Prospects for Inelastic Dark Matter

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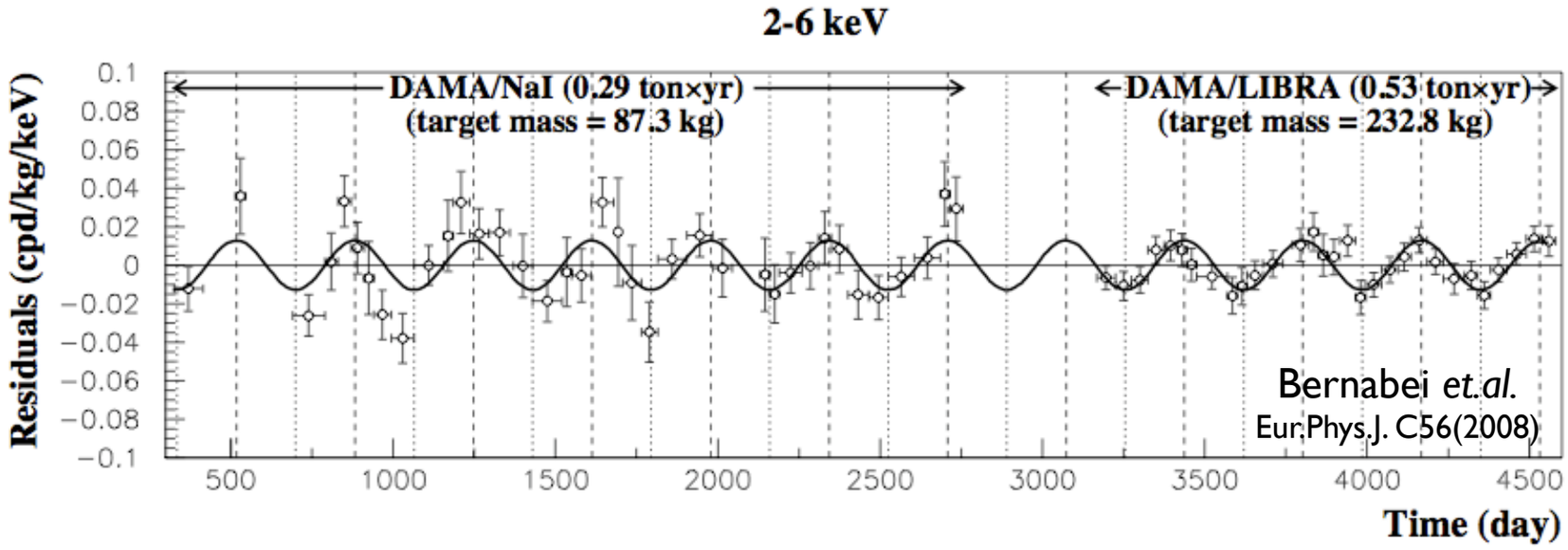
Stanford / SLAC

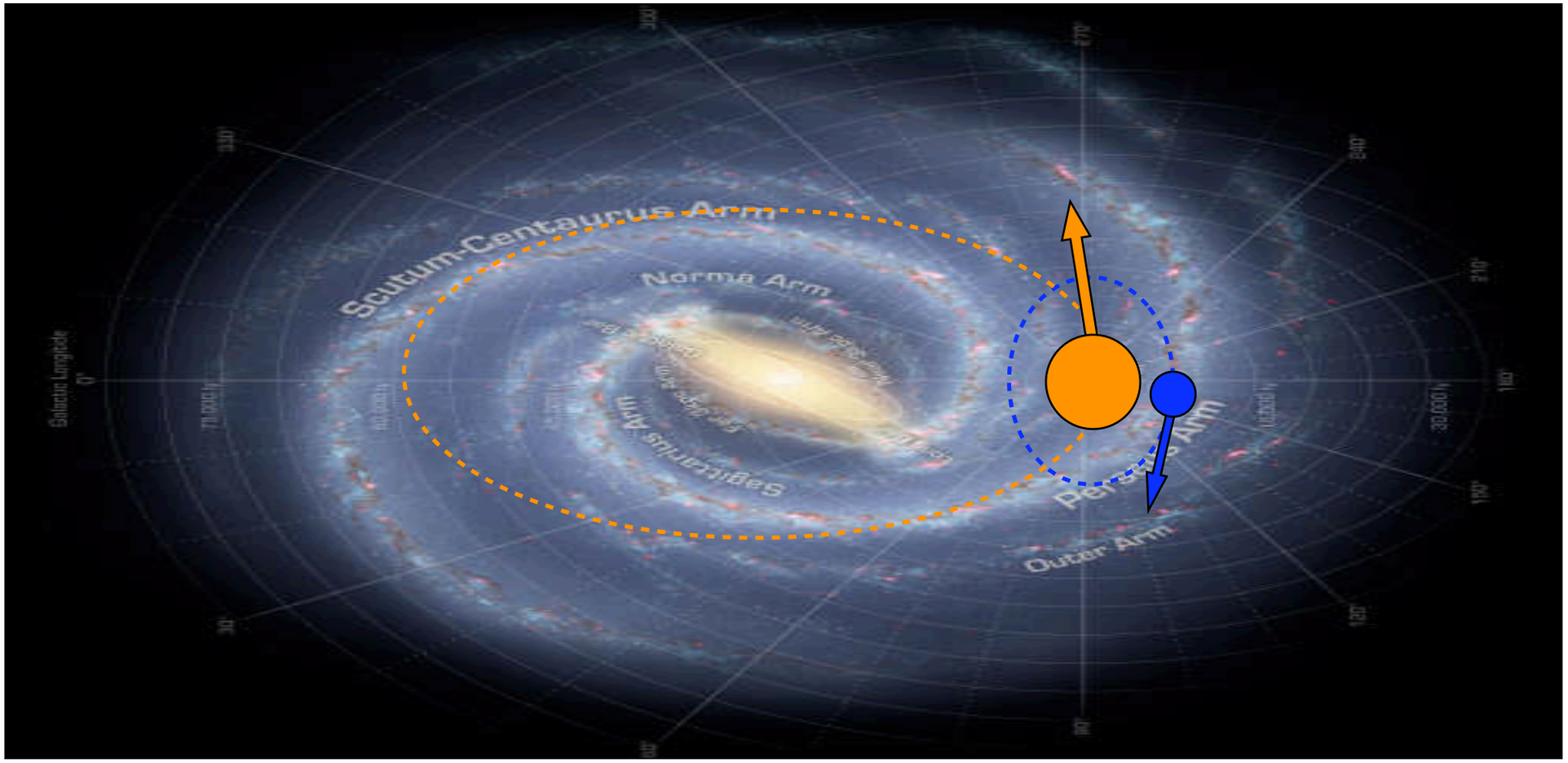
In collaboration with M. Lisanti and J. Wacker

PHENO '10

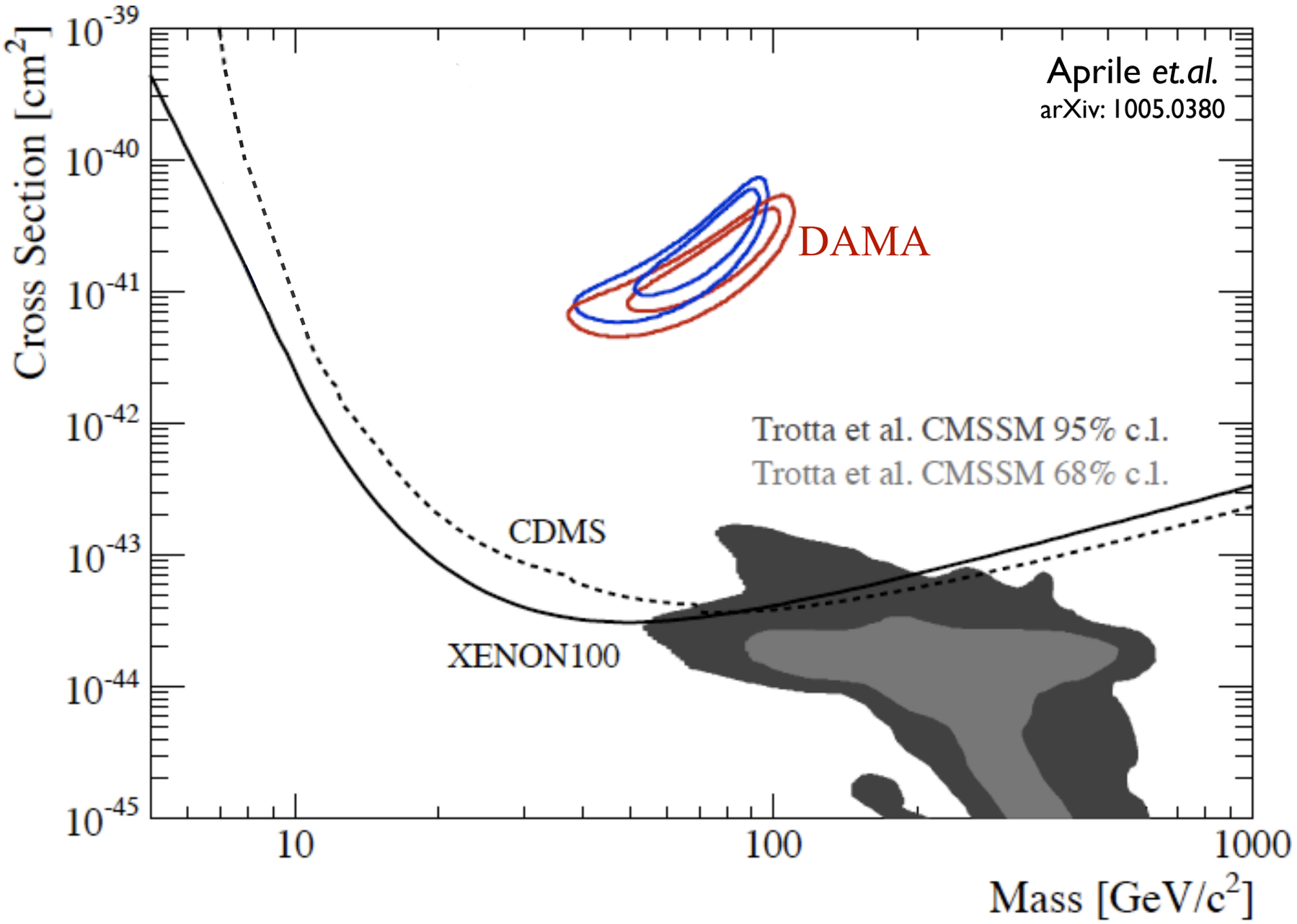
DAMA's 8.9σ annual modulation in single hit rate



