A data parallel digitizer for a time-based simulation of CMOS Monolithic Active Pixel Sensors with FairRoot

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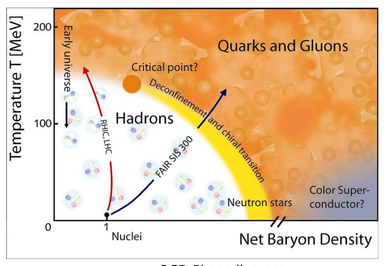
CBM @ FAIR

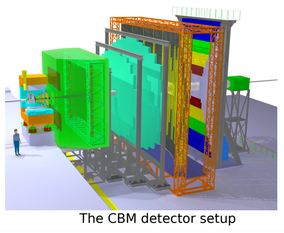
The **C**ompressed **B**aryonic **M**atter-experiment (CBM) at the future **F**acility for **A**ntiproton and **I**on **R**esearch (FAIR) in Darmstadt will explore the QCD phase diagram in he region of highest net baryon densities using high-energy nucleus-nucleus collisions. Among others, rare diagnostic probes such as charmed particles (charmonium, open charm) are considered. Apart from the high interaction rate, the open charm measurement requires a **M**icro-**V**ertex-**D**etector (MVD) [1].

CMOS **M**onolithic **A**ctive **P**ixel **S**ensors (MAPS) are the sensor technology of choice for the MVD of CBM.

MAPS are able to meet the requirements of CBM:
* Excellent spatial resolution (~3µm)
* Low material budget (0.05% X0)
* Good radiation tolerance (>1 Mrad & >1013 neq/cm2)
* Reasonable read-out time (~30 µs)



QCD-Phasediagram

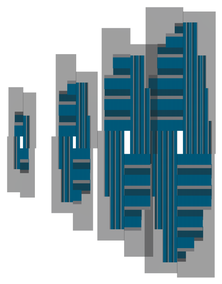


The CBM detector setup

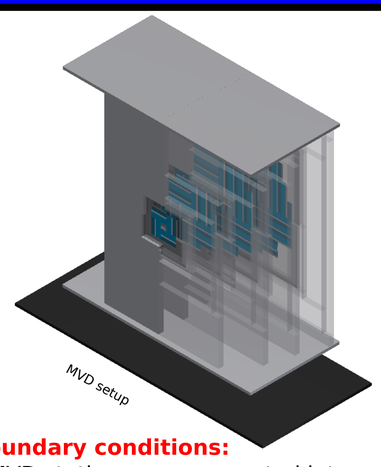
Micro-Vertex-Detector

The MVD:
The MVD consists of 2 up to 4 Stations
-> consists of up to 250 individual sensors
* Needed for high precision vertexing
* Located close to the target and in vacuum

CAD-drawing of the first MVD-Station



CAD-drawing of the whole MVD



MVD setup

Boundary conditions:
* MVD stations are segmented into many individual sensors (each ~1x3 cm²)
* Sensors (and subsequent read-out electronics) provide data independent from one another (no crosstalk)

-> Data parallelism

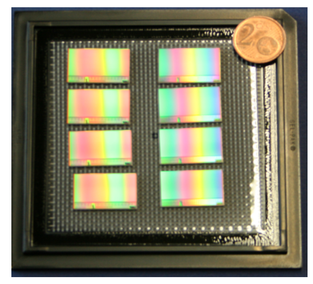
TASK for the integration of MAPS to the CBM simulation framework
* Implemantation of the digitization and data processing (e.g. cluster finding) on sensor level
* Exploit multicore processor architecture making use of data parallelism to perform parallel processing

FairRoot

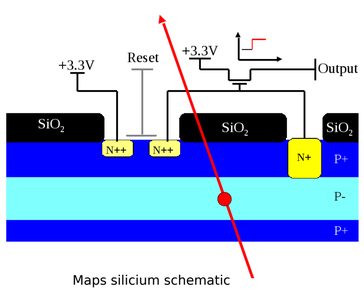
The CBM-/FairRoot framework is fully based on the CERN ROOT system. It is the dedicated simulation and/or analysis framework of CBM. For the simulation an event generator (e.g. UrQmd) and a transport engine (Geant3, Geant4) are interfaced. Moreover, digitizers are needed to mimic the detectors response. Due to the intended high interaction rates, the framework has to take care of event pile-up and hence a time-based analysis process [2].

