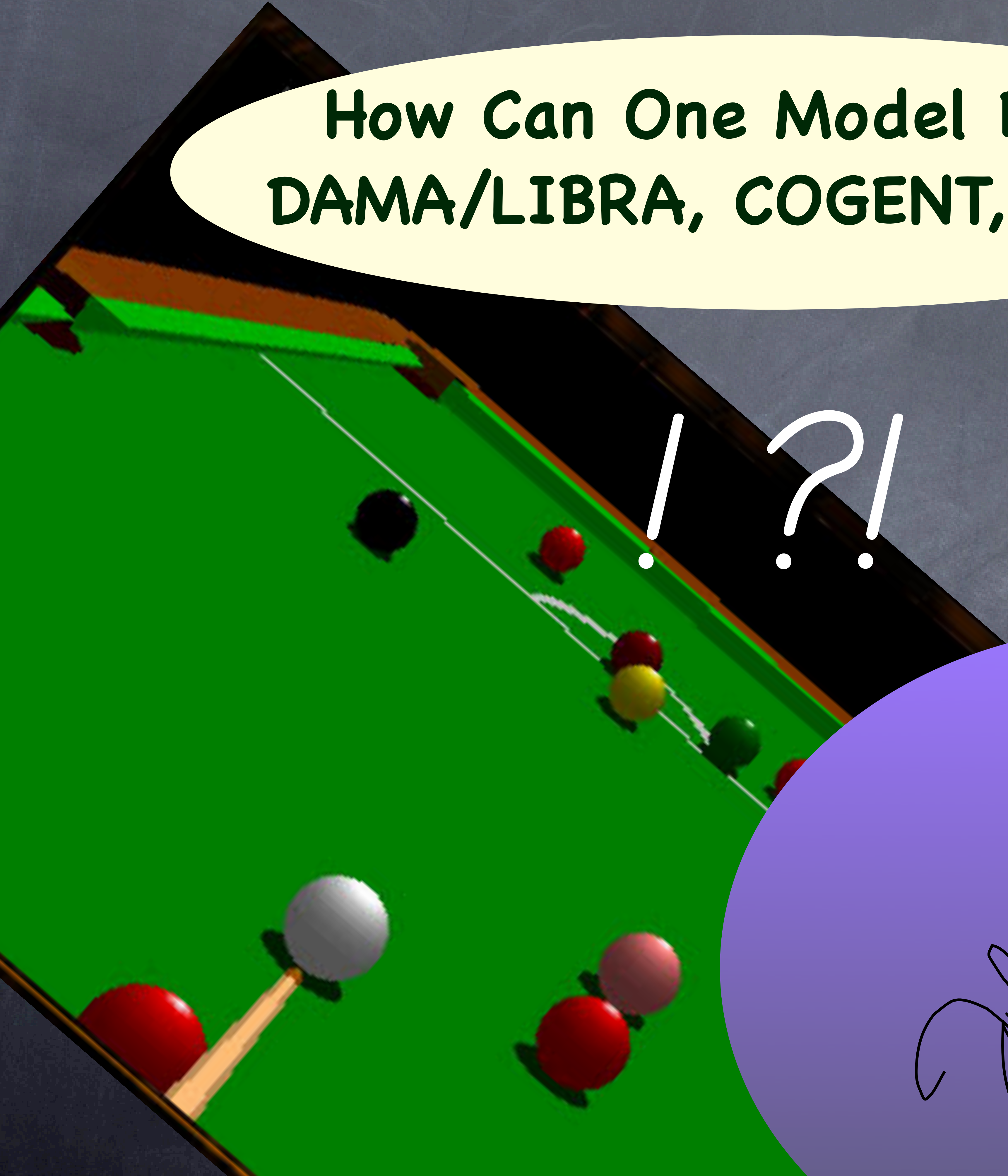
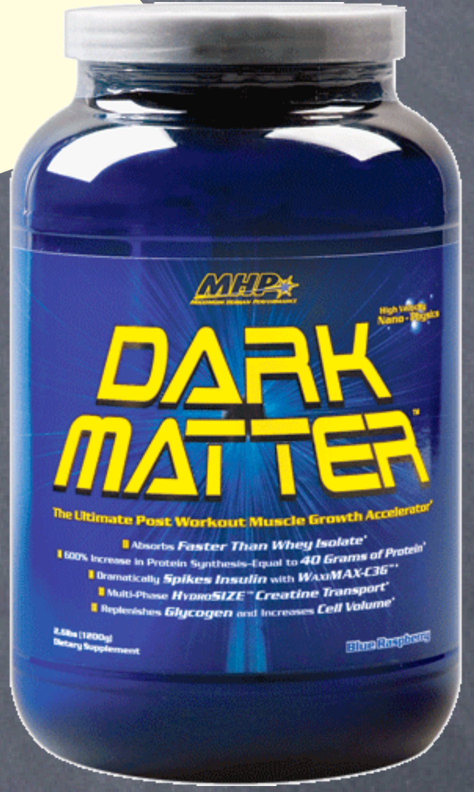
How Can One Model Explain DAMA/LIBRA, COGENT, CDMS ?



! ?!



John Ralston

background !

background !

background !

"the undiscussed problems" of...

- Calibration and backgrounds via naive SIGNAL model
- Consistent neglect of RESONANT processes
- ...and the revenge of the NEUTRON

Basic Misconceptions of Experimental Community I:

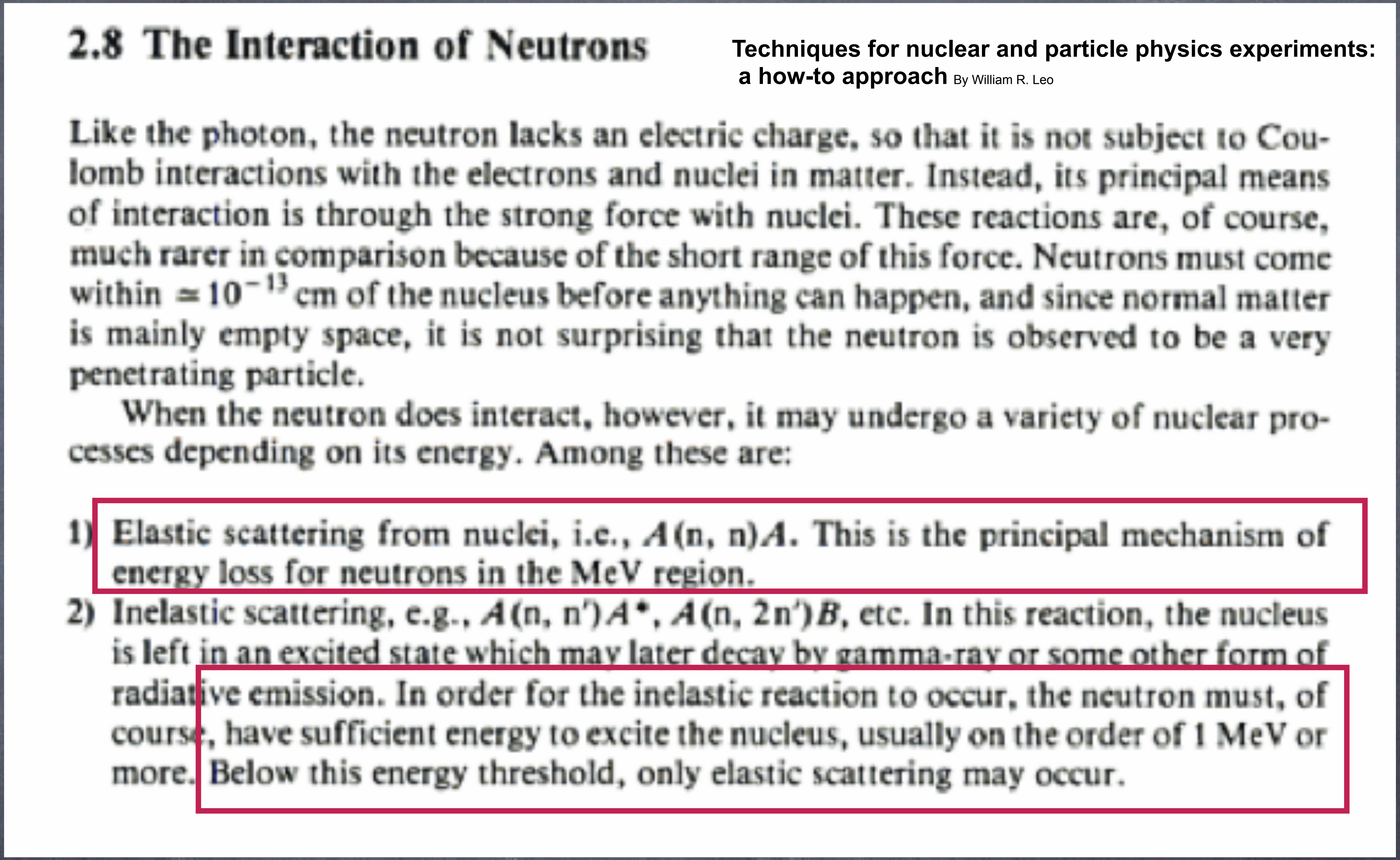
“neutron scattering is elastic 2-2...”

↓

(just like wimps, but with smaller mass...)

↓

...unless enough energy to excite a nuclear level...



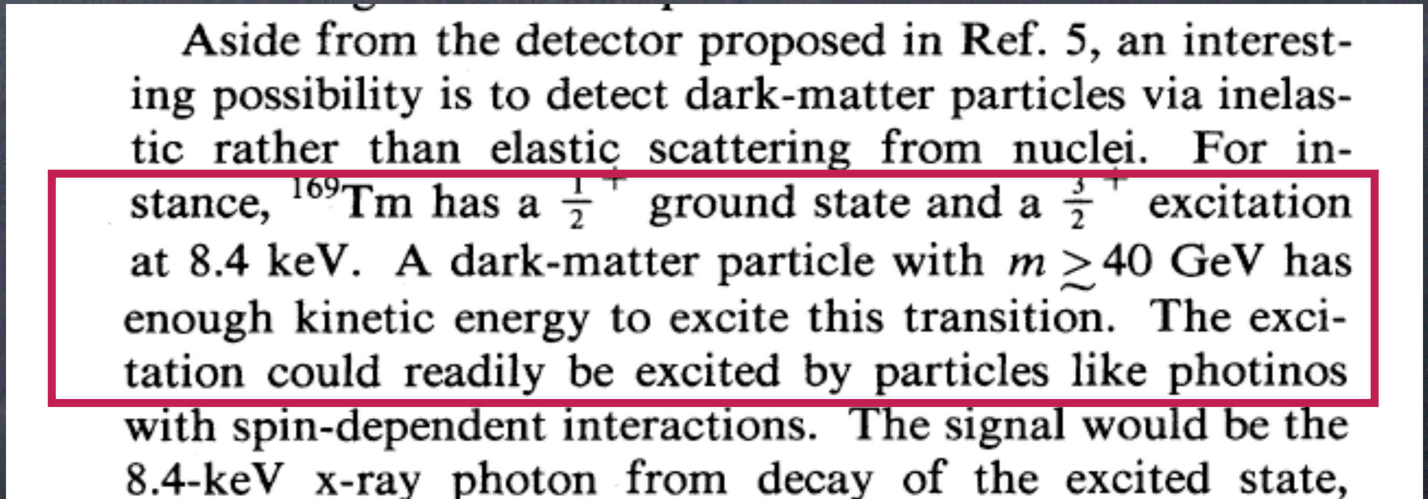
2.8 The Interaction of Neutrons

Techniques for nuclear and particle physics experiments: a how-to approach By William R. Leo

Like the photon, the neutron lacks an electric charge, so that it is not subject to Coulomb interactions with the electrons and nuclei in matter. Instead, its principal means of interaction is through the strong force with nuclei. These reactions are, of course, much rarer in comparison because of the short range of this force. Neutrons must come within $\simeq 10^{-13}$ cm of the nucleus before anything can happen, and since normal matter is mainly empty space, it is not surprising that the neutron is observed to be a very penetrating particle.

When the neutron does interact, however, it may undergo a variety of nuclear processes depending on its energy. Among these are:

1) Elastic scattering from nuclei, i.e., $A(\mathrm{n},\mathrm{n})A$. This is the principal mechanism of energy loss for neutrons in the MeV region.
2) Inelastic scattering, e.g., $A(\mathrm{n},\mathrm{n}')A^*$, $A(\mathrm{n},2\mathrm{n}')B$, etc. In this reaction, the nucleus is left in an excited state which may later decay by gamma-ray or some other form of radiative emission. In order for the inelastic reaction to occur, the neutron must, of course, have sufficient energy to excite the nucleus, usually on the order of 1 MeV or more. Below this energy threshold, only elastic scattering may occur.

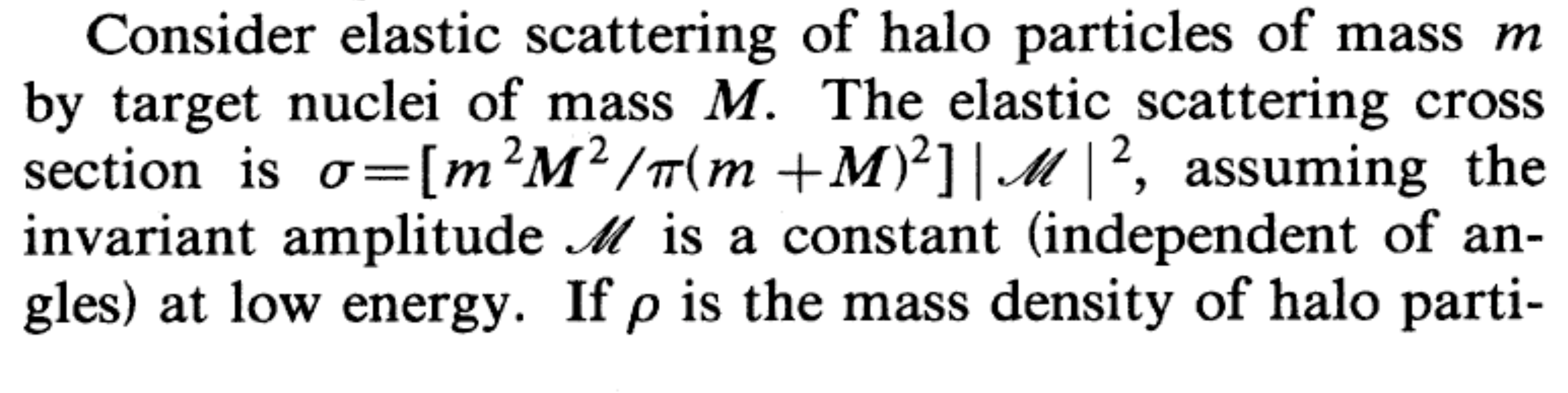


Aside from the detector proposed in Ref. 5, an interesting possibility is to detect dark-matter particles via inelastic rather than elastic scattering from nuclei. For instance, ^{169}Tm has a $\frac{1}{2}^+$ ground state and a $\frac{3}{2}^+$ excitation at 8.4 keV. A dark-matter particle with $m \gtrsim 40$ GeV has enough kinetic energy to excite this transition. The excitation could readily be excited by particles like photinos with spin-dependent interactions. The signal would be the 8.4-keV x-ray photon from decay of the excited state,

M. Goodman and E. Witten, PRD 31,1985

Basic Misconceptions II:

"low energy cross sections are constant (in energy, angle, etc) " (not !)



