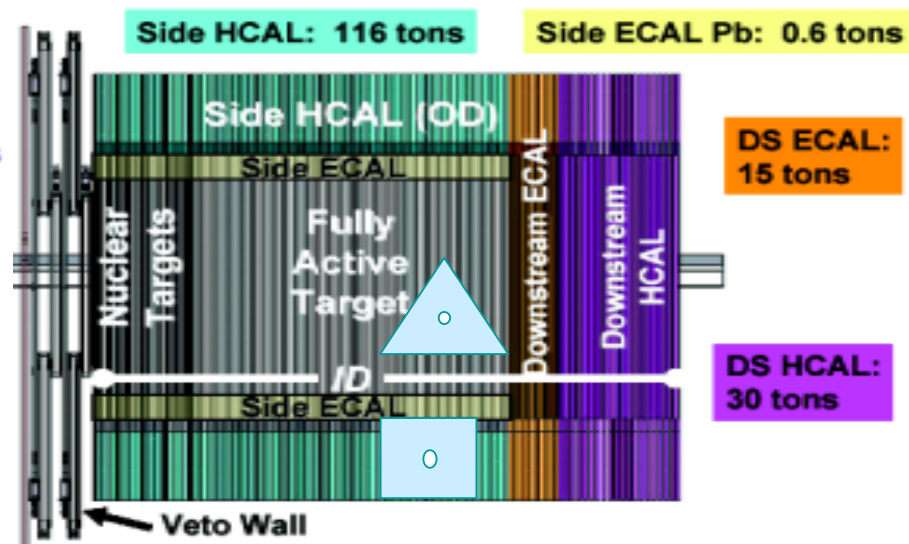
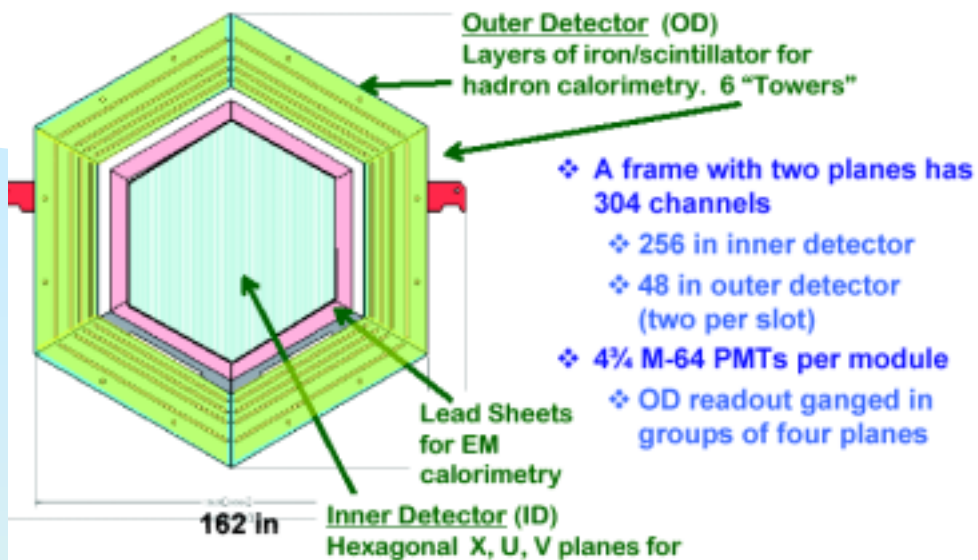
Add optical glue(50%), mirroring(50%) one may expect

