The DarkSide Dark Matter Search

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on behalf of the
DarkSide Collaboration

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Outline

- DarkSide Program
- DarkSide-50
- DarkSide-50 results with atmospheric argon
- DarkSide-50 calibration and underground Ar run
- The future of DarkSide-50
- Summary

DarkSide Program

- Direct detection search for WIMP dark matter
- Based on a two-phase argon time projection chamber (TPC)
- Design philosophy:
  - very low background levels (*all components chosen/designed to have the lowest possible radioactivity*), further reduced through active suppression → toward **background-free** operation:
    - pulse shape discrimination
    - multiple interactions
    - S1/S2 signal ratio
    - active veto detectors

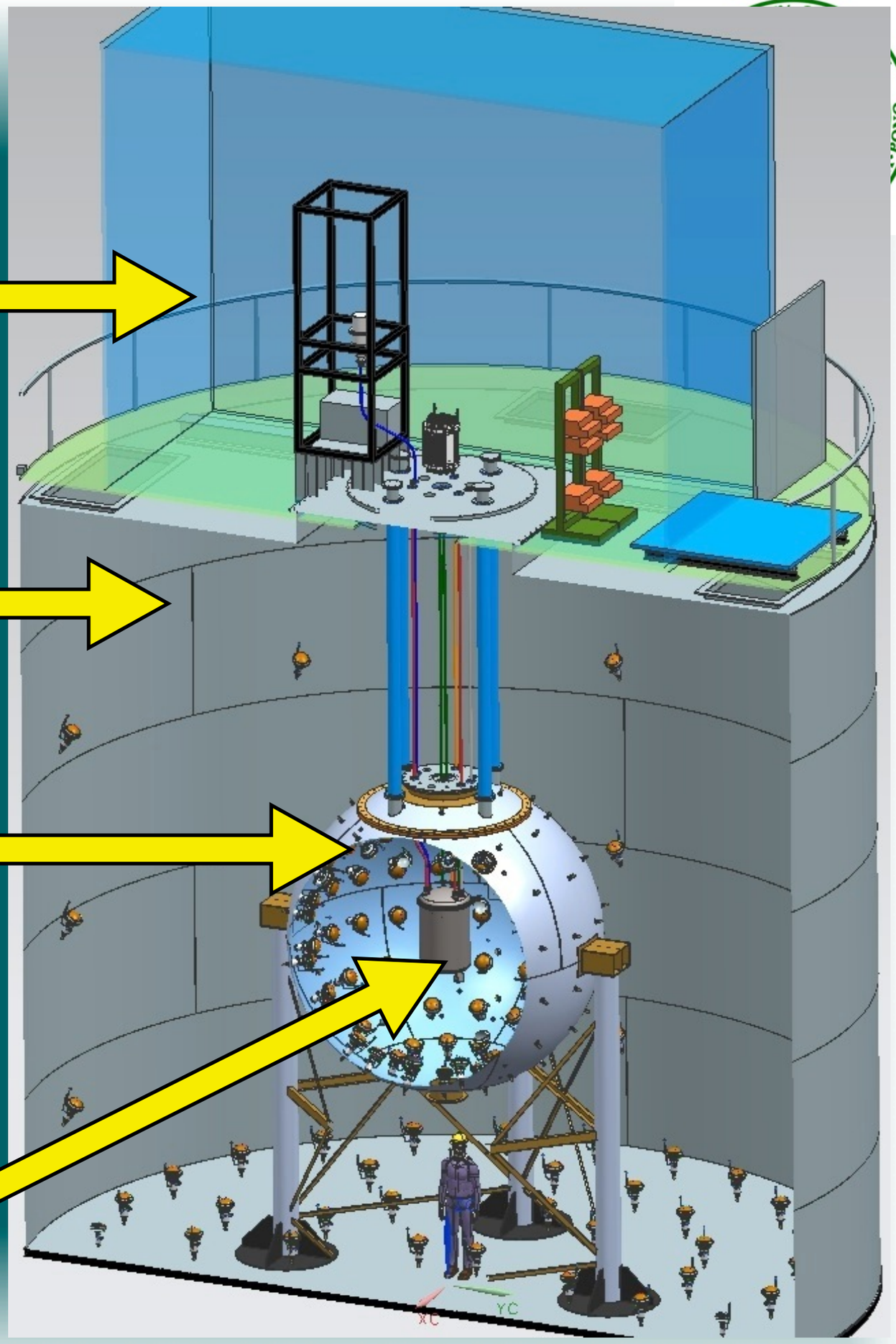
DarkSide 50

Radon-free clean room

Muon veto – water Cherenkov detector (1000 tons)

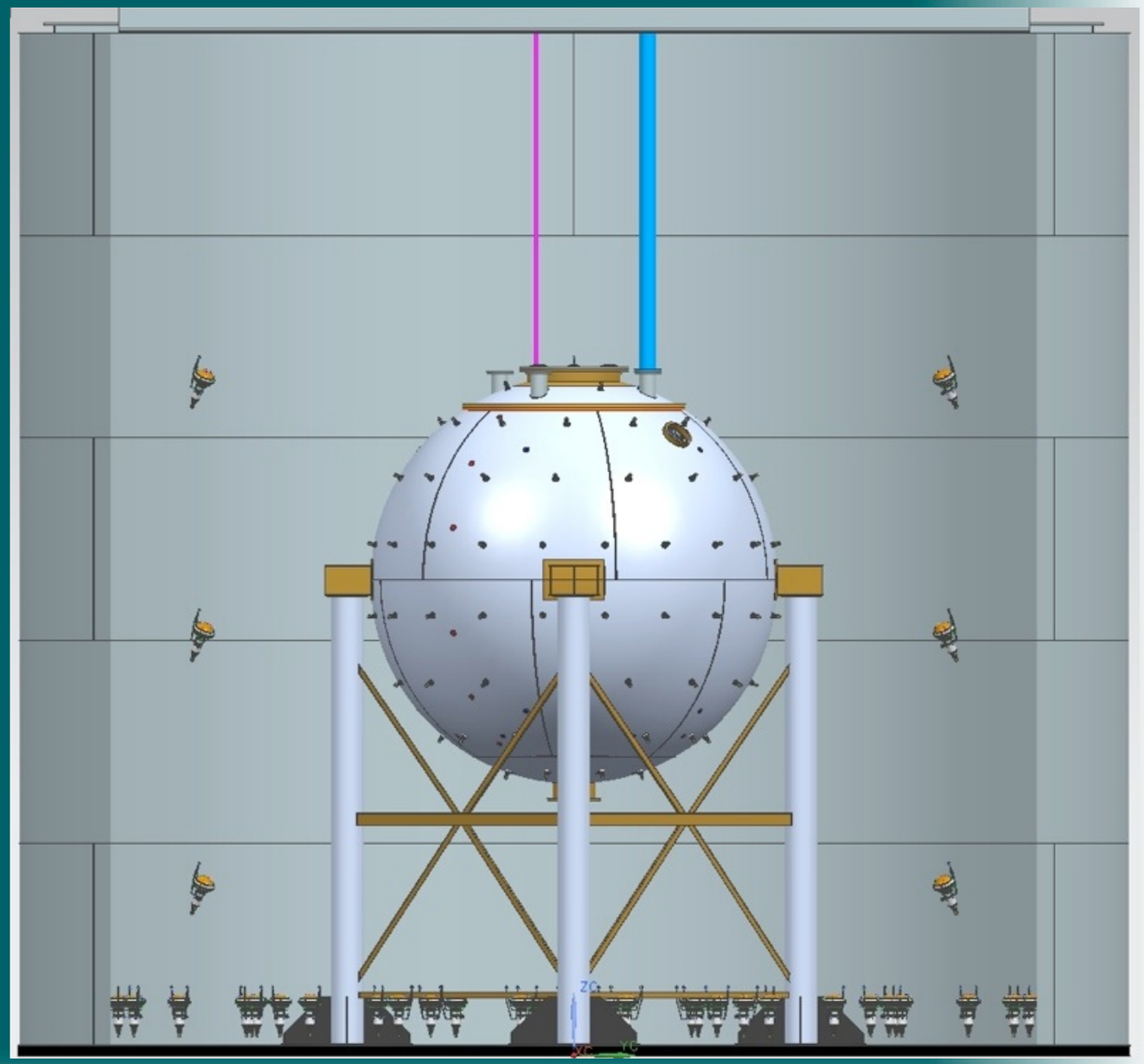
Liquid scintillator veto for neutrons and gamma's (30 tons)

Inner detector TPC (sensitive DM target volume)



External Water tank

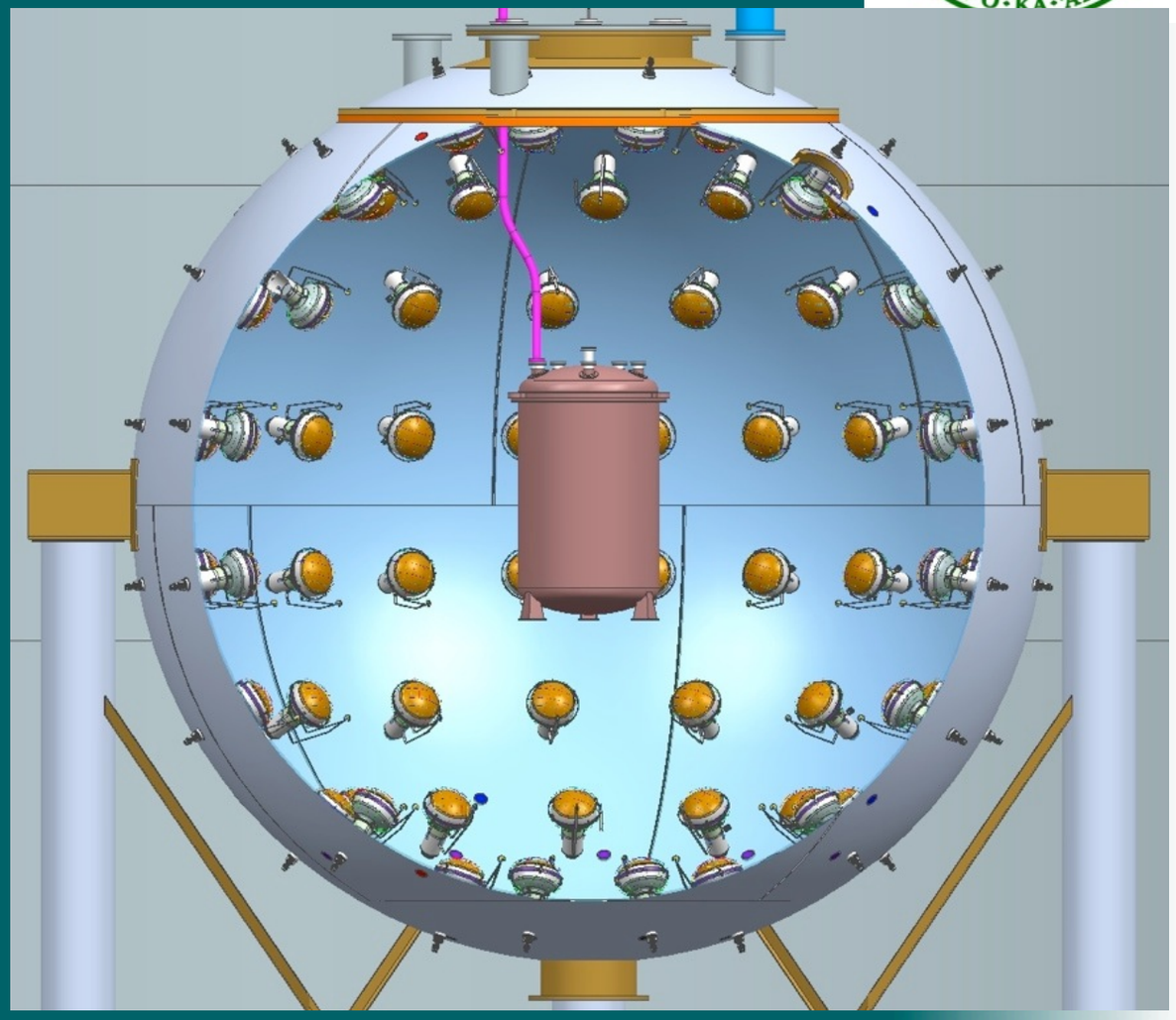
- 80 PMTs within water tank (11m dia. x 10 m high)
- Acts as a muon and cosmogenic veto (~ 99% efficiency)
- Provides passive gamma and neutron shielding



