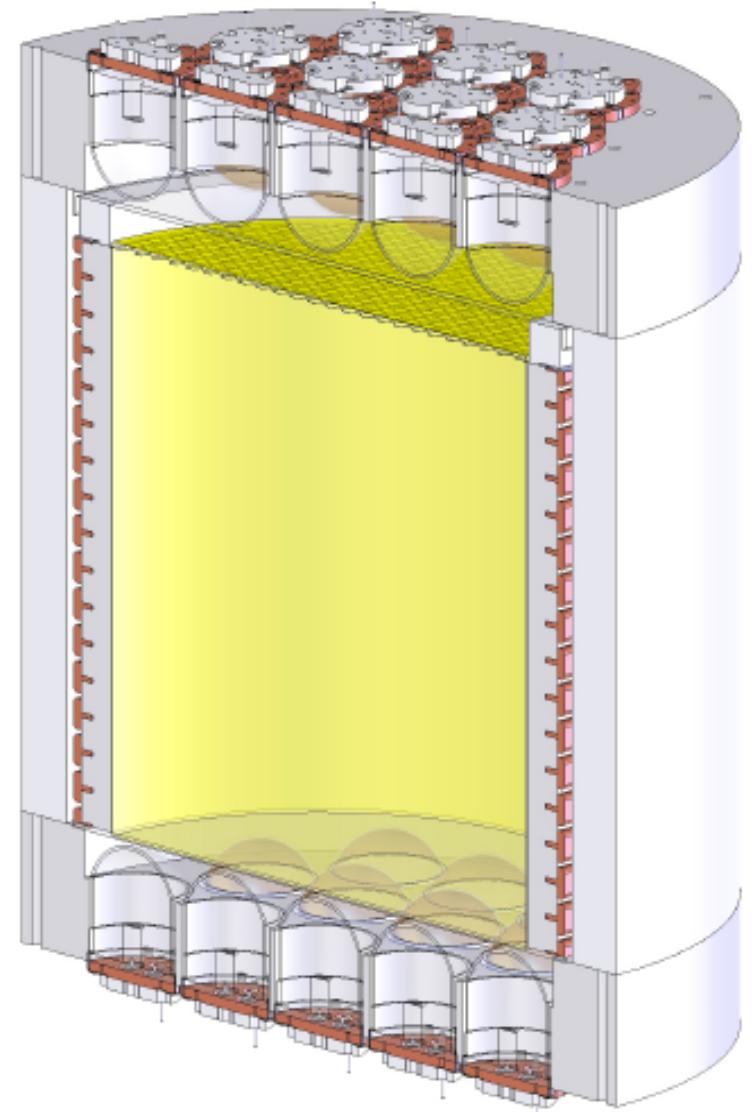


Alex Wright, for the DarkSide Collaboration
ICATPP 2011, 6 October 2011

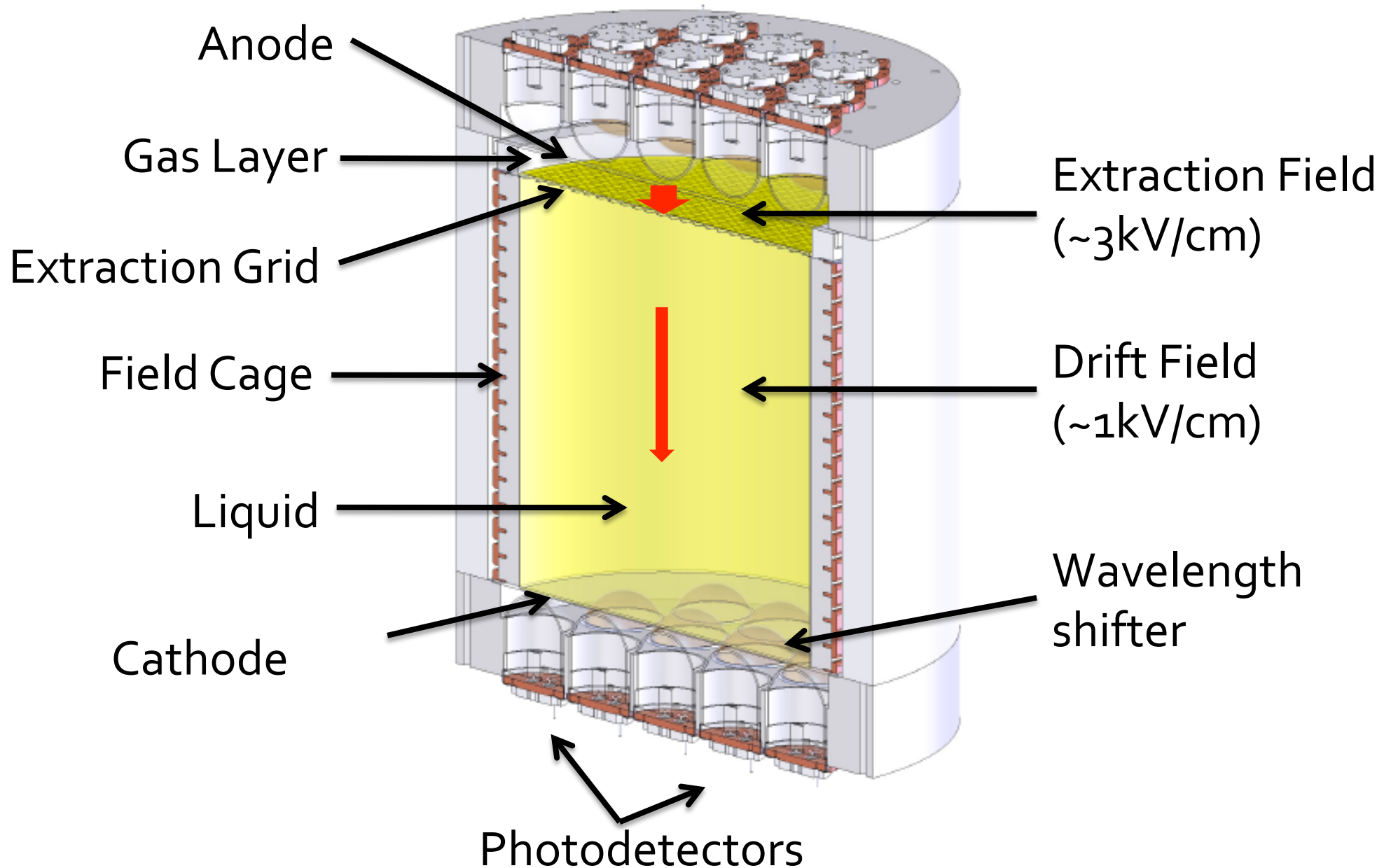
The DarkSide Program at LNGS

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*

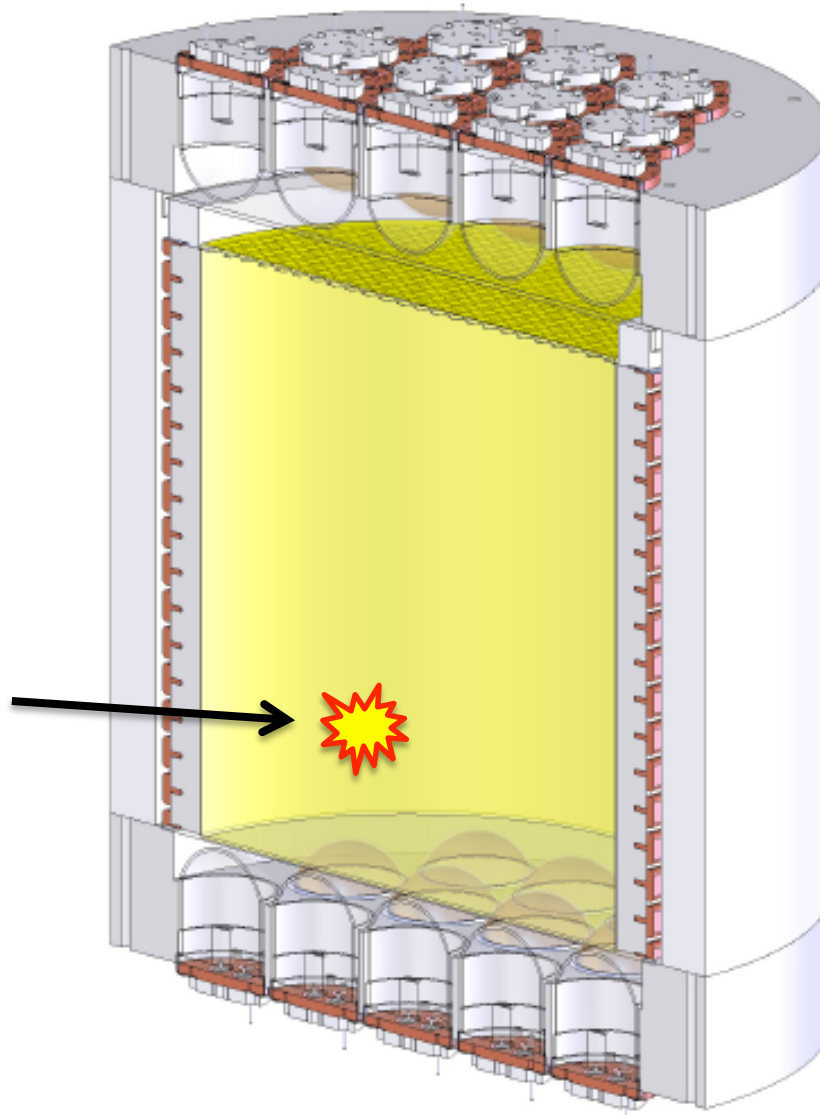


