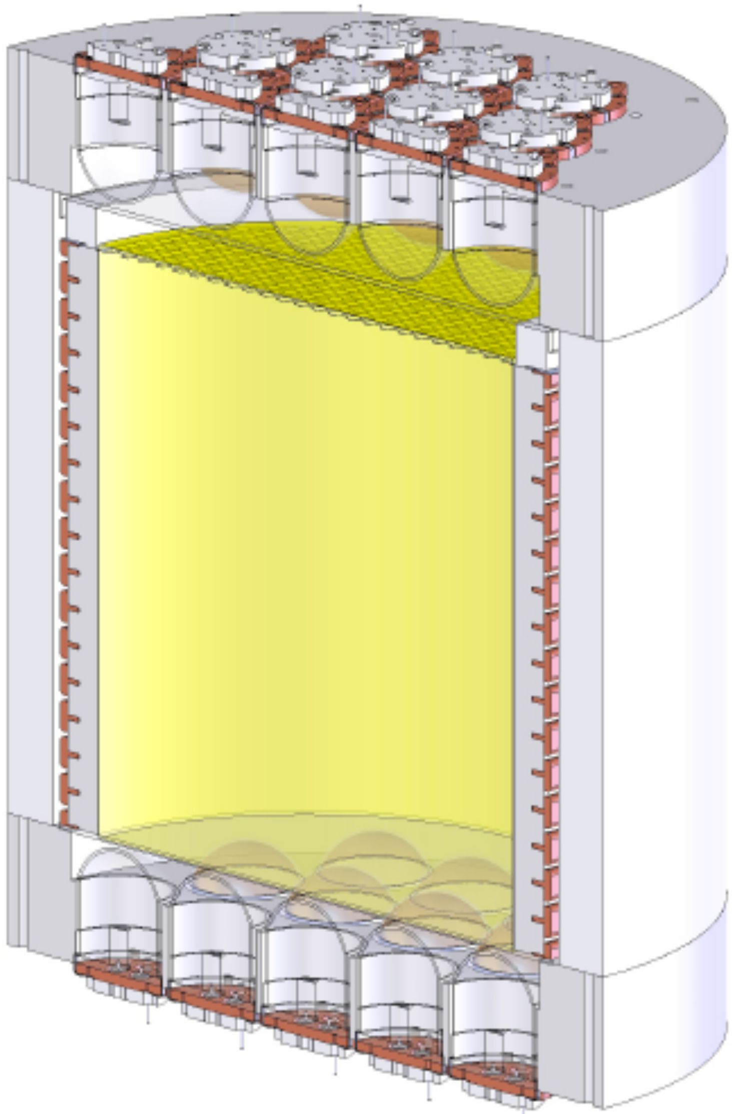
Alex Wright, for the DarkSide Collaboration
DPF 2011, 10 August 2011

The DarkSide Program at LNGS

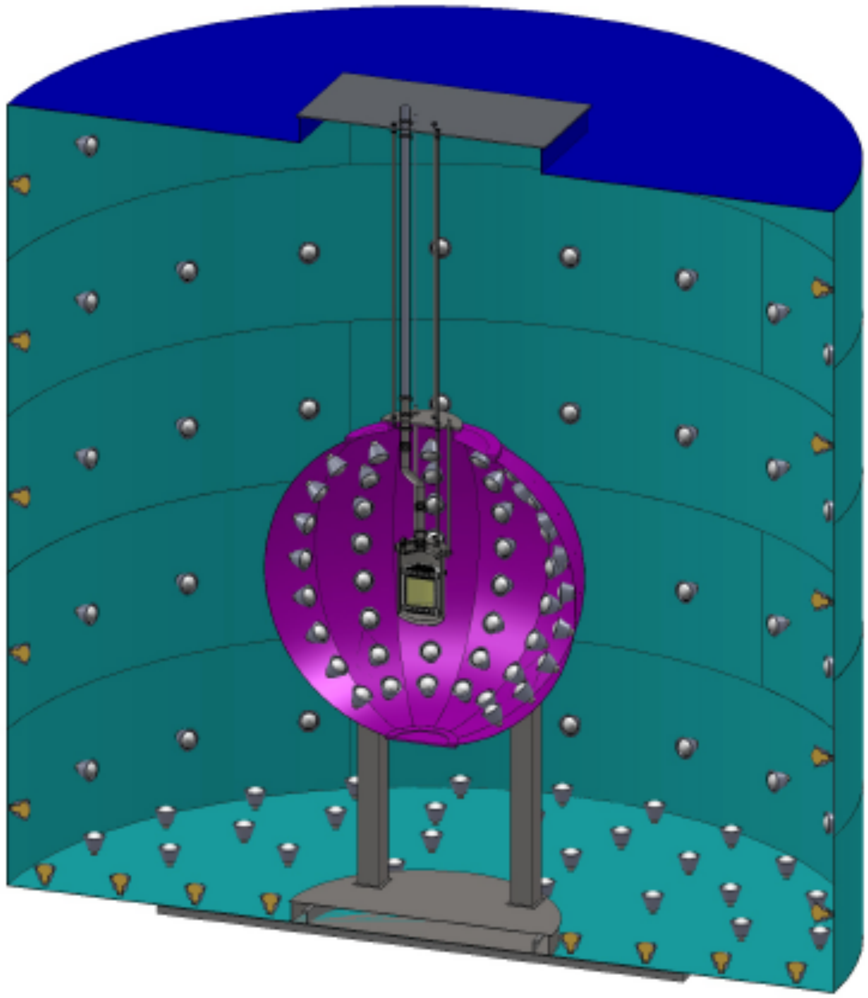
DarkSide

- 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^2 and 10^{-46} cm^2 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}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

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INFN Laboratori Nazionali del Gran Sasso – Assergi, Italy

INFN and Università degli Studi Genova, Italy

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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