$Y11 = 42.7 \text{ PE}$

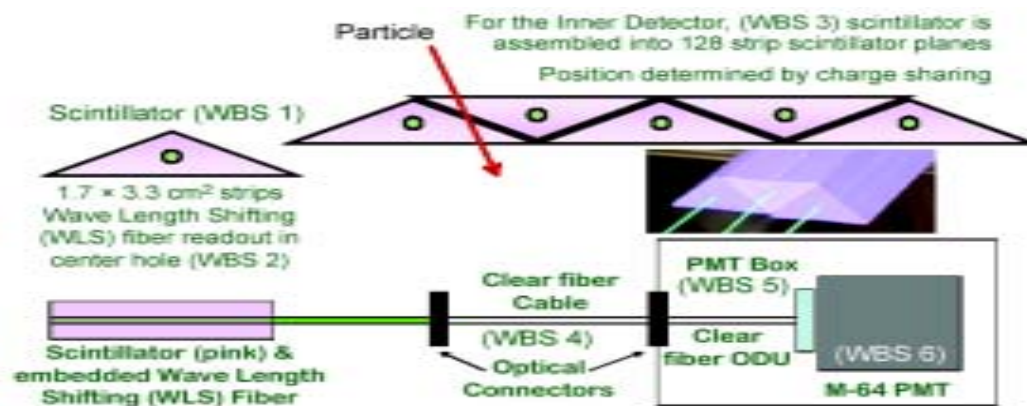
$Y7 = 47.9 \text{ PE}$

Experiments that are considering extruded scintillator as a base line.

- R&D for ALICE upgrade.
- MINERvA (triangular and rectangular co-extruded (TiO₂) scintillators).
R&D stage.
Production scheduled for 2007-2008.
- ILC (CALICE collaboration).
TCMT, R&D completed.
Production run in 2004.
Scintillator has been delivered to the customer.



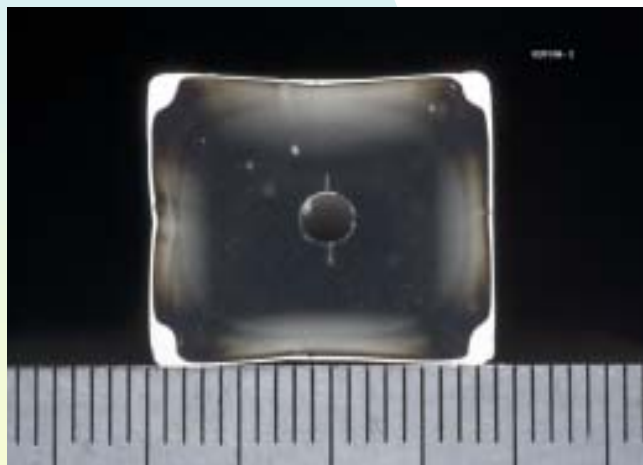
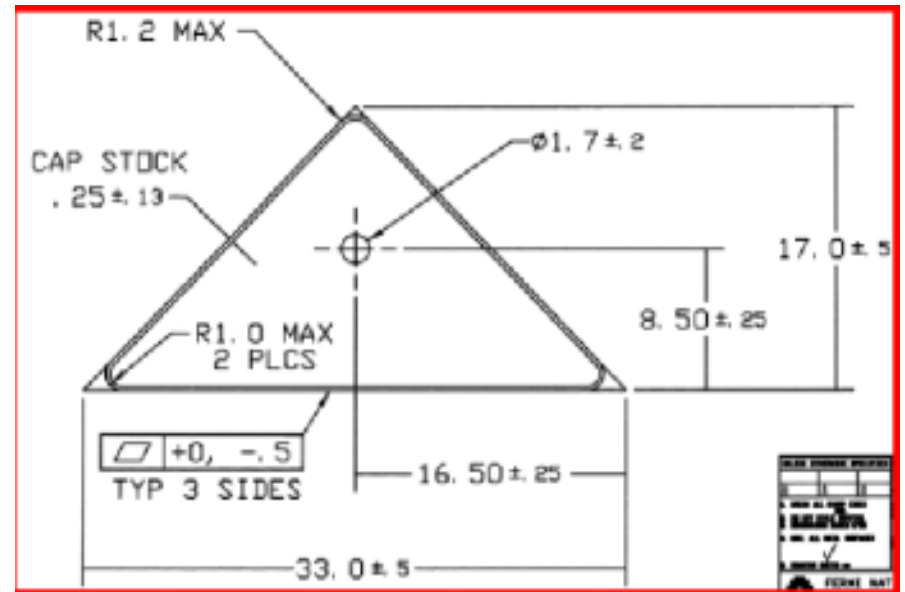
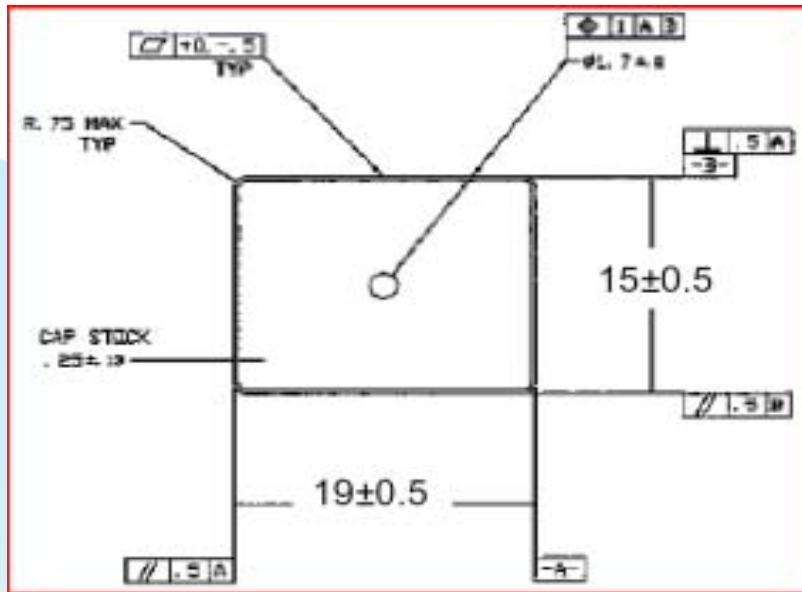
11 PE/MIP per doublet
With M64 PMT read out



