HLS Feature Extraction on the readout FPGA in the mCBM Experiment

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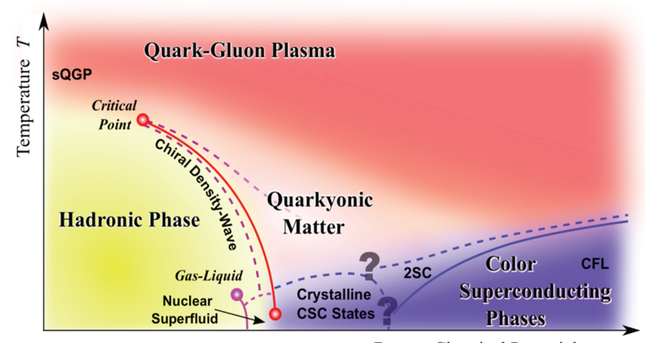
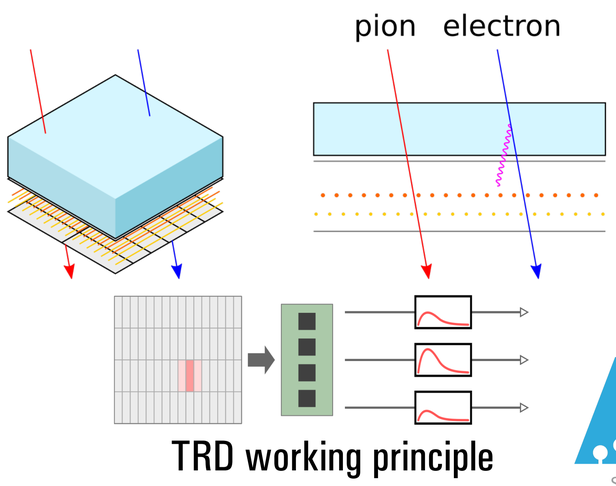
CBM[1] @ FAIR

- Probe QCD at baryon densities similar to neutron star cores
- Fixed target experiment with up to 10 MHz interaction rates
- Self-triggered free streaming data readout
- Implemented in a small scale in mCBM experiment



QCD phase diagram



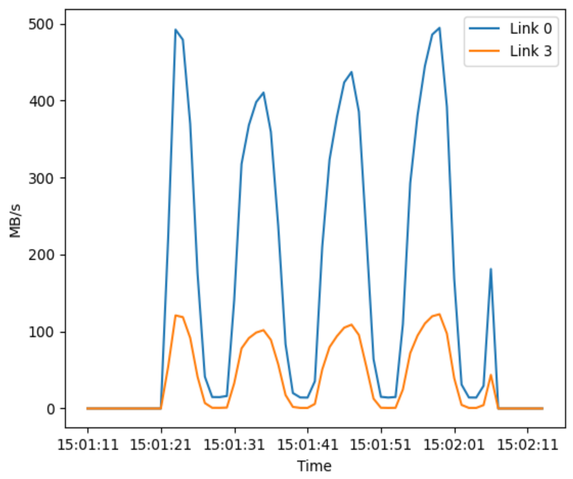
TRD working principle

- CBM-TRD[2] uses SPADIC to read out detector
- Oscilloscope like sampling of the detector signal
- Many features encoded in the transmitted signal shape
  - Baseline, total charge, precise trigger time

