New opportunities for dark matter* experiments

Josef Pradler

HEPHY Institut für Hochenergiephysik

LNGS, March 10, 2015

* and neutrino

Two problems of missing mass

First missing mass problem of the 20th century

Discovery of the nucleus resulted in a disparity

$$m(\text{Atom}) > \text{Zm}(\text{proton})$$

Second missing mass problem of the 20th century

Missing mass on *all* scales that are relevant to astrophysics and cosmology

Century old problem that stays with us

Solutions

First missing mass problem of the 20th century

Rutherford suggests in 1920 the existence of a new massive neutral particle

Chadwick discovers the neutron in early '30s and with it a new force

Second missing mass problem of the 20th century (…and 21st century)

Single, "cold" new neutral massive particle covers the gravitational side

"Dark sector" may contain several states and new dark forces, with consequences for cosmology, for underground rare event searches, and for high-energy or high-luminosity colliders.

Plan of the talk

"Phenomenologically driven approach" to the dark side

using

Underground rare event searches

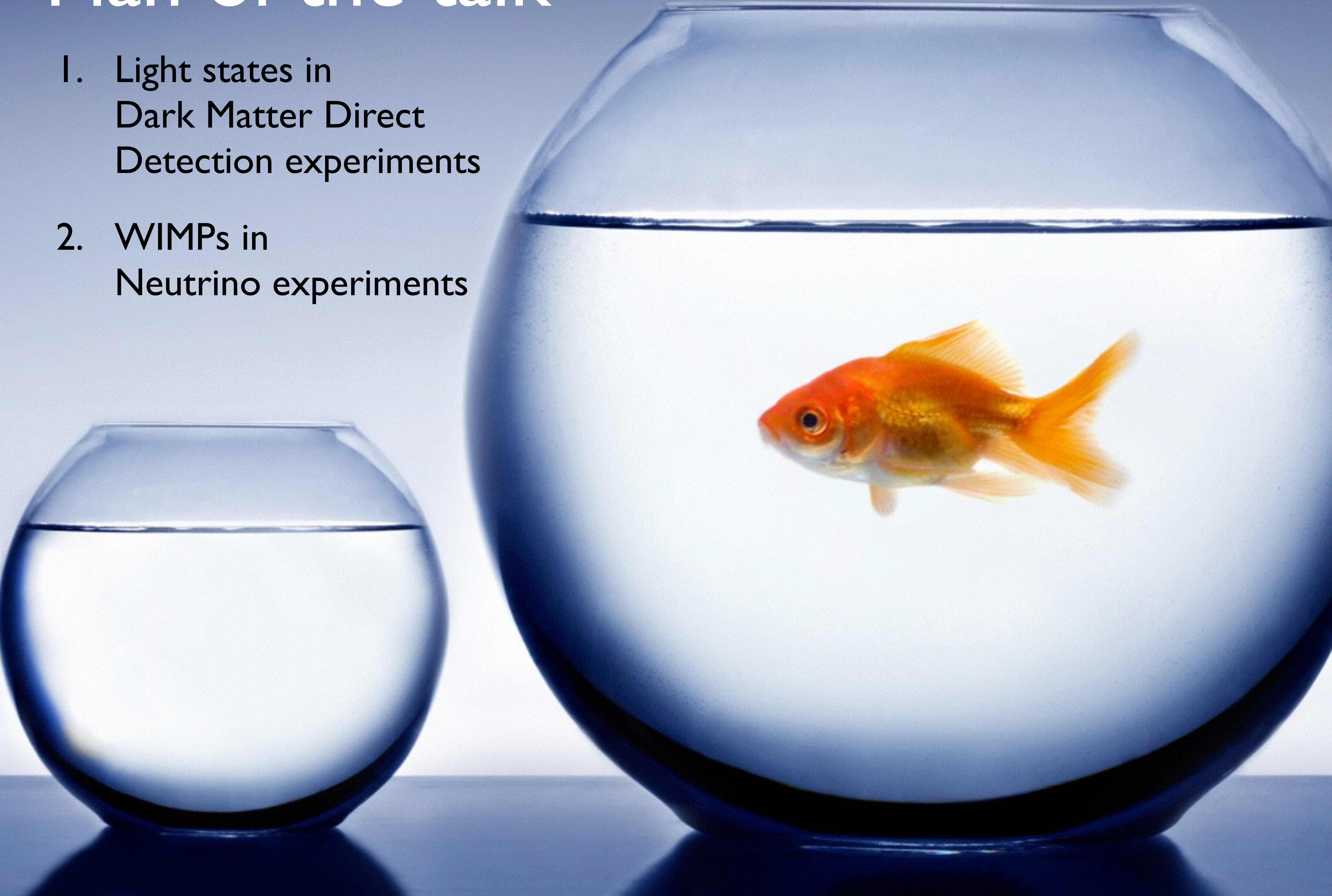
Plan of the talk

1. Light states in Dark Matter Direct Detection experiments

Plan of the talk

1. Light states in
   Dark Matter Direct
   Detection experiments

2. WIMPs in
   Neutrino experiments

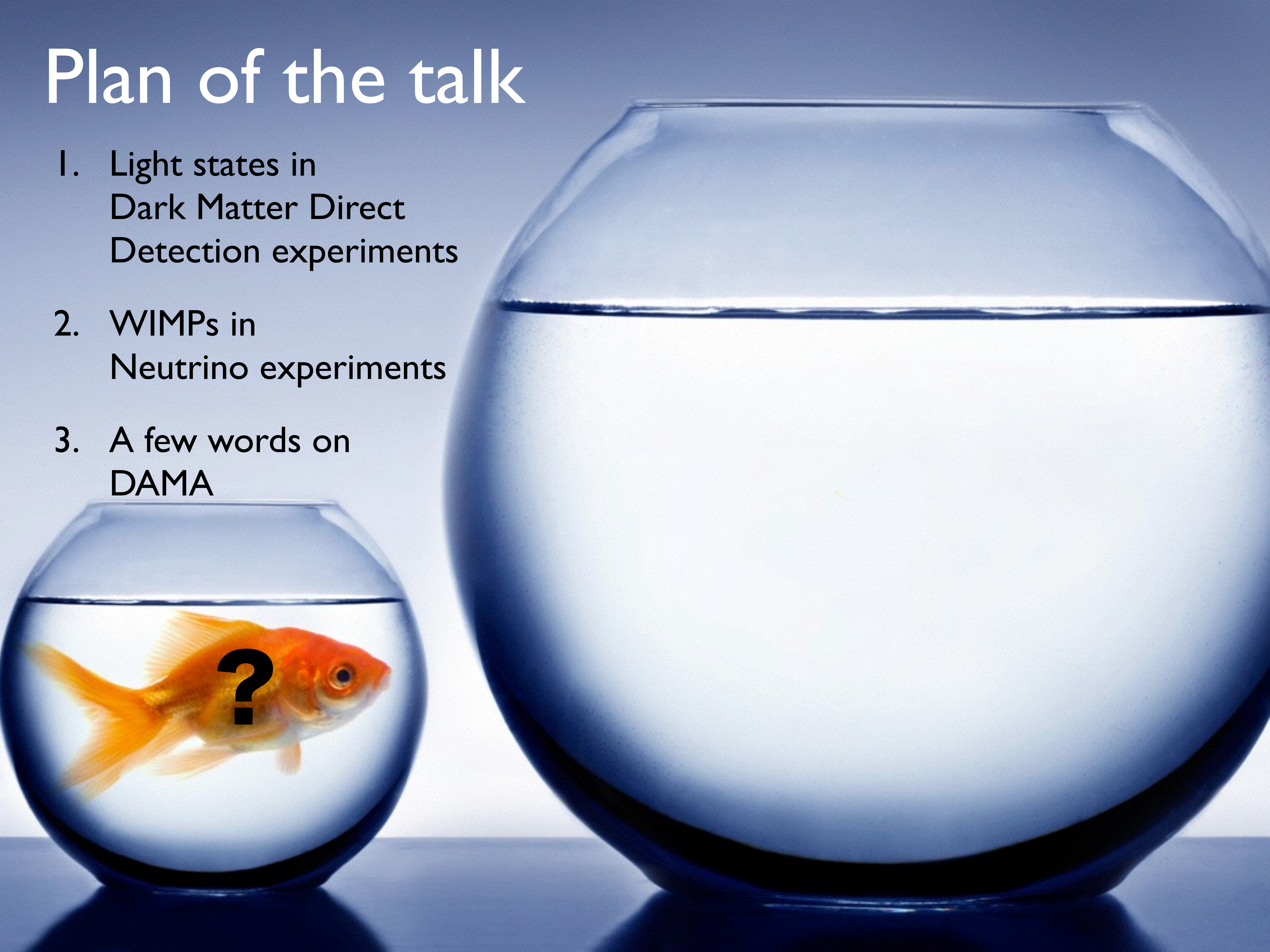


Plan of the talk

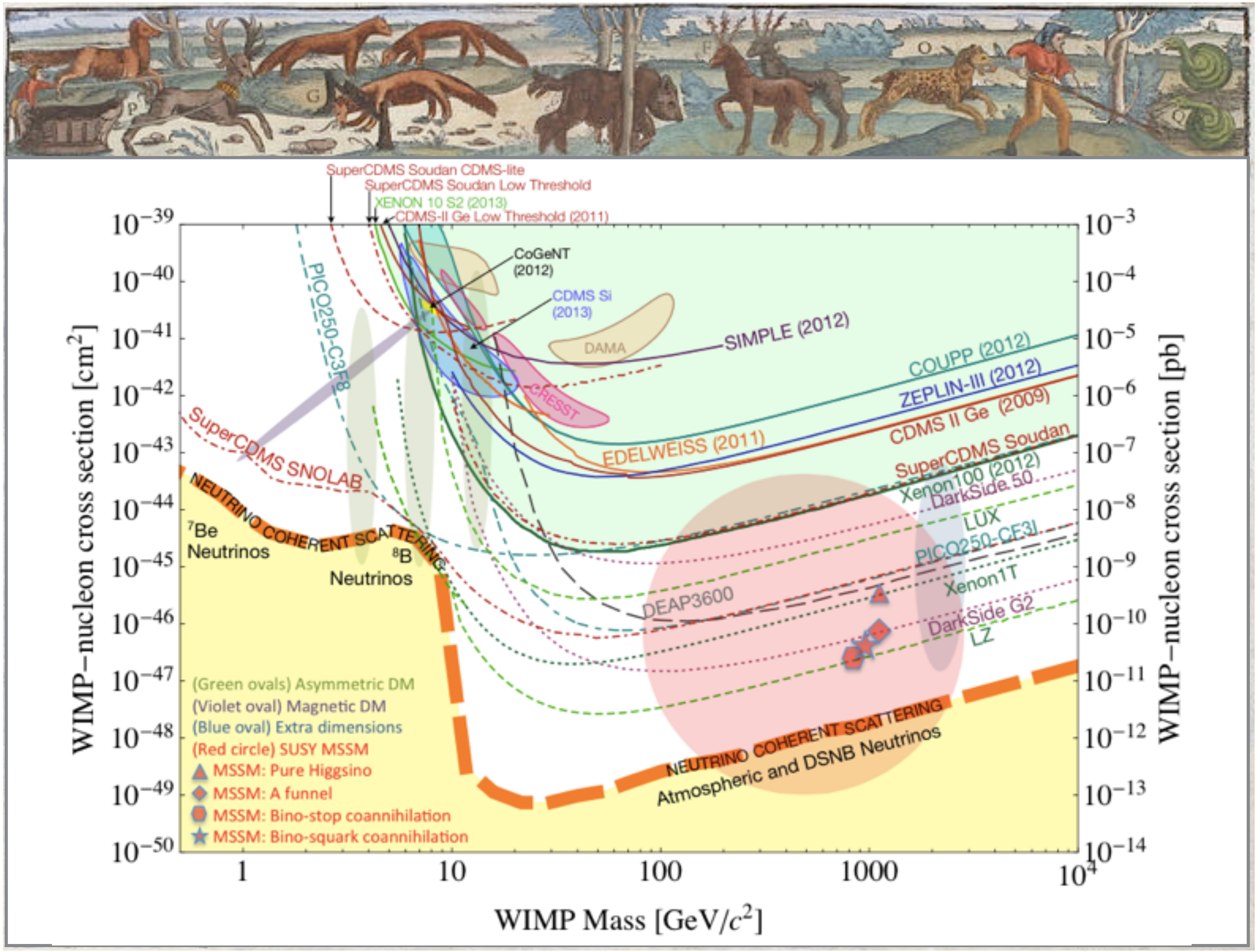
1. Light states in
   Dark Matter Direct
   Detection experiments

2. WIMPs in
   Neutrino experiments

3. A few words on
   DAMA



Looking for new species



There may be more creatures than WIMPs!

Tapping into the Dark Matter "liquid scintillator revolution"

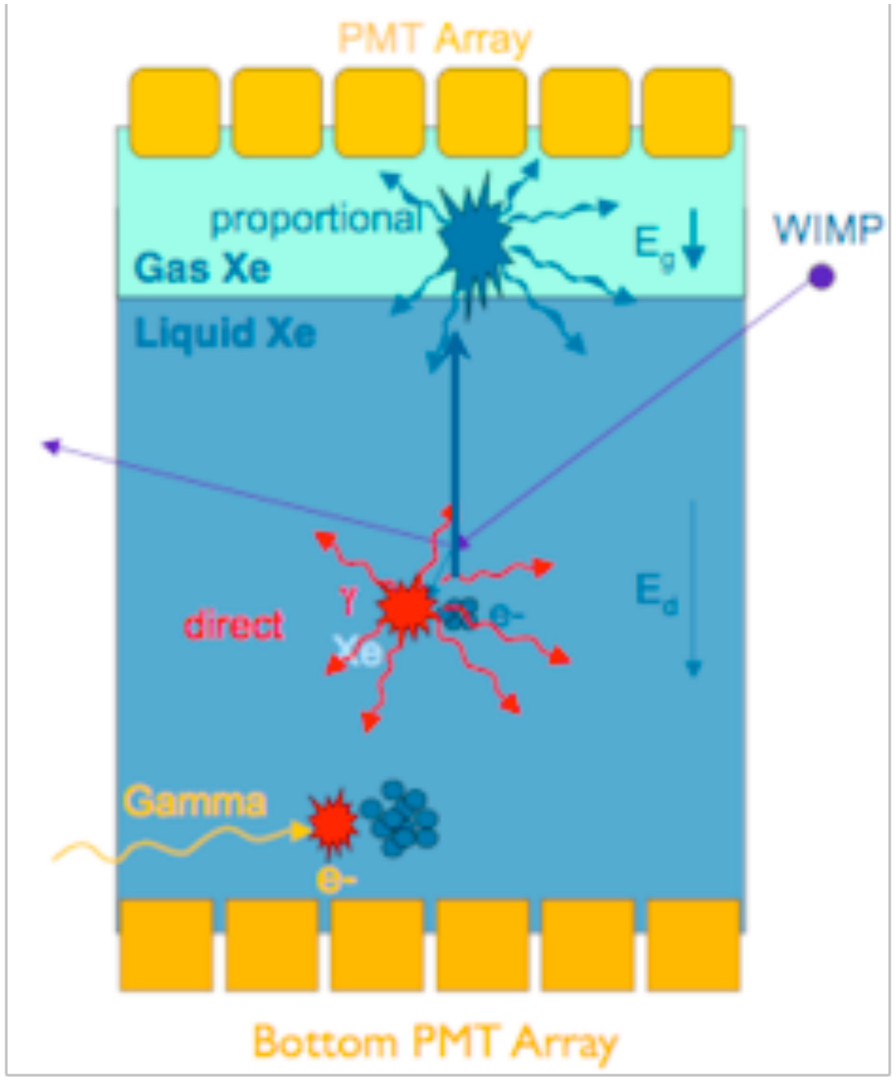
Inexpensive, scalable, dense, and can be purified.

High scintillation yields without absorbing own scintillation light.

Drifting charges in an electric field is a powerful amplification mechanism

$$E_{\text{ion}}(\text{Xe}) = 12\,\text{eV}$$

=> ionization analyses push this boundary.



“Simplified Models” of Dark Matter electron scattering

- (pseudo)scalar $g_S S\bar{\psi}\psi, \quad g_P P\bar{\psi}\gamma_5\psi,$
- (pseudo)vector $g_V V_\mu\bar{\psi}\gamma_\mu\psi, \quad g_A \mathcal{A}_\mu\bar{\psi}\gamma_\mu\gamma_5\psi,$
- tensor $g_T T_{\mu\nu}\bar{\psi}\sigma_{\mu\nu}\psi, \quad \cdots$

ψ …electron

Let’s take the example of a vector V with coupling $g_V = e\kappa$, a.k.a. “Dark Photon”

The Dark Photon Landscape

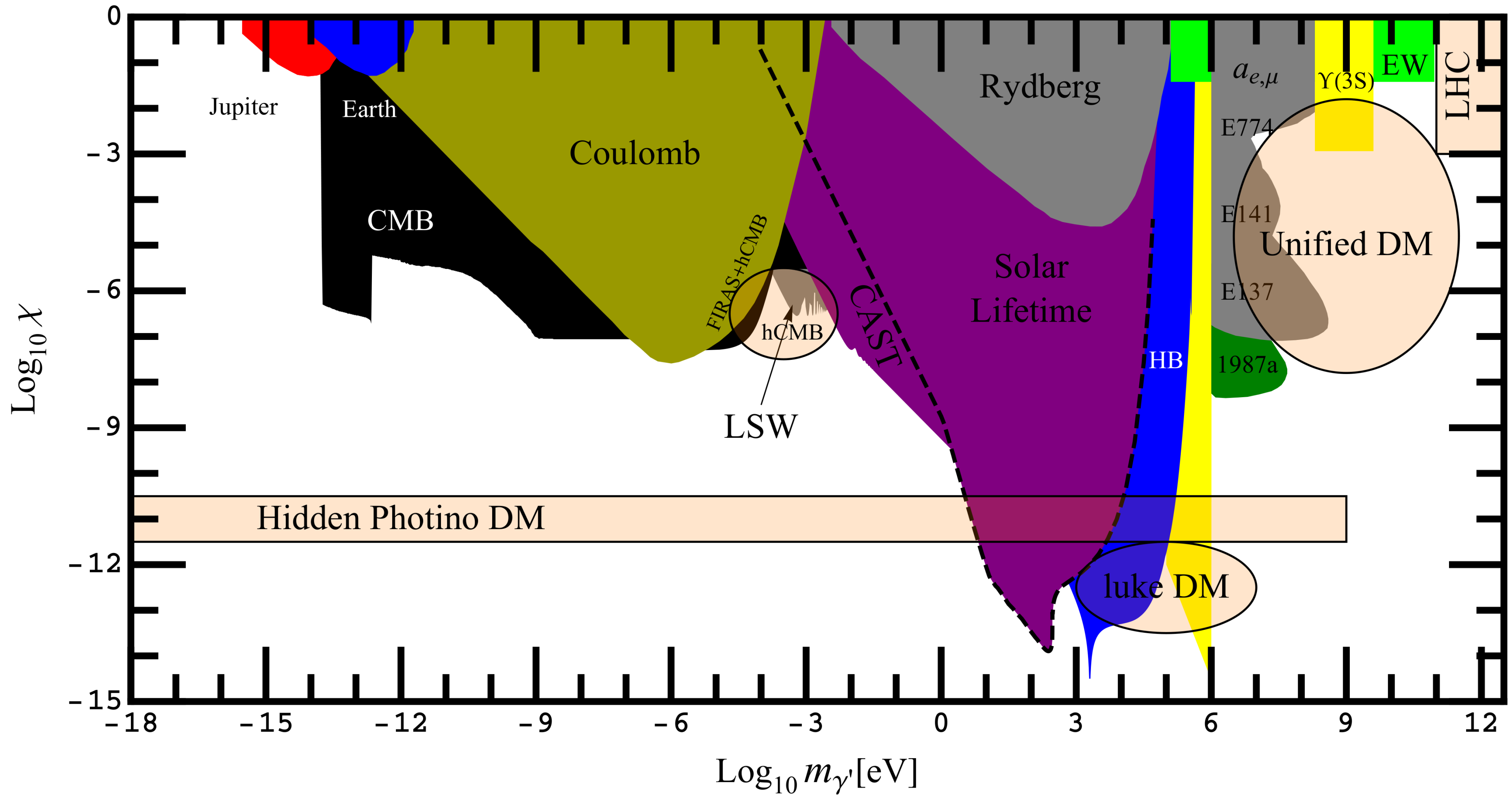


Fig. from Ringwald, Jaeckel, 2010

NB: Many additions (corrections) on this plot in the past few years!

Dark Photon Dark Matter

$$\mathcal{L} = -\frac{1}{4}F_{\mu\nu}^2 - \frac{1}{4}V_{\mu\nu}^2 - \frac{\kappa}{2}F_{\mu\nu}V^{\mu\nu} + \frac{m_V^2}{2}V_\mu V^\mu + eJ^\mu_{\rm em}A_\mu$$

Only two free parameters, κ, m_V. Can we make Dark Matter?

Dark Photon Dark Matter

$$\mathcal{L} = -\frac{1}{4}F_{\mu\nu}^2 - \frac{1}{4}V_{\mu\nu}^2 - \frac{\kappa}{2}F_{\mu\nu}V^{\mu\nu} + \frac{m_V^2}{2}V_\mu V^\mu + eJ^\mu_{\rm em}A_\mu$$

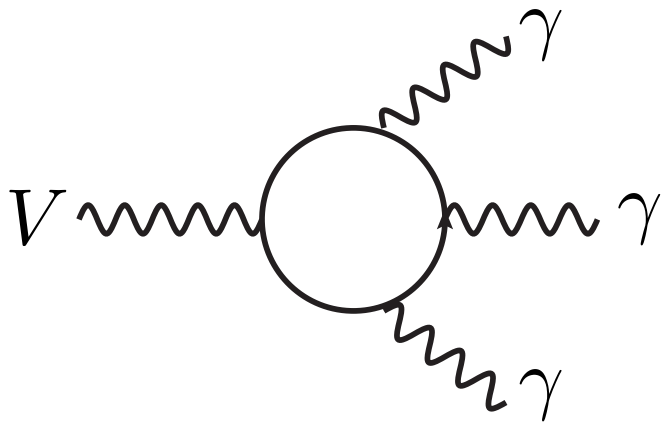
Only two free parameters, κ, m_V. Can we make Dark Matter?

1. Make it light, below 2me. Prevents $V \to e^+e^-$ decay

2. Have small $\kappa \ll 1$, to slow down $V \to 3\gamma$

$$\Gamma_{V\to3\gamma} = \frac{17\kappa^2\alpha^4}{2^7 3^6 5^3 \pi^3}\frac{m_V^9}{m_e^8}$$

Pospelov, Ritz, Voloshin 2008



=> Vectors can be have lifetime greater than the Universe

Dark Photon Dark Matter

$$\mathcal{L} = -\frac{1}{4}F_{\mu\nu}^2 - \frac{1}{4}V_{\mu\nu}^2 - \frac{\kappa}{2}F_{\mu\nu}V^{\mu\nu} + \frac{m_V^2}{2}V_\mu V^\mu + eJ^\mu_{\rm em}A_\mu$$

Early Universe production. Can we make Dark Matter?

1. thermal production insufficient $\Gamma_{\rm int}/H \sim \kappa^2\alpha^2 n_e/sH \sim 1/T$
2. resonant production doesn't help neither
3. field can be generated during inflation (vacuum condensate)

$$\Omega_V h^2 \approx 0.4\frac{g_*(T_{\rm osc})^{3/4}}{g_{*S}(T_{\rm osc})}\sqrt{\frac{m_V}{1\,{\rm keV}}}\left(\frac{\widetilde{V}_{I,i}}{10^{11}\,{\rm GeV}}\right)^2$$ (roughly)

Dark Photon Dark Matter

Can we detect it?

