CEνNS at the Dresden-II reactor and beyond

C.M. Lewis

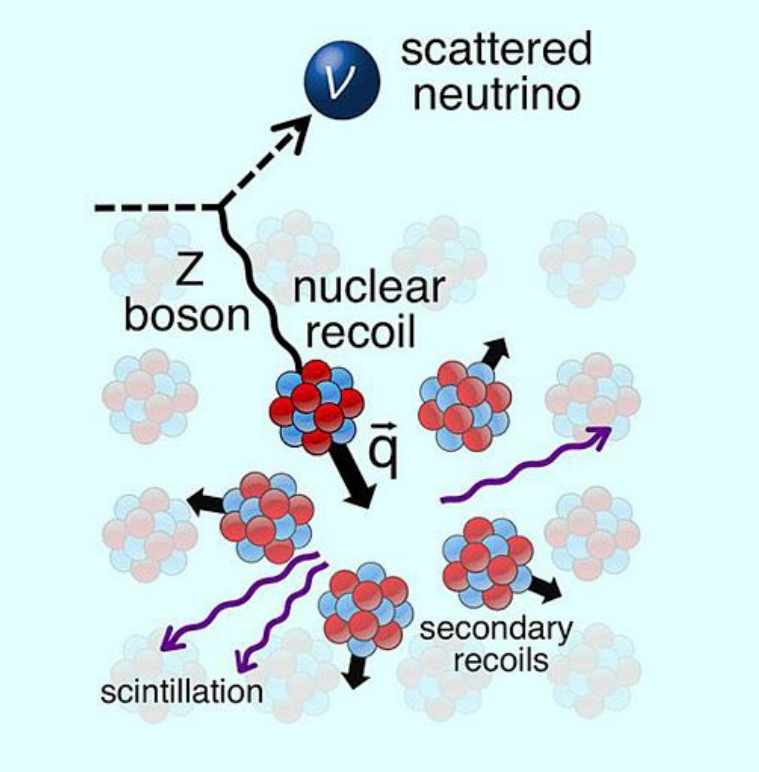
Donostia International Physics Center (DIPC), Universidad del País Vasco
Enrico Fermi Institute (EFI), University of Chicago

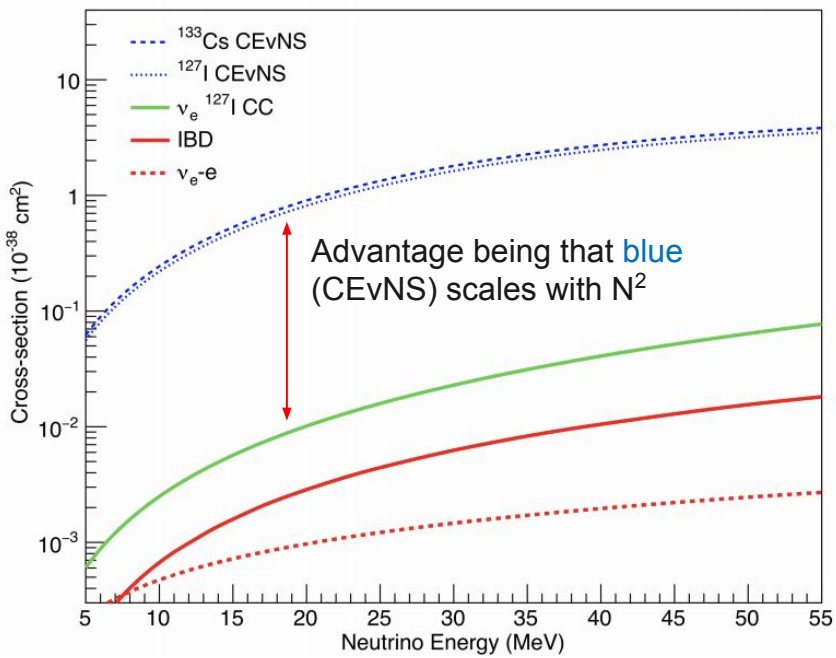
Donostia International Physics Center

THE UNIVERSITY OF CHICAGO

Coherent Elastic Neutrino-Nucleus Scattering (CEνNS)

D.Z. Freedman, Phys. Rev. D 9 (1974) 1389

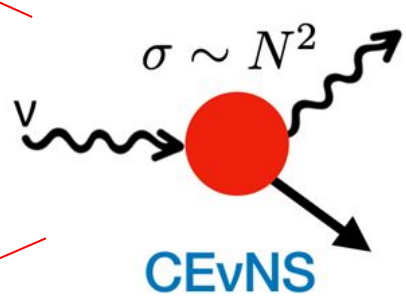




What you can do with it

Probe for non-standard interactions through cross section
(J.R. Wilson, PRL 32 (74) 849)
(J. Barranco et al., hep-ph/0508299, hep-ph-0512029)

Neutrino magnetic moment (enhancement of low-energy recoils) (A.C.Dodd et al, PLB 266 (91) 434)



Neutrino charge radius
(L.M.Krauss, PLB 269, 407)

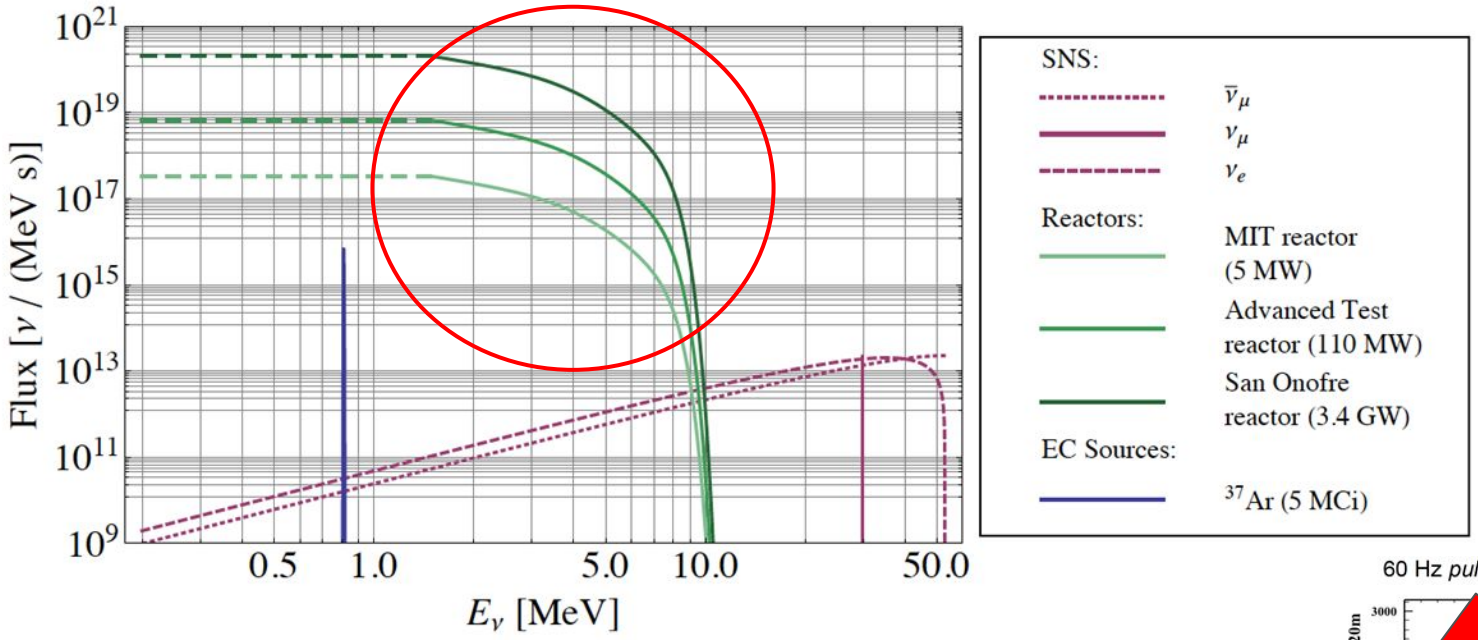
technology-scale detectors

Sterile searches through oscillations (CEvNS is a flavor-blind process)
(A.Drukier & L.Stodolsky, PRD 30 (84) 2295)

Reduce systematics in dark matter experiments (eventually)

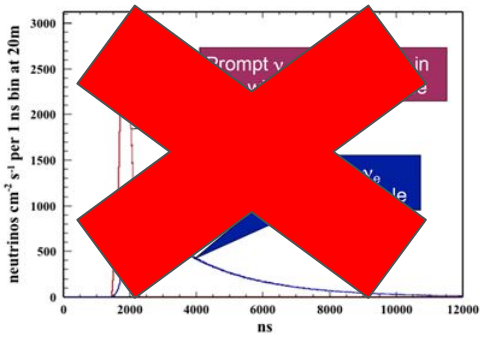
Probe for new neutral candidates

CEνNS sources (reactors)



Enectali Figueroa-Feliciano / vMass 2013 / Milano

60 Hz *pulsed* source



Low recoil energies… but high ν flux

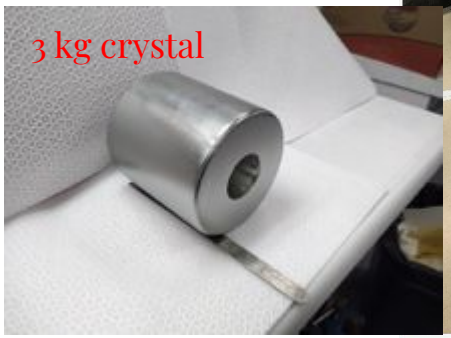
No background subtraction (steady-state source)… but some locations have excellent background reduction

