131.ND.02 ND LAr TPC: Electrical overview

Armin Karcher, ND LAr System Electrical Engineer

ND-LAr Preliminary Design Review

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Schweizerische Eidgenossenschaft
Confédération suisse
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U.S. DEPARTMENT OF ENERGY | Office of Science

Introduction – Who am I?

- Electrical engineer with strong physics background
- I have been with LBNL for 25 years
- Long history with large physics projects
  - BaBar SVT and drift chamber.
  - JDEM optical and NIR detector systems.
  - DESI Spectrograph readout and focal plane control system.

Outline

- Documentation Reference
- ND LAr overview
- Power Delivery
- Grounding – System
- Grounding – Subsystems
- Summary

Documentation Reference

Folder/Document	Description	EDMS Link
ND-LAr Top-Level Folder	Top level folder for all ND-LAr Consortium documentation	https://edms.cern.ch/project/CERN-0000217521
ND-LAr Scope Overview Drawing	Scope overview drawing of Near Site detector	https://edms.cern.ch/document/2459141
ND-LAr TPC Scope Overview Drawing	Scope overview drawing of the ND-LAr TPC	https://edms.cern.ch/document/2459142
ND-LAr Scope and MOU Tables	Tables detailing Consortium subsystem scope and deliverables	https://edms.cern.ch/project/CERN-0000220117
ND-LAr WBS Dictionary	Work Breakdown Structure (WBS) Dictionary for ND-LAr Consortium	https://edms.cern.ch/document/2619609
ND-LAr Resource Matrix	Resource matrix for ND-LAr Consortium	https://edms.cern.ch/document/2619602
ND-LAr Key Document List	List of key documents for ND-LAr Consortium	https://edms.cern.ch/document/2741772
CAD Release Process	CAD release process for ND-LAr official CAD	https://edms.cern.ch/document/2612310
Windchill CAD Model Structure	Windchill CAD model structure definition	https://edms.cern.ch/document/2683349
Environmental, Health, and Safety (ESH)	ESH document detailing key FESHM sections for ND-LAr acitivities at FNAL	https://edms.cern.ch/document/2602421
Hazard Registry	Hazard registry for all ND-LAr activities	https://edms.cern.ch/document/2663898
Prototyping Plan	Prototyping plan for the ND-LAr Consortium	https://edms.cern.ch/document/2459149
Requirements	Spreadsheet with all ND-LAr requirements, see sheet "System"	https://edms.cern.ch/document/2589287
System-Level Interface Flow Diagram	Flow diagram for ND-LAr system design and interfaces from event to data collection	https://edms.cern.ch/document/2636568
N2 Matrix for ICDs	N2 matrix that defines ND-LAr interfaces with EDMS links to unique ICDs	https://edms.cern.ch/document/2640807
Internal ICDs	Interface control documents (ICDs) internal to the ND-LAr Consortium	https://edms.cern.ch/project/CERN-0000223195
External ICDs	Interface control documents (ICDs) external to the ND-LAr Consortium	https://edms.cern.ch/project/CERN-0000229879
Installation ICD	Interface control document between ND-LAr Consortium and Near Site Installation	https://edms.cern.ch/document/2730726
Analyses	Collection of analyses/studies/eng notes	https://edms.cern.ch/project/CERN-0000217538
2x2 Lessons Learned	Spreadsheet with a collection of 2x2 lessons learned	https://edms.cern.ch/document/2737729
Cost	High-level cost estimate for ND-LAr and subsystems	https://edms.cern.ch/document/2742778
Schedule	High-level "one-pager" schedule for ND-LAr Consortium activities	https://edms.cern.ch/document/2603073
CAD Model (Row Assembly, TPC Assembly)	Solidworks "Pack & Go" and Parasolid exports of CAD models	https://edms.cern.ch/project/CERN-0000230732
ND-LAr Grounding Plan	Document that details detector-wide grounding plan	https://edms.cern.ch/document/2459151
ND-LAr TPC Grounding Plan	Document that details TPC-specific grounding plan	https://edms.cern.ch/document/2459152

