FIAS Frankfurt Institute for Advanced Studies

Scientific Computing

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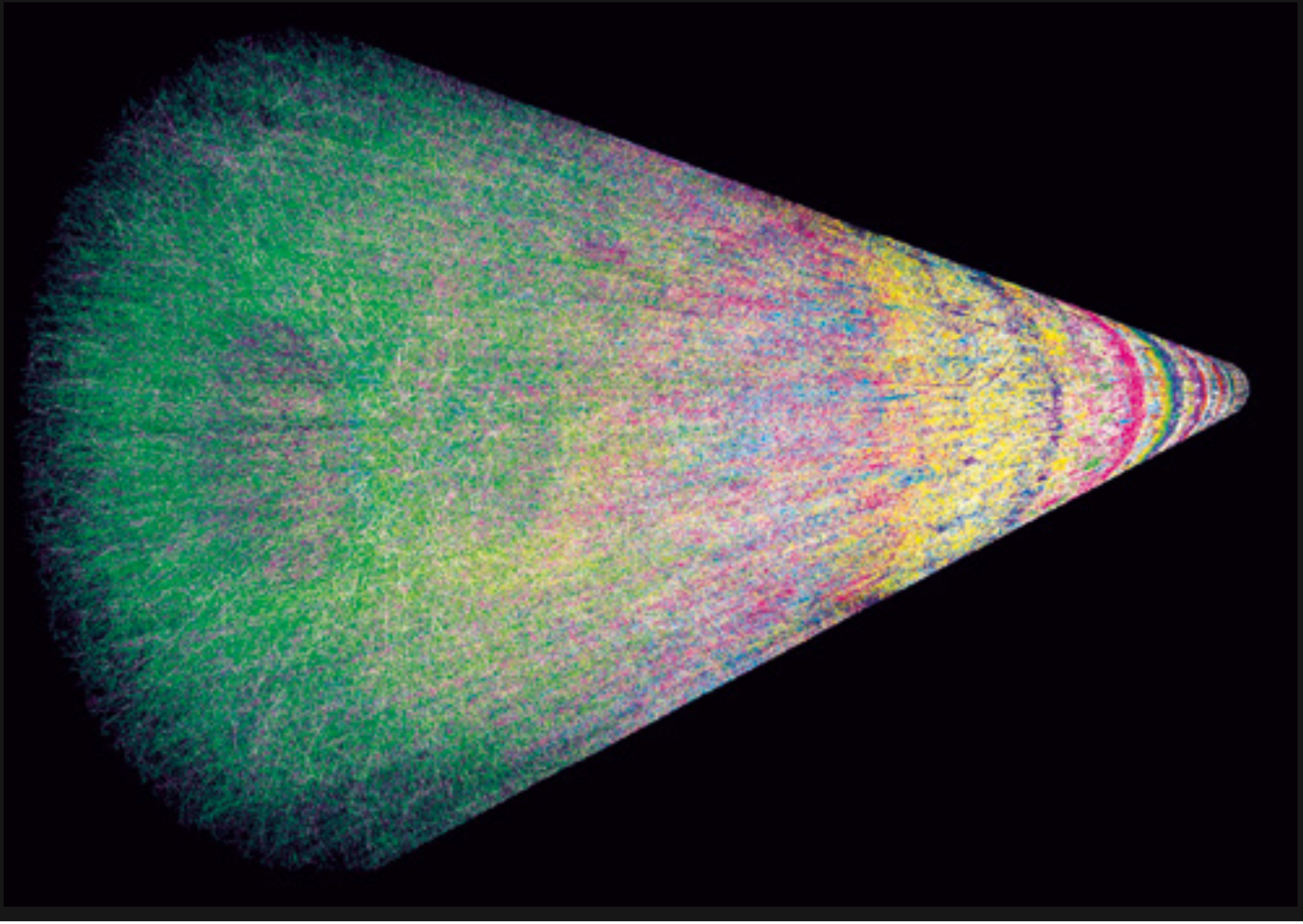
AI for detection of problems in manned space missions

- Transmission time of radio signals between Mars and Earth is 3 to 22 minutes
- Mars missions cannot be controlled from Earth
- The aim of the project is to develop AI support for detecting critical system states in habitation modules on future space missions
- Analysis of recorded data from the Columbus module of the ISS
- Training of the AI
- Test run for validation
- Cooperation project with SVA and the German Aerospace Center (DLR)

Blockchain and distributed ledger in public sector

- New applications and further development of blockchain technology
- Management of authorizations in the context of the RADIUS protocol
- Monitoring access and securing documents in a cloud
- Proof of Useful Work consensus algorithm with data from high-energy physics
- Cooperation with
  - Hessian Center for Data Processing (HZD)
  - KGRZ Hesse - ekom21
  - HFHF