2-Phase Argon TPC

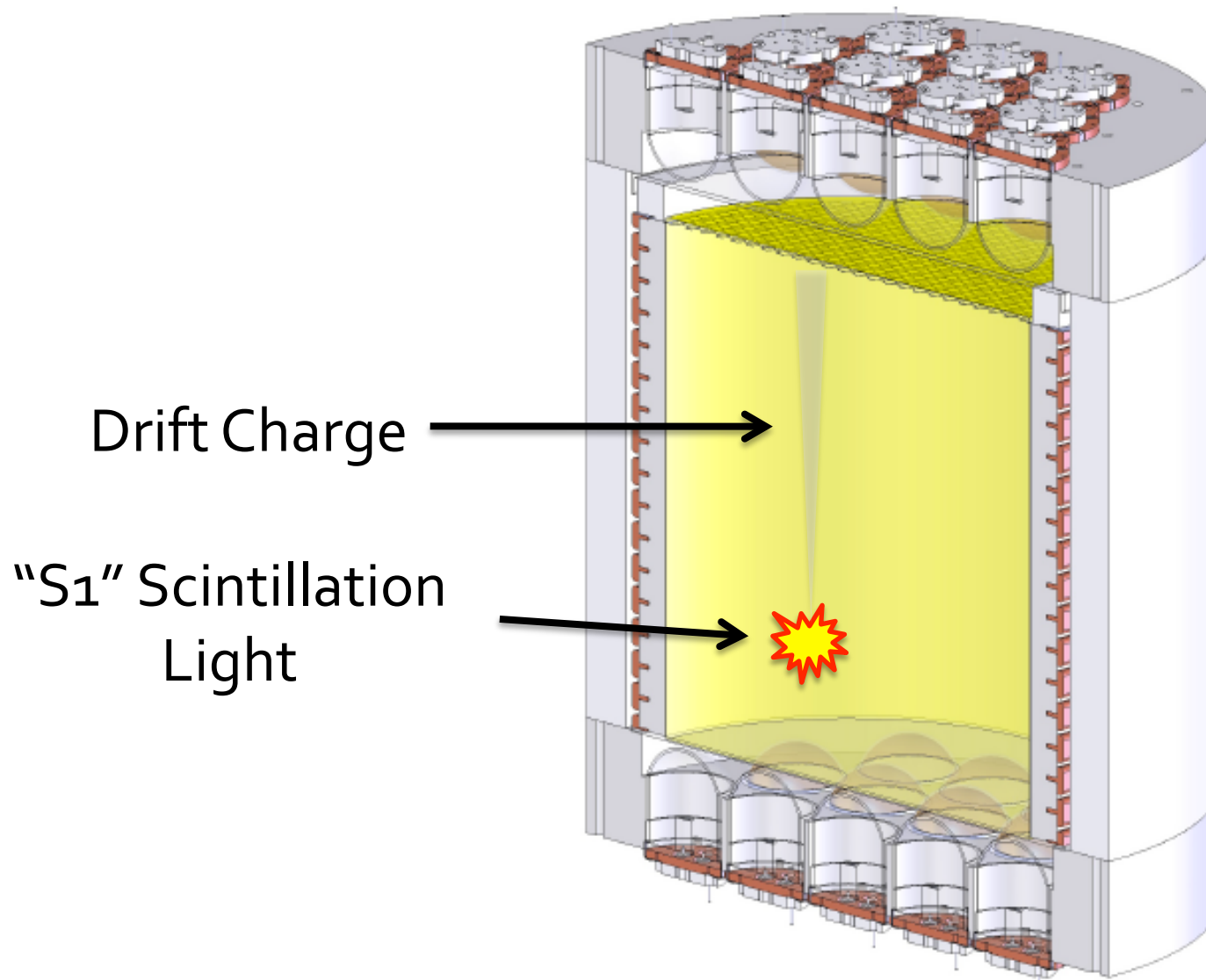


Two Phase Argon TPC

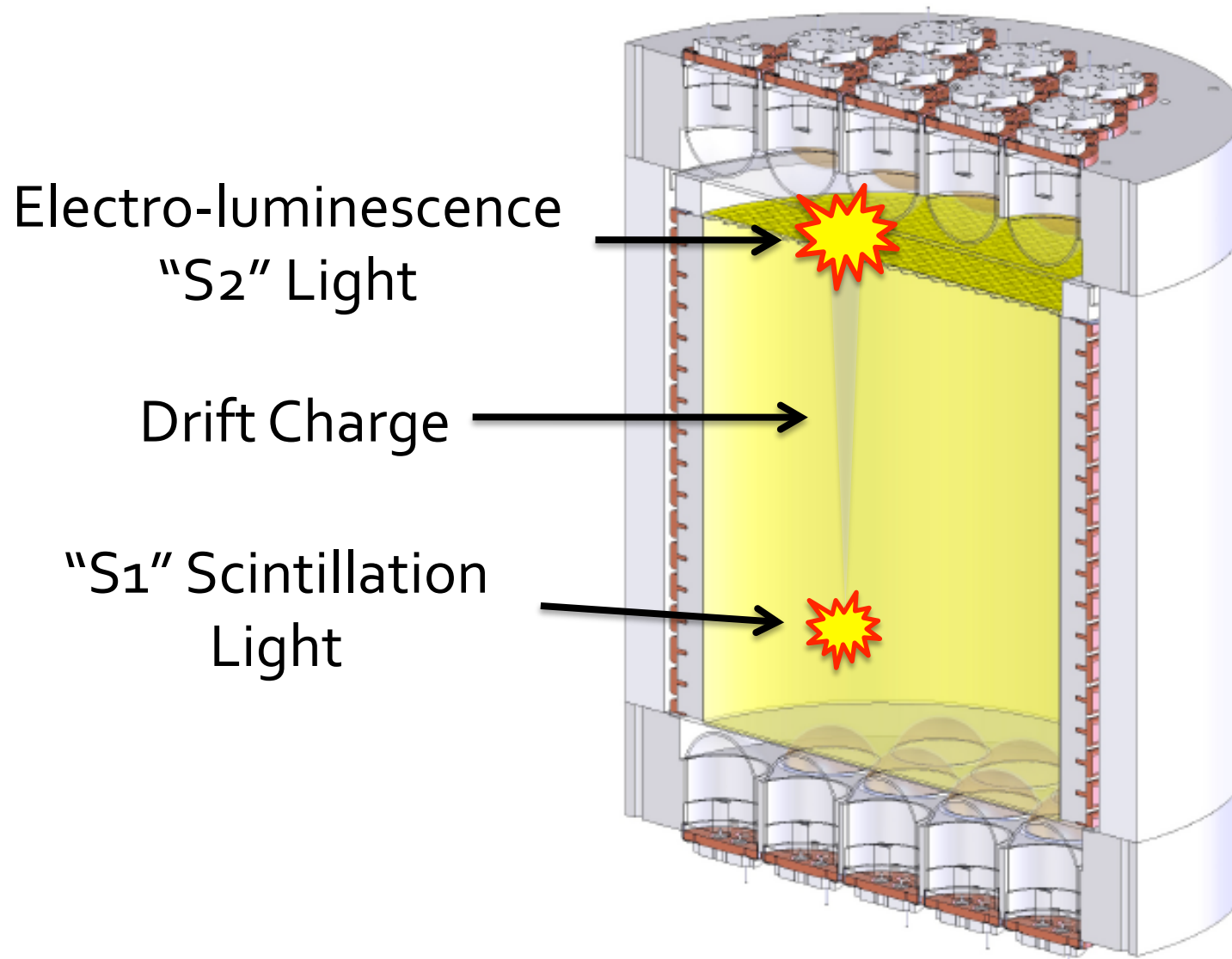
"S₁" Scintillation
Light



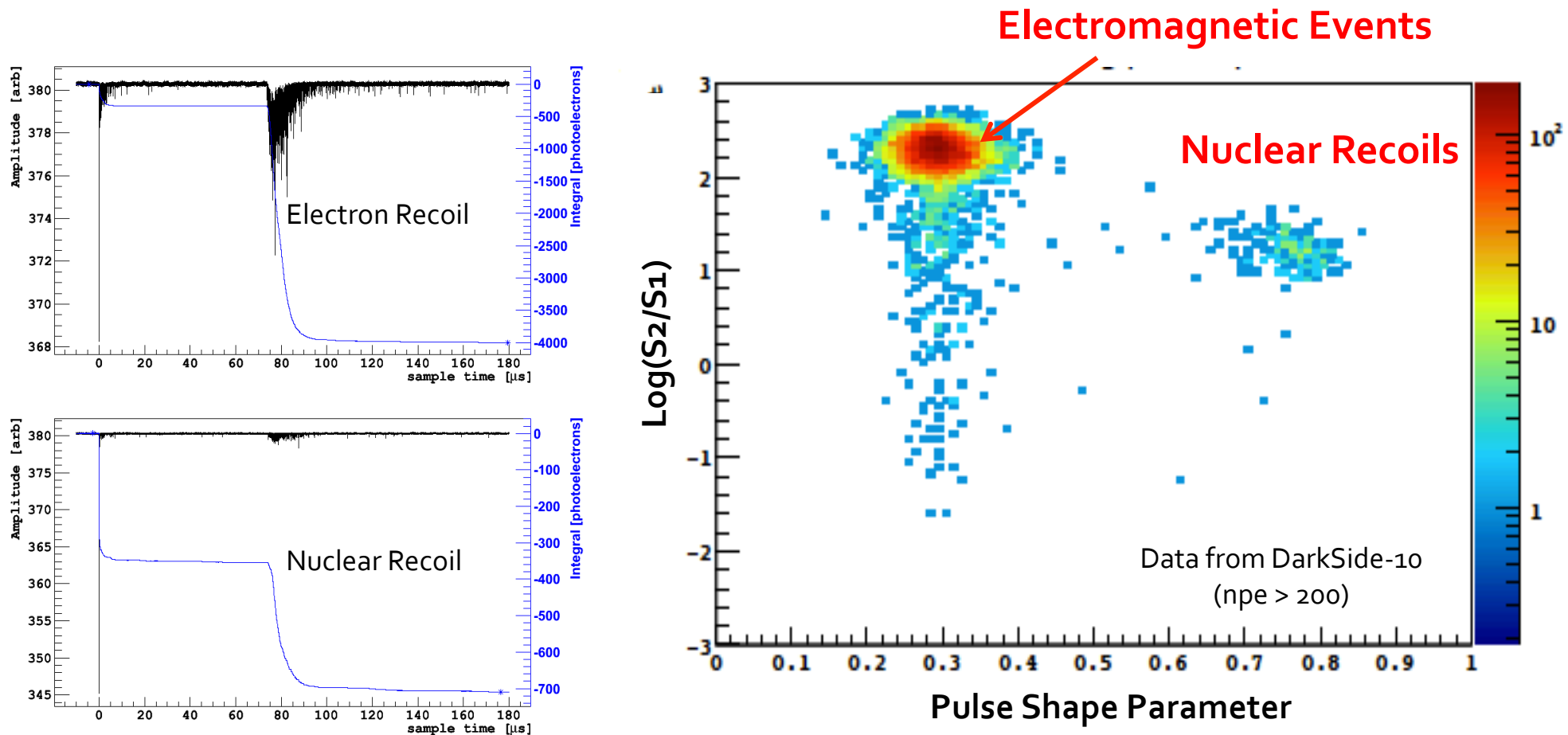
Two Phase Argon TPC



Two Phase Argon TPC

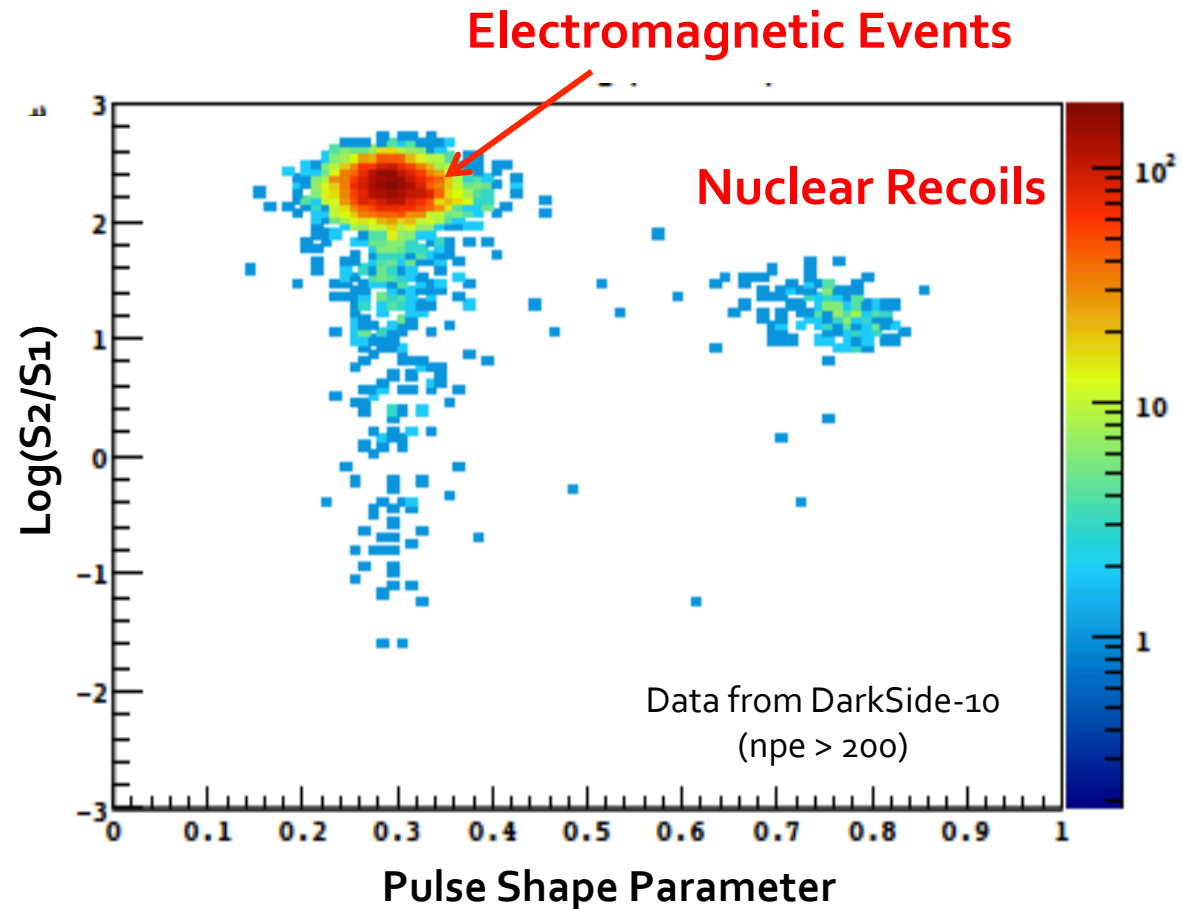
