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The BABAR Level 1 Drift-Chamber Trigger Upgrade with 3D Tracking

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At *BABAR*, the Level 1 Drift Chamber trigger is being upgraded to reduce increasing background rates while the PEP-II luminosity keeps improving. This upgrade uses the drift time information and stereo wires in the drift chamber to perform a 3D track reconstruction that effectively rejects background events spread out along the beam line.

Keywords: *BABAR*; Trigger.

1. Introduction

BABAR[1] is the detector for the SLAC PEP-II B Factory operating at the $\Upsilon(4S)$ resonance. The *BABAR* trigger's task is to select the interesting physics events observed by the detector while rejecting the background events. It is a two-level hierarchy: the Level 1 (L1) trigger[1] in hardware and Level 3 (L3) trigger in software. PEP-II has already exceeded its design luminosity by a factor of three, and the luminosity is expected to increase up to 3×10^{34} cm^{-2}s^{-1} in 2005. To benefit from the increase in physics events, the L1 trigger system has to be upgraded to reject more background and lower the overall L1 trigger rate to reduce the DAQ load. Studies show a large fraction of current L1 trigger background comes from interactions between the beam particles and the beam pipe at $|z_0| \simeq 20$cm from the interaction point (IP) along the z-axis. By upgrading the L1 drift chamber trigger (DCT)[2] to use 3D tracking, this background could be suppressed significantly. The drift chamber (DCH), consists of 7104 small drift cells, arranged in 40 cylindrical layers. The layers are grouped into ten superlayers: four axial layers and six stereo layers.

2. Design implementation

2.1. *Track segment finder (TSF)*

TSF modules receive DCH wire hit patterns, including time information from the sense wire signal for each cell via fiber-optic Gigalinks every 267ns. The time development of the hit patterns gives a hit spatial resolution of 800µm in $r-\phi$. Each TSF module processes a subset of the DCH data and extracts track segments from

a set of contiguous hits within a group of neighbouring cells.
The original TSFs[3], only pass axial layer ϕ data to the transverse momentum discriminator (PTD) modules. To make a z-trigger for 3D tracking, all the 24 TSF boards have been redesigned in order to send both the axial and stereo information to the ZPD. The original 9U Euro cards with 25 XILINX FPGAs each are replaced by the half 9U cards with five FPGAs each. The internal logic speed is increased to 60MHz from 30MHz.

2.2. *z and p_t discriminator (ZPD)*

The TSFs pass data to the binary link tracker (BLT[4]) and ZPD. For the BLT module, where the segments are linked into coarse pattern recognized tracks, the original board is retained. Eight ZPD modules replace the old PTD modules which only extracted the transverse momentum (p_t) information of the track. The ZPDs add the ability to select tracks, which have a seed segment in superlayer seven or ten, based upon their origin along the beamline (z_0). ZPDs receive the fine-ϕ data via the LVDS channel link from the TSFs in 267ns intervals. Each ZPD processes TSF data from a 135° ϕ-span (9 TSFs) and outputs tracks for a 45° wedge.
The ZPD algorithm is composed of two main sections, the seed track finder and fitter. The finder reconstructs tracks by using a Hough transformation [5]. The fitter receives up to ten track segments associated with a track candidate, and first fits them in $r - \phi$ to improve the $1/p_t$ measurement. Then it uses the difference in ϕ between the track and stereo segments to fit linearly in $r - z$ to obtain z_0 and $\tan\lambda$, where λ is the dip angle of the track w.r.t. the $r - \phi$ plane. A combination of p_t, $\tan\lambda$ and z_0 cuts on tracks can be used to make different trigger decisions. A 75-bit multi-drop LVDS bus connects 6 finder and fitter FPGAs together at a 120MHz data transfer rate. The total ZPD latency is about 2µs.

3. System testing strategy

Diagnostic memories are distributed throughout the whole system to help with troubleshooting each subsystem. Monte Carlo events are played from input to output memory to do bitwise validation of the implementation. These memories are also used for interface tests between boards. Parallel commissioning is implemented at the final stage of the system test. In 2003, the upgrade DCT was installed in *BABAR* and is running with the existing DCT in parallel. Fiber splitters supply the drift chamber data to both the new and current trigger system, allowing the comparison between the systems without interrupting data taking. The global L1 trigger and its interface board can switch between new and old L1 DCT systems.

4. Initial performance of the full system

During the Summer of 2004, 24 new TSF boards, eight production ZPD boards, and all the associated upgrade interface boards have been installed into the *BABAR* trigger system, and used for triggering physics data in late July. The ZPD tracking efficiency is $> 97\%$ for isolated tracks and $> 92\%$ for tracks in hadronic events down to $p_t = 250\text{MeV}$, as shown in Fig 1. The measured z_0 resolution is about 4.3cm, consistent with the expectation from Monte Carlo studies, as shown in Fig 1.

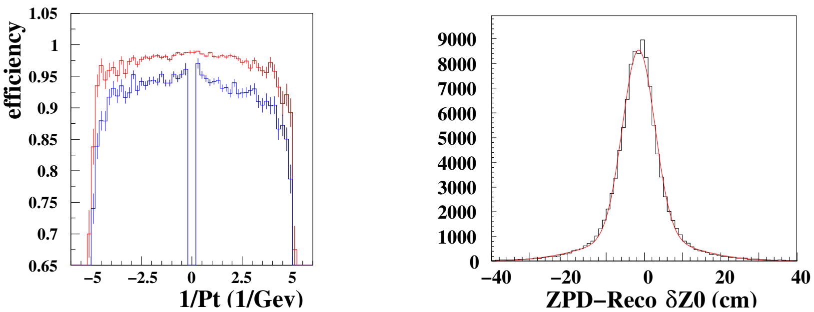

Fig. 1. The left plot is ZPD tracking efficiency, defined as the fraction of tracks offline reconstructed as coming from the IP which pass the L1 trigger selection criteria. Upper (red) is isolated tracks, and lower (blue) is the tracks in the hadronic events. The right plot is ZPD z_0 resolution, defined as the difference between ZPD reconstructed and offline reconstructed tracks.

5. Summary

The trigger system at *BABAR* is being upgraded to implement a 3D tracking reconstruction in order to improve the L1 trigger background rejection as required by the increasing luminosity. The initial performance of the tracking is compatible with the design expectations. Currently, the optimization of the z-trigger configuration is in progress, and expected to cut the track trigger background in half. The new trigger will be the default *BABAR* trigger when data taking starts again in Nov. 2004.

Acknowledgments

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