ALICE tracks in detector



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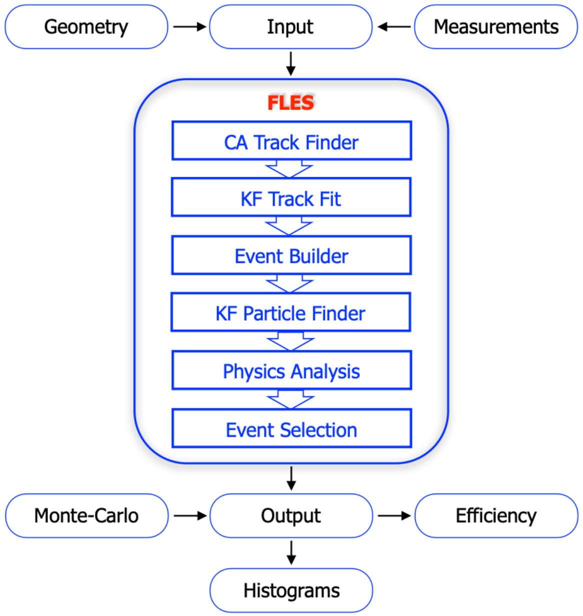
Reconstruction of heavy-ion collisions

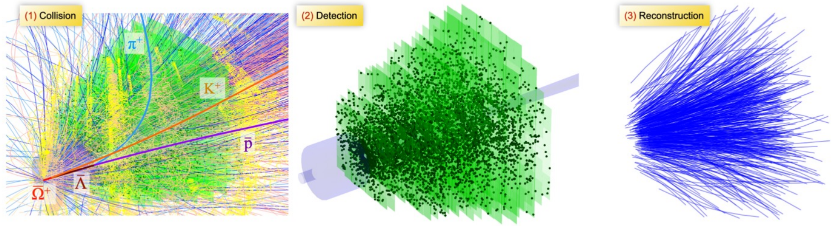


Full event reconstruction in CBM will be done on-line at the **F**irst-**L**evel **E**vent **S**election (**FLES**) and off-line using the same **FLES** reconstruction package.

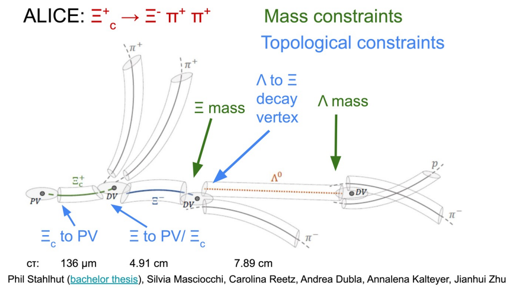
- **C**ellular **A**utomaton (**CA**) Track Finder
- **K**alman **F**ilter (**KF**) Track Fitter
- **KF** short-lived **Particle Finder**

All reconstruction algorithms are vectorized and parallelized.

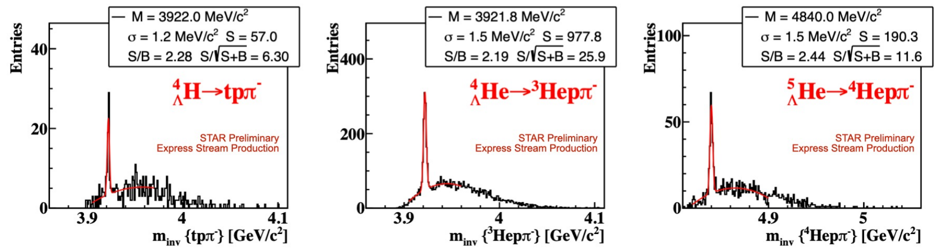
CBM: Tracking with Cellular Automaton at 10^7 collisions/sec



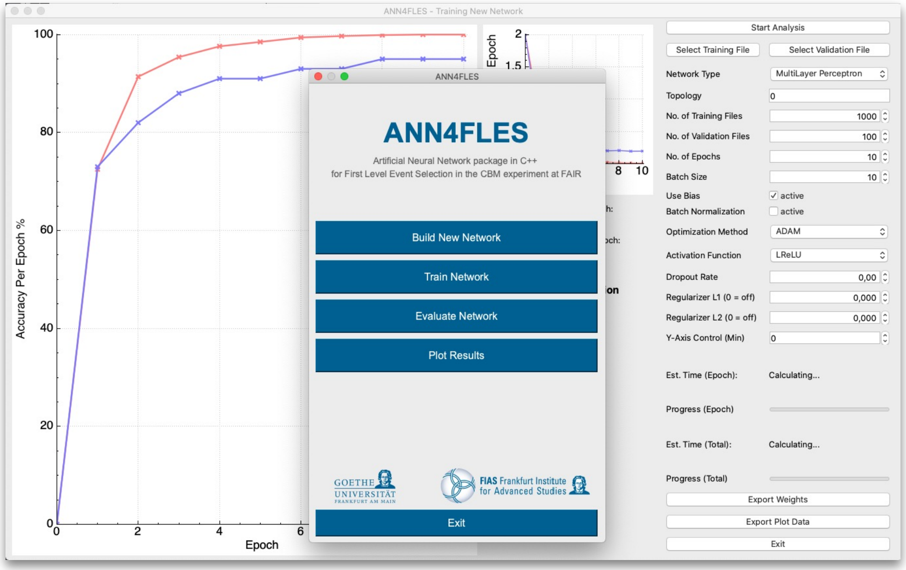
ALICE: Search for charmed baryon decays with KF Particle



