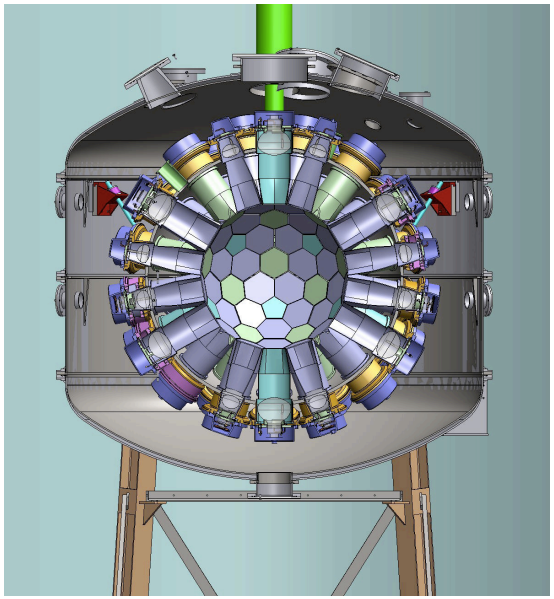
CLEAN Detection of Low Energy Nuclear Recoil

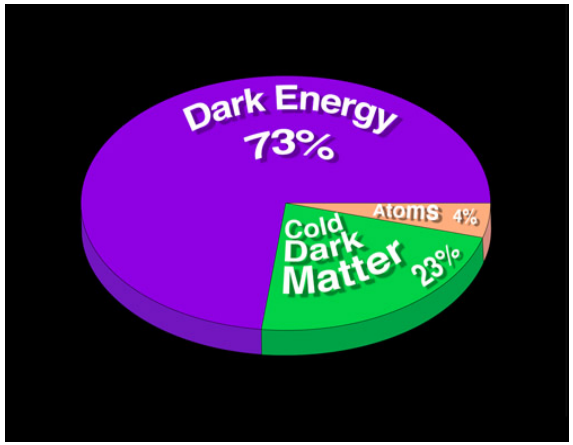


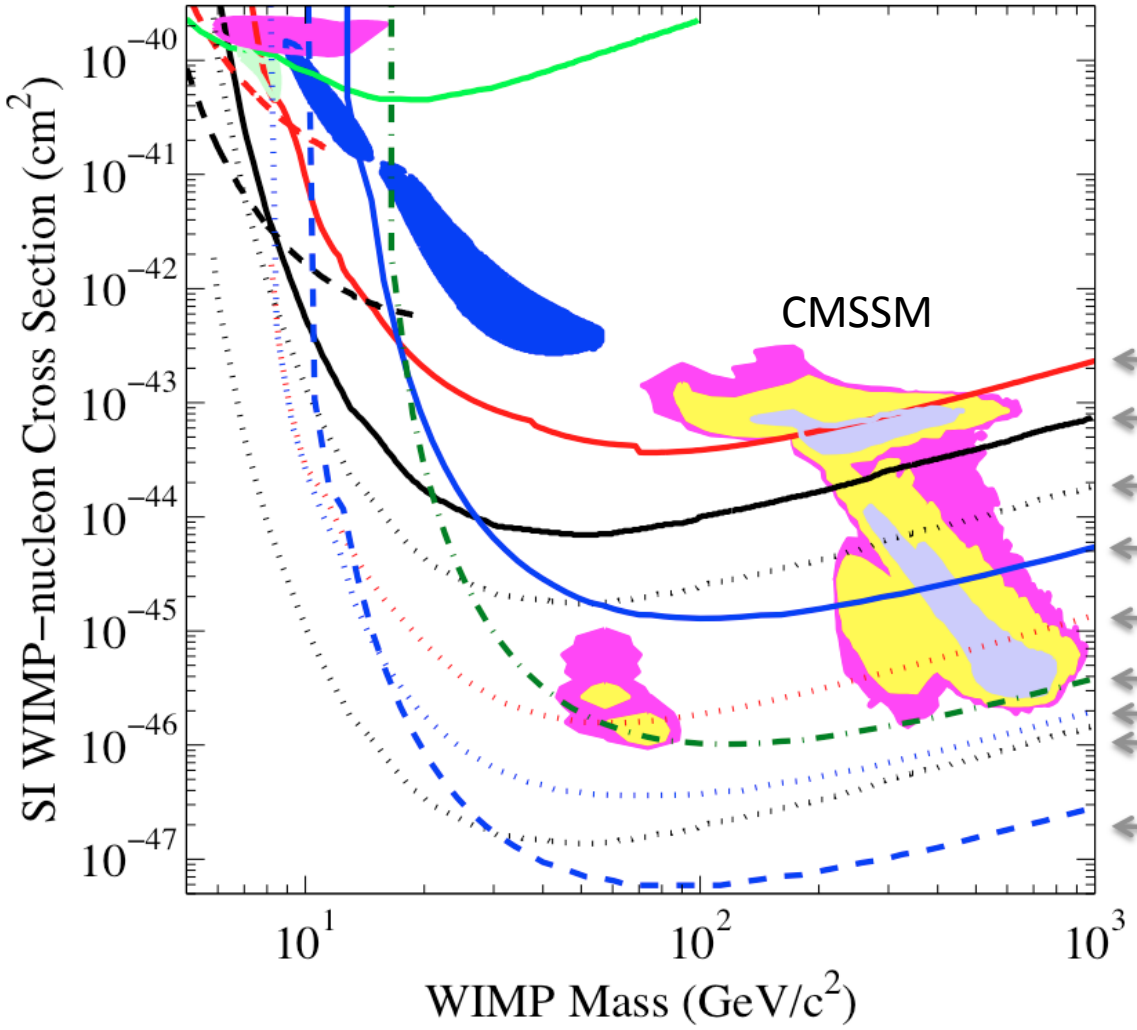
Los Alamos
NATIONAL LABORATORY
EST. 1943

