DAQ Architecture

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DAQ Design Review

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Introduction

- From DUNE DAQ to ProtoDUNE DAQ
- External interfaces and constraints
- DAQ logical architecture
- Main DAQ components and their interaction
- Risks & timescales
- Summary

DUNE Trigger and DAQ Requirements

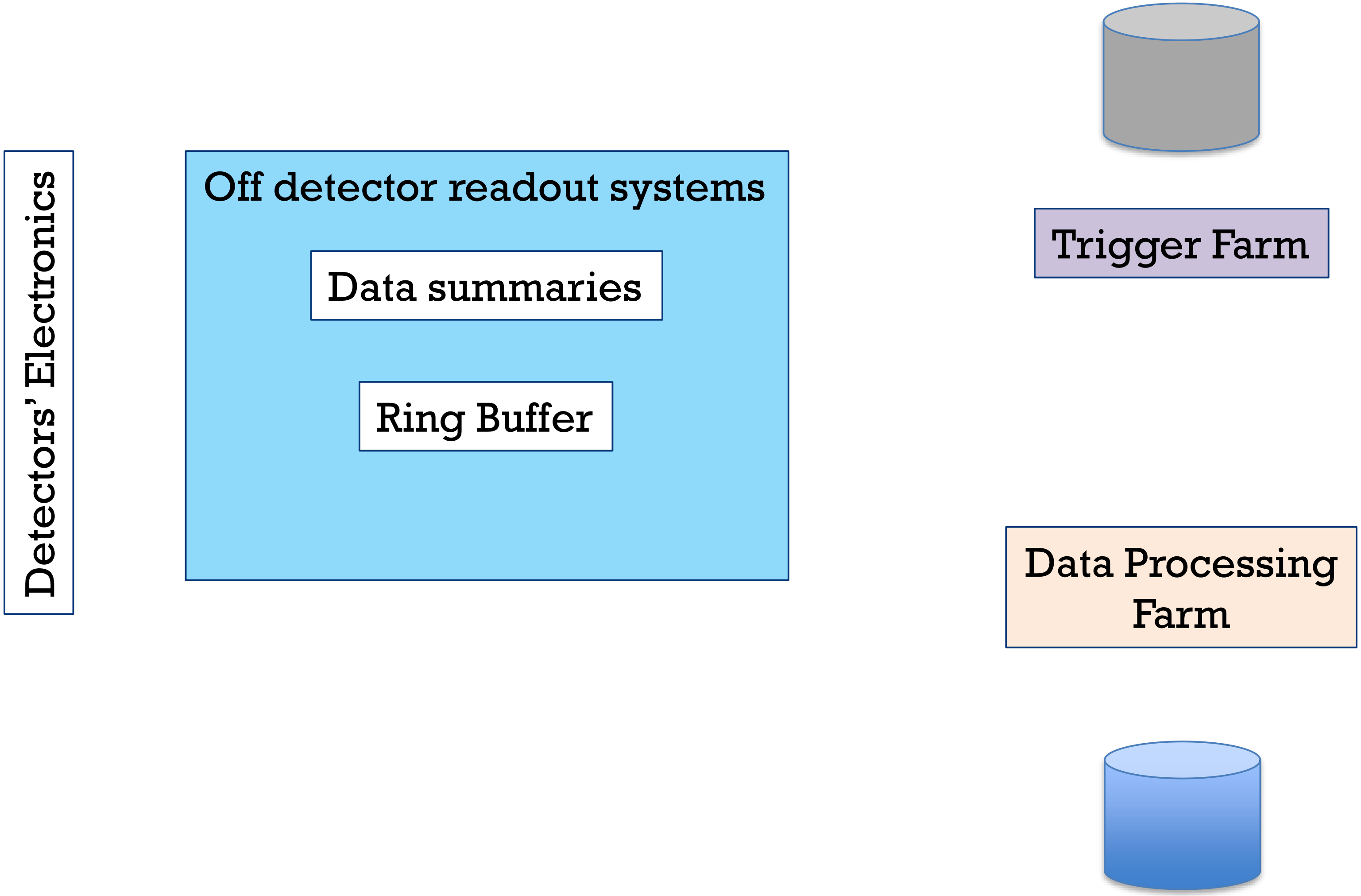
- Very high up-time (>99%)
- Collect beam+atmospheric neutrinos as well as proton decay candidates (E_{tot}>100 MeV) with high resolution and no dead-time
- Collect interactions with E_{tot}<100 MeV with a limited zero-suppression loss
- Be able to trigger on beam pulses irrespective of the deposited energy
- Collect data with the most favorable zero-suppression possible over >10 s periods (supernova trigger)
- + all DAQ ancillaries (event building, calibration, control, …)

Difficult to satisfy so varied requirements!

Main Trigger & DAQ Features

- The DUNE DAQ is designed combining ideas of
  - Continuous readout systems
  - Triggered systems
- No dead time achieved by streaming the data summaries into a trigger farm and keeping raw data in ring buffers on readout system during decision making
  - HE events:
    - trigger request sent to readout system and data fully readout, built, processed, stored
  - LE events:
    - Trigger stream of hits are useful for SNB analysis and will be buffered/stored as long as possible (ring buffer of disk files)
    - When a SNB is noticed in the trigger farm, it directs to also extract data from ring buffers

