

CAMAC BOOSTER ("CAB" SYSTEM)

A versatile Microcomputer for High Rate Camac Data Acquisition

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Abstract

Our group*] at Ecole Polytechnique has constructed and used bit slice processors since 1976. Our first generation processor, named $\mu 77^1$], has been used at C.E.R.N. on a PS experiment from 1977 to 1979. The first results of this S157 experiment are published in ref.²]. Our second generation processor called CAB³] (CAMAC Booster) has been used in 1980 for a follow-up experiment S157b, also at C.E.R.N. PS. During the last year more than 15 CABs have been built, and are used in different applications.

Therefore we have a relatively long experience of using a bit slice processor in a high energy physics experiment. We shall focus this paper on the specific aspects of this experience, namely the "on-line physics" at S157 experiment and the "CAMAC boosting" concept, after an abridged technical presentation of our CAB processor.

I - THE CAB Processor - Technical note.

Short Reference ⁴]. Long Reference ³].

The CAB is a standard 4 Unit-wide CAMAC module. There are 3 basic CAB versions :

- Ordinary CAMAC crate-controller, GPIB-CAMAC crate-controller, CAMAC branch driver. The CAB can be extended through "Fast-Access" modules designed in CAMAC standard.
- ALU and sequencer are from the AMD 2900 family.
- The 16 bit arithmetics includes a TRW multiplier and a special shifter unit.
- The instruction memory is 4k x 24 bits with access time at will from 55 ns to 120 ns.
- The data memory is 4k x 16 bits (from 55 to 120 ns).
- The multiplier has his own 256 x 16 bits memory.

There is a unique instruction cycle ranging from 150 ns to 220 ns, according to the memory speed (see above). The instructions are directly executed (there is no micro code level). The internal data bus and status registers are directly interfaced to :

- The CAMAC dataway
- The CAMAC branch and/or
- The GPIB (IEEE 488) bus
- The "Fast Access" modules :

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Extra Memory (GANIL)
& MWPC or hodoscope readout
& Signal sampling for Fourier Transform
& CCD readout...

II - The high resolution π^+ -p total cross-section measurement.

P. Baillon has pointed out in 1976 that the advent of fast real-time processors had made possible a new generation of total cross-section measurements, with an improved sensitivity to narrow resonances. This, plus the existence of the high resolution focussing spectrometer made for experiment S153 ^{5]} has lead us to the S157 experiment.

A - The need for a very high statistics $\approx 10^{11}$ events and a good numerical precision

For each beam particle the relative momentum $\Delta p/p$ must be computed using a formula which is linear in three coordinates given by the high resolution spectrometer. Moreover many software cuts, some of them asking complex computations on the beam trajectory, are applied in order to validate the $\Delta p/p$ measurement ^{6]}. Then the eight coordinates given by 4 wire chambers situated before and after the hydrogen target are used to compute the square of the scattering angle Θ^2 , and/or to detect on interaction of the incoming particle with the target. The resulting code is optimized by taking into account the probability of each occurrence.

The performance of this program can be judged in Fig.1 which shows the histogram, in logarithmic scale, of the time between two consecutive events. The two peaks at the left, at 1 and 4 μs , corresponds respectively to the rejection of an event with a missing beam coordinate and to the identification of an event with a small Θ^2 caused by the multiple scattering inside the target. One can also see that the maximum processing for complex events lasts $\approx 50 \mu s$.

The mean time between events is approximately 5.5 μs . This means that with an effective 7% PS duty cycle we were able to take 10^9 events/day. The whole experiment has acquired the 10^{11} events which are necessary to reach, taking into account the rejection rate and the probability of interacting with the target, a 0,3% statistical error on each of our 10000 π^+ total cross section measurements. Half of these data, are shown in Fig.2.

B - The On-line Physics

Contrary to a classical high energy experiment, our events are too numerous to be stored permanently and to be reprocessed off-line (they would fill 10^5 magnetic tapes). For that reason we have kept on tape a small fraction, one among 10^4 , of the original events. A typical event is proces-

sed on-line and the relevant quantities, such as $\Delta p/p$ and θ^2 , are accumulated in various histograms.

