DAQ Needs from Calibrations---UPDATE

- What DAQ needs from calibration SYSTEMs
- What DAQ needs to know from calibration TF

Current DAQ Paradigm

"Standard" Triggering

- All data from front-end is passed to a temporary buffer, without zero suppression (~10 Tb/s/10 kt)
  - Rationale: simplicity, preserves flexibility
- Trigger "primitives" from collection wires are passed to data selection
  - Integrated/peak charge, time, time-over-threshold
- If an interaction is above threshold-equivalent (e.g., 10 MeV), 5.4 ms of data from all channels is stored
  - Rationale: best to have low bias at channel-level for "good events"
  - Rationale: 2x maximum drift time ensures we bracket entire event
  - Rationale: u/v zero suppression is still evolving and is noise-sensitive
  - Rationale: neutrons from beam, atmospherics, and cosmics travel far

A single "DUNE Event" is therefore 6.22 GB (uncompressed).
We have a cap of 30 PB/year for all 4 modules=4.8 million events/year.

Exceptions to the Standard Process

Likely exceptions to no zero-suppression/localization paradigm:

- Electronics calibrations (run as pulse train anyway)
- Laser source calibrations (known, fixed tracks)
- Radioactive sources (known location)
- Random triggers for ^{39}Ar calibrations (known trigger type)
- Supernova bursts
  - Lower effective energy threshold (3.5 MeV?) for counting potential burst events
  - Burst criterion on N of these in a fixed window
  - If burst criterion exceeded, 10 s before and 20 s after ALL data is saved.

These can be exceptions because we know time and position or that they are point-like deposits (ie, ^{39}Ar), or are so infrequent (SN bursts) and precious that we do something different.

DAQ Needs from Calibration Systems

Possible generic systems so far:

- Front-end electronics (handled by CE consortium)
- Radioactive sources (includes neutron source)
- Laser
- EMT
- LEDs for PDS (these are handled by PDS consortium)

DAQ will always need a way of knowing when a source is being used=Run Type

And/Or what time a calibration event has been generated=Trigger Type

While we always prefer to drive the latter---force the trigger from the DAQ---it may not always be possible.

DAQ Needs from Calibration TF

- How many calibration sources will there be?

And for each source:

- Can they be run with detector "live" to other physics?
- Can the source be triggered, or will it provide a trigger?
- What is rate of source?
- What is rate of events to be recorded?
- What is the total number of events/year needed?
- Can zero-suppression be used for signals?
- Will it provide a timestamp and if not, is latency known and constant? And how will it be synchronized?
- How much of the detector will be illuminated? (Can we localize events?)

Data Rates

All numbers are 1 10 ktonne SP module, uncompressed

Event Type	Data Volume PB/year	Assumptions
Beam interactions	0.03	800 beam and 800 dirt muons; 10 MeV threshold in coincidence with beam time; include cosmics
Cosmics and atmospherics	10	10 MeV threshold, anti-coincident with beam time
Front-end calibration	0.2	Four calibration runs per year, 100 measurements per point
Radioactive source calibration	0.1	Source rate $\leq$10 Hz; single fragment readout; lossless readout
Laser calibration	0.2	1×10^6 total laser pulses, lossy readout
Supernova candidates	0.5	30 seconds full readout, average once per month
Random trigger	0.06	45 per day
Trigger primitives	$\leq$6	All three wire planes; 12 bits per primitive word; 4 primitive quantities; ^{39}Ar-dominated

Updates to Data Rates

Laser Calibrations

Calibration WG suggests 800k pulses/run; assumption was 1 M/run

Laser can be tightly zero-suppressed, so

$$800,000/\mathrm{cal}/10\ \mathrm{ktonne} \times 100\mu\mathrm{s} \times 1.5\mathrm{Bytes}/\mathrm{sample} \times 2\ \mathrm{MHz} \times 384000\ \mathrm{channels} = 92\ \mathrm{TB}/\mathrm{cal}/10\mathrm{ktonne}$$

If this is done twice/year it is **184 TB/year**

Was 200 TB/year

Updates to Data Rates

Radioactive Source Calibrations

UC Davis "neutron bomb" source is easy; 20k neutrons/pulse, run normally
Total data volume is neglible---don't need many pulses to get a lot of neutrons—
How many total are needed each year?

