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A Fast Track Trigger for the H1 Collaboration

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Abstract

The electron-proton collider HERA will be upgraded to provide higher luminosity in the year 2001. In order to enhance the physics output especially for exclusive channels such as open charm and open beauty quark production a low p_t Fast Track Trigger (FTT) is being investigated for the H1-Collaboration which reconstructs precisely all tracks within 25 μs.

Key words: HERA; H1-Trigger; Drift Chamber; Fast Pattern Recognition

1 Introduction

At the HERA accelerator at DESY collisions of 920 GeV protons and 27.6 GeV electrons (positrons) are studied with the H1 detector. Measurements of rare processes motivate the HERA luminosity upgrade in the year 2000-2001. A factor of 5 more luminosity, a measure for the ep collision rate, is expected.

At HERA every 96 ns bunches of electrons and protons are collided. Events are triggered by a multi-stage triggering system (L1-L4) reducing the event rate to about 20 Hz after the fourth trigger level L4. Events with high transverse momentum transfers $Q^2 > 100\,\mathrm{GeV}^2$ can be triggered with high efficiency also after the upgrade. The production of charm quarks and bottom quarks are more difficult to trigger. They are mainly produced at low Q^2 and low x, the relative momentum of a parton inside the proton, where the ep cross section is highest. These events can only be identified through detailed invariant mass combinations of final state particles. Because exclusive triggers of this type don't exist presently a procedure of downscaling events at low Q^2 is used resulting in low trigger efficiencies even before the upgrade. Therefore, a new Fast Track Trigger is proposed [1] to provide a highly selective final state recognition based on track information from the central drift chamber (CJC).

2 Fast Track Trigger

Level 1:

The H1 central tracker mainly consists of two concentric drift chambers CJC 1, divided into 30 cells with 24 layers of wires, and CJC 2, divided into 60 cells with 32 layers of wires (see Fig. 1 (a)). Out of the 2640 wires of the CJC only 450 are used by the FTT in order to reduce complexity and costs of the project which scale with the wire multiplicity. In total 4 rings of trigger groups, three in CJC 1, and one in CJC 2, provide track segment information. A trigger group is formed by three layers of wires e.g. 2,4,6. All wires are read out at both ends to allow a z-determination [1] via charge division.

The latency time of the first level trigger (L1) is $2.3\,\mu$s. During that time hit finding is performed and the charge of the analogue signal is integrated and converted into a time measurement (Qt-algorithm). Modern FPGA devices provide the necessary speed and flexibility to run the Qt-algorithm in real time. Hits found are synchronised and stored in a shift register (see Fig. 1 (b)) with a possible frequency of 80 MHz (8 times the bunch crossing frequency). The track segment patterns, a 3 layer coincidence in a trigger group, are compared to a given set of valid vertex constrained patterns, which are basically represented by straight lines. That procedure has to resolve the left-right ambiguity which gives in most cases a second unphysical solution with $p_t < 50$ MeV. The corresponding track parameters, p_t and ϕ, of valid patterns are held in an SRAM realised as lookup table. In order to guarantee a high track finding efficiency also for low momentum tracks down to p_t=100 MeV hit information is shared between adjacent cells. A preferred choice for the implementation of the algorithm is FPGAs with internal CAM (Content Addressable Memory), which perform a very fast pattern match on the hardware level. Patterns only valid for the duration of one bunch crossing offer the option to generate an event KEEP signal for the first level trigger L1.

Level 2:

In the maximum available decision time of $20\,\mu s$ valid track segments are

[1] The z-axis is defined by the direction of the proton beam

linked. Via a fast link reconstructed track segments at L1 represented by 32-bit data words are transmitted to the L2 track linking engine. For the linking a $\frac{1}{p_t}$-ϕ-histogram is filled with track segments. This histogram is held in CAMs for the track segment cluster search. A coincidence of at least two trigger segments within a defined cluster radius is required for a track link. A sliding window search is used to find the maximum peak position. Once a track is linked the cluster position is stored in a so called dirty CAM to avoid double processing of track links already found. Finally, the track parameters are fitted by a DSP (Digital Signal Processor) separately in the $r\phi$ and rz plane. The remaining time is used to calculate simple kinematic and topological quantities like track multiplicity n_{tracks}, summed transverse momenta $\sum |p_t|$ and $\sum \vec{p_t}$ from which a trigger decision is generated on the second level trigger L2.

