

21 October 2026
GDR DUPhy & DMLab

The LZ scattering event: a JC-like discussion

Marco Cirelli

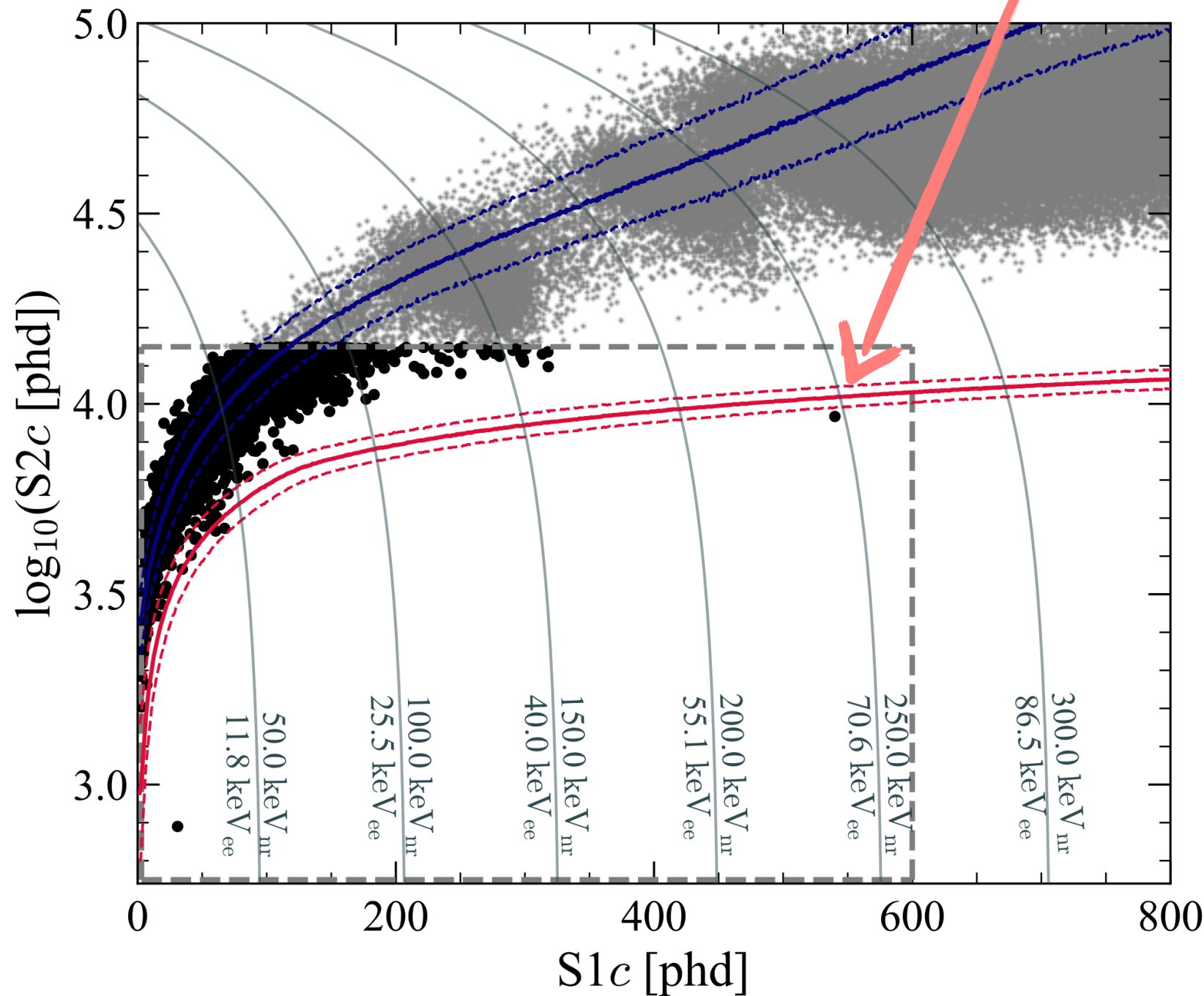
(CNRS LPTHE Jussieu Paris)



LZ event

One event in the signal region

$$E_R = 248 \pm 23 \text{ (stat)} \pm 23 \text{ (sys) keV}$$



*LZ = 7 tons LXe
~1 yr data taking
2.84 ton.yr fiducial expo*

*Extended E_R window:
from 55 to 270 keV_{nr}*

2.6 σ significance

LZ 2609.02823 (appeared 3 september 2026)

Community reaction

2609.01475, L. Su, J. M. Yang, W.-N. Yang, "Inelastic Dark Matter Signature at High Recoil Energy in LUX-ZEPLIN and CRESST"

2609.01504, J. Fan, M. Reece, "Higgsino Above the Sea of Fog"

2609.01583, K. Freese, D. P. Theodosopoulos, "Higgsino Dark Matter Interpretation of the LUX-ZEPLIN 248 keV Nuclear-Recoil Event"

2609.01590, L. Wu, Y. Zhang, B. Zhu, "TeV Higgsino Dark Matter from LZ Nuclear Recoil to Fermi-LAT Gamma Rays"

2609.01592, Y. Lou, C.-T. Lu, "Fermionic Dark Matter Absorption and the High-Energy Event in LUX-ZEPLIN"

2609.02505, Y. Nomura, "Dark Matter as the Z_μ Partner of the Standard Model Higgs Boson"

2609.02608, M. Di Mauro, "Dark Matter at the Kinematic Edge: Interpreting the 248 keV LZ Nuclear-Recoil Candidate"

2609.02775, M. Pospelov, H. Ramani, "Strong Constraints on Higgsino Dark Matter from Solar Capture"

2609.02807, L. Visinelli, "A Peccei-Quinn Origin for Inelastic Electroweak Dark Matter after LUX-ZEPLIN"

2609.02868, K. Yamashita, "Inelastic Dark Photon Dark Matter for the LUX-ZEPLIN High-Recoil Event and the Galactic Halo Gamma-Ray Excess"

2609.02994, U. Chattopadhyay, D. Das, R. Puri, J. Roy, "Sub-TeV Singlino DM in light from Sagittarius A* and LUX-ZEPLIN Nuclear-Recoil Event"

2609.04144, J. Smirnov, S. Griffith, J. F. Beacom, "Inelastic Signatures of Electroweak Dark Matter"

2609.04163, X. Du, F. Wang, "TeV Higgsino Interpretation of the LZ High-Recoil Event with Intermediate-Scale Electroweak Gauginos"

2609.04175, N. L. Rodd, B. R. Safdi, T. R. Slatyer, W. L. Xu, "Confronting the Higgsino Interpretation of the LZ Event with the High-Energy Sideband"

2609.04181, C. McCabe, "Seasonal dark matter from the LUX-ZEPLIN high-energy event"

2609.04185, S. Jeusun, A. Majumdar, "Atmospheric neutrino up-scattering explanation of LZ 2026 excess"

2609.04186, J. Unwin, "Axion Portal Dark Matter and the LUX-ZEPLIN High-Recoil Event"

2609.04673, J. Dent, J. Newstead, "Exothermic and Endothermic Inelastic DM Interpretations at LZ: Sideband Constraints and Future Prospects"

2609.05204, C. H. de Lima, "Exothermic Dark Matter at LZ"

2609.05291, G. Gu, L. Li, S.-S. Tang, Y. Xu, "Inelastic from the Other Side: Xenon Excitation Signals in Light of the LZ High-Recoil Event"

2609.06153, H. Baer, V. Barger, "Exothermic dark matter and the 248 keV nuclear recoil in LUX-ZEPLIN"

2609.06171, H. M. Lee, "Inelastic dark matter and baryon flavor symmetry in light of LUX-ZEPLIN (LZ) experiment"

2609.06571, L. Wang, Y. Xiao, "The Inert Doublet Model of Dark Matter and the LUX-ZEPLIN High-Recoil Event"

2609.06640, M. Yang, Q.-F. Wu, Y.-L. S. Tsai, Y.-Z. Fan, "Multi-Messenger and Paleo-Detector Probes of the LZ Dark Matter Signal"

2609.06750, W. Kotlarski, K. Kowalska, E. M. Sessolo, "GUT-induced FCC signatures of the LUX-ZEPLIN event"

2609.06756, J.-H. Liang, Z. Liu, V. Q. Tran, Y. Xu, "LZ Nuclear-Recoil Excess from Boosted Light Magnetic Dipole-dipole Dark Matter"

2609.06760, M. Di Mauro, H. Shaikh, "Solar Capture Tests of Inelastic Dark Matter after the LZ High-Recoil Event"

2609.06825, P. Das, B. Karmakar, S. Mahapatra, P. K. Paul, "Inelastic Self-interacting DM and LZ 248 keV Event in a Dirac Modular Inverse Seesaw"

2609.06890, H. Alhazmi et al., "High-Energy Nuclear Recoils from Boosted DM for the LZ 248-keV Event: Beyond the Halo-Dep. High-Velocity Tail"

2609.06909, N. Okada, O. Seto, "Inelastic B-L scalar dark matter and the LUX-ZEPLIN event"

2609.07138, W. Ahmed, G. K. Leontaris, "A Dark-Dimension Origin of Geometric Inelastic DM: The LZ High-Recoil Event and Multi-Target Tests"

2609.07225, X. Du, W. Huang, K. Xie, "Pseudo-Dirac Inelastic DM in the Leptophobic U(1)_B Model: Confronting the LZ High-Recoil Event with Collider Searches"

2609.07451, D. Bandyopadhyay, D. Borah, P. Borah, "LZ nuclear recoil event from inelastic singlet-doublet scalar dark matter"

2609.07742, K. Kannike, M. Raidal, A. Strumia, "Boosted dark particles and the LZ nuclear recoil event"

2609.07800, D. Borah, S. K. Sahoo, N. Sahu, S. Sharma, "Inelastic Singlet-Doublet Fermion Dark Matter in light of the 248 keV LZ event"

2609.07807, D. Bose et al., "Not so good vs for Higgsino dark matter as LZ excess: stringent limits from Super-Kamiokande and IceCube"

2609.07811, S. Bisal, J. Cao, F. Li, "Higgsino Dark Matter Interpretation of the LZ High-Recoil Event in the GNMSSM with TeV-Scale Gauginos"

2609.08893, G.-W. Yuan et al., "ALP-mediated inelastic dark matter and the LUX-ZEPLIN high-recoil candidate event LZ230616"