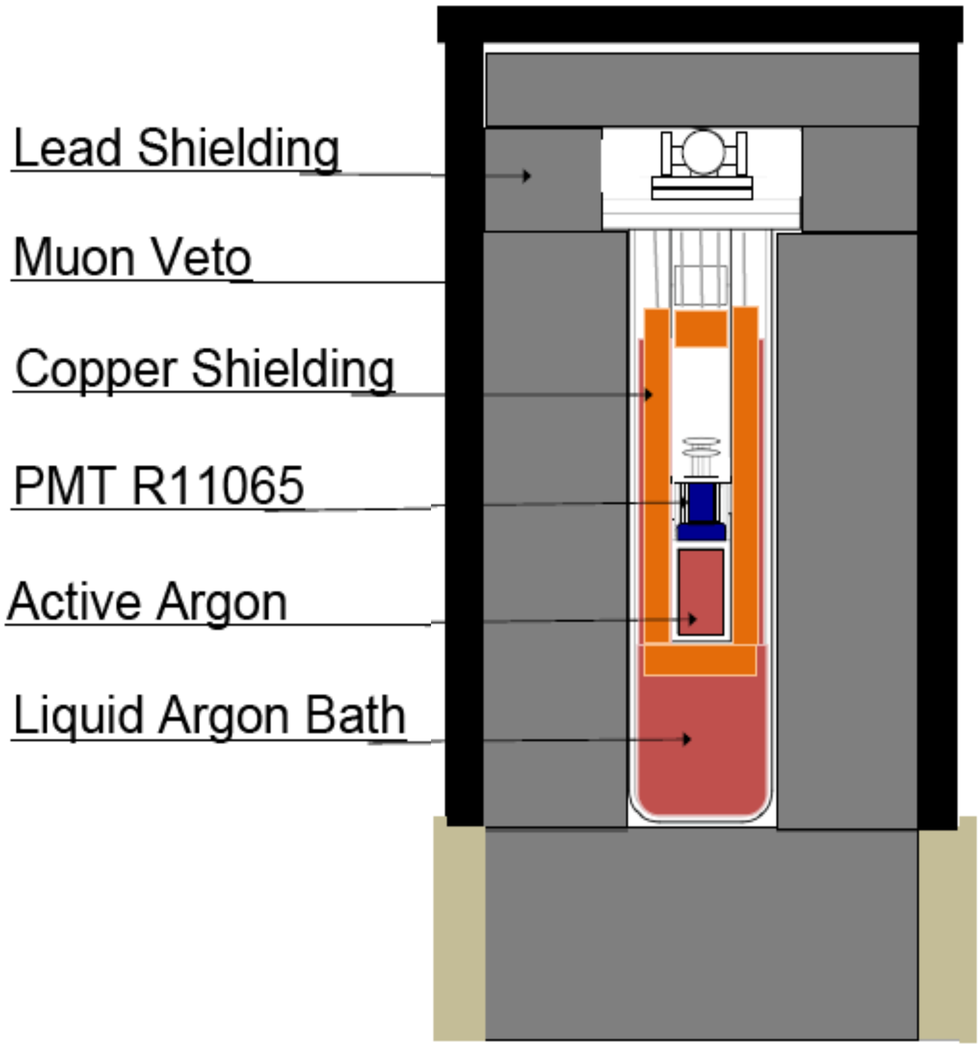
University of Massachusetts at Amherst, USA

Depleted Argon

- ^{39}Ar is produced by cosmic rays in the atmosphere
  - ~1 Bq/kg in commercial argon
- Underground argon is shielded, so contains less ^{39}Ar
- CO_2 from Kinder Morgan Doe Canyon Complex (Cortez, CO) contains ~600 ppm Argon
  - 3 tons Ar produced/day
- ~46 kg of argon collected so far

For details: NIM A **587**:46-51 (2008)

