MIPP Trigger System Overview

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MIPP Upgrade Collaboration Meeting
28 April 2007
Content

• Trigger system in MIPP run 1
  − what worked well and what we need to improve

• Plans for the upgrade
  − Silicon Pixel Detector for interaction triggering
  − Trigger Master board
  − Beam ToF for low momentum

• Implications for detector readout electronics
The trigger in MIPP run 1 - logic

- Trigger logic defines beam triggers and interactions
  - **beam** trigger: Coincidence of TBD•T01•veto beam scintillators
  - **pion beam, kaon beam, and proton beam**: different combinations of four Beam Čerenkov pmτ signals in coincidence with **beam**
  - **int** trigger: logic OR of prescaled
    - **iDC**: multiplicity in drift chamber DC1 ...and...
    - **SciHi**: interaction scintillator ≥ 2 MIP
  - **pion int, kaon int, proton int**: pion beam, kaon beam, and proton beam in coincidence with **int**
    - plus various special triggers (pulser, rf, end-of-spill, ...)
The trigger in MIPP run 1 – logic (cont.)

- The various triggers each had a prescale into the master OR that got fanned out to detectors.

- Prescales programmable from DAQ to
  - take even fractions of π/K/p data
  - enable/disable special triggers

```sql
runs=> SELECT * from trigconfig where run = 16500;
run | bit | name            | logic       | prescale
---+-----+----------------+-------------+----------
16500 | 0   | Beam Trigger   | T01*TBD     | 1834
16500 | 1   | T01 Trigger    | T01 3 of 4  | -2147483648
16500 | 2   | TBD Trigger    | TBD 3 of 4  | -2147483648
16500 | 3   | User Trigger 1 |             | -2147483648
16500 | 4   | Kaon PID Beam  |             | 63
16500 | 5   | Pion PID Beam  |             | 1184
16500 | 6   | Proton PID Beam|             | 120
16500 | 7   | BToF           |             | -2147483648
16500 | 8   | Kaon w/ Interaction|          | 0
16500 | 9   | Pion w/ Interaction|       | 27
16500 | 10  | Proton w/ Interaction|       | 2
16500 | 11  | ToF w/ Interaction|           | -2147483648
16500 | 12  | Raw Pulser     |             | -2147482648
16500 | 13  | Inter Spill Calibration Pulser| | 1500
16500 | 14  | SciHi          |             | -2147483648
16500 | 15  | IDC            |             | -2147483648
16500 | 16  |                |             | -2147483648
16500 | 17  |                |             | -2147483648
16500 | 18  |                |             | -2147483648
16500 | 19  |                |             | -2147483648
```
The trigger in MIPP run 1 - implementation

- all logic in NIM modules
  - UVa trigger module was only special module
- all readout (scalers, latches) in Camac
- Lots of lemo cables
- Trigger fan-out at $T_0 + \sim 200$ns
  - longest delay: gate for iDC
- documentation on www
The trigger in MIPP run 1 - comments

- ToF wanted the trigger without latency
  - keep delay cables short
  - addressed differently in the upgrade
- beam trigger and online beam pid worked well
  - no online beamToF pid for low momentum
- Interaction trigger had problems
  - iDC: beam backgrounds (spray) or chamber noise triggered false interactions
  - ScInt: Landau tails caused beam tracks to trigger interactions
Trigger rates

- Trigger rates were and will be limited by TPC readout
  - ~30-60 Hz in first run
  - ~3000 Hz in next run

- Beam rates
  - 1% target → need at least $100 \times$ trigger rate, 300 kHz
  - prescale majority particles to take even fractions of all three beam species ($\pi/K/p$) → want even more
    - $500 \text{kHz} = 2 \mu s = 8$ beam tracks in TPC drift volume

- MainInjector rf: $53 \text{ Mhz} = 18.9 \text{ ns}$
Trigger Upgrade Plans

• Silicon Pixel Detector for interaction triggering
  - Based on fPix Si Pixels
    • see D. Christian's talks 9 Dec'06 (MIPP-doc-177) and today (MIPP-doc-204)
  - Who will work on it?

• Trigger Master board
  - Will be faster, programmable, have more features, ...
  - Who will build it?

• Beam ToF for low momentum
  - want to prescale based on Beam ToF pid at low momentum
  - need particle specific beam coincidences at lowest momenta
fPix for Interaction trigger

• Si Pixel Detector with fPix readout:
  - 22x128 (x×y) pixels of 400×50 μm² size = 9.2×6.4 mm² per chip – gives fast chip hit signal
  - compare 9.2×6.4 mm² to 50 mm diameter beam spot

• Use Bull's eye trigger and multiplicity
  - prescaled OR gives global Interaction signal

• Hit rate, chip hit pulse length, dead time is ok
Interaction Trigger (cont.)

