清華大學
Tsinghua University

13th Mini-workshop on the Frontier of LHC

Tensions in DM Direct Detection

Qing Wang

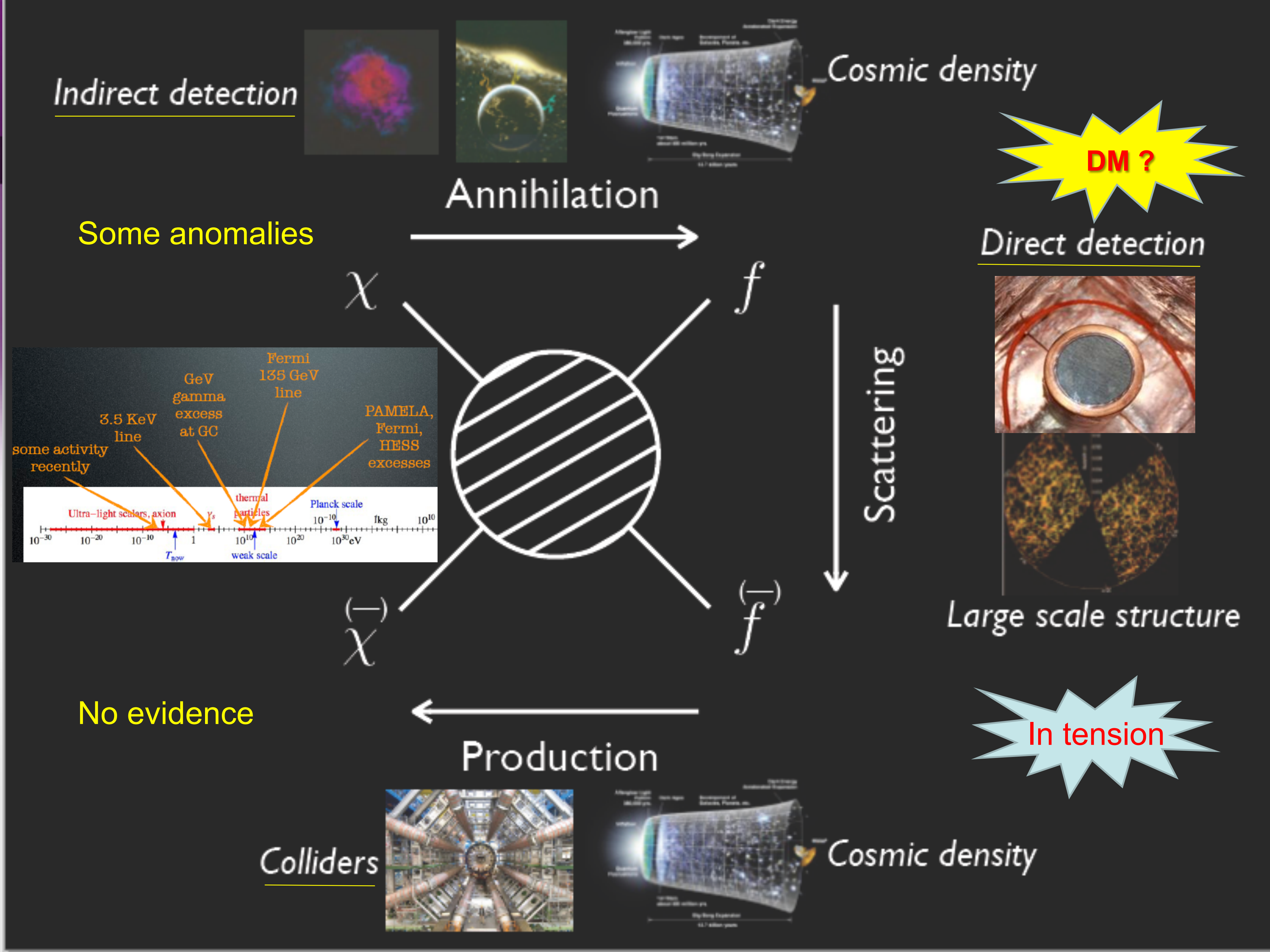
Nov.8, 2014

浙江近代物理中心
场论与粒子物理学

