THE UNIVERSITY *of* NORTH CAROLINA *at* CHAPEL HILL

The MAJORANA Low-Background Experiment at KURF (MALBEK)

Reyco Henning

UNC Chapel Hill and Triangle Universities Nuclear Laboratory

On Behalf of the MAJORANA Collaboration

The MAJORANA Collaboration

Black Hills State University, Spearfish, SD
Kara Keeter

Duke University, Durham, North Carolina , and TUNL
Matthew Busch, James Esterline, Gary Swift, Werner Tornow

Institute for Theoretical and Experimental Physics, Moscow, Russia
Alexander Barabash, Sergey Konovalov, Vladimir Yumatov

Joint Institute for Nuclear Research, Dubna, Russia
Viktor Brudanin, Slava Egorov, K. Gusev,
Oleg Kochetov, M. Shirchenko, V. Timkin, E. Yakushev, I. Zhitnikov

Lawrence Berkeley National Laboratory, Berkeley, California and the University of California - Berkeley
Nicolas Abgrall, Mark Amman, Paul Barton, Yuen-Dat Chan,
Paul Luke, Susanne Mertens, Alan Poon, Kai Vetter, Harold Yaver

Los Alamos National Laboratory, Los Alamos, New Mexico
Melissa Boswell, Steven Elliott, Johnny Goett, Keith Rielage, Larry Rodriguez, Harry Salazar, Wenqin Xu

North Carolina State University, Raleigh, North Carolina and TUNL
Dustin Combs, Lance Leviner, David G. Phillips II, Albert Young

Oak Ridge National Laboratory, Oak Ridge, Tennessee
Fred Bertrand, Kathy Carney, Alfredo Galindo-Uribarri,
Matthew P. Green, Monty Middlebrook, David Radford, Elisa Romero-Romero,
Robert Varner, Brandon White, Timothy Williams, Chang-Hong Yu

Osaka University, Osaka, Japan
Hiroyasu Ejiri, Ryuta Hazama, Masaharu Nomachi, Shima Tatsuji

Pacific Northwest National Laboratory, Richland, Washington
Isaac Arnquist, Jim Fast, Eric Hoppe, Richard T. Kouzes, Brian LaFerriere, John Orrell,
Nicole Overman

Shanghai Jiaotong University, Shanghai, China
James Loach

South Dakota School of Mines and Technology, Rapid City, South Dakota
Adam Caldwell, Cabot-Ann Christofferson, Stanley Howard,
Anne-Marie Suriano, Jared Thompson

Tennessee Tech University, Cookeville, Tennessee
Mary Kidd

University of Alberta, Edmonton, Alberta
Aksel Hallin

University of North Carolina, Chapel Hill, North Carolina and TUNL
Graham K. Giovanetti, Reyco Henning, Mark Howe, Jacqueline MacMullin, Sam Meijer,
Benjamin Shanks, Christopher O' Shaughnessy, Jamin Rager, Jim Trimble, Kris Vorren,
John F. Wilkerson

University of South Carolina, Columbia, South Carolina
Frank Avignone, Vince Guiseppe, David Tedeschi, Clint Wiseman

University of South Dakota, Vermillion, South Dakota
Dana Byram, Ben Jasinski, Ryan Martin, Nathan Snyder

University of Tennessee, Knoxville, Tennessee
Yuri Efremenko, Sergey Vasilyev

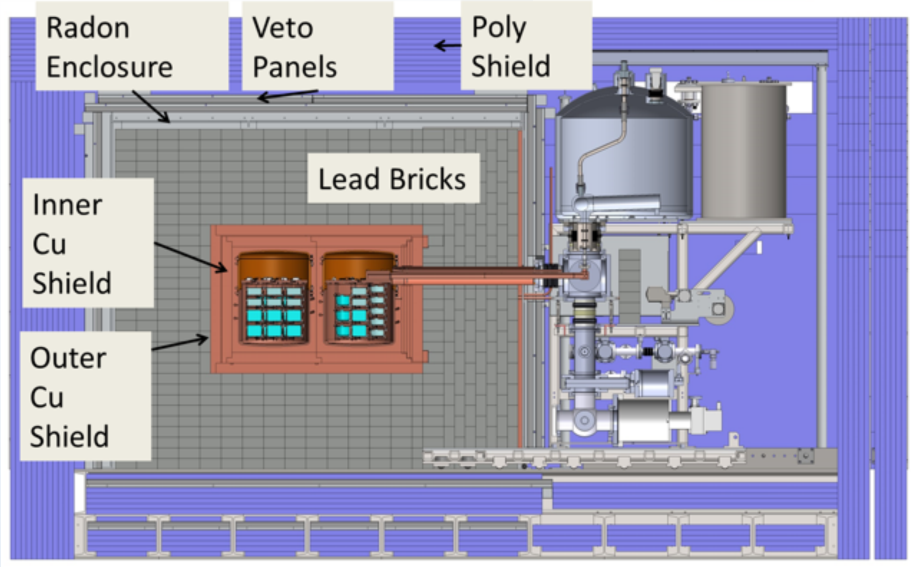
University of Washington, Seattle, Washington
Tom Burritt, Micah Buuck, Clara Cuesta, Jason Detwiler, Peter J. Doe, Julieta Gruszko,
Ian Guinn, Greg Harper, Jonathan Leon, David Peterson, R. G. Hamish Robertson,
Tim Van Wechel

The MAJORANA DEMONSTRATOR

Funded by DOE Office of Nuclear Physics and NSF Particle Astrophysics, with additional contributions from international collaborators.

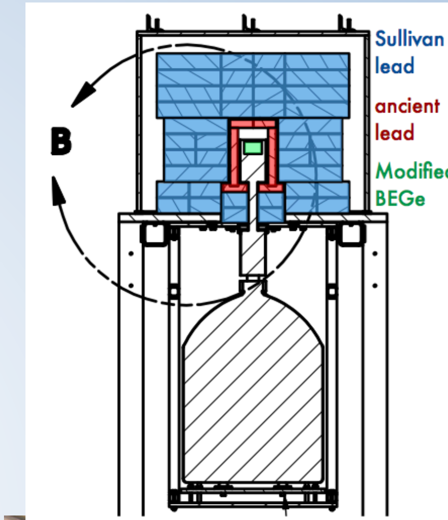
Goals: - Demonstrate backgrounds low enough to justify building a tonne scale experiment.
- Establish feasibility to construct & field modular arrays of Ge detectors.
- Searches for additional physics beyond the standard model.

- Located underground at 4850' Sanford Underground Research Facility
- Background Goal in the 0νββ peak region of interest (4 keV at 2039 keV)
  3 counts/ROI/t/y (after analysis cuts) Assay U.L. currently ≤ 4.1
  scales to 1 count/ROI/t/y for a tonne experiment
- 40-kg of Ge detectors
  - 30 kg of 87% enriched ^{76}Ge crystals
  - 10 kg of ^{nat}Ge
  - Detector Technology: P-type, point-contact.
- 2 independent cryostats
  - ultra-clean, electroformed Cu
  - 20 kg of detectors per cryostat
  - naturally scalable
- Compact Shield
  - low-background passive Cu and Pb shield with active muon veto

