The "DArkSide" of Dark Matter

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DarkSide

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Princeton University, USA
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University of Massachusetts at Amherst, USA
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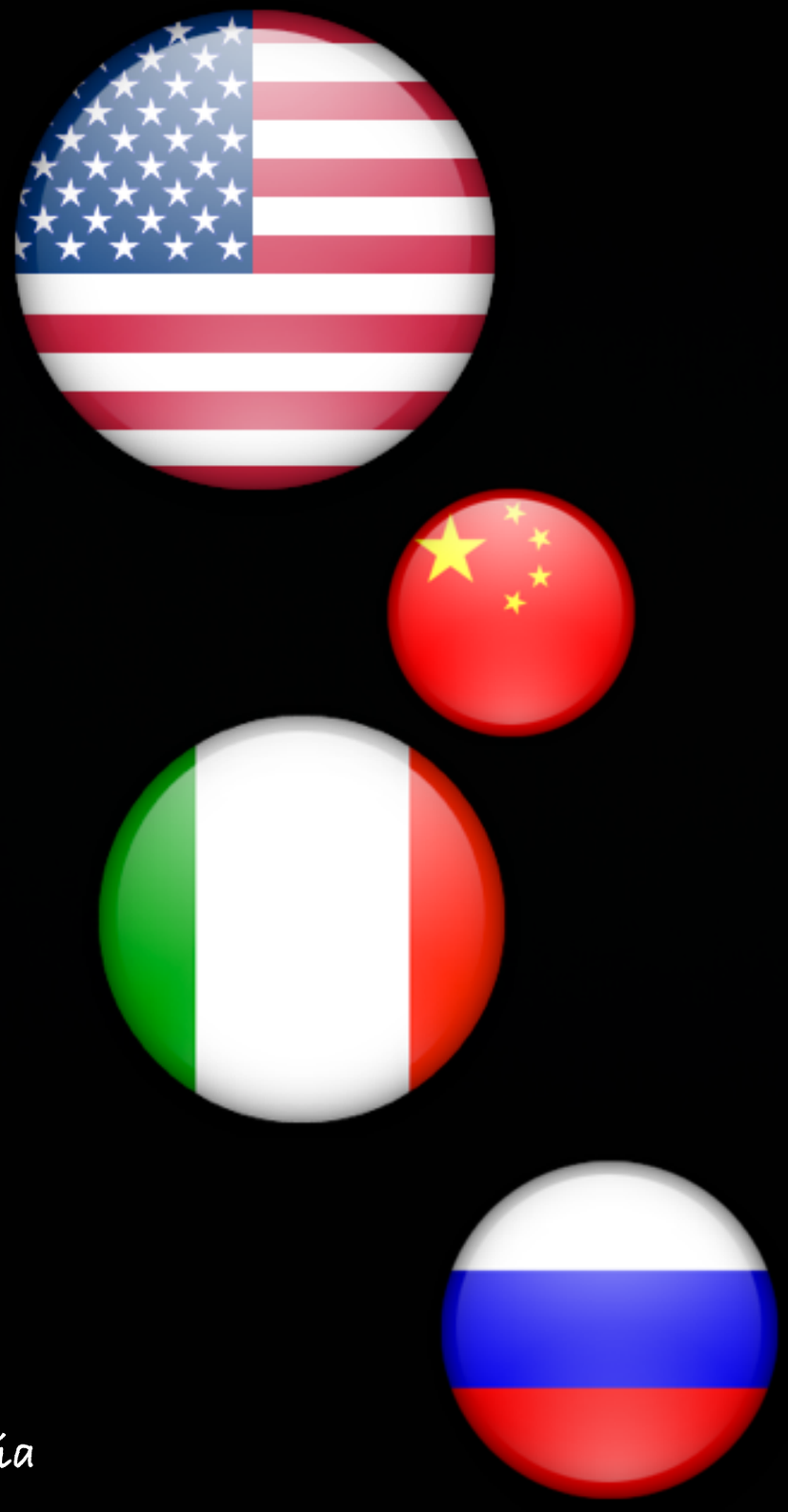
INFN and Università degli Studi Genova, Italy
INFN and Università degli Studi Milano, Italy
INFN and Università degli Studi Napoli, Italy
INFN and Università degli Studi Perugia, Italy

Joint Institute for Nuclear Research – Dubna, Russia
Lomonosov Moscow State University, Russia
RRC Kurchatov Institute – Moscow, Russia
St. Petersburg Nuclear Physics Institute – Gatchina, Russia



DArkSide Project

* Null background strategy for direct Dark Matter search - looking for rare nuclear recoils induced by WIMPs in a specialized low background detector.

* Multi Step program @ LNGS foreseeing:
  - ☑ G1 experiment: DS-50 - 10^{-45} cm^2 GOAL
  - ☑ G2 experiment: DS-5k - 10^{-47} cm^2 GOAL
  - ☑ Plus few prototypes for technical measurements...

DArkSide Recipe

- ☑ TARGET: Underground Argon DEPLETED in its ^{39}Ar isotope to reduce internal contaminations.
- ☑ DETECTOR: two-phase argon time projection chamber.
- ☑ VETO & SHIELD: a compact liquid scintillator VETO (à la Borexino) relying on (n,alpha) on ^{10}B combined with a Water Cherenkov Detector to kill neutron induced background.

