Status of the magnetized neutrino detector Baby-MIND

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Purpose:

- Magnetized Iron Neutrino Detector (MIND) Design;
- Creation and study of detector modules;
- Beam tests result (T9 CERN);
- Determination of the time resolution.
- Baby-Mind SiPM Front End Electronics Design
WAGASCI Design
Baby-MIND Design
Baby-MIND Design
Magnetic field map
Baby-MIND scintillator counters

- Extruded polystyrene plates supplemented with 1.5% paraterphenyl (PTP) and POPOP 0.01%;
- 30-100 micron layer Uniplast acting as a diffusive reflector;
- WLS Y11 KURARAY \( \varnothing 1 \text{mm} \);
- Hamamatsu SiPM with active area 1x1 \( \text{mm}^2 \), 25 micron pixel size (MPPC S12571-025C);
- Optic glue EJ-500.
Vertical scintillator counters for Baby-MIND

Light Yield = Sum of 2 signals (L1+L2) from both ends

LY is measured at far end of counter

1950 mm
Asymmetry of LY: $A = (L1 - L2) / (L1 + L2)$
Horizontal scintillator counters for Baby-MIND

Light Yield = Sum of 2 signals (L1+L2) from both ends

LY summ

<table>
<thead>
<tr>
<th>LY1+LY2</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Entries</td>
<td>1611</td>
</tr>
<tr>
<td>Mean</td>
<td>64.73</td>
</tr>
<tr>
<td>RMS</td>
<td>7.808</td>
</tr>
<tr>
<td>$\chi^2$/ndf</td>
<td>93.35/65</td>
</tr>
<tr>
<td>Constant</td>
<td>74.31 $\pm$ 2.33</td>
</tr>
<tr>
<td>Mean</td>
<td>65.19 $\pm$ 0.17</td>
</tr>
<tr>
<td>Sigma</td>
<td>6.526 $\pm$ 0.120</td>
</tr>
</tbody>
</table>

N
Horizontal scintillator counters for Baby-MIND

Asymmetry of LY: \( A = \frac{(L1-L2)}{(L1+L2)} \)
Horizontal scintillator counters for Baby-MIND

```
# Histogram data

Entries: 1611
Mean: 31.18
RMS: 0.153
\chi^2 / ndf: 109.1 / 43
Constant: 83.79 ± 2.87
Mean: 31.19 ± 0.00
Sigma: 0.1436 ± 0.0033

Entries: 1611
Mean: 7.362
RMS: 0.146
\chi^2 / ndf: 70.08 / 39
Constant: 114.7 ± 3.8
Mean: 7.36 ± 0.00
Sigma: 0.1341 ± 0.0029
```
Test of bar scintillators at PS T9 beam line in CERN

Beam: 10 GeV/c

Beam size:
Trigger counters cut the beam spot
1x5 cm²
Light yield in 3-cm bars

3 bars were irradiated in the beam. The plot shows the average result for all 3 tested bars. Red points are the sum from both ends.

No correction was made for temperature fluctuations (+/- 2 C).
Timing for 3-cm bars vs position along the bars

Time resolution $\sigma_t$ was calculated for distribution $(T_{\text{left}} + T_{\text{right}})/2$, where $T$ is the signal time minus trigger time. Trigger jitter contributes in $\sigma_t$. Each point is the average for 3 bars.

Average $\sigma_t = 724$ ps
Test of BabyMIND vertical bars

The bars were individually isolated and assembled into a single module.

Trigger is made up of four cut TASD bars crosswise in coincidence.

Trigger counters: 1x1 cm²
Average L.Y. is **33.8** p.e.
Dependence the average L.Y. from the line positions
Citiroc SiPM Front End Electronics
CITIROC BLOC DIAGRAM
Readout with peak detector window set to 320 ns

- T2K
- 2.6 s
- ~5 μs
- 80 ns
- 580 ns

μ through sci.
FSB shaper
Digi hits!
SSH shaper
Peak detector "gate"
Charge readout

FEB i, Ch #: i_n
No readout
FEB i, Ch #: i_m
Single channel occupancy issue

For a given channel “Peak detector” will only retain highest amplitude hit occurring in its 10 μs window.

Get some measure of charge from “Time over Threshold”.

μ through sci.

FSB shaper

Digital hits!