► DM interpretation due to Sun and Earth's motion



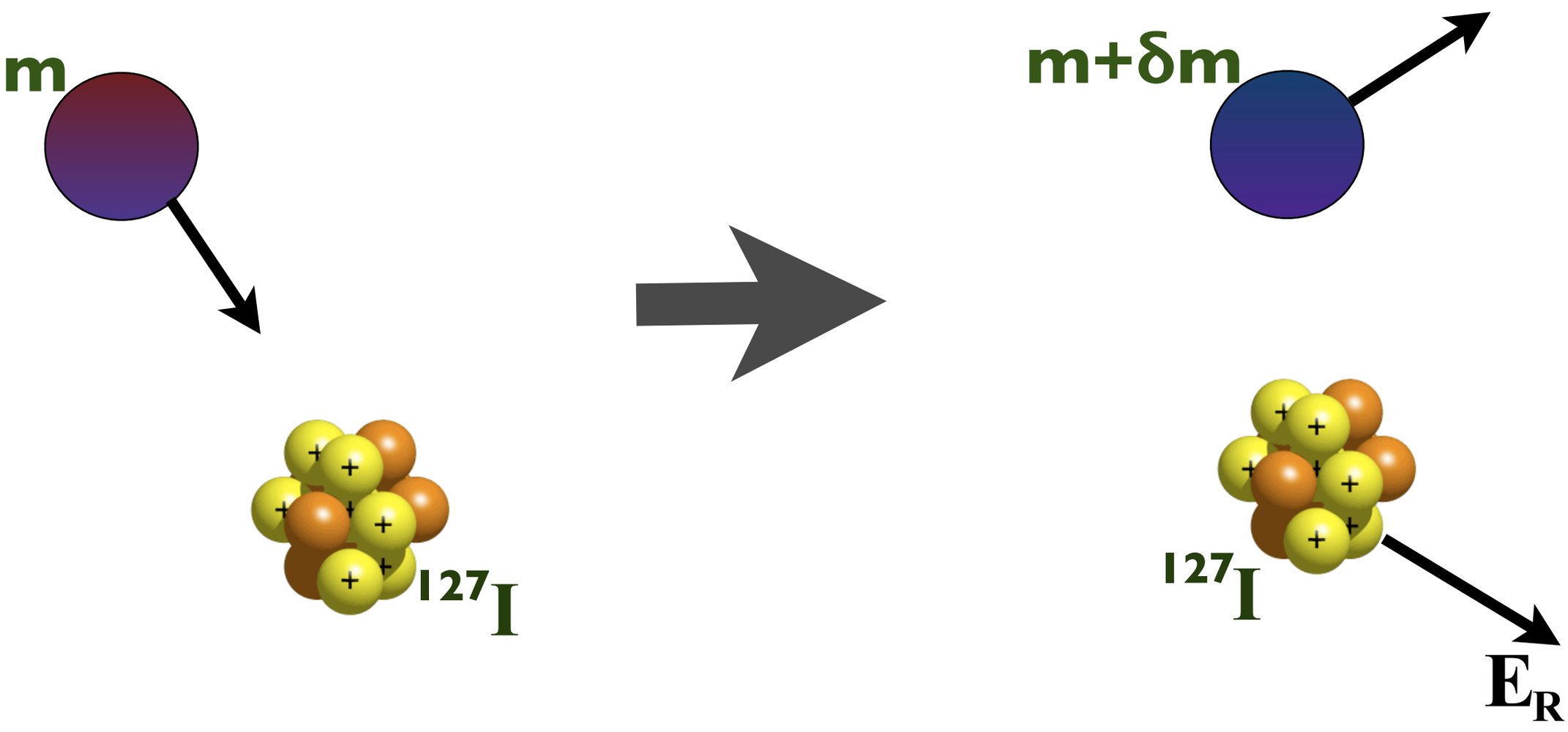
Elastic heavy WIMP interpretation excluded by other searches



Inelastic Dark Matter (iDM)

Tucker-Smith & Weiner

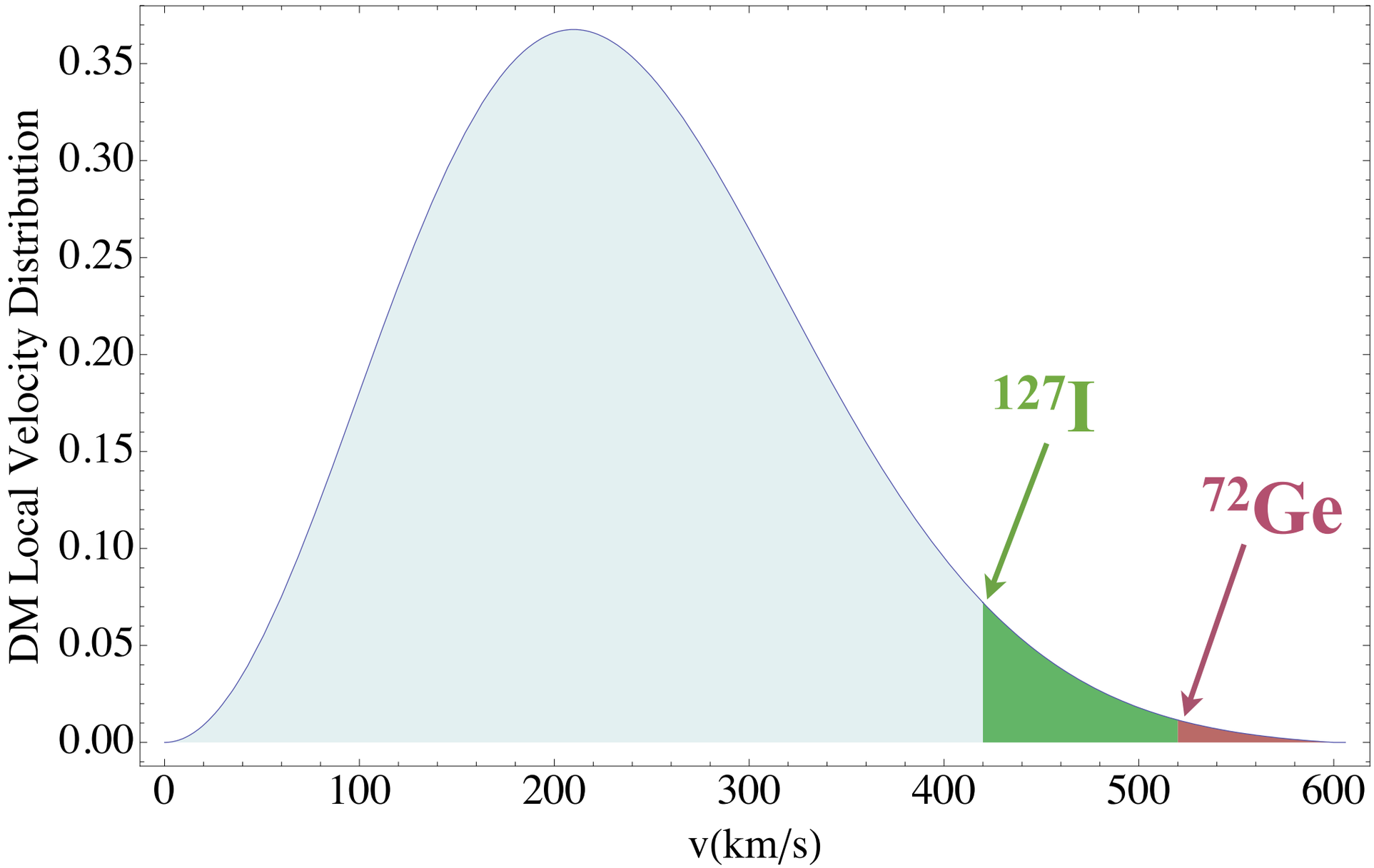
Phys.Rev. D64 (2001) 043502



δm ~ 100 keV

$$v_{min} = \frac{1}{\sqrt{2 m_N E_R}} \left(\delta m + \frac{m_N E_R}{\mu} \right)$$