Consider elastic scattering of halo particles of mass m by target nuclei of mass M. The elastic scattering cross section is $\sigma=[m^2M^2/\pi(m+M)^2]|\mathscr{M}|^2$, assuming the invariant amplitude $\mathscr{M}$ is a constant (independent of angles) at low energy. If ρ is the mass density of halo parti-

M. Goodman and E. Witten, PRD 31,1985

...and so, theory models for *wimps* came to be used for estimating *reality*....

CALIBRATIONS!!

AFTER THAT, everyone's favorite billiard ball model follows...

$$\Delta E \sim E_X \frac{2m_T m_X}{(m_T + m_X)^2}(1 - cos\theta).$$

for 10 KeV, select the angle: $(1 - cos\theta) \sim \frac{2m_T}{m_n}\frac{10KeV}{E_n} \to 0$

- DAMA/LIBRA - calibrate at accelerator 2.45 MeV n beam

  Chagani˙NaIrecoils˙idm2006

- CDMS - calibrate with 252 Cf source, MeV n peak

  Phys.Rev.Lett.102:011301,2009, Phys.Rev.D66:122003,2002.

- COGENT - calibrate with monochromatic n beam, 24 KeV

  JCAP 0709:009,2007; NIM A 574 (2007) 385

P. Barnes, 96 Dissertation, early expressed:

``One line of defense against the muon-induced (underground) neutrons is to moderate the neutrons below detector threshold before they reach the detector. Note than an 18 KeV neutron has a maximum energy deposition on germanium of 1 KeV. ''

(and THERMAL energy is defined as 0.024 eV)

famous quotations, in tiny font

while Ge and Si have similar scattering rates per nucleon for neutrons, Ge is 5–7 times more efficient than Si for coherently scatteringWIMPs **CDMS Phys.Rev.D68:082002,2003**

As in the previous experiment, the propagation of these neutrons was simulated accurately, as confirmed by comparison with veto-coincident and calibration-source neutrons CDMS **Phys.Rev.Lett.102:011301,2009**

Over 600,000 events were recorded using the 252Cf source during five separate periods throughout the runs, including more than 105 nuclear recoils used to characterize WIMP acceptance. **Phys.Rev.Lett.102:011301,2009**

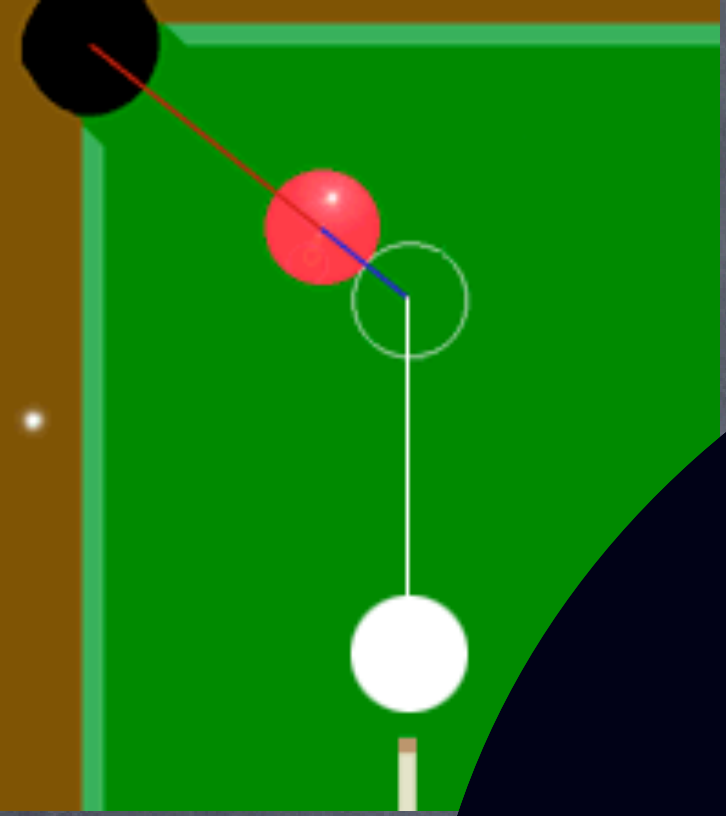
Neutrons induced by radioactive processes or by cosmic-ray muons interacting near the apparatus can generate nuclear-recoil events that cannot be distinguished from possible dark matter interactions on an event-by-event basis. Monte Carlo simulations of the cosmic-ray muons and subsequent neutron production and transport have been conducted with FLUKA [13], MCNPX [14] and GEANT4 [15] to estimate this cosmogenic neutron background. **Phys.Rev.Lett.102:011301,2009**

Two methods are used to measure this flux of unvetoed external neutrons. The first method involves comparing the rate of nuclear-recoil events in the Ge detectors
with the rate in the Si detector, since Ge is more sensitive to WIMPS and Si is more sensitive to neutrons.
The second method is to count the number of events consisting of nuclear recoils in two or more detectors **Phys.Rev.D66:122003,2002**.

The energy deposited in the detector by an interacting particle is called “recoil energy” ER. If the particle interacts with an electron or electrons (e.g. by Compton scattering, K-capture, etc.), the event is called an electron recoil; if the particle interacts with a nucleus (e.g. by WIMP-nucleus or neutron-nucleus elastic scattering), the event is a nuclear recoil. Most of the recoil energy is converted almost immediately into phonons, **Phys.Rev.D66:122003,2002**.

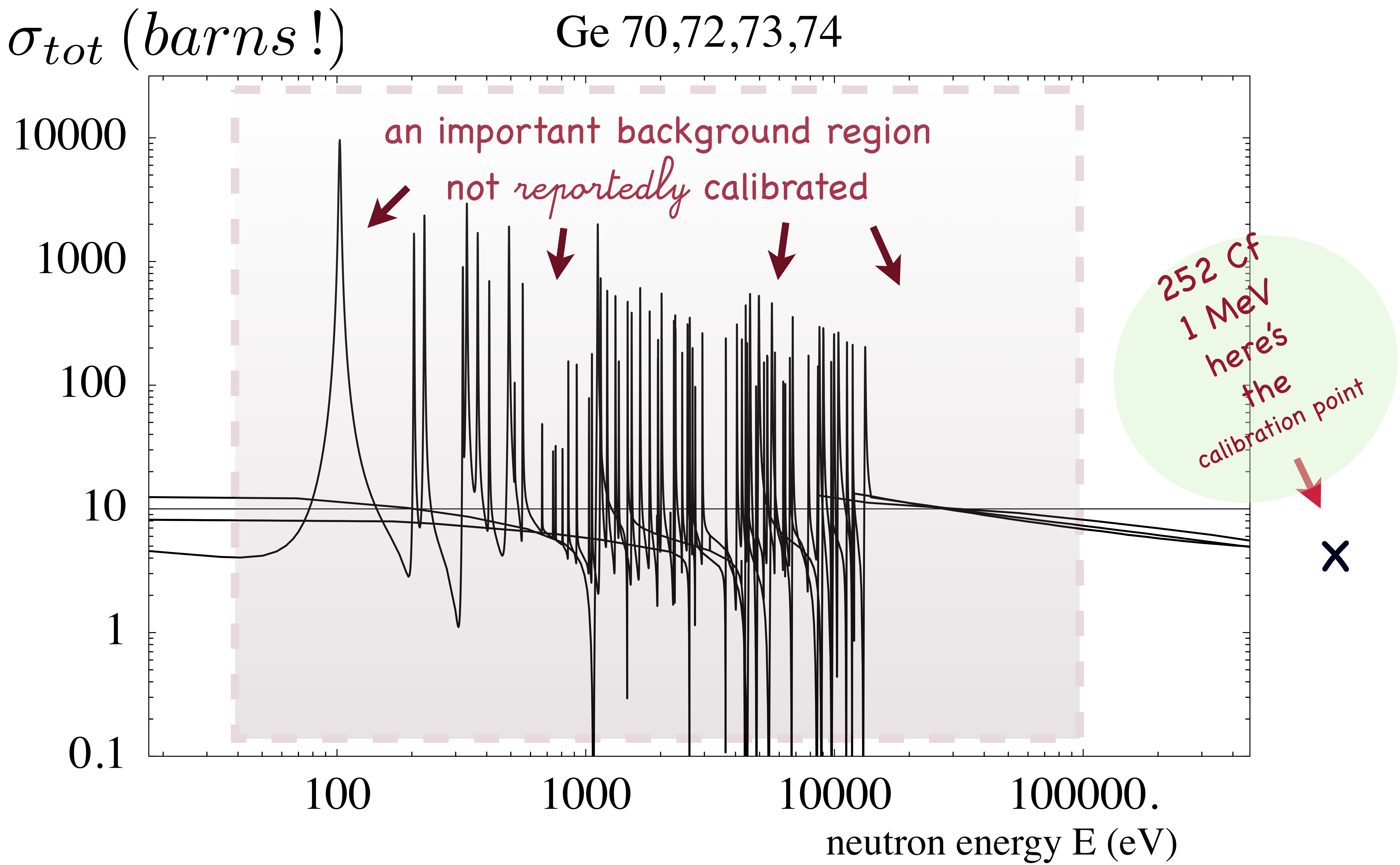
In order to provide nuclear-recoil events that mimicWIMP interactions, a 252Cf-fission neutron source is placed on the top face of the scintillator veto. Because the neutrons emitted by this source have such low energies (see e.g. [54]), the top layers of polyethylene insidethe shield are removed to permit the neutrons to penetrate to the cryostat. With the source and shielding in this configuration, the data set is dominated by neutrons, making the total event rate about 3 times higher than during low-background data-taking. In all other ways, the data-taking conditions are as usual. The source activity is known to ~5% accuracy, so the absolute normalization of the spectrum is well determined **Phys.Rev.D66:122003,2002**.

For a low-mass WIMP, estimates of the neutron background have no effect **Phys.Rev.D66:122003,2002**.



