Dual Phase Electronics

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Dual-phase electronics scope:

- FE cryogenic analog electronics for charge readout
- Signal Feedthrough chimneys hosting the FE analog electronics cards
- uTCA digitization cards for charge readout
- uTCA digitization cards for light readout (based on charge readout design)
- uTCA crates infrastructure and White Rabbit timing distribution system integrated in the digital electronics

Natural involvement of the DP-electronics groups also in the DAQ consortium

Hardware interface to DAQ at the level of the 10 Gbit/s links delivering the data to the DAQ backend from the uTCA crates

ProtoDUNE-DP accessible cold front-end electronics and uTCA DAQ system 7680 ch

Full accessibility provided by the double-phase charge readout at the top of the detector

➢ Digital electronics <u>at warm</u> on the tank deck:

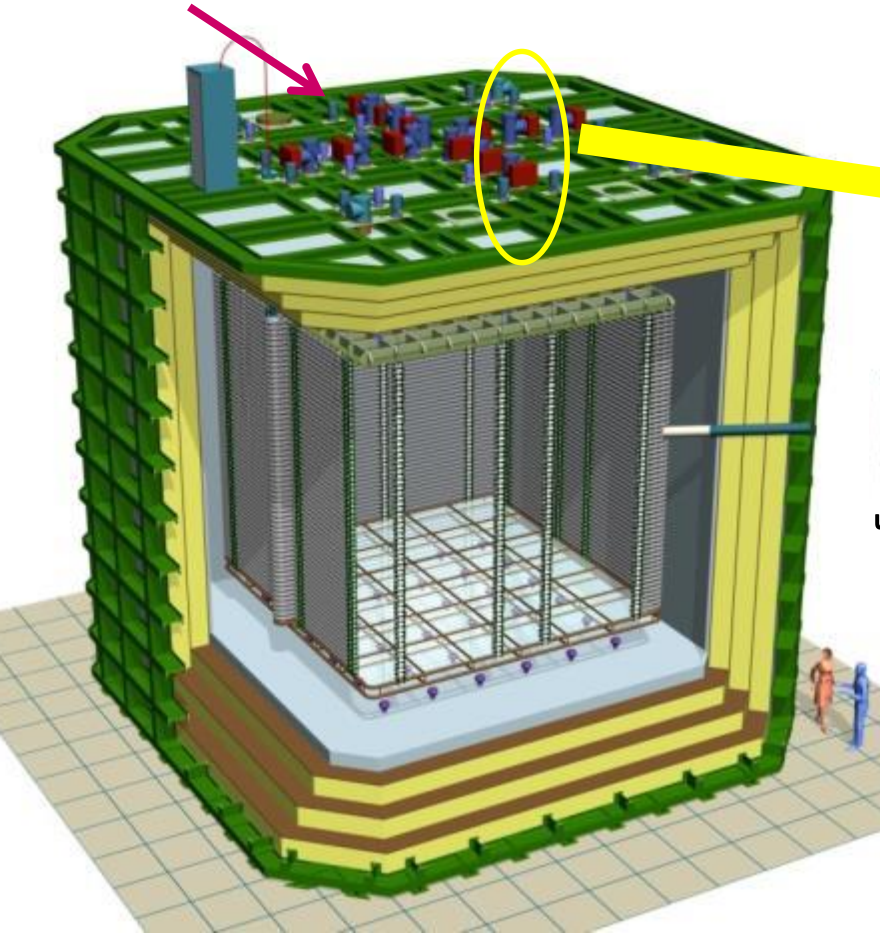
- Architecture based on uTCA standard
- 1 crate/signal chimney, 640 channels/crate

→ 12 uTCA crates, 10 AMC cards/crate, 64 ch/card

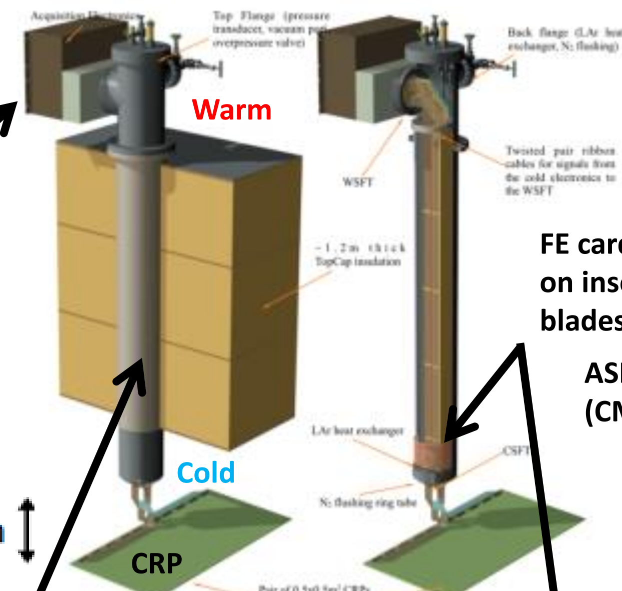
➢ Cryogenic ASIC amplifiers (CMOS 0.35um) 16ch <u>externally accessible:</u>

- Working at 110K at the bottom of the signal chimneys
- Cards fixed to a plug accessible from outside

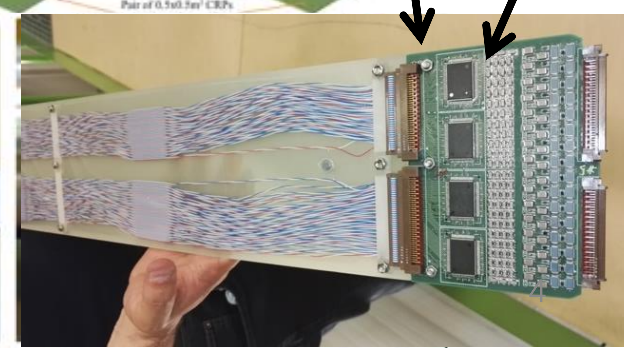
→Short cables capacitance, low noise at low T



uTCA crate

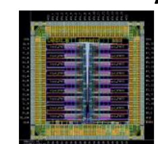


Signal chimney



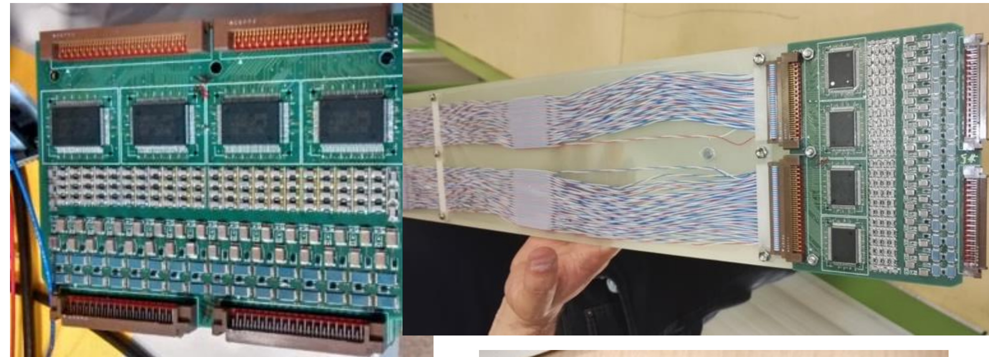
FE cards mounted on insertion blades

ASICs 16 ch. (CMOS 0.35 um)



