Conceptual design: Requirements for the DAQ

Speaker: Giles Barr

Overview of talk

- Organization of DUNE requirements
- DUNE level constraints on DAQ and DAQ top level requirements
  - Interlude: Buffering and readout sequence overview
- DUNE level constraints to help define DAQ
  - Interlude: signals and noise
- Brief: DAQ specifications and interfaces
- Summary

Organization of requirements in DUNE

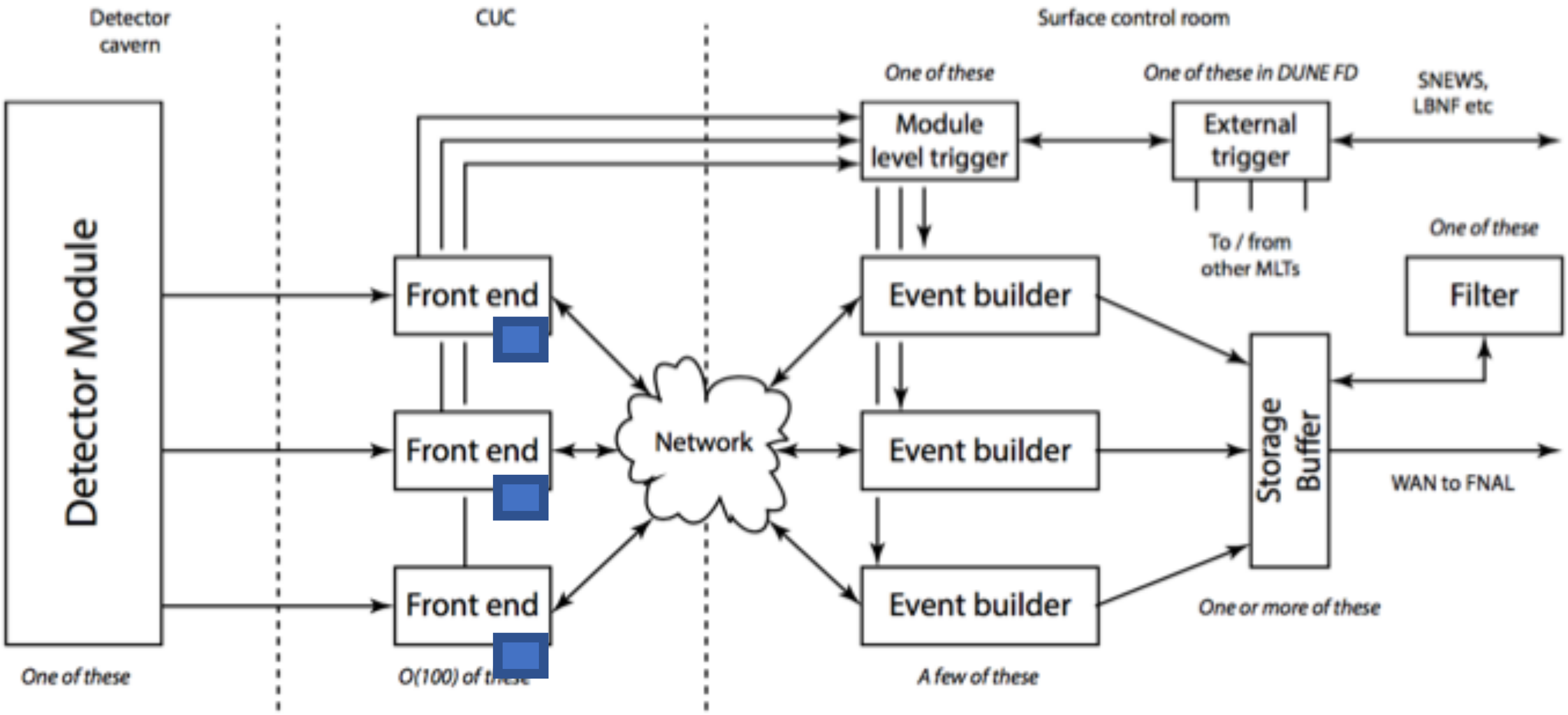
- Centrally managed at collaboration/technical board level
- There are O(30) 'DUNE-level' requirements on the whole experiment, 15 of them are relevant for the DAQ
  - Some place constraints and define our task in DUNE (e.g. how much should we reduce the data volume, down time)
  - Some place constraints on others limiting the functionality we must provide (in particular noise and radiologicals).
- Beneath these, there are 7 'master' DAQ requirements that define the main functionality of the DAQ and trigger.
- Next level down defined by our interface documents – details of e.g. the timing, and how we receive and send data
- Finally we have DAQ specifications that define the functioning of our sub-systems to the level where we can cost them.

