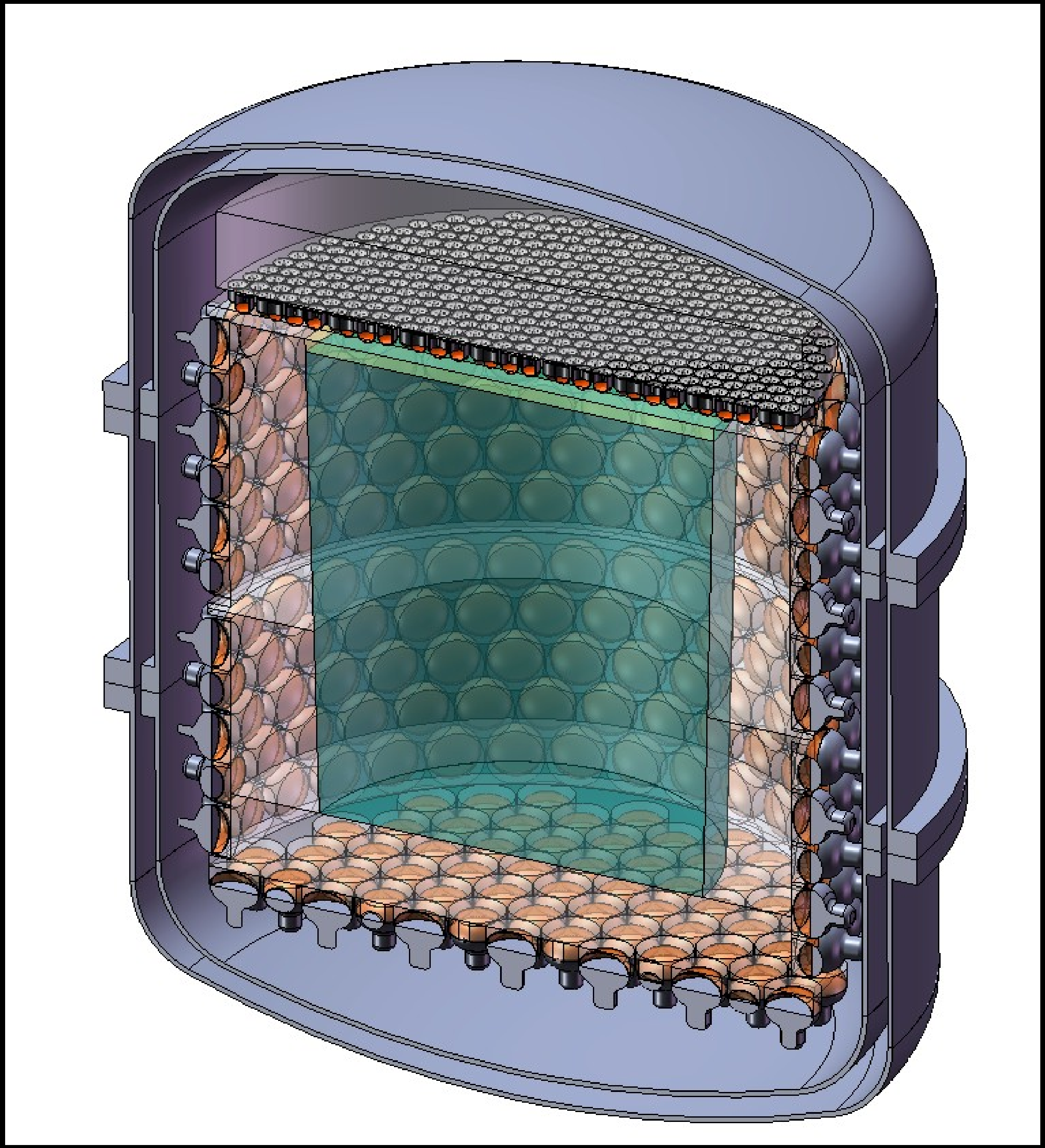
MAX
-
Multi-ton Argon and Xenon

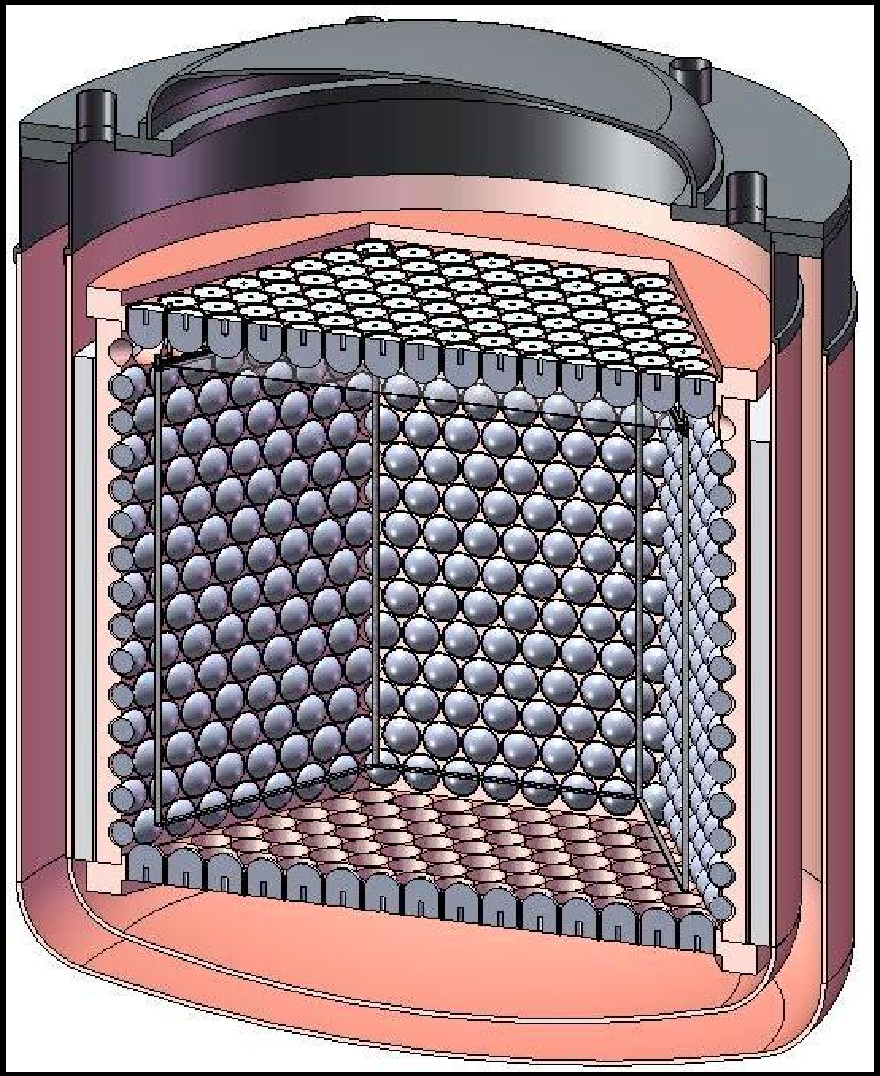
SCREENING REQUIREMENTS

FAARM Collaboration Meeting

Lead, SD



5 ton DAr TPC



2.5 ton Xe TPC

MAX - Multi-ton Argon & Xenon

UMass Amherst
Arizona State University
Augustana College
Black Hills State University
Coimbra University
Columbia University
Fermilab
University of Houston
INAF
LNGS

MIT
University of Münster
University of Notre Dame
Princeton University
Rice University
Temple University
UCLA
University of Virginia
Waseda University
University of Zürich

