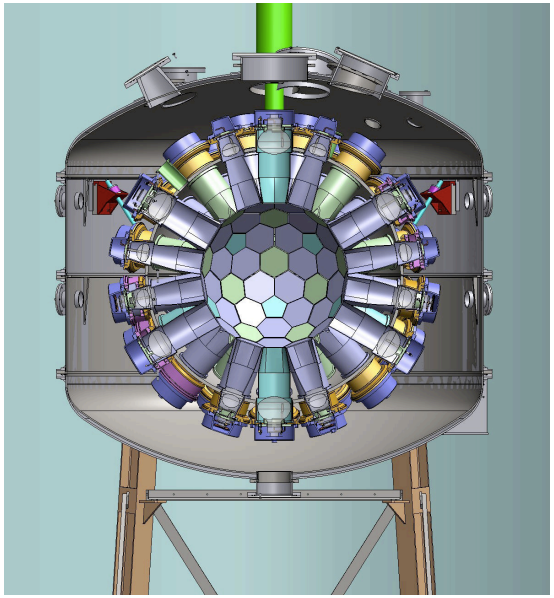
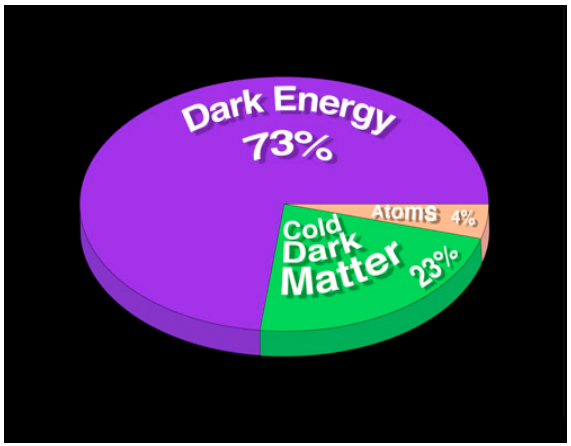
The MiniCLEAN Dark Matter Experiment



Origins & Detection of Dark Matter
University of New Mexico
May 27-29, 2011

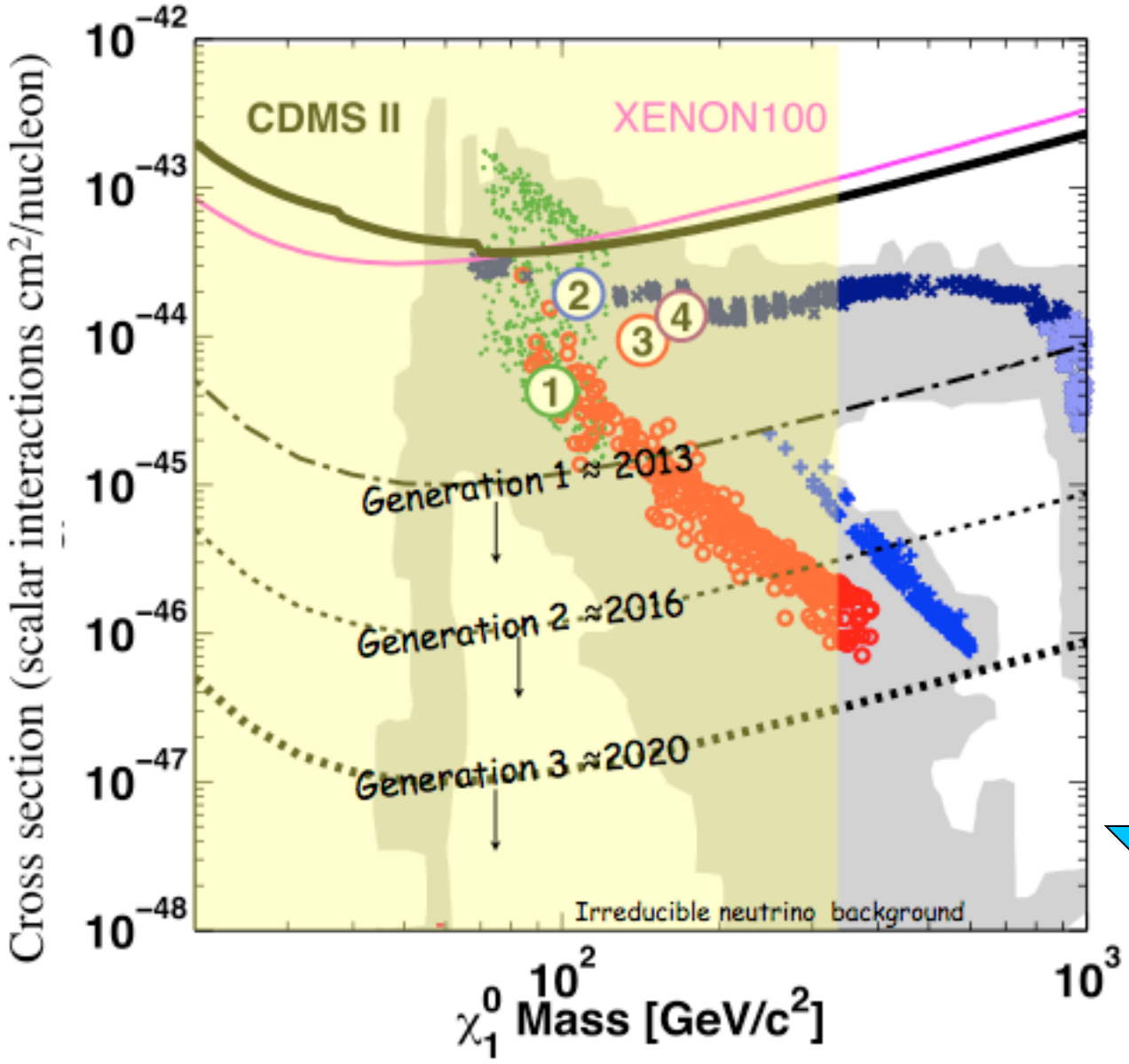
Andrew Hime
Physics Division, MS H803
Los Alamos National Laboratory
Los Alamos, NM 87545