Sketch of the DUNE DAQ



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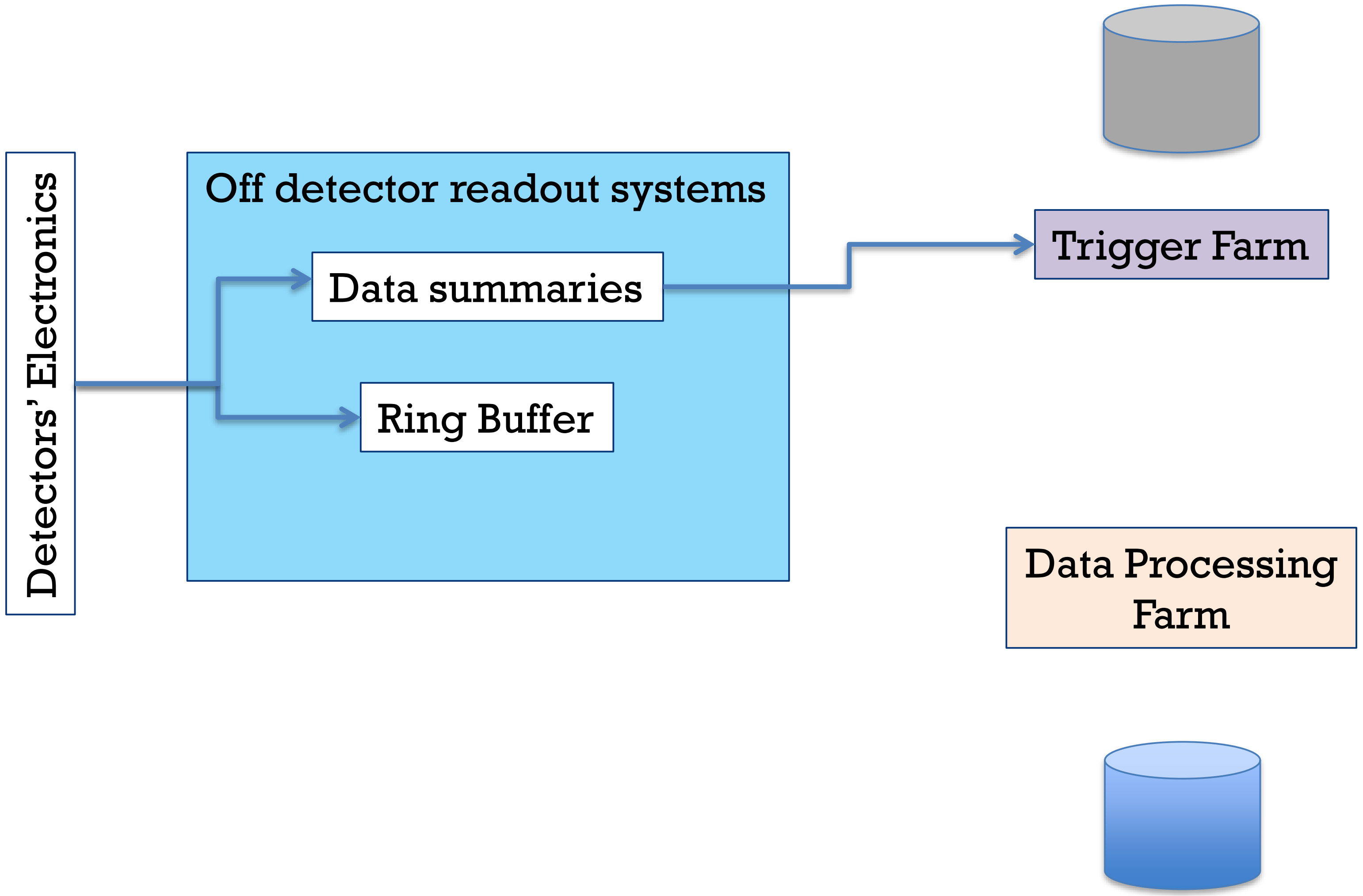

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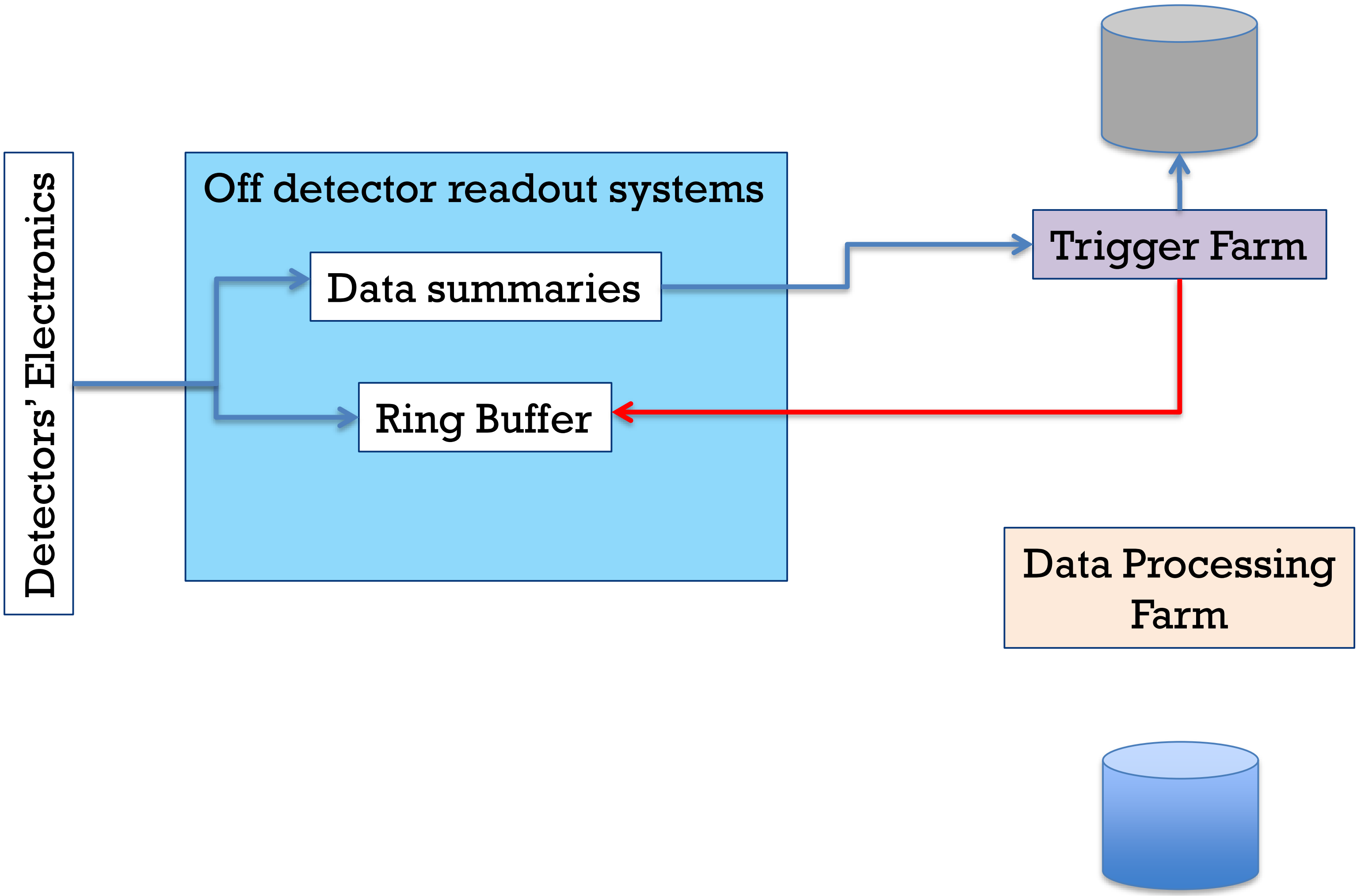