STAR: Online search for hypernuclei on HLT in BES-II (2019-2021)

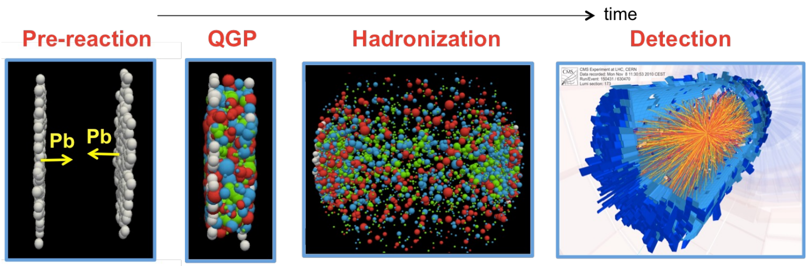


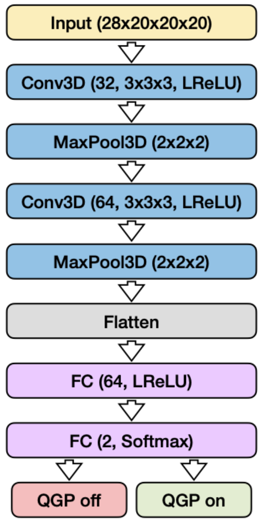
AI package for data analysis in real time

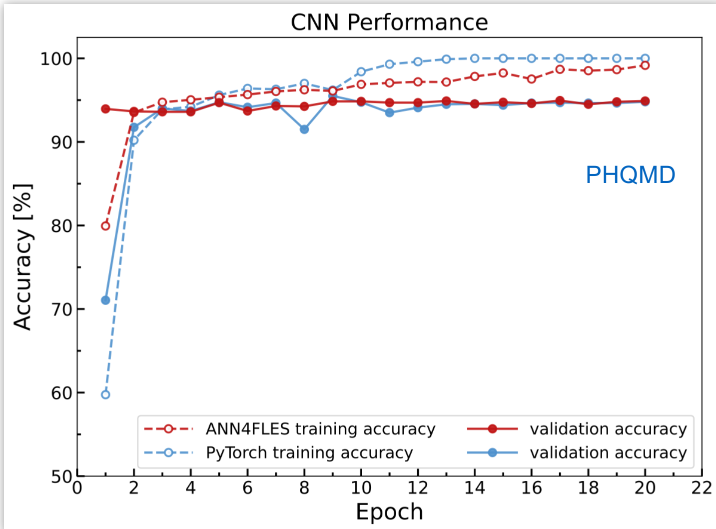


- **ANN4FLES** is a C++ package for use of **A**rtificial **N**eural **N**etworks in the **CBM** experiment.
- It provides a variety of network architectures:
  - Multilayer Perceptron (**MLP**),
  - Convolutional Neural Network (**CNN**),
  - Recurrent Neural Networks (**RNN**),
  - Graph Neural Networks (**GNN**), and
  - Bayesian Neural Network (**BNN**).

CBM: Classification of collisions with Quark-Gluon-Plasma using ANN4FLES

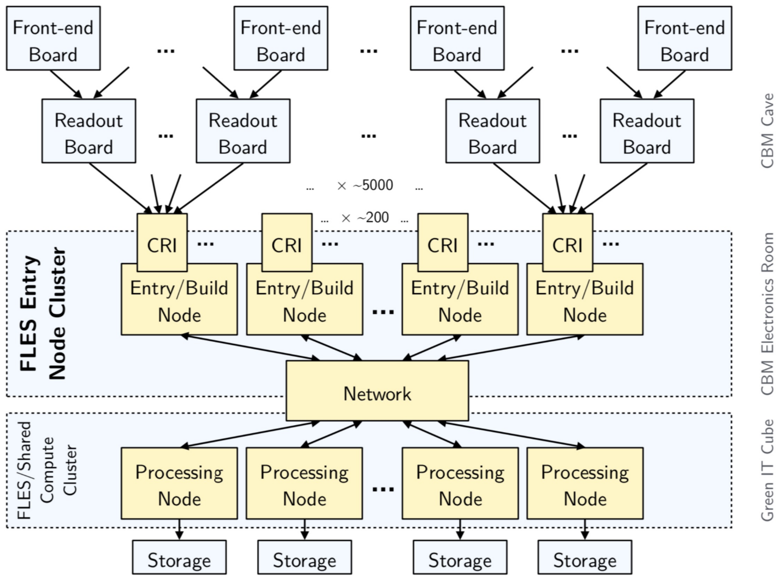






CBM Readout and FLES system

- Readout systems: collect, aggregate and deliver data to online compute farm
- First Level Event Selector: event reconstruction online, up to software trigger decision