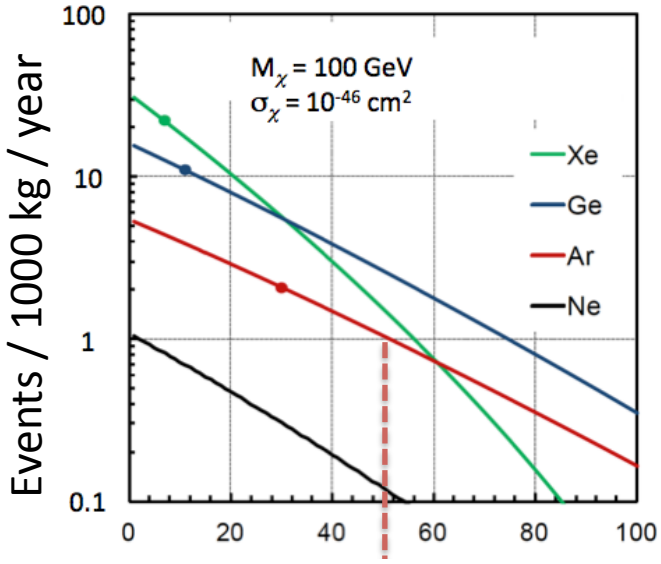
Mini-Workshop for Coherent-NC*v*As

FermiLab, Oct.10, 2012

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







150 kg-yrs

3,000 kg-yrs

45,000 kg-yrs

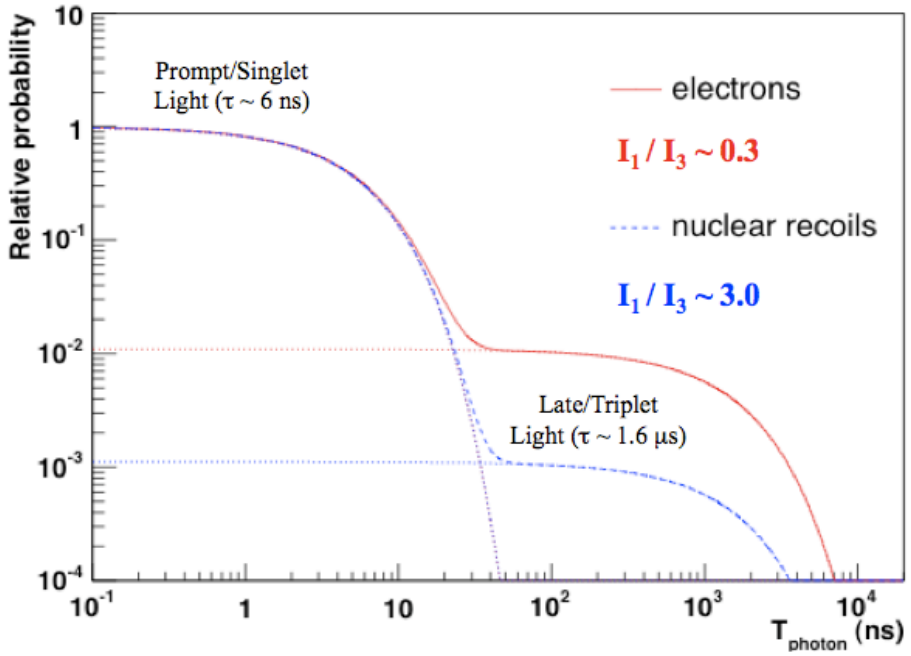
15,000 kg fiducial mass

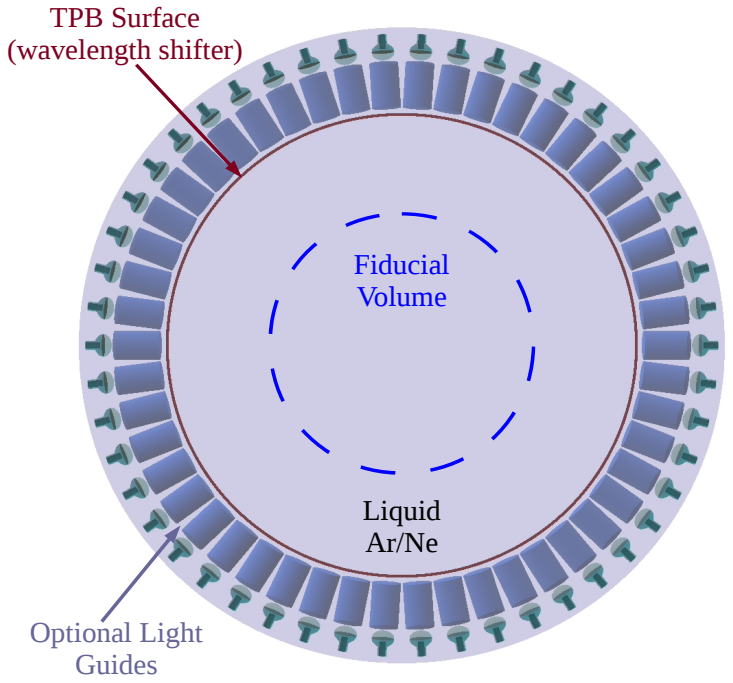
3 yrs

~15 events/yr @ 10^{-46} cm^2

Single-Phase Detector

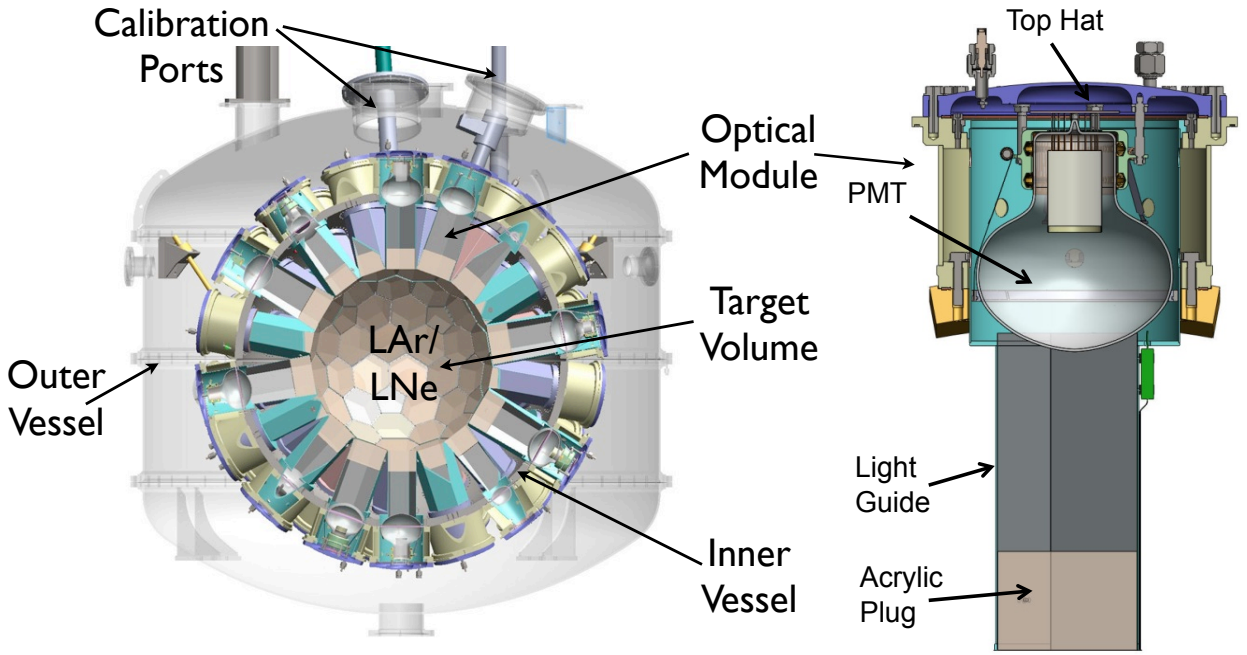
M.G. Boulay and A. Hime
*Astroparticle Physics **25**, 179 (2006)*





MiniCLEAN Modular Design

- 4π coverage to maximize light-yield at threshold …
  - 3D Position Reconstruction
  - Particle-ID via Pulse-shape discrimination
- Radon-reduced assembly …
- "Cold" design allows both LAr & LNe …
- No electric fields … PMTs only active component …
- Fast signals (τ_3 = 1.6 μs) avoid pulse-pileup in LAr …



MiniCLEAN Collaboration

Boston University

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University of California – Berkeley

G.D. Orebi Gann

Los Alamos National Laboratory

M. Akashi-Ronquest, R. Bingham, R. Bourque, E. Flores, J. Griego, R. Hennings-Yeomans, A. Hime, S. Jaditz, F. Lopez,J. Oertel, K. Rielage, L. Rodriguez

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University of South Dakota

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Syracuse University

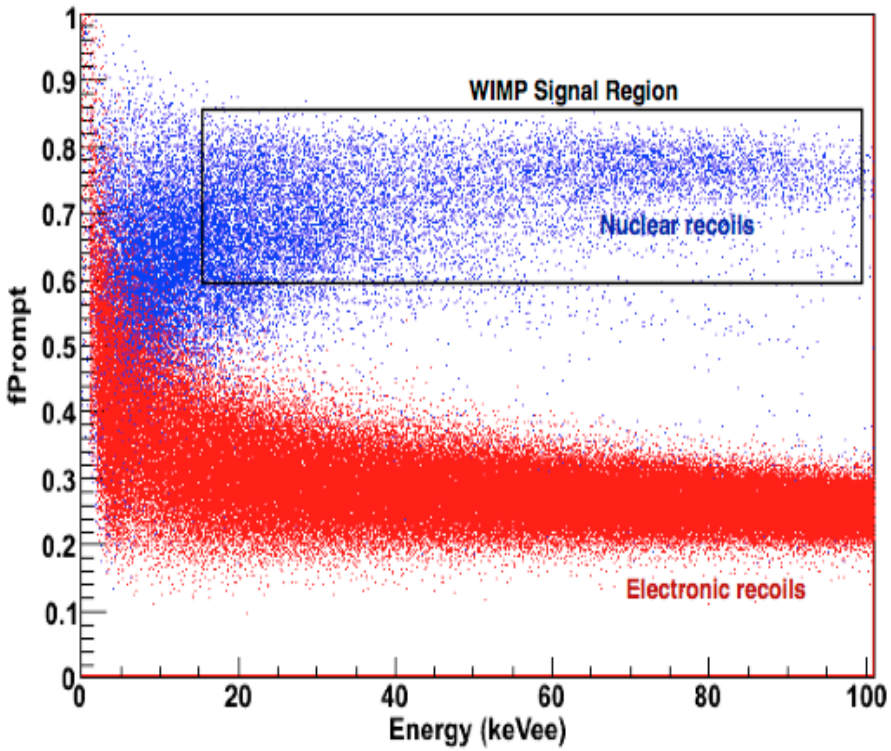
R. Bunker, Y. Chen, R.W. Schnee, B. Wang