SPADIC
Self triggered Pulse Amplification and Digitization asIC

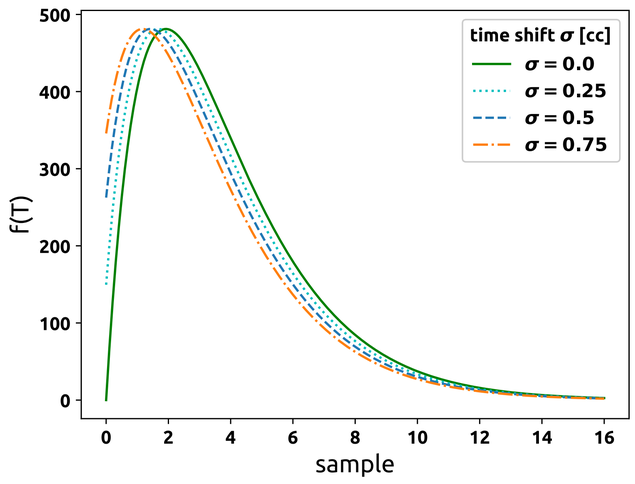
Message Decoding

- C++ template programming is used to adapt the decoding algorithm to the chosen ASIC configuration
  - compile time calculation of ADC sample position efficiently maps to hardware
- HLS[3] implementation of baseline correction and energy reconstruction with maximum throughput
- Reconstructed message reduces data volume by factor ~ 4



Data rate with and without feature extraction

Time reconstruction



SPADIC shaping function visualized with different time shifts

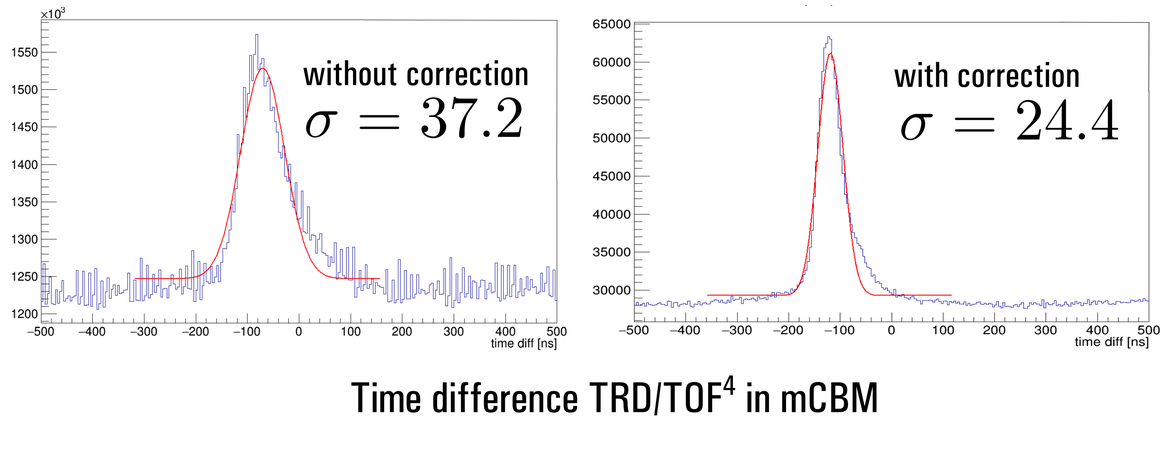
$$f(T) = A\frac{T}{\tau}\exp\left(-\frac{T}{\tau}\right)$$

$$T = t + \varphi$$

$$\varphi = \frac{f(0)\cdot t_2}{f(0) - f(t_2)\cdot\exp\left(\frac{t_2}{\tau}\right)}$$

- ADC sampling rate only 16 MHz (62.5 ns)
- A more precise signal time is encoded in the signal shape
- Analytic calculation derived from SPADIC shaping function

- HLS simplifies implementation substantially
  - Automatically chooses the best division method
  - Auto pipelining for maximum throughput
  - Functional validity determined in C++
- Significant improvement in time resolution
- Data unpacking speed up by factor ~ 30



Time difference TRD/TOF[4] in mCBM

Outlook

- FPGA implementation of a cluster finder for free streaming data based on [1]
- Will further reduce the data load and free up computational resources

1: Compressed Baryonic Matter
2: Transition Radiation Detector
3: High Level Synthesis
4: Time Of Flight

[1] V. Friese, A cluster-finding algorithm for free-streaming data, 10.1051/epjconf/201921401008

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