FNAL-NICADD extruded scintillator

Presented by Victor Rykalin

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FERMILAB ¹
NICADD NIU²

9/3/2004
FNAL-NICADD EXTRUSION FACILITY

• 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

OUTPUT:
Scintillating pellets
Scintillator bars

POLYMER DRYER
CONVEYOR
POLYMER FEEDER
DOPANT FEEDER
EXTRUDER
MELT PUMP
DIE

Scintillator bars
ZE 40A UTS Technical Data

- Screw diameter: 44 mm
- Screw speed: 1200 RPM
- Drive power: 200 HP
- Height: ~1100 mm
- Weight: ~3500 kg
- Theoretical life: ~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)**
- **MINERVA** (~10 T of extruded plastic)

### DHCAL Specifications

- **Cell Area**: ~900 mm$^2$
- **Number of Layers**: 30
- **Inner 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**: 2,100,000

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9/3/2004
Mechanical tolerances, 300 m of extrusion profile.

Thickness 4.98±0.03 mm

Width 101.33±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 1.7 cm)

Calorimeter applications, die is not 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)

Attenuation Length
L=27.1 cm (No-Tyvek)

Attenuation Length
L=29.4 cm (with Tyvek)

9/3/2004
### Light attenuation length

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

#### Attenuation Length

![Attenuation Length Graph]

#### Different sizes and wrappings

<table>
<thead>
<tr>
<th>Type:</th>
<th>Wrapping:</th>
<th>End:</th>
<th>Polished:</th>
<th>L1 (Long):</th>
<th>L2 (Short):</th>
</tr>
</thead>
<tbody>
<tr>
<td>FNAL (2x1 cm)</td>
<td>Tyvek</td>
<td>Black</td>
<td>No</td>
<td>46.3 cm</td>
<td>36.5 cm</td>
</tr>
<tr>
<td>K2K (2x1 cm)</td>
<td>Co-extrusion</td>
<td>Black</td>
<td>No</td>
<td>16.3 cm</td>
<td>7.9 cm</td>
</tr>
<tr>
<td>K2K (2x0.5cm)</td>
<td>Tyvek</td>
<td>Black</td>
<td>Yes</td>
<td>53.8 cm</td>
<td>26.2 cm</td>
</tr>
<tr>
<td>FNAL (2x0.5cm)</td>
<td>Tyvek</td>
<td>Black</td>
<td>Yes</td>
<td>44.6 cm</td>
<td>34.7 cm</td>
</tr>
<tr>
<td>BC404 (2x0.5cm)</td>
<td>Tyvek</td>
<td>Black</td>
<td>Yes</td>
<td>64.5 cm</td>
<td>63.7 cm</td>
</tr>
</tbody>
</table>
Light output

<table>
<thead>
<tr>
<th>Material</th>
<th>Light Output (PE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BC408</td>
<td>2.70 ± 0.25</td>
</tr>
<tr>
<td>F-NICADD</td>
<td>2.01 ± 0.30</td>
</tr>
<tr>
<td>Kuraray SCSN-81</td>
<td>2.03 ± 0.21</td>
</tr>
</tbody>
</table>

Samples 2*2 cm²

$^{106}$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 (MRS Readout, 1*1 mm)

<table>
<thead>
<tr>
<th>WLS FIBER DIAMETER [MM]</th>
<th>SCINTILLATOR THICKNESS [MM]</th>
<th>RESPONSE [PE]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.00(hole+glue)</td>
<td>5</td>
<td>14.5</td>
</tr>
<tr>
<td>1.20(hole+glue)</td>
<td>5</td>
<td>17.0</td>
</tr>
<tr>
<td>1.50(hole+glue)</td>
<td>5</td>
<td>20.5</td>
</tr>
<tr>
<td>1.20(groove+glue)</td>
<td>10</td>
<td>22.1</td>
</tr>
</tbody>
</table>

MRS cosmics from strip (done at NiCADD)
Light yield uniformity response

RESPONSE OF EXTRUDED STRIP ACROSS THE TWO HOLES AT 70 CM

VALUE OF RESPONSE, nA

POSITION OF Sr-90, MM

Uniformity LY σ ~ 4 % NICADD (10 cm)

PMT
Light yield uniformity response

**Uniformity LY $\sigma \sim 2.2\%$ F-NICADD (10*10 cm²)**

$\sigma \sim 2.3\%$ (10*10 cm² SCSN-81)

**Uniformity LY $< 3\%$ 9 cm² HEX. Cell for DHCAL**
Radiation hardness

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

<table>
<thead>
<tr>
<th>Dose absorbed</th>
<th>Before Irradiation (ADC counts)</th>
<th>After irradiation and anneal (ADC counts)</th>
<th>Light yield loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>γ, ^60^Co</td>
<td>264±8.6</td>
<td>266±7.7</td>
<td></td>
</tr>
<tr>
<td>0.5 Mrad (5KGY)</td>
<td>273±5.8</td>
<td>261±7.1</td>
<td>5 %</td>
</tr>
<tr>
<td>1 Mrad (10KGY)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

FNAL-NICADD extruded scintillator, Transmittance and Fluorescence

1% PPO + 0.03% POPOP

Dose absorbed γ, ^60^Co

Before Irradiation (ADC counts)

After irradiation and anneal (ADC counts)

Light yield loss

Transmittance (%)

Fluorescence

Wavelength (nm)
Transmittance of the FNAL/NICADD SCINTILLATOR after different irradiation and annealing conditions.
<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness</td>
<td>$\sigma \sim 0.6%$</td>
<td>(Over 300 m)</td>
</tr>
<tr>
<td>Width</td>
<td>$\sigma \sim 0.2%$</td>
<td>(Over 300 m)</td>
</tr>
<tr>
<td>Uniformity LY</td>
<td>$\sigma \sim 4%$</td>
<td>(across 10 cm)</td>
</tr>
<tr>
<td>Uniformity LY</td>
<td>$\sigma \sim 2.2%$</td>
<td>(10*10 cm²)</td>
</tr>
<tr>
<td>Uniformity LY</td>
<td>~ 3%</td>
<td>(Hexagonal cell 9 cm²)</td>
</tr>
<tr>
<td>Light Yield</td>
<td>66%</td>
<td>of BC408</td>
</tr>
<tr>
<td></td>
<td>~100%</td>
<td>of Kuraray SCSN-81</td>
</tr>
<tr>
<td>Rad. Hardness</td>
<td>&lt; 5% LY degradation</td>
<td>after 1 Mrad (gamma)</td>
</tr>
</tbody>
</table>