Yale University

D.N. McKinsey

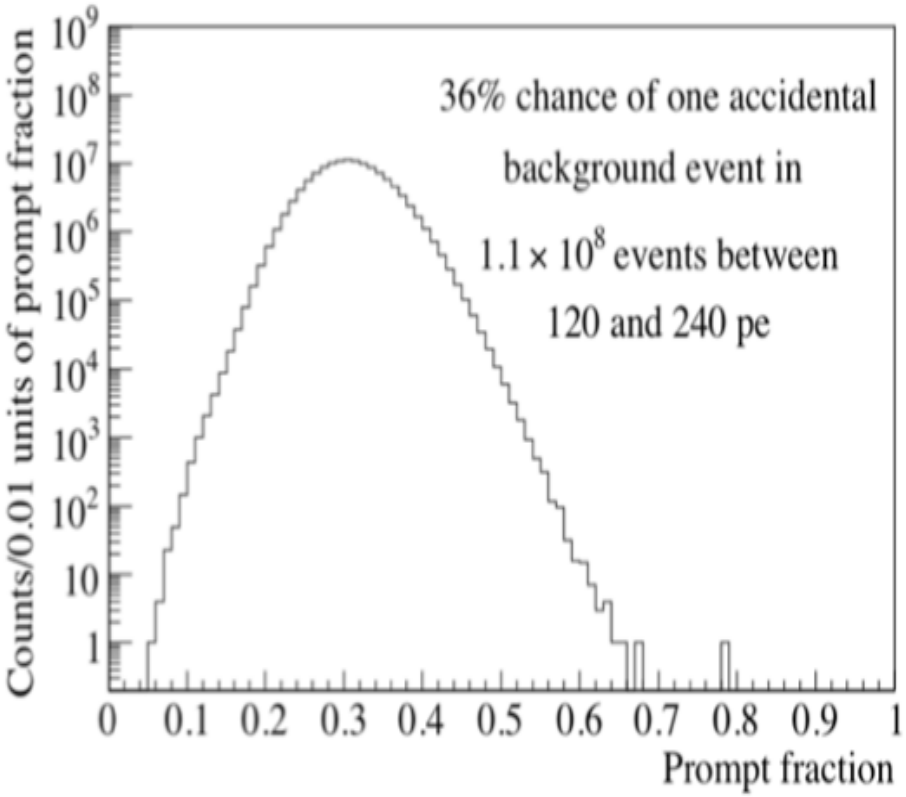
Experimental Measurements of PSD in LAr

microCLEAN

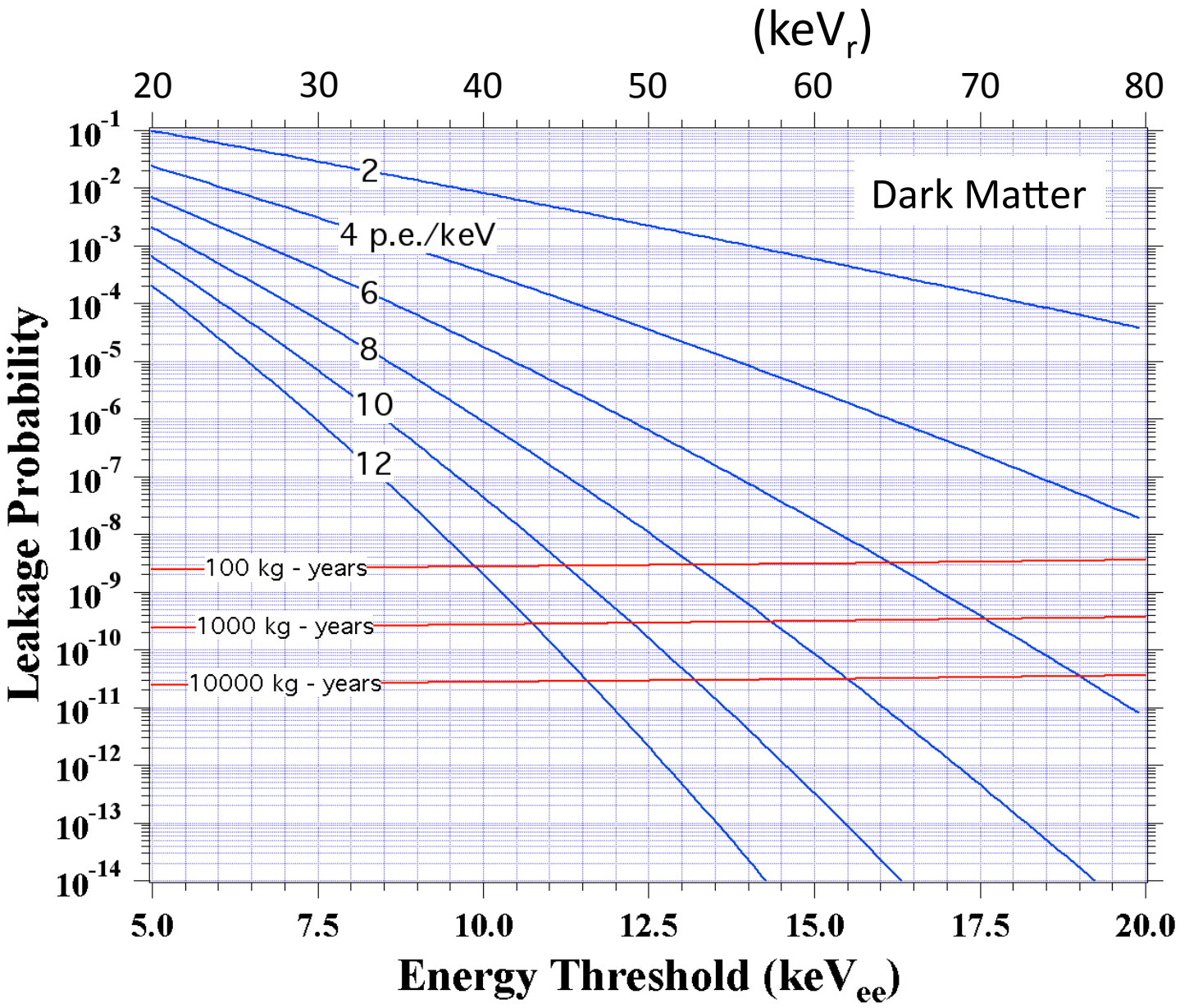


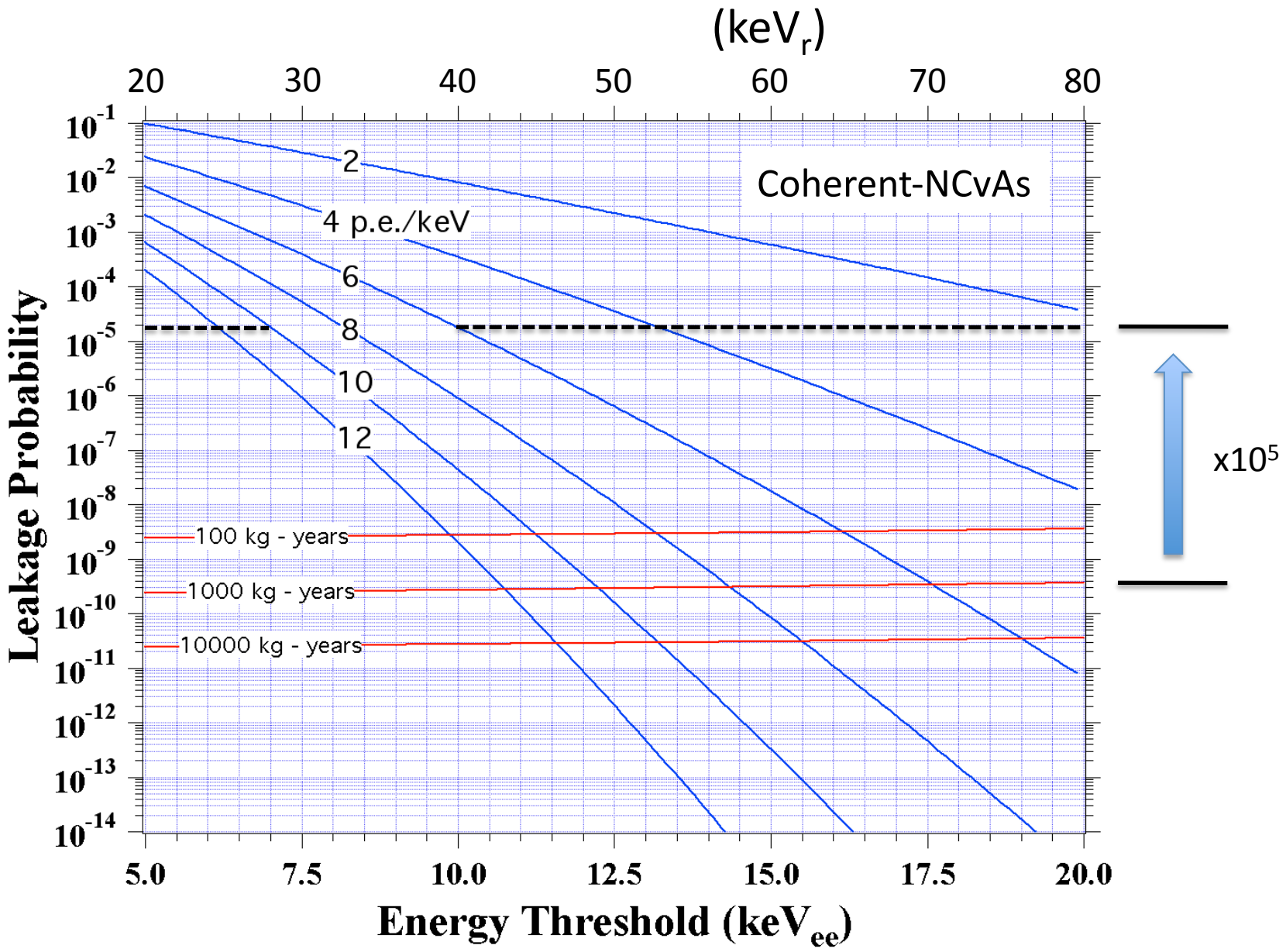
Phys. Rev. C**78**, 035801 (2008)

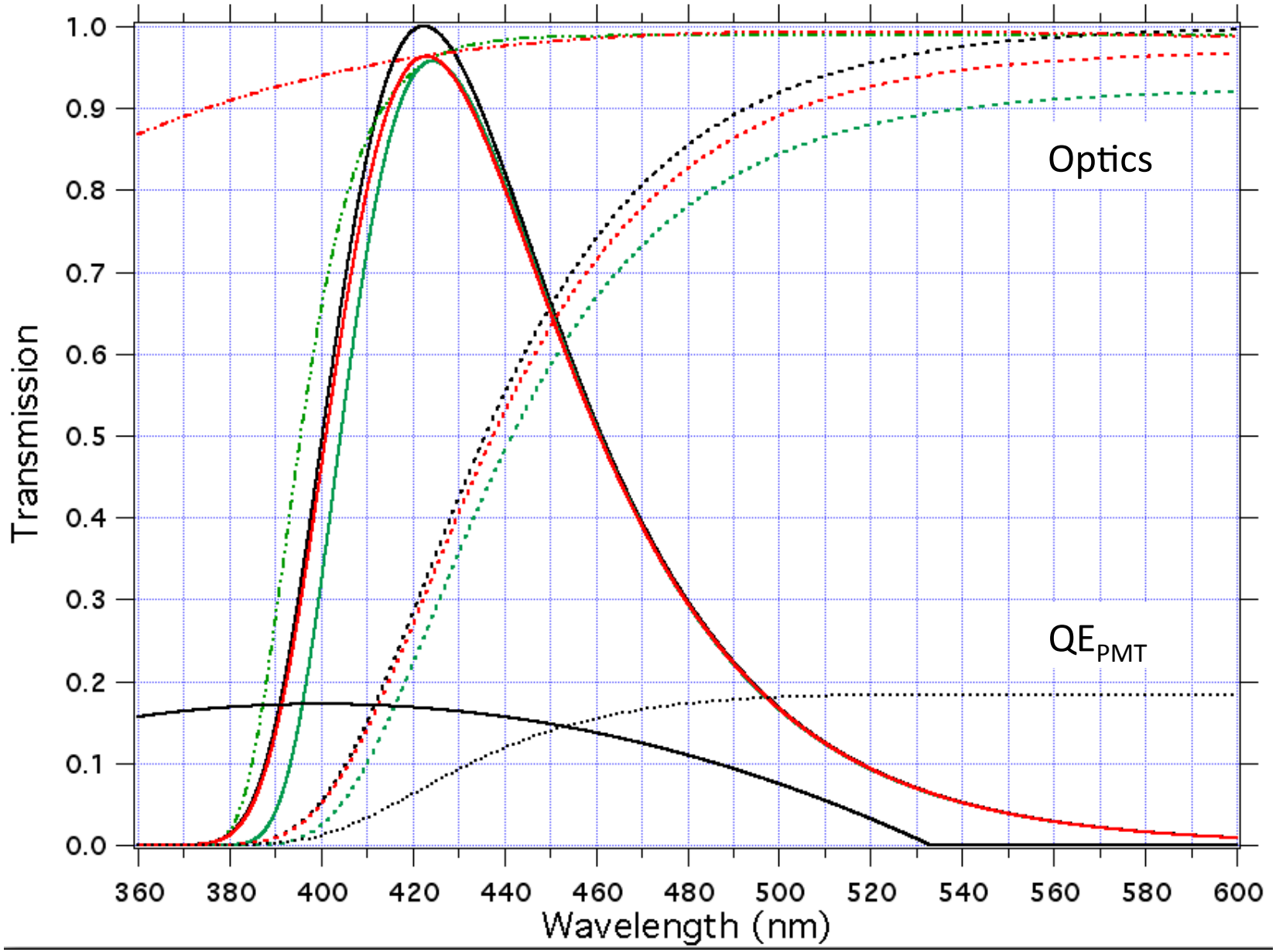
DEAP-1



arXiv:0904.2903 (2009)
TAUP - 2011

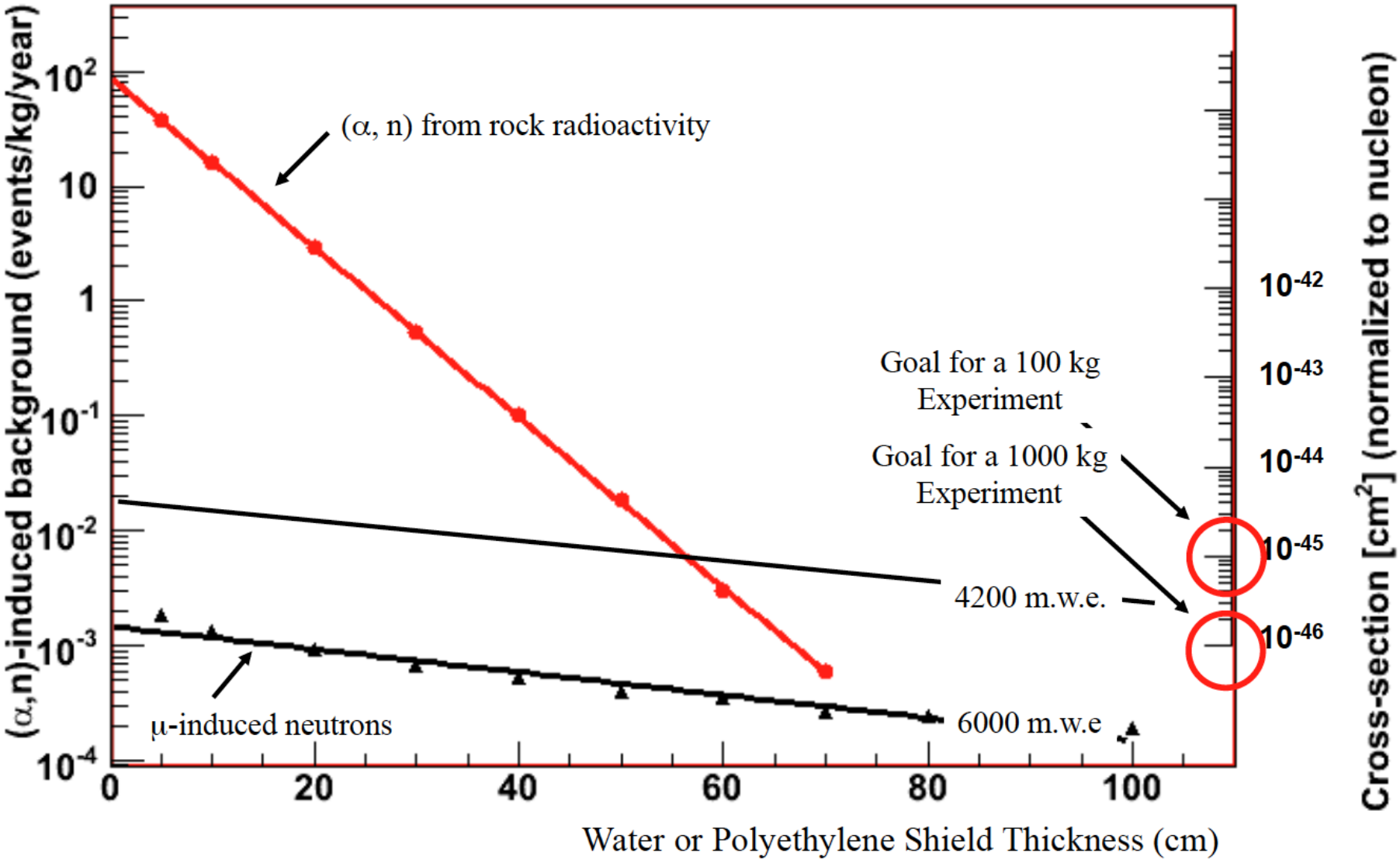

(keV$_r$)
20
30
40
50
60
70
80
Dark Matter
2
4 p.e./keV
6
8
10
12
100 kg - years
1000 kg - years
10000 kg - years
Leakage Probability
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-10}
10^{-11}
10^{-12}
10^{-13}
10^{-14}
5.0
7.5
10.0
12.5
15.0
17.5
20.0
Energy Threshold (keV$_{ee}$)