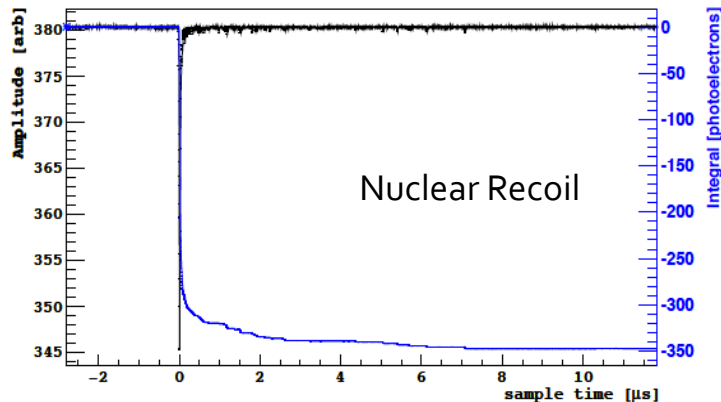
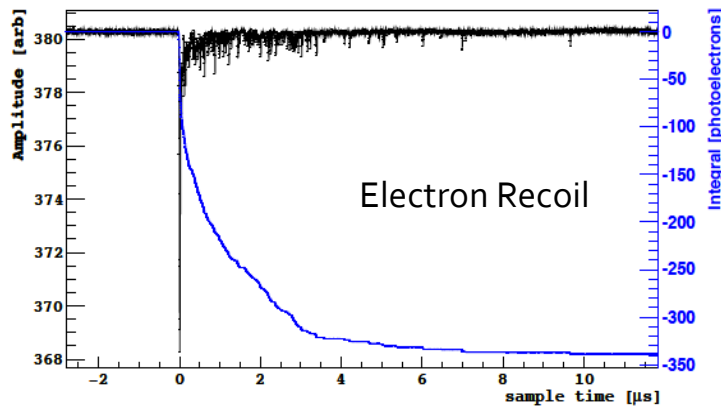


"S₂/S₁" Electron Recoil Discrimination



- The recombination probability (and hence the ratio of S₂/S₁ light) also depends on ionization density
➔ 10²-10³ discrimination

"S₁" Electron Recoil Discrimination



- The ratio of light from singlet (~ 7 ns decay time) and triplet ($1.6 \mu\text{s}$ decay time) depends on ionization density
 - ➡ $>10^8$ additional discrimination from pulse shape
 - ➡ $>10^{10}$ total electron recoil rejection in 2-phase argon!