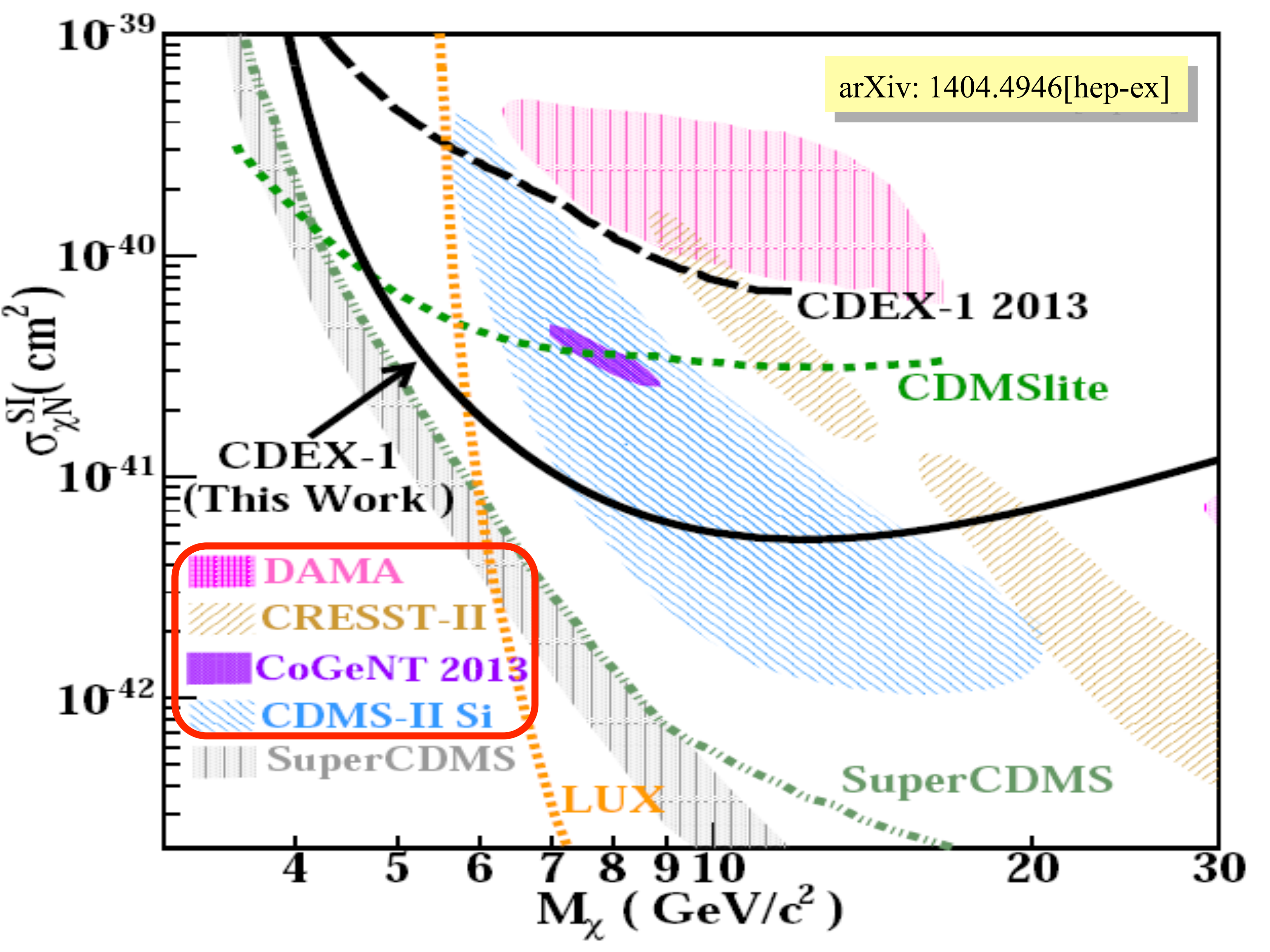
清華大學
Tsinghua University

Outline

- Motivation & Status ✓
- Three old Exps: DAMA；CRESST；CoGeNT
- Reconciliation Methods
- Latest Result
- Theoretical Models



