Supplies and cables on the top of the cryostat

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Outline

- Requirements
- Low voltage power supplies and relative cables
- Bias voltage supplies and relative cables
- Fans / heaters supplies
- Optical fiber connections
    - To FELIX readout
    - To CCM/SC
    - To DDSS
- DDSS connections (see next talk)

Requirements (i)

- Voltage ripples on low voltage power supply and bias voltage supply should not contribute to overall noise
- Low voltage: a ripple of ~2.5 µV at the input of FE amplifier corresponds to a noise of 100 e- (negligible contribution to the overall noise)
- What is the corresponding noise level at the LV power supply ?
- The power supply provides 48V that are stepped down as follows (total reduction factor ~27)
  - On the PTC using a buck converter (LTM8064), ripple ~15 mV
  - On the WIB using first a buck converter (LT4644IY), ripple ~5 mV, and then an LDO (TPS77401)
  - Finally on the FEMB there is another LDO (TPS 74201)

Requirements (ii)

- Noise from the buck converters dominates (LDOs provide overall rejection at the 10^{-4} level)
- LV power supply should have ripple level below that of the buck converters
- Bias voltage: voltage ripples from the supply induce a noise that is $\Delta Q = \Delta V * C$ where C is the wire capacitance (150-200 pF)
- Voltage ripples on the bias supplies are further reduced by filters (2 step RC filter with cutoff at 416 Hz, i.e. overall rejection of $2*10^4$ at ~10 KHz)
  - To get 100 e^- of noise at 10 KHz need a maximum voltage ripple of ~2.5 mV

Requirements (iii)

- LV power supplies: provide 7.5A @ 48V for each APA, power density limited by rack cooling power (few kW)
- Bias voltage supplies: provide -370 V, -665 V, +820 V for the APA wires, provide ~-1 kV for the FC termination electrodes
- All power supplies should be controlled remotely via Ethernet (OPC Unified Architecture interface preferred)
- Configure (target voltage, ramp speed, current limits, thresholds for alarms/trips) individual channels
- Interlocks / inhibits on individual channels
- All supplies are floating, and all cables going from the supply to the cryostat penetration are shielded, with shields connected at both ends (Linda Bagby's presentation)

LV distribution system

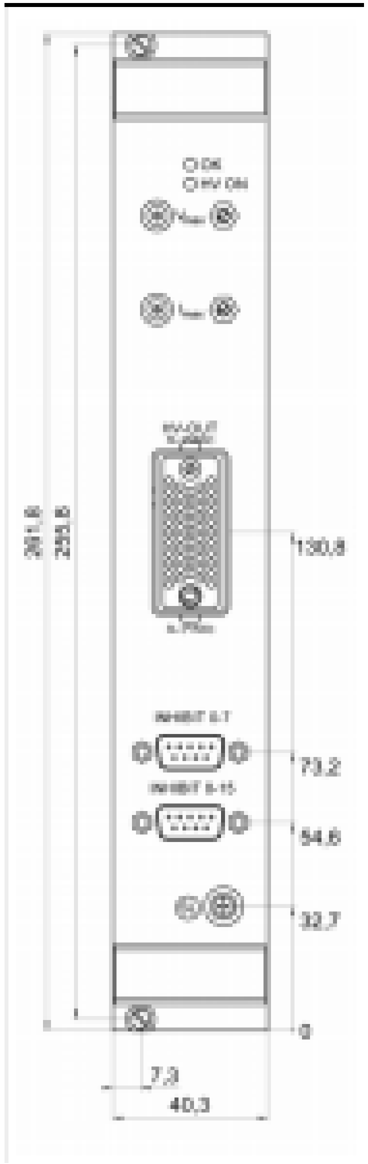
- In ProtoDUNE we have used WIENER PL506 to provide the LV power to the PTCs
- One WIENER PL506 can provide up to 13.5 A in the range 30-60 V for 6 channels
  - Cannot use 12 channel modules due to rack cooling power limitations
  - Require 25 modules, 1 per row of detector
  - In ProtoDUNE interlock system turned off power to entire detector, will have single channel interlock in DUNE
  - Warm cable: 10AWG twisted pair for power, plus 20AWG for remote sensing
    - Voltage drop along cable on top of the cryostat: O(1V)
    - O(1 kW) of power dissipated in the warm cables that run below the false floor on top of the cryostat

Bias Voltage System (i)