Personnel

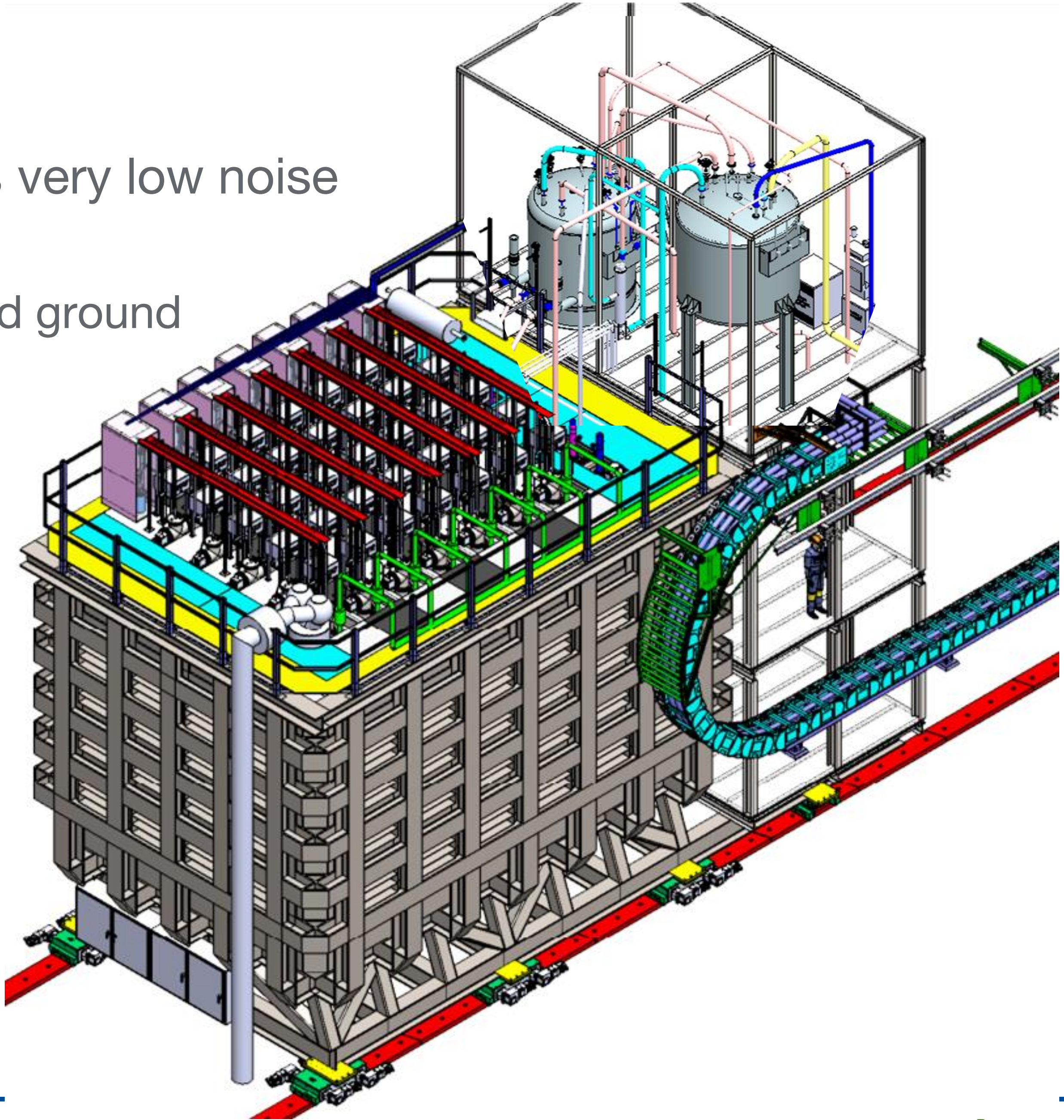
- Armin Karcher LAr detector electrical lead
  - Funded on-project
- Strong electrical engineering teams for sub- systems
- Coordination with FNAL members of DUNE grounding committee
  - Linda Bagby (primary contact)
  - Theresa Shaw
  - Steve Chapas
- Initial Grounding review May19th https://indico.fnal.gov/event/54474/

Name	Area	Institution	Yrs. Exp.
Silas Bosco	Mech	Bern	16
Roger Hanni	Mech	Bern	25
Jan Christen	Mech	Bern	15
Lorenzo Meier	Mech	Bern	10
Camilla Tognina	Elec	Bern	11
Knut Skarpaas	Mech	SLAC	32
Haufai Auyeung	Mech	SLAC	30
Marco Oriunno	Mech	SLAC	26
Brian Qui	Cryo	SLAC	18
Armin Karcher	Elec	LBNL	25
Carl Grace	Elec	LBNL	18
Dario Gnani	Elec	LBNL	18
Tarun Prakash	Elec	LBNL	4
Panos Zarkos	Elec	LBNL	1
Andrew Lawrence*	Mech	LBNL	5
Rama Kuravi*	Mech	LBNL	10
Thomas Rathmann*	Mech	LBNL	20
Hans-Gerd Berns	Elec	UC Davis	31
Priya Sundararajan	Elec	UC Irvine	20
Chithra Kurup	Elec	Rutgers	10
Alexander Selyunin	Elec	JINR	12
Sergei Sokolov	Mech	JINR	9
Dmitriy Fedoseev	Elec	JINR	15
Chetverikov Alexey	Elec	JINR	4
Vladislav Sharov	Soft	JINR	4
Vladimir Kozhukalov	Soft	JINR	17
Denis Korablev	Soft	JINR	17
Kuznetsova Kseniya	Mech	JINR	5
Vyatcheslav Chalyshev	Mech	JINR	48
Morgan Bonnet	Mech	U-Hawaii	17
Dean Schooltz	Mech	MSU	15
Michael Geynisman	Cryo	FNAL	43
Michael Zuckerbrot	Cryo	FNAL	13
Jay Jablonski	Mech	CSU	22
Zach Rautio	Mech	CSU	5
Culmulative Years Experience			**591**

**Moved on to other opportunity*

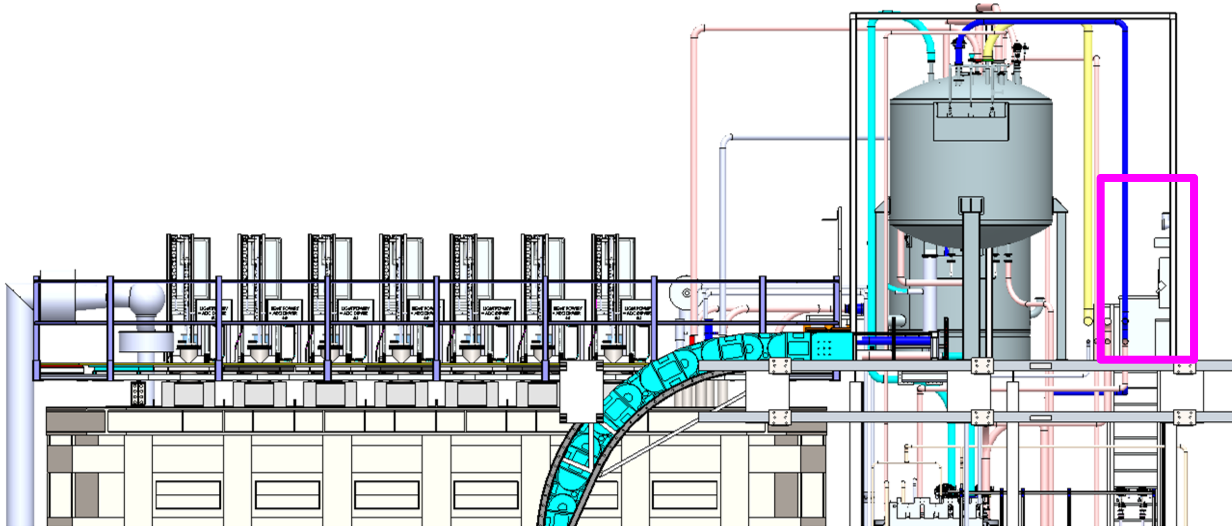
Challenges

- Charge sensitive TPC readout requires very low noise power and ground
  - Isolation from noisy facilities power and ground
- Detector needs to move
  - E-chain
  - PRISM system
  - Cryogenics mezzanine (mobile)
  - Shielded transformer on mezzanine
- Detector grounding system
  - Avoid noise in cryostat