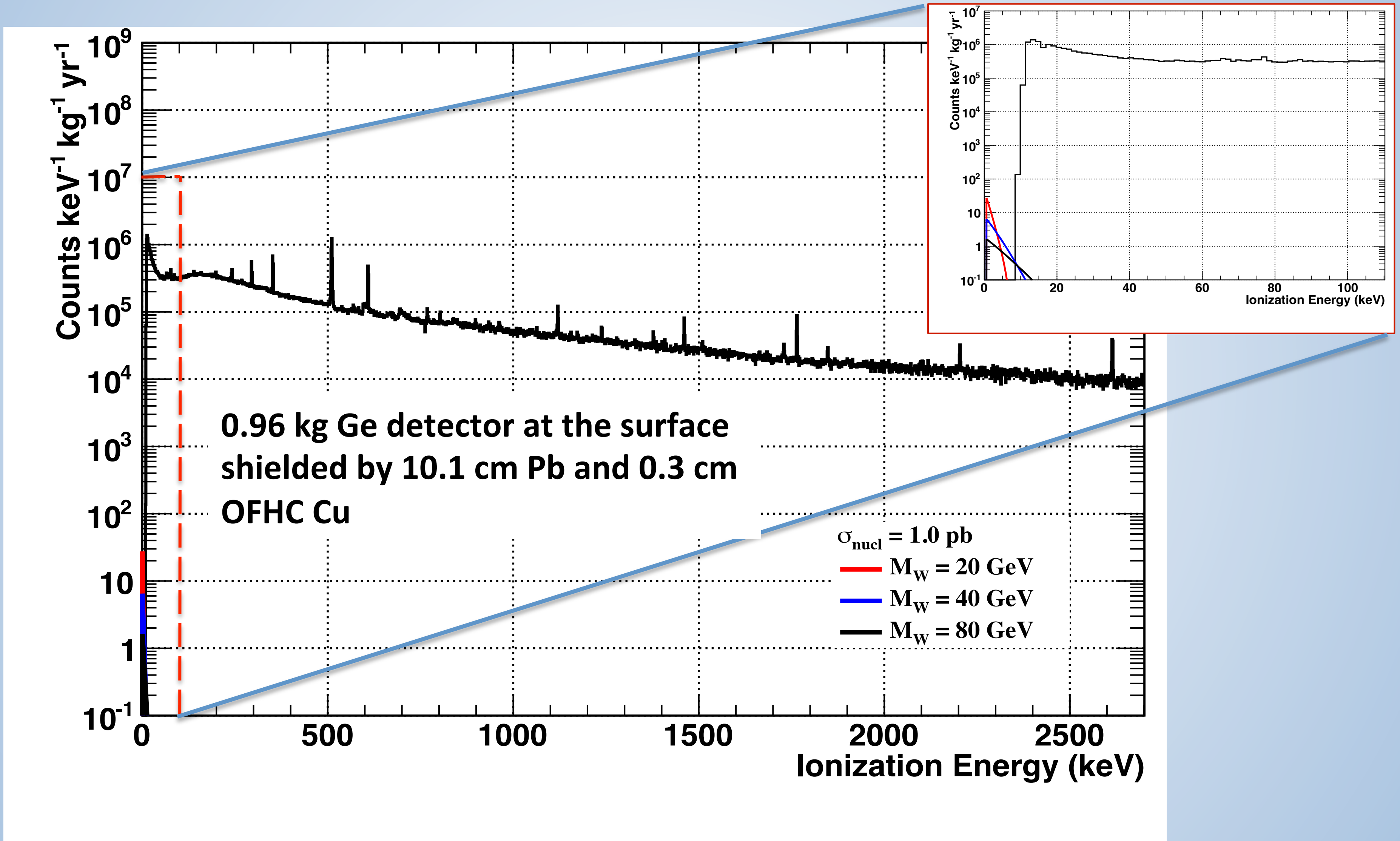


MALBEK (MAJORANA Low-background BEGe Experiment at KURF)

- MALBEK is a 450-g R&D modified BEGe detector, mounted in a low-background cryostat.
- Similar design as CoGeNT, R&D for MAJORANA
- MALBEK is operating since 2010 at KURF (1450 m.w.e.), located in Ripplemead, VA. Goals:
  - Systematically characterize spectrum.
  - R&D low-energy triggering and DAQ (low-energy pulses difficult to distinguish from noise).
  - R&D PSA in low-energy region
  - Background model verification
  - Dark Matter search



