Title: Certainty And Uncertainty In Dark Matter Searches

Date: Sep 23, 2011 09:00 AM

URL: http://pirsa.org/11090074

Abstract: Departing from the context of CoGeNT and COUPP, two direct searches for WIMP dark matter, we will inspect the recent landscape of anomalies observed by these and several other detectors. The aim of this talk is to communicate an appreciation for the subtleties inherent to experimental efforts in this field, and for the considerable difficulties that await for those trying to make sense of WIMP search observations (or lack thereof).

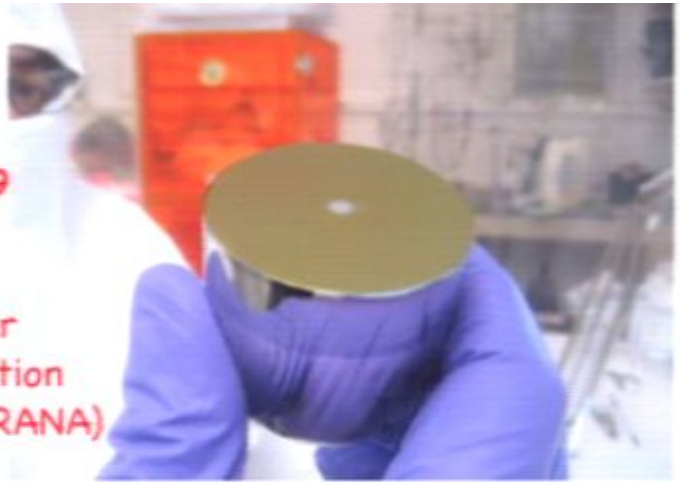
CoGeNT:

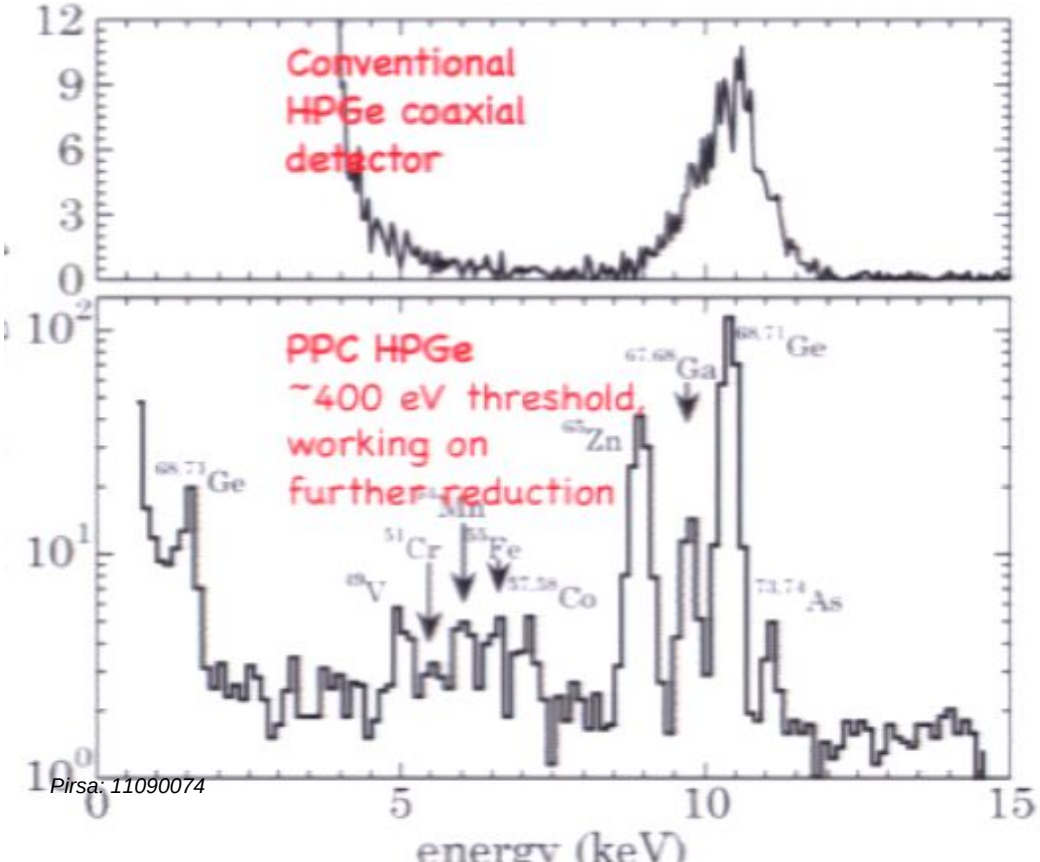
eutrino &
istroparticle physics
sing large-mass,
ltra-low noise
ermanium detectors
CANBERRA, PNNL, ORNL, UC, UNC, UW)

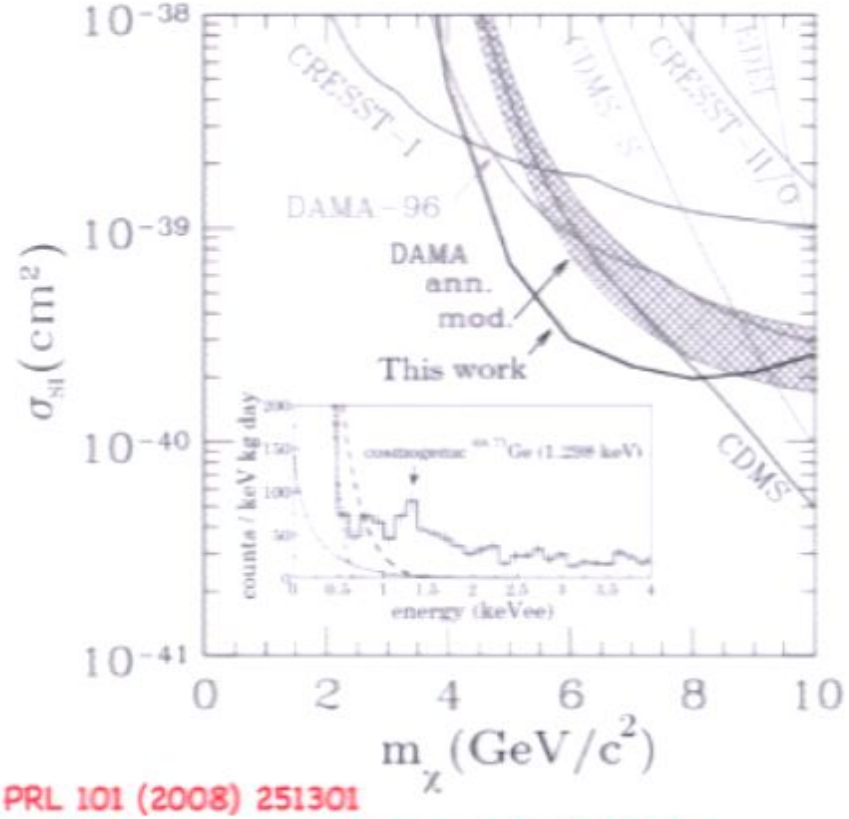
PPC HPGe

JCAP 09(2007)009

Applications:
- Light Dark Matter
- Coherent ν detection
- ββ decay (MAJORANA)



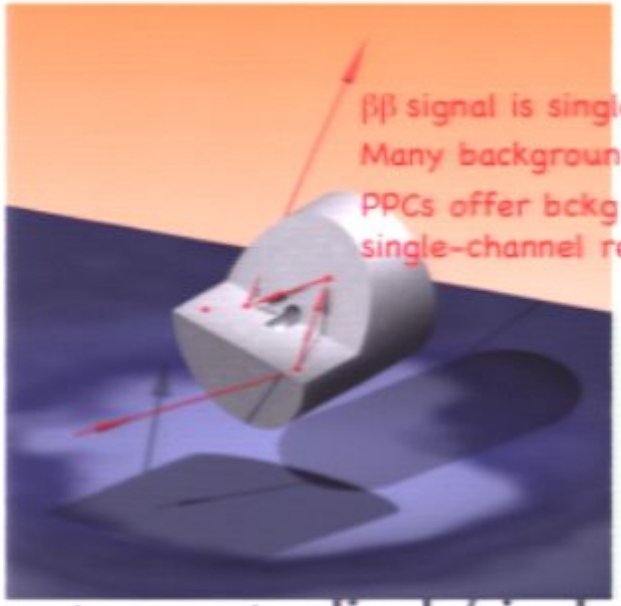


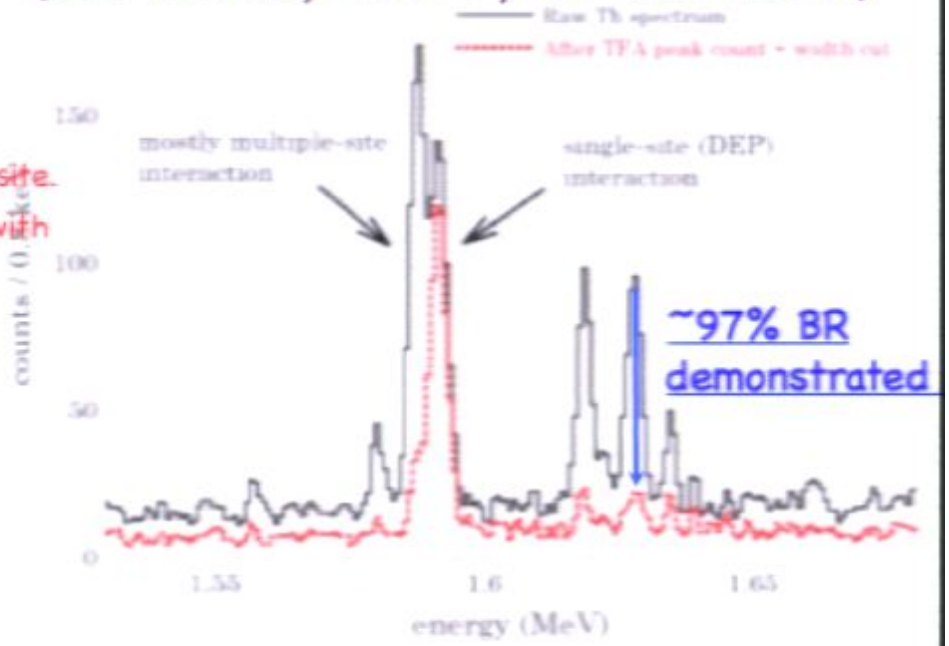


PRL 101 (2008) 251301

Extensive constraints on DAMA's claim:
- Light WIMPs
- Dark scalars
- Dark pseudoscalars

MAJORANA PPCs (see Monday talk by G. Giovanetti)





Detectors studied / in hand:

(table actually missing a few)

Owner	Dimensions	Mass	Resolution (1.33 MeV)	Manufacturer
Chicago (PPCI)	50 mm Ø x 44 mm	460 g	1.82 keV	Canberra
PNNL (PPCII)	50 mm Ø x 50 mm	527 g	2.15 keV	Canberra
LBNL (SPPC)	62 mm Ø x 44 mm	800 g	2.11 keV	LBNL
LANL (MJ70)	72 mm Ø x 37 mm	800 g	2.15 keV	PHD's
ORNL (MJ60)	62 mm Ø x 46 mm	740 g	4-4.5 keV	PHD's
Chicago (BEGe)	"standard"	450 g	<2 keV	Canberra
INL (Mini PPCs)	20 mm Ø x 10 mm	17 g		LBNL
RNL (Big BEGe)	90 mm Ø x 25 mm	850 g	1.95 keV	Canberra

Move to modified commercial "BEGe" detectors (quasiplanar PPCs)

~30 PPCs already characterized and stored for 60kg MAJORANA demonstrator

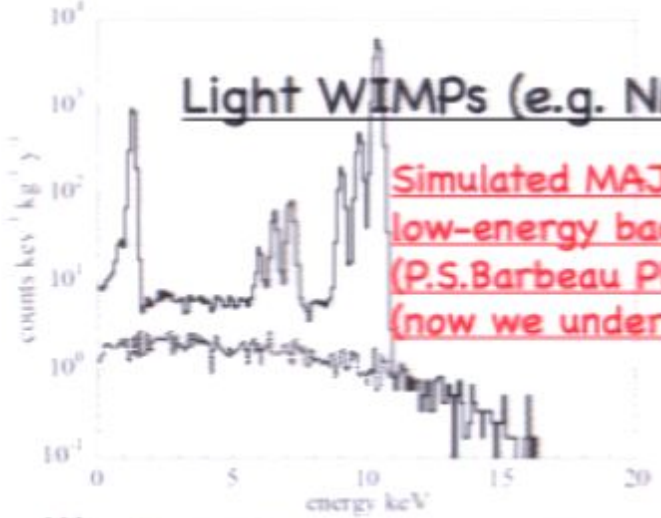
Crystal storage underground

GERDA switching to PPCs for 2nd phase

MAJORANA as a DM detector

(see Monday talk by G. Giovanetti)

Light WIMPs (e.g. NMSSM)



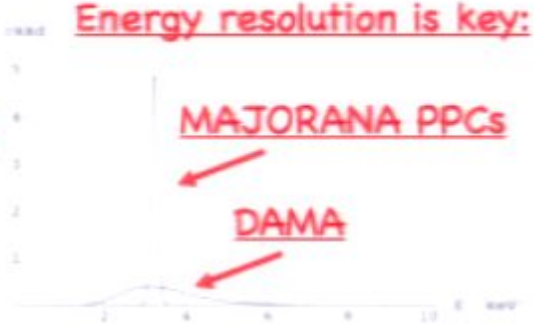
Simulated MAJORANA-demonstrator low-energy backgrounds (P.S.Barbeau Ph.D. Diss.) (now we understand these much better)

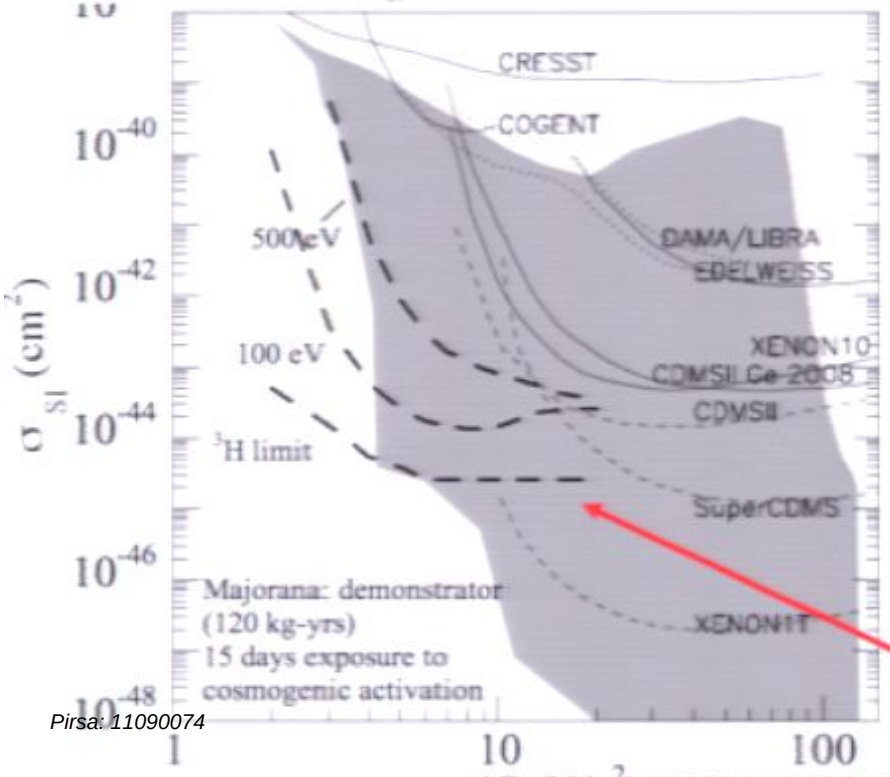
Pseudoscalars etc. (a.k.a. "superWIMPs")

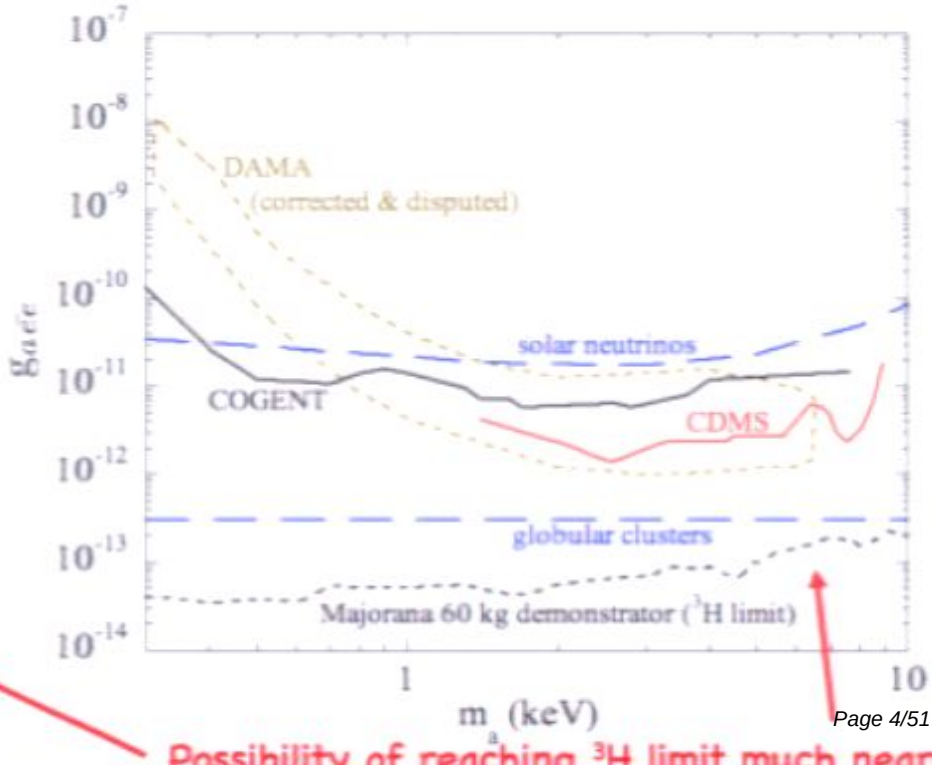
Energy resolution is key:

MAJORANA PPCs

DAMA

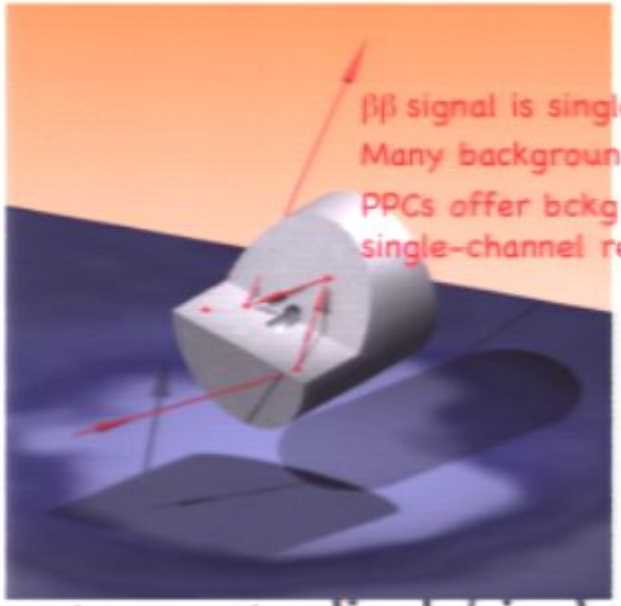


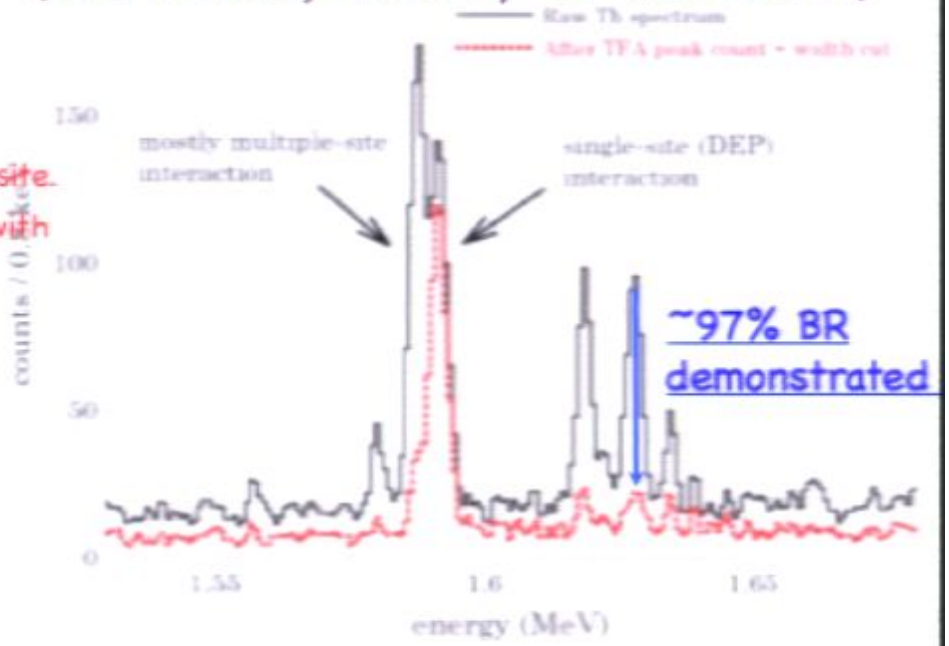




Possibility of reaching ³H limit much nearer

MAJORANA PPCs (see Monday talk by G. Giovanetti)





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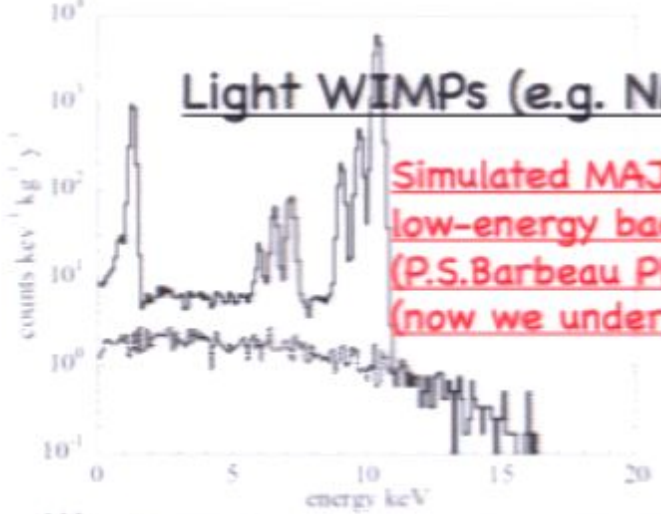

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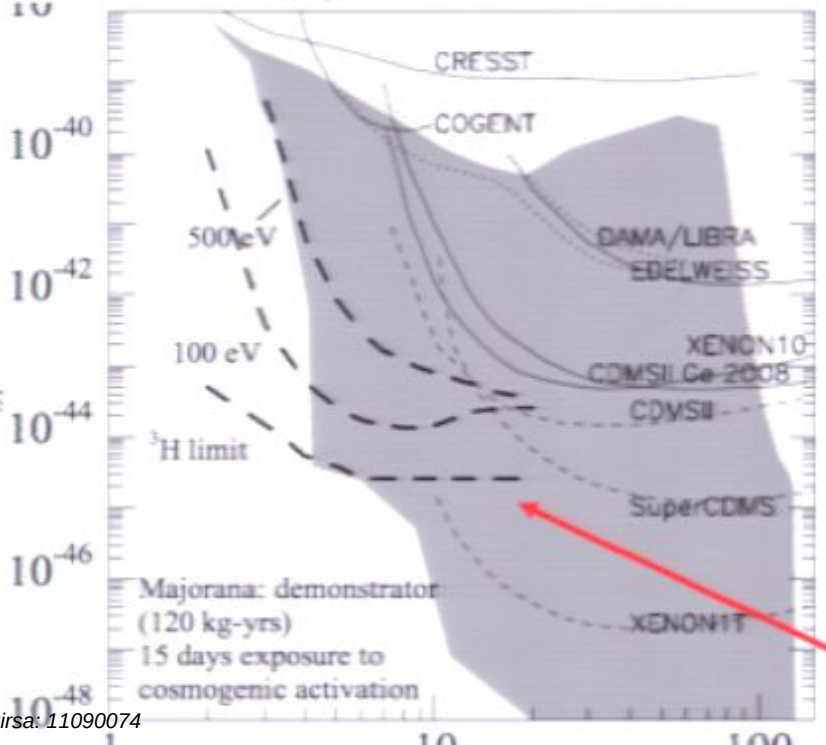
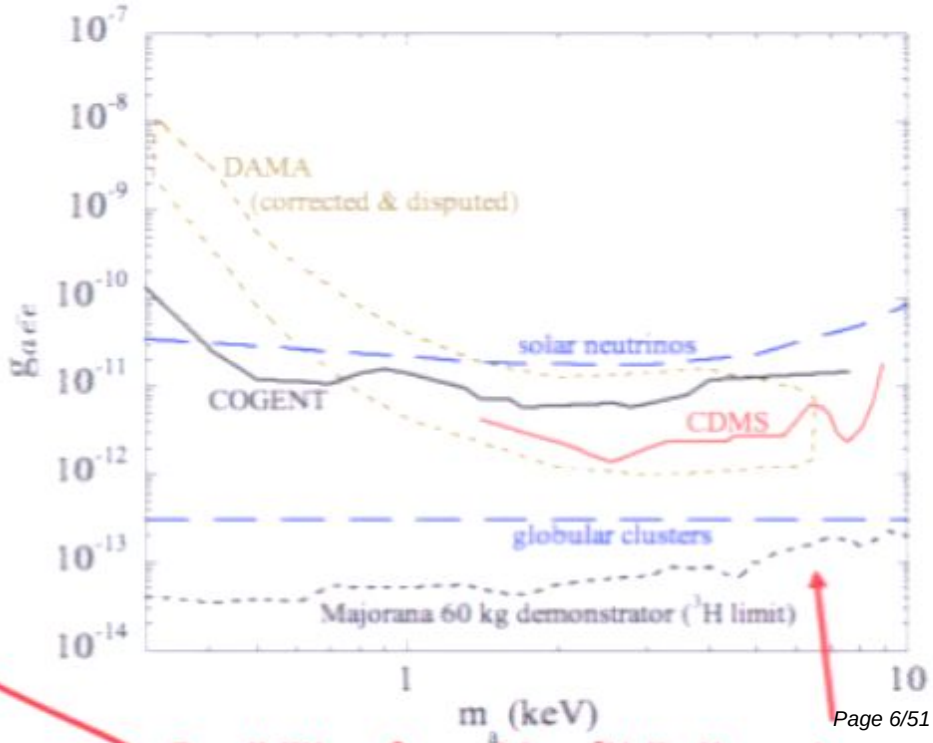


