Streaming readout:
Software aspects

- EIC Computing
- EIC Computing and streaming readout

- Streaming readout software

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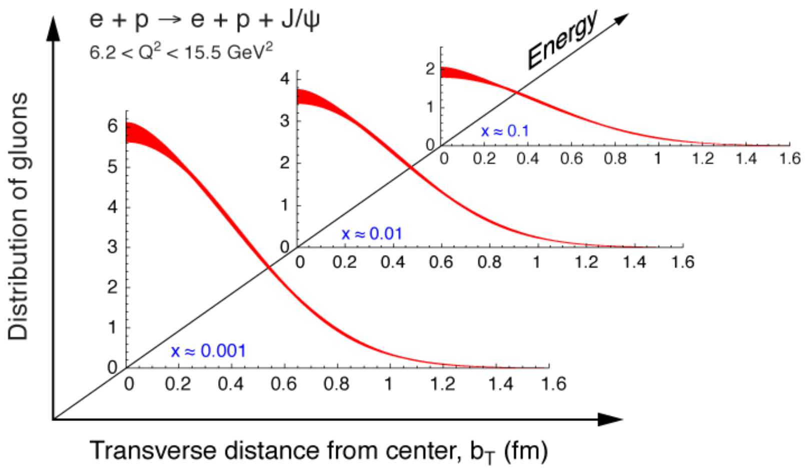
Computing challenges in Nuclear Physics

NP experiments driven by beam intensity, polarization, exquisite control of background and systematics

multi-dimensional challenges

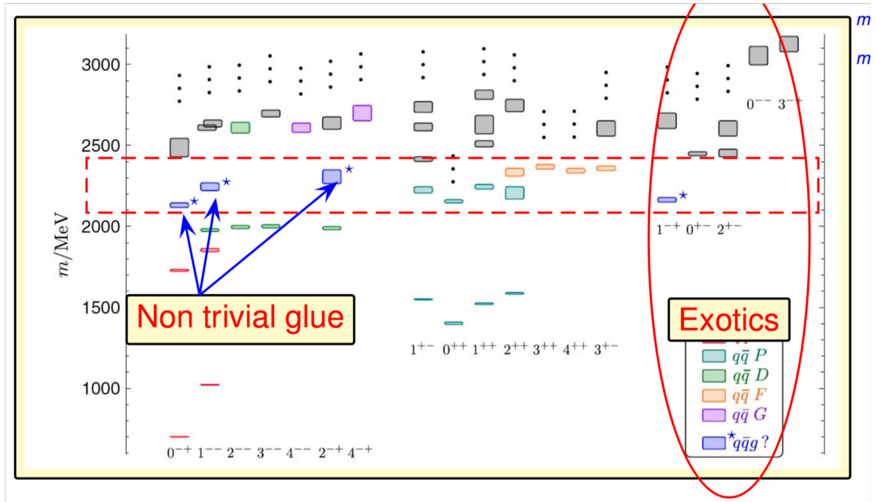
example 3D imaging of quarks and gluons



high statistics in five or more dimensions and multiple particles

multiple channel challenges

example discovery search of gluon-based exotic particles (PWA, 1000s of waves)



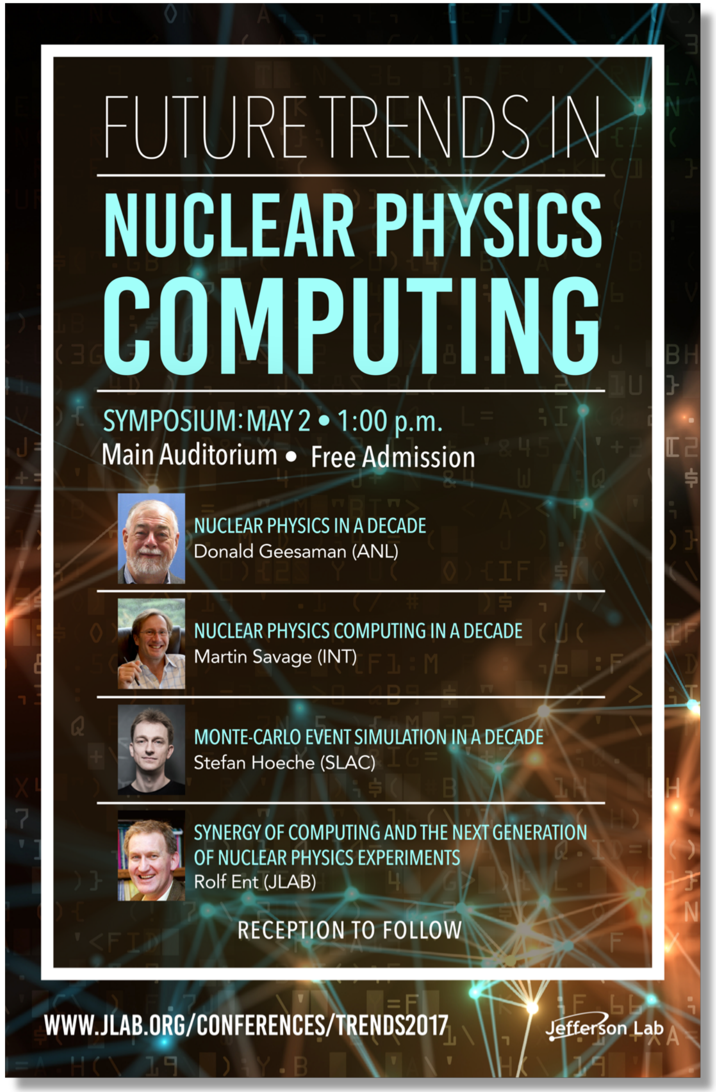
strongly iterative analysis for reliable, model-independent analysis