► Heavy elements are favored



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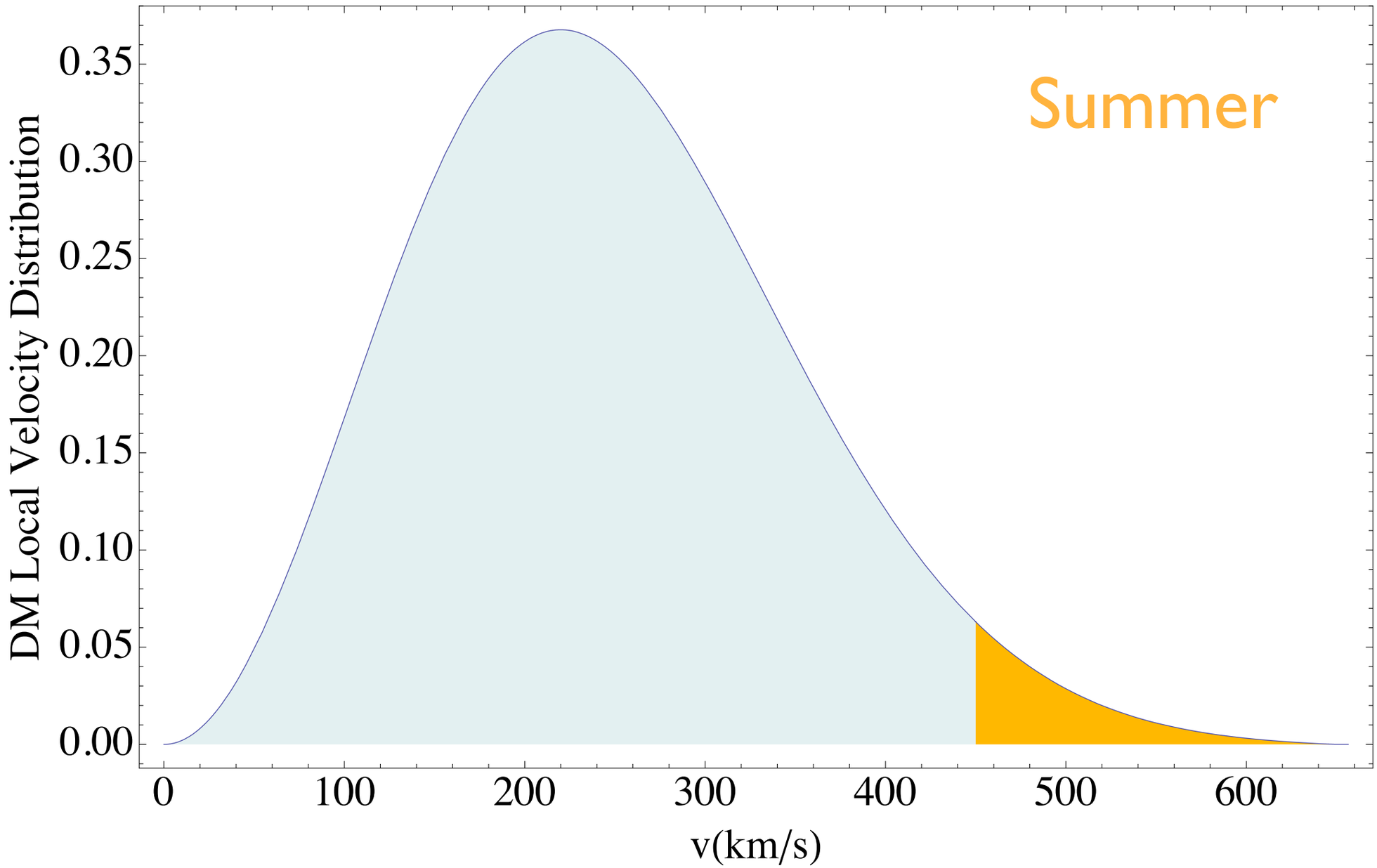

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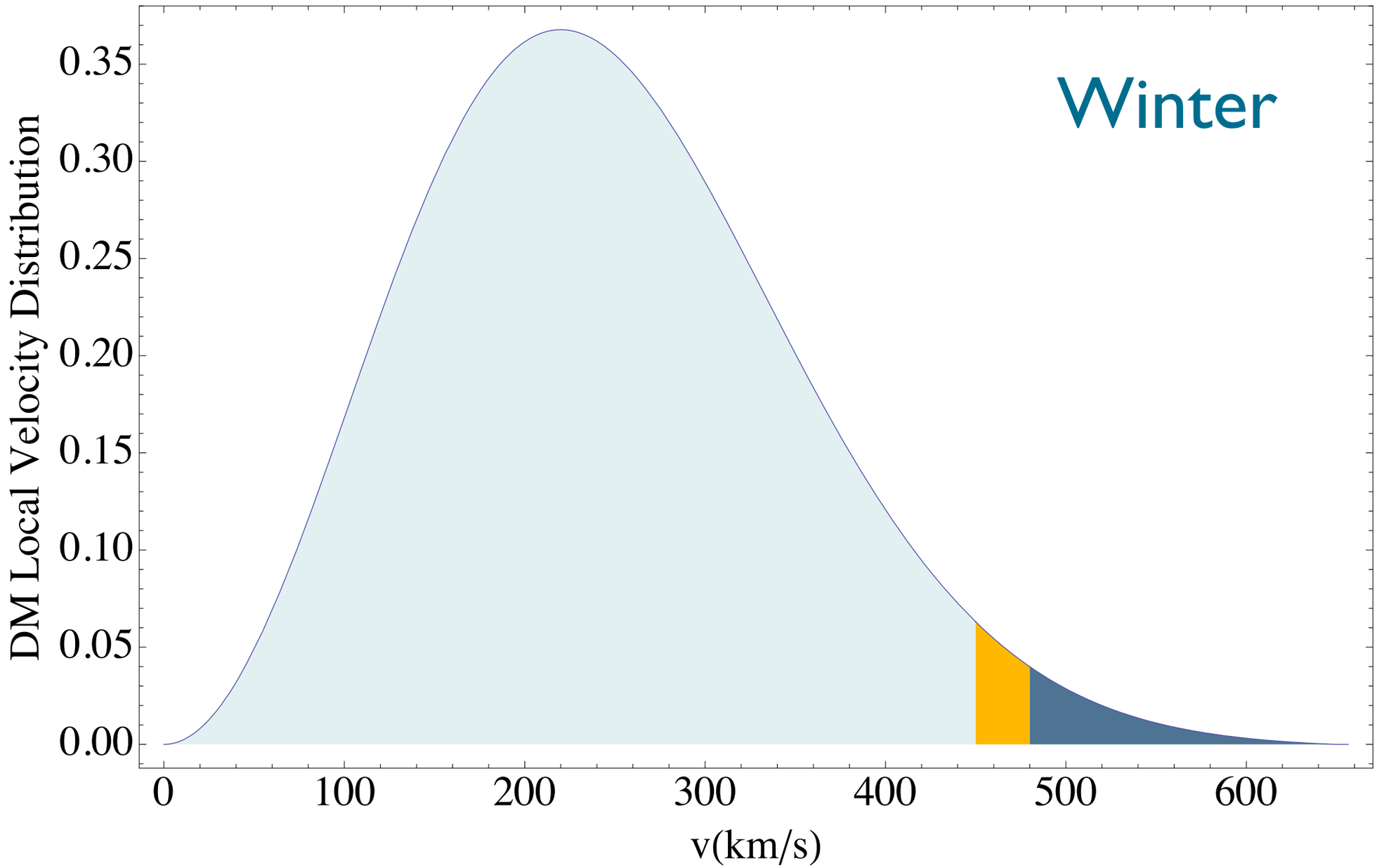

