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GET: A Generic Electronic System for TPCs for nuclear physics experiments^o

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Abstract

GET is an international program to develop a reconfigurable and scalable medium sized system to cover nuclear physics requirements for instruments with up to 30k electronic channels.

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With the advent of radioactive beams the nuclear physics community is active in developing experimental methods (ref. 1) concurrent with beam characteristics to extract spectroscopic information and study novel nuclear reaction mechanisms. Nuclear particle physics instrumentation today require a full cover of the available phase space with good efficiency, angular, energy and particle identification capabilities. The reasons for this are multi-fold; the luminosities are often limited when dealing with the

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production of nuclei close to the drip lines and hence a question of yield; the kinematics are very strongly varying; the ejectiles spectrum is rich; good energy resolution is required for spectroscopy and particle identification. Similar comments can be made for electron and gamma detection. Further, in mature experiments one finds a number of linked detection systems employing different types of detectors in very close geometry (within a sphere of approximately 50cm diameter), around the target, which is often placed in vacuum. Thus, cable packaging and close localization of the front end electronics is imposed. The corresponding instrument innovations have had an important impact in the way the nuclear physics community has had to develop front-end electronics and data acquisition systems. Principally, this is because of the use of highly segmented solid-state, scintillating and gaseous devices. As a result, this has increased the number of channels by a factor of 100 over the last 10 years, while retaining functionalities which are not incongruent with NIM based systems of the past with added novelties like early numerical transition. The functionalities referred to here require transportability, reliability and simplification in setting up based on the need to perform a number of experiments in different installations, requiring different specifications, and allowing only a few weeks to perform calibration and the experiment. Solutions being adopted are ones in which the point-to-point connections are minimized, the ASIC technology is utilized and control of the adjustable parameters are quasi or fully numeric. Thus, the adopted solutions are akin to those of the particle physics community. However the lack of human and financial resources necessitate that the Front End Electronics, FEE, and DAQ development costs to be shared. Consequently, a strong effort is now placed on reconfigurable and expandable electronic systems such that different laboratories can share a single development for major projects.

Generic Electronics for TPCs (GET) is a development where the objective is to build systems for various types of TPCs. Types are distinguished by different configurations, gas amplifiers and gases designed to perform experiments covering the physics of equation of state, EoS, implantation-decay and nuclear particle spectroscopy. The latter has been explored via the active targets technique (ref. 1) where the TPC gas is also the target. Also, provisions are made within the system, so that in the near future the system can be configured to include solid state devices (e.g. DSSSD) and scintillators (e.g. CsI). Basically, GET samples the signals from the sensors to give the position, energy loss and time. GET is designed to be reconfigurable and user-friendly in regard to the choice of components, the front end and DAQ. This is being tried through the choice of architecture and technical options. GET is expandable to 30k channels and will therefore cover small to medium sized systems. GET includes time stamping to couple with other subsystems and has a fully numeric four level trigger allowing for a versatile use in different experimental settings. The ease in setting up both the hardware and software is being sought. GET is tailored for nuclear physics experimental requirements and to fit in various laboratory infrastructures.

Five laboratories actively support the project GET. IRFU, CENBG and GANIL are partially financed by a French ANR grant. RIKEN is self-supporting. NSCL is NSF supported. GET is an R&D program. The aim is to develop the necessary hardware, firmware, software and documentation for beam tested production prototypes. It includes studies corresponding to the cooling, EM immunity, power supplies, onboard security and the full DAQ and control. The project does not, today, cover the manpower nor the funding for the production of approximately 100k channels required for the ten systems that are being built or studied today. The project is funded over four years and the integrated system would be available by mid 2013. We are presently testing the prototype-one. We will test the second and final full version on prototypes of SAMURAI-TPC (RIKEN, Japan), ACTAR-TPC(GANIL, CNBG, IRFU, France), MINOS (IRFU, France) and AT-TPC (NSCL, US).

The hardware architecture is cartooned in fig. 1. Signals are fed into the protection circuit cards, ZAP, which serves also as a hardware interface between the different detectors (different granularity) and the

front-end board, AsAd. As such, ZAP in its bare form is detector dependent. Optionally, ZAP is meant to contain an external preamplifiers and filters (wrt AGET, see below) in an ASIC format. These are in the definition stage and will allow for long cable length between ZAP and AsAd and a preamp plus filter adoptable to various sensors. Signals from ZAP are channelled to AsAd directly or on Kapton/co-axial cables.



