DEAP/CLEAN

Single phase direct DM detection with LAr and LNe

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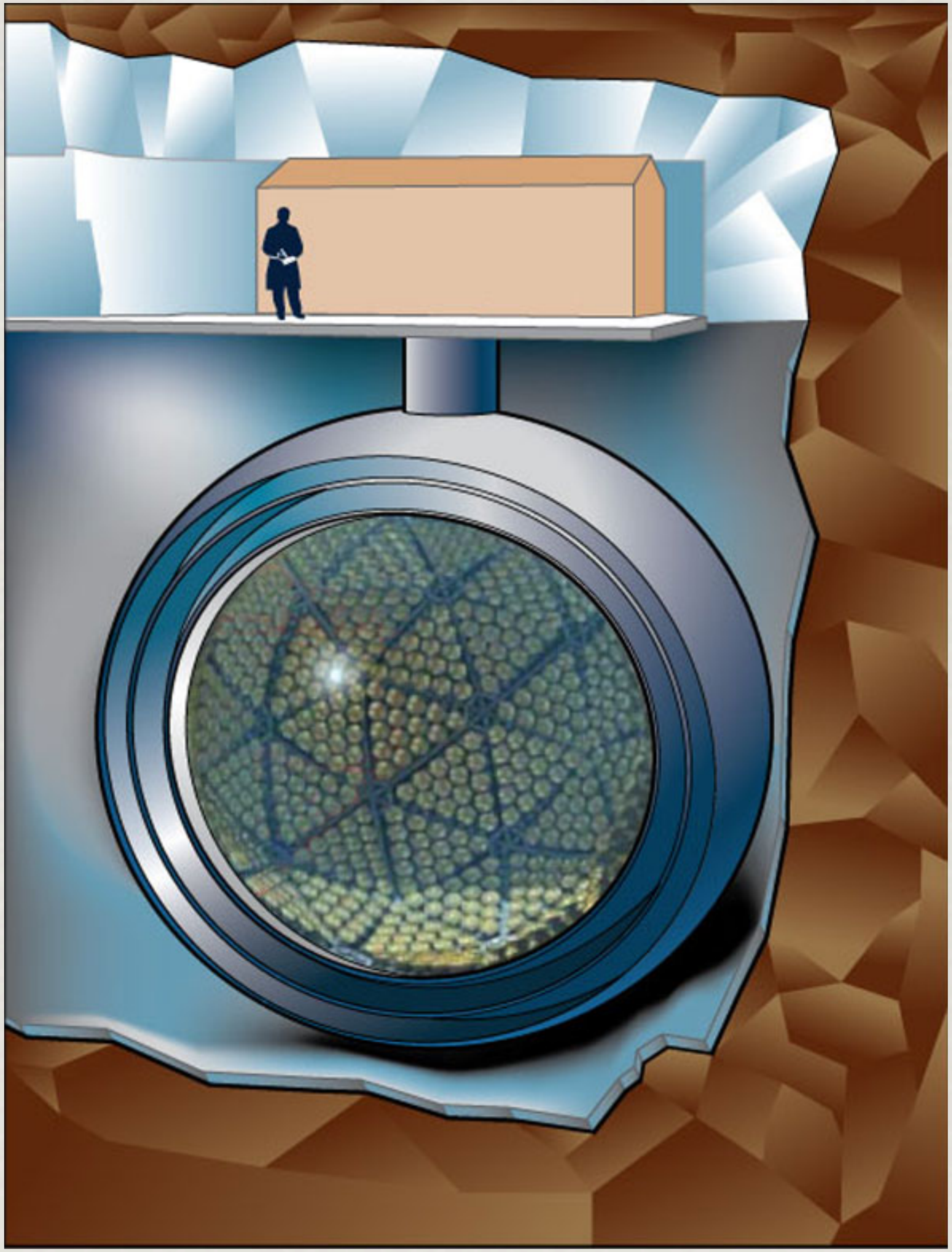
30 March, 2012

The DEAP/CLEAN collaboration has chosen to champion single phase noble liquid detectors for a variety of reasons.

- Simplicity
- Efficiency
- Scalability

We feel that the most sensible way to reach decatonne experiments is in single phase



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DEAP/CLEAN

Ne/Ar low energy neutrino & dark matter detector

40-120 tonne

DEAP-3600

Ar low background dark matter detector

3600 kg

MiniCLEAN

Ar/Ne low background dark matter detector

500 kg

DEAP-1

Ar PSD measurements

7 kg

DEAP/CLEAN detector family

microCLEAN

Low energy Ar/Ne scintillation measurement

4 kg

DEAP-0

initial R&D

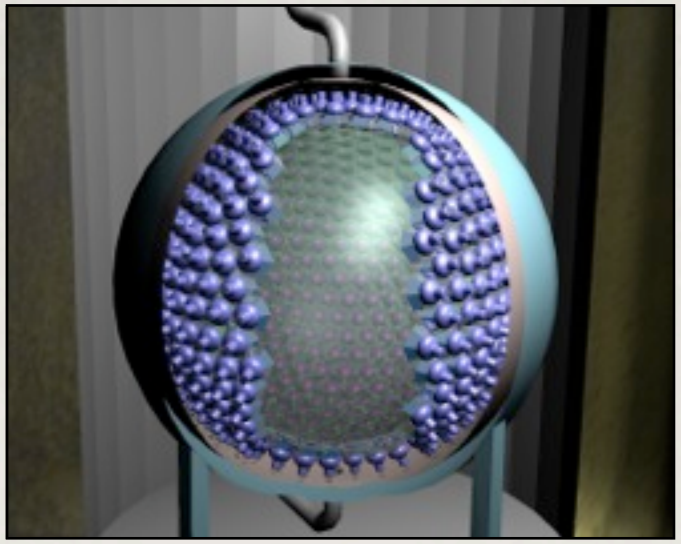
picoCLEAN

Ar/Ne scintillation measurement

nanoCLEAN

initial R&D

10 Year Program

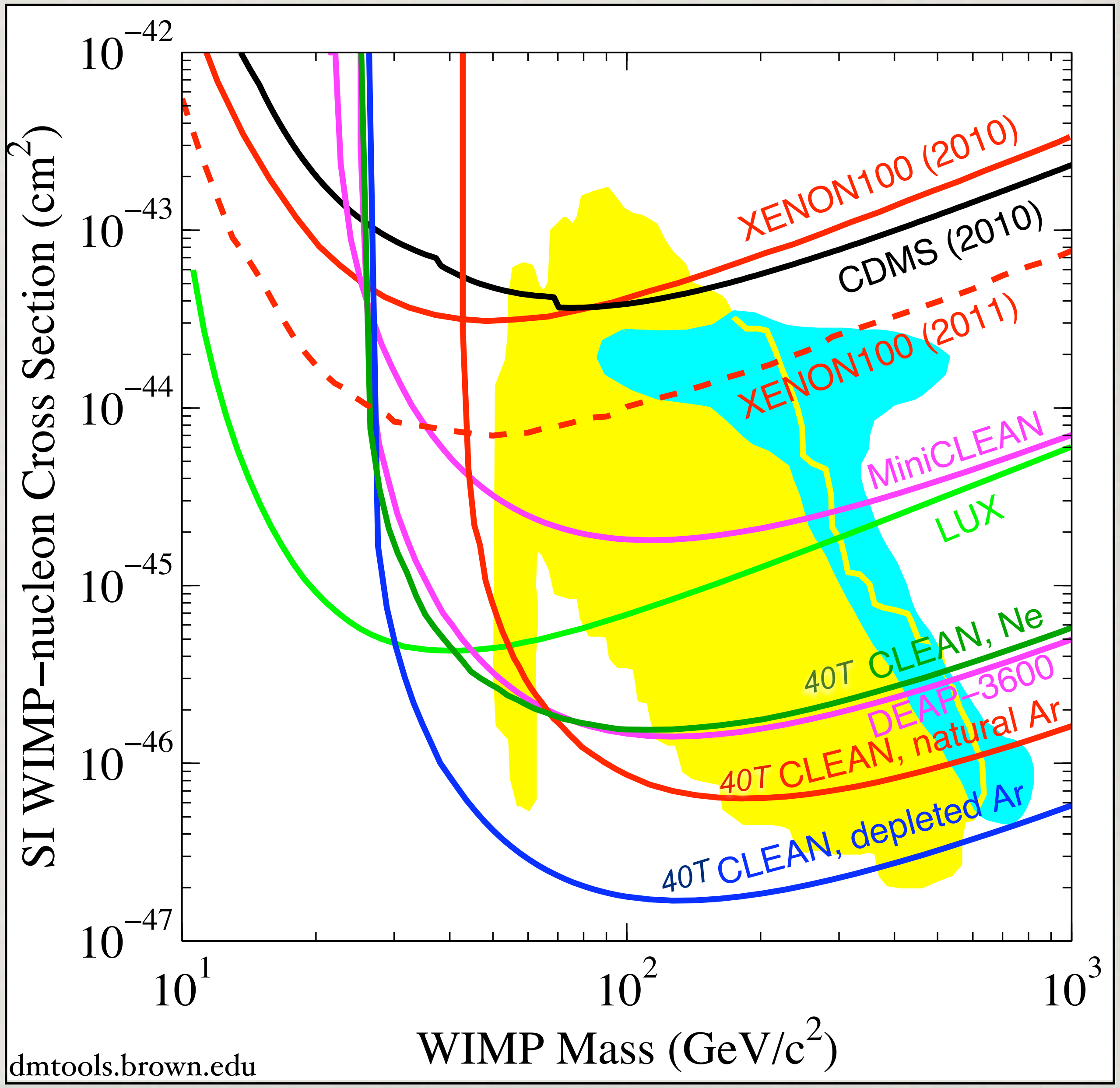


What are the DEAP/CLEAN Physics Goals?

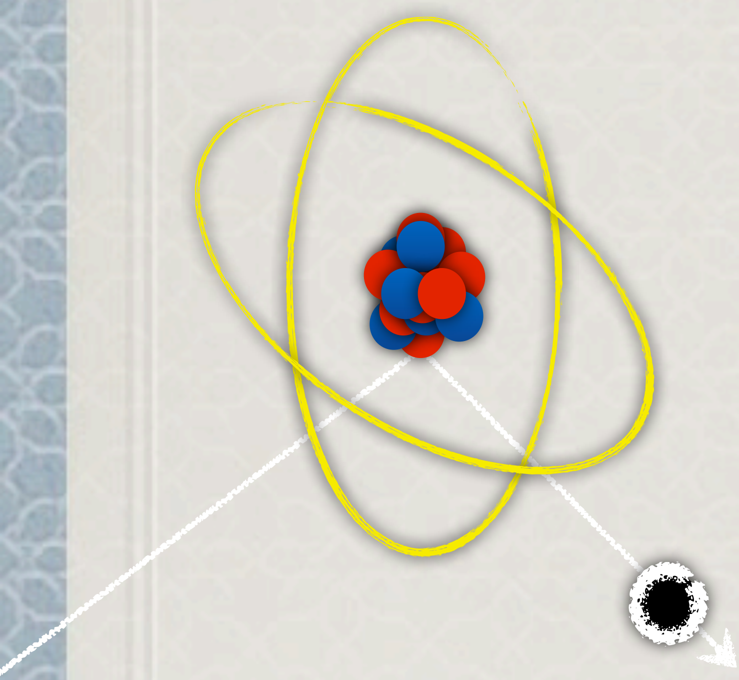
DEAP/CLEAN Goals

- Direct WIMP Dark Matter detection
- pp Solar Neutrinos
- Supernova Neutrinos
- Other low energy searches

- Single phase has a clear path to very large low energy threshold detectors
- With discovery at current scale, need much larger detectors for a measurement