The Physics of MAX

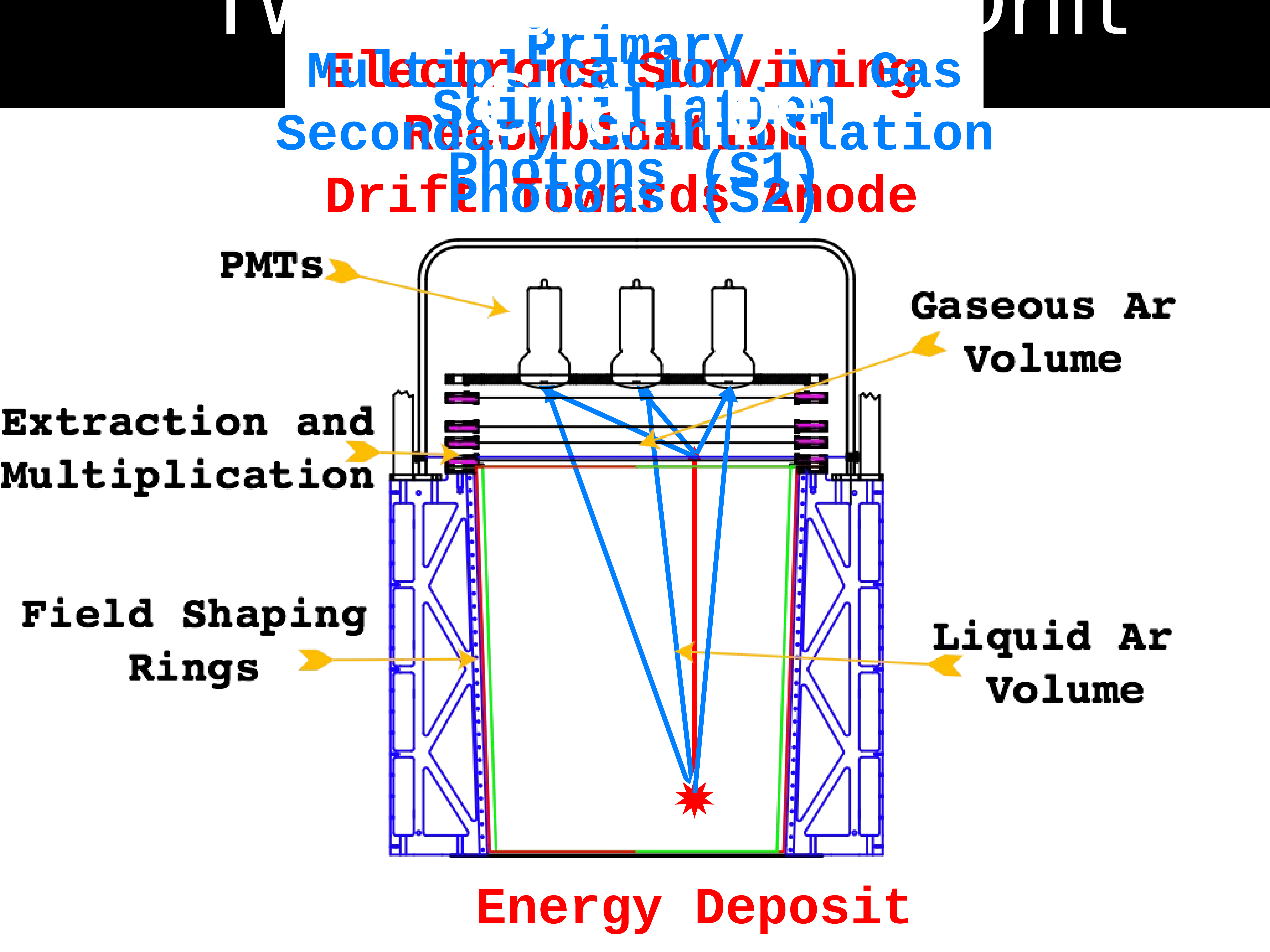
- Discovery potential
- Confirmation in twin target
- Confirmation of A^2 dependence of cross section
- Measurement of the mass of the WIMP by comparison of recoil spectra in different targets
- Indication on spin-dependent or spin-independent nature of interactions

Noble Liquid Detectors

- Excellent scintillation and Ionization detectors.
  - 40 photons/keV (Ar), 46 photons/keV (Xe)
- Con: photons are in UV:
  - 128 nm (Ar), 175 nm (Xe)
- Excellent ionization detectors.
  - 40 electrons/keV (Ar), 64 electrons/keV (Xe)
- Electrons not self captured: long drift distance!
- Photons and electrons not self-absorbed.
- Large multi-ton detectors possible and “cheap”
- Background discrimination possible

Noble Liquid Detectors

- Single-Phase: Scintillation
  - XMASS - Xe (Japan, Kamioka)
  - DEAP/CLEAN - Ar/Ne (US/Canada, SNOLab)
- Two-Phase Liquid and Gas: Scintillation AND Ionization
  - XENON- Xe (US/Switzerland/Germany/France/Portugal/Italy/Japan/China, LNGS)
  - WARP - Ar (Italy/US, LNGS)
  - ZEPLIN - Xe (UK/US, Boulby)
  - LUX -Xe (US, Sanford Lab)
  - ARDM - Ar (Switzerland/Spain/UK, Canfranc)


Primary
Scintillation
Photons (S1)
Multiplication in Gas
Secondary Scintillation
Photons (S2)
Electrons Surviving
Recombination
Drift Towards Anode
PMTs
Gaseous Ar
Volume
Extraction and
Multiplication
Field Shaping
Rings
Liquid Ar
Volume
Energy Deposit

