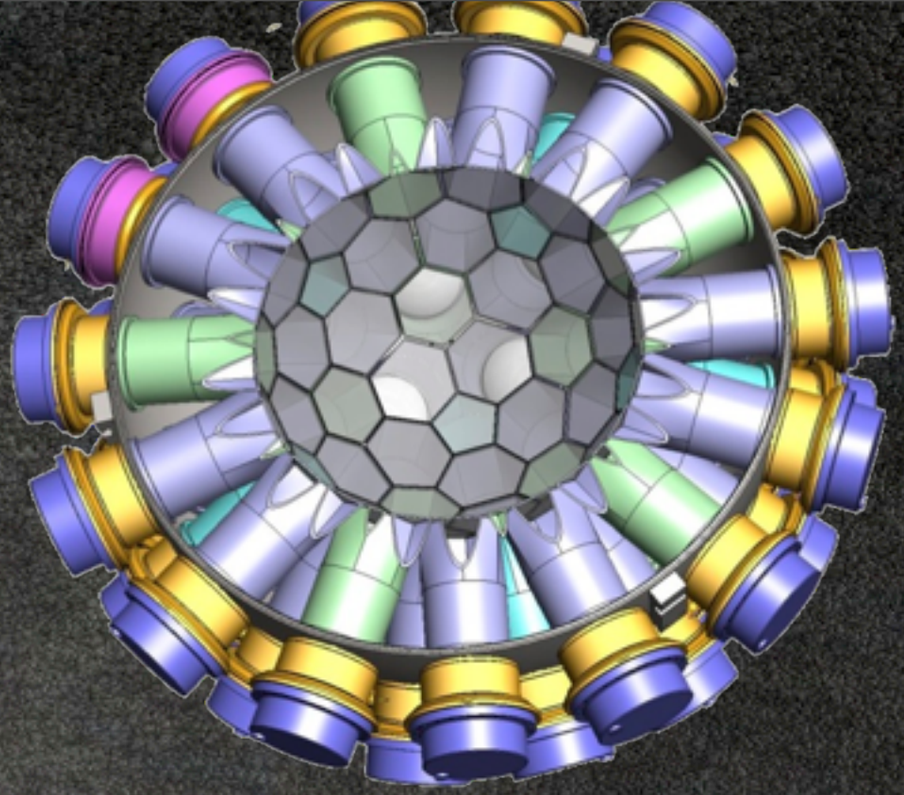


MiniCLEAN: An Update

Kimberly Palladino
MIT Laboratory for Nuclear Science

Laboratory for
Nuclear Science

MiniCLEAN, which experiment is that?

MiniCLEAN, which experiment is that?

CLEAN

AREA OF RESEARCH:
Direct detection of dark matter and low-energy neutrinos

TECHNOLOGY:
Single-phase liquid argon detector

FUN FACT:
CLEAN can operate with interchangeable targets of liquid argon and liquid neon

INSTITUTIONS:
Boston University; Los Alamos National Laboratory; MIT; National Institute of Standards and Technology; Royal Holloway University of London; SNOLAB; Syracuse University; University of New Mexico; University of North Carolina, Chapel Hill; University of Pennsylvania; University of South Dakota; Yale University

CLEAN

TARGET:
LAr, LNe

Mass:
500 kg target, 150 kg fiducial

Light collection:
92 8" Hamamatsu R5912-02 MOD PMTs

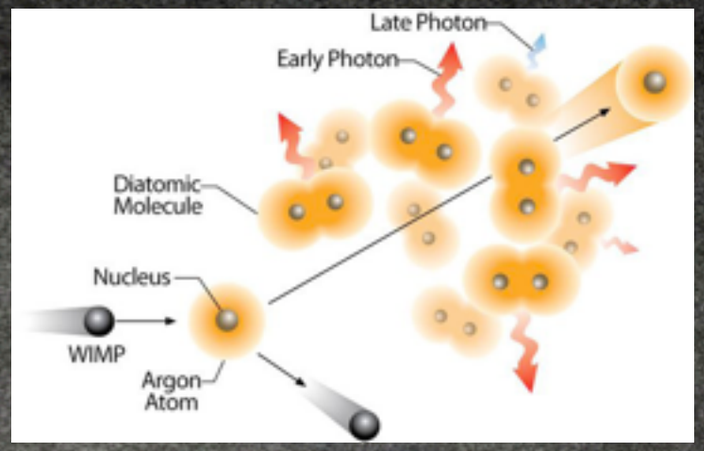
Vessel:
stainless steel, with modular optical cassettes inserted

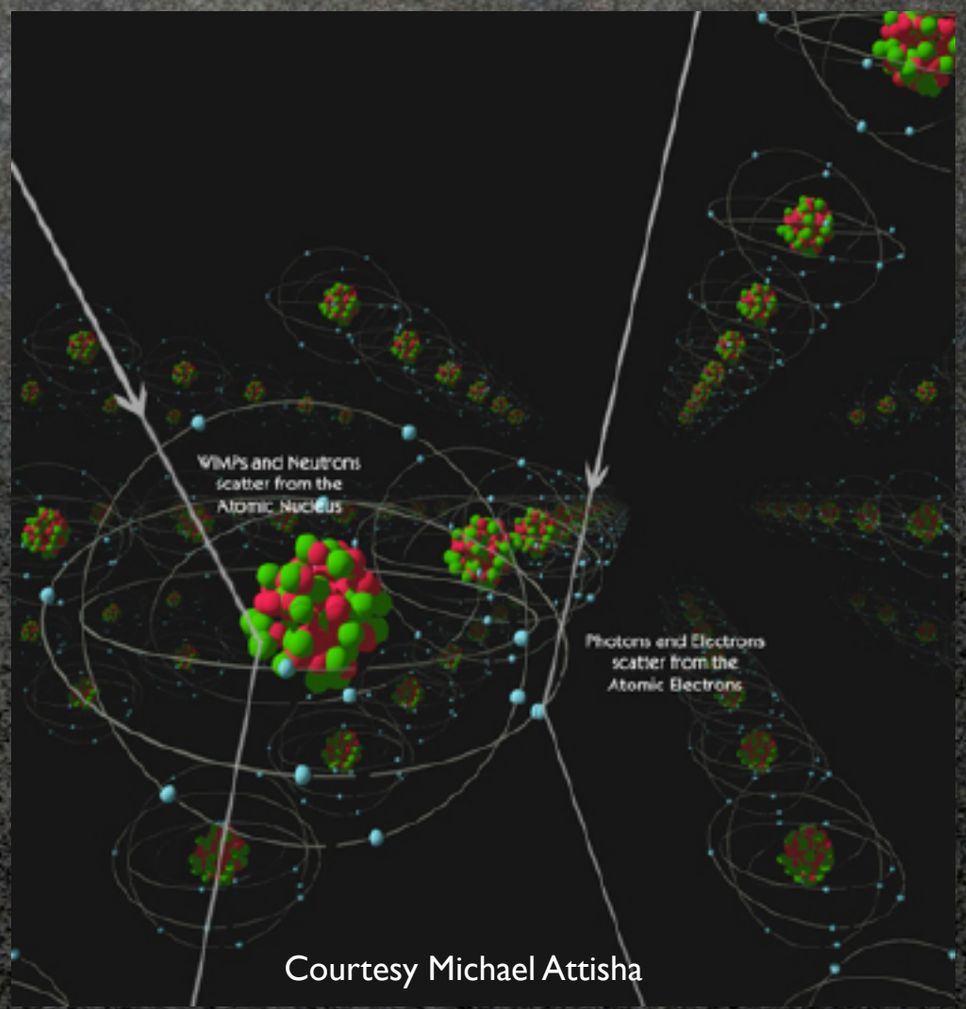
Shielding:
10 cm acrylic & 20 cm Ar, in ~8m water shield

Sensitivity:
SI cross section 2 x10^{-45} cm^2

http://www.symmetrymagazine.org/article/november-2012/voyage-to-snolab

Noble Liquid Detection





Courtesy Michael Attisha

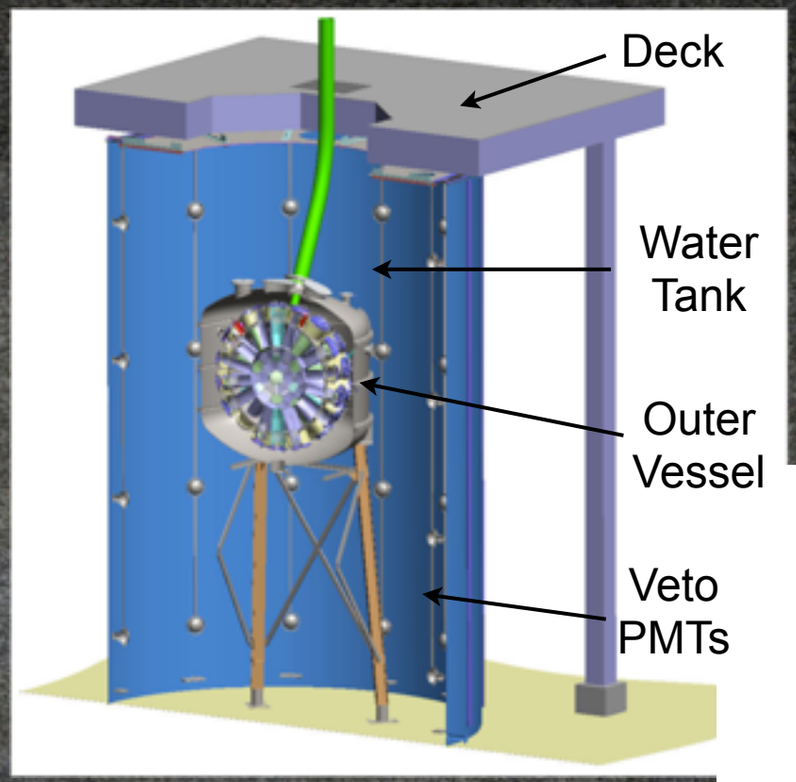
After a recoil liquid noble atoms ionize, and form dimers,
recombine with and then de-excite
and create scintillation,
the molecules may be in singlet or triplet states
with different lifetimes

Table 3: Scintillation parameters for liquid neon, argon, and xenon.

Parameter	Ne	Ar	Xe
Yield ($\times 10^4$ photons/MeV)	1.5	4.0	4.2
prompt time constant τ_1 (ns)	2.2	6	2.2
late time constant τ_3	15 μs	1.59 μs	21 ns
I_1/I_3 for electrons	0.12	0.3	0.3
I_1/I_3 for nuclear recoils	0.56	3	1.6
λ(peak) (nm)	77	128	174
Rayleigh scattering length (cm)	60	90	30

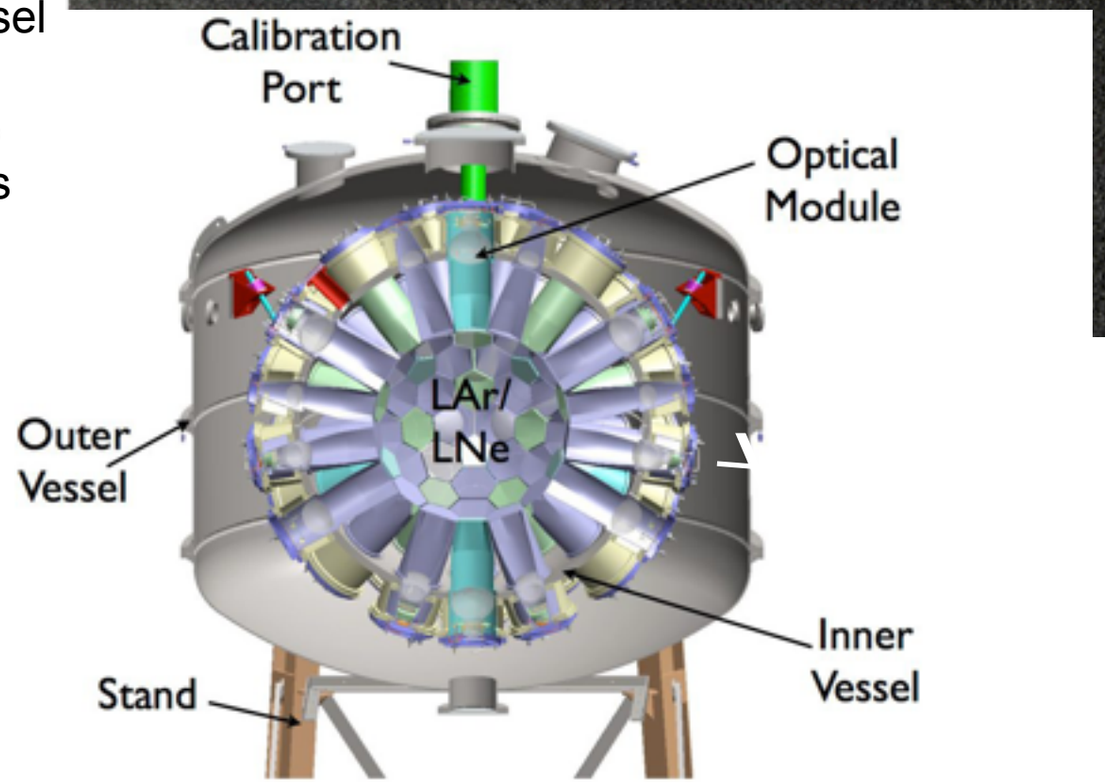
Lippincott et al Phys Rev C78; 035801 (2008)

MiniCLEAN Design

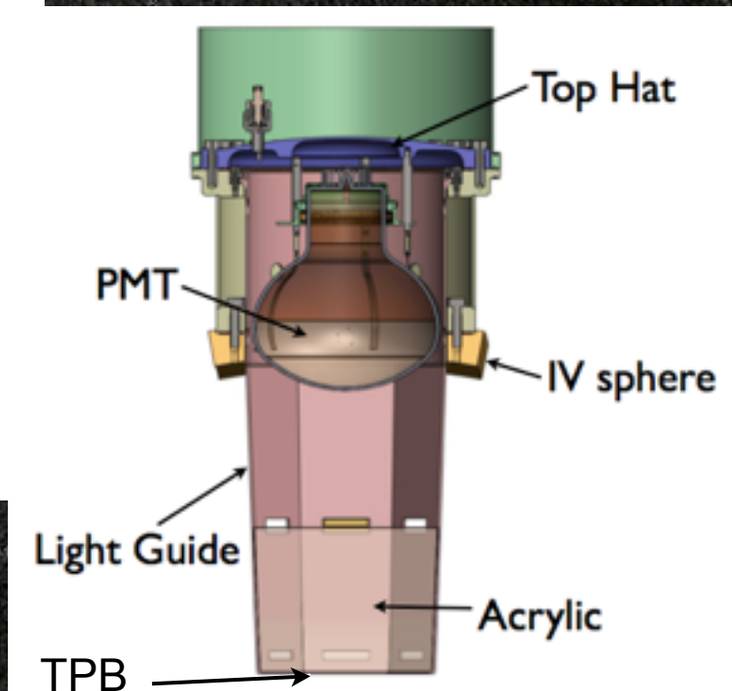


Water veto tank:
25 ft. tall
18 ft. diameter
48 veto PMTs
~1.5 m water on sides
~3.5 m water from bottom

Outer Vessel: ~1.25 m radius
Inner Vessel: ~ .7 m diameter,
~500 kg LAr
Target radius: ~.4 m
Fiducial radius: ~.3 m, 150 kg LAr



