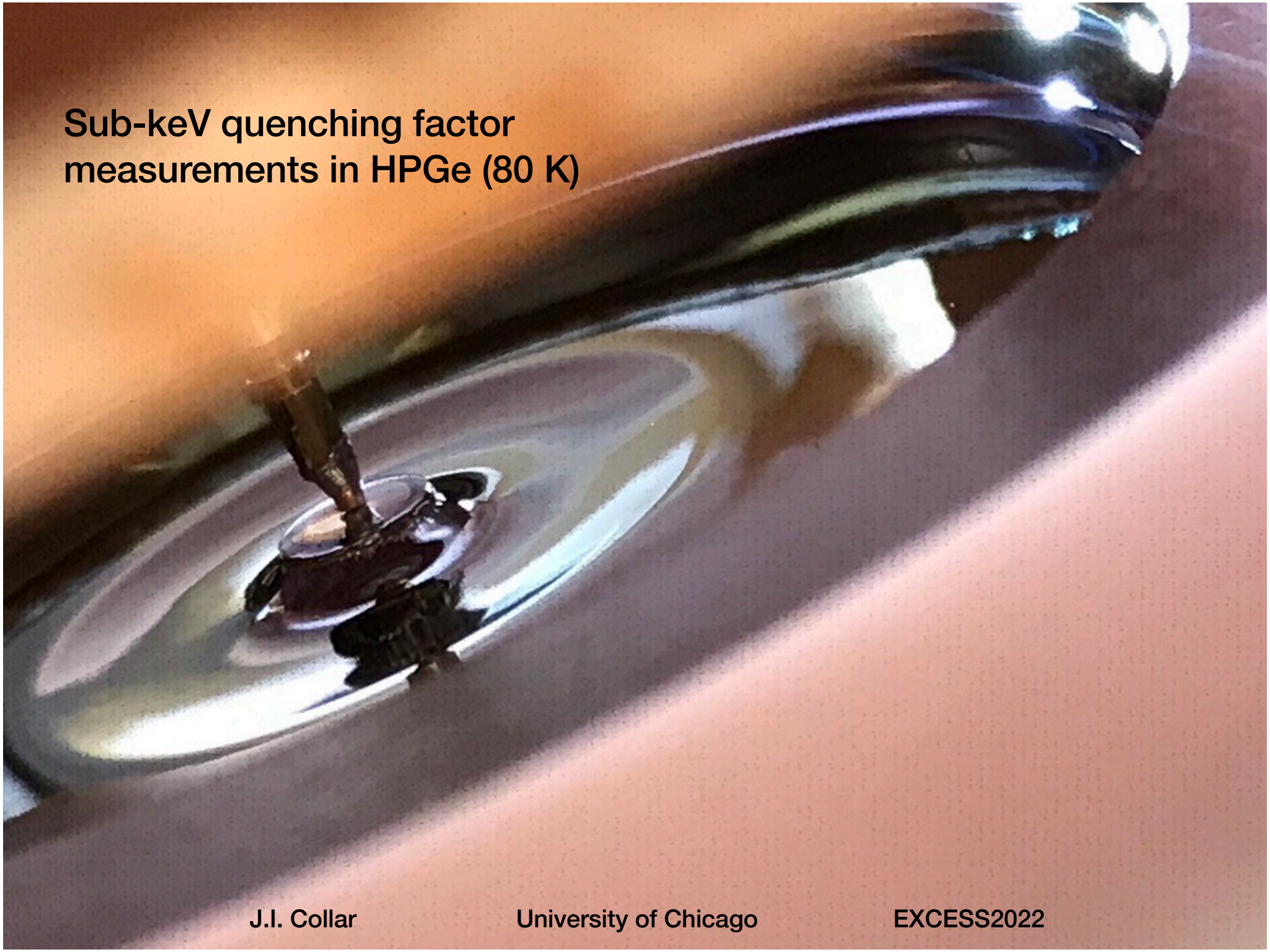


Sub-keV quenching factor measurements in HPGe (80 K)

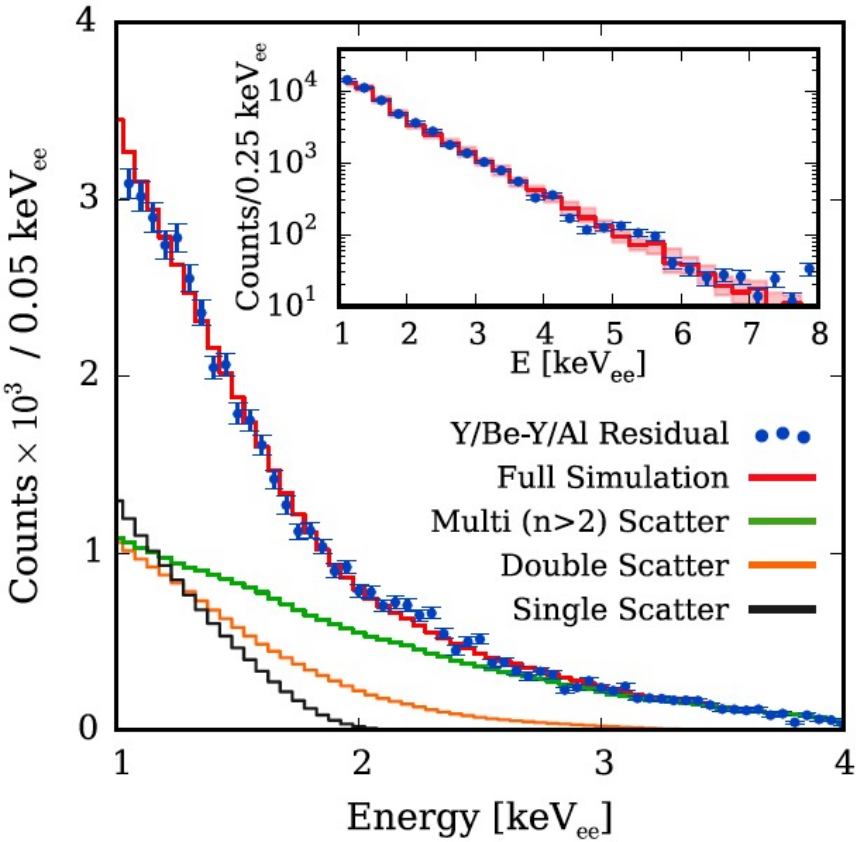
J.I. Collar University of Chicago EXCESS2022

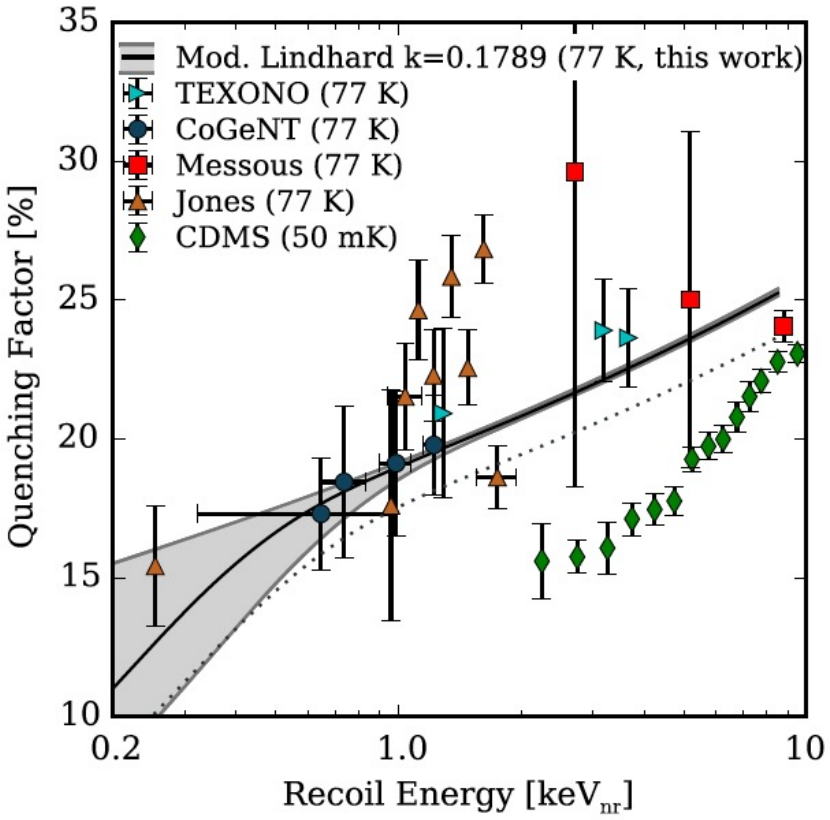
The precedent(s)

PHYSICAL REVIEW D **94,** 122003 (2016)

Measurement of the low-energy quenching factor in germanium using an ^{88}Y/Be photoneutron source

B. J. Scholz,* A. E. Chavarria, J. I. Collar, P. Privitera, and A. E. Robinson†





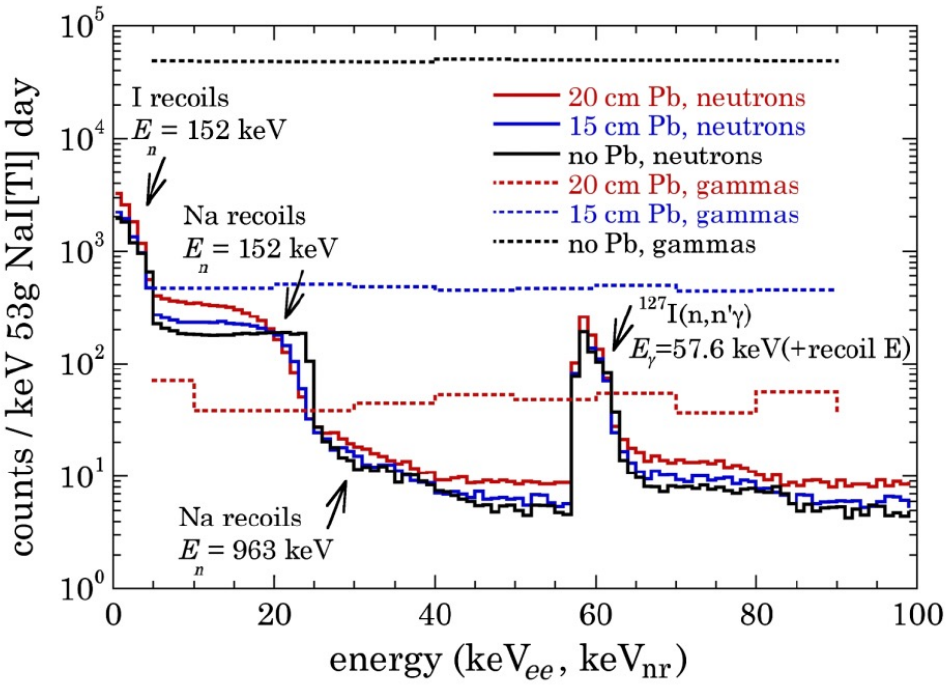
high threshold, large crystal (dominated by multiple scattering)

The precedent(s)

PRL **110,** 211101 (2013)

Applications of an ^{88}Y/Be Photoneutron Calibration Source to Dark Matter and Neutrino Experiments

J. I. Collar*



See also T. Saab's talk in this session (cryogenic Ge)

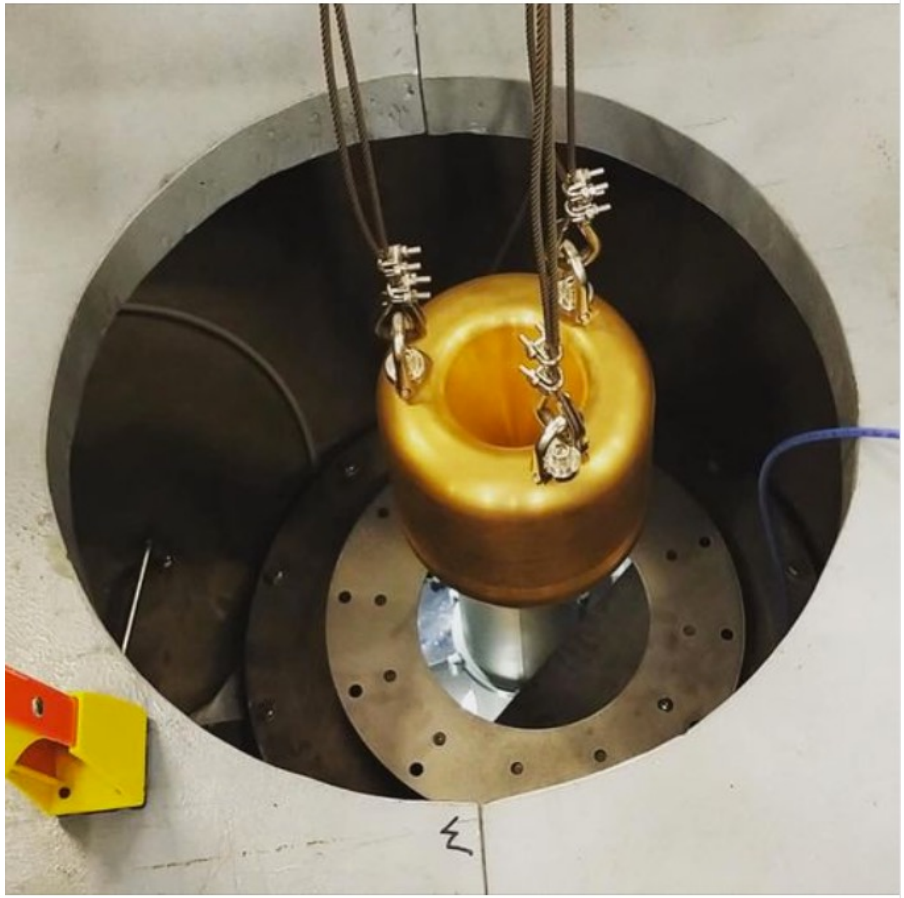
LZ added a new photo to the album: **A to Z of LZ**.
May 4, 2020 ·

Y is for YBe or Yttrium Beryllium!

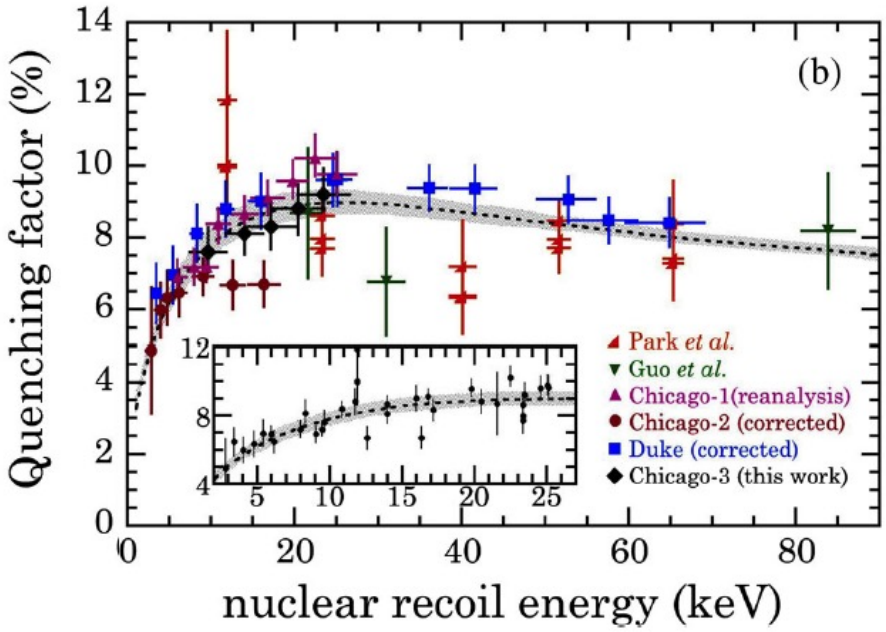
LZ has a special neutron source for calibrations made from the elements yttrium and beryllium that produces almost monoenergetic neutrons. The yttrium decays and releases a gamma ray, which interacts with the beryllium to produce a single neutron of around 200keV. These low energy neutrons are useful for calibrating nuclear recoils within the expected dark matter energy range.