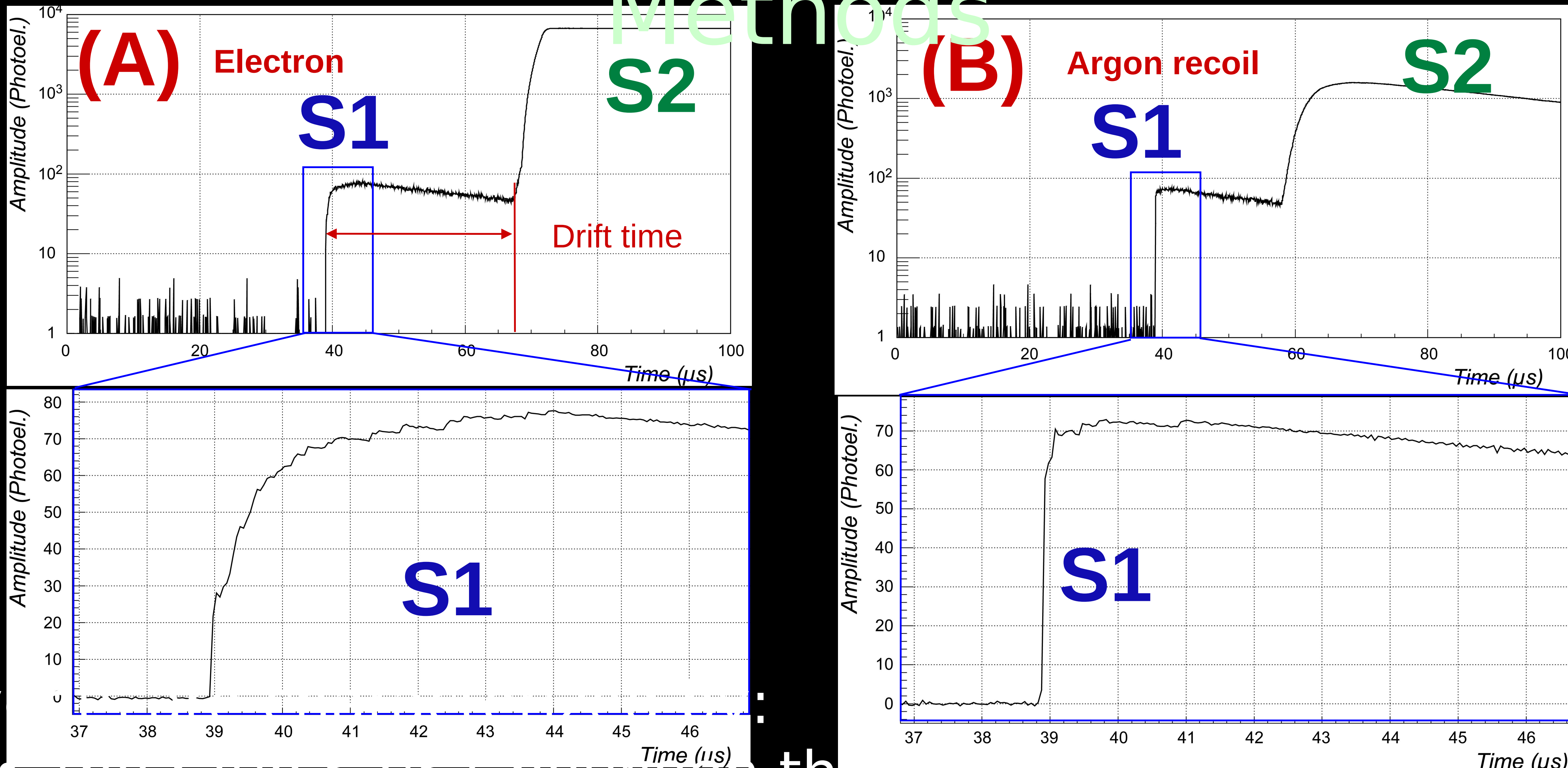
Discrimination in Xenon

- Fiducialization reduces the background from construction and external materials in the fiducial region
- Difference in ratio of the prompt scintillation (S1) to the drift time-delayed ionization (S2) is strongly dependent upon recombination of ionizing tracks, which in turn depends on ionization density
  - Rejection ~ 10^2-10^3
- Precise determination of events location in 3D
  - 1-5 mm x-y, 1 mm z
  - Additional rejection for multiple neutron recoils and γ background

Discrimination in Argon

- Pulse shape discrimination of primary scintillation (S1) based on the very large difference in decay times between singlet (≈ 7 ns) and triplet (1.6 μs) components of the emitted UV light
  - Minimum ionizing: triplet/singlet ~ 3/1
  - Nuclear recoils: triplet/singlet ~ 1/3
  - Theoretical Identification Power exceeds 10^8 for > 60 photoelectrons (Boulay & Hime 2004)
- Difference in ratio of the prompt scintillation (S1) to the drift time-delayed ionization (S2)
- Precise determination of events location in 3D
  - 5 mm x-y, 1 mm z
  - This provides additional rejection for multiple neutron recoils and gamma background

First Two Discrimination Methods



Ev :

- the ratio S2/S1 between the primary (S1) and secondary (S2)
- the rising time of the S1 signal

Minimum ionizing particles: high S2/S1 ratio (~100) and by slow S1 signal

Ar recoils: low (≤10) S2/S1 ratio and fast S1 signal

Discovery of underground reservoir of argon with low level of ^{39}Ar

Discovery of underground argon with low level of radioactive ^{39}Ar and possible applications to WIMP dark matter detectors

