Cold Cable & Signal FT for DUNE TPC Readout

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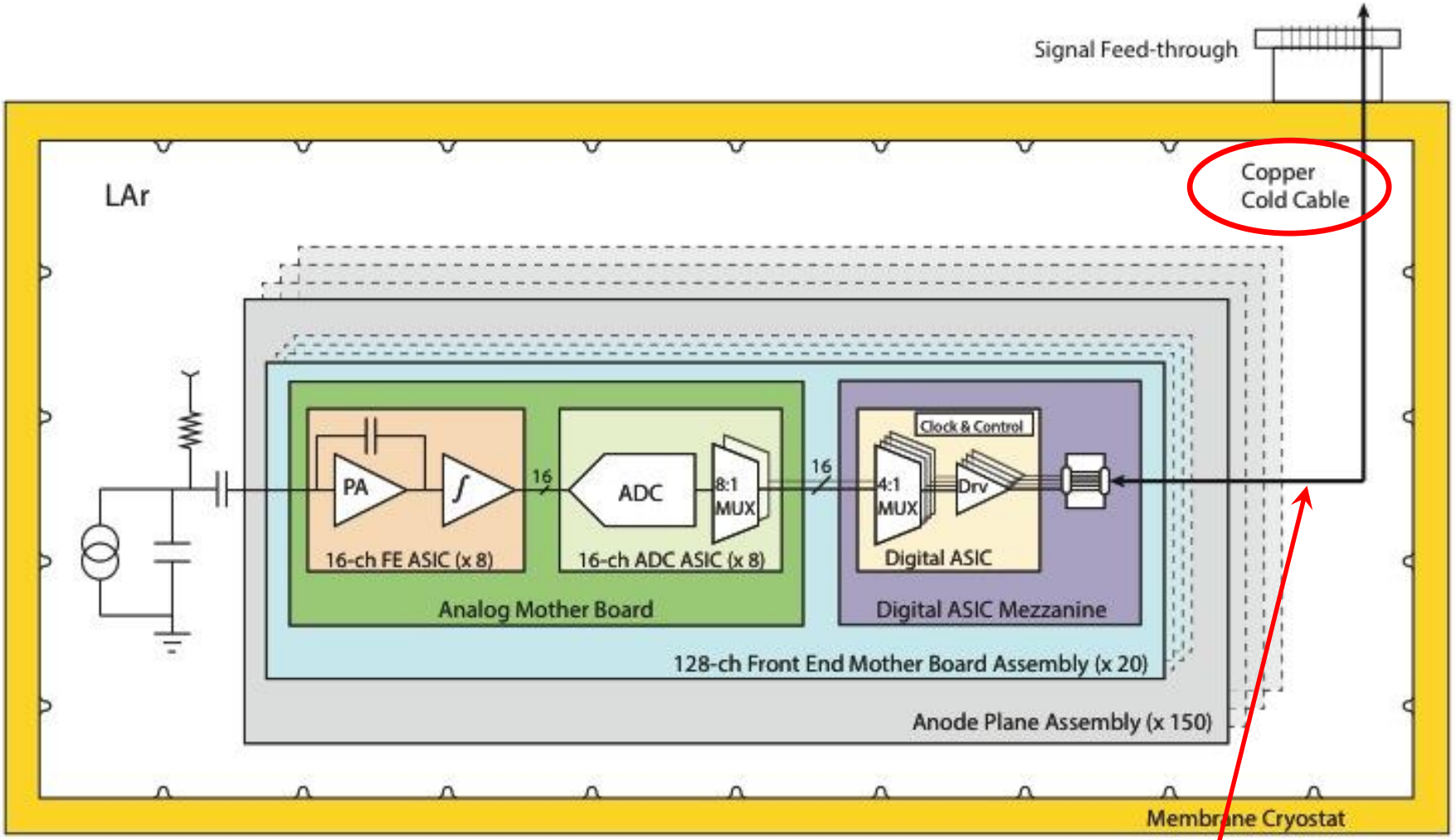
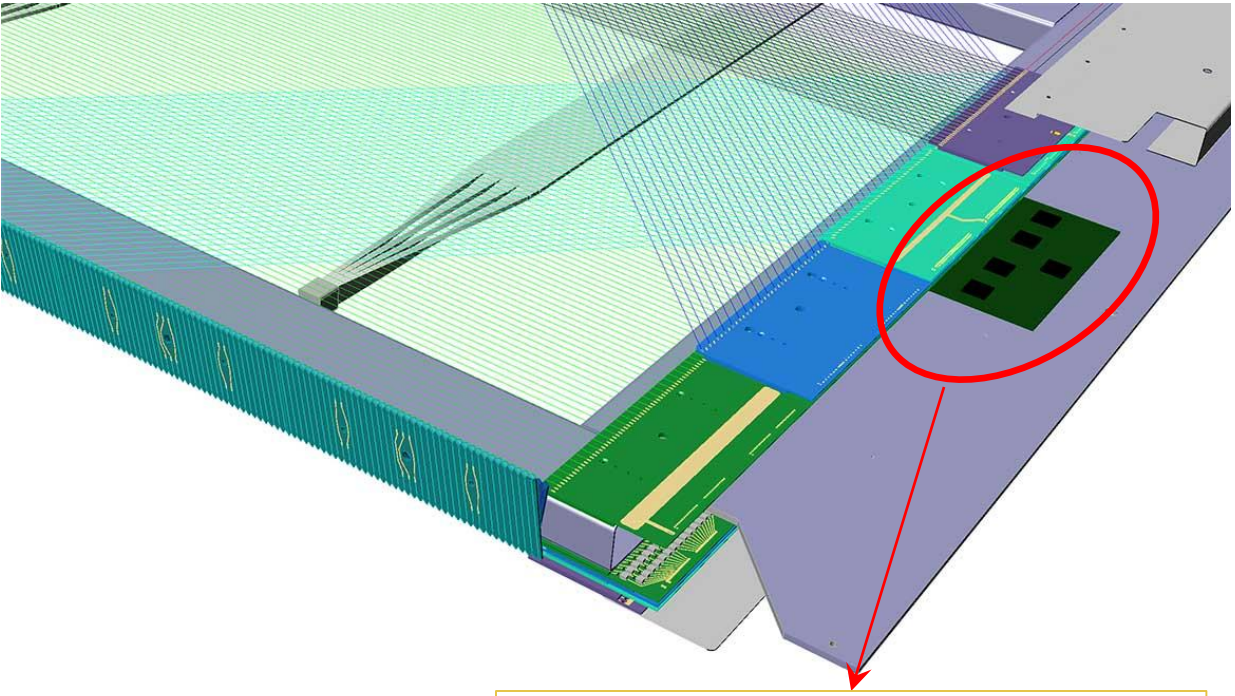
Outline

- Introduction
- Cold Cable
  - 35T Implementation
  - Other option
- Signal Feed-through
  - Single FT with ATLAS pin carrier
  - Other option
- Summary

