The optimization, design and performance of the FBCM23 ASIC for the upgraded CMS beam monitoring system

Grzegorz Wegrzyn, Jan Kaplon – CERN, Meyrin, Switzerland
Contact: grzegorz.jan.wegrzyn@cern.ch, jan.kaplon@cern.ch

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Introduction

We present the development of the FBCM23 ASIC designed for the Fast Beam Condition Monitoring (FBCM) system intended for the Phase-II CMS upgrade. The FBCM23 ASIC will provide reliable luminosity measurement with 1 ns time resolution enabling the detection of beam-induced background.
The FBCM23 ASIC comprises six channels of fast preamplifier working in transimpedance configuration followed with CR-RC3 shaper and leading-edge discriminator. The paper will show the optimization of the design, overall architecture and the detailed implementation in a CMOS 65 nm process as well as preliminary electrical performance.

System

The FBCM system consists of 4 half disks that will be mounted at the two ends of the CMS experiment just outside the last layer of the tracker endcap pixel detector. On each half disk, there are 4 service boards (with lpGBT serializer devices, VTRx+ optical link modules and DC-DC converters), each connected to 3 hybrids housing 6 Si-pad sensors read out by the FBCM23 ASIC.

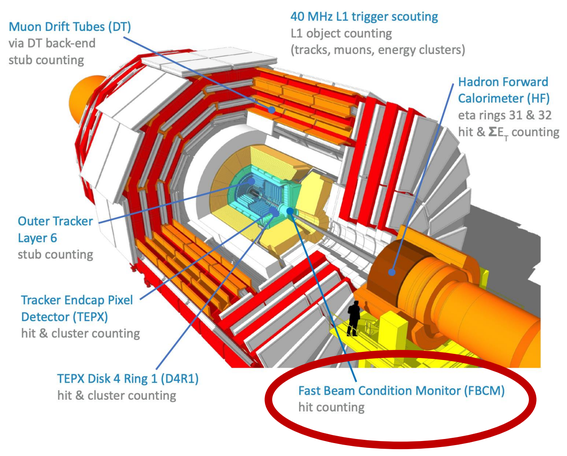

Fig 1. CMS detector with subsystems

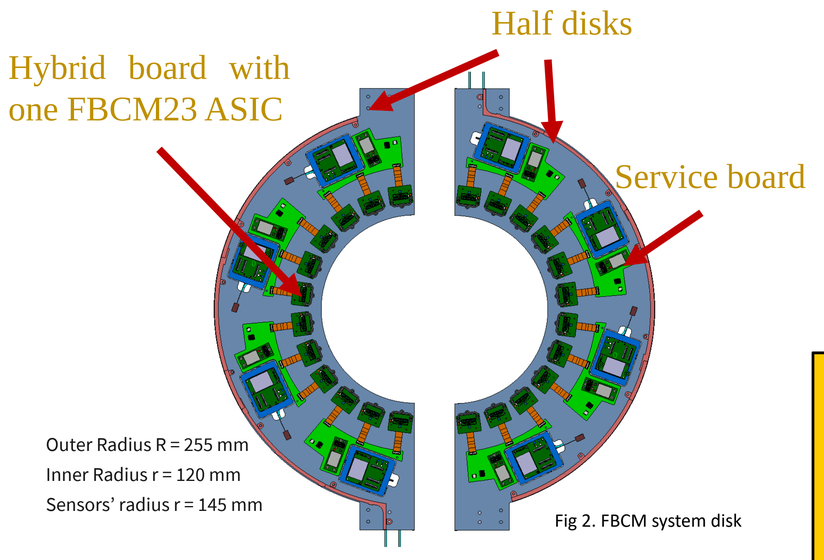

Fig 2. FBCM system disk

LpGBT will provide full service for designed FBCM23 ASIC:

