Scope Review: Purity Monitors for ProtoDUNE-II and DUNE

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Motivation of Purity Monitors

- Detector and cryogenic operation: Argon filling to cryostat during commissioning, alert pump and cryogenic accidents during operation, alert unexpected contamination in cryostat
- Monitoring cryostat purity status during operations such as Xenon doping
- Provide benchmarks LAr purities for recirculation studies and TPC calibration
- Measure e-lifetime for data analysis
- Measure purity stratification and verify Computational Fluid Dynamics (CFD)

Scope for ProtoDUNE-SP-II

Cryostat:

- Reuse and switch the 2 of the 3 standard ProtoDUNE-SP-I PrMs (top and bottom)
- Replace the ProtoDUNE-I middle purity monitor with a new or refurbished long purity monitor

Inline:

- Build or refurbish 1 standard or long PrM within recirculation (inline), after the LAr filter

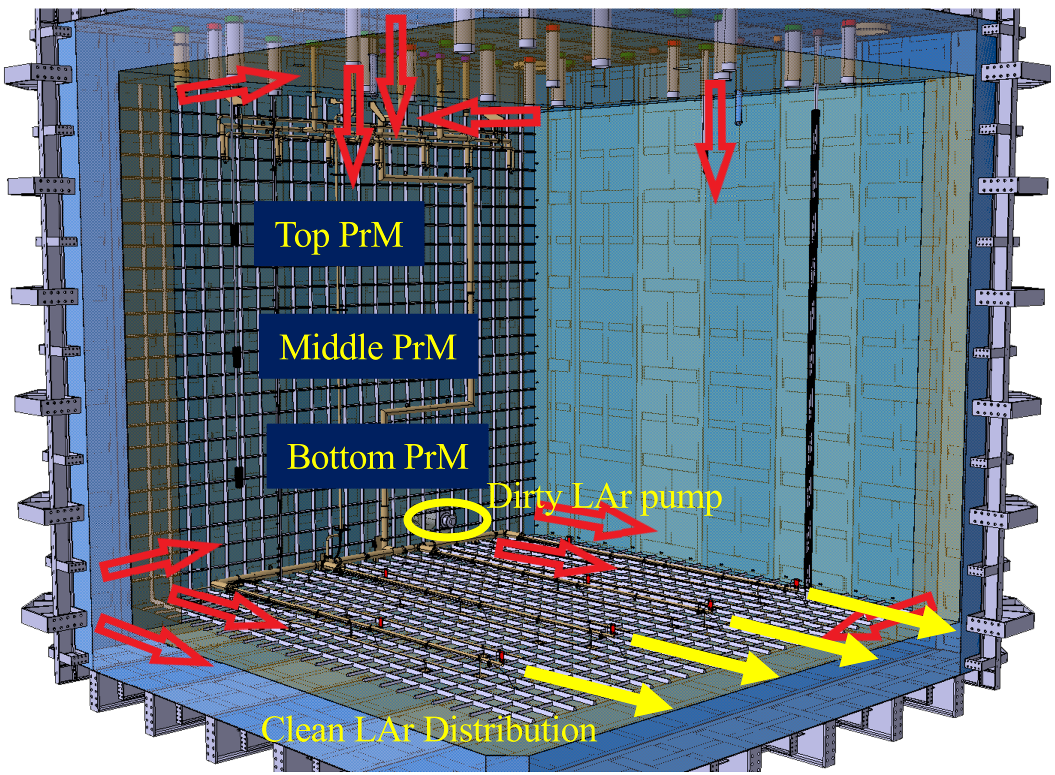
Scope for DUNE

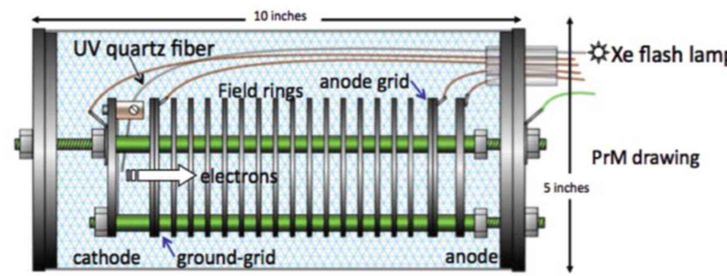
- Build 6 PrMs in the DUNE cryostat, 4 standard and 2 long
- Build 2 standard PrMs within recirculation (inline), before and after LAr filter