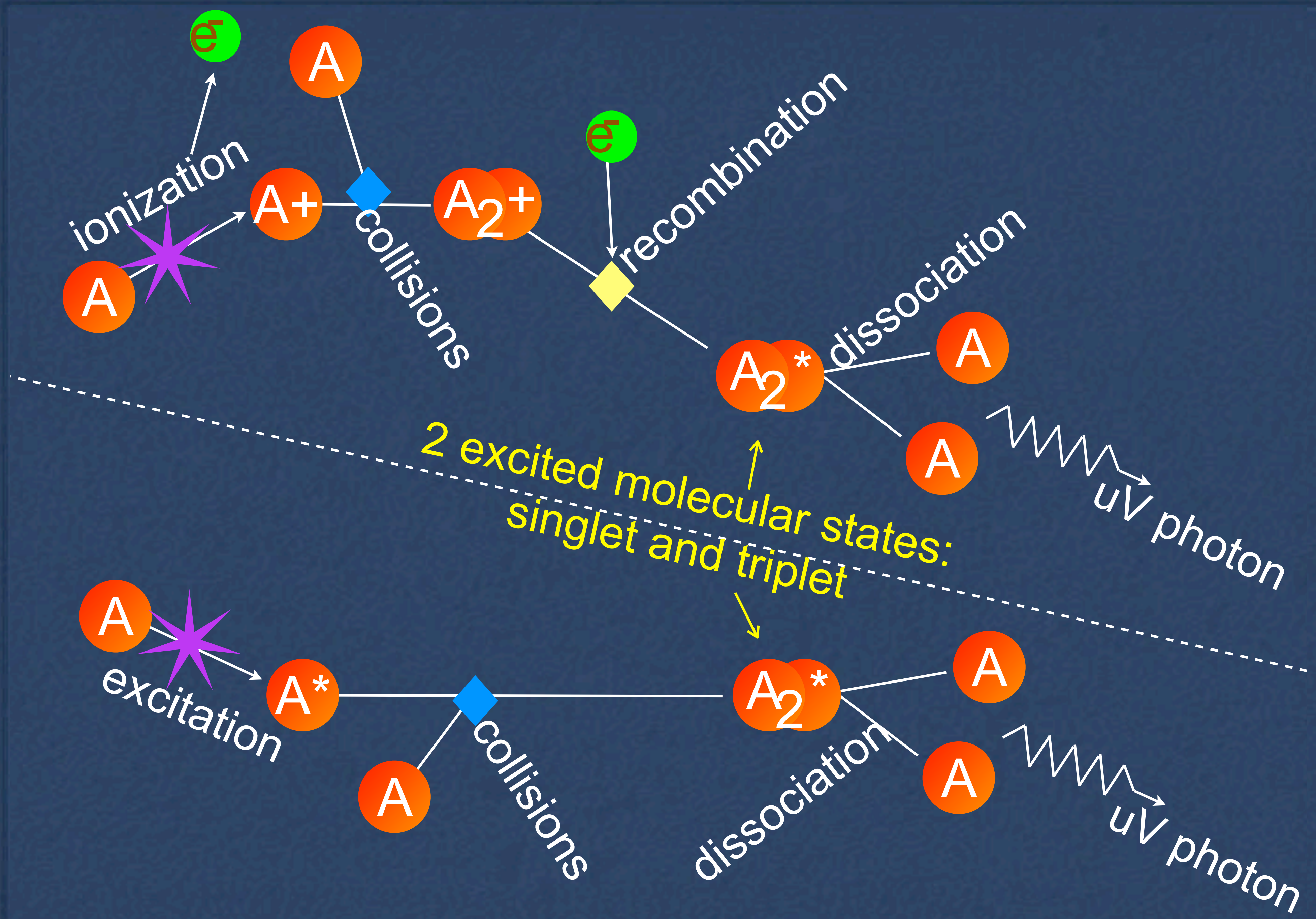
DEAP/CLEAN relies on:



- Material cleanliness to reduce introduction of backgrounds
- Pulse Shape Discrimination (PSD) to remove gamma backgrounds from detector materials, particularly ^{39}Ar (1 Bq/kg)
- Position reconstruction to eliminate surface events
- Target exchange to understand intrinsic backgrounds
- Water tank to shield from the environment
- Underground lab to shield from cosmics

How do single phase detectors work?

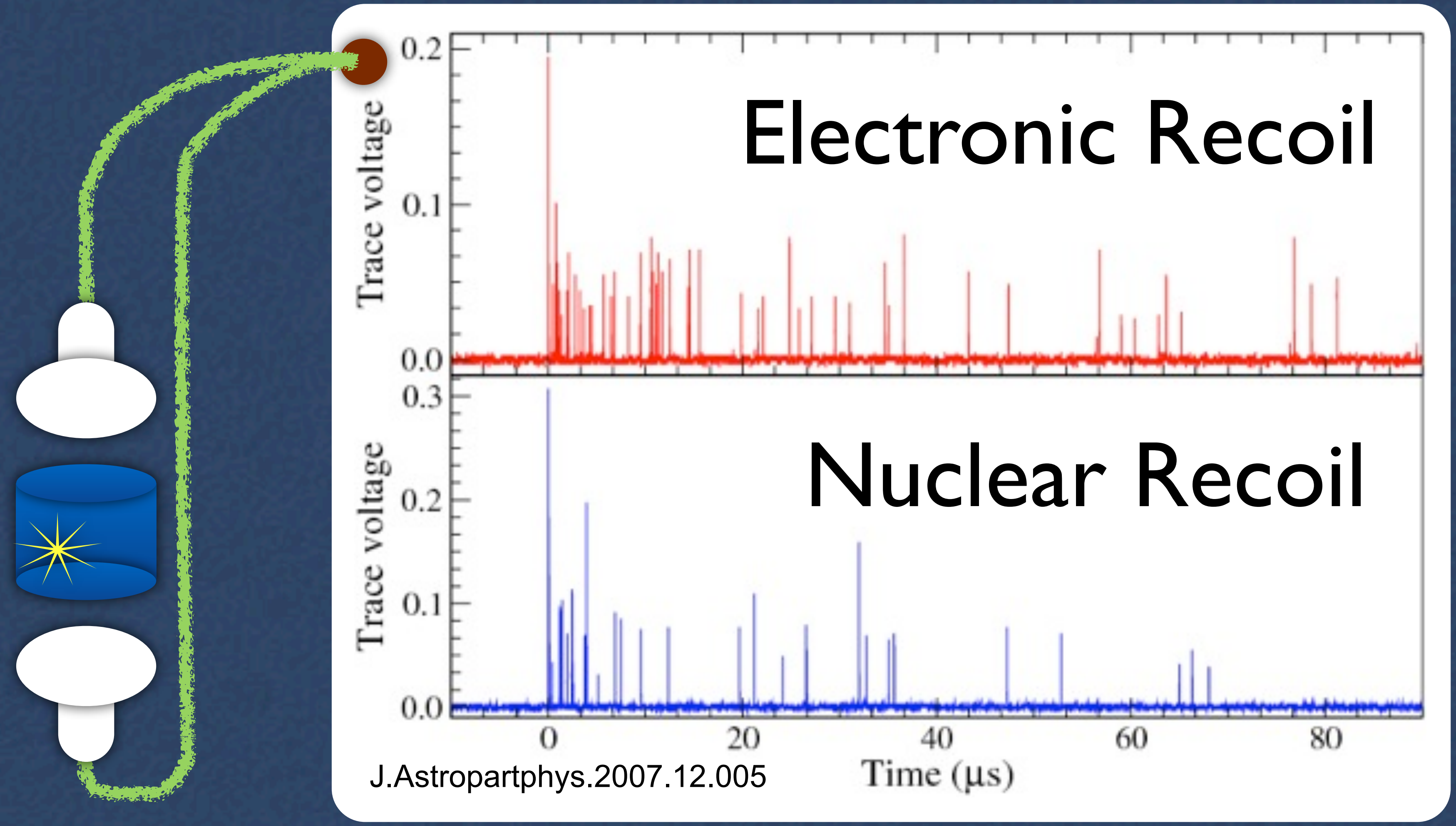
Signal production mechanisms



This mechanism explains how the detector target is transparent to the uV light produced

Particle Identification

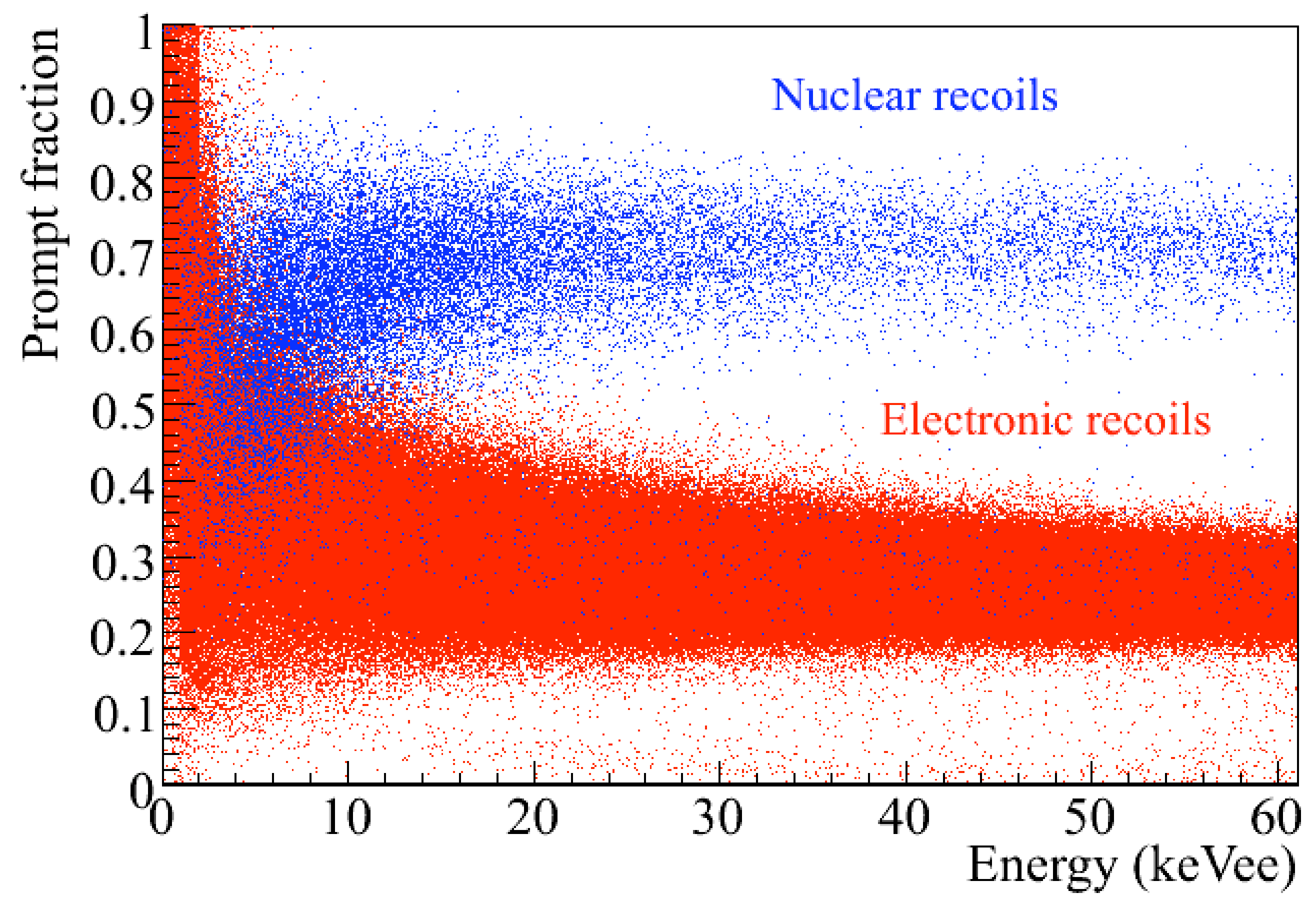
There is a clear qualitative difference between electronic and nuclear recoils



For a WIMP detector, signals are nuclear recoils Background events are mostly electronic recoils

Particle Identification

Quantitatively, we have shown that electronic recoils can be removed to better than 1 part in 10^7

