

Digital Approach To High Rate Gamma-Ray Spectrometry

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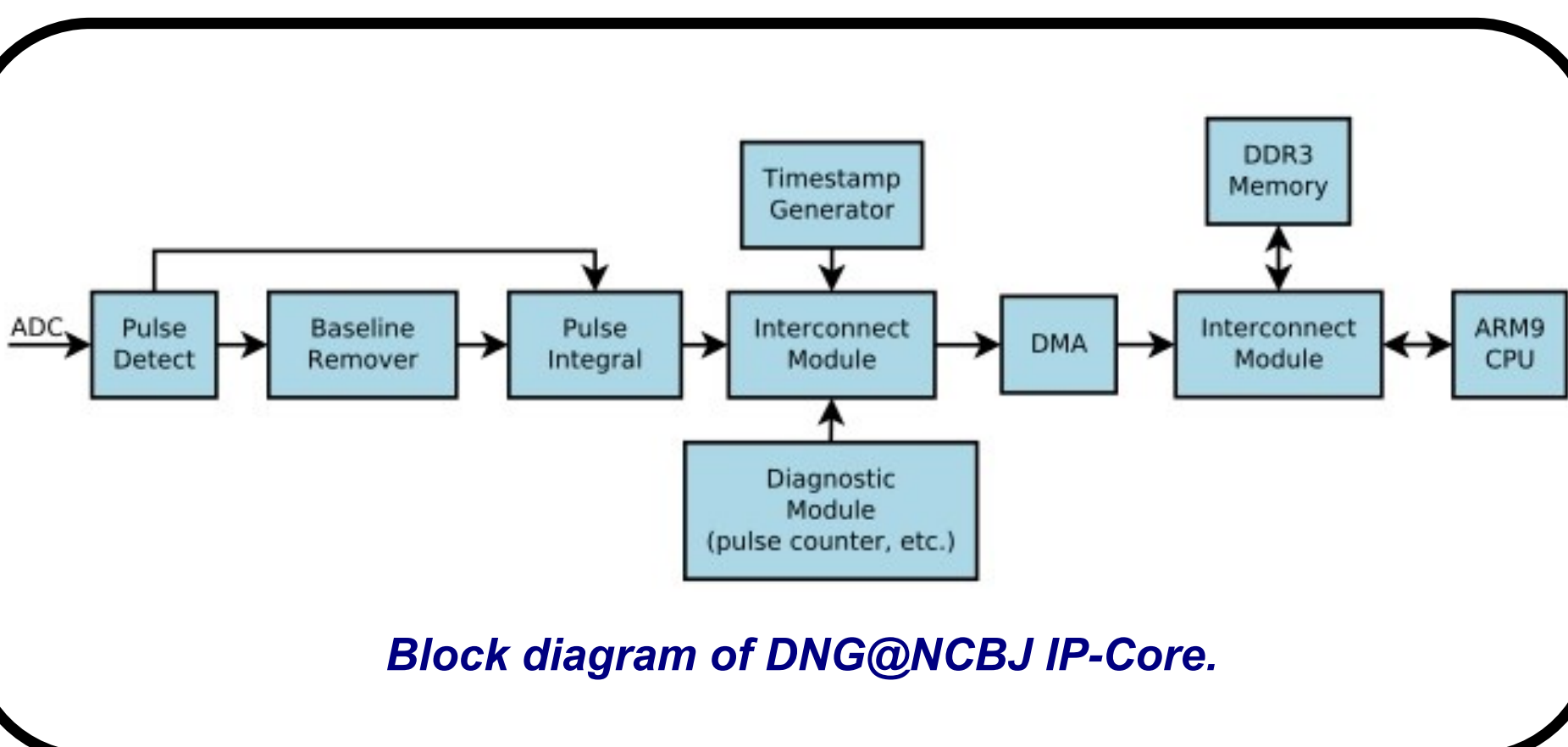
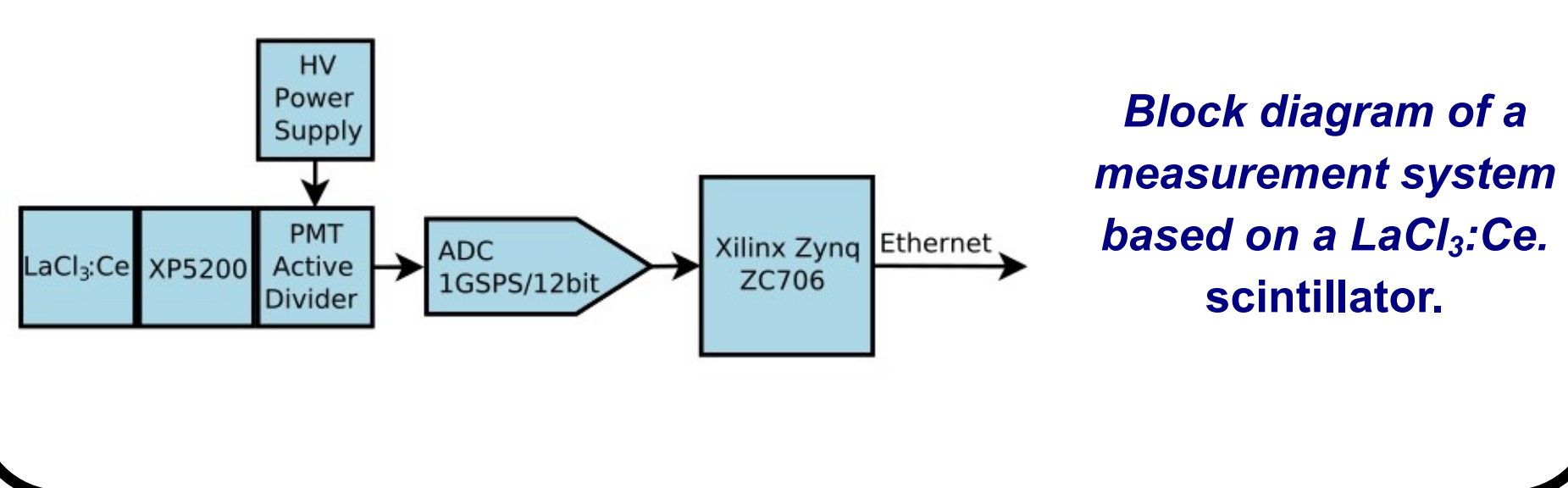
Basic concepts and preliminary results of creating high rate digital spectrometry system using efficient ADCs and FPGA are presented. A data acquisition system DNG@NCBJ (Digital Neutron Gamma @NCBJ) for high resolution spectrometry measurements at Mcps event rates is under development at the National Centre for Nuclear Research (NCBJ).

