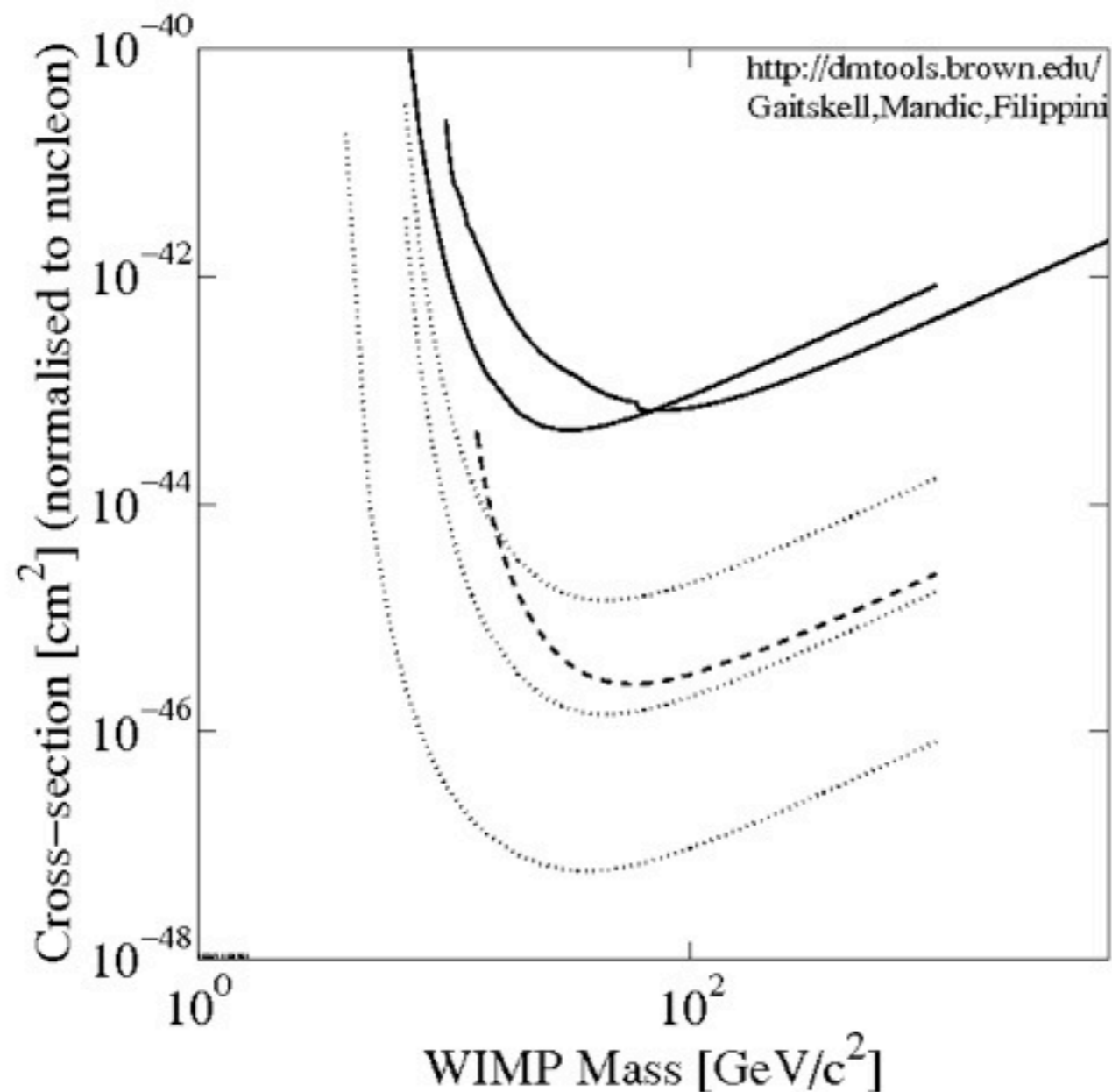


THE STATUS OF DIRECT WIMP
SEARCHES
OR
WHY WE MIGHT FIND DARK
MATTER IN 2011
(OR MAYBE 2012)

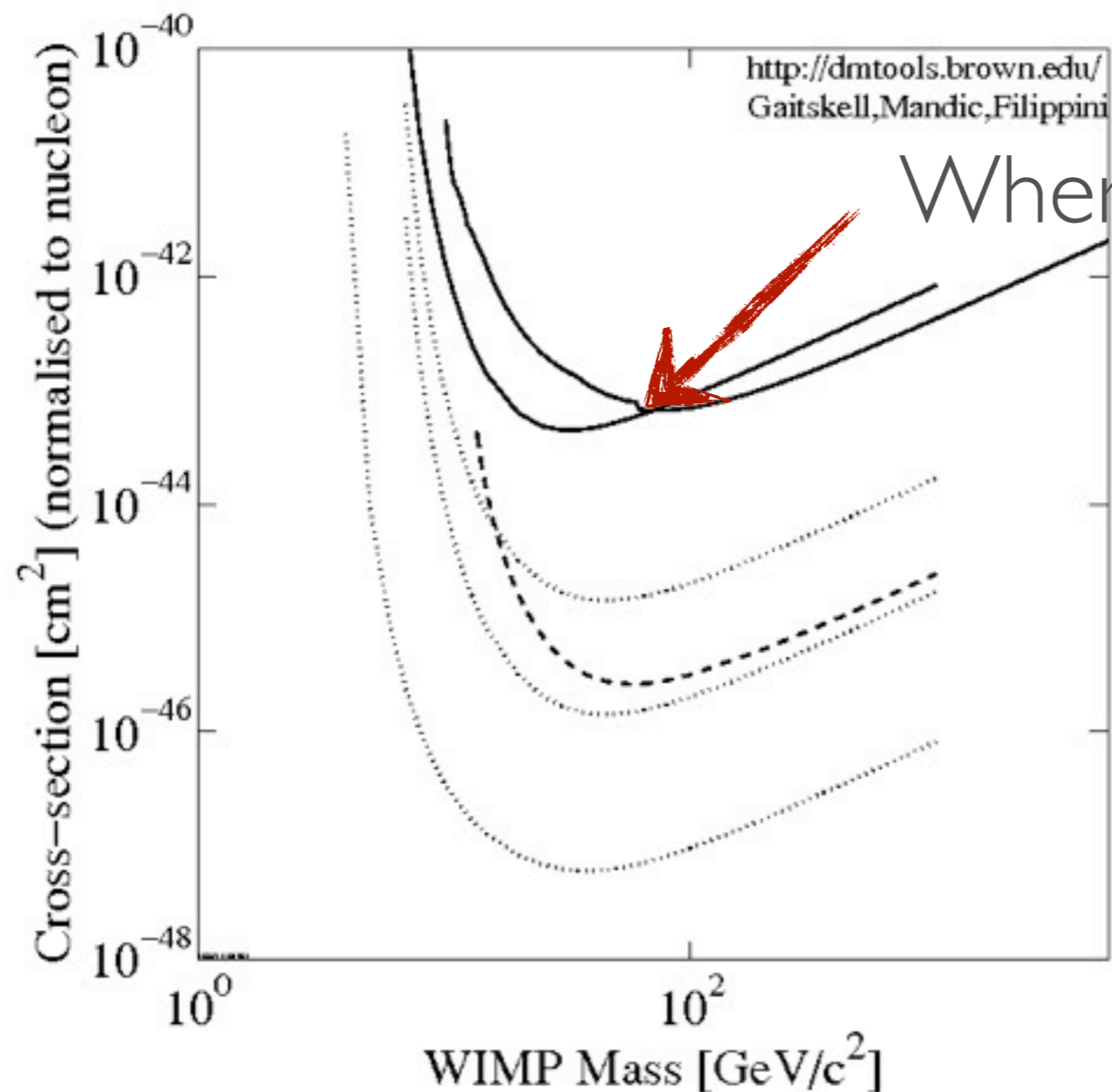
Neal Weiner
CCPP NYU

DARK MATTER EXPERIMENTS ARE GETTING EXCITING!

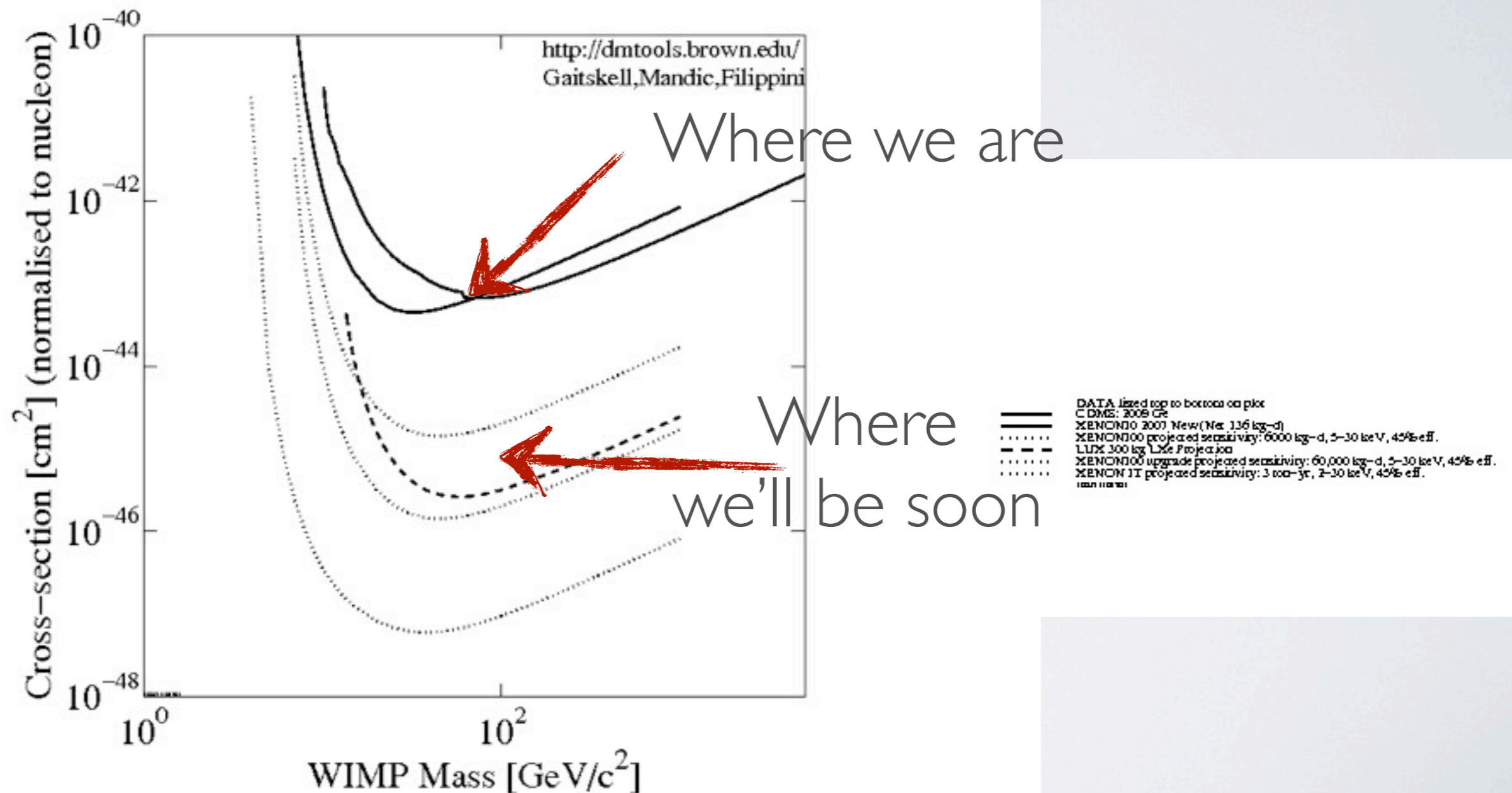


- DATA listed top to bottom on plot
- CDMS: 2009 Ge
- XENON100 2007 New (Net: 136 kg-d)
- XENON100 projected sensitivity: 6000 kg-d, 5-30 keV, 45% eff.
- - - LUX 300 kg LUX Projection
- XENON100 upgrade projected sensitivity: 60,000 kg-d, 5-30 keV, 45% eff.
- XENON 1T projected sensitivity: 3 ton-yr, 2-30 keV, 45% eff.

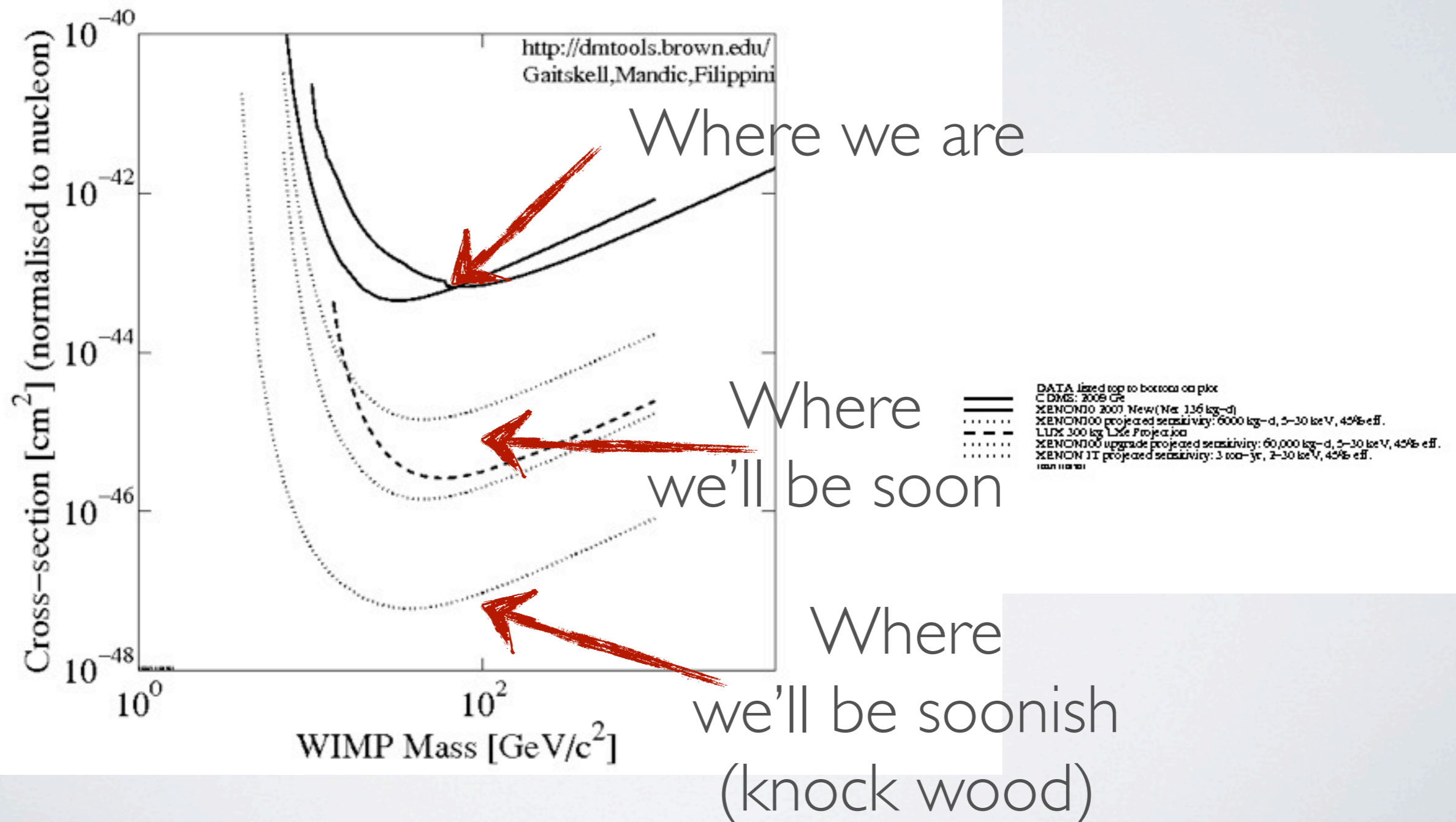
DARK MATTER EXPERIMENTS ARE GETTING EXCITING!



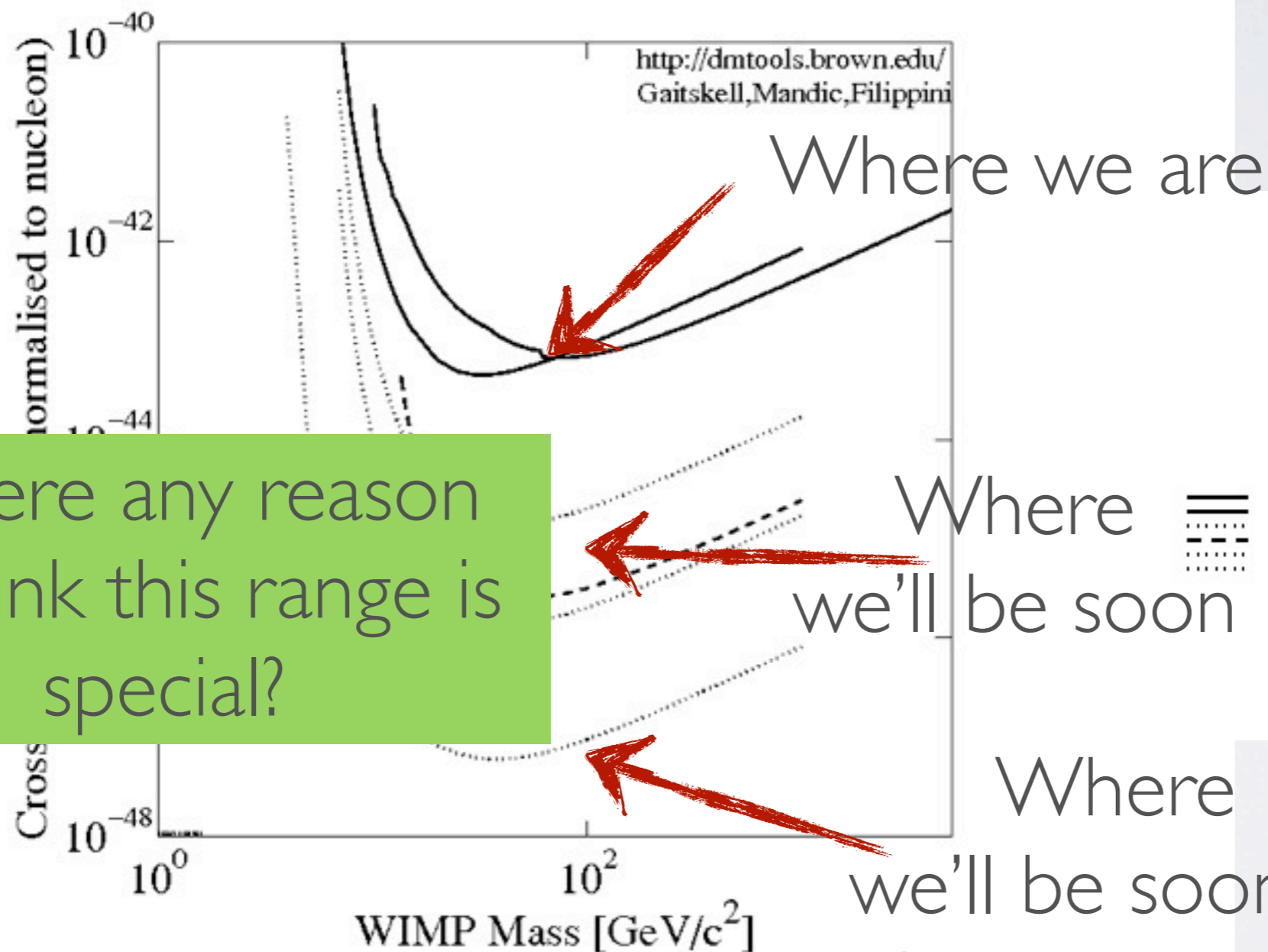
DARK MATTER EXPERIMENTS ARE GETTING EXCITING!



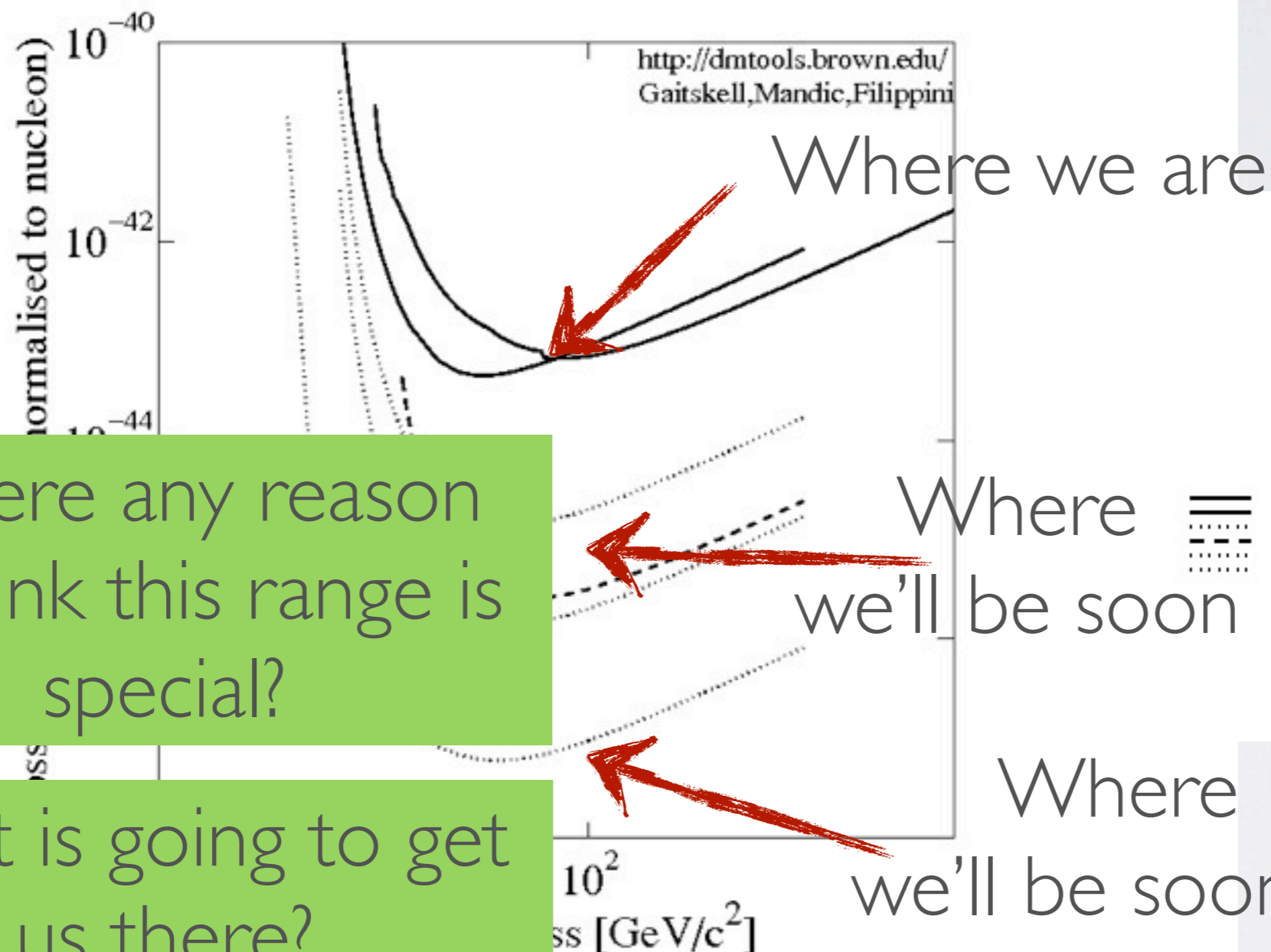
DARK MATTER EXPERIMENTS ARE GETTING EXCITING!



DARK MATTER EXPERIMENTS ARE GETTING EXCITING!



DARK MATTER EXPERIMENTS ARE GETTING EXCITING!



Is there any reason to think this range is special?

What is going to get us there?

CAVEATS

- I am going to focus on “spin-independent” interactions
- Will not discuss R&D programs (e.g., directional)

WHY SHOULD YOU BE EXCITED?



MHP
Dark Matter
2.64 Pounds

- Increases Protein Synthesis by 600%
- Absorbs Faster Than Whey

Your Price \$37.99

MSRP \$ 59.99

Select Flavor:

Qty: Add to Cart



[\[view all MHP products\]](#)

FEATURES

[Write a Review](#)

[Read Reviews](#)

Current Reviews: 0

DARK MATTER takes a quantum leap forward into a new dimension of post-workout muscle growth called the ANABOLIC AXIS. The Anabolic Axis is the time and point at which insulin levels simultaneously peak with amino acids, creatine and glycogen transport into muscle tissue during the critical 1 hour period immediately after your workout. Dark Matter is the first and only supplement to employ a new technology called Precision Nutrient Infusion, which allows for this synergistic anabolic reaction to occur at the Anabolic Axis. In order to achieve this major breakthrough, MHP scientists bio-engineered new compounds and a revolutionary High Velocity Nano-Physics Technology. These new developments have rendered all post-workout creatines, whey protein/high carbohydrate combos and all other post-workout formulas inferior and outdated. DARK MATTER blasts open the critical "Anabolic Window" faster, wider and longer allowing you to enter the ANABOLIC AXIS for the most powerful anabolic reaction ever experienced!

OK, WELL AT LEAST I AM
EXCITED

Theoretical Sweet Spots

OK, WELL AT LEAST I AM
EXCITED

Theoretical Sweet Spots

Rapid Exp Progress

OK, WELL AT LEAST I AM EXCITED

Theoretical Sweet Spots

Rapid Exp Progress

DM(?) anomalies

CoGeNT

DAMA

CRESST

OK, WELL AT LEAST I AM EXCITED

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Light WIMPs?

inelastic WIMPs?

other exotic WIMPs?
(resonant dark matter,
luminous dark matter...)

OK, WELL AT LEAST I AM EXCITED

Theoretical Sweet Spots

Rapid Exp Progress

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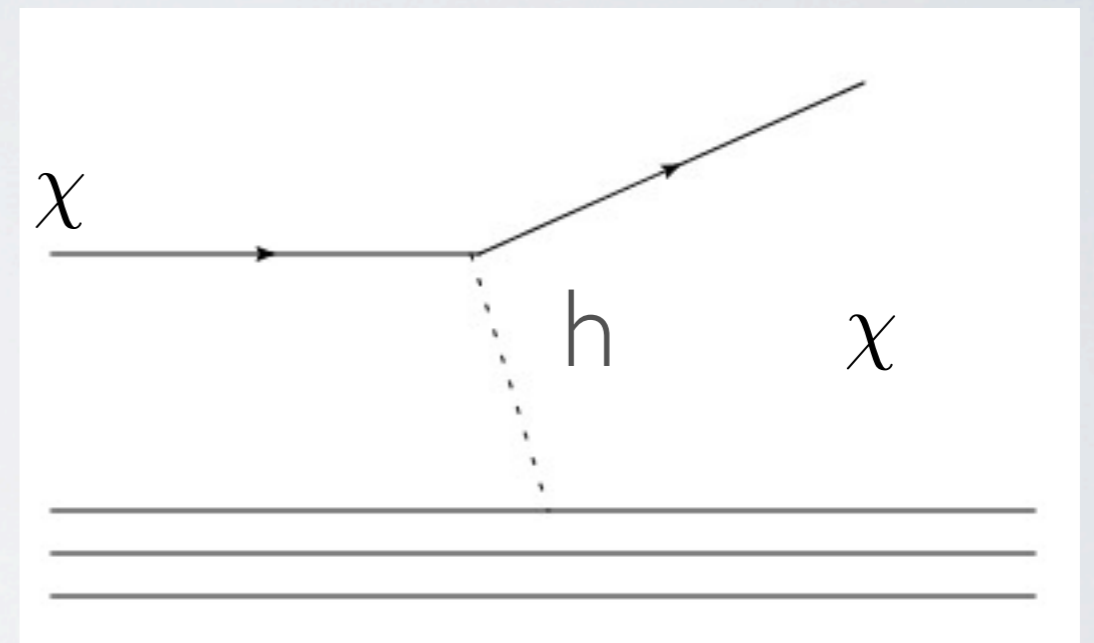
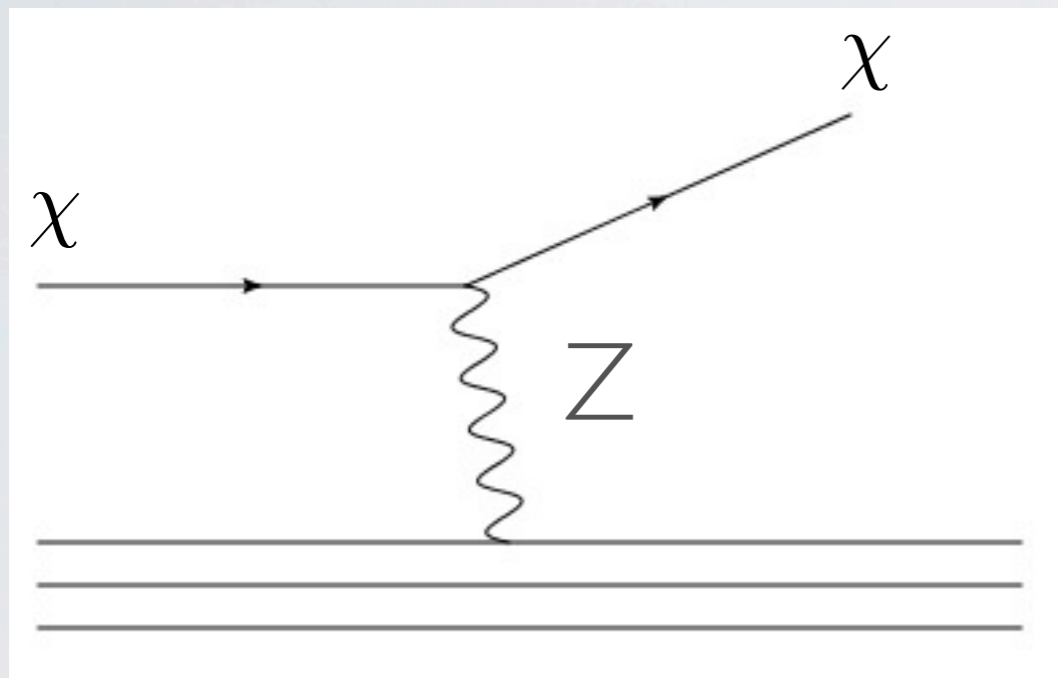
CRESST

Light WIMPs?