Liquid Scintillator Veto

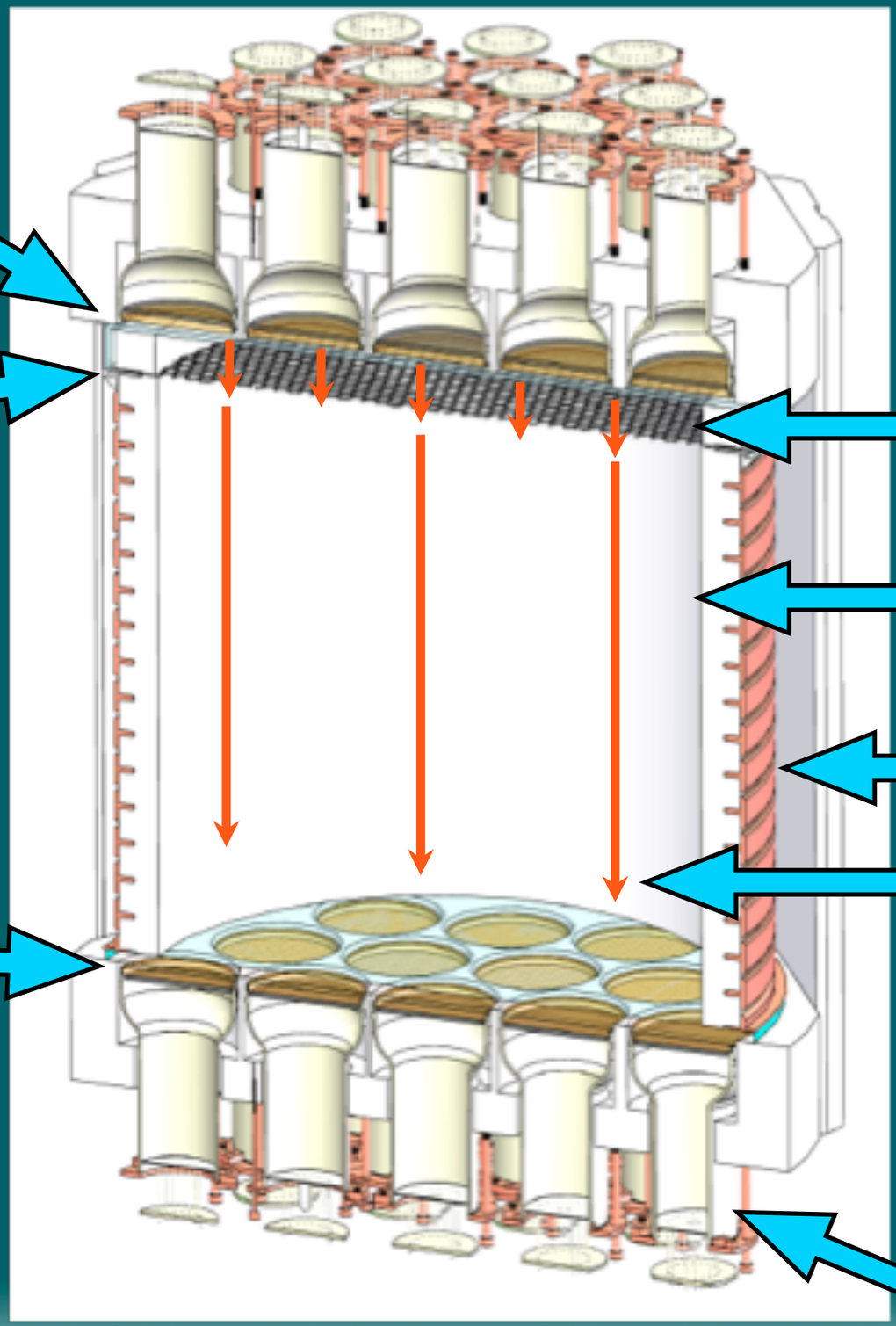
Liquid scintillator allows coincident veto of neutrons in the TPC and provides ***in situ*** measurement of the neutron background rate

99.5% neutron rejection efficiency



- 4 m diameter sphere containing mix of PC + TMB scintillator
- Instrumented with 110 8” PMTs
- High neutron capture c-section on boron allows for compact veto size
- Capture results in 1.47 MeV α particle - detected with high efficiency
- Short capture time (couple of μs) reduces dead time loss