Name	Primary Text	Value	Rationale	Validation	Note
Minimum drift field	The drift field in the TPC shall be greater than \SI[250]{V/cm}, with a goal of \SI[500]{V/cm}.	>250 V/cm	Limits impacts of electron-ion recombination (on particle ID via \dE/dx\ versus range), reduces effect of finite electron lifetime on S/N ratio (with implications on tracking and calorimetry), and limits electron diffusion and to a lower degree space charge effects.	ProtoDUNE will demonstrate if the present HVS design allows reaching the nominal electric field in the drift volume. Initial data taking will be with the maximum obtainable electric field setting, but additional studies at lower fields to study the effect on particle ID will also be targeted. Detector simulation will take advantage of the experimental data collected with ProtoDUNE. Additional runs collected at lower field settings will allow for	MicroBooNE is demonstating that a field of 270 V/cm can be a viable operating point in terms of particle ID. Early simulation results shown at the January collaboration meeting suggest that detector performace would degrade below 200 V/cm. The previous comments apply in case of "infinite" electron lifetime. Degradation of detector performance (e.g. low Signal-to-Noise ratio) associated with finite electron lifetime is enhanced at lower
Front-end electronics noise	The FE electronics shall contribute no more than \num[1000] enc of noise, with a goal of ALARA. This requirement is on total system noise; it is expected that random noise on the FE will dominate.	< 1000 enc	Driven by pattern recognition and two-track separation requirements. Requirement of 5/1 signal to noise ratio on individual ADC wire measurements yields the figure of \num{1000} enc for the induction wires.	ProtoDUNE will demonstrate the noise level achievable by the current electronics and validate the grounding and shielding rules being used. Simulation will quantify how physics reach is correlated to electronics noise for selected physics channels.	Reconstruction algorithms are still under development, but it is clear that lower noise enables better perfromance and allows more access to lower energy events such as those associated with astronomical sources.
Light yield	The light yield shall be sufficient for measuring event	> 0.5 pe/MeV	Minimal requirement is based on events occuring near the		

DUNE-level requirements (1) Ones that define what we do

Time resolution – affects how well we can match up things in different parts of the detector, affects track resolution. 1us. [4]	We have robust timing system. See (David Cussans talk 14h)
Data rate to tape <30PB/year – defines how much junk we can let through [22]	See next talk (Josh Klein)
Detector live-time: 90% (Our contribution must be a small fraction of this) [16]	Independent caverns, robust run-control, exploring ideas
Supernova trigger – must record bursts over a 10sec period 90% efficiency for SNB, 90% efficiency for interactions over 10MeV [23]	Two-stage buffering, see next slide

Interlude: Concept of buffering (1)

