The DarkSide Program

Direct dark matter search with depleted argon

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What is DarkSide?

- A graded program of increasingly larger and more sensitive dark matter detectors.
- Each detector is a two-phase Ar time projection chamber (TPC).
- Employs Ar with low content of radioactive ^{39}Ar, for increased sensitivity.

What is dark matter?

Dark: no electromagnetic interactions

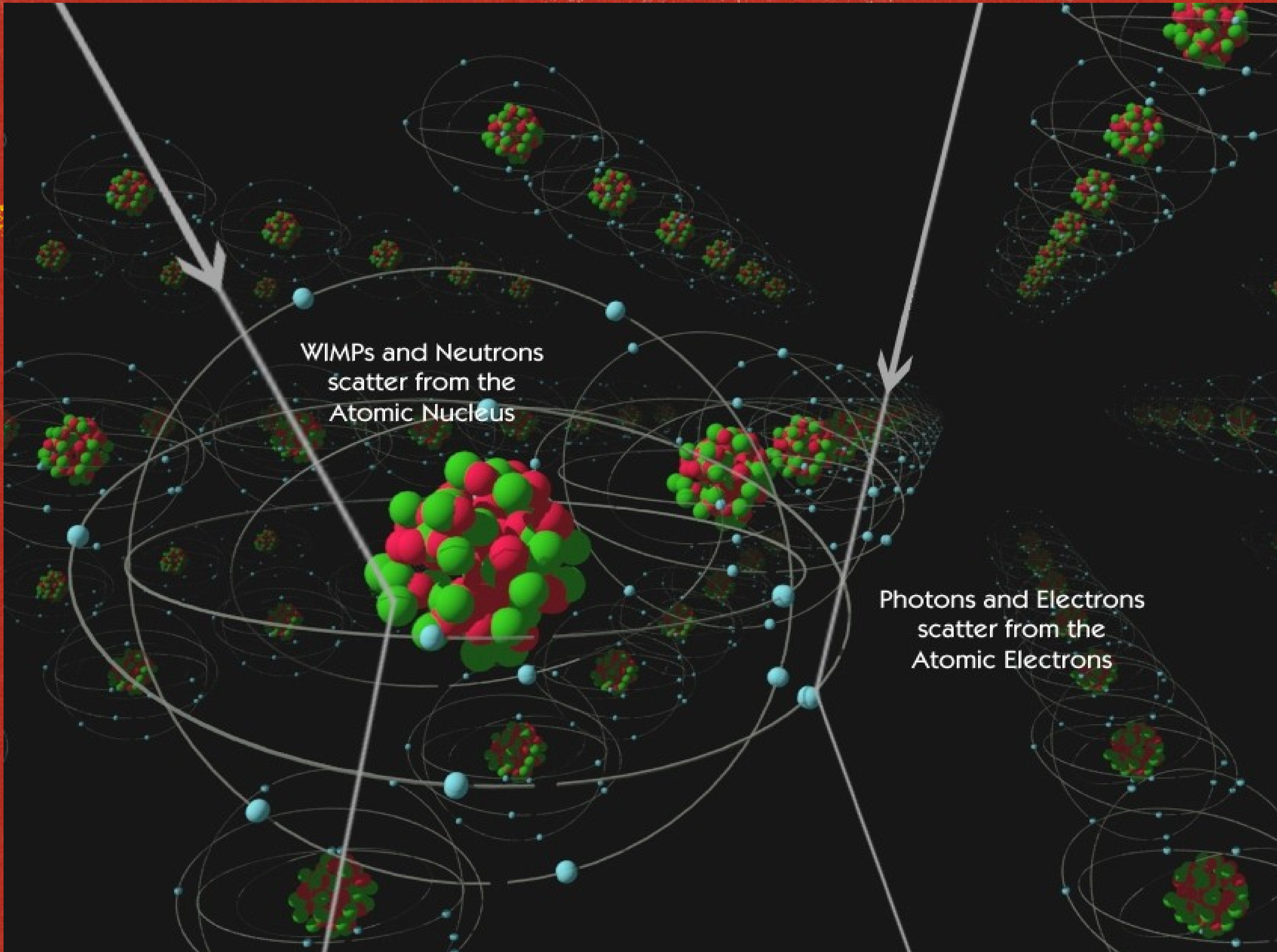
Evidence of dark matter comes from rotational velocity profiles of galaxies and gravitational lensing