Two-Phase Argon TPC

BLAH, BLAH, BLAH
description of technology and
rejection methods

Two-phase Liqu

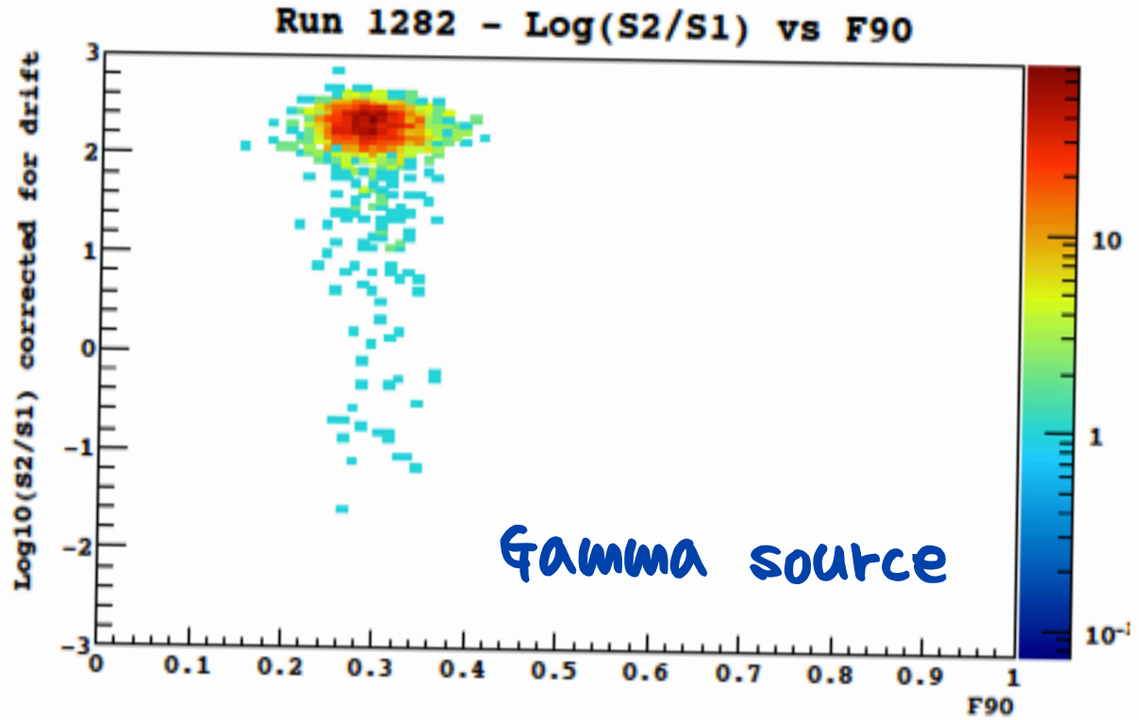
Shape
of the scintillation
signal (PSD)

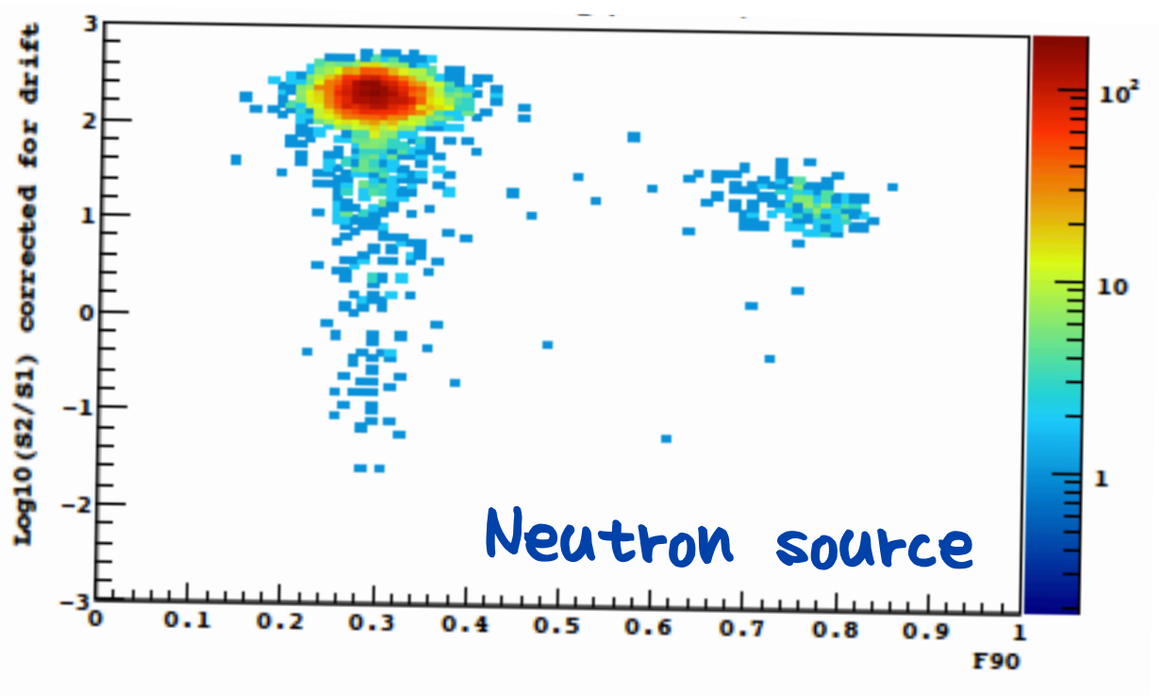
3D localizat

ionizati

Electron recoils (induced
by gamma and beta
natural radioactivity)

How to reject





Data acquired on surface without shielding

Two-phase Liquid Argon technology

Shape of the scintillation signal (PSD)

Ratio between ionization and scintillation (S2/S1)

3D localization of the ionization event

Nuclear recoils from surface contamination (surface events).

How to reject the background?

Two-phase Liquid Argon technology

Shape of the scintillation signal (PSD)

Ratio between ionization and scintillation (S2/S1)

3D localization of the ionization event

Nuclear recoils induced by elastic scattering of radiogenic and cosmogenic neutrons.

How to reject the background?

DS-10kg detector

Two-phase Argon TPC prototype used to test the effects on the two phase argon technology of new solutions pursued by DarkSide program.

