Free-running data acquisition system for the AMBER experiment

V. Frolov, S. Huber, V. Jarý, I. Konorov, A. Květoň, D. Levit, J. Nový, D. Steffen, B. M. Veit, M. Virius, **M. Zemko**

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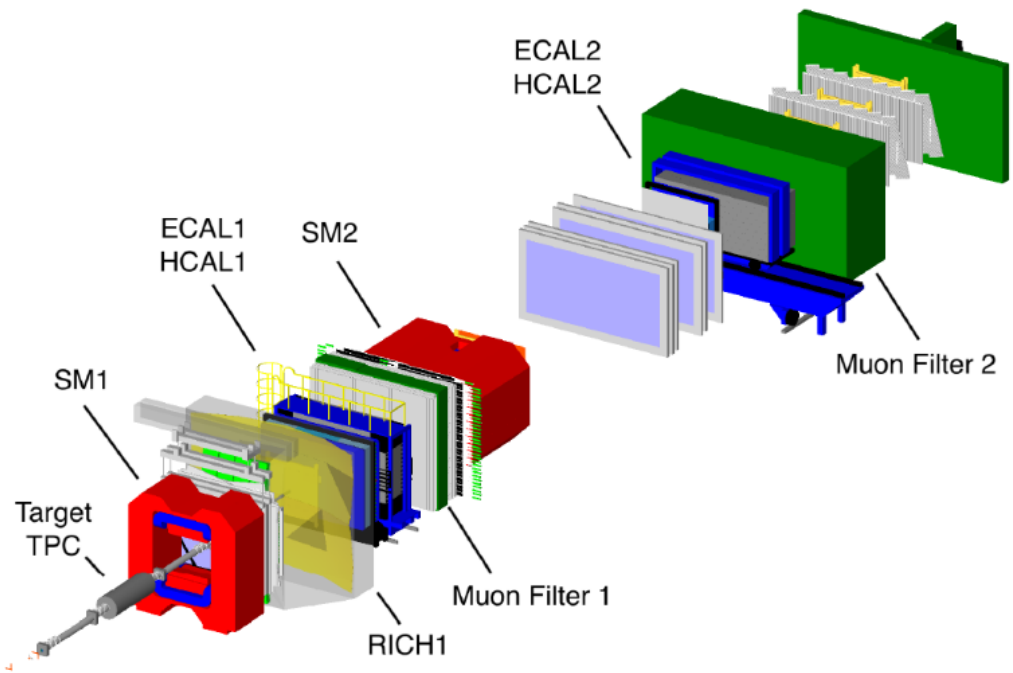
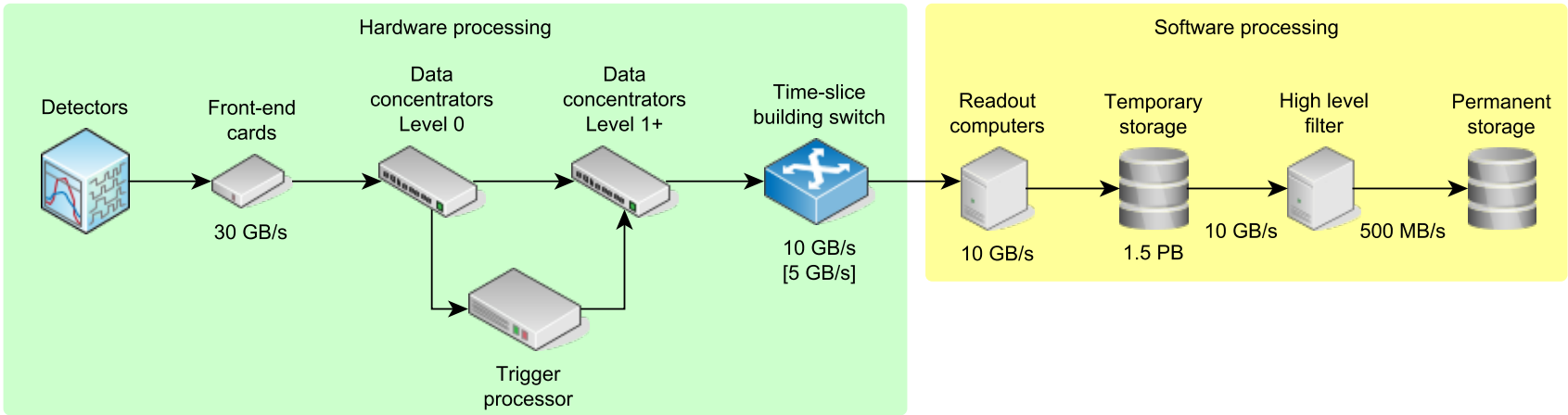
AMBER experiment