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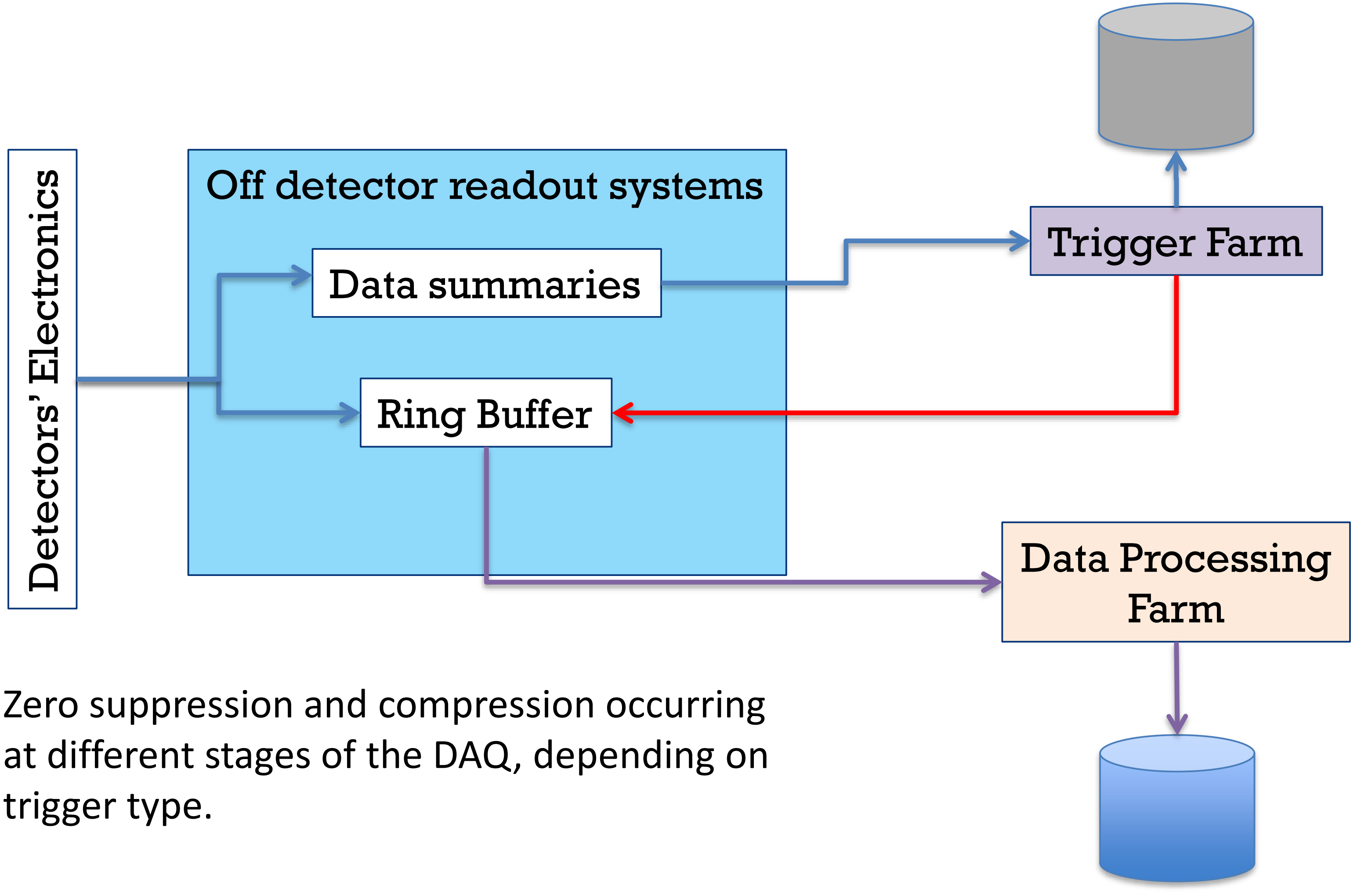
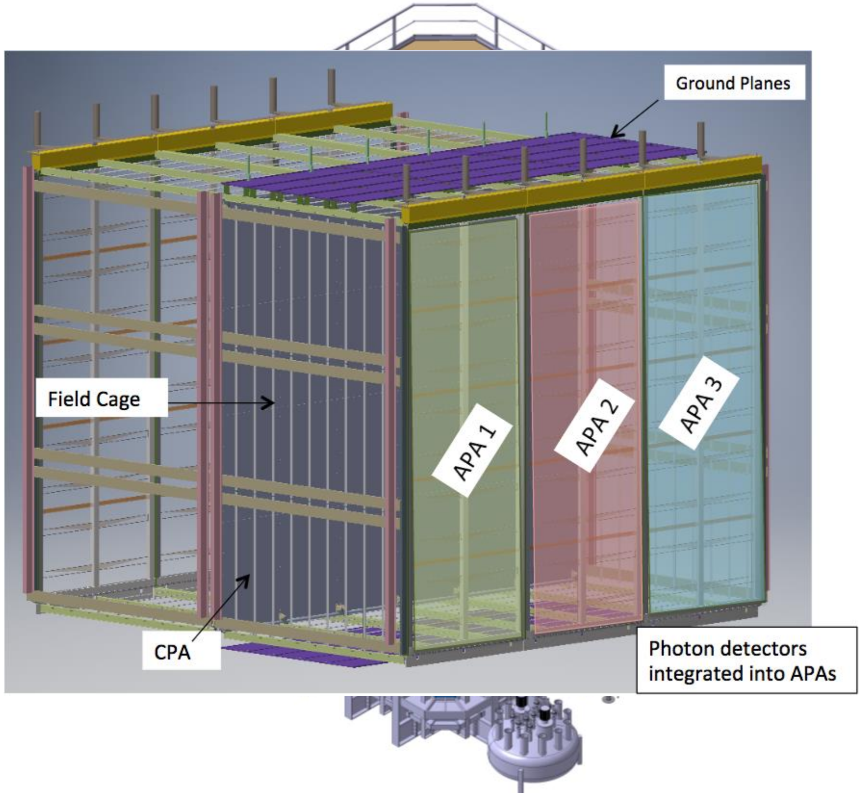


Zero suppression and compression occurring at different stages of the DAQ, depending on trigger type.

From DUNE to ProtoDUNE SP

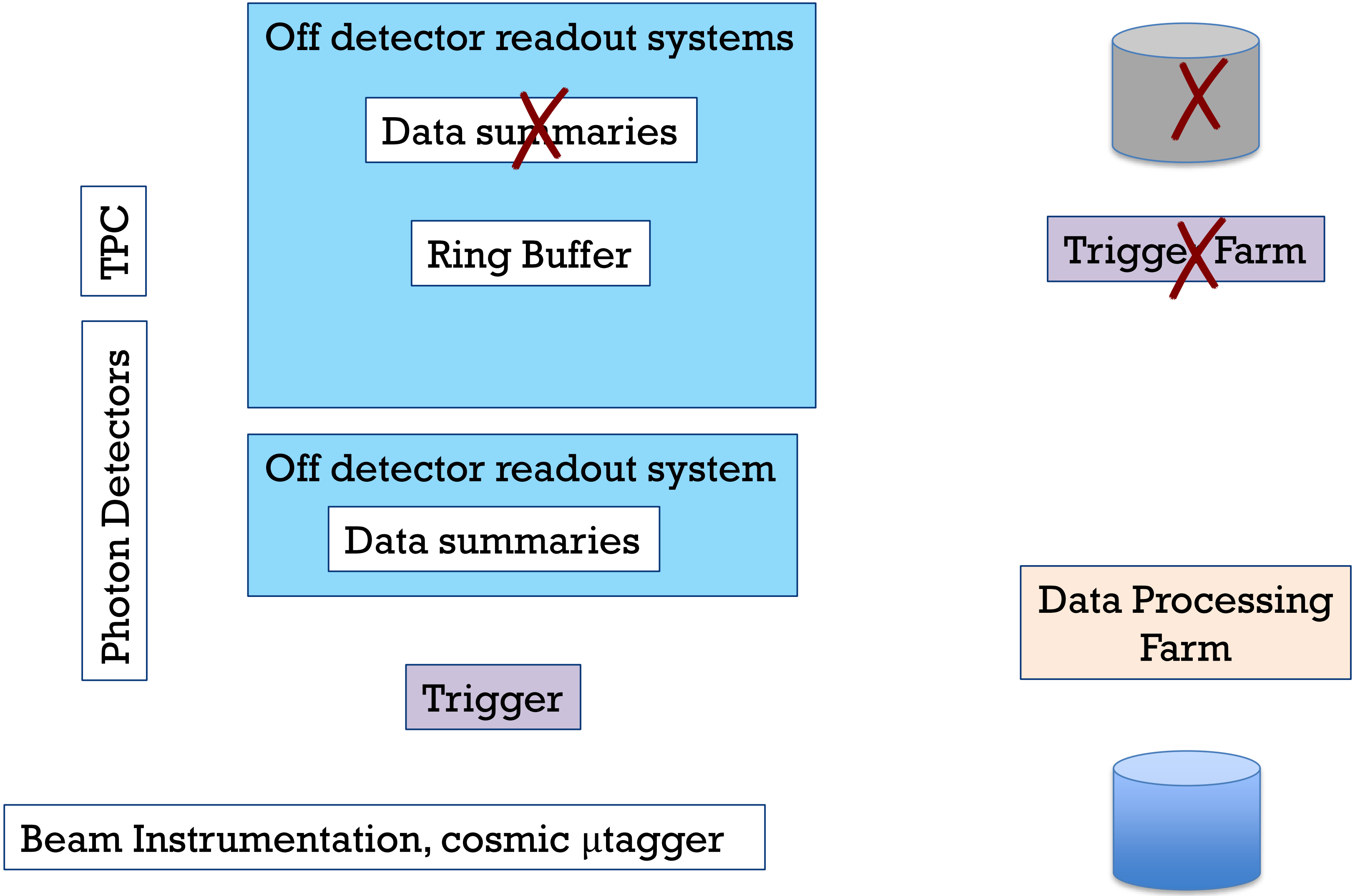
- Smaller
  - 0.77 kt vs 10 kt LAr per DUNE module; only 1 module
  - Less components but each component is full-scale pre-production module; only 6 APA
- On surface
  - Higher flux of cosmic ray particles
- On SPS beam line
  - **charged particles** 0.5 – 7 Gev/c
- The **rate and volume of data** produced by these detectors will be **substantial** (*O*(Tb/s))



