The electronics of the GEM-μRWELL Endcap Tracker

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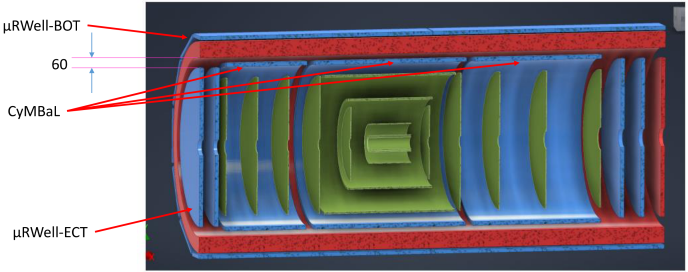
Introduction to MPGDs electronic developments

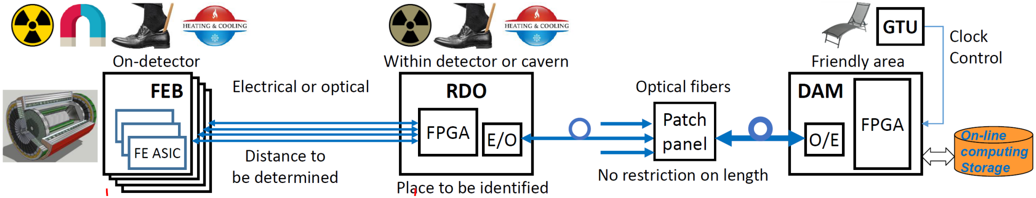


- EndCap Tracker shares common electronics and data acquisition approach with other MPGDs detectors:
    - development of various levels of electronics
    - solutions for power distribution and dissipation
    - strategy on cable media type and lenght and electronics placement
- Hot topics now on discussion (see DAQ meeting on 27/6)
- RM2 and GE personnel started connection in the last weeks with people already involved
- Most of the pictures and informations in these slides are from Saclay group, with permission and many thanks to Irakli M.

Experiment requirements for MPGD Detectors

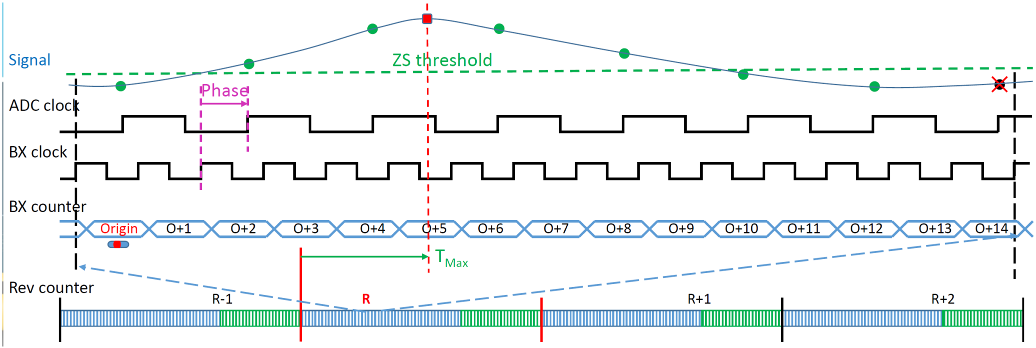
- Typical signal 1-1.5 keV resulting to 15-30 fC per channel
- Aimed dynamic range of 10 bits: Signal / noise of 60 dB
- Timing precision of O(10ns)
- Channel occupancy of ∼10 kHz: Including factor 5 of safety margin
- Streaming readout With support of in situ calibration and of on demand readout
- 1.8 T magnetic field
- Mild radiation environment
  - TID and neutron fluence after 10 years: 10 krad and $10^{11} n_{eq}/cm^2$
  - 20 MeV proton flux: 100 particle$/cm^2/s$
- Stringent space for detector readout and services

General Readout Organization



- FEB frontend board with readout ASICs → detector specific, common design among MPGDs detectors, different form factor
- RDO readout module first stage of FEB data aggregation, last stage to dispatch clock & control → Mostly common design framework between sub detectors, different form factor
- DAM data aggregation module interface with computing and global timing and control unit (GTU) → Common design for all sub detectors
- Downstream towards detector: clock, control, monitoring
- Upstream towards storage: physics, calibration, monitoring data

