LIGHT DM IN THE LIGHT OF CRESST-II

Jure Zupan
U. of Cincinnati

based on T. Schwetz, JZ 1106.6241; J. Kopp, T. Schwetz, JZ 1110.2721

THE QUESTION

- CoGeNT, DAMA, CRESST claim signals

Bernabei et al. [DAMA], 0804.2741
Aalseth et al. [CoGeNT], 1002.4703; 1106.0650
Angloher et al., [CRESST-II], 1109.0702

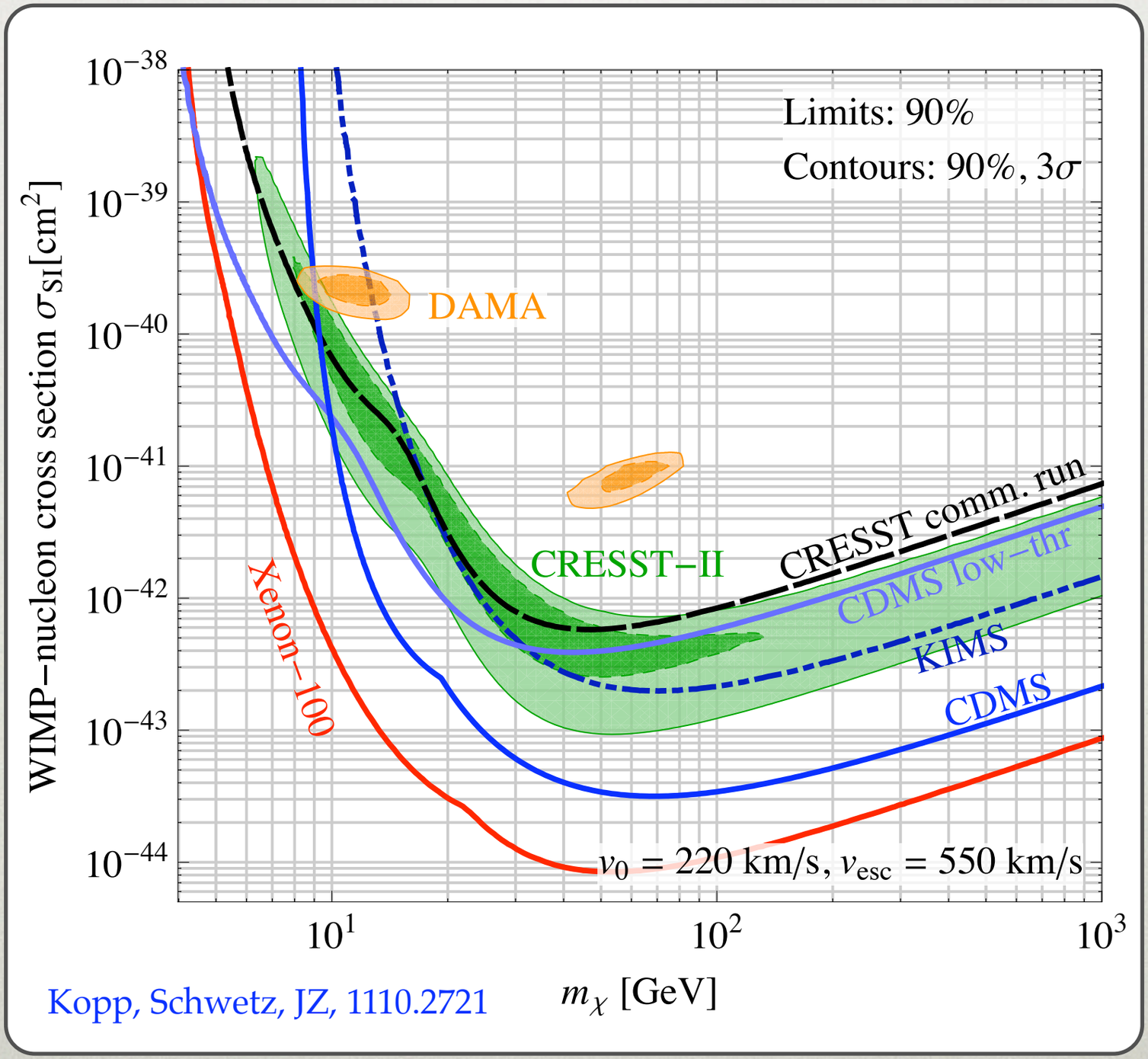
  - Is it (can it be) dark matter?

- three important results at TAUP
  - CRESST-II result
  - surface events in CoGeNT
  - KIMS result

OUTLINE

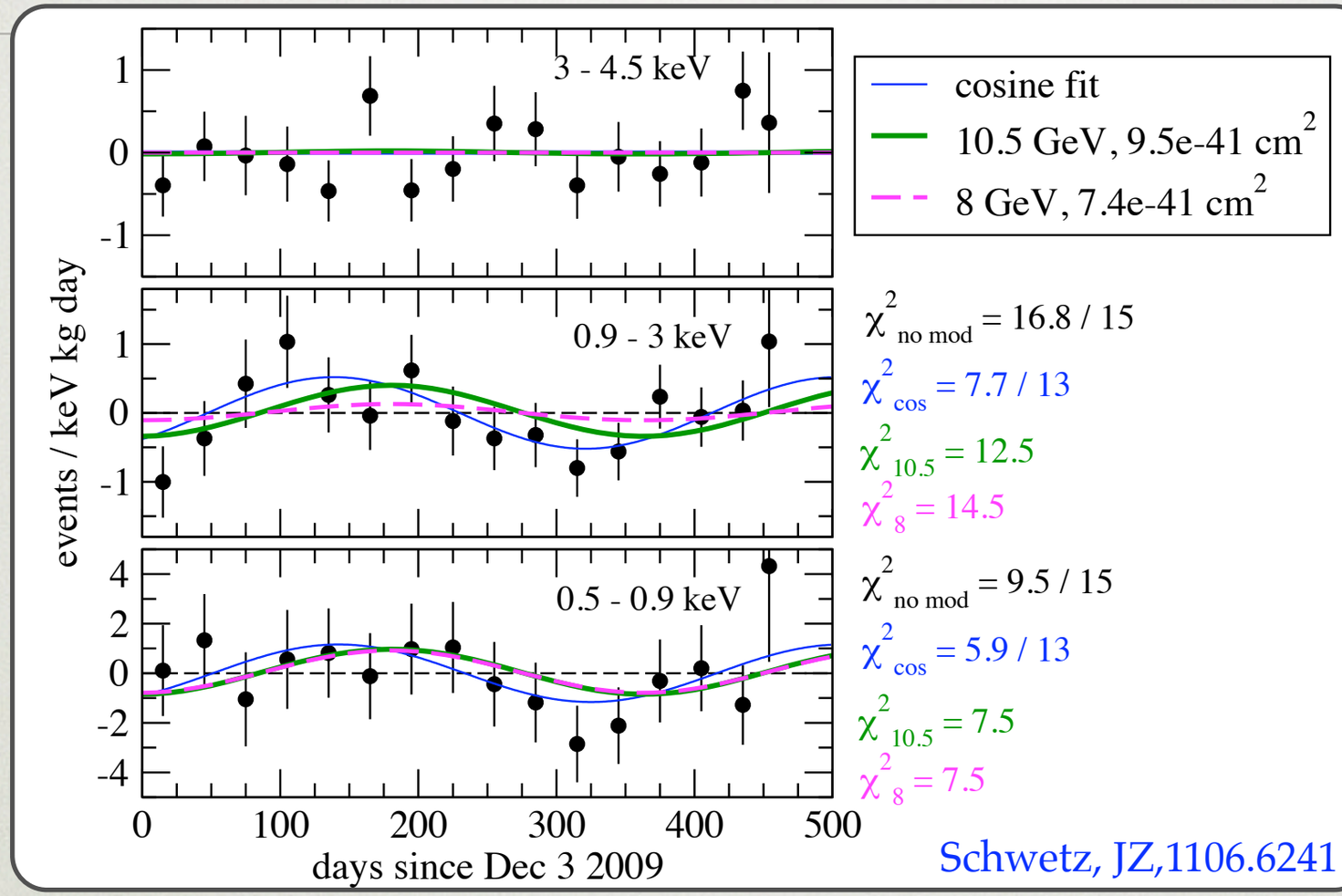
- elastic spin independent scattering
  - several comments on experimental results
- inelastic DM and isospin violating DM
- parameter goodness of fit test

