Depleted Argon for Future Direct Dark Matter Searches

Cristiano Galbiati
Princeton University

WIN'09
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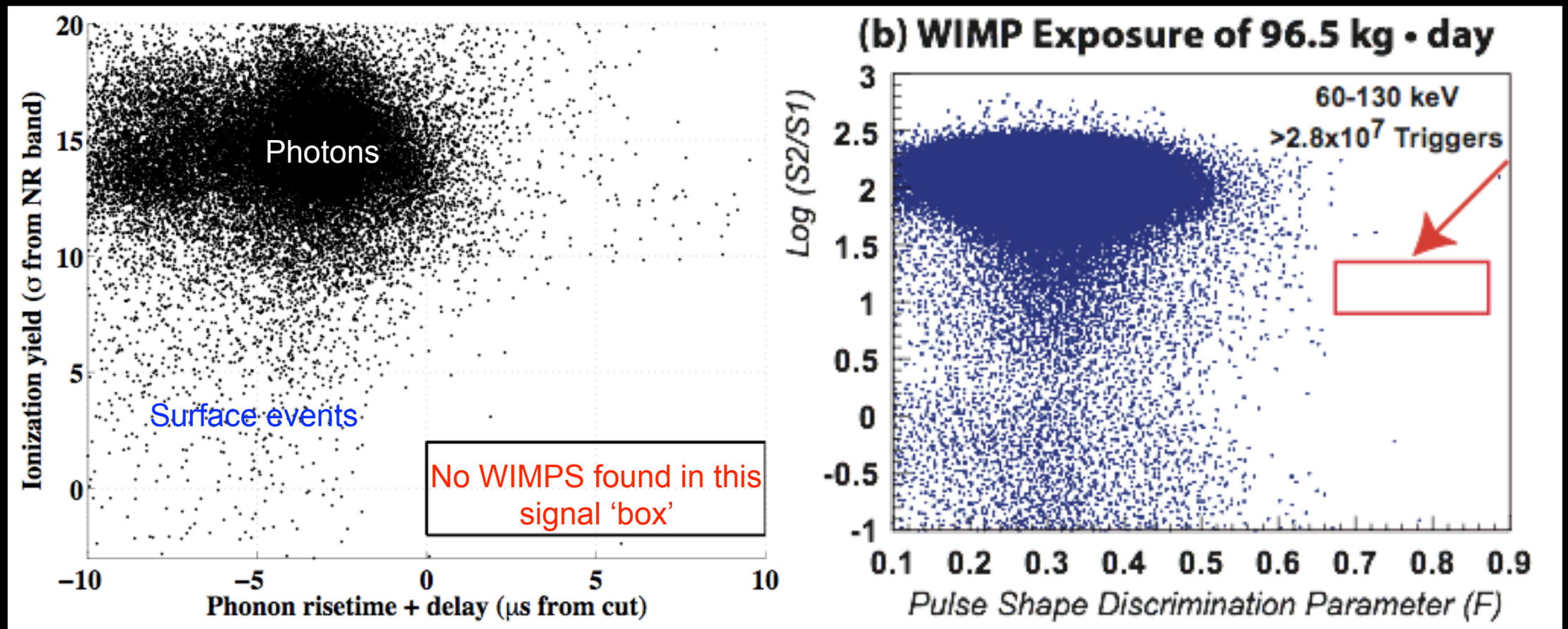
Two is Better than One!



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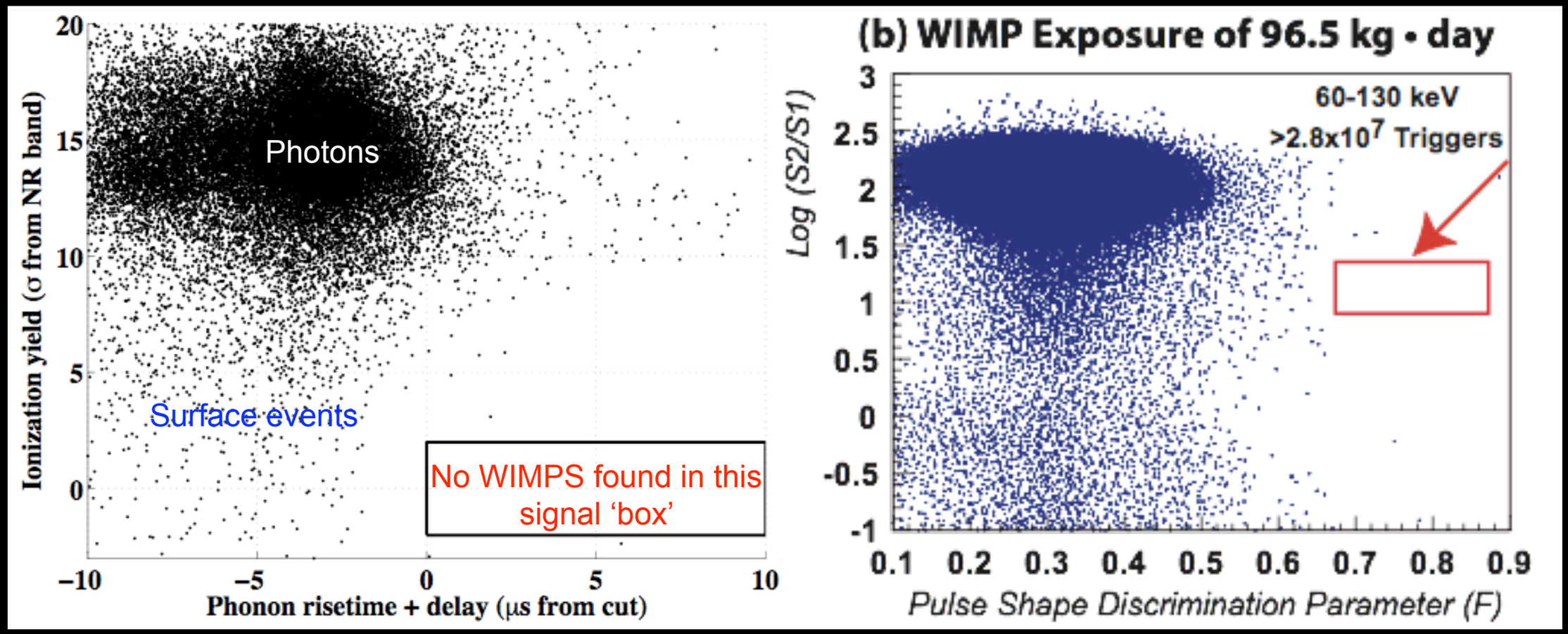


Few Events in ~Tons per Yr at few tens of KeV
Crucial the presence of dual, semi-independent discrimination

Discrimination in Depleted Argon TPC

- Pulse shape discrimination of primary scintillation (S1) based on the difference in decay times between singlet (≈ 7 ns) and triplet (1.6 μs) components of the emitted UV light

  Minimum ionizing: triplet/singlet ~ 3/1

  Nuclear recoils: triplet/singlet ~ 1/3

  Theoretical Identification Power exceeds 10^8 for > 60 photoelectrons (Boulay & Hime 2004)

- Difference in ratio of the prompt scintillation (S1) to the drift time-delayed ionization (S2)
- Precise determination of events location in 3D
- Up-front reduction os large ^{39}Ar cosmogenic rate

Why is underground argon desirable?