MINERvA is a dedicated low-energy neutrino nucleus scattering experiment to be installed in the NuMI near hall.

Main goals are measurements of low-energy exclusive and inclusive neutrino cross sections and studies of the nuclear effects on these cross sections and on neutrino-induced hadron showers.

More about MINERvA <http://minerva.fnal.gov/>



Total of 60,128 m , co-extruded plastic.



The total amount of co-extruded scintillator is

ID **13,312 triangular strips – 3.80 m long**

OD **2,736 square strips – 3.5 m long**

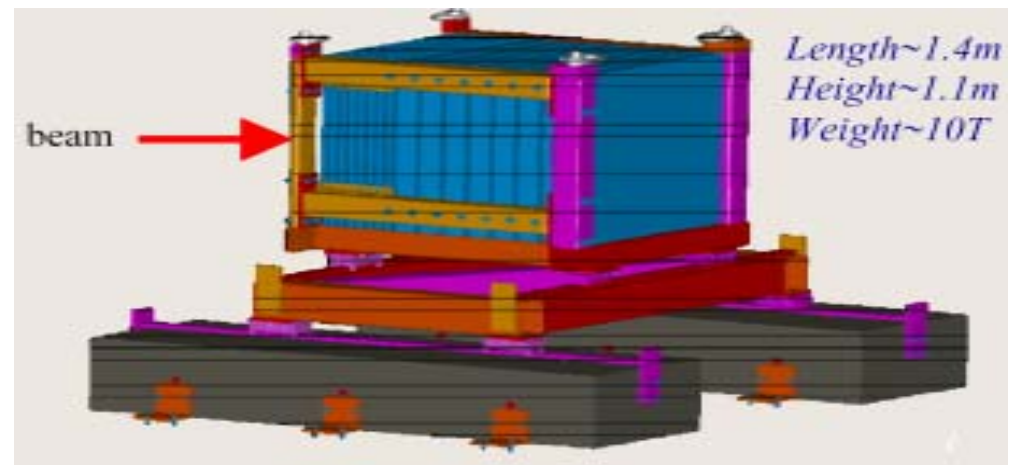
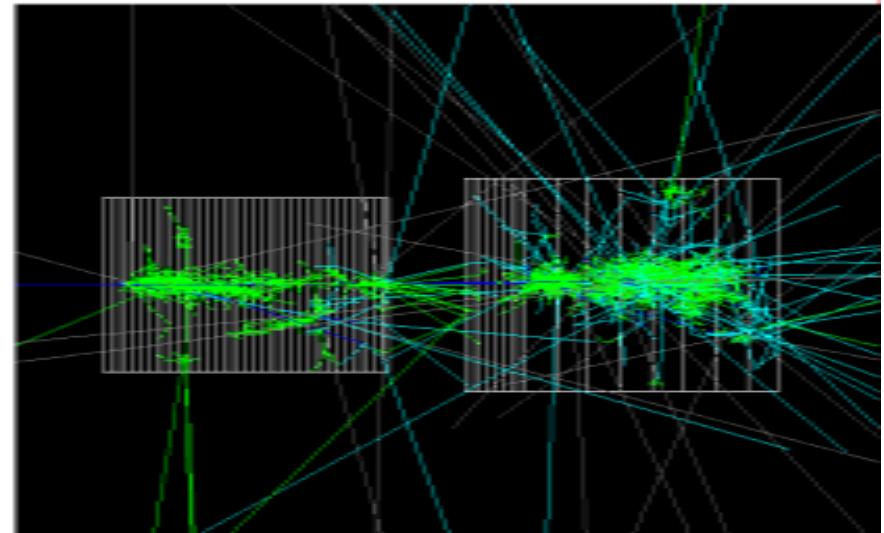
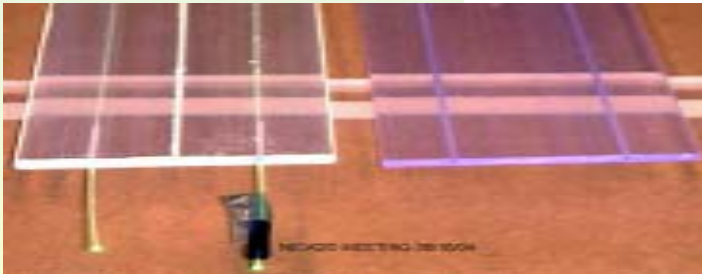
ILC R&D program (CALICE collaboration)

