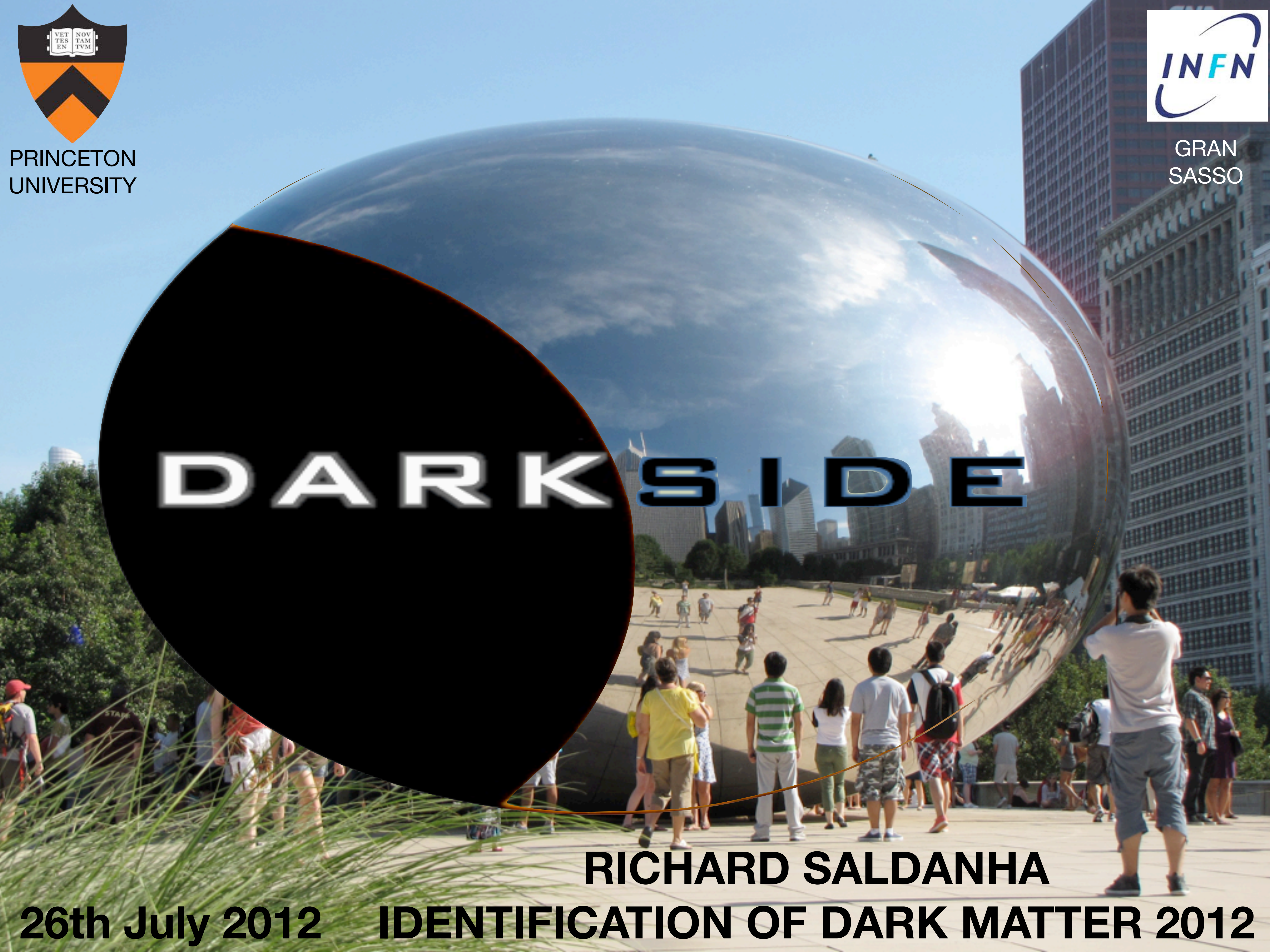


PRINCETON UNIVERSITY

GRAN SASSO

DARKSIDE

RICHARD SALDANHA

26th July 2012 IDENTIFICATION OF DARK MATTER 2012

DarkSide Program

- Direct detection search for WIMP dark matter
- Based on a two-phase argon time projection chamber (TPC)
- Design philosophy based on having very low background levels that can be further reduced through active suppression, for background-free operation