- Radioactive ^{39}Ar produced by cosmic rays in atmosphere
  - beta decays, Q = 565 keV, $t_{1/2}$ = 269 years
- In atmospheric argon:
  - $^{39}Ar/Ar$ ratio 8×10^{-16}
  - specific activity 1 Bq/kq
- Limits size (and sensitivity) of argon detectors to 500-1000 kg due to ^{39}Ar events pile-up

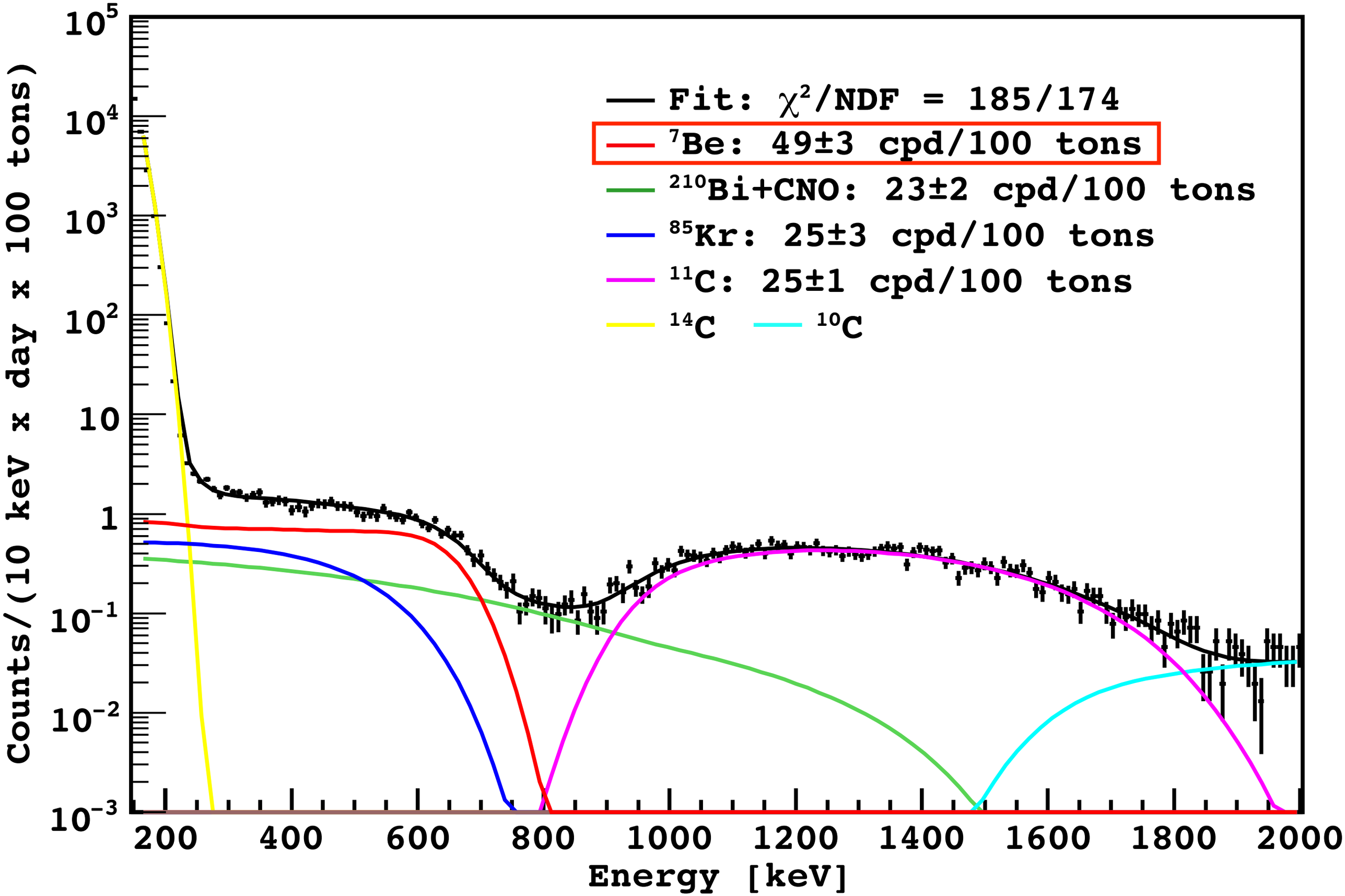
Why is underground argon desirable?

- ^{39}Ar-depleted argon available via centrifugation or thermal diffusion, but expensive at the ton scale!

- ^{39}Ar production by cosmic rays strongly suppressed underground

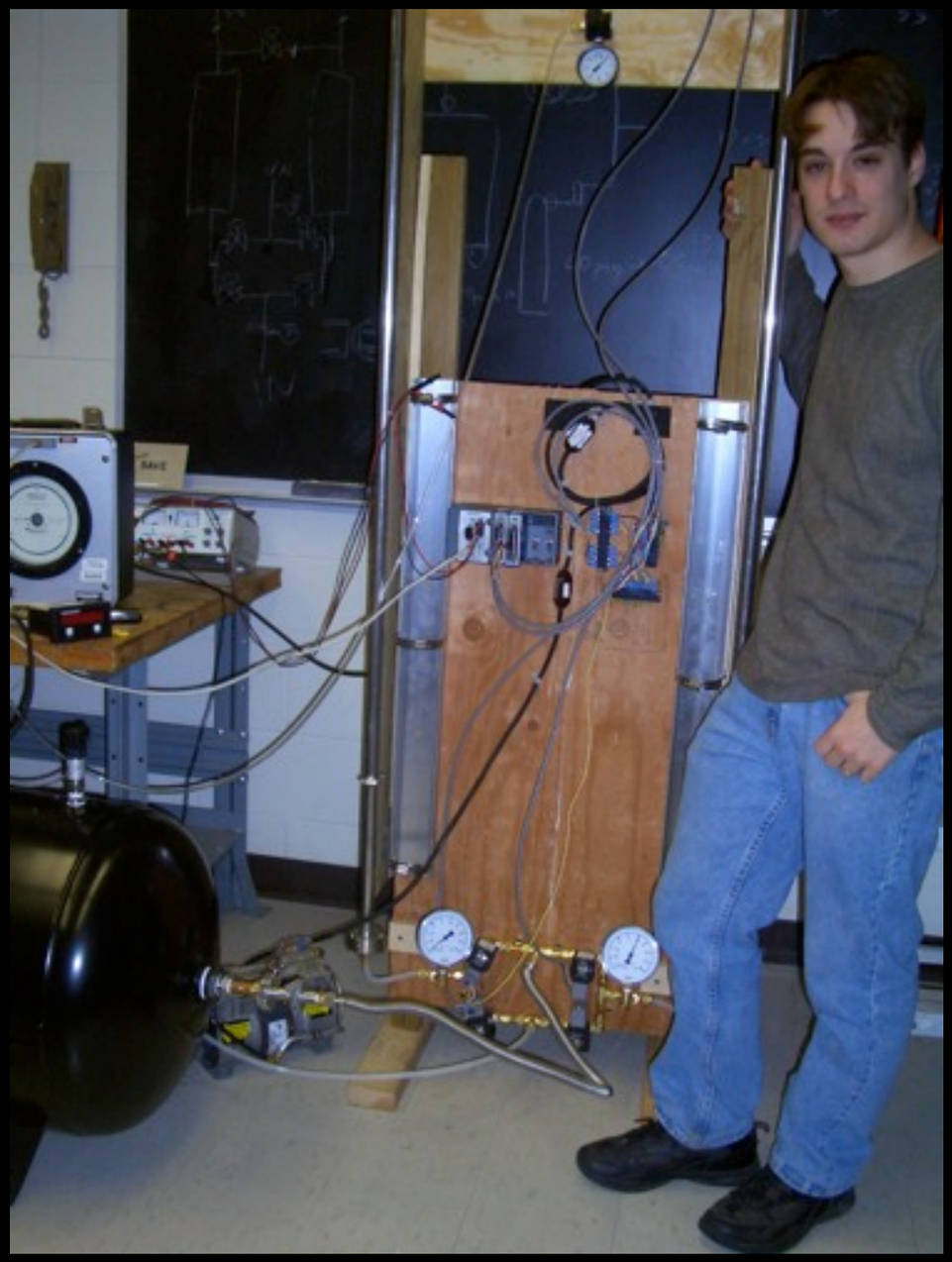
- Motivated by success in Borexino
  - Low background from ^{14}C crucial for observation of low energy neutrinos with organic liquid scintillators.
  - Hydrocarbons in deep underground reservoirs results in low cosmogenic ^{14}C