Electronics components:

(R&D since 2006, long standing effort aimed at producing low cost electronics)



Analog cryogenic FE:

- **Cryogenic ASIC amplifiers DP-V3, 0.35um CMOS → production performed at the beginning of 2016**
- **64 channels FE cards with 4 cryogenic ASIC amplifiers**
- **First batch of 20 cards (1280 channels) operational on the 3x1x1 since the fall 2016**
- **Production of remaining 100 cards for 6x6x6 completed on 2017 budget**

Digitization cards:

uTCA 64 channels AMC digitization cards (2.5 MHz, 12 bits output, 10 GbE connectivity)

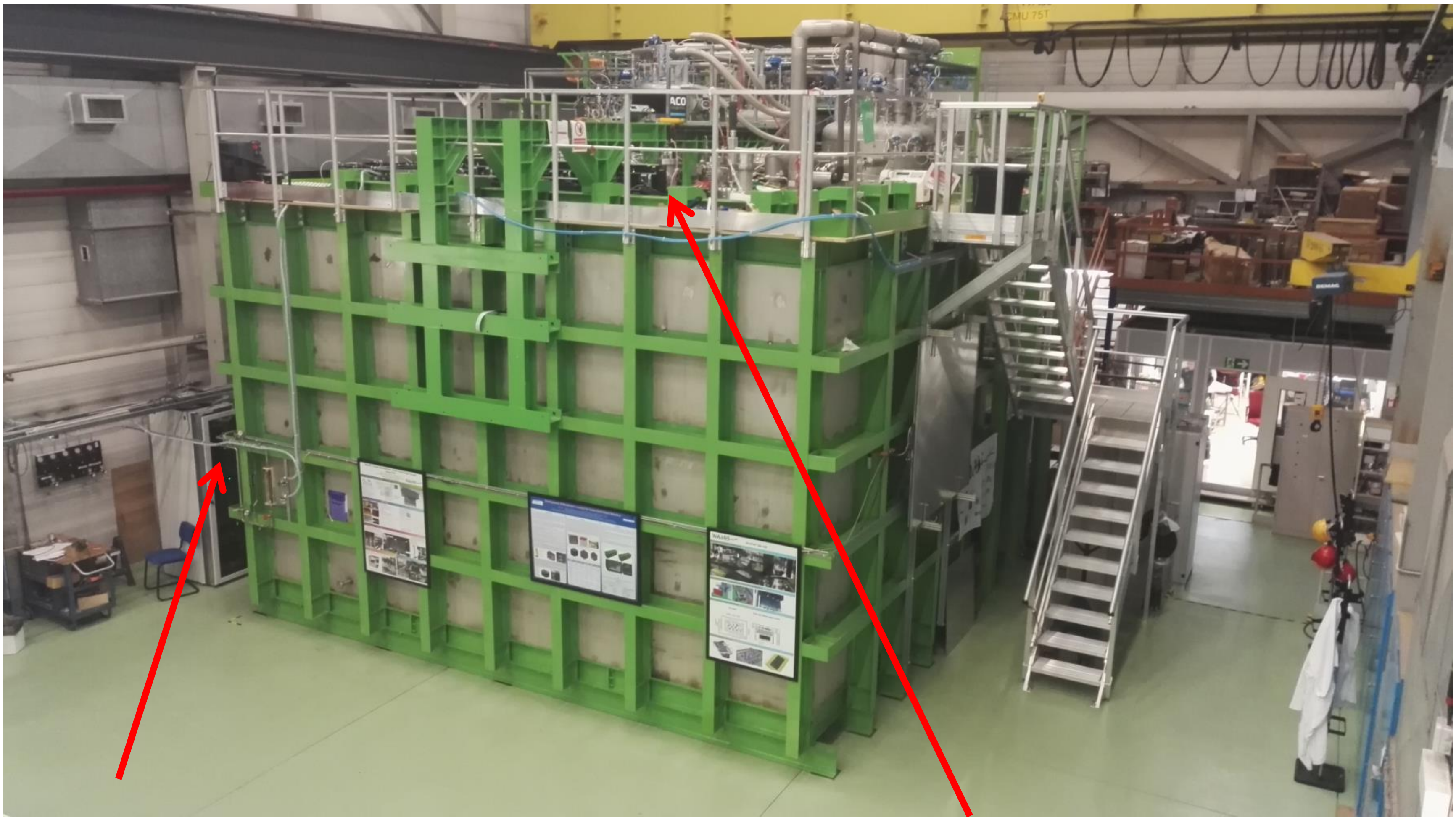
- **20 cards operational on the 3x1x1 since the fall 2016**
- **Production of remaining 100 cards for the 6x6x6 completed on 2017 budget**

White Rabbit timing/trigger distribution system:

- **Components produced in 2016 for the entire 6x6x6, full system operational on the 3x1x1 since the fall 2016**

6x6x6: 12 uTCA crates (120 AMCs, 7680 readout channels)

→ 3x1x1: 4 uTCA crates (20 AMCs, 1280 readout channels) Operational since fall 2016



Event builder, network, GPS/White-Rabbit GM, WR Trigger PC

Signal Chimneys and uTCA crates

Components for a 10 kton dual-phase module

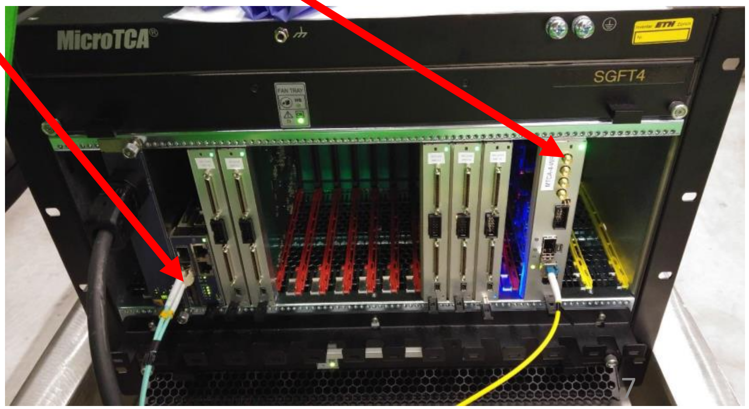
(list based on current 6x6x6 design prior to further optimization and channels density increase)