- $v(r) \sim \sqrt{[M(r)/r]}$ expected but not observed

One possible candidate: Weakly Interacting Massive Particles (WIMPs)

Direct dark matter detection

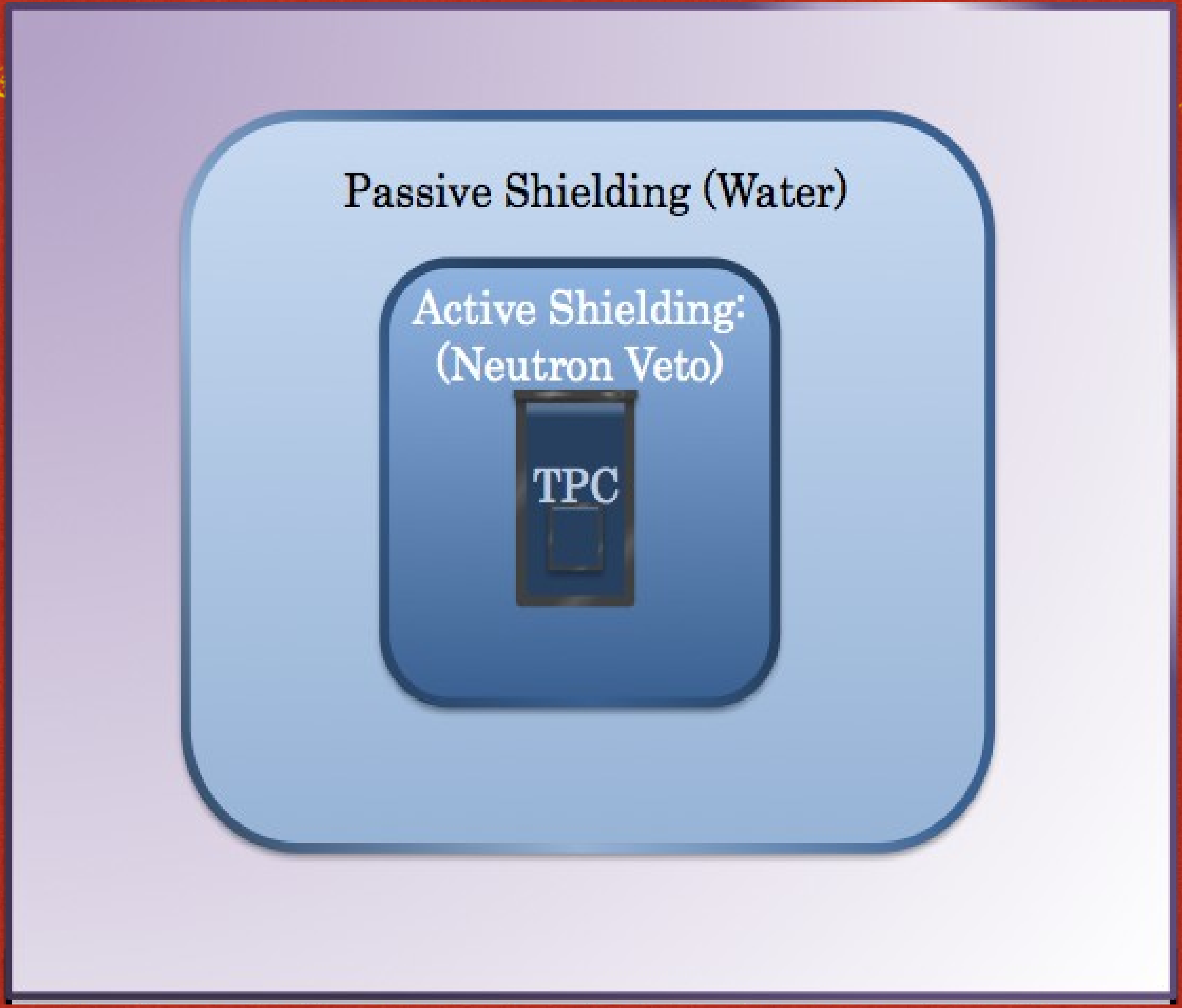
- Most experiments look for WIMPs
- Dark matter particles are expected to pass through the earth, occasionally colliding with a nucleus along their way
- Placing a target, aim to detect the nuclear recoil produced by such a collision


