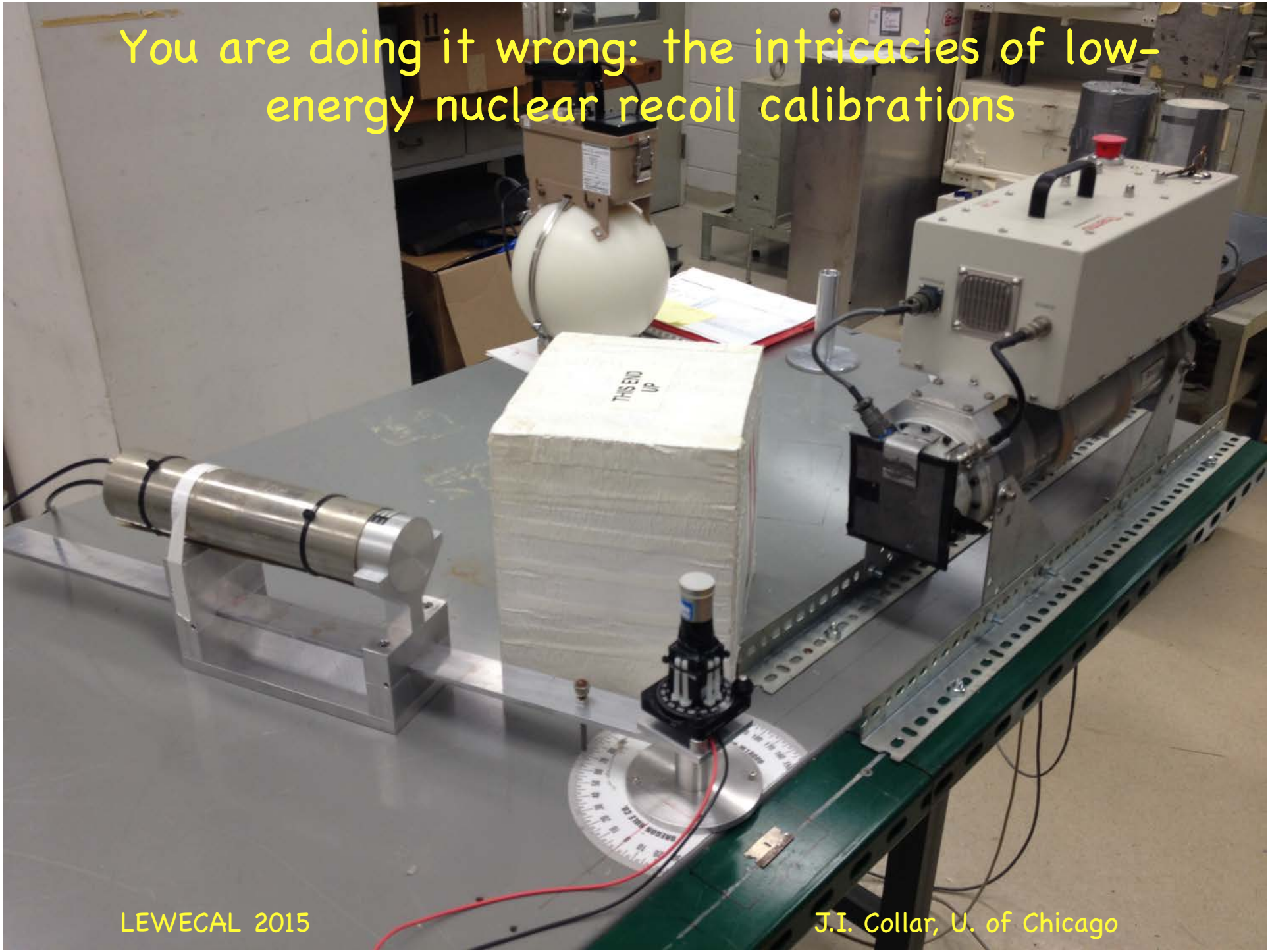
You are doing it wrong: the intricacies of low-energy nuclear recoil calibrations