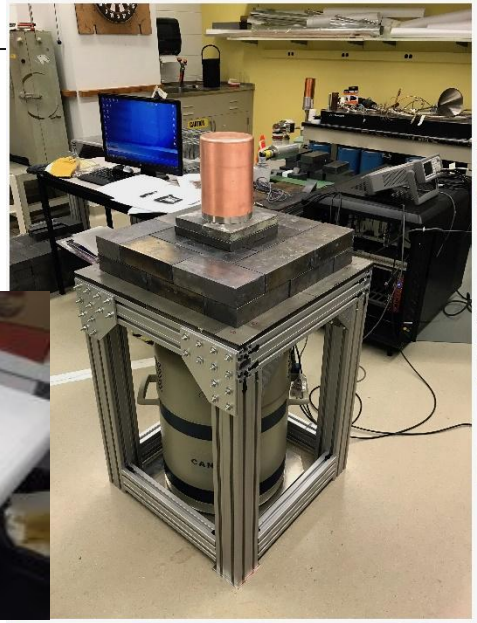
Spallation produces x200 the neutrons per ν

Ge PPCs

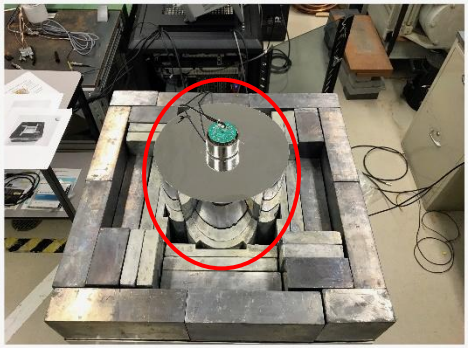
Combination ideal for precision CEνNS studies:

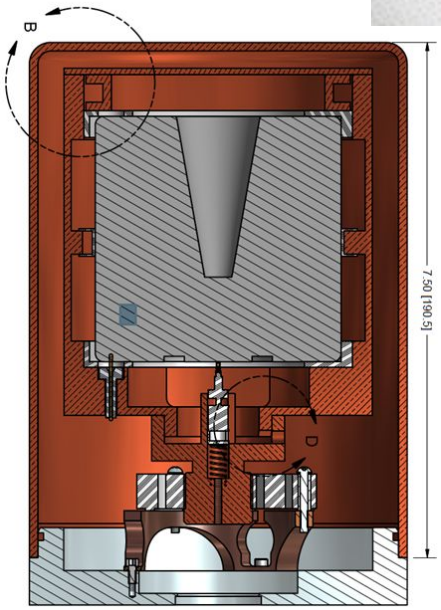
- Mass
- Radiopurity
- Energy Resolution
- Low Threshold

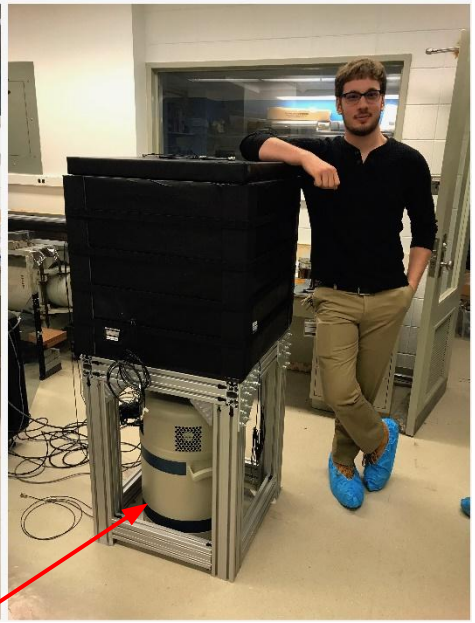




supplementary low-bckgr inner veto

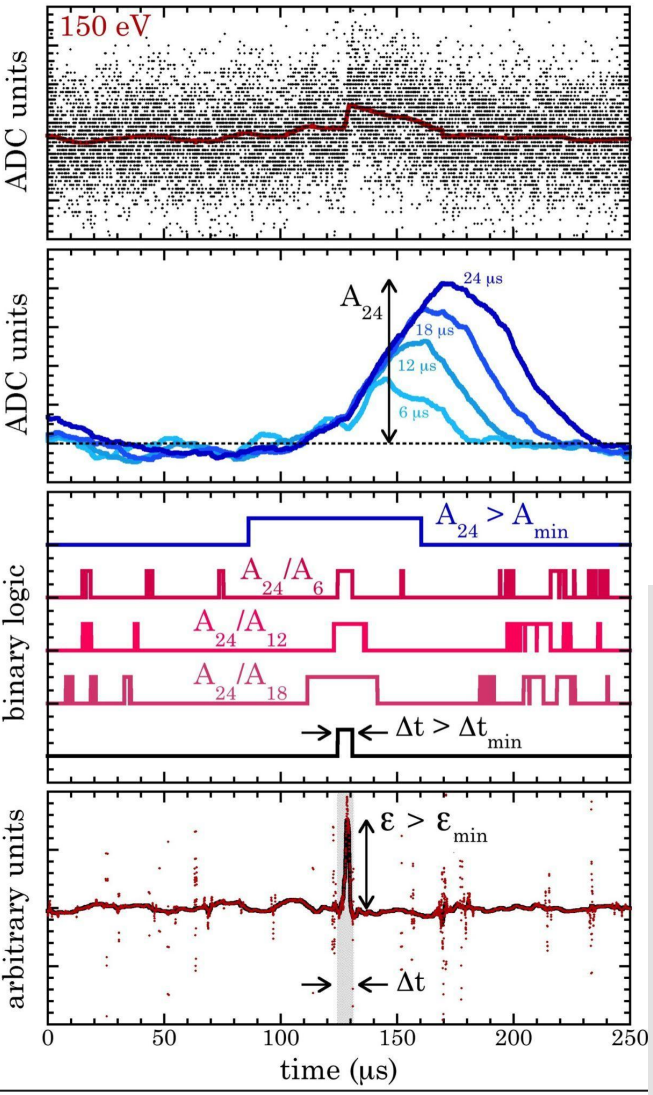




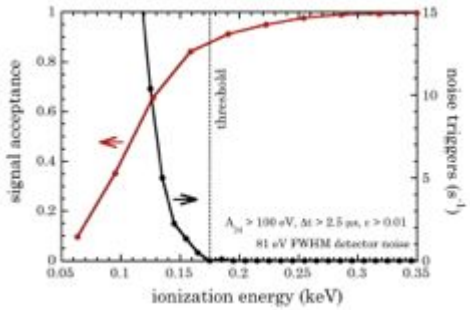


cryocooler

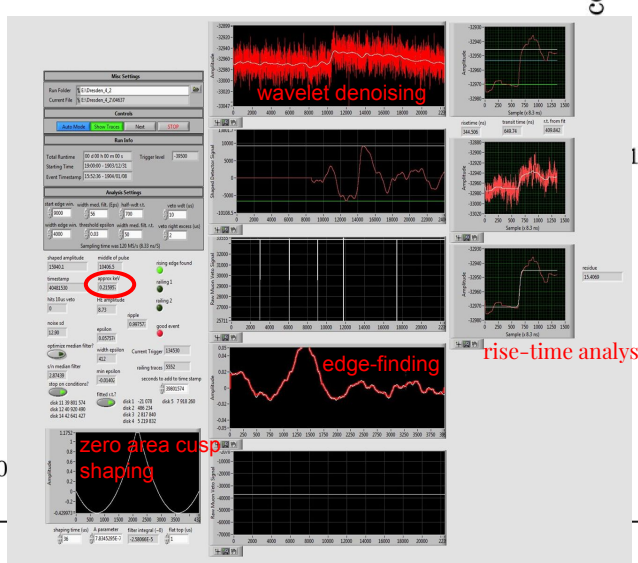
Whats gets a threshold low enough in that environment?