Level 3:

On the third level trigger (L3) a further processing of reconstructed tracks is done thus allowing more time expensive computations. For example 3-particle invariant mass combinations (D^* decay) can be calculated within about $100\,\mu$s using a single commercial processor. The quality of tracks, a p_t resolution of $\frac{\sigma_{p_t}}{p_t} \approx 0.04\,p_t$ and a ϕ resolution of $\sigma_\phi \approx 5\,$mrad, allows an invariant mass reconstruction of particles e.g. D^0, J/Ψ of typically better than 100 MeV.

3 Physics Benefits and Results

Open charm production at HERA is mainly studied using the decay $\mathrm{D}^* \rightarrow \mathrm{D}^0\pi_{slow} \rightarrow K\pi\pi_{slow}$ [2, 3]. This decay channel is characterised by the clear signature of the small mass difference $\Delta m = m(\mathrm{D}^*) - m(\mathrm{D}^0) \approx 150\,\mathrm{MeV}$. Because charmed mesons like D^* are produced by boson gluon fusion $\gamma g \rightarrow c\bar{c}$ they can be used as a direct tool to measure the gluon content of the proton down to small values of x. Triggering this channel is challenging because of the highly curved track from the slow pion π_{slow}, which has typically a transverse momentum of 100 MeV. With already existing simulation tools the FTT response to D^* candidates taken with the H1 detector in the year 1997 has been studied. The results show that the FTT mass resolution is only slightly worse than the off-line reconstruction (see Fig. 2). The D^* trigger efficiency after the upgrade is expected to be 70% with the FTT to be compared with around 1% without FTT due to the necessary trigger downscaling. The potential of the FTT has been studied also for other processes that presently suffer from low statistics but would profit from track based event selection at the trigger level. High trigger efficiencies have been achieved in simulations for the production of vector mesons ρ, J/Ψ and Υ as well.

4 Conclusion

A Fast Track Trigger has been proposed for the H1 experiment to ensure high trigger efficiencies for physics at low Q^2 displaying track based exclusive final state signatures in order to exploit more efficiently the physics potential of upgraded HERA.

References

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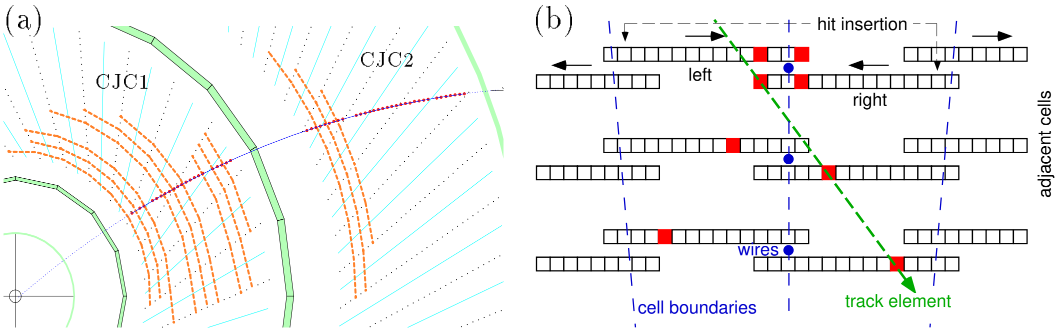

Fig. 1. (a) $r\phi$ view of the central drift chamber showing a track passing through. Layers used for the FTT are highlighted. (b) Schematics showing the hit pattern recognition of track segments using shift registers at the first trigger level L1.

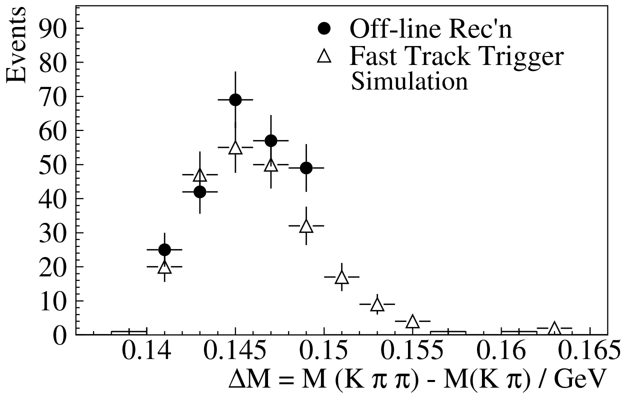

Fig. 2. Comparison of Δm=m($K\pi\pi$)-m($K\pi$) between FTT simulated and full reconstruction. An off-line analyses cut of Δm < 0.15 GeV has been used.