- In ProtoDUNE we have used WIENER MPOD crates with ISEG HV modules (used 8 channel modules, high precision version)
- For DUNE we need a total of 658 channels:
  - 450 bias voltages for the APA wires (300 negative, 150 positive)
  - 208 for the field cage termination electrodes (all negative)
- This can be achieved with
  - 5 MPOD crates (one for every 5 rows of APAs)
  - Each MPOD crate houses two 16-channels modules providing positive bias (5 rows, 6 APAs, 30 channels needed) plus seven 16-channels negative modules (for the APAs need 60 channels, for the field cage termination electrodes need 5 rows times 4 top field cages plus 4 bottom field cages, i.e. 100 negative channels in total, four additional negative channels needed in rows 1 and 25 for the end walls)

Bias Voltage System (ii)

- In this system we are using
  - 10 modules providing positive bias voltage
  - 35 modules providing negative bias voltage
  - 150 out of the 160 available positive channels
  - 504 out of the 560 available negative channels (i.e. we could use 3 fewer modules with a significant complication of the cable arrangement)
- We can have modules with interlock / inhibit signals on individual bias voltages
  - Each module has two DSUB9 connectors for this purpose
  - Bias voltages come out of the ISEG module on Riedel 44 pin connector, will need a patch cord plus nine 1-U patch panels close to each MPOD crate to make the transition to SHV connectors / RG-56 cables



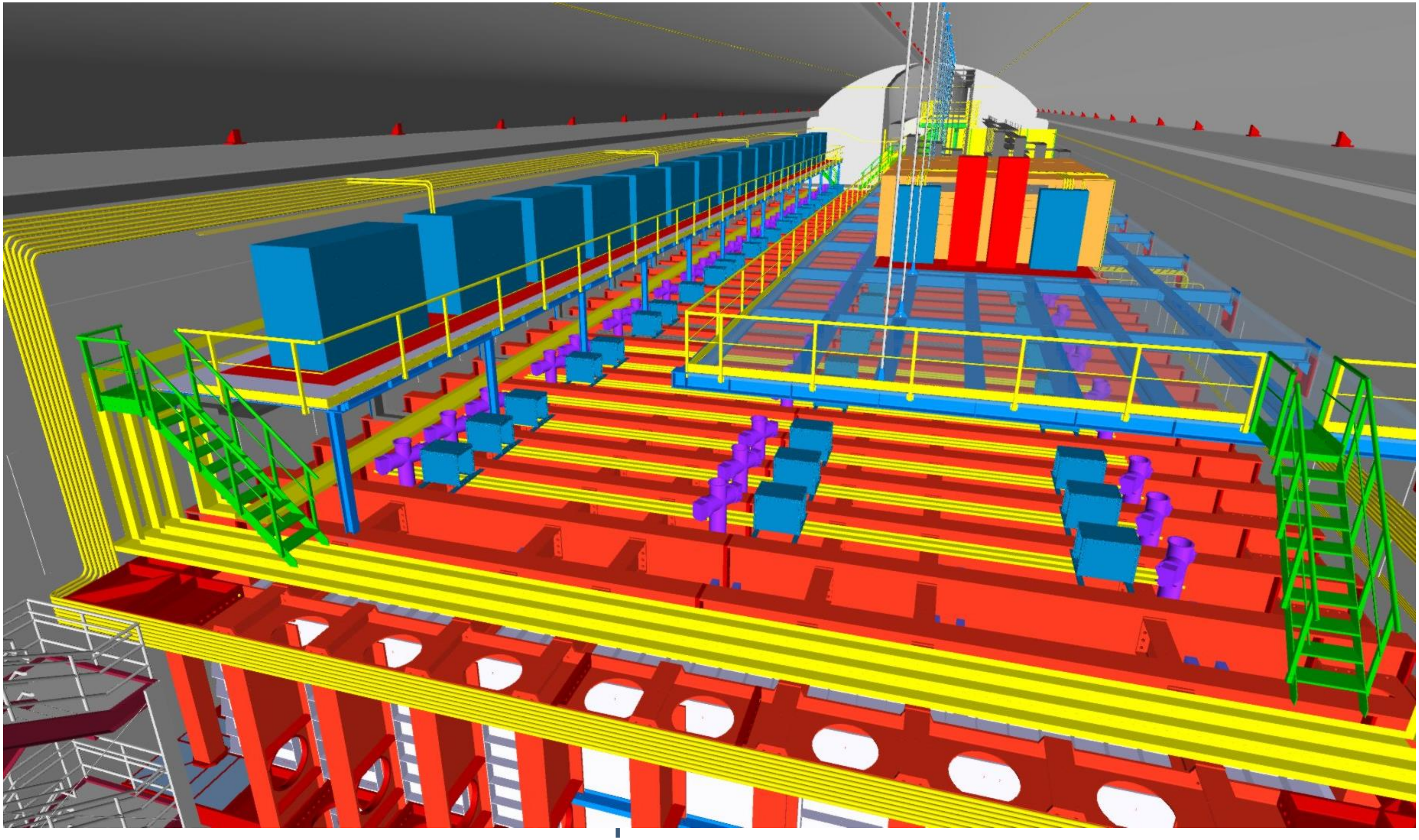
Room for value engineering ?

