Fermi National Accelerator Laboratory

PROCEEDINGS OF THE WORKSHOP
ON
TRIGGERING, DATA ACQUISITION, AND OFFLINE COMPUTING
FOR HIGH ENERGY/HIGH LUMINOSITY HADRON-HADRON COLLIDERS

Fermilab
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INTRODUCTION

This workshop was convened to consider in detail the difficulties of triggering, data acquisition and filtering and to ascertain in so far as is possible at this time the offline computing needs in the high energy (40 TeV), high luminosity ($>10^{33}$ $cm^{-2}sec^{-1}$) environment of the Superconducting Super Collider. These problems were considered both in the context of a generic 4π detector and limited solid angle specialized experiments. There were six working groups which looked at various aspects of the process of handling 10^8 interactions per second. These groups and their coordinators were as follows:

I. Physics Signatures- G. Kane, F. Paige, L. Price and M. Goodman

II. Analogue Triggers- P. Franzini and R. Rameika

III. Higher Level Triggers- M. Abolins, M. Shochet and H. Melanson

IV. Data Filtering/Acquisition- P. S. Cooper, D. Cutts, A. J. Langford and D. Hedlin

V. Offline Computing- M. G. D. Gilchriese, S. C. Loken, C. T. Day and M. Shapiro

VI. Special Triggers- J. D. Bjorken, A. J. Slaughter and P. Peterson

The organizing committee members who set the framework for the workshop and in most cases did double duty as working group coordinators were:

B. Cox, Fermilab (Chairman)
J. D. Bjorken, Fermilab
M. G. D. Gilchriese, Cornell Univ.
J. Lach, Fermilab
S. C. Loken, Lawrence Berkeley Lab
F. Paige, Brookhaven National Lab
L. Price, Argonne National Lab
M. Shochet, University of Chicago

Approximately 150 physicists from the U.S., Canada, Europe and Japan attended this meeting and participated in the working groups. Keynote addresses to the workshop were given by Stan Wojcicki, Deputy Director of the Central Design Group, and by F. Paige, G. Kane and M. G. D. Gilchriese.

The general parameters of the SSC as known at the time of this workshop and which were taken as given were

$\sqrt{s}$ = 40 TeV

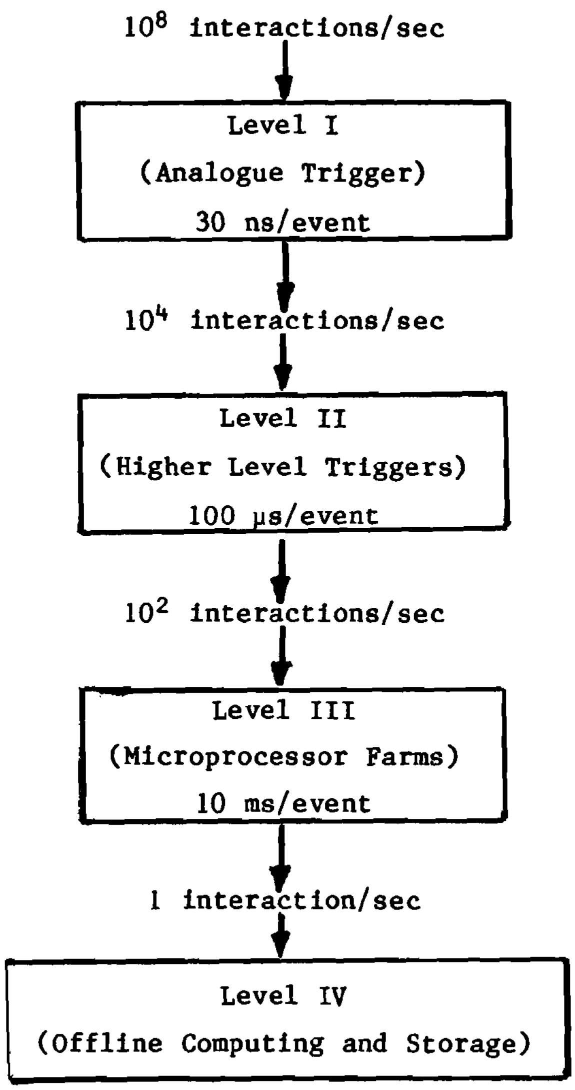
L ≈ $10^{33} cm^{-2} sec^{-1}$ → 10^8 interactions /sec assuming a 100 mb total inelastic pp cross section

Bunch spacing of 30 ns or 3.0 interactions per crossing
(since changed to 15 ns or 1.5 interactions per crossing)

RMS bunch length ≈ 7 cm

Transverse size of the collision region ≈ 7 microns

In the initial discussion of the general guidelines for the technical groups, without reference to either specific detectors or to triggers for specific processes, the goals for each trigger level were set as shown below:



Estimates of event size for the generic 4π detector ranged as high as one megabyte. The Offline Computing Group set the criterion that one such event per experiment per second could be handled by the offline computing machinery. The estimates of the required computing facilities at the SSC were then based on 10^7 seconds of operation of several interaction regions per year at this event rate.