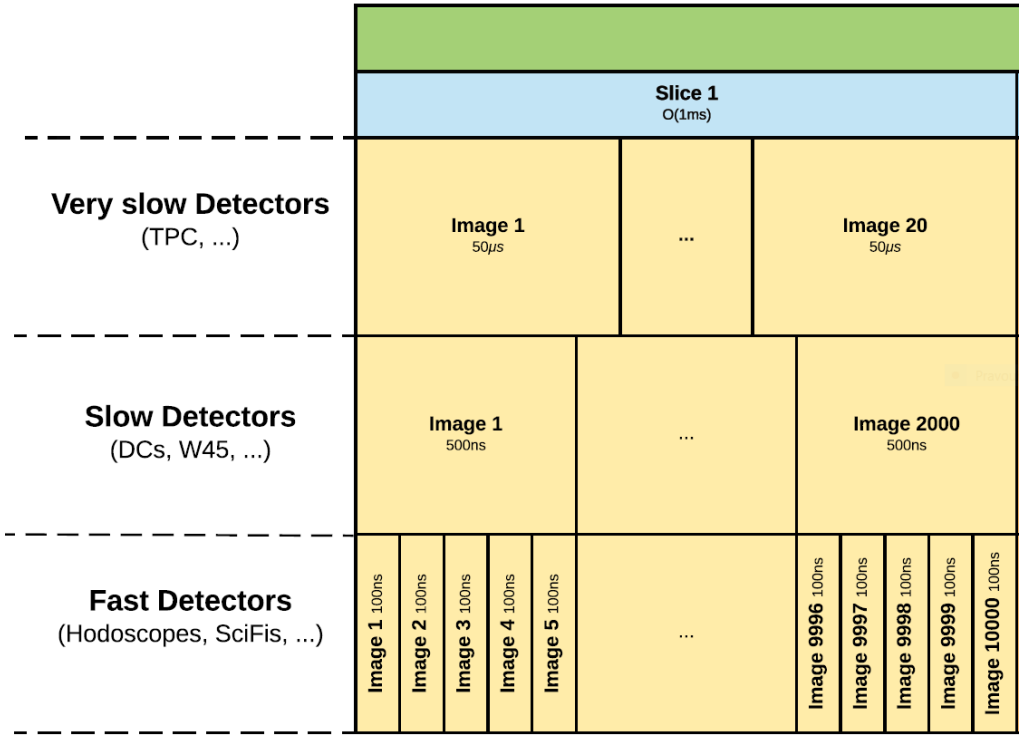
- AMBER is a fixed target experiment located at the M2 beam line of the CERN SPS
- It has been approved by the CERN research board in 2021
- Measurement of the proton radius on an active hydrogen time projection chamber (TPC) with a muon beam is one of the objectives of the experiment
- Slow detectors (as the TPC) have very long drift time (120 ms)
- They can handle only low trigger rates $\rightarrow$ need for a novel triggering approach

Free-running DAQ

- AMBER will use a trigerless data acquisition
- Continuous readout of detectors
- High-level filter is used instead of a low-level trigger logic
- General reduction scheme $\rightarrow$ any detector can participate in the filter



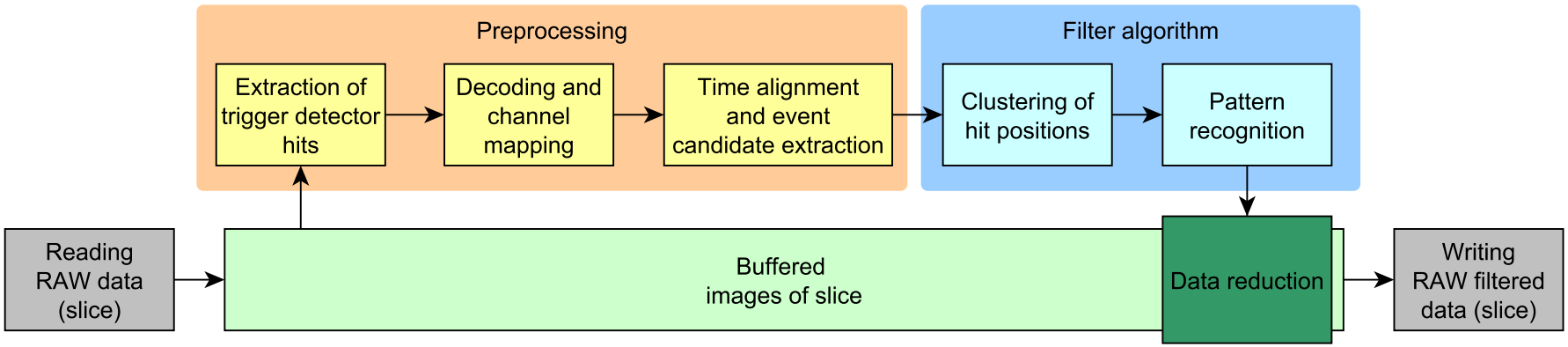
Data protocol



- Custom data protocol consisting of several layers
- Data are divided into time slices and images
- Slice contains all data within a specified time interval
- Slice is an elementary processing unit $\rightarrow$ slice-based processing

