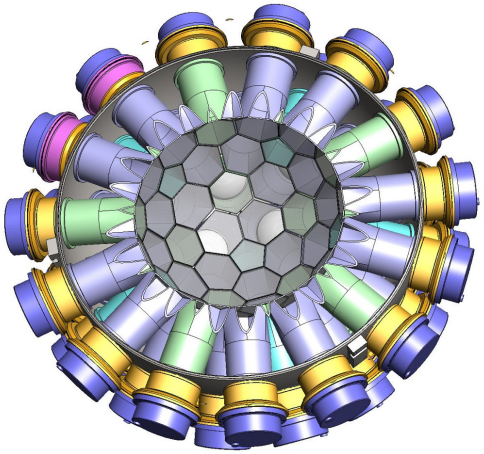

Pacific Northwest
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Update on the MiniCLEAN Experiment

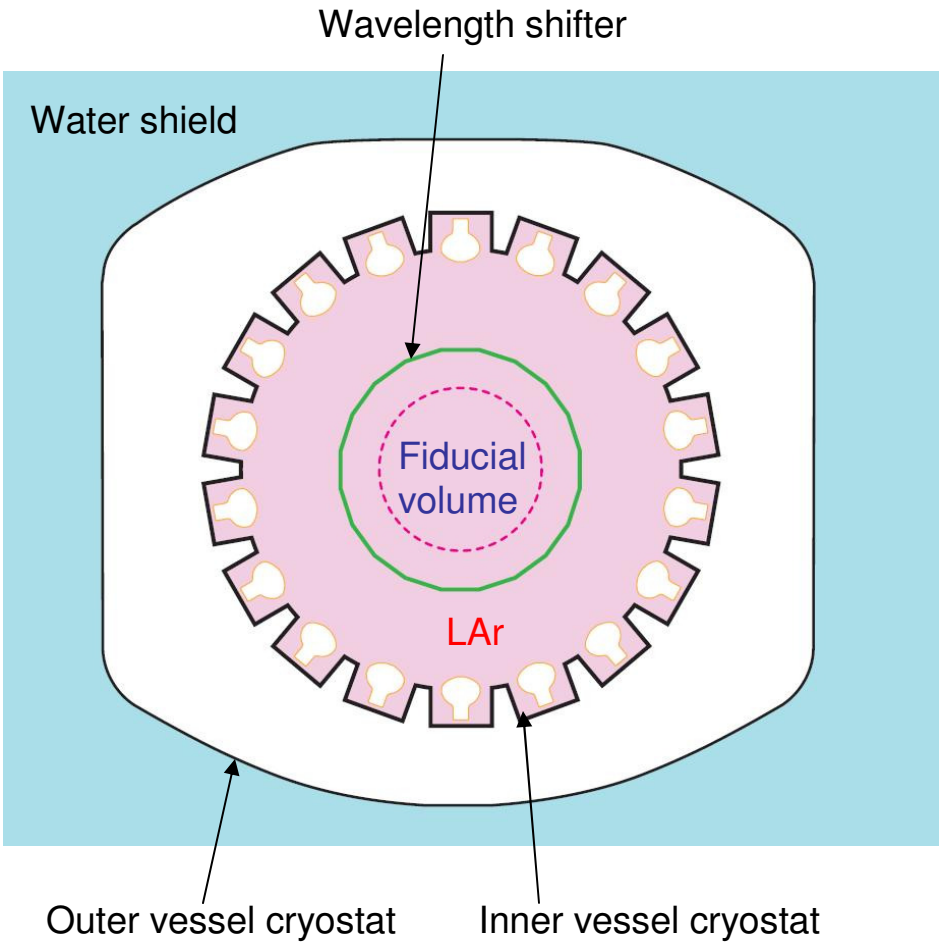
Steven Linden, for the MiniCLEAN Collaboration

24 July 2017

TAUP 2017, Sudbury, Ontario

CLEAN Concept

- Single phase noble liquid detector
- 4π PMT coverage
- Light guides and PMTs in cryogen
- Can exchange LAr/LNe to test for A^2 dependence of WIMP-nucleon cross-section
- Fiducialization provides self-shielding
- Scalable to much larger size for future generations of dark matter detectors



Pulse Shape Discrimination (PSD)

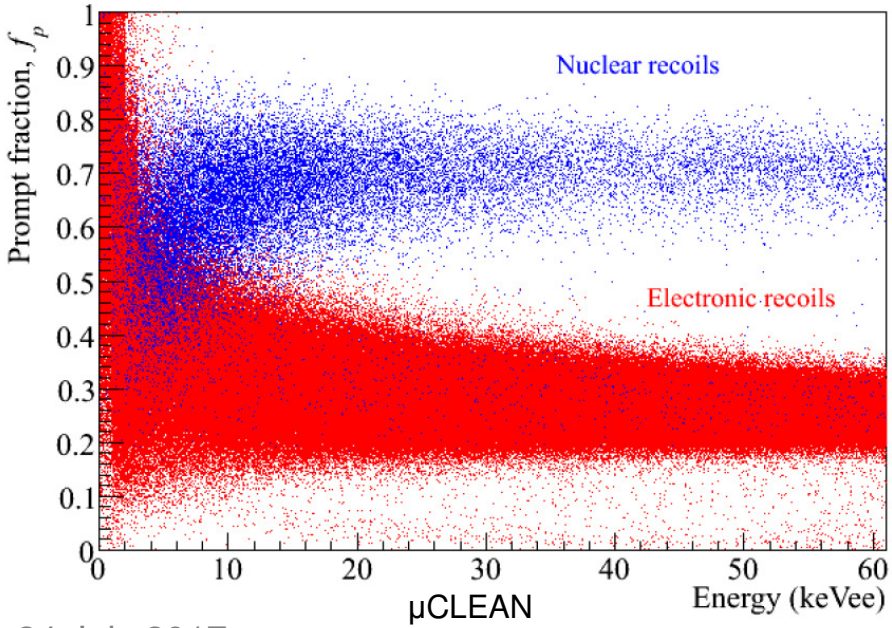
WIMPs collide with argon nuclei → nuclear recoils

LAr scintillates ~40 photons/keV.