With this framework setting the general guidelines for required hardware capabilities at each level of the data flow, the Physics Signatures Working Group selected several important physics processes to investigate. They attempted to develop trigger strategies which would fit within these boundaries. In particular, triggering schemes for the two processes:

$$PP \to \text{Higgs} + X, \quad \text{Higgs} \to W\,W, \quad W \to \ell\nu, \quad W \to tb$$

Heavy Higgs Production ($M_H \approx 200$ GeV/c^2)

and

$$PP \to \tilde{g}\,\tilde{g} + X, \quad \tilde{g} \to q\bar{q}\tilde{\gamma}, \quad \tilde{g} \to q\bar{q}\tilde{\gamma}$$

Supersymmetry Production of gluinos ($M_{\tilde{g}} \approx 100$ GeV/c^2 or 1 TeV/c^2)

were investigated in some detail in the report of that working group. They concluded that for both processes, given the hardware suggested by the technical working groups II, III and IV, the suggested trigger strategies could be implemented and would produce less than one Hz of one megabyte events for offline analysis. Furthermore, these strategies would preserve reasonable efficiencies (20-30%) for these physics signals.

The various hardware groups charged with implementing these strategies investigated several possible methods. In some cases where there was overlap between groups, different solutions were proposed to the same problems, but the general consensus was that mechanisms existed for implementing the trigger strategies at high luminosities. The extraction of the physics from the trigger sample was less clear and should be the subject of future workshops.

The Analogue Trigger Working Group adopted the philosophy that the basic triggering device for the Level I trigger would be the calorimetry associated with an SSC experiment. Finite time differencing of calorimetry signals was thought to be sufficient to eliminate pile-up effects of the integrated calorimetry signals. The general conclusion was that, for the luminosities in question for calorimetry which had a trigger segmentation of $\Delta\phi\Delta\eta$ Ⅲ 0.1×0.1, a time difference between samples of 500 ns would quite easily allow one to trigger-on a 25-GeV energy deposit in the calorimeter. Specific ways to implement electron, jet, E_T and missing p_t triggers were outlined by this group. A 600-750 ns time interval was thought to be required for the formation of these triggers, so other groups have taken 1 μs as the storage time required for the detector pipeline. The reduction of $>10^4$ by the Level I trigger was judged to be quite straightforward for the high E_T physics that was considered.

The Higher Level Trigger Group concentrated on examining the correlations between various pieces of the detector in the events satisfying the analogue trigger level and passing through to the Level II trigger. In the specific case of the Higgs search, the additional requirements of TRD identification of an electron track pointed at an isolated energy dump in the calorimeter were examined. Ways, at the second level of the trigger, of requiring the TRD correlation with a track in a central detector and requiring the pointing of that track and the isolation of the energy dump were discussed. The general conclusion was that these requirements could be implemented using lookup tables and that the rate which would have to be handled by the Level III microprocessor farms would be < 10 Hz for this particular physics process.

A considerable effort was made by the Level III Data Acquisition/ Filtering Group in three areas: the storage and organization of the events as they flow from the detector to the microprocessor farm, the estimation of the size of these events and the architecture and functioning of the microprocessor farms which do the filtering. The general conclusion was that an event from a 4π detector would be approximately one megabyte. The actual digitation and buffering/storage of events of this size constitutes one of the more difficult tasks facing the workshop. The solution of these problems apparently will require the development of custom chips with storage times of a microsecond for both digital and analogue information and ADC chips with faster digitization times and larger dynamic range than currently available.

One of the most significant conclusions of the workshop was that the microprocessor farm is the economically feasible solution to both meeting the online filtering requirements of the Level III trigger, and to providing the bulk of the necessary offline computing power. Both the Data Acquisition/ Filtering Working Group and the Offline Computing Group concurred in this conclusion. The Offline group estimated that when the SSC achieves full operational status, the offline computing needs will be 10^4 million instructions per second (MIPS). For scale, a VAX 780 has one MIP of computing power. Over 95% of this requirement is anticipated to be provided by microprocessor farms. A large state-of-the-art super computer would still be required when fast turn-around of a few events is desired (the time to process one SSC event is estimated to be approximately 1200 VAX seconds). A model containing eight microprocessor farms, each of which contains 125 nodes with 8 MIPS of computing power per node, was advanced as a configuration for consideration. Many other issues were discussed by the Offline group in both the software and hardware areas. No substantial problems other than the general magnitude of the effort were uncovered.

Finally, the Special Trigger Group was charged with the responsibility for consideration of the trigger problems of special detectors such as forward spectrometers and jets spectrometers. The central characteristic of these experiments in general was the coverage of a limited solid angle and the emphasis of a particular piece of physics. In almost all cases the discussions first revolved around the design of the spectrometer and only then could the trigger issues be discussed. In spite of the widely varying designs, this group reached the general conclusion that the data acquisition requirements of these spectrometers were not too different from those of the generic 4π detector except for the extended geometric region from which the data must be collected. The group also raised the general point that the configuration of the intersection regions and the machine lattice design should not preclude the development of extended geometry experiments.

In conclusion, the general feeling of the participants of the workshop was that they had faced the hard issues of triggering at high luminosity and that they could see solutions which were feasible. There was a good deal of optimism generated by the success with which solutions had been arrived at for the specific cases considered. The correctness of the proposed solutions to the many difficult technical problems certainly must be proved by further R&D and actual hardware implementation but, conceptually, all problems seemed to be solvable by reasonable extrapolations of today's technology. In particular, the concept of microprocessor farms received wide approbation.

Thanks must be extended to the working group leaders, the organizing committee and the Fermilab staff members who participated in the implementation of this workshop and the preparation of these proceedings. In particular, Phyllis Hale should be thanked for her normal, extremely competent effort in seeing that everything ran like clockwork. We also thank Richard Fenner for his help in the publication efforts and Angela Gonzales for the design of the cover which so aptly illustrates the problem that we face: separating the elixir from the dross.

Brad Cox, Chairman
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Triggering, Data Acquisition
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for Hadron/Hadron Colliders
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