Depleted Argon

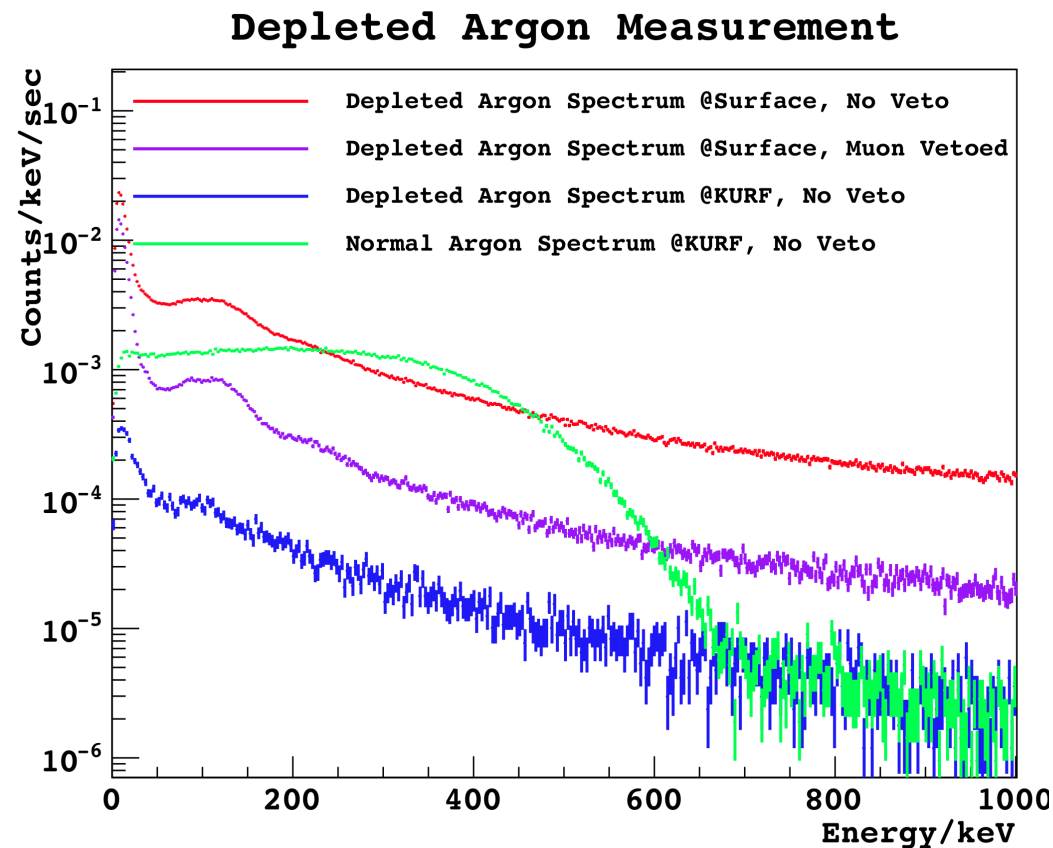
- ^{39}Ar is produced by cosmic rays in the atmosphere
 - ~1 Bq/kg in commercial argon
- Underground argon is shielded, so contains less ^{39}Ar
- CO_2 from Kinder Morgan Doe Canyon Complex (Cortez, CO) contains ~600 ppm Argon
 - 3 tons Ar produced/day
- ~62 kg of argon collected so far



For details: NIM A **587**:46-51 (2008),
AIP Conf. Proc. 1338:217-220 (2011)

Depleted Argon

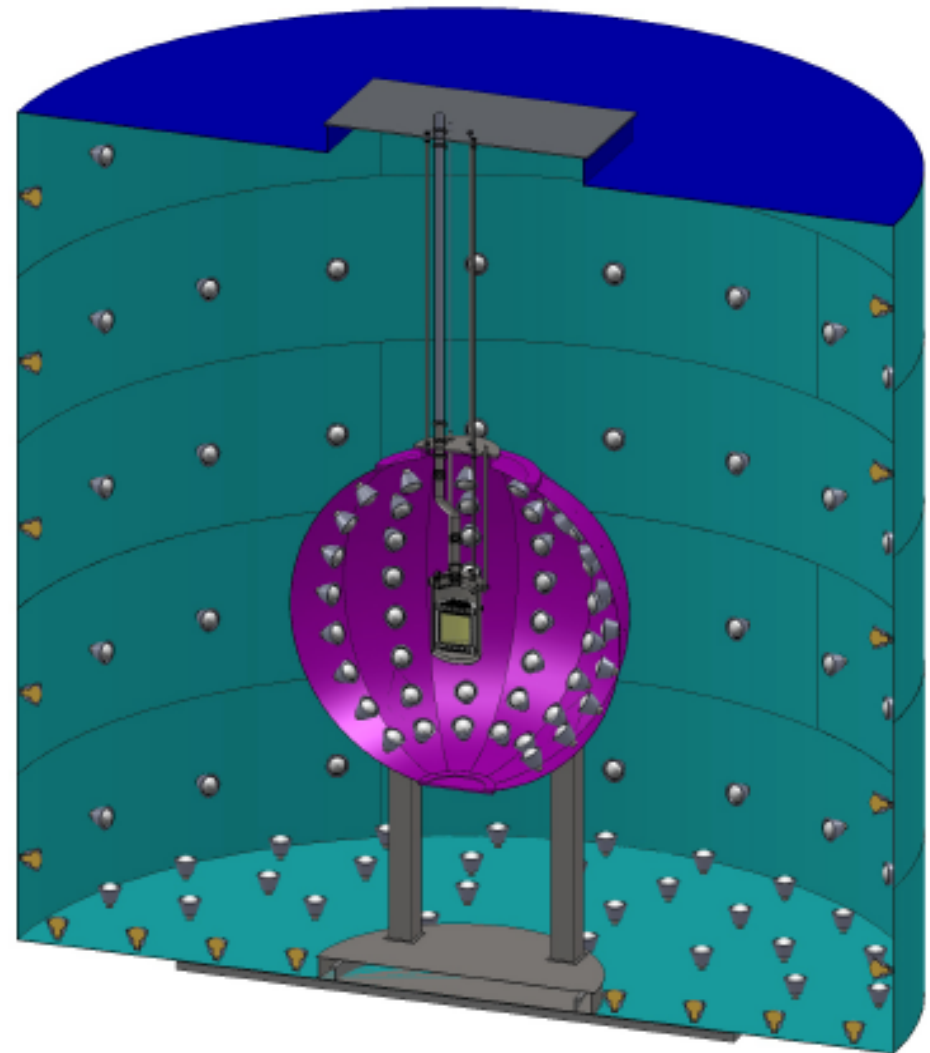
- Measure residual ^{39}Ar using dedicated liquid phase detector
- At KURF (1400 m.w.e.) background reduced to 0.002 Bq in 300-400 keV
- ^{39}Ar depletion factor >50



