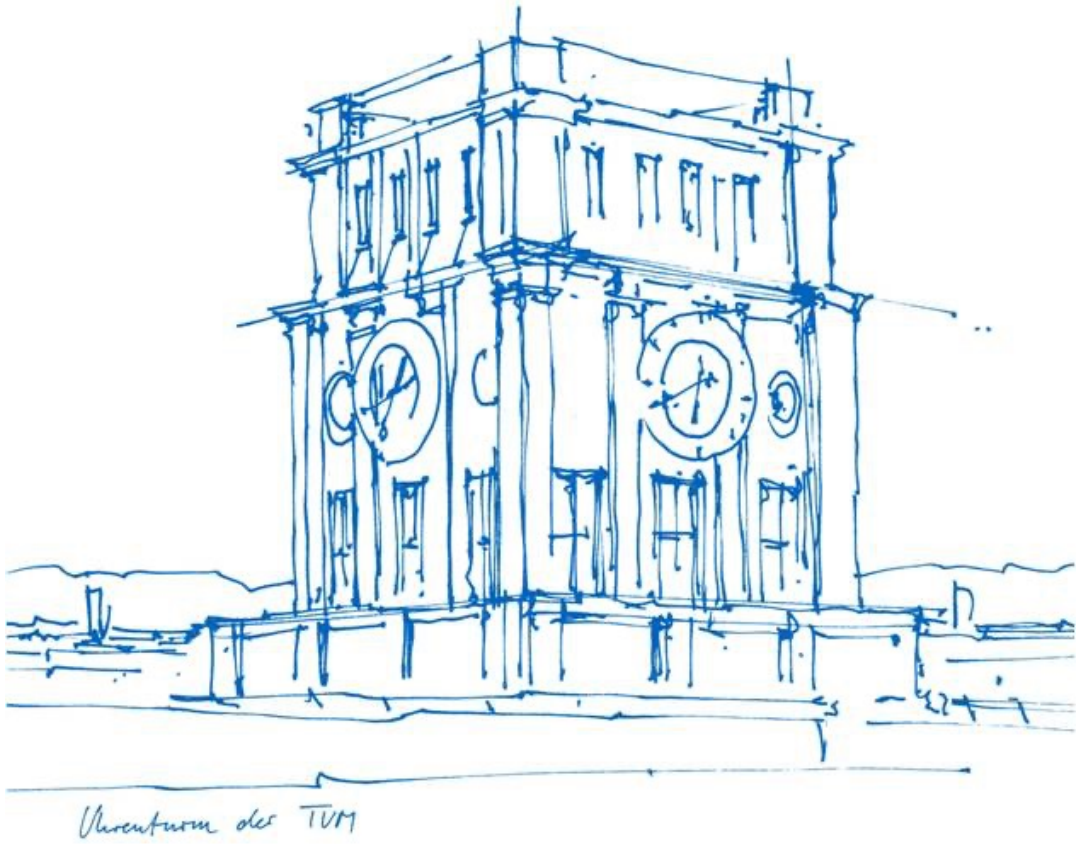
Apparatus for Meson and Baryon Experimental Research

AMBER FriDAQ

Igor Konorov and Martin Zemko

on behalf of DAQ group



PANDA DAQ Workshop

CERN, 26.06.2024

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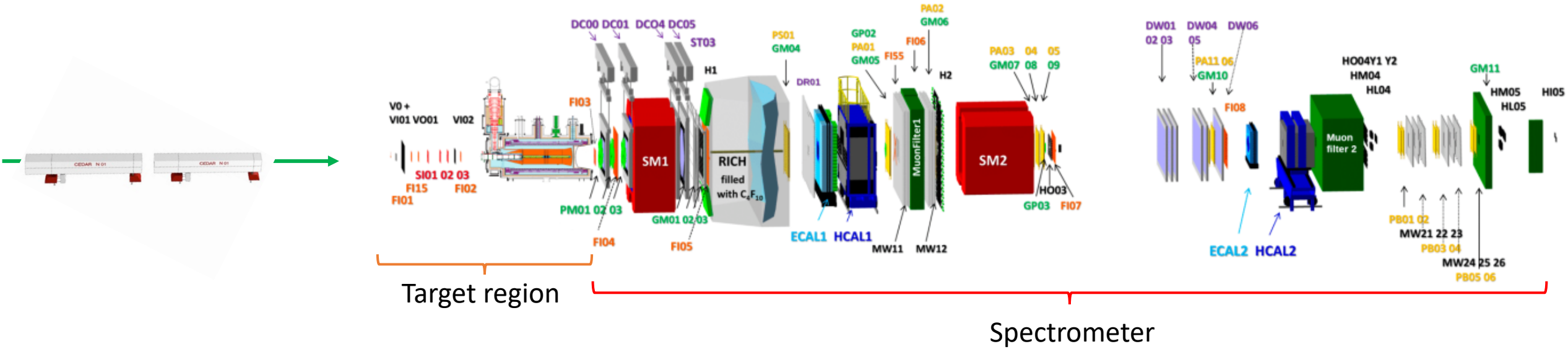
AMBER Experiment



Successor of COMPASS Experiment

- 2023-2024 pbarX : 60 – 250 GeV p LHe, LH2 target Triggered DAQ 20kHz, 300 MB/s

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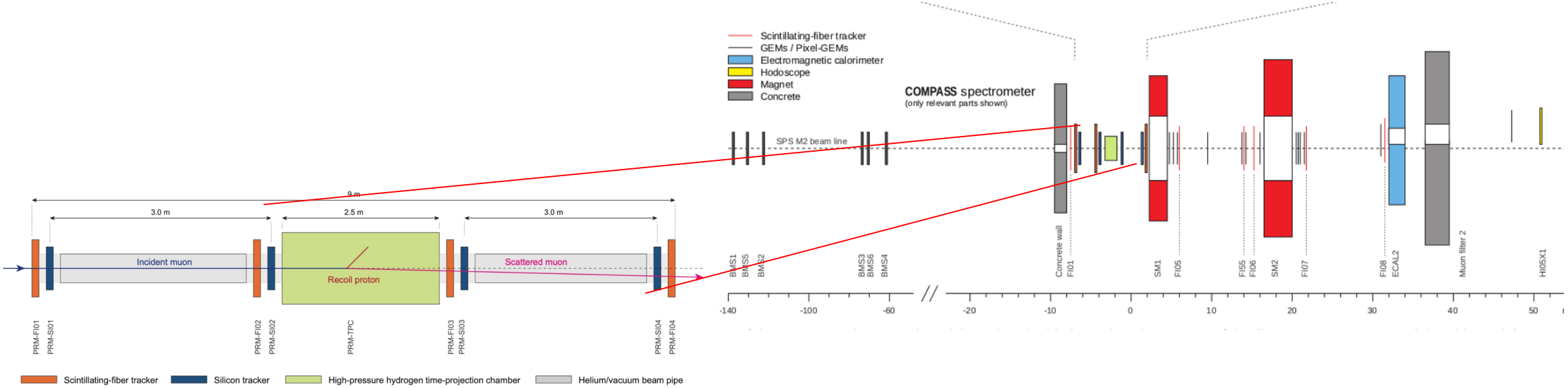
AMBER Experiment



Successor of COMPASS Experiment

- GEM
- MWPC
- ECAL2 Central part

▪ 2023-2024	pbarX	: 60 – 250 GeV p	LHe, LH2 target	Triggered DAQ	20kHz, 300 MB/s
▪ 2025-2026	PRM	: 100 GeV $\mu^{\pm}$	TPC, small spectrometer	Streaming DAQ	1-2 GB/s