Unfortunately,
Neutrons
Misbehave

Neutron Cross Sections

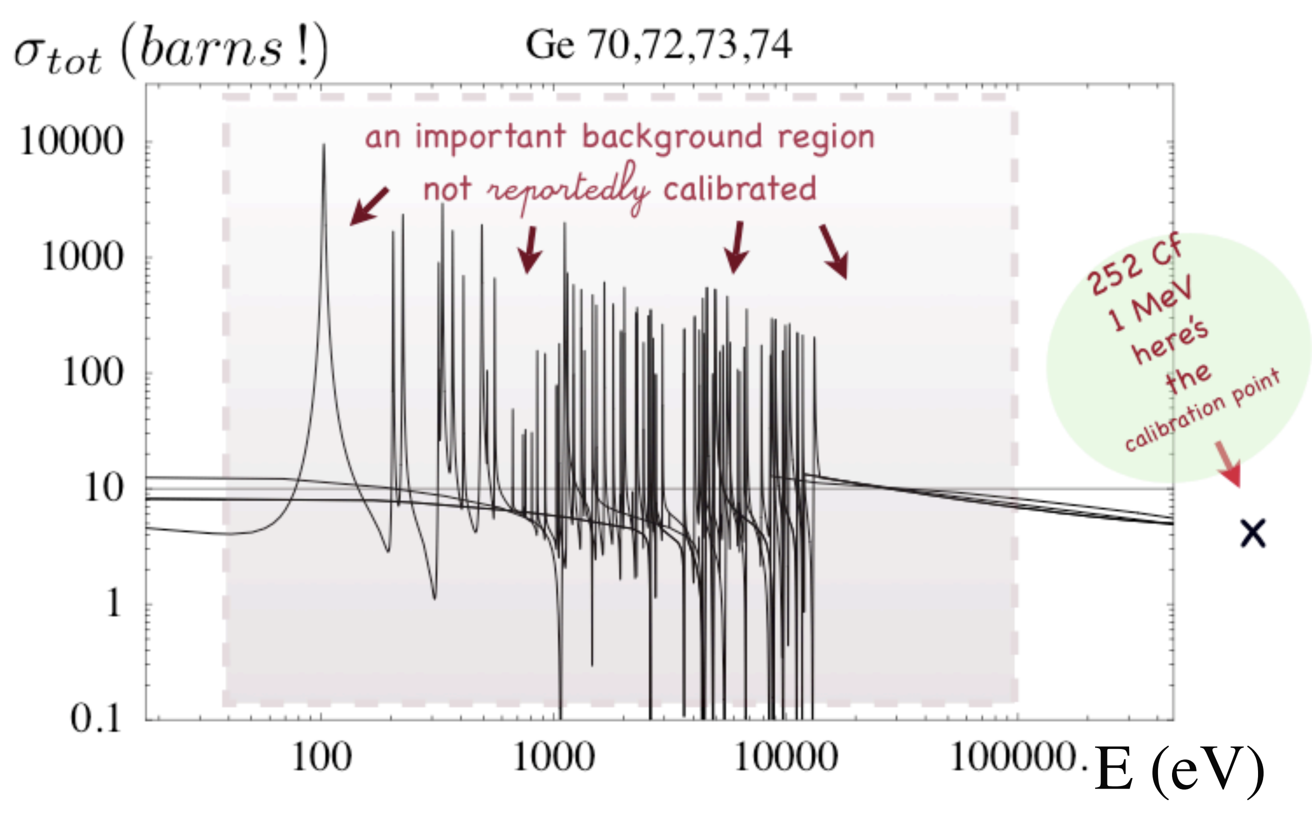


an important background region
not reportedly calibrated

252 Cf
1 MeV
here's
the
calibration point

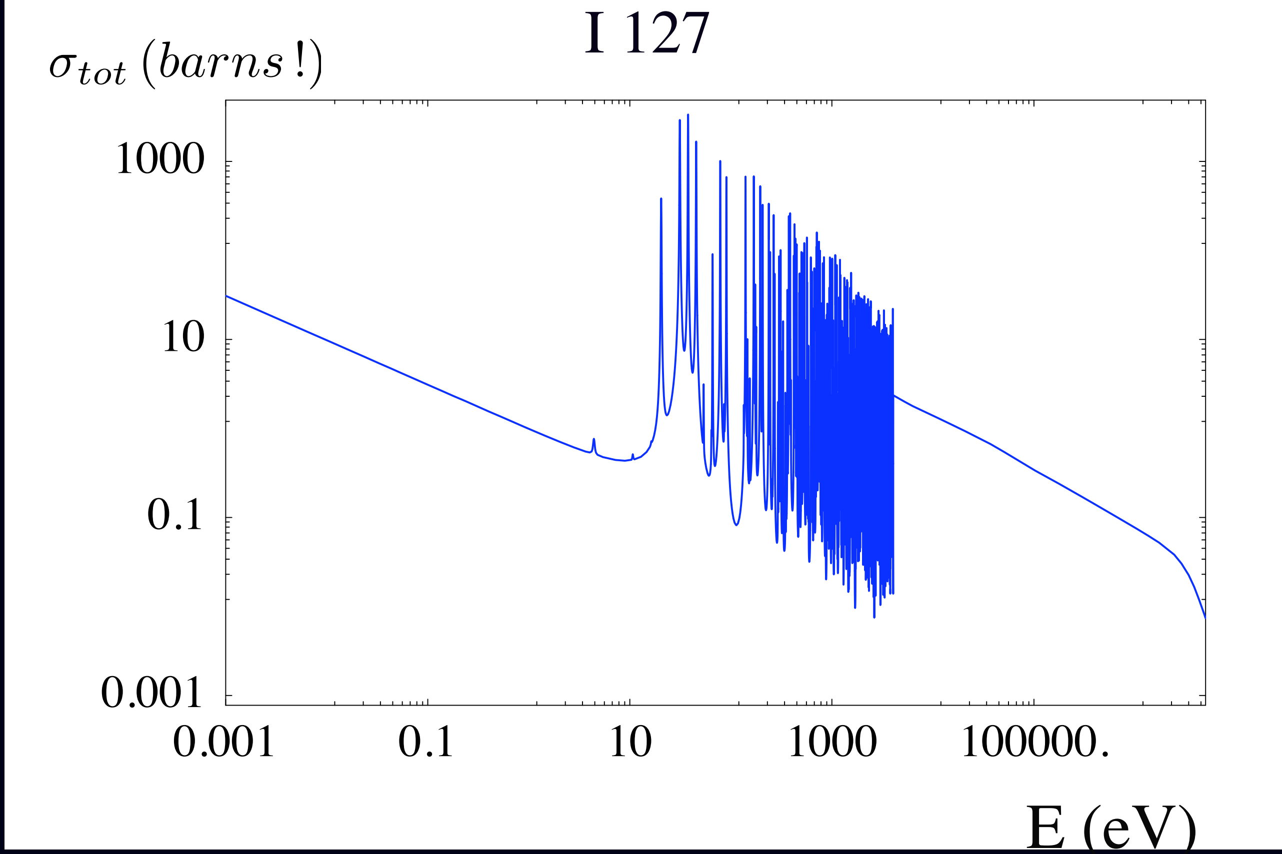
nuDat

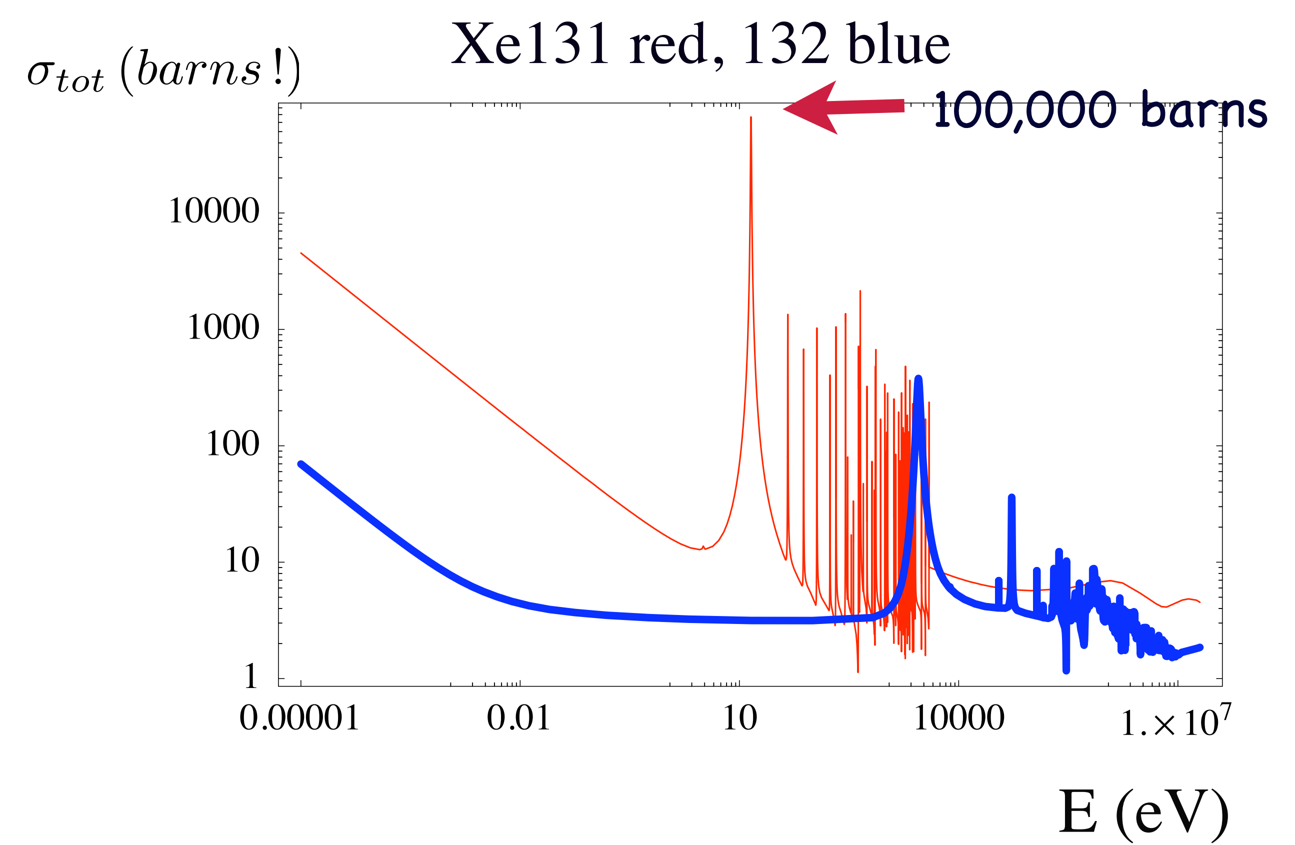
Neutrons Misbehave A Lot


Ge 70,72,73,74

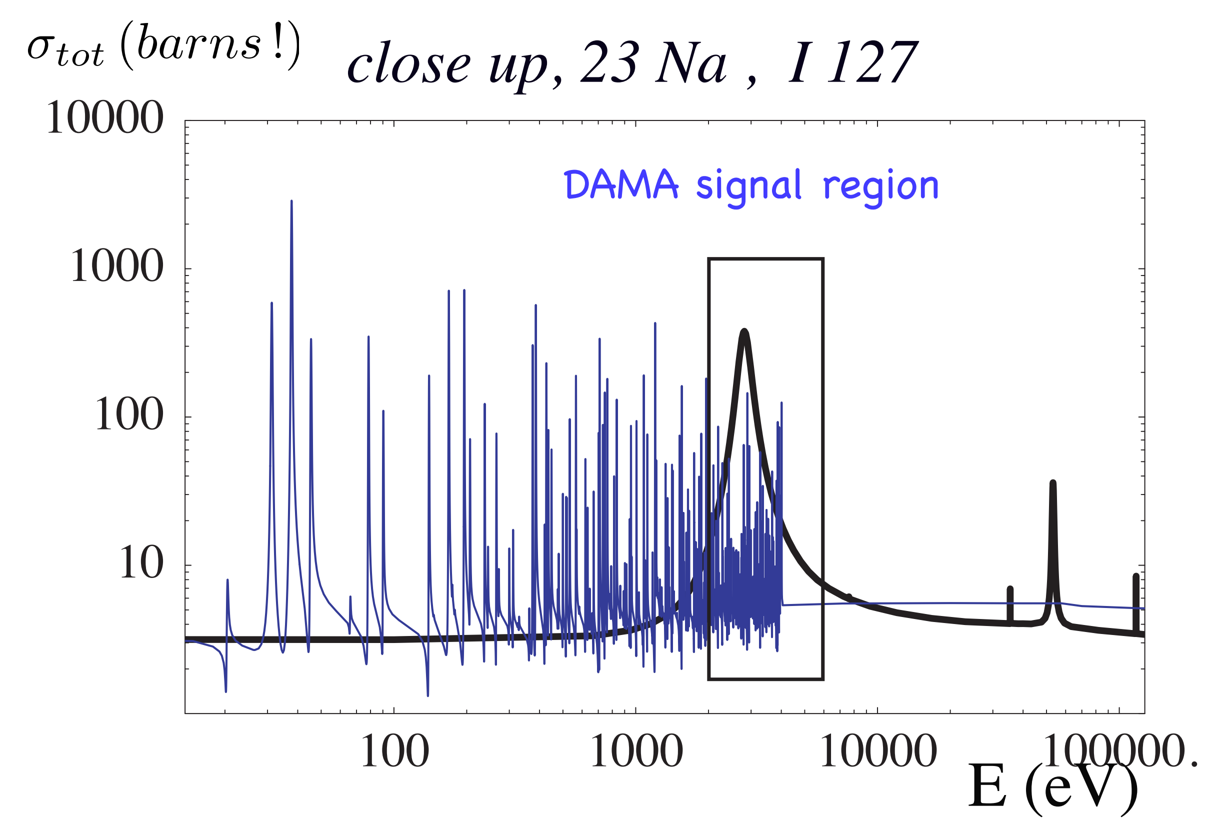
an important background region not reportedly calibrated