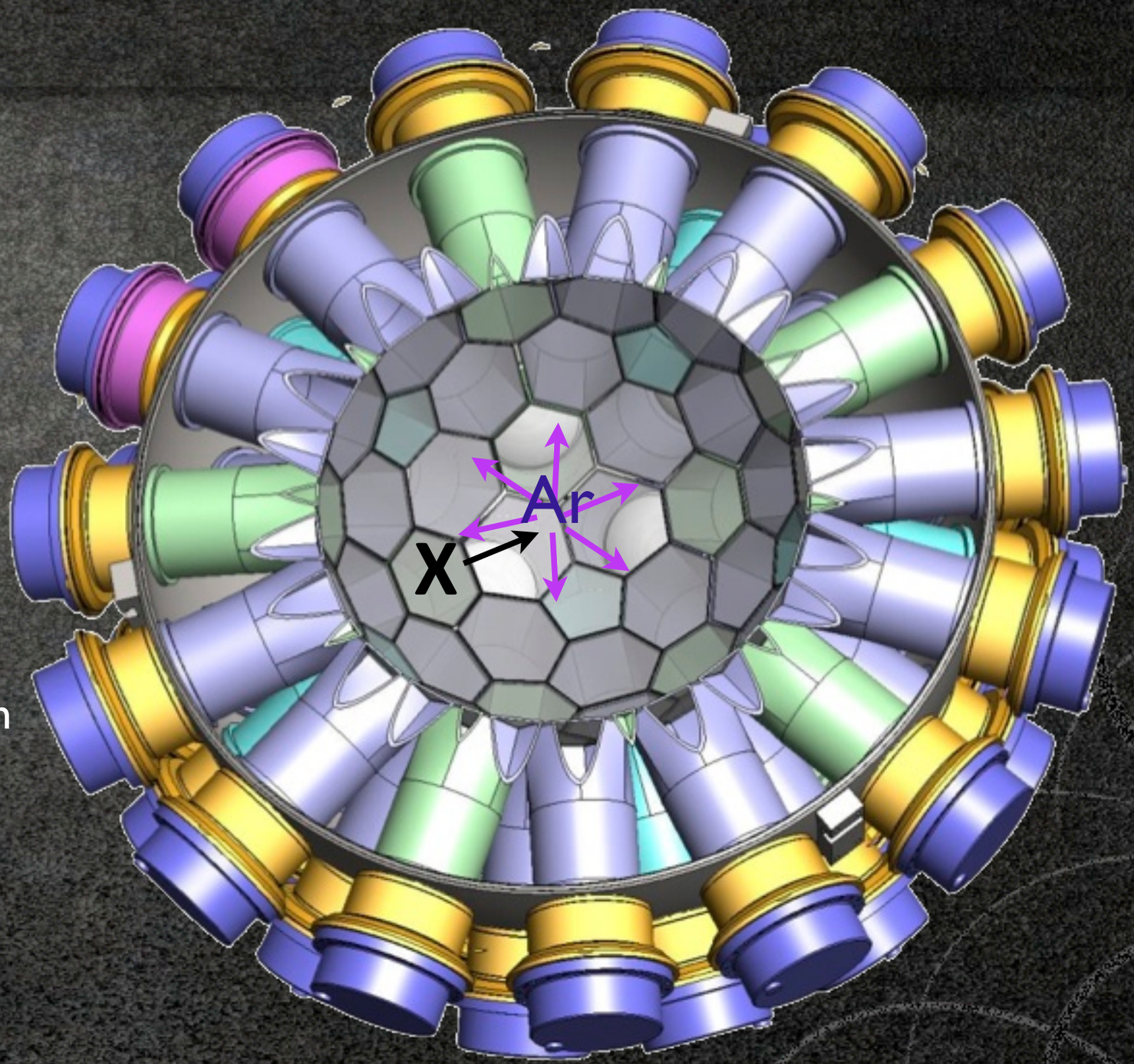
4π coverage
92 modular optical cassettes
PMTs are cold



A WIMP Event

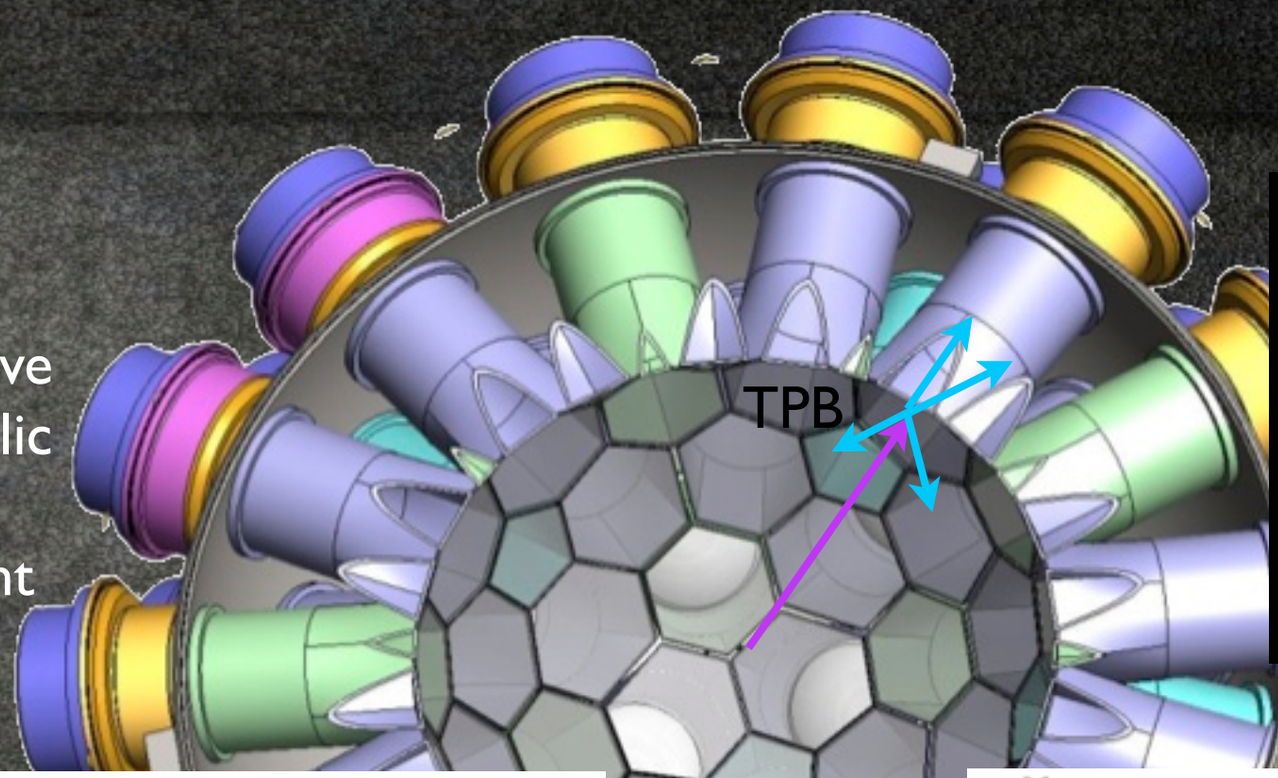
A WIMP, **X**, has a coherent elastic scatter with an argon nucleus

The nuclear recoil then causes EUV scintillation, 128 nm

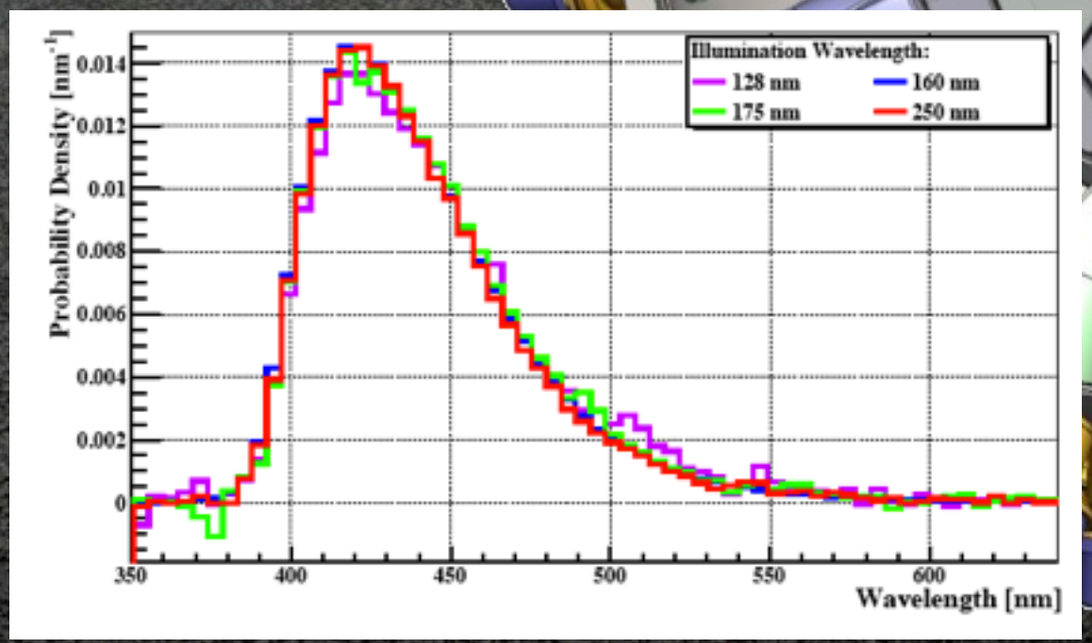


TPB Re-emission

The UV light is absorbed by the TPB wavelength shifter, an evaporative coating on the acrylic face, which re-emits visible light

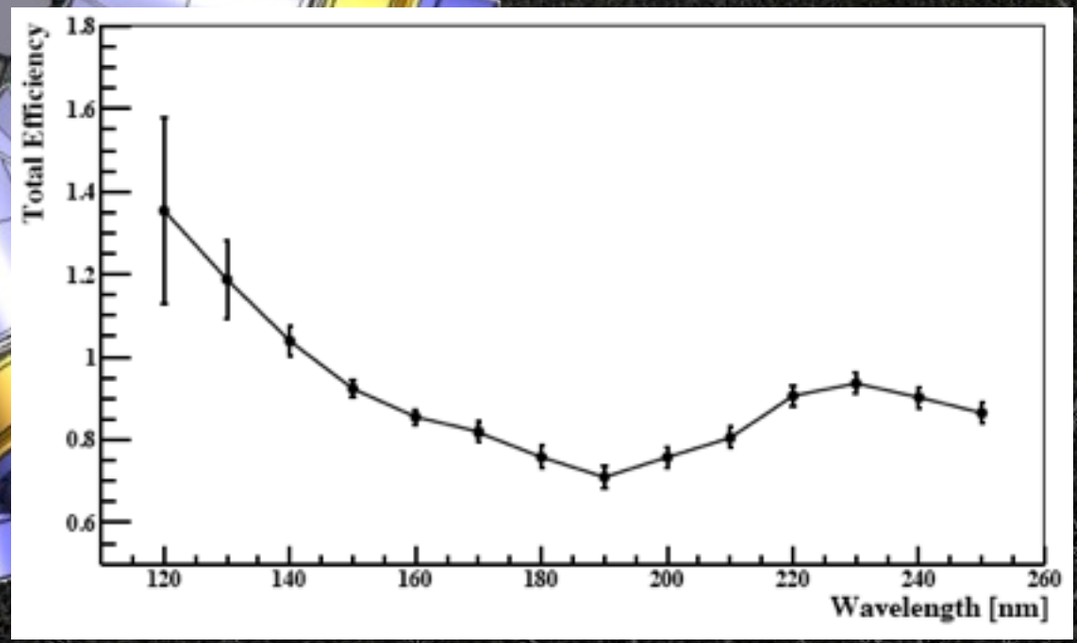


TPB Coating done at International Vacuum



TPB Re-emission spectrum

Gehman et al. NIM A654 (2011) 116-121



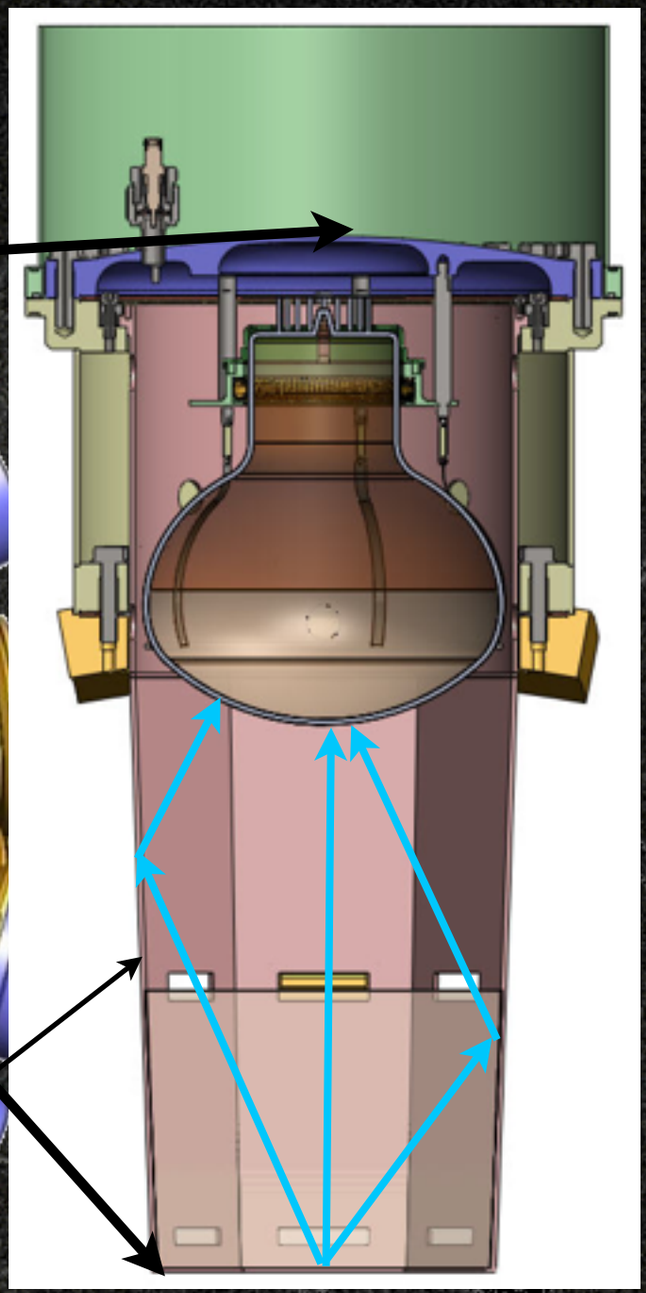
TPB Emission Efficiency

Lightguide

Light then travels through transparent acrylic. UV absorbing acrylic was surprisingly found by our DEAP colleagues to be best, absorption lengths of ~few meters at 420 nm.

Acrylic plug sides will be silver coated, reflectivity >95%

Lightguide covered with 3M DESR foil reflector.