Monolithic Active Pixel Sensors

Monolithic Active Pixel Sensors
* CMOS-Type sensors
* Originally developed for visible light applications
* Adapted to charged particle tracking @ IPHC Strasbourg
* On-Chip hit discrimination and zero suppression
* Typical dye size: 1x2cm^2

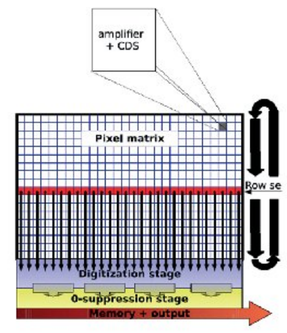


MAPS: Mimosa26 format, with 2 cents coin as size referenz.

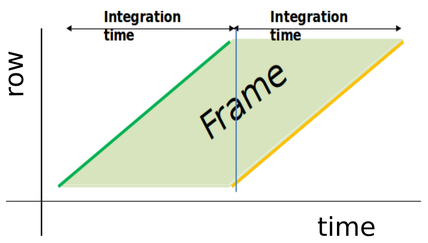


Maps silicium schematic

Working principles:
* Attractive build-in potential for electrons towards diodes (= pixels)
* e/h-pair excitation along particle trajectory in the epitaxial layer
* Charge distribution over several pixels possible (= hit-cluster)



MAPS read-out schematic

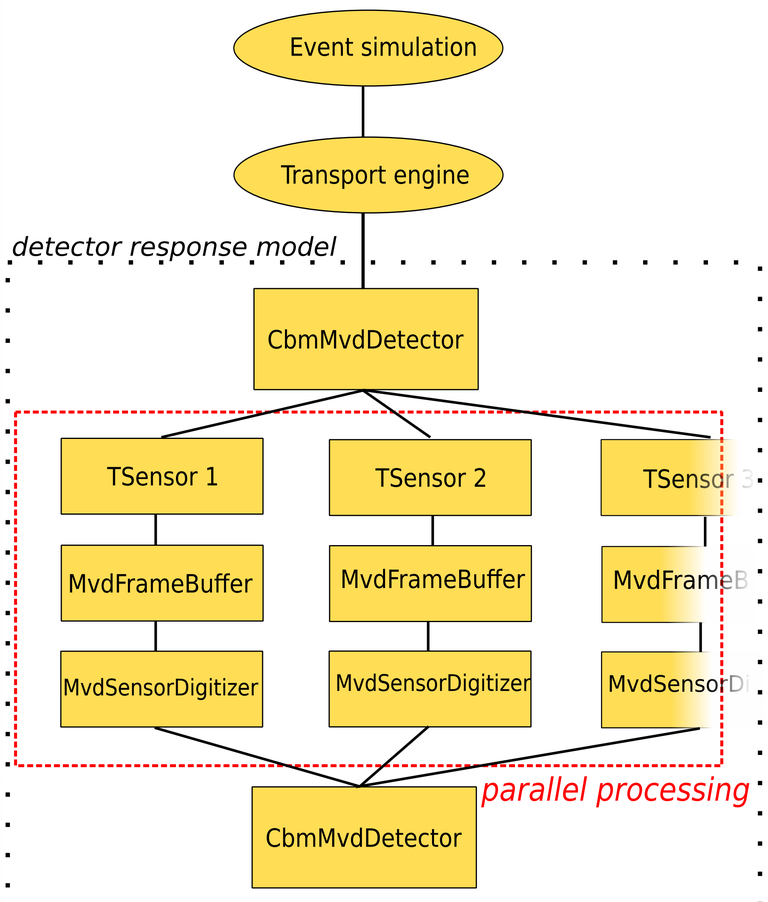


Read-out:
* Column-parallel read-out
  -> each row has specific read-out time
* Response: integrated signal between two consecutive read-outs
  -> integration time

