Development and experimental study of the Read-out ASIC for Muon Chambers of the CBM Experiment

E. V. Atkin[1], A. G. Voronin[1,2], V. V. Ivanov[1,3], P. Yu. Ivanov[1], A.V. Khanzadeev[1,3], E. Z. Malankin[1], D. D. Normanov[1], E.V. Roshchin[1,3], V.M. Samsonov[1,3], V. V. Shumikhin[1]

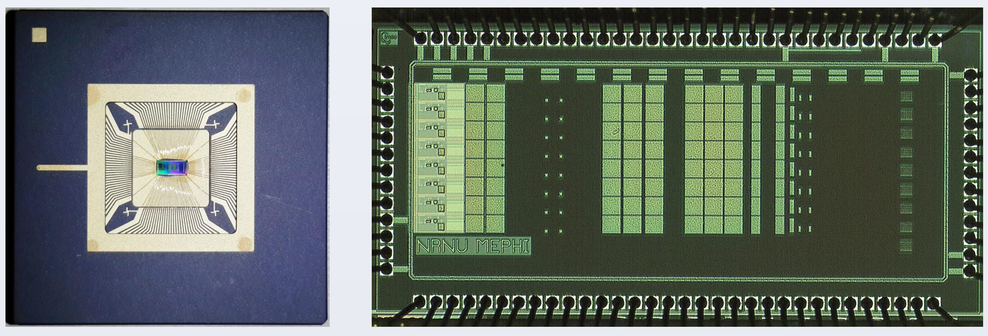
[1] National Research Nuclear University "Moscow Engineering Physics Institute",
[2] Skobel'tsyn Institute of Nuclear Physics, Moscow State University,
[3] Petersburg Nuclear Physics Institute, National Research Centre Kurchatov Institute.

Abstract

The measurement results of the front-end ASIC for GEM detector read-out are presented. The MUCH ASIC v2 was designed and prototyped via Europractice by means of the 0.18 um CMOS MMRF process of UMC (Taiwan). The parameters of the analog channels were measured, including the CSA, fast and slow shapers, discriminators. The channels provide a sufficient dynamic range of 100 fC, low power consumption of 10 mW per channel and ENC of 1500 el at 50 pF detector capacitance.

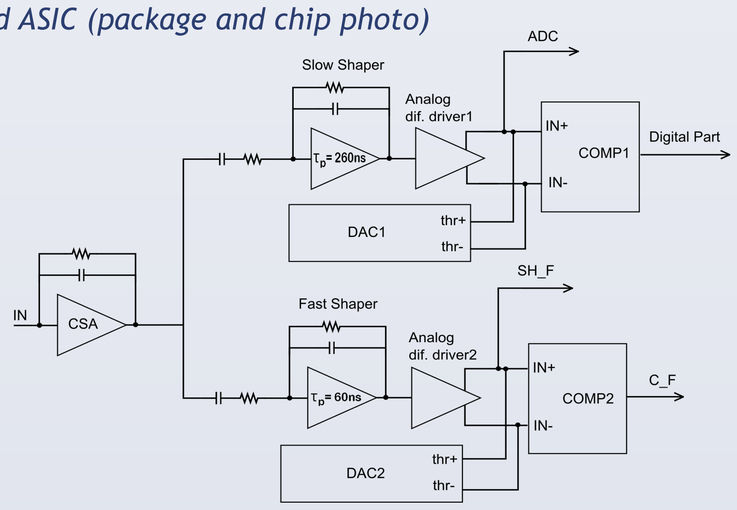
Prototype ASIC

The MUCH ASIC v2 was developed for the use as a part of the muon system in the Compressed Baryonic Matter (CBM) experiment at the upcoming FAIR facility in Darmstadt (Germany). The ASIC was designed and prototyped via Europractice by means of the 0.18 um CMOS MMRF process of UMC. The die size is 3240 x 1525 um^2.



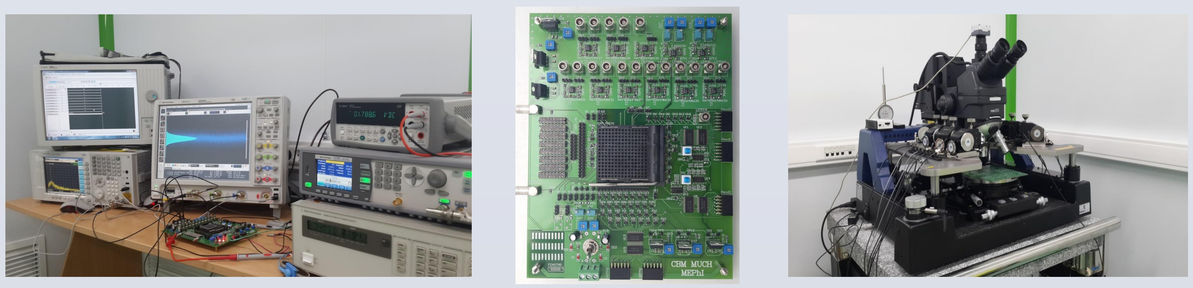
Prototyped ASIC (package and chip photo)

The chip includes 8 analog processing channels, each consisting of preamplifier, two shapers (fast and slow), differential comparator and an area efficient (0.0255 mm^2) 6 bit SAR ADC with 1.2 mW power consumption at 50 Msps. The chip also includes the threshold DAC and the digital part.



