Introduction to DUNE DAQ

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Introduction

Talk covers far detector only

- (Near detector not yet defined)
- Will mainly concentrate on Single Phase (largest data volume)
- Emphasize the hardware aspects and interface to readout

Common DAQ for all detector components

- Single Phase/Dual Phase , Photon Detection/TPC

See DUNE Interim Design report

- DAQ chapters of arxiv:1807.10327 , arXiv:1807.10340

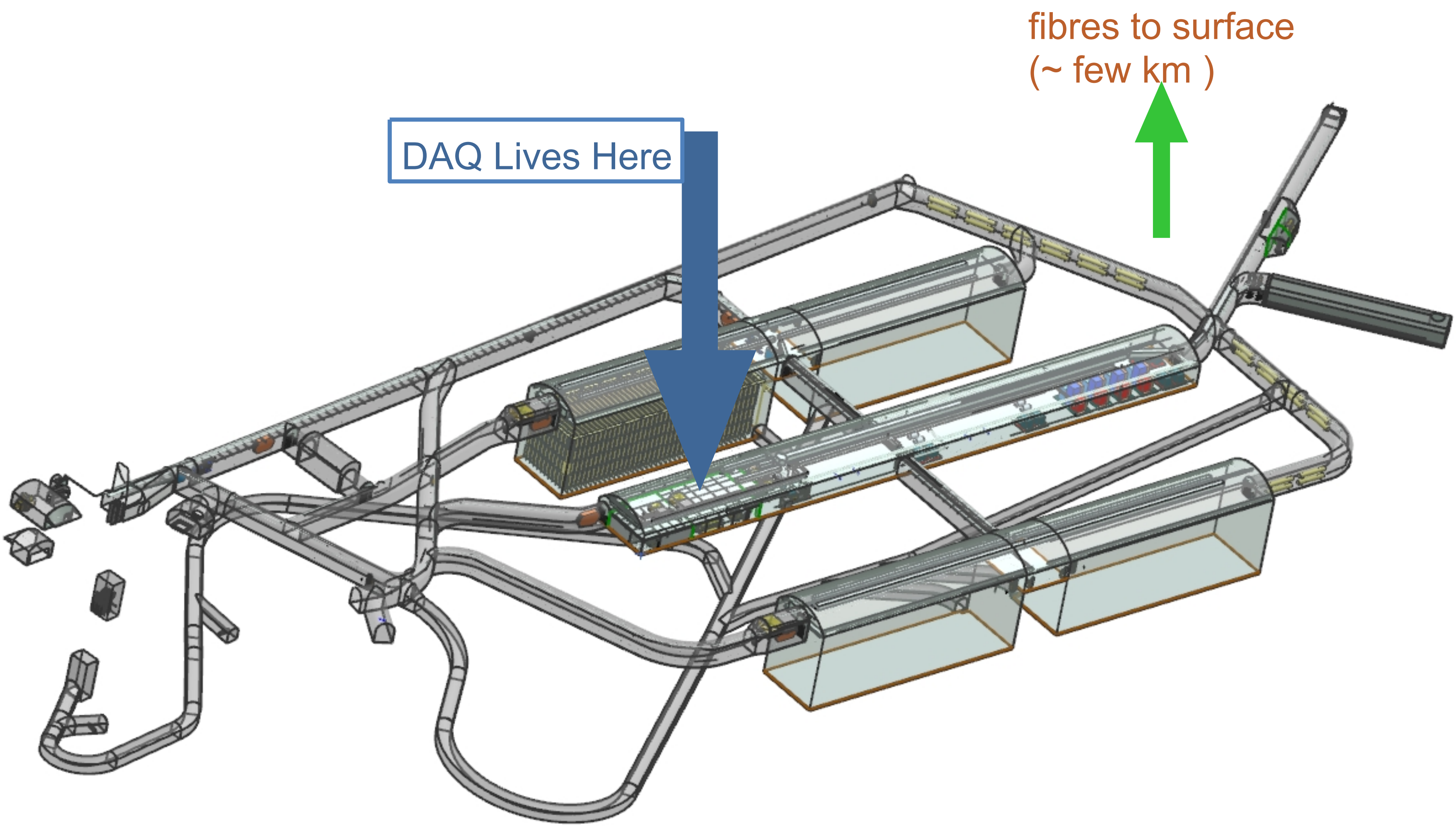
Function

- **Basic functions**
  - Synchronise and **receive digital data** from all FD sub-detectors
  - **Buffer data** pending a trigger decision – without information loss
  - **Form 'trigger primitives'**, summarising observed activity
    - For single phase photon detector system (SP PDS) data may be the same as trigger primitives
  - **Make trigger decisions**
    - local, then global
  - **Select** space & time ranges of data, relay them to permanent **storage**
    - Meaning: across the WAN to off-site computing centres
  - Option: carry out further data selection / refinement before transfer

Special Features

- **What's different and interesting about DUNE?** (compared to collider experiment)
  - System has to be extremely flexible – **'permanent commissioning'** mode
  - There are special requirements from the physics – e.g. SNB data buffer
  - **Inaccessibility**: reliability and full remote operation are essential
  - **Short time scale** to design and build a (up to) 50Tb/s system

Location – Central Utilities Cavern (CUC)



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Scope

- **Detector-facing side**
  - DAQ scope begins at optical links driven off the detector
  - Will will also provide timing / sync / control signals to the detector
  - (N.B. DAQ has no on-cryostat components)
- **Computing-facing side**
  - DAQ will manage all systems running at SURF, up to the WAN link
  - Elements of offline code will run at SURF (e.g. prompt reco, DQM)
- **Other interfaces:**
  - We will provide some basic services to other systems, e.g:
    - synchronisation and handshake with calibration systems
    - transfer of slow control data off-site

