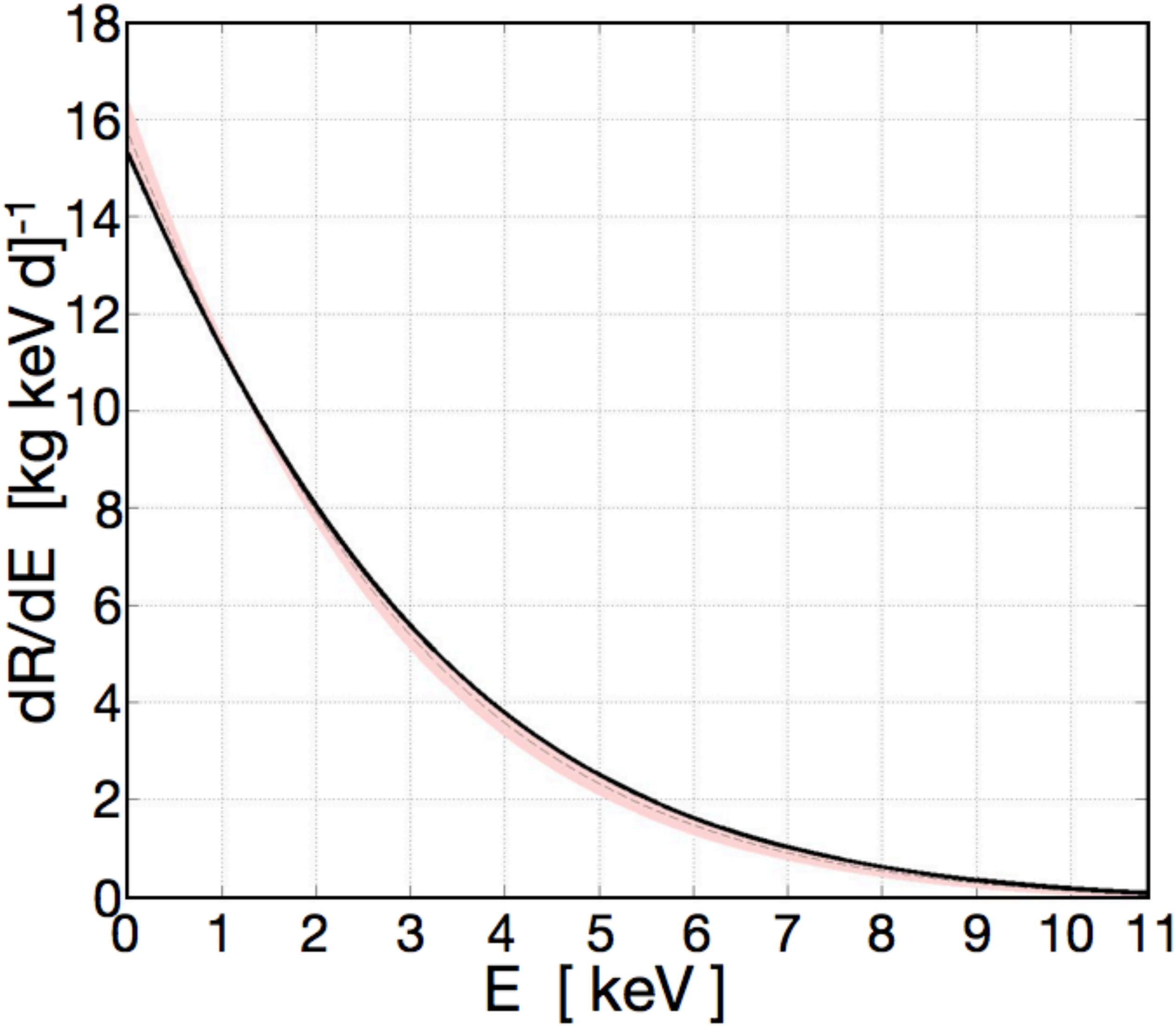
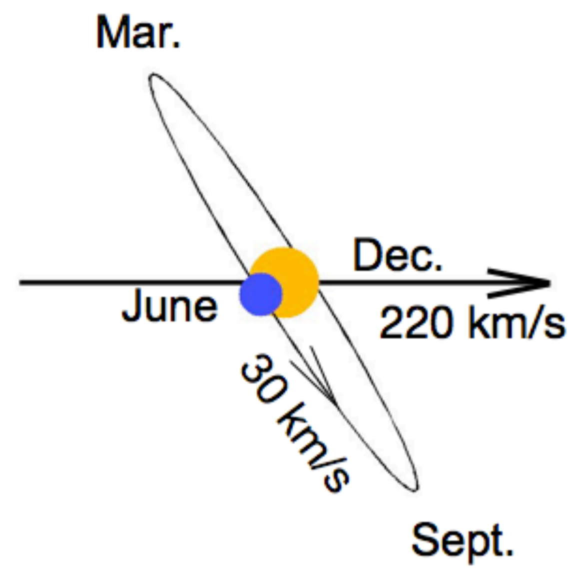
Search for Annual Modulation at Low Energies in CDMS II

Scott Hertel, MIT
for the CDMS Collaboration
IDM Chicago 2012

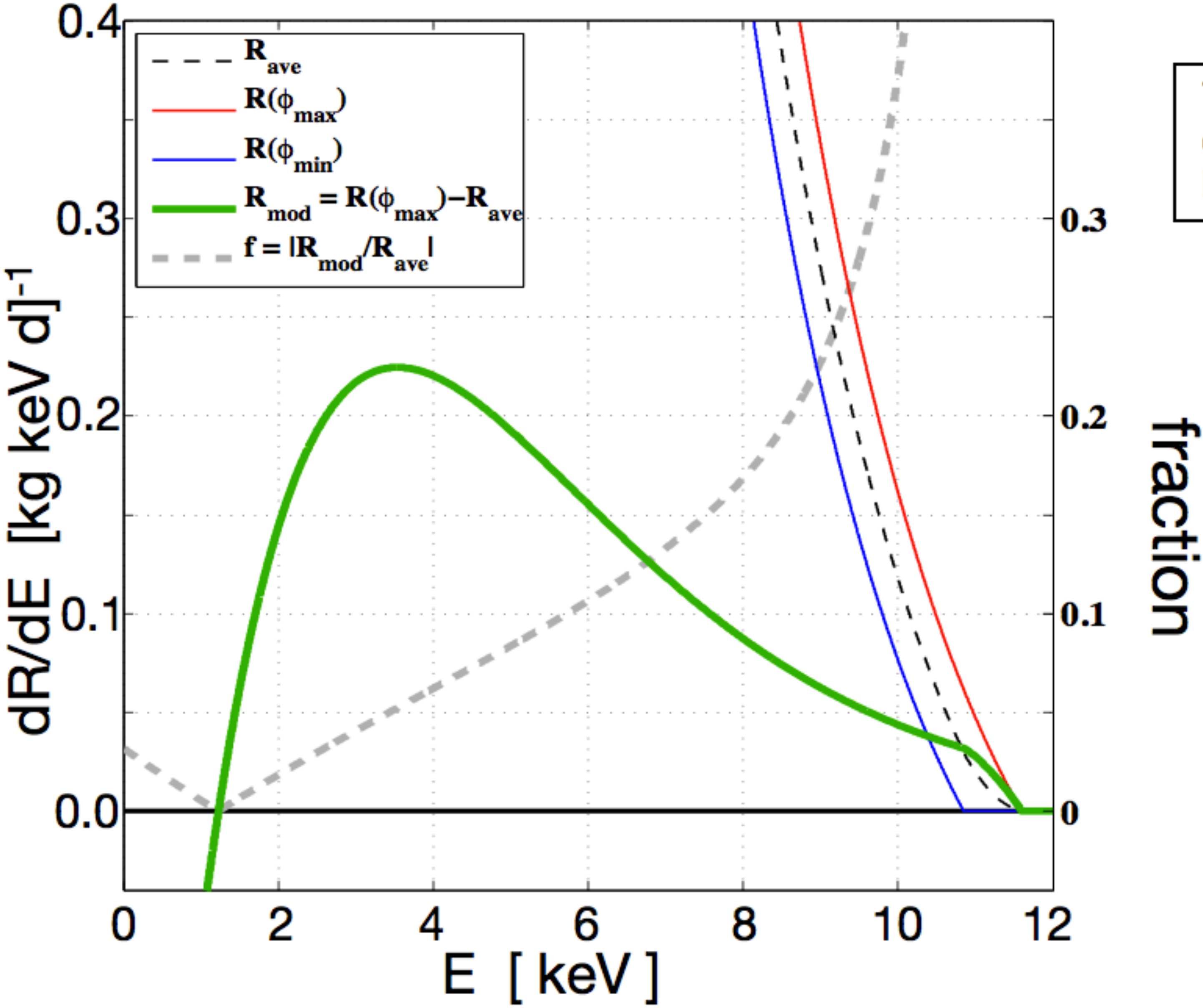
Setting the Stage



Target: Ge
σ_{SI} = 1x10^{-4} pb
M_X = 10 GeV/cm^2



Setting the Stage



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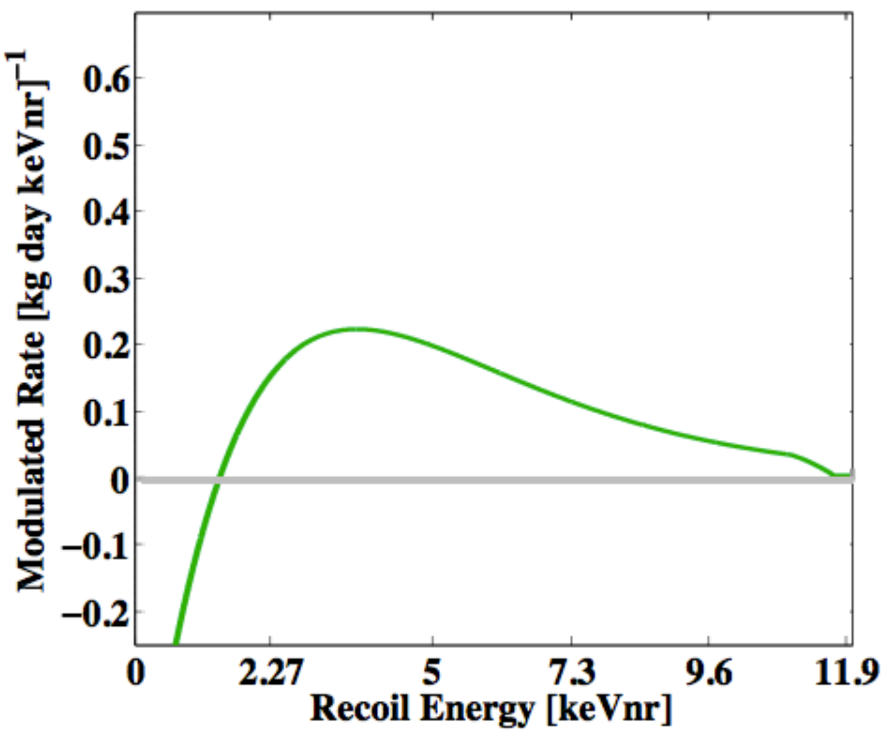
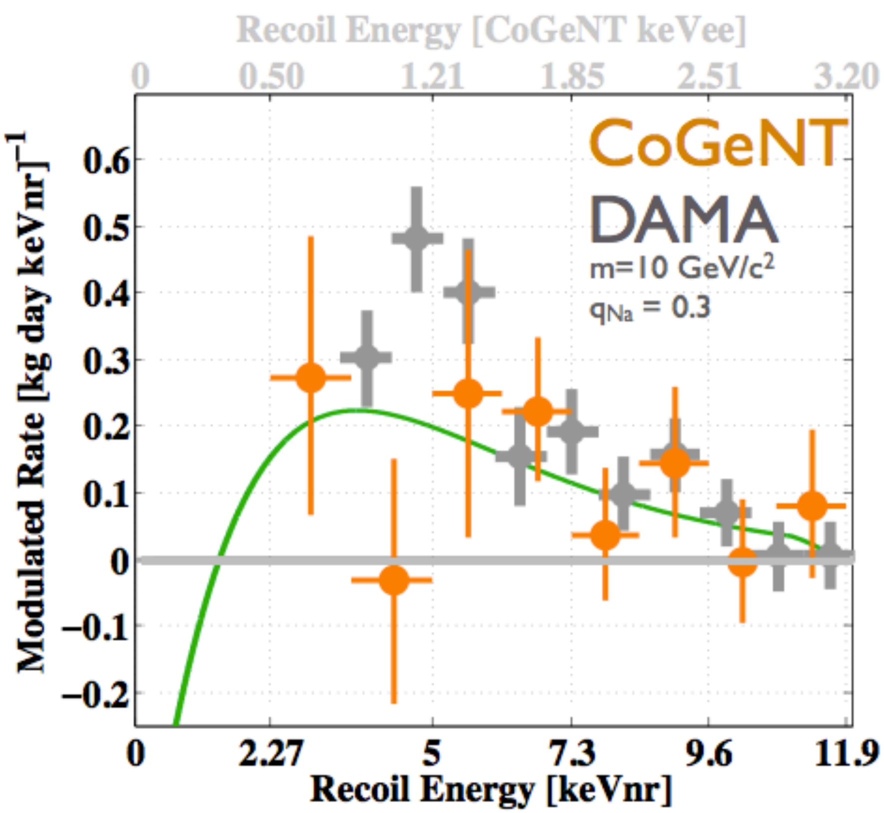


Setting the Stage

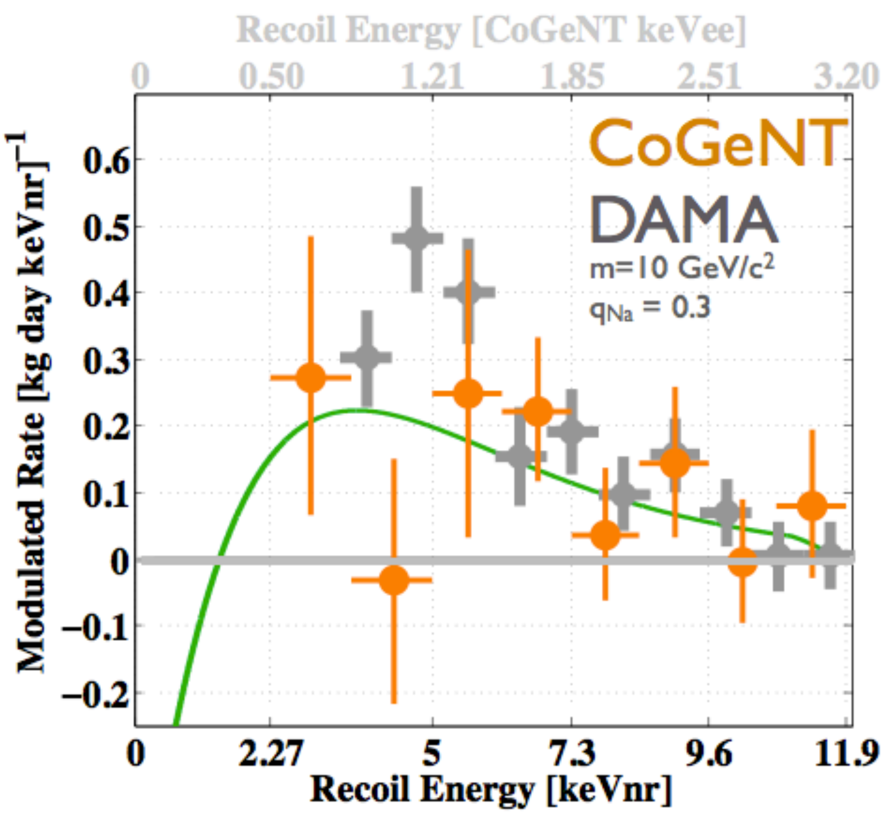


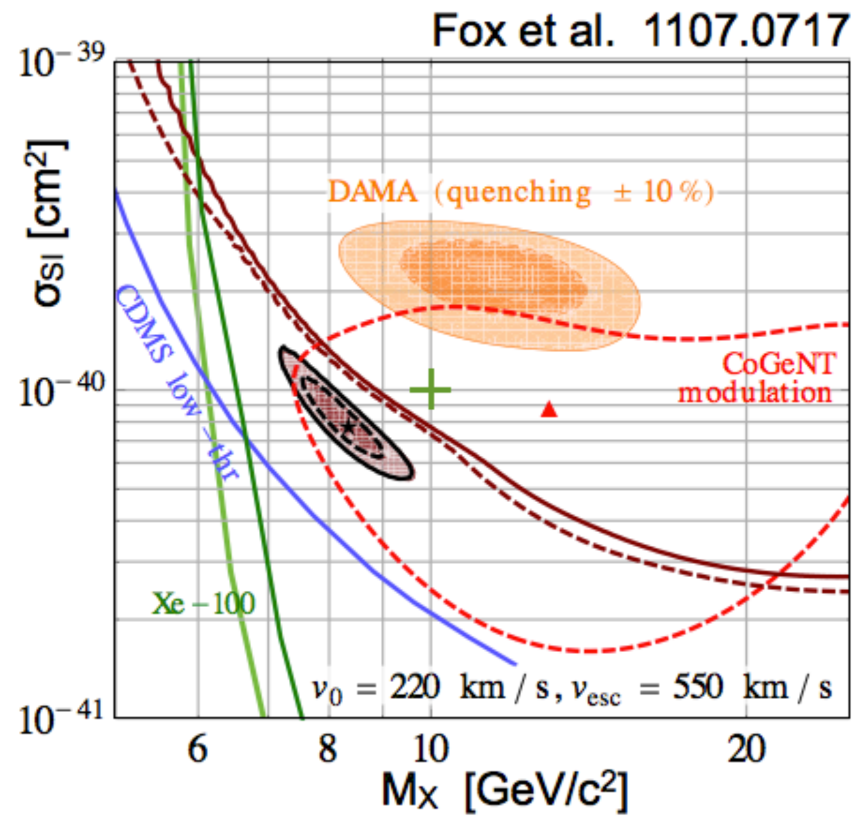
Setting the Stage

CoGeNT modulation
+ origin: simple halo

in tension with...