Growing requirements for high resolution spectrometry in mega counts per second (Mcps) range require a development of new measurement methods. To achieve the highest event rates, short pulses sampled directly at the detector output have to be processed. Digital direct sampling of spectrometry pulses is required in such cases because correct signal processing in the digital domain can be changed by reprogramming the system. Therefore, a system adjustment for processing pulses from a particular detector is relatively easy.

Data acquisition systems based on fast ADCs and a high performance data processing device (Field Programmable Gate Array (FPGA), can process high amount of data in a parallel way. This makes an excellent base for efficient systems for measurements in high resolution gamma spectrometry, performed in harsh radiation environment occurring in modern experiments, e.g., at tokamaks and plasma focus devices.

DIGITAL SIGNAL PROCESSING TECHNIQUE has many advantages in comparison with analog systems

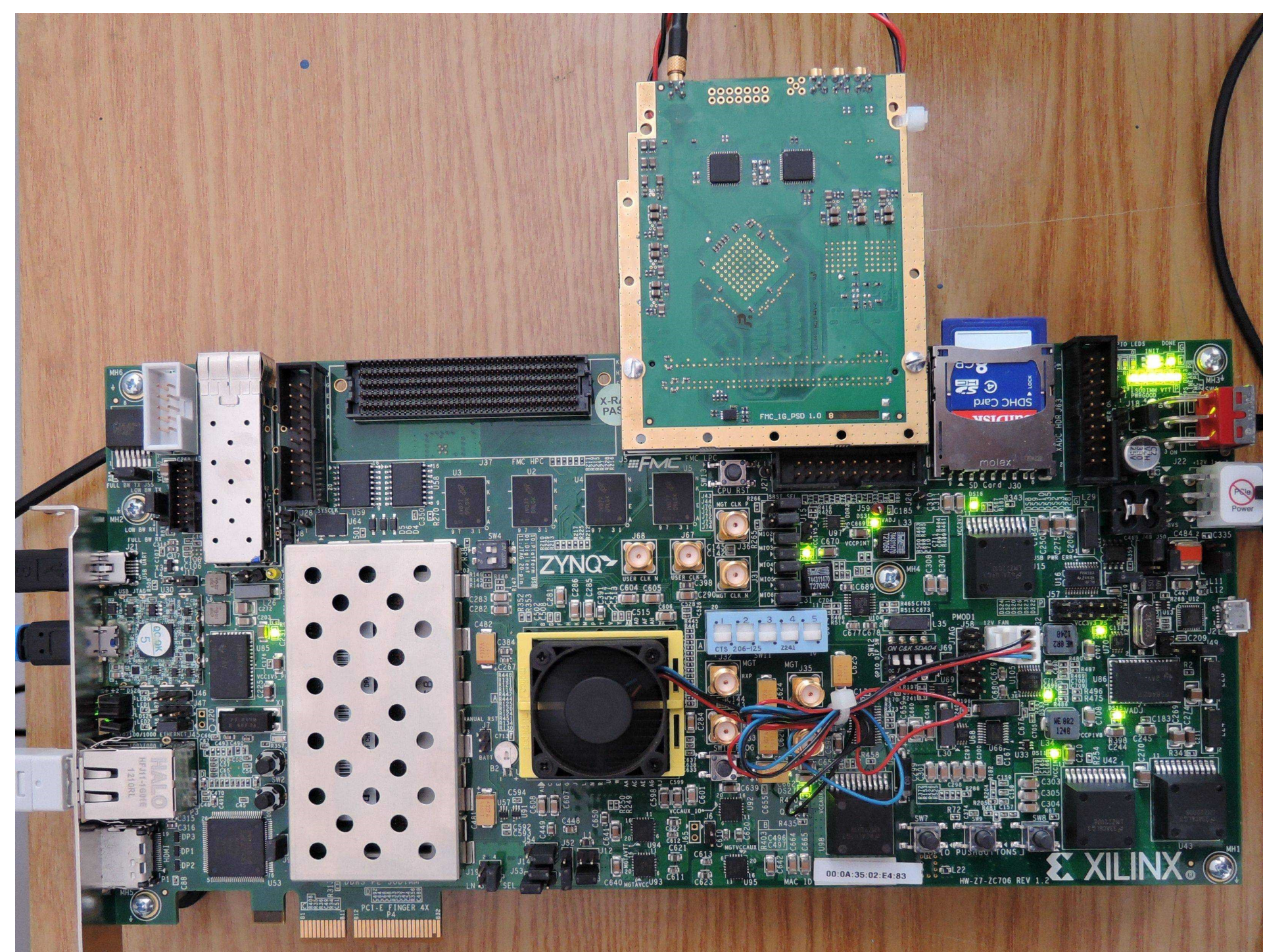
1. one single board can do energy, timing and pulse shape analysis,
2. digital implementation provides good linearity and stability,
3. wider dynamic range and uniformity of the performances over the full range,
4. better correction of pile-up and baseline fluctuation effects,
5. preserve pulse information,
6. low dead-time resulting in high counting rate capability,
7. flexible configuration by FPGA reprogramming instead of resoldering passive components,
8. register programming instead of manual regulations for tuning and calibration.



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DAQ REQUIREMENTS IN HIGH RATE EXPERIMENTS

1. real-time processing of detector signals at high count rate including measurement of energy and time of an event for gamma ray energy up to few MeV,
2. list mode data acquisition based on digital electronics, stored locally for later analysis or for real-time processing; raw acquisition option chosen in system plant configuration to validate the processed real-time data,
3. pile-up reduction in real-time processing,
4. low dead time,
5. reasonable energy and time resolution for few MeV energy gamma ray measurements.



Xilinx ZYNQ-7000 SoC ZC706 evaluation board with ADC board.