Two Phase Argon TPC



Anode

E_{gas} ~ 5 kV/cm

E_{liquid} ~ 3 kV/cm

Grid

E_{drift} ~ 0.2 kV/cm

Cathode

Gas

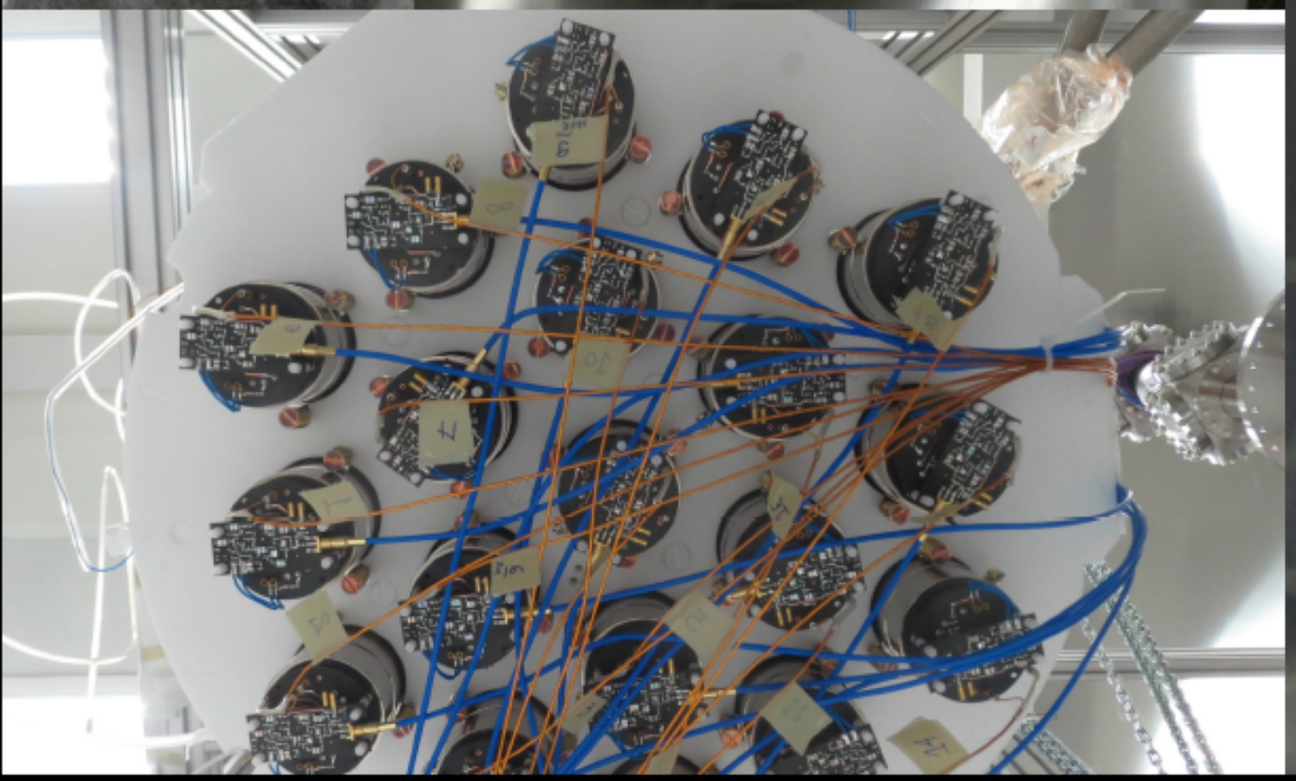
Wavelength Shifter + Reflector

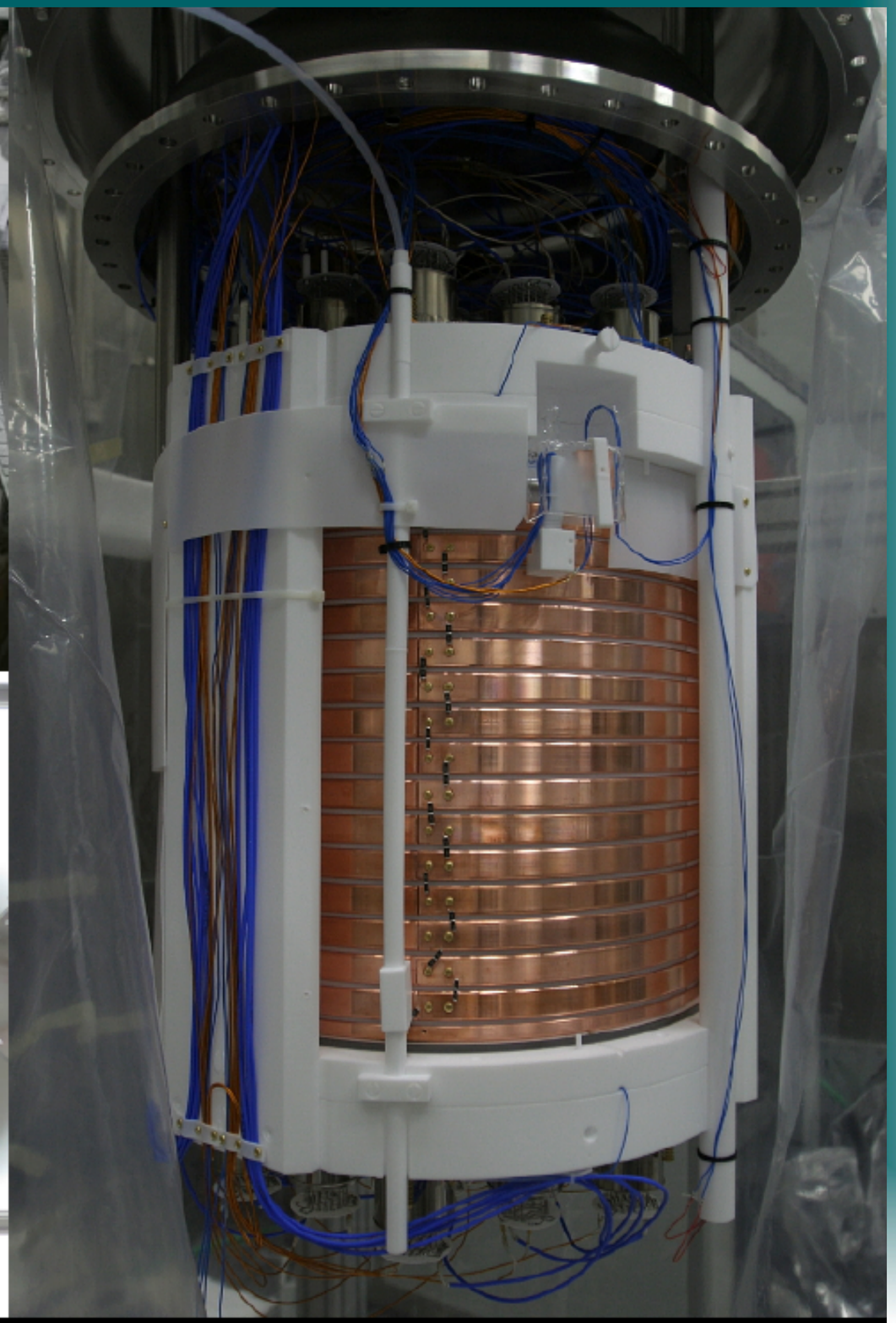
Field Cage Rings

Liquid Ar

Photodetectors

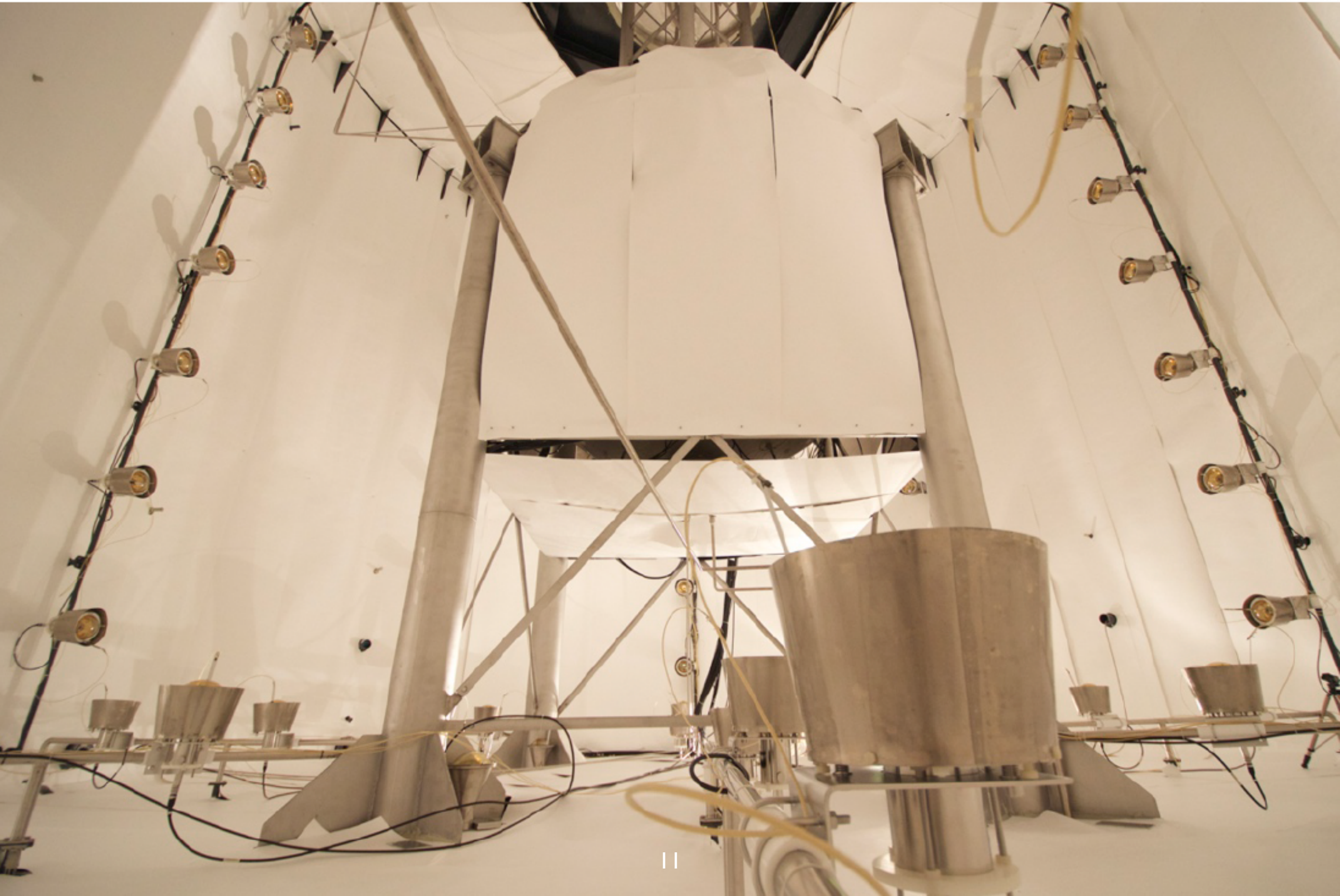
TPC Commissioning



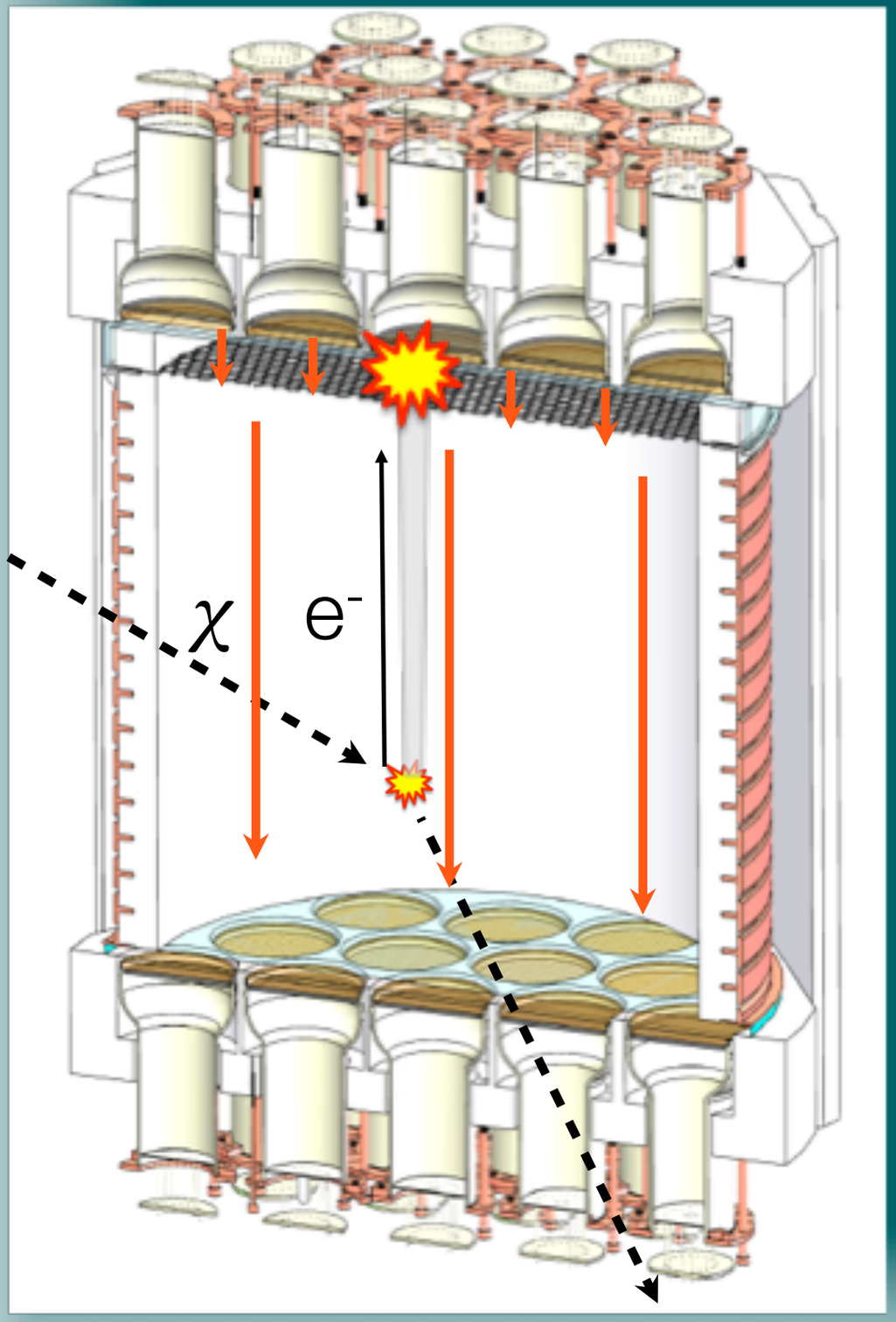


Neutron Veto Commissioning

Muon Veto Before Filling



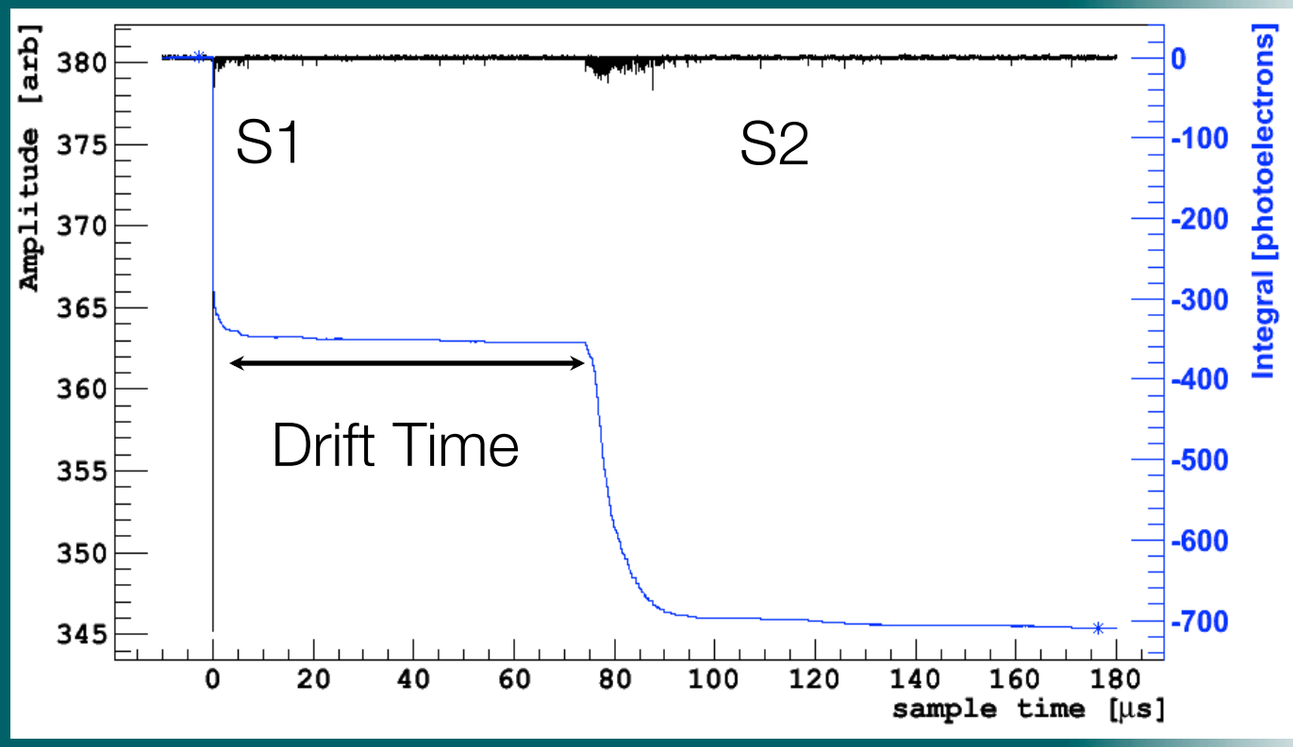
Detecting WIMPs



S1: primary scintillation light
S2: secondary electroluminescence light
(proportional to free electrons from S1)