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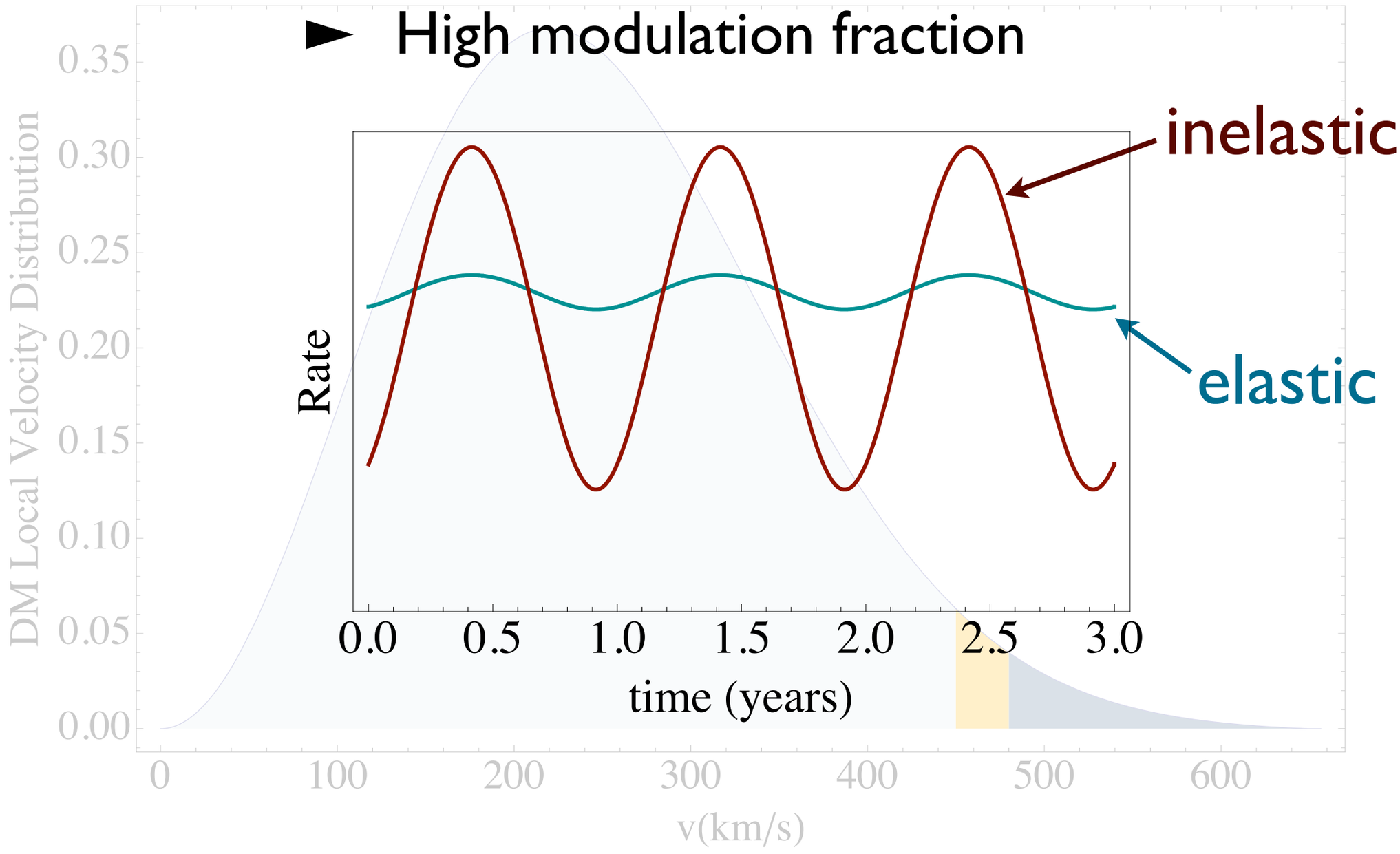
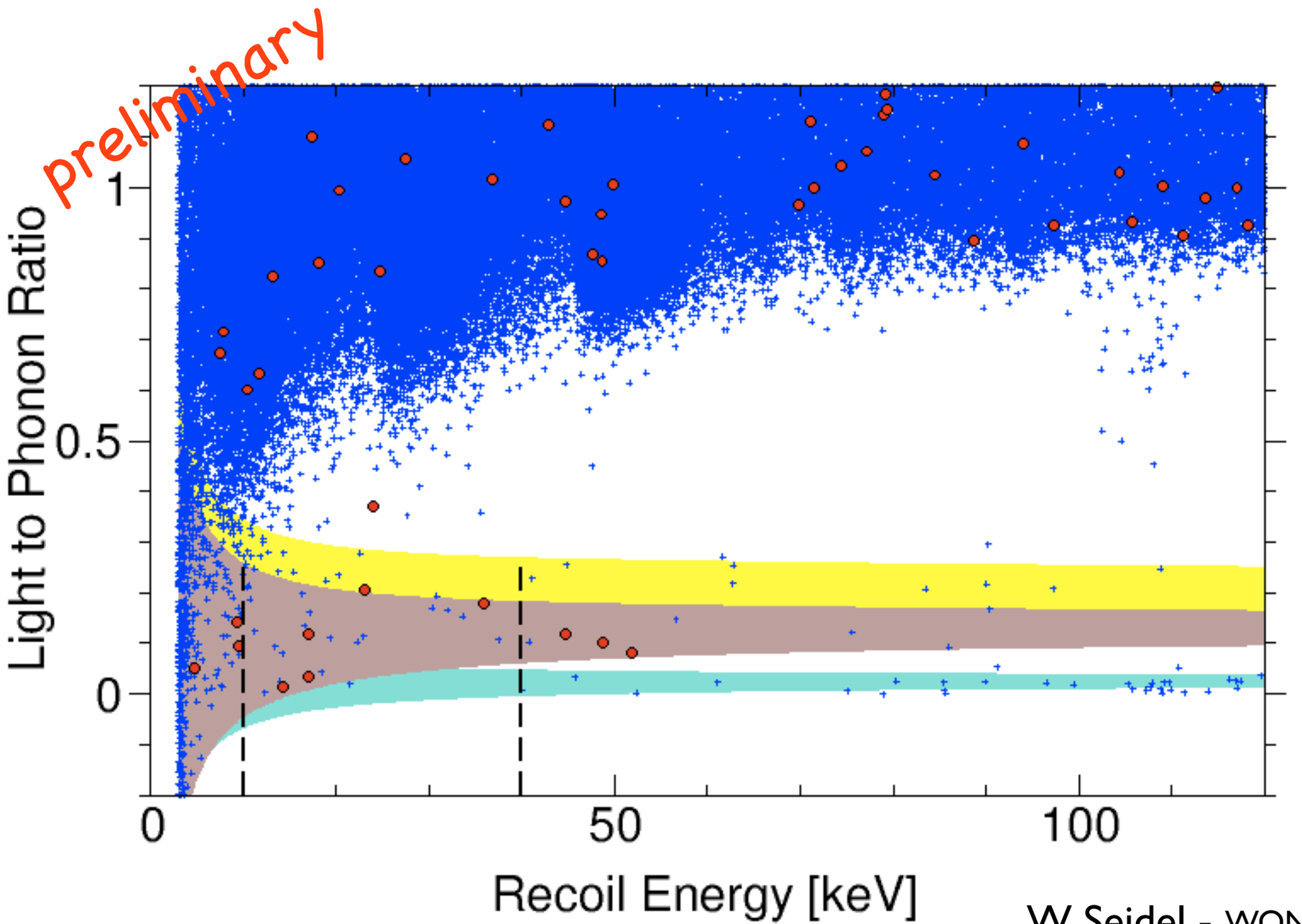


CRESST experiment

- might have seen less events than typically predicted by iDM in the 10 - 40 keV region

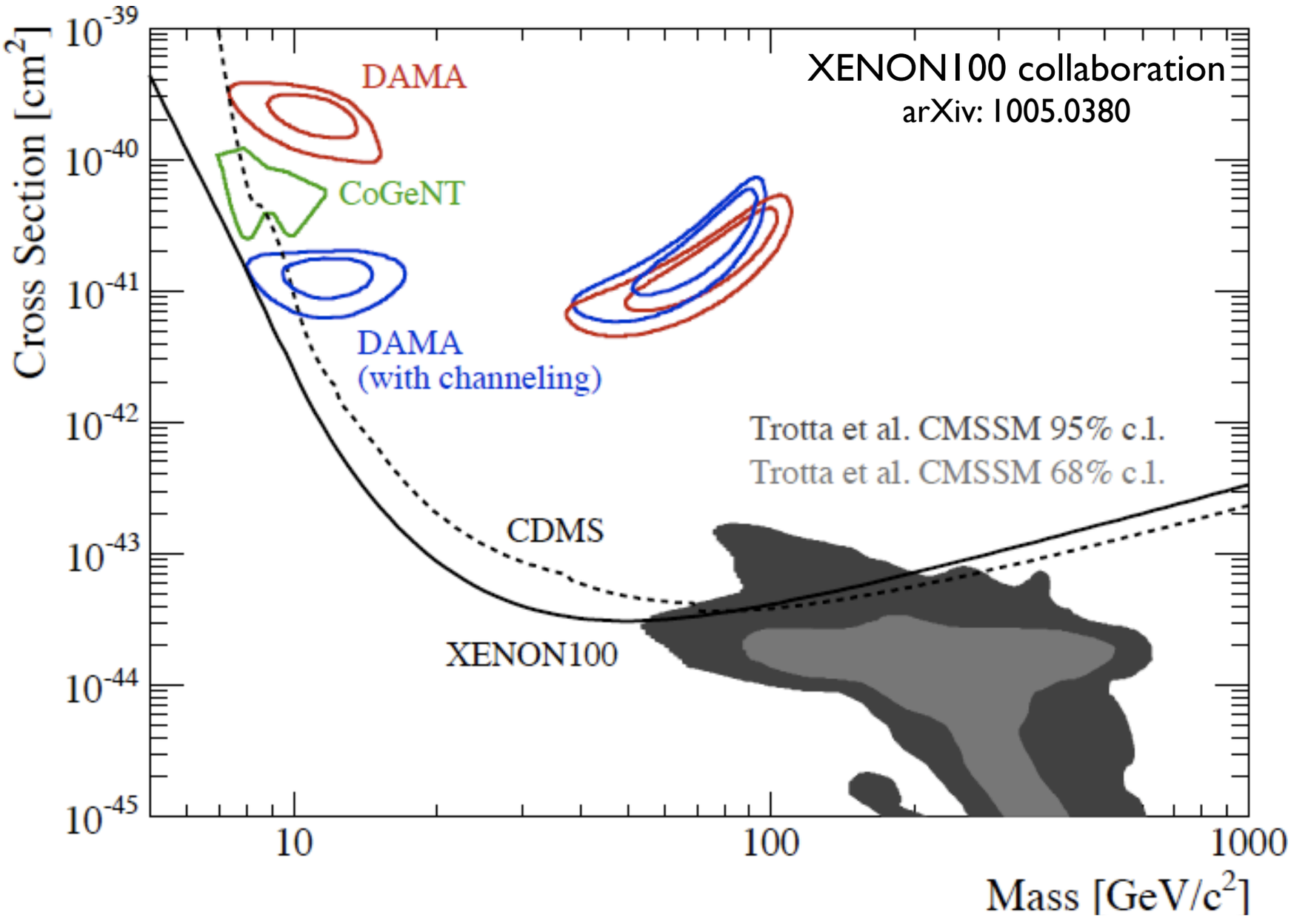


W. Seidel - WONDER 2010 Workshop

XENON100

► only 11 live days of exposure for calibration run

→ ***strongest current limits on DM***



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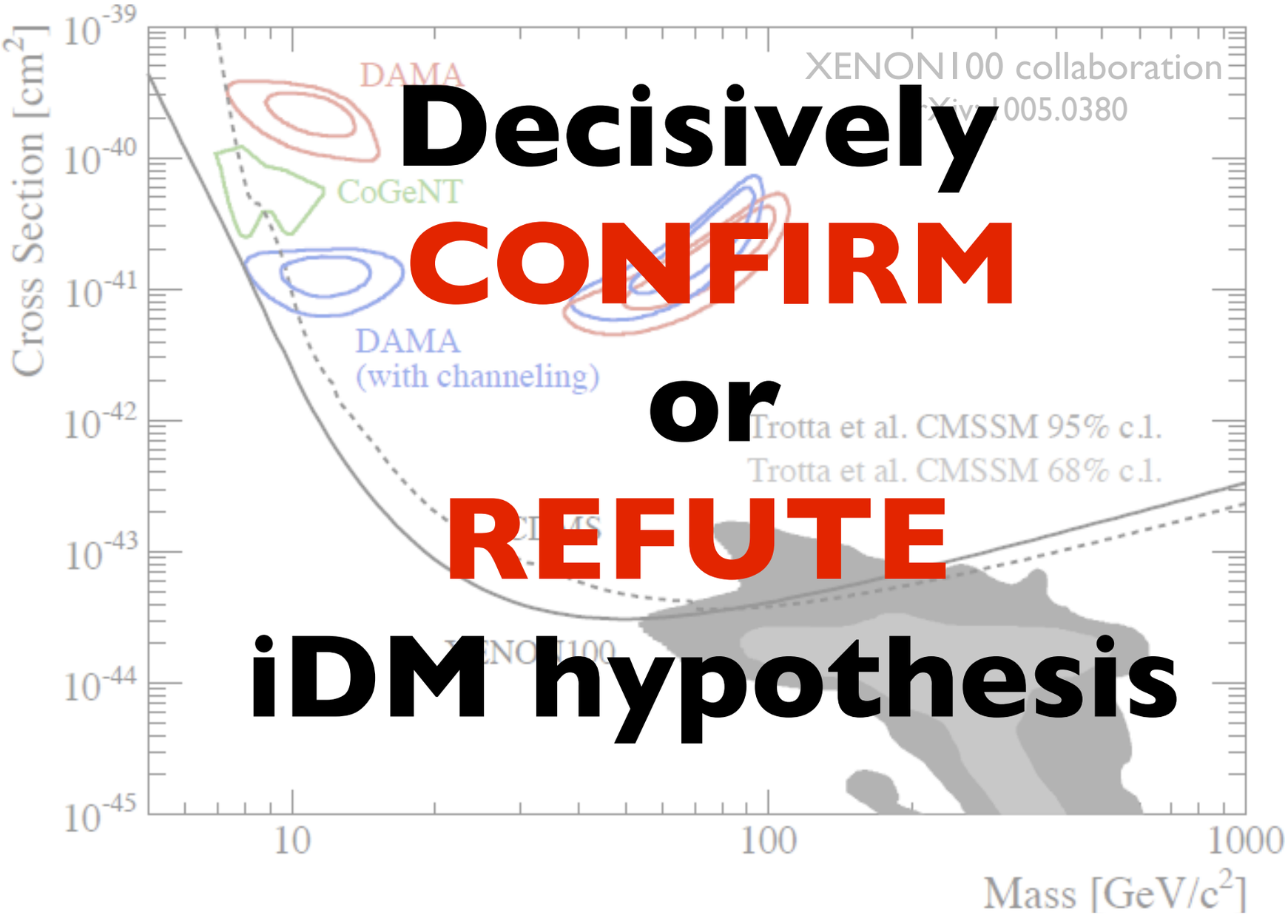