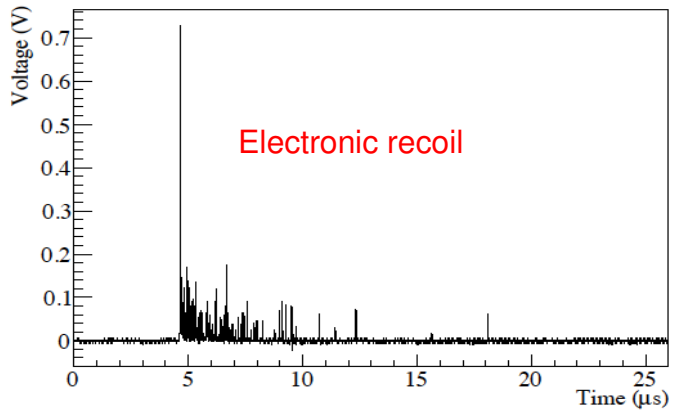
Singlet state with τ = 6 ns.
Triplet state with τ = 1.6 μs.

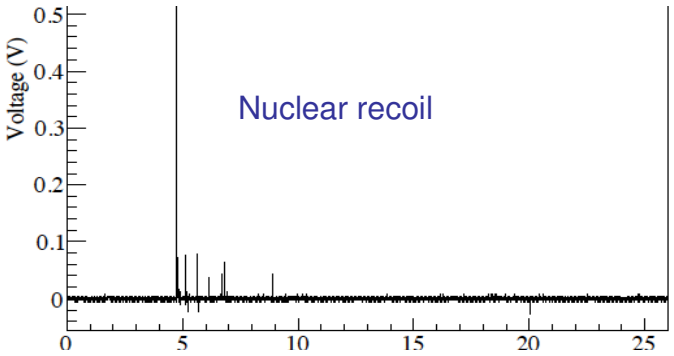
Use pulse shape to distinguish:
Nuclear recoils (e.g. WIMPs) – mostly prompt light
Electronic recoils (e.g. Ar39) – mostly late light

fprompt = ratio of light in first 100 ns. to total for event



μCLEAN data





μCLEAN data

Table 3: Scintillation parameters for liquid neon, argon, and xenon.

Parameter	Ne	Ar	Xe
Yield ($\times 10^4$ photons/MeV)	1.5	4.0	4.2
prompt time constant τ_1 (ns)	2.2	6	2.2
late time constant τ_3	15 μs	1.59 μs	21 ns
I_1/I_3 for electrons	0.12	0.3	0.3
I_1/I_3 for nuclear recoils	0.56	3	1.6
λ(peak) (nm)	77	128	174
Rayleigh scattering length (cm)	60	90	30

PSD references:
McKinsey & Coakley, Astropart. Phys. 22, 355 (2005)
Boulay and Hime, Astropart. Phys. 25, 179 (2006)
Lippincott et al., Phys.Rev.C 78: 035801 (2008)

Pulse Shape Discrimination (PSD)

Natural Ar contains a sizeable Ar39 component, which beta-decays with a lifetime of 269 years.

Expect ~500 hz. of Ar39 events in MiniCLEAN

Reject using timing (pulse shape discrimination).

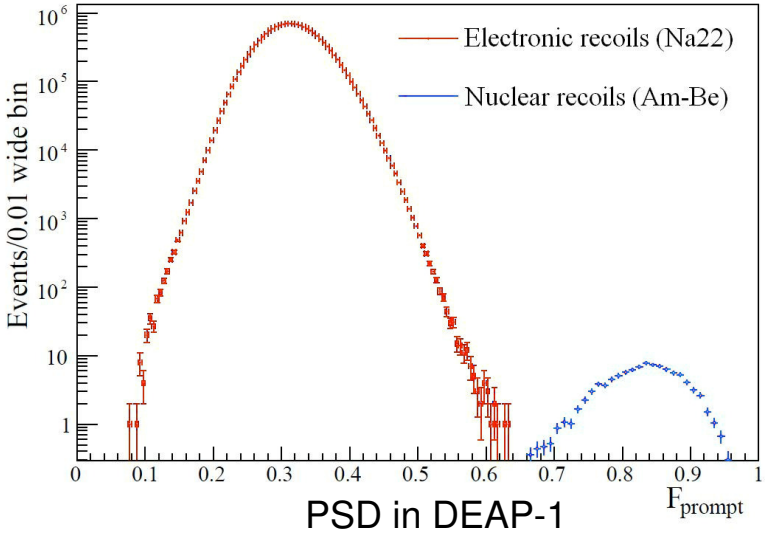
Better than **3×10^{-8}** rejection measured by DEAP-1

Based on DEAP-1 measurement with microCLEAN light yield, expect **10^{-9} rejection** (leakage of <1 event/year) using fprompt cut (with 50% WIMP acceptance and 20 keVee energy threshold)

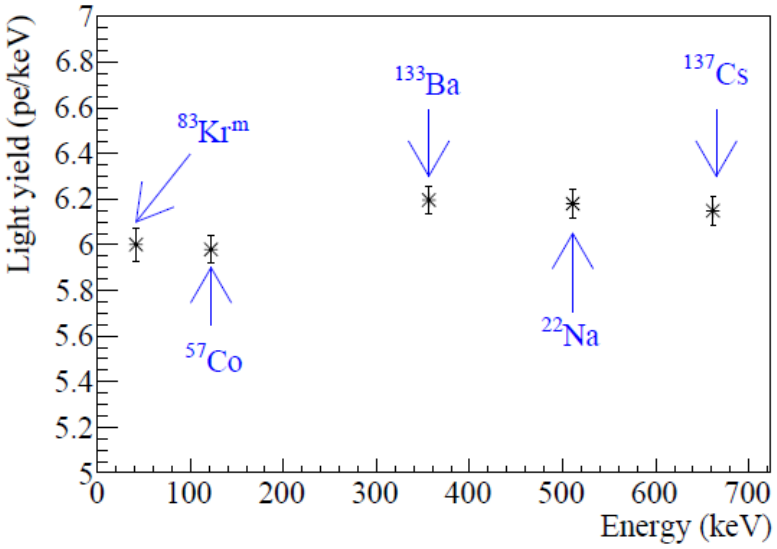
More sophisticated Bayesian techniques (Lrecoil) improve expected discrimination to **10^{-10}**.