ahime@lanl.gov



Los Alamos NATIONAL LABORATORY EST. 1943

LAUR-11-10659



Events / 10 kg / yr

Events / 100 kg / yr

G1

Events / 1000 kg / yr

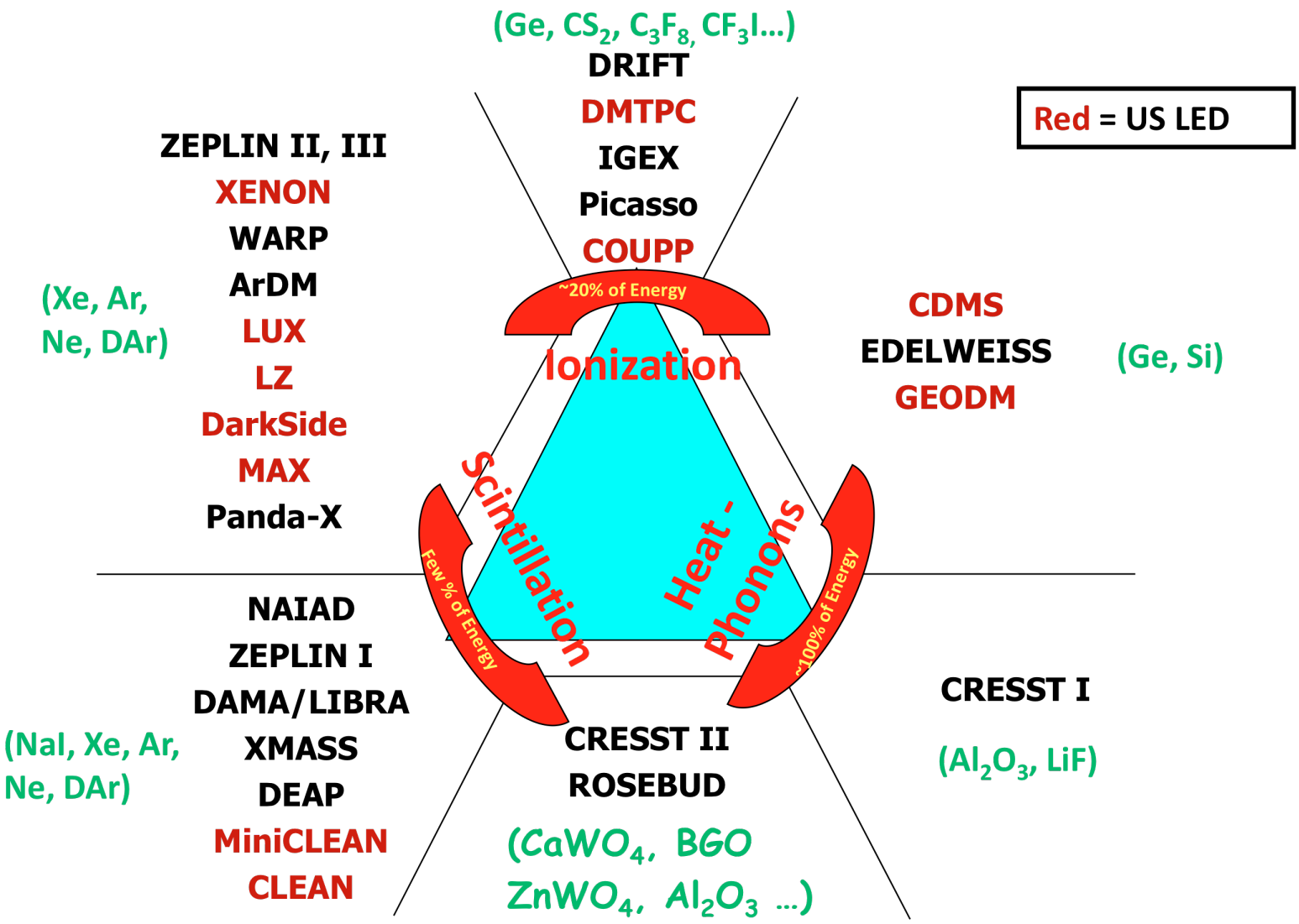
G2

Events / 10000 kg / yr

G3

SCALABILITY

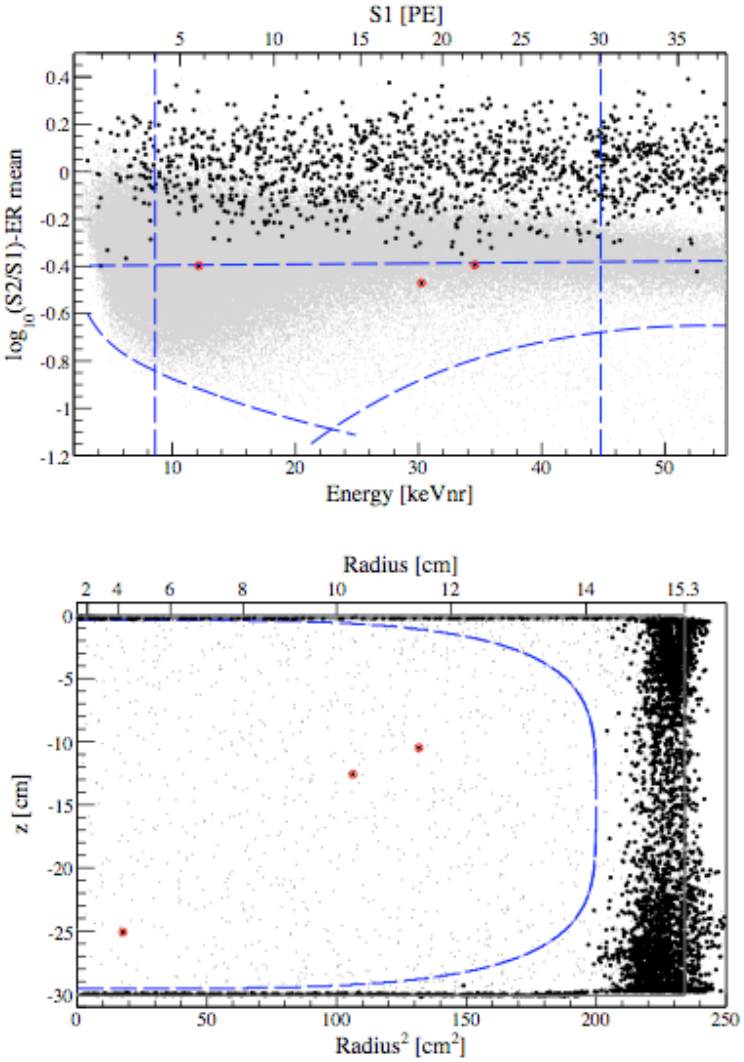
Direct Detection Techniques

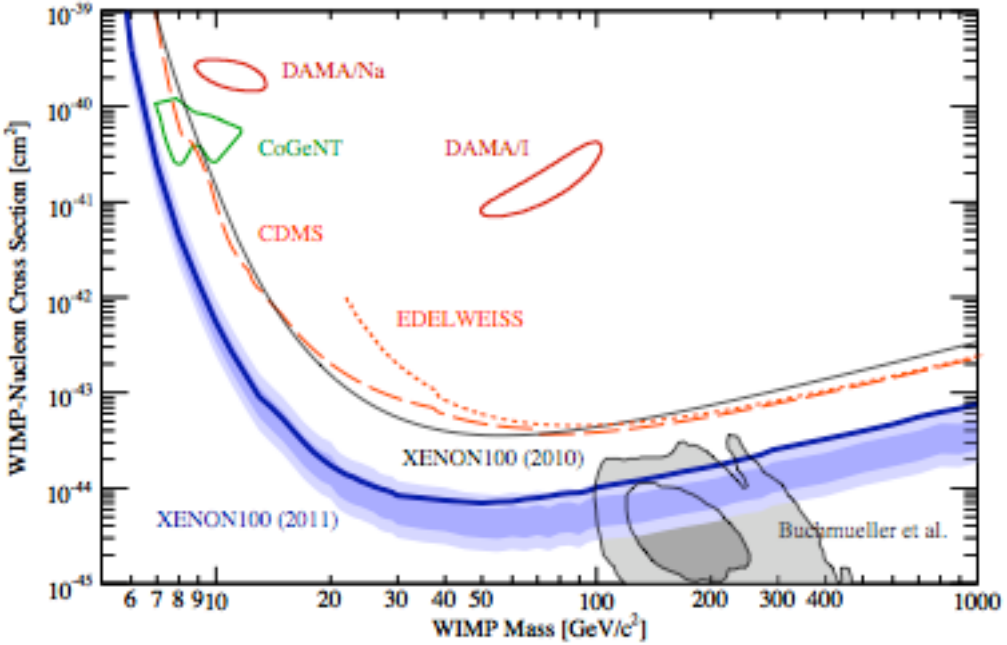


Courtesy DUSEL Dark Matter Working Group

The Latest from XENON-100

arXiv:1104.2549v1

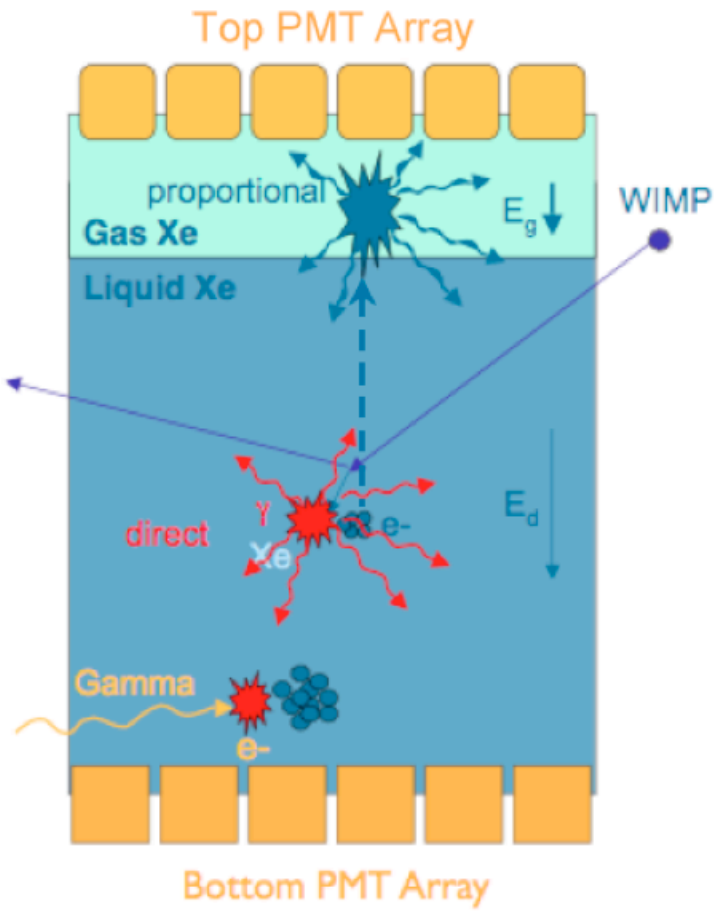




3 Events Observed within Blind-Cuts

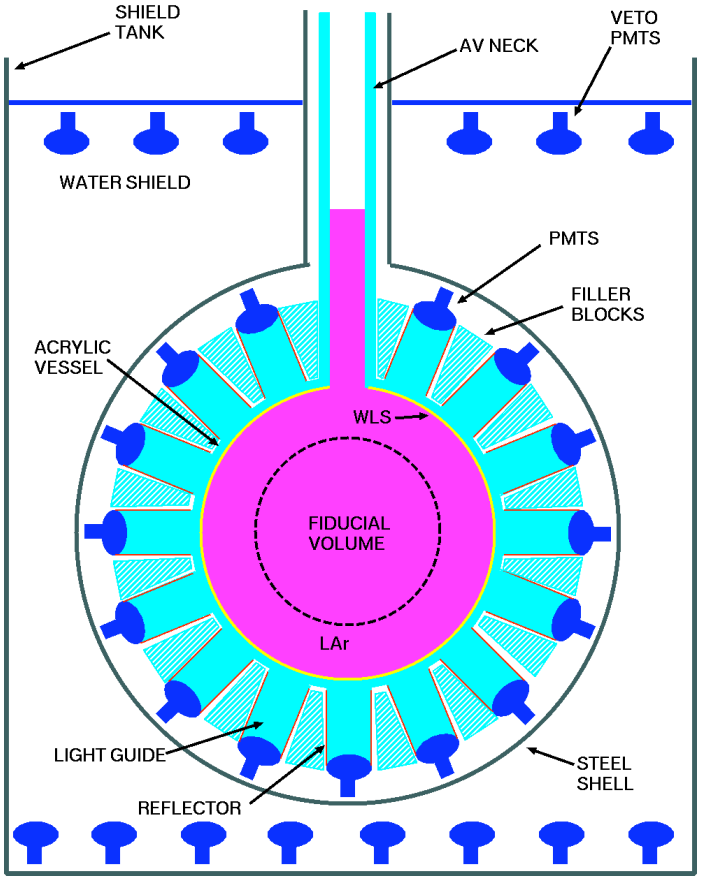
1.8 ± 0.6 Expected from BGND

Dual-Phase



Courtesy E. Aprile

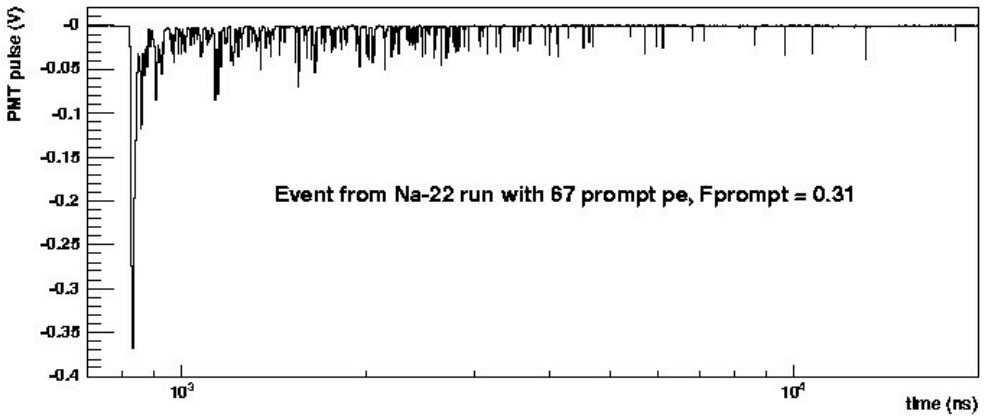
Single-Phase

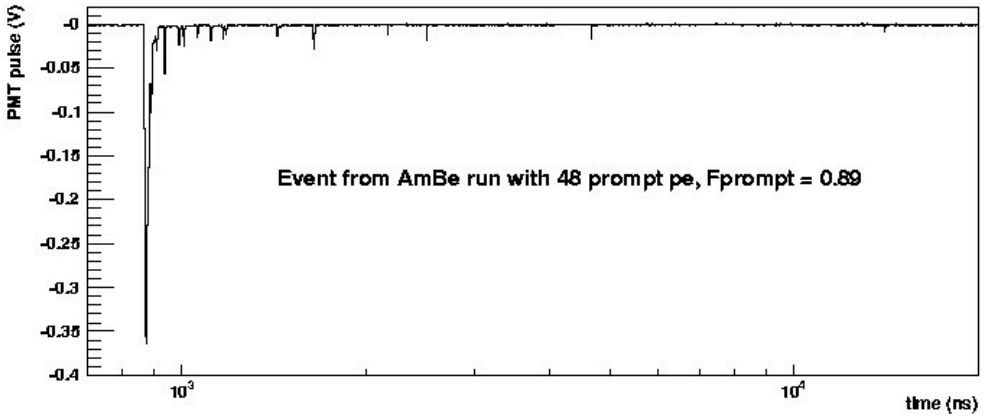


D. N. McKinsey and J. M. Doyle, J. Low Temp. Phys. 118, 153 (2000).
D. N. McKinsey and K. J. Coakley, Astropart. Phys. 22, 355 (2005).
M. Boulay, J. Lidgard, and A. Hime, nucl-ex/0410025.
M. Boulay and A. Hime, Astropart. Phys. 25, 179 (2006).

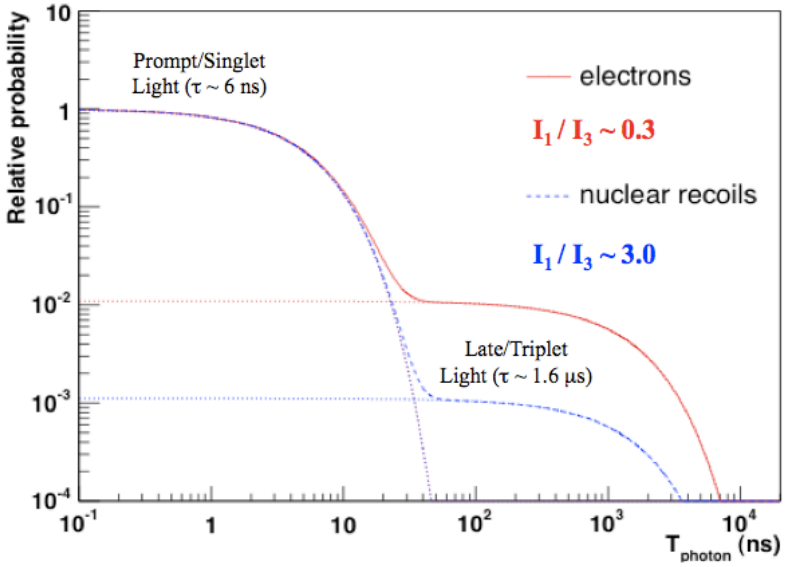
Pulse-Shape Discrimination in LAr

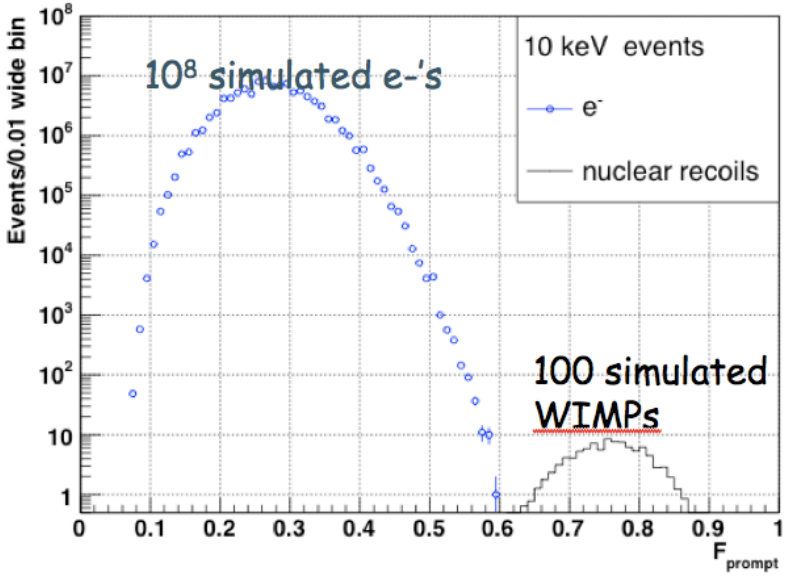
Example Pulses from DEAP-0



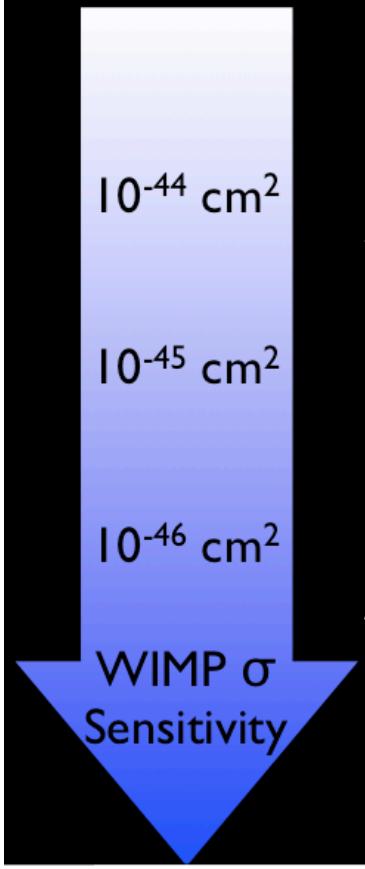


M.G. Boulay and A. Hime
Astroparticle Physics **25**, 179 (2006)





The DEAP and CLEAN Family of Detectors



DEAP-0:
Initial R&D detector

DEAP-1:
7 kg LAr
2 warm PMTs
At SNOLab 2008

picoCLEAN:
Initial R&D detector

microCLEAN:
4 kg LAr or LNe
2 cold PMTs
surface tests at Yale

G1

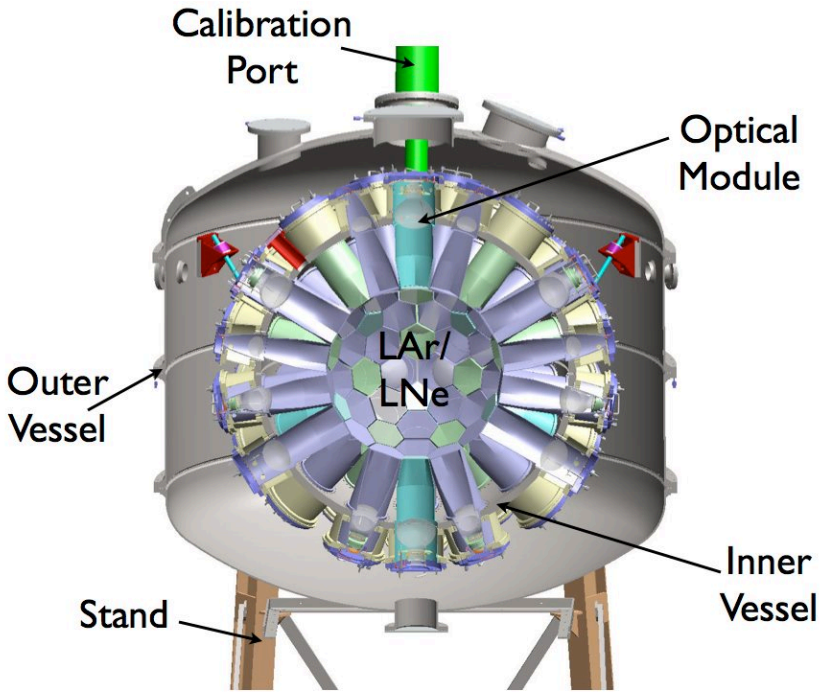
MiniCLEAN:
500 kg LAr or LNe (150 kg fiducial mass)
92 cold PMTs
At SNOLAB mid-2011

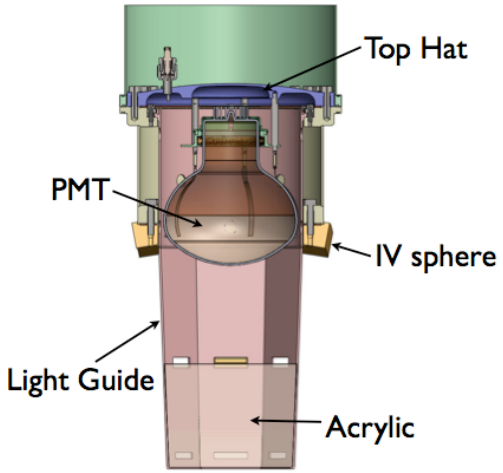
G2

DEAP-3600:
3600 kg LAr (1000 kg fiducial mass)
266 warm PMTs
At SNOLAB late 2012

G3

50-tonne LNe/LAr Detector:
pp-solar ν, supernova ν, dark matter <10^{-46} cm^2
At DUSEL ~2015?