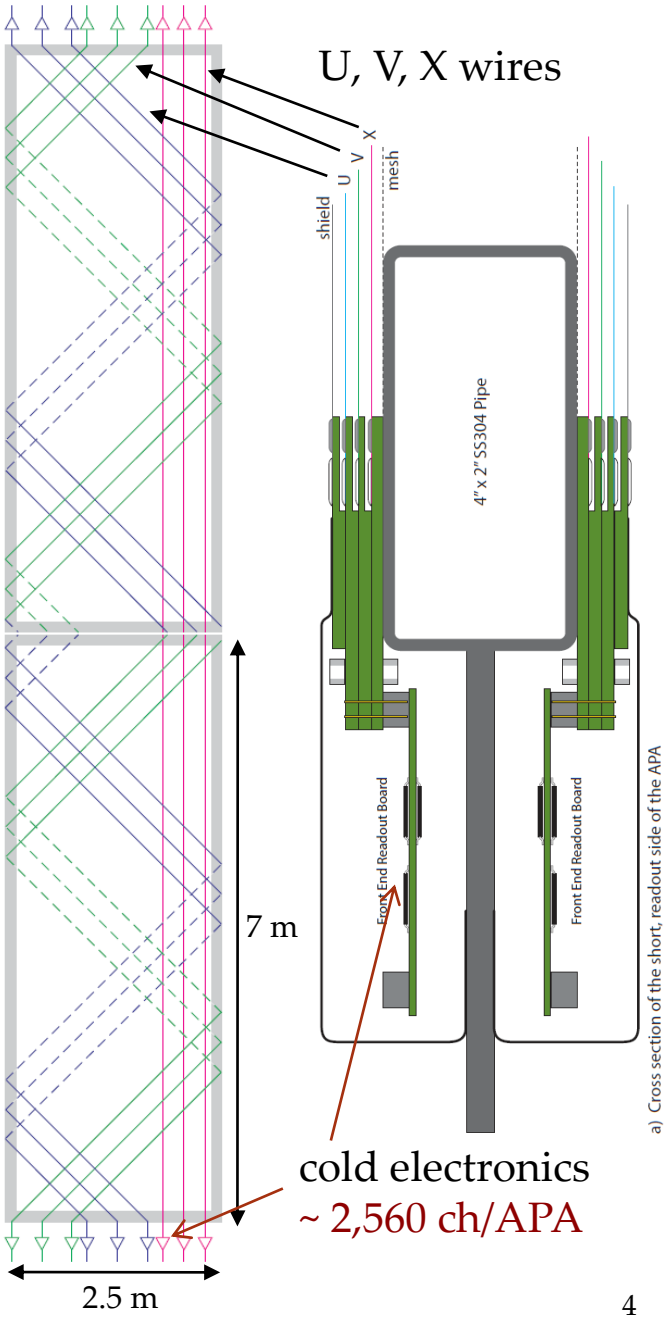
TPC Readout Electronics



Cold Electronics for Far Detector



Cold Electronics on TPC Frame



- Cold electronics will be installed at the end of the TPC frame
  - Close to the top or the bottom of the cryostat
- Cold cable will route the signals from cold electronics to signal feed-through
  - Distance could be short (top) or long (bottom)

Cold Cable & Signal FT

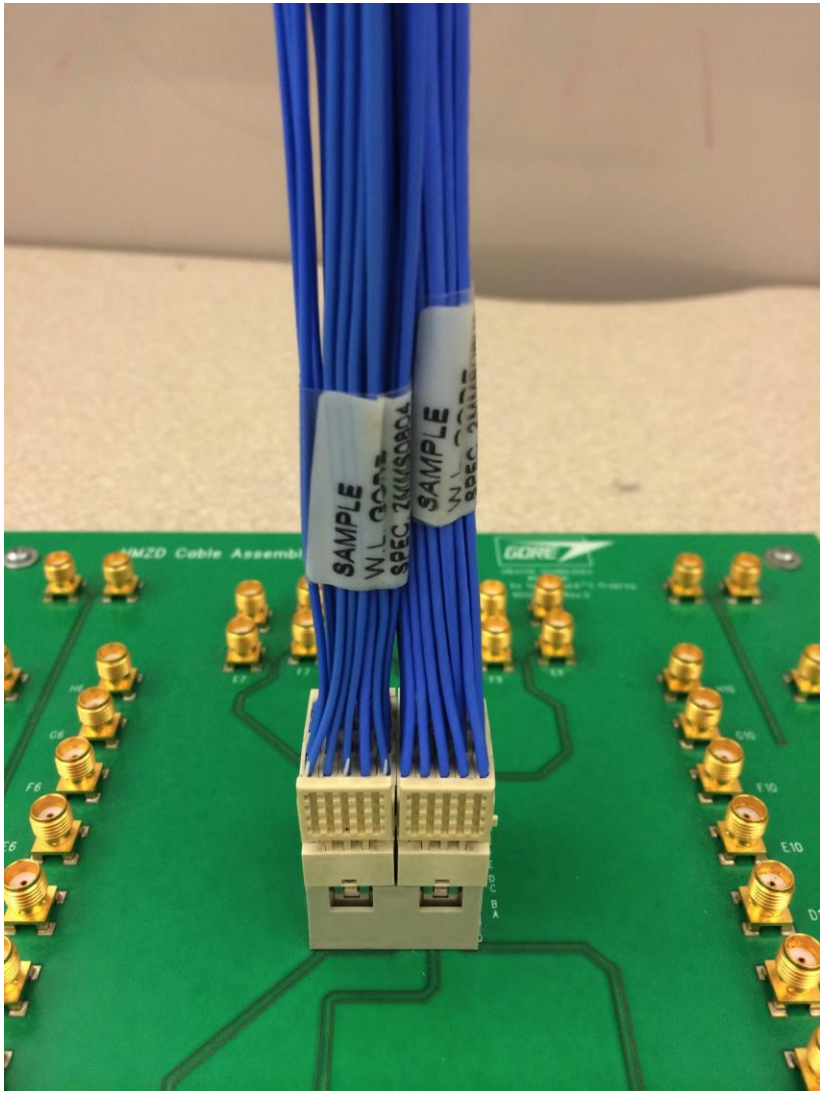
- Cold cable functionalities
  - Data transmission
    - Stream ADC samples out of cryostat
    - Differential cable for high speed signal transmission
    - Data rate is 1 Gb/s
  - Timing and control
    - Receive clock and commands
    - Differential cable for signal receiving
    - Data rate to be determined
  - Slow control
    - I2C for configuration of FEMBs
    - JTAG for FPGA configuration in 35T
  - Power distribution
    - Supply power to cold electronics
    - Low voltage power distribution: <= 5V
- Signal FT is to provide all of these penetrations on cryostat

Cold Cable

# of Wires of Cold Cable	128-ch FEMB/FPGA	128-ch FEMB/Digital ASIC
Data Tx	8	8
Control Rx	4	4
JTAG/I2C	12	4
Power	14	12
Subtotal	38	28
APA (20xFEMB)	760	560