Demonstration of this background rejection capability is perhaps the most important goal of MiniCLEAN

Event Selection	^{39}Ar	γs
Raw rate	1 Bq/kg	1.4×10^{10} γ/yr
Energy between 12.5–25 keV_{ee}	4.2×10^{8}	6.0×10^{6}
Fiducial Volume Cut	1.2×10^{8}	3×10^{5}
F_{prompt} Cut	75 ± 1.1	<0.36
L_{recoil}	0.3 ± 0.2	
Total Background (events/year)	0.3 ± 0.2	< 0.36

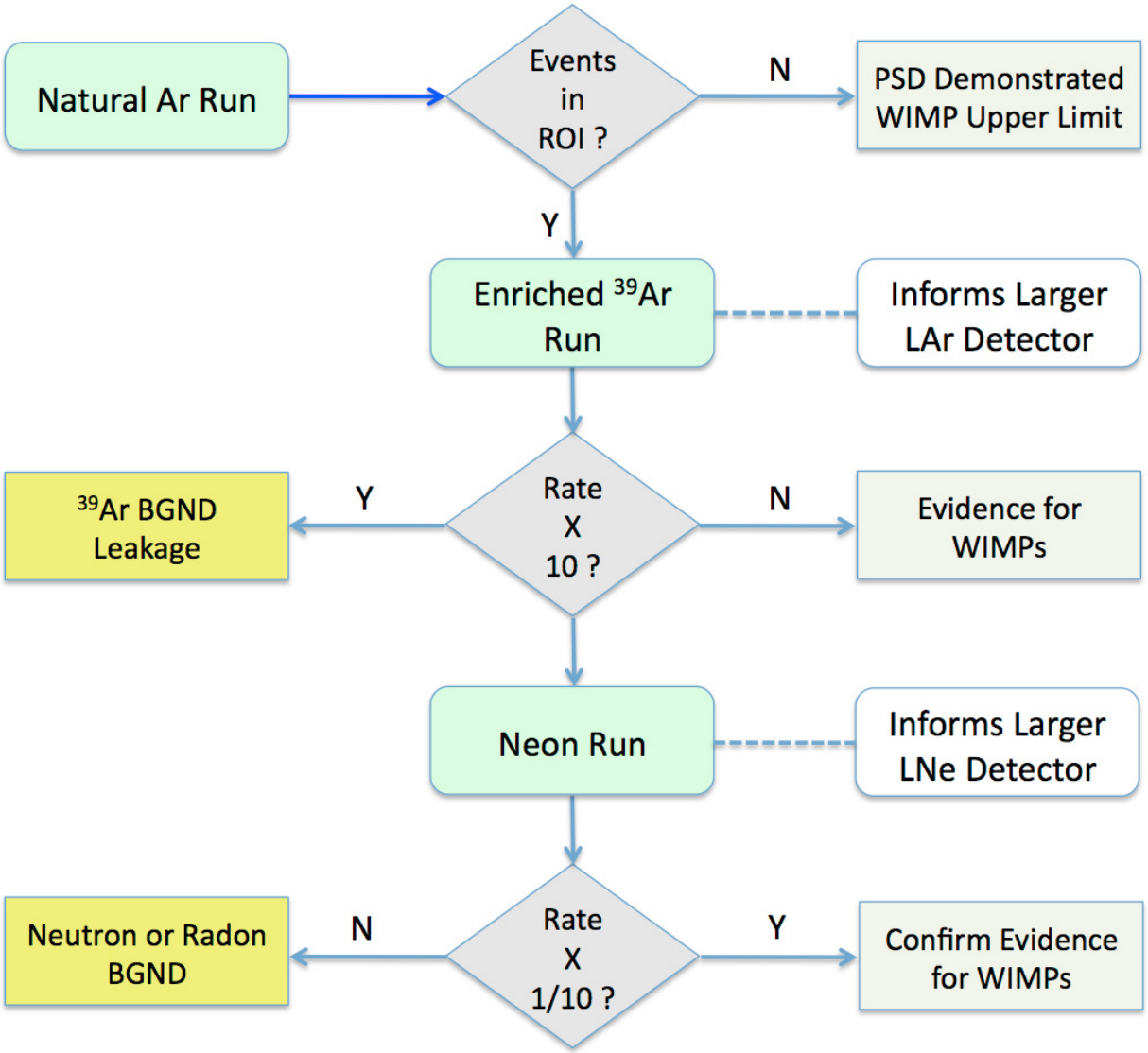


PSD in DEAP-1

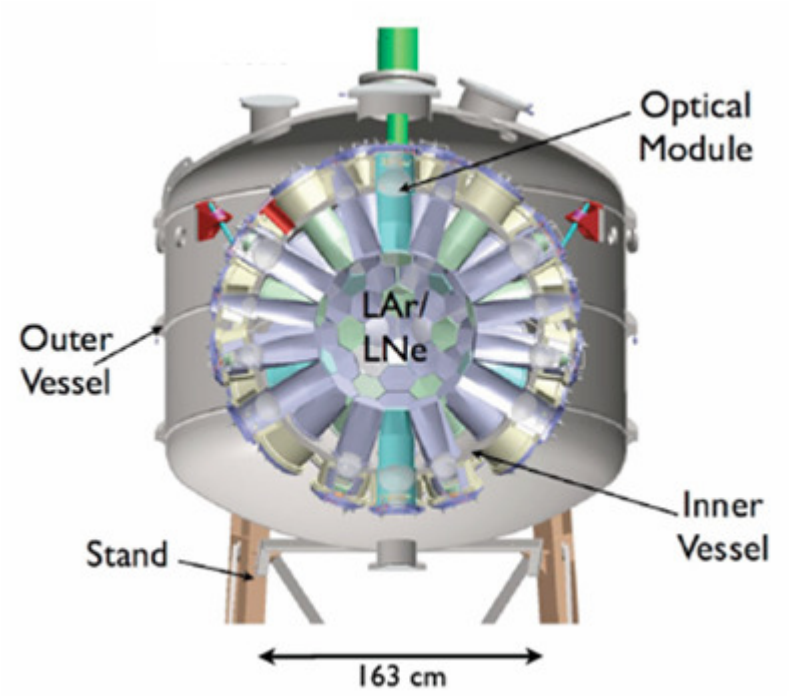