Electron drift lifetime > 5 ms,
compared to max. drift time of ~ 375 µs

Electron drift speed = 0.93 ± 0.01 mm/µs



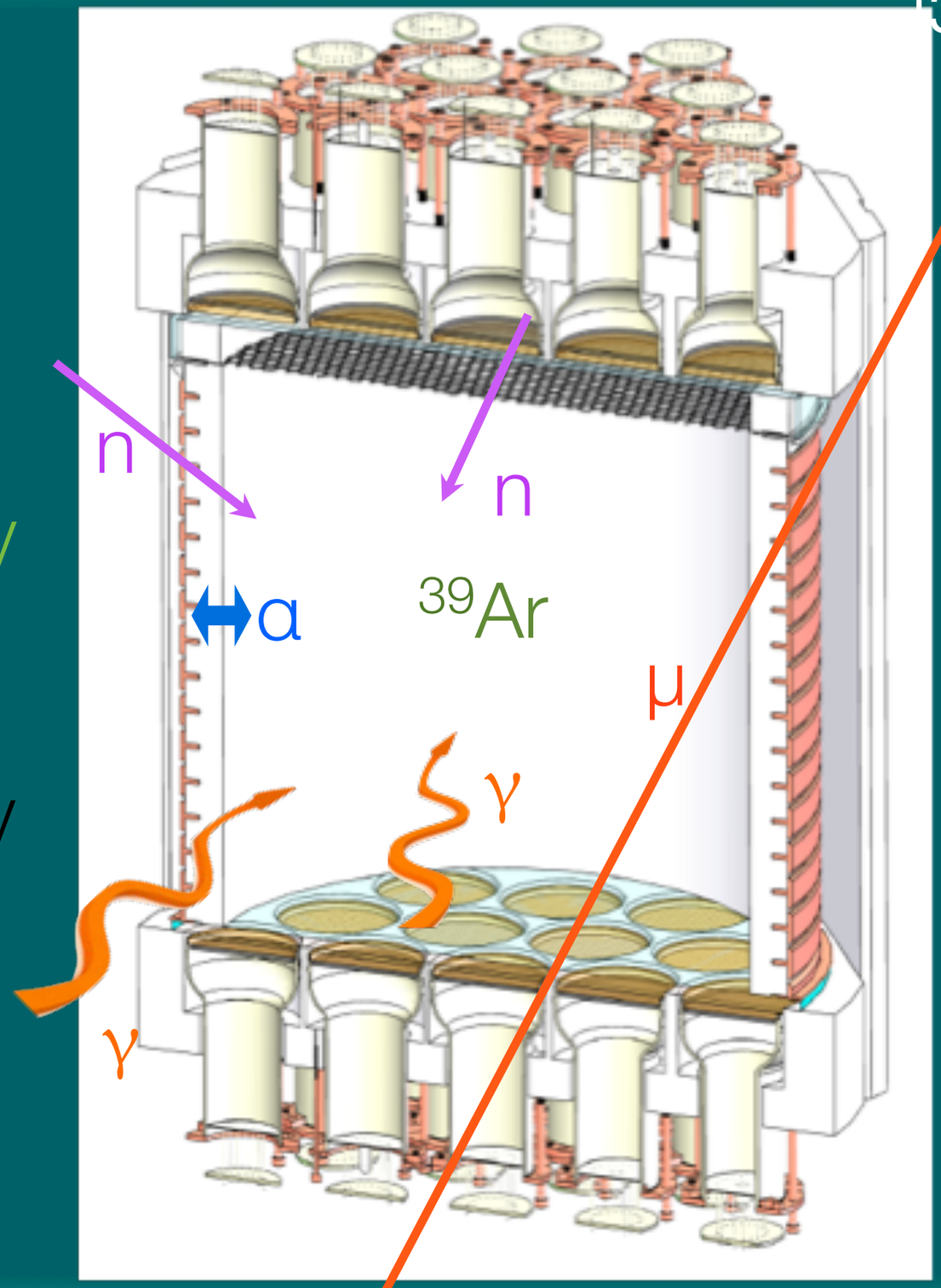
The time between the S1 and S2 signals gives the vertical position

Backgrounds

ELECTRON RECOILS

^{39}Ar
~$9x10^4$ evt/kg/day

γ
~$1x10^2$ evt/kg/day



NUCLEAR RECOILS

μ
~30 evt/m^2/day

Radiogenic n
~$6x10^{-4}$ evt/kg/day

α
~10 evt/m^2/day

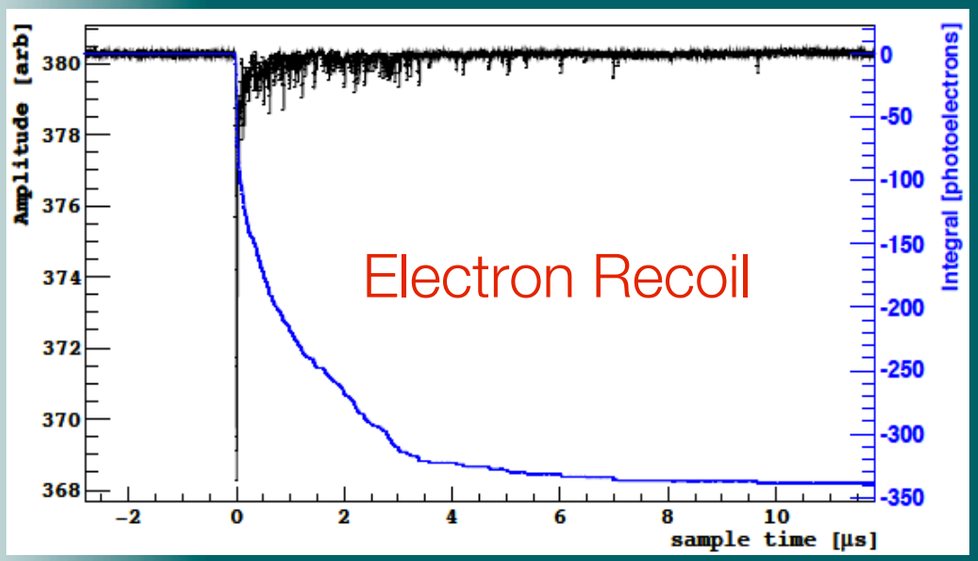
M_χ ~100 GeV, $10^{-45}cm^2$ WIMP Rate ~ 10^{-4} evt/kg/day

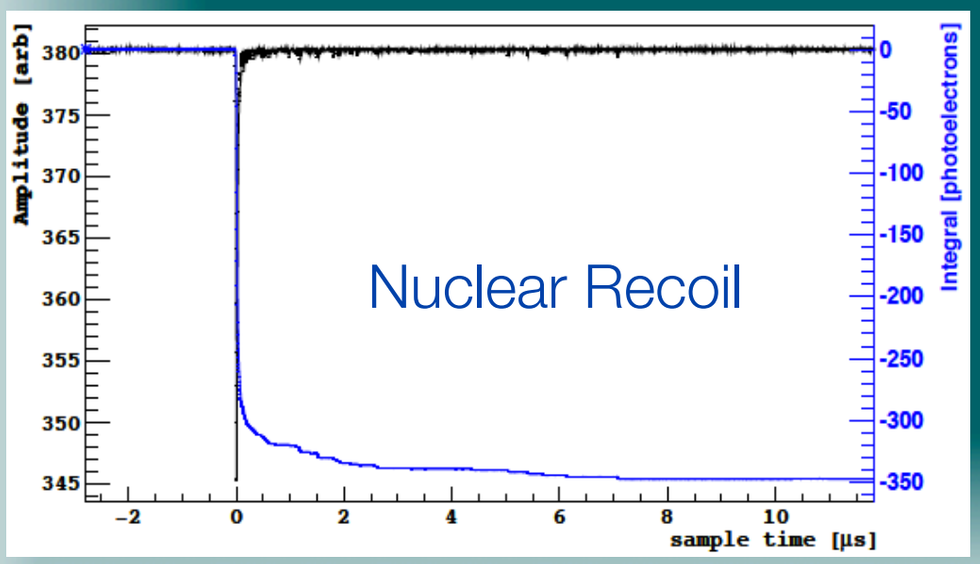
Discriminating Electron Recoils

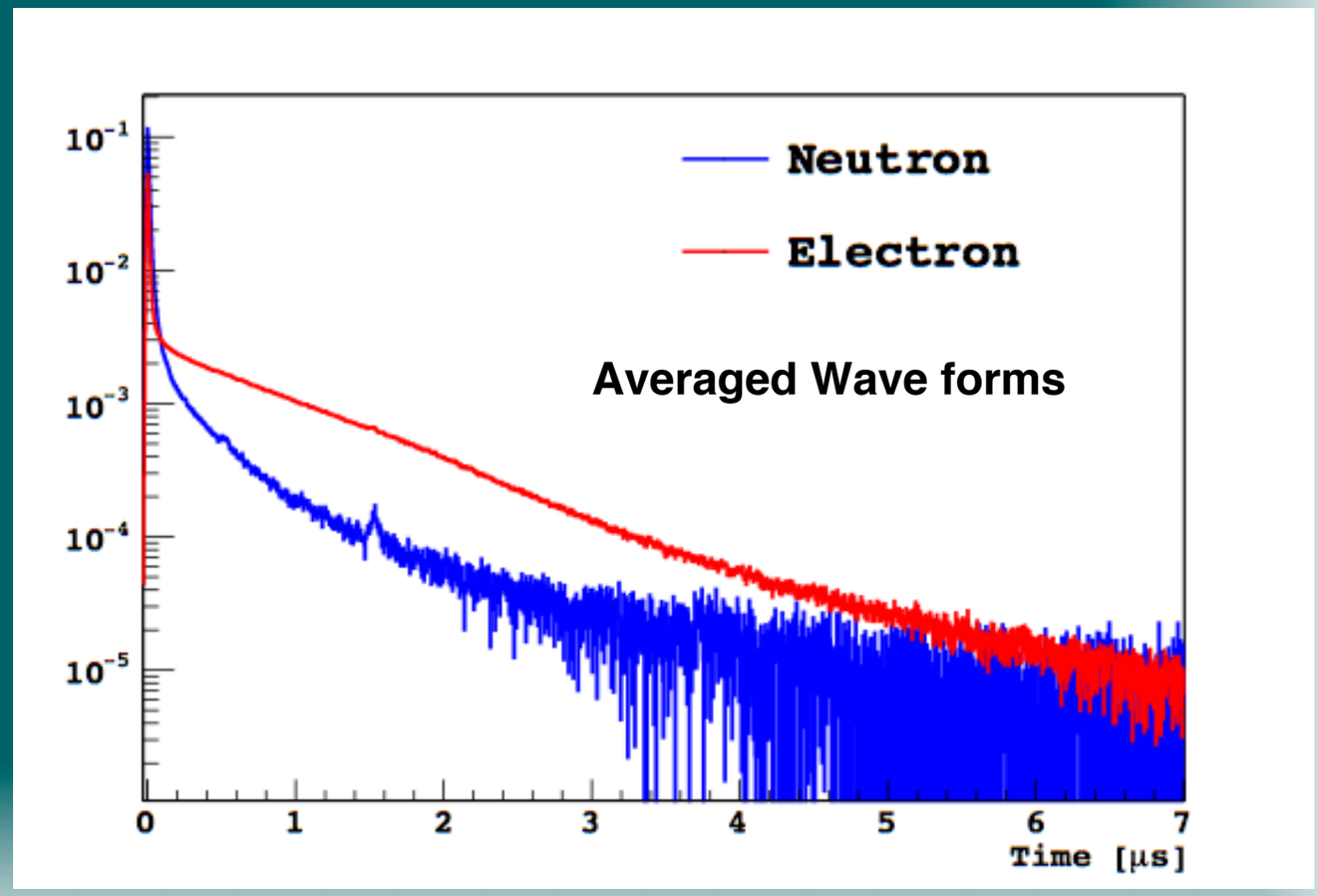
Pulse shape discrimination based on time profile of S1 light signal.
Electron and nuclear recoils produce different excitation densities in the argon, leading to different ratios of singlet and triplet excitation states