DarkSide Program

Multi-stage program at Gran Sasso National Laboratory

DarkSide 10

Currently running full prototype detector

DarkSide 50

First physics detector

Physics goal ~ 10^{-45} cm^2

DarkSide G2

Multi-ton detector

Physics Goal ~ 10^{-47} cm^2

+ multiple smaller test setups and prototypes

DarkSide 10

7x 3” PMTs

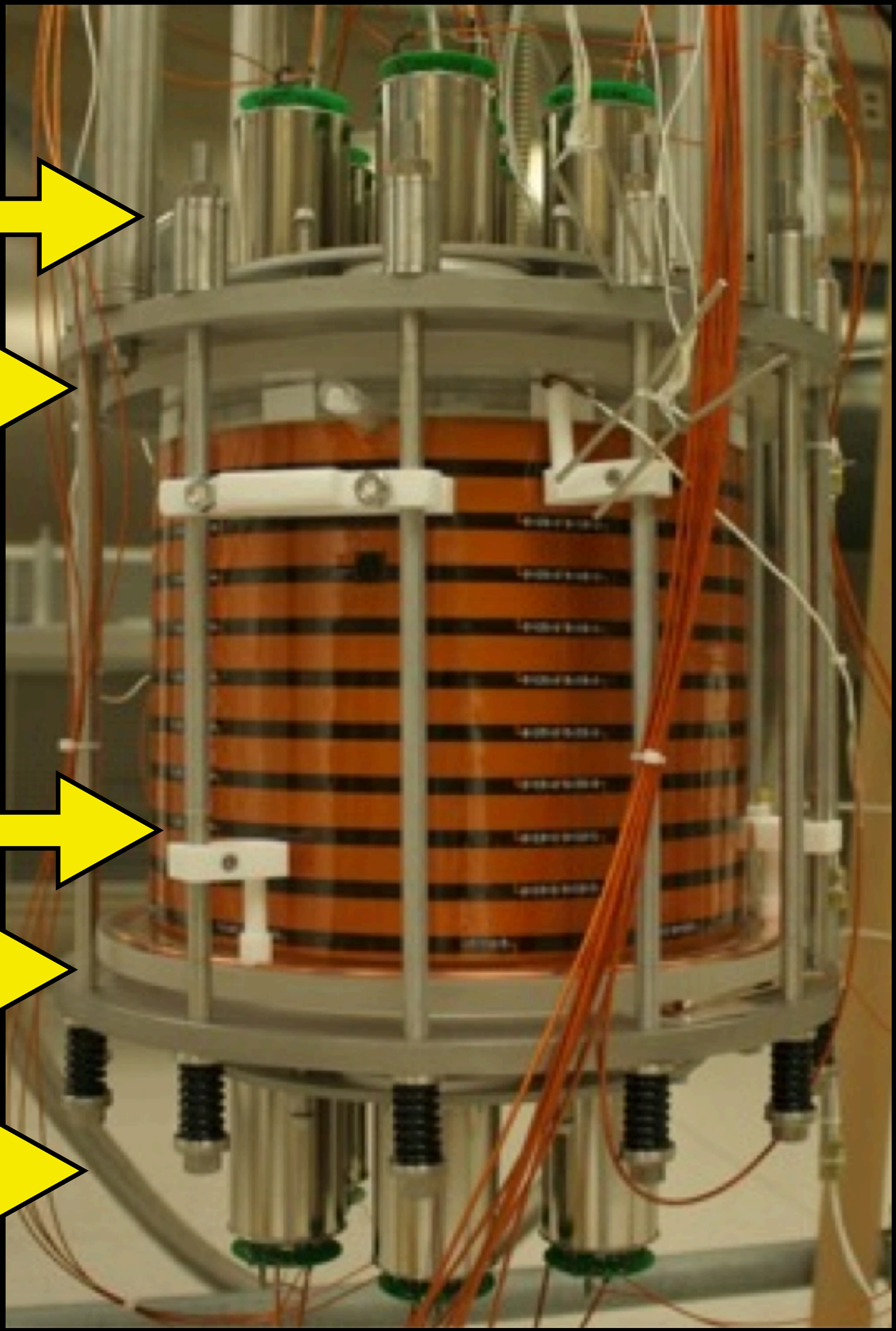
TPB + ITO coated quartz window

Acrylic cylinder
with TPB-coated reflector

Flexible PCB field cage

TPB + ITO coated quartz window

7x 3” PMTs



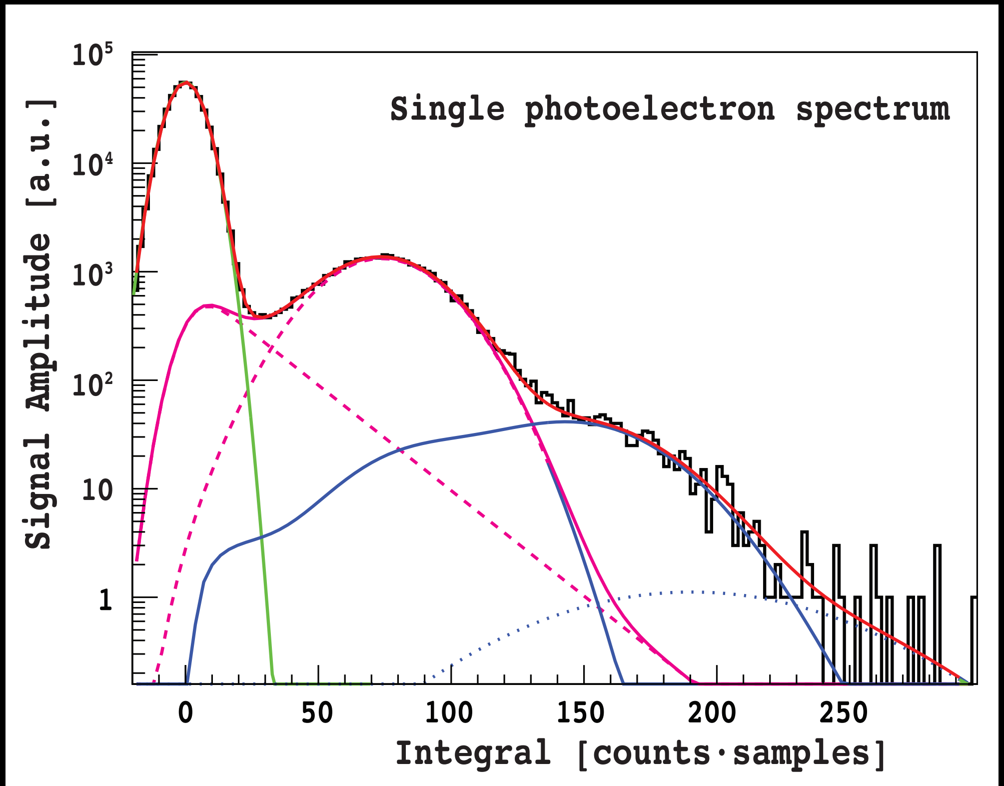
DarkSide 10

First designed, built and operated at Princeton University

Moved underground at Gran Sasso to operate in a low-background environment

Dedicated campaigns to test light collection, high voltage and other technical solutions for future detectors

Light Yield Measurements

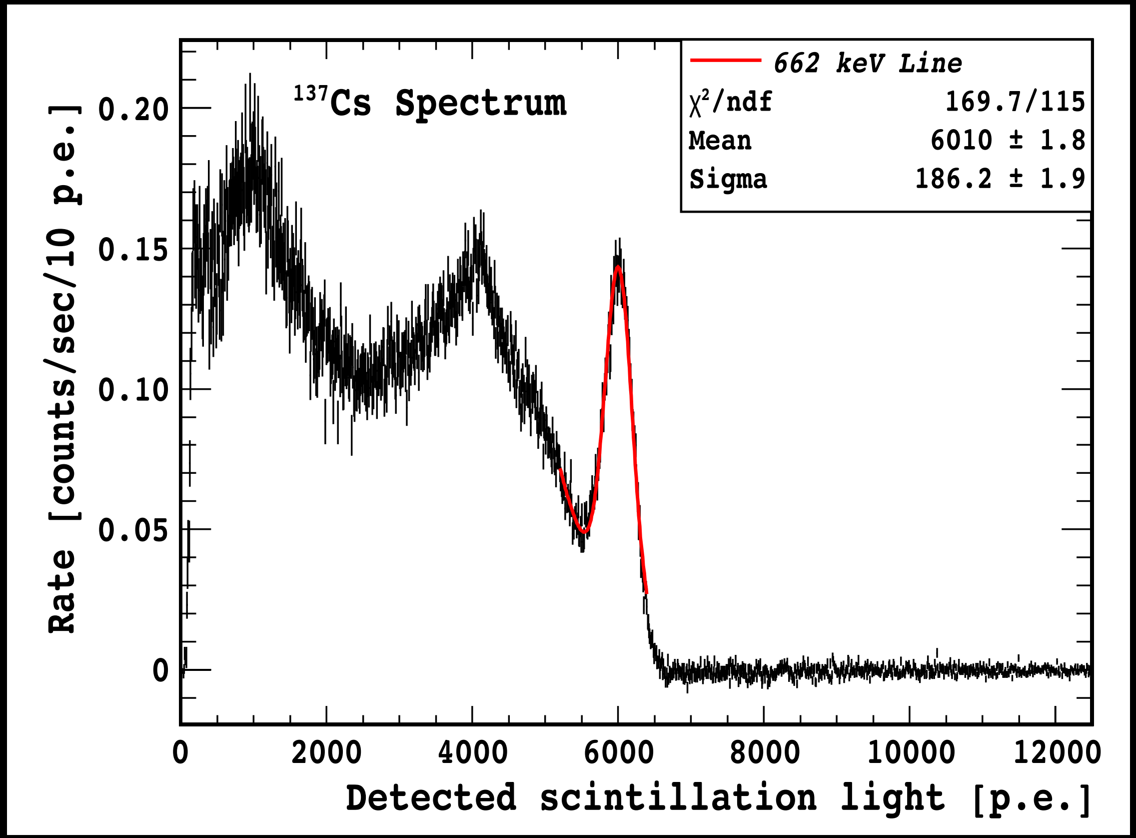


The single photoelectron response of each tube was measured using a fast, pulsed laser

Detector light yield was measured using a series of external γ sources at null field

arXiv:1204.6218 [astro-ph.IM]

Energy [keV]	L.Y. [p.e. / keV]	Resolution (σ)
122	8.87	5.2
511	8.78	3.4
662	9.08	3.1
1275	8.60	2.9
AVERAGE	8.9 +/- 0.4	