Design Principles

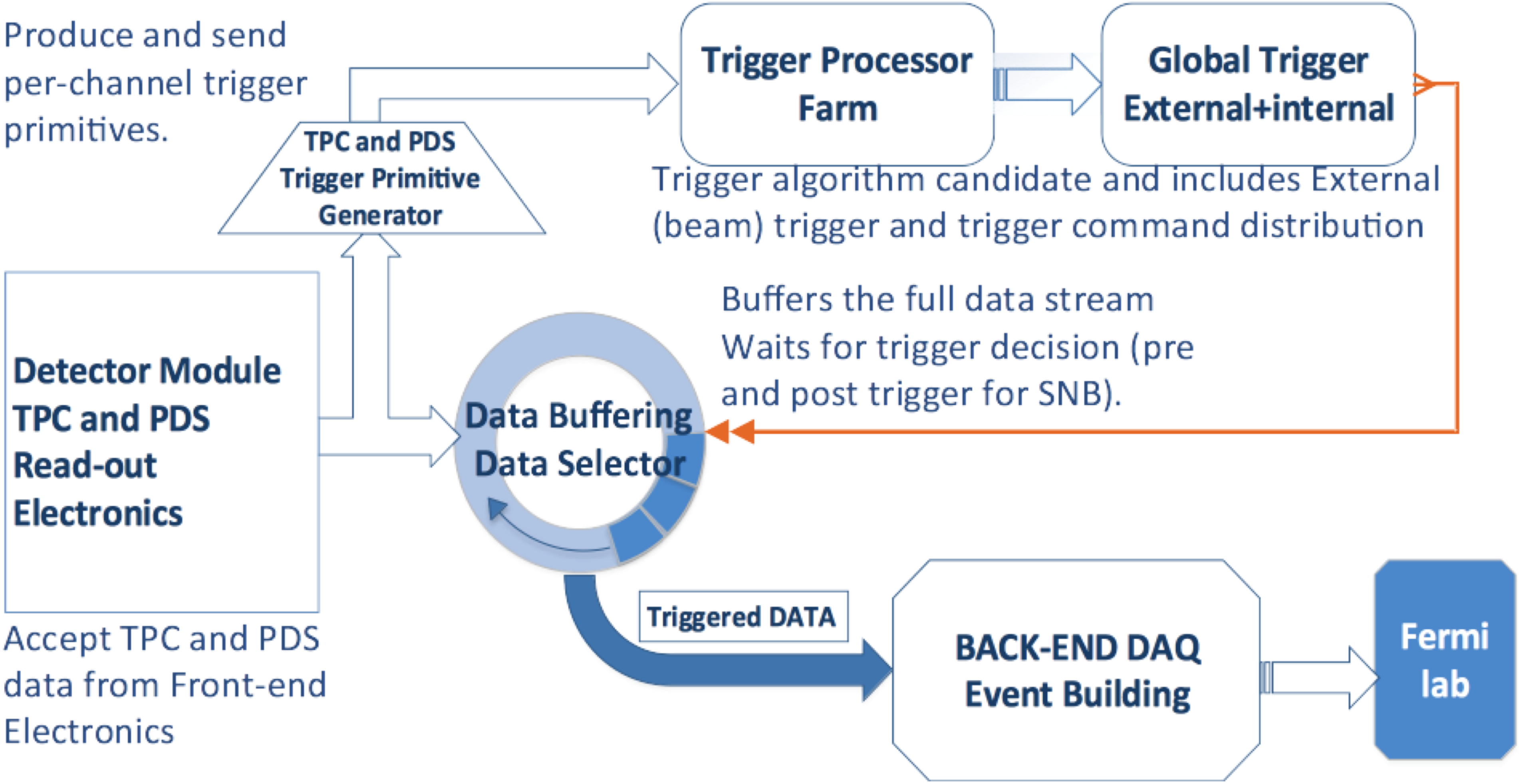
- **DAQ will be a single, scalable system across all detectors**
  - e.g. SP / DP have different interfaces, but there are not separate ‘SP DAQ’ and ‘DP DAQ’
  - Allows use of common components, cross-triggering possibilities
  - System can be divided into “partitions” with complete flexibility
- **DAQ will operate without dead time under ‘normal’ conditions**
  - Storage of overlapping ranges of data in space / time, continuously
- **DAQ will be capable of recording and storing full detector information**
  - e.g. when potential Super Nova detected
  - No lossy compression, no possible bias due to zero suppression
- **DAQ will be sized with `significant conservatism’**
  - LAr TPCs can have more noise than predicted → requires more processing power
  - All fixed infrastructure (e.g. power, network) sized for four detectors from the start
    - Allows a safety factor of ~four in first year of running, when things are most uncertain
- **As we learn about detector performance, will be able to be more selective**
- **Always keep the possibility to add data processing capacity if needed**

Implemention Considerations

- **Robustness**
  - Unacceptable for DAQ to be a dominant cause of lost statistics
  - Must operate without a large local expert crew
  - Avoid all single points of failure where possible
- **Scalability**
  - We must be able to grow and to adapt to unforeseen detector conditions (what if noise is more like 35T prototype or microBoone than protoDUNE ?)
- **Ease of deployment and commissioning**
  - We are likely to have a tight and complex schedule for installation
  - Other elements of DUNE will require DAQ at an early stage
- **Ease of design and construction**
  - Re-use proven technologies where possible, e.g. from ProtoDUNEs
  - Standardise processors, computers, links, data formats, software, firmware
- **Construction cost**
- **Running costs and space requirements**

Single Phase Data Path

Produce and send per-channel trigger primitives.