The YBe source sits inside a tungsten shield (a mock up is shown in gold) to absorb the gamma rays, since we only want neutrons to get to the detector. This is lowered down to the top of the detector through a special port on top of the water tank.

Calibration sources like this are essential for understanding what dark matter looks like in LZ!



The precedent(s)

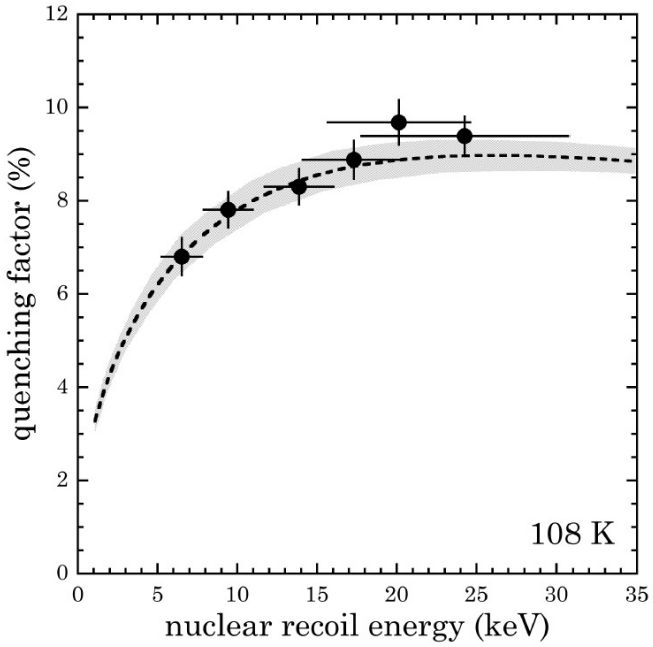


PHYSICAL REVIEW D **100,** 033003 (2019)

Response of CsI[Na] to nuclear recoils: Impact on coherent elastic neutrino-nucleus scattering

J. I. Collar,* A. R. L. Kavner, and C. M. Lewis

Went in hoping for a surprise…
(massive rise in low-E QF for α's)



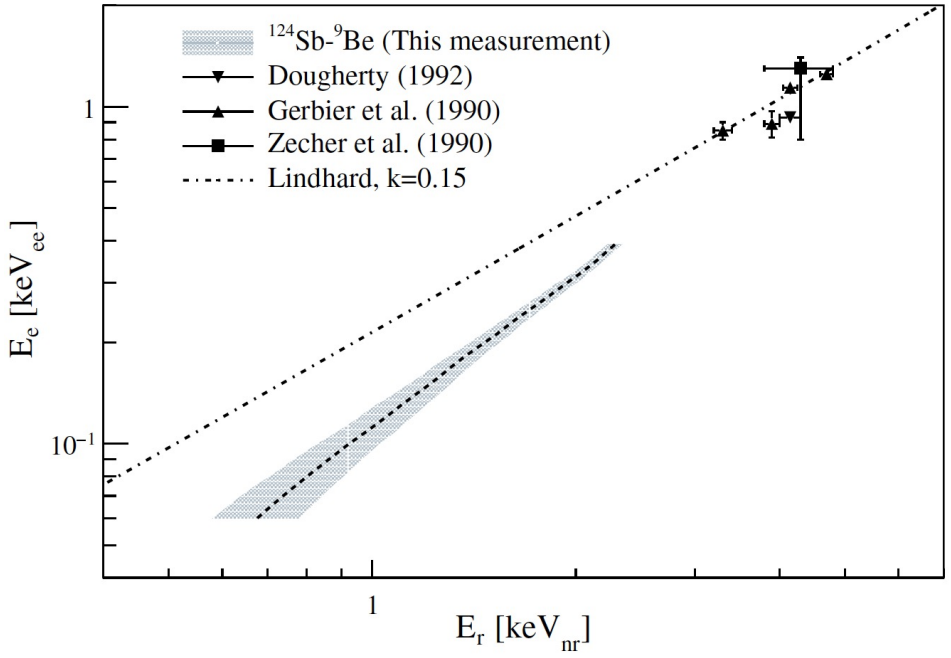
PHYSICAL REVIEW C **104**, 014612 (2021)

Response of undoped cryogenic CsI to low-energy nuclear recoils

C.M. Lewis* and J.I. Collar

Physics-based model (Birks + kinematic cutoff) works here (the exception)

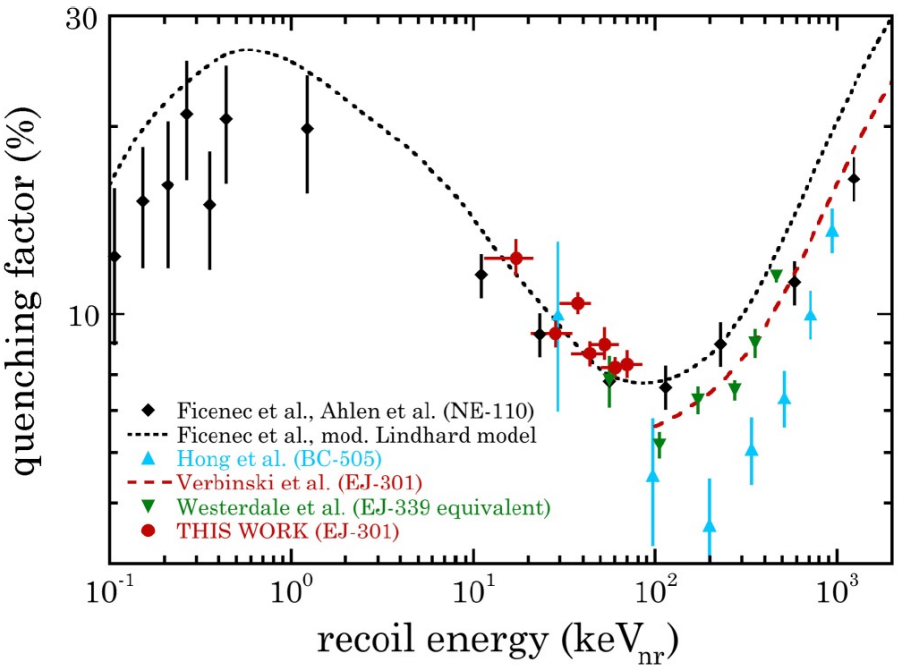
The precedent(s)



PHYSICAL REVIEW D **94,** 082007 (2016)

Measurement of the ionization produced by sub-keV silicon nuclear recoils in a CCD dark matter detector

A. E. Chavarria,[1,*] J. I. Collar,[1] J. R. Peña,[1] P. Privitera,[1] A. E. Robinson,[1,2] B. Scholz,[1] C. Sengul,[1] J. Zhou,[1] J. Estrada,[2] F. Izraelevitch,[2] J. Tiffenberg,[2] J. R. T. de Mello Neto,[3] and D. Torres Machado[3]



PHYSICAL REVIEW C **98**, 045802 (2018)

Liquid scintillator response to proton recoils in the 10–100 keV range

C. Awe,[1] P. S. Barbeau,[1] J. I. Collar,[2,*] S. Hedges,[1] and L. Li[1]

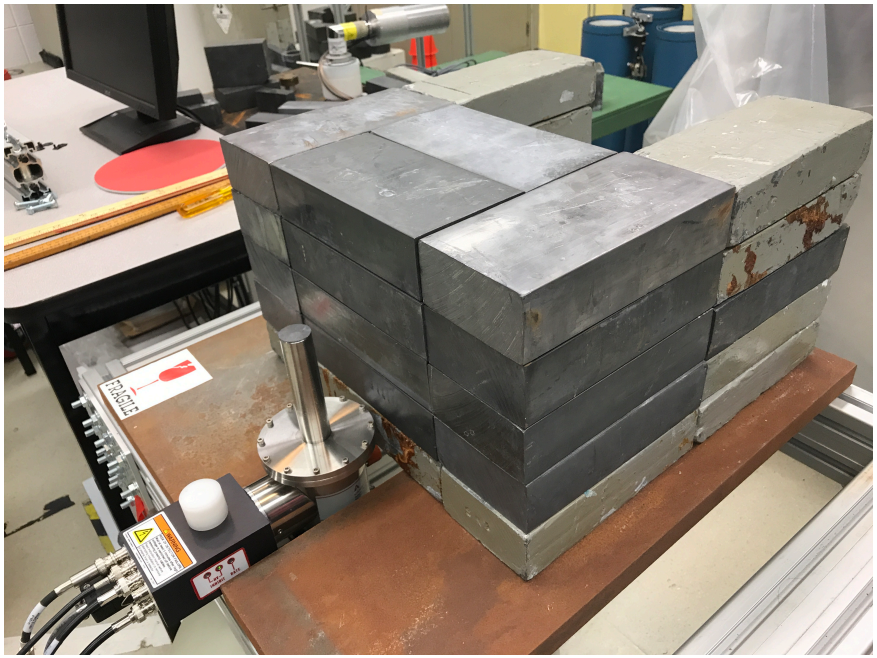
anything goes for the QF at sub-keV energies?

Today's subject: 1) photoneutron sources

PHYSICAL REVIEW D **103,** 122003 (2021)

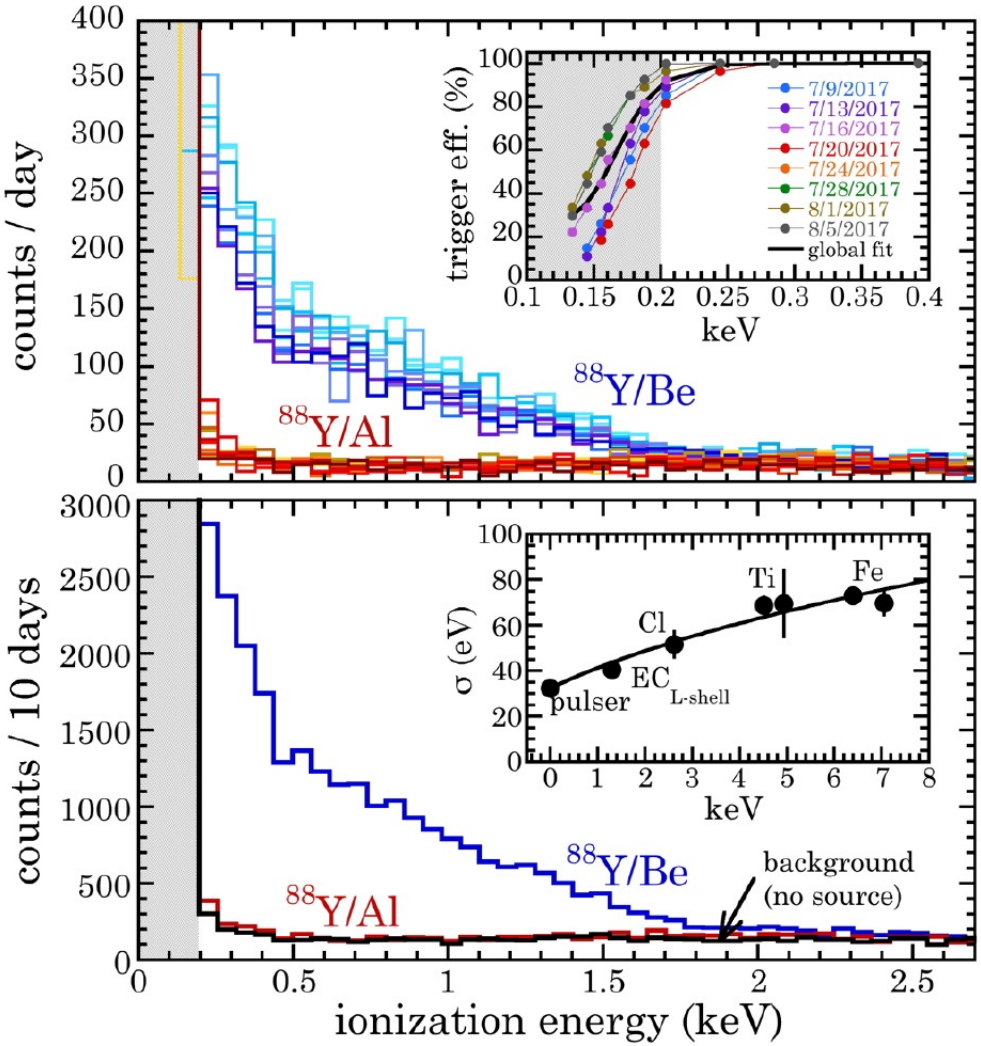
Germanium response to sub-keV nuclear recoils: A multipronged experimental characterization

J. I. Collar,* A. R. L. Kavner, and C. M. Lewis



Improved detector:

- x5 lower threshold
- excellent E resolution
- 1 cm^3 → dominated by single recoils
- n-type (no dead + transition layers)



Today's subject: 1) photoneutron sources

PHYSICAL REVIEW D **103,** 122003 (2021)

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A multipronged experimental characterization