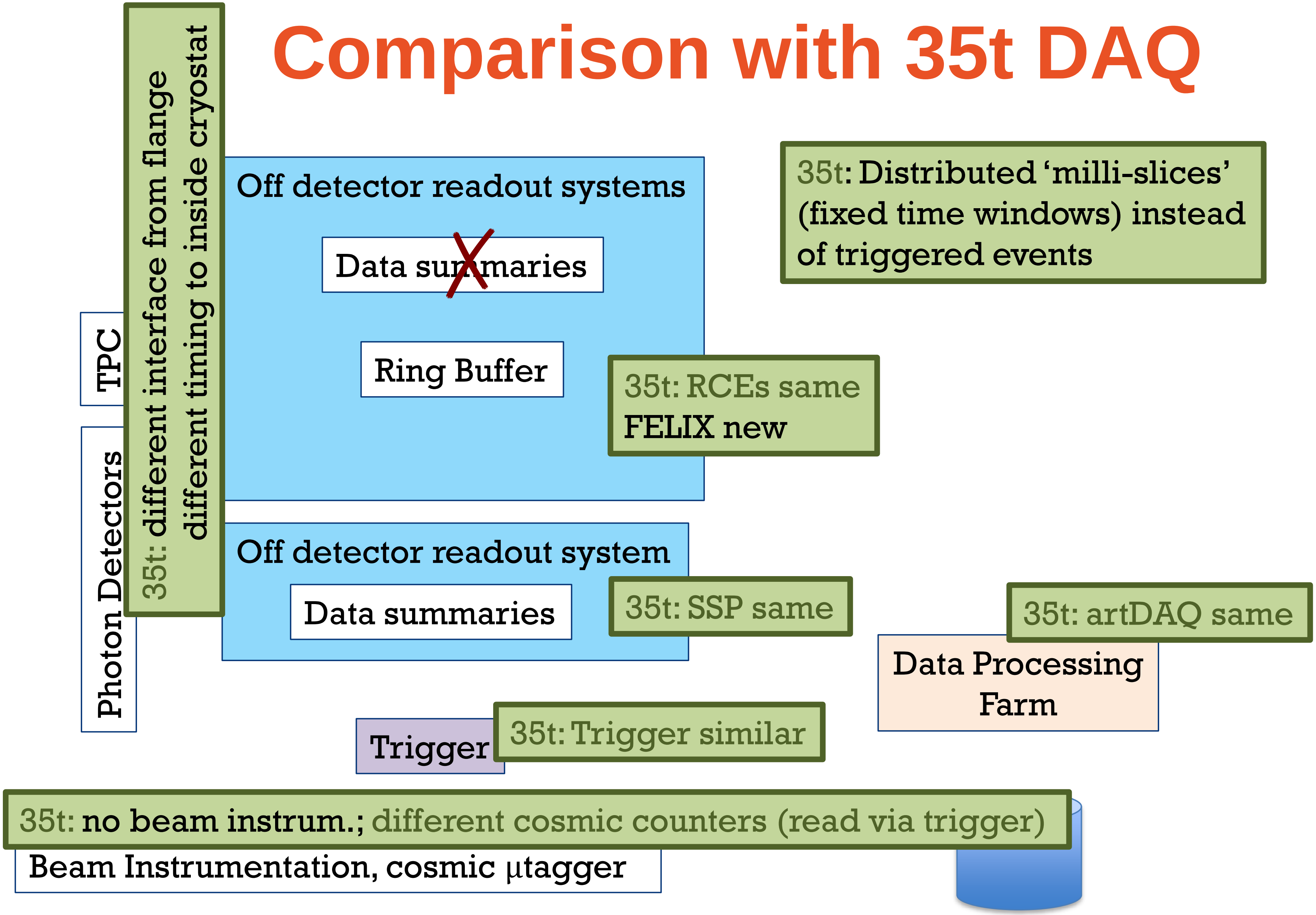
The ProtoDUNE DAQ Environment

- 6 Anode Plane Assemblies (APA)
  - TPC ~ 430 Gb/s (15kCh @ 2 MHz)
  - Photon Detectors ~ 1 Gb/s (720 SiPM/ 240 ch, headers only)
- Beam instrumentation (BI) & Cosmic Rays Tagger (CRT) detectors
  - Negligible throughput
- SPS super cycle structure: 2 x 4.8 s bursts in 48 s
  - Full readout -> ~85 Gb/s
  - Too much for DAQ as well as for storage!
- Introduction of a simple trigger to mitigate data flow
  - Retain full readout off detector
- Use of lossless data reduction techniques