2609.08993, F. Elahi, P. Schwallier, "A Vector-Like Lepton Interpretation of the High-Energy Nuclear Recoil Candidate in LUX-ZEPLIN"

2609.09015, P. Zhu et al., "Endothermic dark matter with a light dark photon and the LUX-ZEPLIN high-energy nuclear-recoil candidate"

2609.09037, M. Aghaie, A. Strumia, "Neutron disappearance and the LZ nuclear recoil event"

2609.09107, P. Asadi, A. Batz, P. J. Fox, S. D. Homiller, G. D. Kribs, "For Whom the Xenon Recoils: Magnetic Inelastic Dark Baryons"

2609.09136, V. S. H. Lee, L. Randall, "A Warped Extra Dimensional Candidate for the LZ 248 keV Event"

2609.09138, S. J. Lee, T. Youn, "Mixing-suppressed inelastic dark matter: a minimal model for the LZ 248 keV event"

2609.09230, I. Khan et al., "Nuclear interference versus dark sector excitation in the 248 keV LUX-ZEPLIN recoil candidate"

2609.09385, K. Langhoff, "Heavy Higgsino Interpretation of the LZ Event"

2609.09830, A. Chatterjee et al., "Radiative Corrections to the Direct Detection of Inelastic Scattering of Higgsino-like Neutralino Dark Matter"

2609.10453, Y. He, "Transition magnetic-dipole dark matter and the LZ230616 high-recoil candidate"

2609.10491, Z.-T. Fan, H.-J. He, Y.-C. Wang, Y. Zhao, "Inelastic Dark Matter and High-Energy Recoil Signatures in LZ"

2609.10504, A. Chattaraj, A. Majumdar, D. K. Papoulias, R. Srivastava, "Can Elastic Neutrino Scattering Account for the LZ230616 Event?"

2609.10636, X. Qi, H. Sun, "Nonthermal Solar Stalling of an Inelastic Scalar Signal in Xenon"

2609.10662, Q. Li, S. Liu, "Implications of Inelastic Dark Matter for Primordial Dark-Star Evolution: Kinematic Thresholds and Nonthermal Capture"

2609.10827, R. Kumar, H. K. Prajapati, "Generalized Chiral U(1)_{B-L} with Inelastic Scalar Dark Matter for the LZ 248 keV Event"

2609.11241, D. Frolovsky, S. V. Ketov, "Higgsino dark matter in the Starobinsky supergravity with the MSSM in light of the LUX-ZEPLIN event"

2609.11600, M. Heikinheimo, N. Zimmermann, "Cosmic ray boosted DM with momentum dependent interactions can explain the LZ 248 keV event"

2609.11833, T. T. Q. Nguyen, T. Linden, D. Hooper, "Solar Neutrino Constraints on Inelastic DM Scattering in Light of Recent LZ Observations"

2609.13038, H. Okada, Y. Shigekami, J.-J. Wu, "Can a minimal radiative seesaw explain the LZ 248 keV event?"

2609.13130, D. Cabo-Almeida, F. Costa, D. Feiteira, V. Oliveira, "A Freeze-In Interpretation of the LZ High-Energy Nuclear Recoil Event"

2609.14799, S. Mahapatra, P. K. Paul, "Boosted or Inelastic? Discriminating Interpretations of the LZ 248 keV Event"

2609.15027, P. Borah, S. Mahapatra, N. Nath, P. K. Paul, "Inelastic Dark Matter at LZ from Radiative Dirac Neutrino Mass Paradigm"

2609.15118, B. Barman, "Did LZ see modified gravity?"

2609.15413, A. Le-Yaouanc, F. Richard, "A DM candidate indicated at Fermi-LAT and LZ ? Connection with LHC and LC prospects"

2609.15600, A. Das, T. Nomura, "Effect of inelastic scalar dark matter in hidden U(1) scenario after the LZ nuclear recoil"

2609.15634, W. Ahmed, A. Ahmad, M. Ur Rehman, "Xenon Isotope Filtering at the Kinematic Edge of Inelastic Dark Matter"

2609.15714, X.-G. He, X. Hong, S. Jeusun, "Hadrophilic inelastic freeze-in dark matter in q_s-q_s gauge extension and the high energy LZ event"

2609.15742, J. Lian, J. M. Yang, "Explain the LZ High-Energy Recoil Event with Inelastic Sneutrino Dark Matter in Supersymmetry"

2609.15782, H. Baer, V. Barger, "Argon as the test of two interpretations of the LZ 248 keV recoil"

2609.15933, P. Uttayarat, J. Julio, R. Primulando, "DM induced neutron disappearance as the origin of the LZ nuclear recoil event"

2609.15985, S. Palmisano, M. Tammaro, A. Tesi, "Inferring dark matter masses and interactions from high recoil energy events in LUX-ZEPLIN"

2609.17196, G. Arcadi, M. Di Mauro, A. Djouadi, F. Queiroz, "A possible interpretation of the LUX-ZEPLIN recoil event in the 2HD+a scenario"

2609.17412, H. An, F. Gao, J. Liu, M. Liu, C. Xu, "Cosmological Constrained Axion-Portal Inelastic Dark Matter for the LZ Event"

2609.17935, C.-Y. Xing, "Galactic Endothermic Production and Exothermic Detection of Excited Dark Matter: Implications for LUX-ZEPLIN"

2609.18564, N. Nagata, T. T. Yanagida, "Asymmetric Inelastic Dark Matter and the LUX-ZEPLIN event"

2609.19176, M. Di Mauro, "Testing Higgs-Coupled Minimal Dark Matter with Solar Neutrinos after the LZ High-Recoil Event"

2609.21011, N. Okada, D. Raut, "Endothermic Z'-Portal Dark Matter: LZ-LHC Complementarity"

2609.21446, C. O'Hare, "The high-velocity dark matter halo of the Milky Way in light of the LZ 248 keV event"

2609.21803, D. Bose, A. Sahu, N. Raj, T. Maiti, R. Laha, "LUX-ZEPLIN's Stairway to Heaven: limits on elastic scatters of DM from solar capture"

2609.22863, R. Paul, S. Sahoo, N. Sahu, S. Sharma, "Resurrecting Electroweak Dark Matter via Type-II Seesaw in light of recent LZ Event"

2609.23739, W. Ahmed, G. Leontaris, "Kaluza-Klein Dark-Photon Mediation of Inelastic Dark Matter at LUX-ZEPLIN"

2609.25096, K. De, "The 248 keV LZ Recoil: A Possible Hint of Non-SM-Like Quark Yukawa Couplings with a Scalar-Portal Dark Matter"

2609.25477, Sheng, K. Zhang, "The LUX-ZEPLIN Event as Hyperfine Spectroscopy of Composite Dark Matter"

2609.25691, I. Khan et al., "LZ-Motivated Pseudo-Dirac Higgsinos in the Supersymmetric 331 Model from the Supersymmetric SU(6) GUT Model"

2609.24993, B. Choudhan, S. Sahasrabudhhe, M. Sen, "A closer look at the LZ 248 keV event through the lens of cosmic-ray boosted dark matter"

2609.28988, E. Sannino, J. Turner, "Interpreting the LZ 248 keV Event using Dark QCD"

2609.29114, I. Khan et al., "Elastic toroidal vector dark matter through a dark photon in the LUX-ZEPLIN high recoil window"

2609.29723, H. Jung and S. C. Park, "Dark Diffraction at LZ from a Screened Neutral Composite Baryon"

2609.30570, C. Gemmel, D. Hooper and G. Krnjaic, "A Simple Dark Matter Model to Explain the LZ Event and Galactic Center Excess"

2609.26698, D. Delpierre and S. Khalil, "Model-Independent Sideband Constraints on Inelastic Dark Matter at the LZ High-Recoil Candidate"

2609.26670, B. Maier, M. Spannowsky, "The LHC is not enough: the LZ High-Recoil Event at FCC-hh and a Muon Collider"

2609.28129, S. Girmohanta, T. Jung, "Environment-dep. mass splitting to suppress solar capture in the inelastic-doublet interpretation of the LZ event"

2609.38318, A. Capolupo, G. Pisacane, R. Serao, "Solar capture and annihilation of fermionic and scalar DM motivated by the LZ high-recoil candidate"

2609.28415, J. Tang and P. H. Gu, "Inelastic dark matter mediated by natural dark photon"

2609.38616, K. Langhoff and H. Xiao, "Sneaky Sneutrino Scattering at LZ"

2609.28819, H. Murayama and B. Noether, "Heavy Inert Doublet Reconciles LZ and IceCube"

2609.30255, V. Bodar and D. S. Chattopadhyay, "A Narrow Neutrino Window for the LZ Event"

2609.29463, J. Kalita, "Limits on Primordial Black Hole Evaporation from LUX-ZEPLIN"

2609.04673, J. Dent and J. Newstead, "Exothermic and Endothermic Inelastic DM Interpretations at LZ: Sideband Constraints and Future Prospects"

2609.32435, S. Centelles Chulià et al., "Escaping Solar Capture: Majoron mediated Elastic DM for the LZ 248 keV Event"

2609.33869, C. Pallis, "Heavy Higgsino Dark Matter With Low Reheating in View of the LZ High-Recoil Event"

2609.33952, M. Dutra, J. Neto and C. Siqueira, "Sub-MeV gamma-ray lines from an endothermic interpretation of the LZ recoil candidate"

2609.35650, V. Oliveira, "The LZ event with a two-state dark matter halo"

2609.35737, A. Das, S. Majumdar, M. Sen and A. Srivastava, "GAIA meets LZ: a high velocity tail-tale sign for dark matter"

2609.36184, N. Borogonia, S. Contreras, G. Gelmini, A. Kamaha, J. Reynoso-Cordova and Y. Xu, "LMC-Perturbed LZ Dark Matter Landscape"

2609.36814, P. Chanda, B. Das and S. Mukherjee, "Does the High-Energy LUX-ZEPLIN Event Suggest Hyperfine Atomic Dark Matter?"