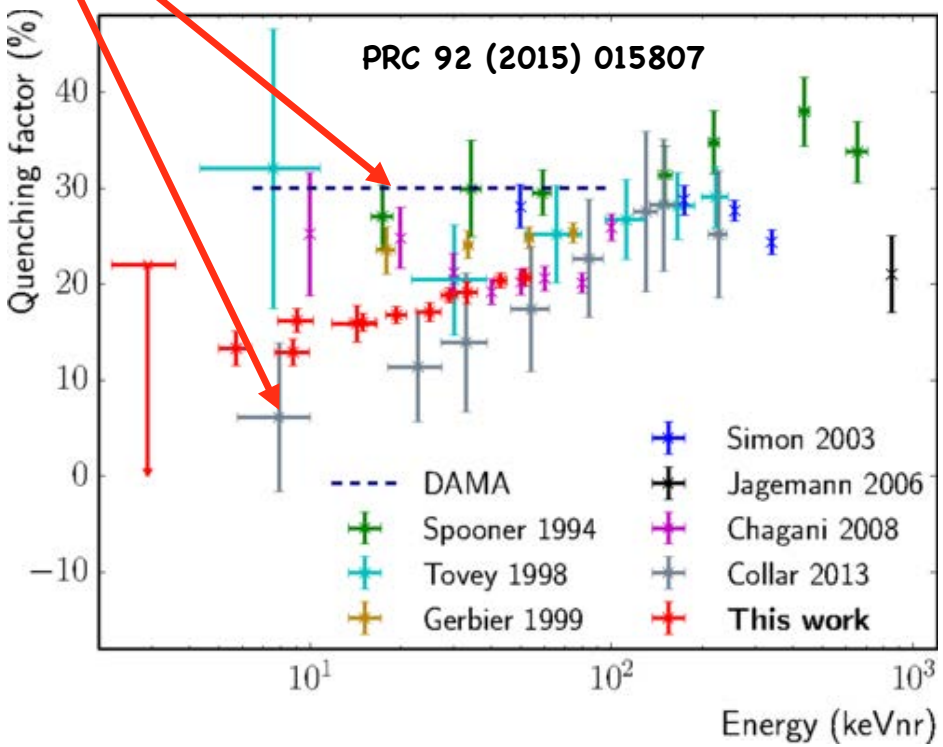
LEWECAL 2015

J.I. Collar, U. of Chicago

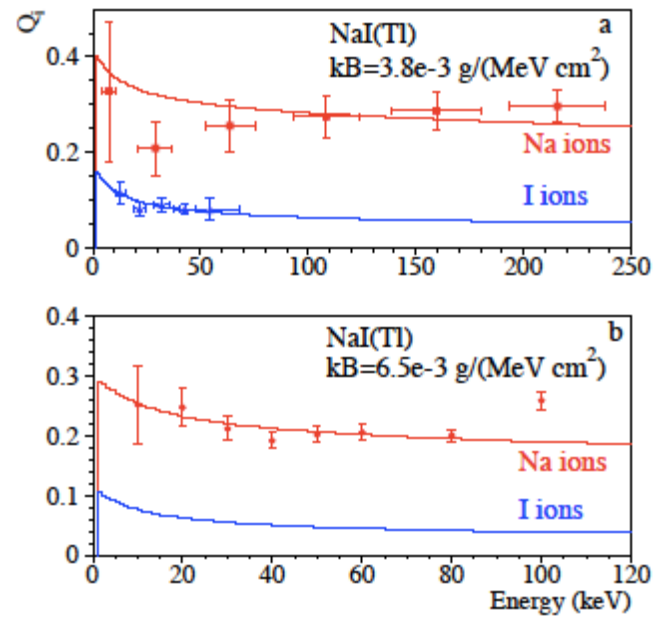
(if this talk feels like it has been thrown together within the past couple of hours...)

A few lessons learned during NaI[Tl] Q.F. measurements:

?!



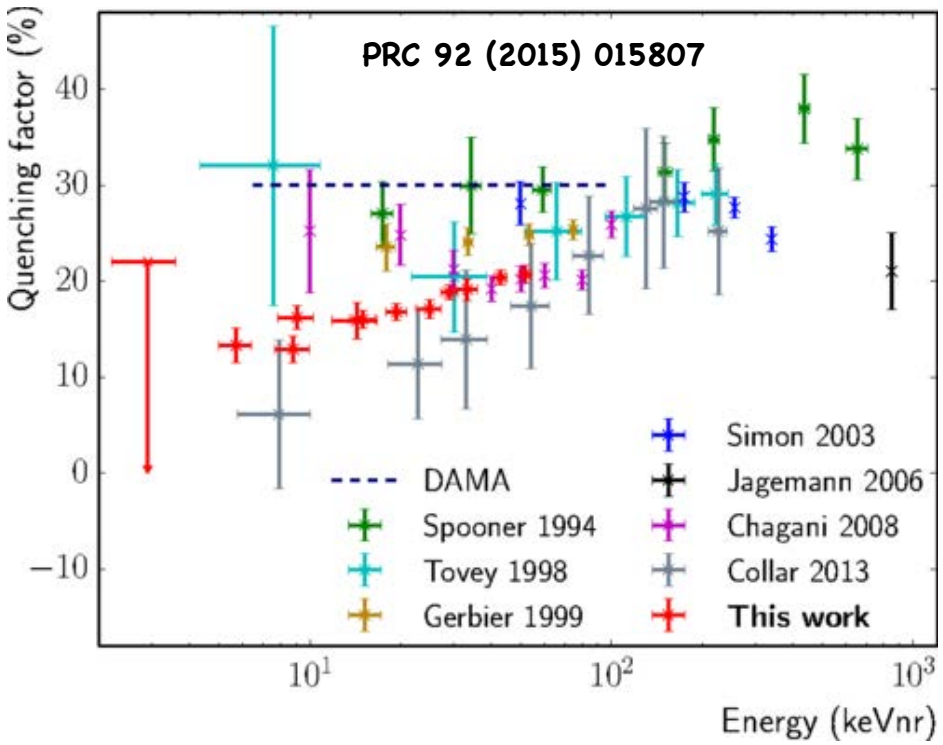
Astropart. Phys. 33 (2010) 40



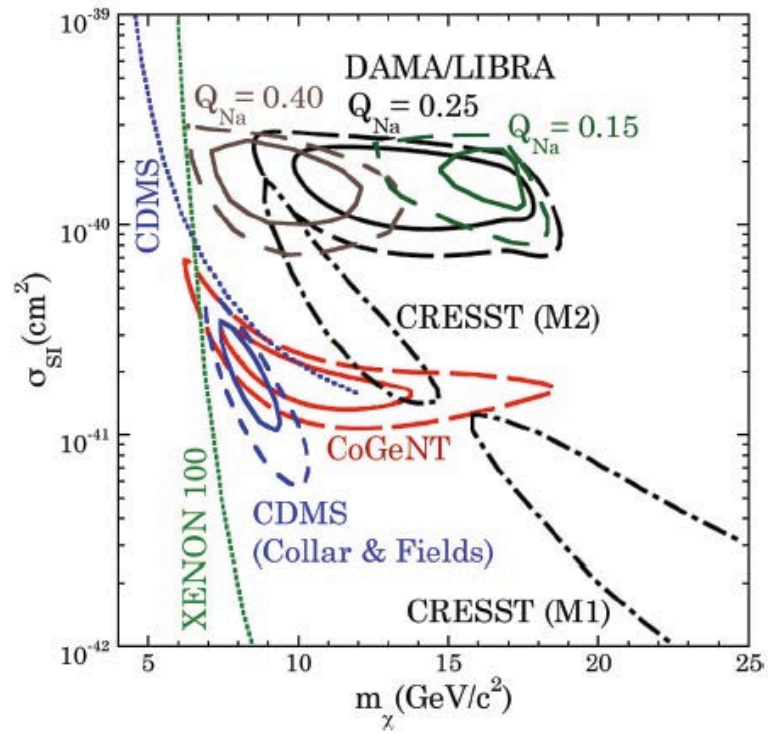
For once, this ascending trend would <u>not</u> have been unexpected (kinematic threshold for Na recoils is ~2 keVnr)

- A semi-empirical model is as good as the data it feeds on (sh*t in, sh*t out).
- Use of broad-energy (or high-energy compared to NR regime sought) neutron sources can spell trouble.