SPIN INDEPENDENT SCATTERING



Kopp, Schwetz, JZ, 1110.2721

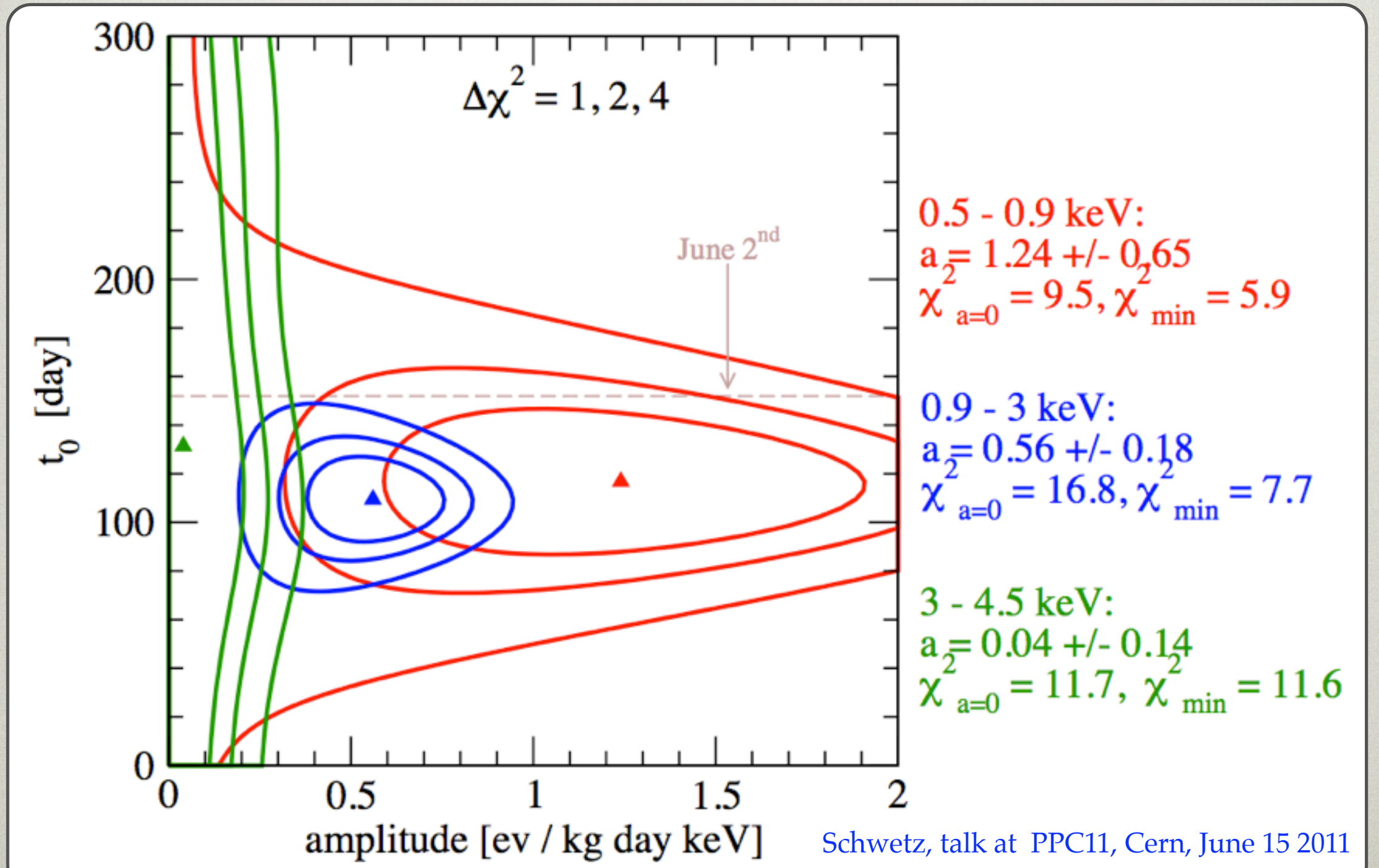
MODULATION IN COGENT?



- fit with no modulation has acceptable goodness-of-fit:
  - $\chi^2_{\text{no mod}}$ is 9.5, 16.8, 11.7 for 15 d.o.f. for 3 eng. bands
  - $\chi^2_{\text{no mod}}$=20 for 15 d.o.f. for 0.5-3 keV (17%)
- 2.8σ preference for modulation

Aalseth et al. [CoGeNT], 1106.0650

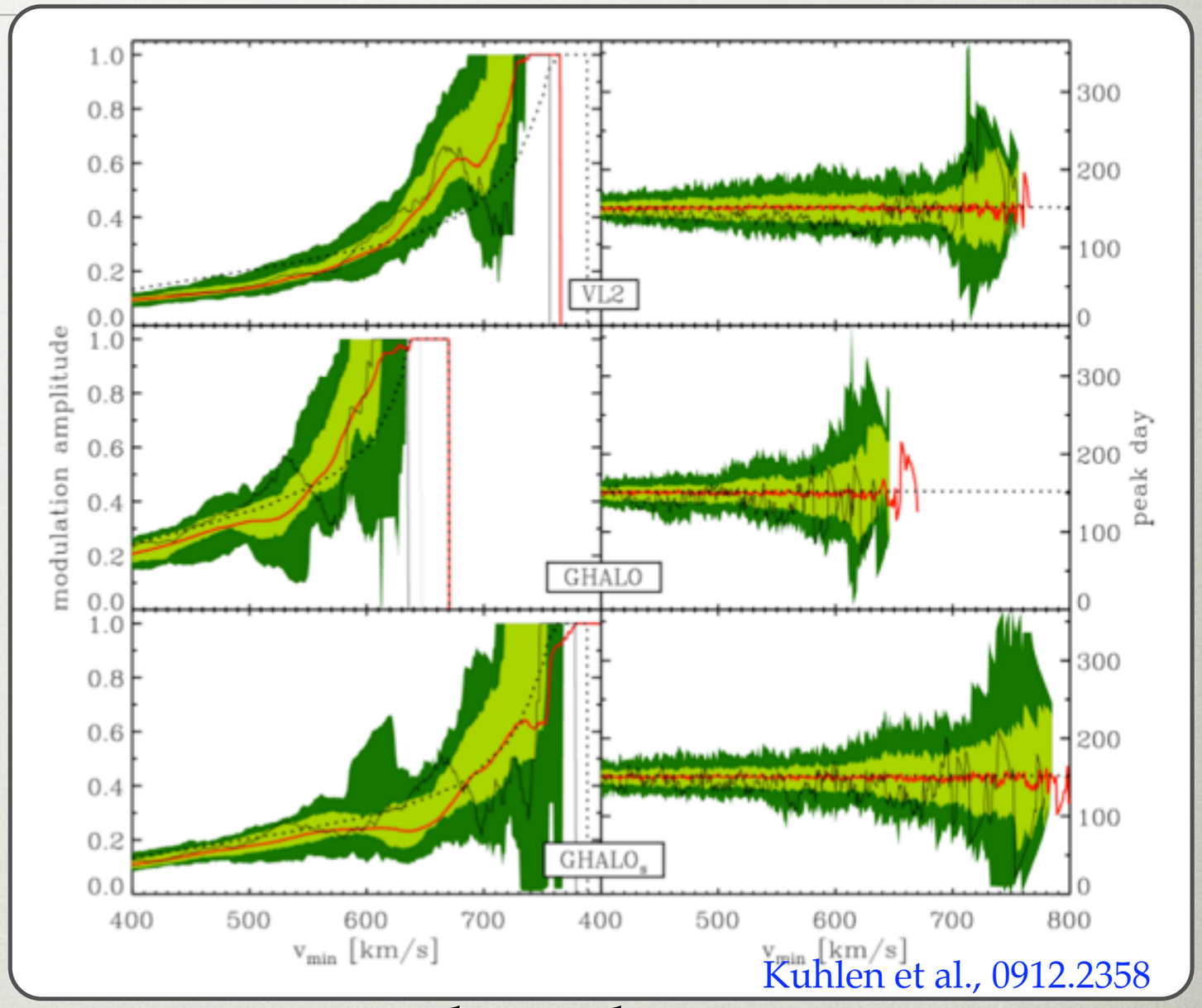
PHASE OF THE MODULATION



Schwetz, talk at PPC11, Cern, June 15 2011

VARIATIONS OF PHASE

- peak at day 152 in standard halo model only
- variations especially pronounced for light DM



Kuhlen et al., 0912.2358

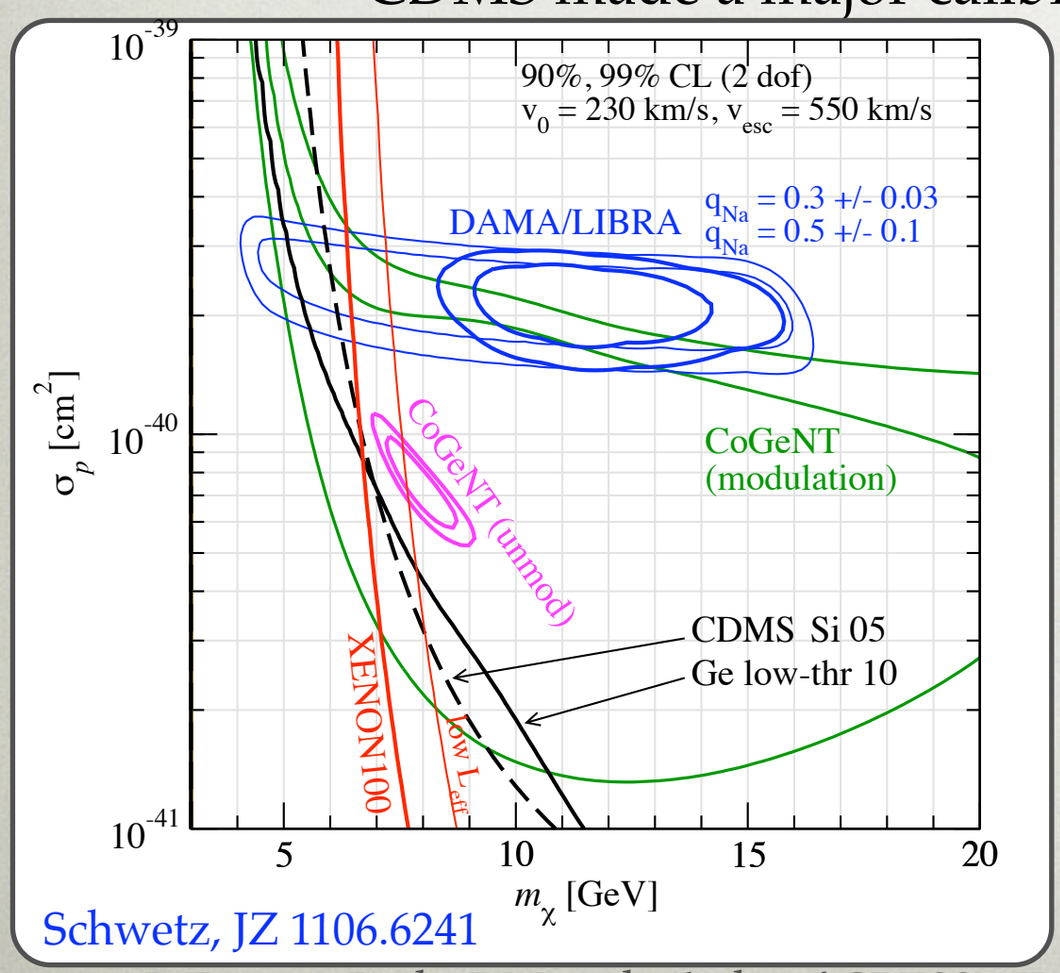
- if experiments compared within the same v_{min} range the phase should be the same

