Update on SoLID Tracking & Reconstruction

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Comments: Dave Mack

Just because the GEMs don't collapse at high rates doesn't mean that a tracking solution exists. The collaboration needs to provide personnel to work with Ole to study the feasibility of tracking at high strip occupancies in a magnetic field.

- Agreed that extra manpower will help speed things up
- GEM tracking at high rates (higher than anticipated for SoLID) was already shown to be feasible for SBS. However, the SBS tracking region is field-free, occupancies are different, etc., so I agree that the SBS results do not translate directly to the SoLID case. SoLID simulations are being developed.

Comments: Chris Cuevas (I)

> *. . . there was one comment that mentioned that this tracking may not be needed because the calorimeter will already provide tracking point to link to vertex.*

Calorimeter hits have fairly coarse position resolution compared to GEM trackers. Additionally the tracks are expected to be (slightly) curved. To get the best track parameters (position and curvature), several precisely measured points along the trajectory need to be fitted. A calorimeter hit is mainly useful as a seed (approximate starting point) for certain tracking algorithms.

Comments: Chris Cuevas (II)

. . . to do real-time processing for L3 trigger it is a challenge and must consider channel count etc. Would be interesting to see if GEM readout boards could provide partial track segments in FPGAs . . .

- We had already anticipated to use FPGAs to perform pulse shape deconvolution (straightforward) and possibly clustering. This alone would absolutely help reduce L3 reconstruction processing time.
- Each readout module can up to $16 \times 128 = 2048$ GEM channels. I agree that these 2048 can be correlated in firmware, which could possibly be used to find track segment candidates between adjacent planes in a given sector.

We should follow up on these ideas once we have implemented reconstruction successfully in software.

Comments: Steve Wood (I)

...it would be helpful to have quantitative arguments (even if simulations are not done) that the tracking hardware and algorithms can function given the expected background rates.

- Hardware:

  Bandwidth and rate limitations of the APV25 readout system were discussed for the SBS Technical Review last year (document available).

  The maximum trigger rate was found to be limited by the 200 MB/s design bandwidth from each 12 GeV DAQ crate to the event builders. Under SBS conditions the trigger rate limit is about 7 kHz. (See details on next slides.)

- Algorithms:

  The SBS MC studies have shown that tracking is feasible with >90% tracking efficiency under SBS conditions (15% average occupancy, 6 planes of GEM trackers with x/y-readout, tracking system in an entirely field free region, etc.)

  Quantitative arguments for SoLID will have to wait at least for the completion of the first round of simulations (in progress ...)

Comments: Steve Wood (II)

Details on hardware bandwidth limitations for SBS GEp(5) conditions

- The 40 MHz APV25 readout clock rate imposes a trigger rate limit of $\approx$ 100 kHz in 3-sample readout mode (300 kHz in 1-sample mode)
- Events occurring during the $\approx$ 10 μs readout time window would require retriggering of the APV25s during readout, possibly multiple times, to avoid deadtime. At present, it is unclear if and how this can be done.
- 100 kHz sustained triggers require the firmware of the MPD readout boards to complete processing of 16 chips $\times$ 3 $\times$ 128 samples/chip $=$ 6144 samples within 10 μs. This appears feasible, although not obviously so. Feasibility obviously also depends on the amount of processing requested (*cf.* Chris Cueva's suggestion to do advanced preprocessing in FPGAs).

(over)

Comments: Steve Wood (III)

- For the data rate between MPDs and DAQ, we estimated for SBS:

$$48.5 \text{ bits/channel/event} \times 10^5 \text{ channels} \times 15\% \text{ occupancy} = 90 \text{ kB/event}$$

assuming 12 bits per sample plus overhead.

Assuming a maximum disk writing rate of 200 MB/s, the maximum physics trigger rate would then top out at about 2 kHz.

Assuming no limit on disk writing (*e.g.* due to L3 data reduction), the next limit is the 200 MB/s/crate bandwidth of the 12 GeV DAQ hardware:

  - A full crate holds 16 MPDs, each processing 16×128 channels, or 32768 channels/crate
  - The event size per crate is then 30 kB/event/crate at 15% occupancy (NB: local occupancies can be higher!)
  - The maximum trigger rate is 200 MB/s/30 kB = 6.7 kHz

This number can be improved in various ways, for instance

  - less data per crate (fewer MPDs per crate, fewer channels per MPD) → $$
  - lower resolution per sample (*e.g.* 8 bits)
  - deconvolution in the MPD firmware, *i.e.* send only pulse integral and centroid

NB: SoLID may have lower average occupancy.

These issues need to be quantified further by the DAQ group & simulations

In Other News

- Rich Holmes has extracted the GEM clustering algorithm into a standalone library. He is ready start on implementing a progressive tracking algorithm
- Rich has also worked on translating track fits to kinematic quantities
- Seamus has discovered that ROOT offers an advanced neural network fitting facility, which could be another useful algorithm for track reconstruction
- TreeSearch:
  - SoLID geometry has been implemented, but there are still bugs. The usual suspects are under investigation
  - Still need to find a fitting algorithm for tracks with slight curvature. Musts:
    - Accomodate parameter range limits
    - Numerically stable
    - Fast (no full-blown Minuit minimization, if possible)
- TreeSearch may not be a particularly good algorithm for the SoLID tracking problem. Curvature of tracks will probably require significant post-processing, and the post-processor (*e.g.* Kalman filter) may already work well on its own.