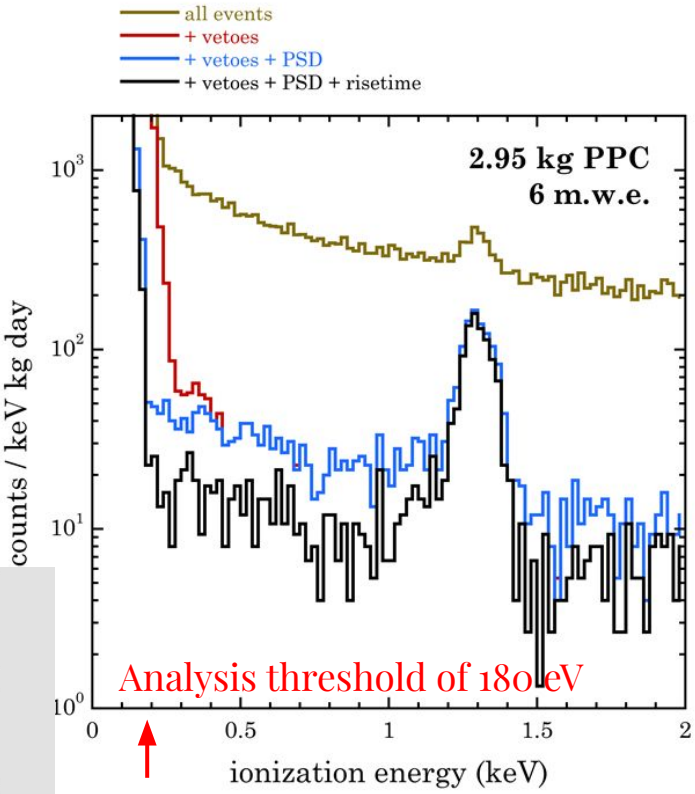
FPGA shaping condition fulfillment



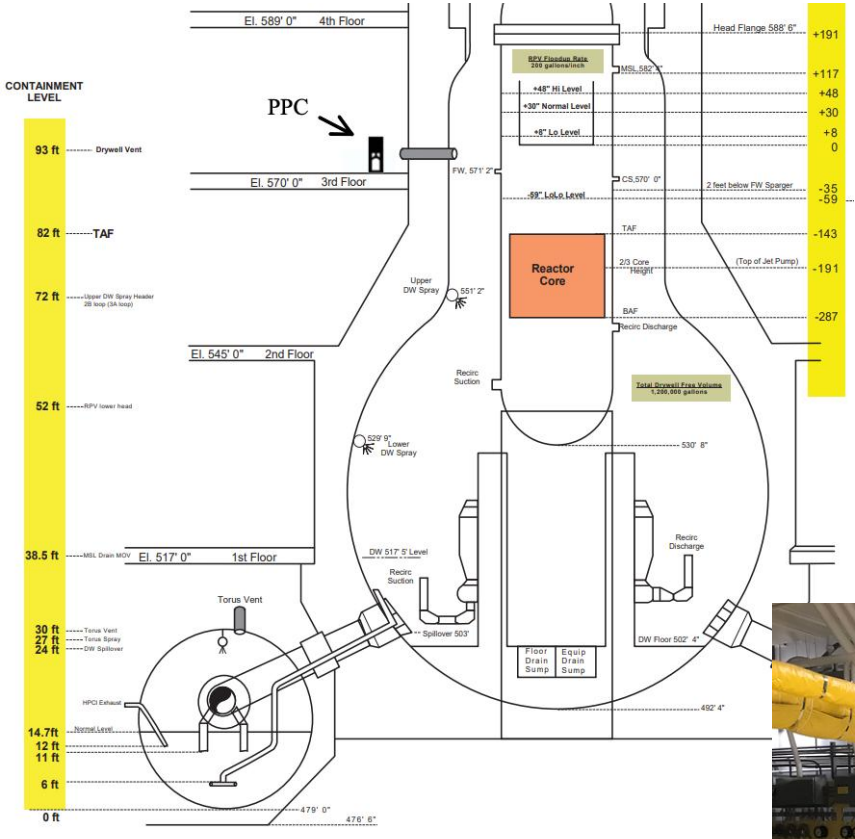
PSD (in action)



rise-time analysis



Dresden-II BWR

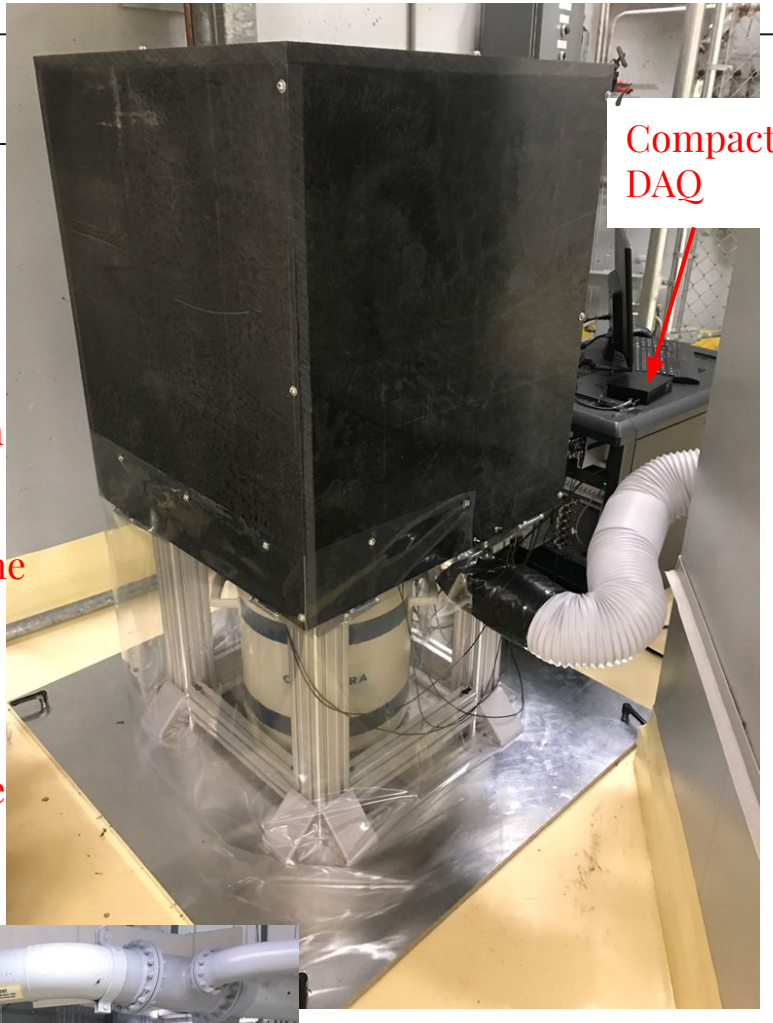


Only a 60x60 cm footprint

Took 3 people one day to assemble

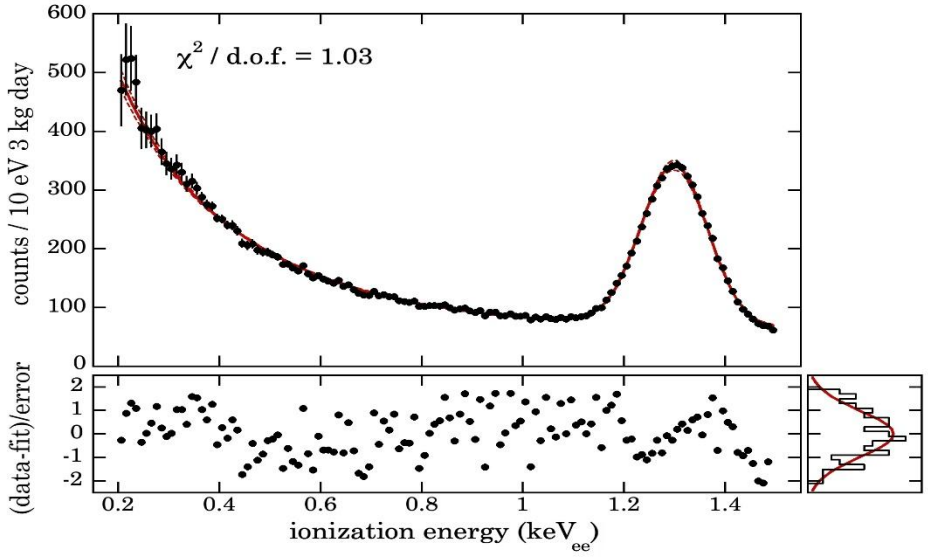
4.8E13 ν/cm^{2}s

10.4 m from core

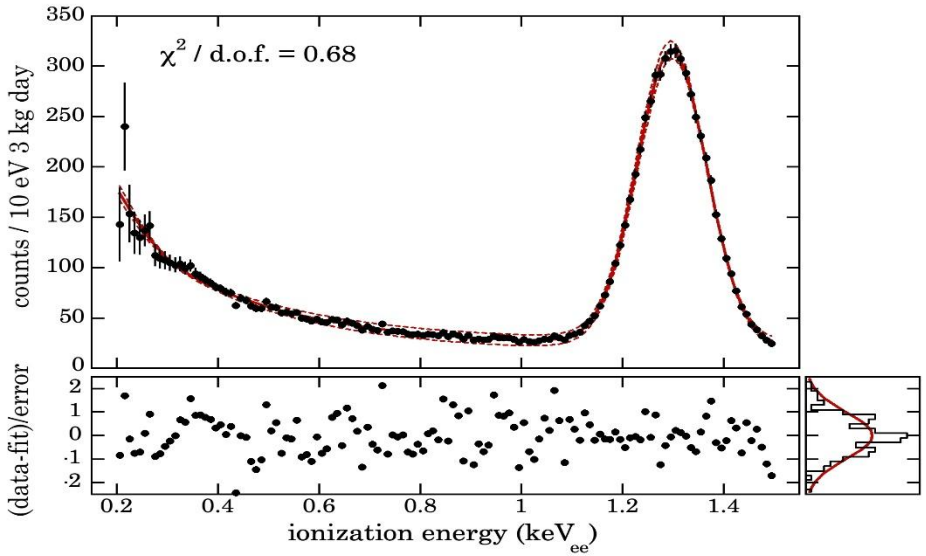


Background Model

No moderator



1 inch moderator



~1 keV wide ROI

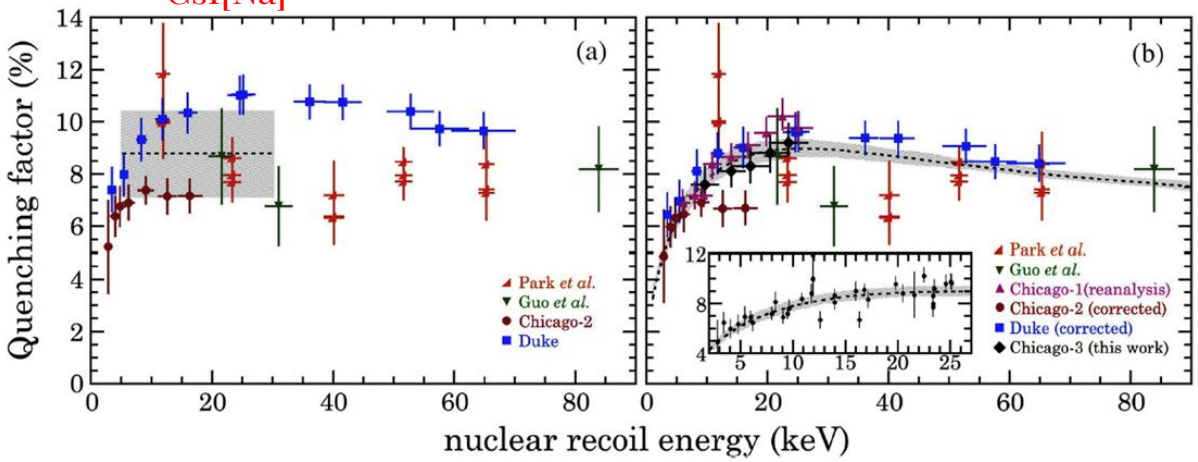
epithermals => $E_n^{-(1+\alpha)}$
where $\alpha \sim 0.2$
(best-match agrees)

no “shark tooth” peaks (fast)

simple falling exponential

Seeing CEνNS means not falling into the old trap… (… of not being able to interpret it!)

