Cosmo-H1

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Abstract: A short overview is given on the present potential of the H1 experiment with respect to cosmic ray physics.

1 Introduction

The H1 [1] and ZEUS [2] experiments at HERA have been conceived for studying *ep* collisions at $\sqrt{s} = 300$ GeV. The detectors have a 4π solid angle coverage and consist of a central and forward tracker, electromagnetic and hadronic calorimeter, a solenoidal magnet with a field of ~ 1 T around the trackers, and muon chambers. The detectors are about 3 m underground, covered with sand and concrete. Recently the H1 experiment was prepared for the collection cosmic data. The changes to H1 and first results are detailed in [3].

The specific nature of the HERA accelerator, with it's multi-bunch structure (potentially up to 210 bunches) and short time between the bunches (96 ns) has posed stringent trigger requirements on the experiments. The H1 trigger, which consists of different trigger levels, similar to the future LHC experiments, has a dead time free Level 1, which is continuously gated (unlike the LEP triggers which are essentially only gated during bunch crossings). Detector front-end information of each bunch crossing is stored in a pipeline. The trigger information is evaluated after roughly 2.5 μs: if the trigger is accepted the pipeline stops and consequently the dead-time starts. The Level 2 trigger makes a refined trigger decision based on topological quantities or neural net information, and after roughly 20 μs an accepted trigger leads to the initiation of the read-out. The Level 4 trigger is a software trigger using a processor farm, which accepts events from the event builder, formats the data and passes it to the data logging. The trigger reduces the Level 1 output of 5 kHz to a Level 4 output of 10 Hz, during *ep* collisions.

2 The muon system and cosmic trigger

The H1 detector has been running for 6 years now. Recently additional triggers were added specifically for cosmic studies, based on the muon system.

The muon system is shown in Fig. 1. It consists of a barrel and forward section, and in total comprising 64 modules. Each module consist of 16 layers limited streamer tubes, Fig. 2, 5 tubes with strip and 11 with pad read-out (on top of the wire read-out), sandwiched between 10 plates of iron of 7.5 cm thickness. Each sector can give a signal to the muon trigger if in

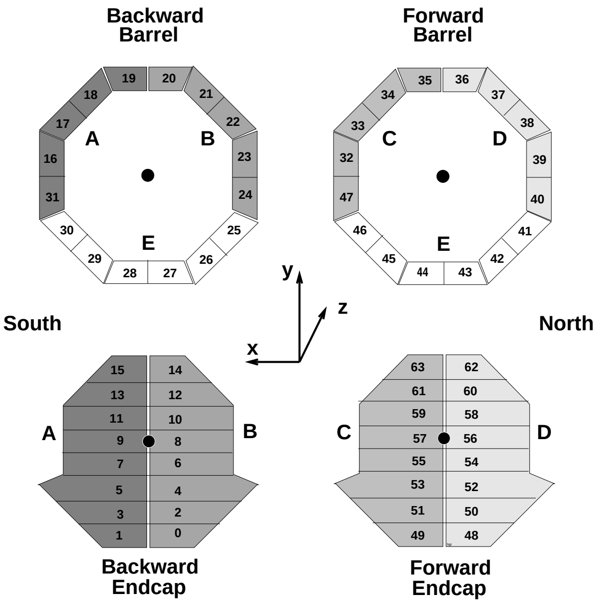

Figure 1: The H1 muon system, with indication of the 64 modules. The z axis is the axis along the direction of the proton beam.

at least 2 out of 5 out of 16 preselected layers of streamer tubes the passage of a particle is measured. Hence the module is the unit of smallest granularity available for the muon trigger.

A new trigger element was introduced which demands that at least 3 modules in the barrel have fired. This means that for cosmics the event should contain at least 2 muons (e.g. two modules fire at the top and one at the bottom). At the Level 2 the topological information was used to reject all events incompatible with at least 2 muons. The filter at Level 4 performs a software reconstruction of the muon system information. Events are kept here if at least 3 muons are reconstructed. The final output rate is in the range of 0.1-0.5 Hz. At most 0.1 Hz is accepted for this trigger by the read-out of the experiment and written to a separate data stream

The cosmic trigger is active since the end of January 1999. H1 operates roughly 8 to 10 Months a year. The trigger is active during the ep lumi phase (roughly $\sim$ 60% of the time) and the rest of the time when the detector is switched on, typically during injection or machine exercises. In the lumi phase all subdetectors are read-out for the cosmic triggers. For the other part, only the muon system and main calorimeters are switched on and correspondingly read-out. The "surface" of the muon system used in the trigger is 8.9 x 9.7 m^2.