We have felt this situation as being very dangerous because, when an information is lost, it is irreversible. We have been obliged to develop an on-line program many times bigger than initially thought of. Most of the 4k memory was used to store 9 finegrained and 32 coarse grained histograms, and hundreds of software counters.

Every 2 minutes all the informations contained in the microcomputer, geometrical constants as well as physical data, were dumped into the mini computer and stored on magnetic tape. The mini computer program performed 30 consistency checks using all the redundancy built in the data. It extracted many relevant quantities, such as the efficiency of the main detectors. The variations of these quantities were logged continuously on a printer in order to detect non-statistical fluctuations. For instance the mean cross-section itself is known within a $\pm 1\%$ error bar every 2 minutes, and the efficiency of the transmission detector with four decimals.

C - The Off-line Analysis : Too much data ?

The paradox of our situation is that, after a quick on line result as shown in Fig.2, we are left with a very complex off-line analysis. The statistical errors are too small to wash out the details of what happened during our 300 different settings !

For instance let us look at Fig.3. It shows the variations of one among the many software counters as a function of momentum for empty target π -runs. This class of events is characterized by no hits in both X and Y planes of chamber 2, and one hit in the X plane and two in the Y plane of chamber 1. The regular behavior with increasing energy shows the physical origin of these events instead of a possible inefficiency of chamber 2.

Moreover this effect is reduced by a factor 2 when a helium bag is introduced in front of chamber 1, or when the gap between the target and chamber 1 is reduced.

These events are interpreted as two prongs interactions of a beam particle with the air in front of chamber 1. The two prongs are not intersecting the chamber 2 and one gets through the region of chamber 1 near the frame which is not covered by the Y plane.

III - The CAMAC Boosting concept.

The CAB's goal is to improve the flexibility and the power of some conventional CAMAC data acquisitions.

A - The insertion of a CAB

When a CAB is inserted in a data acquisition as a standard CAMAC module or as a controller, it can transfer a bloc of data in the read or the write

mode at the maximum CAMAC rate. This is due to the fact that the CAB is faster than the Bus (6 instruction cycles for 1 CAMAC cycle). Moreover it can be programmed to read data at different addresses filter these data and transfer them in a bloc transfer mode. From a software point of view this means that one part of the CAMAC readout can be transferred from the mini-computer to the CAB, where it can run much faster and in parallel with other parts.

B - The CAB networks

The CAB has something of the LEGO system : from the same building blocks one can build very different configurations. First, as seen in I, by exchanging or adding one board to a single CAB, one can make very different objects. For instance one can make a crate controller which not only reads its crate but drives several other CAMAC branches, or a branch driver which can speak alternatively to the main mini computer or to a micro-computer such as CA-VIAR or TEKTRONIX 4051. Second, the possibility to start a CAMAC branch at any point of any crate leads to more ambitious multi-branch configurations.

C - Applications

We are still in the first year of CAB's life. The applications working now are the most straightforward ones. They are small independent data acquisition systems driven by a micro computer, such as PET or TEKTRONIX 4052. At C.E.R.N., one system is dedicated to Cerenkov ring imaging tests, another to calorimeter tests for the proton lifetime experiment. They are cheap and can yield huge amount of data. At Ecole Polytechnique one system is developed for a γ -camera image corrector, another as a real-time signal processor for ellipsometry. With this system solar-energy physicists can study in real-time the properties of an amorphous silicon film during its growth⁷]. We have also a color display driver and several test systems.

Some other systems are being developed with a more complex branch driver configuration.

IV - CONCLUSION

One often thinks of the real-time fast processor as a software trigger system. Our example shows that it can also do on-line physical analysis. This is an extreme case, but not an exception. These techniques could apply to any two or three body reactions, or to K^0 decays any time a high statistical precision is needed.

But we have also reported more mundane applications of the CAB. Small but performant CAB data acquisition systems are already at work. The next step would be, in our opinion, to get around the limitations of the CAMAC standard for big systems along the lines drawn at C.E.R.N. by the ROMULUS system (or by LECROY's ADC compaction system), with the advantage of a local, fully programmable intelligence, preserving the CAMAC standard.