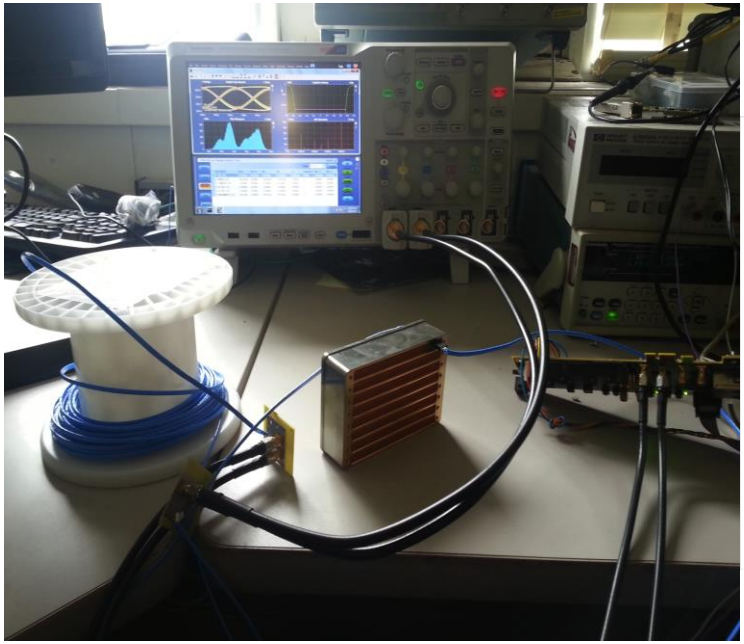
- Cold digital ASIC is taking care of the interface to warm electronics, and configuration of FE and ADC ASICs
  - ***This will make the cable plant reduced by ~30%***
- Each FT will handle 2 APAs, total 1,120 signal penetrations
- This is a conservative approach and further optimization is planed
  - DC-DC converter will be explored with added risks

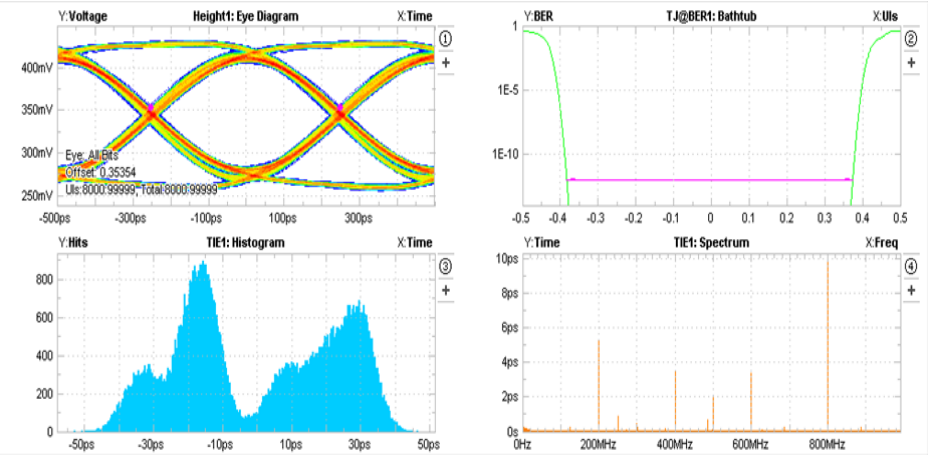
Cold Cable in 35T



- Data transmission, timing and control
  - Custom twinax cable made by Gore
  - AWG24 cable, good quality
  - Bulky, ERNI connector is not fully utilized (only 8 out of 40 pairs)
  - Each FEMB has a dedicated connection

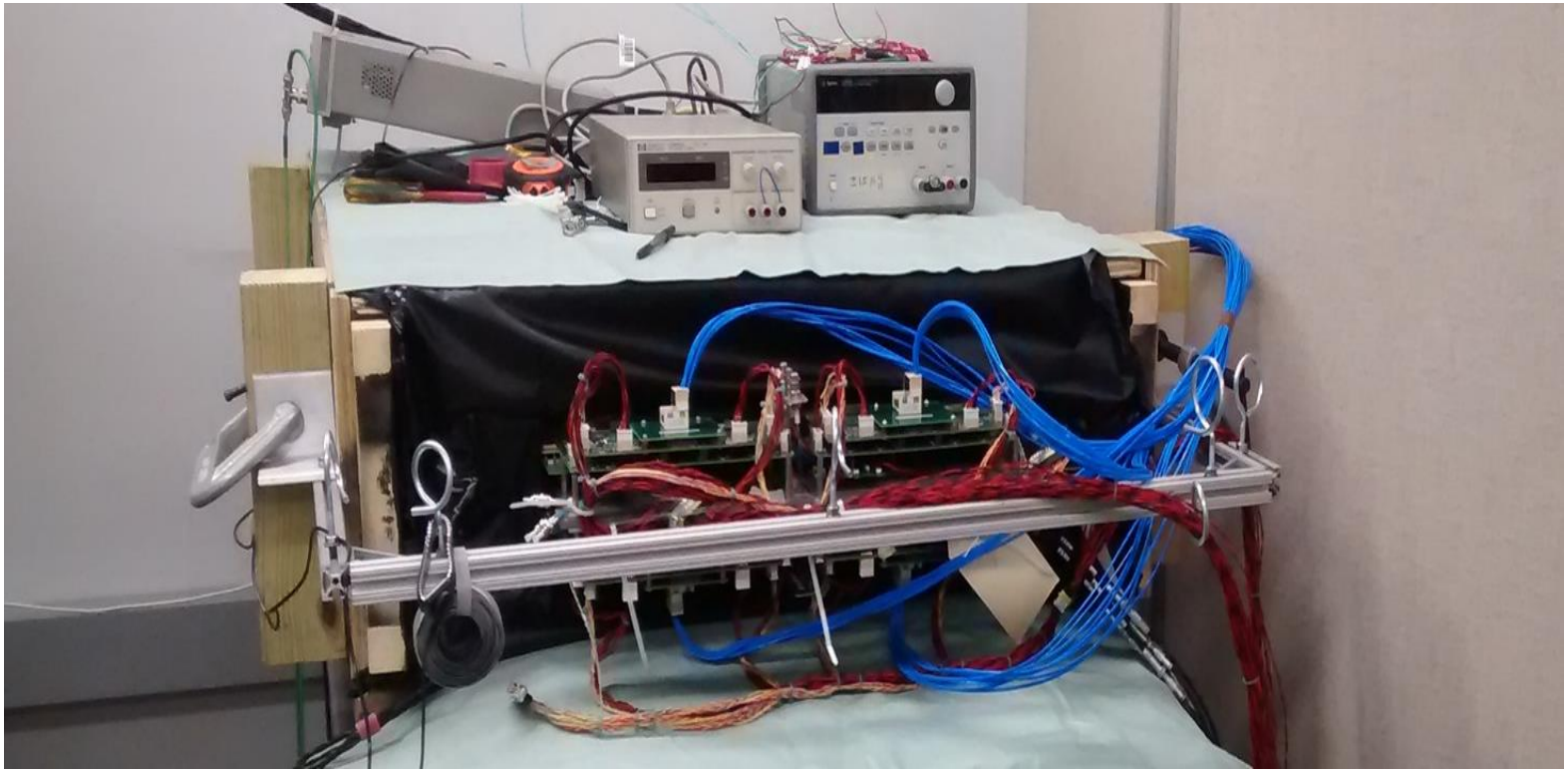
Test of Twinax Cable & ATLAS Pin Carrier