2609.37545, Y. Jho, S. Kim and S. Park, "Endothermic Dark Matter at LZ from a Decaying Parent"

2609.37561, Y. Jho, S. Kim and S. Park, "Decaying Dark Matter for the Exothermic Recoil at LZ"

2609.38316, J. Luengas, M. Pospelov and H. Ramani, "Constraints on Complex Electroweak WIMPs from Solar Capture"

2609.39529, K. Meissner and H. Nicolai, "Supermassive charged gravitinos and the Lux-Zeplin event"

2609.40234, S. Roy, P. Schwallier and C. Wagner, "Interpreting the High-Recoil LUX-ZEPLIN Event with Bino-/Singlino-like and Higgsino Dark Matter"

2610.00226, I. Khan, W. Ahmed, T. Li, S. Raza, A. Muhammad, "Thermal Higgsino DM in GmSUGRA for the LZ Event and Solar-Neutrino Constraint"

2610.00645, D. Choudhury, J. Das and D. Sachdeva, "Inelastic DM from a Higher-Dim Operator: The LZ High-Recoil Event and Thermal Relic"

2610.01613, S. Hor, N. Nagata, T. Yanagida, "From the LZ Event to Grand Unification: Heavy Higgsinos and Proton Decay"

2610.03692, K. Freese and D. Theodosopoulos, "Higgsino DM compatible with the LZ high-energy nuclear-recoil event and IceCube constraints"

2610.09516, R. Sheikh, T. Toma, K. Tsumura, "Exothermic nuclear recoils from thermal quasi-pNGB dark matter"

2610.09753, J. Lian and J. Yang, "Can Nuclear Recoils and Solar Neutrinos Resolve the Composition of Singlino-Higgsino Dark Matter?"

2610.10219, Z. Bao, S. Bisal, J. Cao, "Is the Light Neutralino Dark Matter Still Viable in the MSSM After the LZ-2024 Results?"

2610.13930, S. J. Lee and T. Youn, "The LZ inelastic splitting as a probe of anomaly mediation"

2610.14188, M. Di Mauro, "A Comprehensive Interpretation of the LZ HE Recoil Event: A Minimal U(1)_B Dark Sector and Its Experimental Tests"

2610.16156, X. Wang, J. Yang, Y. Yue, Y. Zhang, "Probing LZ-Motivated TeV Higgsino Dark Matter through Heavier Sparticles at LHC"

2610.18974, K. Deka, "Exothermic dark-photon dark matter and the LZ high-recoil event: finite-reheating constraints"

2610.21041, P. Graham, J. Luengas, H. Ramani, S. Wong, "Testing the inelastic DM interpretation of the LZ event with heavy-element experiments"

2610.23713, K. Abazajian, Y. Li, O. Macias, "Foreground dependence of the 20 GeV halo γ -ray excess and its proposed connection to the LZ event"

2610.25423, J. Kim, J. Kim and P. Ko, "Exothermic Dark Matter with a Dark Higgs: The LZ 248 keV Event and the Galactic Center Excess"

Community reaction

Inelastic higgsinos

2609.01475, **2609.01504**, 2609.01583,
2609.01590, 2609.02608, 2609.04163,
2609.07811, 2609.09385, 2609.09830,
2609.11241, 2610.03692, 2610.13930

Constraints from solar capture

2609.02775, 2609.06760, 2609.07807, 2609.10636,
2609.11833, 2609.21823, 2609.28129, 2609.28218,
2609.38316, 2610.21041

Trouble from high-energy sideband

2609.04175, 2609.09385, 2609.26698

Inelastic 'others'

2609.02505, 2609.02807, 2609.04181
(seasonal variation), 2609.06171,
2609.06571, 2609.07138, 2609.07225,
2609.08893, 2609.09136 (xDims),
2609.10491, 2609.10827, 2609.15027,
2609.22063, 2609.28819

Modified speed distribution

2609.35737, 2609.36184, 2609.38316, 2610.21041

Boosted DM

2609.06756, 2609.07742,
2609.11600, 2609.24982,
2609.37545

Composite DM

2609.23477, 2609.24988,
2609.25723, 2609.36814
(excitation)

Other cute ideas

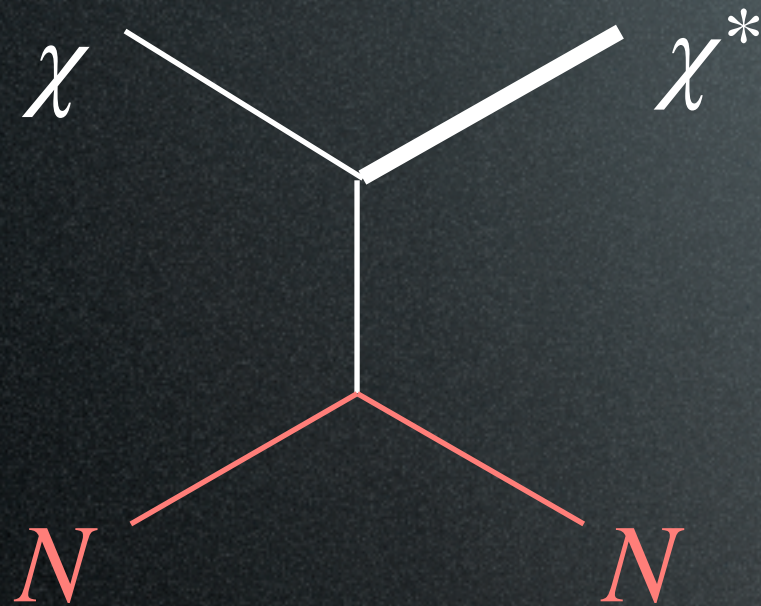
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2609.08993, 2609.09015, 2609.09037,
2609.09107, 2609.10504, 2609.13130,
2609.15742, 2609.15933, 2609.18564,
2609.28616, 2609.30255

Exothermic inelastic

2609.04673, 2609.05204, 2609.10491,
2609.15714, 2609.15782, 2609.17412,
2609.17935, 2609.26570, 2610.09516,
2610.18974, 2610.25423

Inelastic higgsinos

Why **inelastic**?

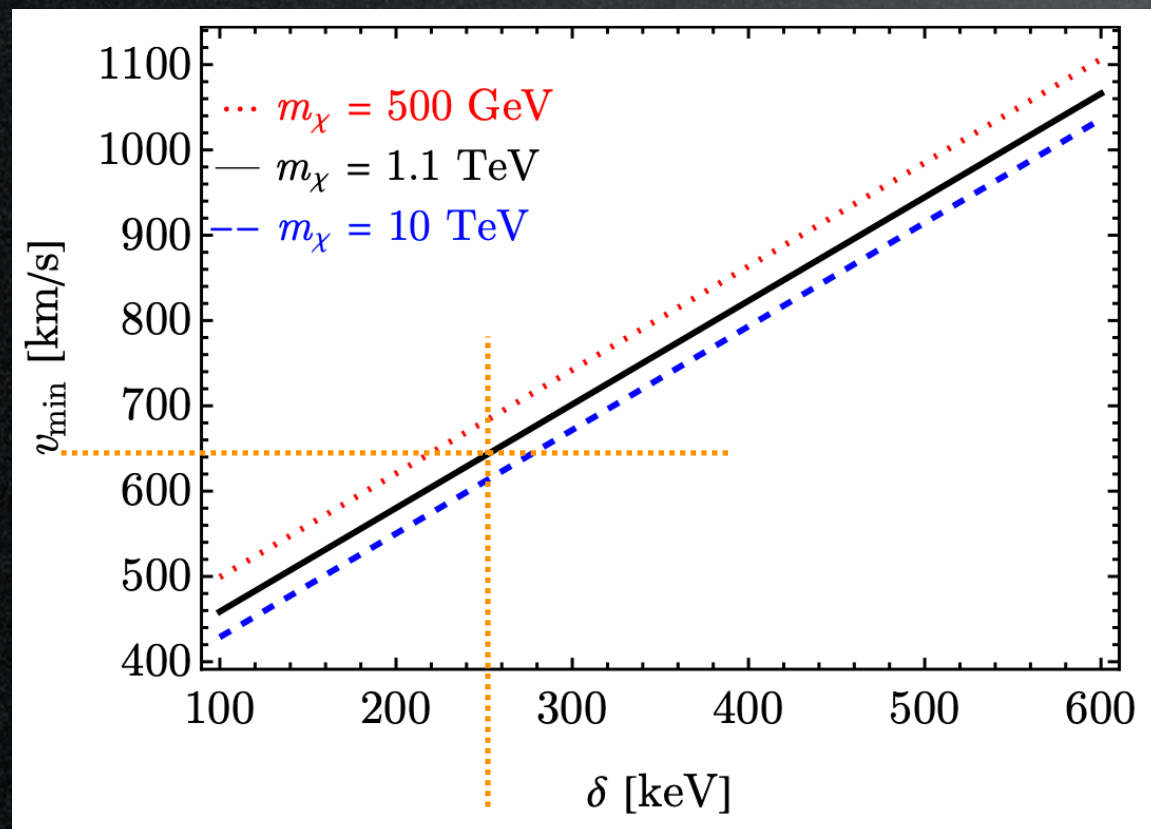


mass splitting $\delta = M_{\chi^*} - M_{\chi} \ll M_{\chi}$

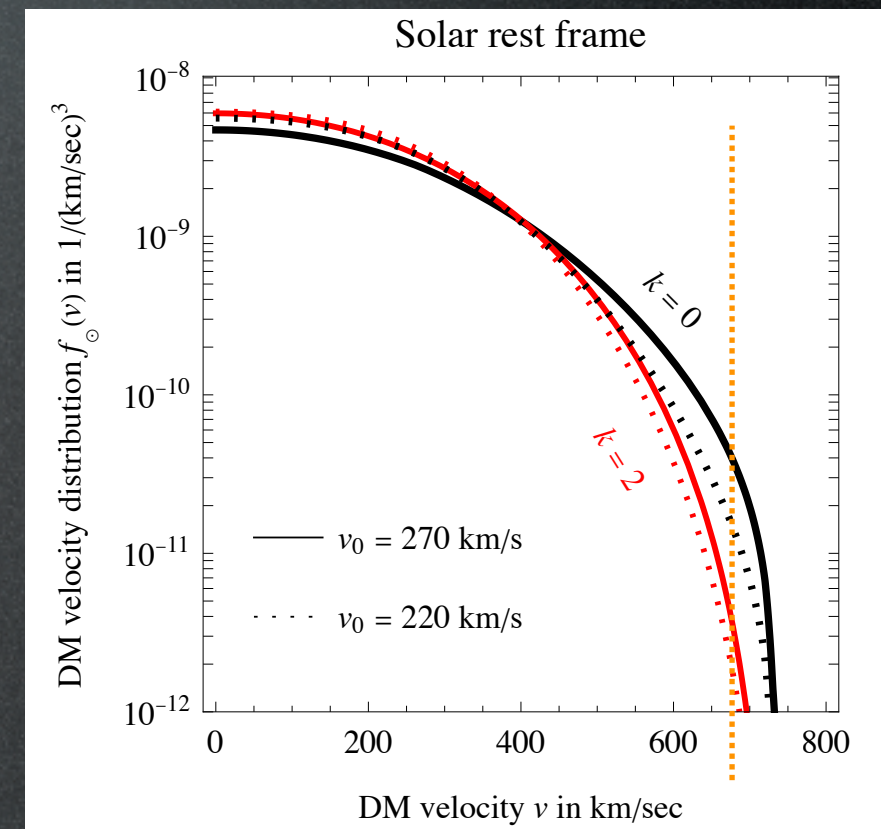
$$v_{\min} = \sqrt{\frac{m_N E_R}{2\mu_{\chi}^2}} + \frac{\delta}{\sqrt{2E_R m_N}}$$