Total number of charge readout channels: 153600

Requirements:
DocDB: DUNE-doc-6428-v1

- Cryogenic ASICs (16 ch): 9600
- Cryogenic FE cards (64 ch): 2400
- Chimneys: 240
- AMC cards (64 ch): 2400
- uTCA White-Rabbit cards: 240
- uTCA crates (including MCH,PU,FU): 240
- 10 Gbe optical links to backend: 240
- VHDCI cables (32 ch) 4800

White-Rabbit switches (18 ports): 16



Light readout (720 channels):
5 uTCA crates
5 uTCA White Rabbit Cards
45 AMC cards

Main Interfaces:

- Cryostat/cryogenics DocDB-6982
- Photon-Detection: Cabling and expected input on number of channels (temporary assumed to be 720) and signals characteristics DocDB-6772
- CRP Assumed same anode cabling as in PD-DP, interface at chimney cold flange DocDB-6751
- DAQ: Network links, data flow, data transmission protocols DocDB-6778
- Slow control: controls of uTCA crates and power supplies DocDB-6784

Interface from uTCA to DAQ:

- DP charge readout (baseline configuration with 240 uTCA crates):

240 ethernet optical links at 10 Gbit/s (or less links: 120, at 40 Gbit/s)
1 link/crate, 640 readout channels/crate, 12 bits, 2.5 MHz sampling, loss-less compression with factor 10 compression, continuous streaming
Compressed data rate per link 1.79 Gbit/s
Data rate per LV1 EVTB (8 links): 14.32 Gbit/s
Total data rate: 430 Gbit/s per 10 kton module

- DP light readout (example corresponding to the same photocoverage as in PD-DP):

5 ethernet optical links at 10 Gbit/s
1 link/crate, 9 cards per crate (16 channels/card) → 144 channels/crate
14 bits, 2.5 MHz sampling continuous streaming → **4.7 Gbit/s per link**
Total data rate: 23.5 Gbit/s per 10 kton module
Some special runs with 40 MHz sampling possible to study the time profile (purity) in self triggering mode (for instance selecting 20 us windows after the trigger)

- Integrated in common SP/DP White Rabbit network → common Grand Master switch, 1 Gbit/s optical fiber links

DUNE Interface Document: Dual-phase Electronics/DAQ

Definition: This document describes the interface between the DUNE dual-phase far detector Electronics and DAQ. This document describes the necessary interfaces for both DP-Electronics and DAQ to complete the design, fabrication and installation of their subsystems. This document describes the elements of the scope of each subsystem at the interface between them.

Hardware: The hardware interface between DP-Electronics and DAQ has two components:

The first interface are the 10 Gbit/s optical fibers for data transfer between the uTCA crates hosting the digitizer AMC boards of the dual-phase electronics and the network interfaces of the DAQ system. In the baseline design for a DP far detector module it is foreseen to have **x240 10Gbit/s optical fiber links for the charge readout uTCA crates and x5 10Gbit/s optical links for the light readout uTCA crates**. The current fibers specifications is based on multimode OM3 fibers with LC-LC connectors, which are suitable for transmissions up to 300 m distance. On the side of the uTCA crate this optical fiber link will be connected to the optical transceiver in the MCH (providing two SFP+ (XAUI) links). On the DAQ side all these fibers will go to the network interfaces of the LV1 machines of the trigger farm, or to switches, depending on the network topology eventually implemented. The DAQ consortium will purchase the fibers while the DP-Electronics consortium will take care of their installation on the cryostat roof down to the locations of the uTCA crates, which will be located at close distance with respect to the signal feedthrough chimneys. The DP-Electronics consortium will also take care of all the digital electronics in the uTCA crates for both charge and light readout.

The second interface is a single optical fiber link 1Gbit/s syncE, which will go from the White Rabbit Grand Master switch of DUNE to a Master switch of the DP-electronics timing system. The White Rabbit Grand Master will be possibly installed on surface with the GPSDO clock unit which as to be on surface in order to receive the GPS signals. The White Rabbit fiber from the Grand Master allows distributing timing underground for tens of km with sub-ns accuracy, also automatically compensating for the propagation delays. The DP-Electronics consortium will take care of all the other steps concerning the purchase and installation of the White Rabbit switches and slave nodes needed by DP-Electronics system, including the related optical fibers cabling. The common Grand Master provided by the DAQ consortium has the purpose of making sure that the common time base is distributed to all DUNE 10kton Modules. In case it will be needed, the DP-Electronics consortium can also provide this common Grand Master unit and the GPSDO unit. The installation of the fibers going from the common WR Gran Master located on surface to the caverns is supposed to be taken care by LBNF.

It is assumed that the 10 Gbit/s data links will distribute a continuous data streaming to a set of network elements and event building machines which will then define triggers on the basis of the charge and/or light readout information. These triggers will be issued by processing the data over a sliding window, contained in a memory buffer on the trigger farm machines. The depth of this sliding window may tipically go up to 10s, as needed by the Supernova events trigger definition. These triggers will determine if the data contained in the event building buffers are eventually written on disk. Several LV1 event building units will be looking at the raw data in parallel and we able to exchange trigger information among them and also with similar units looking at the SP modules.

Any cables associated with DP photon system are described in the DP-Electronics/Photon interface document. Any cable trays or conduits to hold the DAQ/DP-Electronics cables are described in the LBNF/Technical Coordination interface documents and currently assumed to belong to Technical Coordination

Signals:

The DP-electronics is supposed to provide data in continuous streaming (12 bits at 2.5 MHz sampling) of all the charge readout channels over the 10 Gbit/s links. Each 10 Gbit/s link will be used to stream the data of 640 charge readout channels. The links will be operated as standard Ethernet links. The data streaming will be performed at constant rate without zero suppression and by applying lossless compression, derived from an optimized version of the Huffman algorithm. Given the noise characteristics and S/N ratio of DP electronics (RMS noise around 1 ADC count) a compression factor of 10 is expected. Blocks of data will be formatted in UDP packets which will also contain time stamps in the common WR time-base. The typical occupancy of a 10 Gbit/s link is expected to be 1.8 Gbit/s for each one of the 240 charge readout links and 4.7 Gbit/s for the 5 light readout links (sampling in normal conditions also at 2.5 MHz with 14 bits dynamics). Light readout may also operate with a sampling finer than 2.5 MHz in special runs devoted to measure the slow component of the scintillation light for purity measurements. Data transmission latency over the 10 Gbit/s network is expected to be at the level of few us, negligible with respect to the size of the memory buffers on the triggering farm.

