

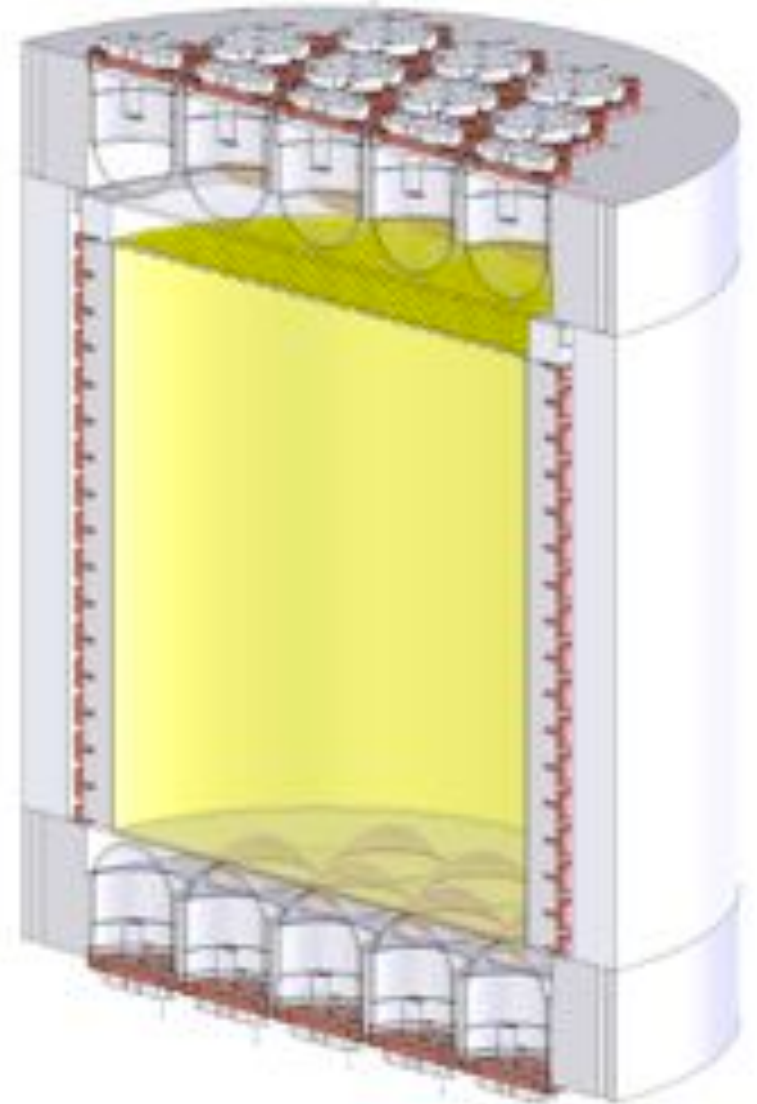
**DARK SIDE**

Alex Wright, for the DarkSide Collaboration  
DPF 2011, 10 August 2011

# The DarkSide Program at LNGS

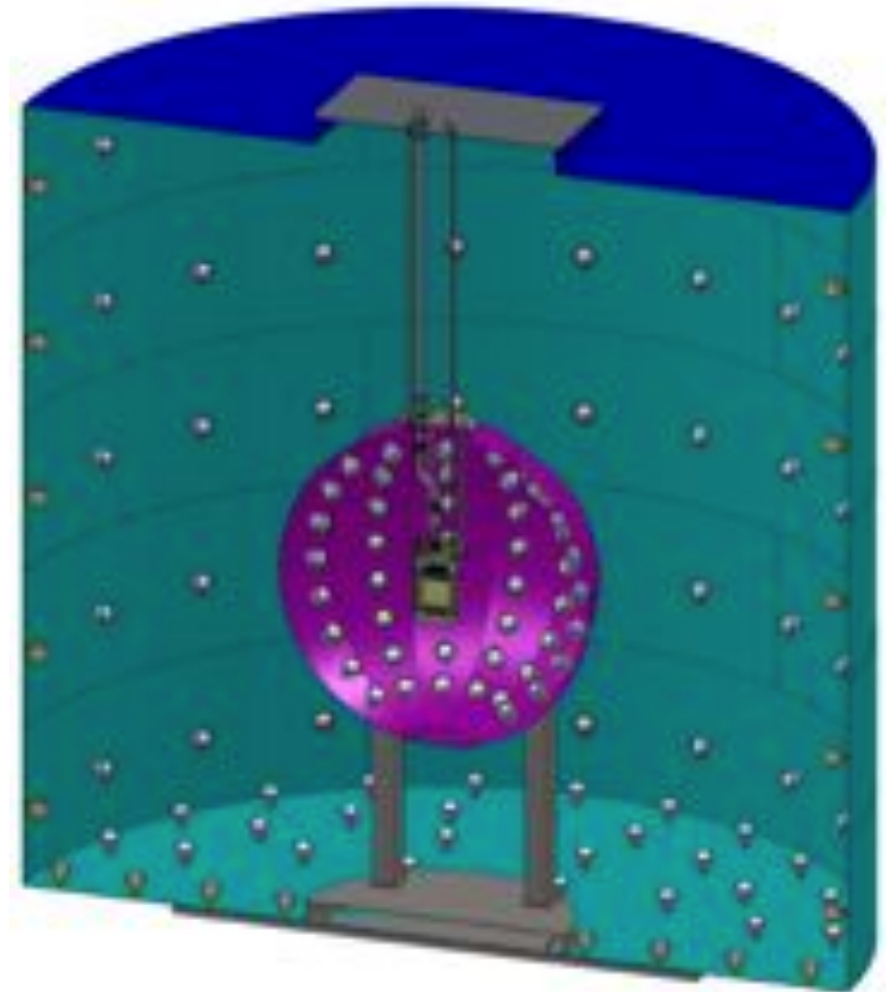
# DarkSide

- Direct-detection dark matter program at LNGS based on 2-phase depleted argon TPCs
- Staged approach, with 50 kg and ton-scale detectors ( $10^{-45}$  cm<sup>2</sup> and  $10^{-46}$  cm<sup>2</sup> target sensitivities)
- Develop technology for ultimate multi-ton detectors
- Aim to have very low backgrounds, and be able to demonstrate them *in situ*