What affects predictions for Dark Matter Direct Detection ?

- Astrophysical uncertainties

  → Local DM velocity distribution

- Particle physics uncertainties

  → DM interactions & scattering kinematics

- Detector uncertainties

  → Target nucleus form factor & quenching factor

Astrophysical uncertainties

- scattering rate in iDM is highly sensitive to velocity distribution

$$\frac{dR}{dt} \propto \int_{v_{\rm min}}^{v_{\rm esc}} d\vec{v} \quad \frac{f(\vec{v}+\vec{v}_{\rm earth})}{v}$$

- standard assumption: **Maxwell-Boltzmann distribution**

$$f(\vec{v}) \propto (e^{-\frac{v^2}{v_0^2}} - e^{-\frac{v_{\rm esc}^2}{v_0^2}})\Theta(|\vec{v}_{\rm esc}-\vec{v}|)$$

- standard procedure: **benchmark** velocity parameters $\mathbf{v_0}$ and $\mathbf{v_{esc}}$

  ⟶ narrows the parameter space and limits the predictions

- broader and more sensible procedure:

  ⟶ marginalize over unknown velocity parameters

Astrophysical uncertainties

- numerical simulations of galactic DM structure:

  → significant departure from Maxwell-Boltzmann distribution

  → substructures and streams?

- observations of Saggitarius stellar tidal steam

  Law & Majewski
  Ap.J. 714 (2010) 229-254

  → triaxial Milky Way halo?

  → symmetry axes of halo and disk unrelated?

Astrophysical uncertainties

Investigate 3 scenarios:

- Standard Maxwell-Boltzmann $$f(\vec{v}) \propto e^{-\frac{v^2}{v_0^2}} \Theta(|\vec{v}_{\rm esc} - \vec{v}|)$$

  marginalize over v_0 *and* $v_{\rm esc}$

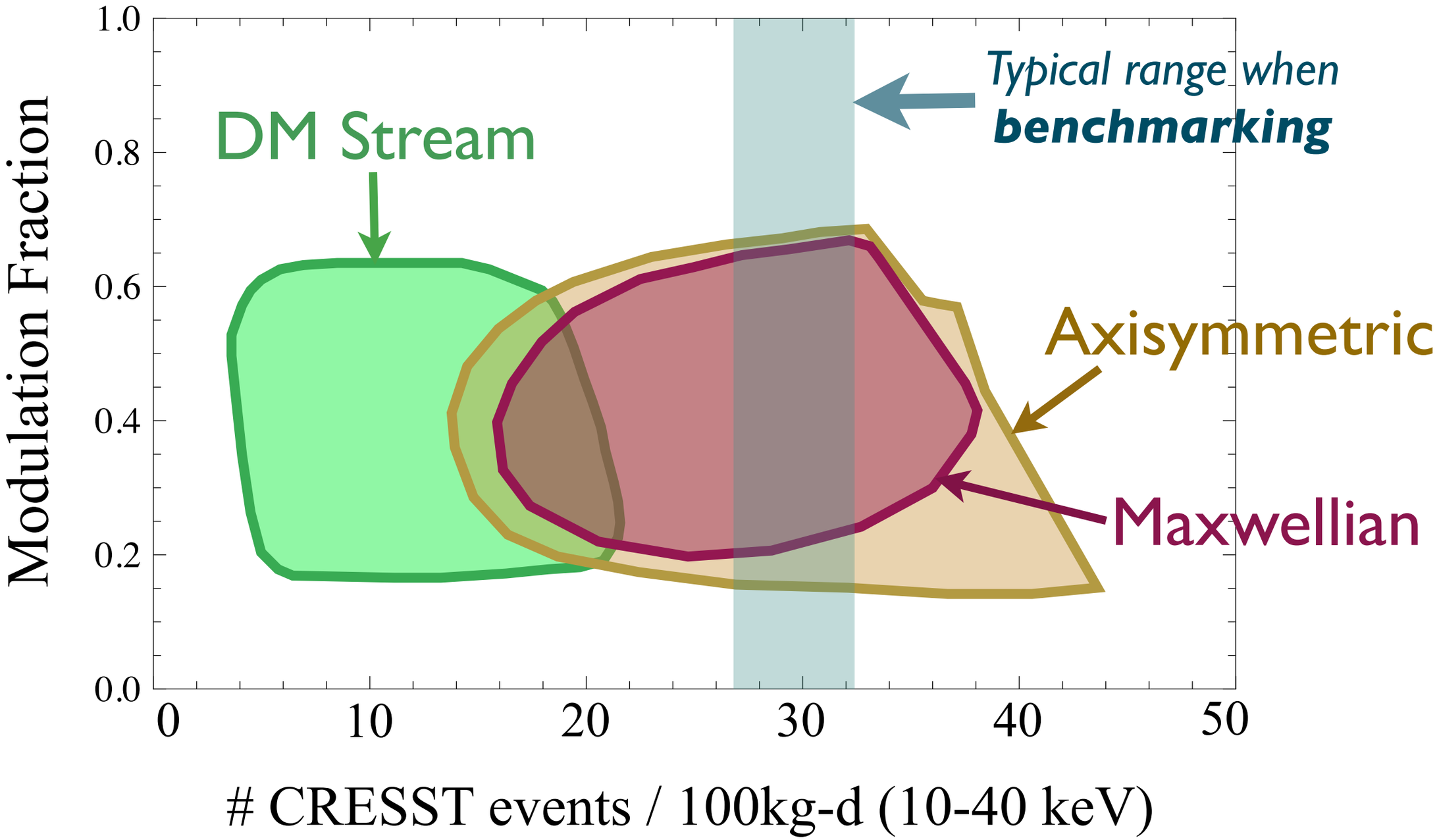
- Local stream $$f(\vec{v}) = \delta^3(\vec{v} - \vec{v}_{\rm stream})$$

  marginalize over magnitude and direction of $\vec{v}_{\rm stream}$

- Axisymmetric halo $$f(\vec{v}) \propto e^{-\alpha L_y^2} e^{-\frac{v^2}{v_0^2}} \Theta(|\vec{v}_{\rm esc} - \vec{v}|)$$

  marginalize over v_0, $v_{\rm esc}$ *and* α

Astrophysical uncertainties



Uncertainties in iDM particle properties

Cross-Section dependence on momentum transfer

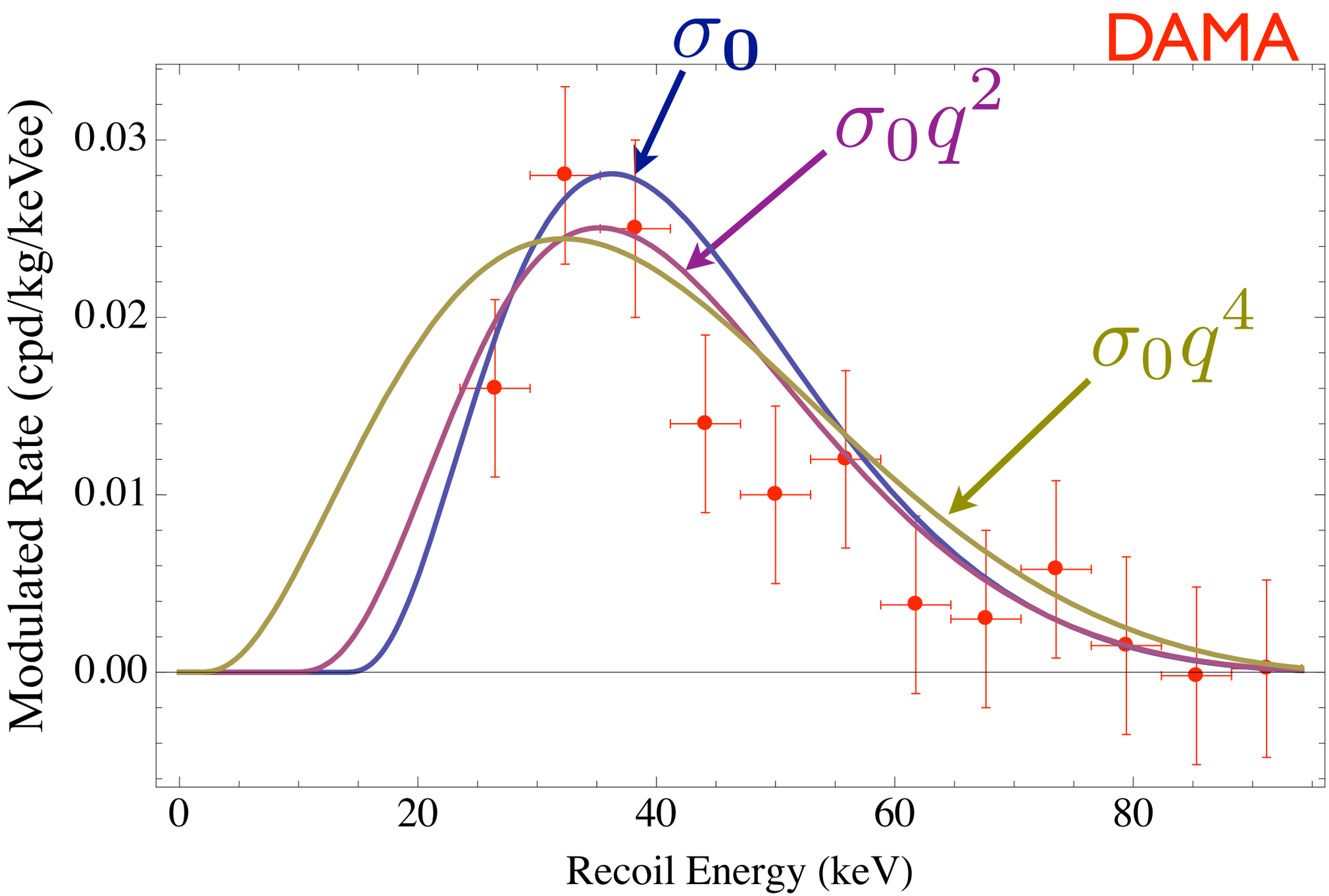
- $\sigma \propto \sigma_0$ *(e.g. sneutrino)*