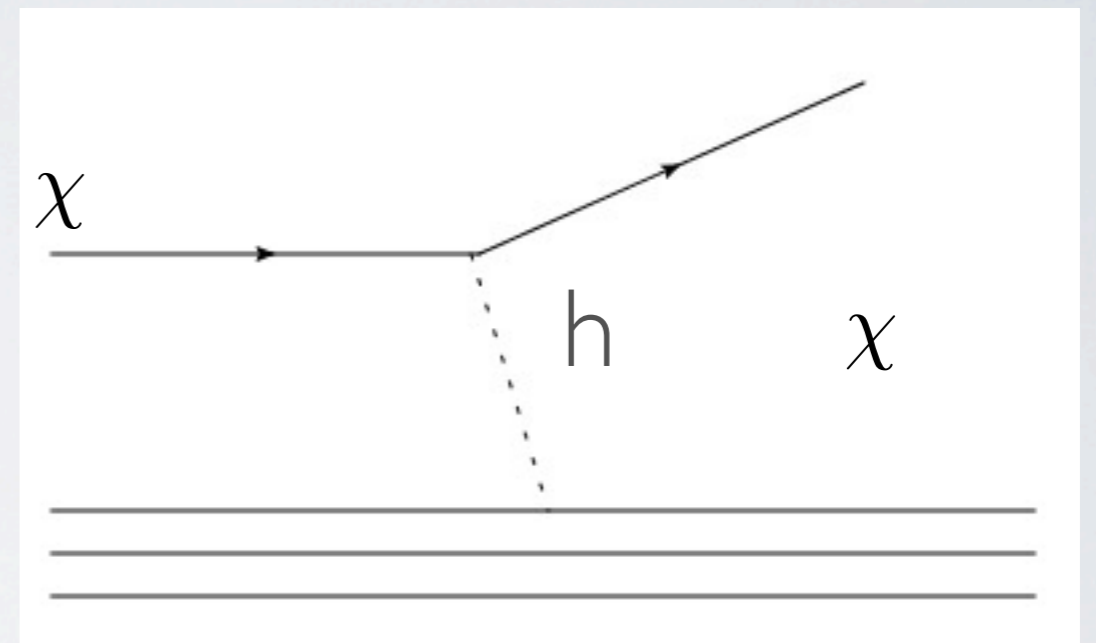
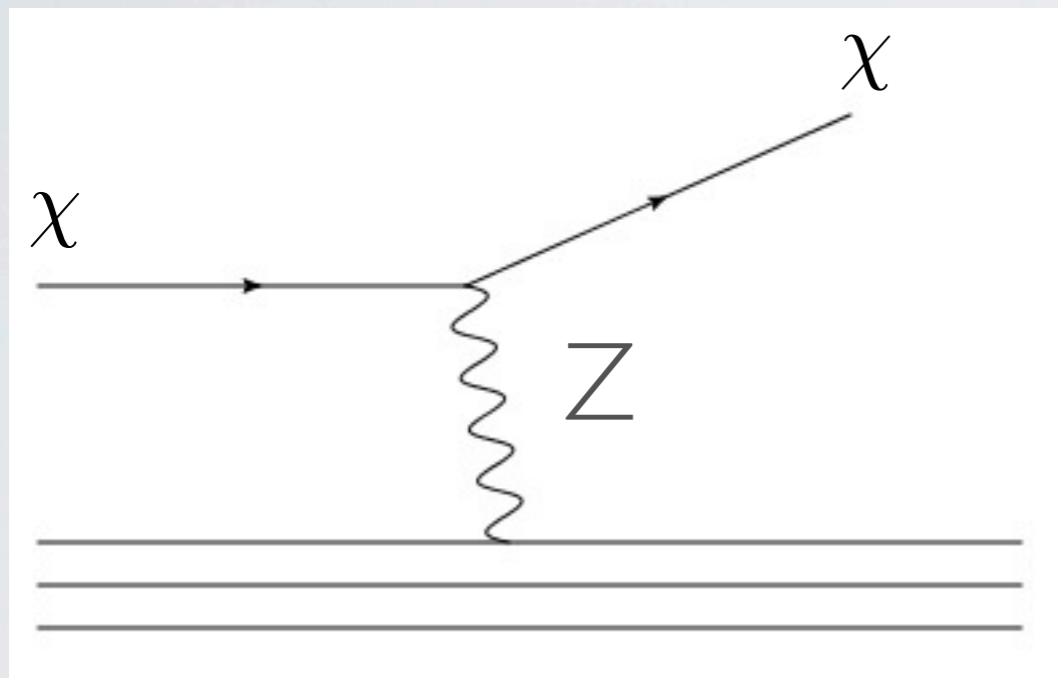
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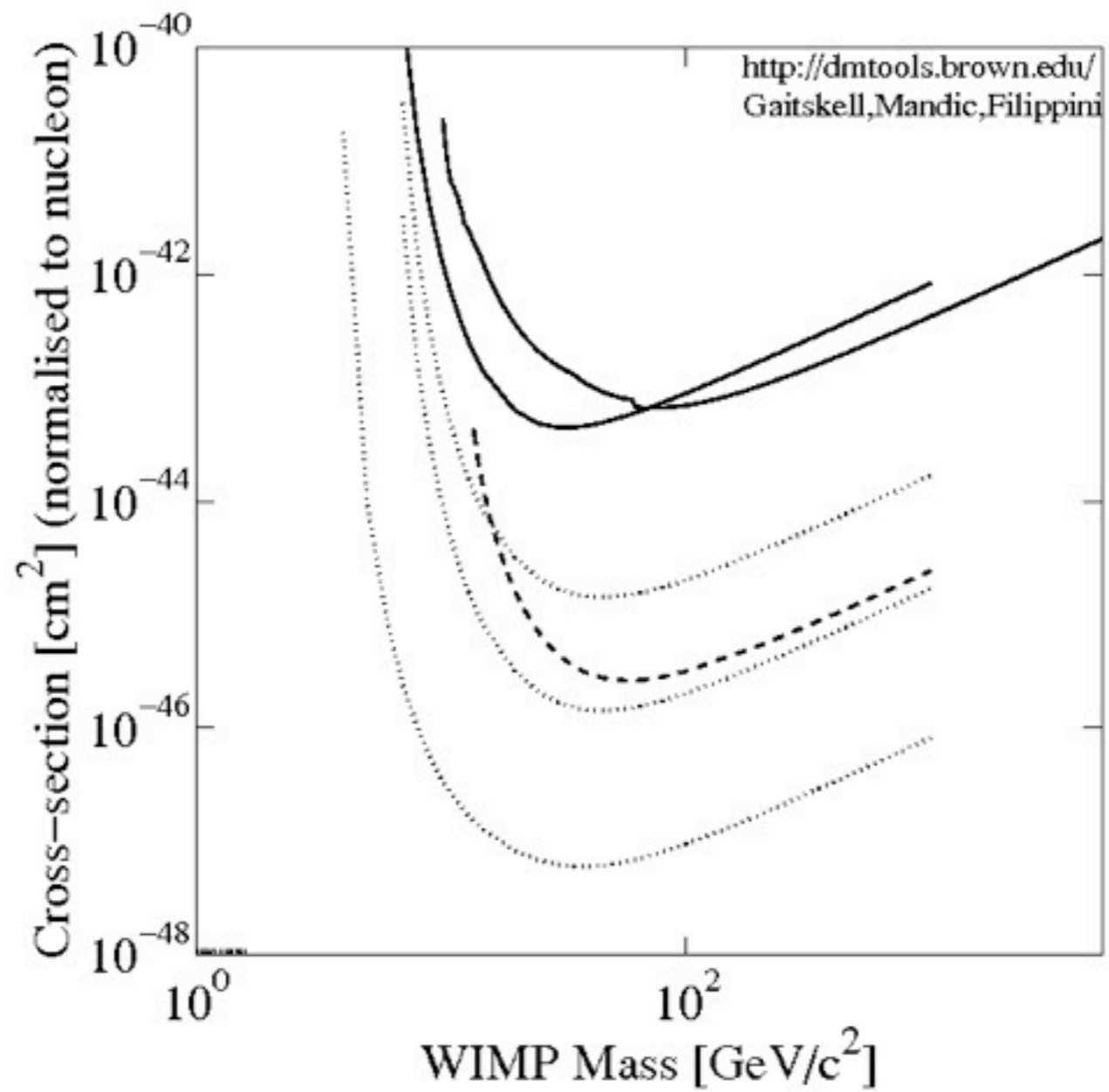
THE TWO CROSS SECTIONS TO THINK ABOUT

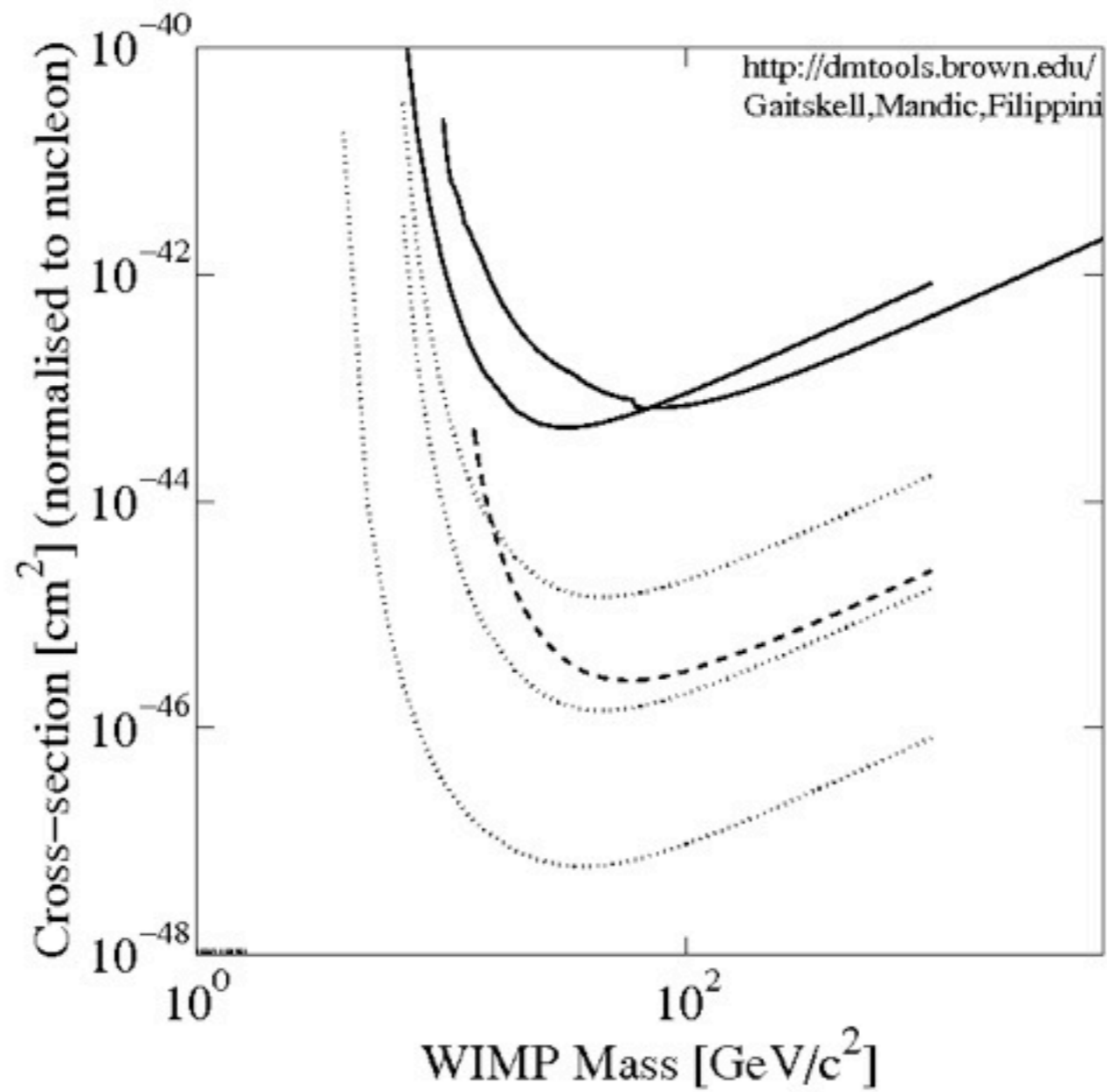


THE TWO CROSS SECTIONS TO THINK ABOUT

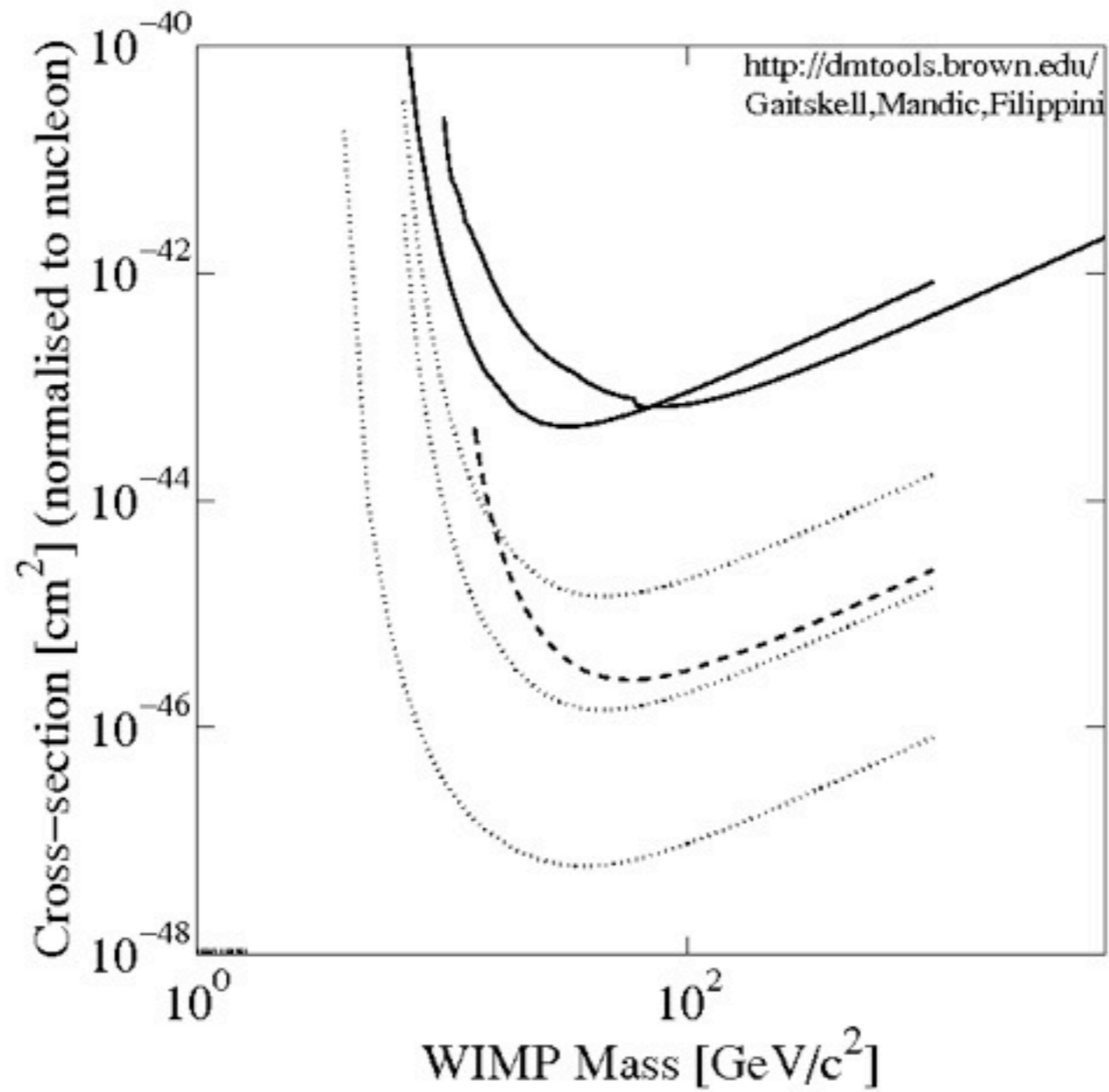


$$\sigma_0 \approx \frac{G_f^2 \mu^2}{2\pi} \sim 10^{-39} \text{cm}^2$$

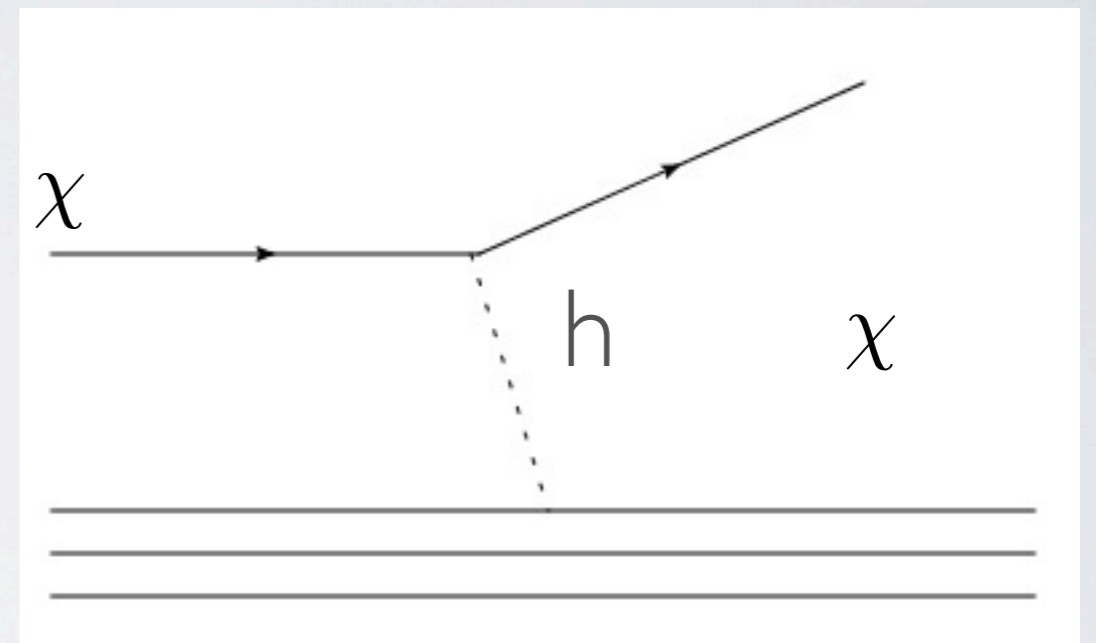
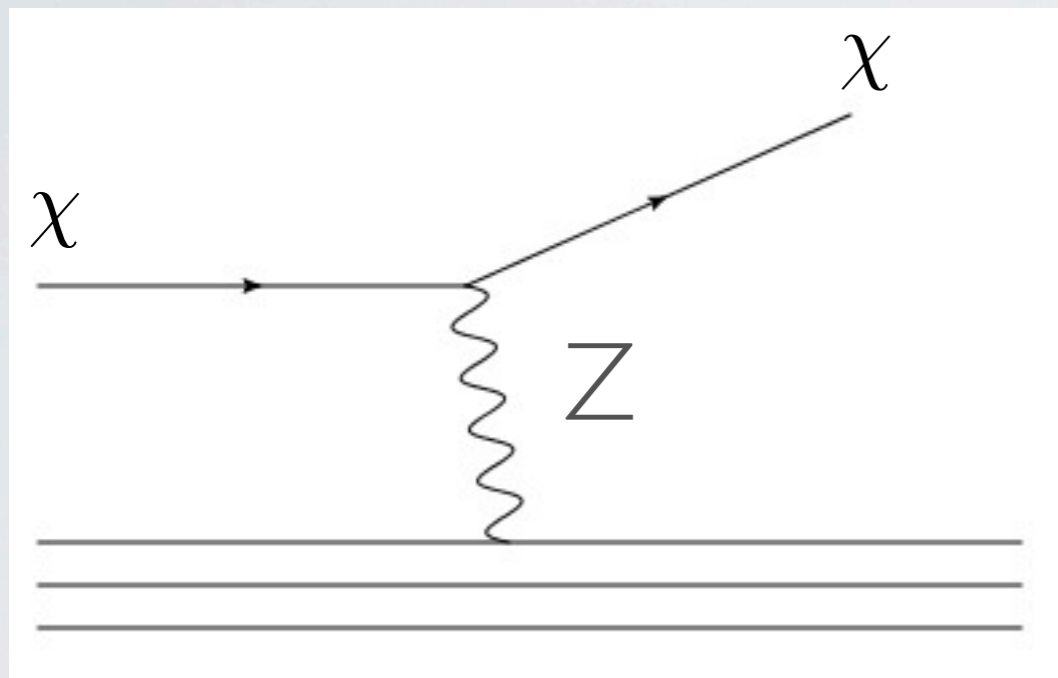




Ruled out
(just a little bit)

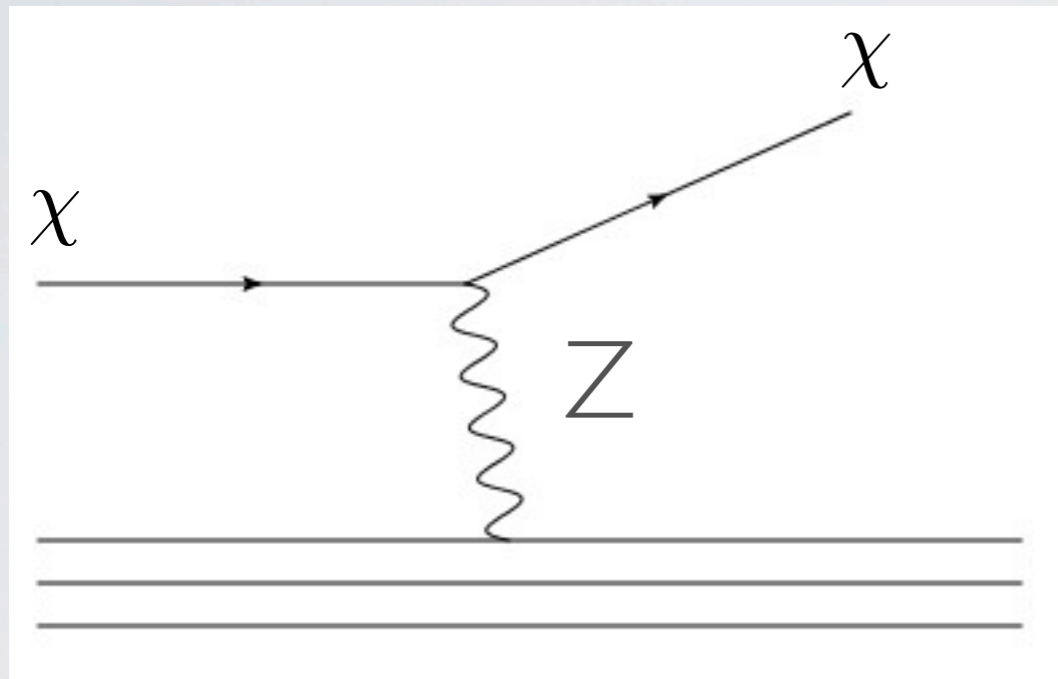


THE TWO CROSS SECTIONS TO THINK ABOUT

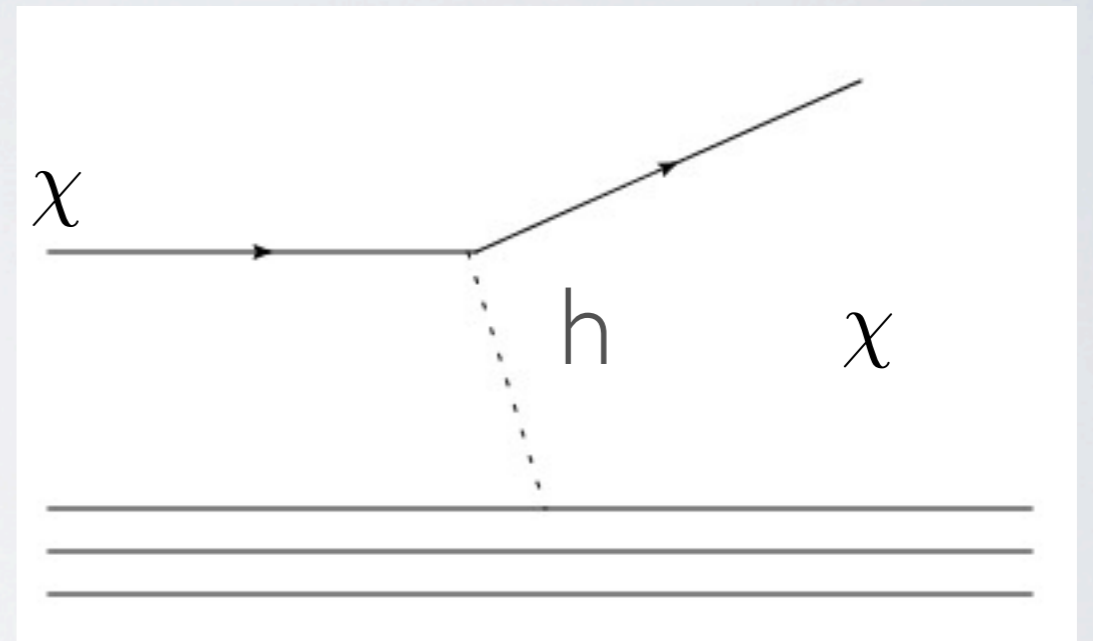


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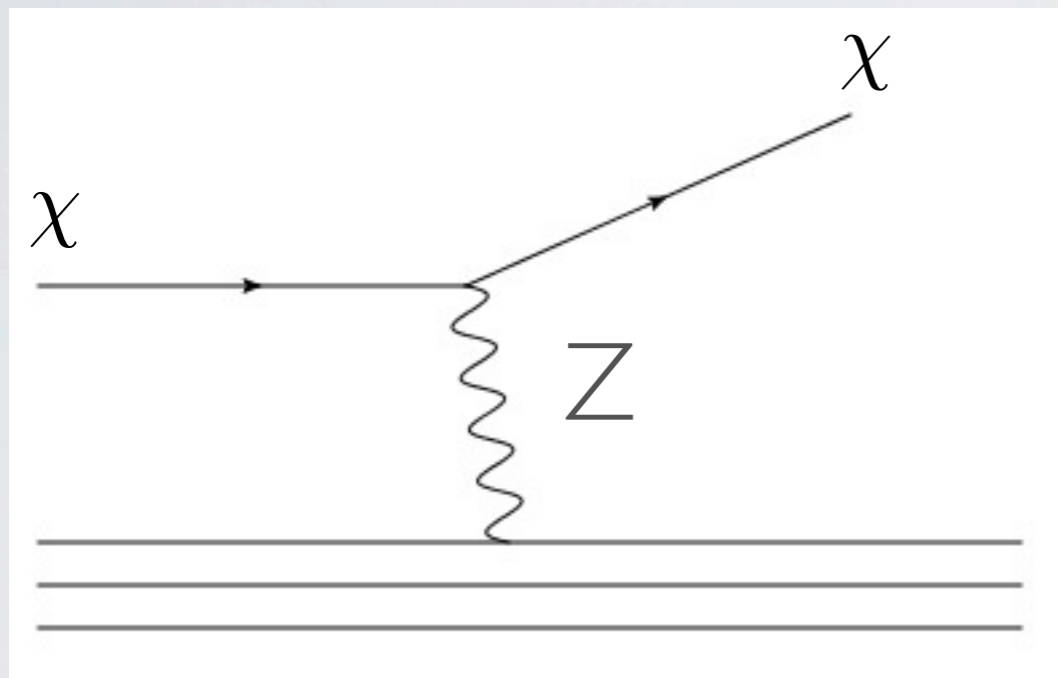


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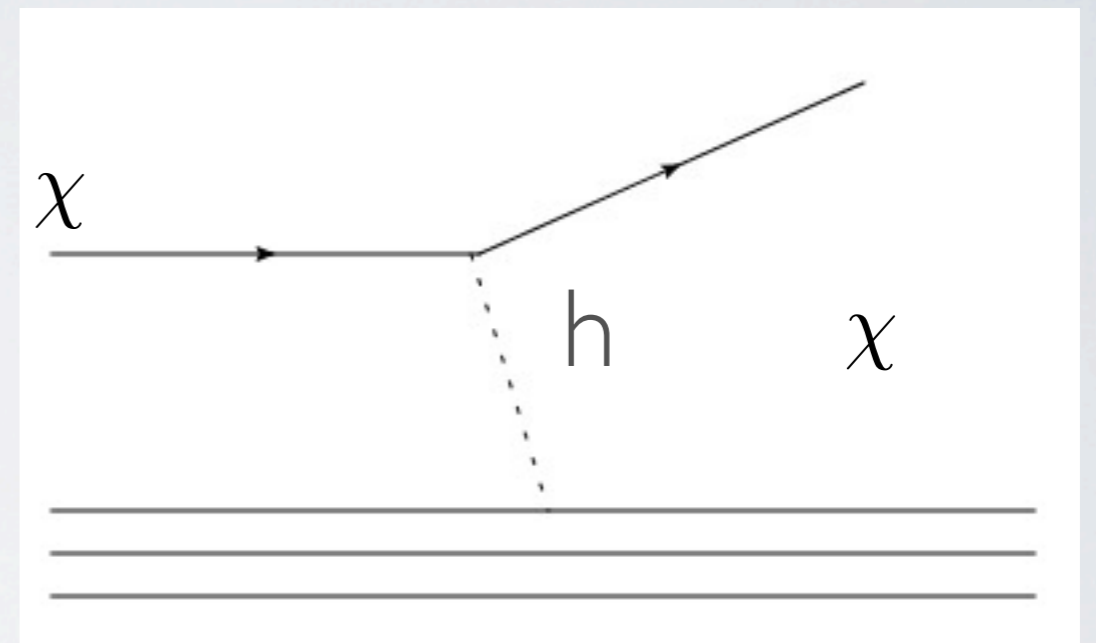


$$g \sim 1 \Rightarrow y_p \sim \frac{1}{\text{few}} \frac{m_p}{v}$$

THE TWO CROSS SECTIONS TO THINK ABOUT



$$\sigma_0 \approx \frac{G_f^2 \mu^2}{2\pi} \sim 10^{-39} \text{cm}^2$$



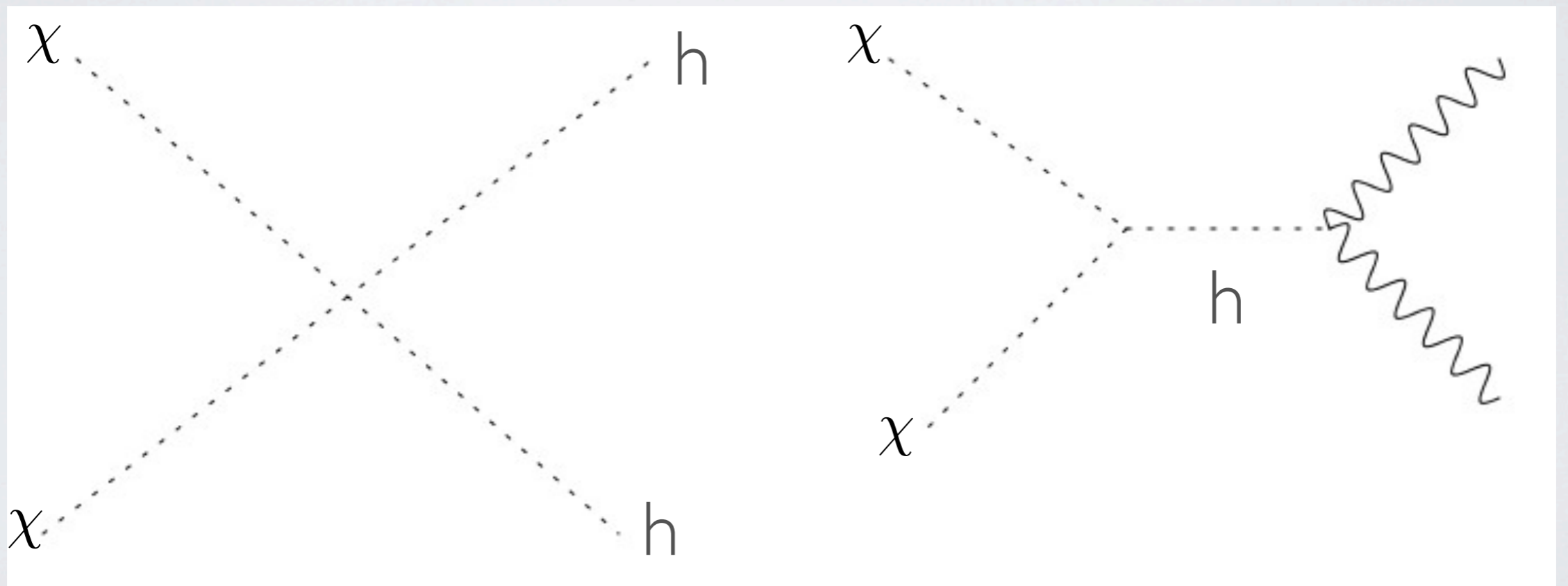
$$g \sim 1 \Rightarrow y_p \sim \frac{1}{\text{few}} \frac{m_p}{v}$$

$$\begin{aligned} \sigma_0 &\sim 10^{-39} \text{cm}^2 \times 10^{-6} \\ &\sim 10^{-45} \text{cm}^2 \end{aligned}$$