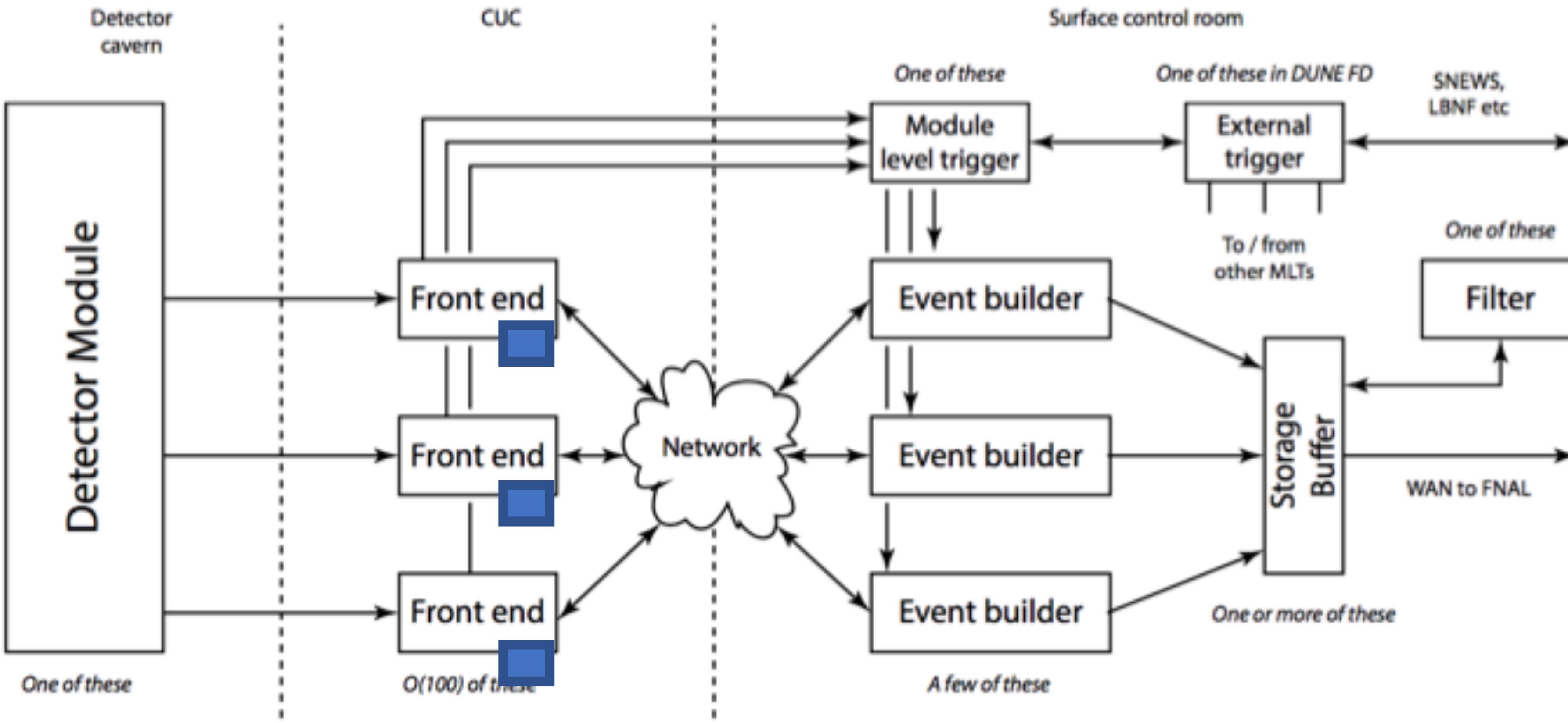


Per-front-end Buffer: Ring buffer of compressed data O(10s) lookback using DRAM
Solid state drive writes when SNB triggered 2-3x per APA for bandwidth

DAQ top-level requirements

Off-beam high-energy trigger: Detector shall trigger on visible energy >100MeV with high efficiency	Intended to pick up all cosmic rays, atmospheric neutrinos and search-phenomena such as proton decay.
Off-beam low-energy trigger: Detector capable of triggering on visible energy >10MeV	Intended to pick up supernova events, solar perhaps
Trigger for beam: Detector shall trigger on beam events when visible energy is >100MeV	Uses beam spill timing information in addition to TPC
Trigger for calibration (and tag the triggers as such)	See Josh Klein talk (next)
Trigger for supernova burst	See DUNE requirement [23] (slide 4)
Physics event record	Defines 'events' and 'runs'
DAQ deadtime: Our deadtime should not contribute significantly to overall detector downtime.	Design is 'deadtime-less by design' Goal is to have no deadtime

