The Abdus Salam International Centre for Theoretical Physics

United Nations Educational, Scientific and Cultural Organization

IAEA International Atomic Energy Agency

2047-3

Workshop Towards the Neutrino Technologies

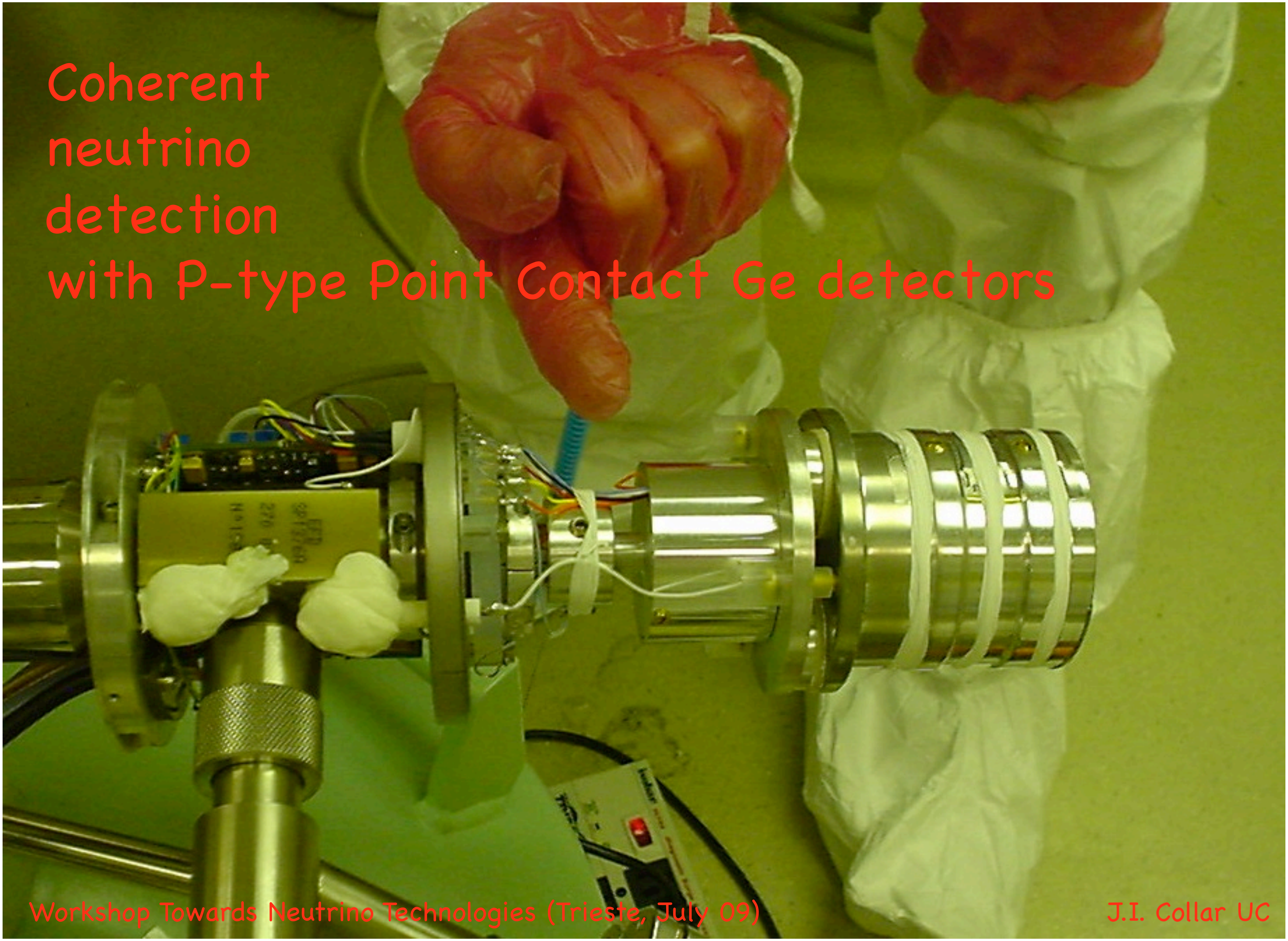
13 - 17 July 2009

Progress on coherent neutrino detection using P-type point contact germanium detectors

Juan COLLAR COLMENERO

University of Chicago
Department of Physics and
Enrico Fermi Institute
5640 Ellis Ave., LASR 214
Chicago, IL 60637, USA

Coherent neutrino detection with P-type Point Contact Ge detectors



A one-page tutorial on coherent ν-N scattering

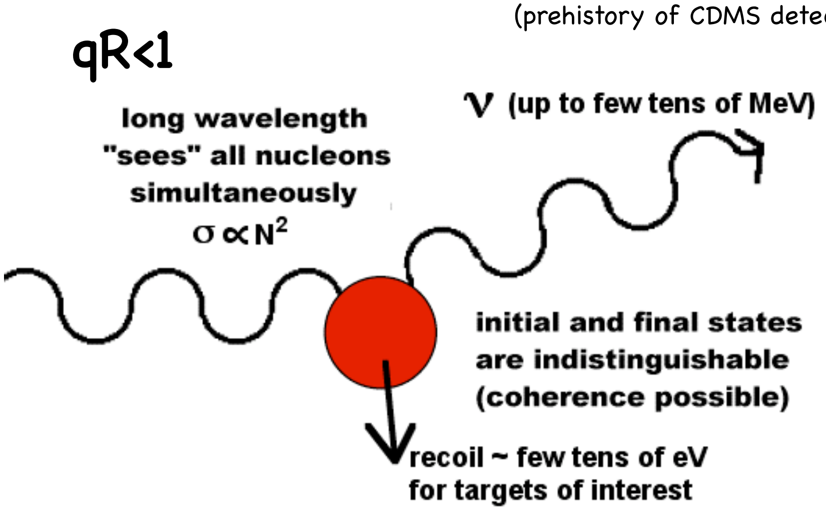
- Uncontroversial Standard Model process
- Large enhancement in cross-section for E_ν < few tens of MeV ($\sigma \propto N^2$, possible only for neutral current)
- However, not yet measured... detector technology has been missing.

Detector mass must be at least ~1 kg (reactor experiment) + *recoil* energy threshold << 1keV

(low-E recoils lose only 10-20% to ionization or scintillation)

- Cryogenic bolometers and other methods proposed, no successful implementation yet

Cabrera, Krauss & Wilczek Phys. Rev. Lett. 55, 25–28 (1985) (prehistory of CDMS detectors)



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Smallish detectors... "ν technology"?

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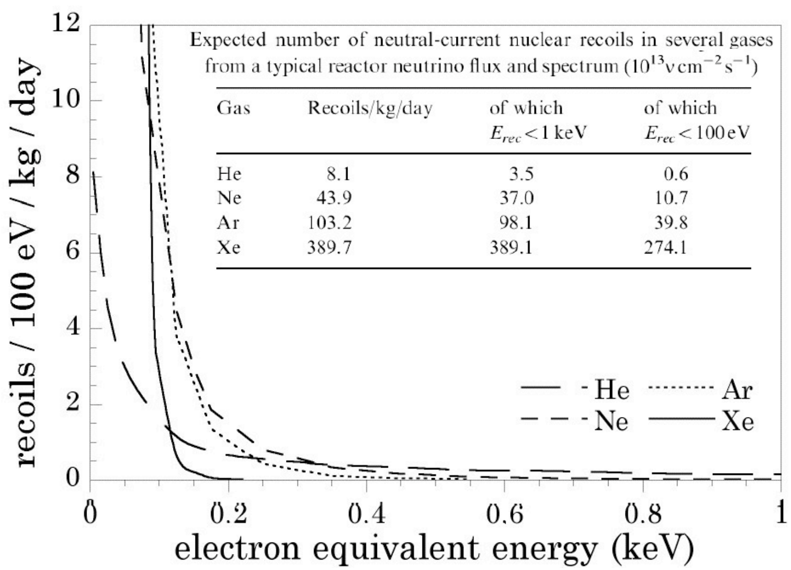

Gas	Recoils/kg/day	of which $E_{rec} < 1$ keV	of which $E_{rec} < 100$ eV
He	8.1	3.5	0.6
Ne	43.9	37.0	10.7
Ar	103.2	98.1	39.8
Xe	389.7	389.1	274.1

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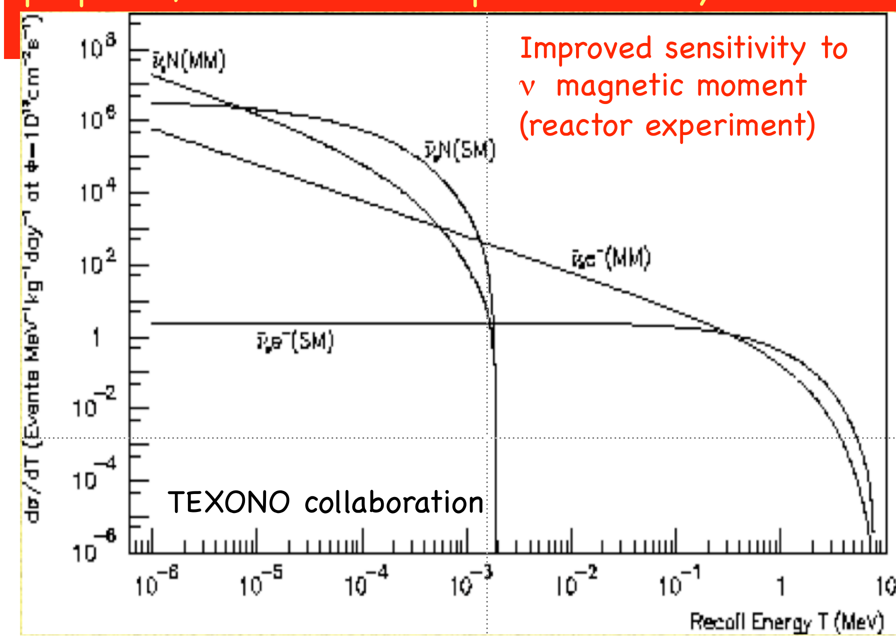

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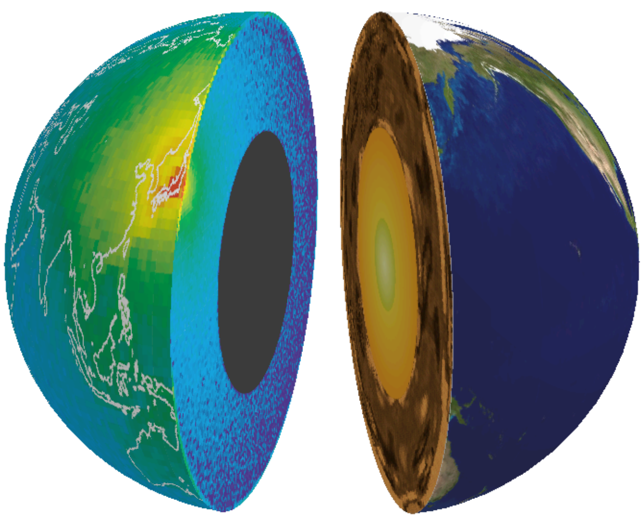

2005: Geoneutrinos detected.

Dawn of the applied neutrino physics era?

Applied Anti-Neutrino Physics Workshops

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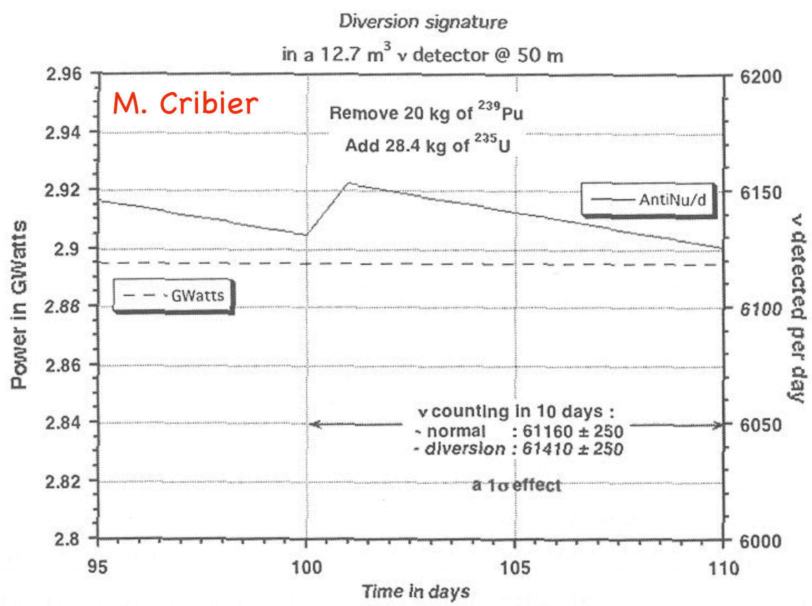

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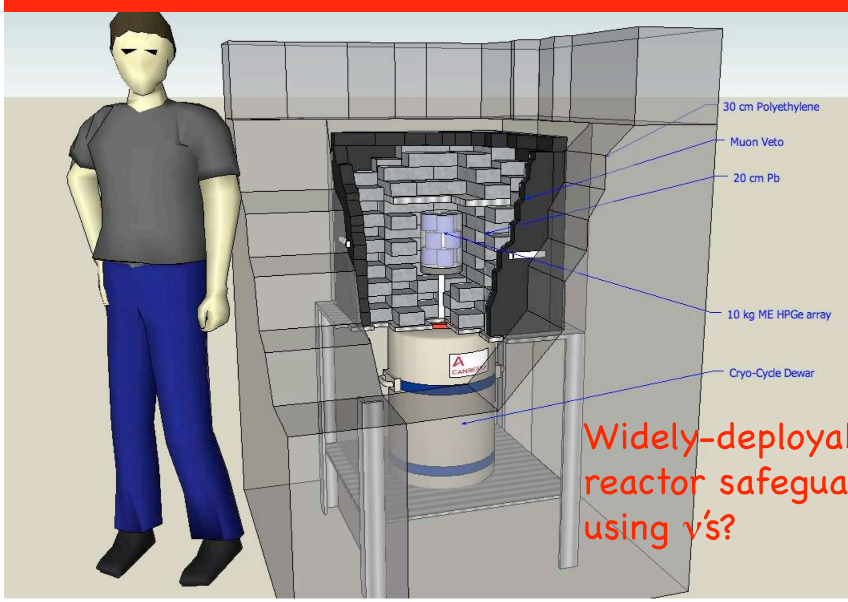

Widely-deployable reactor safeguards using ν's?