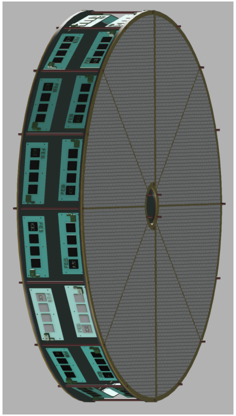
Readout Strategies for MPGDs

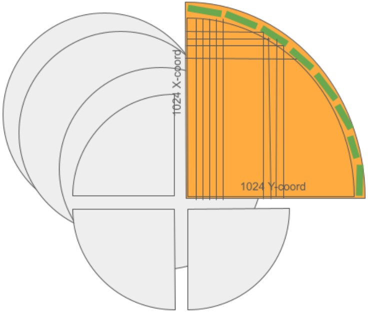


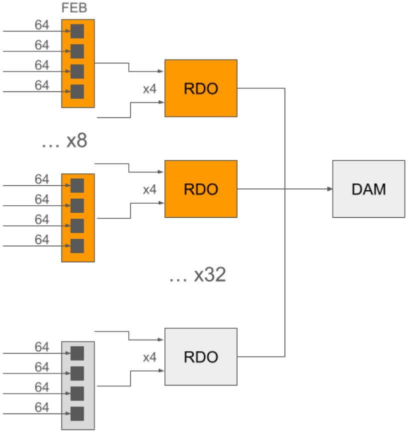
- Signal is continuously sampled with an ADC
- Signal samples above threshold are retained
- Nominal (physics data) readout: signal amplitude and timing is derived → Time of max (as on example) or time of arrival (fitting samples on rising edge)
- On demand readout: signal shapes or raw non ZS data are provided → Calibration, detector studies
- Guarantees best noise immunity and thus best S/N ratio → Allows on line common mode noise (CMN) subtraction before ZS

EndCap Tracker Figures

- 4 disks each composed of 4 quadrants
- Each quadrant has 1024 X-strip and 1024 Y-strip (2048 channels)
- Assuming FE ASIC is 64 channels, grouped in 4 chips FEB, 4 to 1 connection FEB-RDO
- Each quadrant will need 32 ASICs, 8 FEBs, 2 RDOs
- Total amount for ECT is 32k Channels, 512 ASICs, 128 FEBs, 32 RDOs







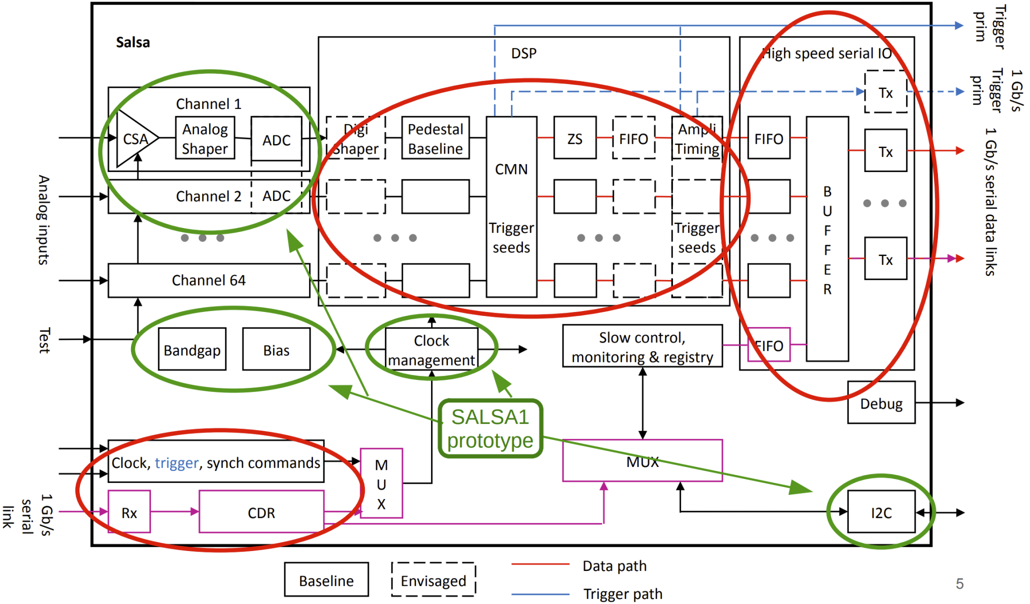
EndCap Tracker Data Bandwidth Estimations