WIMPs and Neutrons scatter from the Atomic Nucleus
Photons and Electrons scatter from the Atomic Electrons

Direct Dark Matter searches: current status

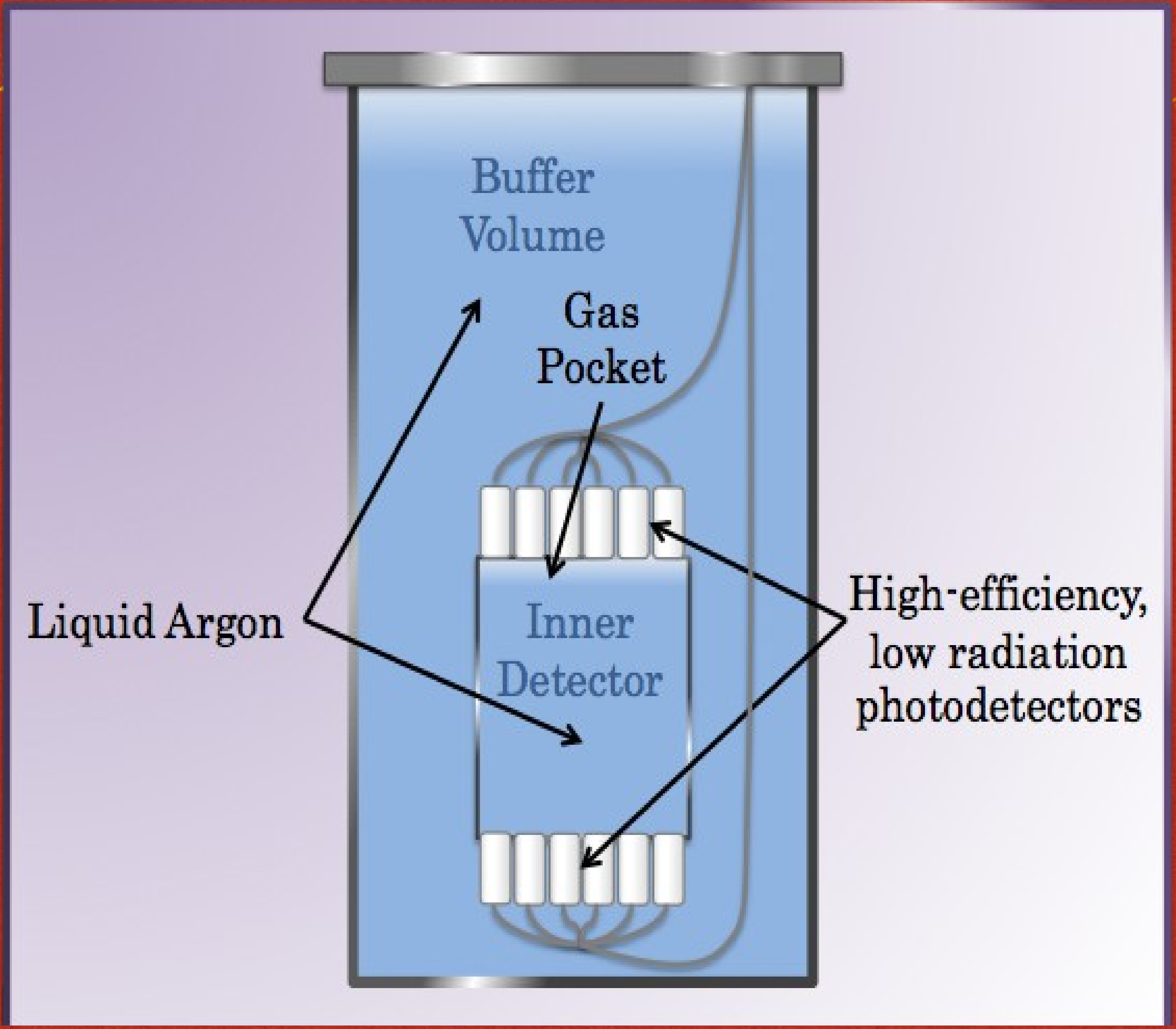
- WIMP dark matter well motivated by cosmological arguments, CMB, astrophysical observations, particle physics models (e.g. supersymmetry)
- Very high discovery potential
- Conflicting results from different experiments (DAMA, CoGeNT, XENON)
- Large leap in sensitivity is possible thanks to liquefied noble gases
- Significant developments in detector technology

