BaBar Trigger Upgrade

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Plan

• BaBar trigger
  – requirements
  – implementation
    • overview
    • DCH trigger

• Need for upgrade
• DCH upgrade - Z cut
• Possible hardware option
• Simulation results
• Conclusion
BaBar trigger requirements

- High efficiency (~100%) for physics of interest
  - tracks with Pt as low as 120 MeV
  - E deposit in EMC as low as 100 MeV (min. ionizing muon)
- Level 1 rate not exceed 2 kHz
- Level 1 latency less than 12 $\mu$S
Two levels: hardware trigger (Level 1) and software trigger (Level 3) – we will discuss only Level 1

Principal Components of Level 1 Trigger System
BaBar Drift Chamber

- 40 cylindrical layers of signal wires
- Grouped in 10 Super Layers
- SL 1, 4, 7 and 10 - axial (wires parallel to Z axis)
- SL 2, 5, 8 stereo (U) 0.05 rad. to Z
- SL 3, 6, 9 stereo (V) -0.05 rad. to Z
- Length 286 cm (-101 to +175 in Z)
- SL1 inner radius 23.6 cm
- SL10 outer radius 80.9 cm
- Signal wires spacing ~1.5 cm
DCH Trigger

Track Segment Finder (TSF)

- Super layer
- Pivot group
- 8 two-bit clock 4 counters
- Look-up Table
- Find Best Track Segment
- Coarse hit data to BLT
- Fine hit data to PTD

1.5 cm

φ = 0
φ = 7
φ = 22
φ = 28

φ L
φ R
ϕ uncertainty
Global Level 1 Trigger

- **Trigger objects - primitives**
  - **DCT objects**
    - B - short tracks \(\text{Pt}>120\, \text{MeV}\)
    - A - long tracks \(\text{Pt}>150\, \text{MeV}\)
    - A’ - High Pt trks \(\text{Pt}>800\, \text{MeV}\)
  - **EMC objects**
    - M - min.ionizing \(\text{E}>100\, \text{MeV}\)
    - G - intermediate \(\text{E}>300\, \text{MeV}\)
    - E - high energy \(\text{E}>700\, \text{Mev}\)
    - X - MIP in forward EC
    - Y - electron in backward barrel
  - **IFT**
    - U - one of IFR trigger object
Global Level 1 Trigger

- **Trigger objects**
  - Back-to-back
    - $B^*, A^*$
    - $M^*, G^*$
    - $E-M$
  - DCT+EMT match
    - $BM$
    - $AM$
    - $A'M$
    - $BMX$

- **Compound objects**
  - $A^+ = 1A & 1A'$
  - $D2 = 2B & 1A$
  - $D2^* = B^* & 1A$
  - $D2^+* = B^* & 1A^+$
  - $Z^* - $any two back-to-back primitive objects$
## Need for upgrade

### Rate extrapolation (by Sybille Petrak)

<table>
<thead>
<tr>
<th>YEAR</th>
<th>PEPII HER(A)</th>
<th>PEPII LER(A)</th>
<th>Lumi (10 33)</th>
<th>L1Rates HER (Hz)</th>
<th>L1Rates LER (Hz)</th>
<th>L1Rates Lumi (Hz)</th>
<th>Rates Total (kHz)</th>
<th>Rates HER/LER</th>
<th>Rates Lumi/Rest</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2000</td>
<td>2001</td>
<td>2002</td>
<td>2003</td>
<td>2004</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.8</td>
<td>1.0</td>
<td>1.1</td>
<td>1.2</td>
<td>1.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>1.1</td>
<td>2.0</td>
<td>2.6</td>
<td>3.1</td>
<td>3.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.5</td>
<td>5.7</td>
<td>7.7</td>
<td>10.5</td>
<td>13.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>290</td>
<td>360</td>
<td>380</td>
<td>430</td>
<td>470</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>140</td>
<td>260</td>
<td>340</td>
<td>400</td>
<td>470</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>180</td>
<td>400</td>
<td>540</td>
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<tr>
<td></td>
<td>0.7</td>
<td>1.1</td>
<td>1.4</td>
<td>1.7</td>
<td>2.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.1</td>
<td>1.4</td>
<td>1.1</td>
<td>1.1</td>
<td>1.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.4</td>
<td>0.6</td>
<td>0.8</td>
<td>0.9</td>
<td>1.0</td>
<td></td>
<td></td>
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</tbody>
</table>
As you can see from this plot, background conditions at the beginning of the PEPII run are much worse than after few months of running. And this leads to much higher L1 trigger rates.
Effect of Z-trigger

