DarkSide-50: a direct WIMP search with a two-phase argon TPC

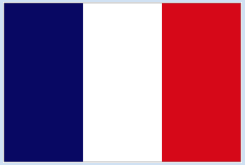
P. Meyers – Princeton

TAUP 2013

DarkSide-50 TPC cryostat deployed in liquid scintillator neutron veto

The DarkSide Collaboration

IHEP



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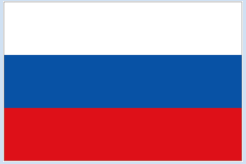
IPHC, Université de Strasbourg

INFN LNGS
Università degli Studi Genova
Università degli Studi Milano
Università degli Studi Federico II Napoli
Università degli Studi Perugia
Università degli Studi Roma Tre

Jagiellonian University

KINR, NAS Ukraine



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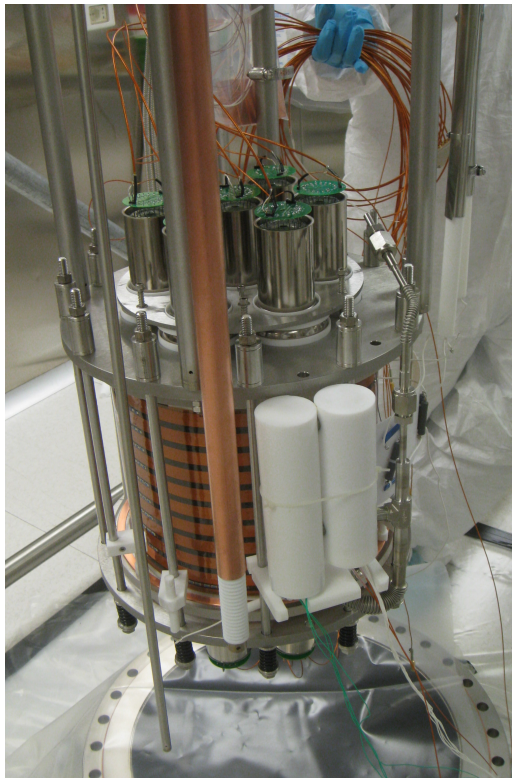
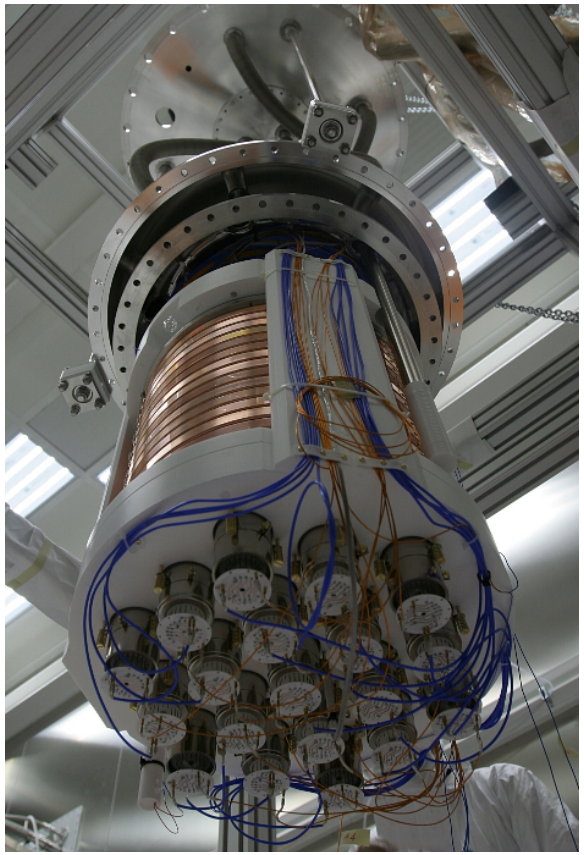
University of Massachusetts
Virginia Tech

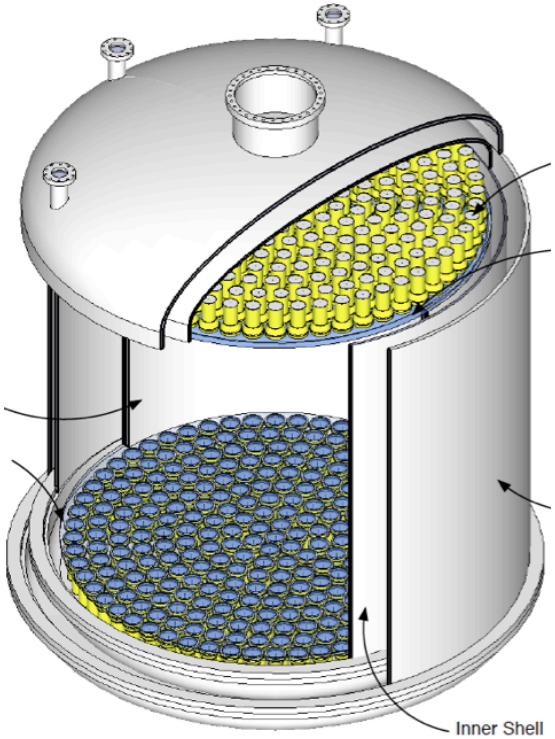
The DarkSide Program at Gran Sasso Lab, Italy