1. Small mass ~keV means large number density
2. photo-ionization cross sections of ordinary photons can be huge, 10^7 bn

Those compensating factors make up for tiny coupling $\kappa \ll 10^{-10}$ that renders V stable on cosmological timescale

=> absorption of V can be looked for in electron band

Absorption rate

$$\Gamma_{T,L} = \frac{e^2}{2\omega}\int d^4x\, e^{iq\cdot x}\kappa_{T,L}^2\varepsilon_\mu^*\varepsilon_\nu\langle p_i|[J_{em}^\mu(x), J_{em}^\nu(0)]|p_i\rangle,$$

Related to the polarization tensor of the photon in the medium

$$\Pi^{\mu\nu}(q) = -\Pi_T\sum_{i=1,2}\varepsilon_i^{T\mu}\varepsilon_i^{T\nu} - \Pi_L\varepsilon^{L\mu}\varepsilon^{L\nu}$$

Effective mixing angle inside the medium

$$\kappa_{T,L}^2 = \kappa^2 \times \frac{m_V^4}{|m_V^2 - \Pi_{T,L}|^2}$$

It follows

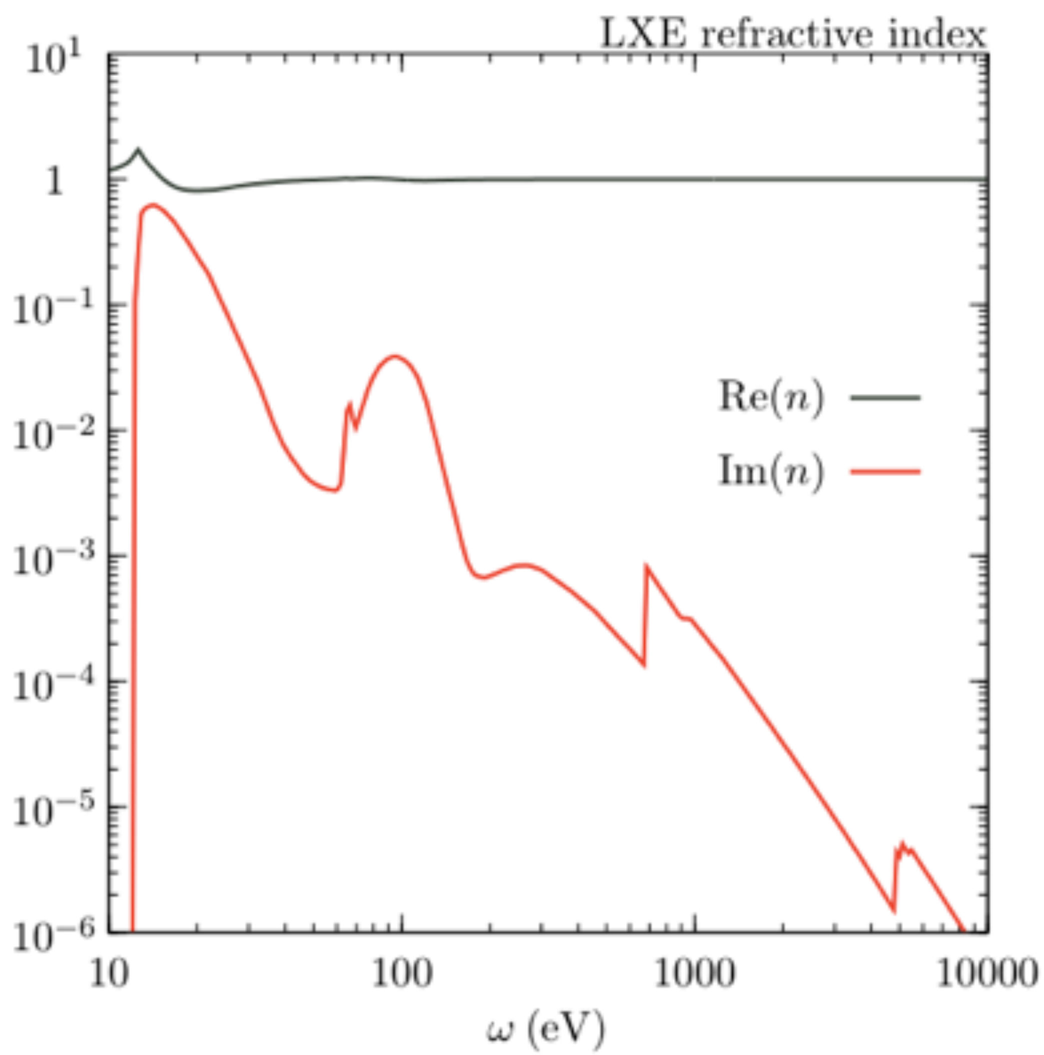
$$\Gamma_{T,L} = -\frac{\kappa_{T,L}^2\,\mathrm{Im}\,\Pi_{T,L}}{\omega}$$

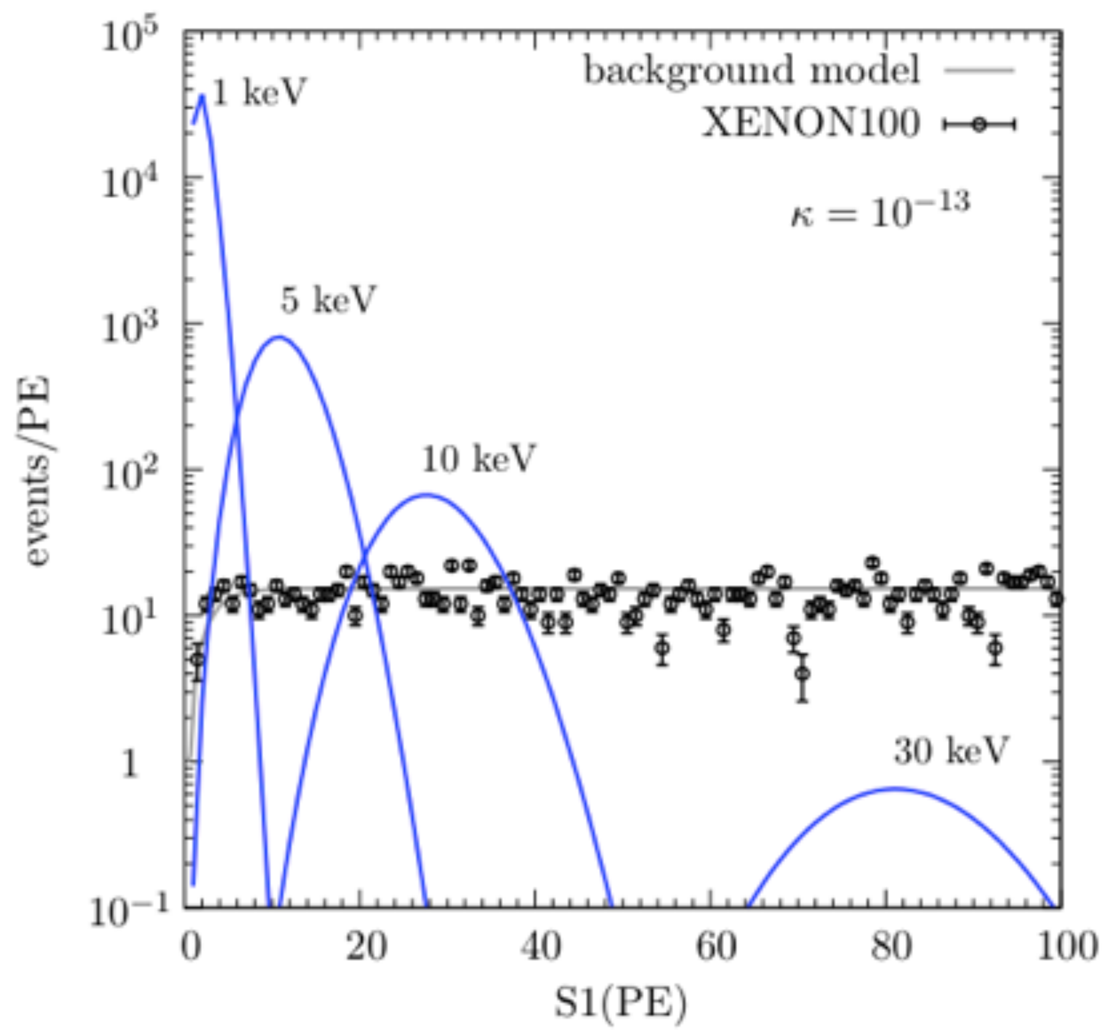
An, Pospelov, JP, 2013
An, Pospelov, JP, Ritz 2014

Case for Xenon

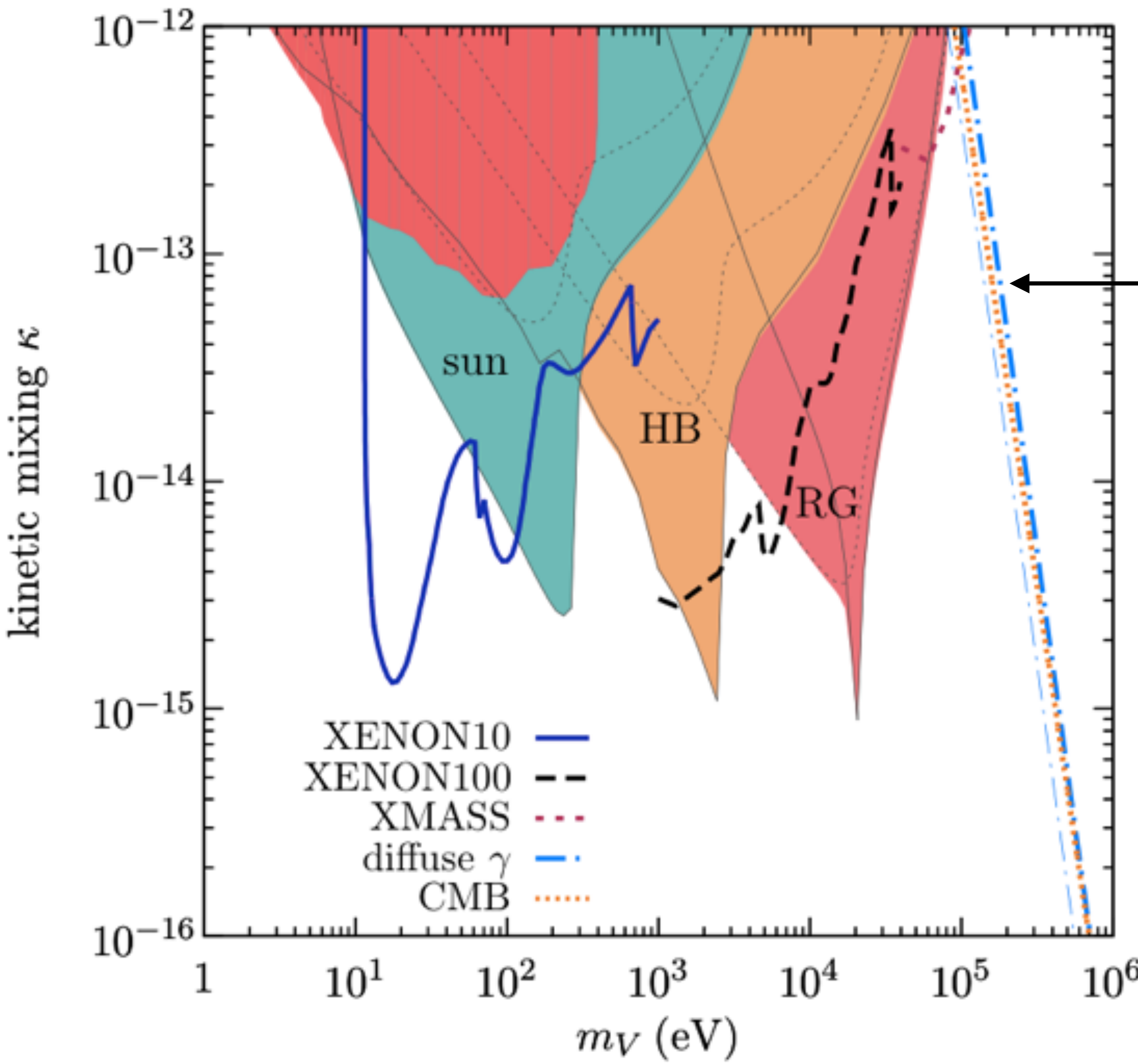
Compute absorption rate from Xenon refractive index

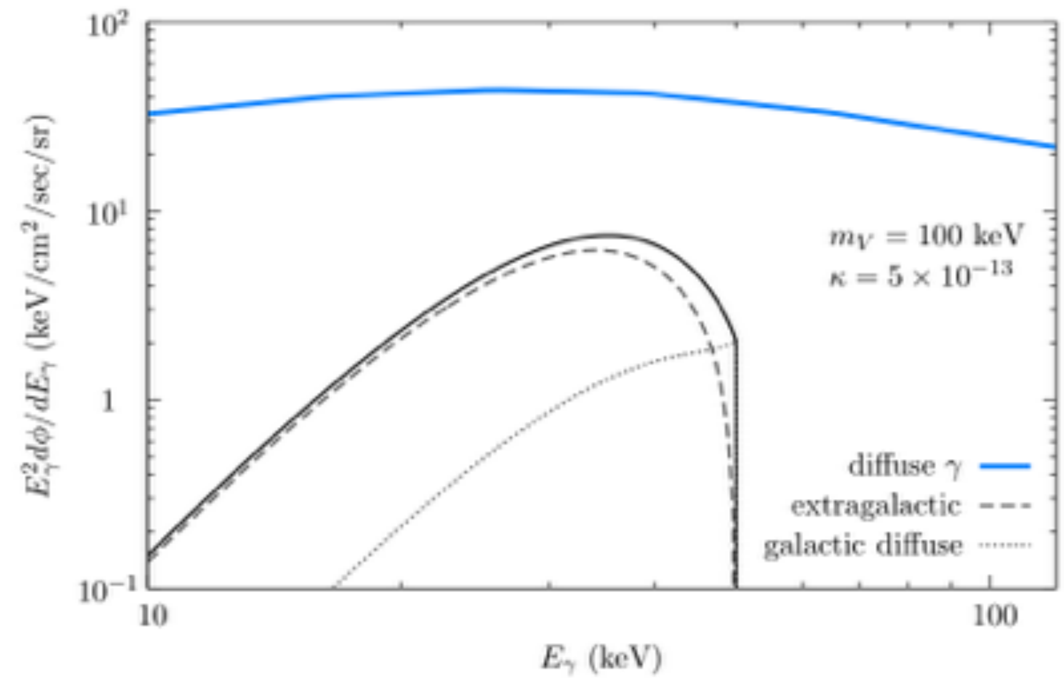
$$\Pi_L = (\omega^2 - \vec{q}^2)(1 - n_{\rm refr}^2), \quad \Pi_T = \omega^2(1 - n_{\rm refr}^2)$$





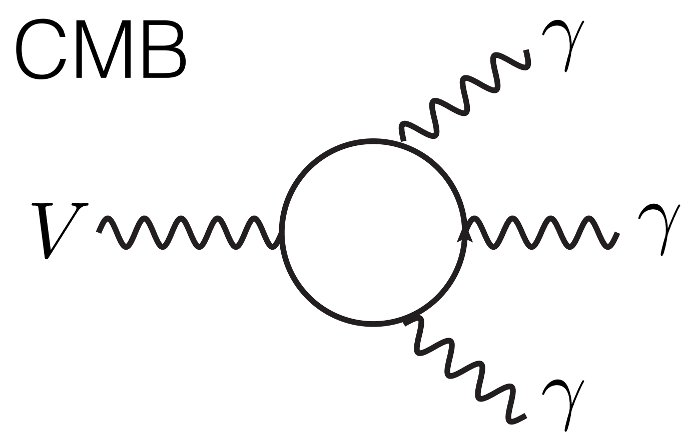
Dark Photon Dark Matter





diffuse gamma ray flux

+ CMB



An, Pospelov, JP, Ritz 2014

(for solar constraints, see An, Pospelov JP PLB 2013)

"Simplified Models" of Dark Matter electron scattering

(pseudo)scalar	$g_S S\bar{\psi}\psi, \quad g_P P\bar{\psi}\gamma_5\psi,$
(pseudo)vector	$g_V V_\mu\bar{\psi}\gamma_\mu\psi, \quad g_A \mathcal{A}_\mu\bar{\psi}\gamma_\mu\gamma_5\psi,$
tensor	$g_T T_{\mu\nu}\bar{\psi}\sigma_{\mu\nu}\psi, \quad \cdots$

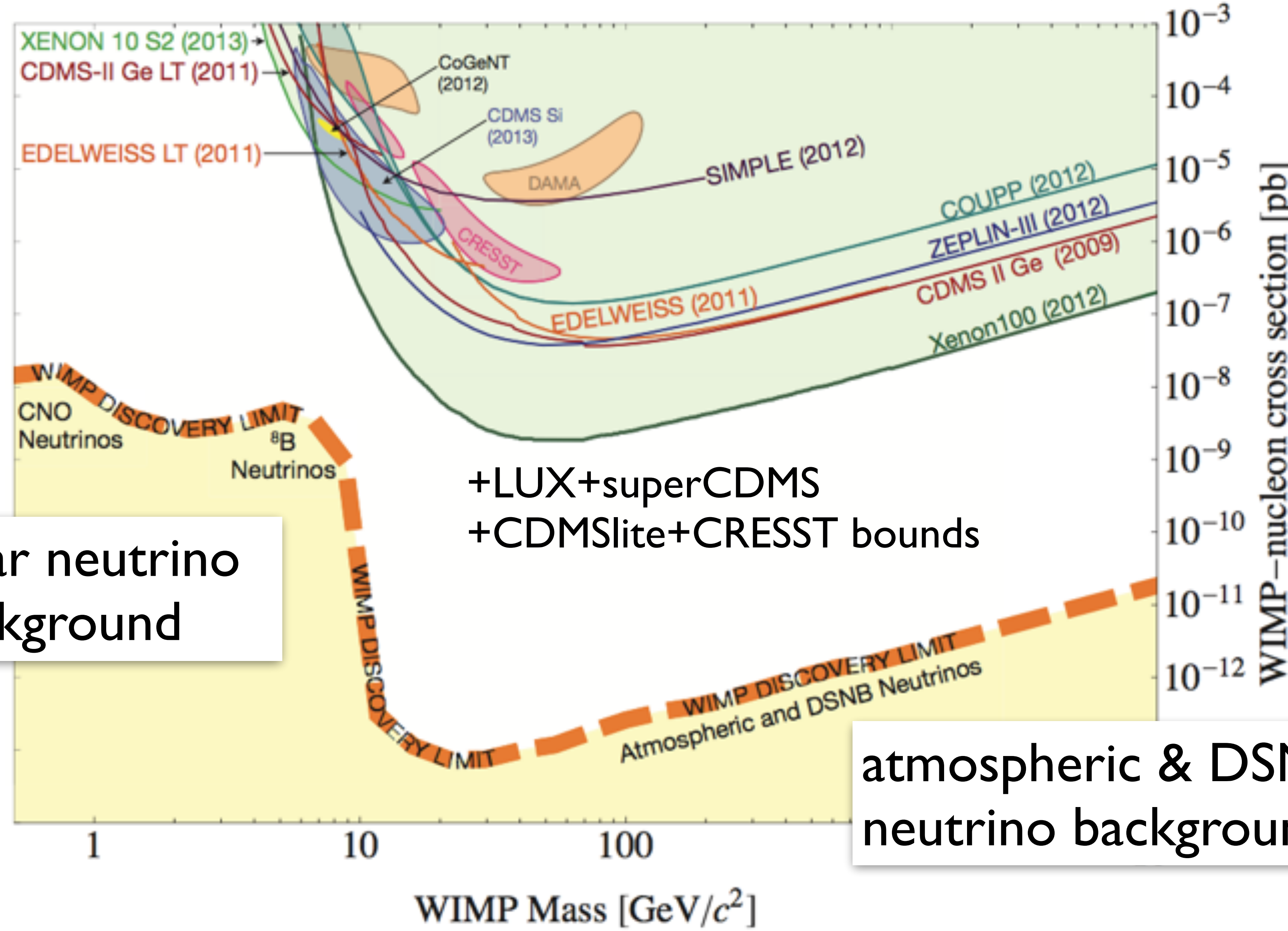
If the DM mass is not protected by some symmetry (like for dark photons or axions), loop corrections induce a mass shift

$\Delta m \sim g_i \Lambda_{\rm UV}$ => $g_i \lesssim 10^{-10}$ for $m \sim 100\,{\rm eV}$

As we have just seen, such couplings in the "naturalness regime" are being probed by direct detection!

Solar Neutrinos in Direct Detection

Snowmass 2013 / Billard et al, 2013



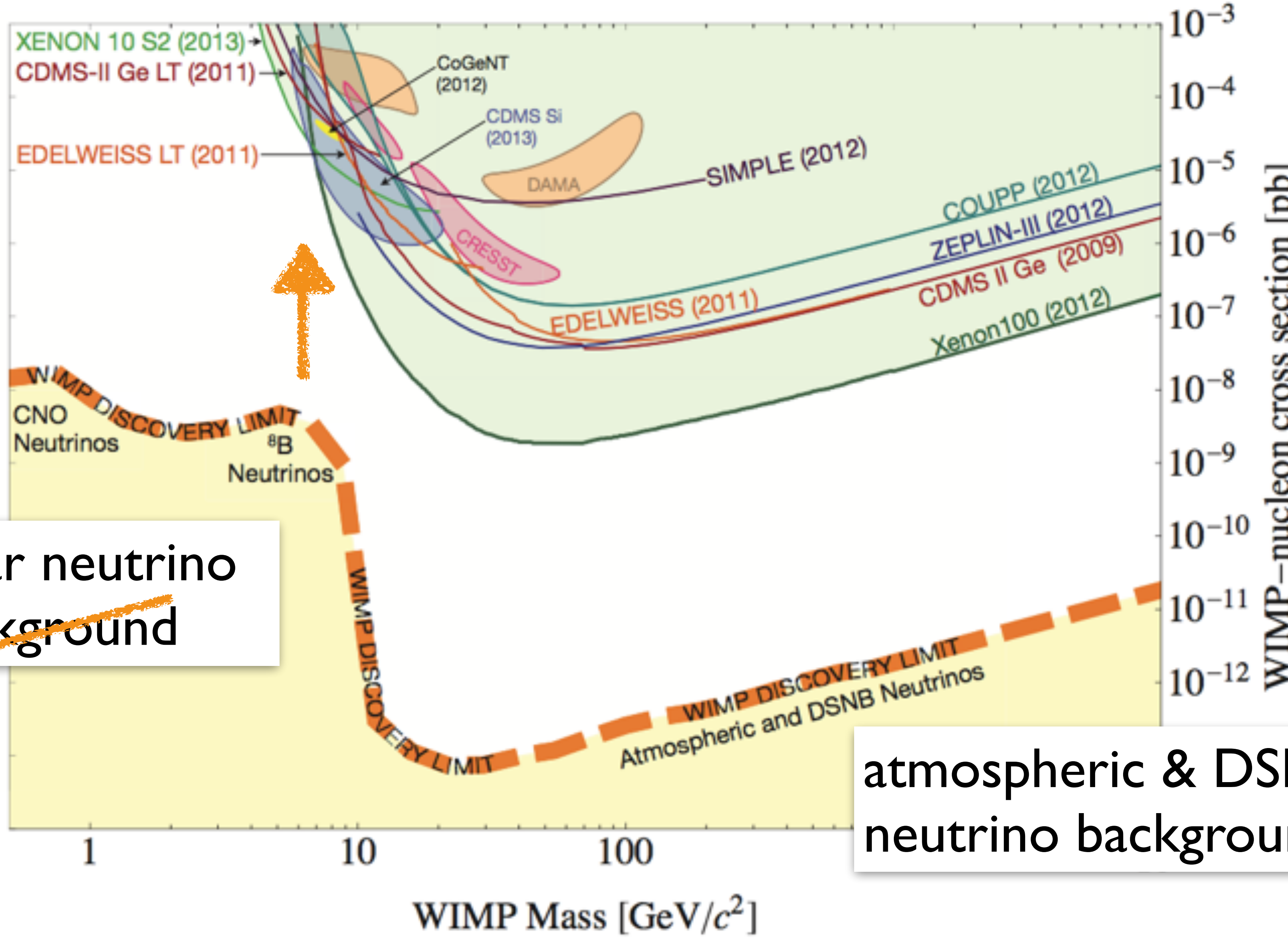
+LUX+superCDMS
+CDMSlite+CRESST bounds

solar neutrino background

atmospheric & DSNB neutrino background

Solar Neutrinos in Direct Detection

Snowmass 2013 / Billard et al, 2013



Solar neutrino Physics with DD experiments

Pospelov (2011)
Harnik, Kopp, Machado (2012)
Pospelov, JP (2012 & 2014)

new neutrino

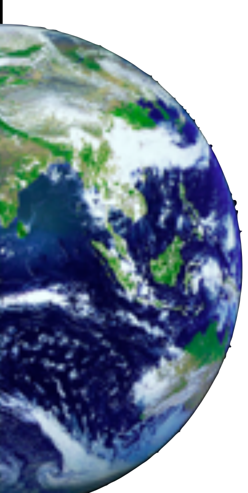
new force

$$\mathcal{L}_{\rm eff} = -G_B(\bar{\nu}_b\gamma^\mu\nu_b)J_{B,\mu}$$

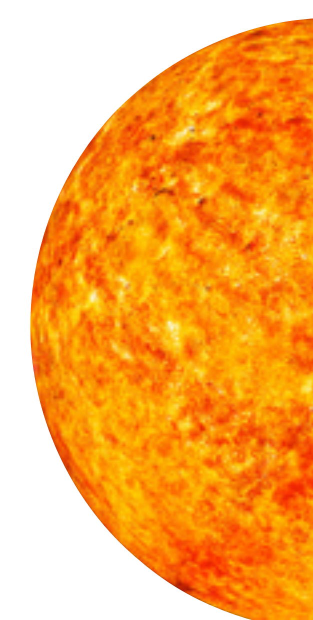
baryon current

=> for MeV-scale ν_b NC-like coherent scattering on nuclei

$$E_R^{\rm max} = \frac{(2E_\nu)^2}{2m_N} = \mathcal{O}(\rm keV)$$



$$L_{\rm osc} = \frac{4\pi E_\nu}{\Delta m^2} \approx 1\,{\rm AU}\left(\frac{10^{-10}\,{\rm eV}^2}{\Delta m^2}\right)\left(\frac{E_\nu}{10\,{\rm MeV}}\right)$$



Solar neutrino Physics with DD experiments

Pospelov (2011)
Harnik, Kopp, Machado (2012)
Pospelov, JP (2012 & 2014)

new neutrino

new force

$$\mathcal{L}_{\rm eff} = -G_B(\bar{\nu}_b\gamma^\mu\nu_b)J_{B,\mu}$$

baryon current

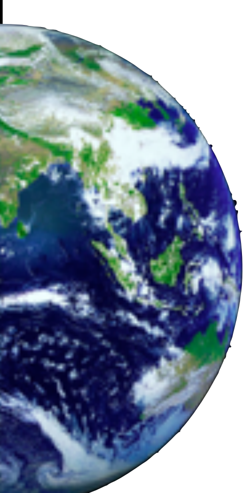
We need:

1. stronger than weak interaction

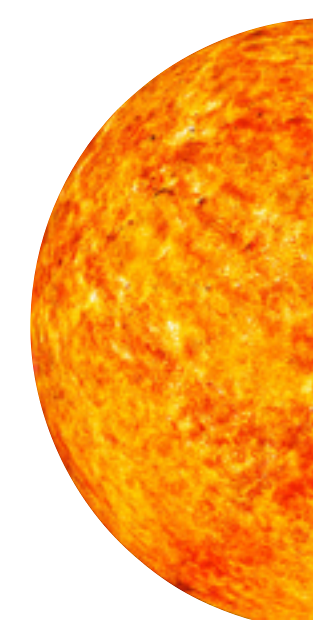
$$G_B/G_F \gg 1$$

2. oscillation lengths

$$L_{\rm osc} \gg 10^3\,{\rm km}$$



$$L_{\rm osc} = \frac{4\pi E_\nu}{\Delta m^2} \approx 1\,{\rm AU}\left(\frac{10^{-10}\,{\rm eV}^2}{\Delta m^2}\right)\left(\frac{E_\nu}{10\,{\rm MeV}}\right)$$



Taps into the original idea of a *true* neutrino$_B$ observatory

PHYSICAL REVIEW D VOLUME 30, NUMBER 11 1 DECEMBER 1984

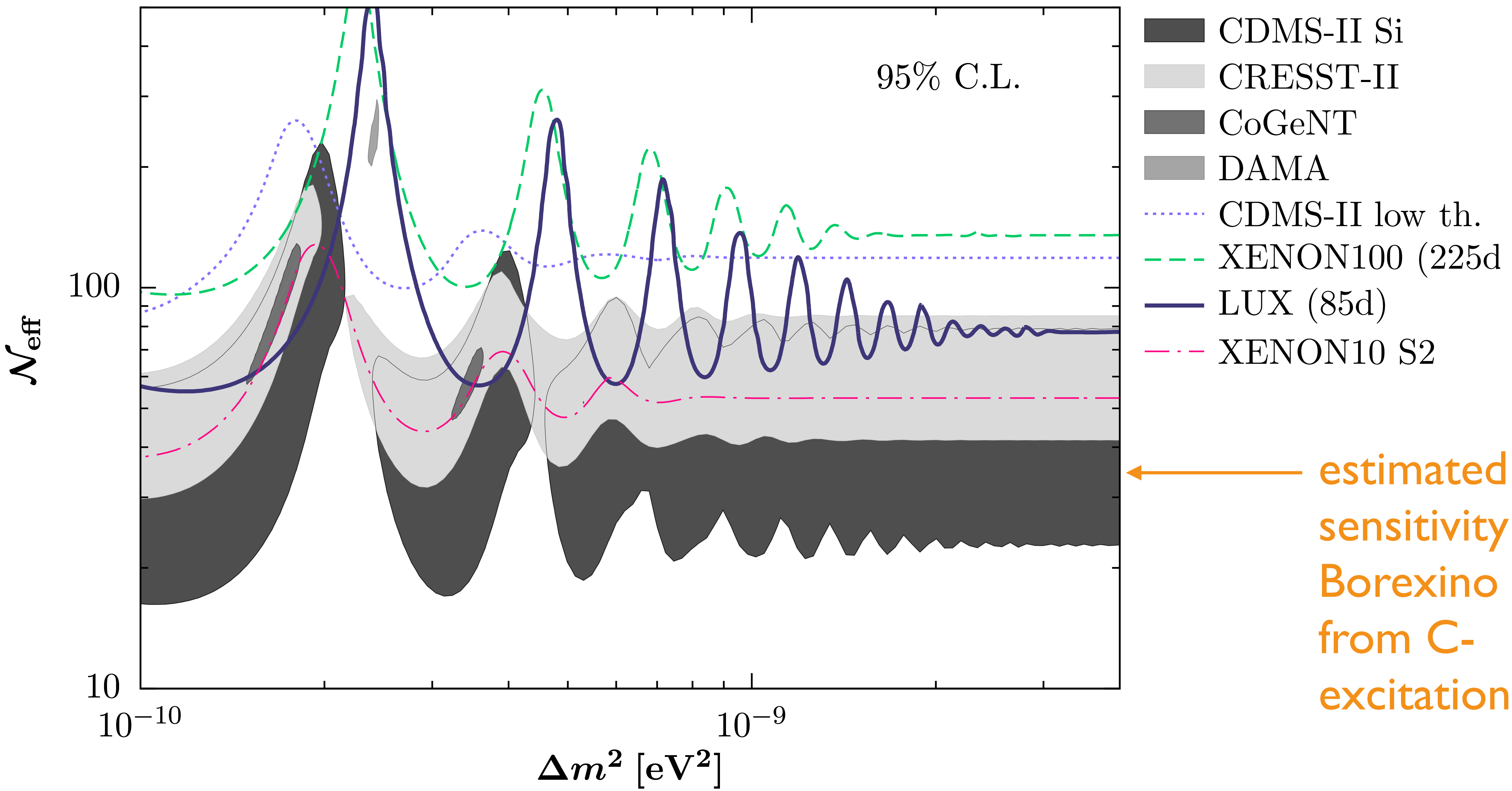
Principles and applications of a neutral-current detector for neutrino physics and astronomy

A. Drukier and L. Stodolsky
Max-Planck-Institut für Physik und Astrophysik, Werner-Heisenberg-Institut für Physik, Munich, Federal Republic of Germany
(Received 21 November 1983)

$$\frac{d\sigma}{d\cos\theta} = \frac{1}{8\pi} \overset{G_B^2}{\cancel{G_F^2}} E_\nu^2 \overset{A^2}{\cancel{\left[Z(4\sin^2\theta_W - 1) + N\right]^2}} (1+\cos\theta)$$

=> maybe direct detection experiments are neutrino observatories?!

