FERMILAB

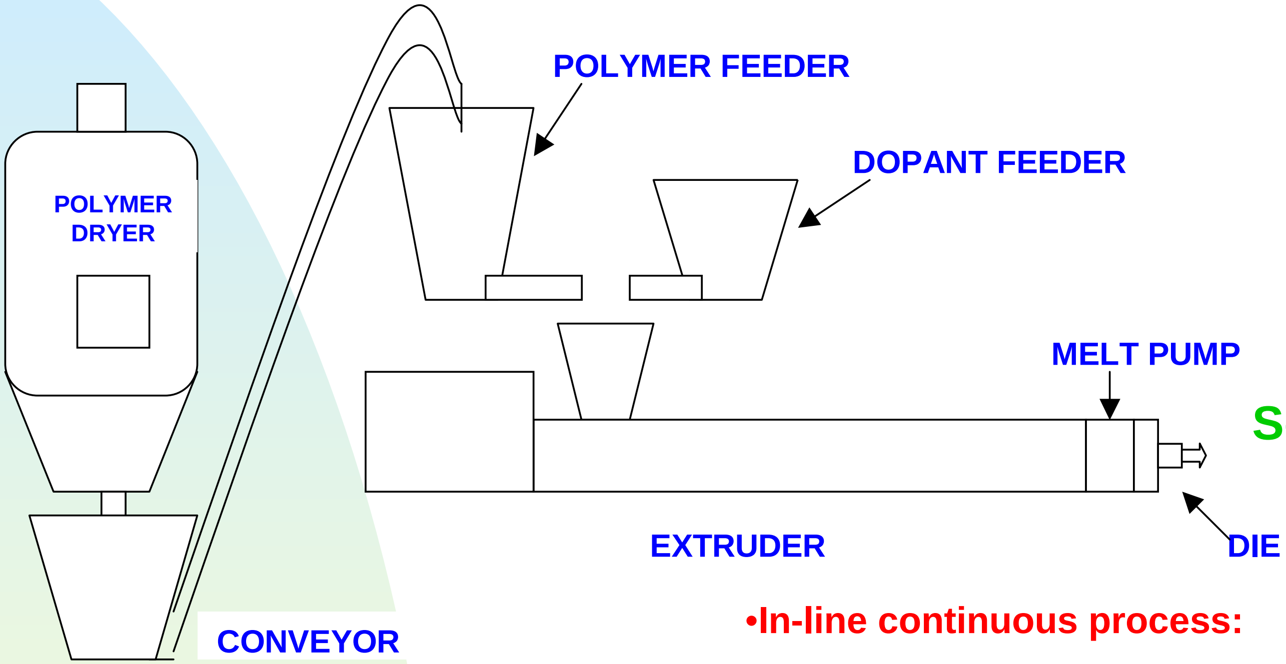
nicadd

FNAL-NICADD extruded scintillator

Presented by Victor Rykalin

Rome 1 , October 2004

FNAL-NICADD EXTRUSION FACILITY



OUTPUT:

Scintillating pellets
Scintillator bars

- **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**

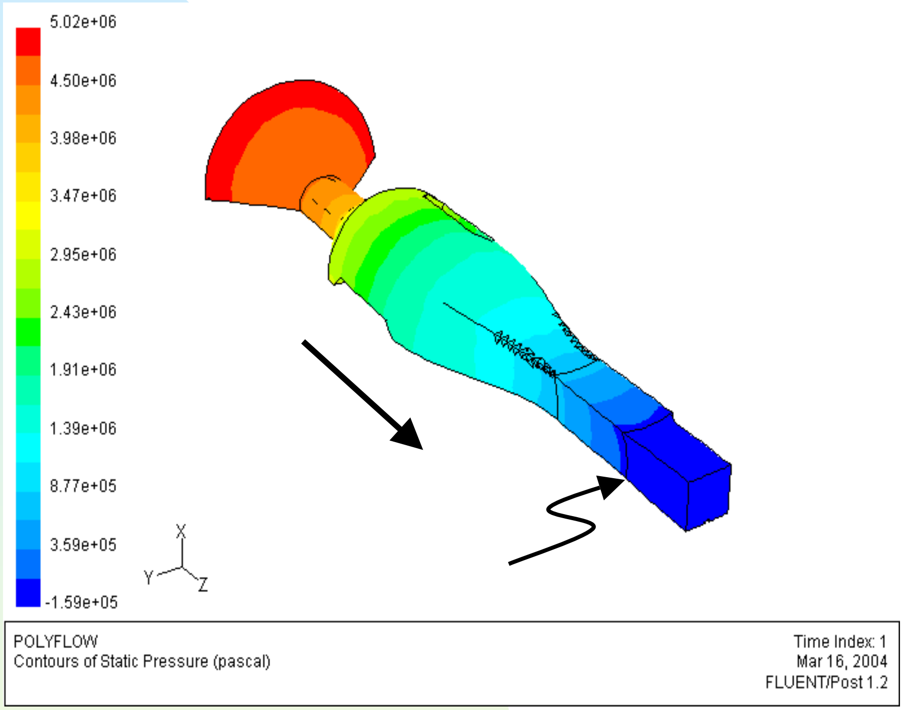
- **Line under nitrogen atmosphere:**
  - **Drying under nitrogen**
  - **Each piece of equipment is purged**