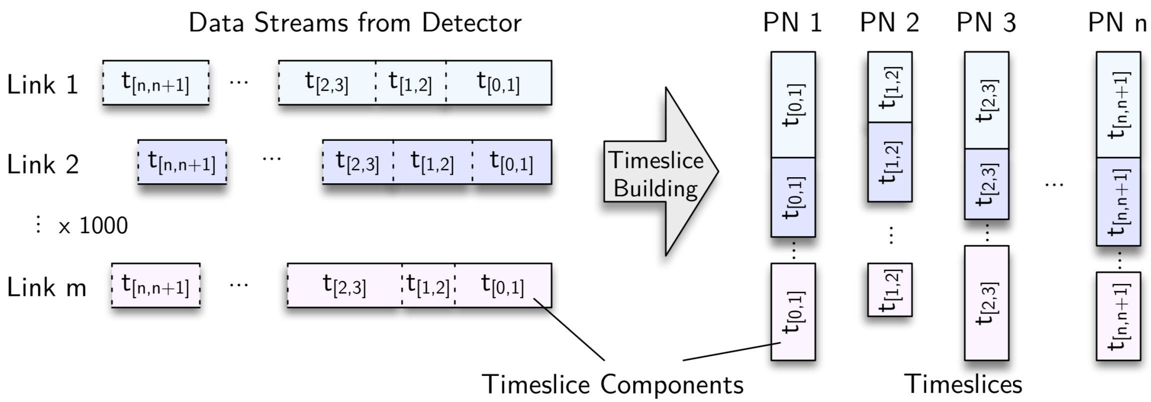
Requirements in Online TDR:

setup avg. int. rate/1/s	hadron 5×10^6	electron 1×10^5	muon 5×10^6	dark 0
	GB/s	GB/s	GB/s	GB/s
BMON	–	0.2	–	0.0
MVD	–	5.0	–	3.5
STS	101.8	9.1	101.8	7.2
MUCH	–	–	37.3	7.5
RICH	–	1.6	–	0.8
TRD	207.6	9.3	24.8	4.3
TOF	42.7	1.0	9.9	0.1
PSD	–	0.3	–	0.0
Sum	352.1	26.4	173.9	23.3

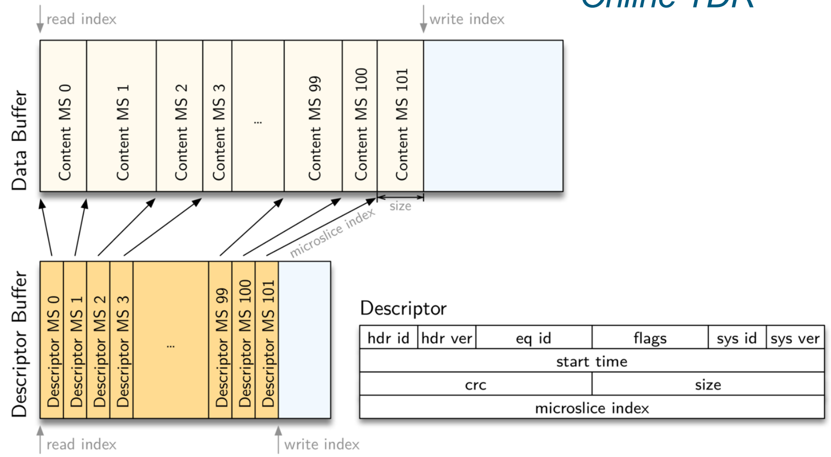
Average total data rates sent from detectors to FLES

CRI

FLES timeslice concept

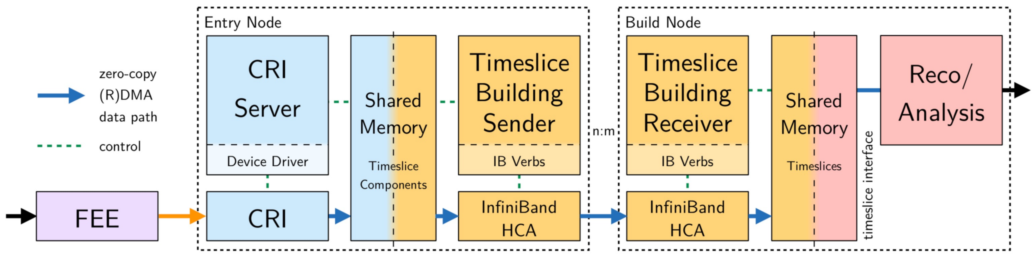


Online TDR



Conceptional idea of timeslice building:
All components from one time interval are combined into a processing interval (timeslice), and sent to the same processing node (PN)