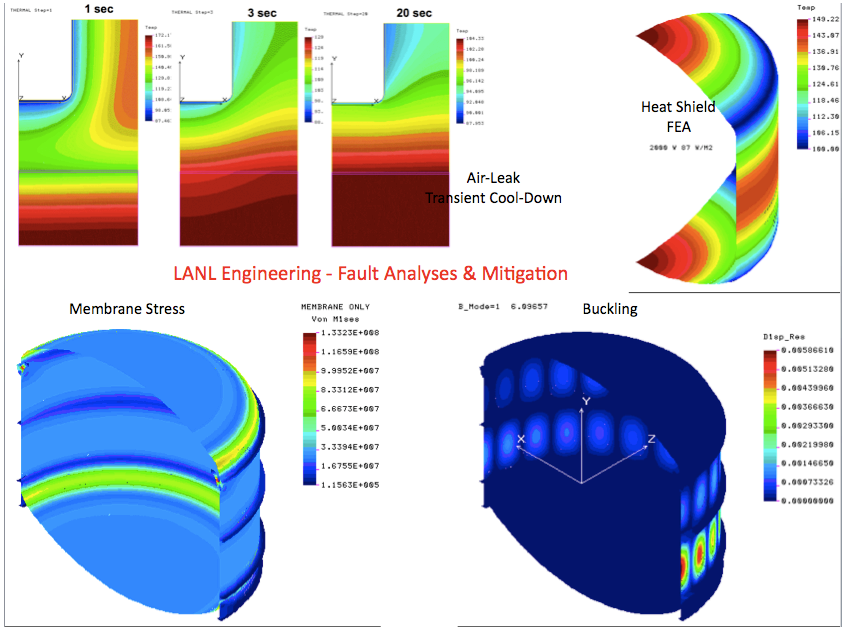
MiniCLEAN
Single-Phase Conceptual Design

- 4π PMT coverage to maximize light yield
- Modular design & radon-free assembly
- LAr & LNe target exchange to test for false backgrounds and A^2 dependence of WIMP-nucleus cross-section
- No high-voltage cathodes, simplifying design and eliminating problems of slow electron drift speed and ^{39}Ar pulse pile-up
- Conceptually simple and economic for scaling to multi-ton targets

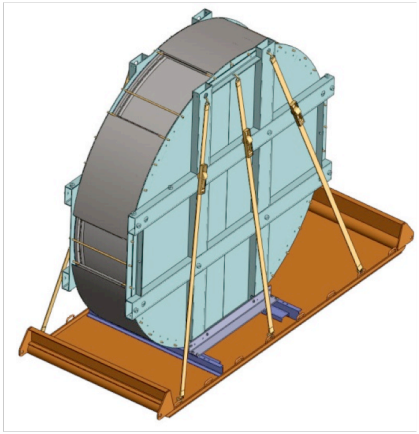
MiniCLEAN Outer Vessel

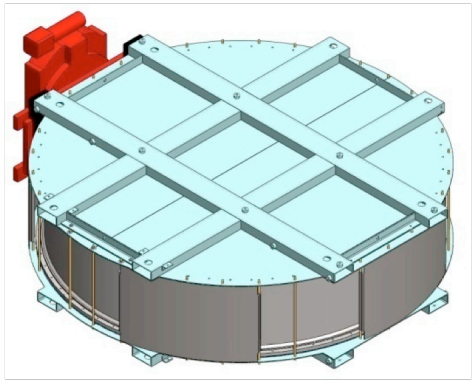
Engineered at LANL
Procured at Yale

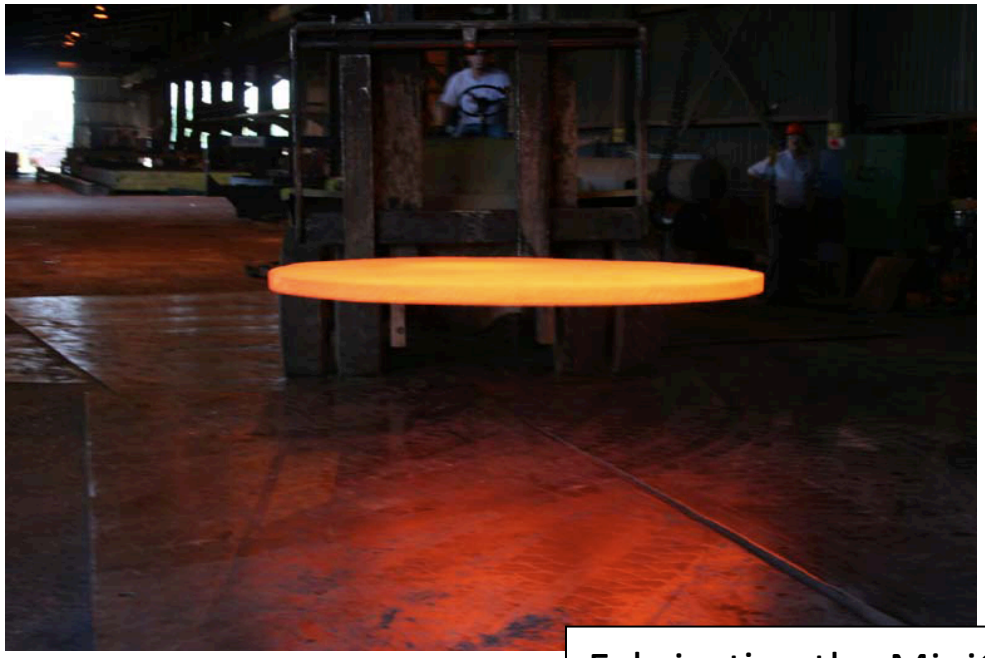
Fabricated at PHPK Technologies
Columbus, OH



Transporting the Outer Vessel Underground

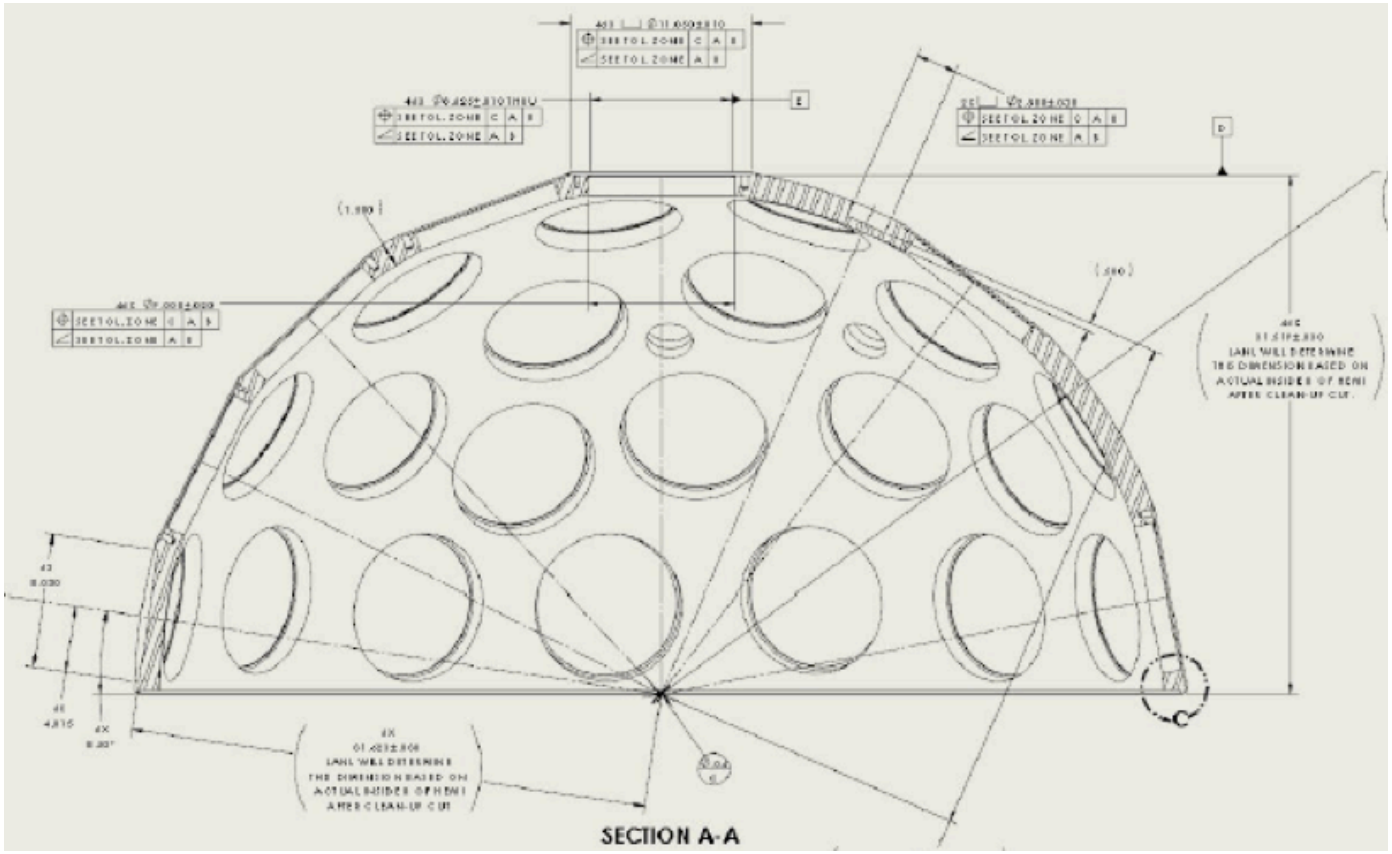






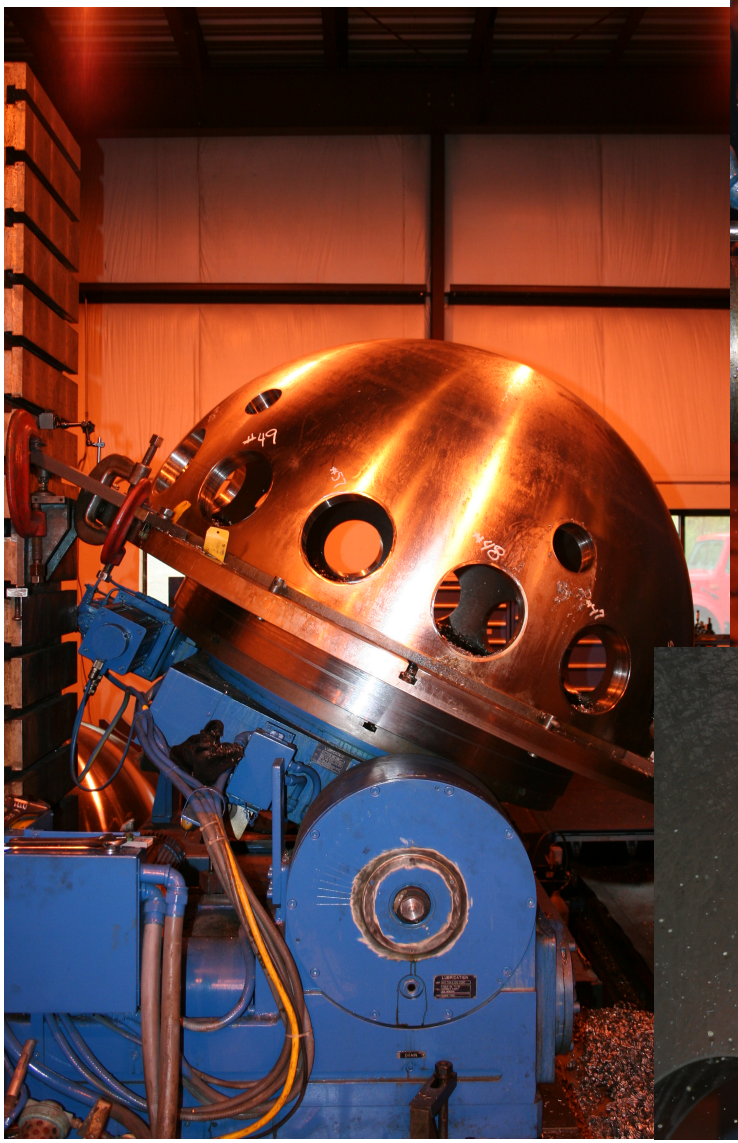
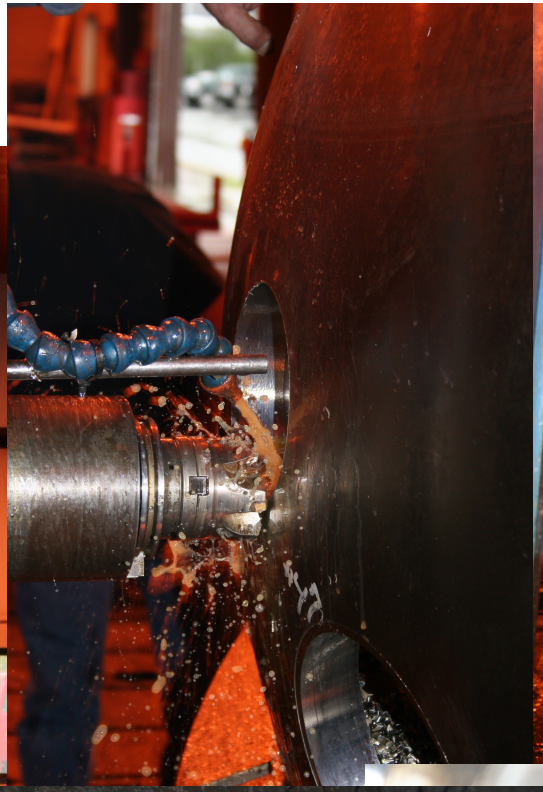
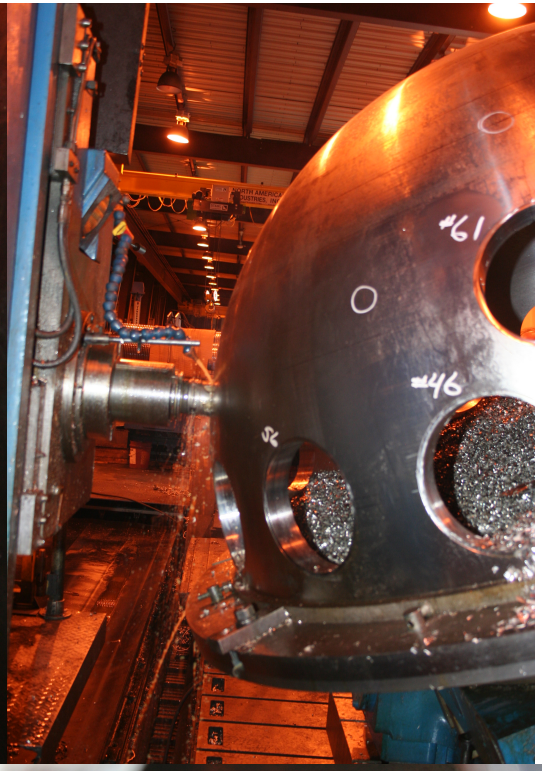
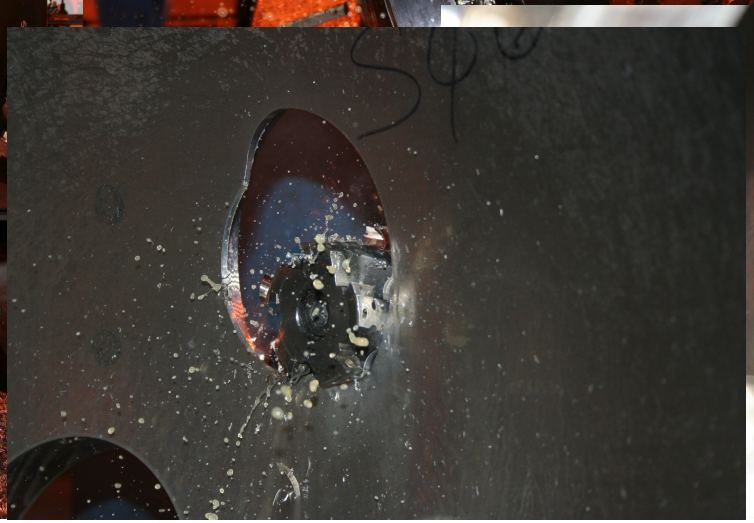
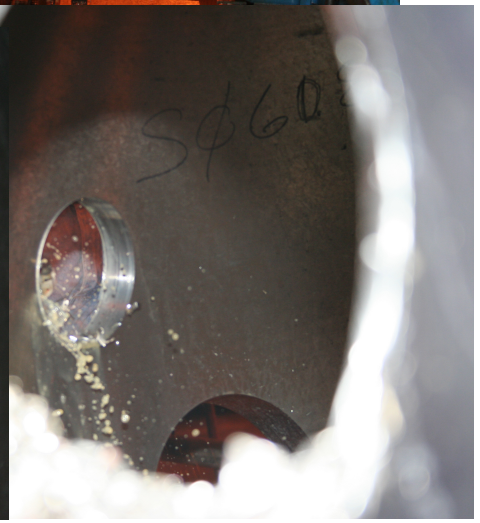
Fabricating the MiniCLEAN Inner Vessel

