Concept of a Software Trigger for an Experiment at the TESLA Linear Collider

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Abstract

TESLA is one of the design proposals for a TeV range linear electron positron collider. The electrons and positrons will collide in bunch trains with a rate of 5 Hz and each train itself will consist of 2820 bunches. The bunch to bunch distance within the train is 337 ns resulting in a total train length of about 1 ms. This operation mode requires a deadtime free data taking within 1 ms. In conjunction with the aim of being able to select rare and maybe as yet unknown event topologies it gives rise to the proposal of a pure software trigger concept in the proposed detector design. All detector signals are digitised and stored in buffers for each collision prior to event building via a fast network. All bunches are then analysed in a processor farm and classified in various streams from interesting physics to background, monitoring and calibration events. Finally, all events are stored in appropriate formats. According to first estimates, the event building process will have to cope with 1 to 2 Gigabytes of data per second. This value is an order of magnitude smaller then the corresponding rates anticipated at the LHC experiments. Presently, the compatibility of the trigger concept with the various subdetector designs is investigated and possible readout schemes are designed.

Keywords: TESLA, Trigger and DAQ

At present, several designs are investigated for a next generation linear electron positron collider. In Europe, a joint ECFA/DESY study group [1] is working on the Technical Design Report for TESLA[1] (figure 1). With the TESLA design, a center of mass energy ($\sqrt{s}$ range from

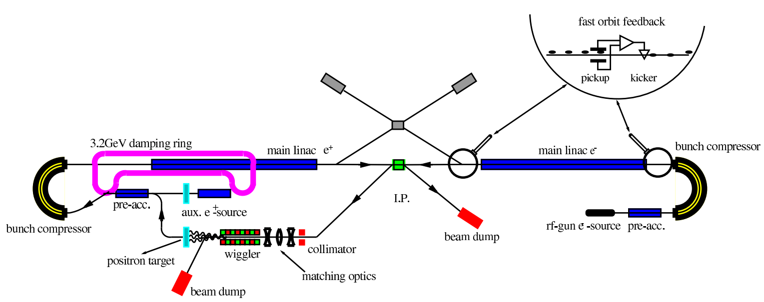

Figure 1: Sketch of the overall layout of TESLA

the Z^0 pole ($\sqrt{s} \sim 90$ GeV) and to about 1 TeV is in reach without considerable difference in luminosity. The design luminosity of $3.1 \times 10^{34} cm^{-2} s^{-1}$ at $\sqrt{s} = 500\,GeV$ opens the door for interesting physics which is expected at mass scales below 1 TeV. The parameters of relevance for the trigger and DAQ concept are shown in table I.

Most important are

[1] TeV Energy Superconducting Linear Accelerator

Table I: TESLA machine parameters

	500 GeV	800 GeV	unit
repetition rate	5	3	Hz
bunches per pulse	2820	4500	
pulse length	950	850	μsec
bunch spacing	337	189	nsec
luminosity	3.1 10^{34}	5.0 10^{34}	$\mathrm{cm}^{-2}\mathrm{s}^{-1}$

- the long time interval between two bunch trains of 199 ms
- the separation of two bunches inside a train of 337 ns
- the train length of $950\,\mu s$.

  Therefore it seems appropriate to propose a two stage trigger and DAQ concept [2]
- readout of the complete bunch train without hardware trigger interrupt, applying zero suppression and data compression when possible or necessary,
- process the complete train using software algorithms on commodity processor farms.

A schematic view of the proposed trigger and DAQ concept is shown in figure 2. The overall design is very similar to those e.g. at HERA-B and CMS, with the exception that no first level harware trigger is proposed. All event data is read out using standardized readout units (RU)

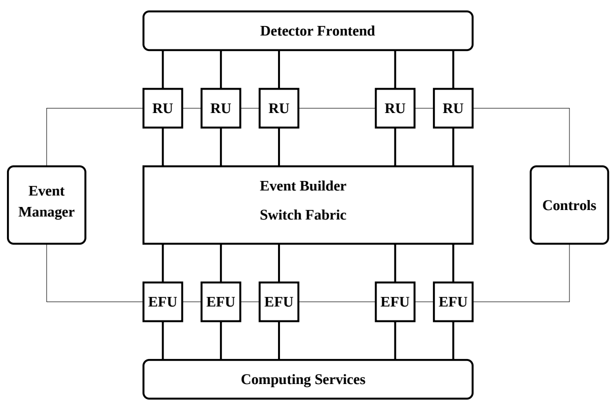

Figure 2: Overall view of the trigger and DAQ Concept

into event filter units (EFU).

The advantages of such a concept are obvious. First of all the system offers the desired flexibility and efficiency because it is programmable to a very large extent and because the full event information is available for decision finding where needed. This allows to accommodate unforeseen (physics and background) rates easily.

Maintenance is rather easy because standard off-the-shelf technology (memory, switches, processors, ...) are used wherever possible. The system also profits from commonly used operating systems and high level programming languages. The rather strict separation of the on-line and off-line worlds of present experiments is obsoleted. On-line computing resources are usable also for off-line computing tasks. The alogorithms which are executed on this system are easily portable between on-line and off-line applications.