Low-E Background Reduction Critical

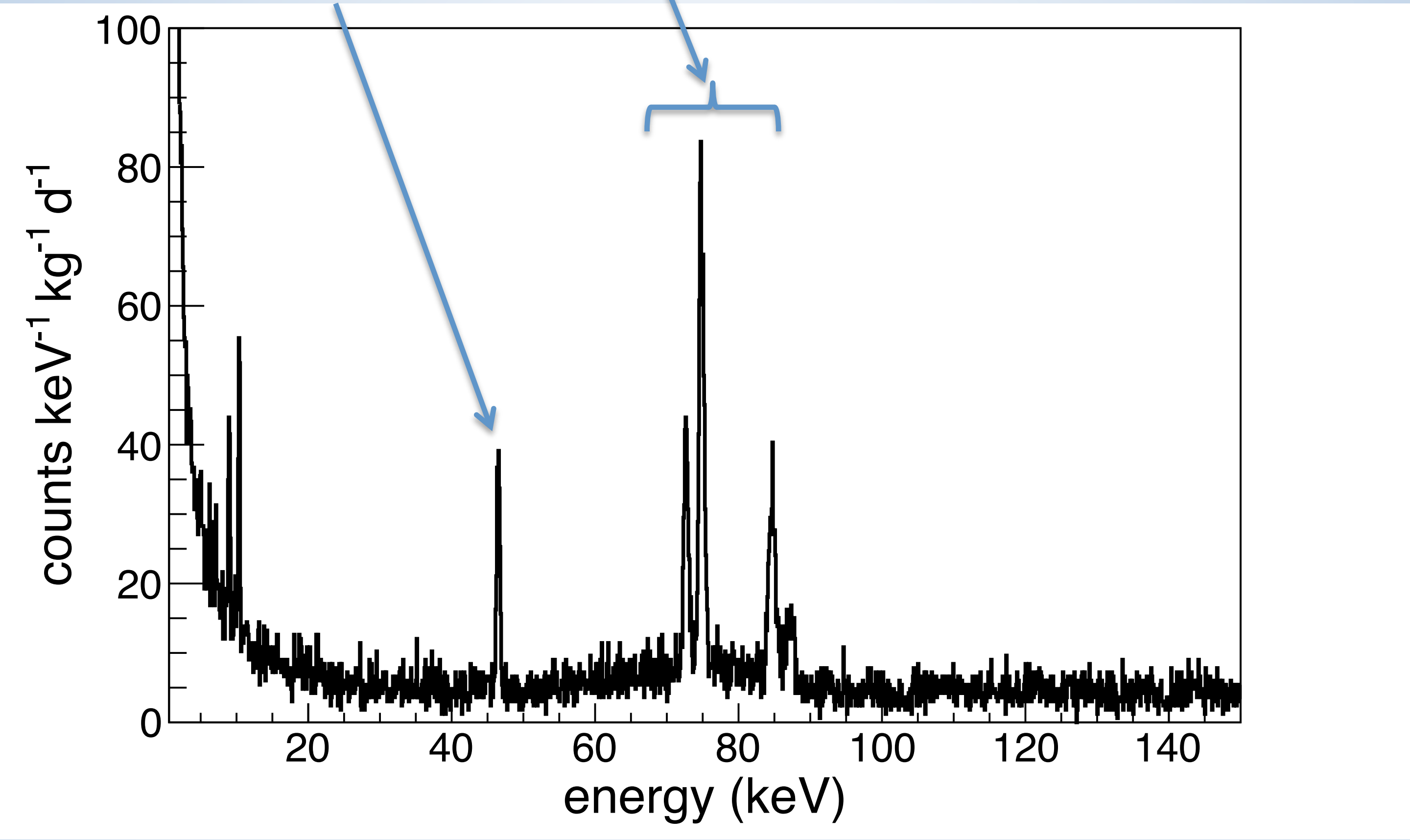


Initial Data showed large contamination of ^{210}Pb near crystal

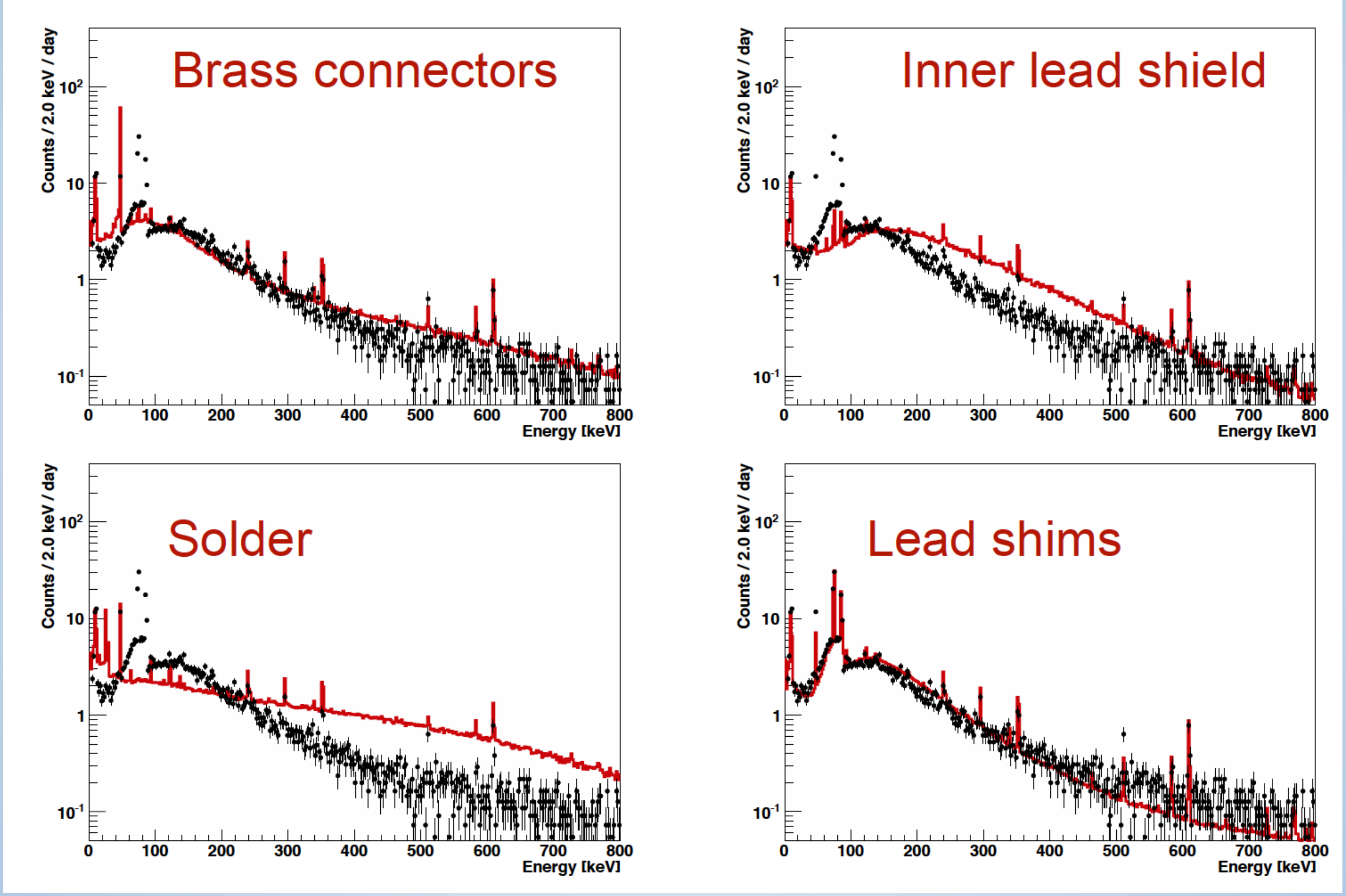
^{210}Pb → **^{210}Bi** → **^{210}Po**

^{210}Pb: Q_{β} = 63.5 keV, $T_{1/2}$ = 22 years

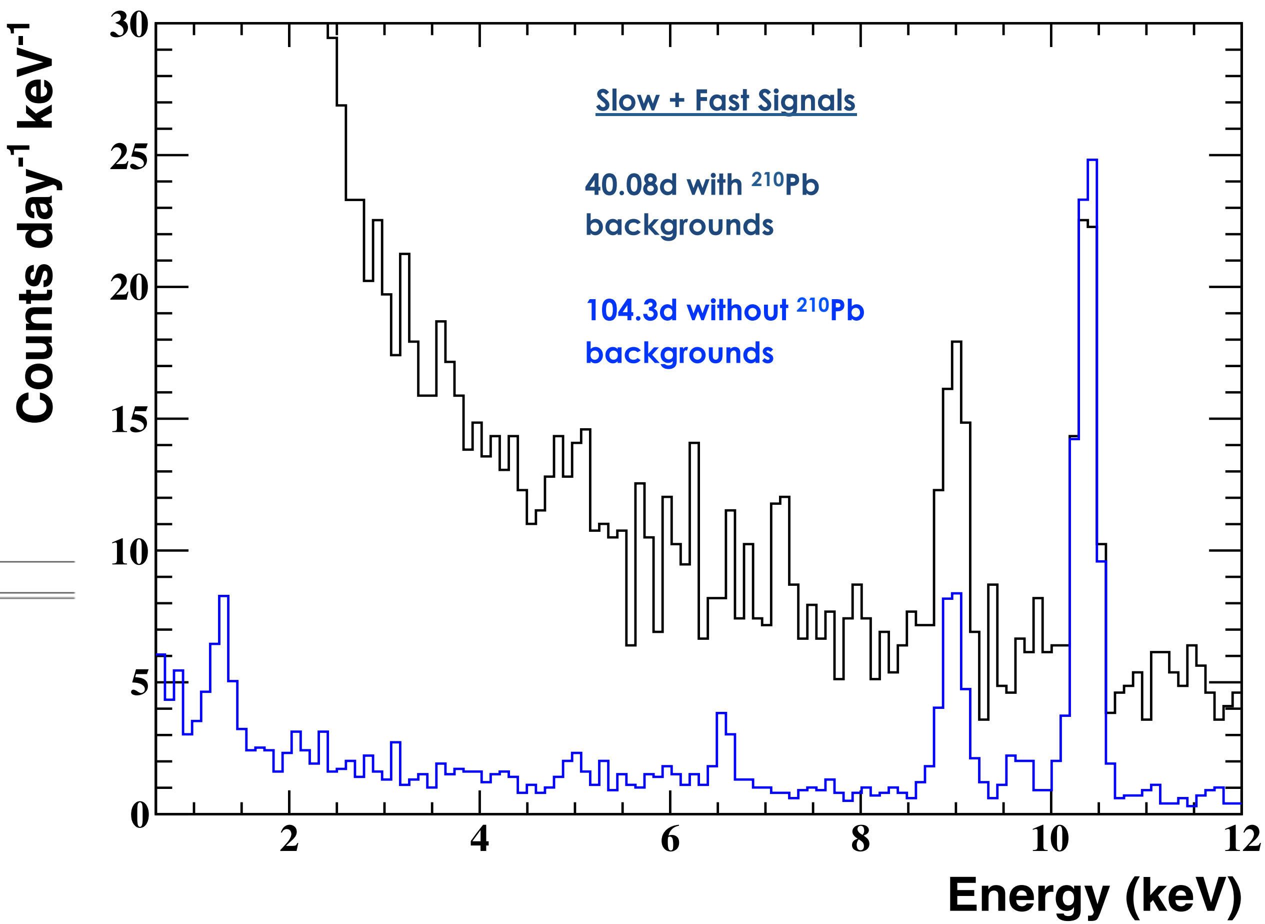
^{210}Bi: Q_{β} = 1162 keV, $T_{1/2}$ = 5 days