Winchester Precision Technologies

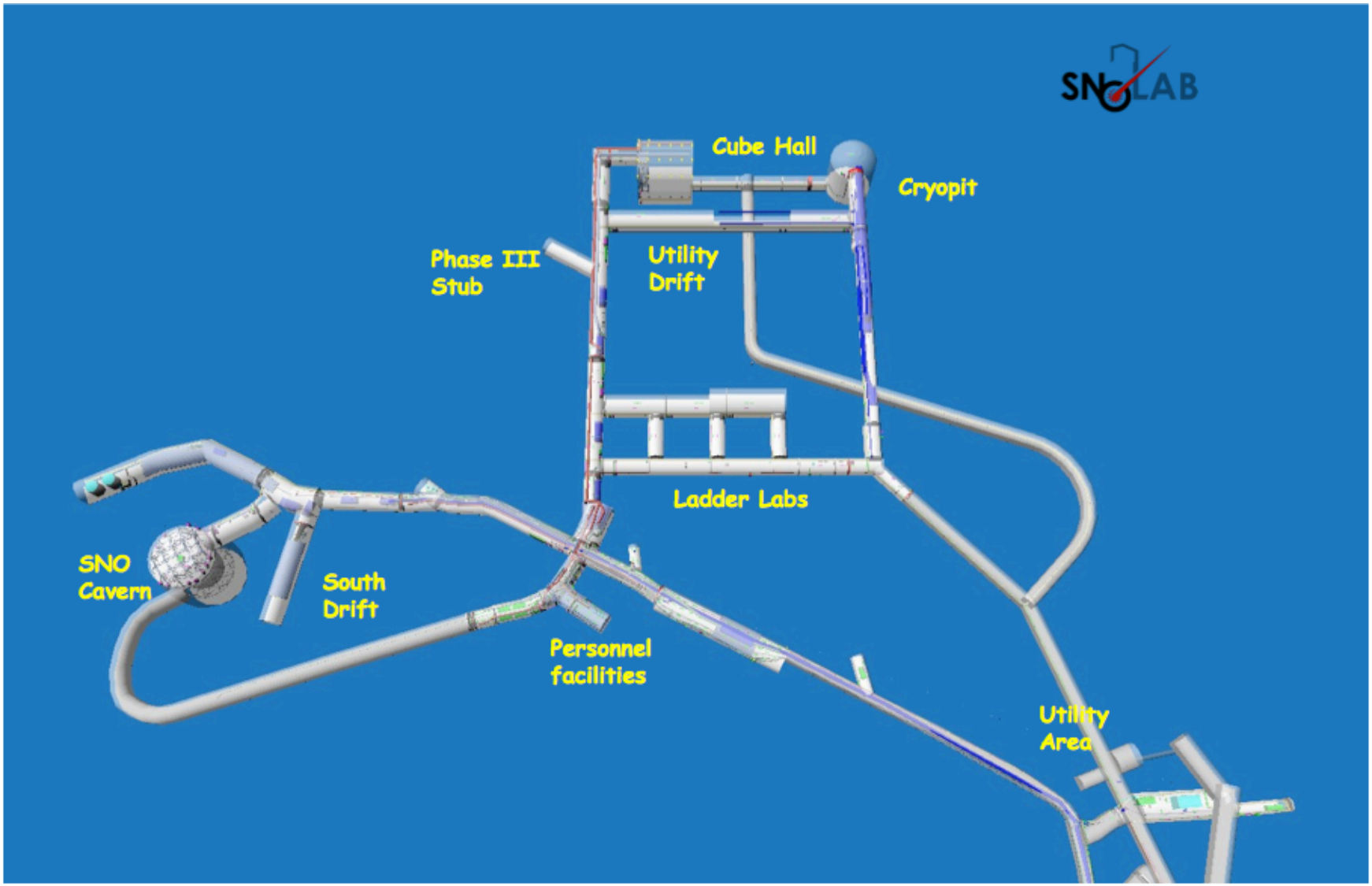

SECTION A-A

MiniCLEAN Inner Vessel - May 4, 2011

MiniCLEAN Inner Vessel
May 4, 2011

MiniCLEAN Inner Vessel – May 12, 2011

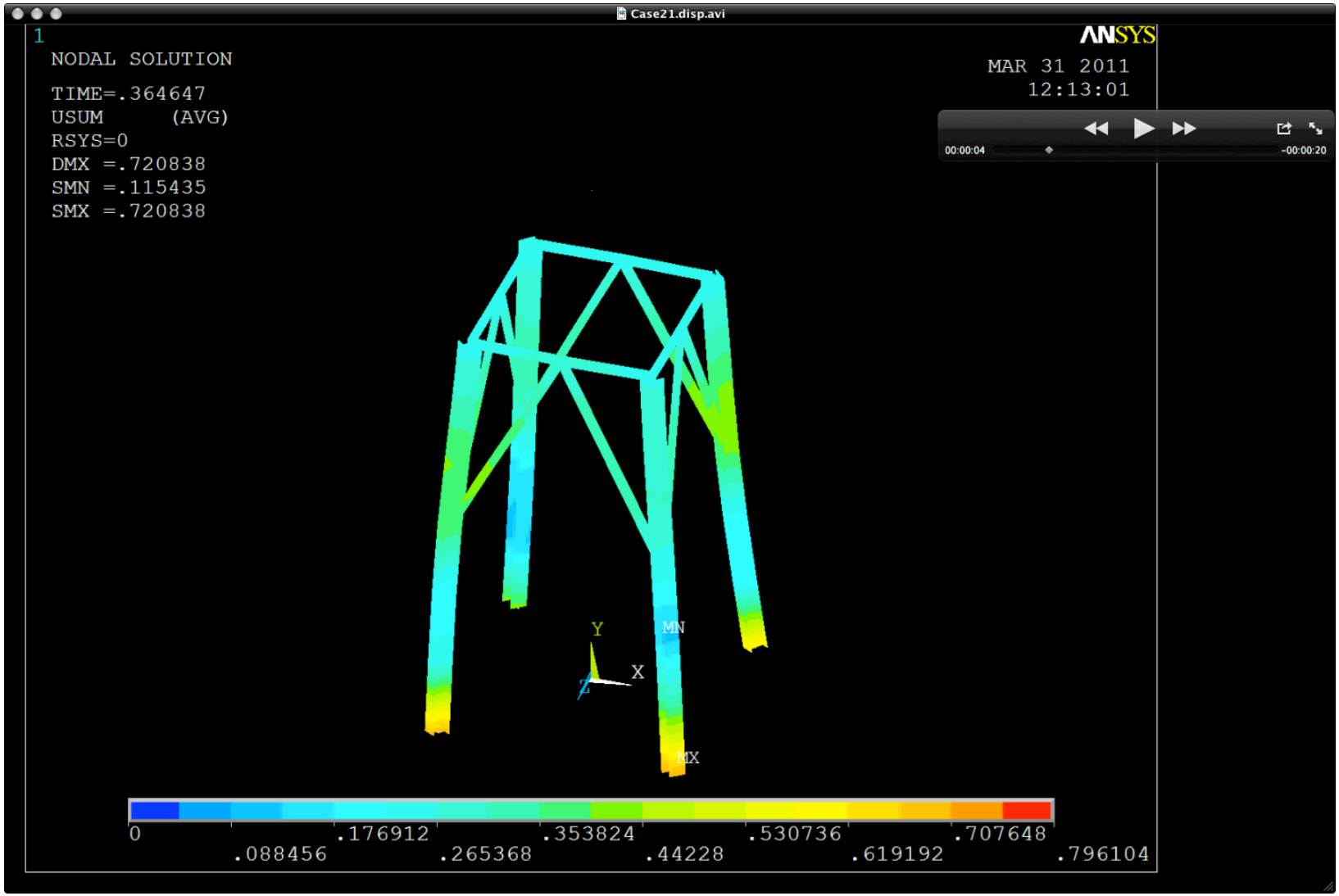

SNOLAB
Cube Hall
Cryopit
Phase III
Stub
Utility
Drift
Ladder Labs
SNO
Cavern
South
Drift
Personnel
facilities
Utility
Area

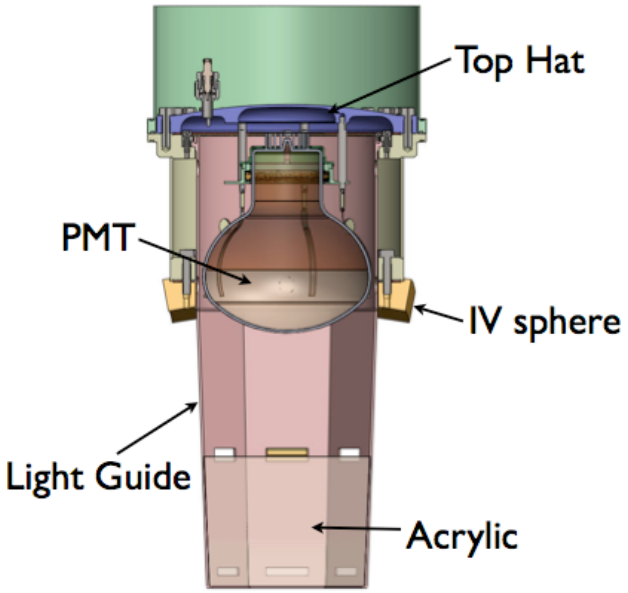
SNOLAB Cube-Hall – January 25, 2011

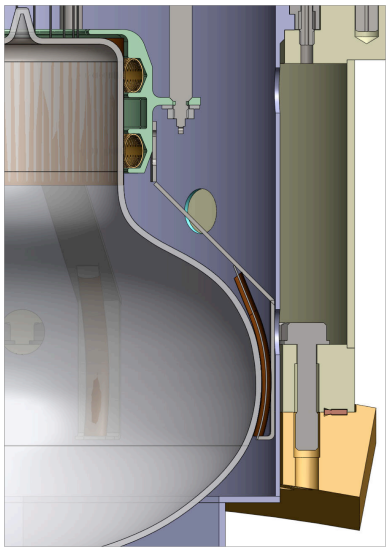
SNOLAB Cube-Hall – MiniCLEAN Water-Shield Tank