- Both the WIENER PL506 and the ISEG HV modules that are in use in ProtoDUNE have ripple voltages that exceed the requirements for DUNE
- There may be room for some value engineering (cheaper power supplies)
  - Could target first the FC termination electrodes bias voltage supplies (cheaper ISEG modules ? Different system ?)
- Not clear that there are a lot of supplies that meet the requirements and that have the same channel density / controls that the WIENER systems have

Cables for LV and bias supplies

- LV supplies:
  - Two 10AWG + two 20AWG with commercial connectors on both ends
  - Assume 1 LV supply on the detector mezzanine at the end of a row of APA
  - Six cables total, 2 each with lengths appropriate for N, C, S arrays of APA (range 20-30 m), run in cable trays below the false floor
- Bias voltage supplies
  - Only 5 MPOD crates (rows 3, 8, 13, 18, and 23)
  - Between 11 and 14 RG59 cables per cryostat penetration (5 to 7 per APA) with lengths in the 25-40 m range
  - Run in the same cable trays below the false floor
- Exact length to be understood once rack assignment on the detector mezzanine is complete

Cables trays on top of the detector (i)



Cables trays on top of the detector (ii)

- Cable trays run between the large beams of the cryostat
- Very large cross section compared to the number of cables / fibers that are going to be installed, plenty of room to accommodate cable slack in the cable trays
  - No need to cut the cables to length and add connectors while working on the top of the cryostat
  - Can test cables with final connectors at a collaborating institution prior to shipment to SURF

Fans and heaters (i)

- Understand whether these will be powered and controlled entirely from DDSS (see next presentation)
- Otherwise we will have custom boxes that
  - Regulate power to heaters and fans depending on status of RTDs on the warm flange, status of fans
  - Provide signal to DDSS in the case of fans
  - Powered by 24V switching supply that is remotely controlled from SC via OPC UA (no need to have low noise supply, the heaters and the fans are isolated from the Faraday cage of the WIEC)
- Cables:
  - Eight 22AWG or 24WG shielded twisted pairs for the fans
  - Could not find the information on the twisted pairs used for the heaters

Fans and heaters (ii)

- Don't know much of how these are going to be powered, could have 1 or 2 supply system for each row of APA
- Need two cables (1 for heaters plus 1 for fans) for each APA, again probably with lengths in the 20-30 m range

Fiber Plant (i)

- Each WIEC needs the following fibers
  - Two 10 Gbit/s readout fibers for each WIB (10 total per APA) with LC connector on the WIB side and MTP12-M connector on the other side (data flows in single direction, toward FELIX), length ~2m
    - Will have 2 spare fibers
    - Go to small patch panel on the photon detector mini-rack, where the 12-fiber ribbon will be matched to another ribbon with MTP12-F connector (technical coordination responsibility, going toward FELIX)
  - Two 1 Gbit/s fiber for each WIB and for the PTC for CCM/SC communications with LC connector on the WIB/PTC side and MTP12-M connector on the other side, length ~2m
    - No spare fibers
    - Same connection to patch panel, from there ribbon with MTP12-F connector goes to network switch

Fiber Plant (ii)

- Timing distribution:
  - Single 1 Gbit/s bidirectional fiber with LC connector on both ends to bring the timing signal to the PTC.
  - Fibers (2 per cryostat penetration) go to the last optical fanout
    - Terri says this is on the detector mezzanine (length 20-30 m)
    - Giovanna says this is on the photon detector mini-rack (length ~2 m)
- Connection between PTC and DDSS (next presentation)
  - One doublet of 1 Gbit/s fibers with LC connector on both ends, goes from the PTC to the DDSS on the detector mezzanine, where the signal is converted from optical to electrical, 6 fiber doublets total per APA row
  - Exact length depends on the distribution of the DDSS elements on the detector mezzanine (25-40 m ?)

Conclusions

- Completion of design of cable / fiber plant on top of the cryostat requires knowing the rack assignment in the detector mezzanine and knowing more about the design of the DDSS
- All power supplies are floating
- All cables going from the power supplies to the cryostat penetrations are shielded, with shields connected at both ends