Fig. 1 GET conceptual design.

The front-end card, AsAd (**A**sic and **A**dc) houses four specifically designed 64 channel ASICs, AGET and ADCs. AGET has a base design similar to that of the AFTER chip (ref. 2.). Namely, a PA, filter (0.1 to 1 μ s shaping), Switched Capacitive Array, SCA, circular buffer (512 buckets/channel at 1 to 100MHz), pulser functions, multiplexer and inspection facilities. Via slow control AGET allows for an

external/internal PAC and/or filter, adjustable gain/channel (0.0, 0.12, 0.24, 1.0 and 10pC), discriminator/channel for trigger and channel hit register (MUTANT calculates the selective read-out pattern). The SCA write and read has number of options to allow for fast read-capacities. In particular, it allows the memory to be configured effectively into two memories to register two rapid consecutive events (e.g. nuclei stopping in the gas followed by a rapid decay). Also, the ADC is in a continuous read mode to give the hit stream (digital time dependent multiplicity) to the trigger module MUTANT via the Concentrating Board, CoBo. The AGET was built and shown to be functional. The performance tests to date are close to the set specifications given in table 1. The 12/14 bit ADC samples at 25Mhz with outputs on two differential lines. The AsAd board has a pulser for tests and calibration purposes. AsAd monitors the temperature, supply voltage levels and power consumption and raises alarm flags in the case of malfunction.

Table 1 Specifications of the ASIC AGET.

Parameter	Value
Polarity of detector signal	Negative or Positive
Number of channels	64
External Preamplifier	Yes; access to the filter or SCA inputs
Charge measurement	
Input dynamic range	120 fC; 1 pC; 10 pC
Gain	Adjustable/(channel)
Output dynamic range	2V p-p
I.N.L	< 2%
Resolution	< 850 e- (Charge range: 120fC; Peaking Time: 200ns; Cinchannel. < 30pF)
Sampling	
Peaking time value	50 ns to 1 μ s (16 values)
Number of SCA Time bins	512 [new]
Sampling Frequency	1 MHz to 100 MHz
Time resolution	
Jitter	60 ps rms
Skew	< 700 ps rms
Trigger	
Discriminator solution	L.E.D
Trigger Output/Multiplicity	OR of the 64 discriminator outputs (pulse of 2*TckADC)
Dynamic range	5% of input charge range
I.N.L	< 5%
Threshold value	4-bit DAC/channel + (3-bit + polarity bit) common DAC
Minimum threshold value	\geq noise
Readout	
Readout frequency	20 MHz to 25 MHz
Channel Readout mode	Hit channel; specific channels; all channels
SCA Readout mode	512 cells; 256 cells; 128 cells
Test	
calibration	1 channel / 64; external test capacitor
test	1 channel / 64; internal test capacitor (1/charge range)
functional	1, few or 68 channels; internal test capacitor/channel
Counting rate	< 1 kHz
Power consumption	< 10 mW / channel

A CoBo receives inputs from 4 AsAd cards and is housed in a μ TCA chassis. It is furnished with a Xilinx Virtex 5 FPGA chip coupled to a fast memory with a double buffer architecture. The principle functions of the CoBo card is (i) to configure the AsAd cards (ii) performs local calibration and (iii) trigger functions, (iv) transits the trigger information (AsAd \leftrightarrow MUTANT), (v) collect ADC outputs and perform data reduction, time stamping, formatting functions and (vi) transfers data at 1Gb/s towards the

10Gb/s μ TCA switch. GET employs Gigabit Ethernet via TCP/IP and embedded LINUX and VxWorks allowing setup switch. Most of the signals transit over differential pairs using LVDS.

MUTANT is a fully numeric 3-level trigger employing two Virtex 5 FPGAs: the first one for the embedded system and the second for the trigger/time stamper engine. The Level-0 is an external trigger option (MUTANT input or via BEM with optic fibres for remote trigger). Level-1 (TPC multiplicity) corresponds to time pattern recognition trigger and will allow, for example, self trigger. Level-2 is an event pattern trigger and will allow for a selective readout with a calculated readout pattern option by modifying the hit pattern in AGET. Level-3 is imposed by the computer farm once the event has been constituted. The latency in Level-0 is coincidence window dependant while an “OK” in the Level-1 analysis is obtained in about 80 nsec. The Level-2 trigger performance is yet to be fully simulated and is mainly algorithm complexity dependant. MUTANT has the CENTRUM like (Ref. 3) interface.