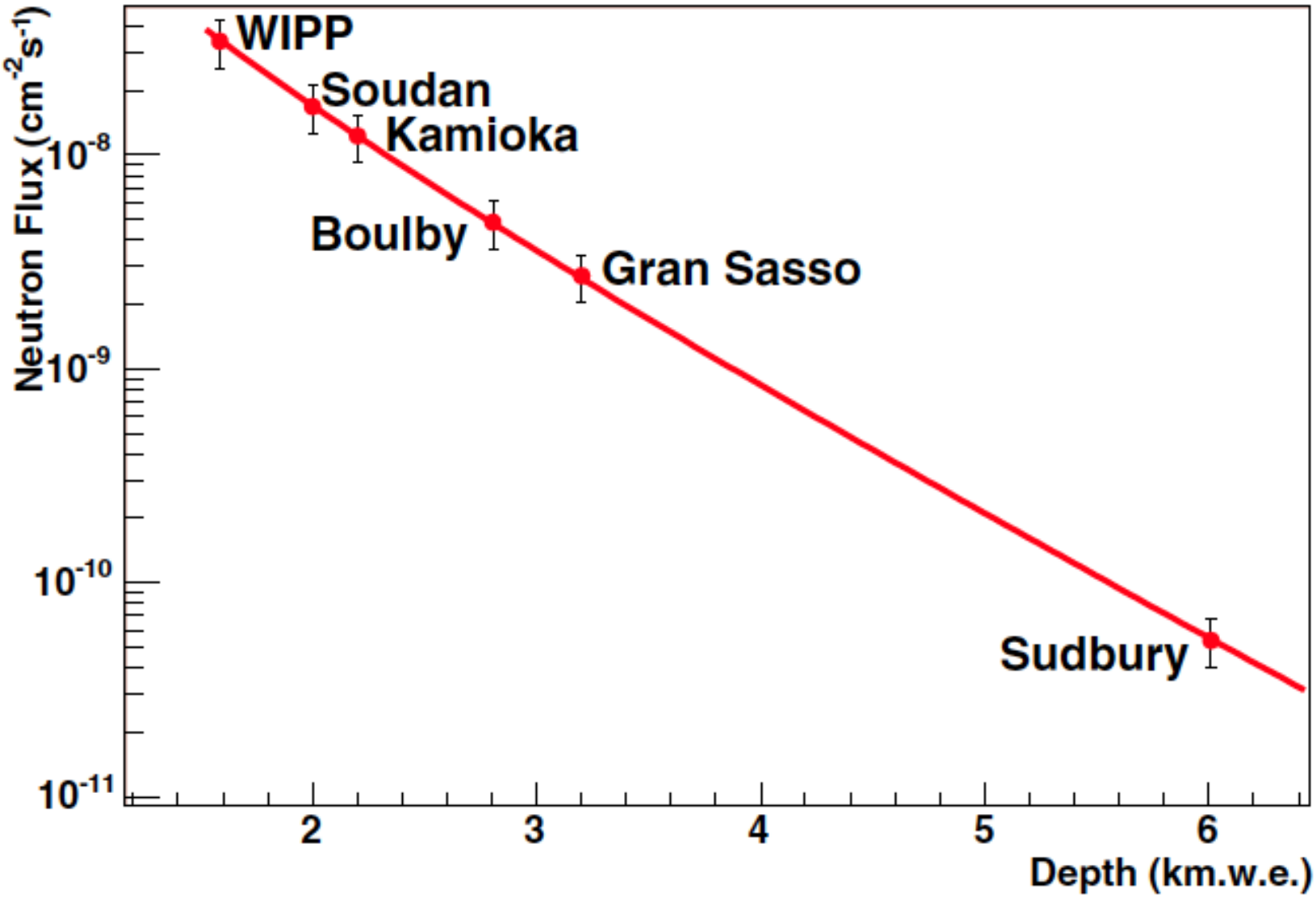

(keV$_r$)
20
30
40
50
60
70
80
Coherent-NCvAs
2
4 p.e./keV
6
8
10
12
100 kg - years
1000 kg - years
10000 kg - years
x10^5
Leakage Probability
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-10}
10^{-11}
10^{-12}
10^{-13}
10^{-14}
5.0
7.5
10.0
12.5
15.0
17.5
20.0
Energy Threshold (keV$_{ee}$)

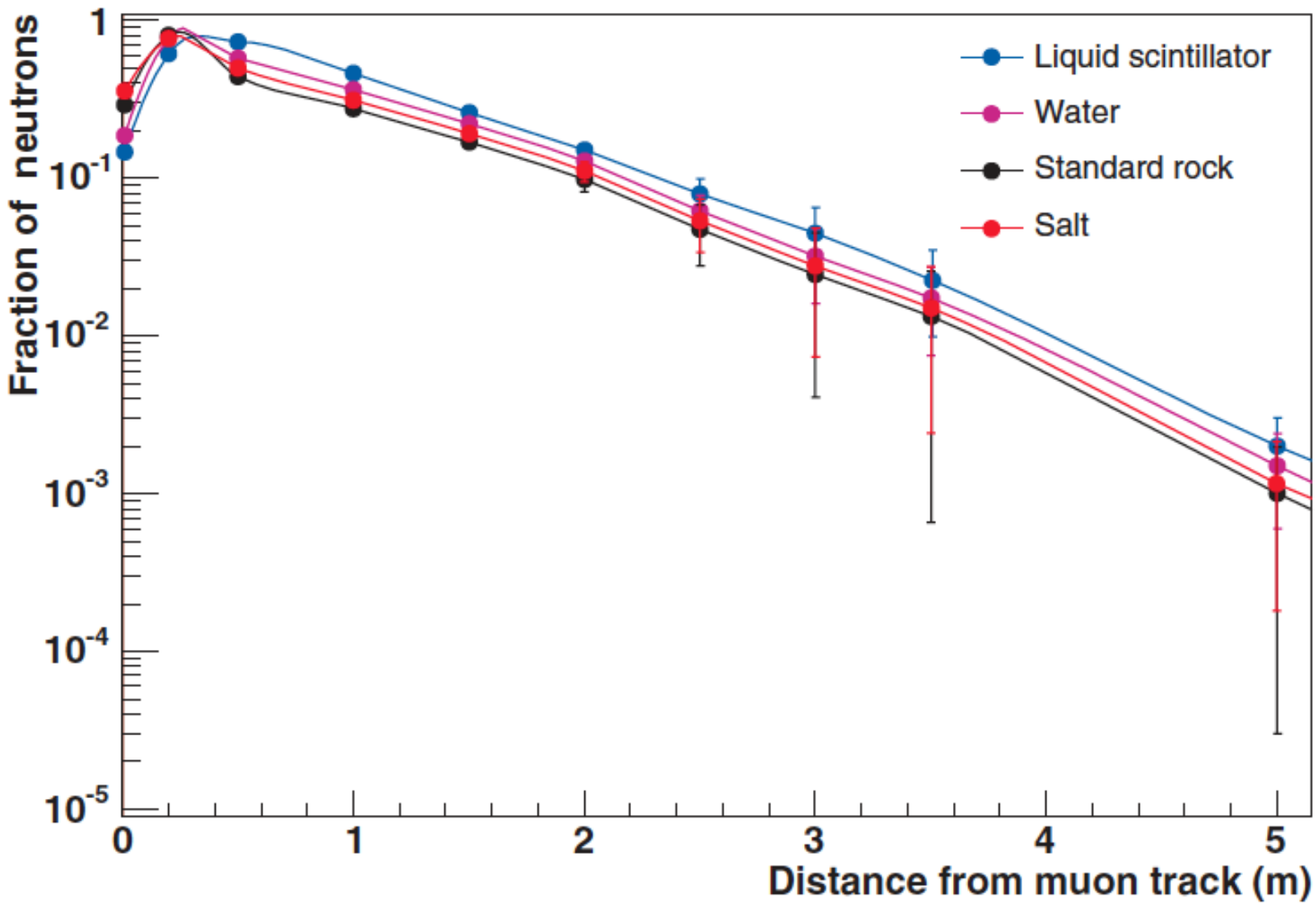

Transmission
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
360
380
400
420
440
460
480
500
520
540
560
580
600
Wavelength (nm)
Optics
QE$_{PMT}$

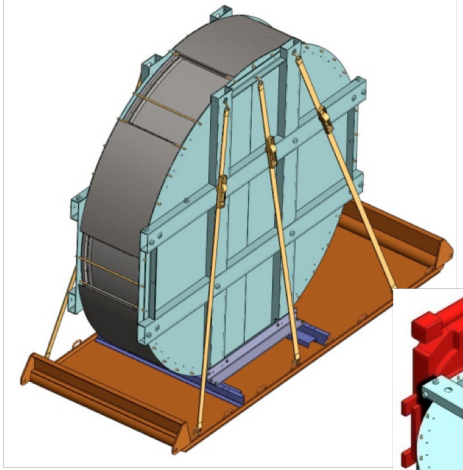
External Shielding

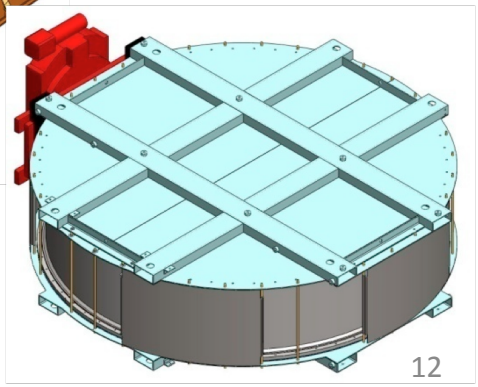
Using Formalism of D.-M. Mei & A. Hime
Phys. Rev. D73, 053004 (2006)