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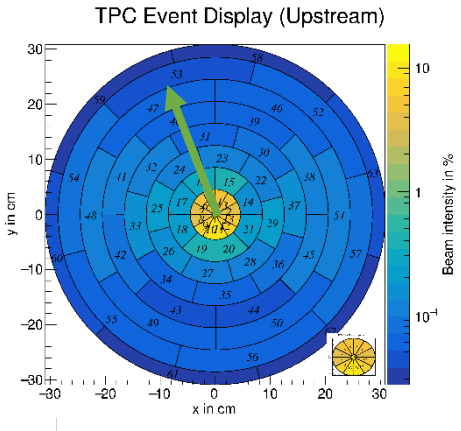
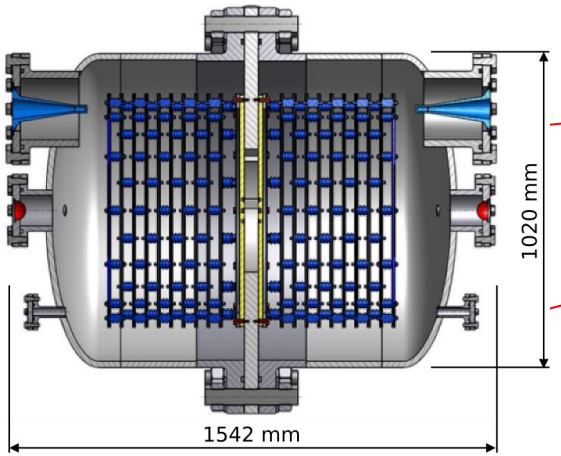
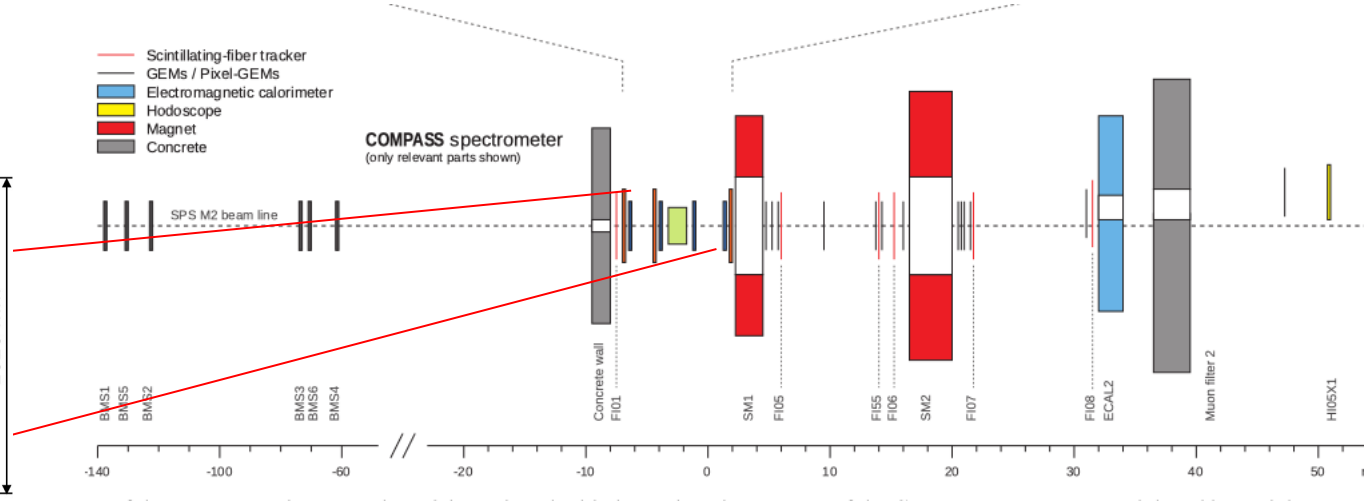
TPC, recoil proton

- < 6% resolution
- H2 at 4,20 Bar
- 150us drift time
- SIS ADC, 120 ch







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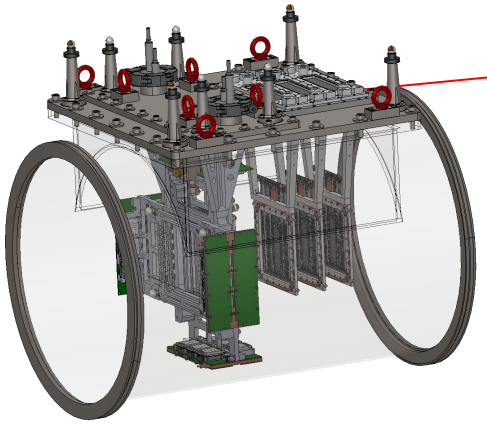
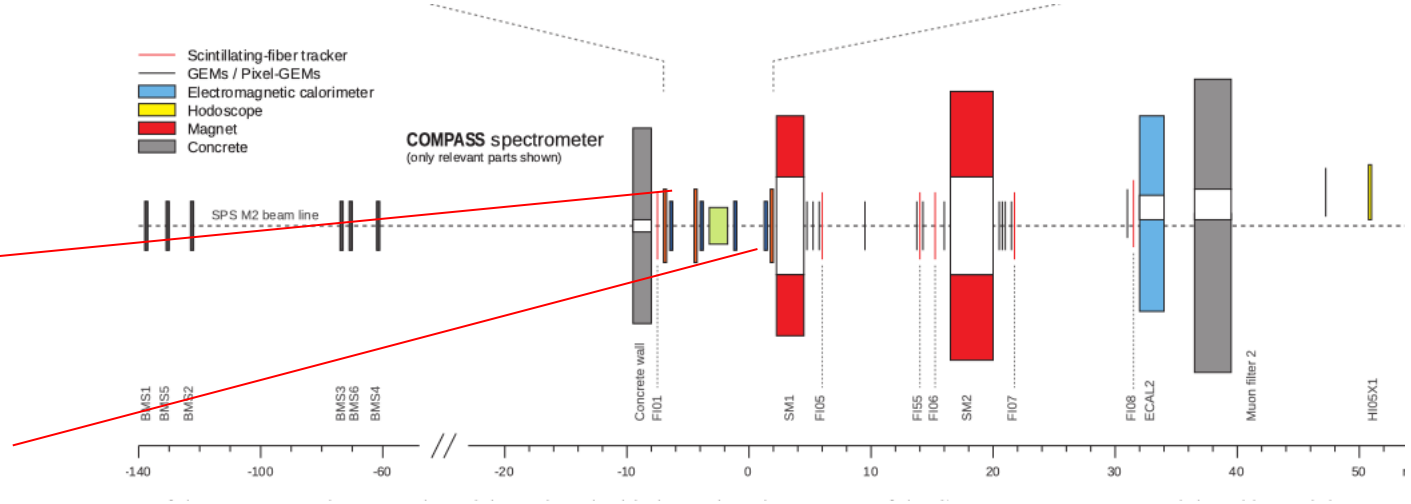
AMBER Experiment

4 stations, 3xPixel planes+4 SciFi planes

Pixel ALPIDE
- 28um x 28um
- 10us gate

SciFi UTS tracking
- 500 um fiber
- < 400 ps resolution





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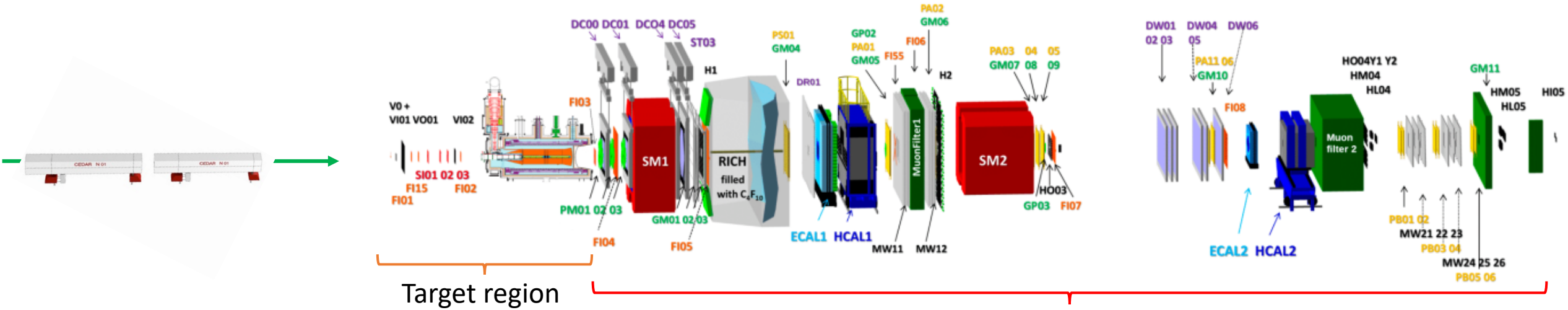
AMBER Experiment