New Results:192 Days



Necessary to pre-scan sources of interest for ^{39}Ar

- ^{39}Ar also produced underground by neutron activation, from fission and (α,n) neutrons
  - $^{39}K(n,p)^{39}Ar$
- ^{39}Ar content depends on local content of U, Th, and K, and on rock porosity
- In some groundwater samples $^{39}Ar/Ar$ ratio measured up to a factor 20× (2000%) of the atmospheric ratio
- Cannot rely on ^{39}Ar simply being low. Pre-scan of ^{39}Ar activity on small samples necessary for program.



← Prototype Purification Plant at Princeton

Sampling gas field in the West

↓

All across the West:
Texas, New Mexico,
Colorado, Kansas

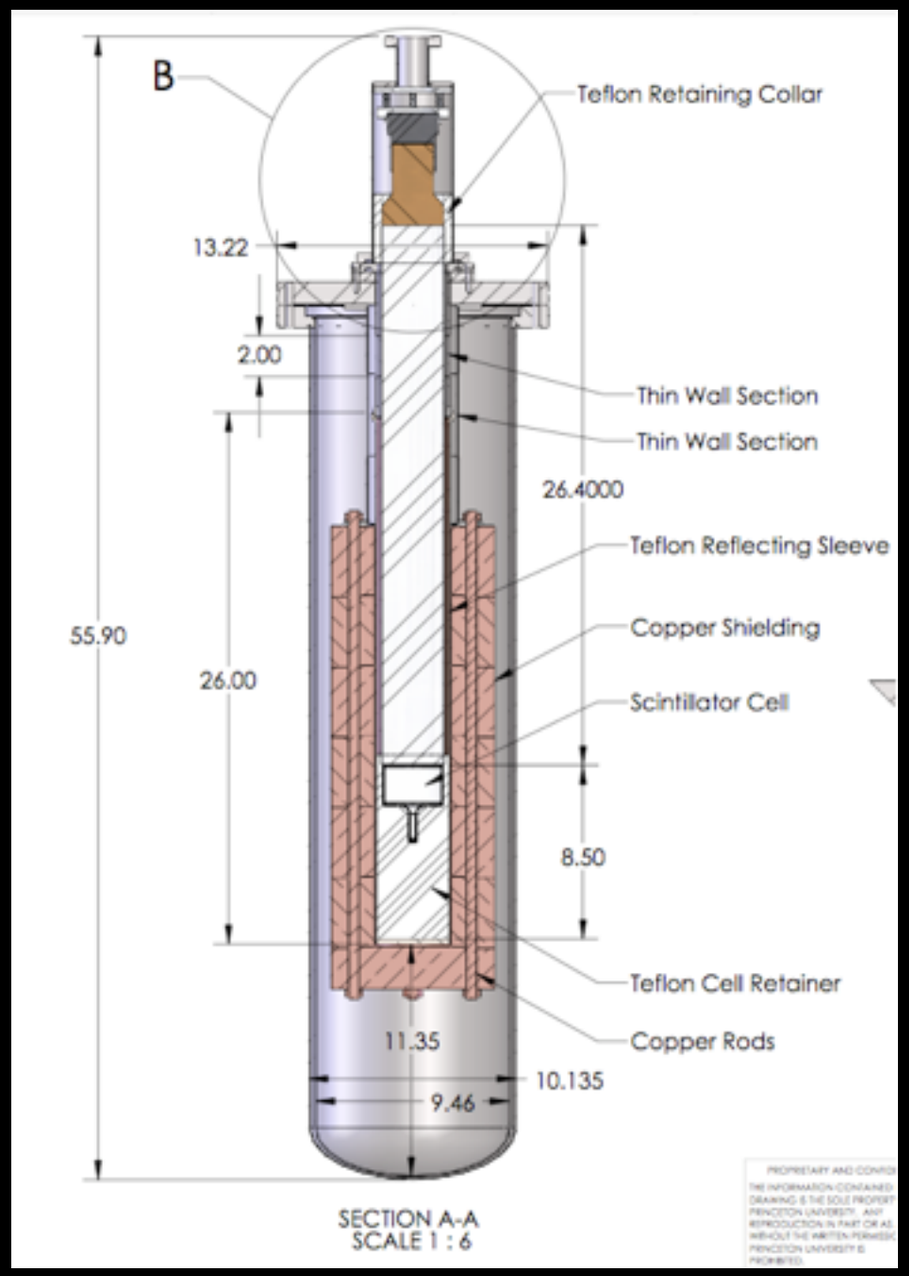
Sources Viable for Large Scale Production

	National Helium Reserve	Doe Canyon Complex
^{39}Ar	<50 mBq/kg	<40 mBq/kg
Depletion	>20	>25
Production capacity	30 tons/yr	>10 tons/yr

Measurements of low levels of ^{39}Ar

- Single phase ~1 kg Ar liquid scintillator
- Long light pipe to Room Temp PMT
- Internal Cu shield. External Pb shielding not shown
- Measure ^{39}Ar spectrum.
- Goal: <1 mB/kg (0.1% atm.)

