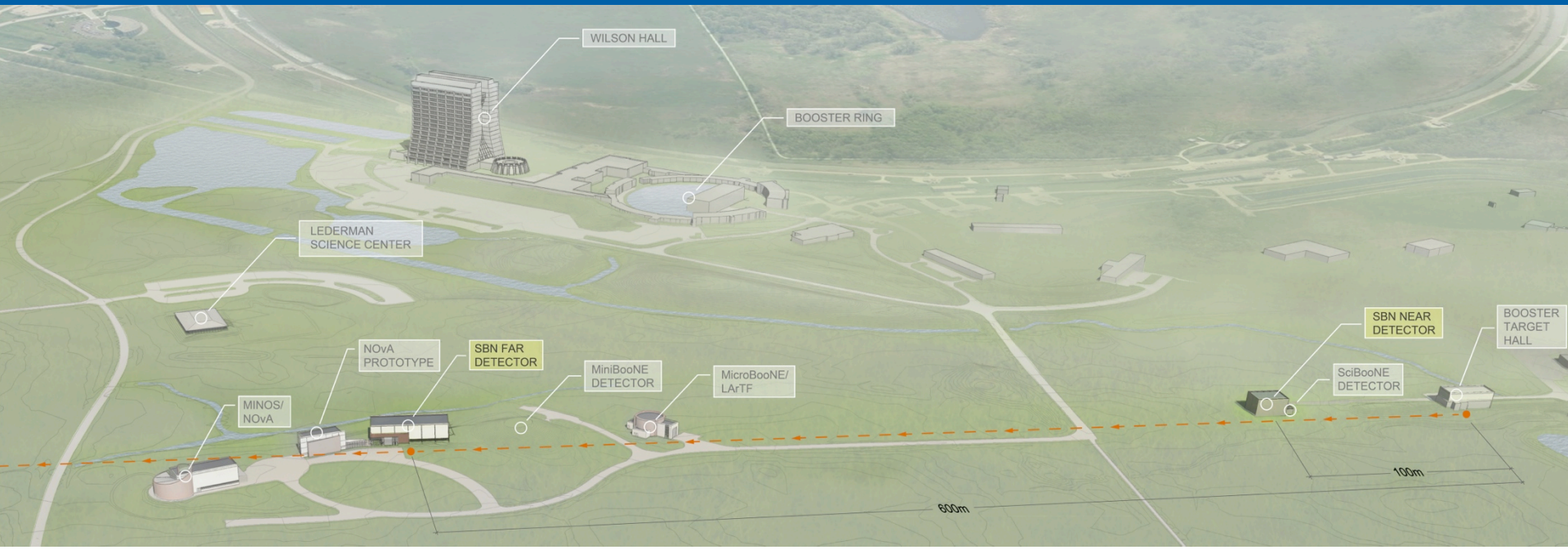


Summary of the SBN-DUNE DAQ Meeting

Wesley Ketchum (FNAL)

SBN Director's Review

15 December 2015

Overview

- DAQ Requirements for the three SBN detectors
- DAQ development plans
- Possible future hardware upgrades/ideas
- Possible common efforts with DUNE

Data requirements

	SBND	MicroBooNE	ICARUS
Number of TPCs	2	1	4
TPC Channels (total)	11,500	8,256	53,000
PMT Channels	100	36	400
CRT Channels	4,000	*1600 (under design)*	*under design*
TPC Digitization	2 MHz, 12b	2 MHz, 12b	2.5 MHz, 12b
PMT Digitization	~1 GHz	64 MHz	~1 GHz
TPC drift/readout period	1.3 ms / 3.8 ms	2.3 ms / 4.8 ms	1.0 ms / 1.6 ms
Uncompressed data size (per event, TPC only)	220 MB	150 MB	330 MB
Compression factor (Hardware + Software)	5	5	*under design* (assume 4*2)
Total data size (per event, TPC only)	45 MB	30 MB	40 MB

Data rate requirements

- Assuming…
  - 15 Hz neutrino beam instantaneous rate
  - 5 Hz average rate
  - Additional 1 Hz for other triggers
  - Desire at beginning of run/commissioning to take every spill
    - i.e. no pmt trigger applied yet

	SBND	MicroBooNE	ICARUS
Instantaneous data rate required (MB/s)	675 MB/s	450 MB/s	620 MB/s
Average data rate required (MB/s)	270 MB/s	180 MB/s	250 MB/s