252 Cf 1 MeV here's the calibration point


I 127


Xe131 red, 132 blue

100,000 barns

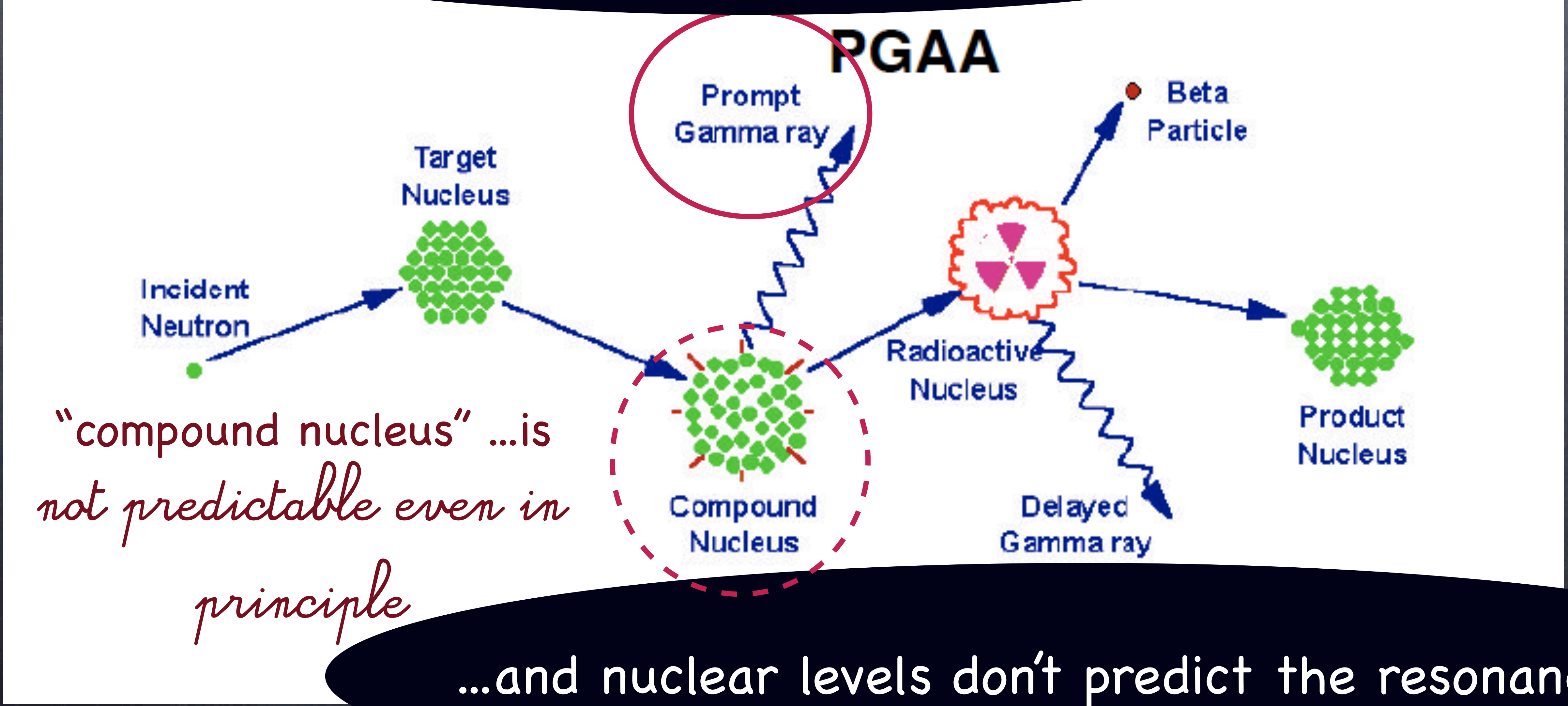

close up, 23 Na , I 127

DAMA signal region

data: nuDat

Processes not reported, for reasons we can't explain

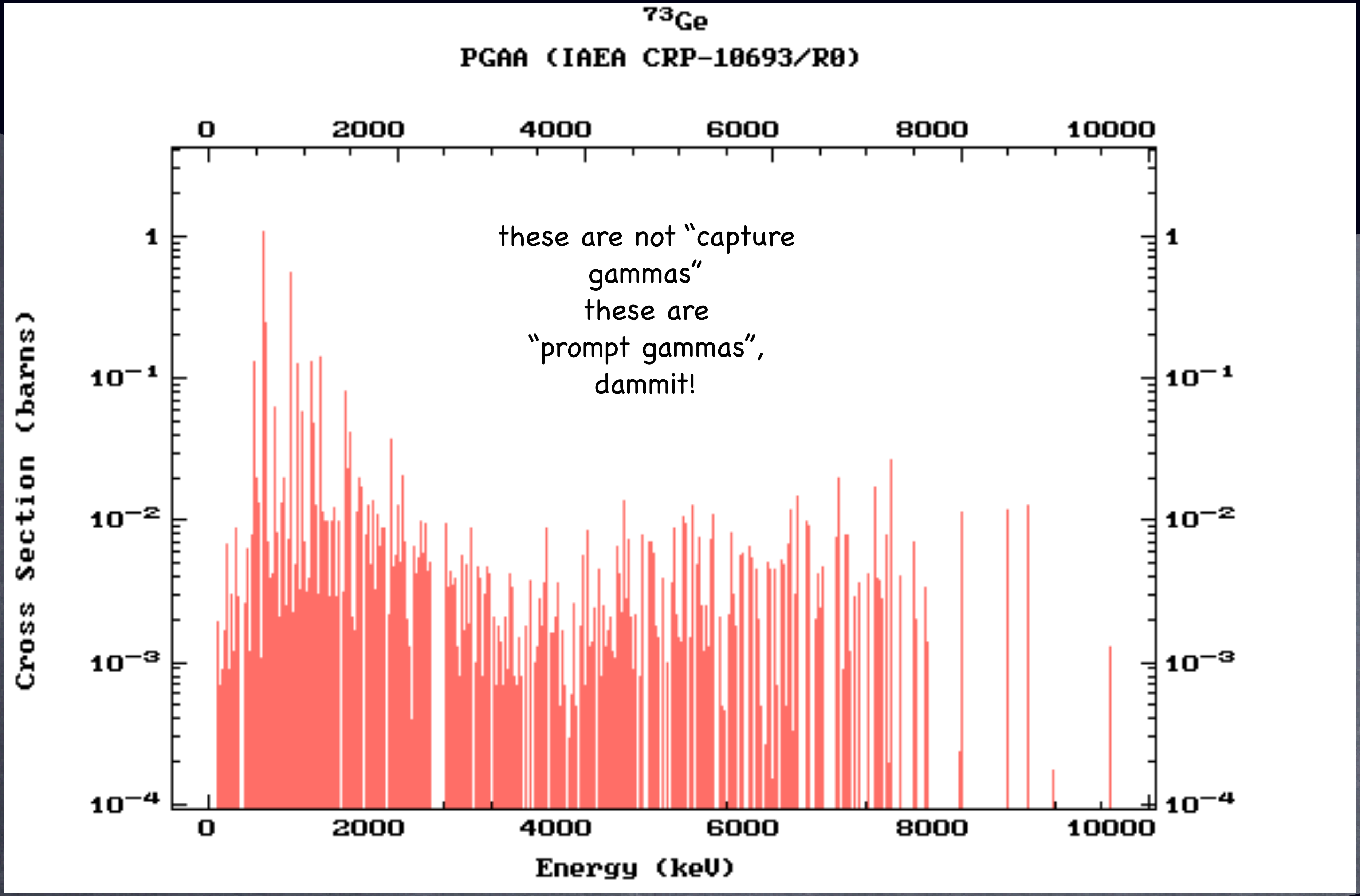
not just captures, but prompt gammas by the score...



"compound nucleus" ...is *not predictable even in principle*

...and nuclear levels don't predict the resonances

Germanium is a complicated substance visa-vis thermal neutrons



these are not "capture gammas"
these are "prompt gammas", dammit!

(and each isotope is different)

(low energy cutoff is due to detectors and *internal conversion*...

not an end to spectrum)

data: iaea PGAA

415 gammas in Budapest set. 831 gammas in ENSDF

70Ge Sigma=3.15 16 b %Abundance=21.23 4
72Ge Sigma=0.98 9 b %Abundance=27.66 3
73Ge Sigma=15.0 20 b %Abundance=7.73 1
74Ge Sigma=0.34 8 b %Abundance=35.94 2

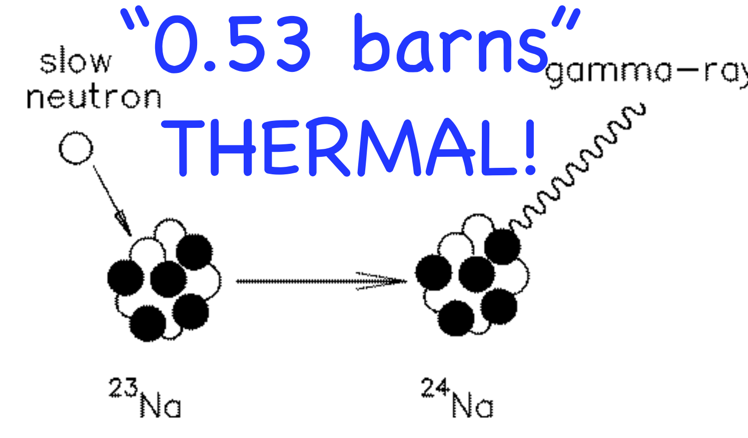
76Ge Sigma=0.060 10 b %Abundance=7.44 2

``The set is not complete, missing about 28\% of the total energy and 74\% of the gamma rays from the capture level." Reedy

"The EGAF database is often incomplete because continuum gamma -rays can comprise up to 90% of the spectrum. " RB Firestone et al,

what's *reported* for neutron backgrounds?

- DAMA/LIBRA: ``In fact, environmental neutrons would induce the reaction $^{23}Na(n; \gamma)^{24}Na$ with 0.1 barn cross-section and the reaction $^{23}Na(n; \gamma)^{24m}Na with 0.43 barn cross-section". NIM A 592 (2008) 297



"0.53 barns"
THERMAL!

- CDMS: determined by simulations. Cannot in principle discriminate against neutrons

Neutrons induced by radioactive processes or by cosmic-ray muons interacting near the apparatus can generate nuclear-recoil events that cannot be distinguis
from possible dark matter interactions on an event-by-event basis. **Phys.Rev.Lett.102:011301,2009**

- COGENT : can't find a mention of neutron cross sections or rates.

Activation on Earth surface ...is mentioned astro-ph /1002.4703v2

Calibration by billiards ...is done JCAP 0709:009,2007; NIM A 574 (2007) 385

No mention found of resonant processes

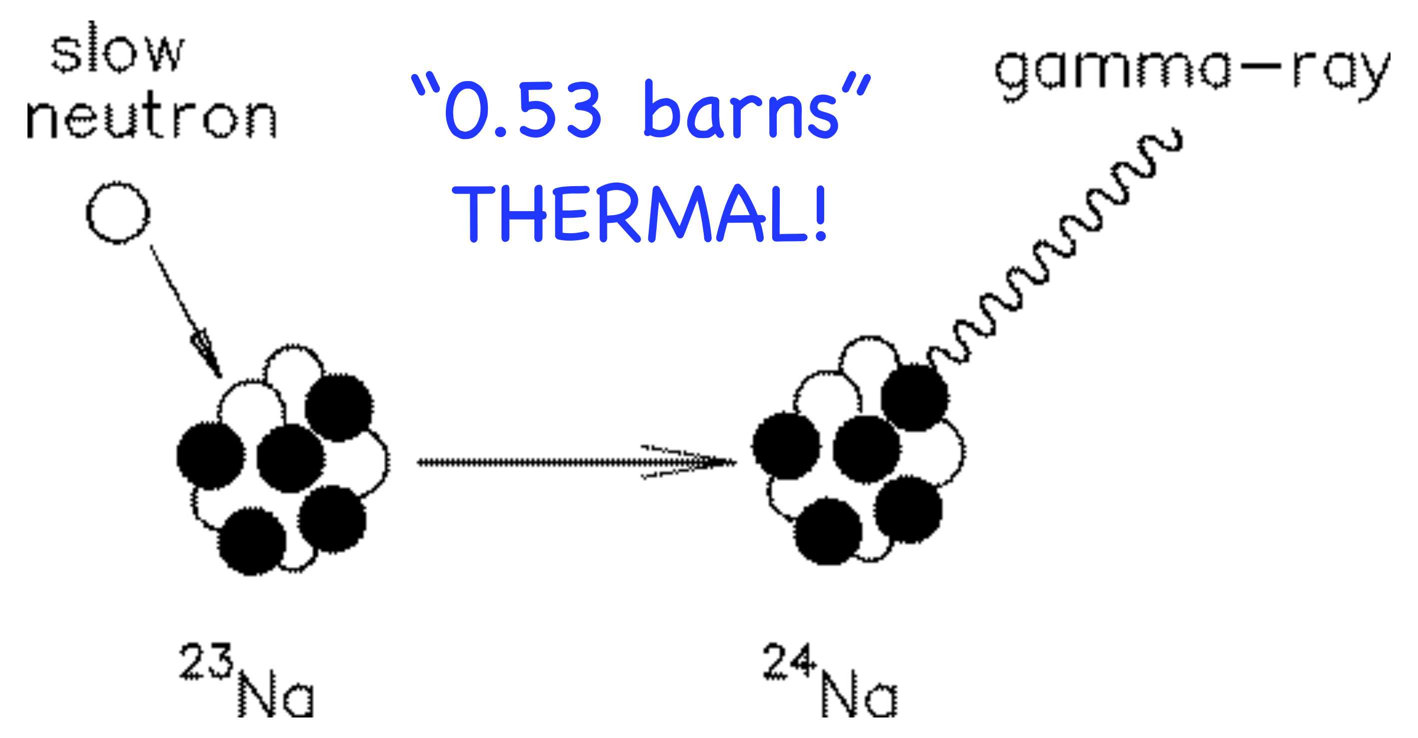
Consequences so far:

- calibrations ...being based on billiard balls... don't cover energy range of experiment
- quenching factors are unknown? why not!
- backgrounds are unknown? why not !
- rates of activation known ? how and why?
- annual variations are everywhere.

Even muon show it!

Dama's *discussed* process of neutron capture and activation...

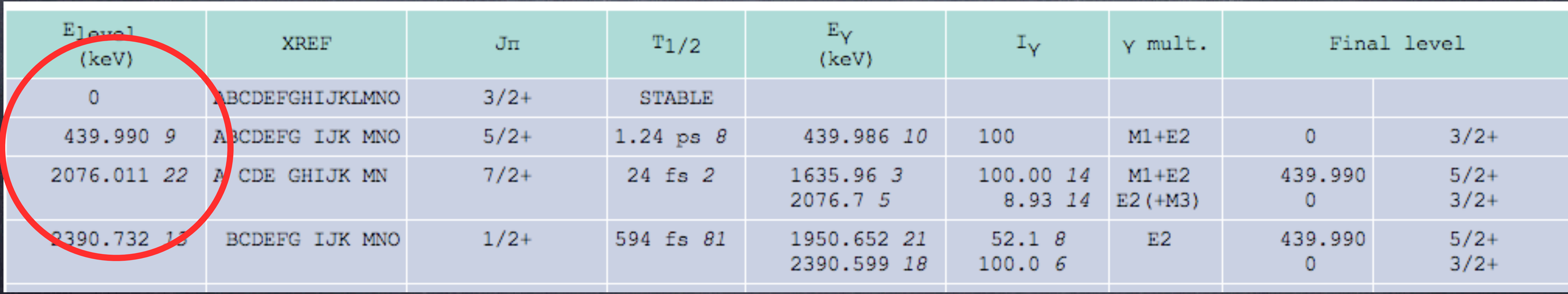
430 KeV gap. Safe !



"0.53 barns" THERMAL!

(OK, *this is discussed*...)

go consult 23Na Levels...looks safe!



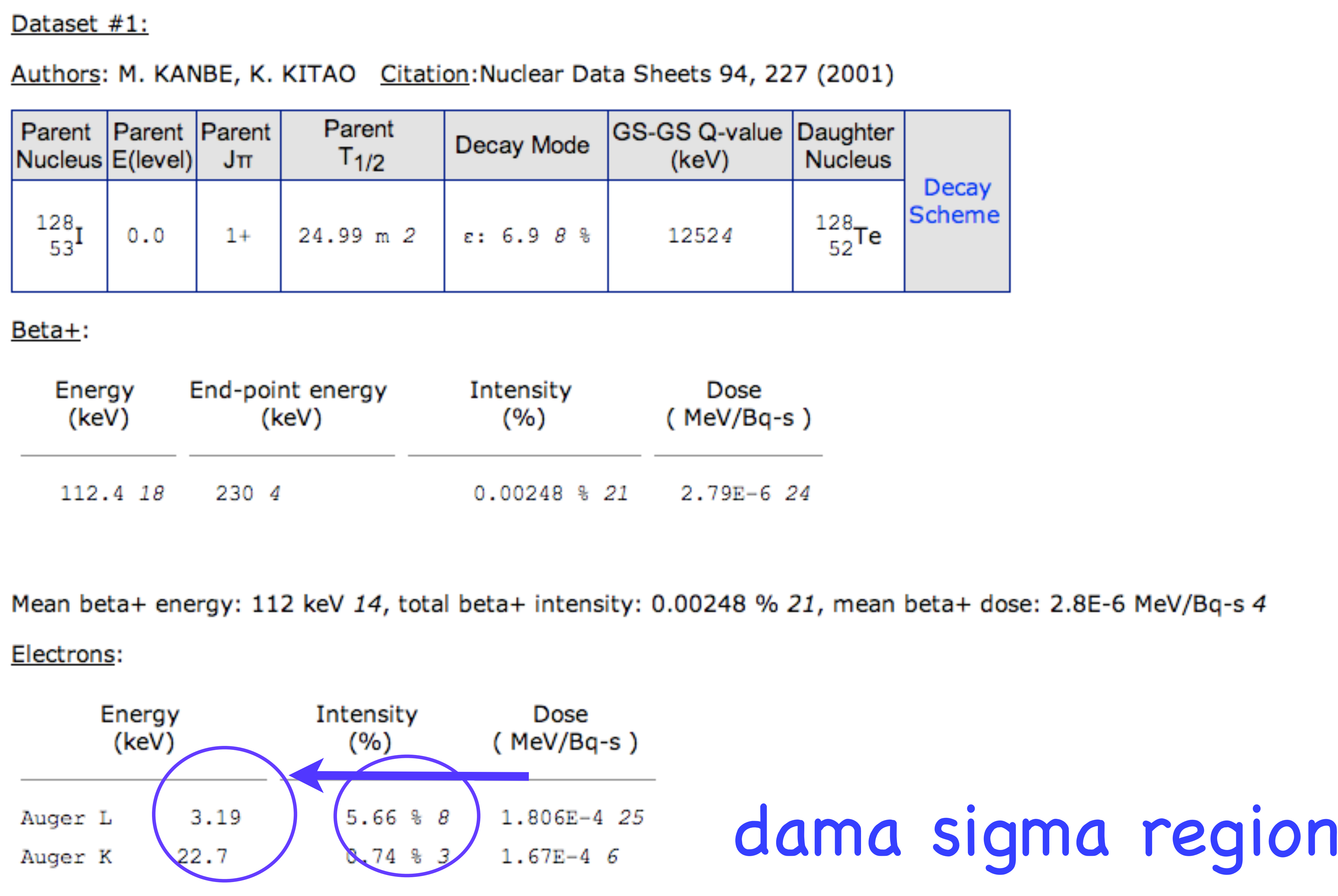
E_{level} (keV)	XREF	Jπ	$T_{1/2}$	E_γ (keV)	I_γ	γ mult.	Final level	
0	ABCDEFGHIJKLMNO	3/2+	STABLE					
439.990 *9*	ABCDEFG IJK MNO	5/2+	1.24 ps *8*	439.986 *10*	100	M1+E2	0	3/2+
2076.011 *22*	A CDE GHIJK MN	7/2+	24 fs *2*	1635.96 *3* 2076.7 *5*	100.00 *14* 8.93 *14*	M1+E2 E2(+M3)	439.990 0	5/2+ 3/2+
2390.732 *13*	BCDEFG IJK MNO	1/2+	594 fs *81*	1950.652 *21* 2390.599 *18*	52.1 *8* 100.0 *6*	E2	439.990 0	5/2+ 3/2+