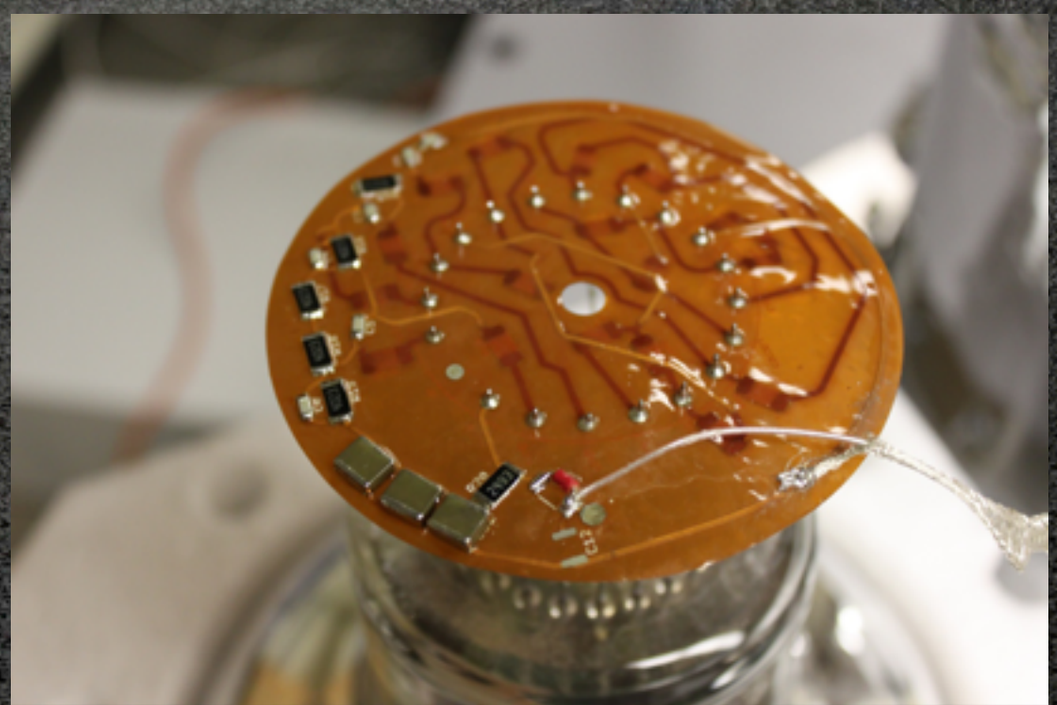


PMTs and Bases

PMTs are 8" Hamamatsu R5912-02MOD
14 dynodes, Pt underlay, frosting

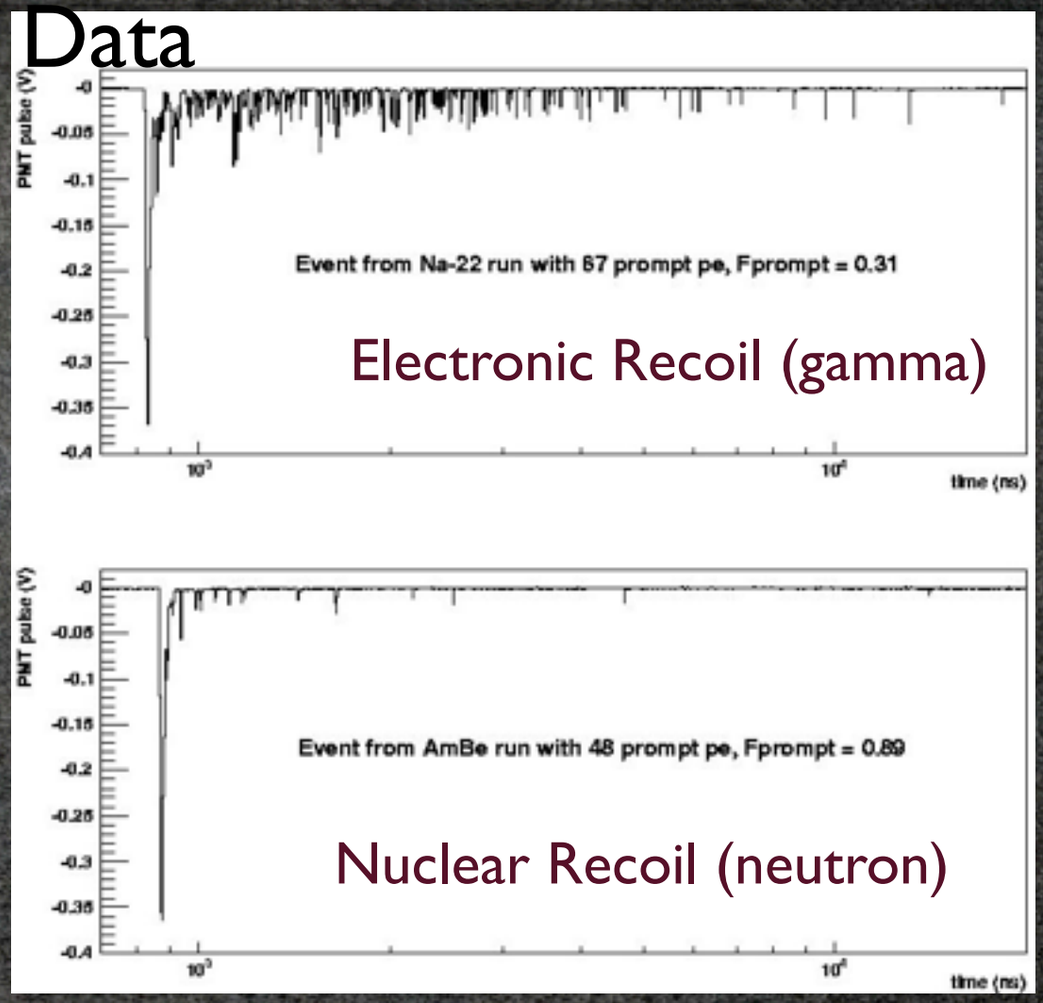
From whole optics chain we expect 6 p.e./keV

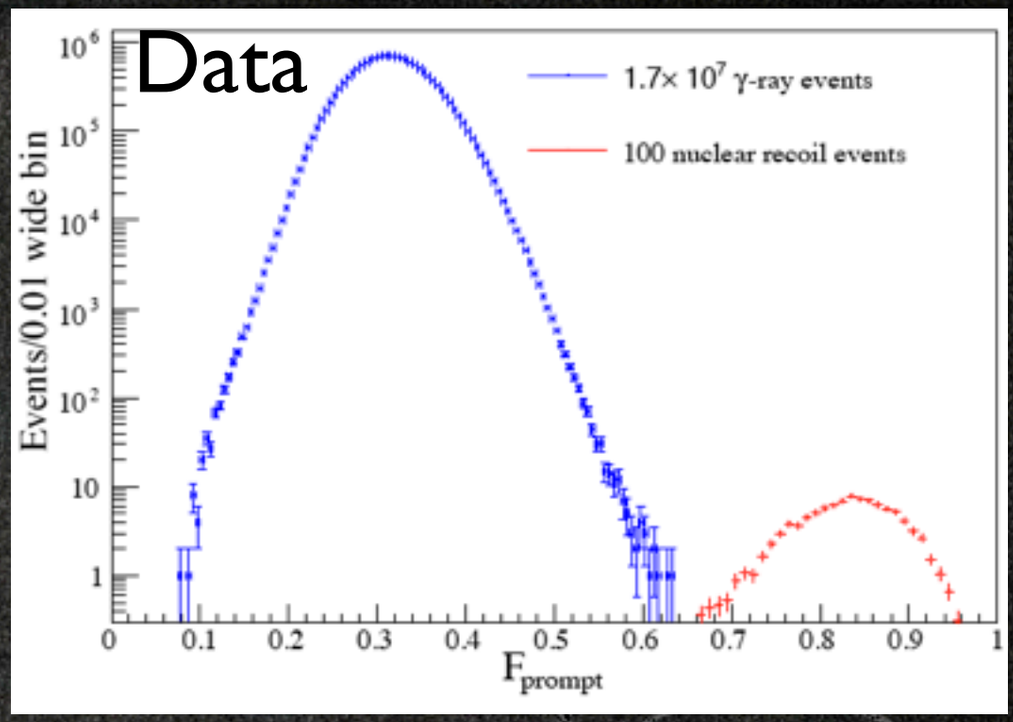
Bases: single layer kapton with conformal coating
low mass Gore HV cable



Pulse Shape Discrimination

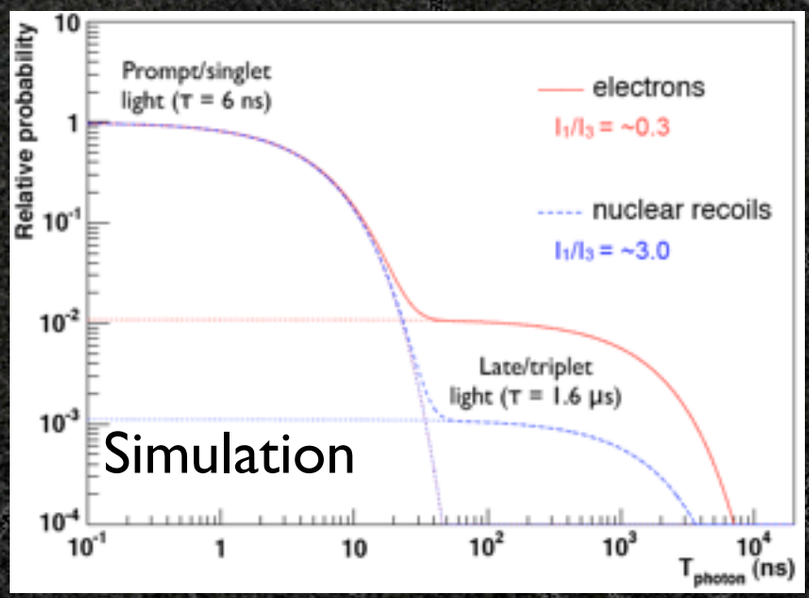
Data





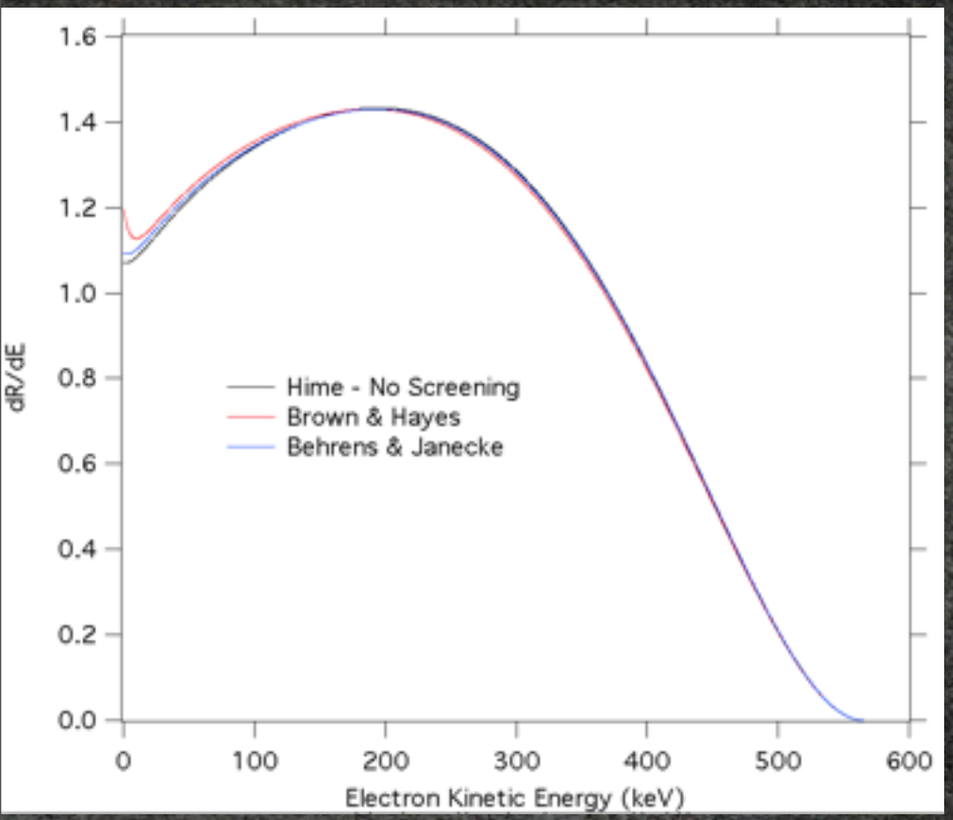
Boulay et al. arXiv:0904.2930

In LAr, $t_{singlet}$ = 6 ns, $t_{triplet}$ =1.6 us
F_{prompt} ~ .3 for electron recoils, .7-.8 for nuclear
How well can discrimination work?
DEAP-1 has demonstrated (stat. Limited)
< 6 x 10^{-8} 43<E< 86 keV_{ee}
Necessary in LAr because of ^{39}Ar

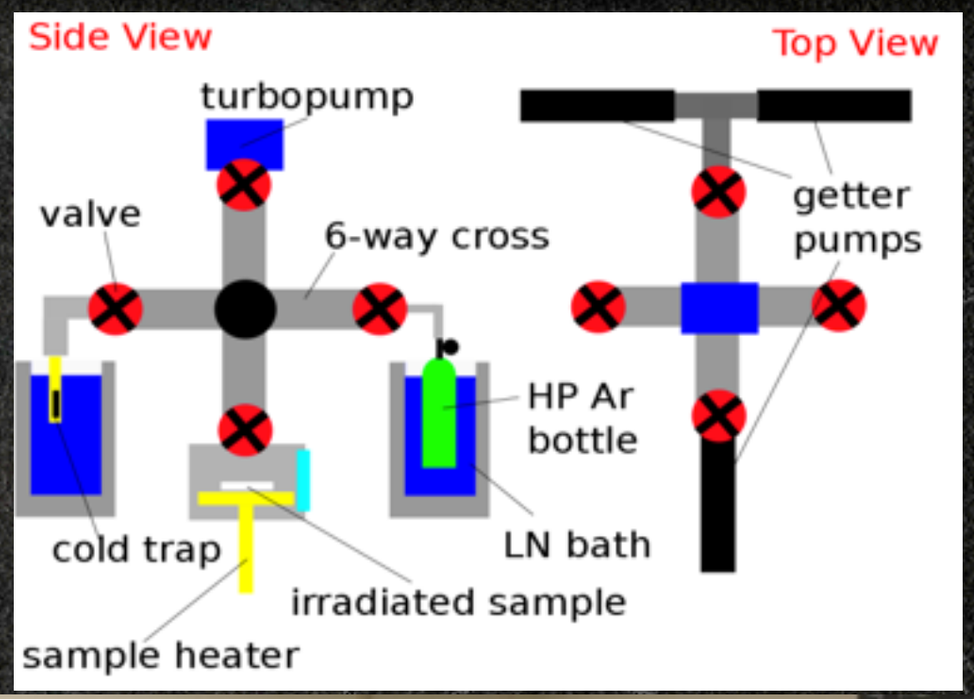


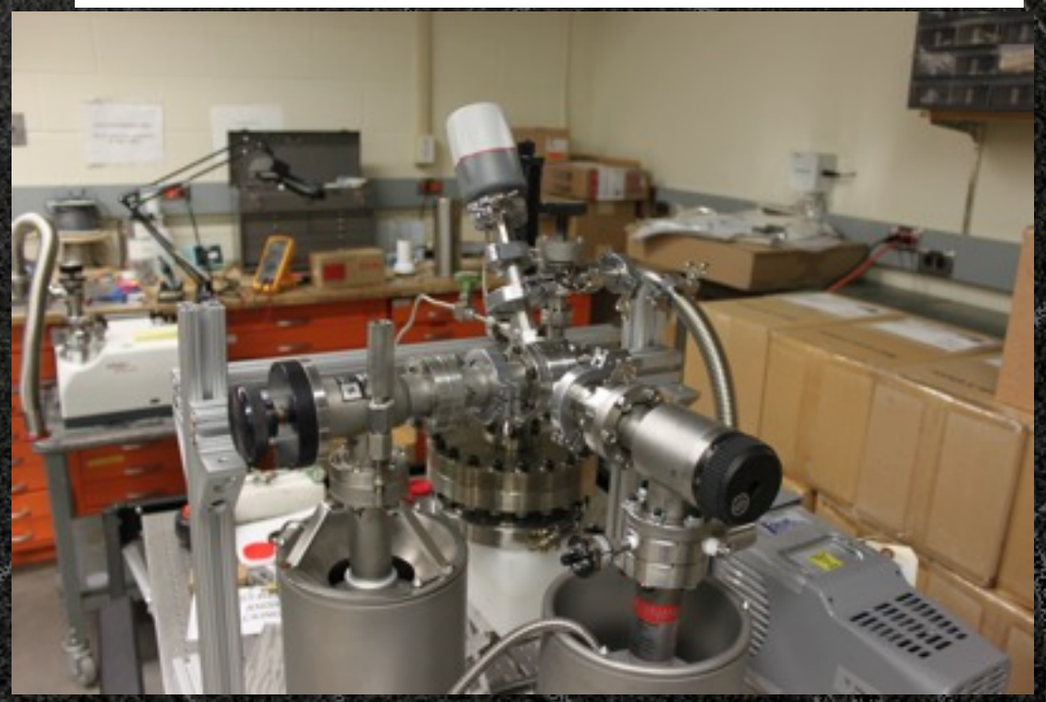
Boulay and Hime, Astropart. Phys. **25**, 179 (2006)

^{39}Ar Spike



MiniCLEAN will dope with ^{39}Ar to establish PSD for larger detectors (rejection of 10^{-10}) plan to increase event rate 3-10 x





KCl target from TRIUMF proton beam, other LANL groups want Si and Al isotopes, we will obtain

~1.7 μCi of ^{39}Ar to spike our natural argon

Background Simulations

- ^{39}Ar beta-decay
- Gamma Rays
- Surface Alphas
- Cosmogenic Neutrons
- Alpha-n Neutrons

Background: Electronic

- ^{39}Ar beta-decay
- Gamma Rays
- Surface Alphas
- Cosmogenic Neutrons
- Alpha-n Neutrons