EIC Computing

"The purpose of computing is insight, not numbers."

Richard Hamming (1962)

Future Trends in Nuclear Physics Computing



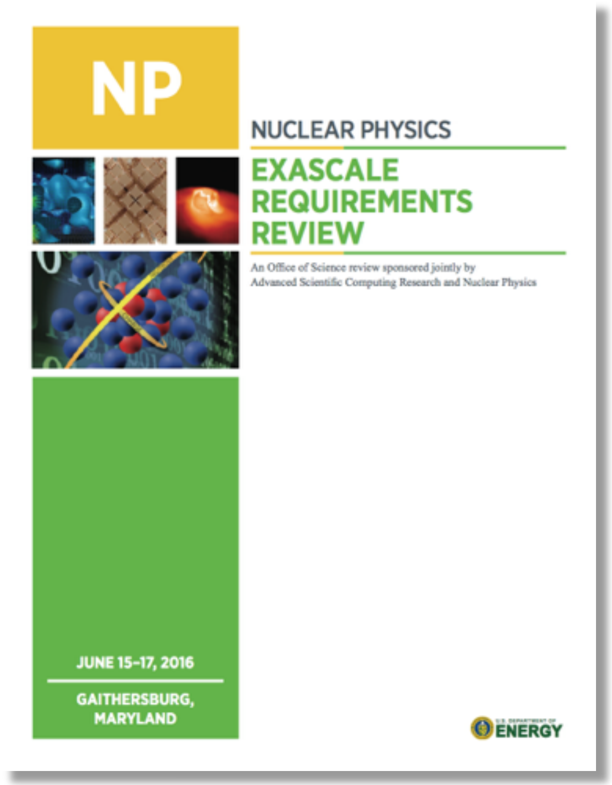
Donald Geesaman (ANL, former NSAC Chair) *"It will be* ***joint progress of theory and experiment*** *that moves us forward, not in one side alone"*

Martin Savage (INT) *"The next decade will be looked back upon as a* ***truly astonishing period in NP*** *and in our understanding of fundamental aspects of nature. This will be* ***made possible by advances in scientific computing*** *and in how the NP community organizes and collaborates, and how DOE and NSF supports this, to take full advantage of these advances."*

Implications of Exascale Computing

Past efforts in lattice QCD in collaboration with industry have driven development of new computing paradigms that benefit large scale computation. These capabilities underpin many important scientific challenges, e.g. studying climate and heat transport over the Earth.

The EIC will be the facility in the era of high precision QCD and the first NP facility in the **era of Exascale Computing**. This will affect the interplay of experiment, simulations, and theory profoundly and result in a new computing paradigm that can be applied to other fields of science and industry.



Petascale-capable systems at the beamline

- **unprecedented compute-detector integration**, extending work at LHCb
- requires fundamentally new and different algorithms
- computing model with machine learning at the trigger level and a compute-detector integration to deliver **analysis-ready data from the DAQ system**:
  - responsive calibrations in real time
  - real-time event reconstruction
  - physics analysis in real time

A similar approach would allow **accelerator operations** to use real-time simulations and artificial intelligence / machine learning over operational parameters to tune the machine for performance.