1. CDMS, Xe100 rates
2. CoGeNT rates
3. simple halo phase





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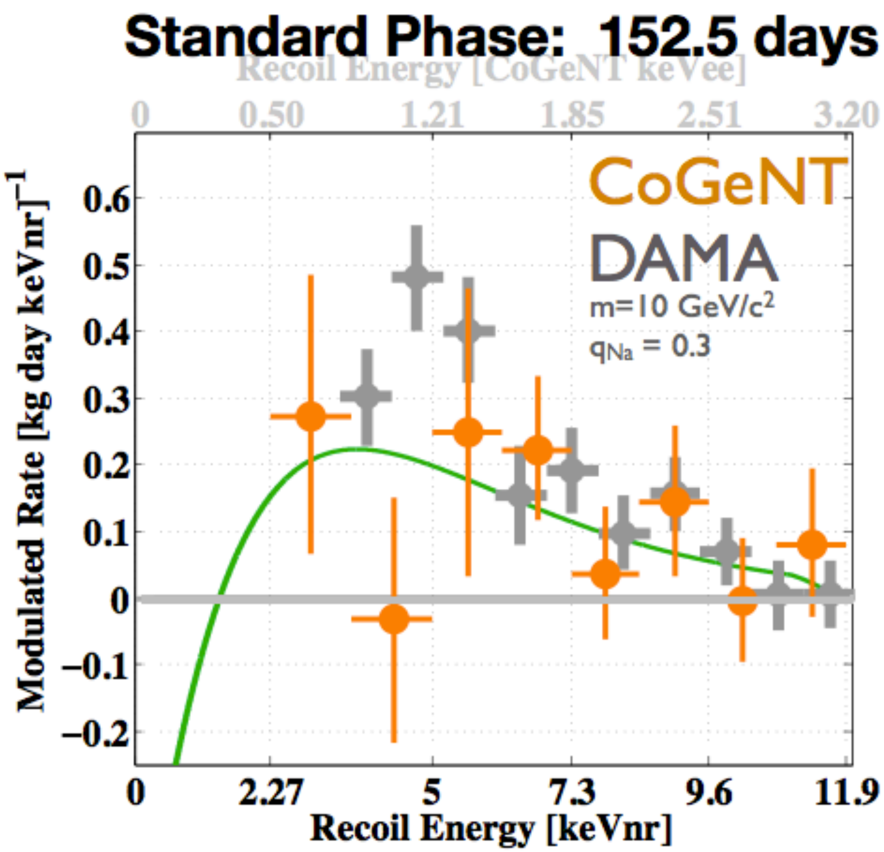
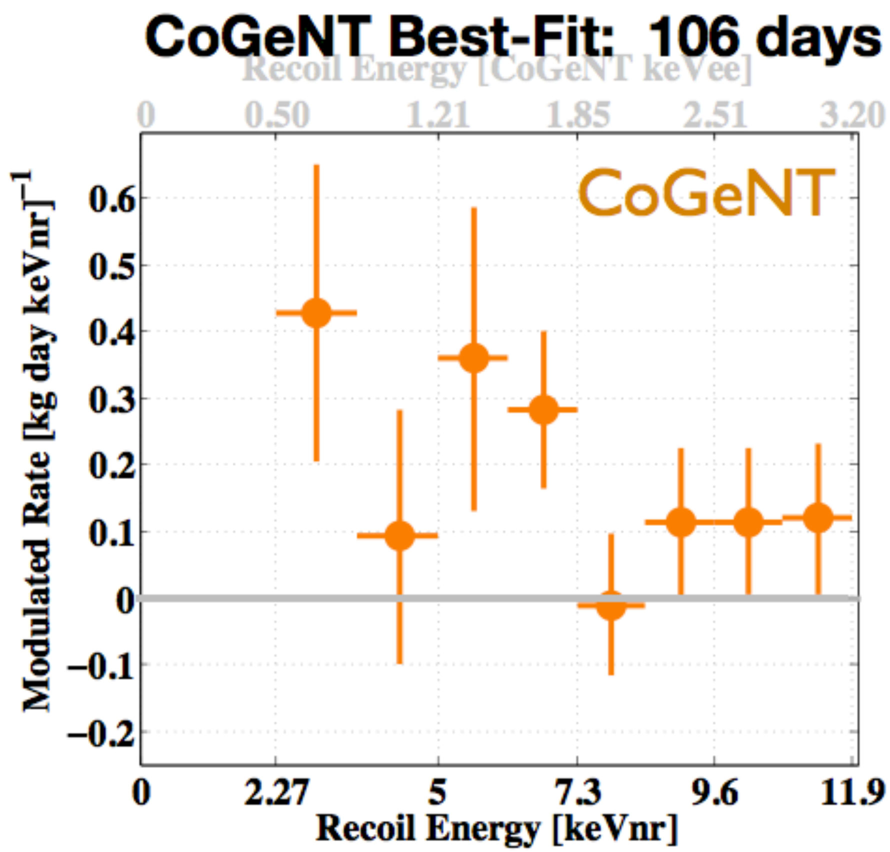
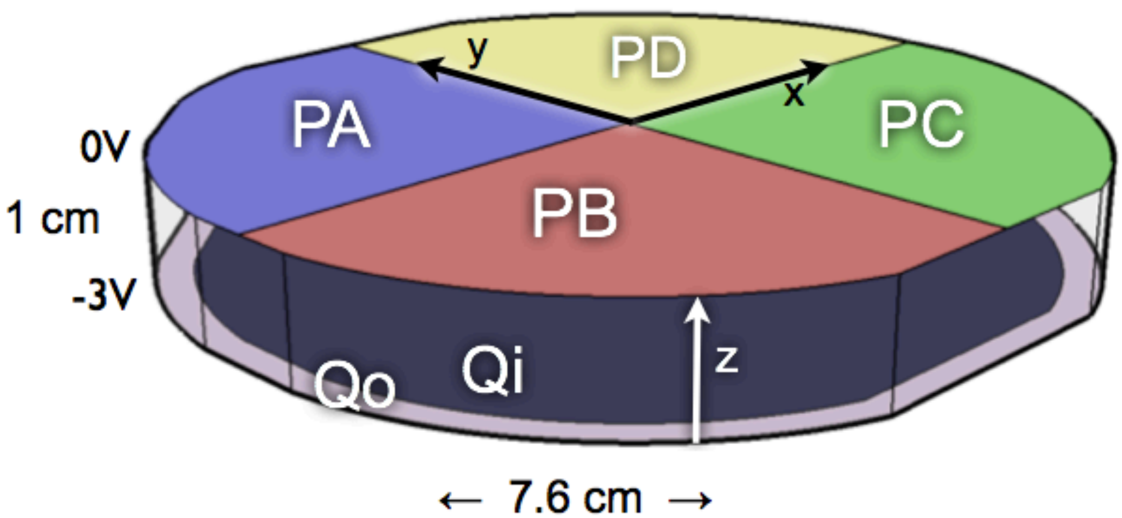




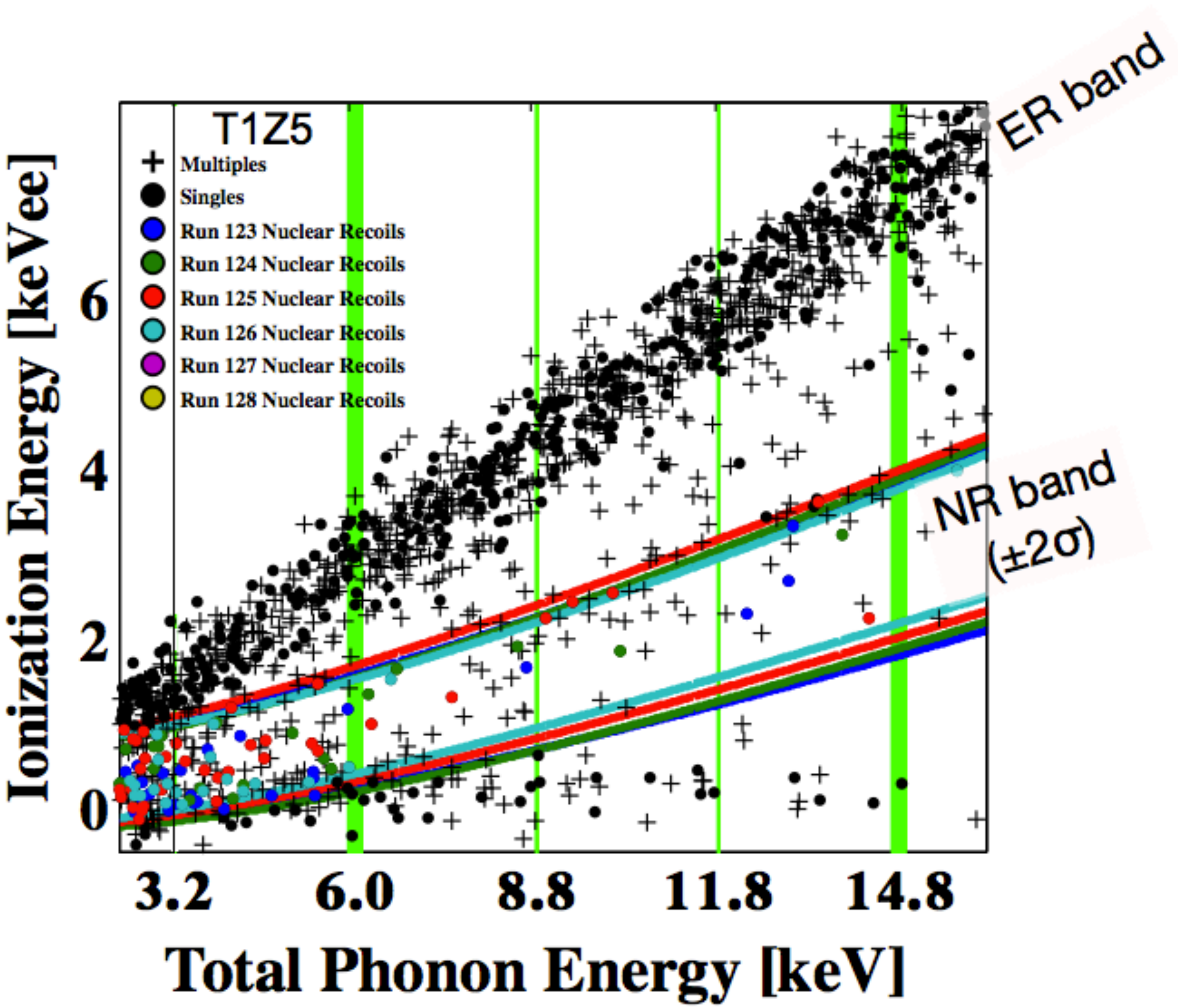
CDMS II at low energies



4 Phonon Channels

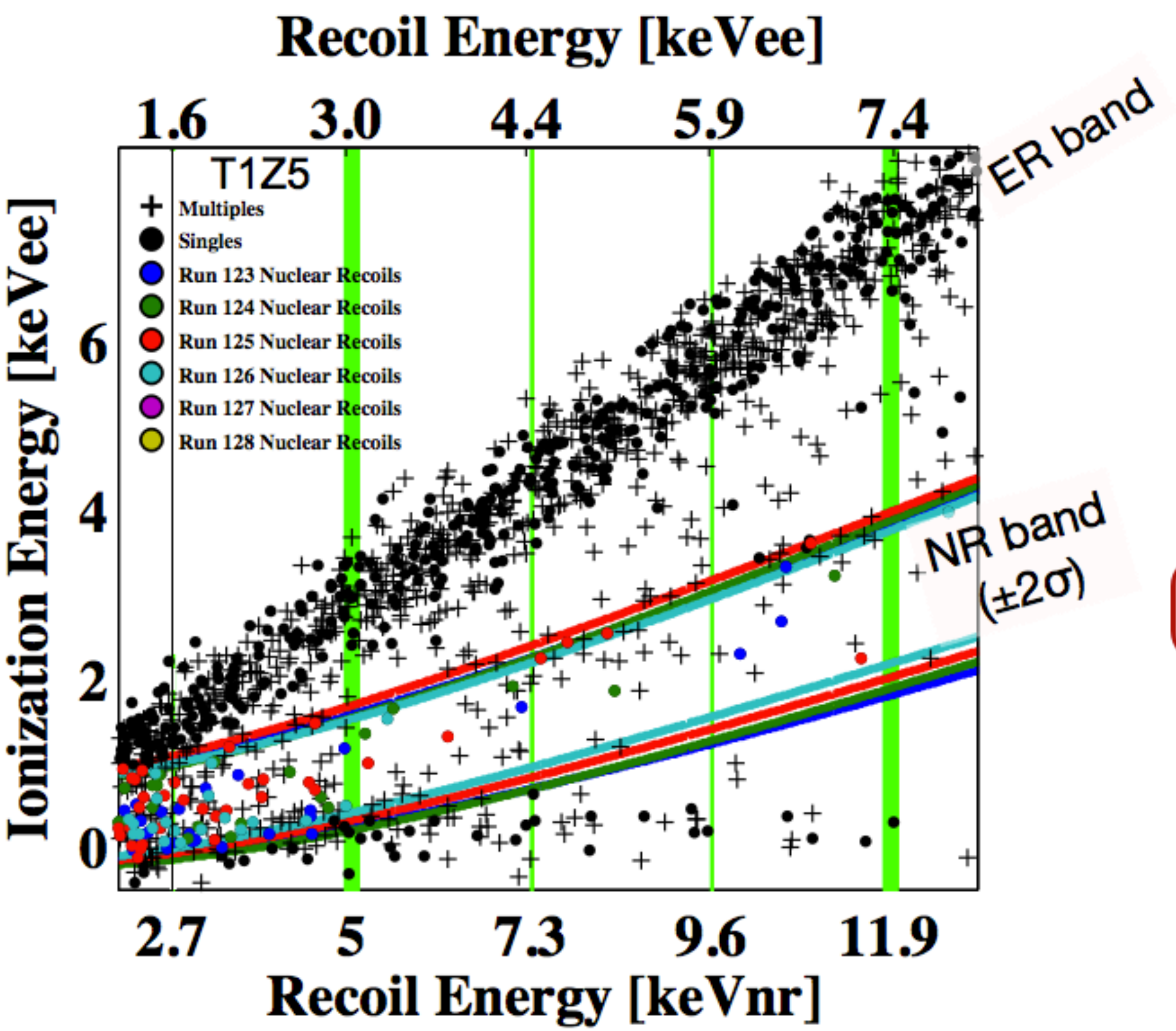
2 Charge Channels

CDMS II at low energies



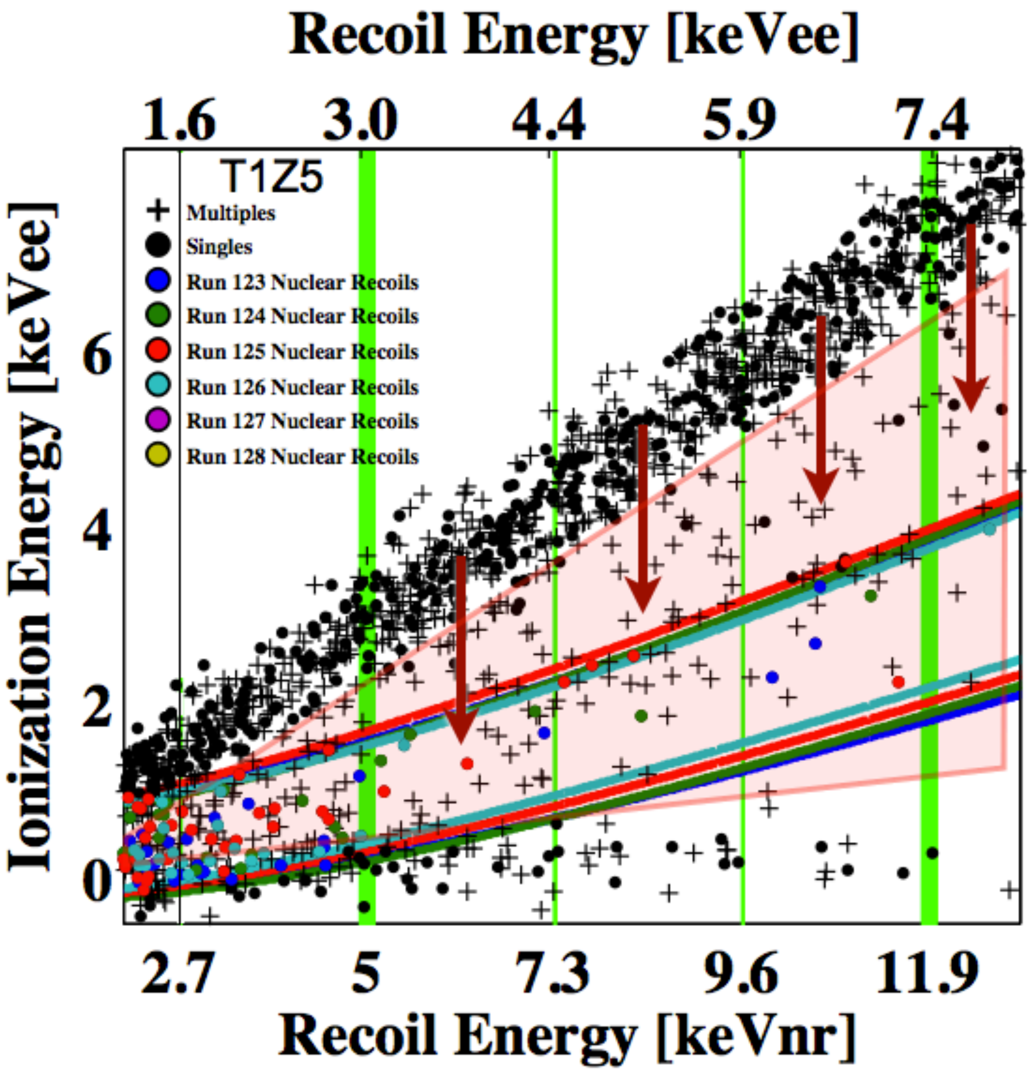
charge energy
(scaled to keVee)
vs
phonon energy

CDMS II at low energies

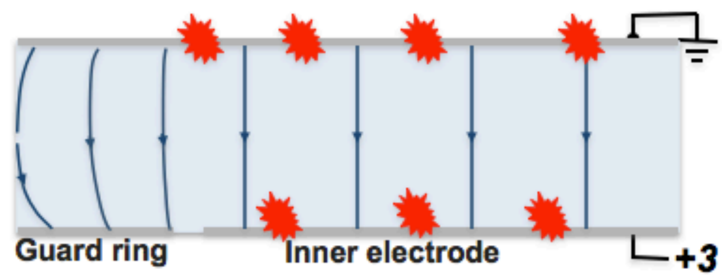


charge energy
(scaled to keVee)
vs
recoil energy
(scaled to keVee
or keVnr)