- 50 ft of Gore twinax cable has been tested with ATLAS pin carrier running at 2Gb/s successfully
- Cable is being used in 35T

Cold Cable in 35T APA Test



Optimization of Cold Cable

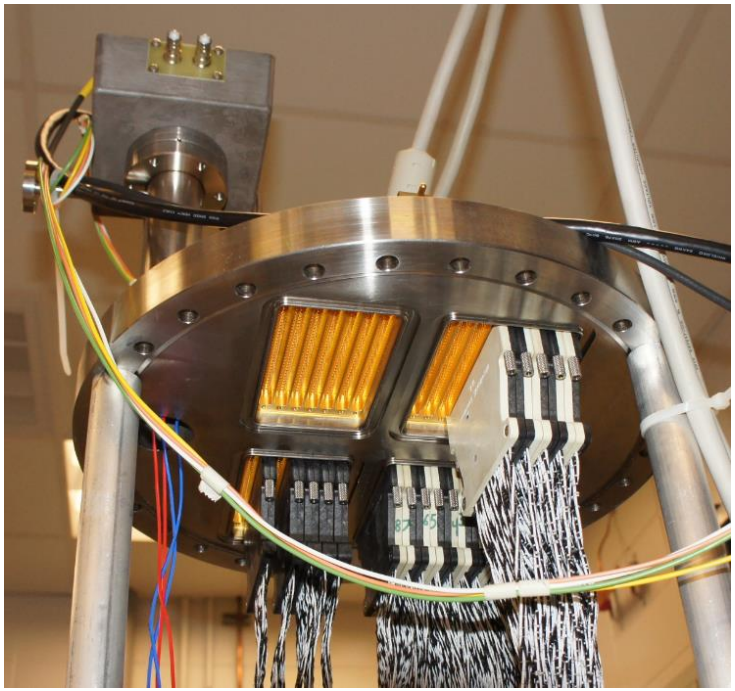
36-position, 8F36 Series

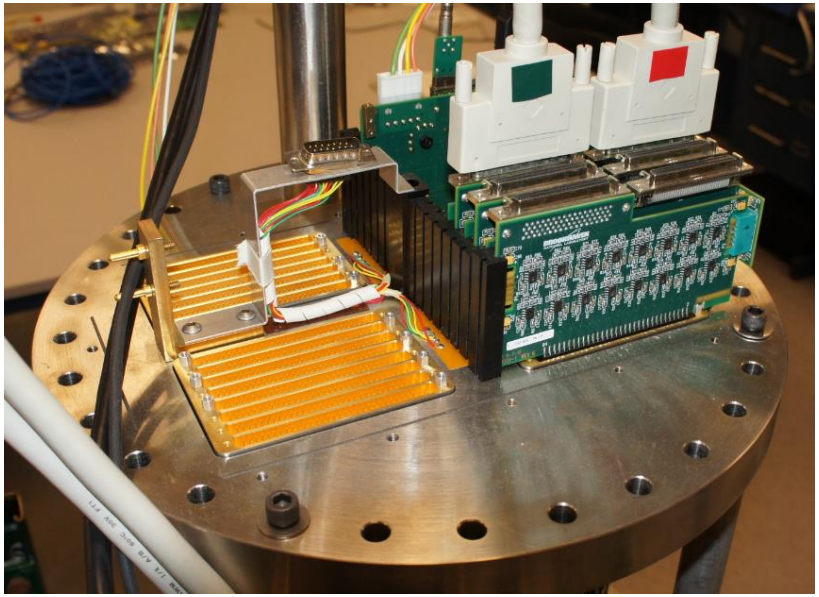
68-position,
8F68 Series

- Various options are being explored to find an alternative solution
  - Termination of cold cable needs to be optimized
- 3M Mini-SAS Twin Axial Cable
  - http://www.3Mtwinax.com
  - Sample of 15 meters & 25 meters 3M cable has been received
  - Test board has been designed and fabricated for cable test
  - Main concern is the attenuation over 15/25 meters cable
- Other manufactures are being contacted
  - Gore
  - Samtec
  - Hitachi
- A sample of Hitachi PFA insulated cable has been tested and certified in MTS at Fermilab in April

Signal Feed-through

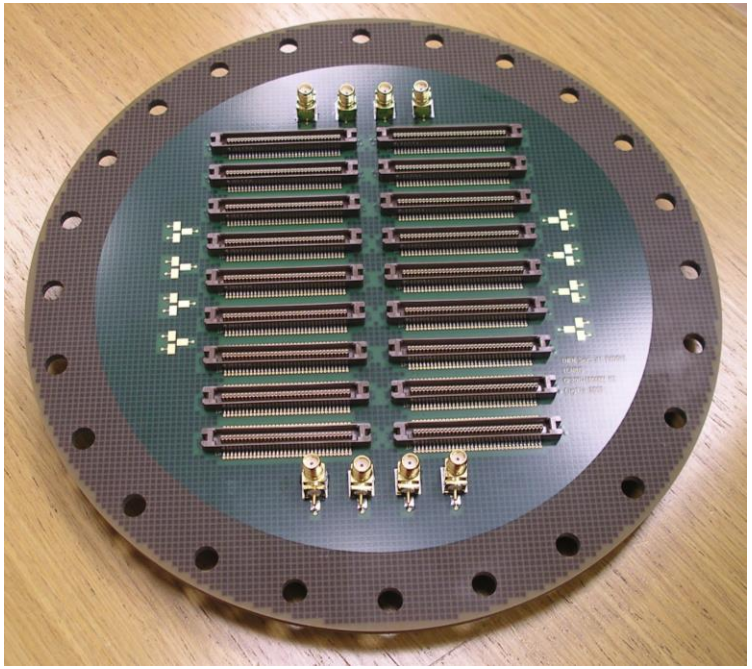
- Baseline design is to use ATLAS pin carrier for a single warm signal feed-through flange
  - MicroBooNE uses a warm flange with ATLAS pin carriers, total 1,920 pins on 14" CF flange
  - ATLAS LAr Calorimeter with ~230 signal feed-through flanges, ~450,000 penetrations in total, has been operated for ~10 years without leaking
  - Methodology of lifetime study of feed-through to be developed