A “MINIMAL MODEL” OF DARK MATTER

Burgess, Pospelov, ter Veldhuis, '01

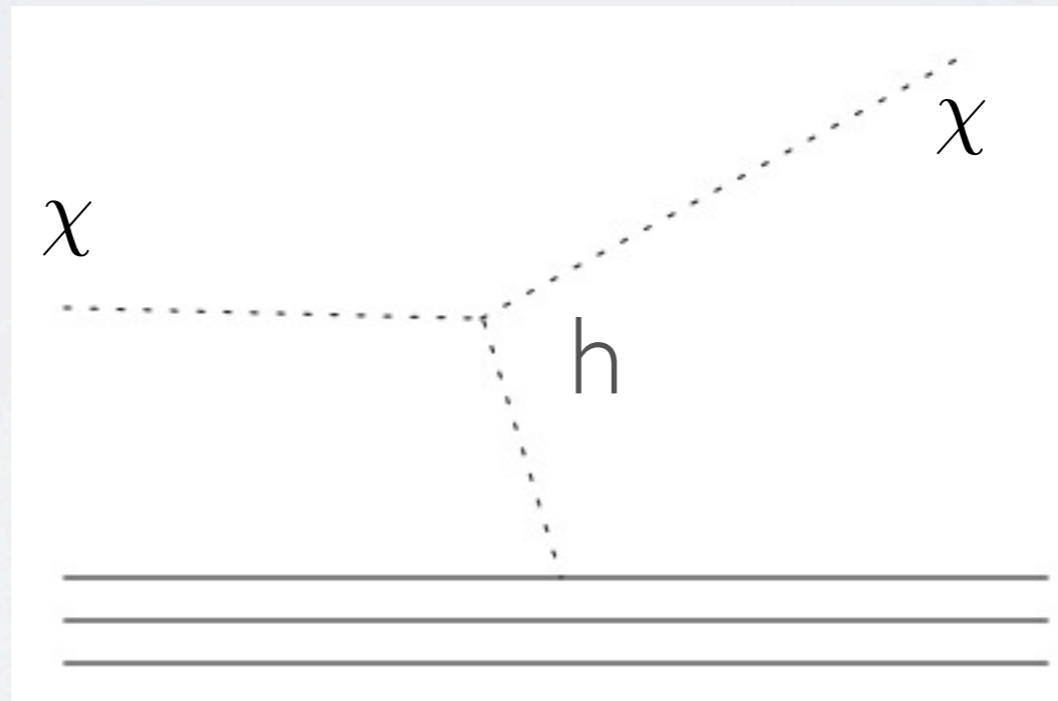
$$V = \frac{m_0^2}{2} S^2 + \frac{\lambda}{2} S^2 h^2 + \frac{\lambda_S}{4} S^4 + \frac{\lambda_h}{4} (h^2 - v_{EW}^2)^2.$$



A “MINIMAL MODEL” OF DARK MATTER

Burgess, Pospelov, ter Veldhuis, '01

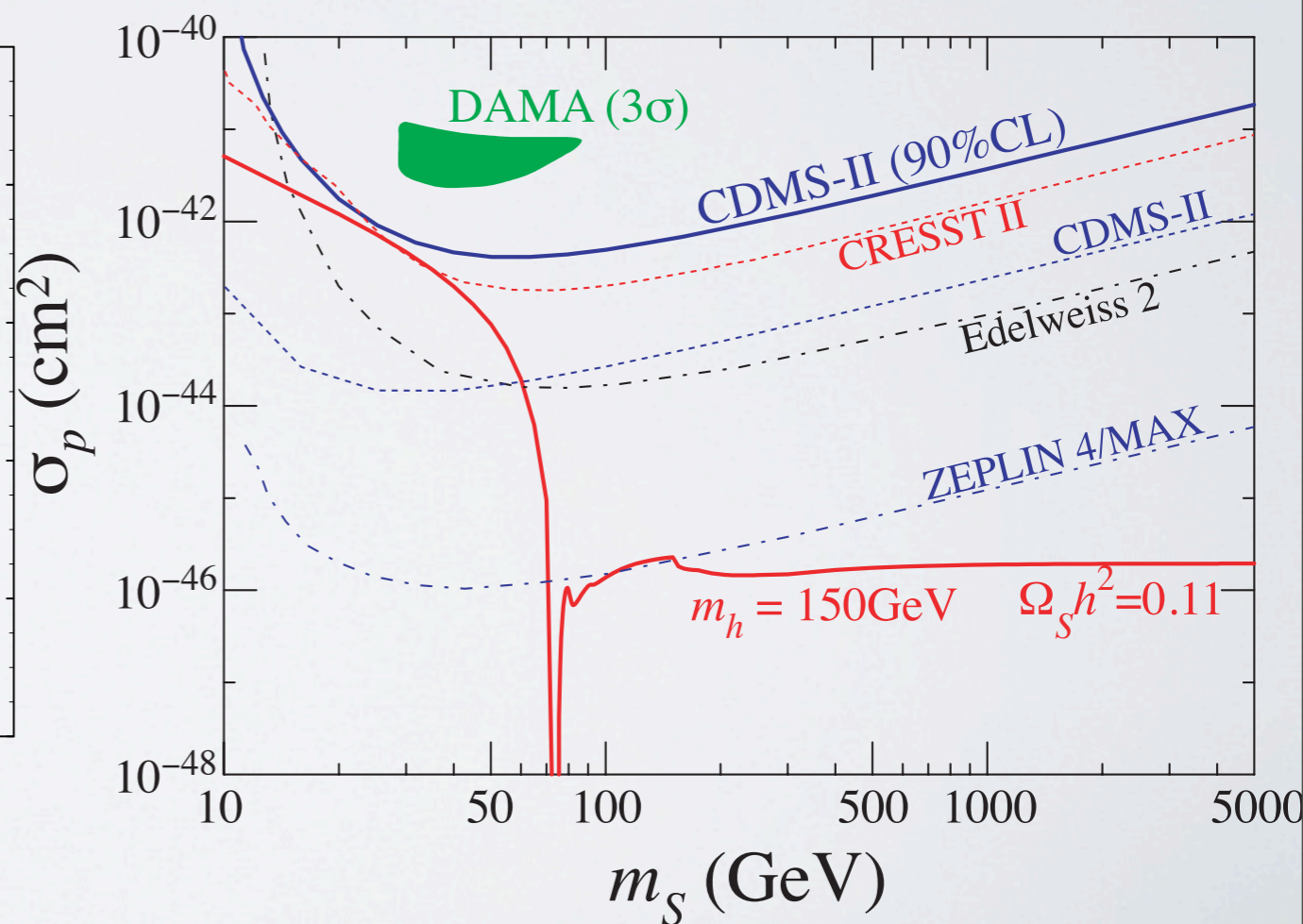
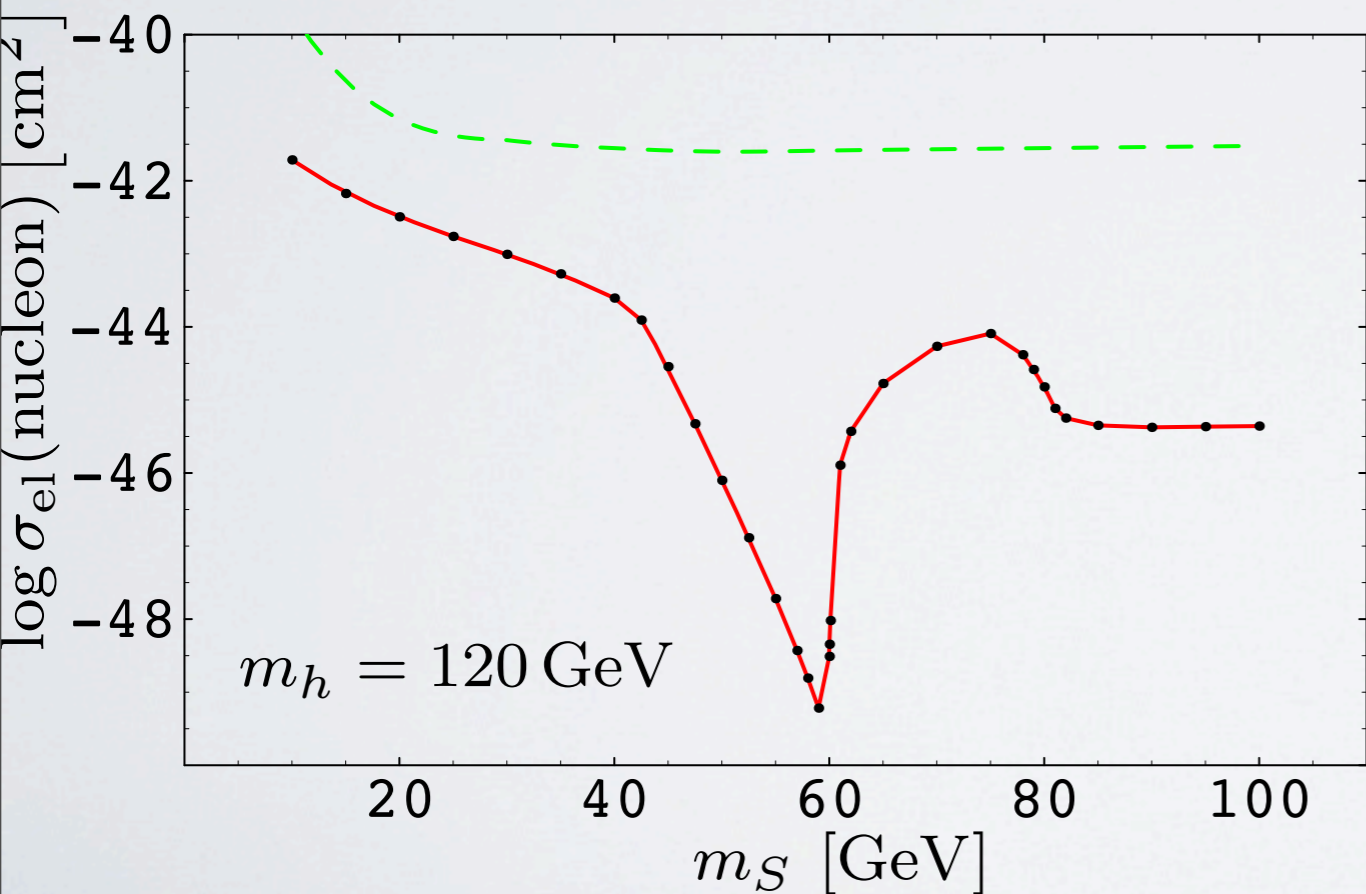
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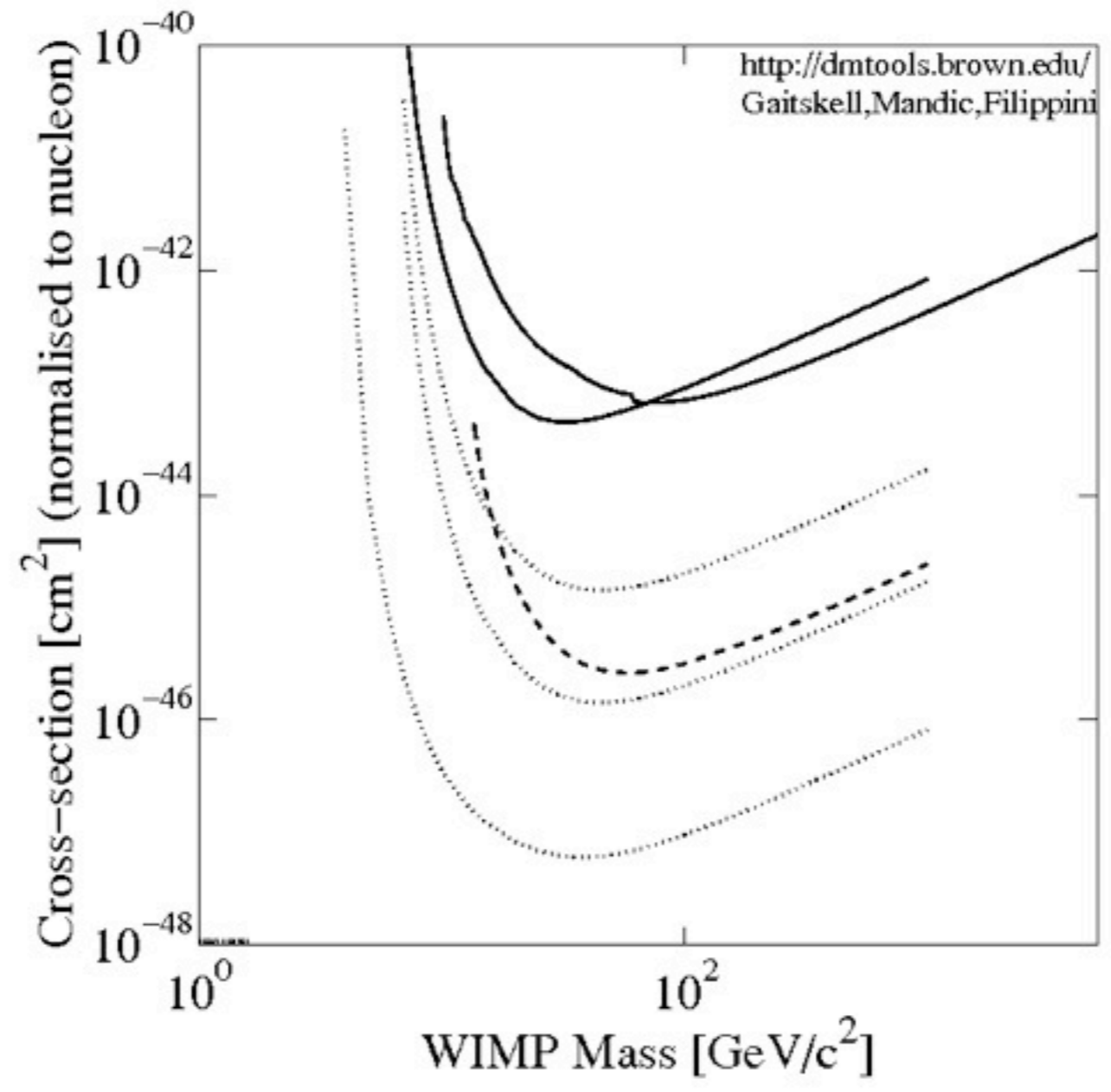
A "MINIMAL MODEL" OF DARK MATTER

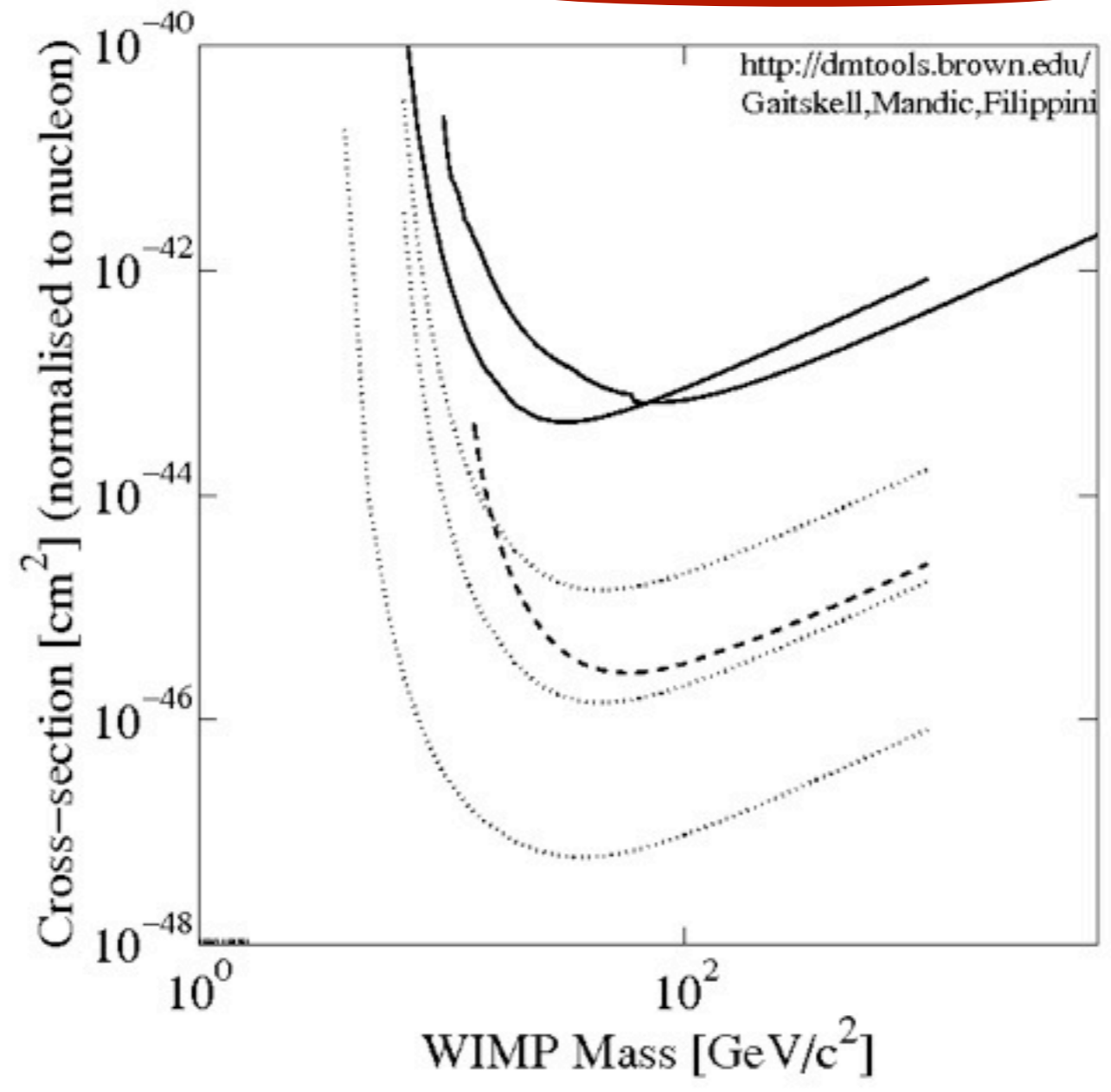
Burgess, Pospelov, ter Veldhuis, '01

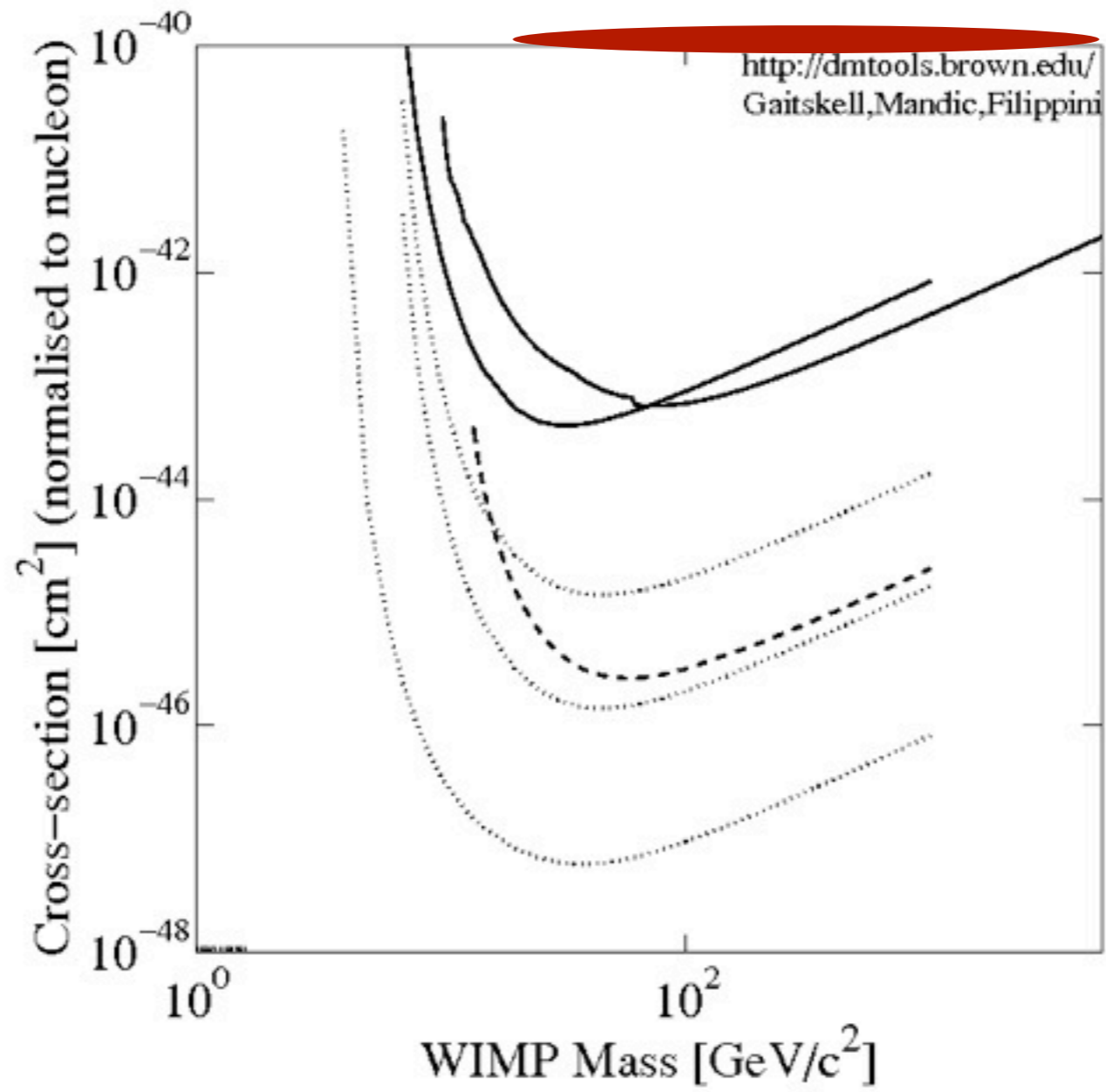
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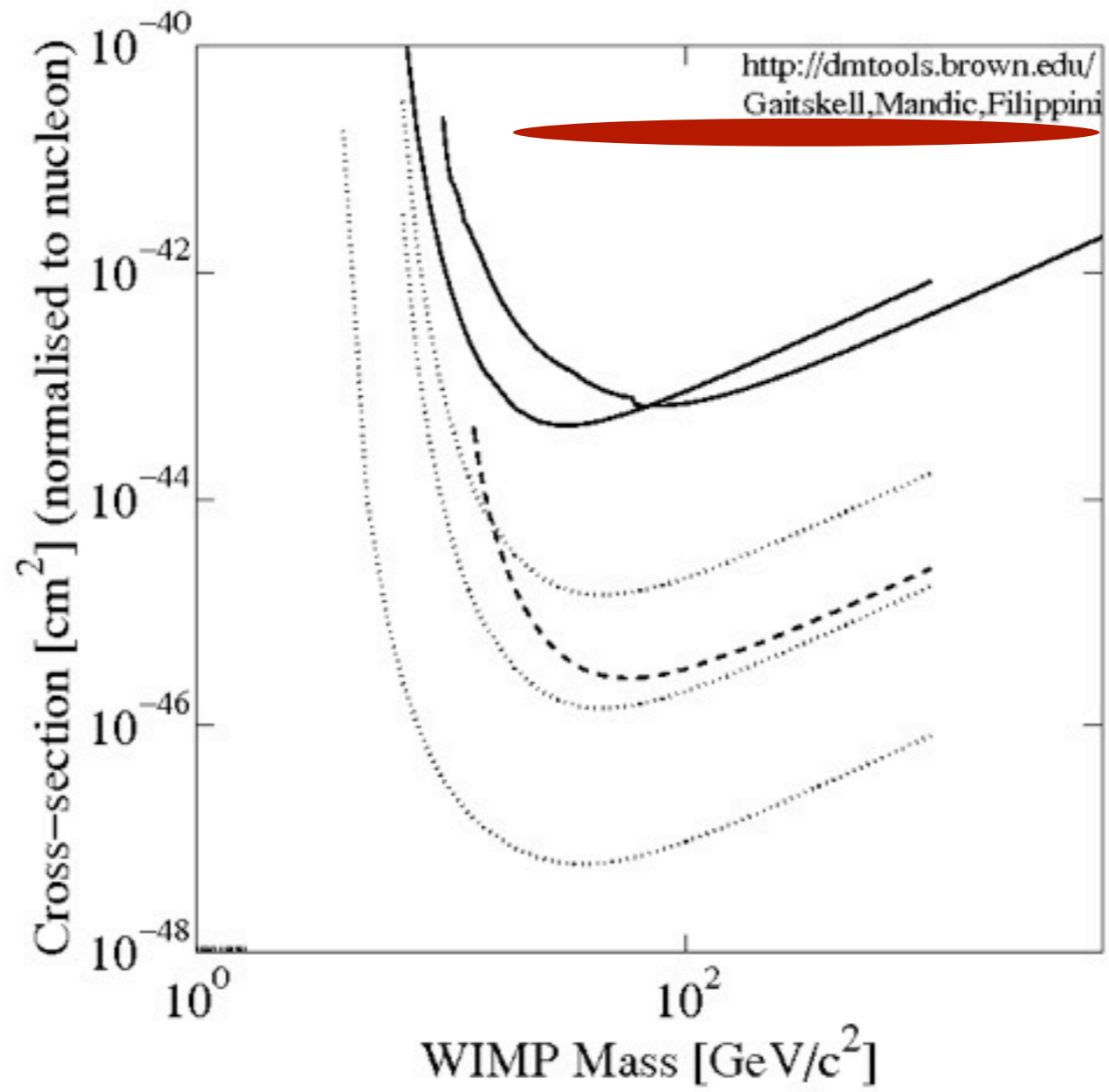


