Trigger Timing Studies

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Martin Kocian, SLAC
Timing in works in 2 steps:

1. Alignment of trigger primitives
   - Front ends for subsystem generate trigger primitives
   - Subsystems have different response times
   - Delay registers allow to align subsystems individually
   - Trigger primitives should line up within a trigger window of 5 - 10 clock ticks

2. Adjustment of TACK signals for optimal data acquisition
   - Subsystems have different shaping times
   - Optimal times for subsystems are different
   - Delay registers allow for individual delays by subsystems

⇒ The task is to find the optimal delays for trigger primitives and data for all subsystems.
Trigger alignment

We use the following method to align triggers:

- An external trigger is provided by the muon telescope
- Ext trigger is used as a reference
- A scan over the full range of trigger primitive delays is performed (0 - 15 for CAL and TKR, 0 - 31 for ACD)
- For each setting cosmic events are recorded and the number of coincidences of ext vs. subsystem trigger within the trigger window is determined and plotted against delay
- A fit is performed to determine optimal delay and also jitter

!! With the current version of the GEM it is not possible to trigger on one trigger line while recording other trigger lines. This means we cannot run the scan for several subsystems at the same time.
ACD trigger alignment

- p0: Optimal delay
- p1: $\sigma$ of trigger jitter
- p2: Maximum coincidence rate
- p3: Trigger window width

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>p0</td>
<td>0.03</td>
<td>±22.72</td>
</tr>
<tr>
<td>p1</td>
<td>0.1585</td>
<td>±0.6137</td>
</tr>
<tr>
<td>p2</td>
<td>0.0042</td>
<td>±0.4306</td>
</tr>
<tr>
<td>p3</td>
<td>0.023</td>
<td>±5.847</td>
</tr>
<tr>
<td>p4</td>
<td>0.0966</td>
<td>±0.3774</td>
</tr>
</tbody>
</table>

$\chi^2 / \text{ndf} = 16.09 / 9$

Prob = 0.06495
CAL trigger alignment

- p0: Optimal delay
- p1: $\sigma$ of trigger jitter
- p2: Maximum coincidence rate
- p3: Trigger window width

\[
\chi^2 / \text{ndf} = 12 / 12 \\
\text{Prob} = 0.4457 \\
p0 = 6.454 \pm 0.058 \\
p1 = 1.921 \pm 0.095 \\
p2 = 0.3982 \pm 0.0061 \\
p3 = 5.941 \pm 0.074
\]
TKR trigger alignment

- **p0**: Optimal delay
- **p1**: $\sigma$ of trigger jitter
- **p2**: Maximum coincidence rate
- **p3**: Trigger window width

\[
\chi^2 / \text{ndf} \quad 33.06 / 12 \\
\text{Prob} \quad 0.0009461 \\
p0 \quad 6.58 \pm 0.09 \\
p1 \quad 2.629 \pm 0.242 \\
p2 \quad 0.1964 \pm 0.0094 \\
p3 \quad 5.349 \pm 0.220
\]
• Scan over TACK delays to find optimum

• For ACD and CAL, plot ADC counts and fit peak for each TACK setting

• For TKR no ADC reading is available, so instead the number of hits per event is used (efficiency)

• We have to use cosmics because the waveform shapes are very different for CsI data and for charge injection
ACD TACK scan

- p1: Maximum = 16 clock ticks = 0 ticks in TKR/CAL delay

\[ \chi^2 / \text{ndf} = 40.17 / 27 \]

<table>
<thead>
<tr>
<th>Parameter</th>
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</tr>
</thead>
<tbody>
<tr>
<td>p0</td>
<td>493.8 ± 1.7</td>
</tr>
<tr>
<td>p1</td>
<td>16.04 ± 0.17</td>
</tr>
<tr>
<td>p2</td>
<td>78.56 ± 1.61</td>
</tr>
<tr>
<td>p3</td>
<td>0.3898 ± 0.0088</td>
</tr>
</tbody>
</table>

\[ \text{HistAcAdc_Tile_40_Step_15} \]

\[ \chi^2 / \text{ndf} = 64.83 / 48 \]

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>823.1 ± 14.1</td>
</tr>
<tr>
<td>MPV</td>
<td>458.2 ± 0.9</td>
</tr>
<tr>
<td>Sigma</td>
<td>14.72 ± 0.65</td>
</tr>
</tbody>
</table>
• p1: Maximum at 44 clock ticks

\[
\begin{array}{l}
\chi^2 / \text{ndf} & 3.257 / 4 \\
\text{Prob} & 0.5158 \\
p0 & 1.211 \times 10^4 \pm 1058 \\
p1 & 3.406 \pm 0.066 \\
p2 & 9.173 \pm 0.492 \\
p3 & 0.7002 \pm 0.1257
\end{array}
\]
TKR TACK scan

- 16 clock ticks in ACD delay (plot) = 0 ticks in TKR/CAL delay
Summary

- Trigger delays and TACK delays were studied with Mini-LAT
- It is possible to set delays for optimal performance
- TKR has large jitter and low coincidence
- Scans need a lot of data
- Hopefully a new GEM version will allow simultaneous alignment of several subsystems