# DarkSide Strategy

- Ultra-low background technology
  - Argon depleted in  $^{39}\text{Ar}$
  - Low background photodetectors
- Active suppression to both reject and assay background:
  - Electron recoil rejection capability of liquid argon
  - Highly efficient neutron veto
  - CTF water tank for suppression of cosmogenics



# Darkside Collaboration

Augustana College – SD, USA 

Black Hills State University – SD, USA 

Fermilab – IL, USA 

INFN Laboratori Nazionali del Gran Sasso – Assergi, Italy 

INFN and Università degli Studi Genova, Italy 

INFN and Università degli Studi Milano, Italy 

INFN and Università degli Studi Naples, Italy 

INFN and Università degli Studi Perugia, Italy 

Institute for High Energy Physics – Beijing, China 

Joint Institute for Nuclear Research – Dubna, Russia 

Princeton University, USA 

RRC Kurchatov Institute – Moscow, Russia 

St. Petersburg Nuclear Physics Institute – Gatchina, Russia 

Temple University – PA, USA 

University of Arkansas, USA 

University of California, Los Angeles, USA 

University of Houston, USA 

University of Massachusetts at Amherst, USA 

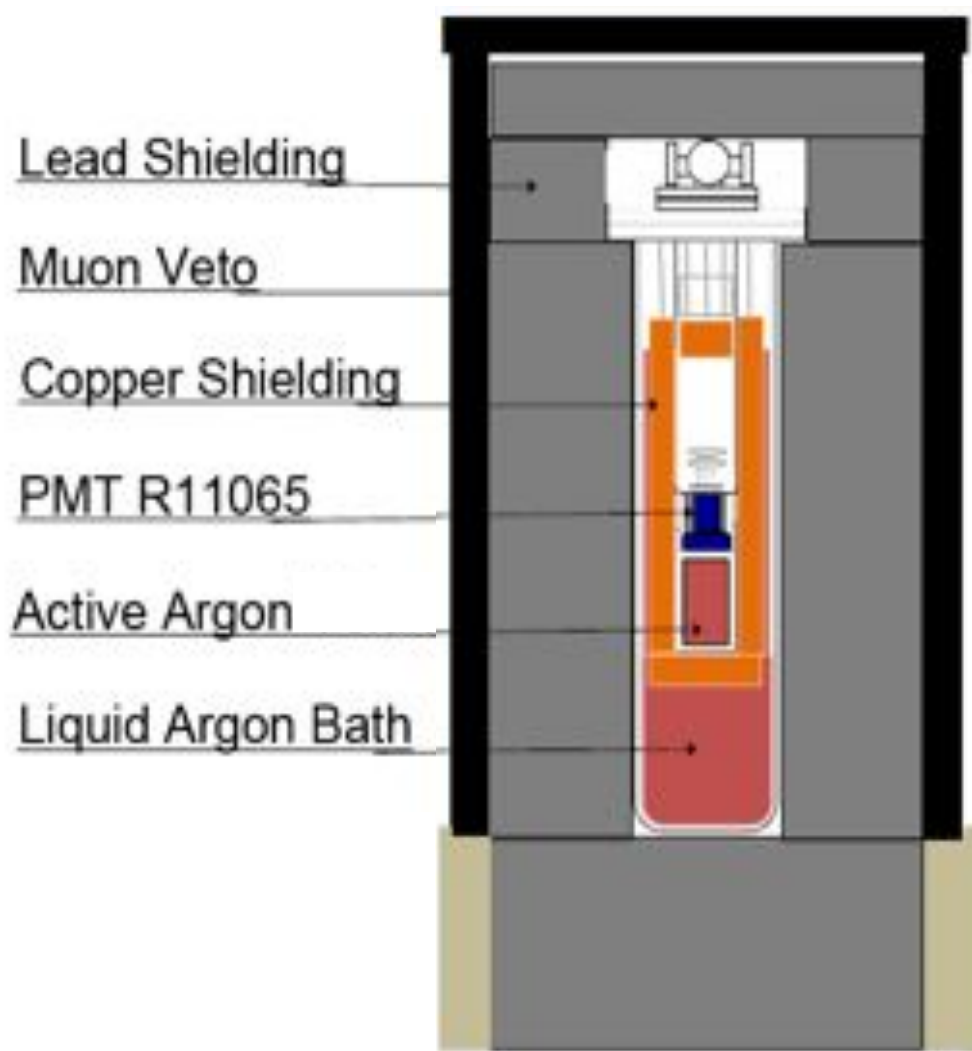
# Depleted Argon

- $^{39}\text{Ar}$  is produced by cosmic rays in the atmosphere
  - $\sim 1$  Bq/kg in commercial argon
- Underground argon is shielded, so contains less  $^{39}\text{Ar}$
- $\text{CO}_2$  from Kinder Morgan Doe Canyon Complex (Cortez, CO) contains  $\sim 600$  ppm Argon
  - 3 tons Ar produced/day
- $\sim 46$  kg of argon collected so far