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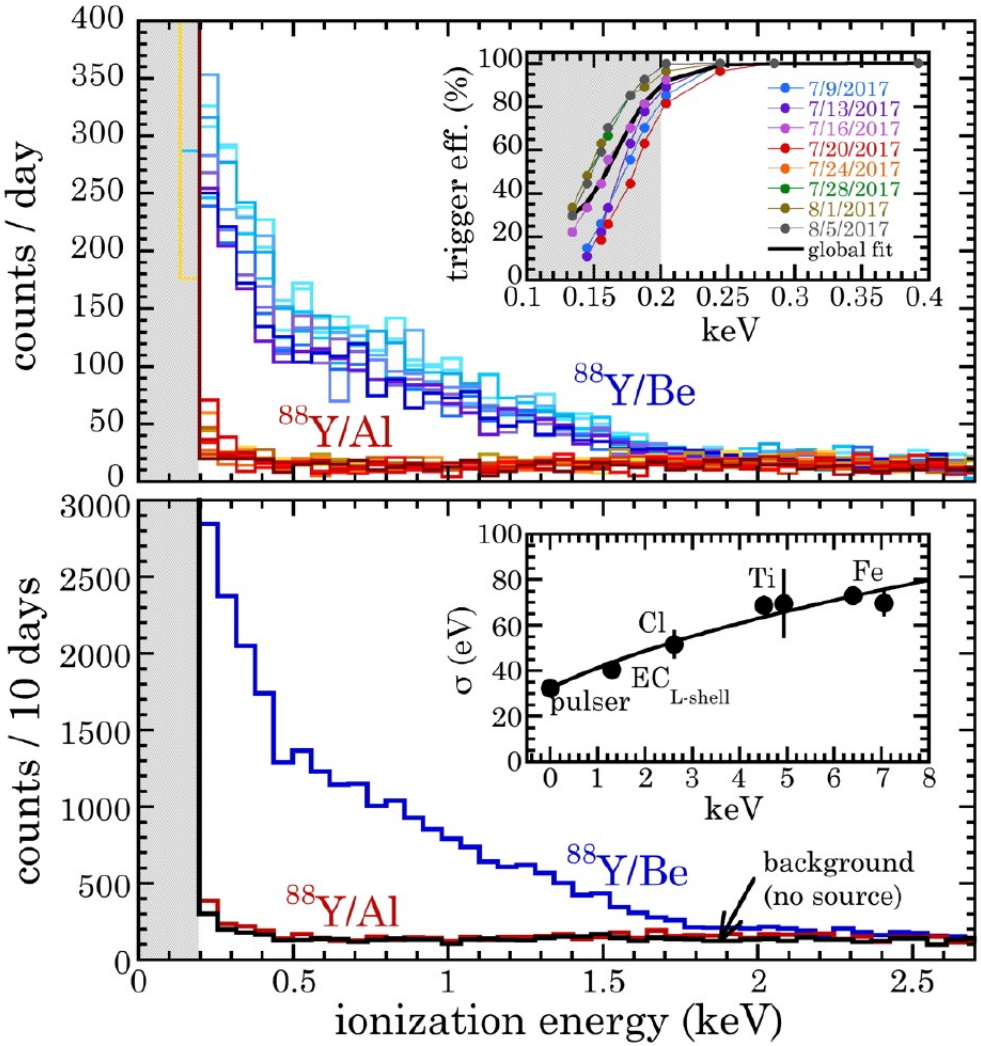

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PHYSICAL REVIEW D **103,** 122003 (2021)

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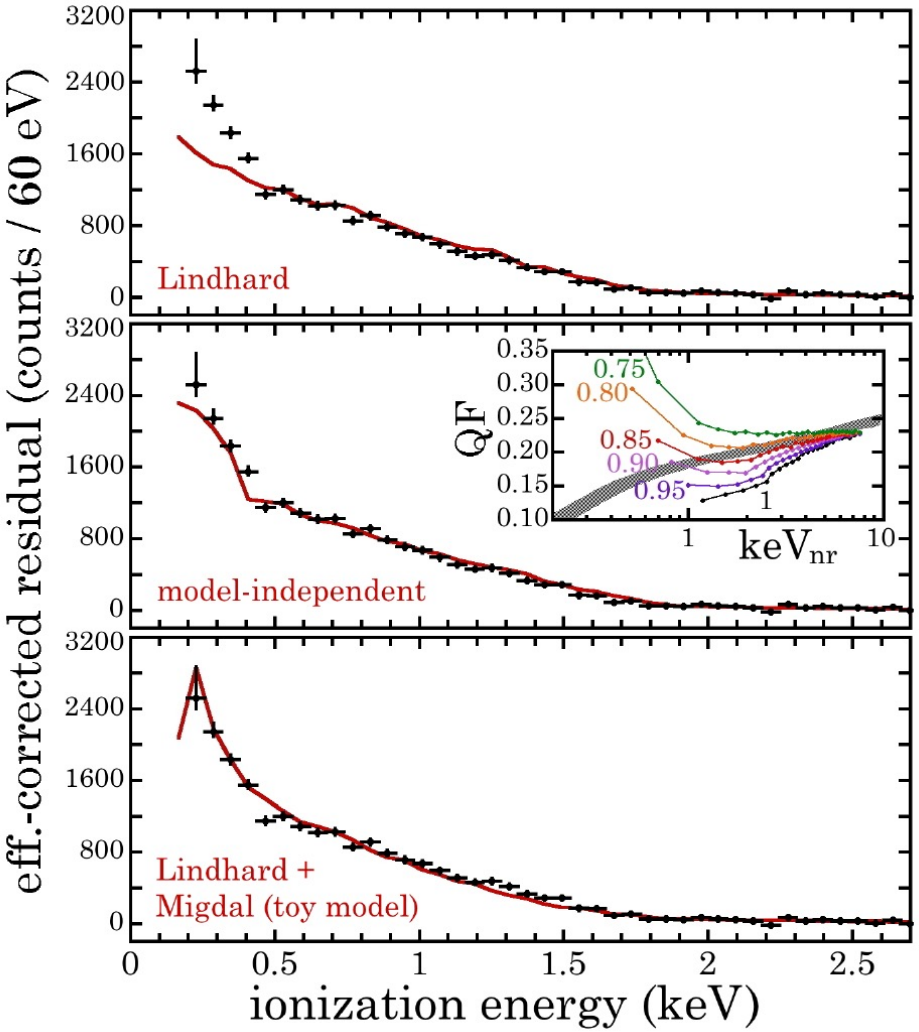

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PHYSICAL REVIEW D **103,** 122003 (2021)

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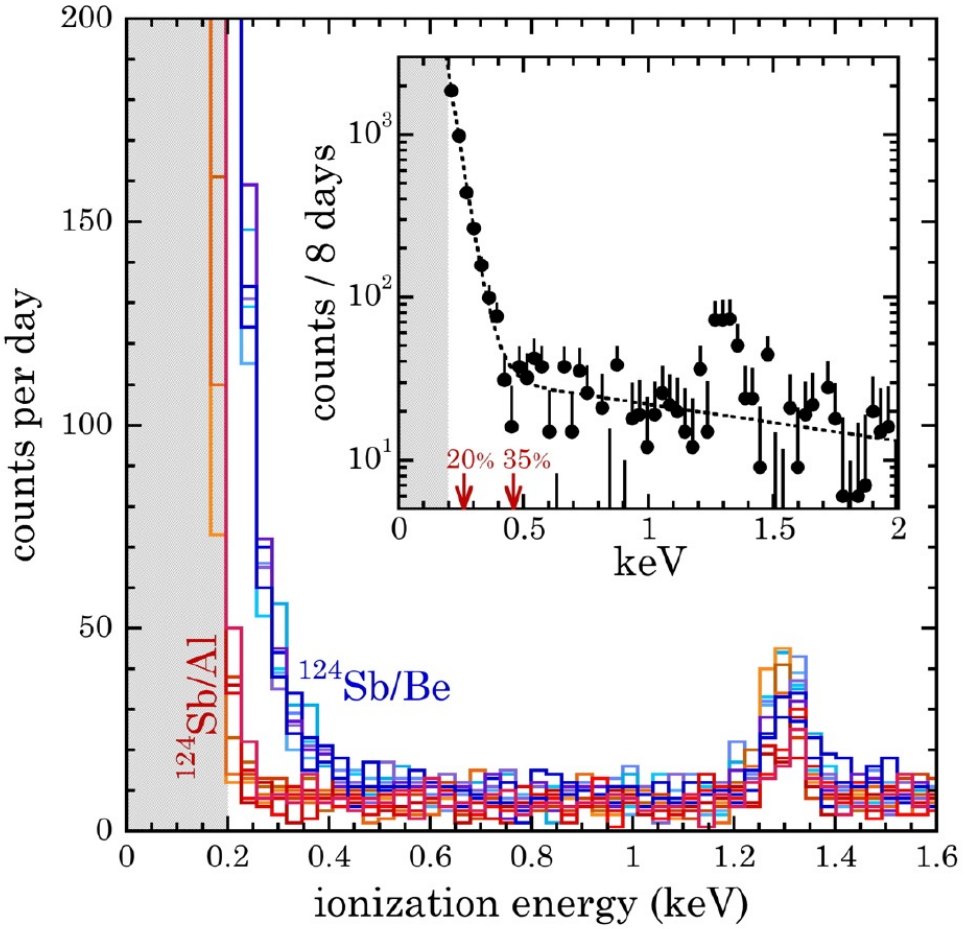


Today's subject: 2) recoils from n_{th} capture

PHYSICAL REVIEW D **103,** 122003 (2021)

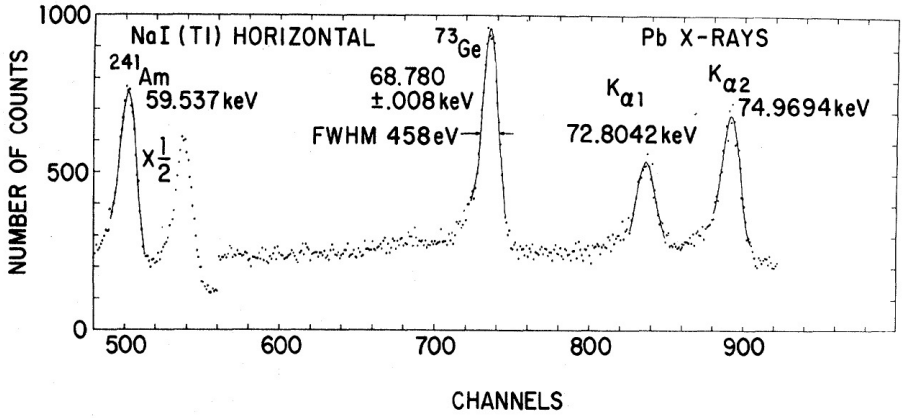
Germanium response to sub-keV nuclear recoils: A multipronged experimental characterization

J. I. Collar,* A. R. L. Kavner, and C. M. Lewis

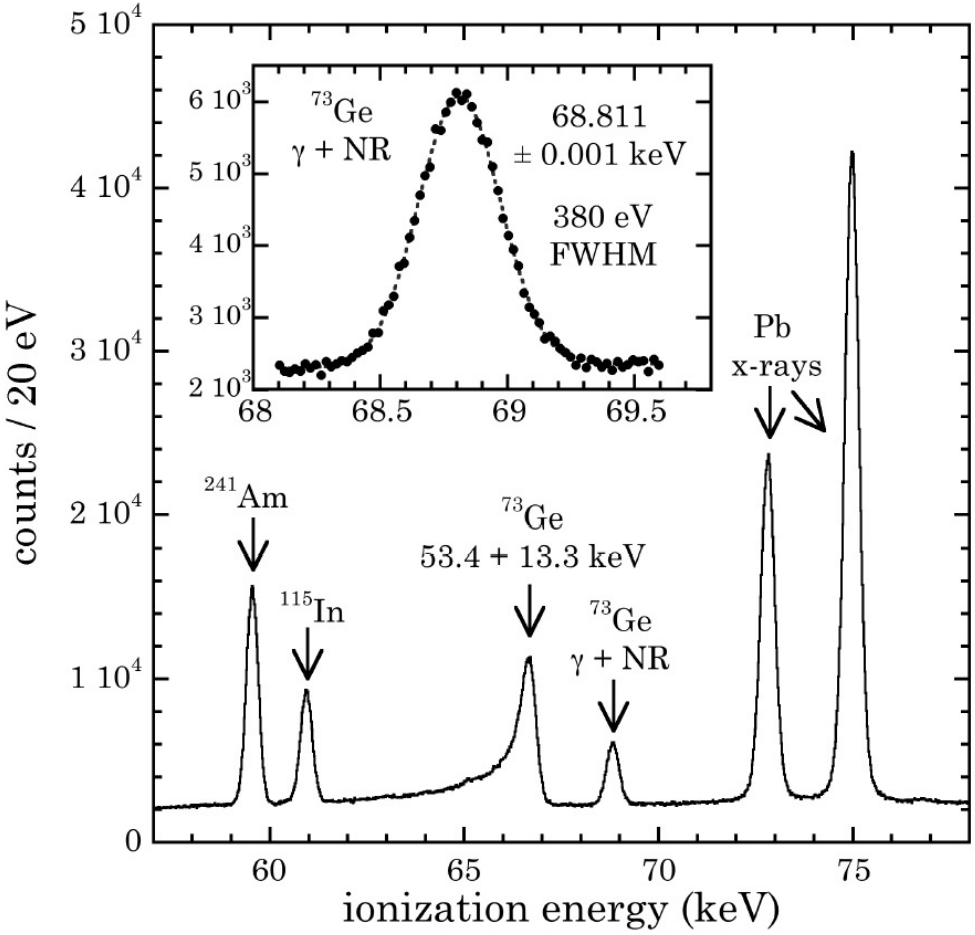
PHYSICAL REVIEW A VOLUME 11, NUMBER 4 APRIL 1975

Energy lost to ionization by 254-eV ^{73}Ge atoms stopping in Ge†

K. W. Jones and H. W. Kraner



notice two orders of magnitude difference in statistics of calibration peaks, tails in Ge(Li) peaks…



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PHYSICAL REVIEW D **103,** 122003 (2021)

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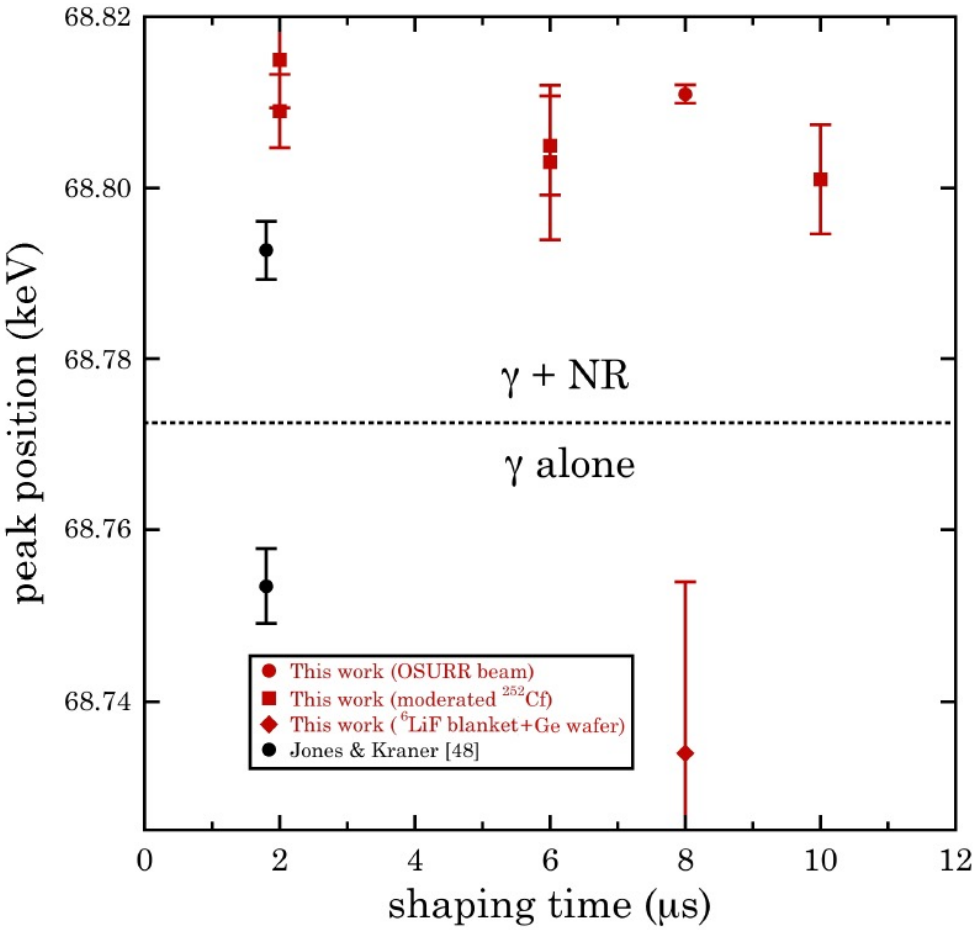

