DNG@NCBJ - high counting rate digital spectrometry system

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A data acquisition system for high resolution spectrometry measurements at Mcps count rates, DNG@NCBJ (Digital Neutron Gamma @NCBJ), is under development at the National Centre for Nuclear Research (NCBJ).

The DNG@NCBJ measurement system is based on direct sampling of the input signal, see Fig. 1.

Data acquisition and signal processing operations are performed digitally by FPGA with an ARM9 processor on a Xilinx ZC706 evaluation board. Since direct sampling of the input signal requires a high speed ADC, a Texas Instruments ADS5400 (12 bit/1 GSPS) ADC is used.

Data acquired from the ADC is processed on line by FPGA. A dedicated IP core has been developed to fulfill the system requirements.

The following major operations have been implemented:

1. pulse detection (triggering),
2. baseline estimation (offset compensation),
3. pulse energy estimation,
4. list mode creation,
5. communication.

The DNG@NCBJ system is optimized for high count rate detection applications. The DNG@NCBJ system is controlled by embedded Linux. The user has access to internal registers in diagnostic modules and can initiate and stop data transfer.

The DNG@NCBJ system is characterized by:

1.12-bit @ 1 GSPS ADC,

2.wideband DC-coupled to ADC input,

3.2 V input full scale,

4.signal processing algorithms implemented in FPGA,

5.communication based on Ethernet,

6.the system is controlled and managed by the Linux operating system.

Table I. Characteristic Parameters of DNG@NCBJ.

	DNG@NCBJ
measured max count rate, Mcps	2.2
dead time, ns/pulse	10
bandwidth, MHz	~2100
sampling rate, MSPS	1000
input voltage	2 V_{PP}
available channel number	1

To perform measurements at higher counting rates under laboratory conditions a PuBe source was used simultaneously with a strong ^{137}Cs source, with an activity of ~400 MBq, in order to increase the event rate. In our experiments a $LaCl_3$:Ce scintillator was coupled to a Photonis XP5200 PMT characterized by high quantum efficiency. Performance of a PMT-based detection system depends on the voltage divider, therefore a dedicated active voltage divider was built to accommodate gain shifts in the presence of high rates and a few MeV energy gamma radiation.

Results from DNG@NCBJ are compared with those obtained using a commercially available device, a CAEN Desktop Digitizer DT5720 with DPP-CI firmware [11].

As an example, in Fig. 1 spectra of PuBe and ^{137}Cs registered with a 1”×1” $LaCl_3$:Ce scintillator with the DNG@NCBJ device and the CAEN Desktop Digitizer are shown. Measurements were performed at a count rate of 0.2 Mcps. Such a count rate allows one to observe peaks from both sources because of the much lower PuBe source activity.

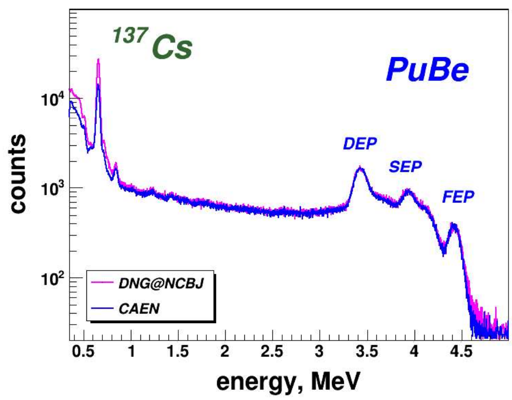

Fig. 1. Spectrum of ^{238}PuBe and ^{137}Cs measured with a 1”×1” $LaCl_3$:Ce scintillator. Measurements were performed with DNG@NCBJ and CAEN Desktop Digitizer DT5720.

The DNG@NCBJ is integrated into a single compact unit and was checked for count rates up to 2.2 Mcps with dead time not exceeding 10 ns/pulse.

This DAQ is well suited for use in plasma experiments in which high count rates are expected.

Almost identical spectra were obtained with DNG@NCBJ and a commercially available CAEN Desktop Digitizer DT5720, especially concerning one of the most important parameters in plasma experiments, the full width at half maximum.

With DNG@NCBJ it is easy to create a data acquisition system for a multi-detector setup. Off-line processing could be used for setting optimization.

An algorithm to correct pile-up events without rejecting them is under development.