REFERENCES

- 1] On-Line Filtering - C. Verkerk
Proceeding of the 1978 C.E.R.N. school of computing C.E.R.N. 78-13.
- 2] E. Barrelet et al, Phys. Letters 94B (1980) 541.
- 3] B. Habiballah, Thesis Orsay 79, unpublished.
- 4] E. Barrelet, R. Marbot, P. Matricon
"CAMAC Booster" ("CAB" system) a versatile microcomputer for high
rate CAMAC data acquisition.
L.P.N.H.E. Ecole Polytechnique, Palaiseau (France)
presented at "Real Time Data 79" (Berlin).
- 5] P. Baillon et al, Phys. Letters 94B (1980) 533.
- 6] D. Lellouch, Thesis Paris VI 79, unpublished.
- 7] B. Drevillon et al,
Growth Characterization of a-Si : H Films by in situ ellipsometry in
a Silane Multipole Plasma
L.P.N.H.E. - Laboratoire Physique des Milieux Ionisés - Ecole Poly-
technique, Palaiseau, France
Topical conference on tetrahedrally bonded amorphous semiconductors
March 12-14, 1981, The Carefree Inn, Carefree, Arizona.

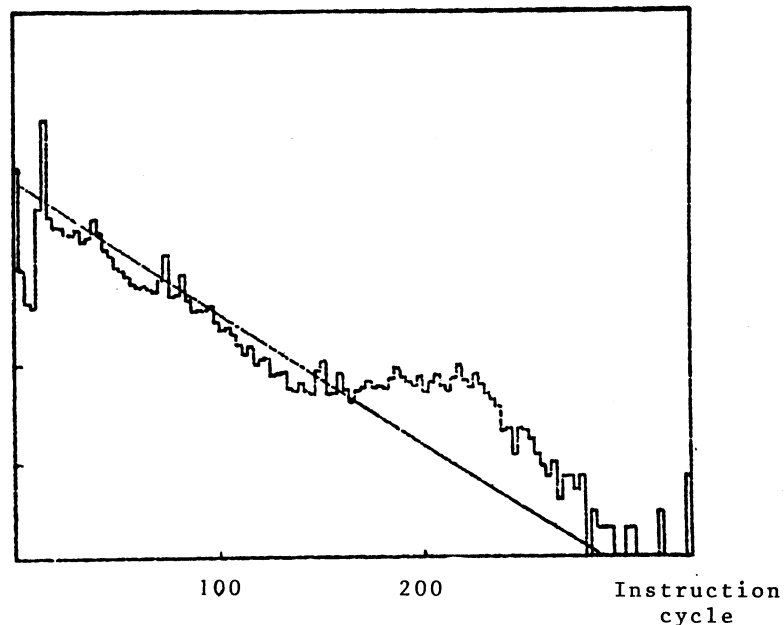


Figure 1

Histogram of the Time Between Events (TBE) observed when the CAB is saturated, i.e. when the TBE is almost equal to the time to process one event. The TBE is expressed in number of CAB instruction cycles. The mean TBE is 5.5 μ s. The Y scale is logarithmic.