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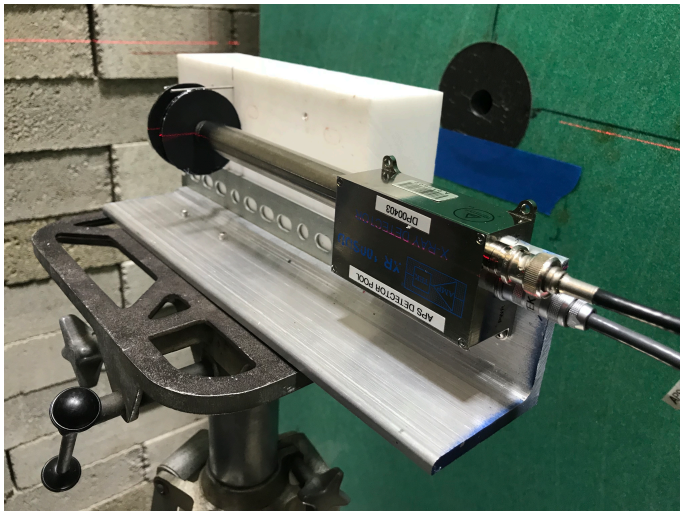
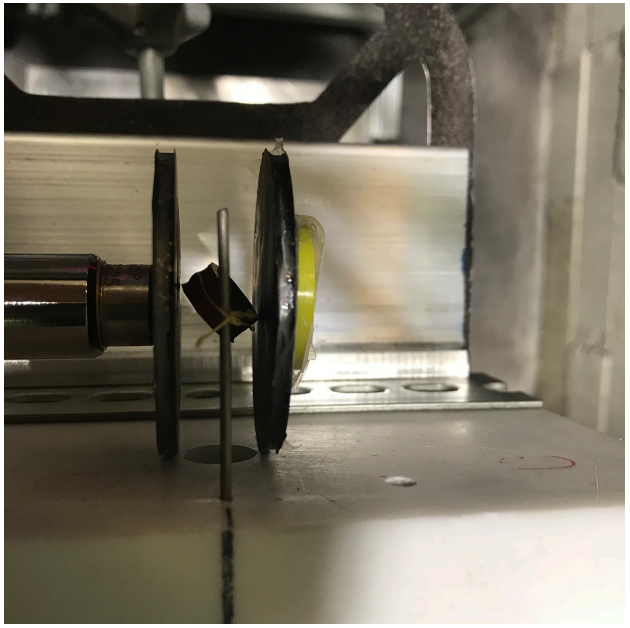
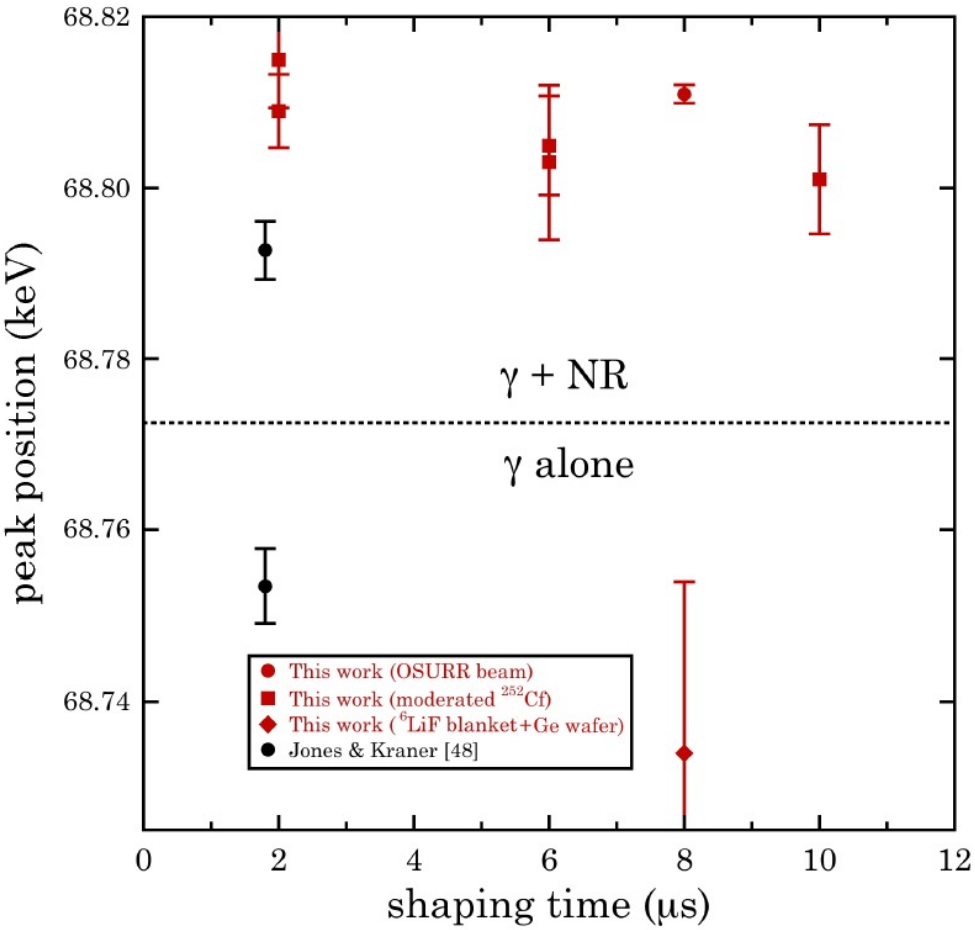
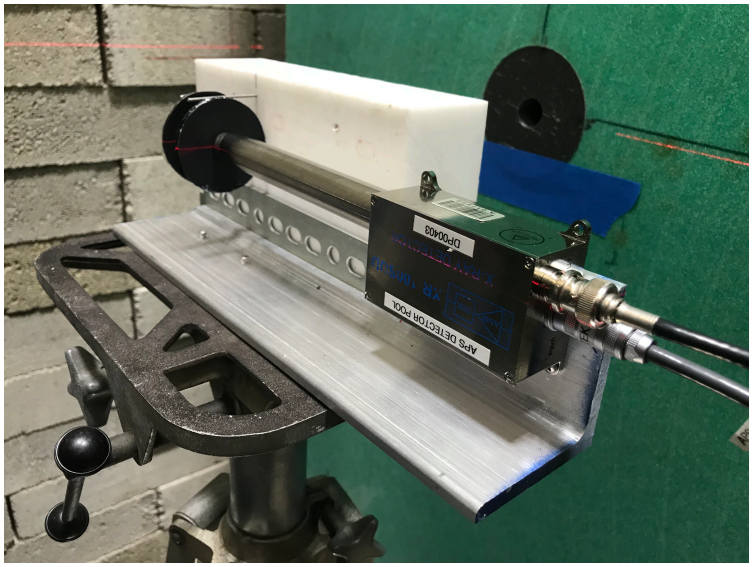
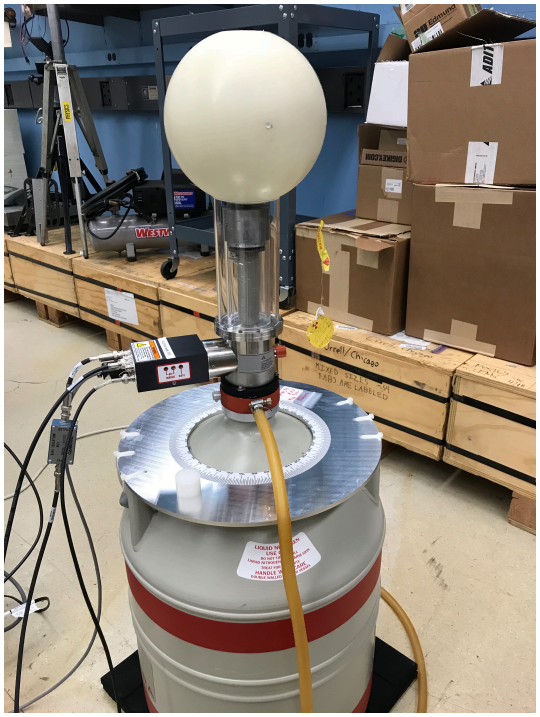


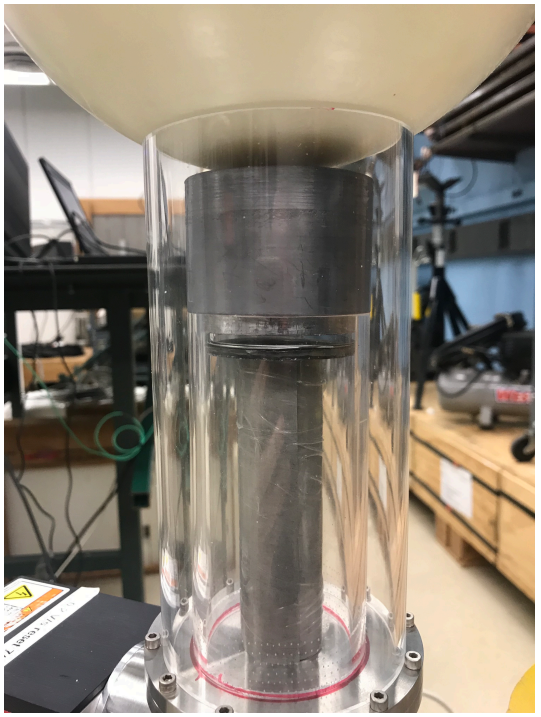


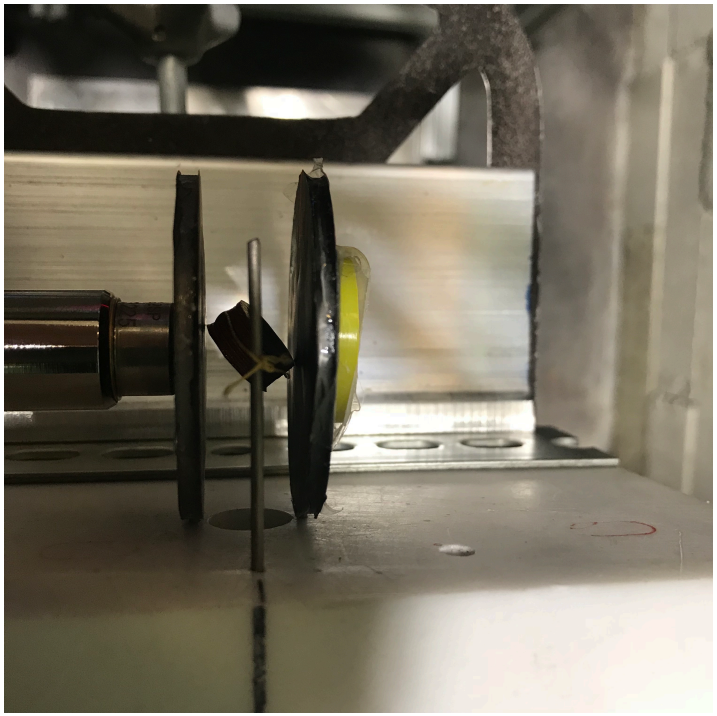


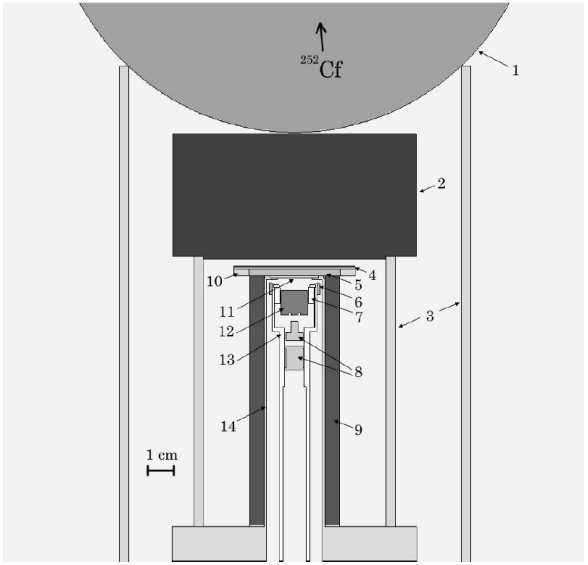
Today's subject: 2) recoils from n_{th} capture

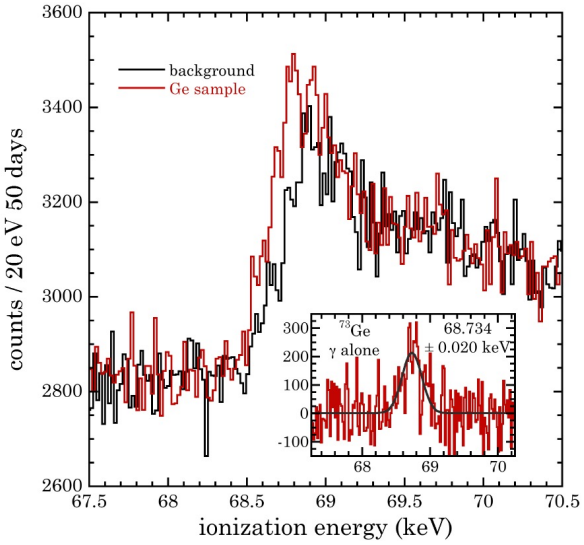










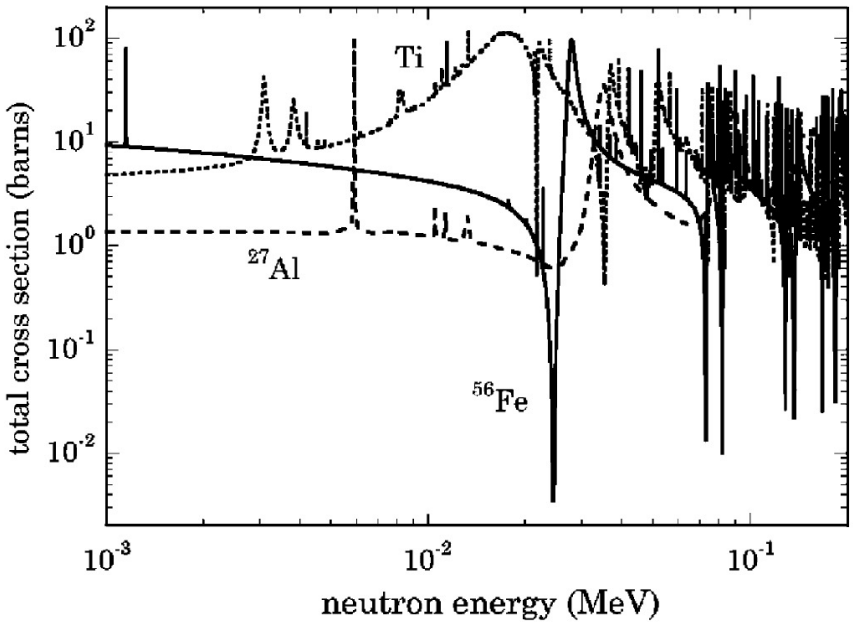


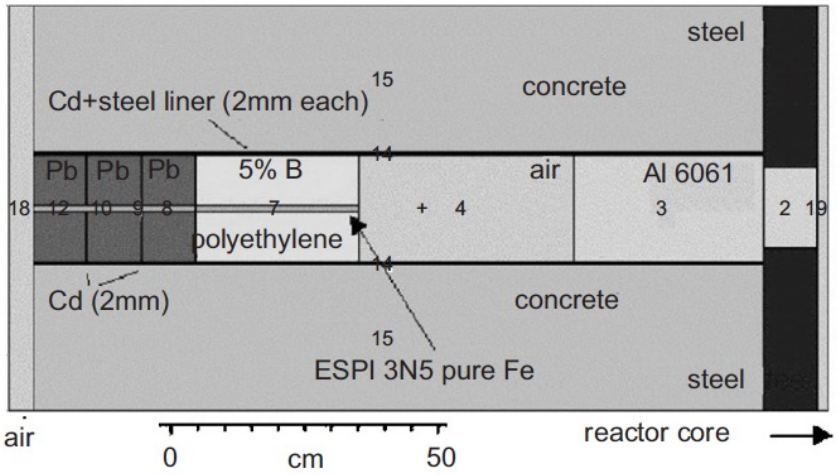
Today's subject: 3) recoils from Fe filter