COMPARING DAMA AND COGENT

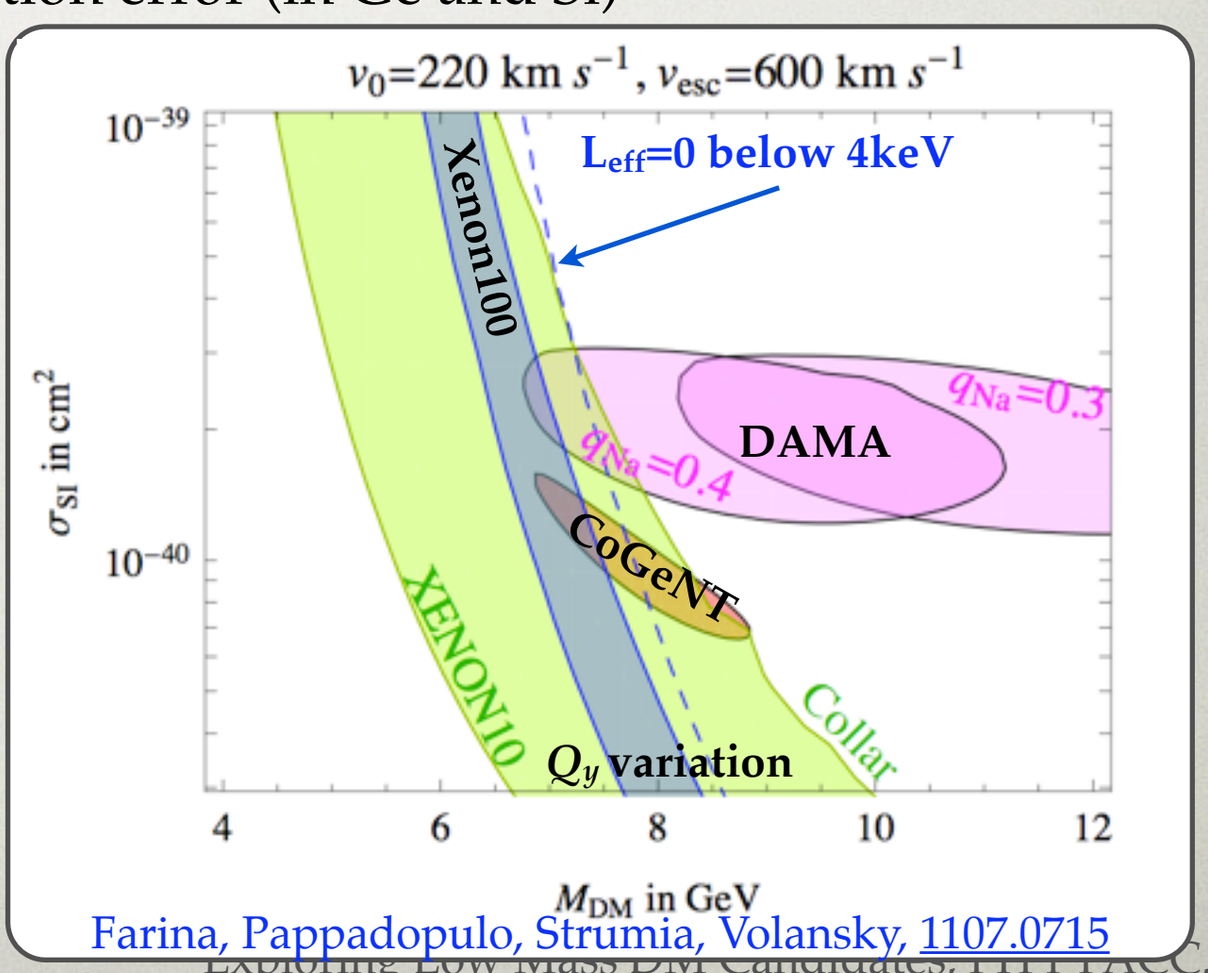
- for eSI CoGeNT (and DAMA) to be consistent with the rest one would need
  - L_{eff} drop to zero below measurements
  - q_{Na} should be significantly larger
  - energy calibration of Xenon10 S2 analysis needs to be off
  - CDMS made a major calibration error (in Ge and Si)

see talk by J. Collar

Hooper, Collar, Hall, McKinsey, 1007.1005;
Hooper, Kelso, 1106.1066



Schwetz, JZ 1106.6241



Farina, Pappadopulo, Strumia, Volansky, 1107.0715

SURFACE EVENTS

- CoGeNT found that bulk of their signal is due to surface event
- will there be a signal left once results finalized?
- what is the effect of this contamination on best fit?
  - makes the disagreement between CoGeNT and DAMA worse
- due to this uncertainty will disregard CoGeNT

SURFACE EVENTS

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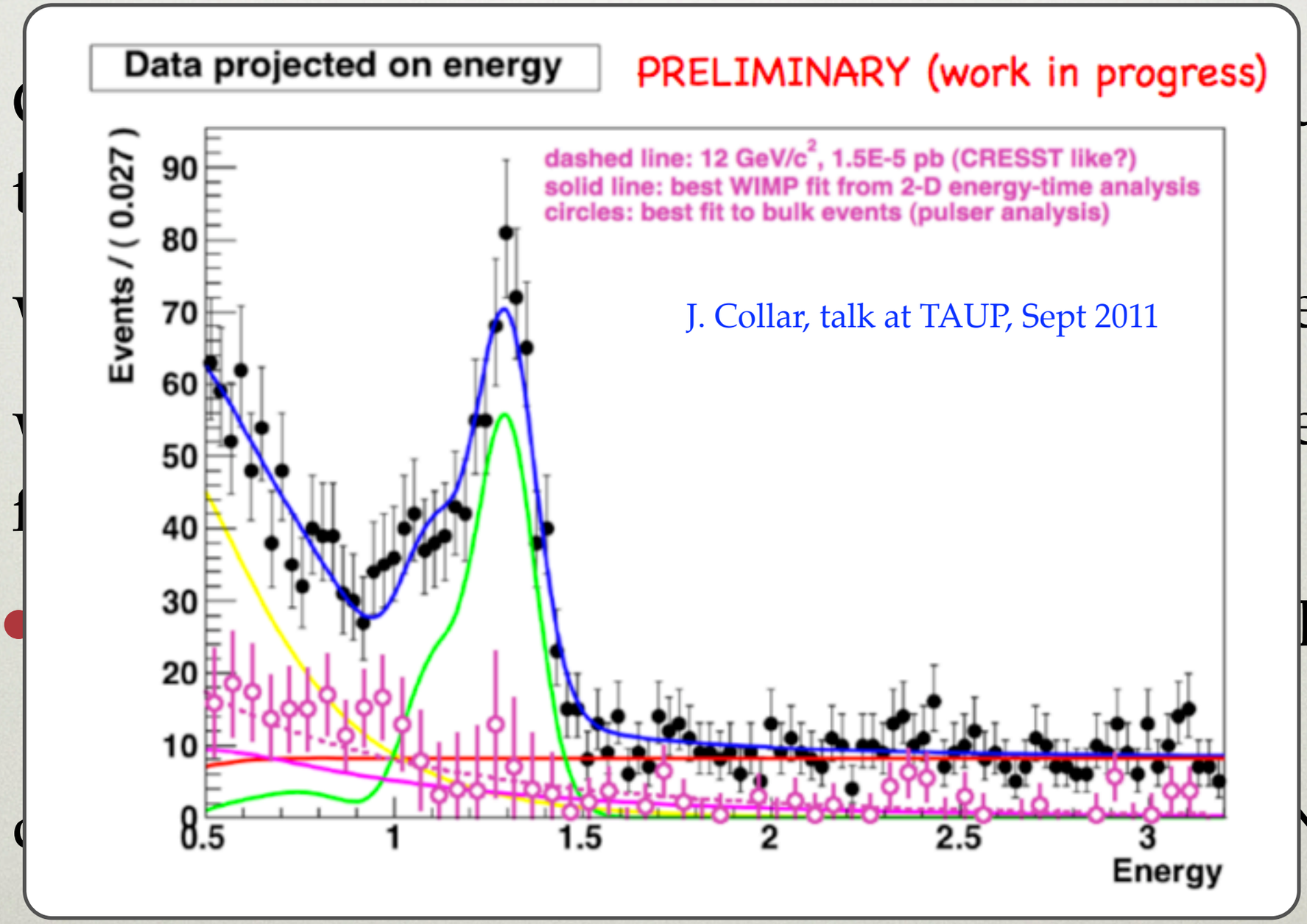