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CoGeNT:

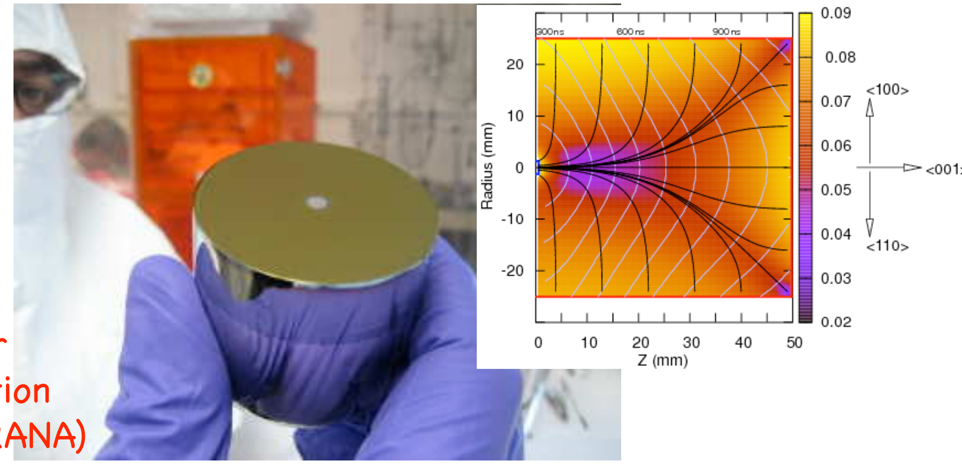
neutrino & astroparticle physics using large-mass, ultra-low noise germanium detectors

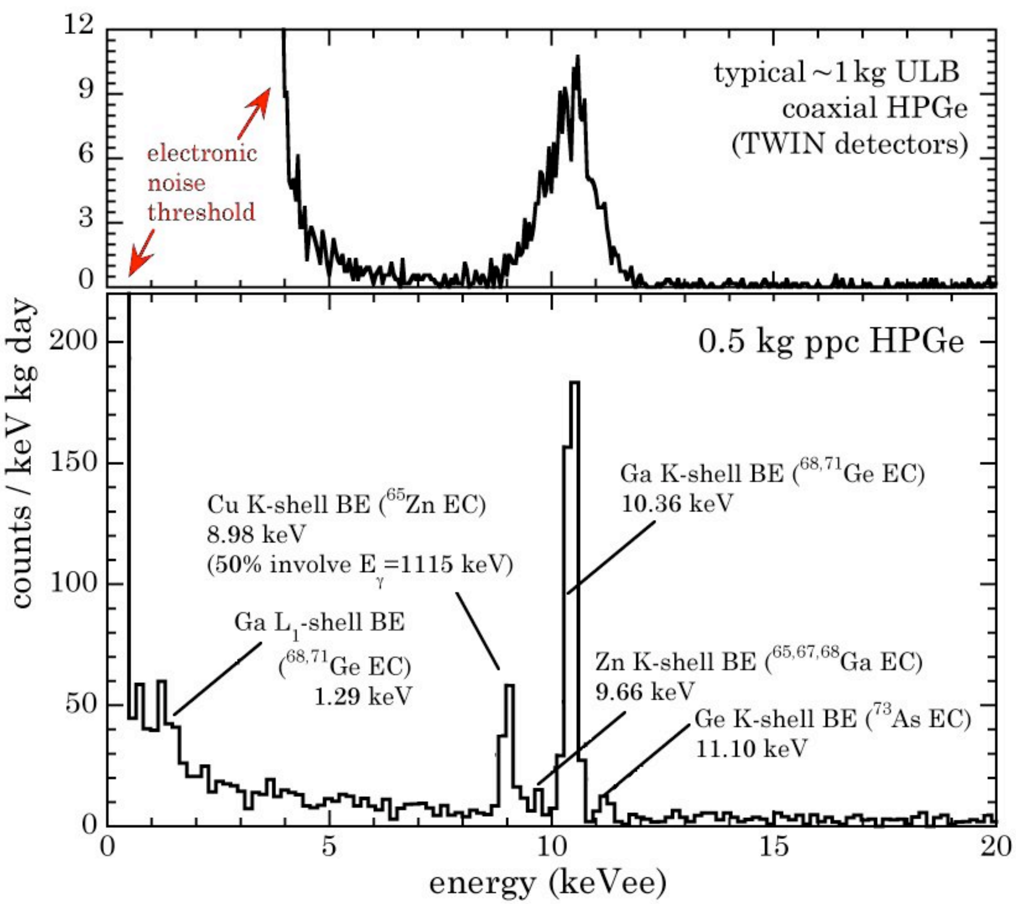
(ANL, CANBERRA, LLNL, PNNL, SNL, UC, UW)

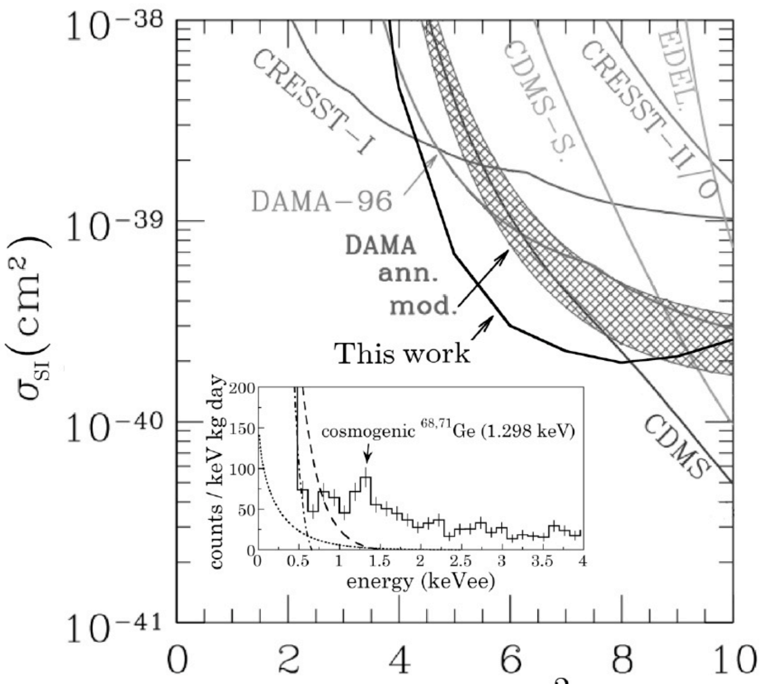
New PPC HPGe

JCAP 09(2007)009

Applications:
- Light Dark Matter
- Coherent ν detection
- ββ decay (MAJORANA)



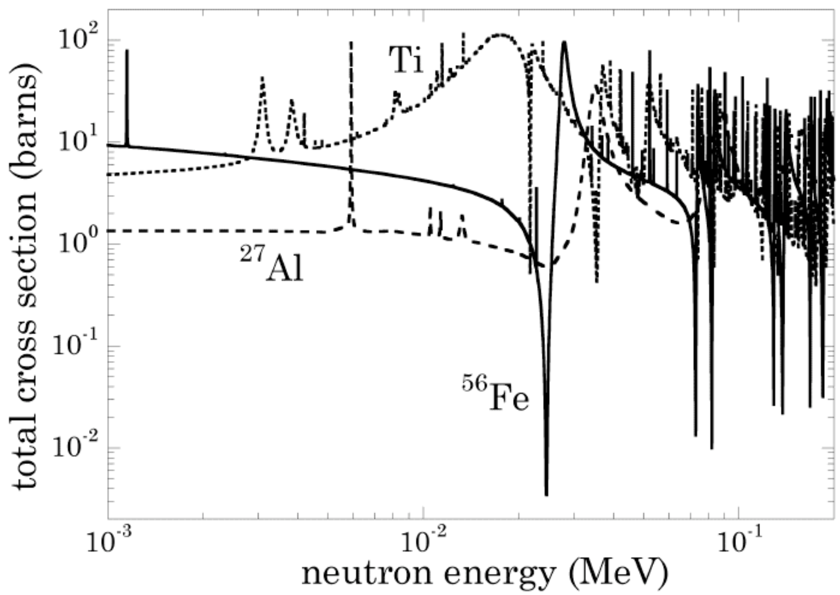




PRL 101 (2008) 251301

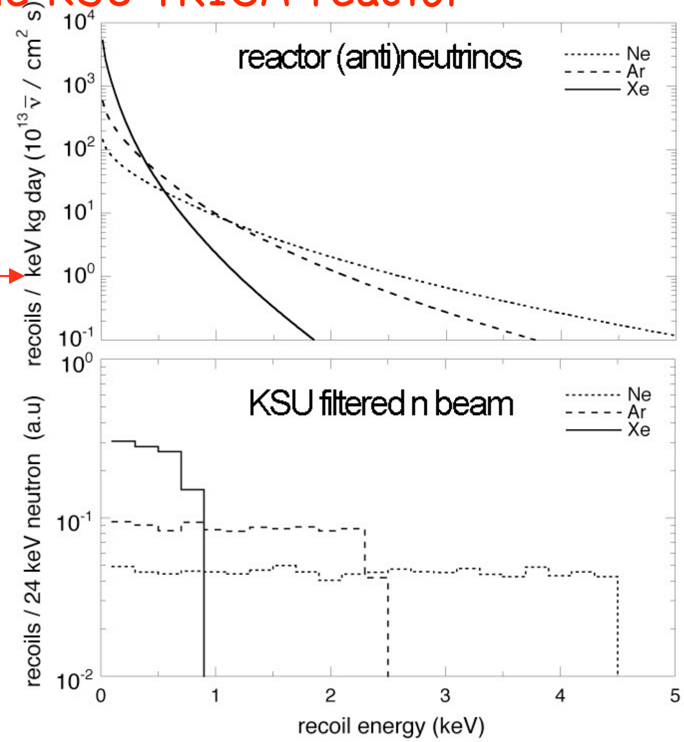
Extensive constraints on DAMA's claim:
- Light WIMPs
- Dark scalars
- Dark pseudoscalars

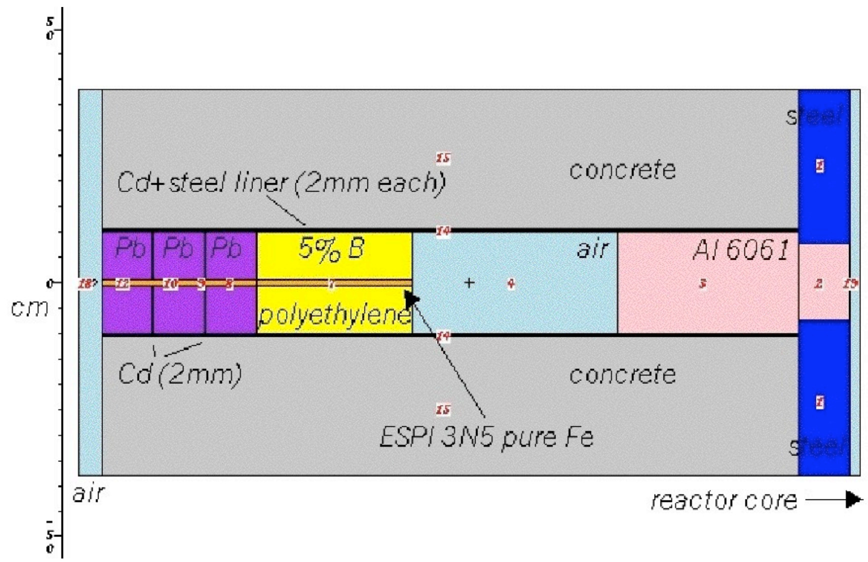
One should always start with the foundations:
sub-keV recoil calibrations at the KSU TRIGA reactor



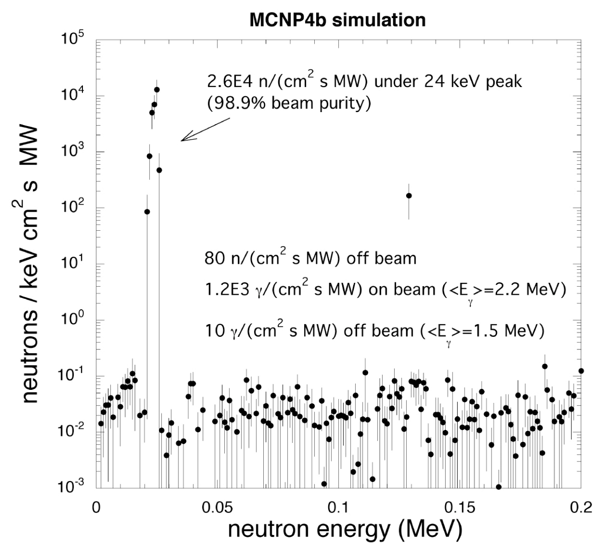
24 keV n's mimic reactor ν's

Fe-Al filter + Ti post-filter





MCNP filter design



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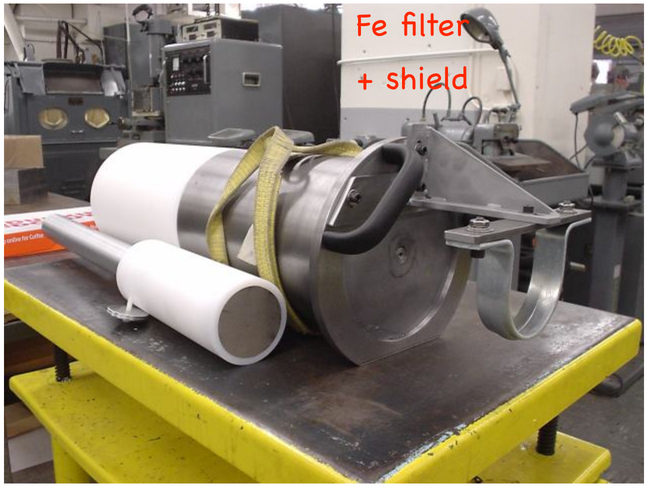
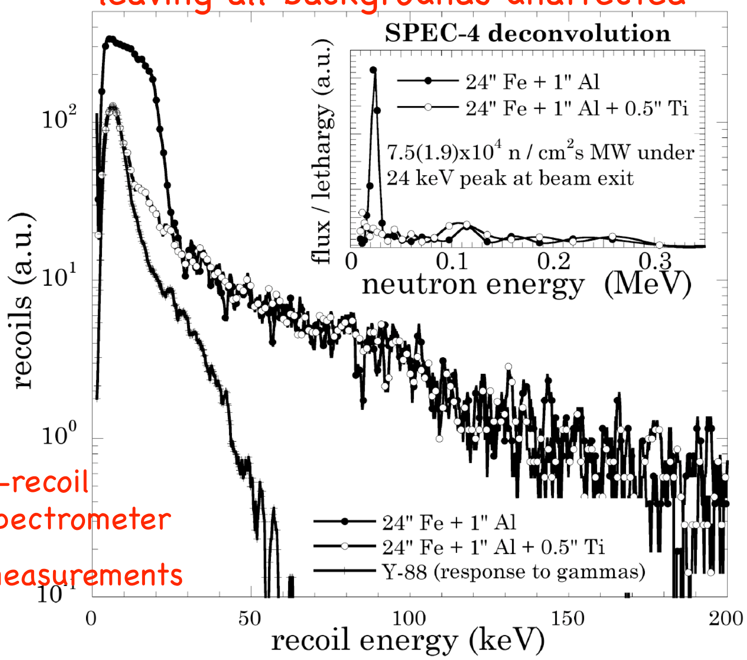