From DUNE to ProtoDUNE DAQ



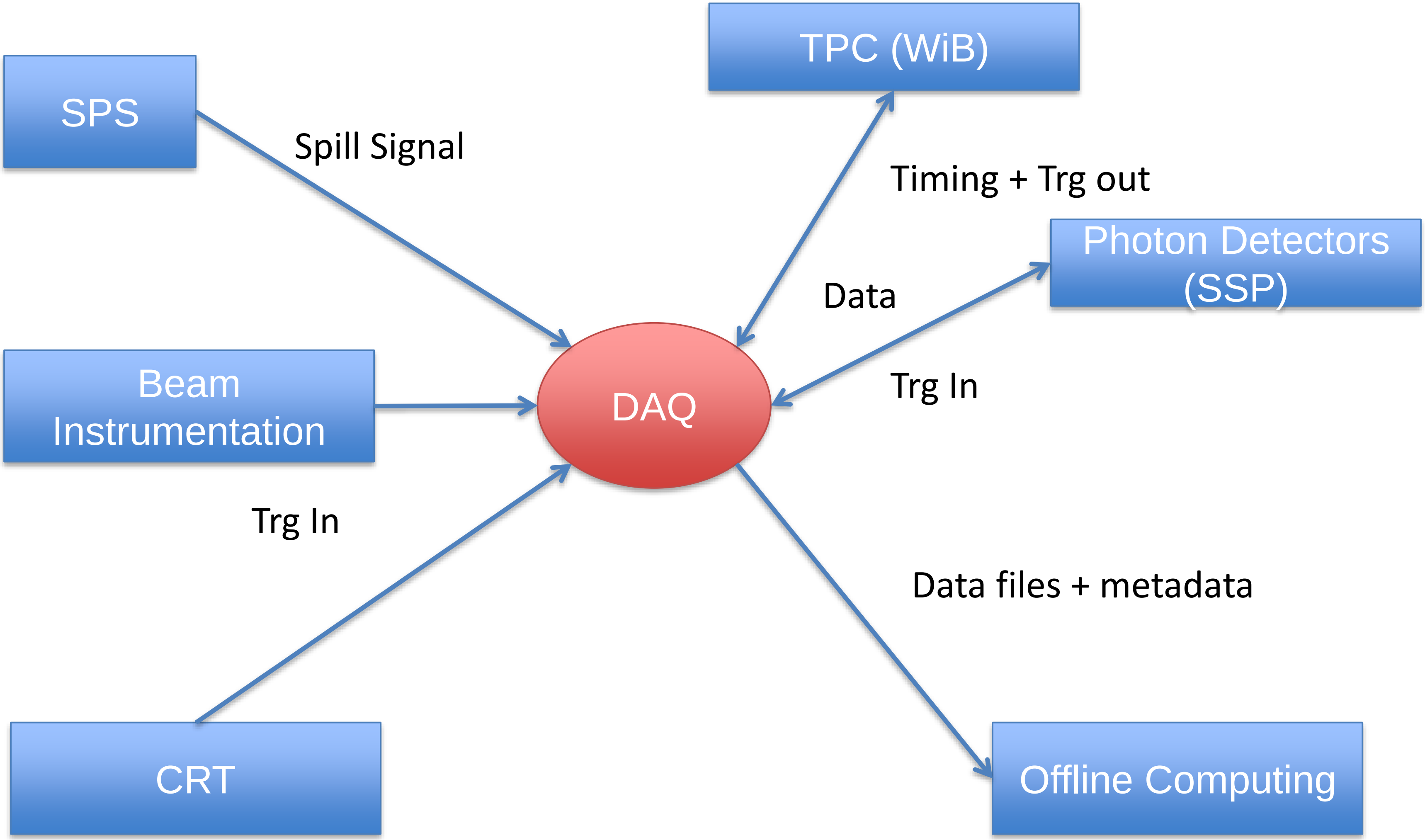
Comparison with 35t DAQ



Scope of the ProtoDUNE DAQ

- Provide service to the detector/electronics validation
  - Take and store data safely and efficiently
  - Reuse existing components, experience, …
- Evaluate DAQ solutions and technologies that may be suitable for DUNE
  - TPC readout system
  - Data storage
  - Dataflow software (hardware fully COTs servers + switches)
  - Control and monitoring software

Interfaces

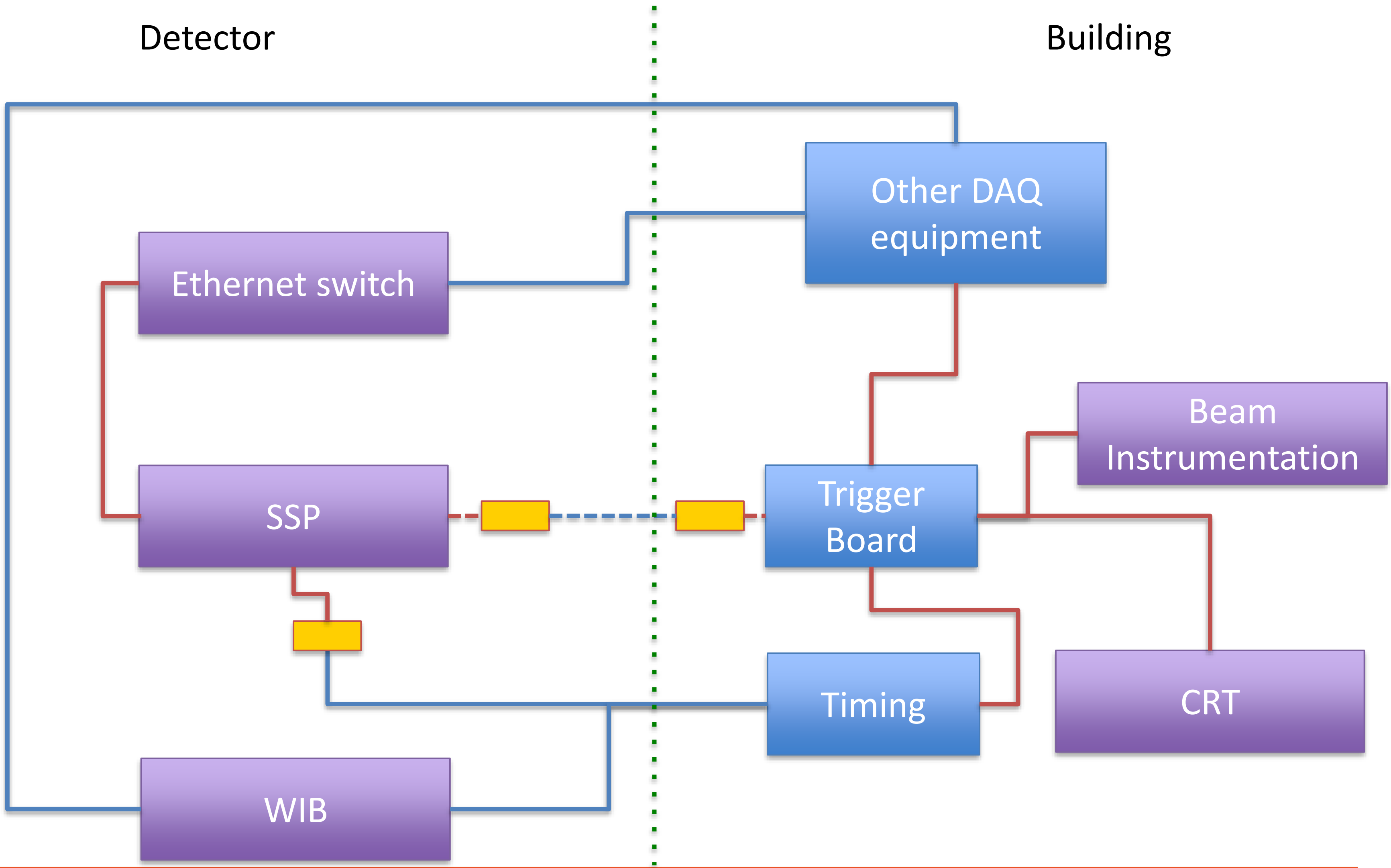


SPS
Spill Signal
TPC (WiB)
Timing + Trg out
Photon Detectors (SSP)
Data
Beam Instrumentation
DAQ
Trg In
Trg In
Data files + metadata
CRT
Offline Computing