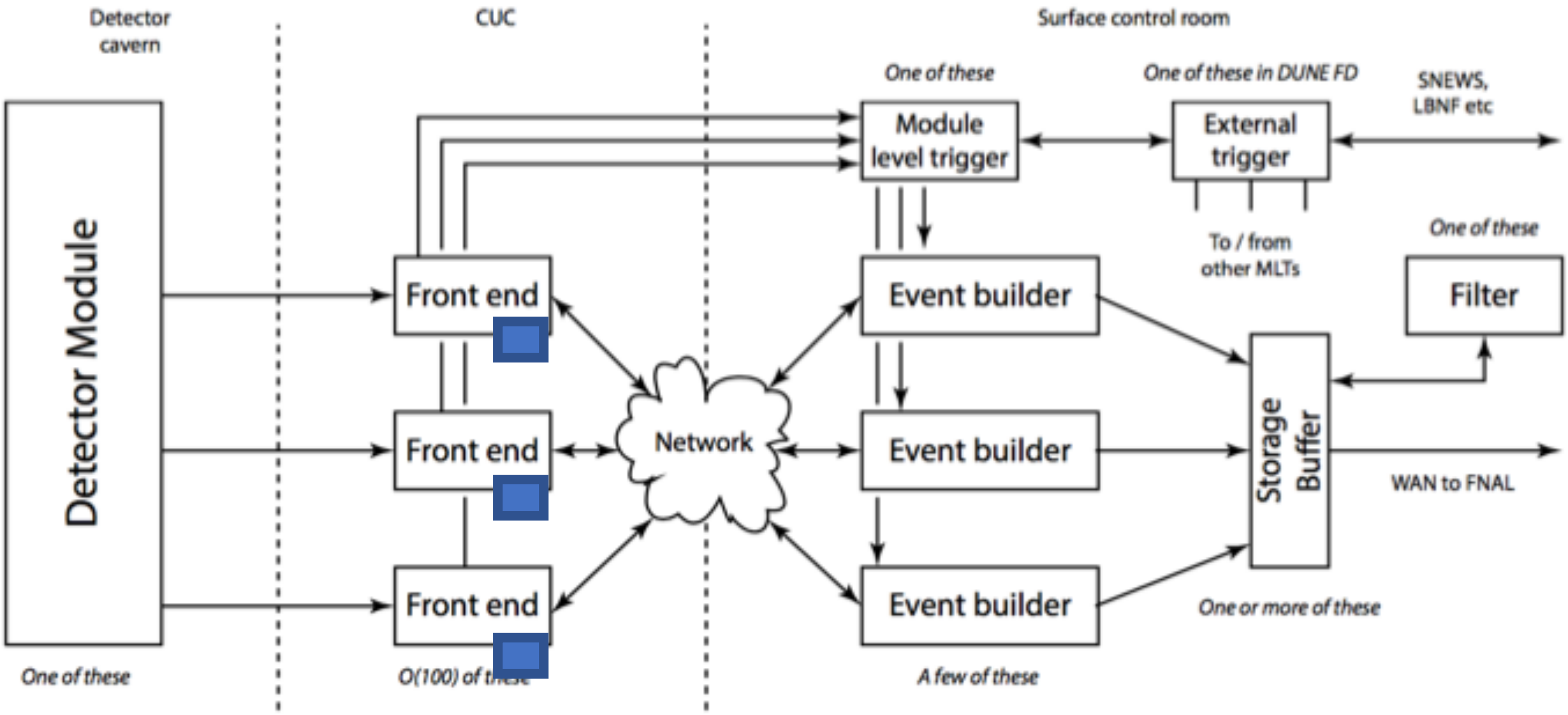
Architecture designed to satisfy these requirements



Sequence (normal trigger):

- Data stored in DRAM ring-buffer,
- Continuously evaluate trigger candidates in window of O(one-drift-time)
- Event builders request data from ring-buffers

Architecture designed to satisfy these requirements



Sequence (SNB trigger):