DarkSide-10
prototype
10 kg active
200 days Princeton
500 days LNGS



DarkSide-50
50/33 kg active/fiducial
Sensitivity~10^{-45} cm^2
in 3-year run



DarkSide-G2
3.3/2.8 T active/fiducial
Sensitivity~10^{-47} cm^2
in 5-year run

Goal: Multi-year, background-free data runs

Signal: **nuclear recoil** of Ar atom from elastic WIMP scatter
Background:

- electron recoil from β decay or γ interaction
  - external/internal
- neutron-induced **nuclear recoil**
  - cosmogenic/radiogenic-internal
- surface α decay **nuclear recoils**

DarkSide-50 Infrastructure

LNGS:

- 3400 m.w.e overburden
- Cosmic μ reduced by 10^6
- Drive-in access

Assembly/deployment Cleanroom

- Class 10-100
- Rn suppression to 5-50 mBq/m^3

Water Cherenkov muon veto

- 11 m ϕ × 10 m high
- 80 8” PMTs

Both sized for DS-G2

Liquid Scintillator Neutron Veto

- See Shawn Westerdale poster
- 4-m sphere
- Boron-loaded scintillator – capture gives charged particles
- 110 8” PMTs
- Efficiency ≥ 99% for radiogenic neutrons from detector components

Sized for DS-G2

TPC Parts-preparation Cleanroom

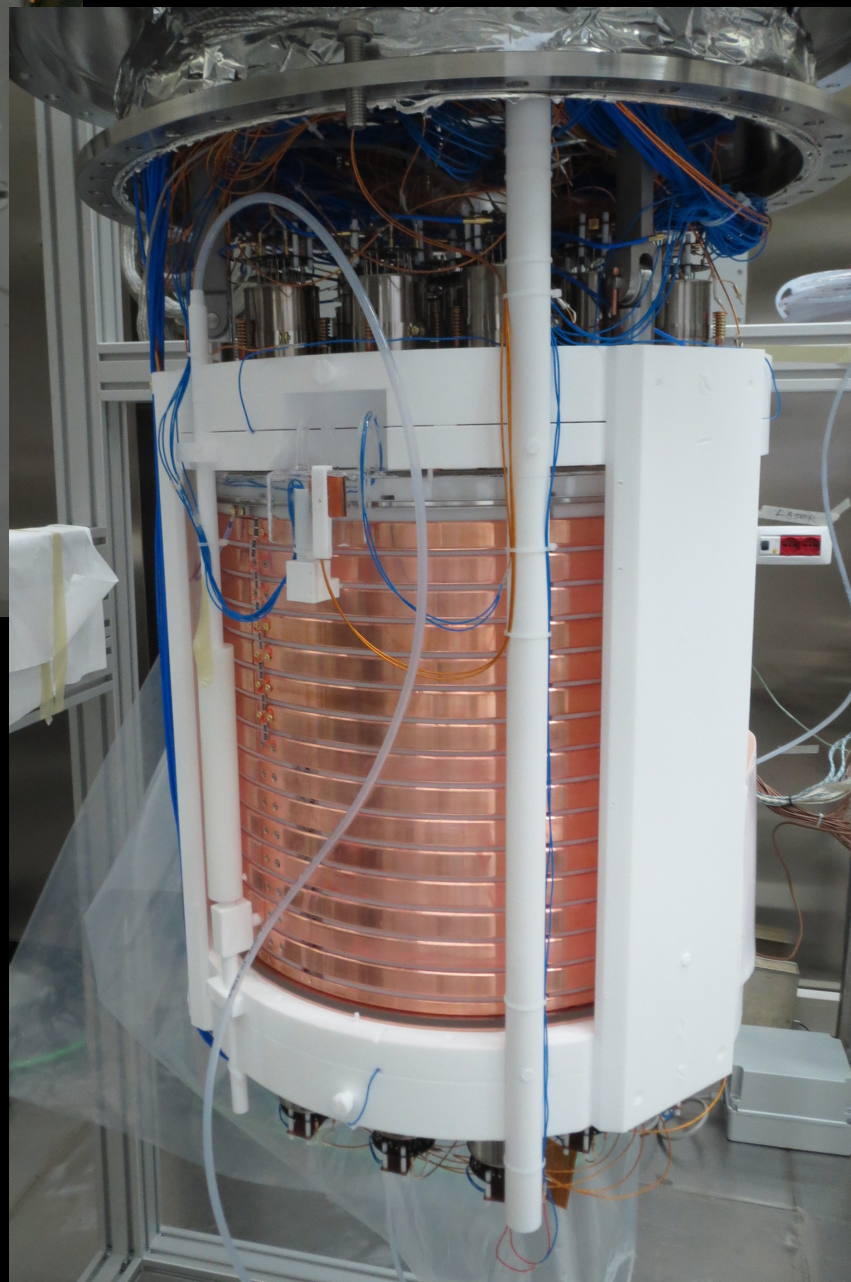
- Class 10-100
- Rn suppression to 5-50 mBq/m^3
- Evaporator for wavelength shifter

Stainless-steel Cryostat

- All-cold design
- Cooled by externally-liquefied Ar in continuous recirculation/purification