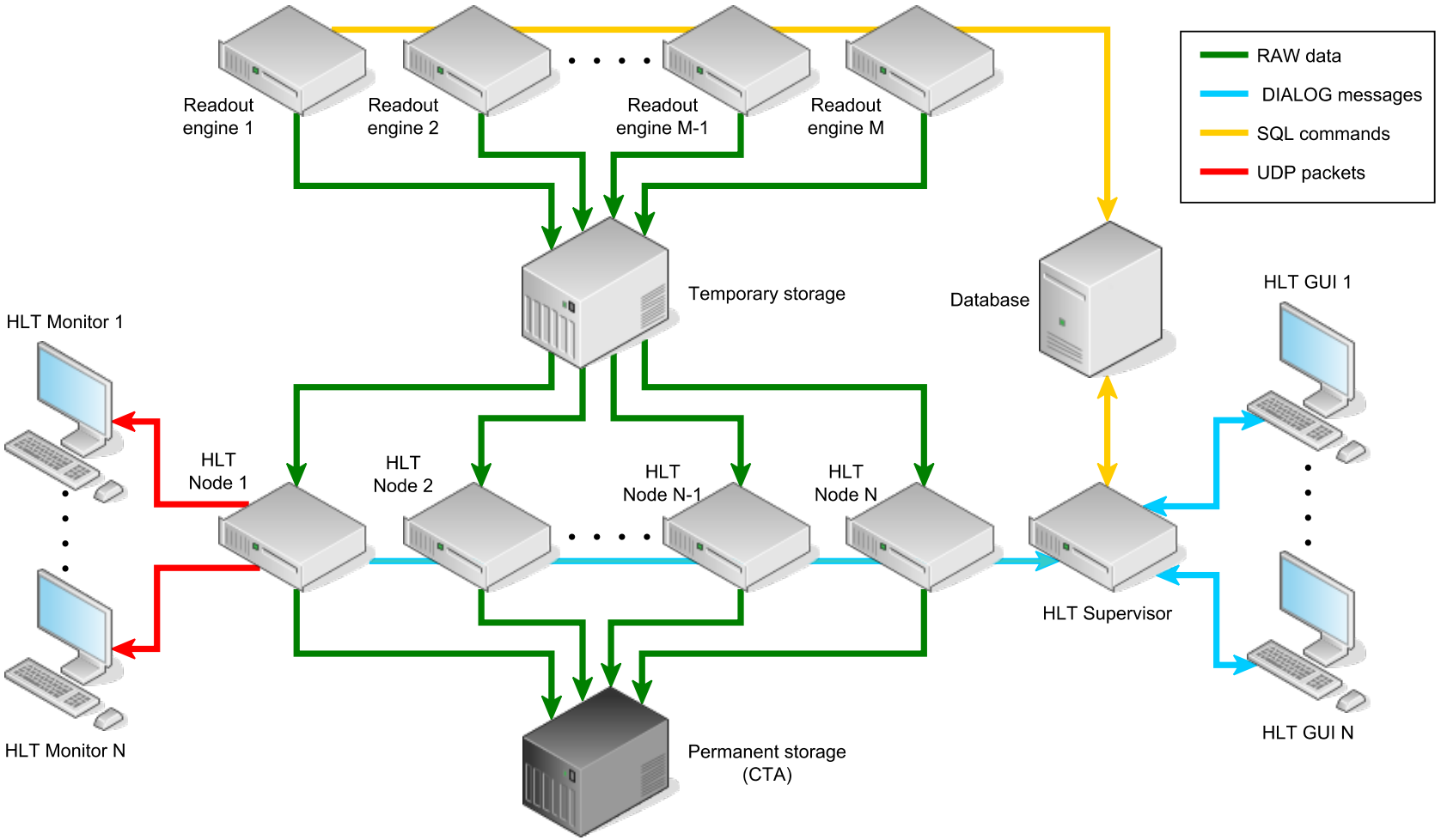
High-level filter

- High-performance distributed computational framework
- Slices are processed on many threads in parallel
- Algorithms are modular and highly optimized
- Filtration process involves several steps → filtration pipeline
- Pattern recognition is an example out of many available algorithms



