A Walk on the DarkSide

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DarkSide Collaboration

Augustana College – SD, USA
Black Hills State University – SD, USA
Fermilab – Il, USA
IHEP – Beijing, China
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 Napoli, Italy
INFN and Università degli Studi Perugia, Italy
Jagiellonian University - Cracow, Poland
Joint Institute for Nuclear Research – Dubna, Russia
Princeton University, USA
RRC Kurchatov Institute – Moscow, Russia
St. Petersburg Nuclear Physics Institute – Gatchina, Russia
Temple University, USA
University of Arkansas, USA
University of California, Los Angeles, USA
University of Houston, USA
University of Massachusetts at Amherst, USA

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Black Hills, USA Dan Durben, Kara Keeter, Michael Zehfus

Cracow, Poland Marcin Wojcik, Gregorz Zuzel

Fermilab, USA Steve Brice, Hans Jostlein, David Montanari, Stephen Pordes, Andrew Sonnenschein

IHEP, PRC Mengyun Guan, Yuqian Ma, Changgen Yang

LNGS, Italy Paolo Cavalcante, Stefano Gazzana, Chiara Ghiano, Aldo Ianni, George Korga, Alessandro Razeto, Roberto Tartaglia

Genova, Italy Marco Pallavicini

Milano, Italy Gianpaolo Bellini, Davide D'Angelo, Paolo Lombardi, Emanuela Meroni, Alberto Pullia, Gioacchino Ranucci, Stefano Riboldi

Napoli, Italy Alfredo Cocco, Giuliana Fiorillo

Perugia, Italy Fausto Ortica, Aldo Romani

Dubna, Russia Oleg Smirnov, Albert Sotnikov, Oleg Zaimidoroga

Princeton, USA Henning Back, Jason Brodsky, Frank Calaprice, Huajie Cao, Alvaro Chavarria, Ernst de Haas, Cristiano Galbiati, Augusto Goretti, Luca Grandi, Andrea Ianni, Emily Lebsack, Ben Loer, Pablo Mosteiro, Peter Meyers, Allan Nelson, Robert Parsells, Richard Saldanha, William Sands, Alex Wright, Jingke Xu

Kurchatov, Russia Igor Machulin, Alexander Etenko, Yuri Suvorov, Mikhail Skorokhvatov, Alexander Bolozdynya, Dmitry Akimov, Nurjan Nurakhov

St. Petersburg, Russia Alexander Derbin, Valentina Murotova, Dima Semenova

Temple, USA Jeff Martoff, Susan Jansen-Varnum, Christy Martin, John Tatarowicz

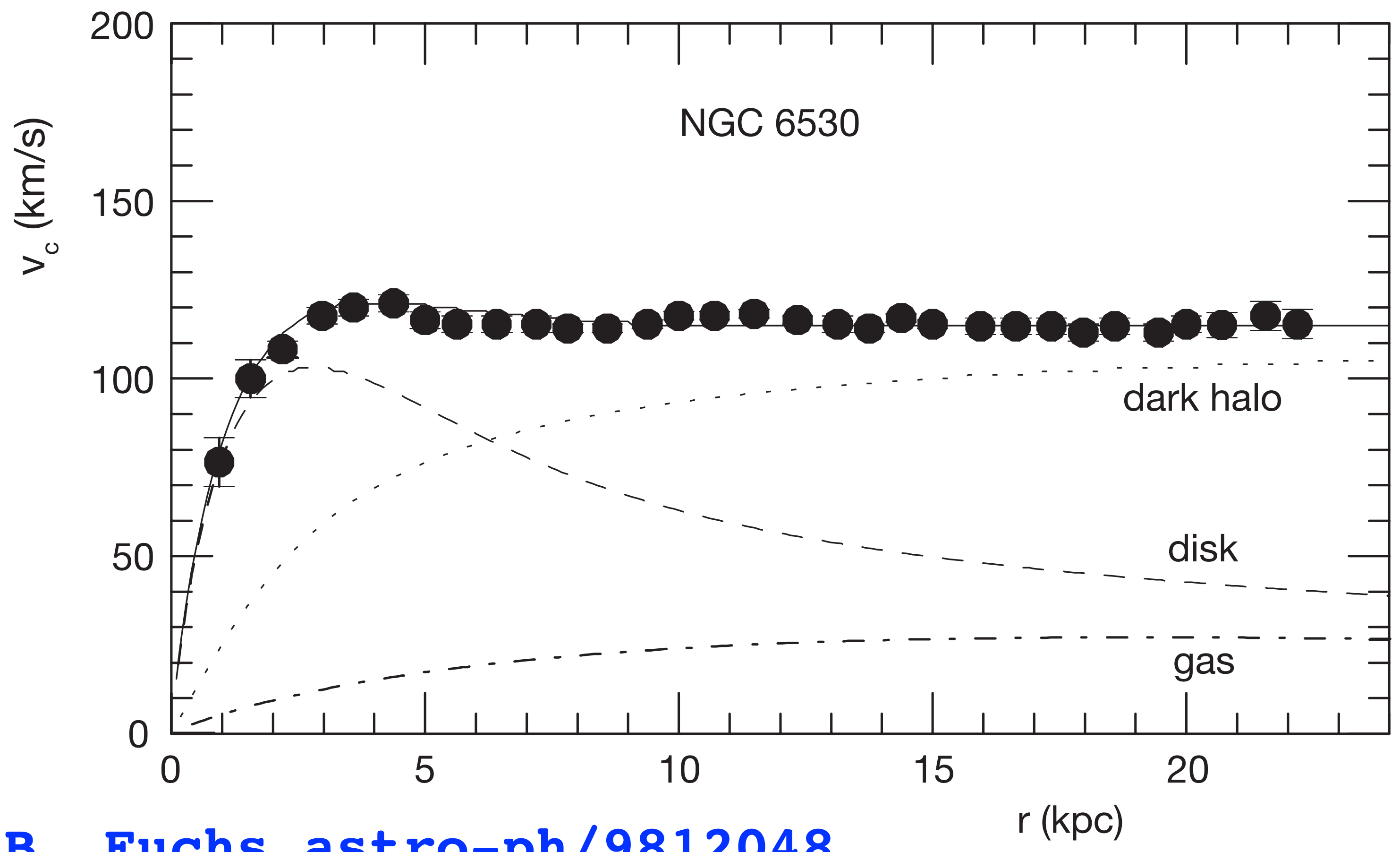
Arkansas, USA Toni Empl, Marc Seigar

UCLA, USA Katsushi Arisaka, David Cline, Peter F. Smith, Dr. Hanguo Wang

Houston, USA Anton Empl, Ed Hungerford

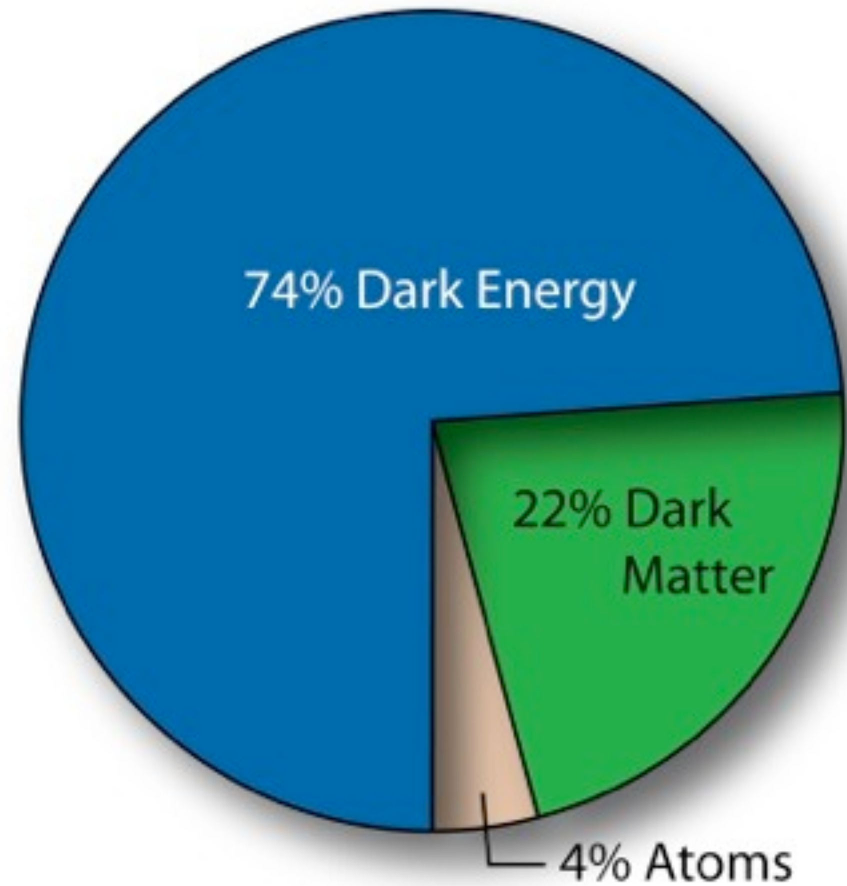
UMass, USA Laura Cadonati and Andrea Pocar