How it works



Diagrams by Emily Lebsack

How it works



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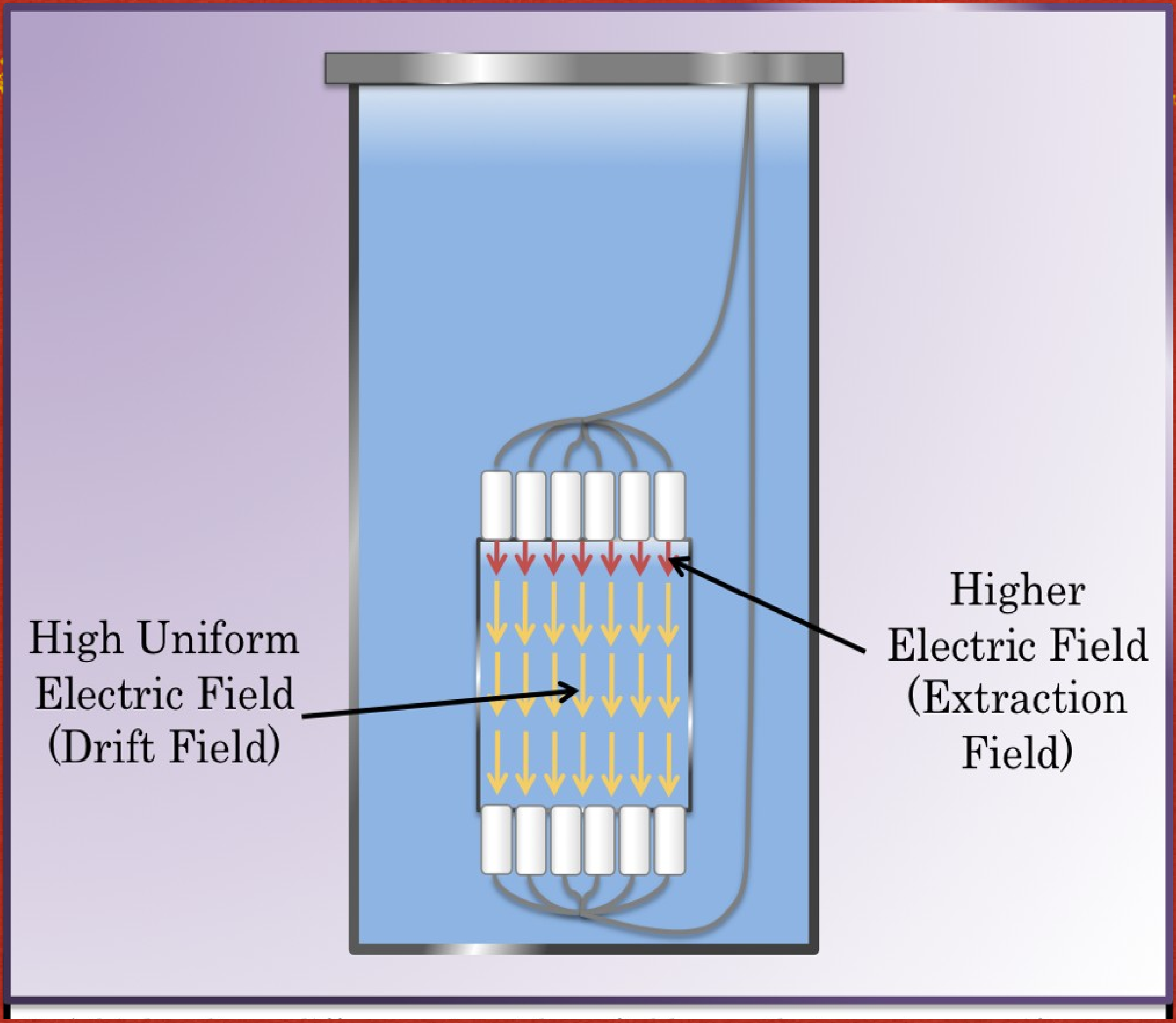