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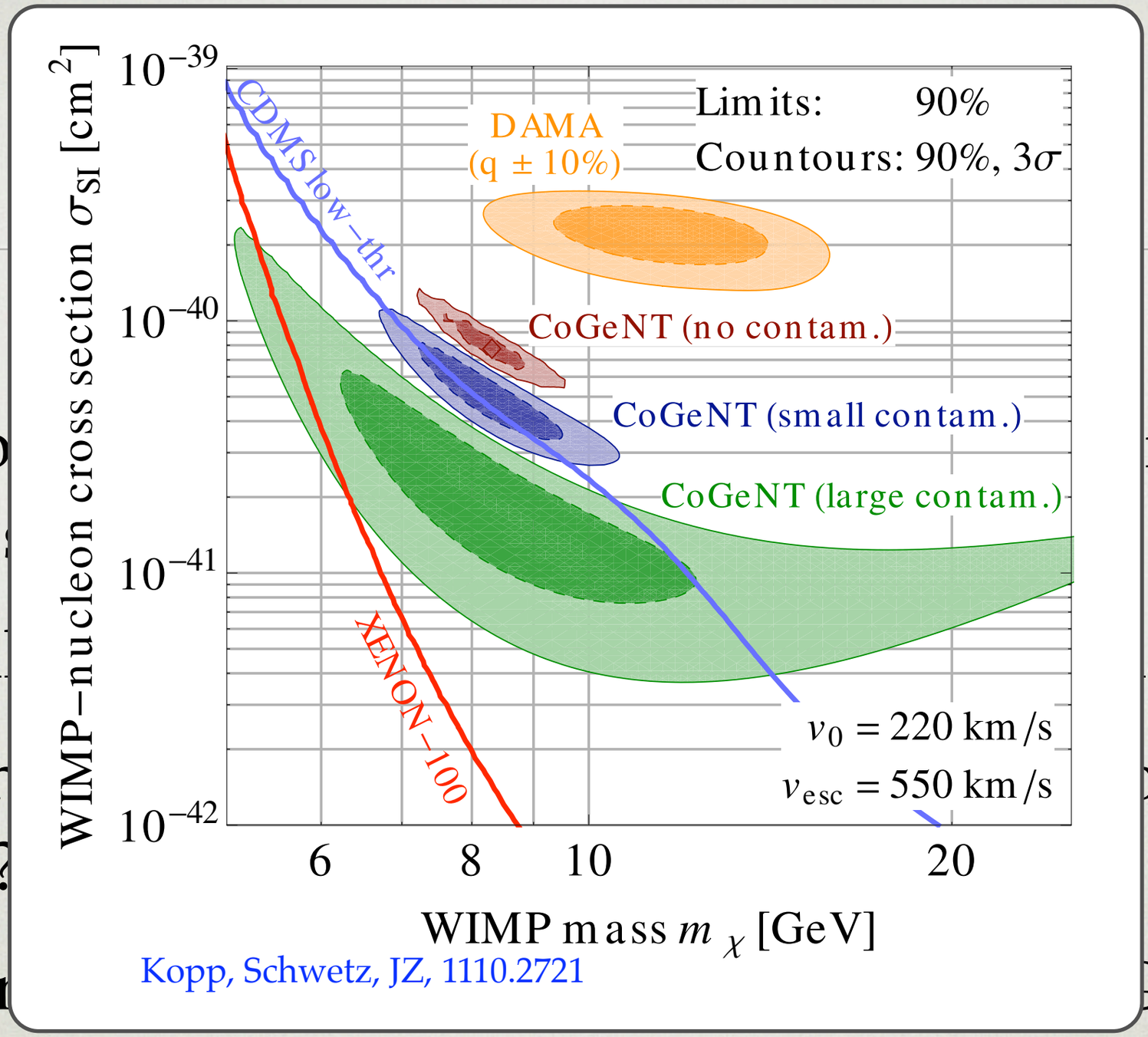
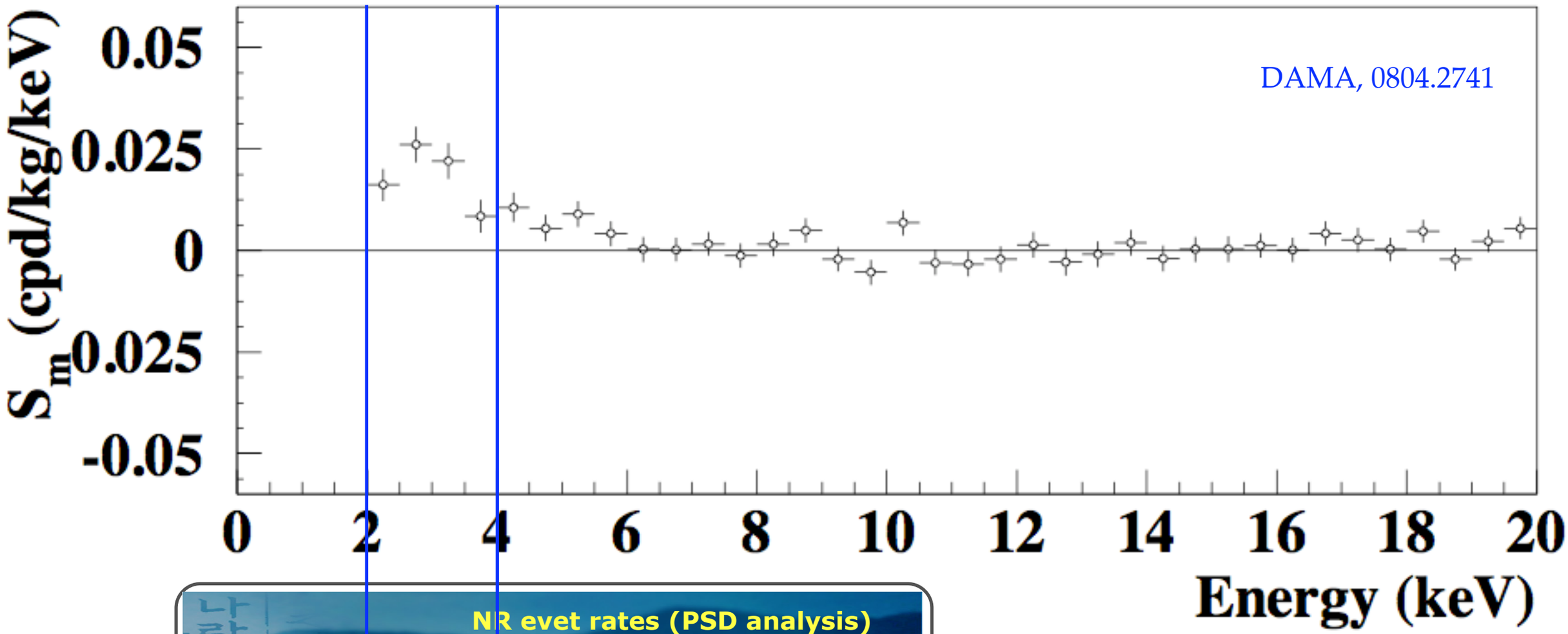
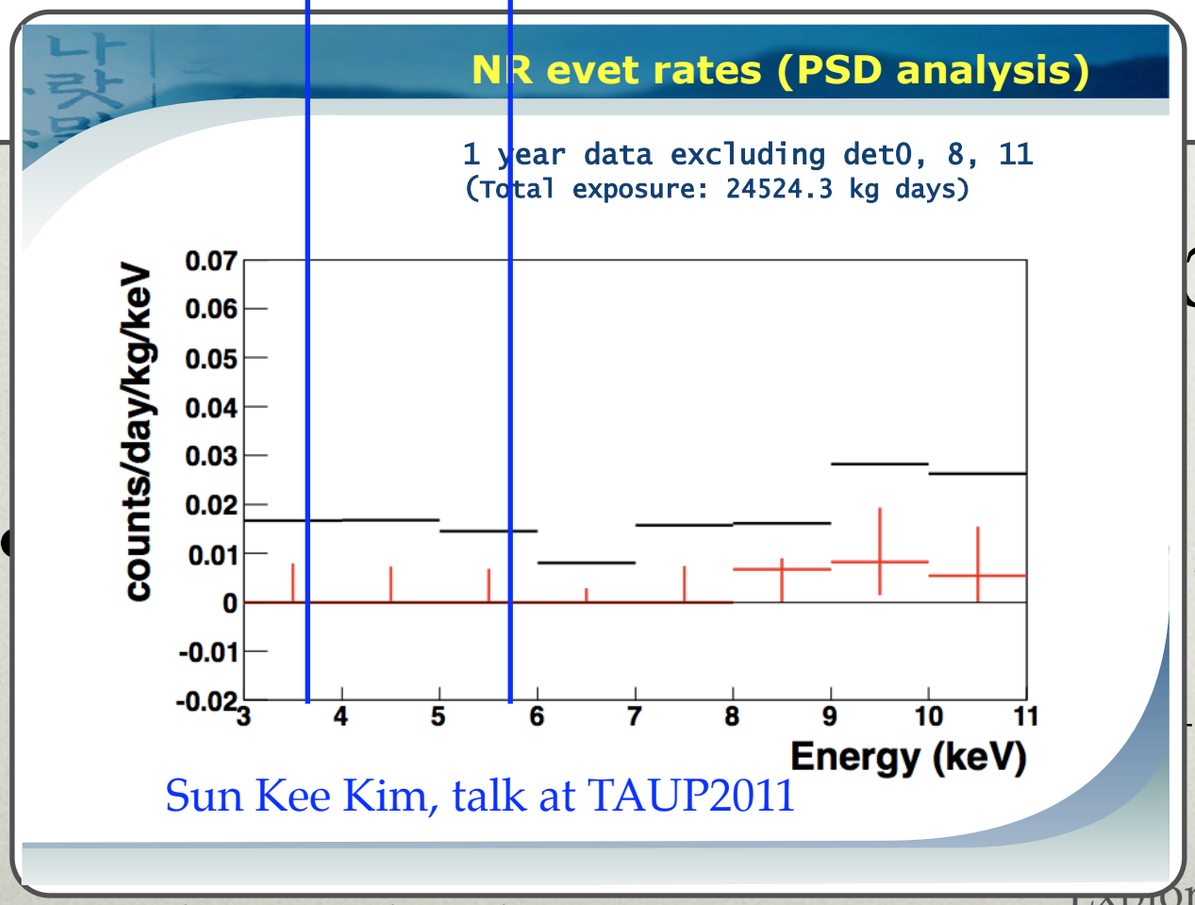


Kopp, Schwetz, JZ, 1110.2721

NEW KIMS BOUND

- CsI detector
- the bound excludes any signal from I for DAMA
  - KIMS rate(3.6-5.8 keV) <0.0098 cnts/kg/day/keV (90% C.L.)
  - DAMA S_m(2-4 keV)=0.0183±0.0022 cnts/kg/day/keV
- if DAMA is due to DM then scattering on Na
  - if due to DM ⇒ points to light DM





Sun Kee Kim, talk at TAUP2011

3±0.0022 cnts/kg/

scattering on Na

ight DM

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SODIUM QUENCHING FACTOR

- what is the quenching factor qNa?
- Collar@TAUP: smaller than previous measurements
- moves the best fit point to higher DM masses
  - dominated by scattering on iodine