Trigger algorithm candidate and includes External (beam) trigger and trigger command distribution

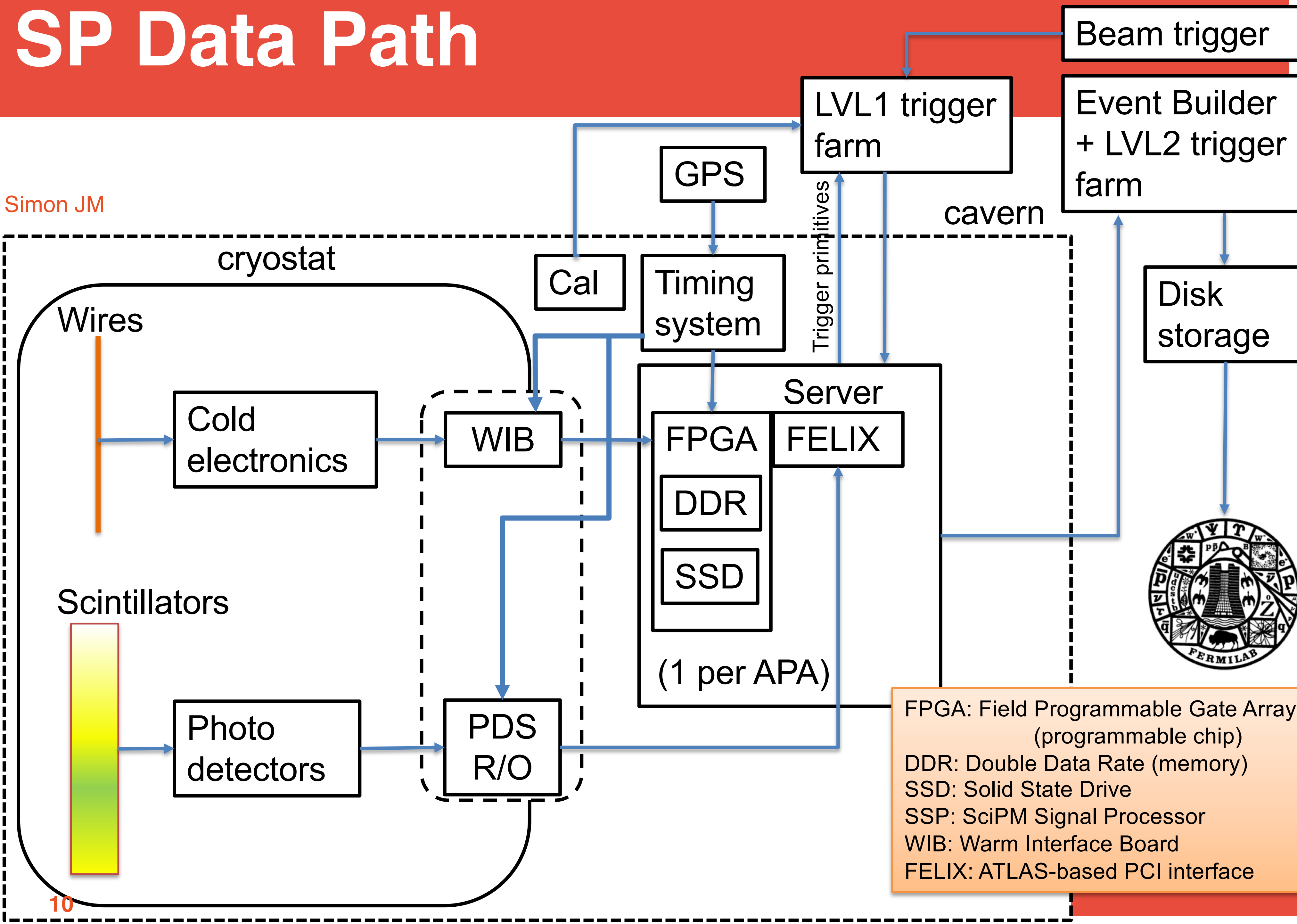
Buffers the full data stream
Waits for trigger decision (pre and post trigger for SNB).