ProtoDUNE-SP Purity Monitors

PrM – miniature TPC using UV on photocathode as electron source,
Measure lifetime τ based on:

$$Q_{anode}/Q_{cathode} = e^{-t_{drift}/\tau}$$





M. Adamowski et al., JINST 9, P07005 (2014).

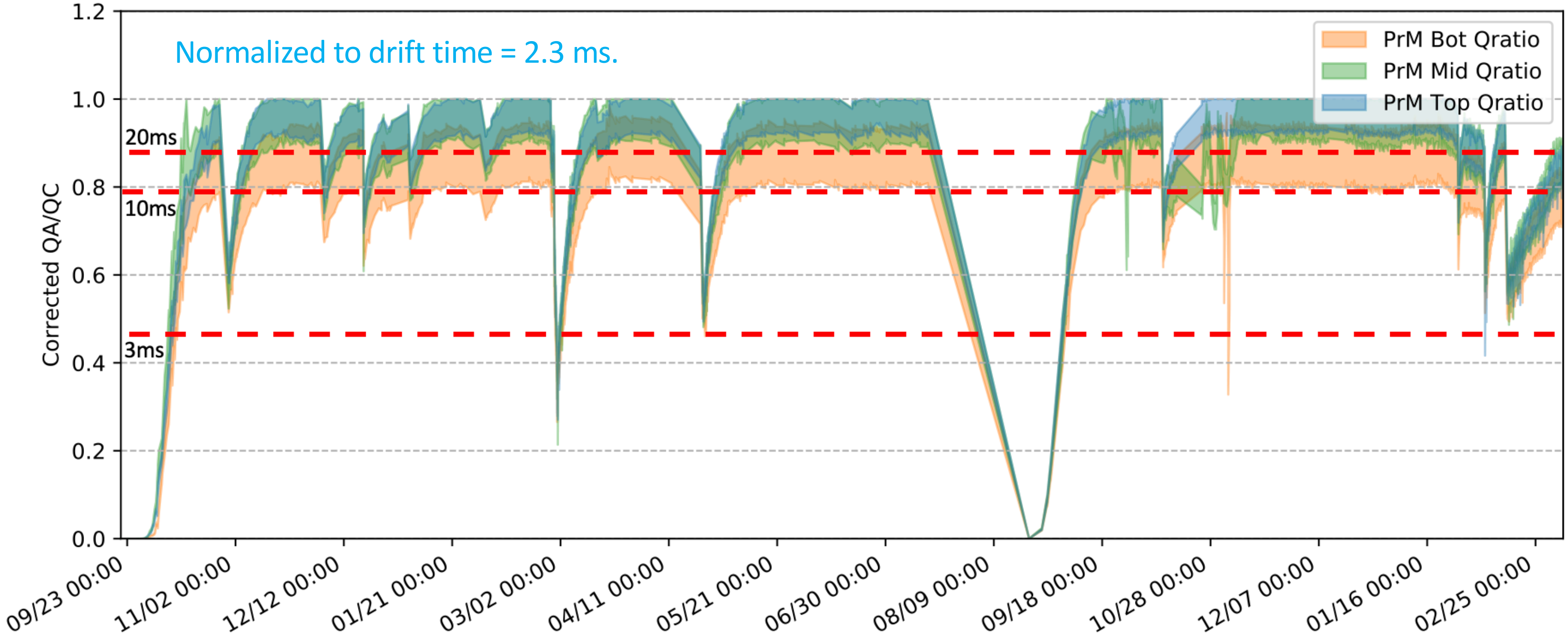
Individual PrMon:

- Xe flash lamp light source
- Al-Ti-Au photocathode for drift electron generation
- Faraday cage and optimized grounding scheme for minimal noise pickup
- Customized Cathode/anode readout electronics
- DAQ, feedthroughs, HV, LV

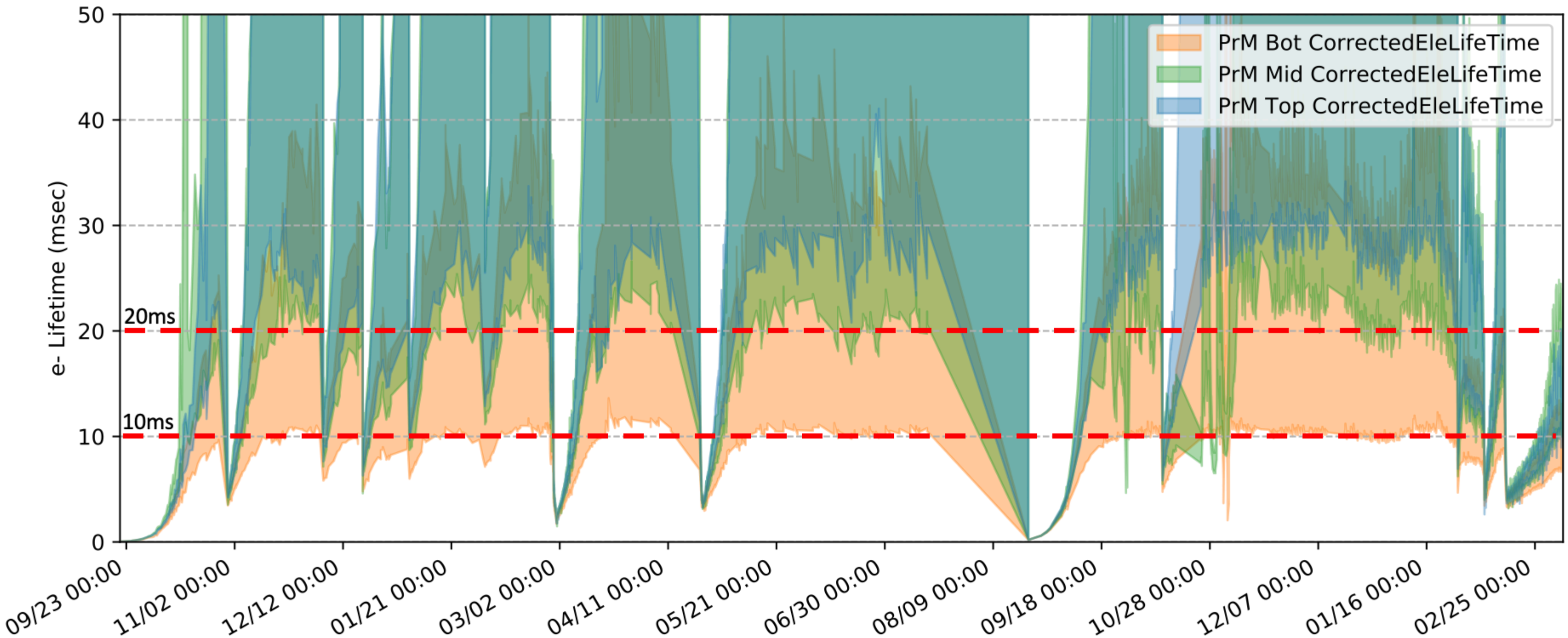
At ProtoDUNE-SP-I, all 3 purity monitors have same drift length, 25 cm
Cathod/Anode disks, field shaping rings and grids from ICARUS PrMs