$m_N = 122 \text{ GeV}$ for Xenon

suppresses events at small E_R
probes high-speed tail of $f(v)$



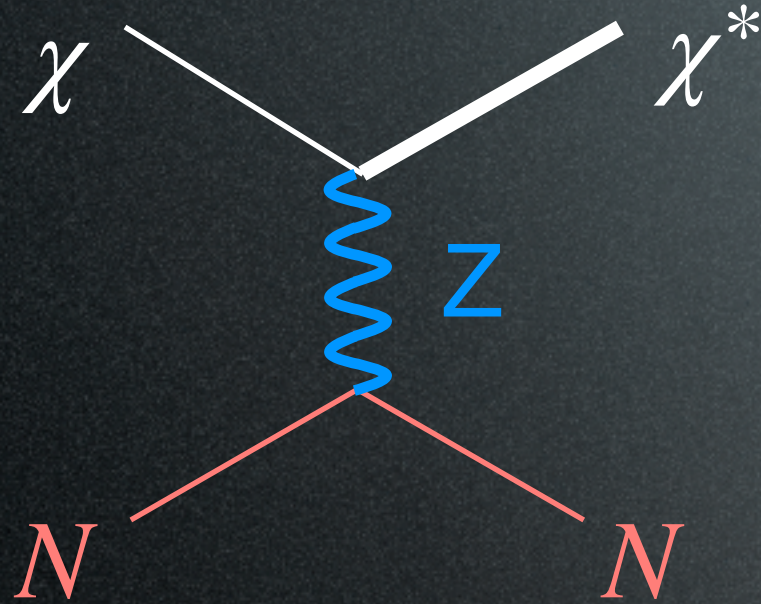
Fan Reece 2609.01504



M. Cirelli, A. Strumia, J. Zupan 2406.01705

Inelastic higgsinos

Why **higgsinos**?



Higgsinos are neutralinos $\tilde{B} - \tilde{W}^3 - \tilde{H}_u^0 - \tilde{H}_d^0$

Neutralino mass matrix in MSSM

$$M_\chi = \begin{pmatrix} M_1 & 0 & -m_Z c_\beta s_W & m_Z s_\beta s_W \\ 0 & M_2 & m_Z c_\beta c_W & -m_Z s_\beta c_W \\ -m_Z c_\beta s_W & m_Z c_\beta c_W & 0 & -\mu \\ m_Z s_\beta s_W & -m_Z s_\beta c_W & -\mu & 0 \end{pmatrix}$$

M_1 bino mass, M_2 wino mass, μ higgsino Dirac mass term ($\mu \tilde{H}_u^0 \tilde{H}_d^0$)

Upon diagonalization

$$M_{\tilde{H}_1^0, \tilde{H}_2^0} = \mu \pm \frac{\delta}{2}$$

$$M_\chi \simeq \mu$$

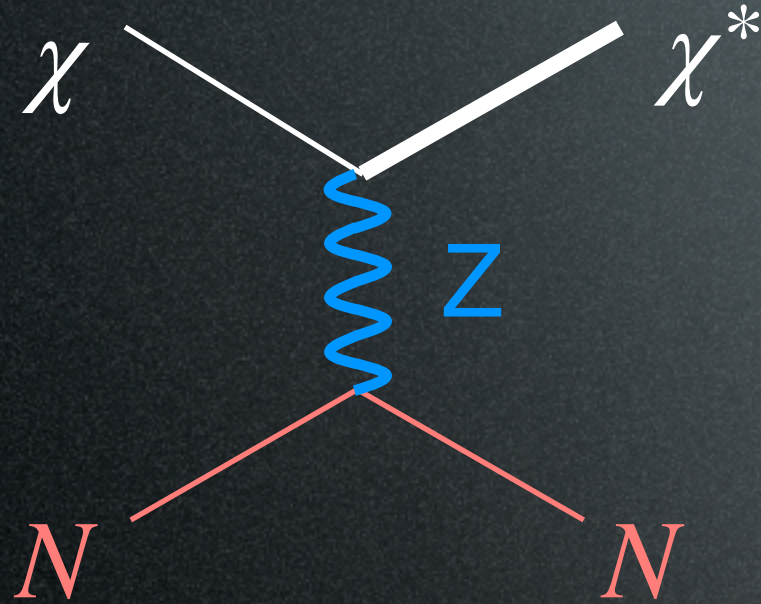
$$M_{\chi^*} \simeq \mu + \delta$$

$$\delta = m_Z^2 \left(\frac{\sin^2 \theta_W}{M_1} + \frac{\sin^2 \theta_W}{M_2} \right)$$

‘Best fit’ of the LZ event: $\mu \simeq 1.1 \text{ TeV}$, $\delta \simeq 350 \text{ keV}$ ($M_1 \approx M_2 \approx 10^7 \text{ GeV}$)

Inelastic higgsinos

Why **higgsinos**?



Higgsinos are neutralinos $\tilde{B} - \tilde{W}^3 - \tilde{H}_u^0 - \tilde{H}_d^0$

Neutralino mass matrix in MSSM

$$M_\chi = \begin{pmatrix} M_1 & 0 & -m_Z c_\beta s_W & m_Z s_\beta s_W \\ 0 & M_2 & m_Z c_\beta c_W & -m_Z s_\beta c_W \\ -m_Z c_\beta s_W & m_Z c_\beta c_W & 0 & -\mu \\ m_Z s_\beta s_W & -m_Z s_\beta c_W & -\mu & 0 \end{pmatrix}$$

M_1 bino mass, M_2 wino mass, μ higgsino Dirac mass term ($\mu \tilde{H}_u^0 \tilde{H}_d^0$)

Upon diagonalization

$$M_{\tilde{H}_1^0, \tilde{H}_2^0} = \mu \pm \frac{\delta}{2}$$

$$M_\chi \simeq \mu$$

$$M_{\chi^*} \simeq \mu + \delta$$

$$\delta = m_Z^2 \left(\frac{\sin^2 \theta_W}{M_1} + \frac{\sin^2 \theta_W}{M_2} \right)$$

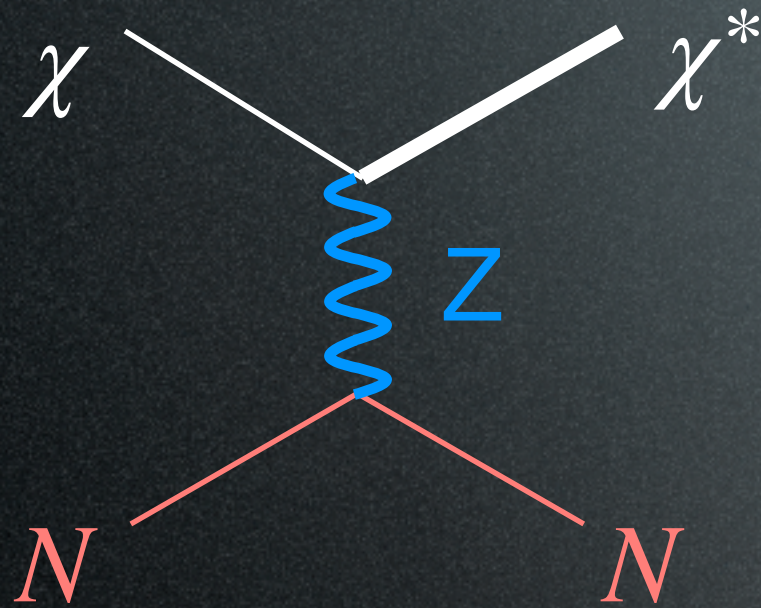
with a lot of uncertainty, actually
 $\sim 500 \text{ GeV} \rightarrow \sim 100 \text{ TeV}$
 (because DD is sensitive to the reduced mass)

rather tightly fit
 $\sim 310 \rightarrow 375 \text{ keV}$

‘Best fit’ of the LZ event: $\mu \simeq 1.1 \text{ TeV}$, $\delta \simeq 350 \text{ keV}$ ($M_1 \approx M_2 \approx 10^7 \text{ GeV}$)

Inelastic higgsinos

Why higgsinos?