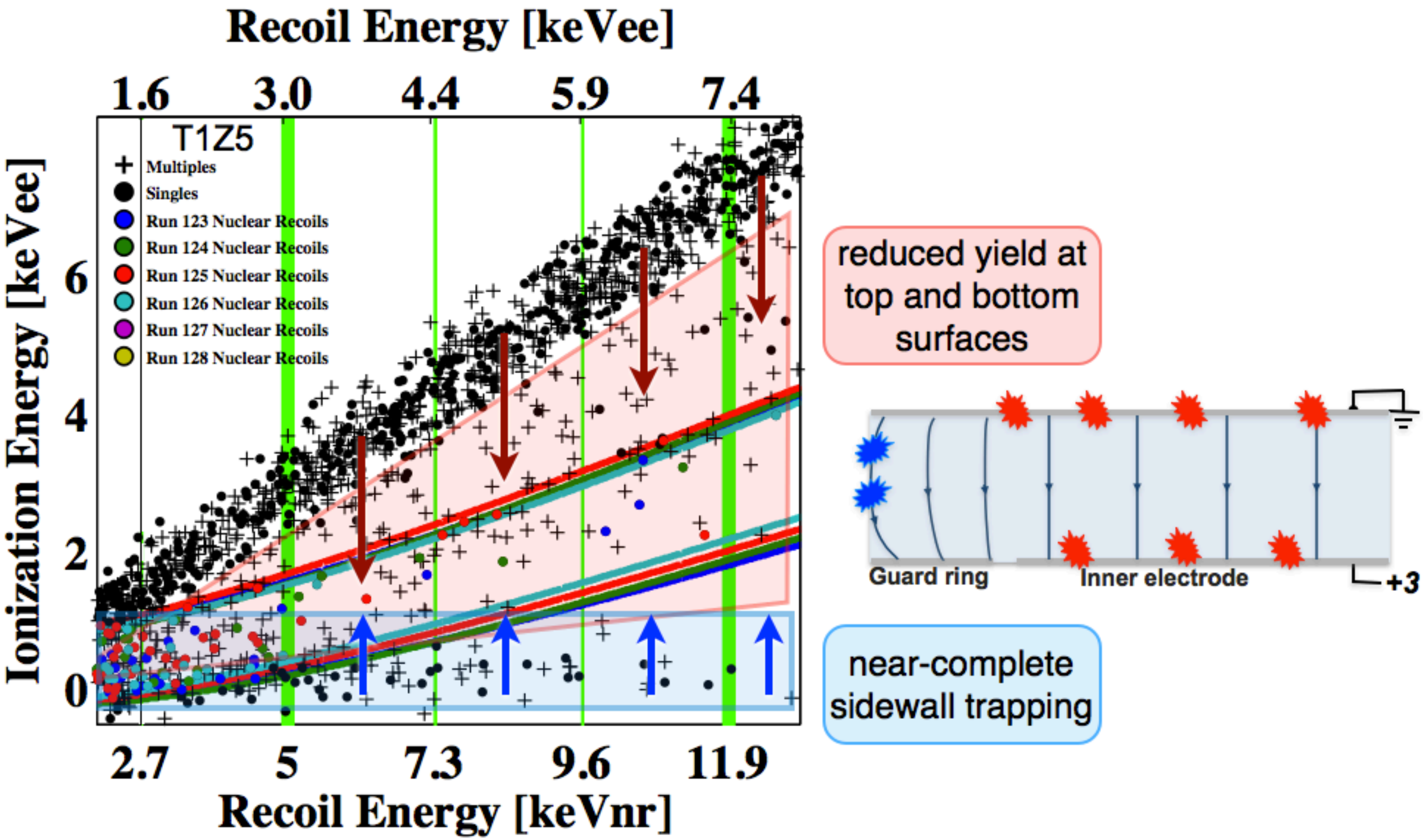
CDMS II at low energies



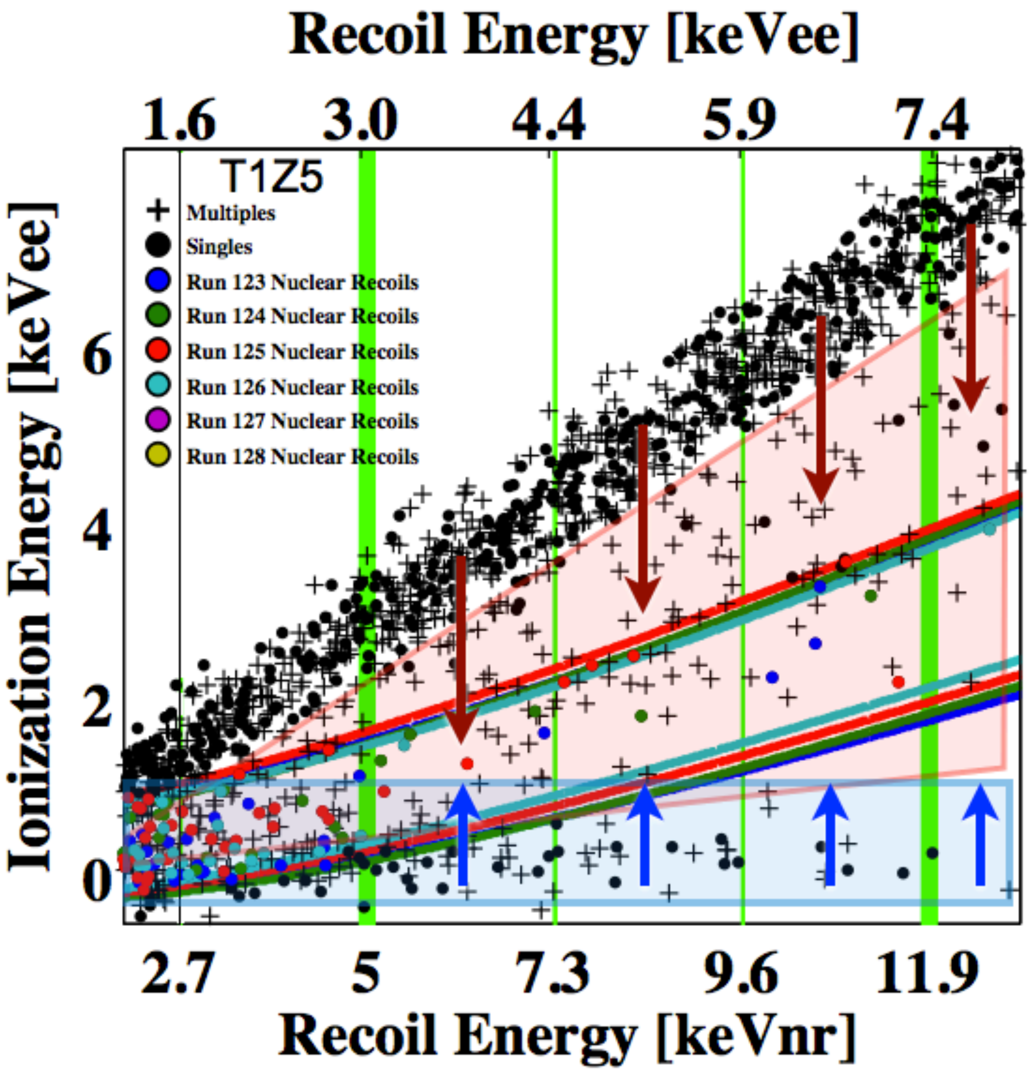
reduced yield at top and bottom surfaces



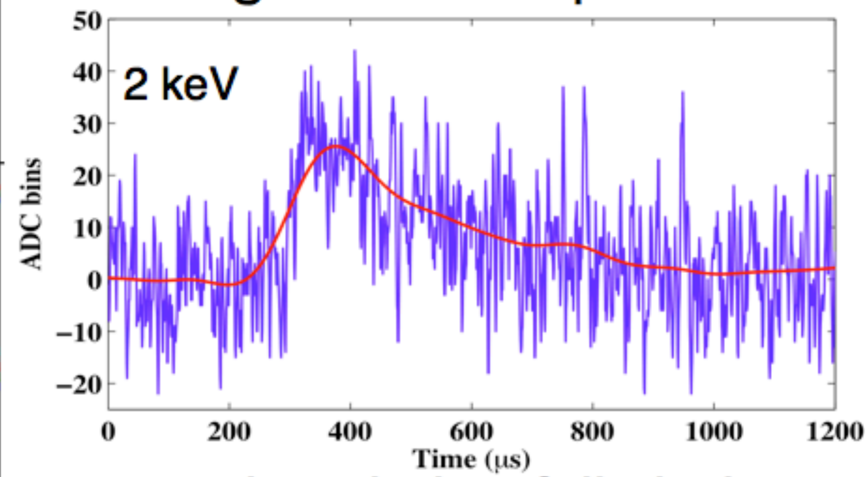
CDMS II at low energies



CDMS II at low energies



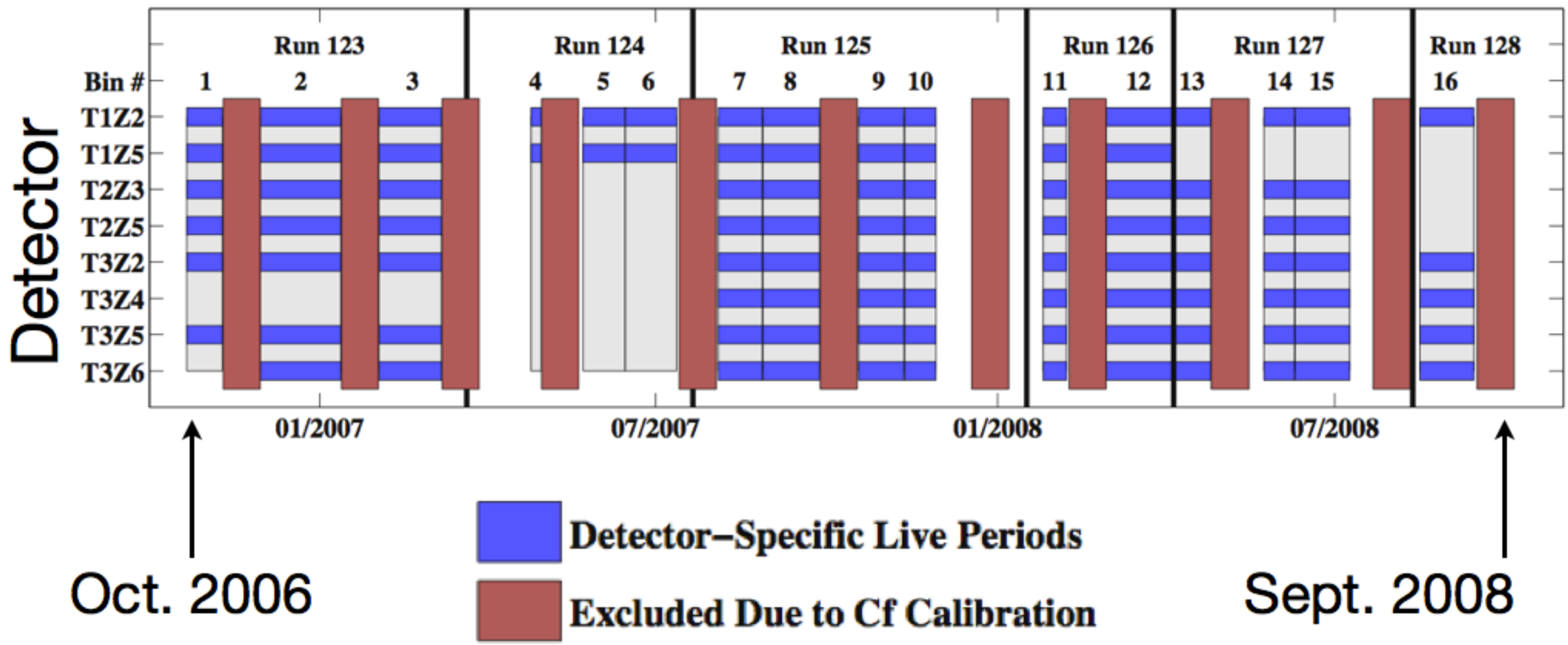
Timing can tell us position...



...but timing fails below ~10keV.

Preparation

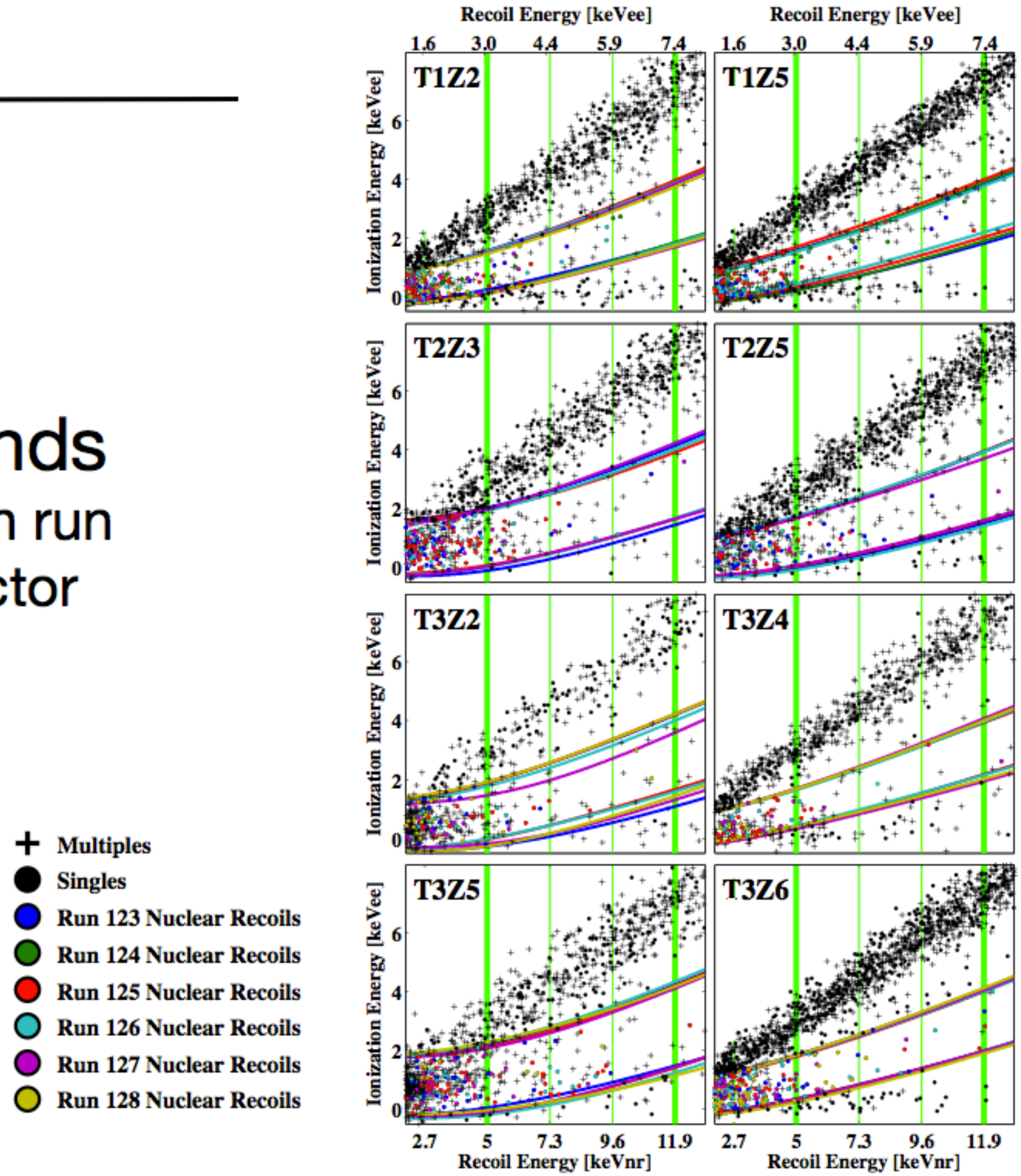
The CDMS II Exposure



Preparation

±2σ NR bands

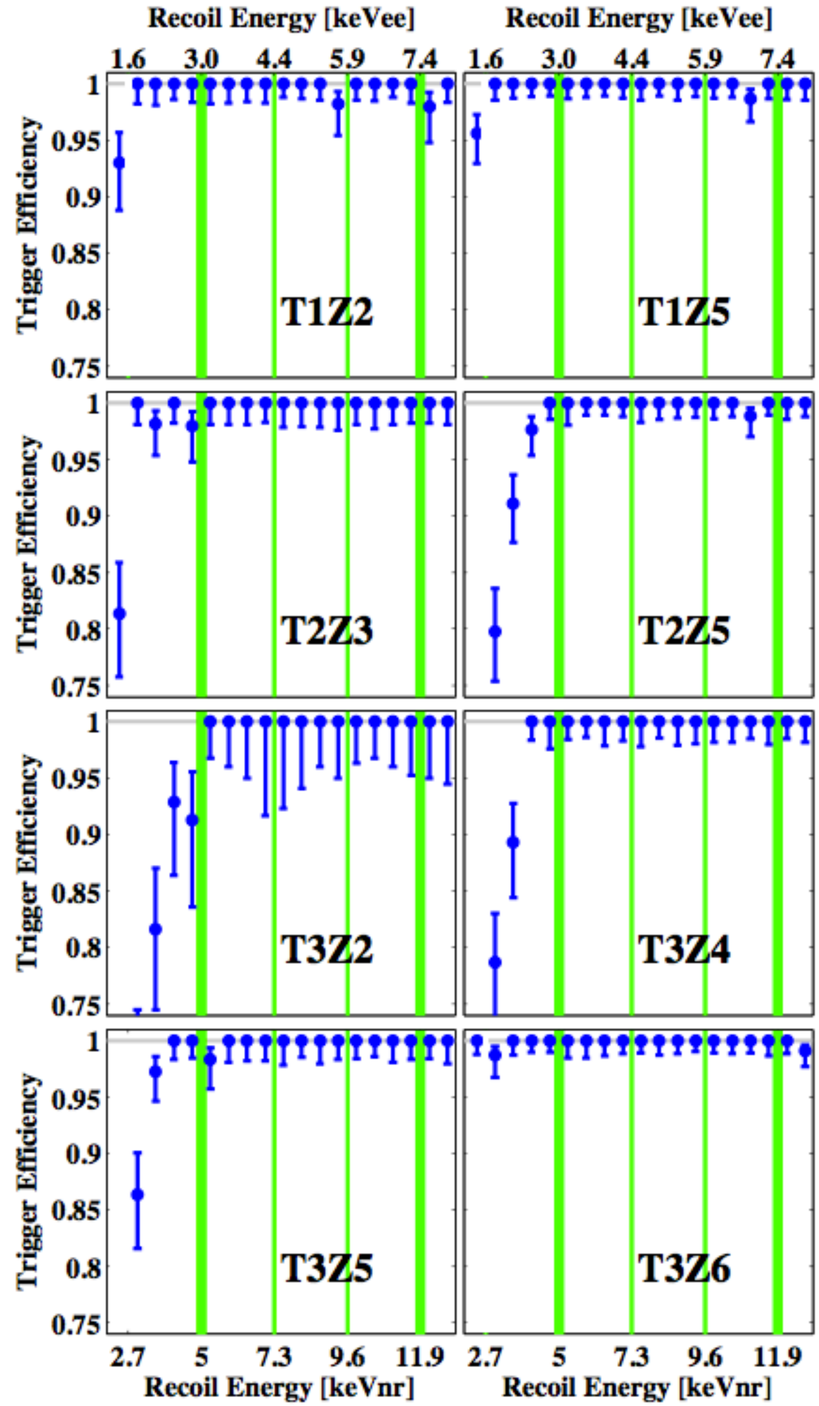
defined for each run
for each detector



Preparation

If we conservatively choose a **5 keV$_{nr}$ threshold,**

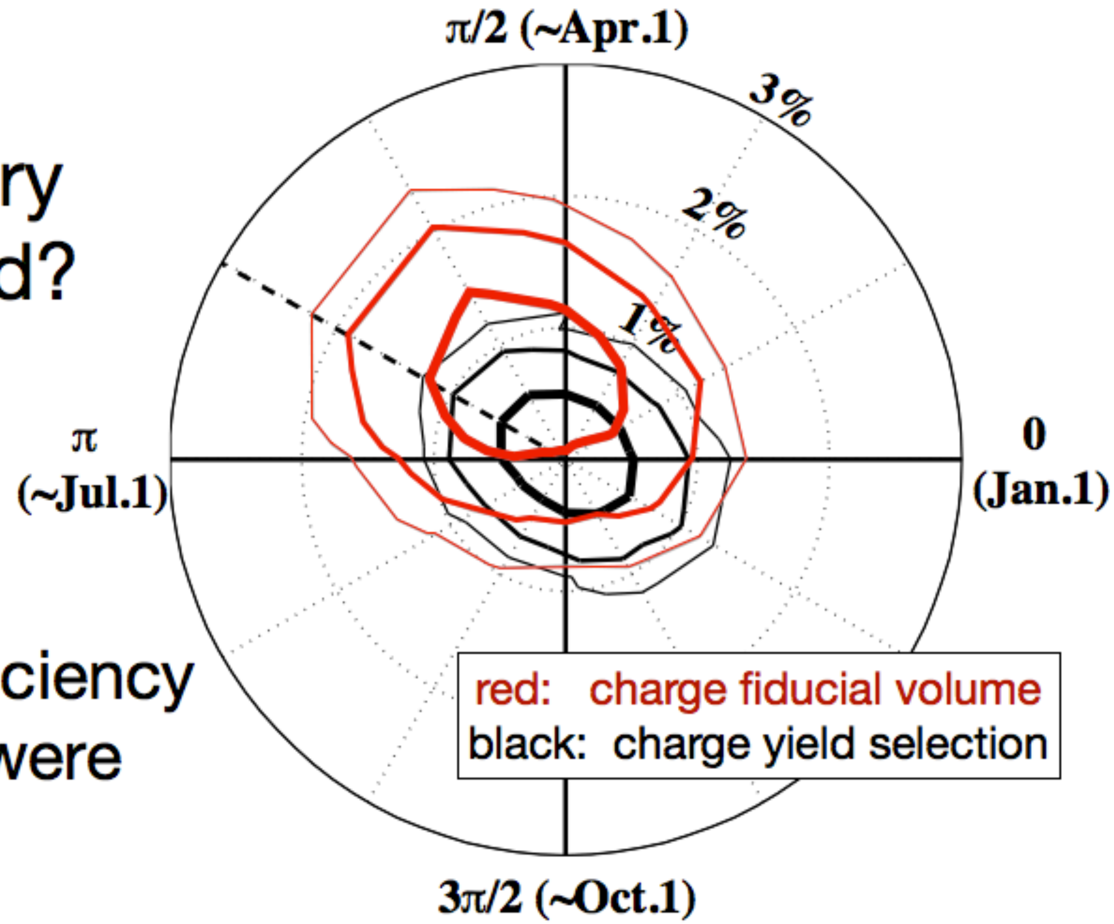
...we can assume **constant trigger efficiency.**



Preparation

Test:
Do cut efficiencies vary with a one-year period?