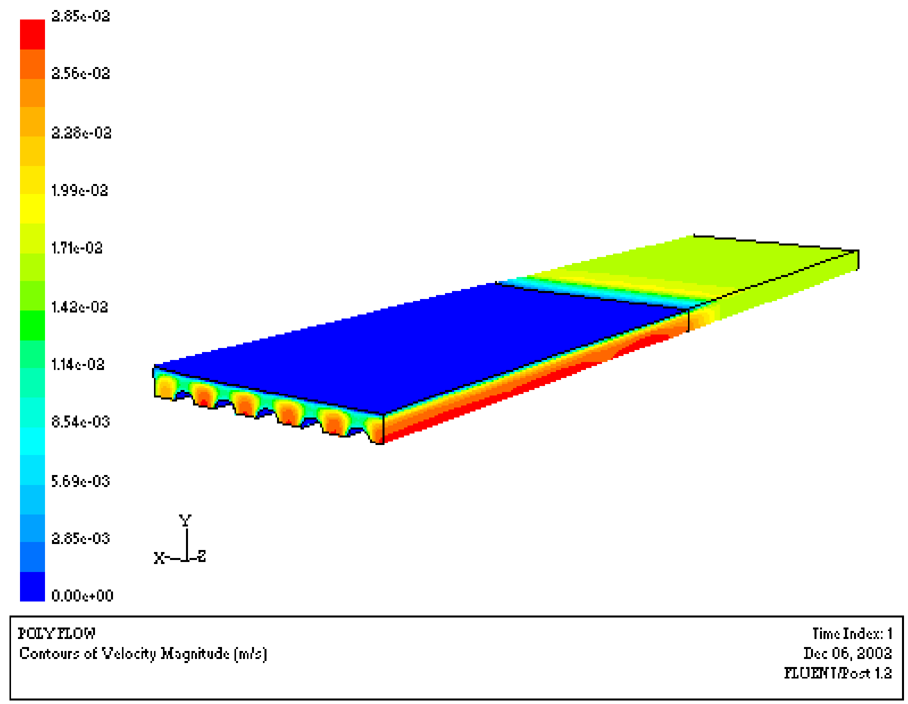
ZE 40A UTS Technical Data

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

Output range 30-200kg/h

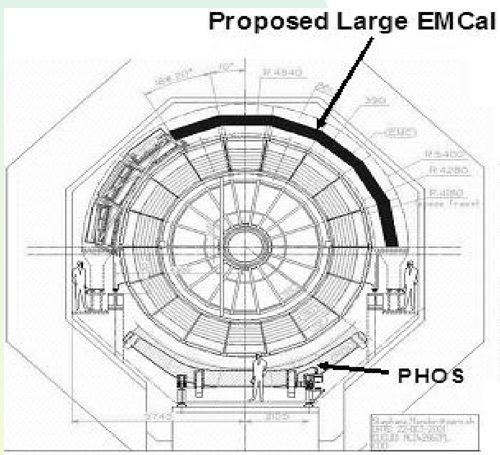
Simulation of the extrusion profiles





The projects on which we collaborate

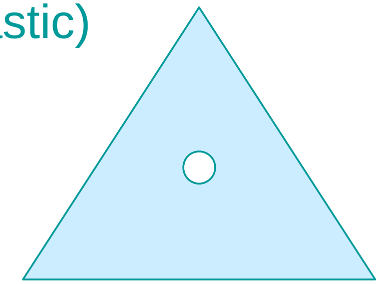
- ALICE ECAL upgrade (~15 T of extruded plastic)

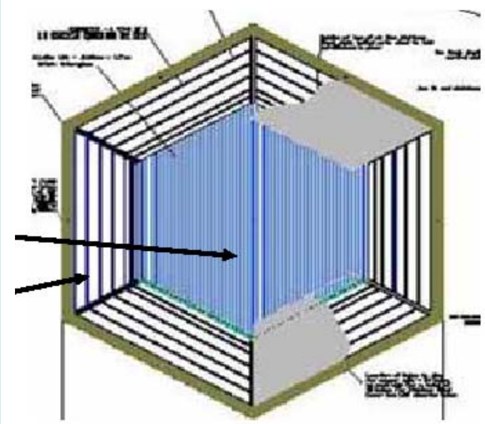


DHCAL (~20 T)

Cell Area	~900 mm^2
Number of Layers	30
Inn Radius of first Absorber Layer (W)	1,530 mm
Inner Radius of first Active Layer	1,555.6 mm
Average Number of Cells/Layer	~70,000
Total # of Cells	2100000

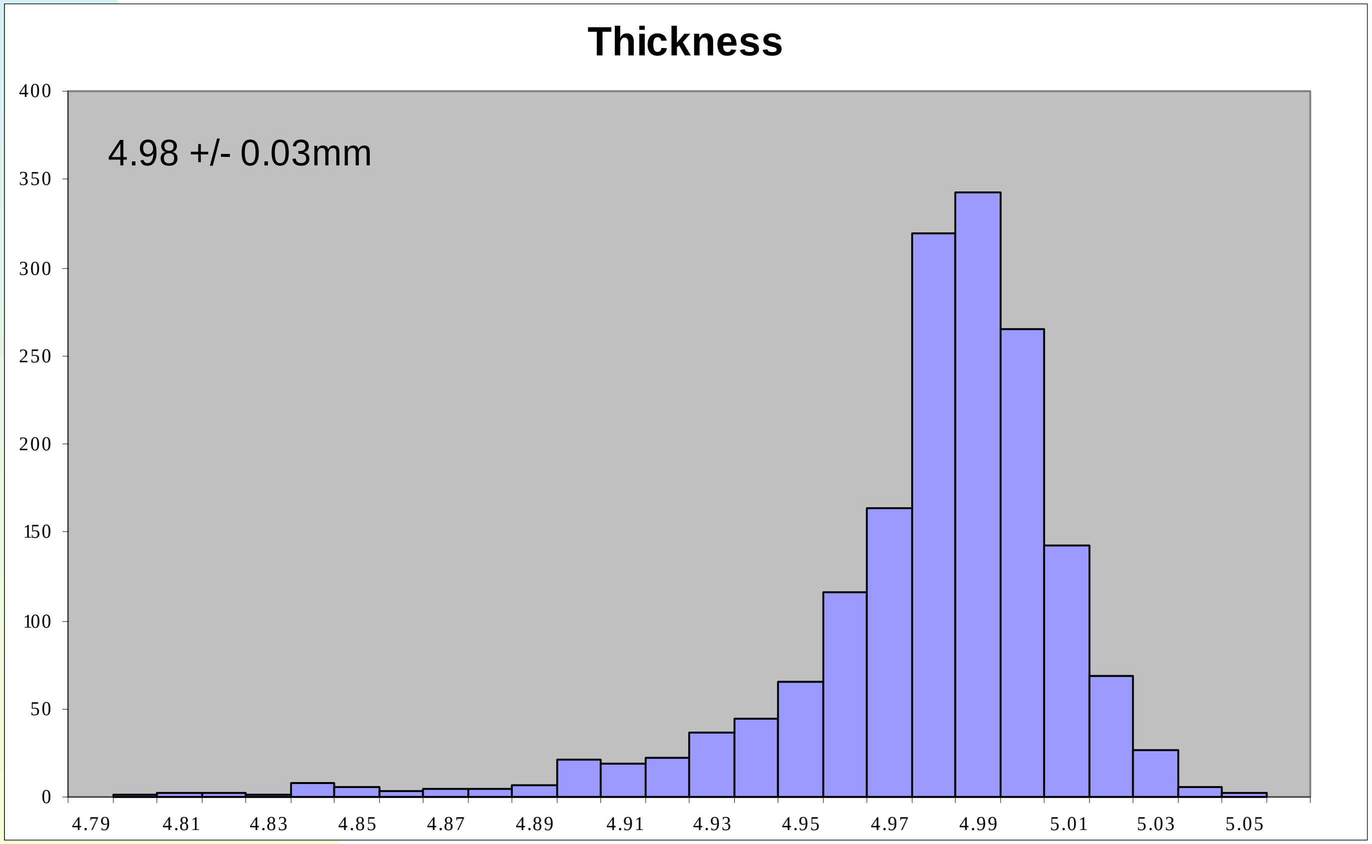
- MINERVA (~10 T of extruded plastic)