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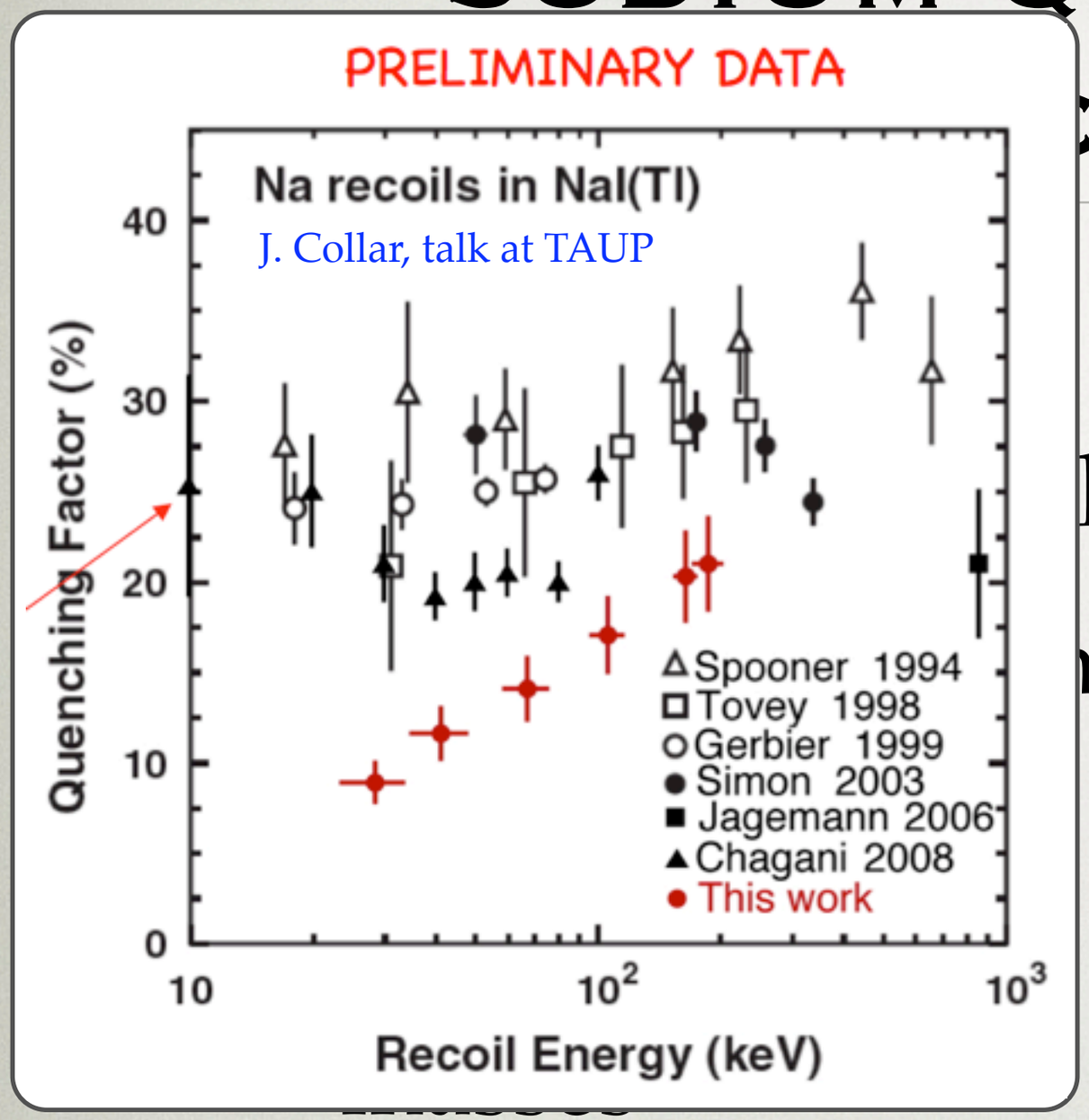

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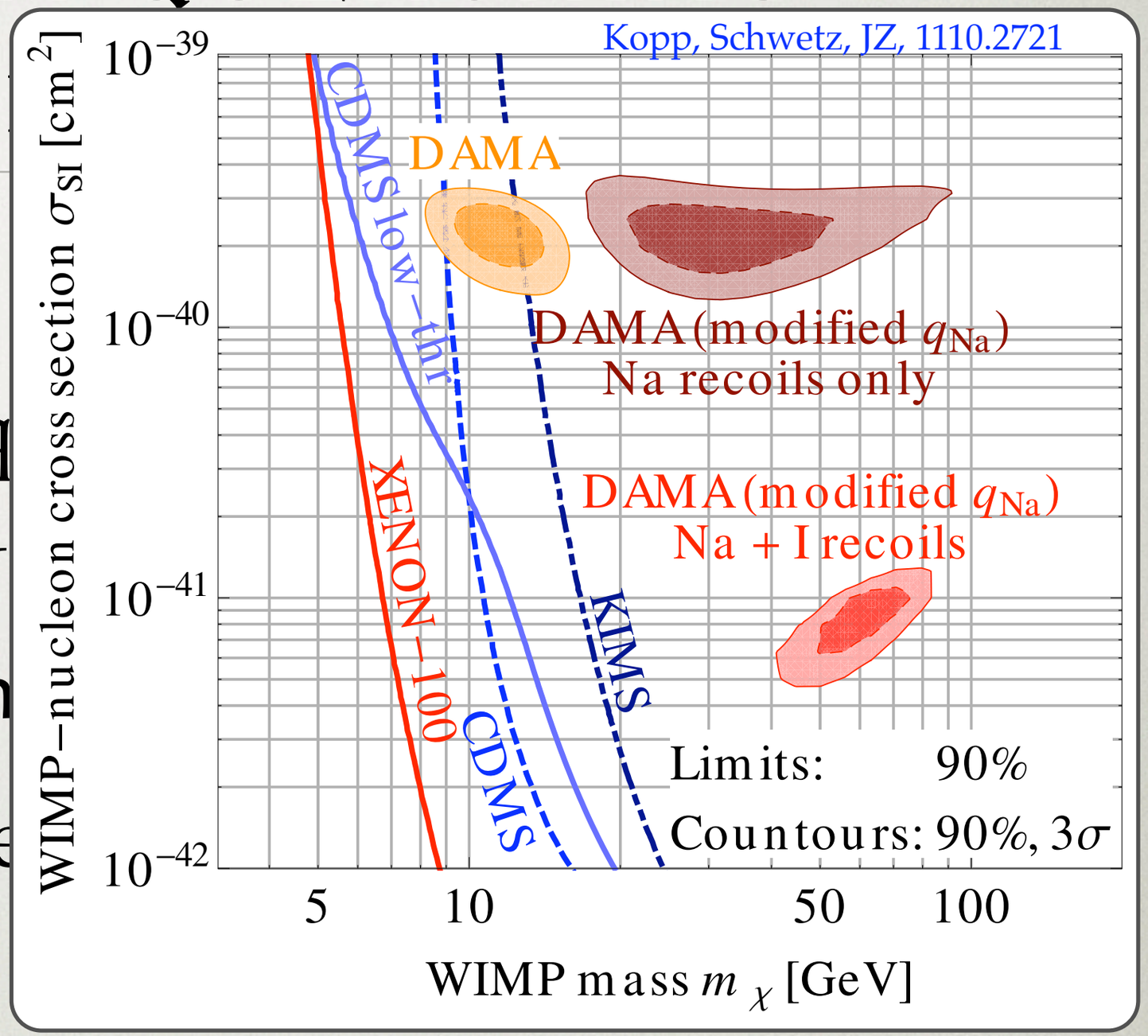

CRESST

Angloher et al. [CRESST-II], 1109.0702

- $CaWO_4$ crystal, 730 kg days of data
- 67 events observed in the signal region
- background from e/γ events, α events, neutron events, Pb recoil
  - signal ~30±9 evnts (24±8 evnts)
- the significance of extra signal is $>4\sigma$

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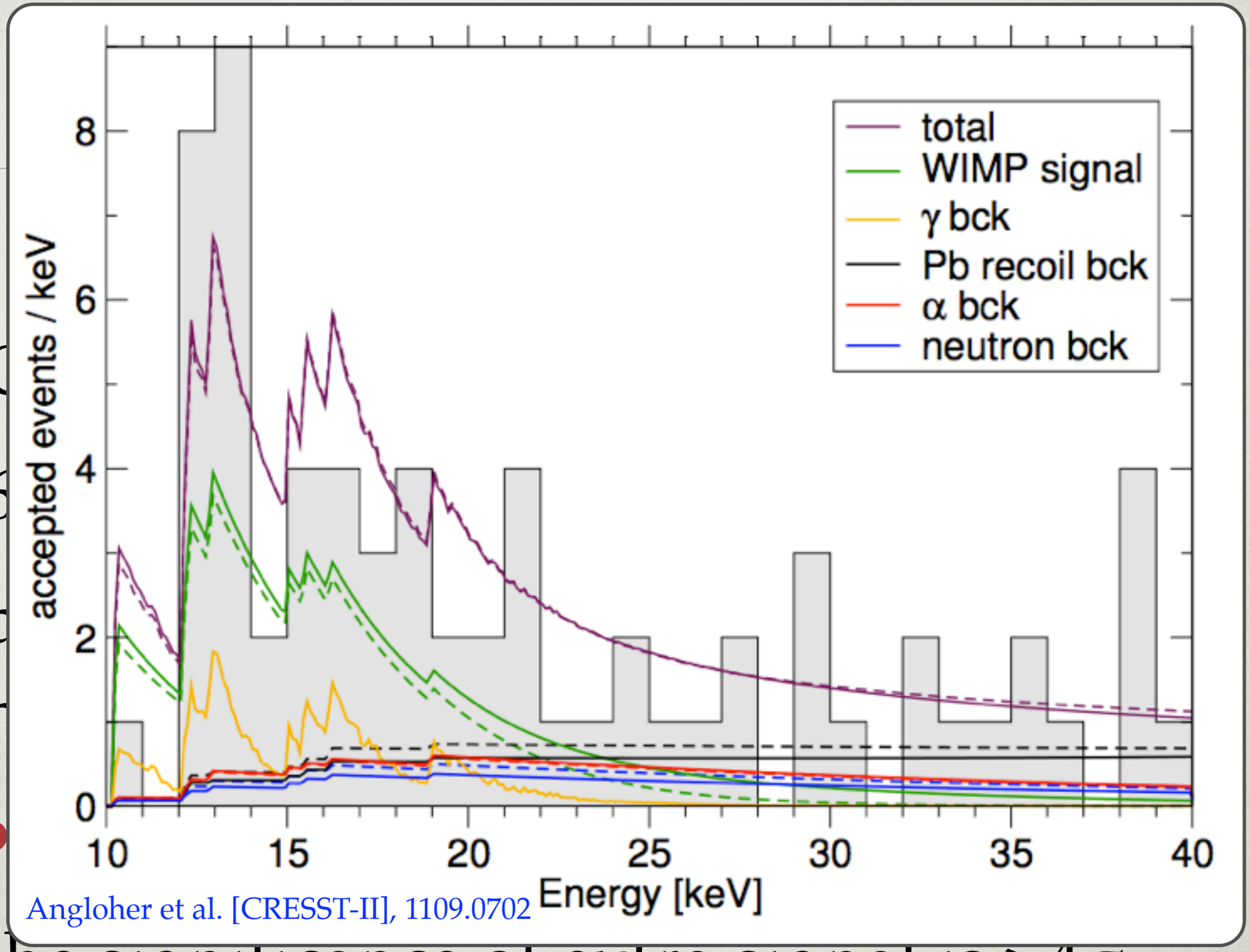

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QUESTIONS

- elastic spin-independent with standard halo: not a good fit to all experiments
- could a nongeneric DM model be viable?
- could nuclear and astrophysical uncertainties make a big difference?