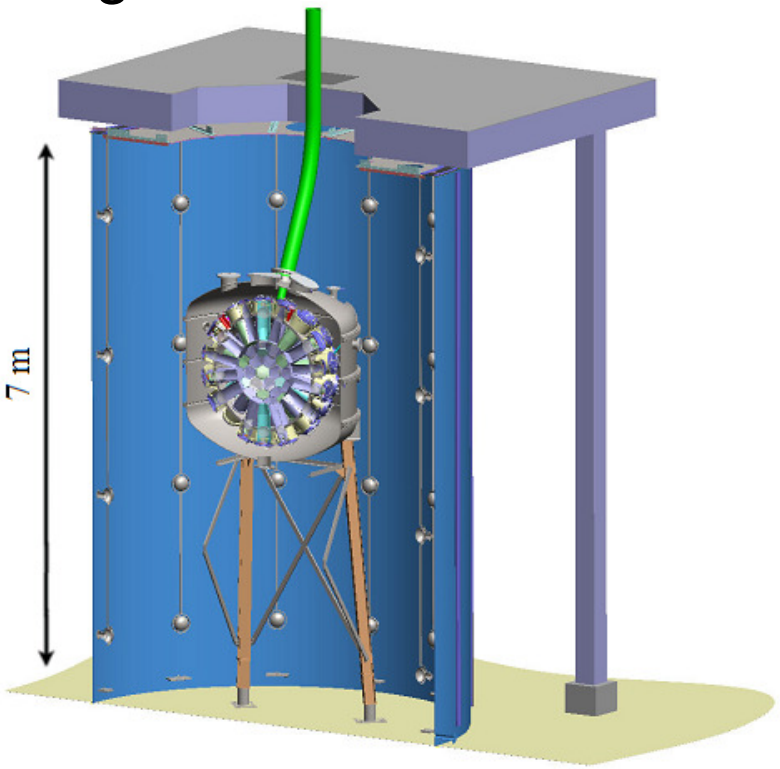
Light yield in microCLEAN

CLEAN Concept: Signal Verification



MiniCLEAN Design





LAr scintillates in extreme UV (80-128 nm)

Converted to visible by wavelength shifter (TPB).

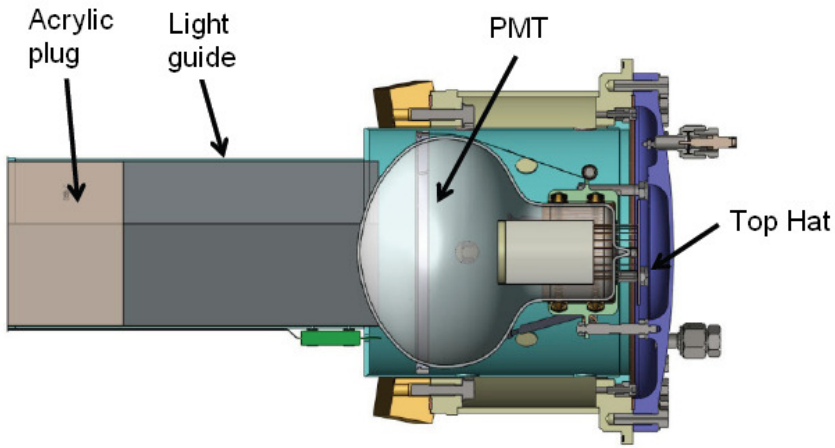
Acrylic provides shielding from PMT-backgroundss.

Light guide brings visible light to PMTs.

92 PMTs housed in optical cassettes.

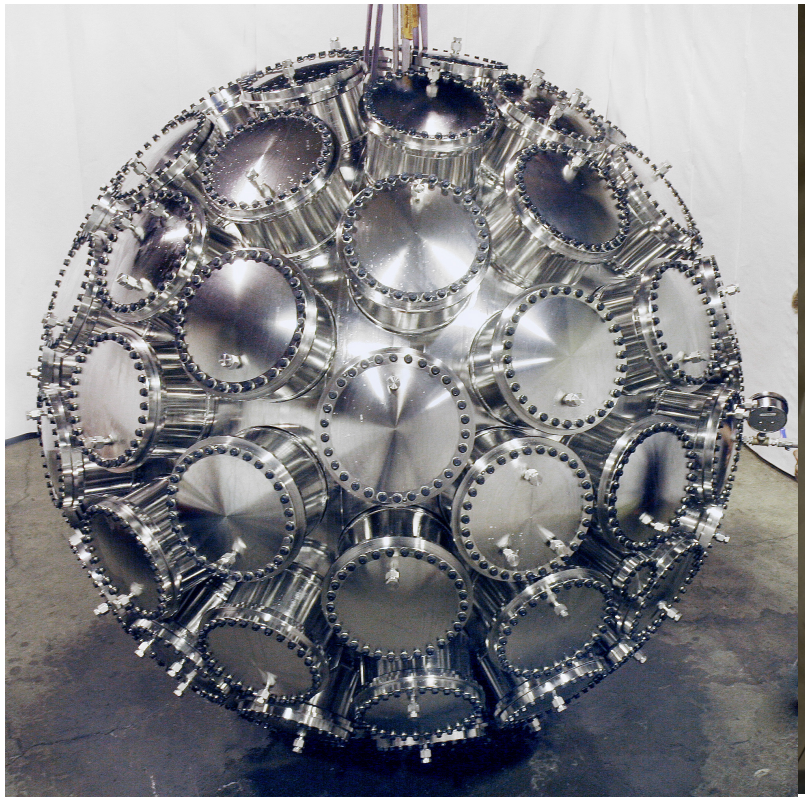
Water shield reduces neutron and rock gamma backgrounds