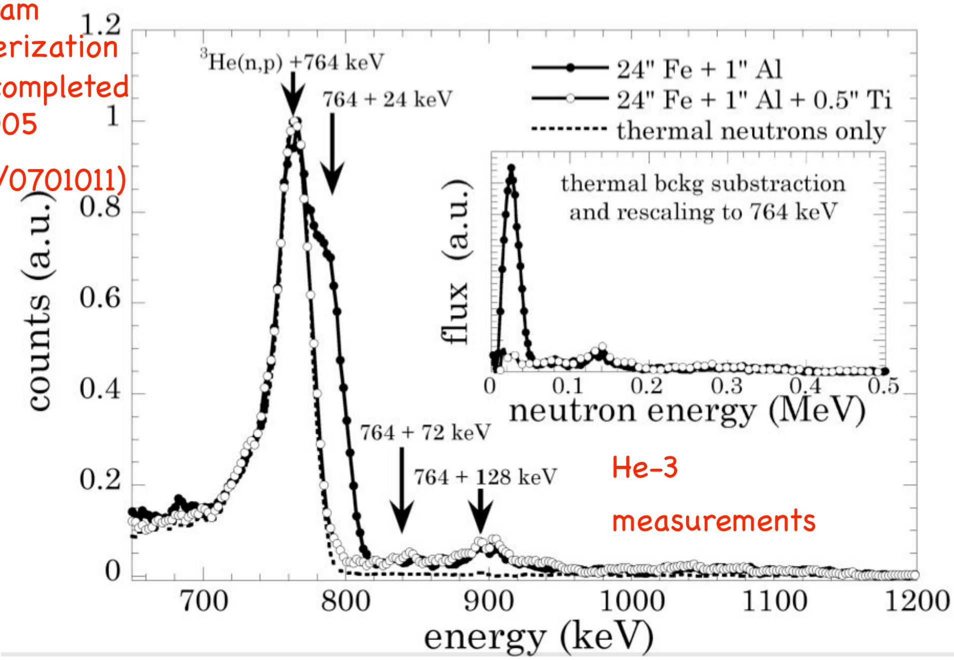
Ti post-filter "switches off" the recoils, leaving all backgrounds unaffected



p-recoil spectrometer measurements

Beam characterization studies completed 2005

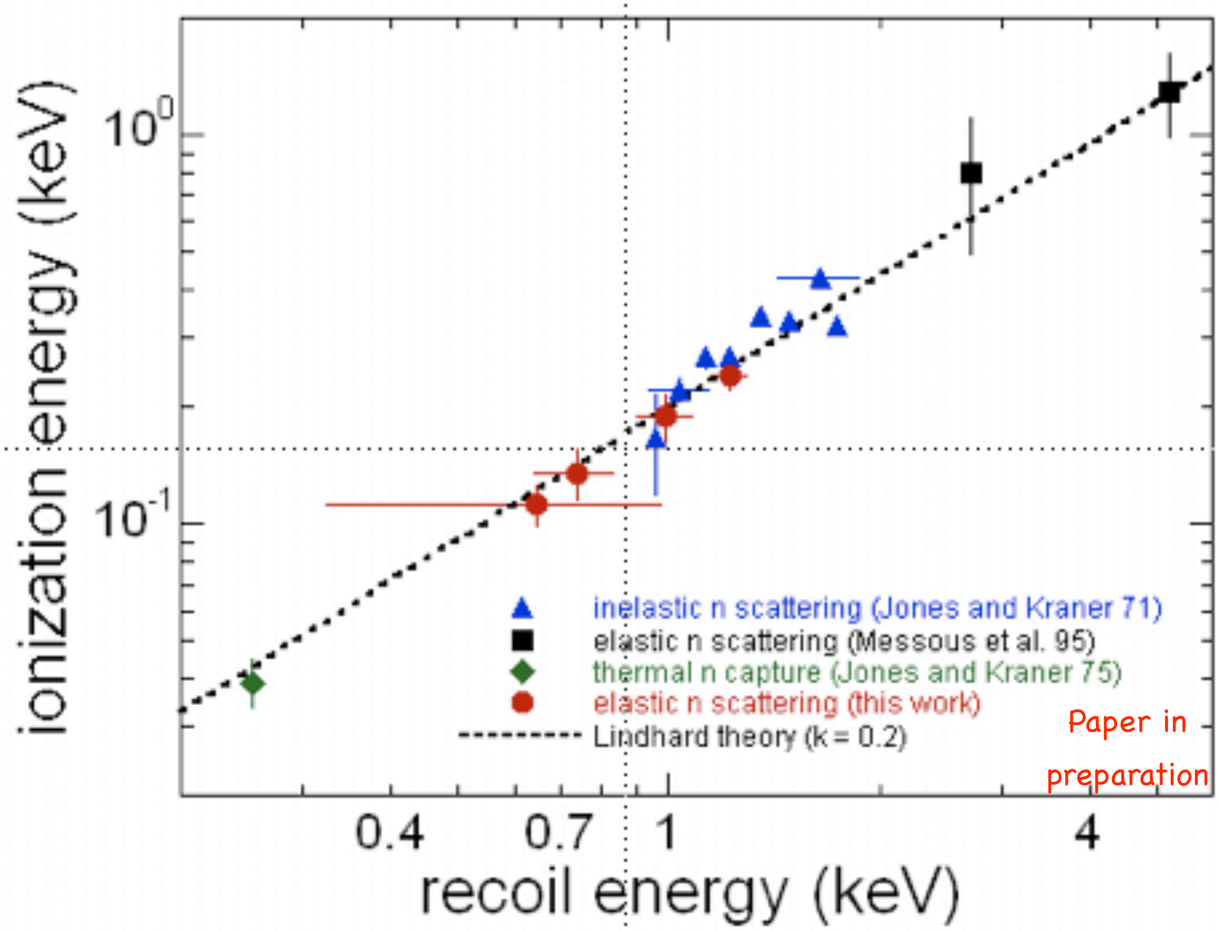
(nucl-ex/0701011)



He-3 measurements

Kavli Institute
for Cosmological Physics
AT THE UNIVERSITY OF CHICAGO

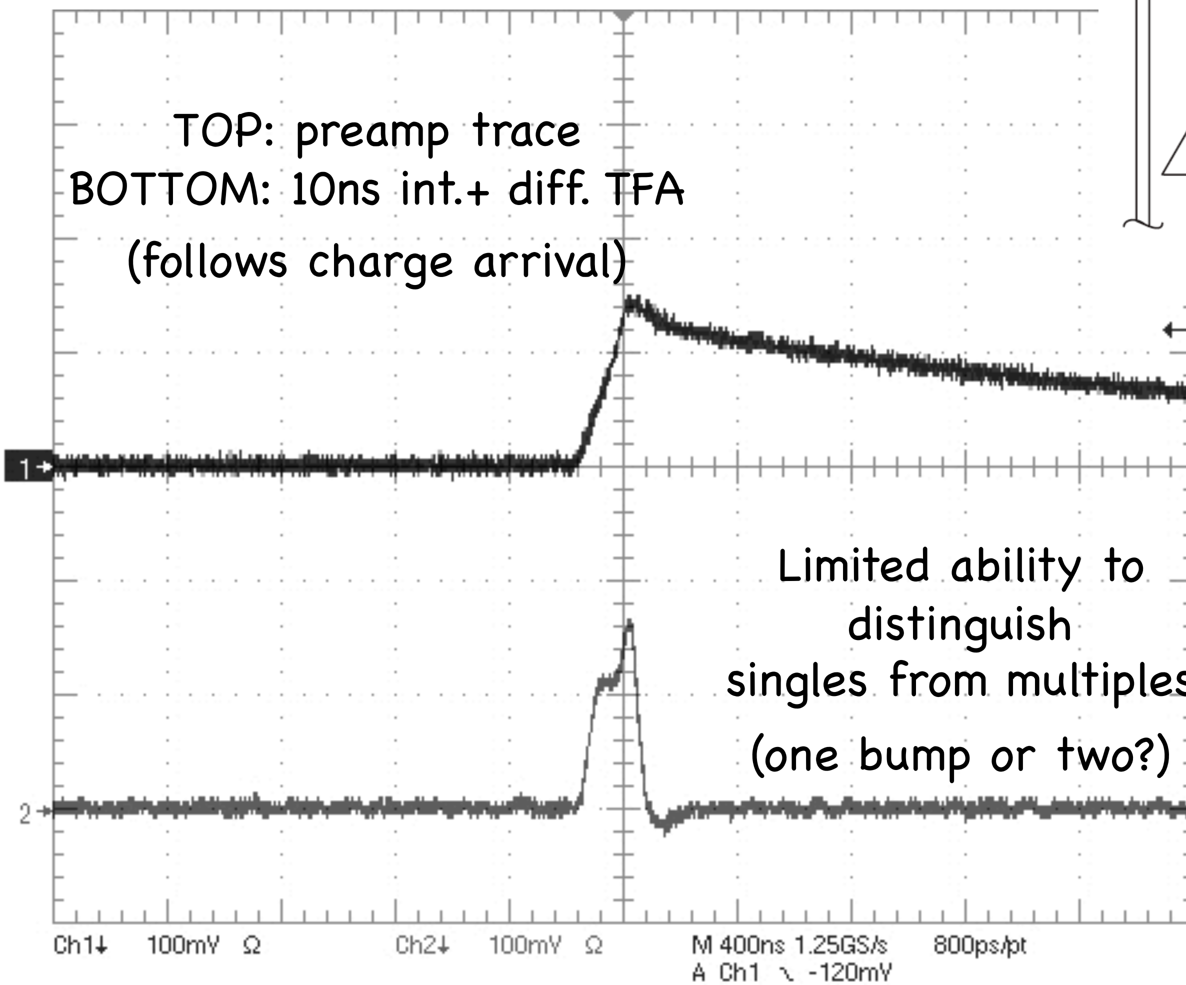
Quenching factor measurement for recoils at discrete angles



•Measurements of ionization from nuclear recoils in Ge is in excellent agreement with the Lindhard theory prediction.

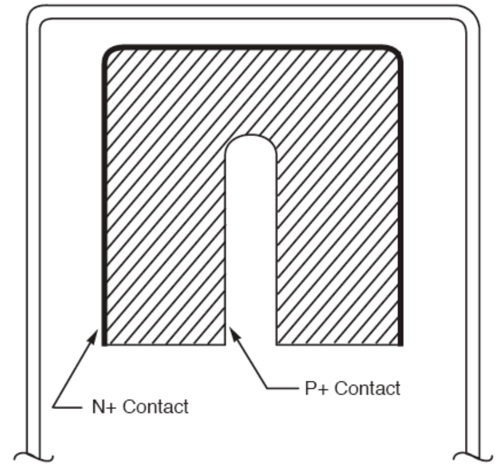
Other nice features brought by the point contact:

That was then...



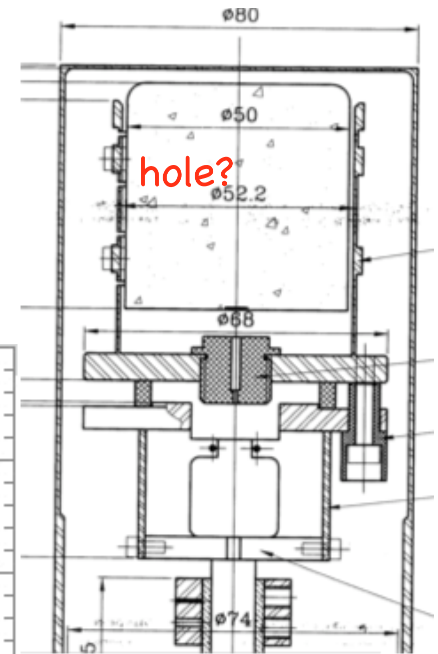
TOP: preamp trace
BOTTOM: 10ns int.+ diff. TFA
(follows charge arrival)

Limited ability to distinguish singles from multiples
(one bump or two?)

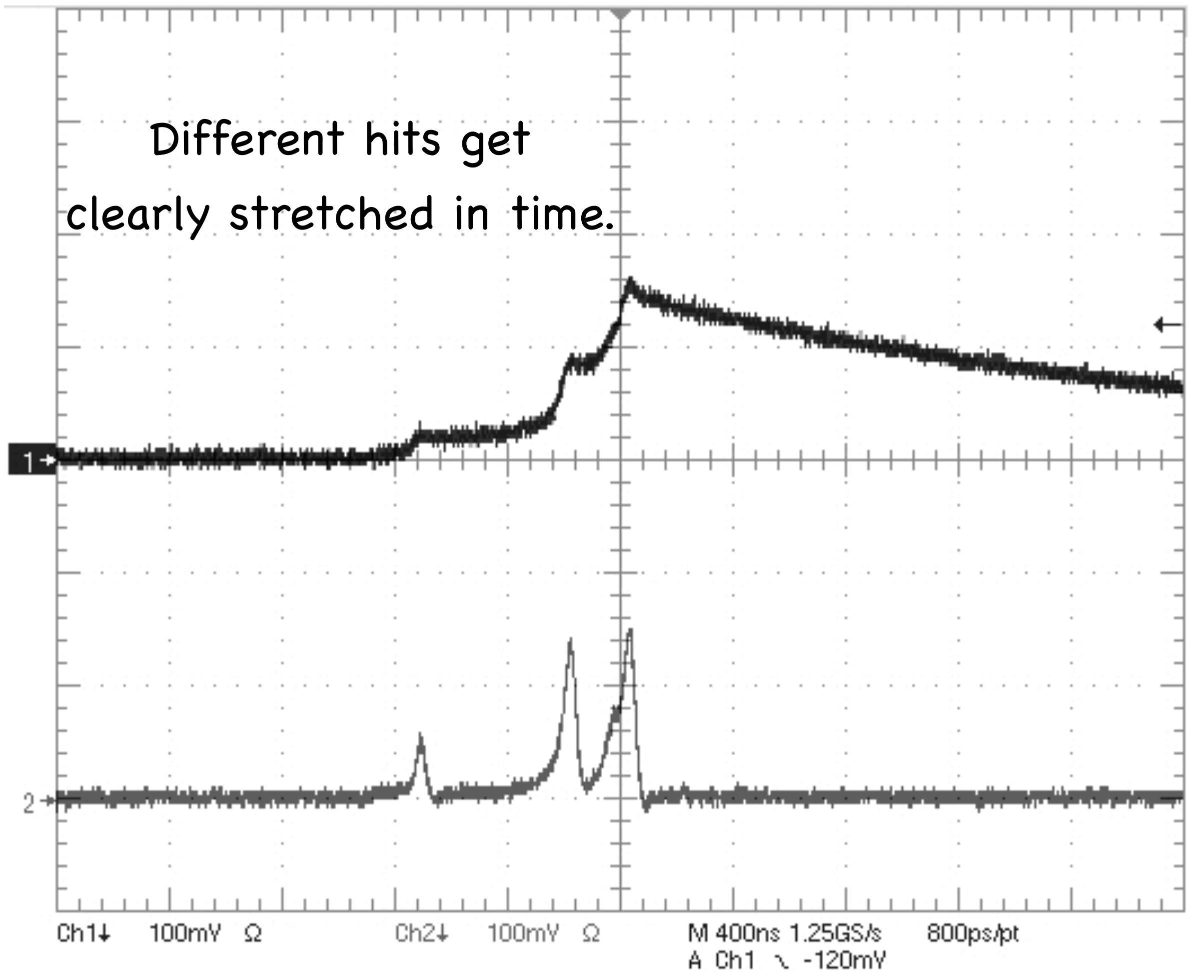


Coaxial Ge Detector Configuration

This is now.