Indirect detection
Cosmic density
DM ?
Annihilation
Some anomalies
Direct detection
χ
f
Scattering
Fermi 135 GeV line
GeV gamma excess at GC
3.5 KeV line
PAMELA, Fermi, HESS excesses
some activity recently
thermal particles
Ultra−light scalars, axion
Planck scale
weak scale
Large scale structure
No evidence
In tension
Production
Colliders
Cosmic density



arXiv: 1404.4946[hep-ex]
10^{-39}
10^{-40}
10^{-41}
10^{-42}
$\sigma_{\chi N}^{SI}$(cm^2)
CDEX-1 2013
CDMSlite
CDEX-1
(This Work)
DAMA
CRESST-II
CoGeNT 2013
CDMS-II Si
SuperCDMS
LUX
SuperCDMS
4
5
6
7
8
9
10
20
30
M_χ (GeV/c^2)

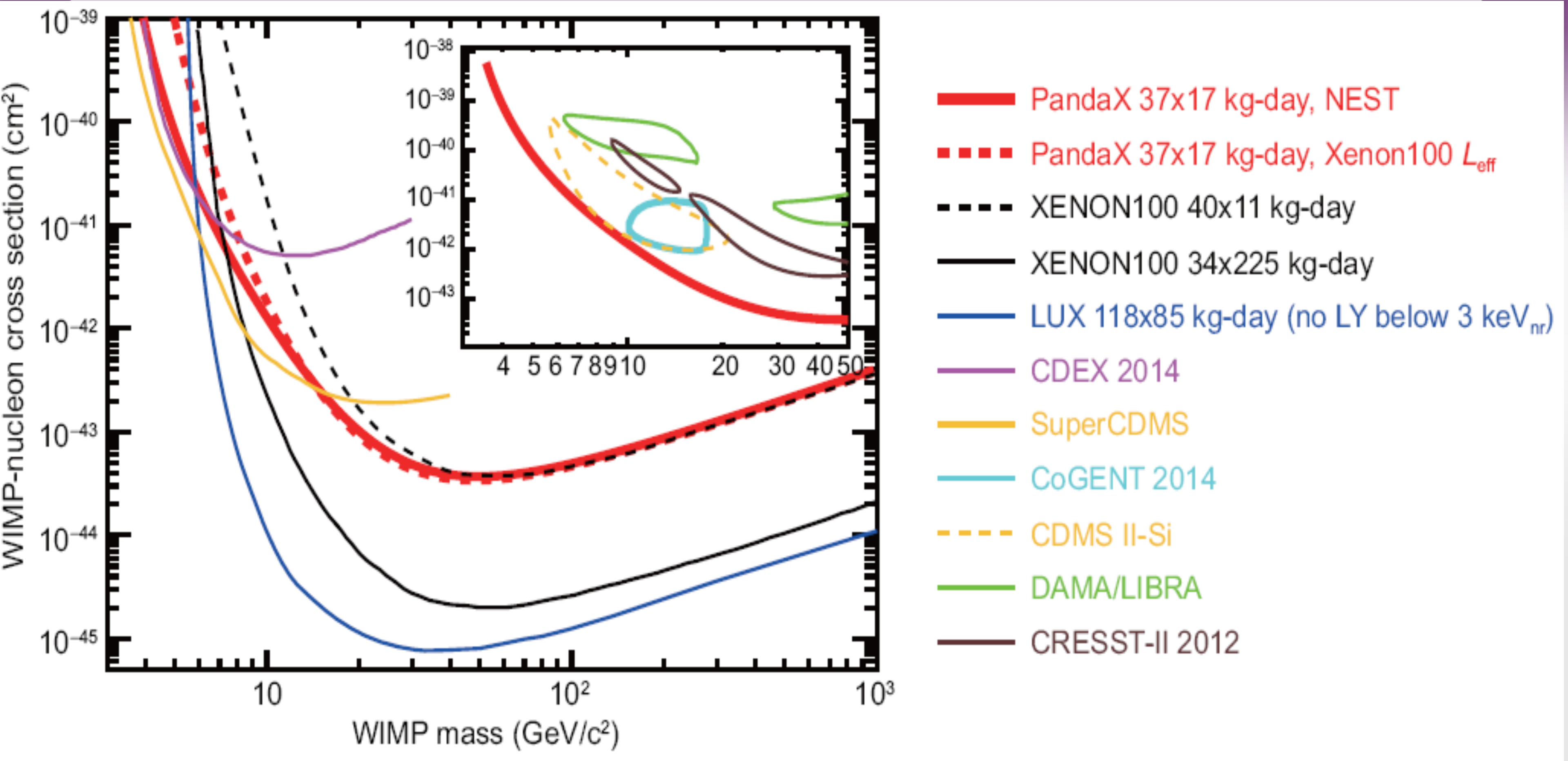
SCIENCE CHINA
Physics, Mechanics & Astronomy