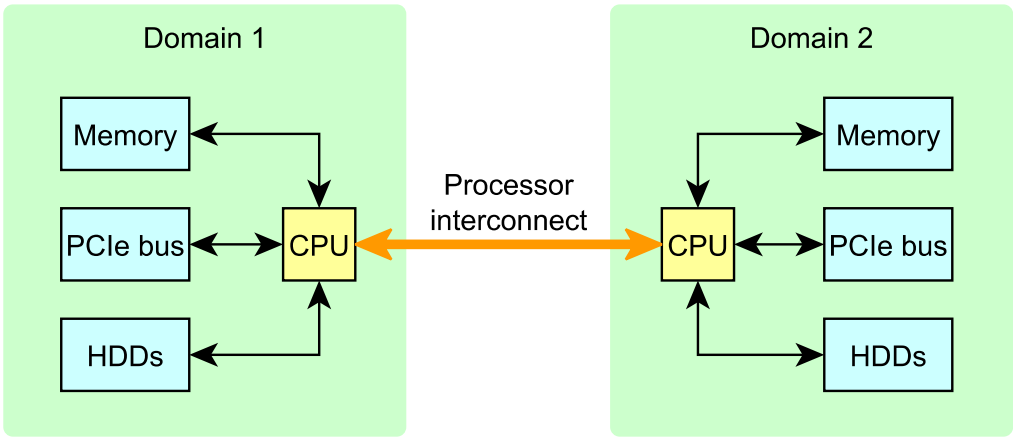
Pipeline of a single computational thread

High-level filter architecture

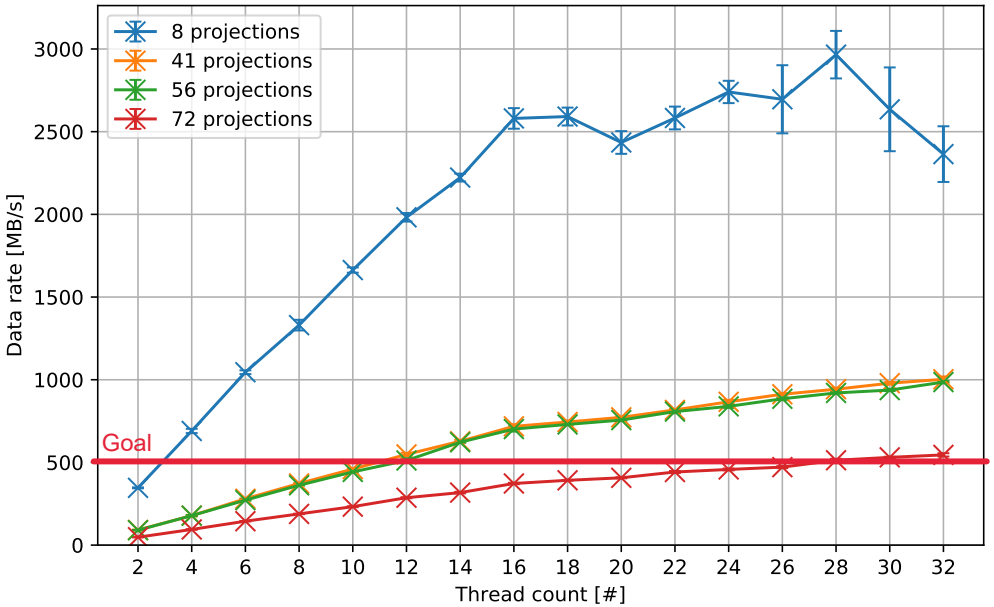


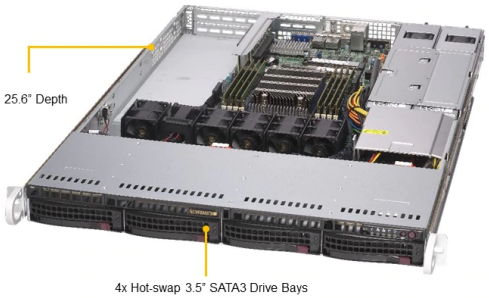
NUMA optimizations

- Servers contain several CPUs, i.e. NUMA domains
- Siloing principle is used → data are processed on the closest CPU to the memory where they are stored
- NUMA-aware processing provides significant boost in performance (approx. 75 %)



Performance benchmark





- Processing rate depends on:
  - number of threads,
  - used filter algorithm,
  - number of projections,
  - slice duration, etc.
- The filter was tested using an artificial data generator
- Test setup:
  - Supermicro A+ Server 1014S-WTRT,
  - AMD EPYC 7282 CPU (16 cores, 32 threads)
  - 128 GB DDR4 memory
  - The best trade-off between cost and performance

Summary

- We designed the free-running data acquisition system for the AMBER experiment at CERN
- The system introduced the custom data protocol and the high-level filtering framework replacing the low-level trigger
- Performance of the filter has been measured and discussed
- The system will be tested in the upcoming pilot run at the end of 2021 with the subsequent data taking in 2022

Thank you for your attention