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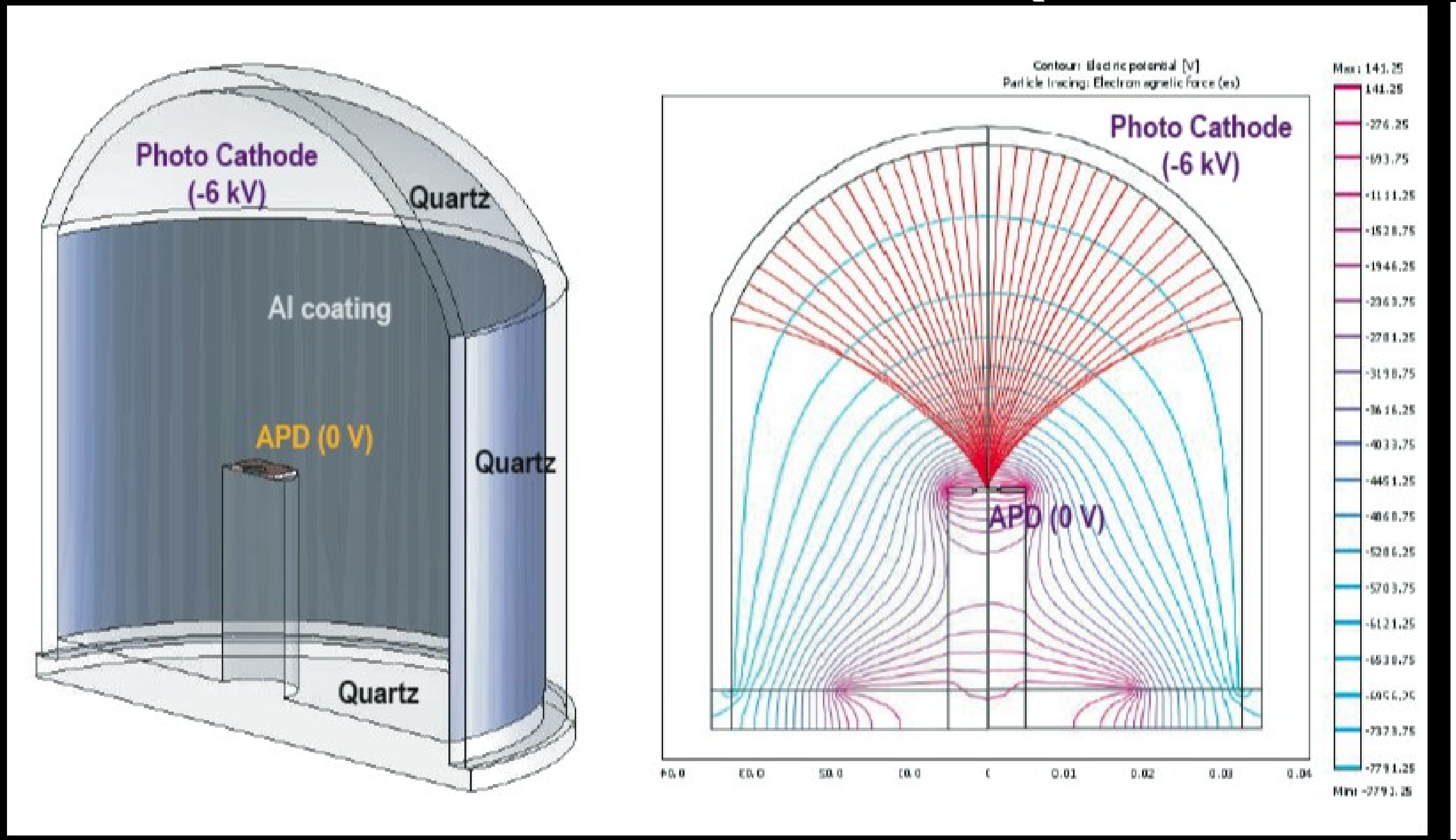
Why is underground argon desirable?