• Letter •
Progress of Projects Supported by NSFC

November 2014 Vol. 57 No. 11: 2024–2030
doi: 10.1007/s11433-014-5598-7

First dark matter search results from the PandaX-I experiment

Received August 22, 2014; accepted August 23, 2014; published online September 5, 2014



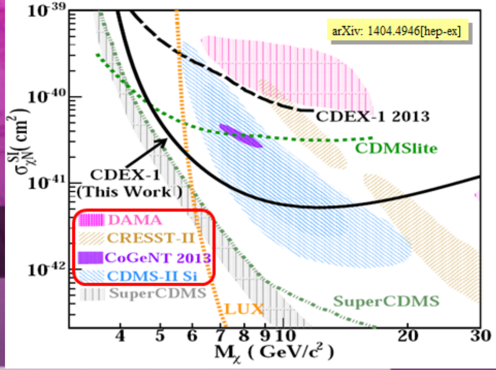
Motivation

- If we cannot reconcile different Exp results
  - ⇨ Need new theory explanation
  - ⇨ Judge which Exp more reliable discover DM?
- If theory cannot reconcile different Exp results
  - ⇨ Need new theory explanation
  - ⇨ Deep understanding Exp

Property of DM?

- **Possible way out** **Direction of future theory & Exp**

Tsinghua University



Outline

- Motivation & Status
- Three old Exps: DAMA; CRESST; CoGeNT ✓
- Reconcilation Methods
- Latest Result
- Theoretical Models

Direct dark matter searches: status and implications

Paolo Gondolo

University of Utah

ICHEP 2014 VALENCIA

37th INTERNATIONAL CONFERENCE ON HIGH ENERGY PHYSICS

2 - 9 - JULY - 2014 - VALENCIA

DAMA modulation

Model Independent Annual Modulation Result

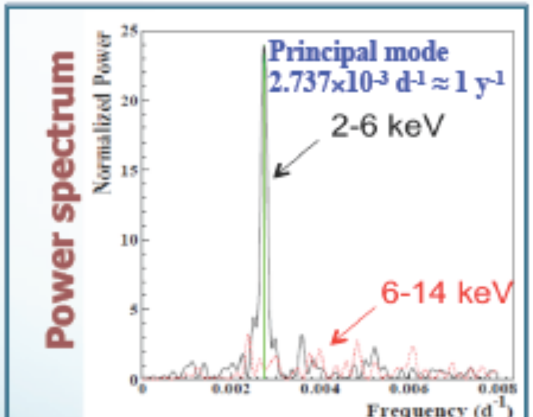
DAMA/NaI + DAMA/LIBRA-phase1 Total exposure: 487526 kg×day = **1.33 ton×yr**

EPJC 56(2008)333, EPJC 67(2010)39, EPJC 73(2013)2648

The measured modulation amplitudes (A), period (T) and phase (t_0) from the single-hit residual rate vs time