NuDat-BNL

Dama's undiscussed problem:

.... no mention *found* of Iodine, *with epithermal* sigma = 160 barns;

24.99 minutes later, 128I decays



Dataset #1:

Authors: M. KANBE, K. KITAO Citation:Nuclear Data Sheets 94, 227 (2001)

Parent Nucleus	Parent E(level)	Parent Jπ	Parent $T_{1/2}$	Decay Mode	GS-GS Q-value (keV)	Daughter Nucleus	Decay Scheme
$^{128}_{53}$I	0.0	1+	24.99 m *2*	ε: 6.9 *8* %	12524	$^{128}_{52}$Te	

Beta+:

Energy (keV)	End-point energy (keV)	Intensity (%)	Dose (MeV/Bq-s)
112.4 *18*	230 *4*	0.00248 % *21*	2.79E-6 *24*

Mean beta+ energy: 112 keV *14*, total beta+ intensity: 0.00248 % *21*, mean beta+ dose: 2.8E-6 MeV/Bq-s *4*

Electrons:

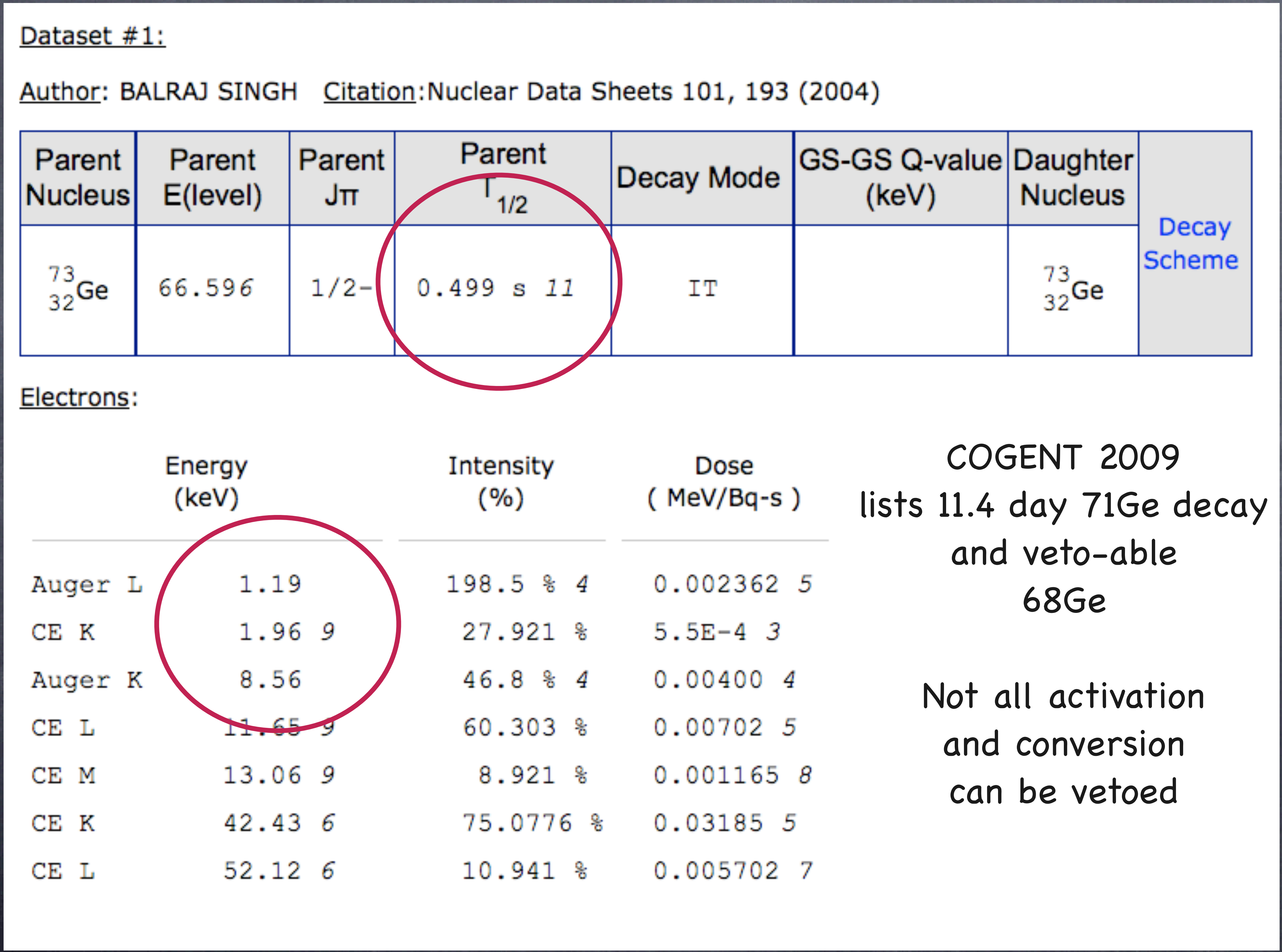
	Energy (keV)	Intensity (%)	Dose (MeV/Bq-s)
Auger L	3.19	5.66 % *8*	1.806E-4 *25*
Auger K	22.7	0.74 % *3*	1.67E-4 *6*

dama sigma region

ya can't veto this

data Nudat-BNL

COGENT's undiscussed problem: internal conversion



Dataset #1:

Author: BALRAJ SINGH   Citation:Nuclear Data Sheets 101, 193 (2004)

Parent Nucleus	Parent E(level)	Parent Jπ	Parent $T_{1/2}$	Decay Mode	GS-GS Q-value (keV)	Daughter Nucleus	Decay Scheme
$^{73}_{32}$Ge	66.596	1/2-	0.499 s *11*	IT		$^{73}_{32}$Ge	

Electrons:

	Energy (keV)	Intensity (%)	Dose (MeV/Bq-s)
Auger L	1.19	198.5 % *4*	0.002362 *5*
CE K	1.96 *9*	27.921 %	5.5E-4 *3*
Auger K	8.56	46.8 % *4*	0.00400 *4*
CE L	11.65 *9*	60.303 %	0.00702 *5*
CE M	13.06 *9*	8.921 %	0.001165 *8*
CE K	42.43 *6*	75.0776 %	0.03185 *5*
CE L	52.12 *6*	10.941 %	0.005702 7

COGENT 2009
lists 11.4 day 71Ge decay
and veto-able
68Ge

Not all activation
and conversion
can be vetoed

data Nudat-BNL

KEV-SCALE GAMMAs tend to INTERNALLY CONVERT

Ge M internal conversion

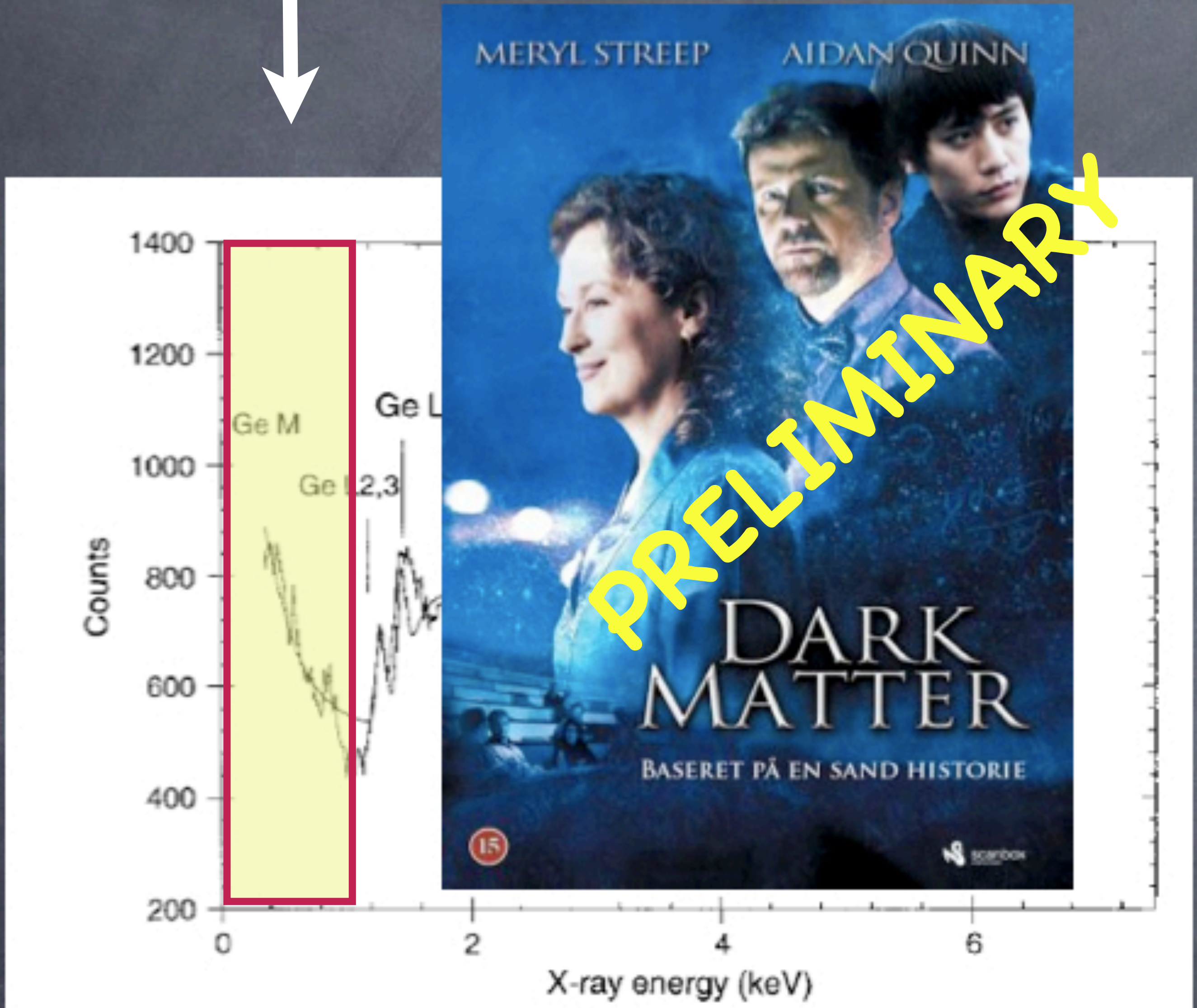
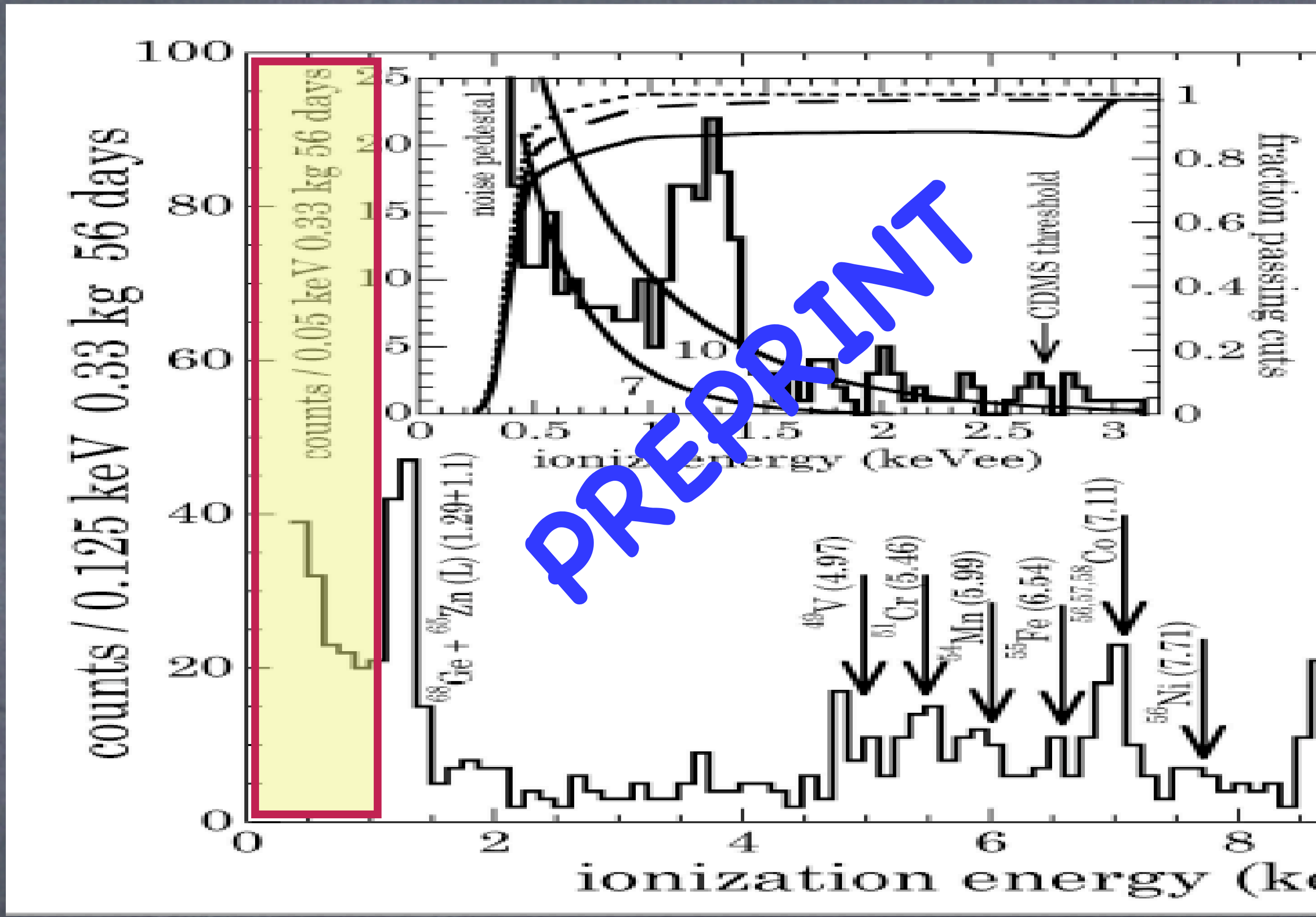


Figure 10. The low-energy part of Fig. 4(b), where the tail originating from energetic electron transport across the detector electrode interface is fitted by Eqn (1) with the kernel of Eqn (2) and convoluted with the Gaussian response of the detector-signal-processor electronics.