U/Th Gammas from PMTs:
~7x10^{9}/yr
high energy, large radius,
fail Fprompt cut

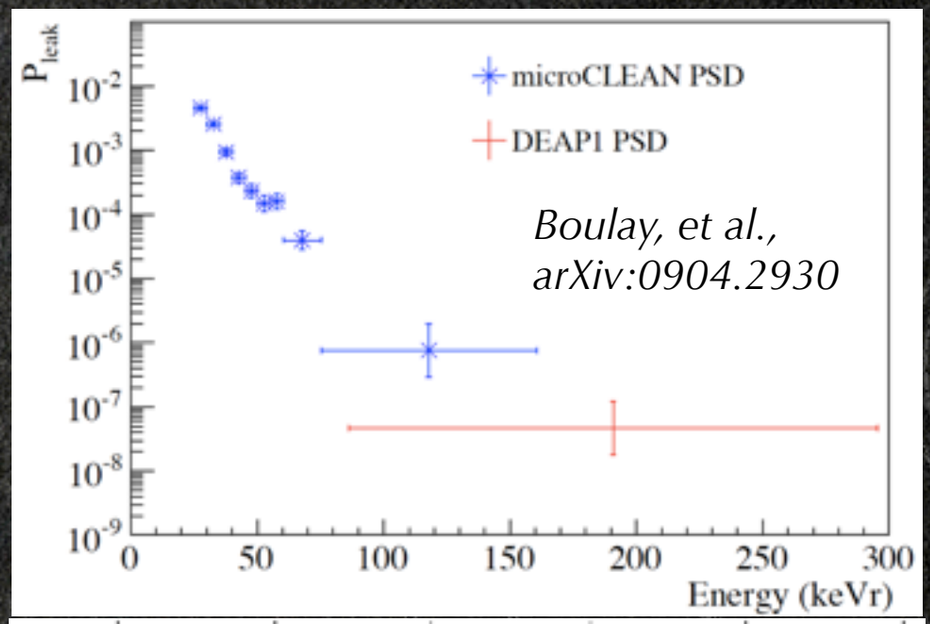
1 Bq/kg ^{39}Ar → Requires 1 x 10^{-9} discrimination

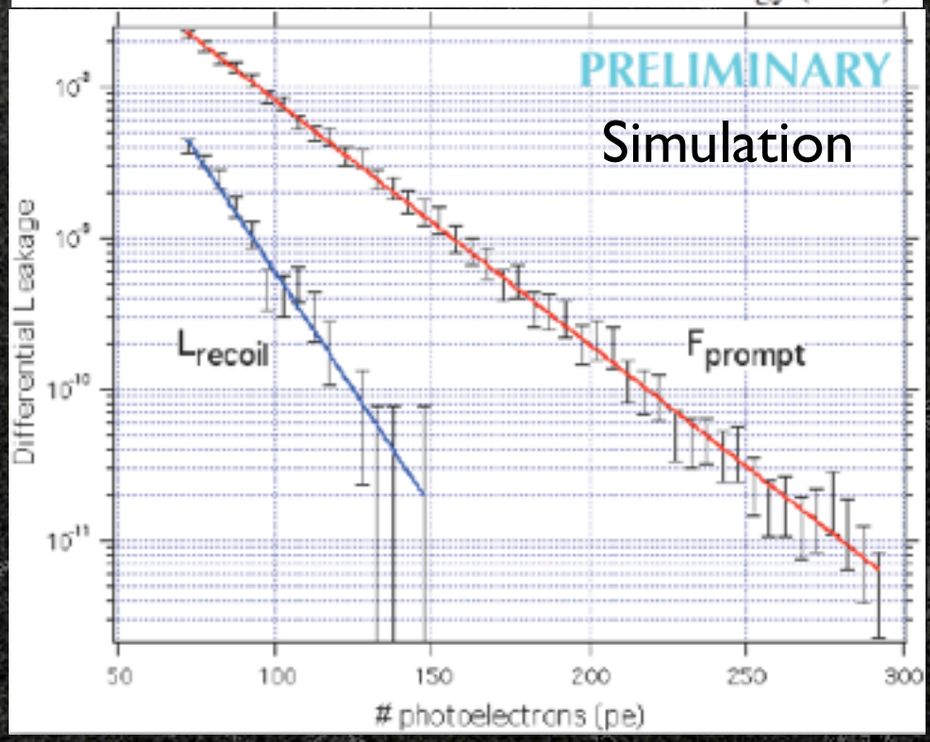
Results from
DEAP-1 at SNOLab
(C. Jillings CAP'11):
Rejection < 3 x10^{-8}
120-240 p.e.

Likelihood ratio, Lrecoil, computed using the p.e. arrival times increases the separation between nuclear and electronic recoils.

Threshold of 12.5 keV$_{ee}$
<1 ^{39}Ar background /yr.

MiniCLEAN collaborators are looking at DEAP-1 data to study L_{recoil} near threshold.

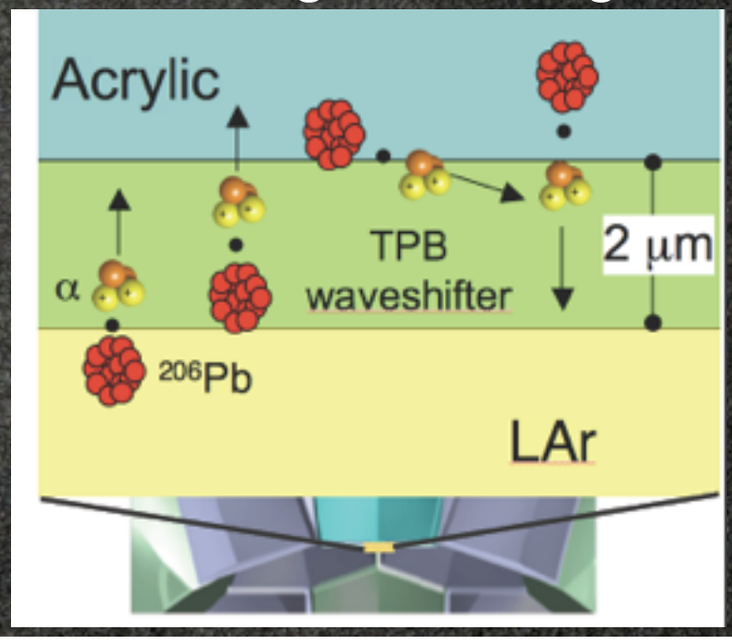




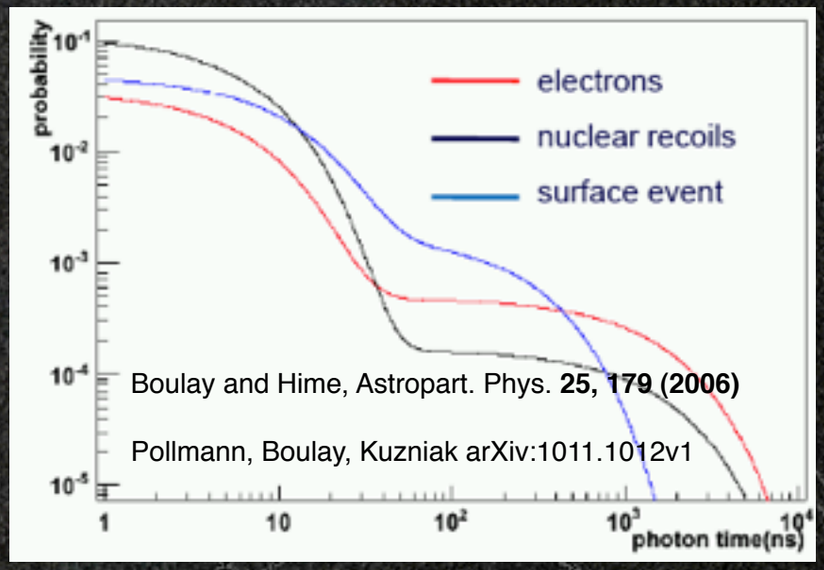
Background: Alphas

- ^{39}Ar beta-decay
- Gamma Rays
- Surface Alphas
- Cosmogenic Neutrons
- Alpha-n Neutrons

Rn daughters plating out on TPB can be a dangerous background



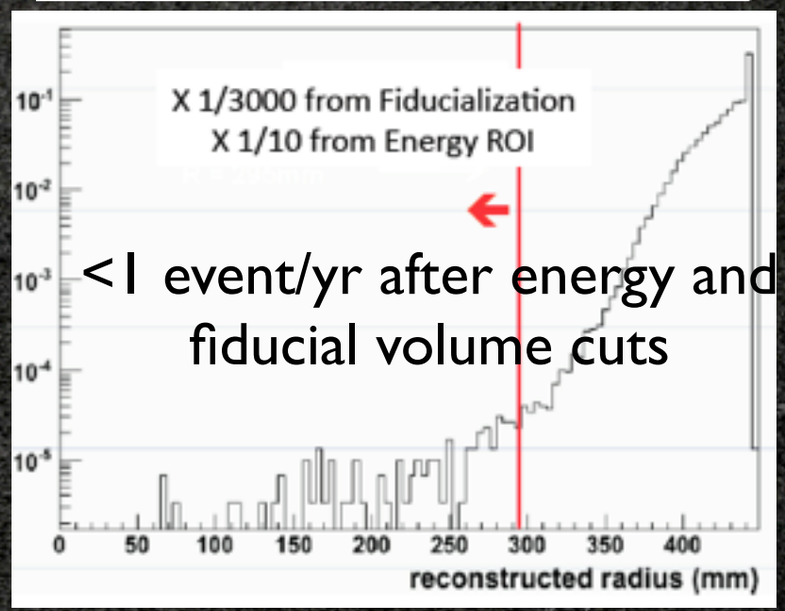
Improved discrimination:

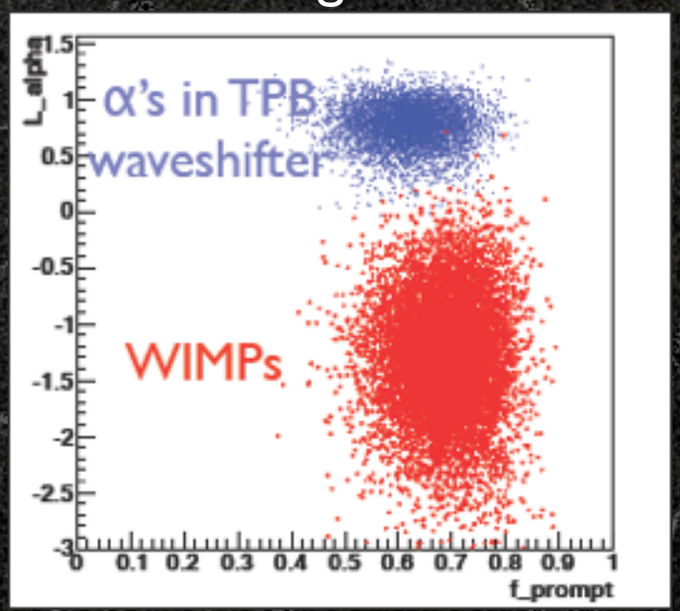


Boulay and Hime, Astropart. Phys. **25, 179 (2006)**

Pollmann, Boulay, Kuzniak arXiv:1011.1012v1

B. Wang APS'11





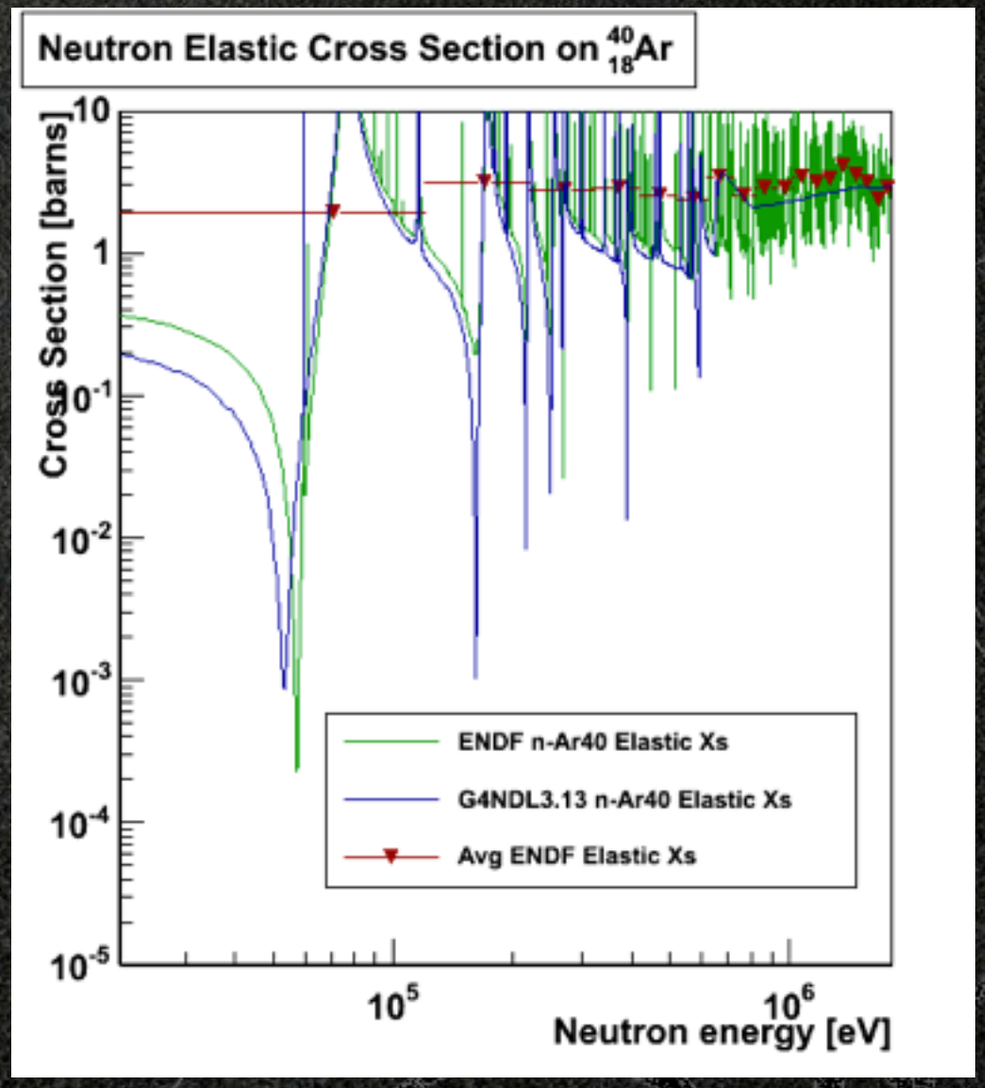
Background: Neutrons

- ^{39}Ar beta-decay
- Gamma Rays
- Surface Alphas
- Cosmogenic Neutrons
- Alpha-n Neutrons

Neutron Verification

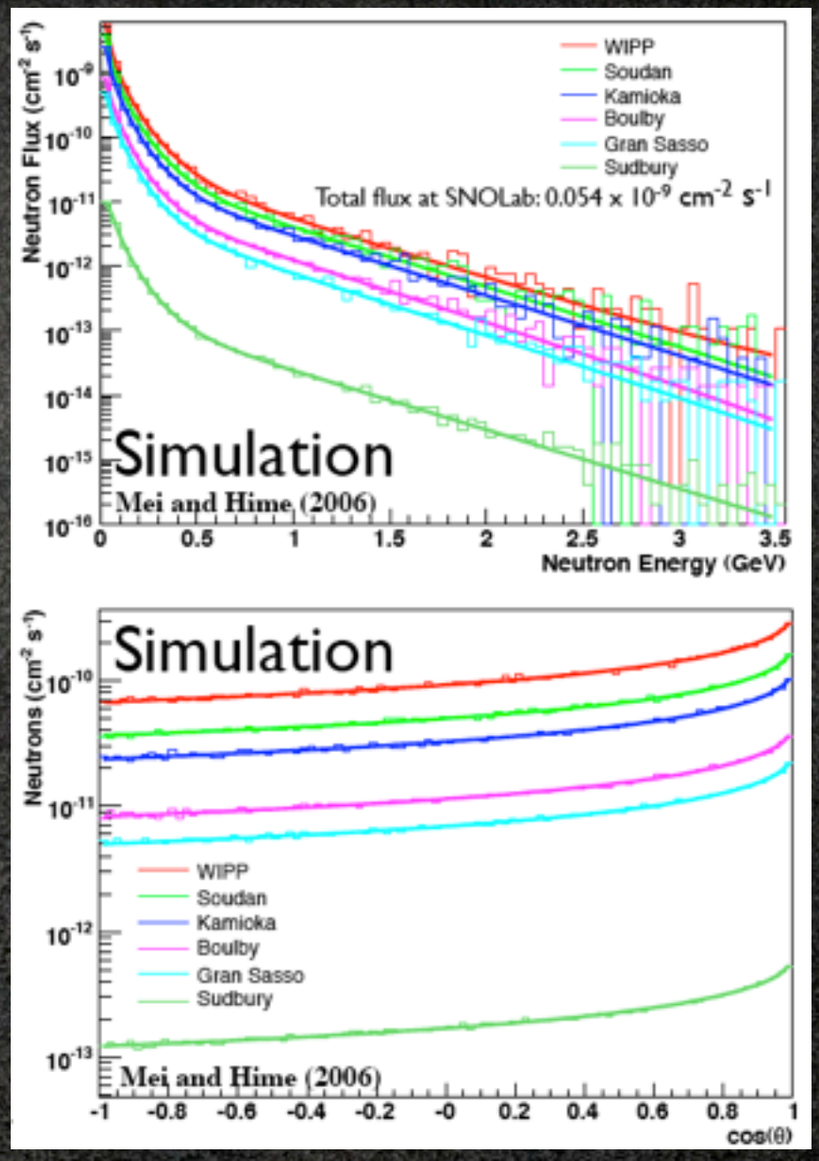
Checked low energy neutron physics in Geant4 (Neutron_HP, using cross sections from G4NDL3.13)