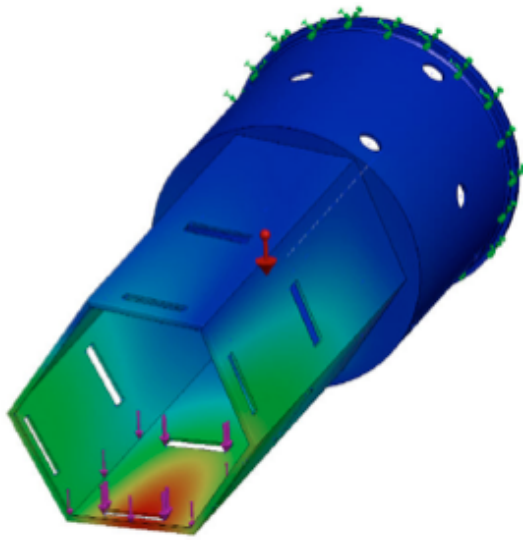
April 15, 2011

Engineering & Fabrication of the OV - Stand





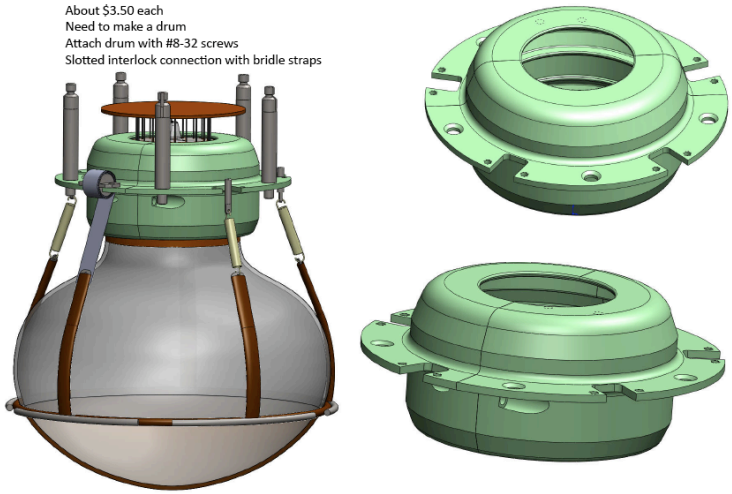




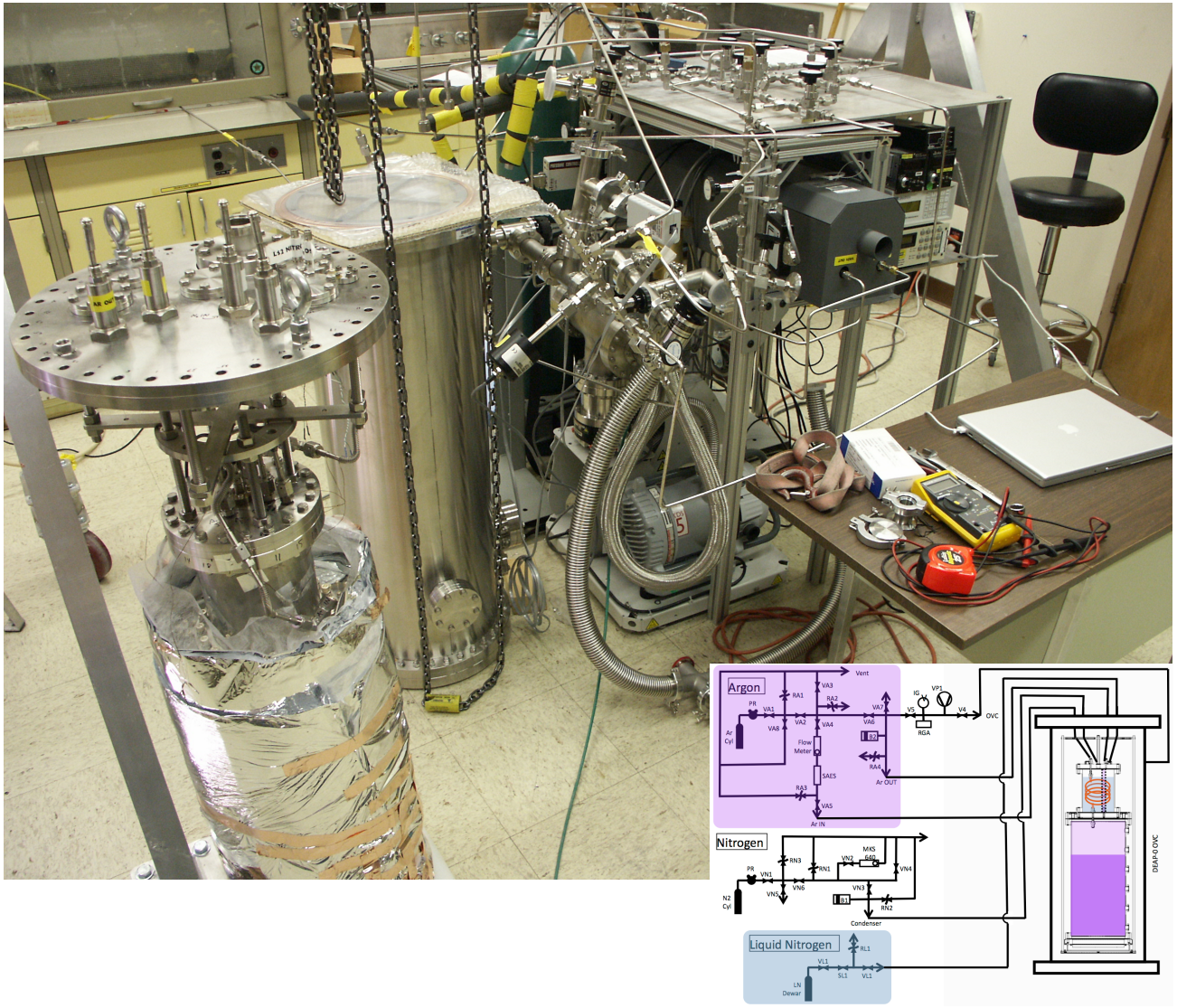
Engineering & Testing Optical Cassette Design

Constant force spring

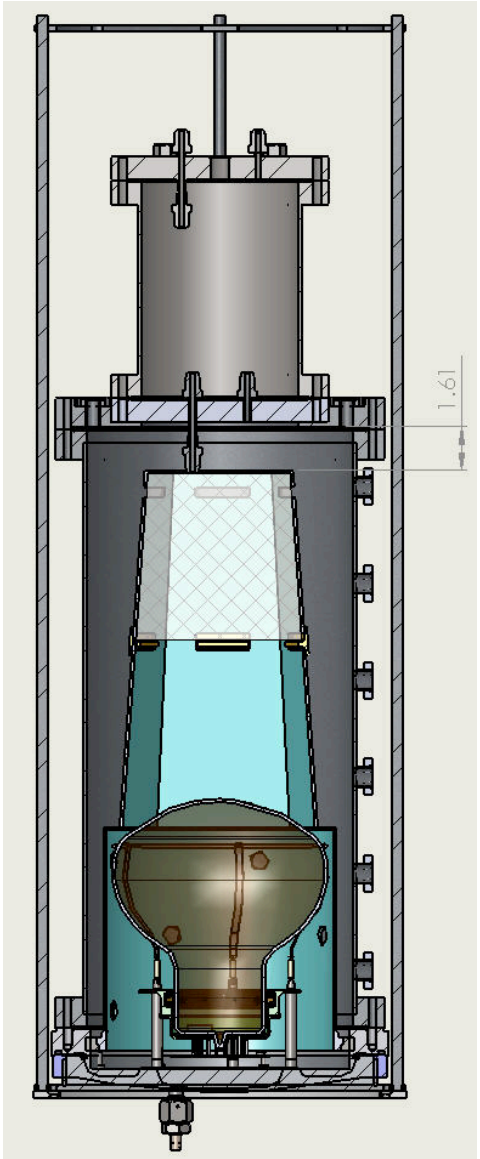
2.63 lbs. constant force regardless of extension range
301 stainless steel
About $3.50 each
Need to make a drum
Attach drum with #8-32 screws
Slotted interlock connection with bridle straps



Dedicated Test Stand for Optical Cassettes



22 in



MiniCLEAN Analysis - Simulations & Calibration

Background Model

Simulation

Calibration

39Ar in Target

PSD

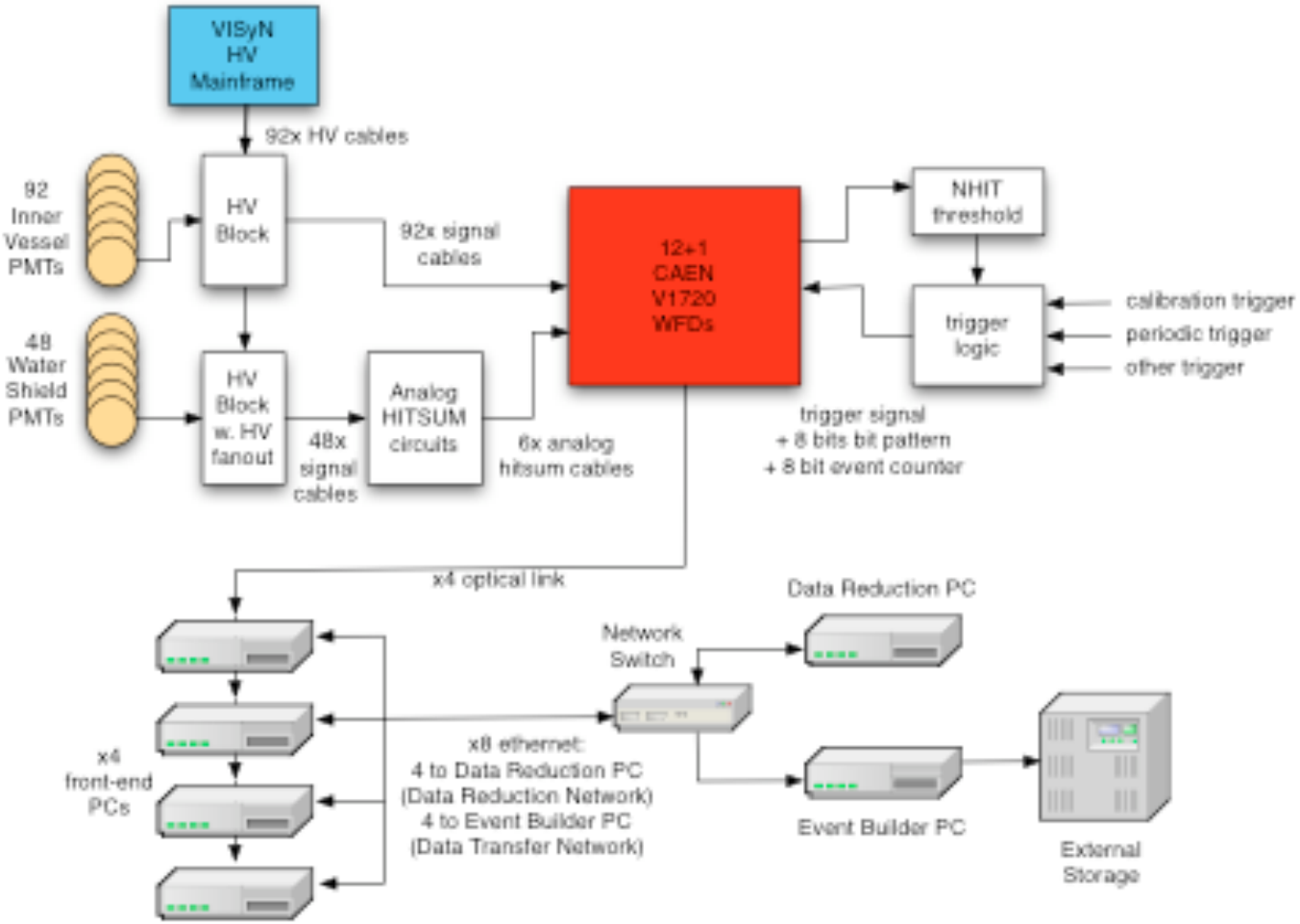
Radon Daughters on WLS-Surface

Control, Fiducialization, PSD

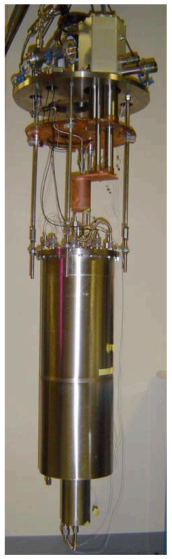
(α, n) in PMTs

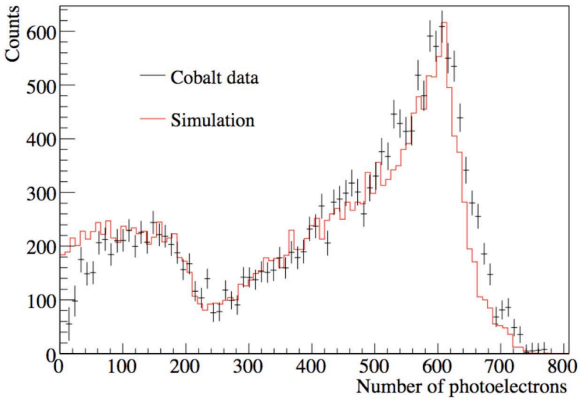
Shielding, Fiducialization, "Tagging"

MiniCLEAN Electronics & DAQ



Micro-CLEAN

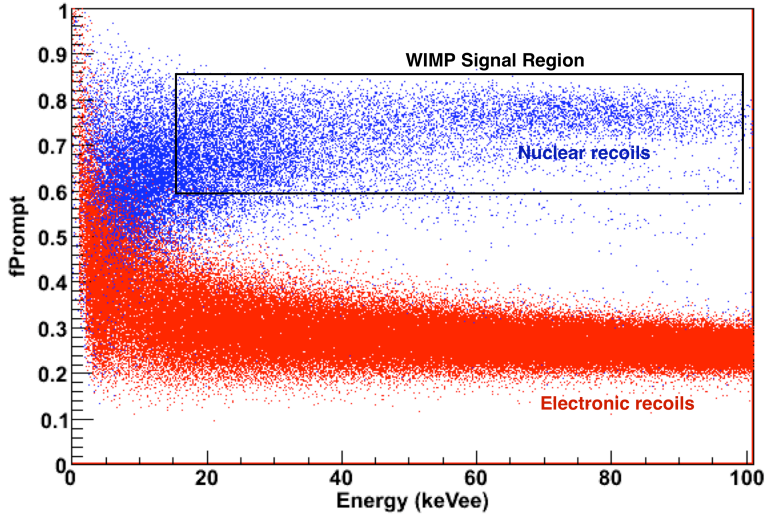




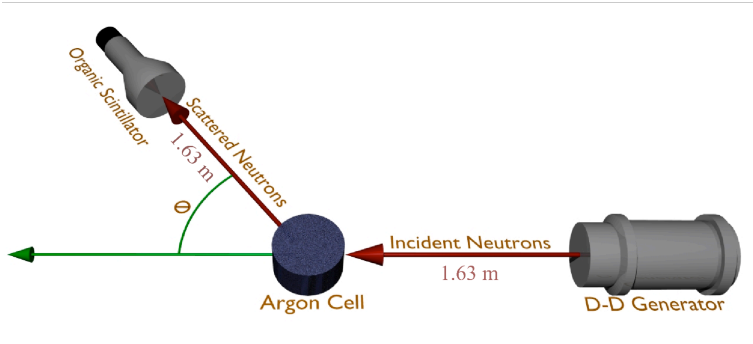
Expected Mini-CLEAN
Light Yield: 6-7 pe/keV