Pseudoscalars etc. (a.k.a. "superWIMPs")

Energy resolution is key:

MAJORANA PPCs

DAMA

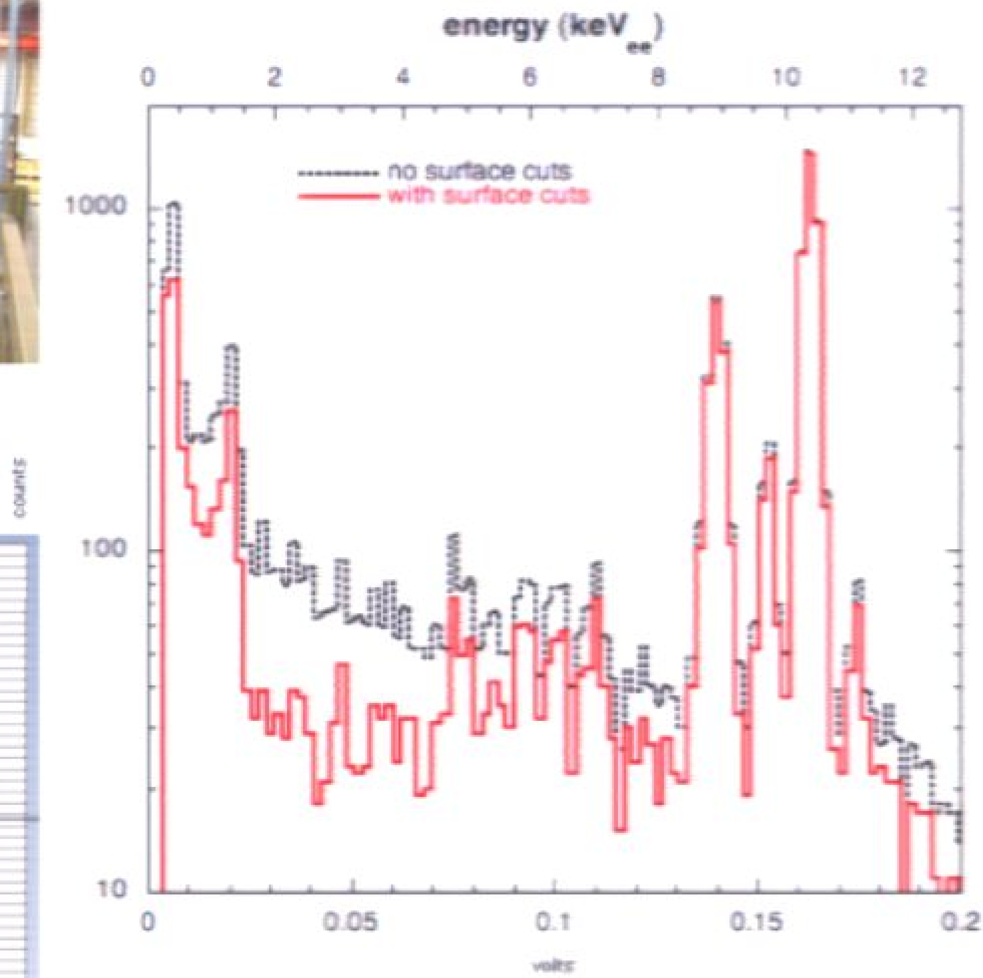


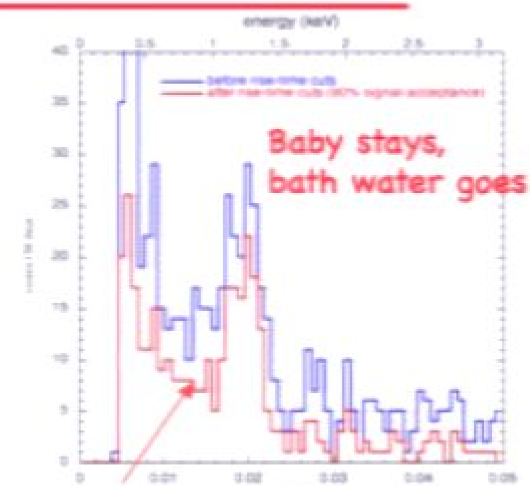
Possibility of reaching ³H limit much nearer

Making an excellent detector even better:
PPCs can reject surface events using rise-time cuts

Based on a phenomenon ~40 years old (embarrasing!)

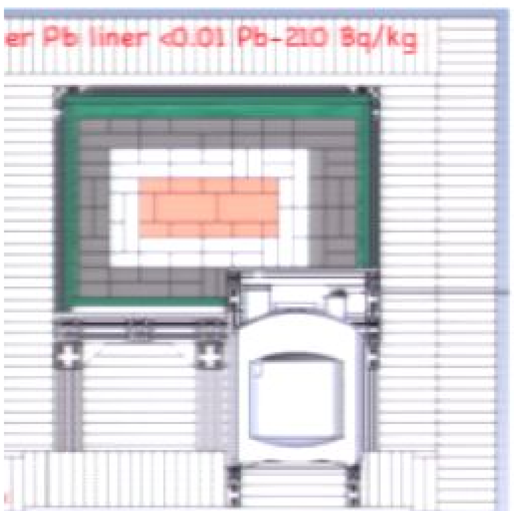
GENT running
) m away from CDMS
st to keep them honest... ;-)



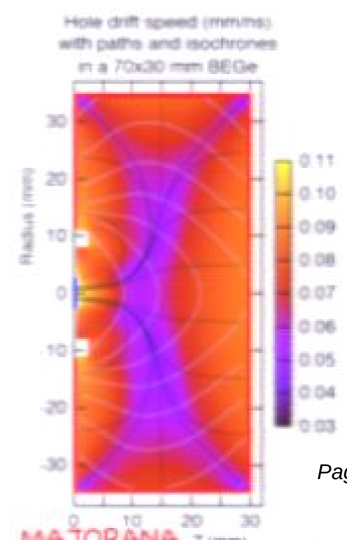


Bulk signal acceptance monitored down to 1 keVee via L/K EC peak ratios and pulser calibrations.

Working on characterizing surface background rejection (large exposure required).



' nearly "best effort" yet.
IORANA Demonstrator
kground goal is ~x1000 lower



Charge Collection time modelled (small 100 ns correction)

MAJORANA

An old "take-home message" transparency (pre-modulation)

or m_χ ~7-11 GeV, a WIMP fits the data nicely
% confidence interval on best-fit WIMP coupling
mpatible with zero, good χ^2/dof).

ed "island" tells you ~where to look (if you believe in MPs). Additional knowledge (e.g., more calibrations for cial volume and SA/BR) could wiggle it around some (so the other regions shown, depending on who plots them).

Not a big deal on its own, it simply means that our ducible bulk-like bckg is ~exponential (the background del without a WIMP component fares just as well).

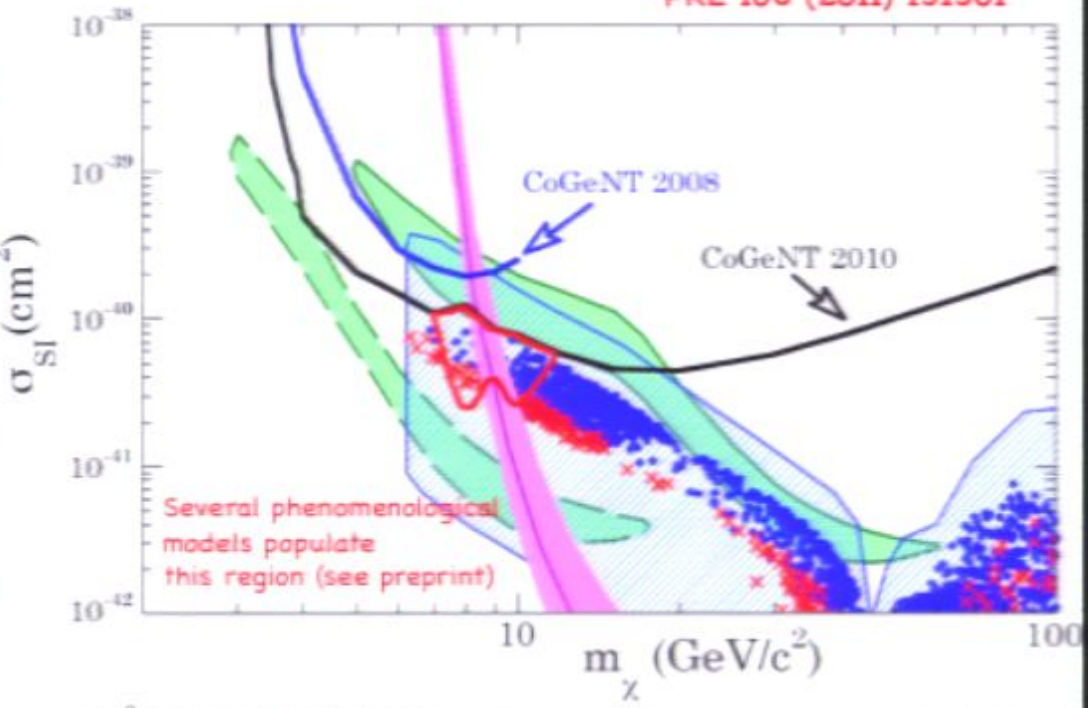
We presently cannot find an obvious known source. But we fancy some unexplored possibilities. It is not neutrons, there is no evidence yet of detector contamination.

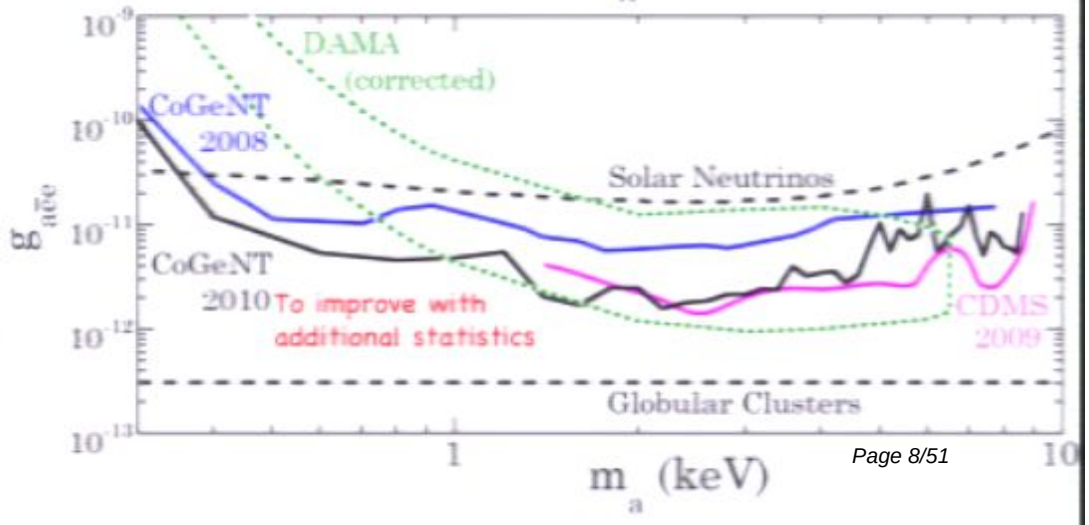
he low-E excess is composed of asymptomatic **bulk-like** nts (very different from electronic noise), coming in at a nstant rate.

he possible subject of interest is where we "got stuck" hase space (a number of curious coincidences there), for pectrum where most surface events are removed major contributors to low-energy spectrum). Caveat tor: without DAMA, would we have models there?

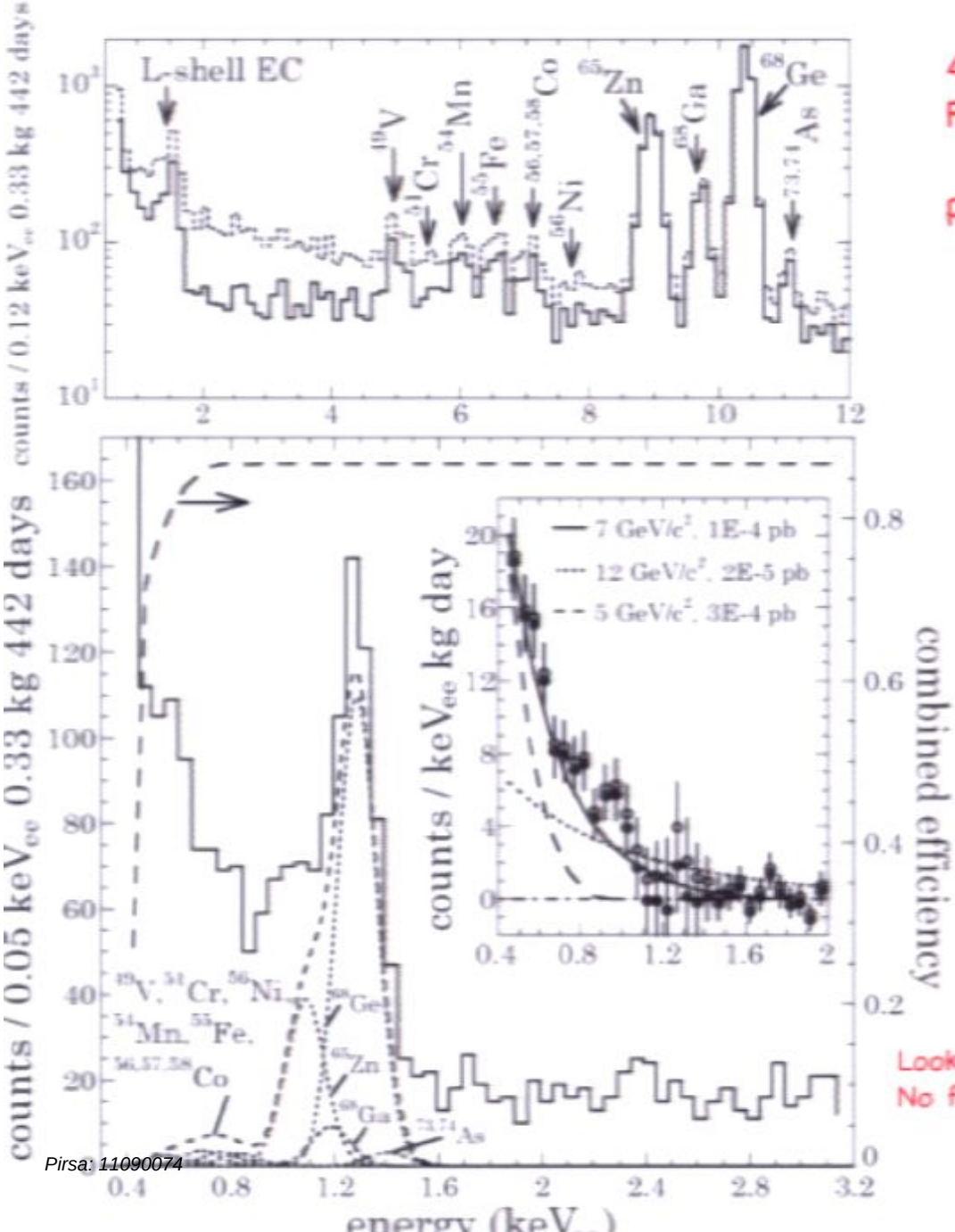
We will attempt to strip the low-E data from known rces of background after a longer exposure, but all of m seem modest (see preprint). Planned additional brations will provide improved information on signal eptance, background rejection and fiducial volume.

PRL 106 (2011) 131301





Everything was going well until March 17th (Soudan fire)...



458 days collected (442d live)
Fiducial mass~330 grams

Phys. Rev. Lett., in press

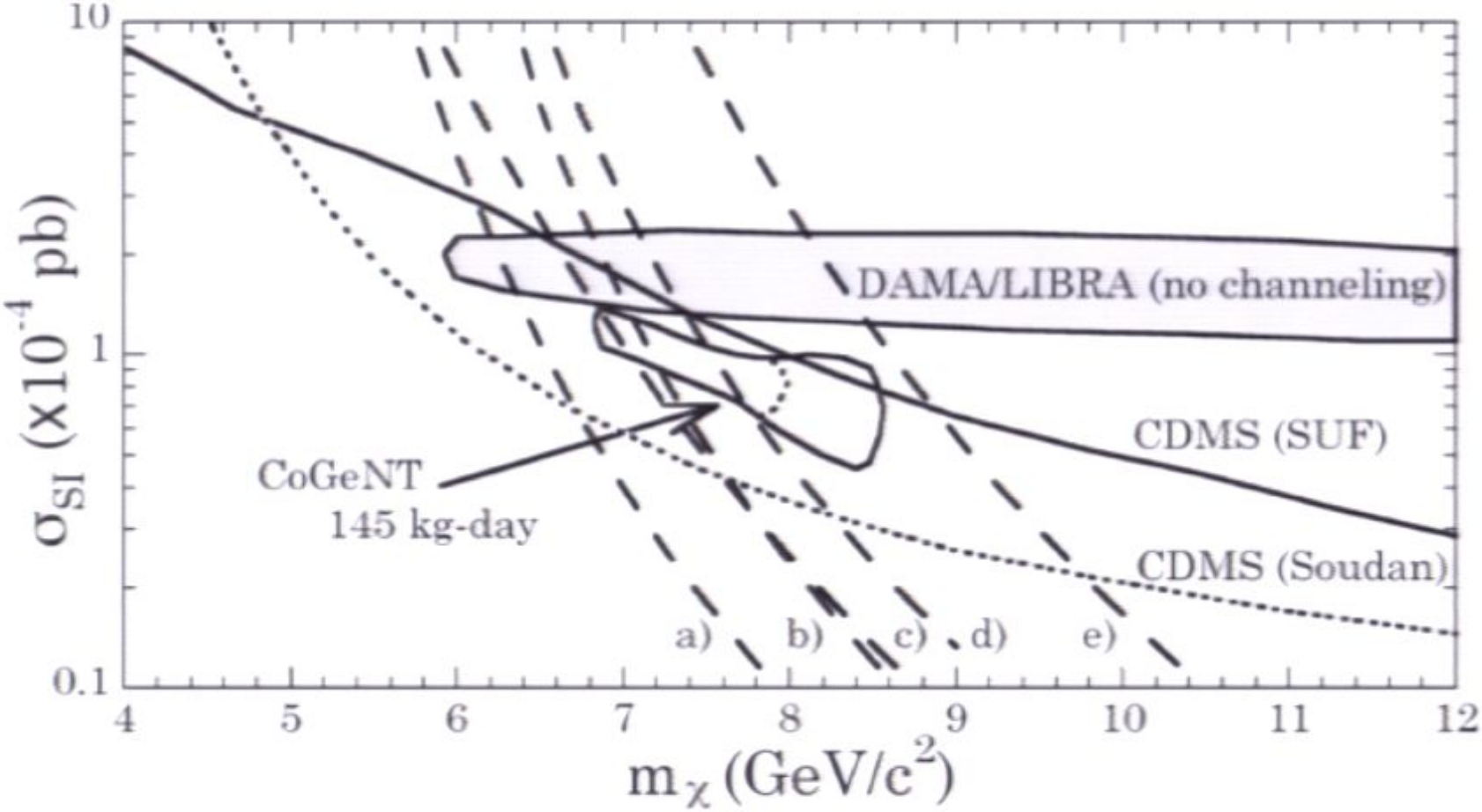
JOHN N. BAHCALL PHYSICAL REVIEW VOLUME 132, 1963

TABLE IV. Comparison of theoretical and experimental L/K capture ratio.

Isotope	$\left(\frac{\varphi(2s')}{\varphi(1s')}\right)^2$	Usual theoretical ratio [Eq. (13)]	Exchange-corrected ratio [Eq. (4)]	Observed ratio	Number of precision experiments
Ar^{37}	1.006	0.0820	0.099	0.100 ±0.003	4
Cr^{51}	1.014[a]	0.0882	0.101	0.1026 ±0.0004	1
Mn^{54}	1.020	0.0898	0.102	0.098 ±0.006	1
Fe^{55}	1.051	0.0936	0.106	0.106 ±0.003	2
Co^{57}	1.017	0.0915	0.103	0.099 ±0.011	1
Co^{58}	1.008	0.0907	0.102	0.107 ±0.004	1
Zn^{65}	1.041[a]	0.0970	0.108	0.119 ±0.007	1
Ge^{71}	1.083	0.103	0.114	0.1175 ±0.002	2
Kr^{79}	1.021[a]	0.102	0.111	0.108 ±0.005	1

Look Ma!
No free-parameters!

verything was going well until March 17th (Soudan fire)...



- CoGeNT region considerably smaller than before (but within previous ROI), next to DAMA.