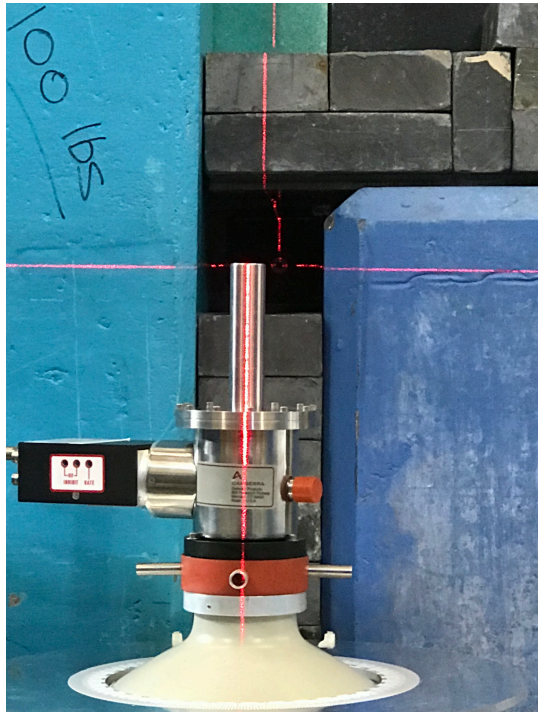
Nuclear Instruments and Methods in Physics Research A 574 (2007) 385–391

Design and characterization of a neutron calibration facility for the study of sub-keV nuclear recoils

P.S. Barbeau[a], J.I. Collar[a,*], P.M. Whaley[b]







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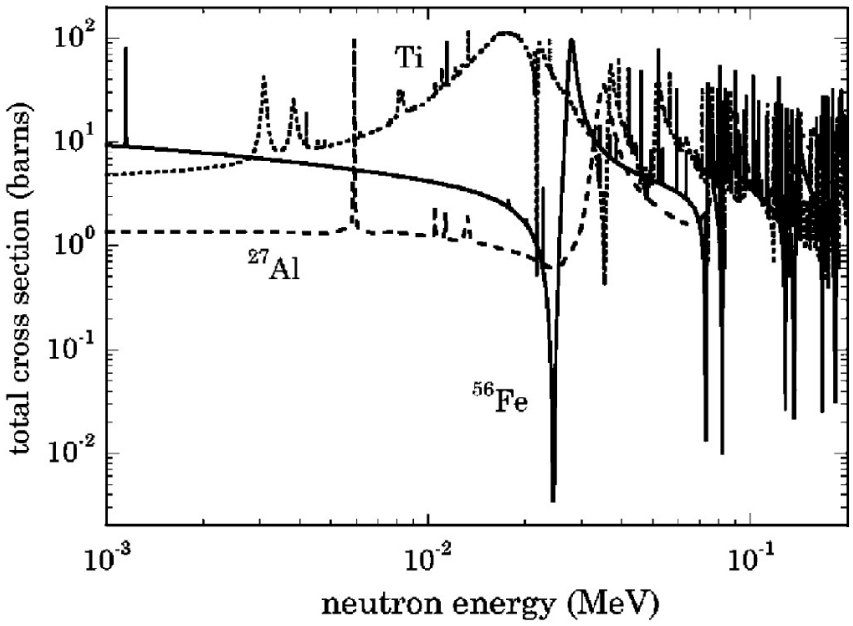

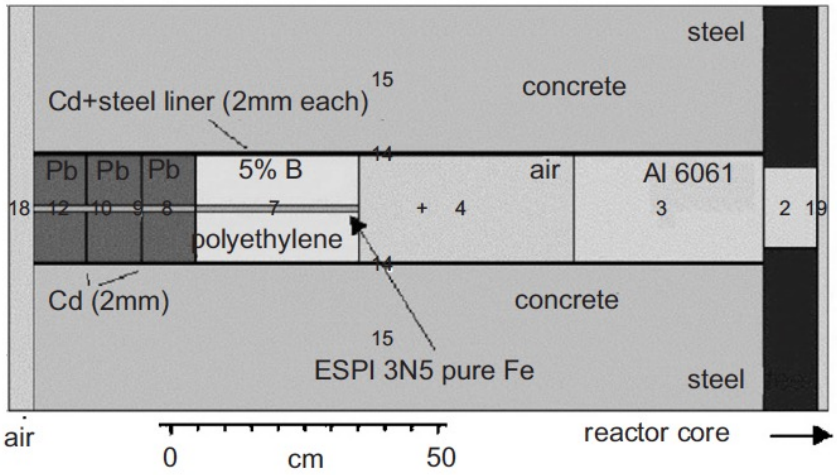

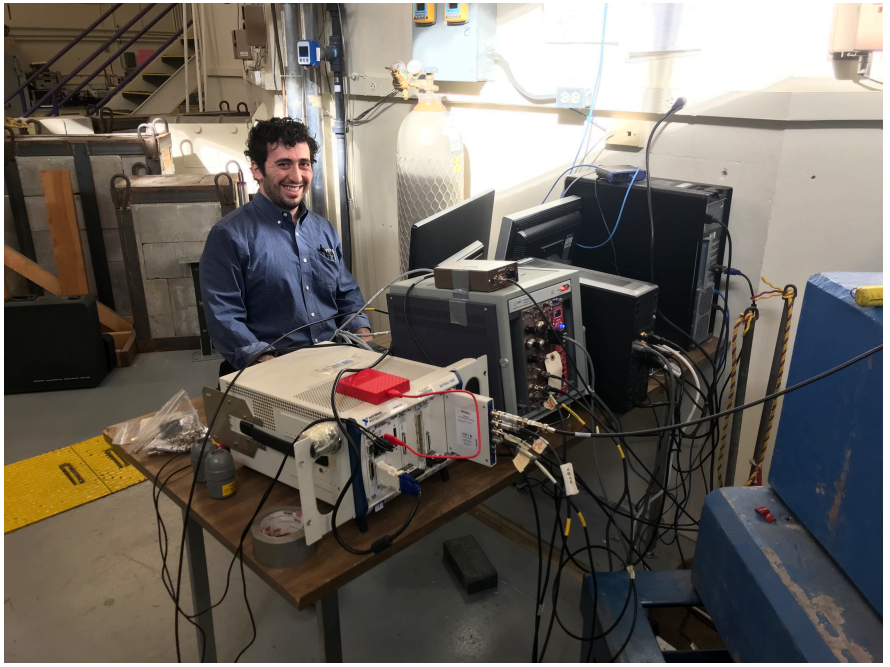

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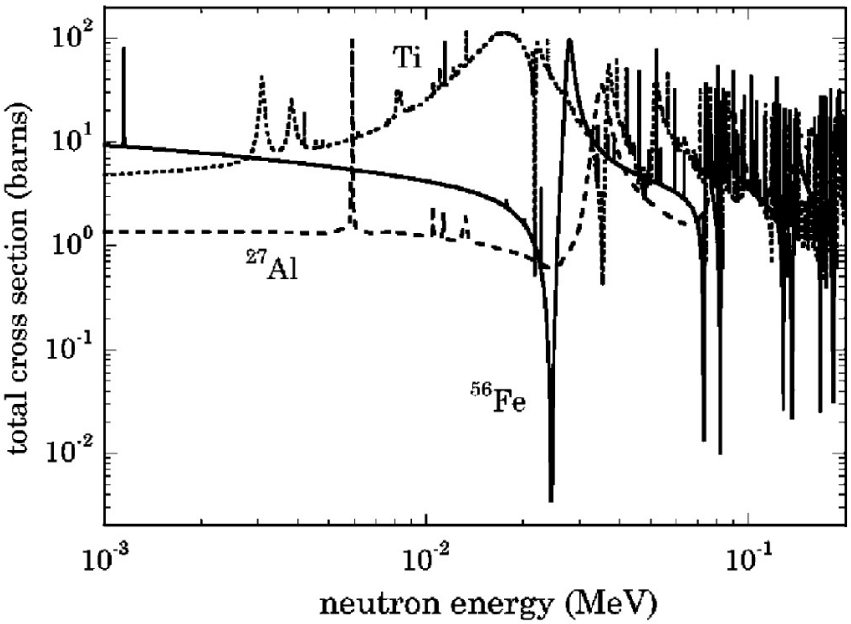
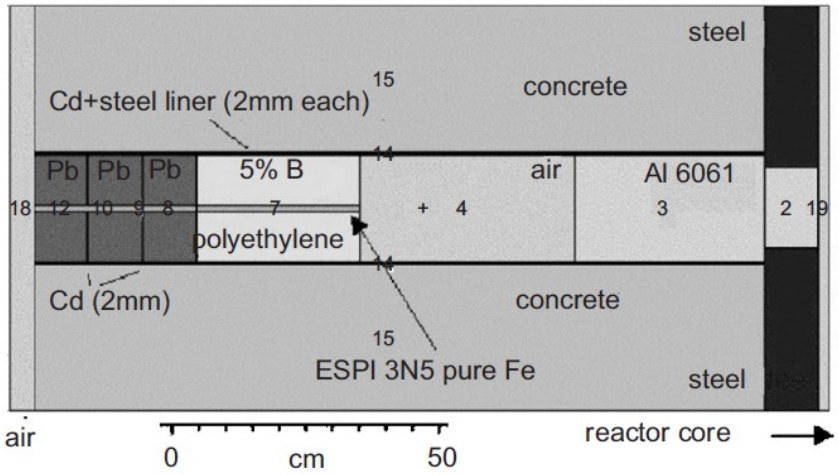
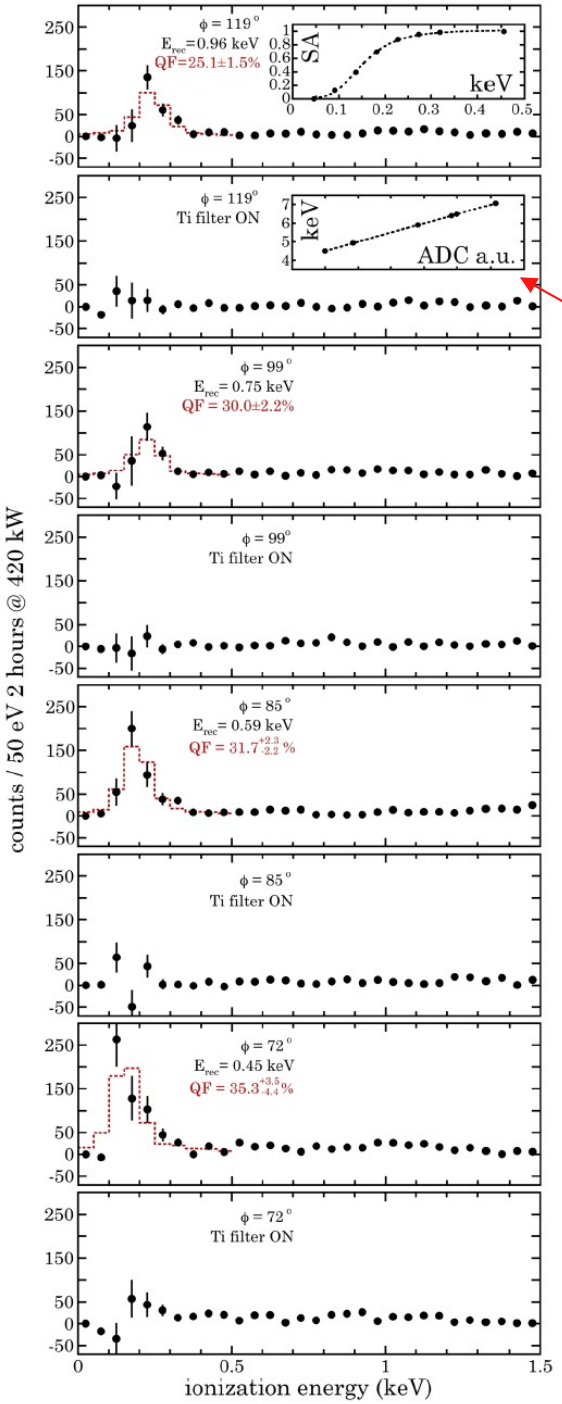