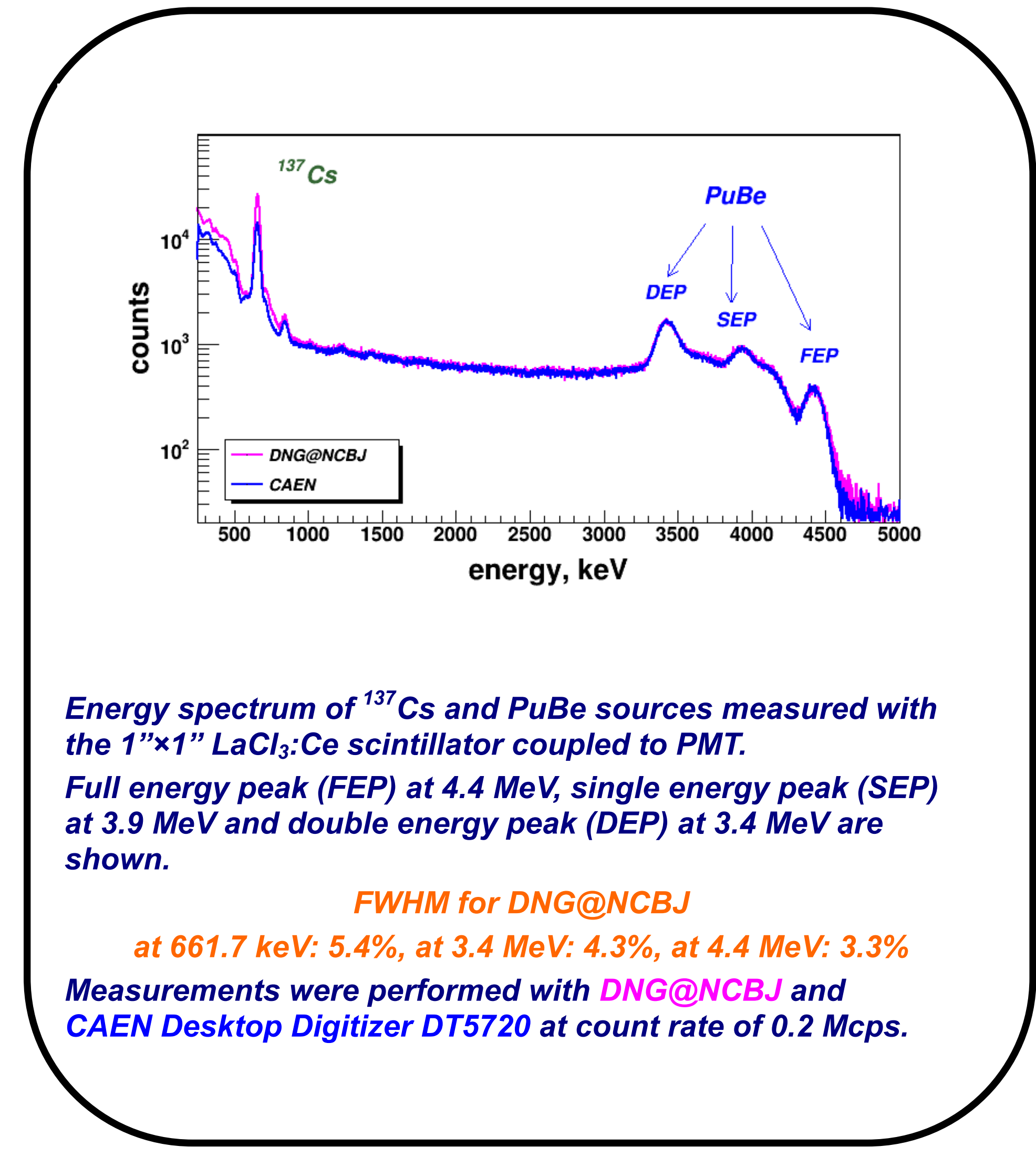