Monte Carlo suggests lead shims

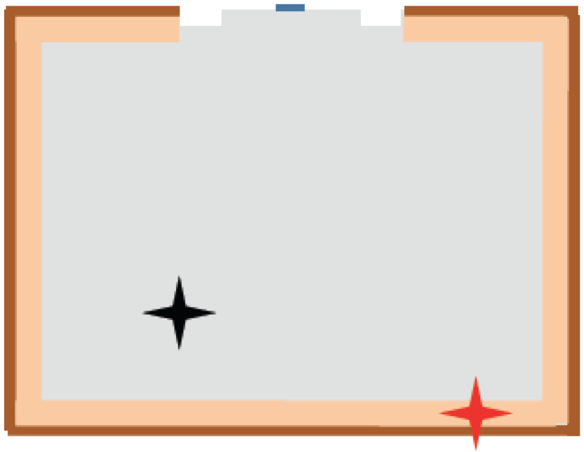


Removed Pb shims – big improvement

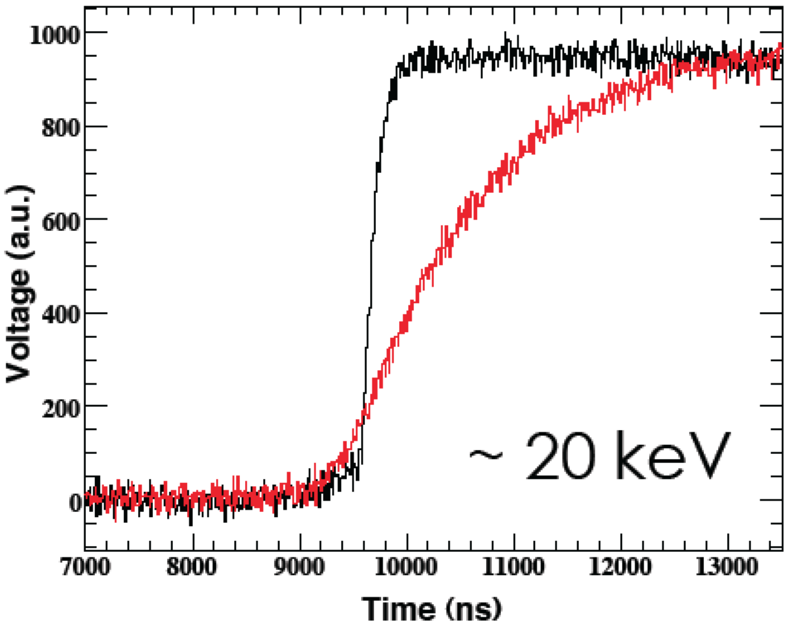


Energy (keV)	Source
1.096	^{65}Zn L-capture
1.299	^{68,71}Ge L-capture
4.966	^{49}V K-capture
6.539	^{55}Fe K-capture
8.979	^{65}Zn K-capture
9.659	^{68}Ga K-capture
10.367	^{68,71}Ge K-capture
46.539	^{210}Pb
72.0→90.0	Pb and Bi X-rays
92.38, 92.80	^{234}Th
122.06	^{57}Co
136.47 + 7.06 (143.53)	^{57}Co γ + X-ray summing