ProtoDUNE-SP-I Cryostat PrMs: Qa/Qc with offline transparency correction

Uncertainties includes statistical and time-dependent fluctuations and uncertainties of grid transparency, others uncertainties found to be small



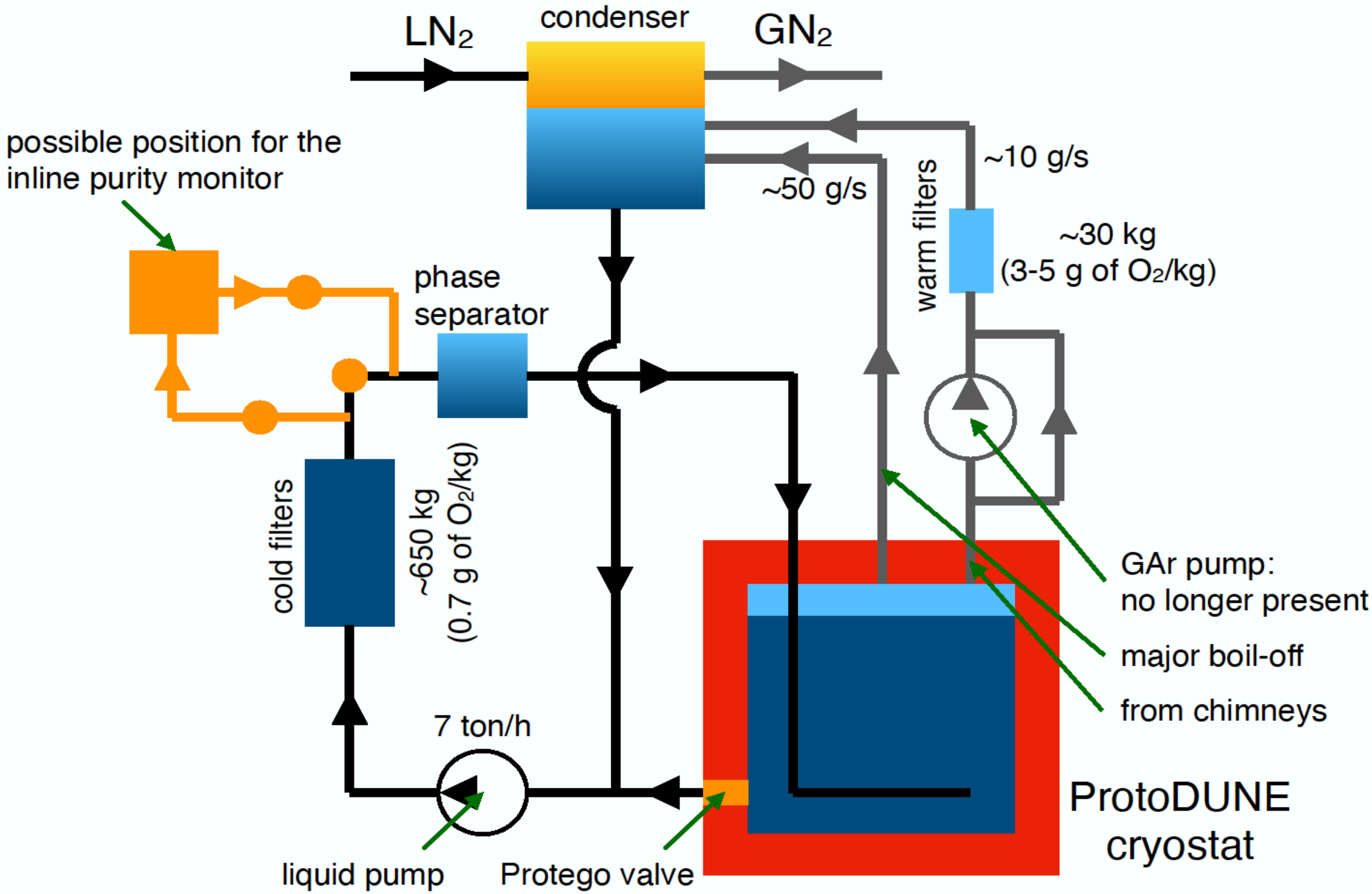
ProtoDUNE-SP-I Cryostat PrMs: Electron Lifetime with offline transparency correction