Active volume holds 500 kg. of LAr; 150 kg. fiducial volume

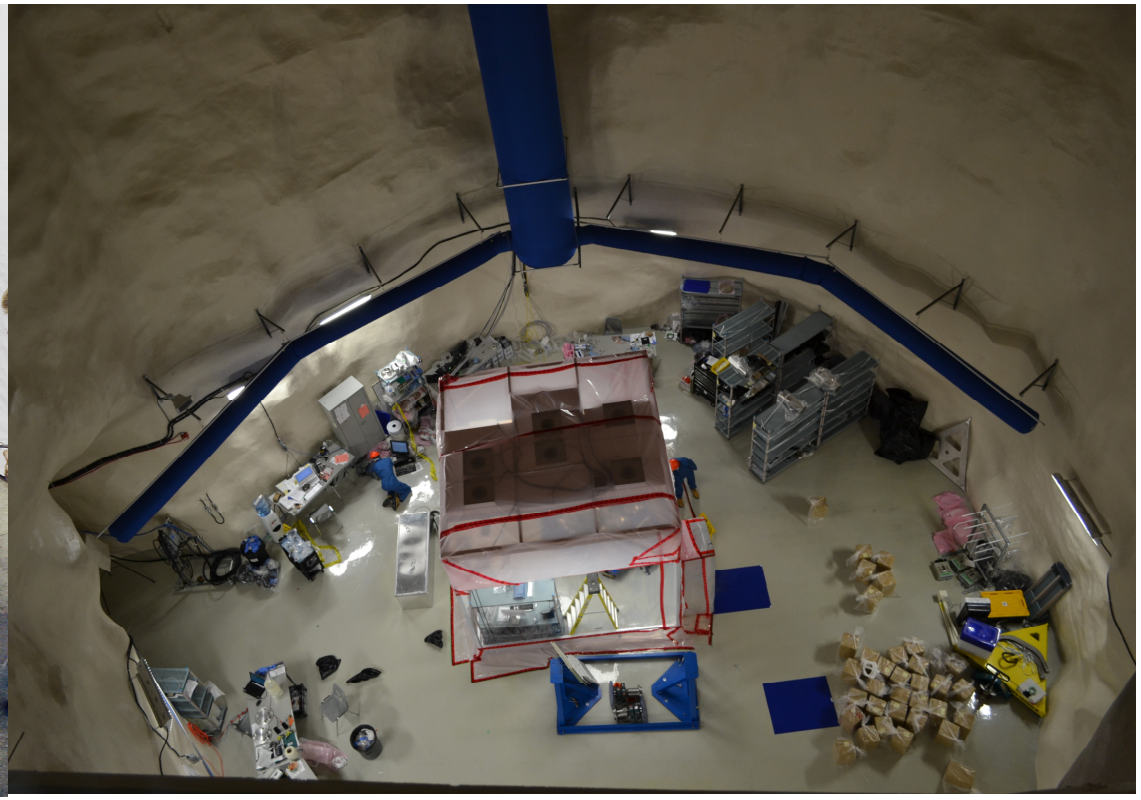


Detector Construction: Inner Vessel

- Assembled underground at SNOLAB in the Cryopit, down the hall from the Cube Hall
- To reduce radon exposure, assembly was performed inside a small clean room with surface air pumped in.