Inner Tube



Cryostat with Inner Tube and internal Cu shield

Princeton Prototype Plant for Industrial Scale Production: Achieved 0.5 kg/day

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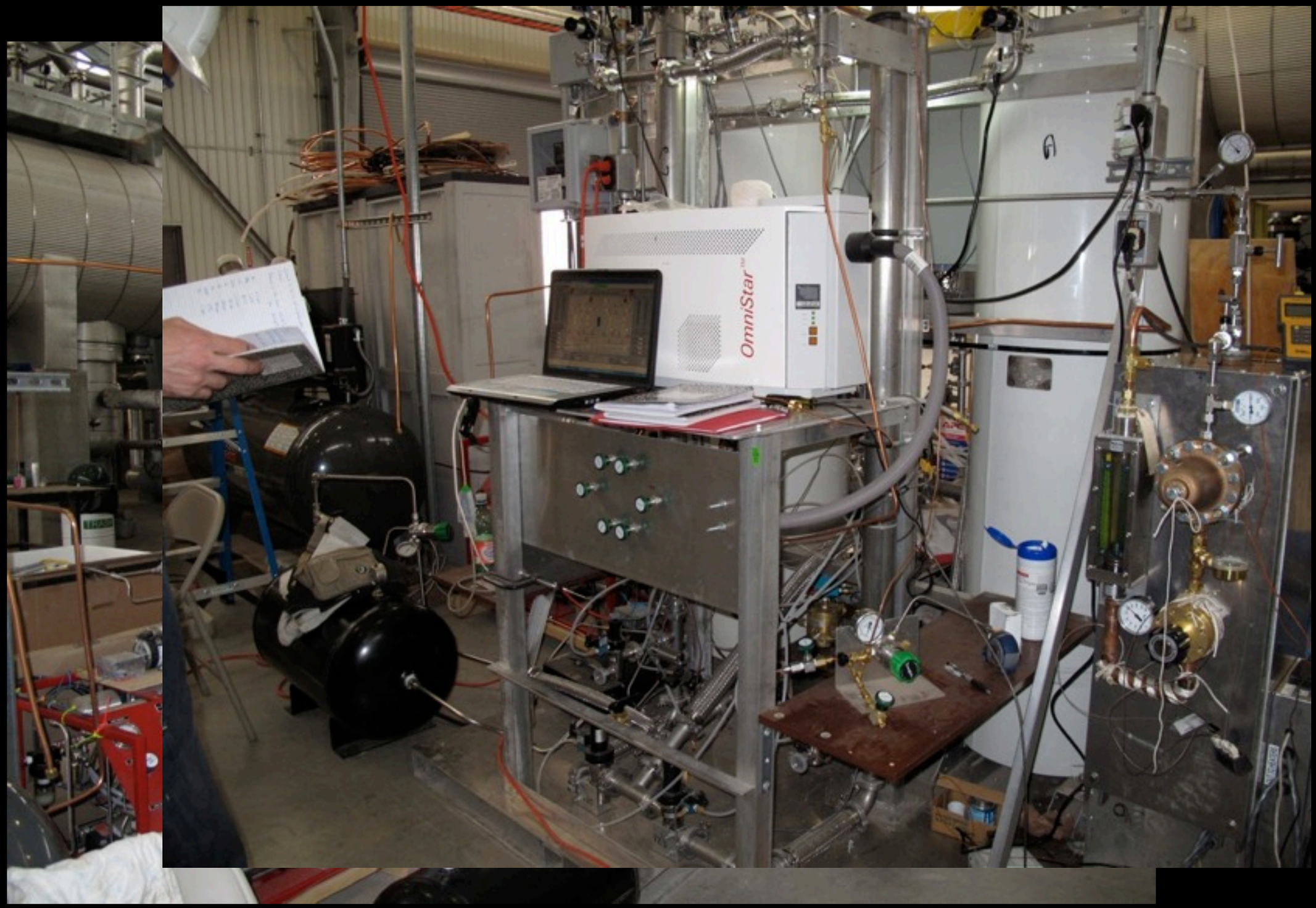