Dark Matter Evidence

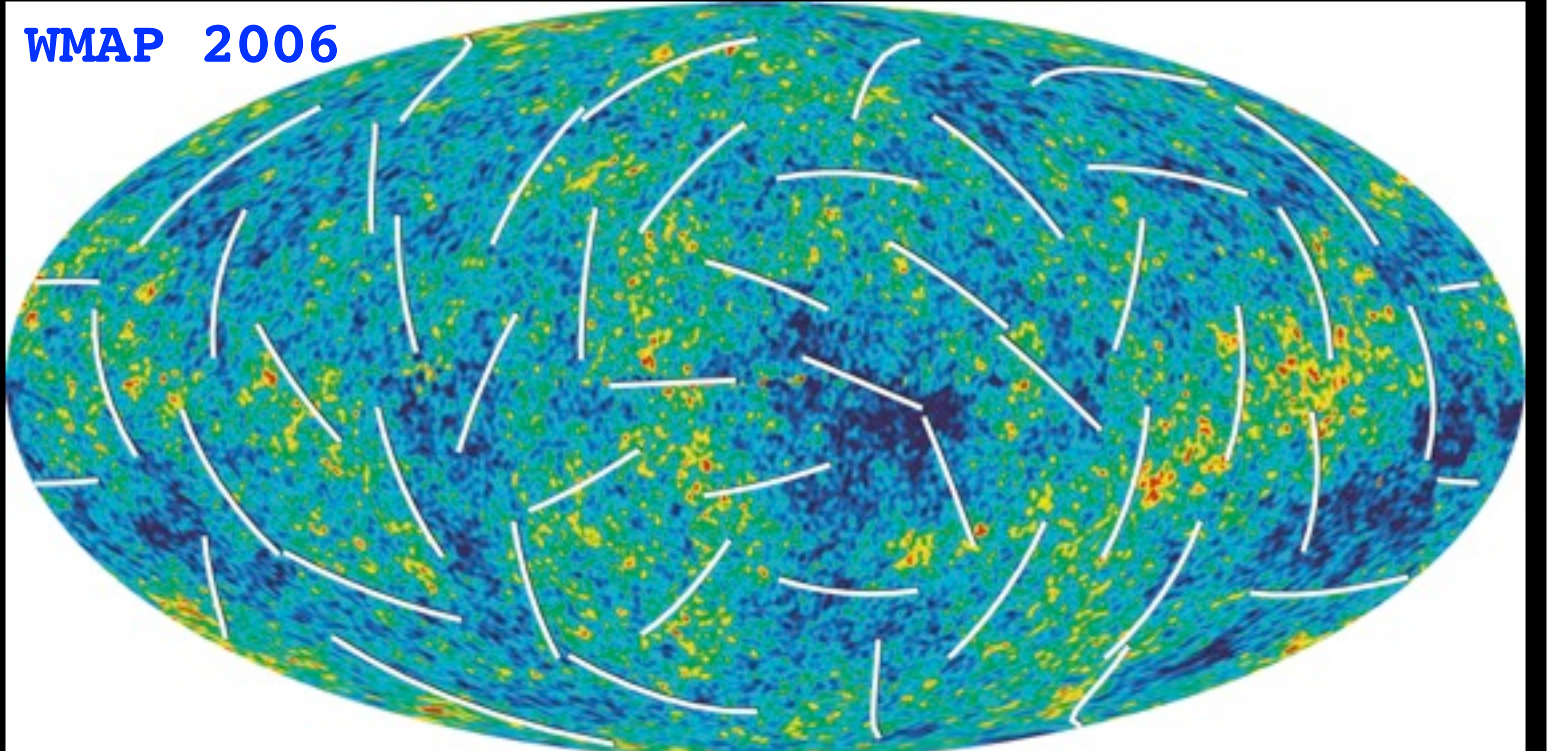


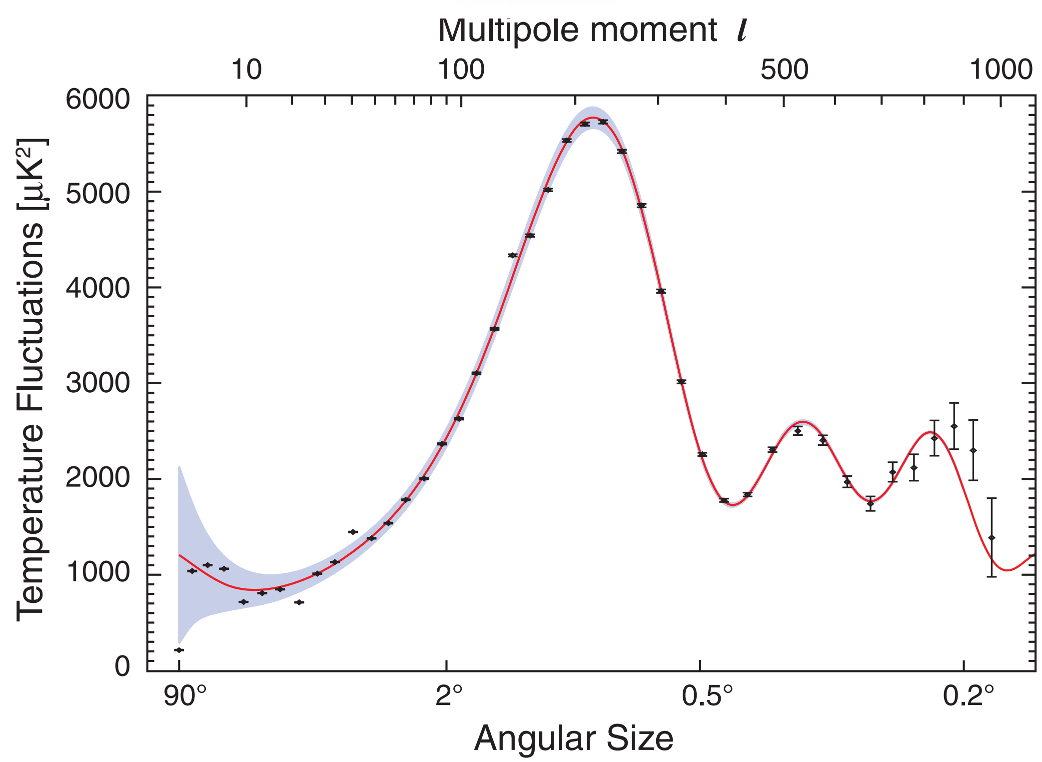
B. Fuchs astro-ph/9812048

WMAP 2006



WMAP 2006

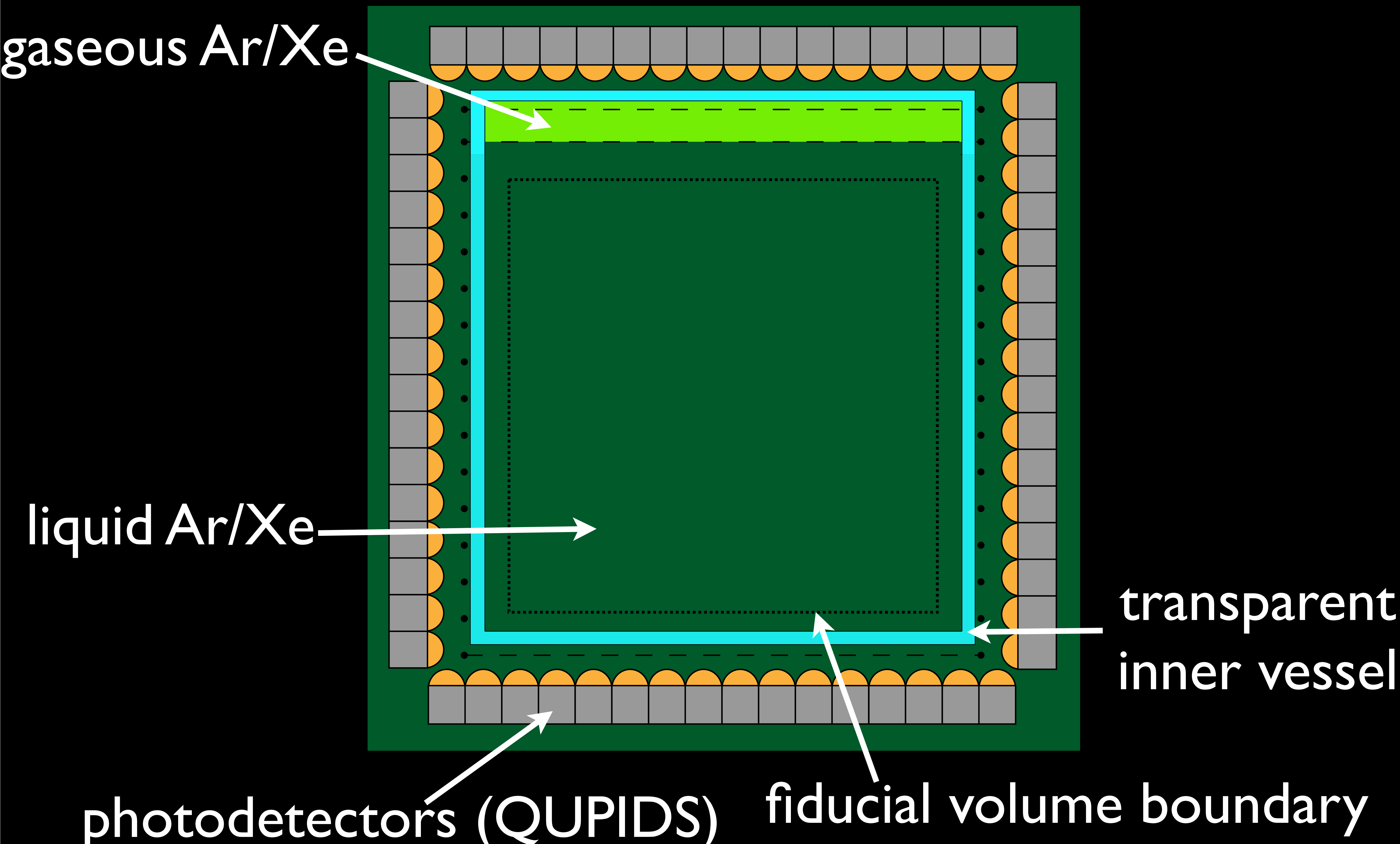




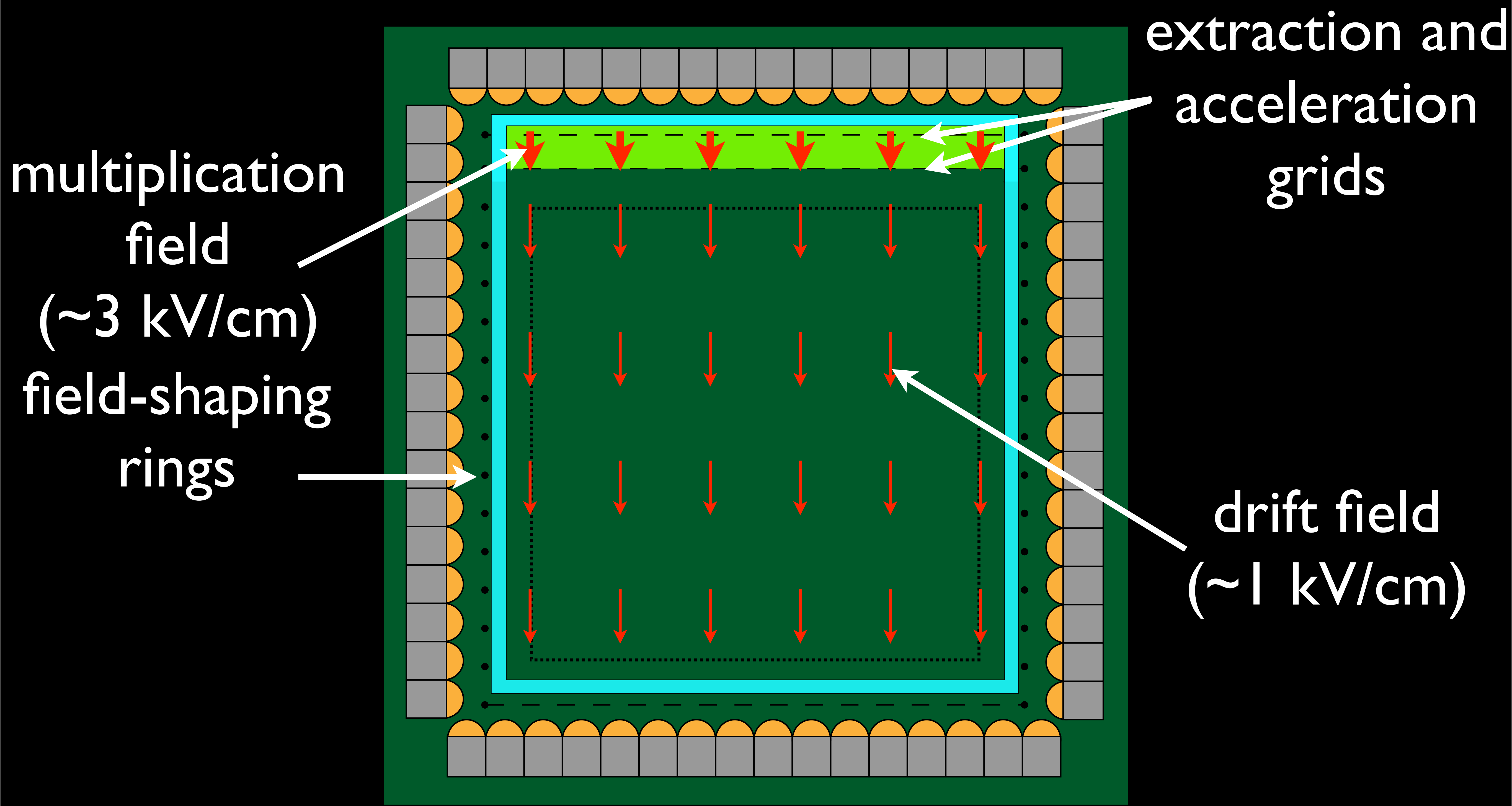
Direct Detection Requirements

- Low energy nuclear recoils (< 100 keV)
- Low rate (~1 event/ton/yr for 10^{-47} cm^2)
- Background, background, background
- Detector designed for "Discovery"