- Most CoGeNT uncertainties not included in this figure

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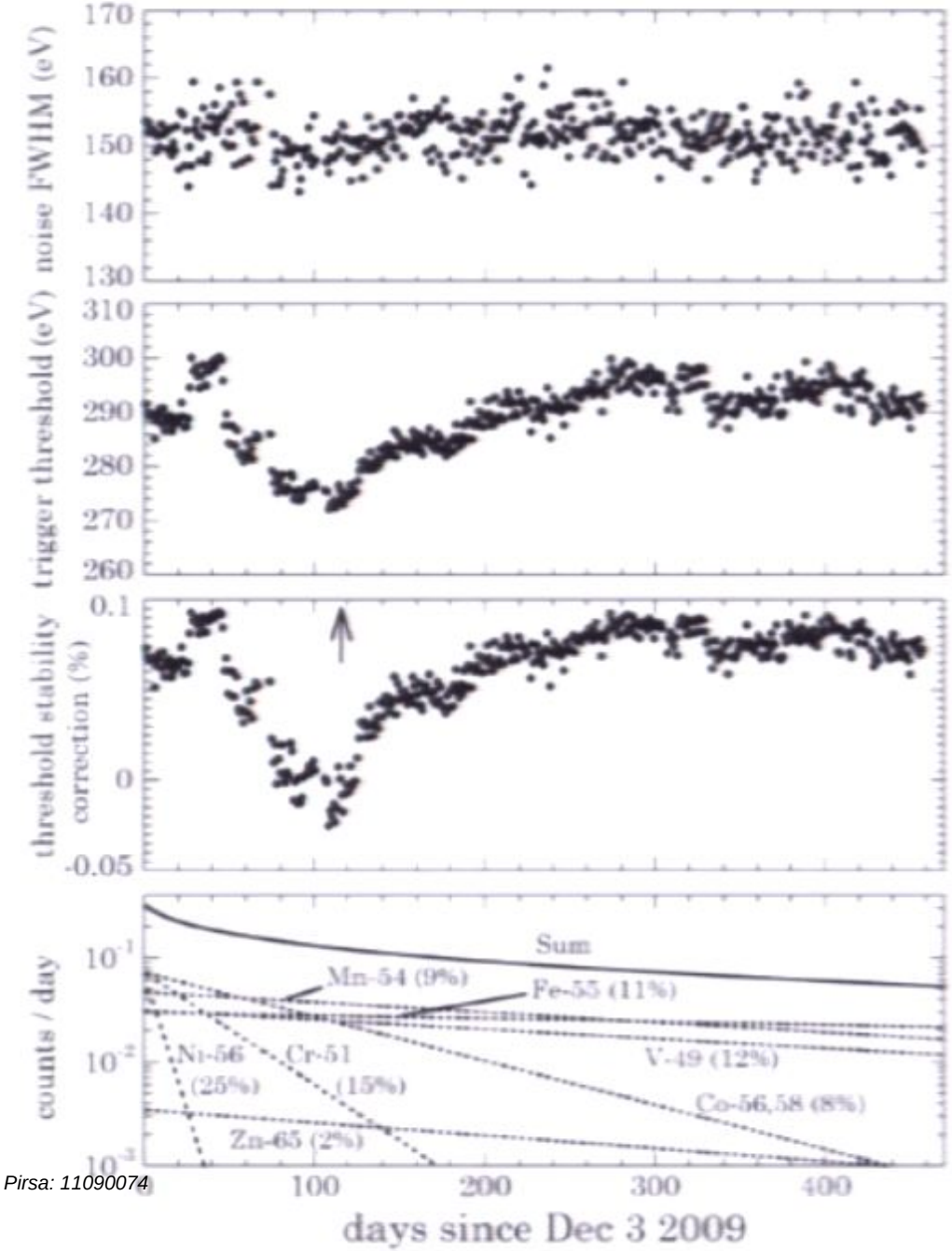
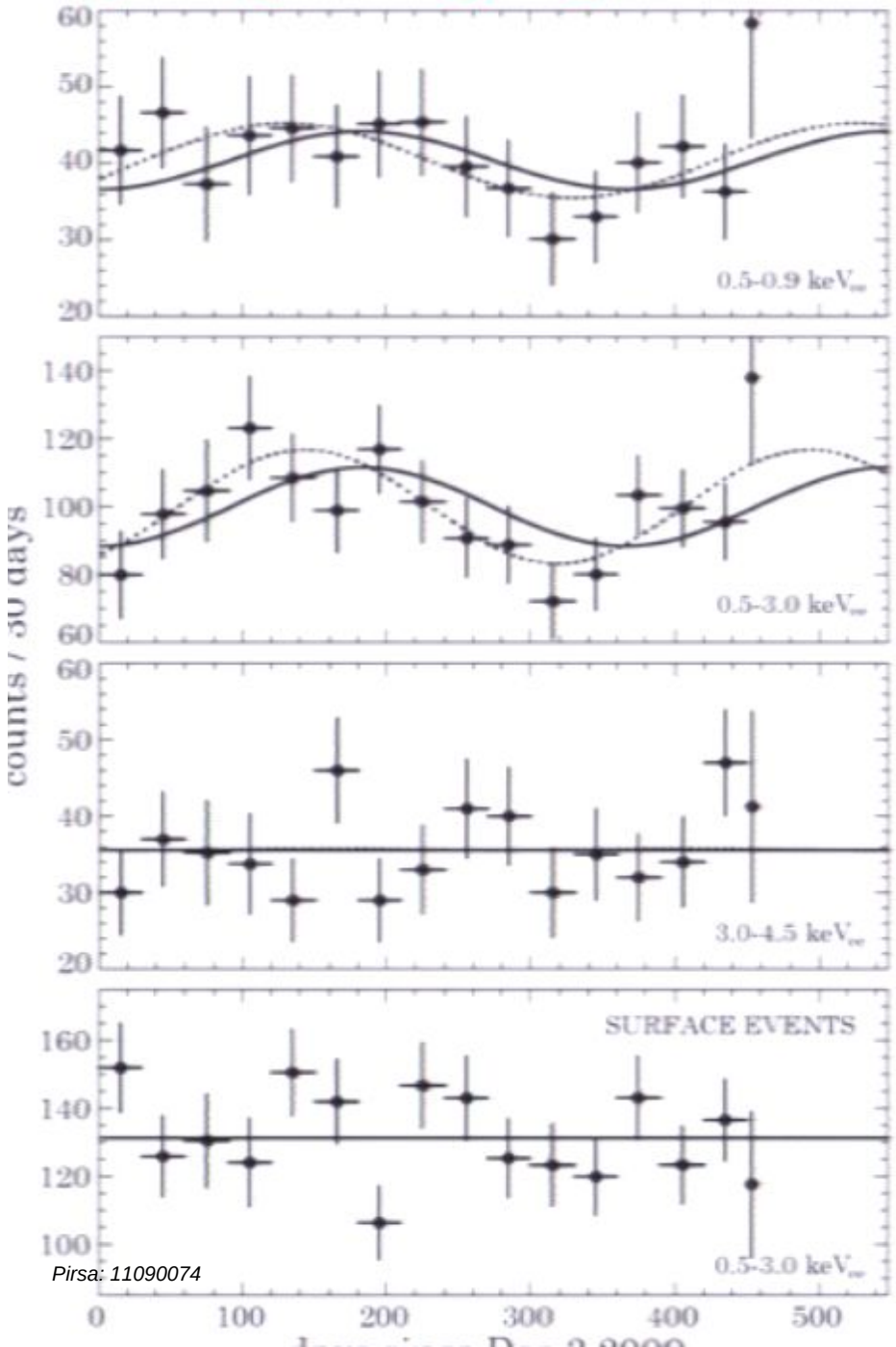


- Excellent stability in detector noise and trigger threshold allows search for annual modulation. Augurs well for other PPC-based searches.

- L-shell peak correction necessary, but prediction is very robust and uncertainties small.

Everything was going well until March 17th (Soudan fire)...

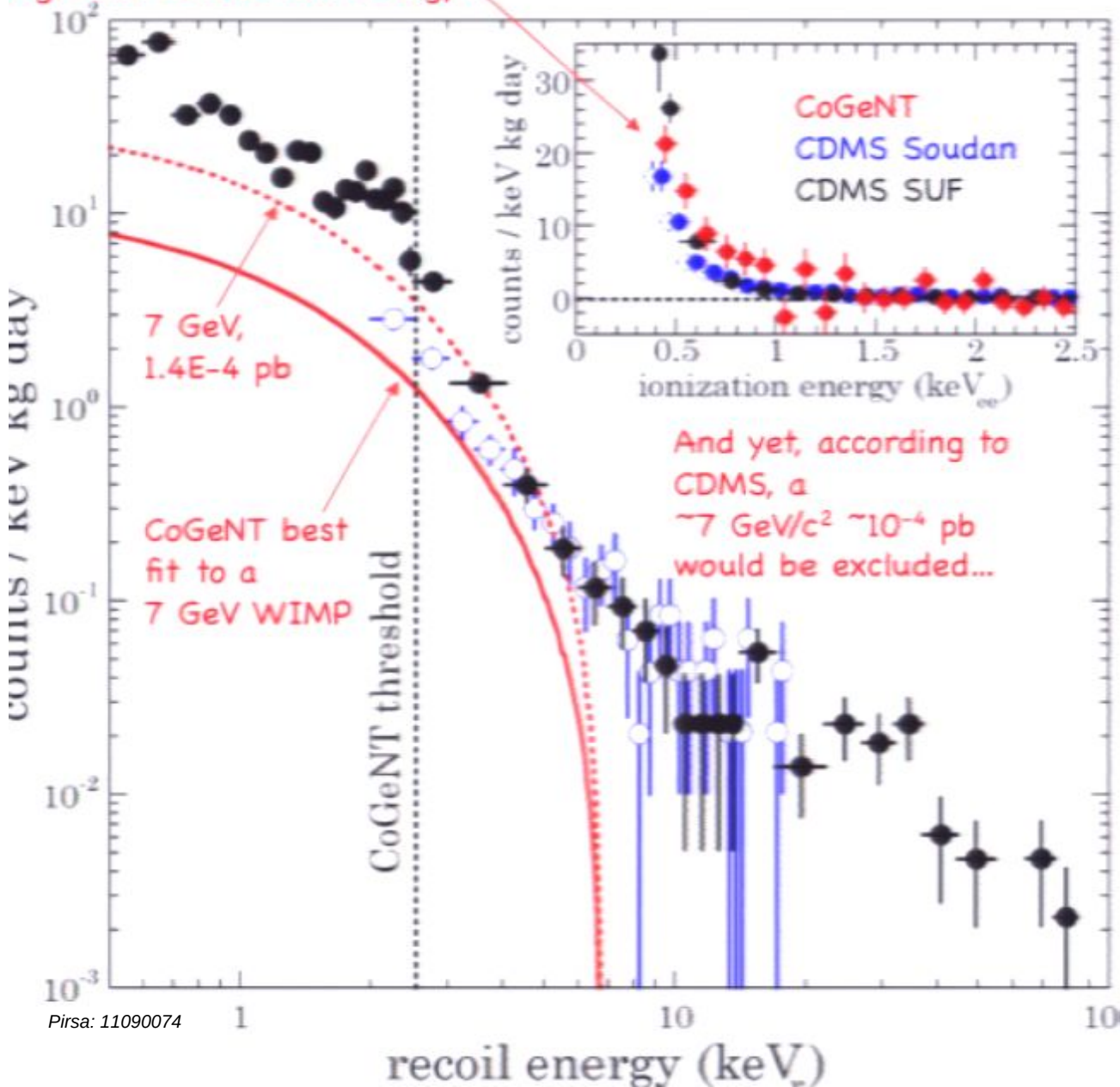


- No fancy estimators tried (several available). Two basic unoptimized methods point at ~2.8σ preference of a modulated rate over the null hypothesis.
- Compatible with WIMP hypothesis expectations (amplitude, phase, period).
- Spectral and temporal analysis are *prima facie* congruent with a light-WIMP hypothesis.
- Modulation absent for surface events and also at higher energies.
- Lots of independent interpretations via data-sharing, but a few are forgetting some basics. Hint: there must be reasons for the experimentalists to always include an exponential background in their models...

an we make sense of the light-WIMP situation?

GeNT and CDMS arrive to similar educible spectra via orthogonal kground cuts at low-energy

CDMS low-E recent results:



And yet, according to CDMS, a ~7 GeV/c² ~10⁻⁴ pb would be excluded...

Critique (arXiv:1103.3481):

- Uncertainties in energy scale and method of calibration
- Uncertainties (and some clear WAGs) in background estimates
- Uncertainty in residual rate from cut selection: limits are mainly extracted from short exposure in a single detector (T1Z5). An alternative CDMS analysis during a different period in Soudan finds a 70% larger irreducible low-E rate for it (!!), but this issue is absent for a second detector (T1Z2).

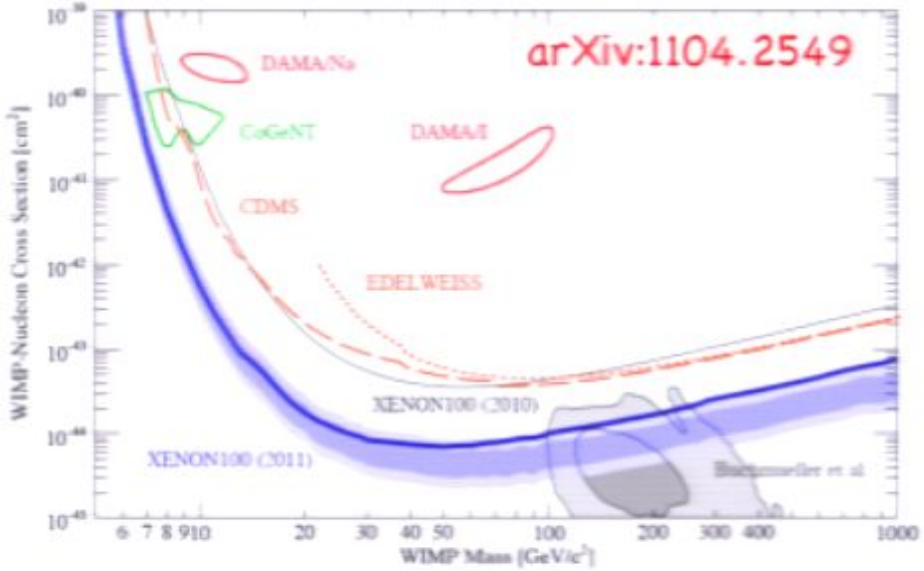
Is T1Z5 stable enough? What is the uncertainty in these limits from the choice of cuts?

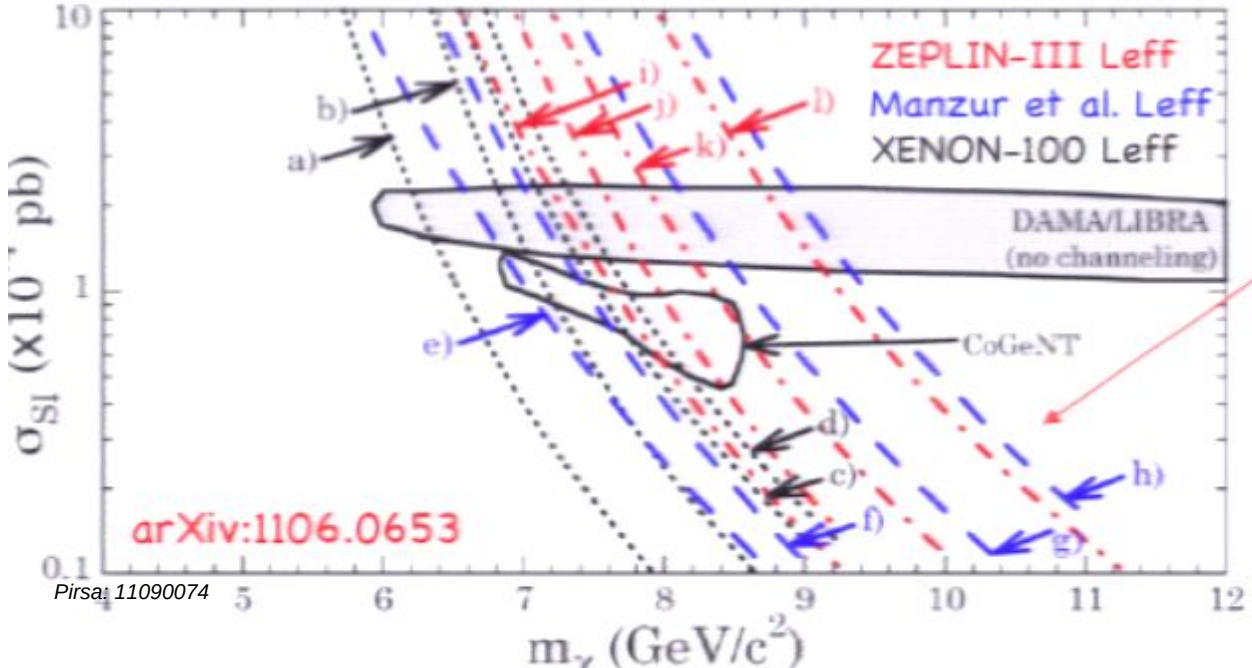
- Direct comparison of CoGeNT-CDMS irreducible spectra initially avoided (a much more straightforward indicator of relative sensitivity for experiments sharing a target)

an we make sense of the light-WIMP situation?

XENON-100 low-E recent results:

ompare these
vo figures:





Critique (arXiv:1106.0653):

- Recent L_{eff} measurement represents progress, but still several important loose ends (energy resolution and L_{eff} <u>are not</u> independent magnitudes)
- Selective display of DAMA region (uncertainties not included)
- Issue with numerical calculation of uncertainties (does not pass self-consistency test = previous XENON100 results)
- Discussion of uncertainties and <u>strong assumptions</u> made (Leff, second-guessed events, Poisson vs. sub-Poisson) broomed under the carpet.
- Most recent ZEPLIN-III L_{eff} (in situ measurement) still pointing at a vanishing value at few keV$_{nr}$.
- Low-energy Am/Be rates: are they what is expected? Crucial for

an we make sense of the light-WIMP situation?

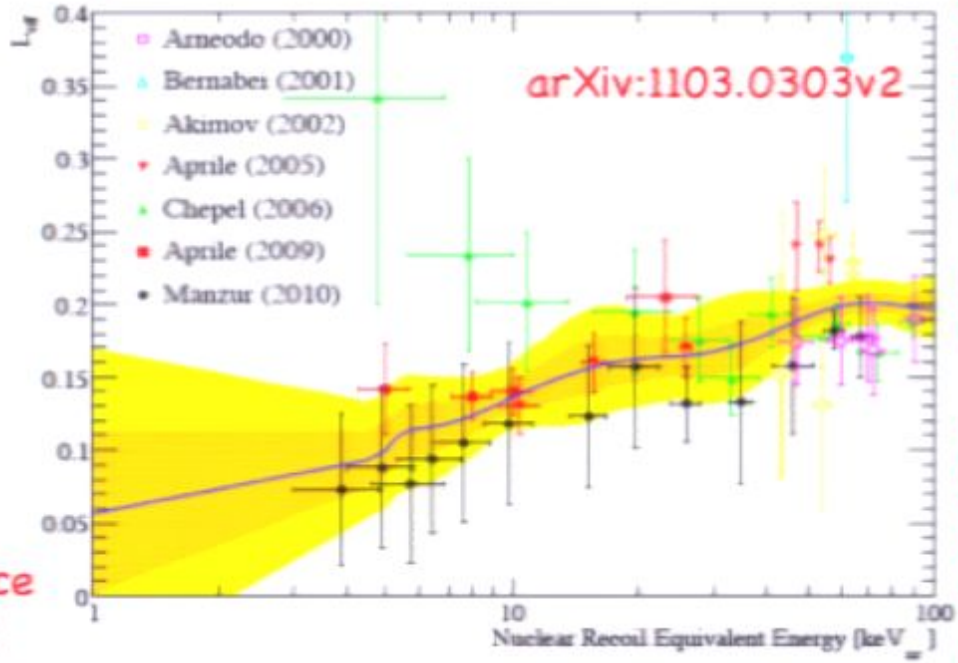
XENON-100 low-E recent results:

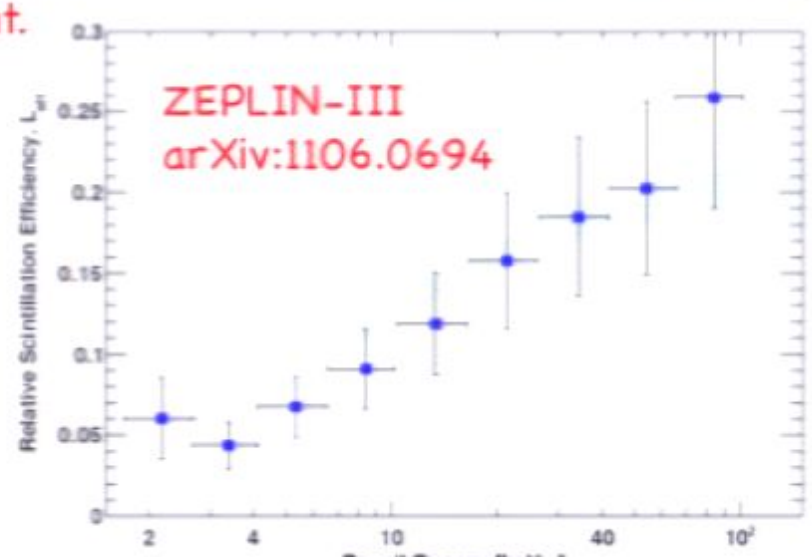
hat is wrong with this picture?

Preserves old sults affected by reshold effects g., Chepel)

Does not include eir own latest NON100 Leff in e fit milar to Manzur)

Denies the existence latest ZEPLIN-III ff (in situ) measurement.





w-mass exclusions are tically dependent on v-E Leff slope... t's play fair.

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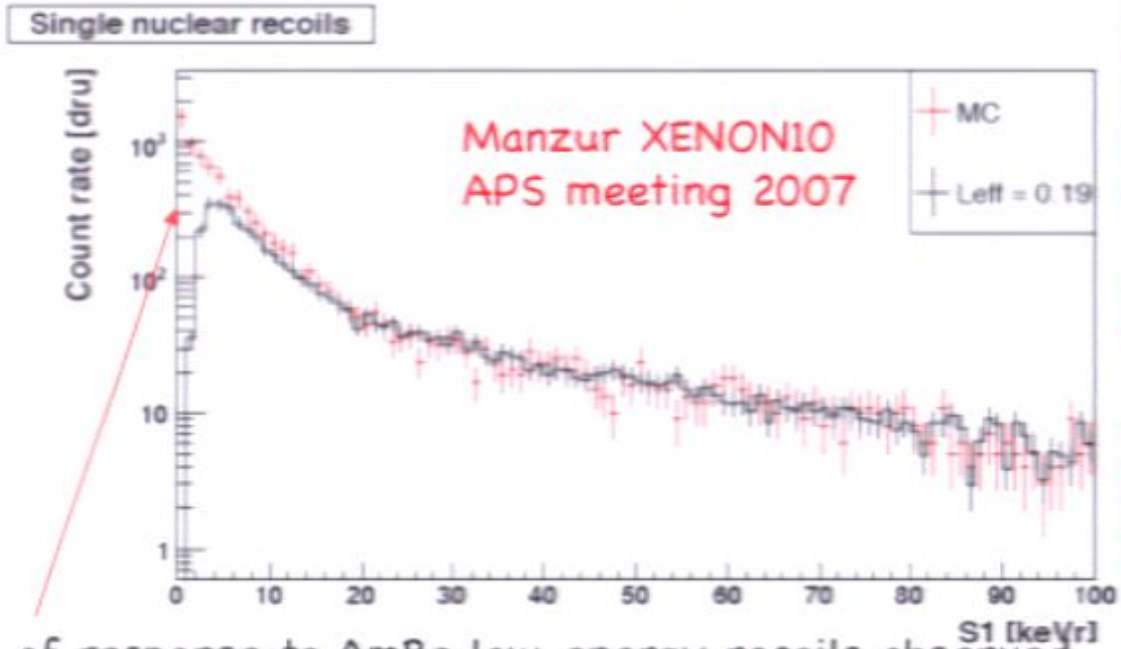
XENON-100 low-E recent results:

alibrations come before exclusions:



Large lack of response to AmBe low-energy recoils observed elow ~10 keV (a 7 GeV WIMP deposits a maximum of 4 keV in Xe), regardless of Leff adopted.

Such data exist for XENON100, but have never been shown we are working on it").

If a similar situation exists for XENON100, there are no low- ass limits to speak of.

Other DM searches adopt a sensitivity penalty even when mparatively minor disagreements between expectations and servations appear (e.g. COUPP). But not XENON100.

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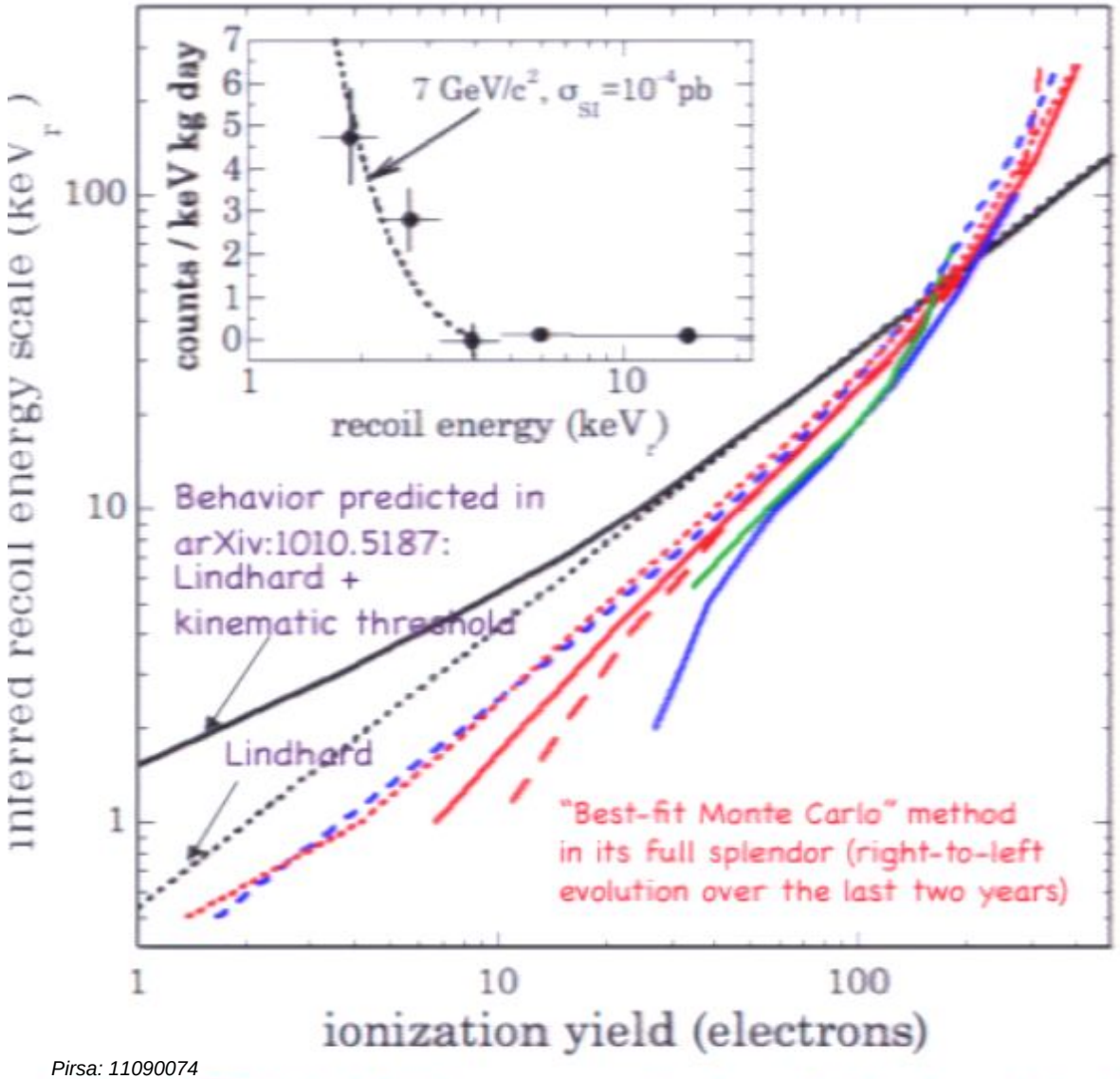
XENON-10 low-E recent results:



Critique (arXiv:1106.0653, 1010.5187):

- Very promising method.
- However, as is stands today: pure drivel.
- Some entirely misleading statements about "interesting" population of low-energy events.
- Energy scale employed clashes (by ~three orders of magnitude) with existing measurements of ionization yield in very low-energy Xe ion-surface literature.
- Seems like some XENON10 authors do not mind contradicting themselves. Continuously.
- No excuse for this (this energy scale can be measured via ($n_{th}\gamma$) calibrations in the relevant range)

additional ~1 keV shift in energy scale turns "robust exclusion" into

an we make sense of the light-WIMP situation?