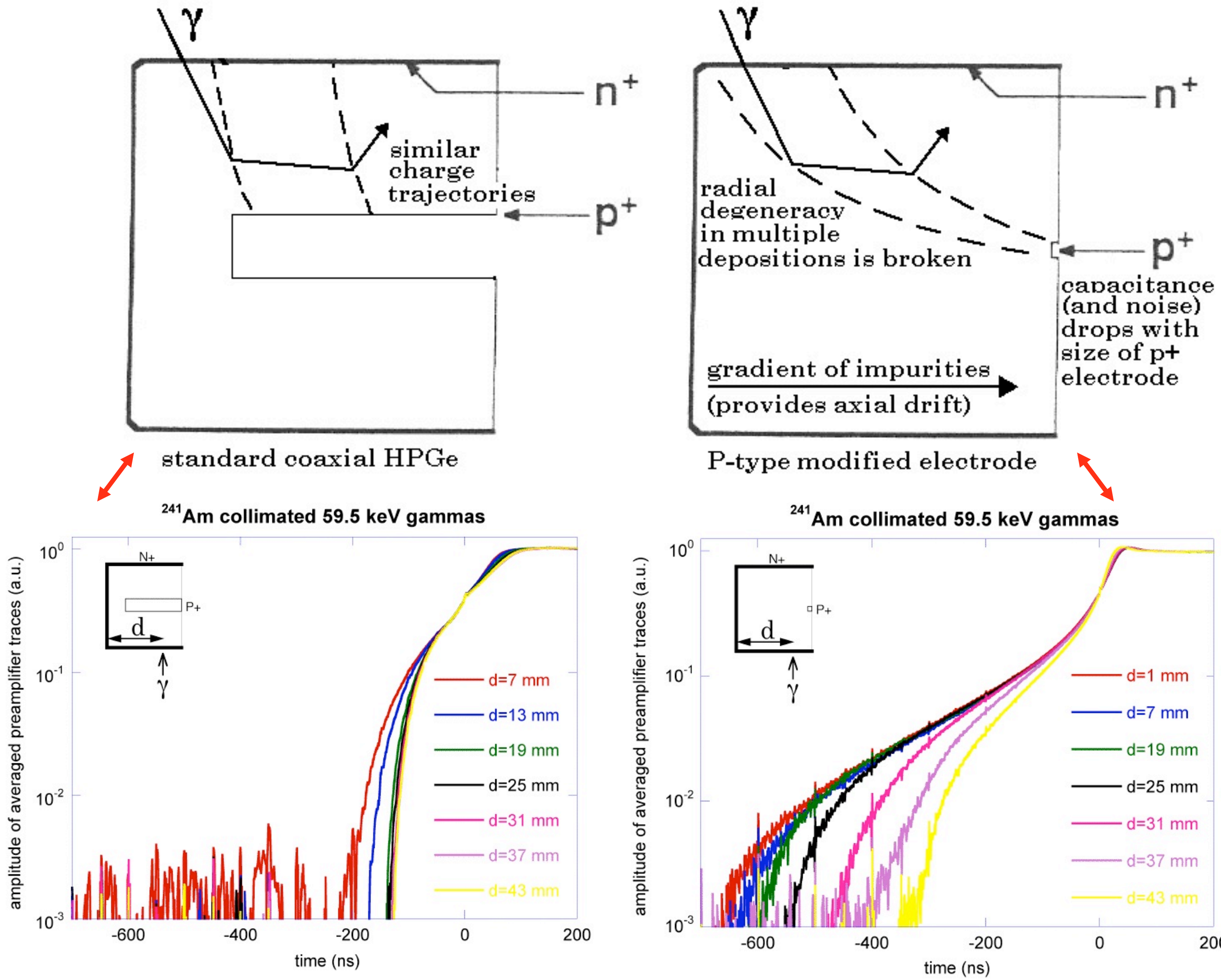


Different hits get clearly stretched in time.

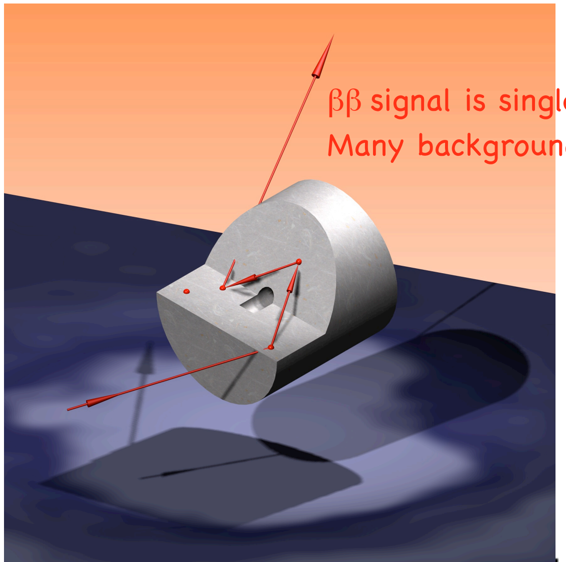


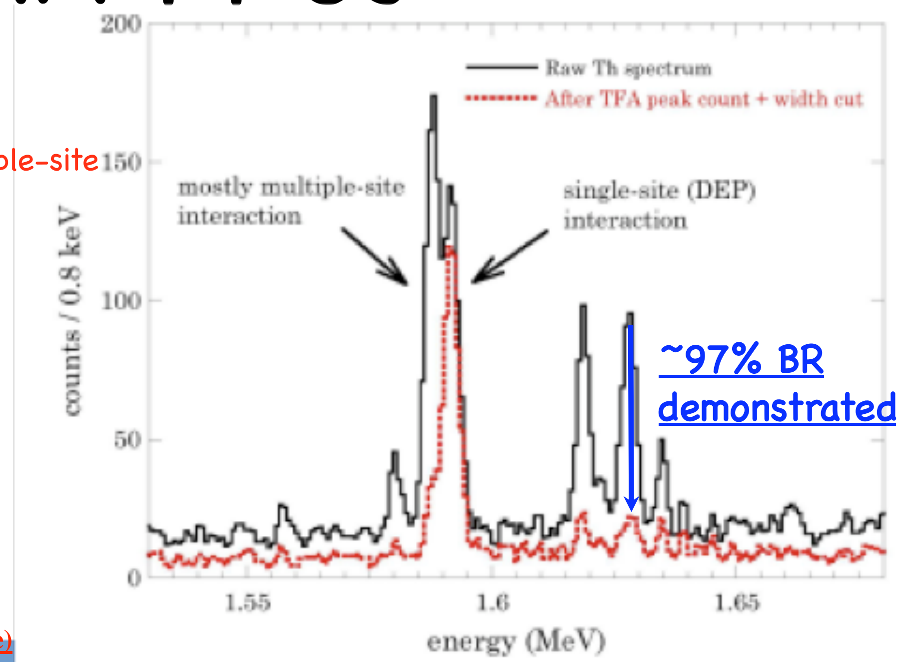
All this with optimal energy resolution and charge collection (<u>and one channel</u>)

What is happening?



MAJORANA PPCs





Detectors studied / in hand:

(actually missing a couple)

Owner	Dimensions	Mass	Resolution (1.33 MeV)	Manufacturer
U. Chicago (PPCI)	50 mm Ø x 44 mm	460 g	1.82 keV	Canberra
PNNL (PPCII)	50 mm Ø x 50 mm	527 g	2.15 keV	Canberra
LBNL (SPPC)	62 mm Ø x 44 mm	800 g	2.11 keV	LBNL
LANL (MJ70)	72 mm Ø x 37 mm	800 g	2.15 keV	PHD's
ORNL (MJ60)	62 mm Ø x 46 mm	740 g	4-4.5 keV	PHD's
U. Chicago (BEGe)	"standard"	450 g	<2 keV	Canberra
LBNL (Mini-PPCs)	20 mm Ø x 10 mm	17 g		LBNL
ORNL (Big BEGe)	90 mm Ø x 25 mm	850 g	1.95 keV	Canberra

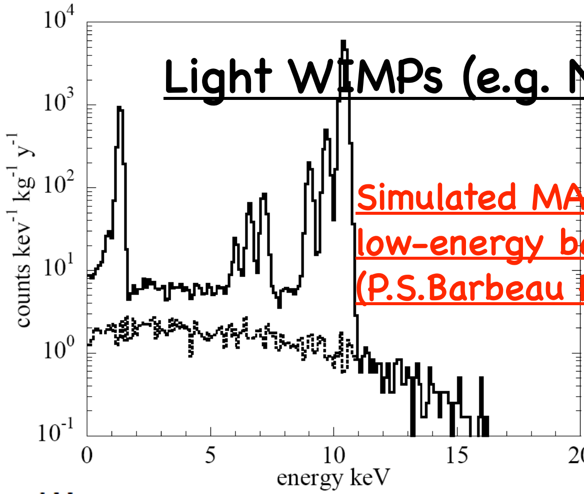
Move to commercial "BEGe" detectors (quasiplanar PPCs)

18 PPCs on order for MAJORANA demonstrator (60kg) (six already at LANL)

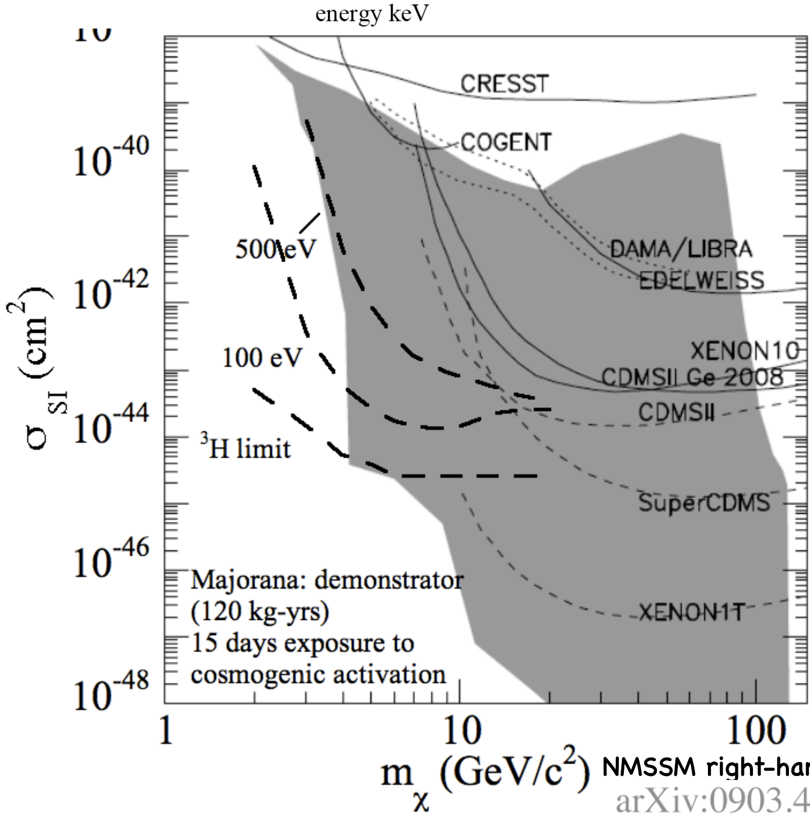
Crystal storage underground following characterization (summer 2009)

MAJORANA as a DM detector

Light WIMPs (e.g. NMSSM)



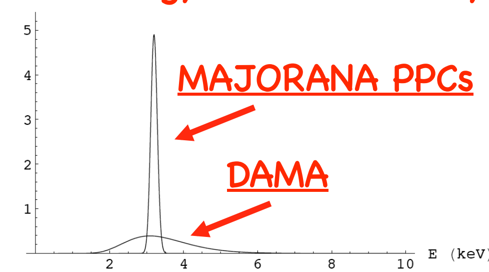
Simulated MAJORANA-demonstrator low-energy backgrounds (P.S.Barbeau Ph.D. Diss.)