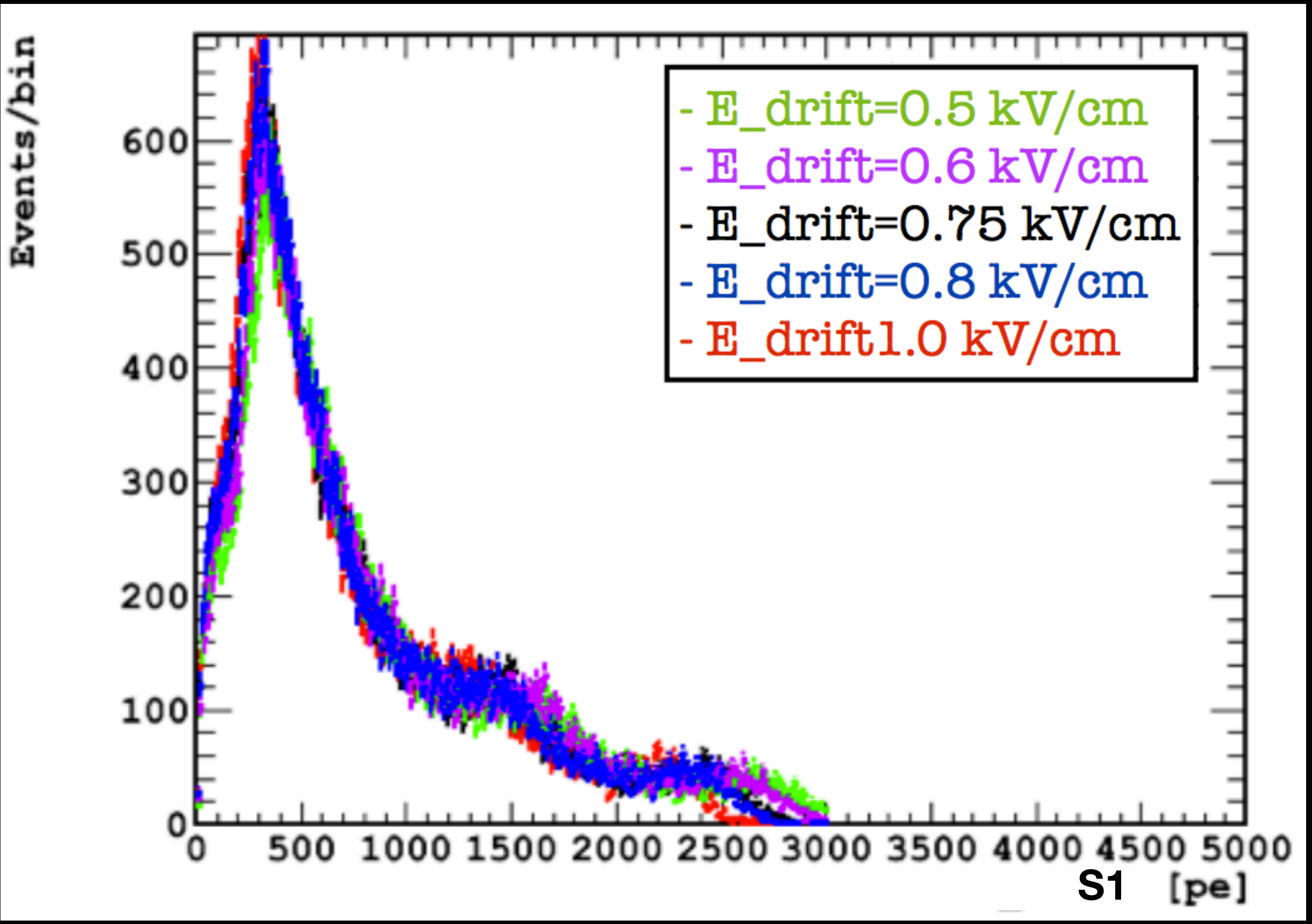
S1 and S2 signals

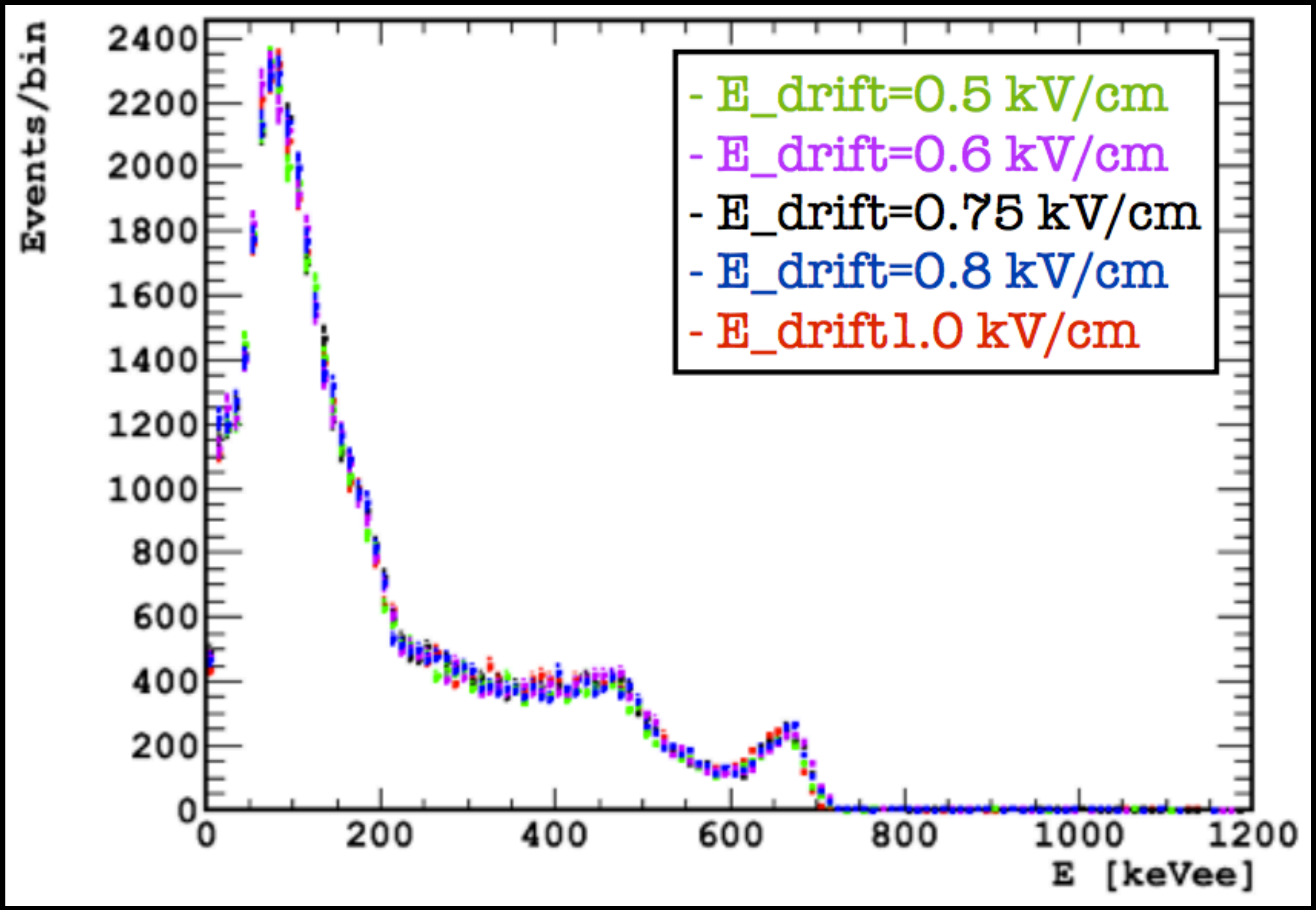
With drift fields on, the recoil energy is divided into a light (S1) and charge (S2) signal

$$E_{rec} \propto S1 + k \cdot S2$$

S1 and S2 are anti-correlated

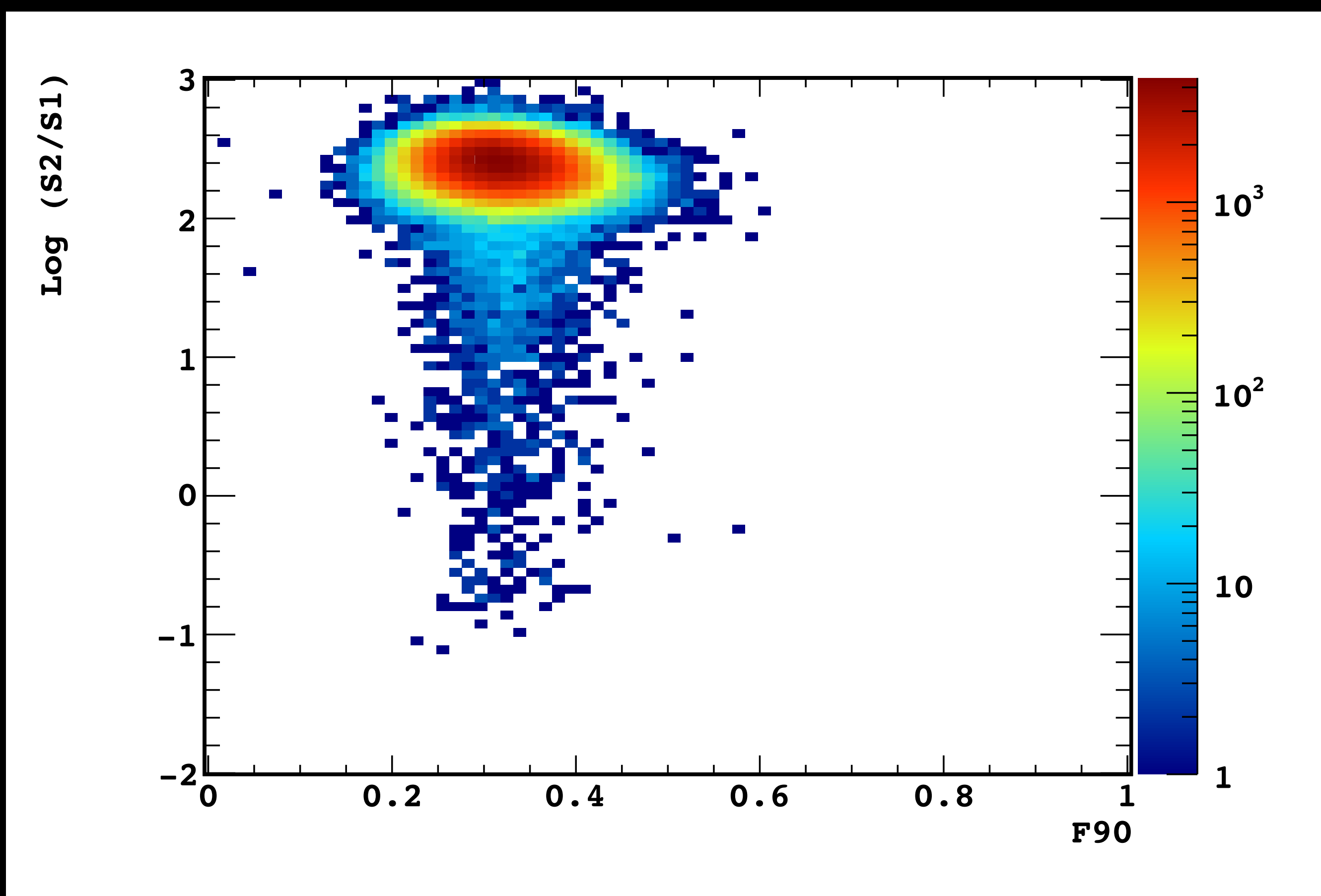
The sum is independent of the drift field