10 kg active mass of Atmospheric Ar

7 PMT (3" Hamamatsu) at the top

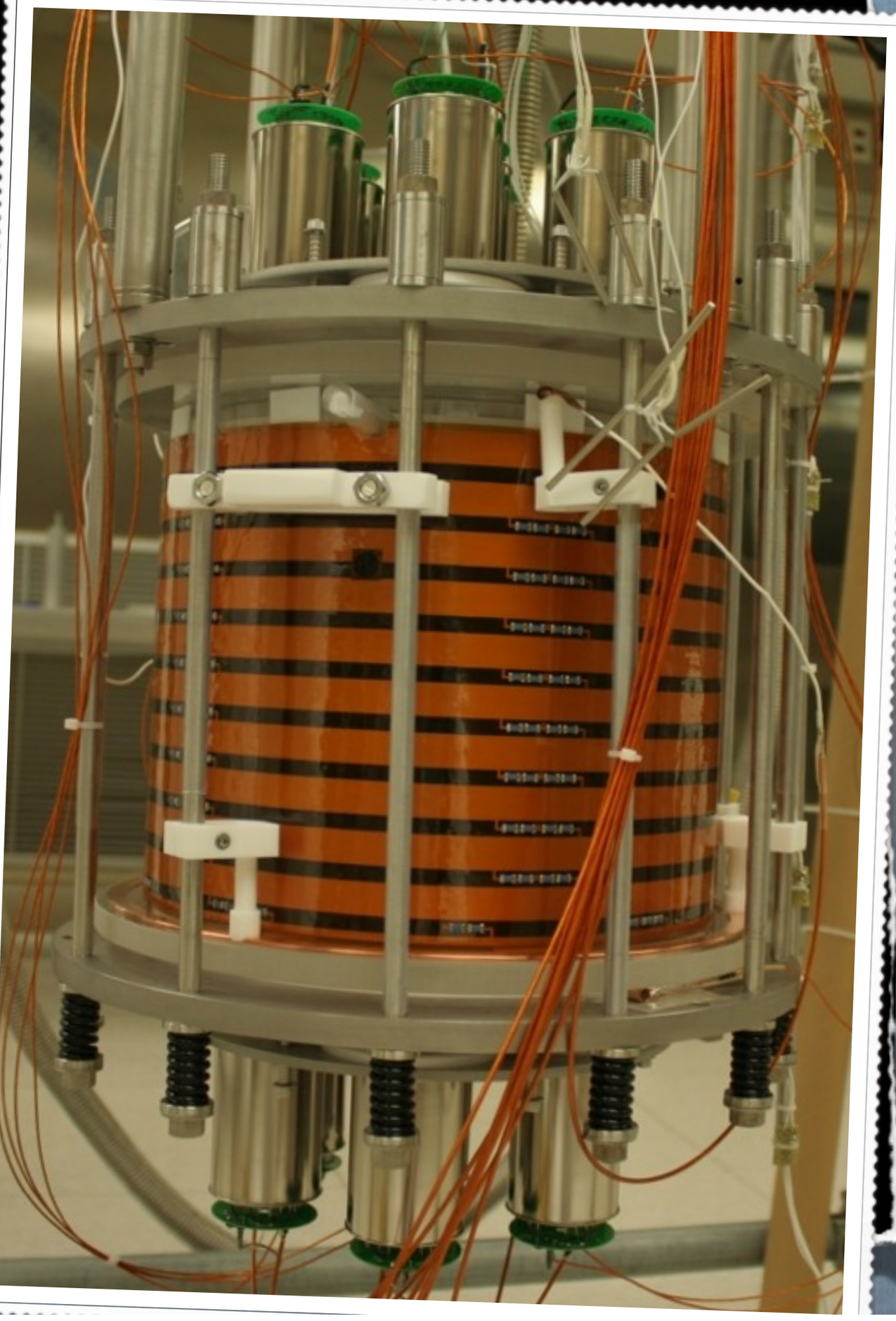
7 PMT (3" Hamamatsu) at the bottom

~20cm drift region

~2cm multiplication region

ITO layers for anode and cathode on fused silica windows (instead of conventional grid)

New HHV feedthroughs



DS-10 @ LNGS

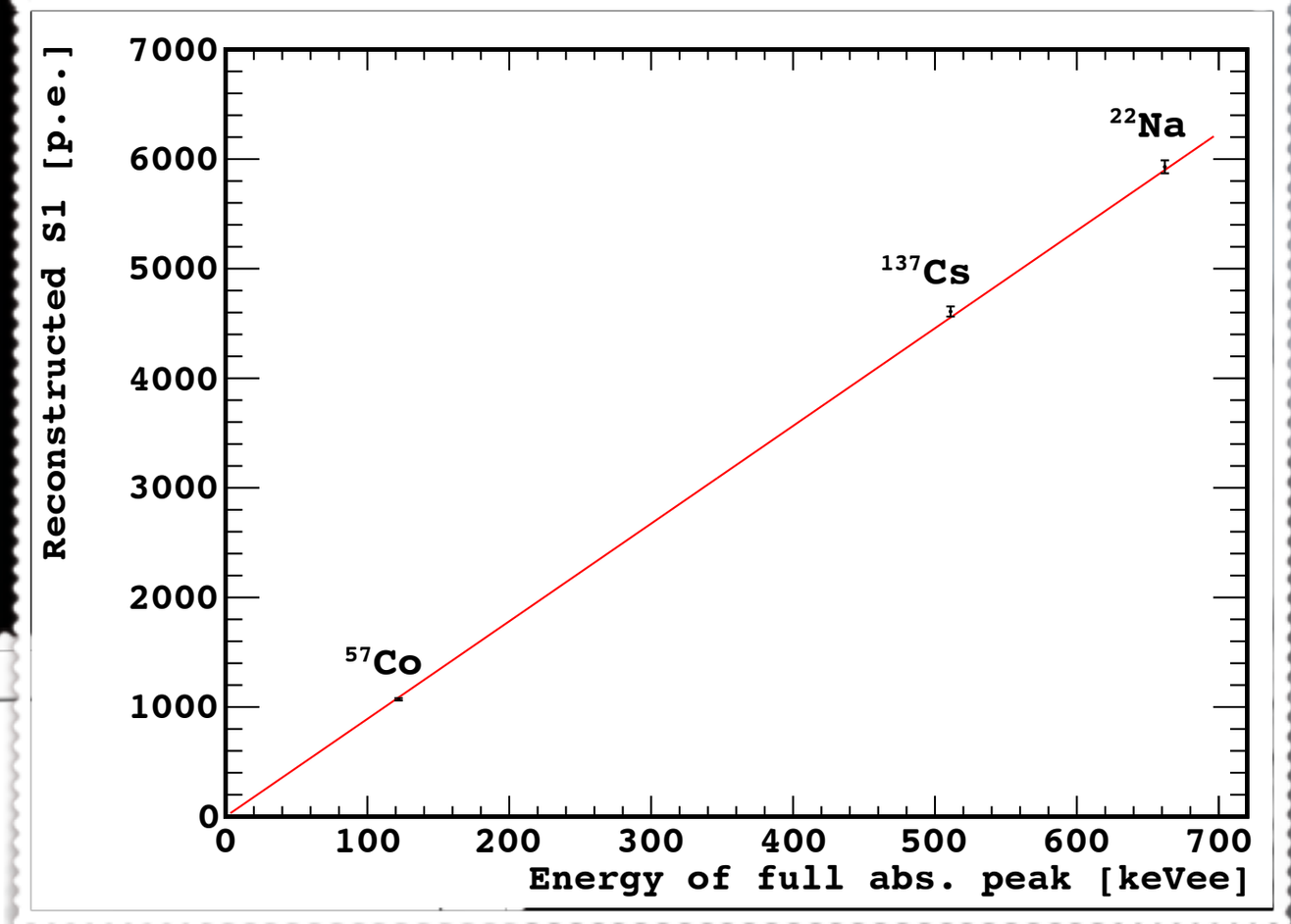
- Detector has been installed during last summer on a dedicated platform in Gran Sasso Hall C (near Borexino CTF).