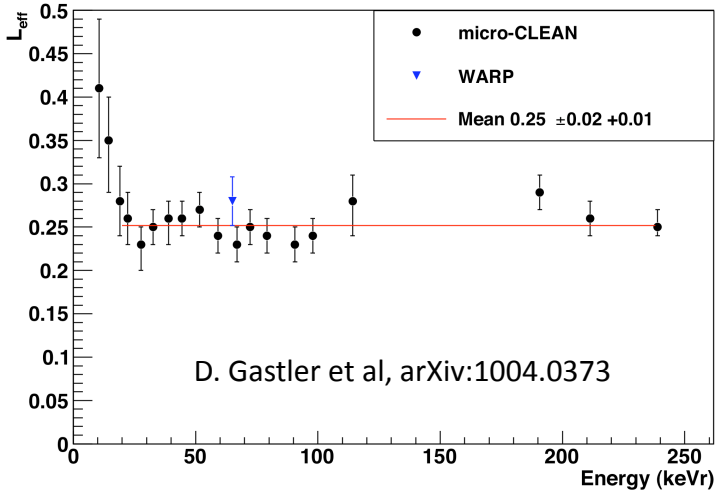
PSD

Lippincott et al, Phys. Rev. C 035801 (2008)

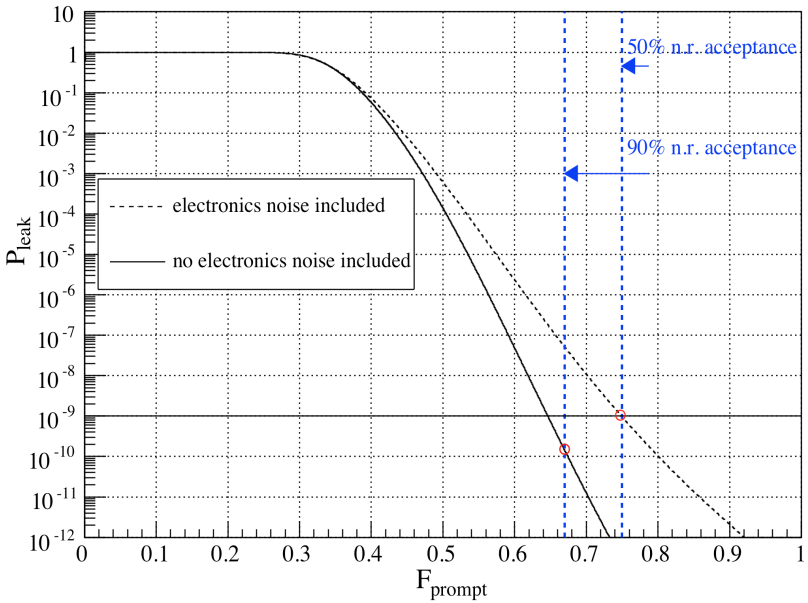


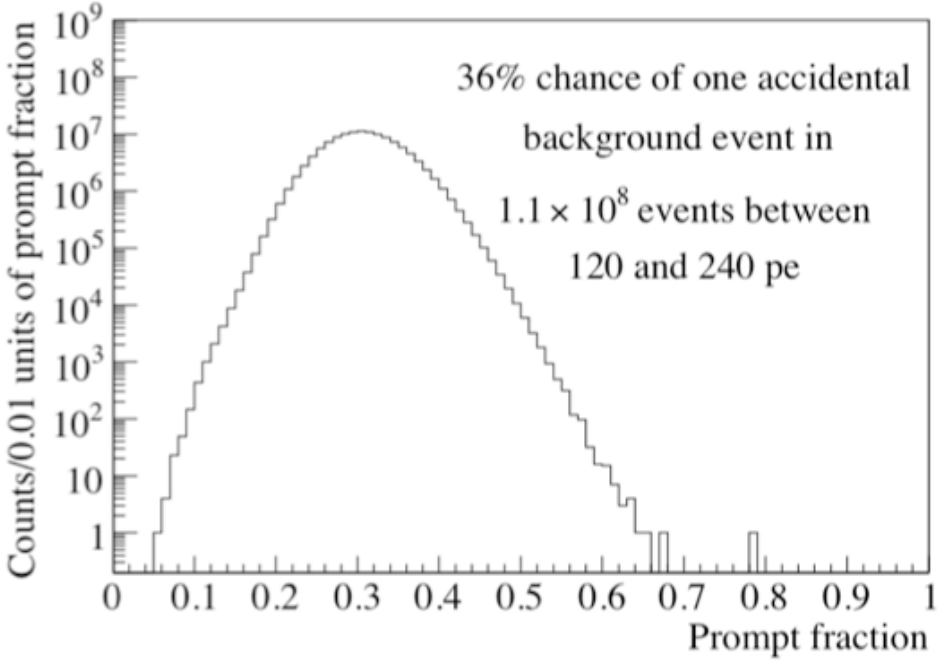
Measurement of Nuclear Recoil Scintillation Yield



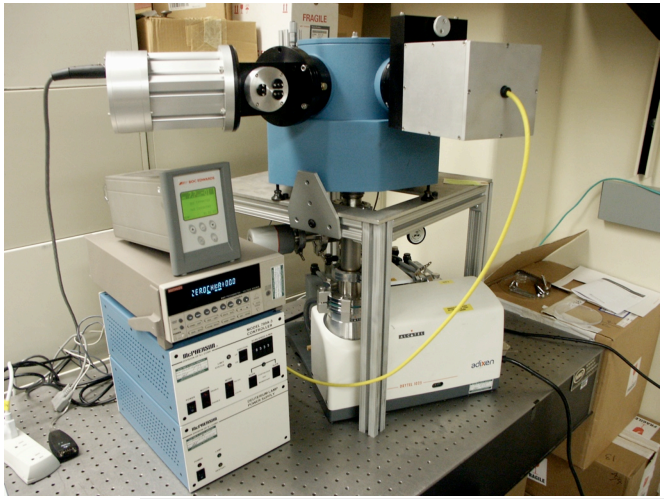


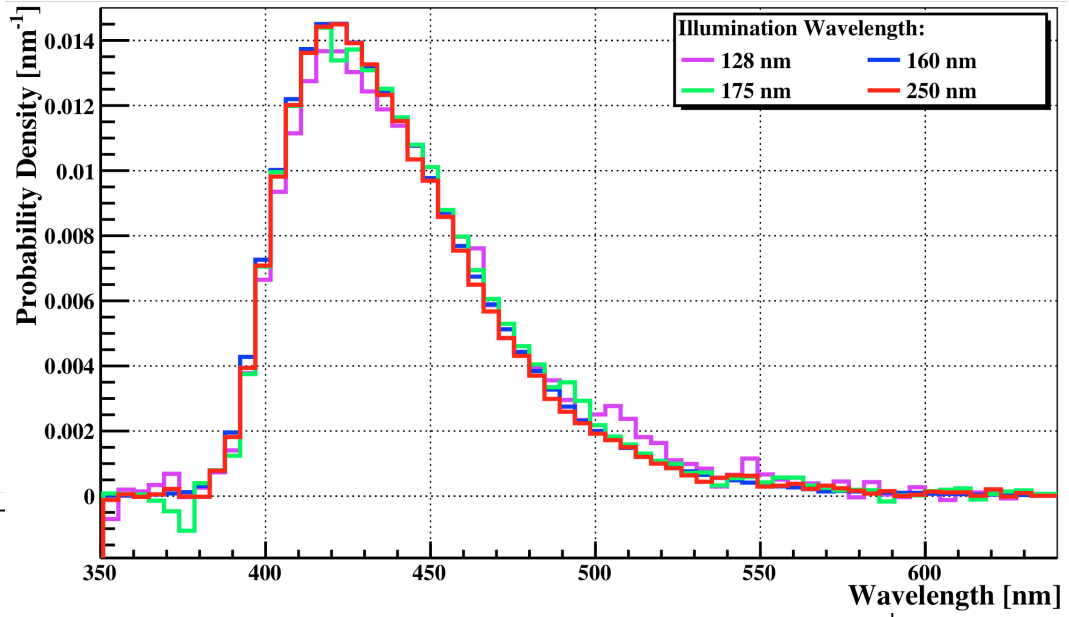
PSD in DEAP-1
(preliminary)