XENON-10 low-E recent results:

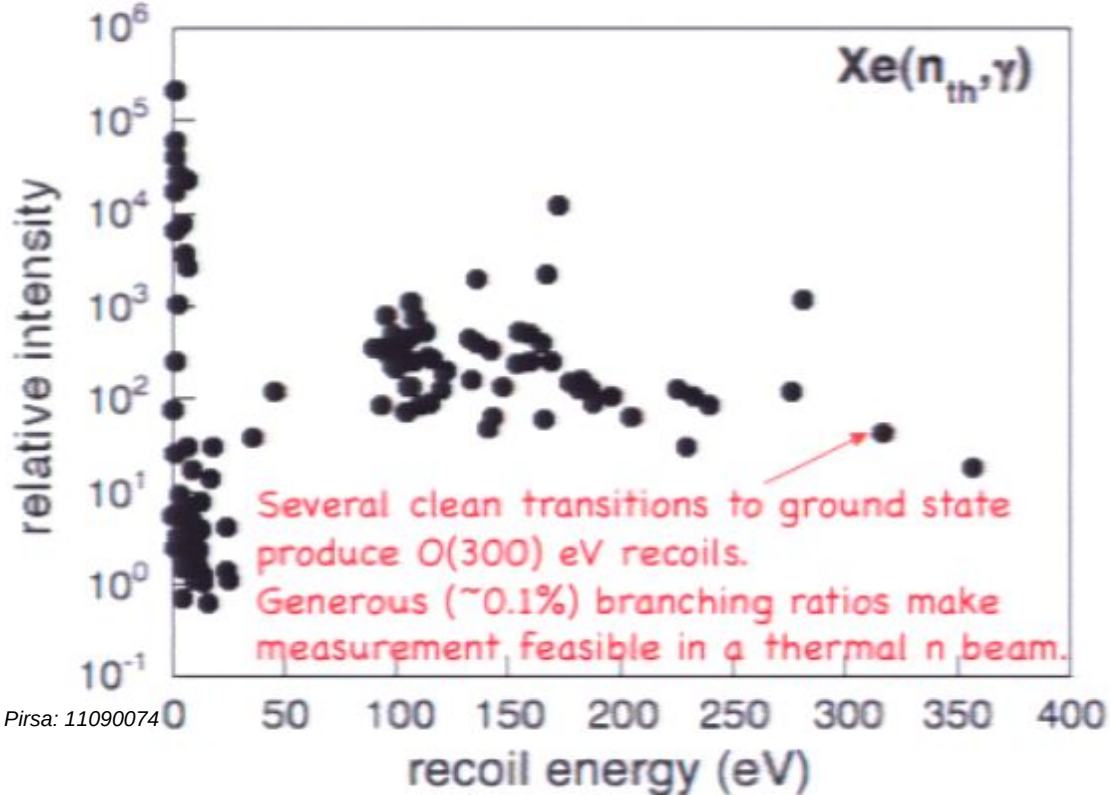
What an experimentalist would do: measure the energy scale (i.e., calibrate the S2 channel in the relevant energy range), THEN attempt to produce an exclusion.

Xenon is a target favorable to use of an old calibration method:

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
Brookhaven National Laboratory, Upton, New York 11973
(Received 30 July 1974)



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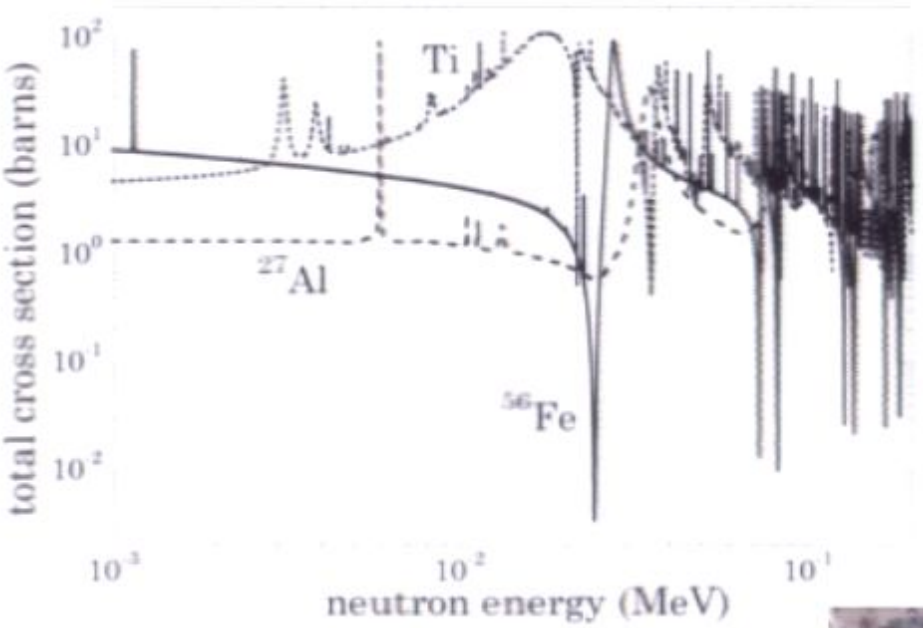
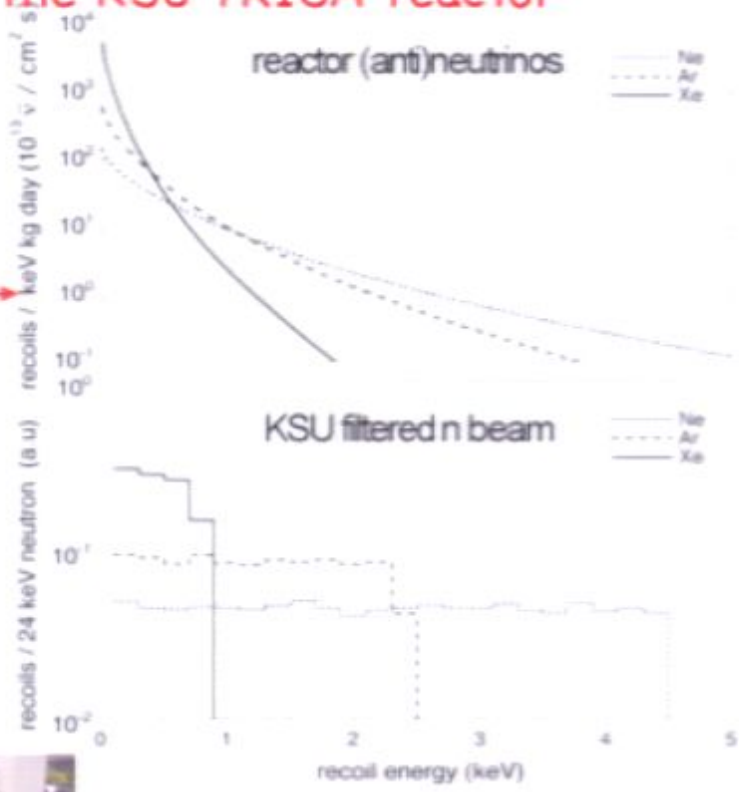
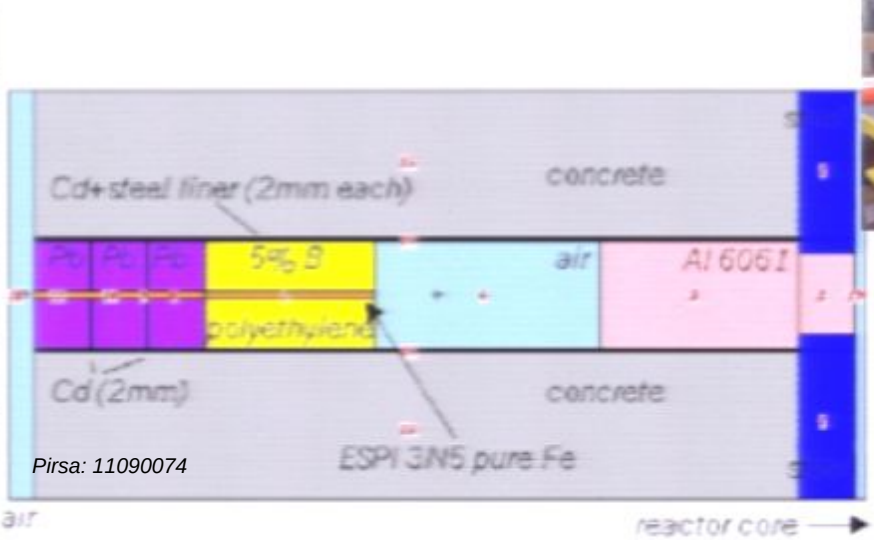
A dose of our own medicine:
PPC sub-keV recoil calibrations at the KSU TRIGA reactor



24 keV n's mimic reactor ν's →

← Fe-Al filter + Ti post-filter





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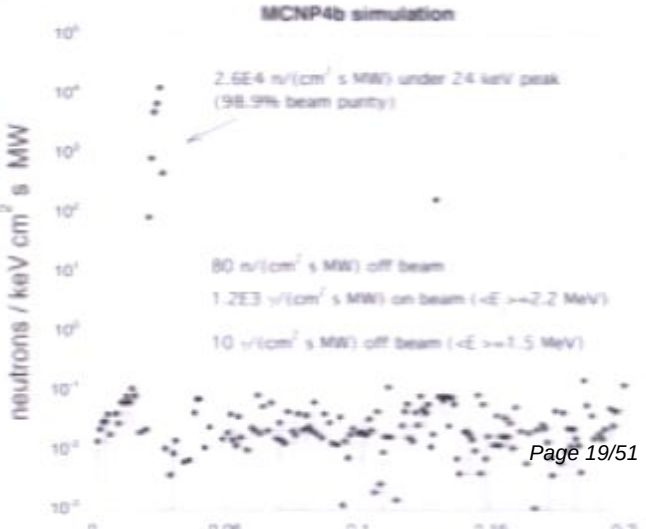


an we make sense of the light-WIMP situation?

XENON-10 low-E recent results:

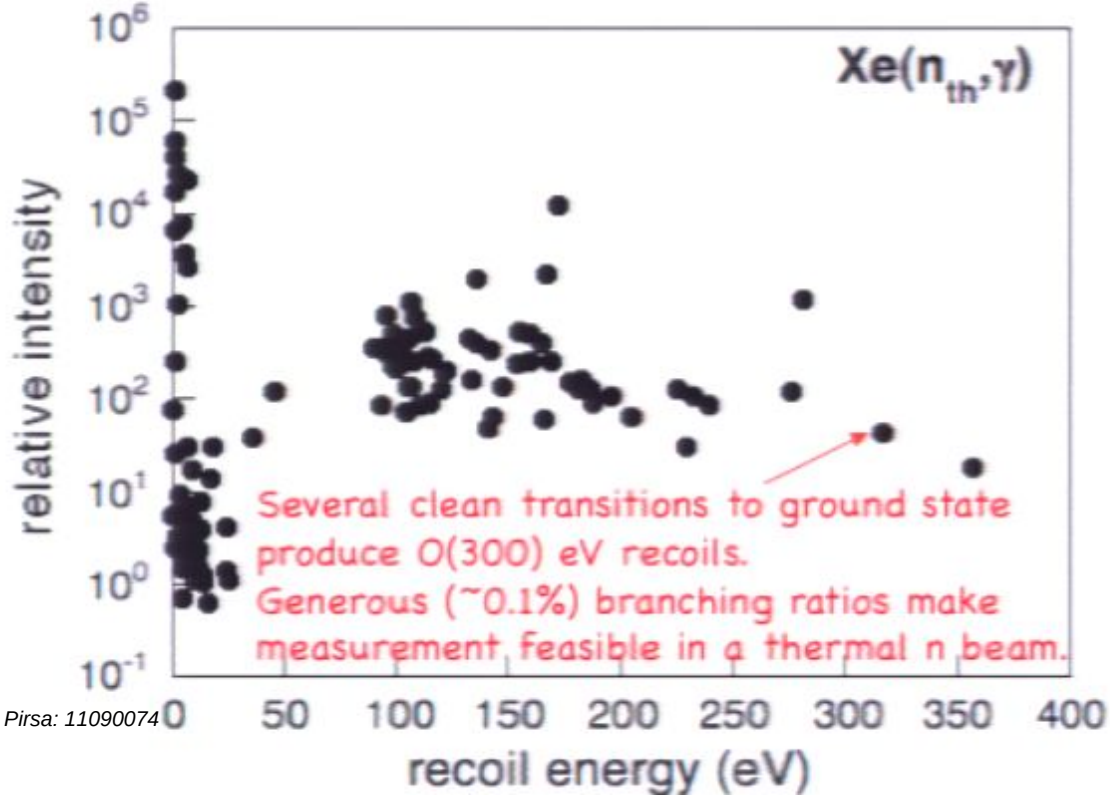
What an experimentalist would do: measure the energy scale (i.e., calibrate the S2 channel in the relevant energy range), THEN attempt to produce an exclusion.

Xenon is a target favorable to use of an old calibration method:

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
Brookhaven National Laboratory, Upton, New York 11973
(Received 30 July 1974)



Critique (arXiv:1106.0653, 1010.5187):

- Very promising method.
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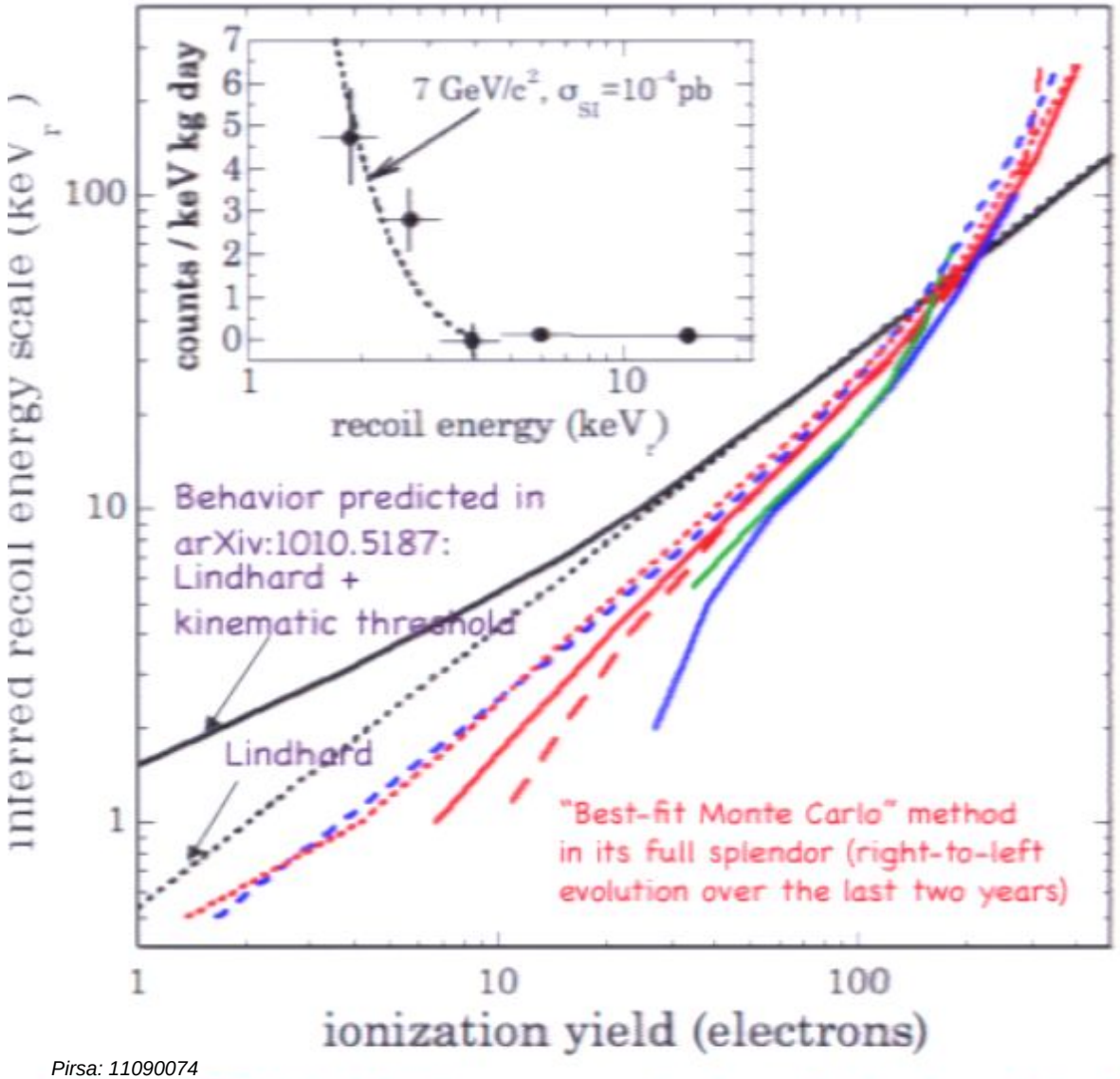

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additional ~1 keV shift in energy scale turns "robust exclusion" into

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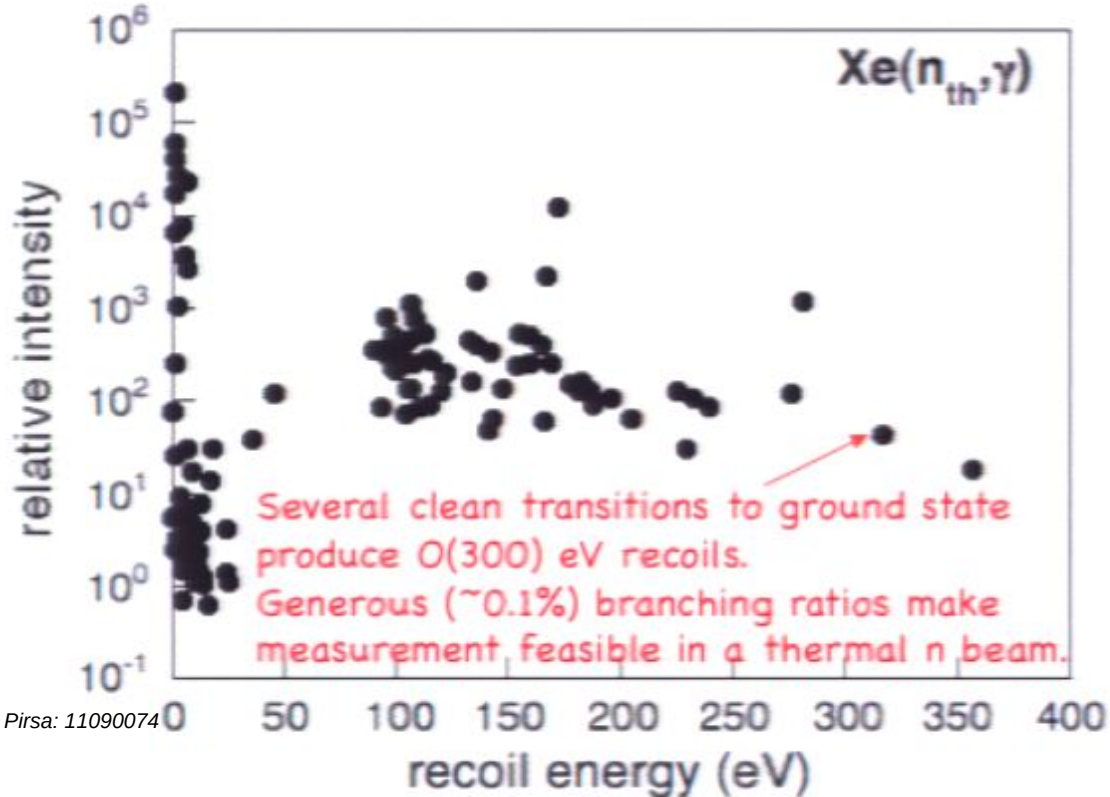

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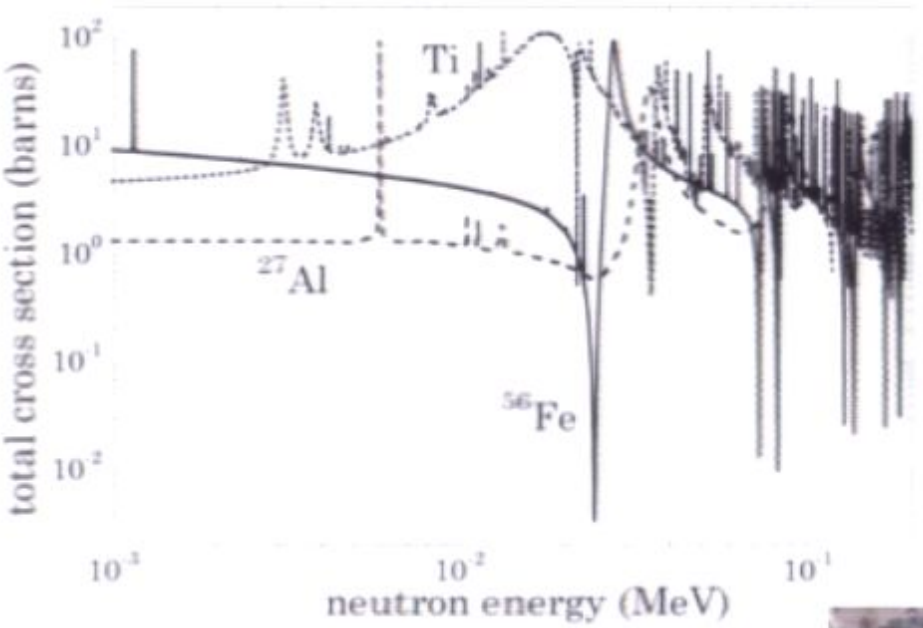
A dose of our own medicine:
PPC sub-keV recoil calibrations at the KSU TRIGA reactor



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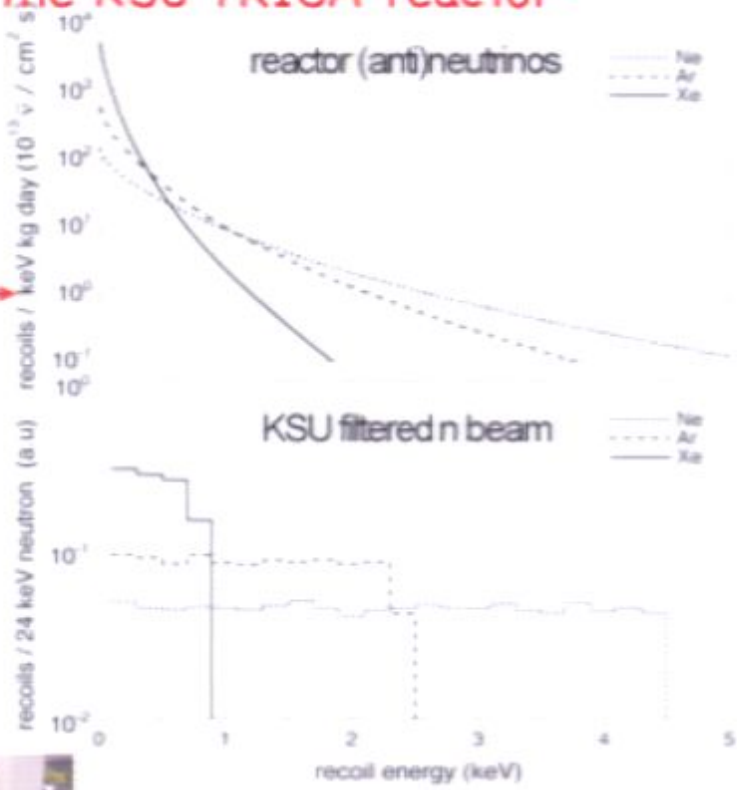

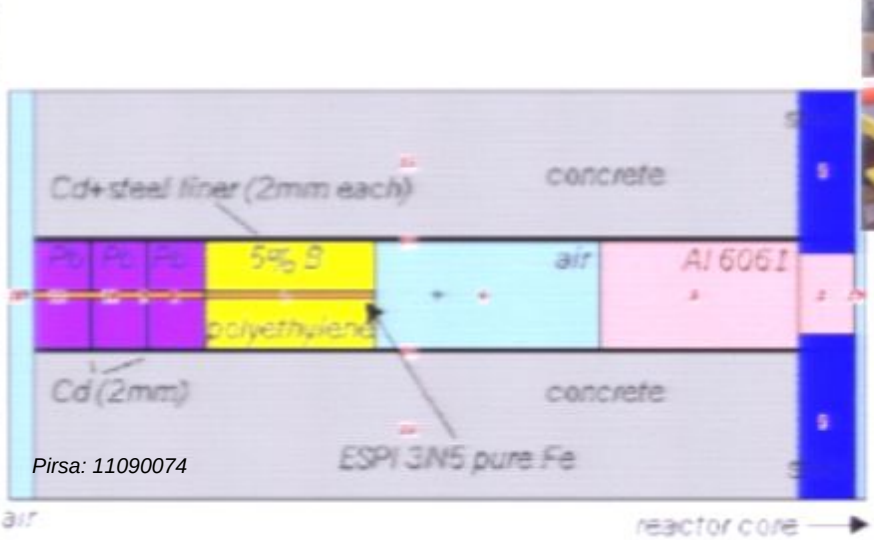

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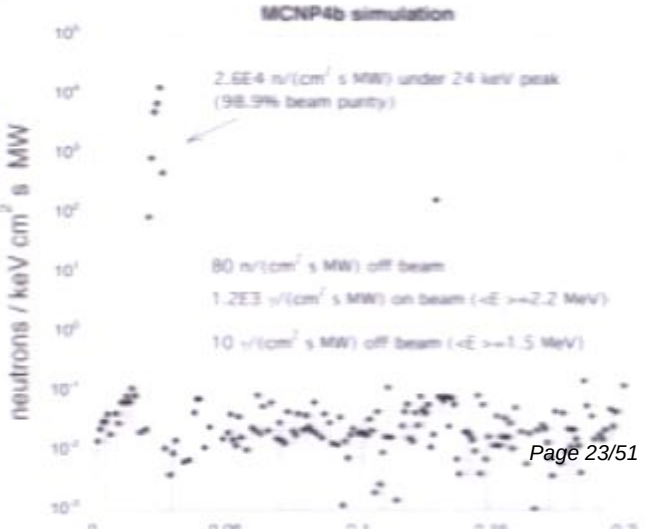