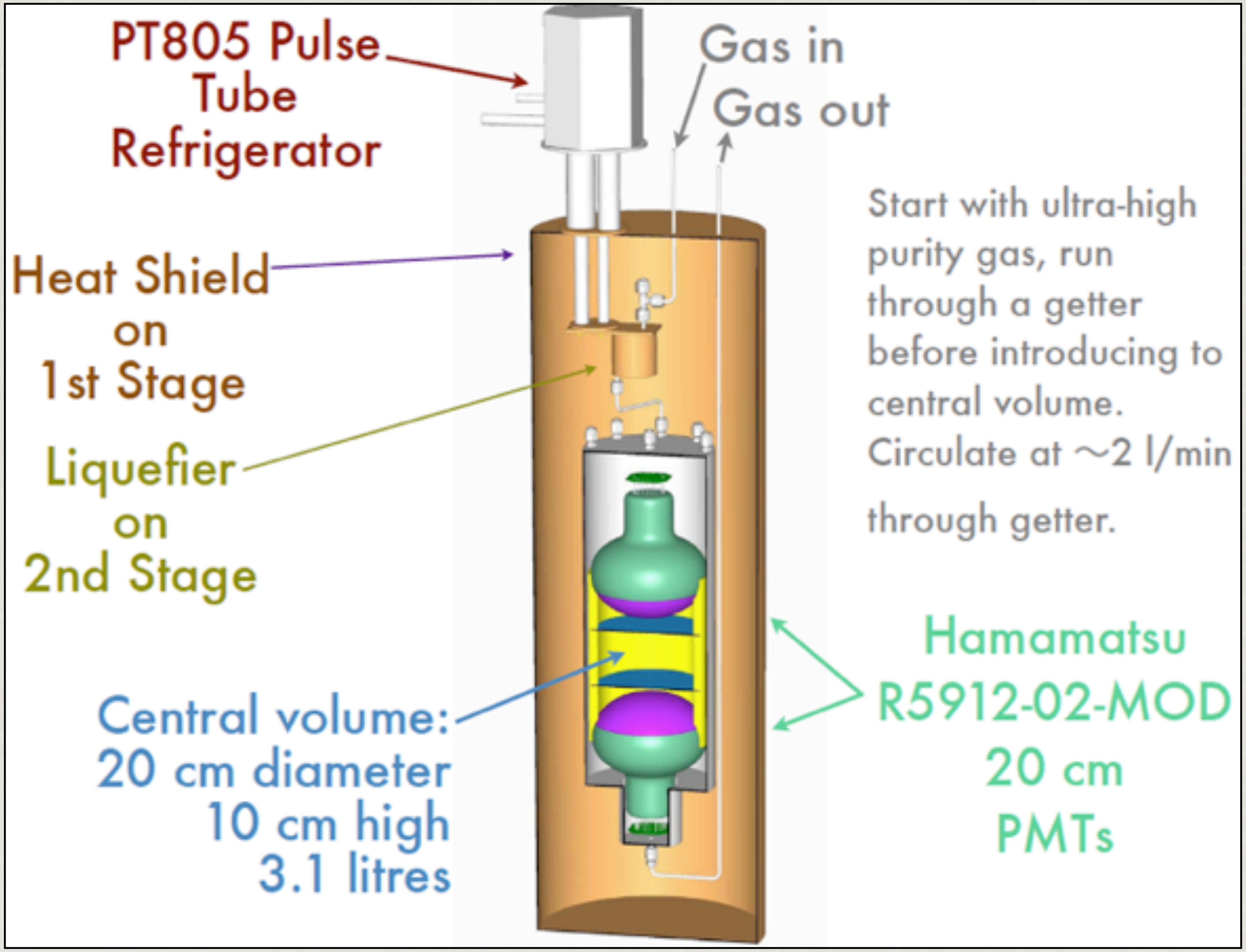


PhysRevC.78.035801

microCLEAN 4.4 kg LAr / 3.8 kg LNe *R&D*

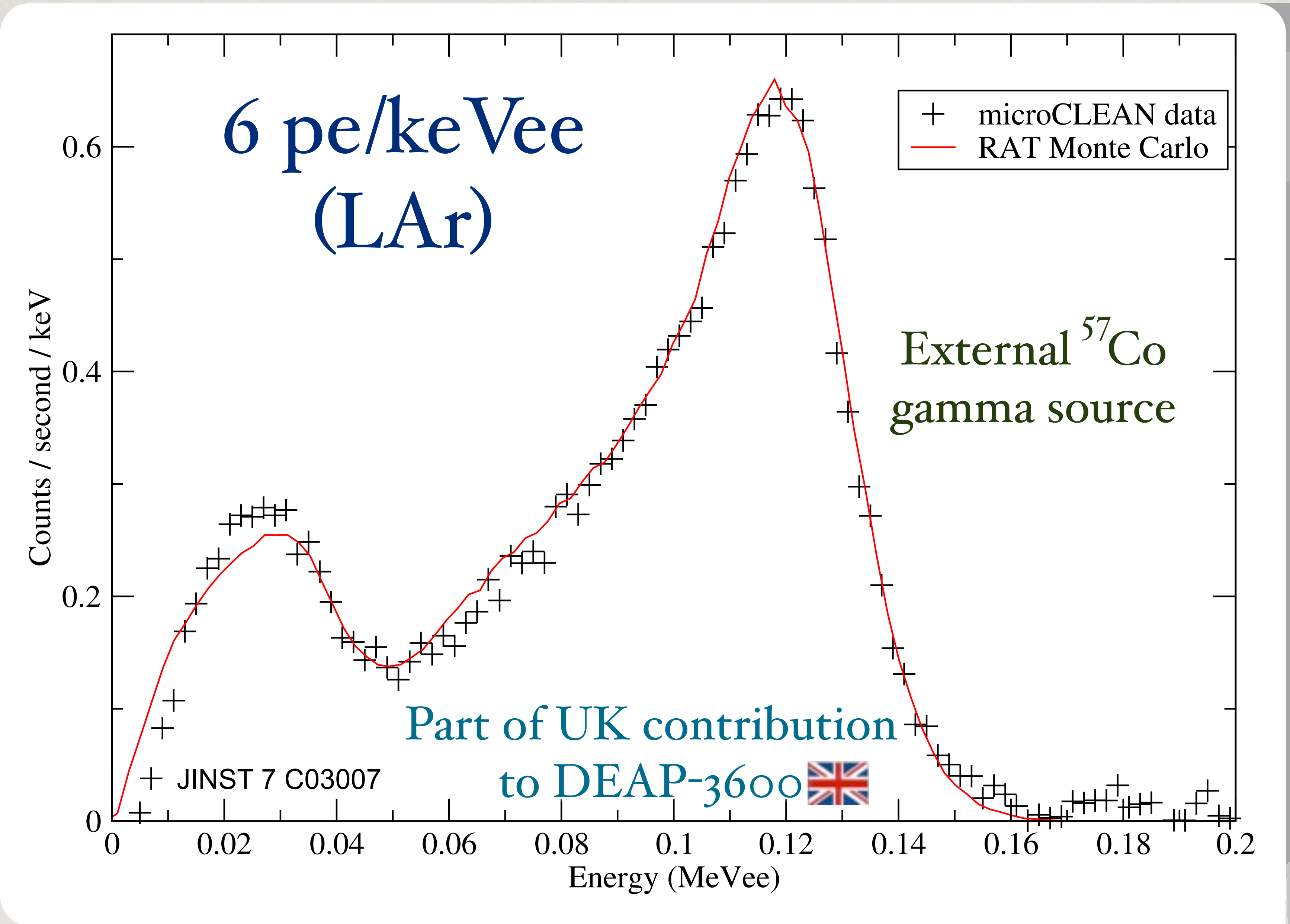
- Scintillation measurements
- Time constants
  - nuclear and electronic recoils
- L_{eff} (Quenching)
- Calibration testing
- Long term stability
- Refrigeration and Purification
- Currently operational

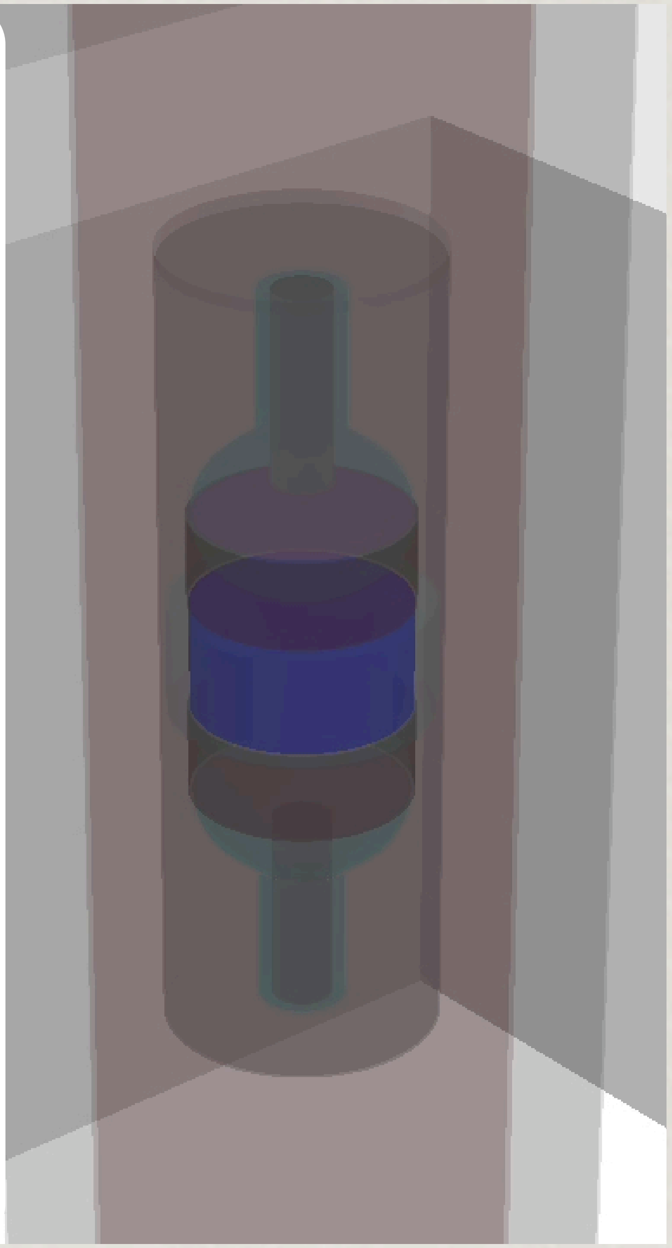
microCLEAN 4.4 kg LAr / 3.8 kg LNe *R&D*



Start with ultra-high purity gas, run through a getter before introducing to central volume. Circulate at ~2 l/min through getter.