CsI[Na]

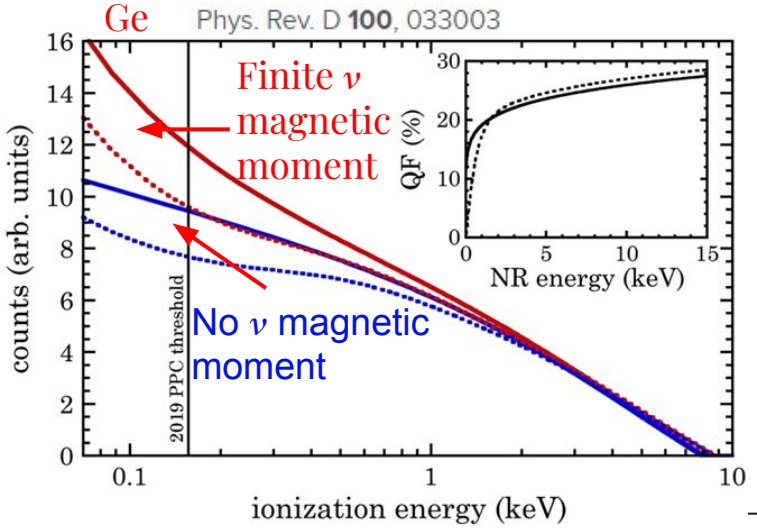


Two slightly different QF models

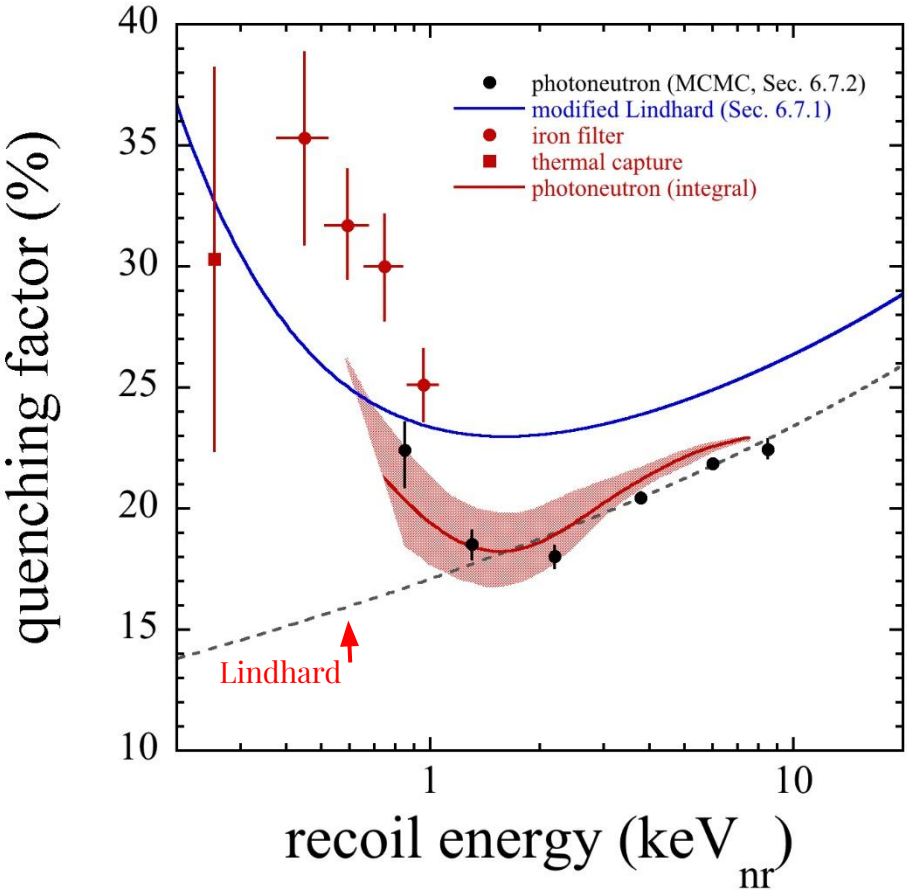
Inclusion of a finite magnetic moment contribution

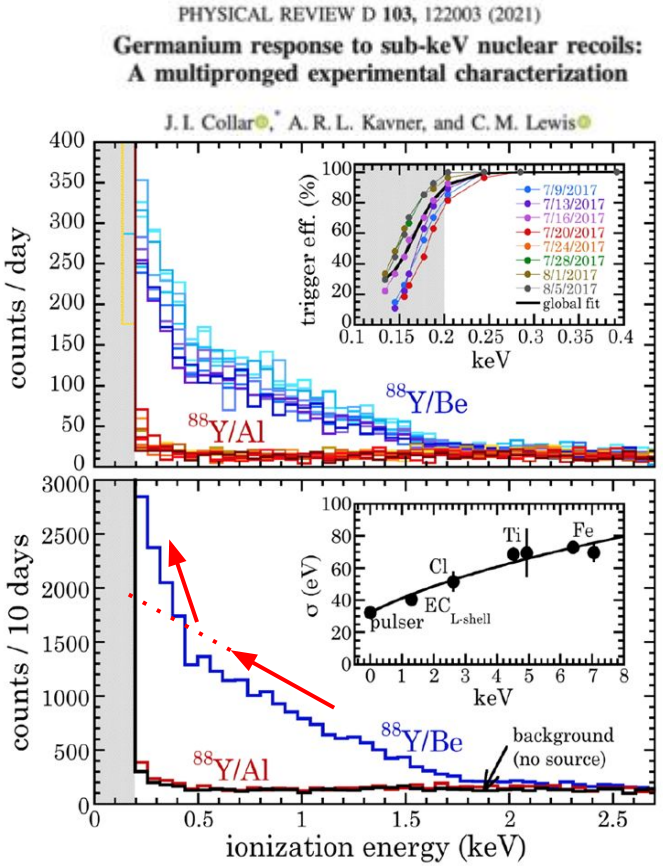
Which is it? New physics when really just unknown detector or missed opportunity?

Ge



A project of passion: Ge NR response



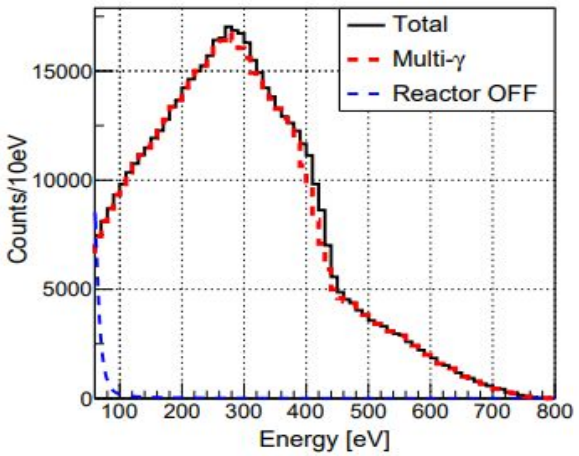


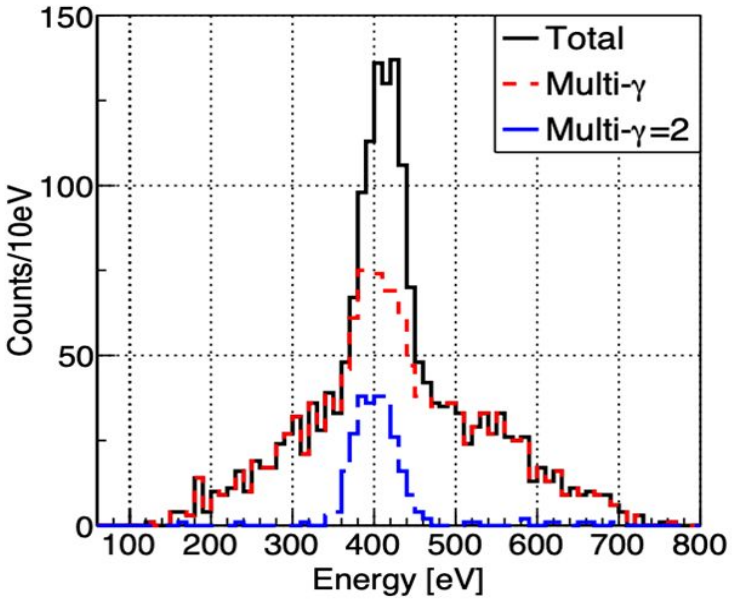
***comments on CONUS QF paper: arXiv:2203.00750**