Tight limits placed on efficiency modulation; efficiencies were then assumed constant.

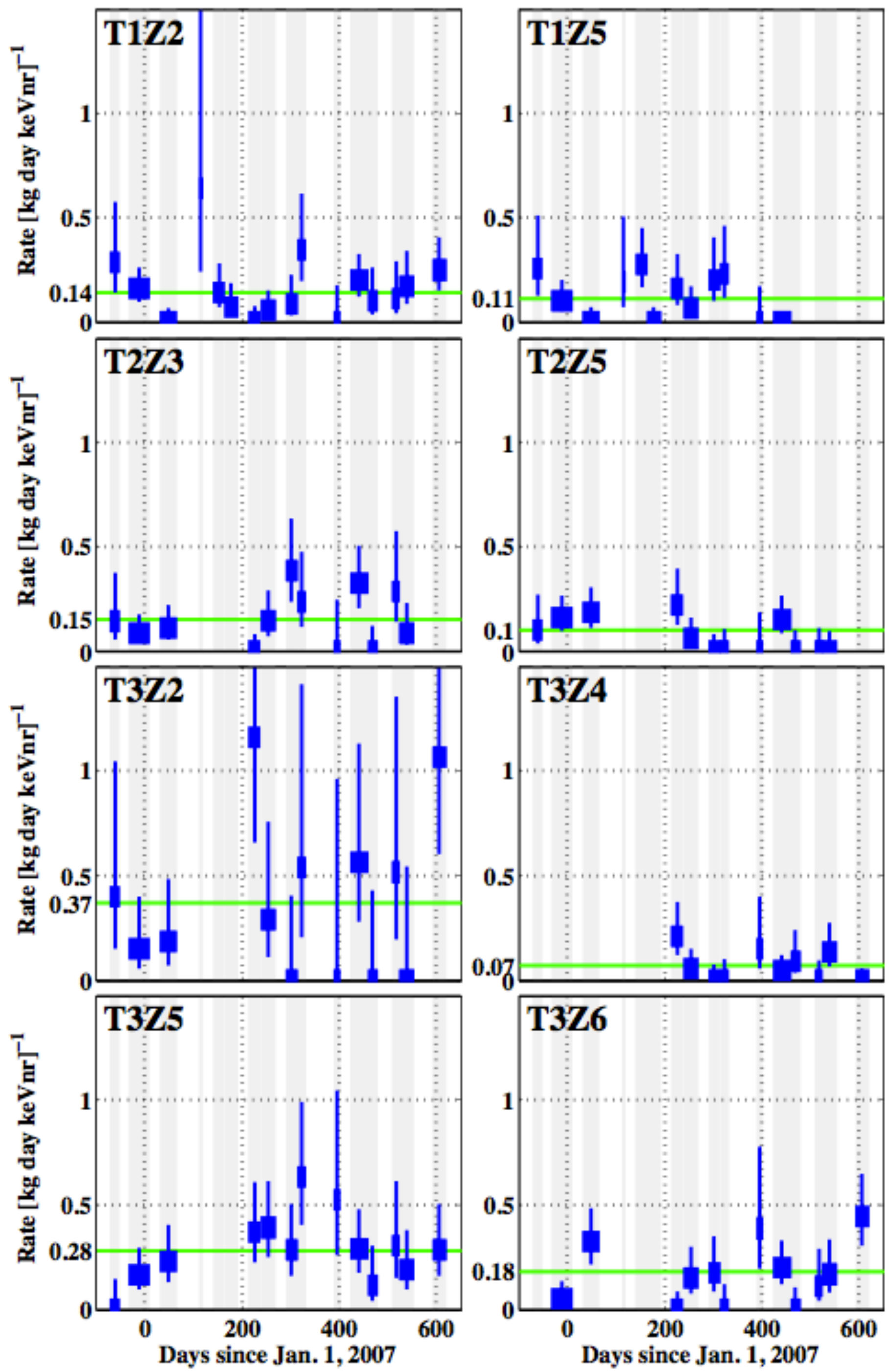


contours: 68,95,99%

CDMS II Modulation

Candidate Event Rate vs. Time

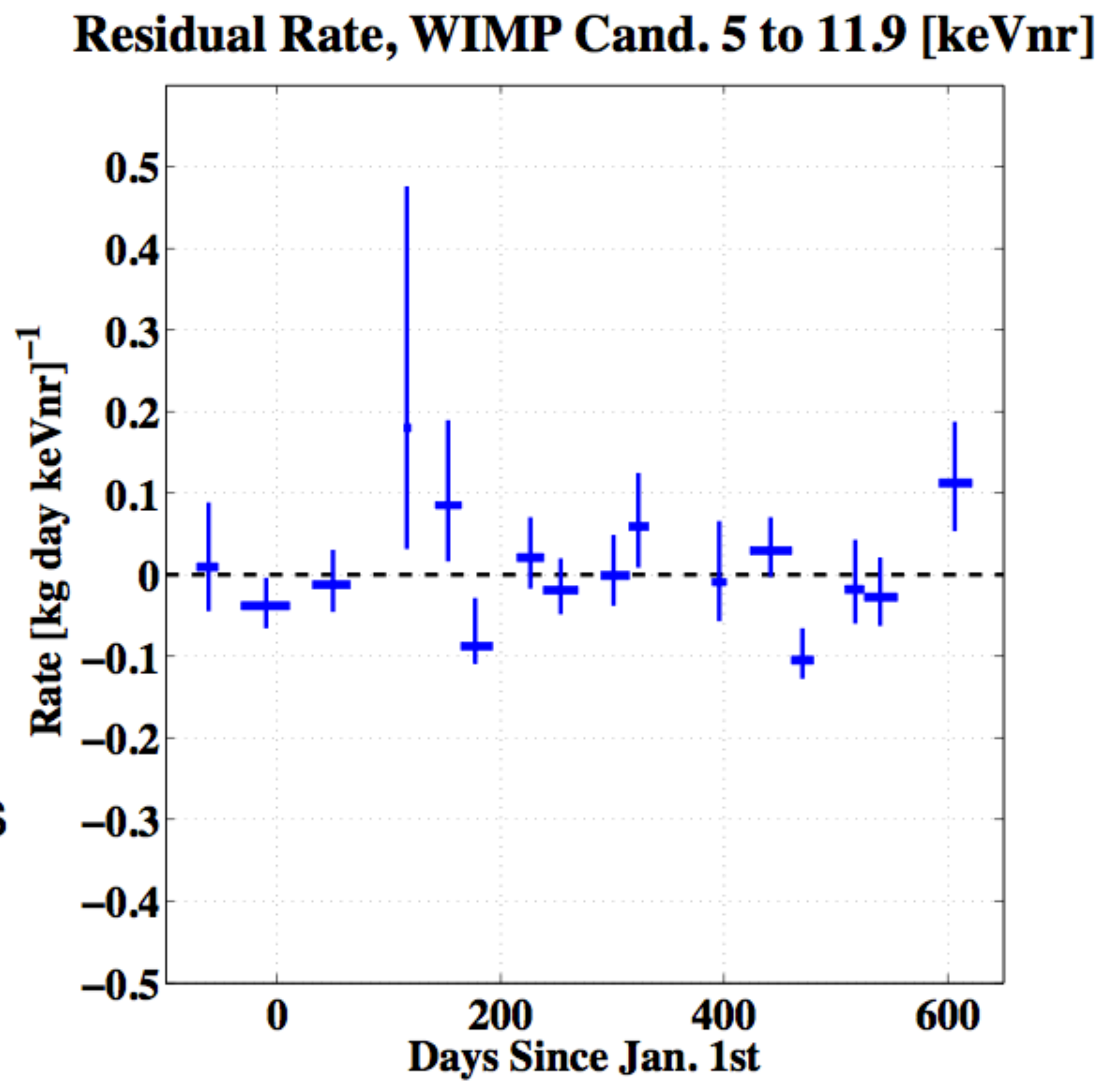
DC rates (in green), *detector by detector*



CDMS II Modulation

Candidate Event Rate
vs. Time

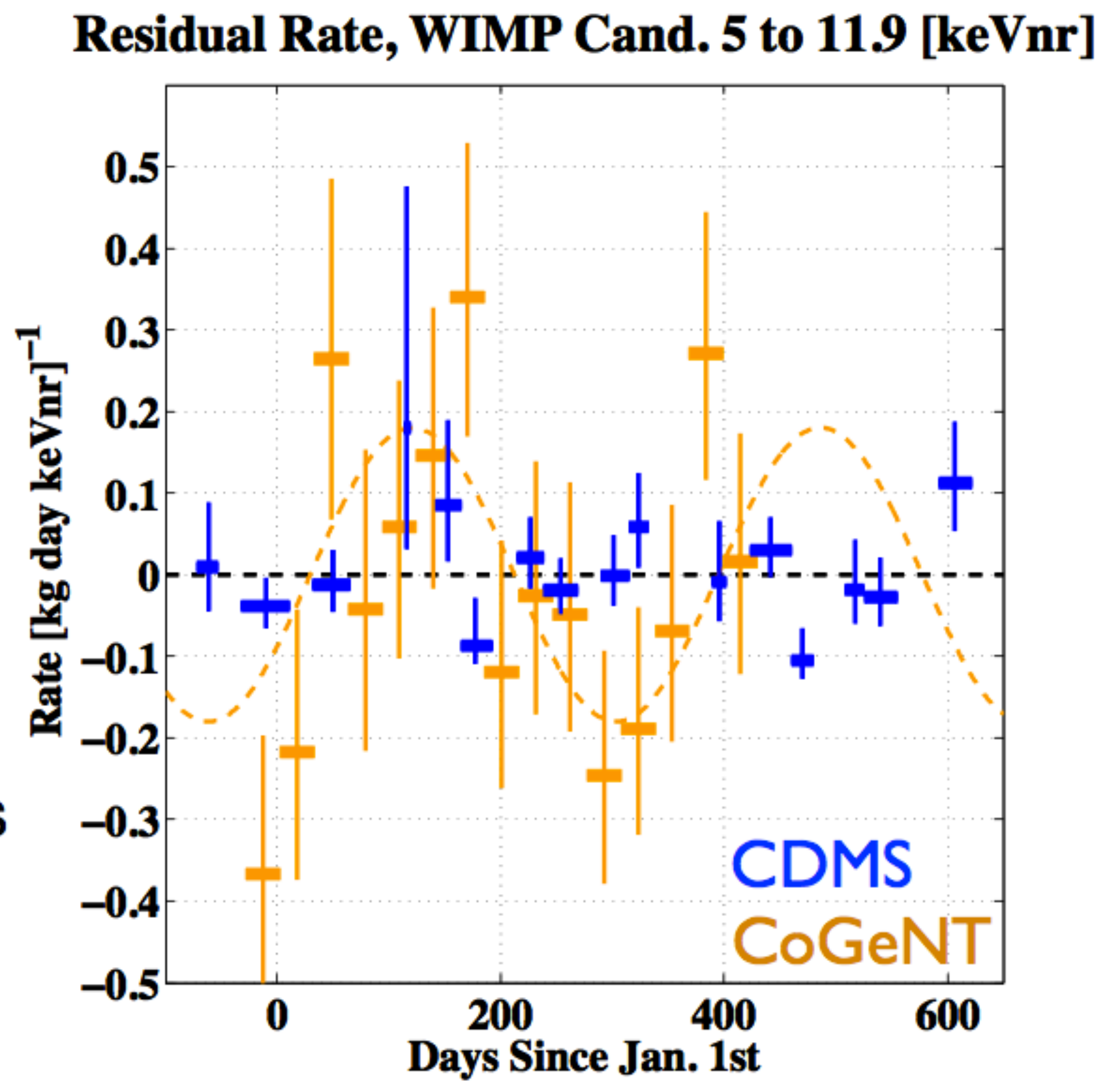
DC-subtracted,
detector by detector
before combining residuals



CDMS II Modulation

Candidate Event Rate vs. Time

DC-subtracted, *detector by detector* before combining residuals



Testing of [R_{mod}, ϕ] models

predicted rate for [det d, bin β]

$$\mu_{\beta d} = \{\Gamma_d + R_{mod} \cos\left[\omega\left(t_\beta - \phi\right)\right]\}[\text{exposure}_{\beta d}]$$

DC Rate — Mod. Rate — Mod. Phase

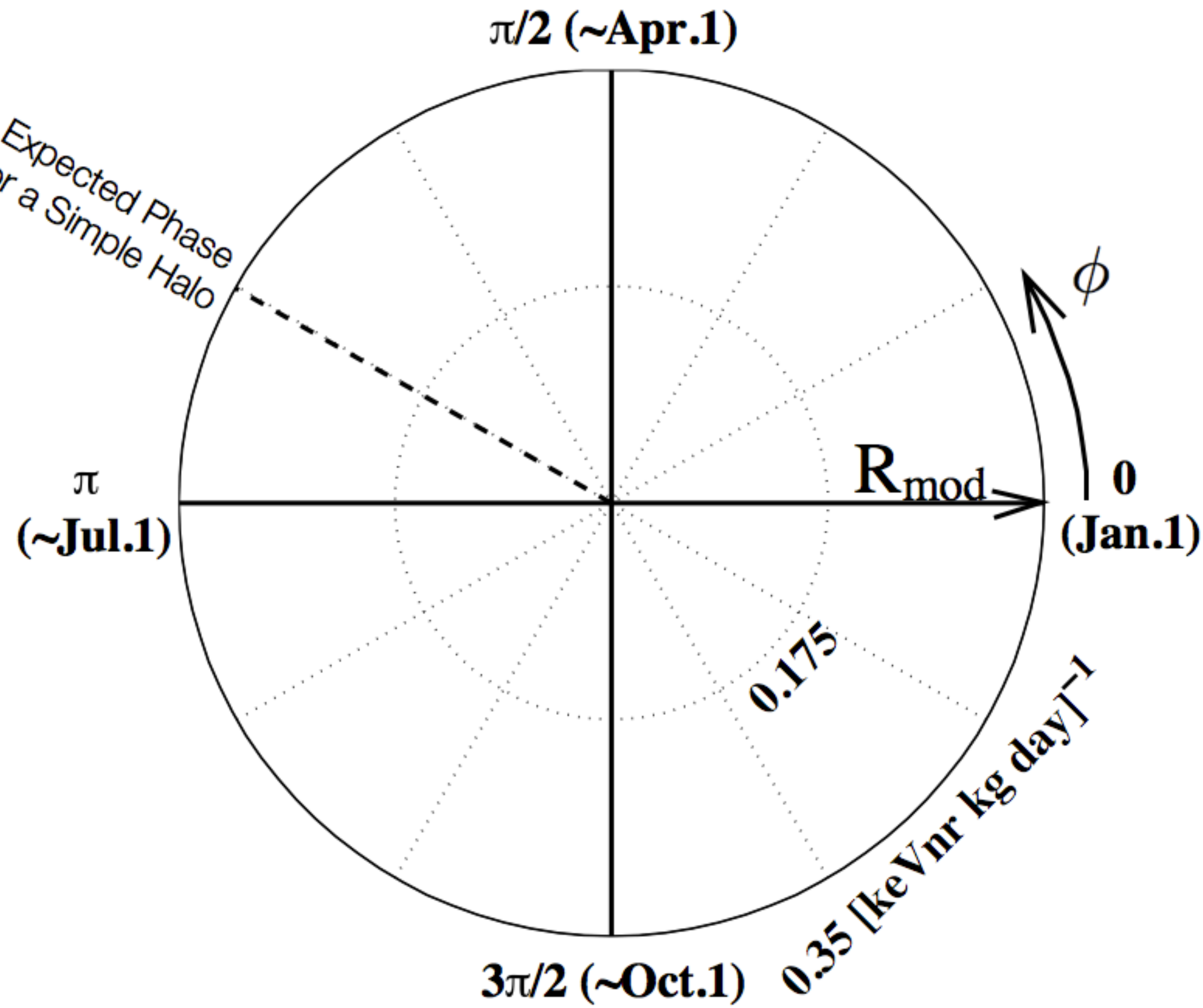
poisson likelihood of data

$$\ell = \prod_{\beta,d} e^{-\mu_{\beta d}} \left(\mu_{\beta d}\right)^{n_{\beta d}}$$