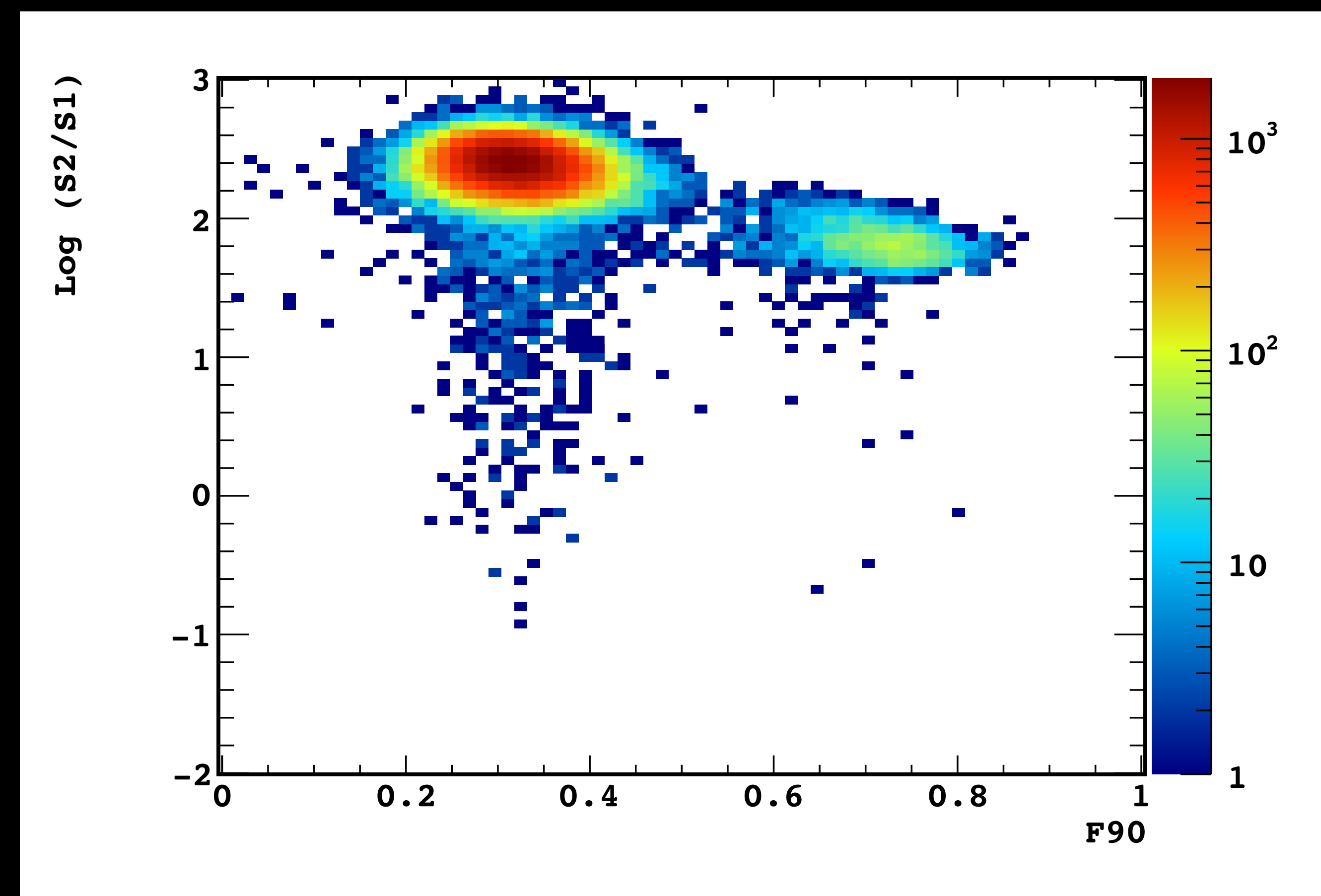


Neutron Calibration

Data was taken with an external Am-Be neutron source with the detector in TPC mode



Background



Am-Be Source

Study of discrimination currently underway

DS-10 Performance

- Compare performance of different reflectors for light collection
  Detector run with both 3M foils (~ 9 p.e./keV$_{ee}$) and highly crystalline PTFE (~ 7 p.e/keV$_{ee}$)

- Study feasibility of ITO coatings

- Test HHV system (feedthroughs, grid etc.)
  Detector running without problems at nominal field configuration (1 kV/cm drift, 3.8 kV/cm extraction)

- Perform calibration of detector
  Calibrations performed with external γ and neutron sources. ^{83}Kr source to be implemented soon

- Optimize field configuration of TPC
  Different field configurations under consideration