Passion without end - more measurements

0.4 keV_{nr} ↠ if Lindhard, it won't be visible

A binary test for the form of the QF below 1 keV





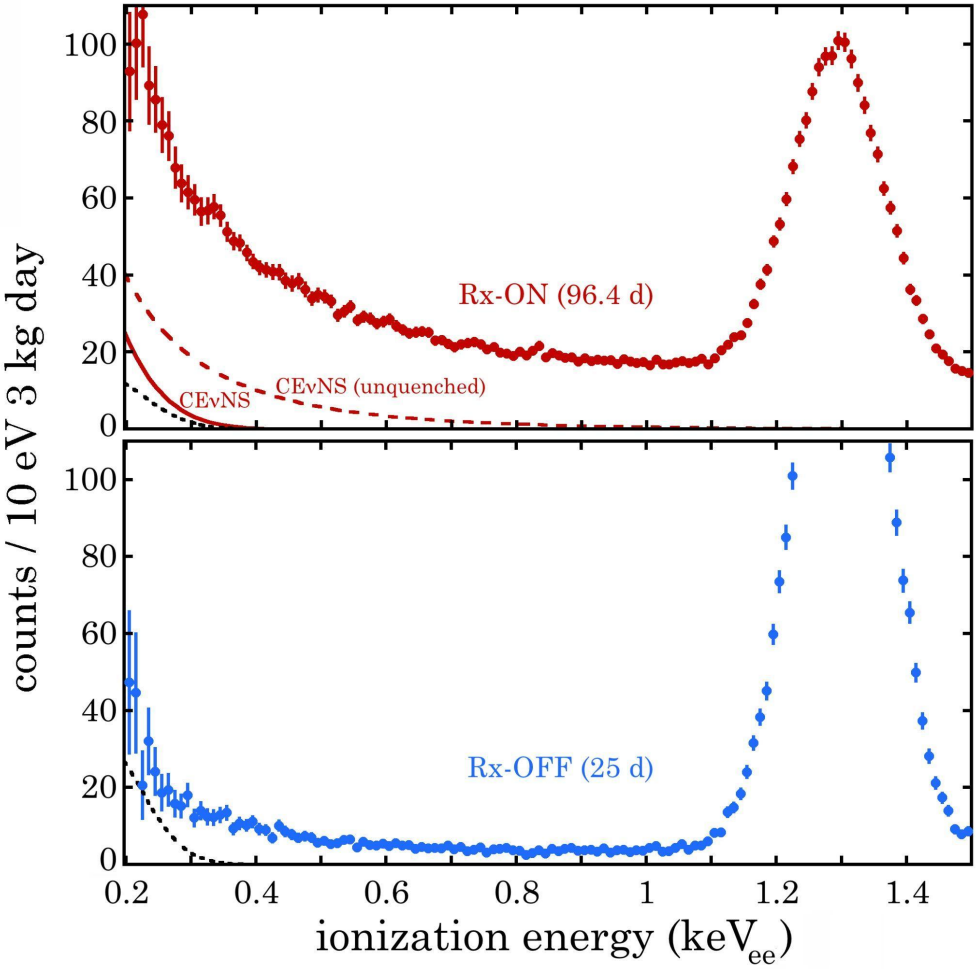
Calibration of nuclear recoils at the 100 eV scale using neutron capture

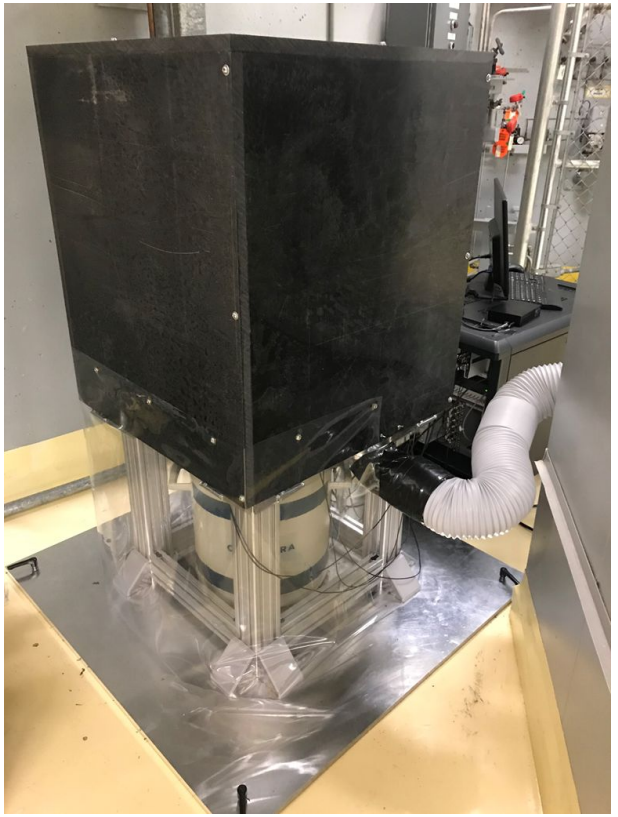
L. Thulliez,[a] D. Lhuillier,[a,*] F. Cappella,[b] N. Casali,[b] R. Cerulli,[c,d] A. Chalil,[a] A. Chebboubi,[e] E. Dumonteil,[a] A. Erhart,[f] A. Giuliani,[g] F. Gunsing,[a] E. Jericha,[h] M. Kaznacheeva,[f] A. Kinast,[f] A. Langenkämper,[f] T. Lasserre,[a,f] A. Letourneau,[a] O. Litaize,[e] P. de Marcillac,[g] 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,[f] R. Strauss,[f] M. Vignati,[b,k] M. Vivier,[a] V. Wagner[f] and A. Wex[f]

2021 JINST 16 P07032

CsI @ OSURR

Returning to our data (+ moderator)