τ singlet ~ 7 ns

τ triplet ~ 1500 ns







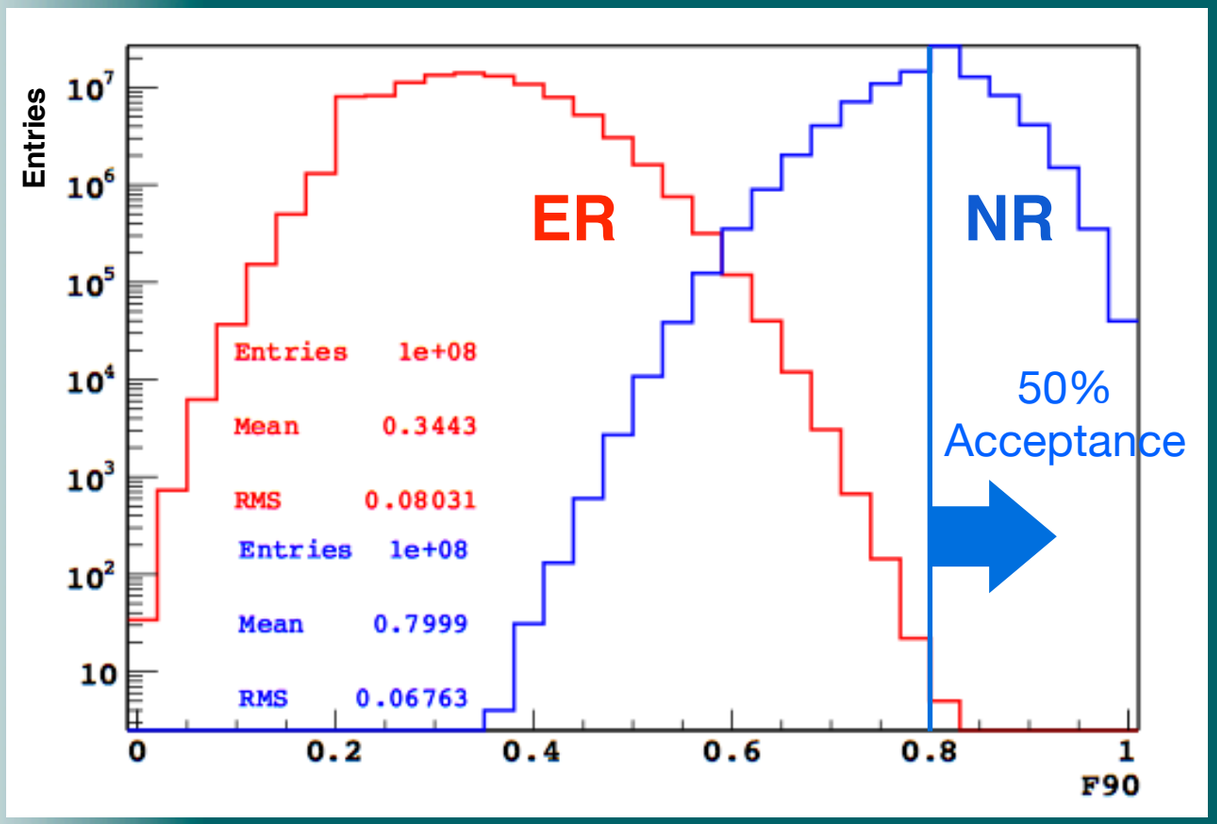
Pulse Shape Discrimination

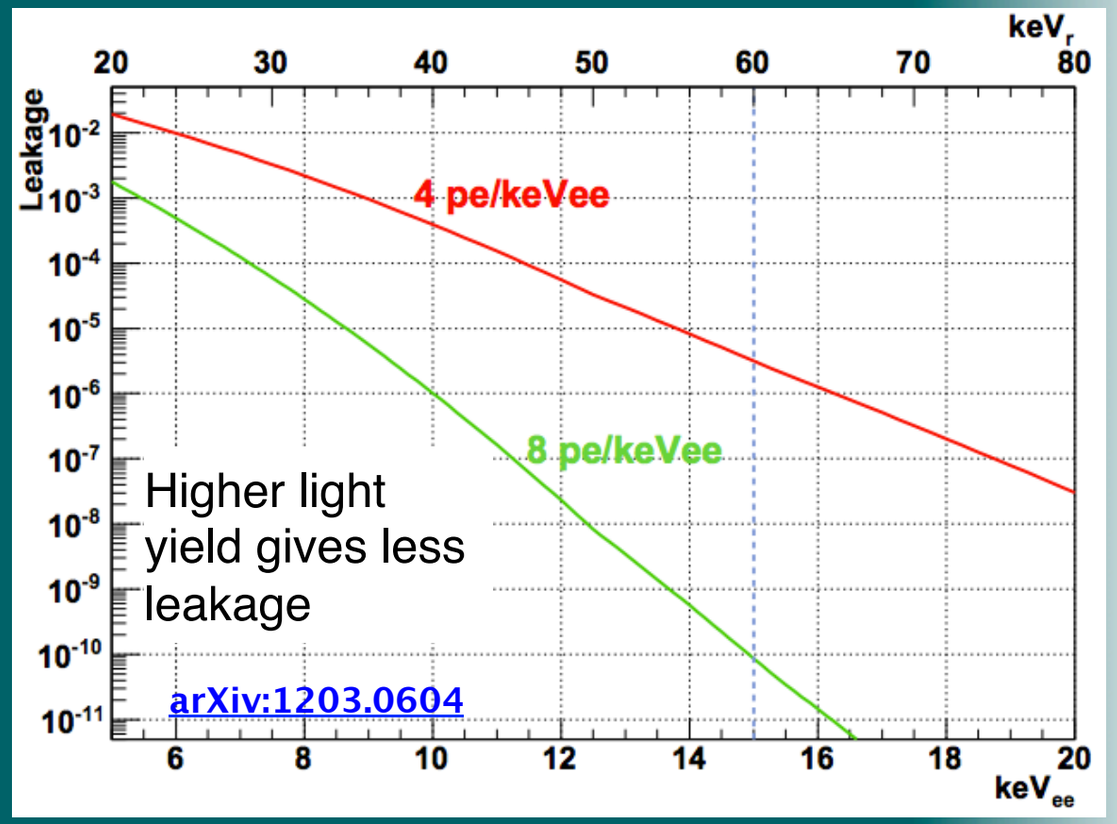
F90: Ratio of detected light in the first 90 ns, compared to the total signal

~ Fraction of singlet states

τ singlet ~ 7 ns

τ triplet ~ 1500 ns

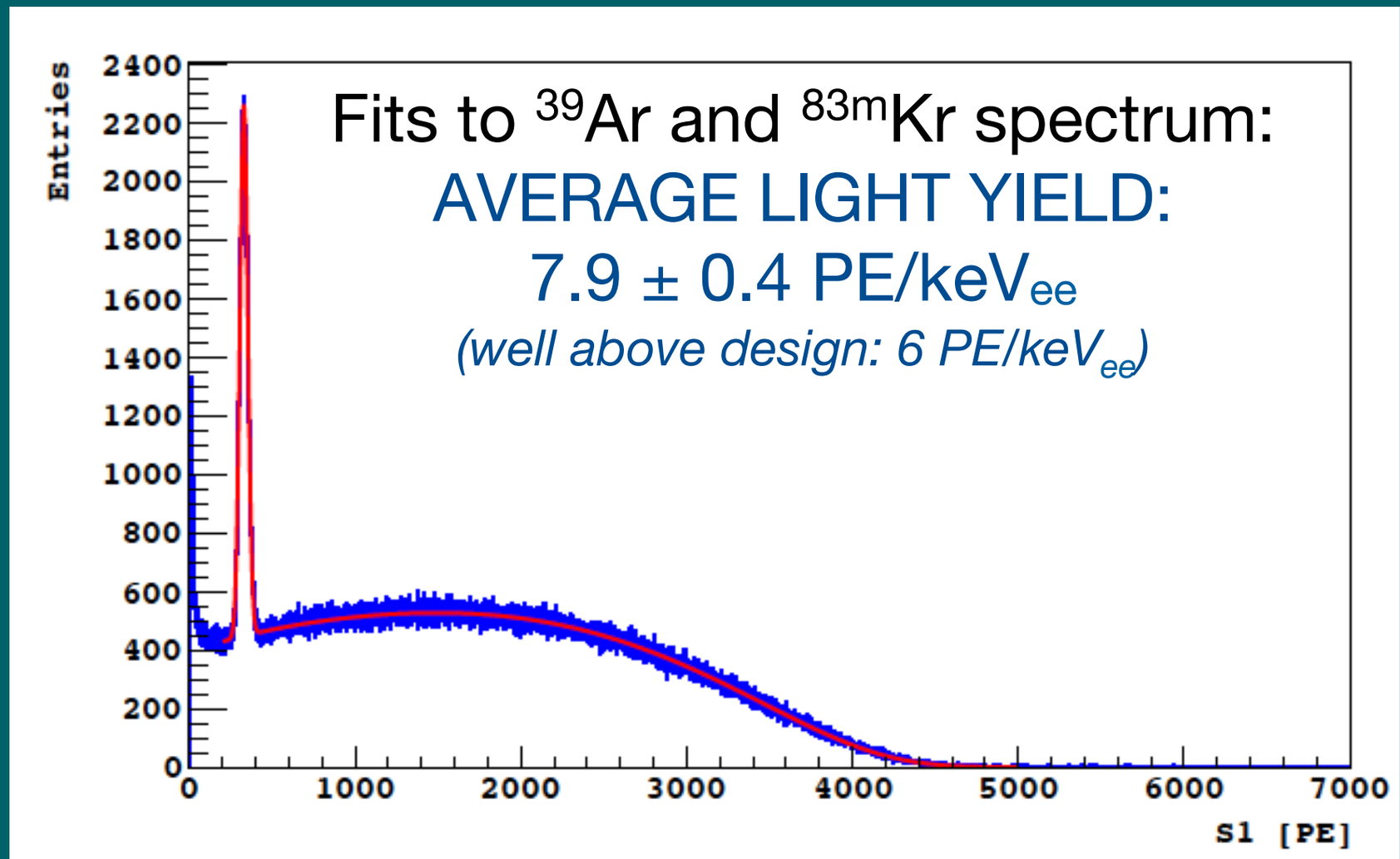




Discrimination power strongly dependent on light collection.

TPC: ER calibration @ null field

^{83m}Kr Half-life = 1.83 hours



Fits to ^{39}Ar and ^{83m}Kr spectrum:

AVERAGE LIGHT YIELD:

7.9 ± 0.4 PE/keV$_{ee}$

(well above design: 6 PE/keV$_{ee}$)

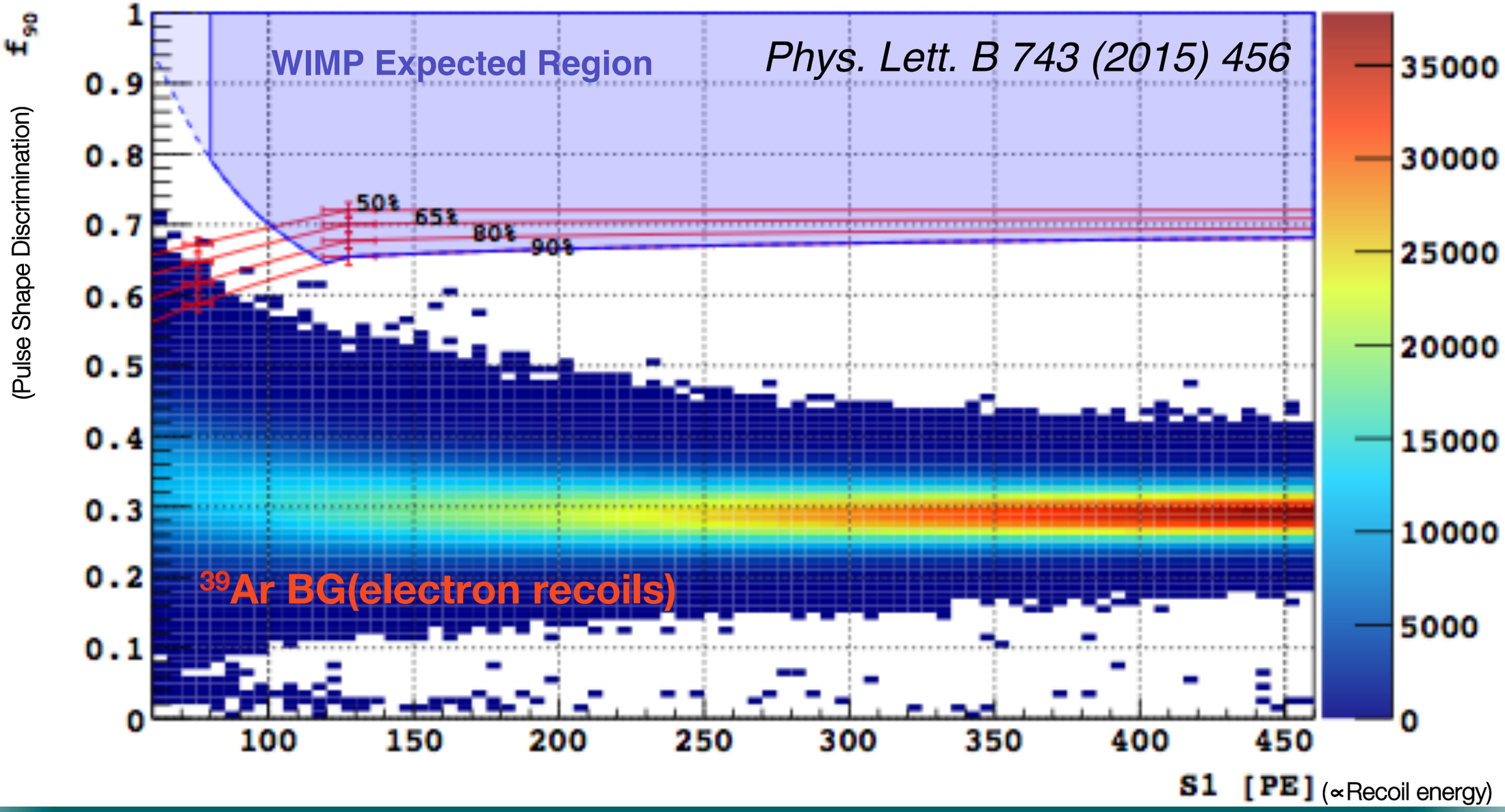
^{83m}Kr gas deployed into detector (41.5 keV$_{ee}$)
in October 2013.
Detector was filled with atmospheric argon at 1 Bq/kg.