Papp 2003 8.4 KeV x-ray beam

COGENT signal 2010

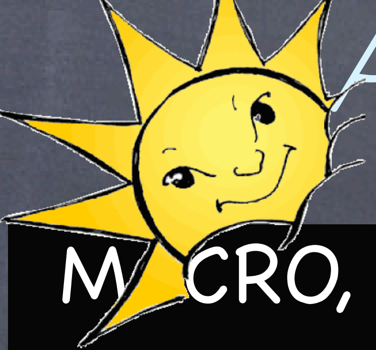
for which we propose Ge M...



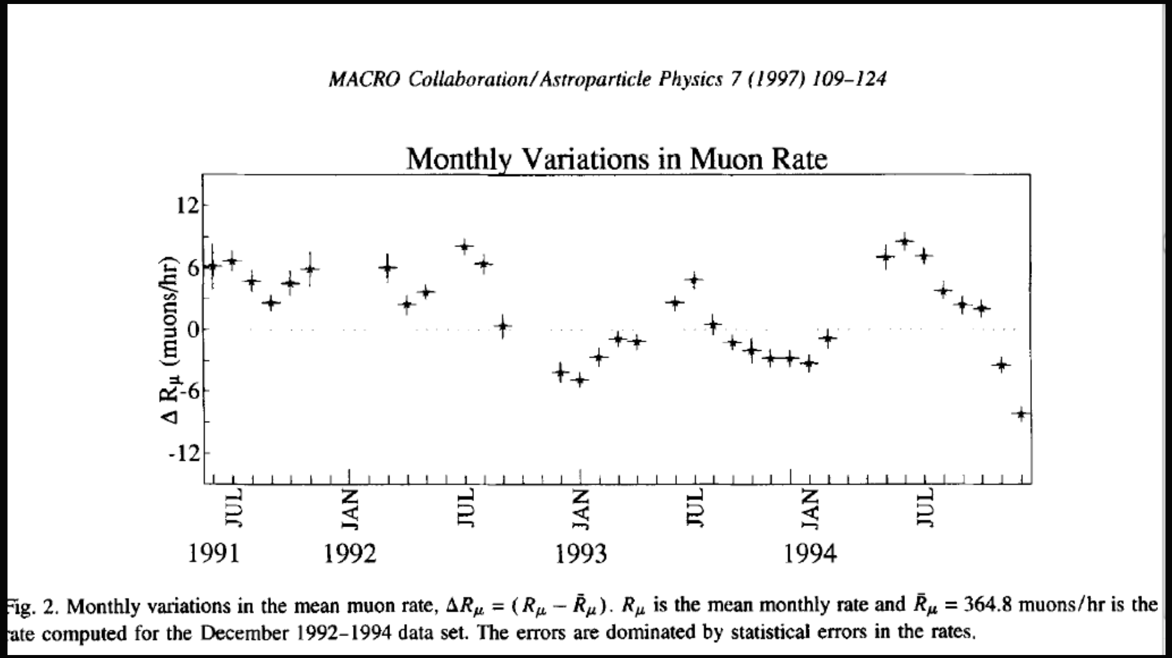
“Prudence and past experience prompt us to continue work to exhaust less exotic possibilities. We extend an invitation to other researchers in this field to proceed with the same caution.”

(...recall 73Ge makes 8.56 KeV Auger)

Annual Variations Everywhere



MACRO, Astropart Phys 7, 109 (1997) measures annual variation of undergound muons



MACRO Collaboration/Astroparticle Physics 7 (1997) 109–124

ig. 2. Monthly variations in the mean muon rate, $\Delta R_\mu = (R_\mu - \bar{R}_\mu)$. R_μ is the mean monthly rate and $\bar{R}_\mu$ = 364.8 muons/hr is the ate computed for the December 1992–1994 data set. The errors are dominated by statistical errors in the rates.

icarus TM/03-01
divulges 5%
annual variation
of underground
"neutron fluxes"

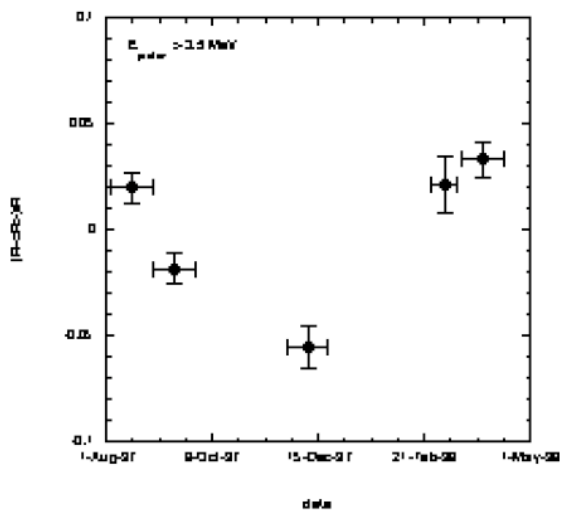


Fig. 2 "Neutron" signal: the mean rate deviation (R-<R>)/R versus time at LNGS.

Radon, Gran Sasso Hall A

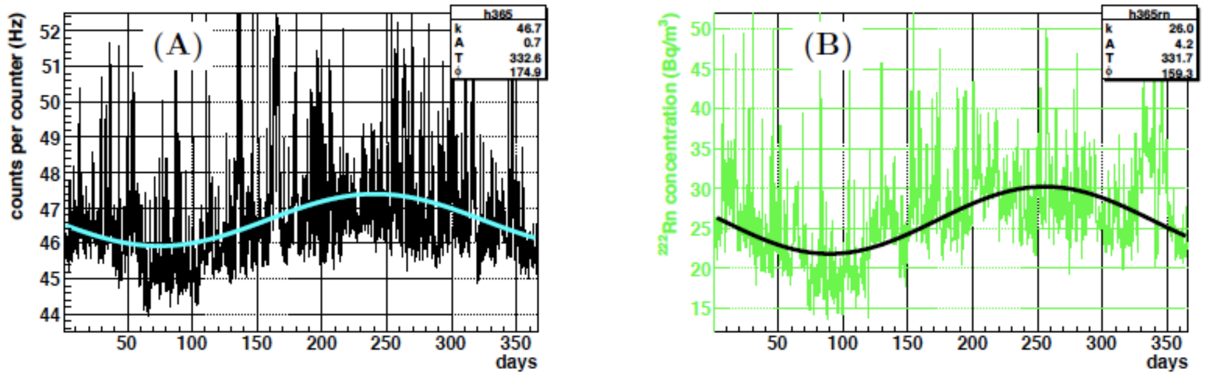


Figure 4. Yearly LTCR (A) and Rn concentration (B) averaged over 6 years (1997-2002) and fitted with the function $k + A \cdot sin(\frac{2\pi}{T}(x+\phi))$.

G. Bruno, Journal of Physics: Conference Series 203 (2010) 012091

(for Soudan, see M. Goodman 98)

radon in bedrooms in England...

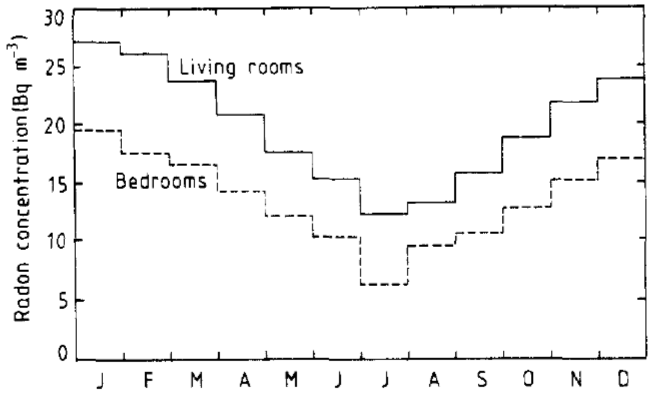


Figure 5. Mean annual variation in radon concentration in ground-floor living rooms and first-floor bedrooms in about 2000 UK dwellings.

Maybe all these problems
are well-known to a few experts
inside collaborations....

...but then why aren't they appearing in every single conference talk and journal article?

(The business of backgrounds is not MY burden of proof)

Positive Suggestions

Why not calibrate everything all beams full energy range at accelerators, reactors, sources, multiples.

Stop assuming elastic recoil model for backgrounds

X-rays help calibrate sub-KeV region where hpge detectors perform for 30 years. S/N>>1. Why not try it?

Check out the limitations of GEANT, FLUKA, etc re: neutrons. Explore the unknowns of neutrons. There's less known than you think. And some of the known is junk

Current stategies are under-determined, hinge on "if not backgound we know, must be dark". Lame ! Develop over-determined multiple-detection consistency. DAMA has led strategy, but with gaps.

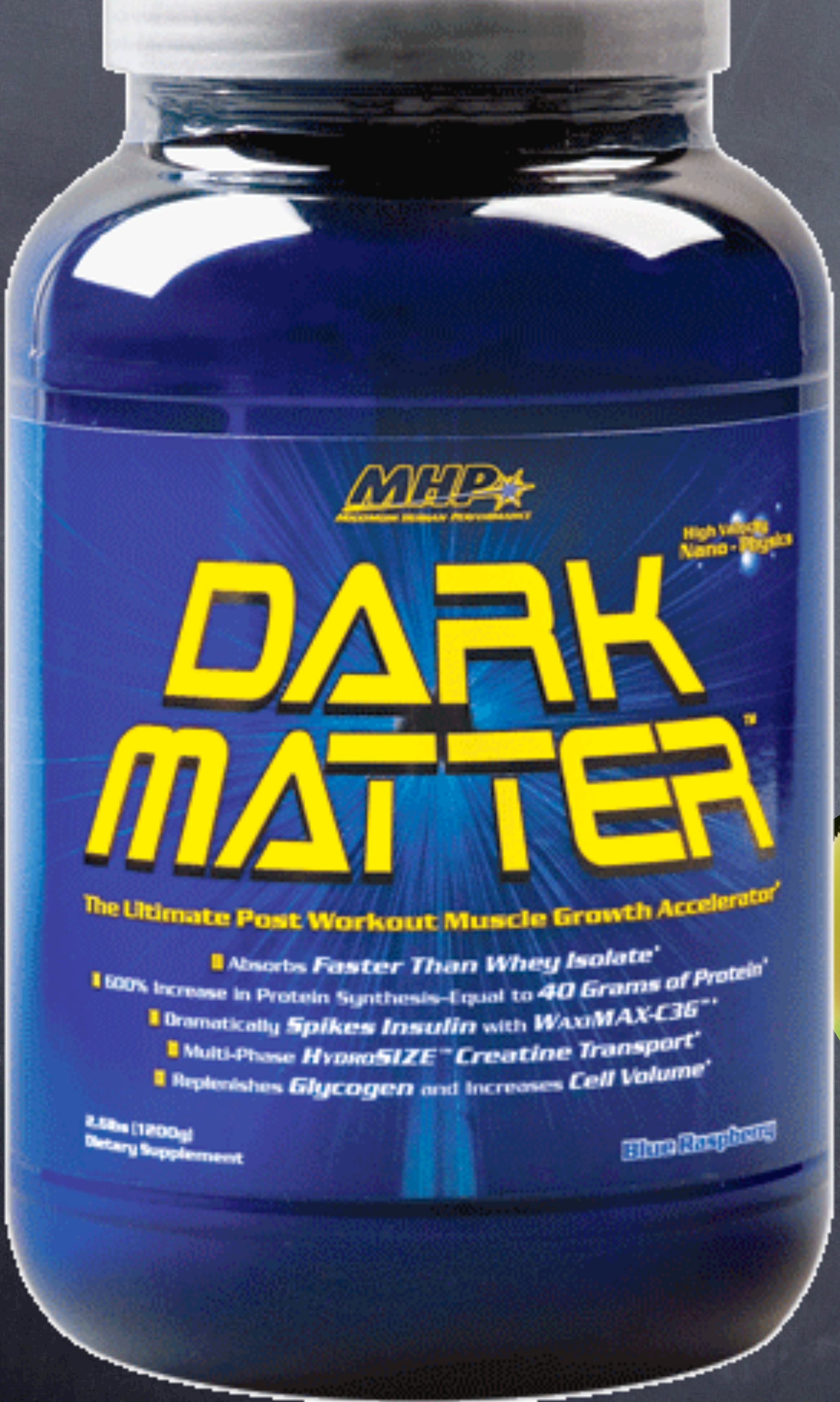
To control ubuitous environmental annual effects, why not duplicate detector in southern hemisphere? It's only money.

Lead is a source of neutrons, almost the worst shield. Cd stops thermals, transmits > eV. Activation, Auger, internal conversion need to be divulged. Divulge !