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

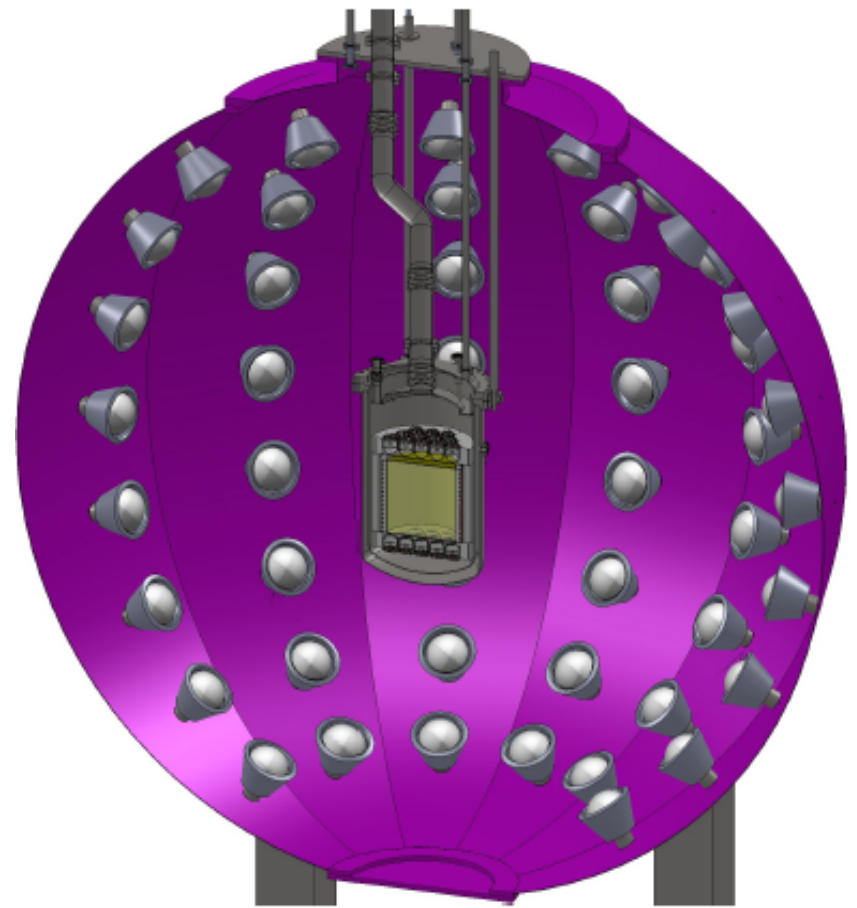
DarkSide Background Strategy

- Depleted argon and other novel technologies give very low background levels
- Further suppress backgrounds and assay them *in situ* using active background suppression techniques



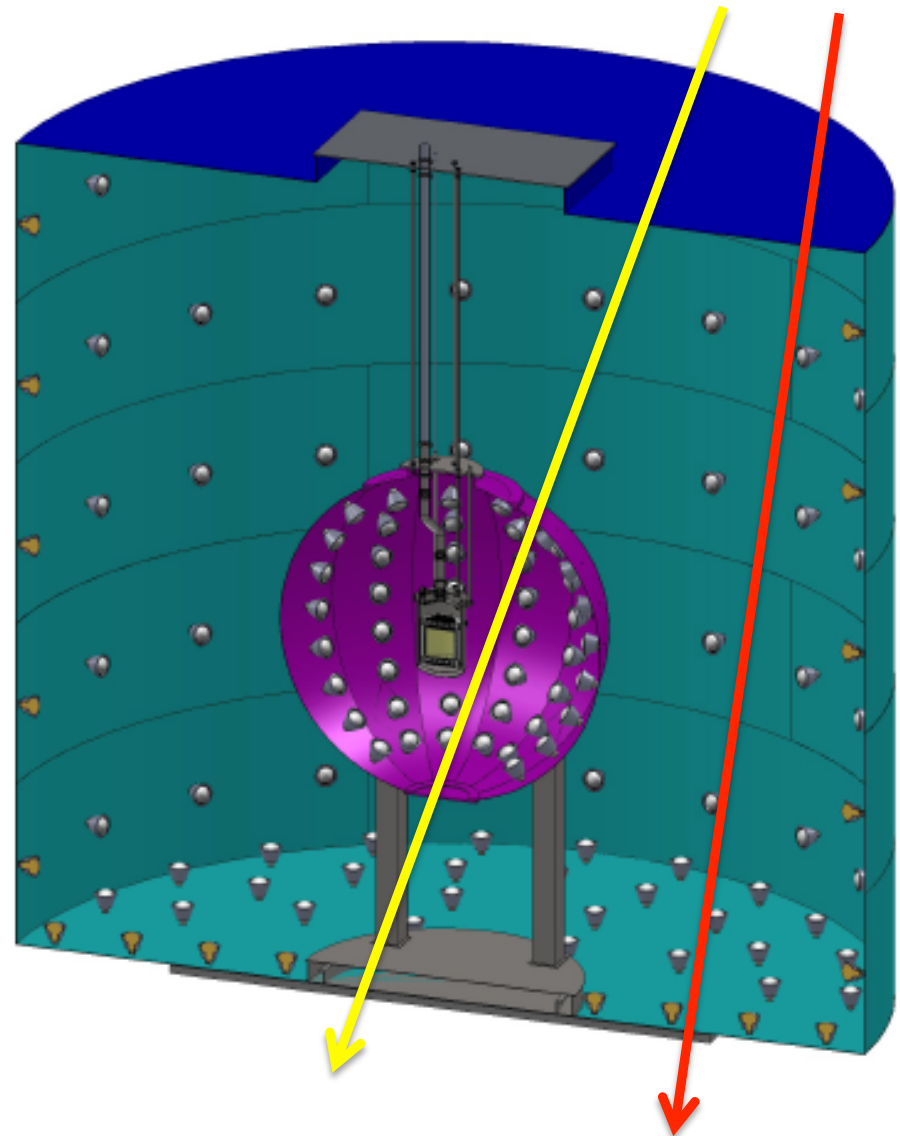
Highly-Efficient Neutron Veto

- 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



Cosmogenic Veto

- Install DarkSide in the Borexino CTF tank in LNGS, Italy
- 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
^{39}Ar (0.04 Bq/kg)	$<2.5 \times 10^7$	<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
4.5×10^3	<0.01