microCLEAN 4.4 kg LAr / 3.8 kg LNe *R&D*



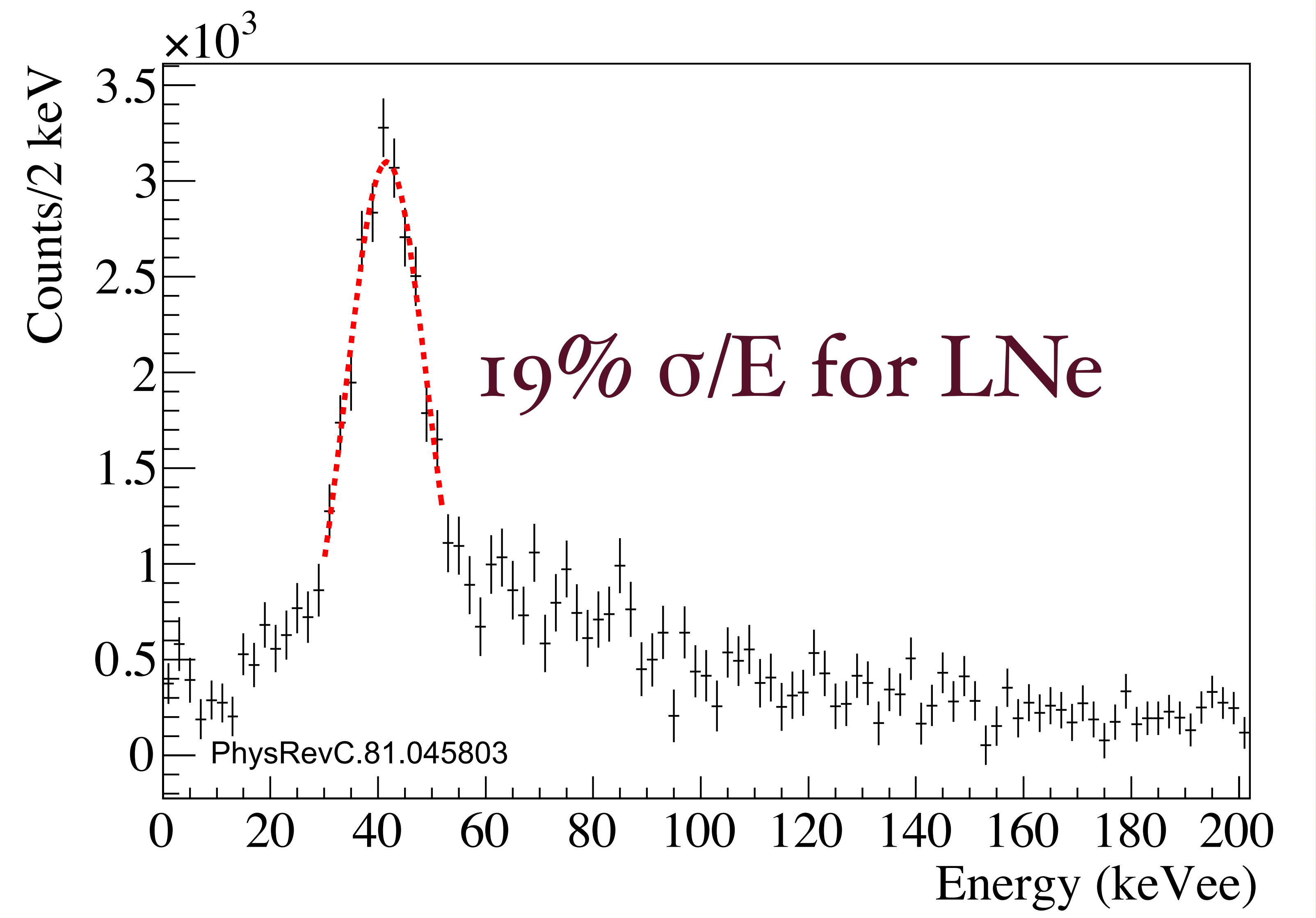


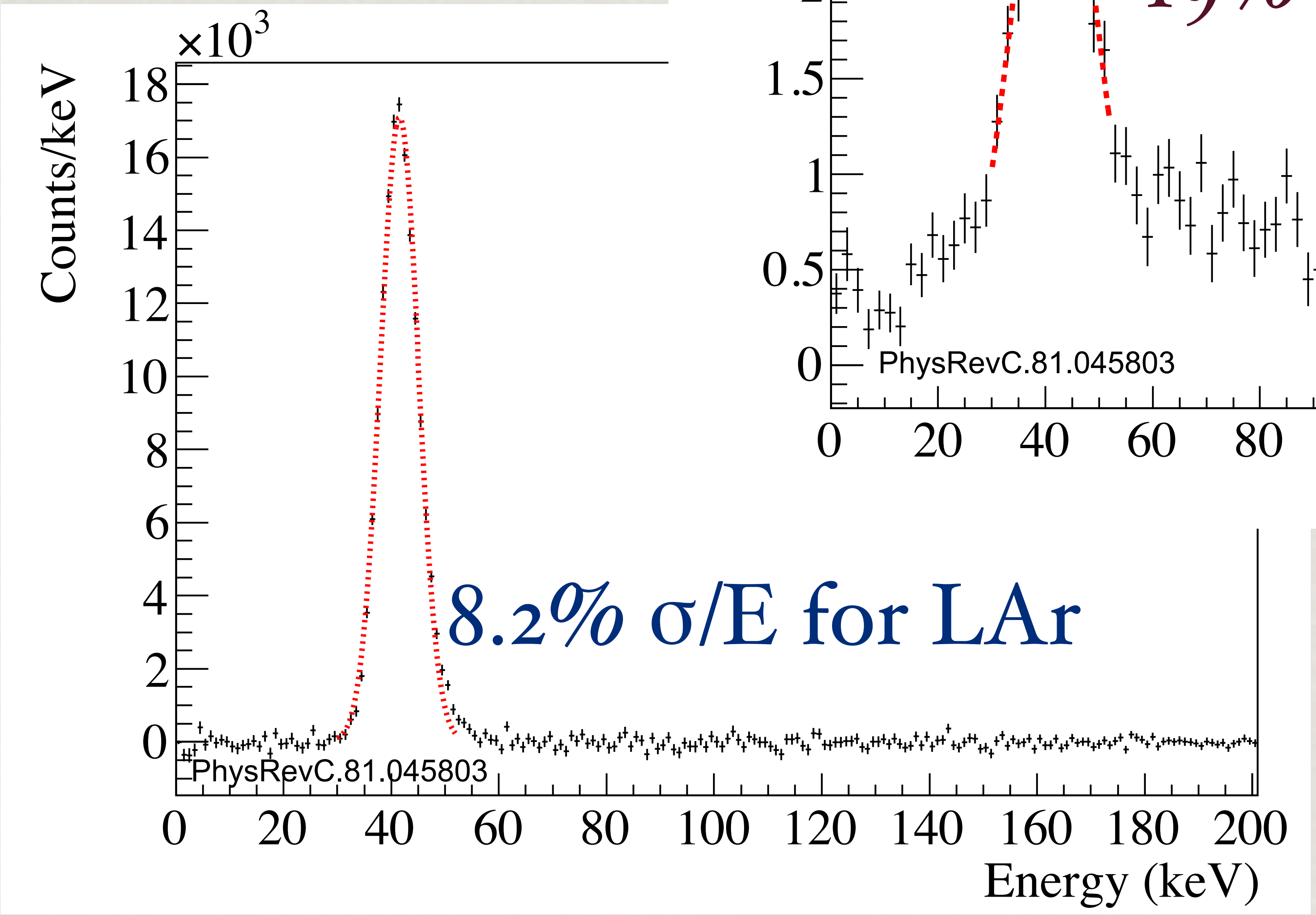
Comprehensive MC matches data with only overall yield adjusted

~3.5 pe/keVee in LNe

microCLEAN 4.4 kg LAr / 3.8 kg LNe R&D

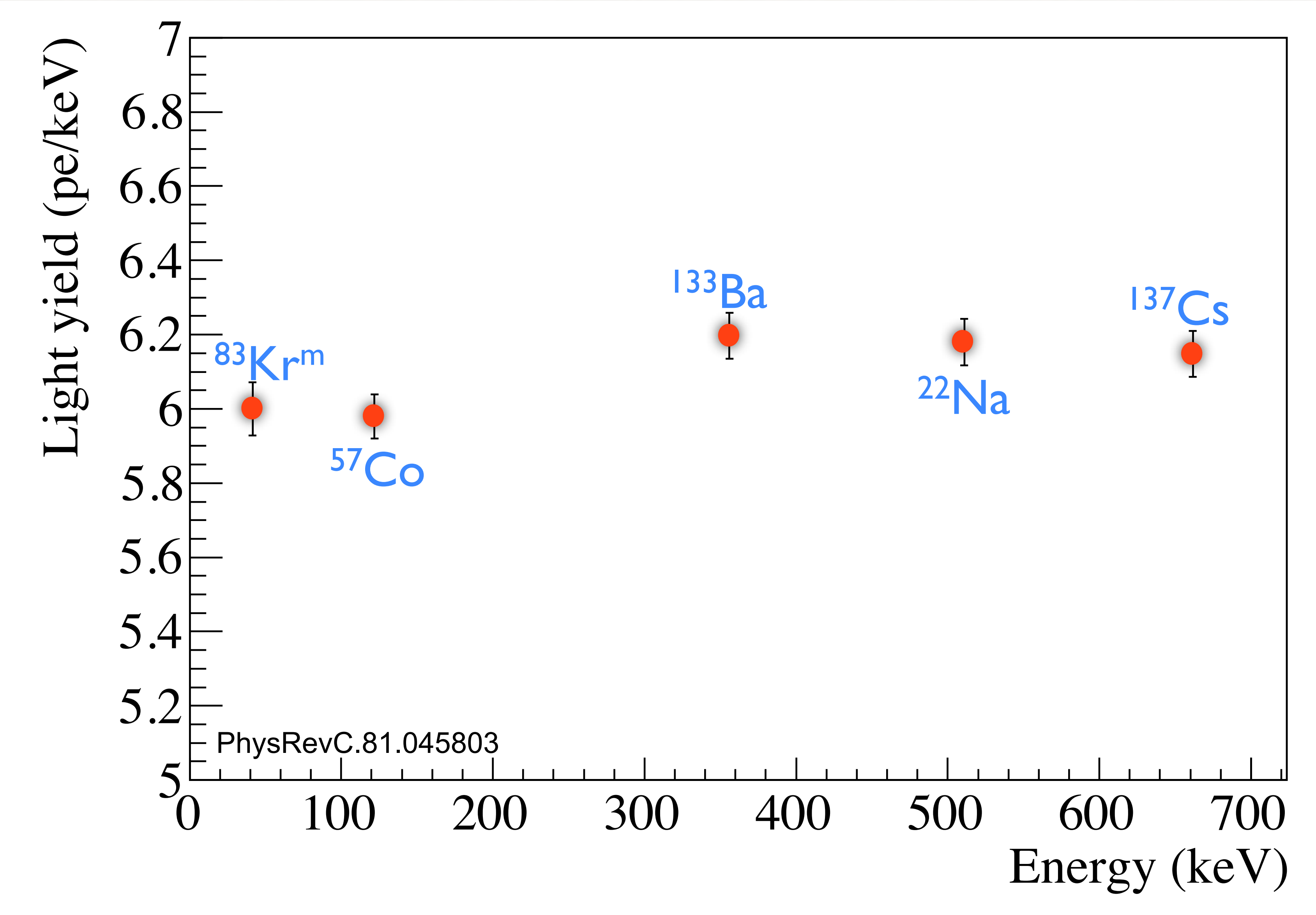
Internal
$^{83}Kr^{m}$
source





Part of UK contribution to DEAP-3600

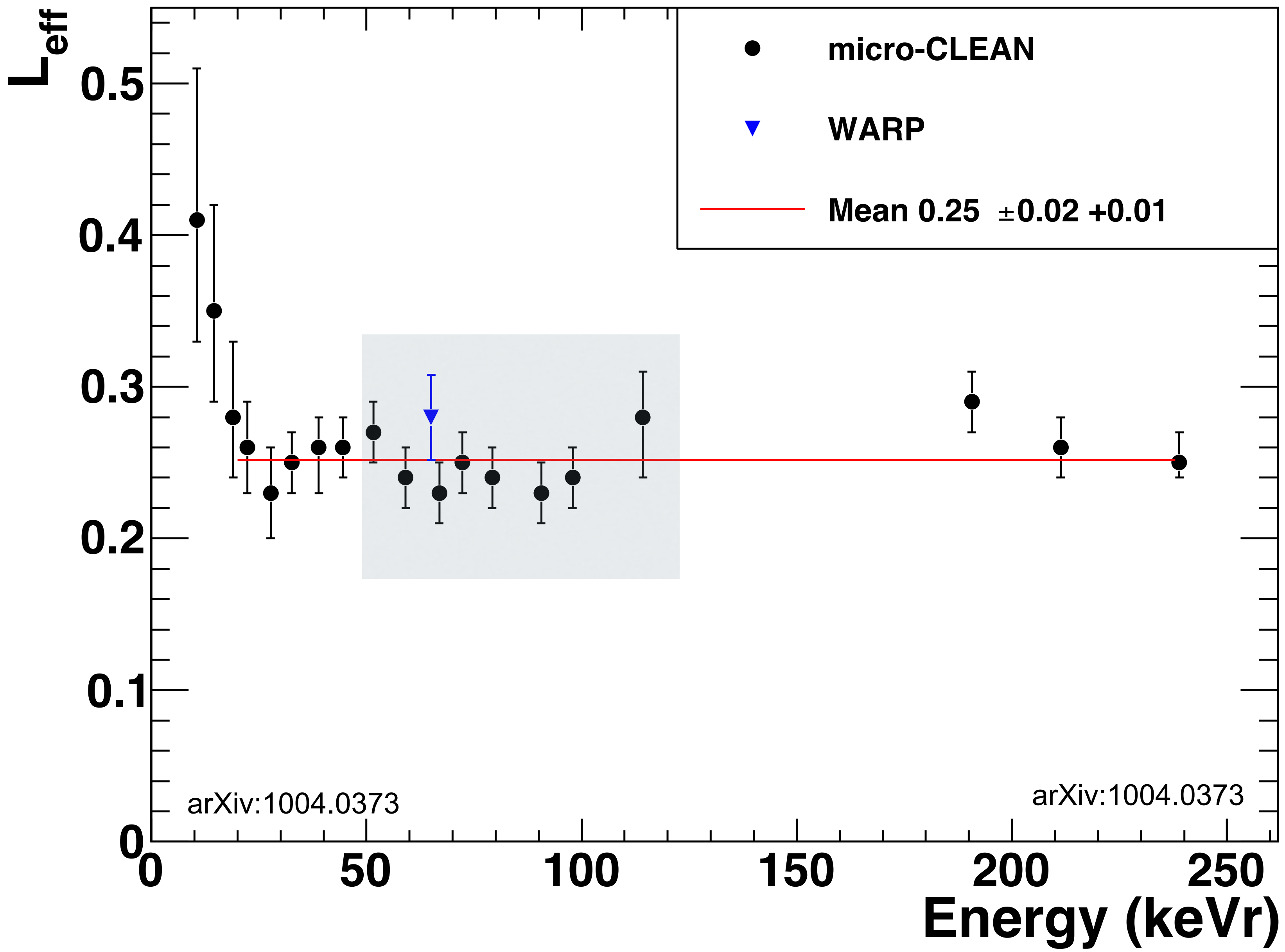
microCLEAN 4.4 kg LAr / 3.8 kg LNe *R&D*