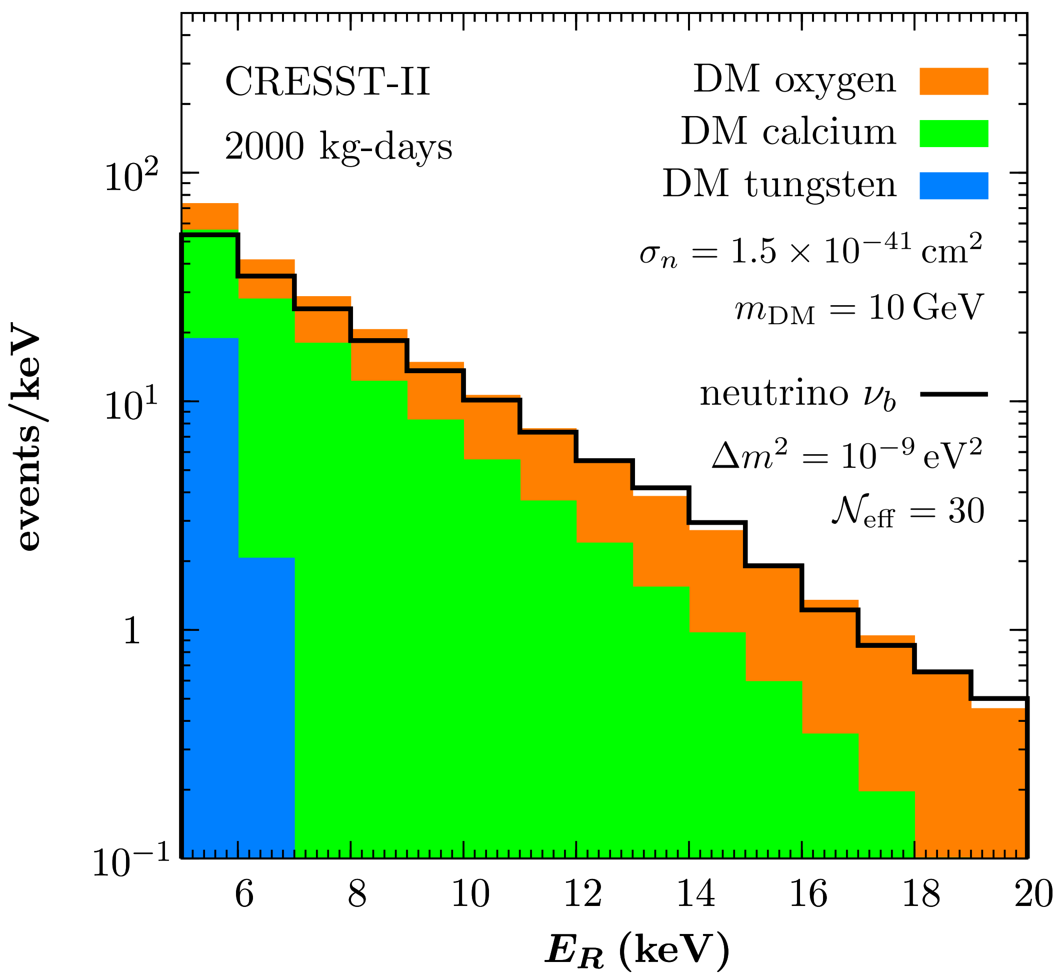
An alternative to light Dark Matter

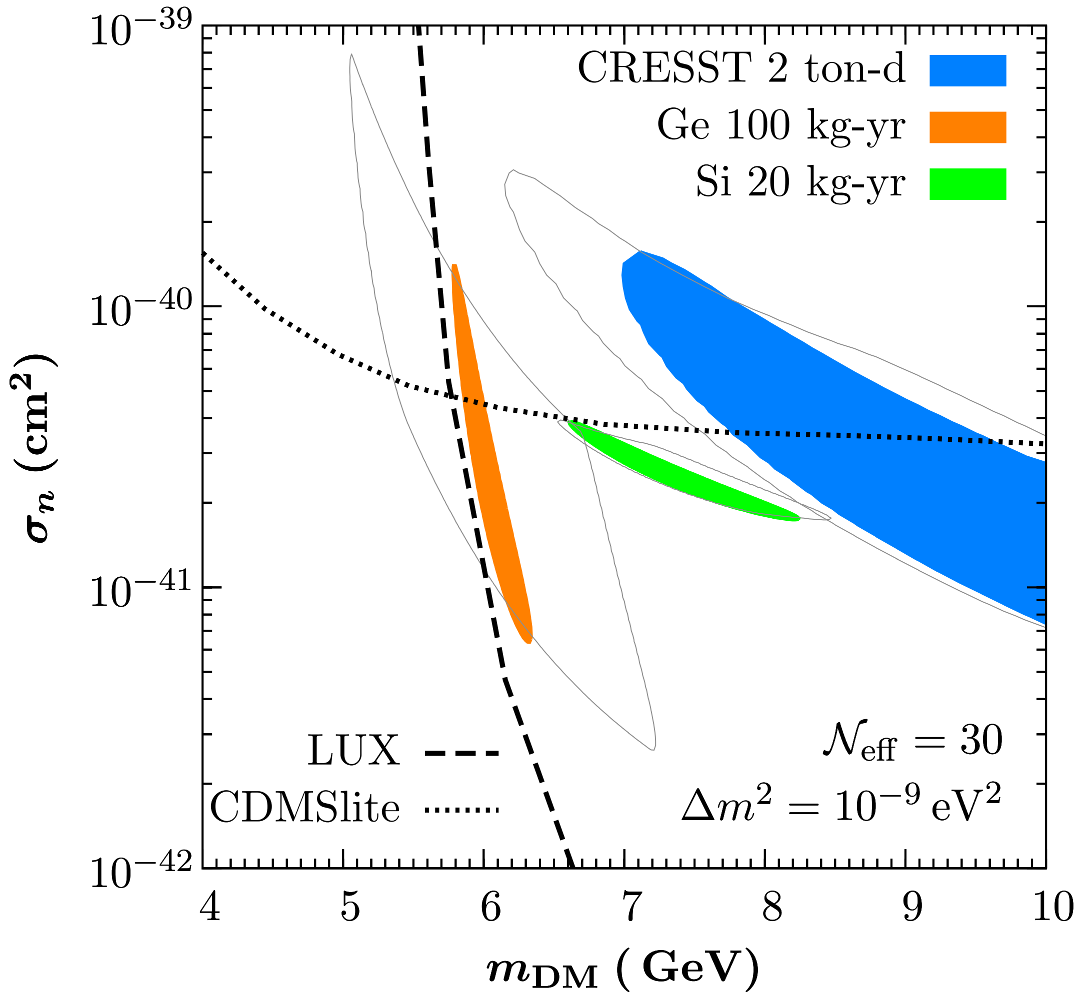


NB: plot needs an update; more stringent limits avail

Light DM vs. neutrinos

signals look alike => DM interpretation of a ν_b signal





=> complementary targets needed

Plan of the talk

1. Light states in
   Dark Matter Direct
   Detection experiments

2. WIMPs in
   Neutrino experiments

cheat-sheet for a WIMP miracle

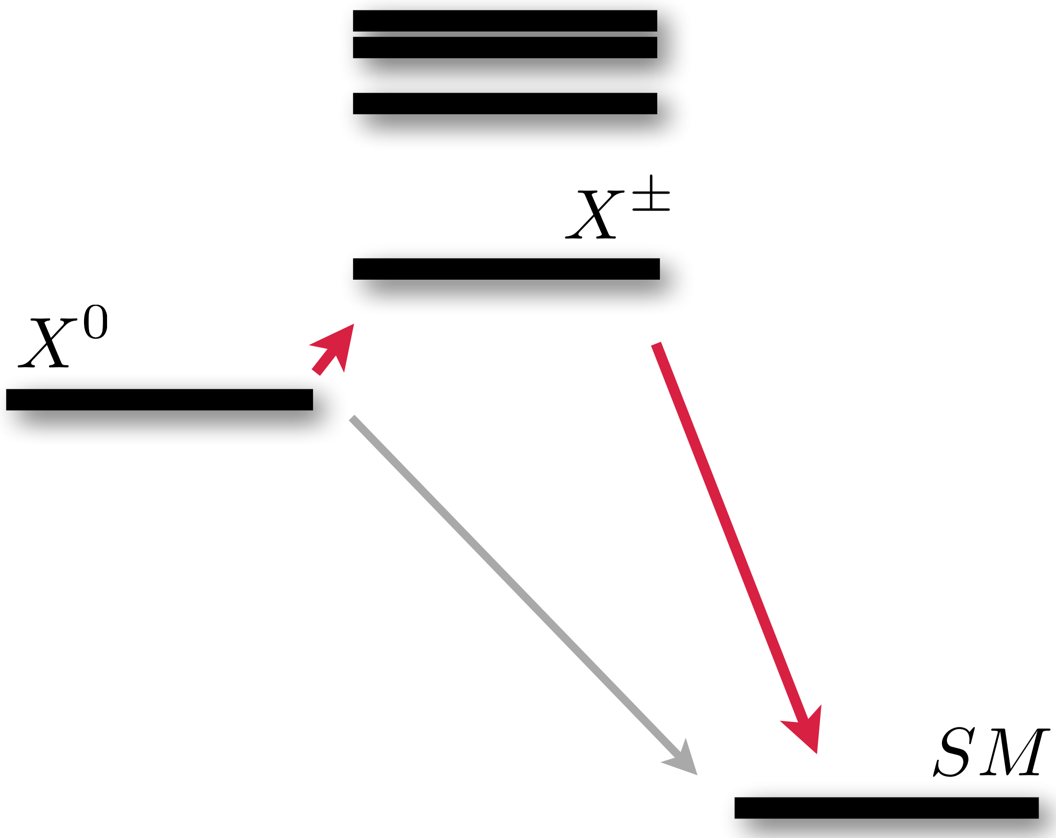
- What if direct link to SM is too feeble?

  => no correct thermal abundance

  => direct detection prospects diminish

- Co-annihilation can guarantee abundance

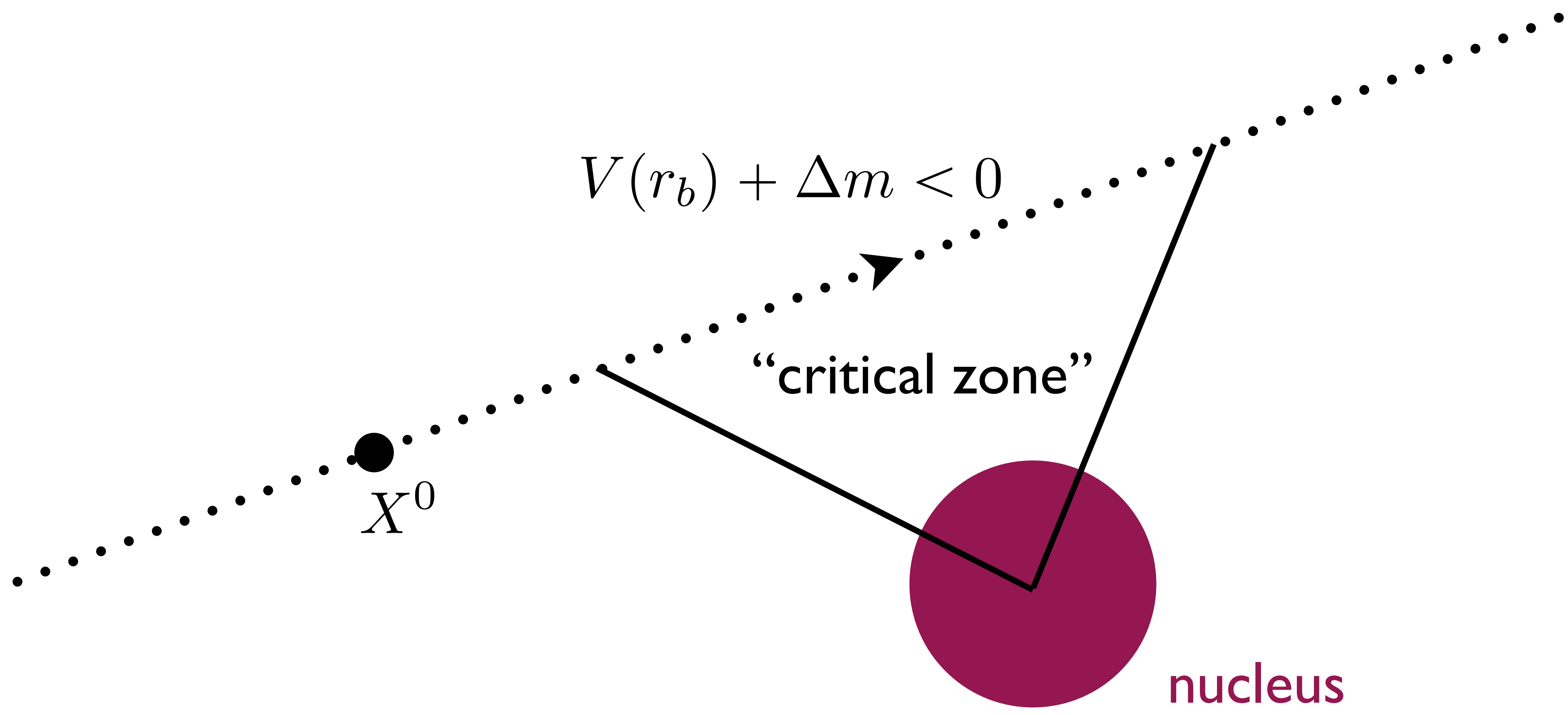
$$X^0 X^\pm \to SM$$
$$X^0 X^0 \to X^+ X^- \to SM$$
$$T_{\rm freeze} \simeq \frac{m_{X^0}}{20} \Rightarrow \Delta m \lesssim 0.05 m_{X^0}$$



Excited states of DM

- in the potential of the nucleus, excited state is accessible

  => capture $E_b = \mathcal{O}(\mathrm{MeV})$



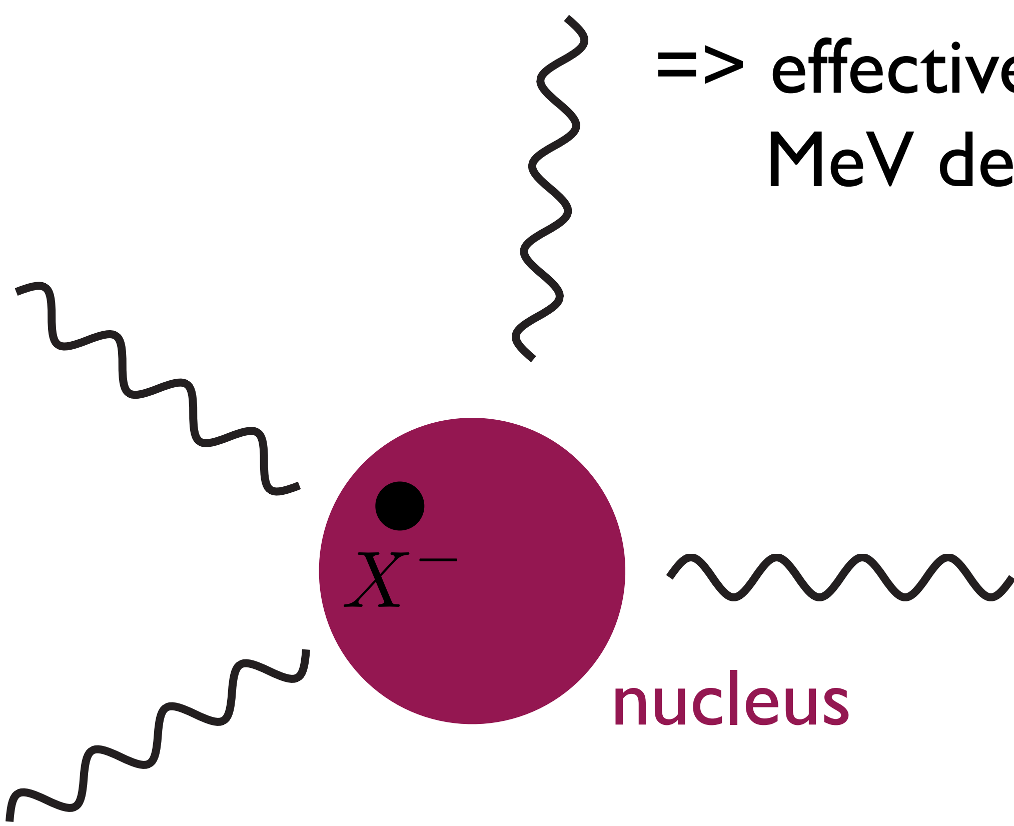
Excited states of DM

- in the potential of the nucleus, excited state is accessible

  => capture $E_b = \mathcal{O}(\mathrm{MeV})$

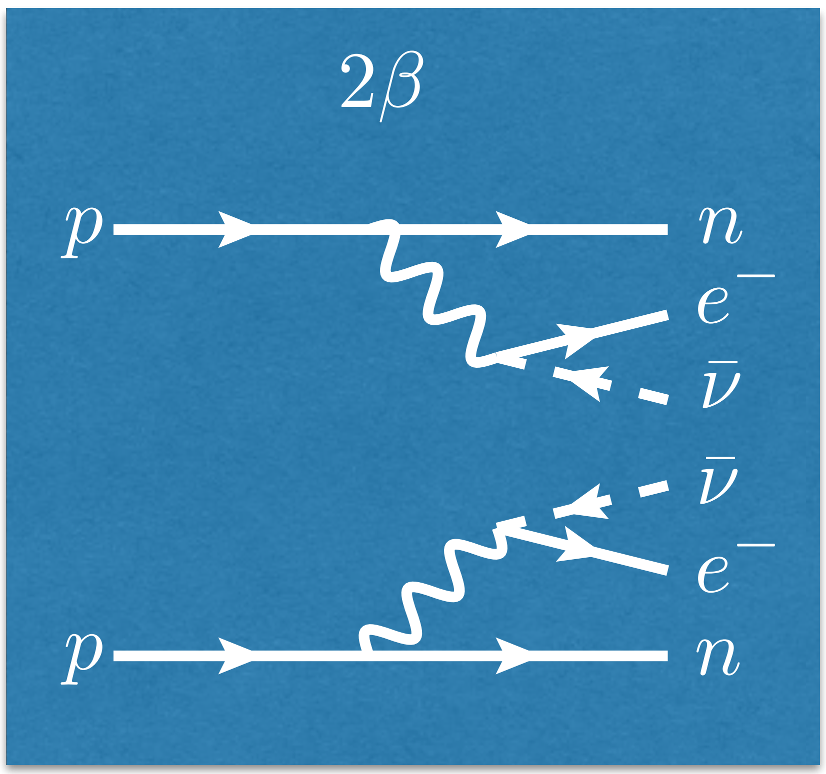
- offers a new kind of signature

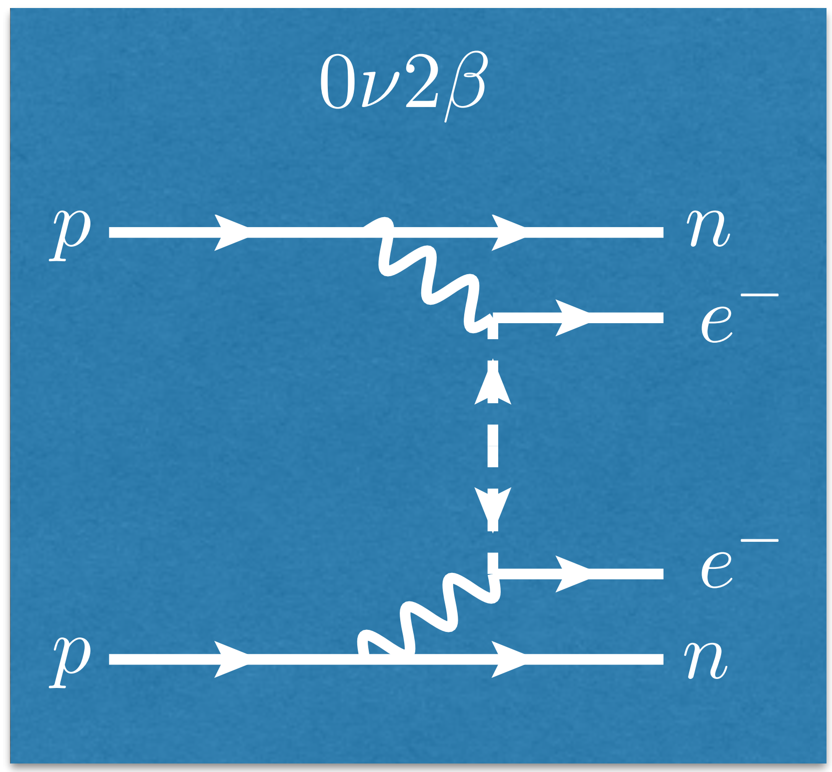
=> effective monochromatic
MeV depositions in the detector!



DM in Neutrino Experiments

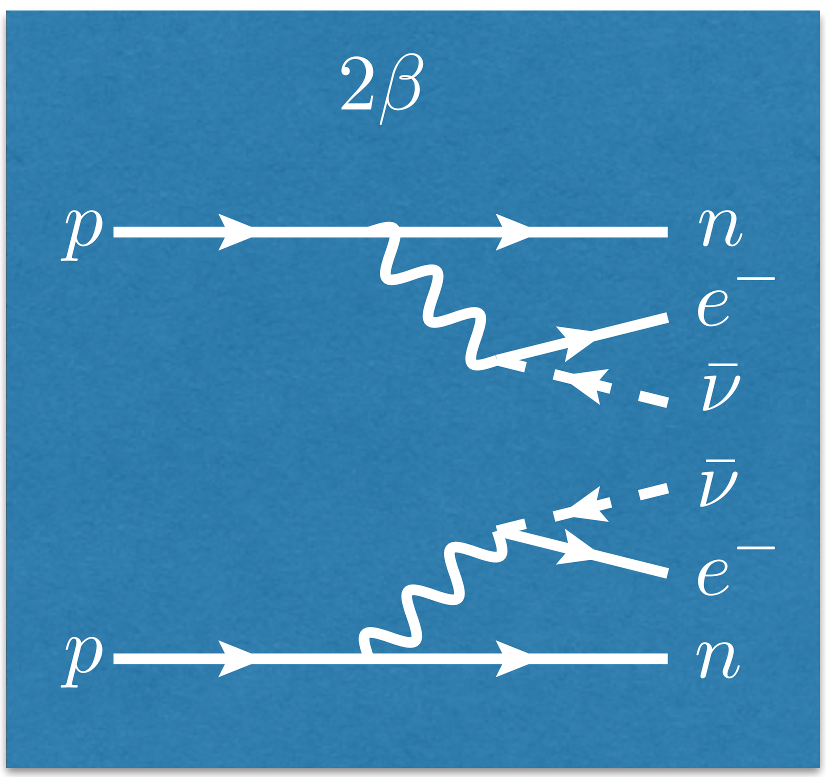
- $0\nu2\beta$ experiments look for extremely rare MeV energy deposits