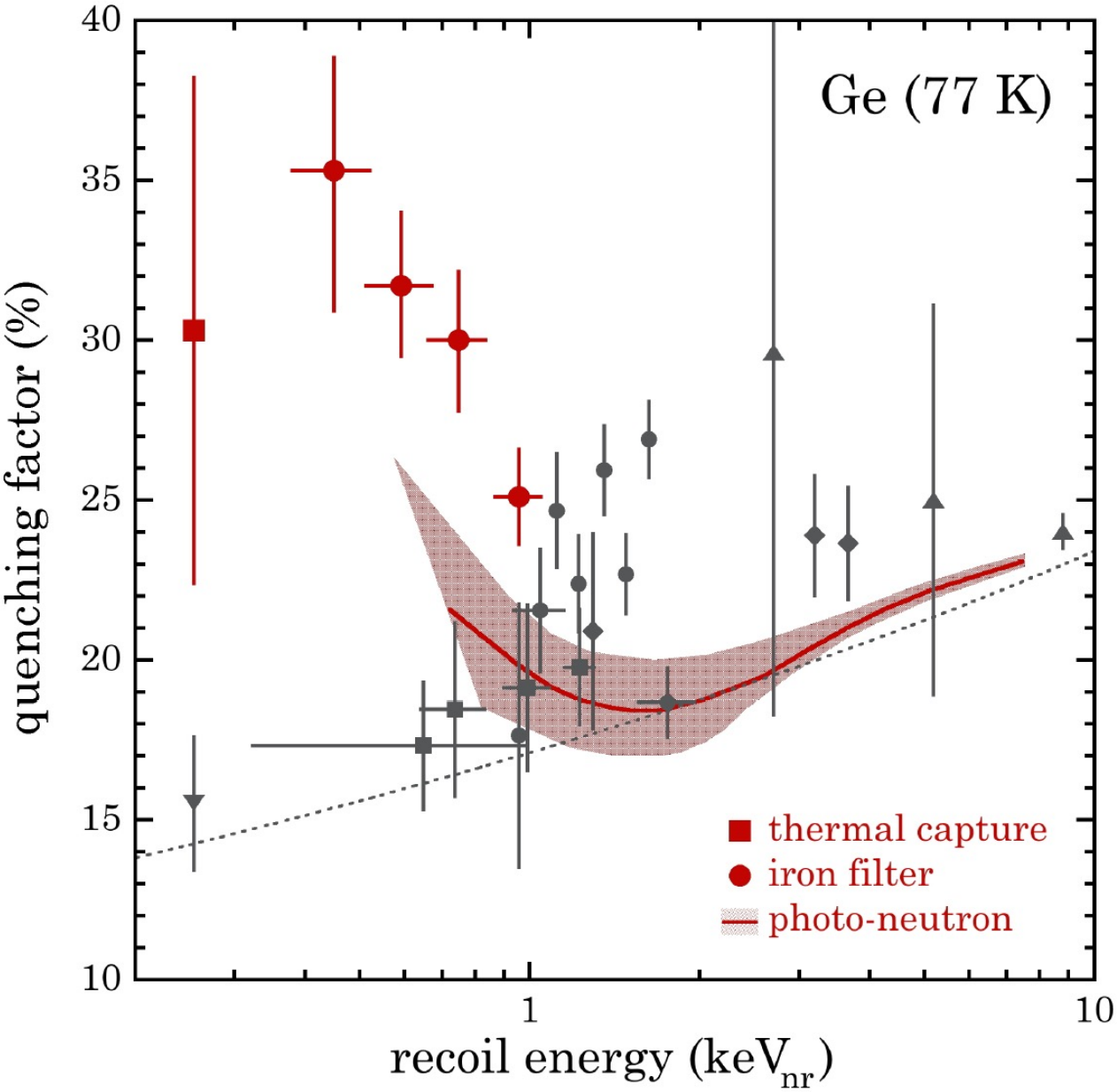




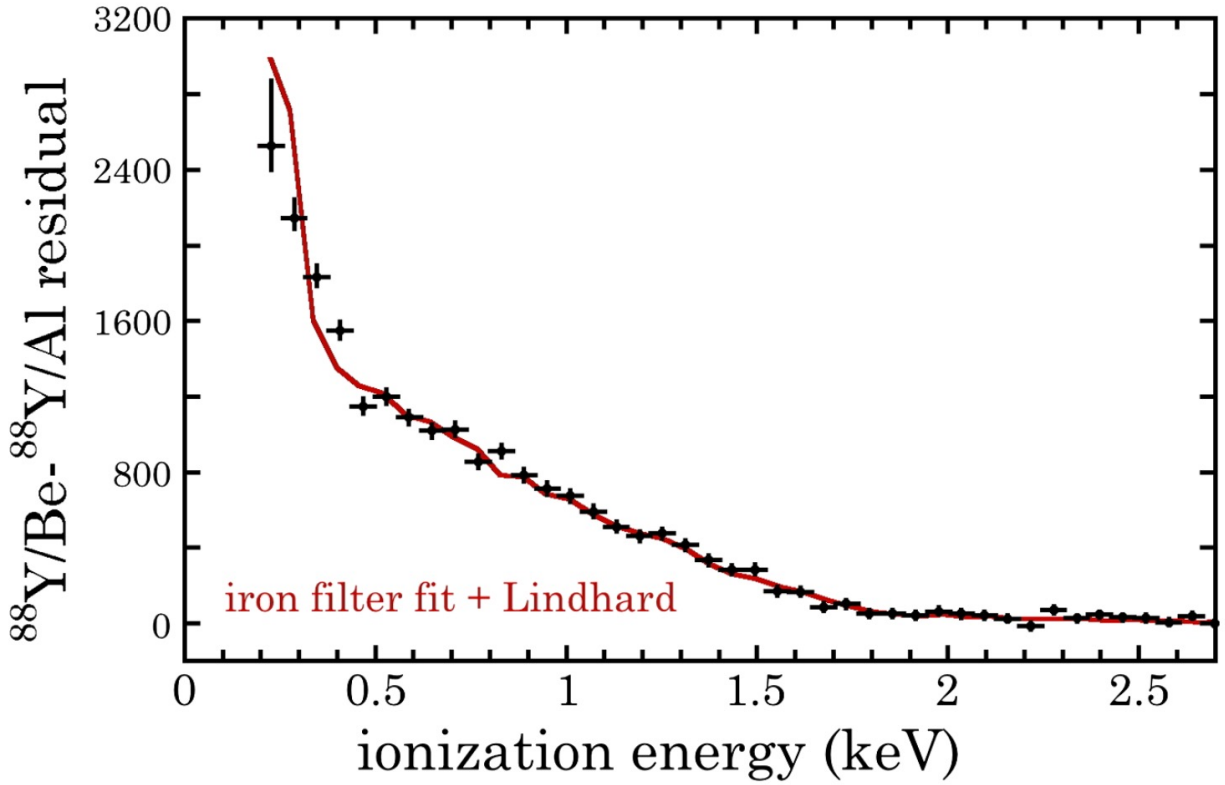
Due attention paid to energy calibration (α PIXE)

This is critical, and not always done…

Et voila


Ge (77 K)
quenching factor (%)
recoil energy (keV$_{nr}$)
40
35
30
25
20
15
10
1
10
thermal capture
iron filter
photo-neutron

Internal consistency x-checks



(going back full-circle to “that ain’t Lindhard”)

Also tested against earlier result with higher (x 5) threshold

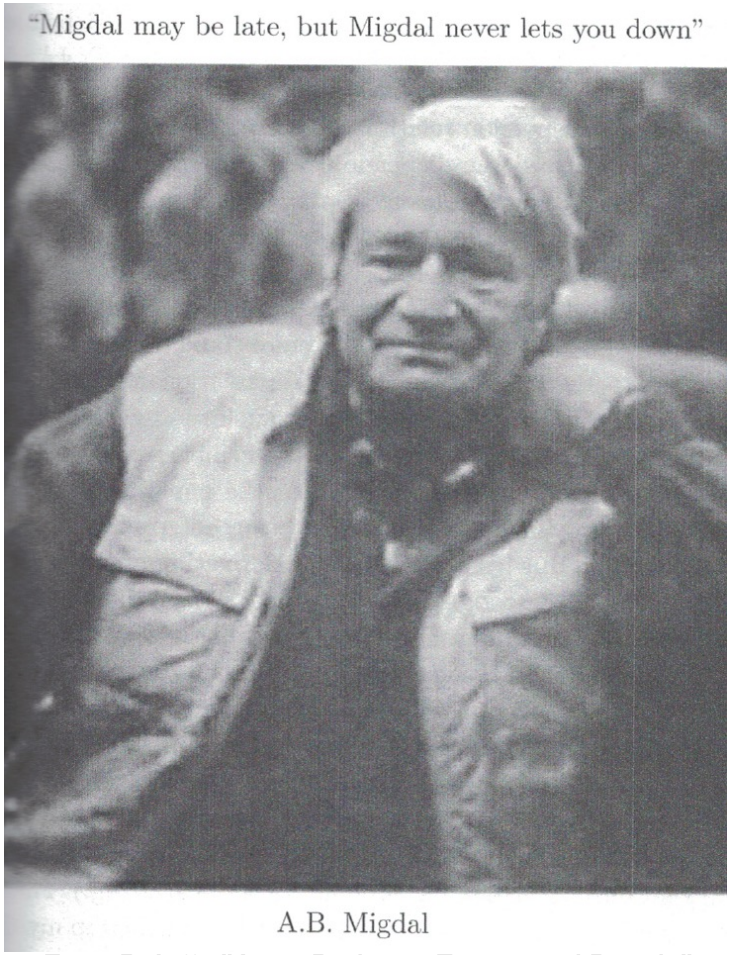
Paging Mr. Migdal?

1941: A.B. Migdal, J. Phys. USSR 4 449

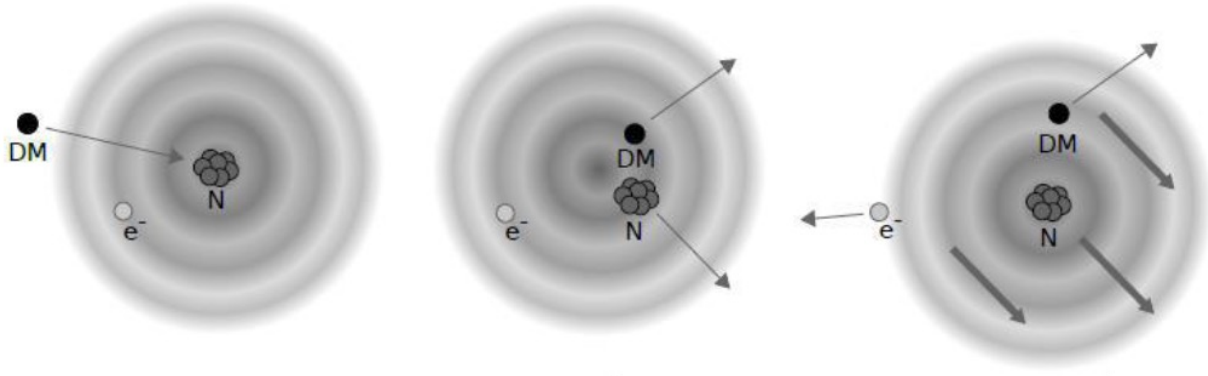
1958: Landau and Lifshitz Vol. 3: Quantum Mechanics, sec. 41:

PROBLEM 2. The nucleus of an atom in the normal state receives an impulse which gives it a velocity v; the duration τ of the impulse is assumed short in comparison both with the electron periods and with a/v, where a is the dimension of the atom. Determine the probability of excitation of the atom under the influence of such a "jolt" (A. B. MIGDAL 1939).

~2000: DAMA invokes Migdal, "Migdal" becomes a dirty word.



From B. Ioffe "Atom Projects: Events and People"



(it would not come as a big surprise…)

PRL **108,** 243201 (2012) PHYSICAL REVIEW LETTERS week ending 15 JUNE 2012

First Measurement of Pure Electron Shakeoff in the β Decay of Trapped $^6He^+$ Ions

C. Couratin,[1] Ph. Velten,[1] X. Fléchard,[1,*] E. Liénard,[1] G. Ban,[1] A. Cassimi,[2] P. Delahaye,[3] D. Durand,[1] D. Hennecart,[2] F. Mauger,[1] A. Méry,[2] O. Naviliat-Cuncic,[1,4] Z. Patyk,[5] D. Rodríguez,[6] K. Siegień-Iwaniuk,[5] and J-C. Thomas[3]

PHYSICAL REVIEW A **97,** 023402 (2018)

Electron shakeoff following the β^+ decay of $^{19}Ne^+$ and $^{35}Ar^+$ trapped ions

X. Fabian,[1,*] X. Fléchard,[1,†] B. Pons,[2] E. Liénard,[1] G. Ban,[1] M. Breitenfeldt,[3,‡] C. Couratin,[1] P. Delahaye,[4] D. Durand,[1] P. Finlay,[3] B. Guillon,[1] Y. Lemière,[1] F. Mauger,[1] A. Méry,[5] O. Naviliat-Cuncic,[1,6] T. Porobic,[3] G. Quéméner,[1] N. Severijns,[3] and J.-C. Thomas[4]

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1958: Landau and Lifshitz Vol. 3: Quantum Mechanics, sec. 41:

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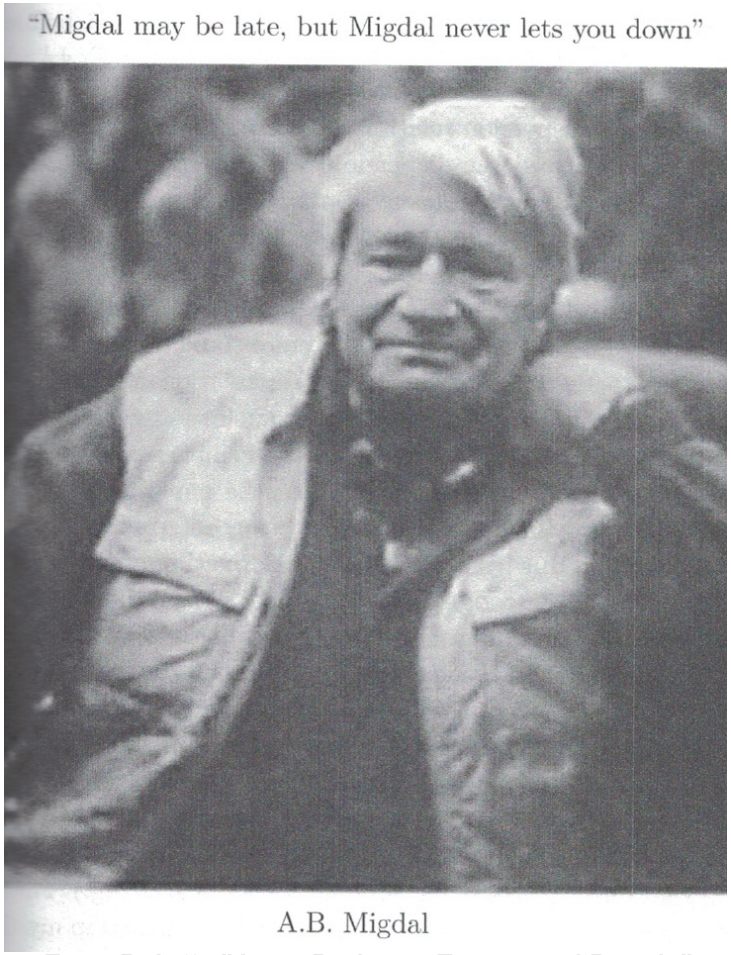
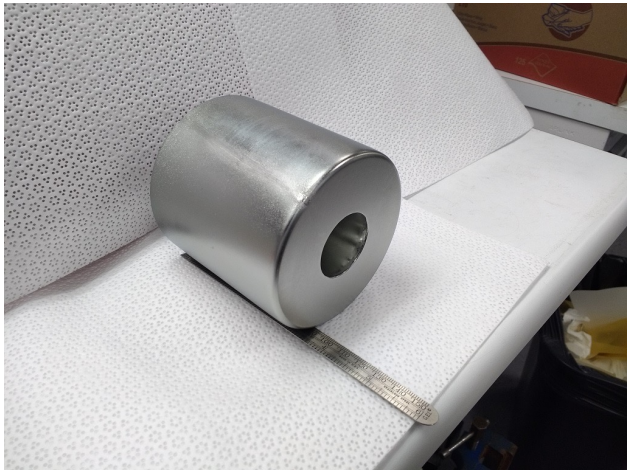
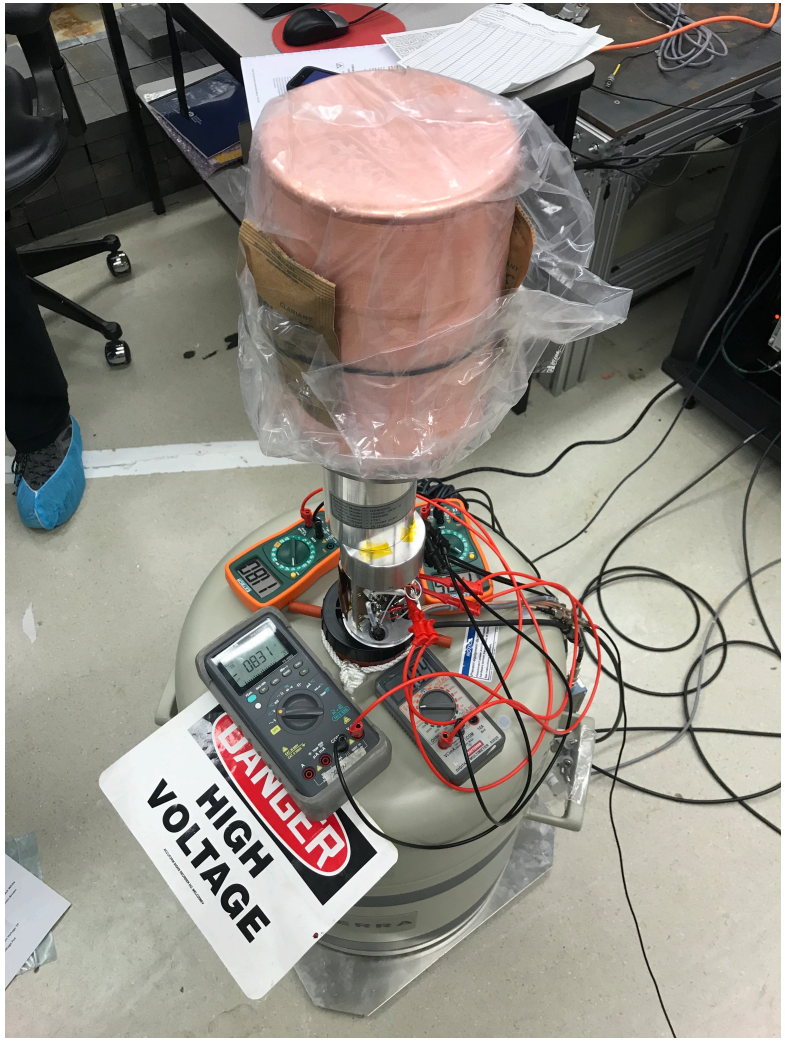