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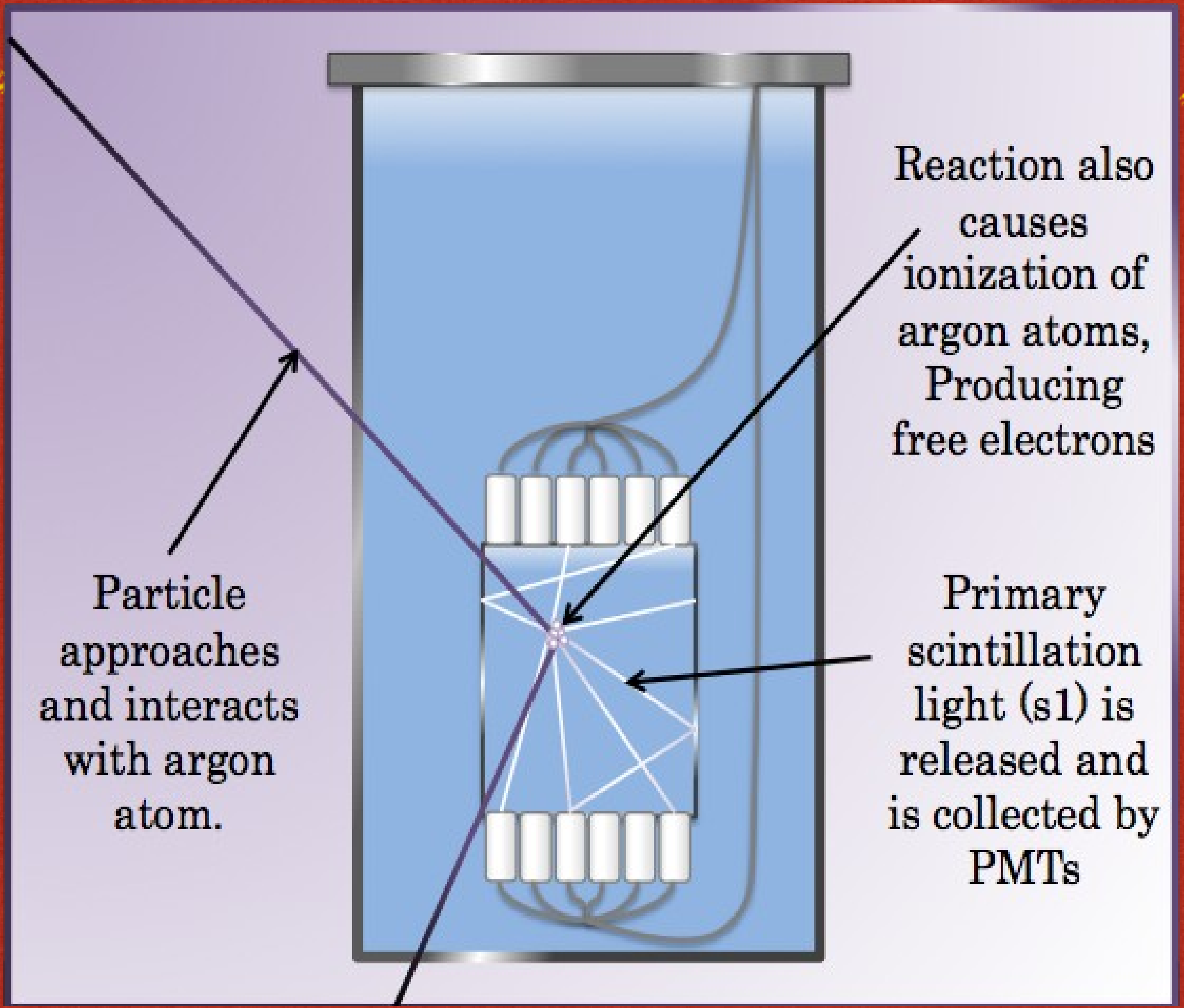