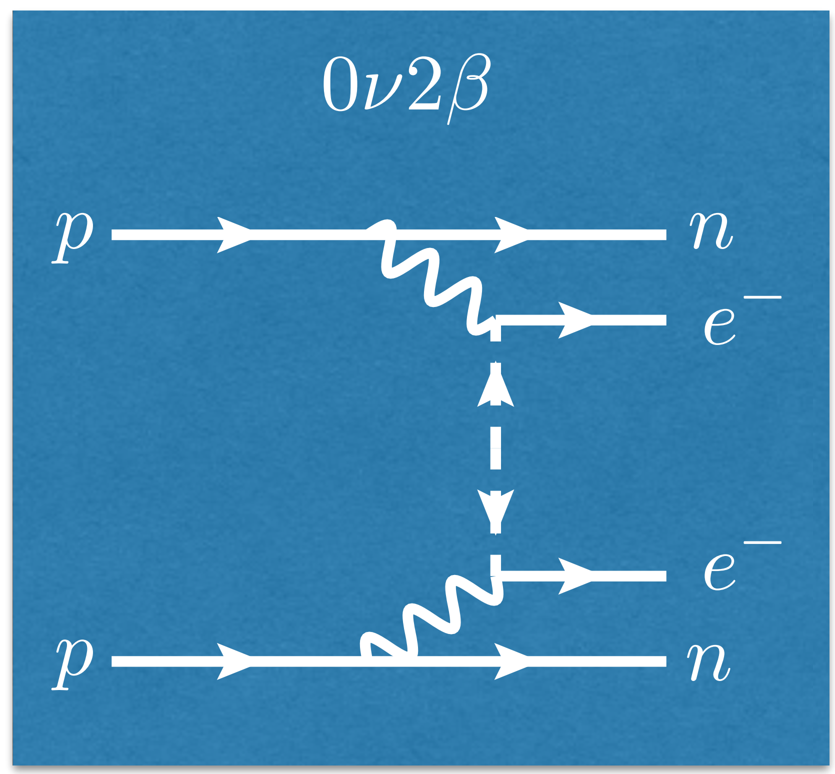


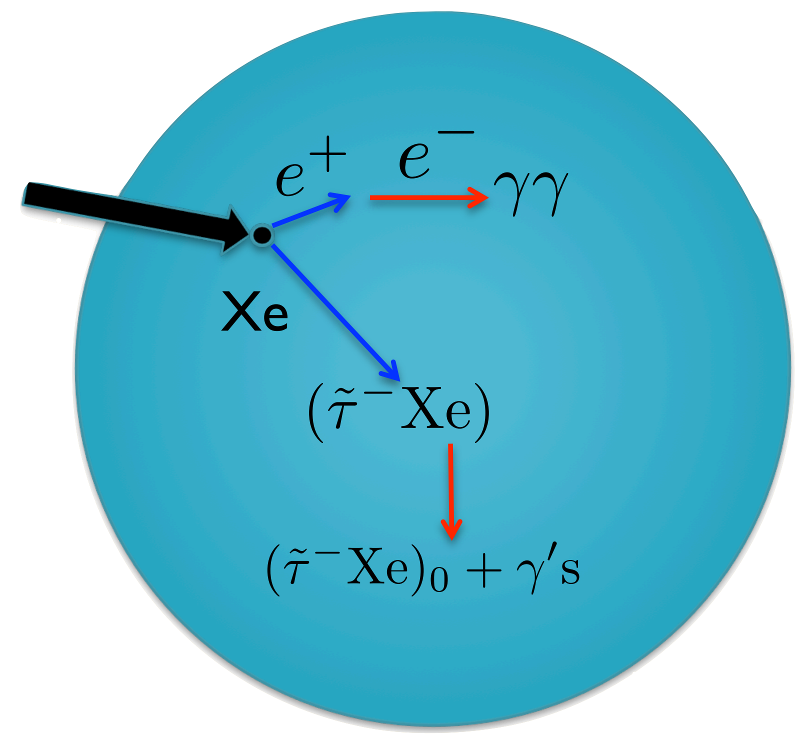


DM in Neutrino Experiments

- $0\nu 2\beta$ experiments look for extremely rare MeV energy deposits







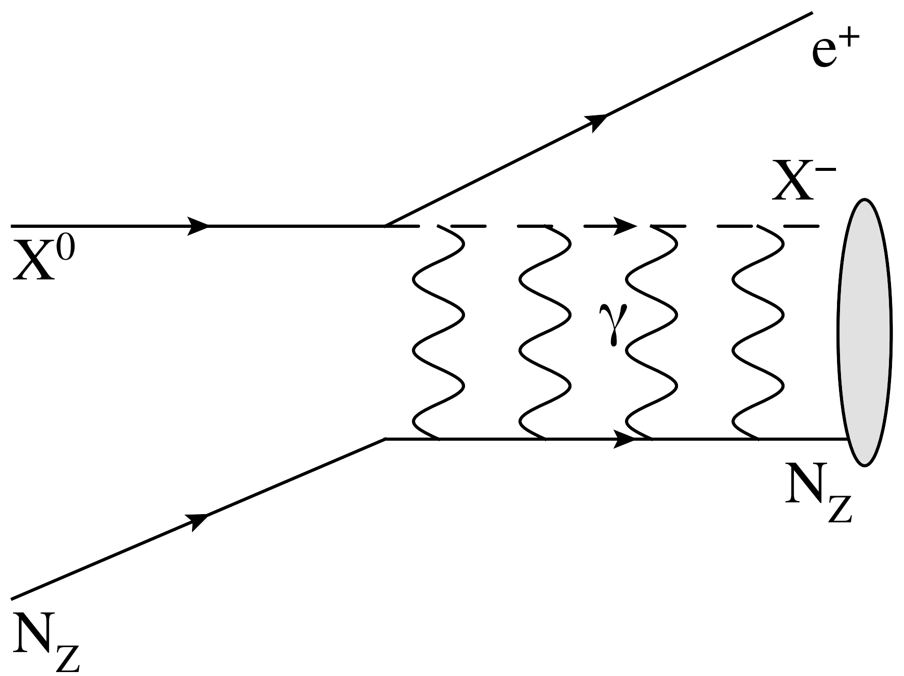
New signal
to look for

=> any "clean" experiment with MeV-sensitivity can do it

Two generic cases for charged excitations

Different spin

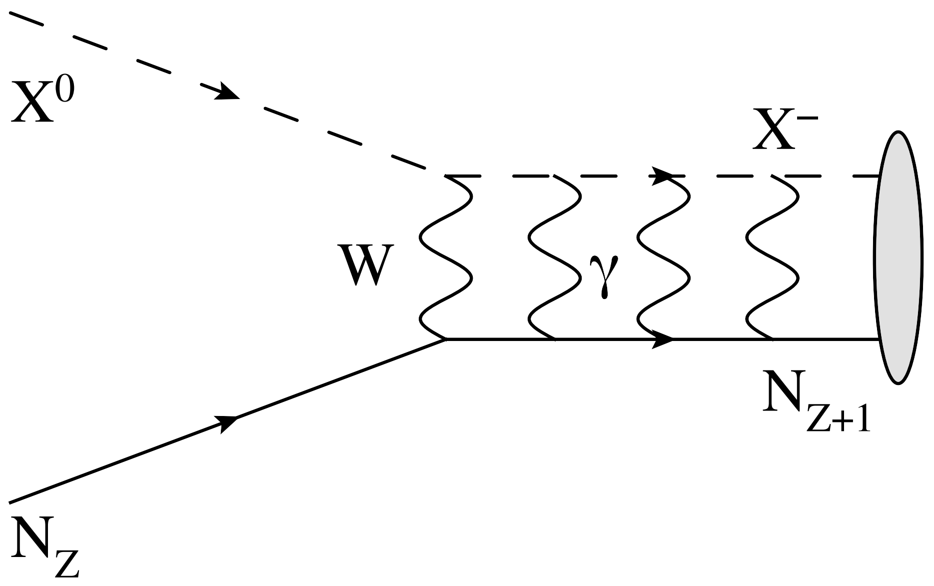
$$\mathcal{L} \supset y X^0 e^+ X^- + h.c.$$



$$N_Z + X^0 \to (N_Z X^-) + e^+$$

Same spin

$$\mathcal{L} \supset g_{\text{eff}}(X^0 \partial^\mu X^+ - X^+ \partial^\mu X^0) W^-_\mu$$



$$N_Z + X^0 \to (N_{Z+1} X^-)$$

Supersymmetric realization

Different spin

$$\mathcal{L}_{\rm A} = \bar{\chi}(g_{eL}\mathbb{P}_L + g_{eR}\mathbb{P}_R)e\tilde{\tau}^\dagger + \text{h.c.}$$

↑ Yukawa interaction

"neutralino-stau scenario"

Same spin

$$\mathcal{L}_{\rm B} = \frac{g_{\rm eff}}{2}W^{-\mu}(\partial_\mu\tilde{\tau}^\dagger\tilde{\nu}^0 - \tilde{\tau}^\dagger\partial_\mu\tilde{\nu}^0) + \text{h.c.}$$

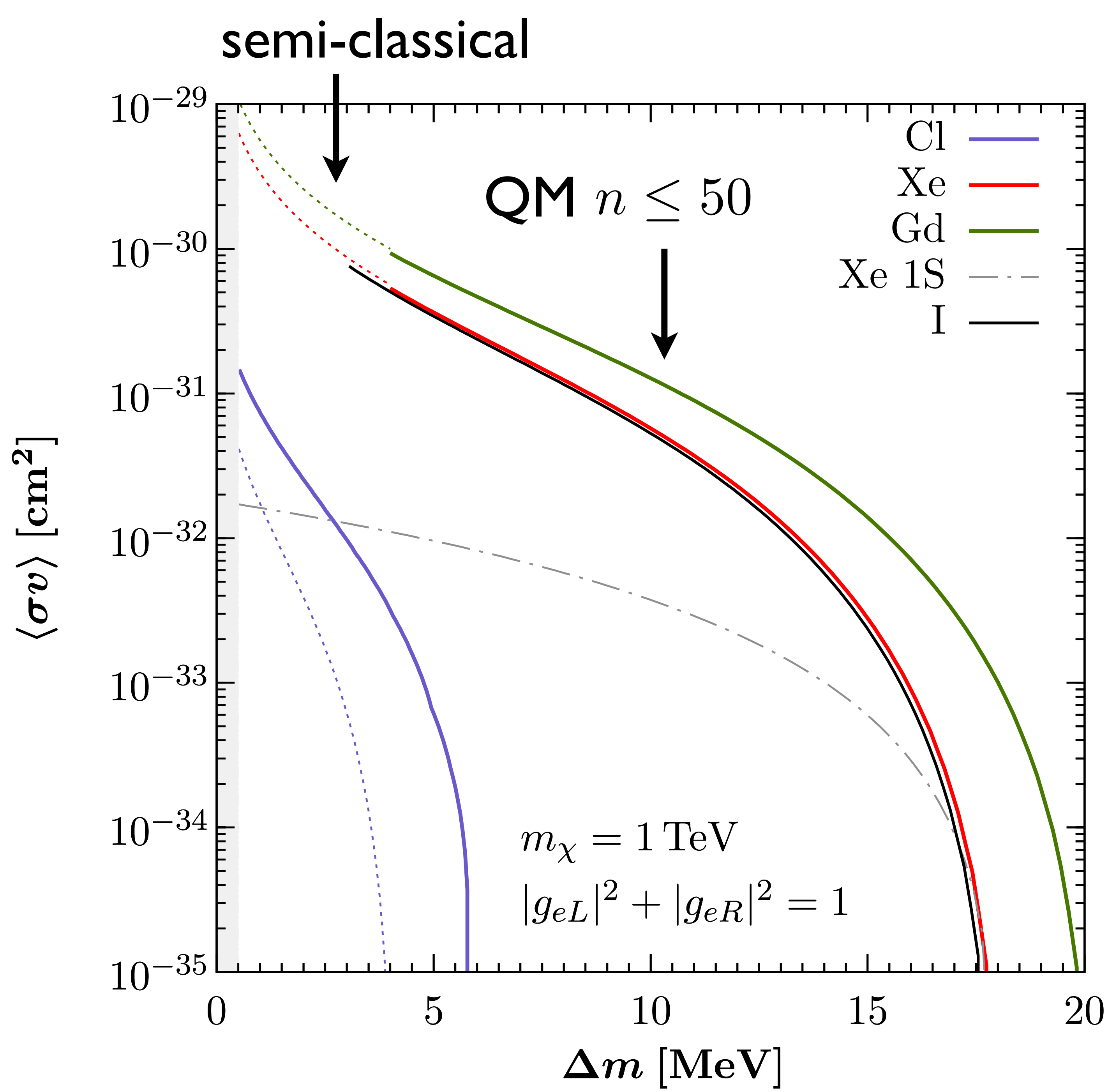
$$g_{\rm eff} = g_2\cos\theta_{\tilde{\tau}}\cos\theta_{\tilde{\nu}^0}$$

↑ LR stau mixing angle ($\cos\theta_{\tilde{\tau}}$)

↑ sterile-active mixing angle ($\cos\theta_{\tilde{\nu}^0}$)

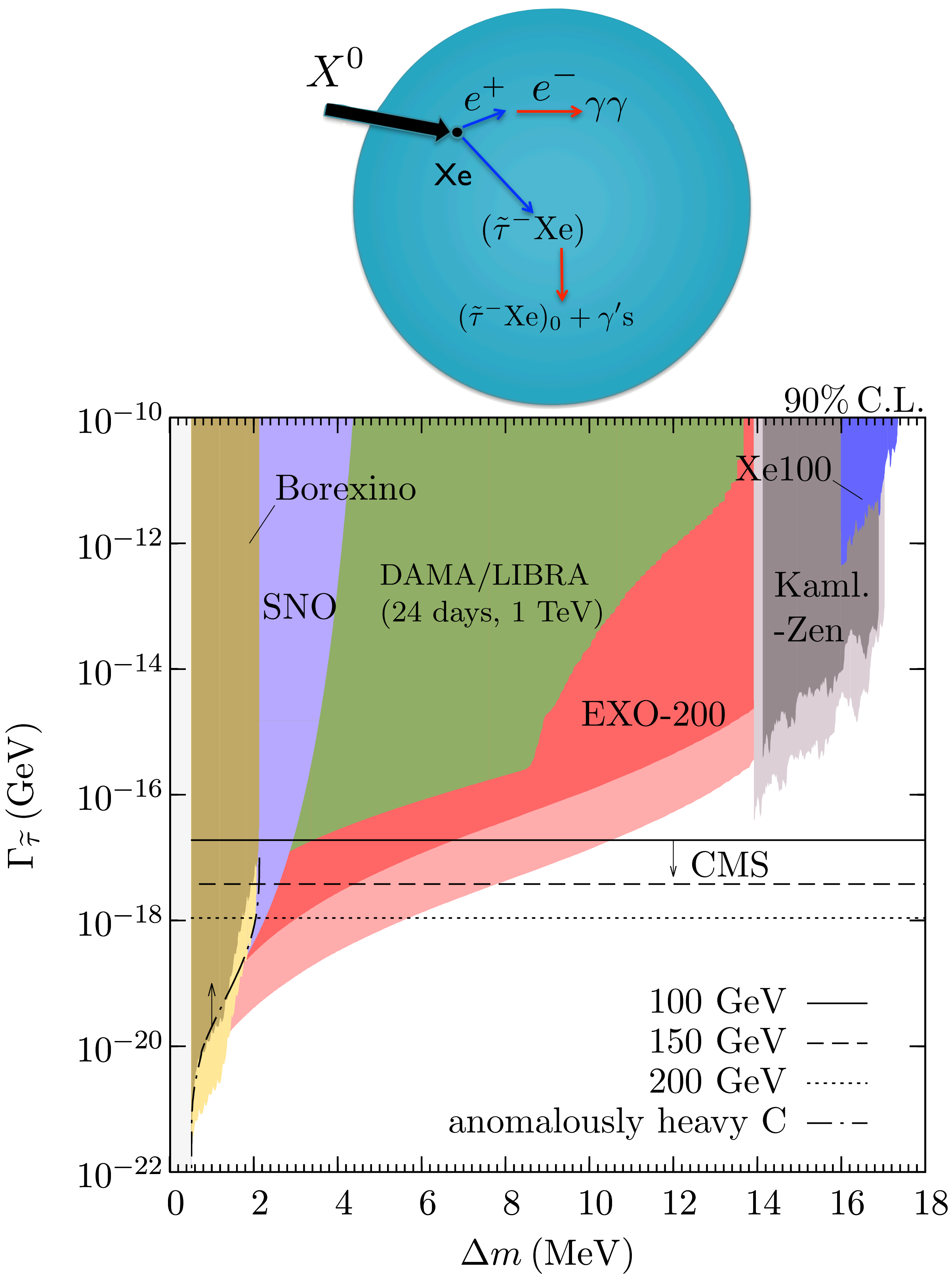
"sneutrino-stau scenario"

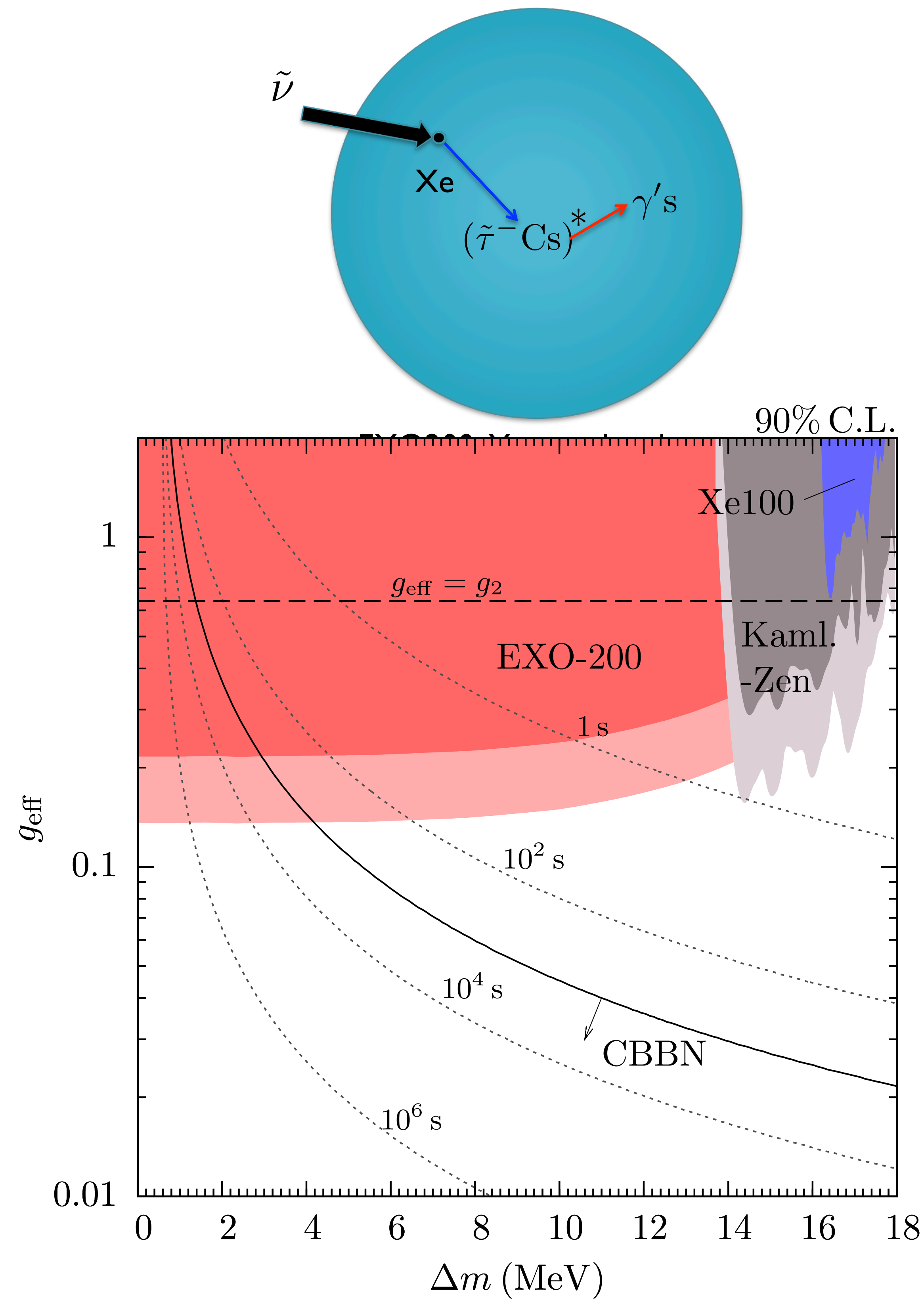
The correspondence principle at work



(different spin case)

Constraints from WIMP-captures

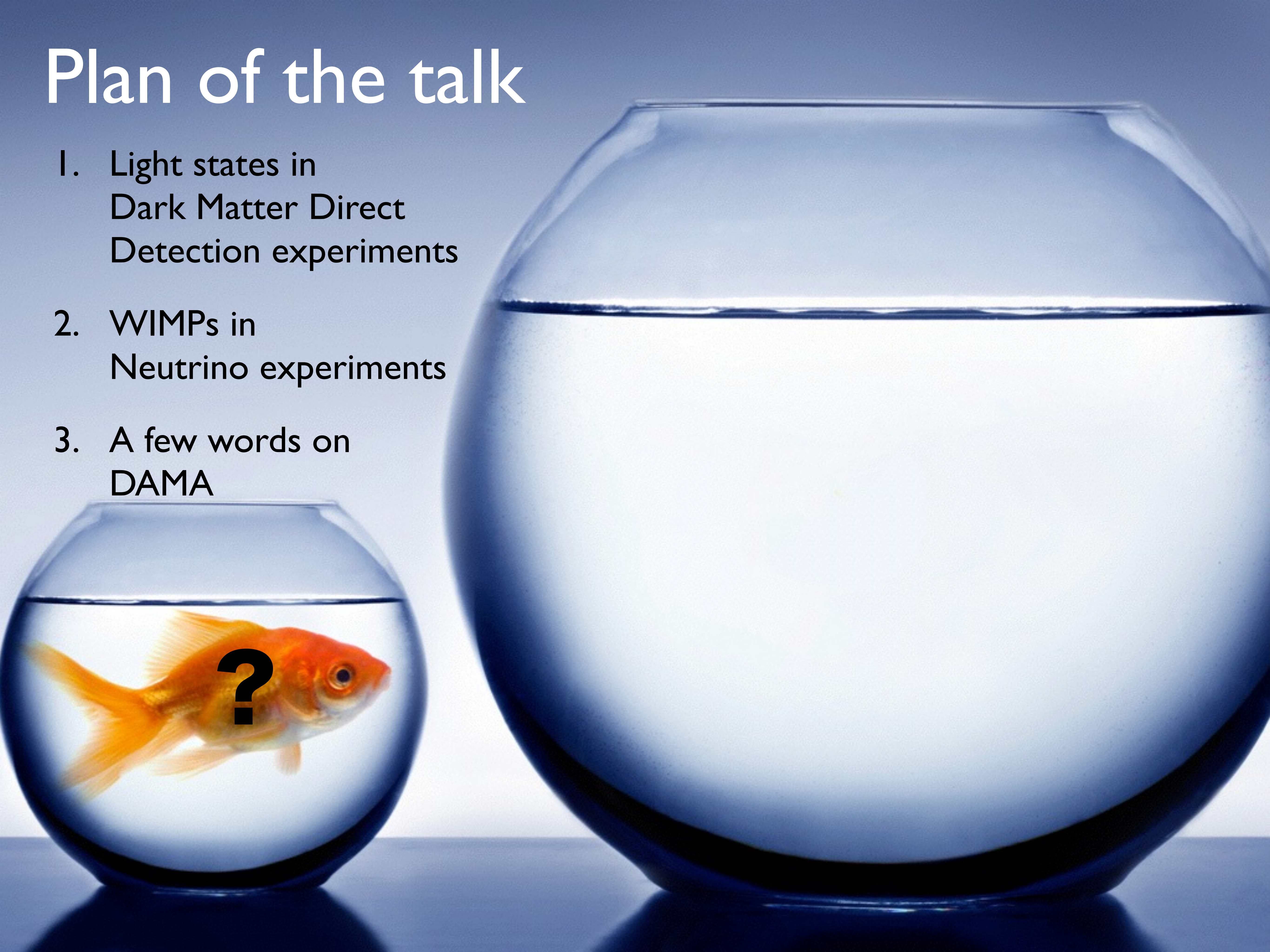




An, Pospelov, JP (PRL 2012)

Plan of the talk

1. Light states in Dark Matter Direct Detection experiments
2. WIMPs in Neutrino experiments
3. A few words on DAMA



A few words on DAMA

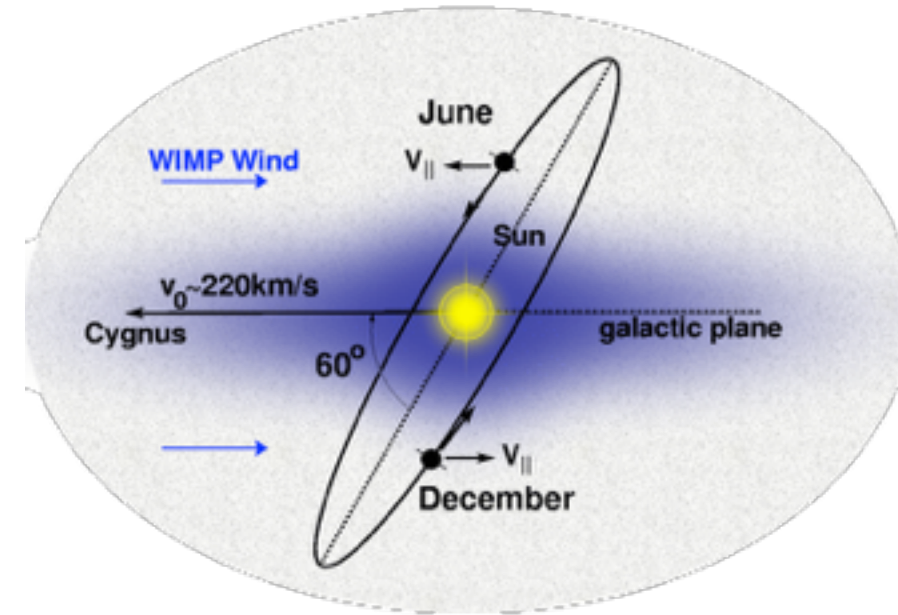
Only experiment with a continuing signal claim for over a decade. If it's there, it is of profound importance.

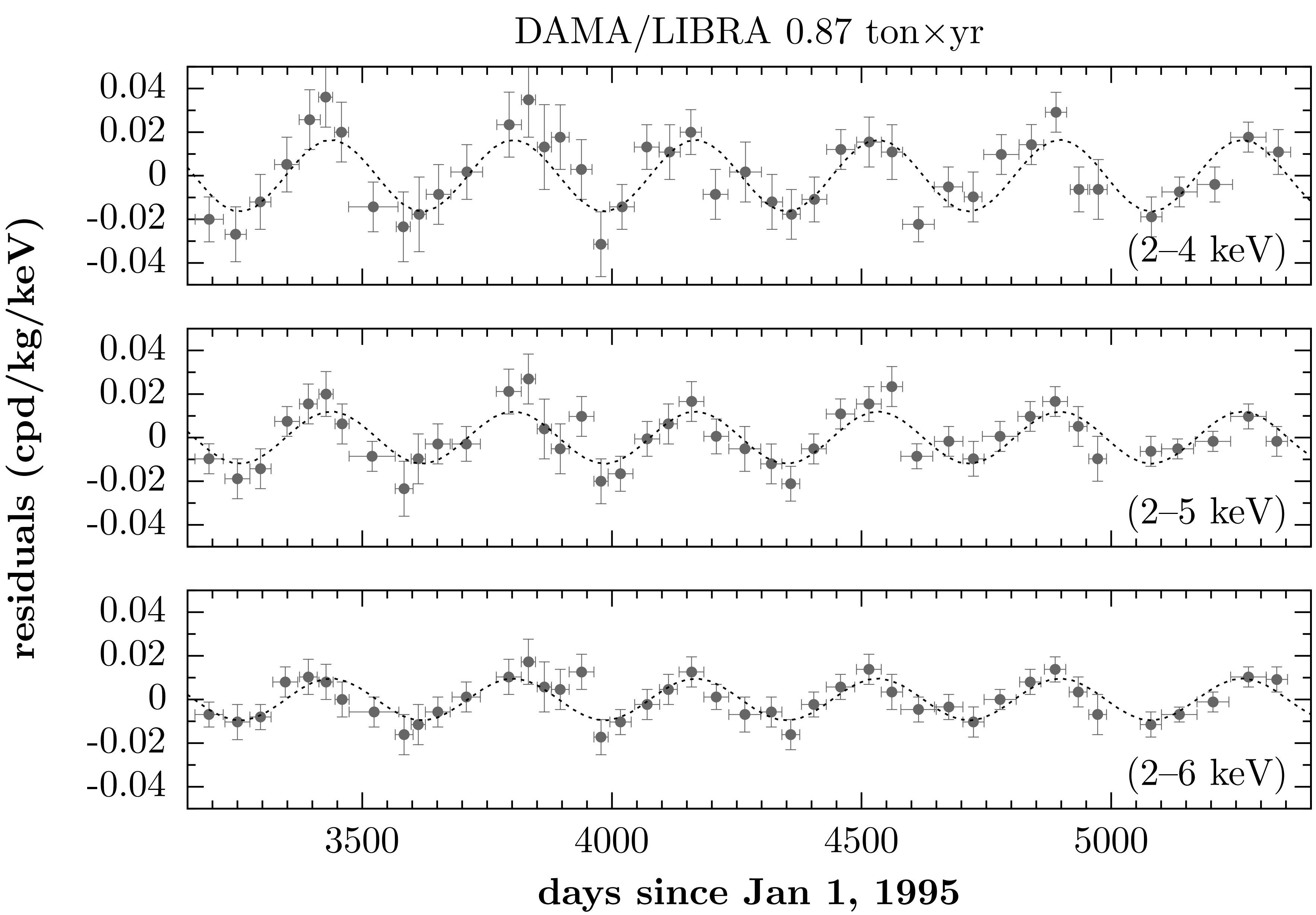
Good reasons to be skeptic about the claim, e.g.