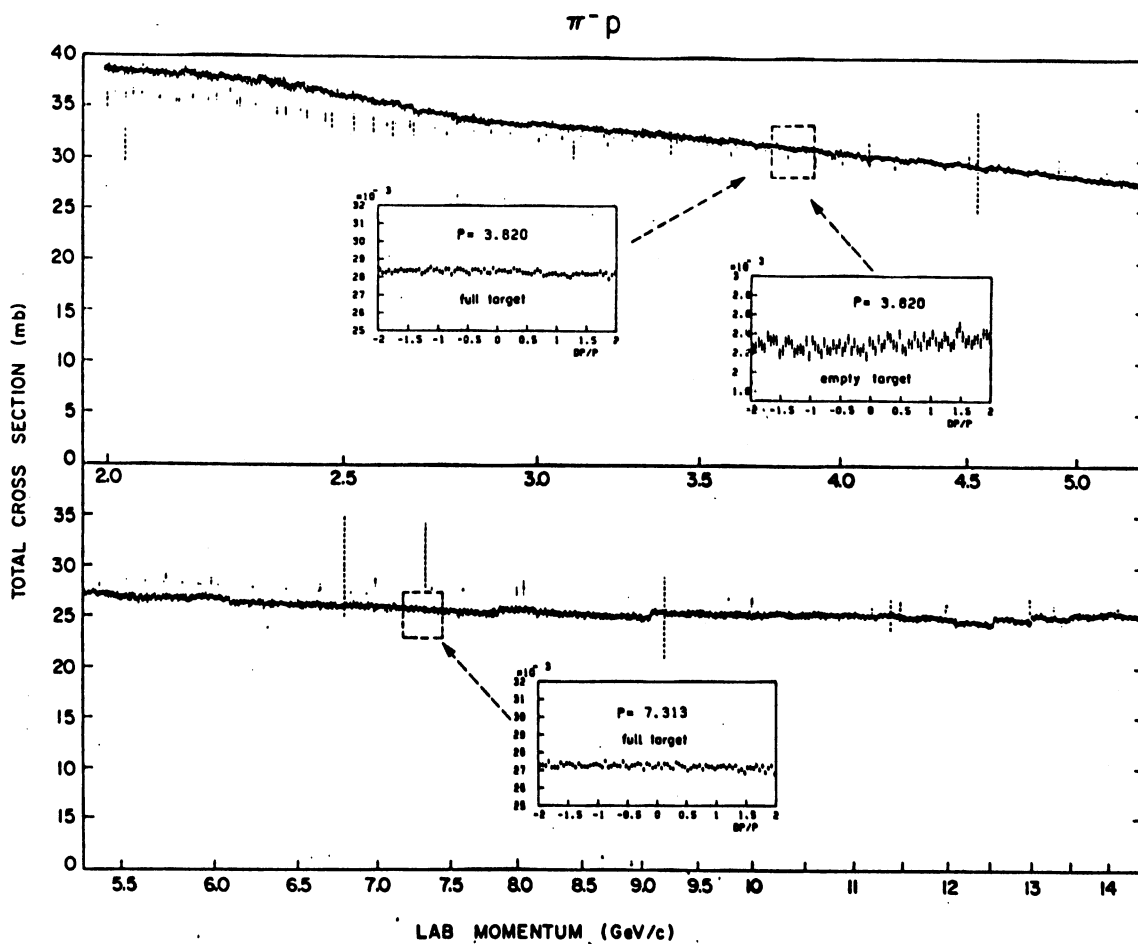


Figure 2

This figure taken from ref.²], shows the ≈ 5000 π -p total cross-section measurements made by experiment S157, together with the older measurements (dashed bars).

The $\pm 2\%$ momentum acceptance of the spectrometer is divided by the micro-computer into 80 bins (see small boxes).

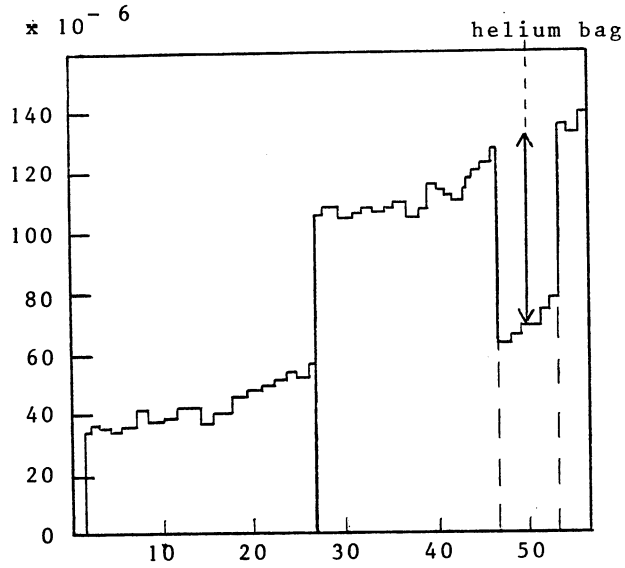


Figure 3

The histogram shows the variation of the software counter $X1, (Y1)$ double, $X2, Y2$ as a function of the run number (1 for 2 GeV/c, 57 for 14 GeV/c, target empty, π - beam), normalized to the total number of good events.

The geometry of such events is shown below. The fact that there is hundred different counters of this sort is an illustration of the complexities of the off-line analysis.