Data stored in DRAM ring-buffer,

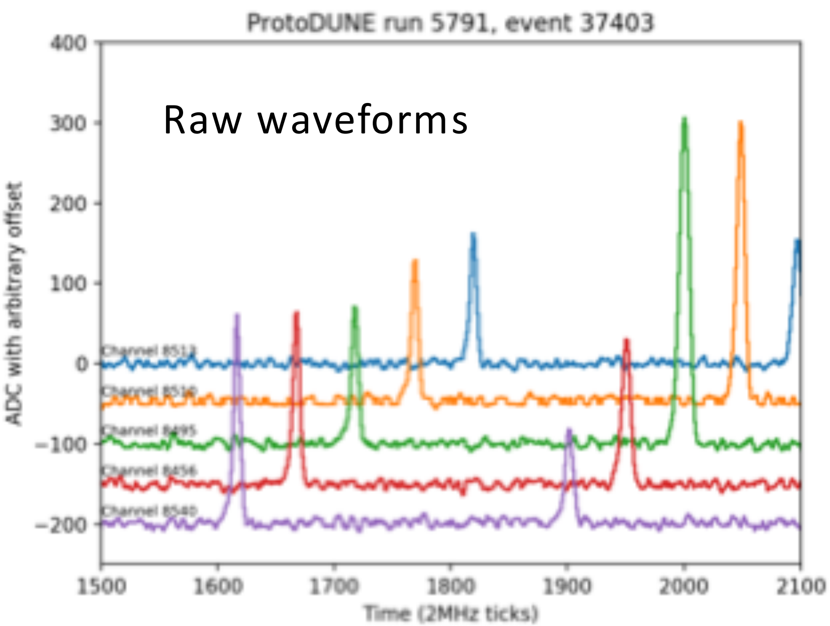
Continuously evaluate trigger candidates in window of O(f1000 drifts = few seconds)

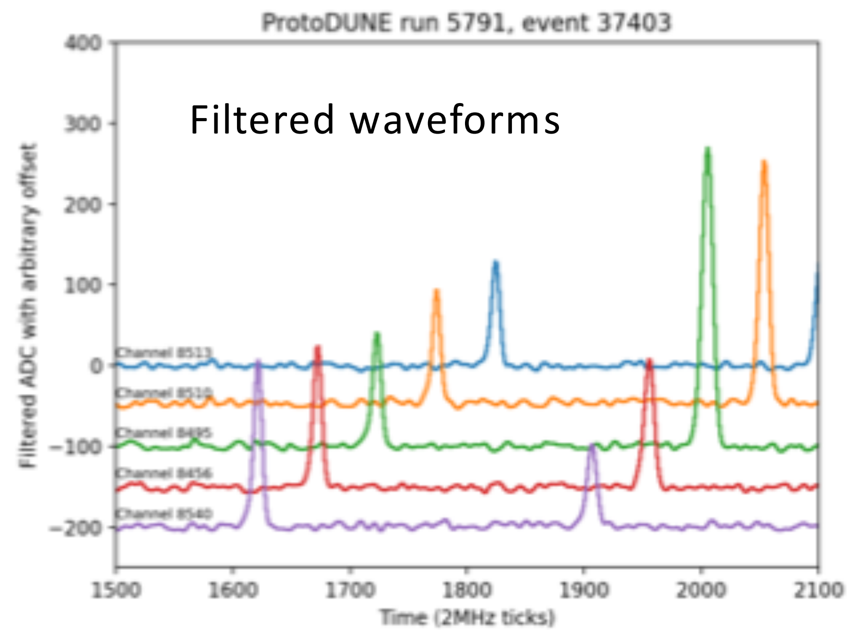
Activate dump of data to SSD.   Read out slowly later

DUNE-level requirements (2) Ones that define what we get

Front-end electronics noise <1000enc [2]	Next page
Non-FE noise contribution <<500enc [25]	
Introduced radioactivity (less than from 39-Ar) [27]	
HV power supply ripple – contributes to noise [12]	
LAr purity – affects the size of our signals [5]	Affects signal shapes Next page
Front-end peaking time – affects signals for triggering [13]	
Photodetector light yield – how easy is it to trigger on photon detectors [3]	Coincidence triggering techniques could help

Signal to noise
We have experience with ProtoDUNE





We have experience with ProtoDUNE and MicroBooNE

Raw incoherent noise around 600 enc, max allowed 1000enc.

Coherent noise is a concern, but low in ProtoDUNE

Vigorous development of filtering (foreseen in FPGA architecture)

DUNE-level requirements (3) Other constraints we must observe

Minimum drift field – affects the drift velocity and therefore the readout window [1]	Well within headroom of bandwidth we foresee. Effect is less stringent than what we handle in ProtoDUNE. Note: we will read out entire detector for all triggers at start to ensure bandwidth is sufficient. See Jim Brooke's talk, for bandwidth tests.
ADC sampling frequency – 2MHz – affects the numerology in our architecture (amount of muxing) [19]	Fixed solidly already, change would ripple to us, would affect firmware a bit. No concern.
ADC dynamic range – affects triggering [20]	Affects our trigger less than physics No concern
Dead channels [28]	Our algorithms are robust against gaps, will add this to our validation.