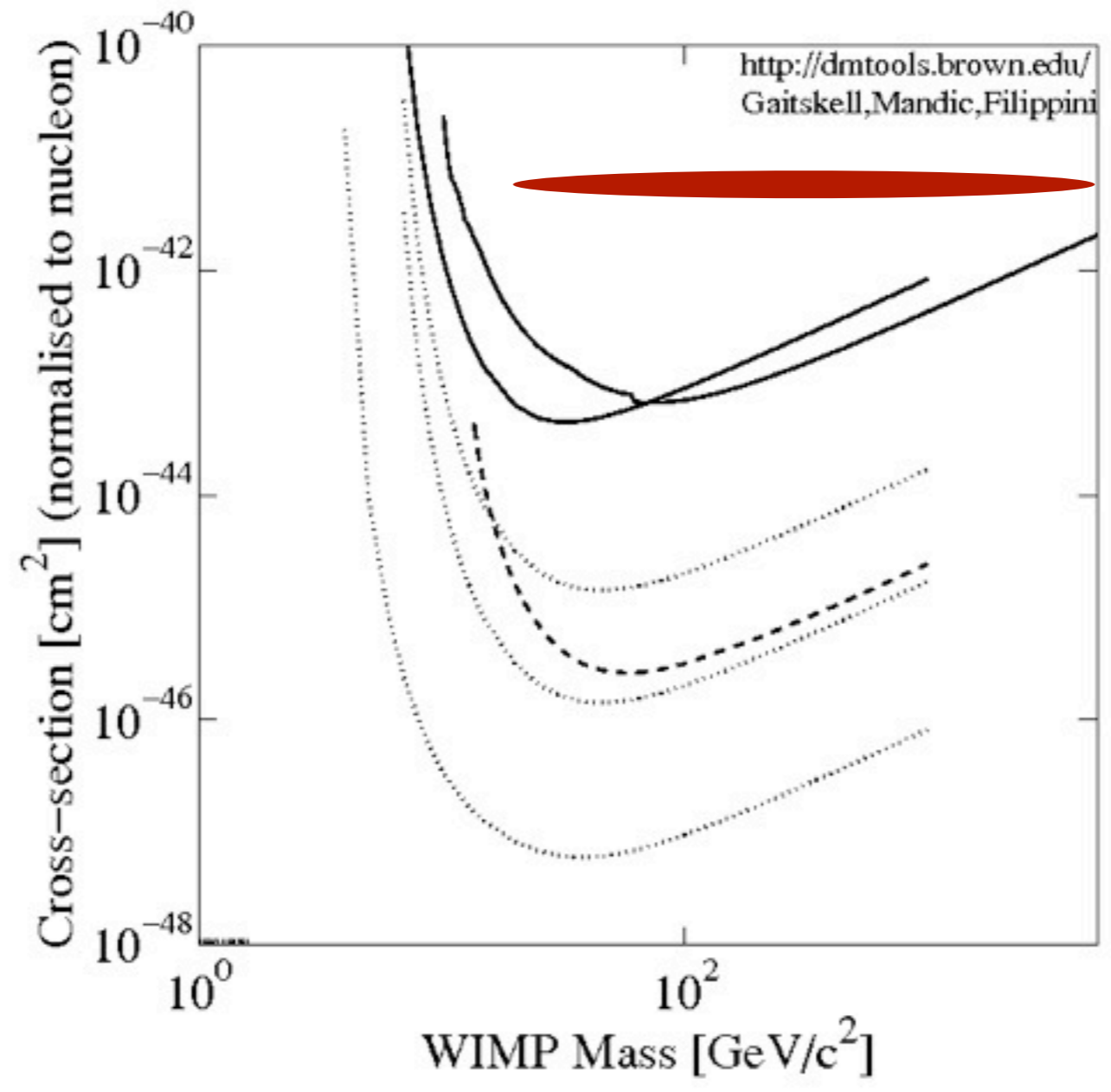
Davoudiasl, Kitano, Li, Murayama '04

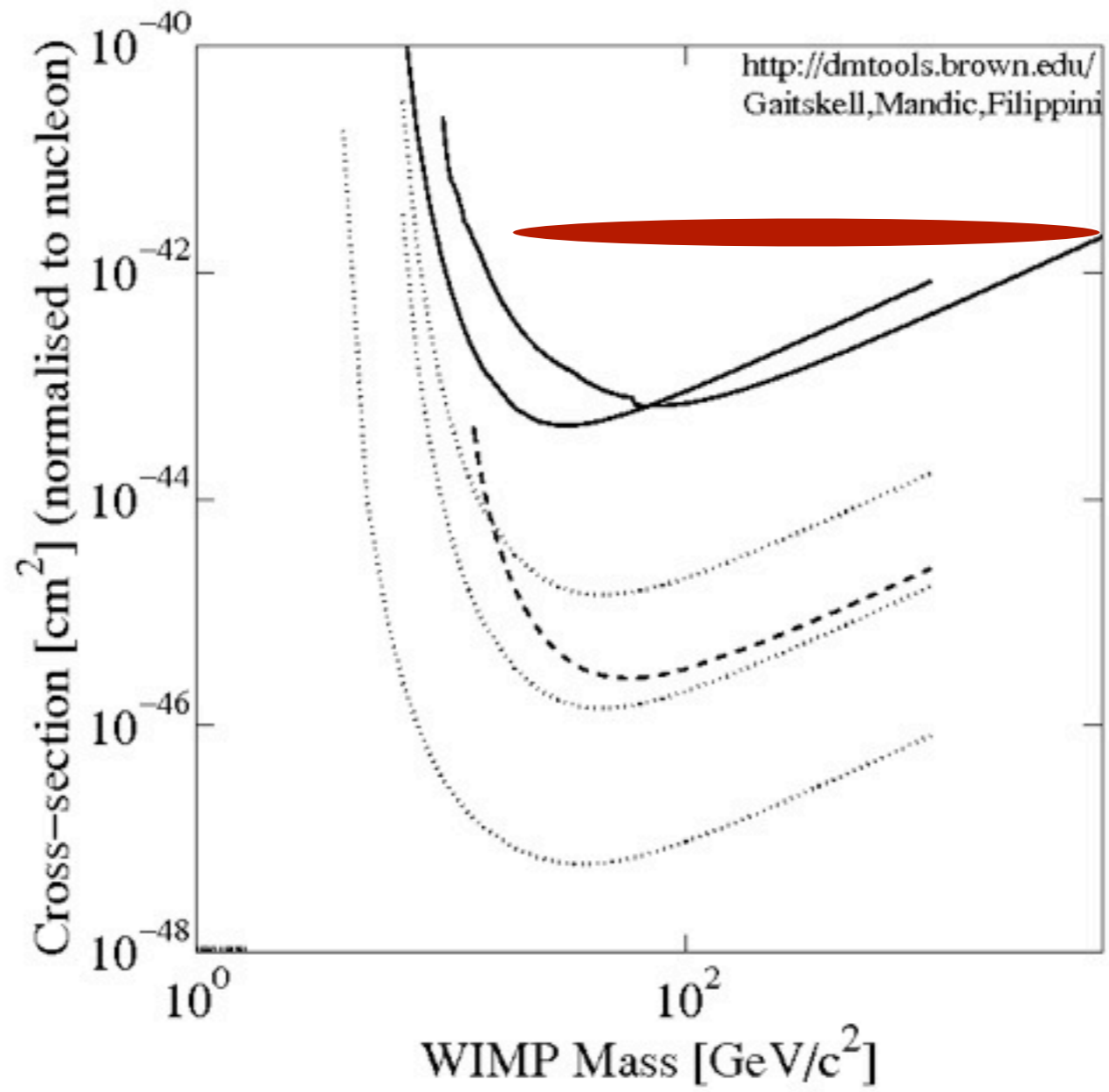


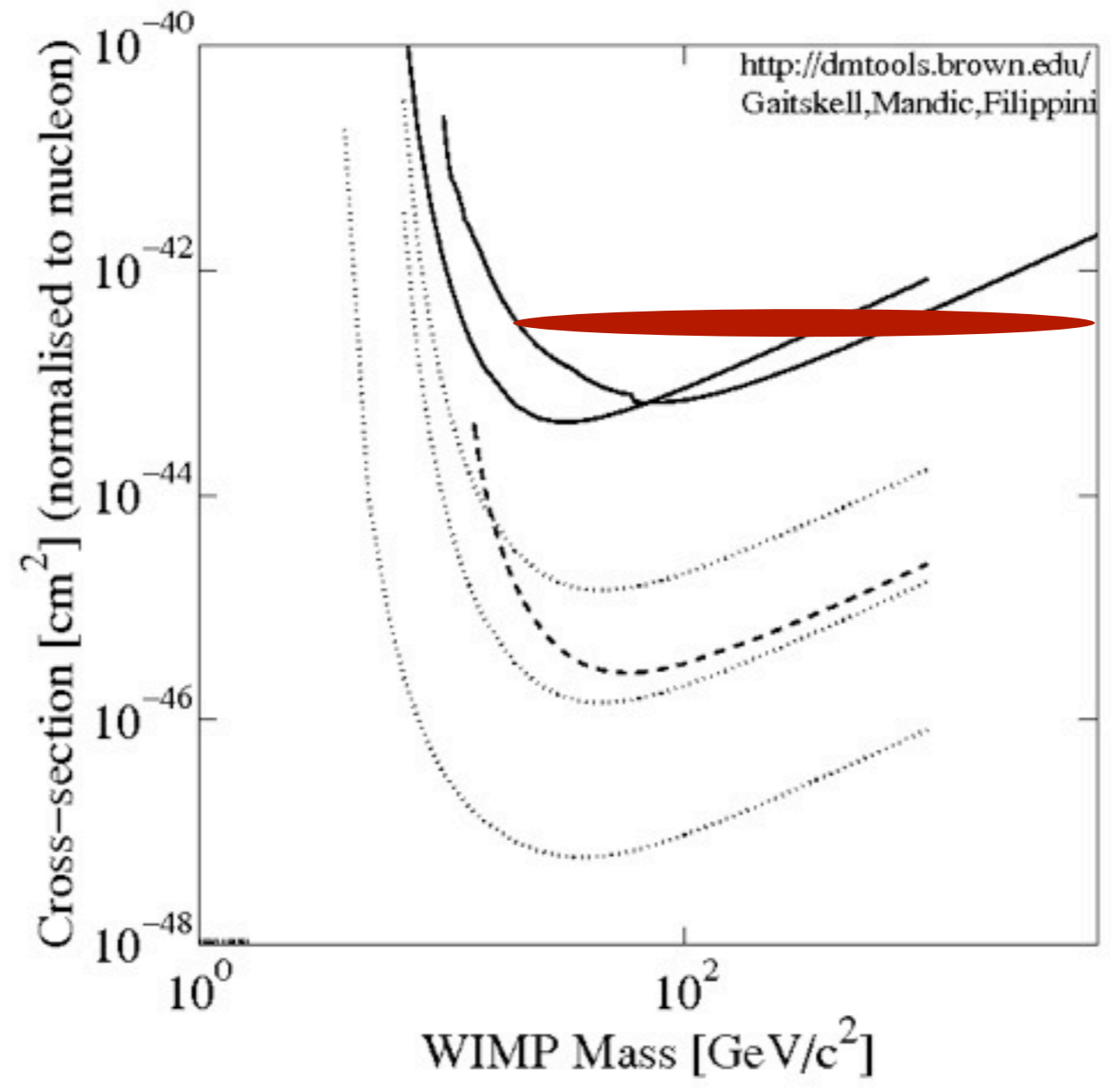


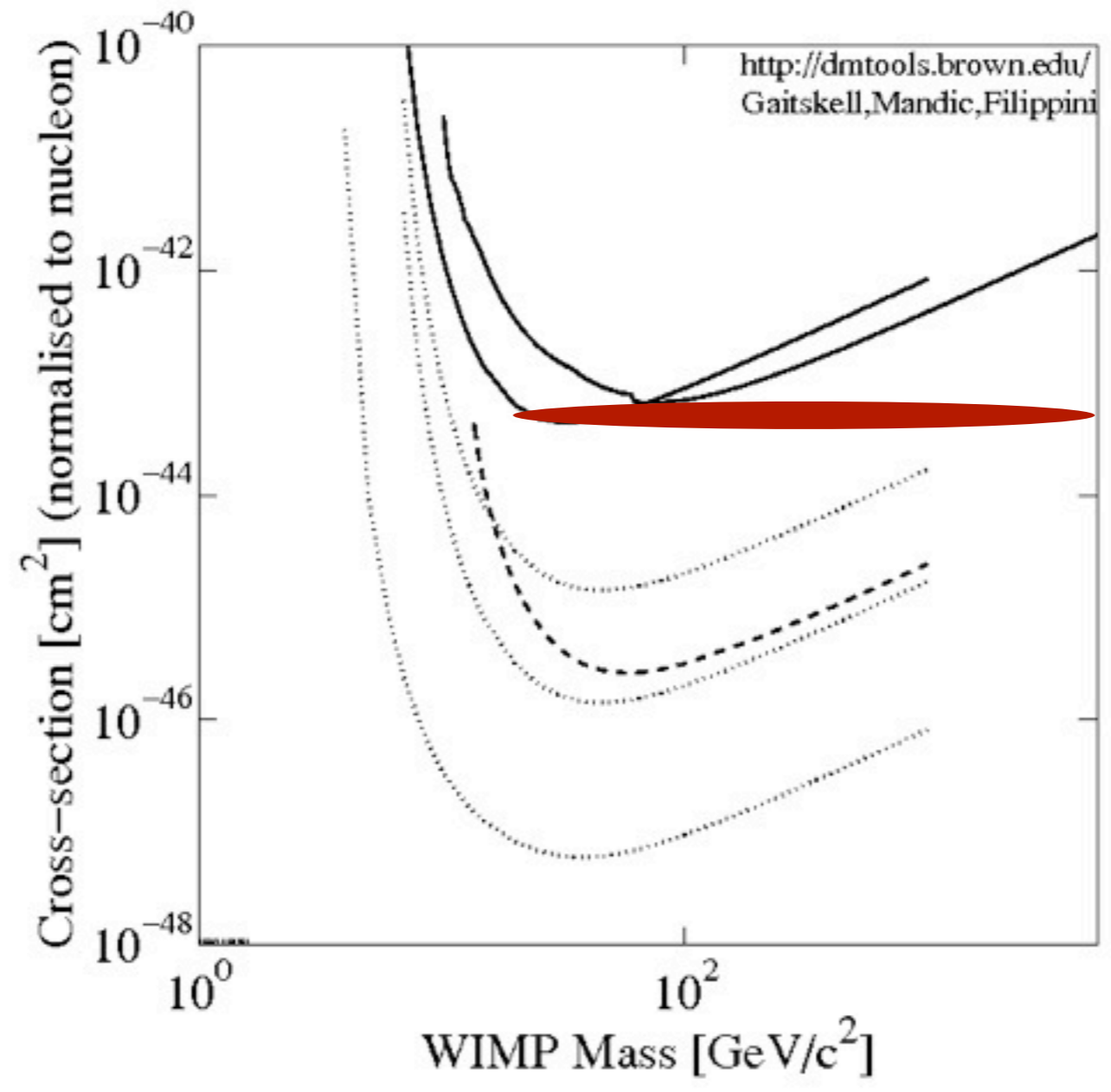


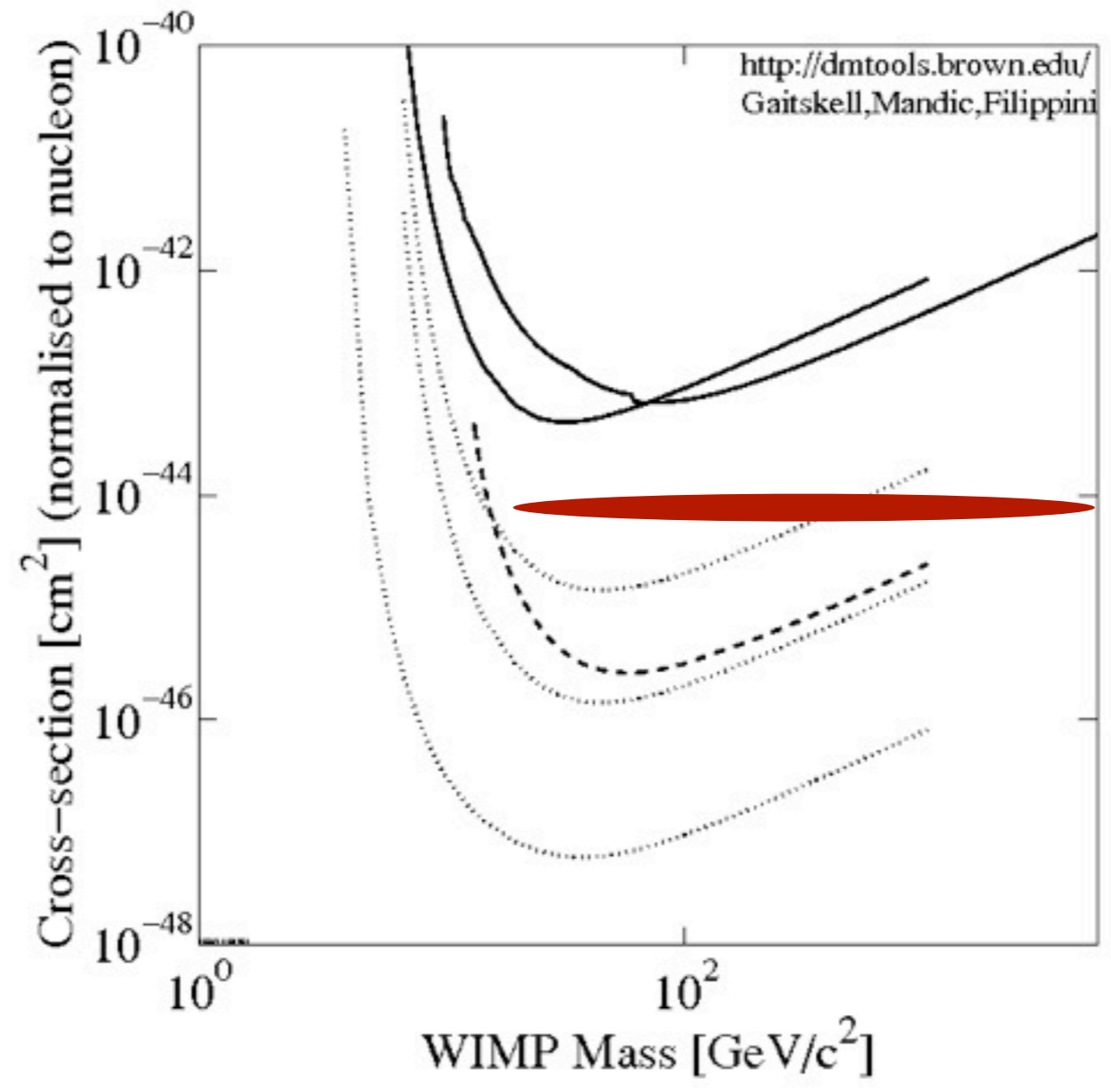


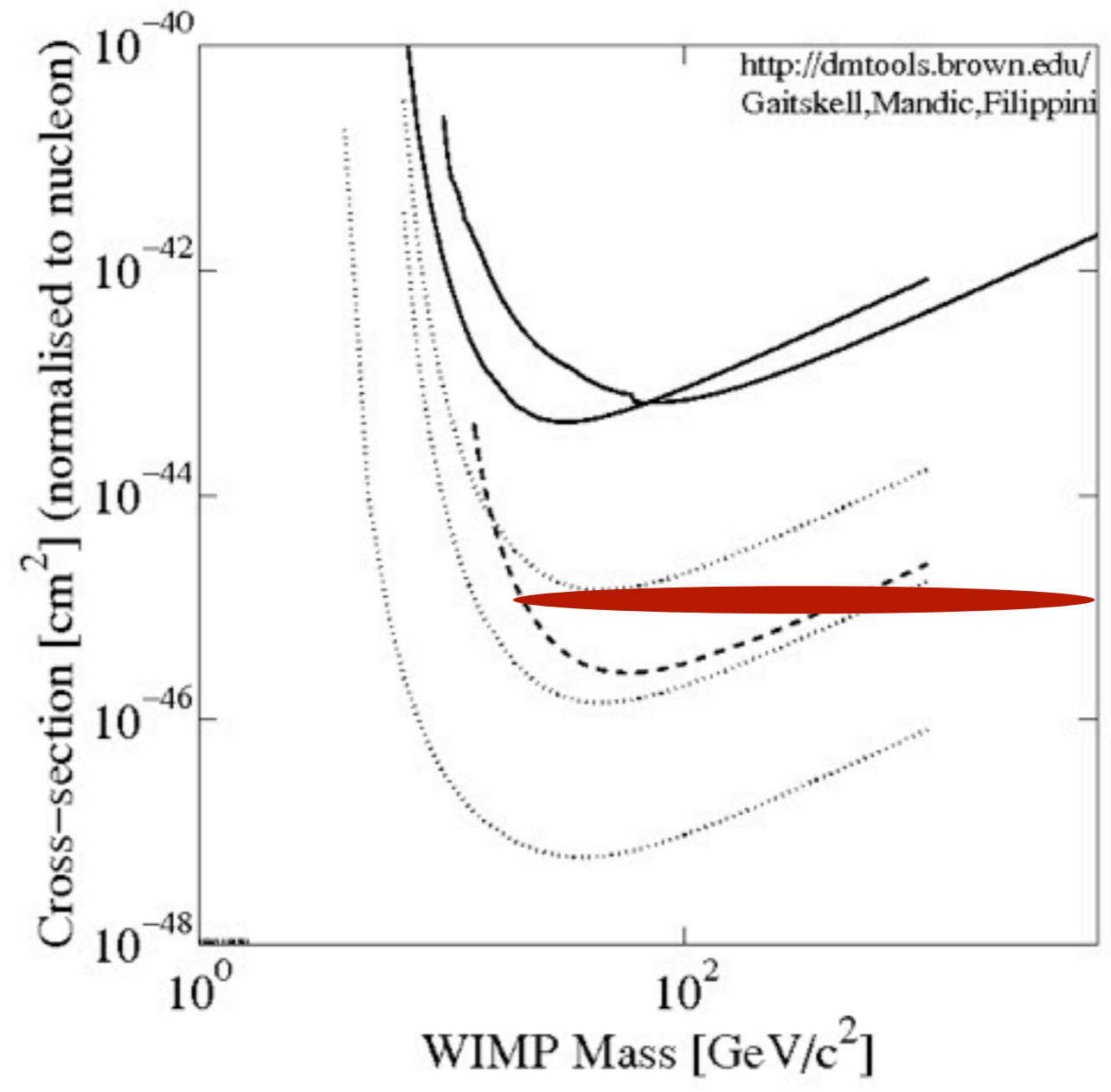


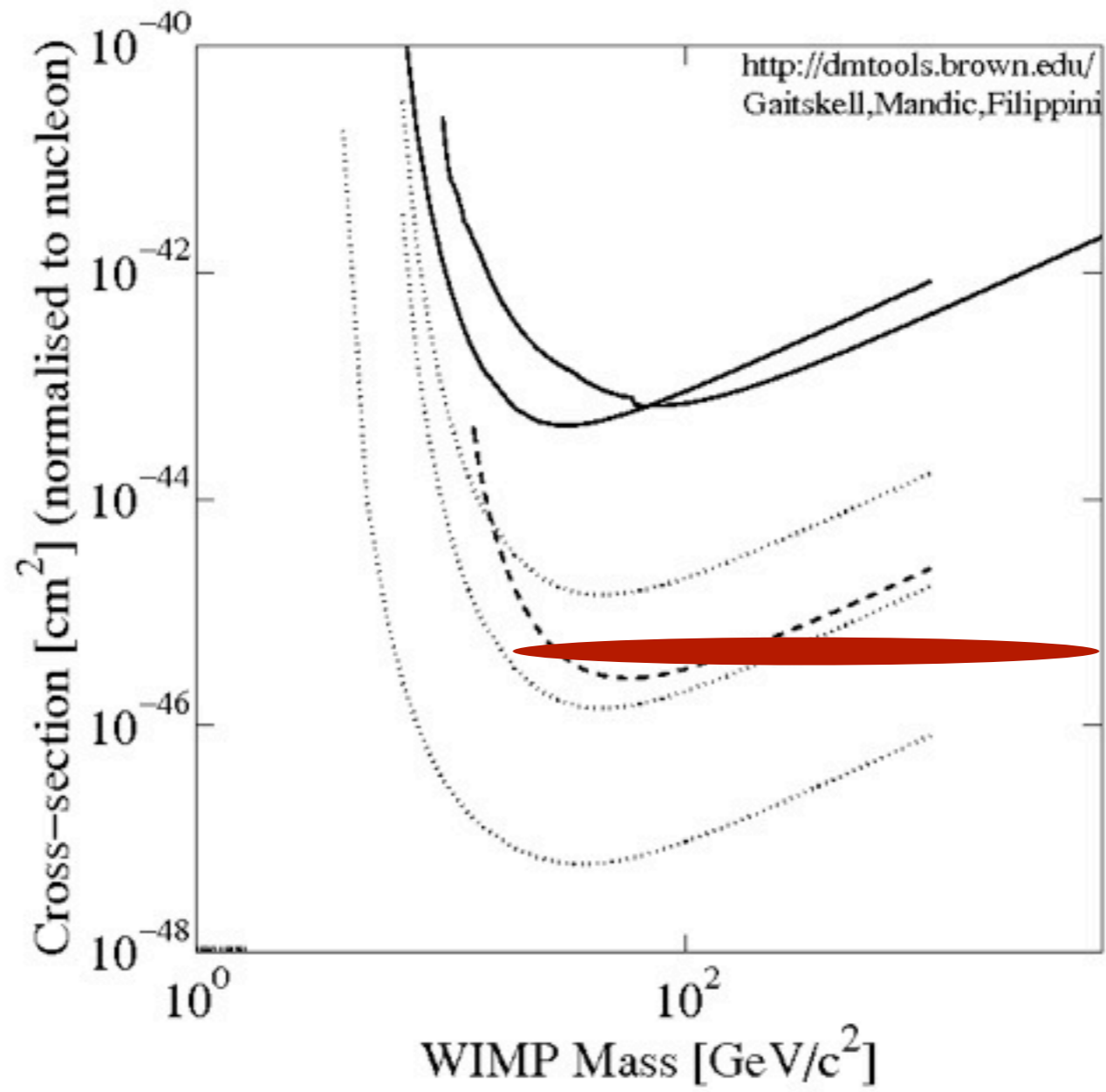


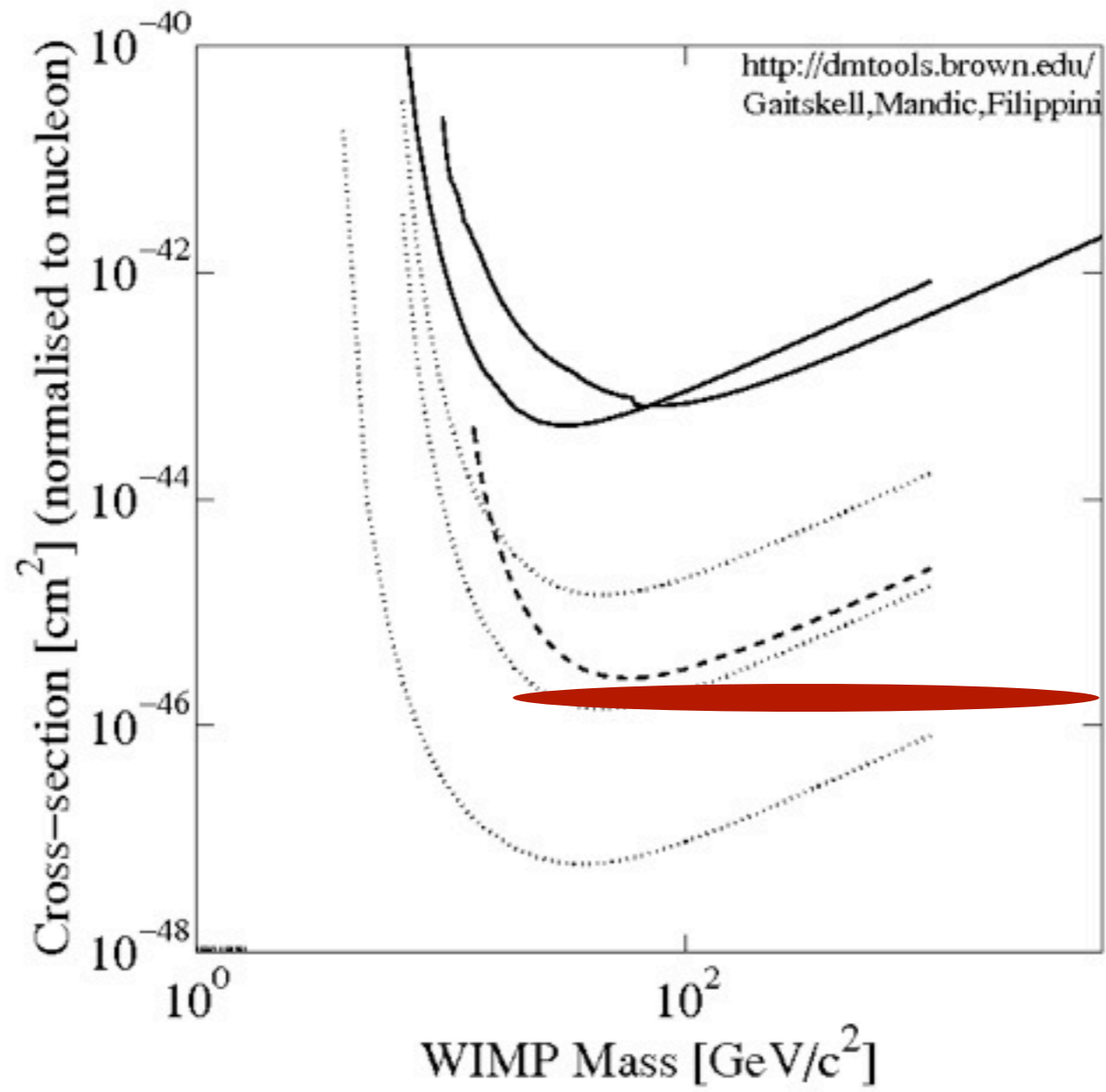


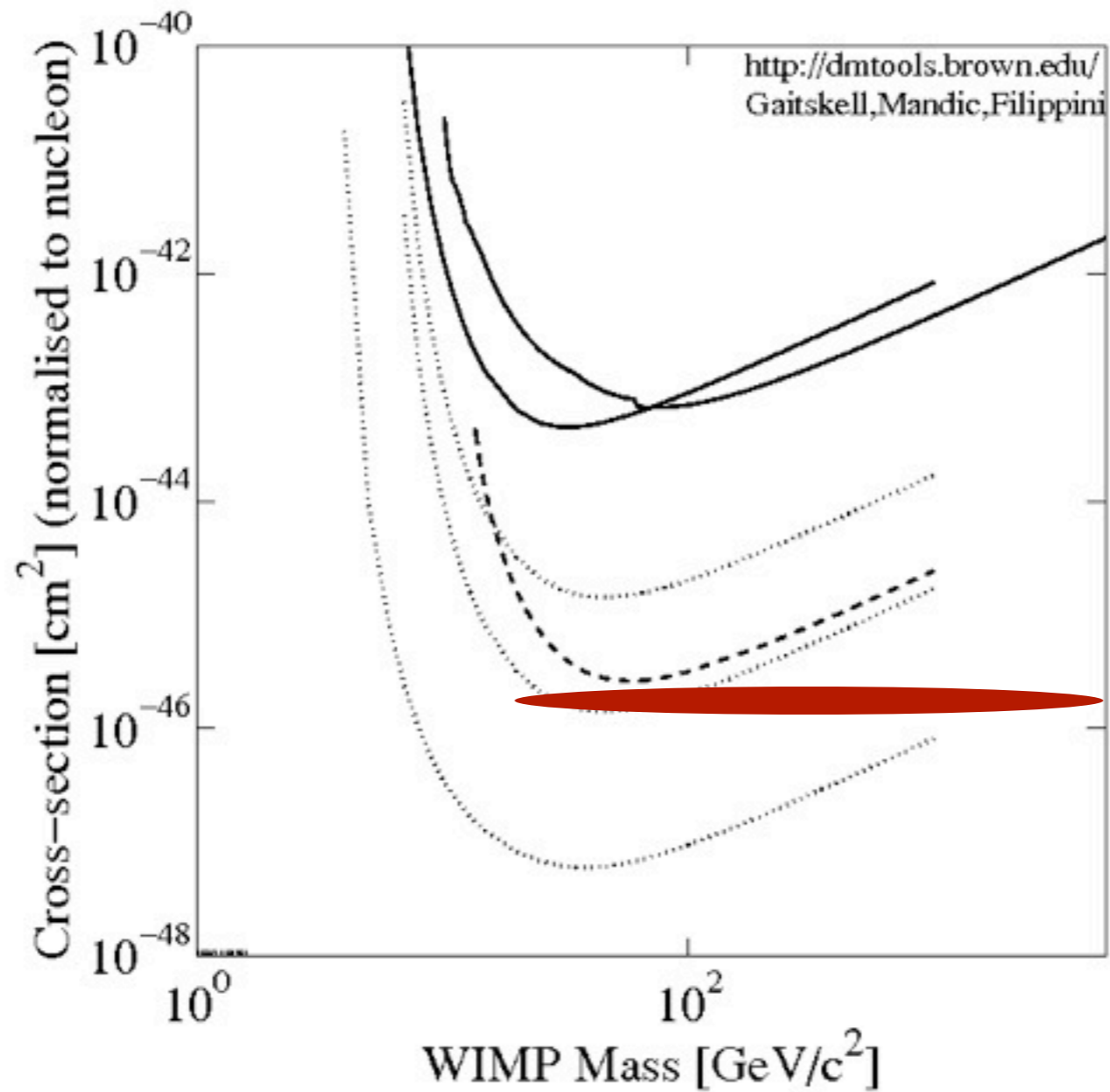












Various physics can move it up or down -
but this is a natural starting point

TWO CROSS SECTIONS

TWO CROSS SECTIONS

- If I had to pick two numbers for the cross section that a WIMP would scatter with, they'd be 10^{-39} cm^2 and 10^{-46} cm^2 .

TWO CROSS SECTIONS

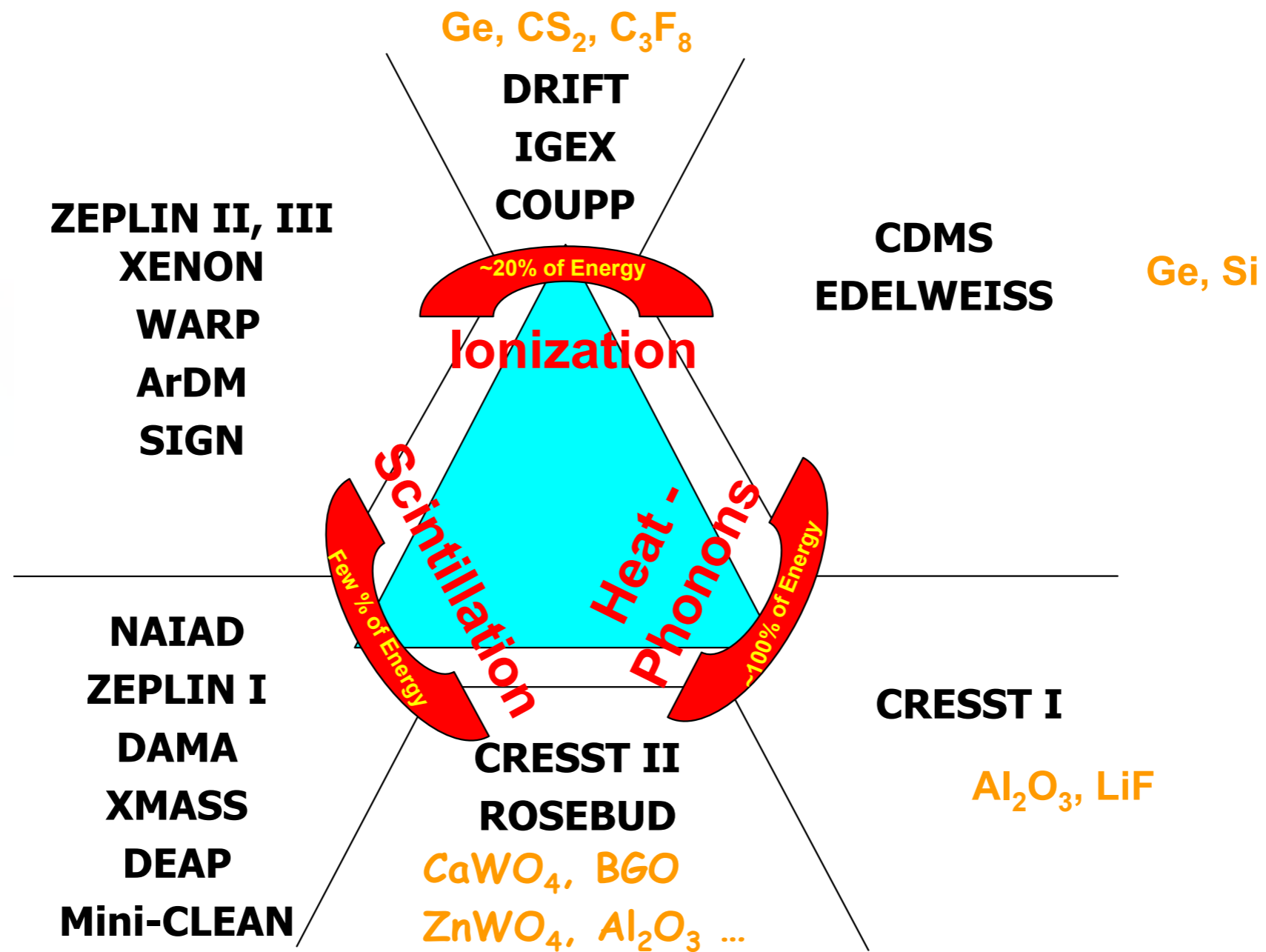
- If I had to pick two numbers for the cross section that a WIMP would scatter with, they'd be 10^{-39} cm^2 and 10^{-46} cm^2 .
- It's not the former.