Feldman-Cousins scan of model space
(marginalizing out the 8 DC rates Γ_d)

space of [R_{mod}, ϕ] models

5.0-11.9 keVnr



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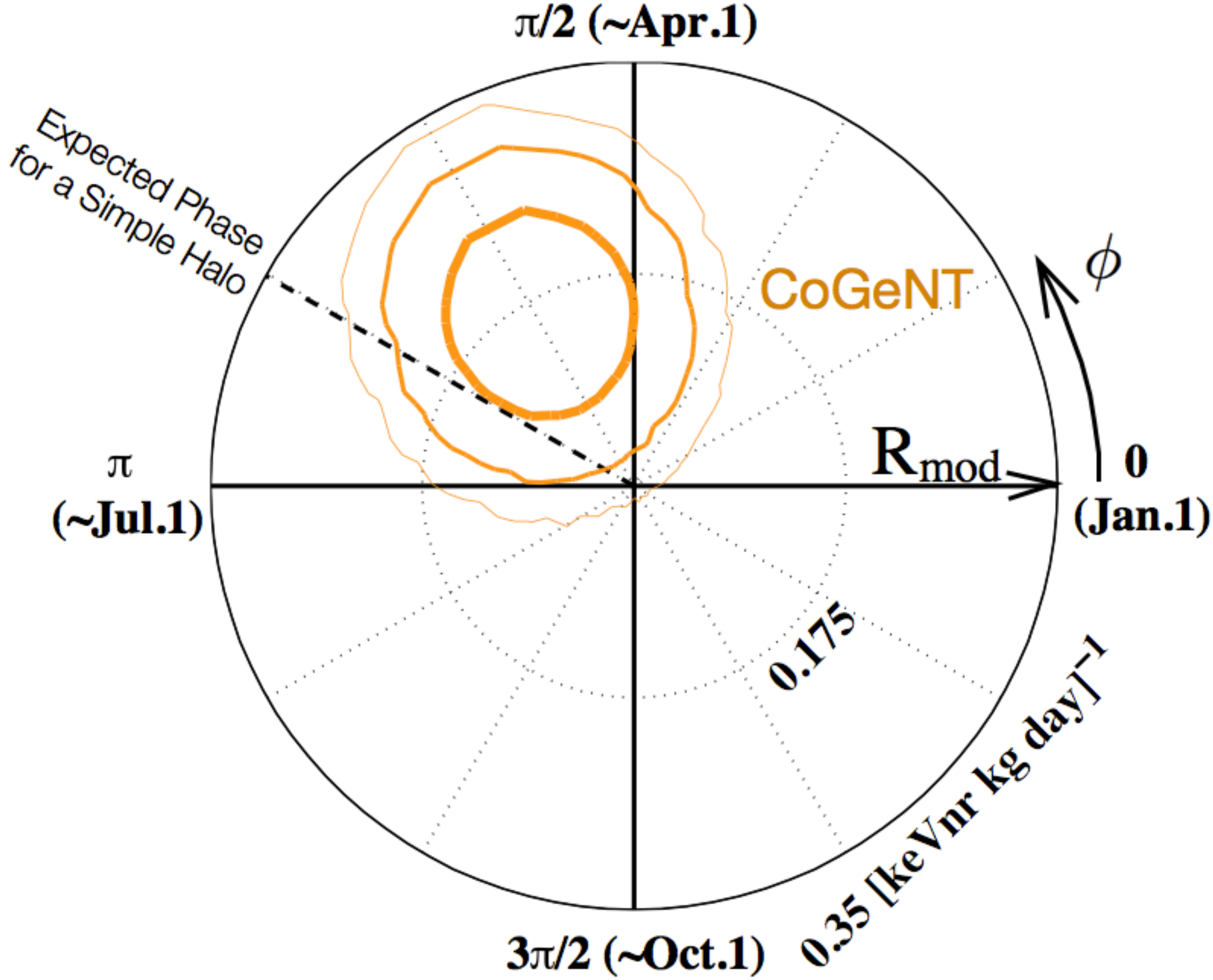

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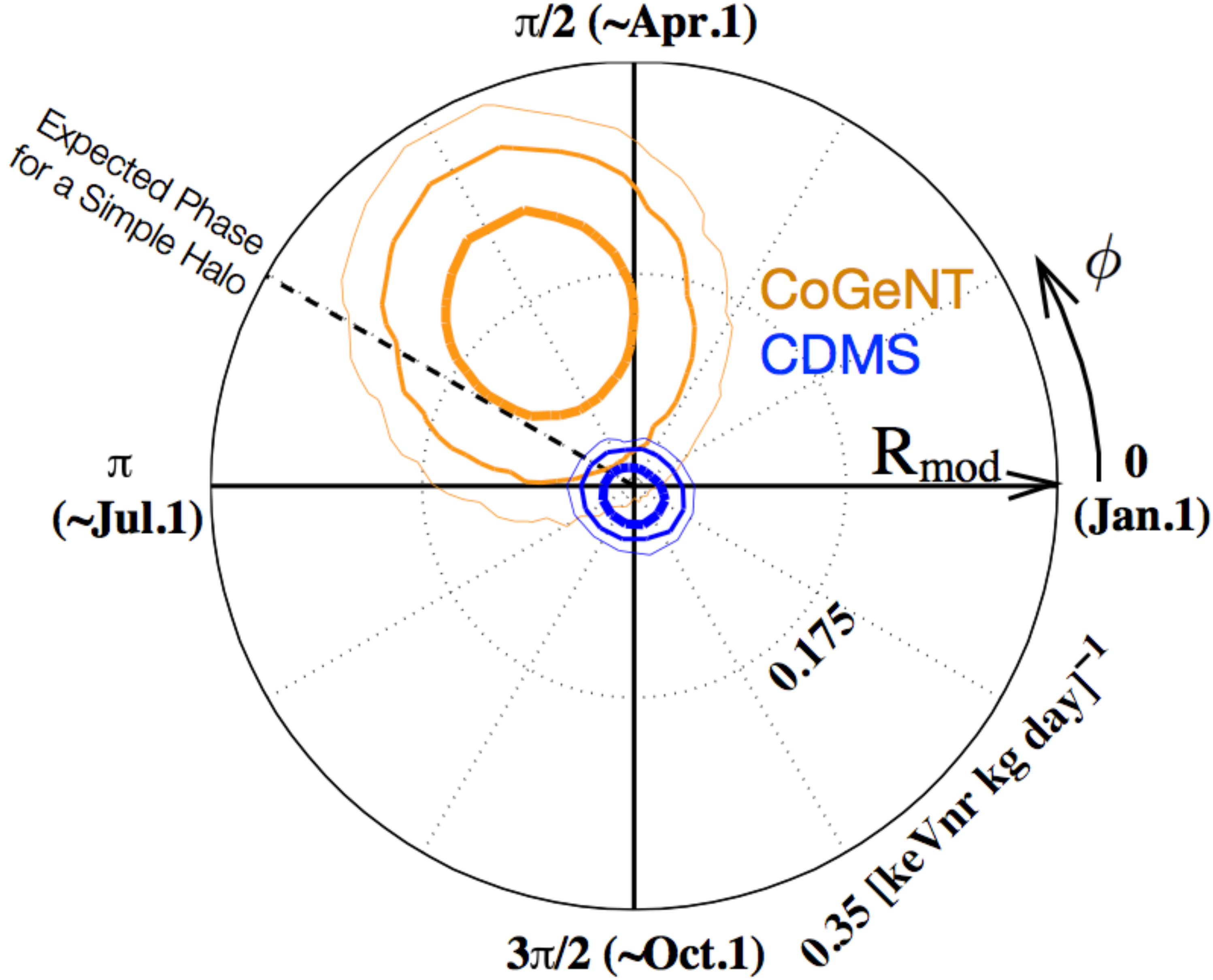
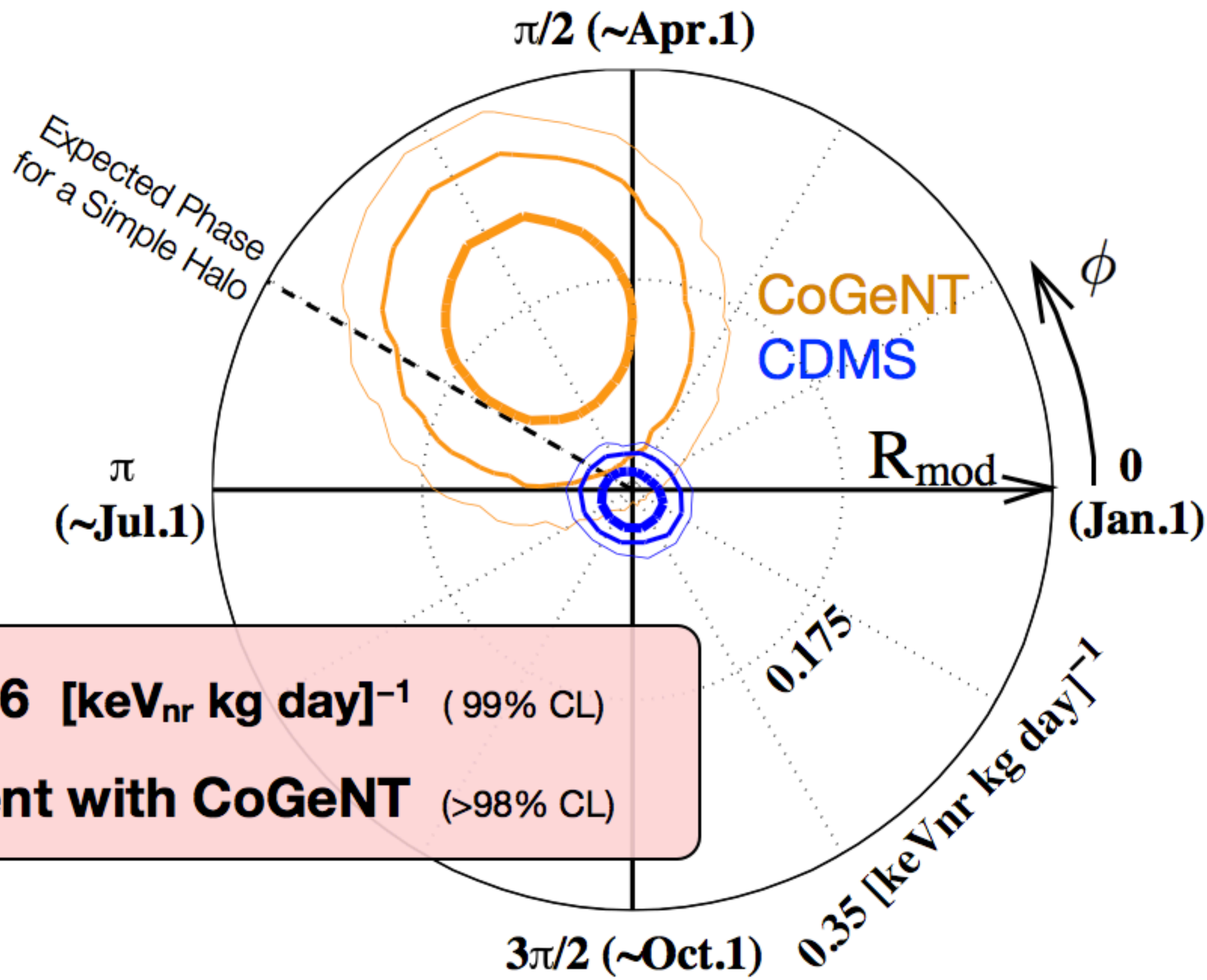


space of [R_{mod}, ϕ] models

5.0-11.9 keVnr

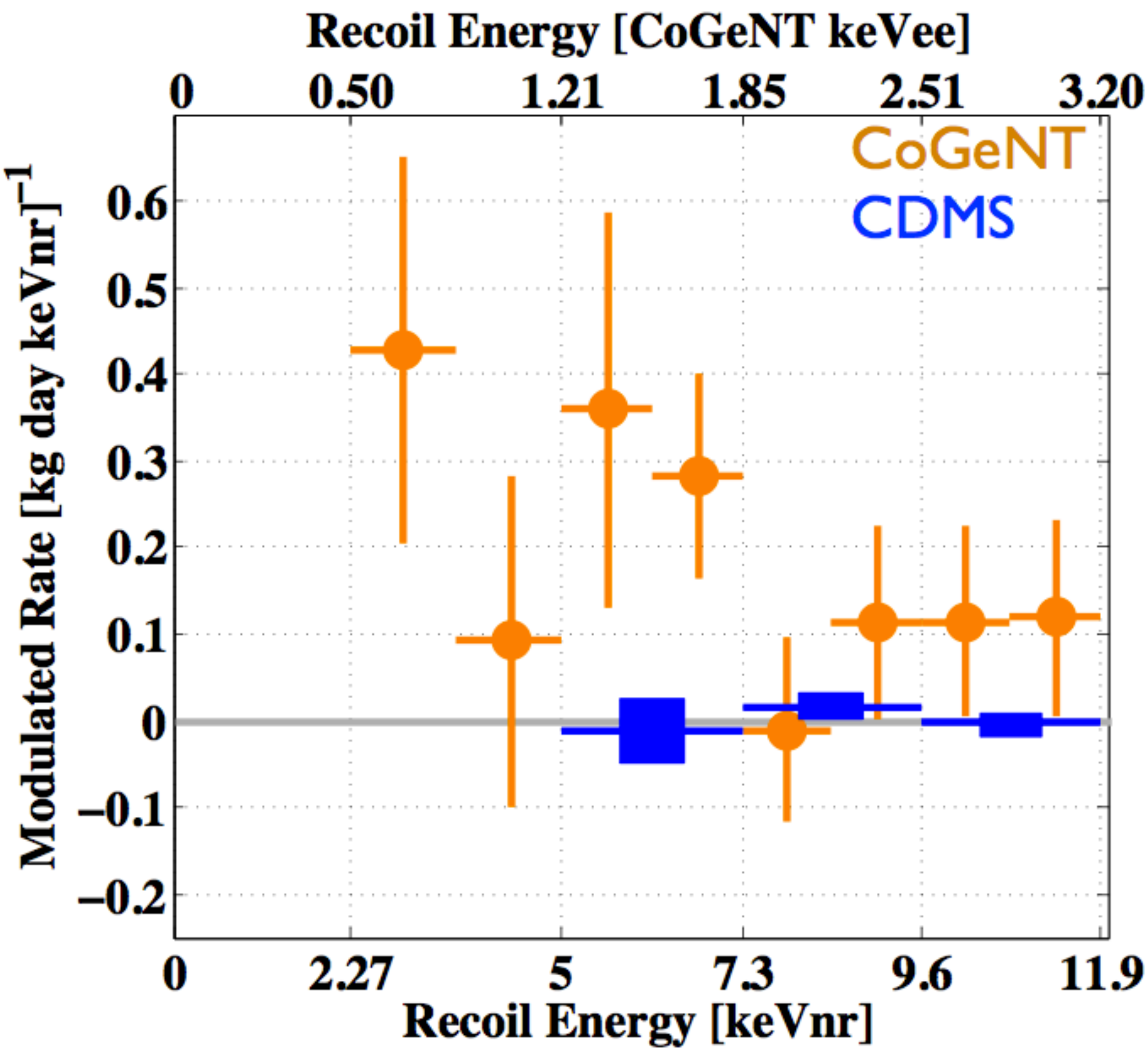


R_{mod} **< 0.06 [keV$_{nr}$ kg day]$^{-1}$** (99% CL)

inconsistent with CoGeNT (>98% CL)

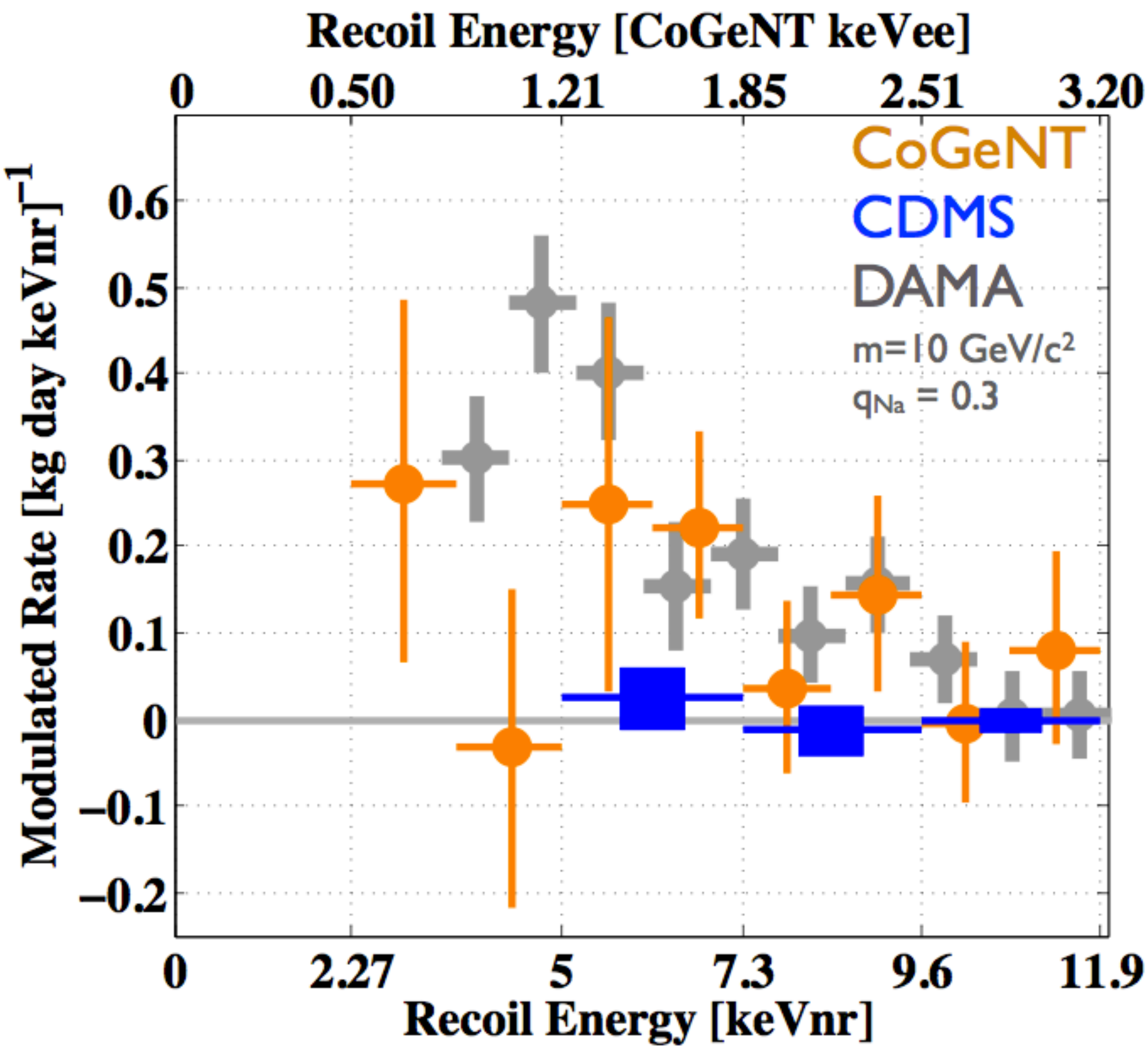
R_{mod} vs Energy (at a particular ϕ)

106-day phase
(CoGeNT Best-Fit)