slow surface events

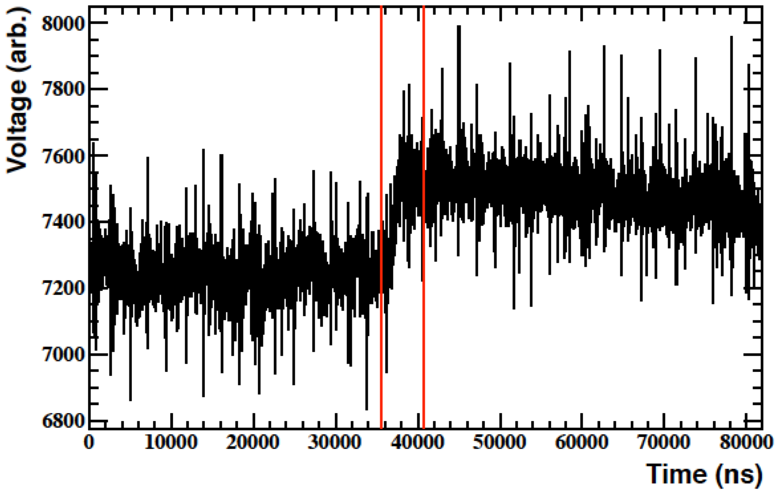


- active volume
- n+ dead layer
- transition region – partial charge collection

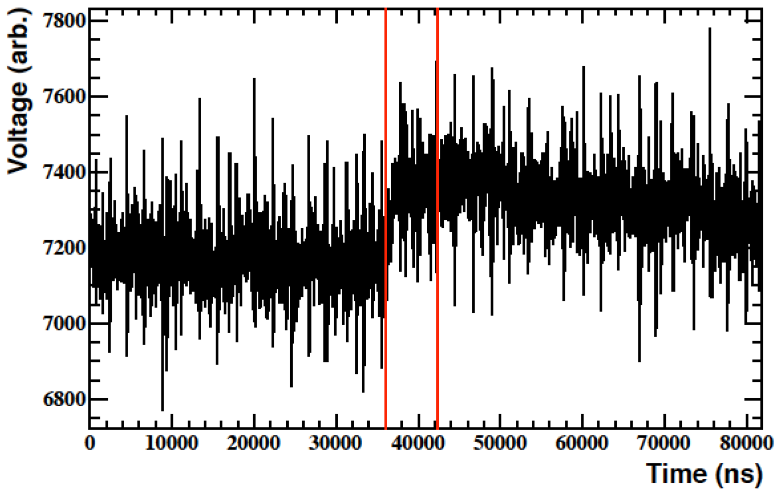


Also energy-degraded

Sample Pulses with mis-reconstructed 10-90 risetimes



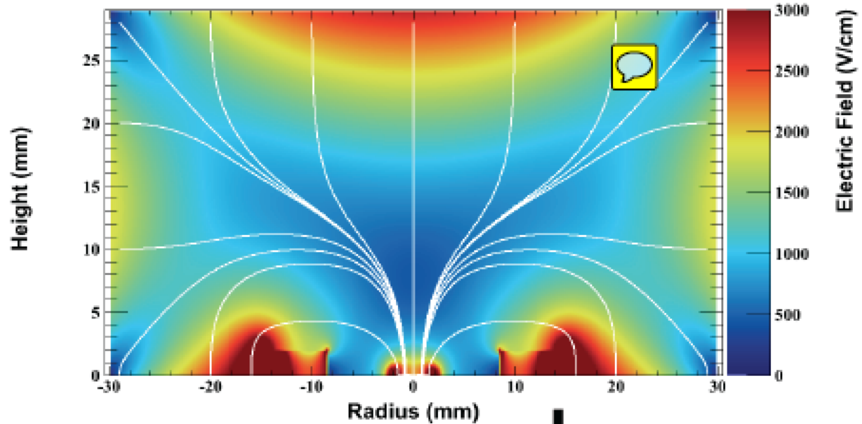
(a) 1.19 keV

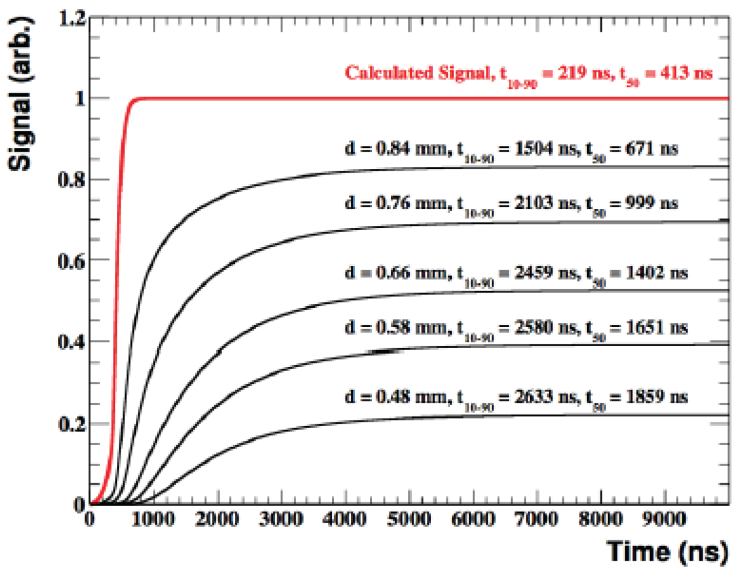


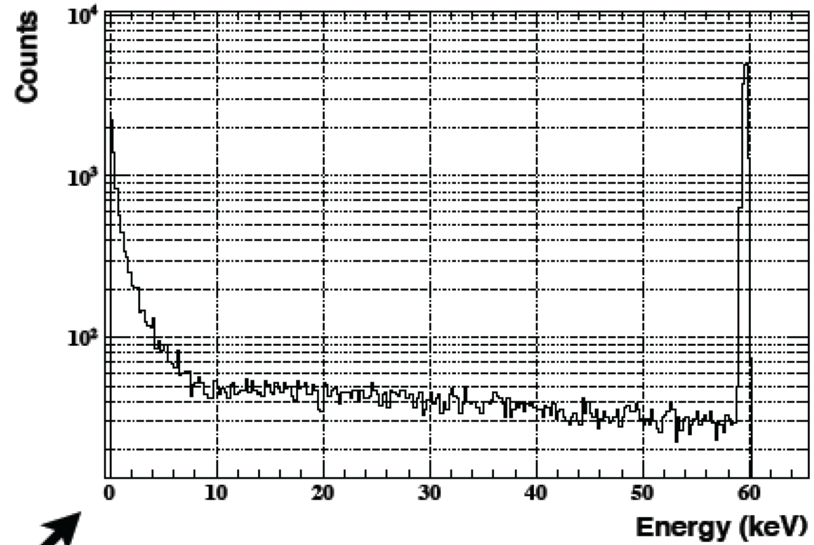
(b) 0.90 keV

a qualitative slow pulse diffusion model

D.C. Radford and P. Finnerty





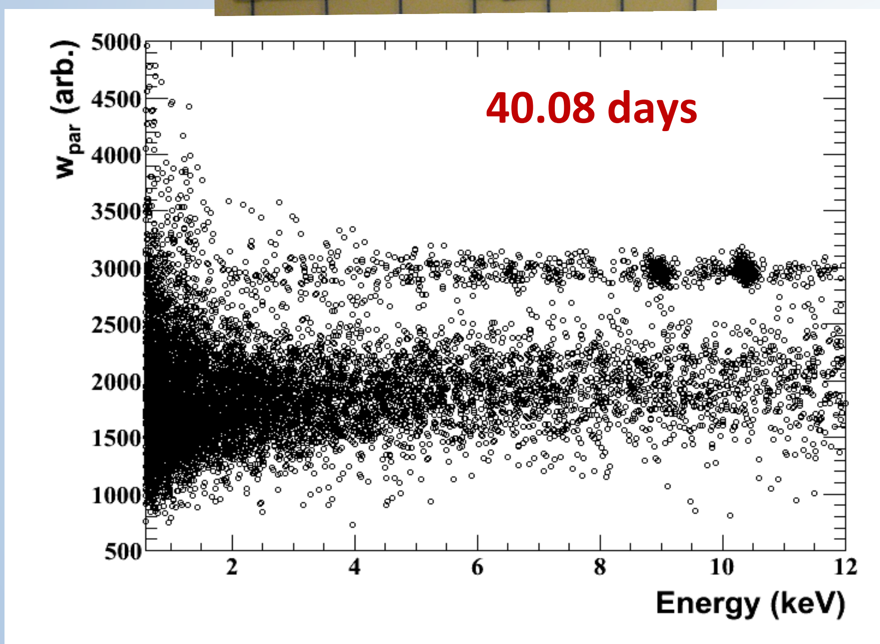


Big first step towards understanding physical mechanism responsible for slow-signals in PPC detectors.

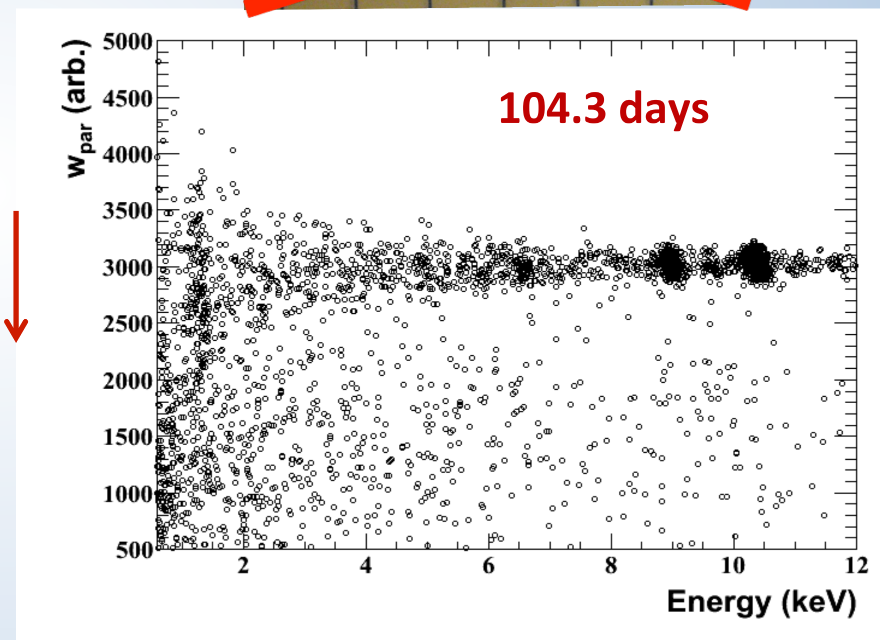
Energy-degraded surface events mimic WIMP signal

^{210}Pb near crystal illuminates transition region → Significant contamination at low-E