DARK MATTER VARIATIONS

- a number of variations on DM one can consider
  - isospin violating couplings — Kamionkowski, Kurylov, hep-ph/0307185; Giuliani, hep-ph/0504157; Cotta et al., 0903.4409; Kang et al., 1008.5243; Feng et al., 1102.4331; Chang et al., 1004.0697; Frandsen et al., 1105.3734
  - velocity suppressed interactions
  - inelastic scattering
    - endothermic, exothermic — Tucker-Smith, Weiner, hep-ph/0101138; Graham, Harnik, Rajendran, Saraswat, 1004.0937
  - scattering through resonances — Bai, Fox, 0909.2900
  - additional momentum dependence — Feldstein, Fitzpatrick, Katz, 0908.2991; Chang, Pierce, Weiner, 0908.3192
    - light mediators, derivative interactions,...
  - leptophilic interactions — Kopp, Niro, Schwetz, JZ, 0907.3159
  - spin dependent interactions
  - ...

OTHER UNCERTAINTIES

- astrophysical uncertainties — see talk by A. Green
  - vary velocity profiles, v_{esc}, etc
  - "integrate them out" — Fox, Liu, Weiner 1011.1915; Fox, Kribs, Tait, 1011.1910
- channeling — Bozorgnia, Gelmini, Gondolo, 1006.3110; 1008.3676; 1009.3325
- nuclear and atomic physics
  - quenching factors, L_{eff} in S1, Q_y in Xenon S2
  - nuclear form factor uncertainties

TENSIONS

Schwetz, JZ 1106.6241; Farina, Pappadopulo, Strumia, Volansky 1107.0715;
Fox, Kopp, Lisanti, Weiner 1107.0717; Hooper, Kelso 1106.1066; McCabe 1107.0741

- a complete check for "old" CoGeNT and DAMA was done by four groups
- the bottom line:
  - none of the models can make both signals +other bounds work
  - including uncertainties
- focus on CRESST-II
  - could it be due to DM?

INELASTIC DARK MATTER

- CRESST target contains W, is heavy
- if scattering of DM inelastic
  - scattering on light nuclei no signal

$$v_{\rm min} = \frac{1}{\sqrt{2 m_N E_d}} \left(\frac{m_N E_d}{\mu_{\chi N}} + \delta \right)$$

- W the heaviest, there is a solution, δ~90keV
- maybe tension with Xenon-100 (PG test values of 2%-20%)
- very dependent on astrophysics details
  - a coincidence problem

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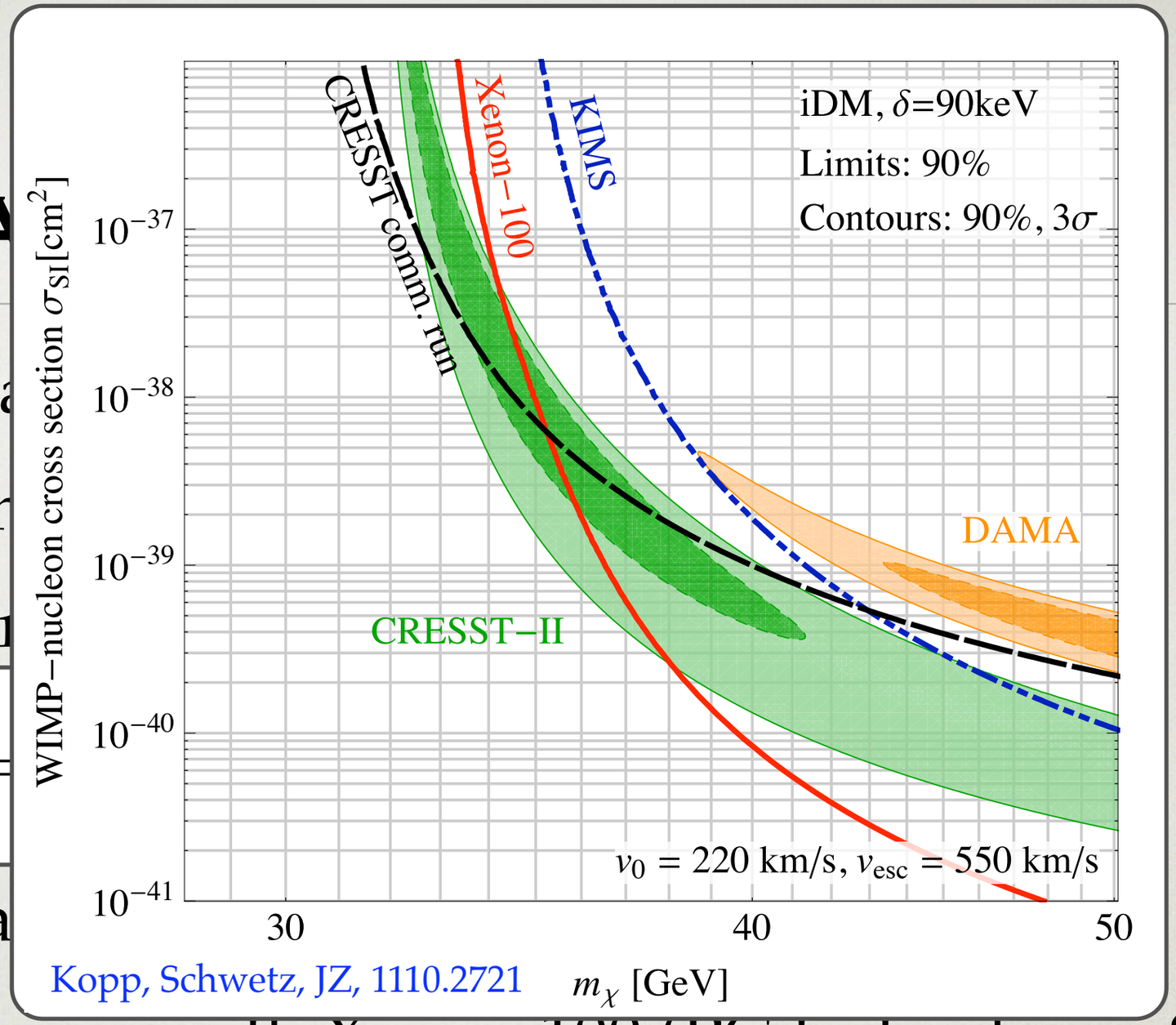

Kopp, Schwetz, JZ, 1110.2721

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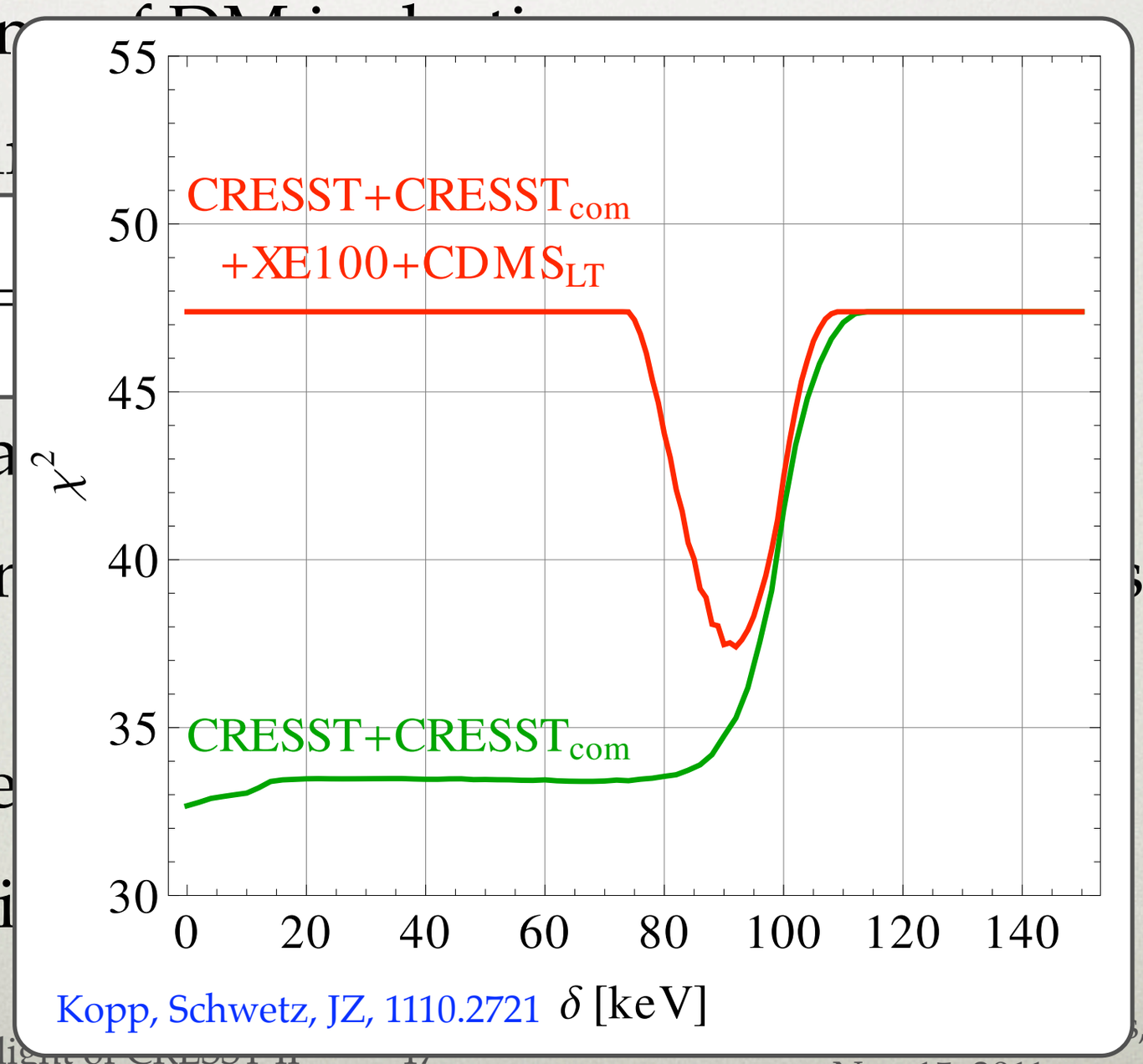