Simplified cryogenic circuit

For ProtoDUNE-SP-II inline purity monitor

Filippo Resnati



Charge Questions

- Does the system have a well-justified role in safeguarding the far detectors and facilitating their operation, and if so, what is the minimum amount of system scope needed to carry out this role? (Cryogenic Instrumentation only)
- Does the system have a well-justified role in facilitating the analysis of far detector data, and if so, what is the minimum amount of system scope required to fulfill this role?
- Have all technical issues related to the feasibility of the system (including those raised in the previous workshops) been resolved?
- Are there any risks to overall detector performance associated with the implementation of the system, and if so, is there a plan in place for mitigating these risks?
- Is there a credible plan in place for demonstrating system performance in ProtoDUNE-II? (inline PrM, switch purity monitors, longer prm to reduce syst. Err)
- Does the functionality of the system justify its overall cost?

Does the system have a well-justified role in safeguarding the far detectors and facilitating their operation, and if so, what is the minimum amount of system scope needed to carry out this role? (Cryogenic Instrumentation only)

- In ProtoDUNE-SP-I, the purity monitor system was found to be essential for providing reliable real-time monitoring of purity in the detector and to catch purity-related changes in time due to LAr recirculation issues.
- Provide key monitoring during LAr filling, purification and in Xeon doping
- The regular measurement of the LAr purity performed by the purity monitors solely alerted the experiment to problems several times (dips in the Qa/Qc and electron lifetime): Filter saturation, recirculation pump outages, and problems with the cryostat-level gauges. These alerts prevented the experiment from termination of data taking

Does the system have a well-justified role in safeguarding the far detectors and facilitating their operation, and if so, what is the minimum amount of system scope needed to carry out this role? (Cryogenic Instrumentation only)

DUNE:

In cryostat: 6 PrMs

- To know liquid argon situation in cryostat
- DUNE FD is huge, liquid argon takes hours to flow from one side to the other side. Using strings on opposite sides of cryostat will help to inform where contamination is coming from.
- The DUNE far detector is deep (12 m) and we need to know purity at different heights:
  - Monitor purity right after filling → bottom PrM
  - Monitor purity closer to outgas from surface → top PrM
  - Monitor purity at mid-point of the cryostat height→ middle PrM
- Three purity monitors on each side will provide good redundancy for long-term running, guarantee at least one purity monitor in each side working.

Inline: 2 PrMs, before and after LAr filtering, to understand the performance of filtering

ProtoDUNE-II:

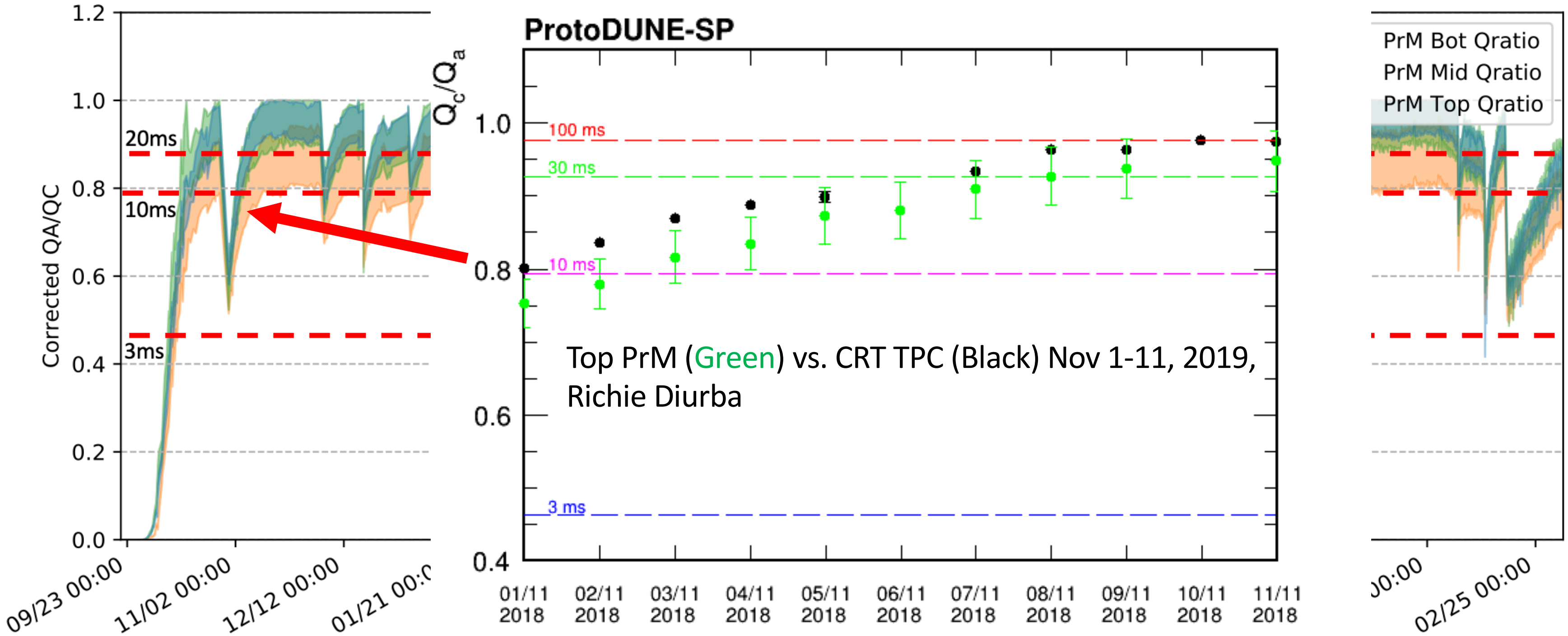
- Cryostat PrMs: Keep the same number as ProtoDUNE-I (3)
- Add a inline PrM

Does the system have a well-justified role in facilitating the analysis of far detector data, and if so, what is the minimum amount of system scope required to fulfill this role?

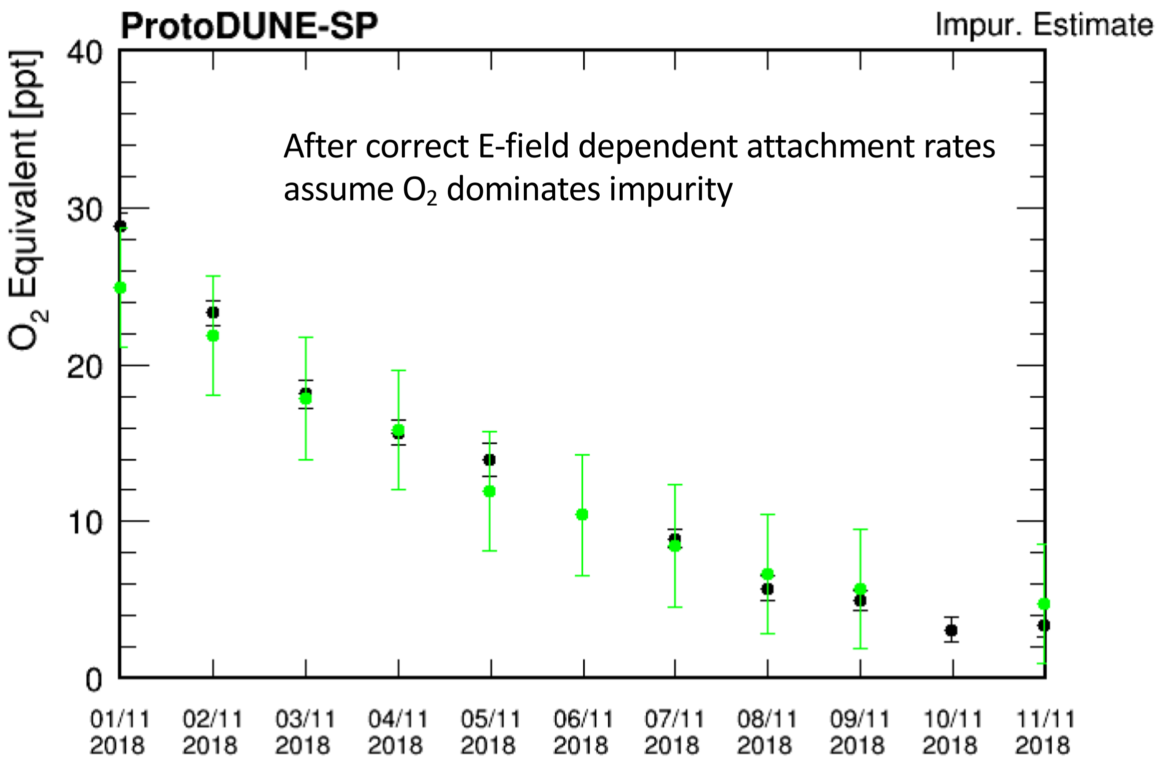
- PrMs can provide continuous electron lifetime for all ProtoDUNE-SP runs
- After correcting E-field difference, PrM electron lifetime is consistent with CRT TPC electron lifetime taken at several points
- Similar technique can be used for DUNE: cosmic rays are rare in DUNE FD but we can accumulate a long time to measure electron lifetime at a few points. After validating the E-field corrected PrM lifetime with CRT TPC lifetime, the PrM can provide continuous electron lifetime measurements to calibrating all DUNE runs
- Three cryostat purity monitors can measure/validate stratification of LAr purity

Qa/Qc with offline transparency correction

Normalized to drift time = 2.3 ms.