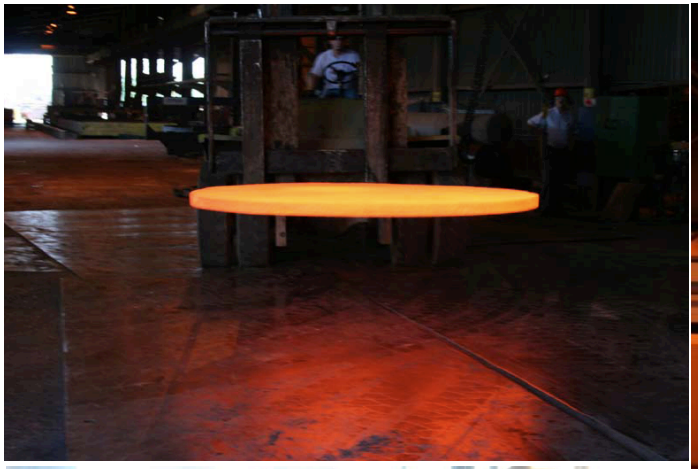


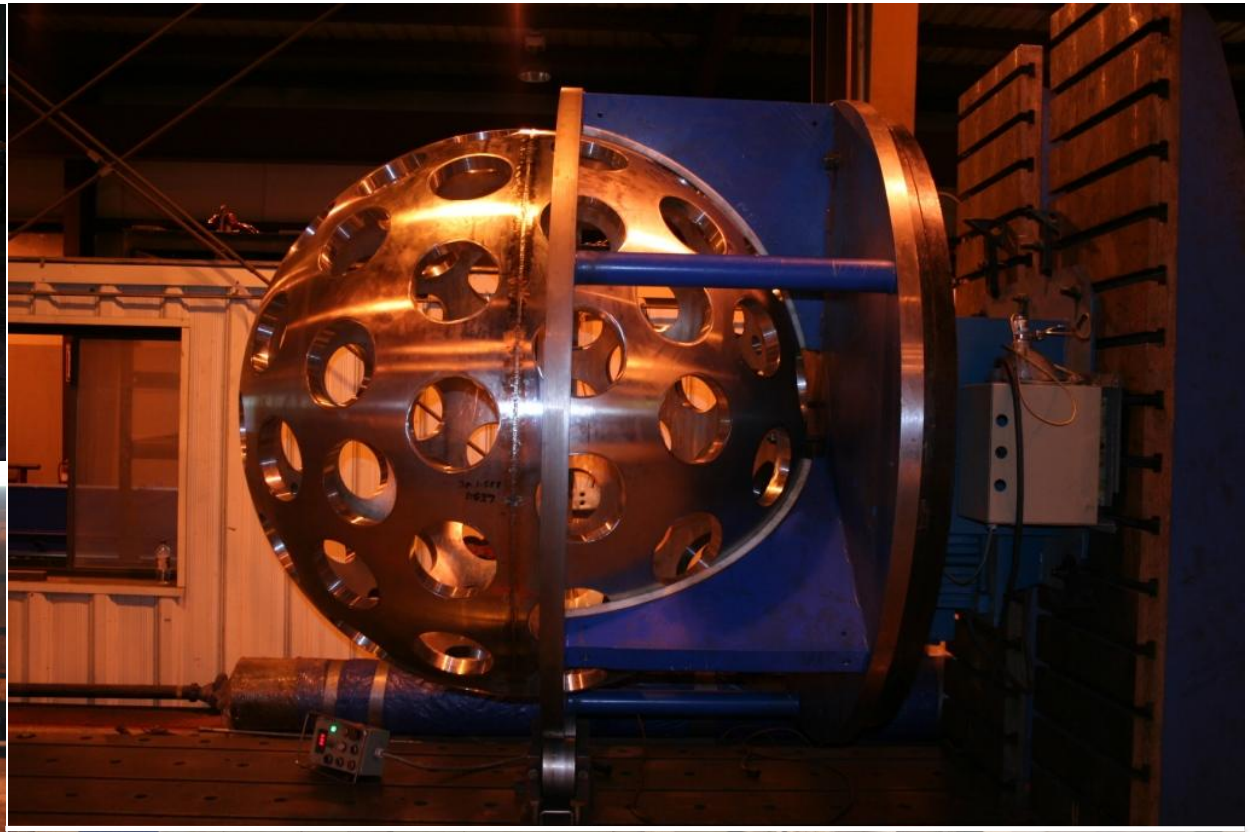

WIPP
Soudan
Kamioka
Boulby
Gran Sasso
Sudbury
Neutron Flux (cm^{-2}s^{-1})
10^{-8}
10^{-9}
10^{-10}
10^{-11}
2
3
4
5
6
Depth (km.w.e.)


Fraction of neutrons
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
0
1
2
3
4
5
Distance from muon track (m)
Liquid scintillator
Water
Standard rock
Salt



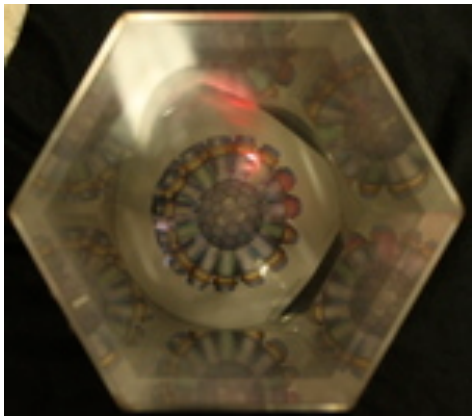


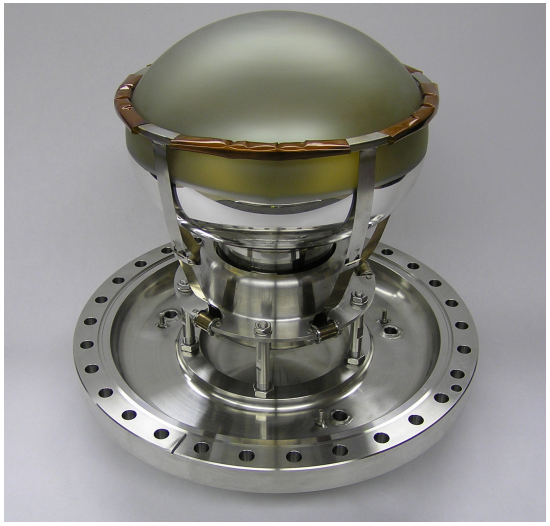




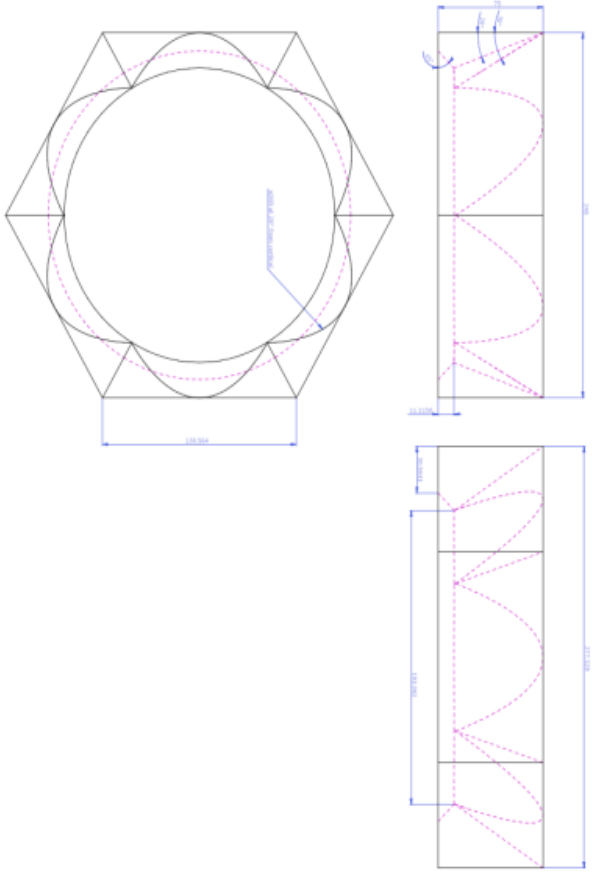

EAR PROTECTION
REQUIRED
IN THIS AREA

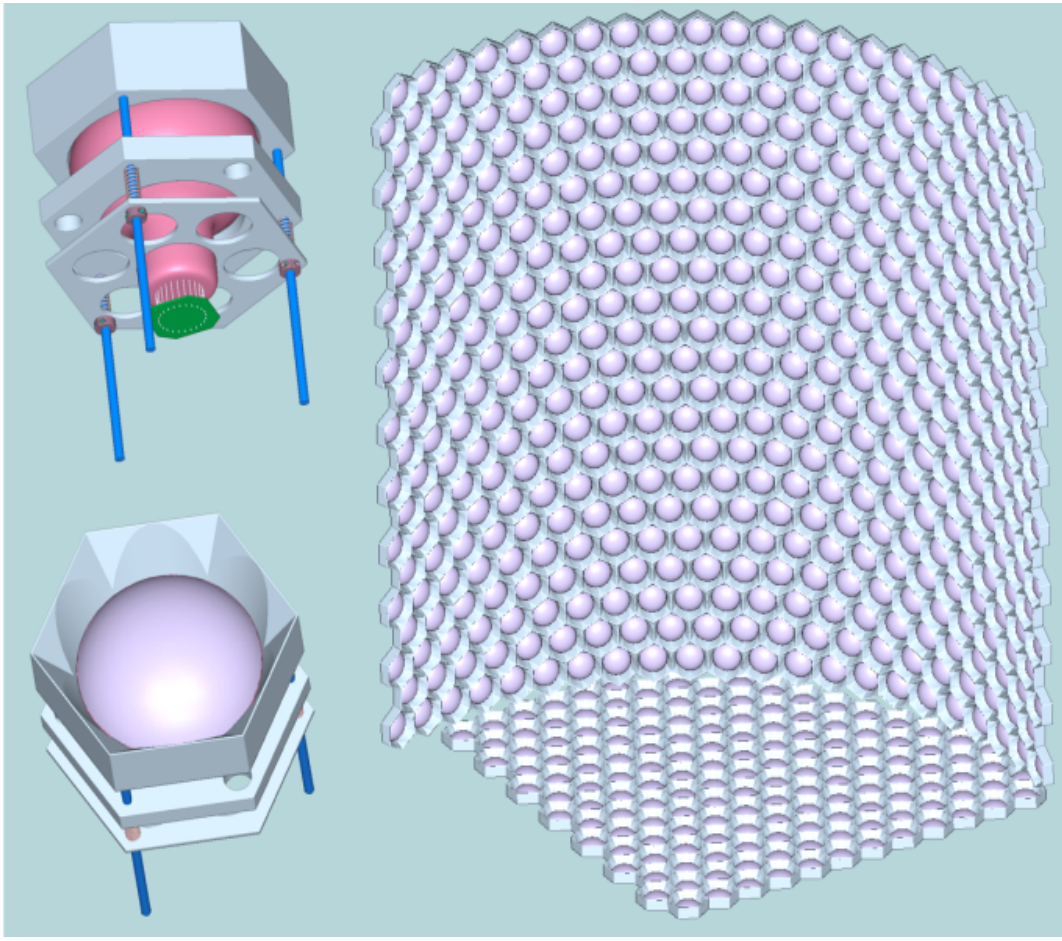
Fabrication of MiniCLEAN Optical Cassettes