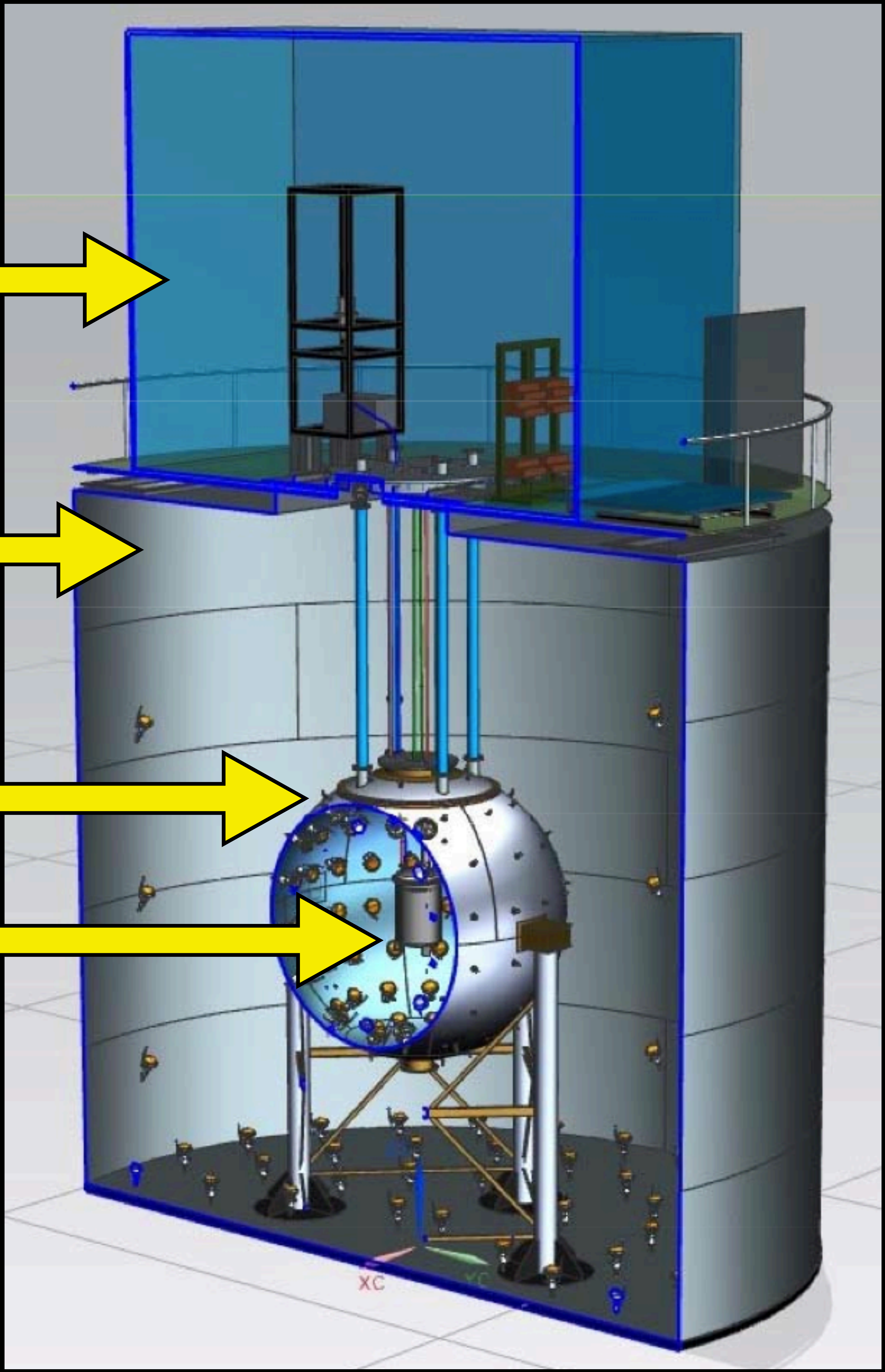
DarkSide 50

Radon-free clean room

Instrumented water tank

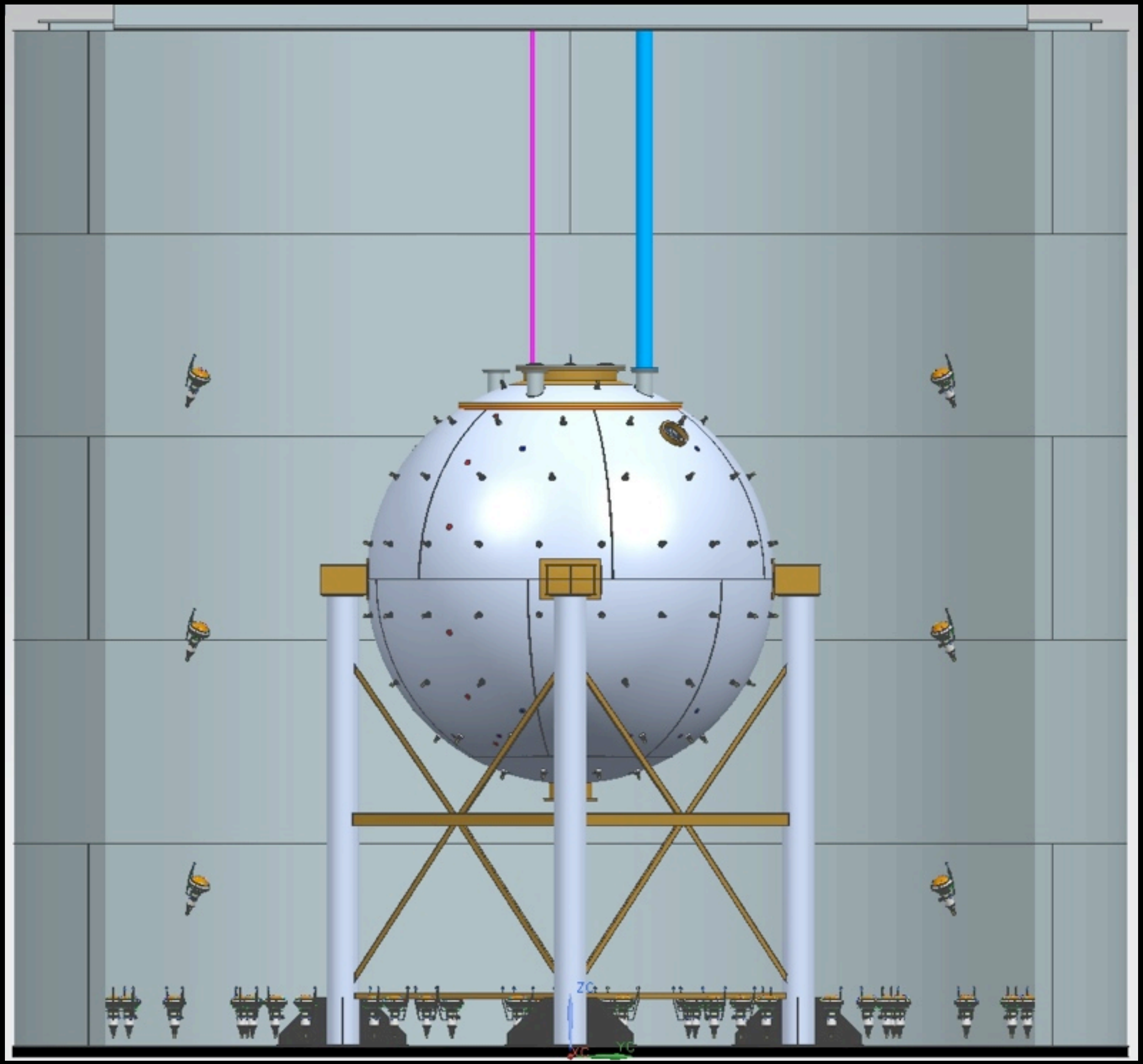
Liquid scintillator

Inner detector TPC
(Underground argon)



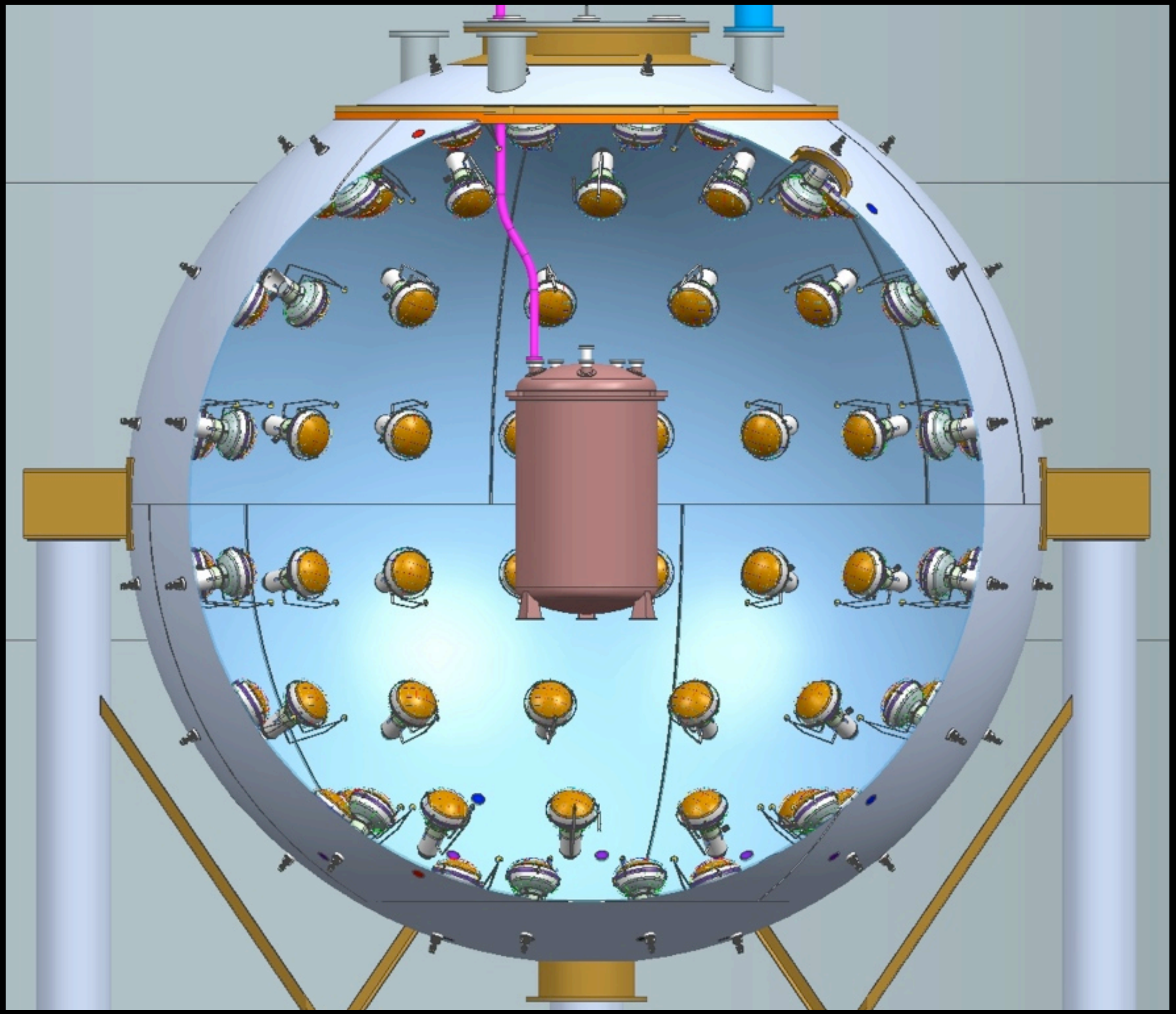
External Water tank

- 80 PMTs within Borexino CTF
(11m dia. x 10 m high)
- Acts as a muon and cosmogenic veto
(~ 99% efficiency)
- Provides passive gamma and neutron shielding



Liquid Scintillator Veto

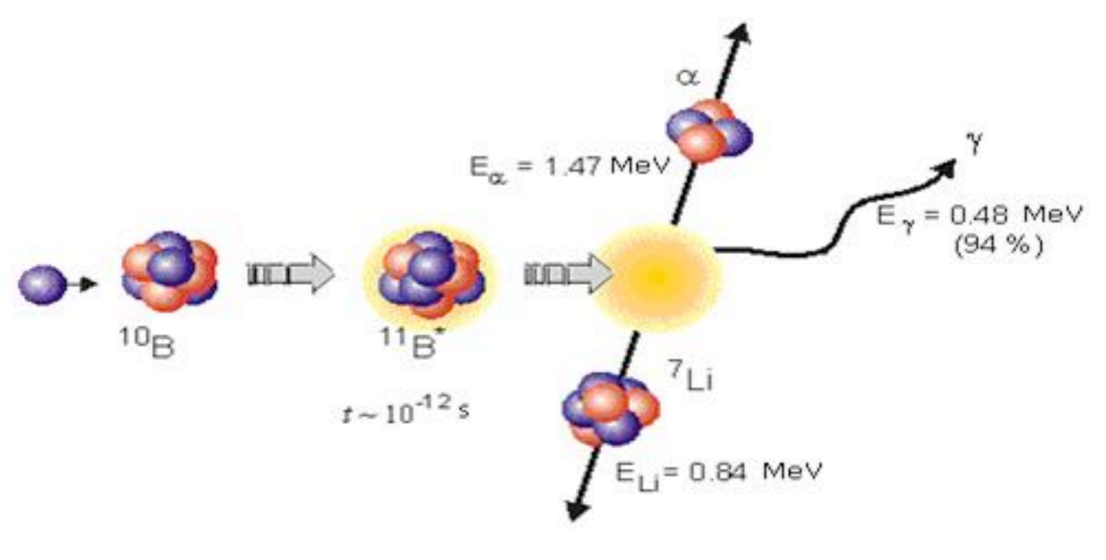
Liquid scintillator allows coincident veto of neutrons in the TPC and provides *in situ* measurement of the neutron background rate