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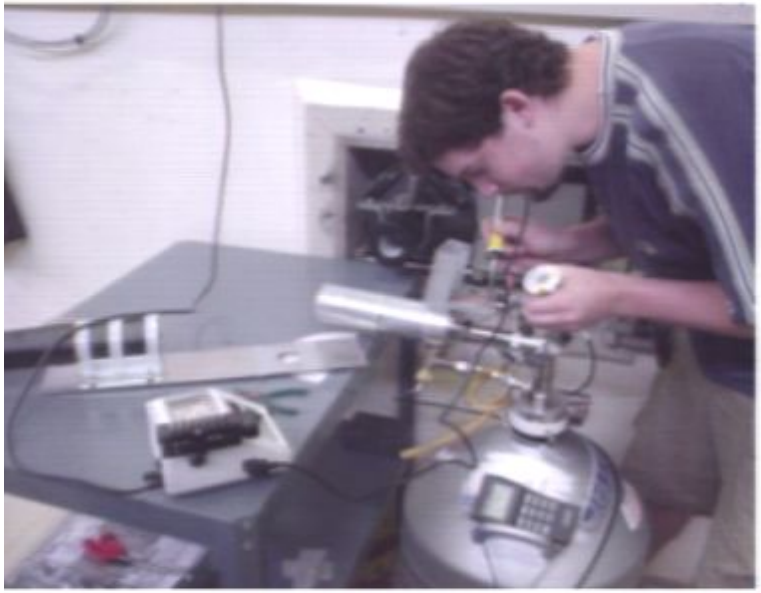
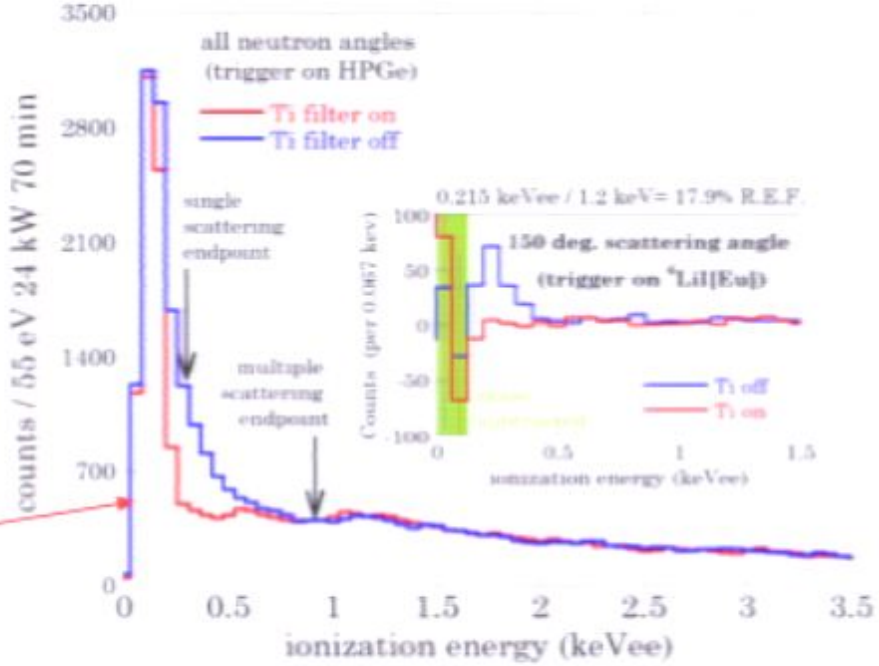
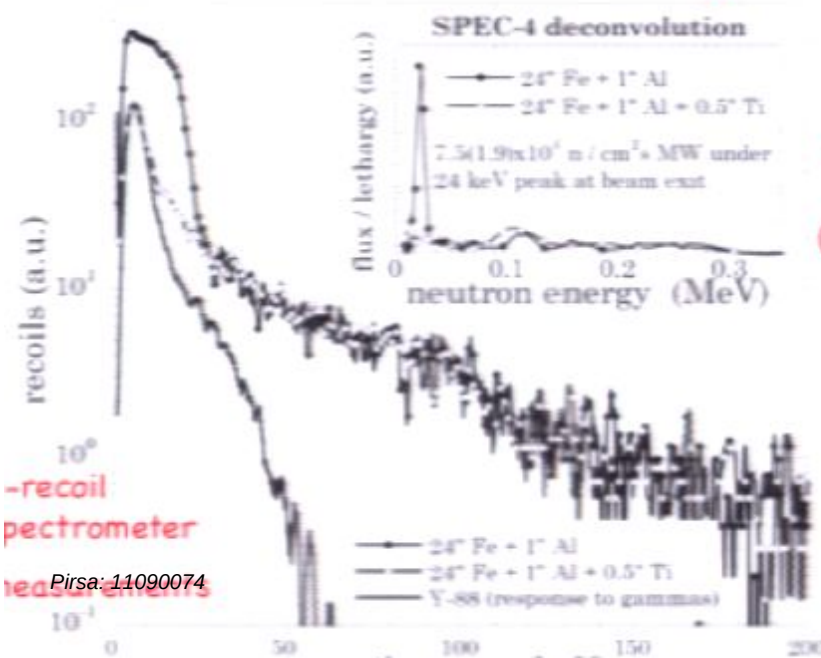


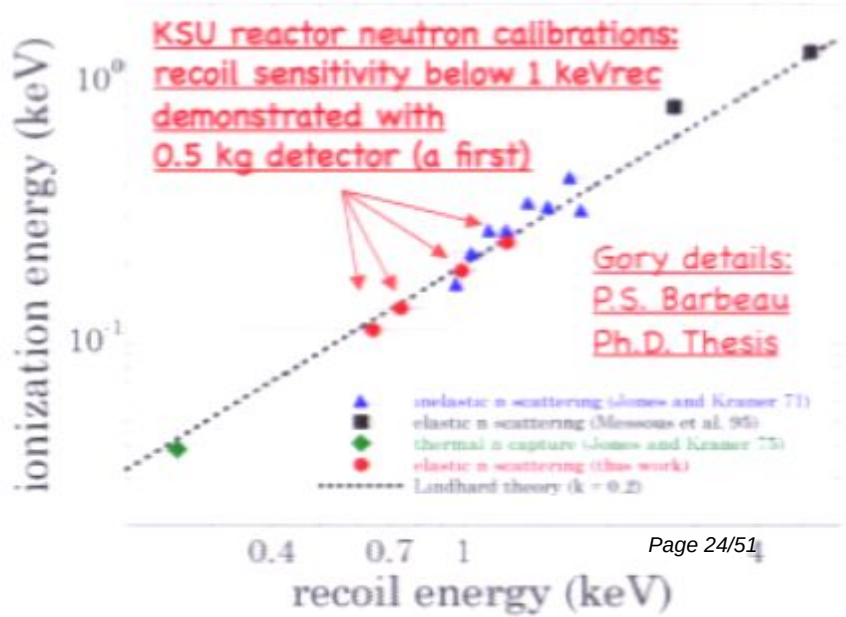
Ti post-filter "switches off" the recoils, leaving all backgrounds unaffected





Beam characterization studies

(nucl-ex/0701011)



an we make sense of the light-WIMP situation?

DAMA uncertainties (Q_{Na}, channeling)

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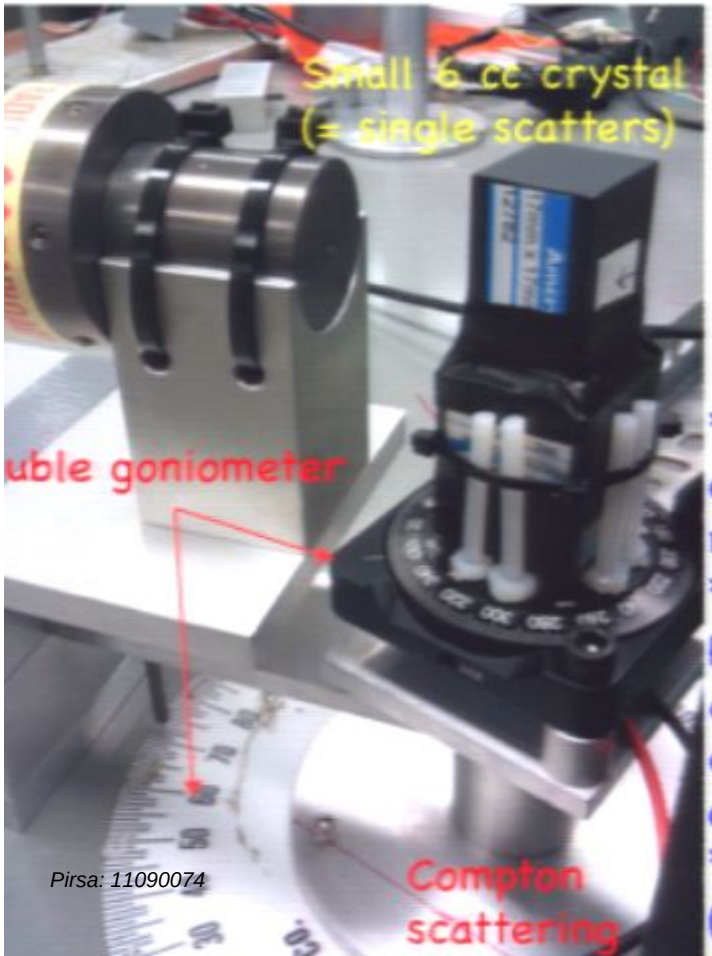

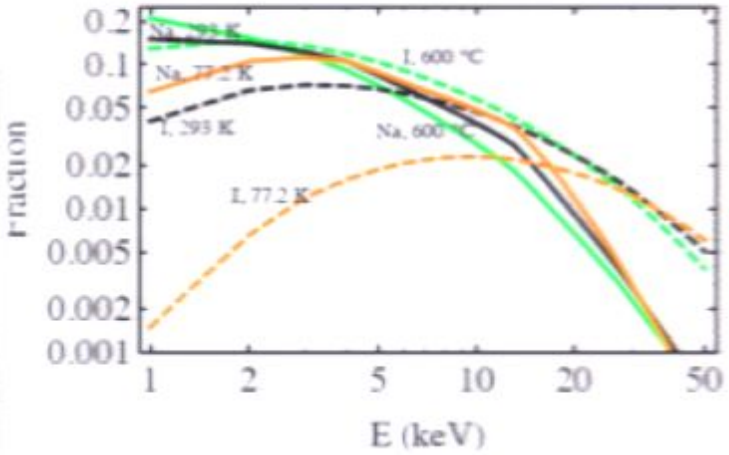

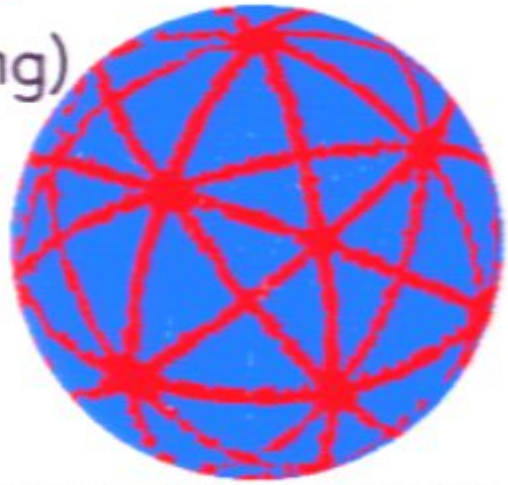

Bozorgnia, Gelmini & Gondolo
arXiv:1006.3110v1

Certain models predict non-negligible channeling: it must be measured!!!

* Response to both electron and nuclear recoils measured.
*Use of ultra bialkali PMT (40% QE) to avoid threshold effects (x3 light yield of previous meas.)
*Crystal with known (growth) axis

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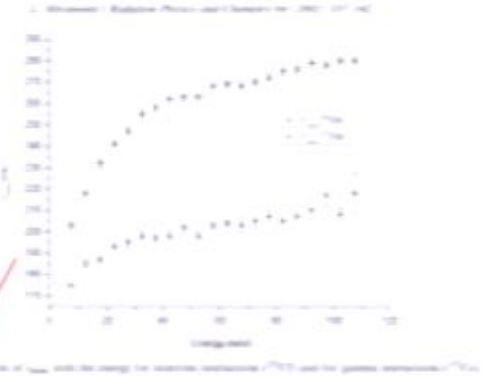

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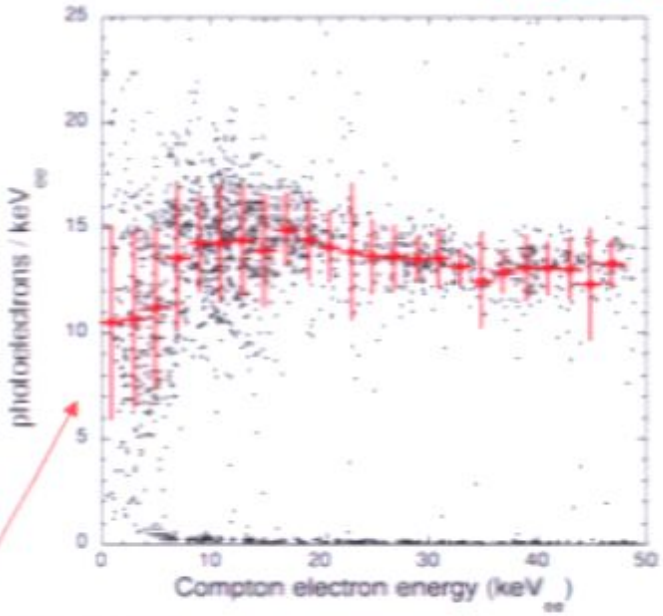

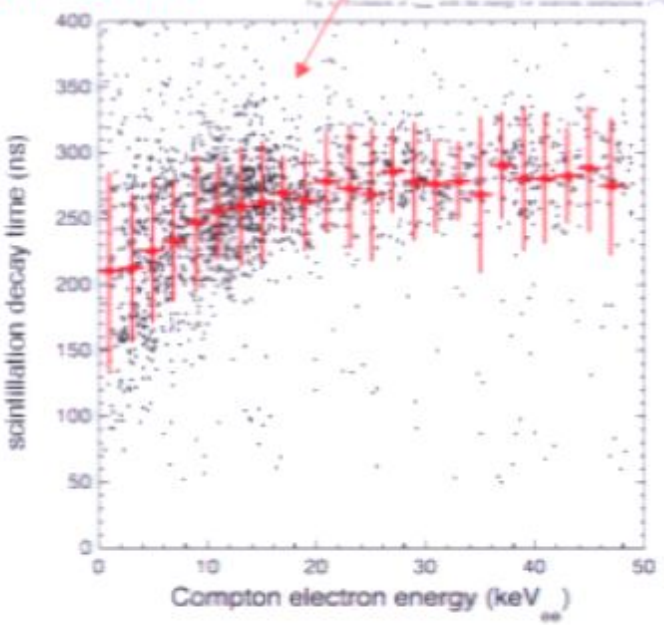

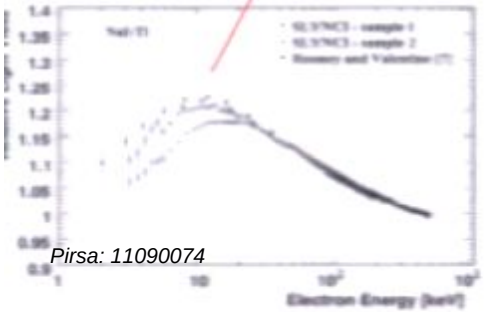

Compton scattering measurements reveal subtle low-E non-linearities expected for NaI[Tl], and excellent light yield via use of ultra-bialkali PMT (up to 15 PE/keV$_{ee}$, compare to 5 PE/keV$_{ee}$ in latest -Chagani 2008-)

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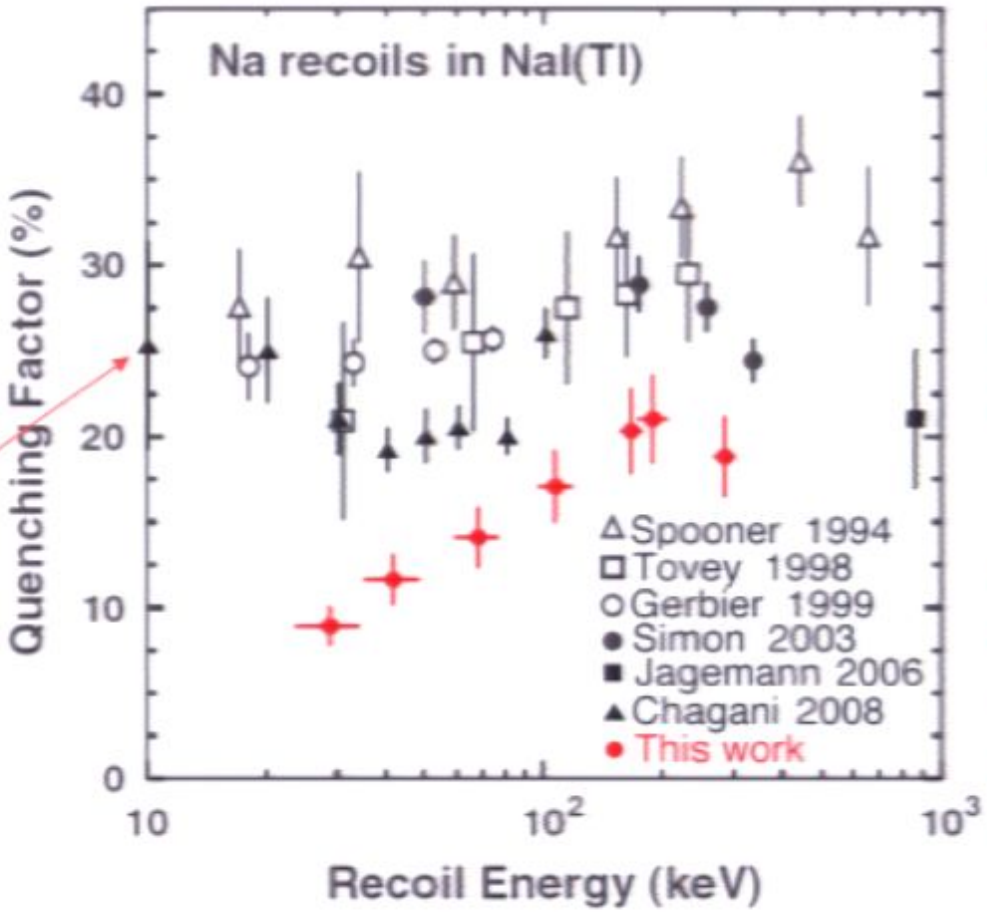

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llar, arXiv:1010.5187

ou cannot expect a
oper measurement
Q at 10 keV_r with
st 5 PE/keV_{ee} and a
00 cc crystal...)

Surprisingly small quenching factor... (in a very clean measurement, away from threshold effects and with negligible multiple scattering).

Several previous measurements do not account for NaI[Tl] non-linearity in electron recoil response.

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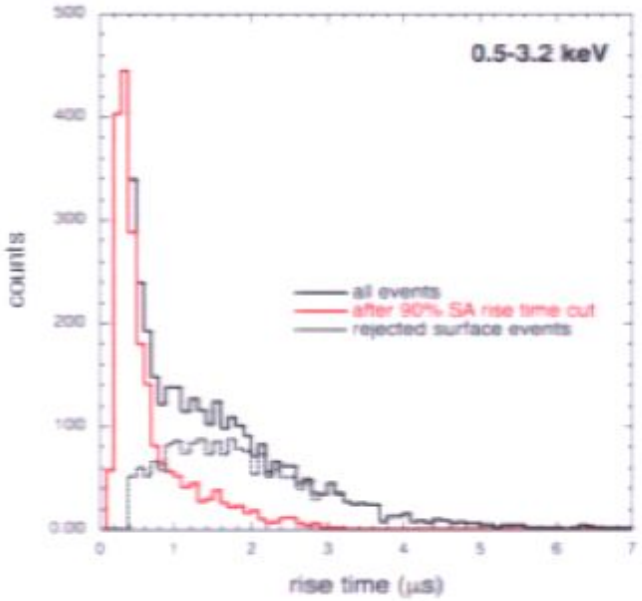
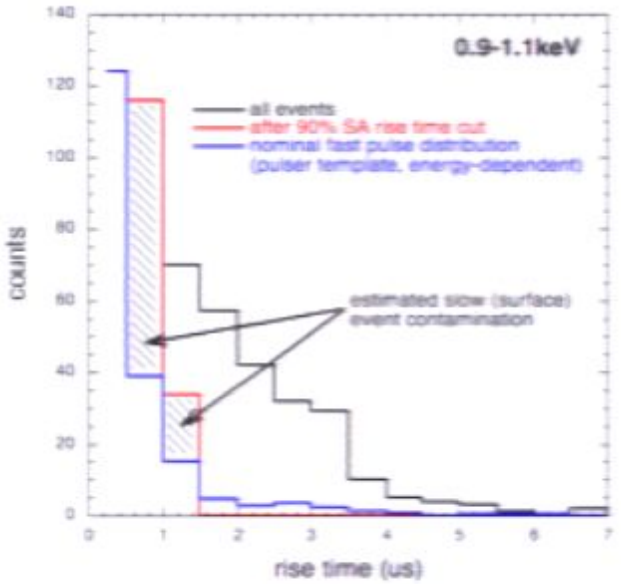
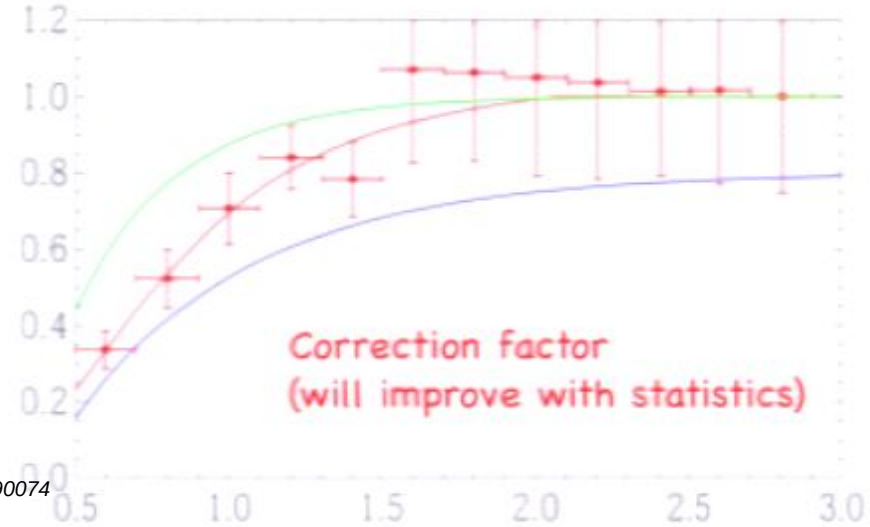
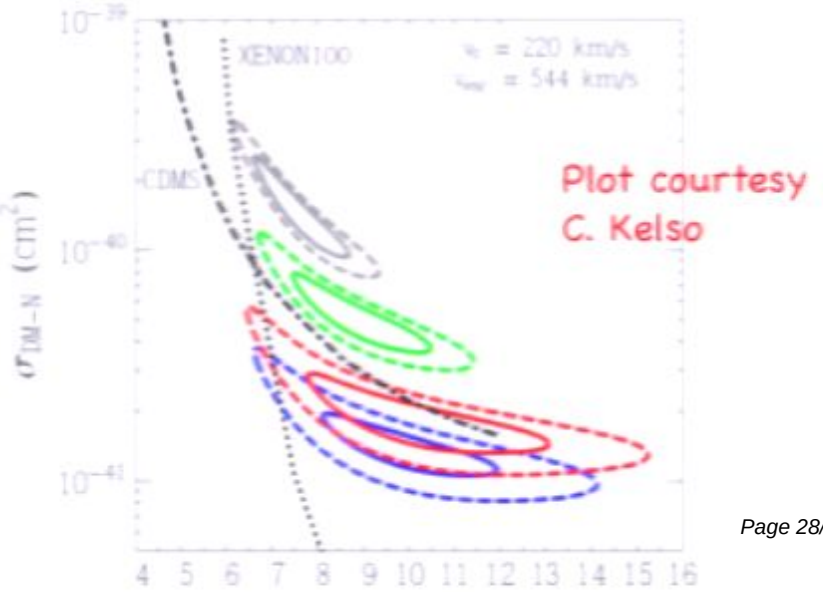
CoGeNT uncertainties (e.g., surface event rejection next to threshold)