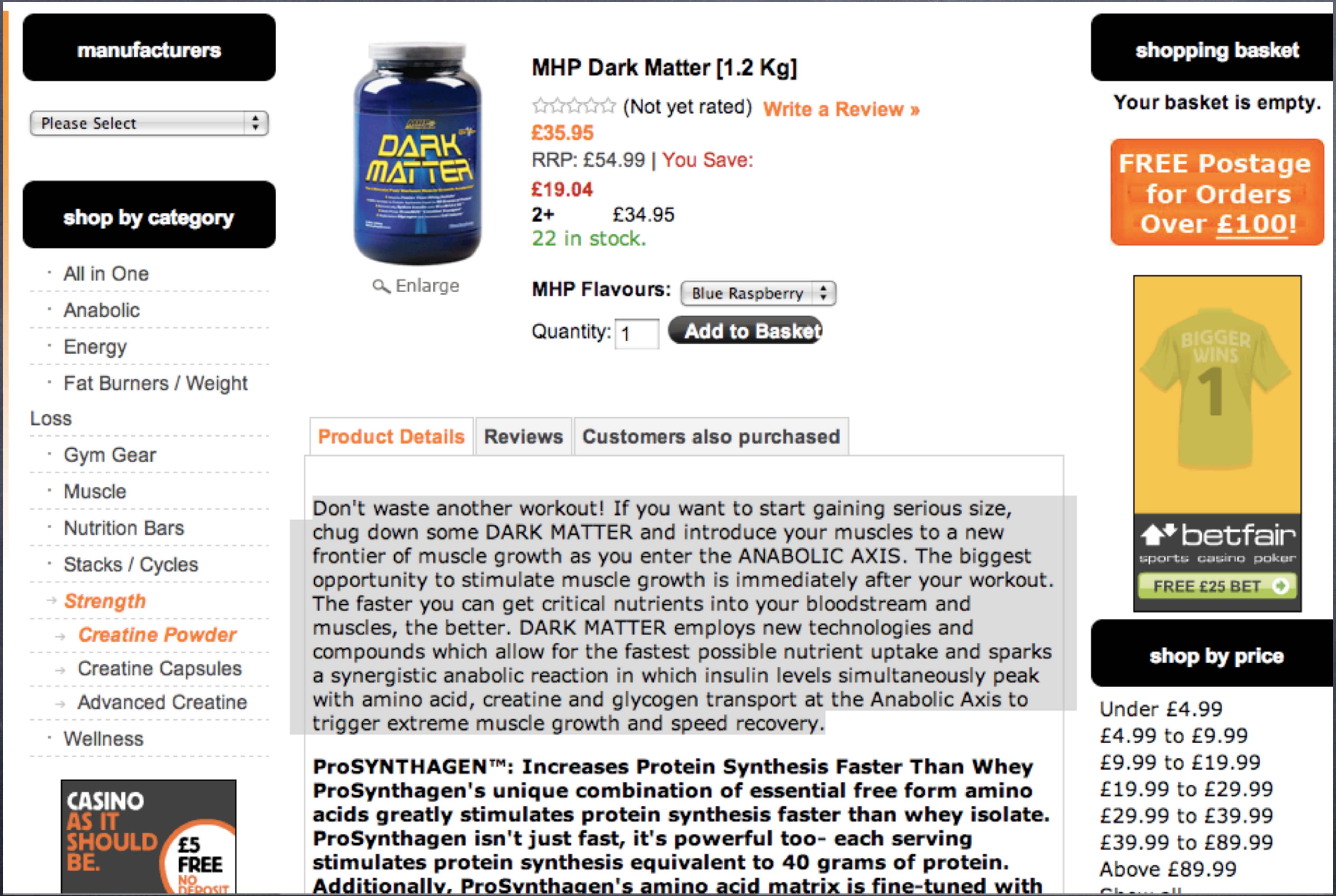
acknowlegements

general discussions/emails with
assorted neutron experts,
plus
Rita Bernabei, Phil Barbeau,
Durdana Balakishiyeva,

under which JPR takes
responsibility for his own
misunderstanding,
if any



it's a long road;
let's hope for discovery...



MHP Dark Matter [1.2 Kg]

☆☆☆☆☆ (Not yet rated)

£35.95

RRP: £54.99 | You Save: £19.04

2+ £34.95

22 in stock.

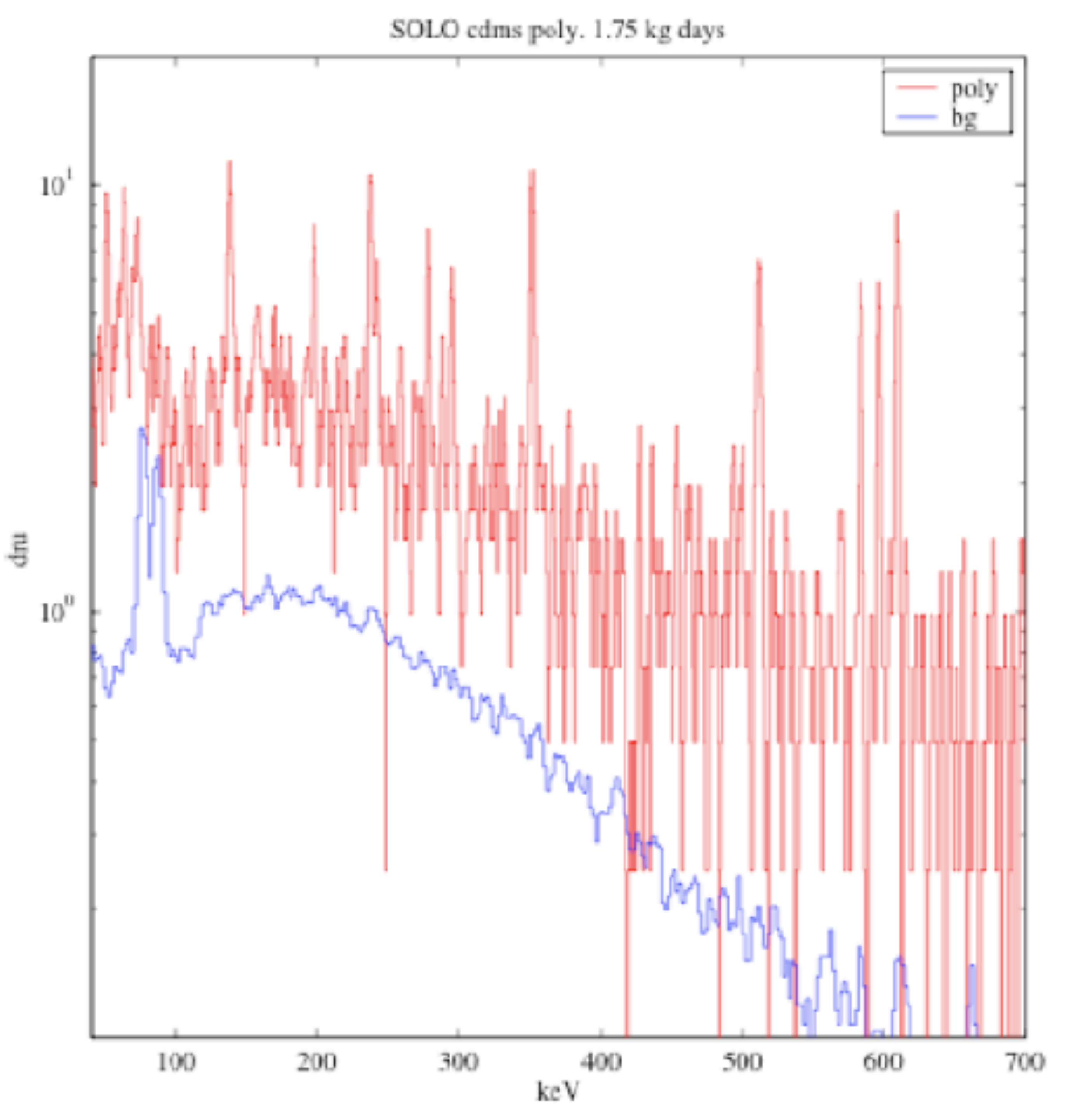
MHP Flavours: Blue Raspberry

Quantity: 1

Your basket is empty.

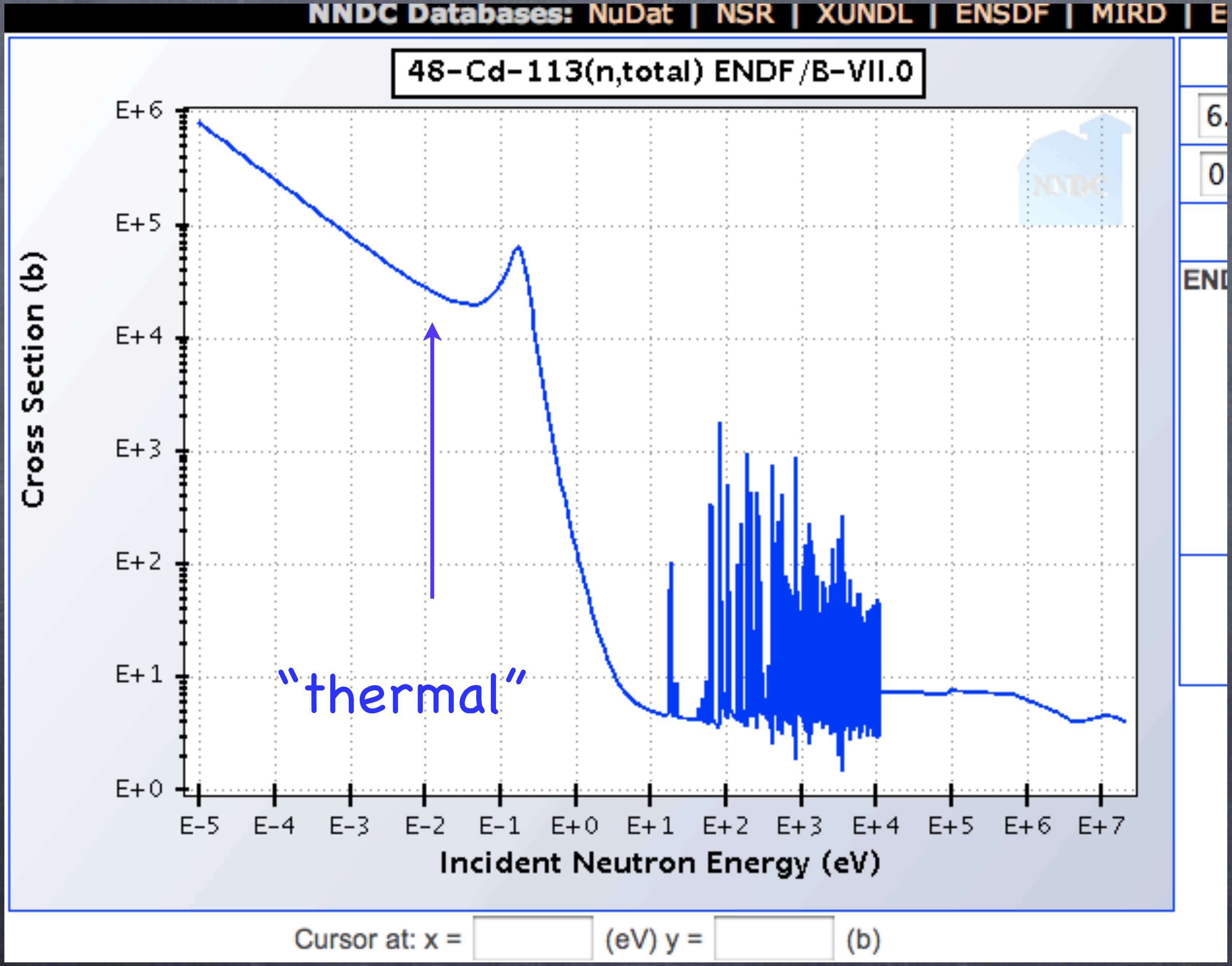
Don't waste another workout! If you want to start gaining serious size, chug down some DARK MATTER and introduce your muscles to a new frontier of muscle growth as you enter the ANABOLIC AXIS. The biggest opportunity to stimulate muscle growth is immediately after your workout. The faster you can get critical nutrients into your bloodstream and muscles, the better. DARK MATTER employs new technologies and compounds which allow for the fastest possible nutrient uptake and sparks a synergistic anabolic reaction in which insulin levels simultaneously peak with amino acid, creatine and glycogen transport at the Anabolic Axis to trigger extreme muscle growth and speed recovery.

ProSYNTHAGEN™: Increases Protein Synthesis Faster Than Whey ProSynthagen's unique combination of essential free form amino acids greatly stimulates protein synthesis faster than whey isolate. ProSynthagen isn't just fast, it's powerful too- each serving stimulates protein synthesis equivalent to 40 grams of protein. Additionally, ProSynthagen's amino acid matrix is fine-tuned with


SOLO cdms poly. 1.75 kg days
poly
bg
dru
10^1
10^0
100
200
300
400
500
600
700
keV

Cd is terrific n-capture at thermal (10^(-2)eV) energies.
1.5 mm shield = 10 absorption lengths