DS-50 TPC

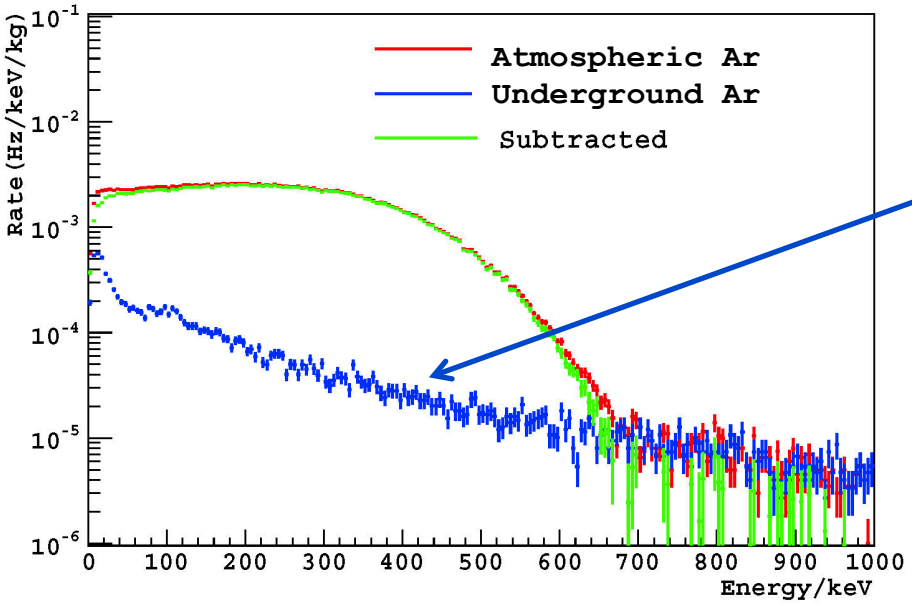
- 38 3” R11065 PMTs
- 36 cm ϕ × 36 cm high
- Ionization detection via electro-luminescence in 1 cm gas pocket



Goal: Multi-year, background-free data run

Signal: **nuclear recoil** of Ar atom from elastic WIMP scatter
Background: electron recoil from β decay or γ interaction

- Initially the dominant background by far
- In turn dominated by ^{39}Ar β decays, 1 Bq/kg in atmospheric argon
- Argon from underground sources can have very low ^{39}Ar

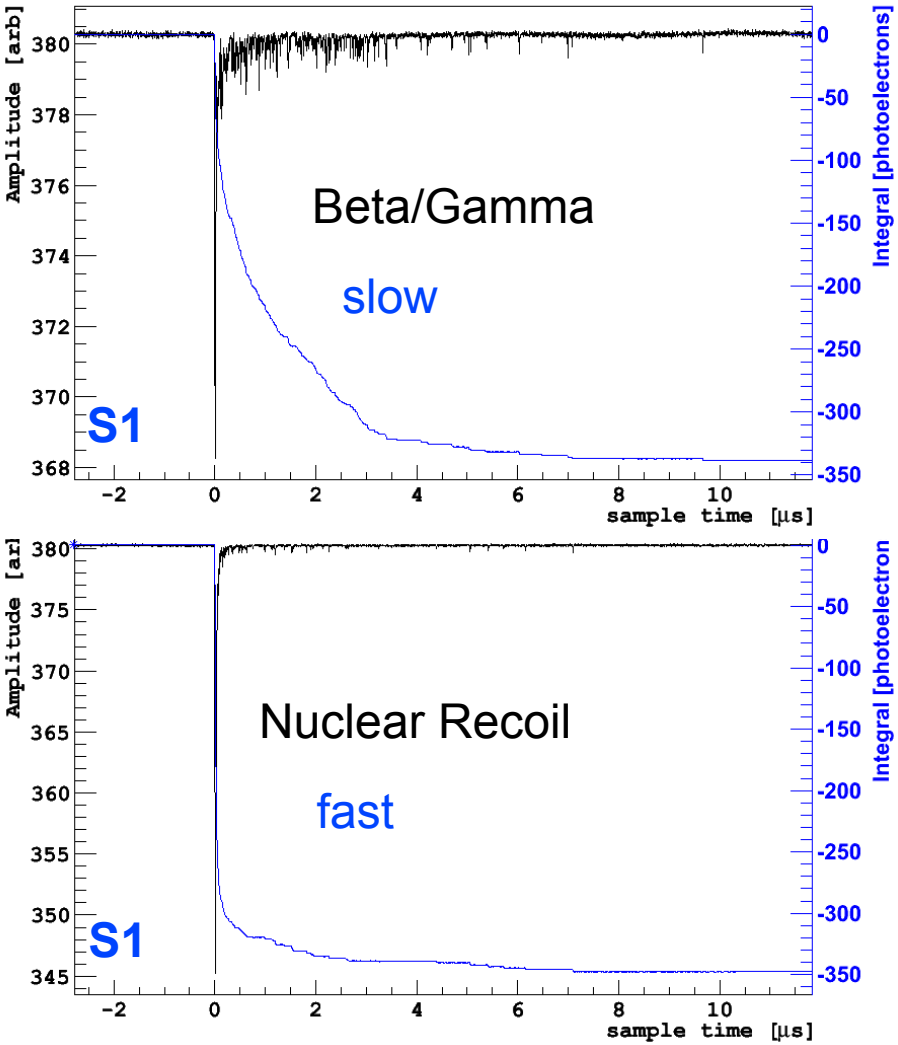


Jingke Xu Ph.D. thesis, 2013

- Our measurements give an **upper limit** of 6.5 mBq/kg, a factor of >150 reduction.
- At this limit, ^{39}Ar still the dominant β/γ background, but not by much.