‘Best fit’ of the LZ event: $\mu \simeq 1.1 \text{ TeV}$
 $\delta \simeq 350 \text{ keV}$

Once bought that, we have a fully predictive model

Higgsino thermal mass? $m_\chi = 1.08 \pm 0.10 \text{ TeV}$ ✓

Higgsino scattering cross-section?

$$\sigma_N \simeq G_F^2 \mu_\chi^2 / 8\pi \simeq 1 \cdot 10^{-38} \text{ cm}^2$$

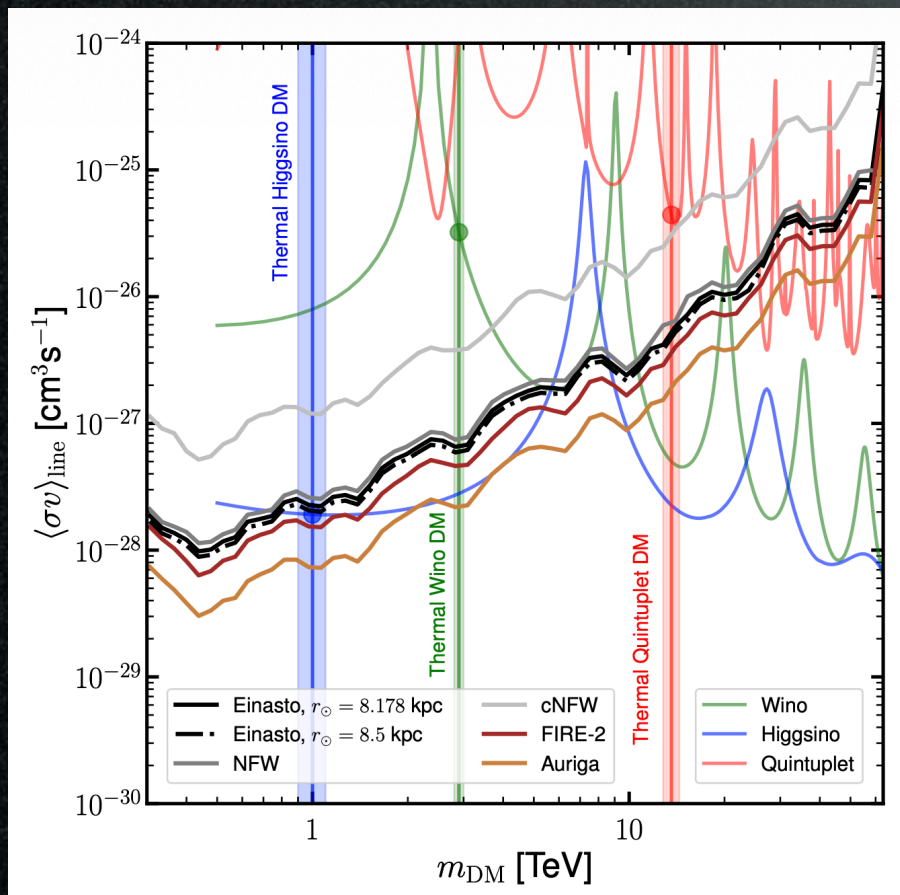
✓
(within a few)

Freese, Theodosopoulos 2609.01583

Higgsino indirect detection?

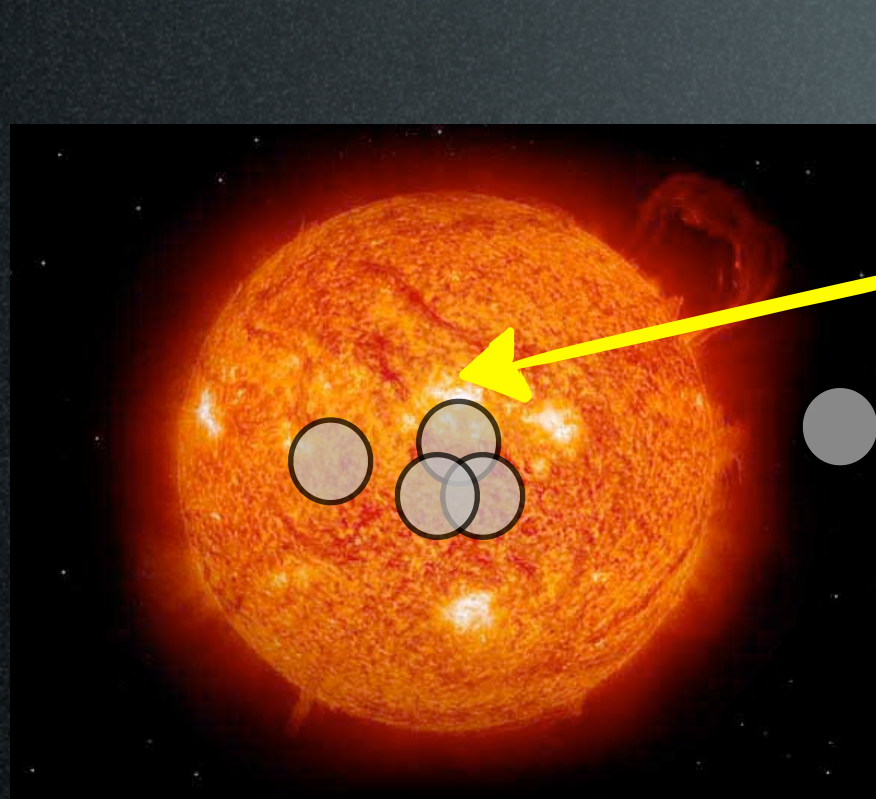
Thanks to halo/core uncertainties ✓

...as good as it can get!



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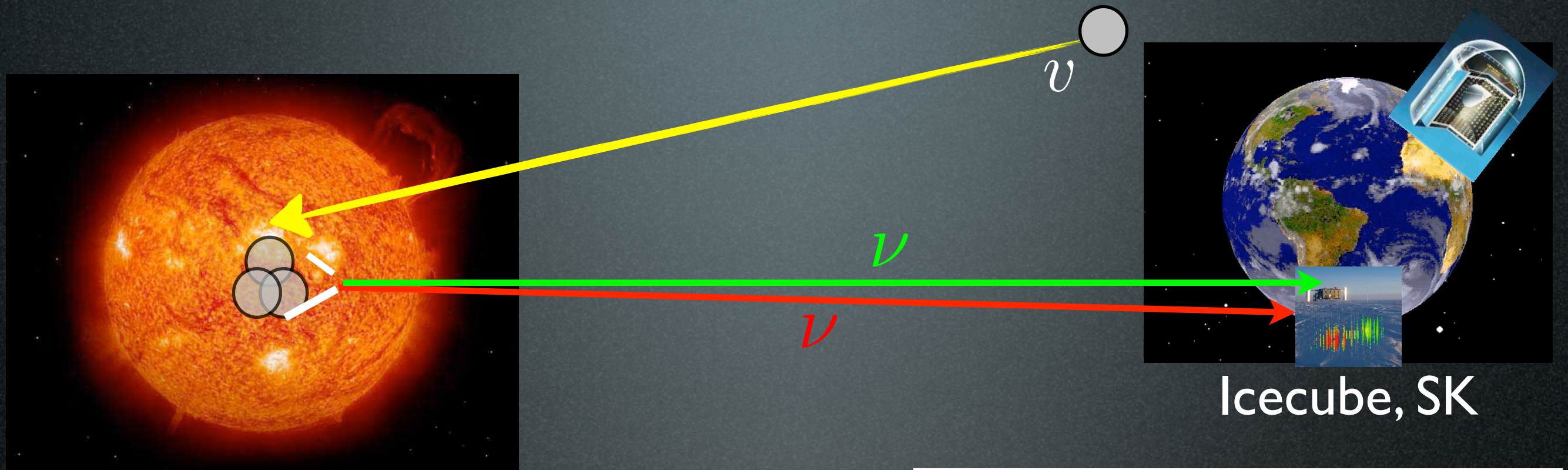
Constraints from solar capture



basics: infalling DM particles acquire large speed
they scatter with nuclei and lose energy
if $v_f < v_{\text{esc}}$, particles are gravitationally trapped
they spiral to center of body and accumulate
they annihilate

$$\begin{aligned} v_{\text{halo}} &\simeq 270 \text{ km/s} \\ v_{\text{esc}, \odot} &\simeq 620 \text{ km/s} \\ v_{\text{esc}, \oplus} &\simeq 12 \text{ km/s} \end{aligned}$$