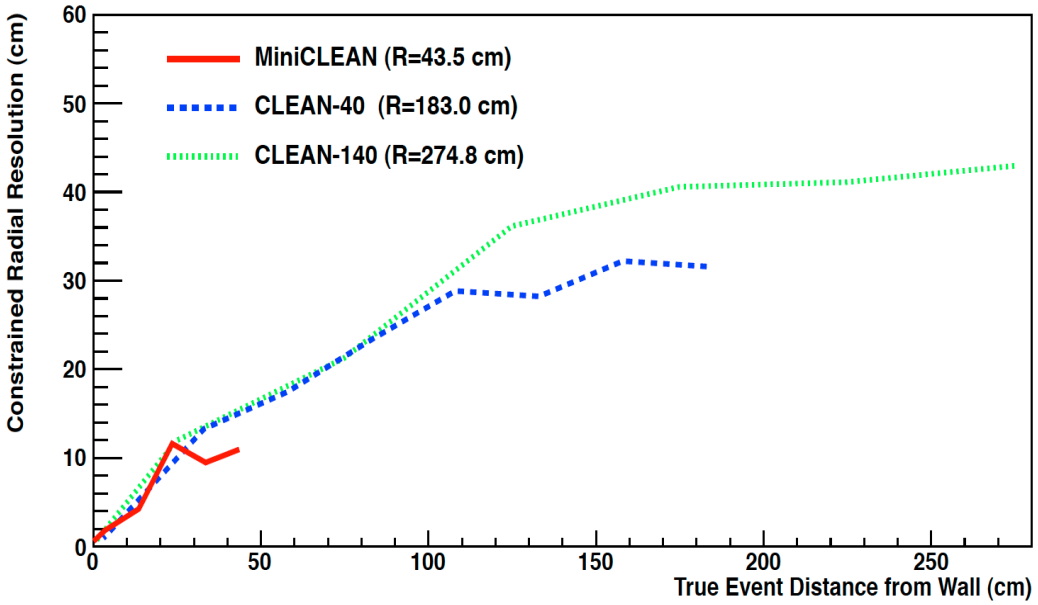
Model for a 45 tonne CLEAN Detector

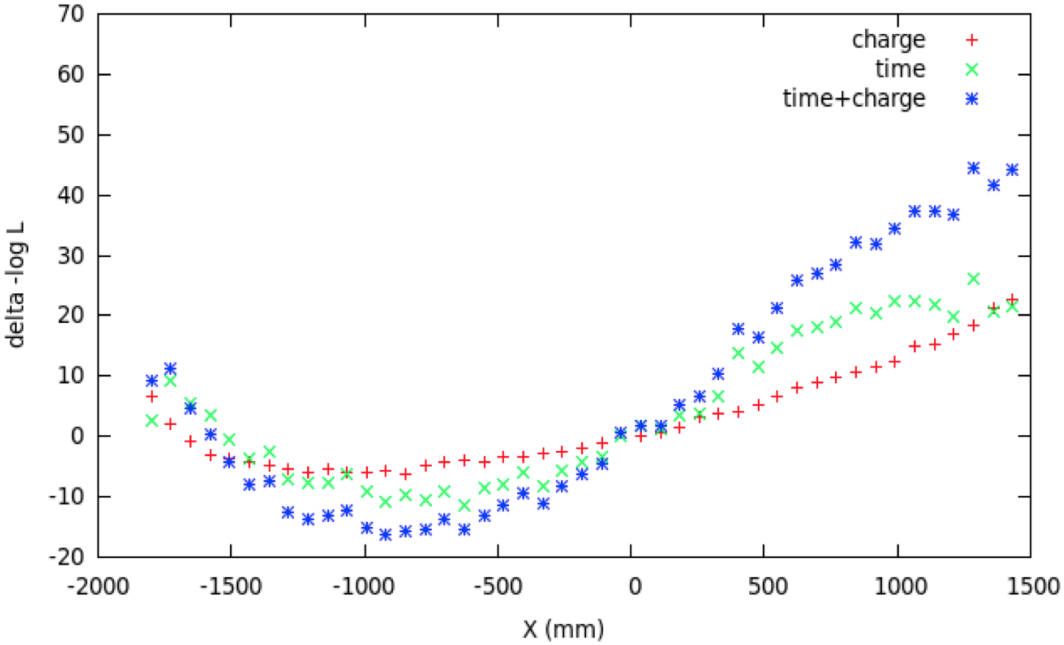


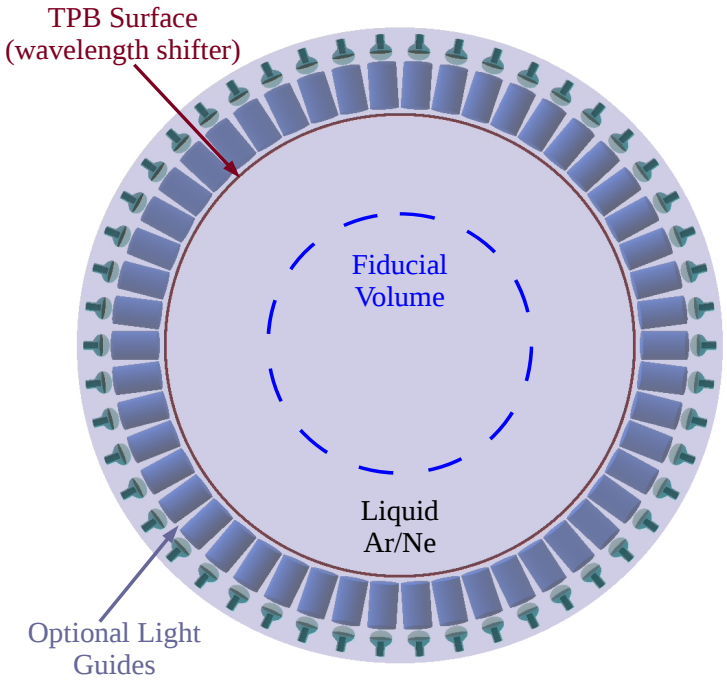


Thank You

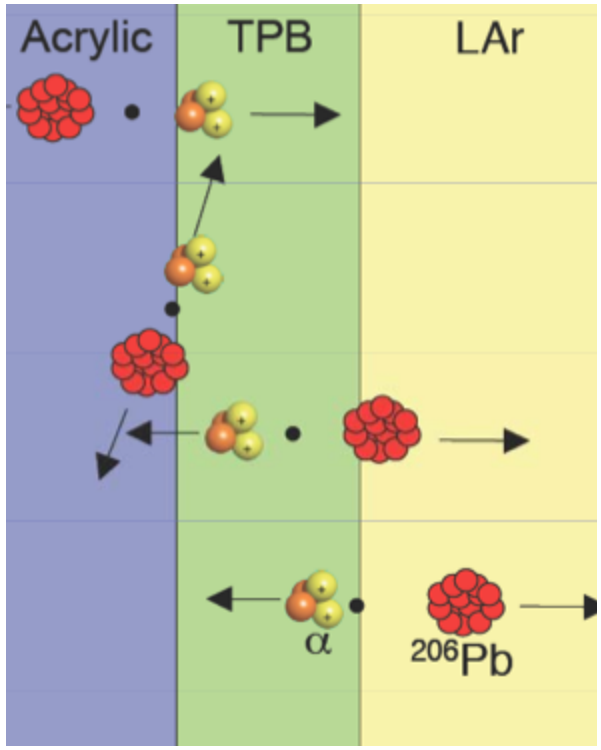
Single-Phase Detector Position Reconstruction