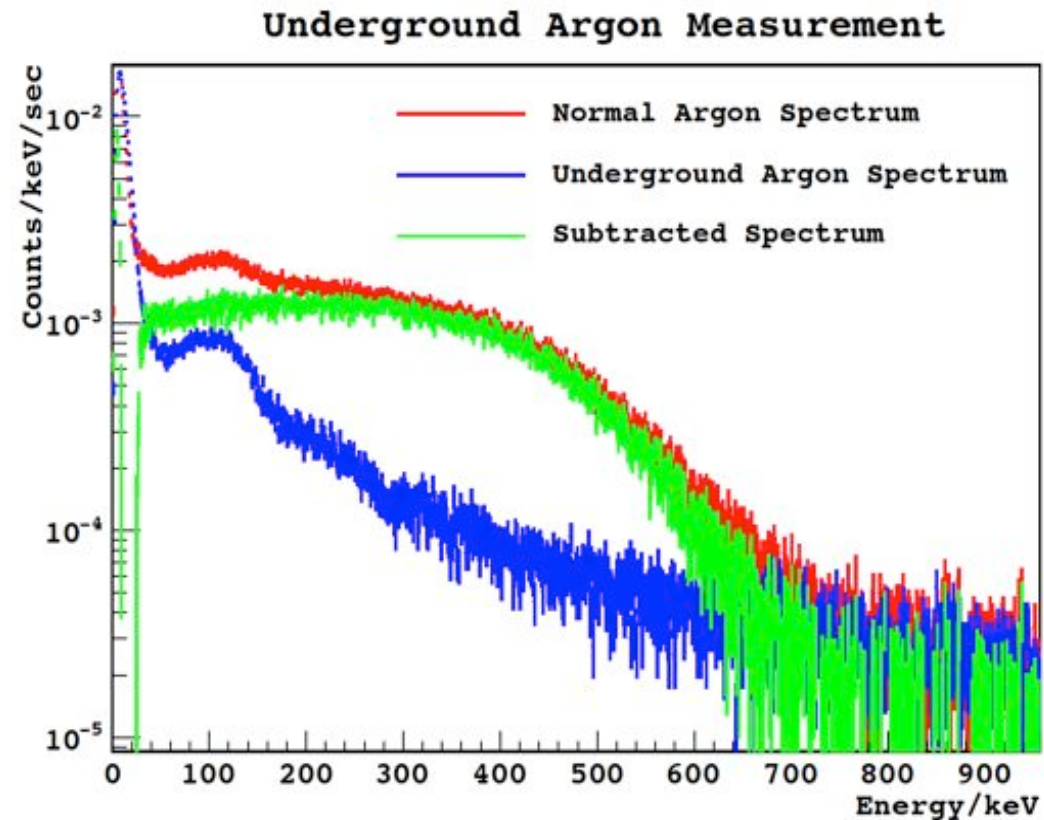
# Depleted Argon Counting



- Dedicated “low background detector”
- ~0.56 kg liquid Ar active mass
- Cryogenic, low background 3” PMT
- 2” Cu, 8” Pb shielding
- Muon veto

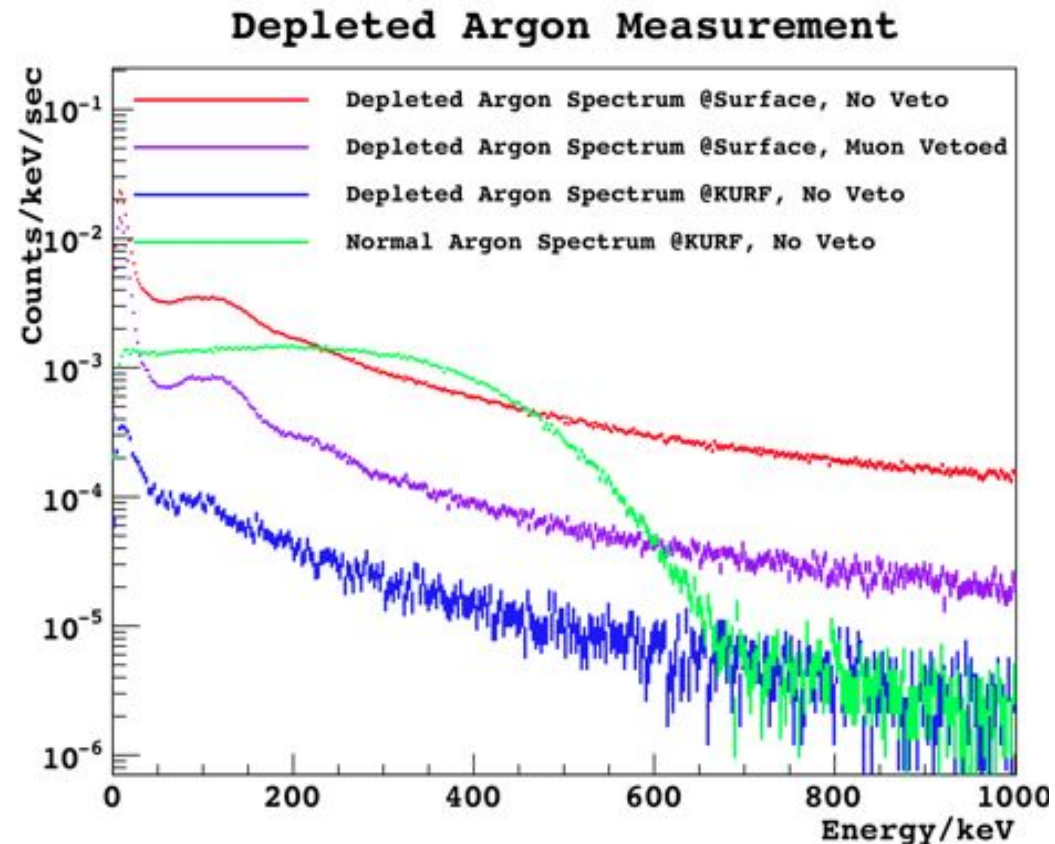
# Depleted Argon Counting

- At Princeton, background in the  $^{39}\text{Ar}$  region is 0.05 Bq in (200,800 keV)
- $^{39}\text{Ar}$  depletion factor of  $>10$  from direct counting,  $>\sim 50$  from spectral fit



# Depleted Argon Counting

- At KURF (1400 m.w.e.) background reduced to 0.002 Bq in 300-400 keV
- Depletion factor of >50 from counting
  - Spectral fit in progress