Dark Matter Form Factor (sign of compositeness)

- $\sigma \propto \sigma_0 q^2$ *(e.g. CiDM)*

- $\sigma \propto \sigma_0 q^4$

Uncertainties in iDM particle properties



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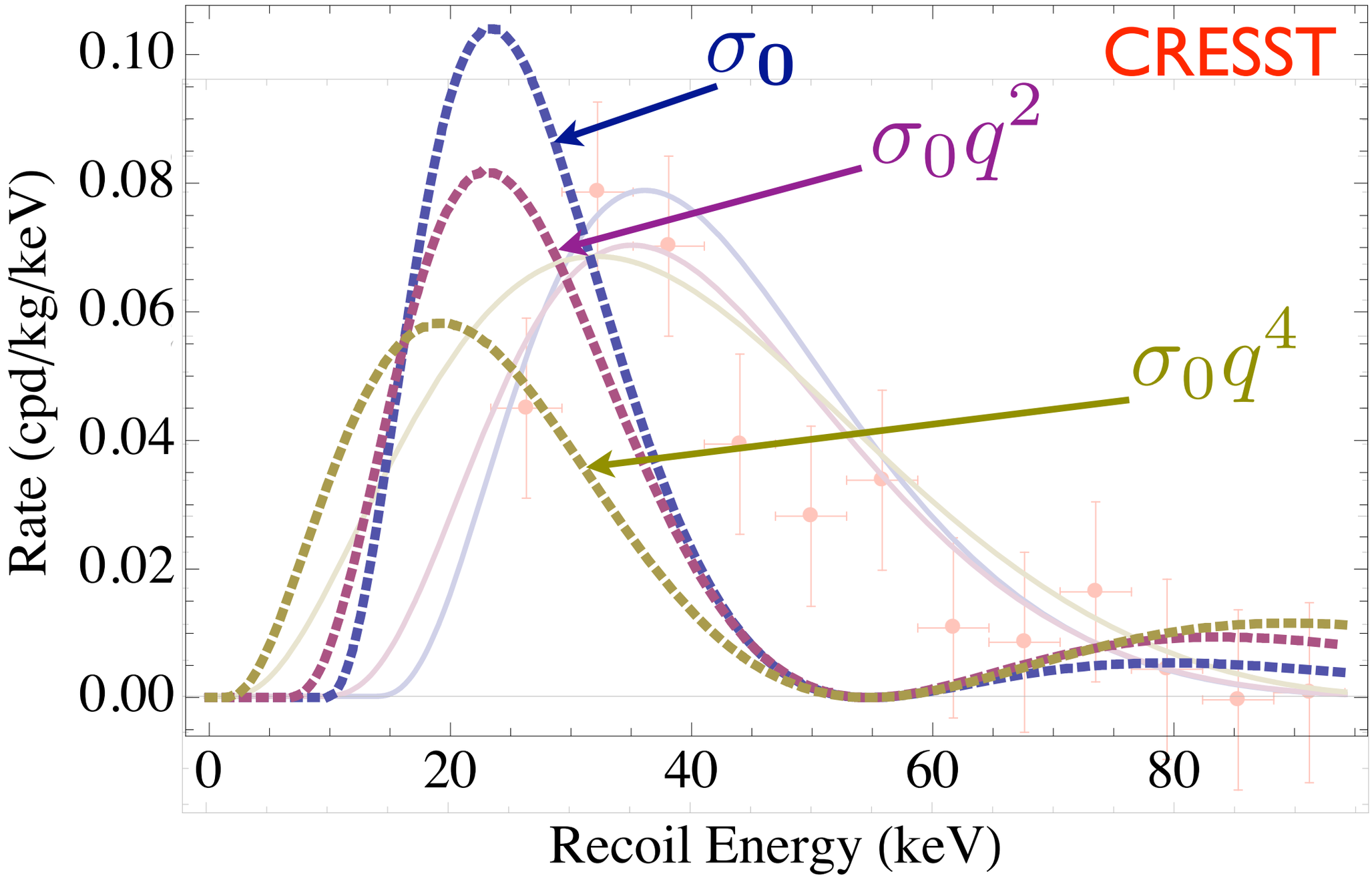

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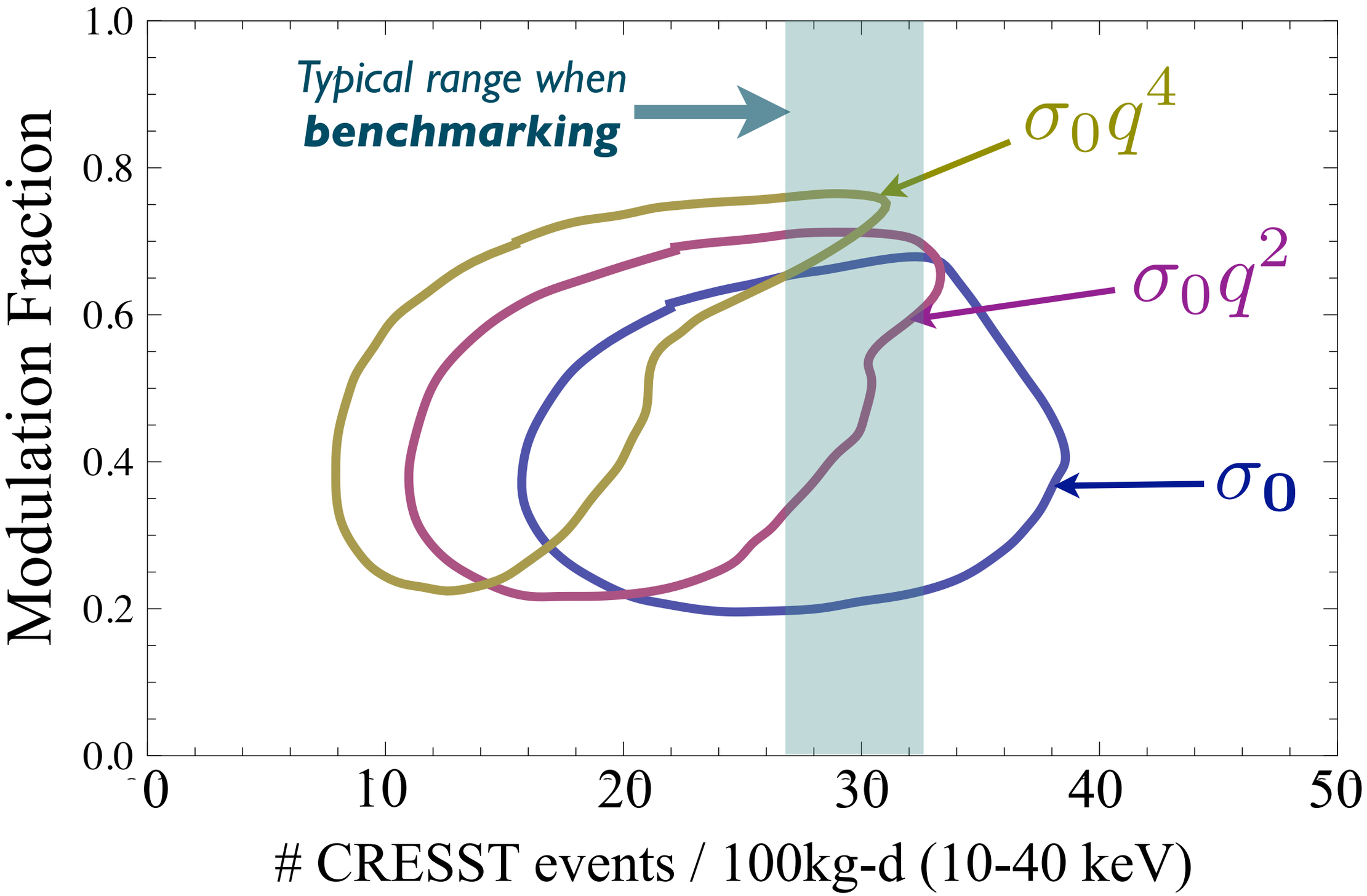


