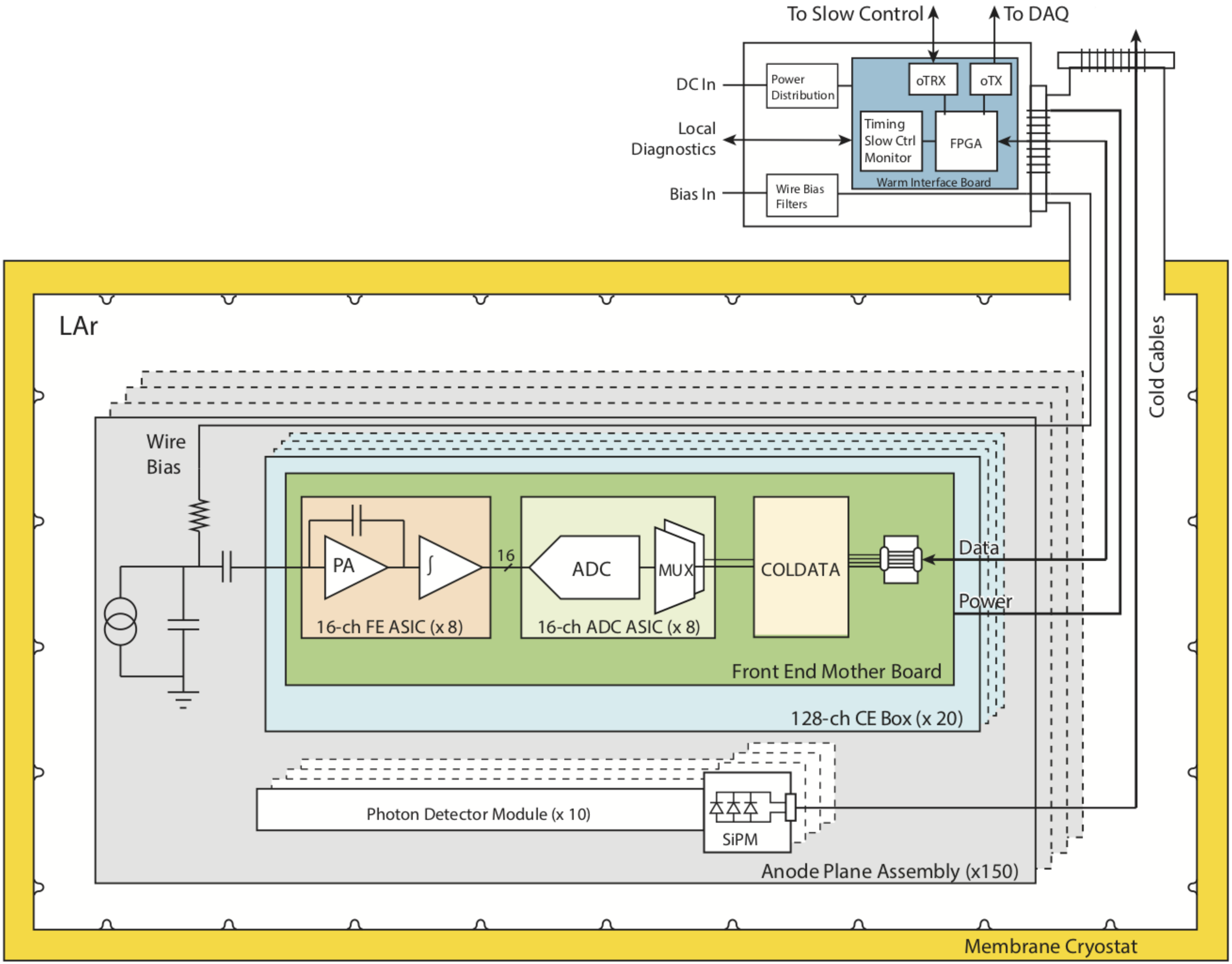
Hardware requirements for the DUNE WIB

Vladimir Tishchenko

Brookhaven National Laboratory

DUNE PDR: Cold Electronics WIB and System
March 10-11, 2020

Components of baseline DUNE CE system



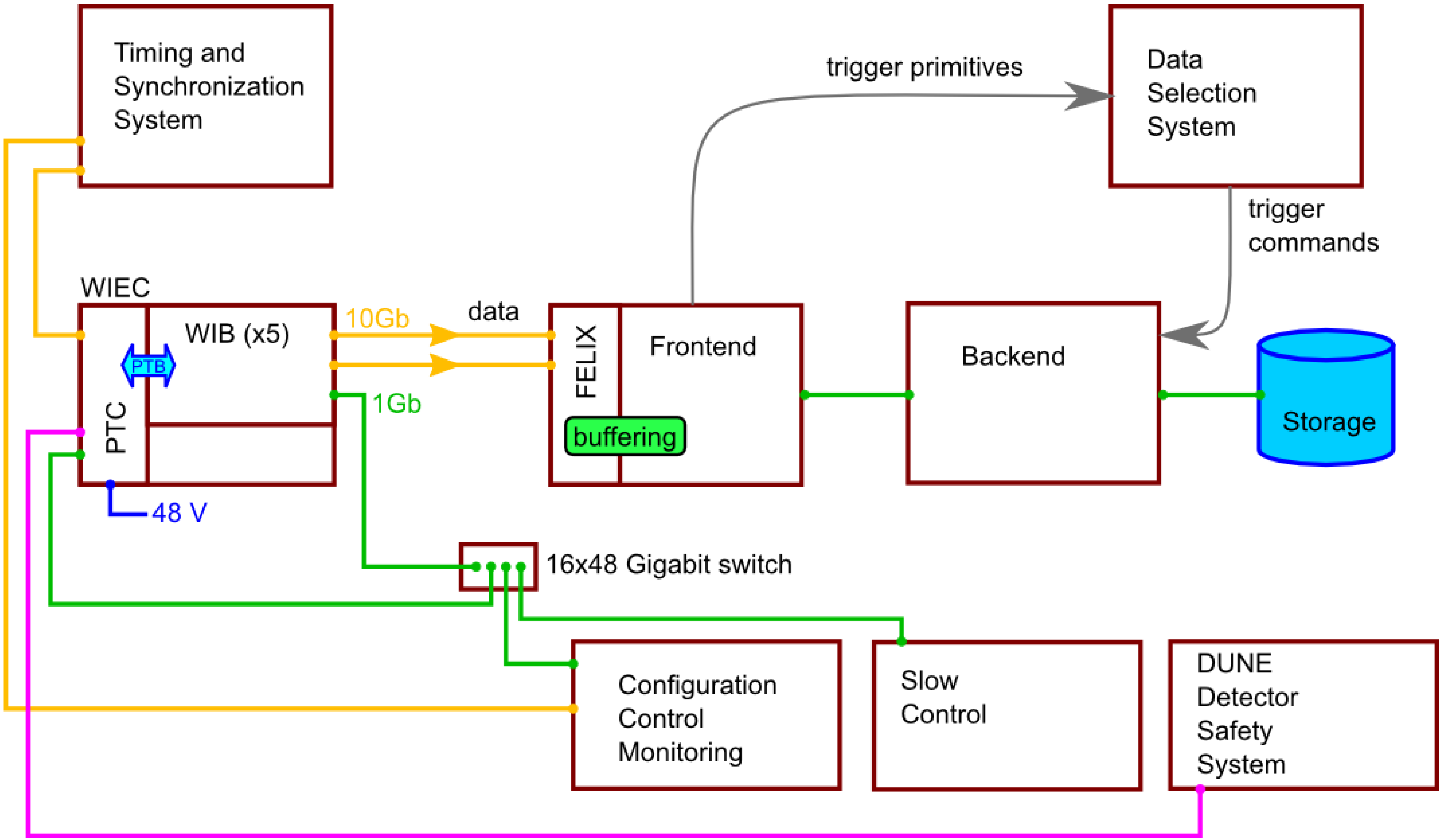
WIB Functional Requirements

- Receive system clock and control signals from the Timing System through Power and Timing Card (PTC) and provide for processing and fan-out of those signals to FEMB(s).
- Receive high-speed data signals from FEMB(s).
- Perform data manipulation/formatting/multiplexing to match the protocol of links to DAQ.
- Transmit data to the DAQ system.
- Provide real-time diagnostic data without impacting data transmission to the DAQ.
- Distribute the power from PTC to FEMBs.
- Control the FEMBs.
- Perform monitoring temperatures on the WIB and currents and voltages being supplied to FEMBs.
- Interact with the following systems from the DAQ consortium:
  1) the Control, Configuration and Monitoring system (CCM)
  2) the Timing and Synchronization system
  3) the Slow Controls system (SC).
  These interactions are required for configuring, synchronizing, and starting the FEMBs, both for normal operation and for calibration purposes.
- The WIB must be able to function both as part of WIEC and as a standalone board for using in Test Stands.

WIB: evolutionary development

A WIB board with similar functionality has been designed, built, and successfully used in ProtoDUNE Single Phase experiment (DUNE DocDB 3327). A WIB board for the DUNE experiment will be an evolution of the ProtoDUNE WIB to meet the new DUNE requirements, expand monitoring capabilities consistently with the separation of responsibilities between the WIB and the DAQ system, and improve upon the existing design.