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

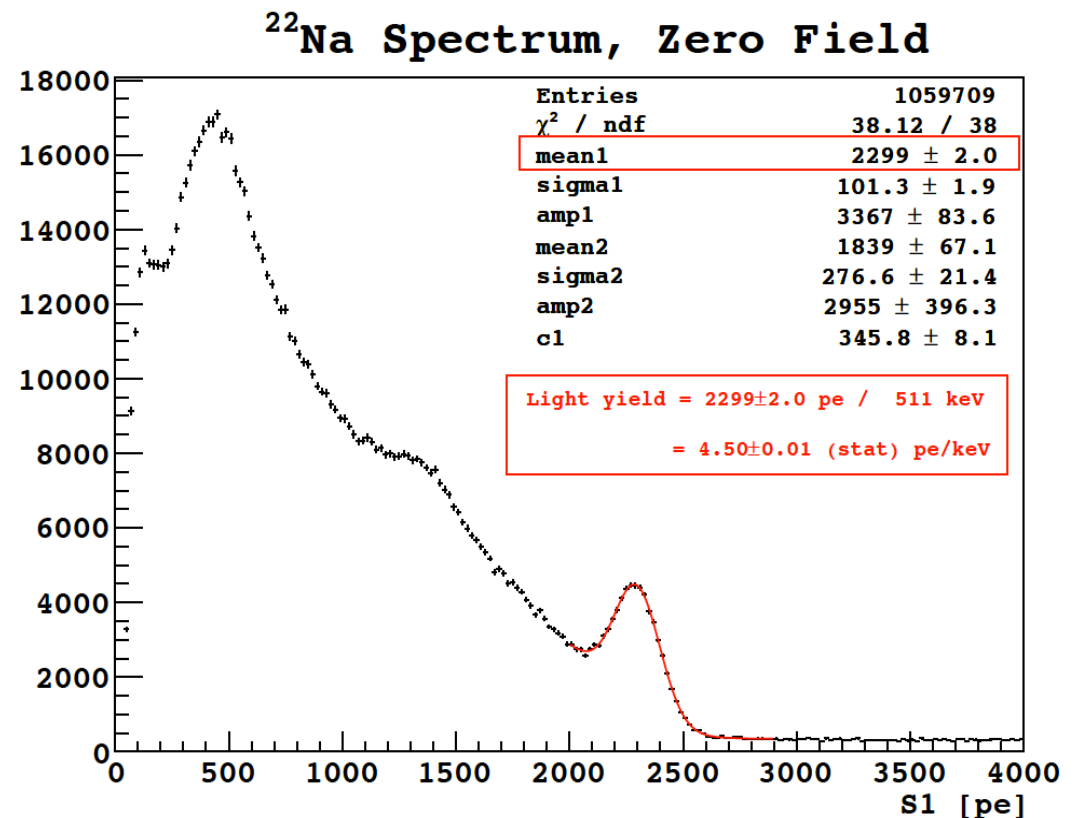
10 kg Prototype

- 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



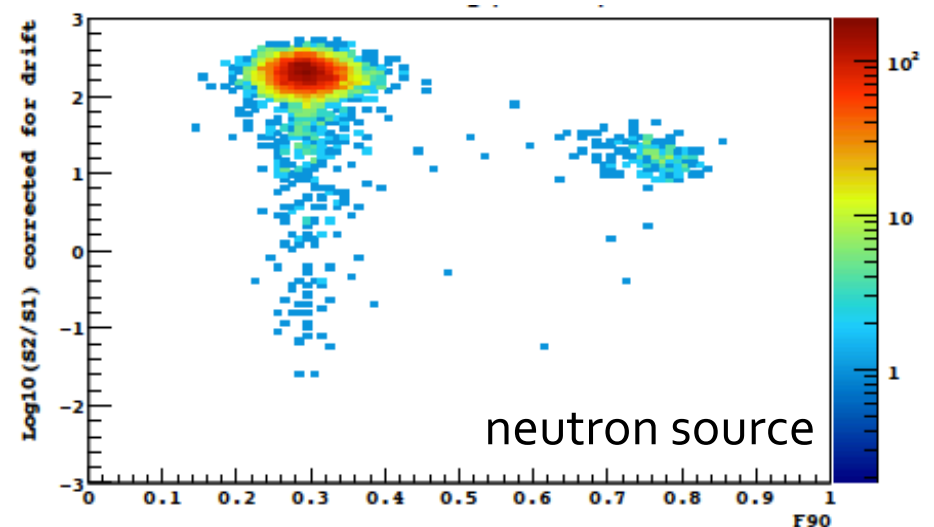
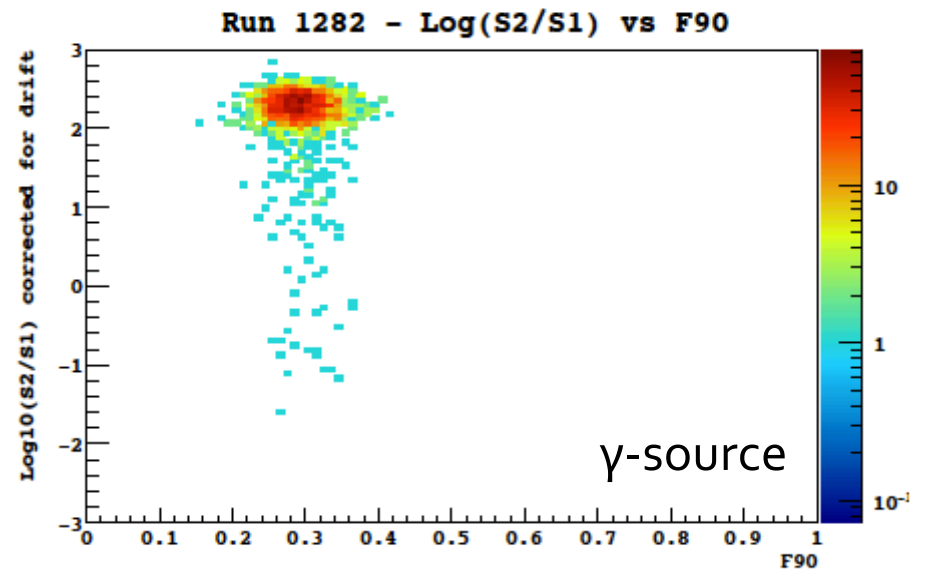
DarkSide-10 at Princeton