More details are described in the document "DP-FE Electronics and DAQ interface aspects". The Data flow will be checked with the exchange of control UDP packets among the DAQ and the DP-Electonics AMC FE-units. This check will be periodically performed for fixed periods in order to make sure that the data streaming is proceeding smoothly and all FE units are aligned. The format and the frequency of exchange of control packets has to be defined.

Software: The software interface between DAQ and DP-electronics includes the software dealing with the data formatting in UDP packets, compression/decompression and exchange of control packets. The basic libraries will be provided by the institutions of the DP-Electronics consortium, which are also committed to the DAQ consortium.

Installation: The DP-electronics consortium will take care of the installation down to the optical fibers included.

Commissioning: DAQ and DP-electronics will provide staffing for common commissioning of the system including the DP-electronics and DAQ.

DP electronics-DAQ Interface document

https://docs.dunescience.org/cgi-bin/private/ShowDocument?docid=7207

+ more detailed document on interface aspects:

https://indico.fnal.gov/event/15366/session/2/contribution/26/material/slides/0.pdf

https://indico.fnal.gov/event/15366/session/4/contribution/29/material/slides/0.pptx

Interfaces:

- 10 Gbit/s data links, fibers, data volume and protocols
- White Rabbit network, fibers
- Software
- Installation

Strategy document, based on DP-electronics consortium expected activities for 2018-2019

https://docs.dunescience.org/cgi-bin/private/ShowDocument?docid=7207

Dual-Phase Electronics Consortium Strategy Document

V1.2

Working framework:

a) The electronics produced for PD-DP was tested since the fall 2016 on the 3x1x1 detector at the level of one sixth of the final number of channels foreseen for ProtoDUNE-DP (1280 channels in the 3x1x1 vs 7680 channels for protoDUNE-DP). This electronics was designed in order to be directly applicable to the 10 kton DP and there are no main milestones foreseen for technological decisions. Costs are quite well known from the productions performed for protoDUNE-DP (see Figures 1 and 2 for the list of components)

b) The main activities foreseen for 2018-2019 are the commissioning of PD-DP (final prototype for the 10 kton DP) and the writing of the TP and of the TDR

On the basis of the assumptions mentioned above the main activities foreseen in between now and the TDR are the following:

1) Costing, already in advanced state, available for the Technical Proposal, further costs optimization may continue beyond the baseline costs (conservative costs) actually known.

2) Development of the installation schedule and of the underground integration.

3) Editing of the Technical Proposal and of the TDR.

4) Installation and commissioning of PD-DP.

5) Finalization of the number of channels needed for Light Readout (currently assumed of the order of 1000). Input needed from PD consortium → no impact on design (which is largely modular) impact on costing. Present costing based on 1000 channels. Timescale to define this part: summer 2018

6) For Light Readout: implementation of final routing of AMC cards, inherited from the design of the Charge readout cards. The Light Readout AMC cards built for ProtoDUNE-DP are based on the architecture of the former Charge Readout demonstrator AMC card built in 2015 (based on a S4-AMC bittware kit). For the 10 kton the LRO architecture should be integrated in the final existing scheme of the Charge Readout AMC cards. The design exists already; what remains to be done it is mainly a routing technical effort in order to have the fabrication schemes for the final cards. Timescale 2018-2019 for completion of routing and tests.

7) Charge readout firmware developments for the 10 kton: actual firmware and DAQ for protoDUNE-DP are trigger based, on the other hand, the DAQ for the 10 kton will be based on a continuous data streaming. This streaming has to be subdivided in time-frames including cross-checks on the data integrity. These cross-checks are performed naturally in the protoDUNE-DP trigger based scheme at the event level. Not having anymore the concept of events at the FE level these crosschecks should be implemented periodically by defining some time-frames in the data transmission. A scheme exists to define the DAQ interface to include these periodical crosschecks of the data streaming, the hardware is designed for that. The firmware for continuous streaming should be finalized , implemented and tested in parallel with finalization of DAQ schemes (Timescale 2019). These software details have no impact on DAQ hardware/costing.

Comments:

6-7 are minor refinements activities. The TDR design can be already documented with the information already available now.

The TDR will contain as option for cost reduction for charge readout based on a AMC design with increased channel density. This AMC with higher channel density is completely based on the current design. It is an evolution just for what concerns the increase of the channels density and it can be prototyped in 2020.

The electronics produced for PD-DP was tested since the fall 2016 on the 3x1x1 detector at the level of one sixth of the final number of channels foreseen for ProtoDUNE-DP (1280 channels in the 3x1x1 vs 7680 channels for protoDUNE-DP).

This electronics was designed in order to be directly applicable to the 10 kton DP and there are no main milestones foreseen for technological decisions. Costs are quite well known from the productions performed for protoDUNE-DP. Some additional costs saving are possible and being considered.

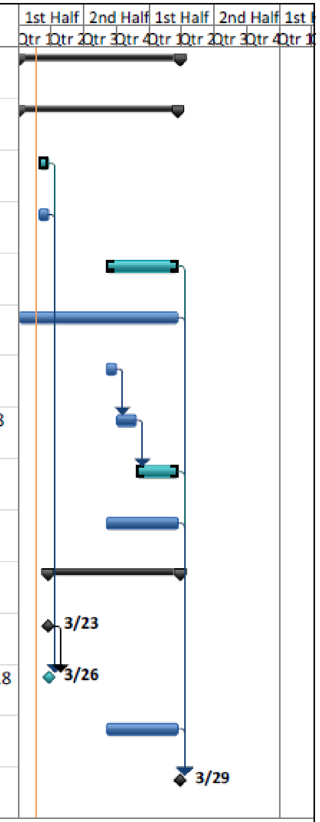
Activities and milestones 2018-2019:

- Editing of TP/TDR
- Development of schedule and installation procedures

- Running of ProtoDUNE-DP (Milestone for results Q1 2019)
- Finalization of number of channels for light readout (Q3 2018)
- Implementation of final AMC routing for light readout (Q4 2018)
- Finalization of firmware to move from the DAQ mode of ProtoDUNE-DP (trigger based) to the DUNE 10 kton (continuous streaming with triggers defined by DAQ backend) (Q1 2019)

Schedule extracted from the international project schedule:

ID	WBS	Task Name	Duration	Start	Finish
79	**4**	**Dual Phase Electronics Consortium**	**324 days**	**Mon 1/1/18**	**Fri 3/29/19**
80	**4.1**	**Technical Activities**	**320 days**	**Mon 1/1/18**	**Fri 3/22/19**
81	4.1.1	Prepare Costing for Technical Proposal	20 days	Mon 2/26/18	Fri 3/23/18
82	4.1.2	Initial Development of Installation Schedule	20 days	Mon 2/26/18	Fri 3/23/18
83	4.1.3	Further development of Installation Schedule	145 days	Mon 9/3/18	Fri 3/22/19
84	4.1.4	Installation and Commissioning of PD-DP	320 days	Mon 1/1/18	Fri 3/22/19
85	4.1.5	Finalization of number of channels needed for Light Readout	20 days	Mon 9/3/18	Fri 9/28/18
86	4.1.6	Implementation of final routing of AMC cards for Light Readout	40 days	Mon 10/1/18	Fri 11/23/18
87	4.1.7	Prepare Final Costing for TDR	85 days	Mon 11/26/18	Fri 3/22/19
88	4.1.8	Charge readout firmware developments for 10 kton	145 days	Mon 9/3/18	Fri 3/22/19
89	**4.2**	**TP/TDR**	**264 days**	**Fri 3/23/18**	**Fri 3/29/19**
90	4.2.1	Editing of TP	0 days	Fri 3/23/18	Fri 3/23/18
91	4.2.2	DP-Elec Technical Proposal - Submit for Internal Review	0 days	Mon 3/26/18	Mon 3/26/18
92	4.2.3	Editing of TDR	145 days	Mon 9/3/18	Fri 3/22/19
93	4.2.4	DP-Elec TDR - Submit for Internal Review	0 days	Fri 3/29/19	Fri 3/29/19



Project: FD Int schedule
Date: Fri 2/16/18

Task	External Milestone	Manual Summary Rollup
Split	Inactive Task	Manual Summary
Milestone	Inactive Milestone	Start-only
Summary	Inactive Summary	Finish-only
Project Summary	Manual Task	Deadline
External Tasks	Duration-only	Progress

Risk analysis and mitigation strategy in risks document:
https://docs.dunescience.org/cgi-bin/private/ShowDocument?docid=7171

Small level risks taken into account:

- Obsolescence of electronic components needed for maintenance during the long operation period of the experiment
- Evolution in the design of the photon detectors require modifications to the FE electronics
- Damages to electronics due to HV discharges or other reasons
- Data flow increase related to coherent noise related to grounding problems and inefficiency in compression
- Overpressure in the signal chimneys
- Leak of nitrogen to the cryostat via the signal chimneys
- Mechanical problems with the extraction of the blades with the FE cards from the chimneys
- Presence of water on the cryostat roof generates short circuits in the uTCA crates
- Air quality is very bad and affects the ventilation of the uTCA crates

Obsolescence of electronic components over 20 years period should be mitigated with an adequate number of spares. A global policy in DUNE should be established in that respect

Conclusions:

- We have a quite well defined baseline design
- Costing is also well understood and the design was studied since the beginning of the R&D to contain costs and have a cheap implementation. Some further cost reductions may be possible.
- We are looking forward to the period in front of us until spring 2019 to:

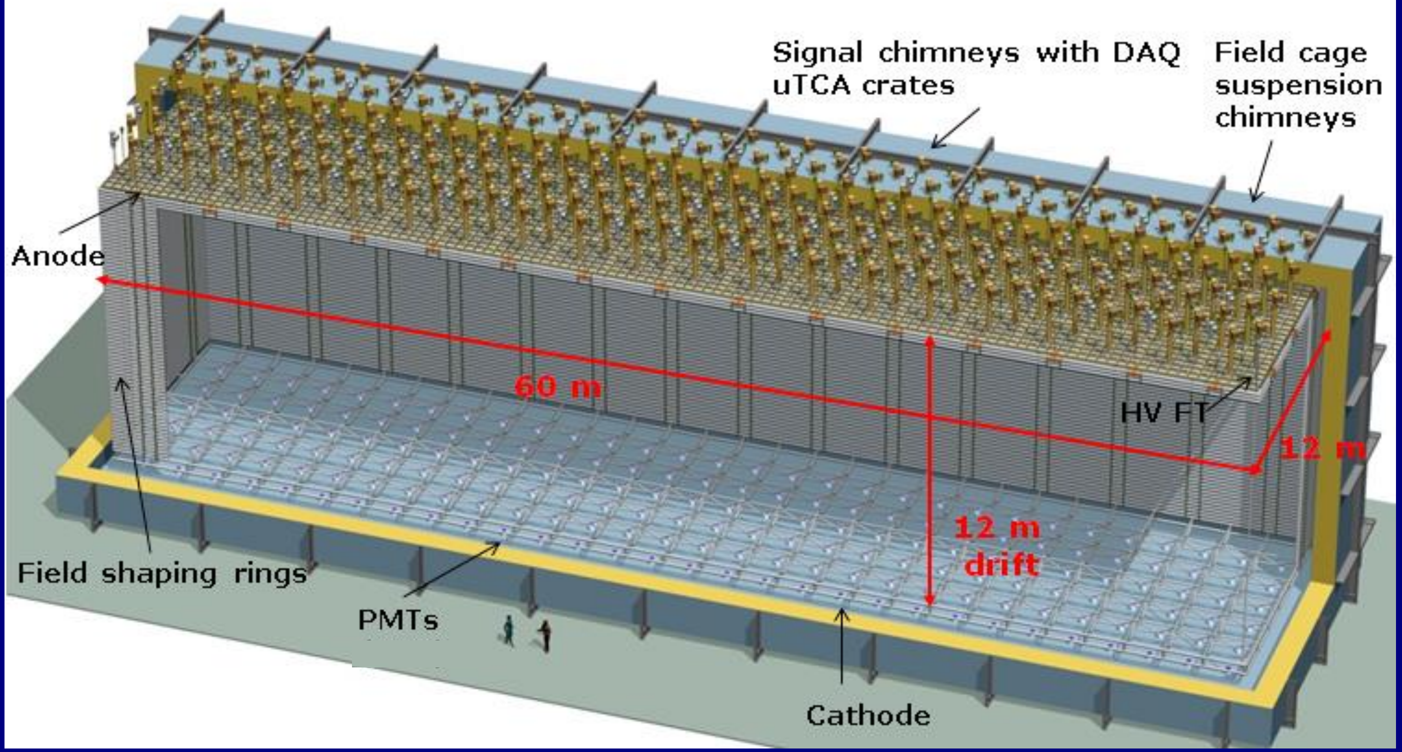
- Get protoDUNE-DP running
- Complete the work for the TDR (including detailed planning and installation scheme)
- Advance together with the DAQ consortium to define the back-end design