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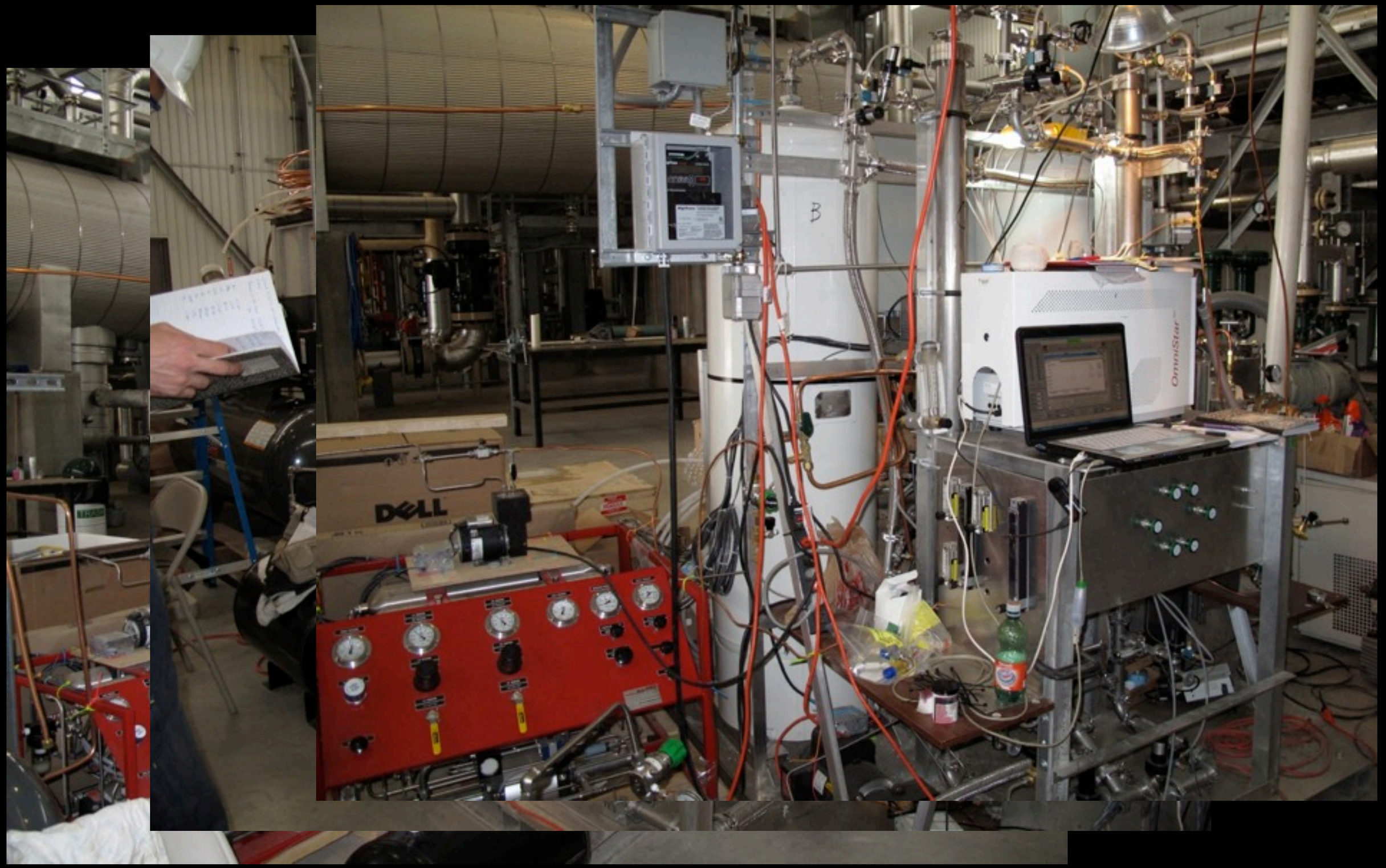
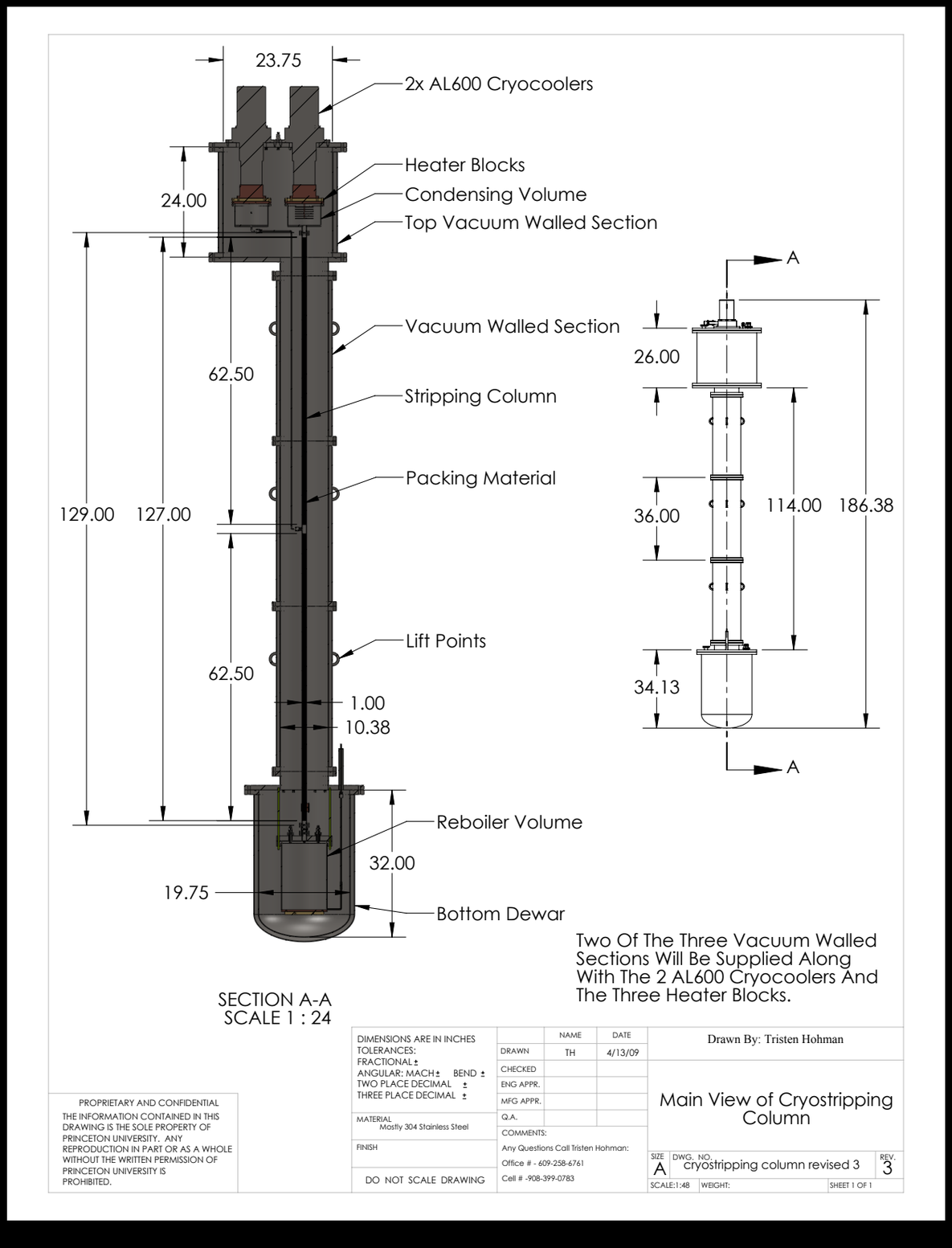
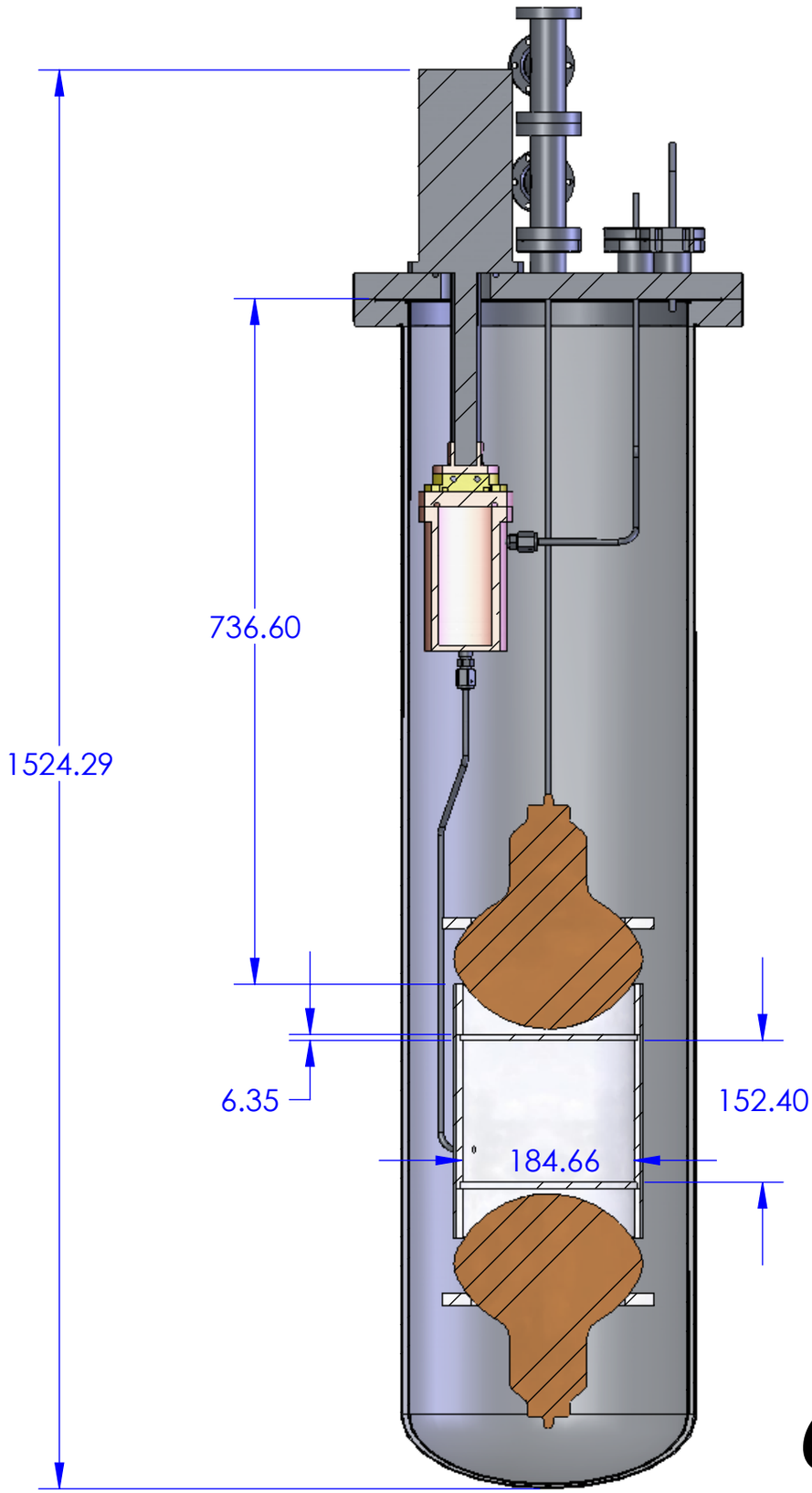


Purification by cryogenic distillation

Cryogenic distillation column designed at Princeton, to be commissioned Summer-Fall 2009

Performance: purification of 20 kg per day of argon to 4-5 nines of purity





SECTION A-A
SCALE 1 : 7

Level Probe Positions
(From top flange)