* As a precision instrument for the calorimeter is essential to get a jet energy resolution $dE/E \sim 30\% \sqrt{E}$.

* A complete calorimeter system includes an integrated tail-catcher and muon system (with extruded scintillator as active media) to be located behind the ECAL and HCAL.

Tail-Catcher uses ~ 300 m of extruded plastic scintillator with co-extruded hole (100cm*10cm *0.5cm)

A. Dyshkant with more details on TCMT



ILC (CALICE collaboration)



NICADD - FNAL extruded scintillator, 5 mm thickness, WLS Y-11, no glue (without co-extrusion)

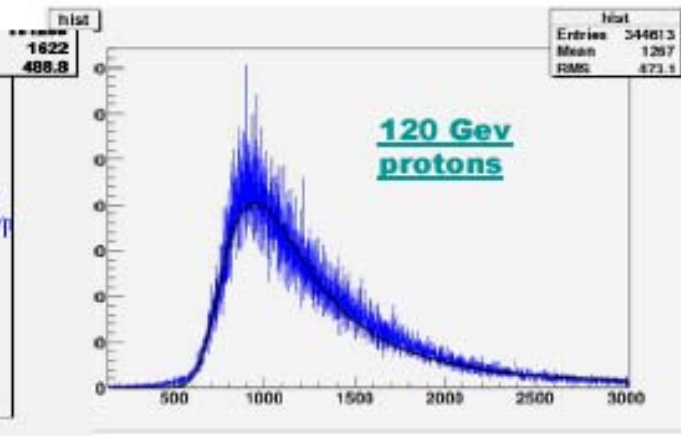
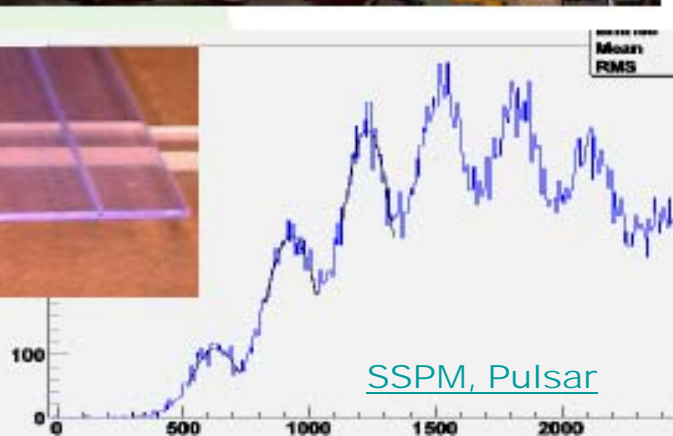
NICADD participates in TCMT, DIGITAL HCAL