The First Physics Result from DS-50

- Atmospheric argon (AAr) target
- ^{39}Ar BG present at 1 Bq/kg
- 47.1 live days
- 1422 kg · day fiducial of AAr

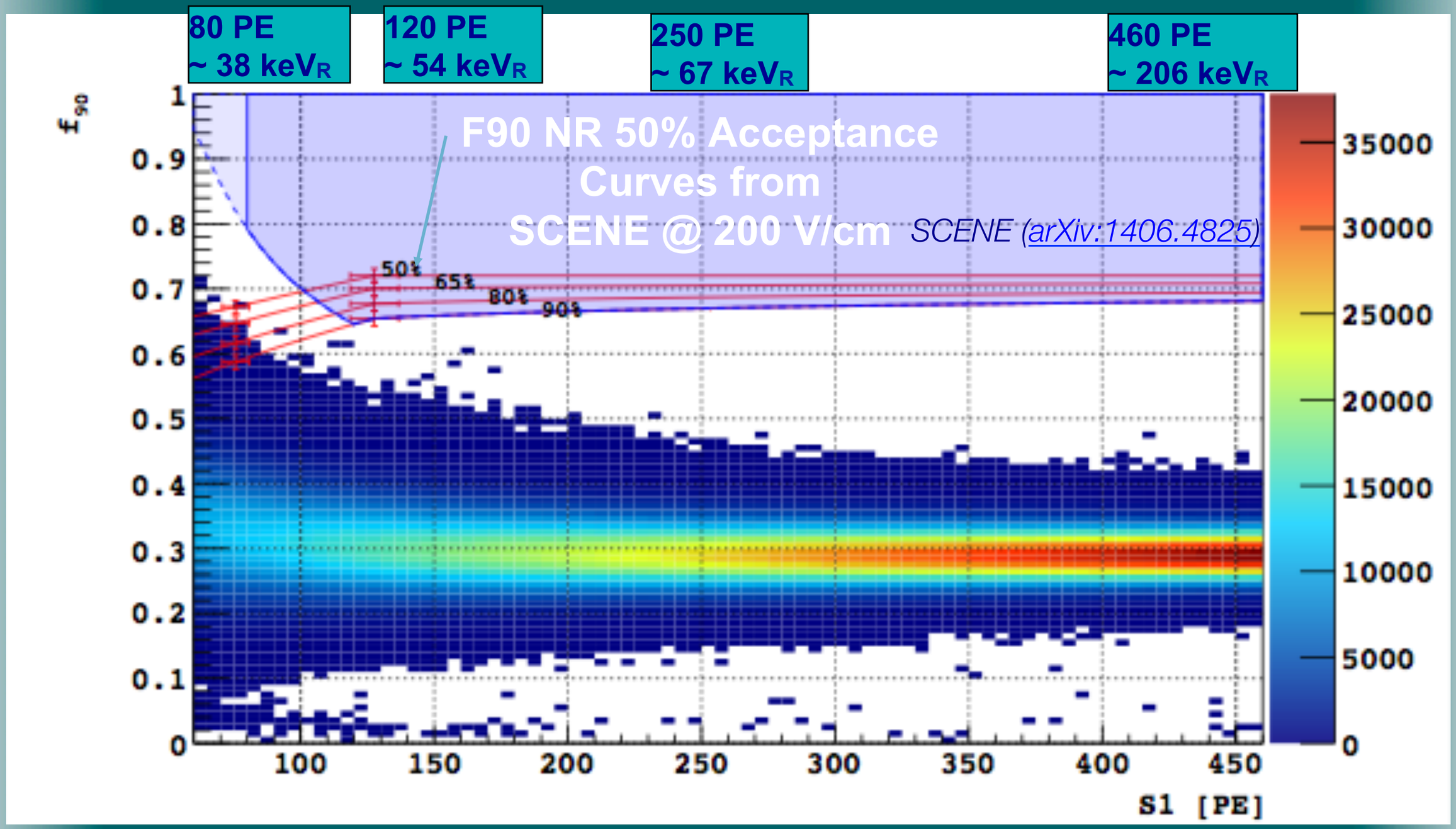
Background-free exposure of 1422 ± 67 kg·day

No background events in nuclear recoil (WIMP) region



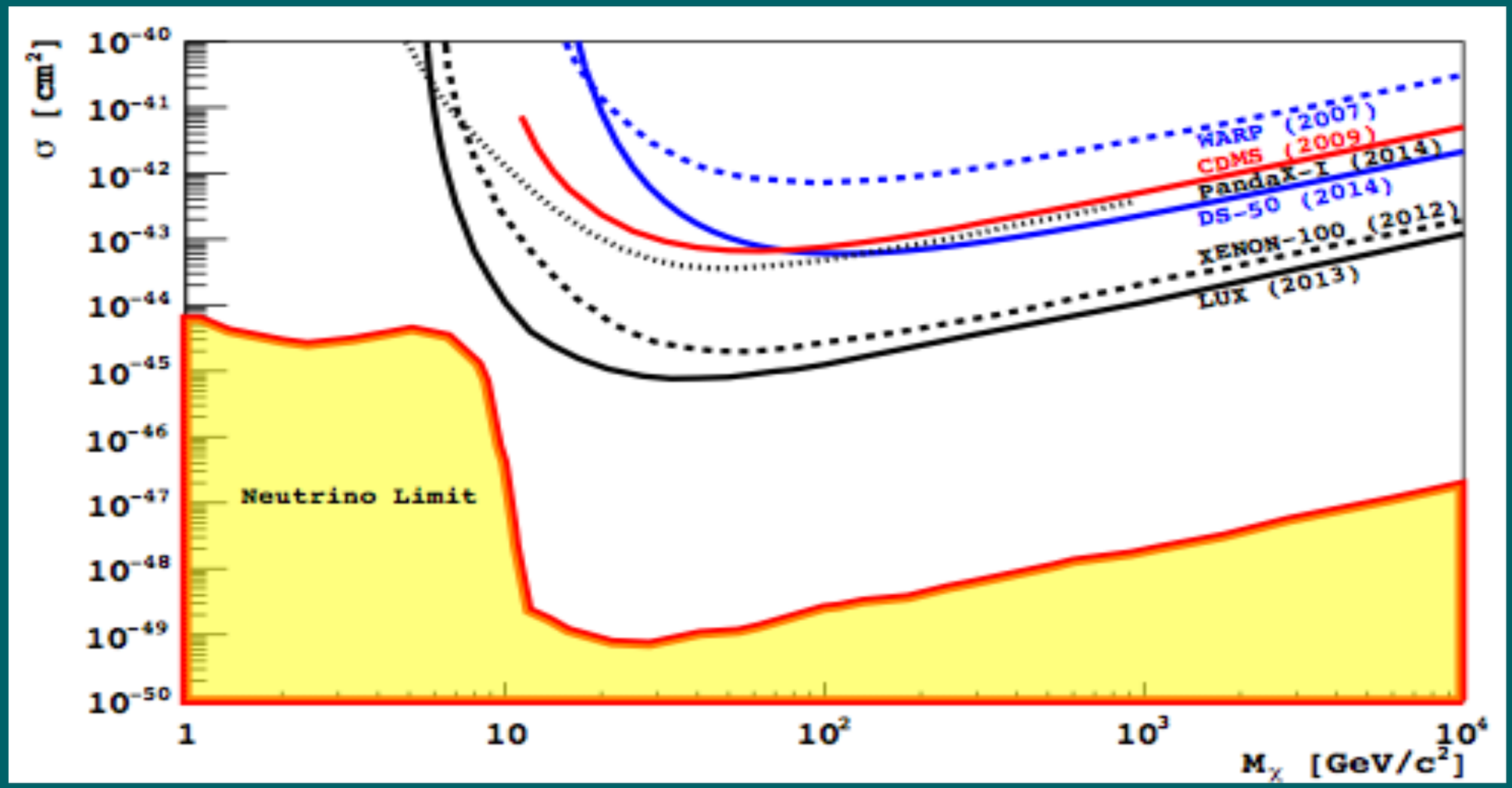
Selected only single-hit interactions (one S1 and one S2 signal) in the TPC fiducial volume (36.9 kg) with no energy deposition in the veto

Background-free exposure of 1422 ± 67 kg·day



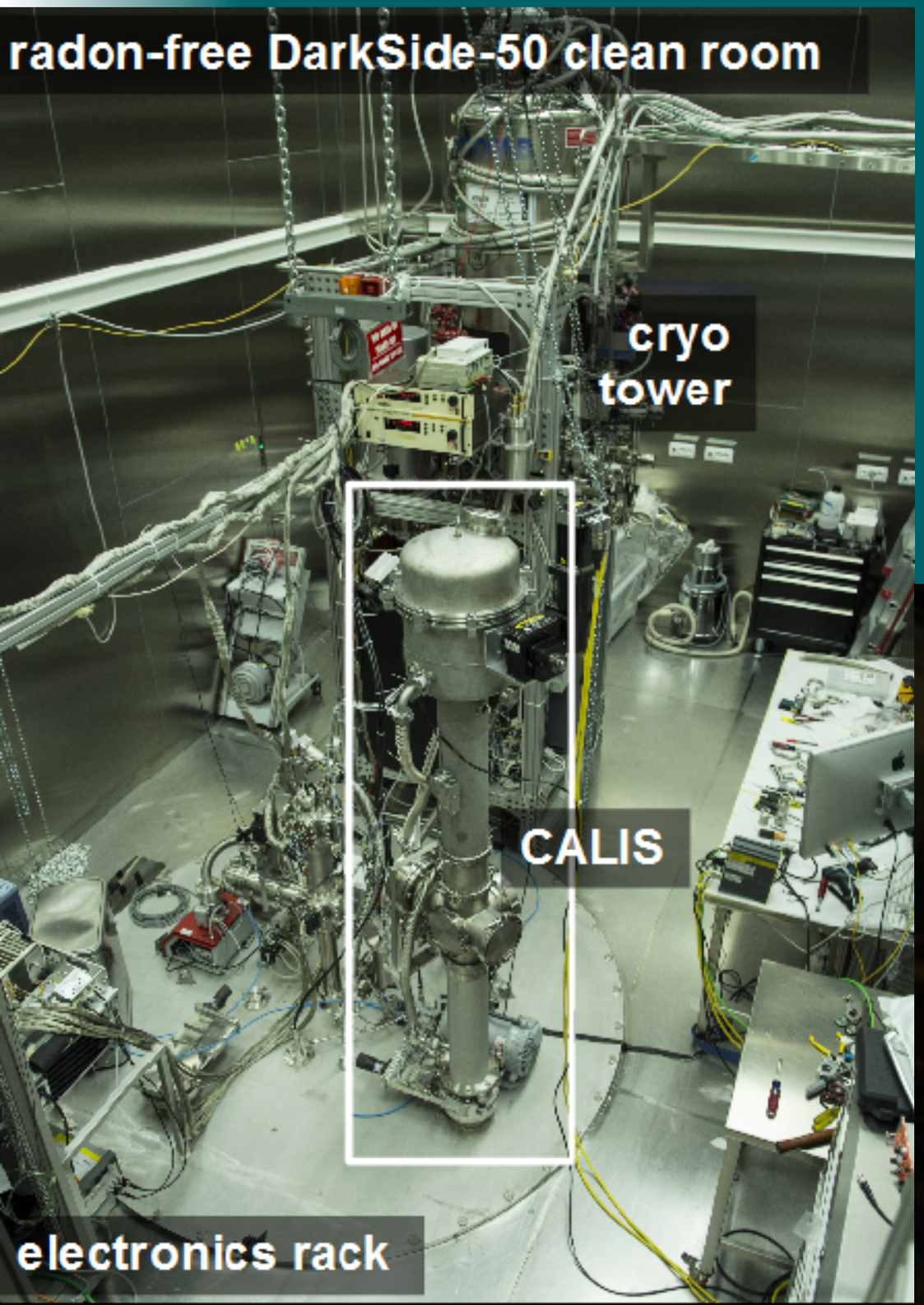
WIMP Sensitivity

This is the most sensitive dark matter search performed with an argon target.
Limit on the WIMP-nucleon spin-independent cross section is 6.1×10^{-44} cm^2 for a WIMP mass of 100 GeV/c^2.