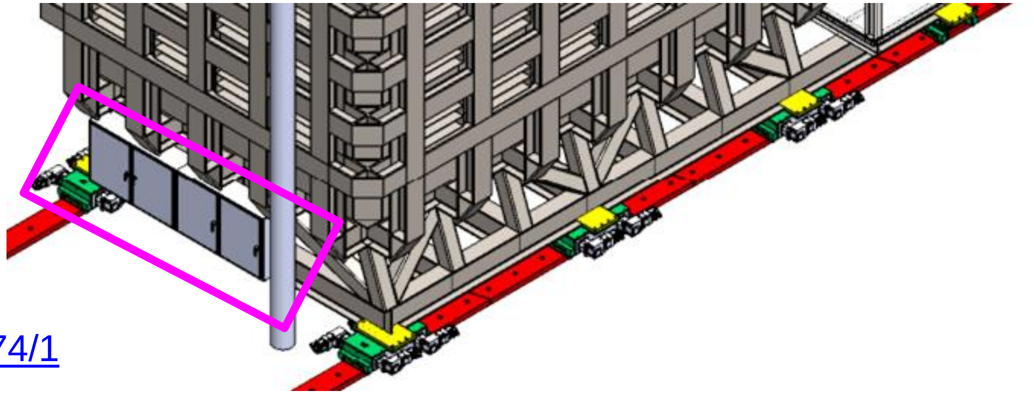


ND LAr Detector support

- E-chain supplies
  - PRISM power
  - Power for cryogenic systems on mezzanine
  - Detector power
  - Cryogenic piping
  - Data fibers



- PRISM system https://edms.cern.ch/document/2458097/1
  - 8 rollers supporting the detector
  - 4 rollers supporting cryo mezzanine
  - Control Panels mounted to cryostat
    - Space on cryo mezzanine is tight
  - Conduit mounted on cryostat

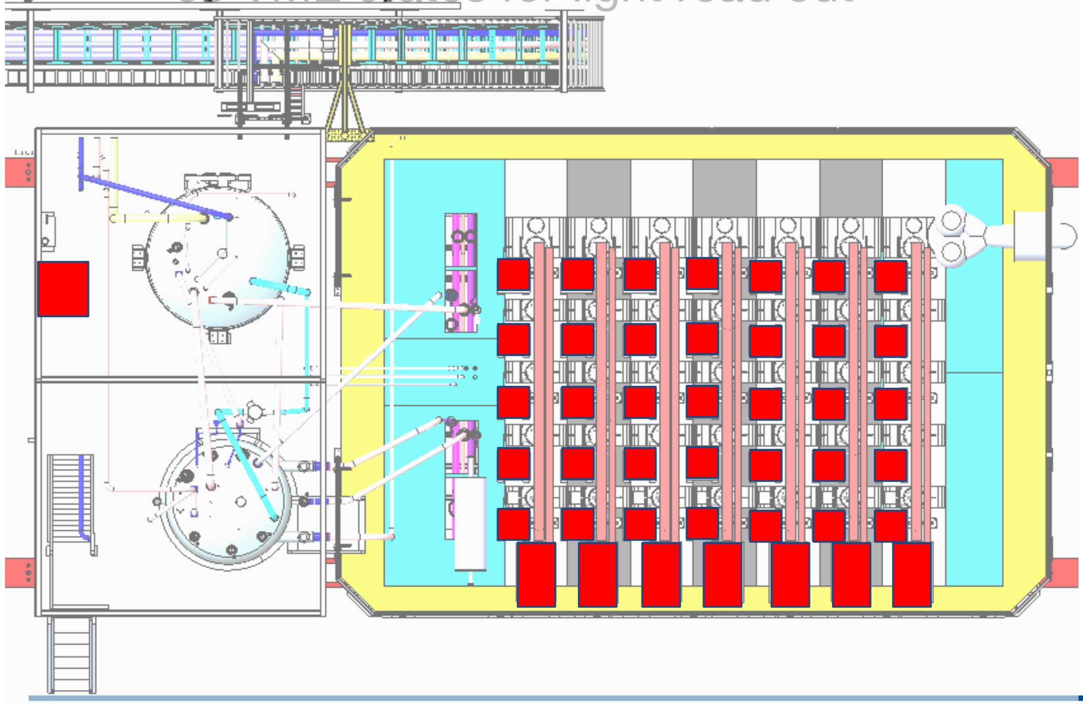


- Cryo mezzanine https://edms.cern.ch/document/2458074/1
  - Houses local cryogenic systems.
  - Supports shielded transformer & saturable inductor for ground decoupling of detector.