- Physics Data: support two zero suppression modes
  - Nominal: peak finding readout → 12 bit amplitude, 12 bit time of max, 8 bit ToT
  - On demand: full signal shape readout → All samples (12 bit) above threshold (typically 15-25 samples)
- Estimated Physics data bandwidth per Salsa ASIC with channel rate 10 kHz:
  - Peak finding 40 Mbit/s
  - Signal shape 265 Mbit/s
- On line calibration: on demand readout
  - Programmable number of non ZS samples
  - Estimated calibration data bandwidth per ASIC $\sim$ 6 Mbit/s
- FEB RDO link occupancy: $\sim$30 % of one 1 Gbit link
- Overall physics frontend data of ECT:
  - $\sim$ 130 Gbit/s for on demand mode
  - $\sim$ 37 Gbit/s for nominal mode

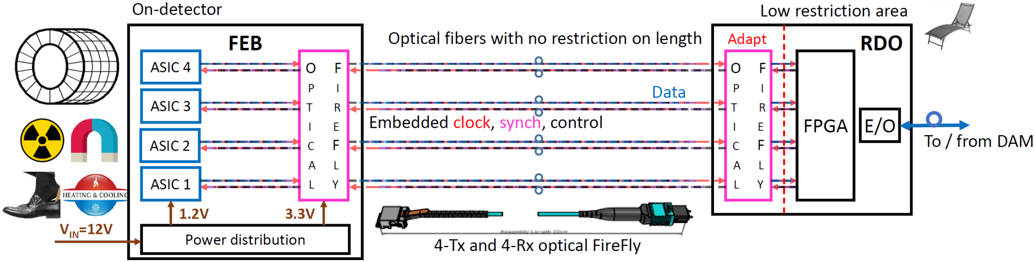
SALSA ASIC Characteristics

- Versatile front-end characteristics
  - Dedicated to MPGD detectors and beyond
  - 64 channels
  - Large range of peaking times: 50-500 ns
  - Large choice of gain ranges: 0-50, 0-250, 0-500 fC or 0-5 pC
  - Large range of input rates, up to 100 kHz/ch with fast CSA reset (limit assumed for EPIC: 25 kHz/ch)
  - Front-end elements can be by-passed
- Digital stage
  - Fast sampling ADC for each channel on 12 bits (¿ 10 effective bits) at up to 50 MS/s
  - Possibility under study to double rates by coupling pairs of channels
- Integrated DSP for internal data processing and size reduction, treatment processes to be selected according to user needs
  - Continuous readout compatible with streaming DAQ foreseen at EIC, triggered mode also available
  - Several 1 Gb/s output data links (will use one)
- General characteristics
  - $\sim$1 cm^2 die size, implemented on modern TSMC 65nm technology
  - Low power consumption 15 mW/channel at 1.2V
  - Radiation hardened (SEU, TID)