TPC DAQ Links

	SBND	MicroBooNE	ICARUS
Readout module producer	Nevis	Nevis	Padova/CAEN
Channels per module	64	64	64
Modules per crate	~16	8-15	~9
Total readout crates	~10	9	~100
Link to DAQ server	Optical fiber → PCIe card	Optical fiber → PCIe card	Optical fiber → PCIe card
Number of DAQ servers	~10	9	*under design (crates can be daisy-chained)*
Number of event builder servers	1	1	*4 (under design)*

DAQ: Additional requirements

- Trigger
  - Can trigger on light+beam gate (BNB and NuMI) signal
  - Can trigger on (BNB and NuMI) beam gate alone
  - Can take additional (off-beam, calibration) triggers
- Event-building
  - Basic event: TPC + light system + CRT data, all built online
  - Sub-system components synchronized in time via GPS
    - Along with some internal clocks
  - Data format: ROOT (SBND), binary (MicroBooNE, ICARUS)
    - Though all options under consideration for both
- Additional (non-triggered) data streams
  - MicroBooNE and SBND plan to have continuous stream
  - No such plans in ICARUS

DAQ development plans: teststands

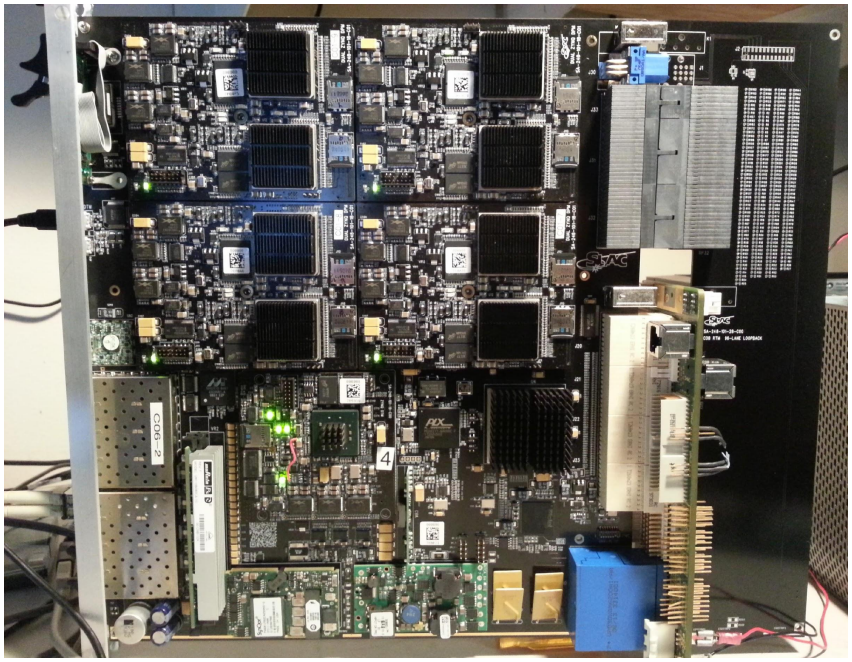
- ICARUS
  - Vertical slice with TPC, electronics, and DAQ server at CERN
    - Could add switch and event builder
  - Development test stand with electronics and DAQ PC at INFN-Legarno
- SBND
  - Vertical slice with (cold+warm) electronics, DAQ server, network switch, and event builder at DAB (FNAL) *in development*
  - Vertical slice with (warm) electronics, DAQ PC, switch, and event builder PC at PNNL *in development*
  - Development stand with readout electronics and DAQ PC at Nevis *in development*
  - CRT test stand with electronics and DAQ server at Bern
- MicroBooNE
  - Vertical slice with readout electronics, DAQ server, network switch, and event builder at LArTF
  - CRT test stand with electronics and DAQ servers at DAB (FNAL) *in development*

DAQ development plans: software

- ICARUS
  - Baseline design is to use existing ICARUS DAQ software, upgraded to handle new electronics
  - Artdaq system being developed and tested side-by-side
- MicroBooNE
  - Existing DAQ in place, with a few planned upgrades for next summer
    - Implementation of the continuous data stream
    - Addition of a CRT system (same system as SBND)
      - CRT system daq will be artdaq-based
  - Some collaborators (*ahem*) thinking about upgrade to artdaq
- SBND
  - Baseline DAQ design is MicroBooNE inspired, with full move to artdaq