Detector power

https://edms.cern.ch/document/2646117/1

- 112kVA double-shielded transformer
- Power panel on detector
  - Supplies 7 end of row racks
    - Network switches
    - HV supplies and filters
    - Charge read out supplies
    - Slow controls
  - 35 VME crates for light read out



system	units	type	output W	Expected peak power [Watt]	Cryogenic power [Watt]
HV	7	Spellman 60x300	300	422	210
total				2957	1470
Charge Readout			power W		
	4	Pacman	94		
	5	module	376		
	7	PL506	1880	2265	87
	7	Network		300	
total				17957	3044
Light Readout			power W		
	5	VME	850	850	
	7	Row	4250	4250	22
	7	Network		600	
total				33950	756
Slow Control	7	Low Power CPU		120	0
			ND total	54864	5270

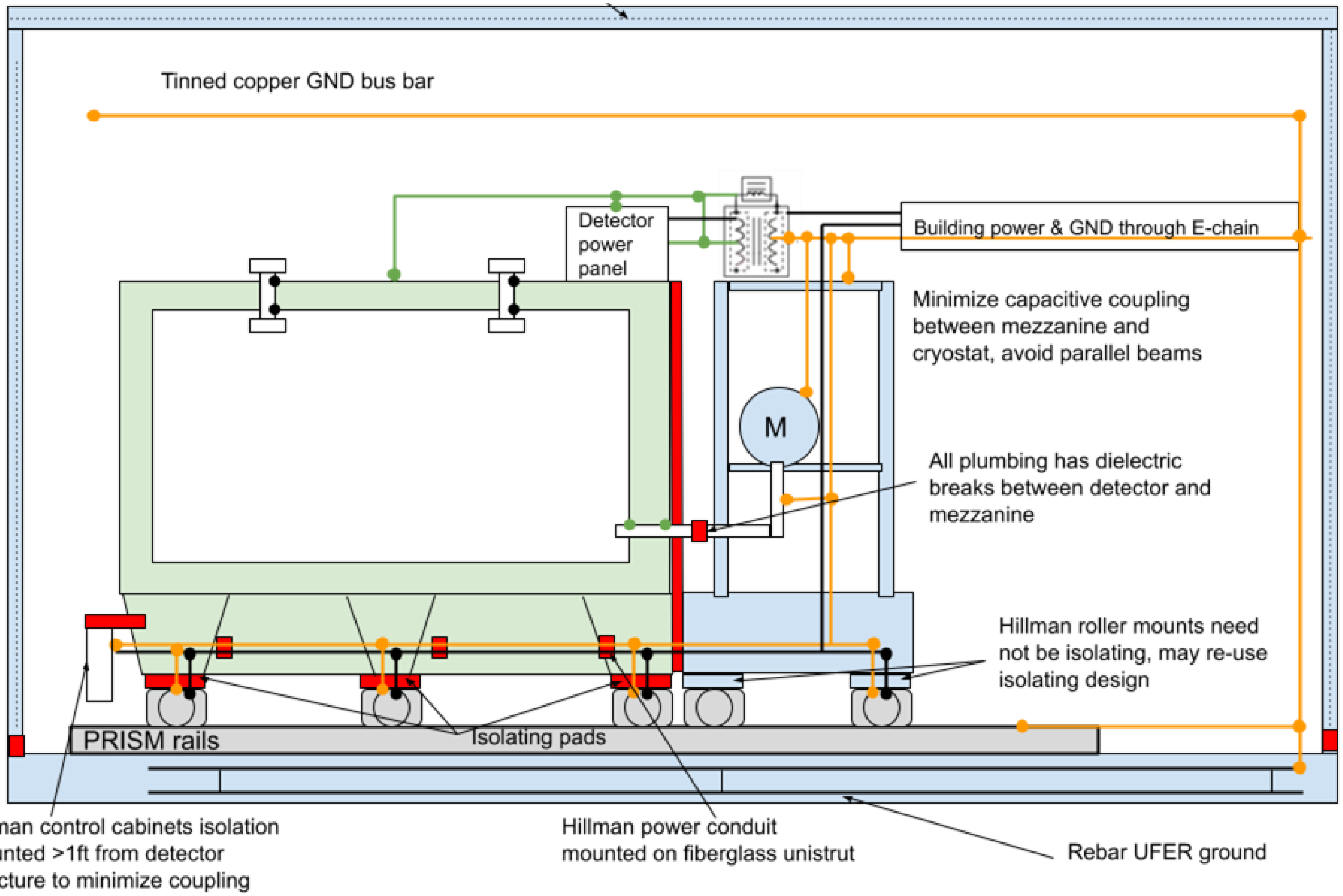
Detector grounding plan

- Hall walls and ceiling are nonconductive reinforced shotcrete, floor has rails and rebar UFER ground
- Facility power and ground wiring in E-chain
- Detector and cryo mezzanine are mechanically coupled, electrically isolated
- Shielded transformer on mezzanine
- Saturable inductor and monitor on mezzanine
- Detector power distribution panel on detector

Grounding system strongly based on ProtoDUNE

Design goal is 10 Ohm impedance to building ground at 1 MHz (Based on ICARUS, ProtoDUNE experience)

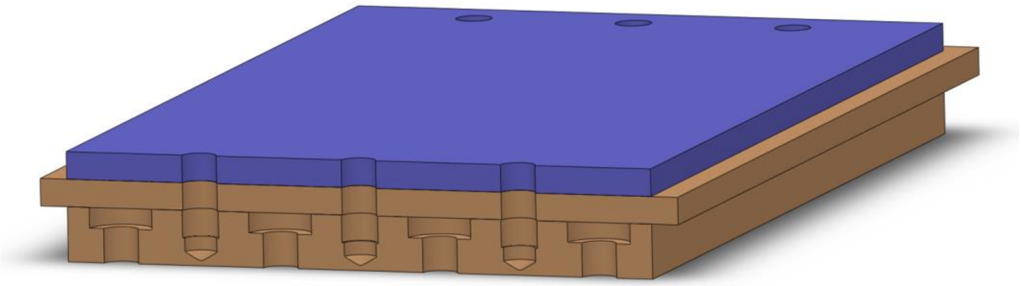
https://edms.cern.ch/document/2459151/1



Detector grounding details

Isolation components

- Conventional Facilities: https://edms.cern.ch/document/2443705/2
  - Double Shielded transformer for detector power
  - Saturable inductor for ground ripple isolation
- DAQ https://edms.cern.ch/document/2458098/1
  - All data transferred on fibers
- Cryogenics https://edms.cern.ch/document/2458074/1
  - Plumbing has dielectric breaks between mezzanine and detector
- PRISM: https://edms.cern.ch/document/2745376/1
  - Isolating pads between rollers and frame
  - Dielectric break in frame between detector support and mezzanine support
  - PRISM conduit & controls mounted with isolators