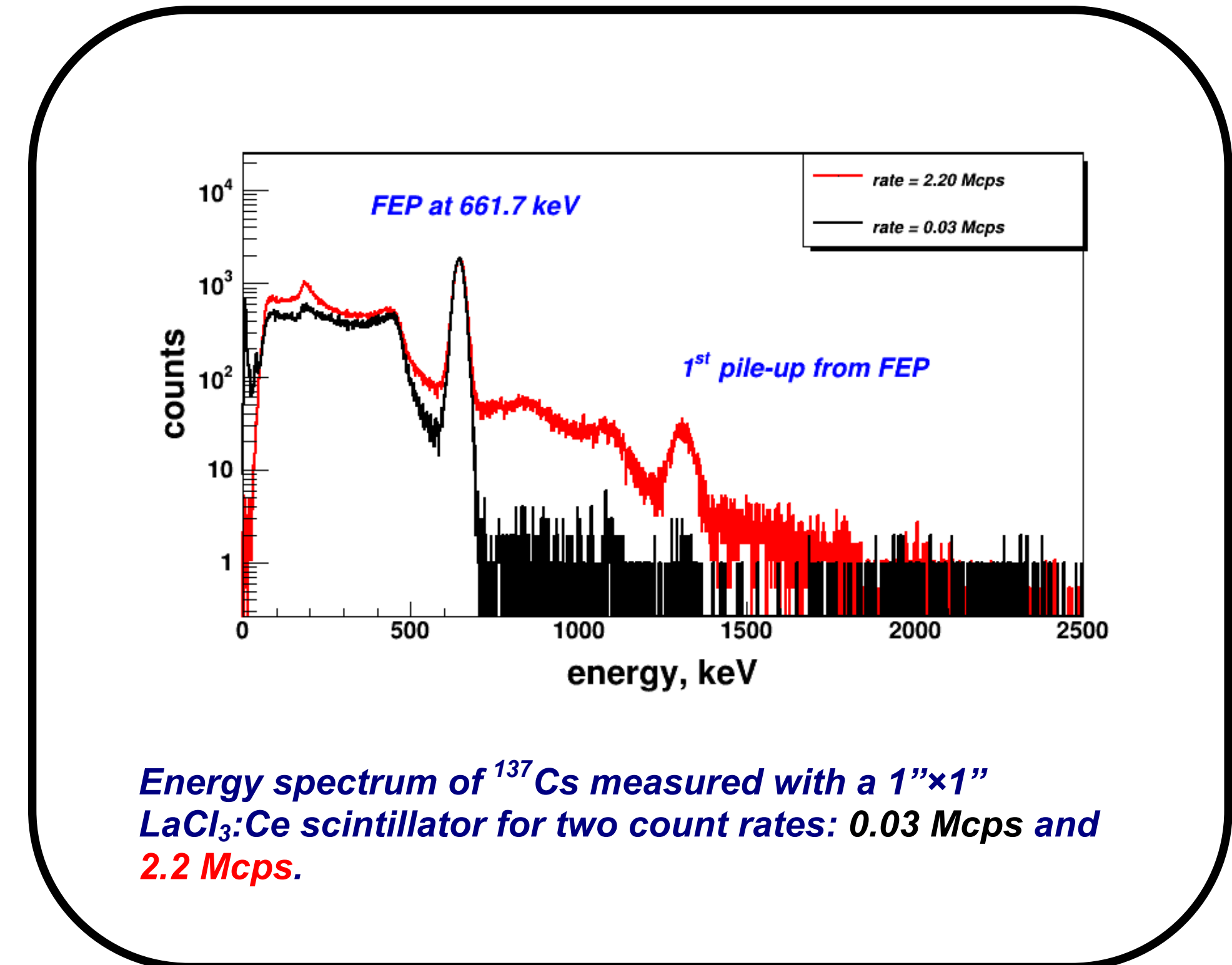
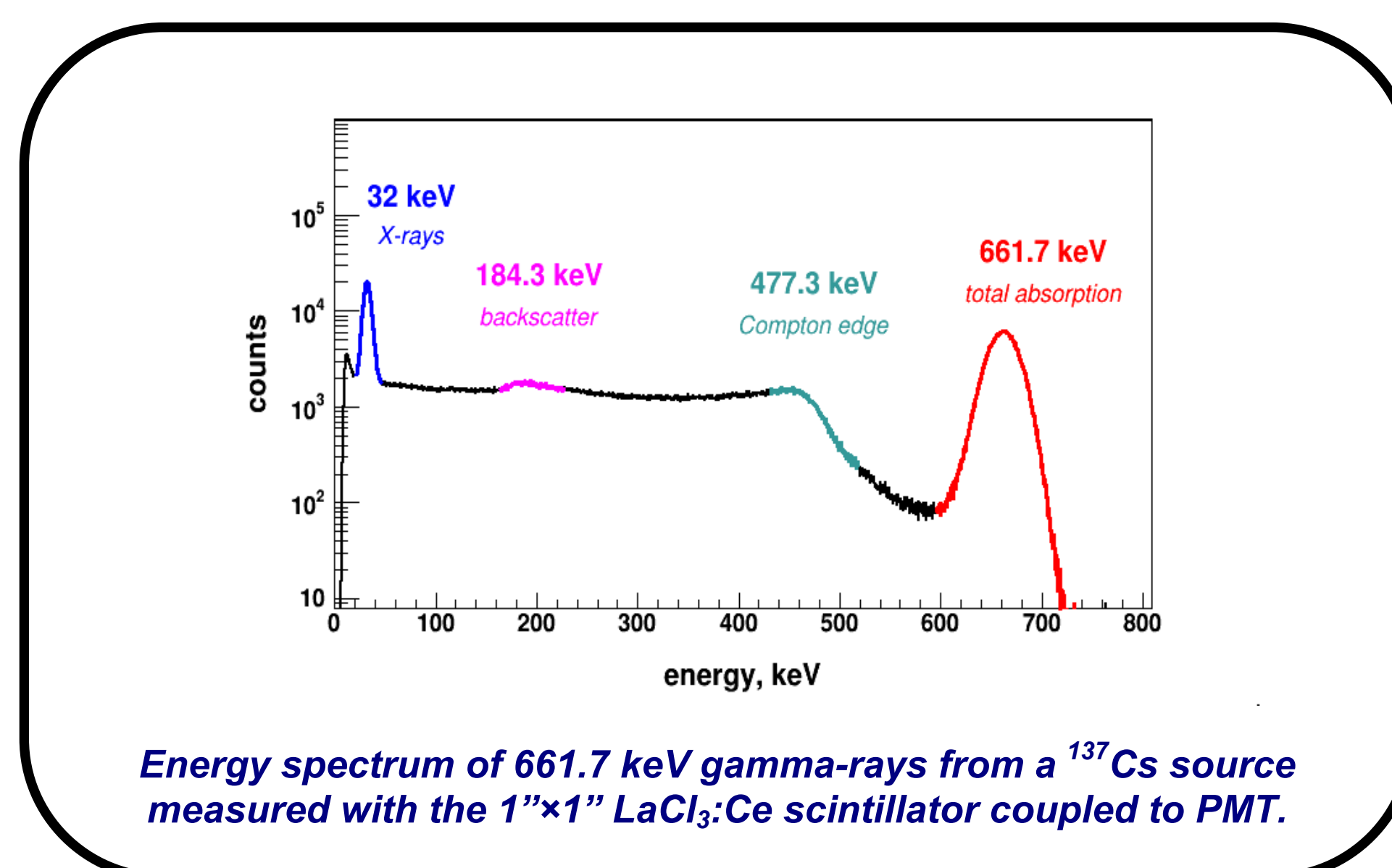
DIGITAL NEUTRON GAMMA DNG@NCBJ