A few lessons learned during NaI[Tl] Q.F. measurements:



PRC 88 (2013) 035806



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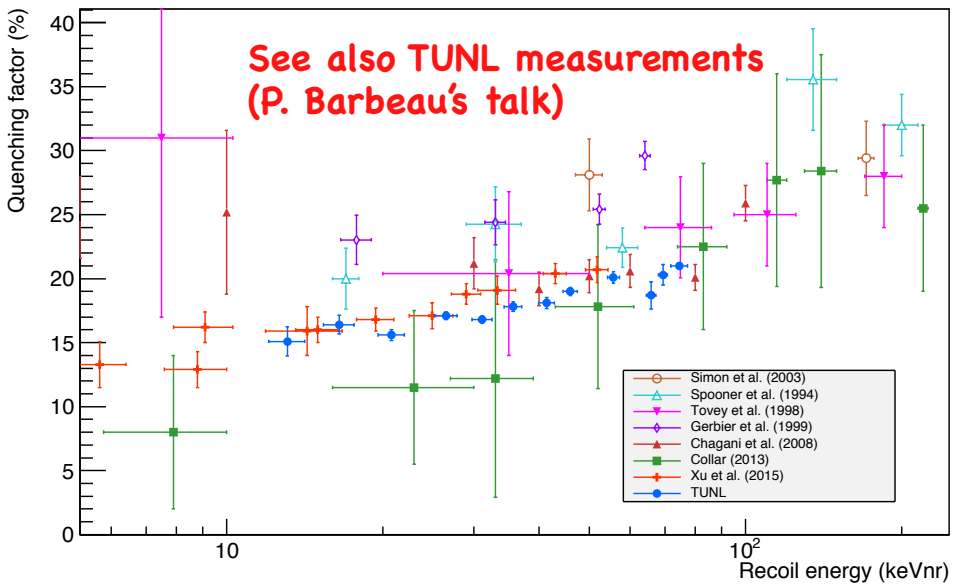

PRL 110 (2013) 211101

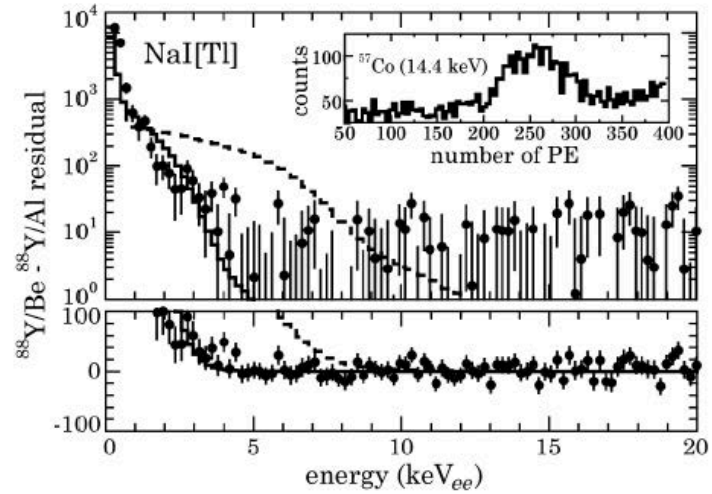

FIG. 2. Measured response of NaI[Tl] to low-energy nuclear recoils from an ^{88}Y/Be source (see text). A solid histogram is the predicted response, allowing no free parameters, obtained by adopting the quenching factors for sodium and iodine recoils recently measured using 2.2 MeV neutron scattering from a D-D generator (a monotonically decreasing Q_{Na} with decreasing recoil energy, and $Q_I = 0.04$ [10]). A dashed histogram, in large disagreement with present data, employs quenching factors typically used in the interpretation of DAMA/LIBRA results ($Q_{Na} = 0.3$, $Q_I = 0.09$ [12]).

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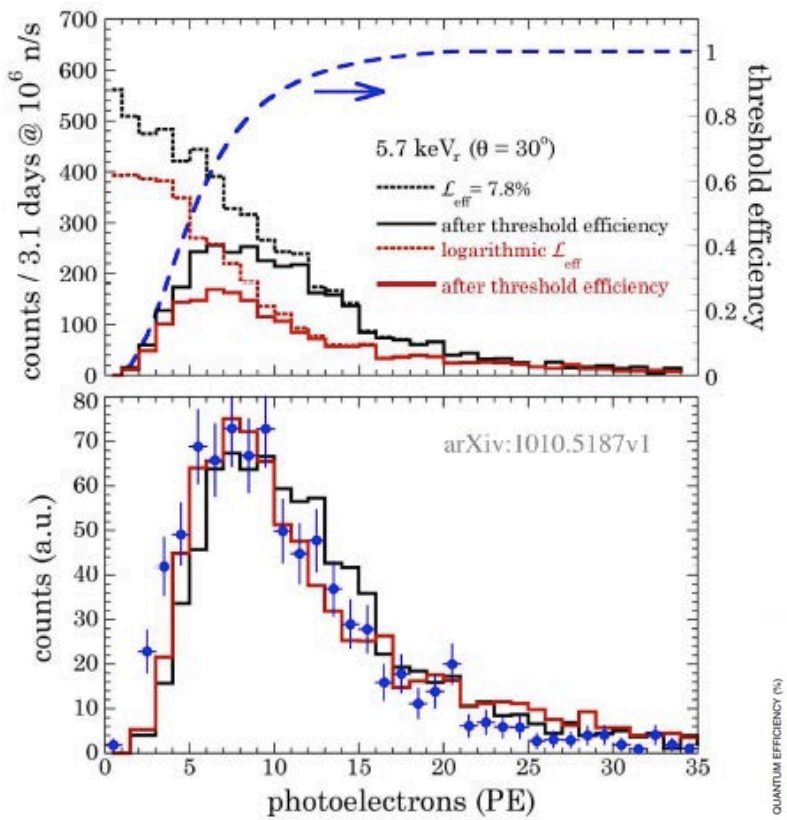
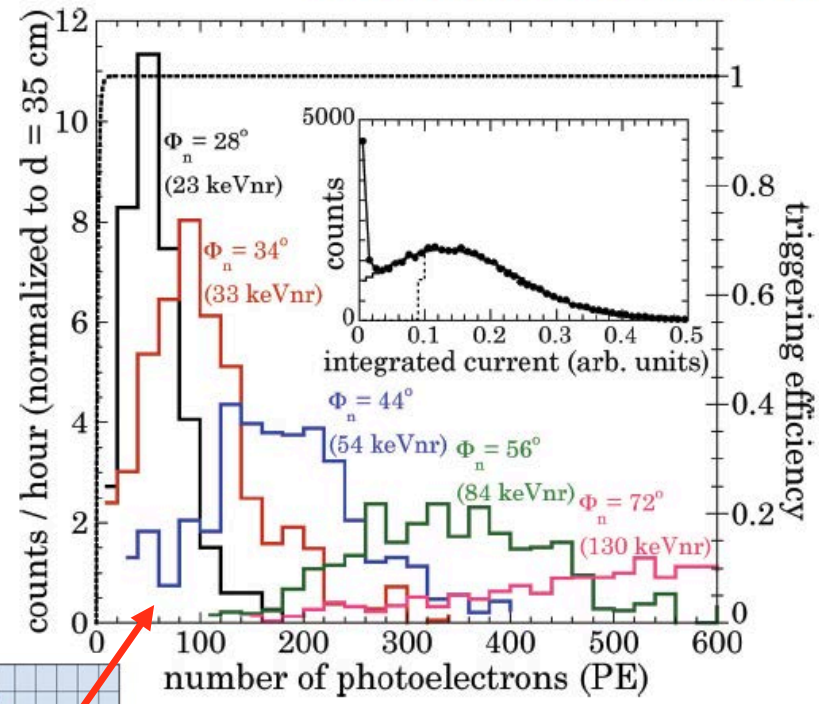
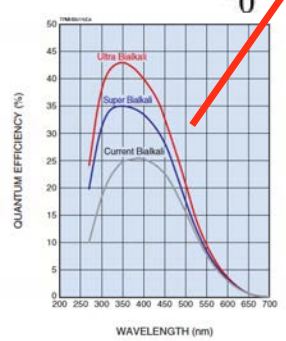
A few lessons learned during NaI[Tl] Q.F. measurements:

arXiv:1010.5187



PHYSICAL REVIEW C 88, 035806 (2013)





UBA provided x4 the light yield of previous NaI measurement

- "Threshold effects" <- increase in light yield is the straightest route to avoid them –as long as you stay away from your new threshold!–.
- Let's not fix one systematic just to introduce another one…

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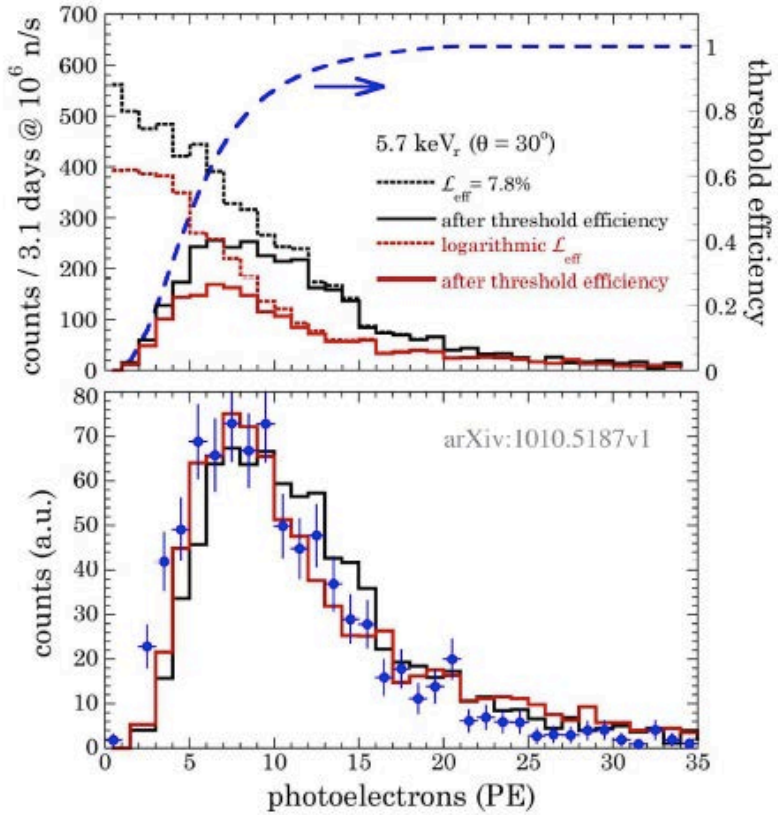