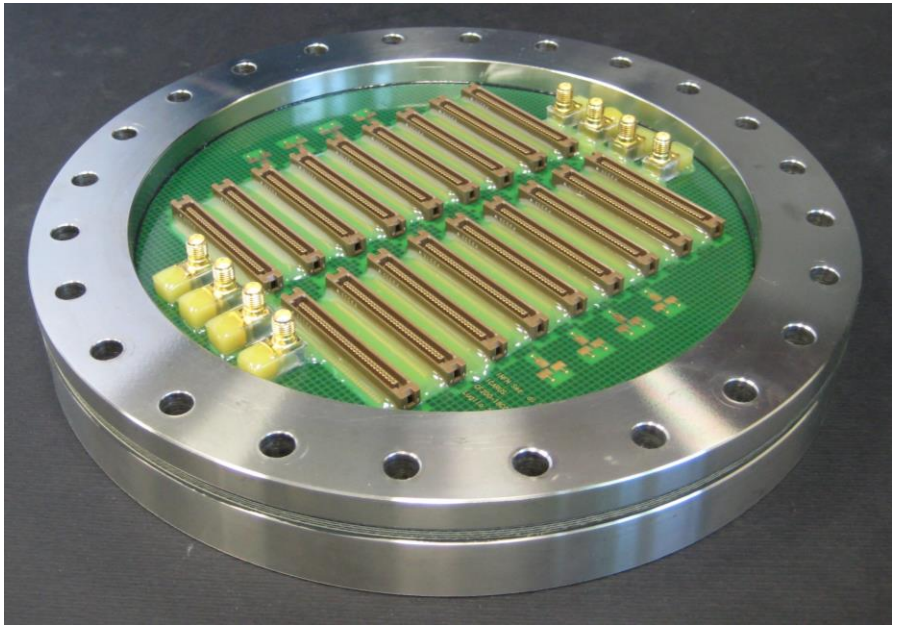




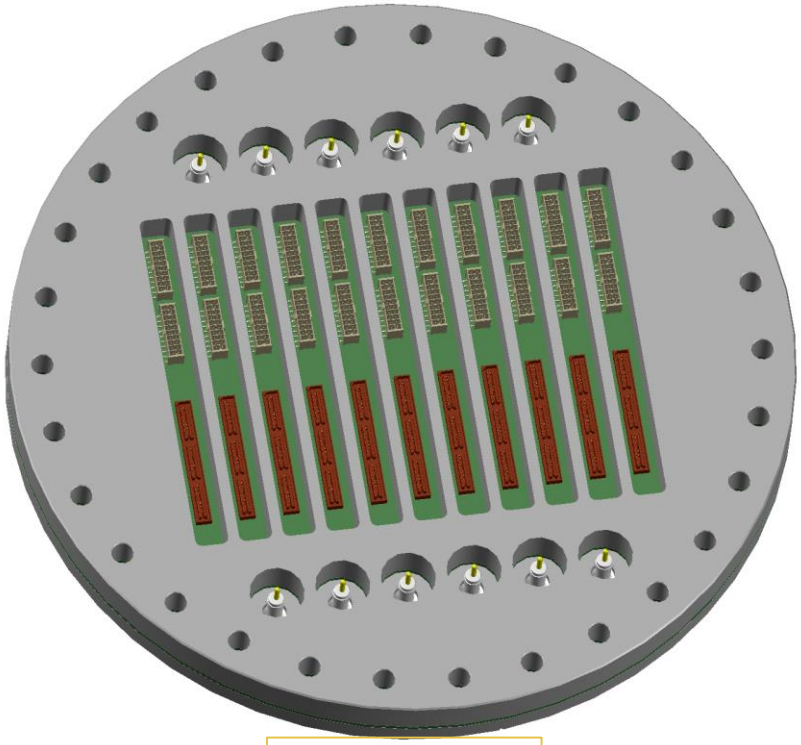
PCB Based Signal Feed-through

- Cost of a signal feed-through with ATLAS pin carrier is > $10k per flange
- A PCB based solution is being considered to reduce the M&S cost
  - ICARUS style feed-through, PCB is glued between SS rings
  - Working on collaboration with INFN Padova