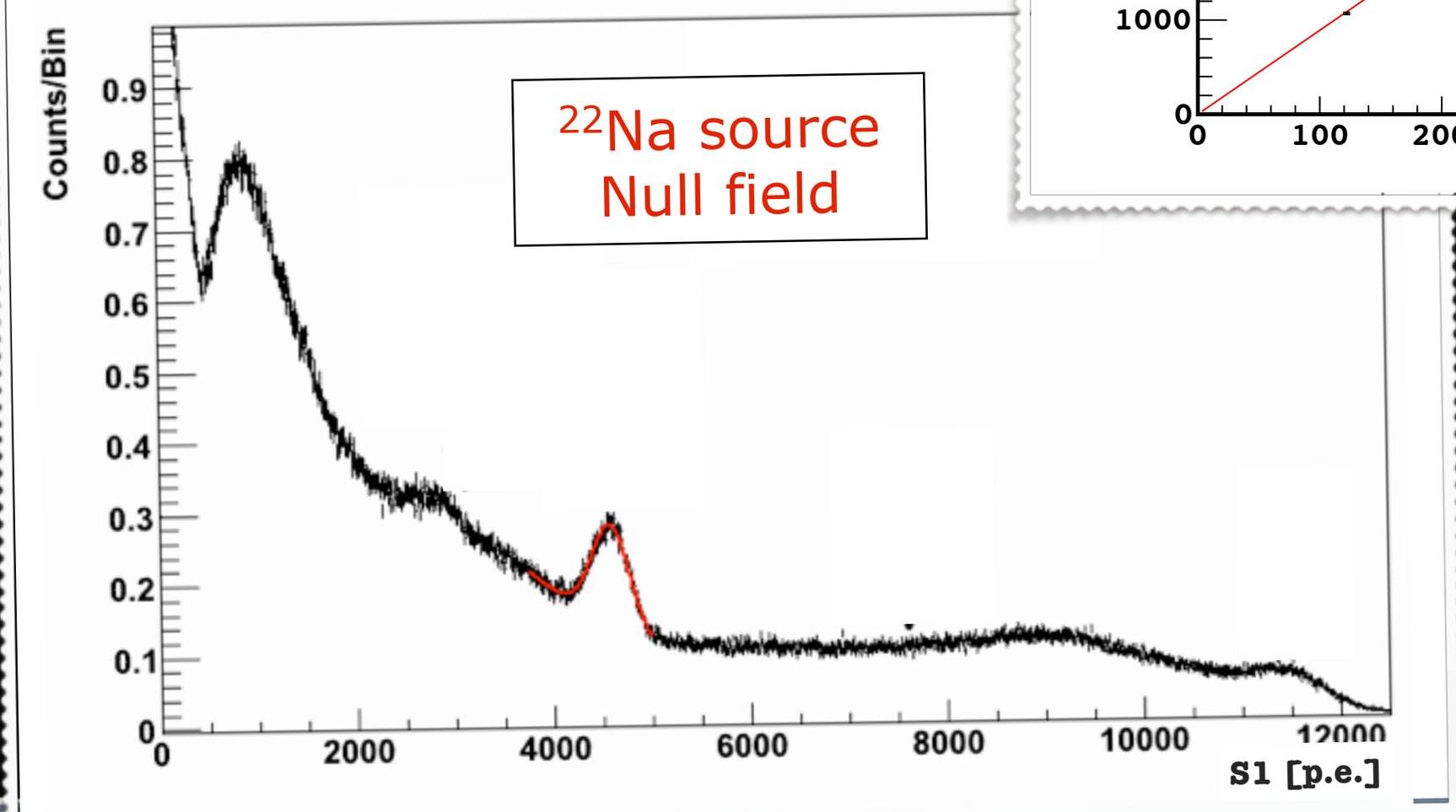
- DS-10 runs @ LNGS are mainly focused on the study of the performance of the detector in low background environment.

- We are studying dedicated short runs for the technical solutions that will be implemented in DS-50.