A schematic view of the detector in its present state of design, is presented in figure 3. The

[2] actually, the detector concepts at the NLC and JLC accelerators - albeit having rather different machine parameters - opt for a similar trigger and DAQ scheme

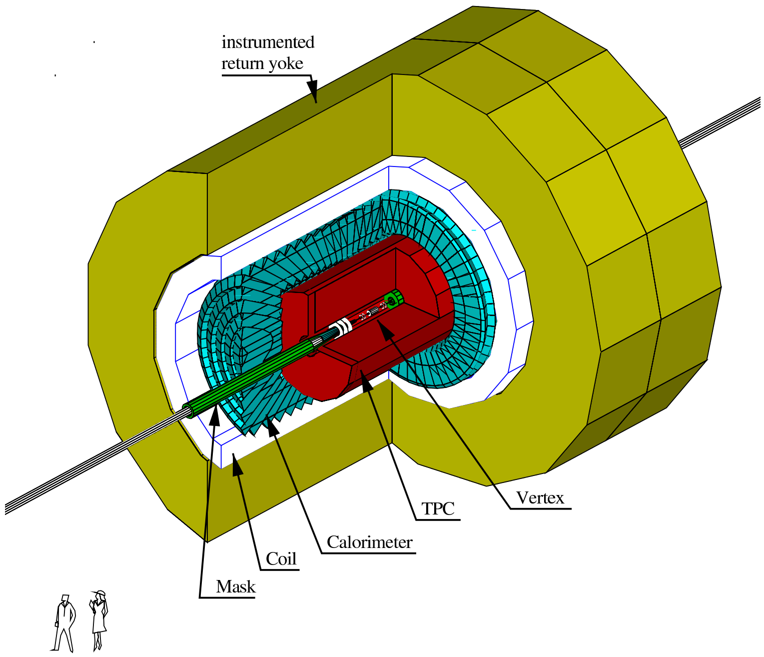

Figure 3: Detector

five-layer vertex detector with the innermost layer as close as 1.4 cm to the beam axis, allows very precise vertexing which is essential for b (and c) tagging, e.g. for Higgs studies. A large TPC, spanning radii of 32 cm to 170 cm allows high precision tracking inside a magnetic field of 4 T which is supplied by a large superconducting coil of 7.5 m diameter. A high granularity calorimeter, consisting of Si/W electromagnetic and scintillator tile hadronic sections, provides excellent energy resolution and enables energy flow measurements over almost the full solid angle. The detector is supplemented by muon chambers placed inside the iron return yoke, intermediate and forward tracking detectors, and instrumented masks, which also shield the detector against the huge beam induced background produced by the accelerator.

The proposed trigger concept of course has implications on the detector design, in particular on the choice of readout technologies. The critical issue is the required 1 ms continous readout. It has for example to be proven that the occupancy, in particular in the inner most layer of the vertex detector, is small enough and that the TPC main tracking chamber can be operated without active gating. On the software side, pattern recognition for complete bunch trains has to be devised.

Extensive calculations have been performed on rates expected for physics and background processes, showing that the data rate will be dominated by background. Making reasonable assumptions for the detector readout, the expected data volume can be estimated, The results are summarized in table II, yielding a total data volume of about 300 MB per bunch train, corresponding to about 1 to 2 GB/s. This value has to be compared with the event building rates of up to a few hundred MB/s common at present or near-future experiments and 50 GB/s as expected at LHC experiments.

Further thoughts have to be put into the design of filter strategies which presently consists of two steps: First, the event building and formatting step is performed over a fast switched network. This is followed by the event classification and filter step which works asynchronously with the event building process. A scheme similar to e.g. the HERA-B L2/L3 system is conceivable. To keep data transfer rates small, in a first level (L2) only a part of the data is read into a processing

Table II: Data Volumes expected at TESLA

component	channels $[10^3]$	hits per train $[10^6]$	MB per train
VXD	730 000	30	60
FTD	20 000	2	4
ITC	10 000	2	4
TPC	720	17	170
CAL	200	8	32
MUON	200	1	4
LAT	10	1	4
total	800 000		278

unit. The full data is only read into the same unit if the event is accepted ("virtual level 2"). Issues like availability of calibration constants have to be carefully investigated. Also, the design of algorithms is a major topic, but completely flexible to adopt the needs and requirements of the physics groups. In summary, a reduction rate of the order of a factor 100 seems to be realistic and reasonable. This yields data logging rates of about 15 MB/s to mass storage or (assuming 10^{7} seconds operation per year) a yearly data volume of 150 TB. These volumes are far below those expected at LHC experiments and in the same region as experiments at RHIC or Tevatron, Run II.

Preliminary studies show that an operation of this trigger will also be possible if TESLA is operated at the Z^0 pole where the expected physics rate is much higher than at 500 GeV.

In conclusion, the proposed software trigger fully exploits the unique operation conditions at TESLA. It offers considerable flexibility both in the design of algorithms and in the choice of data used by these algorithms, which will be written according to the needs of the physics groups. Thus it allows to keep rare physics and unfavourable event topologies.

Event building rates and data volumes are much smaller than anticipated for LHC and comparable to those at present experiments. The use of commodity hardware, high-level programming languages, and widely used operating systems as well as the merging of the on-line and off-line worlds implied by this computing model, will ease the maintainability. In addition, costs as well as personal resources are reduced.

Therefore, we are convinced that this concept offers a better and more efficient trigger which could be build (almost) today.

References

1 Comprehensive overviews on the accelerator and detector designs as well as on the physics program can be found at
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