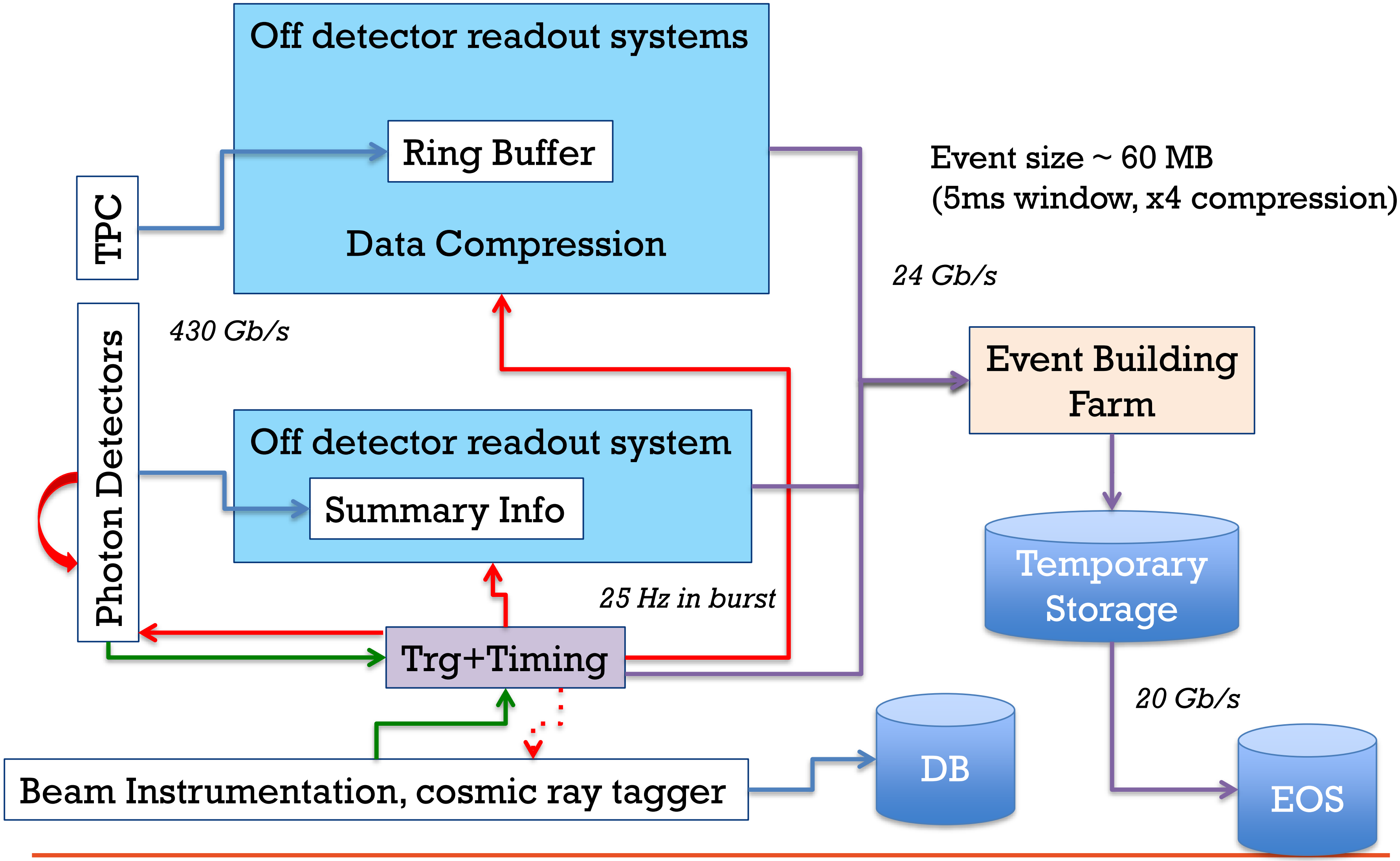
Constraints

- Decoupling
  - The DAQ needs to ensure a proper decoupling between the “online” and the “offline” worlds
    - Sufficient storage space for raw data files on the DAQ side should be available to store up to 3 days worth of data taking.
- Grounding
  - Try to keep all DAQ equipment on building ground
  - Any link connecting the detector must be isolated -> optical
    - Direct impact on readout, timing, trigger