Background: electron recoil from β decay or γ interaction

- Pulse shape discrimination in argon (see Mark Boulay's talk, next)



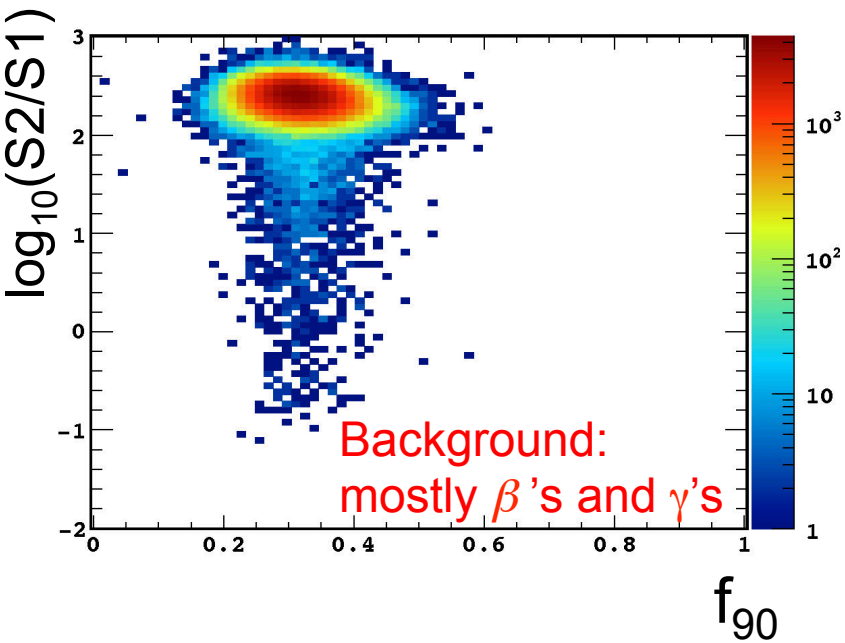
Two events with ~the same integrated scintillation signal from DS-10.

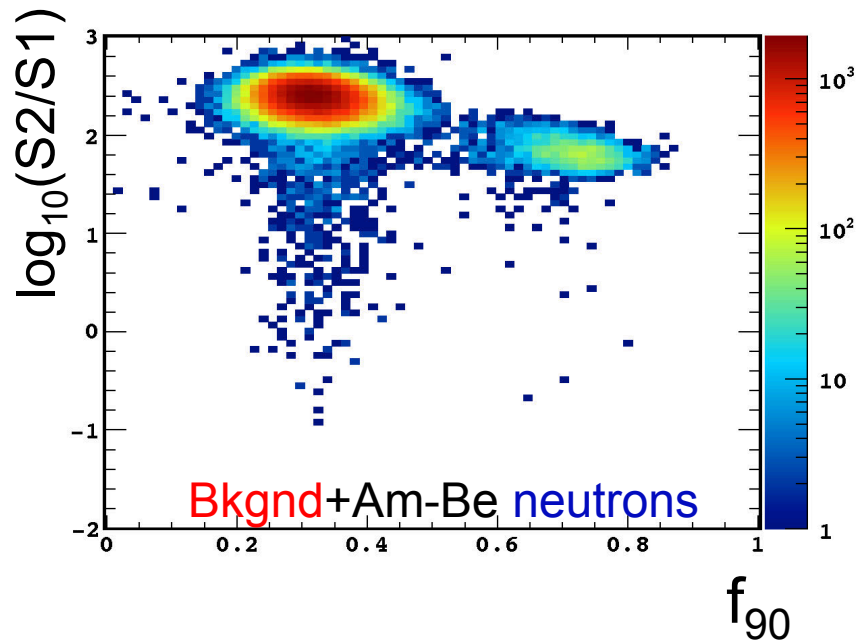
Simple discriminant: f_{90} = fraction of scint in first 90 ns.

- $f_{90} \approx 0.75$ for nuclear recoils
- $f_{90} \approx 0.3$ for electron recoils
- Electron rejection as high as 10^8 with sufficient p.e. statistics

Background: electron recoil from β decay or γ interaction

- Ionization/Scintillation ("S2/S1") – as in xenon, where electron rejection ~100
- S2/S1 appears ~independent of f_{90}
- Indications that rejection in argon weakens at low energy

