MIPs in your Photodiodes

David’s Instr. Ana. task: “How well do we find MIPs?” (Dario’s doing cool stuff) (MIP = Minimum Ionizing Particle)
Benoit’s task: “Make images of the CAL layers.”
Sasha’s task: “What is the light output of tracks crossing the photodiodes?”

Benoit is sharing his tools with me – I’m still settling into Palo Alto & Glast.

In the meantime…
Benoit explains the “standard model” of photodiode MIP response, we concur that our DAQ setup can give a quick reality check.

We’ve taken muon (and 22Na) data in CsI, in a photodiode, and in a CDE. Benoit calculated & simulated expected response. Preliminary result: data apparently x5 lower than predicted. Work-in-progress: explain the phenomenon.
Setup (1 of 2)

“mini-cal” used in Testbeam campaigns

2-scintillator telescope

Photos by J. Bregeon
Setup (2 of 2)

Smaller (top) scintillator: 2cm x 2cm

Same pre-amps, amps, adc, daq as for Ganil, GSI, and CERN (testbeam CsI stack at left…)

We also used:
  i)  A 2cm long “CDE”
  ii) A “naked” photodiode (thanks to G. Bogaert for providing the latter)
Muons look normal in the CDE

1 MIP ~ 12 MeV ~ 1300 dc ~ 1.3 volts
(very roughly: 1 kev per dc for our daq)
In the CDE we said
1 MIP ~ 12 MeV ~ 1300 dc ~ 1.3 volts

For the photodiode without CsI, we see ~250 dc

Zoooom....
The standard calculation is:
\[ \Delta x \frac{dE}{dx} = 300 \, \mu m \times (1.6 \, MeV \cdot cm^2/gm) 	imes (2.3 \, gm/cm^3) = 0.11 \, MeV \quad \text{for Silicon} \]
(Geant confirms this expected energy deposit, see next slide.)

Furthermore, it takes 3.6 eV to liberate an electron-hole pair.

So we expect \(0.11E6/3.6 \sim 30000\) electrons for a MIP crossing just the photodiode *without* CsI .
Recall, \(~60000\) electrons for a MIP in the CsI (using \(~5000\) e-/MeV)

That is, a muon in a photodiode would give **half** what you see for a muon in a CDE.

This is what Sasha coded into the Glast simulation.

We also took data with a 2 cm “mini-CDE” (DAQ triggered by phototube coincidence):
- muon passing CsI only gives a \(~3200\) dc peak
- muon passing photodiode+CsI also gives a \(~3200\) dc peak
(Photodiode contribution smaller than geometrical ambiguity)

Apparent contradiction: data gives MIP/10 where we expect MIP/2…
Muons in a naked photodiode -- simulation

Geant4 simulations by Benoit: top, muon in CsI. Bottom, muon in silicon of photodiode.

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<table>
<thead>
<tr>
<th>ID</th>
<th>Entries</th>
<th>Mean</th>
<th>RMS</th>
</tr>
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<tbody>
<tr>
<td>12345</td>
<td>1000</td>
<td>12.52</td>
<td>2.467</td>
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MeV, in CsI

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<tr>
<td>12345</td>
<td>1000</td>
<td>0.1018</td>
<td>0.4746E-01</td>
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</table>

MeV, in Silicon
Radioactive sodium (22Na) -- Data

Left - the CDE
Right – naked photodiode

LayerCor l b 0
Nent = 20864
Mean = 786.8
RMS = 399.3
Under = 0
Over = 65

LayerCor l b 0
Nent = 31358
Mean = 578.1
RMS = 369.4
Under = 0
Over = 65

511 keV
1275 keV

~340 keV
(see next slide…)

Run 465
Run 481

David Smith w. Benoît Lott
Muons in photodiodes
Radioactive sodium (22Na) -- simulations

e\(^+\) gives 511 keV \(\gamma\) in 300 \(\mu\)m silicon, via photoelectric effect gives max 340 keV (edge)

1275 keV gamma in 300 \(\mu\)m silicon

(data & MC slopes ~match)
Expectations, revisited

The expectation of ~ 30000 electrons for a MIP in the photodiode is pretty solid.

That gives 120 e-/dc for Bordeaux electronics, and hence 156,000 e-/MIP instead of the ~60000 electron “standard number”.

This “std number” of ~5000 e-/MeV comes from 60 keV x-rays from $^{241}$Am from NRL. It applies to MIPs in the middle of a CDE (which is what we did). Benoit says Sasha says it’s closer to 6000 e-/MeV, hence 72,000 e-/MIP.

However, near the ends the light yield is significantly higher:

a) We saw 3200 dc muons with our 2cm mini-cde.


“Andrey: Continued studies of EM data with cal + tracker have demonstrated that most if not all of the spreading of response near the crystal ends is due to the increased influence of direct lighting (as opposed to diffuse lighting) of diodes which leads to a transverse position dependence. See presentation [here](http://www-glast.slac.stanford.edu/software/CAL/weekly_reports/week_of_26July04.htm).“

Bordeaux CDE’s could have better light yield than flight ones, although x2 seems excessive.
## Summary

<table>
<thead>
<tr>
<th>What</th>
<th>data</th>
<th>expectation</th>
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</thead>
<tbody>
<tr>
<td>$\mu$ in middle of CDE</td>
<td>1300 dc (peak)</td>
<td>11 MeV (peak), 60000 e$^-$</td>
</tr>
<tr>
<td>$\mu$ in 2 cm CsI</td>
<td>3100 dc (peak)</td>
<td></td>
</tr>
<tr>
<td>$\mu$ in naked ph.diode</td>
<td>250 dc (peak)</td>
<td>0.11 MeV (peak), 30000 e$^-$</td>
</tr>
<tr>
<td>$^{22}$Na on 2 cm CsI, gain/5</td>
<td>1.275 MeV @ 1500 dc (x5 = 7500 dc)</td>
<td></td>
</tr>
<tr>
<td>$^{22}$Na on naked ph.diode</td>
<td>edge @ 1000 dc</td>
<td>edge @ 0.34 MeV</td>
</tr>
</tbody>
</table>

$\mu$ and $^{22}$Na on ph.diode are semi-consistent: 0.44 and 0.34 keV/dc, respectively. $^{22}$Na on CsI gives $1275/7500 = 0.17$ keV/dc, i.e., 2 to 2.5 times less. $\mu$ in CDE gives 8.5 keV/dc.

**But in any case:** $\mu$ in photodiode gives 10 to 20% of amplitude of $\mu$ in CsI.
Conclusions

1) Accurate MC prediction of MIP pulse height is tricky near CDE ends, because of light collection effects and because of Si+CsI summing.

2) Hence we expect some disagreement between MeritTuple and data. Specifically, when the MIP goes through the photodiode it fractionally increases the pulseheight less than you’d think, because the CsI signal is bigger than you’d think.

3) This shouldn’t compromise GCR et cetera since using both ends of the crystal helps resolve most ambiguity.

4) Therefore, we are now alerted to these subtleties and will come back to studies using the standard Tuples and data.