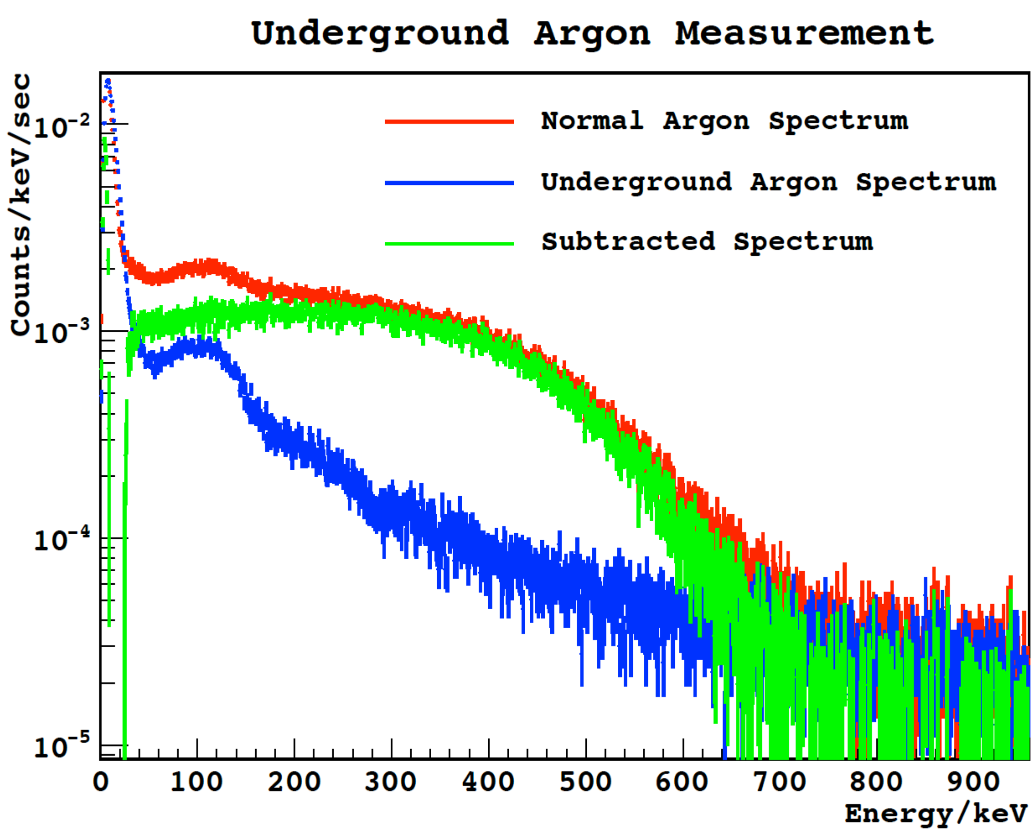
Depleted Argon Counting



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

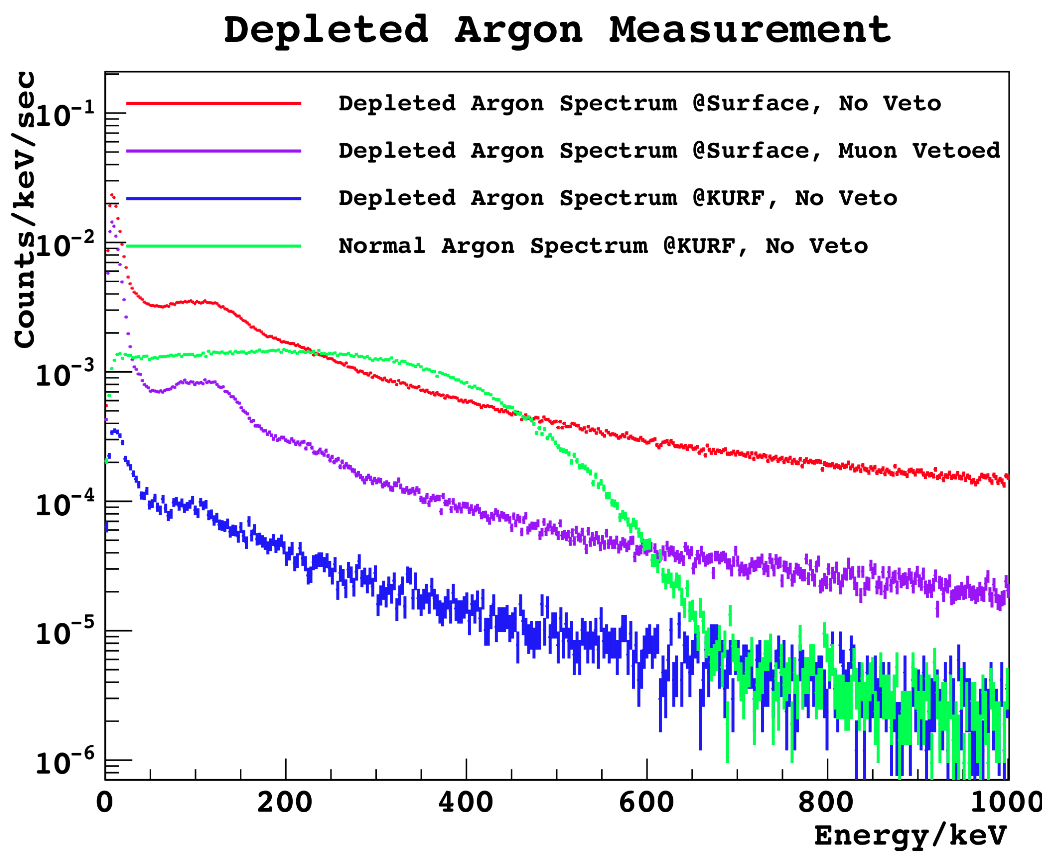
Depleted Argon Counting

- At Princeton, background in the ^{39}Ar region is 0.05 Bq in (200,800 keV)
- ^{39}Ar depletion factor of >10 from direct counting, >~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}Ar likely not the dominant source of electron recoils in DarkSide-50!