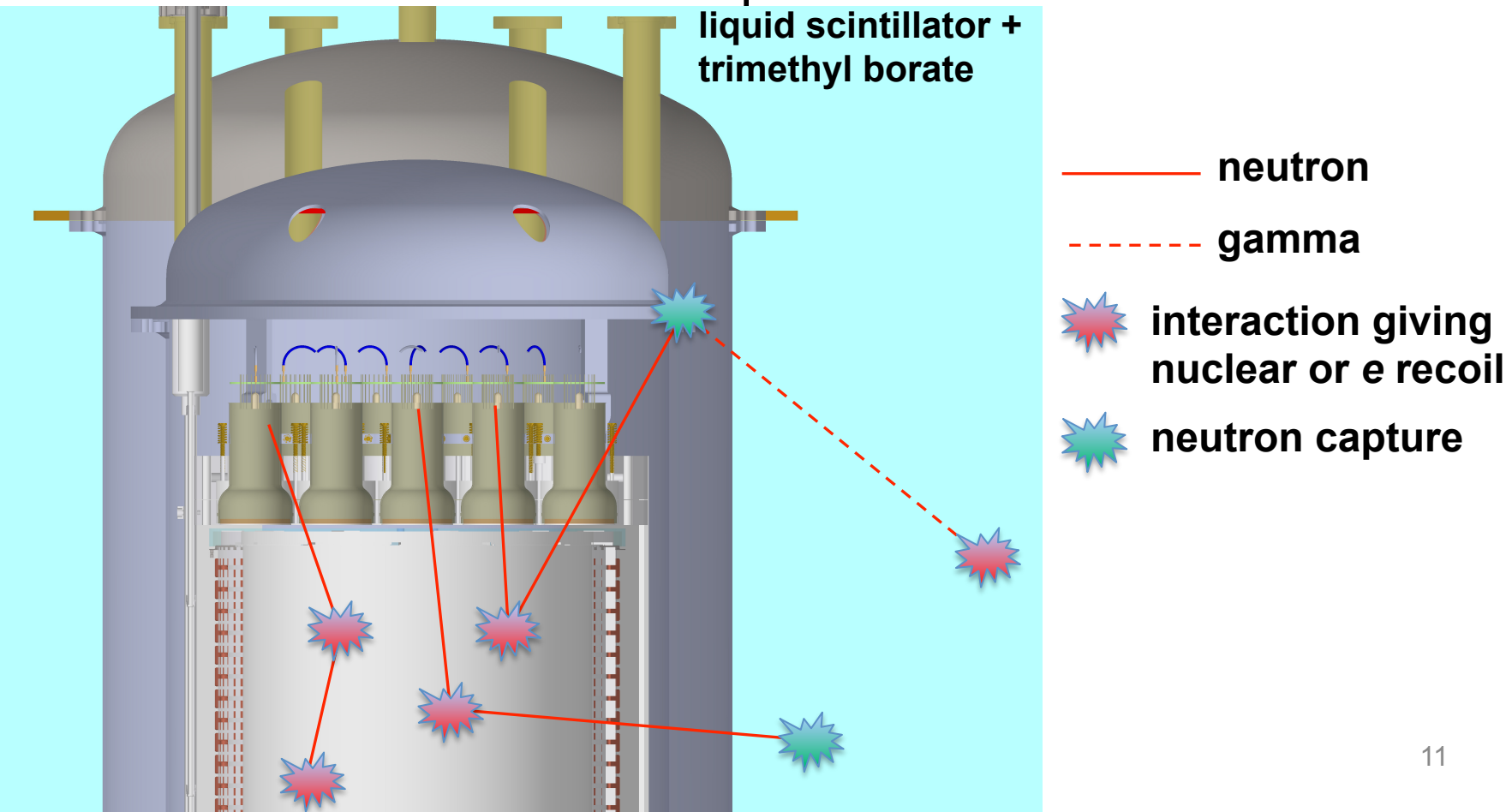




DarkSide-10 data: events with 100-200 scintillation p.e. (≈57-114 keV_r in DS-10, somewhat lower in DS-50)

Background: neutron-induced **nuclear recoil**

- Radiogenic (α,n) from detector components dominates
- Screen and select materials for extremely high radiopurity
- PMTs largest source, then cryostat steel
- Highly efficient neutron veto rejection ≥100
- Position reconstruction/multiple interactions