DAQ specifications and interfaces

Agreements well developed with other consortia in interface documents

Specifications of our sub-systems well defined, but still some development. Indicated in many of following talks. E.g. specifications to:

- Define sizes of internal buffers within our sub-systems
  - Includes the max readout windows for non-SNB and SNB events
- Define where the ordering or timeliness of data reception is critical for operation of a sub-system (requirement on the upstream system).
- Define actions when triggers overlap, establish trigger priority.

These are well informed from experience on ProtoDUNE and other liquid argon detectors.

Summary

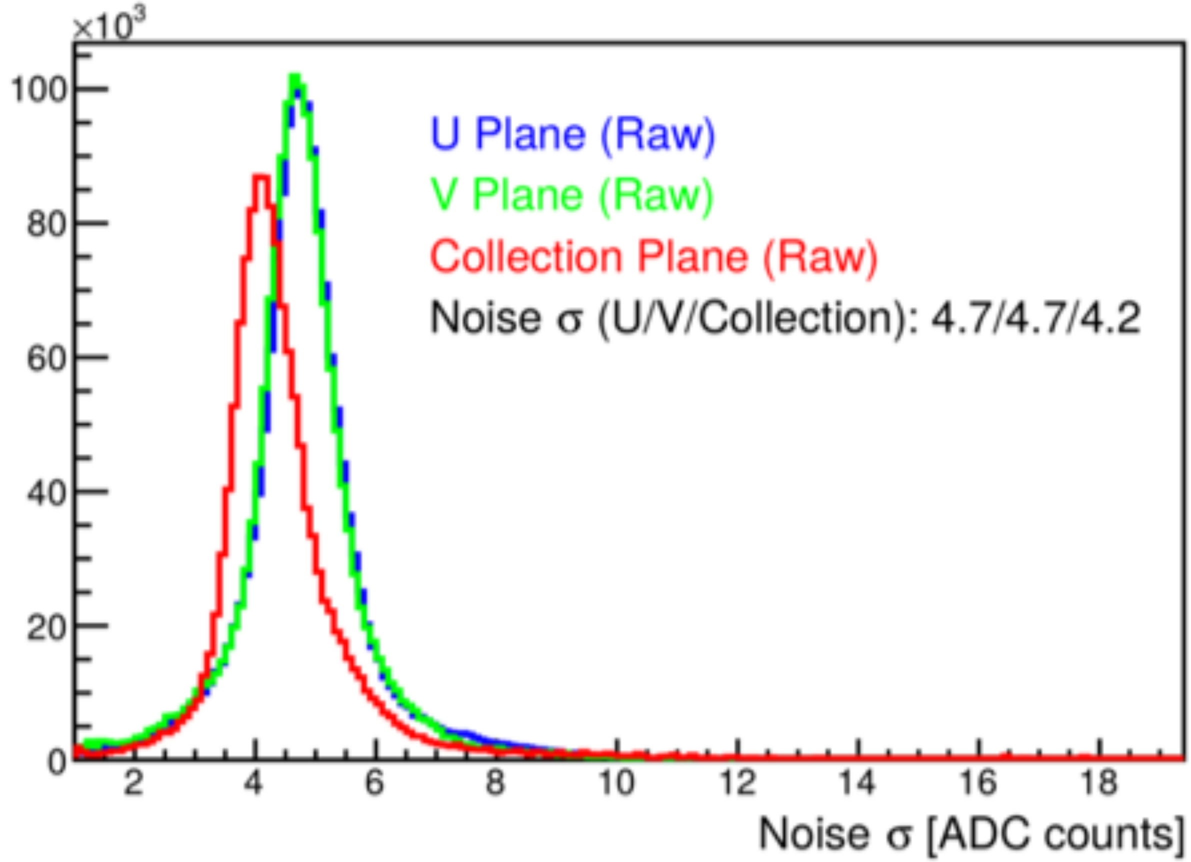
- The requirements from DUNE and our additional DAQ requirements define well the functions that are required of the DAQ
- There are a set of interface documents that are undergoing final iteration that specify the external constraints on our components
- The timing system is a crucial provider of services to other consortia and requirements on these are being developed
- These requirements are "living", i.e. they will adapt in certain areas. There will be change control.