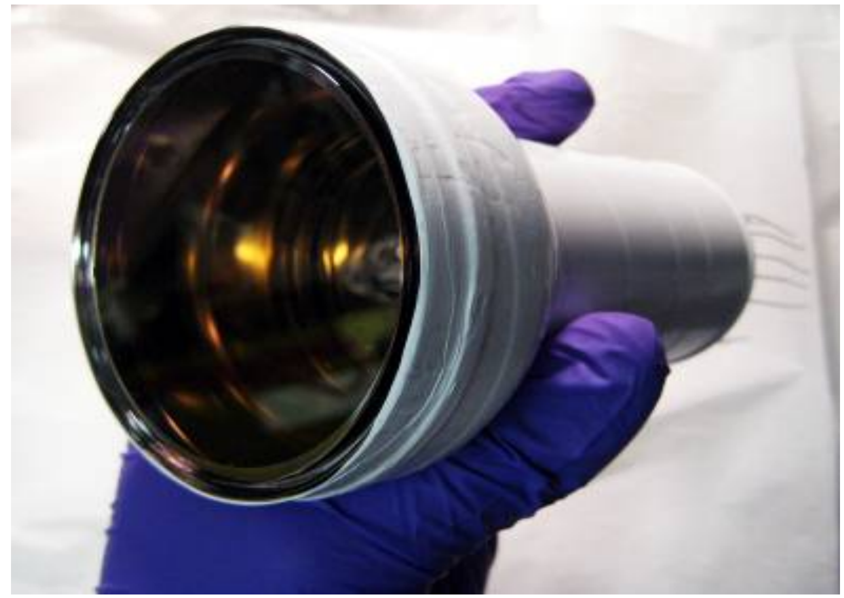
Low Background Photo-Detectors

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

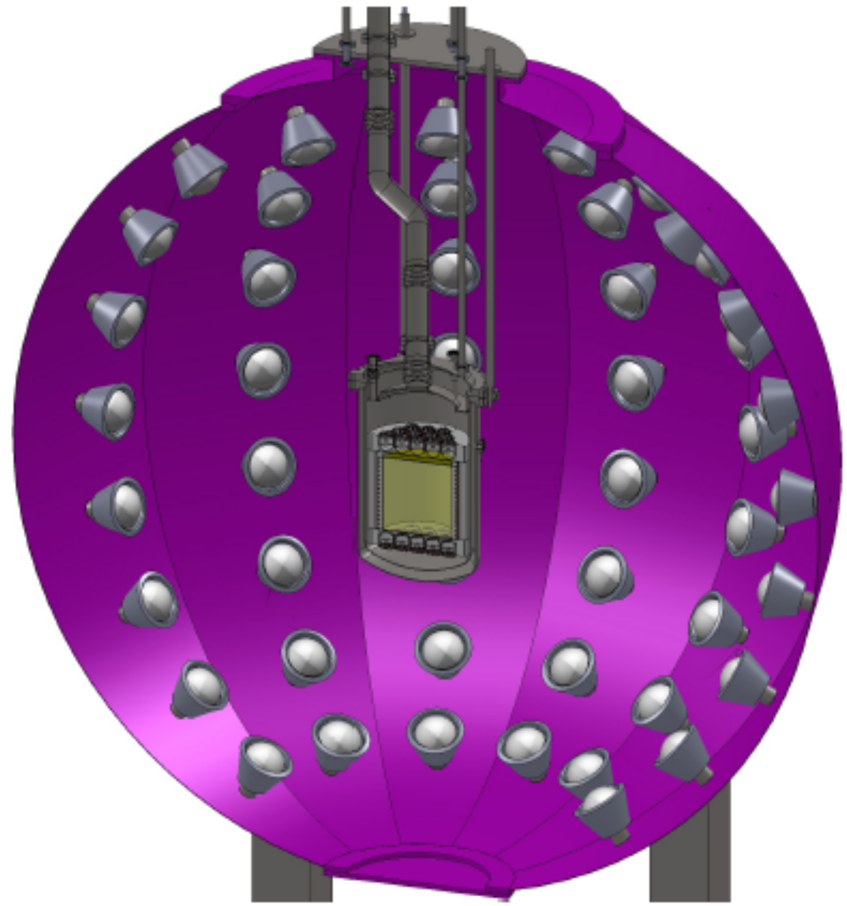
R11065 PMT



- 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

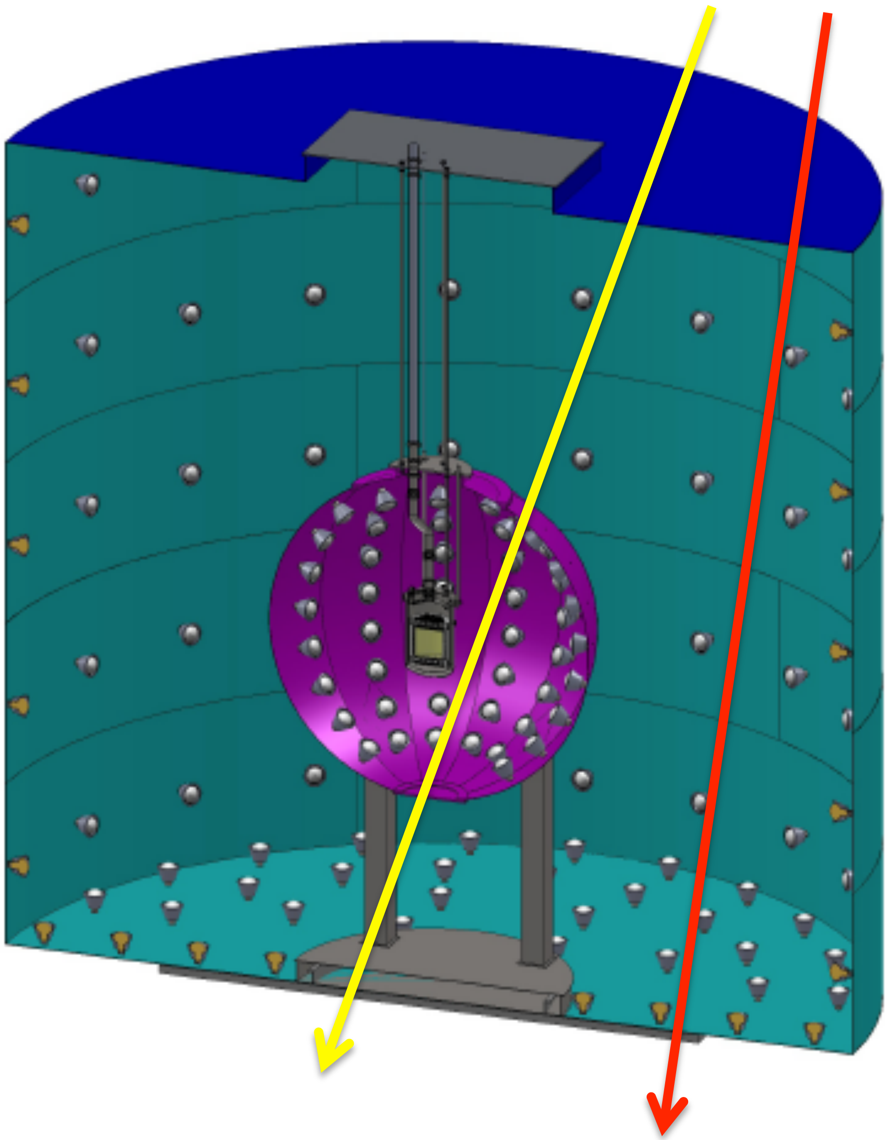
- Surround DarkSide with boron-loaded liquid scintillator
  - Fast neutron captures
  - Detect nuclear recoil products of neutron capture
- Efficiently detect escaping neutrons and veto any associated nuclear recoil backgrounds
  - >99.5% efficiency for radiogenic neutrons
  - >95% efficiency for cosmogenic 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 >>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
^{39}Ar (0.04 Bq/kg)	$<2.5\times10^{7}$	<0.016	–	–	–	–
Fused Silica	3.3×10^{4}	2.0×10^{-5}	0.17	4.3×10^{-4}	0.21	1.3×10^{-5}
PTFE	4,800	3.0×10^{-6}	0.39	9.8×10^{-4}	2.7	1.6×10^{-4}
Copper	4,500	2.8×10^{-6}	5.0×10^{-3}	1.3×10^{-5}	1.5	9.0×10^{-5}
R11065 PMTs	2.6×10^{6}	1.6×10^{-3}	19.4	4.8×10^{-2}	0.34	2.0×10^{-5}
QUPIDs (1 mBq)	7.0×10^{4}	4.2×10^{-5}	0.31	7.8×10^{-4}	0.34	2.0×10^{-5}
Stainless Steel	5.5×10^{4}	3.4×10^{-5}	2.5	6.3×10^{-3}	30	0.0018
Veto Scintillator	70	4.3×10^{-8}	0.030	7.5×10^{-5}	26	0.0016
Veto PMTs	2.5×10^{6}	1.6×10^{-3}	0.023	5.8×10^{-5}	–	–
Veto tank	1.7×10^{5}	1.1×10^{-4}	6.7×10^{-5}	1.7×10^{-7}	19	0.0071
Water	6,100	3.8×10^{-6}	6.7×10^{-4}	1.7×10^{-6}	19	0.0071
CTF tank	8,300	5.1×10^{-6}	3.5×10^{-3}	8.7×10^{-6}	0.068	2.6×10^{-5}
LNGS Rock	920	5.7×10^{-7}	0.061	1.5×10^{-4}	0.31	0.012
Total	–	0.019 (0.017)	–	0.055 (0.008)	–	0.030 (0.030)