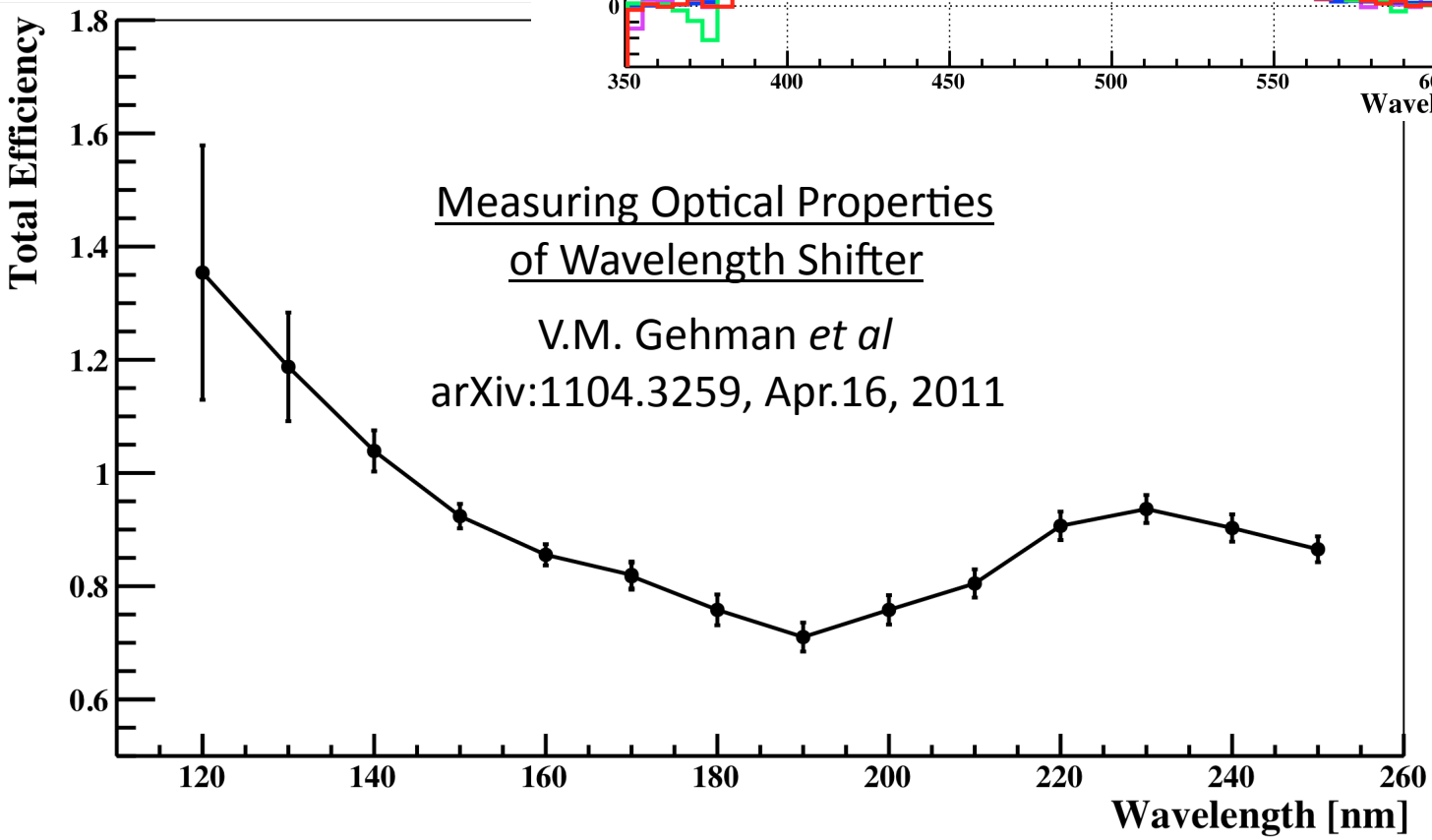




1 Event, consistent with accidental backgrounds,
In the nuclear recoil region of interest … 9.3 x 10^{-9}





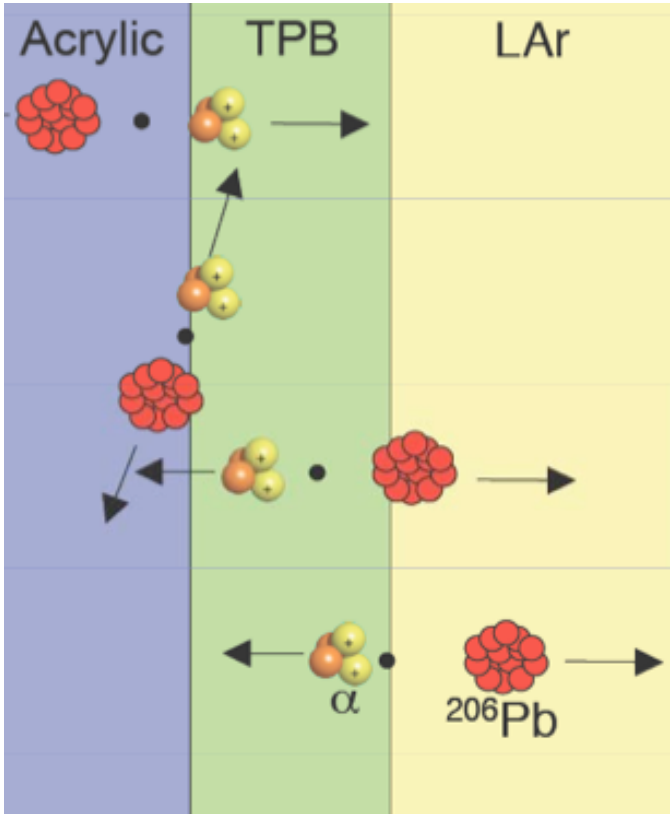


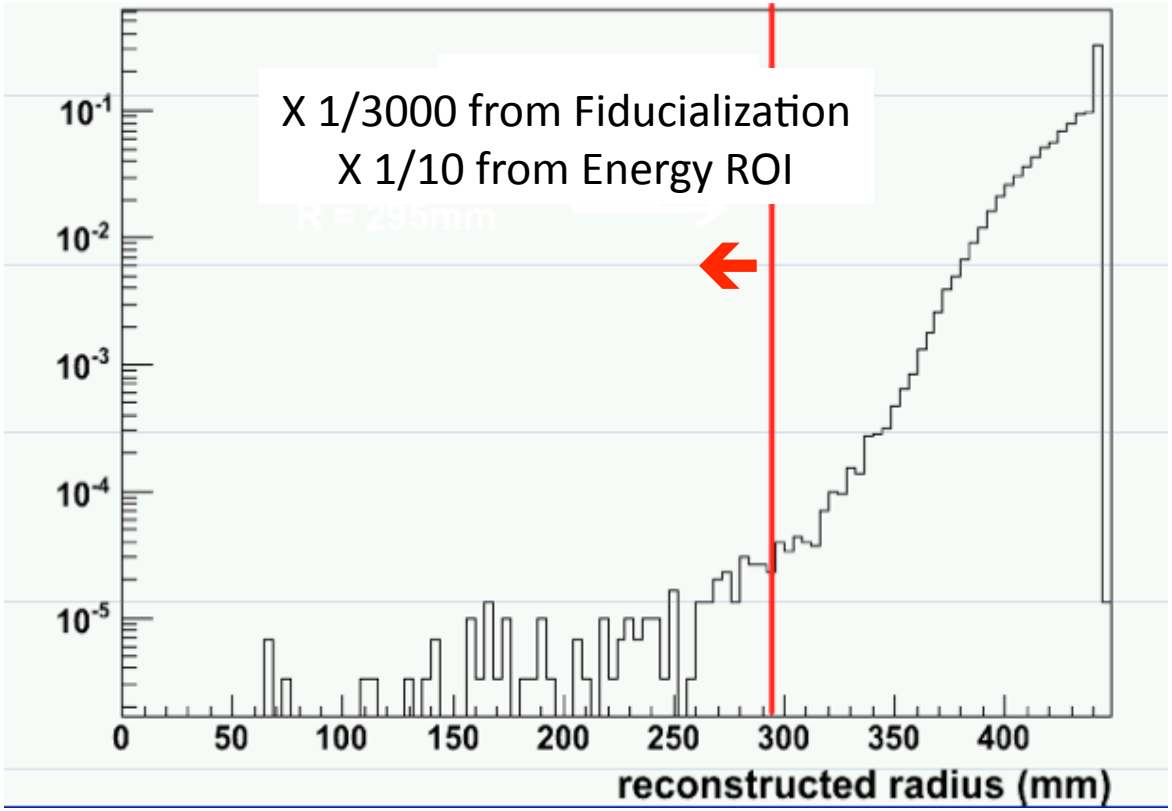
Measuring Optical Properties of Wavelength Shifter

V.M. Gehman *et al*

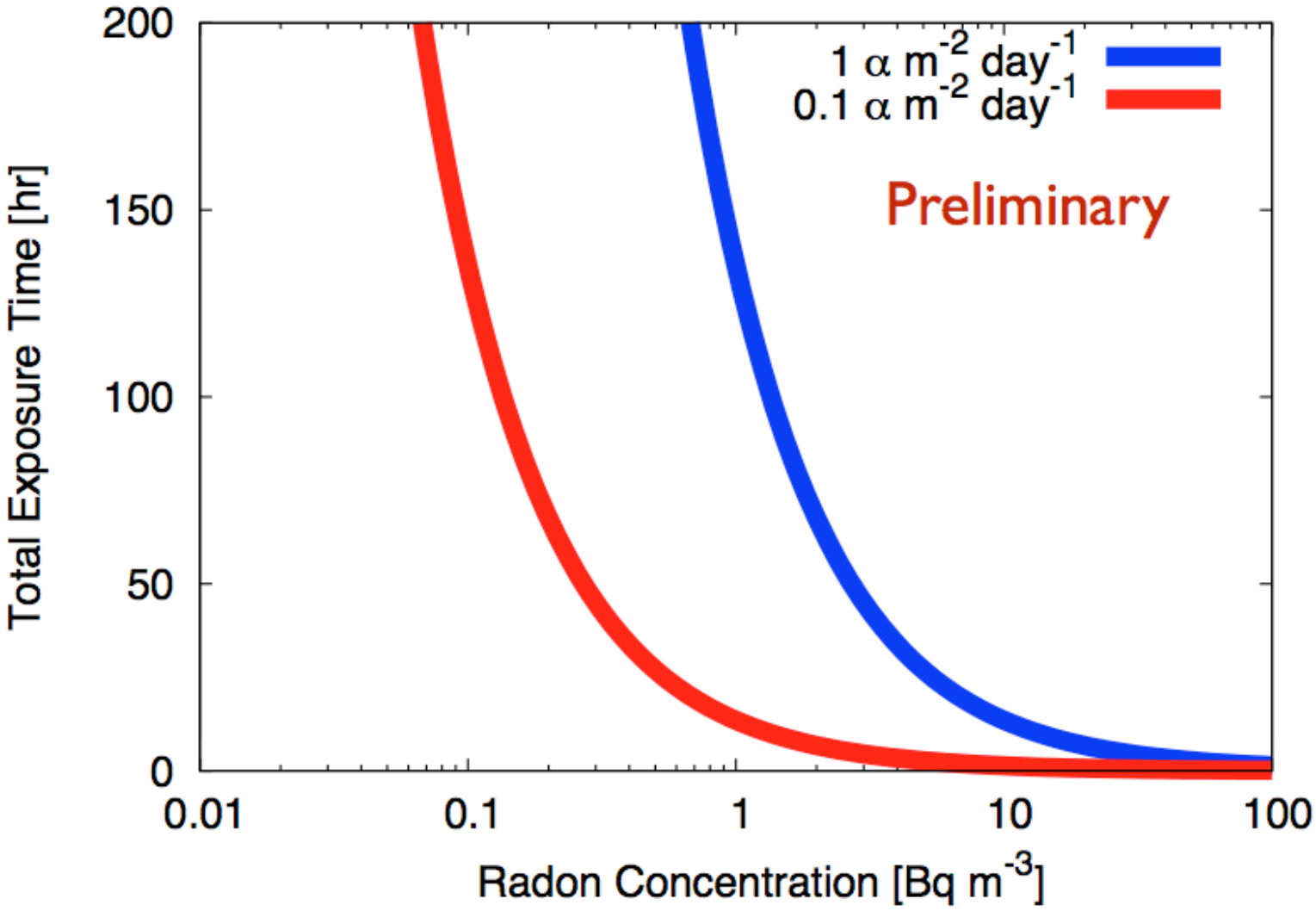
arXiv:1104.3259, Apr.16, 2011

Surface Radon Contamination



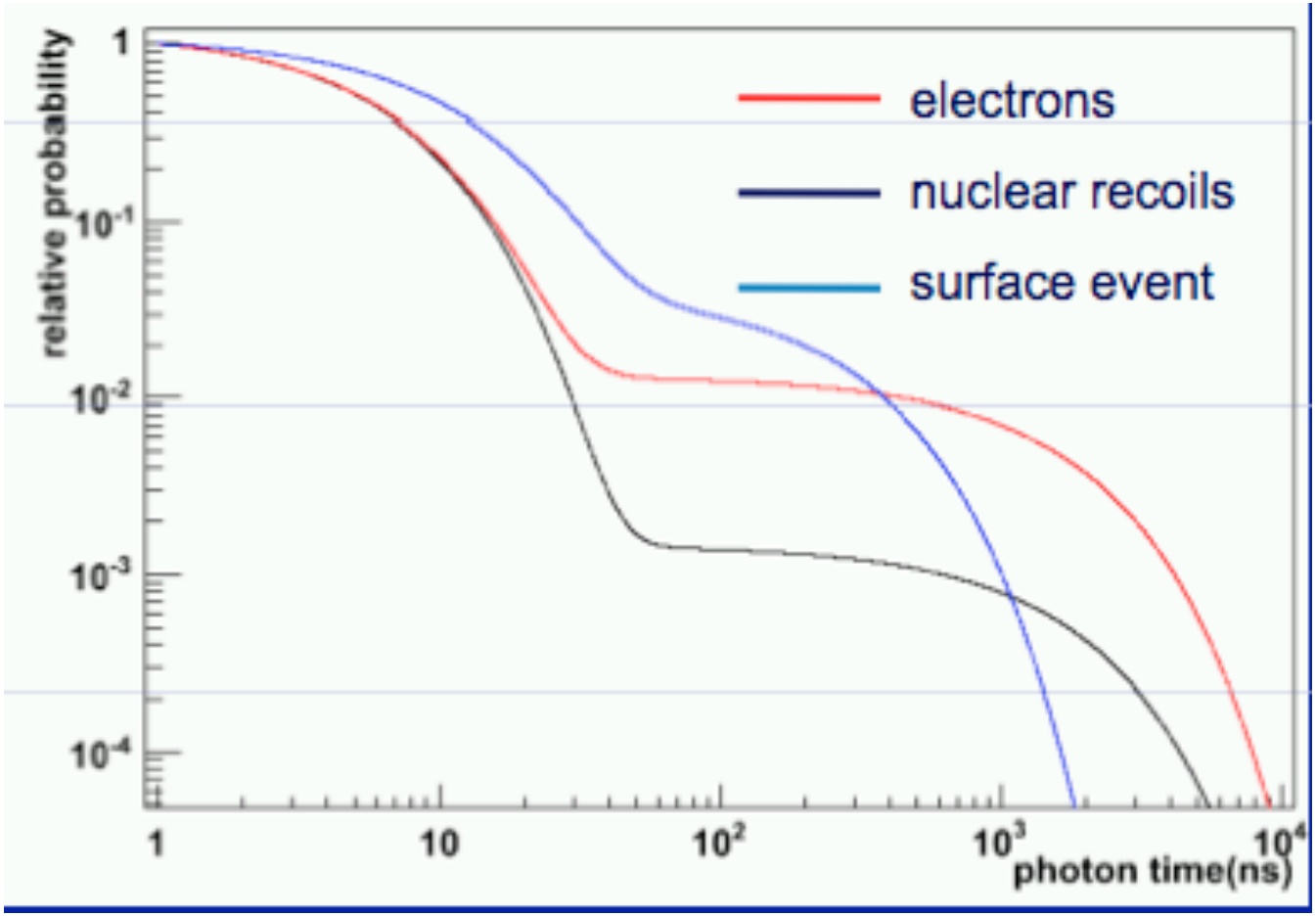


~ 1000 events / year with 1 alpha / sq. meter / day at WLS-Surface


200
150
100
50
0
0.01
0.1
1
10
100
Total Exposure Time [hr]
Radon Concentration [Bq m-3]
1 α m-2 day-1
0.1 α m-2 day-1
Preliminary

Alpha-Scintillation of TPB (WLS) offers Additional PSD-Rejection

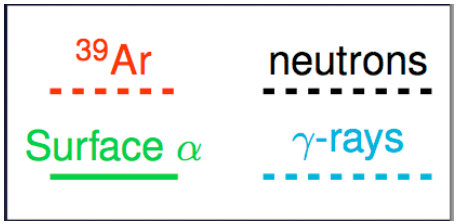
Pollman, Boulay, and Kuzniak, arXiv:1104.3259, Apr.16, 2011

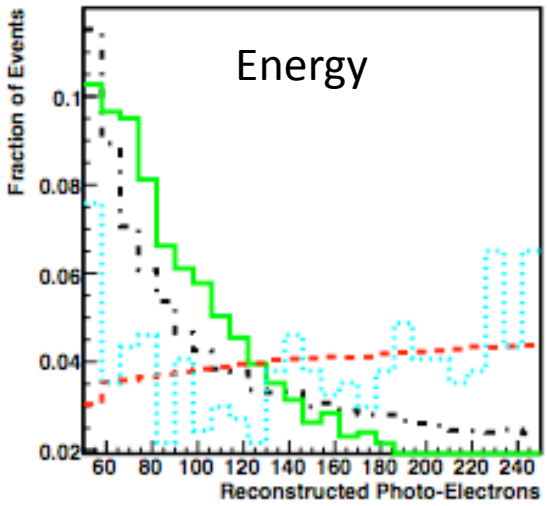


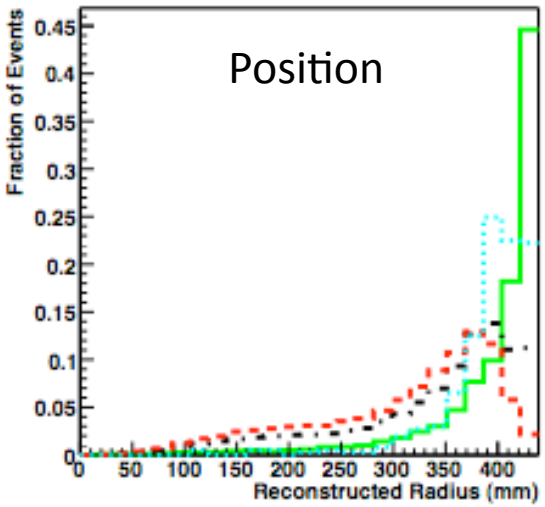
Analysis Philosophy

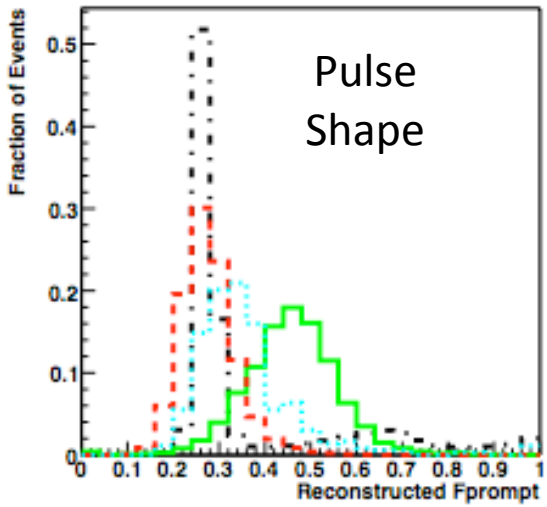
Using our experiences from SNO, SK etc … we aim to develop a robust analysis program where all detector parameters and response to signal and backgrounds are over-constrained through simulation and calibration … signal extraction incorporating a full maximum liklihood algorithm.