TPC in Action

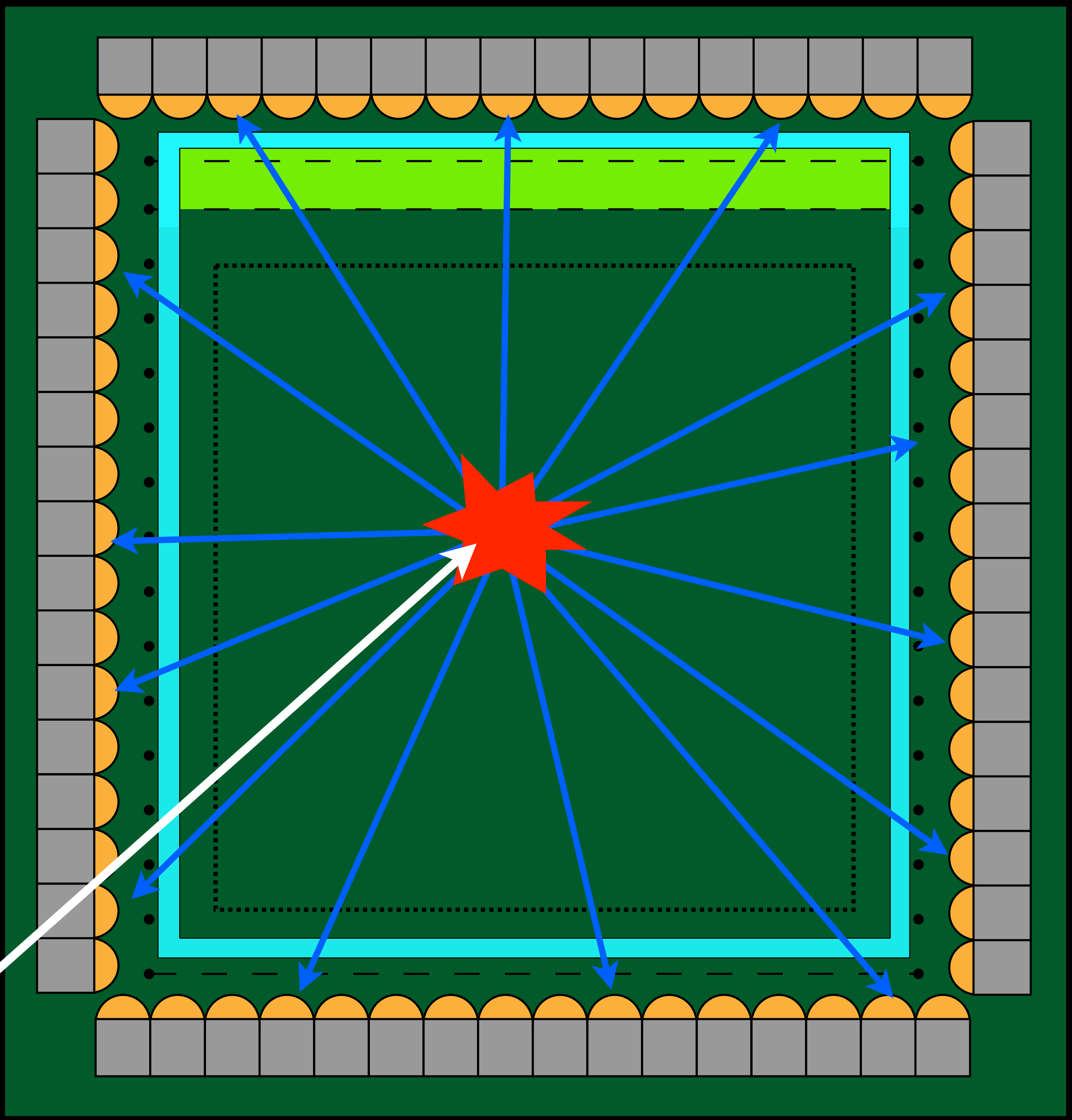


TPC in Action



TPC in Action

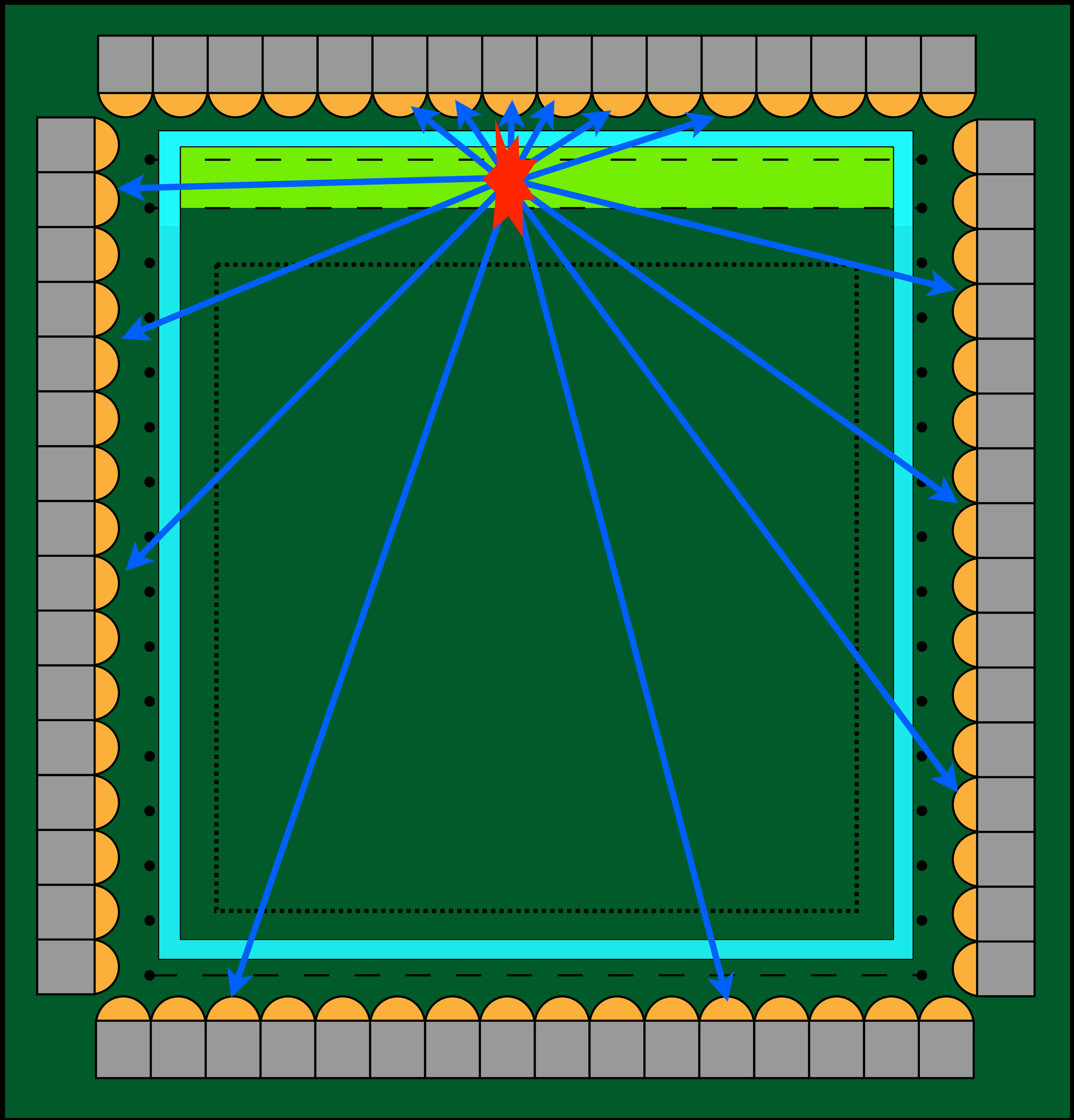
primary scintillation photons
emitted and detected



WIMP Scatter
deposits
energy in FV

TPC in Action

secondary photons emitted
by multiplication in gas region



ionized
electrons
drifted to
gas region

DarkSide
A scalable, zero-background technology

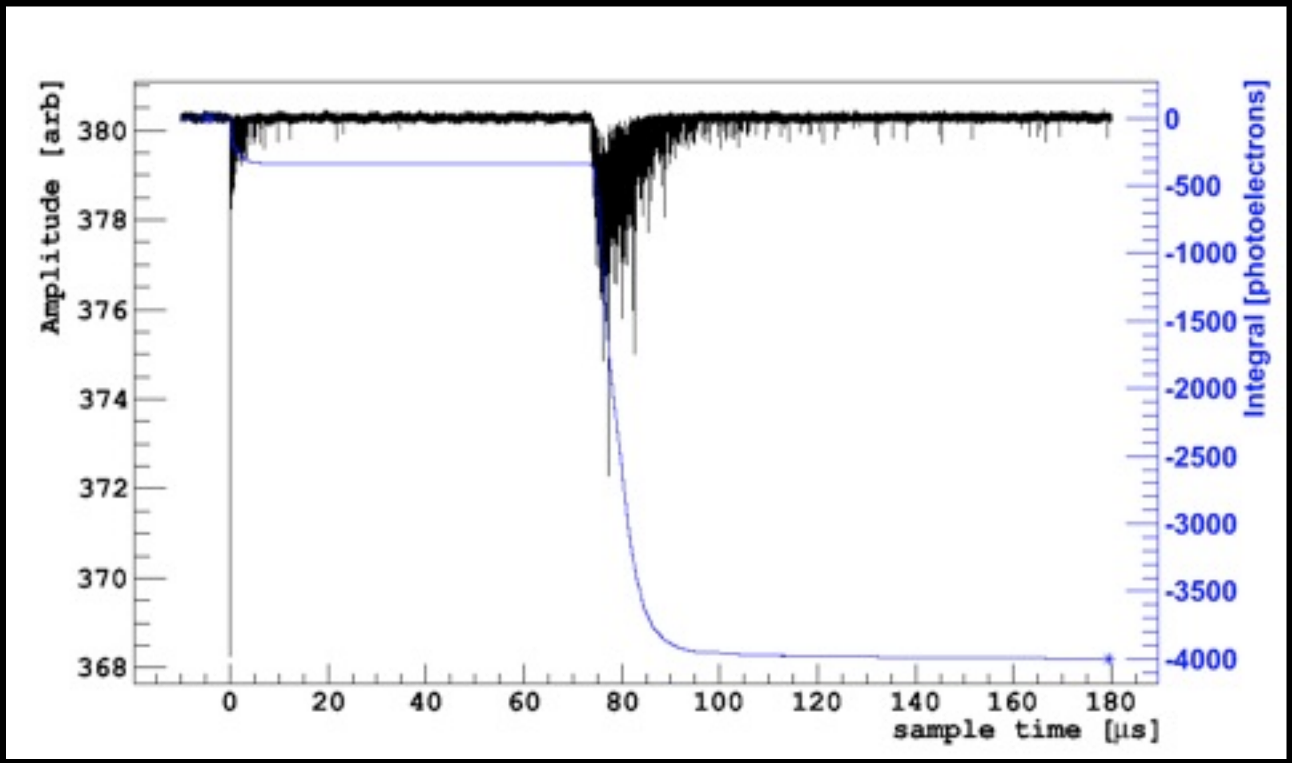
- LAr is one of the brightest scintillators known. Pulse shape of primary scintillation provides very powerful discrimination for NR vs. EM events:
  - Rejection factor $\geq 10^8$ for > 60 photoelectrons:
    - theoretical hint from Boulay & Hime, AstropartPhys **25**, 176 (2006)
    - experimental demonstration from WARP AstropartPhys **28**, 495 (2008)
    - recent confirmation from DEAP
  - Rejection factor depends solely on light yield for nuclear recoils.
  - With DarkSide-10 prototype, demonstrated that light yield for nuclear recoils in two-phase detectors can be ~1.5 ph.el/keV_{nr}, corresponding to 6 ph.el./keV_{ee}, as good as it can be achieved in single-phase detectors!

- Ionization drift is well established technology on very large scale detector. Ionization:scintillation ratio is a strong and semi-independent discrimination mechanism:
  - Rejection factor $\geq 10^2$-10^3 (Benetti et al. (ICARUS) 1993; Benetti et al. (WARP) 2006)

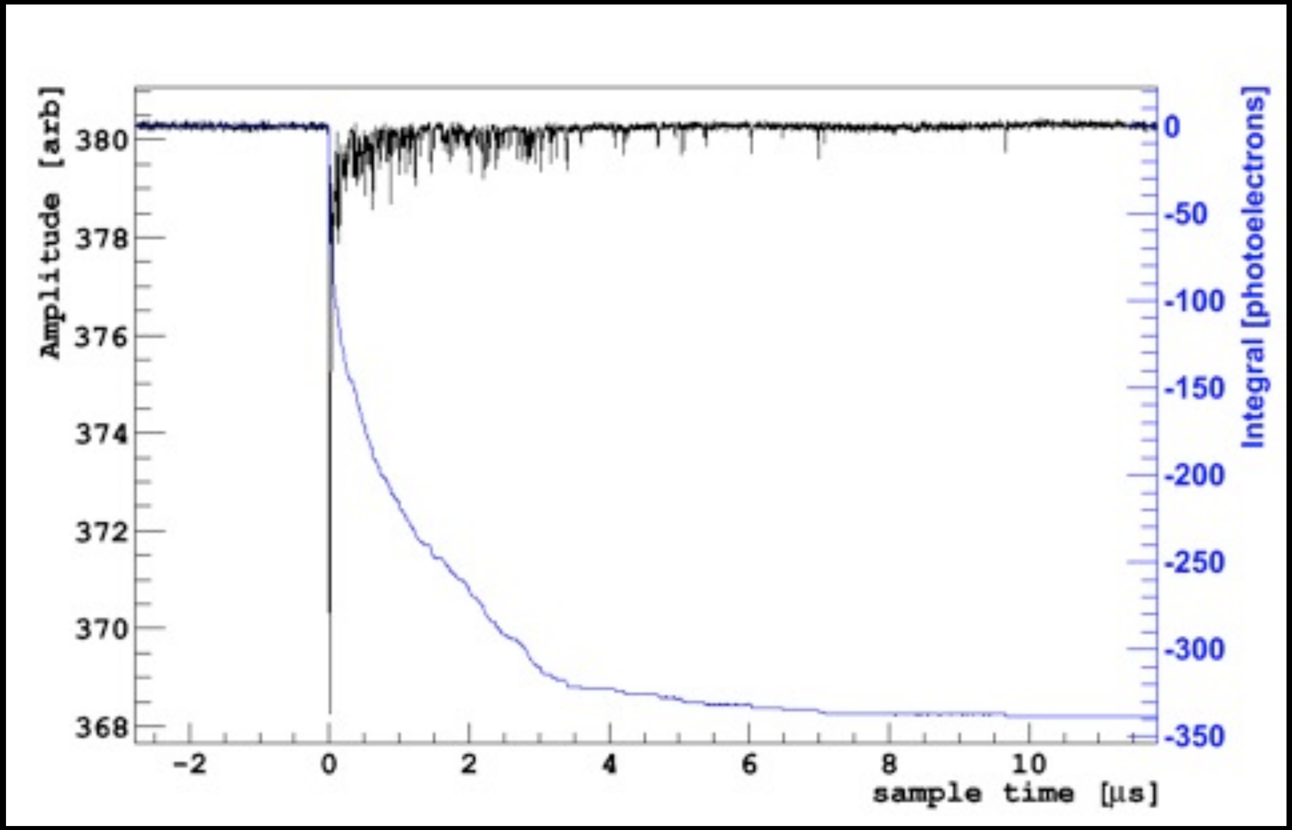
- Depleted argon
  - Production and refinement demonstrated in Princeton & Fermilab
  - Rejection factor ≥ 100!