TEST beams , electrons, protons

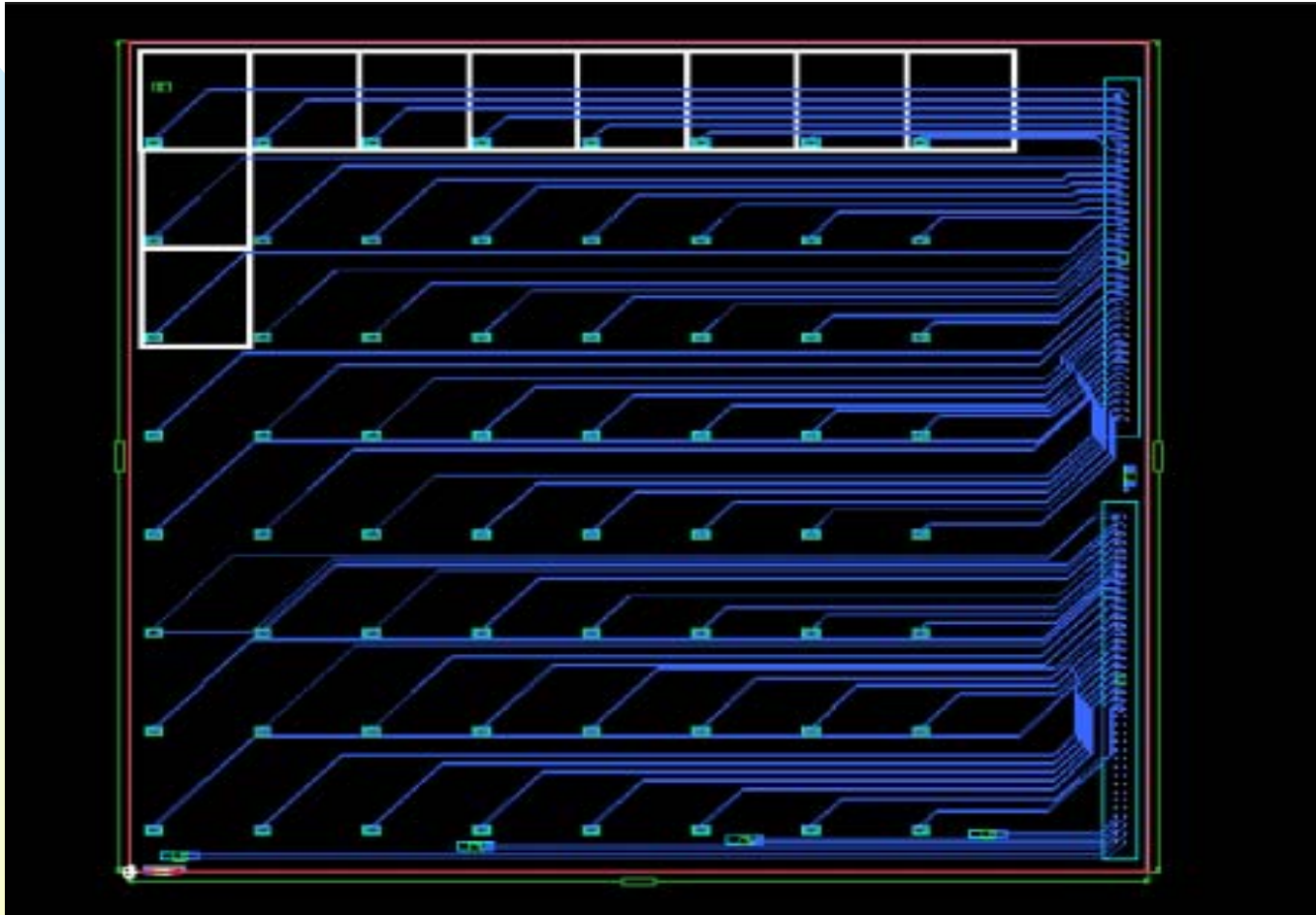
Future tests at CERN

Working DAQ (common for the CALICE collaboration) is running at MTBF and can be used for other tests.