Constraints from solar capture

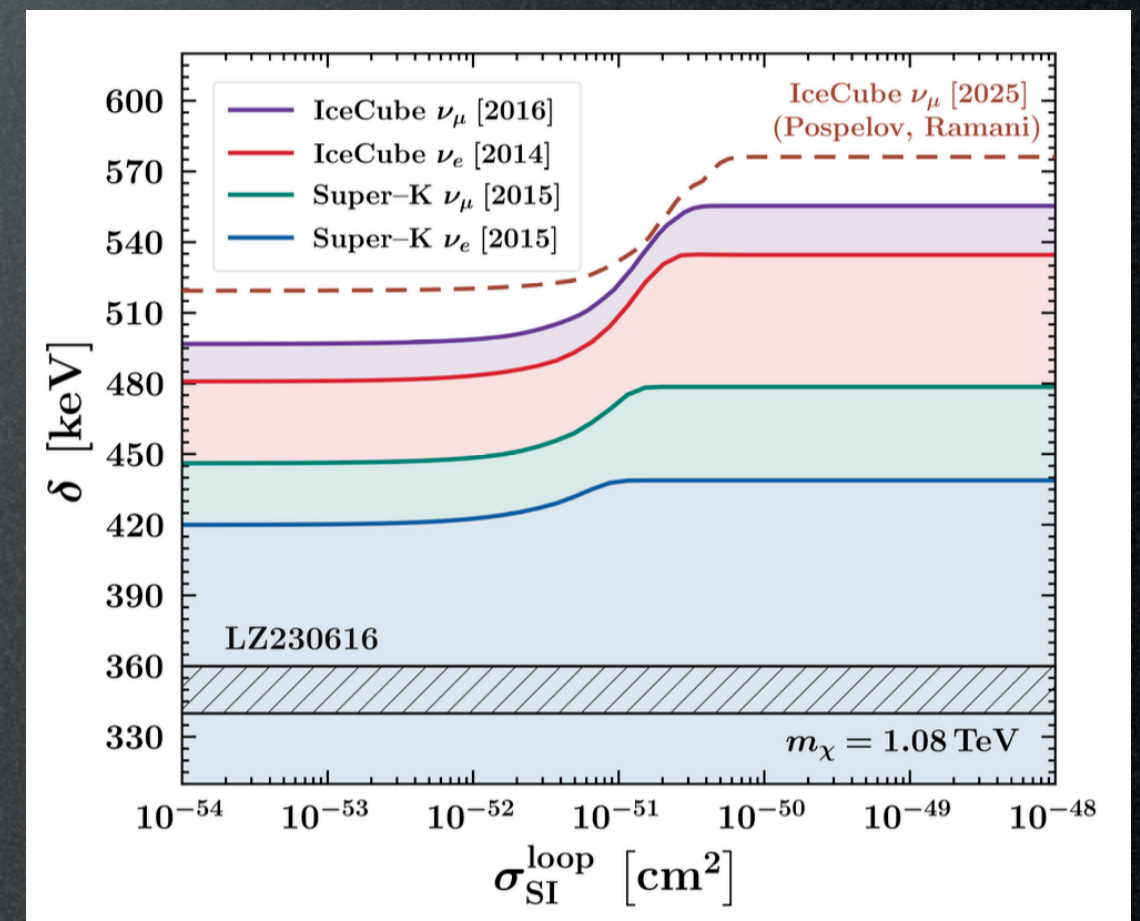


$$\chi\chi^{(*)} \rightarrow W^+W^-, ZZ \rightsquigarrow \nu$$

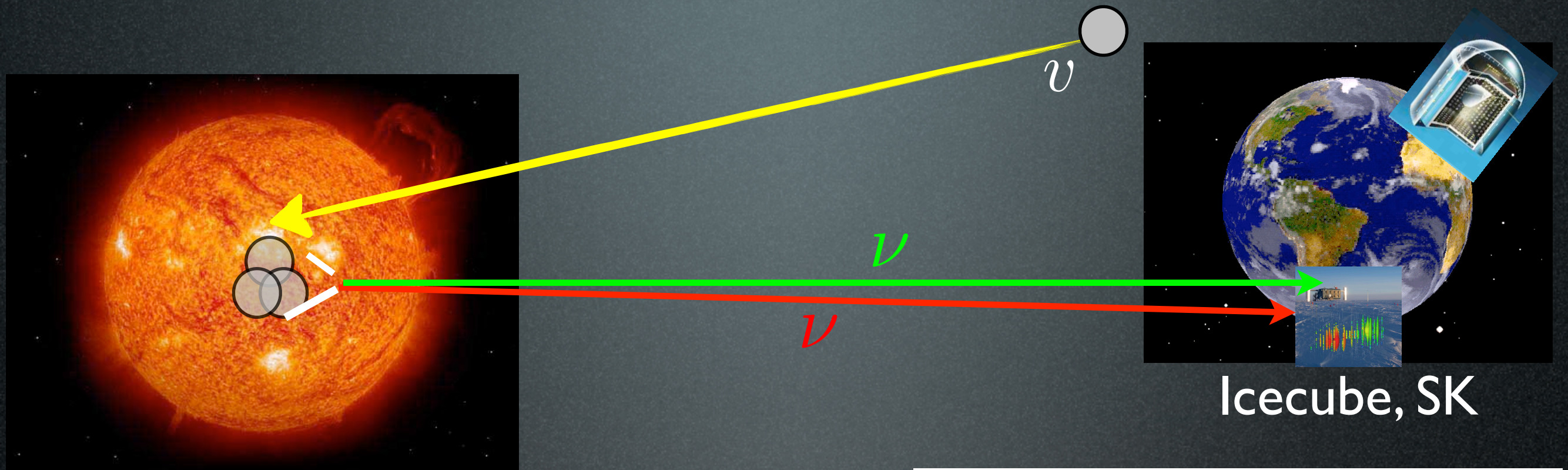
Icecube, SK imply $\delta > 557 \text{ keV}$

Details:

Large acquired speed easily provides δ :
infalling DM is efficiently captured.
Slowed down, inelastic scattering stops.
But I-loop elastic takes over and
leads to accumulation, then annihilation



Constraints from solar capture



$$\chi\chi^{(*)} \rightarrow W^+W^-, ZZ \rightsquigarrow \nu$$

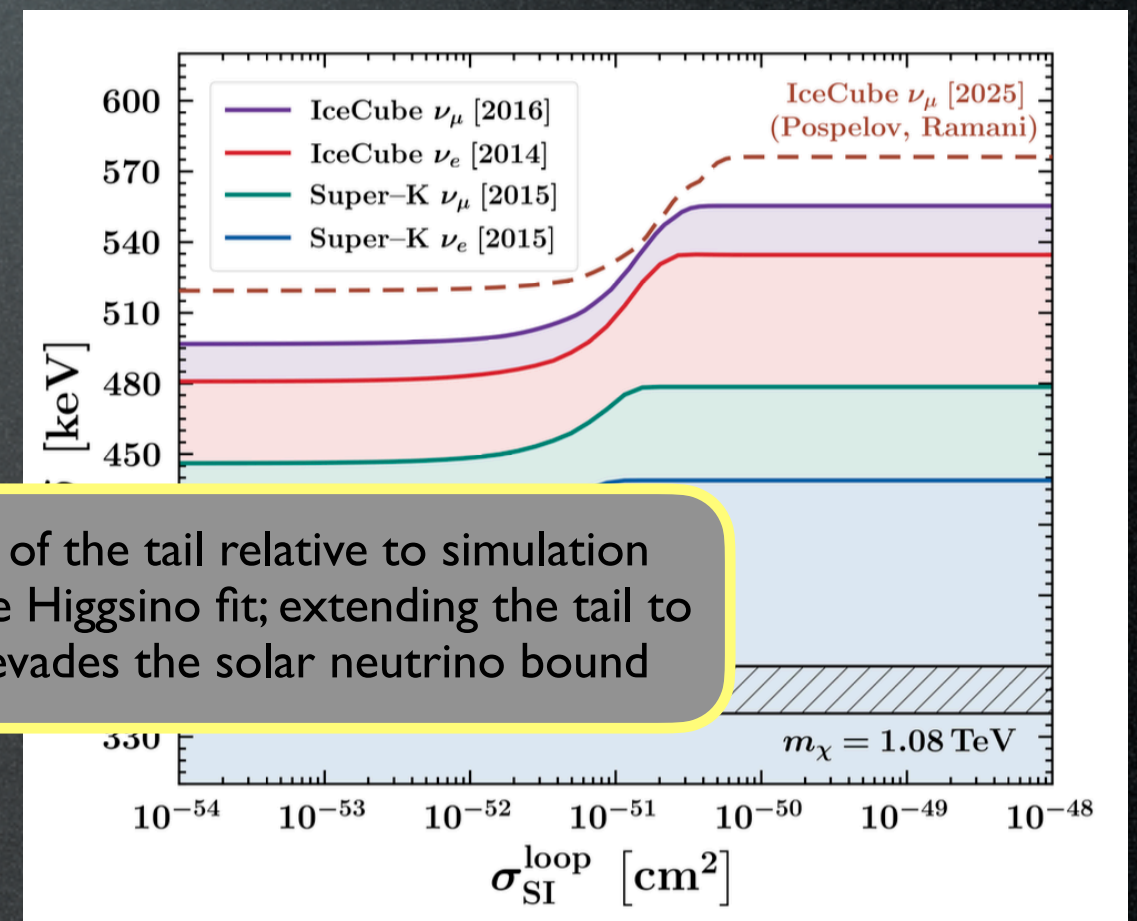
Icecube, SK imply $\delta > 557 \text{ keV}$

Ways-out:

Assume exotic $f(\nu)$, e.g. due to LMC,
assume exotic form factors,
relax m_χ (higher, non-thermal production),
go beyond higgsinos...

Reducing the flux of the tail relative to simulation results improves the Higgsino fit; extending the tail to higher velocities evades the solar neutrino bound

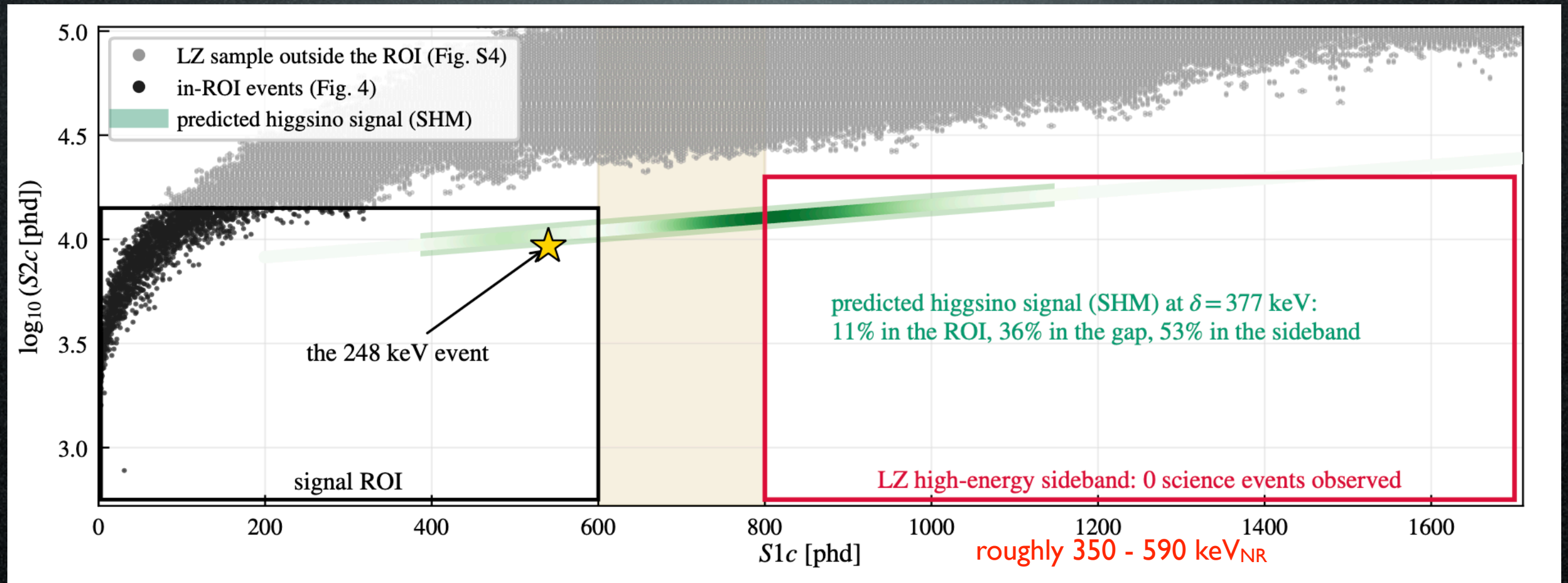
Graham+ 2610.21041



Pospelov Ramani 2609.02775
Bose ... Laha 2609.07807

Trouble from high-energy sideband

LZ should have seen 3-10 more events in the **high-energy band** where instead none are reported