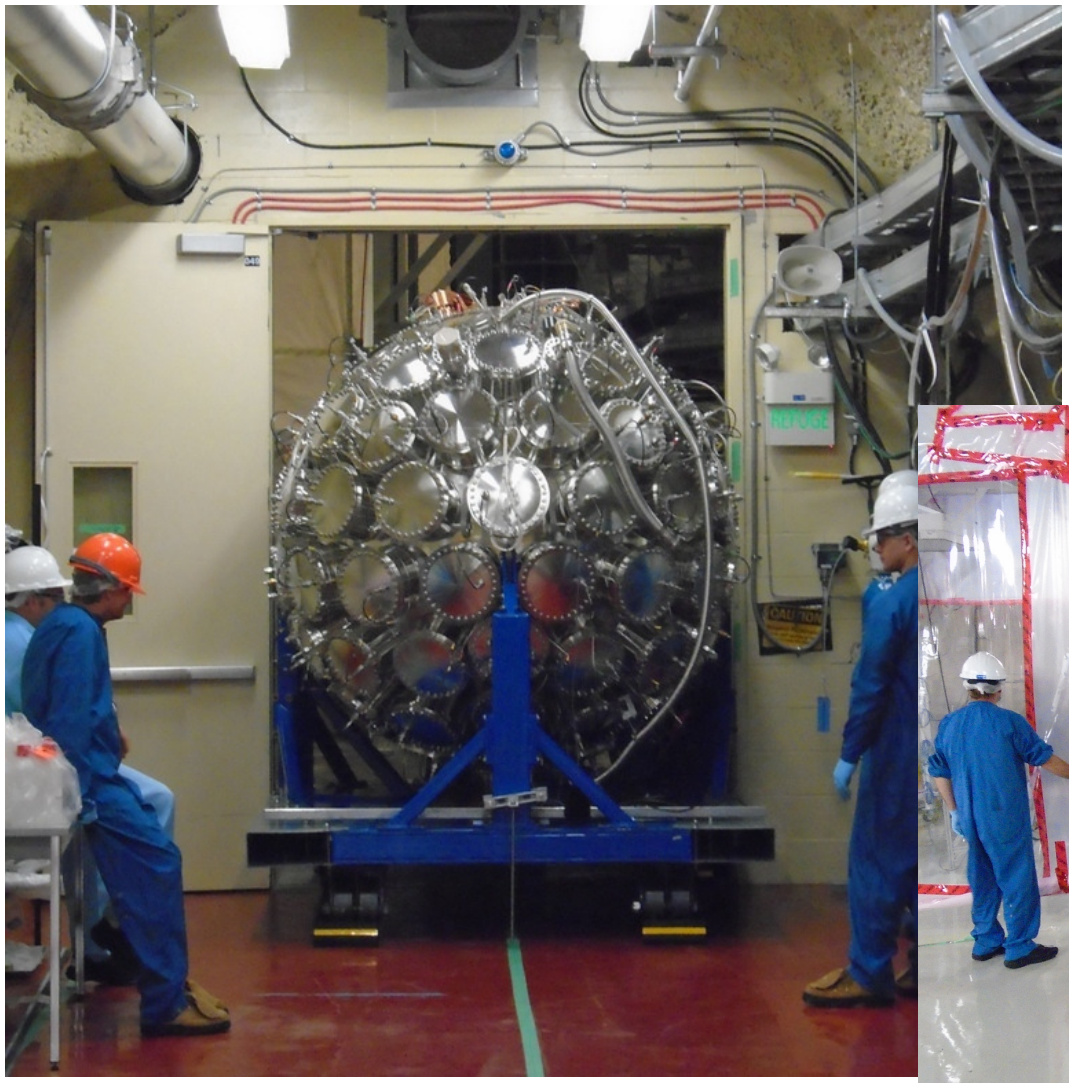


Pressure test at manufacturerer



The Cryopit, with clean room for IV assembly

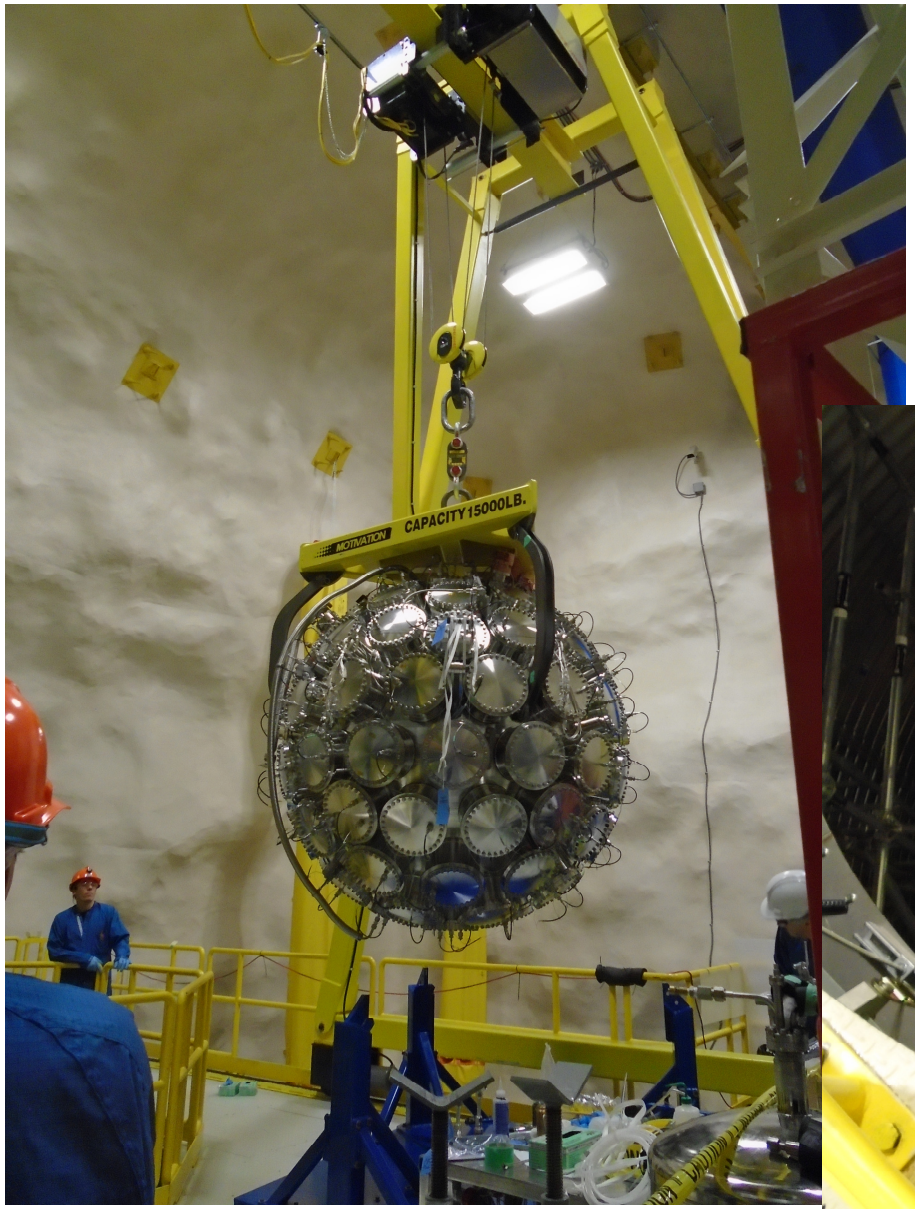
Detector Construction: Inner Vessel into Outer Vessel



With IV completed and infrastructure in the Cube Hall in place, moved the IV down the hall.

Fitting through the doors was a little tricky…

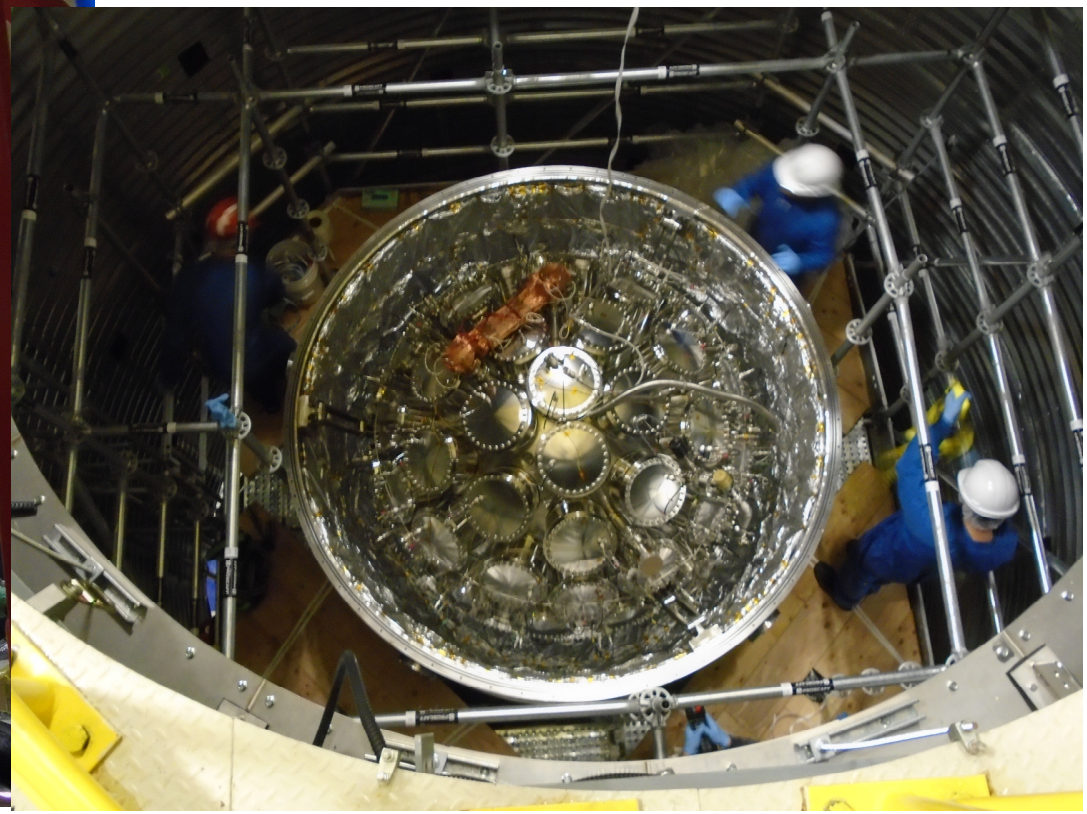
Detector Construction: Inner Vessel into Outer Vessel



Critical lift of IV into OV.

