

A Digital Front-End Electronics for the Neutron Detector NEDA

F.J. Egea, C. Houarner, A. Boujrad, V. González, *Senior Member, IEEE*, M. Tripon, M. Jastrzab, A. Triossi, G. de France, A. Gadea, J.J. Valiente-Dobón, E. Sanchis, *Member, IEEE*, D. Barrientos, M. Blaizot, P. Bourgault, G. de Angelis, M.N. Erduran, S. Ertürk, G. De France, T. Hüyük, G. Jaworski, X.L. Luo, V. Modamio, M. Moszyński, A. Di Nitto, J. Nyberg, P-A. Söderström, M. Palacz, R. Wadsworth

Abstract— This paper presents the design of the NEDA front-end electronics, a first attempt to involve the use of digital electronics in large neutron detector arrays. Among the electronic modules taking part, we emphasize on the front-end analog processing, the digitalization, digital pre-processing, communications firmware, as well as the integration of the Global Trigger and Synchronization system. The NEDA array will be available for measurements in 2015.

I. NEUTRON DETECTOR ARRAYS WITH DIGITAL ELECTRONICS

RESEARCH on Nuclear Structure of exotic nuclei has led physicists to use high-resolution gamma spectrometers coupled with neutron and charged-particle detectors in order to identify the reaction the products from the nuclear reactions. Special effort is put into obtaining efficient detectors for neutron identification, with reduced neutron

Manuscript received May 22, 2014.

This work has been supported by the Generalitat Valenciana, Spain, under grant PROMETEO/2010/101. Some authors have been partially supported by INFN, Italy, and by the Spanish MINECO under grants AIC-D-2011-0746, FPA2011-29854 and FPA2012-33650.

F.J. Egea, V. González, and E. Sanchis are with Departament d'Enginyeria Electrònica (Universitat de València), Escola Tècnica Superior d'Enginyeria, Burjassot (Valencia, Spain).

A. Gadea, D. Barrientos and T. Hüyük are with Institut de Física Corpuscular (CSIC-UV), Valencia, Spain. Corresponding author: Francisco Javier Egea Canet; e-mail: jaegea@ific.uv.es

M. Tripon, A. Boujrad, C. Houarner, G. de France, P. Bourgault and M. Blaizot are with Grand Accélérateur National d'Ions Lourds (GANIL), 14706, Caen, France.

M. Jastrzab is with the Niewodniczański Institute of Nuclear Physics, Polish Academy of Sciences, Kraków, Poland.

J.J. Valiente-Dobón, G. De Angelis, D. Barrientos, A. Triossi and V. Modamio, are with INFN, Laboratori Nazionali di Legnaro, Padova IT-35020, Italy.

G. Jaworski is with Faculty of Physics, Warsaw University of Technology, Warszawa, Poland.

G. Jaworski, M. Moszyński and M. Palacz are with the Heavy Ion Laboratory, University of Warsaw, Warszawa, Poland.

J. Nyberg, P-A. Söderström and X. L. Luo are with Department of Physics and Astronomy, Uppsala University, Uppsala, Sweden.

M. Moszyński is with National Centre for Nuclear Research, A. Soltana 7, PL 05-400 Otwock-Swierk, Poland

X. L. Luo is with Department of Instrument Science and Technology, National University of Defense Technology, Changsha, China

P-A. Söderström is with RIKEN Nishina Center, Wako-shi, Japan.

A. di Nitto is Johannes Gutenberg-Universität Mainz, 55099 Mainz, Germany.

M.N. Erduran is with Faculty of Engineering and Natural Sciences, Istanbul Sabahattin Zaim University Istanbul, Turkey.

S. Ertürk is with Nigde Üniversitesi, Fen-Edebiyat Fakültesi, Fizik Bölümü, Nigde, Turkey.

R. Wadsworth is with Department of Physics, University of York, York, United Kingdom.

cross-talk, being so one of the main goals for the new-generation NEDA [1] (NEutron Detector Array). NEDA is expected to play a major role as a neutron detector array for future experiments using high-intensity stable and radioactive ion beams coupled with the gamma-ray spectrometers AGATA [2], EXOGAM [3] GALILEO [4], and GRETA [5].

NEDA (NEutron Detector Array) design has been focused on obtaining large neutron efficiencies, low cross-talk, excellent NGD (Neutron-Gamma Discrimination) [6] and high counting rates capabilities leading to a detector design with large volumes of BC501-A organic scintillator combined with a geometry capable to minimize the effects of scattered neutrons. BC501-A-based detectors provide high neutron detection efficiency, although, as they are also sensitive to gamma rays, it is required to perform NGD techniques, which require accurate TOF (Time-of-Flight) measurements [7] and PSA (Pulse-Shape Analysis) techniques to enhance NGD performance. The experiments using XP4512 PMTs have shown that signals involved in the process carry on fast rise-times around 10 ns, followed by a double-component tail, which fluctuates between 300 ns and 500 ns.

Another design criterion is the highest experimental counting rate, expected not to be higher than 50 kHz with high-intensity beams, allowing the design of the communication links.

In terms of resolution, according to the simulations performed in [6], it is evidenced that at least 100 Msps with 12-bit resolution to deal with the PSA for some algorithms. Nevertheless, the results from [7], show, that TOF measurements require at least of 200 Msps in order to achieve a timing resolution less than 1.15 ns, reason for which a sampling system with 12-bit and 200 Msps is at least needed.