Lead shims with ^{210}Pb

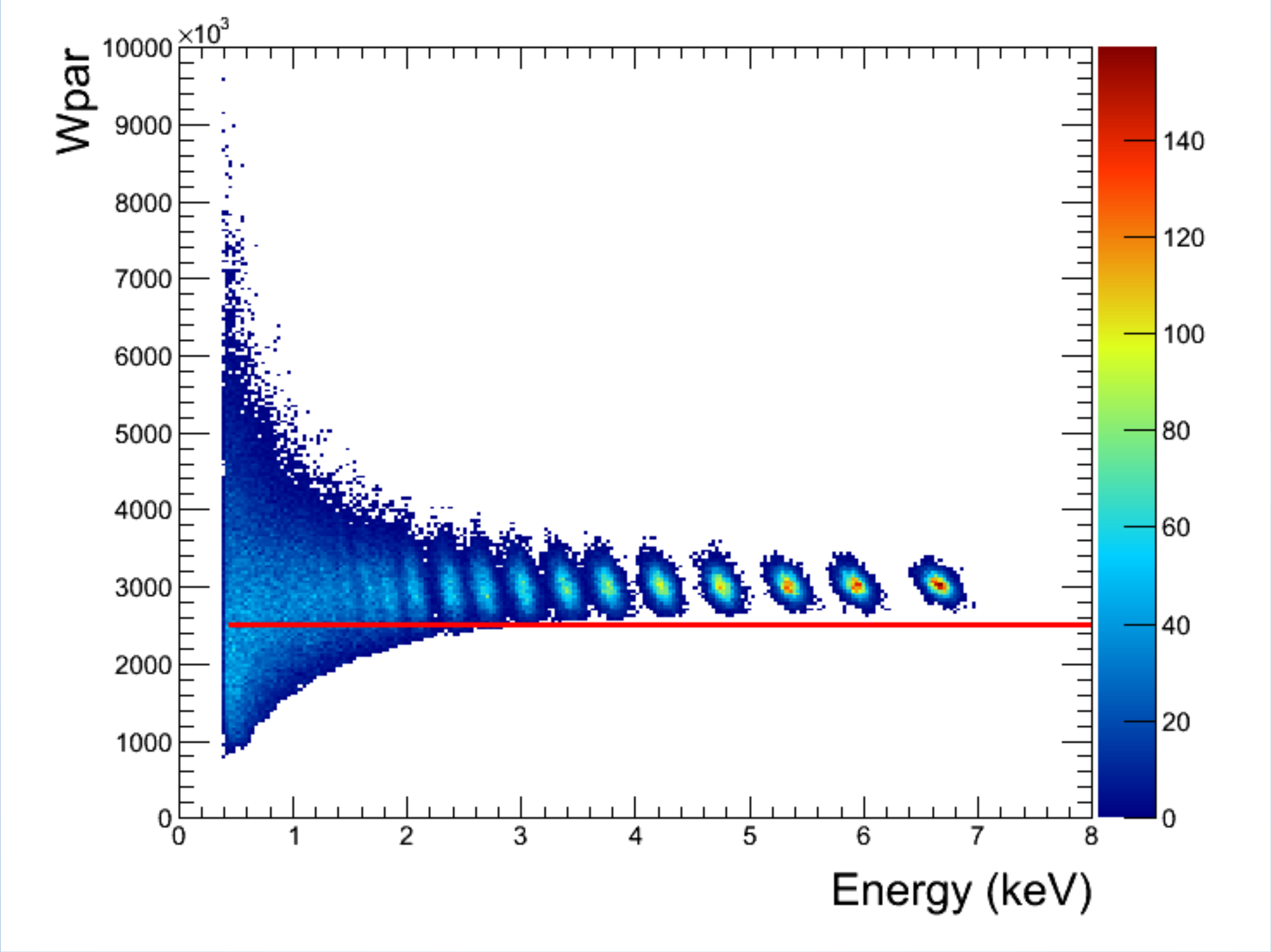


Increasing Pulse Risetime

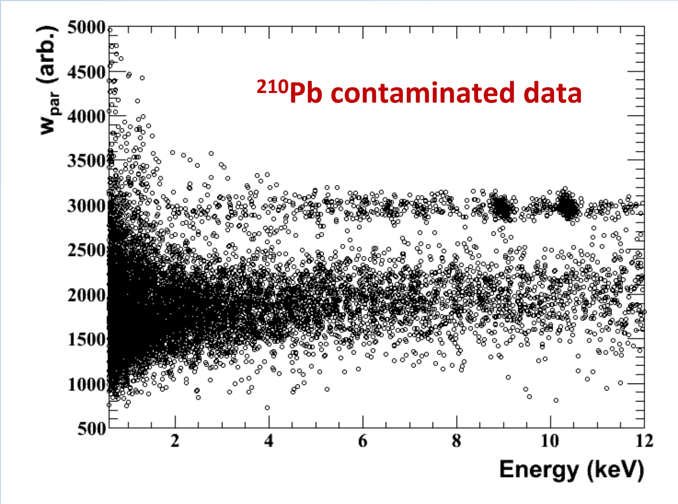


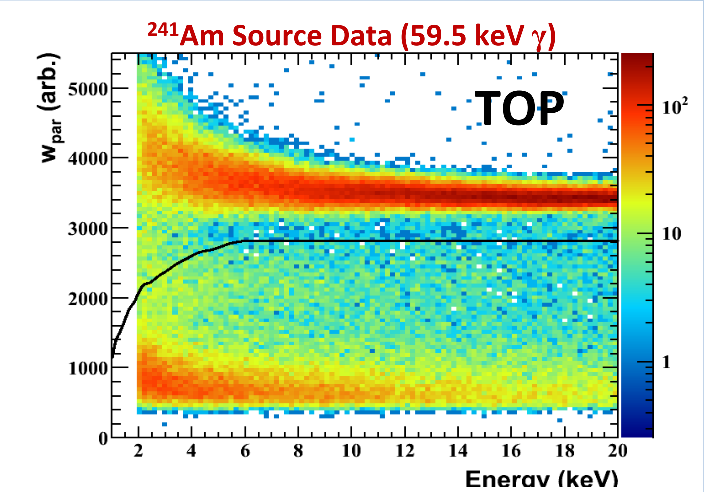
Can we determine slow/fast distributions directly and independently below 1keV?

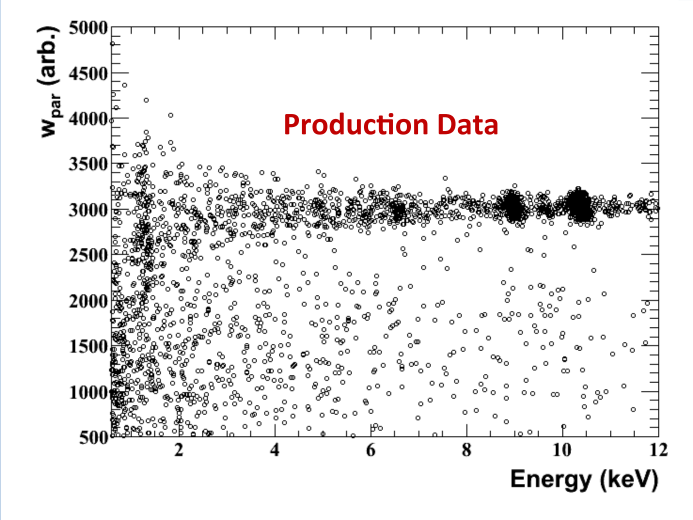
Fast pulse acceptance calibrated with pulser