Successor of COMPASS Experiment,

▪ 2023-2024	pbarX	: 60 – 250 GeV p	LHe, LH2 target	Triggered DAQ	20kHz, 300 MB/s
▪ 2025-2026	PRM	: 100 GeV $\mu^{\pm}$	TPC, small set of detectors	Streaming DAQ	1-2 GB/s
▪ 2028-…	DY	: 190 GeV $\pi^{\pm}$	Full Spectrometer	Streaming DAQ	10 GB/s
▪ …	…				

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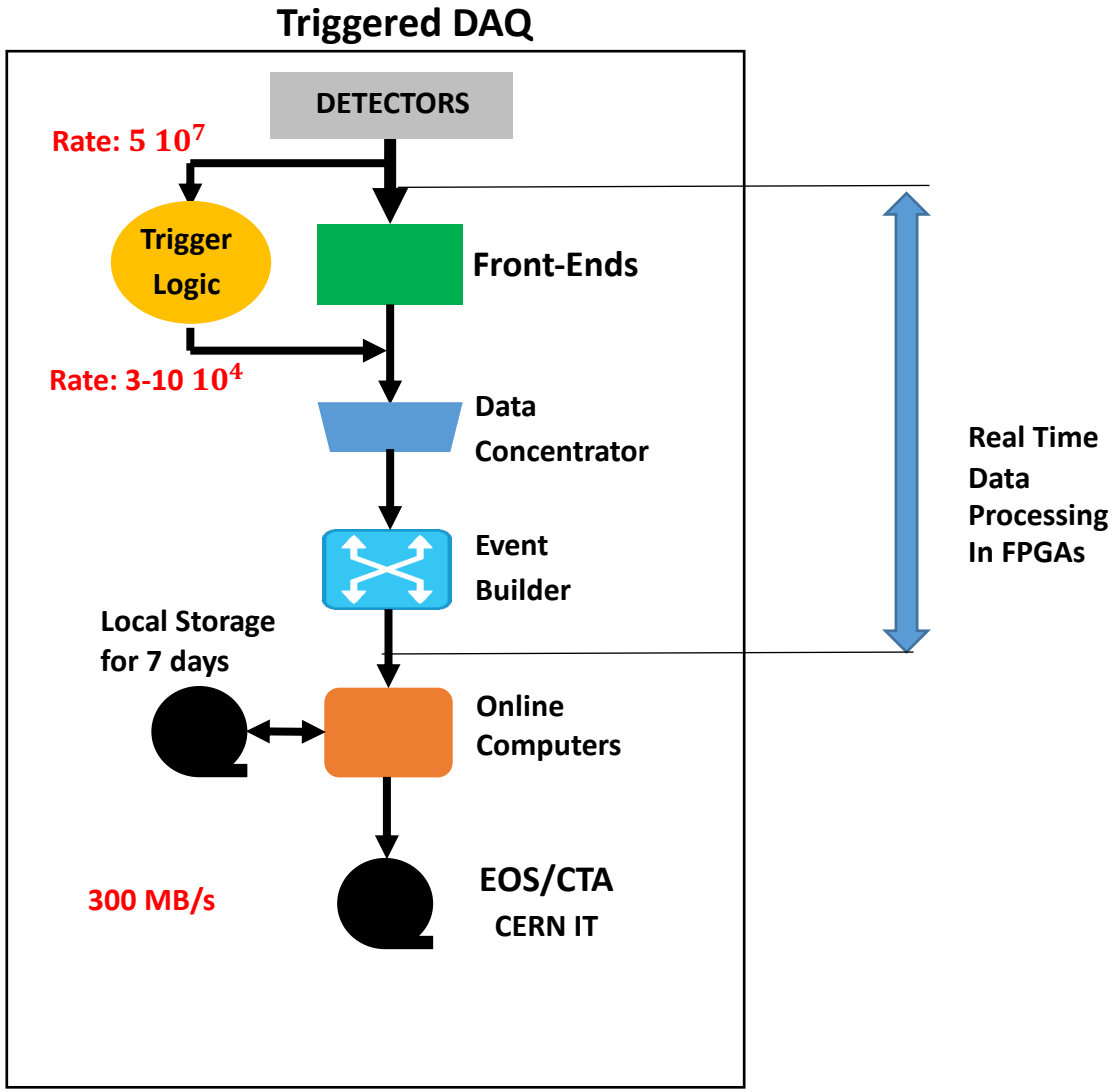
DAQ Architecture Evolution



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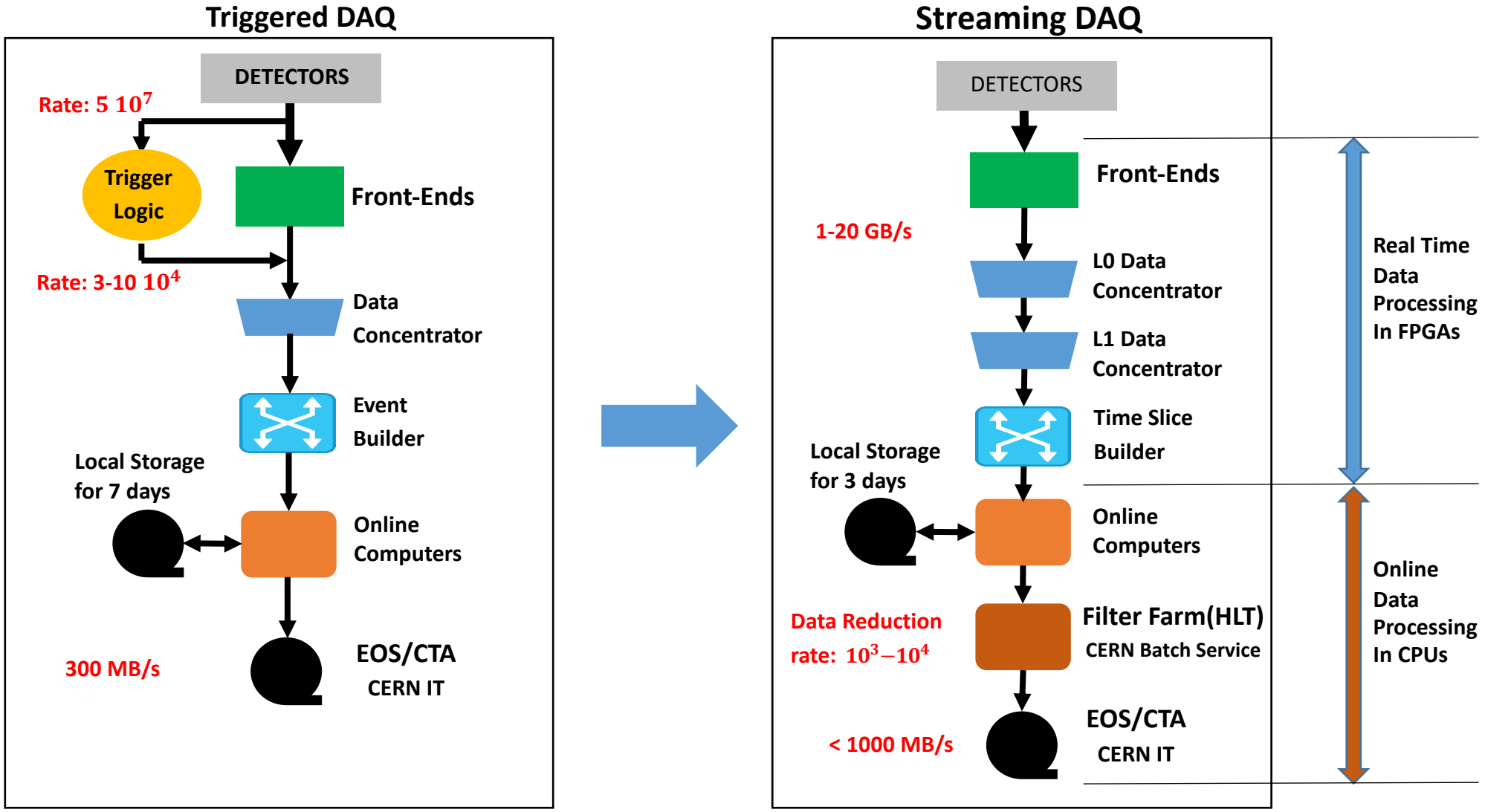
DAQ Architecture Evolution