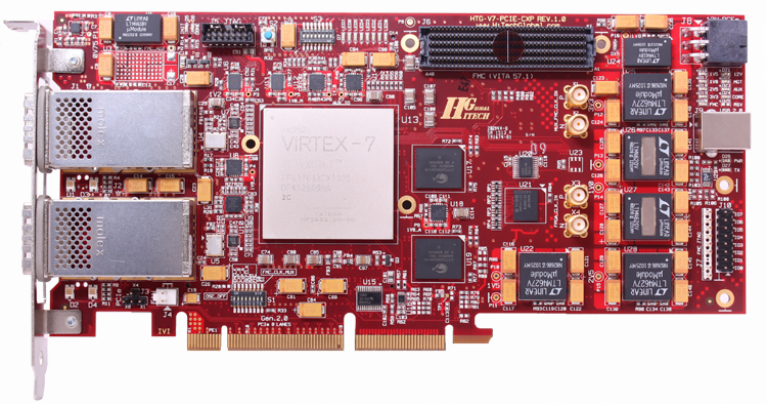
Possible hardware upgrades: RCE

- Some discussion at ICARUS on using SLAC Reconfigurable Cluster Element (RCE)
  - ATCA-based DAQ system
  - “Cluster on a board”
  - Tight coupling between application firmware and software
- RCEs part of readout chain for DUNE 35-ton
  - Triggered+continuous readout modes, waveform zero-suppression
  - artdaq software



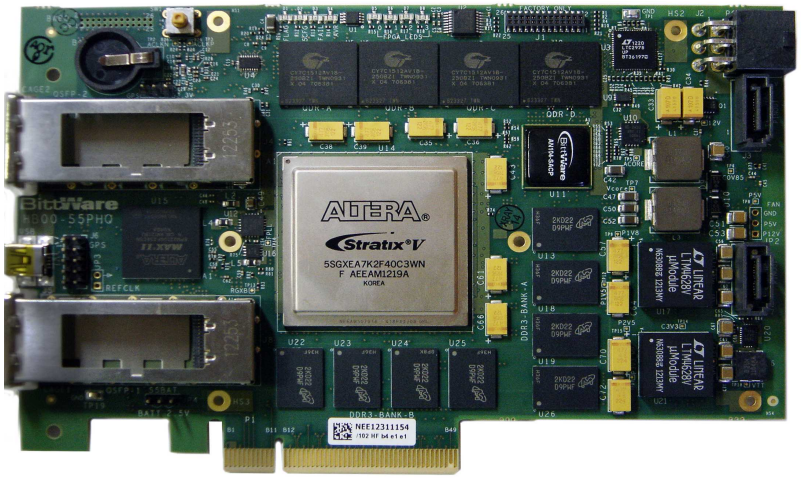
Possible (future) hardware upgrades: FELIX

- FELIX (FrontEnd LInk eXchange) could be used in place of CAEN 3818 boards (CONET-2 protocol)
  - Drive signals from readout boards
    - GBT protocol now, but more lightweight in future
  - FELIX PC collects data (PCIe card) and routes to commercial network switch → event builders
    - Mirrors ICARUS DAQ after that point
- Currently considered as an R&D project at ICARUS CERN test stand
  - Not on timescale of ICARUS installation/start of data



Possible (future) hardware upgrades: Bittware S5-PCIe-HQ board

- High-performance PCIe back-end board could collect data straight from detector
  - Couple data concentration on feedthroughs with cold ADCs
  - Stream data to high-bandwidth card on PCIe bus of commercial server
  - Signal processing / event building all done in software or card firmware (OpenCL)
- Currently considered as R&D project at SBND PNNL test stand
  - Not on time scale of SBND construction/start of data



SBN-DUNE common interests

- DUNE is pursuing/considering many of these same things
  - Artdaq (35 ton & protoDUNE?, SBND & ICARUS? & MicroBooNE?)
  - RCEs (35-ton, ICARUS?)
  - S5PHQ-D8 (WA105, SBND?)
  - White Rabbit timing (WA105, SBND?)
- Successful meeting 3 weeks ago on shared interests
  - https://indico.fnal.gov/conferenceDisplay.py?confId=10599
- Next steps: decisions, and possible combination of resources on shared goals

Questions/Discussion

(And thank you!)