- Spatial resolution from ionization drift localizes events, allowing rejection of multiple interactions, "wall events", etc.

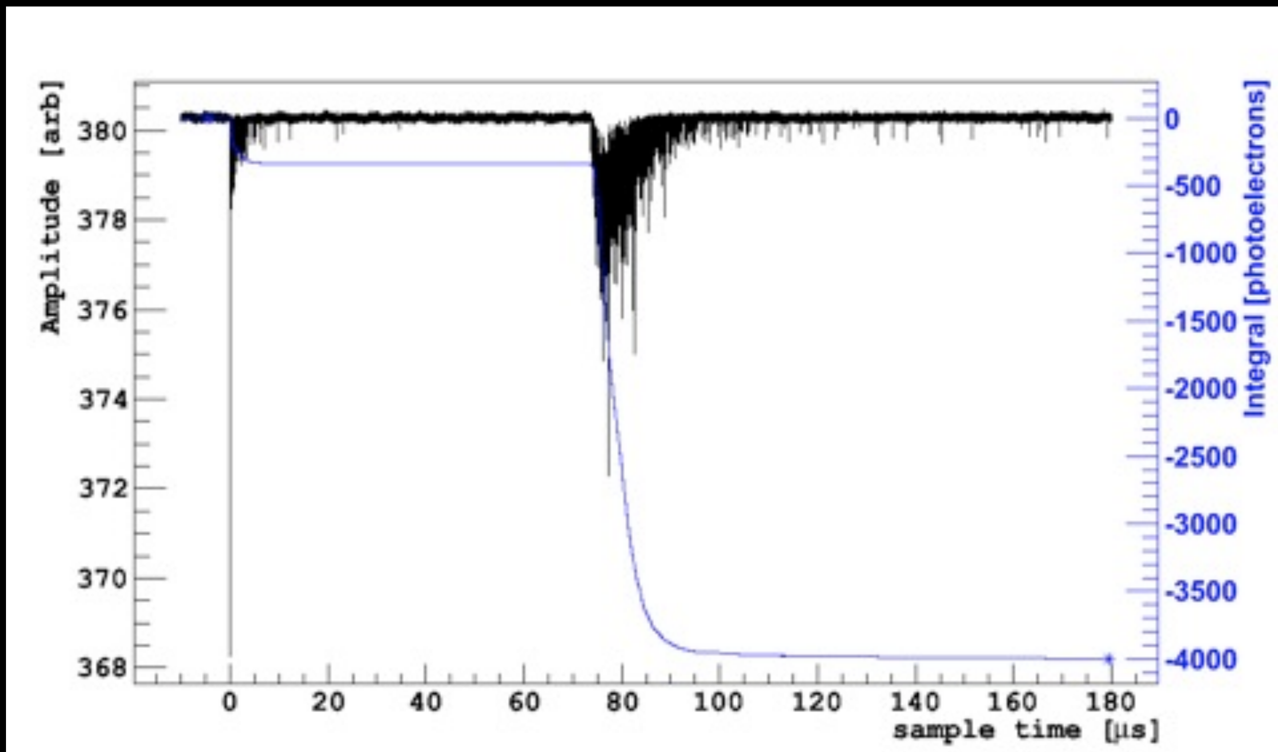
DarkSide-10

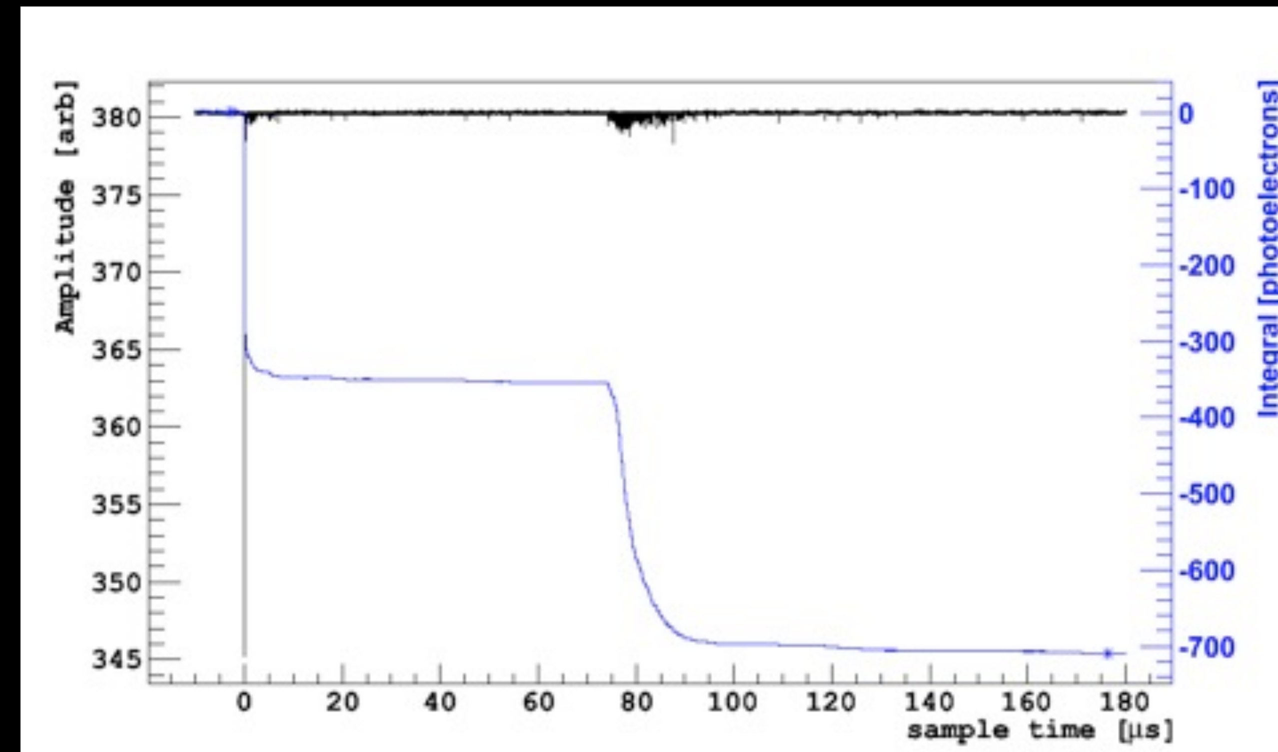


Beta/Gamma



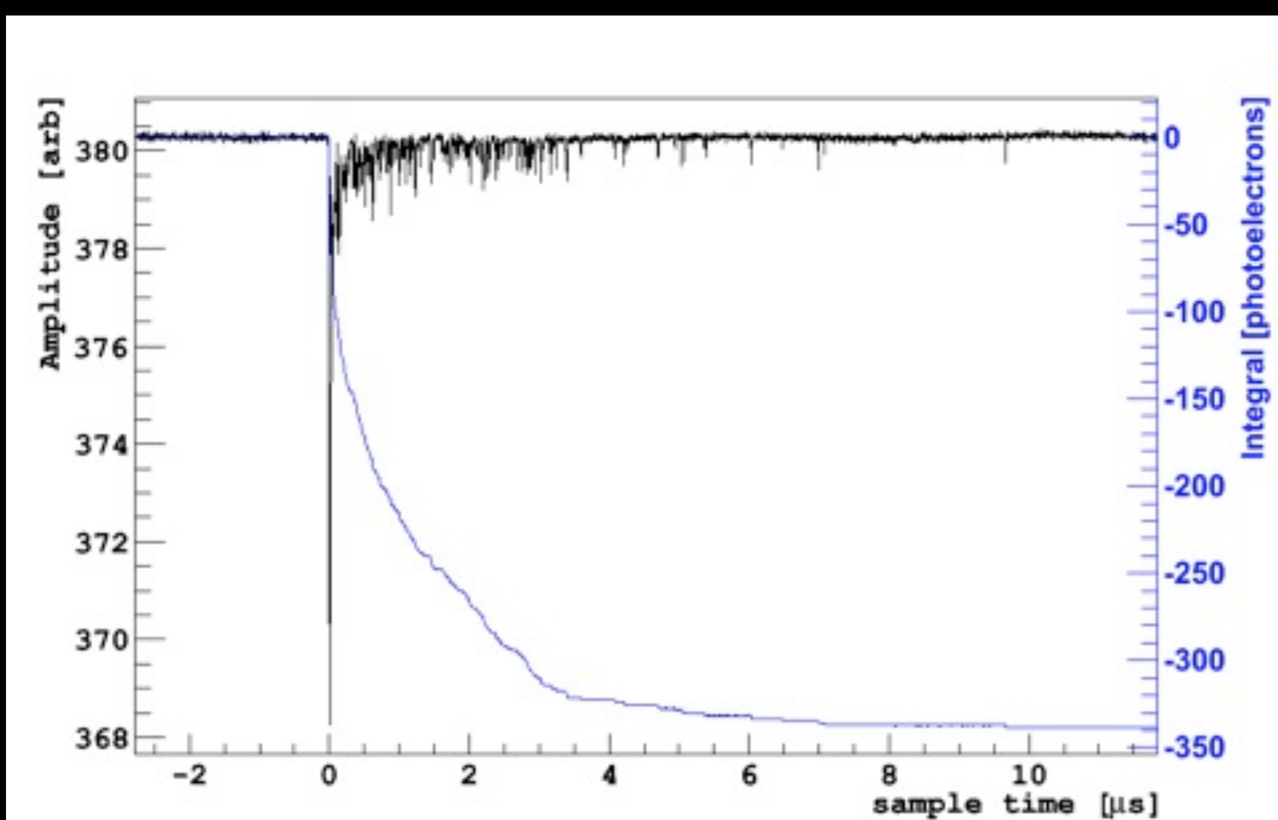
DarkSide-10

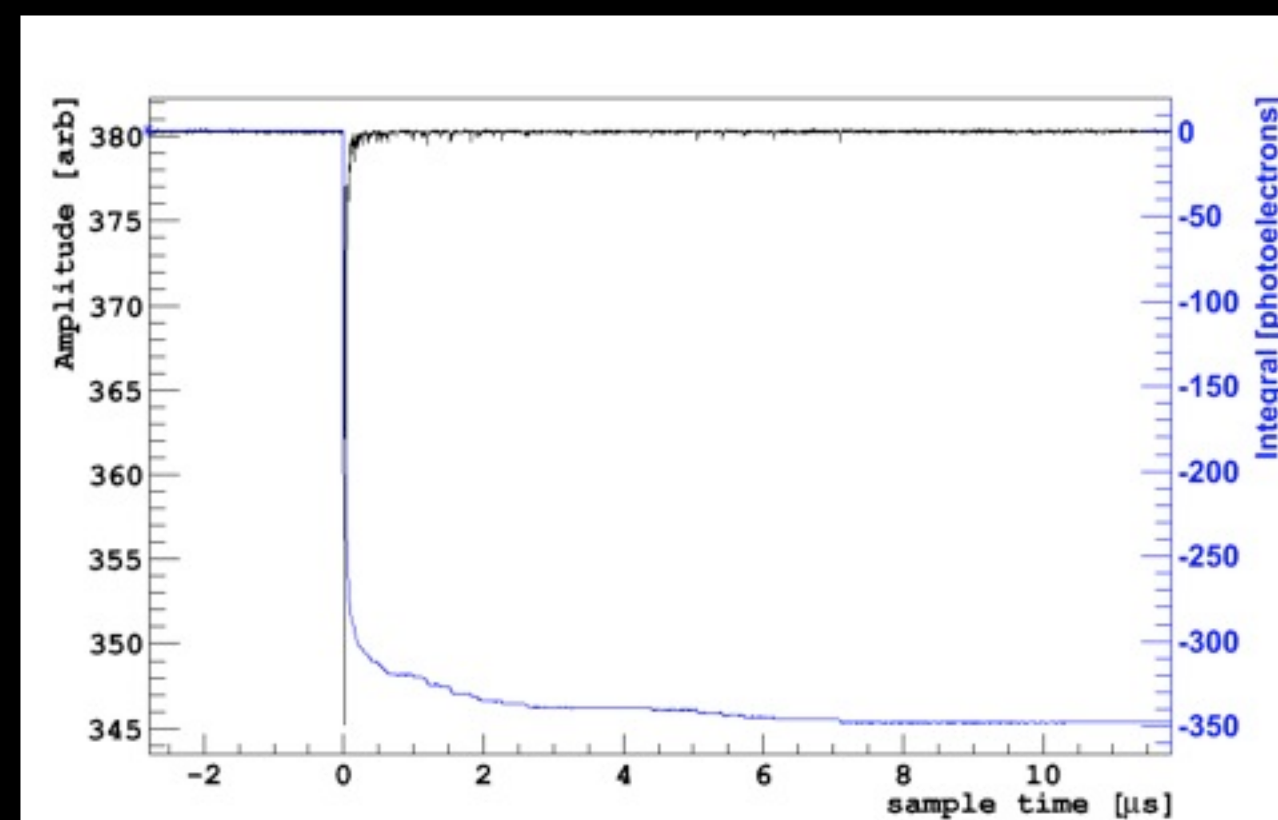




Beta/Gamma

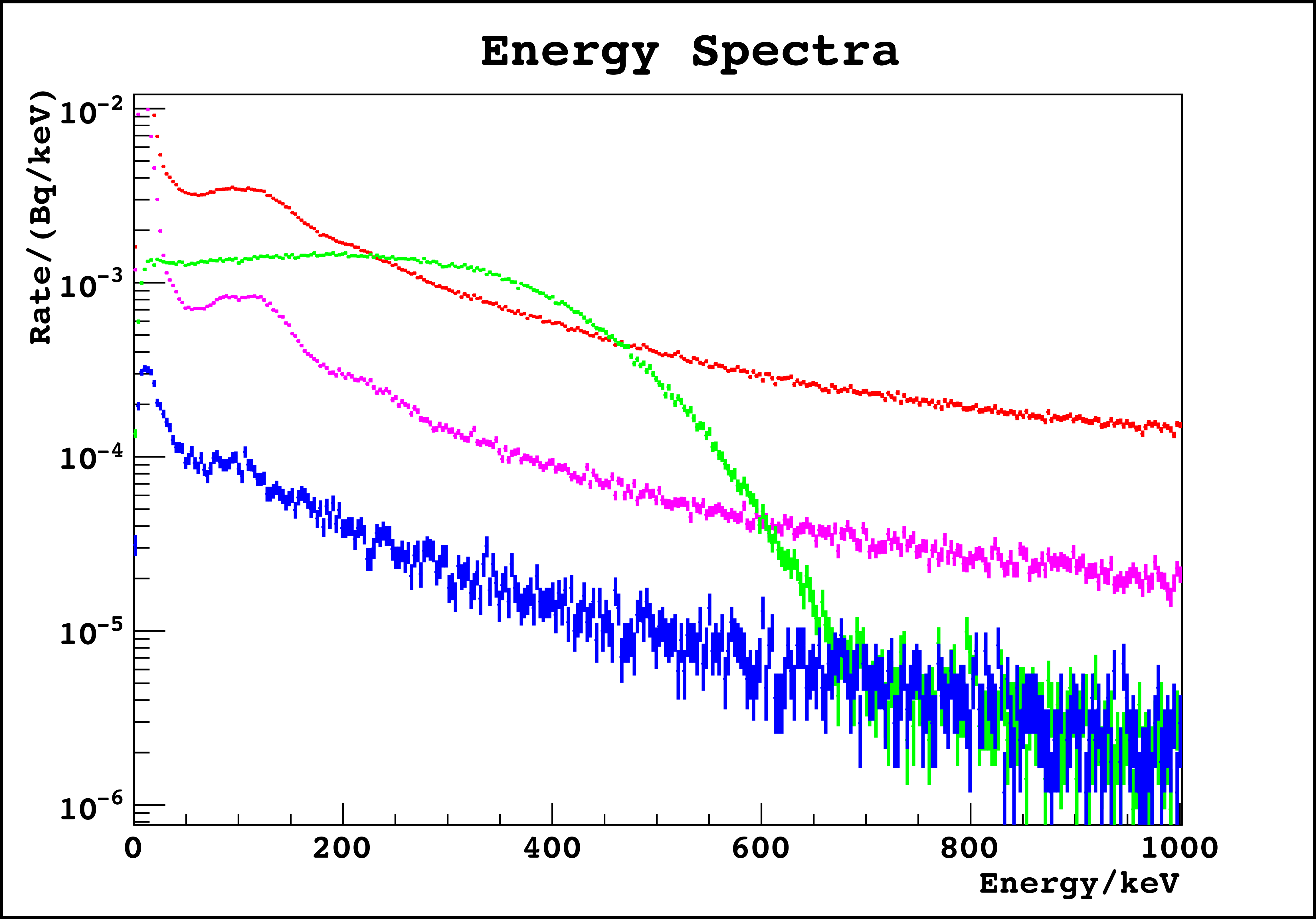