3 GPS timing

A GPS timing module has been installed and its signal included in the H1 data stream. The change-minute TTL is used and logged in the data stream, together with the HERA bunch crossing counter, which has a granularity of 96 ns. Each event records the bunch crossing counter. This allows via interpolation to determine the arrival time of an event to within the GPS time uncertainty, which is 250 ns. In fact by calibrating the GPS system to the HERA

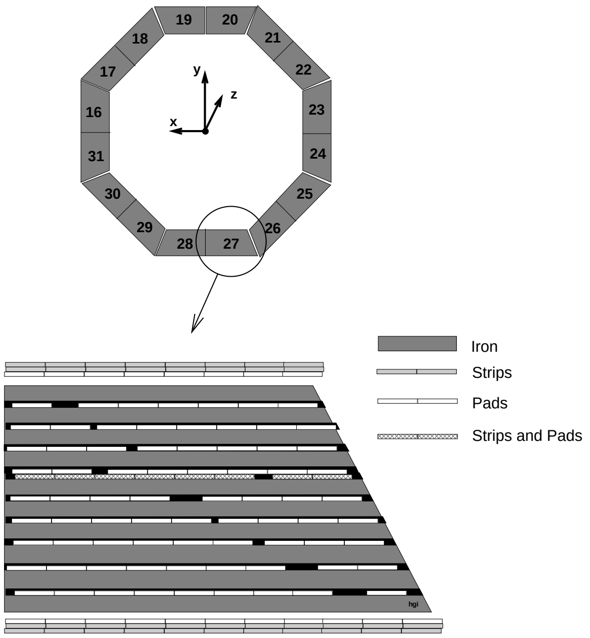

Figure 2: The H1 muon system, details of a module

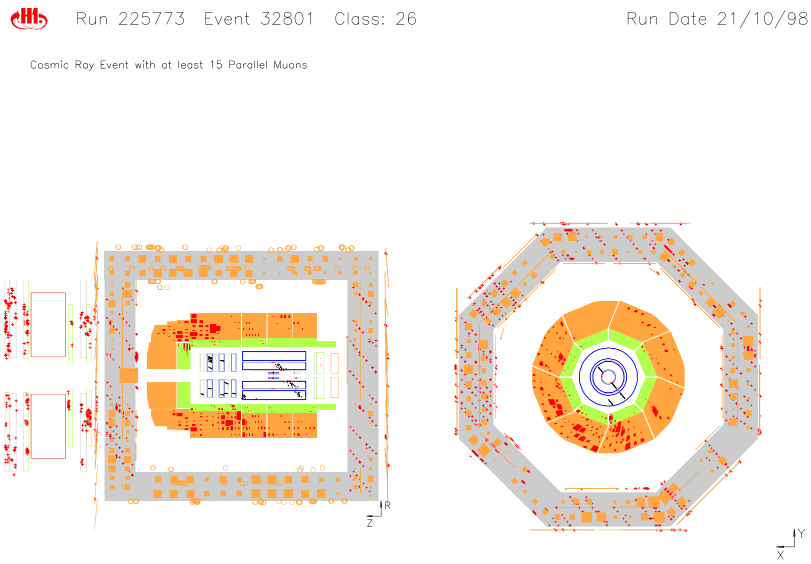

Figure 3: A cosmic event in the H1 detector

clock one can reduce the GPS timing uncertainty to 100 ns, which is more than sufficient for cosmic data which have generally a time spread of order μs.

4 Data logging and reconstruction

The read-out window for cosmic triggers has been enlarged to 4 bunch crossings ($\sim$ 400 ns). Data outside that time window are lost. Presently the read-out buffer for muons of cosmic events amounts to a maximum of 50 tracks, hence large multi-muon events will be truncated. Note that for data taken during the luminosity phase of the experiment also the central tracking chamber is read-out, which could actually record up to about 1000 tracks. The 'surface' of this tracker is approximately 4 m^2. The offline reconstruction is presently limited to single module reconstruction, i.e. connections between tracks in the top and bottom part are not yet made. The resolution in the polar angle Θ for the reconstructed muons amounts to 0.06 rad, but the resolution in the azimuthal angle is presently not usable. The resolution of the tracks in the central tracker in Θ and ϕ are of the order of 1 mrad.

5 Outlook

There are some obvious improvements possible, which are planned for the near future. Nevertheless cosmic shower data with precise timing are on tape now and can be used for coincidence measurements with e.g. ZEUS or a LEP experiment (or any other experiment which also has GPS timing). The distance to ZEUS is about 1.5 km, ideal for coincidence measurements, but still awaits a universal timing signal to be incorperated in the ZEUS data stream. The distance to LEP is about 1000 km, and some experiments at LEP already have the GPS timing information [5]. Unfortunately the duty factor of the LEP detectors for cosmics during normal e^+e^- data taking is only a few %. Agreement on a common format would be however welcome.

Further possible topics for physics studies include measuring the muon spectrum, which can be accessed due to the low muon momentum cut-off: the 3 m material between the surface and the detector leads to a muon cut-off of 2 GeV, on top of the 2 GeV from the atmosphere. For high muon multiplicity studies the low momentum muon cut-off here is actually a hinder: multi-muon (say above 100 muons) events seen in the LEP experiments will have at least 10 times more muons in the HERA experiments, leading to saturation effects of the data read-out stream.

A typical multi-muon event is shown in Fig. 3.

Outlook

I thank the organizers for a splendid workshop within an exellent atmosphere and environement. I also thank S. Ryf and Y. Tsipolitis, who made the team to get H1 into cosmic mode.

References

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