TWO CROSS SECTIONS

- If I had to pick two numbers for the cross section that a WIMP would scatter with, they'd be 10^{-39} cm^2 and 10^{-46} cm^2 .
- It's not the former.
- How will we get there?

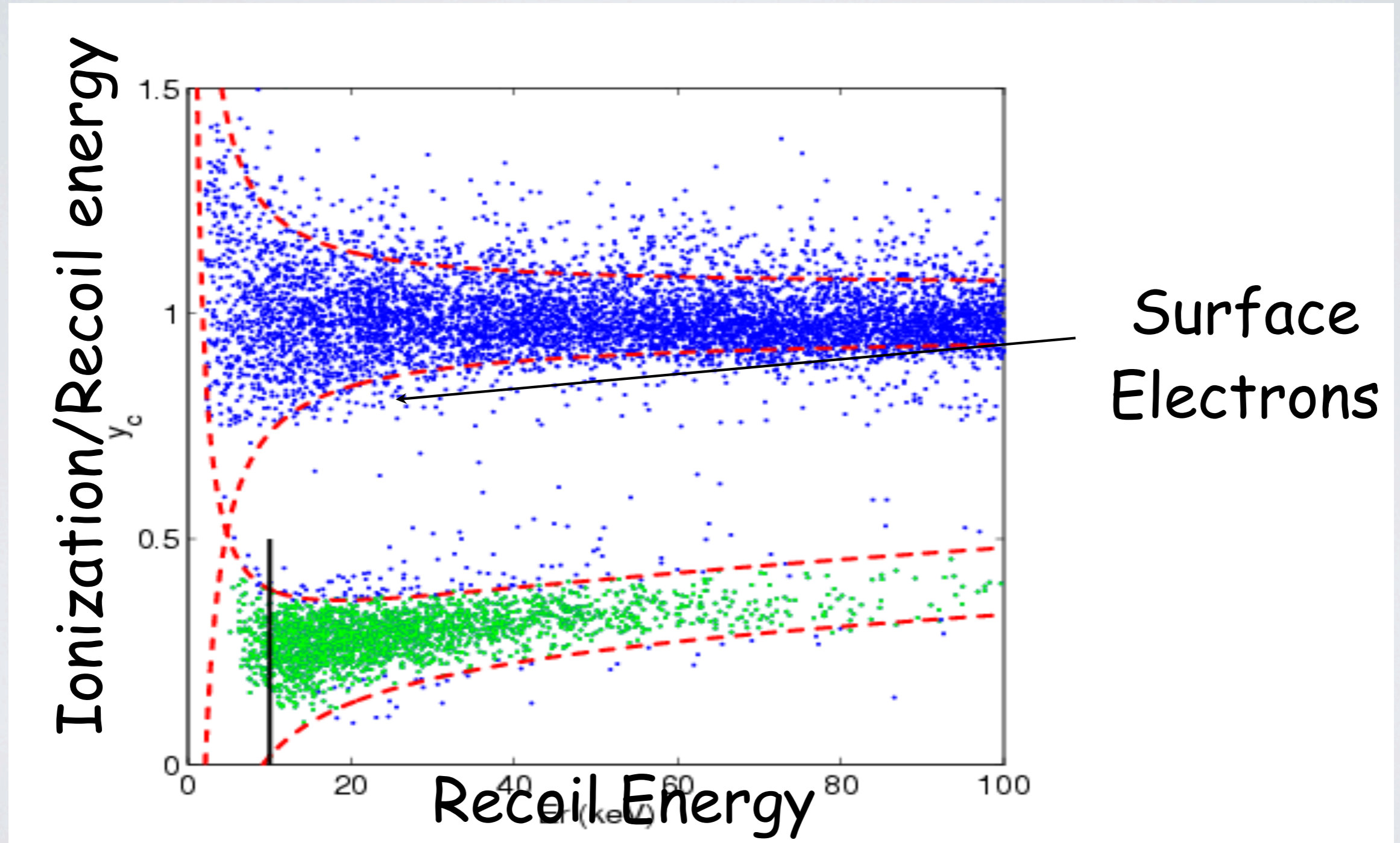
need: low threshold (\sim keV) signal, eliminate bkg (shielding), discriminate bkg

Direct Detection Techniques



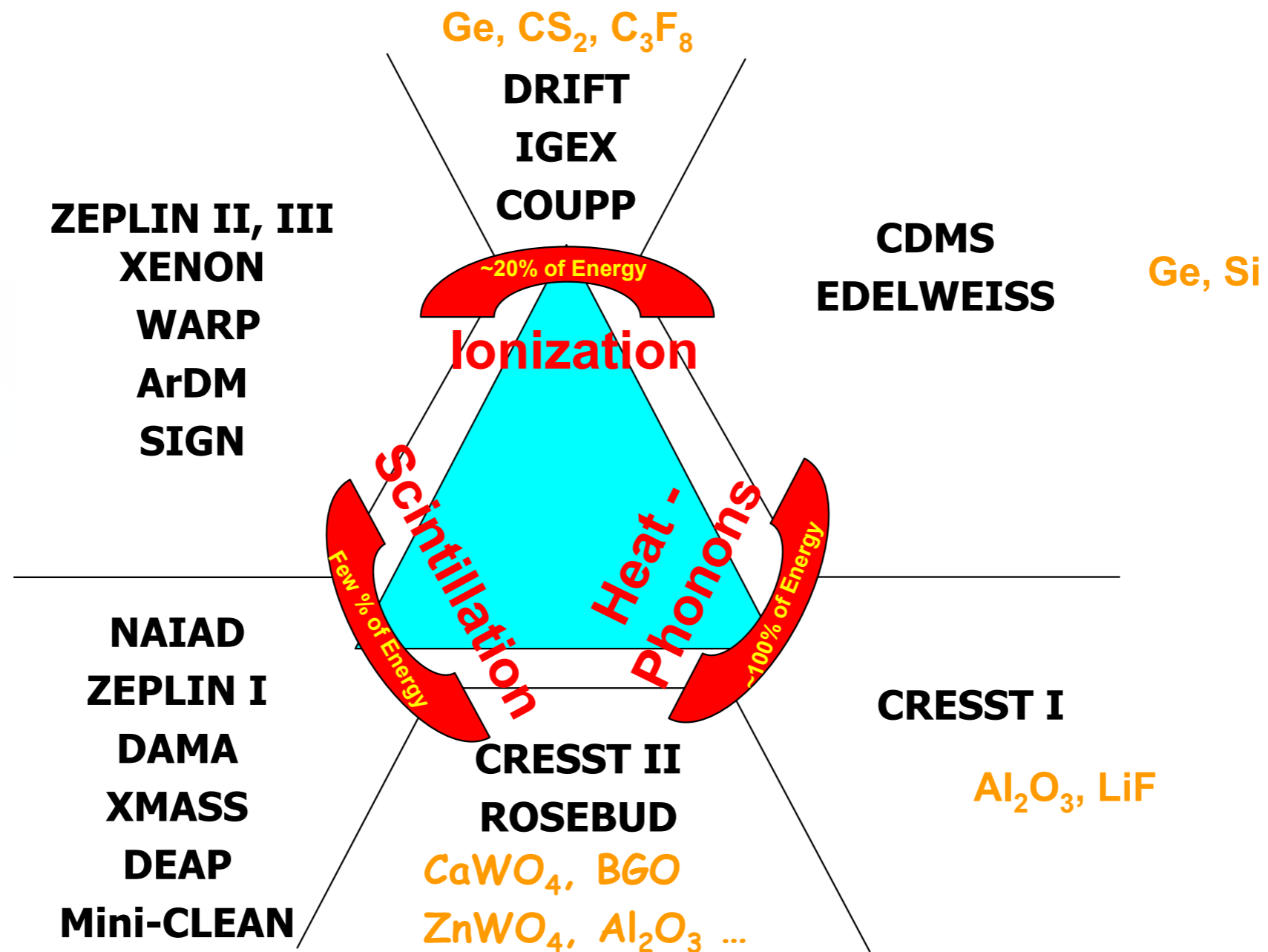
(plot shamelessly stolen from B. Sadoulet)

E.G., CDMS



need: low threshold (\sim keV) signal, eliminate bkg (shielding), discriminate bkg

Direct Detection Techniques

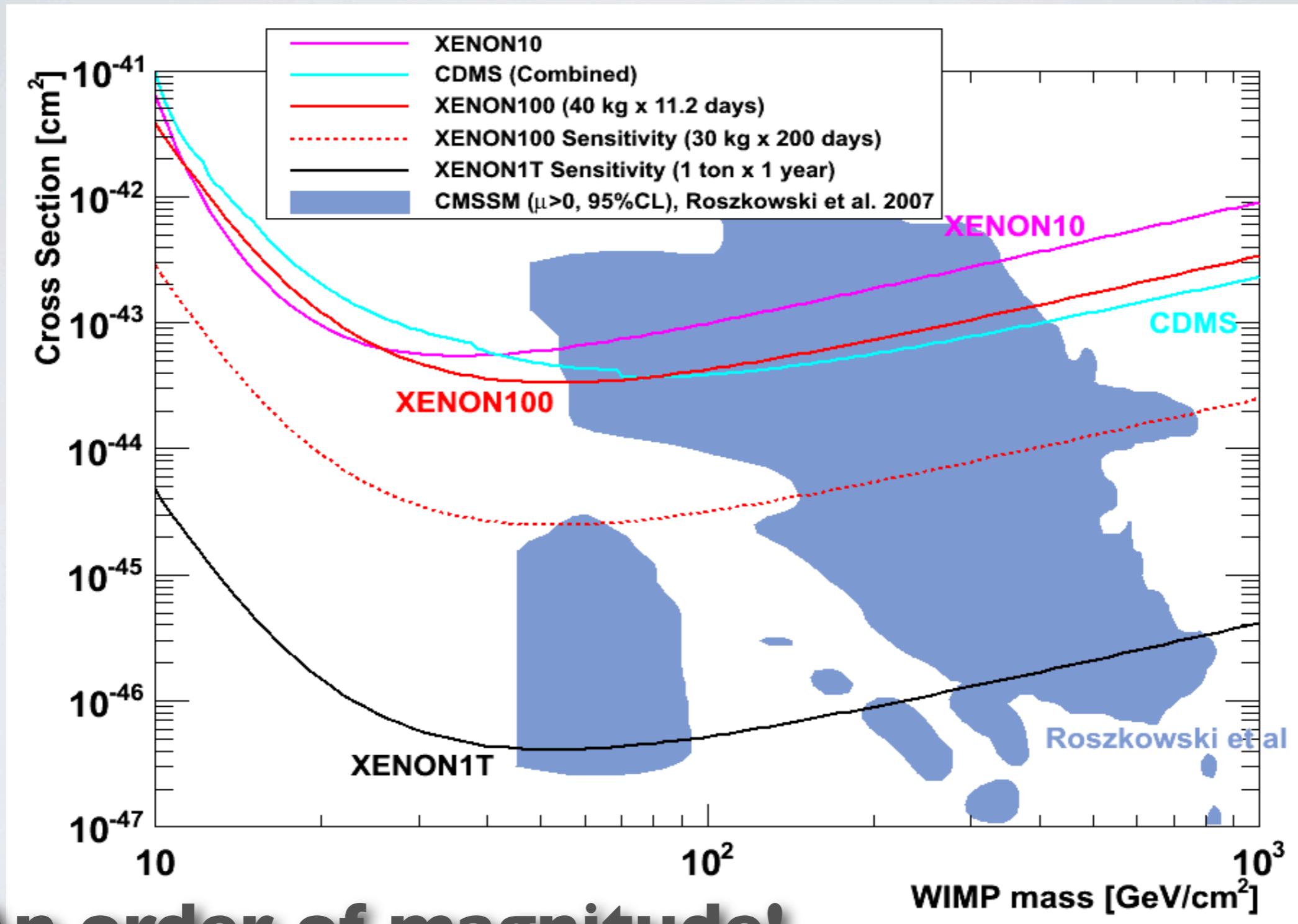


(plot shamelessly stolen from B. Sadoulet)

KEY EVENTS IN 2011

- XENON100 (Unblinding and first results)
- COUPP (First results)
- KIMS (1 year results)
- COGENT (Update)

XENON100

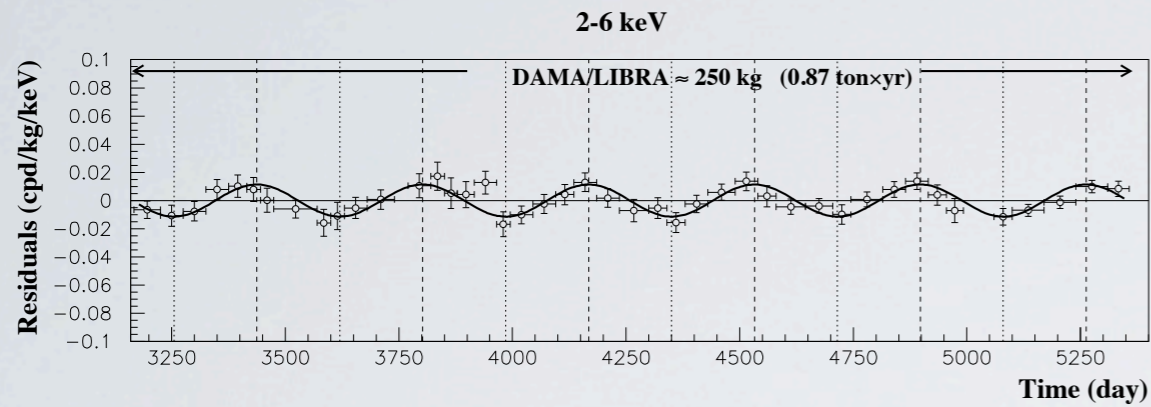


An order of magnitude!

(shamelessly stolen from E. Aprile)

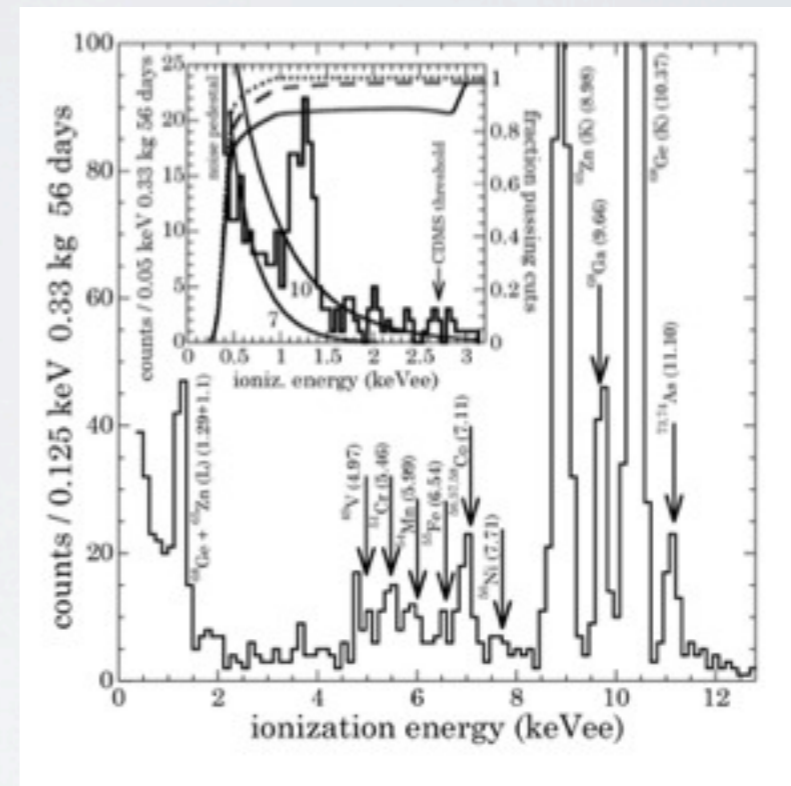
February/March first results ~ 100 days

ANOMALIES

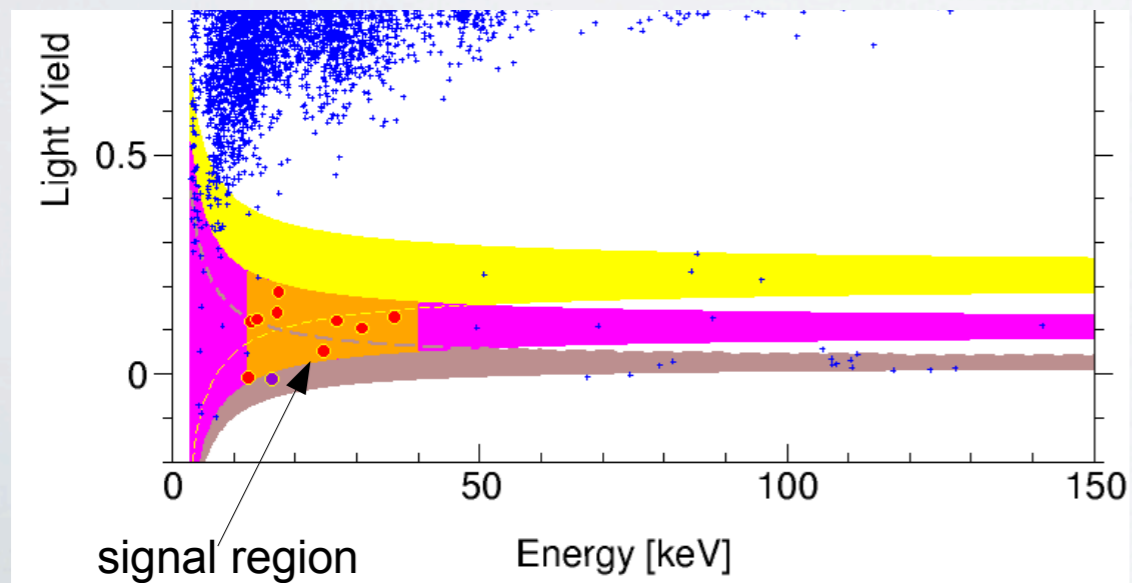


DAMA

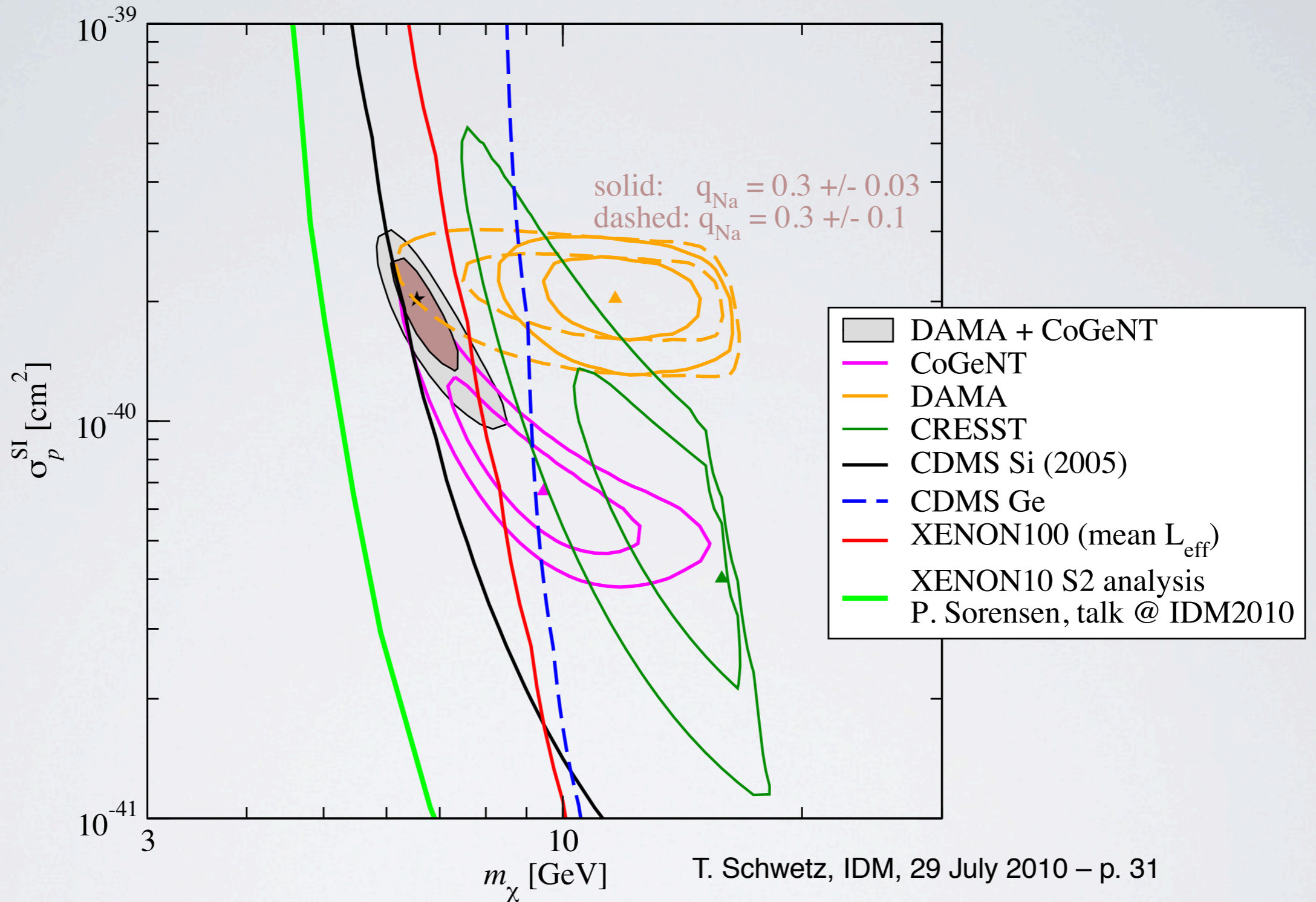
CoGeNT



CRESST

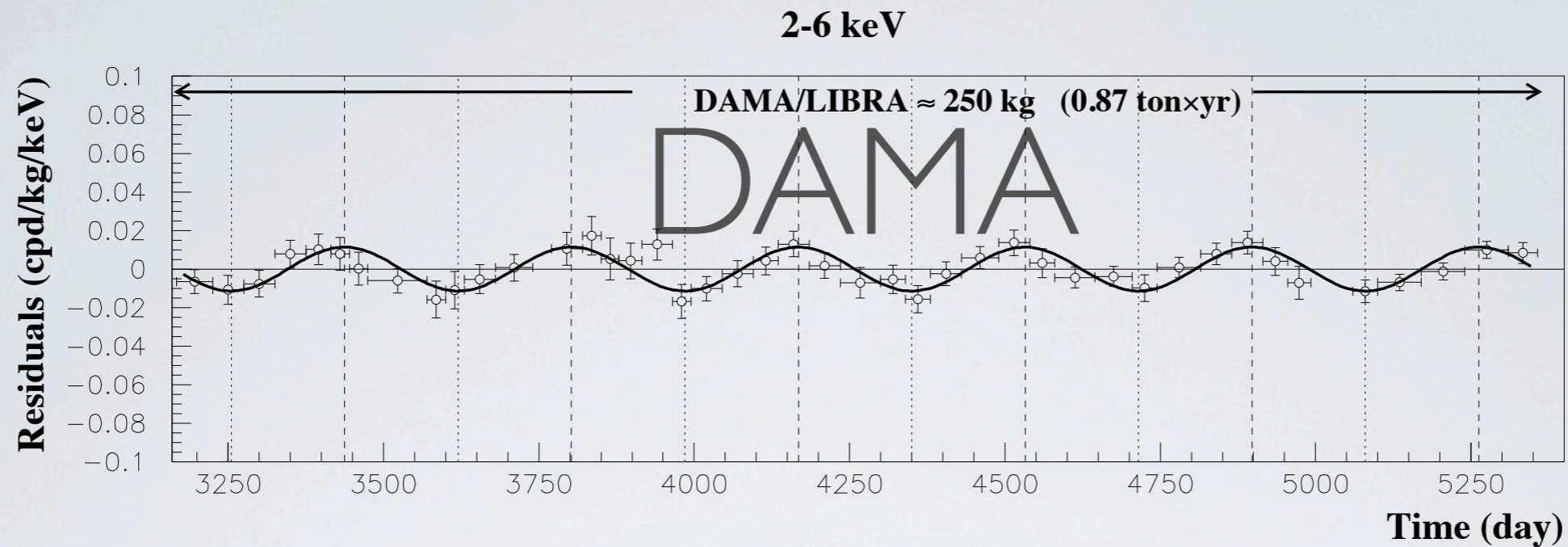


- The same beast?



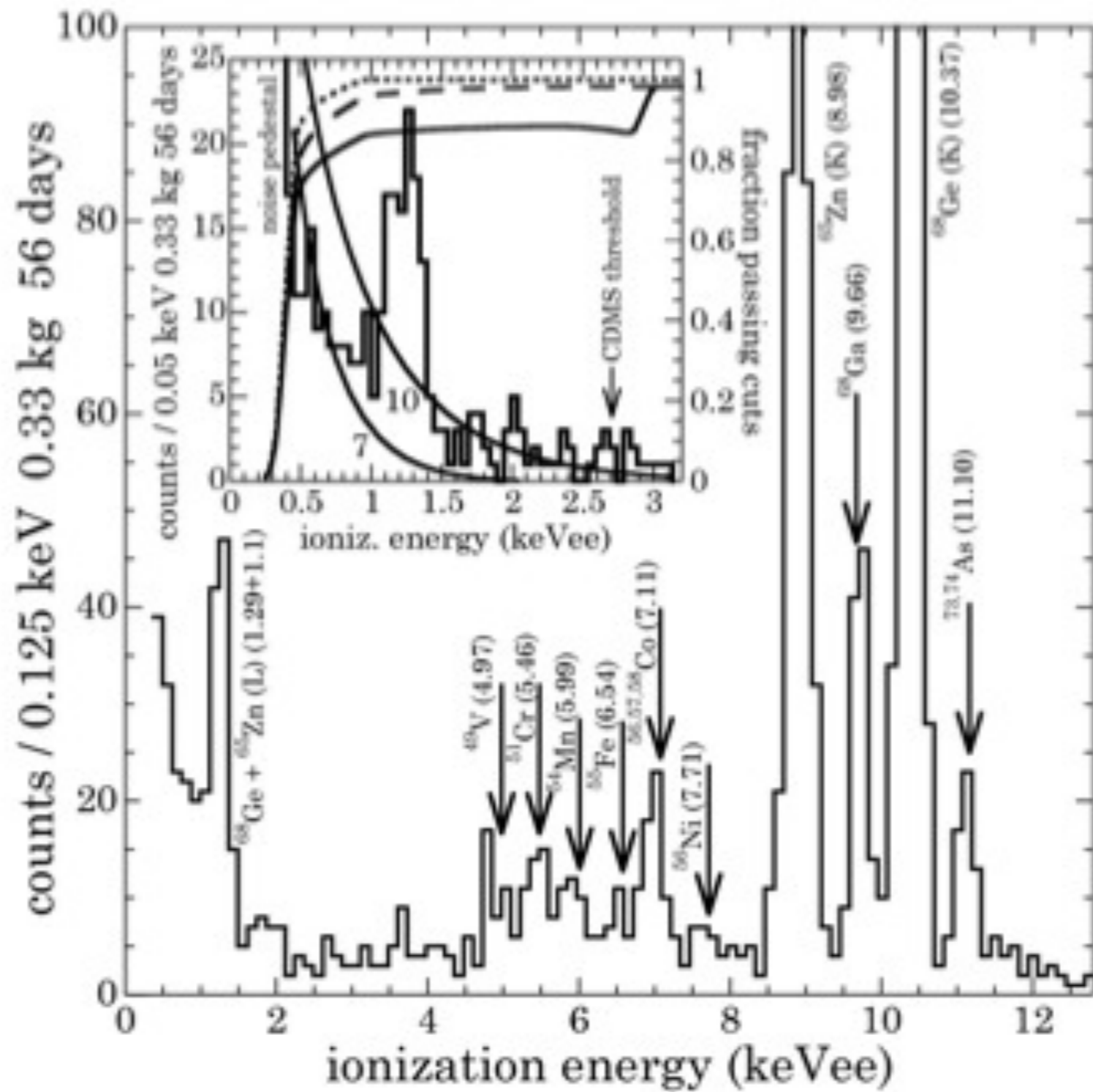
don't *really* line up, but within spitting distance

NB: *Not* MSSM (Kuflick, Pierce, Zurek '10)

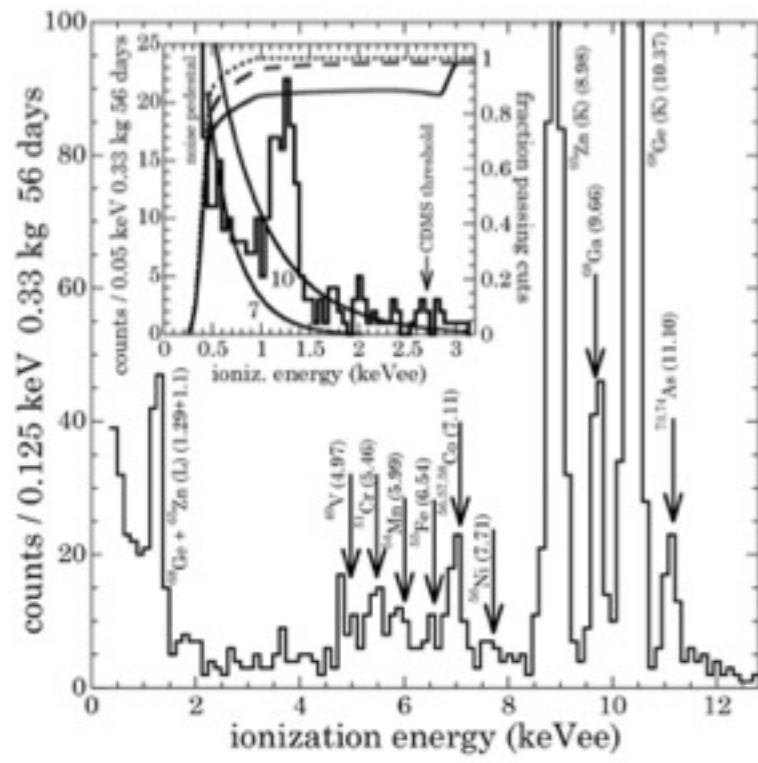


- What is it: annual modulation in scintillation events in 100/250 kg NaI(Tl) crystal - DM?
- What's to like: single hit, stable phase, low energy, no candidate "conventional" explanations
- What's not to like: null results from other exps, data are still unavailable, no event discrimination