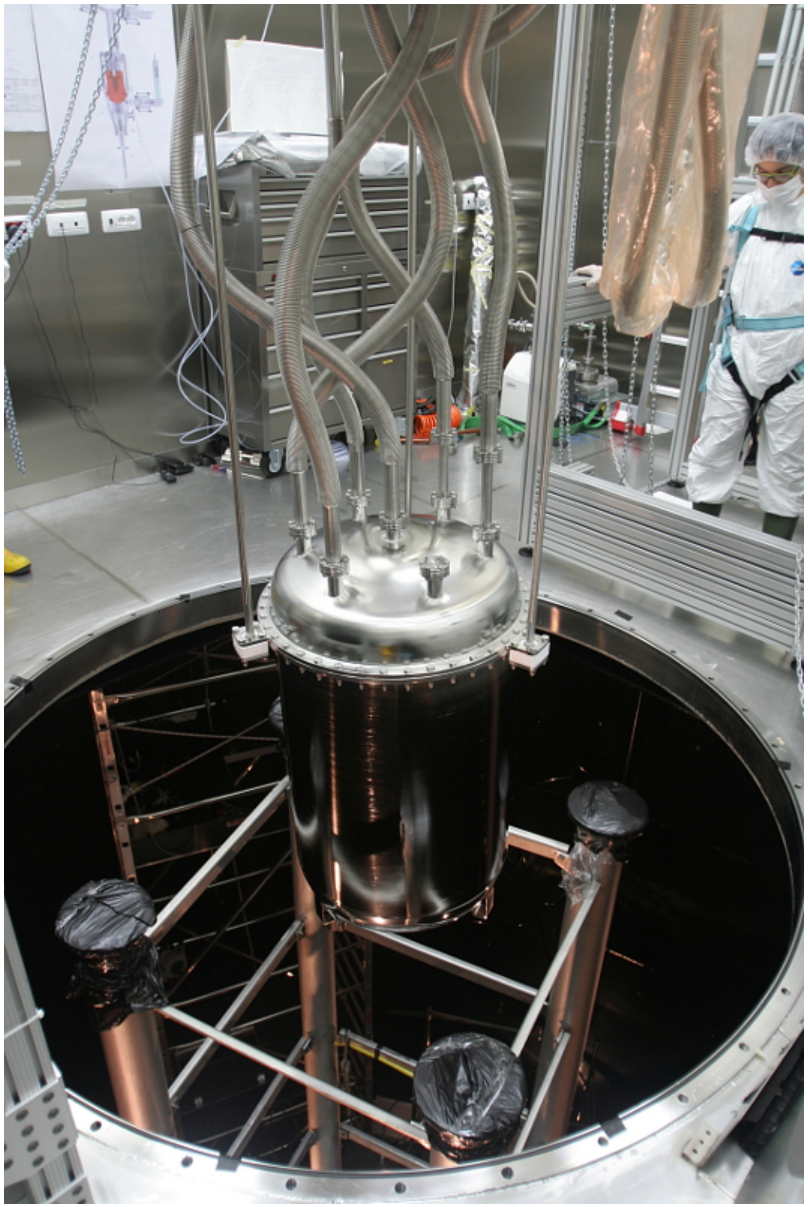


Background: surface α decay **nuclear recoils**

- Radon daughters on surfaces
- Decay daughter atom recoils into active argon
- Preparation of parts in radon-suppressed cleanroom, notably wavelength-shifter evaporation
- Fiducialization with TPC 3D position reconstruction
- Hard to quantify at this point

DarkSide-50 Status

- Water tank instrumented
- Neutron veto instrumented, tested in air
- 185 kg of Underground Ar collected (~150 kg needed)
  - Still to be purified to ~5 ppm
- TPC test assembly and deployment
  - 38 PMTs – a mix of Hamamatsu R11065, -10, and -20
- Test run May 13 – June 27, 2013
- Stable running at 26 kV (0.5 kV/cm)
- R11065-20s do not work at LAr temperature!
  - Working with Hamamatsu on this – already much progress
- Cooling, purification, gas pocket, TPC leveling tested
- Very long electron-drift lifetime >3 ms



DarkSide-50 Status

- Final assembly complete
- Using R11065s
- Deploying TPC in neutron veto tank this week

Next

- 1-2 weeks of TPC commissioning
- Fill Water Tank and Neutron Veto
- Background run with atmospheric argon (1 week ≈ 3 years of UAr background)
- Fill with underground argon for long data run

Background and sensitivity estimates

- Based on radioactivity measurements of materials in TPC and cryostat, assuming R11065-20 PMTs
- Allow for out-of-equilibrium U and Th chains using multiple measurements
- Pulse Shape Discrimination rejection using empirical model built on DarkSide-10 data → assumes older electronics and DS-10 occupancies and light yield (7 p.e./ keV_{ee}). This is conservative for DarkSide-50.

Neutron-induced Background

- R11065-20 PMTs are largest single source

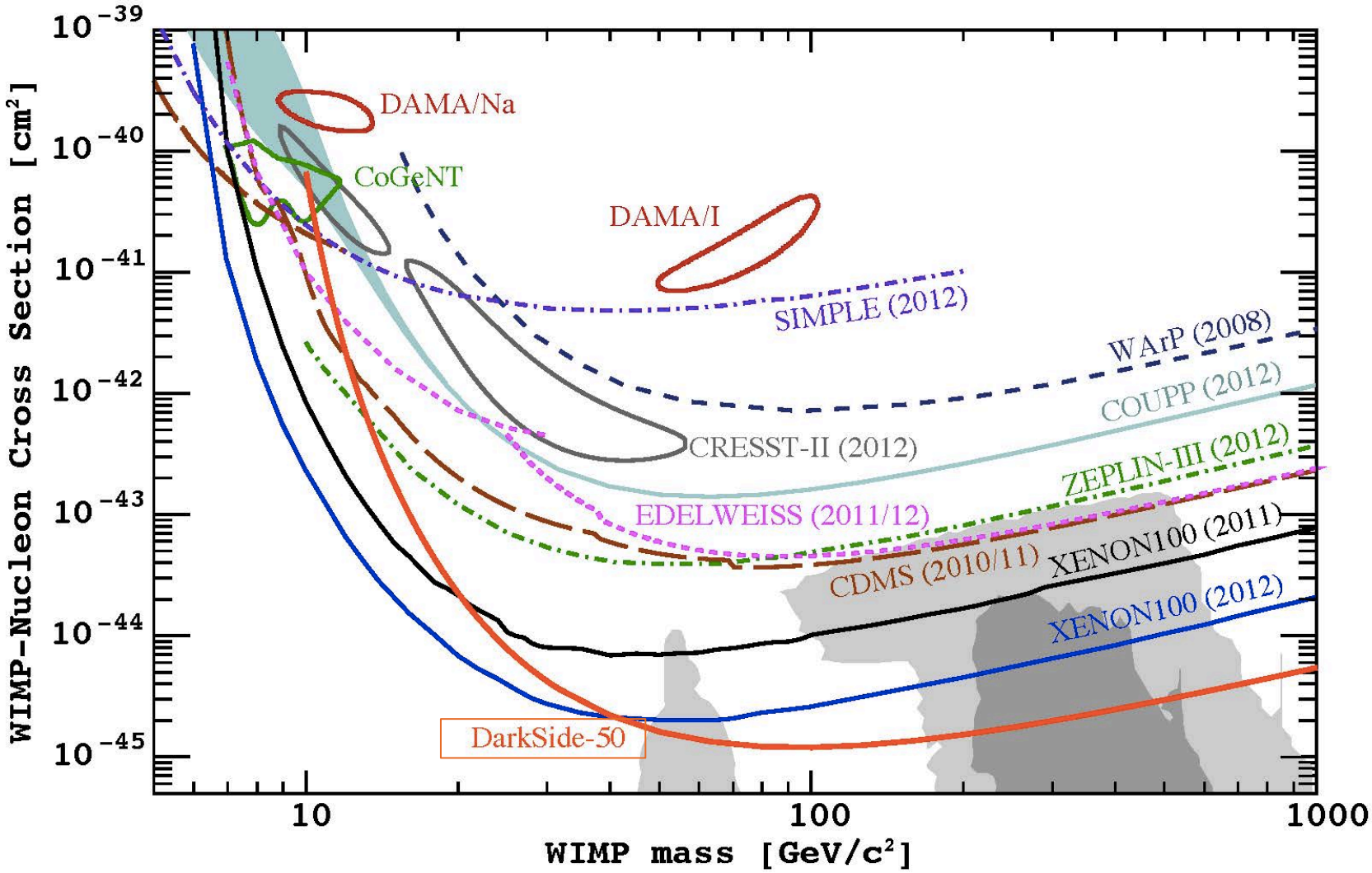
Predict < 0.1 neutron event (total) in 0.1 ton-yr exposure (3 year run with 33 kg fiducial mass) with R11065-20s.