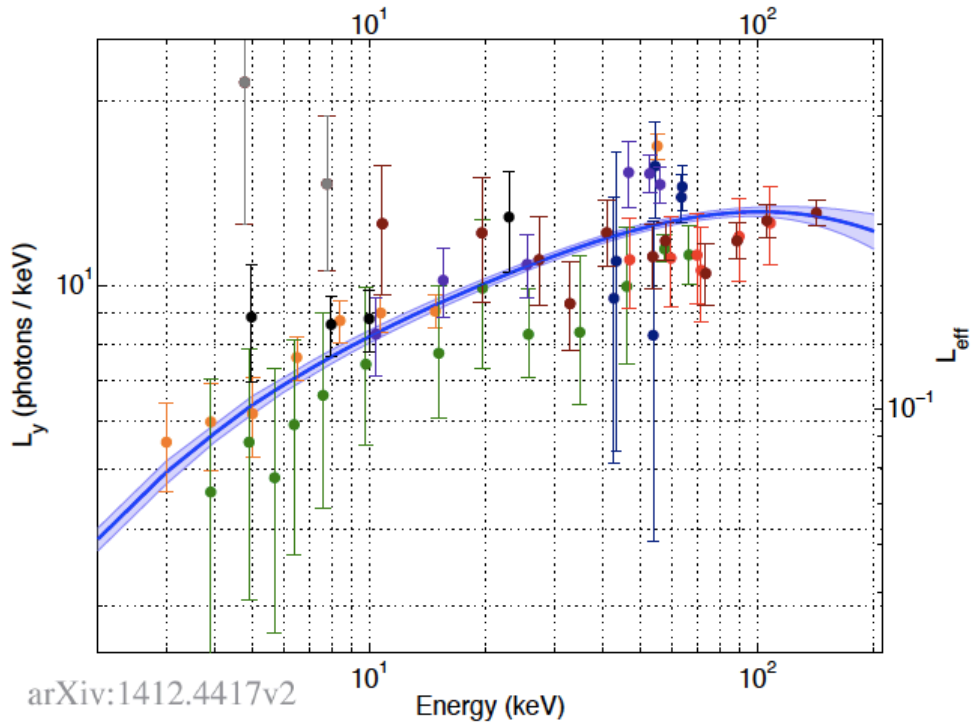

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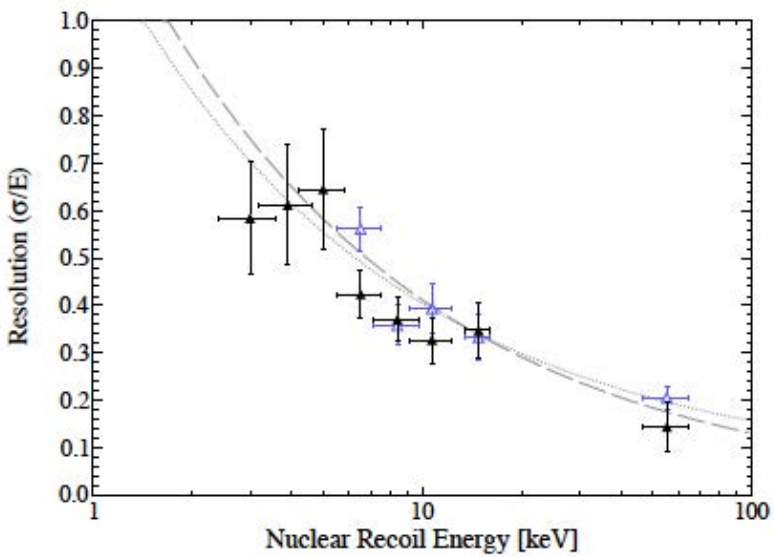
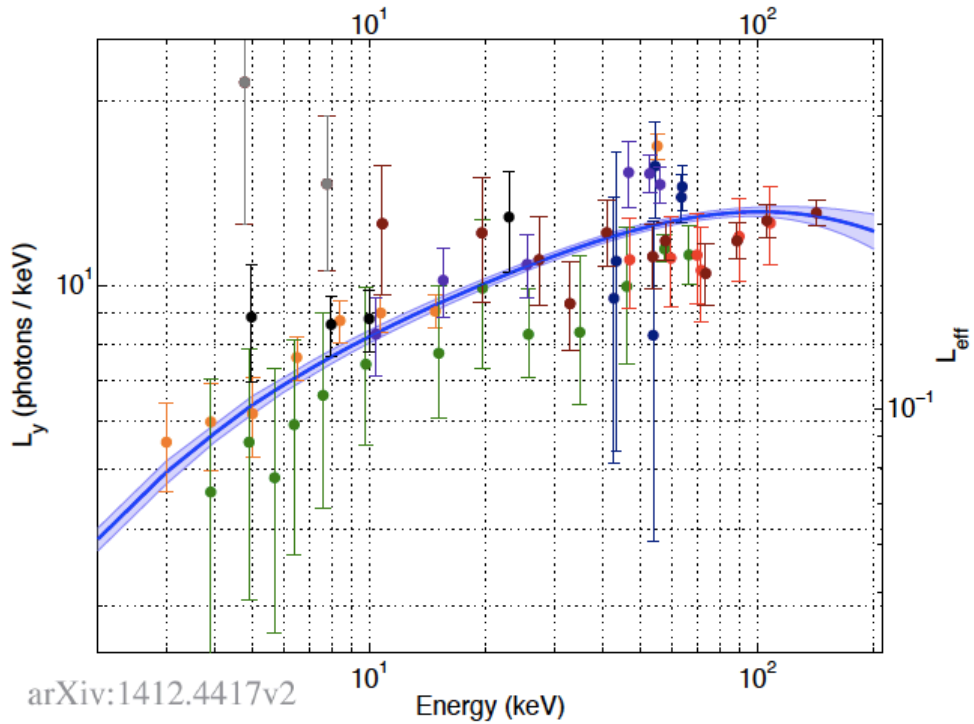
G. Plante. PhD thesis





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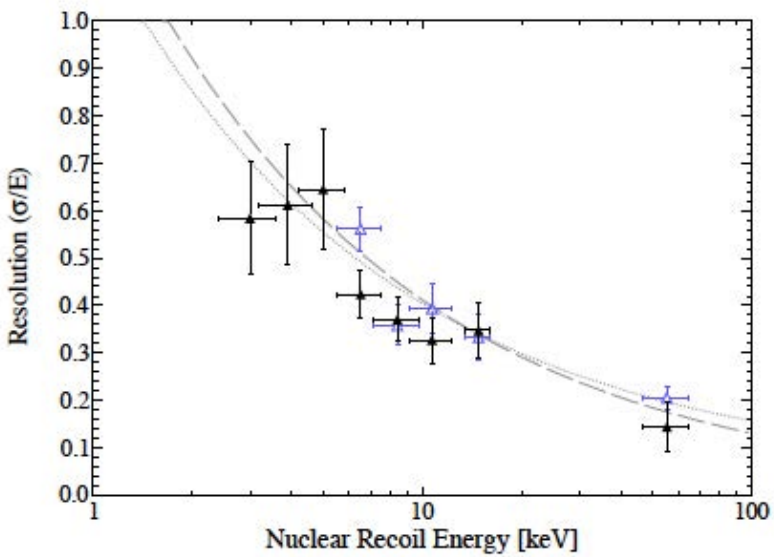

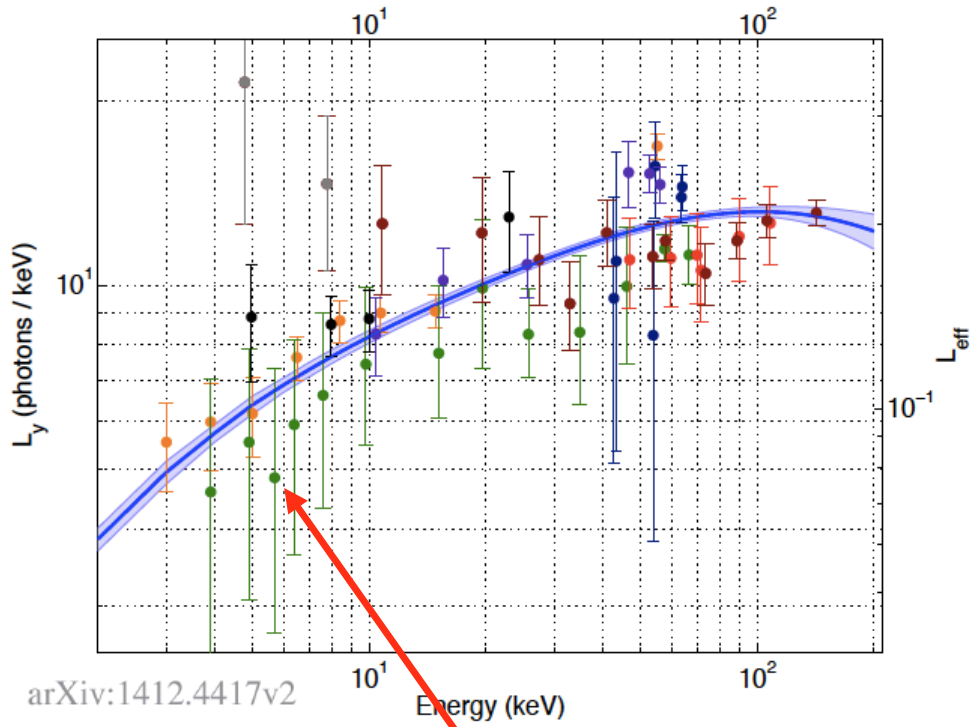

arXiv:1412.4417v2

Quite probably overestimated...