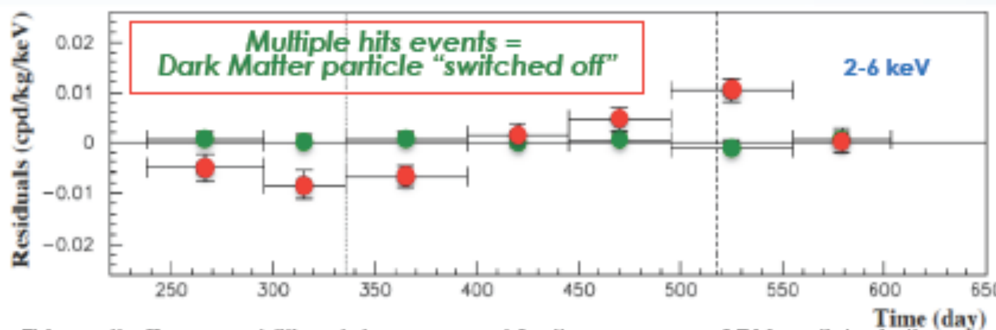
	A(cpd/kg/keV)	$T=2\pi/\omega$ (yr)	t_0 (day)	C.L.
DAMA/NaI+DAMA/LIBRA-phase1				
(2-4) keV	**0.0190 ±0.0020**	**0.996 ±0.0002**	**134 ± 6**	**9.5σ**
(2-5) keV	**0.0140 ±0.0015**	**0.996 ±0.0002**	**140 ± 6**	**9.3σ**
(2-6) keV	**0.0112 ±0.0012**	**0.998 ±0.0002**	**144 ± 7**	**9.3σ**

$A\cos[\omega(t-t_0)]$



Comparison between **single hit residual rate (red points)** and **multiple hit residual rate (green points)**; Clear modulation in the single hit events; No modulation in the residual rate of the multiple hit events

A=-(0.0005±0.0004) cpd/kg/keV



This result offers an additional strong support for the presence of DM particles in the galactic halo further excluding any side effect either from hardware or from software procedures or from background

No systematics or side reaction able to account for the measured modulation amplitude and to satisfy all the peculiarities of the signature

The data favor the presence of a modulated behaviour with all the proper features for DM particles in the galactic halo at about 9.2σ C.L.

Belli, IDM2014

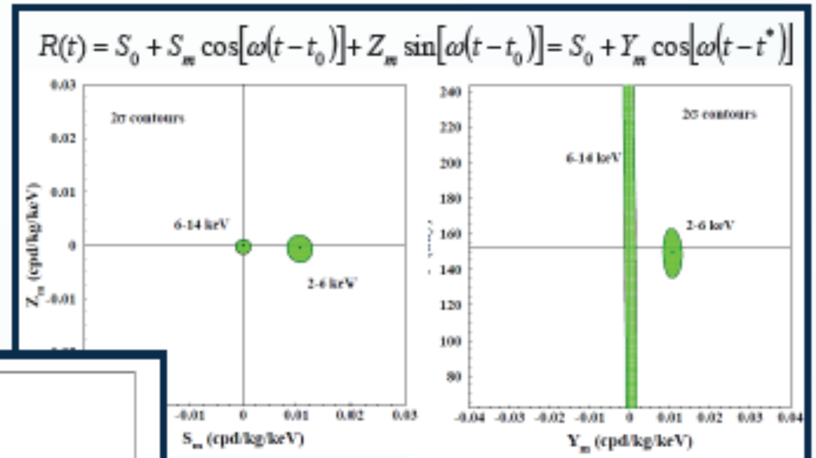
DAMA modulation

Model Independent Annual Modulation Result

DAMA/NaI + DAMA/LIBRA-phase1 Total exposure: 487526 kg×day = **1.33 ton×yr**

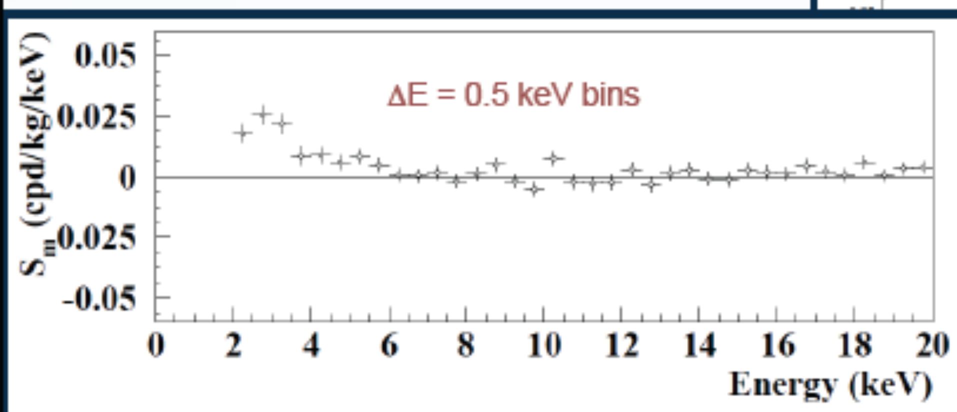
EPJC 56(2008)333, EPJC 67(2010)39, EPJC 73(2013)2648

- No modulation above 6 keV
- No modulation in the whole energy spectrum
- No modulation in the 2-6 keV multiple-hit events



$$R(t) = S_0 + S_m \cos[\omega(t - t_0)]$$

here $T=2\pi/\omega=1$ yr and $t_0= 152.5$ day



No systematics or side processes able to quantitatively account for the measured modulation amplitude and to simultaneously satisfy the many peculiarities of the signature are available.