Interference between s-wave and hard-sphere scattering gives deep resonant dip in the elastic cross-section

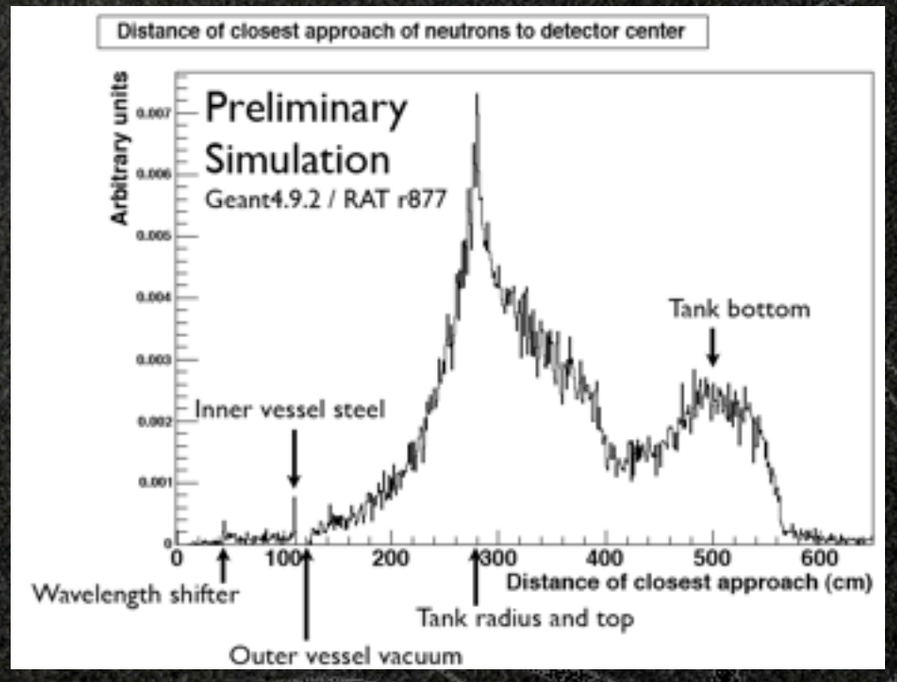


Background: Neutrons

- ^{39}Ar beta-decay
- Gamma Rays
- Surface Alphas
- Cosmogenic Neutrons
- Alpha-n Neutrons



Simulation of Mei & Hime neutron distribution <<1 event/yr



S. Jaditz APS '11

Background: Neutrons

- ^{39}Ar beta-decay
- Gamma Rays
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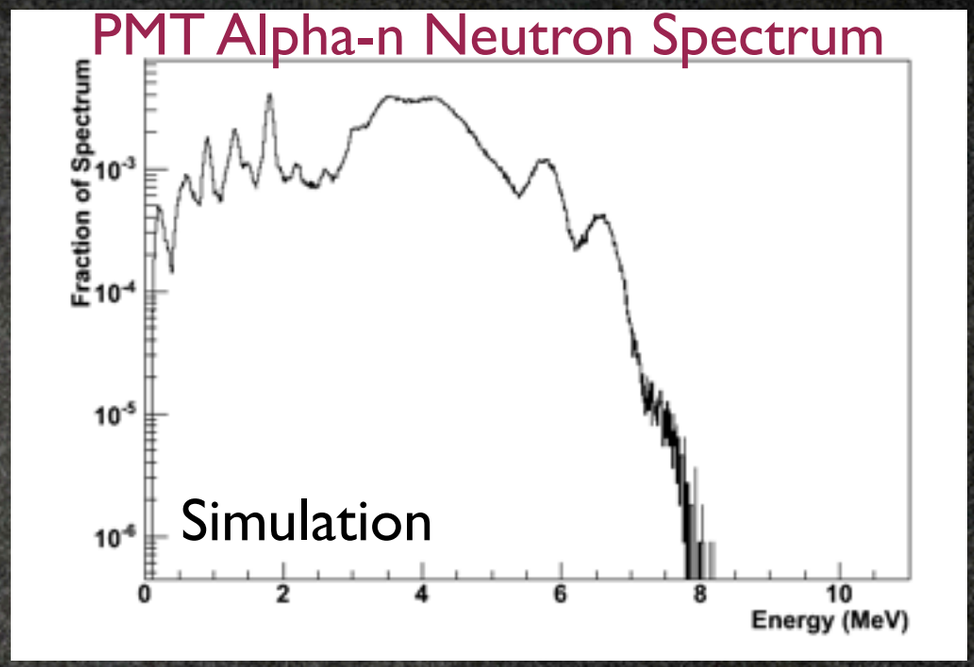
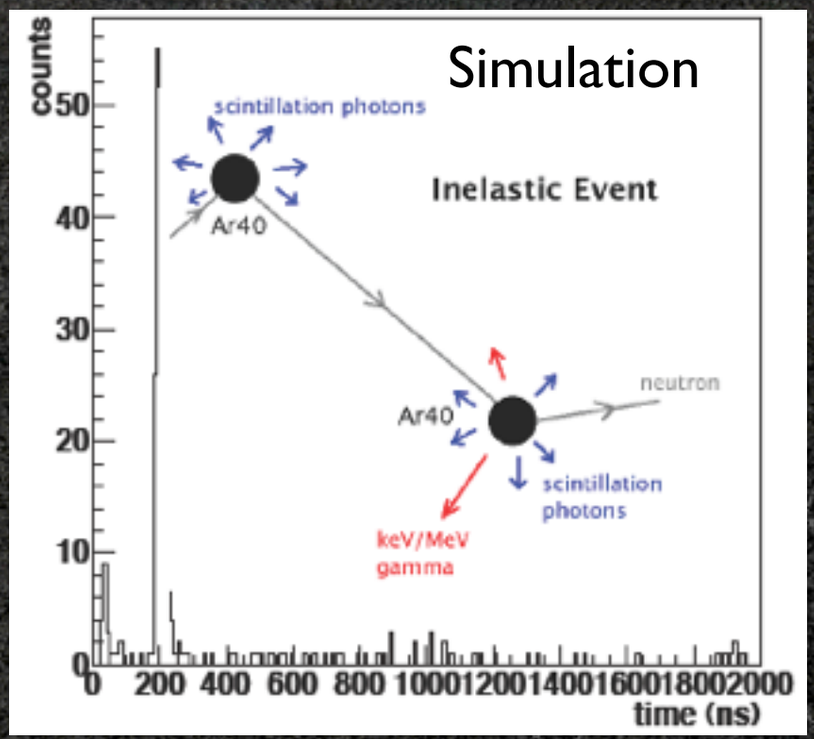




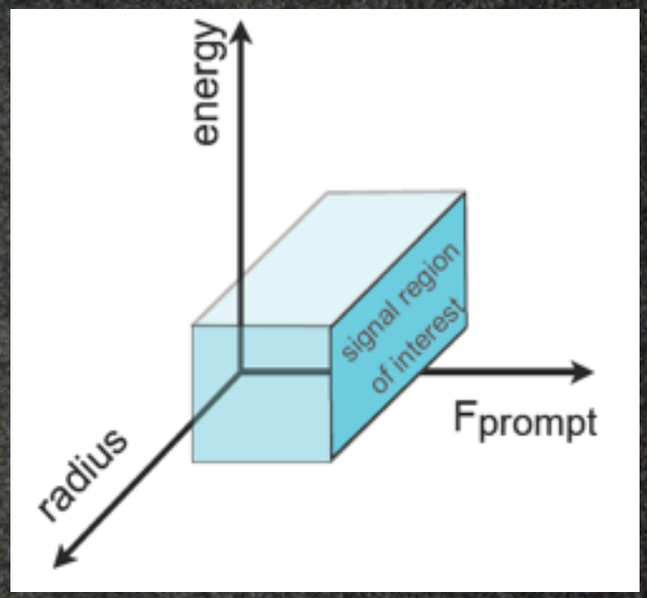
U/Th decay chain alphas in PMT glass produce neutrons (primarily off Boron)

Neutrons will have multiple scatters - and >90% scatter inelastically

~few events/yr prior to Lrecoil and multi-scatter cuts

Background Simulations

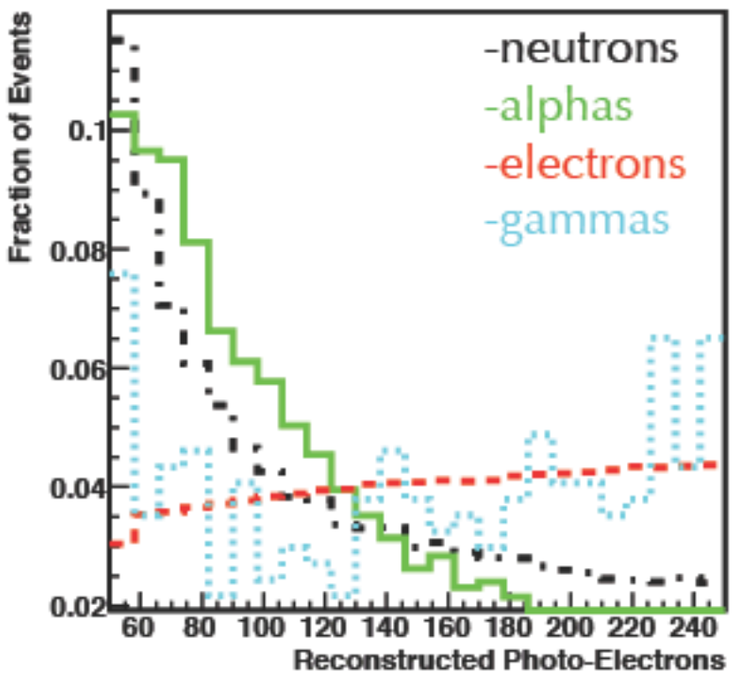
Current Simulation of Backgrounds
Reconstructed Distributions
No Cuts
All Unit Normalized