***$^{39}\text{Ar}$  likely not the dominant source of electron recoils in DarkSide-50!***



# Low Background Photo-Detectors

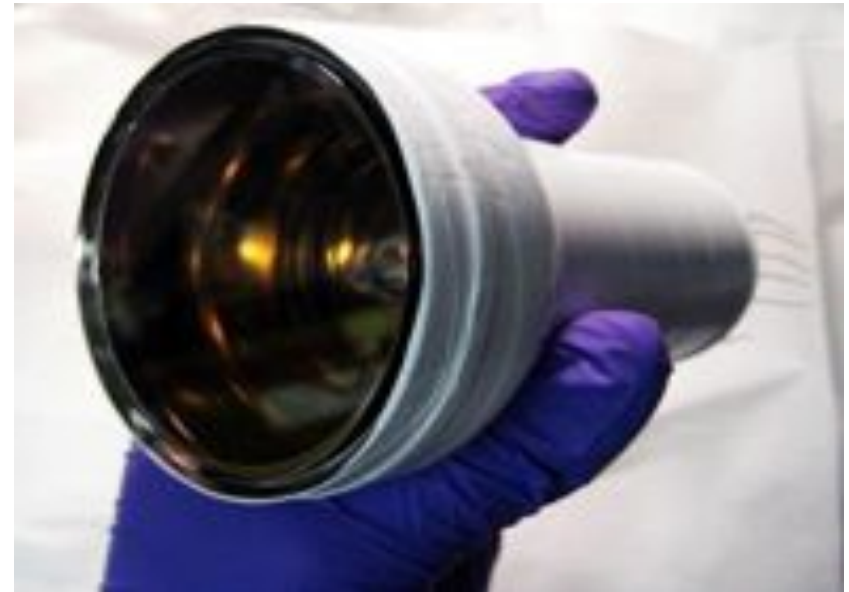
Quartz Photon Intensifying Device



- All fused silica construction
- Photoelectrons accelerated directly onto a low background APD
- Potential for extremely low background
- Cryogenic operation
- High quantum efficiency (>35%)

For details: [arXiv:1103.3689](https://arxiv.org/abs/1103.3689)

R11065 PMT



- Metal bulb, fused silica window
  - <60 mBq gammas
  - <3 neutrons/PMT/yr
- Cryogenic operation
- High quantum efficiency (>30%)
- To be used in DarkSide-50 before QUPIDs

# High-Efficiency Neutron Veto

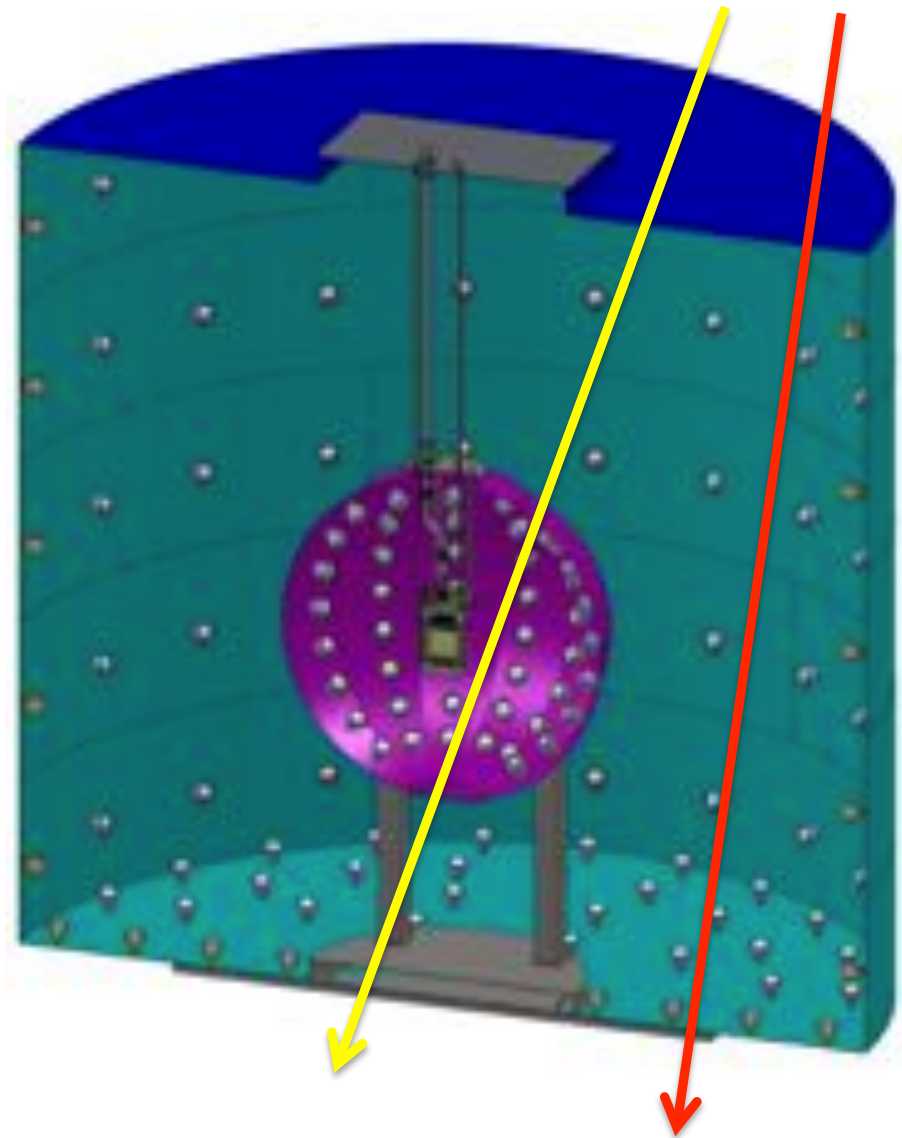
- Surround DarkSide with boron-loaded liquid scintillator
  - Fast neutron captures
  - Detect nuclear recoil products of neutron capture
- Efficiently detect escaping neutrons and veto any associated nuclear recoil backgrounds
  - >99.5% efficiency for radiogenic neutrons
  - >95% efficiency for cosmogenic neutrons



For details: NIM A 664:18-26 (2011)