Nuclear Recoil



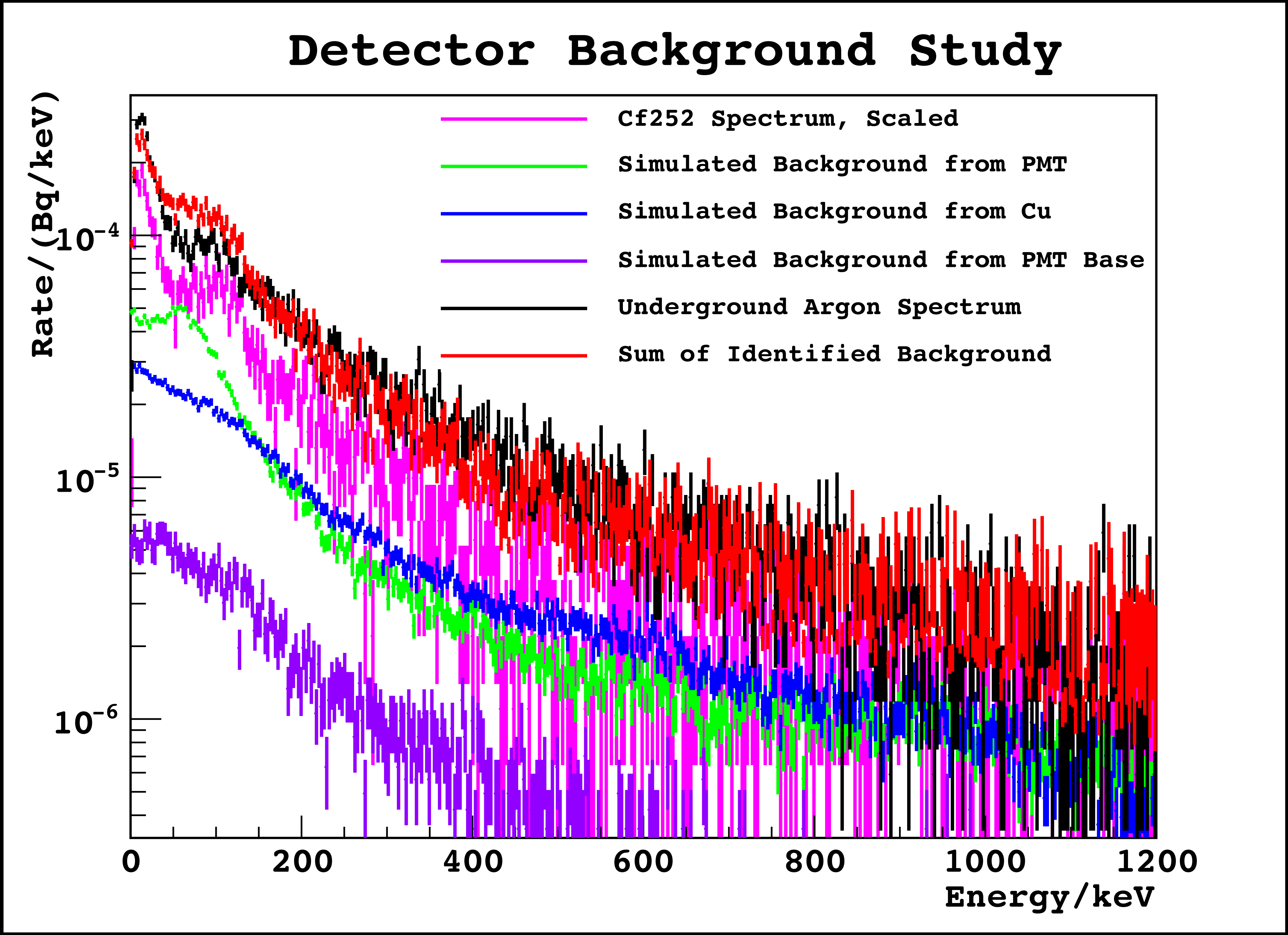


Underground Argon Extraction Plant

Depletion factor >100



Depletion factor >100



Cryogenic Distillation Column

Assembled and operated at the Fermilab PAB

Special thanks to PAB staff!

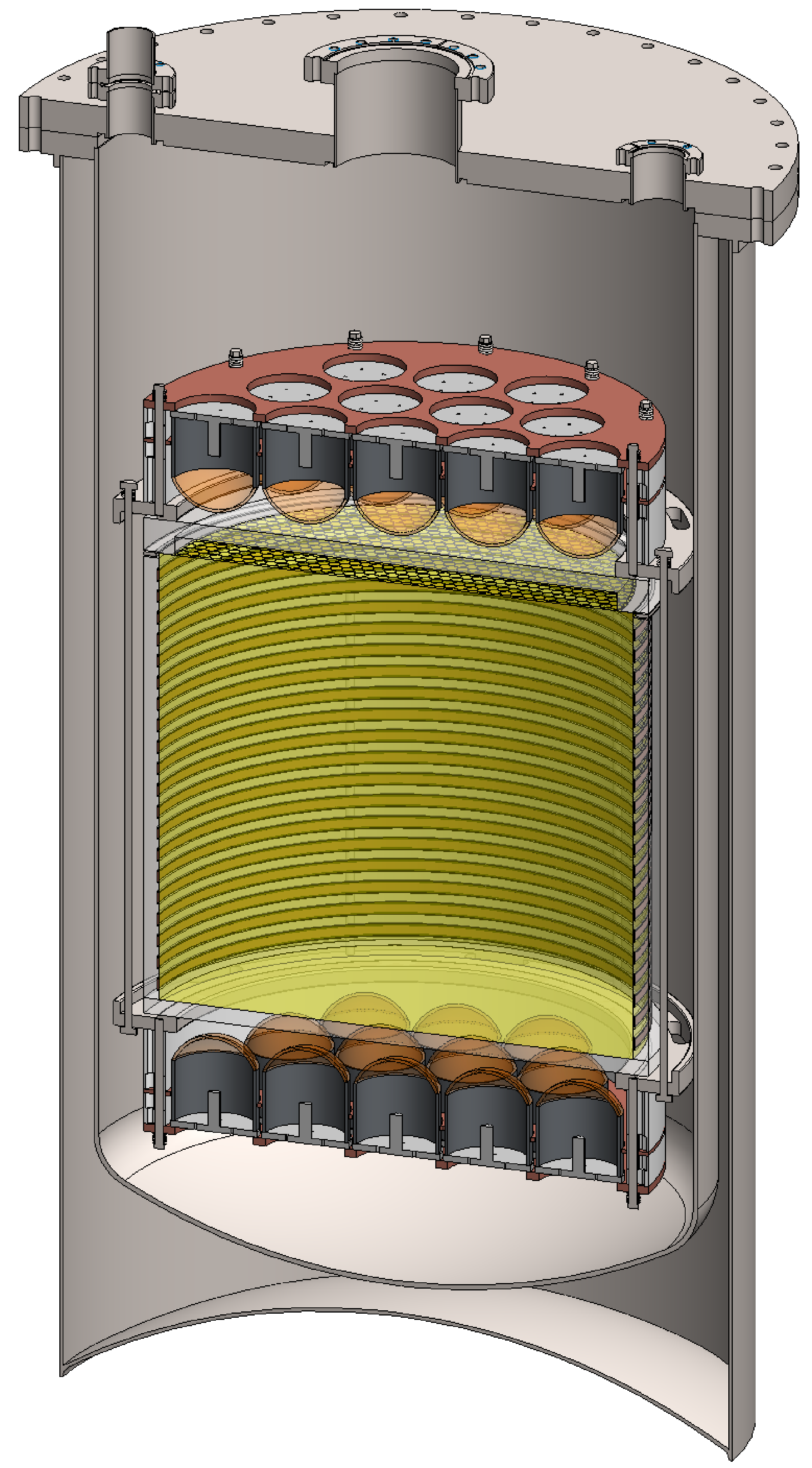
Princeton Prototype Cryogenic Distillation Column @ FNAL PAB