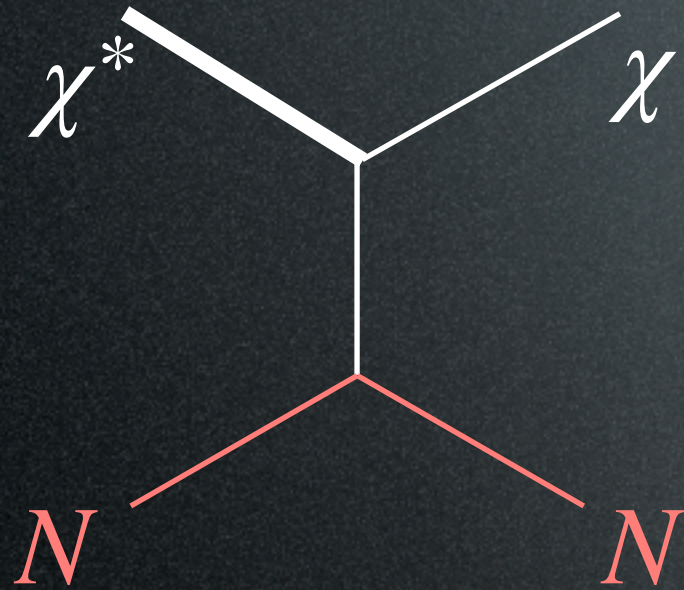


Rodd Safdi Slatyer Xu 2609.04175

Caveats: i) assuming acceptance = 1 in HE band
ii) uncertainties due to tail of the speed distribution

Exothermic inelastic

Exothermic



Dent Newstead 2609.04673

De Lima 2609.05204

Baer Barger 2609.06153

mass splitting $\delta = M_{\chi^*} - M_{\chi} \ll M_{\chi}$

(Some) DM in the halo is
in the heavier χ^* state,
(meta-)stable if $\delta < 2m_e$

‘Best fit’ of the LZ event: $m_{\chi} \simeq 30 - 200 \text{ GeV}$
 $\delta \simeq 0.5 - 1 \text{ MeV}$

Much less dependent on $f(v)$

NB: Ar experiments can discriminate: no events for endothermic (too large E_R),
sharp recoil lines for exothermic

Baer Barger 2609.15782

Boosted Dark Matter

Basic idea

Bringmann Pospelov 1810.10543

Ema, Sala, Sato 1811.00520

Also: Yin 1809.08610



(Light) DM particles are **accelerated** by hits from CR.
The same interaction produces a **high-energy recoil** in DD.

Application to the **LZ event**?

Doesn't work, predicts many events at lower recoil energy
or in neutrino experiments

Needs ad-hoc speed distributions

Backup

Direct Detection: **basics**



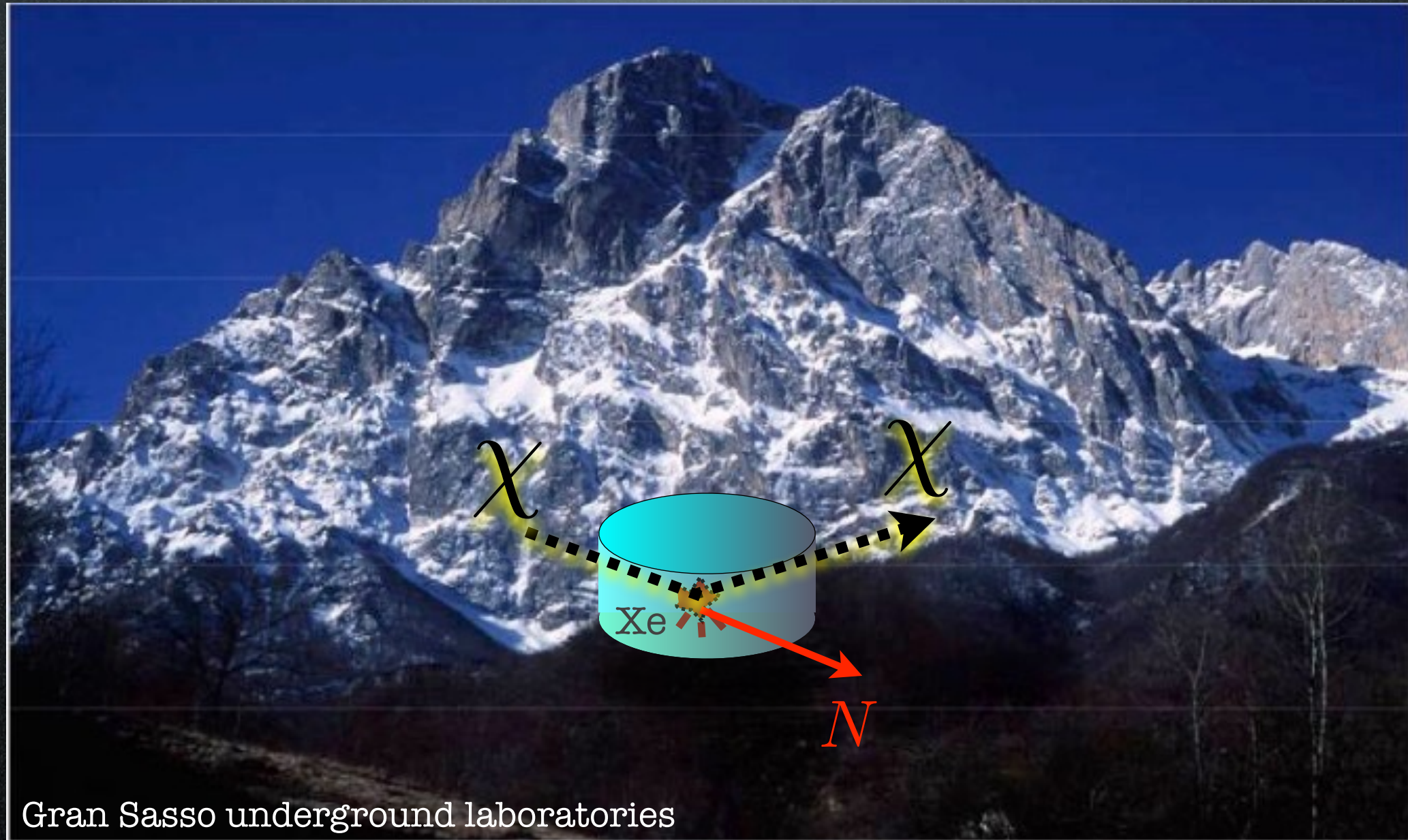
Gran Sasso underground laboratories

Direct Detection: basics



Gran Sasso underground laboratories

Direct Detection: basics

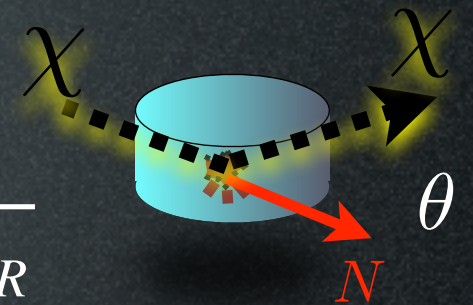


Direct Detection: basics

recoil energy $E_R = \frac{\mu_\chi^2 v^2}{m_N} (1 - \cos \theta)$

$$\mu_\chi = \frac{m_\chi m_N}{m_\chi + m_N} \rightarrow \begin{cases} m_\chi & \text{for small } m_\chi \\ m_N & \text{for large } m_\chi \end{cases}$$

$$v_{\min} = \sqrt{\frac{m_N E_R}{2\mu_\chi^2}}$$



recoil energy spectrum

$$\frac{dR}{dE_R} = \frac{1}{2} \frac{\rho_\odot}{m_\chi} \frac{\sigma}{\mu^2} \int_{v_{\min}(E_R)}^{v_{\text{esc}}} \frac{1}{v} f(\vec{v}) d\vec{v}$$

with $f(\vec{v}) \propto e^{-v^2/V_c^2}$ + motion of Earth
in (static?) halo

$$\sigma \approx \sigma_n^{\text{SI}} A^4 \times \text{nuclear form factors}$$

number of events

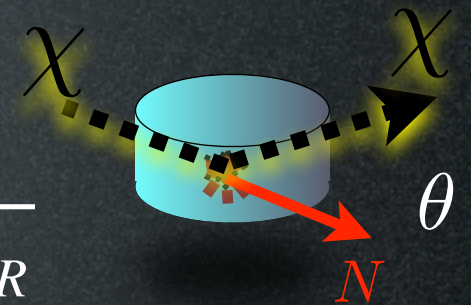
$$N = \mathcal{E} \mathcal{T} \int_{E_{\text{thres}}}^{E_{\text{max}}} \frac{dR}{dE_R} dE_R$$