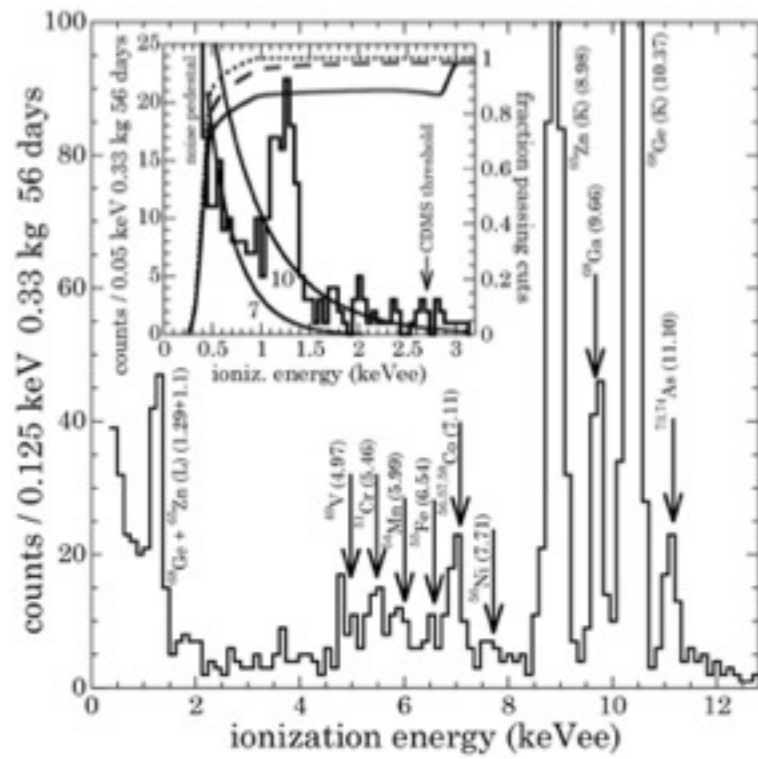
COGENT



COGENT

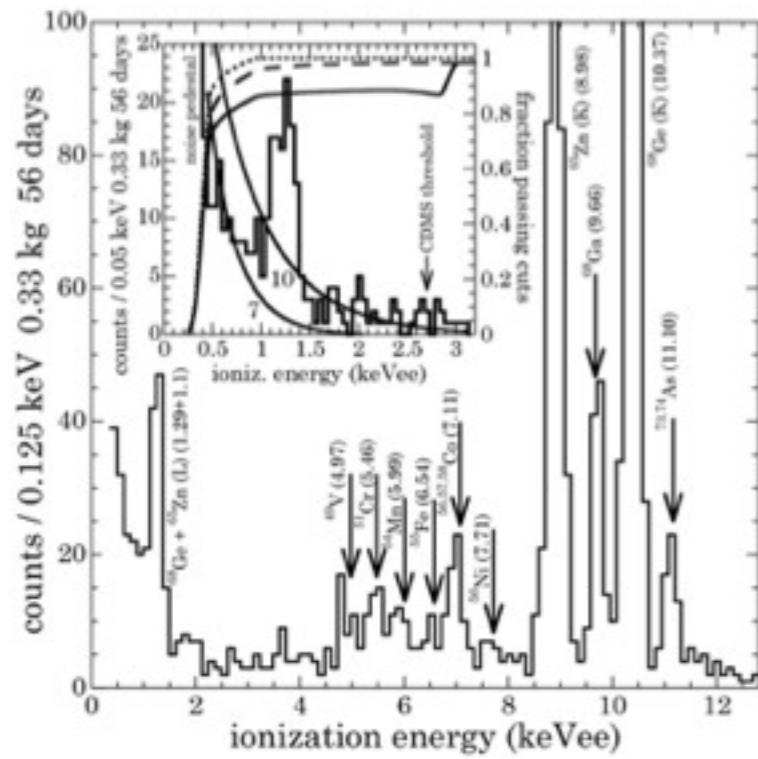


COGENT



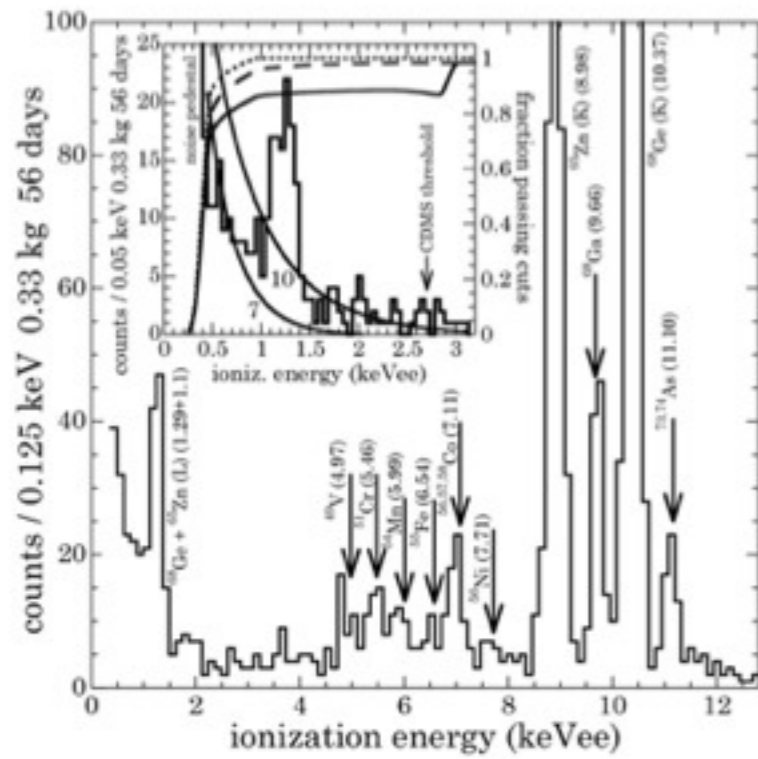
- What is it: events in an ionization experiment, x10 larger than expected background - DM?

COGENT

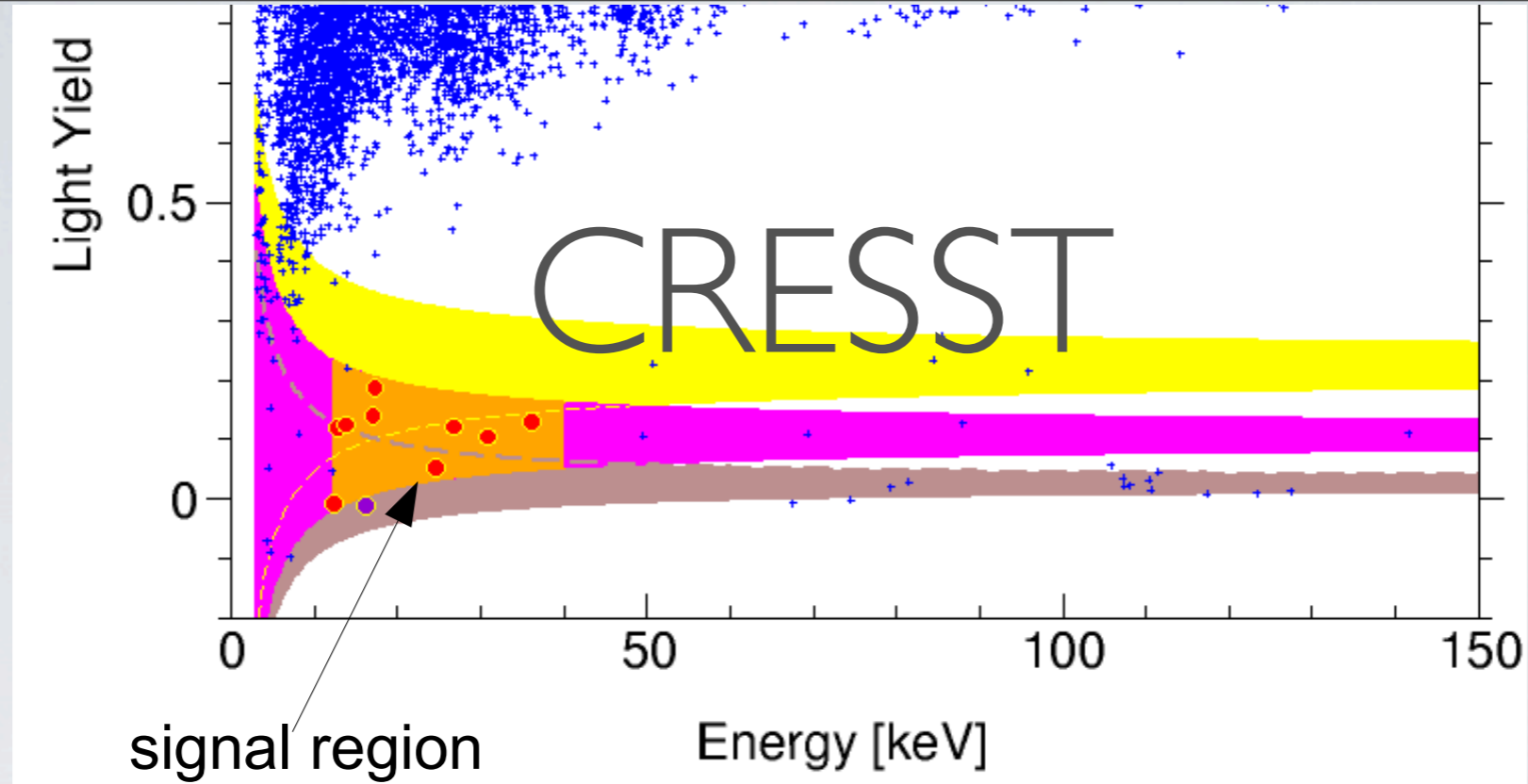


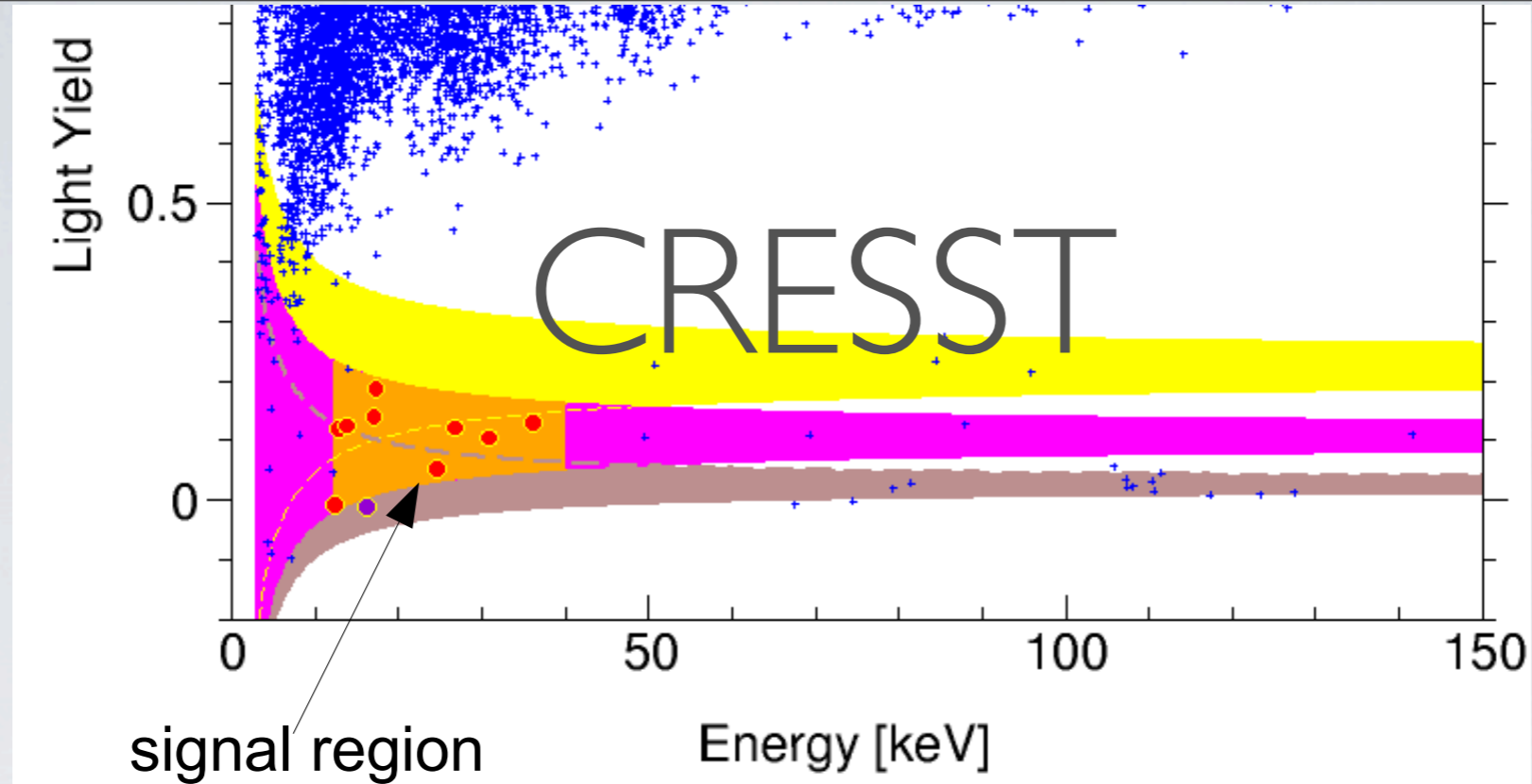
- What is it: events in an ionization experiment, x10 larger than expected background - DM?
- What's to like: excellent energy resolution/calibration, good statistics

COGENT

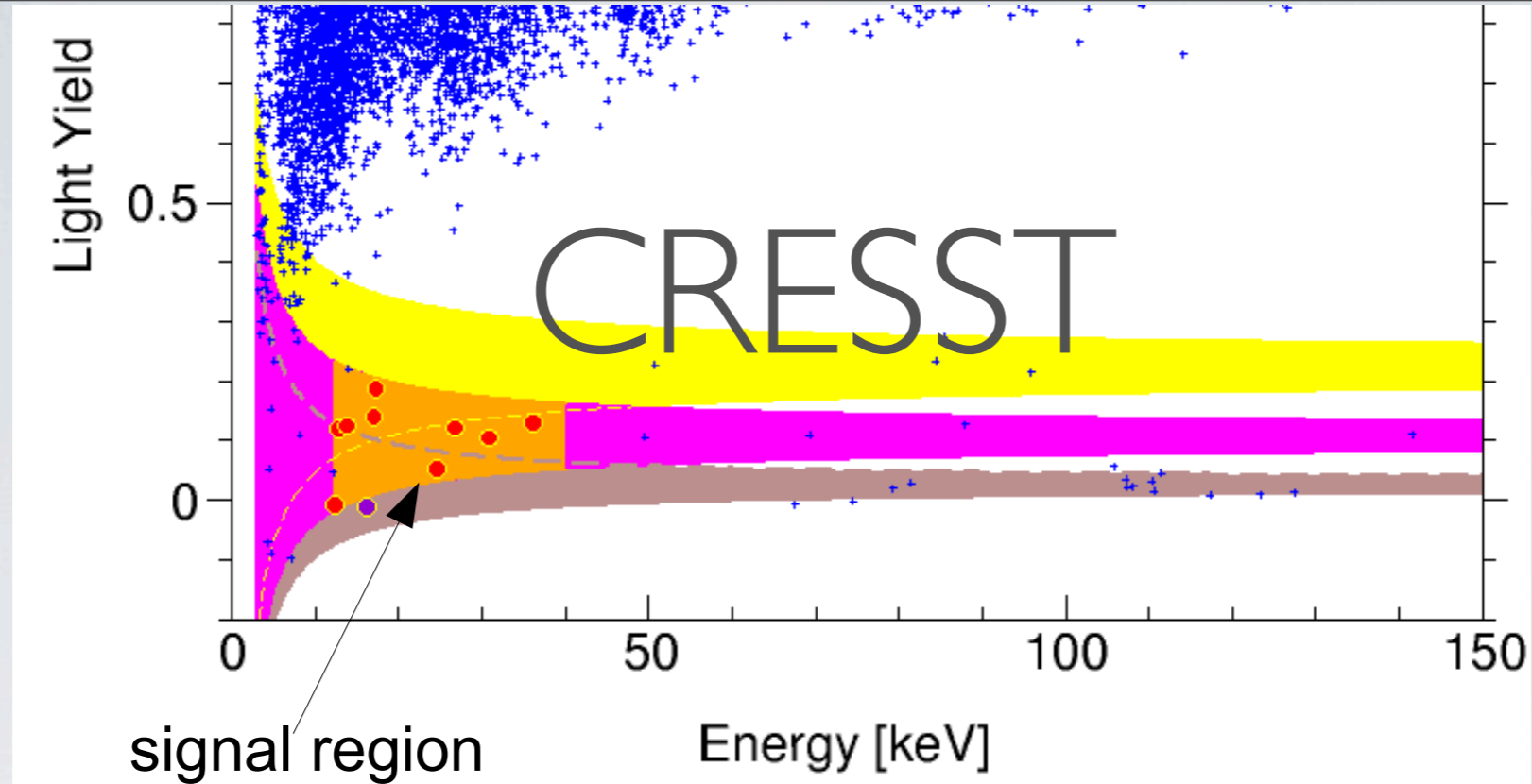


- What is it: events in an ionization experiment, $\times 10$ larger than expected background - DM?
- What's to like: excellent energy resolution/calibration, good statistics
- What's not to like: no discrimination, hasn't been mercilessly beaten for a decade, no corroborating features [yet] (e.g. modulation), null results from other exps

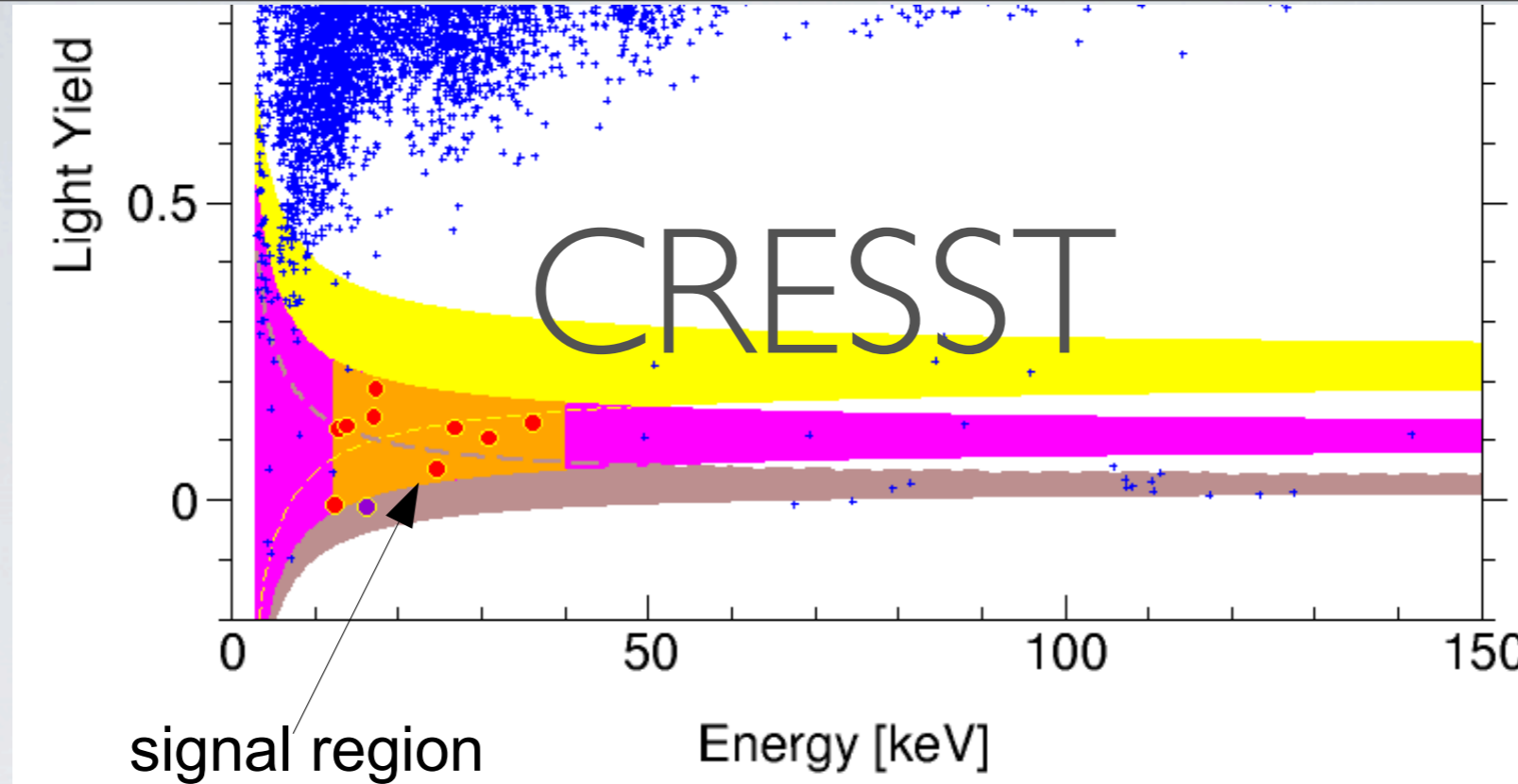




- What is it: an excess of events in a CaWO_4 detector, consistent with Oxygen scattering ($\sim 10\text{-}40$ keV)



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- What's to like: good discrimination vs electron recoil, not muon induced neutrons



- What is it: an excess of events in a CaWO_4 detector, consistent with Oxygen scattering ($\sim 10\text{-}40$ keV)
- What's to like: good discrimination vs electron recoil, not muon induced neutrons
- What's not to like: lots of events at high (15 keV+ energy, should have been seen elsewhere), signal lies left, right, above and below clear background sources, still have only seen 2 of 9 detectors, naively low energy looks too clean to be WIMP

THE CONTROVERSY

3) Comments on arXiv:1006.0972 'XENON10/100 dark matter constraints in comparison with CoGeNT and DAMA: examining th
J.I. Collar, . Jun 2010. 2pp. [Temporary entry](#)
e-Print: [arXiv:1006.2031](#) [astro-ph.CO]

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[Bookmarkable link to this information](#)

4) Response to arXiv:1005.2615.
J.I. Collar, D.N. McKinsey, . May 2010. [Temporary entry](#)
e-Print: [arXiv:1005.3723](#) [astro-ph.CO]

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[Bookmarkable link to this information](#)

5) Reply to the Comments on the XENON100 First Dark Matter Results.
The XENON100 Collaboration, . May 2010. [Temporary entry](#)
e-Print: [arXiv:1005.2615](#) [astro-ph.CO]

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[Bookmarkable link to this information](#)

6) Comments on 'First Dark Matter Results from the XENON100 Experiment'.
J.I. Collar, D.N. McKinsey, . May 2010. [Temporary entry](#)
e-Print: [arXiv:1005.0838](#) [astro-ph.CO]

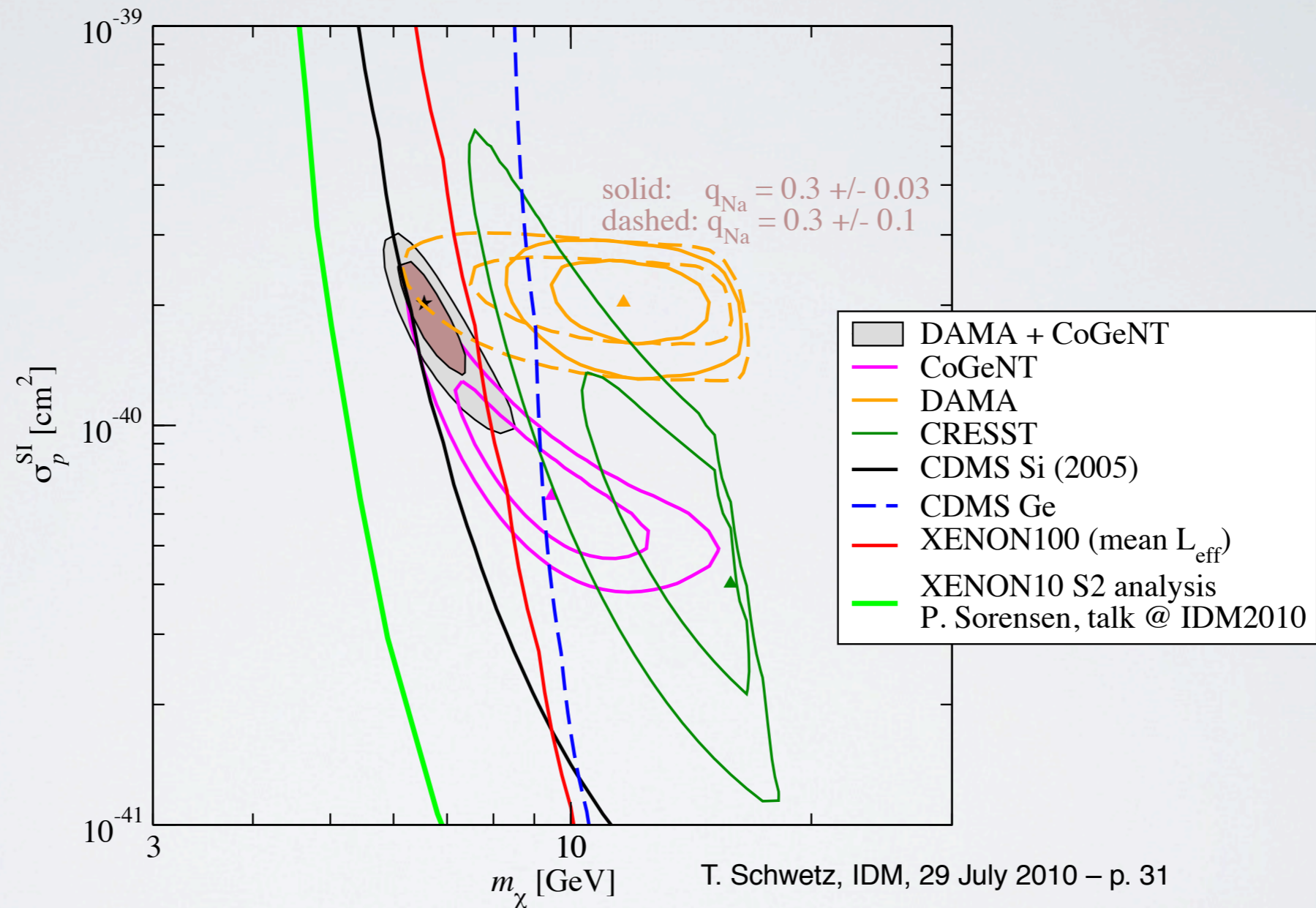
[References](#) | [LaTeX\(US\)](#) | [LaTeX\(EU\)](#) | [Harvmac](#) | [BibTeX](#) | [Keywords](#) | Cited [22 times](#)
[Abstract](#) and [Postscript](#) and [PDF](#) from arXiv.org (mirrors: [au](#) [br](#) [cn](#) [de](#) [es](#) [fr](#) [il](#) [in](#) [it](#) [jp](#) [kr](#) [ru](#) [tw](#) [uk](#) [za](#) [aps](#) [lanl](#))
[Bookmarkable link to this information](#)

7) First Dark Matter Results from the XENON100 Experiment.
By XENON100 Collaboration (E. Aprile *et al.*). May 2010. (Published Sep 24, 2010). 4pp.
Published in **Phys.Rev.Lett.** **105:131302,2010.**
e-Print: [arXiv:1005.0380](#) [astro-ph.CO]

TOPCITE = 50+

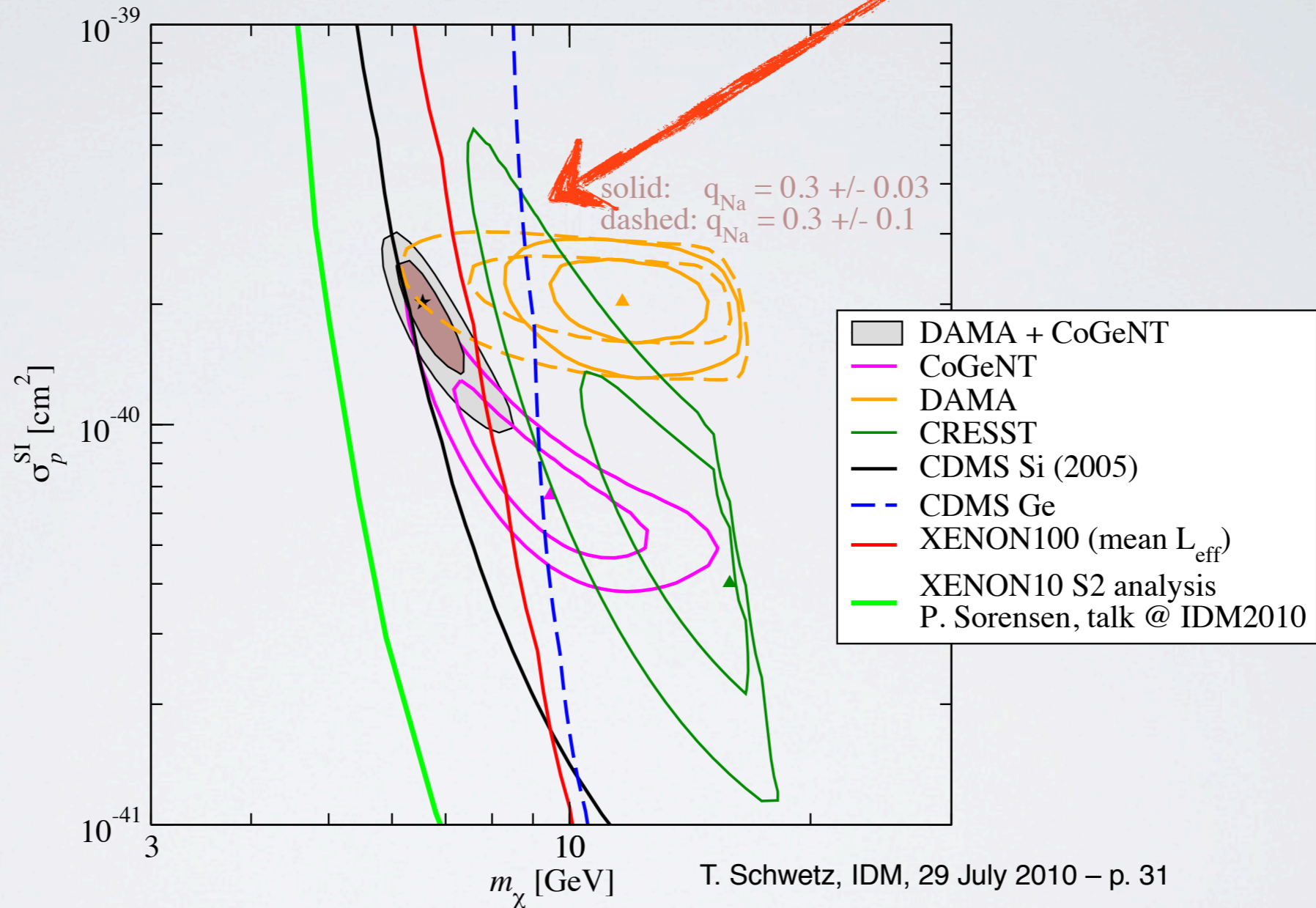
[References](#) | [LaTeX\(US\)](#) | [LaTeX\(EU\)](#) | [Harvmac](#) | [BibTeX](#) | [Keywords](#) | Cited [103 times](#)
[Abstract](#) and [Postscript](#) and [PDF](#) from arXiv.org (mirrors: [au](#) [br](#) [cn](#) [de](#) [es](#) [fr](#) [il](#) [in](#) [it](#) [jp](#) [kr](#) [ru](#) [tw](#) [uk](#) [za](#) [aps](#) [lanl](#))
Journal Server [doi:[10.1103/PhysRevLett.105.131302](#)]
[EXP XENON](#)
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THE CONTROVERSY