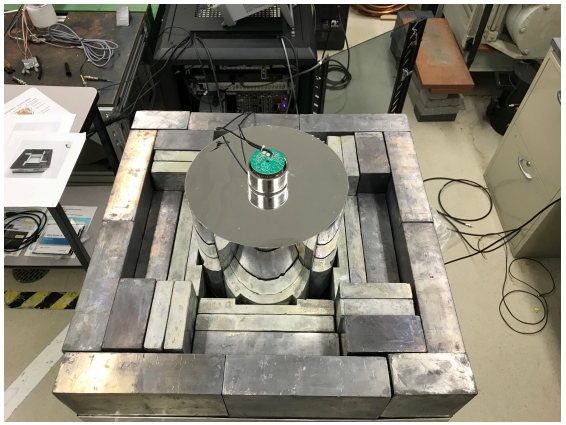
From B. Ioffe "Atom Projects: Events and People"

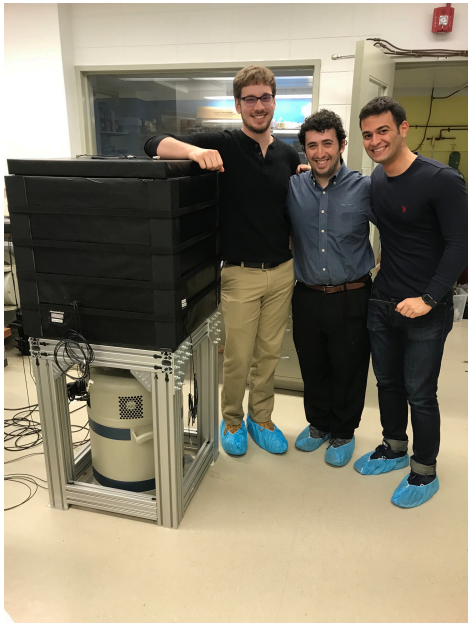
(perturbation theory for pedestrians)

Epilogue: why bother?





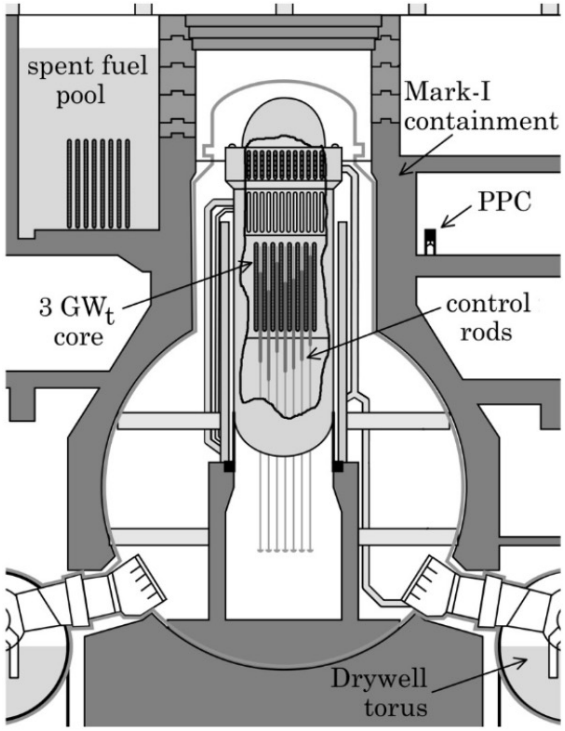




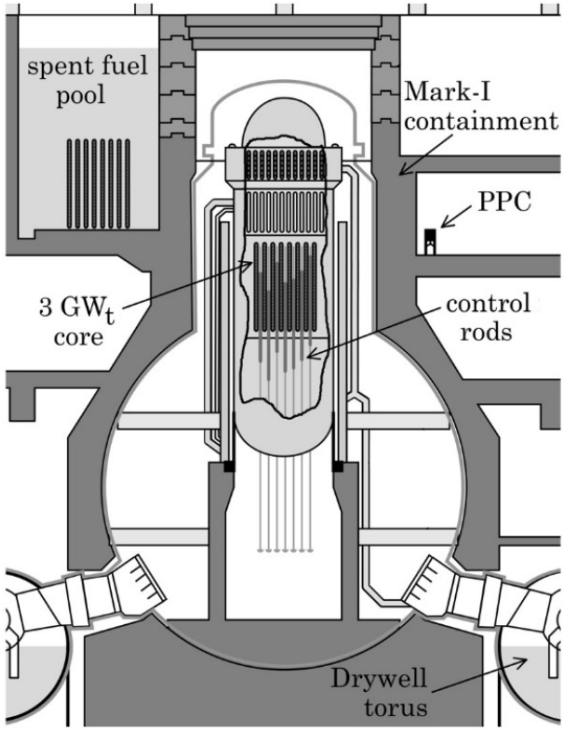
Epilogue: why bother?

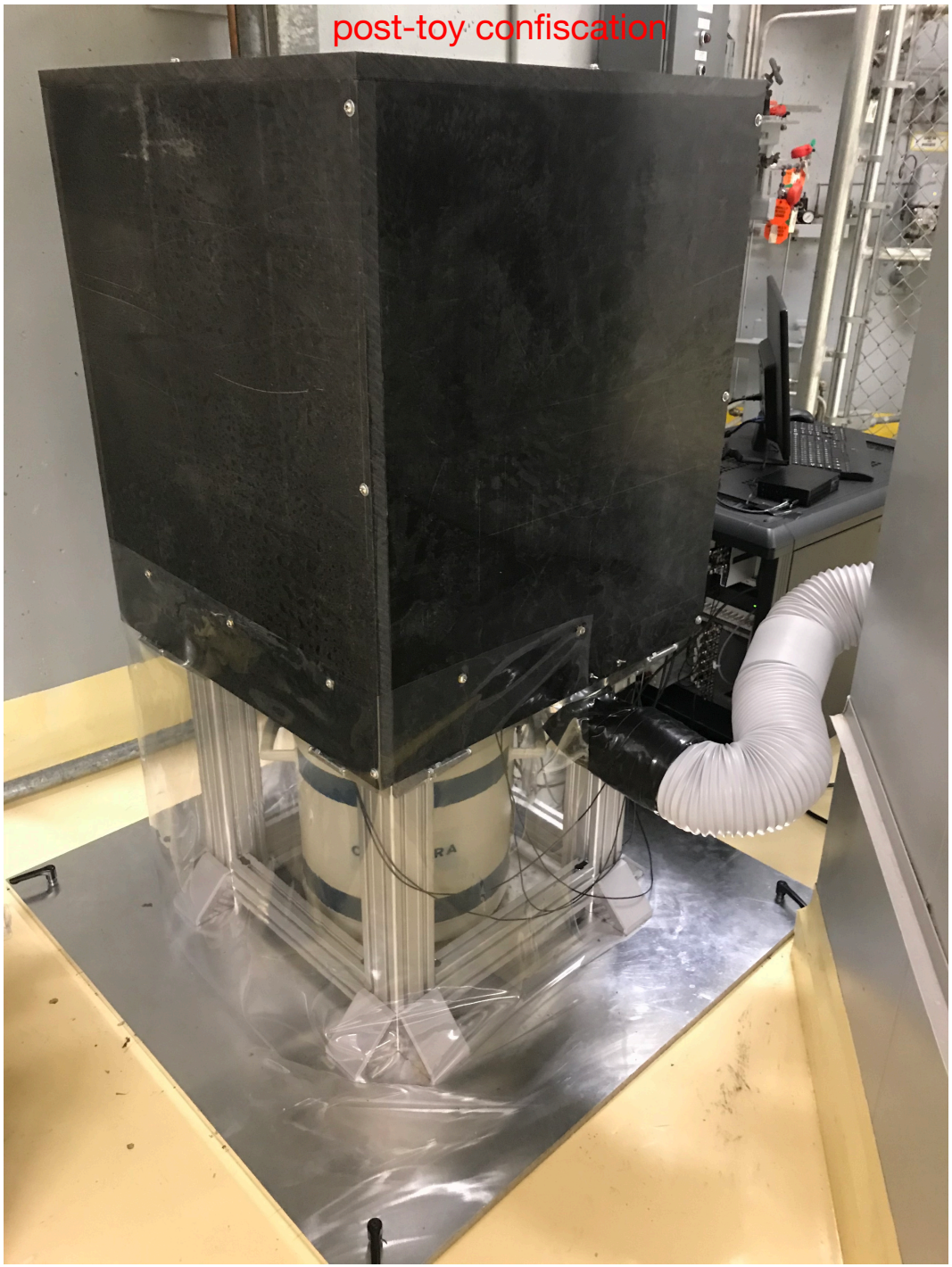
De rigueur selfie

Epilogue: why bother?



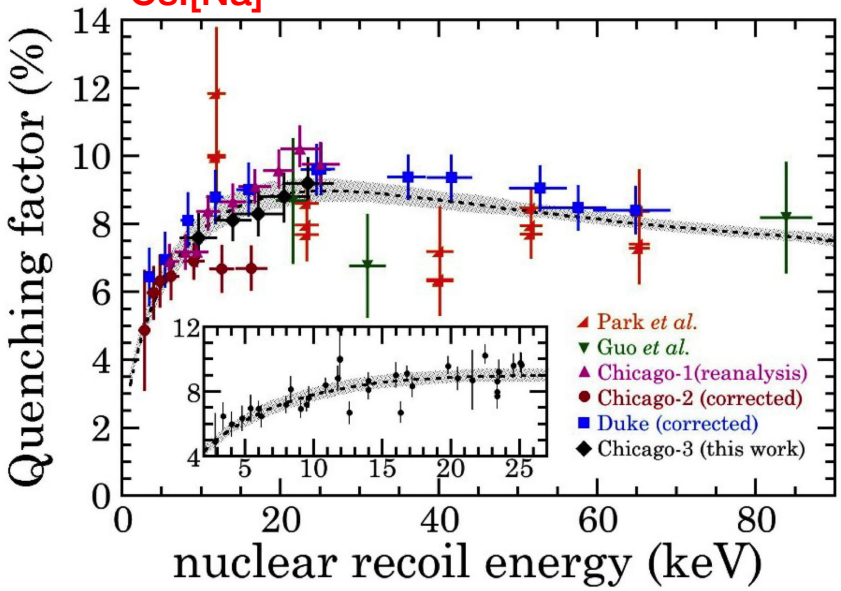
Epilogue: why bother?





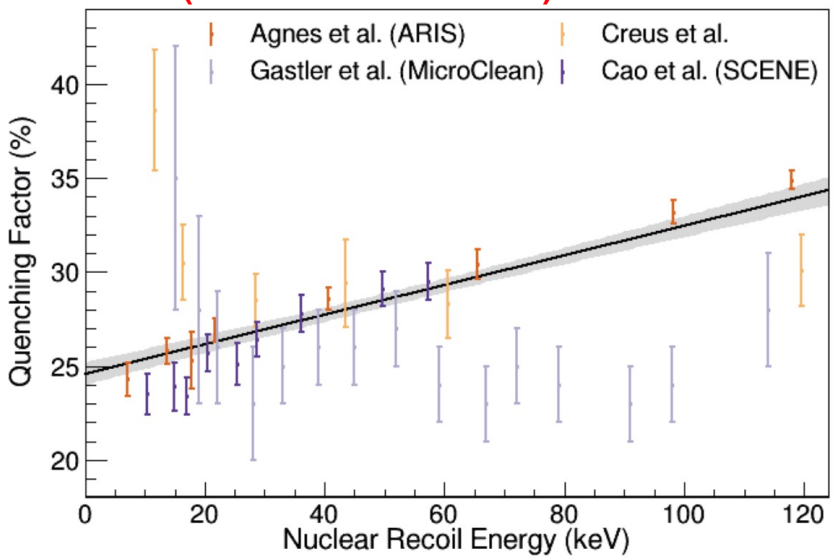
Toto, we're not in Kansas anymore:
for CEνNS studies, the QF is the crux

CsI[Na]



5% uncertainty in 5-25 keV ROI
Physics-based model (Birks + kinematic threshold)

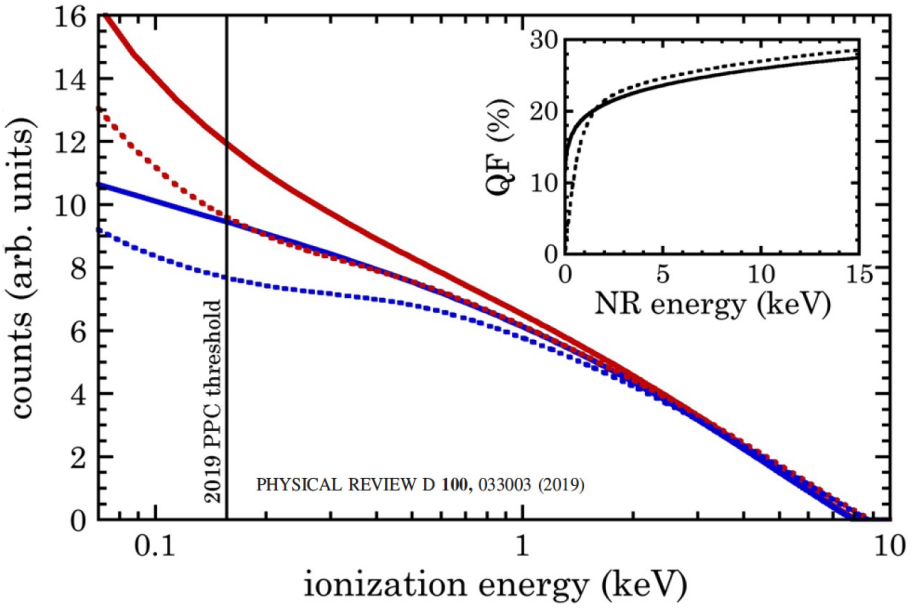
LAr (COHERENT collab.)