Accept TPC and PDS data from Front-end Electronics

Abi, NNN18

SP Data Path

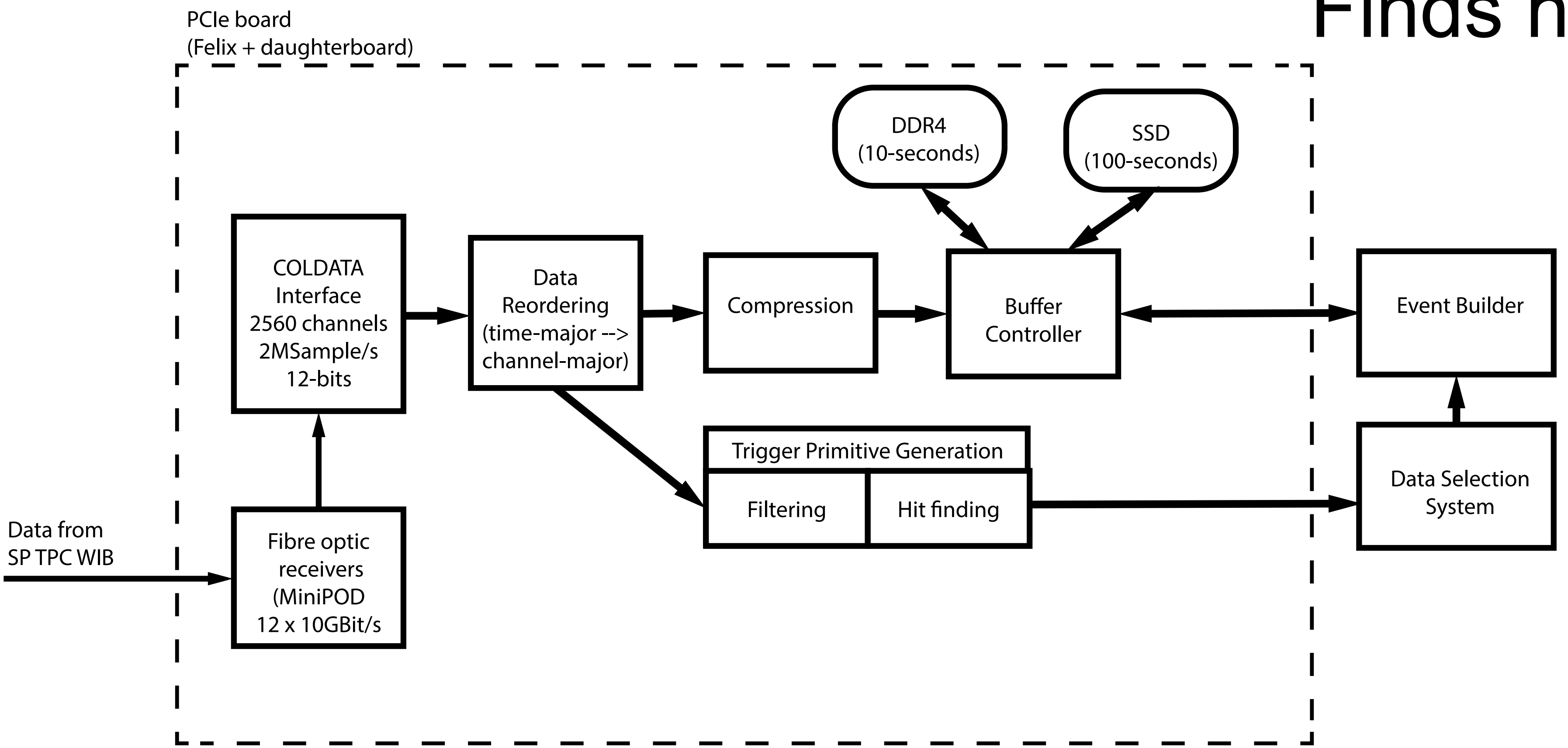
Simon JM



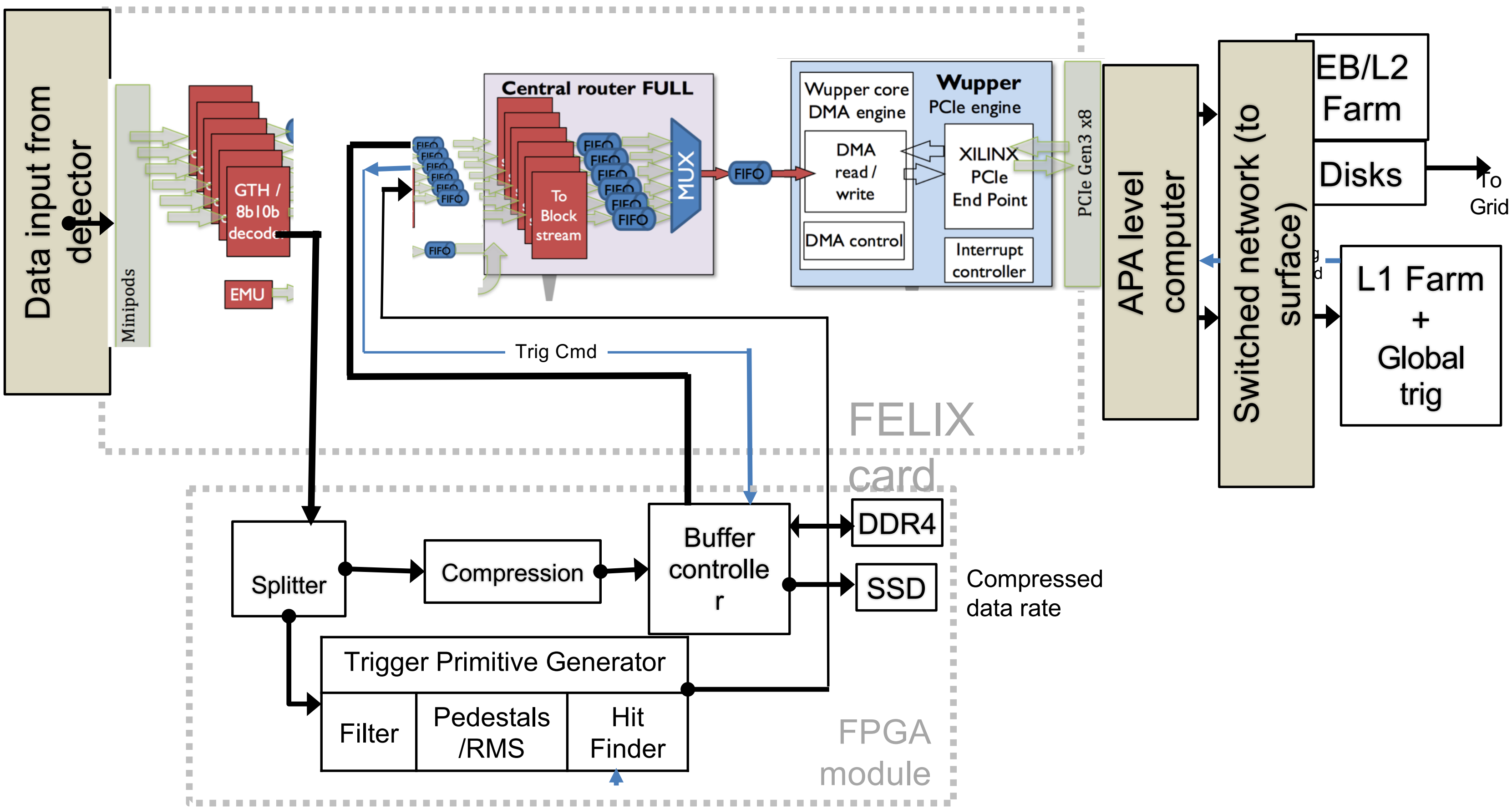
FPGA: Field Programmable Gate Array (programmable chip)
DDR: Double Data Rate (memory)
SSD: Solid State Drive
SSP: SciPM Signal Processor
WIB: Warm Interface Board
FELIX: ATLAS-based PCI interface