Impurity Measurement



Richie Diurba (UMN)

Green is top purity monitor and black is CRT-TPC.

Have all technical issues related to the feasibility of the system (including those raised in the previous workshops) been resolved?

- Have solved feasibility of the system such as installation and operation during the running of purity monitors in ProtoDUNE-SP-I
- ProtoDUNE-II:
  - Operate the long purity monitor and the inline purity monitor
  - Further study photocathodes degradation (only happen when operating purity monitors with high frequency in low purity, daily running doesn't degrade photocathodes)
  - Study running schedule of cryostat and inline purity monitors, try replacement of inline purity monitor.

Are there any risks to overall detector performance associated with the implementation of the system, and if so, is there a plan in place for mitigating these risks?

There are minor risks to other systems and they have been considered and mitigated during ProtoDUNE-I's running:

- Light noise to PDS: schedule PrM running in DCS, automatically lower PDS's HV during PrM running, include PrM trigger in DAQ
- Electronic noise to TPC: ground PrM and Flash lamp properly, include PrM trigger in DAQ

Is there a credible plan in place for demonstrating system performance in ProtoDUNE-II?

- Switch top and bottom purity monitors to understand purity stratification
- Use longer PrM to eliminate syst. error in transparency correction and see if stratification is real
- Compare PrM measurements with CRT TPC
- Compare Inline PrM with Cyrostat PrM

Add more details …

Does the functionality of the system justify its overall cost?

- Purity monitors are essential to the operation of the detector, provide continuous electron lifetime measurement for data analysis, with a long purity monitor we can …

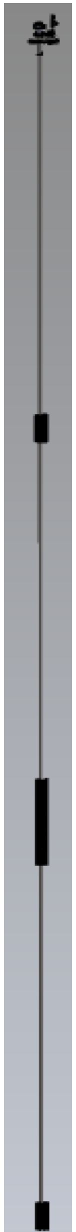
- Working on pricing for ProtoDUNE-II PrMs