SALSA ASIC Characteristics

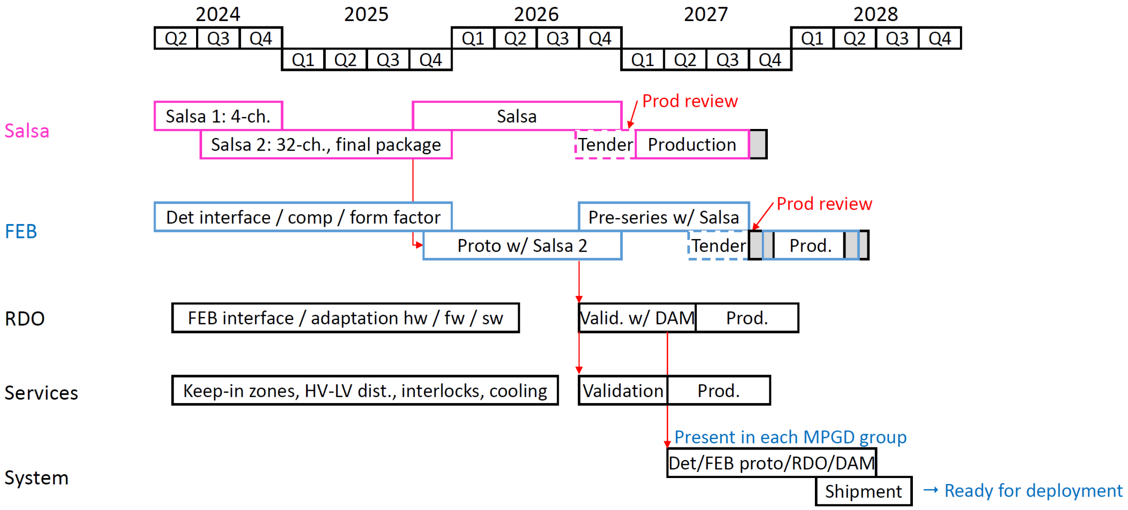


Aimed FEB Design



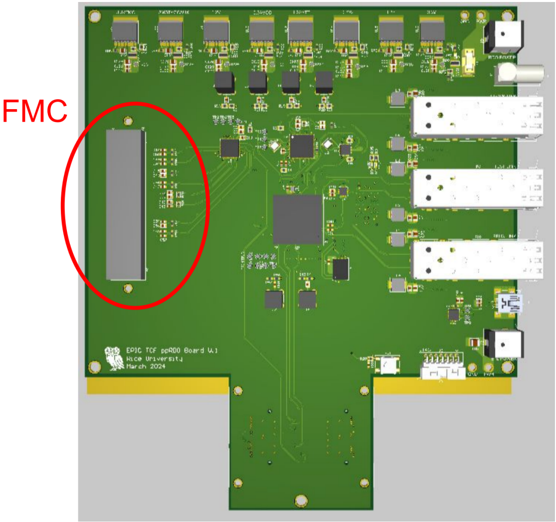
- ASICs directly connected to 4 lane bidirectional parallel optic FireFly transceivers from Samtec
  - Single 1 Gbit /s Rx line encoding clock, sync run control and asynchronous slow control and monitoring commands
  - Single 1 Gbit /s Tx line for physics, calibration, control and monitoring data
- Low active component count
  - Easier to adapt to challenging on detector environment
  - Samtec FireFly: reported to stand TID of 50-100 krad and neutron fluence of at least $5 \times 10^{11} n_{eq}/cm^2$
- RDO can be placed anywhere in experimental hall with no particular environmental restrictions

developement planning



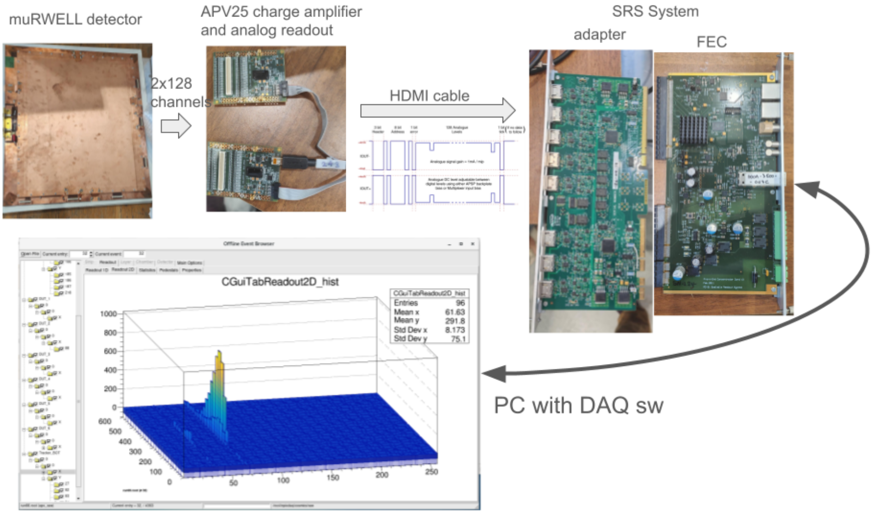
RDO development via eRD109 (ppRDO)

- Aim is to produce a generalized RDO using the Xilinx Artix Ultrascale+ FPGA
- Used to finalize the timing distribution schemes
- It has an FMC connector and at least one 10gb connection (lpGBT to DAM)
- Allows flexibility with developing custom FMC daugher card for custom interconnections
- ppRDO is in the production stage



Experimental Setup

Our Setup in LNF for preliminary development of muRWELL detector



Collected second-hand material from 2012

Summary and Conclusions

- interaction with other MPGDs groups started
- a clear picture of the subsystem and how to fit it at global level is on the way
- we are driven by other groups timelines
- in charge of our group will be the form factor customization of FEB
- to evaluate a customization of RDO if needed
- need to find a way to start operate on other groups technology (SALSA, RDO) before it is already available
- emulate (part of) SALSA and RDO on COTS
- perform transition from actual experimental setup to production hardware