Dual ring buffer memory scheme



Overview of the main data path in FLES

FLES online systems - TDR


Technical Design Report for the CBM

Compressed Baryonic Matter Experiment

Online Systems – Part I

DAQ and FLES Entry Stage

The CBM Collaboration

July 2023

FLES pivotal for aggregating and processing of all CBM data online

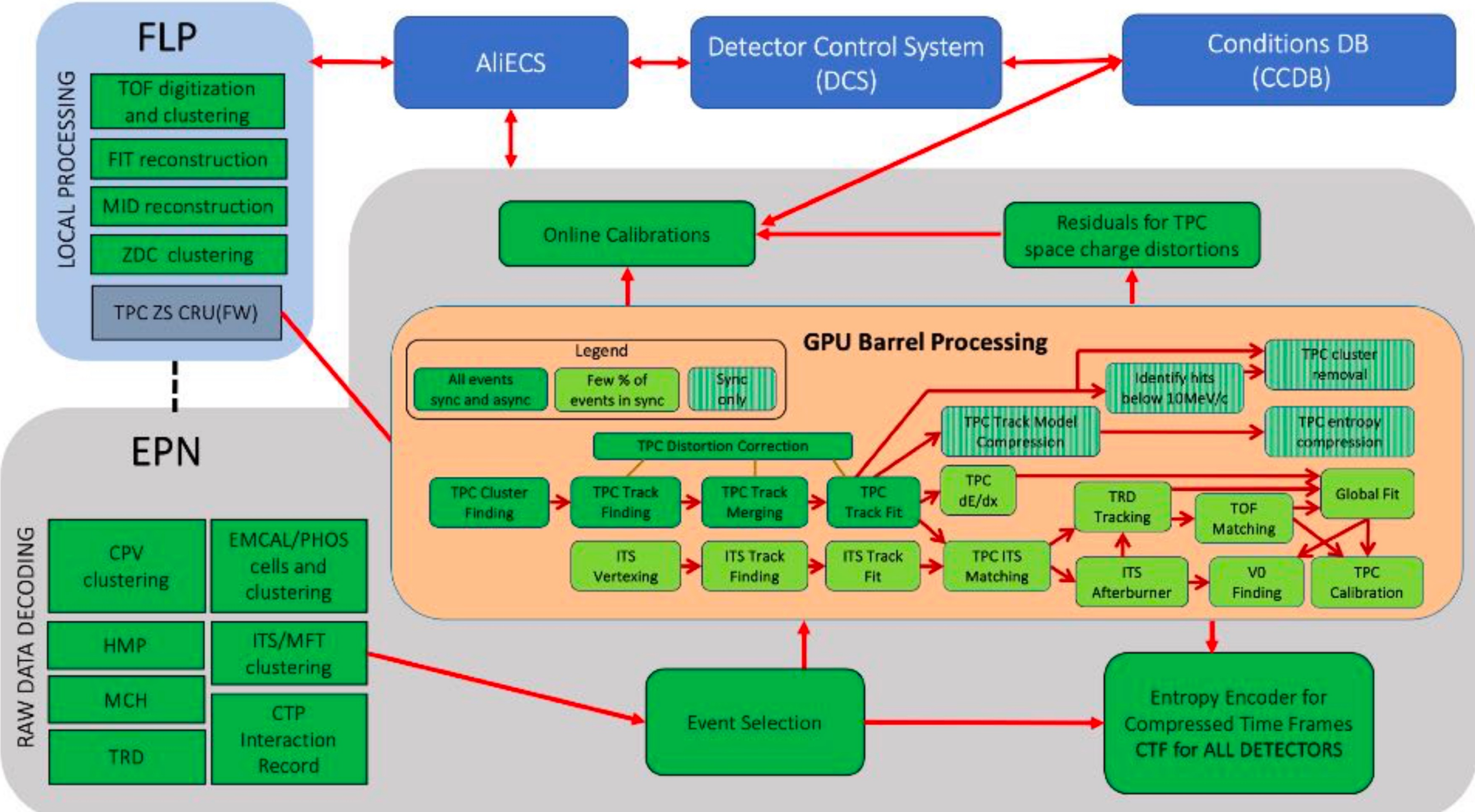
First CBM TDR for a central system containing several subsystems