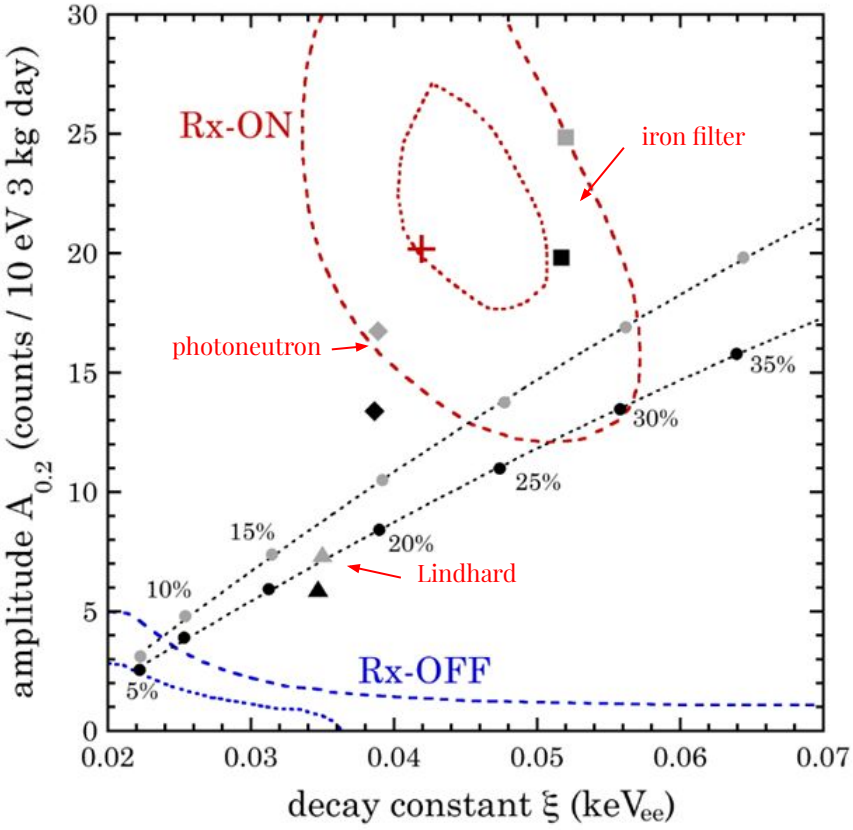


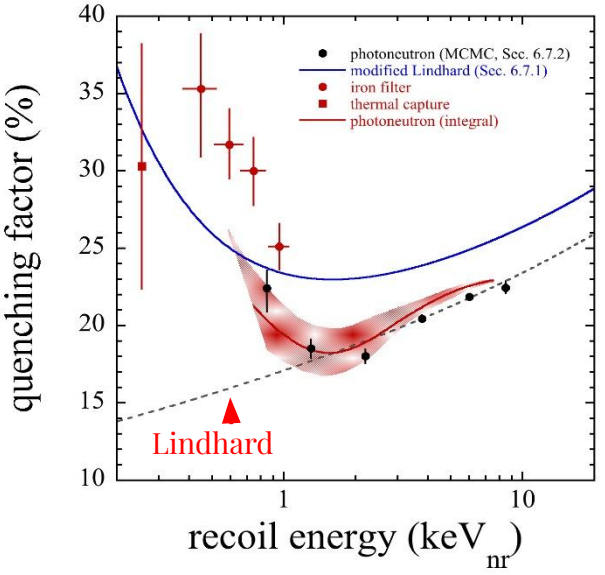


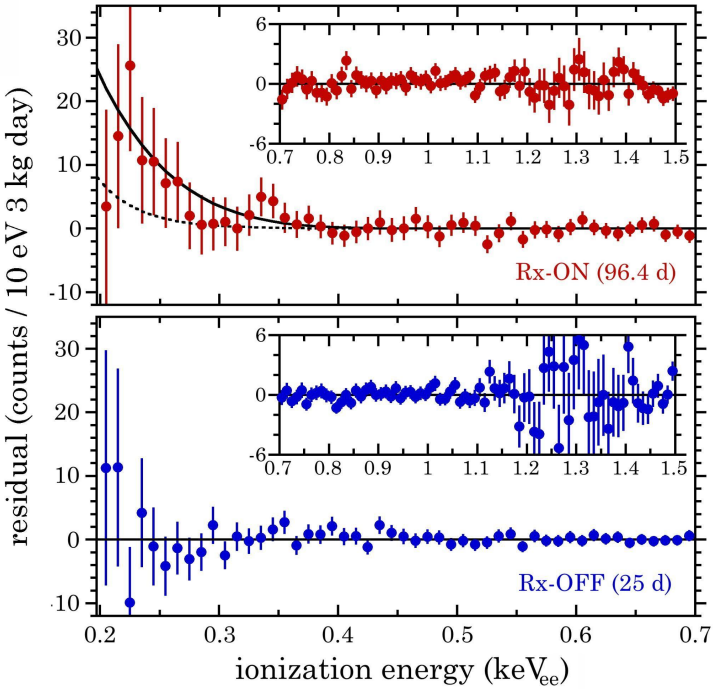
Final data run:
- extra HDPE
- climate control (cryocooler was working overtime)

Now, with a small, but clear, CEvNS spectrum overlaid, statistical significance may be achieved

Dresden Results (part 1)







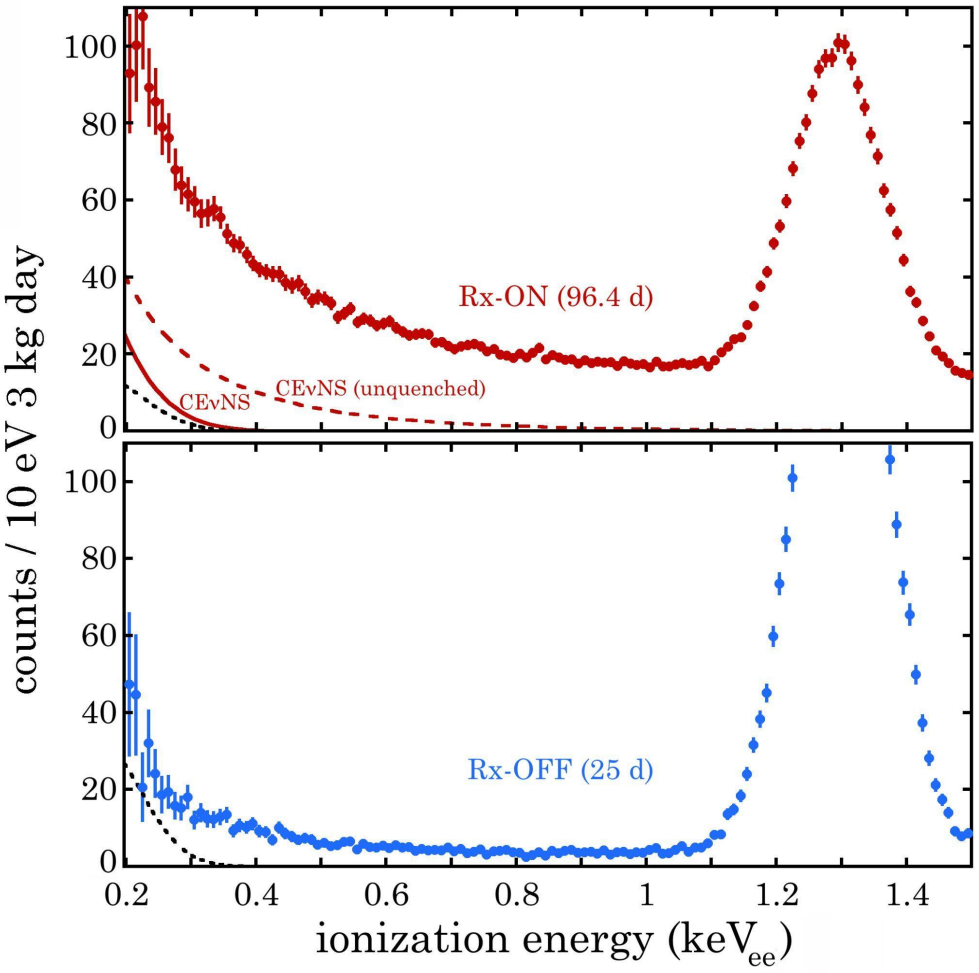
This is what gets everyone hot-and-bothered

The Bayesian Takeover

$$P(\Theta|\boldsymbol{D}, M) = \frac{P(\boldsymbol{D}|\Theta, M)P(\Theta|M)}{P(\boldsymbol{D}|M)}$$

$$P(\boldsymbol{D}|M) = \int P(\boldsymbol{D}|\Theta, M)P(\Theta|M)d^N\Theta$$

Bayesian evidence integral



Likelihood ratio approach untenable (Δk = 0)

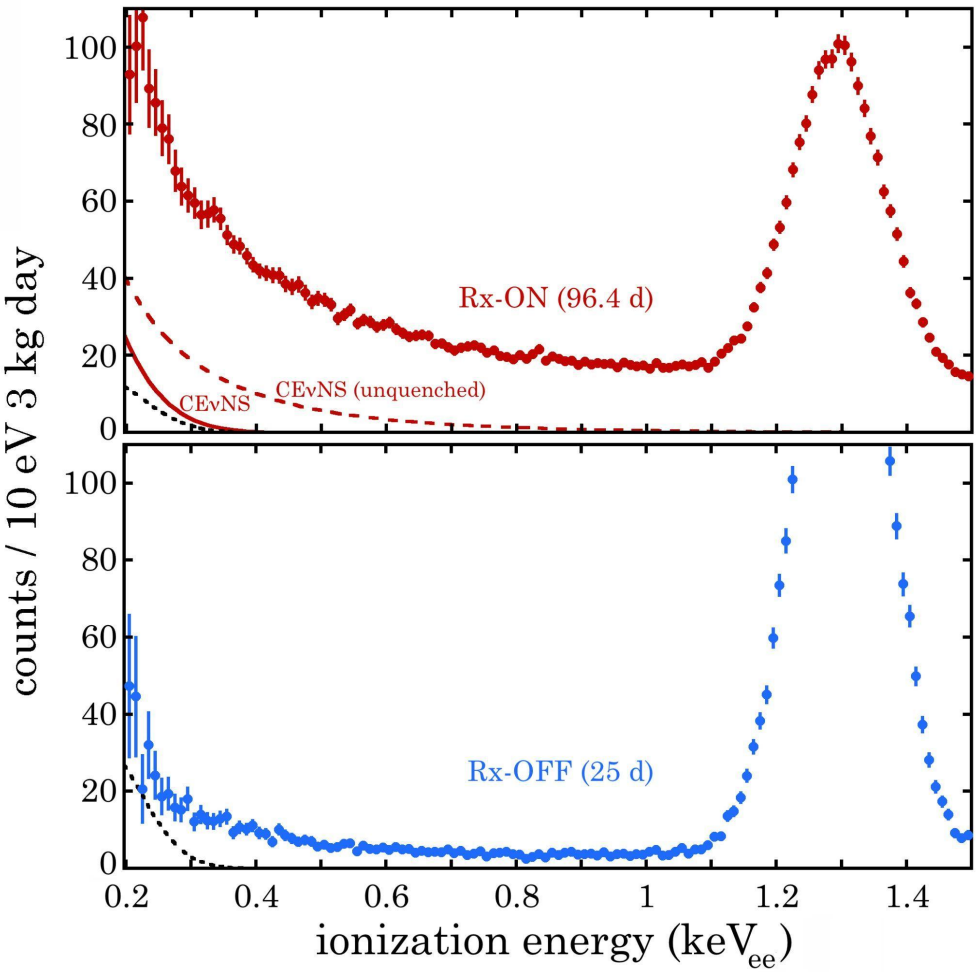
Bayes factor method can handle non-nested models

Most common complaint: priors (subjectivity)

Only prior here is an experimentally measured EC peak (and equivalent between alternative and null)

With MCMC techniques and computational power, they can be widely applied

Dresden Results (part 2)



Bayesian evidence ratio

$log_{10}(B_{10})$	B_{10}	Interpretation
0 to $\frac{1}{2}$	1 to 3.2	Weak
$\frac{1}{2}$ to 1	3.2 to 10	Moderate
1 to 2	10 to 100	Strong
>2	>100	Decisive