Preliminary









MiniCLEAN Calibration

39Ar Uniformly Distributed in Detector Target…

R(Energy, Position)

External Neutron Sources…

(α, n) in PMTs

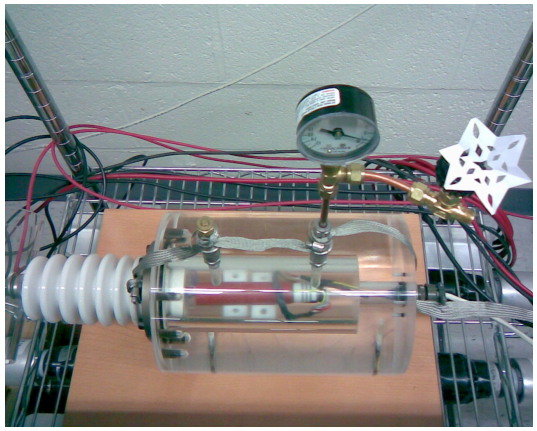
External Gamma Sources…

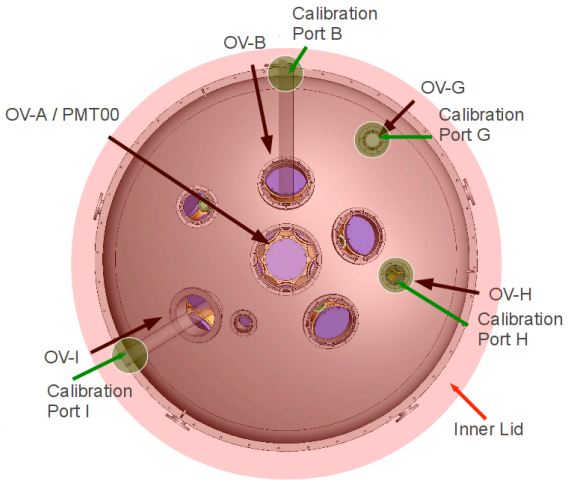
Internal Spikes…

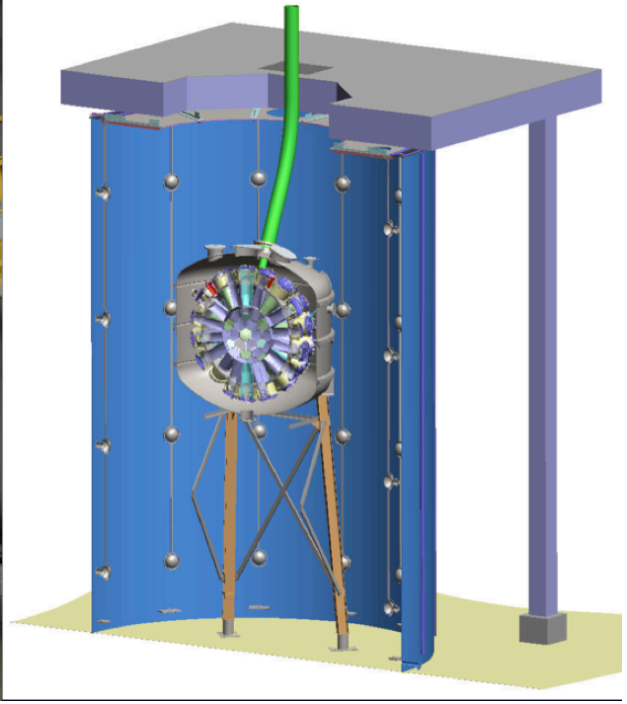
83mKr

39Ar Enrichment

In Situ Optical Sources…

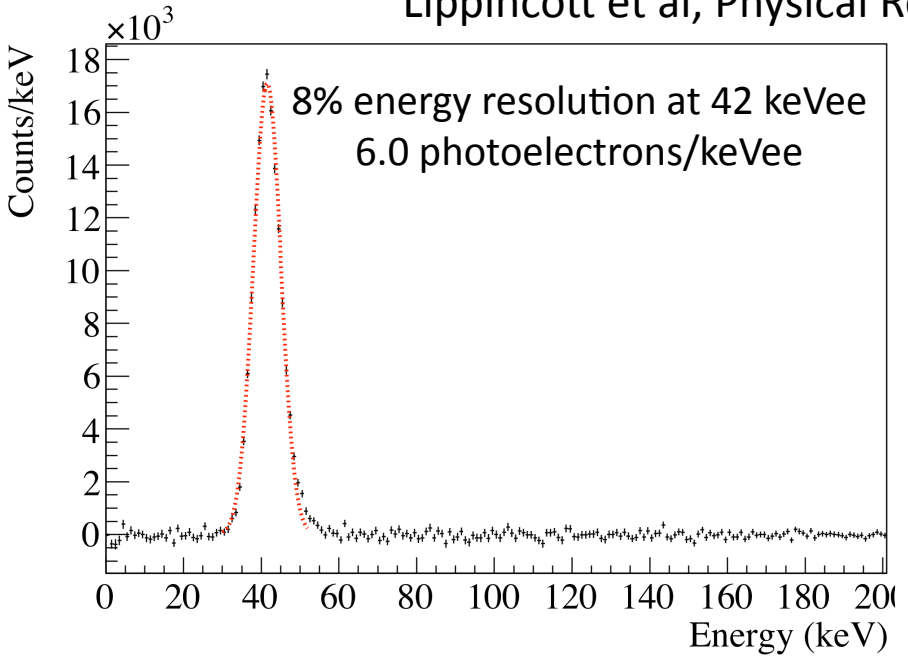


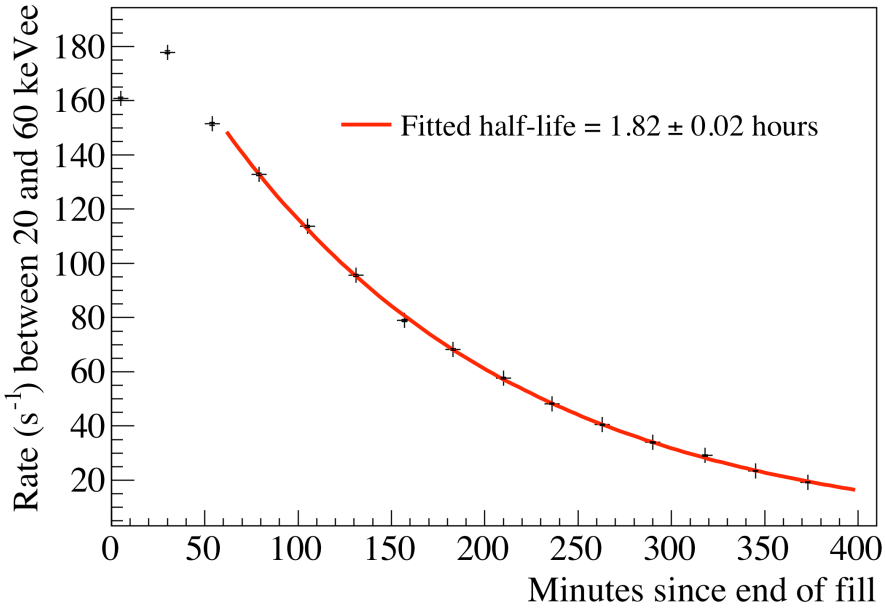


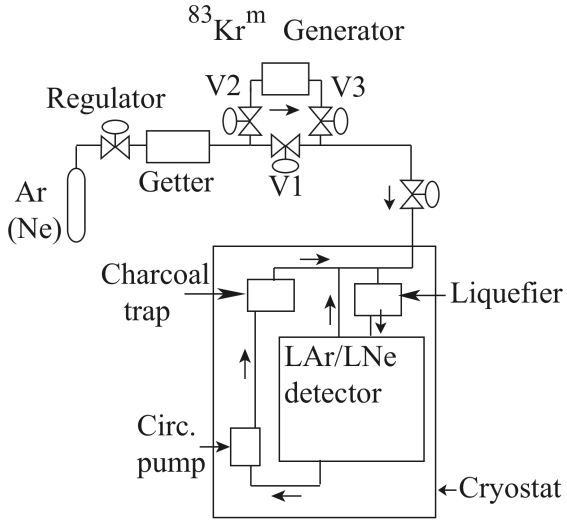


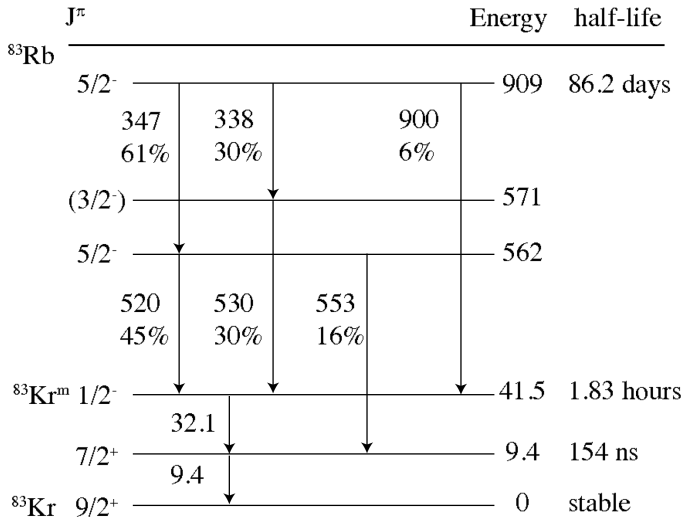
Kr-83m in MicroCLEAN

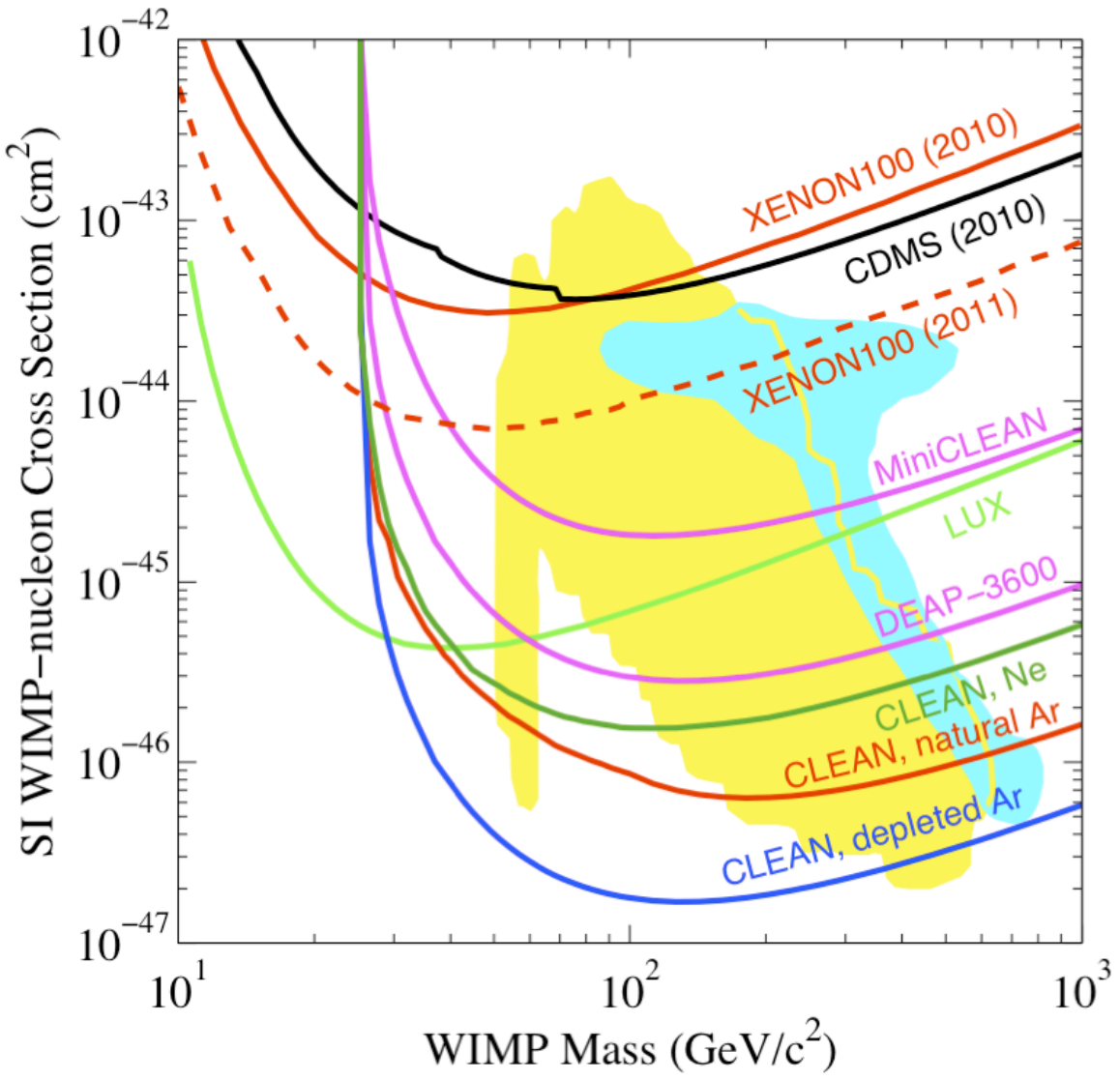
Lippincott et al, Physical Review C 81, 045803 (2010)










SI WIMP–nucleon Cross Section (cm^2)
WIMP Mass (GeV/c^2)
10^{-42}
10^{-43}
10^{-44}
10^{-45}
10^{-46}
10^{-47}
10^1
10^2
10^3
XENON100 (2010)
CDMS (2010)
XENON100 (2011)
MiniCLEAN
LUX
DEAP–3600
CLEAN, Ne
CLEAN, natural Ar
CLEAN, depleted Ar

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Thank You