- 4 m diameter sphere containing 1:1 PC + TMB scintillator
- Instrumented with 110 8” PMTs

Borated Liquid Scintillator

- High neutron capture cross section on boron allows for compact veto size
- Capture results in 1.47 MeV α particle - detected with high efficiency
- Short capture time (2.3 μs) reduces dead time loss

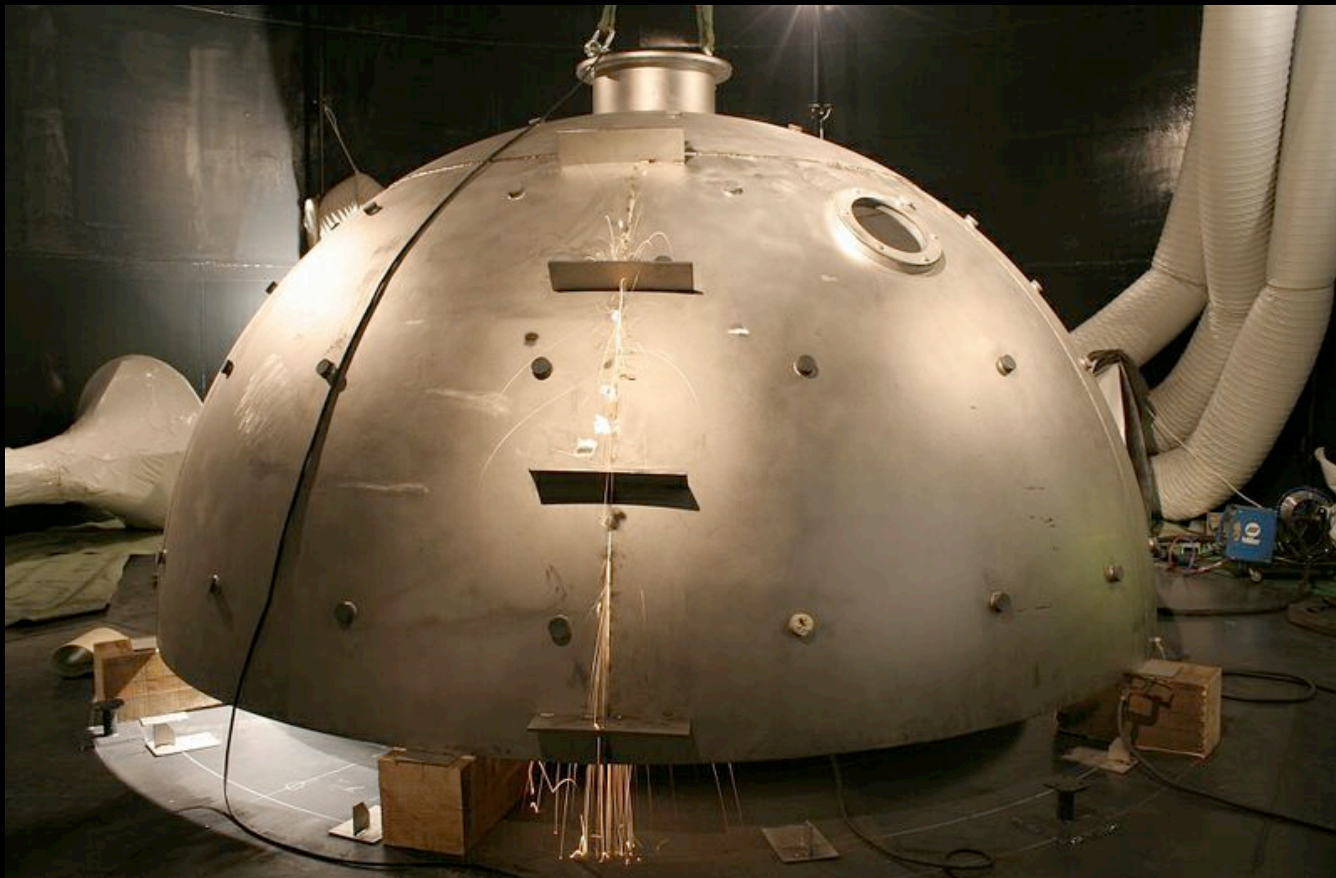


	Veto Efficiency
Radiogenic Neutrons	> 99.5%*
Cosmogenic Neutrons	> 95%

Nuclear Instruments and Methods A 644, 18 (2011)

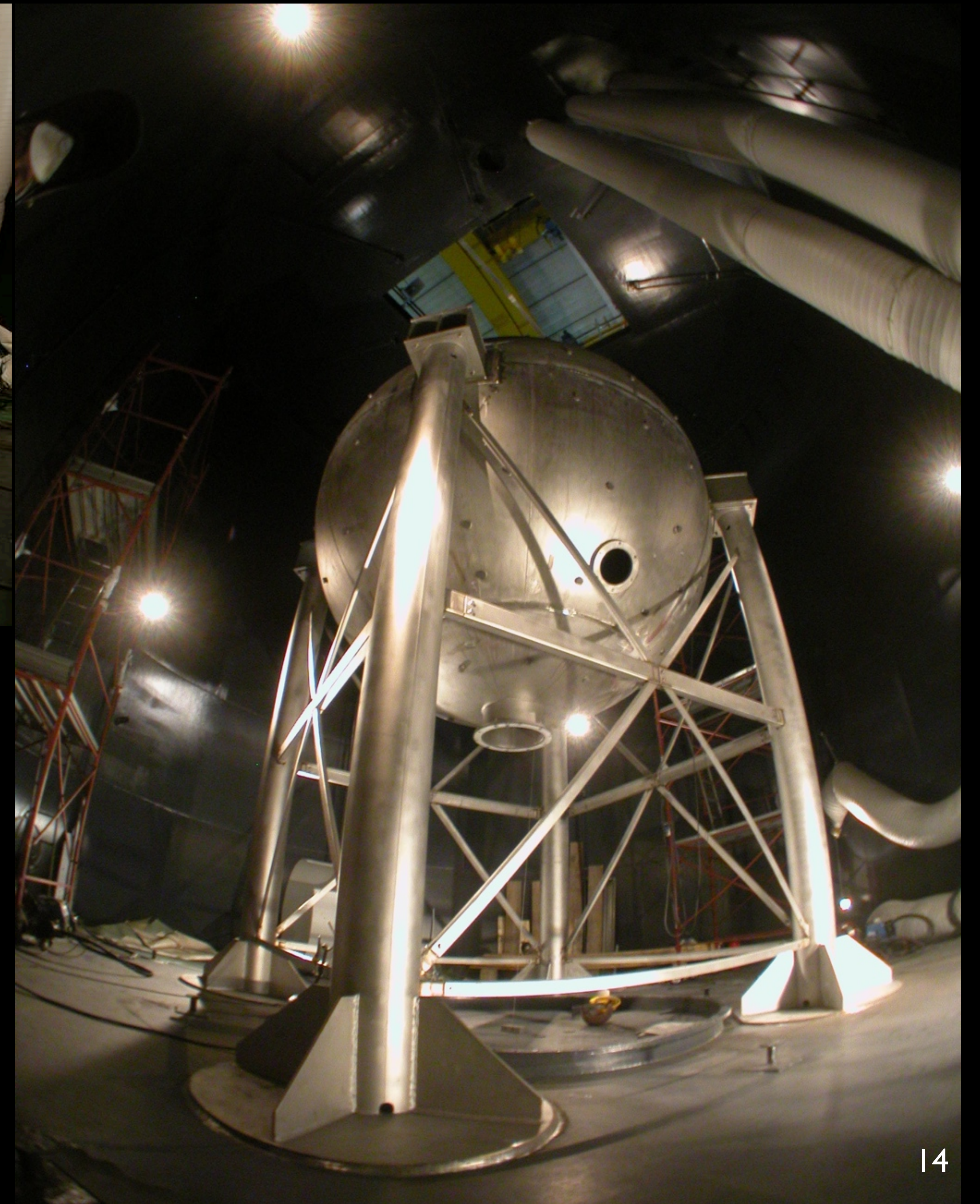
*60 μs veto window (2% dead time)

