ELECTRONICS AND DATA ACQUISITION FOR G^0 (FORWARD-ANGLE MEASUREMENTS)

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The electronics for G^0 forward-angle measurements can broadly be grouped into two classes : the monitoring system and the time-encoding electronics providing Time of Flight spectra for each detector corresponding to each helicity state. For cross-checking purposes, the G^0 experiment benefits from two designs of time-encoding electronics : one associated to the North American detectors and the other to the French detectors. In the following, the common features of the two designs and their distinctions are described. The last part is dedicated to comments on the current status.

1. Introduction the G^0 experimental set up

1.1. *The G^0 experimental set up*

As described extensively in C. Furget's contribution, the experimental set up for G^0 consists of 8 sectors called octants. Each octant holds 16 pairs of plastic scintillators, where each scintillator is instrumented by two photomultiplier tubes. Therefore the total number of signals to be handled by the electronics is 512. One detector (referred to as Focal Plane Detector, or FPD) is defined as a pair of one Front and one Back scintillators. For forward-angle measurements, particle detection is based on Front/Back coincidences and particle identification (separation of recoil elastic protons from inelastic background) relies on time of flight (TOF) measurements. The start signal (referred to as "YO") for TOF spectra

* On behalf of the G^0 collaboration : http://www.npl.uiuc.edu/exp/G0

is generated by a beam pick-off monitor located upstream the G^0 target. This "YO" signal indicates the arrival time of a beam pulse on the target.

1.2. *The G^0 beam structure and readout frequency*

For TOF requirement in forward-angle measurements, the G^0 beam is a 31.2 MHz pulsed beam rather than the nominal continuous CEBAF beam (499MHz). Therefore, a burst of longitudinally polarized electrons is delivered every 32ns.

The helicity of the beam is flipped at 30Hz. One helicity state lasts 33ms (referred to as one MacroPulSe, or MPS) and the helicity reversal takes 500µs as represented on figure 1.

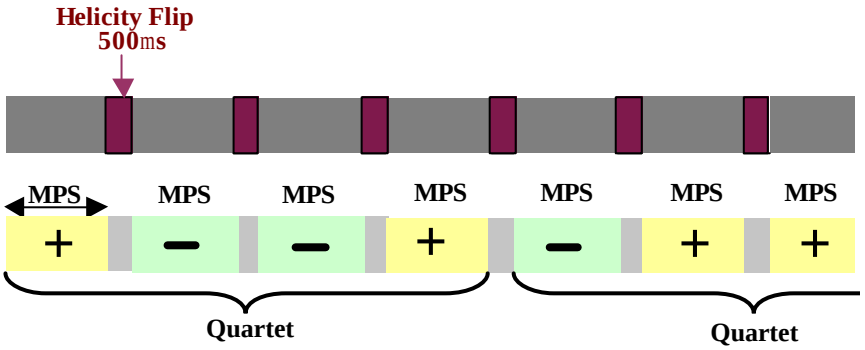

Figure 1 : the G^0 beam structure.

The macropulses are grouped into quartets as shown on figure 1. The first helicity state of each quartet is chosen pseudo-randomly, and the other helicity states follow in the quartet pattern.

During production runs, the data readout from all electronics sub-systems is performed at 30Hz at the end of each MPS during helicity flip. These time-encoding data are TOF spectra built all along one MPS for each detector.

Dedicated runs at 120HZ allow to over-sample the data in order to detect eventual 60Hz noise.

2. G^0 electronics for forward-angle measurements

The electronics is divided into two main parts : the monitoring and time-encoding electronics. Both of these sub-systems receive all the 512 PMT signals coming up from the experimental hall. By design, the signals coming from North American (NA) octants (1, 3, 5 and 7) and the signals coming from French octants (2, 4, 6 and 8) are treated differently in their associated sub-systems. The general scheme of the G^0 electronics[1] is illustrated on figure 2.