Belli, IDM2014

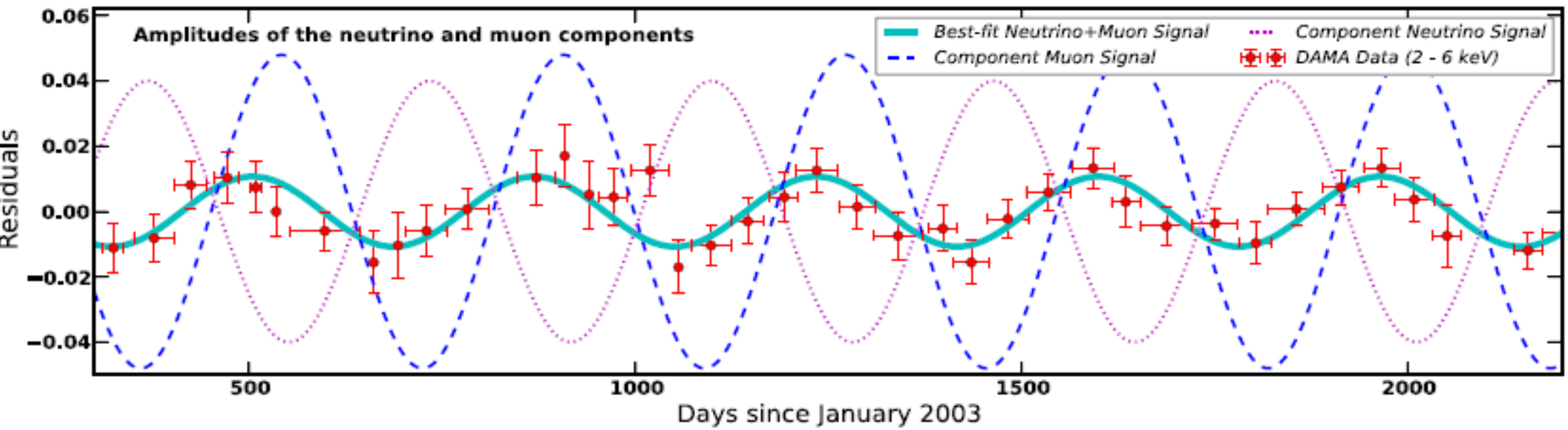
PRL 113, 081302 (2014) PHYSICAL REVIEW LETTERS week ending 22 AUGUST 2014