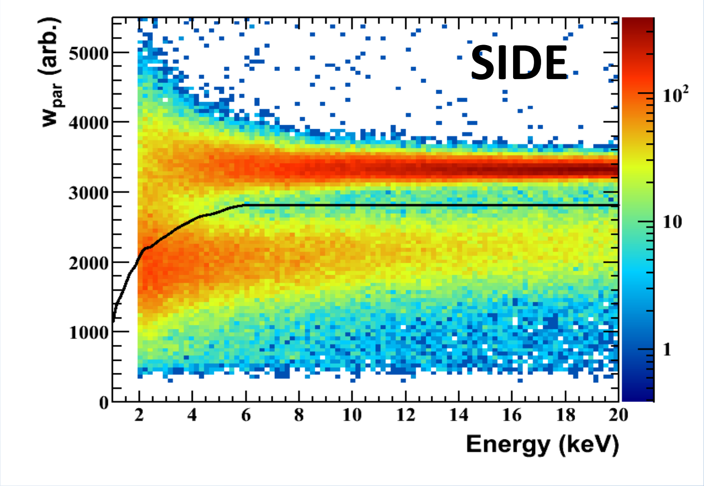


Slow pulse distributions



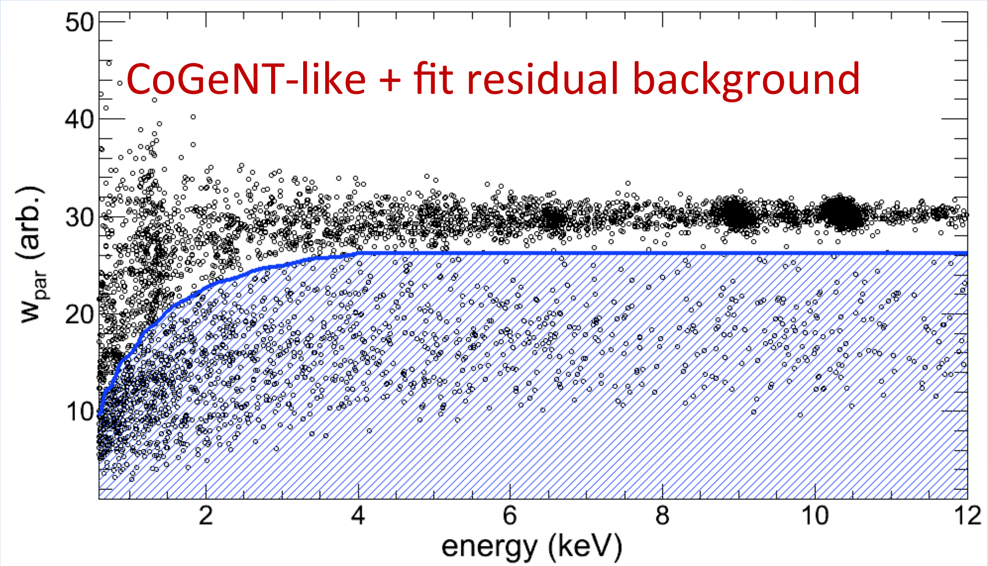


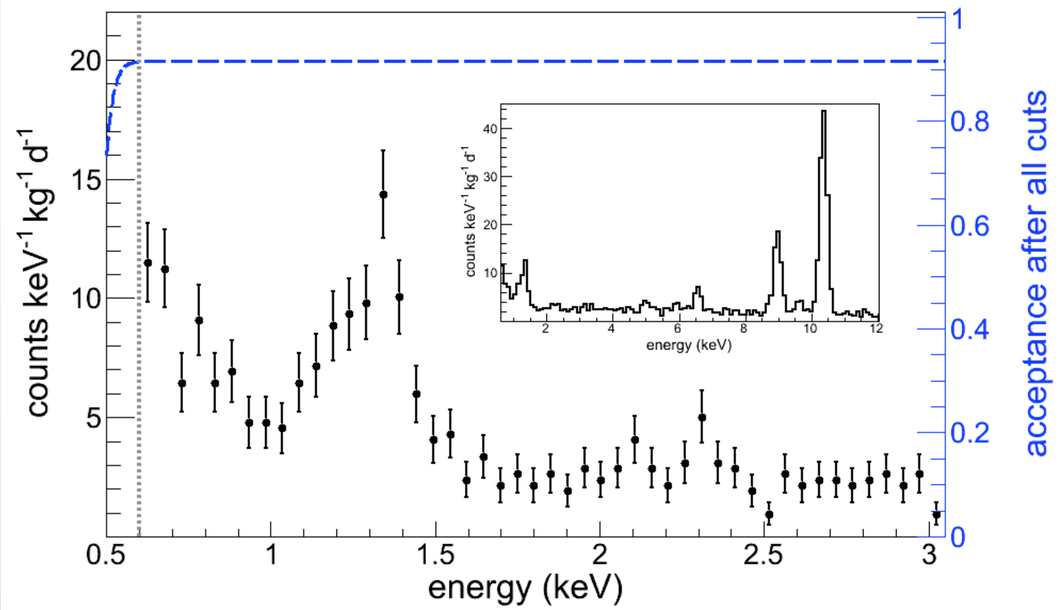




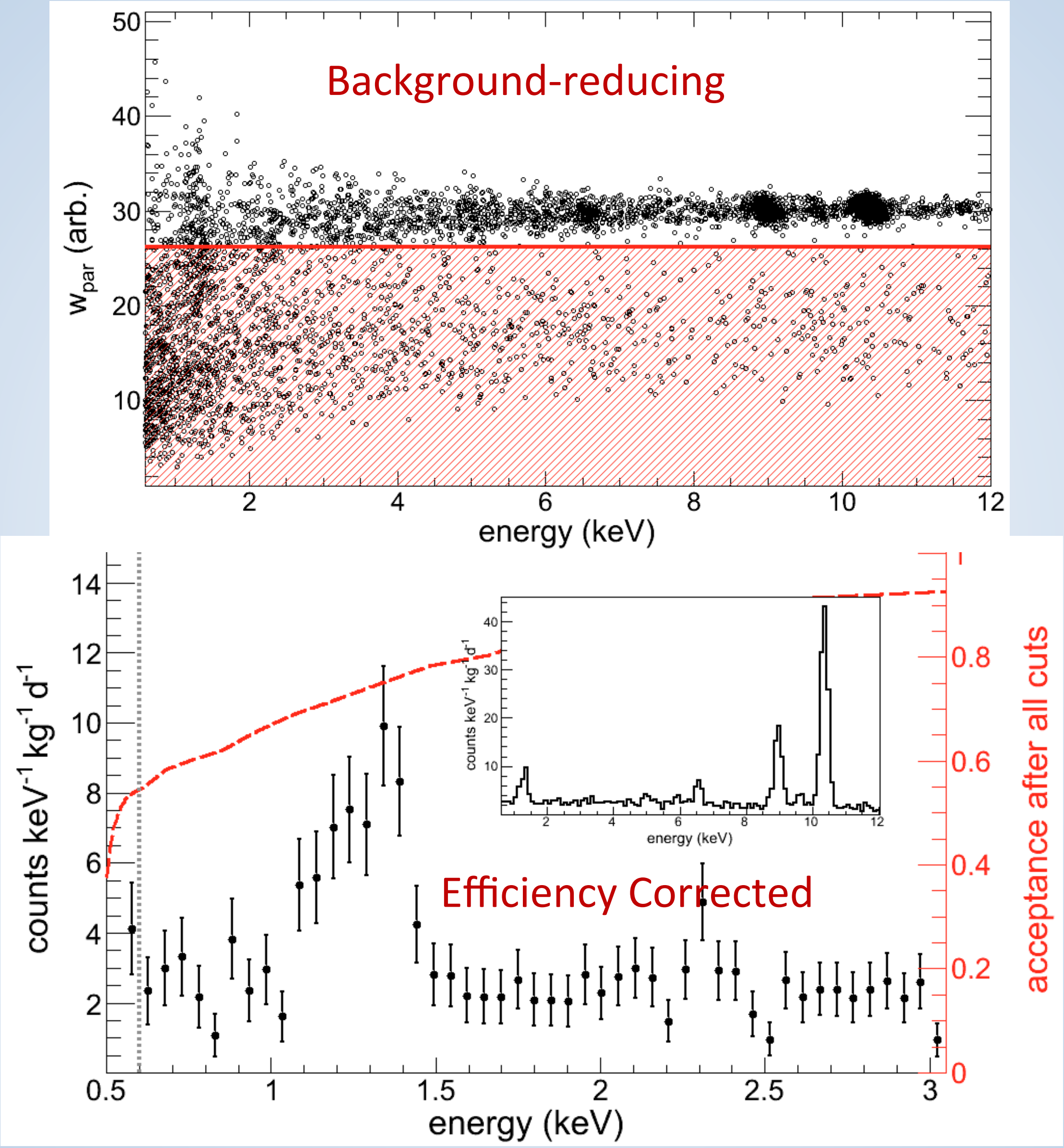
Difficult to determine. Depends on source energy and location
Studies ongoing

Can implement different analysis philosophies(1)