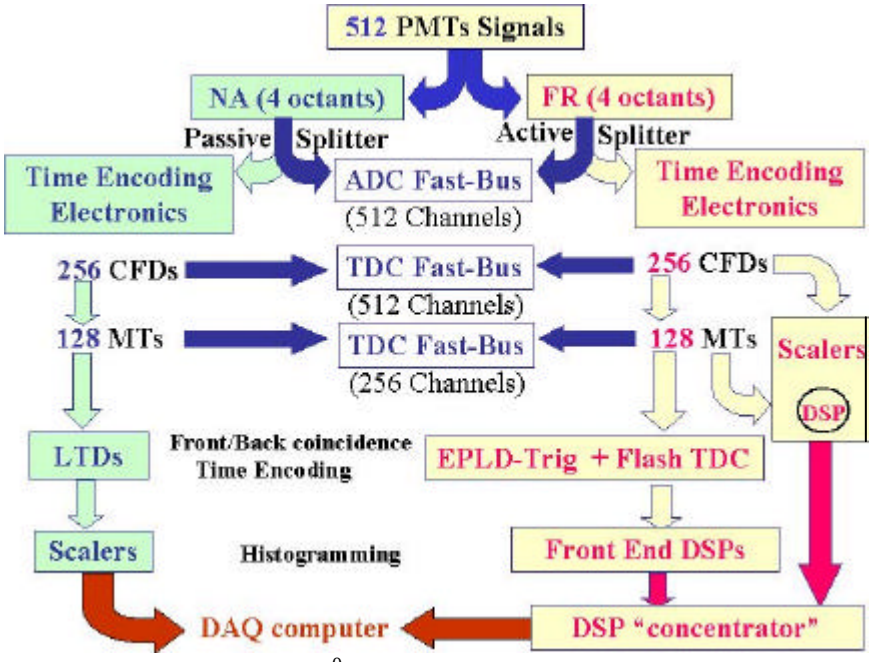

Figure 2 : General scheme of G^0 electronics for forward-angle measurements. CFD : Constant Fraction Discriminator, MT : Mean Timer, EPLD-Trig : Programmable Logical Device, DSP : Digital Signal Processor, LTD : Latching Time Digitizer.

2.1. *The monitoring sub-system*

The monitoring electronics consists of commercial Fastbus ADC and TDC modules collecting signals event-by-event for a small fraction of beam pulses. This set of electronics gathers very useful information to monitor PMTs (gain shifts or degradation) and detector properties (efficiency, time resolution, single-hit rates, …). Moreover, as this sub-system samples time of flight spectra, it is used to cross-check and calibrate the front-end time-encoding electronics. As shown on figure 2, the type of splitters used for NA and French signals being different (respectively passive and active), the amplitude fraction of the signals entering Fasbus ADCs is 1/3 for NA and 1 for French. Consequently, the fraction amplitude of signals sent to time-encoding electronics is 2/3 for NA and 1 for French. The Fastbus TDCs receive the signals processed by the 2 types (NA and French) of front-end time-encoding electronics (all CFDs and MTs signals).

2.2. *Common features for time-encoding electronics*

As mentioned above, the purpose of Time-Encoding Electronics (TEE) is to build time of flight spectra corresponding to one helicity state for each detector. Unlike the Fastbus TDCs, the challenge of TEE is to accept all of the coincidences (Front and Back scintillators) at a mean rate of over 1MHz per detector. Due to the very high encoding rate, only mean-time spectra are accumulated. Subsequently, no information is stored concerning time differences between 2 CFDs signals of one scintillator. On the other hand, the 2 designs of TEE (NA and French) include common features to control dead-time and to reduce the effect of any possible helicity-correlated fluctuation in beam properties. In order to make dead-time effects more deterministic, we perform Next Pulse Neutralization (NPN), which means that encoding is disabled for the next beam pulse after a coincidence event occurred. The other feature which has been implemented in both schemes is the "global buddy" system which allows correction for any helicity dependence of dead-time effects. Similar detectors (symmetric to each other at 180°) are paired as "buddies" and separate count is kept of hits occurring on a detector's buddy while the electronics of that detector is, itself, busy. Missed events due to dead-time may be expected to scale like these "buddy events". Besides these 2 functions, we will now describe the 2 types of designs, each of them having its own characteristics. In particular, the North American have chosen a very modular architecture whereas the French TEE is highly integrated.