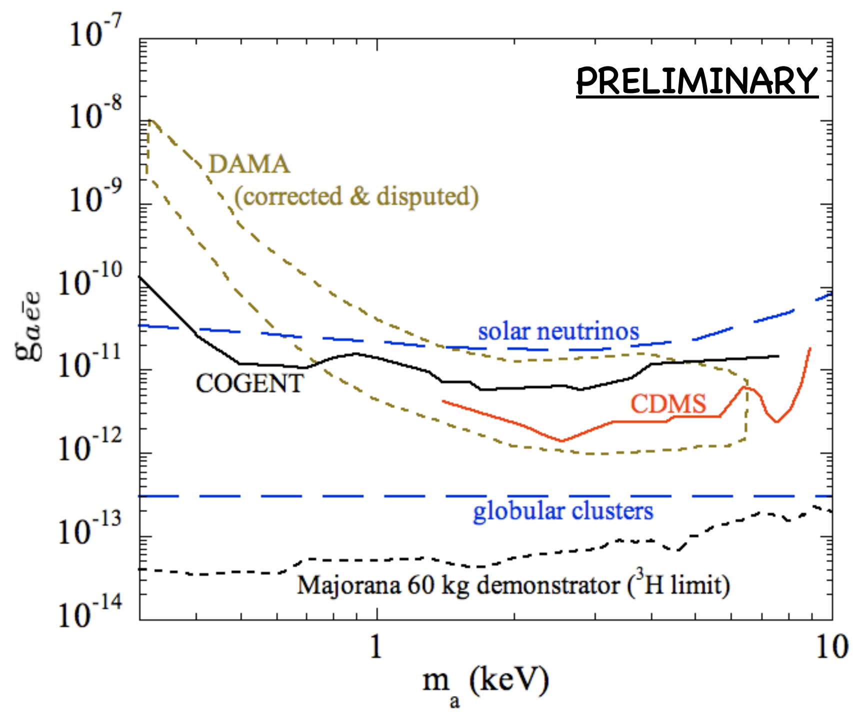


NMSSM right-handed sneutrino
arXiv:0903.4677v1

Pseudoscalars etc. (a.k.a."superWIMPs")

Energy resolution is key:

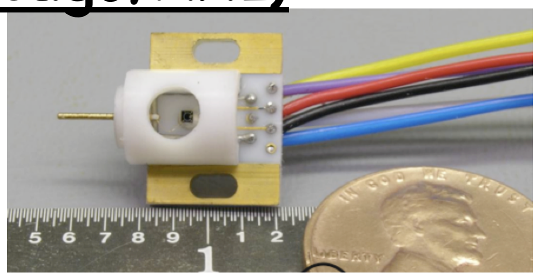




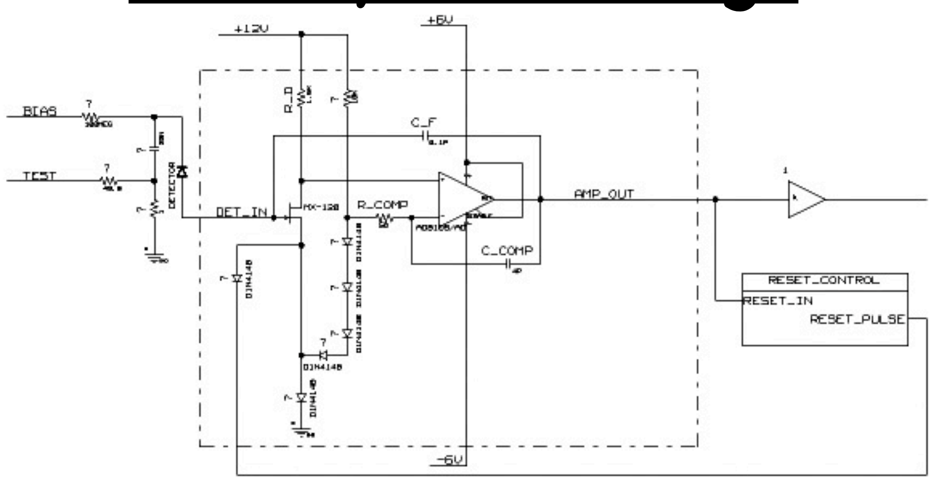
Front End Electronics

Pulse Reset

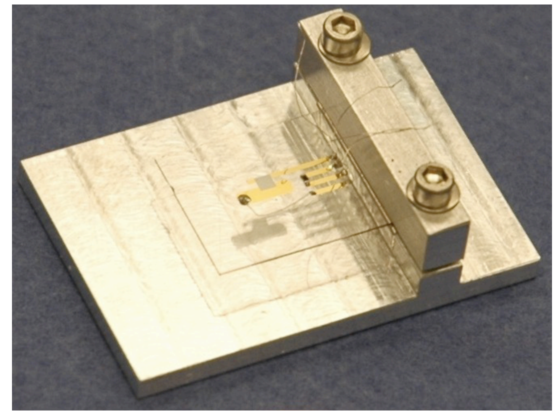
COGENT front ends (U Chicago/ANL)



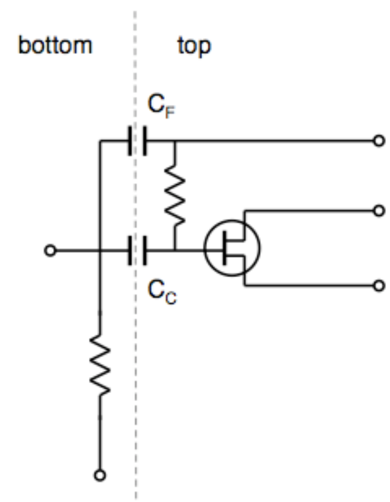
UW "Hybrid" Design



Resistive Feedback



LBNL Design



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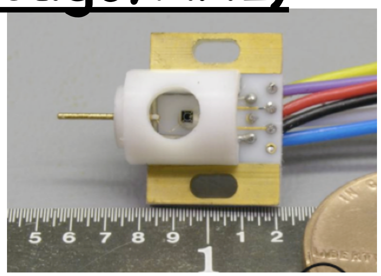
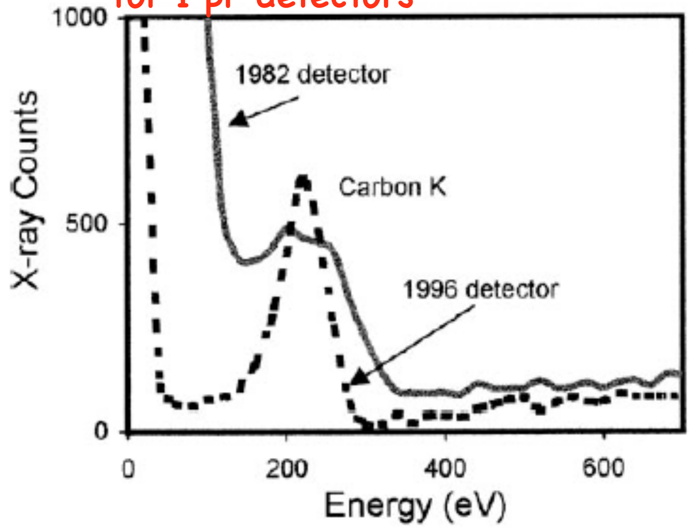


State-of-the-art
for 1 pF detectors



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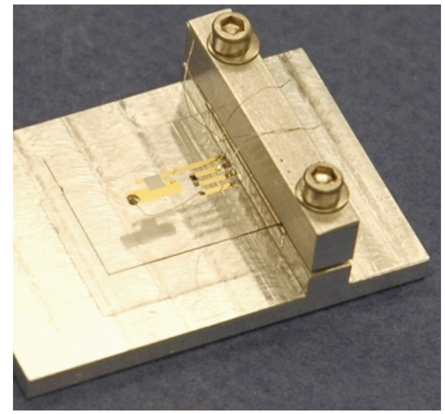
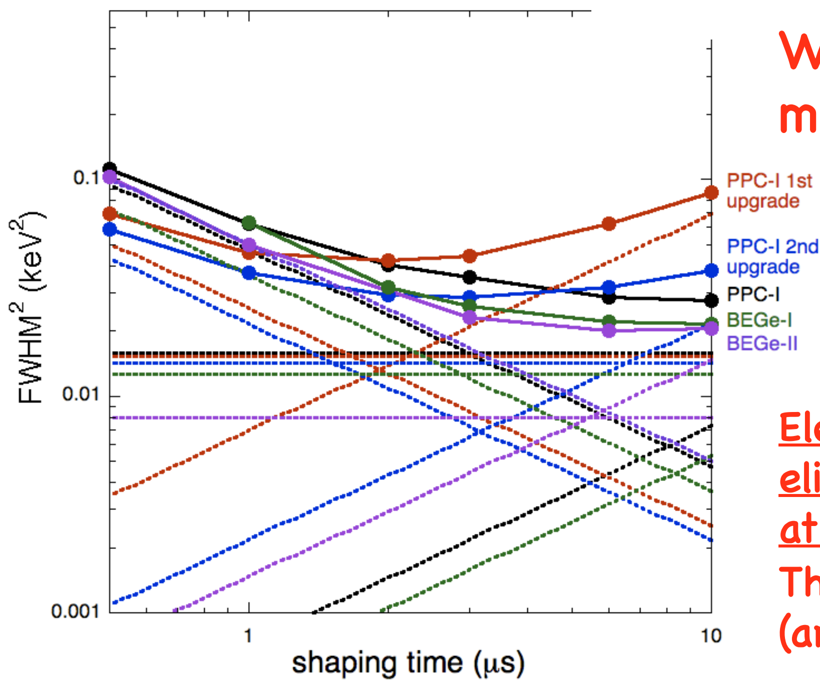
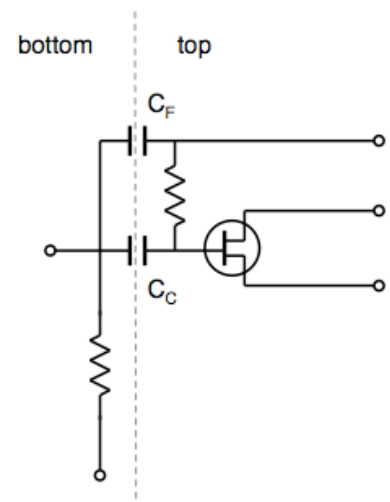




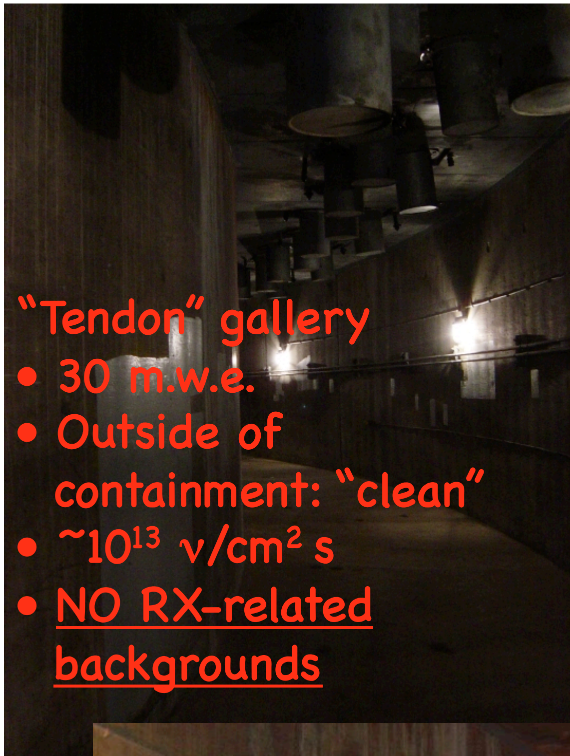
We can do
much better!

LBNL
Design

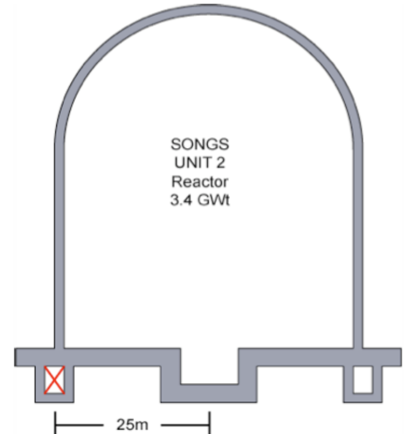


Electronic noise must be
eliminated
at the hardware level.
There is no other way around it
(arXiv:0806.1341)

SONGS-III deployment



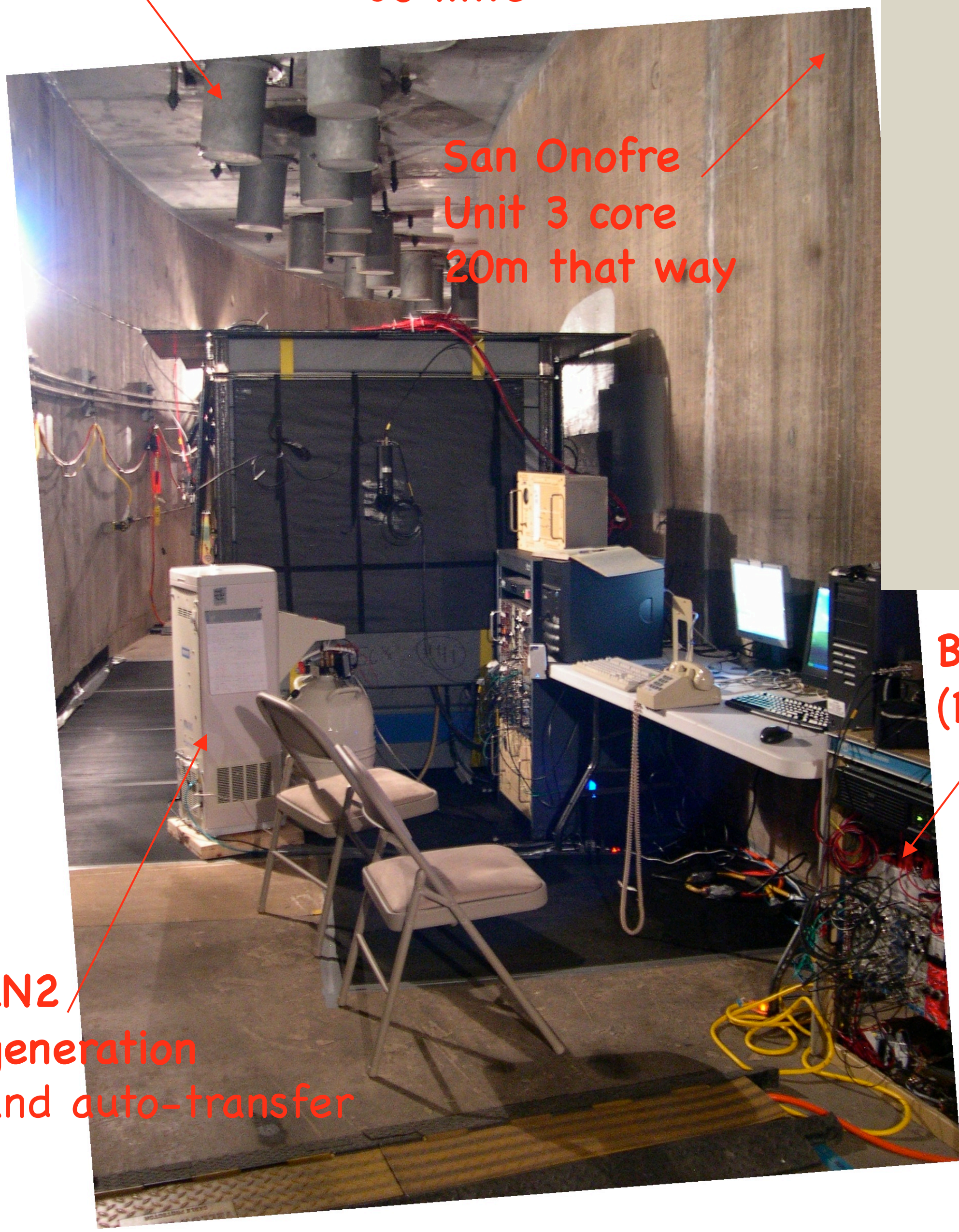
"Tendon" gallery
- 30 m.w.e.
- Outside of containment: "clean"
- ~10^{13} ν/cm^2 s
- NO RX-related backgrounds