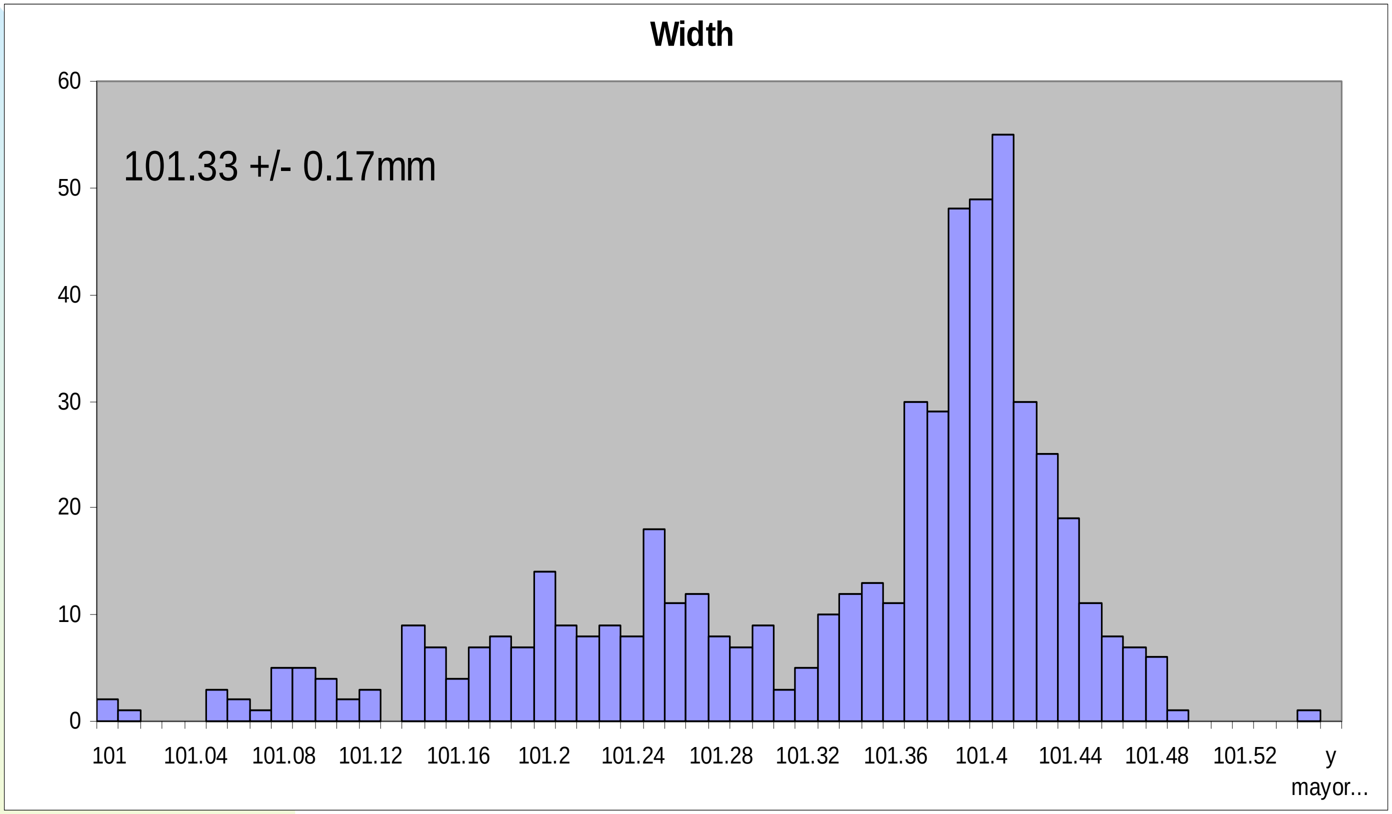


Mechanical tolerances, 300 m of extrusion profile.

Thickness 4.98±0.03 mm



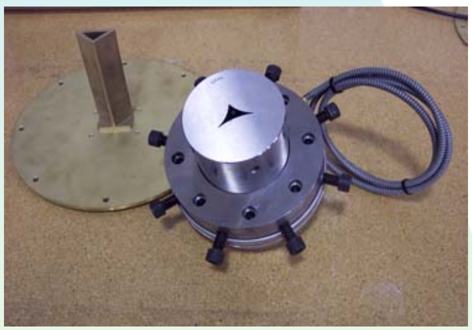
Tolerances, continued.



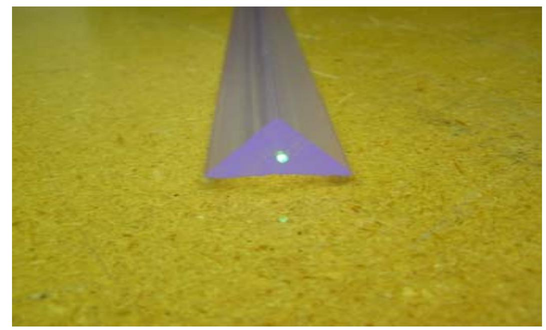
Width101.33±0.17 mm

Die impact on the scintillator profile

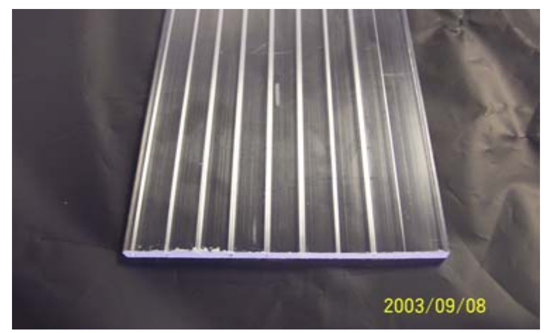
Rectangle, with or without hole to host 1.2 mm WLS fiber



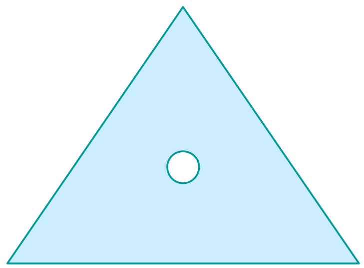
Triangle, with or without hole to host 1.2 or 1.5 mm WLS fiber



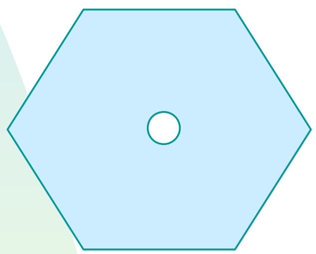
Rectangle, with 10 holes, or without them, to host 1.2 mm WLS fibers



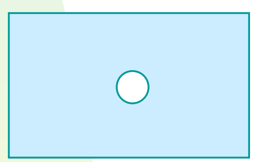
Possible shapes of the extrusion process



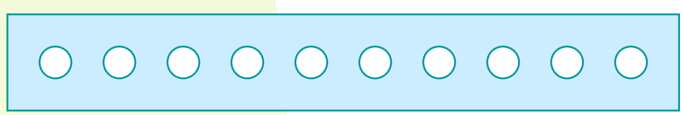
MINERVA, D0 approach, gives very good coordinate resolution, die is at our disposal(base 3.3 cm, height 1.7cm)



Calorimeter applications, the die is not currently available.

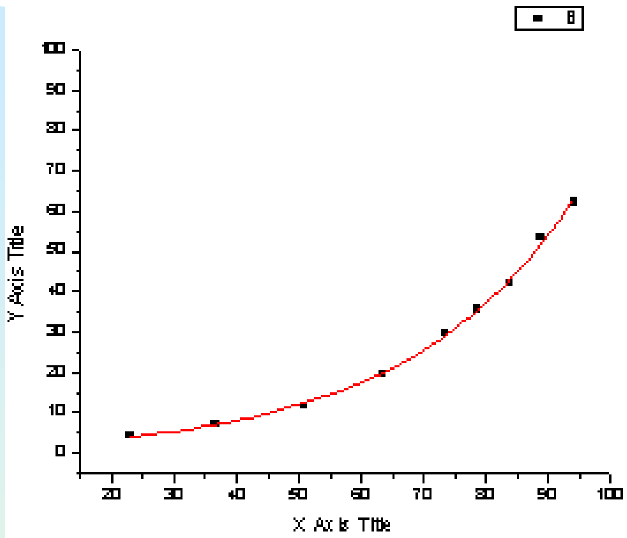


K2K solution, the die is available(2cm*1cm)



Imagination is limited by the fiber cost, the die is in our disposal(10cm*0.5cm)

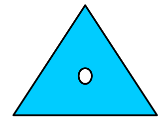
Light attenuation length(short component)