Liquid Scintillator Tank

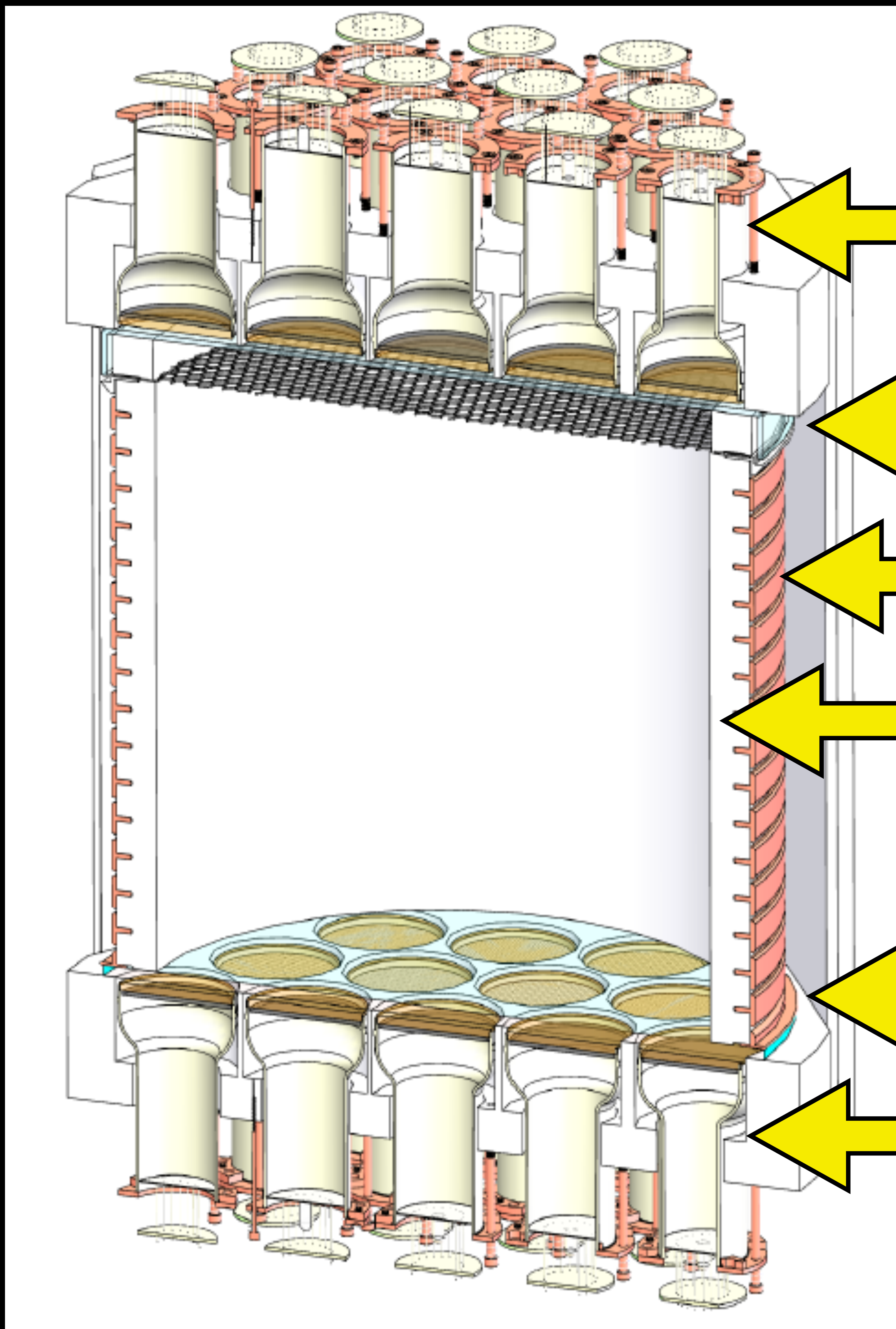


CTF tank has been emptied

Liquid scintillator tank assembly has recently been completed



Inner detector TPC



19x 3” PMTs

TPB + ITO coated quartz diving bell

Copper field cage rings

TPB coated Highly Crystalline PTFE

~ 50 kg LAr

TPB + ITO coated quartz window

19x 3” PMTs

^{39}Ar

- Intrinsic ^{39}Ar radioactivity in atmospheric argon is the primary background for argon-based detectors
- ^{39}Ar activity sets the dark matter detection threshold at low energies (where pulse shape discrimination is ineffective)
- Size of large argon TPC's is limited by the pileup rate induced by ^{39}Ar

Underground Argon

- ^{40}Ar is mostly produced underground (through decay of ^{40}K)
- ^{39}Ar is cosmogenic, produced by ^{40}Ar(n,2n) interactions in the atmosphere
- Argon that has remained underground can therefore have extremely low levels of ^{39}Ar
- However, ^{39}Ar can also be produced underground through ^{39}K(n, p) interactions, where the neutron originates from (α, n) reactions.

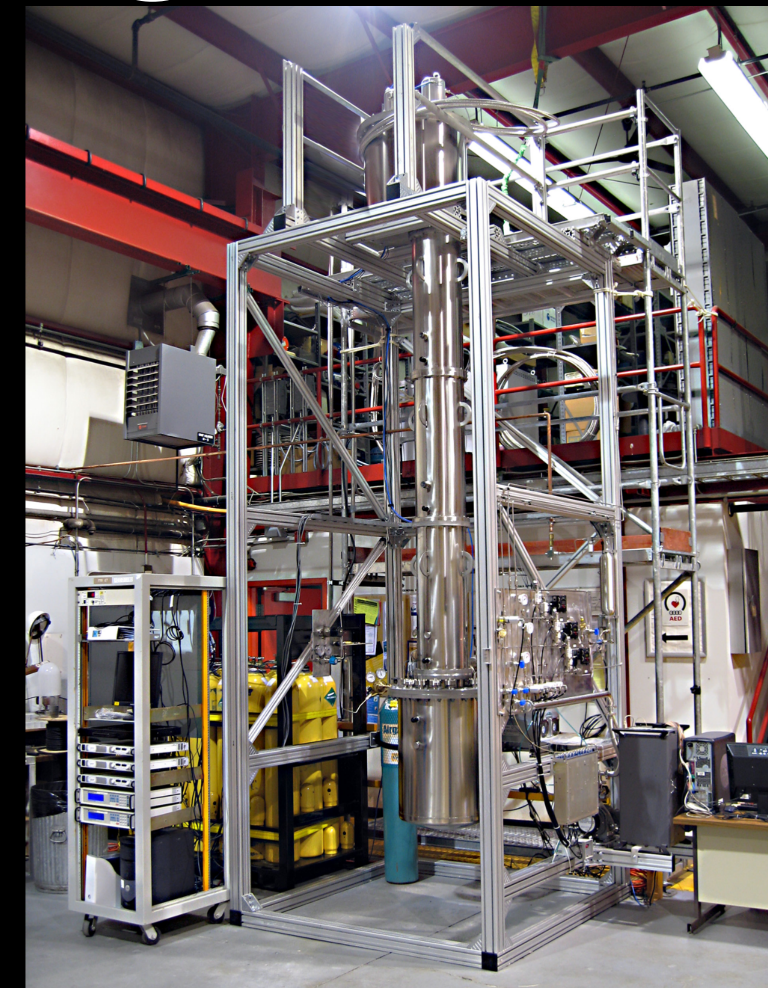
^{39}Ar/^{40}Ar depends on the local concentration of ^{238}U and ^{232}Th

Underground Argon

Underground Argon from CO_2 plant in Cortez Colorado

VPSA system (Cortez)
0.5 kg/day production
110 kg produced so far

arXiv:1204.6024 [astro-ph.IM]



Cryogenic Distillation system
0.9 kg/day production
70 - 81% efficiency
~ 19 kg produced so far