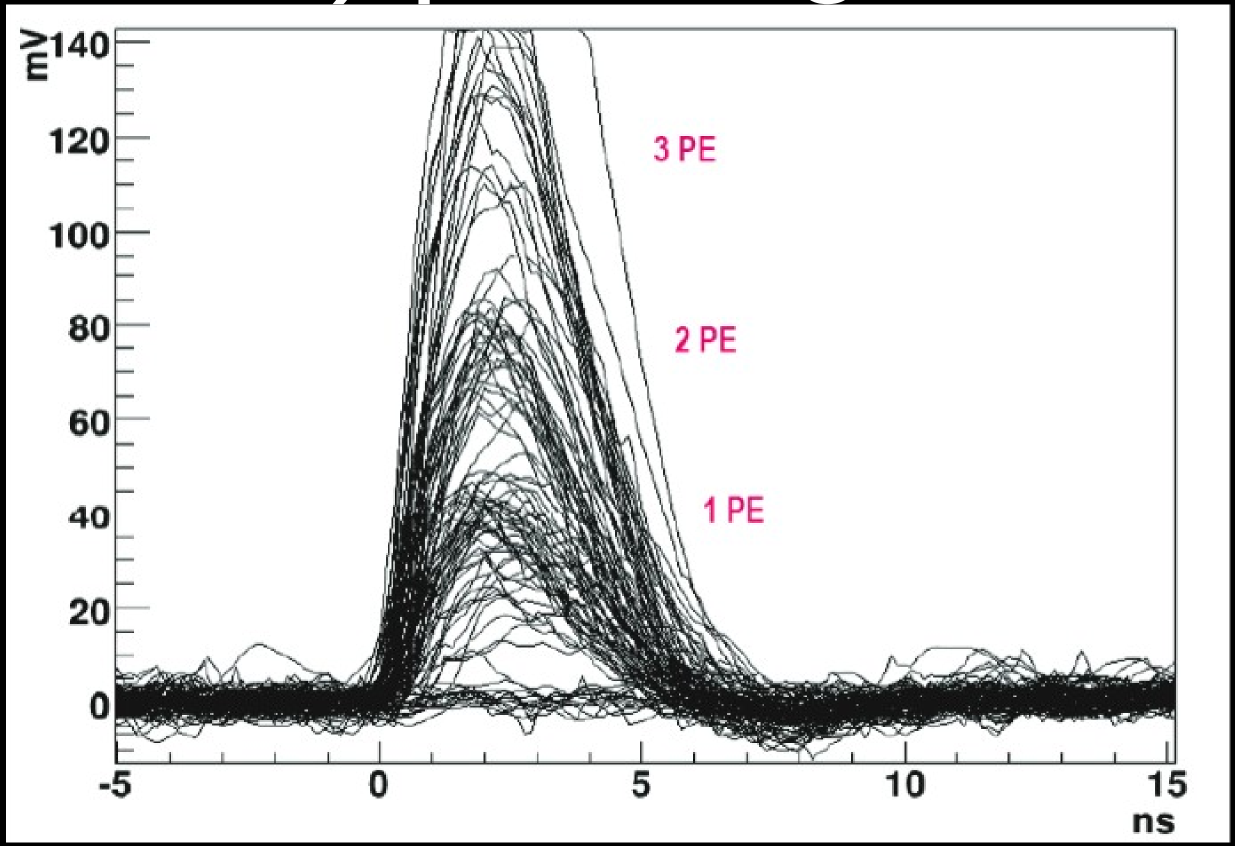
- Radioactive ^{39}Ar produced by cosmic rays in atmosphere
  - beta decays, Q = 565 keV, $t_{1/2}$ = 269 years
- In atmospheric argon:
  - $^{39}Ar/Ar$ ratio 8×10^{-16}
  - specific activity 1 Bq/kg
- Limits size (and sensitivity) of argon detectors to 500-1000 kg due to ^{39}Ar events pile-up

QUPID:

QUartz Photon Intensifying Detector

US Patent (No. 5374826) pending





Extremely low radioactivity: < 1 mBq

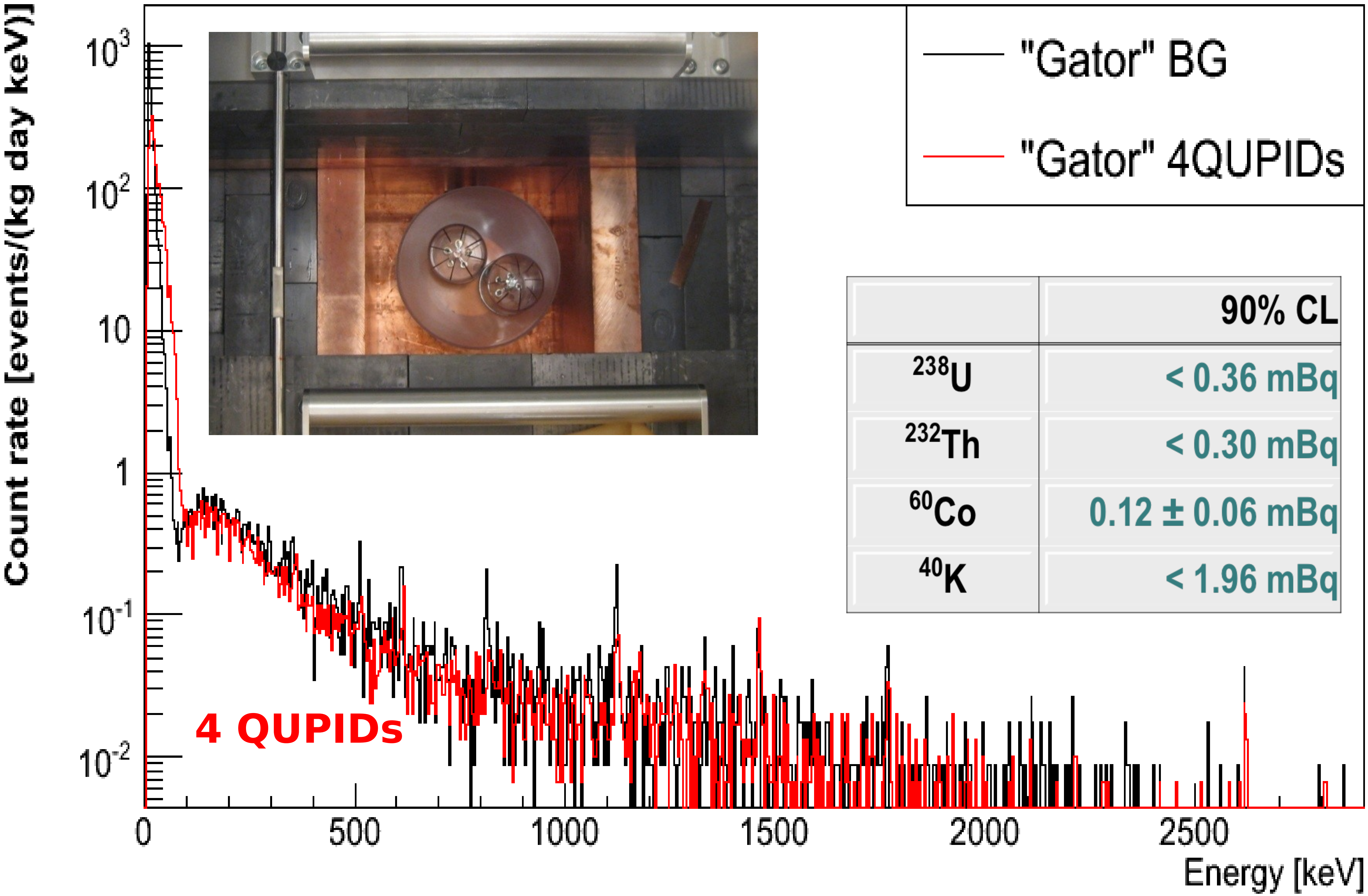
< 0.1 neutron / year

<< 10 times lower than conventional low radioactive PMTs.

New 3” QUPID (Production Version)

Slide courtesy of Hanguo Wang, UCLA

Spectrum of QUPIDs and Background (4 QUPIDs x 1 month data)