SNOLAB installation group did a great job, and everything went smoothly.

After the lift, took vacuum data to verify PMTs were all still working

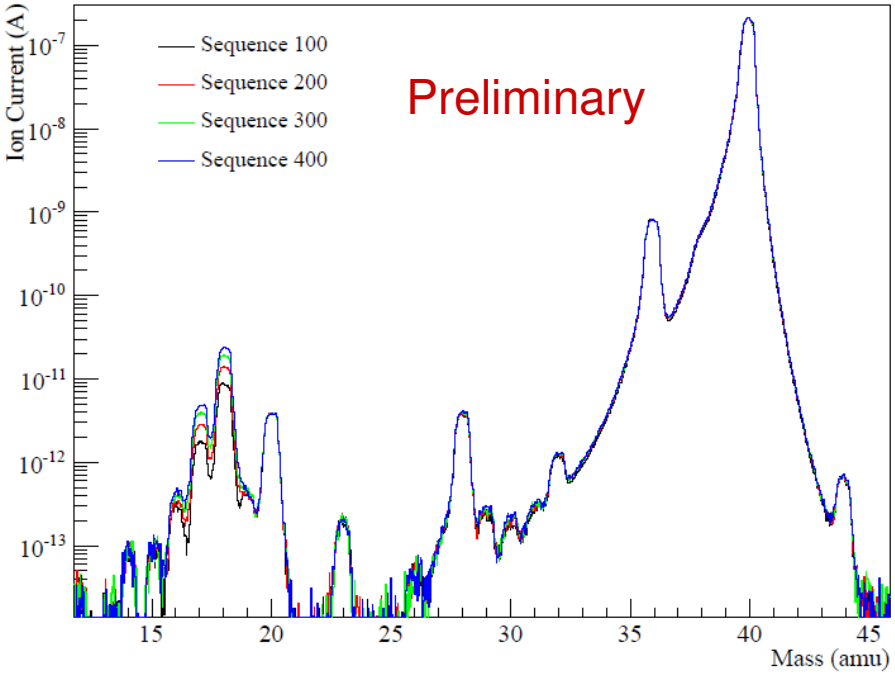


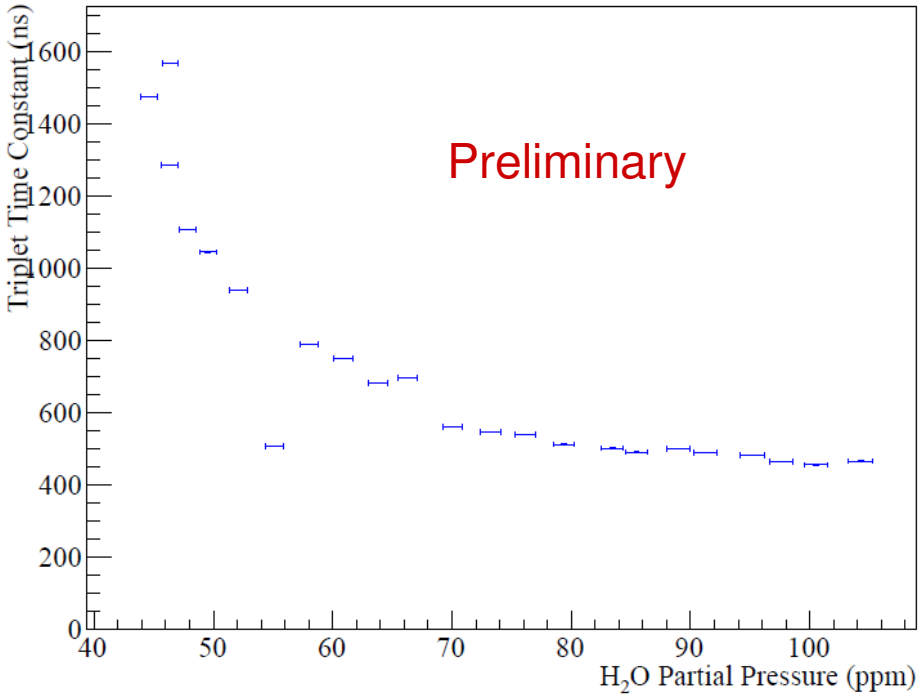
Warm Gas Data

• In warm gas, triplet light is rapidly quenched as water vapor outgasses from acrylic.