Accepted by ECE with no change request

DOI: 10.15120/GSI-2023-00739

FLES for mCBM operational and used in many beam times and data challenges

ALICE EPN farm



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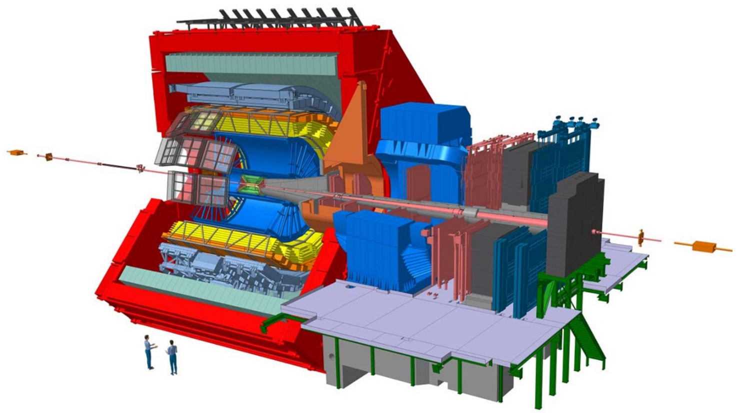
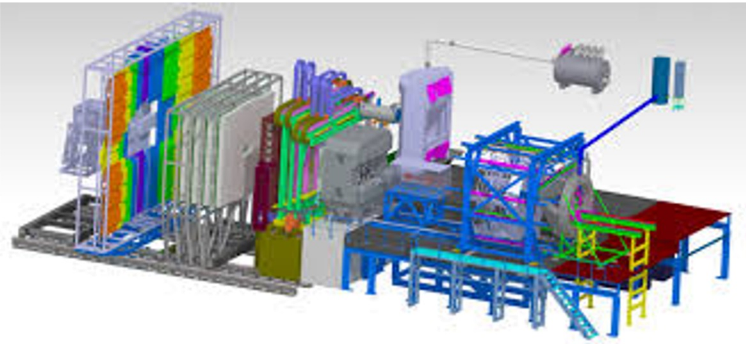
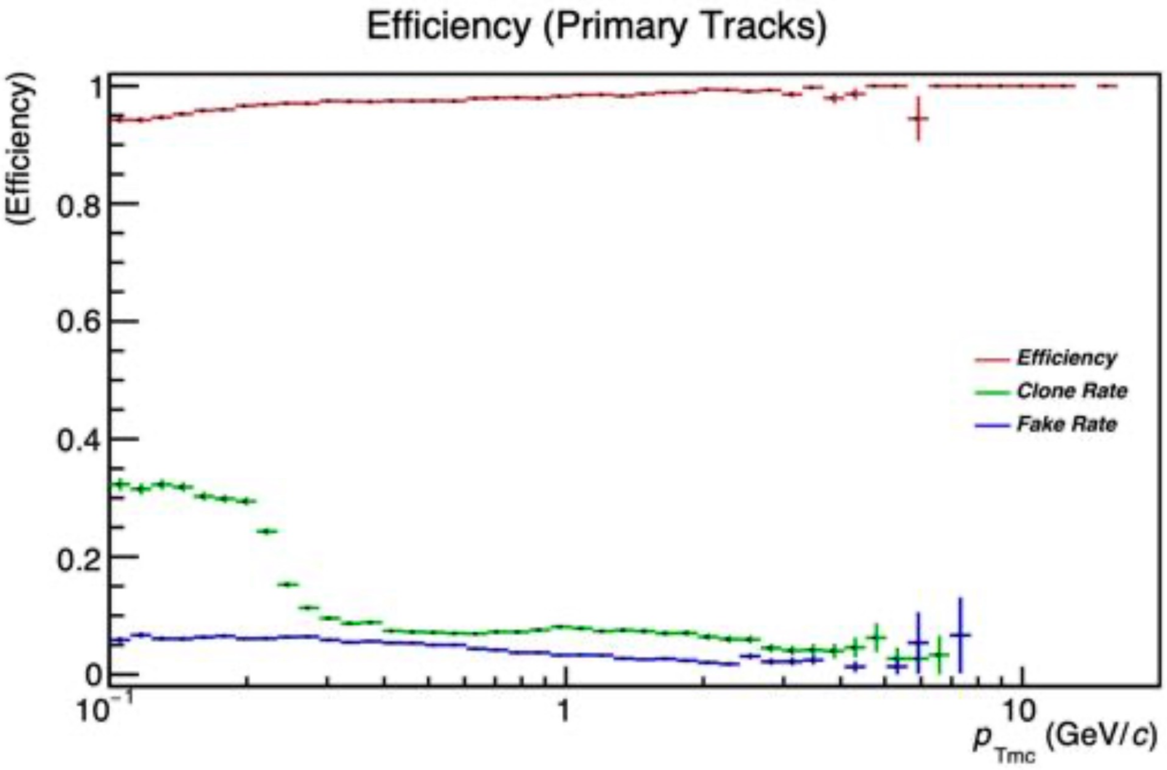
High-Level FPGA synthesis in HEP