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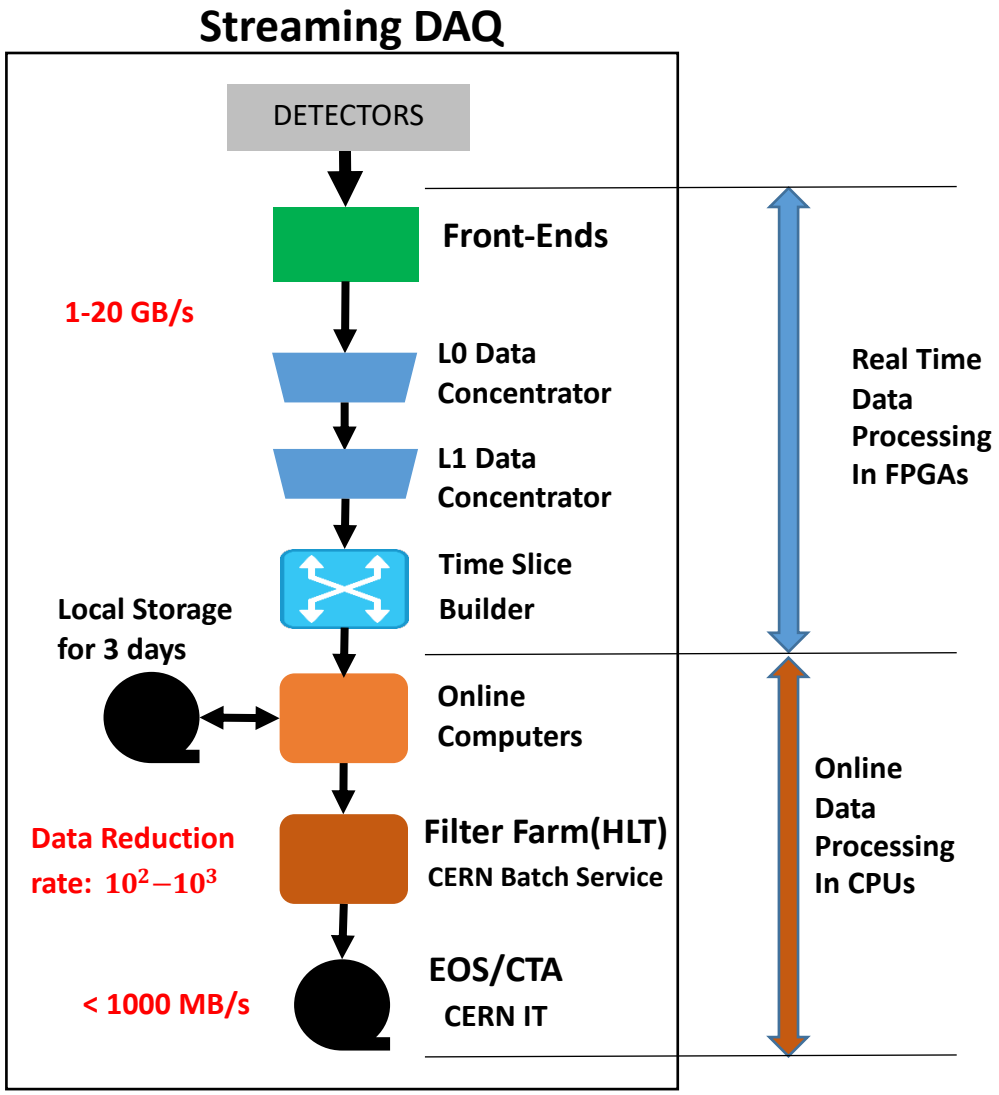

DAQ Framework

- Intelligent data handling, no DAQ crashes
- Congestion free Time Slice Builder in FPGA
- Unified Communication Interfaces (UCF) to FE
- Unified IP Cores

Advantages

- No real time software processes
- Scalability and High performance
- Compactness
- Diagnostics and Reliability
- Low cost
- Data filtering in IT center

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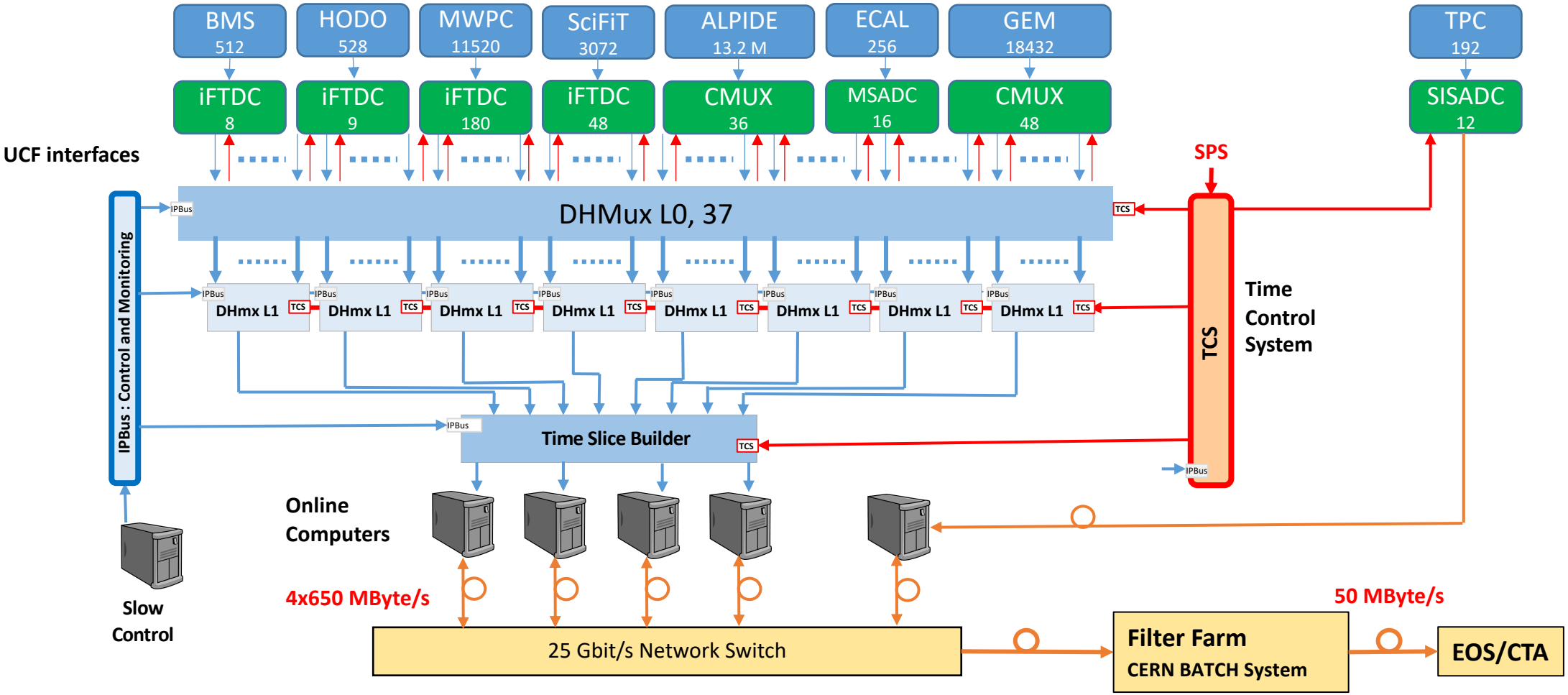
FriDAQ for PRM with TPC