…but we don't have R11065-20s

Electron-recoil background

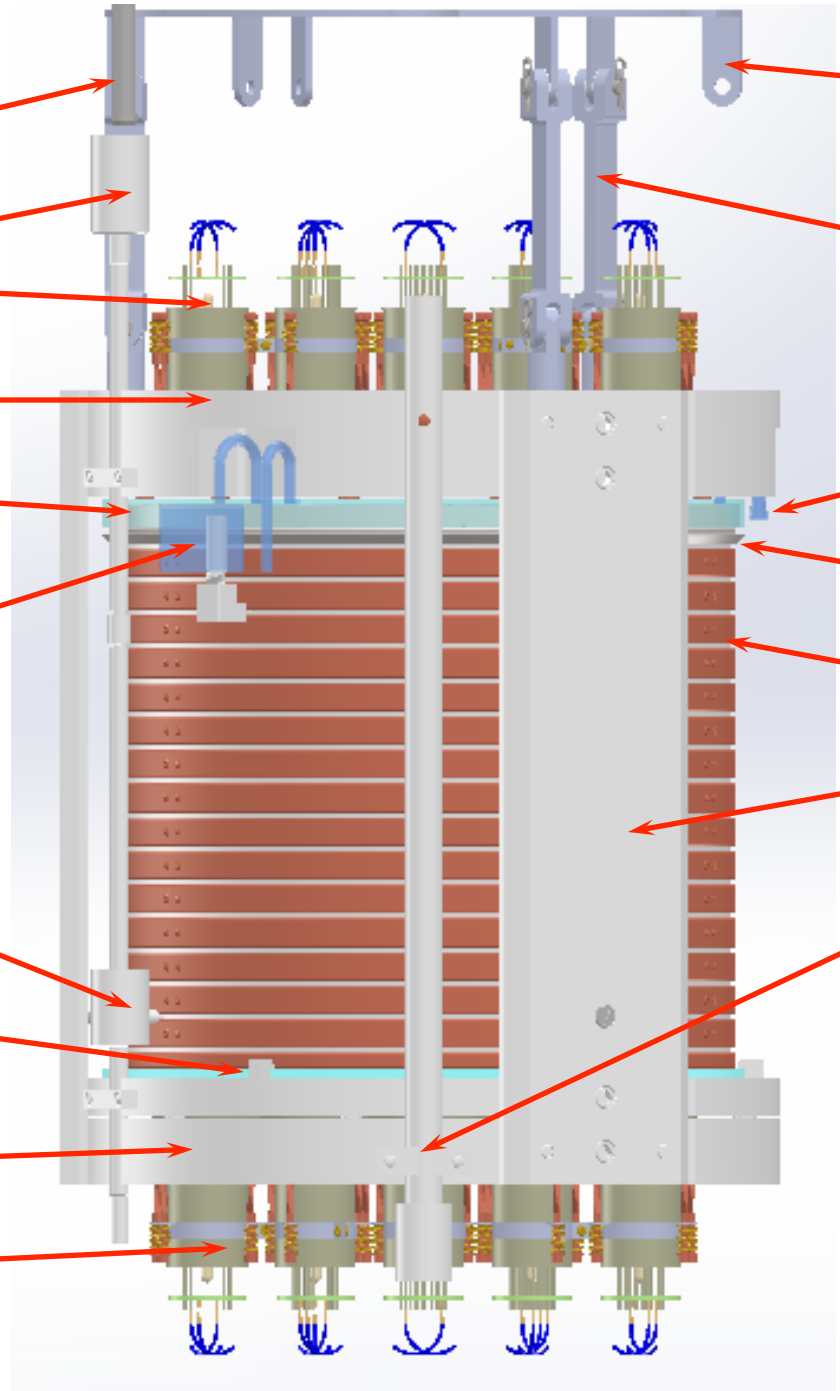
- Assume underground argon with ^{39}Ar at upper limit of 6.5 mBq/kg
- This is the dominant source; likely still true with R11065s
- Assume **no** rejection from S2/S1
- Set PSD f_{90} cut to give 0.1 event of surviving e/γ background, ~optimized vs. energy
- For 0.1 ton-yr exposure, get a PSD acceptance that turns on at 20 keV_r and reaches 50% (~100%) at ~40 (~70) keV_r