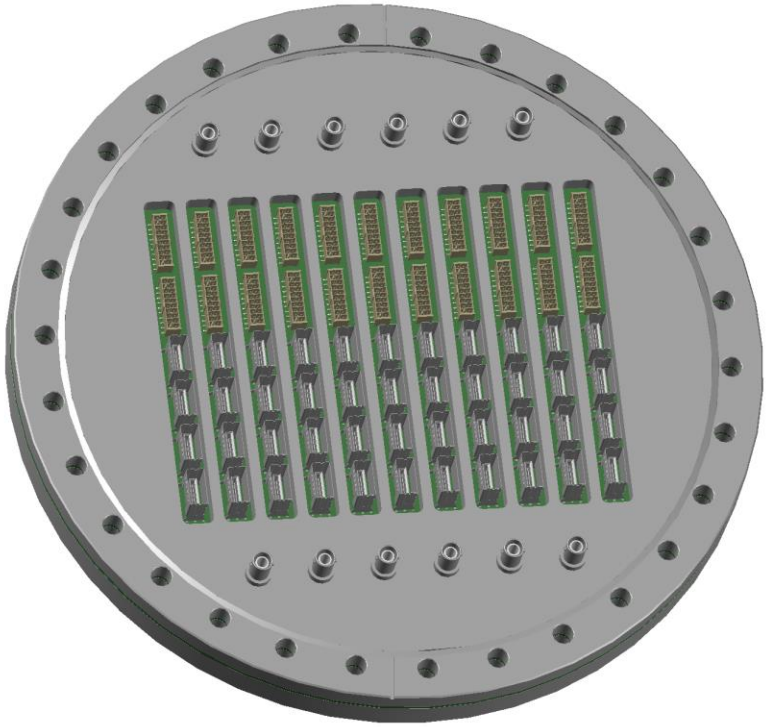




3D Model of PCB Based Signal FT



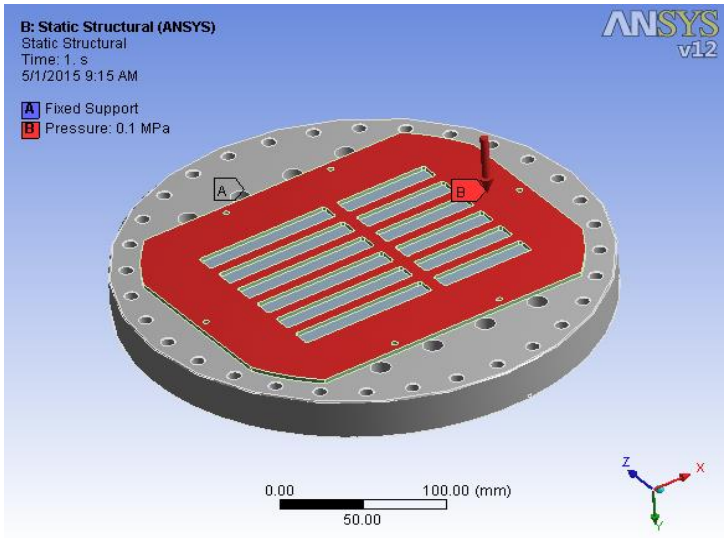
Warm Side

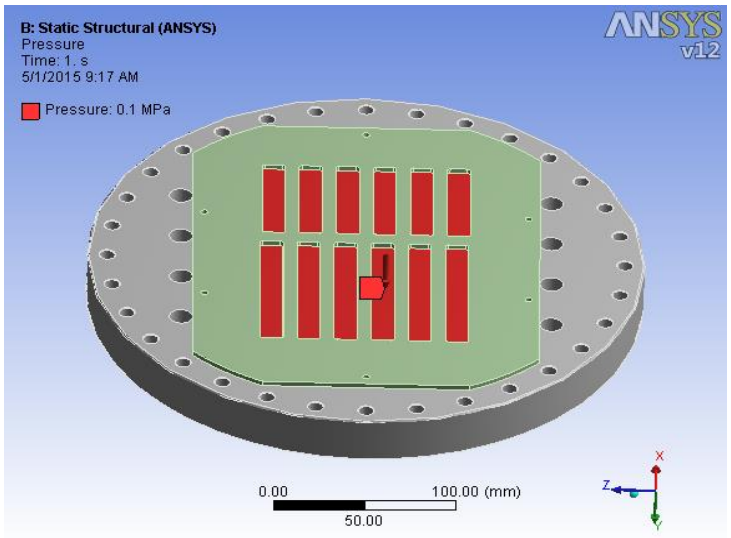


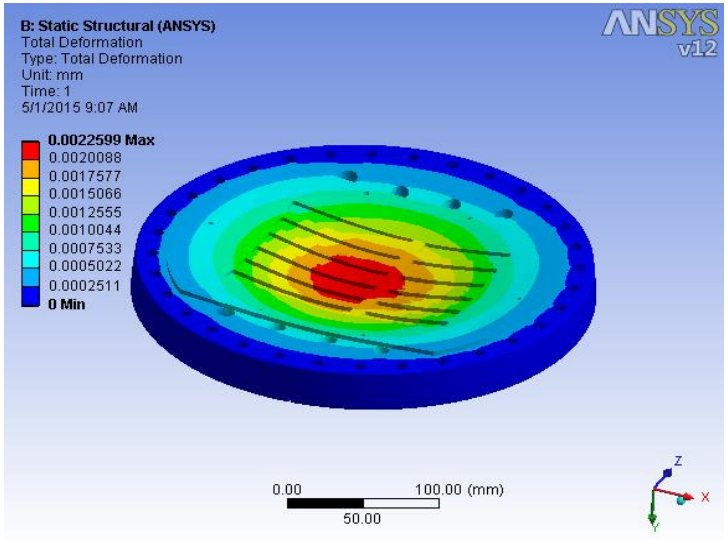
Cold Side

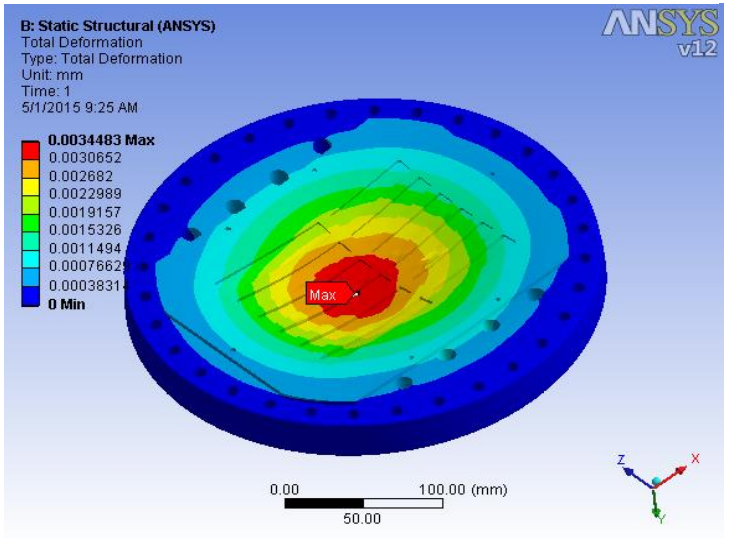
- Warm signal FT built with a PCB and a 14" CF flange with long slots
- The standard CF flange is cut into 2 pieces with a printed circuit board sandwiched in
- The PCB is glued on both sides to the two stainless steel pieces
- SHV connectors are welded on CF flange
- Stress analysis and thermal analysis are ongoing

Stress Analysis of 12” Flange



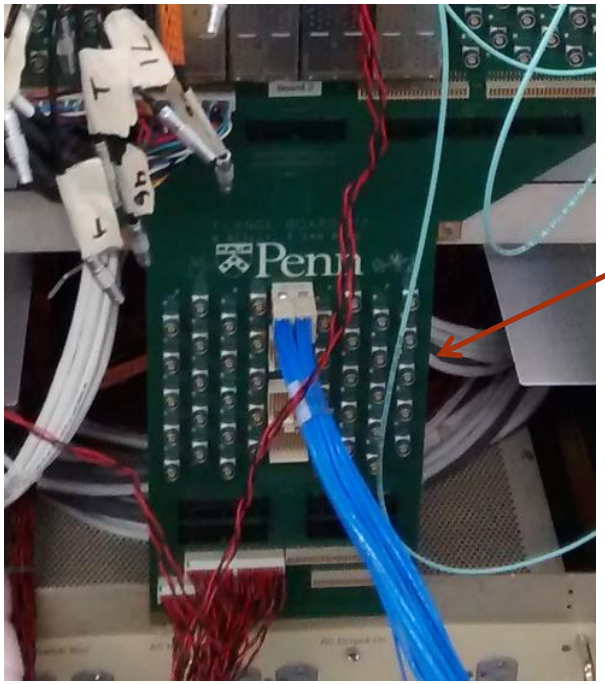






- Deformation is less than 4um at 0.1 MPa
- Model will be adjusted for 14” CF flange configuration

Summary



- Conceptual design of cold cable and signal feed-through have been presented
  - Lessons and experience are learned from 35T implementation – flange board potted in SS flange
- Various options are being explored to optimize the cold cable design
- Signal feed-through design is based on existing design of ATLAS pin carrier
- Low cost PCB based feed-through design is being explored, with aim to reduce the M&S cost
  - Collaboration with INFN Padova is being sought on signal feed-through development

Backup Slides

Cold Electronics Cabling

- One 128-ch FEMB (front end mother board assembly)
  - Data transmission
    - 4 differential pairs running at 1 Gbit/s
  - Timing and control
    - 2 differential pairs for clock and command
  - Slow control
    - 4 wires for I2C: differential signals
    - 8 wires for JTAG: 4 wires are JTAG signals, 4 wires are return lines
      - FPGA only
  - Power distribution
    - 14 wires for 7 voltage lines and 7 return lines
    - 3 voltage lines for analog mother board
    - 3 voltage lines for digital mezzanine with cold digital ASIC
    - 4 voltage lines for FPGA mezzanine

Cold Electronics Cabling

- One 128-ch FEMB
  - Signal cable – 26 wires, tentatively AWG24
  - Power cable – 12 wires, tentatively AWG20
- One APA has 20 128-ch FEMBs
  - Signal cable – 520 wires
  - Power cable – 240 wires
- Assuming each FEMB has separate cable sets
  - No redundancy is provided
  - No daisy chain among different FEMBs
  - Cabling might have three different sets: one for high speed signals, one for control signals, and one for power distribution
- Routing of cold cable needs to be developed
  - One possibility is to route the cables along the cryostat walls
  - Will it be possible to route the cables along the APA frames?
  - Will cables be connected to FEMB directly, or through an intermediate interface?