Grounding Isolation



The ProtoDUNE DAQ



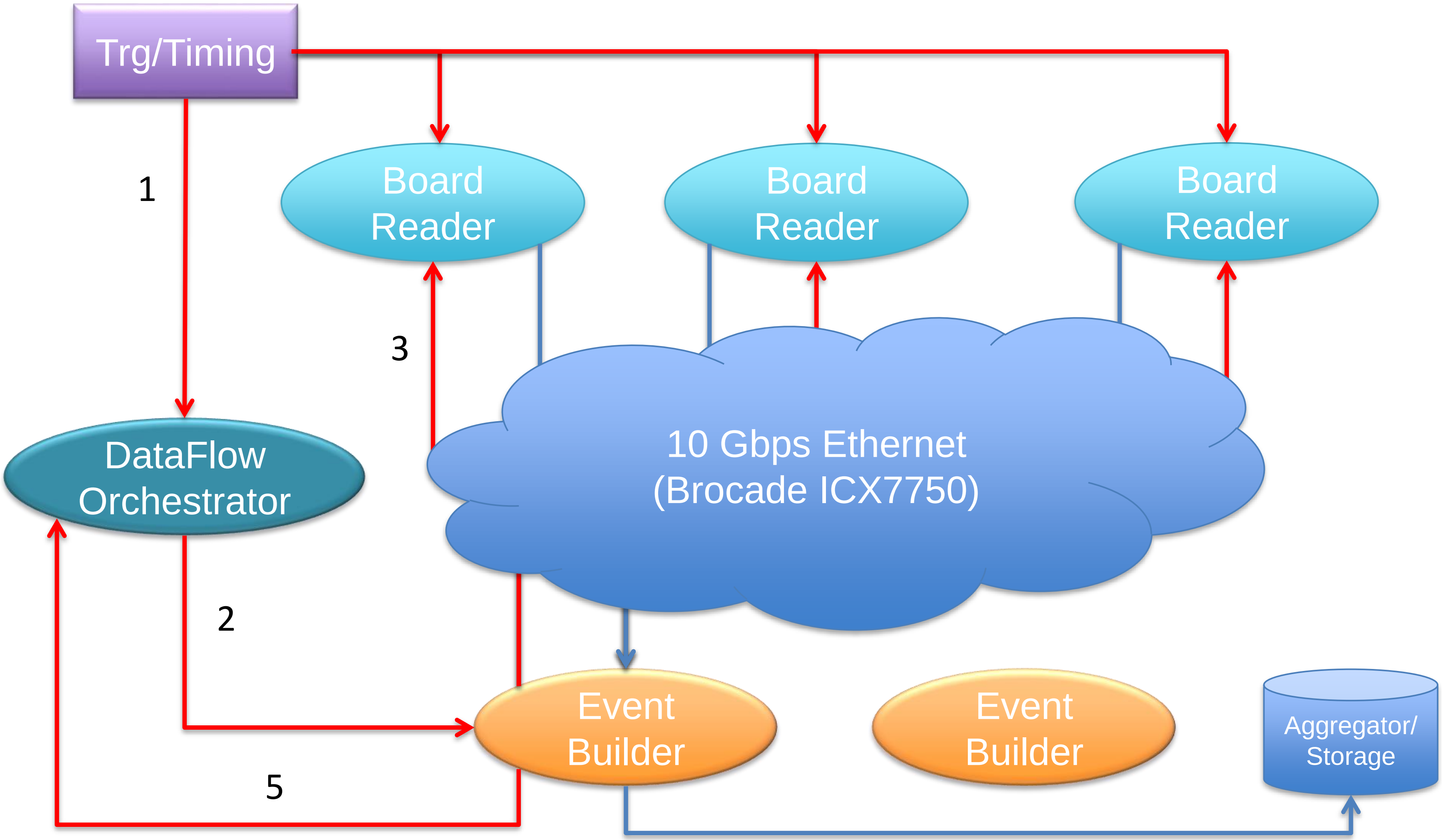
ProtoDUNE Software

- Dataflow software is based on artDAQ developed at FNAL
  - Customizable “Board Reader” application
  - Event building
  - Dispatching to monitoring apps
  - Aggregation
  - Storage
- Control, operational monitoring, graphical UIs
  - Joint COntrols Project (JCOP) toolkit developed originally for LHC experiments
  - Uniform interface also for detector control and safety systems
- Software approach
  - Minimize the risks by relying on existing frameworks
  - Focus effort only on experiment specific needs

Readout of External Systems

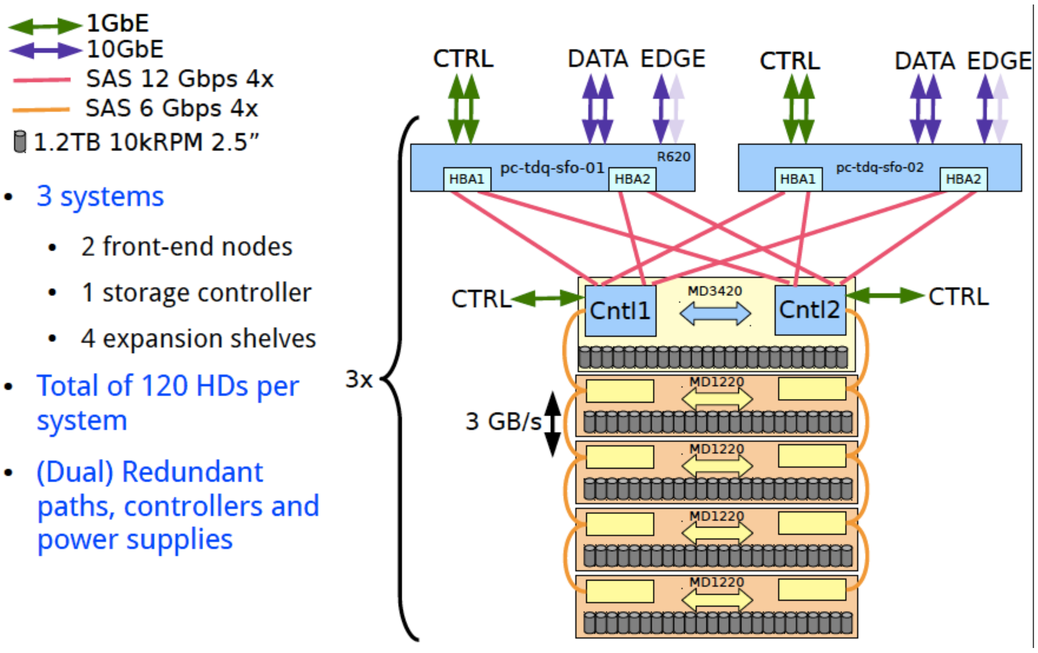
- PDS
  - On detector electronics already does data reduction and sends data over TCP/IP (-> DAQ starts at Board Reader)
- TPC (point-to-point optical links from WiB)
  - 2 solutions being implemented
    - Baseline: ATCA platform from SLAC
    - Prototype alternative: ATLAS FELIX + network connected PCs
  - 5 APAs will be readout via ATCA boards (12800 ch), 1 APA (2560 ch) via FELIXs
    - 2 firmware variants in electronics (WiB)
    - API for transparently treating data at software level
    - Provision to read out all system with ATCA
- From a software point of view the interface towards the event builder is the Board Reader application for all readout systems

ProtoDUNE Data Flow



DAQ Temporary Storage

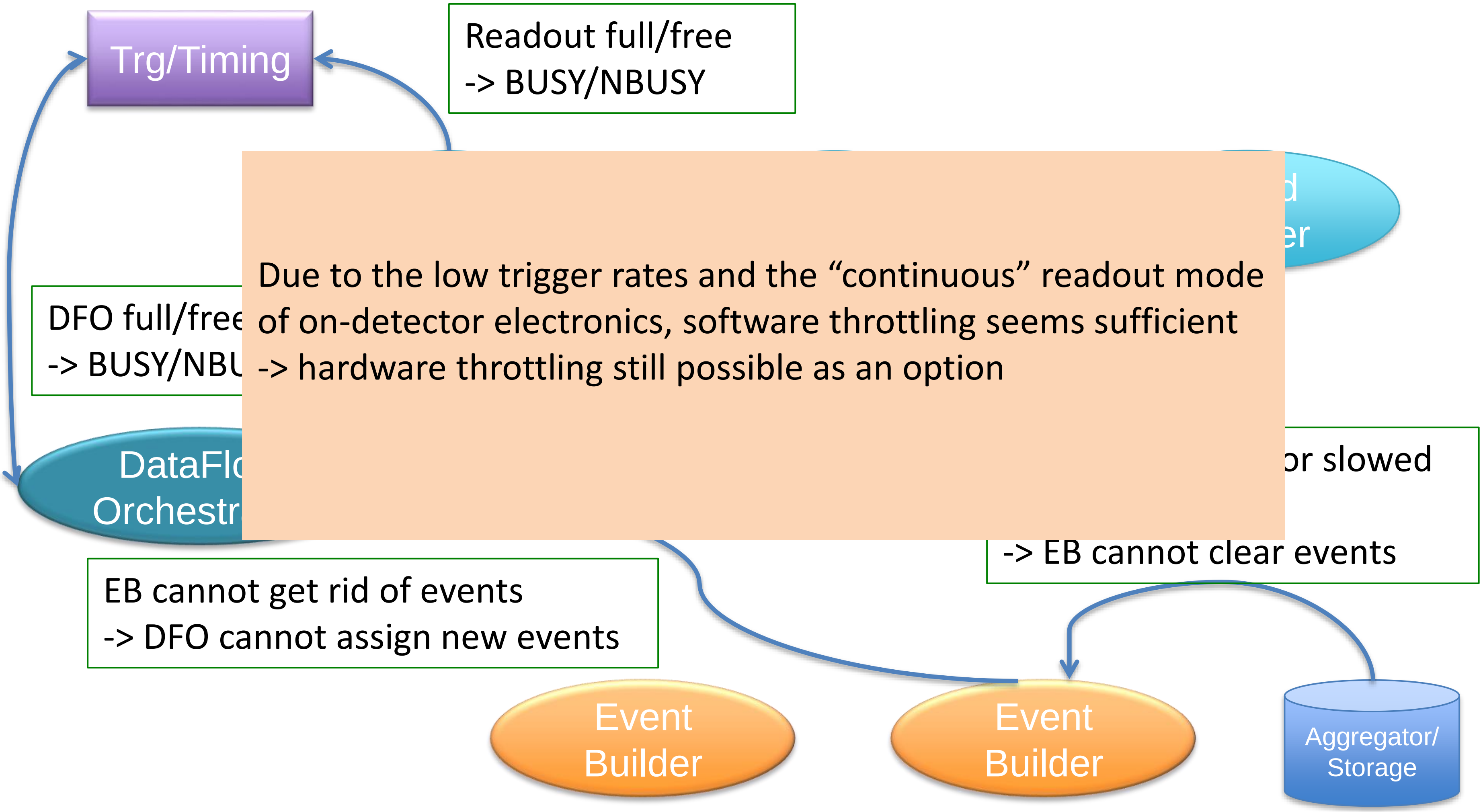
- I/O requirements similar to ATLAS/CMS now
- Hardware solution similar to ATLAS data loggers (modular!)
- Transfer to EOS using F-FTS and XRootD