PRISM isolation pads

Subsystem grounding

https://edms.cern.ch/document/2459152/1

- Due to electrical safety considerations racks and electrical enclosures shall be tied to dewar ground.
- The dewar acts as a faraday cage for the detector electronics.
  - A low impedance ground to the dewar structure at the feed through is required
    - Design goal is 1 Ohm DC to 10MHz
  - The High voltage current return path is of particular concern as an interruption in this path has severe machine safety implications. It has to be guaranteed that this path can not be accidentally broken.
- Great care must be used to avoid ground loops
- Low voltage supply cables shall be shielded with 360deg. connector ground.
  - Use twisted equal AWG for supply and return.
  - Both braided and foil shields are acceptable.

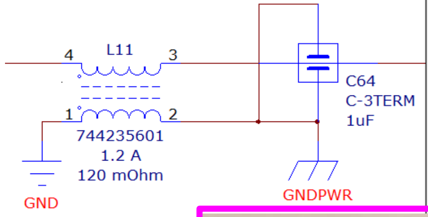
Charge Readout Grounding

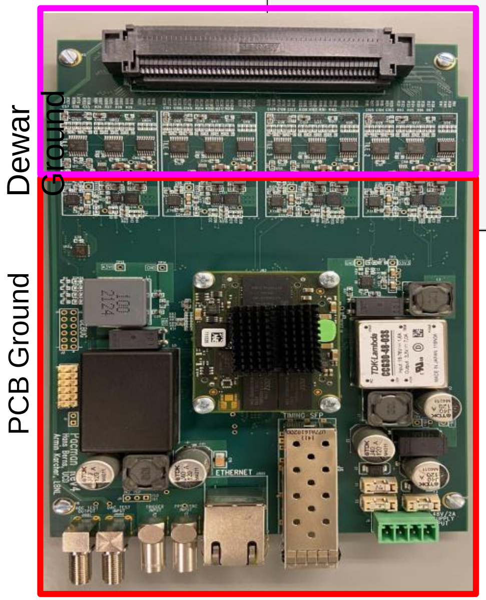
- Anode support panel acts as common ground plane per TPC
- All tiles are grounded to anode support
- Tile ground shorted to dewar ground at feed-through using PCB plane
- Low voltage PSU output is floating (PL506)
- PACMAN GND is tied to dewar gnd through common mode power filters
- Power cable is 10 AWG shielded twisted pair

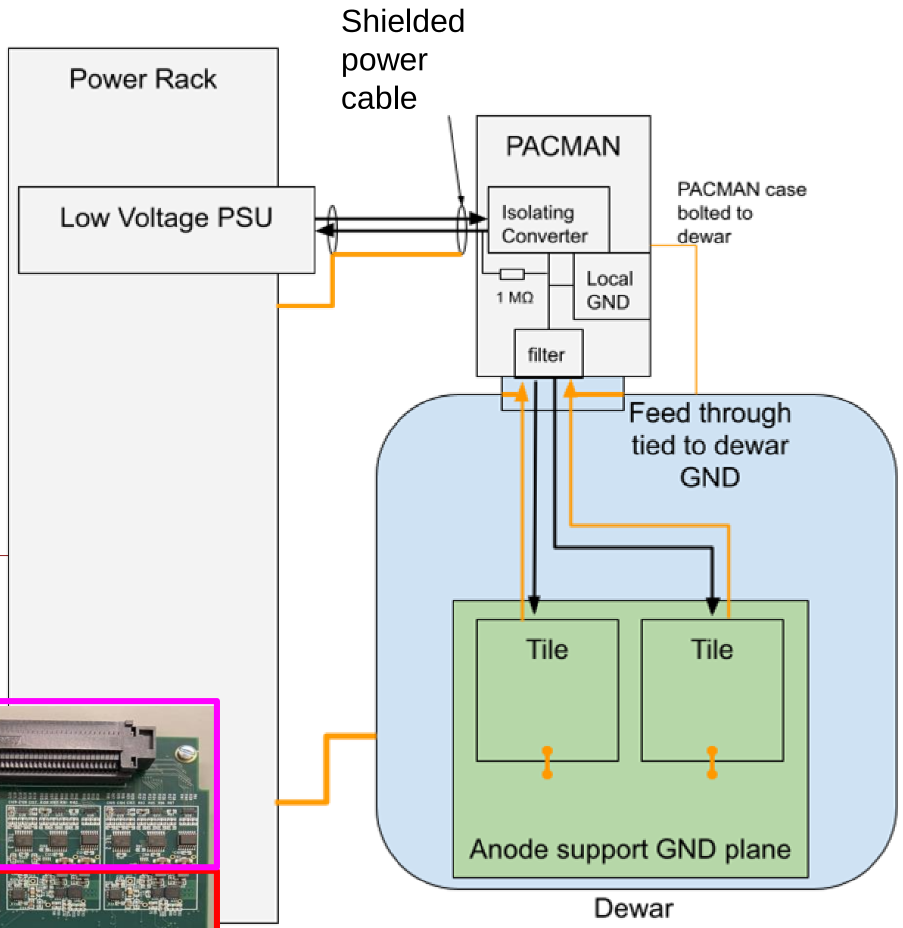
❖ Tile ground connection is power return.

Very similar to DUNE WIEC/FEMB grounding.