QF Model	B_{10} (MHVE)	B_{10} (KOP)
Fef	34.0	34.8
YBe	13.2	11.2
Lindhard	4.0	3.1

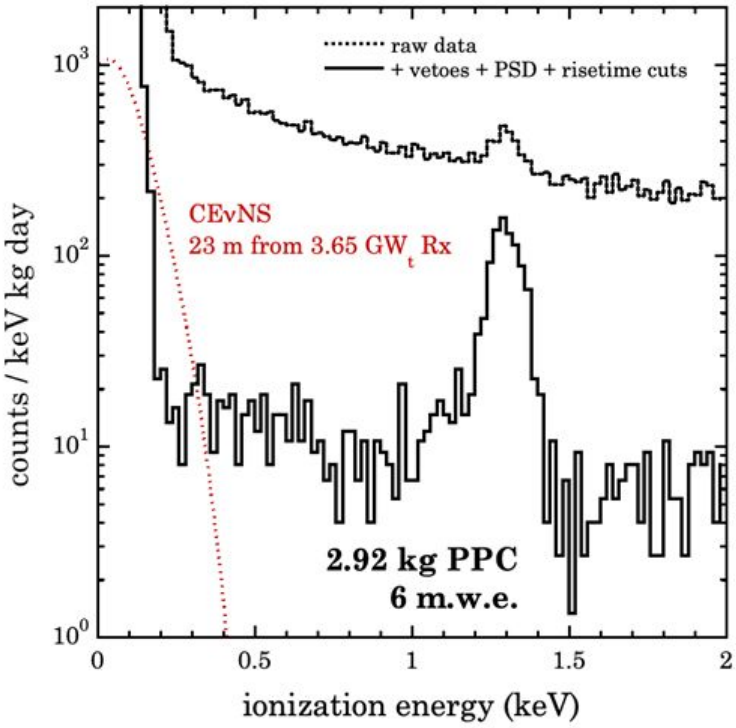
Relative likelihood => 6.7 (Fef)

p-value => ~ 1 x 10^{-3} => ~ 3.2 σ

PHYSICAL REVIEW LETTERS **129,** 211802 (2022)

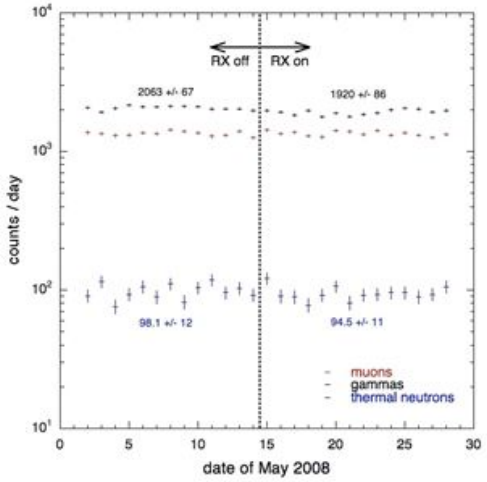
Measurement of Coherent Elastic Neutrino-Nucleus Scattering from Reactor Antineutrinos

J. Colaresi,[1] J. I. Collar,[2,*] T. W. Hossbach,[3] C. M. Lewis,[2] and K. M. Yocum[1]

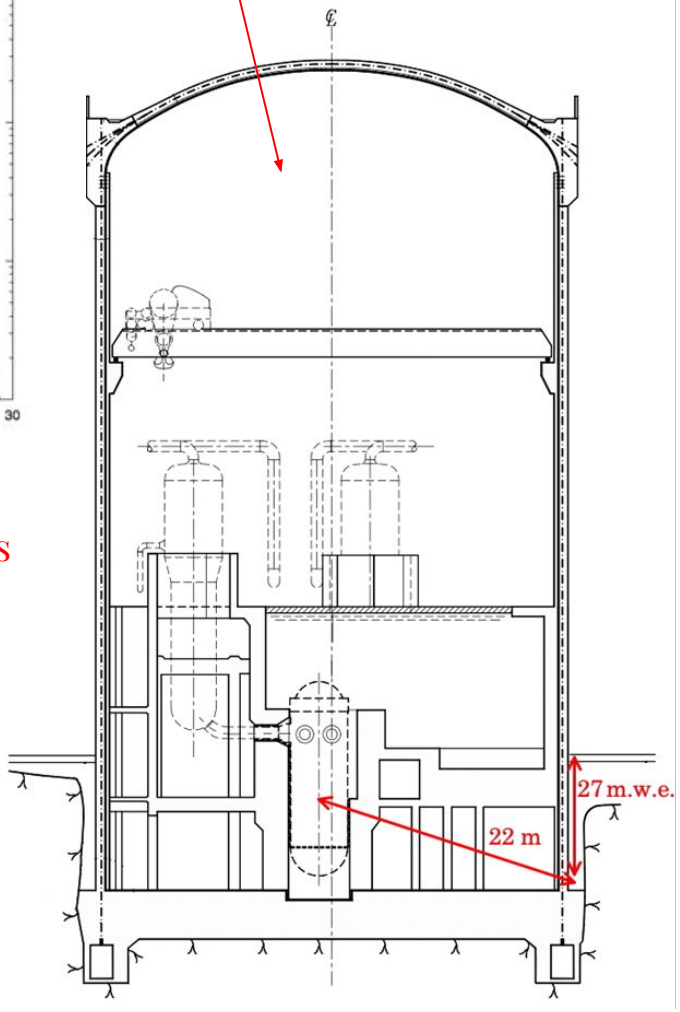


But this is not the end…

Ringhals nuclear plant



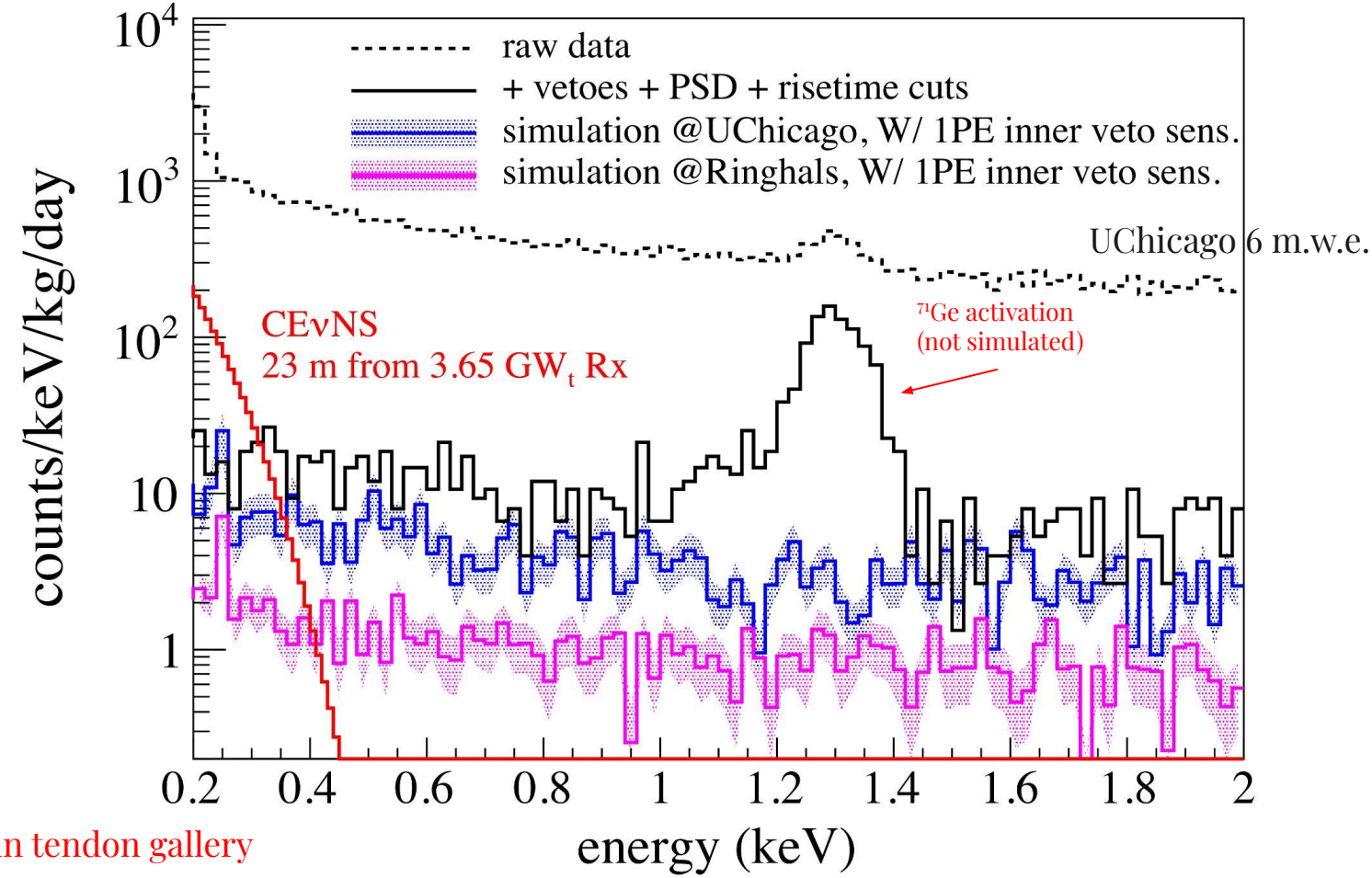
San Onofre background stability vs reactor status