SP TDC Dataflow

receives data
Compresses
Finds hits



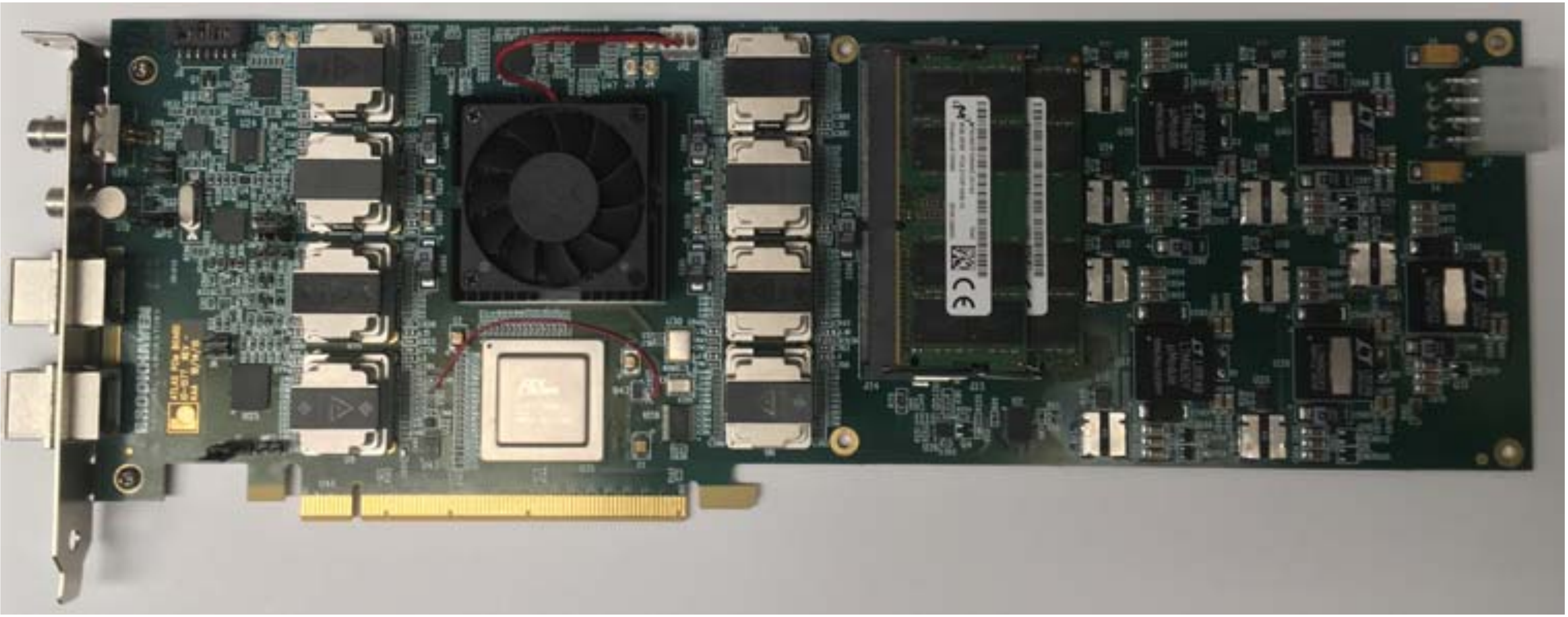
DAQ: detail FPGA + FELIX



Simon JM

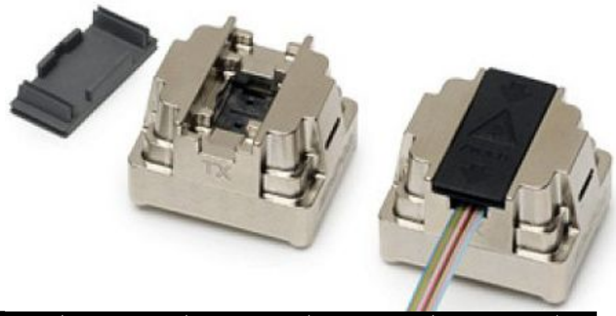
Existing Felix

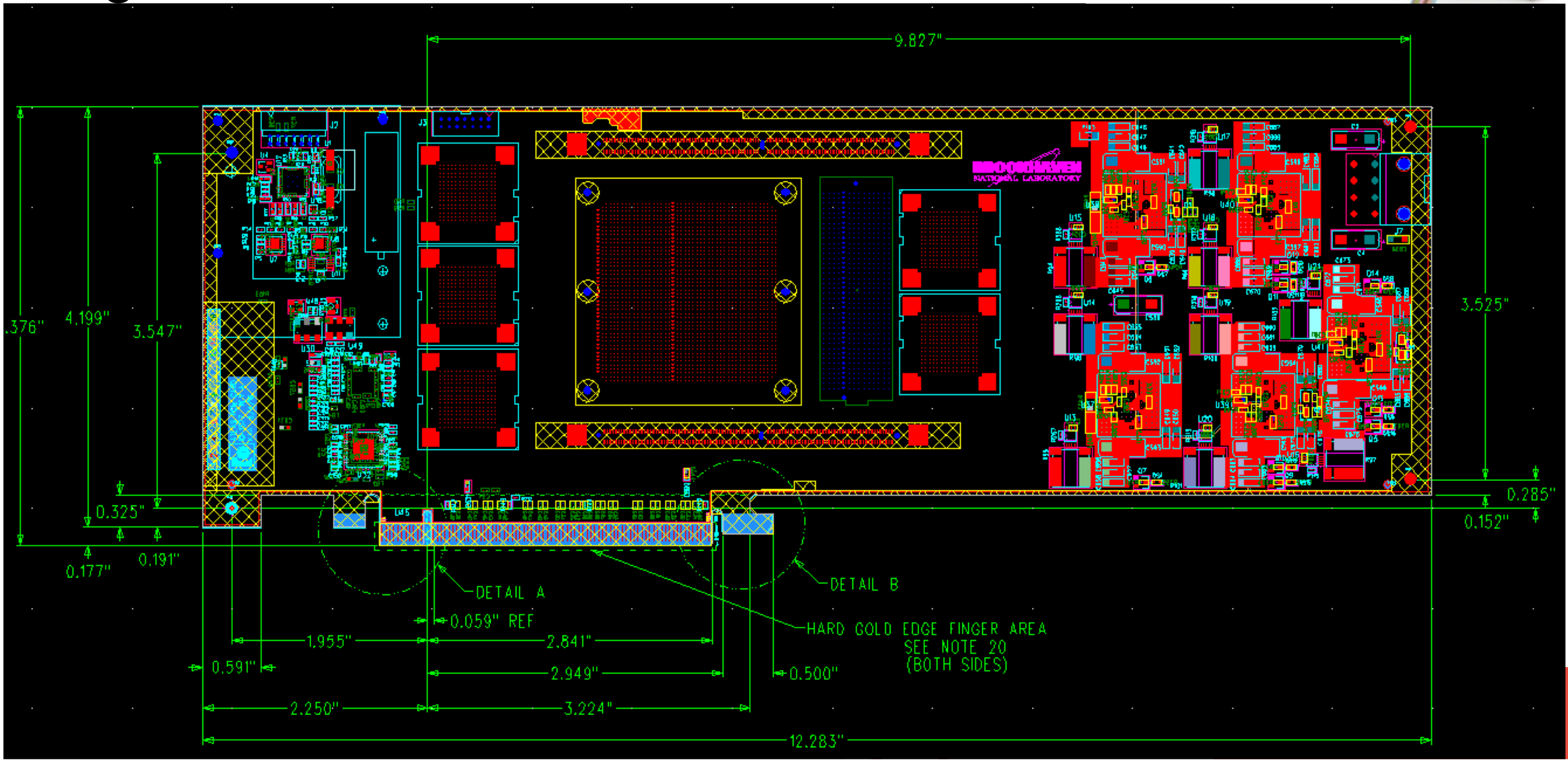
- FLX-711 (BNL)
  - See http://iopscience.iop.org/article/10.1088/1742-6596/898/3/032057/pdf



Felix with Daugherboard

See Hucheng Chen’s (BNL) talk at
https://indico.fnal.gov/event/16526/session/11/contribution/90/material/slides/0.pdf
FMC+ connector.