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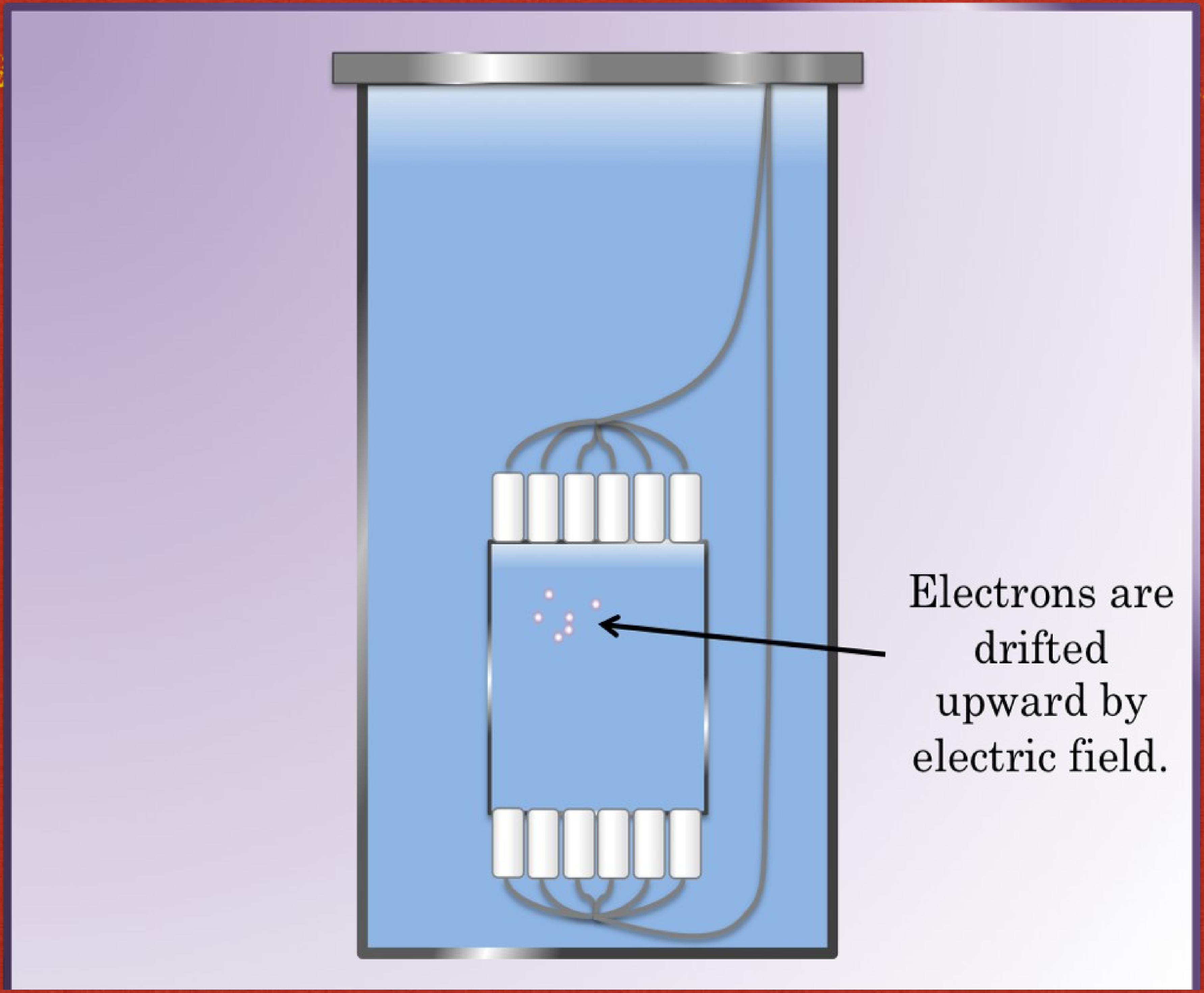