Dual-phase 10 kton FD module

- **80 CRP units**
- **60 field shaping rings**
- **240 signal FT chimneys**
- **240 suspension chimneys**
- **~1000 PMTs**
- **153600 readout channels**

Dual-Phase DUNE FD: 20 times replication of Dual-Phase ProtoDUNE (drift 6m → 12m) DUNE Conceptual Design Report, July 2015

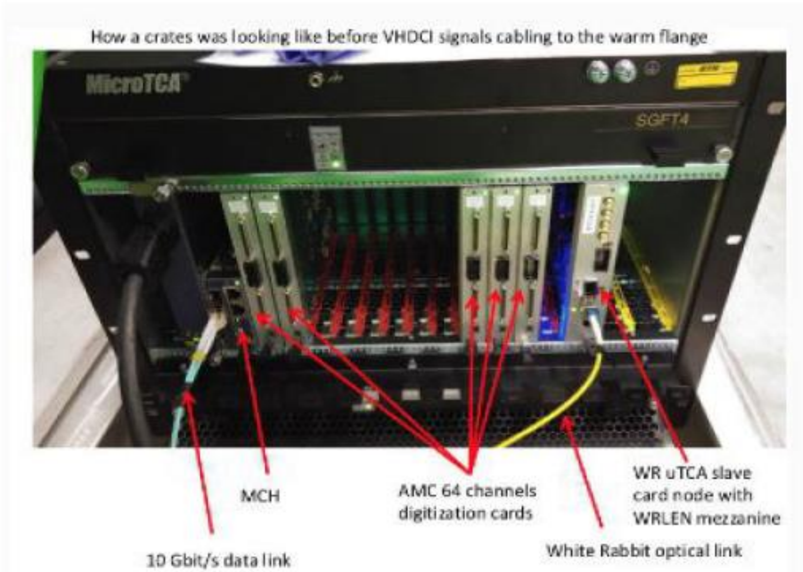
Active LAr mass:12.096 kton, fid mass:10.643 kton, N. of channels: 153600



Advantages of double-phase design:

- Anode with 2 collection (X, Y) views (no induction views), no ambiguities
- Strips pitch 3.125 mm, 3 m length
- Tunable gain in gas phase (20-100), high S/N ratio for m.i.p. > 100, <100 KeV threshold, min. purity requirement 3ms → operative margins vs purity, noise
- Long drift projective geometry: reduced number of readout channels
- No materials in the active volume
- Accessible and replaceable cryogenic FE electronics, high bandwidth low cost external uTCA digital electronics

Global Scheme



LRO Card fully integrable into existing framework (Charge ReadOut)

uTCA standard

Synchronised channels per card

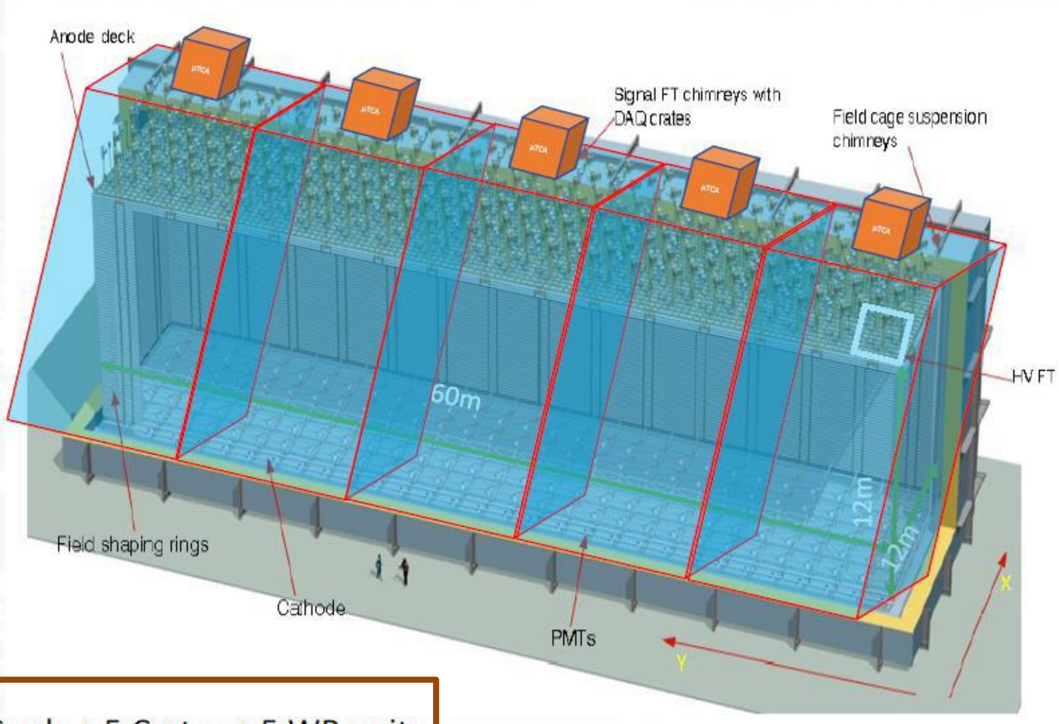
AMC motherboard takes clock through uTCA backplane

Crate Sync – dedicated White Rabbit, uTCA slave node acts a sync receiver distributing clocks to the back plane

Data readout through data link

Optimized version 1: 720 PMTs (1 PMT/ m^2)

Item	Details	Quantity
PMTs		720
FE-Cards	16 channels	45
	Components	
	printed cirquid	45
	PCB masques	1
	Mounting of components	
	Cabels SMA	720
	Catyroc	45
	ADC	45
micro-TCA crate		5
	MCH	5
	Power Module	5
	XAUI (x4)	5
	Uplink SFP+	5
	Uplink SFP+850	5
White Rabbit		5
	SPEC Card	5
	FMC DIO	5
	SFP (x2)	5



45 FE Cards + 5 Crates + 5 WR units

The distribution of the cards and number of crates to be optimized wrt to cable length and signal attenuation

First idea: cut detector in 5 12 m long segments

(5 x 12 m) long x 12 m wide -> 5 crates on top of the detector

Light Readout system (example assuming similar photodetectors coverage as in ProtoDUNE-DP)

TP Outline and current status

Editors: J. Dawson, S.Galymov

Contents

Cost estimates:

For DP electronics these are quite solid since they rely on the electronics already purchased for PD-DP (all money has been already spent and we know very well the costs at that production scale) → little risk associated

Last activities: to evaluate the large scale production savings: several meetings with CAEN, the actual PCB and components producers and suppliers, NAT/EMG2 for the uTCA and White Rabbit components

NAT in addition to evaluations related to uTCA (270 systems/module including spares) is also evaluating the cost for shipping the crates pre-mounted.