Thermal and mechanical issues being worked out





Single Phase TPC Readout

1- Warm interface electronics crates (WIECs)

- Mounted on the signal flanges
- Warm interface boards (WIBs)
- Power and timing cards (PTCs)

2a- CE flange

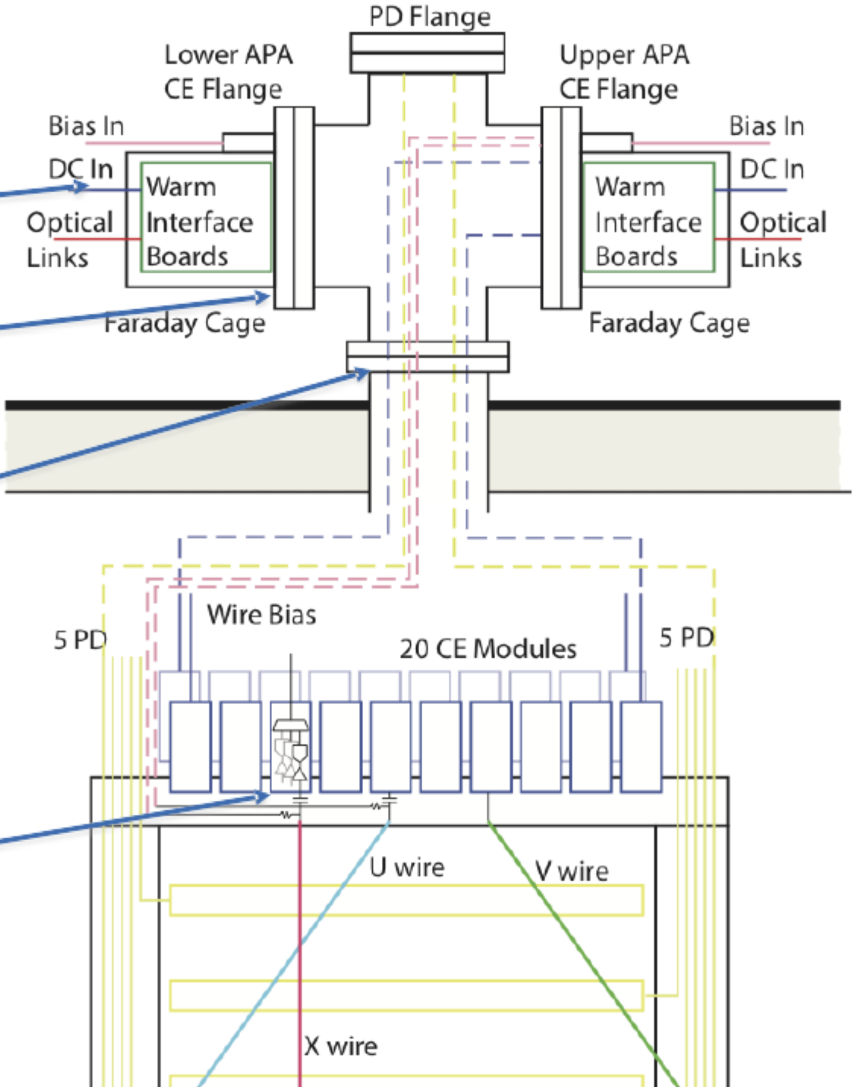
Flange assembly with cable strain relief and flange PCB for cable/WIB connection

2b- Signal feed-through

CE feedthrough to pass the data, clock and control signals, LV power and APA wire-bias voltages