- No muon veto (muons modulate) [I will show you that seems OK]
- Spectrum not publicly reported [that's troublesome for the outsider]
- Excluded by other direct detection searches [only one counterexample is needed…]

$s_m^{\mathrm{obs}} \simeq 2\%$

DAMA/LIBRA



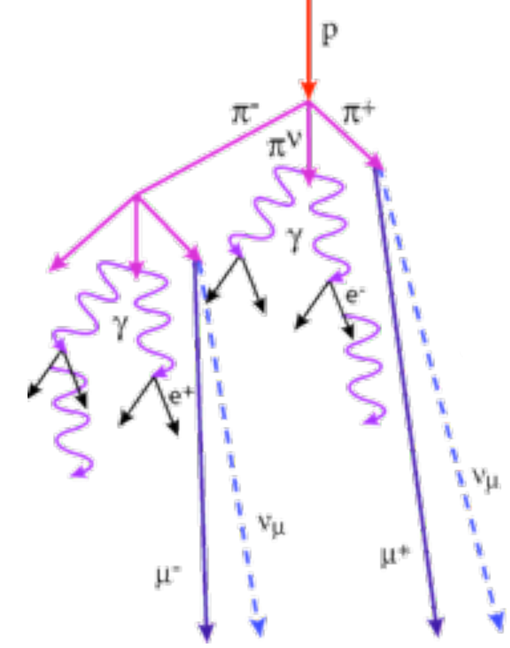


- scintillation from NaI-crystals
- 8σ+ modulation
- phase consistent as expected from WIMPs

$$t_0 \simeq 2\ \text{June}$$
$$= 152.5\ \text{days}$$

[Bernabei et al. 2010, …]

DAMA
muon flux underground



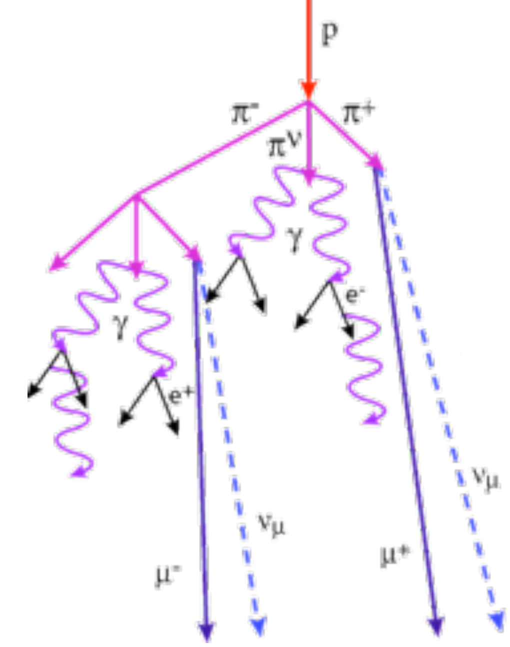
- underground flux sourced mainly by primary meson decays (pions, kaons,...) => muons need to be TeV-like to reach underground
- correlated with temperature

$$\frac{\Delta I_\mu}{I_\mu^0} = \alpha_T \frac{\Delta T_{\mathrm{eff}}}{T_{\mathrm{eff}}} \qquad T_{\mathrm{eff}} = \int_0^\infty dX\, T(X) W(X)$$

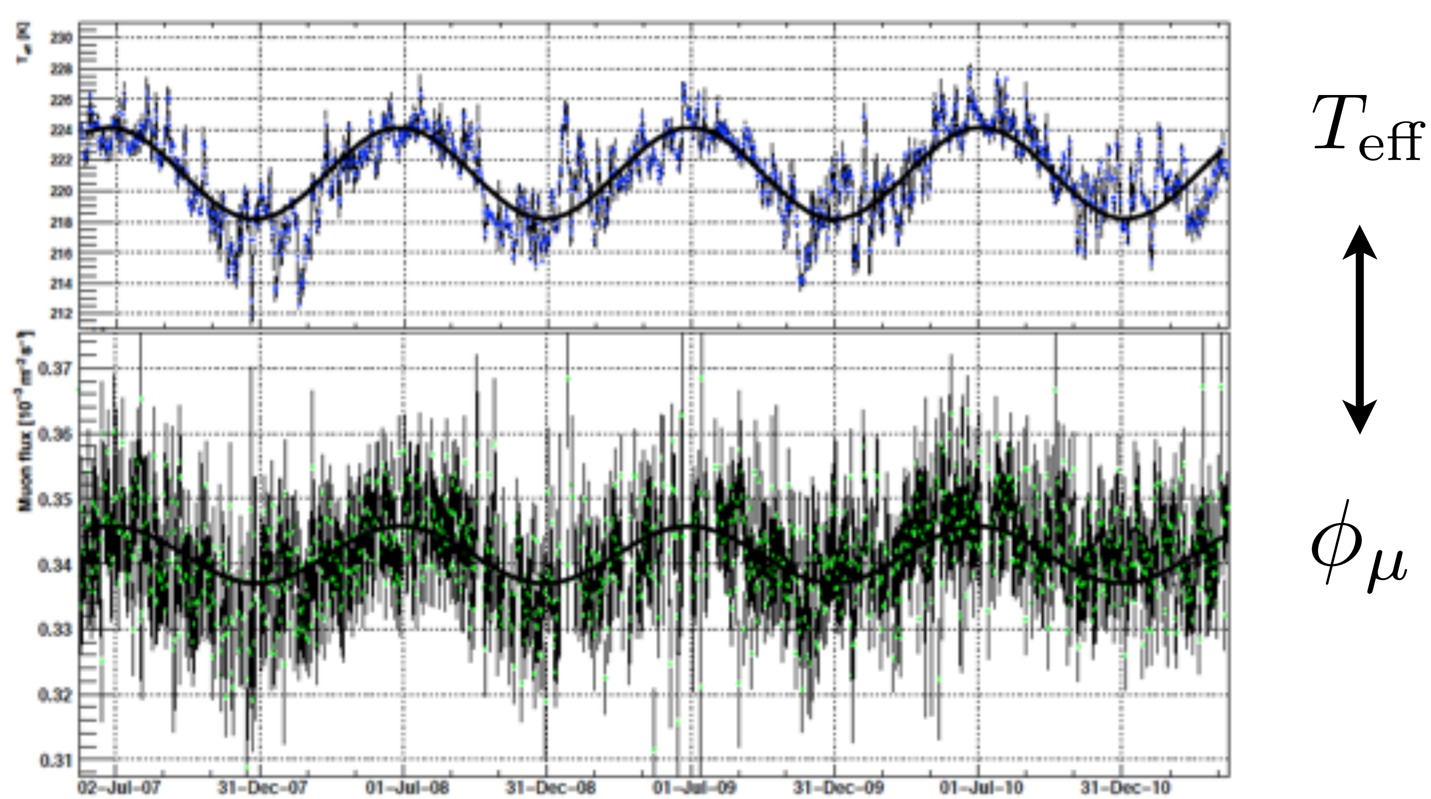
flux modulates

- flux peaks in Summer (on northern hemisphere)

DAMA
muon flux underground



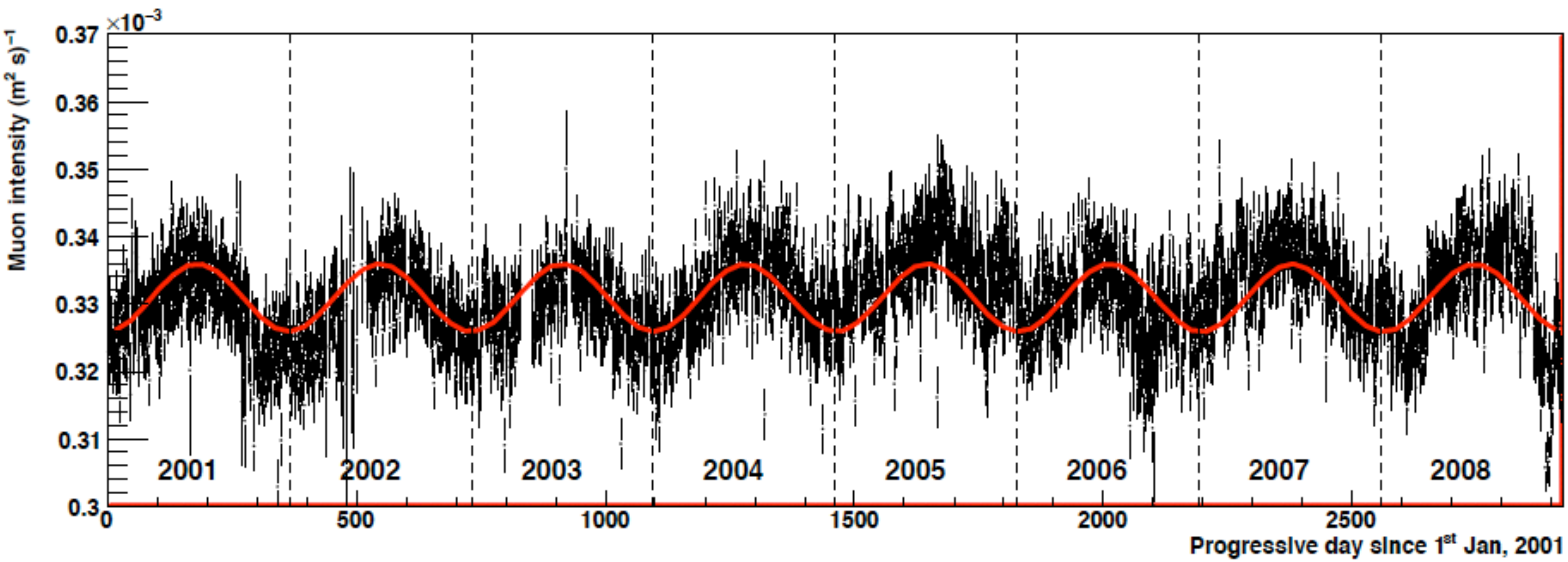
- many measurements available, correlation with T_{eff} firmly established
  - LNGS: Macro, LVD, Borexino (DAMA location)
  - Soudan Mine: MINOS (CoGeNT location)
  - South Pole: Amanda, Icecube



[Borexino 2011]

DAMA
vs. LVD

- Large Volume liquid scintillator Detector (LVD) reports underground muon-flux at LNGS => temporal overlap with DAMA data

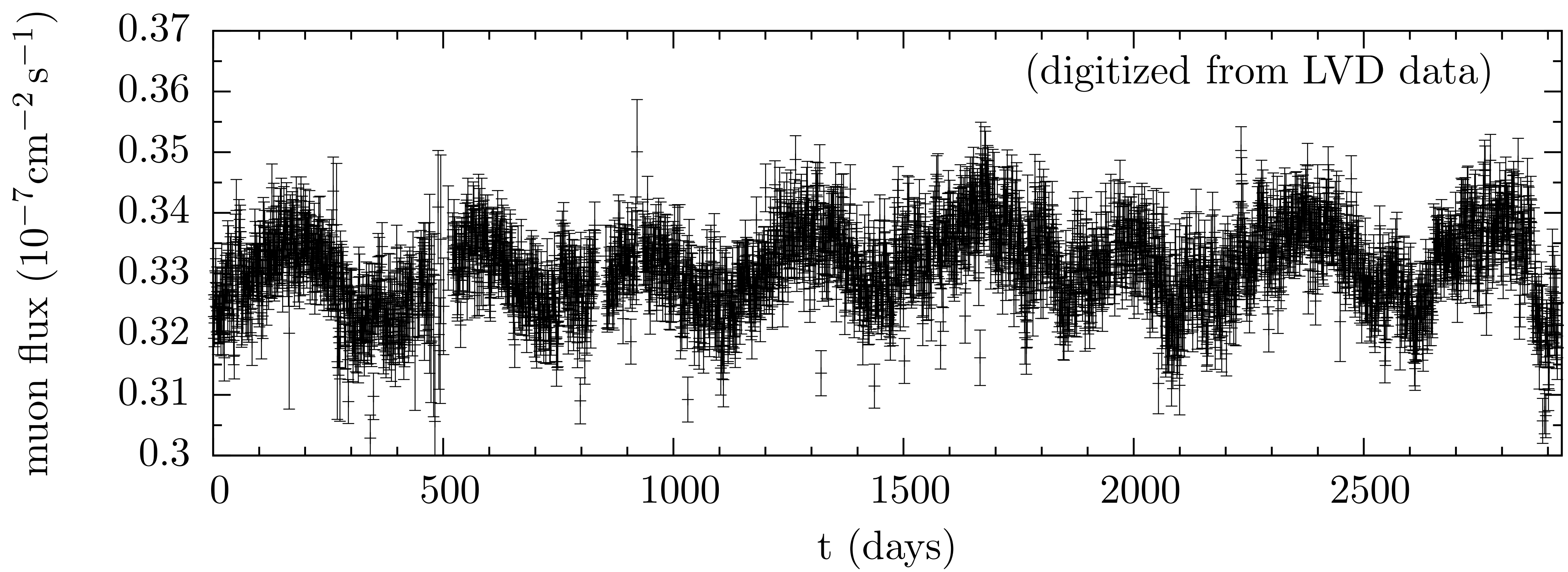


[Selvi, 2009]

$\overline{I}_\mu \sim 30/\mathrm{day}/\mathrm{m}^2$ @ DAMA site

DAMA
vs. LVD

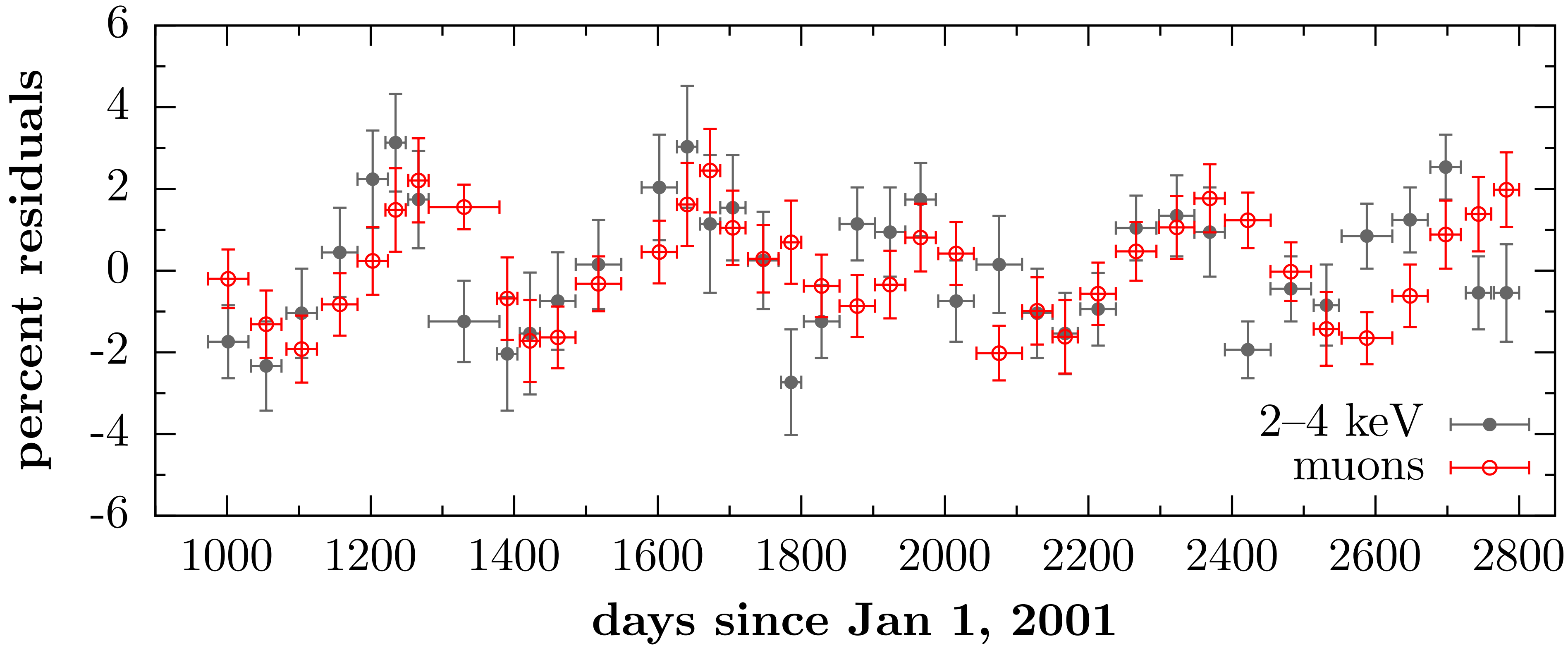
- Large Volume liquid scintillator Detector (LVD) reports underground muon-flux at LNGS => temporal overlap with DAMA data



$\overline{I}_\mu \sim 30/\text{day}/\text{m}^2$ @ DAMA site

DAMA
vs. LVD

- Large Volume liquid scintillator Detector (LVD) reports underground muon-flux at LNGS => temporal overlap with DAMA data



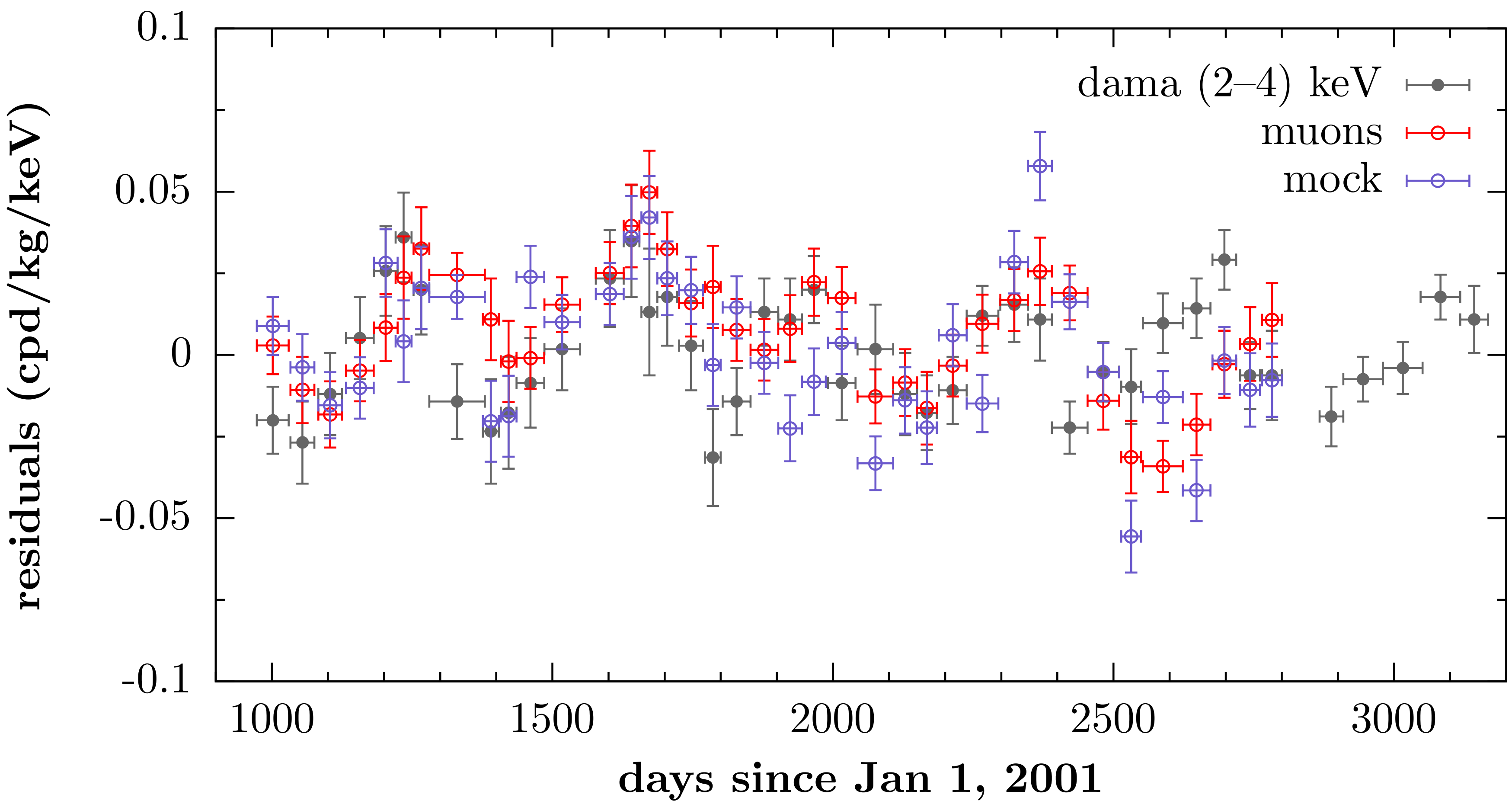
$\overline{I}_{\mu} \sim 30/\mathrm{day}/\mathrm{m}^2$ @ DAMA site

DAMA vs. LVD

$$s_i = \frac{y N_{\mu,i}}{M \Delta E \epsilon_i \Delta t_i},$$

$$\langle N_{\mu,i} \rangle = A_{\text{eff}} I_{\mu,i} \epsilon_i \Delta t_i.$$

- Large Volume liquid scintillator Detector (LVD) reports underground muon-flux at LNGS => temporal overlap with DAMA data

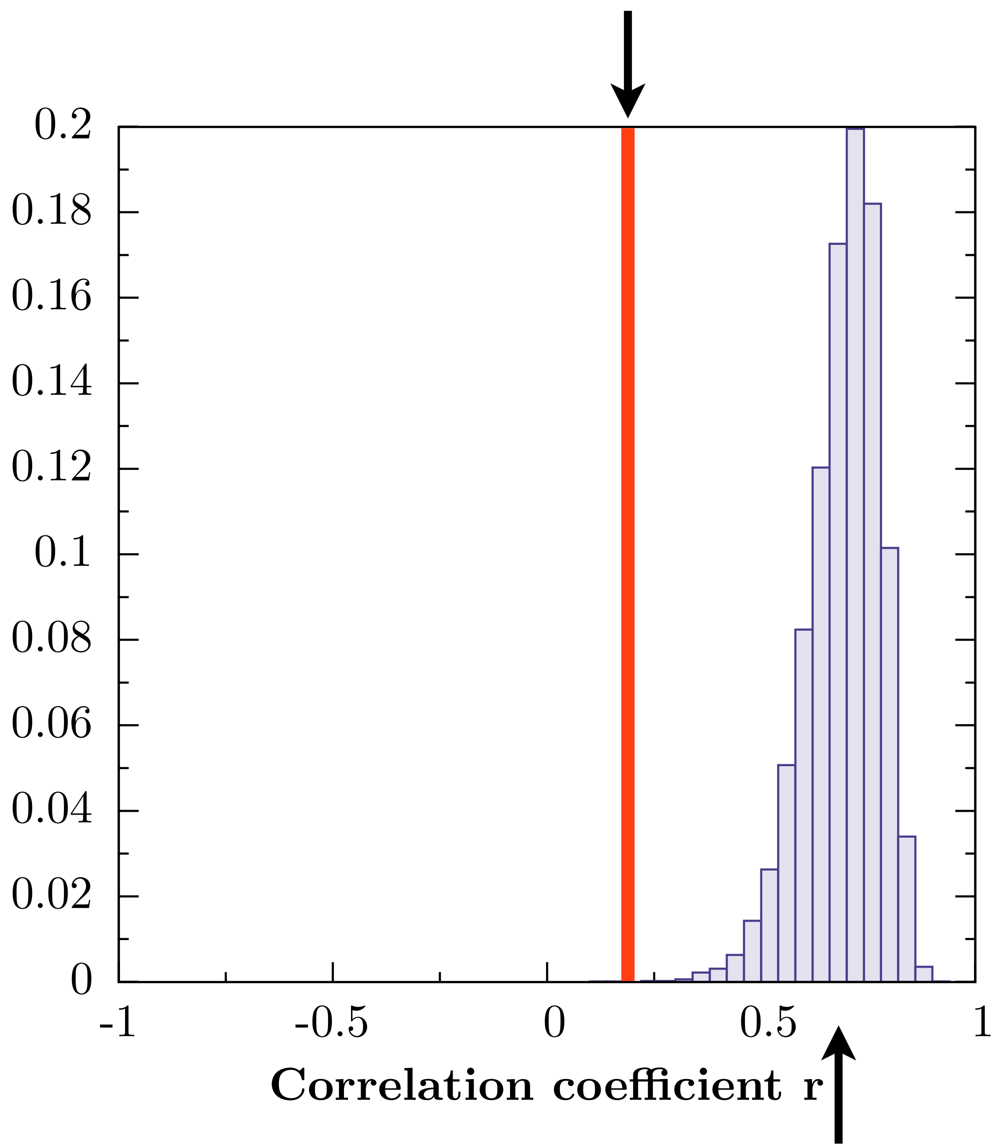


=> use LVD data to produce realizations of DAMA

Correlation study

power of the approach: no assumption on the functional form of the signal has to be made

correlation
r(muon,mock=DAMA)



correlation
r(muon,mock)

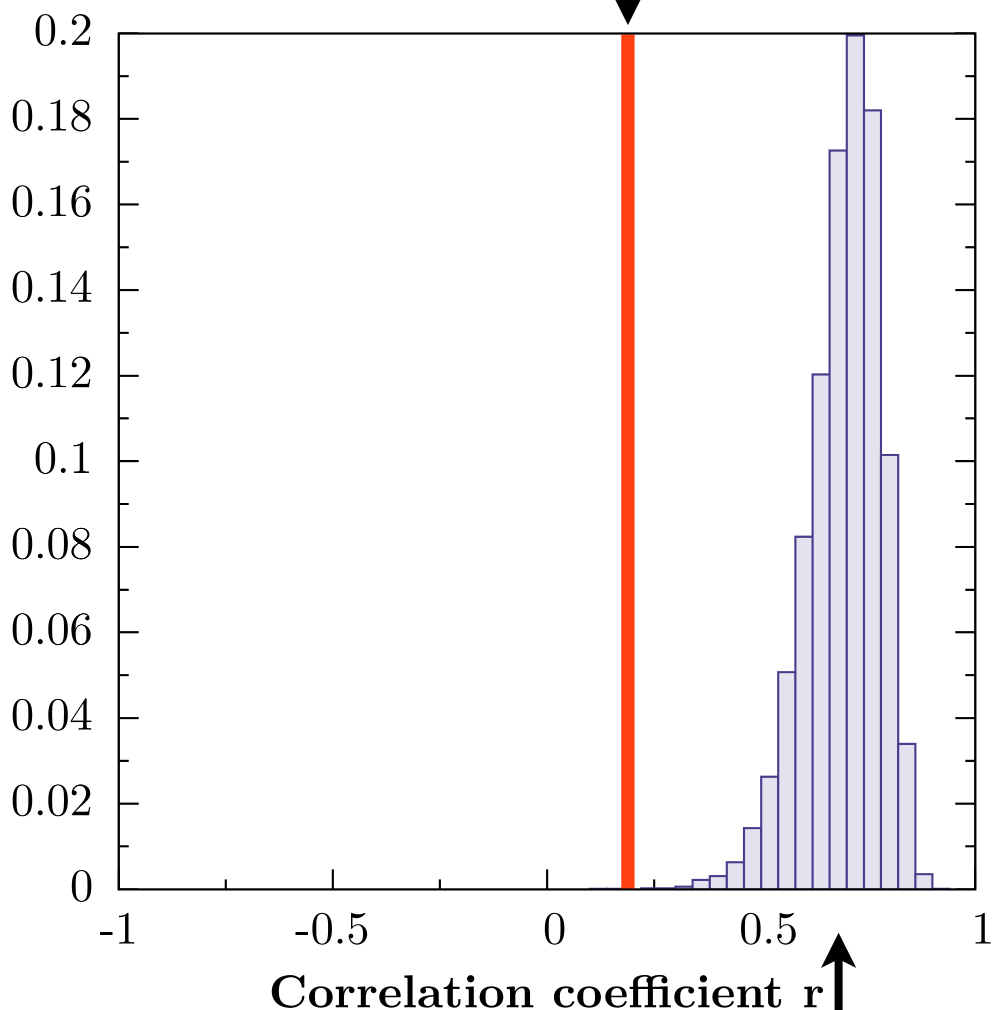
Q: how significant is the difference between these two?