PRELIMINARY (work in progress, not an exact science yet)









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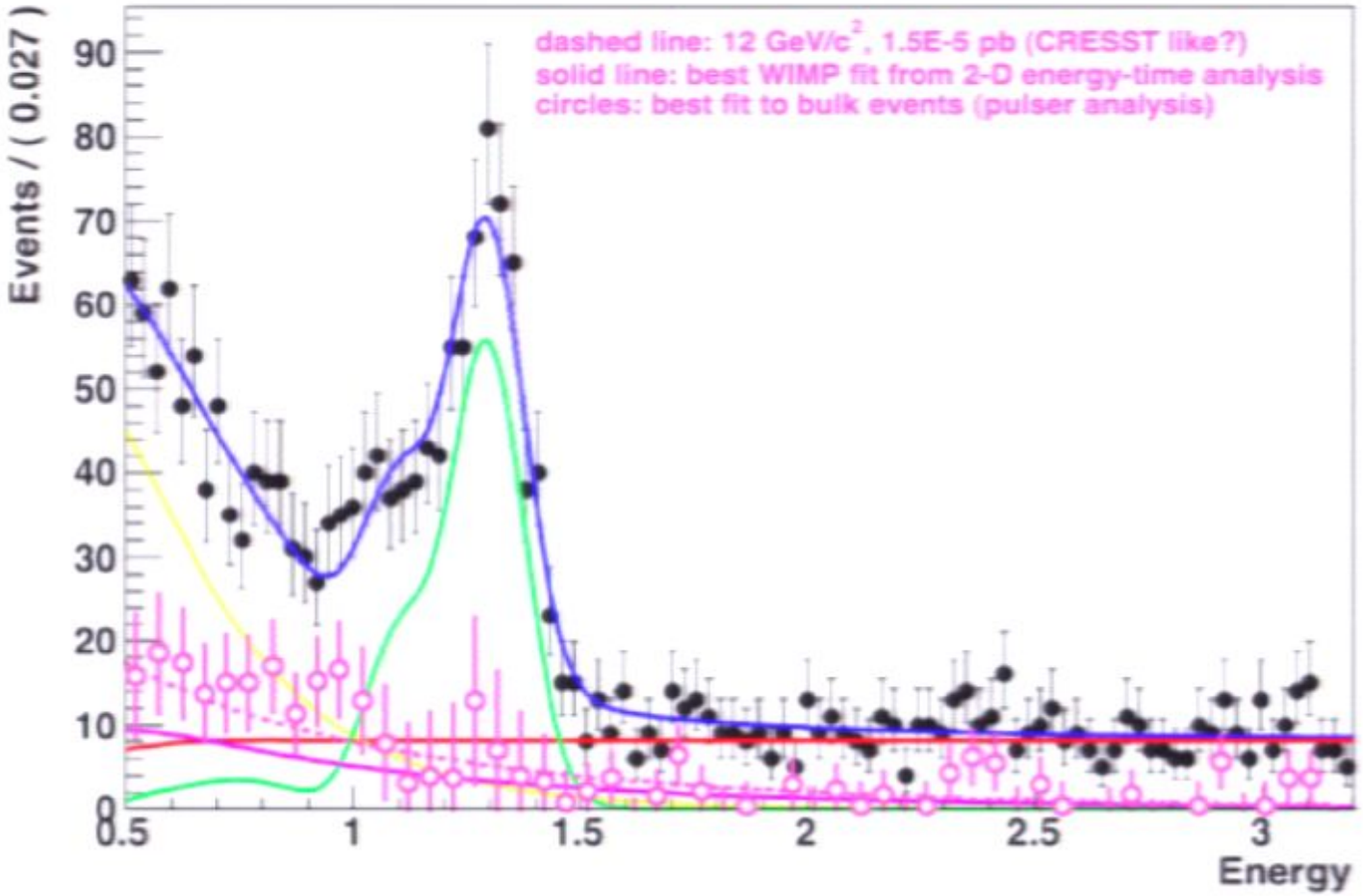

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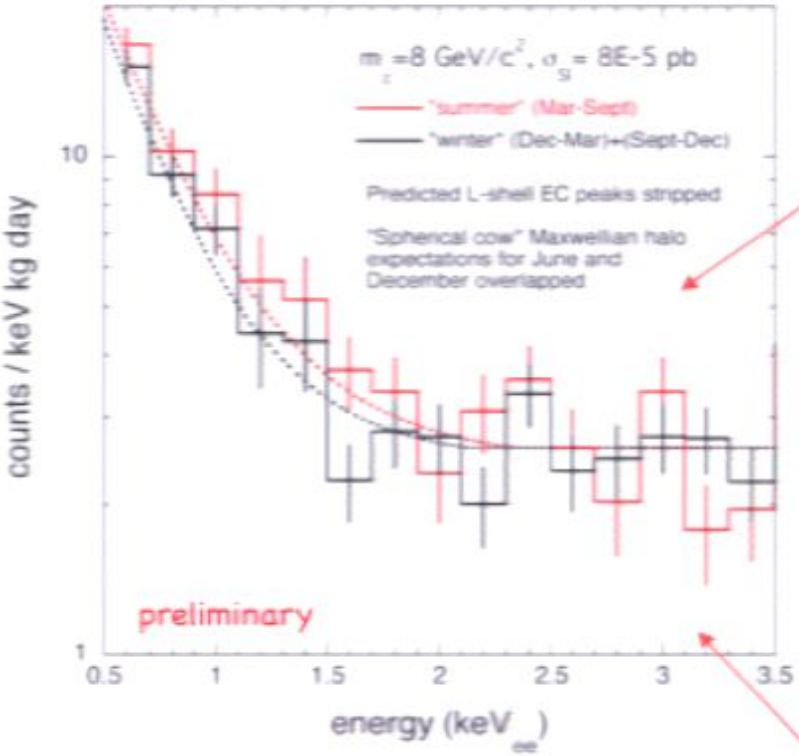
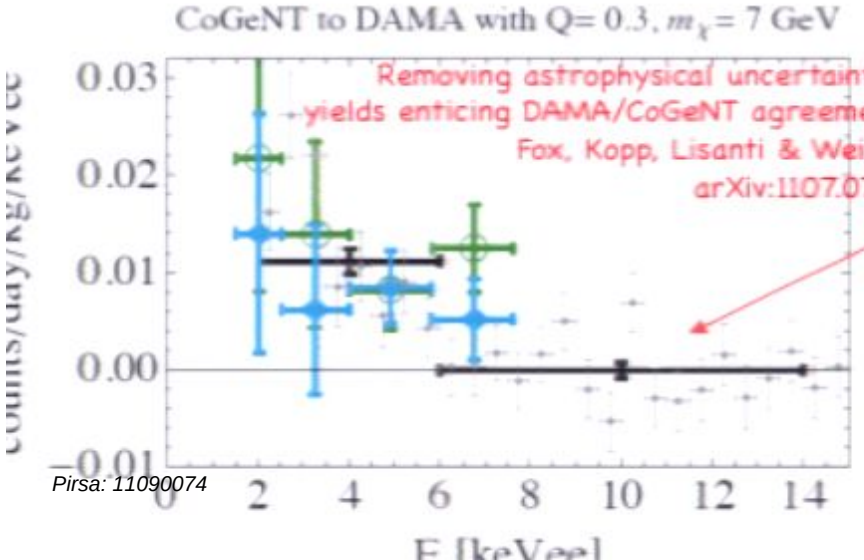
BUT then modulated amplitude is definitely not what you would expect from a vanilla halo (way too large).

Are DAMA, CoGeNT and CRESST in agreement, or not at all?





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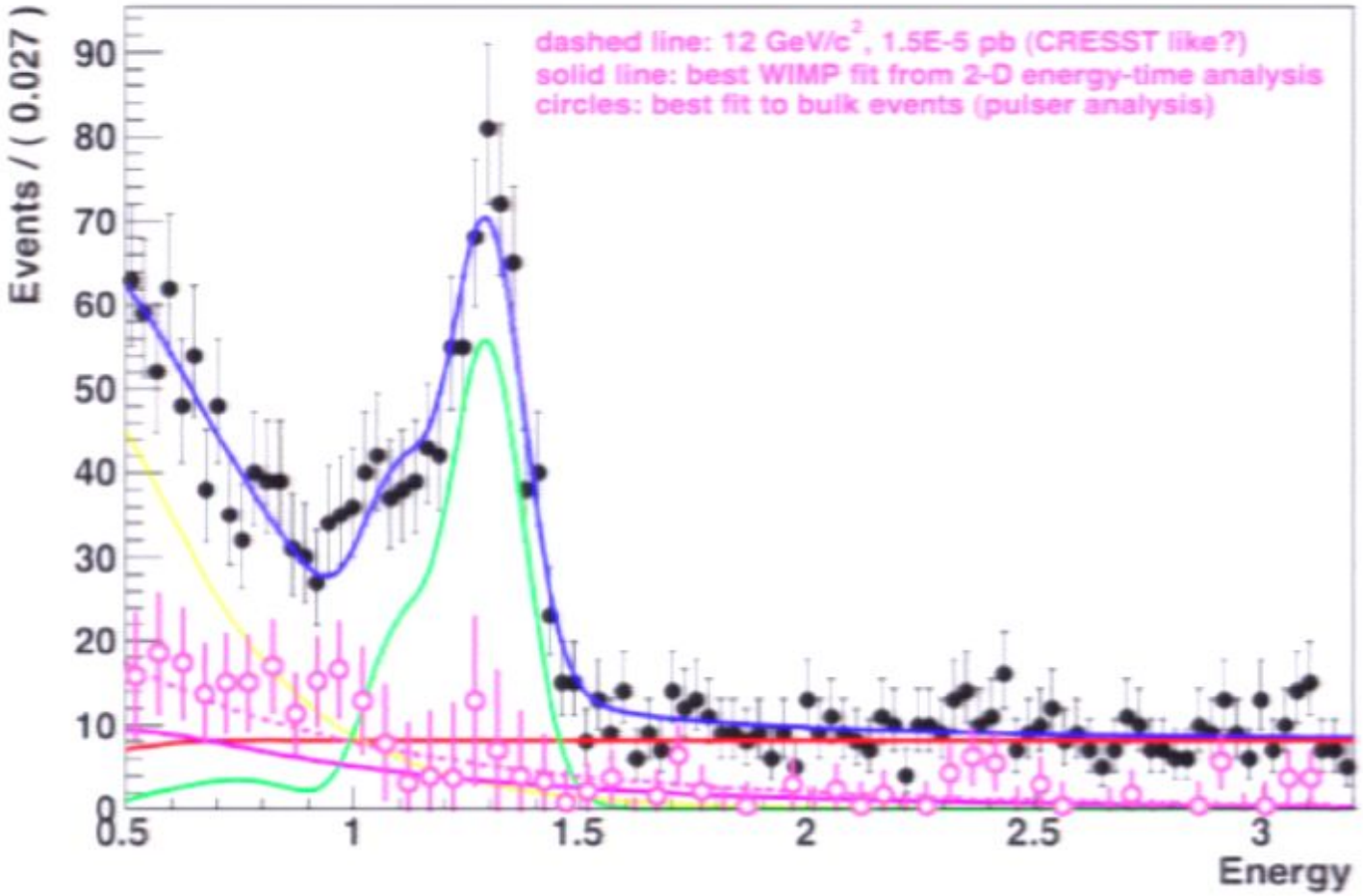

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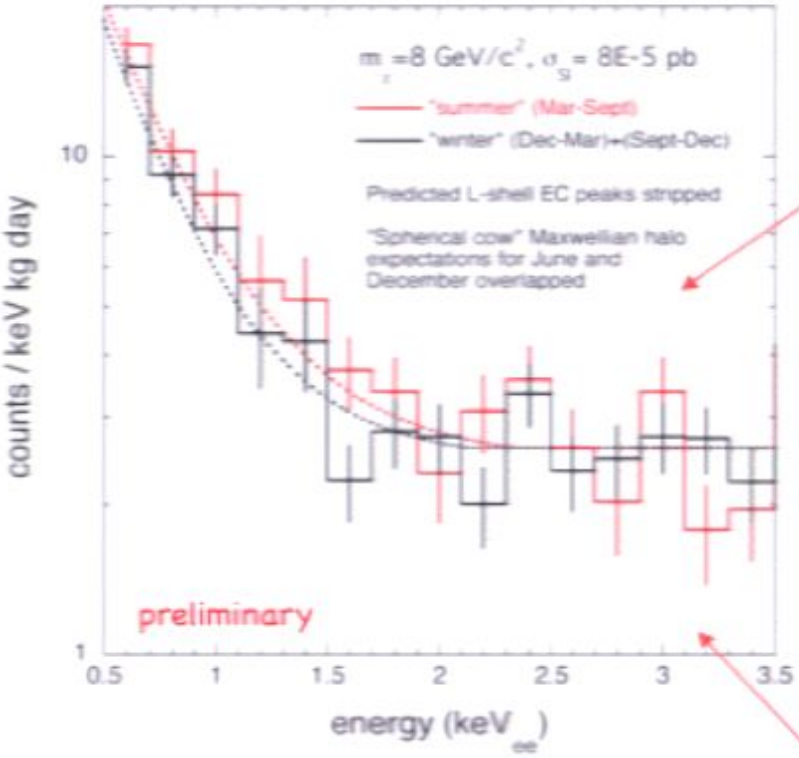

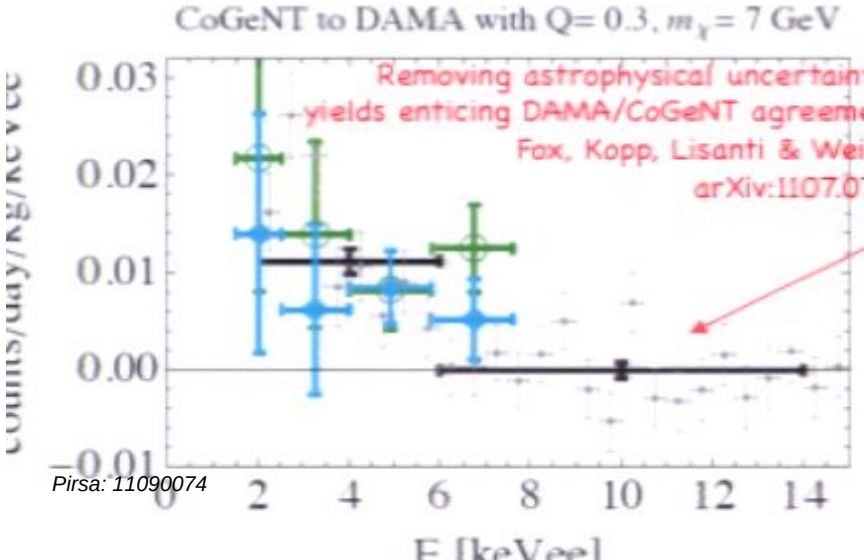

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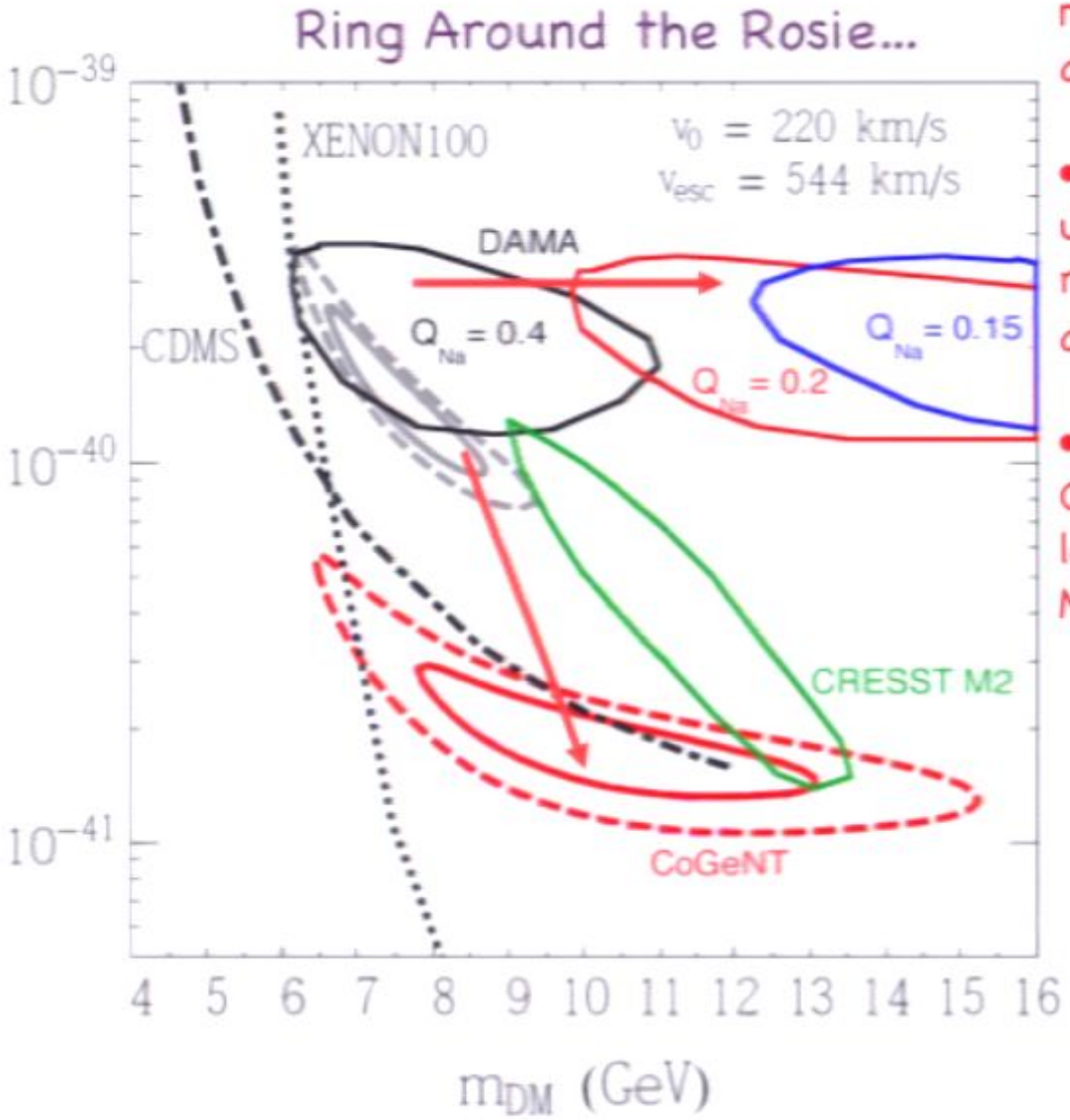

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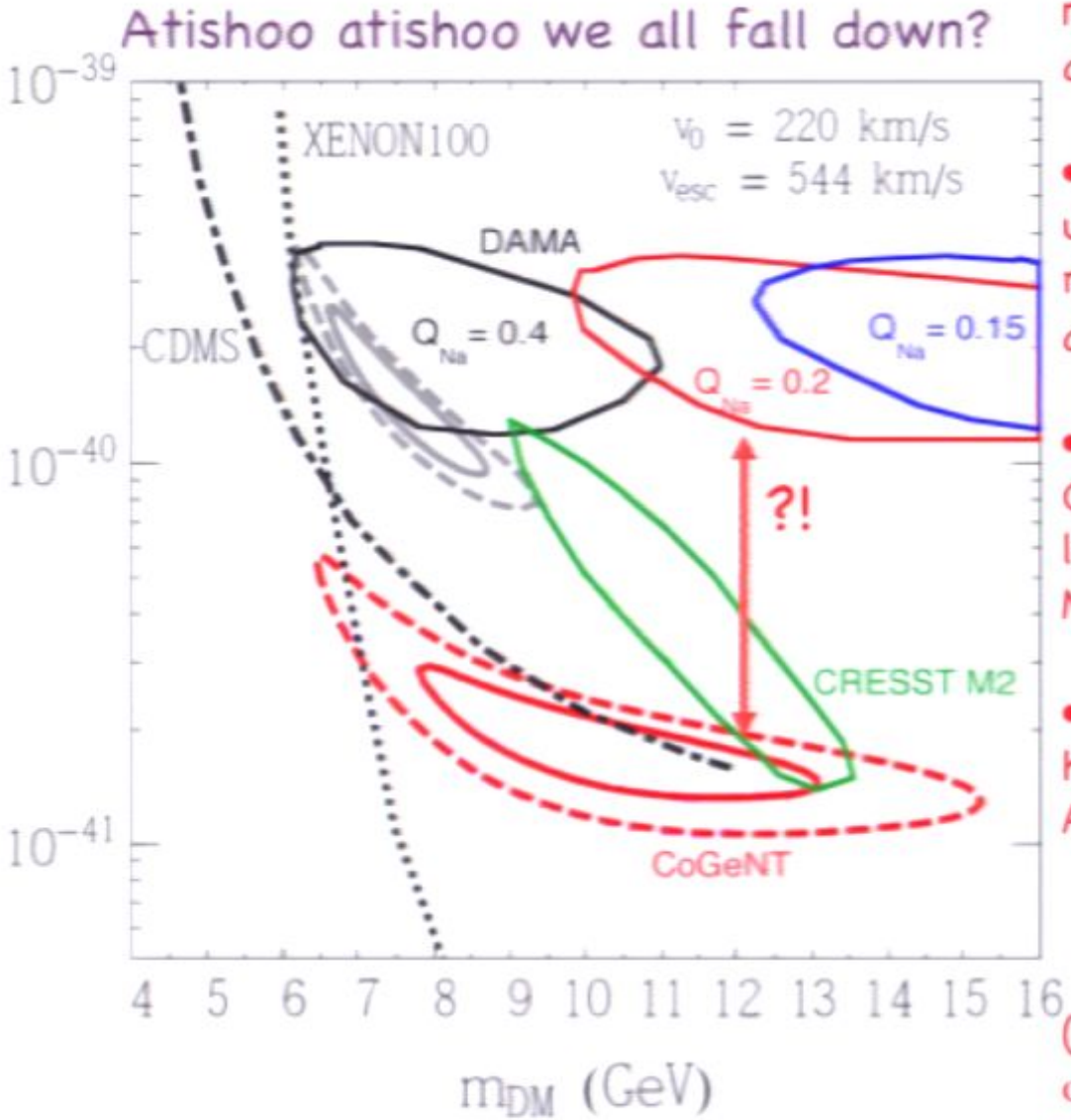

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  - * IVDM...
  - * streams, dark disk, etc...