DarkSide-50 sensitivity



Backup slides

Tour of DS-50 TPC



Parameters and dimensions

Dimensions
- Active volume diameter 35.6 cm
- Active volume height 35.6 cm
- Gas pocket height 1.0 cm
- LAr above grid 0.5 cm
- TPC full height 69.0 cm

Masses
- Active LAr 49.4 kg
- Total LAr ~145 kg

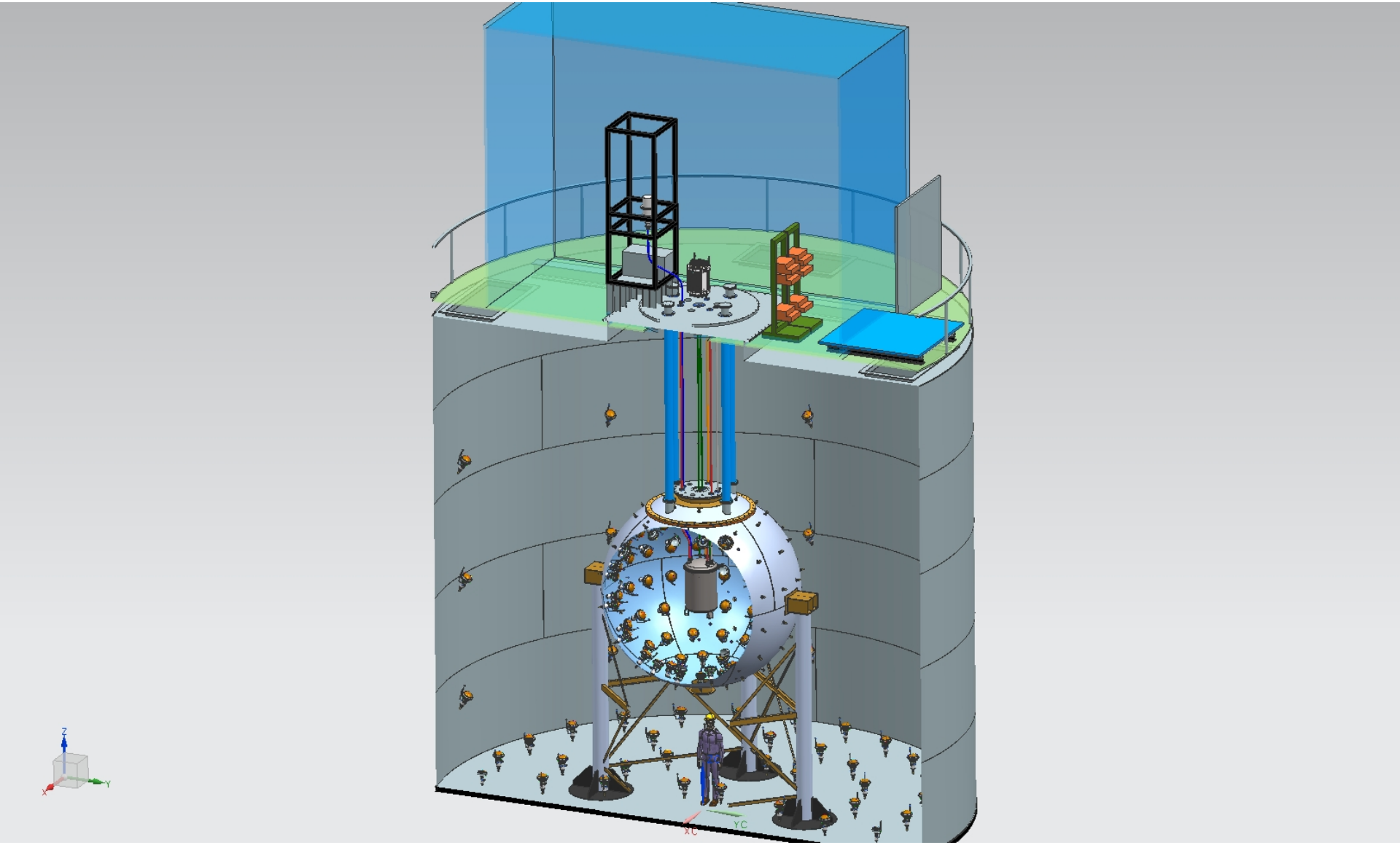
- Main PTFE reflector 22.8 kg
- Total PTFE 59.2 kg
- Total fused silica 3.5 kg
- Copper field cage rings 23.5 kg
- 38 R11065 PMTs 7.9 kg

Total TPC ~100 kg

Other parameters
- Recirculation rate (min) 10 slpm
  (max) 50 slpm
  ~5 kg/h

- Drift field (typical) 1.0 kV/cm
- Extraction field (typ) 3.8 kV/cm
- Electroluminescent field 5.7 kV/cm
- Grid potential −7.6 kV
- Cathode potential −43.2 kV

- Photocathode coverage ~20%
  of top and bottom ~60%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