- ^{3}He counter(s)
- NaI
- Plastic scint
- overburden
- radon

still with just a 60x60 cm footprint

Ringhals – viability



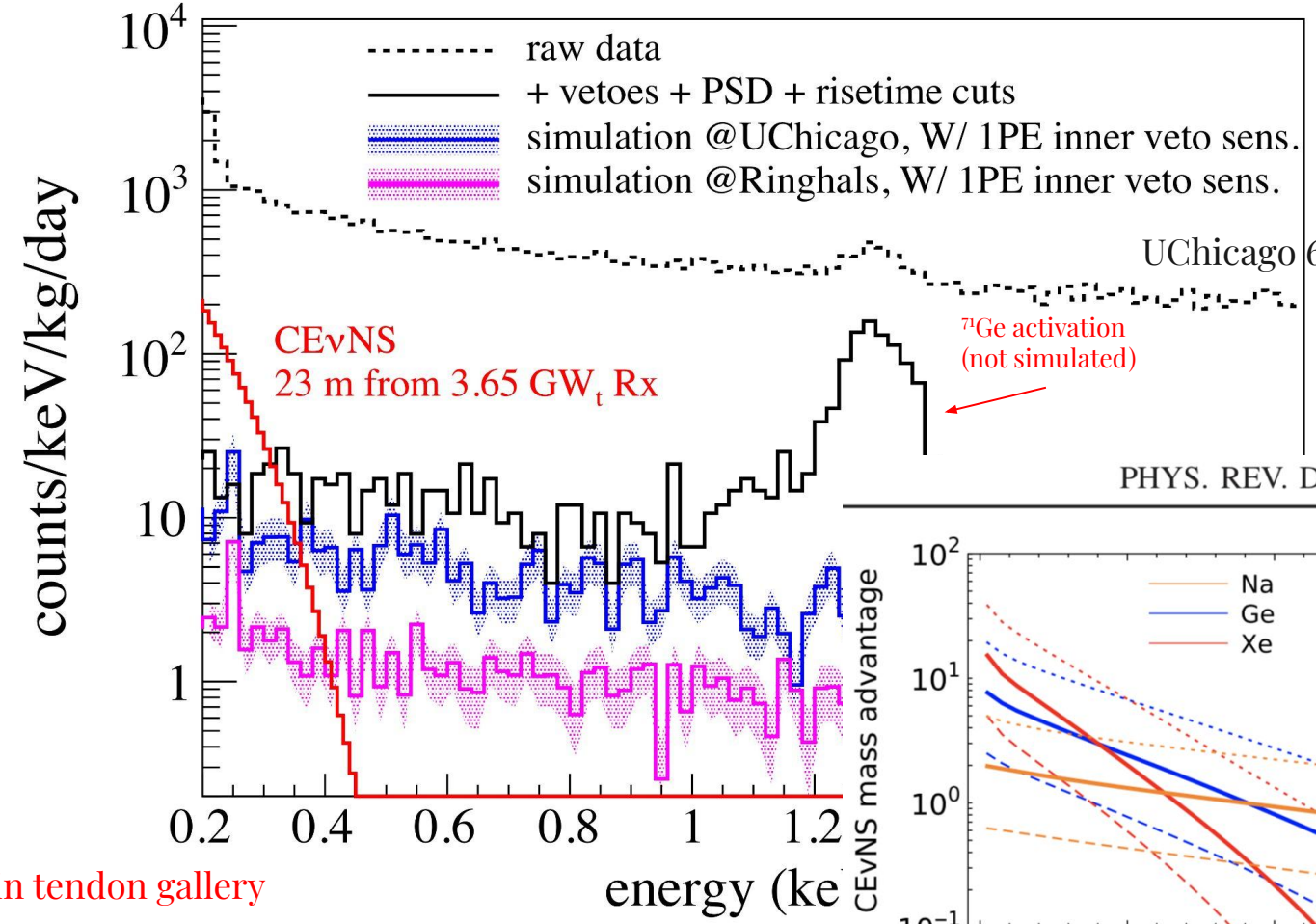
30 m.w.e. in tendon gallery

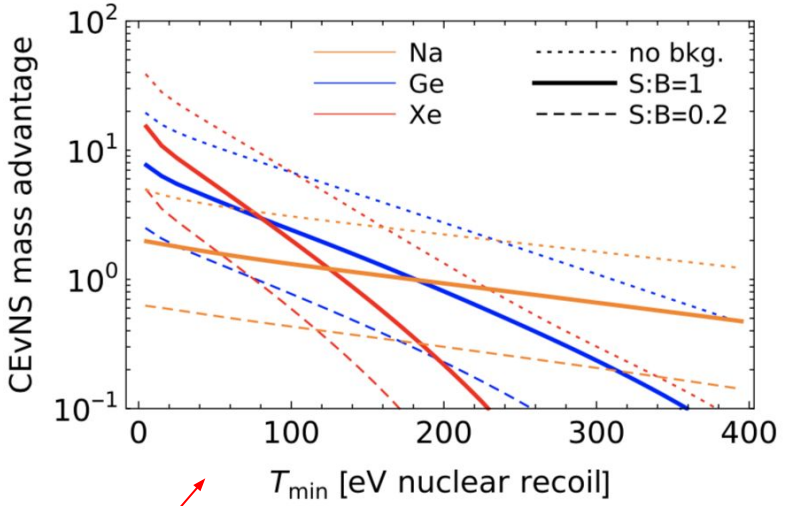
Signal-to-background of ~ 40 expected (present was ¼)

refurbished specs ⇾ significantly reduced threshold

⇾ Backgrounds O(1 ckkd) fairly constant all the way to threshold

quick note about CEvNS vs IBD





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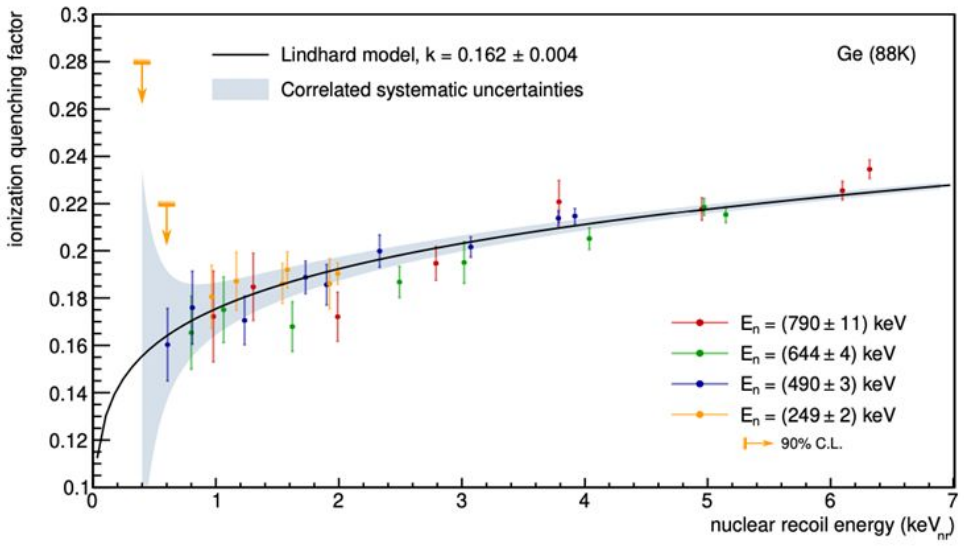
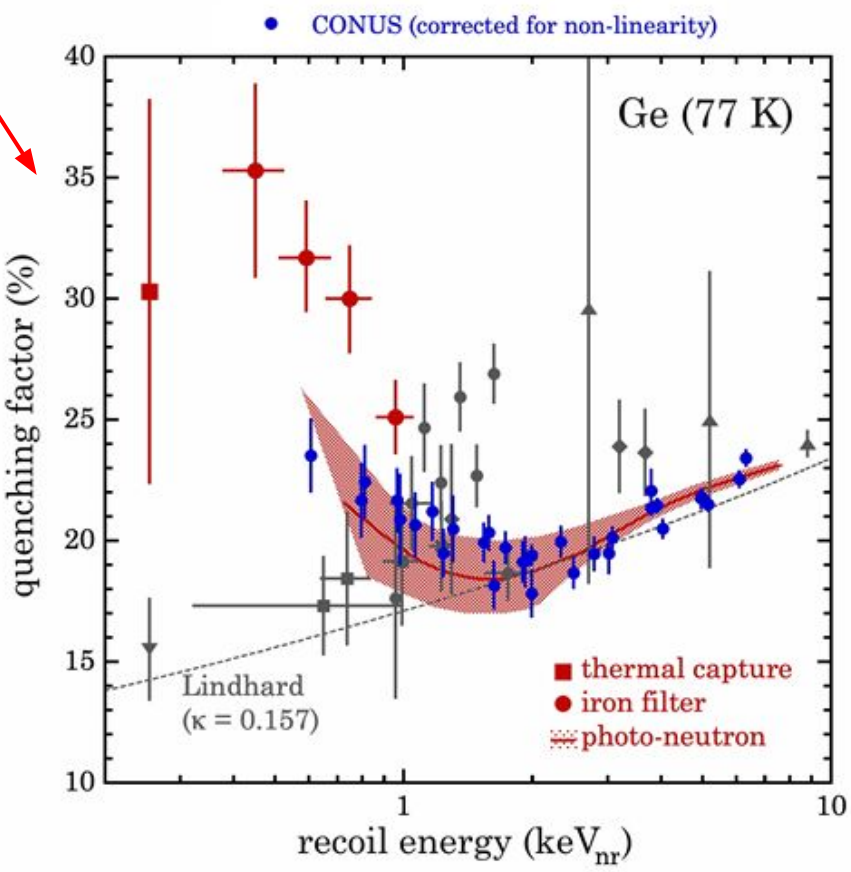
⇢ Backgrounds O(1 ckkd) fairly constant all the way to threshold

Thanks

Questions?

Extra: QFs in Ge





two main points:

improvised energy scale uncertainty ↠ (Monte Carlo used to demonstrate)

underestimated treatment (flat 10 eV) of ballistic deficit from DAQ ↠ quoted numbers used to infer the correction (see right)

*comments on CONUS sub-keV QF paper: arXiv:2203.00750