2% uncertainty in >20 KeV ROI claimed (?)
Linear fit (because "it isn't completely unreasonable")

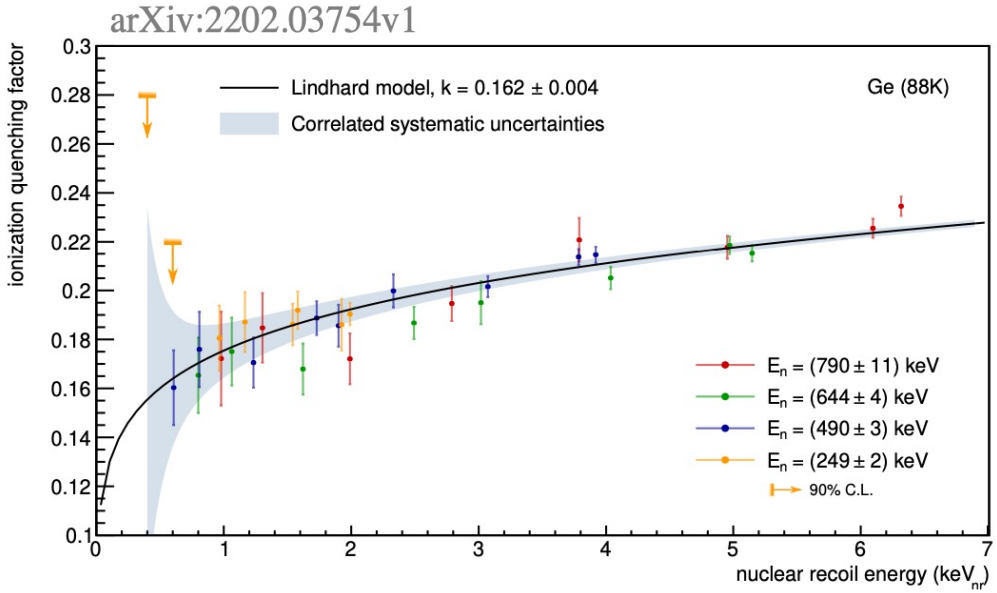
We are not looking for WIMPs: we have predictable signals, from particles known to exist.

Time to start taking this subject seriously… it can make the difference between discoveries and embarrassment.

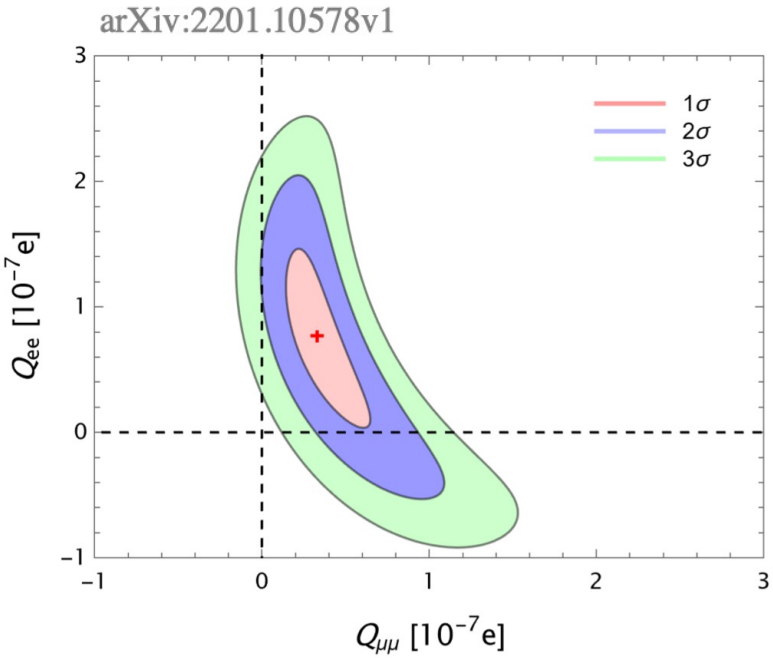


HPGe

Recent developments



→ underestimated uncertainty in energy scale?
→ negative non-linearity (60% @ threshold) unaccounted for?
TBD

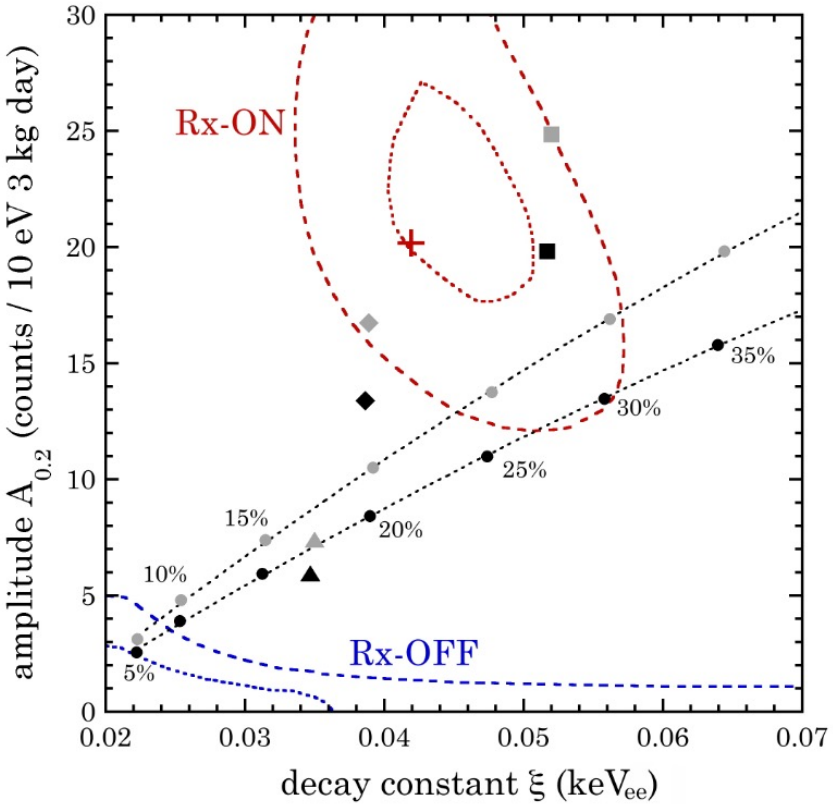


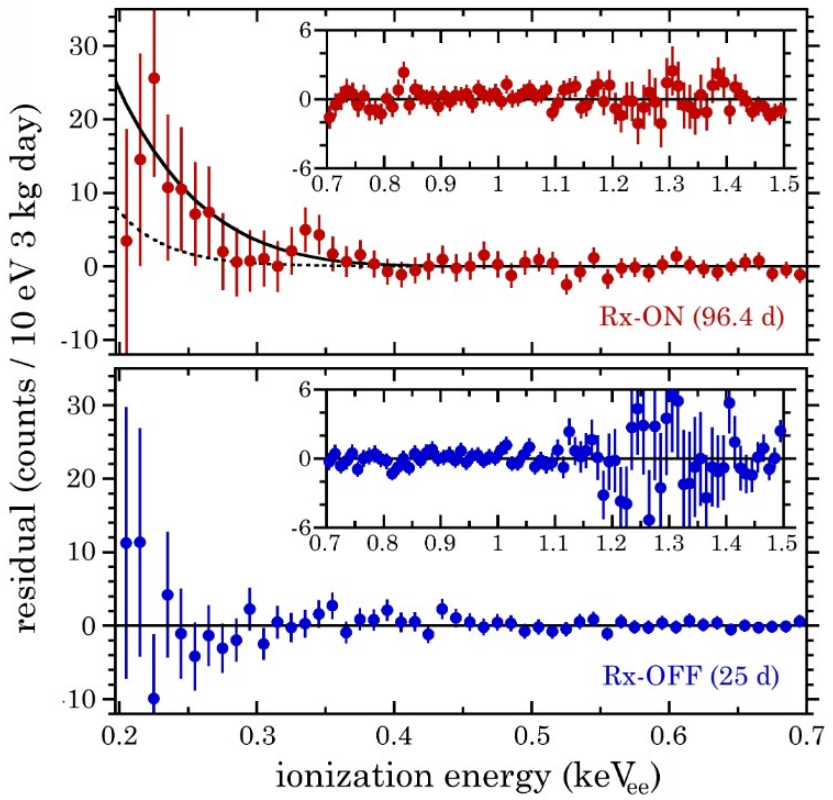
3.5 σ for millicharged ν's
or use of a biased QF?

See also T. Saab's talk in this session

80K HPGe and 25 mK Ge bolometers…
possibly pears and apples when it comes to low-E QF.
→ much rich physics to investigate!

Talking about excesses…

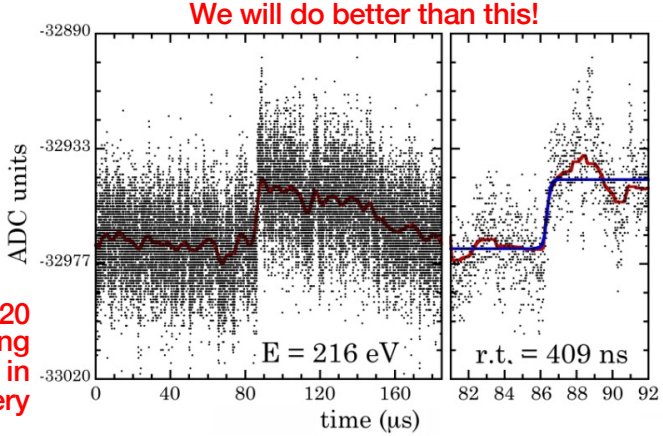




(available in arXiv next week)

We will do better than this!

S/bckg >20 expected following redeployment in tendon gallery



There is no peace for the living

(upcoming work at OSURR thermal beam)

Calibration of nuclear recoils at the 100 eV scale using neutron capture

L. Thulliez,[a] D. Lhuillier,[a,*] F. Cappella,[b] N. Casali,[b] R. Cerulli,[c,d] A. Chalil,[a] A. Chebboubi,[e] E. Dumonteil,[a] A. Erhart,[f] A. Giuliani,[g] F. Gunsing,[a] E. Jericha,[h] M. Kaznacheeva,[f] A. Kinast,[f] A. Langenkämper,[f] T. Lasserre,[a,f] A. Letourneau,[a] O. Litaize,[e] P. de Marcillac,[g] S. Marnieros,[g] T. Materna,[a] B. Mauri,[a] E. Mazzucato,[a] C. Nones,[a] T. Ortmann,[f] L. Pattavina,[d,i] D.V. Poda,[g] R. Rogly,[a] N. Schermer,[f] O. Serot,[e] G. Soum,[a] L. Stodolsky,[j] R. Strauss,[f] M. Vignati,[b,k] M. Vivier,[a] V. Wagner[f] and A. Wex[f]

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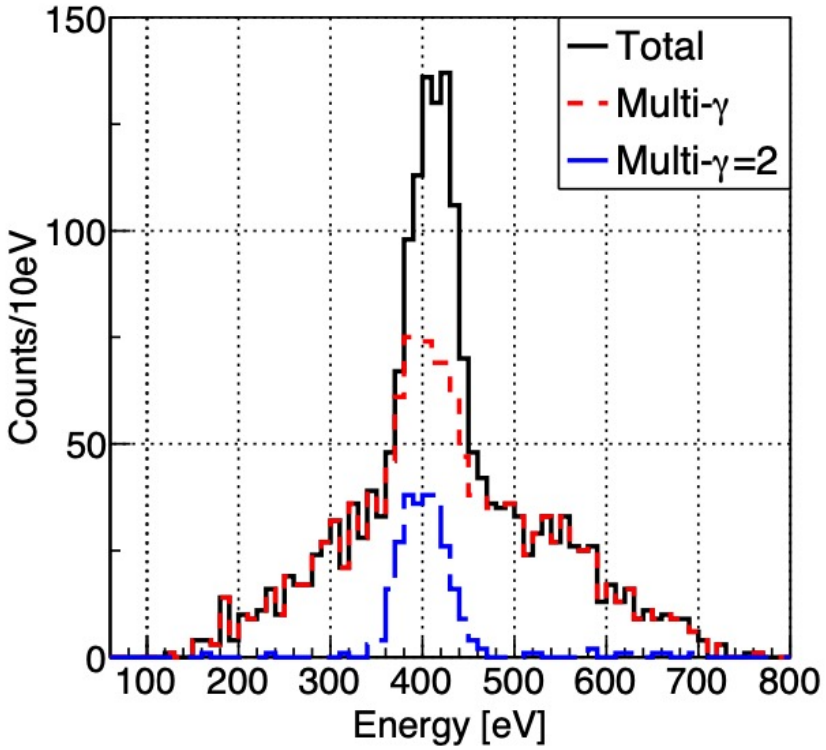
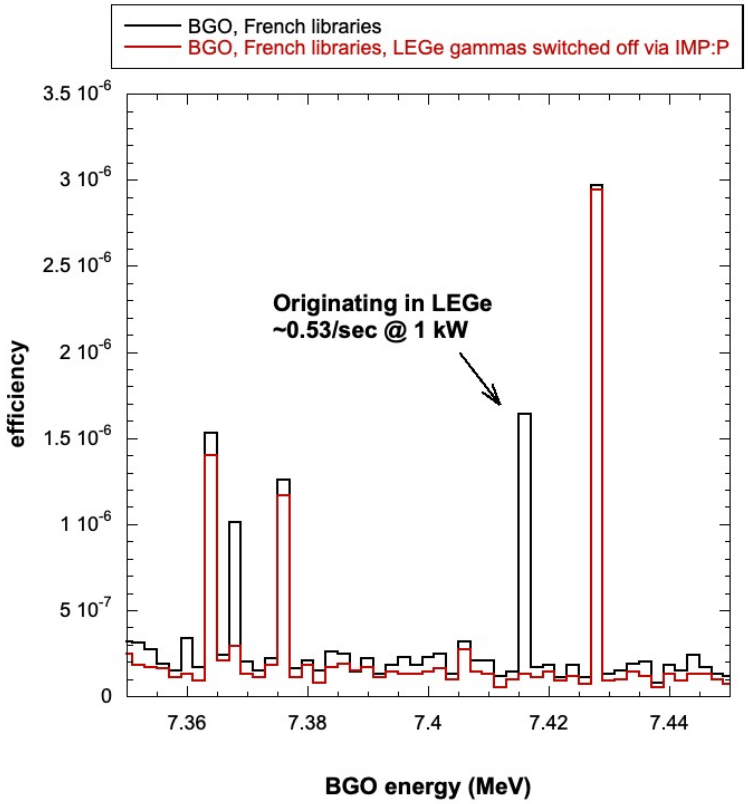


(should be possible w/ Si as well)



Will provide dramatic test of Lindhard in HPGe at 0.4 keVnr

In addition to this:

→ attempt to reduce error bar in 0.25 keVnr datapoint
→ improved analysis of Y/Be data with MCMC