See subsystem talks for implementation details

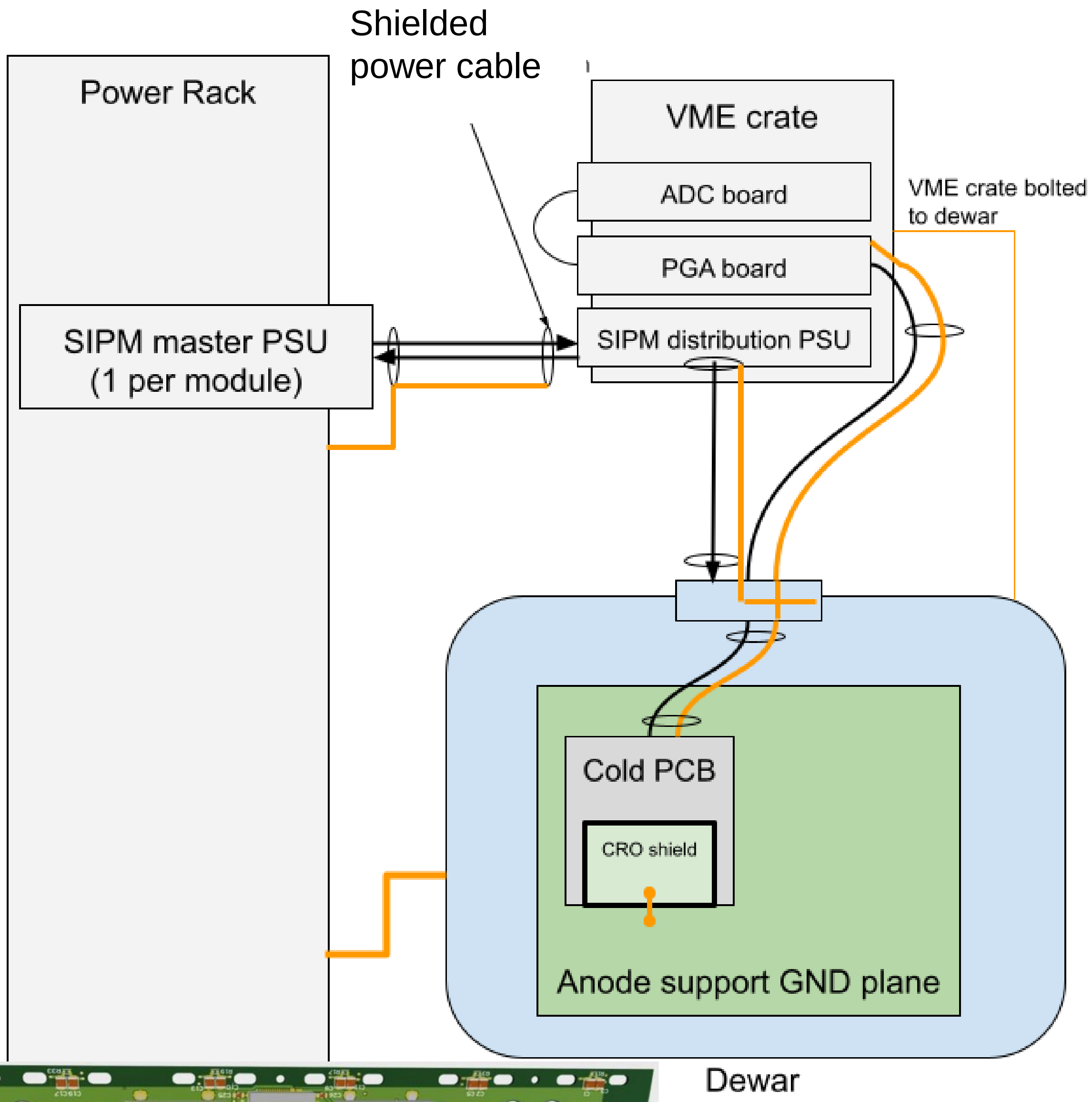


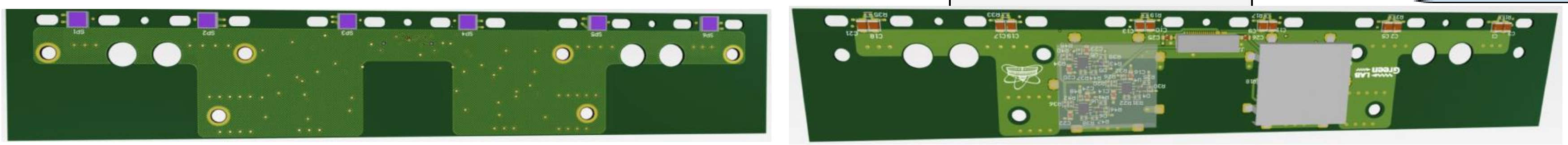




Light Readout Grounding

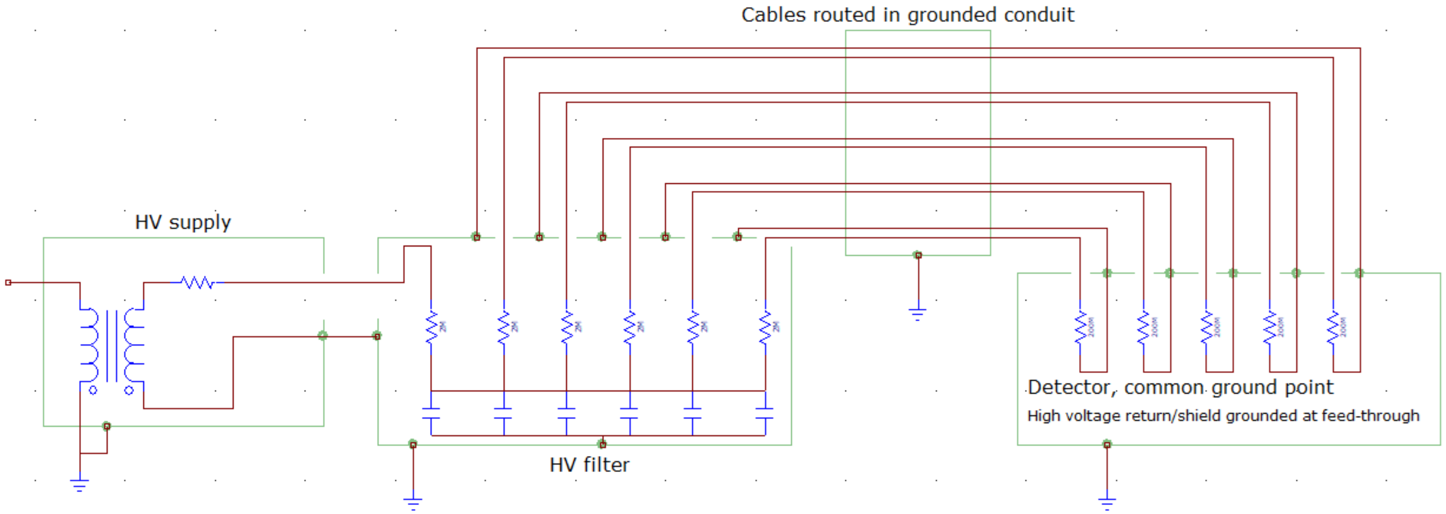
- Light Readout electronics are located in a VME crate close to the TPC feed through
- Power and signals transmitted on micro coax
- Micro coax shield tied to dewar ground at feed through
- Cold electronics except SIPMs enclosed in 6 sided shield
- bottom of PCB is a shield tied to anode support (charge readout ground).
    - Prevents light readout gnd noise from coupling into charge readout
- External mid voltage supply uses floating output, shielded cable