DS-10 @ LNGS
Light Yield

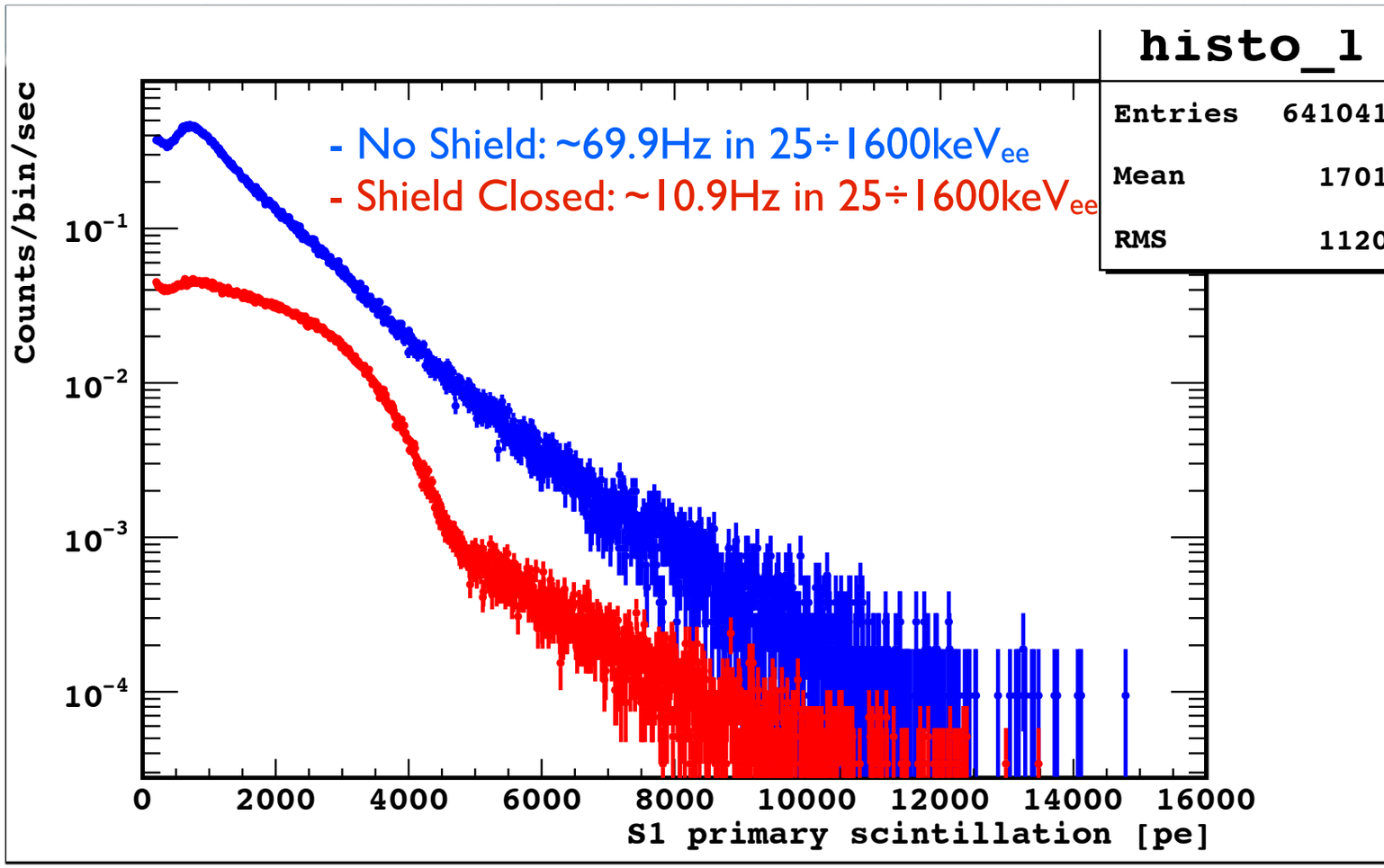
$LY = 9.0 \pm 0.1$ p.e./keV$_{ee}$





DS-10 @ LNGS
gamma-like background

- The trigger configuration is a majority of 4 PMTs each detecting at least 0.5 p.e..