# Cosmogenic Neutrons

- Install DarkSide in the Borexino CTF tank in LNGS, Italy
  - Muon flux reduced by  $10^6$
- Detect the Cerenkov light produced by the muons and other shower particles
  - Veto the (~simultaneous) neutron-induced background events
- CTF tank + neutron veto reduce cosmogenic backgrounds by  $\gg 10^3$



# DarkSide-50 Background Estimates

Total WIMP background in (ev / 0.1 tonne-yr) for R11065 (QUPIDs):

Detector Element	Electron Recoil Backgrounds		Radiogenic Neutron Recoil Backgrounds		Cosmogenic Neutron Recoil Backgrounds	
	Raw	After Cuts	Raw	After Cuts	Raw	After Cuts
<sup>39</sup> Ar (0.04 Bq/kg)	$<2.5 \times 10^7$	$<0.016$	–	–	–	–
Fused Silica	$3.3 \times 10^4$	$2.0 \times 10^{-5}$	0.17	$4.3 \times 10^{-4}$	0.21	$1.3 \times 10^{-5}$
PTFE	4,800	$3.0 \times 10^{-6}$	0.39	$9.8 \times 10^{-4}$	2.7	$1.6 \times 10^{-4}$
Copper	4,500	$2.8 \times 10^{-6}$	$5.0 \times 10^{-3}$	$1.3 \times 10^{-5}$	1.5	$9.0 \times 10^{-5}$
R11065 PMTs	$2.6 \times 10^6$	$1.6 \times 10^{-3}$	19.4	$4.8 \times 10^{-2}$	0.34	$2.0 \times 10^{-5}$
QUPIDs (1 mBq)	$7.0 \times 10^4$	$4.2 \times 10^{-5}$	0.31	$7.8 \times 10^{-4}$	0.34	$2.0 \times 10^{-5}$
Stainless Steel	$5.5 \times 10^4$	$3.4 \times 10^{-5}$	2.5	$6.3 \times 10^{-3}$	30	0.0018
Veto Scintillator	70	$4.3 \times 10^{-8}$	0.030	$7.5 \times 10^{-5}$	26	0.0016
Veto PMTs	$2.5 \times 10^6$	$1.6 \times 10^{-3}$	0.023	$5.8 \times 10^{-5}$	–	–
Veto tank	$1.7 \times 10^5$	$1.1 \times 10^{-4}$	$6.7 \times 10^{-5}$	$1.7 \times 10^{-7}$	19	0.0071
Water	6,100	$3.8 \times 10^{-6}$	$6.7 \times 10^{-4}$	$1.7 \times 10^{-6}$	19	0.0071
CTF tank	8,300	$5.1 \times 10^{-6}$	$3.5 \times 10^{-3}$	$8.7 \times 10^{-6}$	0.068	$2.6 \times 10^{-5}$
LNGS Rock	920	$5.7 \times 10^{-7}$	0.061	$1.5 \times 10^{-4}$	0.31	0.012
<b>Total</b>	–	0.019 (0.017)	–	0.055 (0.008)	–	0.030 (0.030)

Surface Backgrounds	
Raw	After cuts
$4.5 \times 10^3$	$<0.01$

*Very conservative estimates: DarkSide should demonstrate background free ton-yr exposures!*



# Demonstrating Discrimination Power

- DarkSide designed to have the ability to calibrate each major background rejection technique:
  - Compare PSD to charge/light, use  $\gamma$  sources (or refill with “normal” Ar!) to demonstrate electron rejection
  - Use neutron sources to calibrate neutron veto efficiency
  - Spike surfaces with  $^{220}\text{Rn}$  daughters to demonstrate surface background rejection
  - Compare water and neutron veto with each other and with calculations to calibrate cosmogenic veto efficiency



