Time over Threshold (TOT) Studies

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Outline

• Monte Carlo study of TOT distributions for various types of particles in a FULL TOWER
  – TOT could be used to distinguish between $\gamma$ and backgrounds statistically

• Study of EM data (MINI TOWER)
Why is the TOT useful?

$$\text{TOT} \sim E_{\text{strip}} \sim 1 \text{ MIP}$$

$$\gamma \rightarrow e^+ e^- \sim 2 \text{ MIPs}$$

( if both particles fall onto the same strip)

$$\text{TOT}_\gamma \sim 2 \text{ TOT}_{\mu, e^-, e^+}$$
Is it possible for two particles to go into the same strip?

Multiple scattering
Can 2 particles hit the same strip?

- **Assumptions:**
  - Photon converts at the top of the W layer
  - Opening angle is sum of angle between pair conversion products given by the MC truth and the calculated multiple scattering from PDG

<table>
<thead>
<tr>
<th>Energy (MeV)</th>
<th>Thin W</th>
<th>Thick W</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Opening angle (rad)</td>
<td>Track separation at SSD below converter (mm)</td>
</tr>
<tr>
<td>17.6</td>
<td>0.540 30.94 0.25</td>
<td>0.920 52.71 1.05</td>
</tr>
<tr>
<td>100.0</td>
<td>0.112 6.42 0.05</td>
<td>0.180 10.31 0.19</td>
</tr>
<tr>
<td>500.0</td>
<td>0.022 1.26 0.012</td>
<td>0.040 2.29 0.02</td>
</tr>
</tbody>
</table>

Si strip pitch = 0.23 mm
Method

- It is possible that e+/e- produced by the $\gamma$ go into a single strip, especially at relatively high energy.

- How to use the TOT to distinguish statistically between $\gamma$ signal and background?
  1. **Determine conversion position**
     - **With reconstruction**
       - Use recon to find vertex
       - Correct TOT for path length dependence
     - **Without reconstruction**
       - Simply deem the first hit layer from the top as the layer where $\gamma$ converts
  2. Use maximal TOT value obtained from the XY bilayer below the conversion point
Conversion layer is determined by the reconstruction

**TOTAL distributions**

- **100 MeV straightly down gammas**
- **100 MeV straightly down electrons**
- **100 MeV straightly down muons**
Conversion layer is determined by the reconstruction

**100 MeV straightly down gammas**

**100 MeV straightly down electrons**

**100 MeV straightly down muons**
TOT distributions, recon NOT used

Conversion layer is deem as top hit layer

100 MeV straightly down gammas

100 MeV straightly down electrons

100 MeV straightly down muons
Monte Carlo Runs

- **Assumptions:**
  - Particle spectrum simulated as $1/E$
  - One full tower only

<table>
<thead>
<tr>
<th>Source Particle</th>
<th>Flux direction</th>
<th>$E_{min}$ (GeV)</th>
<th>$E_{min}$ (GeV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\gamma$</td>
<td>all directions from upper hemisphere</td>
<td>0.018</td>
<td>18</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>all directions from lower hemisphere</td>
<td>0.018</td>
<td>18</td>
</tr>
<tr>
<td>$e^-$</td>
<td>all directions from 4 pi</td>
<td>0.018</td>
<td>18</td>
</tr>
<tr>
<td>$\mu$</td>
<td>all directions from 4 pi</td>
<td>0.018</td>
<td>18</td>
</tr>
</tbody>
</table>
Conversion layer is determined by the reconstruction.

**FULL TOWER Monte Carlo Simulation**

**TOT distributions**

- **γ**\(_\text{down}\)**
- **γ**\(_\text{up}\)**
- **e**
- **µ**
Summary of MC study

- Preliminary MC studies indicate that the TOT distributions can be used to distinguish statistically between $\gamma$ signal and background, especially at relatively high energy.
VDG on the EM

Cosmic Background

CAL  TKR

66% 17.6 MeV, 34% 14.6 MeV
Reasonably good agreement between DATA and MC

Data: ebf031009105206
Monte Carlo

zDir < -0.9

1 count = 200 ns

TOT (counts) Path length corrected
Agreement between DATA and MC is not as good as in cosmic rays only

Data: ebf031007191651

Monte Carlo

zDir < -0.9

1 count = 200 ns
TOT Distributions, $\gamma$ + cosmic rays

Require only 1 strip hit on top layer

Data: ebf031007191651

zDir < -0.9

BariDigi produces similar results as SimpleDigi

Monte Carlo

2 MIPS?

zDir < -0.9
• Preliminary studies indicate that it is hard to extract the TOT $\gamma$ signal from the $\sim$20 MeV $\gamma$ because of the following reasons

  – **Experimental set-up**
    – There is a steel shield ($\sim$7% radiation lengths) in front of the accelerator. It produces lots of electrons, which could overwhelm $\gamma$ events
  
  – **Compton Scattering**
    – At such low energies, $\sim$20% of photons produce single electron by Compton scattering, thus creating a TOT no different to that of a single electron
  
  – **Multiple Scattering**
    – At such low energies, both opening angle and multiple scattering angle of the e-/e+ become large, thus makes it less likely two particles hit the same strip

• At such low energies, almost everything such as reconstruction becomes harder
Conclusion

• Preliminary Monte Carlo simulation studies indicate that
  – for a FULL tower, the TOT could be used to separate $\gamma$ from backgrounds statistically for a range of energies from 18 MeV to 18 GeV.
  – For the EM (minitower), Monte Carlo predictions at very low energy do not agree well with data

• Work is in progress to quantify the observations above