Surface Backgrounds	
Raw	After cuts
4.5 x 10^{3}	<0.01

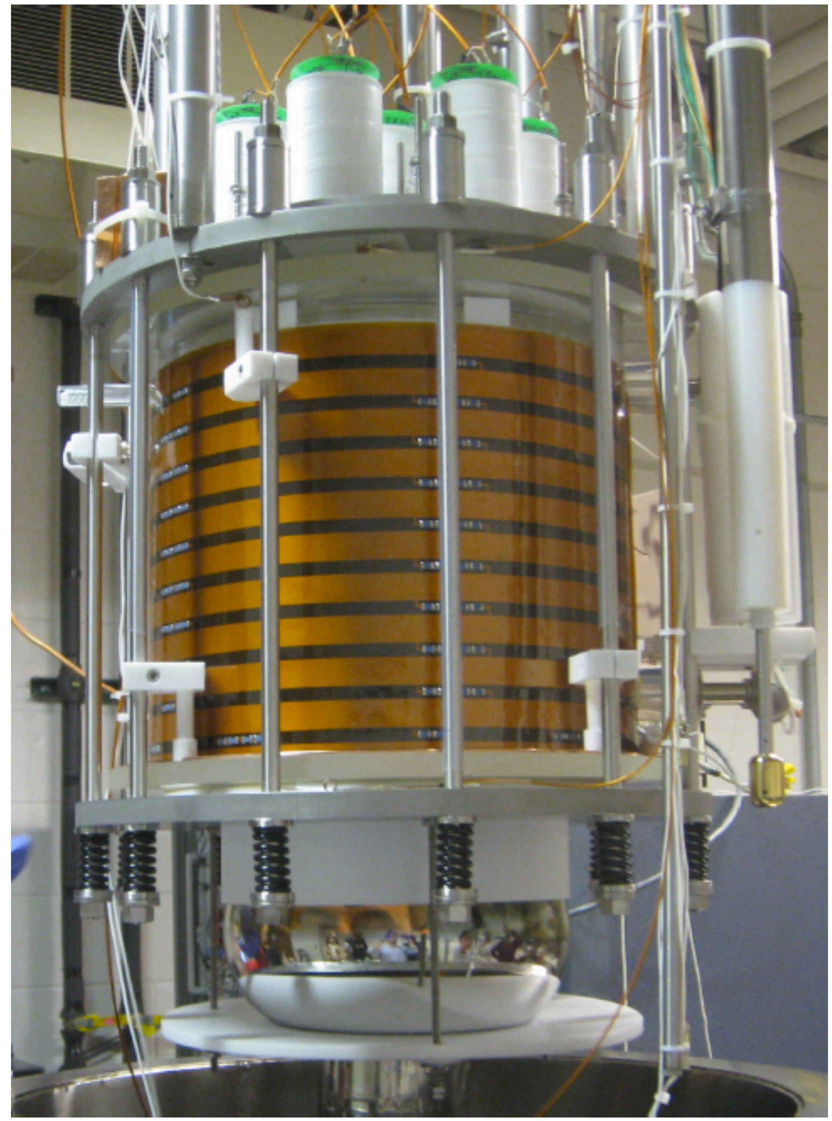
Very conservative estimates: DarkSide should demonstrate background free ton-yr exposures!