Add more details …

Thank you

Backup

Total: 12 m



Cryostat Purity Monitors

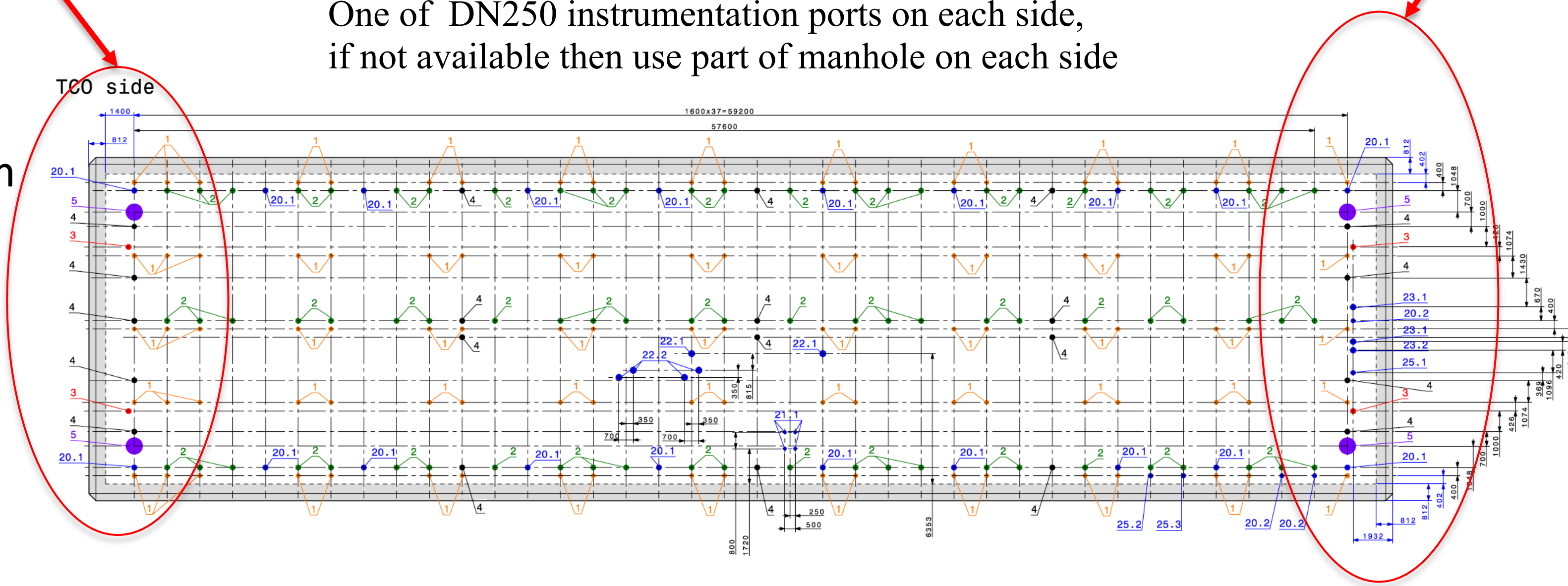
4m

Two strings of purity monitor assemblies on TCO and back sides, each string mounts 3 purity monitors on a supporting tube, in total 6 purity monitors in cryostat

Need ports for straight deployment

One of DN250 instrumentation ports on each side,
if not available then use part of manhole on each side

4m



Detector penetrations

3.6 m

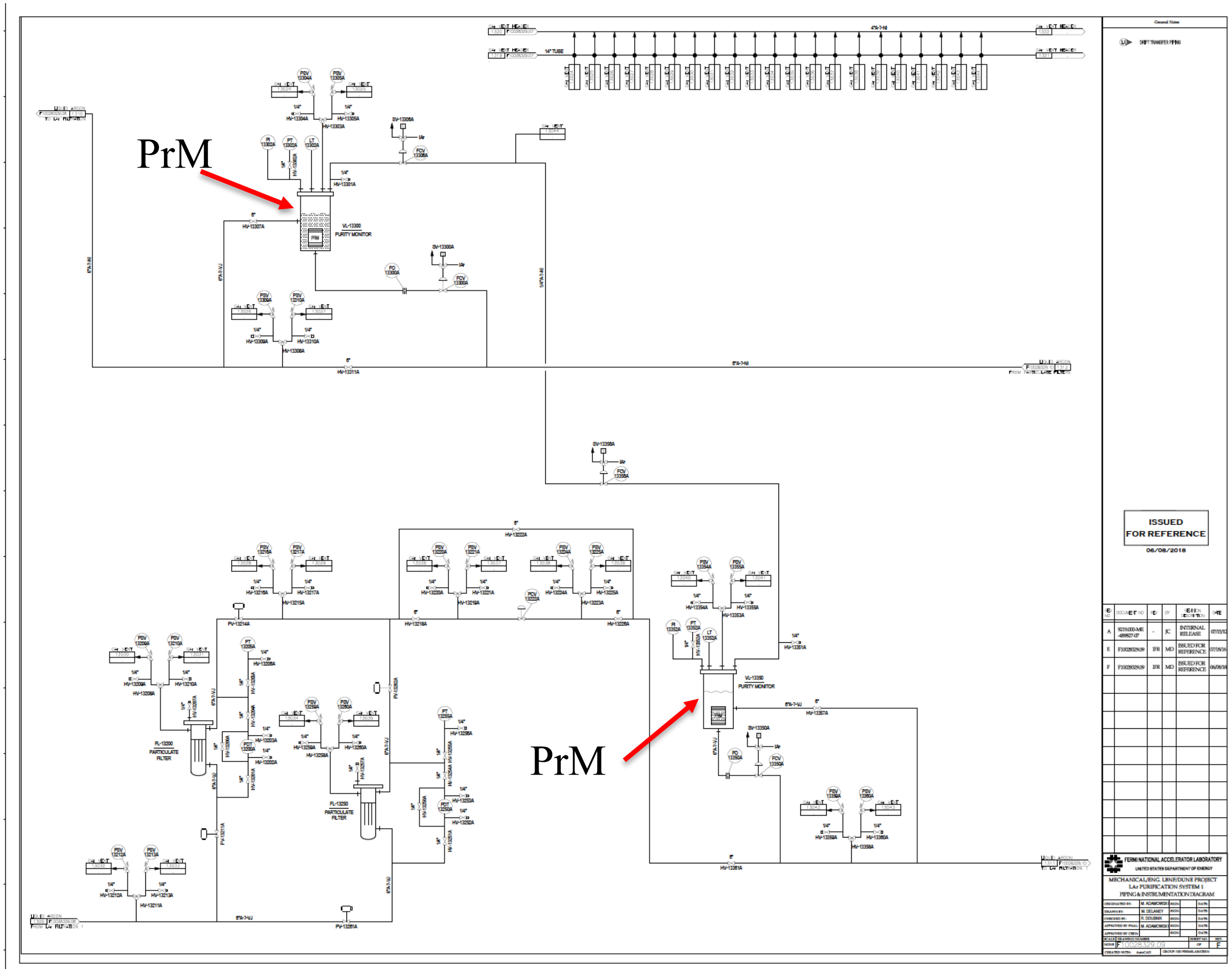
Pos.	Diameter [mm]	Quantity	Description
1	Ø200	100	Support
2	Ø250	75	Cable
3	Ø250	4	High voltage
4	Ø250	21	Instrumentation
5	Ø800	4	Manholes
7	2680x13428	1	Temporary Construction Opening