Towards the next generation research model in Nuclear Physics

NP research model not changed for over 30 years
Science & Industry remarkable advances in computing & microelectronics

goal evolve & develop **NP research model** based on these advances

rethink

how measurements are compared to theory
- examine capabilities of event level analysis (**ELA**) taking the multi-dimensional challenges of NP fully into account

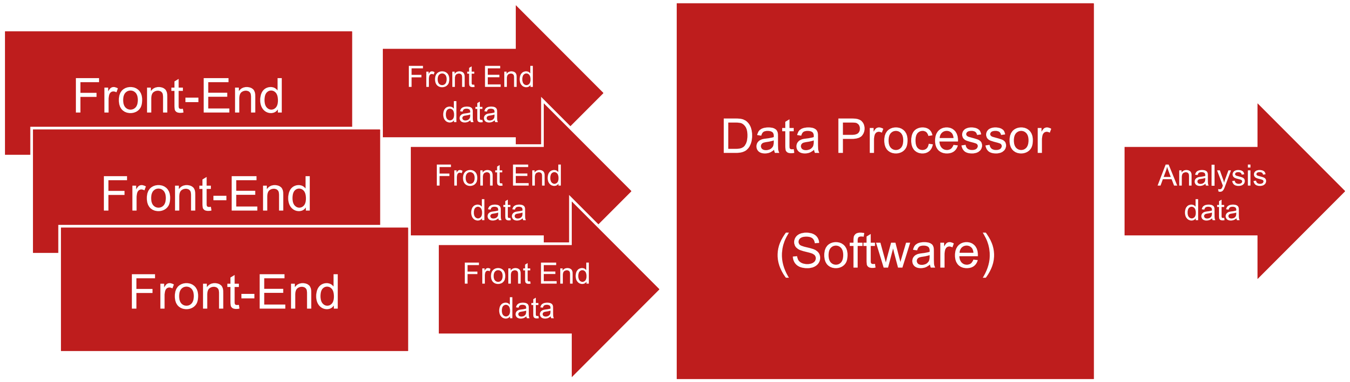
how experimental data are handled
- identify ways to speed up analysis in the context of **ELA**

how we read out detectors and assemble detector data
- investigate capabilities of streaming readout in view of **ELA**

Streaming Readout

Software aspects

Streaming readout and real-time processing



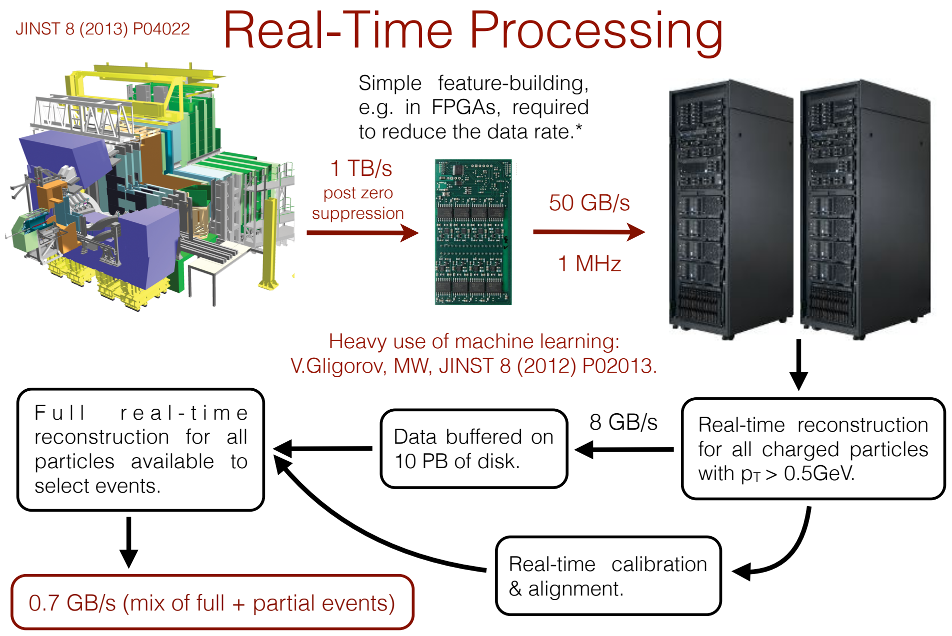
Data Processor

- assembles data (into events)
- outputs data suitable for final analysis (**Analysis data**)

Features (among others)