DNG@NCBJ measurement system is based on a direct sampling of the input signal. Data acquisition and signal processing operations are performed in the digital way by FPGA SoC with ARM9 processor on Xilinx ZC706 evaluation board. NCBJ prototype acquisition system is based on Texas Instruments ADS5400 (12 bit/1 GSPS) ADC. Data acquired from ADC is processed on line by FPGA. Dedicated IP core was developed to fulfill system requirements. Following major operations are implemented:

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

MEASUREMENTS

Deuterium-tritium (DT) plasma experiments, planned at JET, demand measurements of few MeV gamma-ray spectra at Mcps count rates with a good energy resolution. At NCBJ measurements with a $1'' \times 1''$ $\text{LaCl}_3\text{:Ce}$ scintillator coupled to a Photonis XP5200 PMT, equipped with a dedicated active voltage divider, were performed with ^{137}Cs (661.7 keV) and PuBe (4.4 MeV) gamma sources. In laboratory conditions the PuBe source was used simultaneously with the strong ^{137}Cs source in order to increase the rate of events.



CONCLUSIONS

- DNG@NCBJ integrated into a single compact unit.
- Measurements with DNG@NCBJ performed up to 2.2 Mcps.
- Almost identical spectra obtained with DNG@NCBJ and commercially available CAEN Desktop Digitizer DT5720.
- Easy to create data acquisition system for a multi-detector setup.
- Off-line processing for setting optimization.
- In progress: pile-up corrections. The corrected piled-up events can still be used without being discarded.
- Continuation with dedicated software for, e.g., ITER experiments.

Acknowledgement

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