THE CONTROVERSY

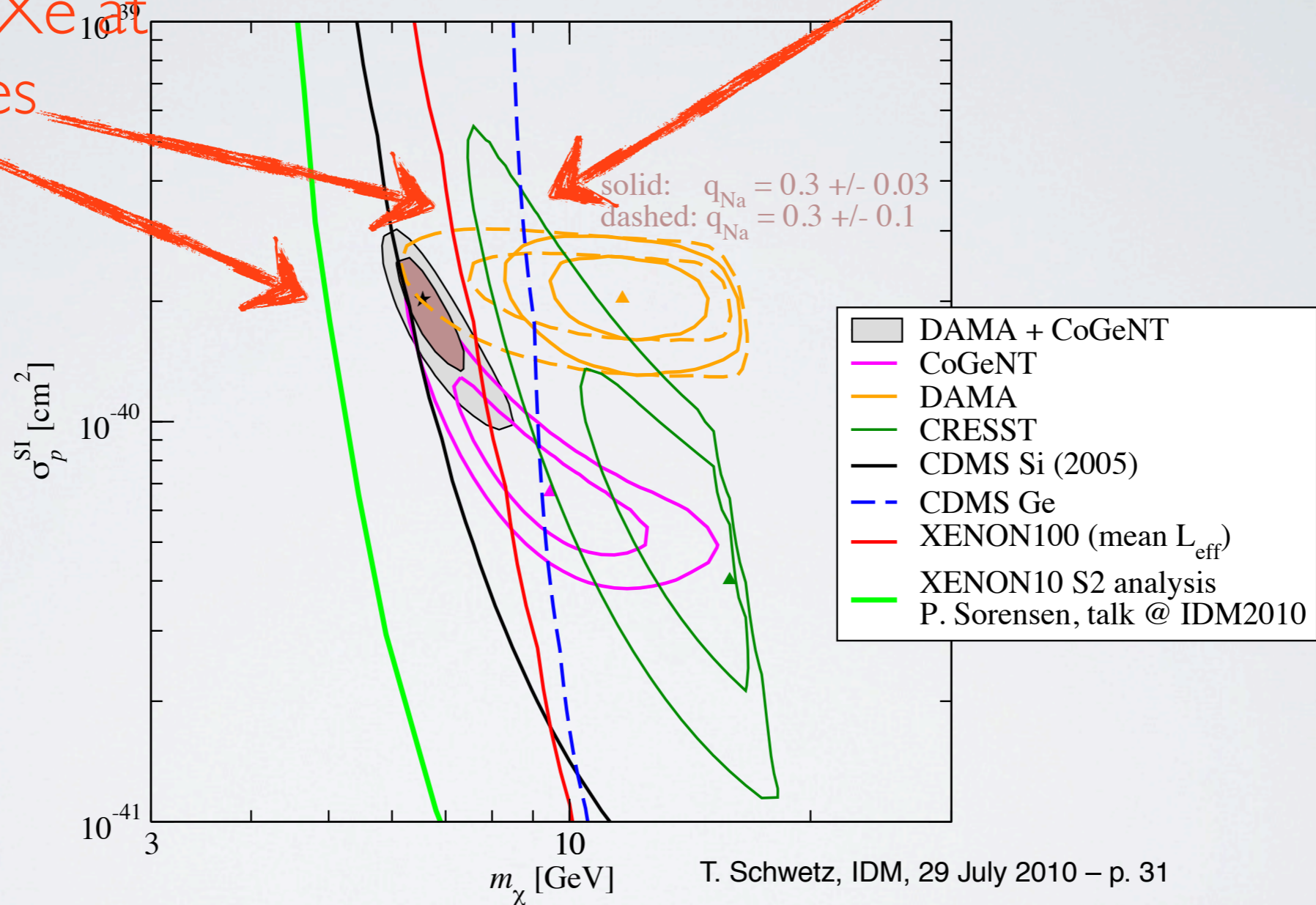
DAMA/CoGeNT agreement requires generous assumptions about Q_{Na}



THE CONTROVERSY

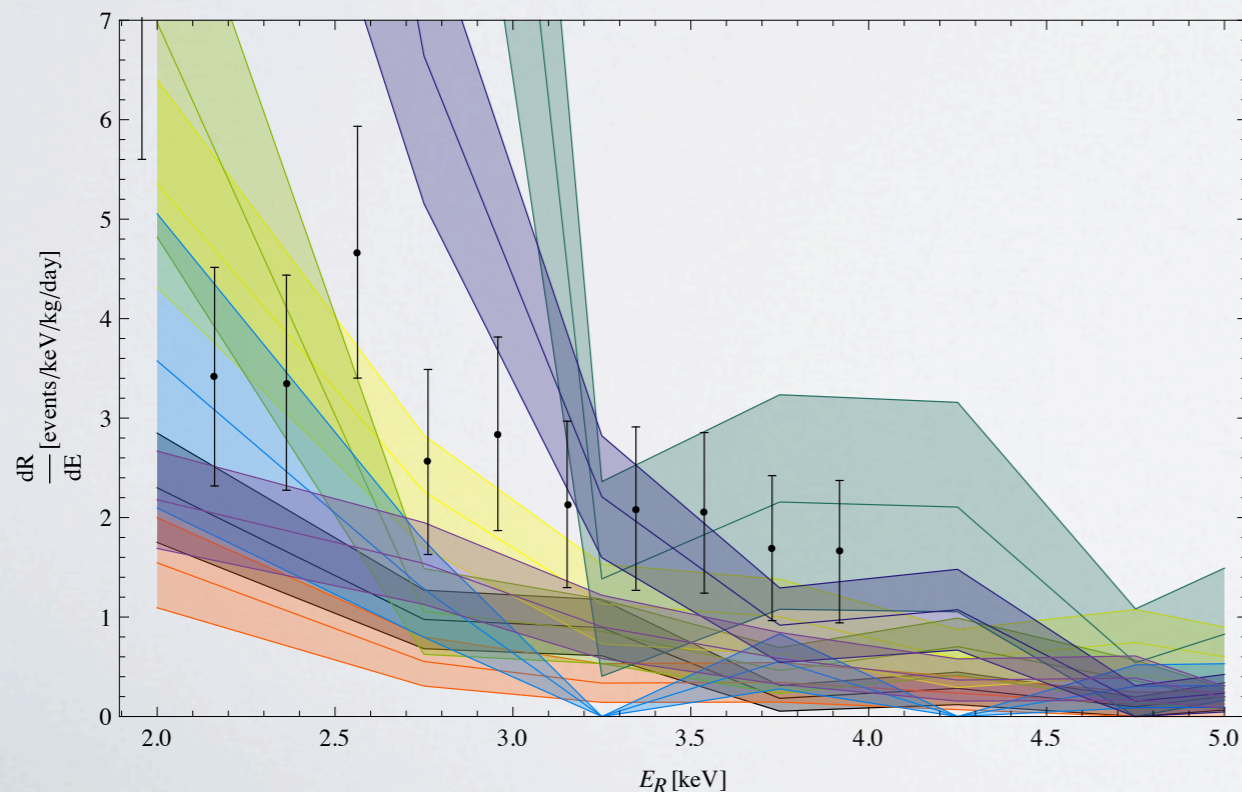
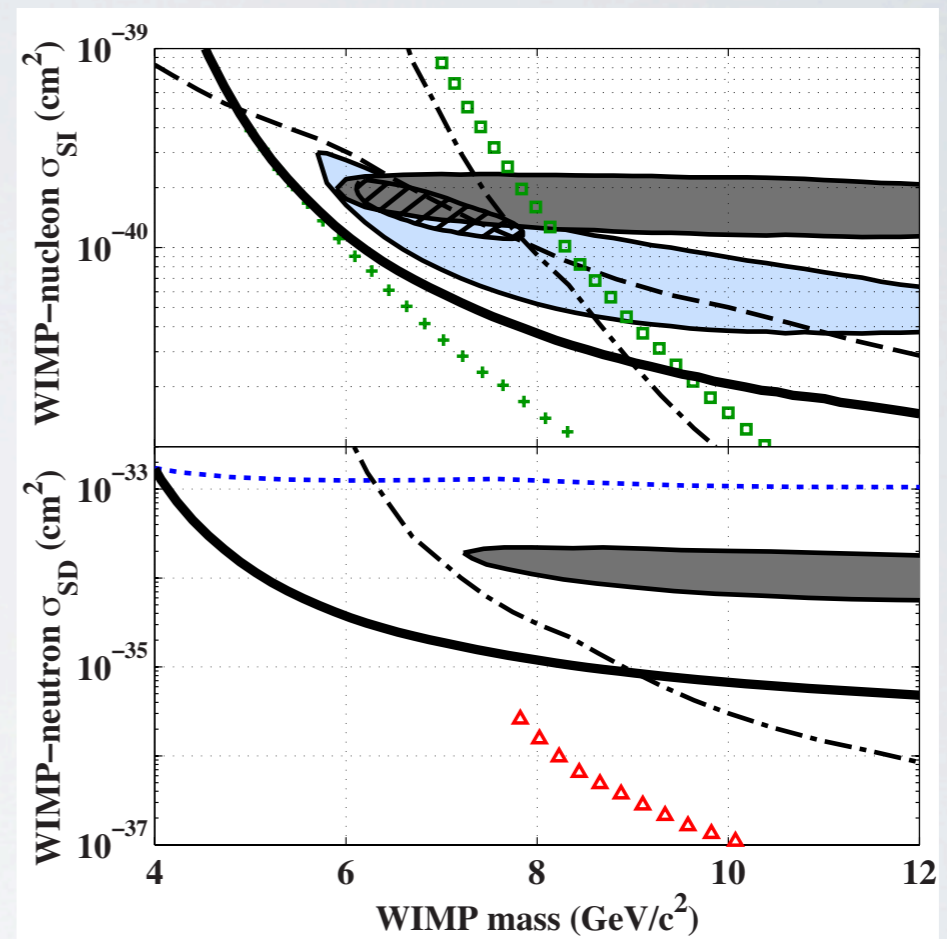
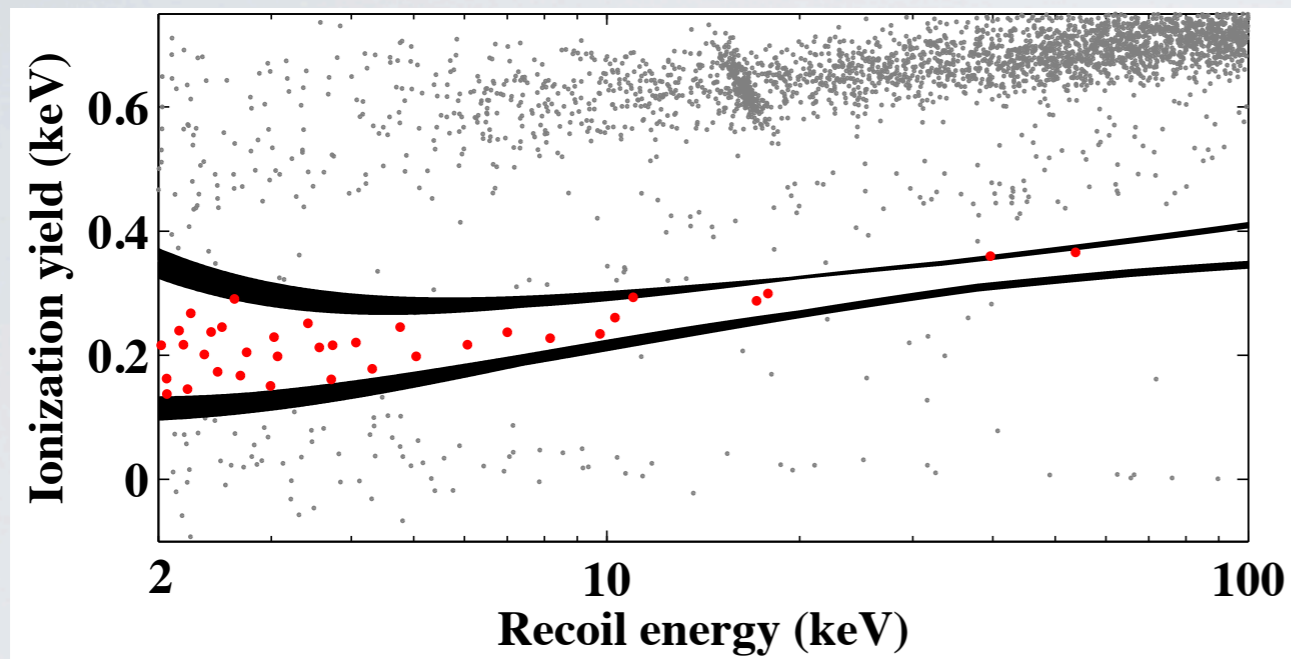
Limits from XENON
invoke unmeasured
properties of LXe at
low energies

DAMA/CoGeNT agreement requires
generous assumptions about Q_{Na}



T. Schwetz, IDM, 29 July 2010 – p. 31

CDMS LOW THRESHOLD



Same target. Appears to exclude CoGeNT...

WHERE ARE WE W/ COGENT

- Limits from CDMS, XENON (ionization+scintillation, ionization only) seem strong
- Ball is in CoGeNT court: better knowledge of shape, look for modulation, etc - new info can reinvigorate
- Status: already 120 kg day recorded (vs 18.5), expected update 2-3 months; CoGeNT-4 installation this summer. Modulation may require 18 months+

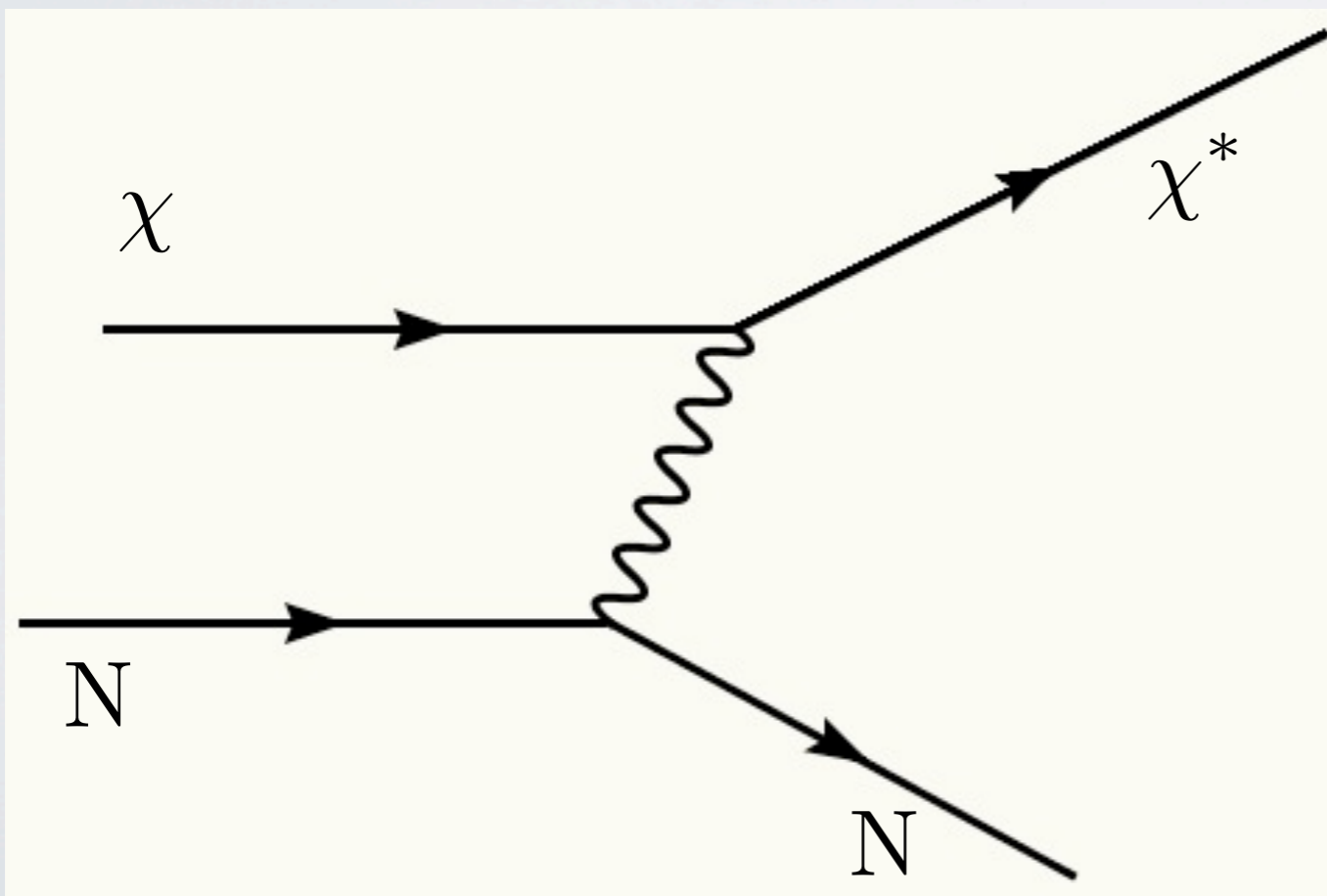
OTHER EXPLANATIONS OF DAMA

- What if it's not a light WIMP?

“INELASTIC” DARK MATTER

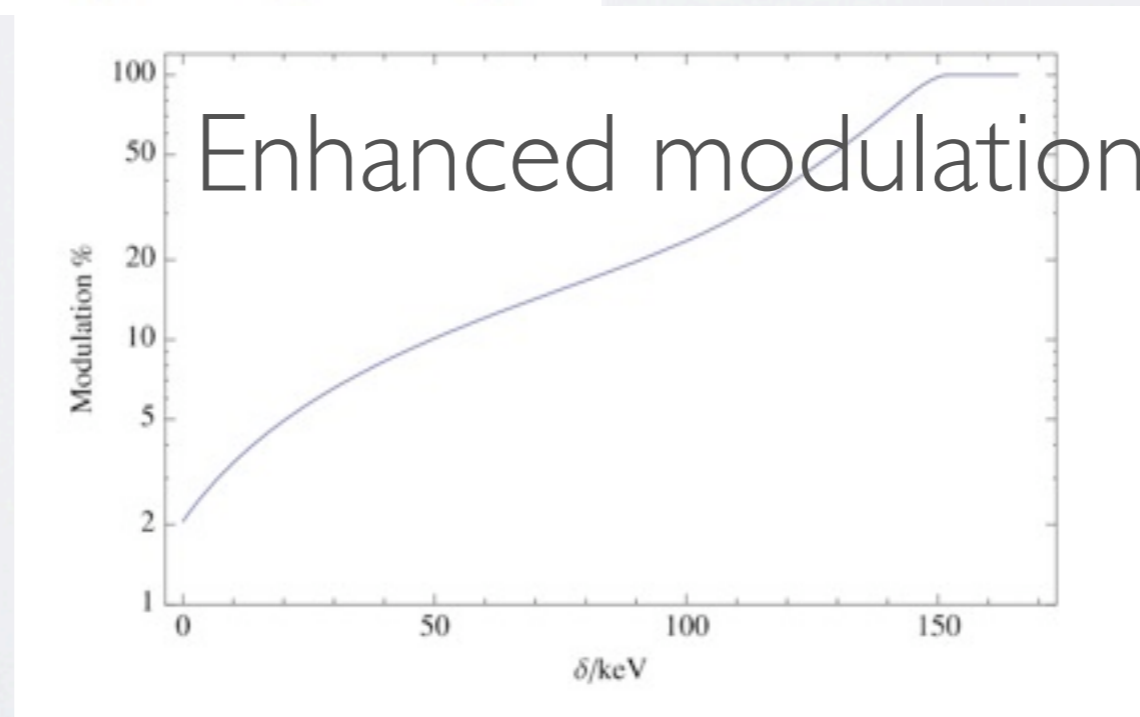
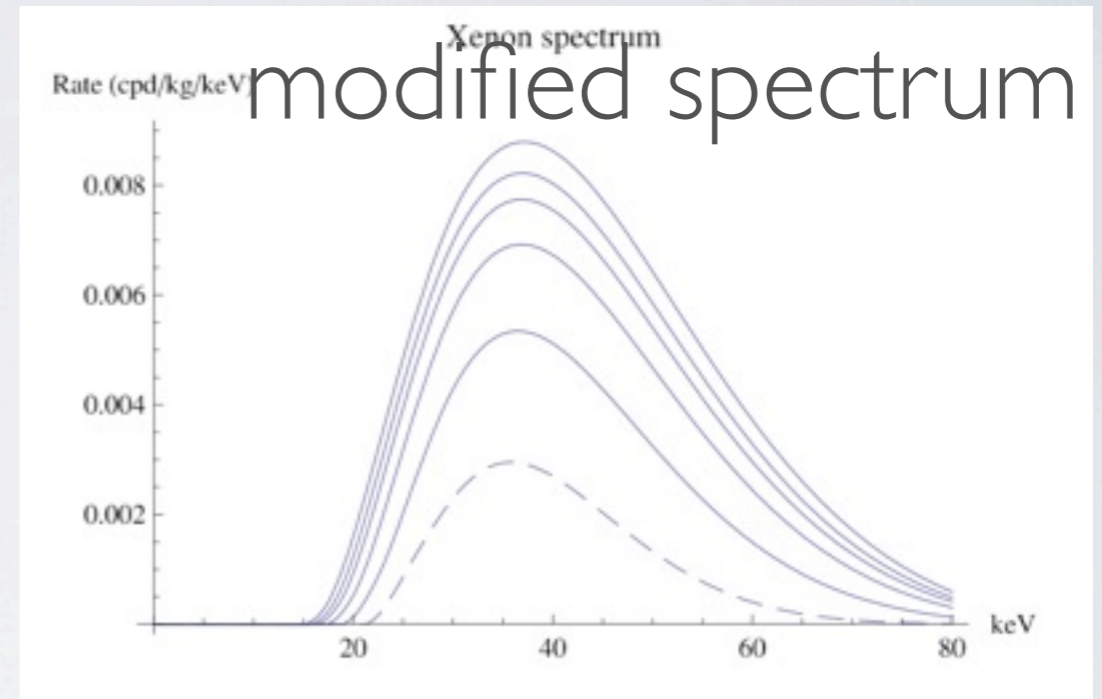
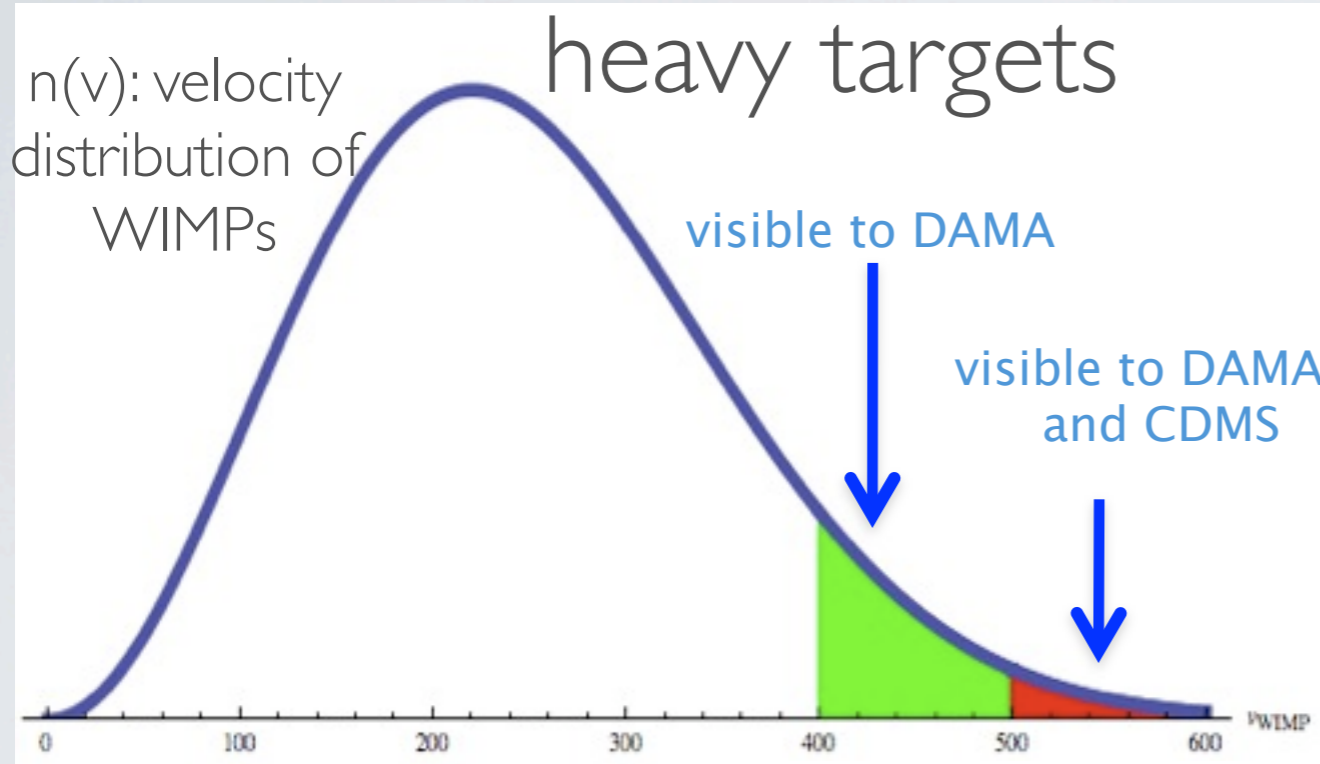
D.Tucker-Smith, NW, Phys.Rev.D64:043502,2001;Phys.Rev.D72:063509,2005

- With dark forces, DM-nucleus scattering must be inelastic
- If dark matter can only scatter off of a nucleus by transitioning to an excited state (100 keV), the kinematics are changed dramatically

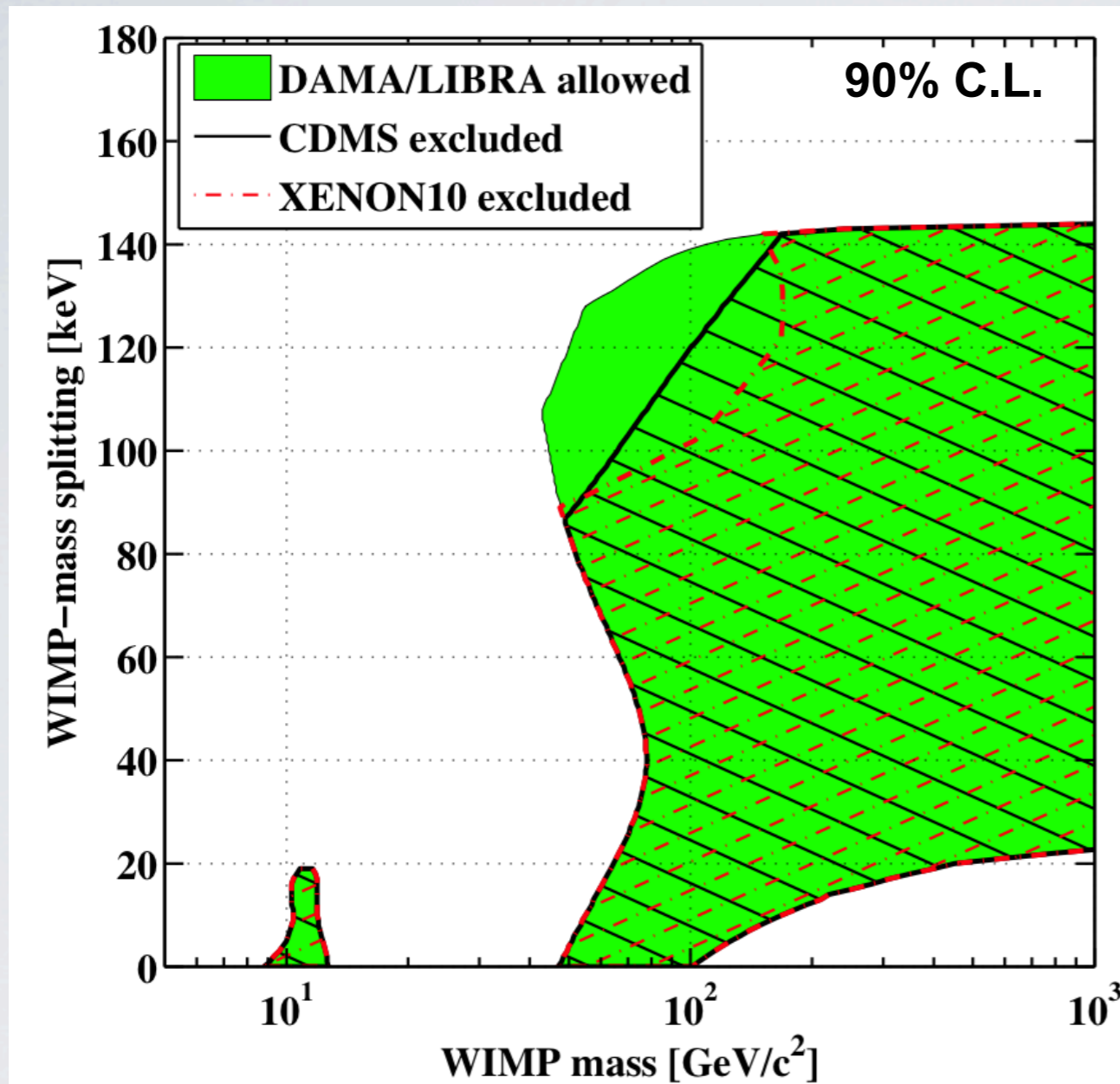


$$\frac{\mu_{\chi N} v^2}{2} > \delta$$

EFFECTS ON WIMP SEARCHES



IDM CONSTRAINTS

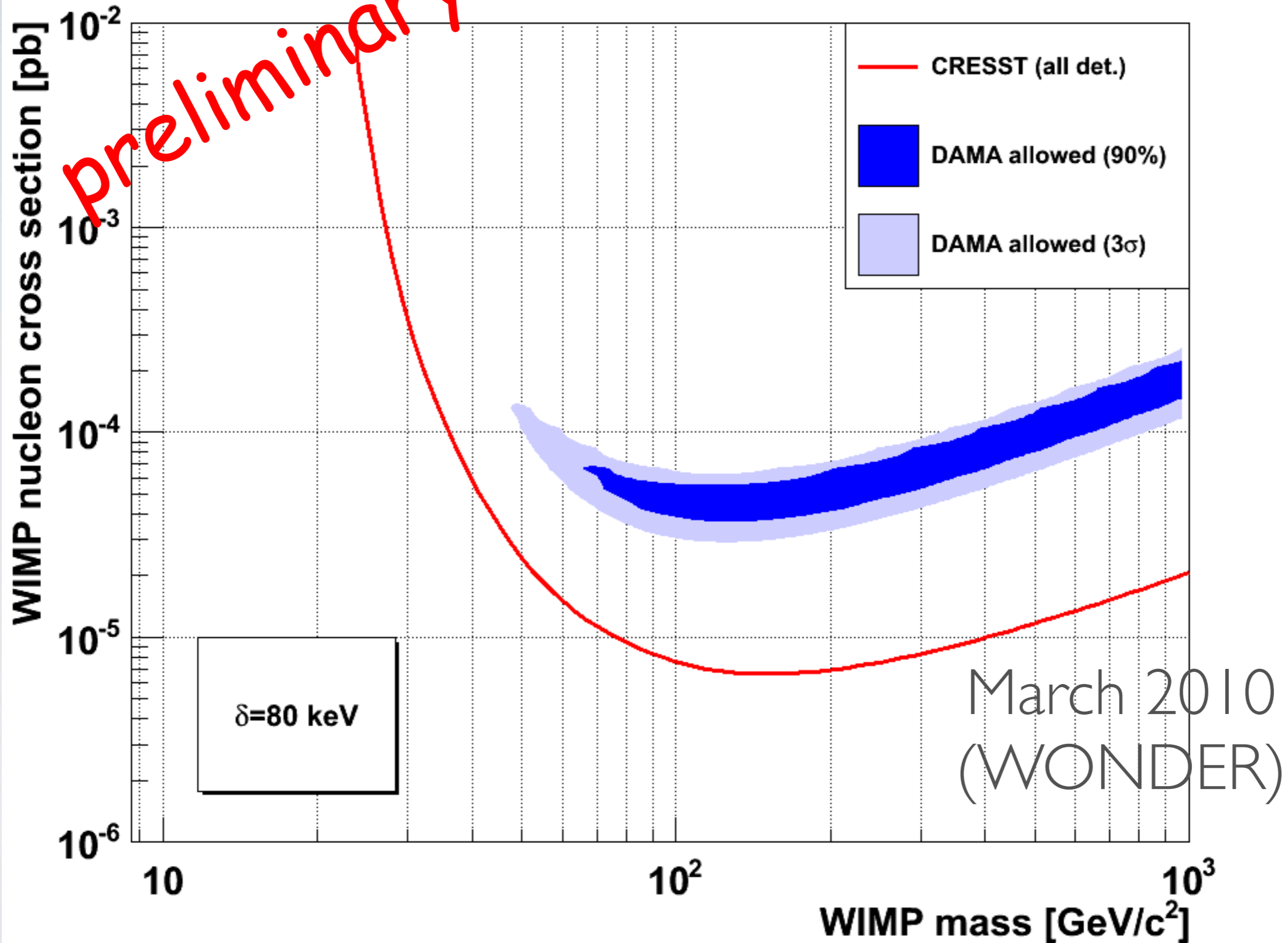


Tight constraints from CDMS, XENON (shown), also ZEPLIN,

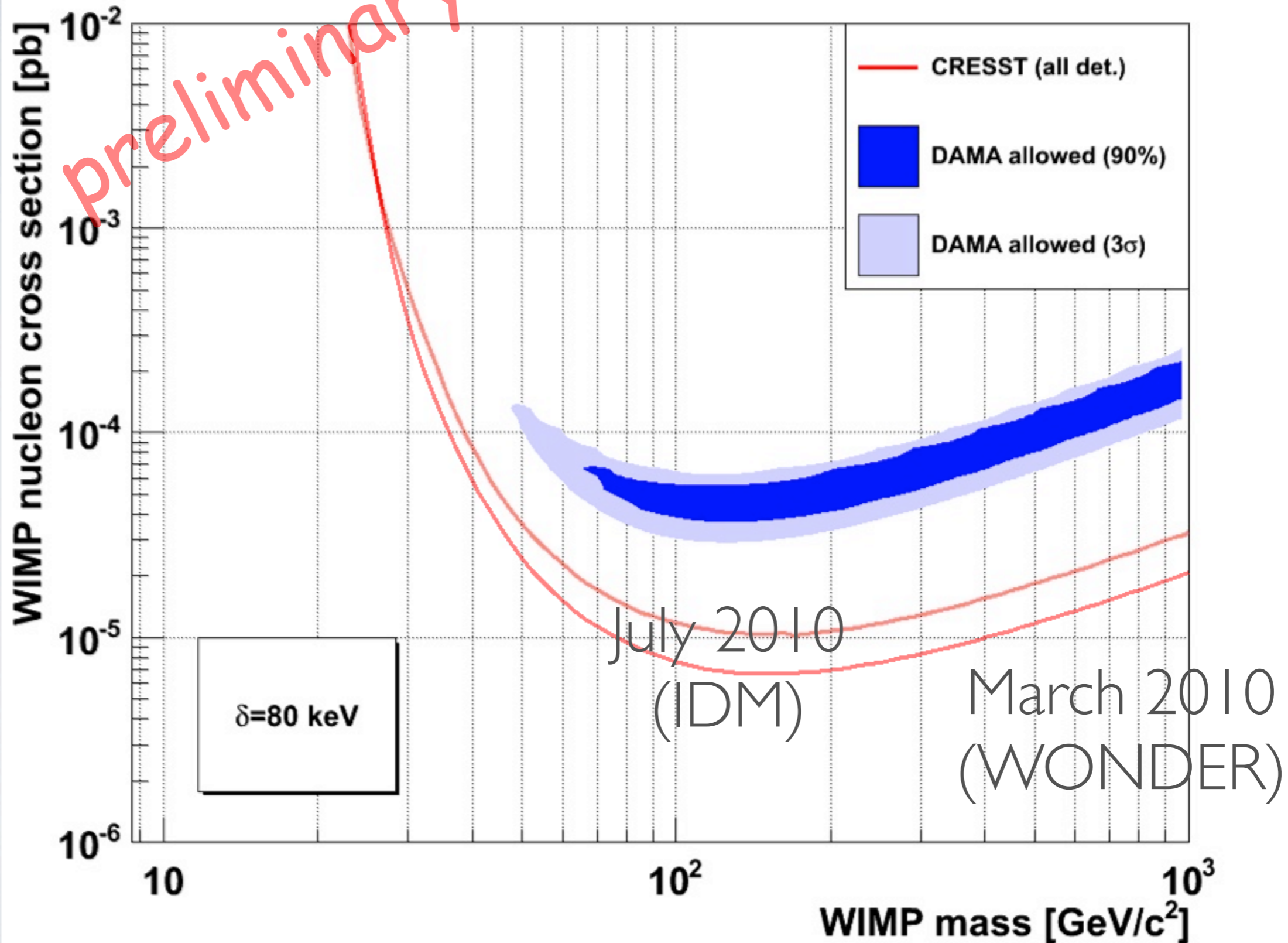
Assume Maxwellian - must be in the highly modulated regime