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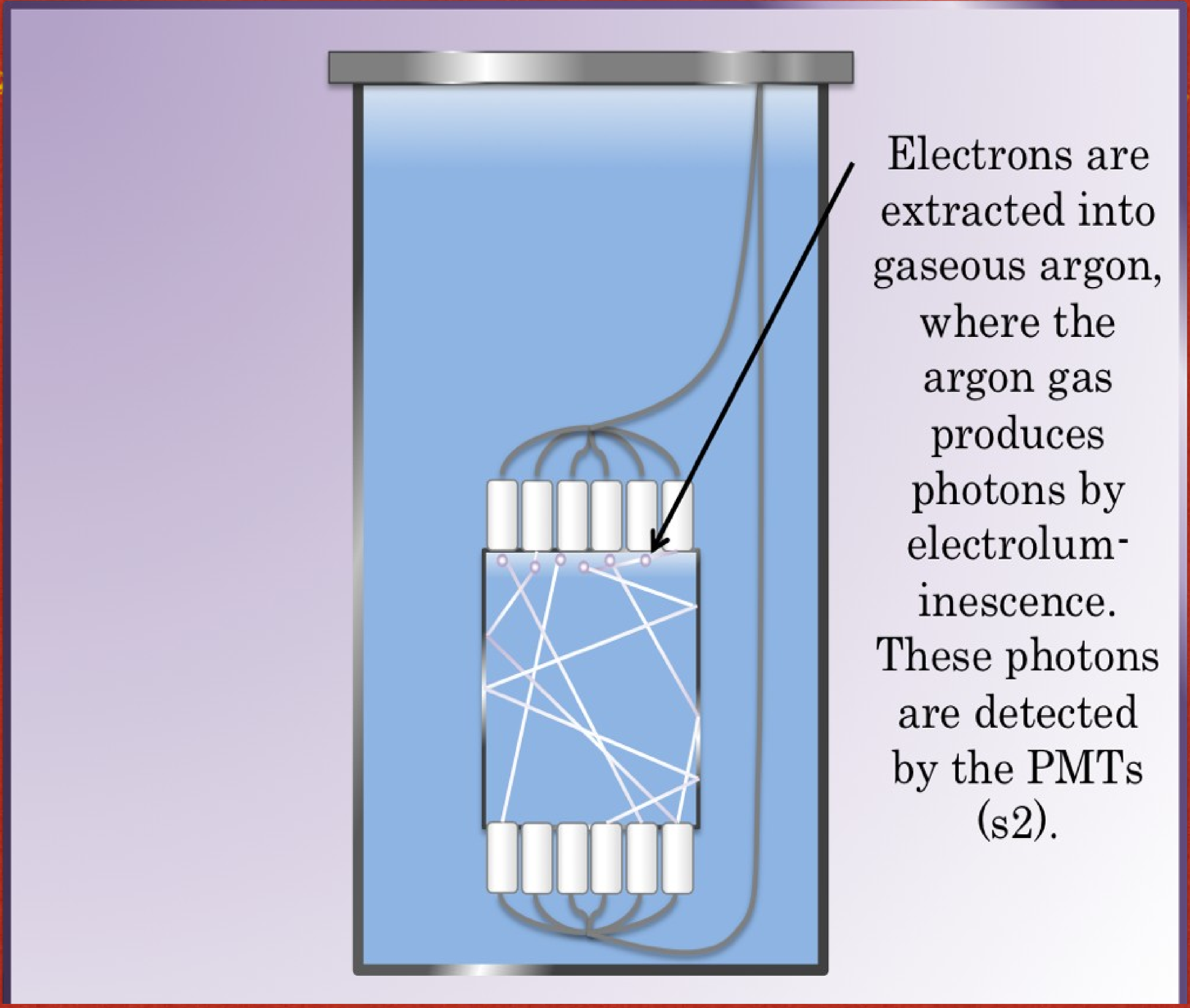

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Key features

LOW BACKGROUND: key requirement of all direct-detection experiments

Depleted Ar: underground gas sources are less exposed to cosmic rays, and hence have low content of ^{39}Ar (cosmogenically created in the atmosphere).

Active neutron veto: boron-loaded liquid scintillator surrounds the active detector, enabling the detection and veto of neutrons passing through the TPC.

QUPIDs: QUartz Photon-Intensifying Detectors. New photodetectors with low radioactive background and high quantum efficiency.

Depleted Ar

Distillation column running at FNAL. Will separate argon from underground gas.