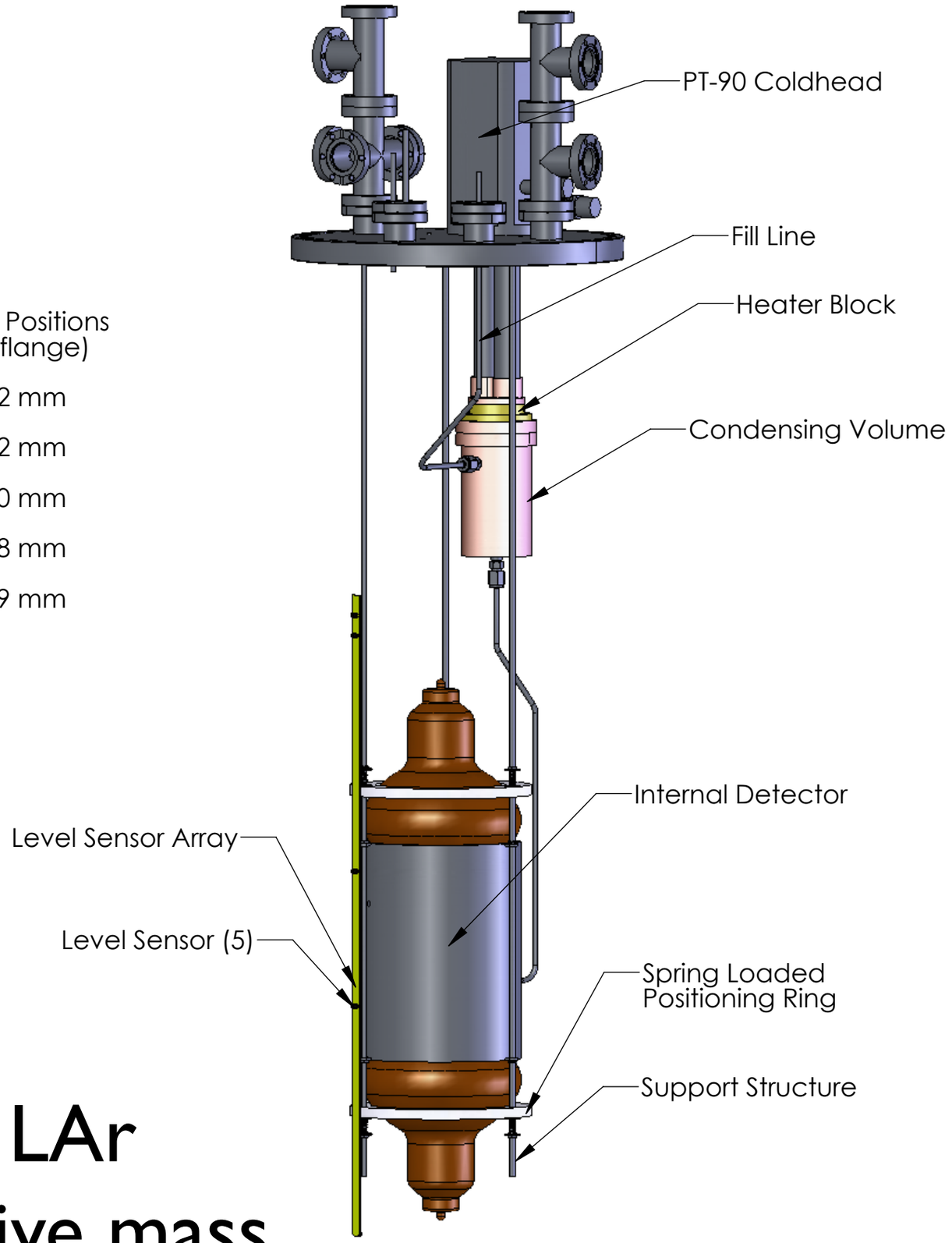
1 - 454.12 mm

2 - 477.52 mm

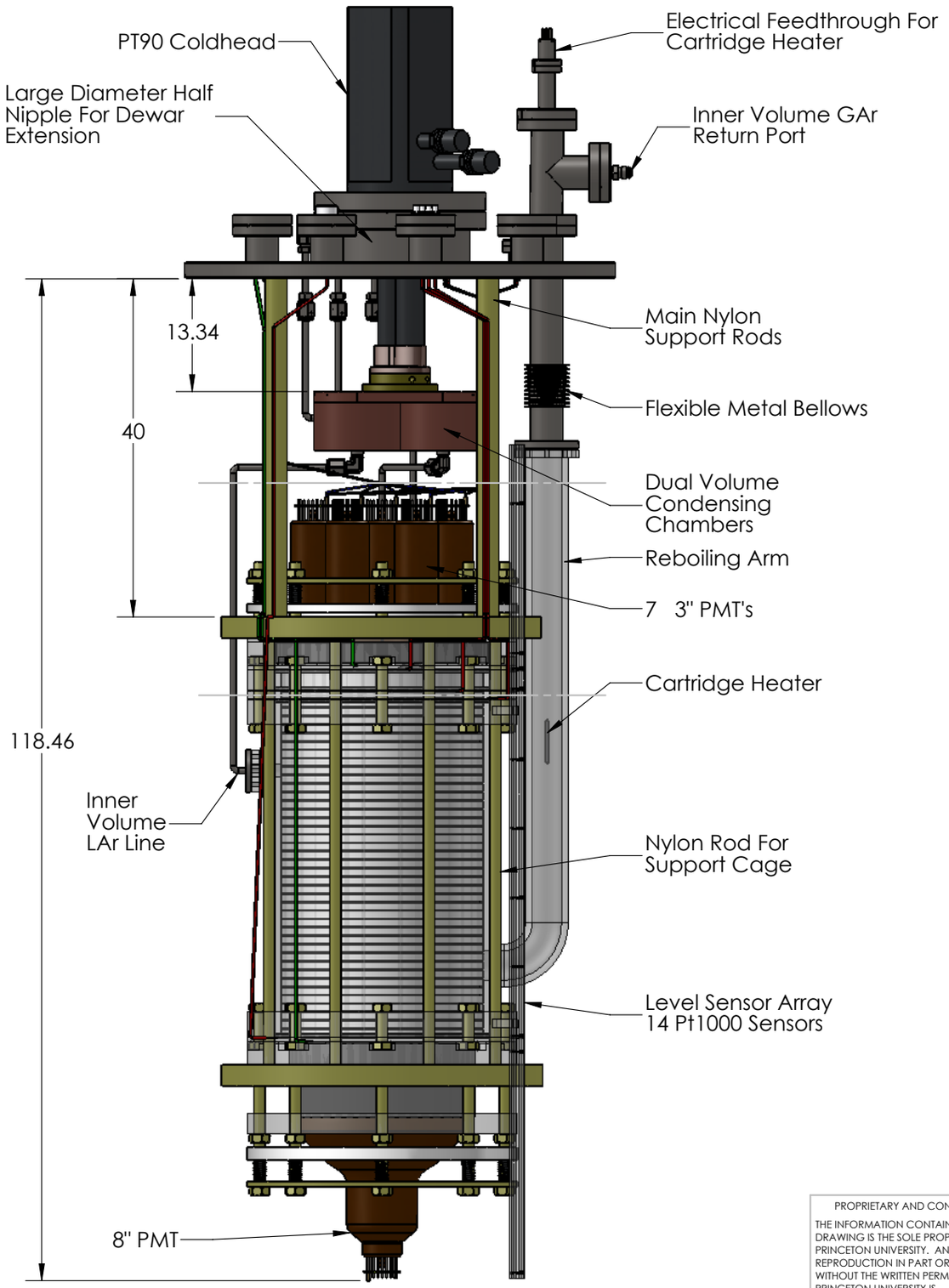
3 - 774.70 mm

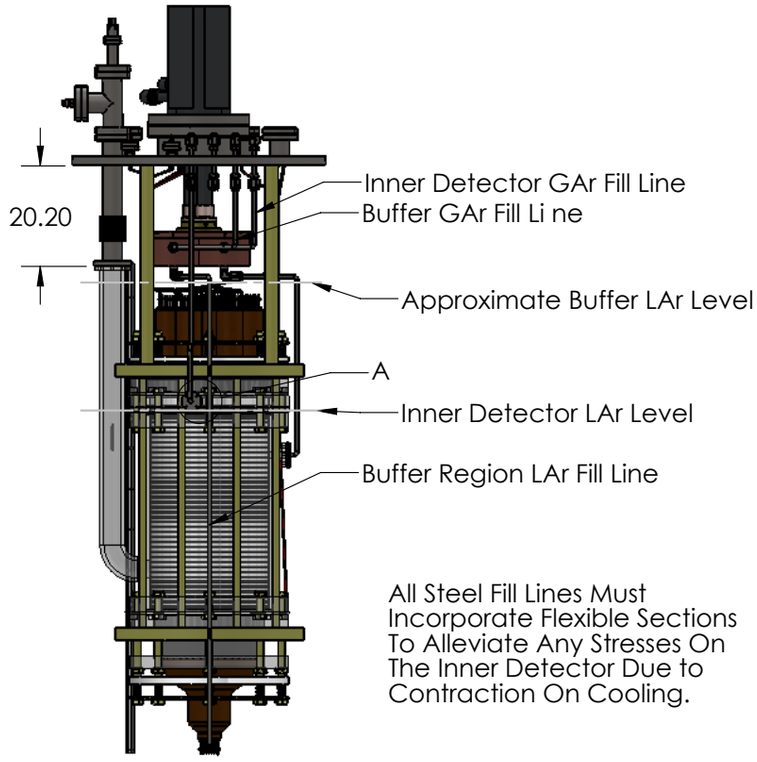
4 - 944.88 mm

5 - 1231.9 mm

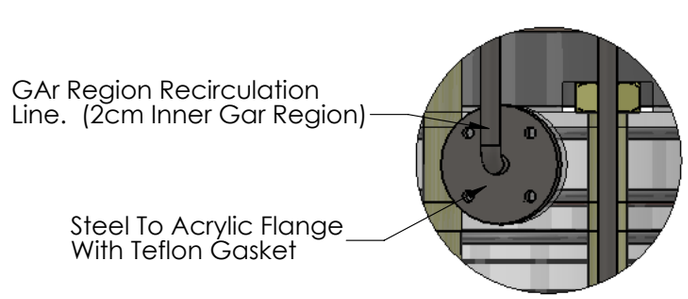


64 kg LAr
6.7 kg active mass
Light Yield: 5 pe/keV

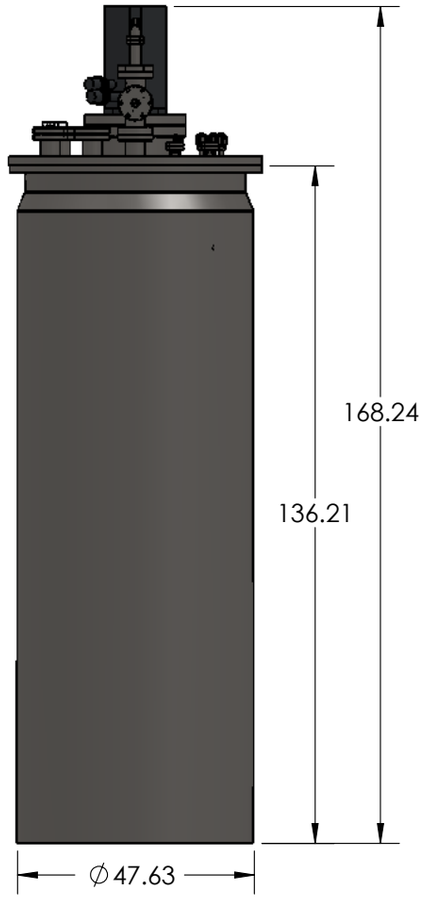