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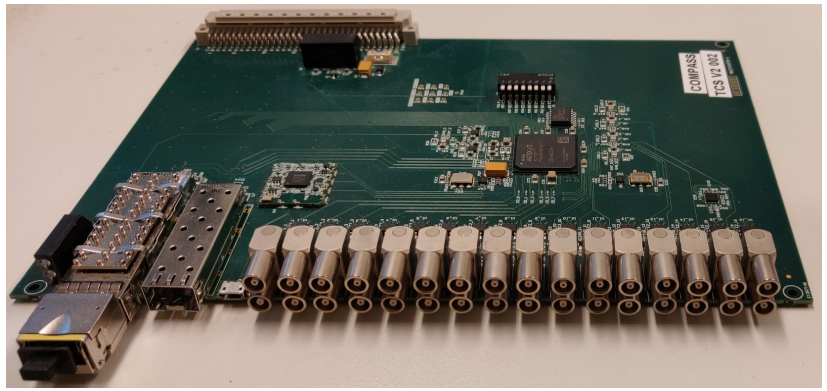
AMBER DAQ Hardware

TCS, Time Synchronization

- **Passive optical network**
- **> 300 destination**
- **Reset, 38.88 MHz clock**
- **RUN , SPILL, END**
- **Time Slice, 1kHz**



- **DHMux, TS Builder**
  - **Virtex6 XC6VLX130T FPGA**
  - **4 GB DDR3**
  - **16 High speed links 6.5 gbps**
  - **MUX L0/L1**
  - **TimeSlice Builder**

- **MUX L0, detector specific, 4GByte**
  - **12x3.1Gbps UCF FE links**
  - **1x6.25 GbpsAurora**
  - **Chronological data ordering**
  - **iFTDC version developed**
- **MUX L1, generic, 4GByte**
  - **Multiplexing Time Slices**
  - **12:1**
  - **Being developed**
- Buffering data of entire spill

- **ATCA Integration**

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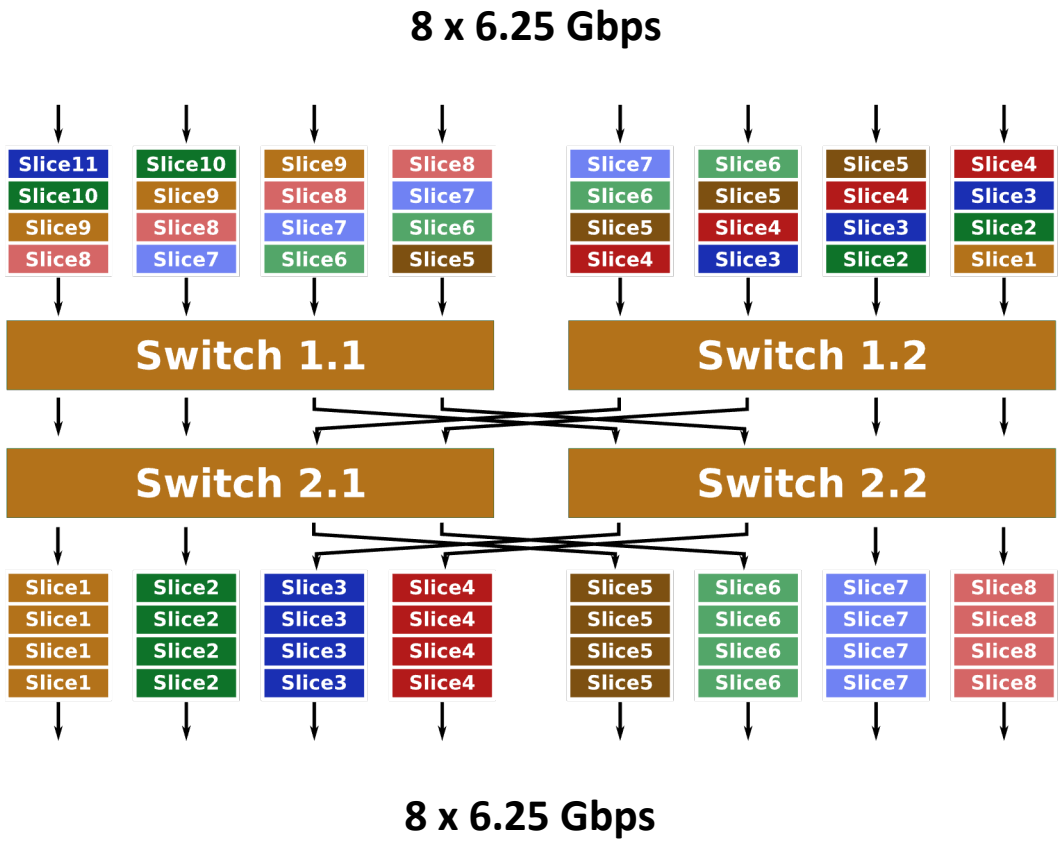
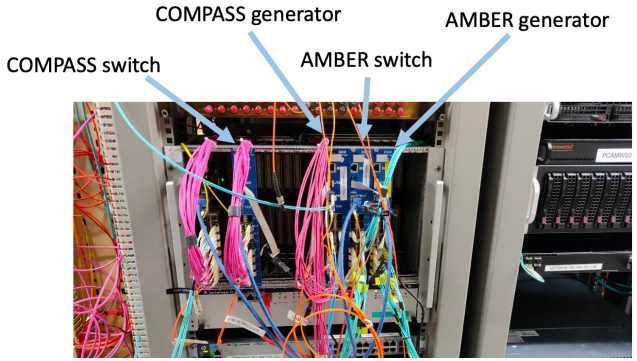
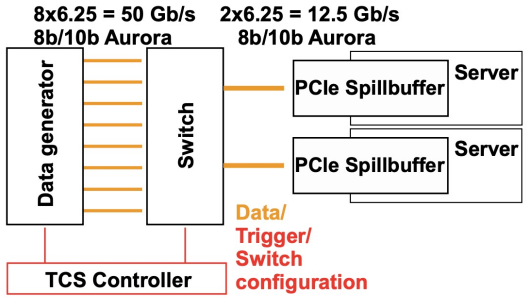
Time Slice Builder