- Background free
  From this result, the ^{39}Ar BG in the full DS-50 run w/ UAr can be suppressed, and future ton-scale LAr TPCs can be free of ^{39}Ar BG.

CALIS – CALibration Insertion System



- Calibrated both TPC and Neutron veto (11/2014)
- **Gamma sources**: ^{57}Co (122 keV), ^{133}Ba (356 keV), ^{137}Cs (663 keV)
- **Neutron source:** AmBe
- **Drift fields**: null, 100, 150, 200 V/cm

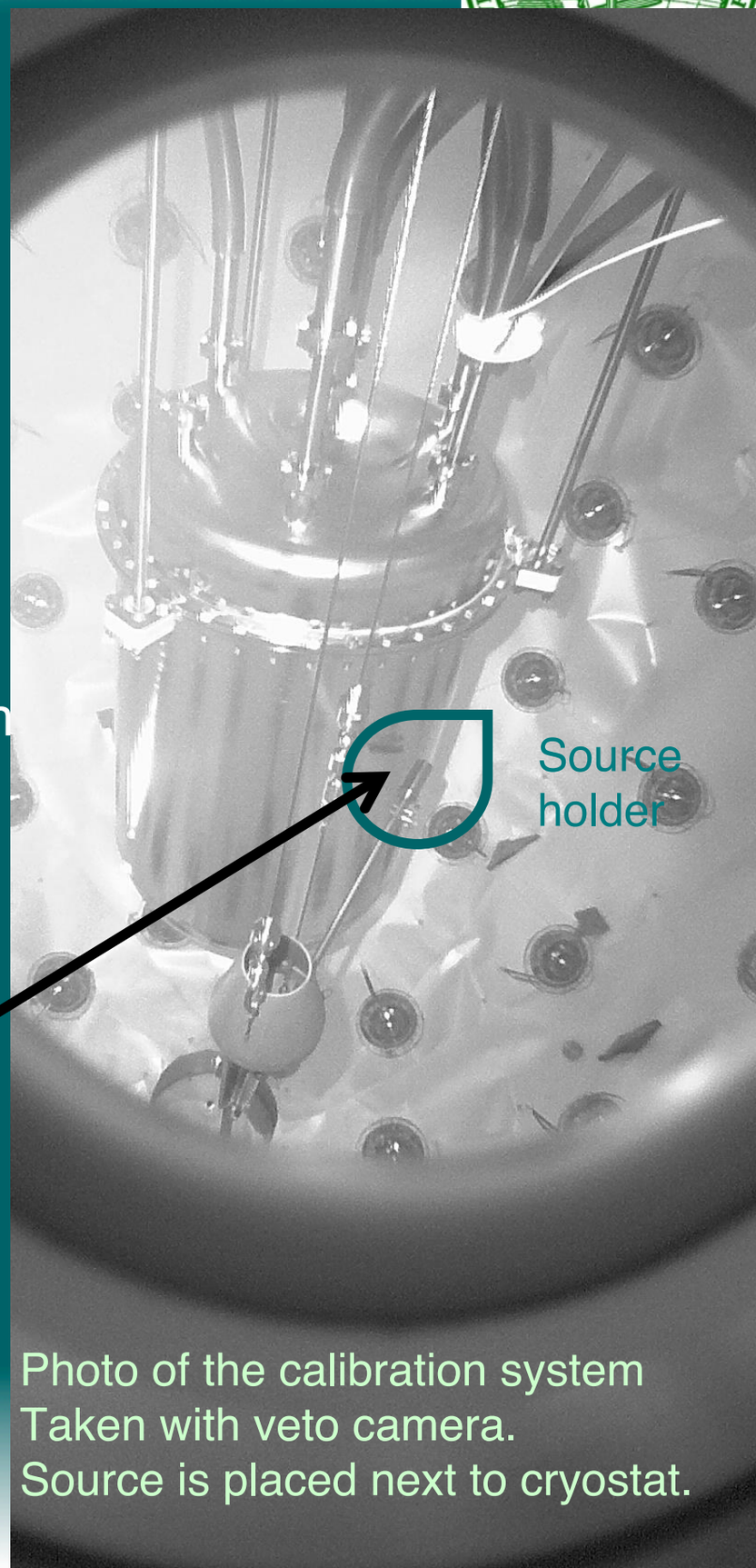
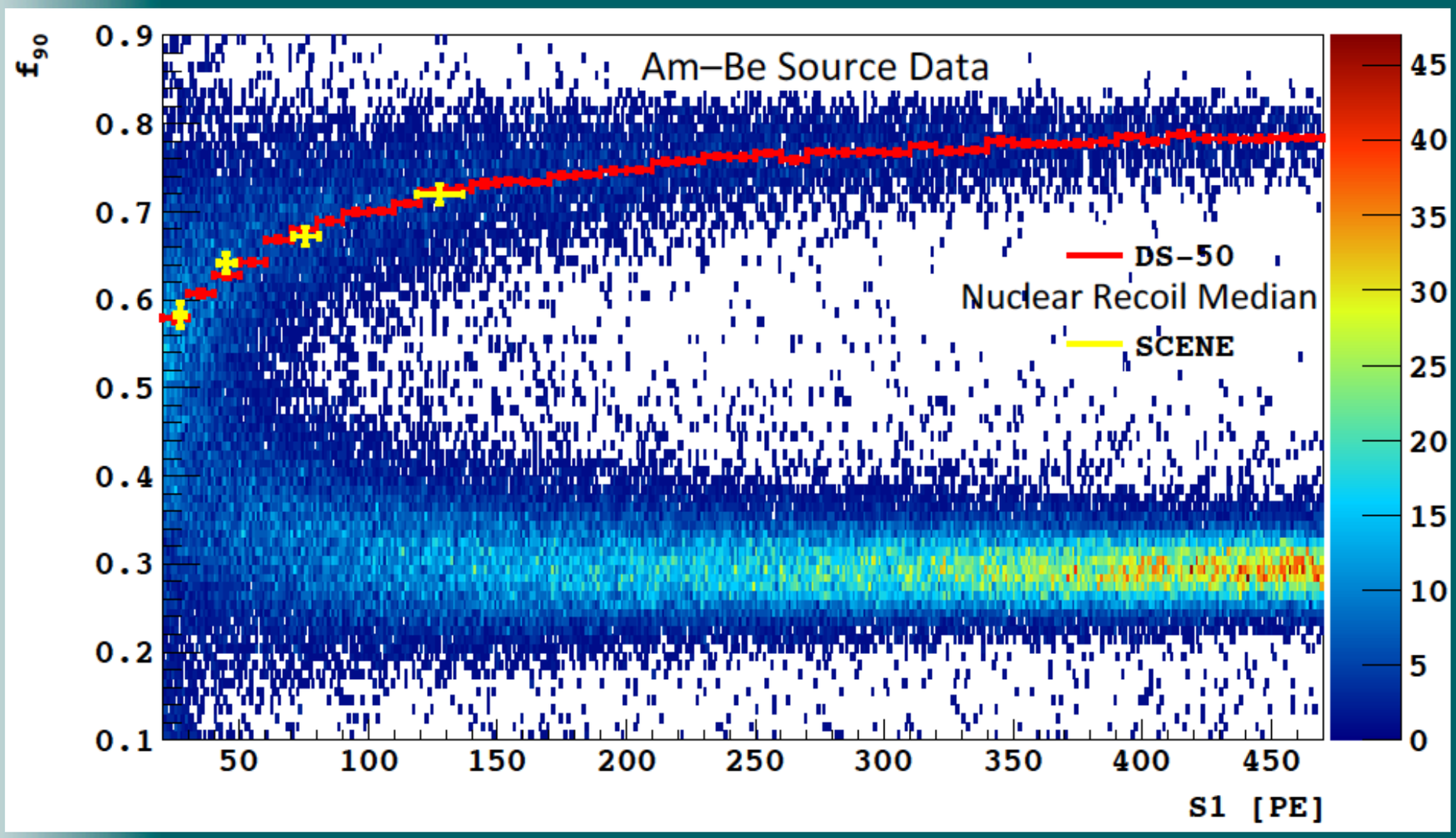
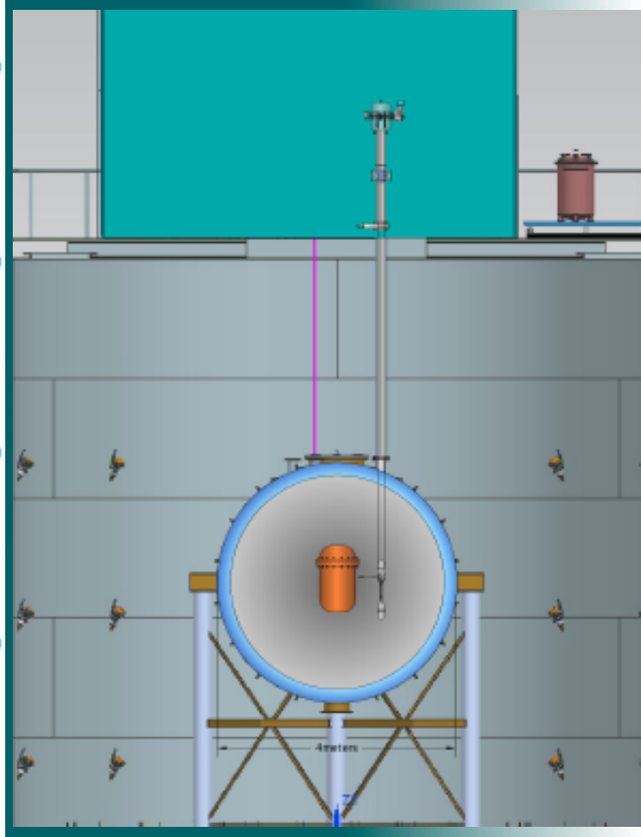


Photo of the calibration system
Taken with veto camera.
Source is placed next to cryostat.