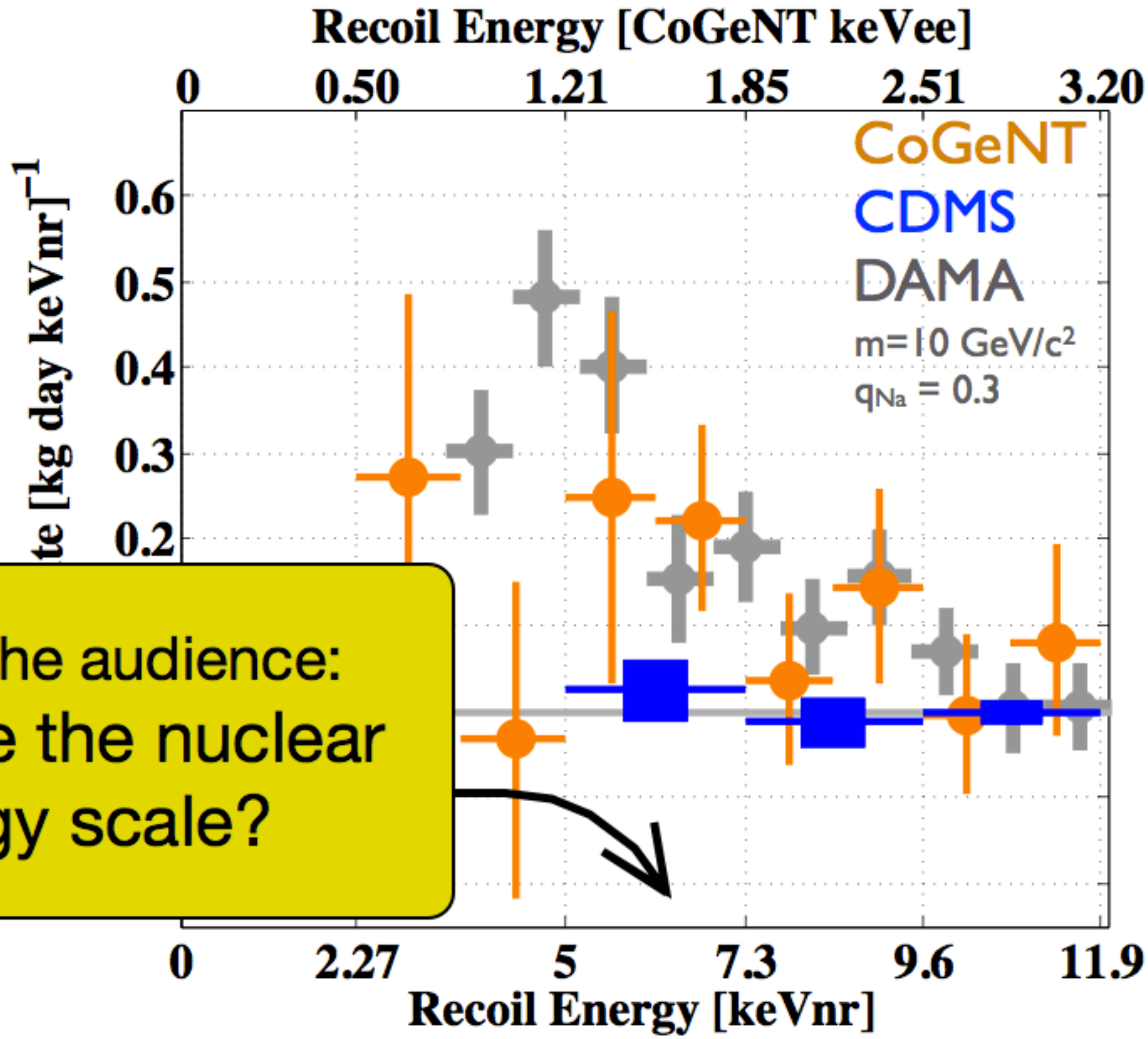
R_{mod} vs Energy (at a particular ϕ)

152.5-day phase
(Simple Halo Model)



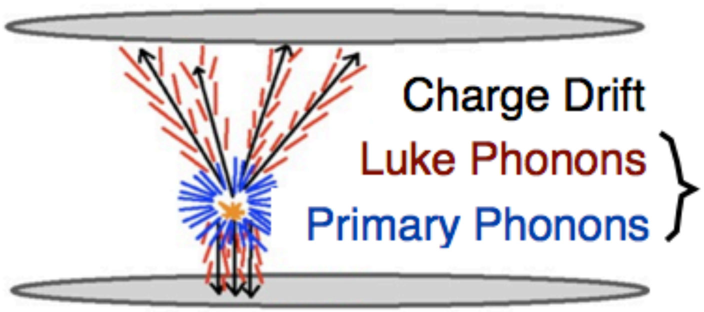
R_{mod} vs Energy (at a particular ϕ)

152.5-day phase
(Simple Halo Model)



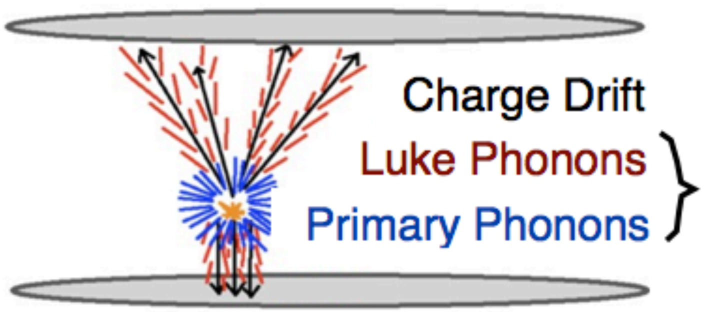
Question from the audience:
Can we believe the nuclear recoil energy scale?

Phonon energy: two components



Phonon Signal
= Primary + Luke

Phonon energy: two components



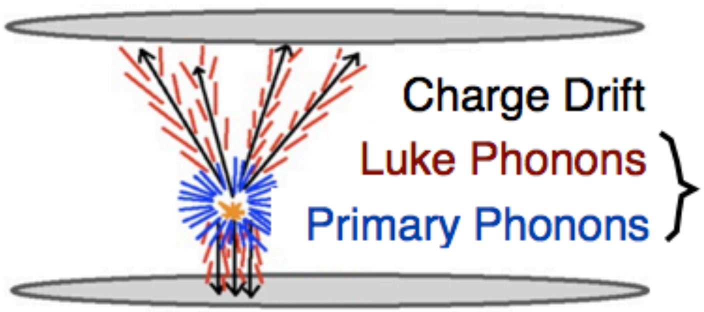
Phonon Signal
= Primary + Luke

At 3V running in Ge...

Luke = Yield x Primary

Electron Recoils: | Primary | 1.0 x Primary |

Phonon energy: two components



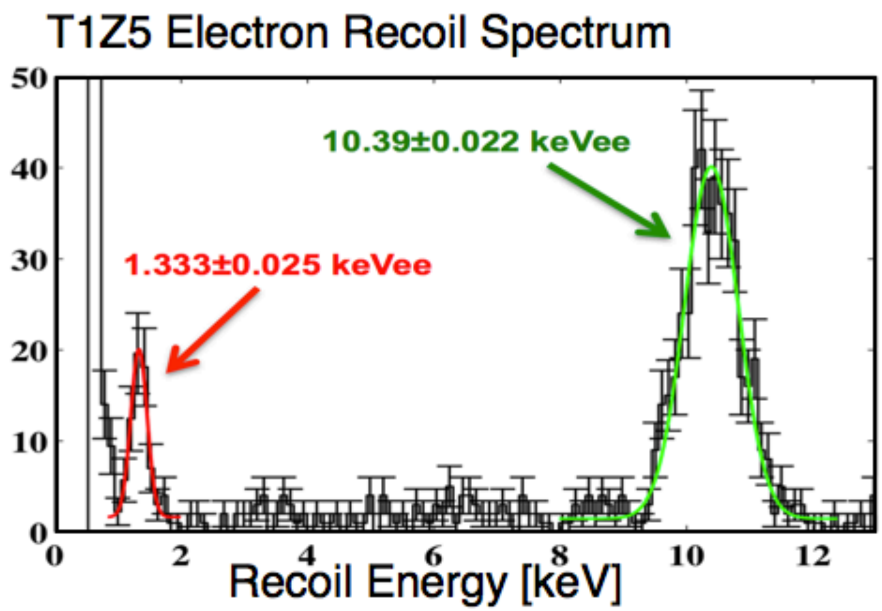
Phonon Signal
= Primary + Luke

At 3V running in Ge...

Luke = Yield x Primary

Electron Recoils: Primary | 1.0 x Primary

Nuclear Recoils: Primary | ~0.2 x Primary

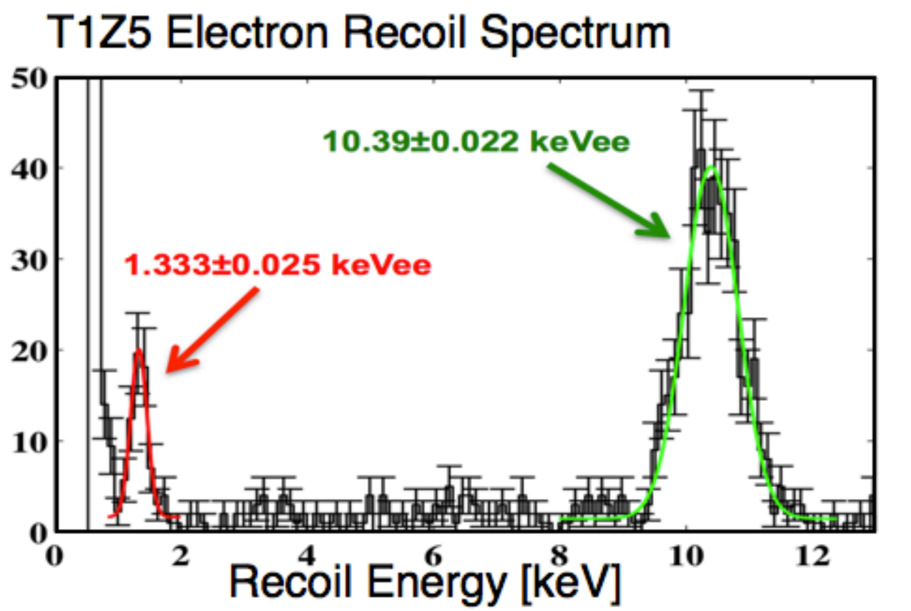


How to define a NR energy scale:

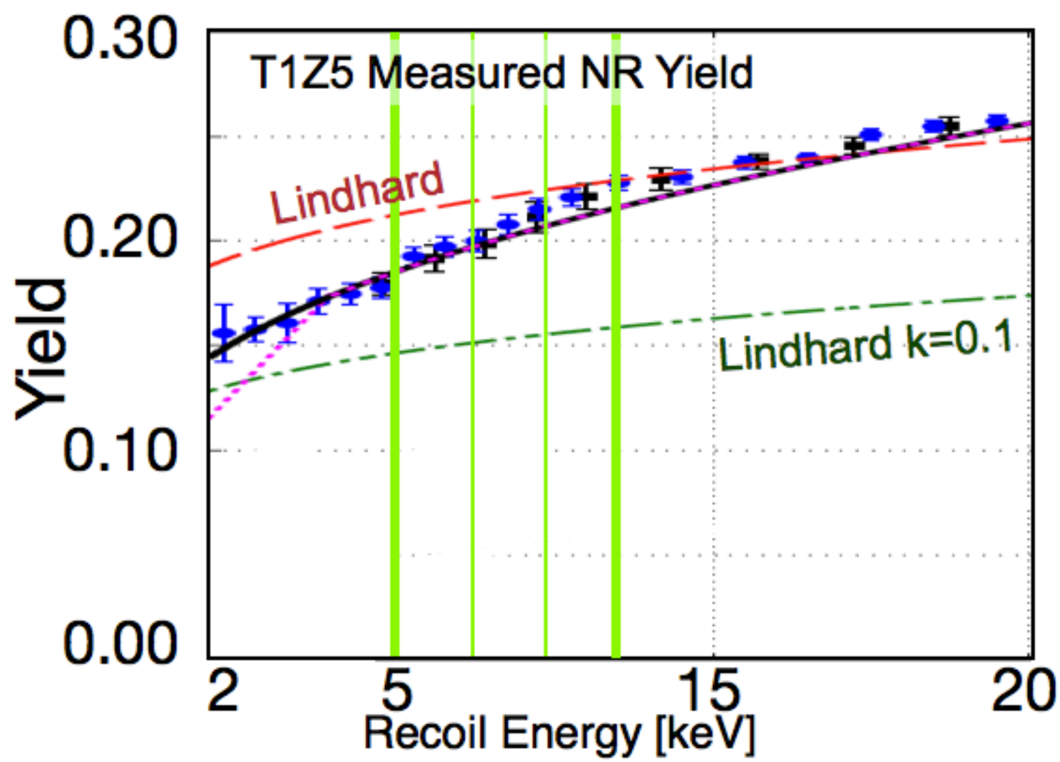
STEP 1:

Calibrate using ER lines

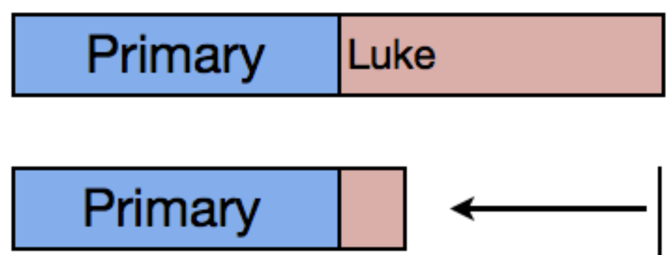
How to define a NR energy scale:



STEP 1:
Calibrate using ER lines



STEP 2:
Scale from ER to NR

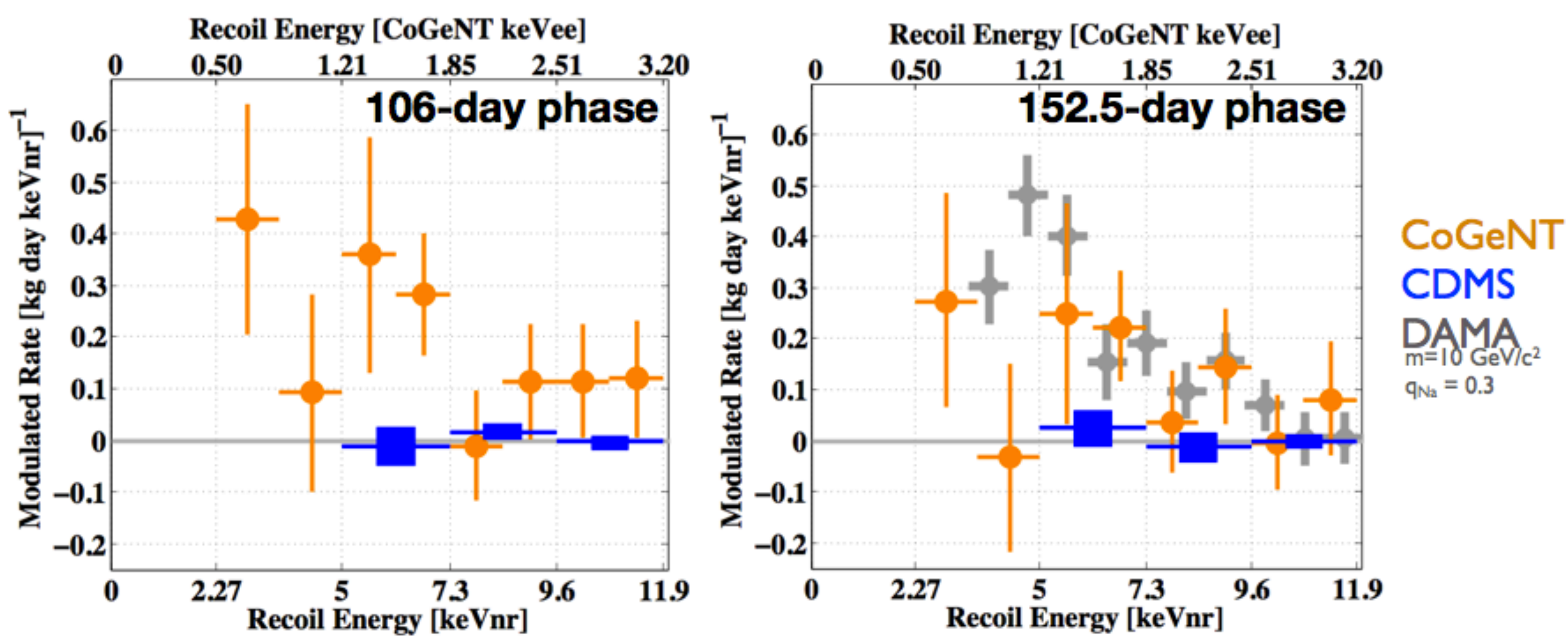


Conclusions

Between 5.0-11.9 keVnr,

R_{mod} < 0.06 [keV_{nr} kg day]$^{-1}$ (99% CL)
Inconsistent with CoGeNT (>98% CL)

→ Relative energy scales well known
→ Same target material
→ No dependence on halo model



extra slides

The Collar-Fields Maximum-Likelihood Analysis
1204.3559

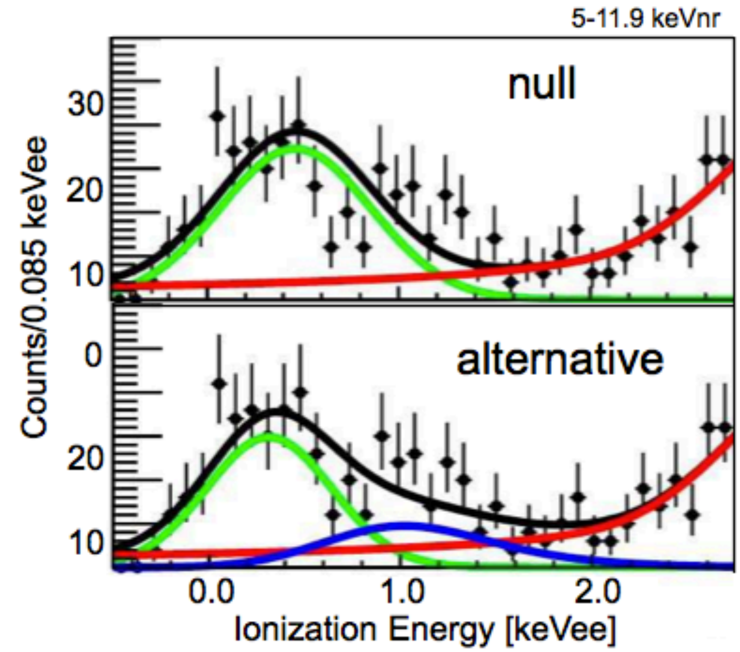
Background model critique

Surface event distribution unmotivated

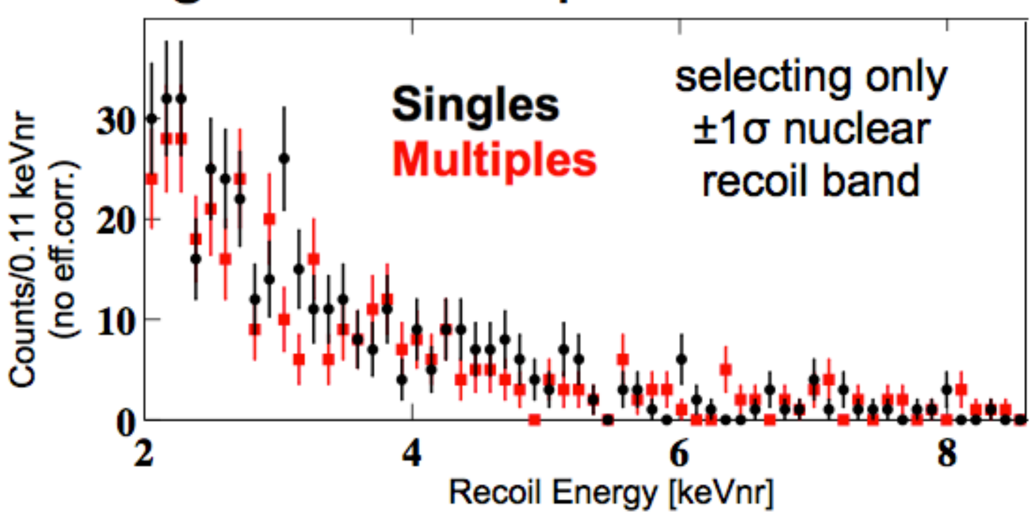
energy: expect the low-yield rate to increase faster than the high-yield rate at low energies

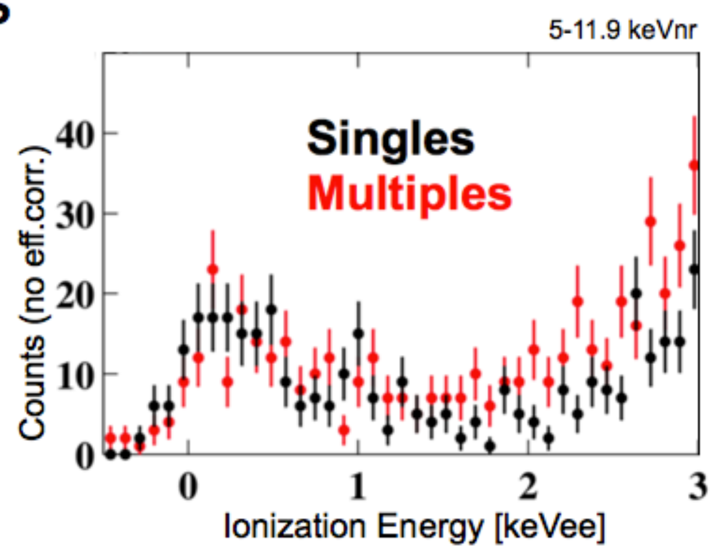
yield: no reason to think surface yield constant in energy

Zero charge distribution should not be fit in such a model (these events follow the *measured* charge noise dist.)