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ISOSPIN VIOLATING DM

- DM could couple differently to p than n
  - counter example: higgs mediated scattering
    - dominated by strangeness content
- if couplings to u, d dominate IVDM possible
- phenomenologically interesting if couplings such that scattering on Xe suppressed
- not possible to suppress it completely
  - in detector several isotopes

IVDM and CRESST

- define effective atomic number

$$A_{\rm eff}^2 \equiv \sum_{i \in \text{isotopes}} 2 r_i [Z \cos\theta + (A_i - Z)\sin\theta]^2$$

here $\tan\theta \equiv f_n/f_p$

- Xe suppressed for $f_n/f_p=-0.7$
  - but then Si, Ge large
  - also W suppressed, Ca and O large
  - in CRESST-II scattering exclusively on Ca an O now
    - 39% scattering on O, 61% on Ca
    - exactly opposite to iDM solution where only W

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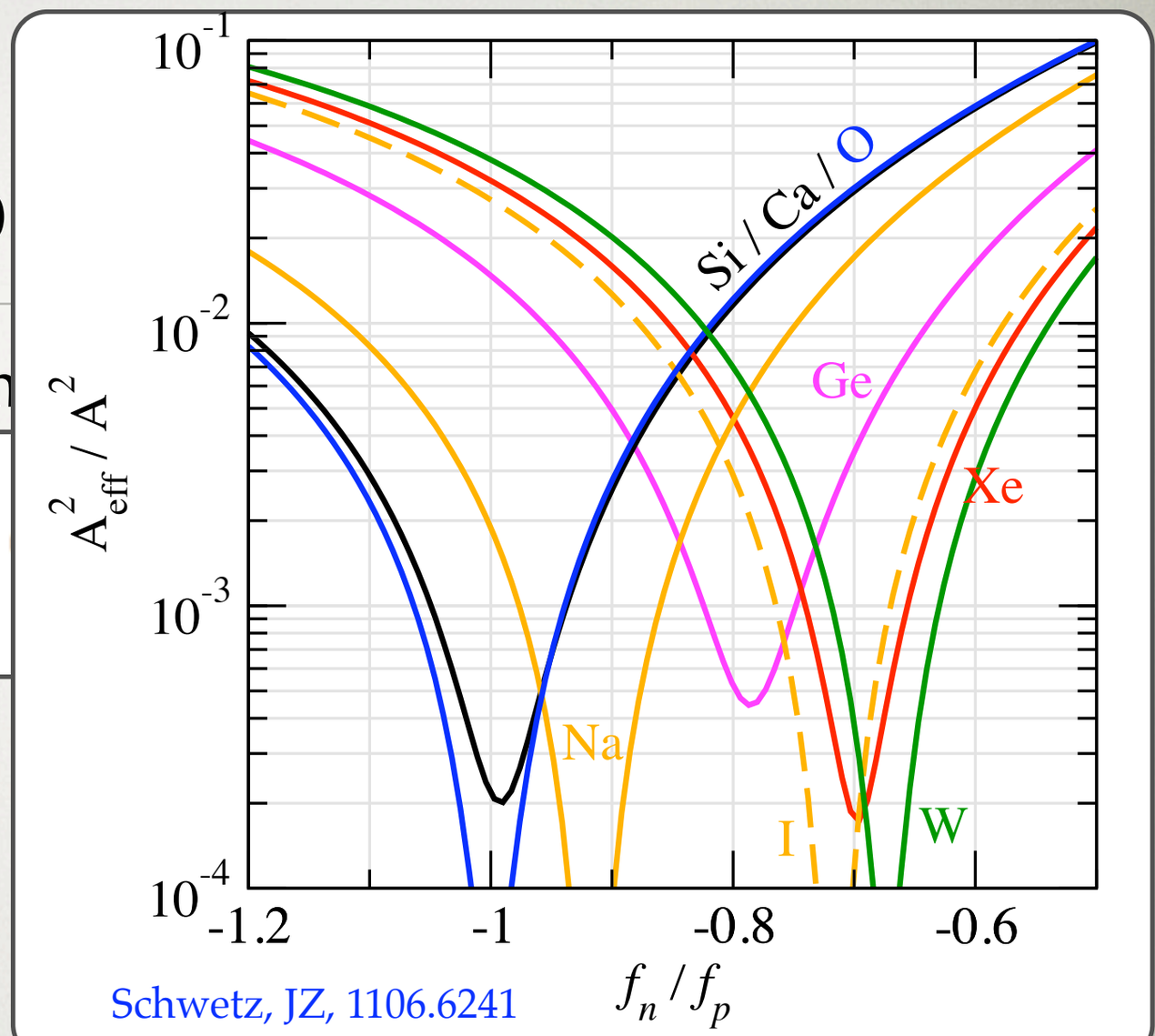
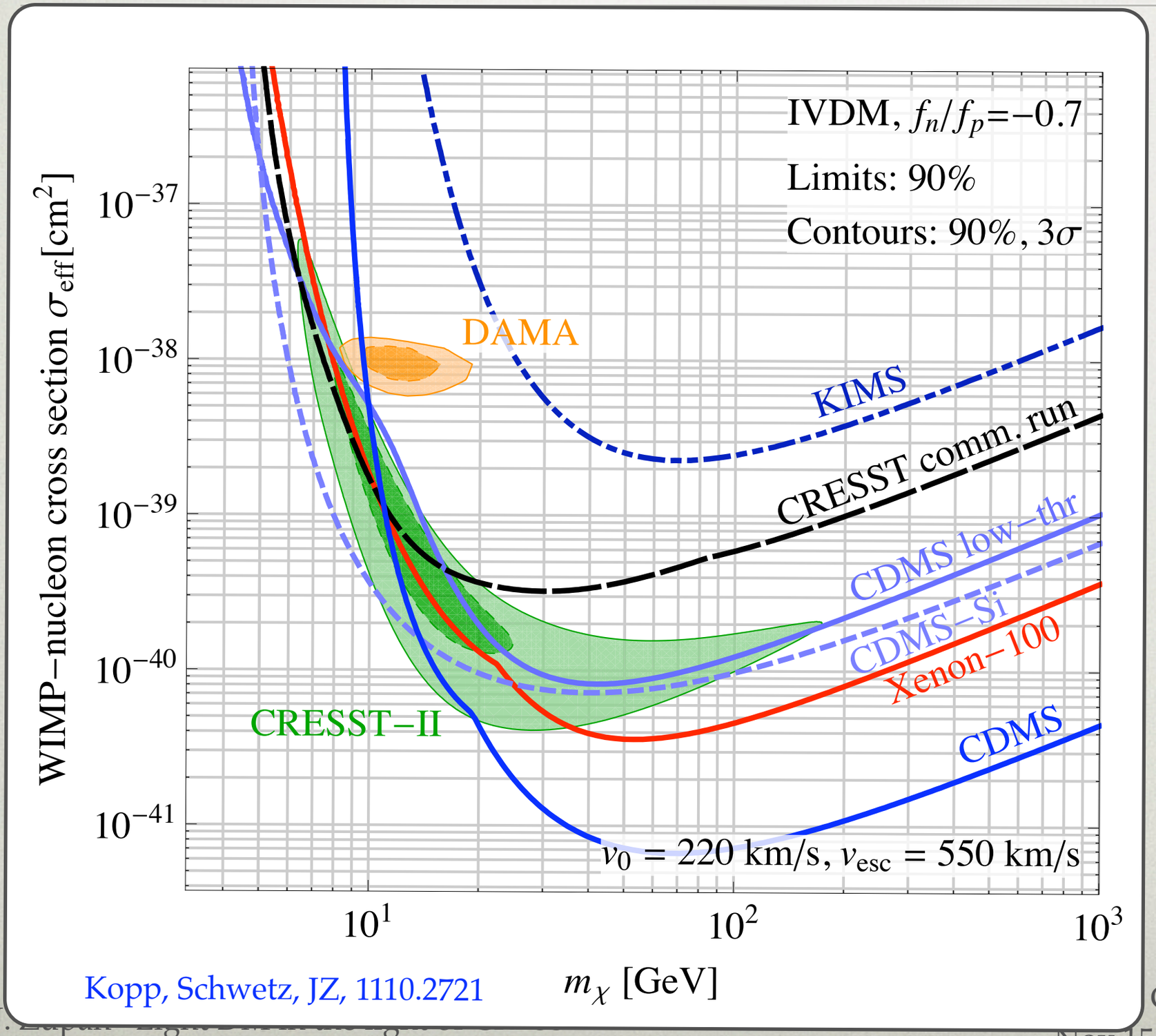