3- Front End Motherboard

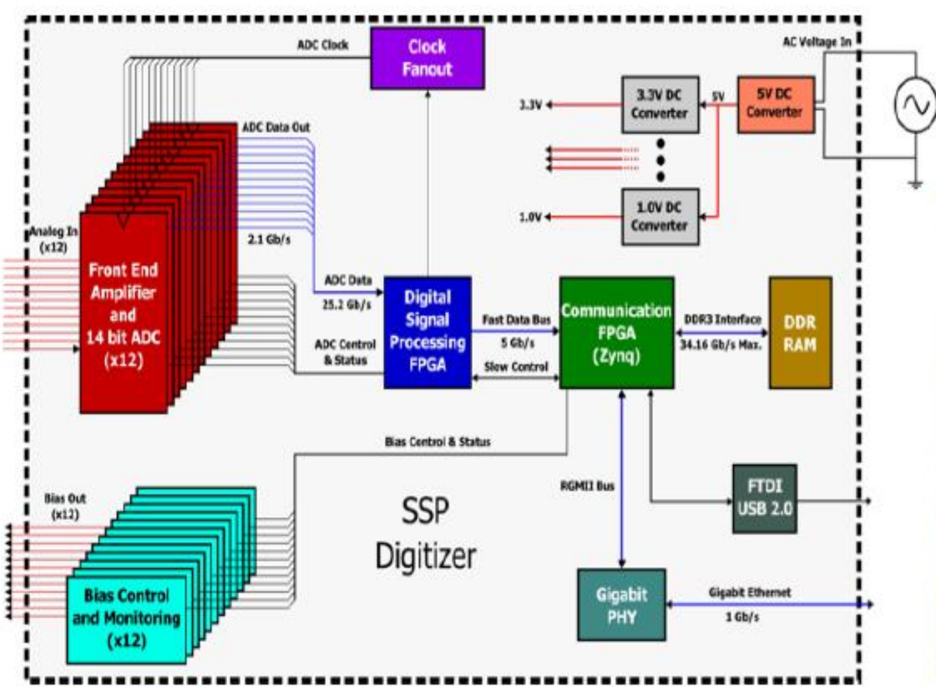
(FEMB) 128 channels of digitized wire readout enclosed in CE Box



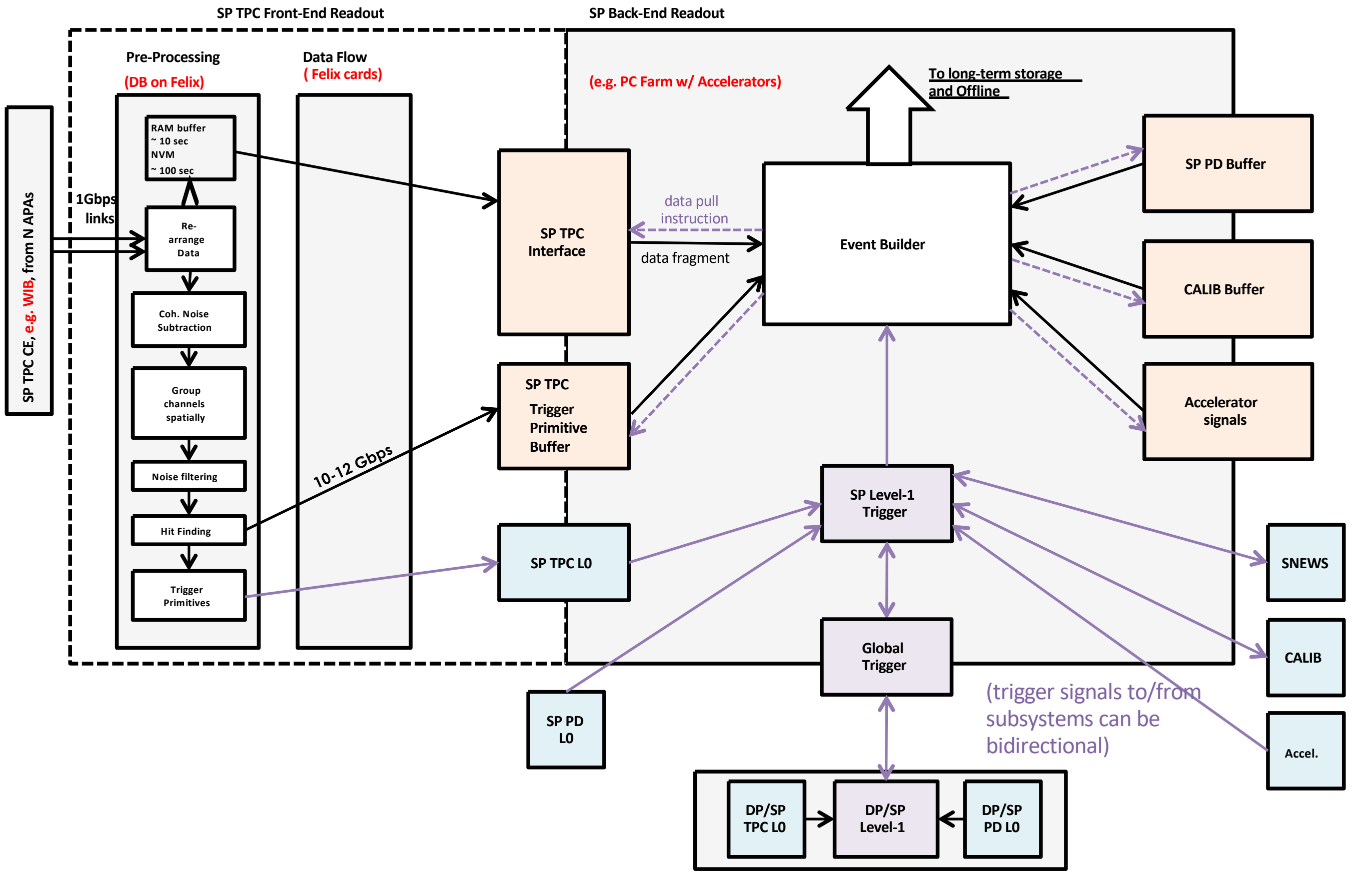
protoDUNE Photon Detector Readout

SiPM Signal Processor (SSP) developed for ProtoDUNE-SP.