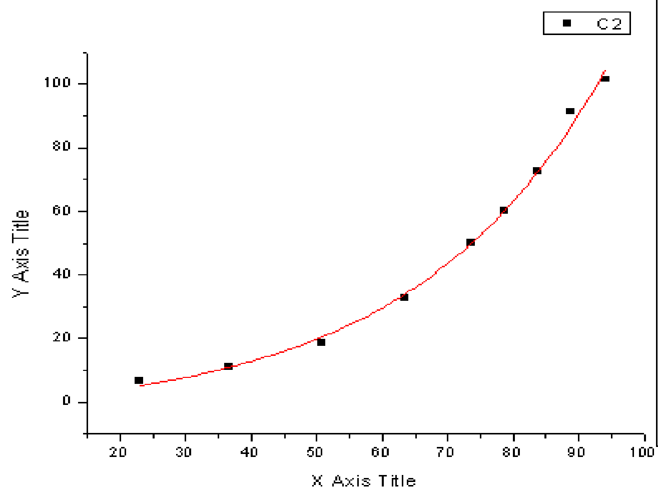
Data: Data1_B
Model: ExpDec2
Equation: y = A1*exp(-x/t1) + A2*exp(-x/t2) + y0
Weighting:
y No weighting

Chi^2/DoF = 1.20041
R^2 = 0.99858

y0	-0.58879	±--
A1	0.9824	±--
t1	-27.06481	±--
A2	0.9824	±--
t2	-27.06482	±--



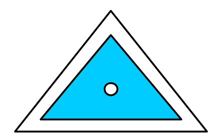
Attenuation Length
L=27.1 cm (No-Tyvek)



Data: Data1_C2
Model: ExpDec2
Equation: y = A1*exp(-x/t1) + A2*exp(-x/t2) + y0
Weighting:
y No weighting

Chi^2/DoF = 9.35515
R^2 = 0.99612

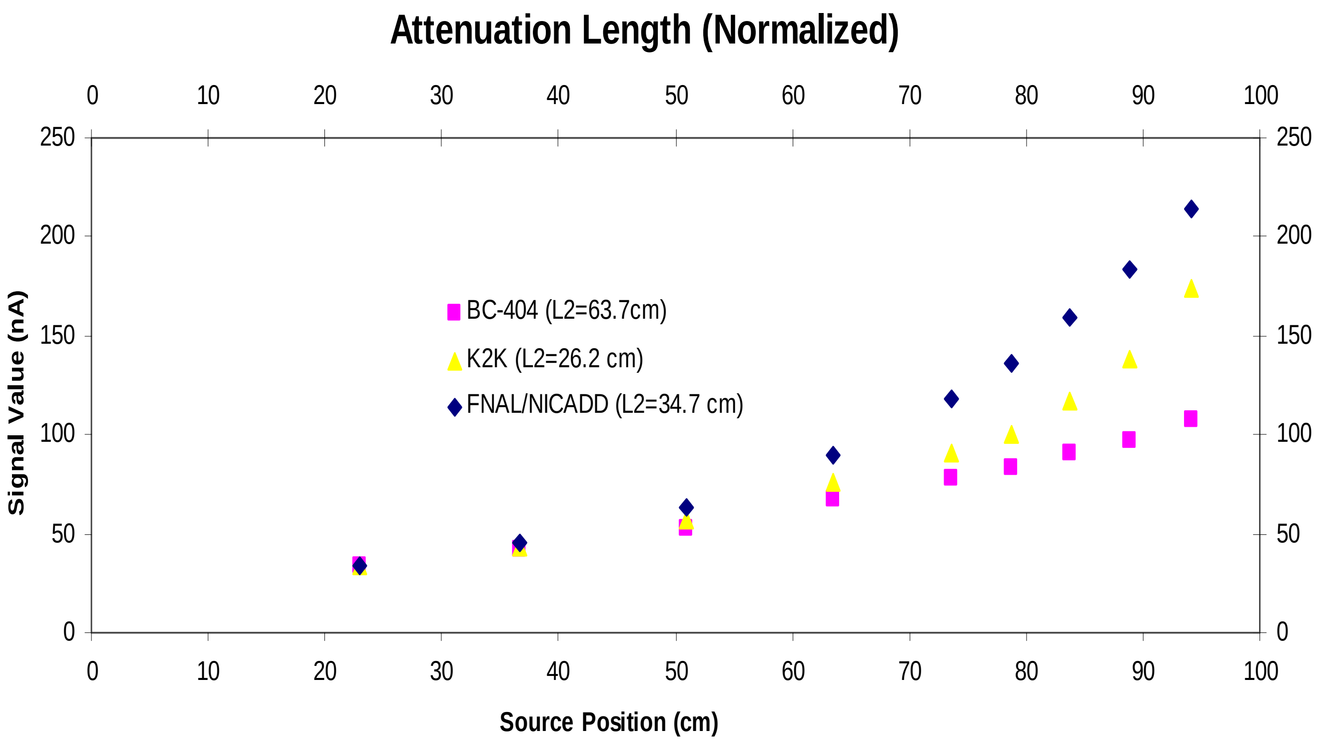
y0	-4.58359	±4.63456
A1	2.22998	±--
t1	-29.4206	±--
A2	2.22998	±--
t2	-29.4206	±--



Attenuation Length
L=29.4 cm (Tyvek)

Light attenuation length

1. Samples are cut to the same size(2*0.5*100 cm^3)
2. All edges are polished to the same level
3. Far end is painted black
4. The samples are consecutively wrapped in the same Tyvek.



Different sizes and wrappings

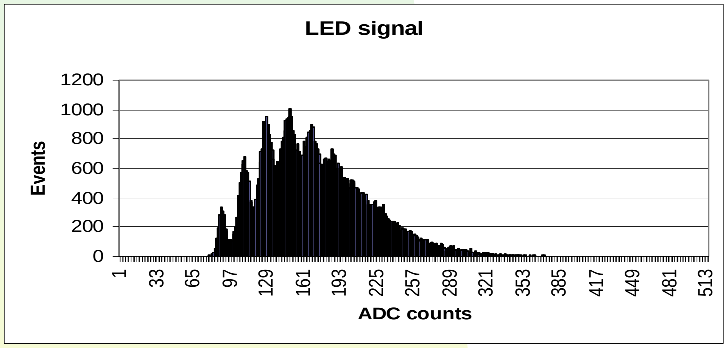
Type:	Wrapping:	End:	Polished:	L1 (Long):	L2 (Short):
FNAL (2x1 cm)	Tyvek	Black (Taped)	No	46.3 cm	36.5 cm
K2K (2x1 cm)	Co-extrusion	Black (Taped)	No	16.3	7.9 cm
K2K (2x0.5cm)	Tyvek	Black (Painted)	Yes (All edges)	53.8 cm	26.2
FNAL (2x0.5cm)	Tyvek	Black (Painted)	Yes (All Edges)	44.6 cm	34.7
BC404 (2x0.5cm)	Tyvek	Black (Painted)	Yes (All Edges)	64.5cm	63.7

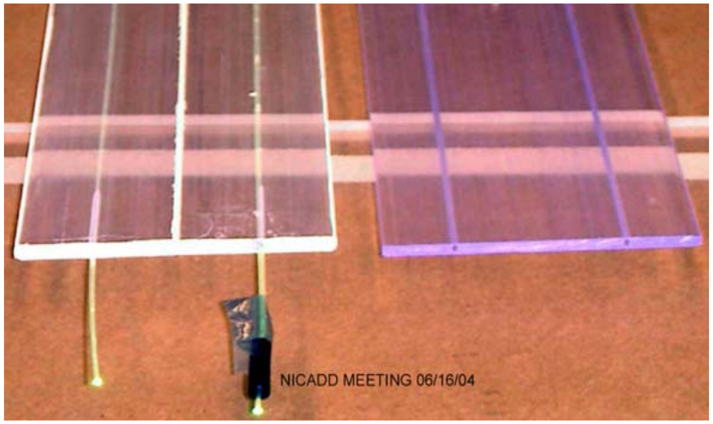
Light output

BC408 ADC counts	**2.70 ± 0.25**	
F-NICADD	**2.01 ± 0.30**	
Kuraray SCSN-81	**2.03 ± 0.21**	