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



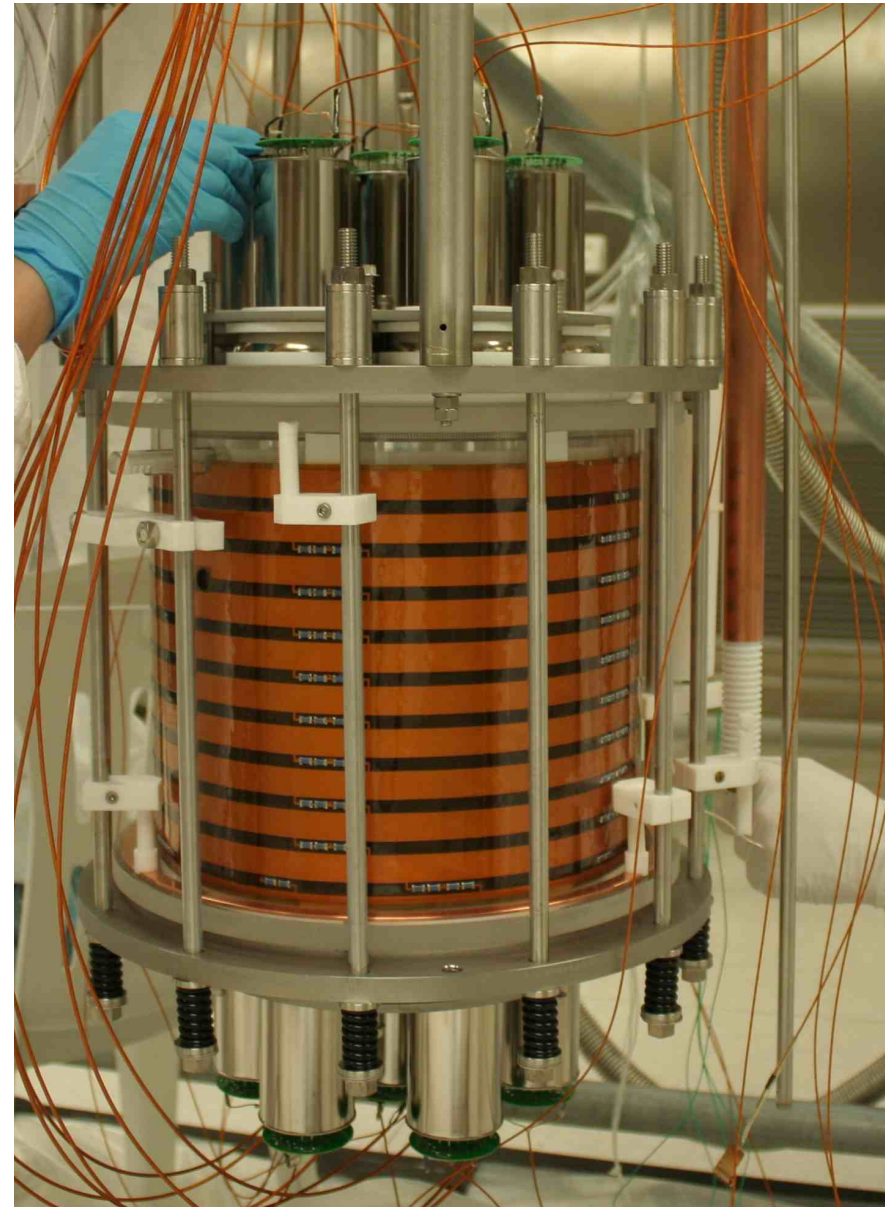
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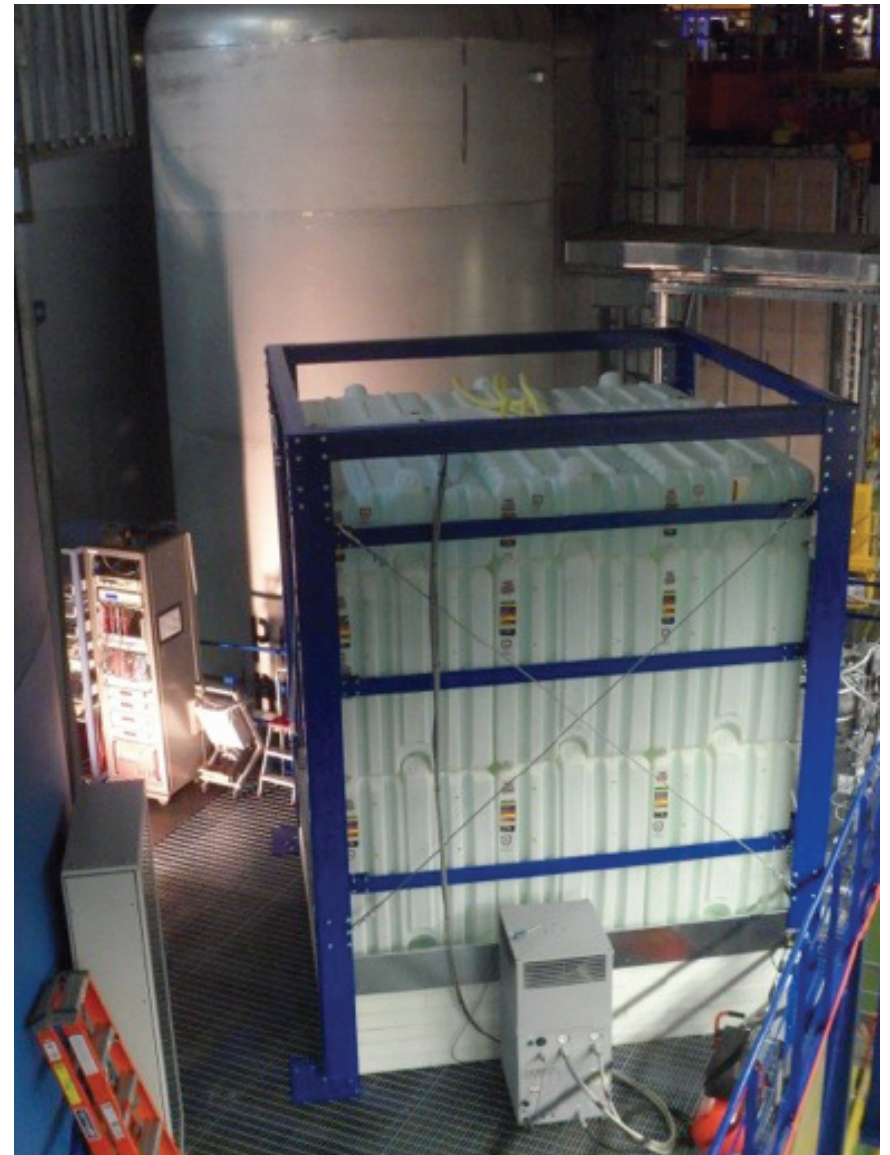
DarkSide-10 at LNGS

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



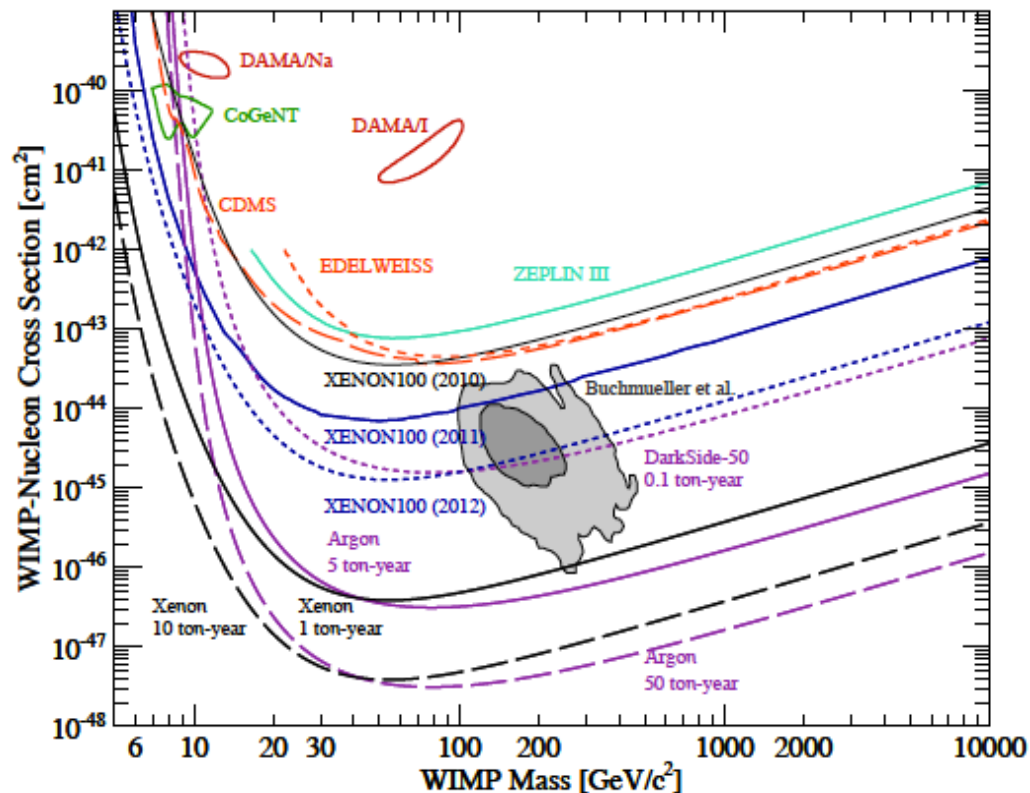
DarkSide-10 at LNGS

- DarkSide-10 upgraded, moved to LNGS
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- Study low background operation
 - Electron recoil rejection
 - Surface backgrounds



Summary

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



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 