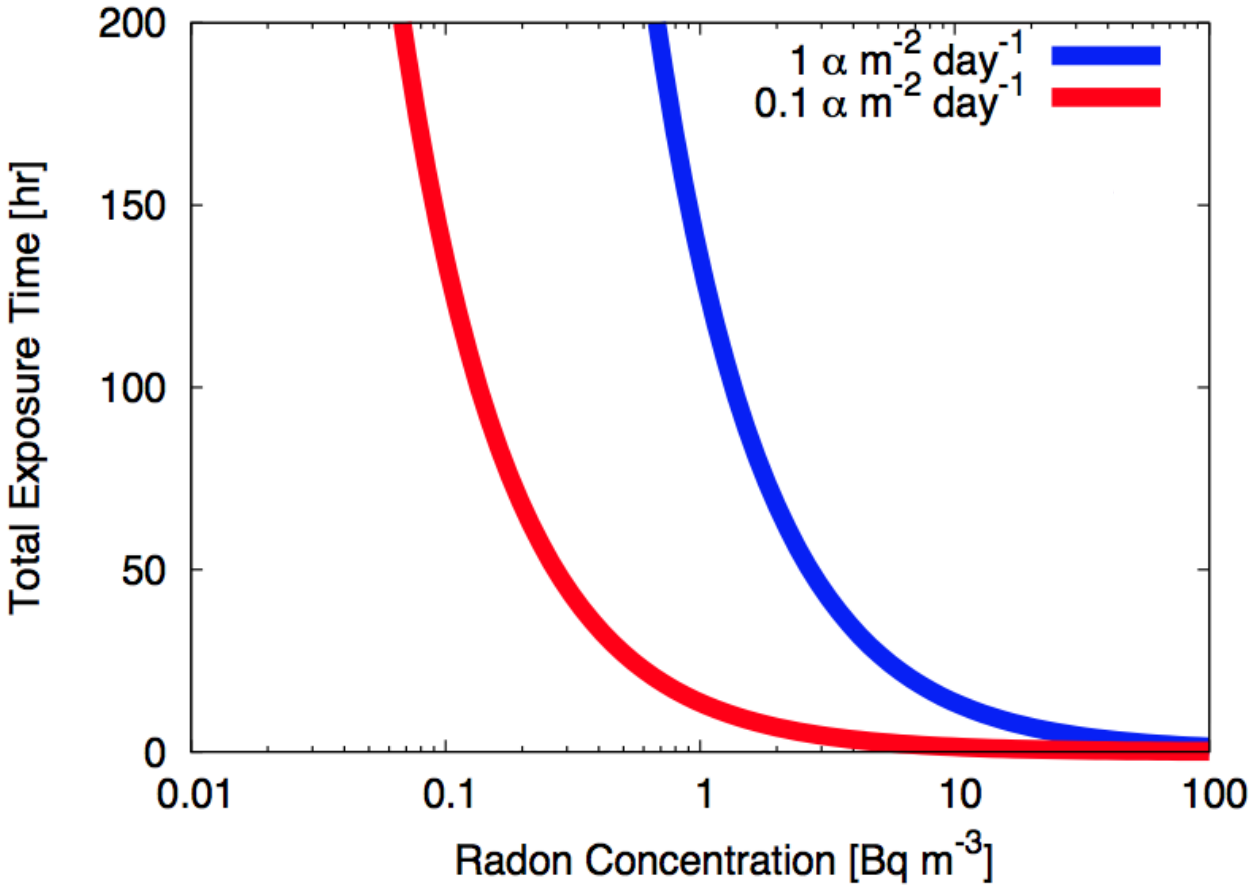






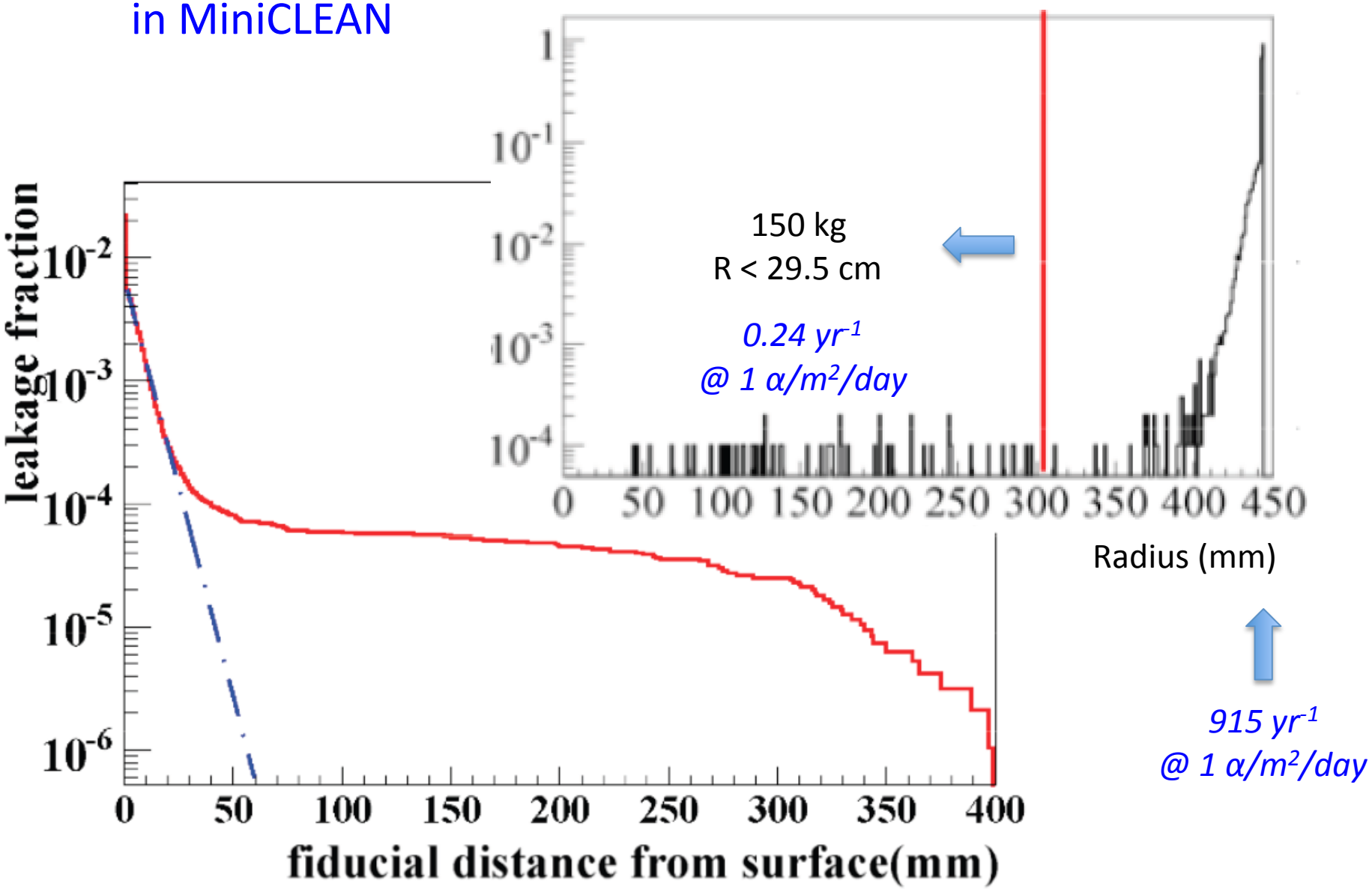
Surface Contamination - Radon Plate Out Measurements & Modeling

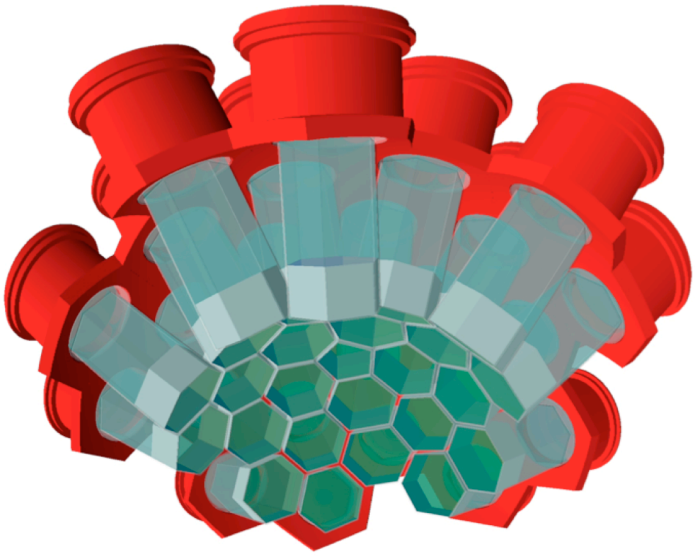


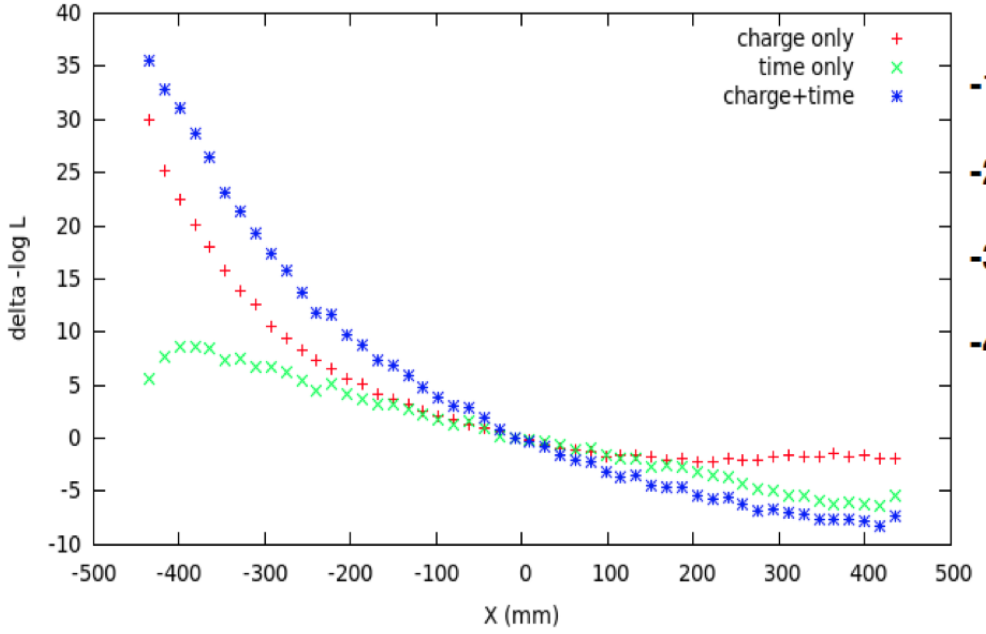


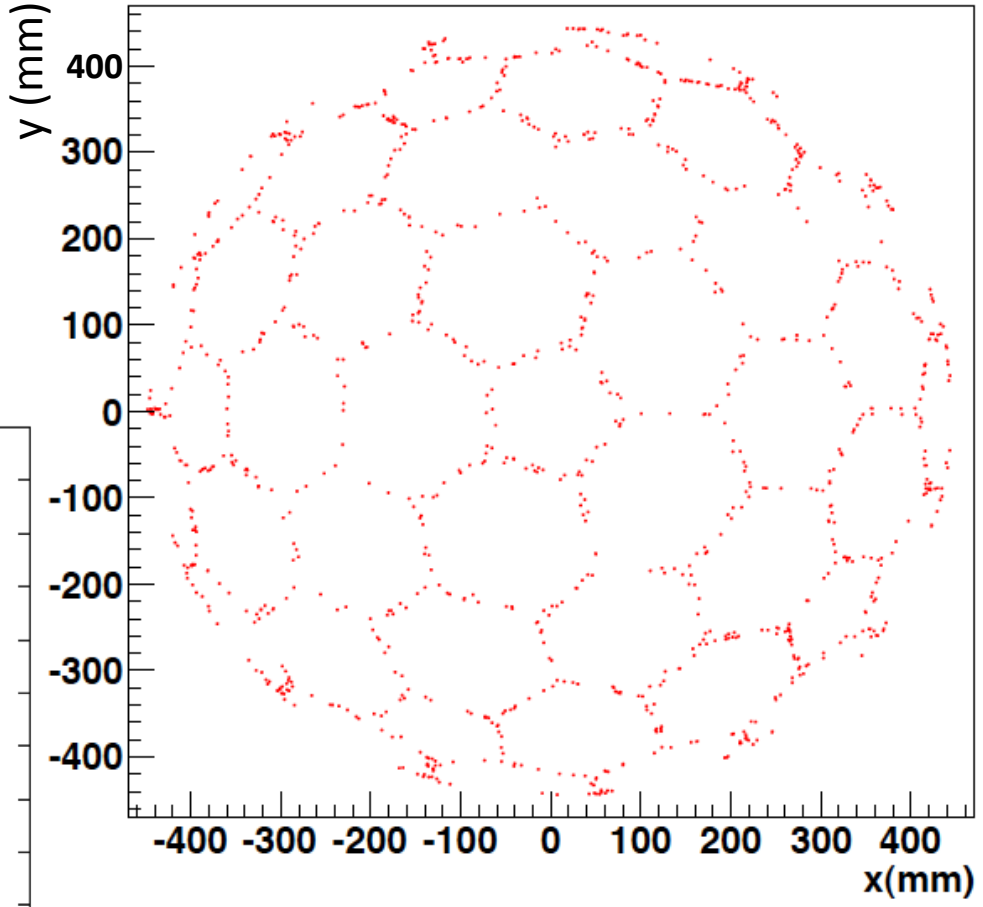
V.E Guiseppe et al, AIP **1338**, 95 (2011); arXiv:1101.0126

Fiducialization of Surface Events in MiniCLEAN

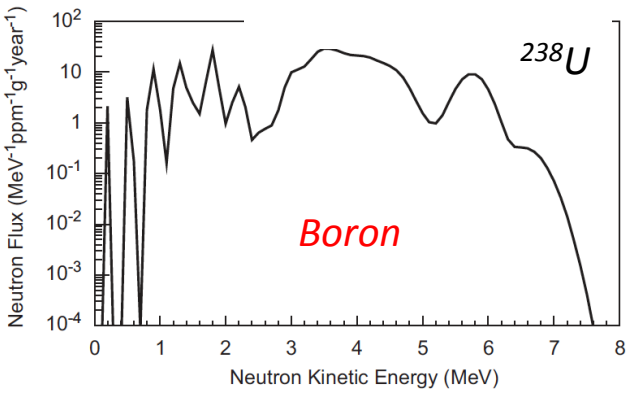


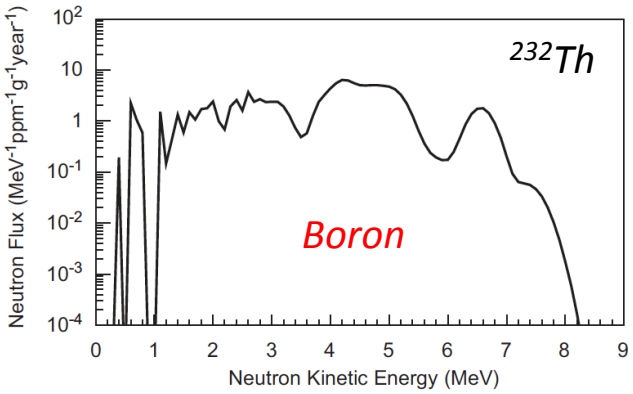


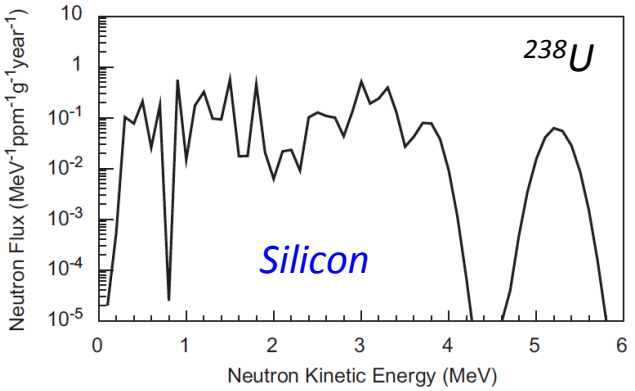

charge only
time only
charge+time
delta -log L
X (mm)
40
35
30
25
20
15
10
5
0
-5
-10
-500
-400
-300
-200
-100
0
100
200
300
400
500