Gamma source requires special handling.
We *assume* rate in detector is 10 Hz and it illuminates just 1 APA (2560 channels)
So we localize readout to just 1 APA. For an 8 hour run in 4 feedthroughs, so

$$8 \text{ hours} \times 4 \text{ FTs} \times 10\ Hz \times 1.5 \text{ Bytes} \times 2 \text{ MHz} \times 5.4 \text{ ms} \times 2560 \text{ channels} = 50 \text{ TB/run}.$$

If this is done 4x/year it is **200 TB/year**

How many total events are needed? What is interaction rate in detector?
May need a coincidence trigger between source tag and TPC trigger.
Zero-suppression for this source would be a bad idea.

Updates to Data Rates

External Muon Tracker (EMT)

If only in front of cryostat and looking at rock muons from beam, Diurba (DocDB 6628) calculates 735 pass through EMT each year.

Configuration is a telescope with x and y counters, so expect each muon to hit 4 counters. Each hit is 4 12-bit words (time, charge, channel, timestamp)

$$735\text{year}/10\text{ktonne} \times 24 \text{ B}/\text{event} = 17.6 \text{ kB}/\text{year}$$

Which is ~ 10^{-11} PB/year. If we include cosmics and as an upper limit say that every single cosmic goes through the EMT…it is at the very most 40 MB/year=4e-8 PB/year (=4500/day x 365 days x 24 B/event).

Updates to Data Rates

Front-End Calibrations

M. Worcester/Dave Christian

Test stand data is 10 ms pulse train (100 μs between pulses) for two gains and four shapings:

10 ms * 2 MHz * 2 gains * 4 shapings * 384000 channels = 61 GB/run/10 ktonne

Plus 4 points to determine linearity of ADC:
+ 10 ms * 2 MHz * 4 points * 384000 channels = 15 GB/run/10 ktonne

= 75 GB/run/10 ktonne

If this is done 1/week it is 4 TB/year; ***was*** 200 TB/year

This assumes DNL is good; worst case is 1000x more data.
Not clear yet how much needed for crosstalk measurement

Updates to Data Rates

^{39}Ar Calibration

Mike Mooney calculates that to calibrate lifetime daily with ^{39}Ar (ignoring cosmics) for each (projected) 1 m^2 of detector to 1% requires a 1 Hz trigger rate.

In current paradigm, this is not possible (=200 PB/year).

Options:

1. Use collection-wire only trigger primitives (= 2 PB/year)
2. Save induction trigger primitives also (=6 PB/year)
3. Zero-suppress some fraction of random triggers and increase rate
4. Apply very low threshold just above noise and pre-scale rate
5. Do ~1 Hz of randoms and delete data after analysis every day

1 comes for free but means only 2D granularity---cosmics can help with other dimension?
2 increases data volume enough that we need to dump data after short (~ 4 mos.) time
2 also needs development of induction wire zero-suppression+testing for calibration
3 requires some real work to develop algorithm and test it
4 may not actually get enough statistics
5 will be limited by event builder bandwidth but could be close; analysis has to turn around fast

Constraints on Calibration Sources

- Other than random triggers, it is anticipated that the TPC threshold will be >10 MeV for normal running
- If event rate in detector is 1/2.25 ms=400 Hz this is DC running and t0 is useless
- If event rate in detector is such that there is more than 1 event in 2.25 ms, determining t0 will require position reconstruction with photon system or some other method
- If event rate in detector is > 0.5 Hz, in existing paradigm event builder may not keep up
- If event rate in detector is > 1.6×10^6/year, you are dominant source of data for DUNE

(unless events are zero-suppressed or geo-suppressed)

- Self zero-suppression of u/v wires means you lose field response information, and probably can't do 3D recon

Updated Table

All numbers are 1 10 ktonne SP module, uncompressed

Event Type	Data Volume PB/year	Assumptions
Beam-related Events	0.03	926 beam and 1368 dirt muons; 10 MeV threshold in coincidence with beam time; include 2800 accidental cosmics
Cosmics	10	10MeV threshold, anti-coincident with beam time
Front-end calibration	0.004	Existing test-stand scheme
Atmospheric *nus*	0.007	CDR interaction rates
Solar νs	0.07	*Upper limit* assuming rate above 4.5 MeV ν energy
Radioactive source calibration	0.2	Source rate $\leq$10Hz; single fragment readout; lossless readout, 4 times/year
Laser calibration	0.184	800,000 total laser pulses, lossy readout
External μ Tagger	1.8×10^{-11}	Rock μs only, 4 hit counters, 4 12-bit words/hit
Supernova candidates	0.414	30 seconds full readout, average once per month
Random triggers	0.1	45 per day
Trigger primitives	$\leq$6	All three wire planes; 12 bits per primitive word; 4 primitive quantities; ^{39}Ar-dominated