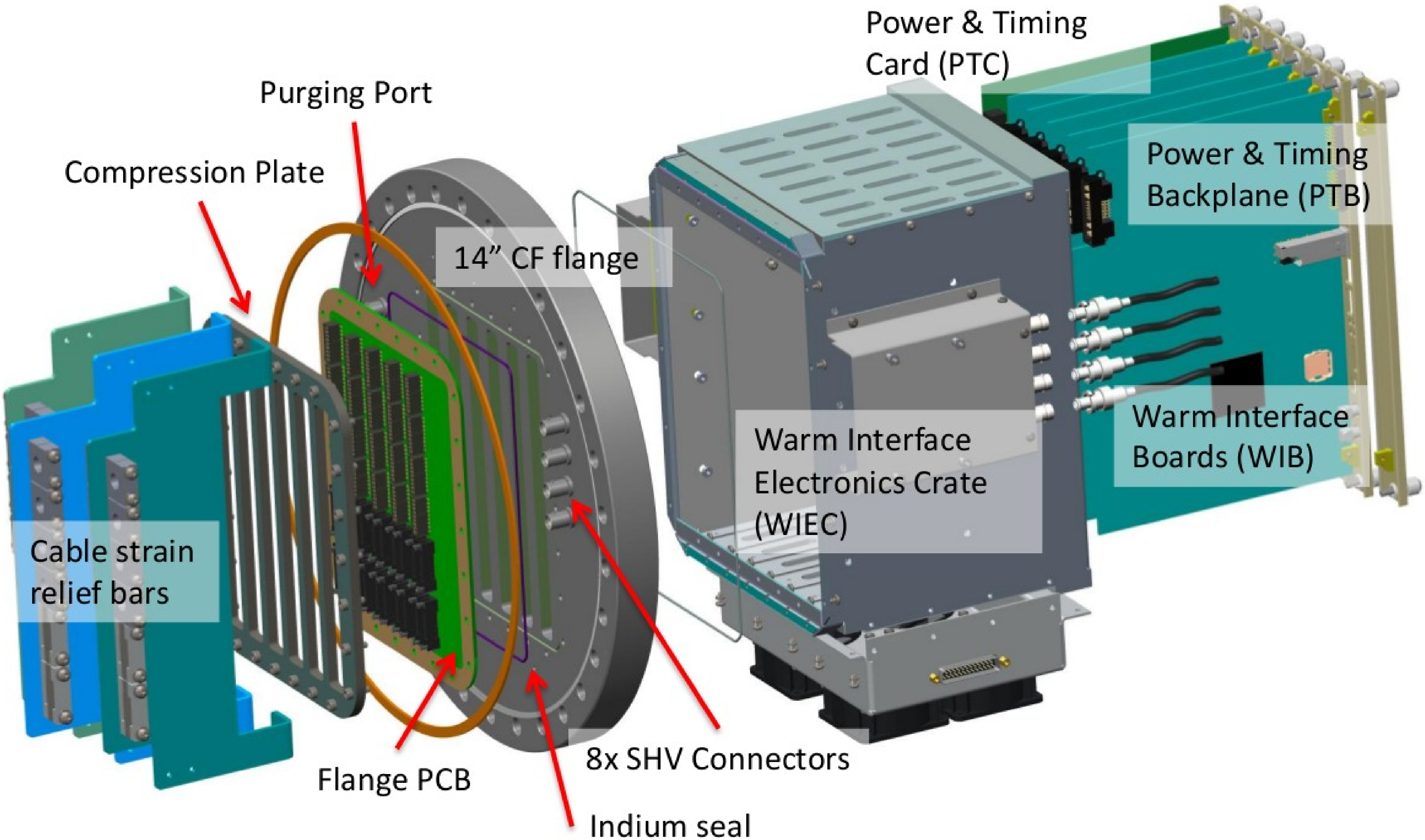
WIB interfaces with other DUNE systems



Mechanical requirements

- The WIB is supposed to be installed in a custom-built Warm Interface Electronics Crate (WIEC, see next slide) which is mounted to TPC signal feedthrough flange (DUNE DocDB 2774).
- The Warm Interface Electronics system (which includes WIBs) must be designed to keep the total weight low and form-factor small and consistent with cryostat deck limitations and constraints.
  Ideally, the WIB must be compatible with the existing WIEC to minimize the design cost.
  The existing WIEC contains five WIBs.