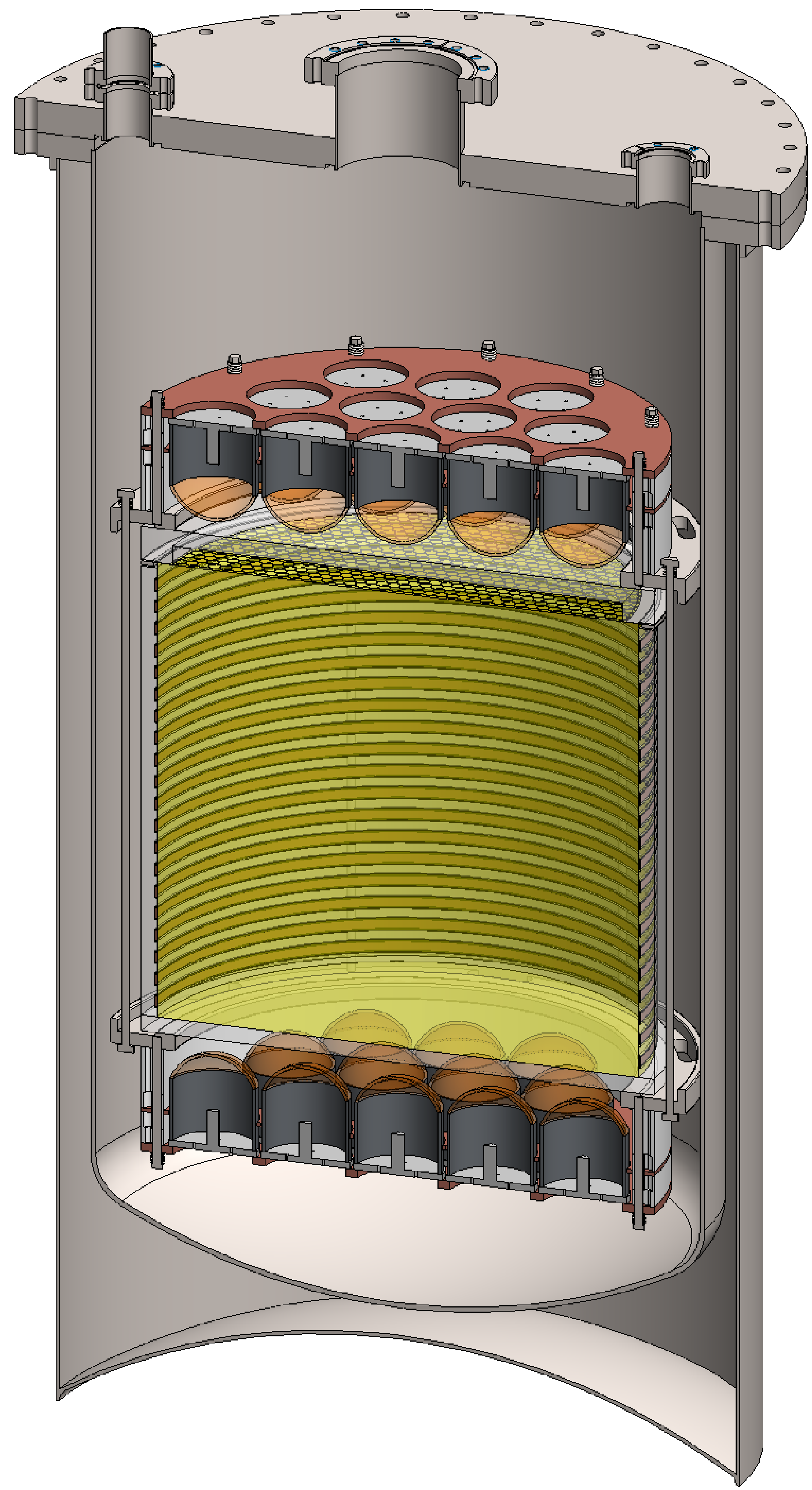
DarkSide-50

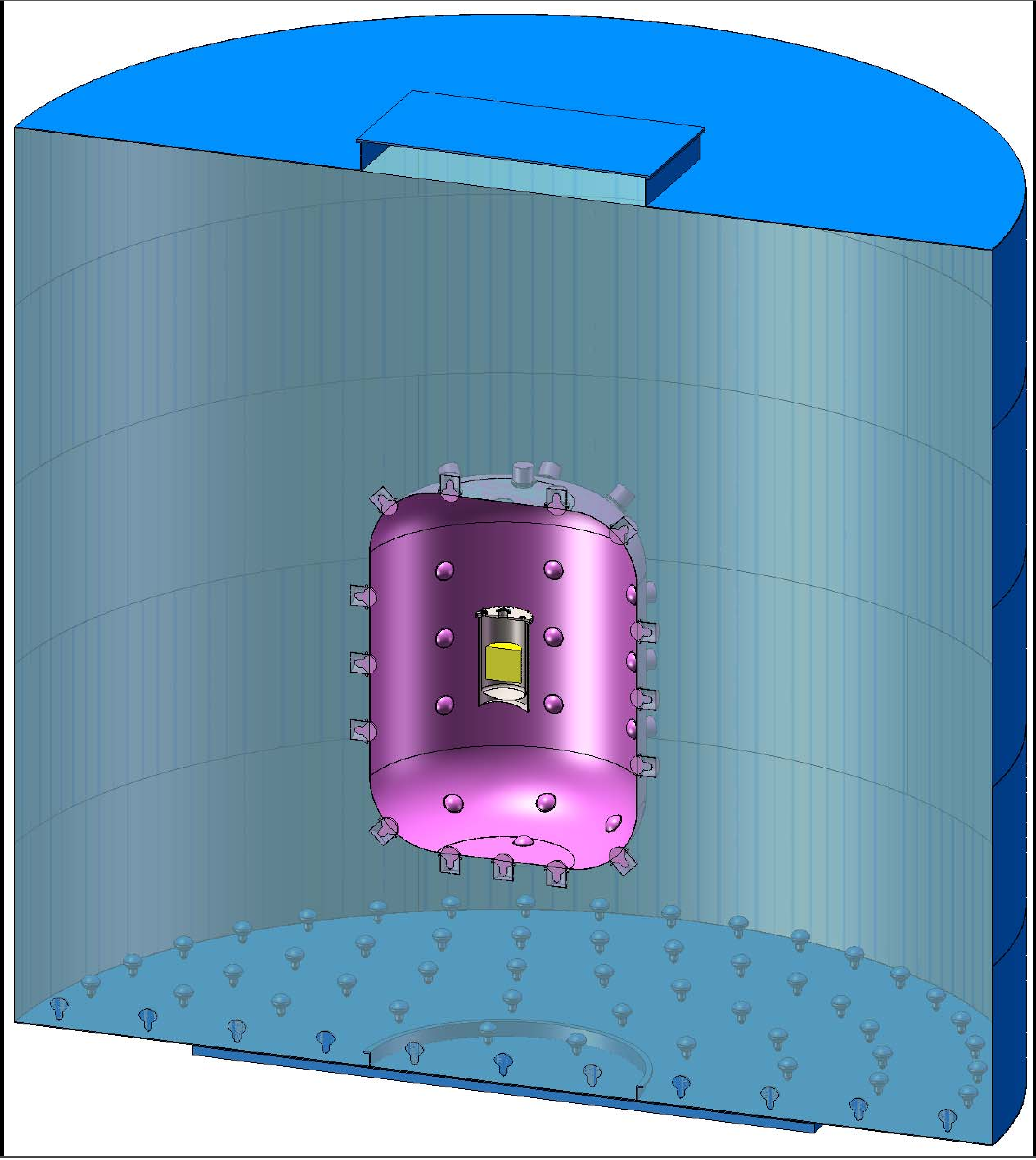
- New technologies for large background-free exposure
    - depleted argon
    - liquid-scintillator based neutron veto
    - QUPIDs

- DarkSide-50 sensitivity 10^{-45} cm^2
    - Demonstrate potential of the technology for multi ton-year ***background-free*** sensitivity