Current status

- DarkSide-10 completed two technical runs in Princeton
- DarkSide-50 currently being designed, will begin construction in June
- Distillation column is extracting argon with low 39Ar content at FNAL
- QuPIDs being developed by Hamamatsu and UCLA

Backgrounds in DS-50

- Cosmogenic backgrounds reduced by water tank
- Radiogenic neutron-induced backgrounds reduced by active veto
- β/γ-induced background reduced by depleted Ar and discrimination techniques

Active Neutron Veto

- B-loaded scintillator tank outside cryostat
- High capture cross-section of ^{10}B reduces capture time, allowing little external shielding and use of conventional PMTs for veto
- Veto efficiencies found from simulations:
  - γ’s: 50%
  - Radiogenic neutrons: 99.5%
  - Cosmogenic neutrons: 95%
    - (only for neutrons produced outside the liquid scintillator volume)

Cosmogenic neutrons

Cosmogenic μ’s traverse the lab rock and impinge on the detector

Neutrons produced by (μ,n) reactions on lab rock and detector components

Simulate neutrons, not entire μ showers. Conservative, because we ignore veto-able secondary showers

Soon, will simulate μ showers in Fluka, then carry particles through detector in Geant4

Electron recoil background

- γ-INDUCED:

γ's emitted by radioactive nuclei produce electron recoils

- ^{39}Ar-INDUCED:

^{39}Ar in liquid Ar undergoes β decays (Q=565keV)

Natural Ar: ~200 cts/(kg keV_{ee} d)

Backgrounds in DS-50

Detector Element	Electron Recoil Backgrounds		Radiogenic Neutron Recoil Backgrounds		Cosmogenic Neutron Recoil Backgrounds	
	Raw	After Cuts	Raw	After Cuts	Raw	After Cuts
^{39}Ar	$<1.7\times10^{7}$	<0.0050	–	–	–	–
Fused Silica	1.8×10^{5}	5.5×10^{-5}	1.5	3.8×10^{-3}	1.9	1.5×10^{-4}
PTFE	150	4.6×10^{-8}	0.020	5.0×10^{-5}	0.14	1.1×10^{-5}
Copper	1100	3.2×10^{-7}	0.0020	5.0×10^{-6}	0.60	4.8×10^{-5}
QUPIDs	3.5×10^{4}	1.1×10^{-5}	0.26	6.5×10^{-4}	0.28	2.2×10^{-5}
R11065 PMTs	1.2×10^{6}	3.6×10^{-4}	16.2	4.1×10^{-2}	0.28	2.2×10^{-5}
Titanium	1.2×10^{5}	3.6×10^{-5}	0.92	2.3×10^{-3}	11	8.8×10^{-4}
Veto Scintillator	35	1.1×10^{-8}	0.025	6.3×10^{-5}	22	0.0013
Veto PMTs	1.2×10^{6}	3.7×10^{-4}	0.019	4.8×10^{-5}	–	–
Veto tank	8.5×10^{4}	2.6×10^{-5}	5.6×10^{-5}	1.4×10^{-7}	16	0.0060
Water	3100	9.2×10^{-7}	5.6×10^{-4}	1.4×10^{-6}	16	0.0060
CTF tank	4200	1.2×10^{-6}	2.9×10^{-3}	7.3×10^{-6}	0.057	2.1×10^{-3}
LNGS Rock	460	1.4×10^{-7}	0.051	1.3×10^{-4}	0.26	0.0098
Total	–	0.0055 [0.0059]	–	0.0070 [0.047]	–	0.026 [0.026]

Unit: cts/(0.1 ton y); window: 10-100 keV$_r$; depletion factor: >25; square brackets: PMTs

Summary

Distillation column will begin purification of large quantities of depleted argon

DarkSide-50 inner detector: end of 2011

DarkSide-50 + neutron veto in operation at LNGS: mid-2012

Ton-scale detector DS-1k: ~2014

Collaborators

Princeton University

FermiLab (FNAL)

Temple University

Augustana College

Black Hills State University

UCLA

UMass – Amherst

University of Arkansas

University of Houston

University of Notre Dame

Universita degli Studi Napoli

Universita degli Studi Milano

Universita degli Studi Genova

Universita degli Studi Perugia

INFN-Gran Sasso

IHEP Beijing

JINR Dubna

RRC Kurchatov Institute Moscow

St. Petersburg Nuclear Physics Institute

More information

- 2009 & 2010 DarkSide proposals.
- Article on NIM: A. Wright/P. Mosteiro/B. Loer/F. Calaprice, “A Highly Efficient Neutron Veto for Dark Matter Experiments”. arXiv:1010.3609.
- Soon our website...