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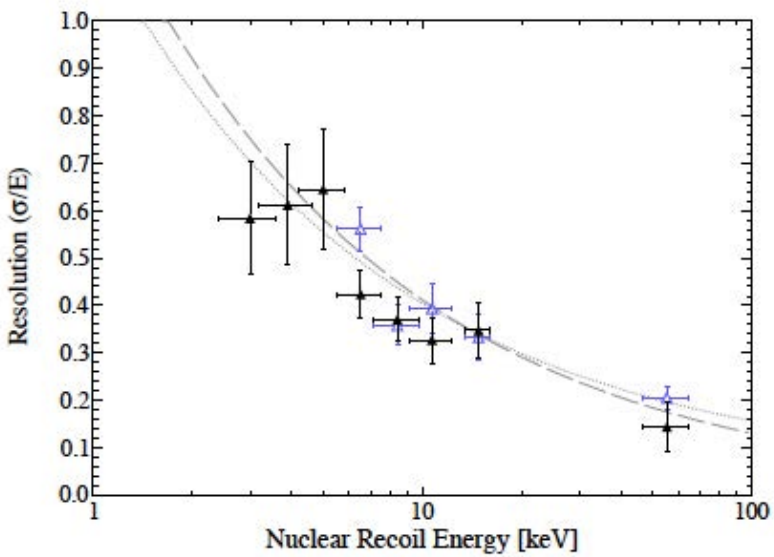

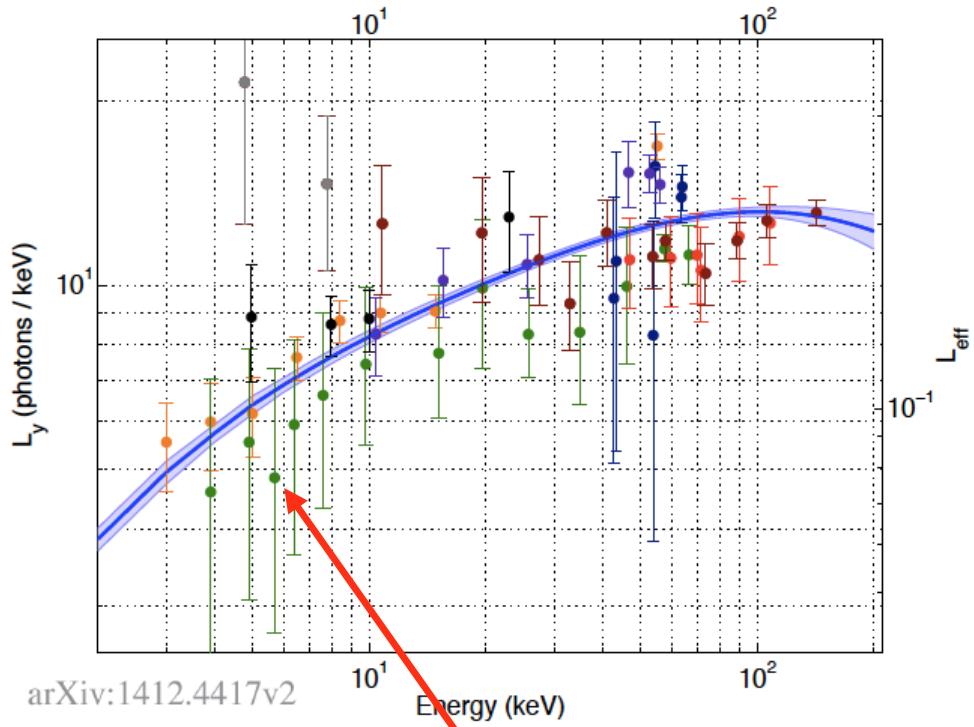

arXiv:1412.4417v2

But wait, I am about to give you a reason why this Leff might be <u>underestimated</u>…

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A few lessons learned during NaI[Tl] Q.F. measurements:

10 *CRC Handbook of Fast Neutron Generators*

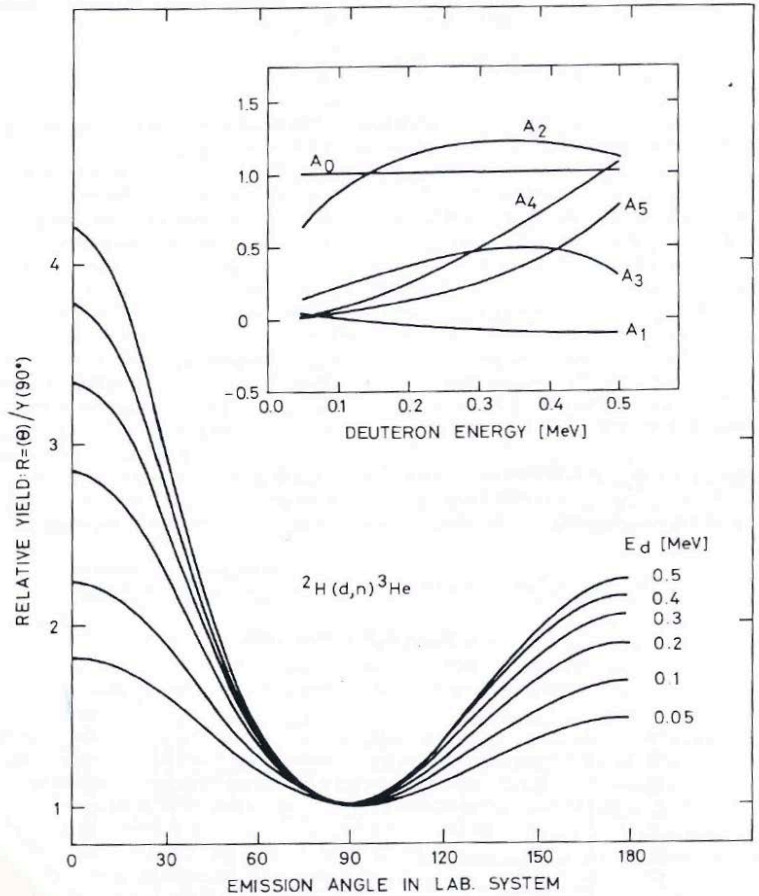


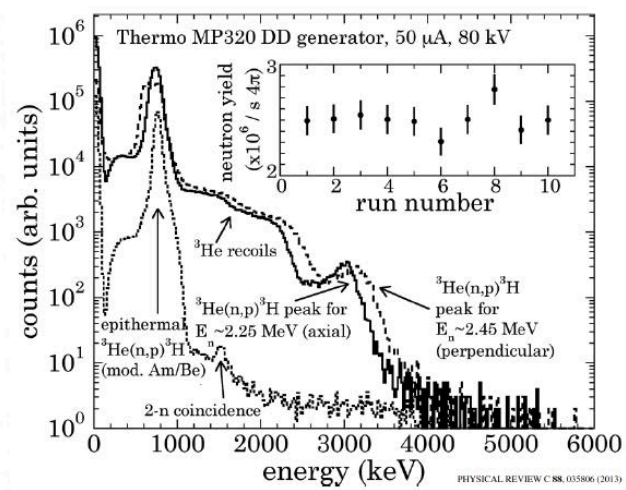
FIGURE 6. Relative angular distributions of the D-D neutrons vs. deuteron energy.