Test setup & measurements

The test PCB was developed to provide the measurements of the ASIC. The PCB includes analog 50 Ohm buffers, linear power supplies, equivalent detector capacitance blocks, calibration capacitances, digital drivers. The logic signal level shifters, transceivers and connectors are placed to the PCB to use it with FPGA development board and measuring instruments and generators.

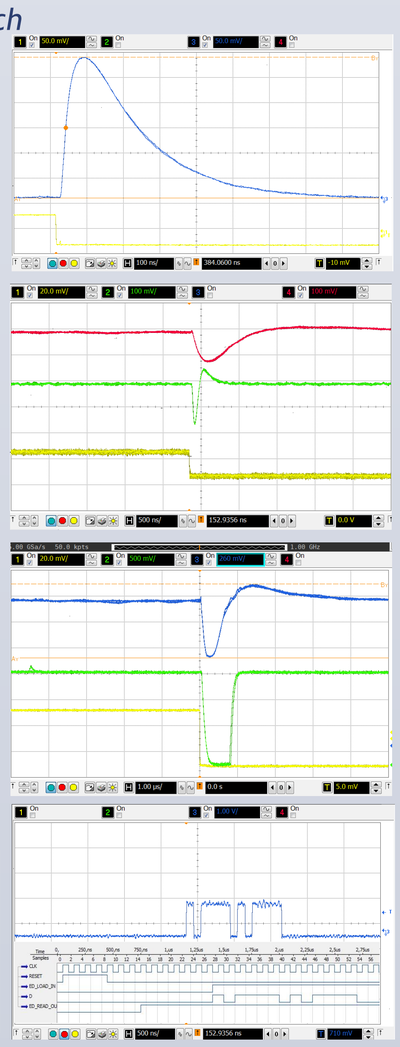


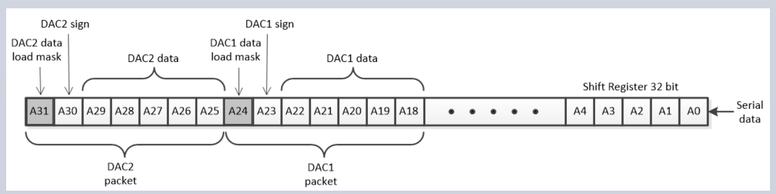
Test PCB and electrical test bench

Functionality tests

Generator tests of the prototype ASIC functionality were provided on the test bench described above. The test pulse from generator was supplied through the calibration capacitance of 1.2 pF at the input of the each of 8 channels. Functionality of the CSA, Shapers, Comparators and DAC with DAC registers were checked. The following results were obtained:

- Output CSA response on the test input pulse via 1.2 pF capacitor has the following parameters: rise time – 30 ns, fall time – 500 ns, signal duration – 600 ns.
- Slow and fast shaper output signals were obtained. Shaping times of the slow and fast shapers are equal to 250 ns and 50 ns consequently. Due to the double differentiation of the fast channel, the fast shaper output response has a bipolar form. Such a form allows to recognize 2 neighbor hits when the discriminator threshold is low.
- Comparator and threshold DAC functionality were tested.





DAC register structure

Channel linearity and noise measurements

- Channels linearity were studied in the signal dynamic range of 1 – 100 fC. Transfer functions of the CSA, fast and slow channels are shown below

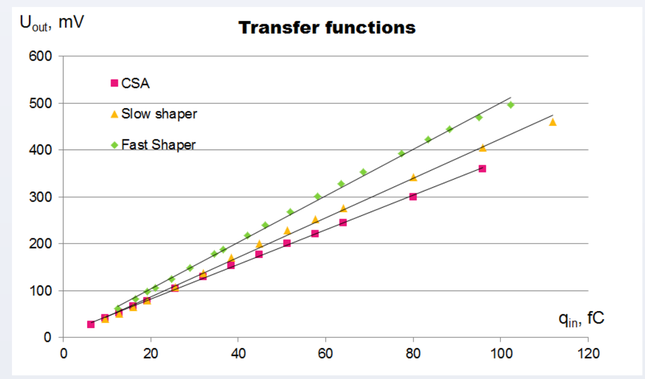
Parameters of the measured are the following:

Gain:

- CSA – 3.8 mV/fC
- Slow channel – 4.4 mV/fC
- Fast channel – 5 mV/fC

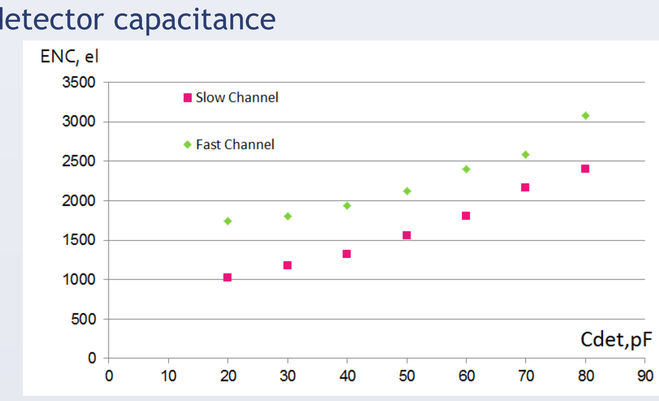
Linearity:

- Slow channel – 2%
- Fast channel – 2%



- ENC as a function of equivalent detector capacitance

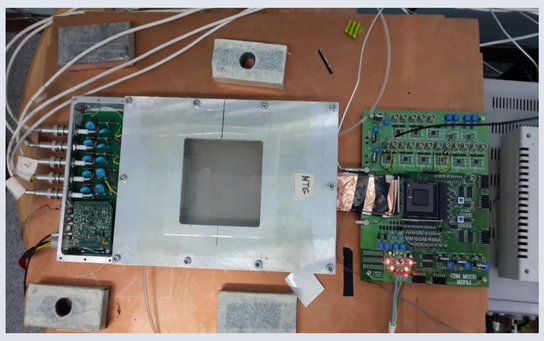
Slow channel optimized for S/N ratio in order to use it in the periphery of the CBM MUCH, and fast channel, adapted to the hit rate of the inner detector part, where the occupancy is the highest. The ENC of the fast and slow shaper are 2000 el and 1500 el correspondently at 50 pF of the equivalent detector capacitance.



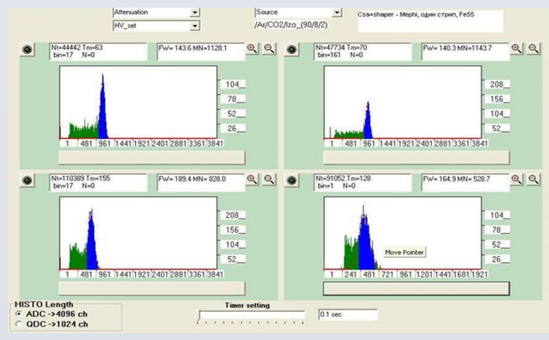
ENC vs C_{det}

Tests with GEM prototypes

Prototypes of the gas-filled detectors based on the GEM and TGEM technologies have been studied with the prototype front-end ASIC. A prototype read-out system is being developed jointly by PNPI and MEPhI. ^{55}Fe spectrum were obtained. The measured noise of 1000 electrons at 20pF input capacitance increases up to 2500 electrons at input capacitance of 80 pF.



GEM detector with read-out prototype



^{55}Fe Spectra

Measured parameters

№	Parameter	Simulation	Measurements
1	Dynamic range	1 – 100 fC	1 – 100 fC
2	Detector capacitance	up to 100 pF	up to 80 pF
3	CSA rise time	50 ns	30 ns
4	Shaping times (fast and slow)	60 and 260 ns	50 and 250 ns
5	Slow channel gain	5 mV/fC	4.4 mV/fC
6	Fast channel gain	5.5 mV/fC	5 mV/fC
9	Slow channel ENC @ 50 pF Cdet	800 el	1500 el
11	Fast channel ENC @ 50 pF Cdet	1200el	2000 el
10	Power consumption	10 mW / channel	13 mW / channel

Summary

The measurement results of the front-end ASIC for GEM detectors read-out in the CBM experiment are presented. The main parameters of the channels were studied. The results of the functionality tests, noise and dynamic range are given. Spectra of ^{55}Fe obtained current ASIC and GEM prototype are measured as well. The ASIC parameters generally met the requirements to the read out of the CBM MUCH. Further development of the MUCH ASIC is proceeded.

Acknowledgments

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Contacts

E. Malankin is with the ASIC lab and the Department of Electronics, National Research Nuclear University "MEPhI", Kashirskoe shosse 31, Moscow, 115409, Russia, E-mail: ezmalankin@mephi.ru, tel. +7 499 3242597