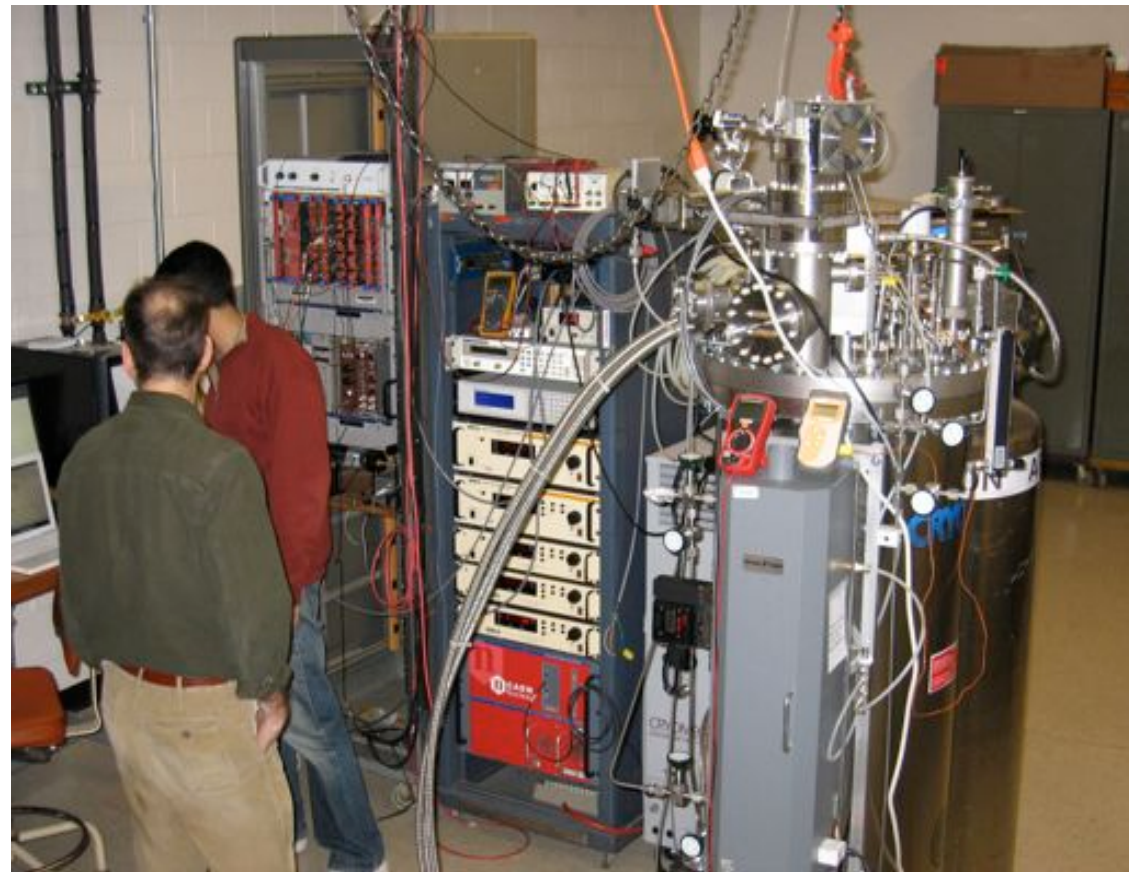
# 10 kg Prototype

- Test some important DarkSide technologies
  - Control of gas layer
  - Charge drift and S2 light collection
  - Light yield
- Background suppression studies
- Give us experience building and operating an argon TPC



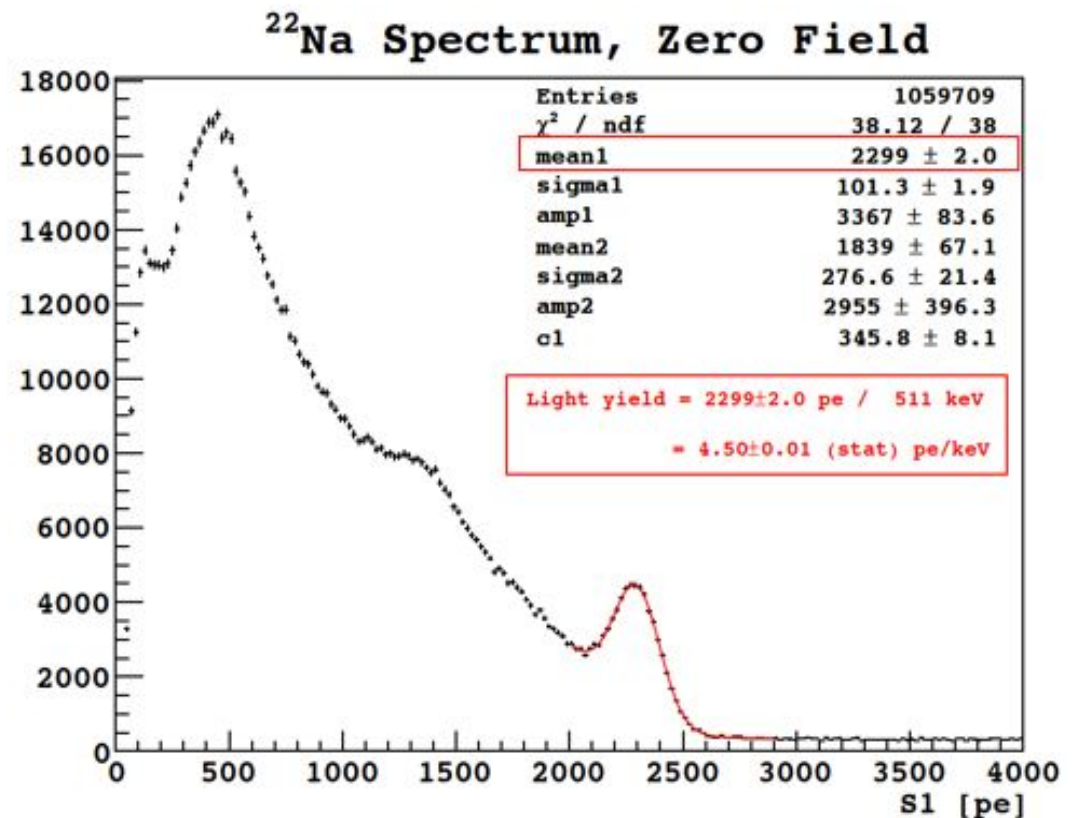
# DarkSide-10 at Princeton

- Two runs, seven months total, during 2010-2011
  - Good light yield
  - Good control of gas pocket
  - Successful 2-phase operation!