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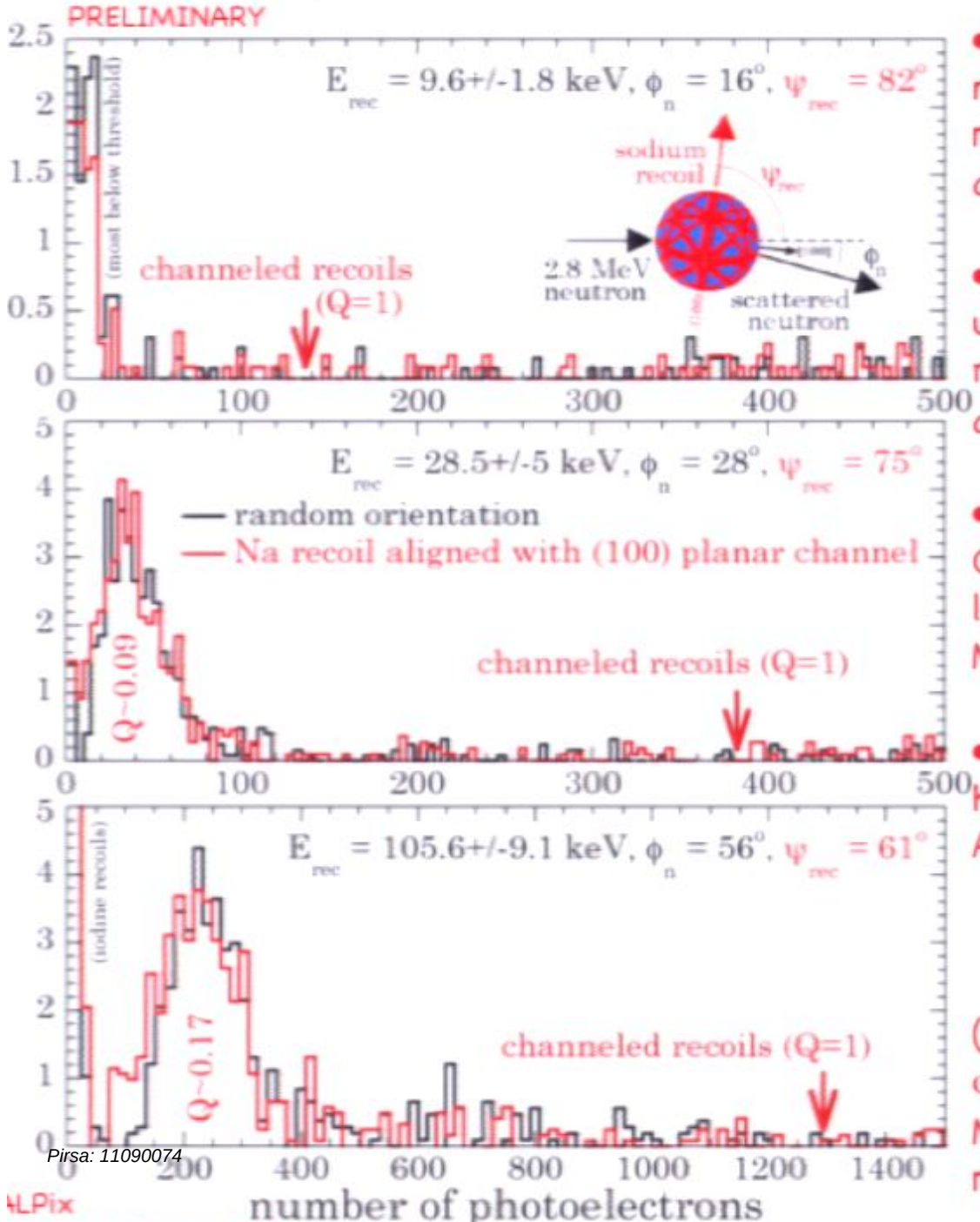

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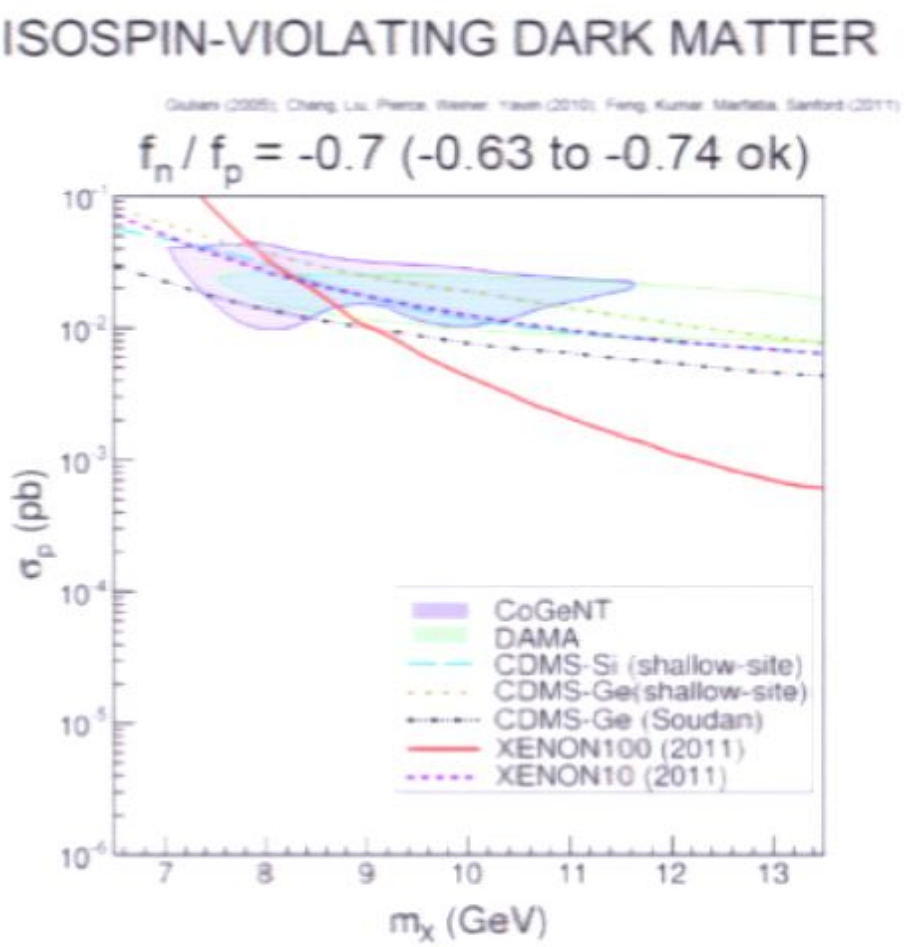

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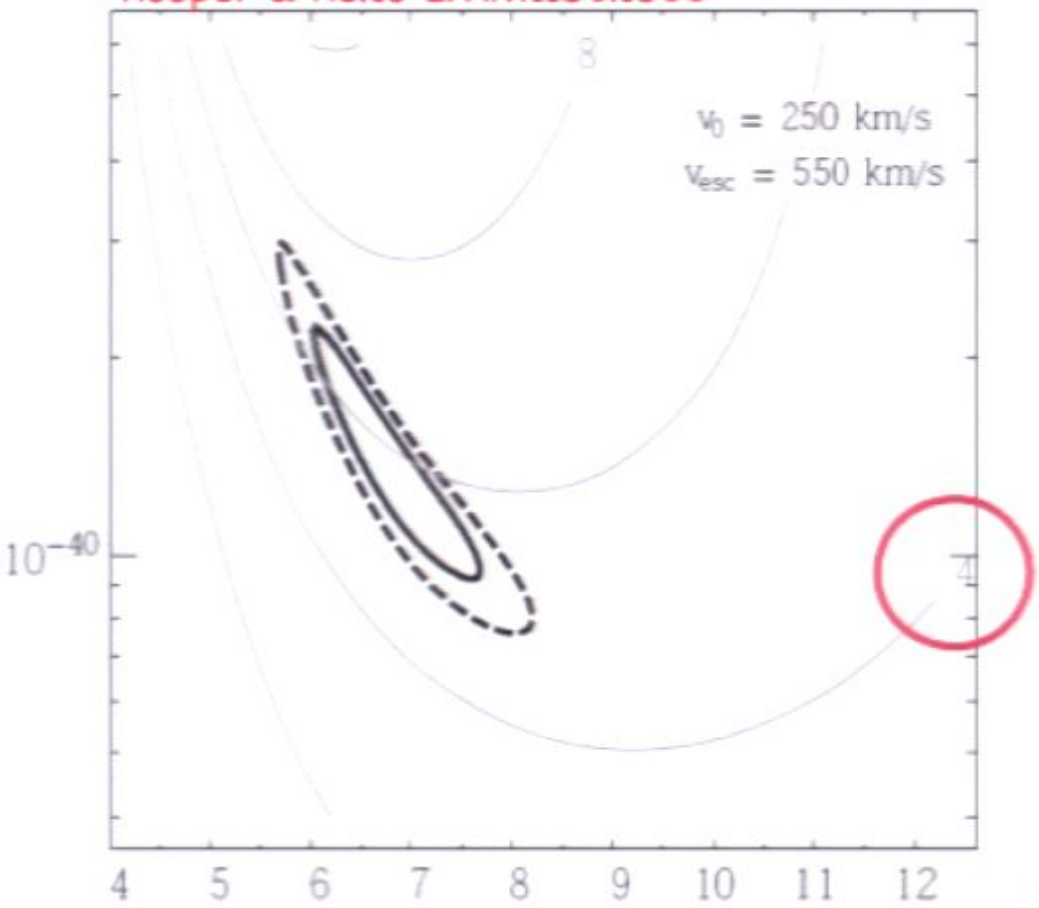
Hooper & Kelso arXiv:1106.1066



Some interesting incipient work:
A.M. Green: arXiv:1109.0916
Natarajaran, Savage & Freese: arXiv:1109.0014

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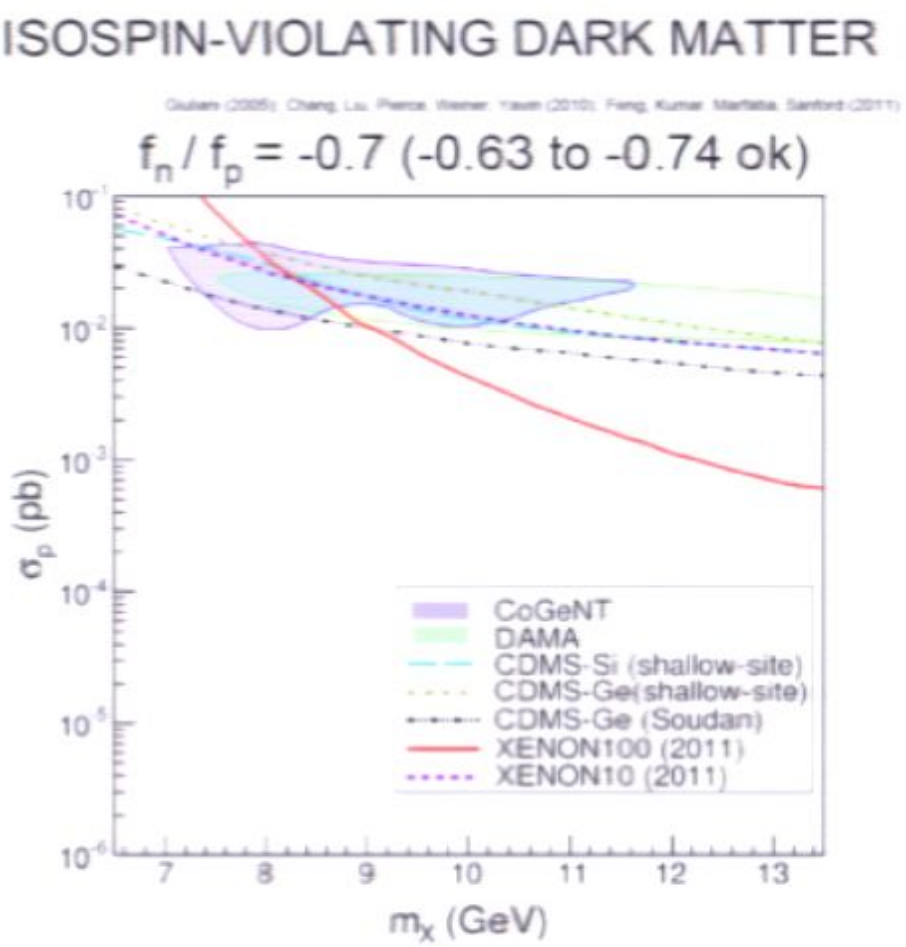

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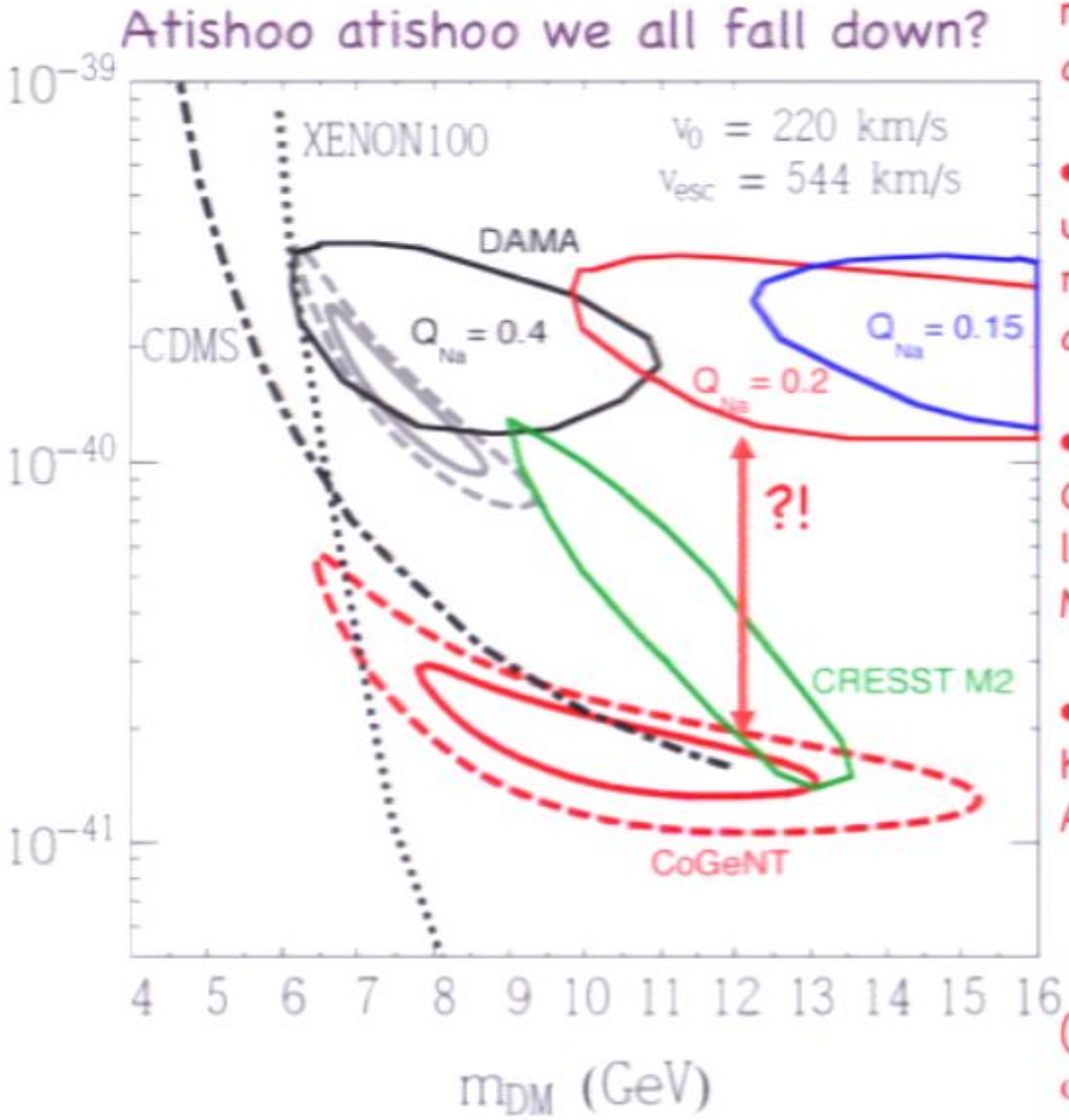
Are DAMA, CoGeNT and CRESST in agreement, or not at all?



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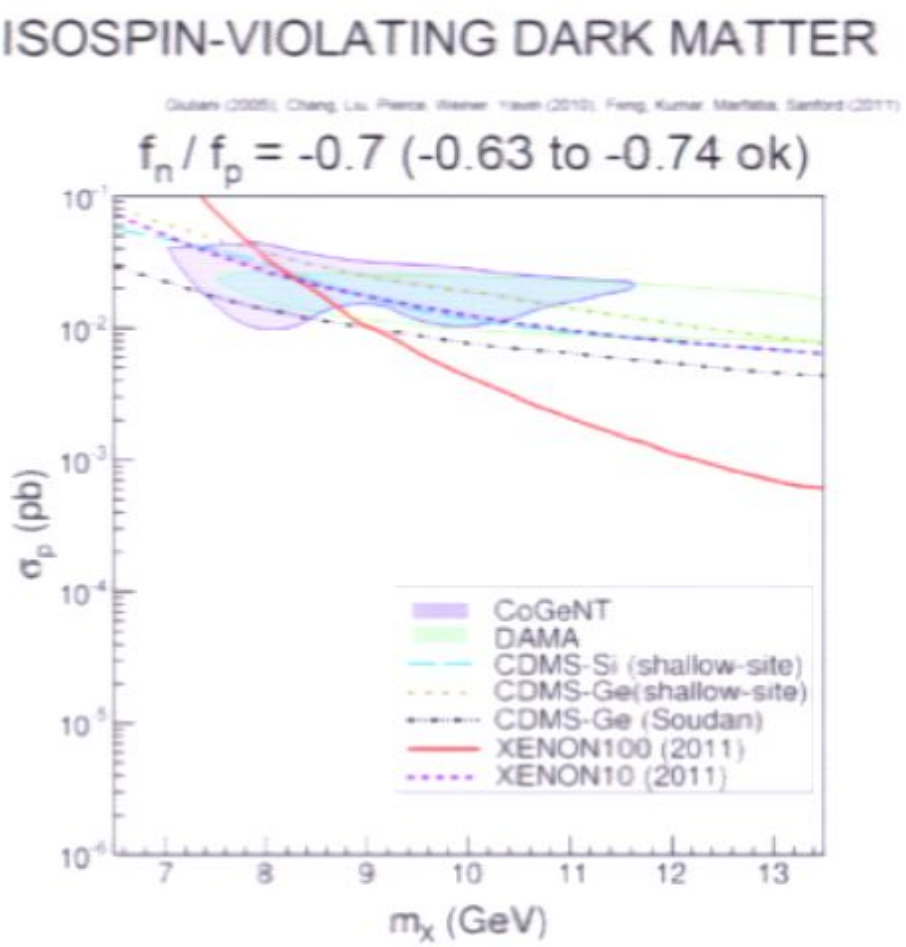

Very intriguing possibility
(but let us hope XENON "tension" is not the motivation for such departures... we are not quite there yet)

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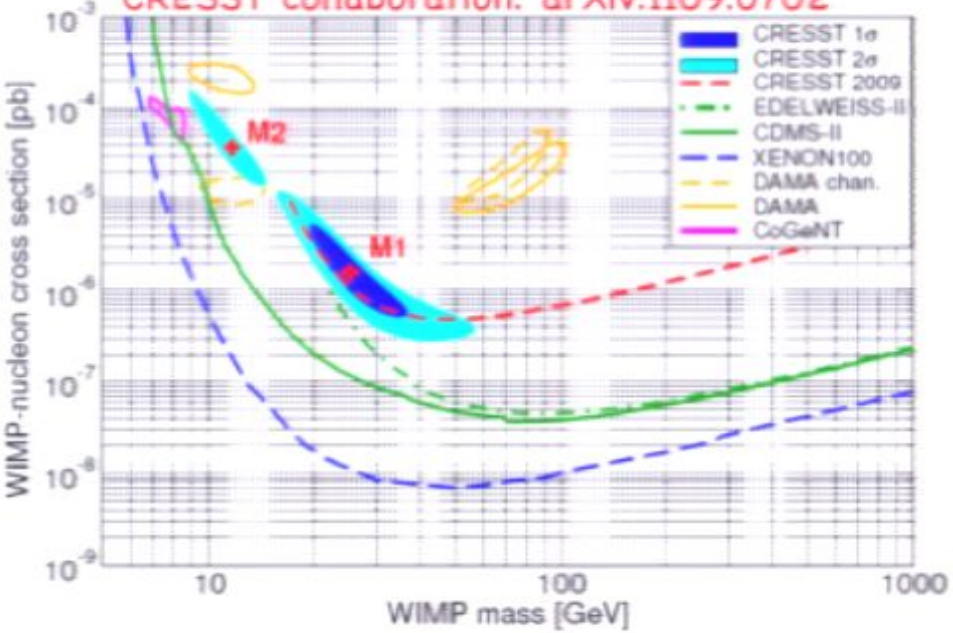
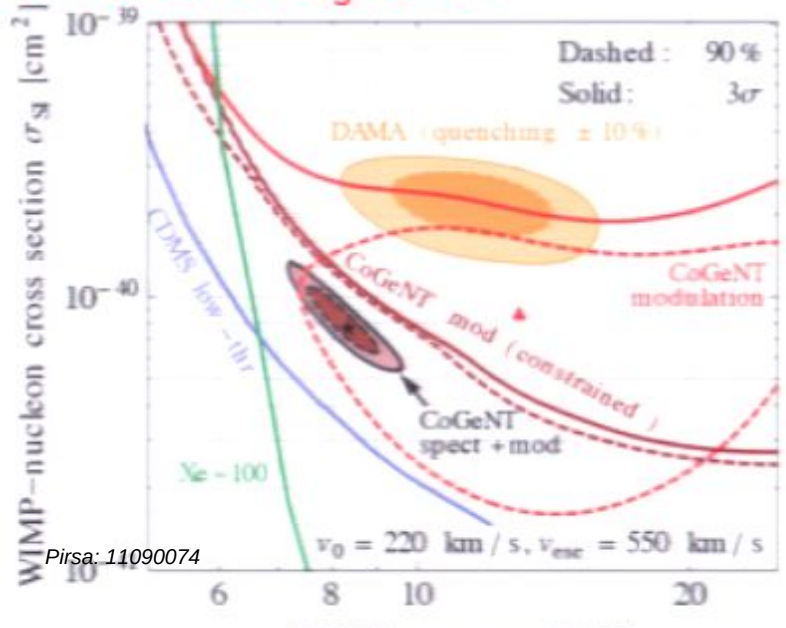
CRESST collaboration: arXiv:1109.0702



CoGeNT modulation ROI and CRESST M2 region seem to be in remarkable agreement.



P. Fox et al., arXiv: 1107.0717
See also Schwetz & Zupan arXiv: 1106.6241, P. Belli et al. arXiv: 1106.4667, etc.

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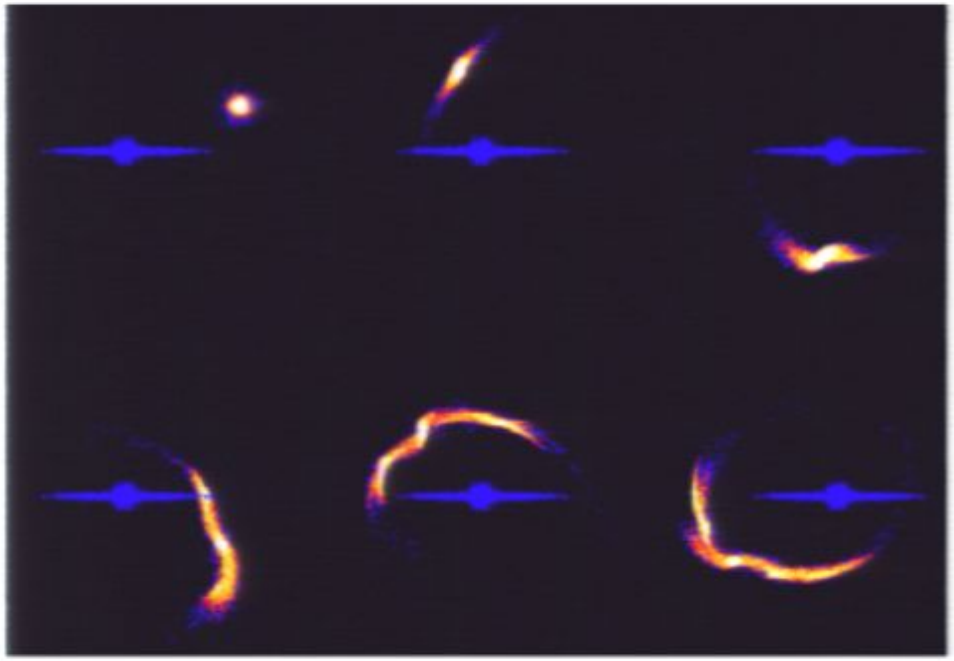
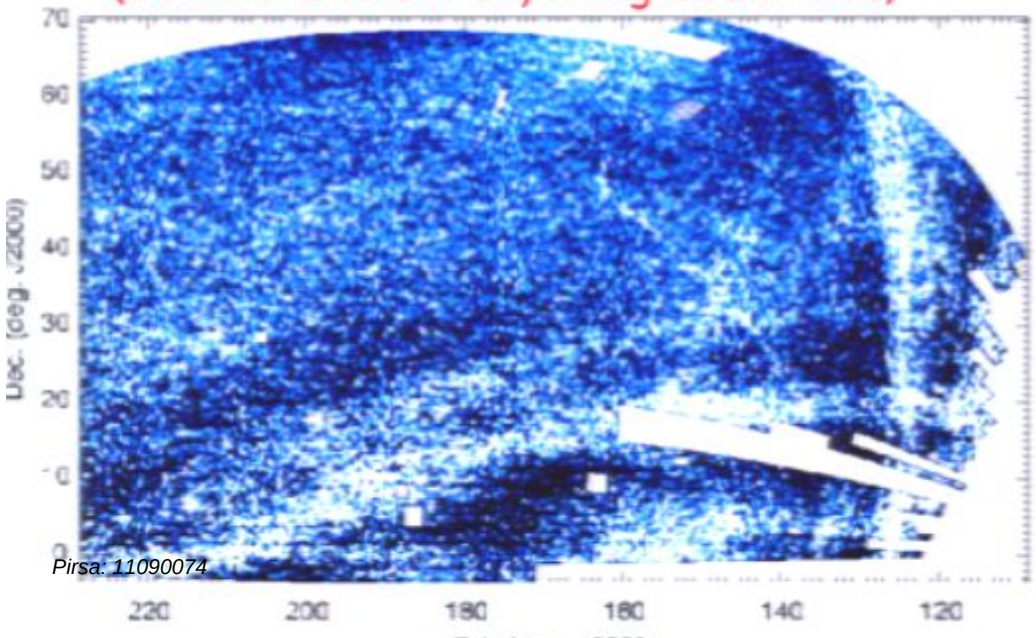


(Damn if I know anything about this)



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A few (personal) reflections:

* On a bad day: do we know enough about the halo, DM coupling mechanisms, etc. to be playing this game? The last few transparencies follow very precisely the Popperian definition of pseudoscience... (and yet, a cynic would argue that this may be the beginning of "precision" DM work).

* On a good day: I am reminded of the Adams/Leverrier prediction for Neptune (i.e., maybe we are about to learn something new out of this royal mess). Also of how much fun we've been poking at the "spherical cow" halo model.

("bad day" and "good day" above are exchangeable)

* On any given day: I look forward to more experimental data, and to an absence of bias in their interpretation.

And a brief desiderata:

* CDMS has collected ~10 times the low-E exposure of CoGeNT, spanning >4 annual cycles. Interest in light-WIMPs as a solution to the DAMA conundrum goes back to 2004 (Bottino *et al.*, later re-examined by Gelmini & Gondolo). This was the motivation for CoGeNT. For when a CDMS annual modulation analysis?

* Calibrations come before exclusions: the last time XENON presented a comparison between low-E neutron recoil rates and corresponding expectations was in 2007 (Manzur, APS meeting). It did not look good at all. Such data exist for XENON100. If the disagreement is as for XENON10, there are no low-mass exclusions to speak of.