L1 FCT trigger line rates (Hz)

Traks Z0 for all events and events with 1 good Z0 track

Background and good event tracks

Simulated effect of Z0 cut on trigger rates
## Benefit of Z-trigger

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<thead>
<tr>
<th>YEAR</th>
<th>2000</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
</tr>
</thead>
<tbody>
<tr>
<td>HER(A)</td>
<td>0.8</td>
<td>1.0</td>
<td>1.1</td>
<td>1.2</td>
<td>1.3</td>
</tr>
<tr>
<td>LER(A)</td>
<td>1.1</td>
<td>2.0</td>
<td>2.6</td>
<td>3.1</td>
<td>3.6</td>
</tr>
<tr>
<td>Lumi (10 33)</td>
<td>2.5</td>
<td>5.7</td>
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<td>10.5</td>
<td>13.3</td>
</tr>
<tr>
<td>HER (Hz)</td>
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<td>380</td>
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<tr>
<td>LER (Hz)</td>
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<tr>
<td>Lumi (Hz)</td>
<td>180</td>
<td>400</td>
<td>540</td>
<td>740</td>
<td>930</td>
</tr>
<tr>
<td>Total(kHz)</td>
<td>0.7</td>
<td>1.1</td>
<td>1.4</td>
<td>1.7</td>
<td>2.0</td>
</tr>
<tr>
<td>Begin run (kHz)</td>
<td>1.1</td>
<td>1.6</td>
<td>2.0</td>
<td>2.4</td>
<td>2.8</td>
</tr>
</tbody>
</table>

| DOCAZ Total(kHz) | 0.4  | 0.67 | 0.9  | 1.1  | 1.34 |
| Begin run (kHz) | 0.54 | 0.82 | 1.1  | 1.3  | 1.6  |
Possible implementation

- If track originates in the IP, and phi0 dependence of TSF data is removed by subtracting phi value of TSF segment in SL10 (or SL7) from phi values of other segments, then pair of axial SL defines Pt, and, thus, phi of 2 remaining axial segments. One pair of axial-stereo segments together with Pt defines dip angle. So, 3 out of 10 segments are enough to define track. If the rest confirms found track parameters, good track is found.

- Set of logical elements (OR and AND gates) can be used to implement such method.
Pattern recognition method.

DocaZ discriminator for 1 Supercell in SL10, positive tracks, positive tandip
(we will need 16 of this for 1/8 wedge of the chamber)

SL10 data

General diagram of 1 of 16 chips on one of 8 ZD boards
Pattern recognition method.

Diagram of Superlayer Information Transformation block

Superlayer information transformation block

(About 5000 logic elements per SL)

N

A

Ax14

A+B

A−B

Ψ

Ψ

B

ΔΨ

DMX

EXPN

From 154 to 210 outputs

n x (154 - 210)

Shift value from SL10 LUT

Supercell block

Supercell block

Supercell block

Supercell block

from 168 to 420 OR gates
Pattern recognition method.

Diagram of Pattern Recognition block

Pattern logics block

Axial SL

Stereo U

Stereo V

SL 1,2,3

SL 4,5,6

SL 7,8,9

Layer triplet block

Layer triplet block

Layer triplet block

One for every tandip bin

Combine close Pt

Number of gates $N_1 = 5040$

Number of gates $N_2 = 640$

Number of gates $N_1 = 7560$

Number of gates $N_2 = 640$

Number of gates $N_1 = 10920$

Number of gates $N_2 = 640$

OR

OR

OR

OR

>1

>1

Numbmer of gates

$4 \times Pt\ bins$

$x\ Tandip\ bins$

$4 \times 640 = 2560$

( total 28000 logical elements)
Simulation results

- Is there enough resolution in TSF data?
Simulation results

Bad track rejection

Effect on trigger rate
Problems and plans

- To understand proposed trigger efficiency for physics new simulation software urgently needed.
- Existing TSF modules are not suitable for proposed upgrade. Redesign is needed.
- Proposed hardware implementation of Z discriminators requires very large number of logical elements. Optimization is needed. New ideas would be useful.
- Conceptual design deadline is approaching fast - in March we need it if we want to be ready for planned BaBar upgrade brake.
Conclusion

- Proposed upgrade of DCT can help in keeping level 1 rate within set limit (2 kHz)
- Hardware implementation scenario is not finalized yet. But it looks feasible.
- Much more work is needed.