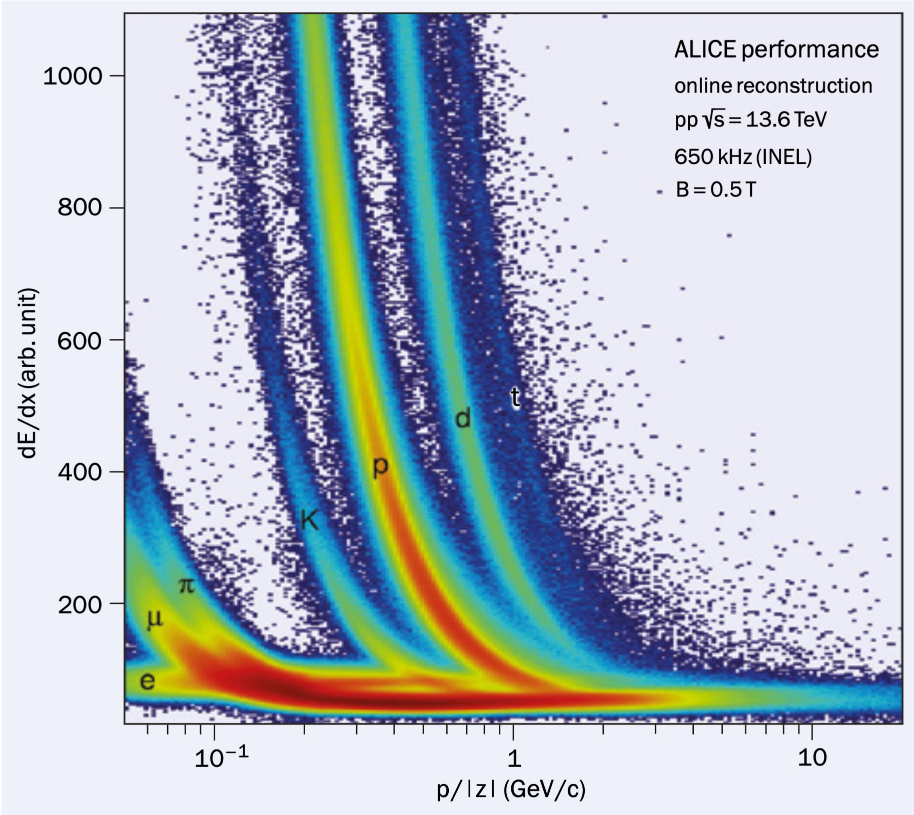
- Compared to VHDL, high-level circuit synthesis significantly reduces the effort required to implement algorithms in hardware
- Use of the data flow paradigm for calculation with a large number of functional units, combined with pipeline parallelization
- Ideally suited for complex algorithms on data streams
- Applications in high-energy physics:
  - CBM: Online Feature Extraction for the Transition Radiation Detector in the triggerless run
  - ALICE: Development of a template library for the intuitive use of the data flow paradigm for the implementation of algorithms





ALICE on-line event reconstruction





- 2800 GPUs, 32 GB each
- 24640 CPU cores
- 200 TB main memory
- 200 PB mass storage
- Up to 1.3 TB/s ingres
- 200 GB/s egres
- 95% of processing on GPU

- Data distribution framework developed at FIAS

ALICE collab.

New nodes *The event processing node racks in the ALICE computing farm, part of a completely new computing model for Run 3 and beyond.*

ALICE UPS ITS GAME FOR SUSTAINABLE COMPUTING

The design and deployment of a completely new computing model – the O^2 project – allows the ALICE collaboration to merge online and offline data processing into a single software framework to cope with the demands of Run 3 and beyond. Volker Lindenstruth goes behind the scenes.

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CMMS – Image Analysis for Microscopy

Quantitative Microscopy is evolving

- Deep Learning
- Increasing Data Sizes
- Streaming (Online) Analysis
- Smart Microscopy

Computing Requirements

- **Support for Machine Learning Hard- and Software (Nvidia, AMD, Intel)**
- **Use of Dedicated Compute Resources**
- **Framework for Quantitative Microscopy**

Arkitekt

Bioimage Analysis Framework

- Containerization (Reproducible)
- Machine Learning
  - Content-Aware Image Restoration
  - StarDist Registration

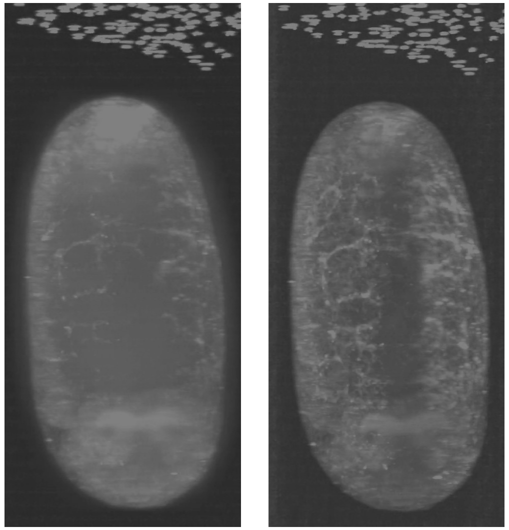
Collaborators:
J. Roos (Bordeaux University)