- 3 systems
  - 2 front-end nodes
  - 1 storage controller
  - 4 expansion shelves
- Total of 120 HDs per system
- (Dual) Redundant paths, controllers and power supplies

Courtesy W. Vandelli, CERN

ProtoDUNE Trigger Throttling

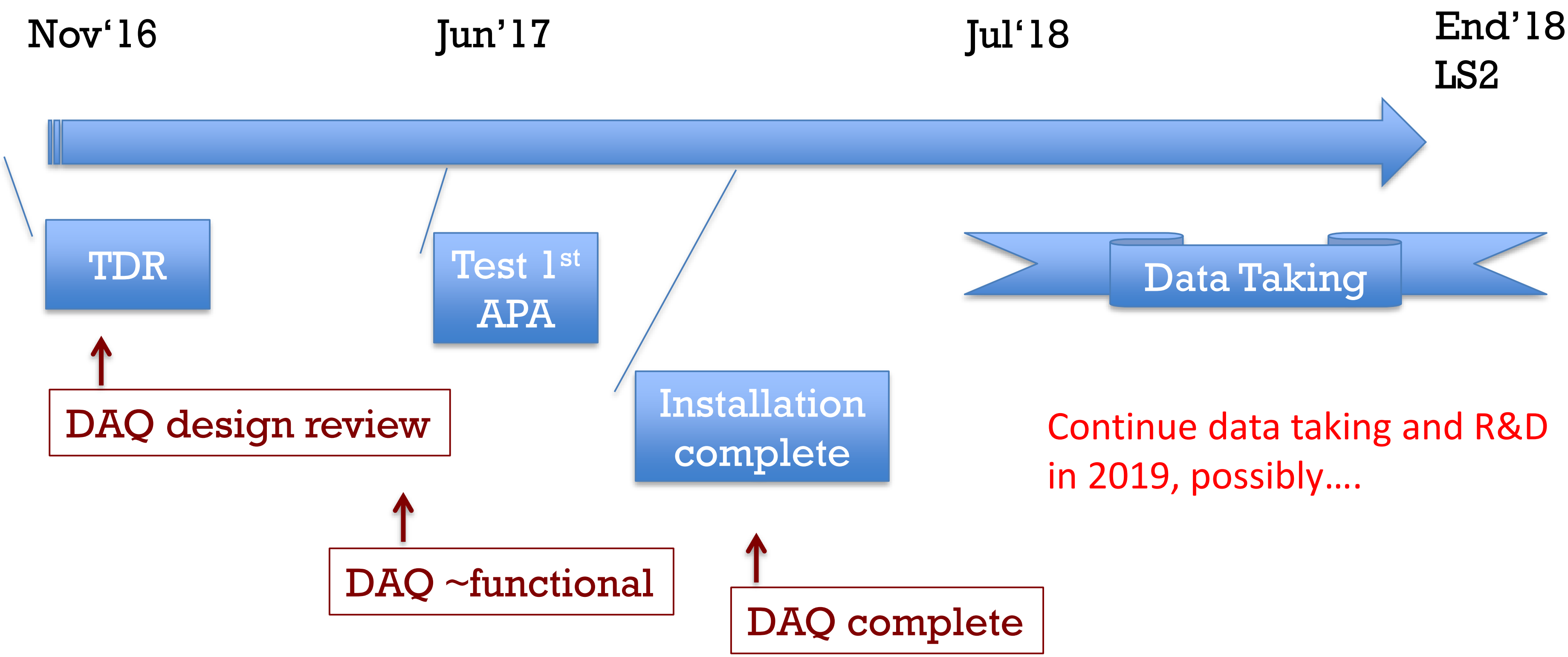


Due to the low trigger rates and the “continuous” readout mode of on-detector electronics, software throttling seems sufficient
-> hardware throttling still possible as an option

A Word on Partitioning

- Partitioning = the mechanism by which multiple copies of the DAQ can run on a same installation
- The DAQ has a few elements that cannot be split
  - (Virtual) duplication to allow for parallel running
- Partitioning is normally extremely useful during commissioning & testing
  - Even if it wasn't a requirement from the experiment point of view it is a requirement from the DAQ side
- Proposal to be able to partition the system into vertical slices, i.e. by APA
  - Only one partition will make use of the central trigger board, while others will use random or constant rate triggers

ProtoDUNE Timeline



Risks

- External Interfaces
  - Detailed specs (physical links, connectors, protocols, information content)
  - Continuous interaction between sub-system leaders AND detailed work sessions with sub-system specialists
- Internal Interfaces
  - New timing system to be integrated with trigger and many endpoints
  - Detailed specs and regular meetings
  - Continuous integration testing!
- Resources
  - We are confident that the people and institutions that committed to the DAQ will deliver on their components
  - Sufficient effort will be needed @CERN to ensure smooth integration, commissioning, tuning, operation

Summary

- A complete design of the DAQ system exists
  - Interfaces
  - Components model, Interactions and data flow
- All hardware components required for the DAQ identified
  - COTs servers, switches, interconnects (not a large system!), storage solution
  - ATCA based SLAC solution
  - FELIX PCIe cards
  - Timing units
  - Central Trigger board
- Main risks have been identified at the external interfaces level
  - Mitigation through direct discussions at different levels
- We are confident that the proposed DAQ design can be implemented on the timescales required by ProtoDUNE, that it satisfies the requirements that have been put forward by the experiment and that it has sufficient modularity to allow for flexibility, in case of additional performance needs.