All Steel Fill Lines Must Incorporate Flexible Sections To Alleviate Any Stresses On The Inner Detector Due to Contraction On Cooling.



DETAIL A
SCALE 1 : 2



ALL UNITS ARE IN CENTIMETERS

NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN CENTIMETERS
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	TH	2/26/2009
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

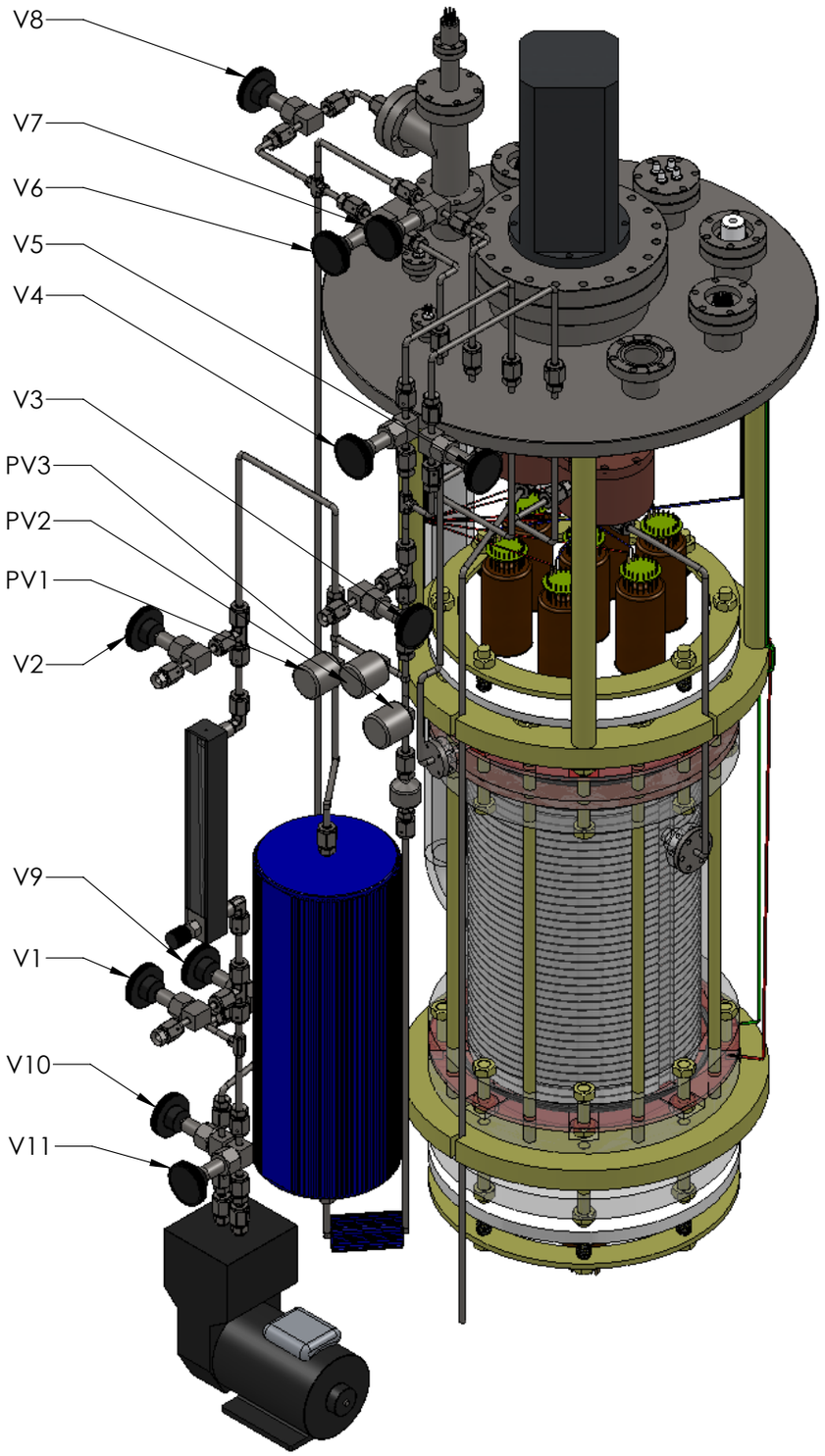
COMMENTS:

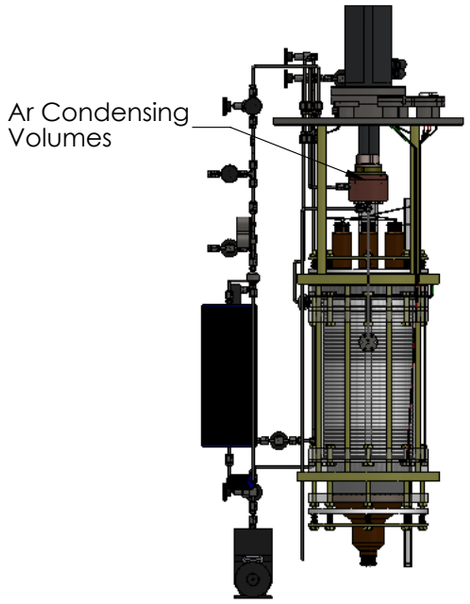
Drawn By: Tristen Hohman

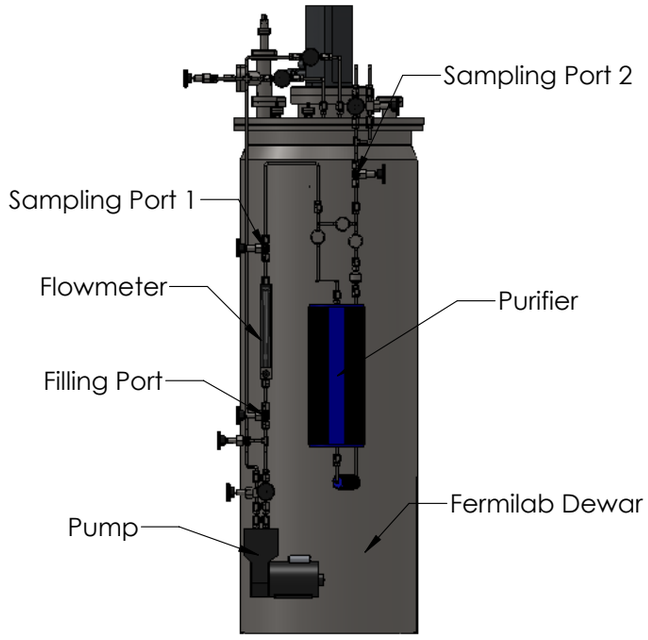
TITLE:
Layout Of Internal Detector And Recirculation Lines

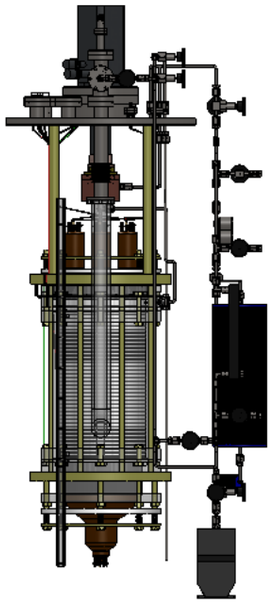
SIZE	DWG. NO.	REV
B	Internal Layout	1

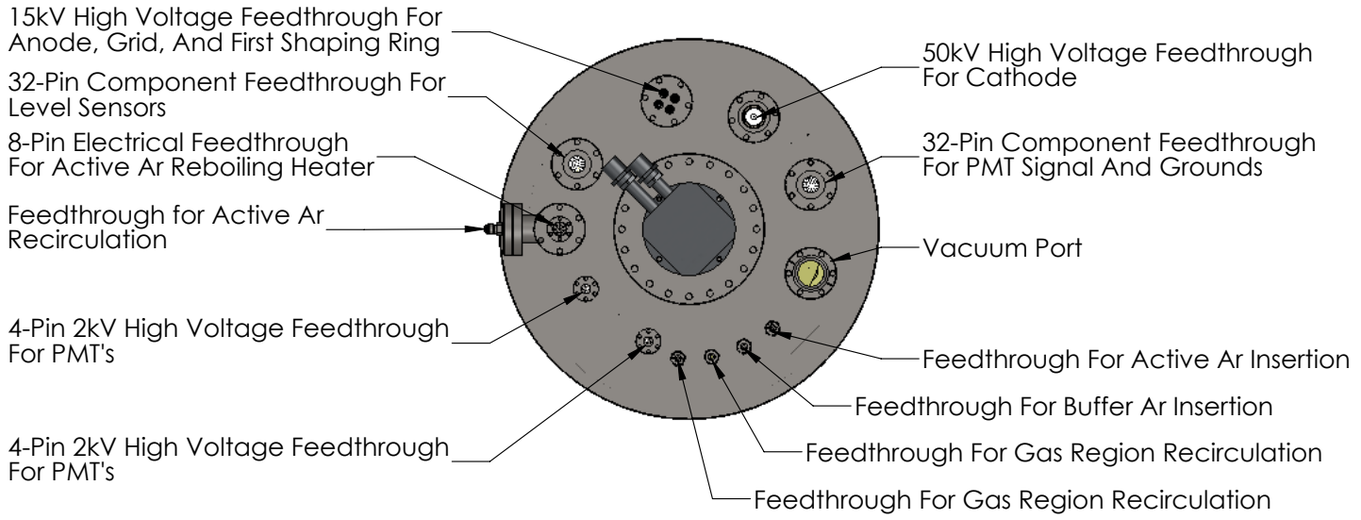
SCALE: 1:16 WEIGHT: SHEET 1 OF 1











		UNLESS OTHERWISE SPECIFIED:		NAME	DATE
		DIMENSIONS ARE IN CENTIMETERS TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN	TH	2/26/09
			CHECKED		
			ENG APPR.		
			MFG APPR.		
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
		MATERIAL	COMMENTS:		
NEXT ASSY	USED ON	FINISH			
APPLICATION		DO NOT SCALE DRAWING			

Drawn By: Tristen Hohman

TITLE:

External Detector And Recirculation System Layout

SIZE	DWG. NO.	REV
B	External Layout	1
SCALE: 1:16	WEIGHT:	SHEET 1 OF 1

Past and Current Efforts

- WARP 3.2-kg
  - funded by INFN, construction at Pavia, operation at LNGS with participation from Princeton
  - completed 2006 - first and so far only dark matter result with argon - Astropart. Phys. **28**, 495 (2008)

- WARP 140-kg [NSF PHY-0603376]
  - funding from INFN and NSF (through Princeton)
  - installation completed; commissioning ongoing

- Investigation of depleted argon from underground wells [NSF PHY-0704220] [Princeton U. Seed Fund]
  - demonstrated availability of large quantity of depleted argon, ^{39}Ar reduced by >25

Short- and Long-Term Future

- DUSEL (2013 and beyond) [NSF PHY-0919363]
  - MAX - Multi-ton Argon and Xenon
  - 20 institutions, 5-t DAr and 2.5-t Xe TPCs
  - NSF announced intention to fund S4 proposal
- Depleted Argon Production [NSF PHY-0811186]
  - funded from NSF through Princeton
  - 2 kg/day, depletion >25, by end of 2009
- DarkSide Detector (2009-2012)
  - first depleted argon TPC
  - demonstration of key features
  - competitive dark matter search

DarkSide

UMass Amherst
Arizona State University
Augustana College
Black Hills State University
Fermilab
University of Houston
University of Notre Dame
Princeton University
Temple University
UCLA

Like the jelly beans in this jar, the Universe is mostly dark: 96 percent consists of dark energy (about 70%) and dark matter (about 26%). Only about four percent (the same proportion as the lightly colored jelly beans) of the Universe - including the stars, planets and us - is made of familiar atomic matter.

The End