Backup slides

Timescales

- Both SBND and ICARUS plan to be operational ~2018
- Both experiments plan to have final hardware designs finalized ~Spring 2016
  - TPC hardware decisions largely already made
  - PMT + trigger hardware decisions still being finalized
  - Expect software architecture/framework decisions to be finalized on similar timescale

Teststands

- Both experiments need a DAQ operating on TPC test stands
  - ICARUS
    - Vertical slice with TPC, electronics, and DAQ PC at CERN exists
      - Could add switch and event builder
    - Development test stand with electronics and DAQ PC at INFN-Legarno
  - SBND
    - Vertical slice with (cold+warm) electronics, DAQ PC, network switch, and event builder PC at FNAL in development
    - Vertical slice with (warm) electronics, DAQ PC, switch, and event builder PC at PNNL in development
    - Development stand with readout electronics and DAQ PC at Nevis in development
    - CRT test stand with electronics and DAQ PC at Bern exists
- Plans for PMT, trigger, CRT (ICARUS), and laser (SBND) test stands to be developed with hardware decision
- Requirement: basic DAQ applications be able to operate on test stand in production-level mode

Detector subsystems: SBND

- TPC: ~11,500 channels
  - 64 channels per readout module, with 16 modules per readout crate
  - 2 MHz sampling, 3.84 ms readout → ~220 MB/event, uncompressed
    - ~20 MB/event per readout unit
  - Links: same as MicroBooNE (Nevis design optical links + PCIe card)
- PMT: ~100 channels
  - ~up to 1 GHz sampling → total data rate unknown, expected < TPC
- CRT: ~4000 channels
  - 32 channels per front-end board, with 18 FEBs per readout unit
  - About 6 MB/s data volume
- Laser
  - Readout of laser mirror positioning during calibration runs

Detector subsystems: ICARUS

- TPC: ~53,000 channels
  - 64 channels per readout module, with ~9 modules per readout crate
  - 2.5 MHz sampling, 1.64 ms readout → ~330 MB/event, uncompressed
    - ~3.4 MB/event per readout unit, though higher concentration possible
  - Links: presently deployed CAEN CONET-2 proprietary protocol
    - Used for testing, not final configuration
- PMT: ~400 channels
  - ~1 GHz sampling → total data rate unknown, expected < TPC

Total data rate requirements
Front-End

- Assume just TPC data for now (as that is dominant, and designed)
- Maximum required instantaneous rate
  - Beam operation: ~15 Hz
  - Commissioning: 50 Hz (SBND),
    AFARA (as fast as reasonable achievable) (ICARUS)
- Expected average rate
  - Beam operation: ~5 HZ (ICARUS), ~5 Hz* (SBND)
    - *Assumes fully operational and commissioned PMT trigger at start of data-taking
- Uncompressed data rates:
  - Instantaneous: 5 GB/s (ICARUS), 3.3 GB/s (SBND)
  - Average: 1.7 GB/s (ICRAUS), 1.1 GB/s (SBND)

Compression

- SBND
  - Assumes factor ~5 compression from Huffman scheme (similar to MicroBooNE)
  - No additional software compression assumed
- ICARUS
  - New scheme (compared to LNGS run) needed for new 12-bit ADCs
    - To be determined
  - Software compression factor ~2 from gzip of files (achieved at LNGS)
  - Additional compression could be implemented at FE PC or EventBuilder
    - Let's assume factor 4, like Nevis-style Huffman compression
- Total data rates with compression:
  - Instantaneous: 2.5 GB/s (ICARUS), 2 GB/s (SBND)
  - Average: 200 MB/s (ICRAUS), 220 MB/s (SBND)

What to make of all of that?

- There's a lot of varying assumptions/ideas in those numbers, so let me give the three numbers I think are most relevant
- Max accelerator structure rate is 15 Hz
  - With conservative compression assumptions, this is 625 MB/s and 660 MB/s in ICARUS and SBND, respectively
- Likely beginning operational average rate is 5 Hz
  - → ~200 MB/s and 220 MB/s in ICARUS and SBND, respectively
- Incorporating a light-coincidence trigger will lower rates
  - Expected factors are approximate 1/40 and 1/15 in ICARUS and SBND, respectively
  - This leads end-data-rate assuming 5 Hz beam rate of 5 MB/s and 15 MB/s in ICARUS and SBND, respectively