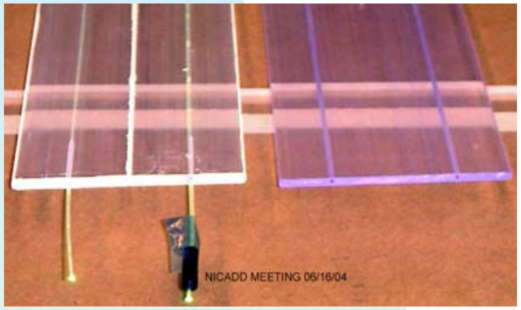
⇔ **Samples 2*2 cm^2**
^{106}Ru
Normalized to the thickness of 1 mm

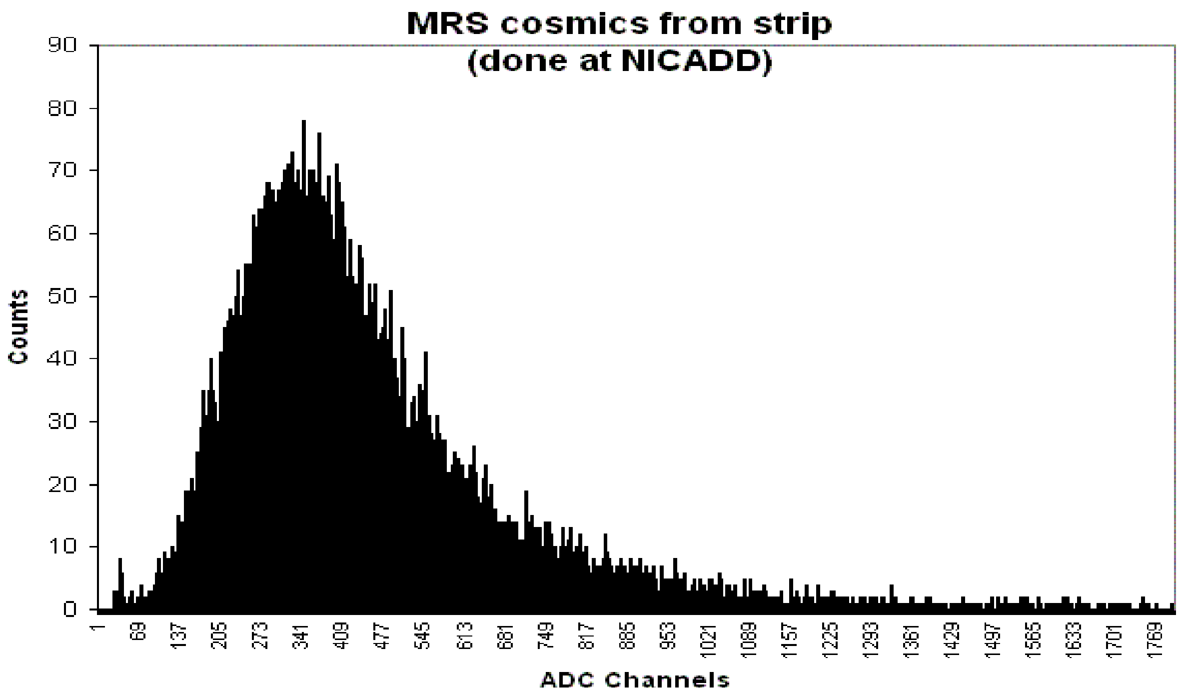
5 mm extruded scintillator thickness, extruded hole,1.2 mm Y11 fiber, 10 cm out of scintillator, MRS readout ~ **17 PE**





Light output





5 mm extruded scintillator thickness, extruded hole,1.2 mm Y11 fiber, 10 cm out of scintillator, MRS readout ~ **17 PE**

Light output (MRS Readout, 1*1 mm²)

WLS FIBER DIAMETER [MM]	SCINTILLATOR THICKNESS [MM]	RESPONSE [PE]
1.00(hole+glue)	5	14.5
1.20(hole+glue)	5	17.0
1.50(hole+glue)	5	20.5
1.20(groove+glue)	10	22.1

Basics

1 PRINCIPLE OF OPERATION

One μ–cell of a photodiode designed in mesa-technology is shown schematically in Fig.1. Each of 1 mm^2 diodes produced in this technology contains 1370 such cells connected electrically to each other and to common readout by means of Al metallization lines. Photosensitive area composes approximately 60% of the total area. Doping concentrations are such that a high local electric field, exceeding breakdown voltage, is reached in the photosensitive layer at relatively low reverse bias voltages (45-48 V). Each photoelectron, which is created by incident photon or by the leakage current and reaches multiplication zone, initializes an avalanche creating up to $\sim 10^6$ secondary electrons.

The avalanche is locally quenched by a film resistor formed on the surface of each pixel from the n-side, therefore the pulse amplitude from each μ-cell does not depend on the amount of initial charges. Quasi-linearity of the device is reached when it detects light uniformly distributed over the whole area, in this case the total pulse-hight is determined by the amount of fired μ-cells, and the dynamic range - by the total amount of cells on the detector area (typically $\sim 10^4/mm^2$). In mesa-technology pixels are optically isolated due to deep inter-pixel etching and metallization. Each cell has its own film resistor connected to common Al grid. This layout gives the following advantages:

- optical separation reduces probability of photo-ionization, i.e. secondary avalanche ignition in adjacent pixels by UV photons emitted from a primary avalanche,
- resistor values are under better control,
- avalanche process in one cell does not influence sensitivity of the others,
- localized quenching by individual film resistors reduces total dead time, which in this case is defined by a single pixel and does not depend on the total amount of fired pixels.

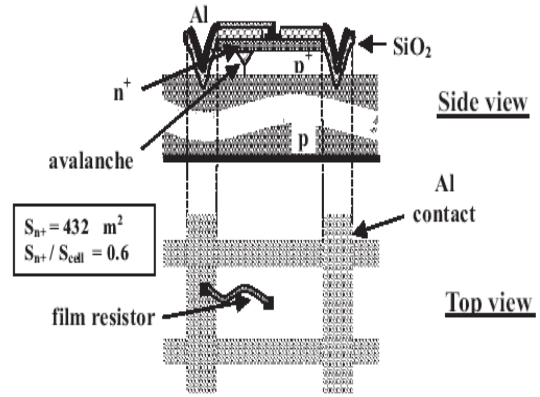
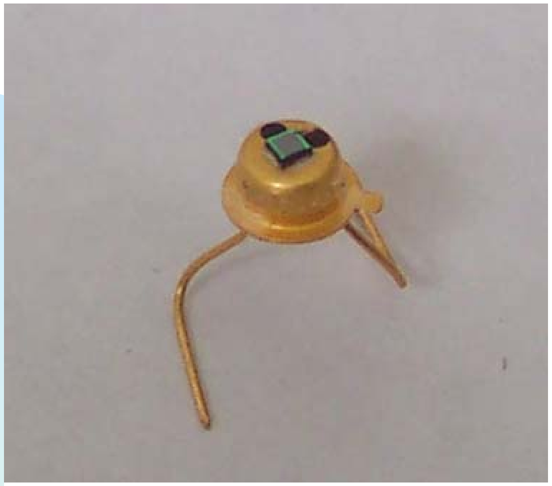
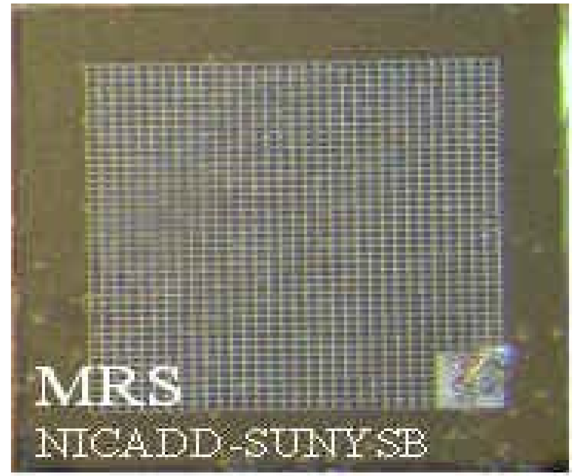


Figure 1. Schematic view of one MRS APD$_G$ μ-cell.