BEM (Back End Module) is cabled to the master MUTANT. It can receive external triggers. It allows for a choice of external clock input (CENTRUM, BuTiS or GTS) or an internal stand alone clock. The 100MHz clock is distributed to the CoBo via MUTANT on the μ TCA shelves. Ten CoBos and a MUTANT will be housed in a μ TCA chassis. Thus each full μ TCA will cover 10,240 channels. Presently the system is designed for a 30,720 channels where two of the MUTANT will be software designated as slaves. Modification of GET for more than 30k channels is possible. For high multiplicities, which are expected in EoS experiments, the data capture rate is estimated to be 1kHz.

The software and firmware developments are schematically shown in fig. 2. CoBo and MUTANT are implemented with dedicated processors. The architecture is based on a multi-platform framework with a full object oriented client-server design. Two control cores (CC) are present. The Electronic Control Core employs a database and acts on the CoBo and MUTANT boards for parameter setting, reading and logging (ref. 4). Data selection, buffering and real time processing (time stamping, formatting, zero removal...) are jointly executed by the CoBo firmware and embedded software and then sent to the computer farm over Ethernet/TCP-IP via the μ TCA switch. The DAQ-oriented generic binary data format, *MultiFrame MetaFormat* (MFM), has been specified and implemented. It is meant to define binary data serialization that is self-contained, layered and includes both backward and forward compatibility schemes for format evolution. The data flow functions (Run Control Core) are set on the NARVAL data acquisition system developed at IPN, Orsay (ref. 5). It is a distributed and entirely reconfigurable framework, which can be adopted with ease to different detector configurations, event building and filtering. Where possible commercial or freeware has been employed for the developments (ICE,...) and, where possible with human resource constrains, a generic methodology is implemented.

In brief, the GET project is an international collaborative effort to investigate a novel approach towards building medium sized scalable system with a presently maximum of 30k channels having multiple possible applications with comparatively high throughput capabilities and resolution. The choice of new technological solutions allows a reduction in the number of point-to-point connections in the system and should therefore provide for a more reliable system. A fully computerized and distributed control approach will give fast calibration and significant reduction in the set-up time of the system.

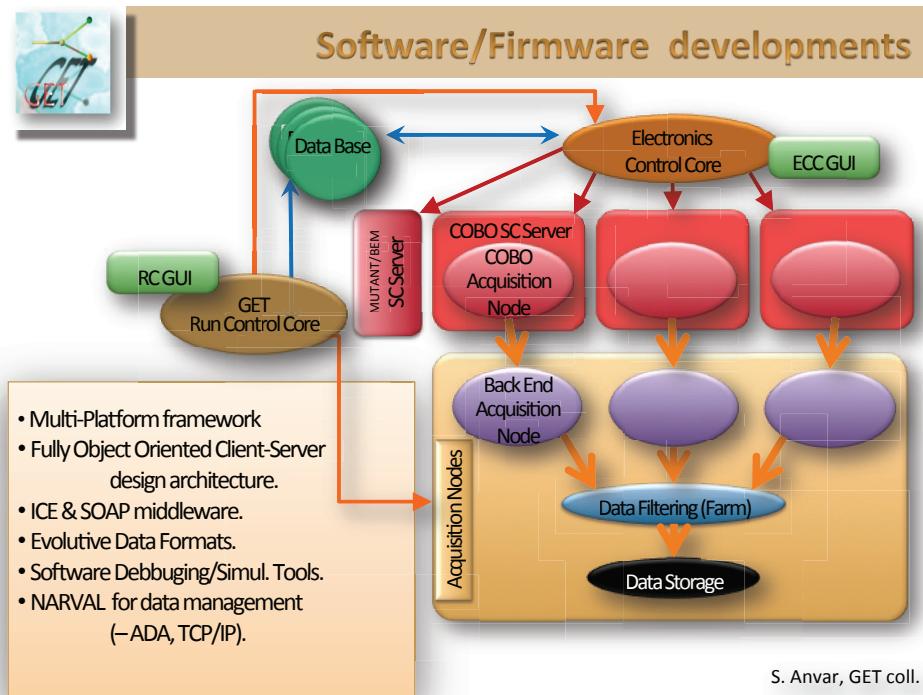


Fig. 2 Software and firmware developments.

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