- DarkSide-5k sensitivity 10^{-47} cm^2





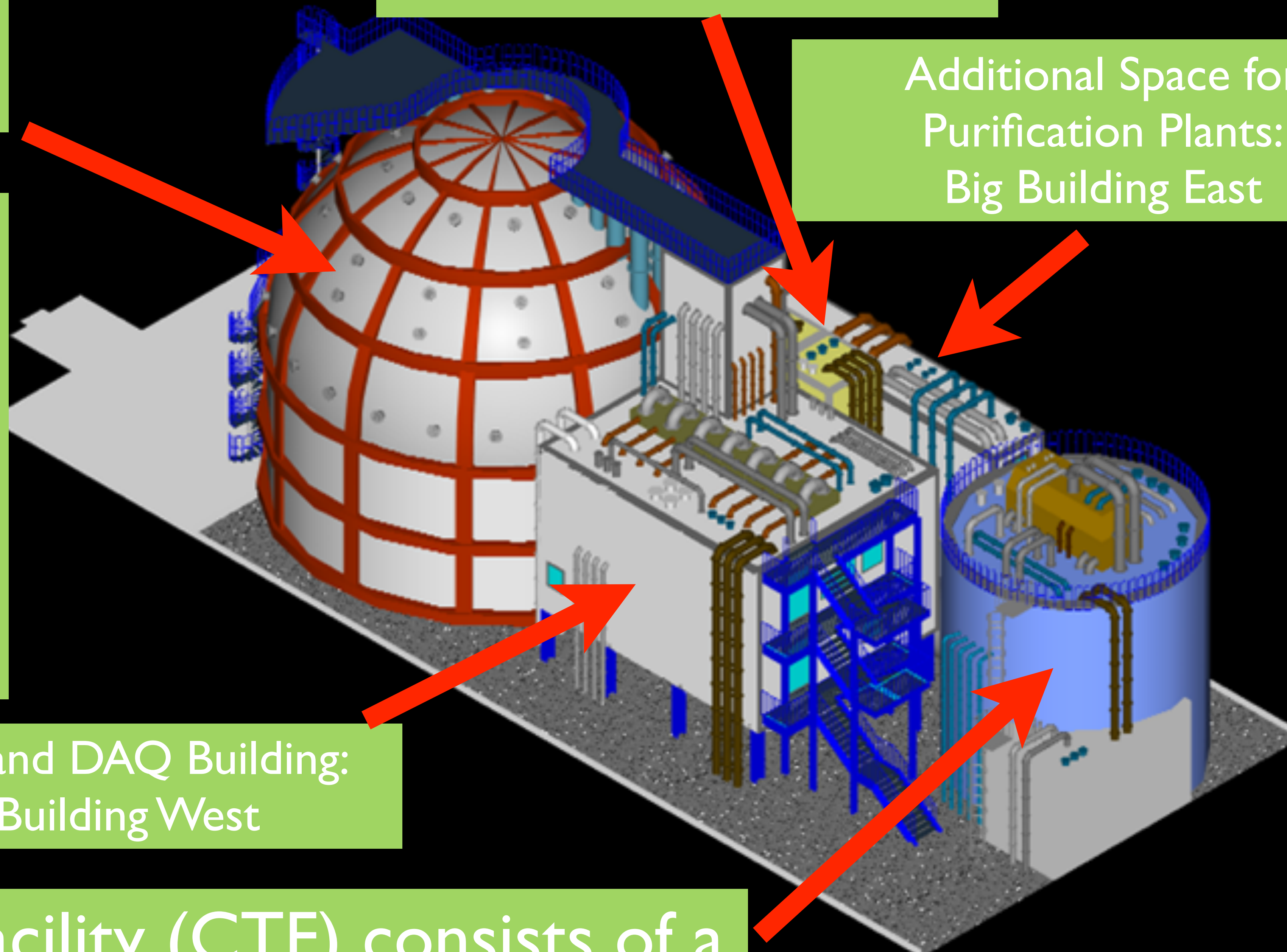


The Borexino detector

The Borexino installation in LNGS Hall C occupies an area of 20 x 55 m^2

Scintillator Handling and Purification Skids

Additional Space for Purification Plants: Big Building East

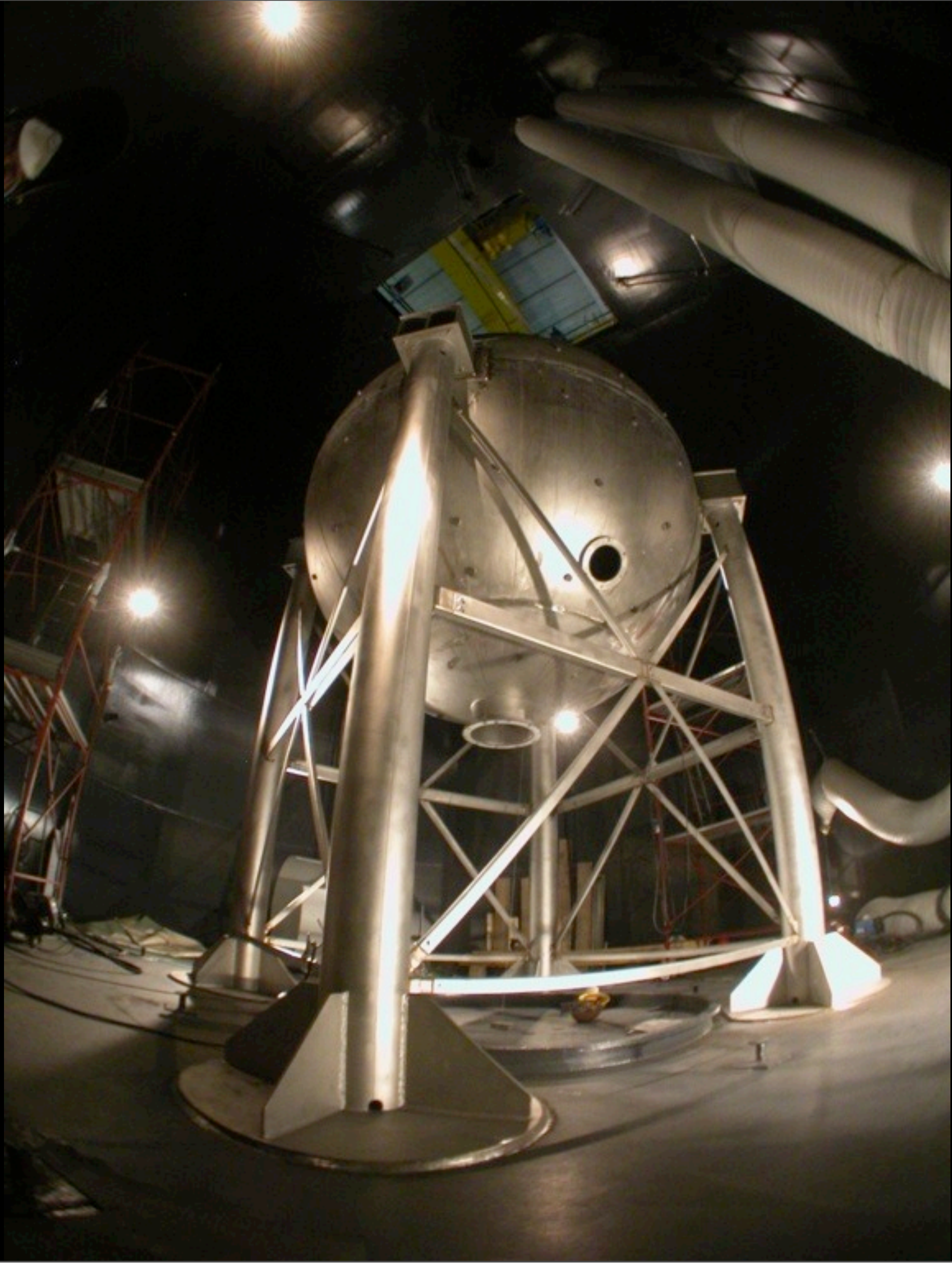


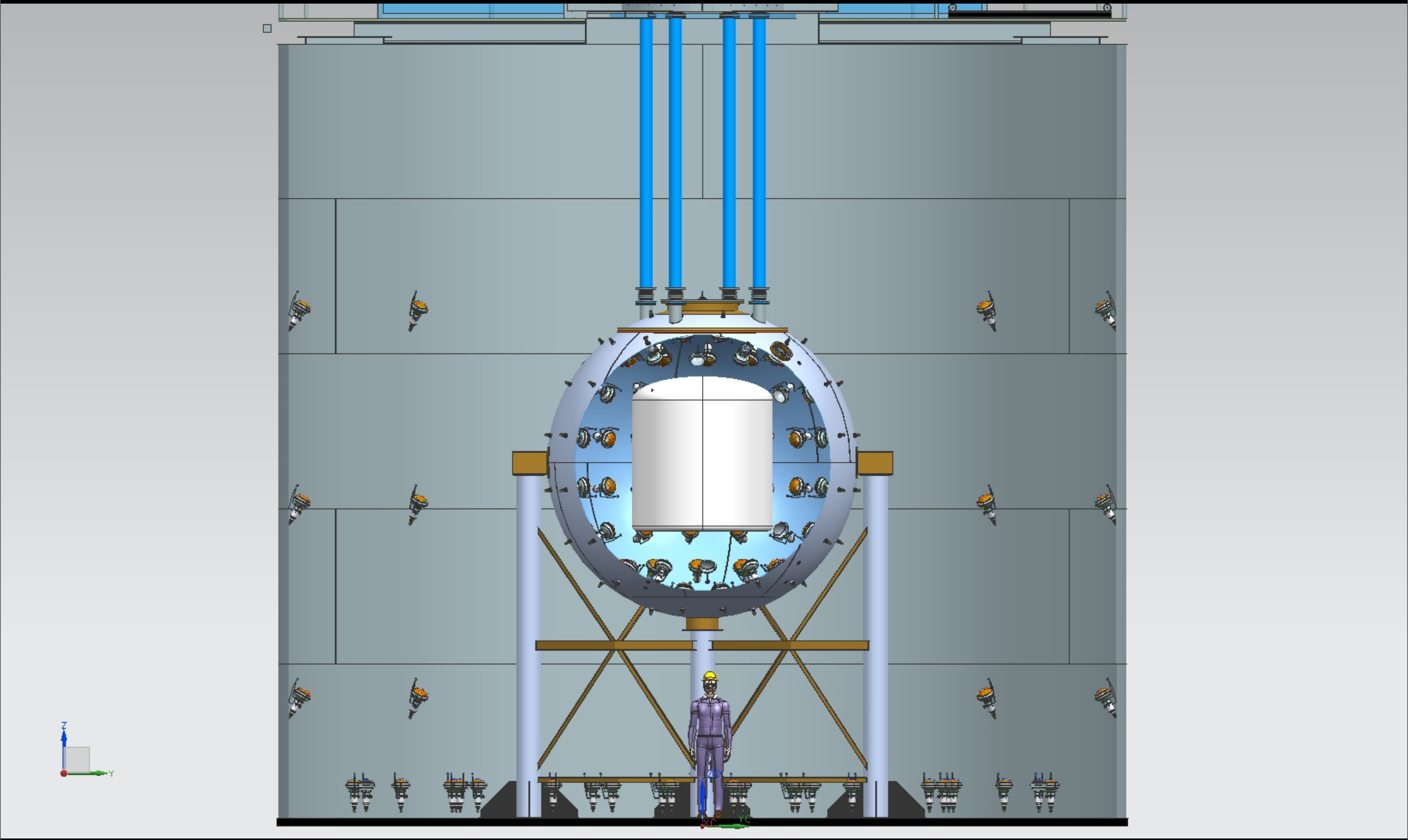
Offices and DAQ Building: Big Building West

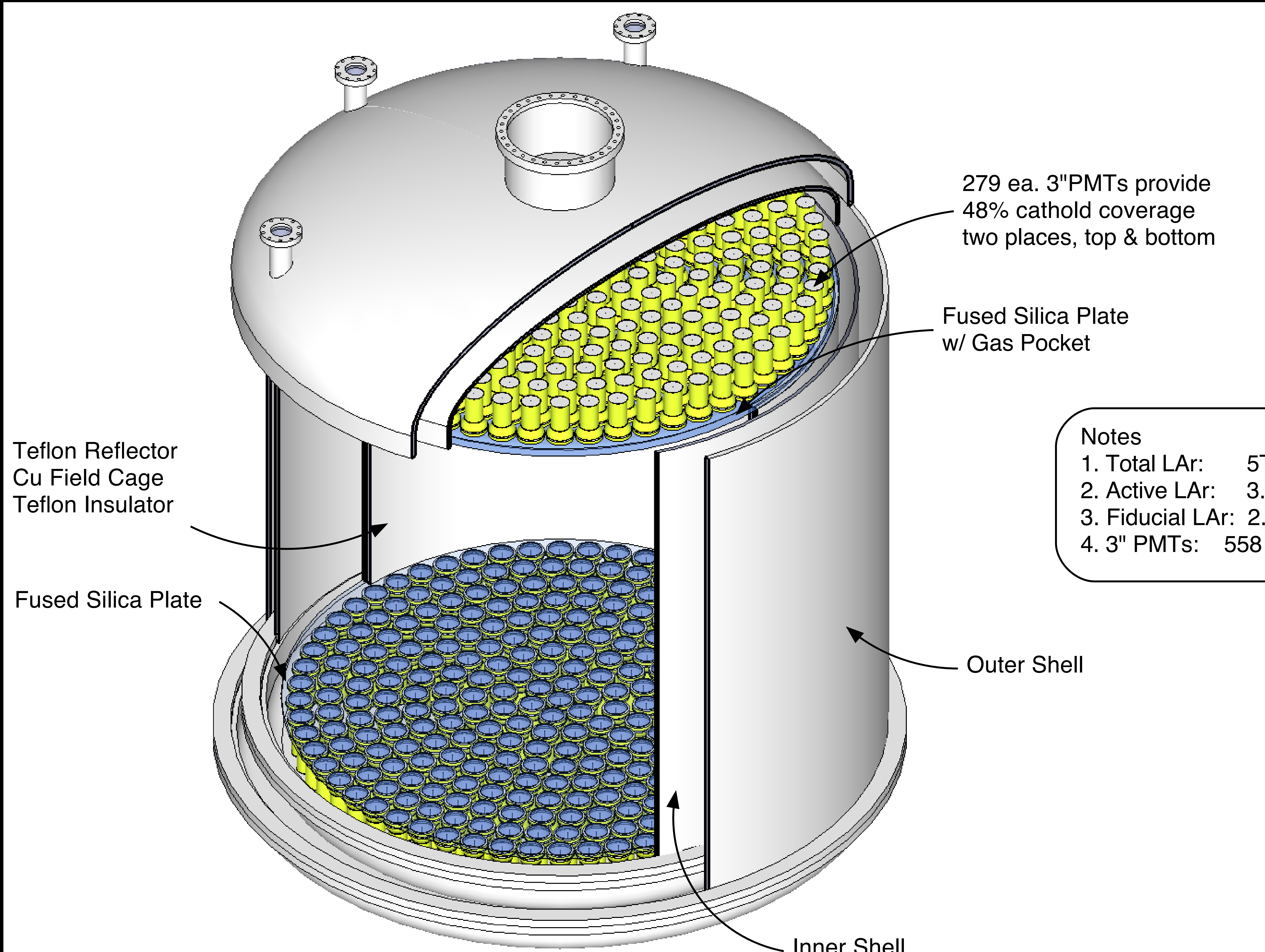
The Counting Test Facility (CTF) consists of a 10 m high, 11 m diameter water tank containing the Borexino prototype.
It will be re-converted in the facility housing the DarkSide-50 detector starting in the Summer 2011

Water Purification Plant and Scintillator Storage also available (not shown)

The Borexino Counting Test Facility (1995)






279 ea. 3"PMTs provide
48% cathold coverage
two places, top & bottom
Fused Silica Plate
w/ Gas Pocket
Notes
1. Total LAr: 5T
2. Active LAr: 3.3
3. Fiducial LAr: 2.8
4. 3" PMTs: 558 e
Teflon Reflector
Cu Field Cage
Teflon Insulator
Fused Silica Plate
Outer Shell
Inner Shell

Backgrounds

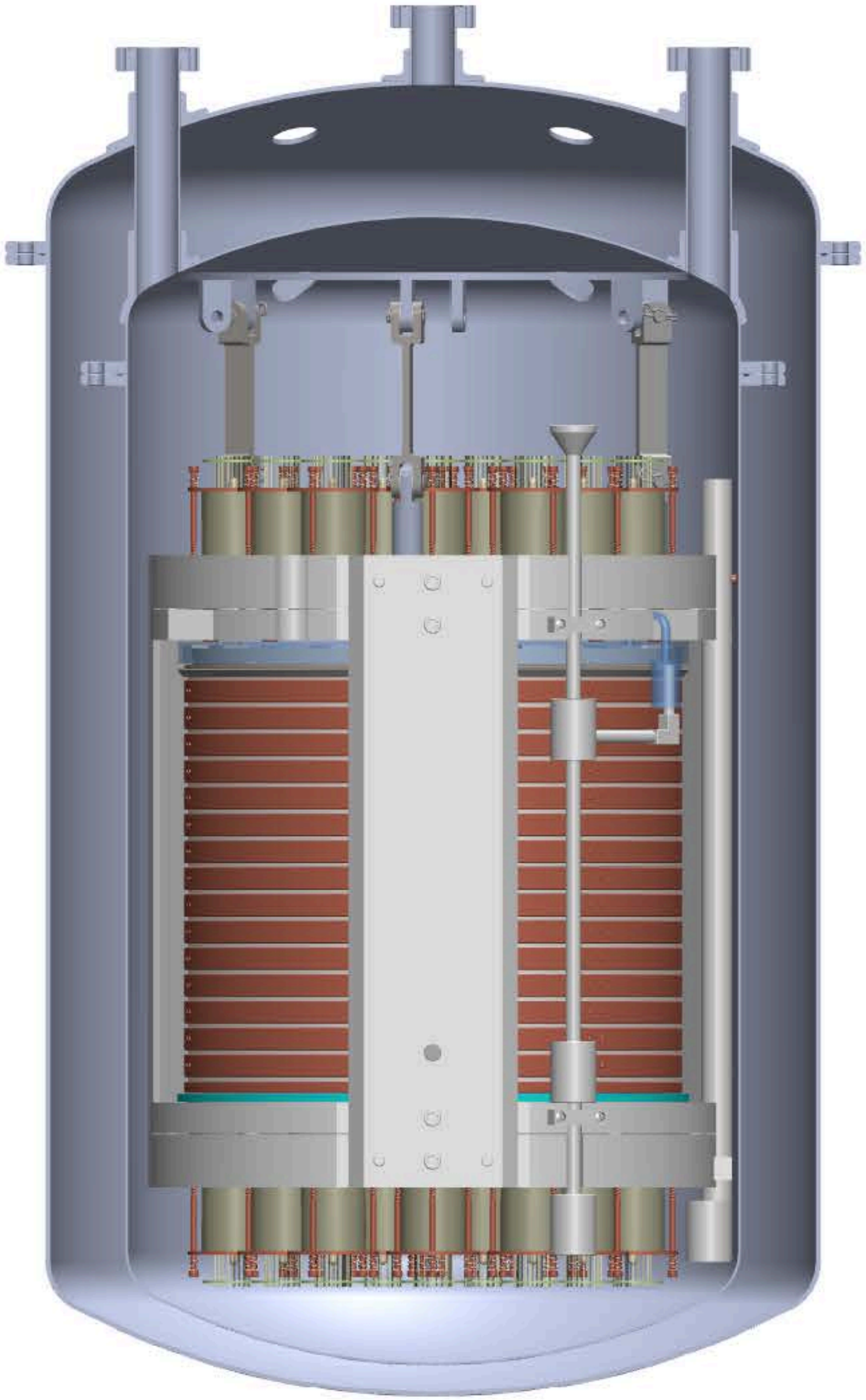
Detector Element	Electron Recoil Backgrounds		Radiogenic Neutron Recoil Backgrounds		Cosmogenic Neutron Recoil Backgrounds	
	Raw	After Cuts	Raw	After Cuts	Raw	After Cuts
^{39}Ar	2.5×10^{7}	$<1\times10^{-2}$	–	–	–	–
Fused Silica	3.6×10^{5}	1.4×10^{-4}	1.8	4.5×10^{-3}	2.3	1.4×10^{-4}
PTFE	306	1.2×10^{-7}	0.024	6.0×10^{-5}	0.17	1.0×10^{-5}
Copper	2,146	8.6×10^{-7}	0.0024	6.0×10^{-6}	0.72	4.3×10^{-5}
QUPIDs	7.0×10^{4}	2.8×10^{-5}	0.31	7.8×10^{-4}	0.34	2.0×10^{-5}
R11065 PMTs	2.6×10^{6}	1.0×10^{-3}	19.4	4.9×10^{-2}	0.34	2.0×10^{-5}
Titanium	2.4×10^{4}	9.6×10^{-6}	1.1	2.8×10^{-3}	13	7.7×10^{-4}
Veto Scintillator	70	2.8×10^{-8}	0.030	7.5×10^{-5}	26	0.0015
Veto PMTs	2.5×10^{6}	1.0×10^{-3}	0.023	5.7×10^{-5}	–	–
Veto tank	1.7×10^{5}	6.8×10^{-5}	6.7×10^{-5}	1.7×10^{-7}	19	0.0076
Water	6,100	2.4×10^{-6}	6.7×10^{-4}	1.7×10^{-6}	19	0.0076
CTF tank	8,300	3.3×10^{-6}	3.5×10^{-3}	8.7×10^{-6}	0.068	2.7×10^{-5}
LNGS Rock	920	3.7×10^{-7}	0.061	1.5×10^{-4}	0.31	0.012
Total	–	1.1×10^{-2} (1.2×10^{-2})	–	0.0082 (0.056)	–	0.030 (0.030)