The number of spares is an issue related to the obsolescence of components over 20 years of running of the experiment (there should be a common policy in DUNE)

This is not directly due by our consortium but we made also an estimation of the DAQ backend based on an evolution of what has been designed for PD-DP.

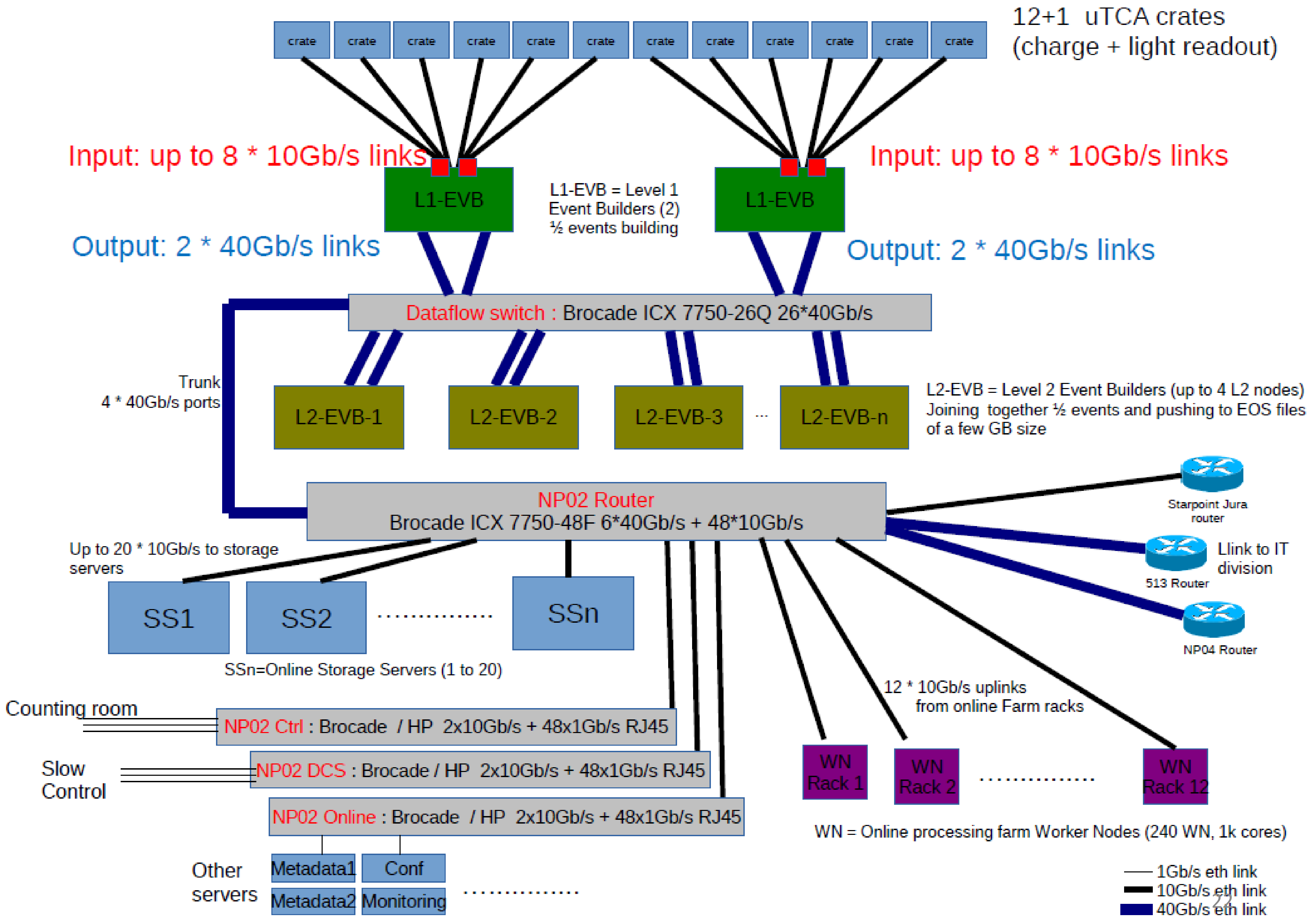
Expectations from the DAQ system:

The DAQ system, common to both single and dual phase, is expected to be a network based DAQ system capable of:

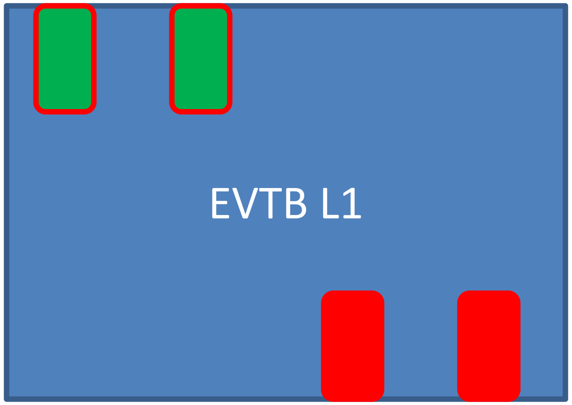
a) Collecting this high bandwidth data volume coming from the data links of the FE crates
b) Putting together the data streams from different crates in Regions Of Interest (ROIs) or over the entire detector volume
c) Processing this data flow by an online trigger farm in order to select relevant events to be recorded on disk: neutrino beam, and off-beam events.
d) Producing charge readout triggers independently on the light readout triggers and beam spill information. In particular, triggers over a sliding timing window of about 10 seconds may be issued by the trigger farm for the search of SN neutrinos based on the presence of low energy depositions, in order to dump on disk the entire content of the SN trigger sliding time window.

