Development of the Level-1 track trigger with Central Drift Chamber detector in BelleII experiment and its performance in SuperKEKB 2019 Phase 3 operation

Belle II experiment at the SuperKEKB collider is designed for rare B/charm/t physics study, Dark Matter search, and CP violation in B decays with 40 times higher expected luminosity compared to that in Belle. We have achieved Lint = 10.57 fb^{-1} up to 2019.

- Level-1 trigger system (TRG): designed to select physics events with interest and to reduce the beam background in the data acquisition.
- Central Drift Chamber (CDC) TRG: Real-time charged particle trajectory reconstruction with FPGA chips.
- Performance of CDCTRIG in SuperKEKB 2019 phase 3 operation will be presented.

**CDC detector**

![Diagram of CDC detector](image)

**Belle II**

- SL0
- A U A V A A V A

**Why L1 TRG?**

Buffer storage are not enough for all data due to high event rate and short bunch spacing in collider experiment.

- Determines data section of interest with physics event from continuous data flow, and issues trigger to DAQ.

**Requirements:**

- Overall latency < 4.4 \mu s
- ~100% for Y(4S) events

**Belle-II TRG System**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max 30 kHz</td>
<td>8 \cdot 10^3 cm/s^-1</td>
</tr>
<tr>
<td>Timing precision</td>
<td>&lt; 10 ns</td>
</tr>
<tr>
<td>Event separation</td>
<td>500 ns</td>
</tr>
</tbody>
</table>

**CDCTRG**

**User-defined protocols for optical data transmission developed by CDCTRIG group:**

- Smaller latency than Aurora’s: Latency reduction is critical for L1 TRG!
- User-friendly interface like Aurora’s
- BB/10B and 64B/66B encoding
- Support Xilinx Virtex-5 GTX and GTH, and Altera.
- Bit error rate < 10^{-9} with few weeks BERT.
- Flow control functionality.

**Latency comparison of our designs:**

<table>
<thead>
<tr>
<th>Protocol</th>
<th>Laser rate</th>
<th>net clk</th>
<th>Link type</th>
<th>Latency (\mu s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aurora 8B/10B</td>
<td>5.6 Gbps</td>
<td>254 MHz</td>
<td>GTX-GTX</td>
<td>81–90</td>
</tr>
<tr>
<td>Base-level 8B/10B</td>
<td>5.6 Gbps</td>
<td>223 MHz</td>
<td>GTX-GTX</td>
<td>132–136</td>
</tr>
<tr>
<td>6B/6B</td>
<td>5.0 Gbps</td>
<td>223 MHz</td>
<td>GTX-GTH</td>
<td>91–95</td>
</tr>
<tr>
<td>6B/6B</td>
<td>5.0 Gbps</td>
<td>223 MHz</td>
<td>TXC-GTX</td>
<td>95–101</td>
</tr>
<tr>
<td>UT4</td>
<td>5.6 Gbps</td>
<td>10 Gbps</td>
<td>100BASE-TX</td>
<td>290–392</td>
</tr>
<tr>
<td>UT4</td>
<td>6G/6G</td>
<td>10 Gbps</td>
<td>100BASE-TX</td>
<td>68–112</td>
</tr>
</tbody>
</table>

**UT4:** Next generation of universal trigger board. Support up to 25 Gbps. Higher speed transmission design is under development.

**Tracking performance**

- **Full 2D tracking:** Finding full tracks passing through all axial SL and reaching barrel region.
- Based on Hough transformation algorithm.

**Effective eff. within hadronic events: Stable in 2019 operation.**

- **Conventional 3D tracking:**
  - Although 2D associated trigger bits have high eff., high trigger rate from beam background causes stress in DAQ.
  - By using 2D tracking and stereo TSF, 3D calculates the intersection of the track and the z-axis (z_0) by fitting method. z_0 is critical to reduce off-IP 2D full tracks.

**Short tracking:**

- Tracks finding up to SL4. → Reaching endcap region or curling-back inside CDC.
- Critical to enhance Bhabha/\gamma decay, and low-multiplicity physics trigger.
- Compressing the full 2D tracking.

- **Realization is close to expectation.**
- **Correlation between offline z_0, 3D z_0 can be roughly seen.**
- **Still in debugging stage.**
- **Will be ready within Spring 2020 after more improvement.**

- **Occupancy in endcap region.**
- **Improvement in low-p, tracking.”**