• This will need to be studied more
  - Determine best placement for all pixel planes
    • Beam divergence: \(~1\) mrad, first pixel plane to target: \(~1\) m
    • Vertex resolution
  - Material behind the target
    • Pixels: \(~270\) \(\mu\)m
    • Mounting and readout for pixels
  - Who is going to do this?
MIPP trigger board

• Collect signals from
  • T00, TBD, T01, beam Veto
  • Beam Čerenkovs
  • fPix hit signals
  - Scale everything (for cross section normalizations)
• Form trigger similar to old logic
  - allow at most 2μs (significantly longer than before)
  - new readout electronics on ~all detectors make this possible
MIPP trigger board (cont.)

- Will we ever want to do anything more fancy?
  - Special charm triggers?
  - High rate special runs (without TPC)?
    - How high?
    - If so, we need to plan for it now.

- “Easy”: All digital logic, need only one (no mass production, cost not a problem)
  - Who will do it?
Triggering at low beam momentum

- Beam particles can be significantly below $\beta=1$

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>3</td>
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<tr>
<td>Beam-length</td>
<td>95.85 [m]</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Pion</td>
<td>0.14</td>
<td>26.03</td>
<td>18.01</td>
<td>56.48</td>
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<tr>
<td>Kaon</td>
<td>0.49</td>
<td>12.38</td>
<td>0.00</td>
<td>1.43</td>
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<tr>
<td>Proton</td>
<td>0.94</td>
<td>1E+39</td>
<td>100.00</td>
<td>100.00</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Particle</th>
<th>Mass $M$ [GeV/$c^2$]</th>
<th>Livetime $\tau$ [ns]</th>
<th>Particle Beta:</th>
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<tbody>
<tr>
<td>Pion</td>
<td>0.14</td>
<td>26.03</td>
<td>0.99</td>
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<tr>
<td>Kaon</td>
<td>0.49</td>
<td>12.38</td>
<td>0.90</td>
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<tr>
<td>Proton</td>
<td>0.94</td>
<td>1E+39</td>
<td>0.73</td>
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</table>

<table>
<thead>
<tr>
<th>X(T01-TBD)</th>
<th>37.69 [m]</th>
<th>Time of Flight [ns] between TBD and T01:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pion</td>
<td>0.14</td>
<td>126.94</td>
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<tr>
<td>Kaon</td>
<td>0.49</td>
<td>140.21</td>
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<tr>
<td>Proton</td>
<td>0.94</td>
<td>172.40</td>
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</table>

<table>
<thead>
<tr>
<th>X(T01-TBD)</th>
<th>37.69 [m]</th>
<th>Time of Flight [ns] between TBD and T01 wrt beta=1:</th>
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</thead>
<tbody>
<tr>
<td>Pion</td>
<td>0.14</td>
<td>1.22</td>
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<tr>
<td>Kaon</td>
<td>0.49</td>
<td>14.48</td>
</tr>
<tr>
<td>Proton</td>
<td>0.94</td>
<td>46.67</td>
</tr>
</tbody>
</table>
MIPP beam tests at low momentum

-5 GeV/c

-3 GeV/c

-1 GeV/c

+1 GeV/c

+3 GeV/c

+5 GeV/c
Implications for detector readouts

• Of course the trigger specifications impact the detector readout systems

• Specifications for detector readouts (subject to change)
  - c.f. MIPP-doc-186

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
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<tbody>
<tr>
<td>Maximum trigger latency</td>
<td>2 µsec</td>
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<tr>
<td>Minimum time between events</td>
<td>16 µsec</td>
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<tr>
<td>Maximum spill length</td>
<td>6 seconds</td>
</tr>
<tr>
<td>Maximum readout time after spill</td>
<td>54 seconds</td>
</tr>
<tr>
<td>Maximum number of events per spill</td>
<td>20,000</td>
</tr>
</tbody>
</table>
Trigger summary

- MIPP trigger is conceptually simple (minimum bias)
- Trigger is at the heart of the experiment
  - Without a good trigger we don't have an experiment!
- MIPP needs a Trigger Group
  - Coordinate and lead all aspects of the trigger design
    - with help from Fermilab EED&EPP
  - High profile/visibility/responsibility
  - A small/new group can do this well