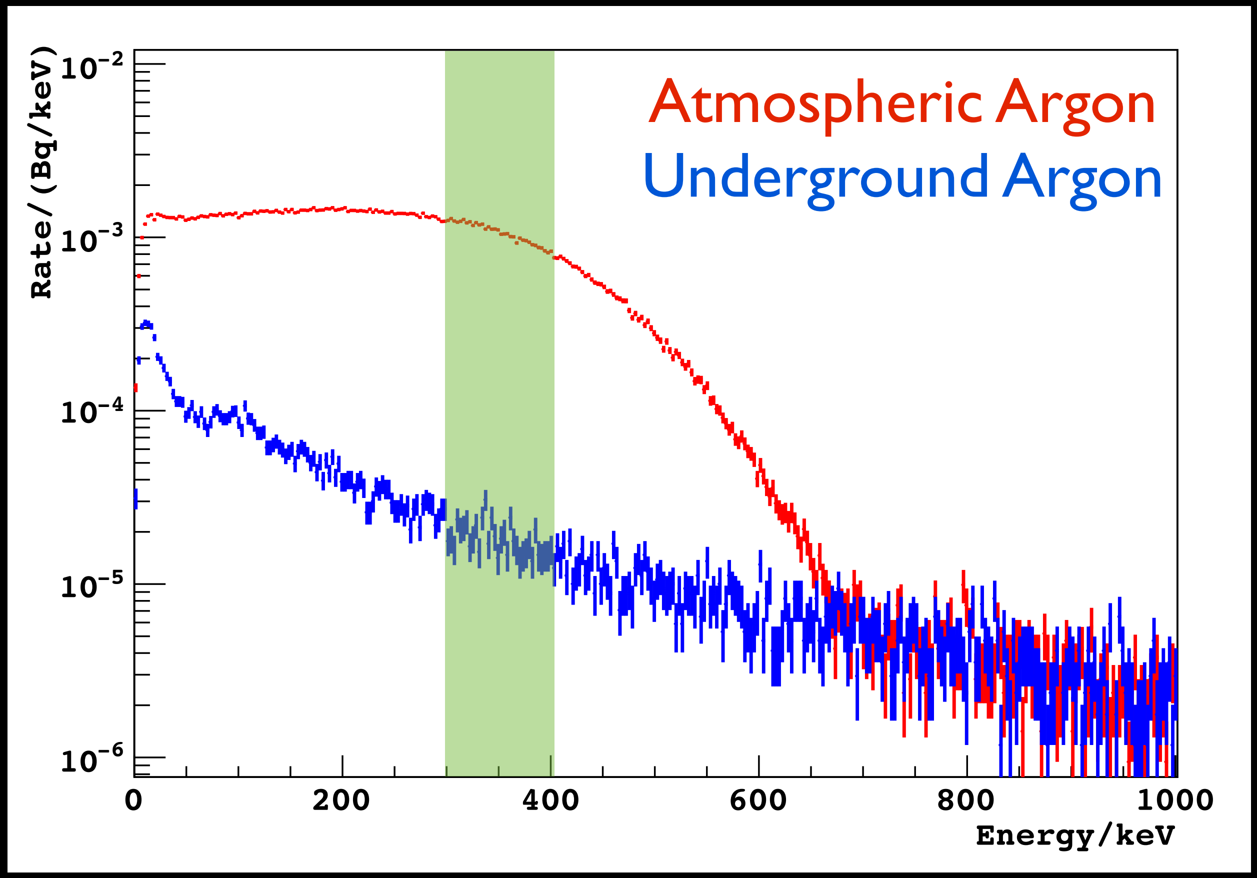
arXiv:1204.6061 [astro-ph.IM]

	CO_2 [%]	N_2 [%]	He [%]	Ar [%]
CO_2 Plant Output	96	2.4	0.4	0.06
VPSA output	~ 0	40	55	5
Cryogenic Distillation output	~ 0	< 0.05	~ 0	> 99.95

Underground Argon Measurement

Low background LAr detector was operated underground at KURF with both atmospheric and underground argon

arXiv:1204.60111 [physics.ins-det]



	Total Rate [mBq/100 keV]	Estimated Background Rate [mBq/100 keV]	Background Subtracted Rate [mBq/100 keV]
Underground Argon	1.87 +/- 0.06	1.5 +/- 0.2	0.32 +/- 0.23
Atmospheric Argon	108.8 +/- 0.4		107.2 +/- 1.9*
^{39}Ar Depletion Factor	1.71 +/- 0.05 %		< 0.65 % (95 CL)

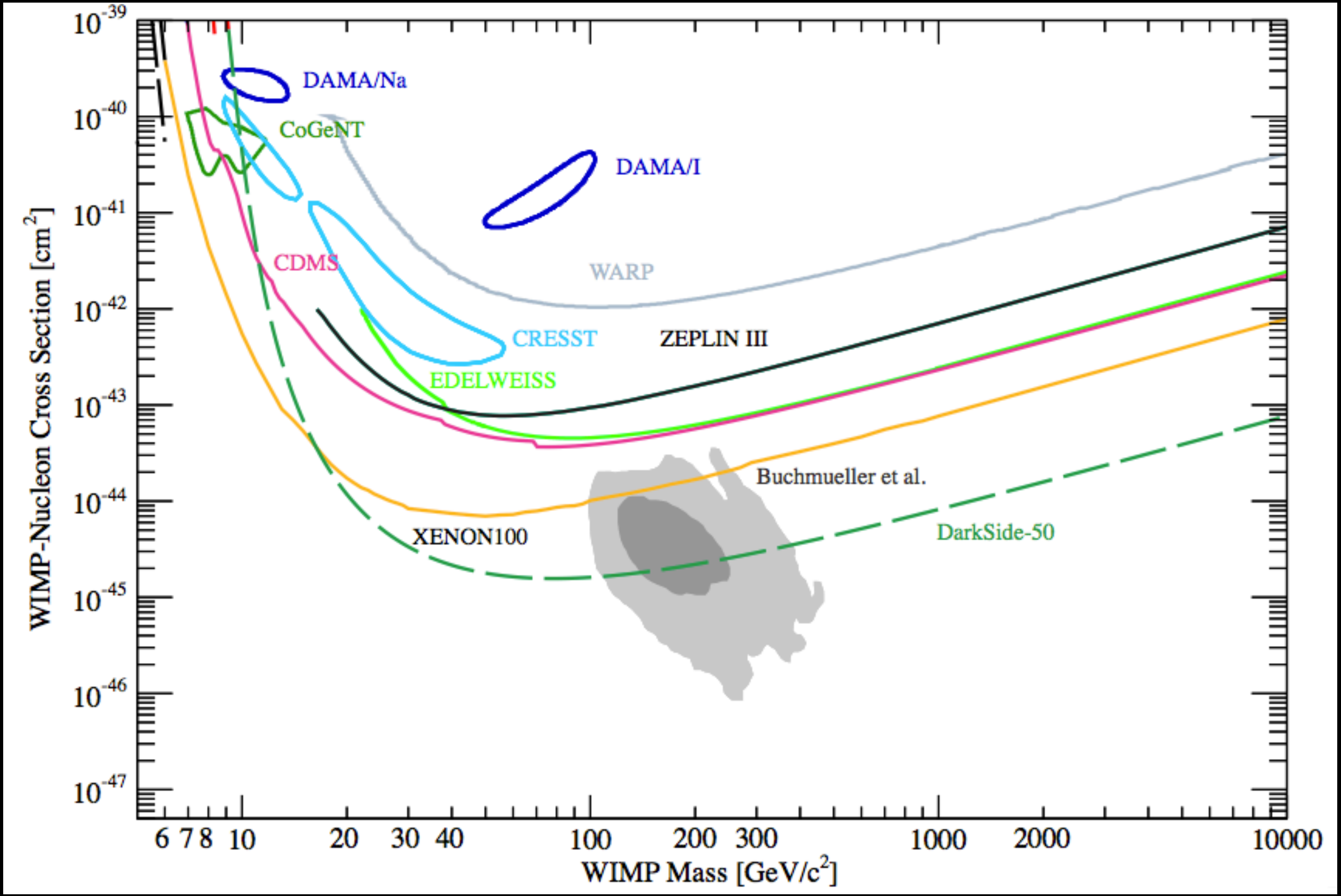
* Includes ^{85}Kr upper limit

Expected Backgrounds

Detector Element	Electron Recoil Backgrounds		Radiogenic Neutron Recoil Backgrounds		Cosmogenic Neutron Recoil Backgrounds	
	Raw	After Cuts	Raw	After Cuts	Raw	After Cuts
^{39}Ar (<0.01 Bq/kg)	$<6.3\times10^{6}$	$<4\times10^{-3}$	–	–	–	–
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}
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	–	0.007	–	0.055	–	0.030

0.1 ton x year exposure, 30 - 200 keV$_r$ window, 50% nuclear recoil acceptance

Sensitivity



DarkSide Collaboration

Augustana College, SD
Black Hills State University, SD
Drexel University, PA
Fermi National Accelerator Laboratory, IL
Princeton University, NJ
Temple University, PA
University of Arkansas, AR
University of California, Los Angeles CA
University of Houston, TX
University of Massachusetts, Amherst, MA
Virginia Tech, VA

Joint Institute for Nuclear Research, Dubna
Skobeltsyn Institute for Nuclear Physics, Moscow
National Research Centre Kurchatov Institute, Moscow
St. Petersburg Nuclear Physics Institute, Gatchina

Laboratori Nazionali del Gran Sasso, Assergi
Universita degli Studi and INFN, Genova
Universita degli Studi and INFN, Milano
Universita degli Studi and INFN, Perugia
Universita degli Studi Federico II and INFN, Napoli

Smoluchowski Institute of Physics, Krakow

Institute of High Energy Physics, Beijing

Institute of Nuclear Research, Kiev

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