SONGS deployment

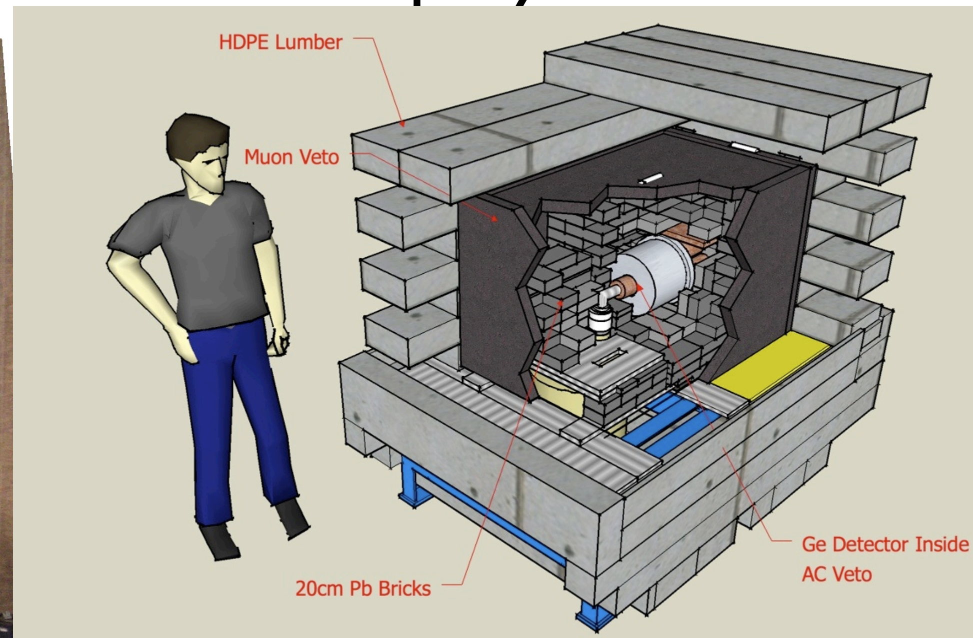
"Tendons"

30 mwe

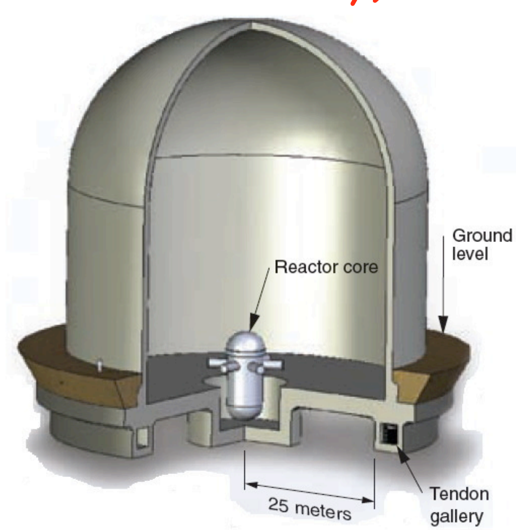


San Onofre
Unit 3 core
20m that way

LN2
generation
and auto-transfer



BaDAss
(Background Detector Assembly)



SONGS deployment

Backgrounds well-understood
~30 m.w.e. equivalent
"Clean" (outside of containment)
Additional fast n and Rn channels to be added

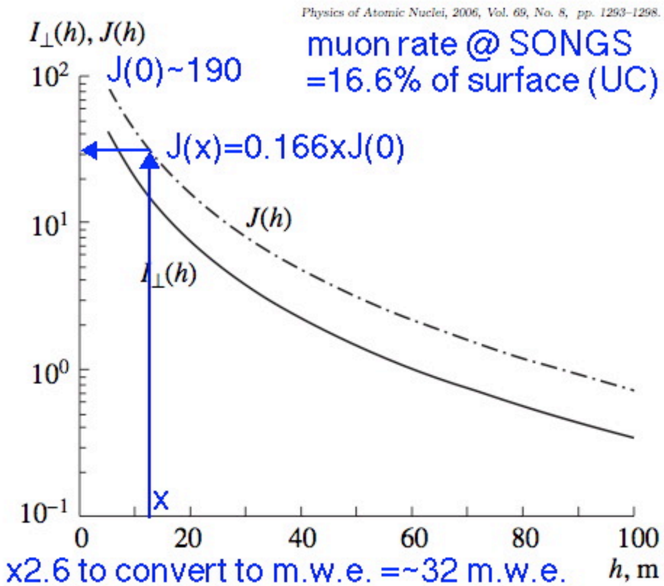
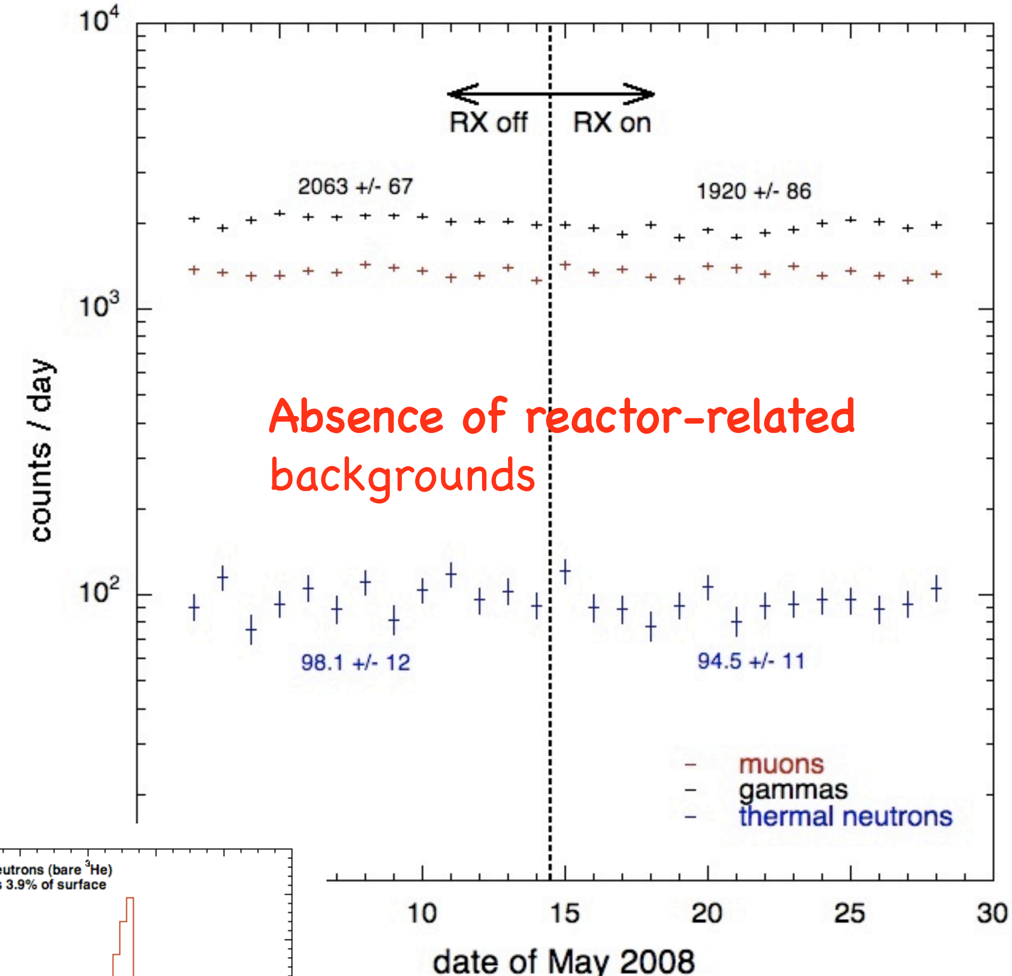
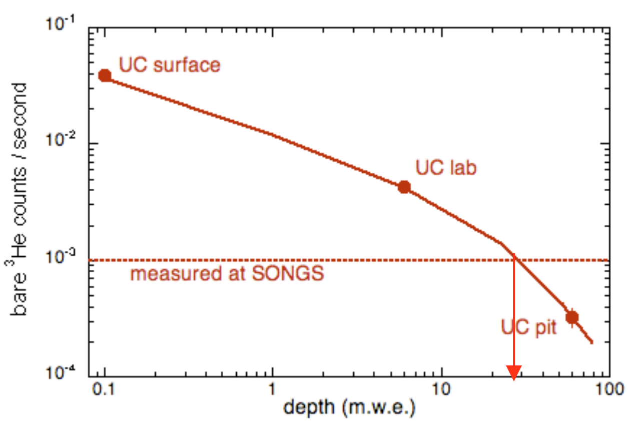
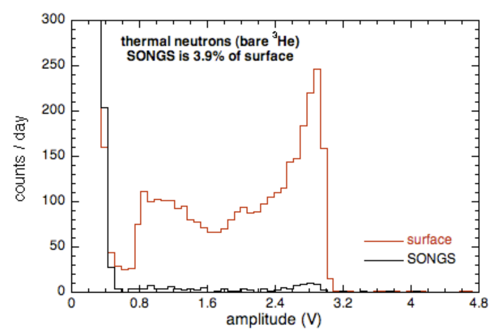


Fig. 2. Vertical muon intensity $I_\perp(h)$ [m^{-2} s^{-1} sr^{-1}] and the integral muon flux $J(h)$ [m^{-2} s^{-1}] vs. the standard rock overburden thickness h.







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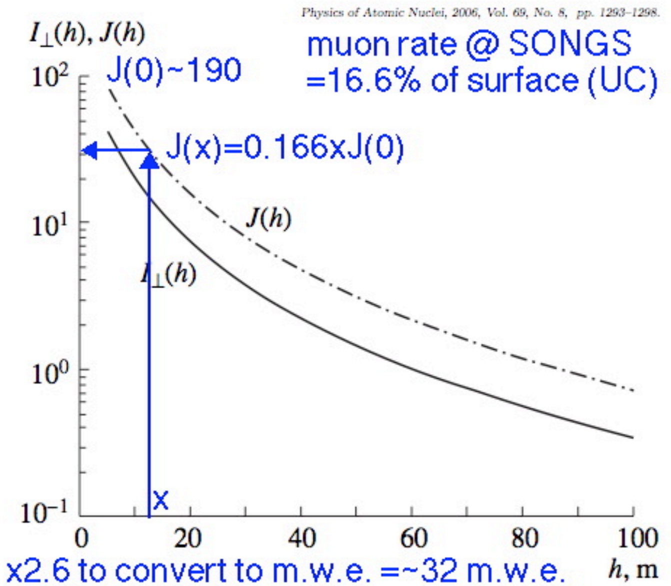

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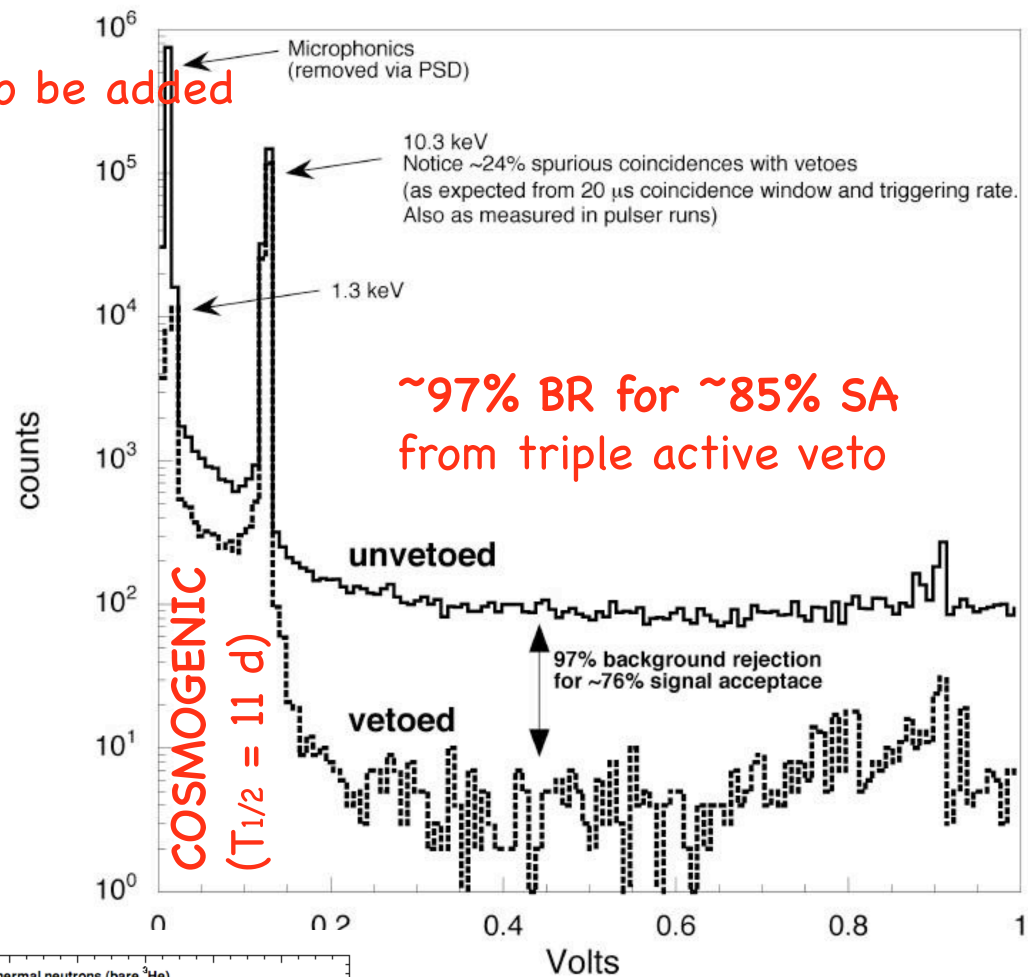