Demonstrating Discrimination Power

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

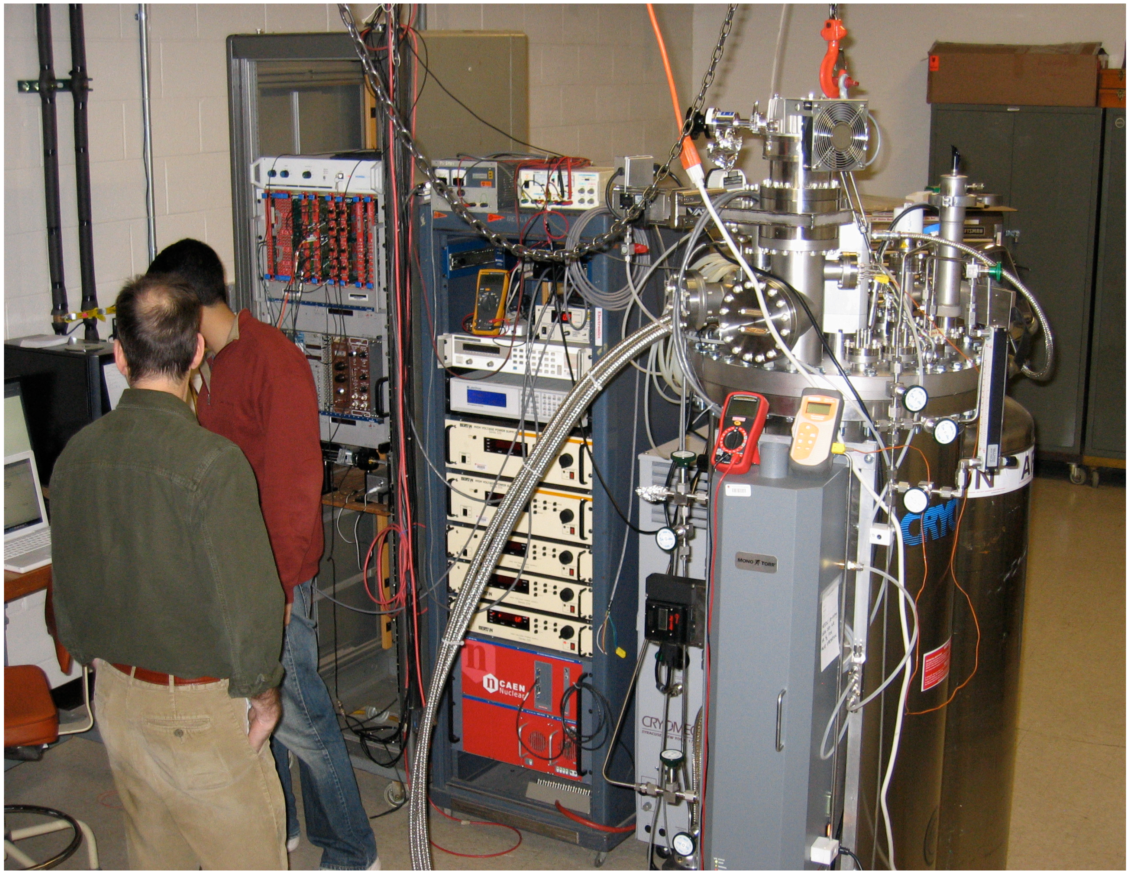
10 kg Prototype

- 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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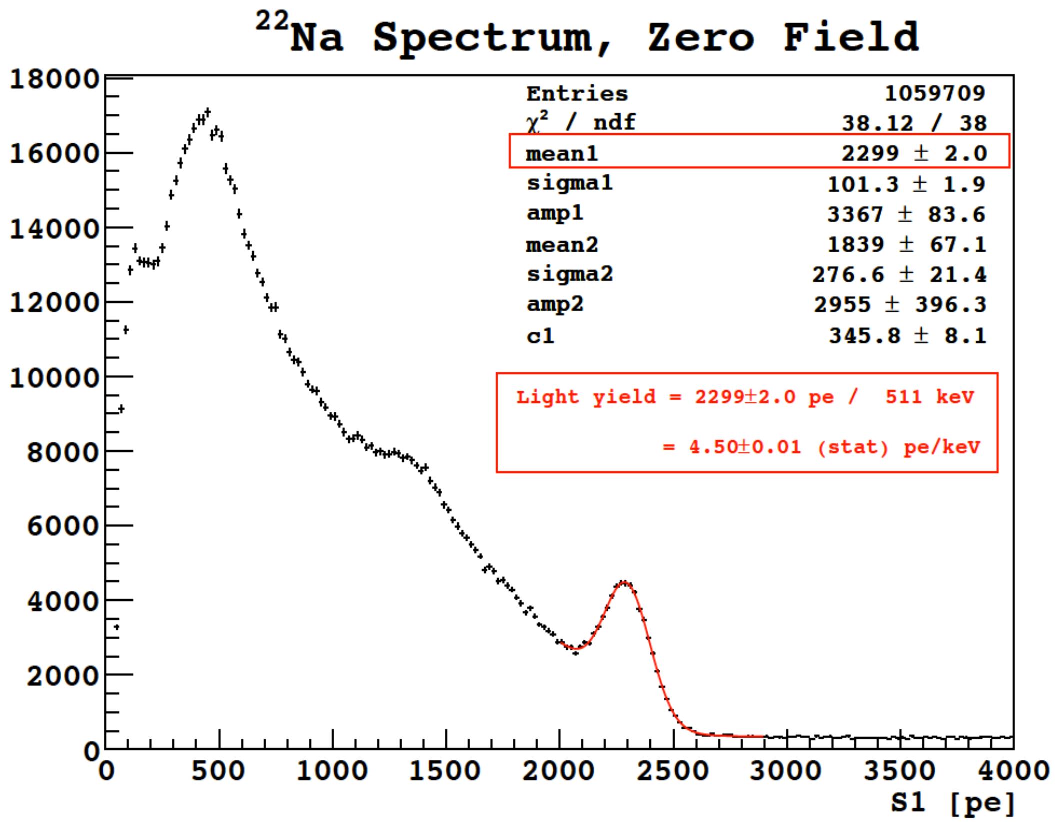

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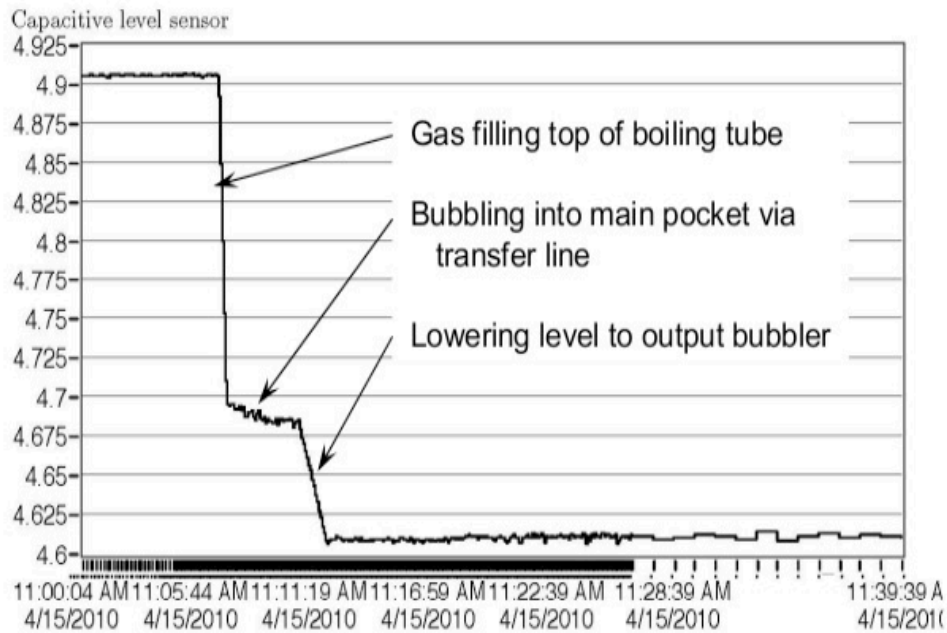