Correlation study

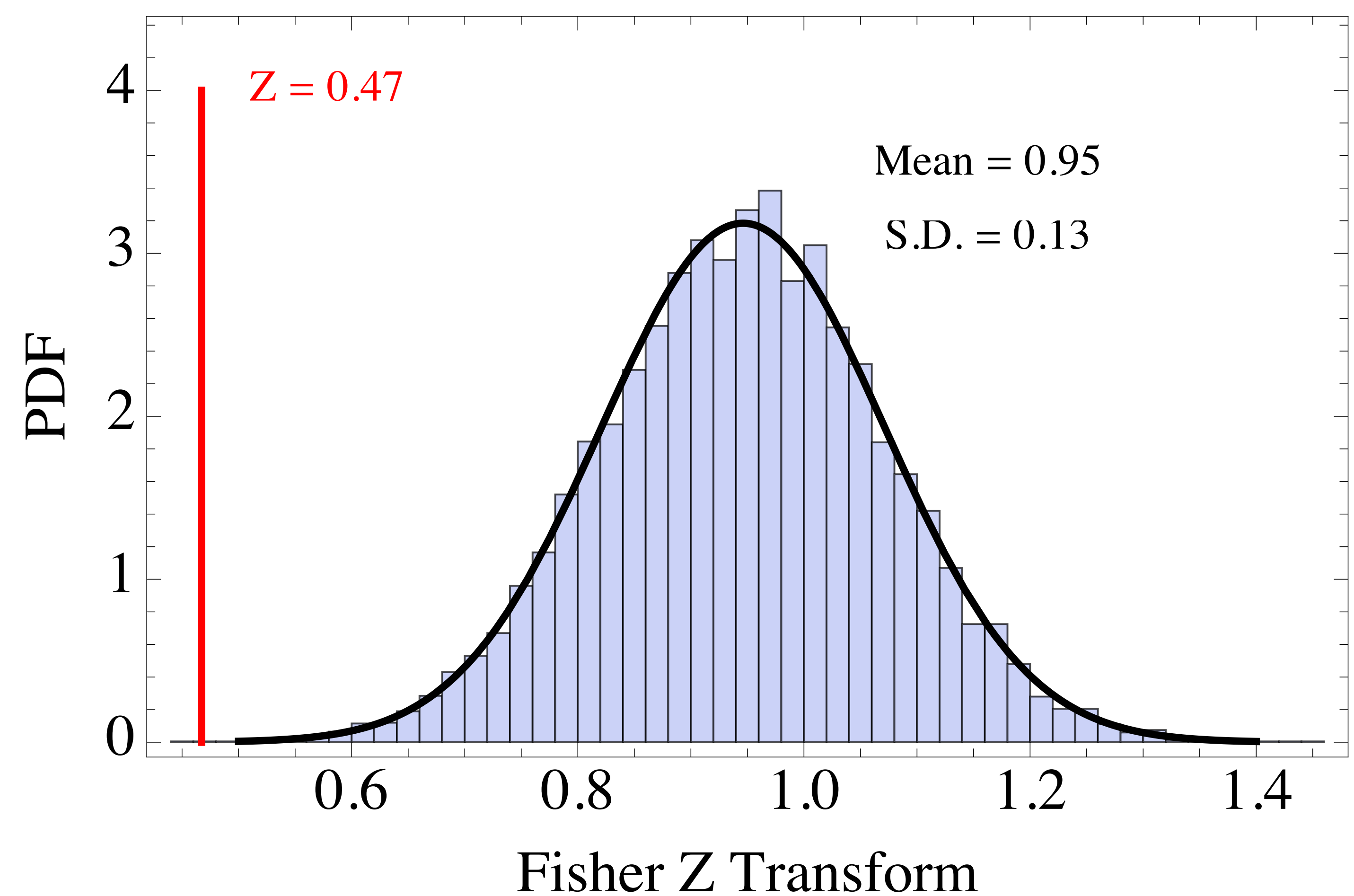
power of the approach: no assumption on the functional form of the signal has to be made

S. Chang, JP, I. Yavin 2012

correlation
r(muon,mock=DAMA)



correlation
r(muon,mock)



Muons excluded $\gtrsim 99\%$ C.L.

DAMA signal interpretation
in the presence of backgrounds

Observed modulation amplitude $S_m \simeq 0.02\,\mathrm{cpd/kg/keV}$

$$s_m^{\mathrm{obs}} = \frac{S_m}{R} = \frac{S_m}{B + S_0} \simeq 2\%$$

$$S = S_0 + S_m \cos\omega(t - t_0)$$

The higher the background, the stronger the signal must be modulated

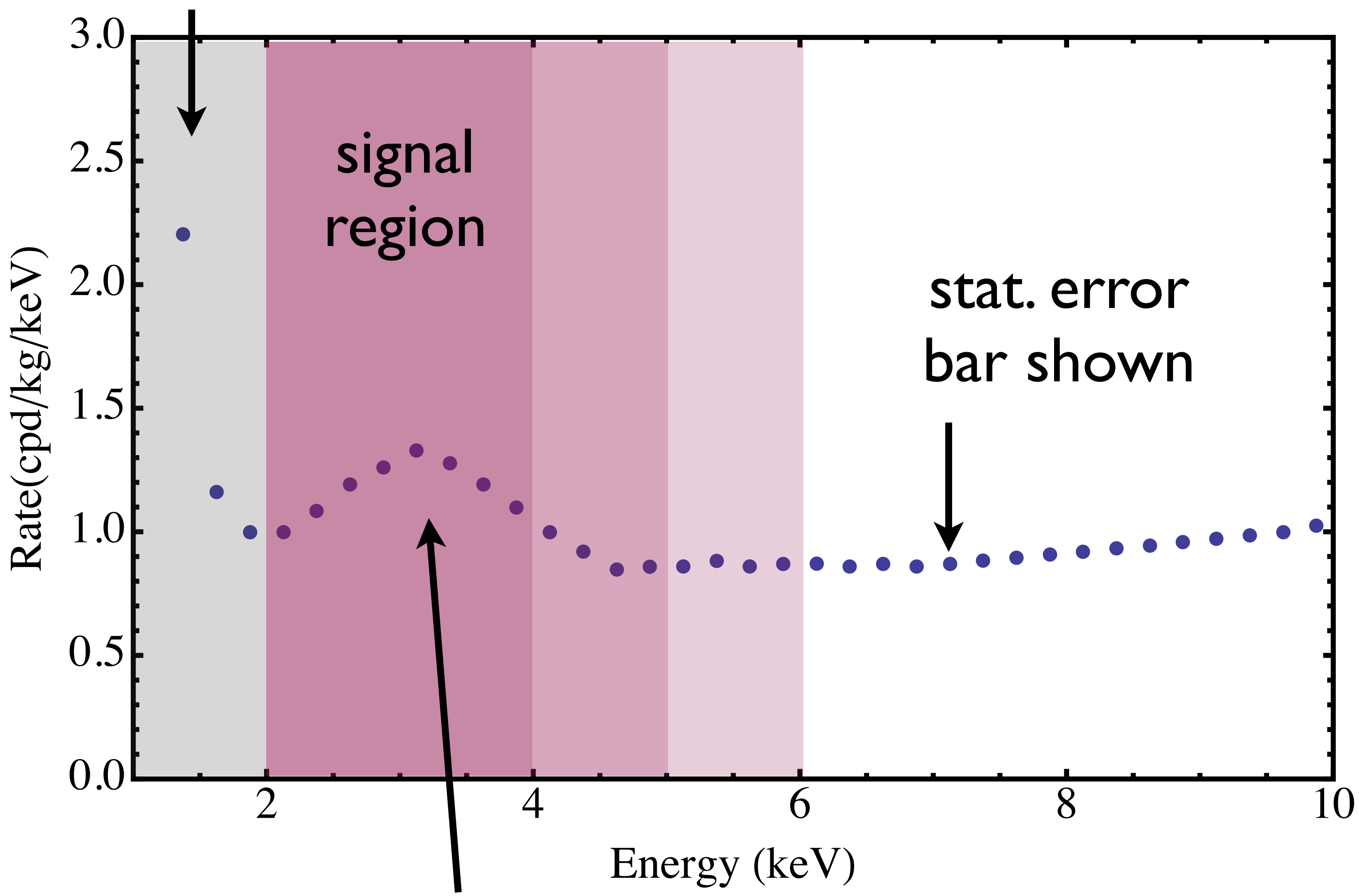
$$s_m^{\mathrm{max}} \geq s_m^{\mathrm{obs}} \left(1 + \frac{B_0}{S_0}\right) \approx 2\% \times \left(1 + \frac{B_0}{S_0}\right)$$

$$s_m^{\mathrm{max}} = S_m / S_0$$

=> take a closer look at the DAMA backgrounds to see what is needed

DAMA signal interpretation
in the presence of backgrounds

noise

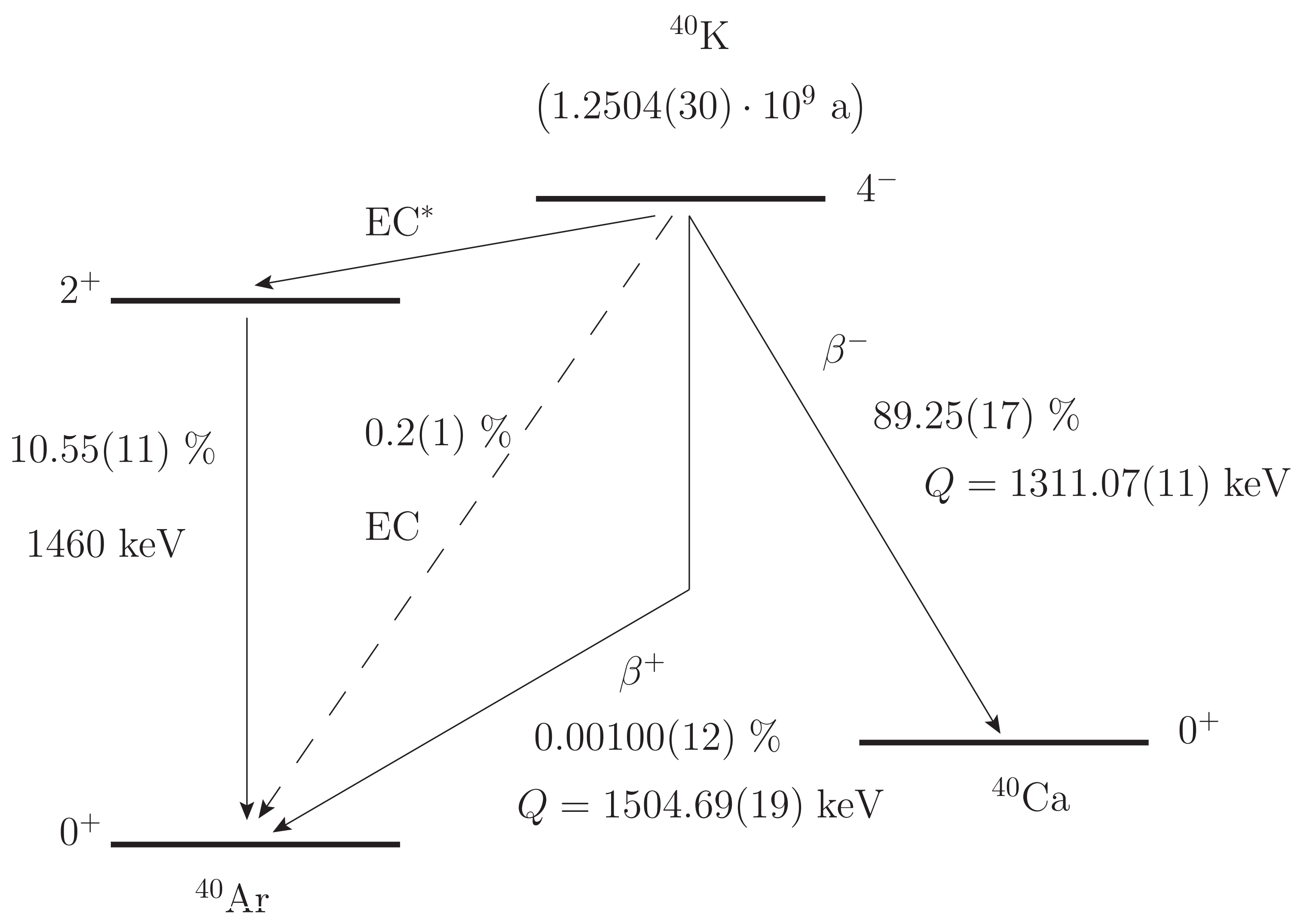


increased backgrounds in the signal region?

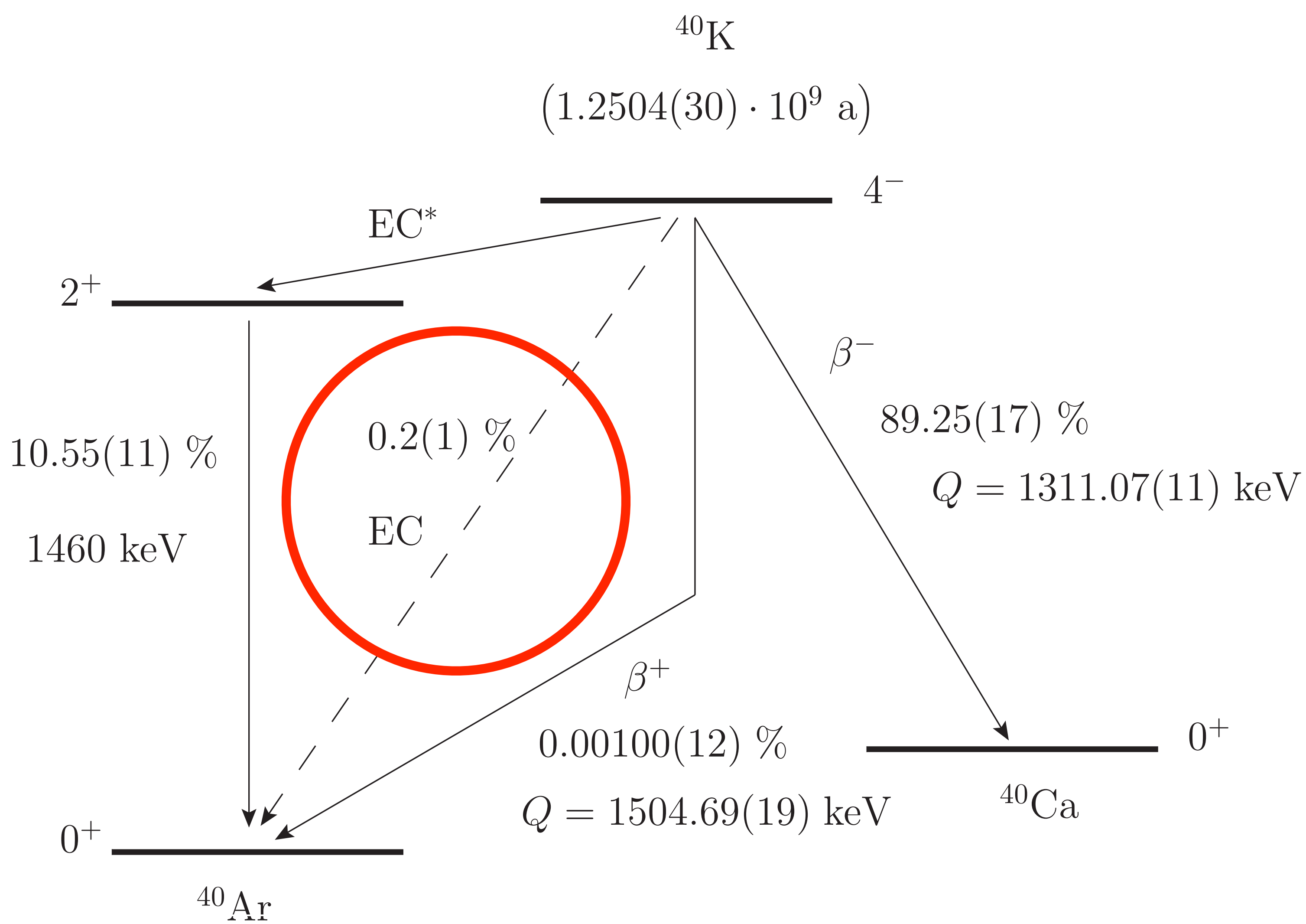
- “Single-hit” spectrum (all other detectors act as a veto)

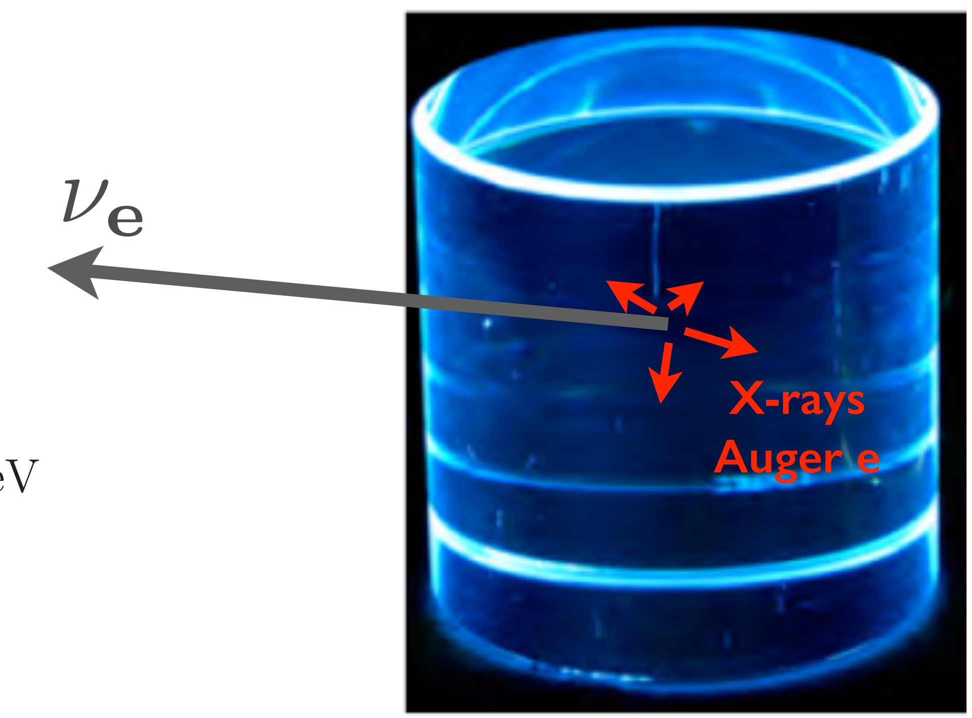
$$R \sim 1\,\mathrm{cpd/kg/keV}$$

Potassium background in DAMA
at 3 keV

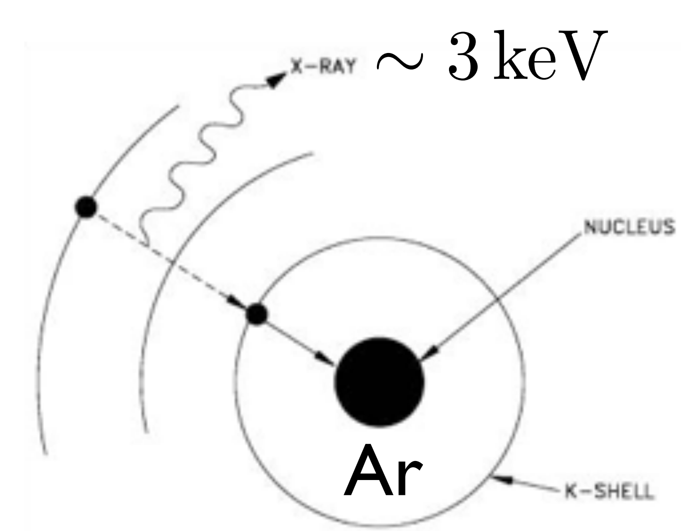


Potassium background in DAMA
at 3 keV

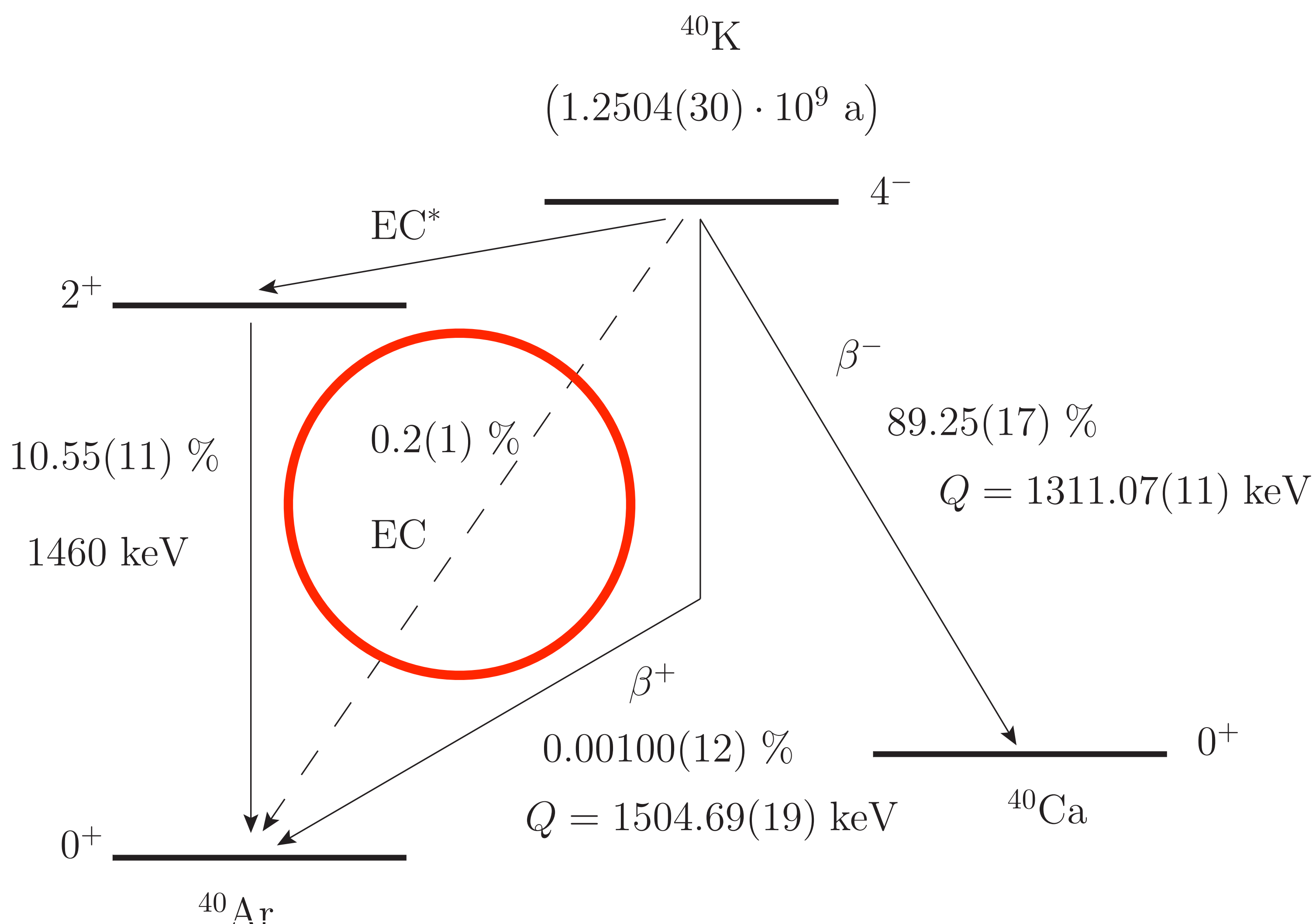


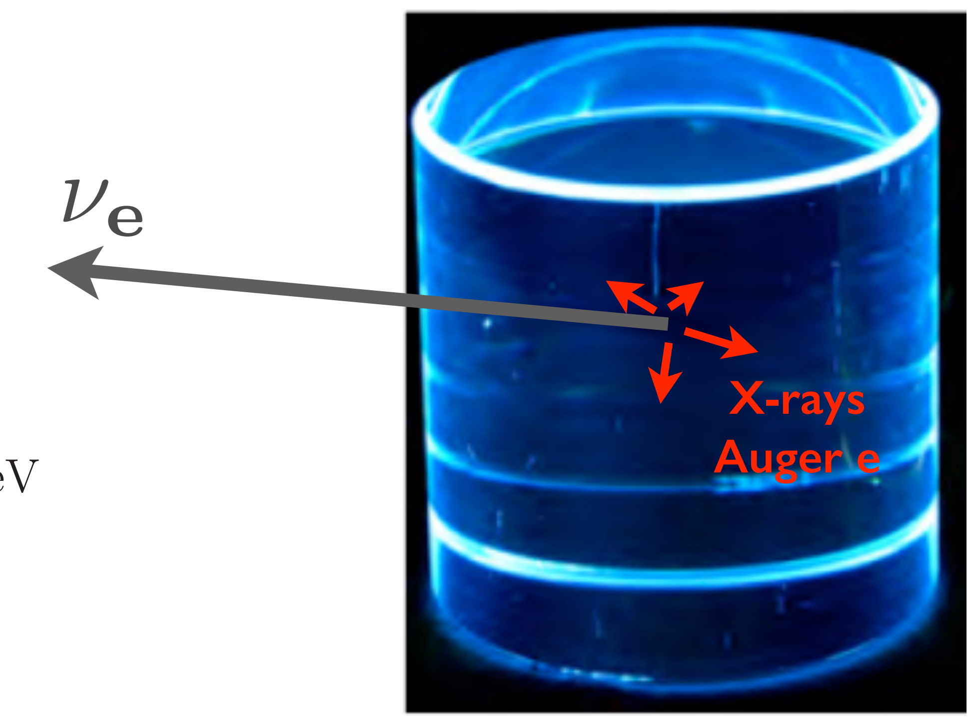


(nuclear recoil $\ll 1\,\mathrm{keV}$)

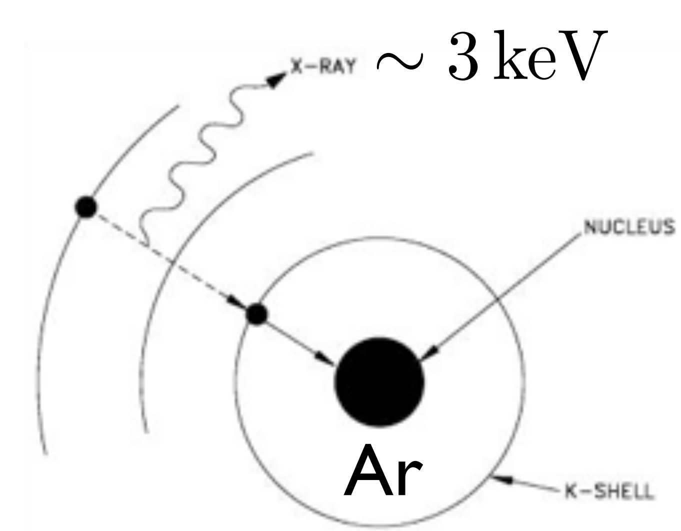


Potassium background in DAMA
at 3 keV





(nuclear recoil $\ll 1\,\mathrm{keV}$)



angular momentum change by 4 units,
"3rd forbidden unique weak decay"
=> the ONLY such EC realized in nature