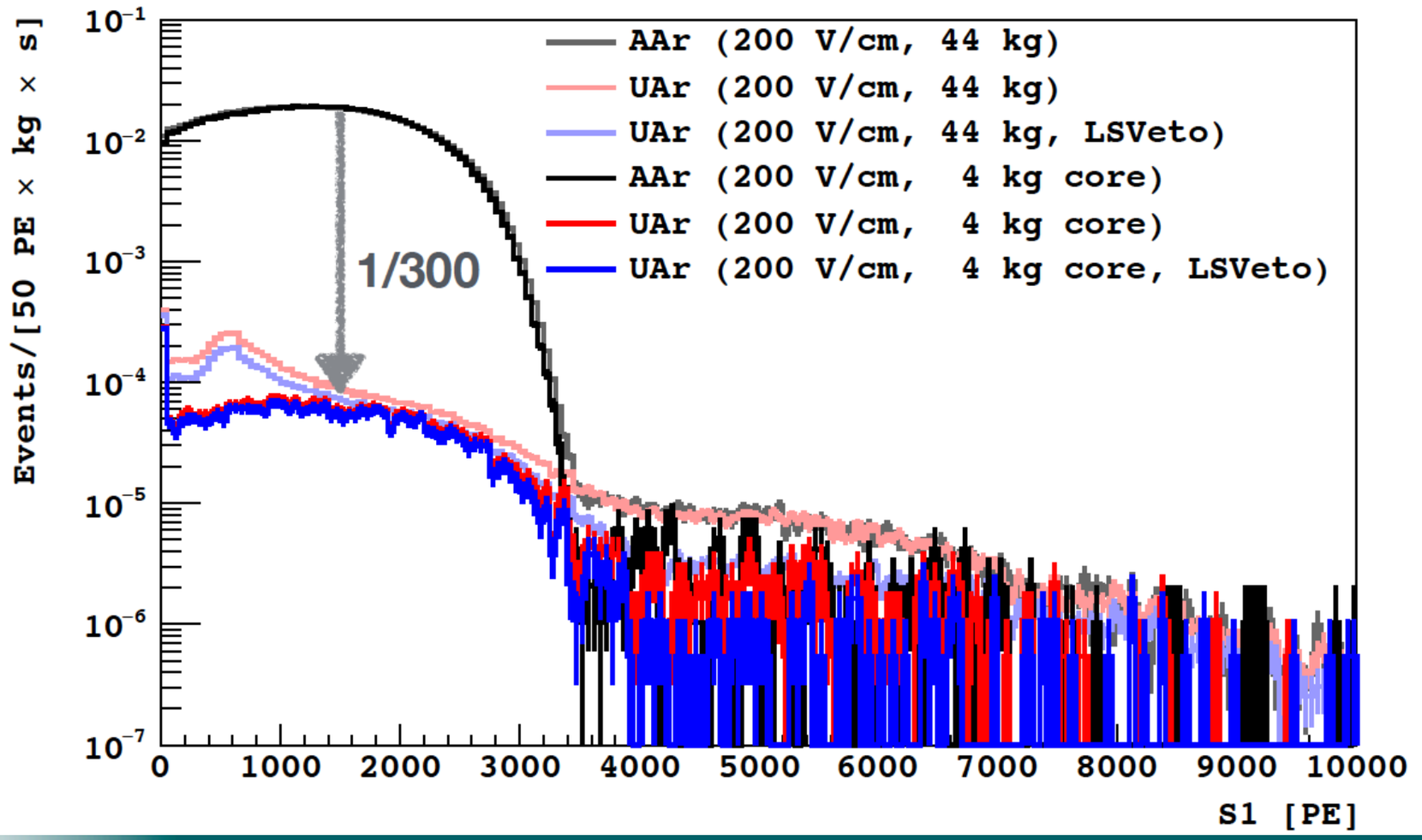
NR from AmBe Source Calibration

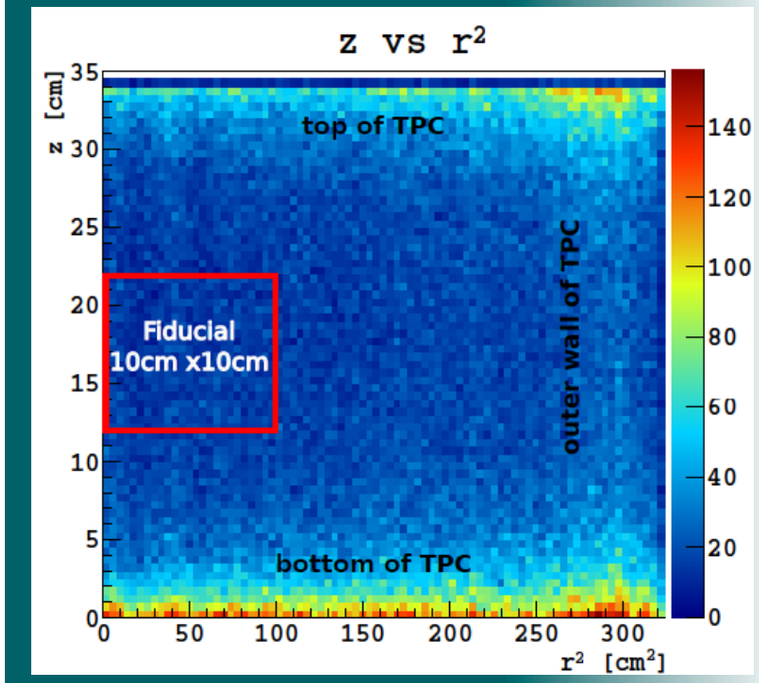




NR band from AmBe source data matches the points extrapolated from SCENE.

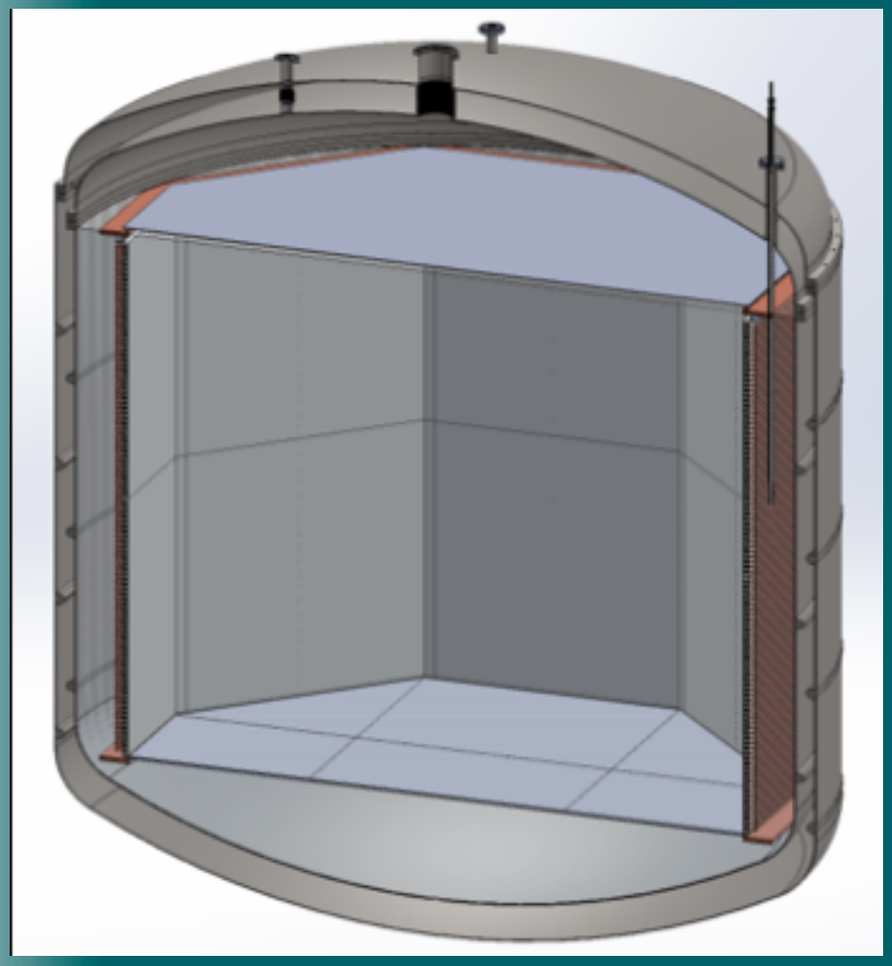
Underground Argon Fill results



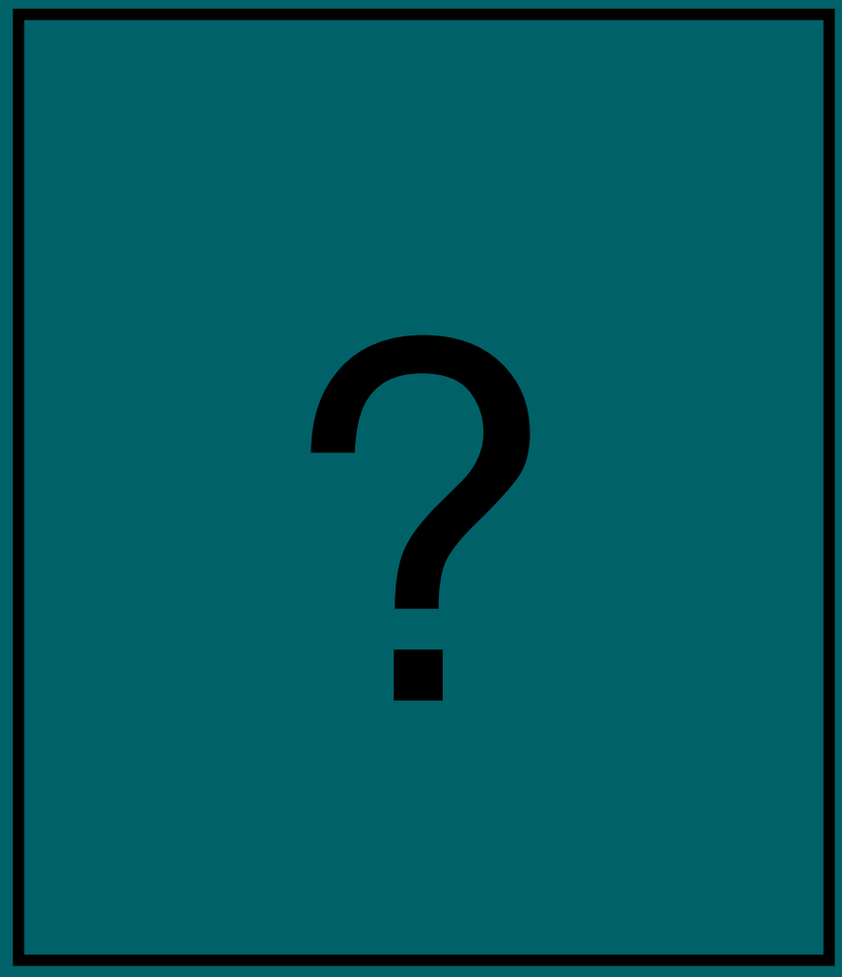


- In March 2015, DS50 was filled with underground argon UAr. Major undertaking – extracted from Colorado mine and purified at FNAL.
- Exhibits at least 300 times smaller content of ^{39}Ar in UAr than AAr!
- **Low level of ^{39}Ar allows extension of DS to ton-scale detector.**

Future detectors



DS-20 ton fiducial (30 ton)



ARGO (200 ton fiducial?)

UAr combined with powerful PSD in argon →

Promising path toward large scale argon WIMP detector.

Summary and DS Timeline

- **Oct. 2013:** LArTPC, Neutron Veto and Muon Veto commissioned
  - TPC filled with **atmospheric** argon (AAr).
- **Nov. - Jan. 2014:** detector comissioning (improve DAQ, DATA HANDLING and PROCESSING).
- **June 2014:** data taken with high ^{14}C content in LSV.
- **October 2014**: First physics results show ^{39}Ar BG from **47.1 live days** (1422 kg·day fiducial) of AAr corresponds to that expected in **38.7 year** of **UAr** DS-50 run (3 years planned) → BACKGROUND FREE RUN
- **Feb 2015**: New neutron veto doped with 5% TMB (low in ^{14}C) achieved 99.5% neutron rejection efficiency.
- **March 2015**: DS50 filled with UAr and new DM run started.
- **April 2015**: **>300 x lower ^{39}Ar → ton-scale DS detector possible**.

  → LOI for future multi-ton Ar dark matter detector submitted to LNGS.

THE END