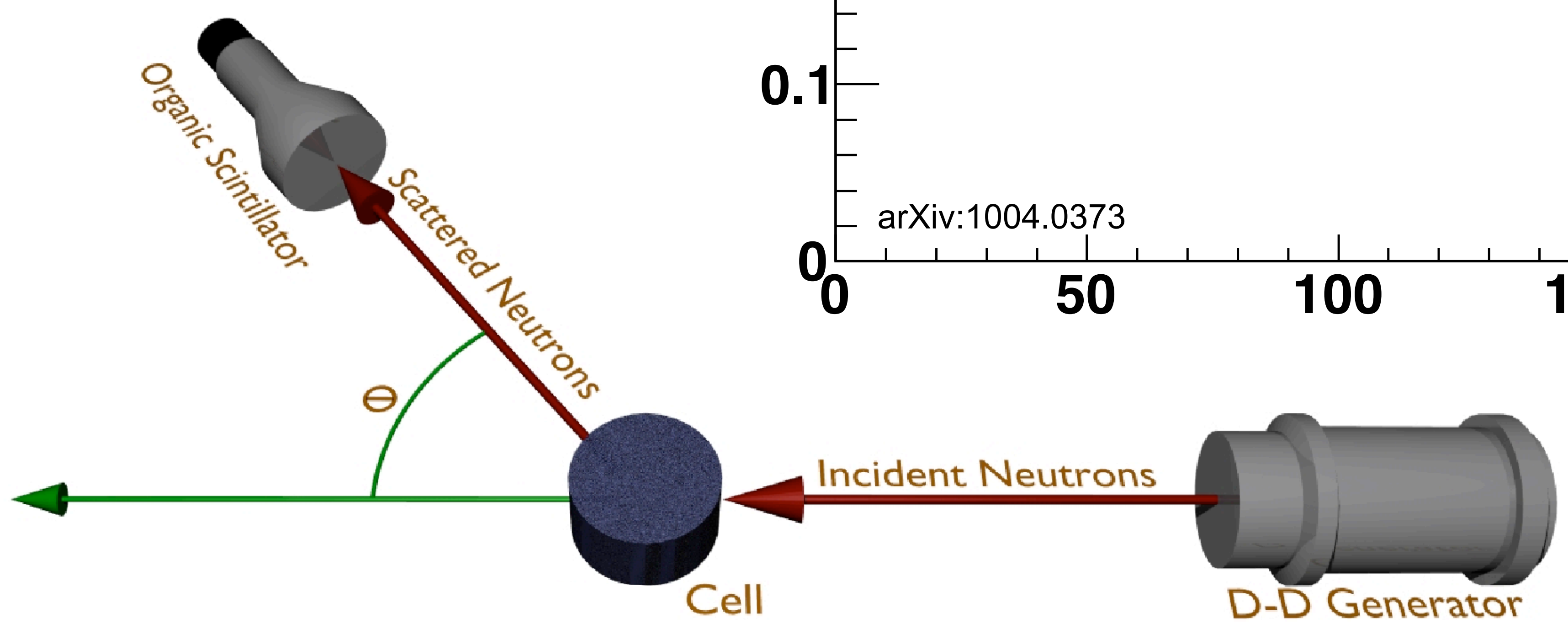


Liquid argon scintillation demonstrates good linearity from 40 to 700 keV

microCLEAN 4.4 kg LAr / 3.8 kg LNe *R&D*

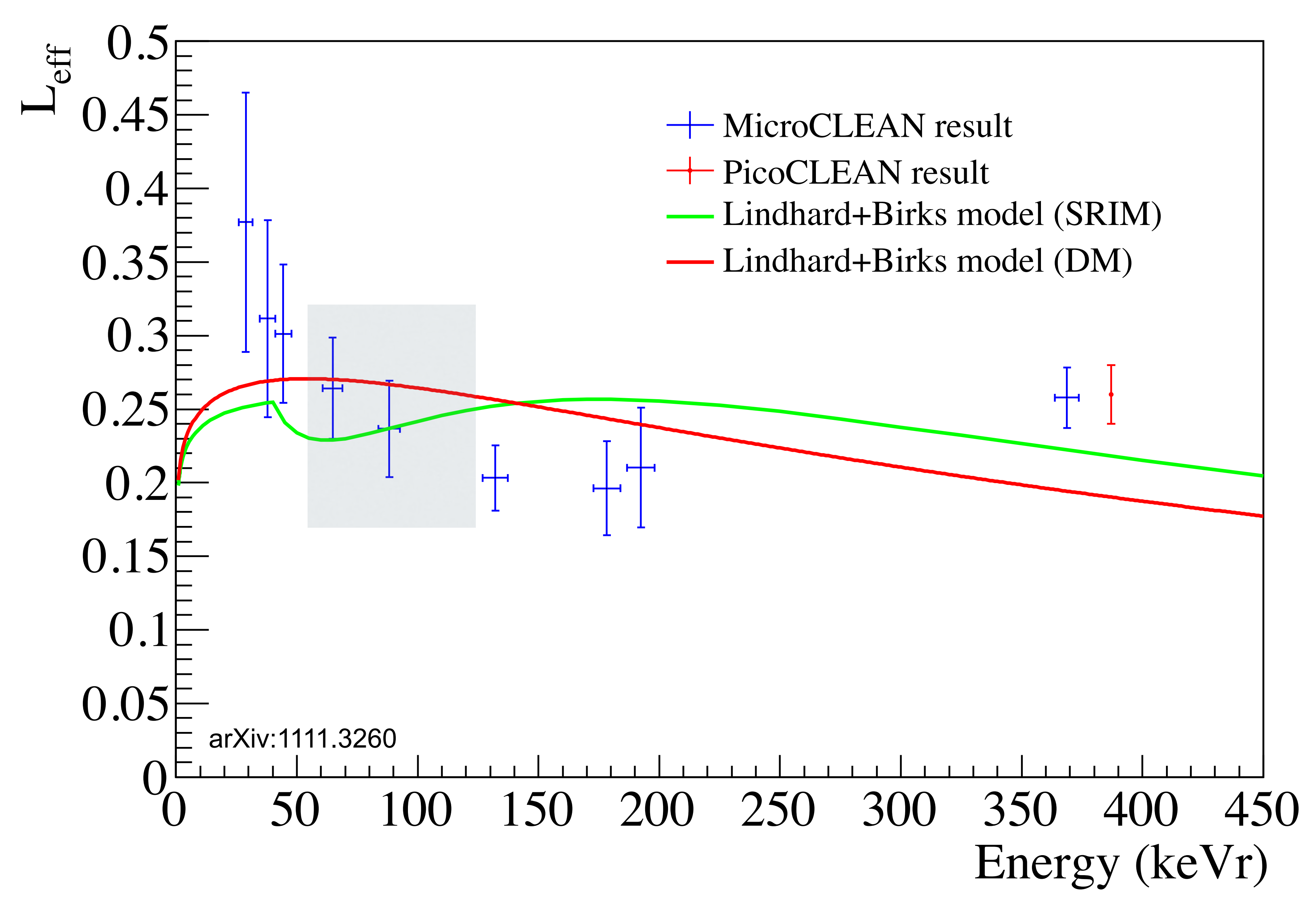
L_{eff} = 25% for LAr in WIMP ROI





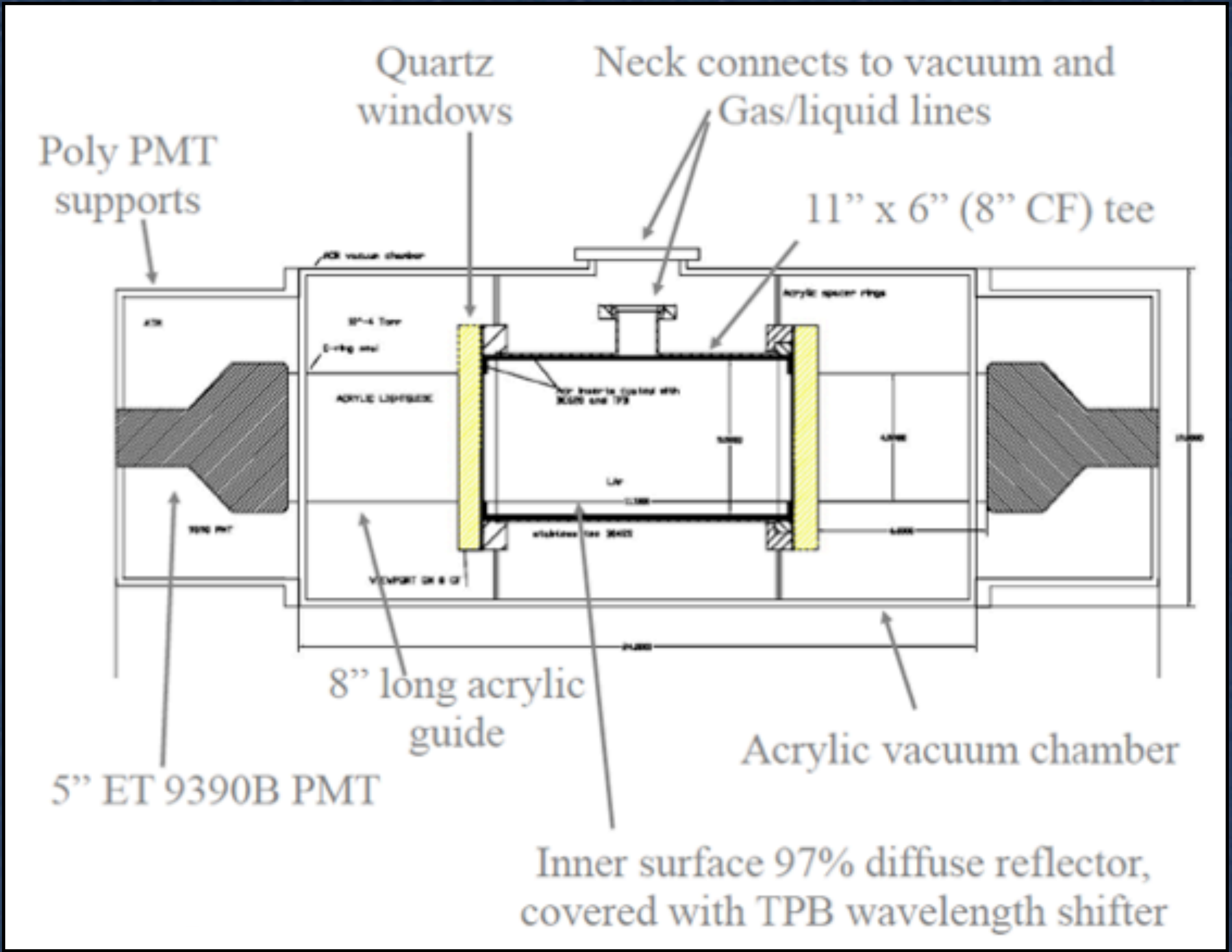
microCLEAN 4.4 kg LAr / 3.8 kg LNe *R&D*