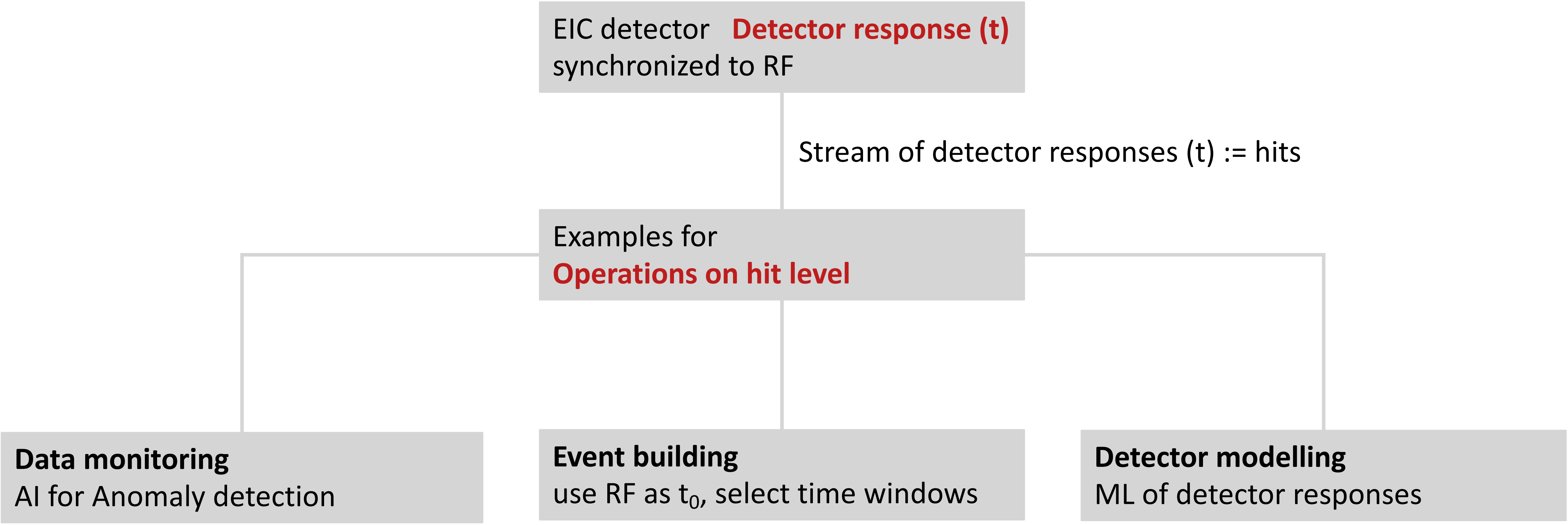
- ideal for AI / ML
- automated calibration and alignment
- (partial or) full event reconstruction
- event selection and/or labeling into analysis streams
- automated anomaly detection
- responsive detectors (conscious experiment)

LHCb Example



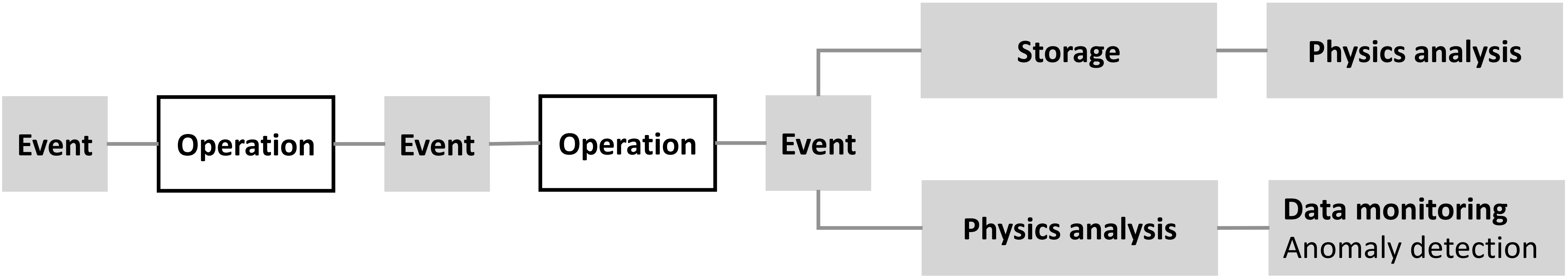
*LHCb will move to a triggerless-readout system for LHC Run 3 (2021-2023), and process 5 TB/s in real time on the CPU farm.