MRS





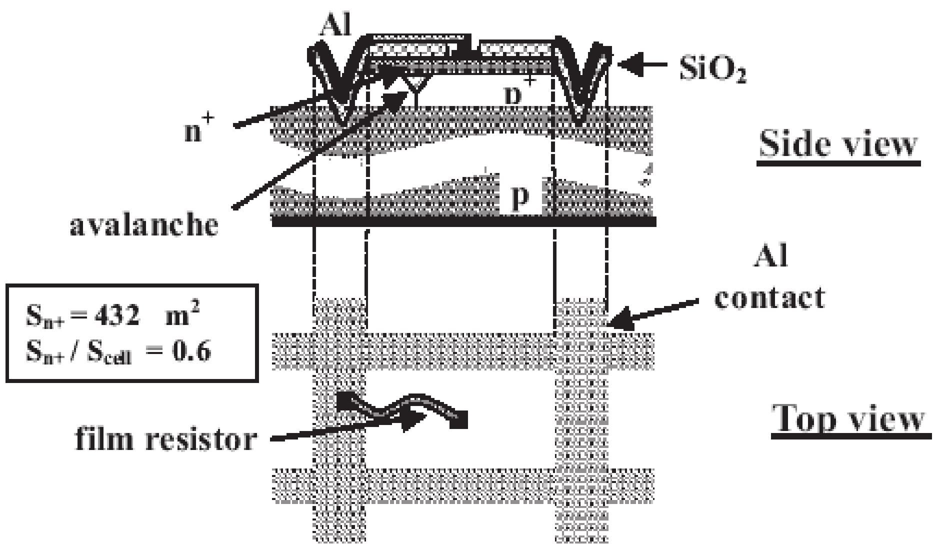
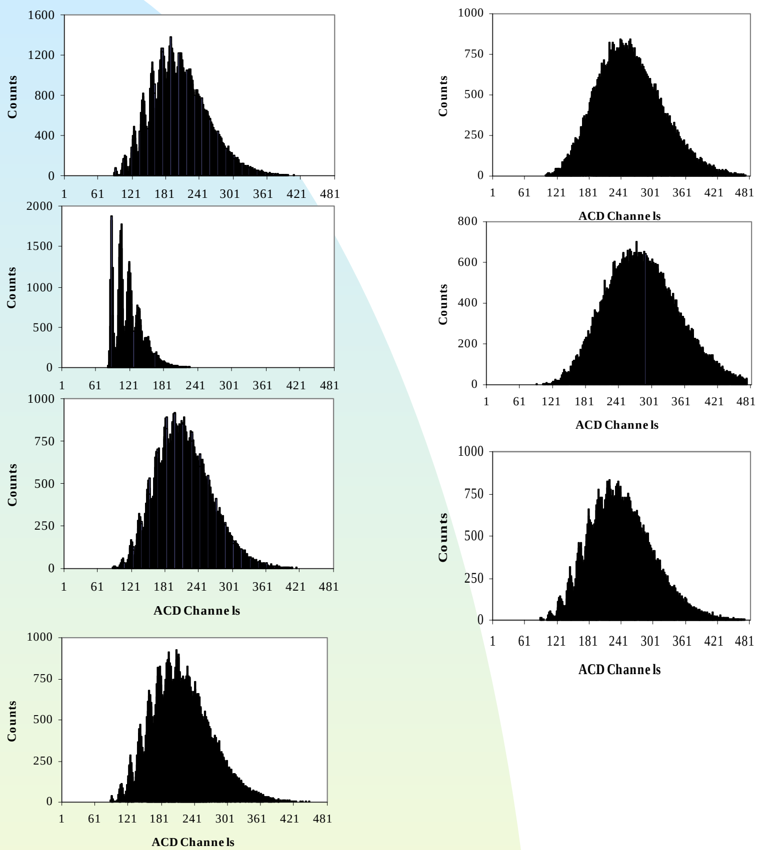


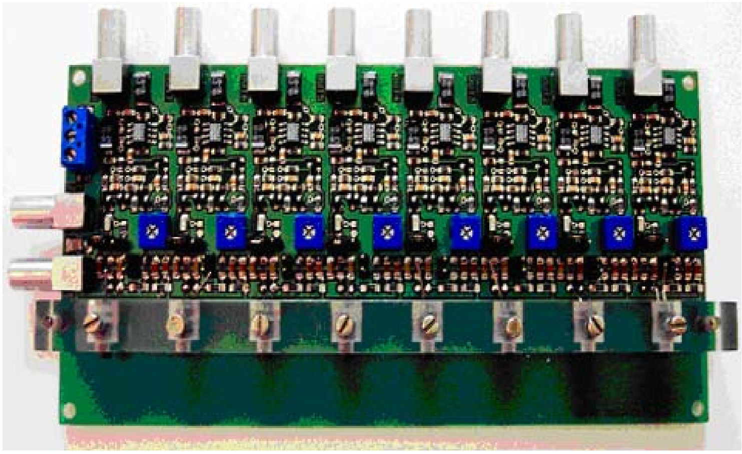
Figure 1. Schematic view of one MRS APD$_G$ μ-cell.

General introduction

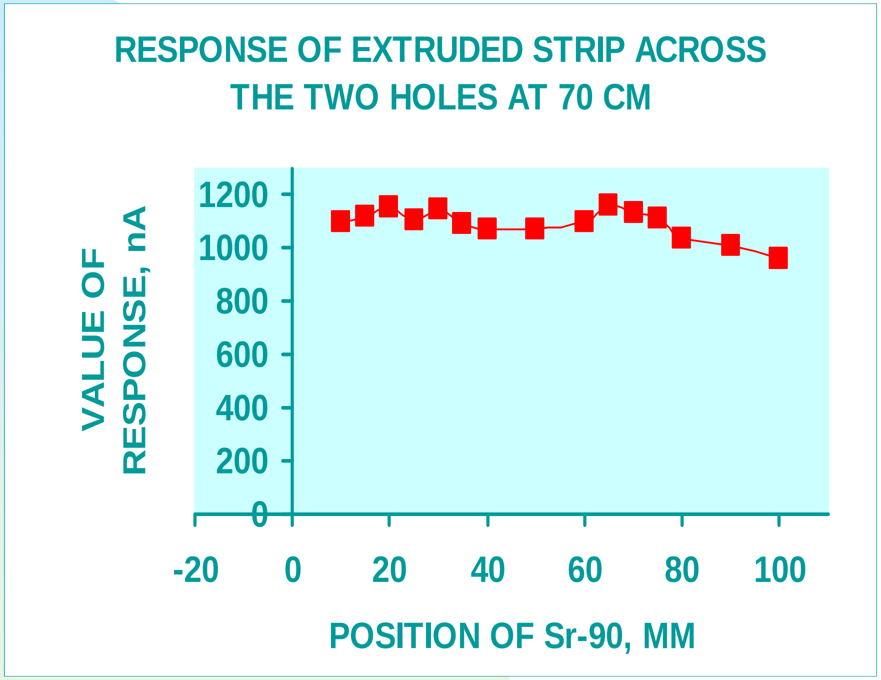
- Spectral response range 420-1000 nm
- Peak sensitivity wavelength 670 nm (MRS)
- ε (670 nm) 23 % — Photon detection efficiency $\varepsilon = QE \cdot \varepsilon_{geom}$
- Operating voltage 45-65 Volts
- Dark current ~ 2 µA
- Capacitance ~25 pF
- Gain $\sim 5 \cdot 10^6$
- Time response ~ 1-2 ns
- Time resolution < 300 ps
- Price (~100000) expect ~ $10/ch
- Price (1-5) really ~ $ 80/ch