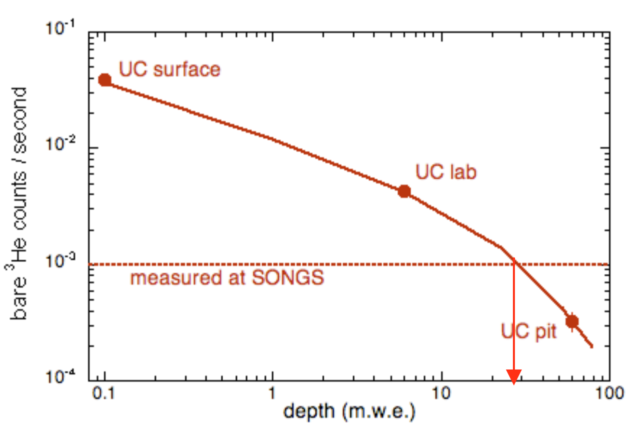

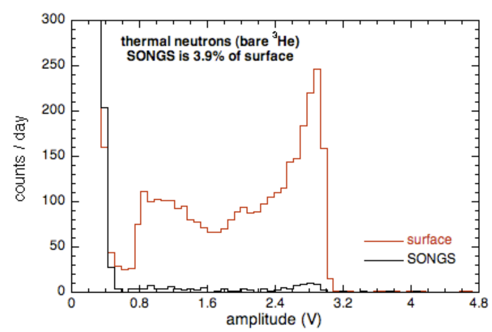

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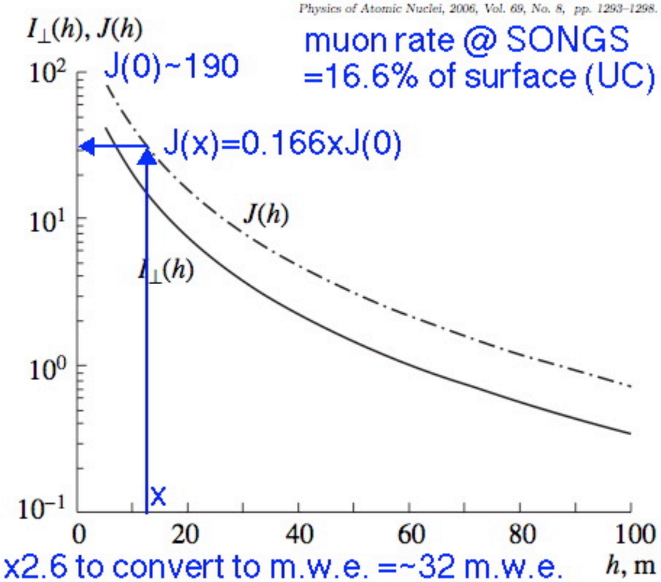
Physics of Atomic Nuclei, 2006, Vol. 69, No. 8, pp. 1293–1298.



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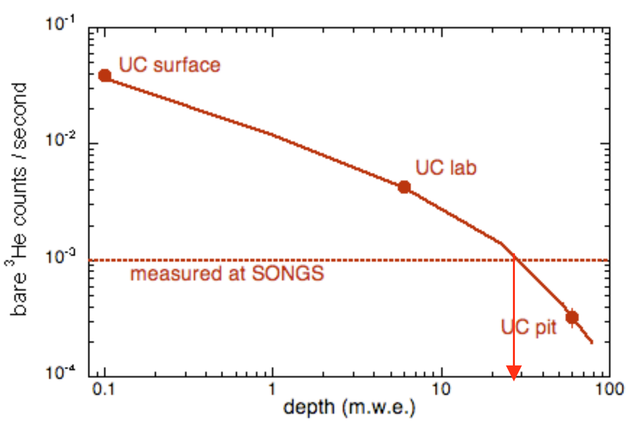
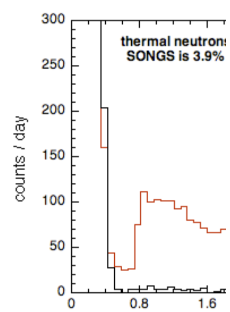
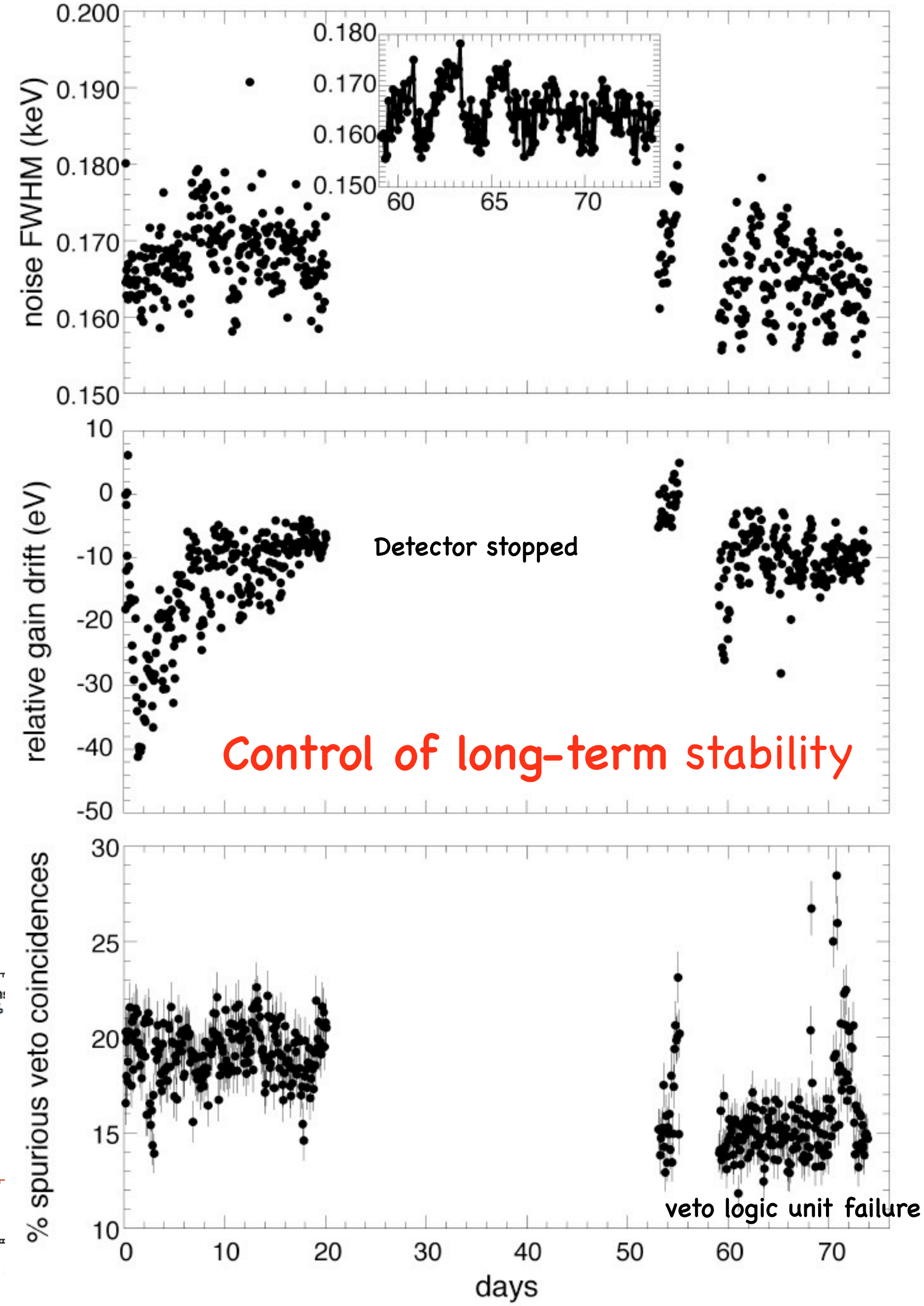
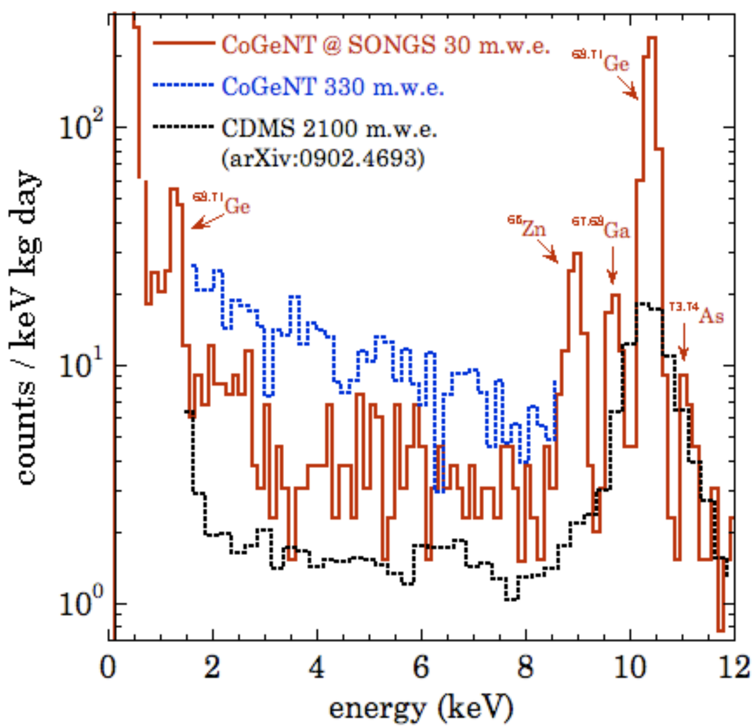


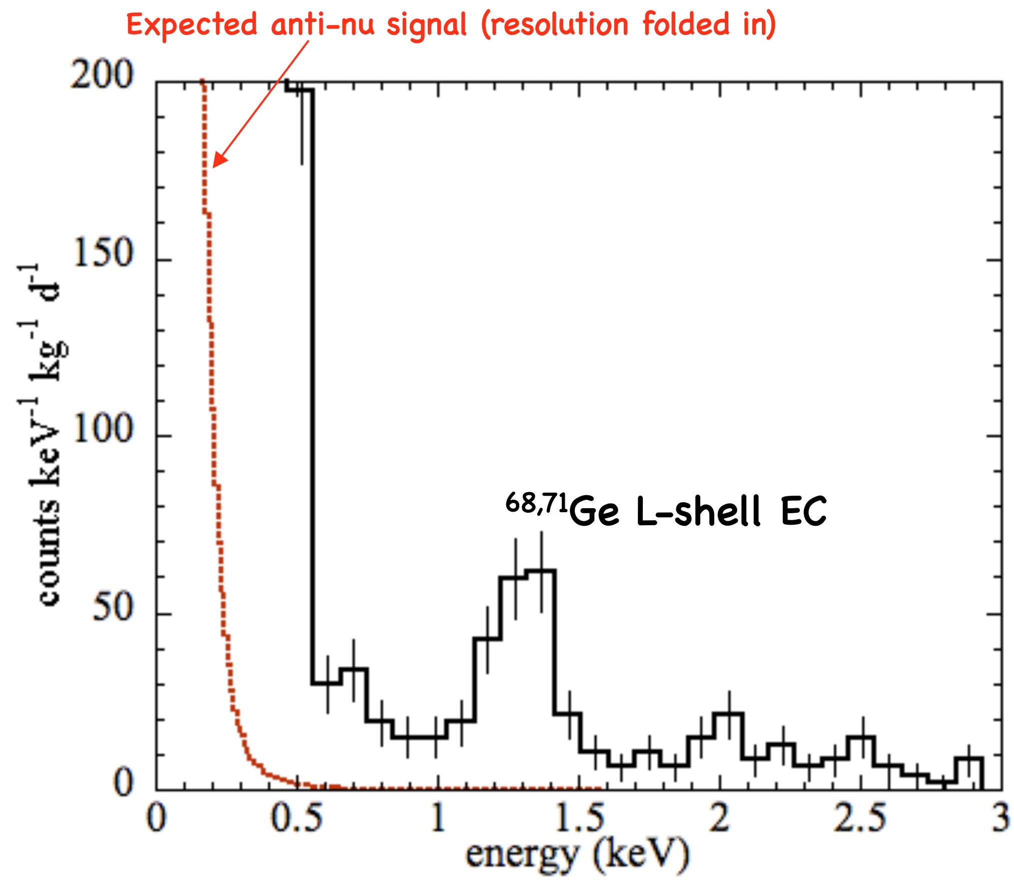




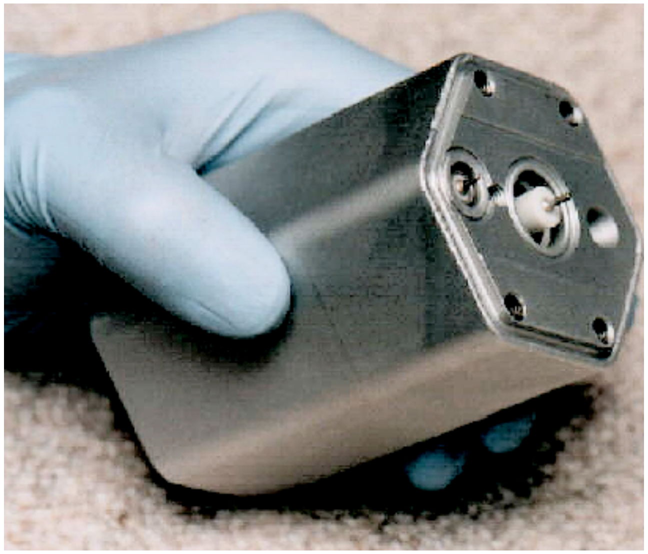
The bottom line:

- Have met our background goals. Factor ~2 larger background than CDMS, at 30 m.w.e.
- Demonstrated long-term stability, absence of RX-associated backgrounds.
- Need 2-3 improvement in noise to see neutrinos. Almost there!