CRC Handbook of Fast Neutron Generators Volume

Table 6
ENERGIES OF RESIDUAL PARTICLES OF T(d,n)^{4}He, D(d,n)^{3}He, AND D(d,p)^{3}H REACTIONS FOR 0°, 90°, AND 180° LABORATORY EMISSION ANGLES AT DIFFERENT BOMBARDING DEUTERON ENERGIES (NONRELATIVISTIC CASE)

Residual Particles	Bombarding deuteron energy (MeV)	Energy of residual particles (MeV) 0°	90°	180°
n from D-T reaction	0.050	14.554	14.068	13.599
	0.100	14.783	14.088	13.432
	0.150	14.960	14.108	13.304
	0.200	15.117	14.128	13.203
	0.250	15.259	14.148	13.117
	0.300	15.390	14.167	13.042
n from D-D reaction	0.050	2.723	2.462	2.225
	0.100	2.852	2.474	2.146
	0.150	2.958	2.486	2.090
	0.200	3.052	2.498	2.045
	0.250	3.139	2.511	2.009
	0.300	3.220	2.524	1.978
^{4}He from D-T reaction	0.050	4.041	3.531	3.086
	0.100	4.261	3.520	2.910
	0.150	4.436	3.551	2.779
	0.200	4.587	3.501	2.672
	0.250	4.723	3.491	2.581
	0.300	4.848	3.481	2.499
^{3}He from D-D reaction	0.050	1.093	0.807	0.596
	0.100	1.223	0.795	0.516
	0.150	1.329	0.782	0.460
	0.200	1.423	0.769	0.416
	0.250	1.510	0.757	0.380
	0.300	1.591	0.745	0.349
p from D-D reaction	0.050	3.324	3.036	2.772
	0.100	3.465	3.048	2.657
	0.150	3.579	3.061	2.617
	0.200	3.681	3.073	2.566
	0.250	3.773	3.085	2.523
	0.300	3.860	3.098	2.486
^{3}H from D-D reaction	0.050	1.311	0.997	0.758
	0.100	1.451	0.984	0.668
	0.150	1.565	0.971	0.603
	0.200	1.666	0.959	0.552
	0.250	1.758	0.946	0.509
	0.300	1.844	0.933	0.472

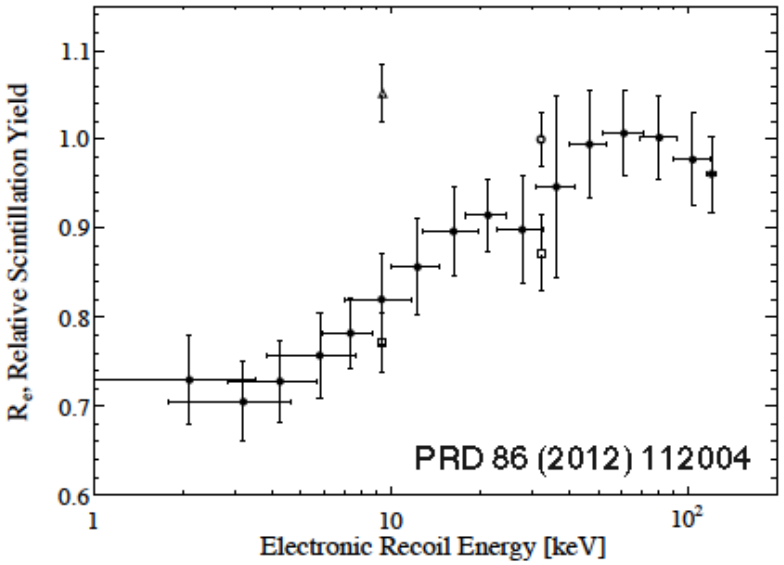
Cuttler-Shalev counter

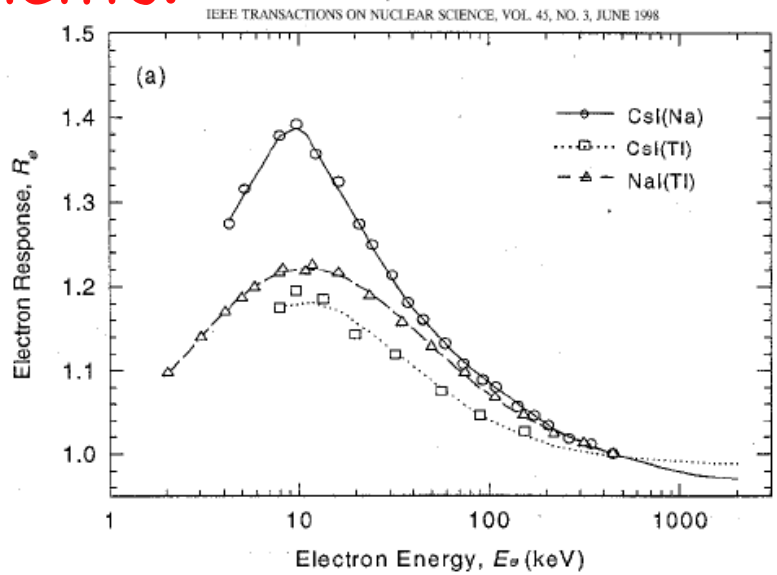


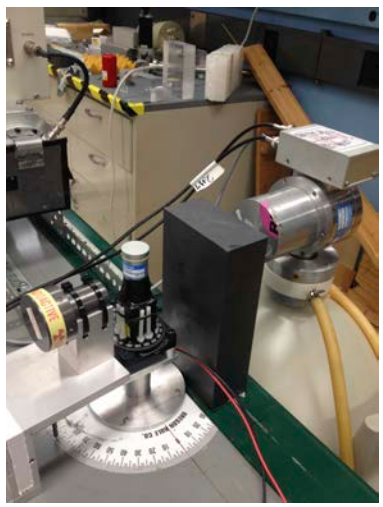
See E. Dahl's talk on difficulties in understanding other n sources

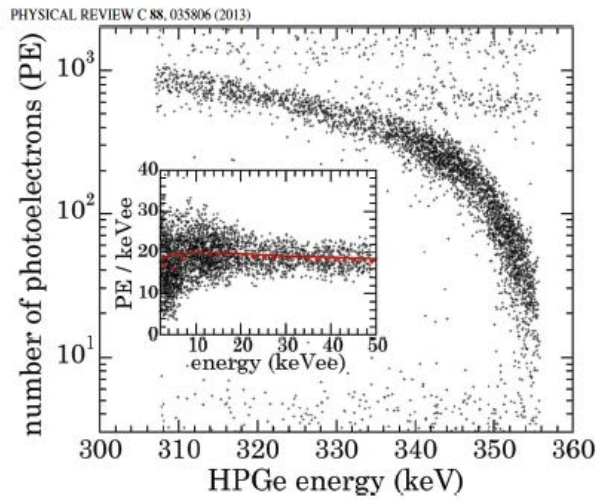
- You can never understand your neutron source too well (in my case, knowing my head from my behind).