TABLE I: A summary of the expected electron- and neutron-recoil backgrounds in 0.1 ton-yr of data from DarkSide-50 before and after applying the background rejection cuts described in the text (all units are events/(0.1 ton-yr)). The ^{39}Ar rates are given for the gas collected at Cortez (depletion factor of 25 or more). The "Total" row assumes the configuration with QUPIDs (numbers in parenthesis apply to the initial configuration with R11065 PMTs). Note that the majority of the entries in this Table are based on limits on, rather than measurements of, the radioactive contaminants in the different detector component materials.

DS-10 Activity

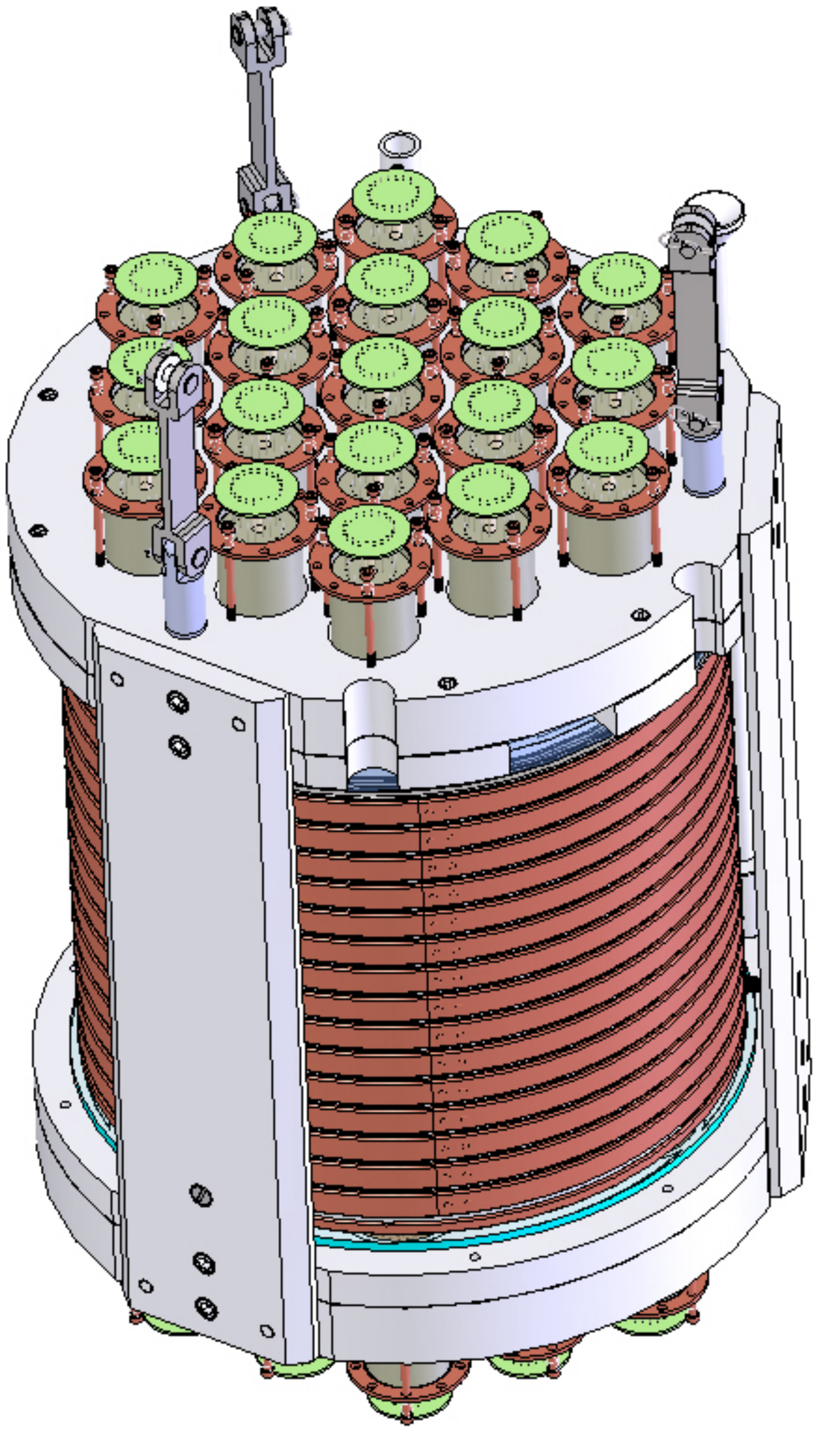
- Compare performance of different reflectors for light collection;
- Test HHV system (feedthroughs, grid etc.);
- Perform calibration of detector. Diffuse ^{83}Kr gaseous source just arrived to LNGS. Test foreseen in few weeks;
- Test of front-end amplifier for DS-50 TPC (presently undergoing);
- Optimize field configuration of TPC

DS-50 TPC



- Stainless Steel cryostat (138 kg);
- Active Volume diameter 35.6 cm;
- Active Volume height 35.6 cm;
- Gas Pocket 1.0 cm;
- Active LAr mass 49.4 kg;
- Total LAr mass ~145 kg;

DS-50 TPC

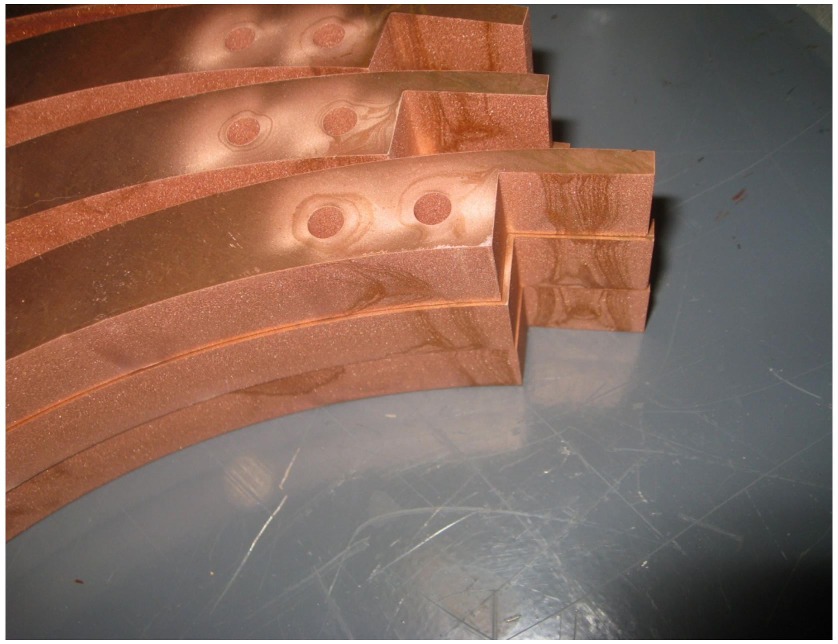


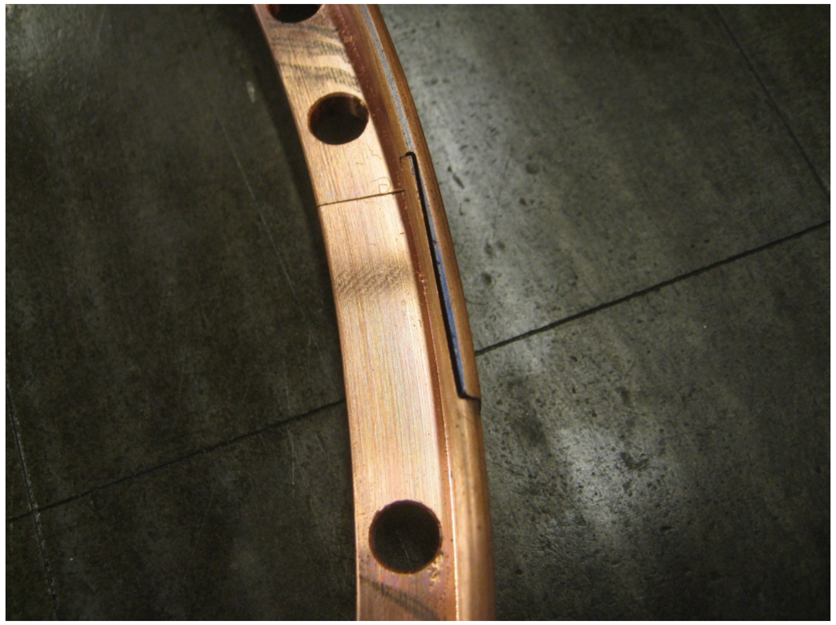
- 38 PMT R11065;
- Drift field (typical) 1.0 kV/cm;
- Extraction field (typical) 3.8 kV/cm;
- Multiplication field (typical) 5.7 kV/cm;
- HHV voltage -43.2 kV

DS-50 TPC

- Mockup copies of the PTFE structural support and of the PTFE reflector body have been used to test the assembly and the mechanical behavior of the TPC at LAr temperature;

- Final PTFE parts already ordered and waiting for the delivery;





DS-50 TPC

- T-Shaped copper rings for field cage are already manufactured (23.5 kg).
- An assembly test of the field cage system has been performed. Even during cool down the copper rings stay centered with respect to the reflector body. This will ensure an extremely uniform electric field in the sensitive volume.
- The HHV feedthrough (PE based) has already been designed and it is under construction at UCLA. An identical feedthrough has demonstrated to hold the maximum voltage applied to it (100kV).

DS-50 TPC

- An extensive screening program is in place to measure the radioactivity of all components and ensure that they meet the requirements by means of detailed Geant4 simulation.
- All the components of the TPC will be properly treated and cleaned to reduce as much as possible surface contamination.
- A dedicated cleaning module, connected to the Borexino plants, is ready to be located inside the refurbished Radon Free CR1.
- Evaporations of TPB on inner TPC surfaces will be performed inside the Radon Free CR1.
- After cleaning and evaporation all the parts will be temporary located in vacuum tight containers filled with dry argon gas.
- Final assembly will be performed in the Radon Free Hanoi CR at the top of CTF.

The End

Like the jelly beans in this jar, the Universe is mostly dark: 96 percent consists of dark energy (about 70%) and dark matter (about 26%). Only about four percent (the same proportion as the lightly colored jelly beans) of the Universe - including the stars, planets and us - is made of familiar atomic matter.

The End