SSH shaper

Peak detector “gate”

Charge readout

FEB i, Ch #: i_n

FEB i, Ch #: i_n

10 μs

No readout
There is linear correlation between LG and HG.
Correlation between ToT (Vertical scale units of 2.5ns) and:
LG55 (Horizontal scale ADC units) in BLUE.
HG50 (Horizontal scale ADC units) in RED.
## Summary

<table>
<thead>
<tr>
<th></th>
<th>Horizontal bars</th>
<th>Vertical bars</th>
<th>Total (hor. + vert.)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Plastic scintillators</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td># bars per layer</td>
<td>48/47</td>
<td>8</td>
<td>56</td>
</tr>
<tr>
<td># bars per module</td>
<td>95</td>
<td>16</td>
<td>111</td>
</tr>
<tr>
<td># bars total</td>
<td>1710</td>
<td>288</td>
<td>1998</td>
</tr>
<tr>
<td><strong>Readout per module</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td># SiPMs per module</td>
<td>190</td>
<td>32</td>
<td>222</td>
</tr>
<tr>
<td># CITIROC per module</td>
<td>6</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td># Front End Boards per module</td>
<td>TBC</td>
<td>TBC</td>
<td>TBC</td>
</tr>
<tr>
<td><strong>Readout total (18 modules)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td># SiPMs total</td>
<td>3420</td>
<td>576</td>
<td>3996</td>
</tr>
<tr>
<td># CITIROC total</td>
<td>108</td>
<td>18</td>
<td>126</td>
</tr>
<tr>
<td># Front End Boards total</td>
<td>TBC</td>
<td>TBC</td>
<td>TBC</td>
</tr>
</tbody>
</table>
Summary:

• 700 scintillation counters for Baby-MIND are created and tested;
• Light yield for horizontal bars is 67 P.E./MIP;
• Light yield for vertical bars is 37 P.E./MIP;
• Scintillation bars sizes in range of 0.14mm;

Planned to test Baby-MIND on T9 CERN beam area by the end of 2016
background slides
d: detector module
s: steel module

Note 1: d0 is smaller since it has to fit close to (right up against) WAGASCI neutrino targets
Note 2: this layout will definitely evolve!!
Note 3: ... must integrate all WAGASCI sub-detectors!

Gaps to improve angular resolution with “lever arm”

Thicker steel to better resolve angular deflection by B-field from angular deflection by M.S.

Thinner steel here to improve cross-calibration of detector:
i.e. momentum resolution by range vs B-field
(F_{loss} = 35 MeV in 30 mm of steel for MIP μ)
Distribution of detector modules amongst magnetized steel plates

- 18 detector modules
- 33 steel plates
  - not all steel plates can be instrumented

**detector module:**
31 mm thick: mostly plastic scintillator
  - 4 layers x 7.5 mm
  - 2 envelopes x 0.5 mm (carbon fiber)

**steel module:**
50 mm thick:
  - 30 mm Fe
  - 10 mm Al
  - 10 mm insulator + gaps

= 60 mm including tolerances!

For illustration only! In practice, there are gaps between adjacent bars on one plane!
x2 layers of **vertical bars**:  
- 8 vert. bars/layer  
- 210 mm-wide bars  
- 45 mm overlap between bars of different layers  

**Material Details**  
- Plastic scintillator  
- Empty space (or passive plastic)
View showing horizontal bars
Timing with bars

\[ t_1 = t_{\text{flight}} + \frac{x}{v} \]
\[ T_1 = \frac{x}{v} \]
\[ T_2 = \frac{(L-x)}{v} \]
\[ t_2 = t_{\text{flight}} + \frac{(L-x)}{v} \]

**trigger scintillator**

\[ t_{\text{flight}} = \frac{(t_1 + t_2)}{2} - \frac{L}{2v} \]

\[ x = \left( \frac{(t_1 - t_2)}{2} \right)v + \frac{L}{2} \]
Calculation of time coordinate

For timing we fit with the straight lines the baseline before a signal pulse and the front of this pulse. Crossing of the lines gives relative time coordinate of the pulse.

Fit area on pulse front is determined in the following way:

1. Pulse height is taken as 100%.
2. First time stamp is at the level of 5% from the baseline.
3. Last time stamp is at the level of 85% from the baseline.
4. All points between first and last time stamps are fitted with the straight line. Typical number of fitted points are 40-50.

The baseline is fitted with horizontal straight line.