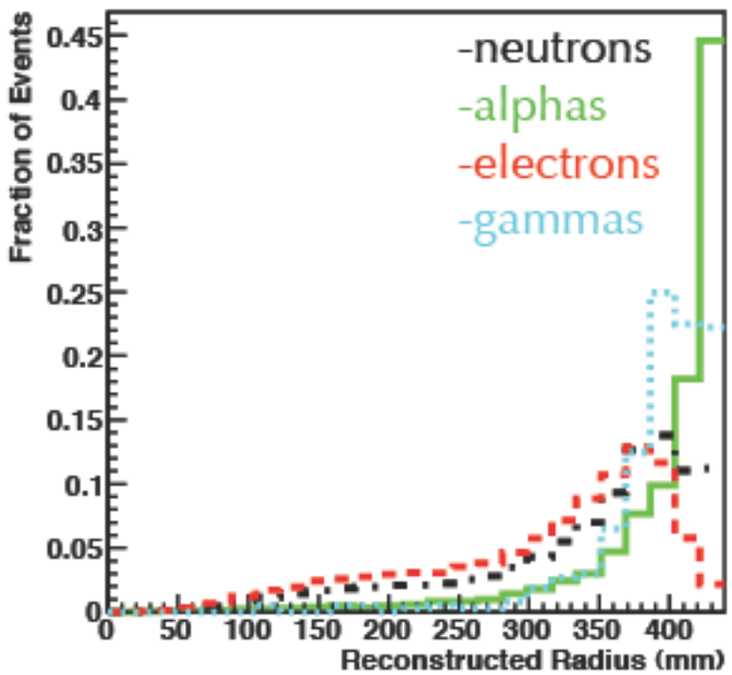


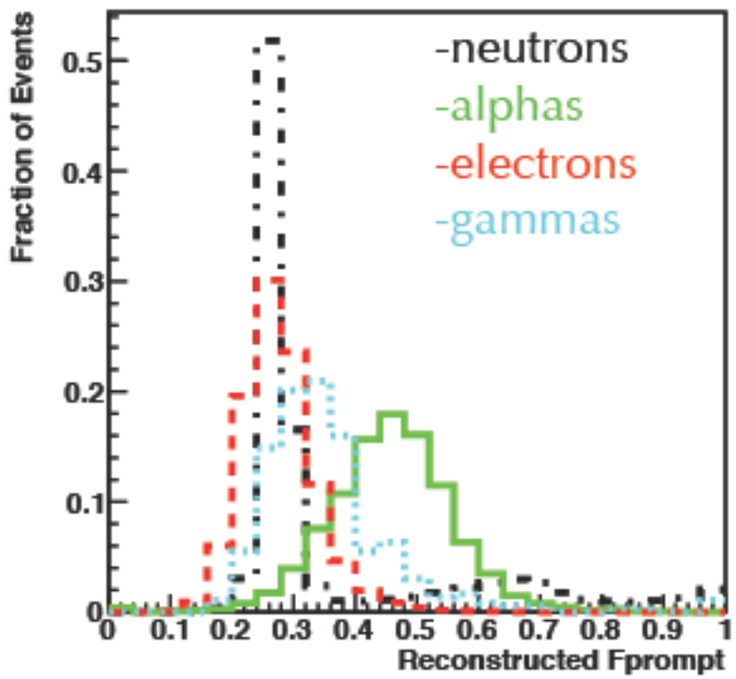
Planned Analyses

Analysis with a blind signal box defined by radius, energy and particle ID

Likelihood-based fit for PDF of signal over background using calibration data

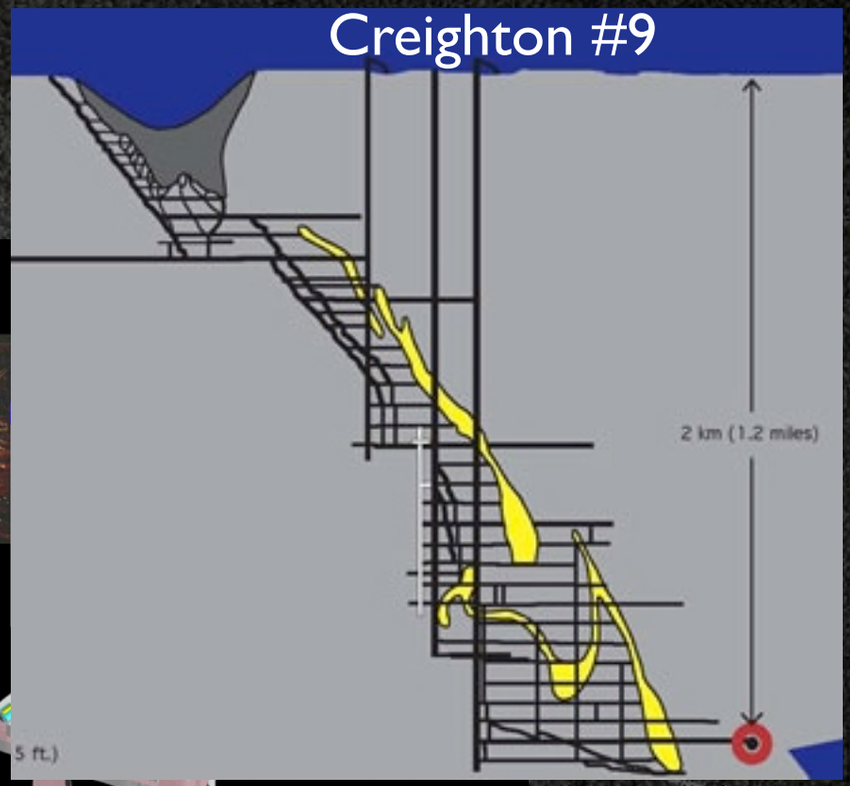






Making It So

SNOLab Cube Hall



SNOLAB
MINING FOR KNOWLEDGE
CREUSER POUR TROUVER... L'EXCELLENCE

Construction: Veto Tank

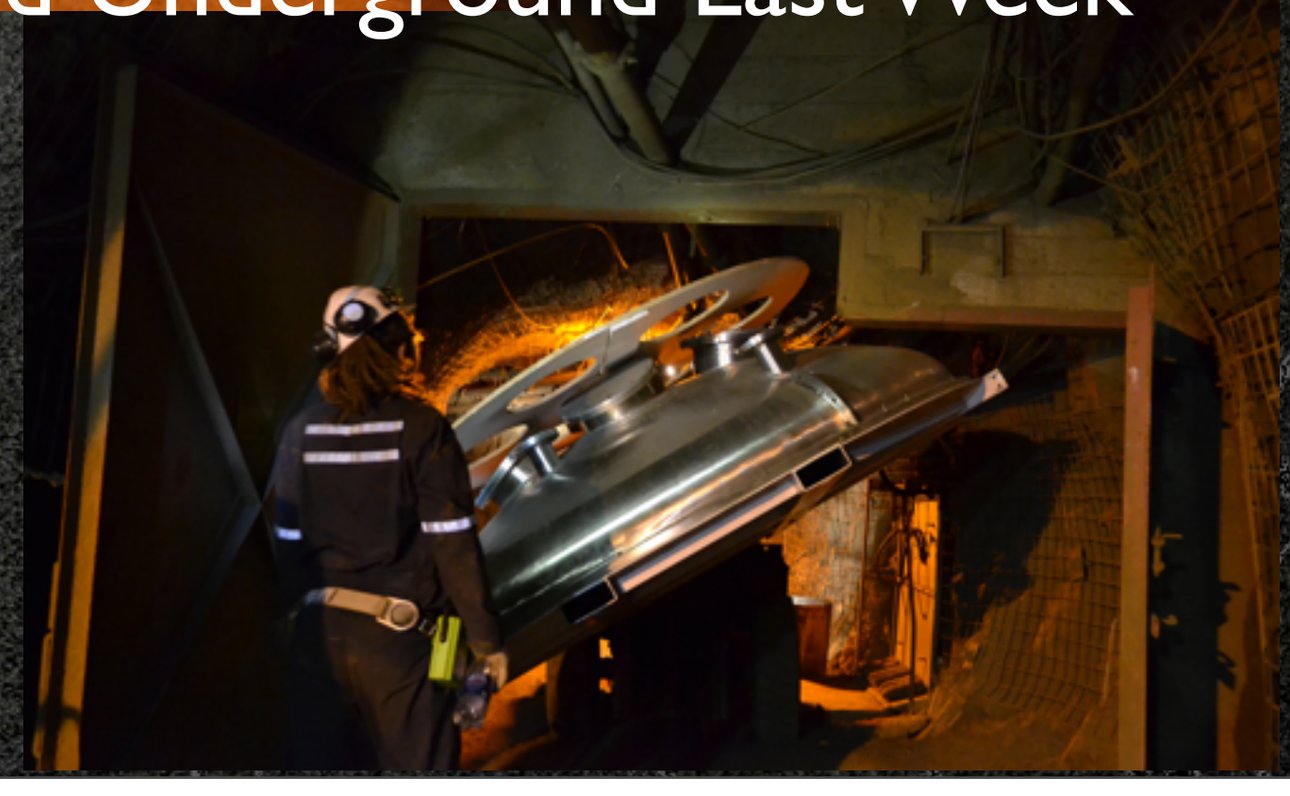
DEAP-3600 MiniCLEAN

Veto String Test Assembly at Bates

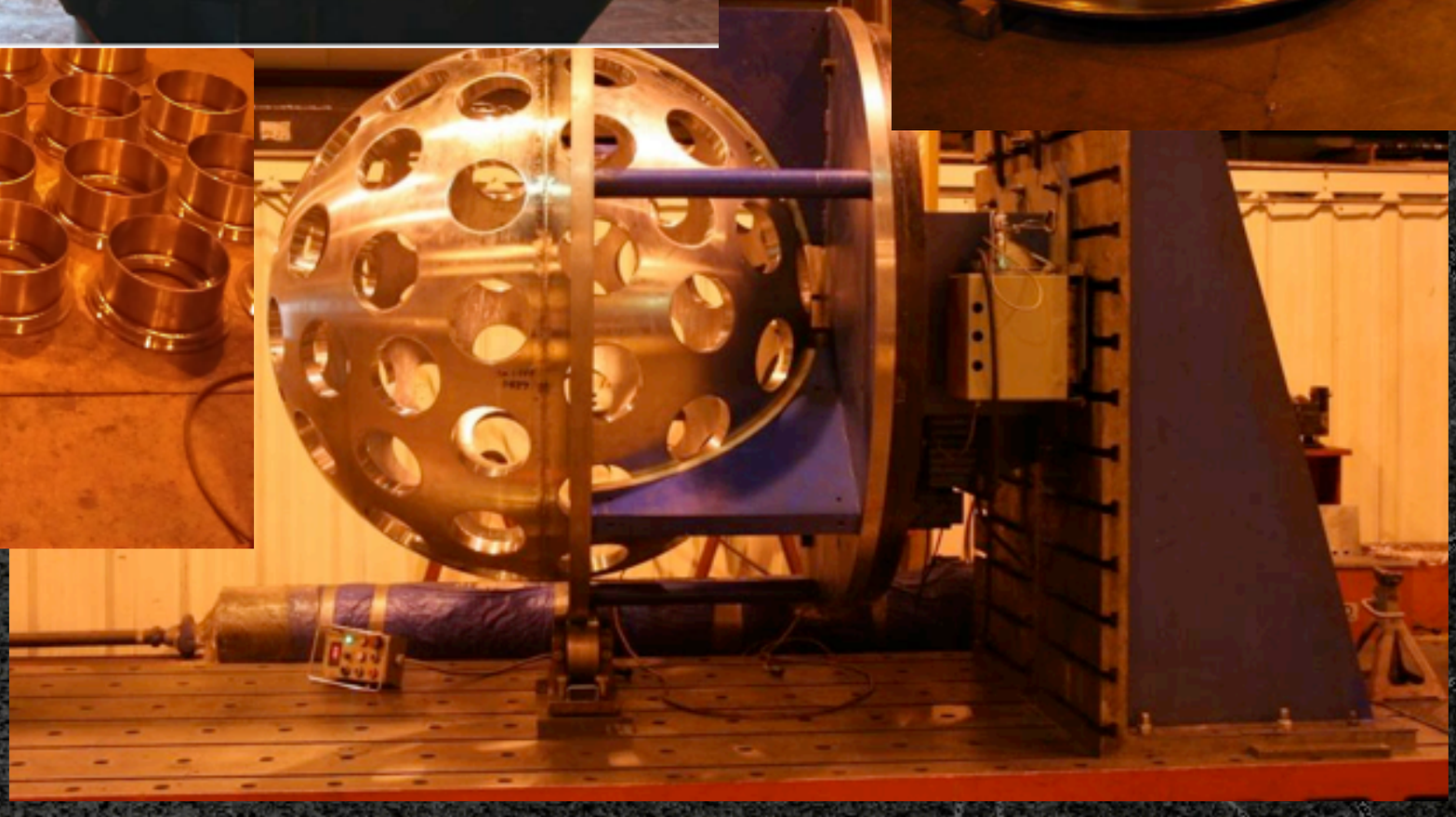
Construction: Outer Vessel

Outer Vessel Transport

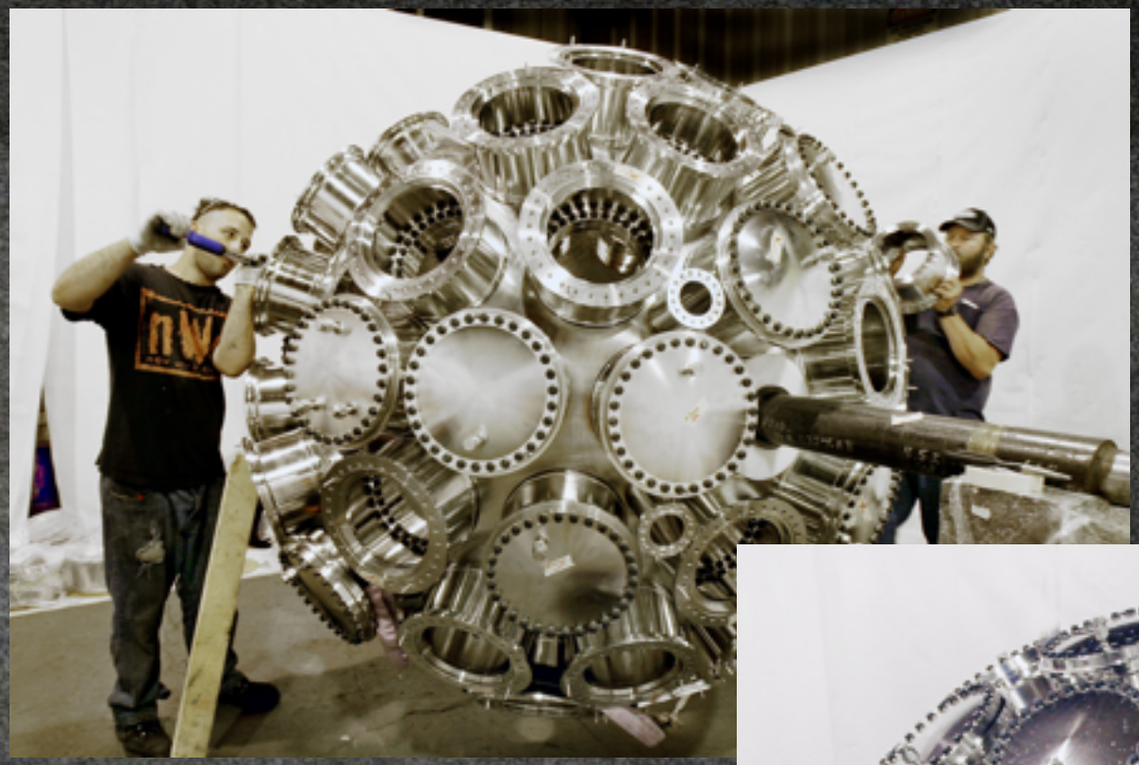
Outer Vessel Transported Underground Last Week