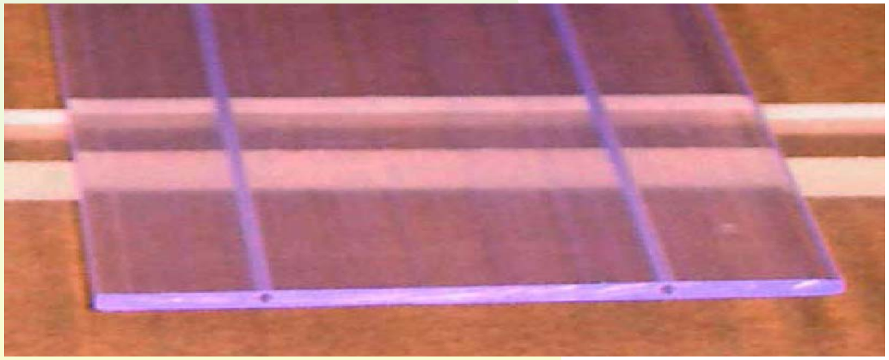
Tested PC board + MRS



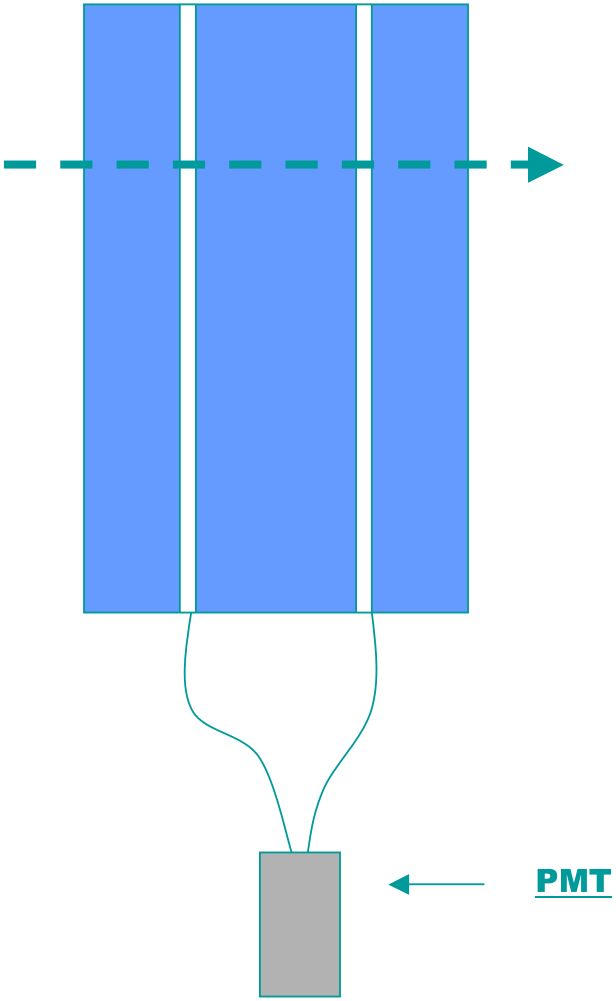


Light yield uniformity response

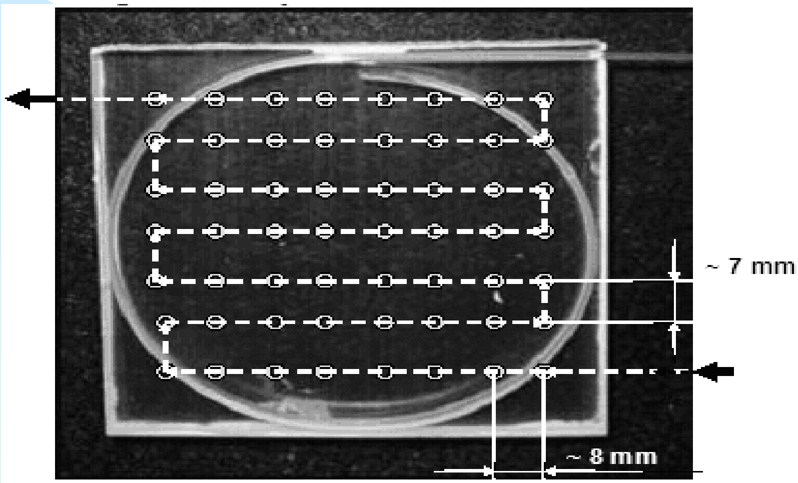




LY non-uniformity σ ~ 4 %   NICADD (10 cm)