II. GLOBAL ELECTRONICS LAYOUT

NEDA electronics design is going to be conducted in three phases. Firstly, the new digital electronics are envisaged to instrument the former Neutron Wall detector, consisting of 45 detectors, to which 45 more new NEDA detector modules are expected to be coupled in 2015. Finally, NEDA final stage comprehends 355 detectors. The coupling with AGATA and other detectors has still to be foreseen.

The electronic chain is built of the following parts: the front-end single-ended to differential converters, the NUMEXO2 [8] digitizer and the FADC Mezzanines, the LINCO2 PCIe readout interface, the Global Trigger and

Synchronization (GTS) [9] and the workstations for data acquisition and processing.

Each single detector module is readout by one single Front-End electronics channel whenever a current signal is provided from the corresponding PMT. Those current signals are connected to the front-end single-ended to differential converter board before sending the signal through a 10m cable to NUMEXO2. Each conversion board contains a total amount of 8 channels. As the signal reaches NUMEXO2 digitizer, each contains plugged onto it 4 FADC Mezzanines, where the pulse is sampled periodically [10] at 200 Msp/s with a resolution of 14-bits (11.3-11-7 ENOB).

As the signal is digitized, digital pre-processing techniques are carried out using a Virtex-6 Field Programmable Gate Arrays (FPGAs). After the signal is deserialized, a first-level triggering algorithm based on PSA is applied in order to reduce the events produced by gamma-rays and hence, to optimize the readout bandwidth capabilities.

A second FPGA, now a Virtex-5 handles the communication links (SPI, Serial, TCP/IP and PCIe) and the connection to the GTS (Global Trigger and Synchronization) system. The trigger requests, now produced mostly by neutrons, are received and sent to the GTS (Global Trigger System) where either a validation or rejection is being waited. The main component of the Virtex-5 is an embedded processor containing a Linux OS, in charge to cope with the slow-control and the communication management tasks. Each NUMEXO2 deals with 16 channels and a GTS leaf optical connection. Fig.1 illustrates the global electronic layout for 45 detectors.

The readout tasks are performed using the PCIe Endpoint lanes, using the Virtex-5 transceivers, capable to deliver data up to 10 Gbps and a LINCO2 board [11], which converts the PCIe optical connection into a PC standard legacy bus. However, assuming a data transfer rate of 200 Msp/s at 50 kHz, and using 250 samples to transfer each event for 16 channels, it is at least needed 3.2 Gbps for the readout link.

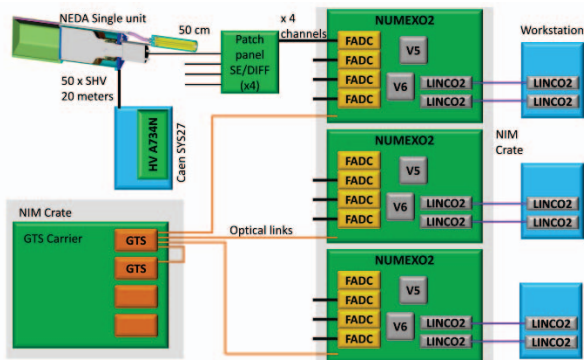


Fig.1: Global electronics layout for NEDA involving the use for 45 detectors

III. CONCLUSIONS

A comprehensive front-end electronics system envisaged for the acquisition and pre-processing for NEDA detector has been presented, starting from the next-to-the-detector analog single-to-differential conversion stages until the readout and

GTS system. Currently, the status is still under development, where some parts of the firmware are still being tested. First experiments with the new front-end electronics are envisaged for early 2015.

ACKNOWLEDGMENT

We would like to thank also to the Swedish Research Council and the Scientific and Technological Research Council of Turkey (TUBITAK) for the financial support.

REFERENCES

- [1] G. Jaworski et al, «Monte Carlo simulation of a single detector unit for the neutron detector array NEDA,» *NIM A*, vol. 673, pp. 64-72, 2012.
- [2] S. Akkoyun. et. al., «AGATA - Advanced Gamma Tracking Array,» *NIM A*, vol. 668, 2012.
- [3] GANIL, «EXOAM Detectors,» [En línea]. Available: <http://pro.ganil-spiral2.eu/laboratory/detectors/exogam/exogam-detectors>.
- [4] D. Barrios et. al., «Front-end electronics for the GALILEO detector array,» [En línea]. Available: http://www.lnl.infn.it/~annrep/read_ar/2012/contributions/pdfs/064_C_138_C112.pdf.
- [5] C.W.Beausang, «GRETA. The gamma-ray energy-tracking array. Status of the development and physics opportunities,» *NIM B*, vol. 204, pp. 66-74, 2003.
- [6] P-A. Söderström, J. Nyberg «Digital Pulse Discrimination of fast neutrons and gamma rays,» *NIM A*, vol. 594, pp. 79-89, 2008.
- [7] V. Modamio, «Timing resolution for liquid scintillators,» de *Presented at NuPNETT meeting*, Acireale, 2013.
- [8] M. Tripon, «EXOAM2 Technical Specifications,» 2012.
- [9] M. Bellato et al. «Sub-nanosecond clock synchronization and trigger management in the nuclear physics experiment AGATA,» *Journal of Instrumentation*, vol. 8, n° P07003, 2013.
- [10] F.J. Egea et al., «Design and test of a high-speed flash ADC mezzanine card for high-resolution and timing performance in nuclear structure experiments,» *IEEE Transactions on Nuclear Science*, vol. 60, n° 5, 2012.
- [11] A. Triossi et al. «A PCI Express Optical Link Based on Low-Cost Transceivers Qualified for Radiation Hardness,» *Journal of Instrumentation*, vol. 8, n° C02011, 2013.