Streaming readout on hit level



Streaming readout on event level

Stream of events



Type of operations (examples)

Align | **Calibrate** | **Filter** | **Tracking** | **PID**

implemented in various languages

Alignment and calibration obtained from set of events

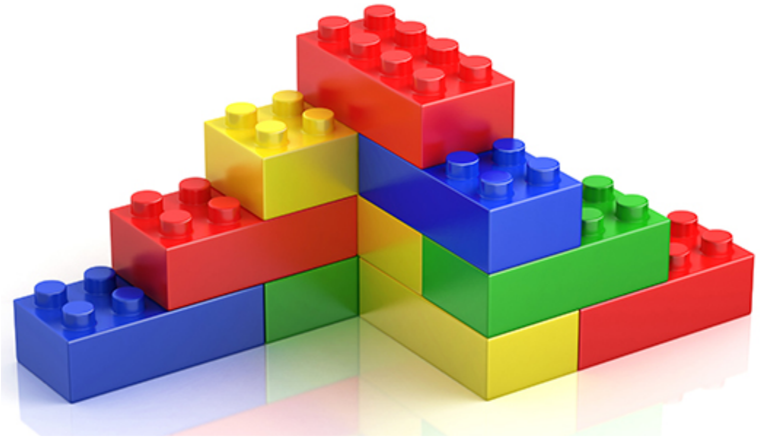
Filter for data quality
Selection of events according to type (**trigger**)

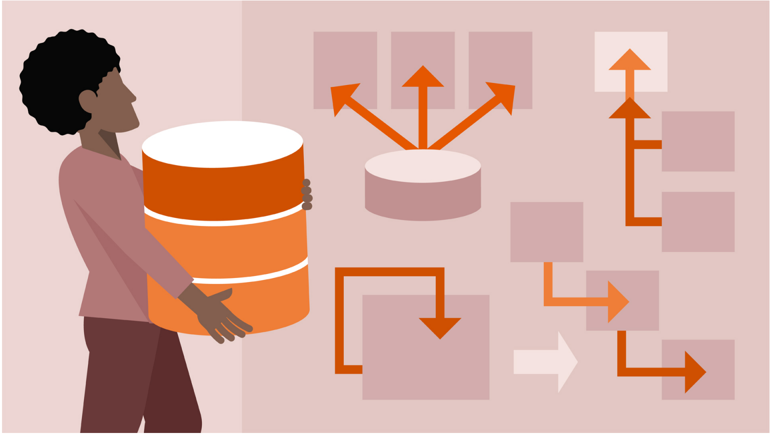
Streaming readout software requirements

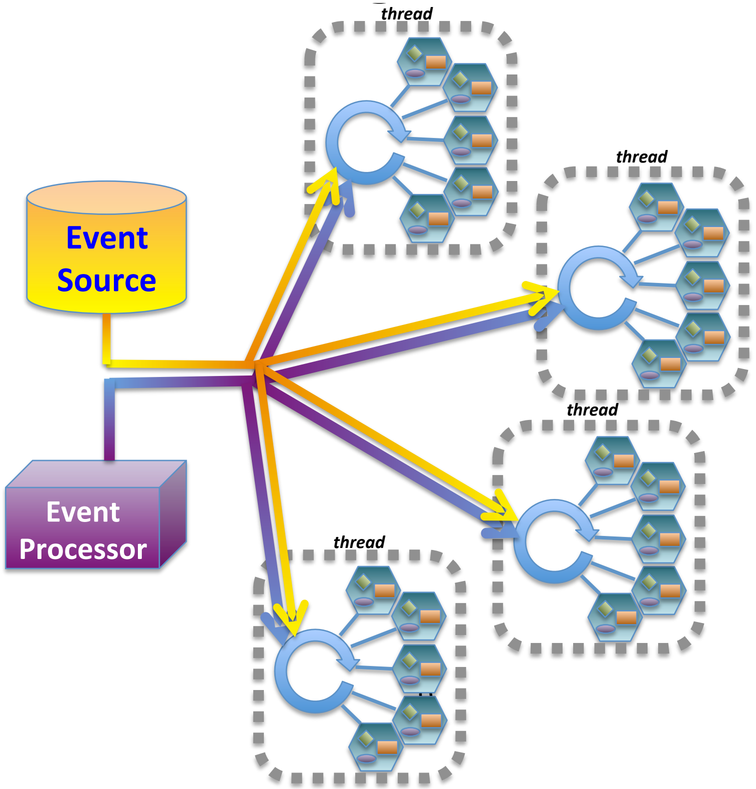
Modular design

Common data model (conceptual logical and physical), instead of common framework

Common parallelizer







Streaming readout: Software aspects

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Discussion about possible next steps

- agree on requirements
- implement prototype system in the next months
- evaluate prototype system, show first results in May