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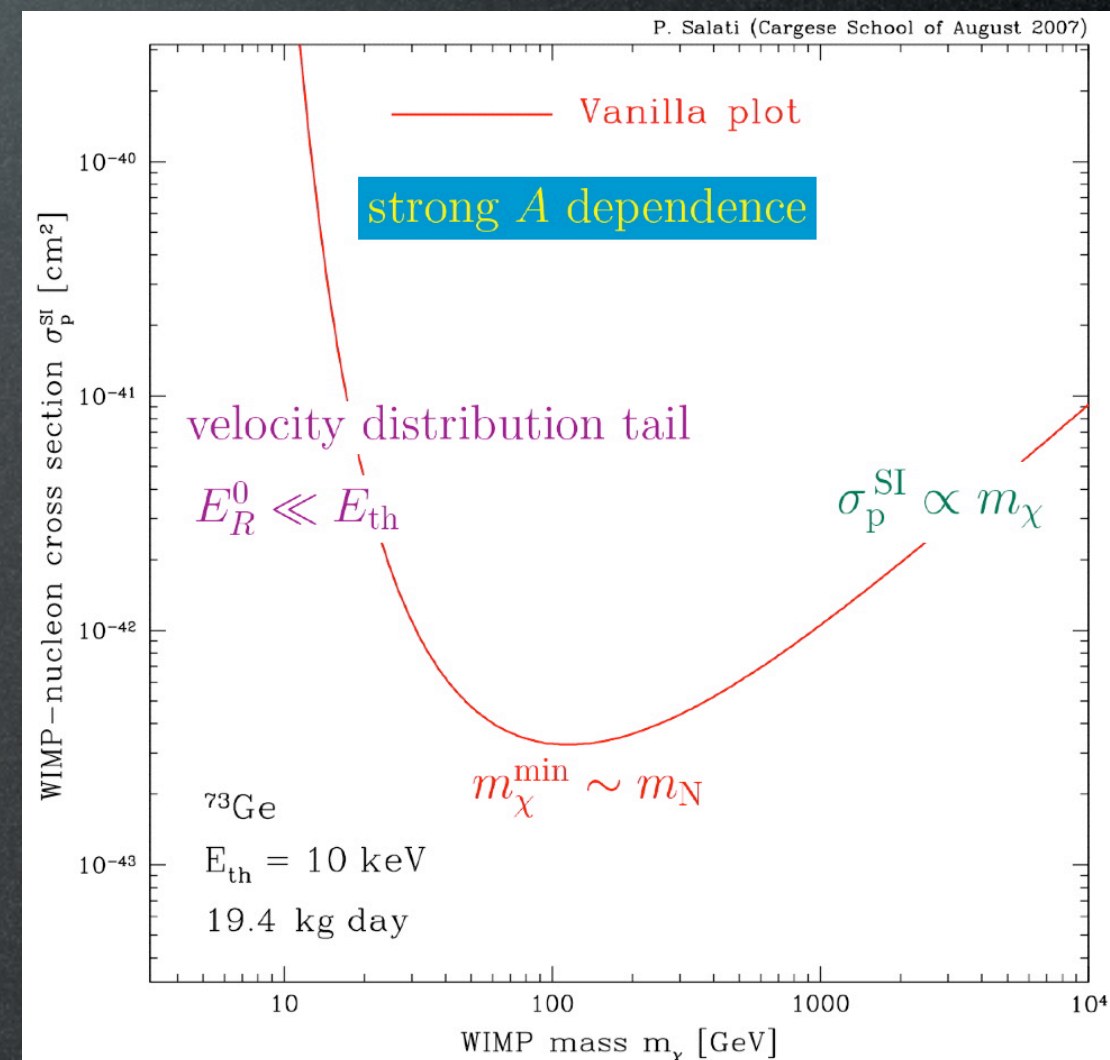
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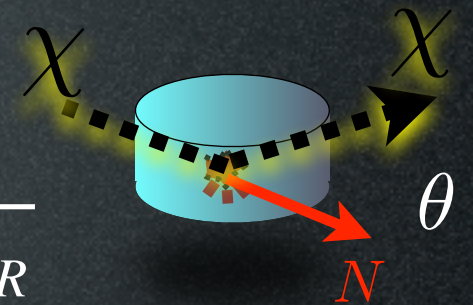


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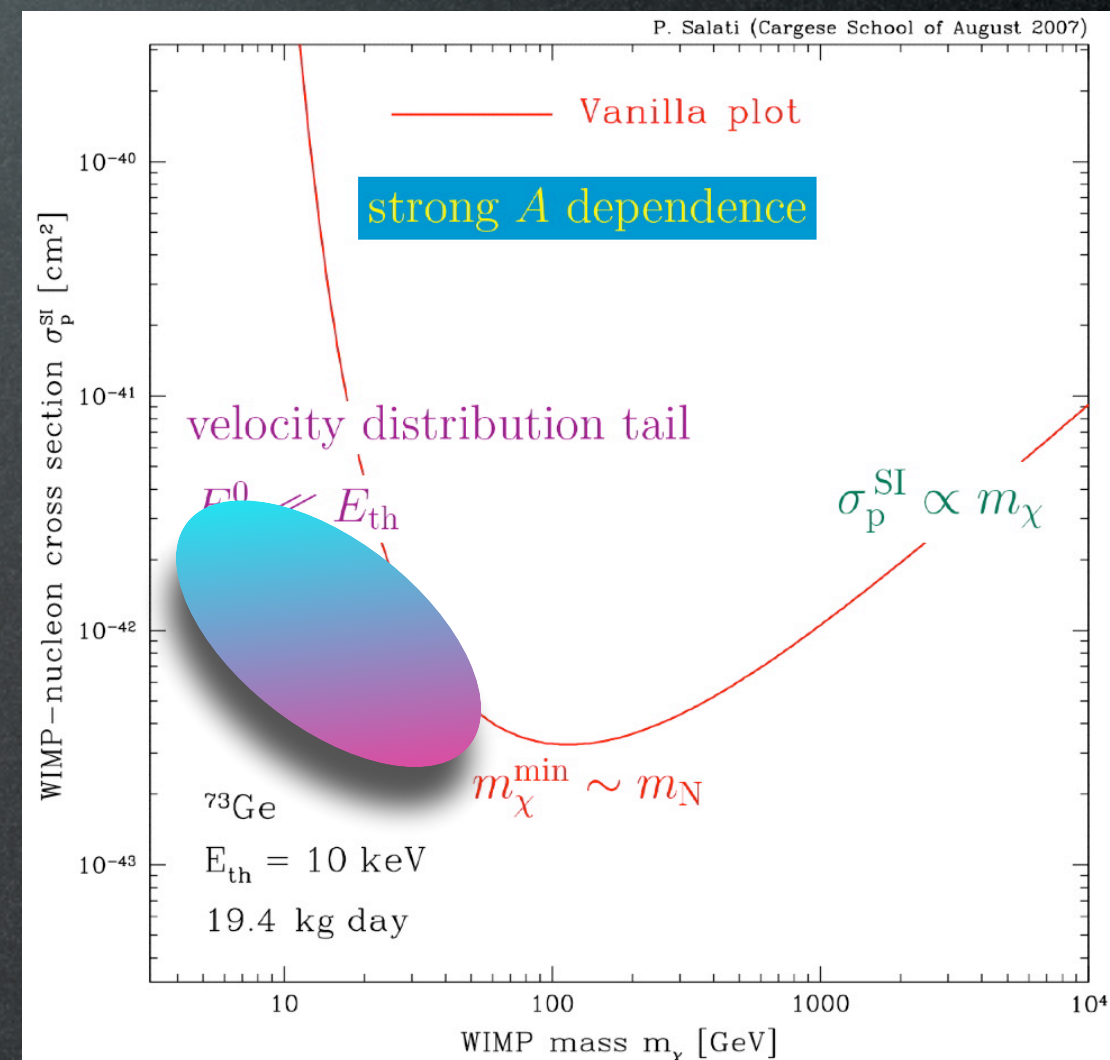
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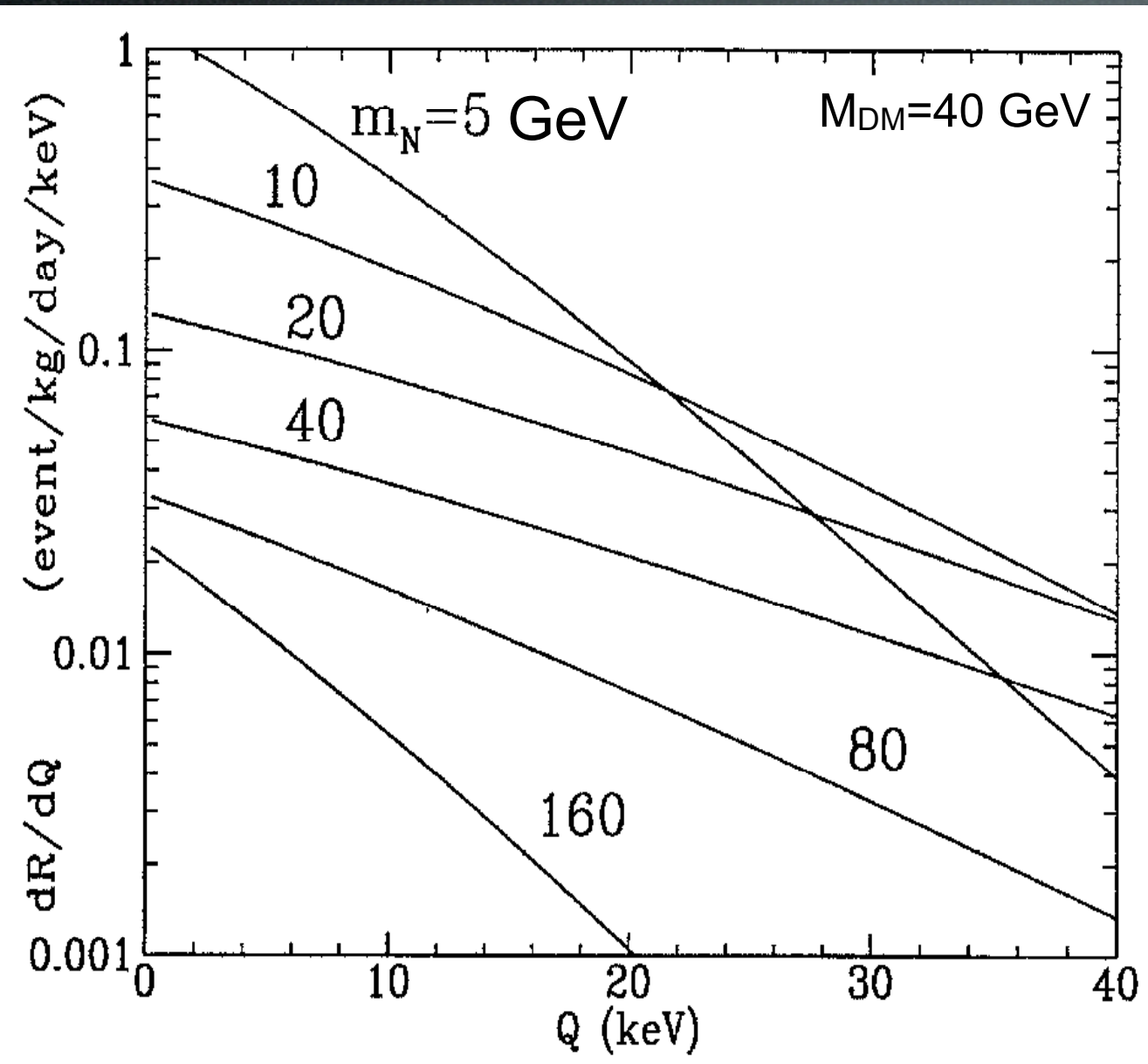
$$N = \mathcal{E} \mathcal{T} \int_{E_{\text{thres}}}^{E_{\text{max}}} \frac{dR}{dE_R} dE_R$$



Direct Detection

Recoil spectra

fixed M_{DM}



fixed M_{nucl}