A few lessons learned during NaI[Tl] Q.F. measurements:



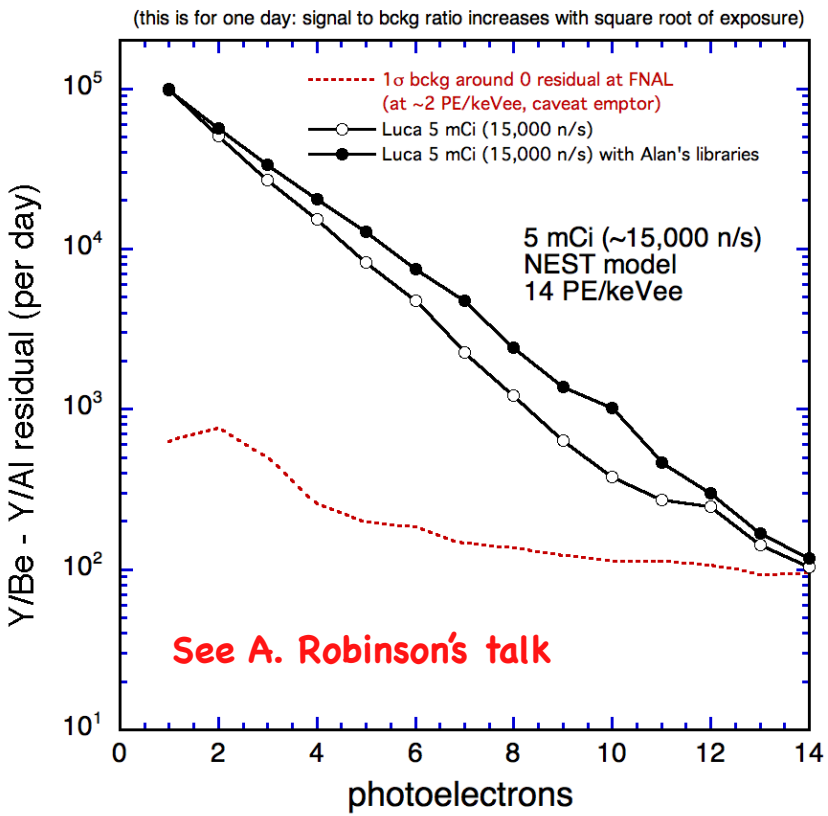




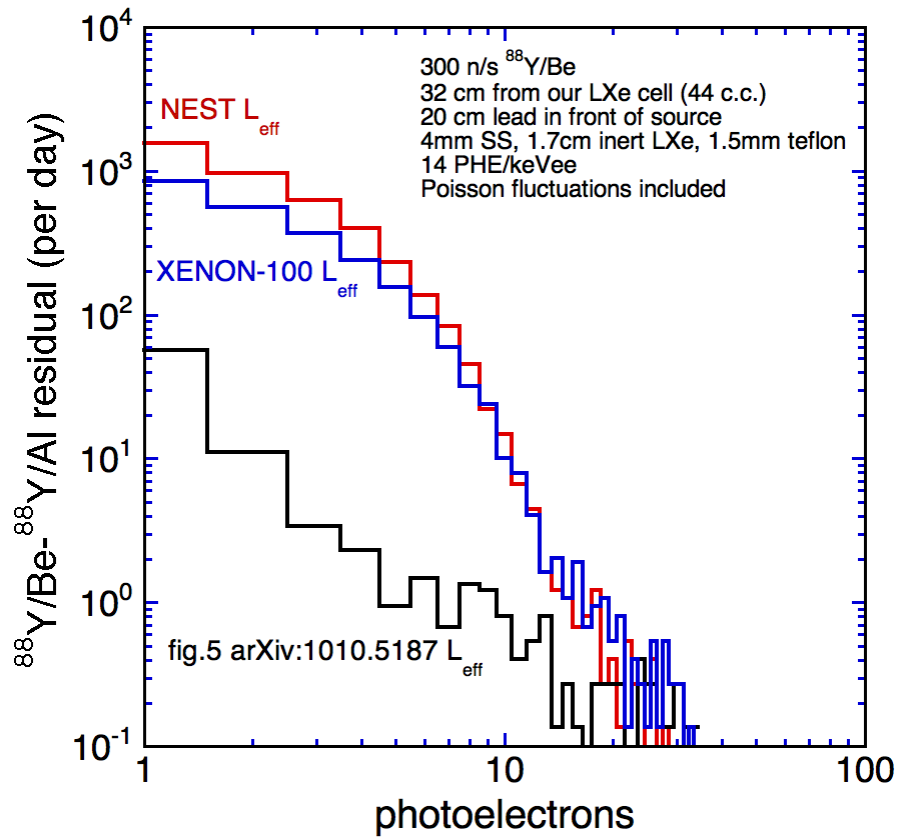


- Non-linearities in ER response: best is to always measure NR and ER together, if at all possible. Chicago-Princeton-TUNL NaI[Tl] measurements are in even better agreement than it seems, when using common ER reference.

A few lessons learned during NaI[Tl] Q.F. measurements:



U. Chicago Y/Be on LXe
(did we have a talk on this?)



- How well do you trust your Monte Carlo? Use of different cross-section libraries produces a significant effect on best-fit quenching factor. This problem is exacerbated when neutron source is broad, or too high in energy.

Wee conclusions:

(besides all of the other minutiae covered)

- Do not take semi-empirical calculations (e.g., SRIM, NEST, etc.) as an article of faith: fixate instead on quality of measurements they are based on.

- Broad and/or too high in energy sources can result in a perpetuation of mistakes. How well do you trust your Monte Carlo calculations?

- On the good news front: we have been making a lot of recent progress.