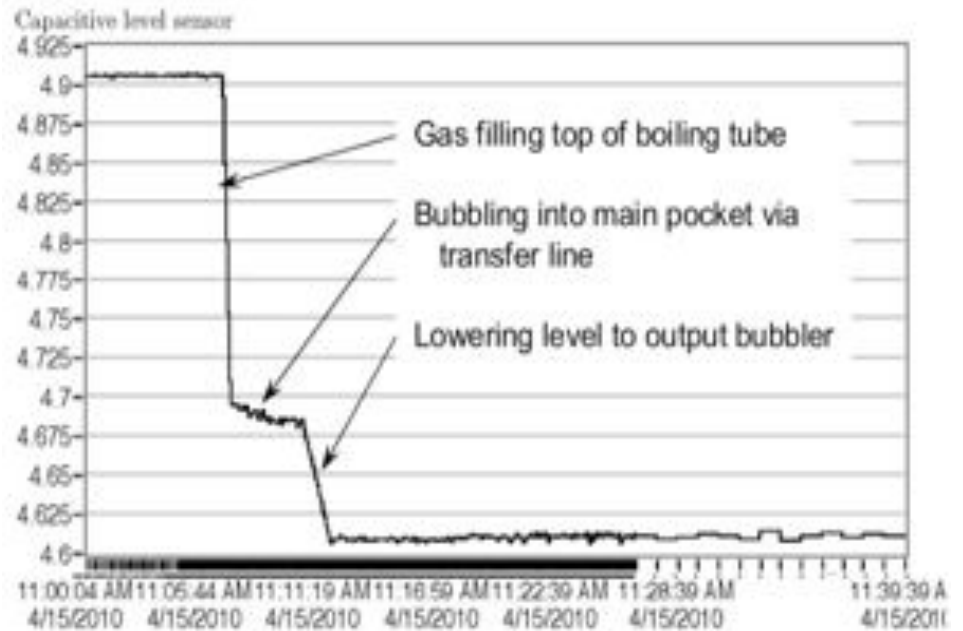
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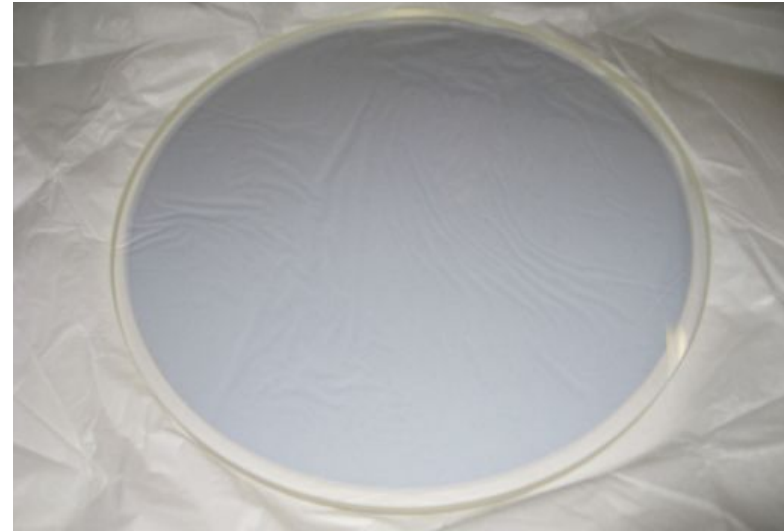
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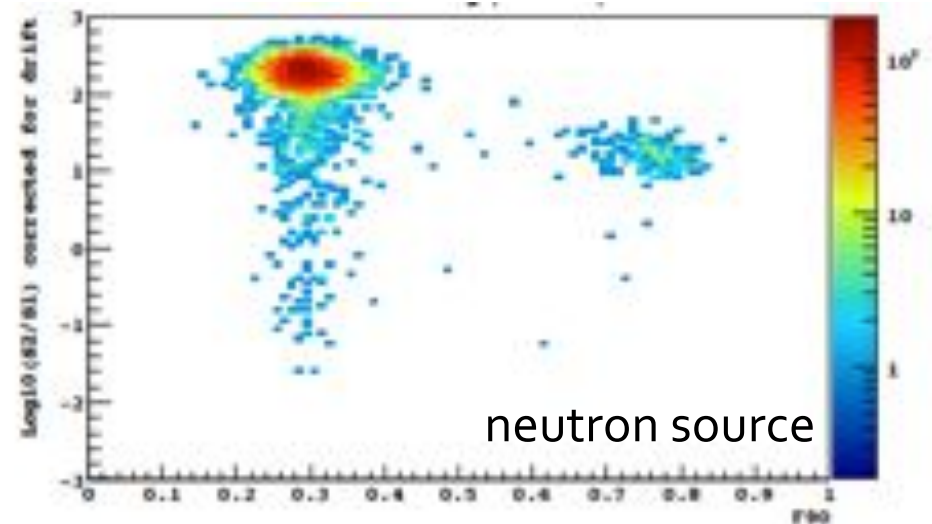
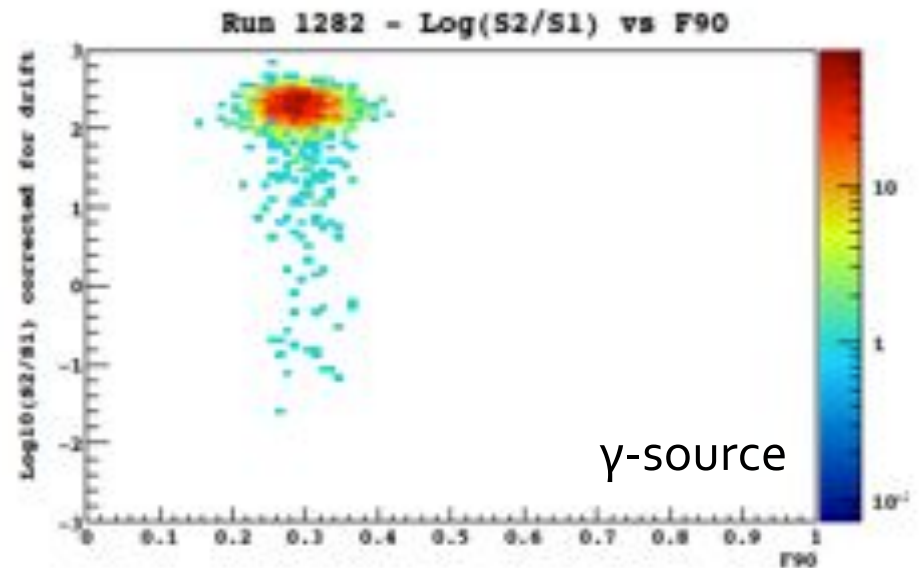
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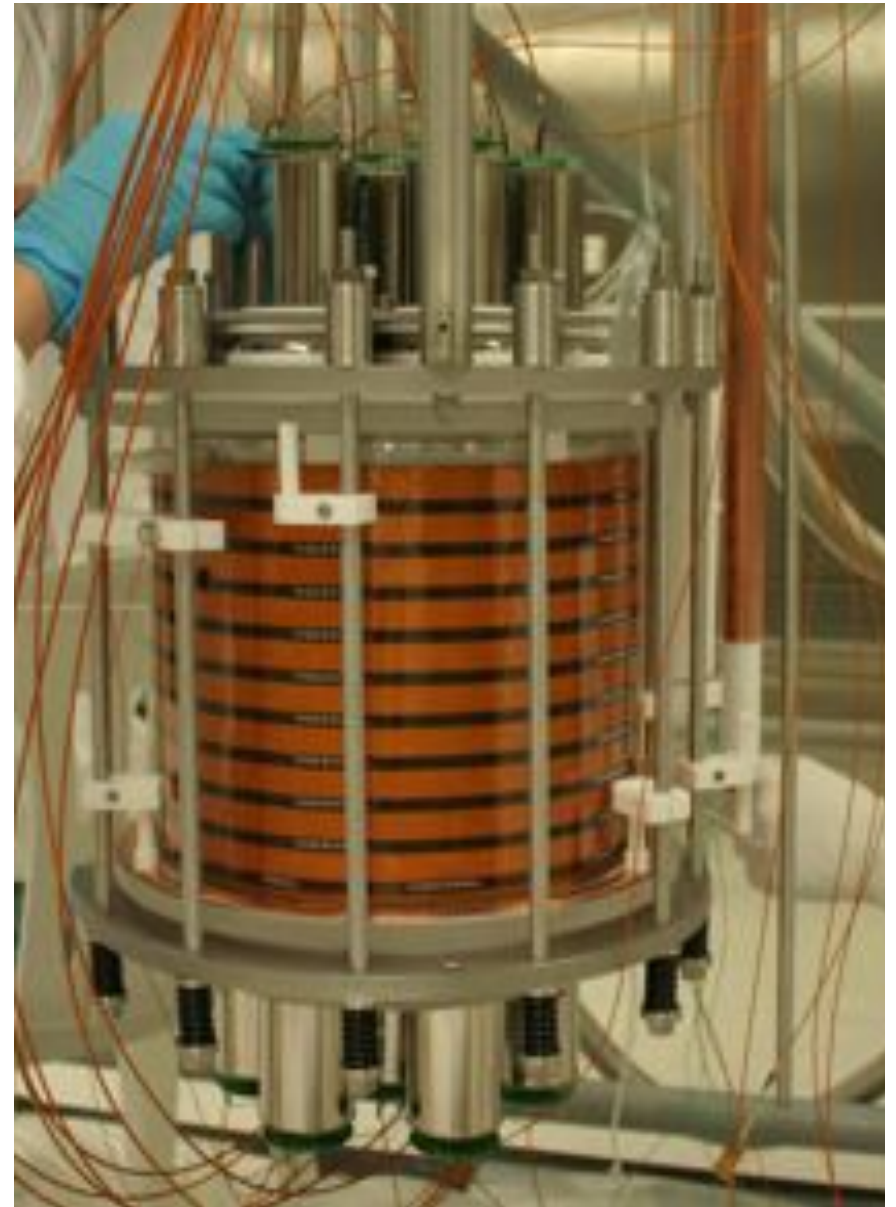
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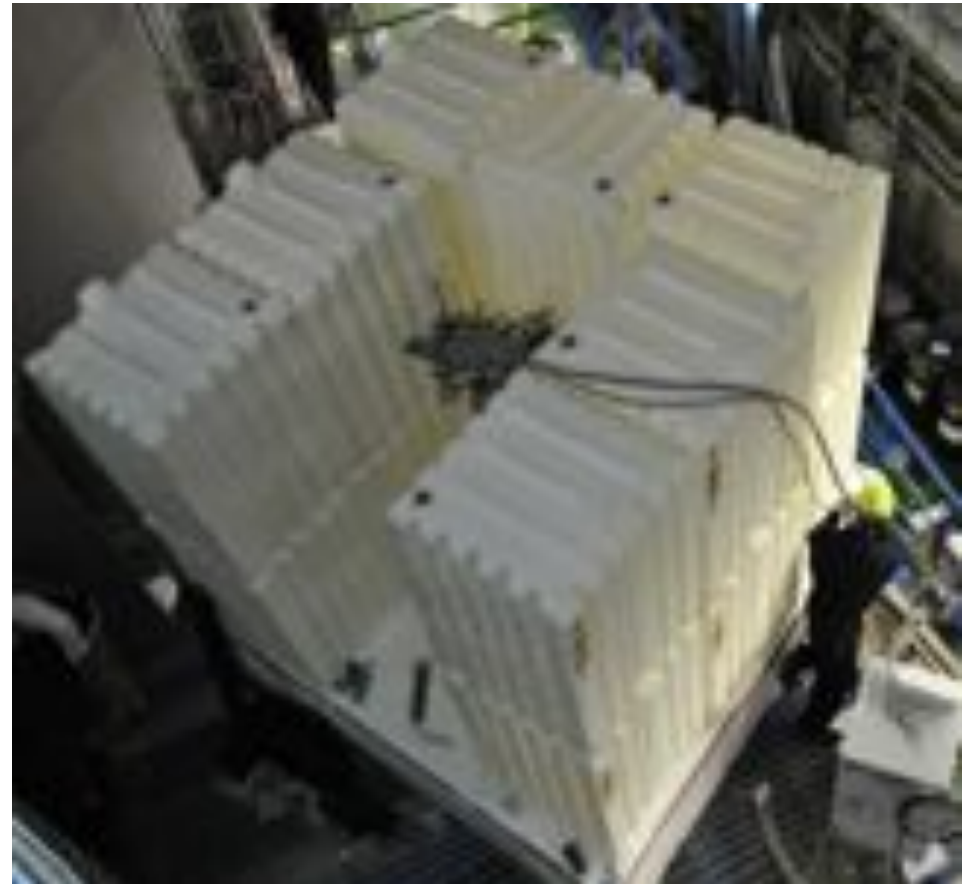
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- Water shielding to reduce background rate
- Study low background operation
  - Electron recoil rejection
  - Surface backgrounds
- Commissioning in progress!



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# Summary

- DarkSide designed to have very low, very well understood backgrounds
- DarkSide-10 operating at LNGS
- DarkSide-50 under construction
  - Designs mostly final, material screening underway
  - Deployment in late 2012
- Neutron veto will be large enough for a 5T detector
- DarkSide is well positioned to contribute to the continuing program of ever more sensitive experiments