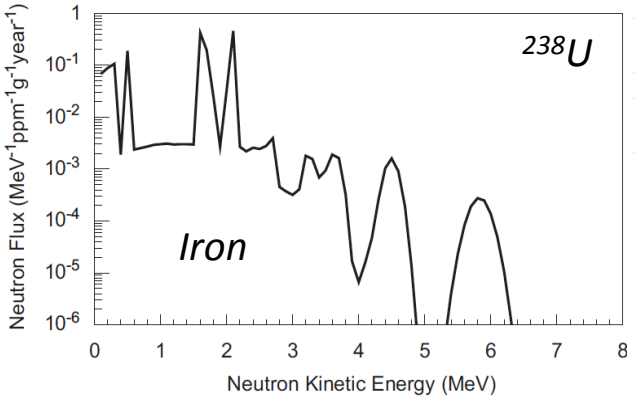

y (mm)
x(mm)
400
300
200
100
0
-100
-200
-300
-400
-400 -300 -200 -100 0 100 200 300 400

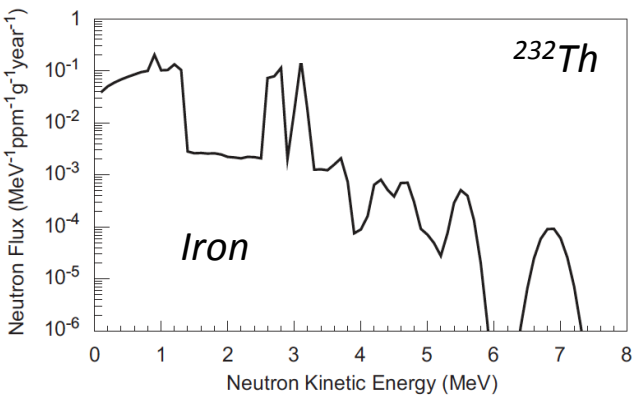
(α,n) Yields











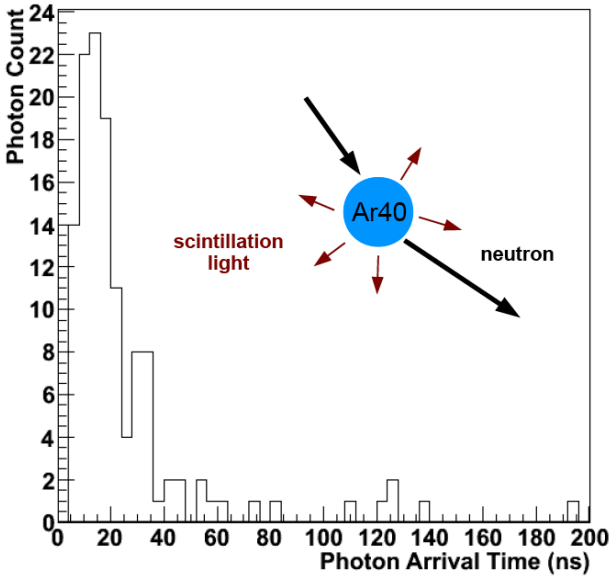
D.-M. Mei, C. Zhang and A. Hime
*NIM A**606**, 651 (2009)*

Borated Silica Glass

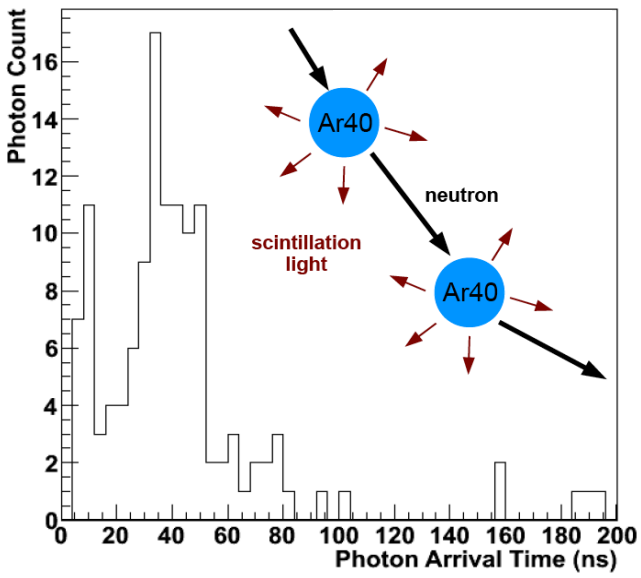
Hamamatsu
R5912-02MOD

Neutron Scattering Processes and Rejection

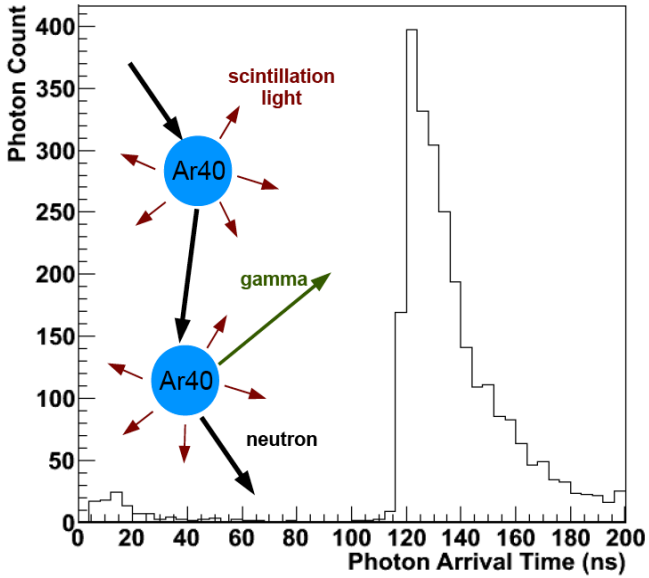
Single Elastic Scatter



Multiple Elastic Scatter



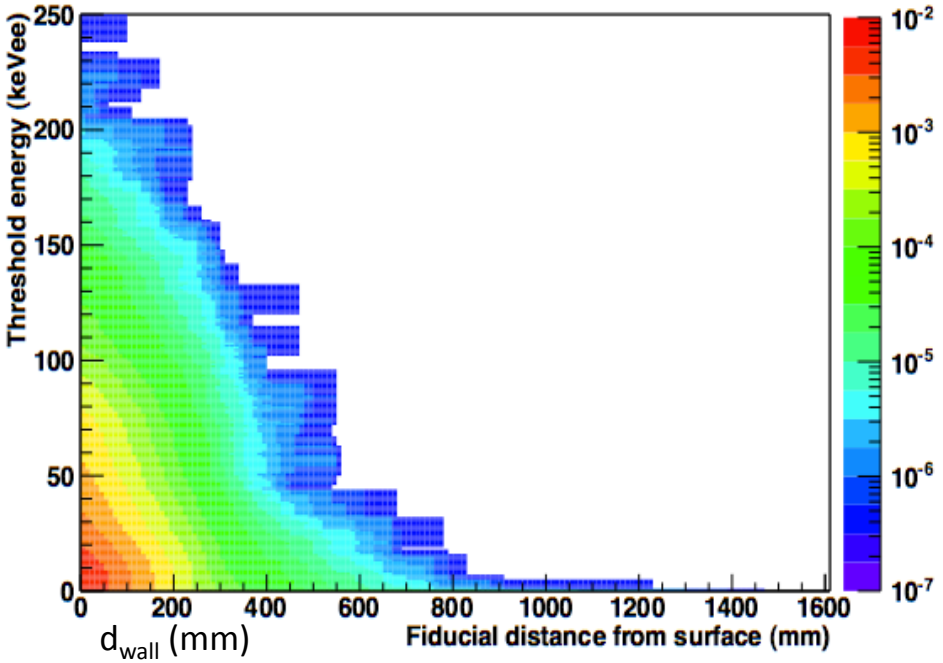
Inelastic Scattering

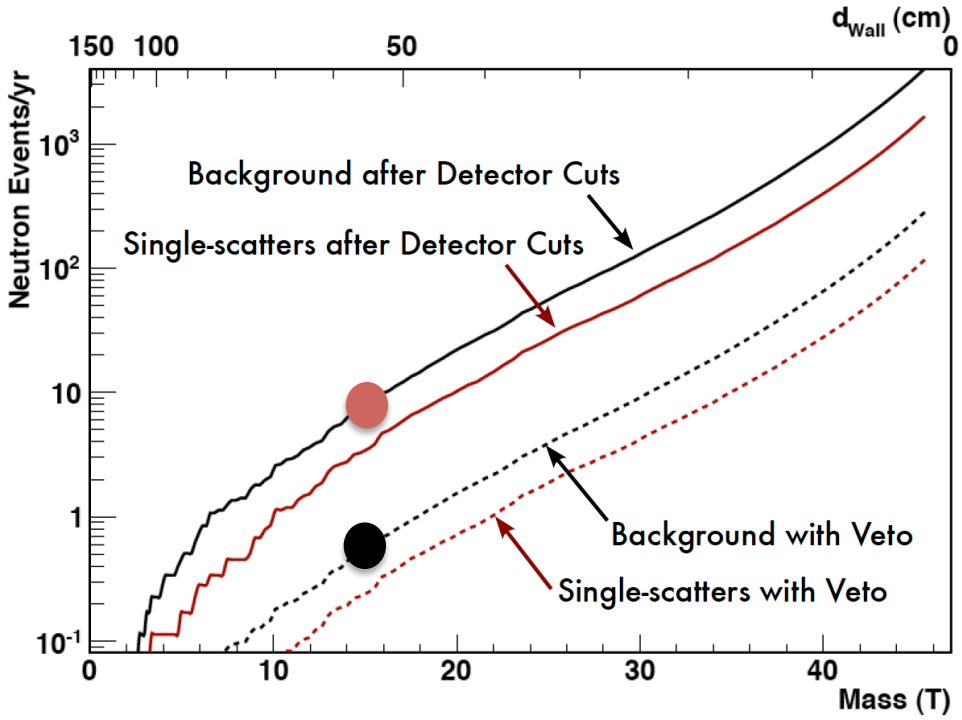


MiniCLEAN

Raw Yield	42,000 yr^{-1}	92 PMTs
Reconstructed	5668 yr^{-1}	
Energy ROI	352 yr^{-1}	12.5 – 25 keV_{ee}
Fiducial Volume	92 yr^{-1}	R < 29.5 cm M = 150 kg LAr
F_{prompt} + Timing	3.8 yr^{-1}	
Tagging	0.9 yr^{-1}	Irreducible BGND

Fast Neutrons in 45-tonne CLEAN





Raw Yield	499,000 yr^{-1}	1100 PMTs
Reconstructed	386,997 yr^{-1}	
Energy ROI	10,424 yr^{-1}	12.5 – 25 keV_{ee}
Fiducial Volume	421 yr^{-1}	d_{wall} > 55 cm M = 15,000 kg LAr
F_{prompt} + Timing	5.9 yr^{-1}	
Active Veto	0.53 yr^{-1}	Irreducible BGND