12 readout channels in 1U unit
Unamplified SiPM signals carried over 25m shielded twisted pair (Cat6 Ethernet)



Dataflow



Karagogi

- **Example: the `dataflow plane' of SP TPC**
  - There are also control, trigger command and fast control/monitoring planes
  - Each `plane' can be split into partitions for commissioning, debugging and tests.

DUNE SP Photon Detector Readout

Continuous sampling ADC?

Like protoDUNE

Like Dual Phase PDS

Pulse processing system?

Dual Phase PDS includes “CATIROC” which detects and measures pulses

If continuous sampling ADC, zero suppressed readout with trigger primitive generation in DAQ ?

One of the modes currently used in protoDUNE

Data Volume

Source	Annual Data Volume/ 10 kt	Assumptions
Beam interactions	20 TB	700νs+700 "dirt μs"; everything read out for 5.4ms (no ZS); 10 MeV threshold in coincidence with beam; include cosmics
Cosmics (+atmospherics)	10 PB	All wires in 5.4ms window around high energy event
Radiologicals	< 1 PB	Weighting scheme for SN bursts and other low energy events; dump 10s for each burst trigger; tune fake SN rate to be < 100/year
Front-End calibrations	200 TB	Worst case of measuring every single ADC bin with 100 measurements/point; four times/year
Radioactive source calibrations	100 TB	Source rate < 10 Hz; only one APA readout; PDS is negligible; full readout window per tag; no lossy ZS
Laser calibrations	200 TB	1×10^6 total laser pulses; tight ZS for both induction and collection wires; ½ of all wires in TPC illuminated
Random Triggers	60 TB	Same as cosmics scheme; rate is 45/day
Trigger Primitives	< 2 PB	Only collection wires; 12b/primitive; 4 primitive types; 39Ar dominates

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Key Decisions

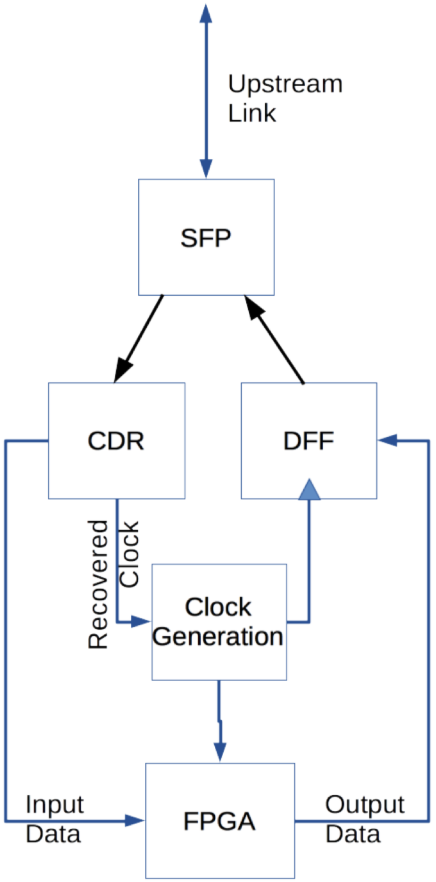
- **Noise assumptions for sub-detectors**
  - What are reasonable assumptions? What are worst-case assumptions?
    - Currently planning to use protoDUNE signal to noise as baseline.
- **Final data rate to offline computing; DAQ parameters for SNB physics**
- **Trigger primitive generation implementation**
  - How much in FPGAs, how much in CPU / GPU?
    - Currently assuming hit-finding for SP TPC done in FPGA
- **RAM buffer and NVM buffer implementation**
  - Currently assuming 10-second buffer and 100-second NVM memory for SP TPC attached to FPGA
- **Custom hardware, or commodity computing?**
  - Current assumption – variant of Atlas Felix PCIe board with daughter-board for SP TPC
- **Slice test strategy and location**
  - See Dune FD DAQ Development plan DUNE-doc-11242 (evolving)
  - Where is our base of operations for test and integration in 2019? In 2021? In 2023?
- **We have a baseline set of assumptions for the Technical Design Report (TDR), but these will (should) be challenged via further R&D and review**

Interfaces

- **Documents defines the interface/ interaction between each system. For DAQ:**
  - 6727-v2 SP Photons
  - 6742-v6 SP TPC
  - 7042-v0 Integration facility
  - 6988-v1 Facilities
  - 6802-v1 DP Photons
  - 6790-v1 Slow controls, calibration
  - 6736-v0 HV
  - 6778-v1 DP TPC
  - 7015-v1 Installation interfaces
- **For SP PDS → DAQ defined to be a UDP/IP based protocol at up to 10GBit/s per APA**

Timing and Synchronization

- **Need to distribute a common clock and synchronization signals.**
  - See DUNE-doc-11233
  - Dual Phase and Single Phase use different distribution mechanisms.
    - Different development histories, different numbers of end-points.
    - Dual Phase: White Rabbit implementation of PTP (IEEE1588-2008)
    - Single Phase: Development of protoDUNE timing system
      - See DUNE-doc-1651
      - Designed to be simple to integrate into “end point”
        - Timing/synchronization distributed over 250MBit/s 8b/10b encoded link.
        - Need CDR and clock generator able to generated sub-detector clock from recovered 250MHz clock.
        - Firmware block and reference designs available.



Summary

- **DUNE will have the largest data rate into the DAQ of any neutrino detector built up to now.**
- **System has fewer sub-systems than a typical collider experiment but requires great flexibility**
  - Beam physics , Super Nova physics, rare decays , ….
- **Common DAQ for dual phase and single phase caverns**
- **Interface by optical fibre:**
  - If it is on the detector it is readout electronics. If it is in the CUC it is DAQ