Detector uncertainties

- ***Quenching Factor for*** $^{127}\mathbf{I}$

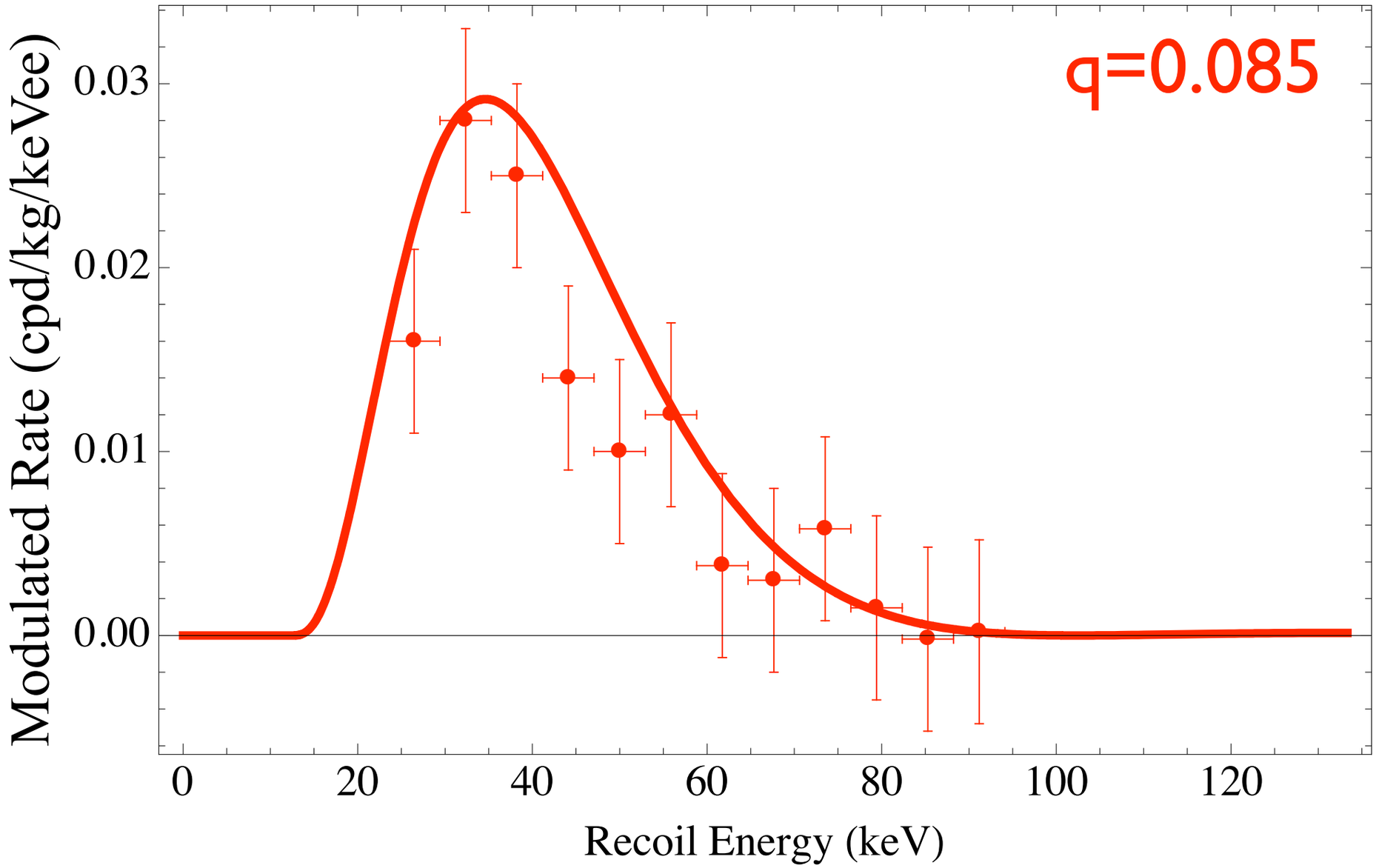
$$\mathbf{q} = \frac{\mathbf{E}_{\mathrm{scintillation}}}{\mathbf{E}_{\mathrm{nuclear\ recoil}}}$$

- Several independent measurements found $\mathbf{0.05 \leq q_I \leq 0.09}$

Recoil Energy (keV)	q_I	
22-330	0.09 ± 0.01	Bernabei *et.al.* PLB389 (1996)
40-100	0.08 ± 0.02	Pecourt *et.al.* ApJ11 (1999)
10-71	0.086 ± 0.007	Tovey *et.al.* PLB433 (1998)
40-300	0.05 ± 0.02	Fushimi *et.al.* PRC47 (1993)

Detector uncertainties

DAMA



Detector uncertainties

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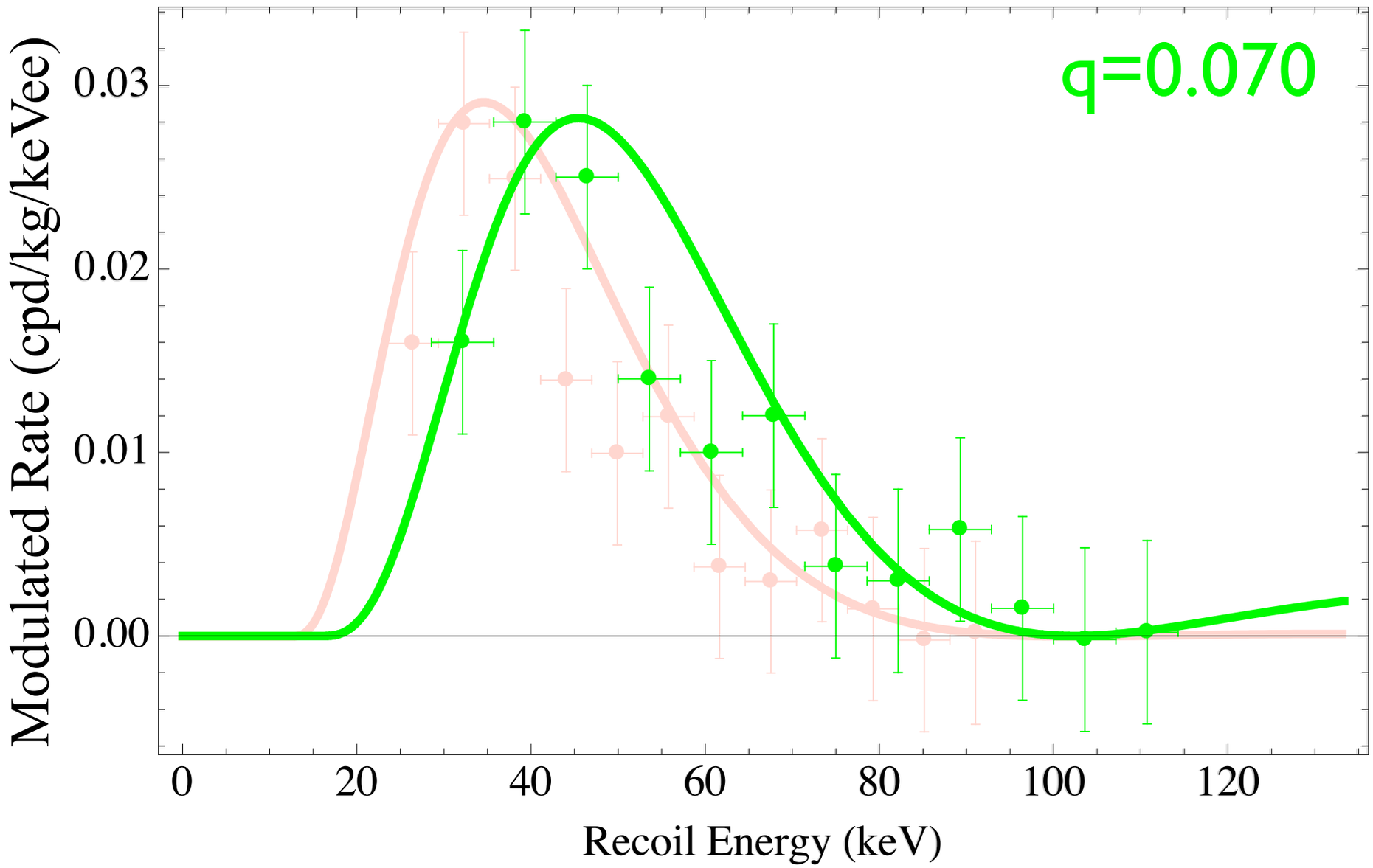