IVDM and CRESST



Kopp, Schwetz, JZ, 1110.2721

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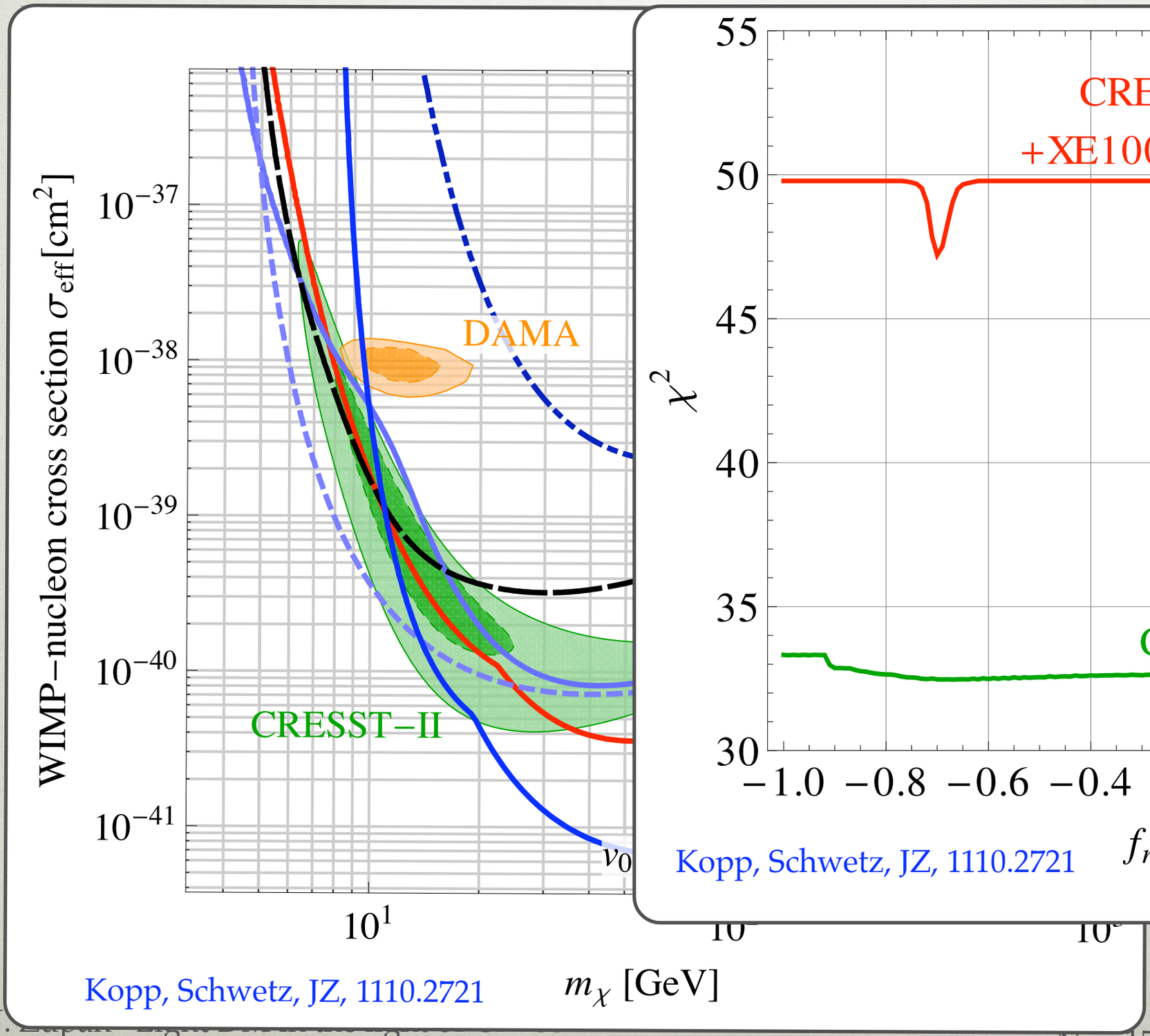

SPECTRUM

- pick three points close to minima for the three models
- iDM - reasonable description of data but only 12.2 signal events predicted
  - scattering off W exclusively
- eSI - much better description with 24.8 events
  - scattering from W negligible, mostly off O and Ca
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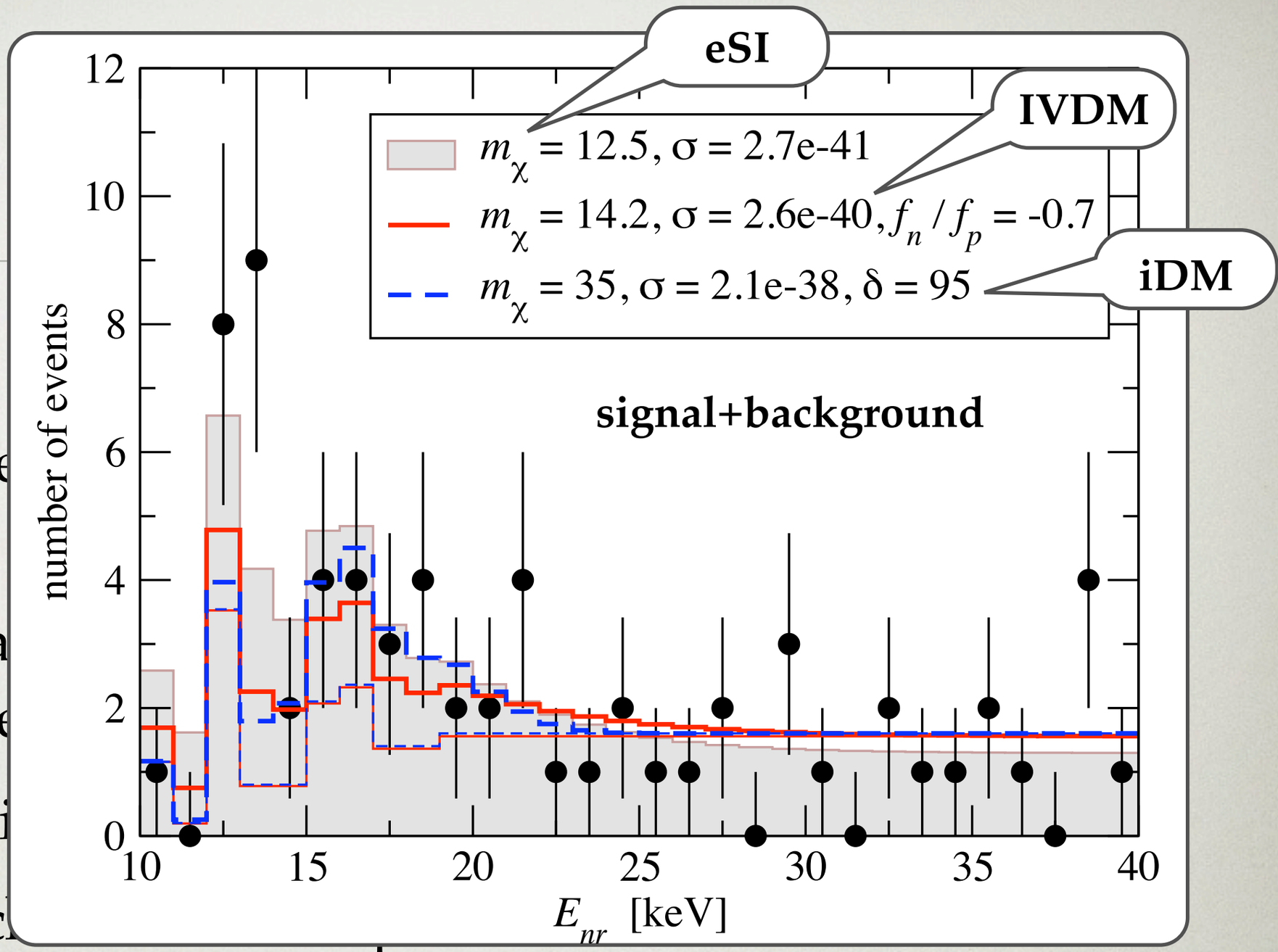

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PG test

Maltoni, Schwetz, hep-ph/0304176

- parameter goodness of fit test
- based on χ^2 function

$$\chi^2_{\rm PG} = \Delta\chi^2_1 + \Delta\chi^2_2$$

$$\Delta\chi^2_i = \chi^2_i(\text{global bf}) - \chi^2_{i,\rm min}$$

- i=1,2 datasets whose compatibil. are tested
- $\chi^2_{\rm PG}$ gives the penalty due to additional data
- if follows a χ^2 distribution

PG test

Data set	$\chi^2_{\rm min}$	m_χ [GeV]	σ [cm^2]	δ [keV]	f_n/f_p	$\Delta\chi^2$ [$\chi^2_{\rm PG}$]	PG
Elastic spin-independent scattering (eSI)							
CRESST	28.5	12.6	3.2×10^{-41}	0	1	0.5	
$\text{CRESST}_{\rm com}$	0	0	0	0	1	3.7	
Combination	32.7	13.2	2.0×10^{-41}	0	1	[4.2]	13%
CRESST	28.5	12.6	3.2×10^{-41}	0	1	18.9	
$\text{Xe100+CDMS}_{\rm LT}\text{+CRESST}_{\rm com}$	0	0	0	0	1	0.00	
Combination	47.4	4.0	1.0×10^{-44}	0	1	[18.9]	$<10^{-4}$
Inelastic spin-independent scattering (iDM)							
$\text{CRESST+CRESST}_{\rm com}$	32.7	13.3	2.0×10^{-41}	0	1	3.2	
$\text{Xe100+CDMS}_{\rm LT}$	0	0	0	0	1	1.5	
Combination	37.4	35.5	1.0×10^{-38}	92	1	[4.7]	19%
Isospin-violating dark matter (IVDM)							
$\text{CRESST+CRESST}_{\rm com}$	32.5	14.1	4.5×10^{-40}	0	−0.67	8.0	
$\text{Xe100+CDMS+CDMS}_{\rm Si}$	0	0	0	0	1	4.3	
Combination	47.2	18.8	7.1×10^{-41}	0	−0.70	[12.3]	0.6%

CONCLUSIONS

- CRESST could be a signal of DM, if scattering inelastic or isospin violating