Yet Cd also captures nothing above 10 eV
1.5 mm shield = 0 absorption lengths



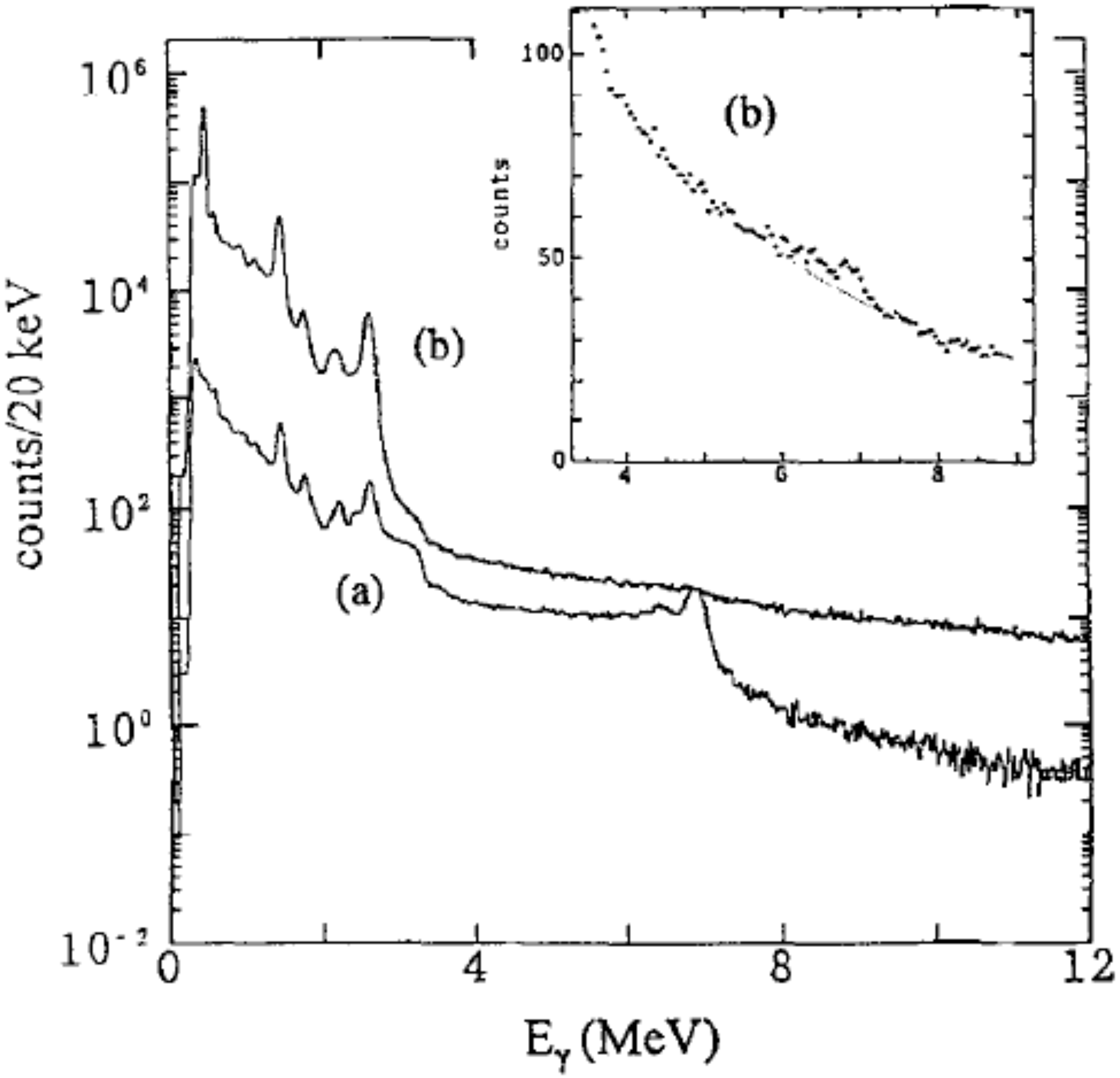
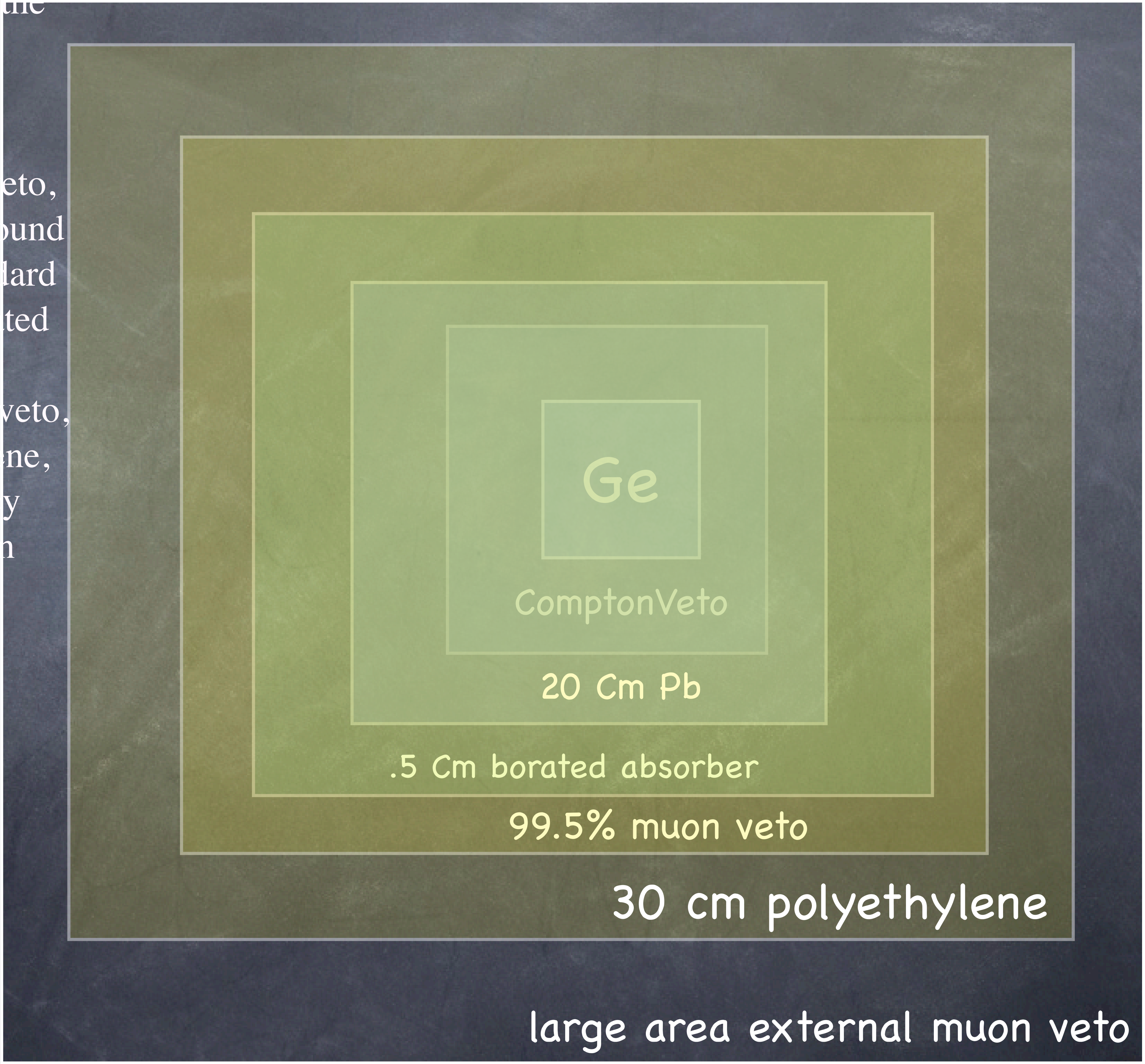


Fig. 2. Background spectra of the NaI(Tl) detector in anticoincidence with the plastic counter with (a) and without Pb (b), respectively. A part of the spectrum (b) is shown in the linear scale.

Listing from innermost to outermost components, the shielding around the detector was: (i) a low-background NaI[Tl] anti-Compton veto, (ii) 5 cm of low-background lead, (iii) 15 cm of standard lead, (iv) 0.5 cm of borated neutron absorber, (v) a >99:9% efficient muon veto, (vi) 30 cm of polyethylene, and (vii) a low-efficiency large-area external muon veto.



billiards work sometimes....

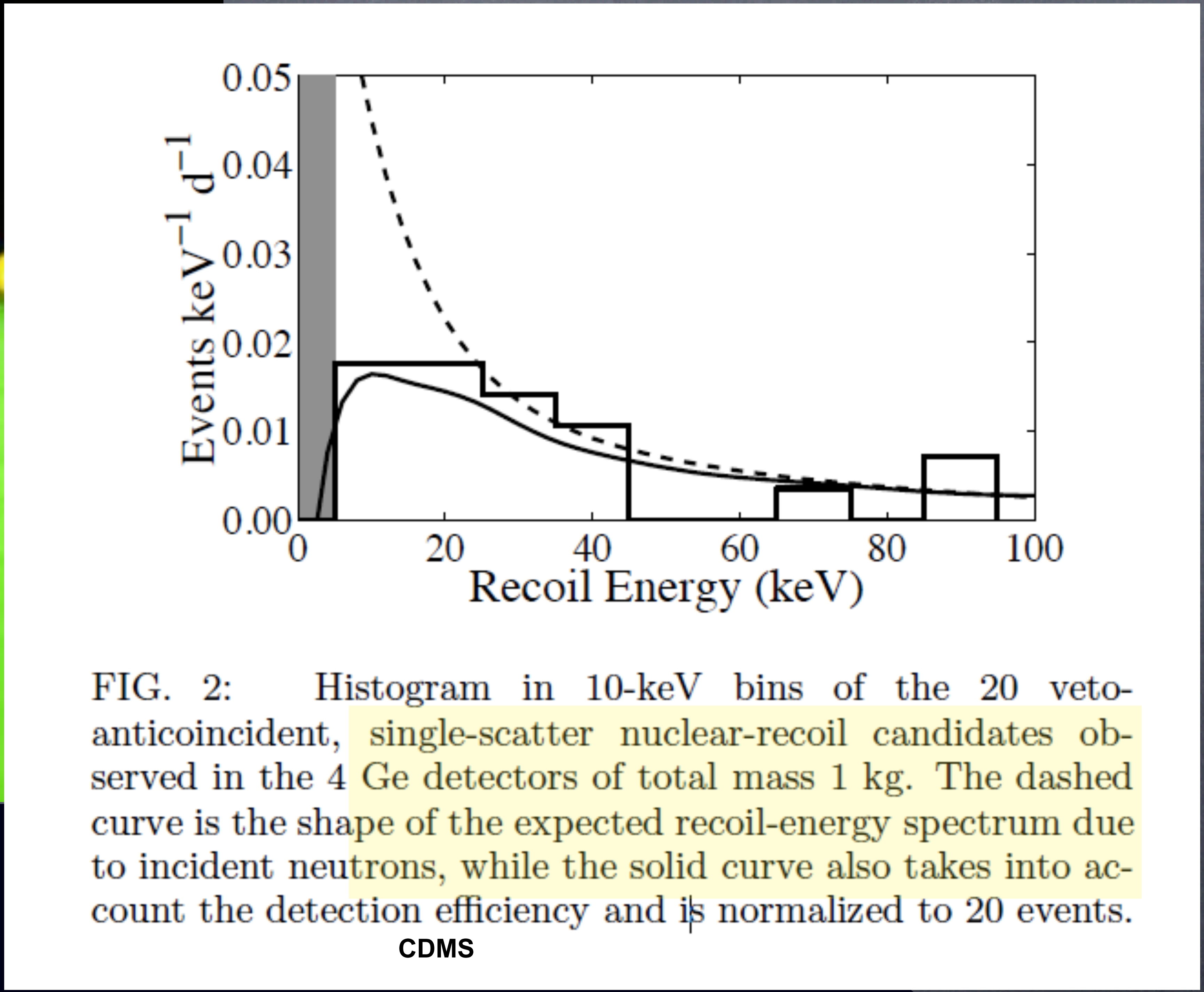


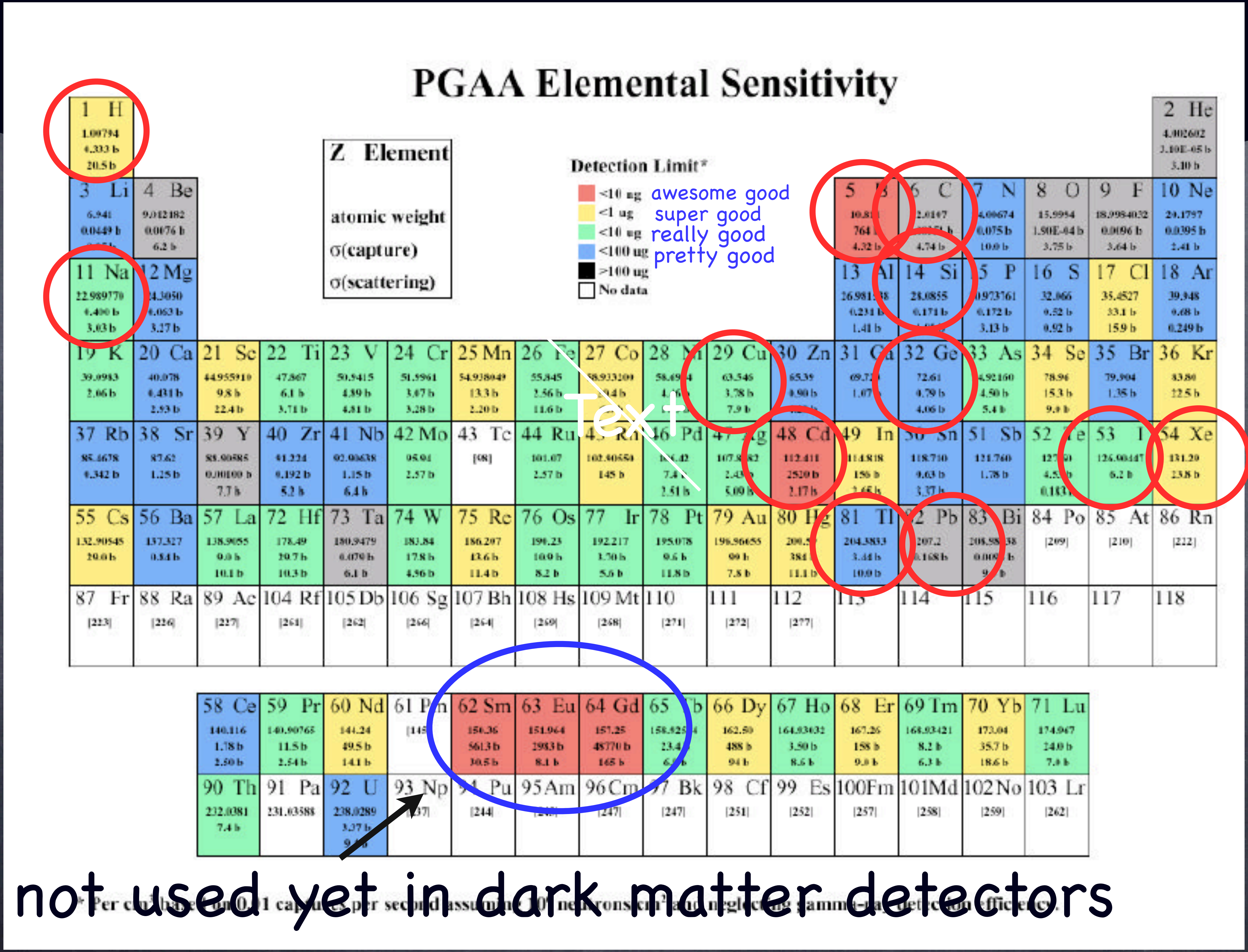
FIG. 2: Histogram in 10-keV bins of the 20 veto-anticoincident, single-scatter nuclear-recoil candidates observed in the 4 Ge detectors of total mass 1 kg. The dashed curve is the shape of the expected recoil-energy spectrum due to incident neutrons, while the solid curve also takes into account the detection efficiency and is normalized to 20 events.

CDMS

CDMS Observes Some Billiard Ball Events !

that's just peachy

experiments have selected *pretty good* neutron/prompt gamma emitters - catalogued by the *prompt gamma activation analysis* engineers



not used yet in dark matter detectors