Potassium background in DAMA at 3 keV

Author: JOHN A. CAMERON AND BALRAJ SINGH   Citation: Nuclear Data Sheets 102, 293 (2004)

Parent Nucleus	Parent E(level)	Parent Jπ	Parent $T_{1/2}$	Decay Mode	GS-GS Q-value (keV)	Daughter Nucleus	Decay Scheme	ENSDF file
$^{40}_{19}K$	0	4−	1.248E+9 y *3*	ε: 10.72 *13* %	1504.69 *19*	$^{40}_{18}Ar$		

Beta+:

Energy (keV)	End-point energy (keV)	Intensity (%)	Dose (MeV/Bq-s)
238.2 *3*	482.69 *19*	0.00100 % *13*	2.4E-6 *3*

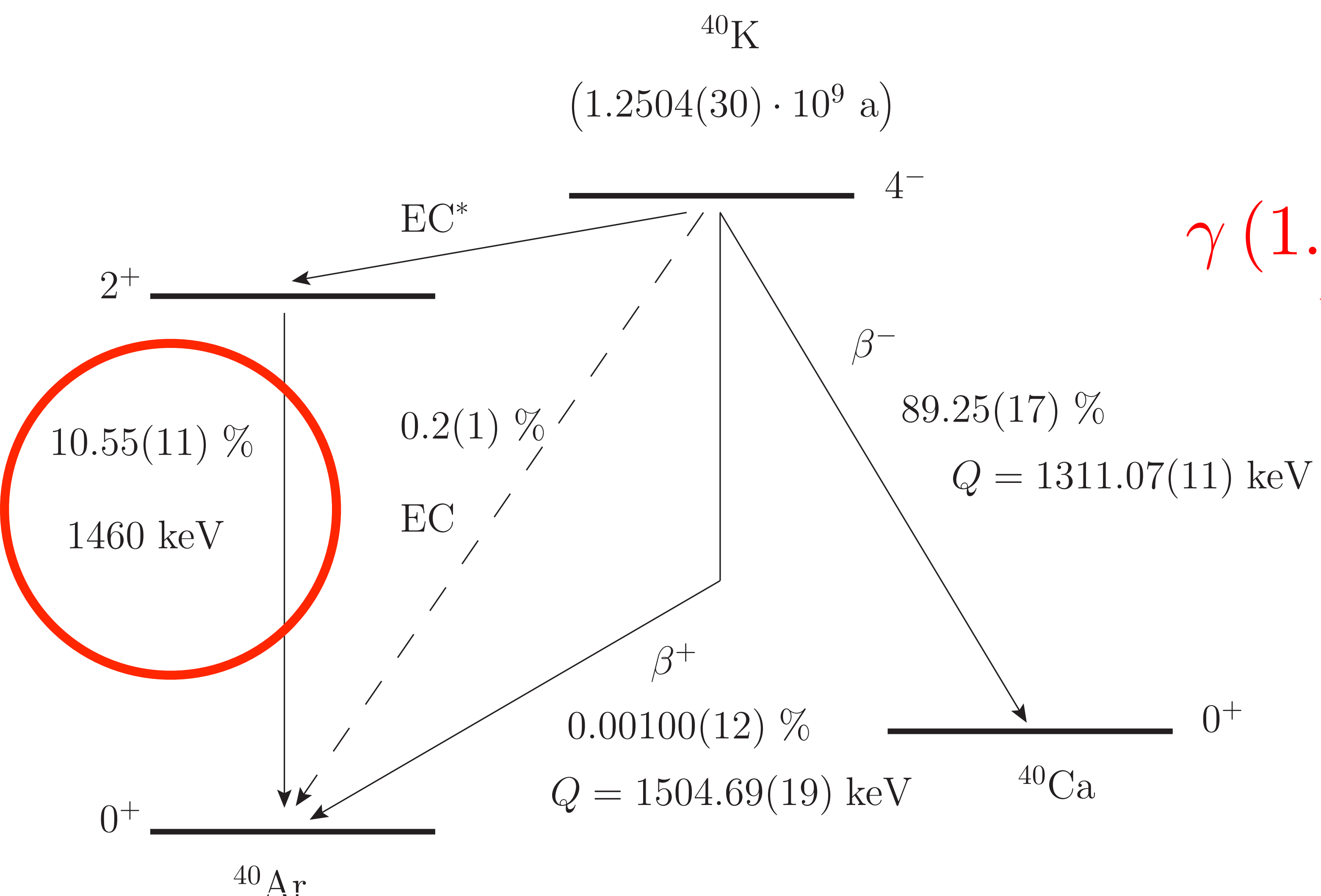
- no reported measurement for EC to g.s. of Ar!
- branching in nuclear data tables is an extrapolation
- leading order prediction can be calculated from $\lambda_{\beta+}$

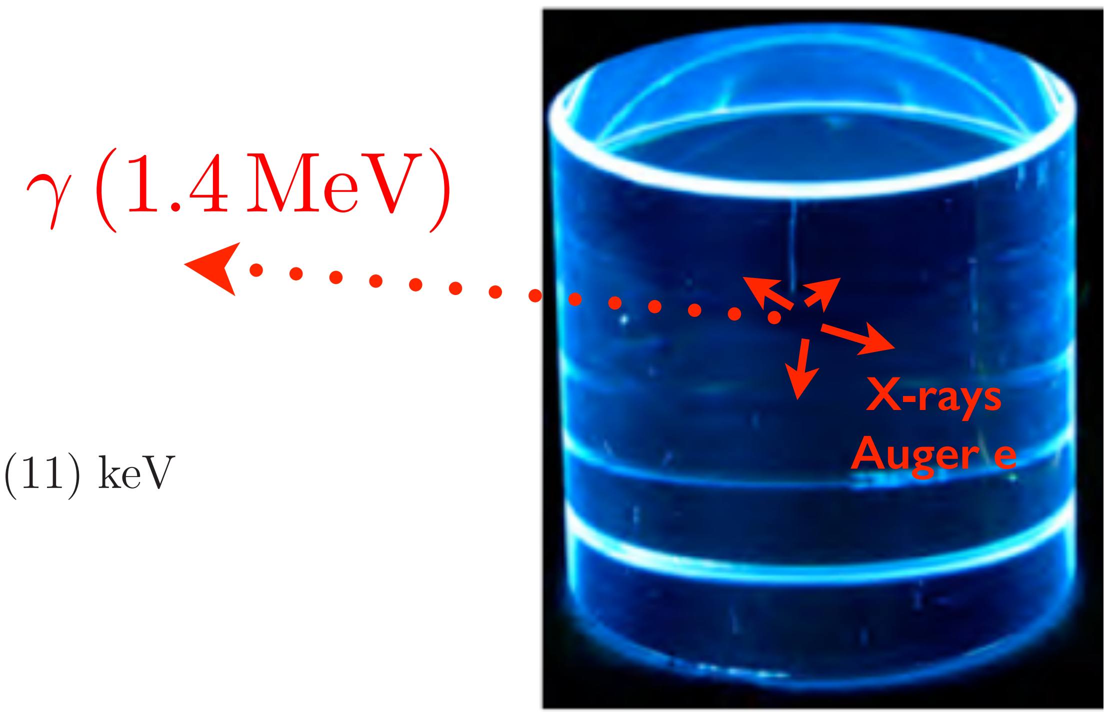
=> probably no surprises here, but:

=> its strength is of direct relevance for DAMA (but turns out not to be important)

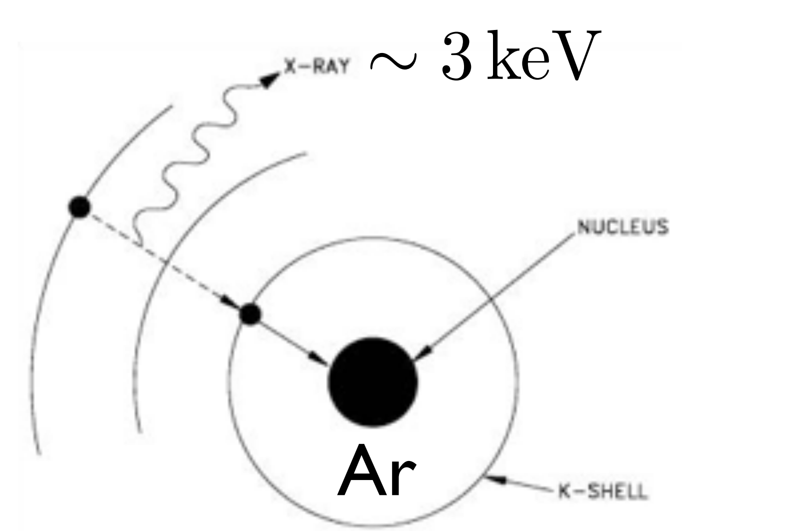
=> calls for measurement to confirm leading order prediction

Potassium background in DAMA
at 3 keV





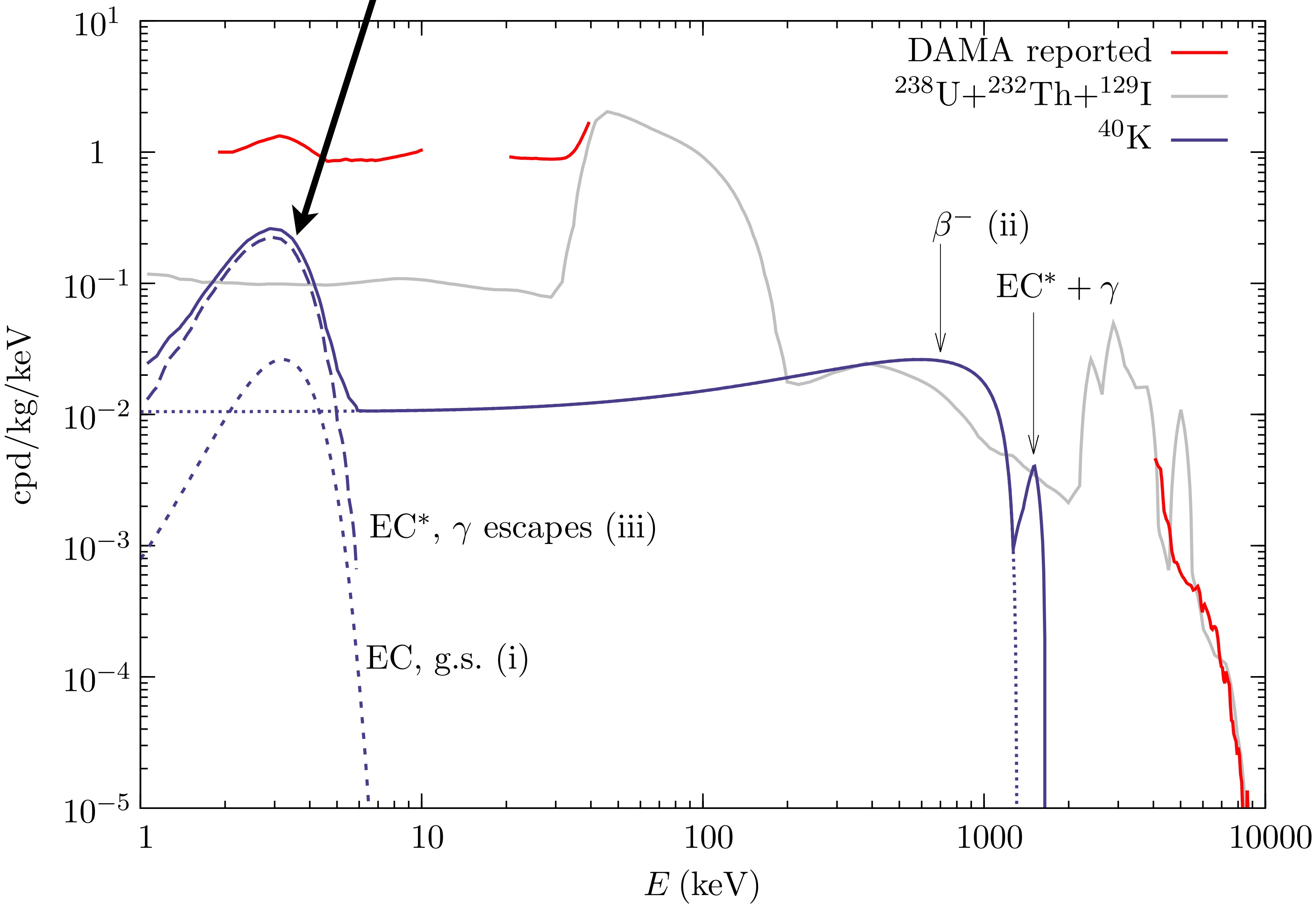
(nuclear recoil $\ll$ 1 keV)



needs MC to find rate at 3 keV
=> we employ the results from
Kudryavtsev et al 2010

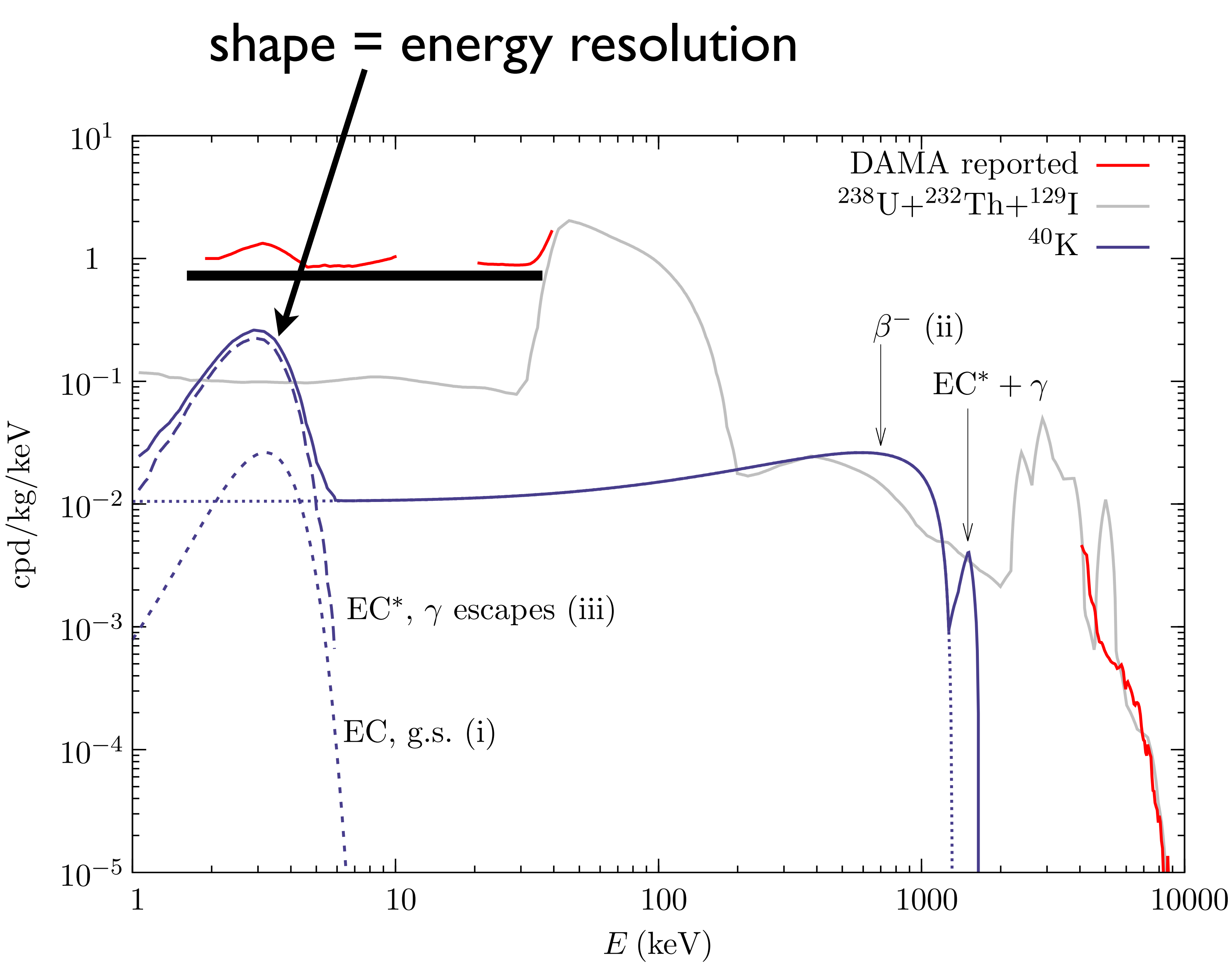
Simulated DAMA spectrum
using reported contaminations

shape = energy resolution



Simulated DAMA spectrum
using reported contaminations

shape = energy resolution



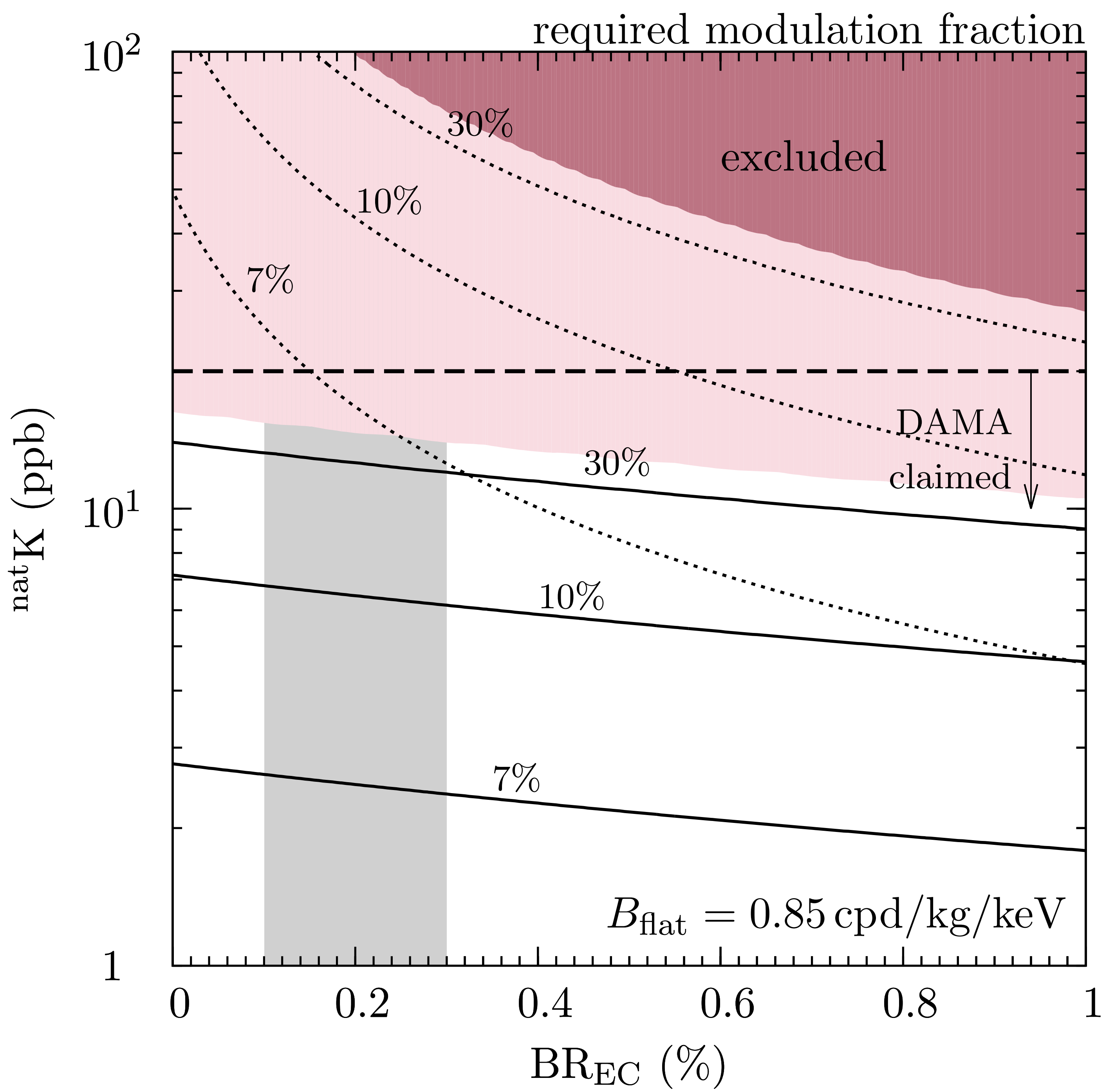
- indication of a flat background component

$$B_{\text{flat}} \simeq 0.85 \text{ cpd/kg/keV}$$

- β^- and Compton background at low energies are **flat**

=> work out implication for modulation fraction

Required modulation fraction
if a flat background is present



- challenges DM interpretation of WIMP with Maxwellian velocity distribution:

  $s_m \lesssim 10\%$

- for 13 ppb potassium contamination

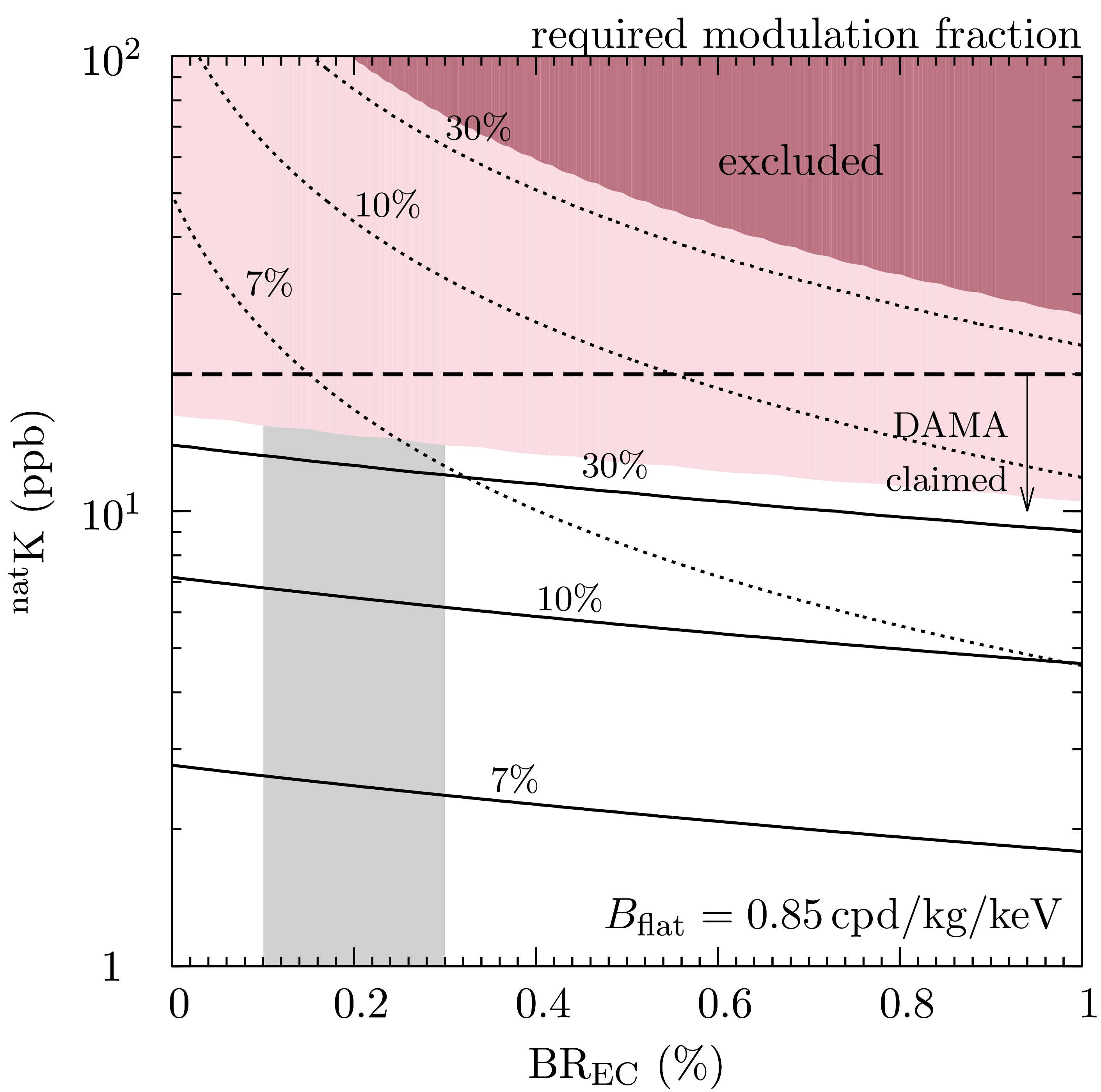
  $s_m \gtrsim 20\%$

  required!

JP, I. Yavin, B.Singh 2012

=> DAMA responded

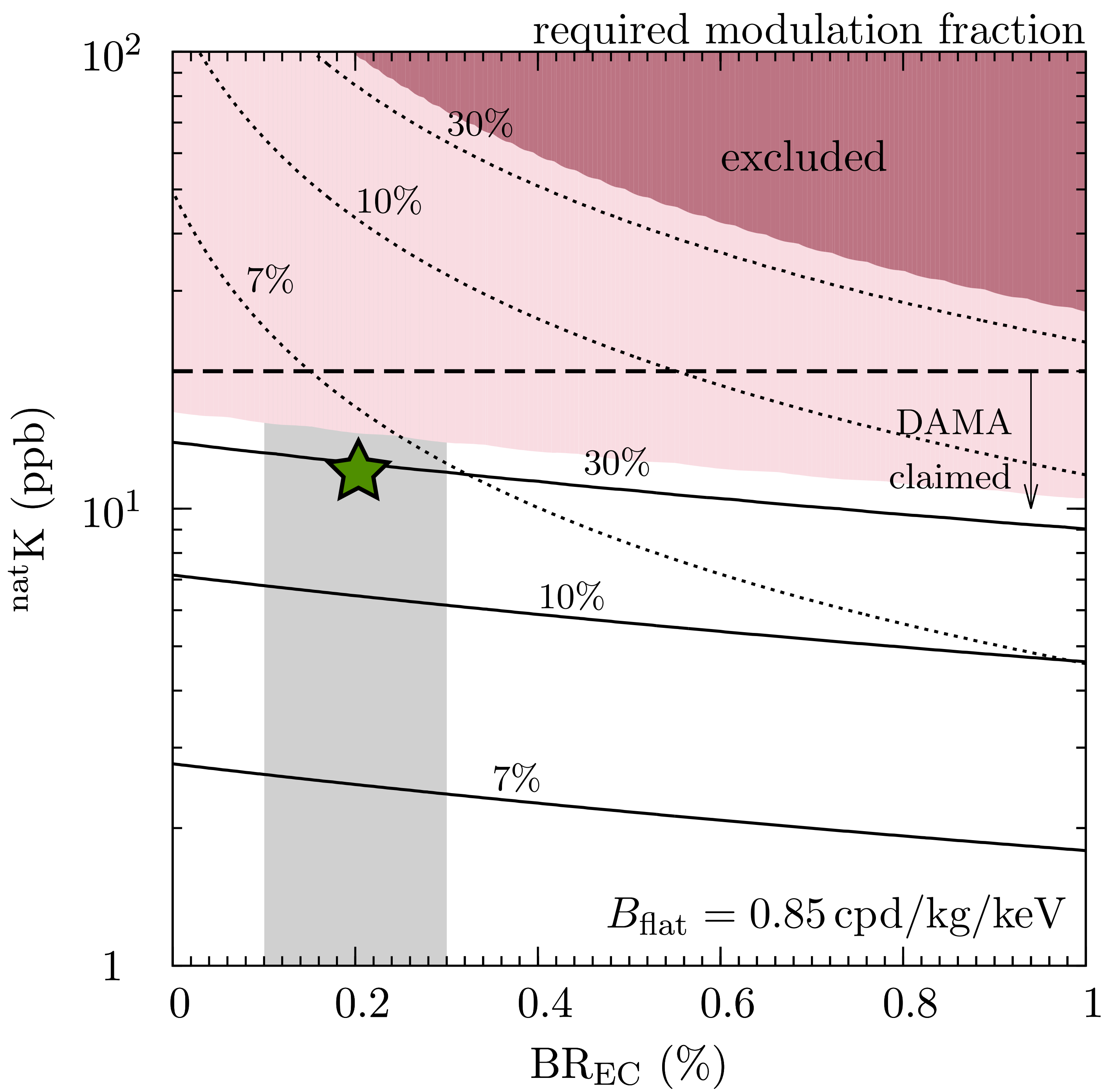
Bernabei et al. 1210.6199 & 1211.6346



- **critique 1:** avg. potassium is measured at 13ppb
- **critique 2:** EC to g.s. is only 10% => our discussion is "captious"
- **critique 3:** DAMA claims upper limit on signal => allows for 6-10% modulation!