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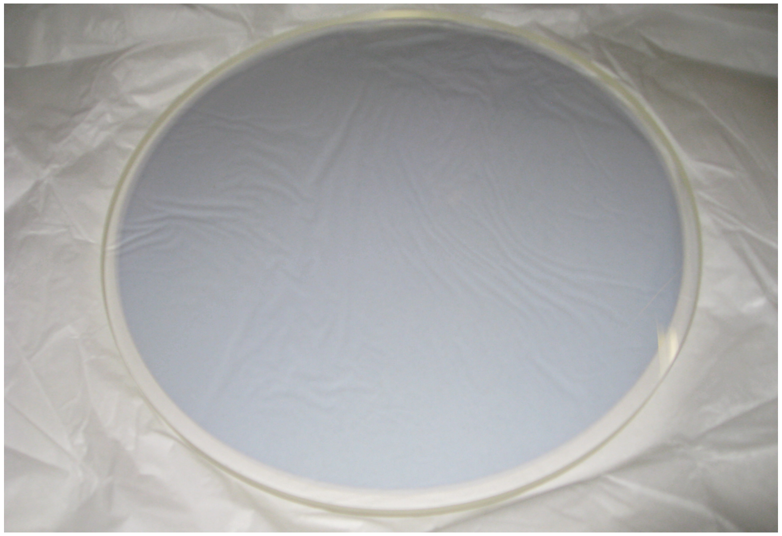

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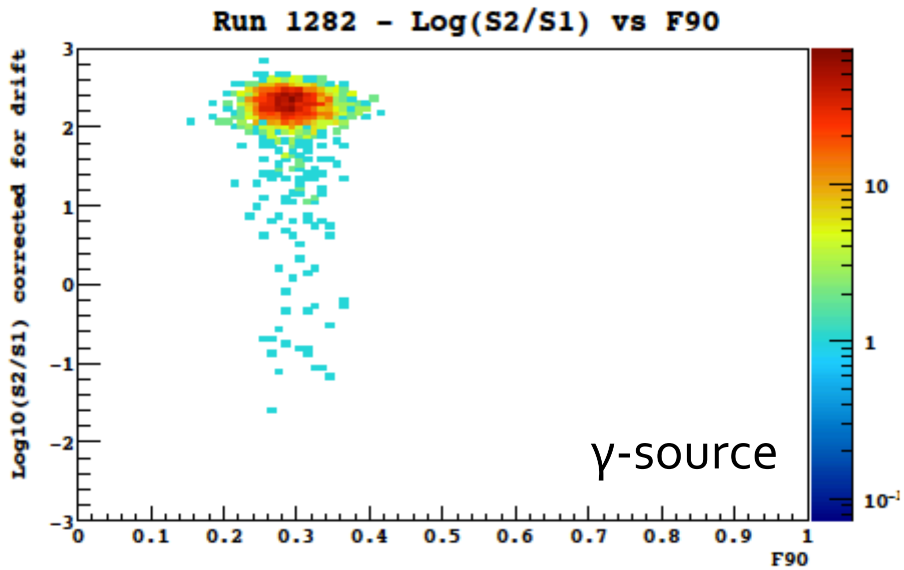
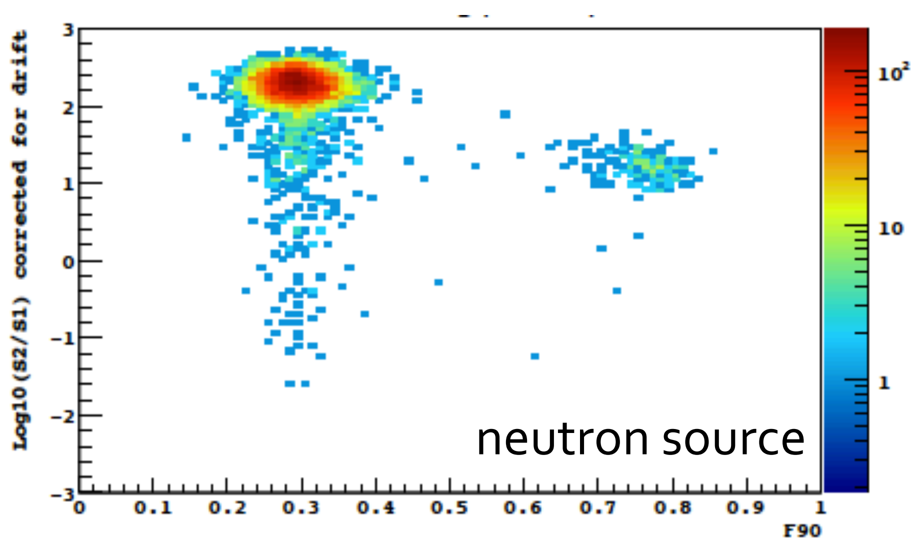
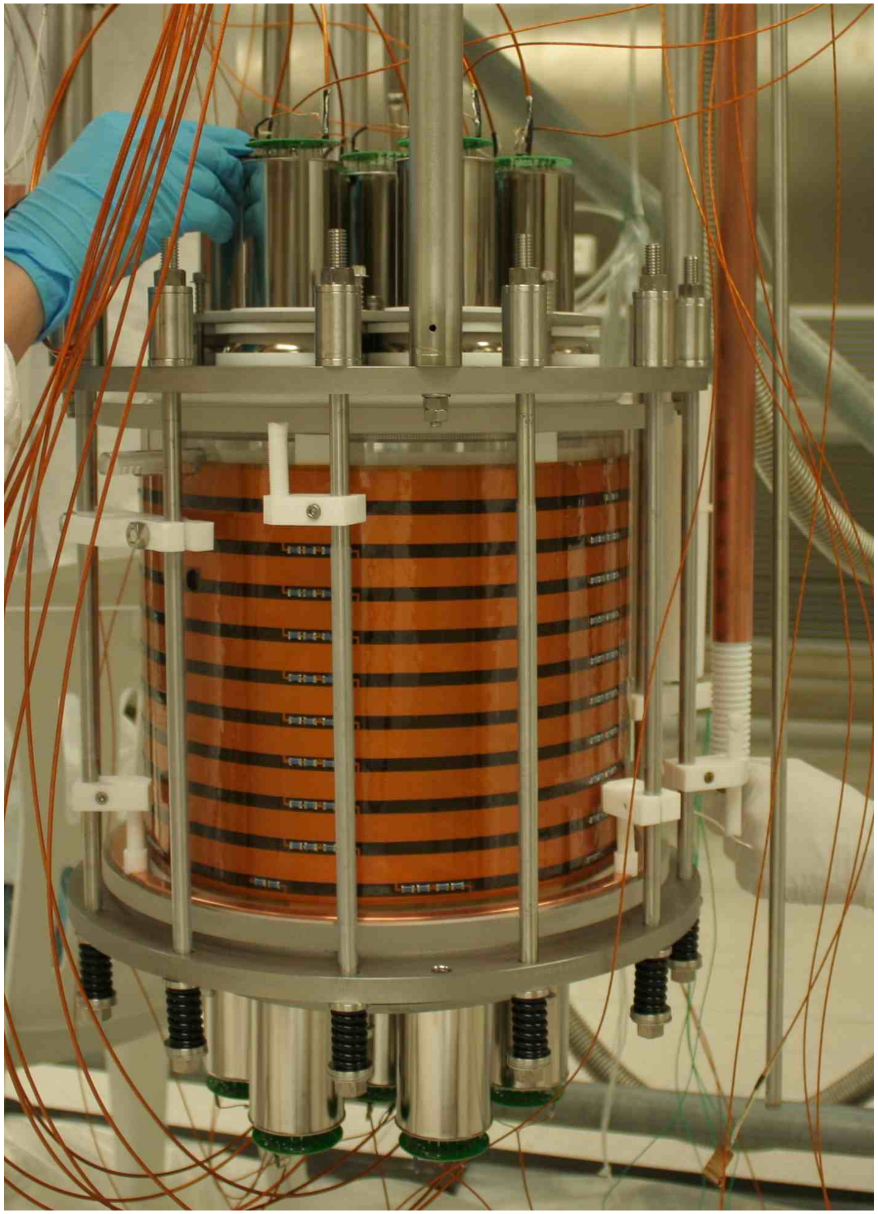