L_{eff} ~20% to 25% for LNe in WIMP ROI



DEAP-1 7 kg LAr

R&D



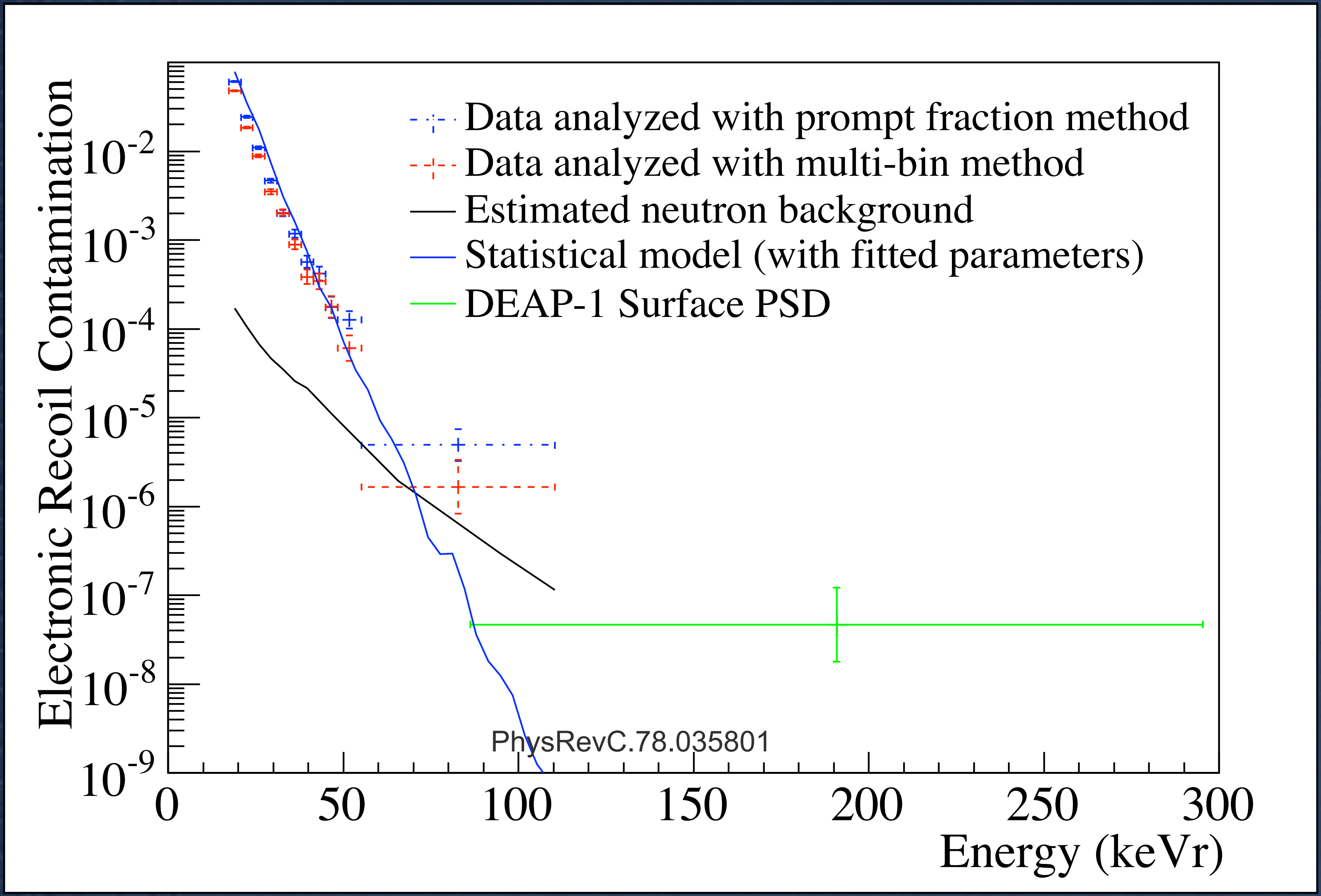
Differences from microCLEAN:

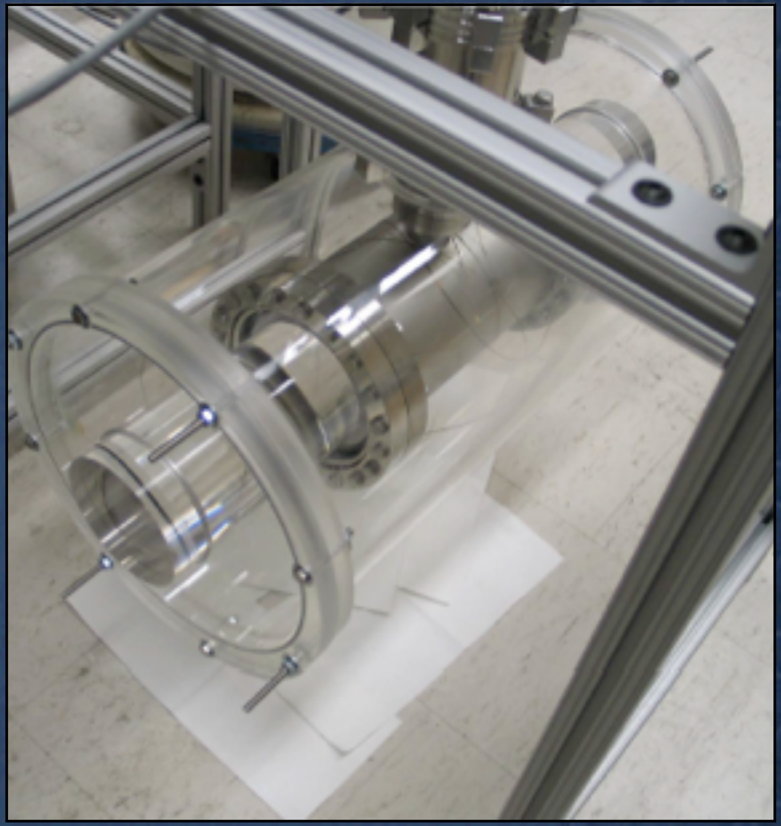
- Room temperature PMTs
- Constructed of cleaner materials
- Different cryogenic approach

- Pulse shape discrimination measurements
- Alpha backgrounds
- PMT and light guide testing
- Currently operational underground at SNOLAB

DEAP-1 7 kg LAr

R&D





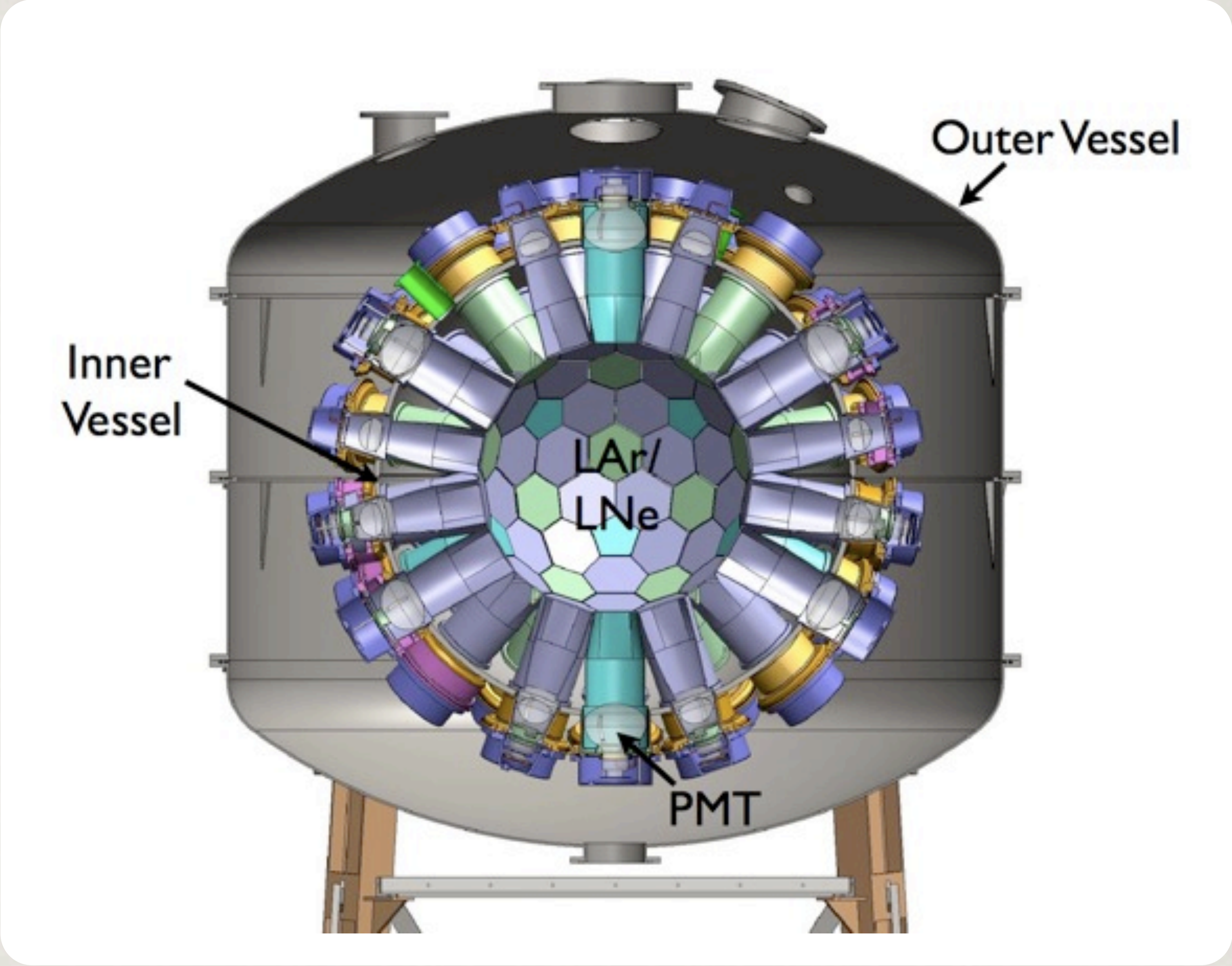
Surface run data limited to 10^{-8} contamination

Underground runs at SNOLAB are underway

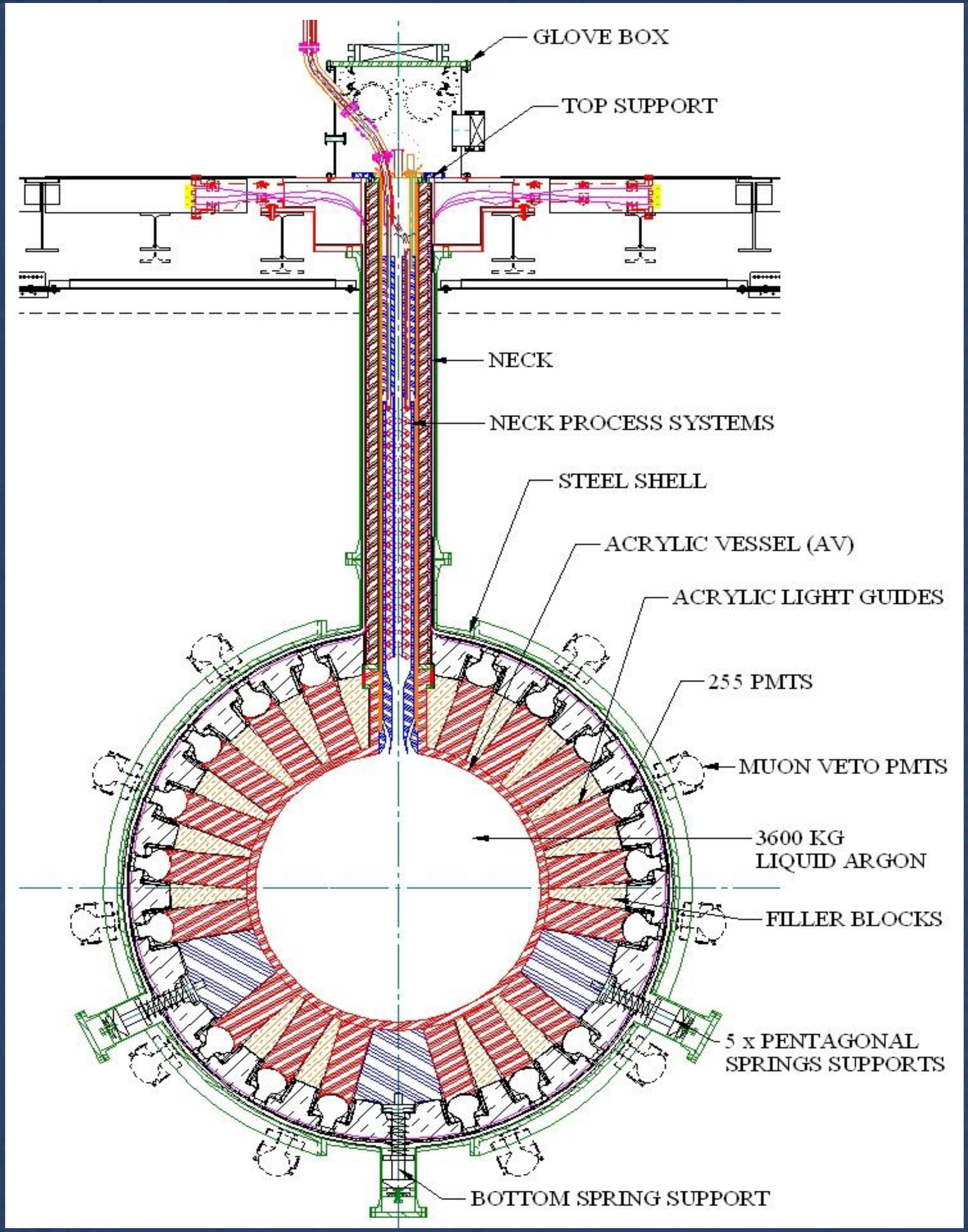
MiniCLEAN 500 kg LAr / 430 kg LNe

- Modular design
  - no underground fab
- 92 PMTs
- 10 cm acrylic for neutron shielding
- In 6m water shield tank at SNOLAB
- On-site construction in Fall 2012
- Commissioning Spring 2013
- Demo target exchange between argon and neon
- Will demonstrate position reconstruction
- High statistics PSD
- Competitive DM limit