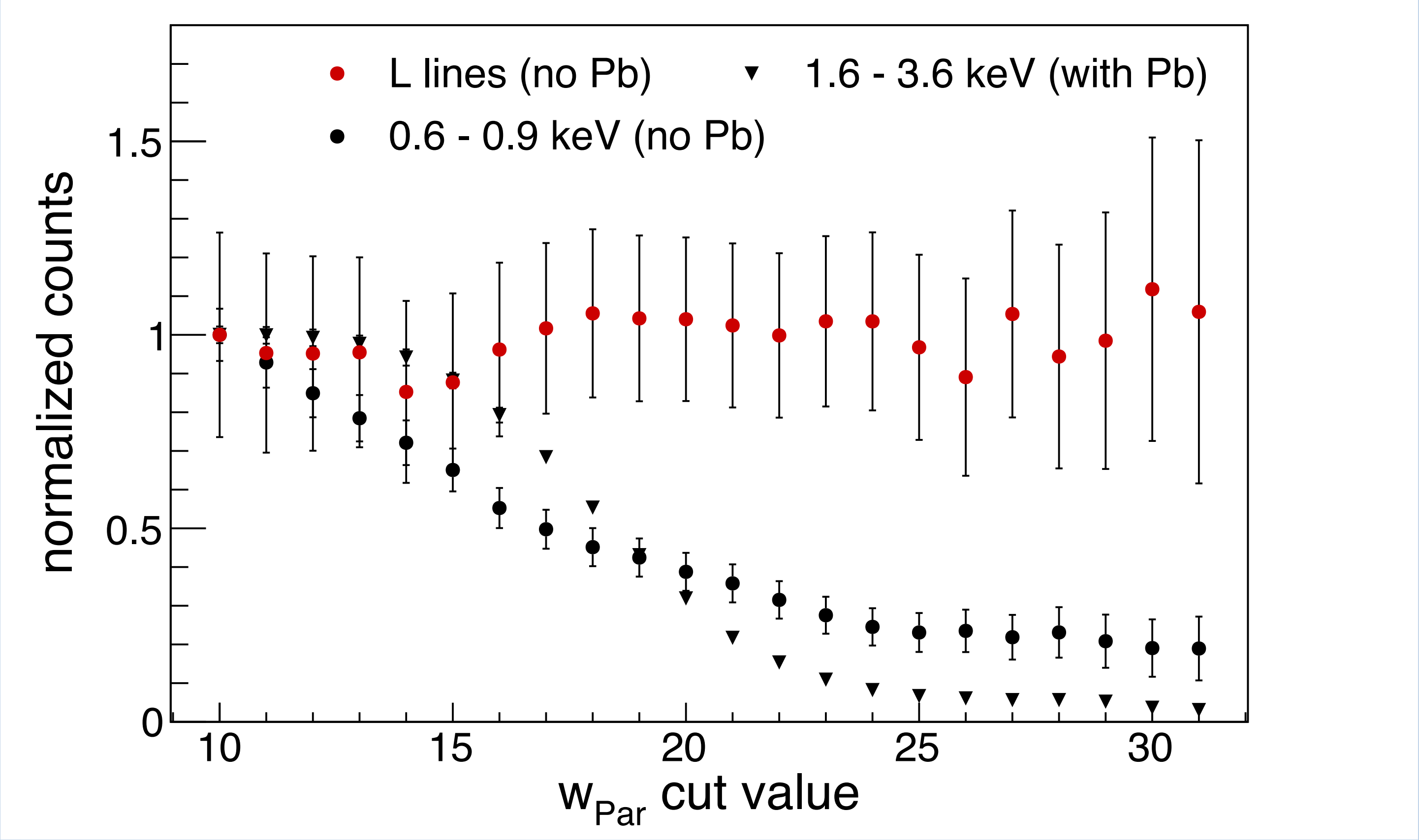




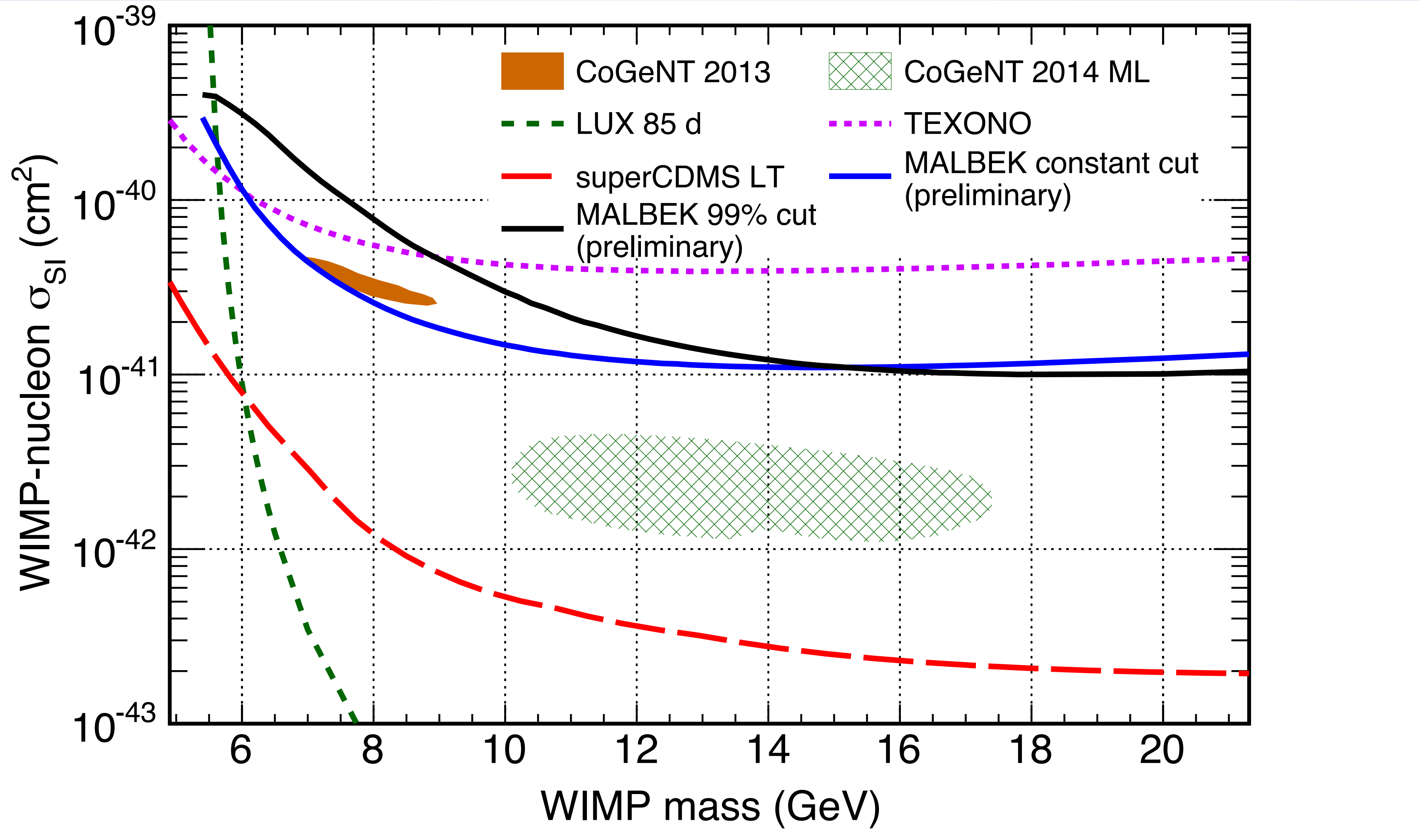
Can implement different analysis philosophies(2)



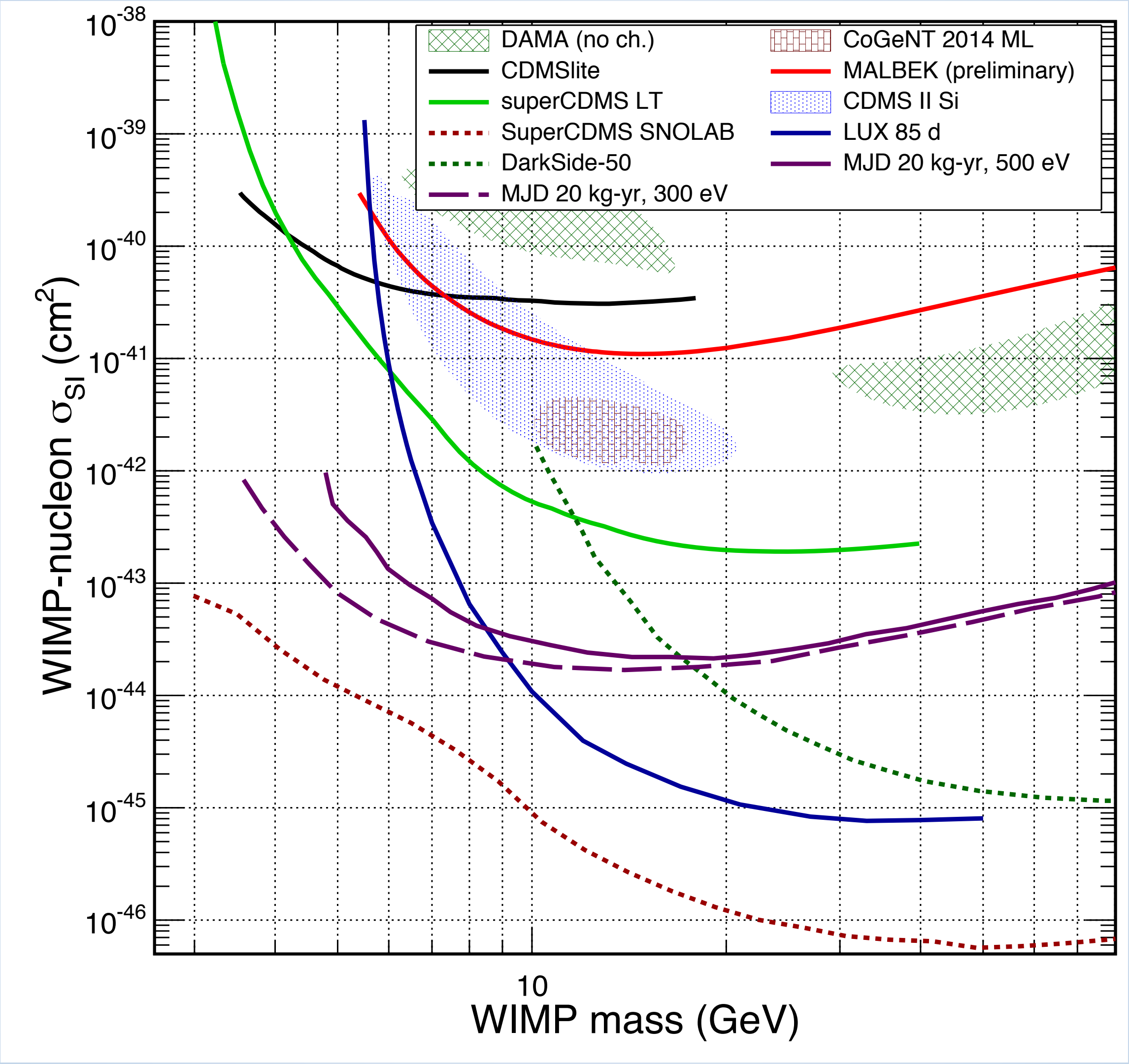
Constant cut reduces slow pulses at expense of fast pulse uncertainty



90% confidence limits



MAJORANA Projected Dark Matter Sensitivity



Conclusions

- There are significant uncertainties in the risetime vs energy distributions for surface and bulk events
  - Depends on location in crystal
  - Depends on origin outside of crystal and initial energy
  - Detectors require detailed characterization, background simulations, and microphysics modeling to determine distributions *independently* of data.
- Using production data to determine PDFs introduces correlations between signal and background and difficult-to-quantify systematic uncertainties.