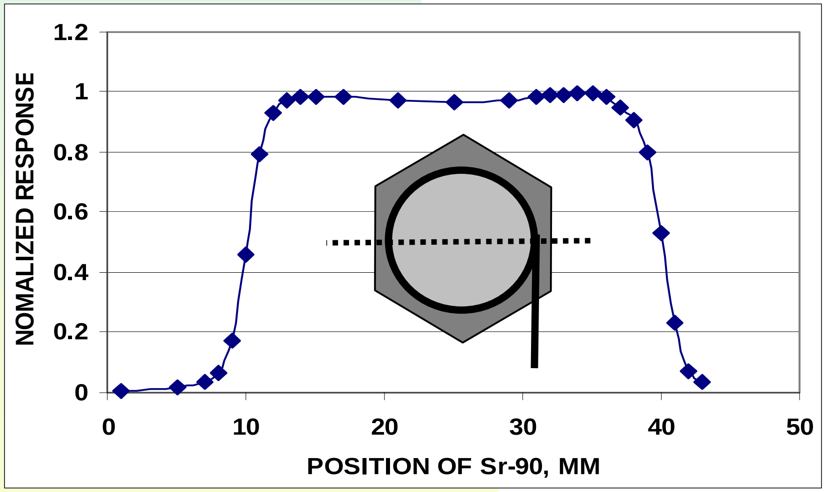


Light yield uniformity response



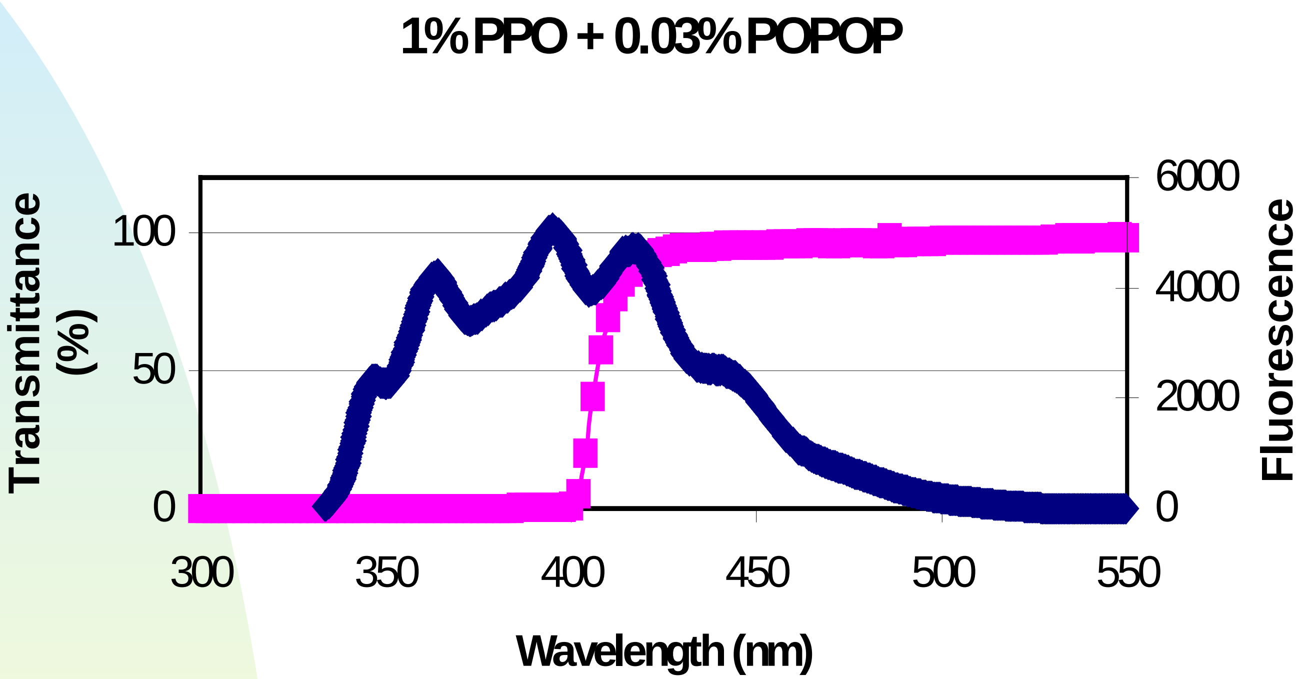
LY non-uniformity σ ~ 2.2 % for F-NICADD (10*10 cm^2)

σ ~ 2.3 % (10*10 cm^2 SCSN-81)



LY non-uniformity < 3 % for 9 cm^2 HEX. Cell for DHCAL

FNAL-NICADD extruded scintillator, Transmittance and Fluorescence before irradiation

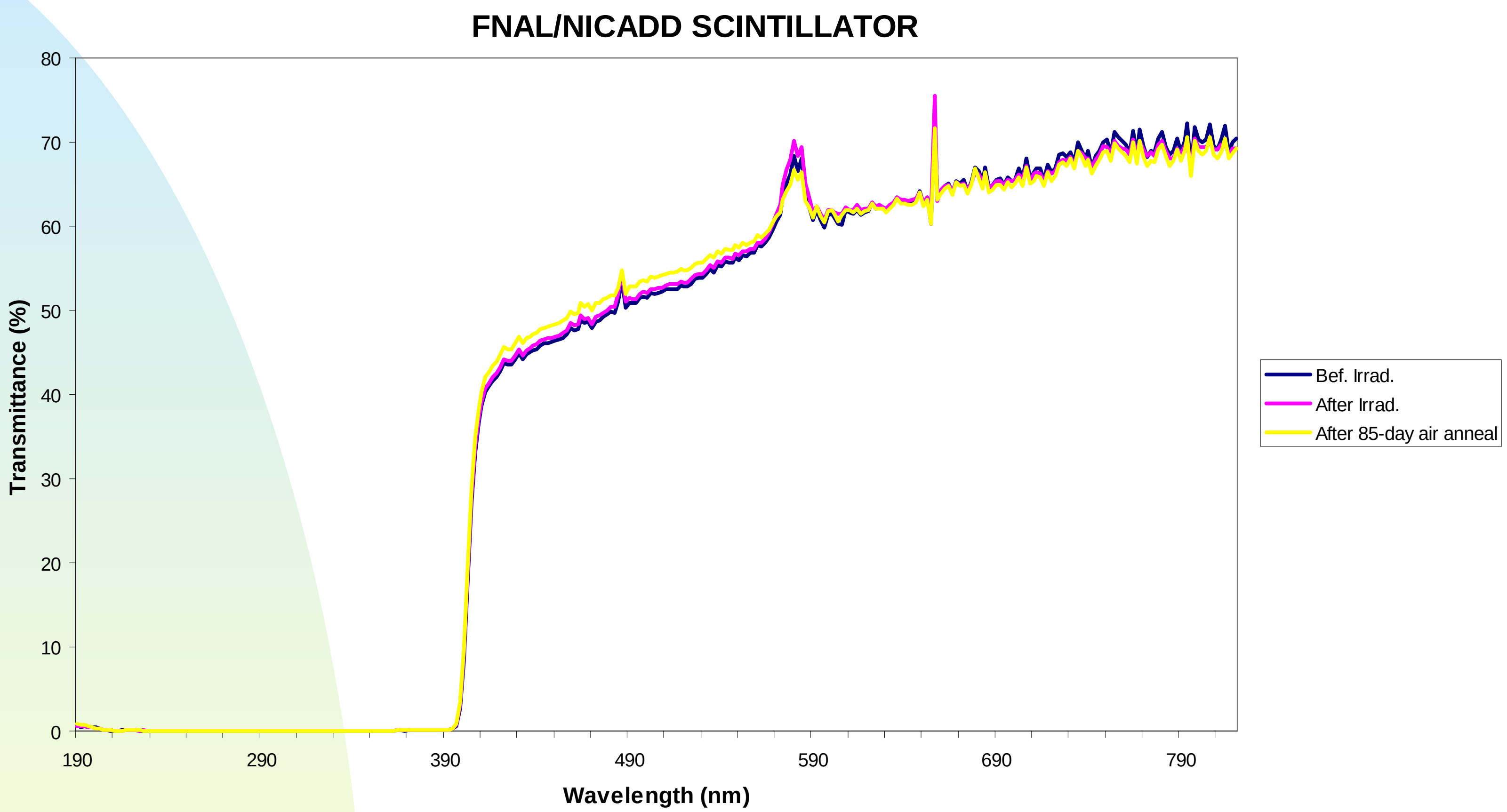


Radiation hardness

FNAL-NICADD extruded scintillator, 18 samples of $2*2\ cm^2$, Irradiation in air and annealing in air during 85 days, 9KGy/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 %

Transmittance



Brief summary of the FNAL-NICADD extruded scintillator characteristics.

Thickness:	σ ~ 0.6 %	(Over 300 m)
Width :	σ ~ 0.2 %	(Over 300 m)
LY non-uniformity	σ ~ 4 %	(across 10 cm)
LY non-uniformity	σ ~ 2.2 %	(10*10 cm^2)
LY non-uniformity	~ 3 %	(Hexagonal cell 9 cm^2)
Light Yield	66 % of BC408	
	~100% of Kuraray SCSN-81	
Rad. Hardness	< 5 % LY degradation after 1 Mrad	(gamma)