- RHUL responsible for process systems, slow controls, muon veto

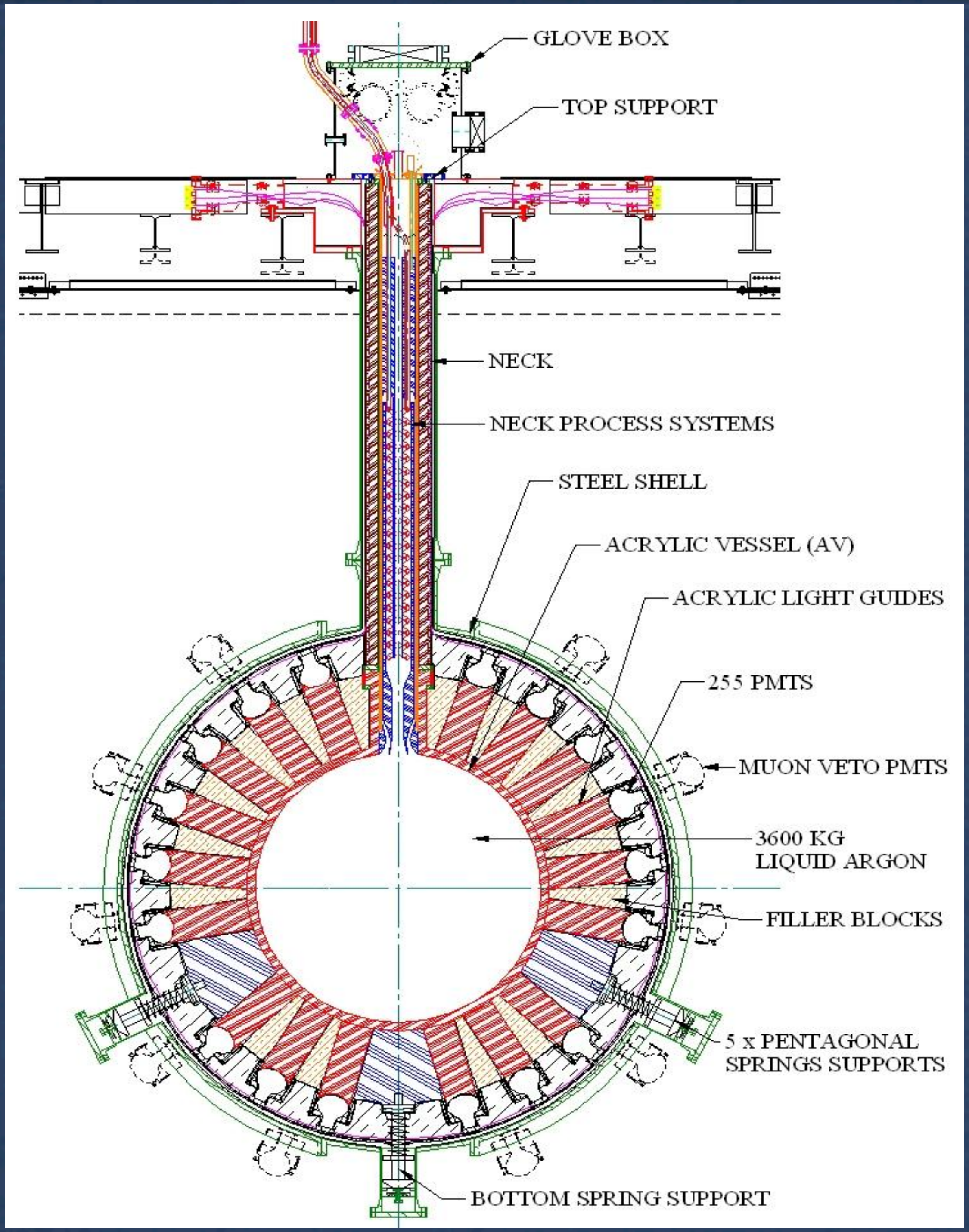


DEAP-3600   3600 kg LAr



- Sealed ultraclean Acrylic Vessel
- Vessel is “resurfaced” in-situ to remove deposited Rn daughters after construction
- 255 Hamamatsu R5912 HQE PMTs 8-inch
- 50 cm light guides + PE shielding provide neutron moderation
- Detector in 8m water shield at SNOLAB
- On-Site Construction 2012
- Commissioning 2013
- Demonstrate 10x scale over MiniCLEAN
- World Leading DM limit

DEAP-3600   3600 kg LAr



Current UK responsibilities

Detector Calibration

Systems:

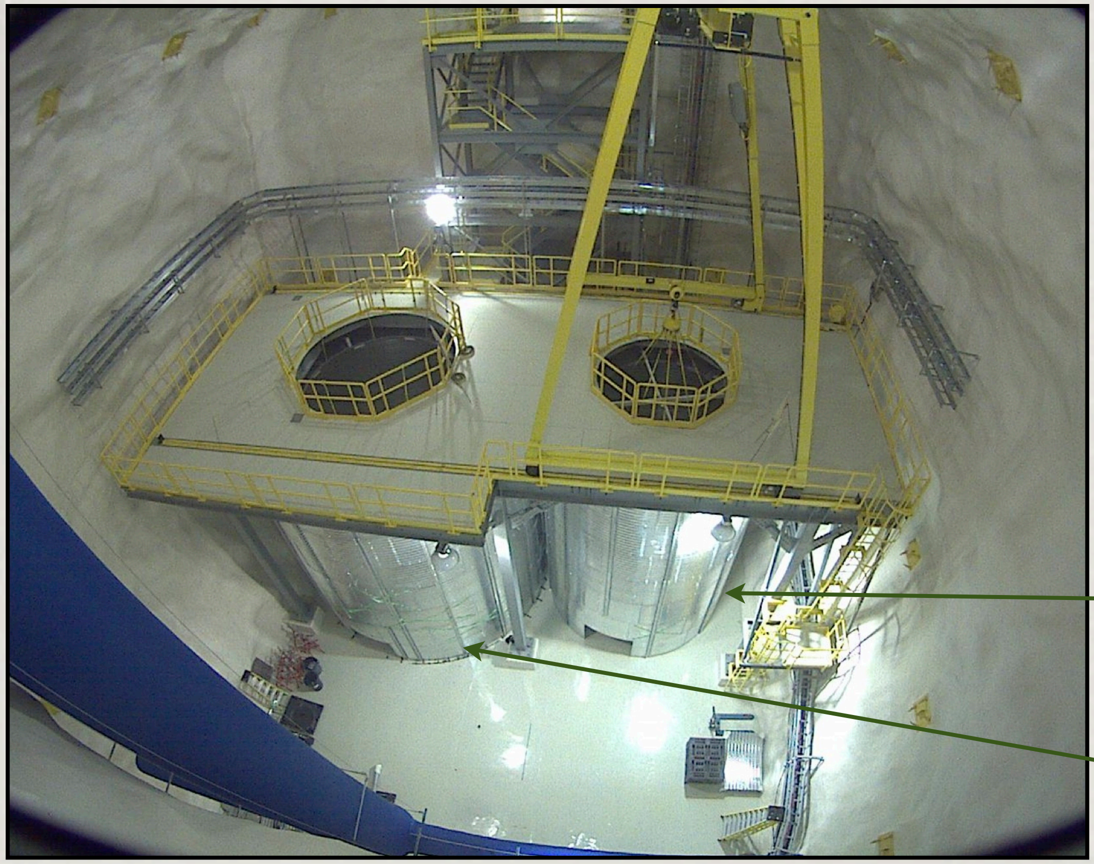
- -Internal sources
- -External gamma and neutron sources
- -Optical calibration

Analysis and Monte Carlo

The vast majority of a dark matter detector's data comes from calibrations, so this is a very critical role

Detectors at SNOLAB

DEAP-3600 and MiniCLEAN will be in the Cube Hall



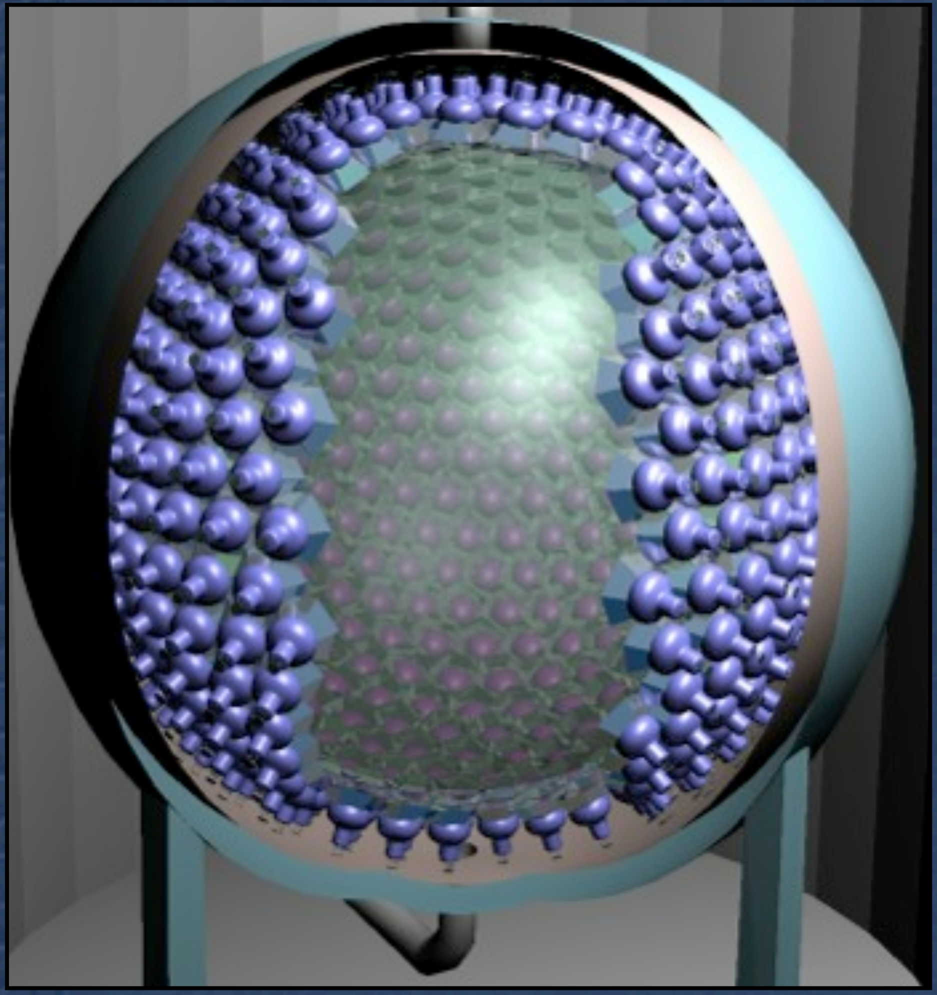
The lab is situated 2 km underground to reduce cosmic induced backgrounds

MiniCLEAN water shield tank

DEAP-3600 water shield tank

Where are we headed?

The Future



The goal is an O(100) tonne low background low energy threshold detector for dark matter and neutrino physics

Pileup eventually limits the size of large argon detectors due to the presence of ^{39}Ar, which also precludes solar neutrino studies.

Though it has a lower WIMP scattering event rate per kg, neon is a natural choice for a target exchange due to its low intrinsic background.

A large (120 tonne) Ne detector would be sensitive to DM, pp solar neutrinos (~1% measurement) and be a very sensitive supernova neutrino detector (4 events/tonne).