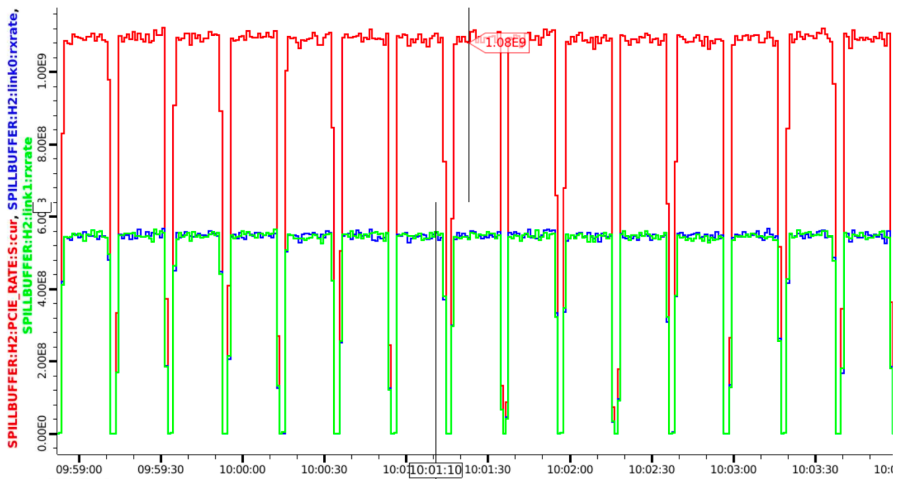


Data rate test

- **Random TS size variations**
- **580 MB/s => 10 % loss due to data size variation**
- **8x 580 MB/s => 4.5 GB/s throughput**







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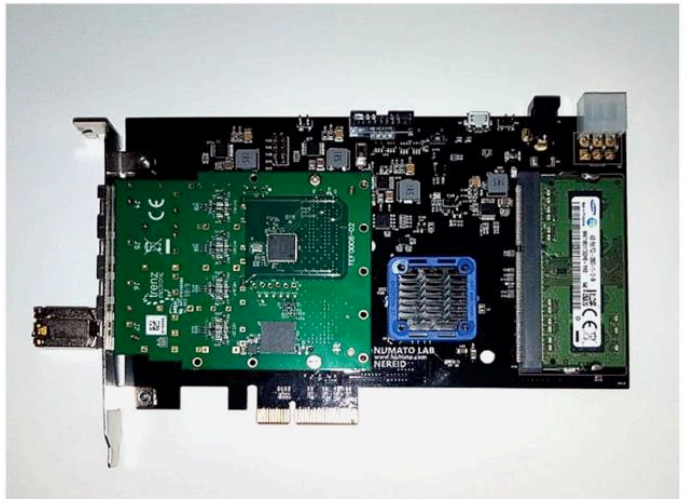
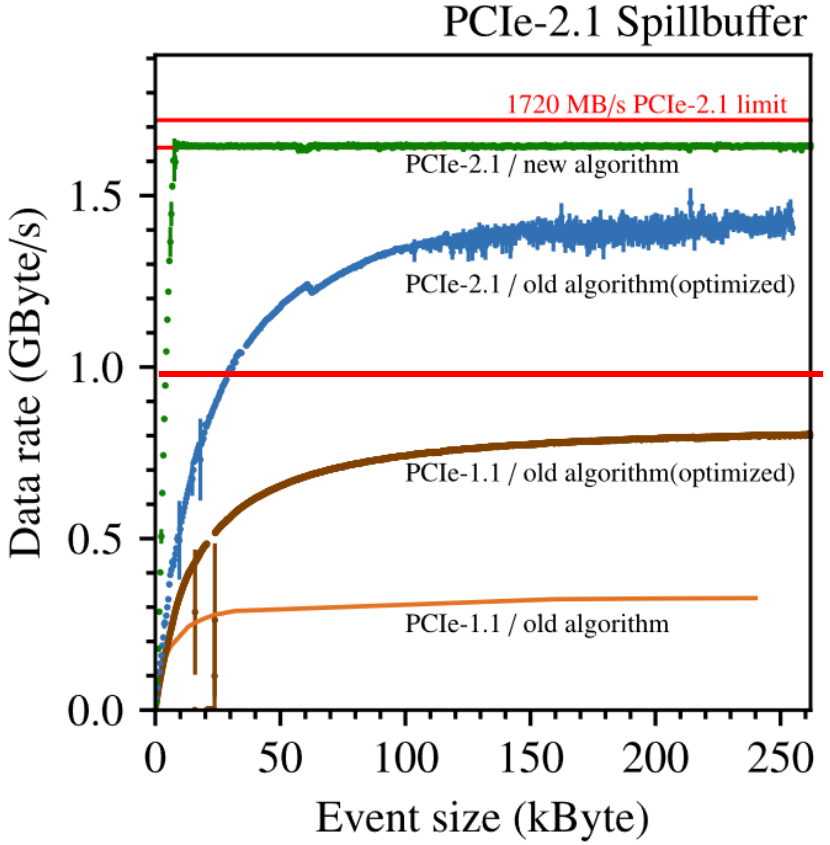
AMBER DAQ Hardware

PCIe card

- **Nereid Kintex 7 XC7K160T**
- **4 x PCIe-Gen2 interface**
- **4 GB DDR3 memory**



DMA Performance



DAQ Requirements:

> 1 GB/s/Compute Node

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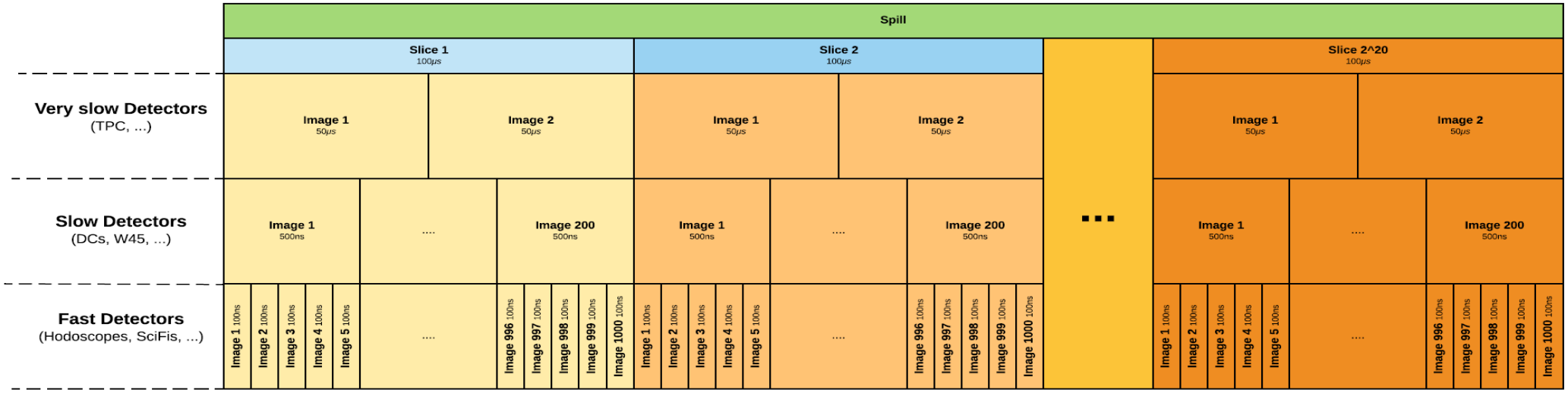
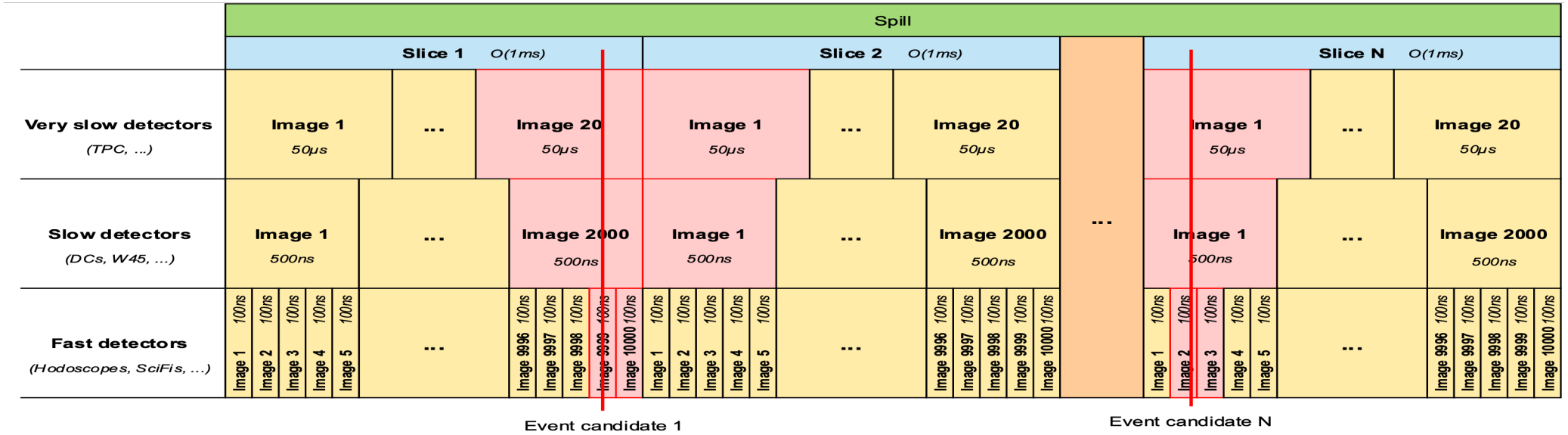
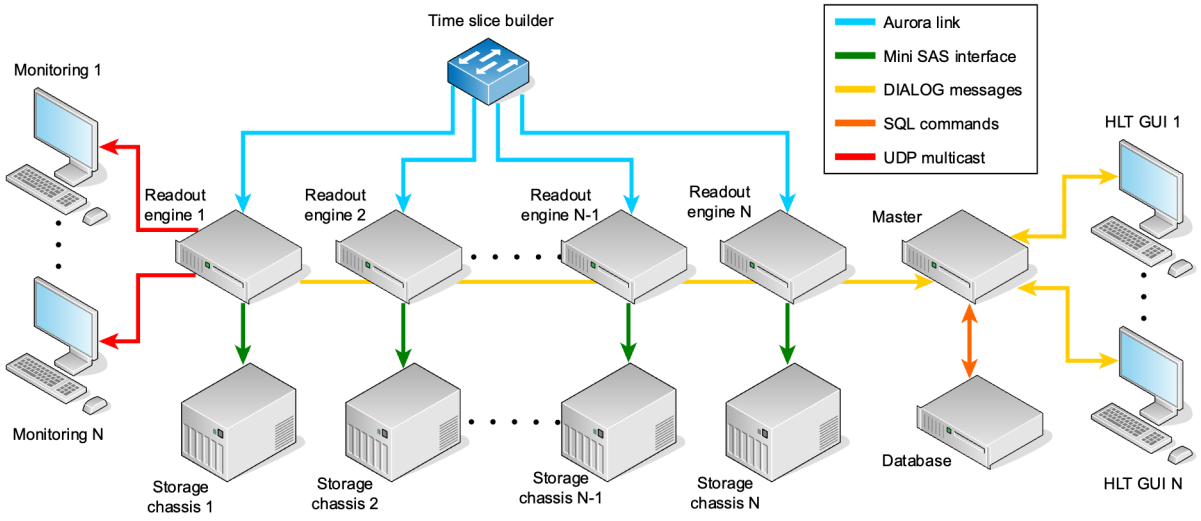
Data Structure and Data Reduction





Computing

- 4 readout servers + 4 x 250 TB external chassis connected via Broadcom MegaRAID 9580-8i8e RAID controller
- Storage space split to 3 x RAID 50 volumes and accommodates 3 days of data-taking
- Optimized for maximum sustained throughput of 1 GB/s/server



Databases

- Databases deployed on centralizes CERN Database-on-demand service
- Clustered database design with 3 nodes – one primary and two replicas

Networking

- Star network topology with a central 100 Gbps switch, custom DHCP and DNS servers
- Second 100 Gbps switch for uplink to data center
- Full data stream is sent to the CERN data center via 2 x 100 Gbps links

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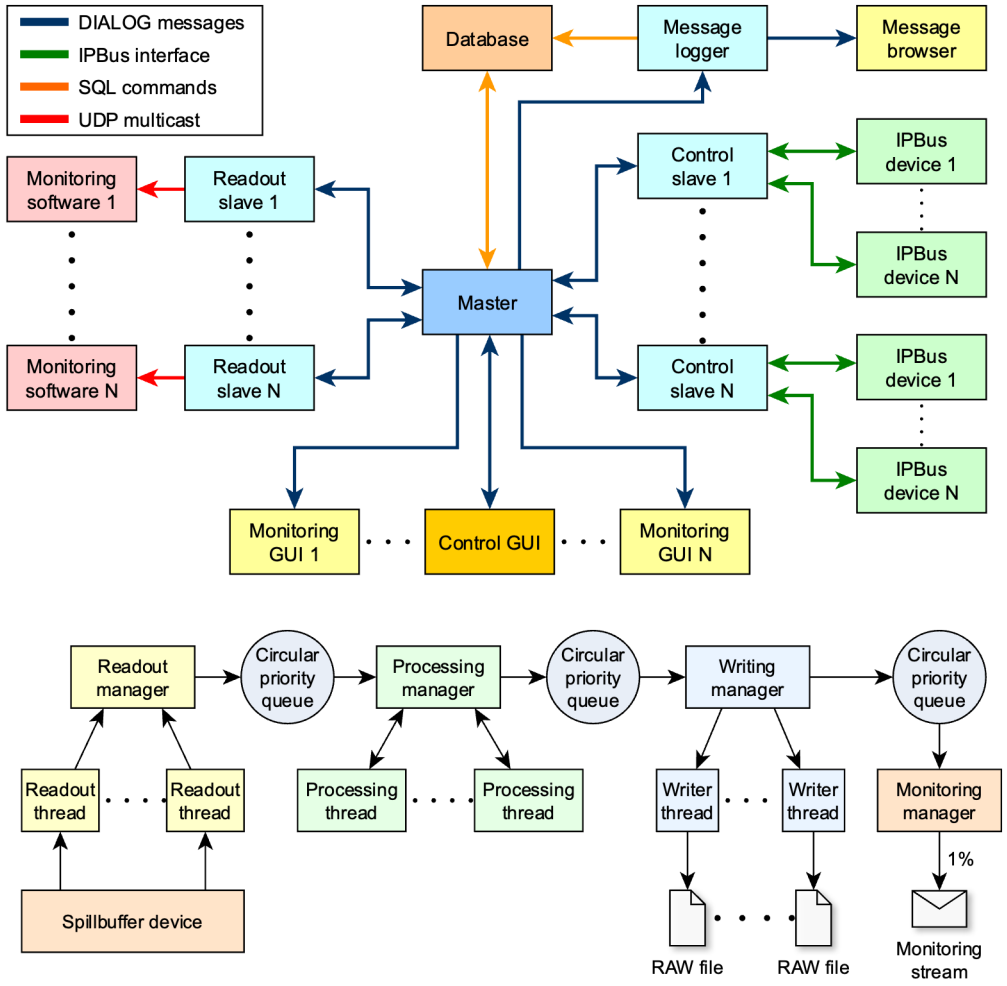
Readout Software

- Master-slave architecture executed on several machines
- Master is central hub and controller
- Two worker processes:
  - **Readout slave** – data extraction from readout cards and processing
  - **Control slave** – monitoring and configuration of IPbus devices
- Custom DIALOG library for message exchange between processes
- Qt graphical user interface for run control and configuration
- Monitoring stream provided by readout servers via UDP multicasting
- All processes contain a global state machine (33 states)
- Centralized log handling