2.3. *North-American Design*

The NA time-encoding electronics[2] has been designed by Carnegie Mellon University, Pittsburgh, PA . This design is mainly made up of 4 different types of modules as described on figure 2. The front-end electronics consists of 16 modules of commercial Constant Fraction Discriminators (CFD) and 8 NIM "Mean Timer" boards. Each "Mean Timer" board holds 8 custom digital Mean Timer (MT) ASICs which have been designed by ISN Grenoble[3]. Each MT ASIC processes 4 CFD signals providing 2 output MT signals. The 32 time-encoding boards called Latching Time Digitizer (LTD) are based on two 16 bit high-speed shift registers, one being moved forward 1ns with respect to the other as illustrated on figure 3. As the 2 registers are shifted every 2ns (499MHz) synchronized to beam pulses, the time resolution over 32ns is 1ns.

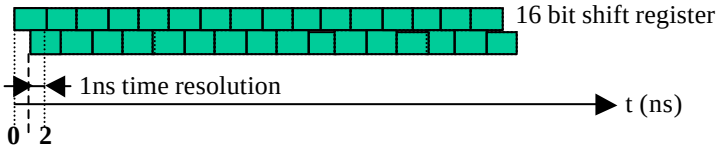

Figure 3 : Basic principle of LTD based on 2 16bit shift registers.

Furthermore, the coincidence between front and back scintillators is made within the LTD boards. Actually, each LTD receives as input 4 MT signals and provides outputs of 2x24 bits (only 12 bits of each 16 bit registers are used among the 16) distributed into scaler channels incrementing the time of flight spectra stored there. Each of the 24 bits correspond to a TOF bin in the NA TOF spectra, as shown in figure 4. For each beam pulse the first bin gathers all hits arriving within the first 6.5ns, the other bins are 1ns wide, and the hits in the last 2.5ns are not recorded (the shift registers).

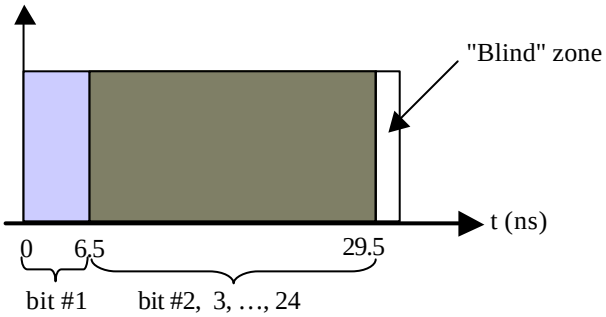

Figure 4 : the bin distribution of North American time of flight spectra.

The 48 VME scaler modules are built after a 32 channels latching scaler ASIC running at 100MHz and developed by ISN Grenoble.

2.4. *French design*

Compared to NA design, French time of flight spectra contain 128 bins of 250ps to describe the whole 32ns beam pulse period. Moreover, contrary to NA design where modules are connected to each other via ribbon cables, the architecture of the French electronics is based on a very integrated design and is so very compact : everything stands within one C-sized VXI crate. It has been designed and developed by IPN Orsay. The French TEE consists of 8 custom boards called DMCH-16X (Discriminator, Mean timer, time digital Converter, Histogramming, 16 channels within vXi standard) orchestrated by a module referred to as Interface Box which provides common signals (MPS, YO, …) to

DMCH-16X boards through the VXI back-plane. One DMCH-16X board receives 32 PMT analog signals and builds 8 TOF associated to detectors (front/back coincidences) of one half of an octant. Each board includes 3 types of daughter boards : 16 CFD-MT, 1 S-DMCH (scalers) and 1 G-DMCH (internal generator), see figure 5.