- Sampling binary output
- Calibration signals
- I2C interface for configuration

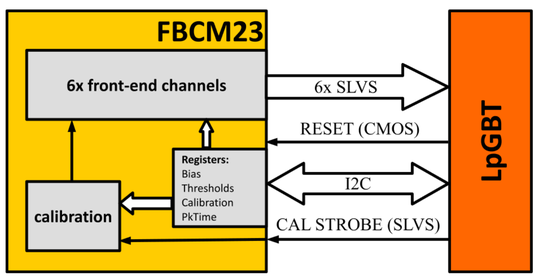

Fig 3. FBCM23 architecture and connection to lpGBT

Specifications

- 6 channels with binary outputs
- ENC below 1000 e^-
- Double pulse resolution: 25 ns (bunch crossing)
- Fast return to baseline: < 50 ns (2x bunch crossing)
- Rad hard up to 200 MRad and 2.5 x 10^{15} n/cm^2
- SEU protection

ASIC design

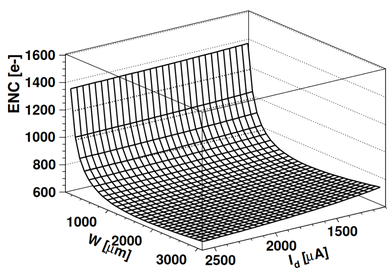

Fig 4. Input transistor noise performance analysis for L=200nm

The input stage is built with a regulated telescopic cascode amplifier, with an NMOS input transistor. The dimensions and bias current have been optimized for an input transistor length equal to 200 nm, safe from the standpoint of excess noise factor.

Adjustable discharge time constant by selecting Rf to 25 k or 50 kΩ (controlled by configuration bit).

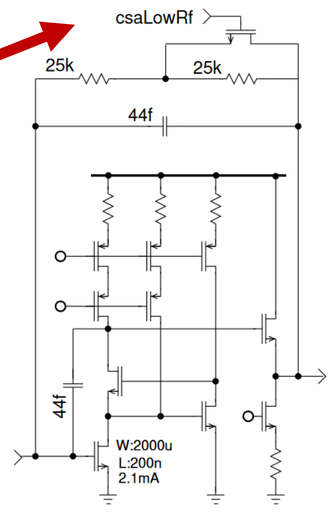

Fig 5. Preamplifier architecture

Key parameters:

- Open loop gain: 69 dB
- GBP: 3.5 GHz

Threshold – Threshold settings are provided by 3 DACs: 1 global common for all channels and 2 locals. One of these two will be used for trimming while the second one for threshold scan.

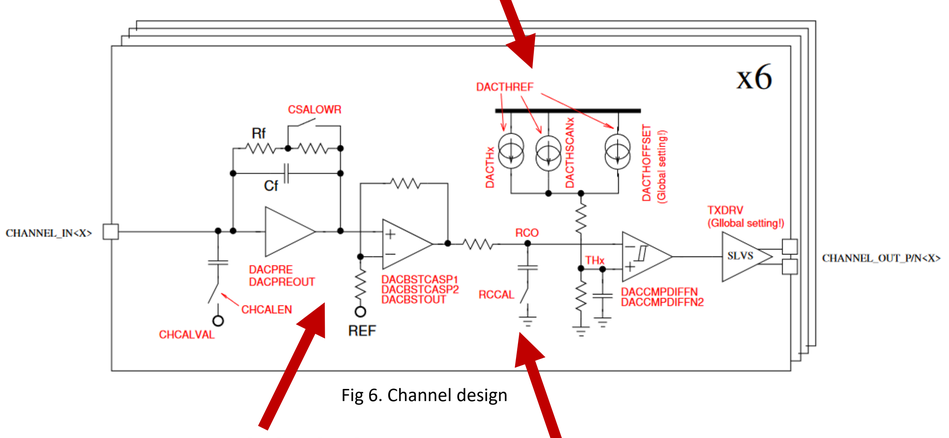

Fig 6. Channel design

Booster – DC coupled which increases PVT sensitivity but provide better noise performance with unipolar shaping.