DarkSide-10 at LNGS

- DarkSide-10 upgraded, moved to LNGS
- Water shielding to reduce background rate
- Study low background operation
  - Electron recoil rejection
  - Surface backgrounds
- Commissioning in progress!



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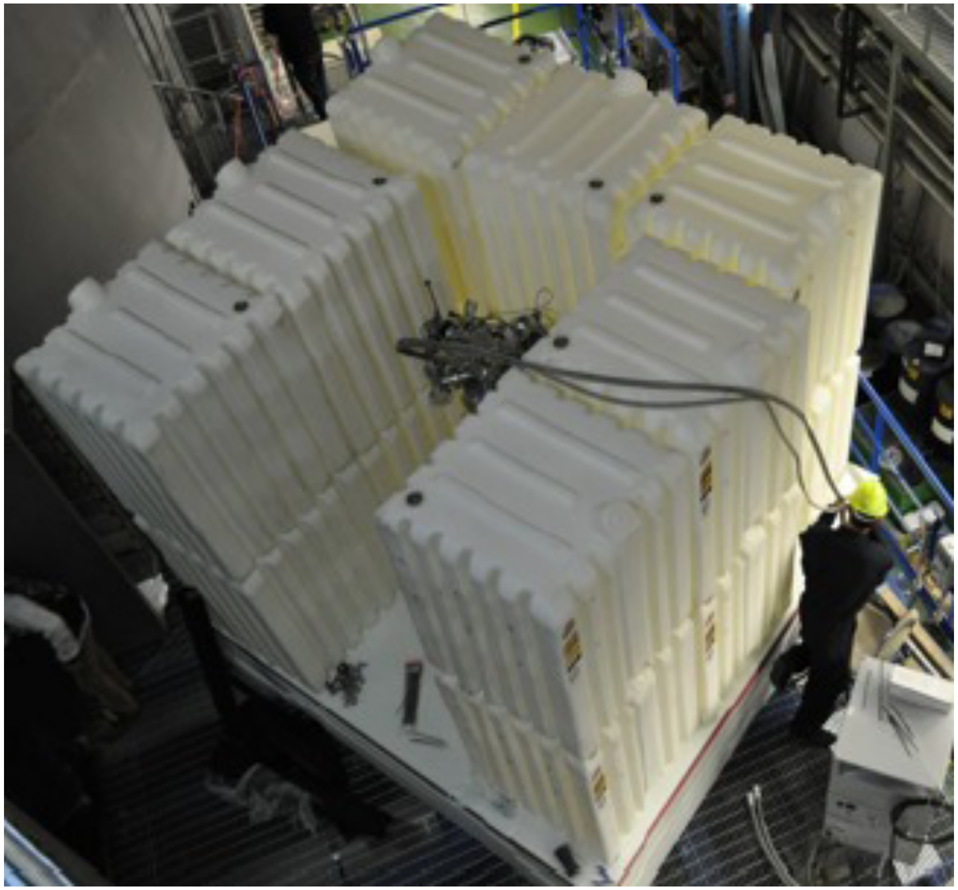

Summary

- 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