=> DAMA responded

Bernabei et al. 1210.6199 & 1211.6346



- **critique 1:** avg. potassium is measured at 13ppb

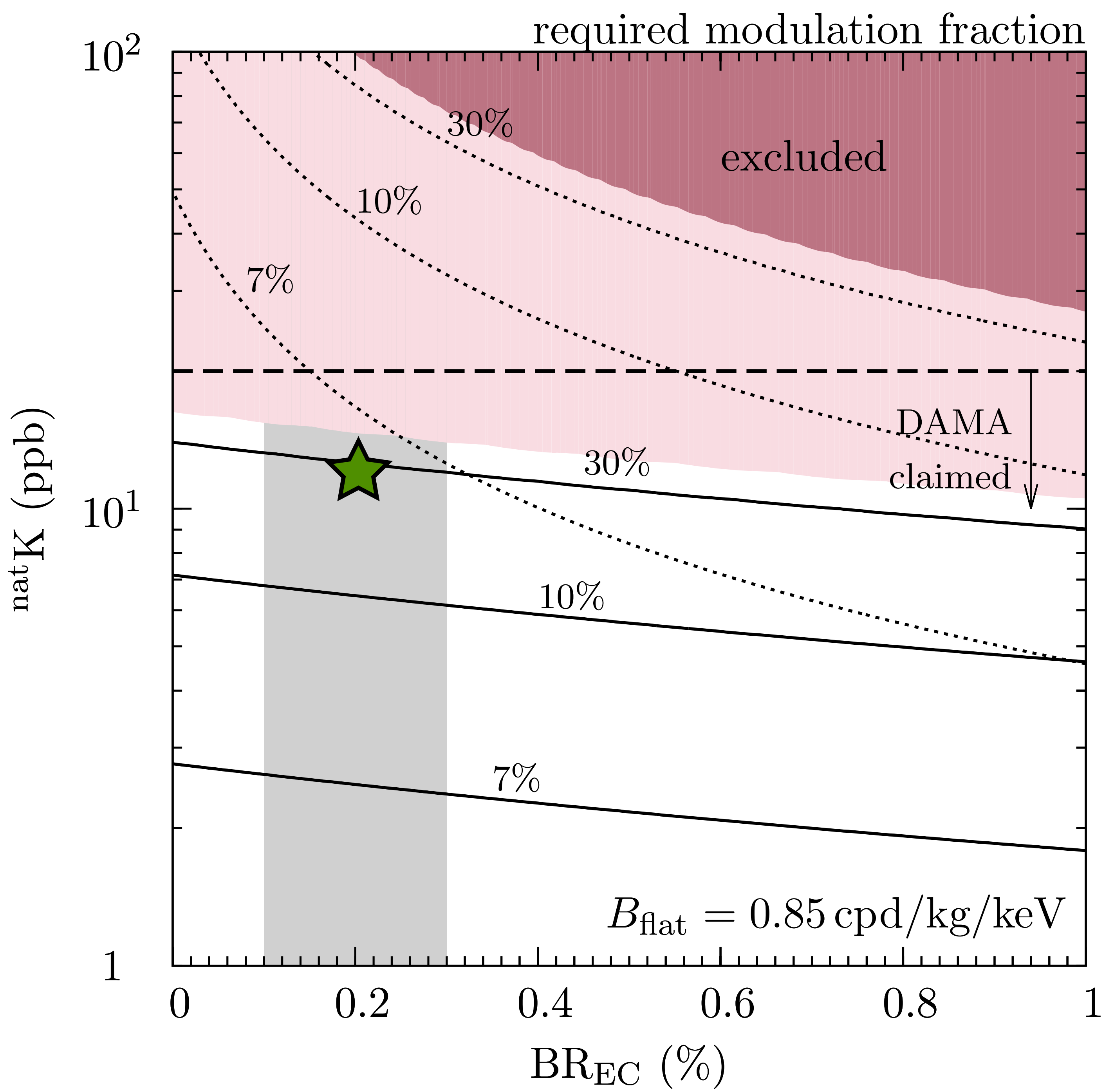
  Great. A new number in print!

- **critique 2:** EC to g.s. is only 10% => our discussion is "captious"

- **critique 3:** DAMA claims upper limit on signal => allows for 6-10% modulation!

=> DAMA responded

Bernabei et al. 1210.6199 & 1211.6346



- **critique 1:** avg. potassium is measured at 13ppb

  Great. A new number in print!

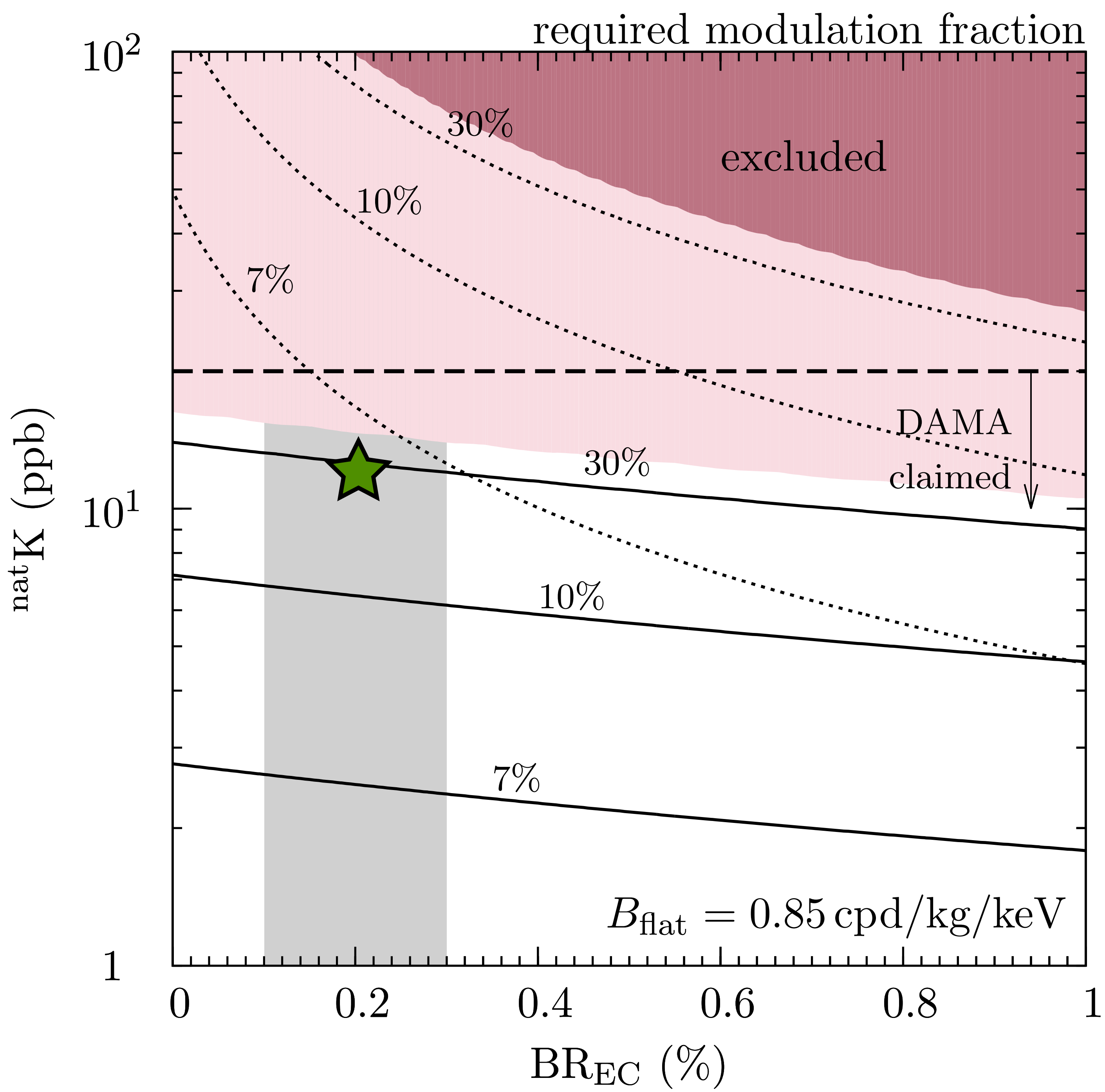
- **critique 2:** EC to g.s. is only 10% => our discussion is "captious"

  Confirms our findings.

- **critique 3:** DAMA claims upper limit on signal => allows for 6-10% modulation!

=> DAMA responded

Bernabei et al. 1210.6199 & 1211.6346



- **critique 1:** avg. potassium is measured at 13ppb

  Great. A new number in print!

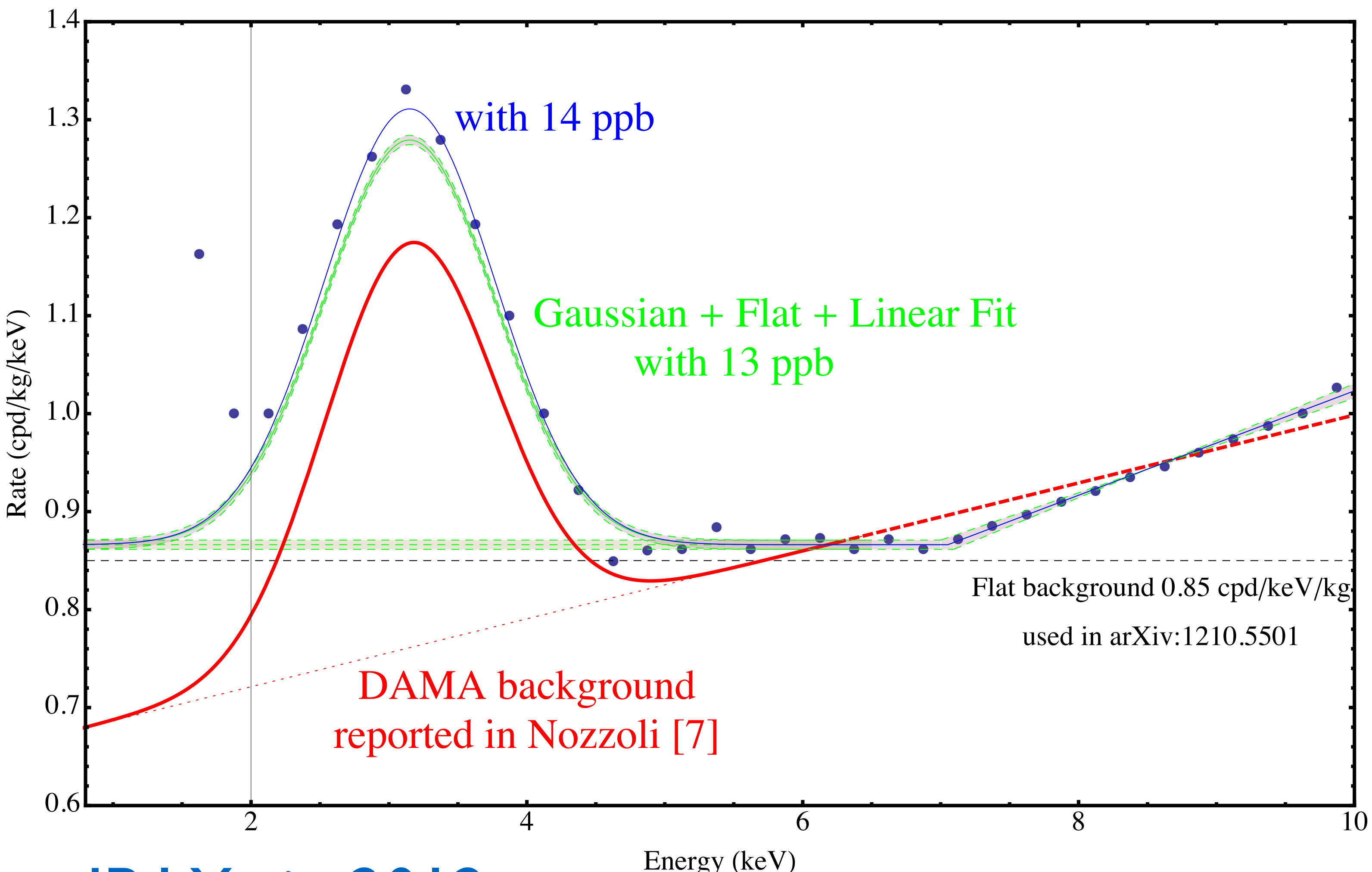
- **critique 2:** EC to g.s. is only 10% => our discussion is "captious"

  Confirms our findings.

- **critique 3:** DAMA claims upper limit on signal
  => allows for 6-10% modulation!

=> let's check.
Requires "slide-forensic".
Number not in print.

DAMA's critiques to our paper raised more questions



JP, I. Yavin 2012

our assumption of a flat background was criticized as being ad hoc …

=> however DAMA's own background model [taken from slides - no publication is available] seems in poor contact with data

Interpretation of the signal in terms of DM very sensitive to assumptions on the background! **That's all we say.**

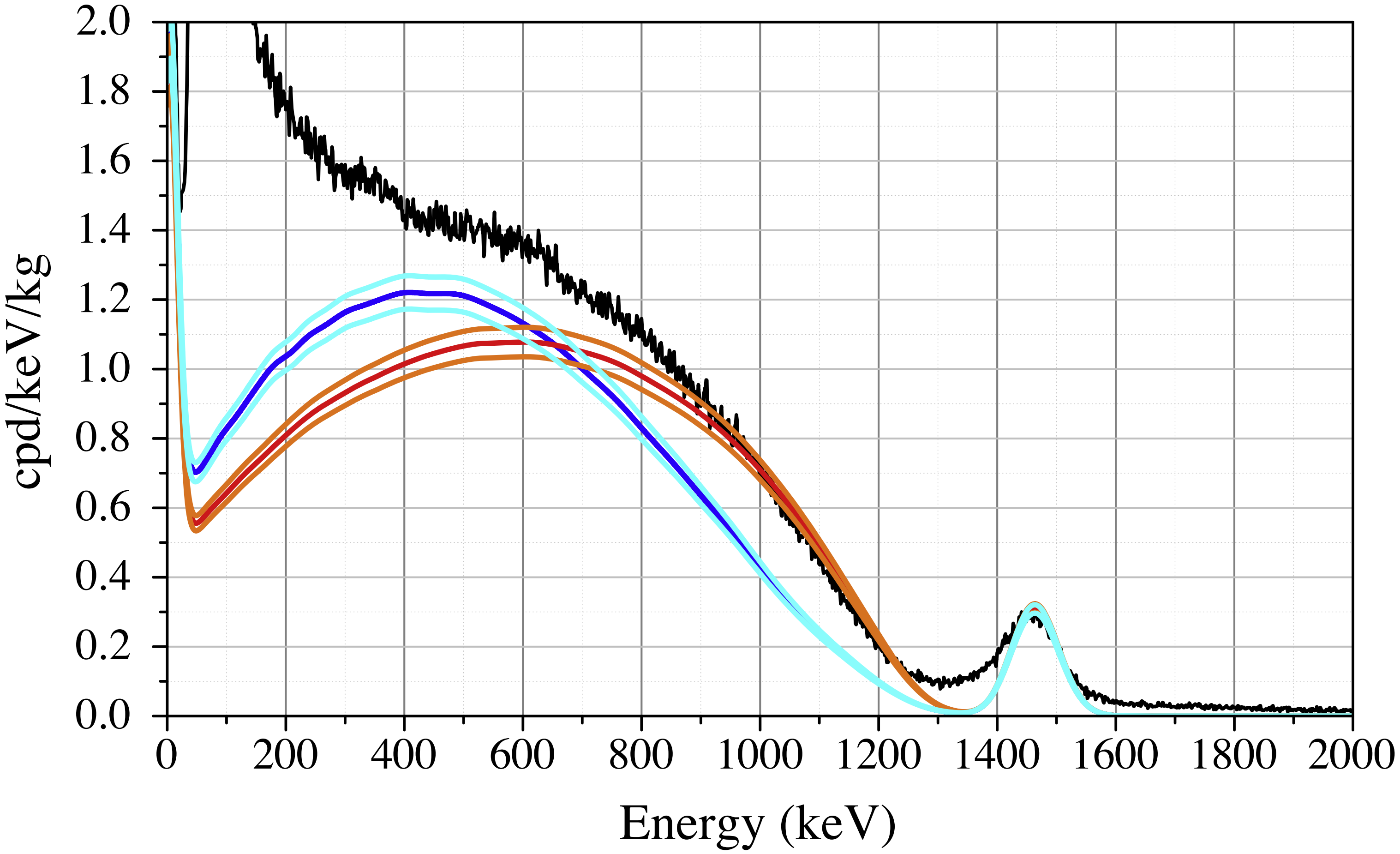
Other experiments…

ANAIS collaboration

Background model for a NaI (Tl) detector devoted to dark matter searches

S. Cebrián [a,b], C. Cuesta [a,b], J. Amaré [a,b], S. Borjabad [b], D. Fortuño [a], E. García [a,b], C. Ginestra [a,b], H. Gómez [a,b], M. Martínez [a,b], M.A. Oliván [a,b], Y. Ortigoza [a,b], A. Ortiz de Solórzano [a,b], C. Pobes [a,b], J. Puimedón [a,b], M.L. Sarsa [a,b,*], J.A. Villar [a,b]

[a] Laboratorio de Física Nuclear y Astropartículas, Universidad de Zaragoza, C/ Pedro Cerbuna 12, 50009 Zaragoza, Spain
[b] Laboratorio Subterráneo de Canfranc, Paseo de los Ayerbe s.n., 22880 Canfranc Estación, Huesca, Spain

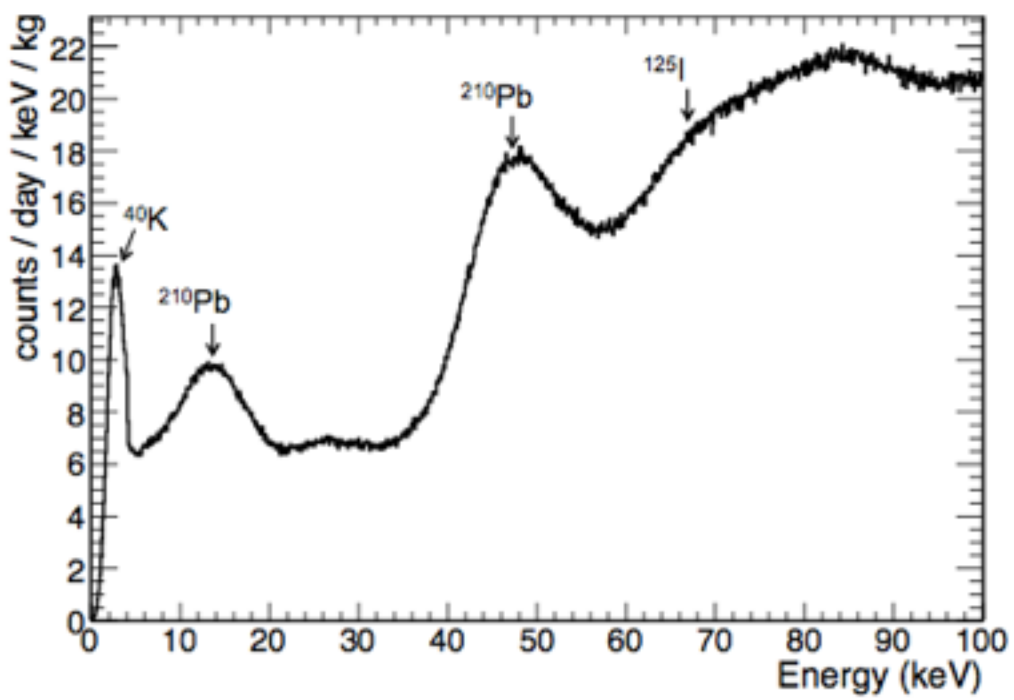


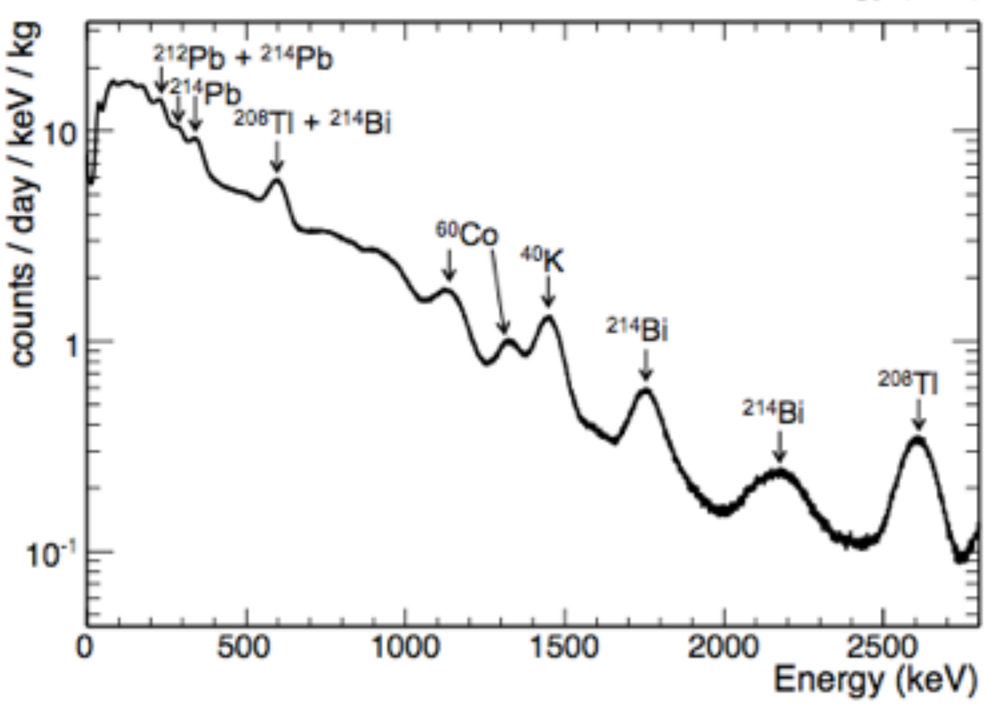
DAMA should show the K40 shoulder. Is it visible?

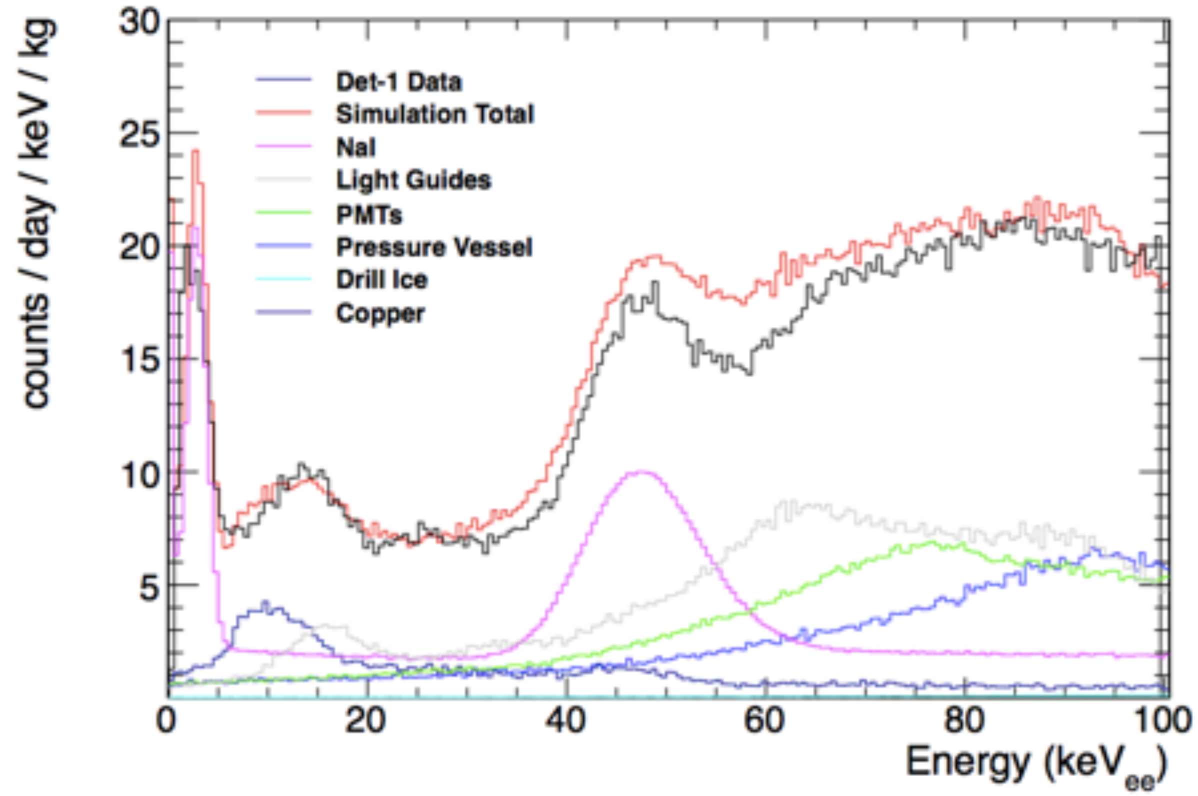
A count rate in DAMA much greater than 0.04 cpd/kg/keV at 1MeV will challenge a DM interpretation of the signal (assuming flat bkg. at 0.85 level is indeed present)

…report their MC efforts of understanding it

DM-Ice collaboration
2014







=> DAMA should show us their attempt of understanding the low energy event rate from MC simulation

Summary - I

Shown you "out-of-the-bowl" scenarios of new physics that can be tested with underground rare event searches

Liquid scintillator limits on Dark Photon Dark Matter superior to astro-constraints

Solar neutrinos with new interactions can mimic light DM

DM multiplets lead to new signatures in $0\nu 2\beta$ decay searches

Such work helps building new science cases for existing searches
(Identifying new search strategies is equally important)

Summary - II

- A theorist's take on the DAMA anomaly:

  => cosmic ray muons are unlikely the source of the annual modulation signal

  => *interpretation* of the signal in terms of DM is challenging given seeming levels of backgrounds from radioactive decays

  => more detailed communication of nuclear backgrounds would help judging the claim

  40K peak with contribution of unmeasured EC branching to 40Ar g.s. located right at the modulating signal (calls for separate measurement)

  Insight into the full spectrum would allow to compare with MC's

eps-hep2015.eu

"Extraordinary claims require extraordinary evidence."

Carl Sagan

Thank you.