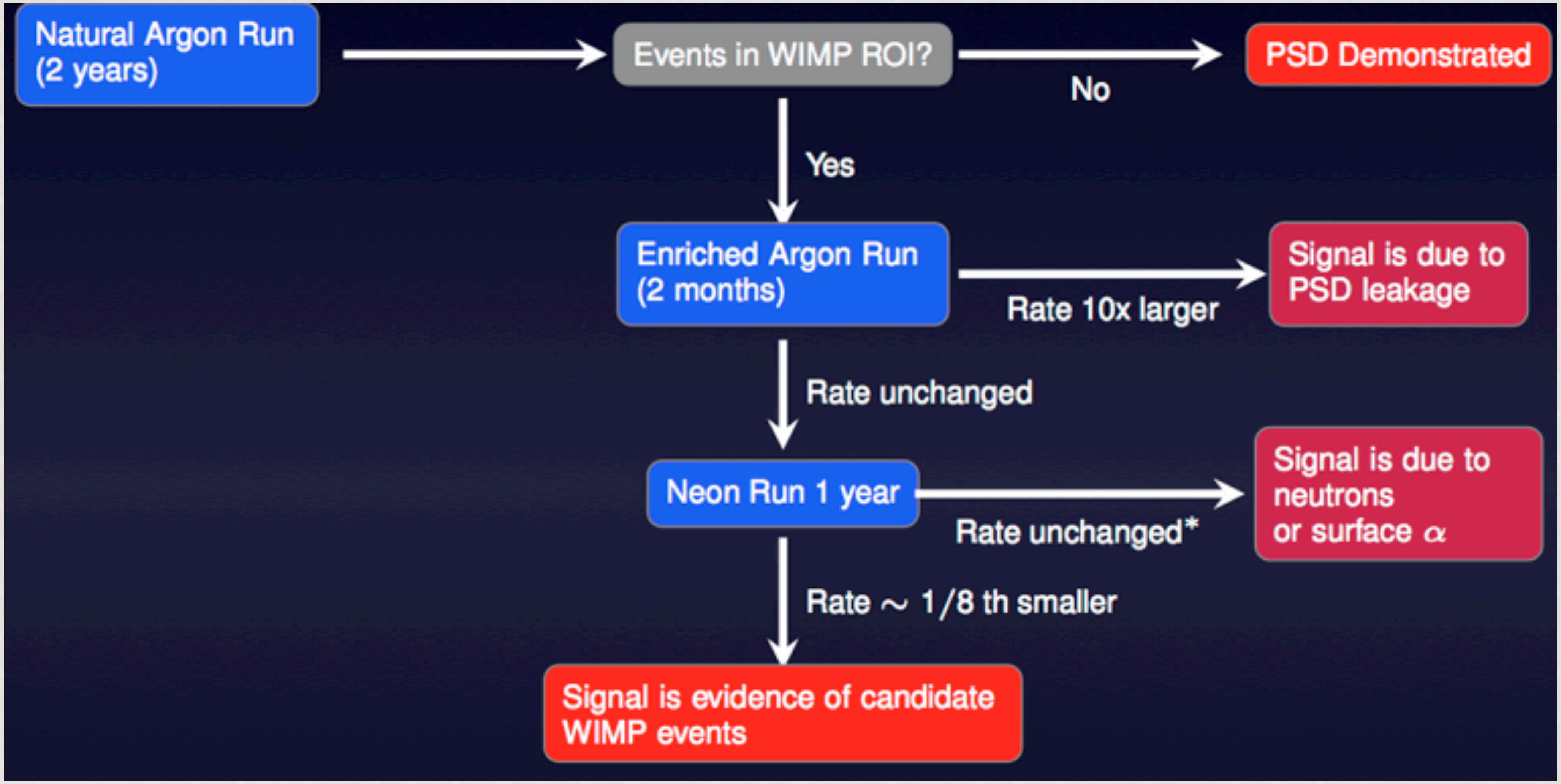
Conclusions

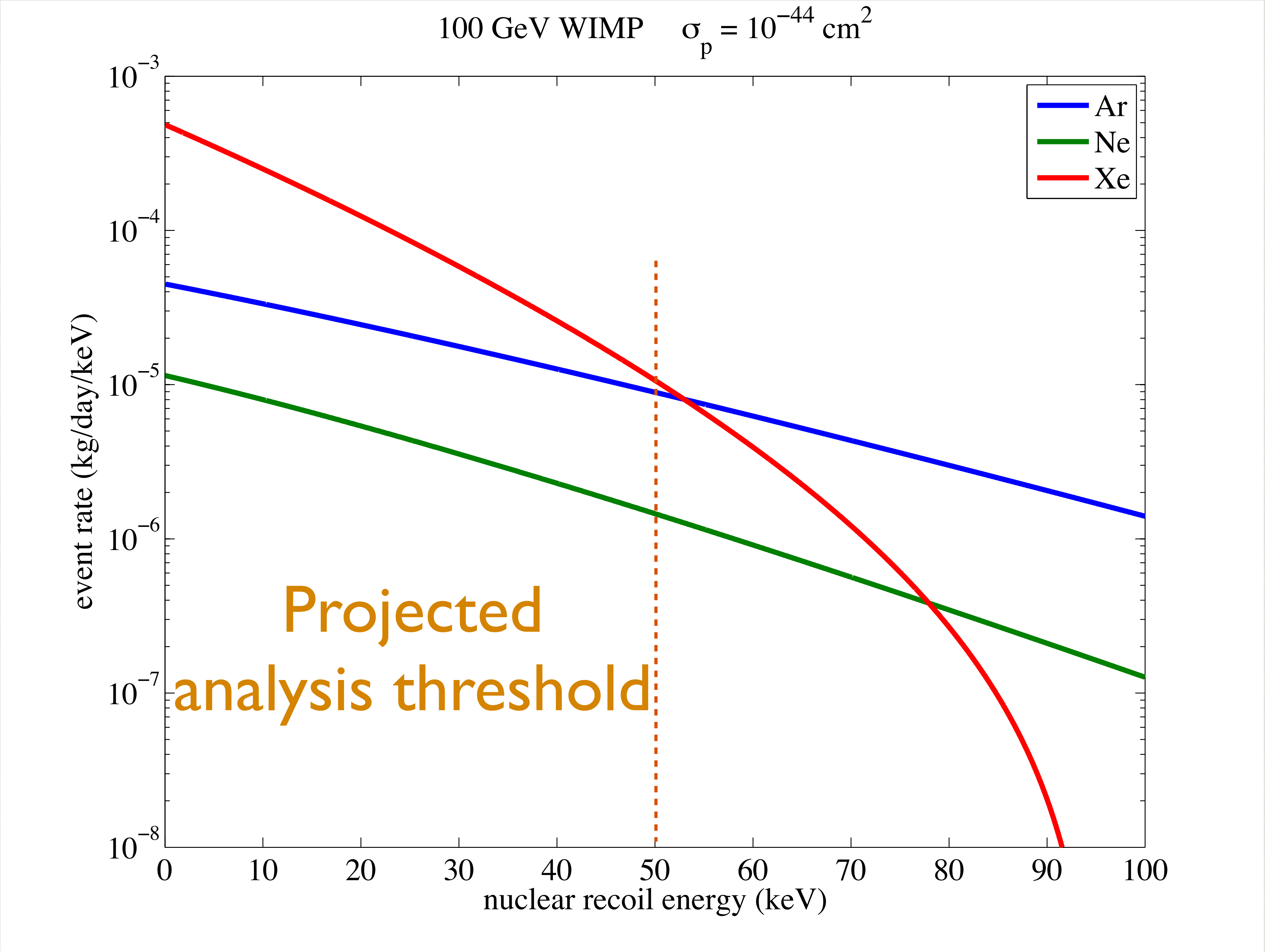
- DEAP/CLEAN is developing single-phase detectors with an eye to the 100 tonne scale
- We emphasise scalability and target exchange for beam on/off and for neutrino detection

- UK activities include detector calibration systems and analysis, process systems, veto systems and detector design
- Construction is now underway with commissioning in 2013
- Project DEAP-3600 DM sensitivity at 10^{-46} cm^2

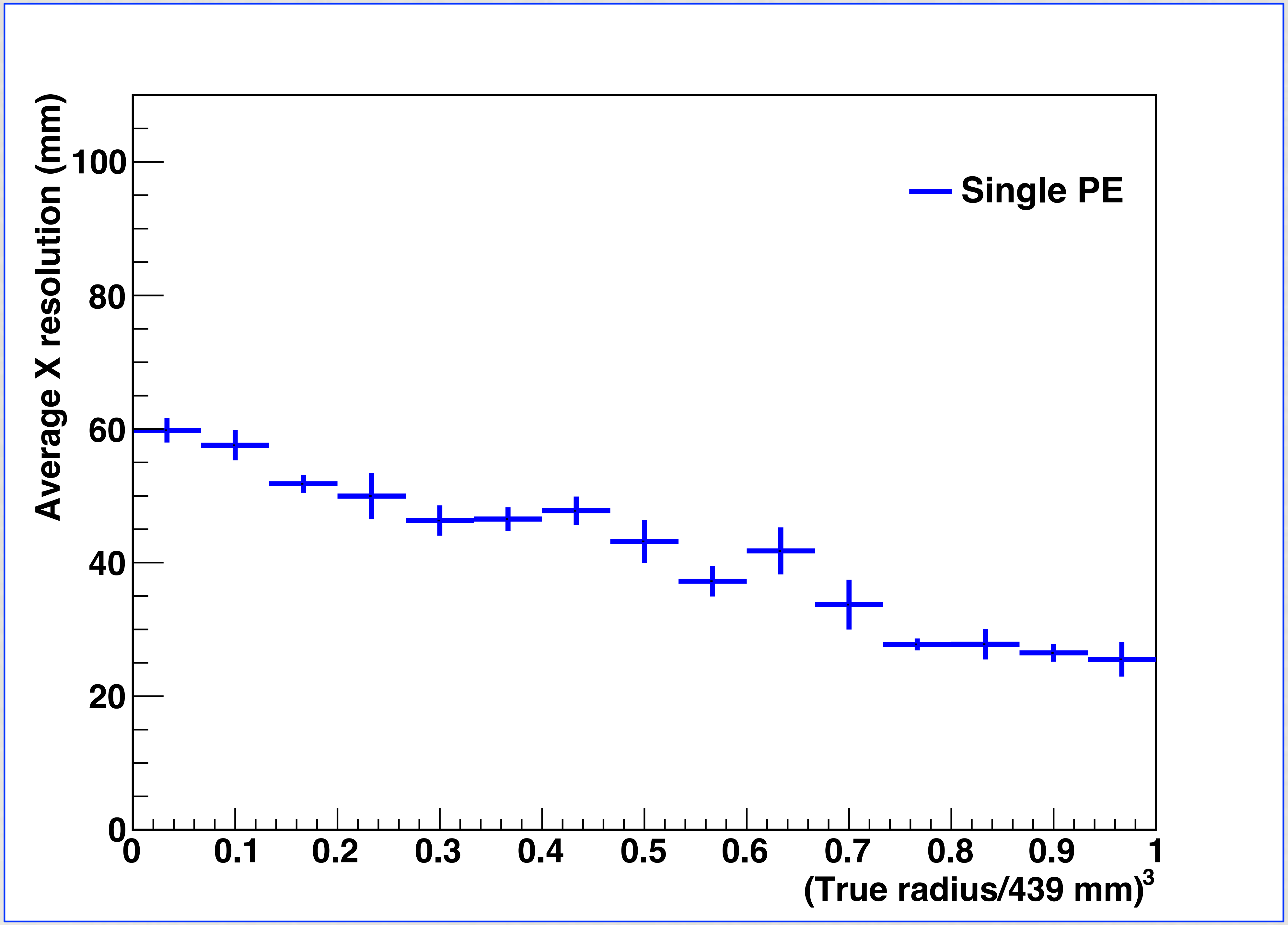
Additional

Target Exchange Run Plan Decision Tree




100 GeV WIMP $\sigma_p = 10^{-44}$ cm^2
event rate (kg/day/keV)
nuclear recoil energy (keV)
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
0
10
20
30
40
50
60
70
80
90
100
Ar
Ne
Xe
Projected
analysis threshold

MiniCLEAN Position Reconstruction



MiniCLEAN and DEAP-3600 Comparisons

	MiniCLEAN	DEAP-3600
Target Capability	LAr & LNe	LAr
Target Radius (cm)	45 cm	85 cm
Target Mass (kg)	500	3600
Fiducial Mass (kg)	150	1000
Light Collection	92 Modular Optical Cassettes with PMTs Submerged "Cold"	266 "Warm" PMTs outside of Cryogen
Cryogenic Containment	Code Stamped Stainless Steel Pressure Vessel	Monolithic Acrylic Vessel
Neutron Shielding	30 cm of Acrylic & Cryogen	50 cm Acrylic
Surface Radon Mitigation	Modular Cassettes Assembled in Vacuum	In Situ Resurfacing of inner Acrylic Vessel Surface
Process Systems	Pulse-Tube Refrigerators with Heat Exchange	LN-Cooled Thermal Siphon

Noble Liquid Properties

Element	Liquid density g/ml	Boiling point (K)	Electron yield (e^-/keV)	Photon yield (γ/keV)	Singlet decay time	Triplet decay time	Scintillation wavelength (nm)	Radioactive
2 ^{4}He	0.13	4.2	39	22	10 (ns)	13 (s)	80	No
10 ^{20}Ne	1.2	27.1	46	32	10 (ns)	15 (μs)	78	No
18 ^{40}Ar	1.4	87.3	42	40	7 (ns)	1.5 (μs)	128	^{39}Ar 1 Bq/kg
36 ^{84}Kr	2.4	119.9	49	25	7 (ns)	85 (ns)	148	^{85}Kr 1 MBq/kg
54 ^{132}Xe	3.1	165.0	64	42	5 (ns)	27 (ns)	175	^{136}Xe <10 μBq/kg

(some of these have large uncertainties)