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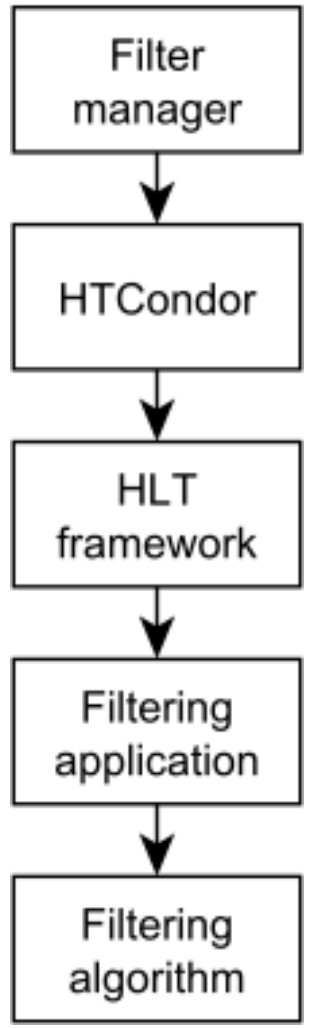
High Level Filter

- High-throughput computational and reconstruction framework written in optimized C++ and Qt
- Runs on the virtualized CERN infrastructure shared with other users → significant cost optimization
- Various algorithms for different physics programmes → modular architecture

- 2 main components:

1. **Filtering framework**
   - performs actual data analysis and reduction
   - includes additional tools for data browsing, quality monitoring
2. **Filter management system**
   - handles and manages filtering requests



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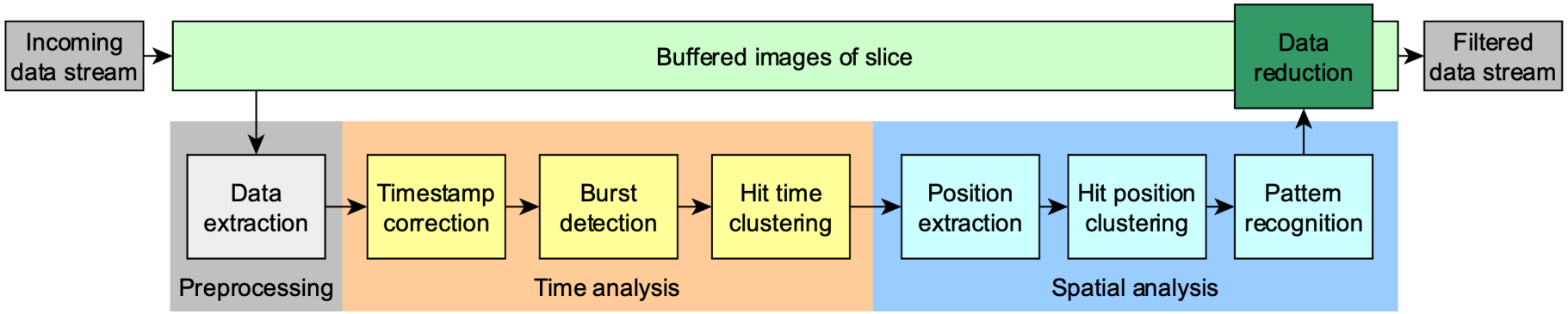
Filtering Pipeline

- Event selection and data reduction based on TPC proton detection and/or partial track reconstruction
- Initially, images are sorted into two exclusive groups:
  - **Primary images** – produced by detectors participating in filter decision
  - **Secondary images** – other images to be filtered
- We analyze primary images to make a decision using two phases:
  - **Time alignment** – processing and calibration of timestamps
  - **Spatial analysis** – analysis of hit positions to determine particle trajectory



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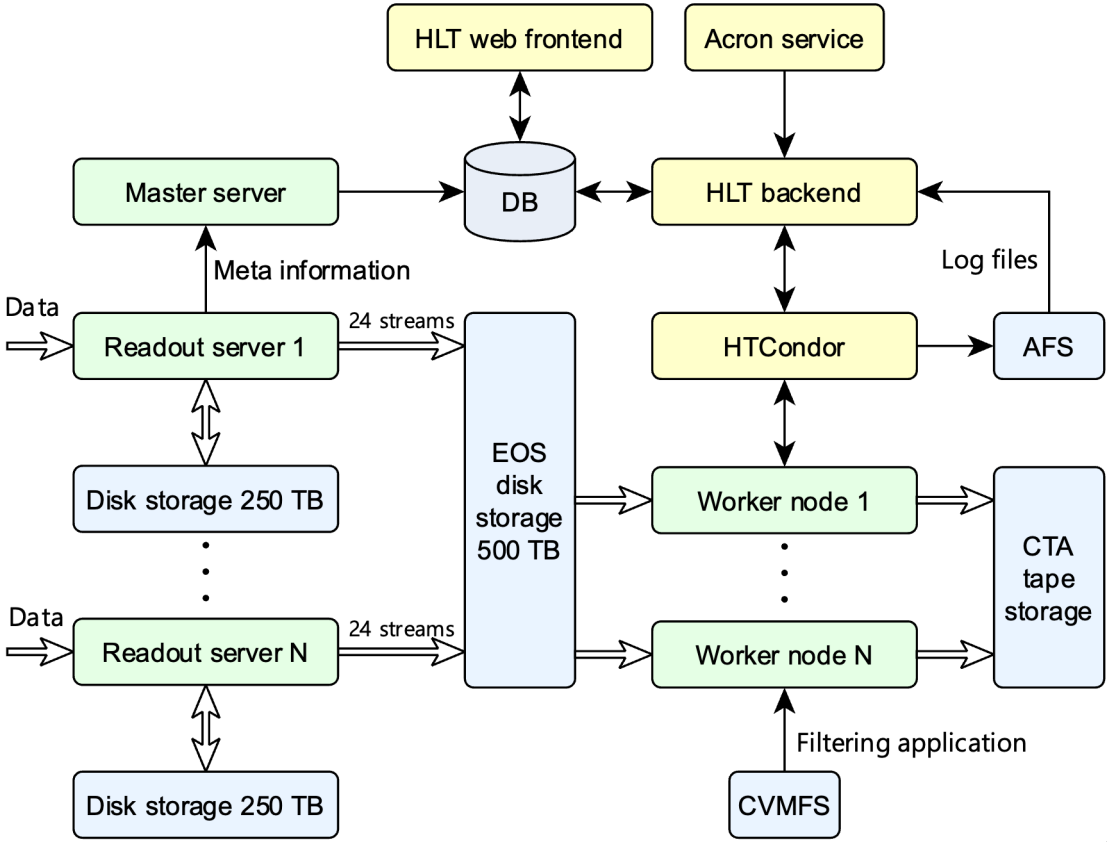
Filter Management System

- Automatic handling and monitoring of filtering jobs and tasks
- It consists of two main parts:
  - **Back-end** – based on HTCondor platform for high-performance computing
  - **Front-end** – end user web application, serving as the main user interface
- Runs in the private CERN cloud shared with other experiments (approx. 100k CPU cores)
- Filtered data files are safely written to tapes



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Summary

- FriDAQ is successful evolution of FPGA-based triggered DAQ to FPGA-based Streaming DAQ
- FPGA provides real real time solution for Data Handling : error handling, fast recovery
- Readout software decoupled from real time operation by intermediate FPGA buffers and provides average performance of 1GB/s/compute node
- High Level Filtering implemented in CERN virtualized infrastructure replacing triggering system
- The system demonstrated sustained data rate capability of 4 GB/s and fulfils requirements for PRM physics run
  - For DY program two Time-Slice Builders to be employed and number of RE engines increased to 8
  - High Level Filtering is scalable to a higher rates

- Test of FriDAQ with limited number of detectors will be performed in October 2024