ON-LINE USE OF THE 168/E EMULATOR AT THE CERN ISR SFM DETECTOR

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ABSTRACT

The Split Field Magnet Detector at the CERN ISR has been used in recent years to study events with a high transverse momentum charged particle. As a first level computer based trigger a linear estimate of the track momentum by fixed point arithmetic was calculated on-line by a minicomputer. In addition appreciable further rejection was obtained by off-line filtering on the IBM-370/168, using pattern recognition and a fit of the triggering particle in the magnetic field. The availability of the 168/E emulator makes it possible to transfer the proven methods used off-line to real time data reduction. Preliminary results on filter efficiency and speed for an experiment triggering on a high pT hadron at 10 to 20° with respect to the outgoing beam (Exp. R419) are given. Possible improvements and extensions are discussed.

1. INTRODUCTION

In summer 1980 CERN decided to construct [1] a few units of the 168/E emulator developed at SLAC [2] and to install them on two pilot experiments (EMC [3], SFM). Aim of the project was to estimate the range of application of such processor to current and future CERN experiments. On purpose, experiments already running under stable hardware and software conditions and capable of immediately benefitting from the 168/E were selected.

SFM users were not only interested to use the processor as intended originally at SLAC, to run an off-line event filter and reconstruction chain of programs, but also to use it on-line as a high level trigger. The latter application constitutes the first attempt to apply in real time large FORTRAN algorithms requiring up to a few hundreds milliseconds of 168/E processing time. Generally this implies that the data flow has to be reduced earlier by more time-critical trigger levels normally achieved by fixed point processors. In this sense the use of the 168/E would open the additional facility of applying versatile triggers developed, tested and previously executed off-line.

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The present contribution will concentrate essentially on the recent test made at SFM to introduce such a kind of sophisticated trigger.

2. IMPLEMENTATION OF THE 168/E FOR A TEST IN AN ISR EXPERIMENT

2.1 Choice of the test experiment

The SFM three levels of trigger (fast, slow and integer filter) are described in [4]. Events rate after these three stages is a few Hz. The data recorded on tapes are currently processed off-line through a spline fit filter program to refine the on-line momentum estimate and follow the trigger track through the magnetic field up to the particle identifiers. The average IBM-370 spline fit time per event is of the order of 200 ms.

Experiments for which the trigger rate can be made low enough are good candidates for a further level of trigger using the 168/E to perform the spline fit on-line. We have chosen one experiment of this type (R419) where triggers are requiring a high $p_T$ charged hadron in the range 10 to 20° with respect to the outgoing beam direction.

2.2 Data acquisition configuration

Fig. 1 shows the SFM standard data acquisition configuration including the various trigger stages, read out paths and the PDP-11/45 data acquisition computer. One also sees that the 168/E has been implemented with its own PDP-11/40 control computer and CAMAC interface to the selective read-out module. No real integration in the existing system has yet been attempted, in order to bring the least disturbance to the physics experiment in progress.

Schematically the events are read by the PDP-11/40 from the selective read-out (normally after being accepted by the PDP-11/20 filter) and sent to the 168/E for processing. On return a yes/no flag is delivered as well as a short summary of the spline fit results ($p_T, x^f$). The flag is used by the PDP-11/45 to decide on the read-out of the full event.

2.3 Control software on the PDP-11/40 computer

The control software covers the following main tasks:

- Addition of the 168/E filter system to the SFM data acquisition scheme.
- Initialization of the 168/E system, i.e. loading of program and data overlays in the 168/E Mostek buffer memories and initializing the system software responsible for the control of the 168/E system.
- Control of the filtering process: event read-out, build up of a list of commands used to drive the 168/E (passed as input to the 168/E device driver) and handling of the emulator answer.

- Update and display of statistics used to monitor the 168/E filter system.

The software developed for program loading and overlay control in the off-line application [5,6] has been inserted in the on-line context with minor modifications.

2.4 The 168/E program

The first approach to using the 168/E on-line is directly derived from the off-line strategy which will be sketched now.

The raw data tapes are passed through an off-line filter program to attempt precise reconstruction of the triggering track. This track should be lying in a well defined detector region and its parameters should satisfy specific criteria. If indeed such a track is found, more stringent cut-offs can be applied to the now precisely known parameters. Events accepted by the filtering step are later processed by the time consuming full reconstruction program.

The SFM programs are well tested and stable programs, written in standard FORTRAN. They have been run on many computers of various sizes and they are written in modular fashion using H DRA dynamic memory management [7] and assembly time options provided by the PATCHY [8] system. Therefore the preparation of a filter program complying with the 168/E restrictions is not much of a problem.