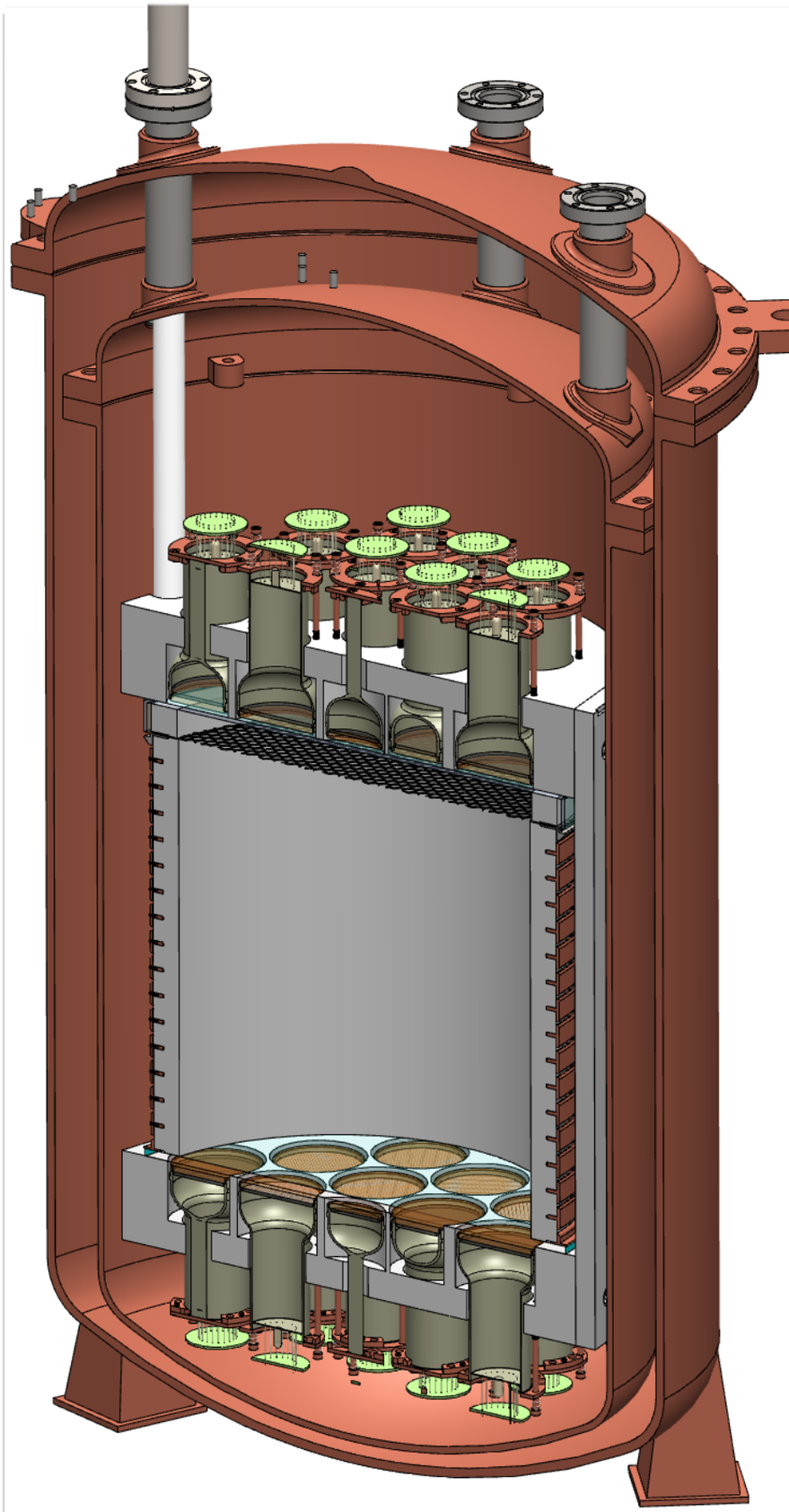


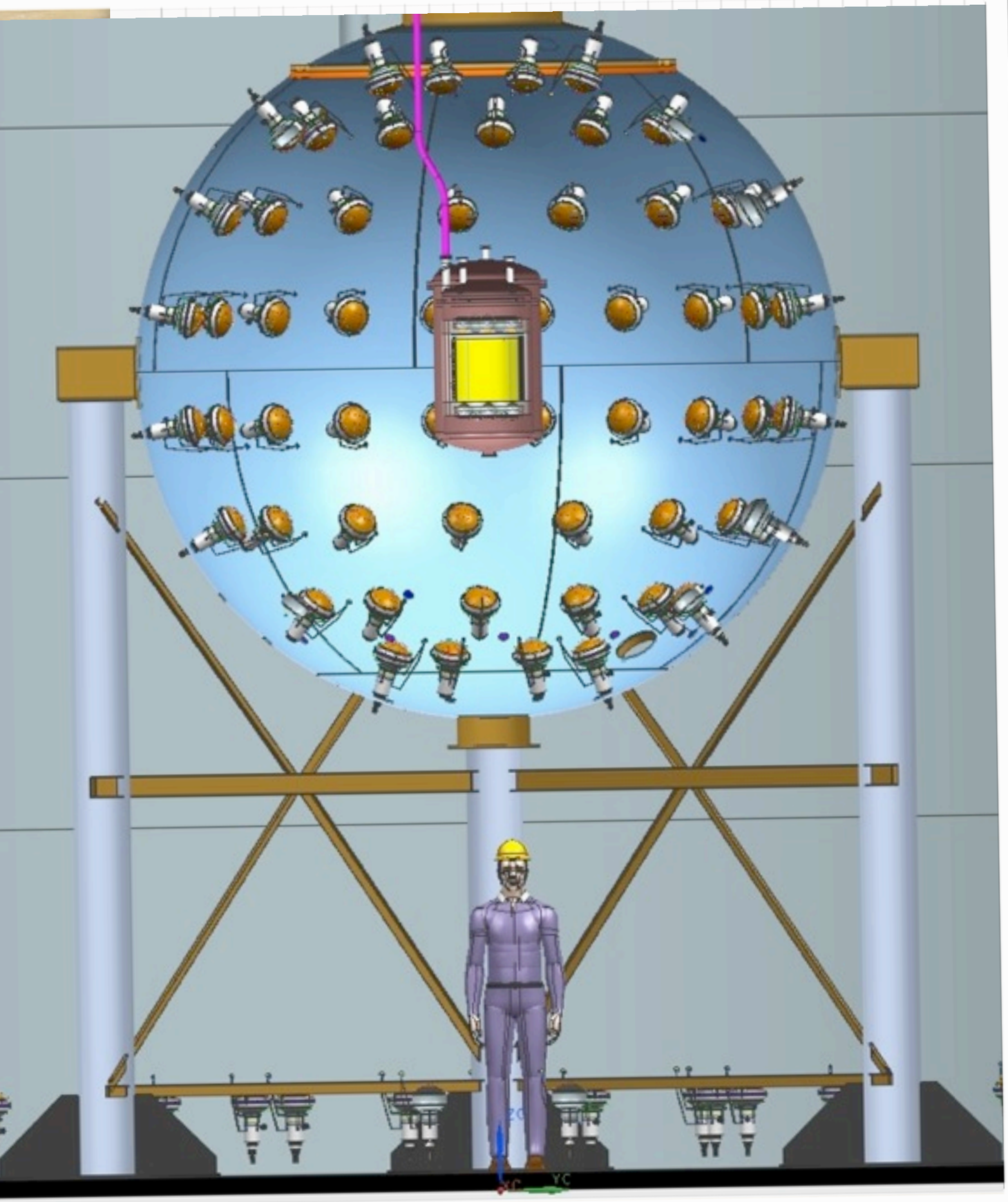
- Total trigger rate in DS-10, once filled with water the shield, is ~ 17Hz.
- Extremely low hardware threshold, corresponding to ~few keV$_{ee}$.
- Presently operating at nominal fields (E_{drift}=1kV/cm and E_{ext}=4kV/cm)
- It will be an ideal tool for testing at very low energy the performance of the two-phase TPC.

DS-50 two-phase Argon TPC

- 50 kg DAr sensitive volume (cylinder with 36 cm diameter and 38 cm height)
- 19+19 cryogenic high QE Hamamatsu PMTs
- All inner surfaces are coated with a wavelength shifter (TPB) to convert the VUV light into visible (detectable by PMTs)
- Lateral walls made of high reflectivity polycrystalline PTFE.
- Quartz diving bell (top) and window (bottom) in front of the PMT arrays coated with ITO (thin metallic layer highly transparent to visible light).
- Ready by fall 2012.

Designed to provide an extremely high Light Yield, decreasing the detection energy threshold.





Neutron VETO

- The Argon time projection chamber is surrounded by a liquid scintillator spherical veto, 4m diameter, instrumented with 110 low background 8" PMTs.
- Liquid scintillator (PC) loaded with TMB (^{10}B).
- Based on (^{10}B, ^{6}Li) reaction so that it can be both relatively compact and highly efficient (99.9% with a 60μs window).
- SS sphere installed and ready by Fall 2012.
- Designed to host a multiton DAr TPC.