Similar system runs successfully in ProtoDUNE-SP

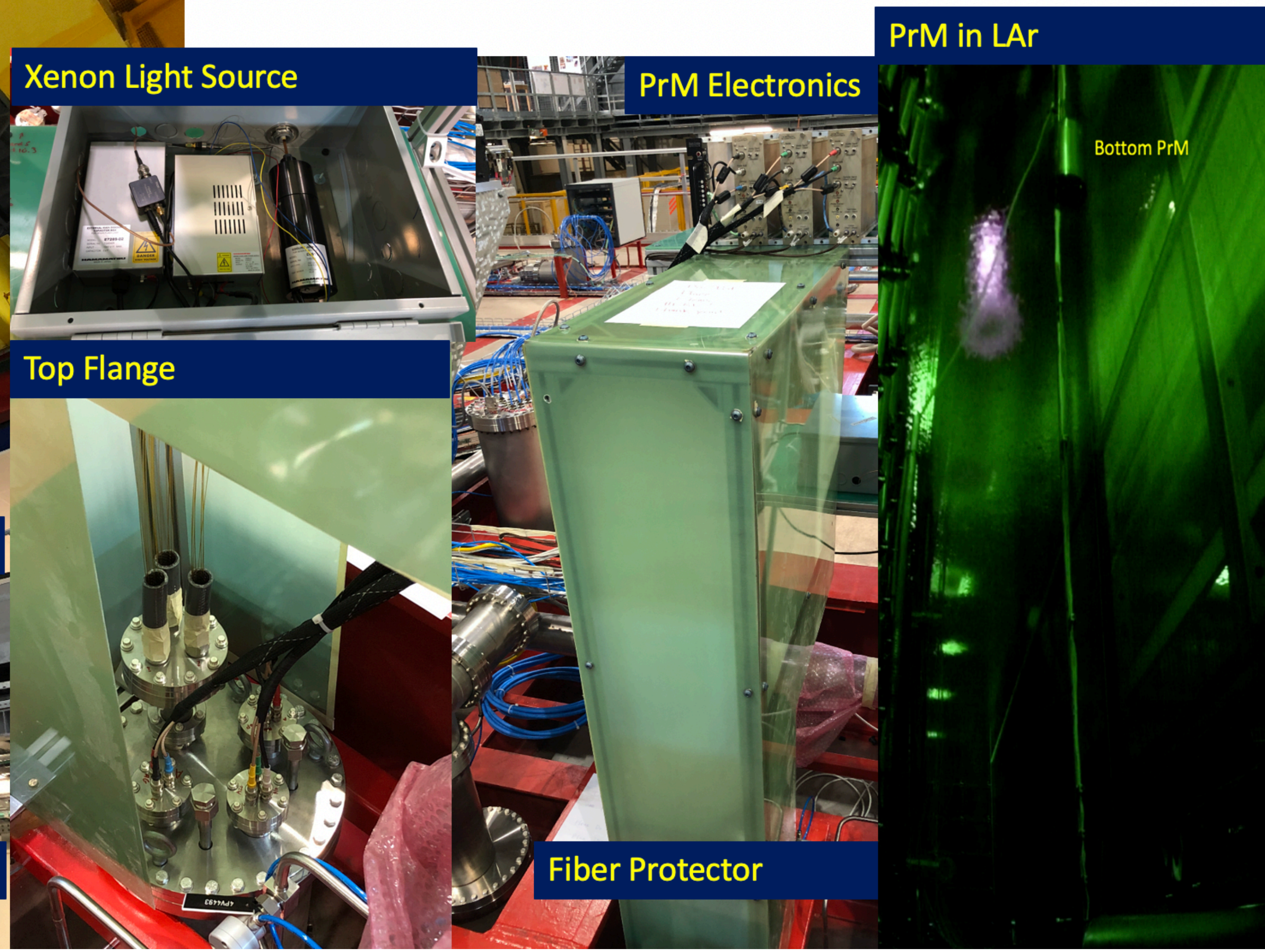
Locations for Inline Purity monitors under discussion

Inline Purity monitors

2 PrMs outside of cryostat inline with cryogenics system, before and after filtration system



ProtoDUNE-SP Purity Monitors



Improved PrM Signal in ProtoDUNE-SP

- PrM HV varied from 0.25 kV to 3 kV), allows for range of drift time from 150 us to 3 ms
- Increase UV light on cathodes by using 8 optic fibers for each PrM
- When e-lifetime ~7ms, Qa/Qc ~ 0.7 → anode signal significantly smaller than cathode → no saturation
- Each PrM measurement lasts 20 seconds with 200 UV flashes, provide high precision, localized electron lifetime
- Measured e-lifetime at ProtoDUNE-SP: 35us - 8 ms

ProtoDUNE PrM signals at e-lifetime = 6 ms