Comparison of Feed-through

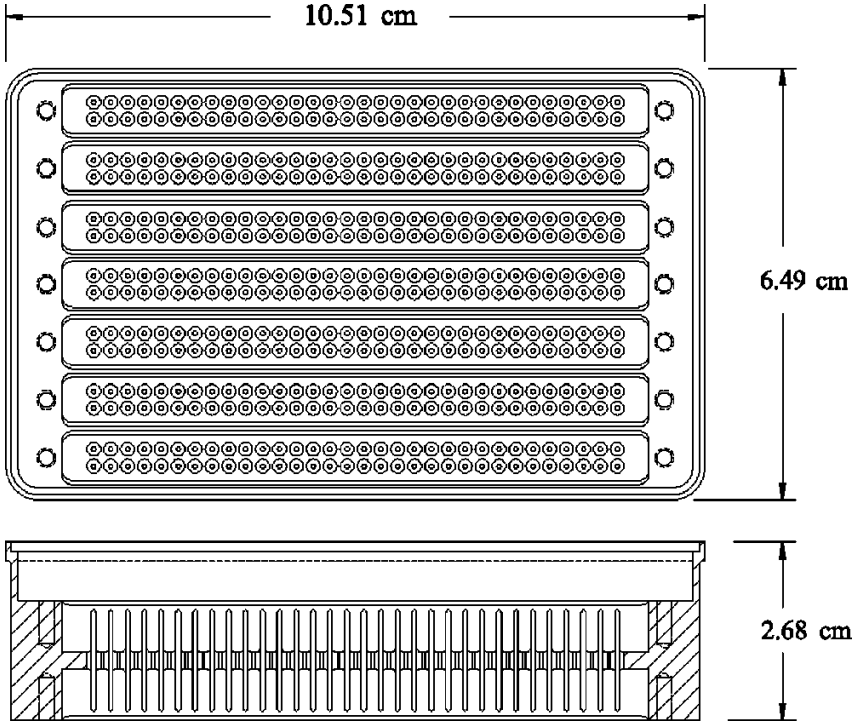
	# of Channels/FT	# of Pins/FT	Ratio (Ch/Pin)
MicroBooNE	768	1664	0.46
SBND Cold FPGA	2816	836	3.37
DUNE FD Digital ASIC	5120	1120	4.57

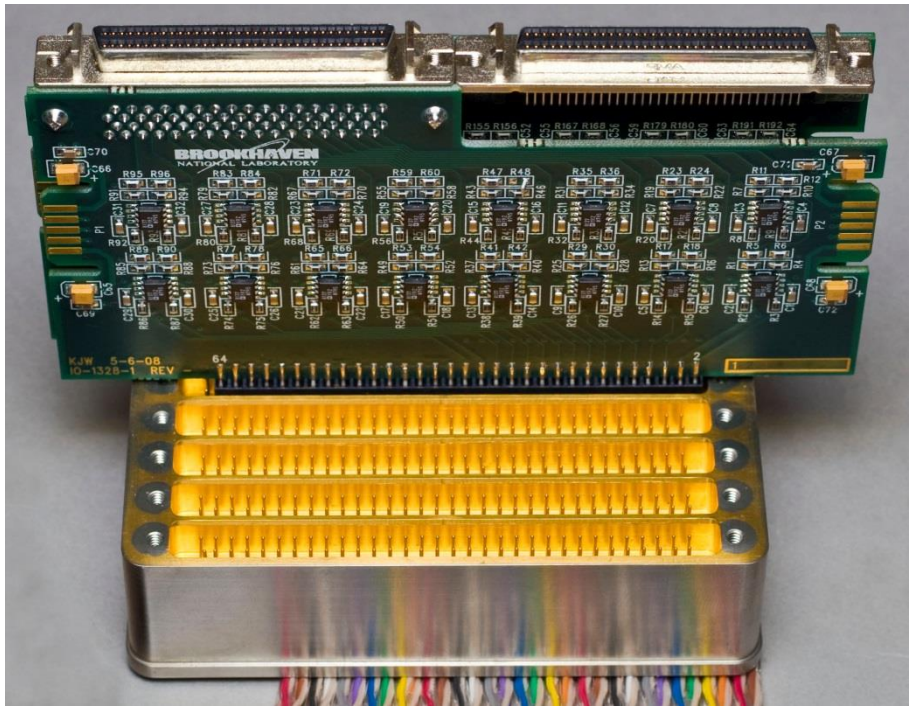
- Comparison of number of readout channels vs. number of pins (or penetrations) on feed-through
- ADC and multiplexing in DUNE FD will make the efficiency of feed-through penetration improved by ***factor of 10*** compared to MicroBooNE
  - There will be 75 signal FTs instead of ***750*** for 10 kt detector

ATLAS Pin Carrier

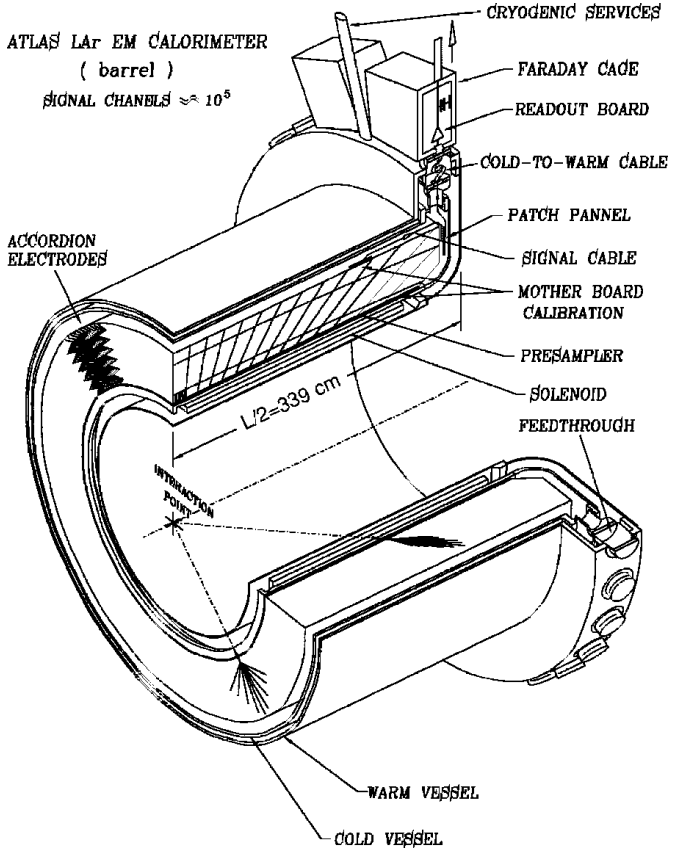
Manufactured by:
Glasseal Products, Inc., 485 Oberlin Ave., Lakewood, N.J. 08702