It is assumed that the DAQ system will be constituted by a set of event building/trigger machines, high performance network elements and a high bandwidth distributed storage system based on an array of storage servers operating in parallel.

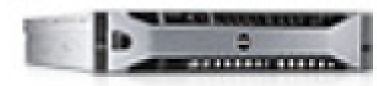
Details of WA105 DAQ back-end network structure



Input x8 10 Gbit/s from uTCA crates in two network cards with 4 inputs/card (total occupancy 6 Gb/s for the 8 links)



x2 L1 event building PCs:



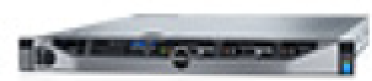
DELL R730, 256 GB RAM
x2 Intel X710 Quad Port 10Gbit/s
x1 Ethernet Mellanox Connect X3, Double port, 40Gbit/s, DA/QSFP

Output x2 40 Gbit/s

Task in ProtoDUNE-DP DAQ: put together data from the uTCA crates for the same drift widow corresponding to half of the detector → Two L1 EVTBs

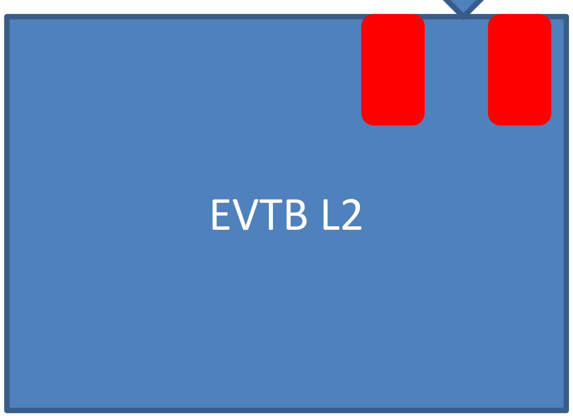
Figure 3: The Brocade ICX 7750-26Q features 26 40 GbE QSFP+ ports that can be split into as many as 96 10 GbE SFP+ ports.

x4 L2 event building PCs:



DELL R630, 128 GB RAM RDIMM
x1 Ethernet Mellanox Connect X3, Double port, 40Gb, DA/QSFP

I/O x2 40 Gbit/s



Task in ProtoDUNE-DP DAQ: put together events halves in single events and assemble multi-events files to be written on EOS → 4 LV2 units working in parallel

Interconnectivity via Brocade ITX7750-26Q switch, 26 ports at 40 Gbit/s

PD-DP back-end vs 10 kton DAQ

protoDUNE-DP DAQ/back-end:

a) external triggers not generated by the charge readout itself (triggers from: beam counters, large area cosmic ray counters or light readout system) defining events corresponding to a drift window

b) very large data volume to be written continuously on disk (all drift windows at 100 Hz rate during the spills without zero suppression and using lossless compression)

c) data quality online-analysis (aimed at measuring the LAr purity and the detector gain) performed with batch jobs on the processing farm on cosmics overlapping beam events, each job corresponding to a multi-event file written on disk.

DAQ for 10 kton DP module: several similarities in the architecture and some differences related to new aspects related to the specific operation mode of the 10 kton detector (proton decay an SN neutrino searches):

a) Continuous trigger-less, non zero-suppressed, loss-less compressed data streaming from the AMC cards to the event builders situated in the DAQ system. The AMC cards operating in ProtoDUNE-DP function by dumping from their internal dual-port memories the drift windows corresponding to the time-stamps of the external triggers but they are already capable of working in a continuous sampling mode, as foreseen for the 10 kton operation.

b) Charge triggers to be generated by the data analysis on the events builders, this is a main difference with respect to the ProtoDUNE-DP working mode and it will require to implement the proper algorithms at the level of the event building farm.

c) Smaller data volume to be written on disk, just for the selected events (beam events, cosmic rays and proton decay candidates, SN burst candidates)

d) Necessity of keeping a sliding 10s window on the event builders for SN events searches

e) Different requirements on the online analysis: smaller rate of events, mainly cosmics

Possible architecture:

10 kton DP readout architecture organized in 20 ROI, each similar to the PD-DP back-end architecture

- Triggers searched on EVTB L1 on sliding windows of 10 s
- Combination with beam data and with light data to define the window T0 and select streams
- Decompression + keeping compressed data in memory for further writing on disk from LV2

→ Definition of streams output streams: beam, cosmics/proton decay, SB burst

For beam/cosmics → dump in the event format one drift window

Charge readout data:

a) 0.43 Gbytes compressed per event if all ROIs dumped

b) 22 Mbytes compressed per event for one ROI (reasonable choice for beam and cosmic events)

→ Writing of multi-events files organized on EOS by LV2 EVBs, size ~6 GB/file

SN burst searches:

- Each L1 EVTB can look continuously at the 10s sliding window, can send trigger signals over the network to a general supervisor
- Criteria applied: compactness of the energy deposition, threshold, some channels excluded in order to define a fiducial volume to shield from environmental radioactivity also by detector elements.

→ Supervisor can order the dump on disk of the EVTBs windows if a certain number of candidate energy depositions is found from the EVTBs. It is possible to put in communication in this scheme also parts of different 10 kton modules

→ Decide to dump on disk compressed data for selected ROIs or the entire 10 kton detector if it is the entire DP 10 kton module this corresponds to 536 GB compressed data (about 100 files from LV2)

Events sizes

→ Event Size for 10kt Dual phase module 4.2GB
due to a good S/N ratio (the RMS noise at the level of 1-2 ADC counts)
loss-less compression is applied at the front-end allowing compressing the readout data flow by a factor 10 → event size = 0.42 GB

To write on disk the entire detector drift window can be considered as a pessimistic figure: events are normally contained in smaller detector regions. The 10kton detector can be seen as 20 ProtoDUNE-DP detectors running in parallel, each one defining a Region Of Interest (ROI). For beam or cosmic events, it is possible to dump on disk only the interested ROI(s).

→ Size of a single ROI: 22MB (compressed)

Source	Event Rate	Event size	Annual data volume
Neutrino beam	2000 $year^{-1}$	44MB (2ROIs)	86 GB (860 GB all ROIs)
Cosmic-muon	$6.5*10^{-2}$ Hz	44MB (2ROIs)	86 TB (860 TB all ROIs)
Atmospheric neutrino	1000 $year^{-1}$	44MB(2ROIs)	44 GB
SNB	12 $year^{-1}$	563 GB	6.6 TB

Conservative total annual data volume assuming some contingencies ~ 100 TB