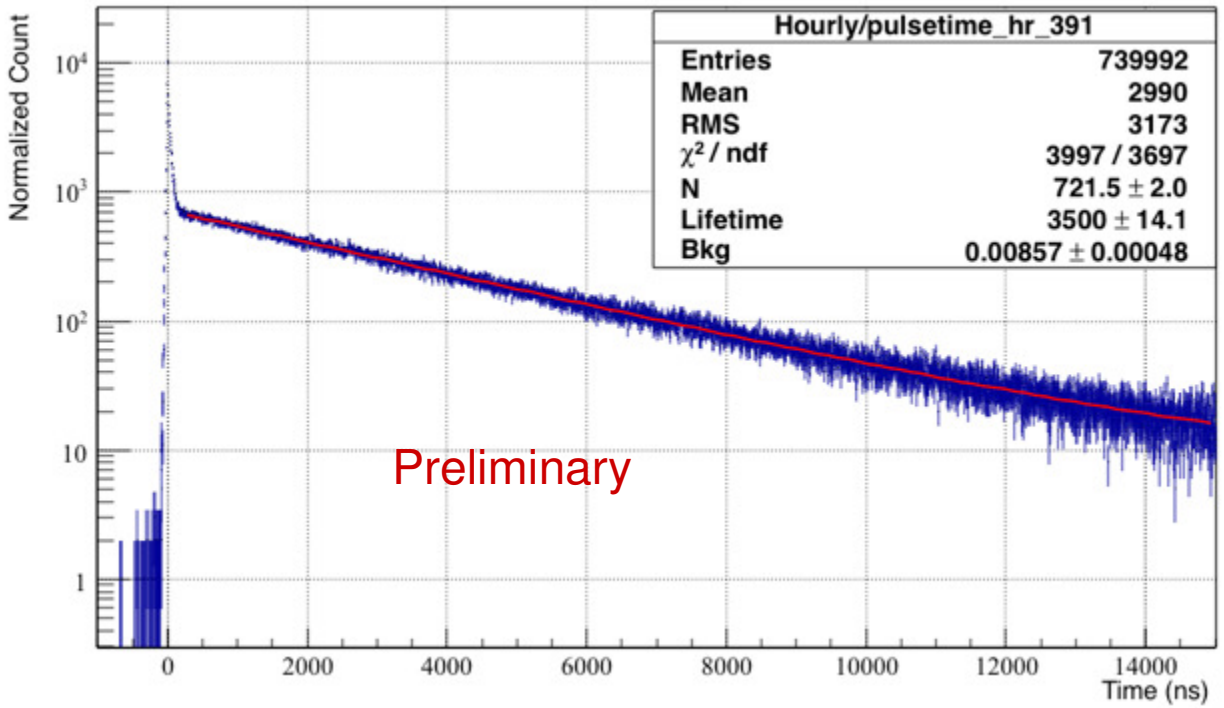
• Monitored with an RGA - can see water vapor peak rising over several hours.

• Allows us to measure the triplet time constant as a function of water vapor partial pressure.





Cold Gas Data: Triplet Lifetime



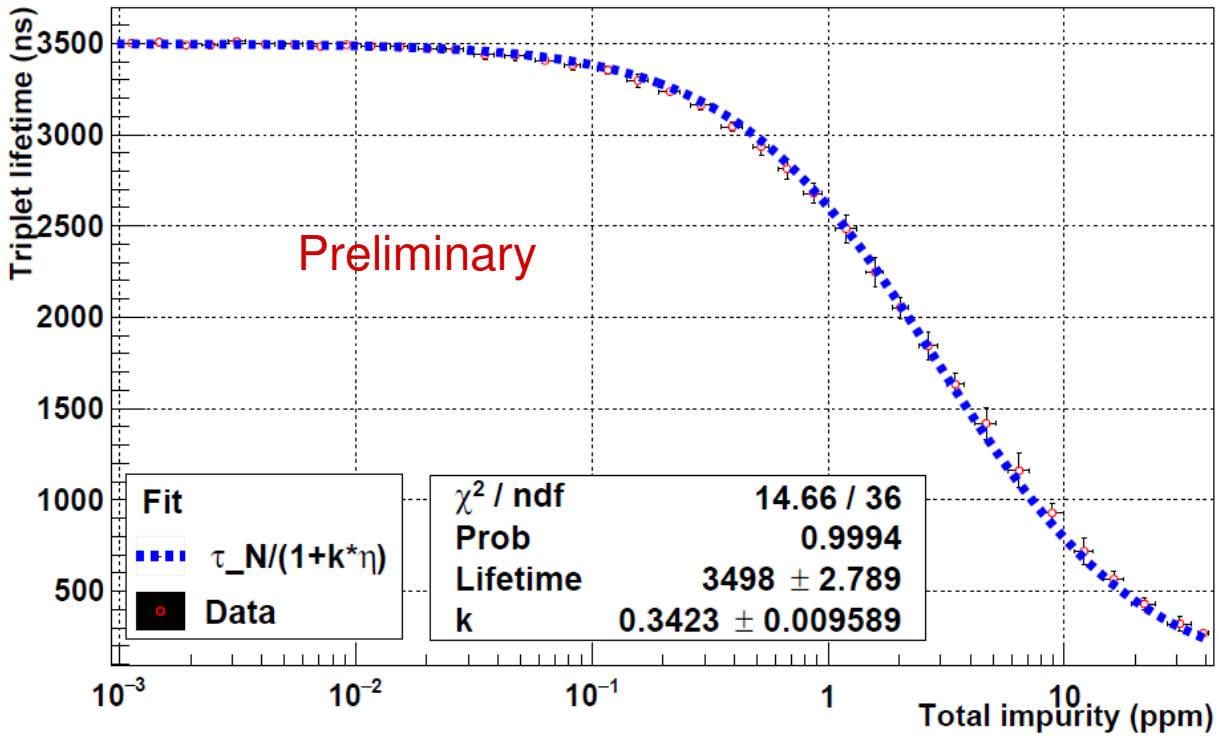
- Gas temperature 110 to 140 K.
- Fit pulse time distribution with exponential: $F(t) = p_0 \cdot [(1 - p_1)e^{-t/\tau} + p_1]$
- Find a triplet time constant of 3500 ns - longer than most previous measurements.
- Indicates very pure argon.

Cold Gas Data: Triplet Lifetime vs. Impurity

• In the course of cooling and commissioning, we performed an accidental experiment with nitrogen and oxygen impurities present in the IV argon.

• Fortunately, the lifetime was fully recoverable with sufficient purging.

• As we purged the impurities, we monitored the triplet lifetime, thus performing a measurement of lifetime vs. impurity.



Run Plan

- Currently filling with liquid argon, while continuing to take gas and partial fill data.

- Final commissioning (gain-matching of PMTs and calibration) - ~1 month

- Natural argon data - ~ 3 months

- Ar39 spike - ~ 3 months
  - Run with x10 Ar39 content to demonstrate PSD at high event rate
  - Spike allows unequivocal demonstration of beta origin of backgrounds
  - Tests scale-up to a level required for 200T detector

Conclusion

- CLEAN detectors
  - Simple, scalable design
  - Low background
  - Ar39 spike, target exchange for signal verification

- MiniCLEAN is a technology demonstrator for 200T detector:
  - PSD (natural argon vs. spike)
  - Cold gas data shows excellent purity
  - Liquid data imminent