RC filter – provides tunable shaping time what is important to deal with degraded sensor after irradiation

Simulation results

Simulated parameters

- ENC below 700 e^- (before irradiation)
- Fast return to baseline: < 40 ns (up to 150 fC)
- Adjustable shaping time 5-10 ns
- Linear region: 6 fC
- Time walk < 4 ns
- I2C SEU protected

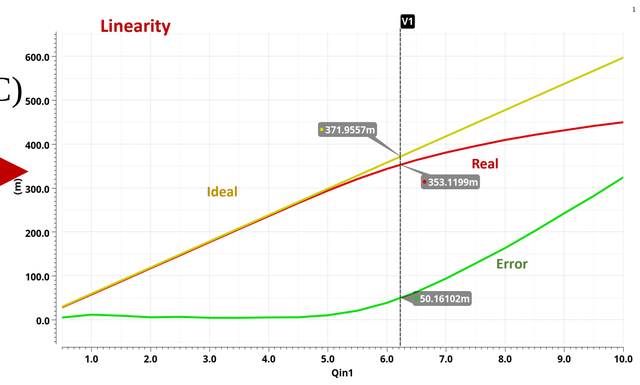

Fig 7. FBCM23 dynamic range

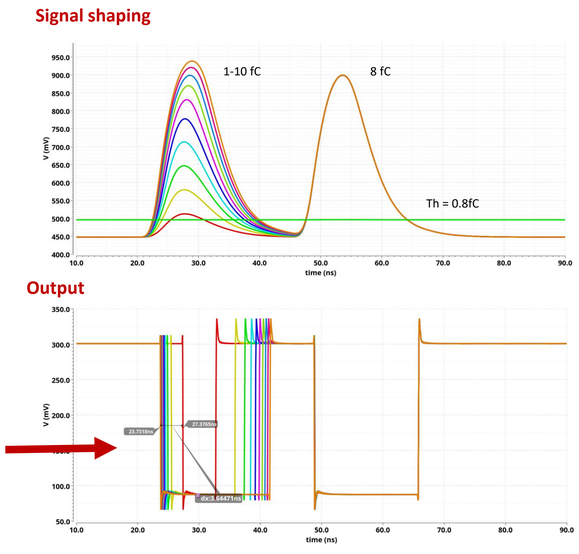

Fig 8. Signal shaping and binary output

Time-walk <4ns

Crosstalk: post-extraction simulations

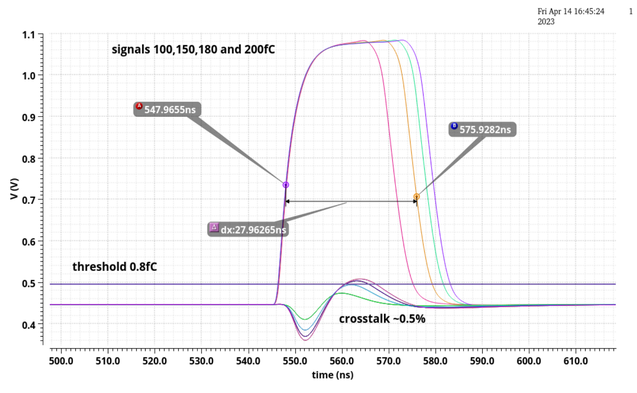

Fig 9. FBCM23 overdrive and crosstalk

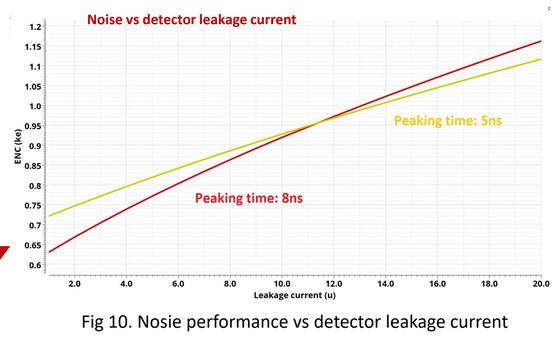

Fig 10. Nosie performance vs detector leakage current

Measurements... in progress ☺