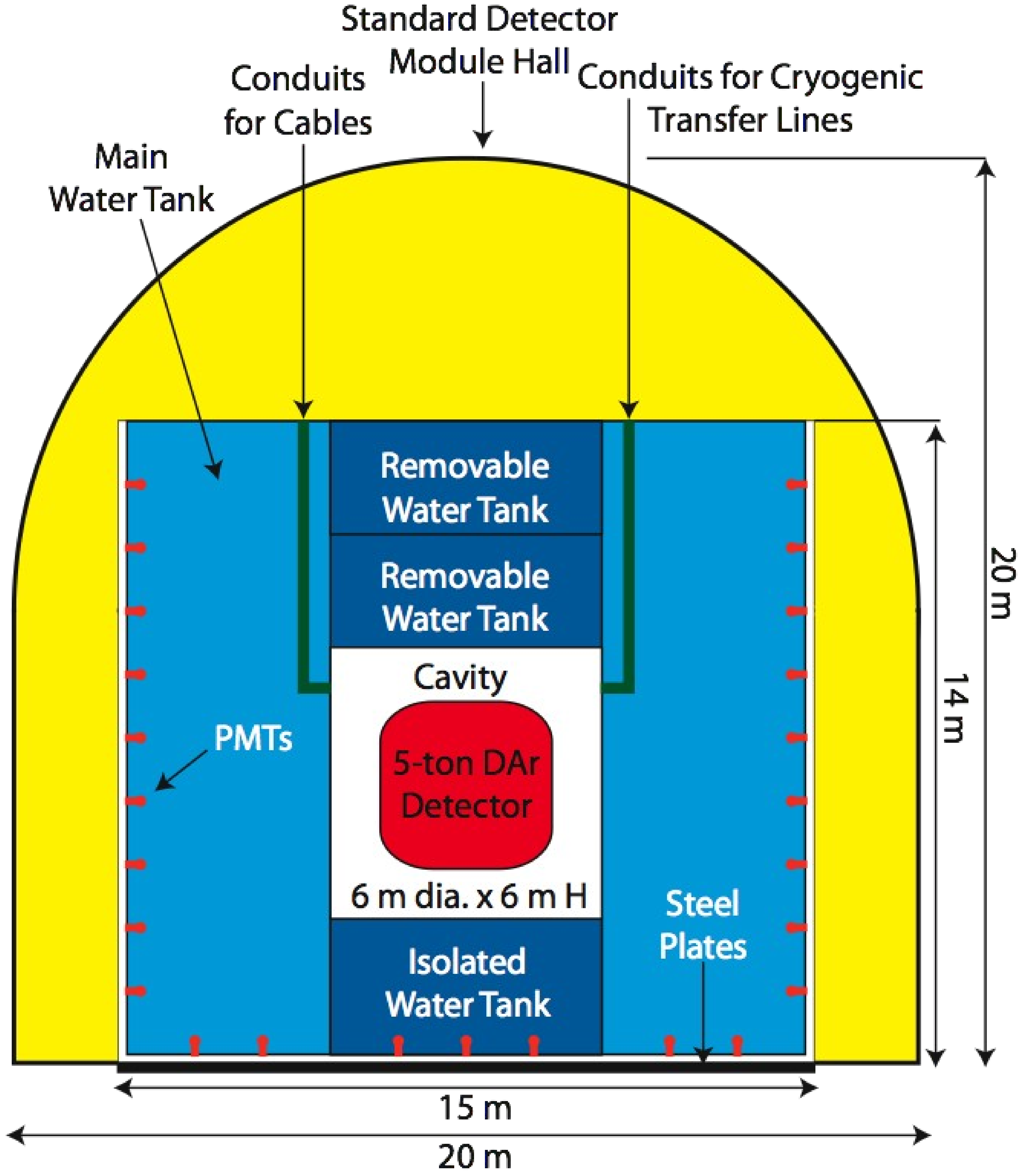


	90% CL
^{238}U	< 0.36 mBq
^{232}Th	< 0.30 mBq
^{60}Co	0.12 ± 0.06 mBq
^{40}K	< 1.96 mBq

Slide courtesy of Hanguo Wang, UCLA

Summary of QUPID

- **Extremely low radioactivity: < 1 mBq**
  - **< 0.1 neutron / year**
  - **<< 10 times lower than conventional low radioactive PMTs.**
- **Large diameter: 3 inch**
  - **6 inch is also under investigation.**
- **Special Photocathode: Bialkali LT**
  - **> 30 % QE at 170 – 450 nm**
  - **Low resistivity even at Liquid Ar temperature (- 185 ^{o}C)**
- **True photon counting.**
  - **1, 2, 3… photoelectron peaks clearly visible.**
  - **100% collection efficiency.**
- **Simple HV supply (?).**
  - **Common HV (-6 kV) for all QUPIDs**
  - **Resister chain not necessary**
- **The first successful operation in Liquid Xenon at UCLA!**



Standard Detector
Module Hall
Conduits
for Cables
Conduits for Cryogenic
Transfer Lines
Main
Water Tank
Removable
Water Tank
Removable
Water Tank
Cavity
PMTs
5-ton DAr
Detector
6 m dia. x 6 m H
Steel
Plates
Isolated
Water Tank
20 m
14 m
15 m
20 m

Screening in Ge Detectors

- We anticipate the need of use, starting in 2015 and going through 2020, of one Ge detector, with sensitivity of ~10 μBq/kg, for screening and qualification of materials. We expect that MAX will keep busy one of such a detector almost continuously.

- We strongly recommend the early development and procurement of a set of high sensitivity Germanium counters at DUSEL as part of the FAARM program.

Radon Counting

- We anticipate the need of a dedicated underground Rn counter, able to measure Rn concentration in the air of the assembly clean room with a sensitivity of 1 mBq/m^3. We anticipate that the duty cycle for the use of such Rn counter will be almost continuous, starting in 2017 and going through the entire duration of the experiment.
- We anticipate the need of a high-sensitivity Rn counter capable of performing dedicated measurements of Rn in pure gases (Ar, N_2, and Xe) with a sensitivity of 1 μBq/m^3.
- We anticipate the need of performing Rn emanation measurements with a sensitivity of 1-10 decays/day or better. We recommend development of low-background chambers for Rn emanation studies of adequate size (1 m × 1 m × 0.5 m).

Screening of Non-Radioactive Impurities in Noble Gases

- We anticipate the need of screening impurities (H_20, O_2, N_2, etc) in noble gases at the sub-ppb level. A dedicated CRDS system is being developed in the BHSU campus by MAX collaborators and should be available starting 2015.
- We anticipate the need of measuring Kr contamination in noble (Ar and Xe) and non-noble (N_2) gases with sensitivities of 0.1 ppt or better. We also anticipate the need of measuring Ar contamination in Xe and N_2 gases with sensitivities of 0.1 ppb or better.

Screening of Radioactive Impurities in Noble Gases

- We anticipate the need of screening of radioactive contaminants in noble (Ar and Xe) and non-noble gases (N_2) at the level of sub-μBq/m^3.

Alpha Screening

- We anticipate the need of measuring α contaminations of surfaces of up to 0.25 m^2 (0.5 m × 0.5 m) with a sensitivity of 10 events/(m^2·d).

Other Screening Facilities

- We anticipate the need of performing ICPMS analysis at DUSEL. At present, it is difficult to estimate the duty cycle for occupancy of the ICPMS station. We strongly recommend procurement of one ICPMS station.