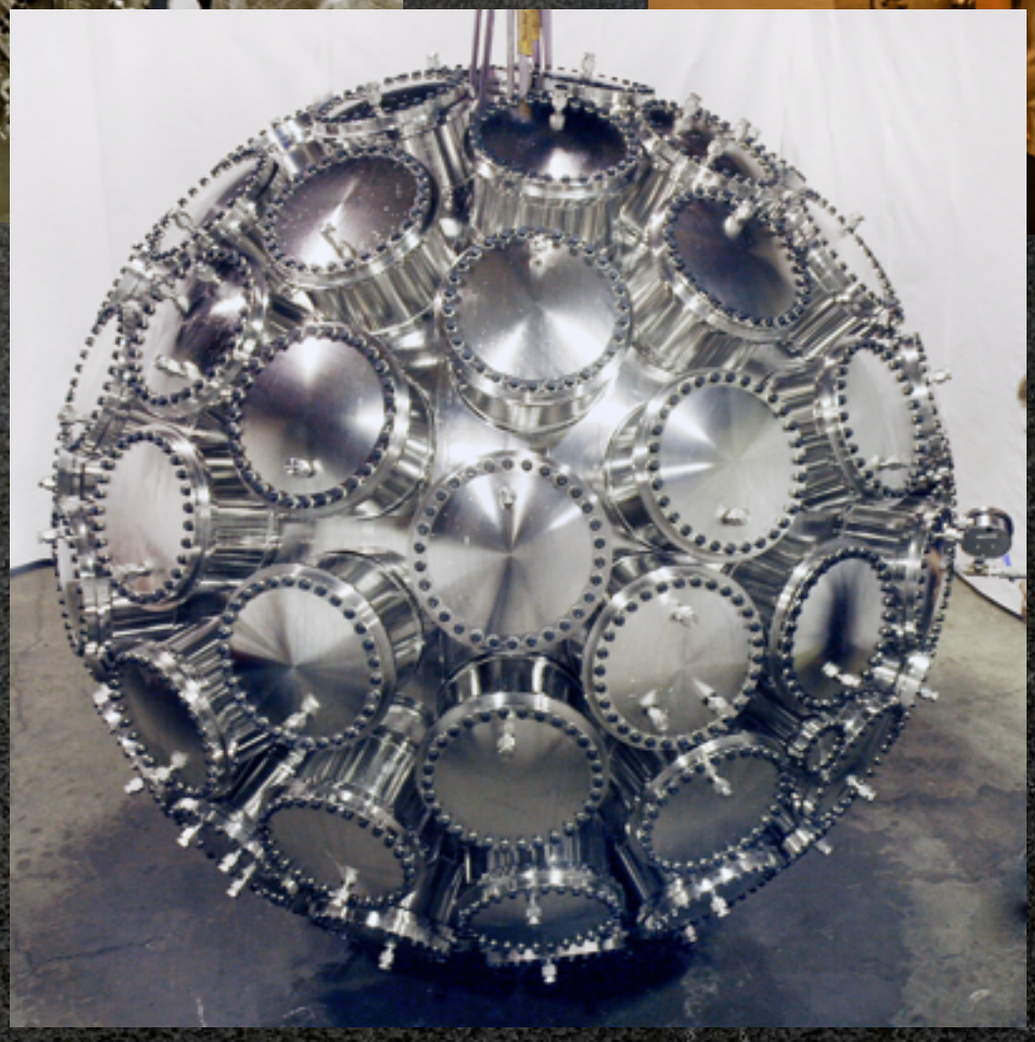


Construction: Inner Vessel



IV Pressure and Vacuum Test



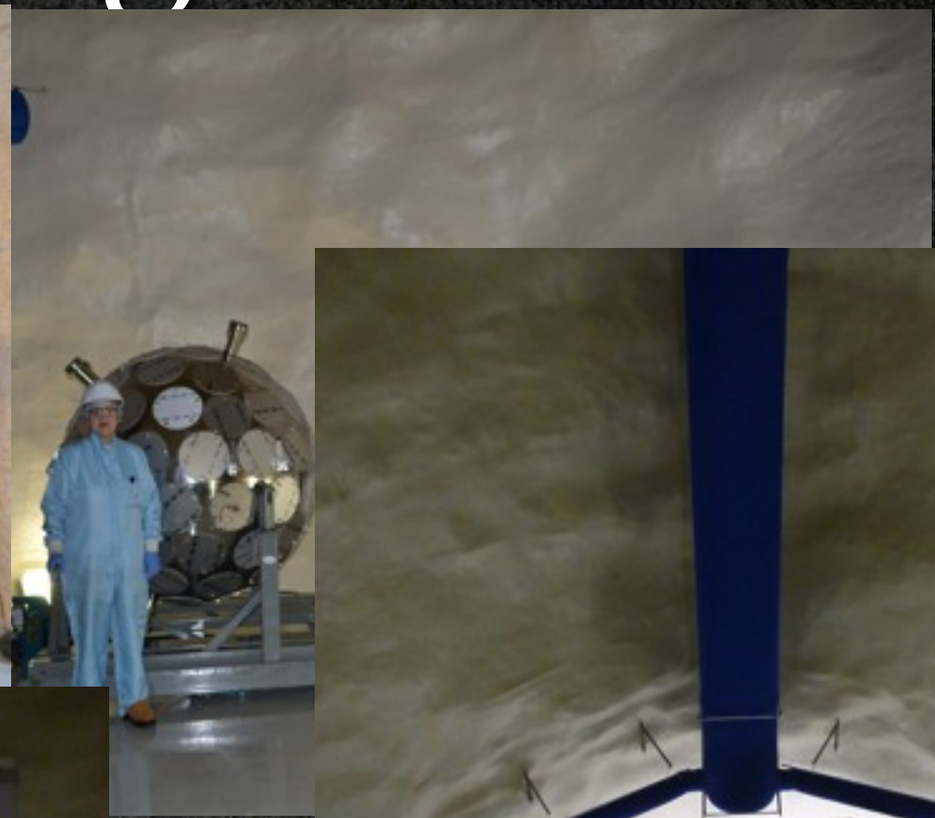


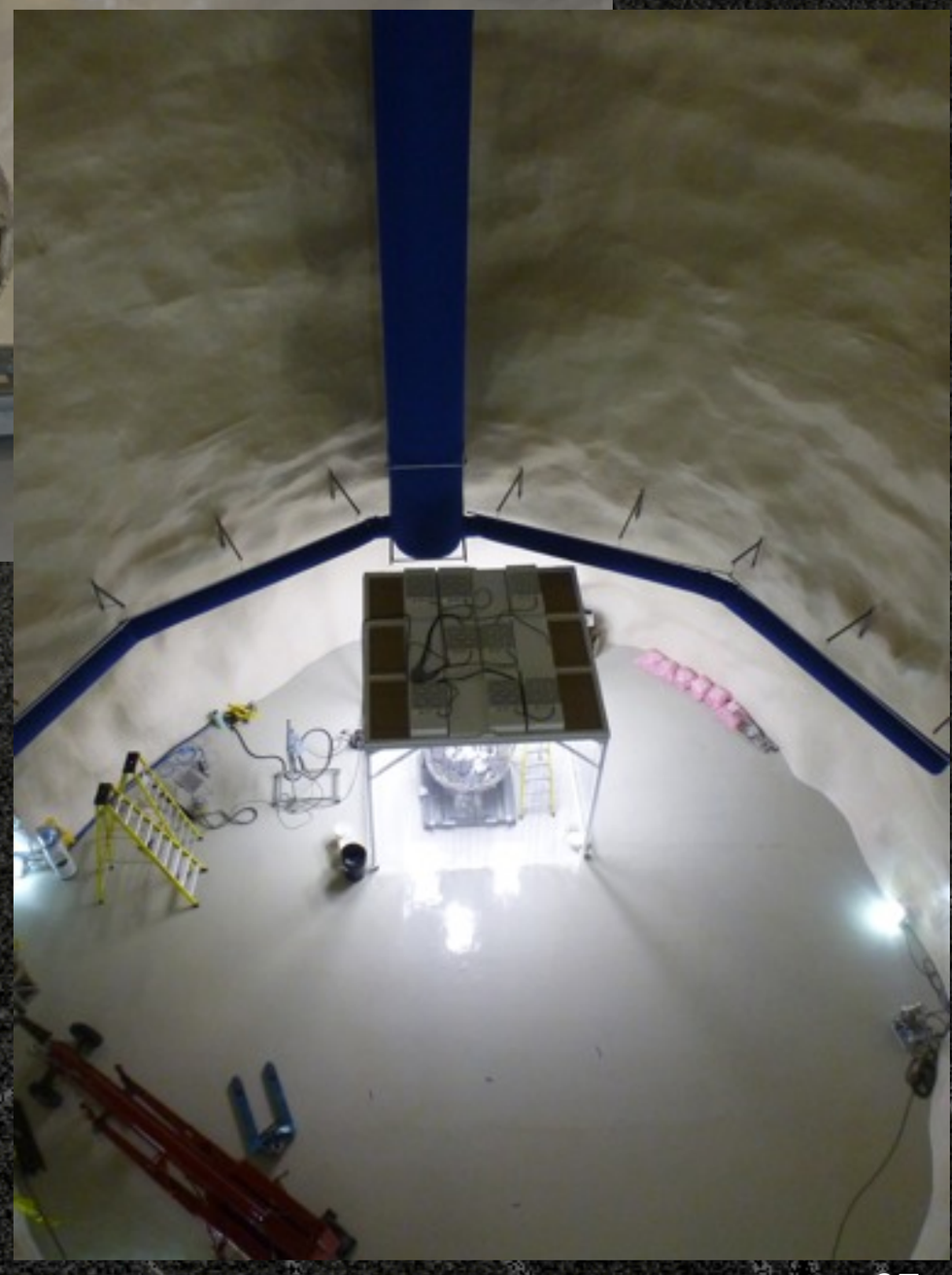
Assembly, Pressure test and Vacuum test completed at Winchester Precision Technologies, in NH, in September 2012

Inner Vessel Transport

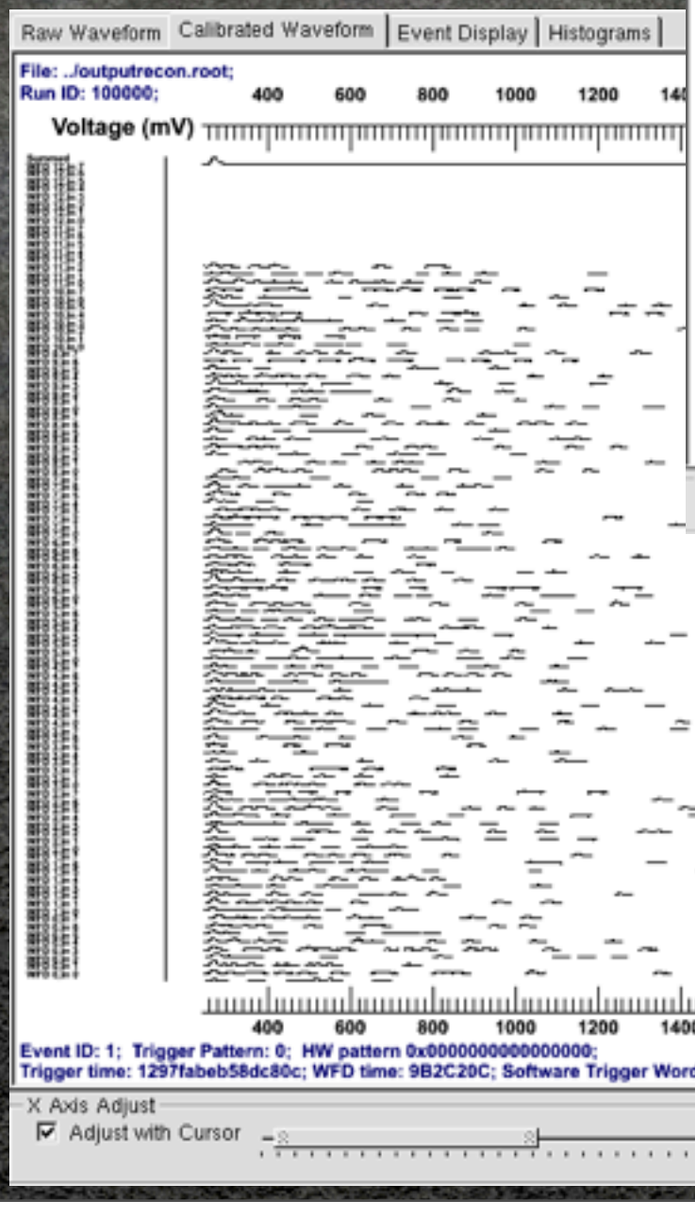
Inner Vessel Transported Underground December 9th, 2012

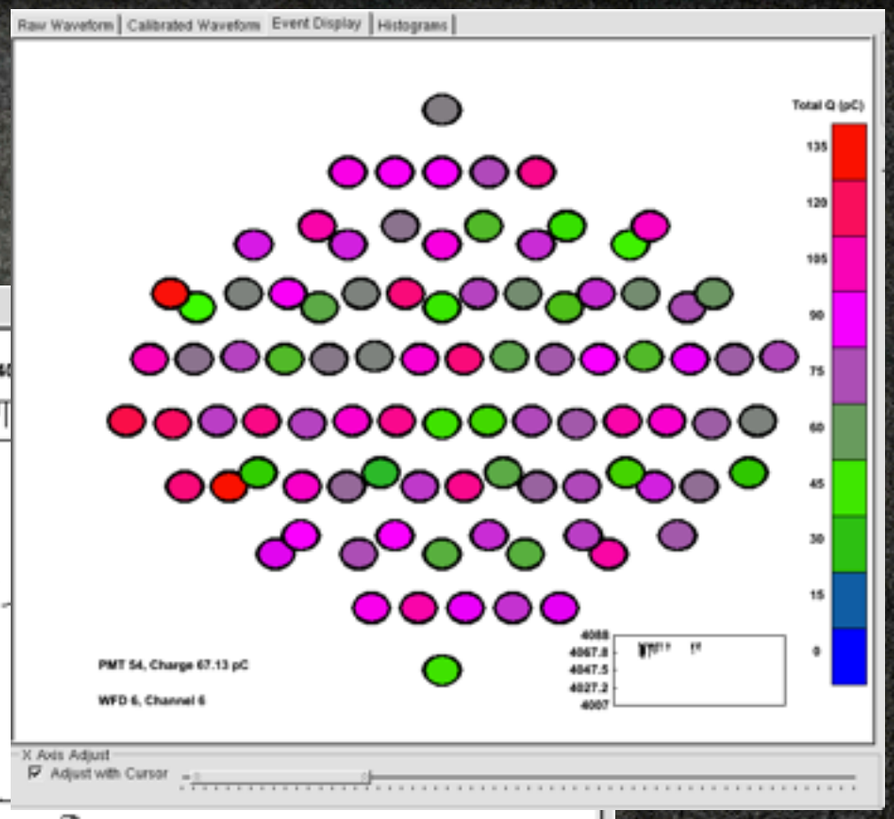
IV Underground

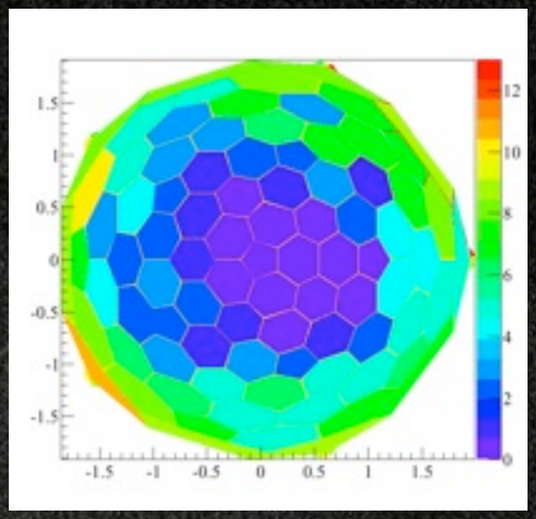


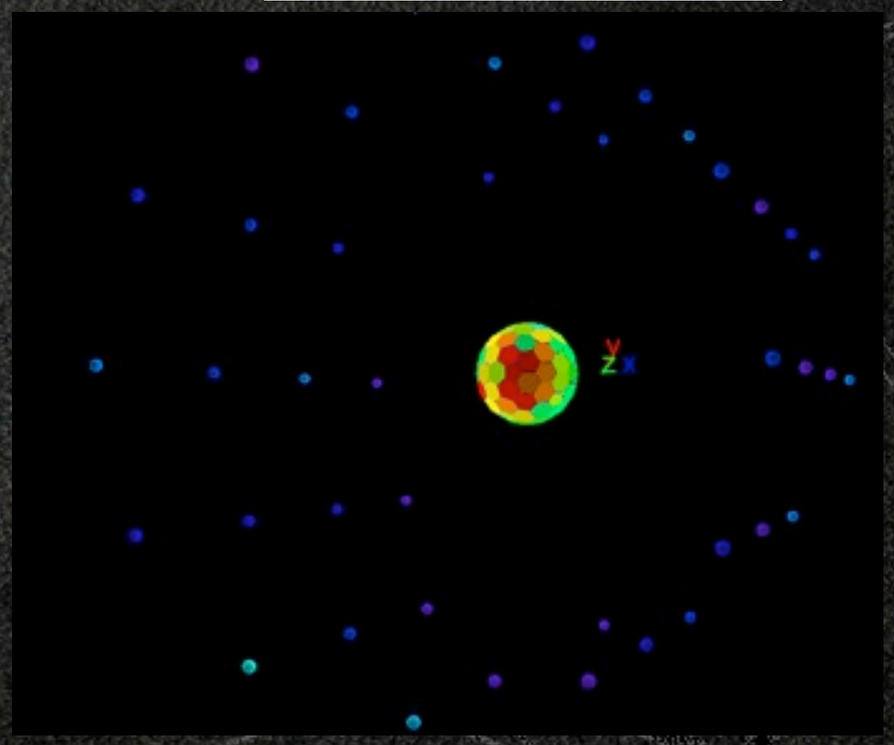


Simulation → Operation Software



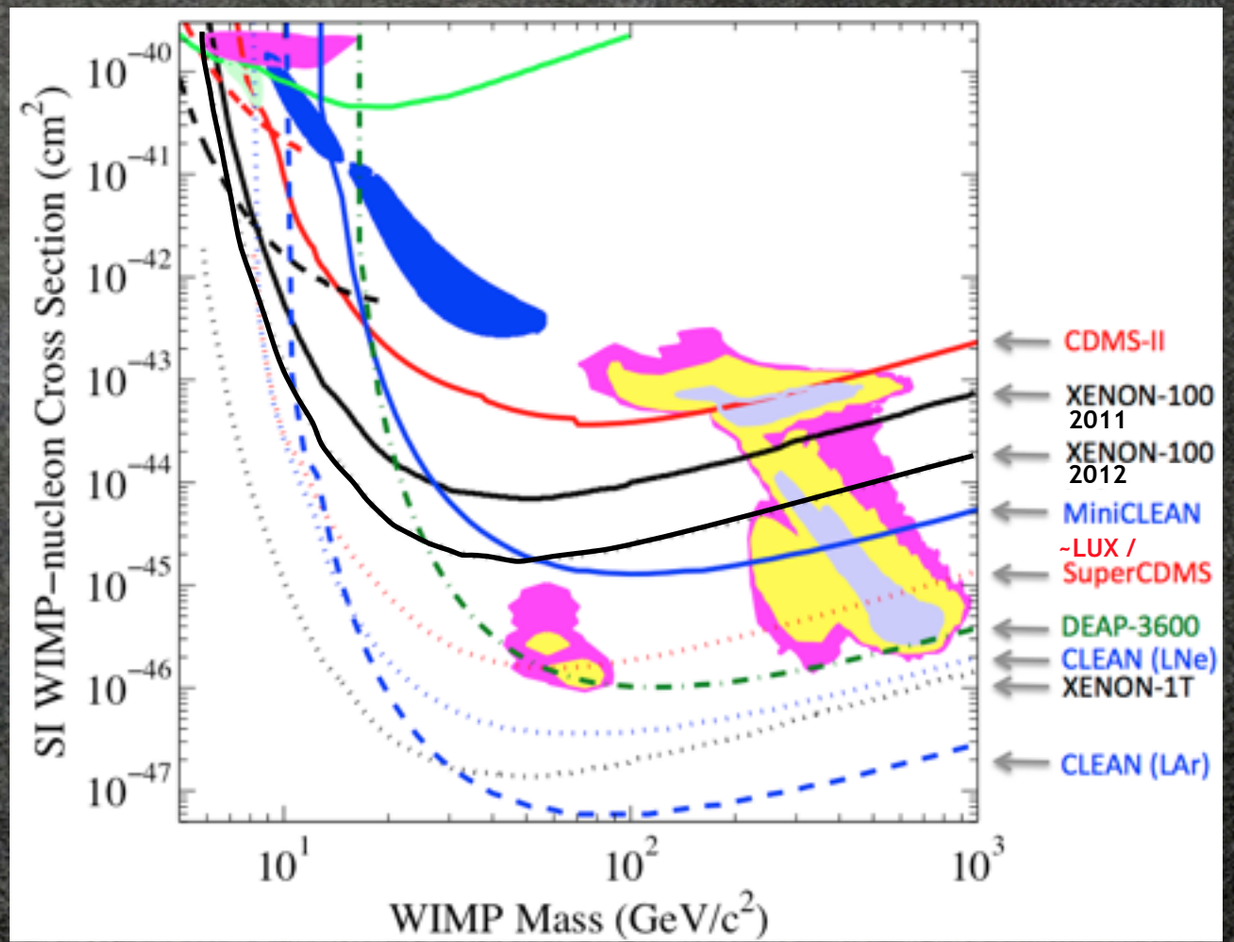






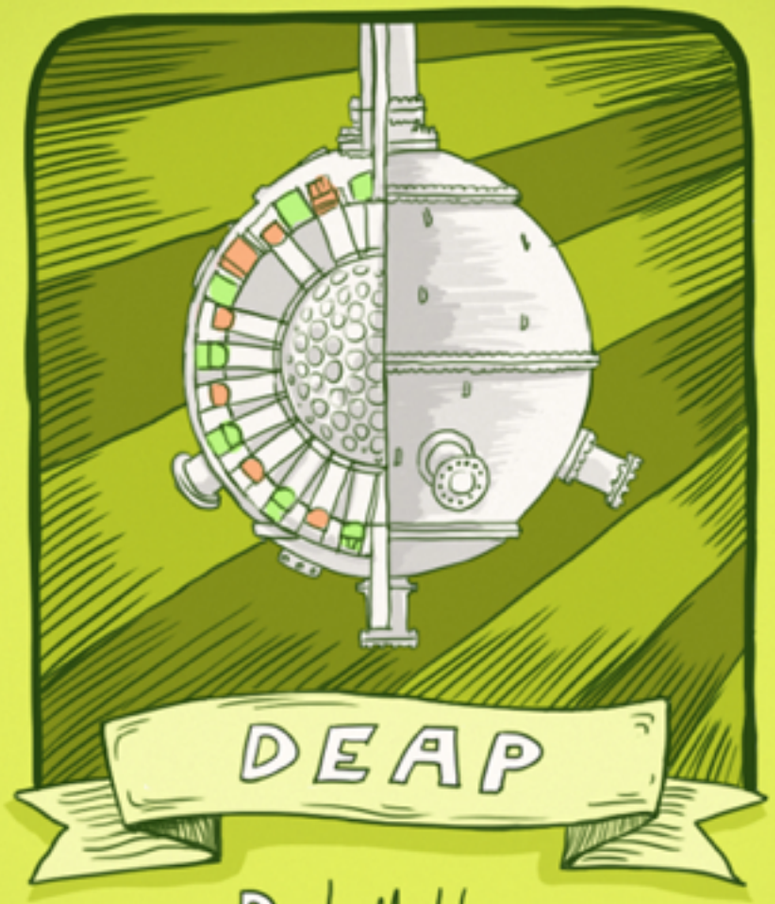
Event viewers utilizing a number of views and organizational tools for future troubleshooting, from BU and UPenn software groups