Backup

Review charge

1. Are the requirements and technical constraints on the DAQ system, deriving from the DUNE FD top-level science requirements and DUNE FD operational regime, clearly documented and understood? Is the DAQ conceptual design compatible with these requirements?
2. Is the envisioned conceptual design for the system technically sound, with evidence that it can form the basis for the detailed design phase?
3. Are the plans for R&D, including the use of ProtoDUNE-SP, well understood and documented? o TowhatextenthasProtoDUNEdemonstratedsystemsubcomponentperformance?
   o Whichadditionaltestsareneededtodemonstratesubcomponentperformance?
   o Isthereanyevidencethatanycriticalcomponentsmaynotbetechnicallyfeasible?
4. Is an adequate project plan in place, capable of generating and demonstrating a detailed DAQ design on the required time scale?
5. Are interfaces with detector components (e.g. slow control and detector front ends) and external data sources (e.g. accelerator, other detectors) well defined and documented?
6. Are interfaces with the infrastructure (e.g. underground conventional facilities, utilities, networking, computing and detector safety system) well defined and documented? Is the interaction of DAQ with the DUNE FD grounding and shielding regime understood?
7. Are the requirements on DAQ, and by DAQ, from and to the overall DUNE FD integration and commissioning plan understood? Does the DAQ project plan adequately address them?
8. Are the planned DAQ firmware and software design and development practices appropriate and adequate?
9. Is there an online data selection strategy in place? Does it meet the DUNE science requirements? Are the requirements for data storage and transfer understood and documented?
10. Are the requirements on DAQ from the FD calibration strategy clear and compatible with the DAQ conceptual design?
11. Have resource estimates and schedule been established at an appropriate level of detail?

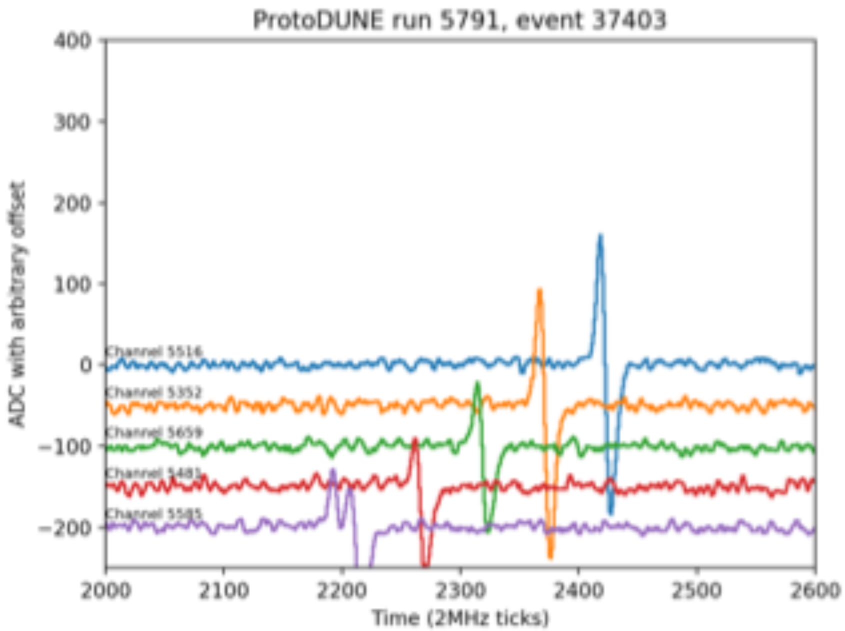
Noise σ Distribution



ProtoDUNE September talk:
David Adams (BNL) September 27, 2018

Over much of detector, noise level is

- Collection: 3.5 ADC (500 e)
- Induction: 4.5 ADC (600 e)
- Nice!



- Main slides show collection wire waveforms
- Here is a similar plot for induction wires from ProtoDUNE
- Our trigger efficiency studies are based on collection wires only and show good efficiency, so this is the requirements.
- With ProtoDUNE level of S/N, we could clearly use information from induction wires