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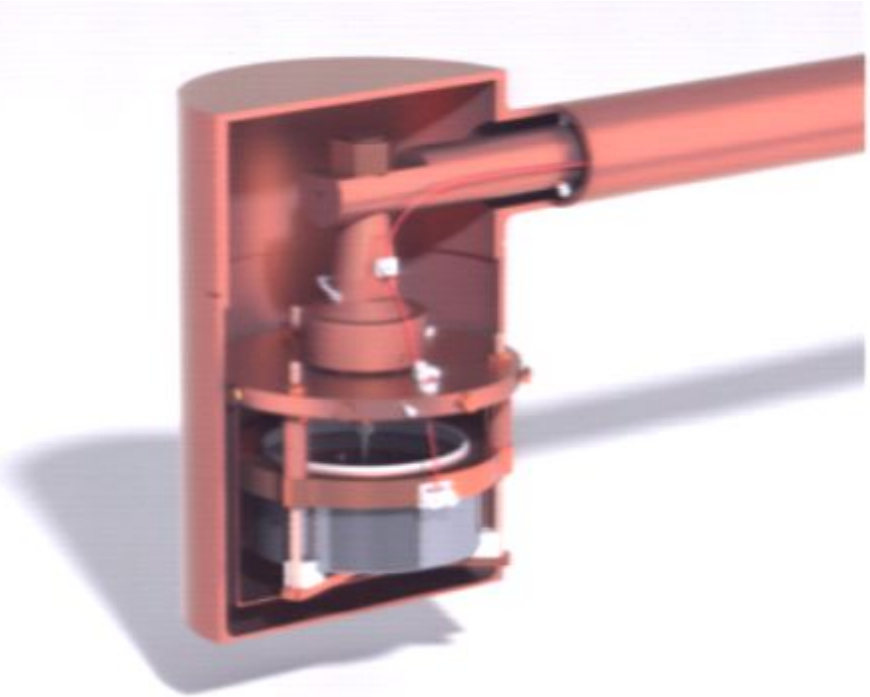
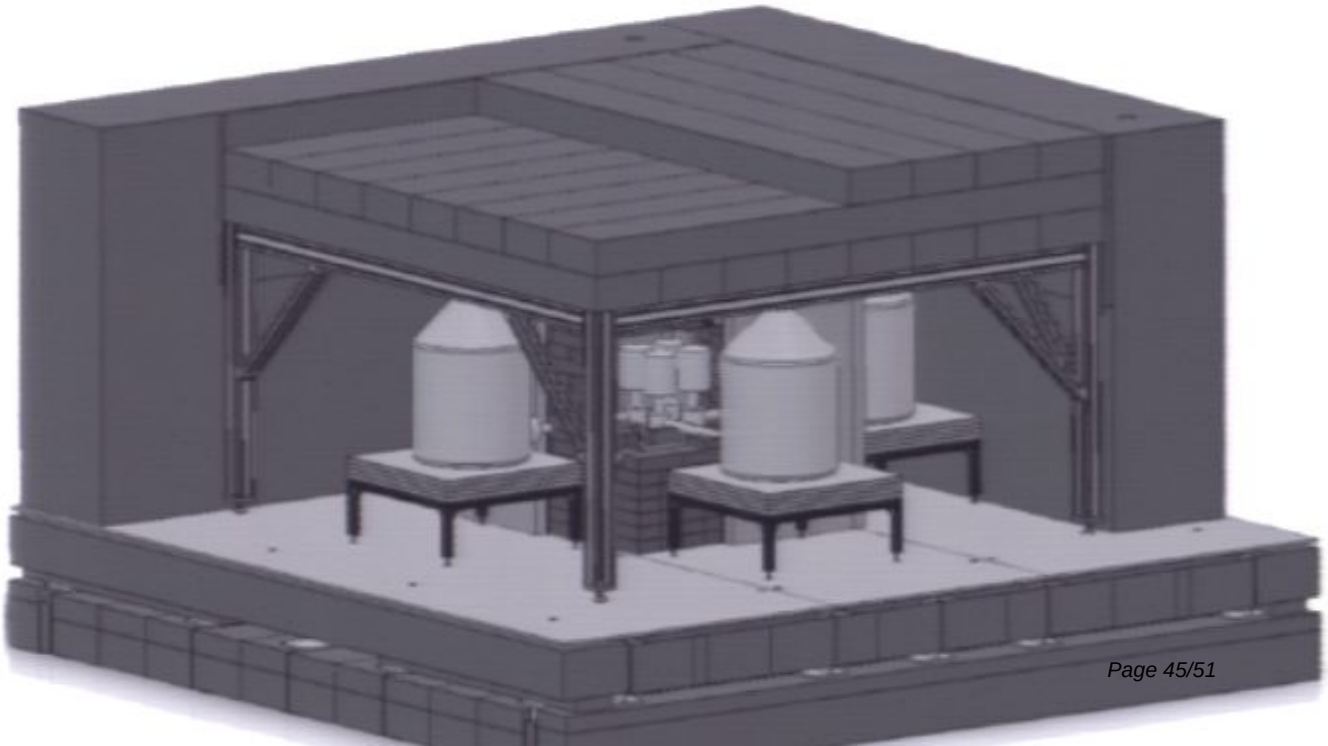
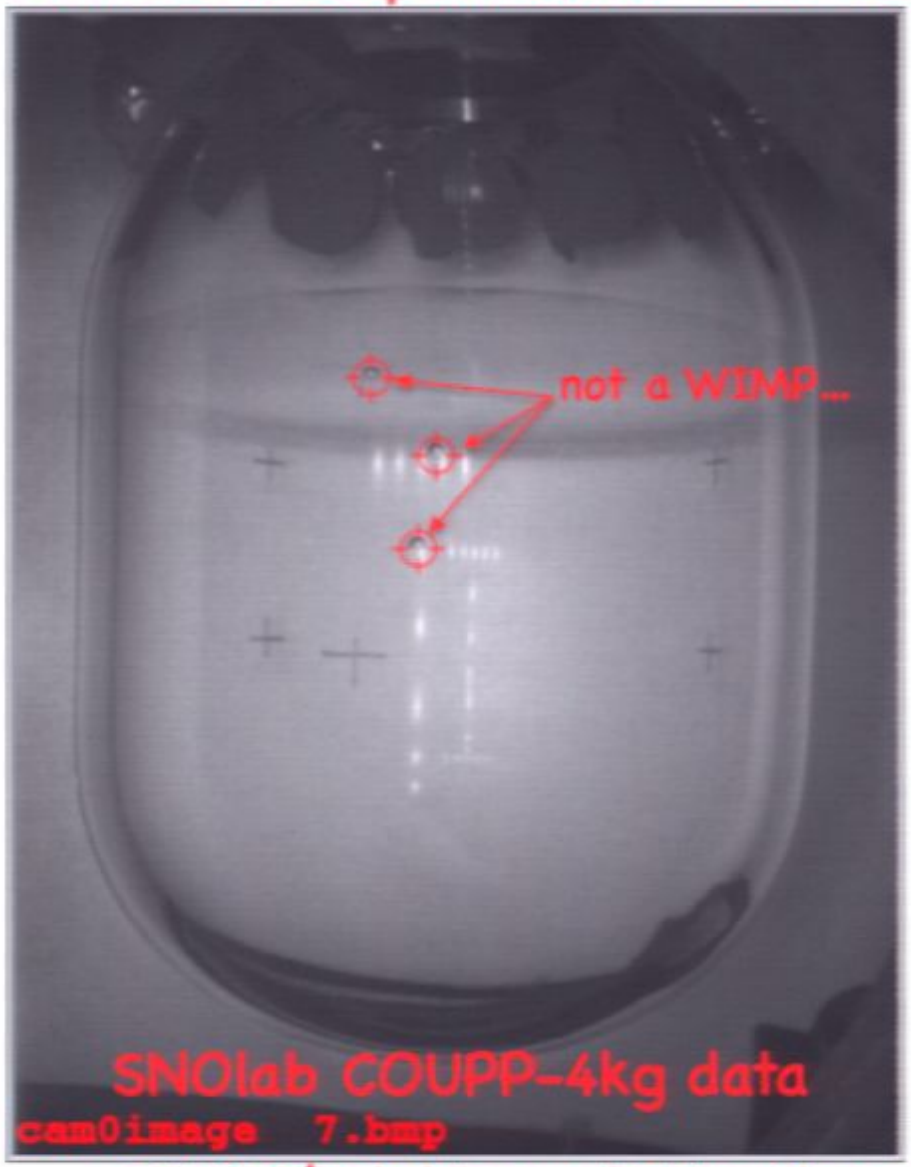
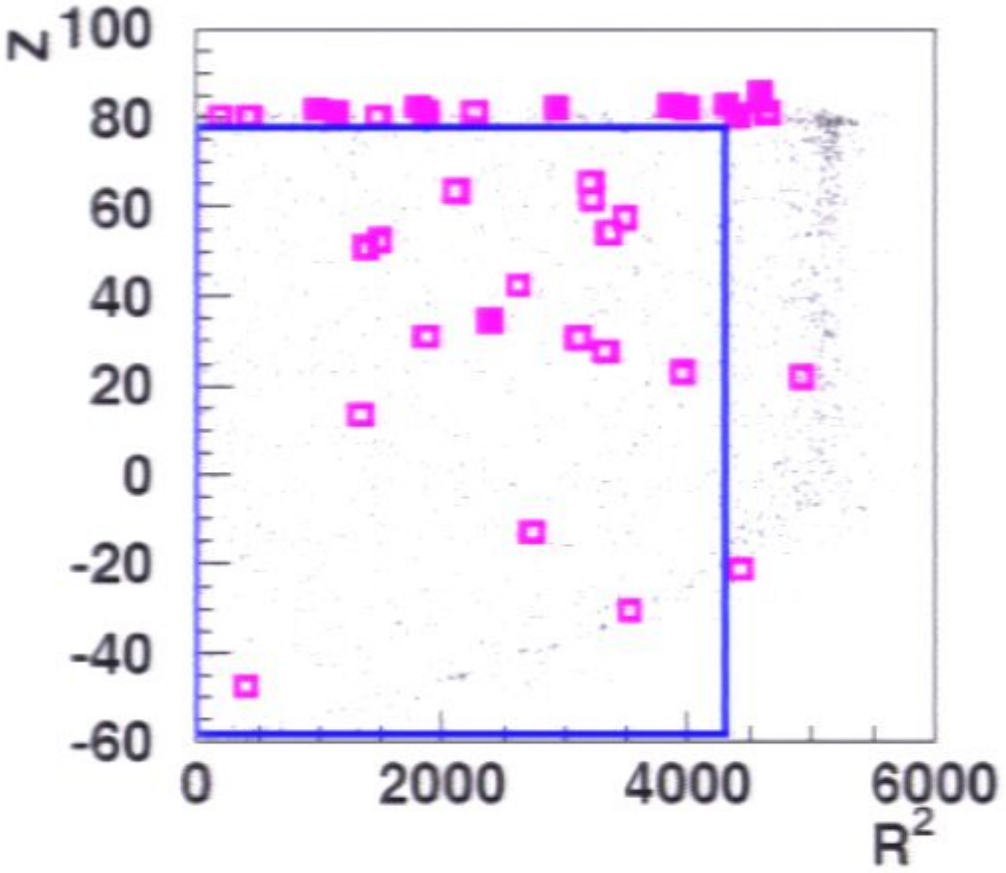




We have crossed the Rubicon:

Dark Matter experiments from now on to produce their own "WIMPs"





In agreement with Po-210 and U, Th in PZT and inspection windows. Replacement in progress.
About to say something meaningful about light-WIMPs...

COUPP's dubious distinction:

Reserve

We have crossed the Rubicon:

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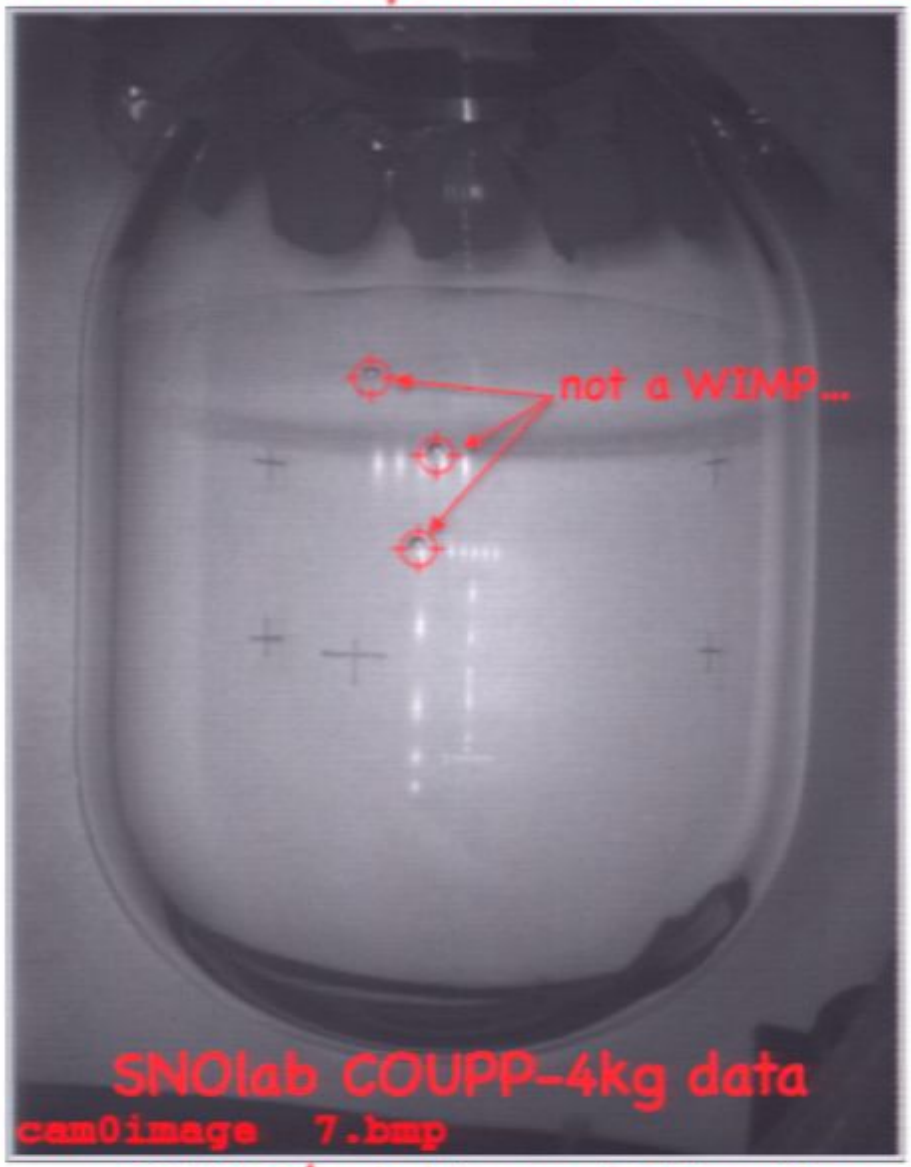

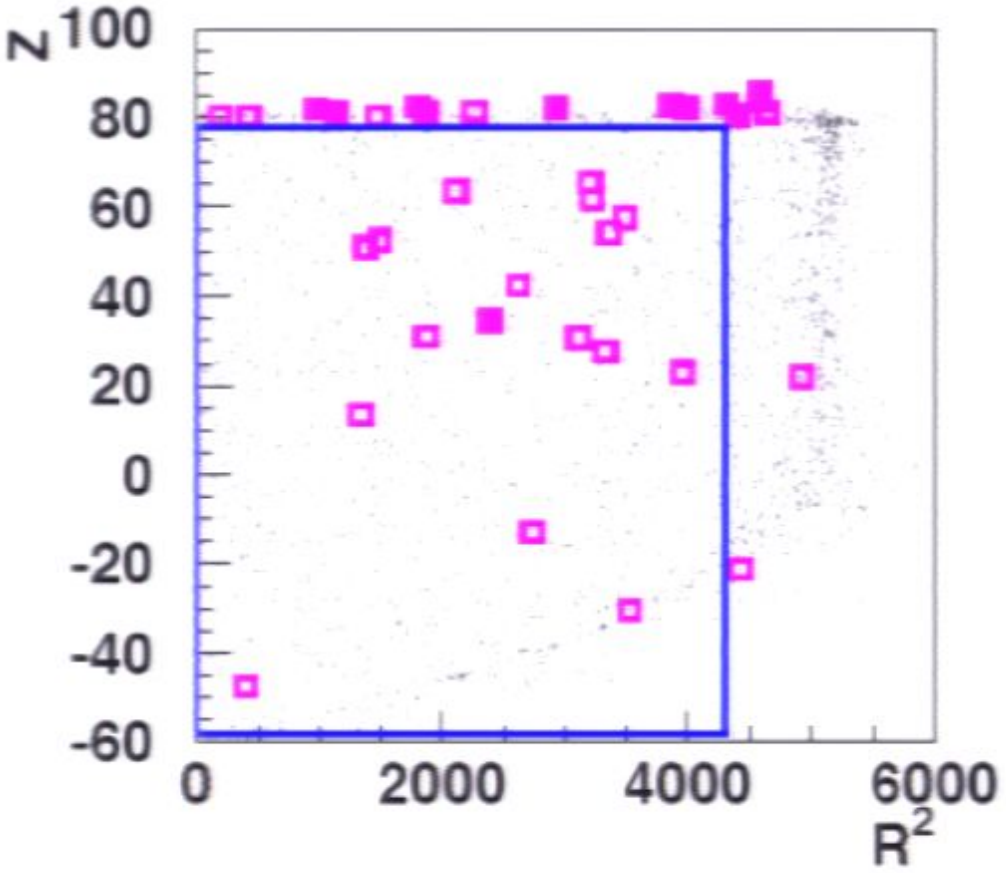

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COUPP's dubious distinction:

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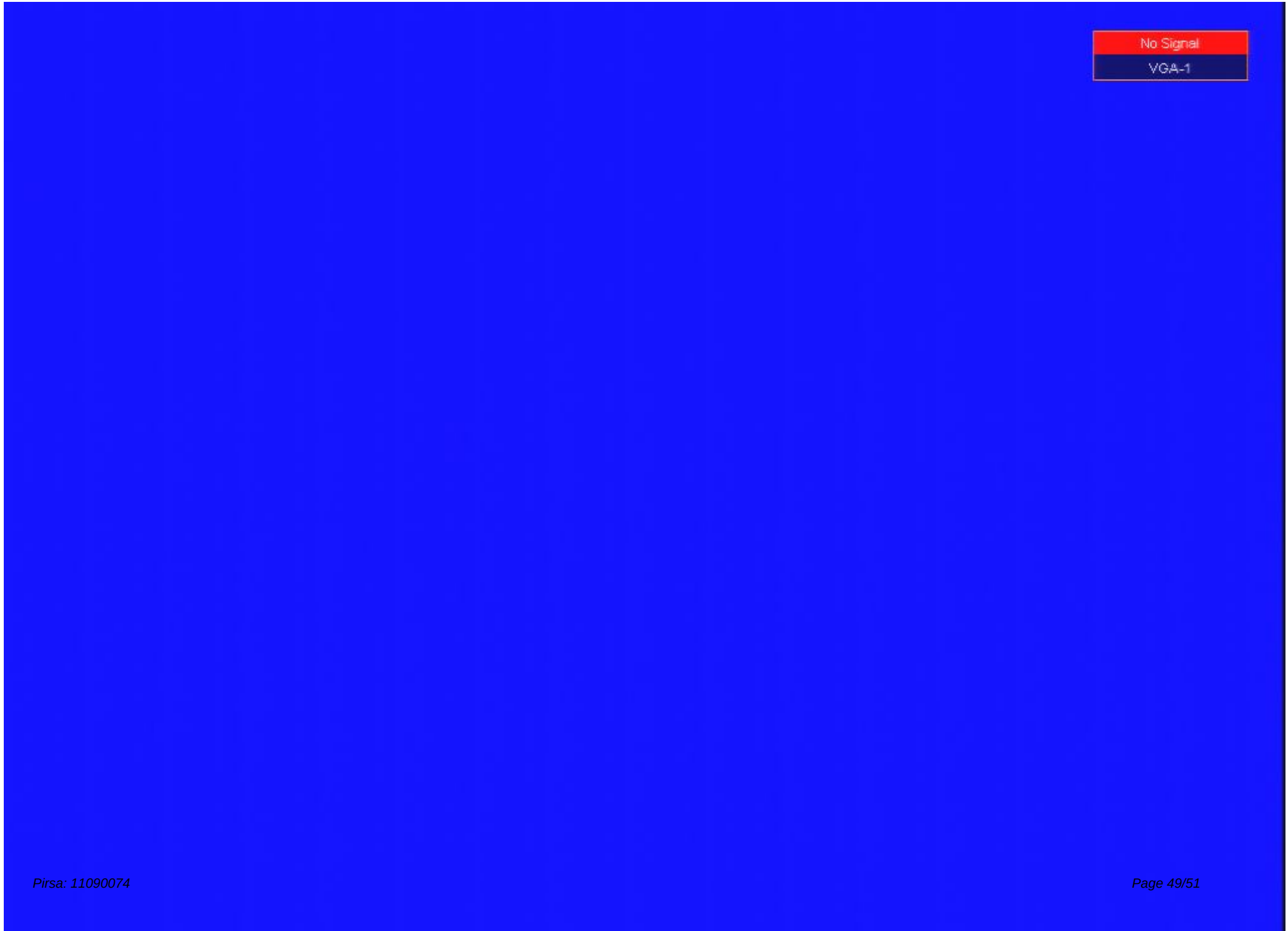
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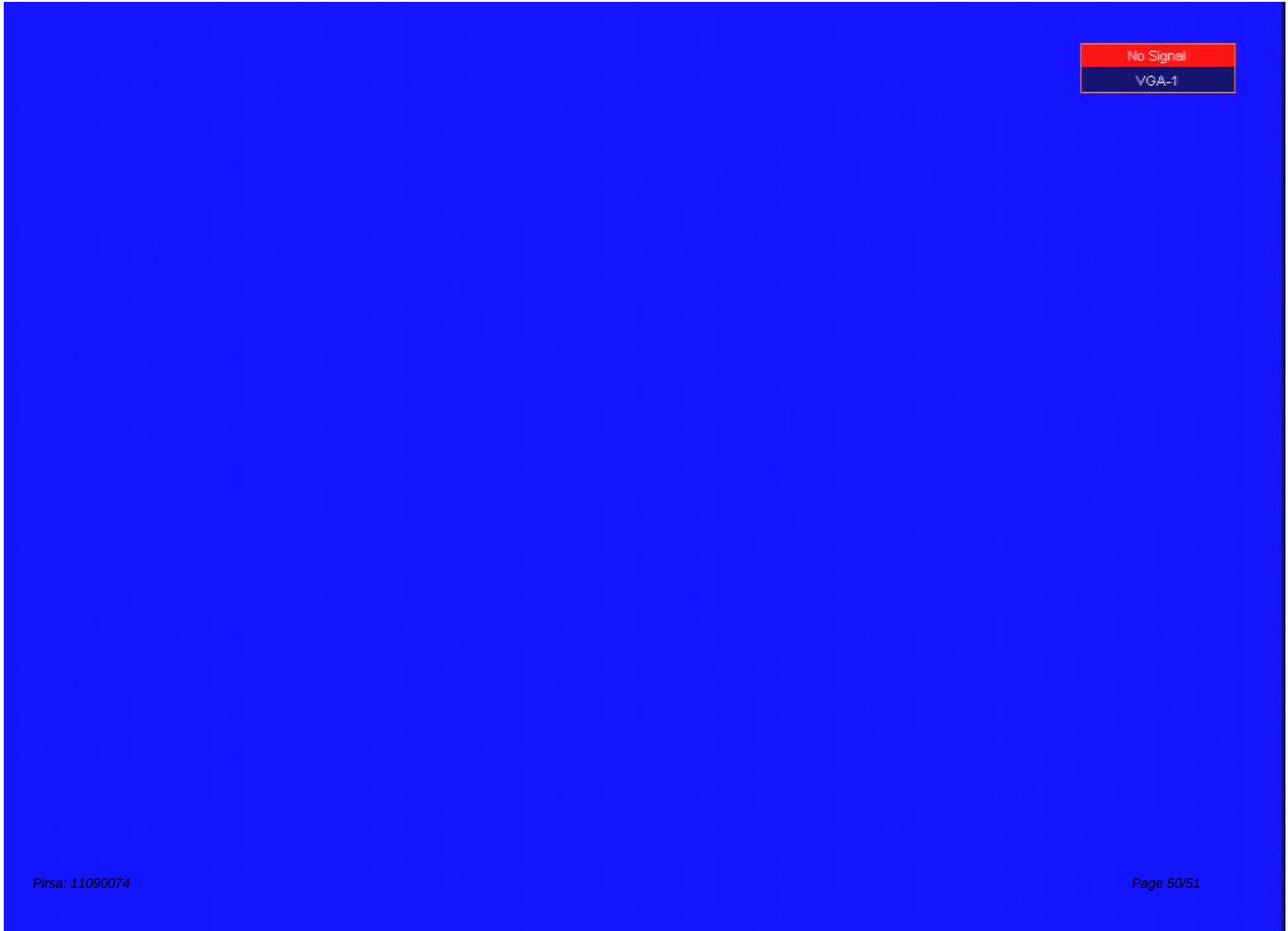
VGA-1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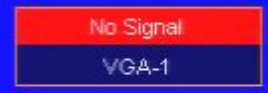
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