Trigger

- Basic strategy is the same
  - Activity in light detection system in coincidence with neutrino beam spill
  - Both experiments require ability to trigger on neutrino beam spill alone
  - Both experiments require storage of trigger bits fired for each event
  - ***NOTE***: Neither experiment likely requires trigger-level veto from CRT system
    - To be determined with final decisions
  - Trigger signal broadcast to all TPC readout crates
    - PMT and CRT still under discussion for ICARUS
    - PMT not defined for SBND, but CRT will not see trigger signal
- Trigger hardware
  - Still being discussed for both experiments, along with PMT readout hardware
- Trigger backpressure from DAQ?
  - SBND: No requirement, readout electronics buffering sufficient
  - ICARUS: Required. DAQ must be able to issue temporary trigger inhibit

Synchronization

- TPC (both experiments)
  - All crates synchronized to each other
  - Crates synchronized to trigger clock
  - GPS time stamps
- PMT (both experiments)
  - Still undefined, but likely similar to TPC
- CRT
  - SBND: GPS time-stamps for each event, matched to time stamps from other fragments
  - ICARUS: still under discussion
- Beam (both experiments)
  - Online: trigger sees beam signal (properly timed in), and BNB RWM signal recorded
  - Offline: merge to beam data from IFDB based on GPS time stamps

Event-building

- Merge data from subsystems into one file online?
  - YES (both experiments)
    - Challenge for systems with only time-stamps to merge
- Additional information
  - YES (both experiments)
    - Run, event, timing info, trigger source, number of triggers dropped (ICARUS), etc.
- Format
  - SBND: Under discussion, but ROOT format likely sufficient
  - ICARUS: Under discussion, but probably ability to write binary (LNGS compatible) format alongside ROOT

SBND: Continuous stream

- SBND will have a “Supernova” stream for readout out data continuously
  - Expect total rate ~100 MB/s in each front-end crate
    - Requires zero-suppression in readout electronics
  - Data streamed to local DAQ PCs, and moved to permanent storage and processed only on receipt of external trigger (e.g. SNEWS alert)
    - Otherwise overwritten after 1-2 days
  - Should run simultaneously with triggered stream
- ICARUS does not currently have plans for a continuous data stream

Data flow

- See talks from MicroBooNE and ICARUS DAQ experience: these serve as the models for data flow
- In both experiments, fully built events can be moved towards offline storage after integration with beam data
- Both experiments plan to save raw (unprocessed) data, and (potentially) a processed data file
- Both experiments need 10 Gb links to offline storage
- Details on amount, features, and exact path towards permanent storage need to be defined
  - ICARUS: will be ironed out along with decisions on software
  - SBND: will follow MicroBooNE model
  - Both: will benefit from details of MicroBooNE's practical experience

Monitoring Tools

- Again, see talks from MicroBooNE and ICARUS DAQ experience
- ICARUS would like to retain database for tracking of files, data flow, and monitoring
  - Details of those to be discussed/depend on final software decisions
- SBND will use custom ganglia metrics for monitoring of DAQ quantities, and likely retain a database for monitoring data files after being fully built
  - Higher-level monitoring to be discussed, but can be accomplished through dedicated art modules running in an artdaq system
- System accessibility and maintenance
  - MicroBooNE heavily utilizes services of Scientific Linux and Architecture Management team: expect both ICARUS and SBND will do the same

Content Slide [28pt Bold]

Bullet points are optional. If preferred, only first level bullets can be used or bullets can be set to “NONE.” [24pt Regular]

- First level bullet [24pt Regular]
  - Second level bullet [22pt Regular]
    - Third level bullet [20pt Regular]
      - Fourth level bullet [18pt Regular]
        - Fifth level bullet [18pt Regular]

Comparison Slide [28pt Bold]

- First level bullet [24pt Reg]
  - Second level bullet [22p]t
    - Third level bullet [20pt]
      - Fourth level bullet [18pt]
        - Fifth level bullet [18pt]

Click to add caption text [16pt Bold]

- First level bullet [24pt Reg]
  - Second level bullet [22pt]
    - Third level bullet [20pt]
      - Fourth level bullet [18pt]
        - Fifth level bullet [18pt]

Click to add caption text [16pt Bold]

Content and Caption Slide [28pt Bold]

Click to add caption text [16pt Bold]

- First level bullet [24pt Reg]
  - Second level bullet [22pt]
    - Third level bullet [20pt]
      - Fourth level bullet [18pt]
        - Fifth level bullet [18pt]

Picture and Caption Slide [28pt Bold]

Click to add caption text [16pt Bold]

Collaborations / Partnerships / Members 28pt Bold
Logos shown are examples