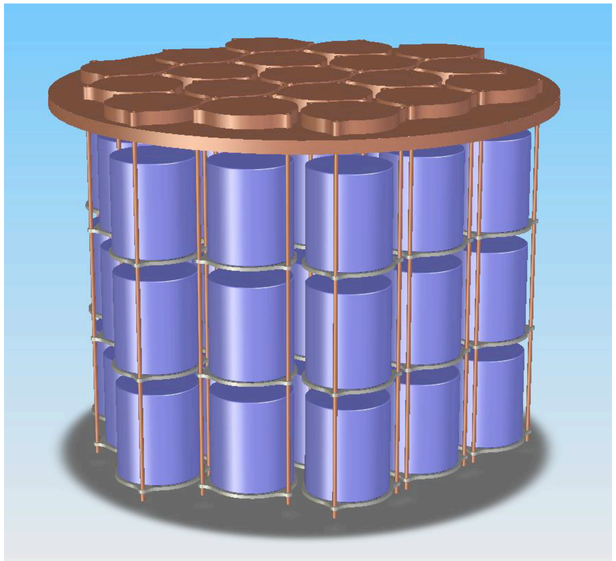




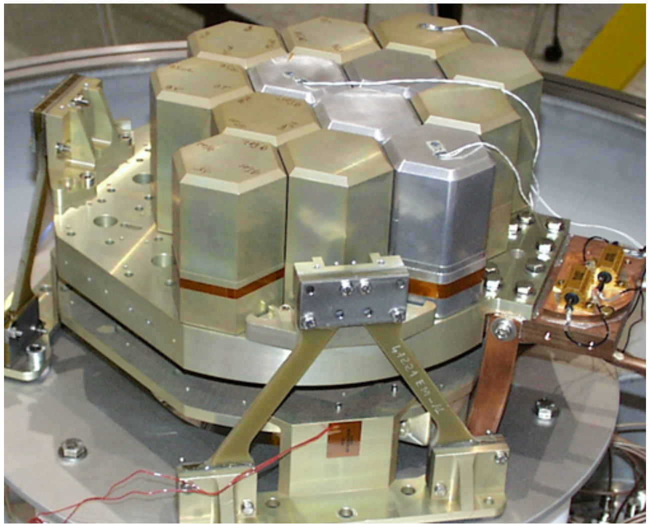
Reactor Monitoring: Right technological timing
(HPGe technology flourishing:
segmentation, encapsulation, arrays and (silent) mechanical cooling)



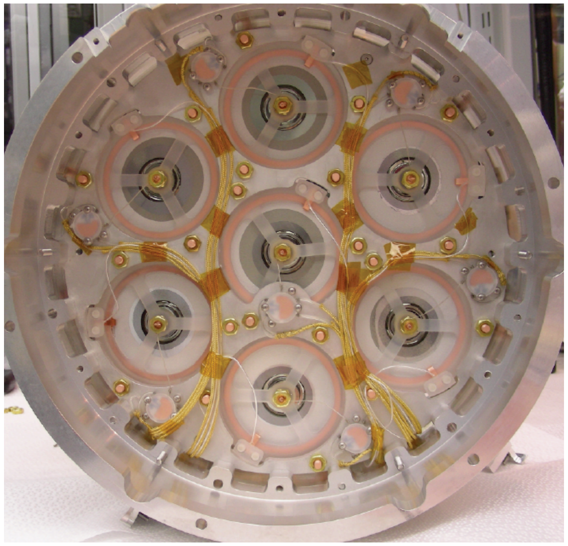
CLUSTER



MAJORANA



INTEGRAL



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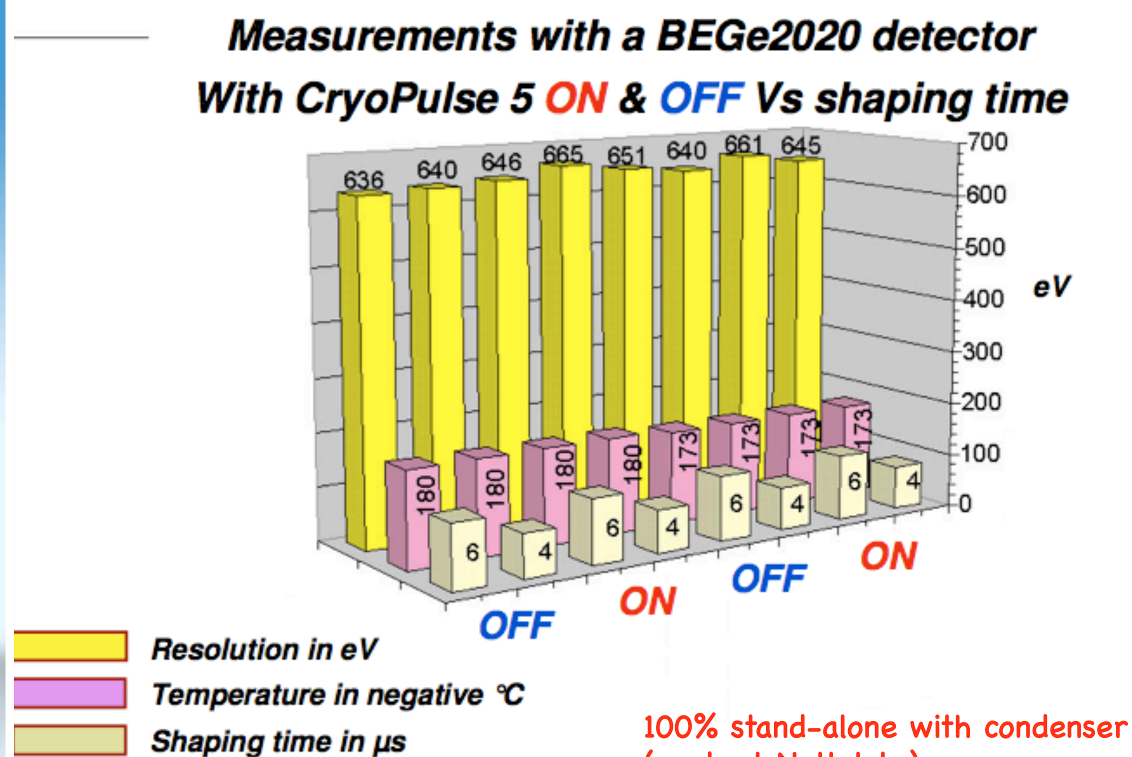
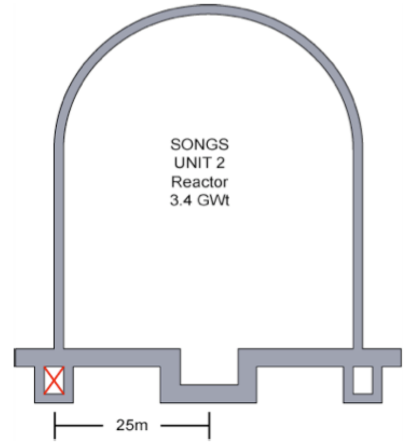


100% stand-alone with condenser
(work at Natl. labs)

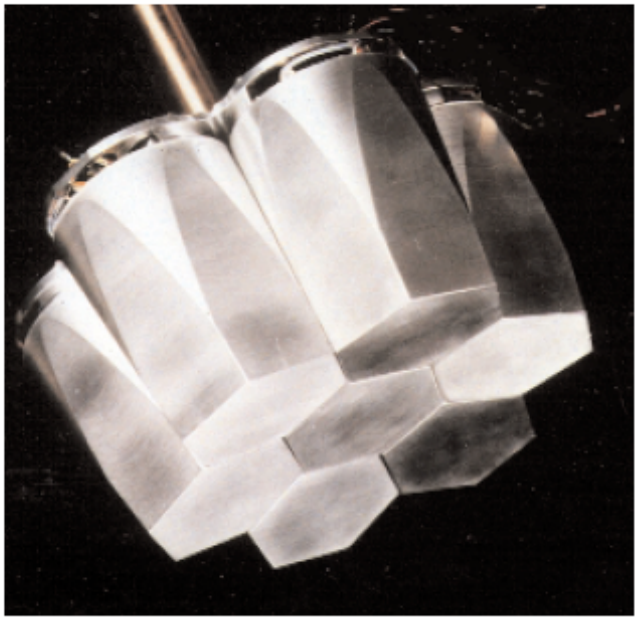
New generation of recondensing Dewars add
almost no microphonic noise and need topping (not refilling)
every ~ 1yr (can be filled from N2 gas cylinder!)
Ideal for reactor deployment.

11 kg, encapsulated, single cold finger (CANBERRA)

A reality fast approaching?



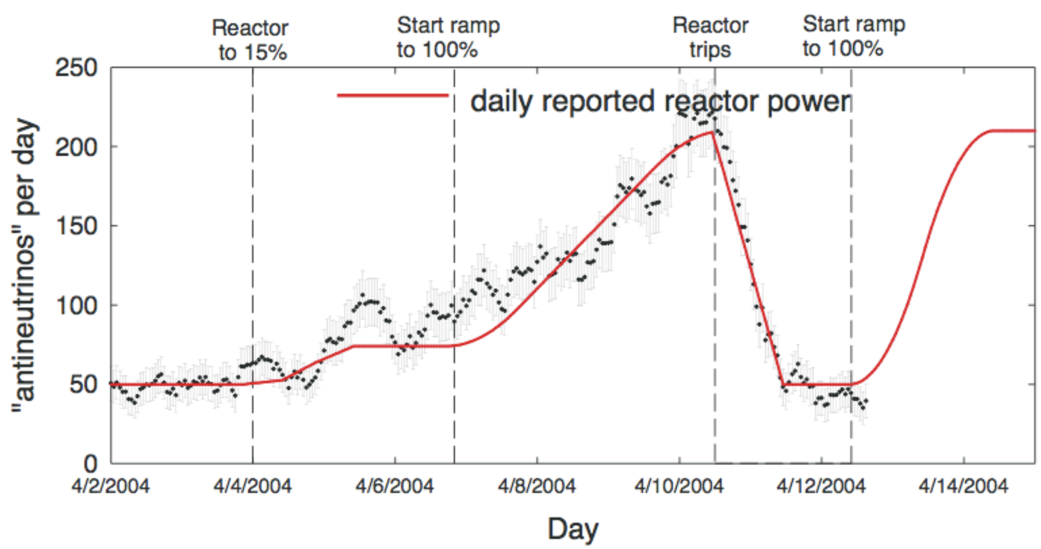
With 100 eV threshold, the equivalent of a few tons of liquid scintillator (plus an additional x10 in rate beyond!)



CLUSTER array for EUROBALL
(7 encapsulated HPGe detectors)

Hexagonal tapering - diam.: 70 mm - height: 78 mm
FWHM resolution : ≤ 2.3 keV
Efficiency: ≥ 55%
Alu wall thickness: 0.7 mm
Cap-to-Ge distance: 0.7 mm.

SANDS Sees Reactor Turn-on in Detail
(Antineutrino Rate, Running Average)



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single cold finger
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A reality
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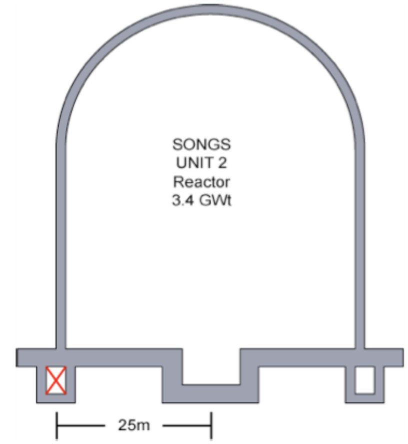

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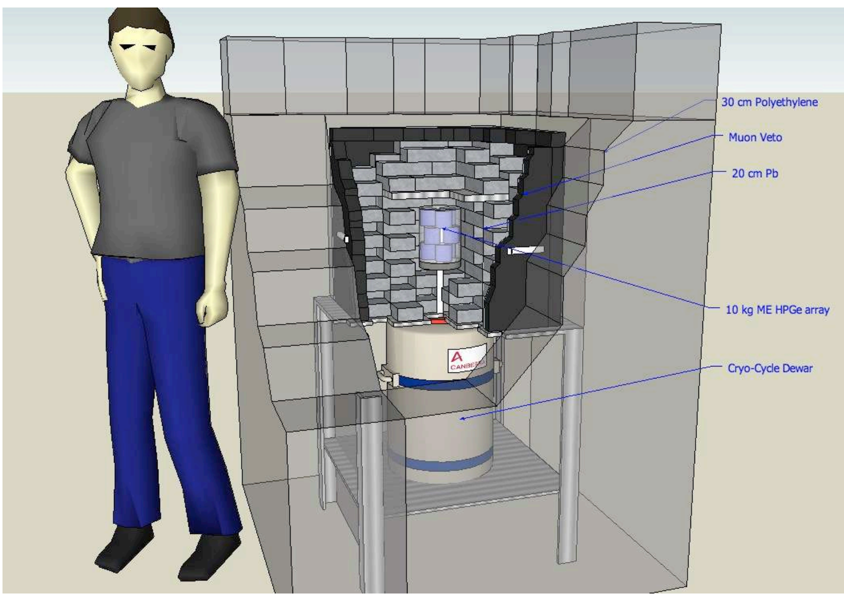

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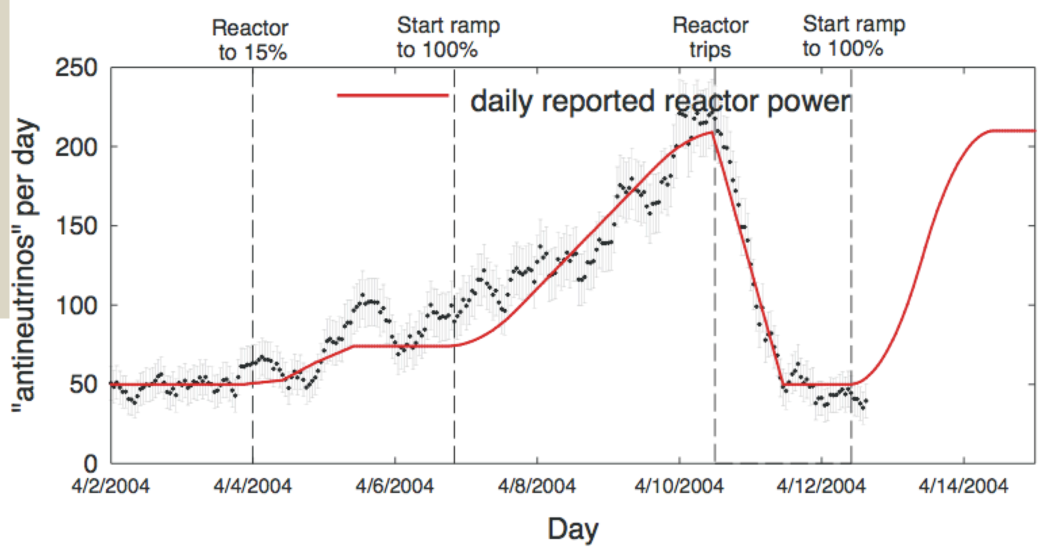

The team:

ANL: Pat de Lurgio, Gary Drake, Richard Talaga
CANBERRA: Jim Colaresi, Orren Tench, Mike Yocum
LLNL: Adam Bernstein, Nathaniel Bowden, Steven Dazeley
PNNL: Craig Aalseth, Jim Fast, Todd Hossbach, Jeremy Kephart, Harry Miley, John Orrell
SNL: Belkis Cabrera-Palmer, Jim Lund, David Reyna, Lorraine Sadler
UC: Phil Barbeau, Juan Collar, Nicole Fields, Charles Greenberg
UW: Mike Marino, Hamish Robertson, Tim Van Wechel, John Wilkerson

(+ <u>much help</u> from other MAJORANA collaborators)

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National Nuclear Security Administration