Warm Electronics components



Electrical powering scheme requirements

- In WIEC crate, the filtered power is supplied to WIBs by the PTC through Power and Timing Backplane (PTB). The PTC receives 48 V low-voltage (LV) power from an external power source and steps it down to 12 V via a DC-DC conversion for WIBs.
- The WIB must provide the necessary 12 V DC-DC conversion to FEMBs.
- The WIB must supply a filtered low-voltage power to FEMB. The baseline plan assumes that only 2.5 V will be provided by the WIB to FEMB (at 2.4 A). To account for voltage drop along the wires for the upper APA (9 m cable length) and for the lower APA (22 m cable length), the WIB needs to supply 2.7 and 3.0 V output voltage for the upper and lower APAs, respectively. Alternative powering schemes require separate voltages to LArASIC (2.0 V).
- The WIEC crate (PTC card) must be able to power on/off individual WIBs by a remote command. The WIB must be compatible with this feature.
- Any potential noise introduced by the WIB to the FEMB must be sub-dominant to intrinsic noise of the FE ASICs.

Safety / hardware interlocks

- The system design must comply with all applicable low voltage electrical safety standards. For DUNE operation, the WIB will be installed in WIEC crate which provides proper safety grounding.
- The WIB must provide hardware interlock(s) for any potential dangers to equipment.
- Since the WIB is responsible for supplying the power to FEMBs, the WIB must provide current and voltage monitors and interlocks to protect FEMBs.
- Direct connection between the WIEC and the DUNE Detector Safety System (DDSS) could be required in the future.

Interface to Cold Electronics

- The WIB design must be compatible with the existing CE signal flange board (DUNE DocDB 2777) (presumably with minor modifications to account for the reduction in the number of cables compared to ProtoDUNE).
- The (prototype) WIB hardware must be compatible with various CE solutions (COLDATA, CRYO).
  - The communication of clock and control signals to the FEMBs and of the data from the FEMBs must be compatible with the requirements of COLDATA and CRYO.
- Commercial equalizers are to be used on the WIB to recover the data signals given the length of the cables, even if the line drivers alone can probably achieve very low bit error rates.

Monitoring

- The WIB must perform real-time diagnostic and monitoring of
  - Data readout
  - Voltages
  - Currents
  - Temperatures
  - FEMB timestamps / data integrity
  - PLL lock status
  - Synchronization

Interface to Timing System

- The physical link to the Timing System is provided by the PTC card in WIEC crate. Low voltage power, clock and control signals are transmitted from the PTC to the WIBs on the Power and Timing Backplane (PTB).
- The WIB must forward system timing signals to FEMBs.
- The WIB must monitor the time synchronization of CE.

BROOKHAVEN NATIONAL LABORATORY

Interface to DAQ system

- The WIB must receive the high-speed data from FEMBs, perform data formatting to match the protocol of links to DAQ and transmit the formatted data to the DAQ.
- The data must be transmitted from the WIB to the FELIX board over two SPF+ transceivers.

Interface to SC and CCM

- The WIB must receive configuration information from CCM.
- WIB must provide the monitoring information (voltages, currents, temperatures, etc.) to CCM and SC.
- The WIB must use Ethernet fiber link (1-10 Gbps) for communication and data transfer from/to CCM and SC.
- For commands and data transmission over the Ethernet link the preferred communication protocol is TCP/IP.

Lifetime

- The system must be designed and built with 20+ years of lifetime and maintainability expectancy.
- No obsolete or close to end-of-life components may be used in the design. When there is a choice, components with longer shelf life must be used.
- Components with the shortest lifetime must be identified and a plan developed for replacing / substituting those components without redesigning the WIB. The number of failures that cannot be repaired by replacing a component over the lifetime of DUNE must be smaller than the number of fabricated spares.

Environmental

- The WIB must be designed with low power dissipation in mind to minimize the load on the air conditioning and cooling system.
- The WIB must be able to operate in an environment with temperature range 5° to 45° C and relative humidity 10% to 80%, non-condensing.
- We require that WIEC must provide adequate air cooling and air filtration for dust to WIB. Air flow tests with the ProtoDUNE system are described in DUNE DocDB 1809. These tests do not include filters though. We will perform measurements at SURF in a location where we expect the dust level to be similar to that of DUNE.

Hardware architecture

Even though we do not make a special requirement to the hardware architecture, we recognize that to implement sophisticated monitoring, diagnostic, calibration, configuration, communication and recovery functionalities outlined in this document, it will be beneficial to use a Xilinx Zynq® UltraScale+™ architecture for the WIB. This will also help to simplify the firmware development by offloading some of the tasks to the software side, increase flexibility, and reduce the overall cost of firmware development.