Program Goals



- WIMP sensitivity to 2 x 10^{-45} cm^2 from two year run
- Show Position / energy / Particle ID reconstruction
  - PSD is the primary goal of MiniCLEAN in 2013: Achieved with ^{39}Ar spike
- Measure background rates in-situ
- Constrain systematics with calibration

DEAP-3600



DEAP

AREA OF RESEARCH:
Direct detection of dark matter

TECHNOLOGY:
Detector filled with liquid argon

FUN FACT:
The sensors in the DEAP detector can distinguish individual particles of light

INSTITUTIONS:
Carleton University; Laurentian University; Queen's University; Royal Holloway University of London; Rutherford Appleton Laboratory; SNOLAB; TRIUMF; University of Alberta; University of Sussex

DEAP

TARGET:
LAr, DAr

Mass:
3600 kg target, 1000 kg fiducial

Light collection:
255 8" Hamamatsu R5912 HQE PMTs

Vessel:
monolithic acrylic, resurfaced and coated with wavelength shifter in situ

Shielding:
50 cm acrylic & PE, in 8m water shield

Sensitivity:
SI cross section 10^{-46} cm^2

http://www.symmetrymagazine.org/article/november-2012/voyage-to-snolab

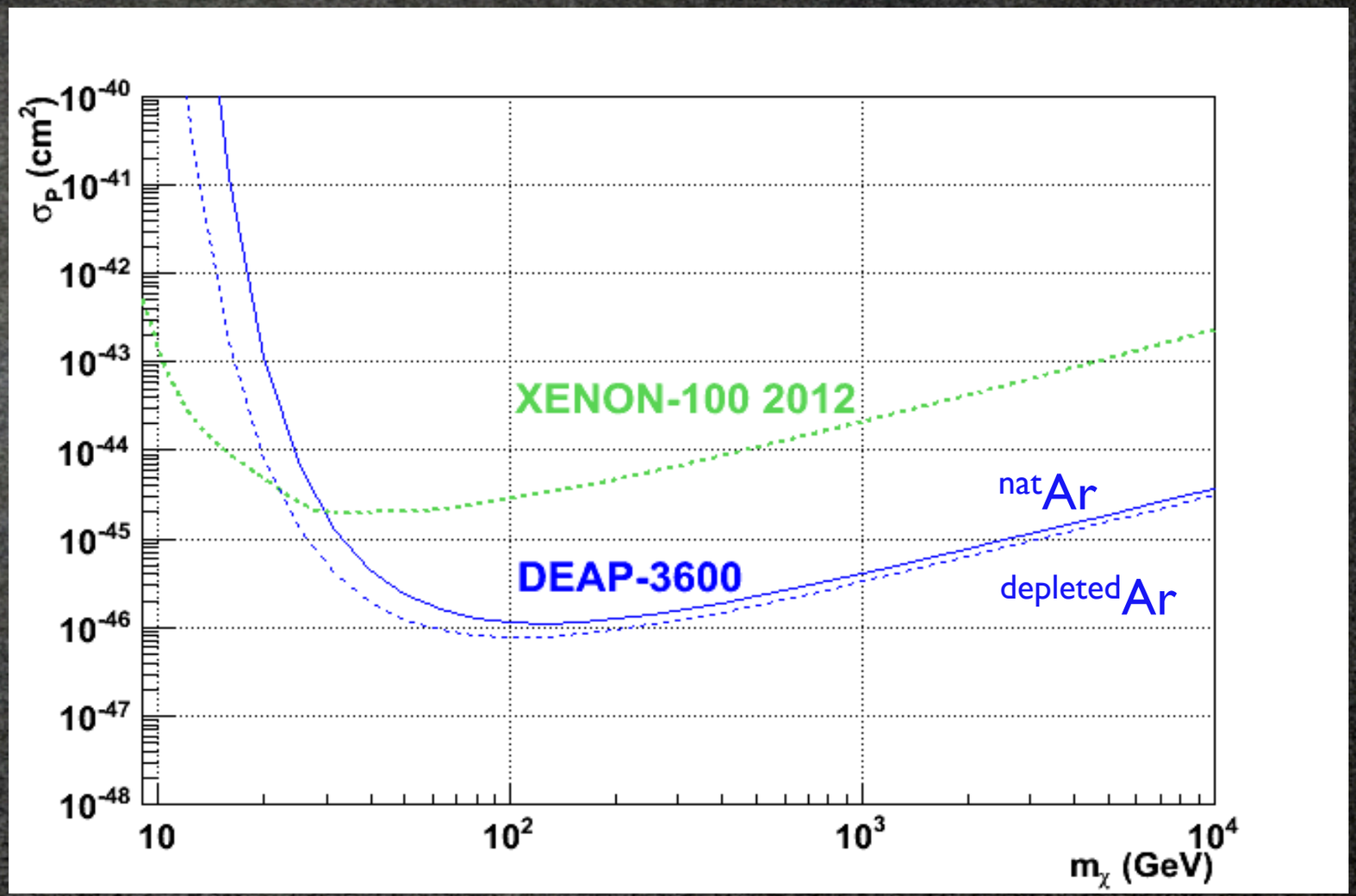
DEAP Construction

Steel Shell

Photos from M. Boulay & T. Flower, DEAP-3600 collaboration

Acrylic Vessel

DEAP-3600 Outlook



Plot M. Boulay 2012

Sensitivity for:

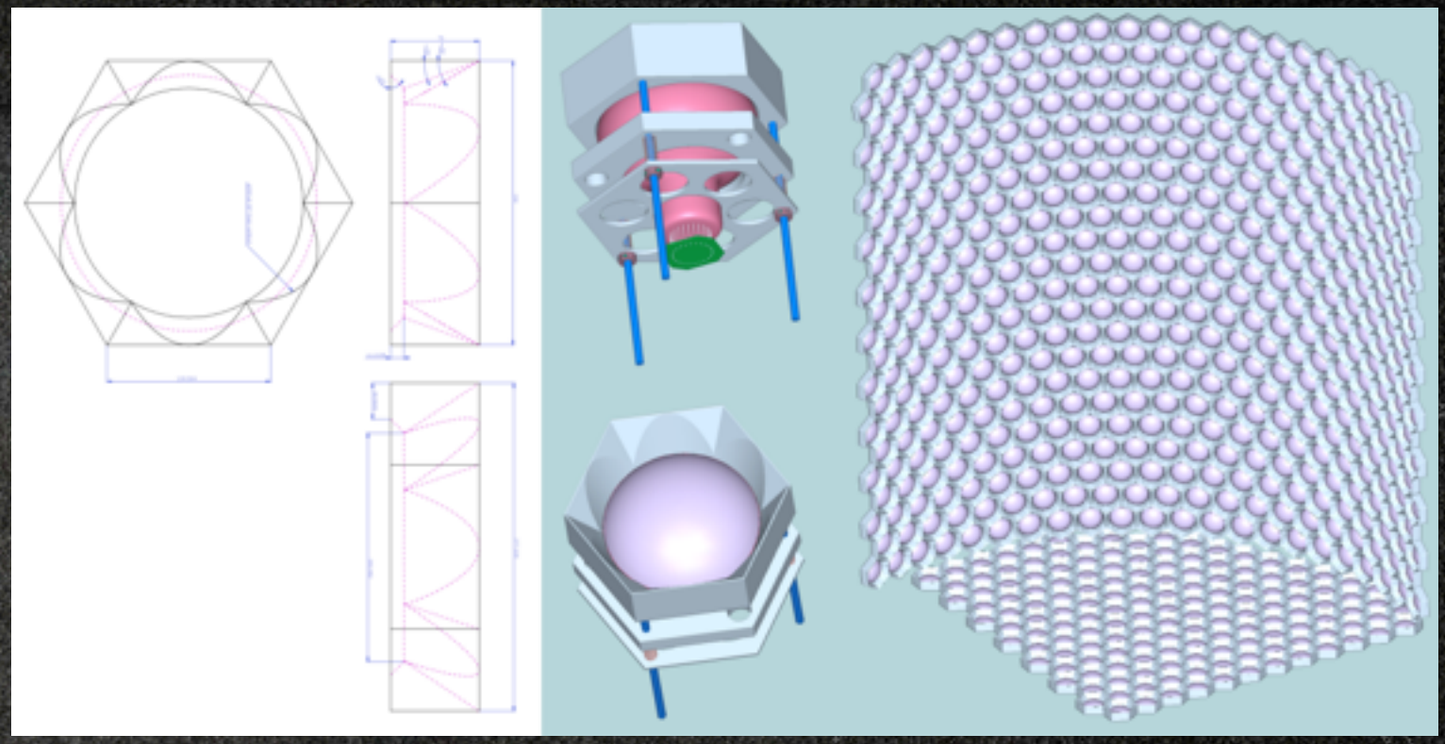
- 3 year run
- 60 keV$_r$ threshold

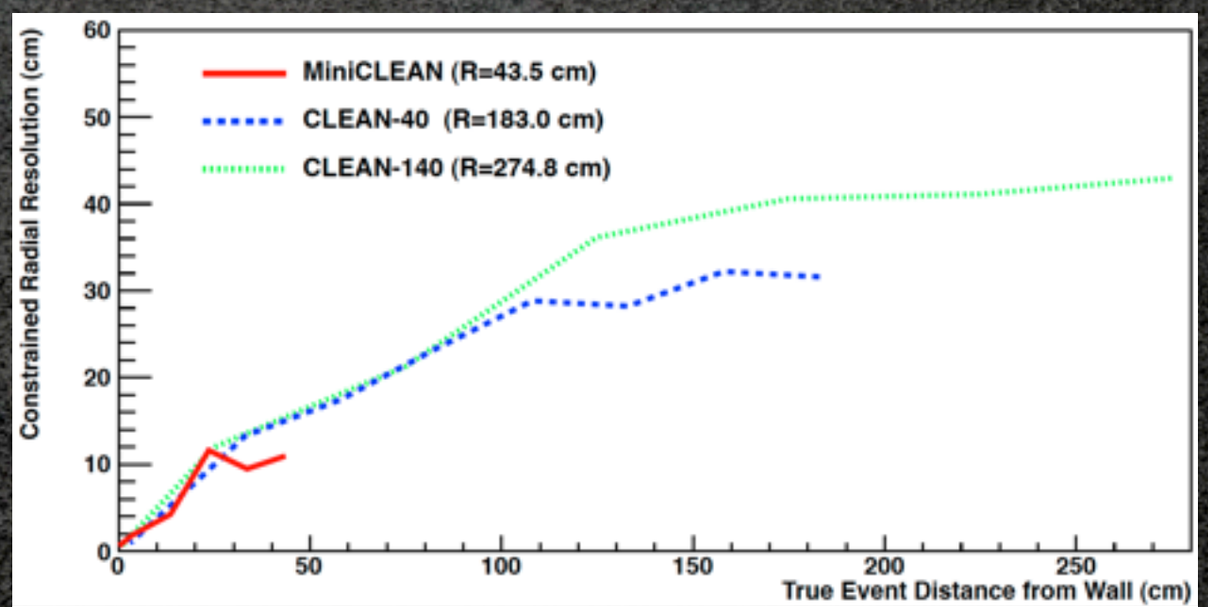
with natural argon
10^{-46} cm^2
with depleted argon
8×10^{-47} cm^2

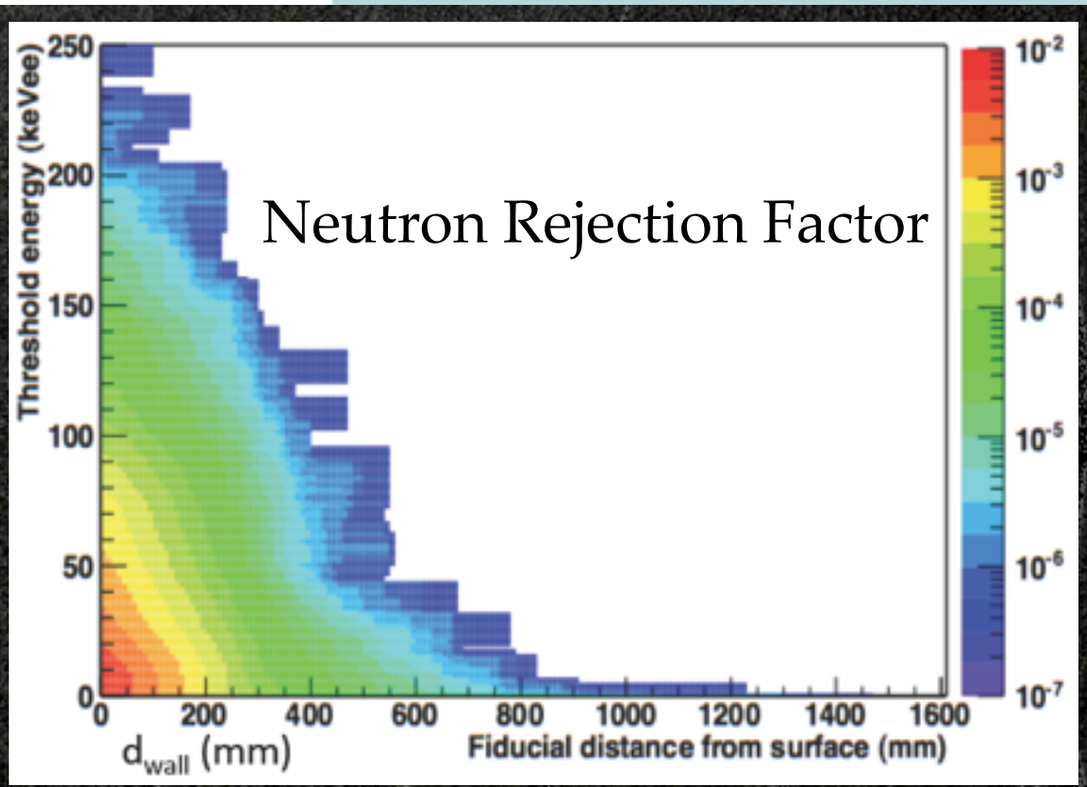
DEAP-3600 is in construction for an early 2014 turn on date

CLEAN

- 45T CLEAN detector proposed in G2
- Simple cylindrical design
- 15T fiducial volume, capable of seeing ~15 events a year if a 10^{-46} cm^2 cross section







Conclusion

Punxsutawney Phil (Keith Srakocic - AP)

- MiniCLEAN/CLEAN in G2 R&D process in 2013
- MiniCLEAN running summer 2013
- ^{39}Ar spike in MiniCLEAN Fall 2013
- DEAP-3600 running early 2014