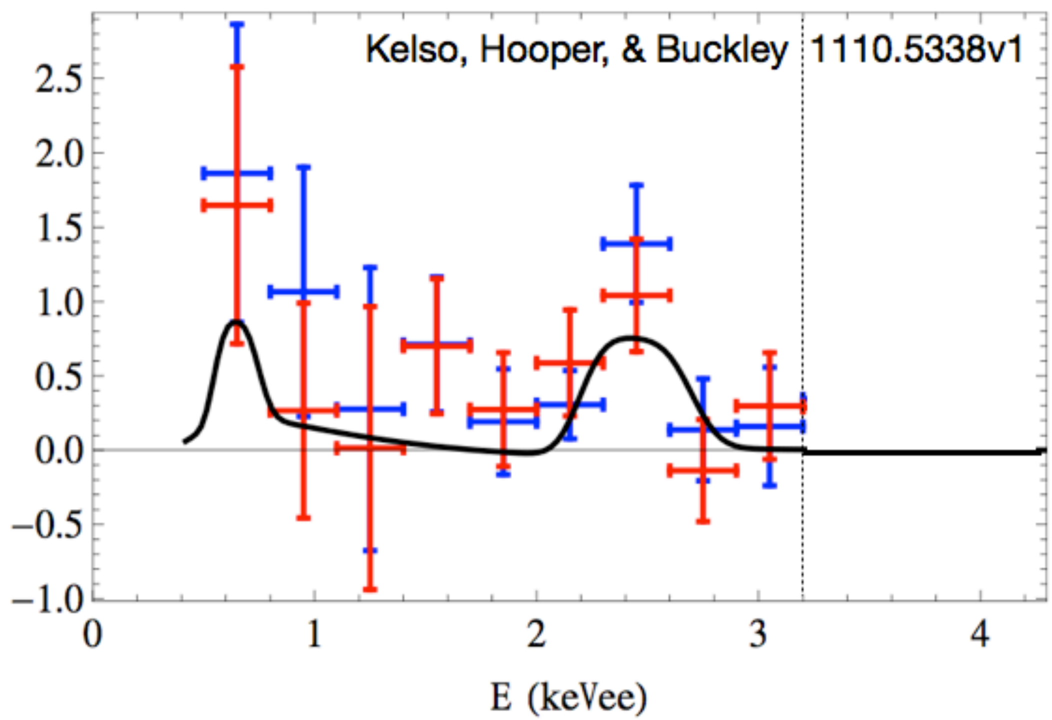


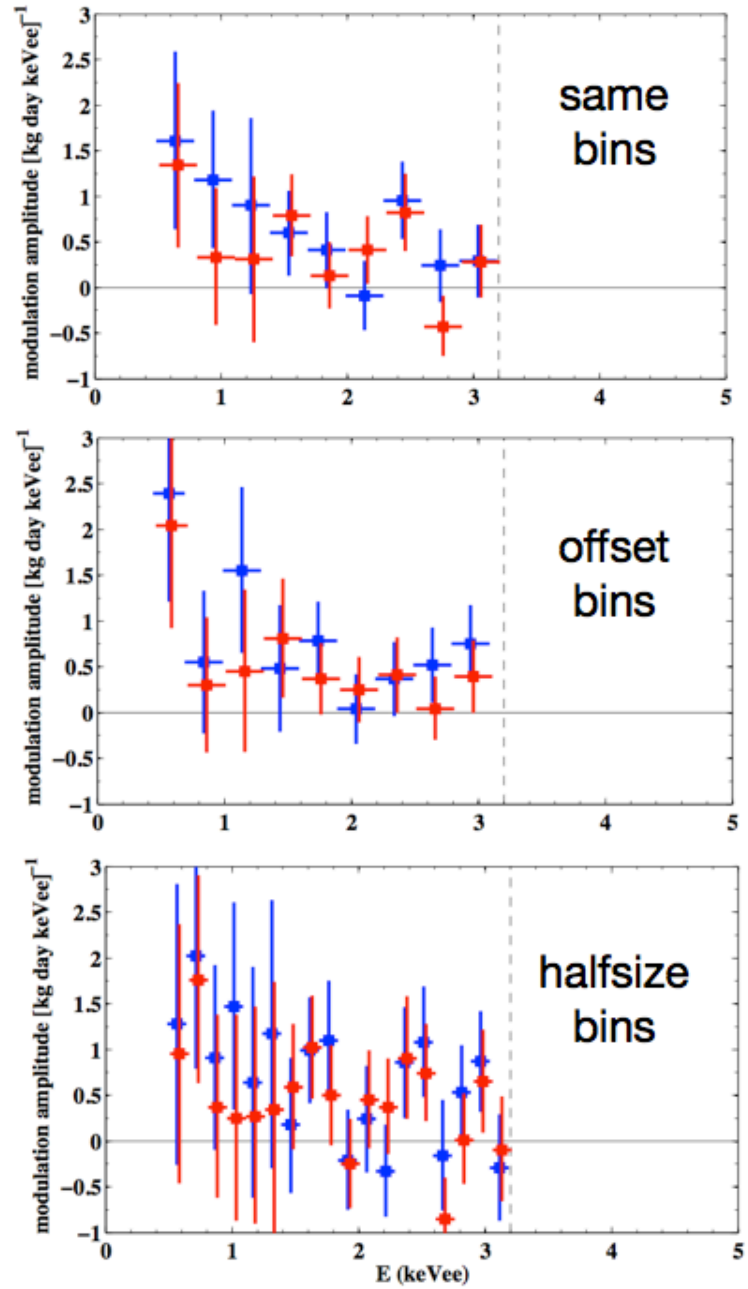
Looking at the multiple-detector events





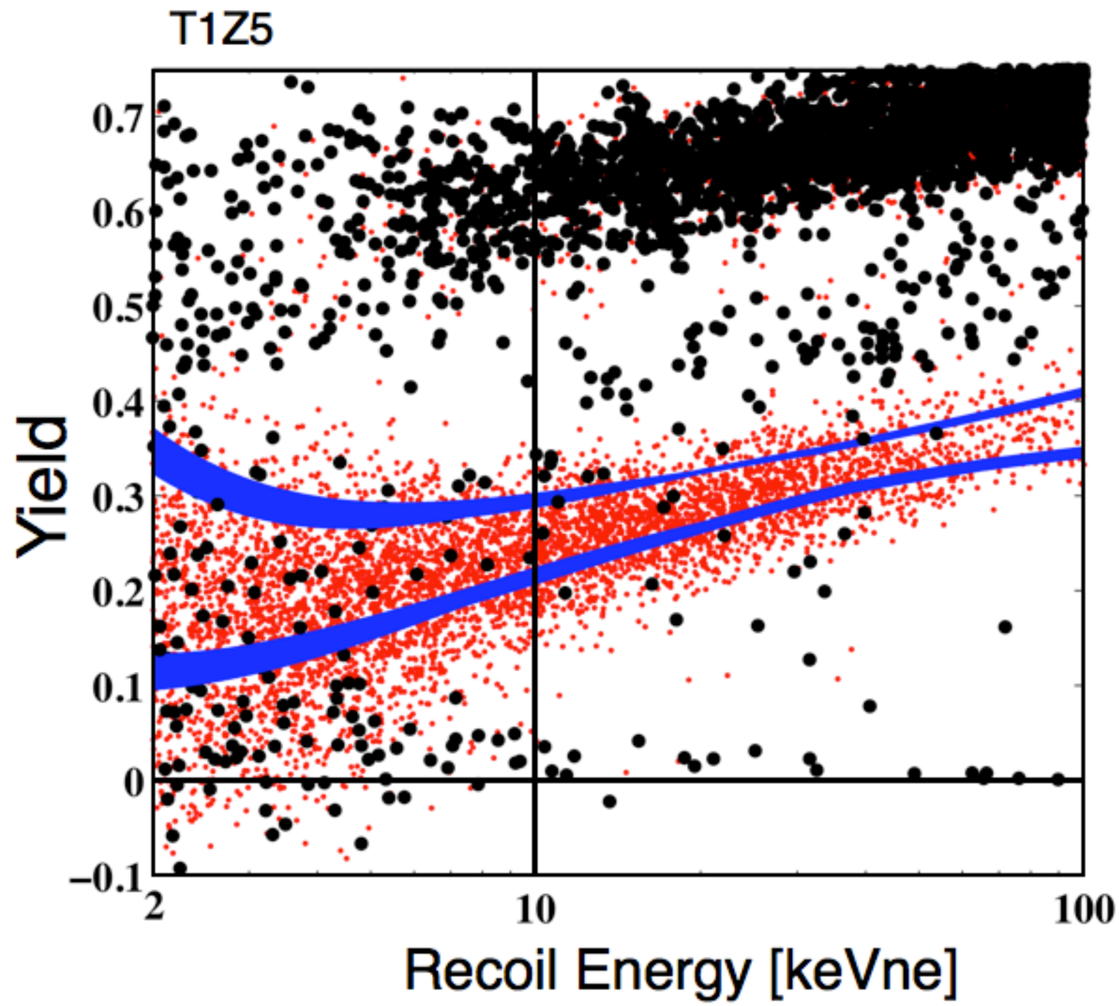
A ‘spike’ seen by Kelso *et al.* may be dependent on the choice of energy bins