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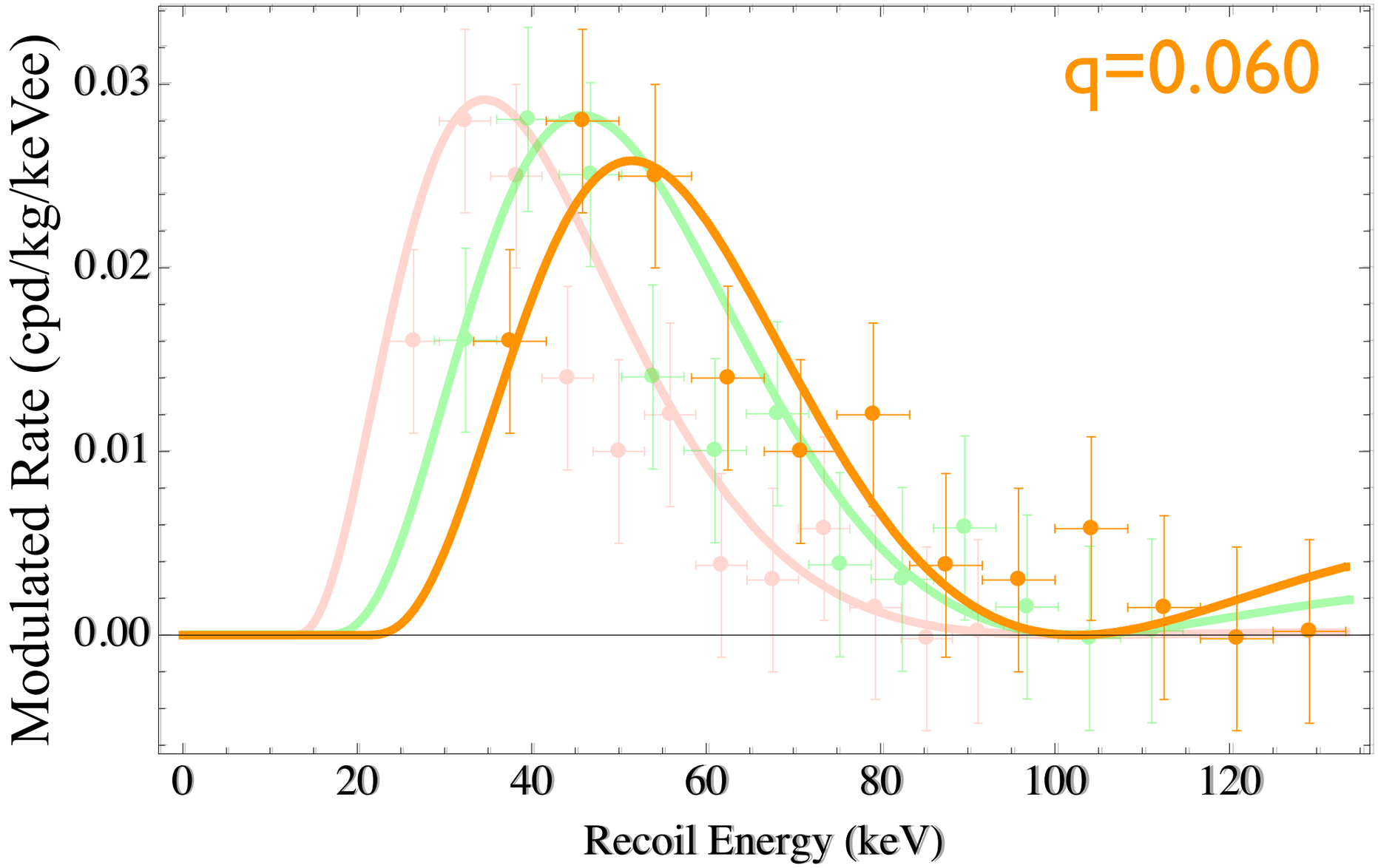
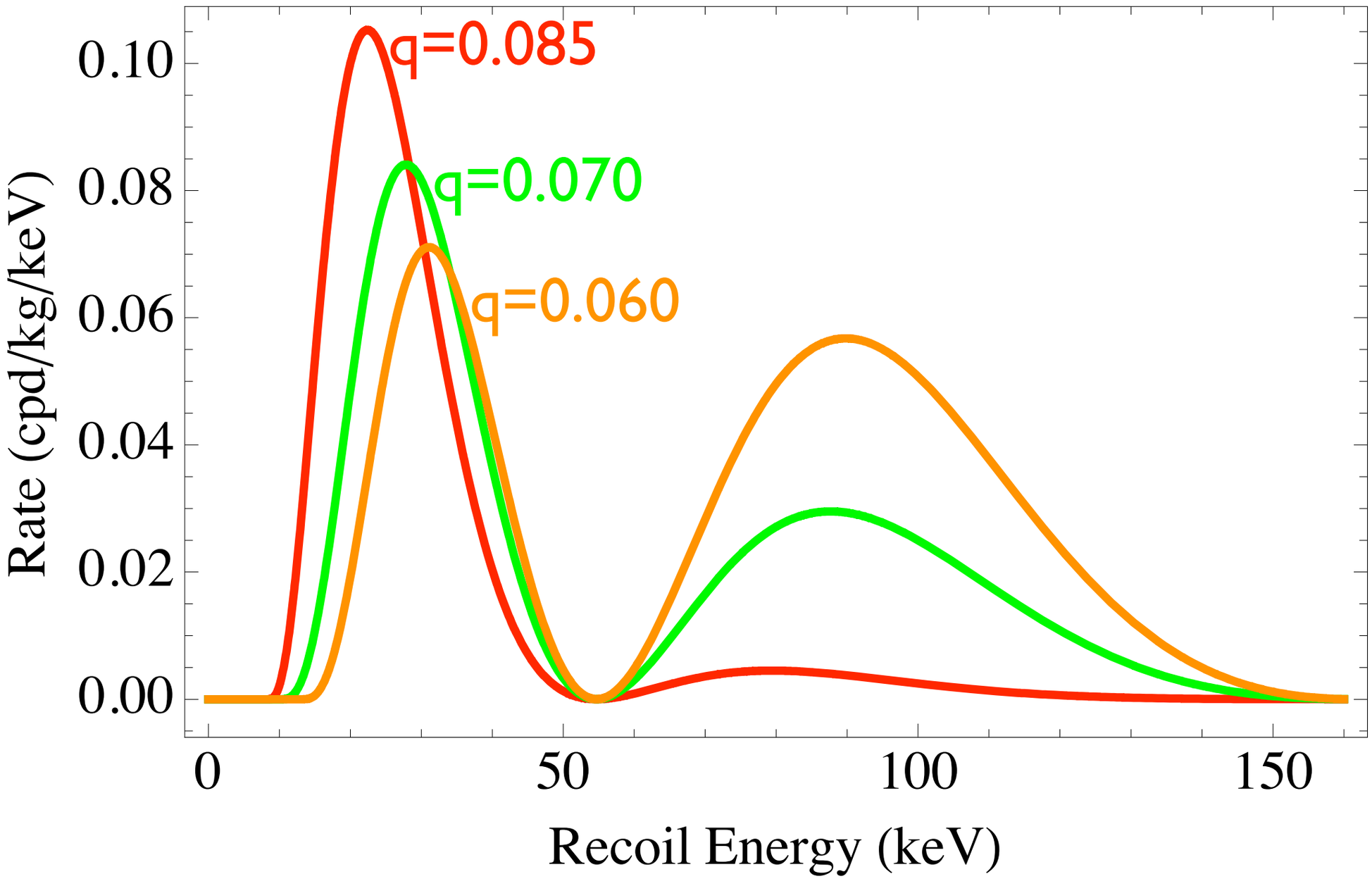


Detector uncertainties

CRESST



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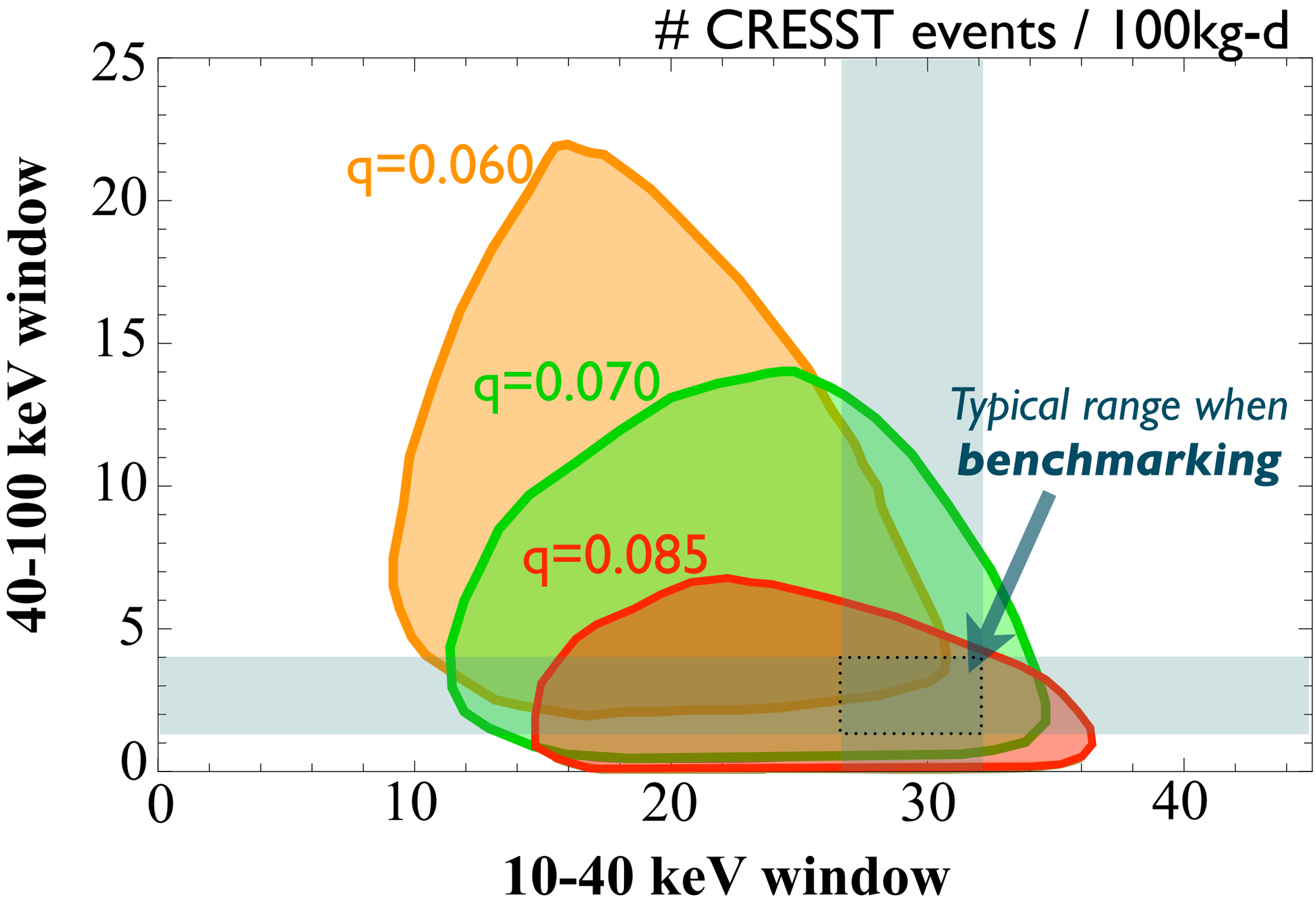

Summary and Conclusions

- Uncertainties on the DM velocity distribution, DM form factor and ^{127}I quenching factor have a dramatic impact on predictions for direct detection

- In light of that, it is unlikely that the next CRESST data release will rule out iDM in a completely model independent way.

- XENON100 data from this summer will decisively exclude of confirm iDM.

- In case it confirms iDM, it might tell us a lot about properties of the dark matter particle and our Milky Way halo.

THANK YOU