If WIMP scatters via magnetic dipole, limits are much weaker (Chang, NW, Yavin '10); Also, if scattering is off Thallium some parameter range available (Chang, Lang, NW'10)

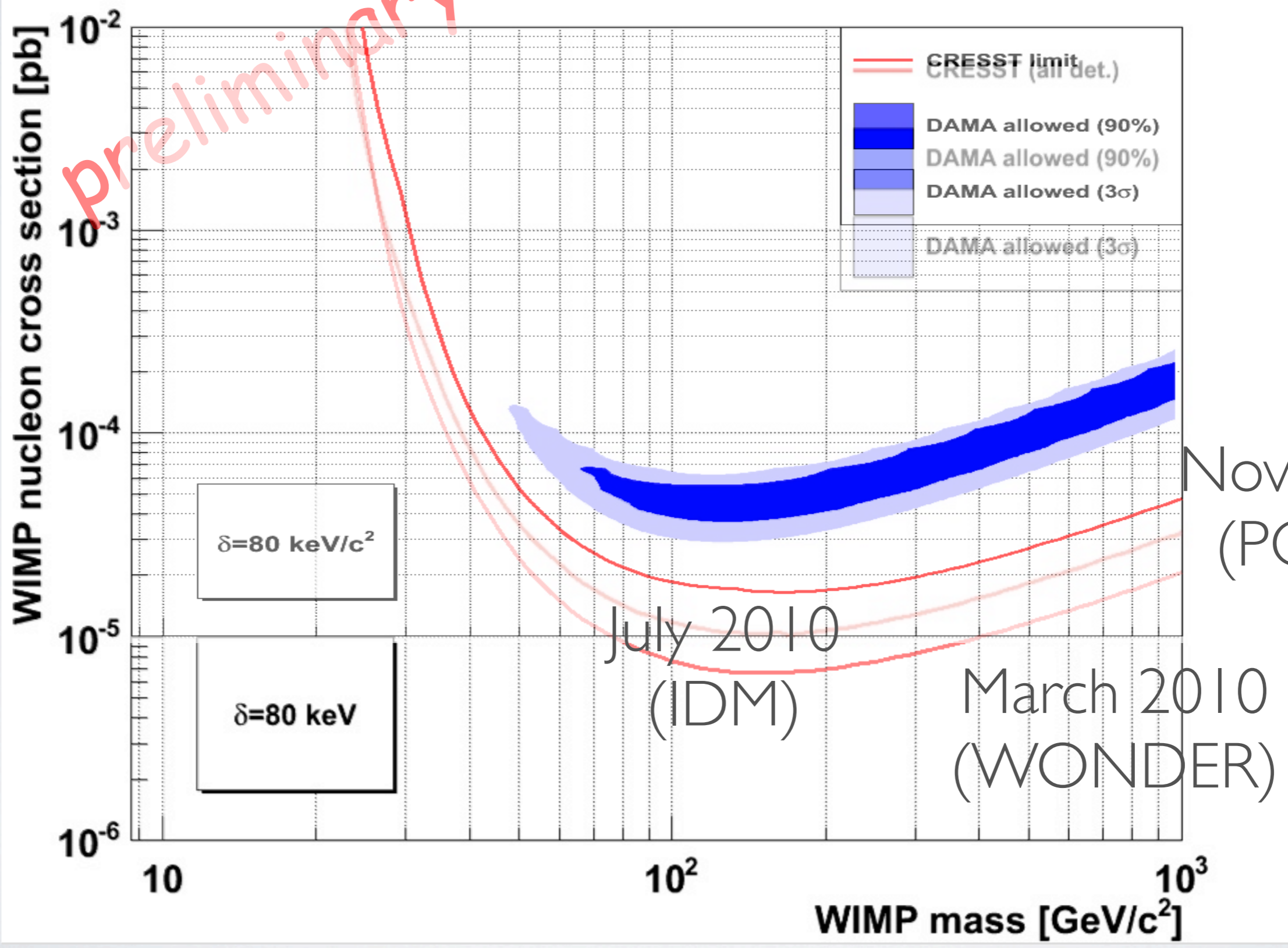
Inelastic Dark Matter



Inelastic Dark Matter



Inelastic Dark Matter



Currently excluded by $\times 1.5$ assuming MB halo

WHAT WILL CLEAR THIS UP ?

(THIS YEAR)

WHAT WILL CLEAR THIS UP ?

(THIS YEAR)



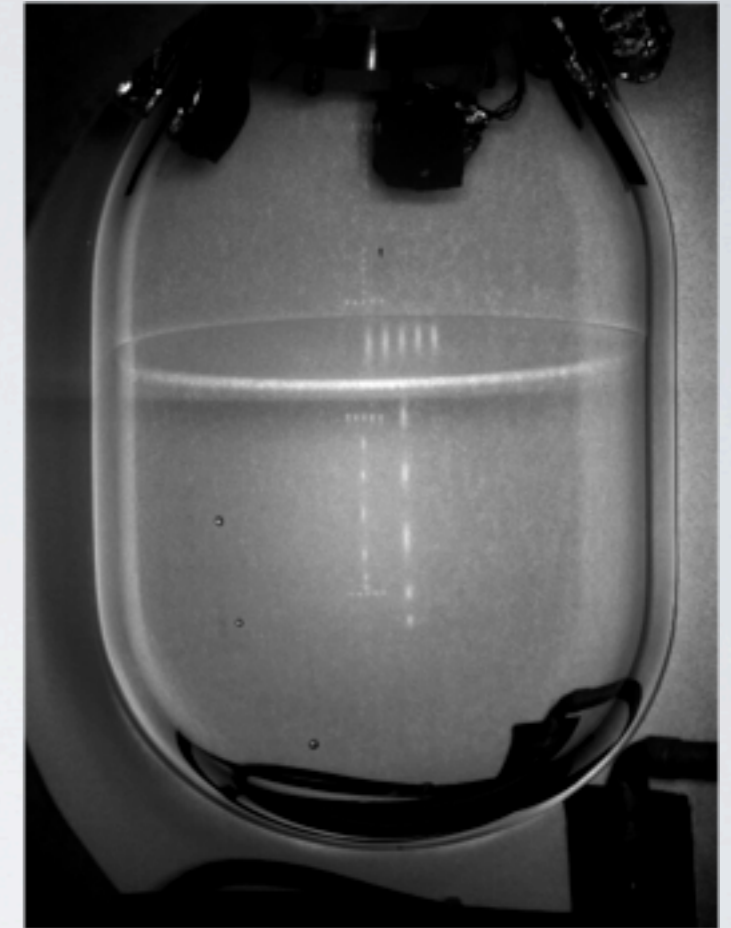
XENON100:
3000 kg days => tens
of events (at least,
somewhat model
dependent)

WHAT WILL CLEAR THIS UP ?

(THIS YEAR)



XENON100:
3000 kg days \Rightarrow tens
of events (at least,
somewhat model
dependent)



COUPP: 4kg (current) CF_3I ,
operating in SNOLAB; will
probe
heavy+light interpretations
of DAMA

WHAT WILL CLEAR THIS UP ?

(THIS YEAR)

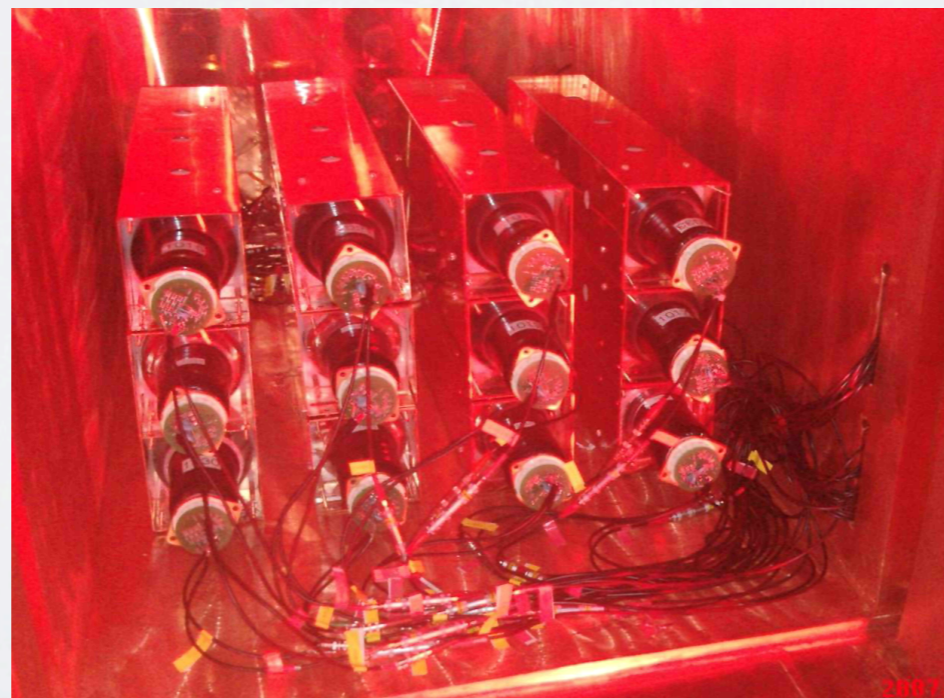


XENON100:
3000 kg days => tens
of events (at least,
somewhat model
dependent)



COUPP: 4kg (current) CF_3I ,
operating in SNOLAB; will
probe
heavy+light interpretations
of DAMA

KIMS: 100kg CsI(Tl)
target, running stably
1 yr; should
report this winter



A FEW COMMENTS ON OTHER ONGOING EXPERIMENTS

CDMS

- Upgrading to SuperCDMS using interleaved electrodes (to better reject backgrounds)
- Should be operational this Summer
- Comparable exposure by ~ Summer 2012



LUX



*Science***Insider**

Breaking news and analysis from the world of science policy

NSF Balks at Continuing Design Work for Underground Science Lab

by Jeffrey Mervis on 9 December 2010, 3:10 PM | [Permanent Link](#) | [2 Comments](#)

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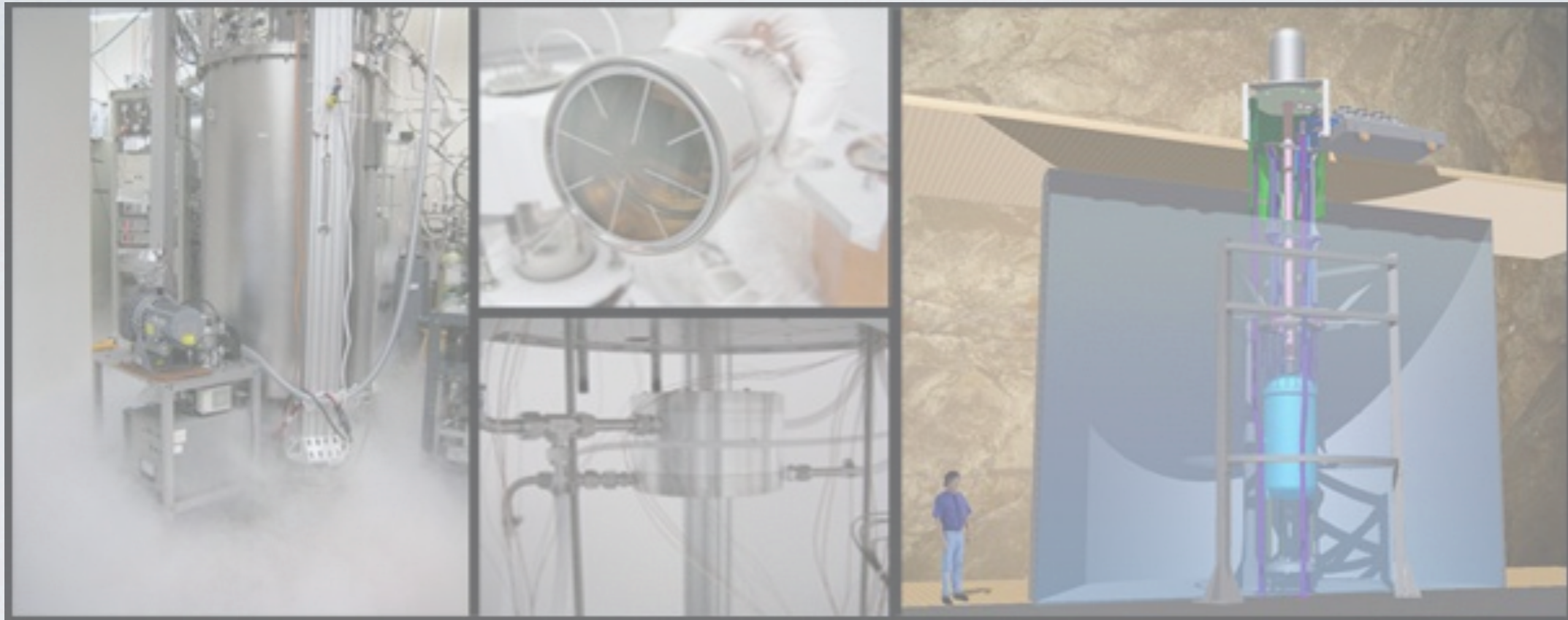
The oversight board for the National Science Foundation (NSF) has rejected a request for additional funding to design an \$875 million underground laboratory in South Dakota. Its reasons suggest that the Department of Energy (DOE), NSF's partner in the proposed Deep Underground Science and Engineering Laboratory (DUSEL), may have to go it alone.

"We don't like the stewardship model, and we are concerned with the cost and scope of the project," explained Mark Abbott, chair of the Committee on Programs and Plans for the National Science Board, about the proposed partnership. Last week, the committee rejected a recommendation from the NSF director to provide a "bridge" award that would allow the project team to finish a preliminary design for DUSEL and address ongoing safety concerns. In September 2009, the board approved \$29 million for such activities, but the cost to complete the work has since doubled. The new request was for \$19 million in 2011, Abbott said, with the expectation that NSF would provide an additional \$10 million in the spring.

Scientists [hope](#) that DUSEL will allow them to explore a host of challenging questions about the origins of matter. One key experiment would be to capture neutrinos beamed from Fermilab, a DOE particle physics lab in Illinois. Another would search for the elusive dark matter that makes up 85% of the universe. A third would search for a type of radioactivity that would blur the distinction between matter and antimatter. Project officials

LUX

(350KG LXE 2 PHASE, ~100 KG FIDUCIAL)



- Clearly some budgetary issues to be addressed
- Still an expectation to go underground at Homestake
- Plan would be late 2011, then commissioning

XMASS

- 800 kg LXe, 100 kg fiducial
- Last status update, Oct, was in installation phase



(c) Kamioka Observatory, ICRR(Institute for Cosmic Ray Research), The University of Tokyo

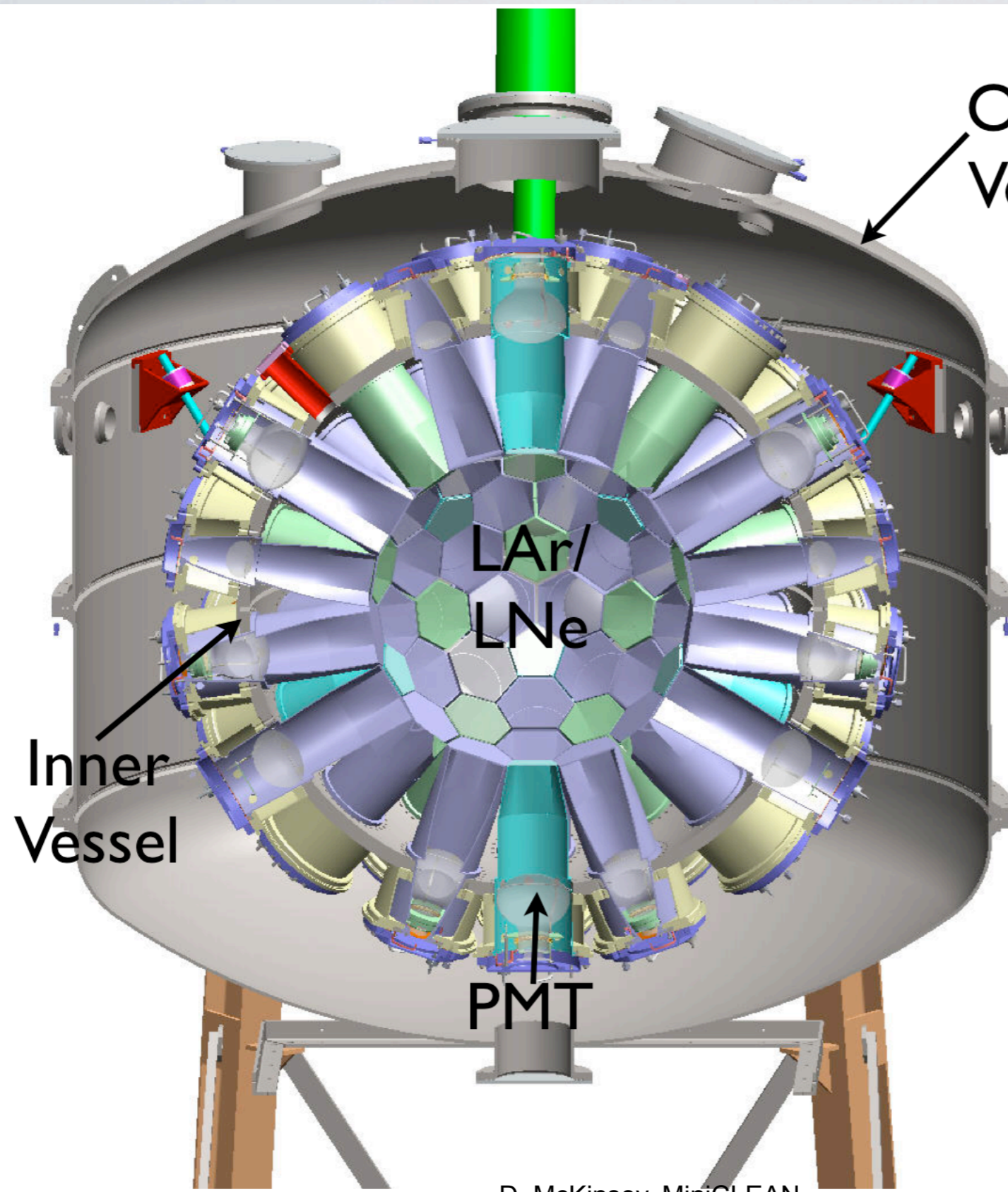
MINICLEAN



2010-11-30 13:17:17

- LAr/LNe detector (*switchable*)
- Cryostat to be delivered summer 2011, DM run start 2012





Outer
Vessel

Designed for maximal
light collection (5 pe/keV),
to optimize beta/gamma
pulse shape discrimination.

Position resolution attained
through PMT hit pattern

Projected WIMP sensitivity:
 $2e-45 \text{ cm}^2 @ 100 \text{ GeV}$
(300 kg y fiducial exposure)

Inner
Vessel

PMT

D. McKinsey, MiniCLEAN

Courtesy J. Griego

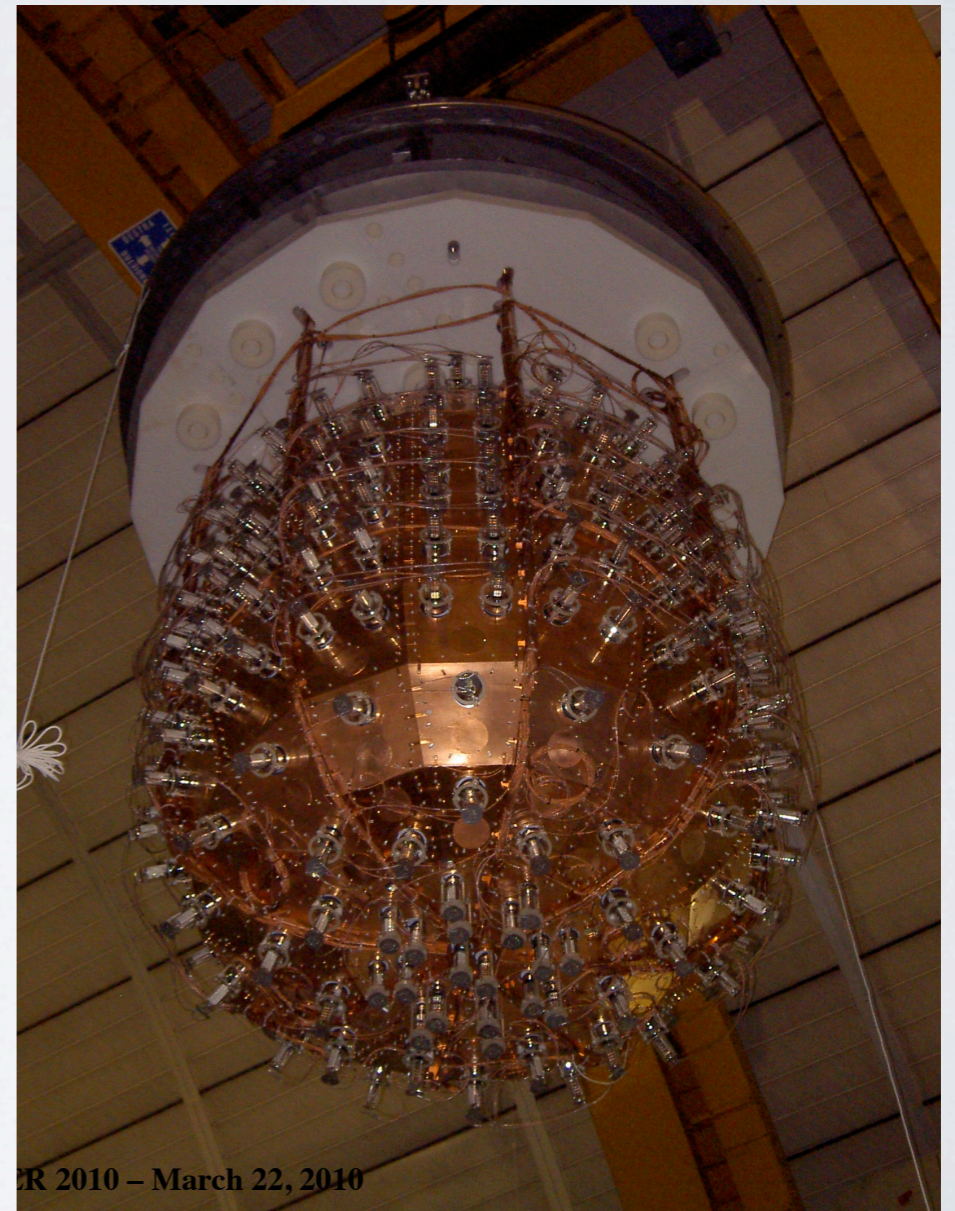
ZEPLIN-III

- Similar to XENON10;
higher field
- Should report update 2011

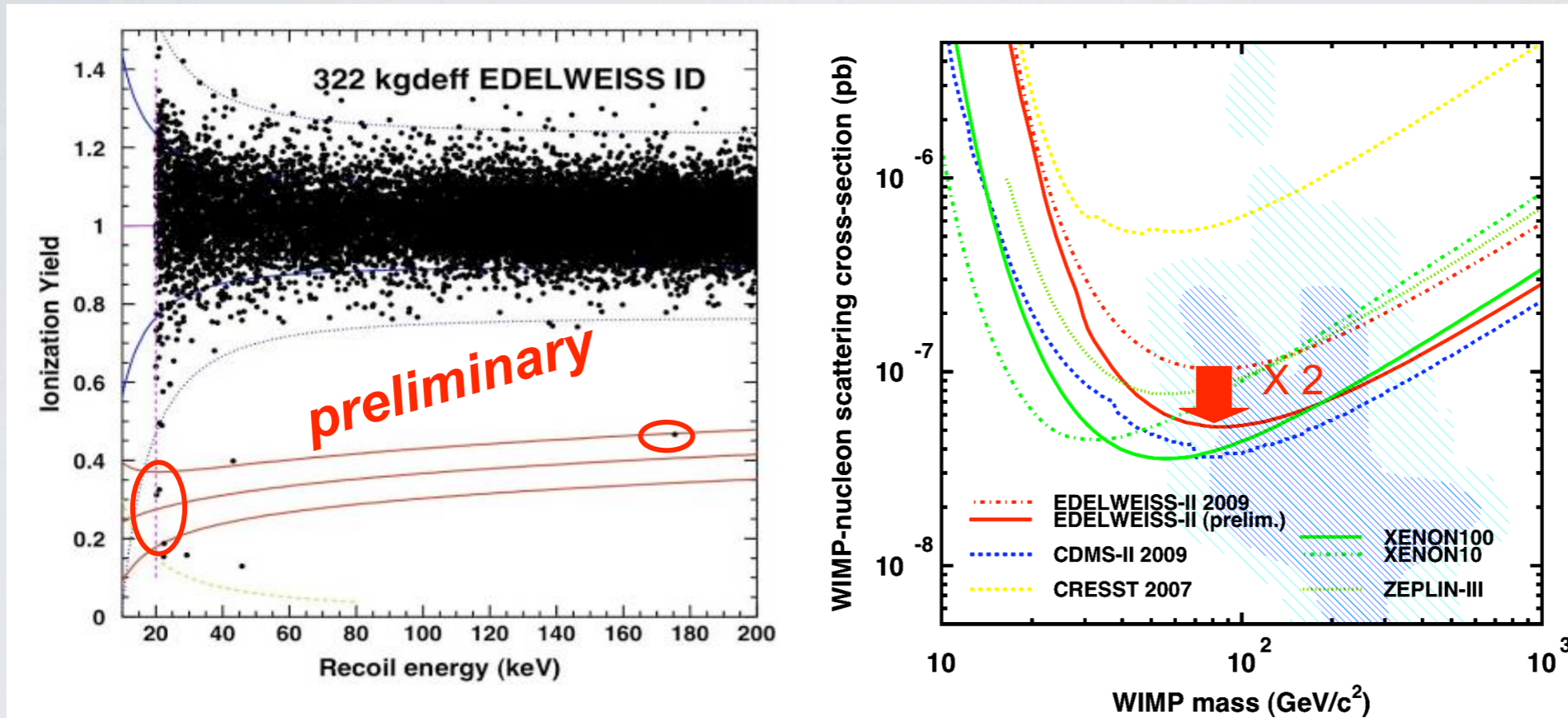


WARP

- Filled March 2010
- Should continue to run, limit few $\times 10^{-45} \text{ cm}^2$



EDELWEISS



Ge detector, interleaved electrodes

New Goal 5×10^{-9} pb

- Improvements wrt future backgs
 - Increased redundancy for ionisation and heat measurements
 - Fast readout (multisite, pile up)
 - Lower μ phonics, internal PE shield
- New prototypes FIDs 800g now working at LSM
 - 2011 = 1000 kg.d
- Build 40 detectors, upgrade set-up
 - 2012 = 3000 kg.d

FUTURE WORK

- Directional: DRIFT, DMTPC...
- Spin dependent bubble: PICASSO, SIMPLE...
- Other light studies: TEXONO...
- Large scale future: EURECA, DARWIN...

SEARCHING FOR NEW PHYSICS AT **KEV** ENERGIES

- Progress in WIMP searches is rapidly evolving -> OoM in the next year
- Interesting range in parameter space generically
- DAMA/CoGeNT(/CRESST?) suggest that something may be lurking
- Light WIMPs in rough shape - update from CoGeNT soon
- Heavy WIMPs for DAMA: XENON100/KIMS/COUPP this year