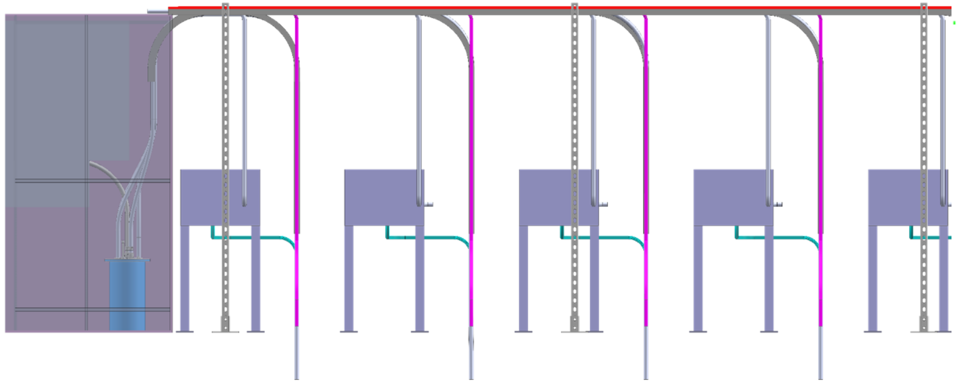




HV distribution

- Commercial supply
- Oil bath filter
- Resistive distribution cables

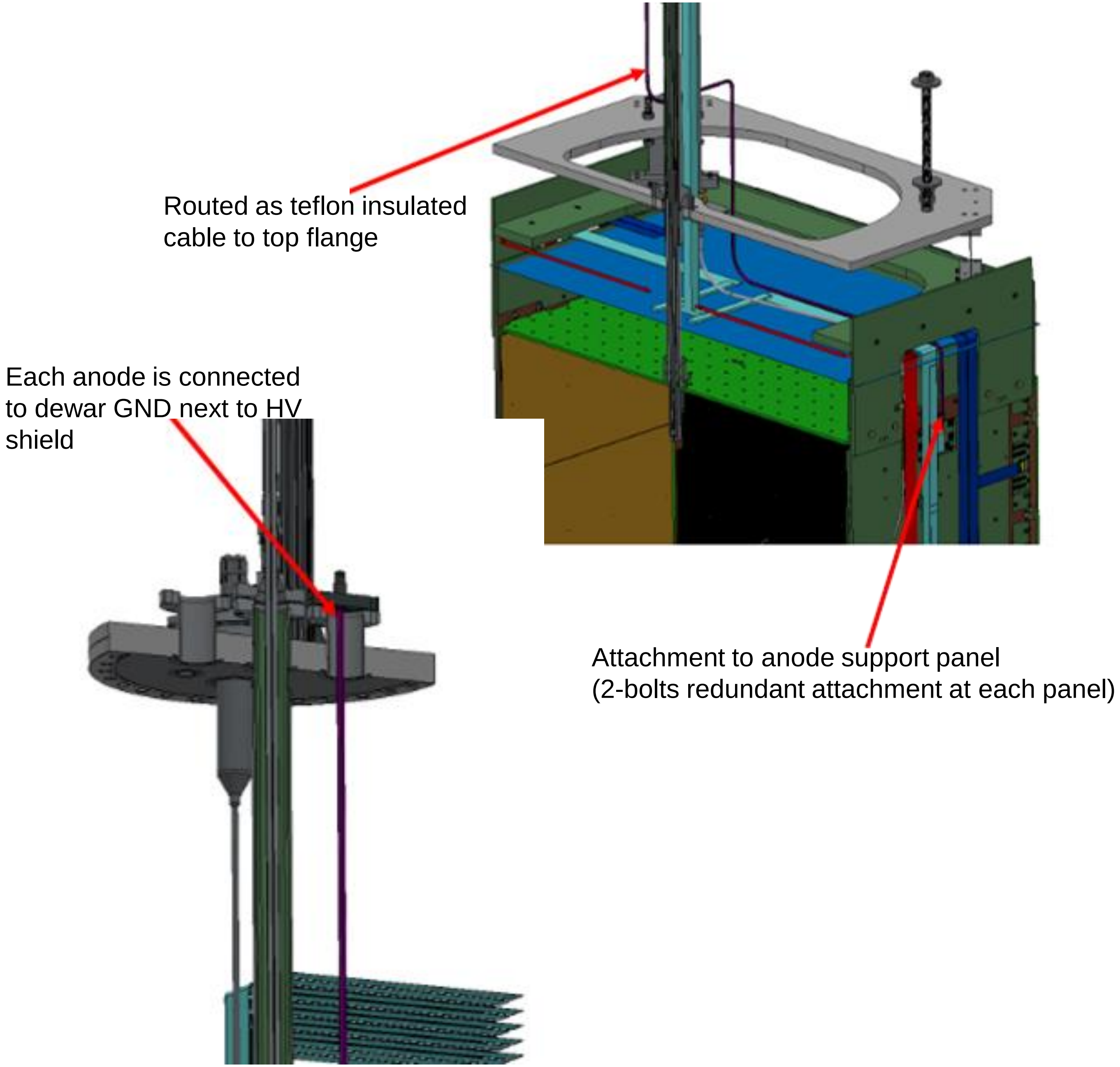




LBNF/DUNE

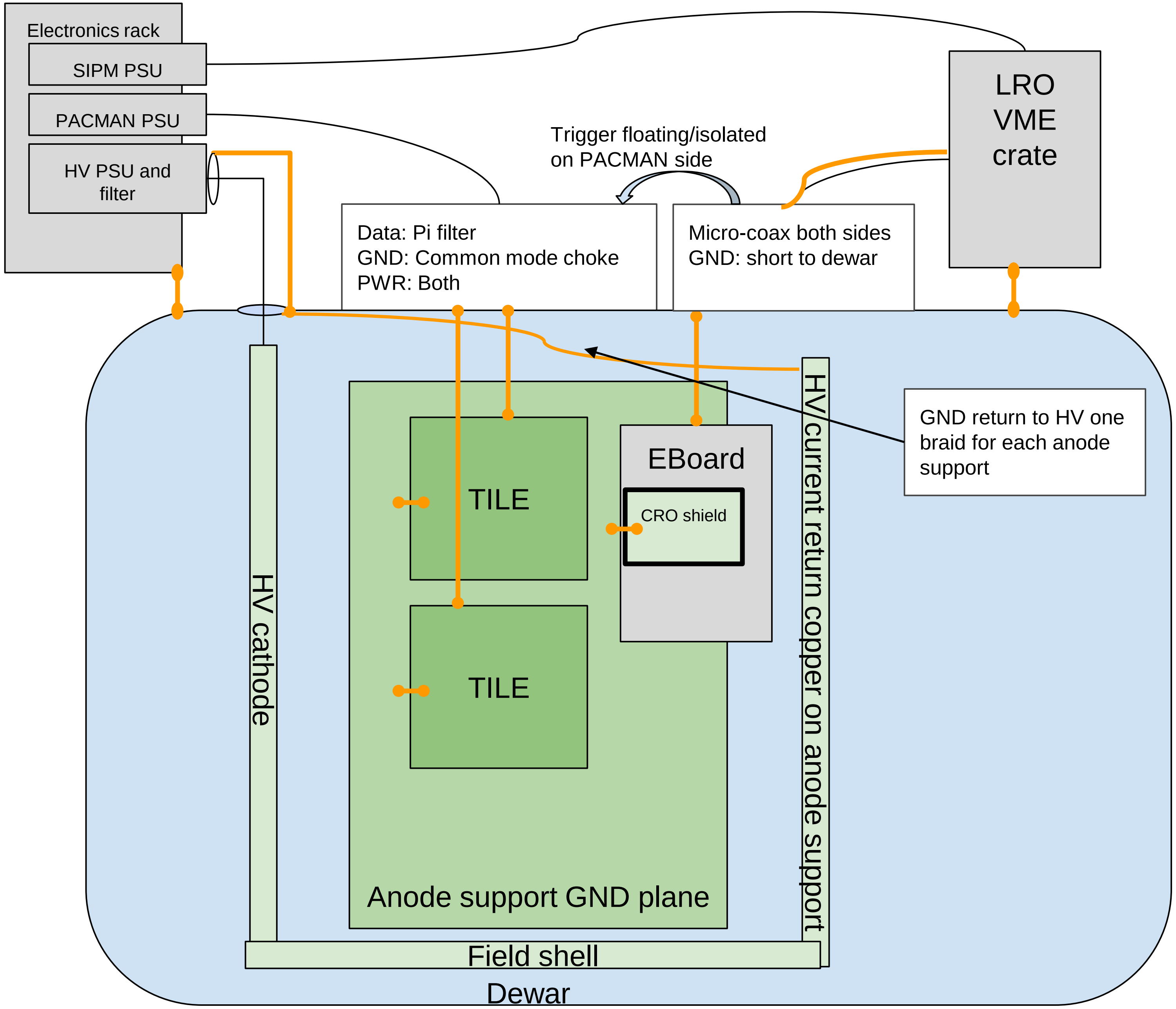
HV ground return

- HV supply system is all resistive, minimizes current available during break-down, acts as a distributed filter
- HV current return on the back of anode support is a narrow copper band to minimize capacitance to tile ground
- Current return is tied to dewar near HV cable entry



Combined diagram

- All subsystems have independent grounding
  - No shared current returns
- Prototyping in module 0, 1 has informed grounding plans
- Multi-module grounding in 2x2 will validate system level grounding



Summary

Status

- Power distribution and grounding plan is well defined.
    - Subsystem grounding plans have been coordinated.
    - Subsystems are coordinating for rackspace and power usage.
    - Rack heat loads relatively modest due to high PSU efficiency.
- Power loads are well understood.
    - Based on individual subsystem component power.
- Cryogenic heat load is well understood.
    - Cryogenic circuitry has been prototyped for 2x2.
- FDR preparation to focus on procedure formalization to ensure grounding system is implemented as designed.