The program we implemented on the 168/E can be characterized as follows: about 15000 FORTRAN statements, or in terms of 168/E memory space 40 kbytes of local data, 60 kbytes of working space, 80 kbytes of physical constants and 220 kbytes of microcode.

The overlay scheme was mostly derived from the one used on non-paging machines like the CDC-7600 which provides (in 60 bit words) a memory size only slightly larger than that available in the 168/E data and program memories. There was no more effort in preparing a version of the program for the 168/E than for any other computer used by the SFM Collaborations.

Debugging a 168/E program could be viewed a priori as a tedious and difficult task due to the lack of I/O. This was not however the real problem since

- we did run on the 168/E only completely sound and debugged code,
- each slight modification required for the 168/E was first fully tested on IBM. Even the overlay structure was roughly checked, although it is in certain respect more difficult to implement IBM overlays than 168/E overlays.

SFM code uses HYDRA dynamic memory management, hence all input and output data, together with significant intermediate variables, are held into a single array, furthermore a formatted dump facility is provided. To investigate a problem one just transfers back the whole array to the control job on the IBM and takes a dump there. Since we always keep a working IBM version of the 168/E program, automated comparison can most of the time be used to compare content of the dynamic core on both machines at corresponding program stages. We have been using the CERN 168/E's as soon as they were available and still rather unstable. Hence most of the debugging we did was related with hardware testing problems. Undoubtedly, had we been waiting three months, the software installation effort would have been much reduced.

3. RESULTS OF THE TEST RUNS

3.1 Run conditions

During ISR period 3 of spring 1981 when the R419 experiment was turning the 10° negative trigger, few hours were dedicated to test the on-line spline fit.

An option was introduced in the SFM data acquisition software to activate the 168/E path, the 168/E filter program being previously loaded from the IBM via the existing OMNET [9] link into the buffer memories of the Bermuda Triangle (microcode as well as all the constants relevant to the program and the current state of the detector).

3.2 On-line test results

Before introducing the 168/E in the data acquisition chain we measured a trigger rate of 1.8 Hz. The fraction of good events accepted by the spline fit is 25%. Due to dead-time losses on account of the 168/E the good events rate drops from .45 Hz in the ideal case to .15 Hz.

For the sample of approximatively 5000 events the results of the analysis performed on-line are identical to the same selection performed off-line on the IBM.

These results were obtained over a period of less than 15 hours ISR machine time and may be improved as far as the speed is concerned. We have
Indeed already upgraded both the hardware and software of our 168/E and are expecting to increase the good events rate to $\sim 0.30$ Hz in the ISR and trigger conditions under which the test was performed. On the other hand, using the 168/E on-line with other triggers of R419 like the 20° positive trigger which has a rate five times smaller, we expect to bring the deadtime problem to a manageable level. Savings for an experiment of this type lasting of the order of 1000 hours ISR time would amount to $\sim 200$ out of 300 magnetic tapes and 200 hours IBM CPU time.

4. Further Extensions of the 168/E USE

The on-line use of the 168/E at the SFM appears as a new way of using this processor for real time computations of great complexity. The success of the first tests suggests that other trigger configurations could benefit of the 168/E like for instance the large -t elastic $\pi$-$p$ and $p$-$p$ scattering experiments. However, for many time-critical applications the absence of event buffer memory in the present set-up may suggest immediate more efficient use of the 168/E in an off-line filter mode, where more complicated situations could be faced, such as:

- Pattern recognition of particle other than the trigger.
- Find no track, one track, two tracks ... within a specified phase space region around the trigger track.
- Find a second track near the trigger and compute the two particle invariant mass.
- Perform track finding in a phase space region disconnected from the one of the trigger.
- Run the full event reconstruction program (presently about 20 s IBM 370 time per event). Here the gain in IBM CPU time could be an order of magnitude larger than in the case of the on-line spline fit.

Some of these applications are more demanding than a single particle trigger on the data memory size, due to the number of magnetic field coefficients necessary to cover larger regions of space. Typically 16 kbytes are needed for the field for a single particle trigger, while as many as 250 kbytes (necessarily overlaid) may be needed for the entire field map for full event reconstruction.

With the latter goal in mind we have designed and tested a "double" memory board which we will use initially to double the data memory of the processor, thus bringing full event reconstruction within reach.
CONCLUSIONS

Used at the SFM detector as a new type of high level trigger the 168/E has been shown to be a valuable tool in the data purification process. Important saving in the number of magnetic tapes written and central computer time can be obtained. Equally promising are the perspective to run versatile off-line filters and the full reconstruction program. Here the aim is to significantly augment the CP capacity of SFM experiments and thus to keep the analysis of high sensitivity experiments within reasonable time limits.

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REFERENCES


SFM TRIGGER AND READ-OUT SCHEME WITH THE 168/E

Fig. 1