Multiview-Stitcher

Image Stitching Toolbox

- Registration
- Fusion
- Distributed Processing
- Hardware Acceleration

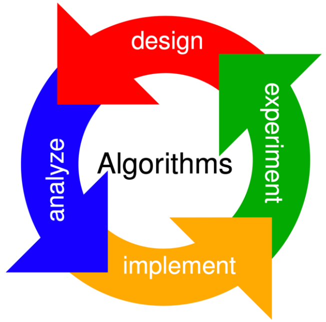
Collaborators:
M. Albert (Institut Pasteur)
A. Golden (Goethe-University)



Without (left) and with (right) Content Aware Fusion

FIAS Frankfurt Institute for Advanced Studies Wilhelmi

CMMS Efficient Generation of Synthetic Networks



- Performance of many graph algorithms depend on specifics of the input graph class
  - Experiments yield crucial insides !
- Real networks
  - are hard to acquire
  - pose legal or privacy concerns
  - are difficult to share, store & reproduce
  - contain noise or sampling artefacts
  - are often static / do not scale
  - lack ground-truth
  - are not well understood
- Parameterized synthetic models allow more systematic experiments
- Our network generators:
  - I Handle billions of nodes & edges
  - Various models: pref. attachment, hyperbolic, fixed degree sequences, . . .
  - Open source
  - Often orders of magnitude faster than previous solutions
  - Mathematically sound
  - Guaranteed quality & performance
- Future challenge: Models and generators for *temporal* networks.

Quantum Computing Research Activities

- Quantum Computer for computational purposes
- Development of algorithms
- Error mitigation methods
- Programming models for classical-quantum hybrid workflows
- Development of algorithms for quantum annealers
- Smart schedulers for modular supercomputer architecture (MSA) systems
- Quantum Computer at GU already ordered
- Close collaboration with NIC Jülich
- Quantum-Call in NHR Mid 2024

Quantum Computing Research Activities

- Error mitigation methods
  - Post processing for quantum computers in NISQ era to decrease noise
  - Development of a scalable method to support state of the art qubit numbers
  - New method developed
- Programming models for classical-quantum hybrid workflows
  - Extension of the task based programming model OmpSs to support QPUs
  - Allows users to offload tasks to a quantum computer from within C++ code
  - Libraries close to being completed
- Development of algorithms for quantum annealers
  - Focus on real-world optimization problems (e. g. portfolio optimization)
  - Research on different encodings and annealing techniques
  - Several new algorithms under development, patent applications under evaluation
- Smart schedulers for MSA systems
  - MSA systems have the potential to use compute resources more efficiently
  - Static scheduling limits the exploitation of this potential
  - Development of a more flexible scheduler which assigns resources dynamically

Quantum Computing Research Activities

- ➢ Procurement and integration of a quantum computer at GU
  - Arrival of QC planned for spring 24
- ➢ Size and technology
  - 5 qubits
  - Nitrogen-vacancy center based technology
- ➢ Software
  - Open Source access software system is developed
  - Integration into a HPC environment under way
- ➢ NHR
  - Making the quantum computer available to NHR members
- ➢ Connection of the GU to the JUNIQ infrastructure of the FZ-Jülich
- ➢ Quantum-Call in NHR Mid 2024

Cooperations

- Connection between GU and JUNIQ-Infrastructure of FZ-Jülich
  - GU member of John-von-Neumann-Institute for Computing is decided in NIC
  - Cooperation contract about joint usage of infrastructure completed
    - Use of Jülich D-Wave Quantumnannealer
    - Use of Frankfurt Baby Diamond for JUNIQ
- Quantum-Call in NHR Mid 2024

Collaboration with humanities

Organisationsberatung, Supervision, Coaching (2024) 31:63–78
https://doi.org/10.1007/s11613-023-00861-z

OSC Organisationsberatung Supervision Coaching

Check for updates

HAUPTBEITRÄGE

„Wo die Cloud die Erde berührt". Rechenzentren zwischen Nachhaltigkeitsanforderungen und Innovationsblockaden

Simon Heyny · Mardeni Simoni · Katarina Busch · Vera King · Volker Lindenstruth

Eingegangen: 5. Oktober 2023 / Angenommen: 23. November 2023

Outlook

Support for Digital Twin development in HPC context (e.g. SCALE)

Fast and efficient event reconstruction

ALICE EPN / Outer Tracker for ALICE

CBM (?)

Quantum Computing