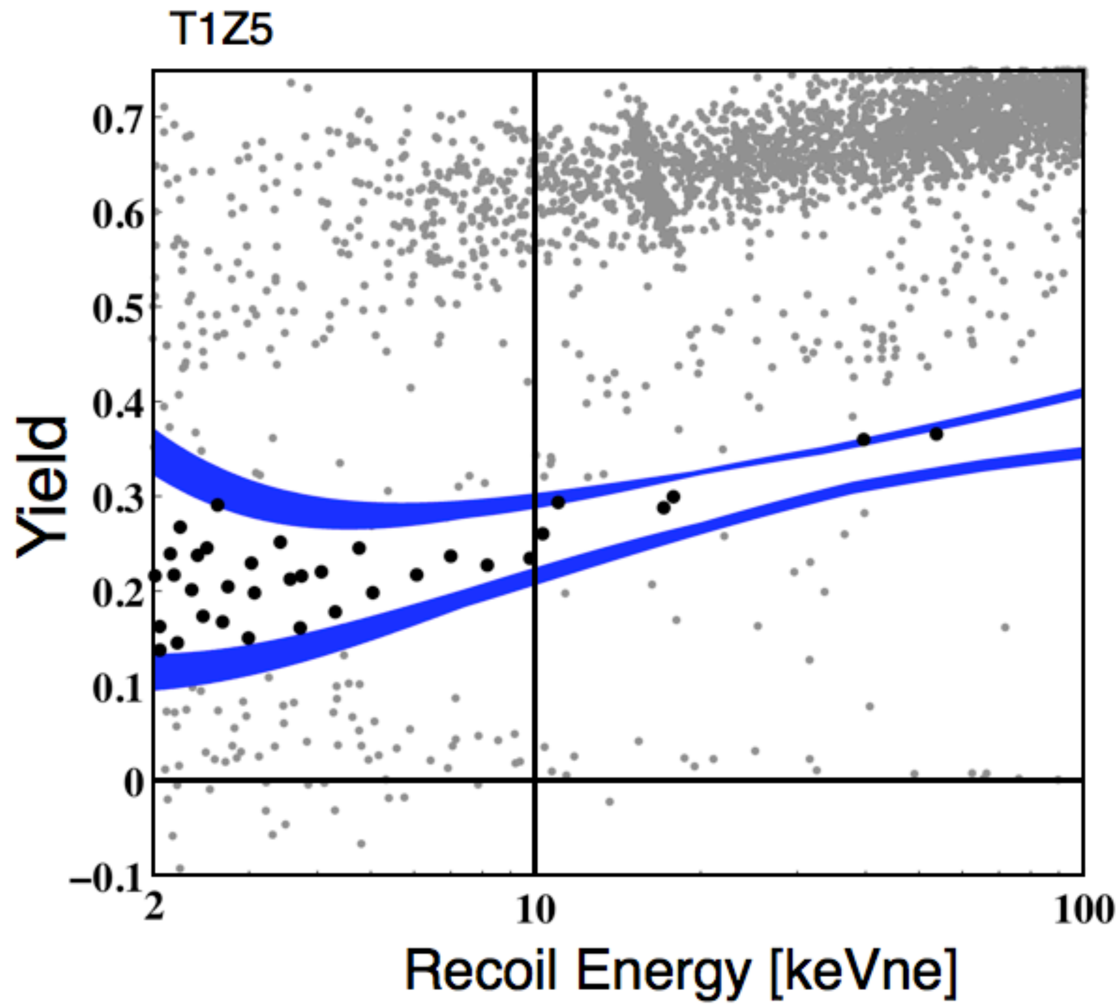


The tighter nuclear recoil yield band, defined as

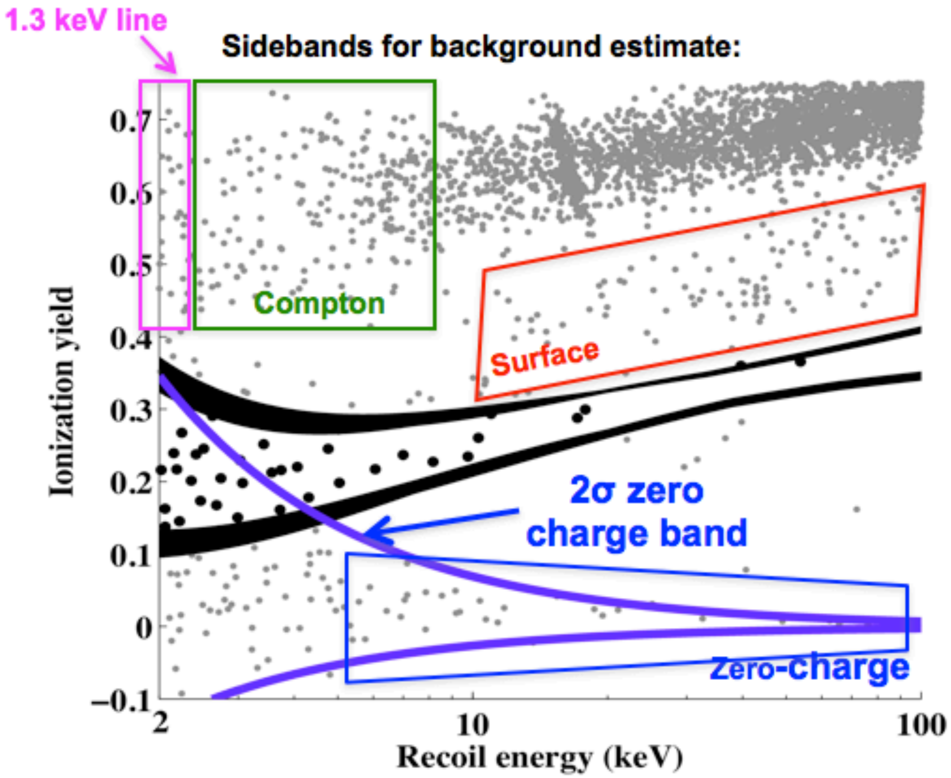
-0.5σ to +1.25σ

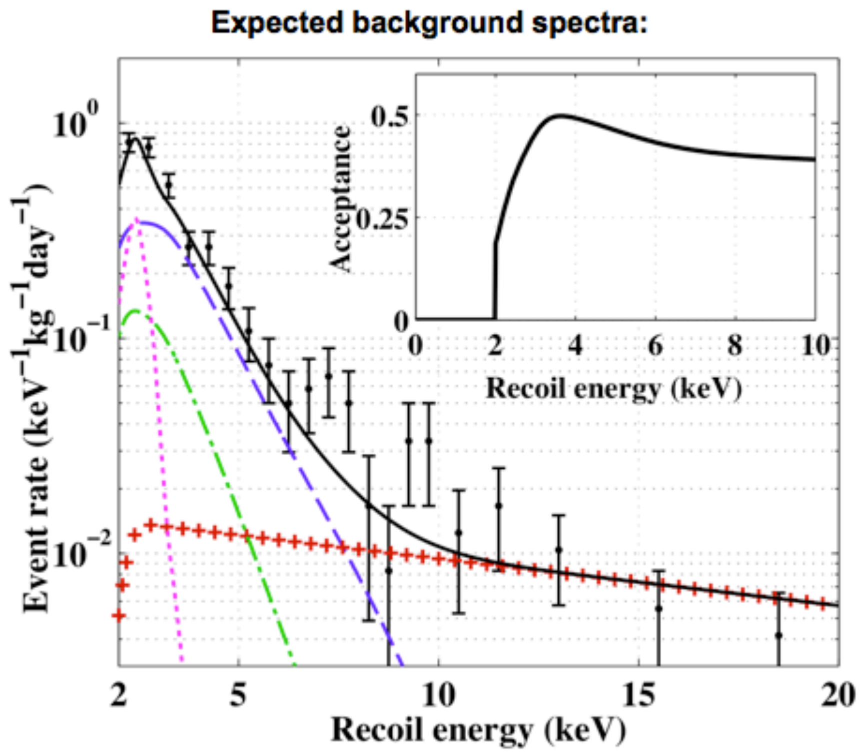


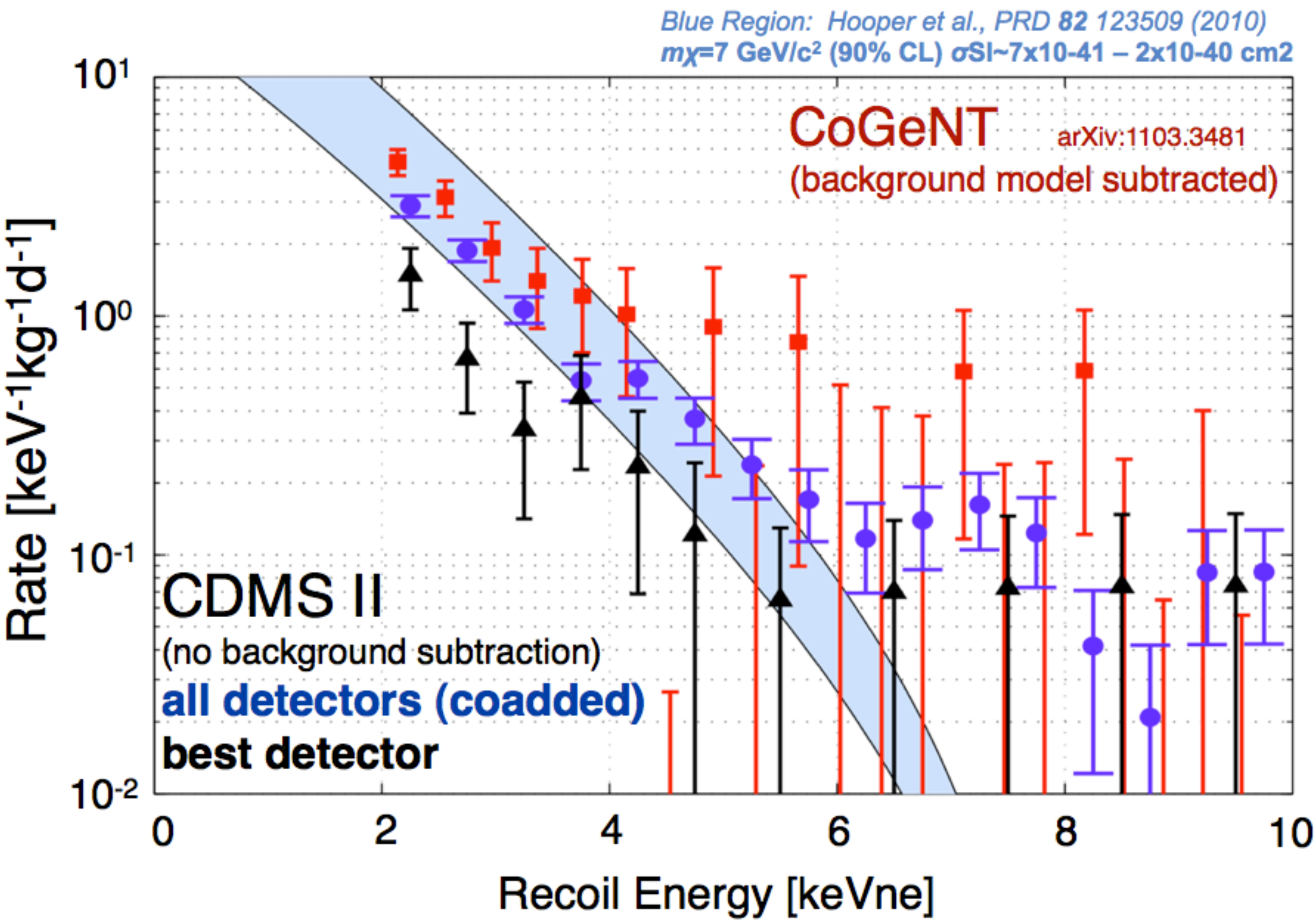
The 'candidate' events were selected from WIMP-search data, ignoring pulse shape.



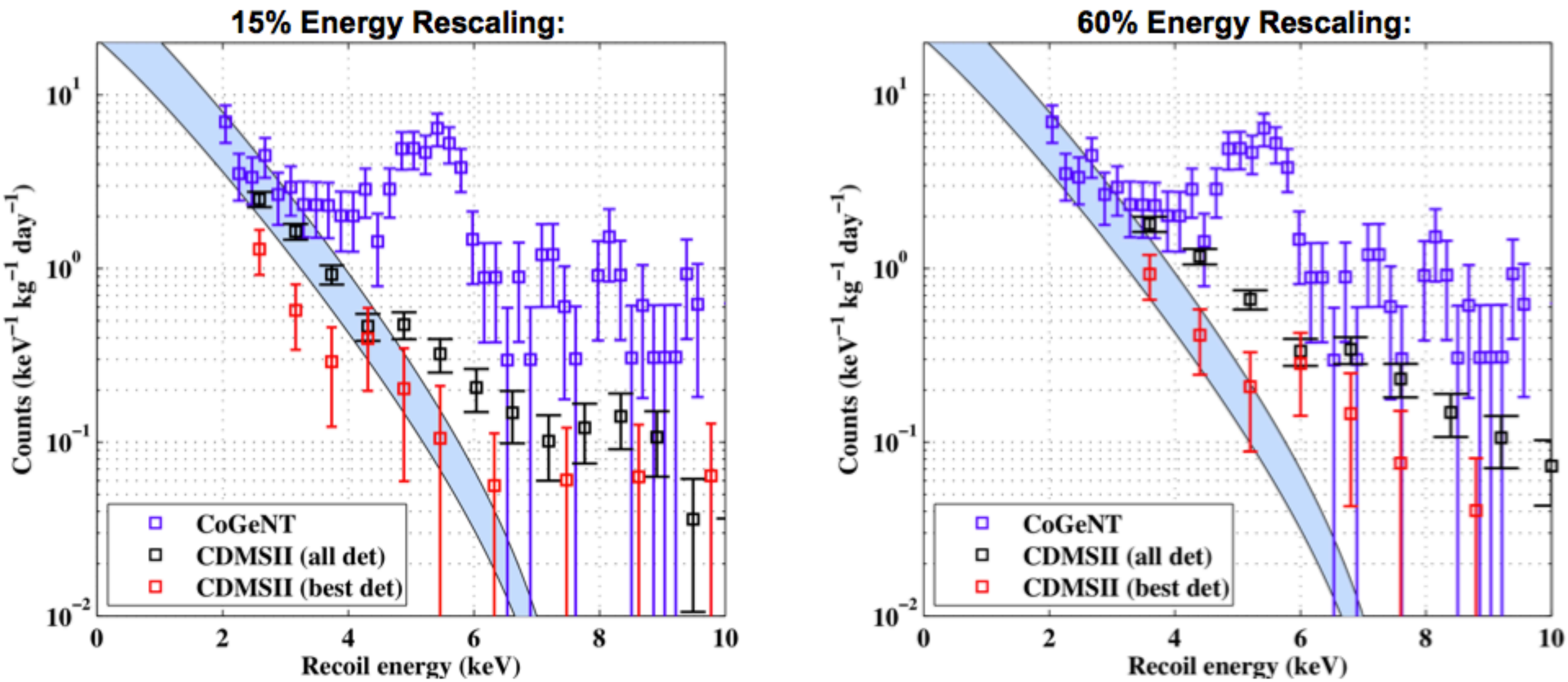
Interpretation of CDMS II at Low Energies

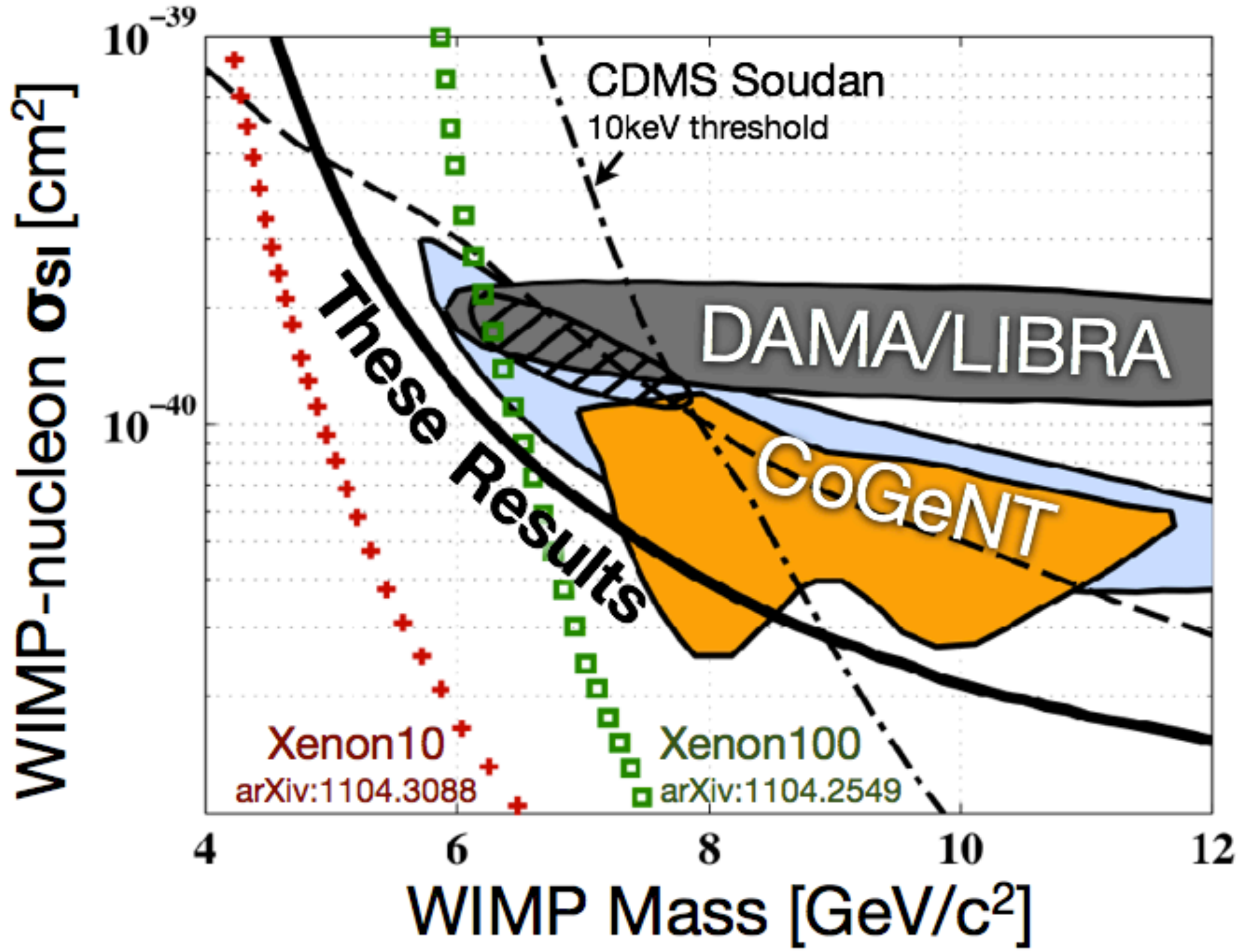




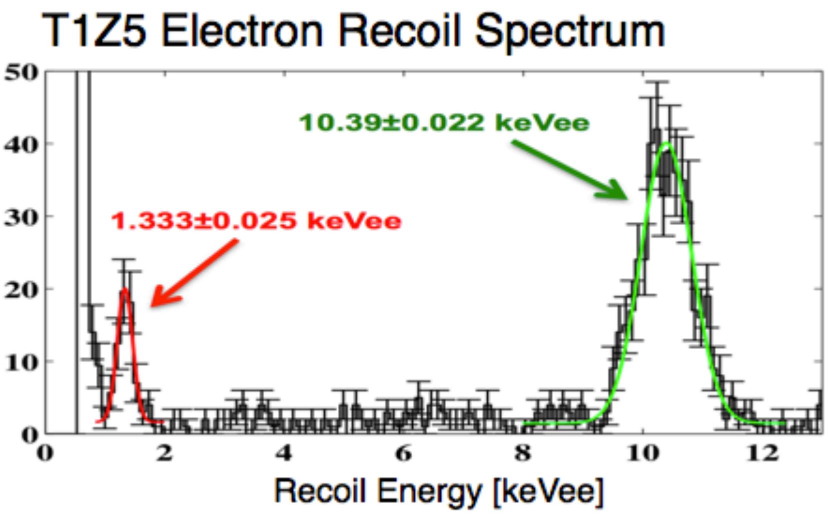


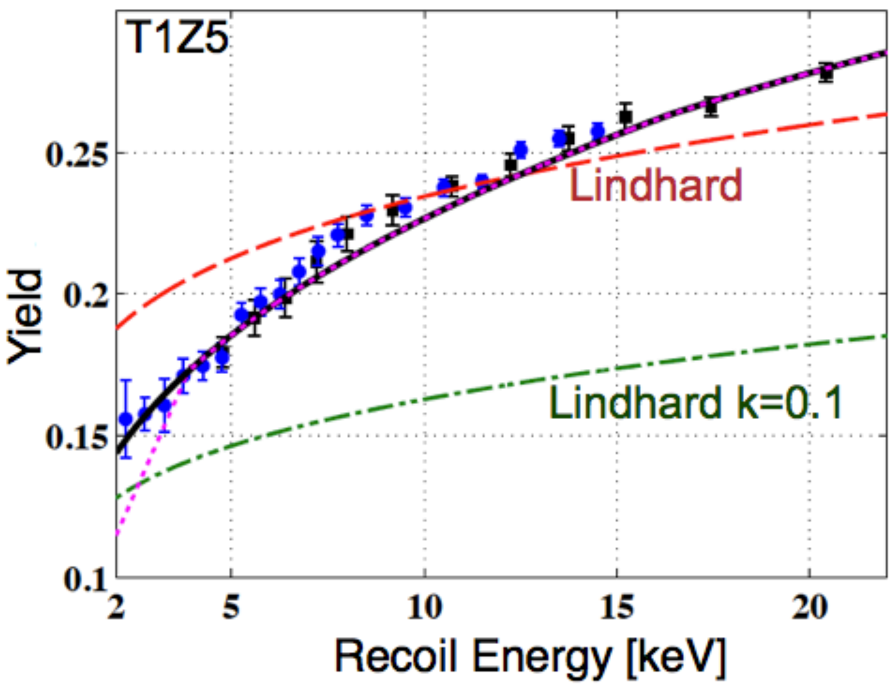
Blue Region: Hooper et al., PRD 82 123509 (2010)
mχ=7 GeV/c² (90% CL) σSI~7x10-41 – 2x10-40 cm2
CoGeNT arXiv:1103.3481
(background model subtracted)
CDMS II
(no background subtraction)
all detectors (coadded)
best detector
Rate [keV-1kg-1d-1]
Recoil Energy [keVne]
10¹
10⁰
10⁻¹
10⁻²
0
2
4
6
8
10

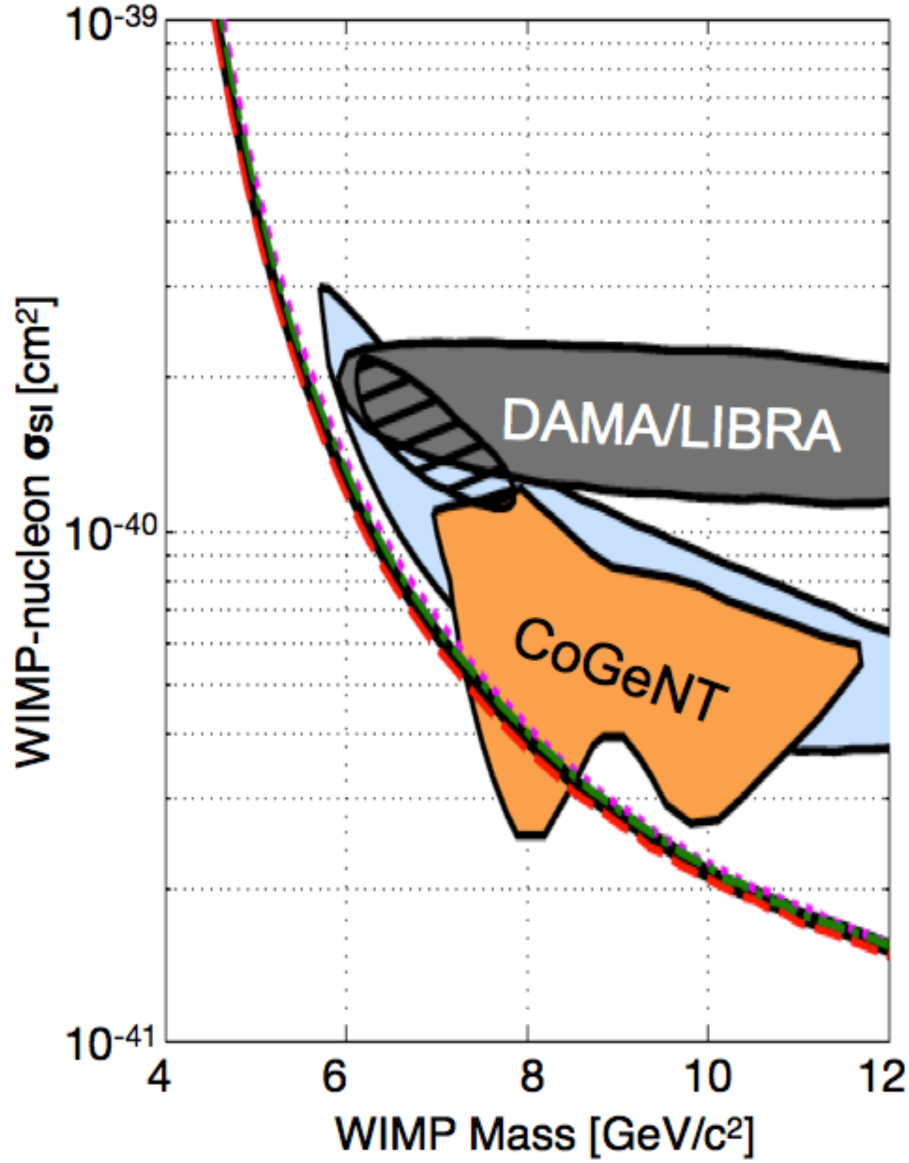

15% Energy Rescaling:
60% Energy Rescaling:
Counts (keV^{-1} kg^{-1} day^{-1})
Recoil energy (keV)
CoGeNT
CDMSII (all det)
CDMSII (best det)



DAMA/LIBRA, light blue CoGeNT region, and combined region:
*Hooper et al., PRD **82** 123509 (2010)*


T1Z5 Electron Recoil Spectrum
10.39±0.022 keVee
1.333±0.025 keVee
Recoil Energy [keVee]


T1Z5
Lindhard
Lindhard k=0.1
Yield
Recoil Energy [keV]


DAMA/LIBRA
CoGeNT
WIMP-nucleon σSI [cm2]
WIMP Mass [GeV/c2]