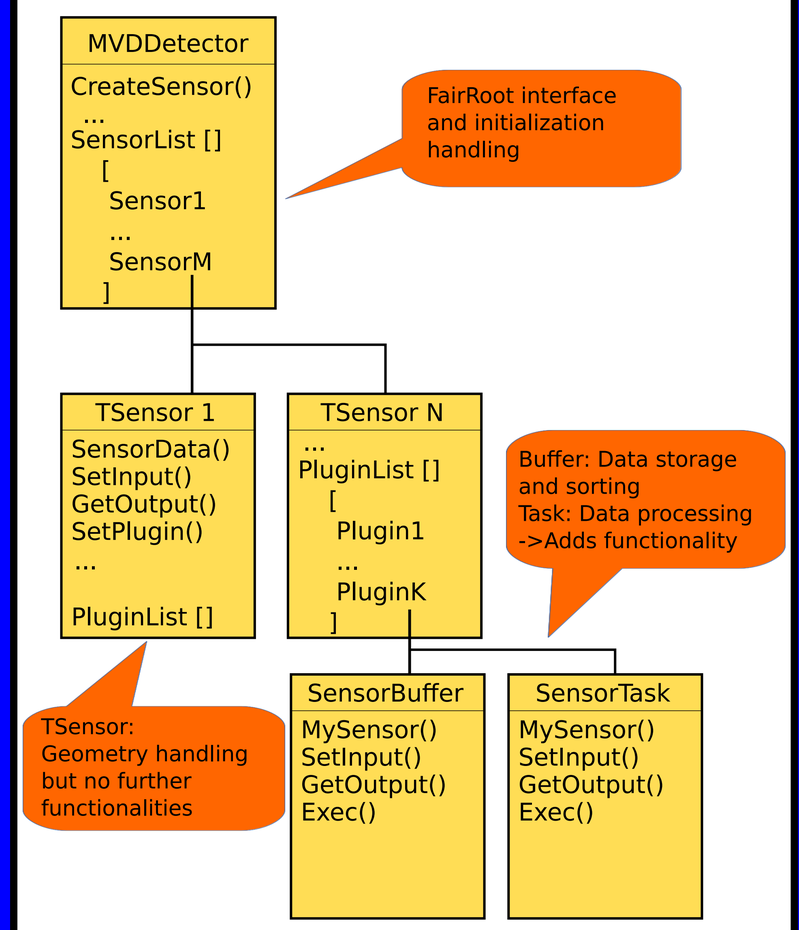
TASK: Implementation of the precise read-out sequence according to a system time.

Note:
Due to the high interaction rate in CBM events might pile-up before complete read-out

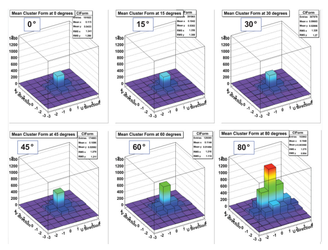
Data chain



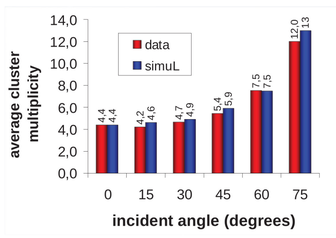
Class structure



Digitizer model / results

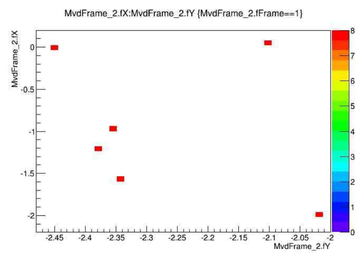


Clustershape evaluation:
Clusters created by inclined tracks. The incident angles are from 0° – 80°. Each square in the horizontal plane corresponds to a pixel and the charge is plotted in vertical dimension [3].

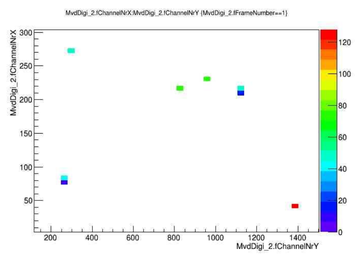


Average cluster multiplicity as a function of the angle of incidence of the track for simulated (blue) and real data (red).

The digitizer reproduces the sensor response with a good accuracy



MC-Hits assigned to one arbitary sensor and given in global coordinates. For one specific frame.



Hit response as outputted by the digitizer (implemented on sensor level) given in local sensor coordinats (pixel number)

Implementation of the data parallel digitizer in a time-based simulation perfoms well

Summary and Outlook

- The CBM MVD digitizer was updated to handle a segmented detector geometry and to run in a time-based simulation.
- The corresponding data parallelism of the sensors was prepared for their parallel processing

- Handling of the parallel processing has to be implemented and tuned

Acknowledgement:
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References:
[1] B. Friman, C. Höhne, J. Knoll, S. Leupold, J. Randrup, R. Rapp, (editors), The CBM Physics Book: Compressed Baryonic Matter in Laboratory Experiments, Springer Verlag, 2011
[2] http://fairroot.gsi.de/
[3] C. Dritsa, A Digitizer for Monolithic Active Pixel Sensors, XLVIII International meeting in nuclear physics, Bormio, 2010