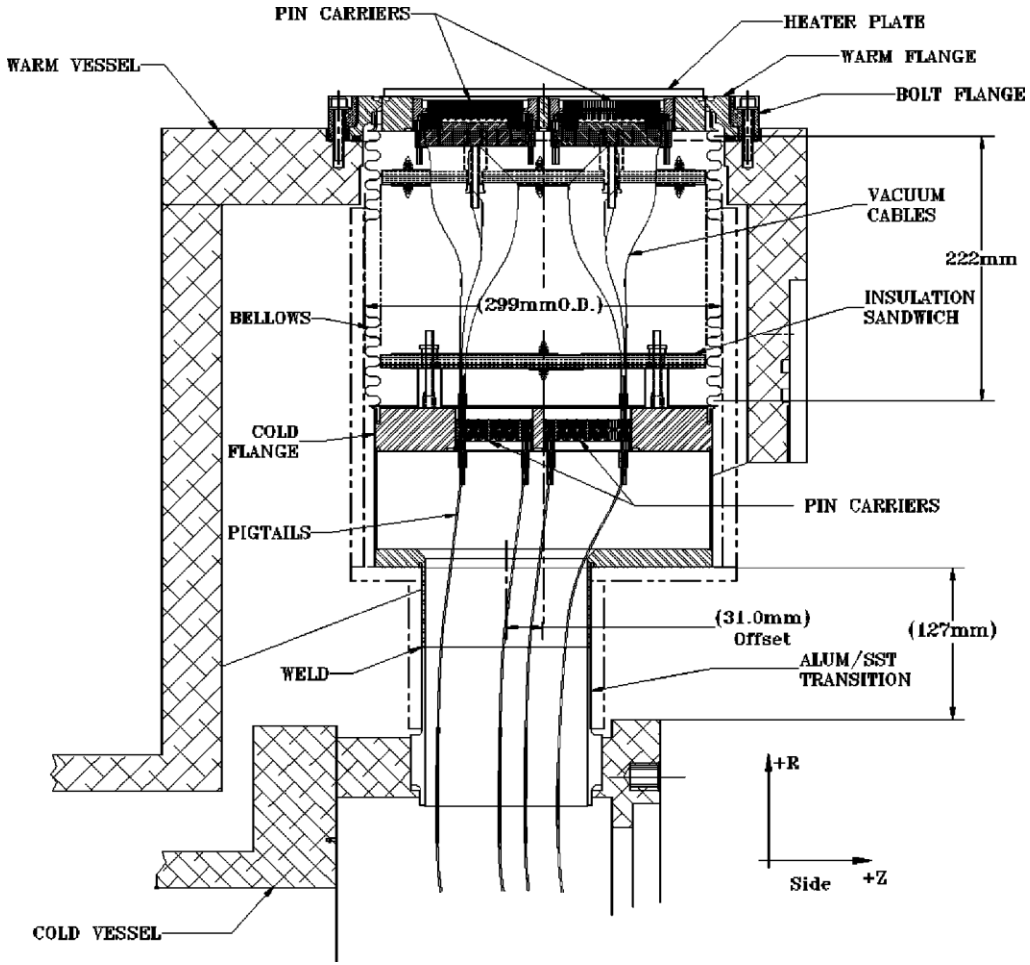
Either 64x7 or 64x8 pins per unit. 0.1” pin pitch



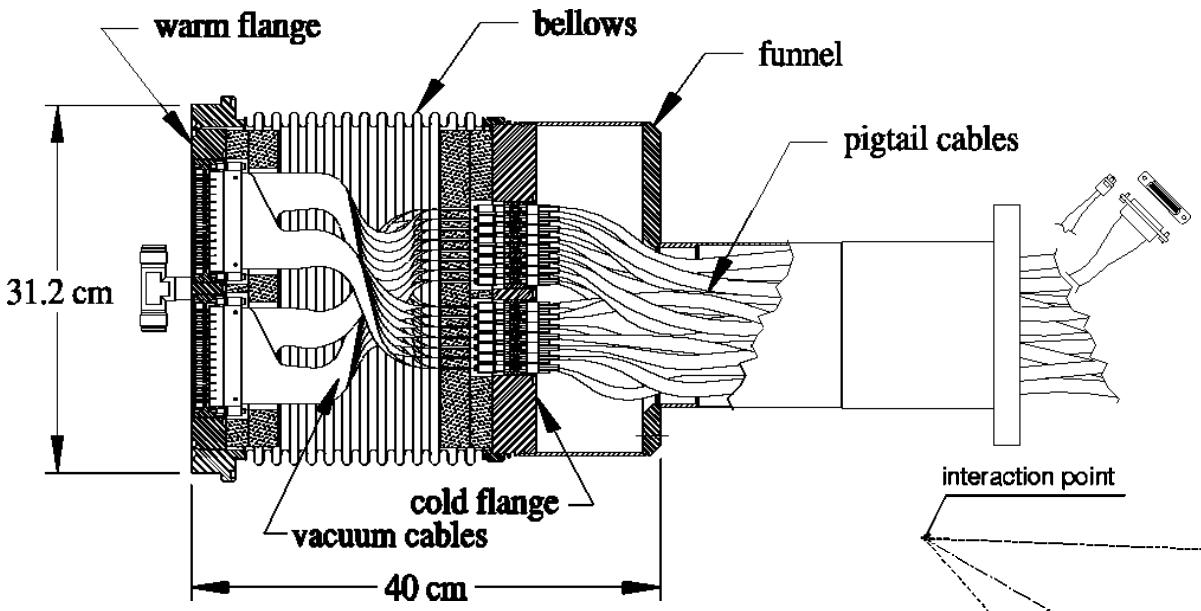


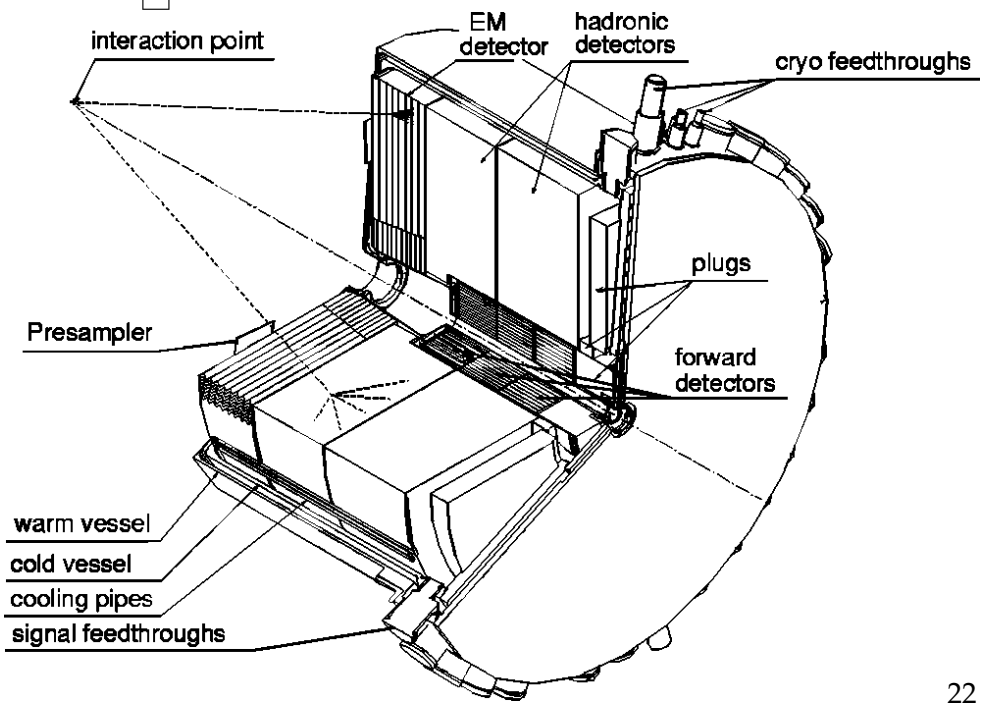
ATLAS Barrel Calorimeter





ATLAS Endcap Calorimeter





Photos of an ATLAS Warm Flange