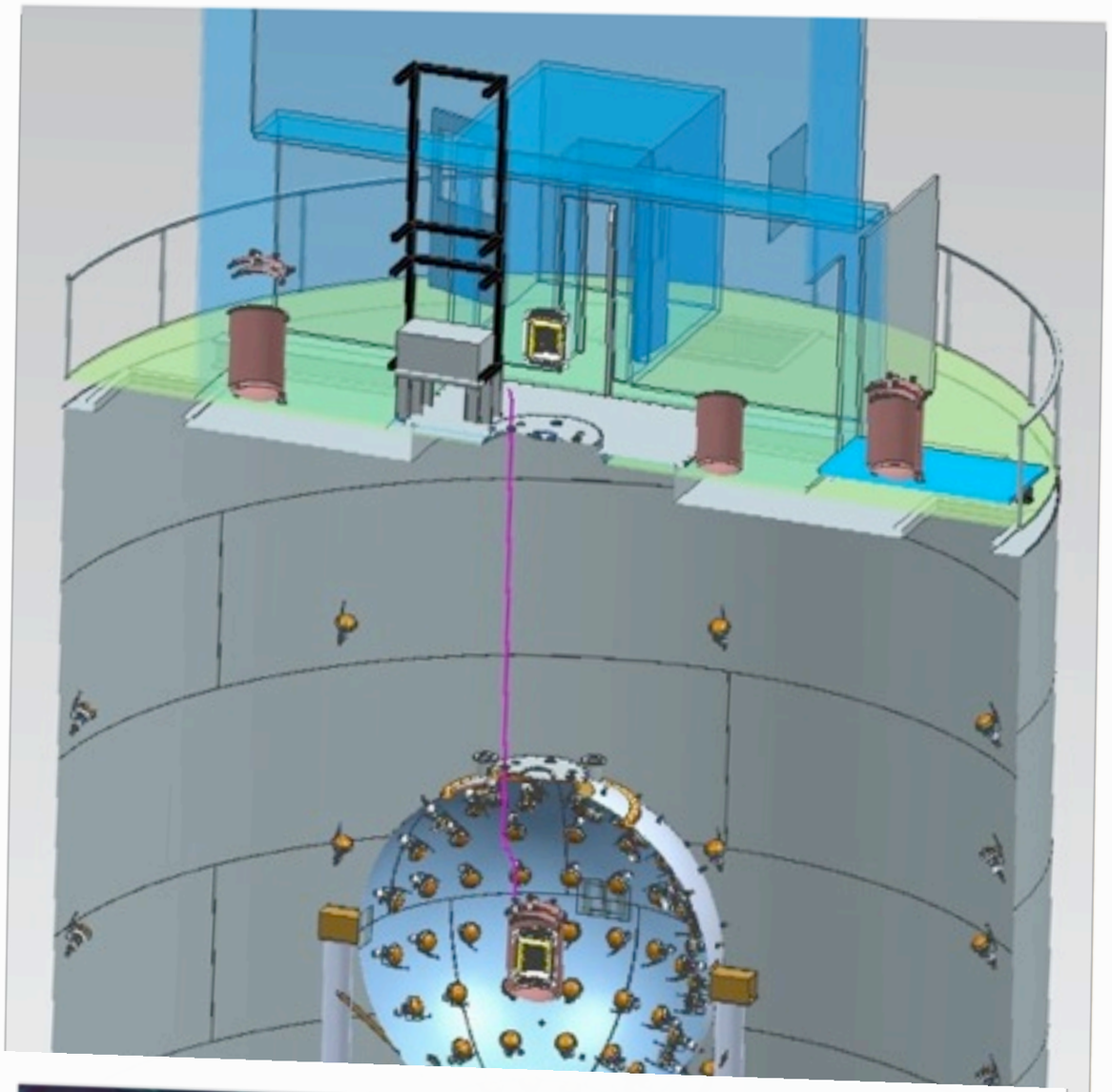
CTF Water Tank

- The scintillator vessel will be hosted in the water tank of Borexino Counting Test Facility (CTF), an EXISTING infrastructure @ LNGS.

- It is a 11mx10m stainless steel tank filled with water and working as Cherenkov detector for vetoing muon (and hence muon-induced neutrons) and as neutron passive shielding.

- The CTF has been fully drained and its refurbishing has just started for preparing the assembly of the sphere. It will be instrumented with 80 PMTs.

- Darkside-50 will be integrated with the already existing Borexino water and scintillator plants.



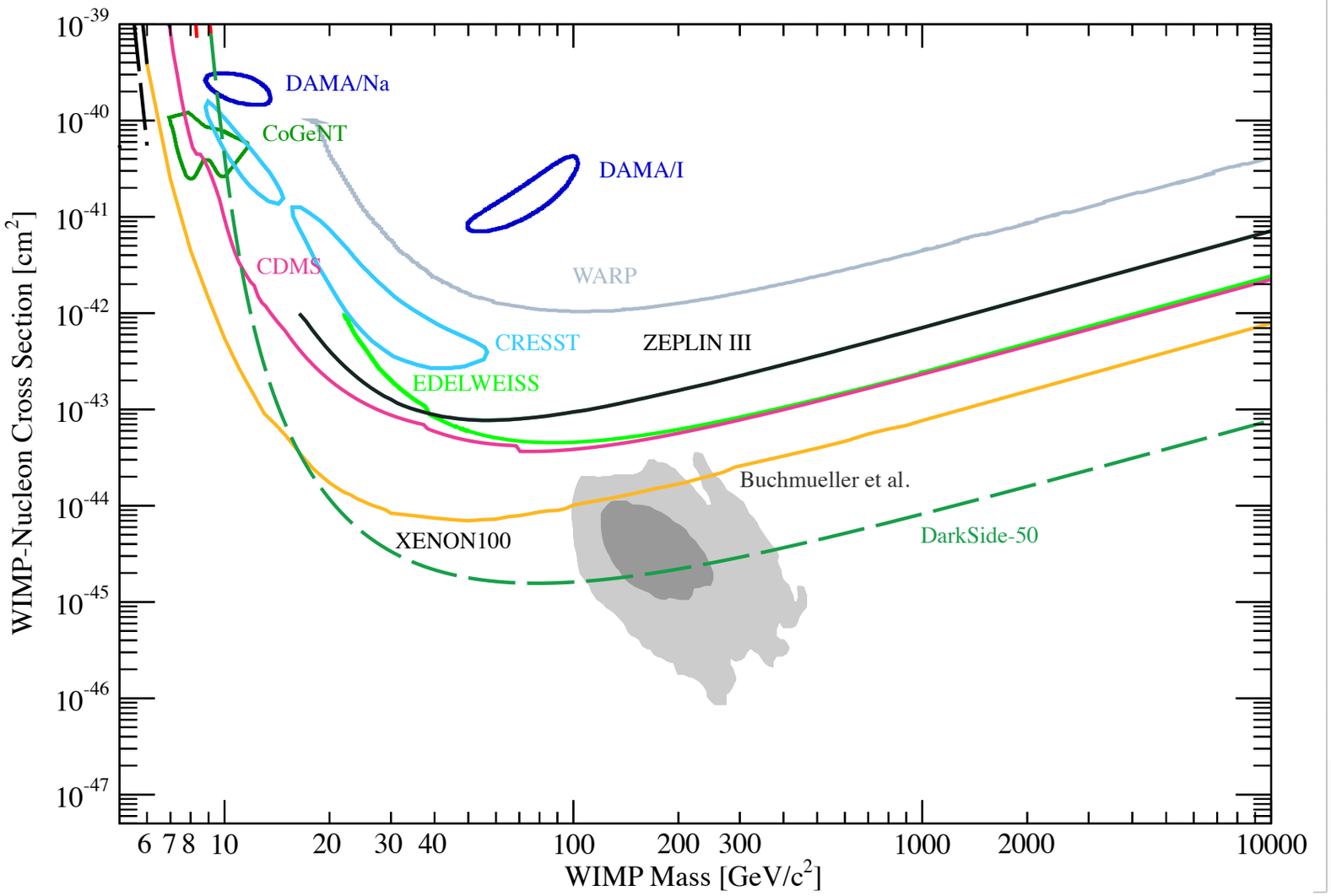
DarkSide-50 expected background

The combination of:

- ☐ Underground laboratory;
- ☐ Material screening for radiopurity;
- ☐ Low-background PMT (and QUPIDs);
- ☐ Depleted Argon;
- ☐ Boron loaded Liquid Scintillator;
- ☐ Water tank;
- ☐ two-phase Argon TPC;

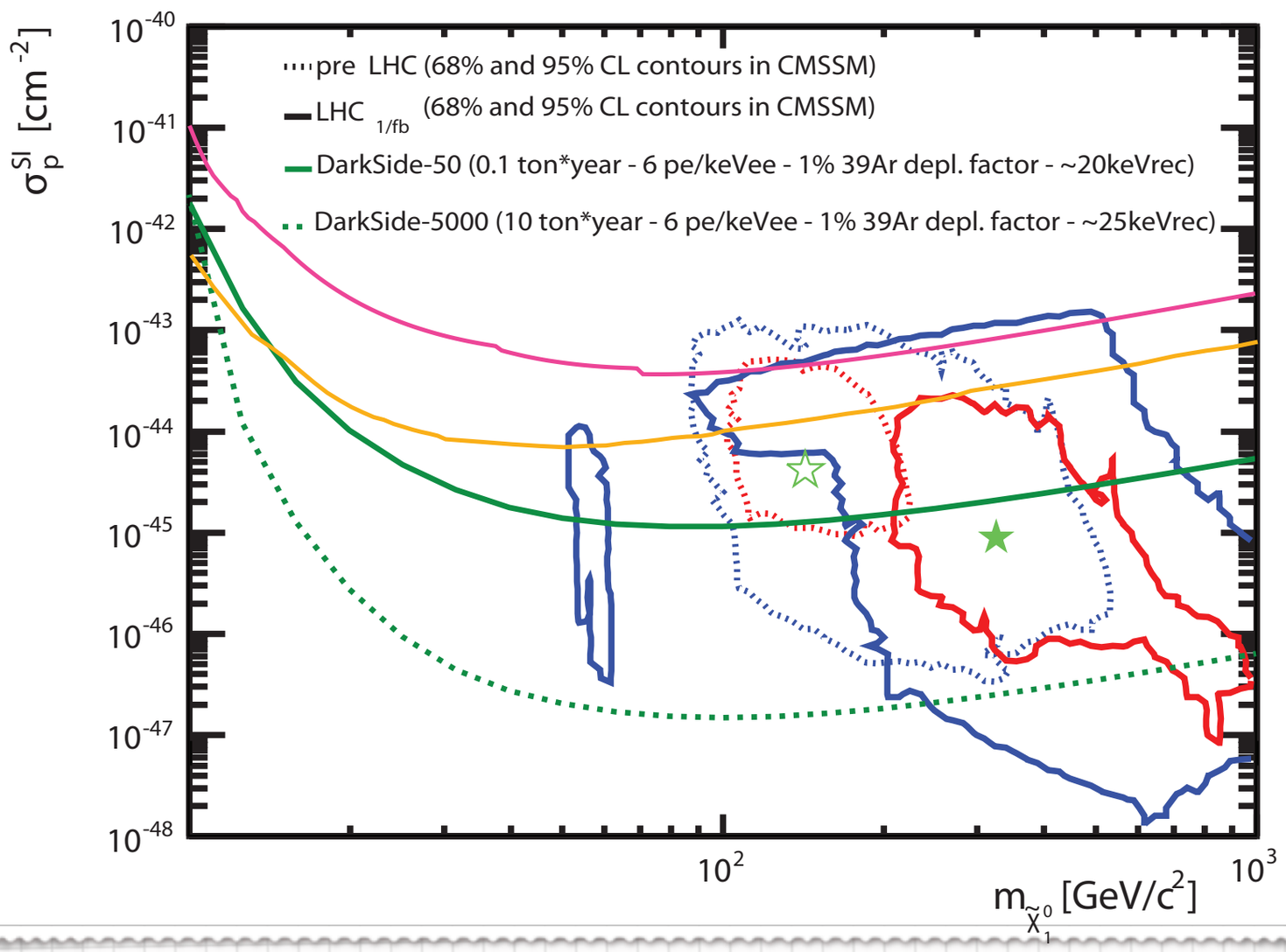
Detector Element	Electron Recoil Backgrounds		Radiogenic Neutron Recoil Backgrounds		Cosmogenic Neutron Recoil Backgrounds	
	Raw	After Cuts	Raw	After Cuts	Raw	After Cuts
^{39}Ar (<0.01 Bq/kg)	$<6.3\times10^{6}$	$<4\times10^{-3}$	–	–	–	–
Fused Silica	3.3×10^{4}	2.0×10^{-5}	0.17	4.3×10^{-4}	0.21	1.3×10^{-5}
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}
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	–	0.007 (0.006)	–	0.055 (0.008)	–	0.030 (0.030)

exp. background events in 0.1 ton-year



The unique combination of background rejection techniques coming from Argon technology and the extremely powerful veto system, leads to expected background lower than 0.1 events in 0.1 ton-year.

The projected sensitivity with a threshold of ~20keV$_{rec}$ is the order of ~1 x 10^{-45} cm^2 for a 100GeV WIMP (3 years of background free exposure).



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Summary

- Depleted Argon is a reality.
- Argon two-phase technology combined with Borexino liquid scintillator technology looks very promising for future ton scale detectors.
- DarkSide-10
  - successfully deployed at LNGS:
  - producing results in a low background environment:
  - tested the solutions that we are going to implement on DS-50. Excellent performance in terms of LY has been observed.
- Darkside-50
  - Detectors ready by Fall 2012:
  - DAr procurement finished by Fall 2012:
  - Commissioning starting Q4 of 2012.