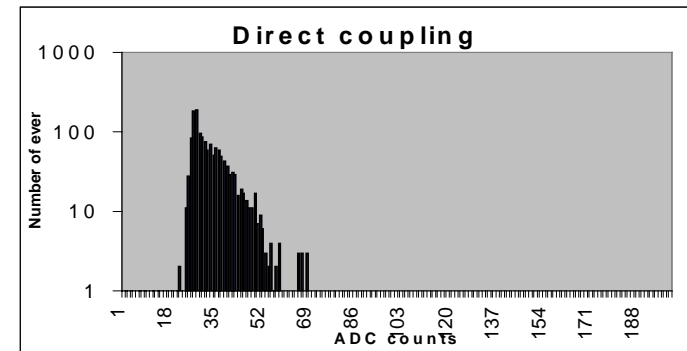
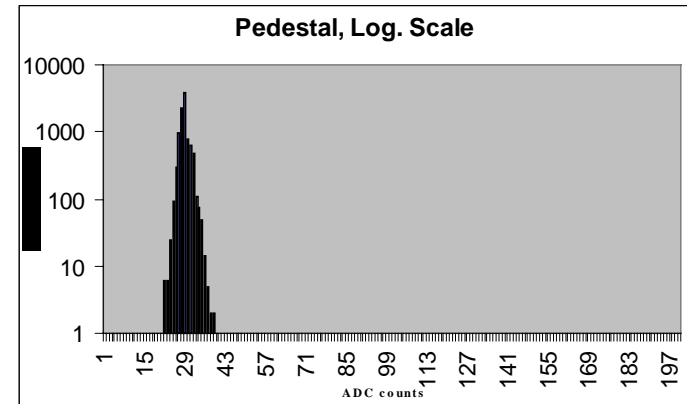
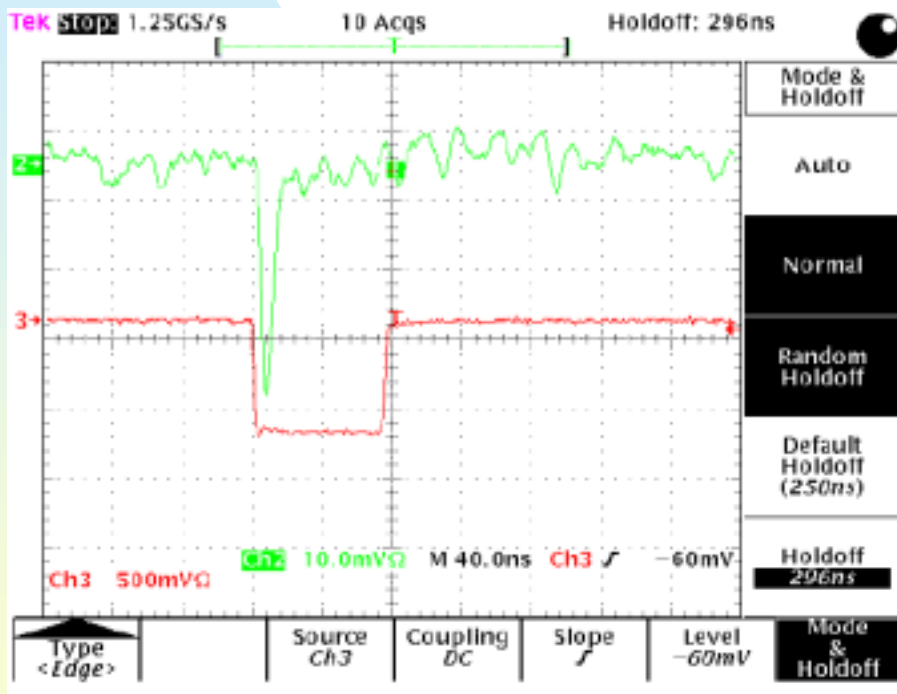
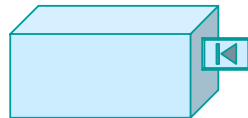
10-14 PE per strip as average



ILC R&D. Direct coupling of
extruded scintillator and
SSPM ?



Direct SSPM-scintillator read-out by SSPM(CPTA),
 QE (420 nm) ~ 2 %, 2*2 cm, 5 mm thickness,
 extruded scintillator, cosmic events.



! Sensitive area is 1*1 mm²

Summary



- **Cheap and robust scintillator built based on the developed extrusion technique.**
- **Successful application of the extruded scintillator for MINERvA R&D, ILC R&D.**
- **SSPM read-out developed for the extruded scintillator.
SSPM perfectly matches this application.**
- **More R&D is under way.**