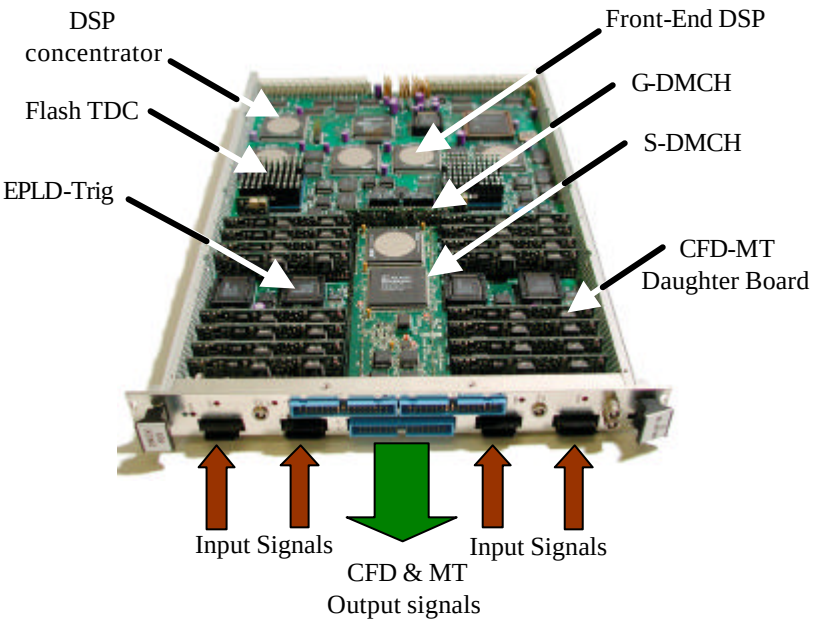

Figure 5 : description of DMCH-16X module.

The arrival time of a hit is encoded by numerical time encoder ASICs (9 channels flash TDCs) designed by IPN Orsay. By design, the time resolution of this TDC is 250ps. For G^0 purposes, these ASICs are synchronized to the YO signal so that they work within implicit start mode. The 9th channel of the TDCs may be used as explicit start for PMT gain monitoring. Each DMCH-16X mother board holds 2 TDCs which distribute data through FiFo buffers to 4 front-end DSPs (Digital Signal Processors) where TOF spectra are accumulated in different memory registers associated to each detector.

The DMCH-16X board also includes programmable logical devices (EPLD-Trig) to make the coincidence between front and back scintillators. Furthermore, these EPLD-Trigs have been programmed to offer many other features which can easily be selected by software : NPN enabled/disabled, 2 coincidence gate widths (7ns or 11ns) and different modes of acquisition which are very useful for tests such as “inclusive front or back”, the mode used in production runs being

"coincidence front/back – NPN On – Differential Buddy". The "differential buddy" system is complementary to the "global buddy" mentioned above. Whereas the global buddy provides a number of counts integrated over an MPS, the differential buddy builds TOF spectra of these counts allowing dead-time correction within specific bin ranges.

Besides, most of the settings are software controlled such as CFD thresholds, MT internal delays (fine tuning of the coincidence timing), differential non-linearity of the TDCs, buddy marker delays used for differential buddy, amplitudes of the signals generated by the internal generator (G-DMCH). The G-DMCH generator is used from time to time to check CFD thresholds and MT outputs.

In addition to TOF spectra, each DMCH holds a S-DMCH daughter board which keeps track of individual countings (32 CFDs, 16MTs, 8 Global Buddies) whatever the acquisition mode. The S-DMCH includes a FPGA chip and a DSP. At the end of the MPS, the 4 front-end DSPs and the DSP on S-DMCH send their data to another DSP, referred to as DSP concentrator, which transfers the block of data associated to one DMCH-16X board over the VME bus to the CPU board. For the 8 boards, the total flux for French TEE is 1.2 Mbytes/s which represents 4/5 of the G^0 data flux for forward-angle measurements.

3. Current Status

The two sets of electronics for forward-angle measurements have been extensively tested and they both showed during commissioning runs that all the requirements have been met. The main advantage of French electronics is the 250ps time resolution compared to 1ns for NA. The NA architecture allows more flexibility to track module breakdowns but requires lots of spares corresponding to the different modules. Due to the high integration level of the French electronics, the whole board has to be replaced whatever element is defective. During the first commissioning of G0, we have greatly benefited from havicng these 2 different types of time-encoding electronics as cross-check and it will be of great help to control and minimize systematic errors.

References

1. G^0 electronics : http://www.npl.uiuc.edu/exp/G0/elec/elec.html
2. NA electronics : http://www.npl.uiuc.edu/exp/G0/elec/na.html
3. ISN Grenoble : http://isnwww.in2p3.fr/g0/dev_electro_ang.htm