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Silicon photomultipliers in scintillation detectors used for Gamma-Ray energies up to 6.1 MeV

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The aim of this work was to the study usefulness of SiPM light readout in the detection of gamma rays up to 6.1MeV in combination with various scintillators. The reported measurements were made with 3 samples of one type of Hamamatsu TSV (Through Silicon Via technology) MPPC arrays. These 4x4 channel arrays have a 50x50 μm^2 cell size and 12x12 mm^2 effective active area. All the tests were done in a climatic chamber. The following scintillators were used: CsI(Tl), $CeBr_3$, NaI(Tl). The studies were focused on optimization of the MPPC performance for practical use in the detection of high energy gamma rays. The optimization included selection of the optimum operating voltage in respect to the energy resolution, verification of the dynamic range, linearity and pulse amplitude. The energy spectra for energies between 320keV and 6.1MeV are presented and compared with data acquired with a classic photomultiplier. Such a comparison allowed the of nonlinearity of the tested MPPCs to be studied, correction of the energy spectra and proper analysis of the energy resolution. The temperature tests showed strong breakdown voltage dependence on the temperature change and defined requirements for the stabilization method in real life applications.

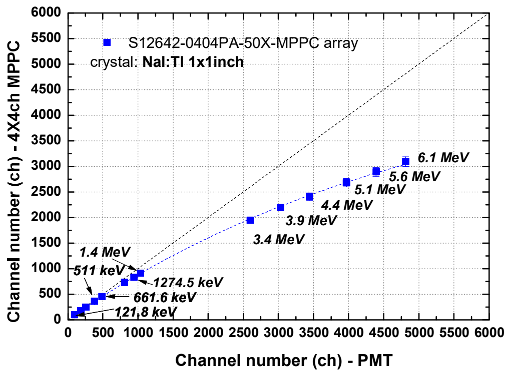

Fig. 1. Linearity characteristics for NaI(Tl) coupled to a 12x12 mm^2 TSV MPPC Array. The plots show the relation of gamma peaks measured using the MPPC Array (Y-axis) and a classic photomultiplier (X-axis).

In the case of gamma spectrometry the optimal operating voltage in MPPCs (and all SiPMs) is a trade-off between an increase in the photoelectron (PHE) number at higher bias voltage due to higher photon detection efficiency (PDE) and worsening of energy resolution due to an increase in the excess noise factor (ENF). The optimal value of 66.4V for the tested MPPC was determined in measurements with a 12x12x12mm BGO and a low gamma energy of 320keV from ^{51}Cr.

Nonlinear response of the MPPC (and all SiPMs) is the main problem that appears in the detection of high energy gamma rays. Measurement of the linearity range allows correction of the recorded data and proper identification of gamma lines. Fig. 1 presents an example of the linearity characteristics recorded for the NaI(Tl) scintillator. The nonlinear behaviour is strong, especially for few MeV events, however far from saturation. Even stronger nonlinearity was recorded for a $CeBr_3$ scintillator, nevertheless the spectra can still be corrected and gamma lines up to 6.1 MeV can be clearly resolved. In Fig. 2 the corrected energy spectrum for the NaI(Tl) scintillator and a PuBe neutron source is presented. The weakest influence of the MPPC nonlinear response to the observed energy spectra was observed for the slowest CsI(Tl) scintillator.

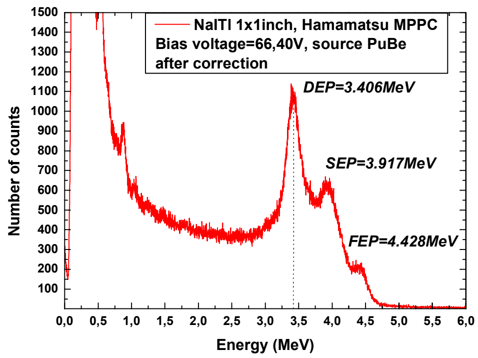

Fig. 2. Energy spectrum recorded for PuBe neutron sources with a NaI(Tl) scintillator coupled to the MPPC array. In the case of the MPPC data the raw spectrum has to be corrected for the nonlinearity.

The large capacitance of MPPC matrices is another problem during readout of these detectors as a single, large area device (like classic photomultipliers). In the case of the tested 12x12 mm^2 detector, read by a 50ohms input resistance of the electronics, the decay time of the output pulse is much longer than the scintillator decay. It may have a negative influence on data acquisition, especially in applications with high counting rates (Mcps). The long decay time of the MPPC pulse can be shortened by means of a 10ohms loading resistance added at the output. Such a circuit can change the decay time from 1ms to about 100ns without destroying the detector performance, in particular the energy resolution [1].