Fitting the Annual Modulation in DAMA with Neutrons from Muons and Neutrinos

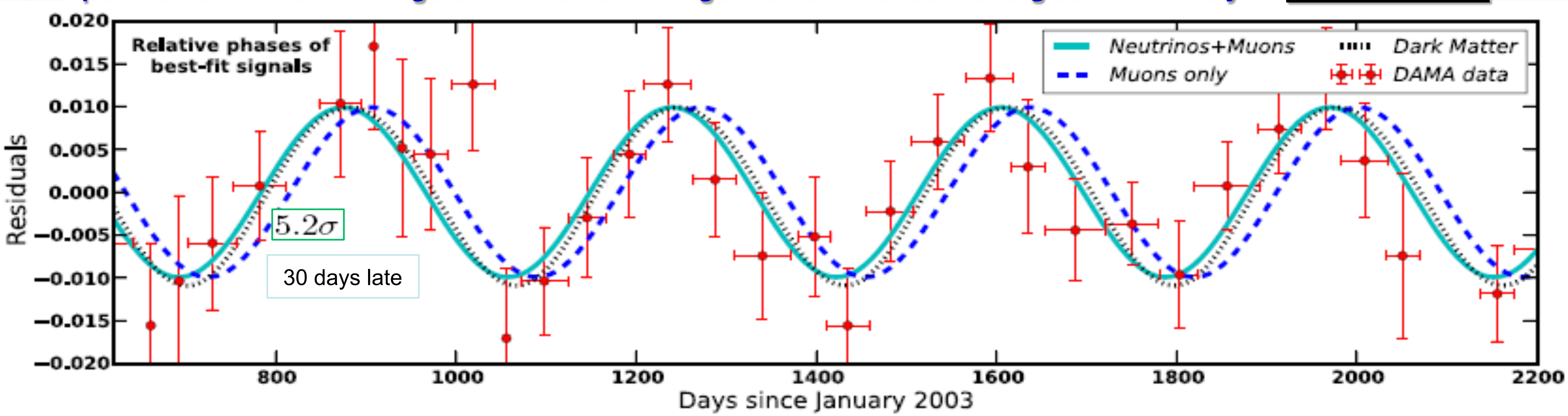
cosmic ray atmospheric ^{8}B solar

Jonathan H. Davis*
Institute for Particle Physics Phenomenology, Durham University, Durham DH1 3LE, United Kingdom

(Received 10 July 2014; revised manuscript received 5 August 2014; published 21 August 2014)



For experiments with heavier targets such as xenon or germanium the recoil energies would likely be below threshold.



:1409.3185v1 10 Sep

Comment on "Fitting the annual modulation in DAMA with neutrons from muons and neutrinos"

P.S. Barbeau[a], J.I. Collar[b], Yu. Efremenko[c], and K. Scholberg[a,*].
[a]*Department of Physics, Duke University, Durham, NC 27708 USA*
[b]*Department of Physics, University of Chicago, Chicago, IL 60637 USA*
[c]*University of Tennessee, Knoxville, TN 37996 USA*
[*]*Corresponding author. E-mail: schol@phy.duke.edu*

We estimate rates of solar neutrino-induced neutrons in a DAMA/LIBRA-like detector setup, and find that the needed contribution to explain the annual modulation would require neutrino-induced neutron cross sections several orders of magnitude larger than current calculations indicate. Although these cross sections have never been measured, it is likely that the solar-neutrino effect on DAMA/LIBRA is negligible.

1409.3516v1 11 Sep

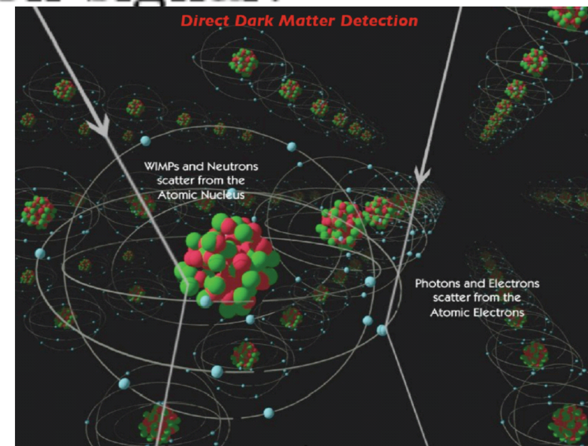
No role for neutrons, muons and solar neutrinos in the DAMA annual modulation results

R. Bernabei[a,b], P. Belli[b], F. Cappella[c], V. Caracciolo[c], R. Cerulli[c], C.J. Dai[d], A. d'Angelo[e,f], S. d'Angelo[a,b], A. Di Marco[a,b], H.L. He[d], A. Incicchitti[e,f], H.H. Kuang[d], X.H. Ma[d], F. Montecchia[b,g], X.D. Sheng[d], R.G. Wang[d] and Z.P. Ye[d,h]

Abstract

This paper summarizes in a simple and intuitive way why the neutrons, the muons and the solar neutrinos cannot give any significant contribution to the DAMA annual modulation results. A number of these elements have already been presented in individual papers; they are recalled here. Afterwards, few simple considerations are summarized which already demonstrate the incorrectness of the claim reported in PRL 113 (2014) 081302.

Can dark matter - electron scattering explain the DAMA annual modulation signal?



R. Foot[1]

ARC Centre of Excellence for Particle Physics at the Terascale,
School of Physics, University of Melbourne,
Victoria 3010 Australia

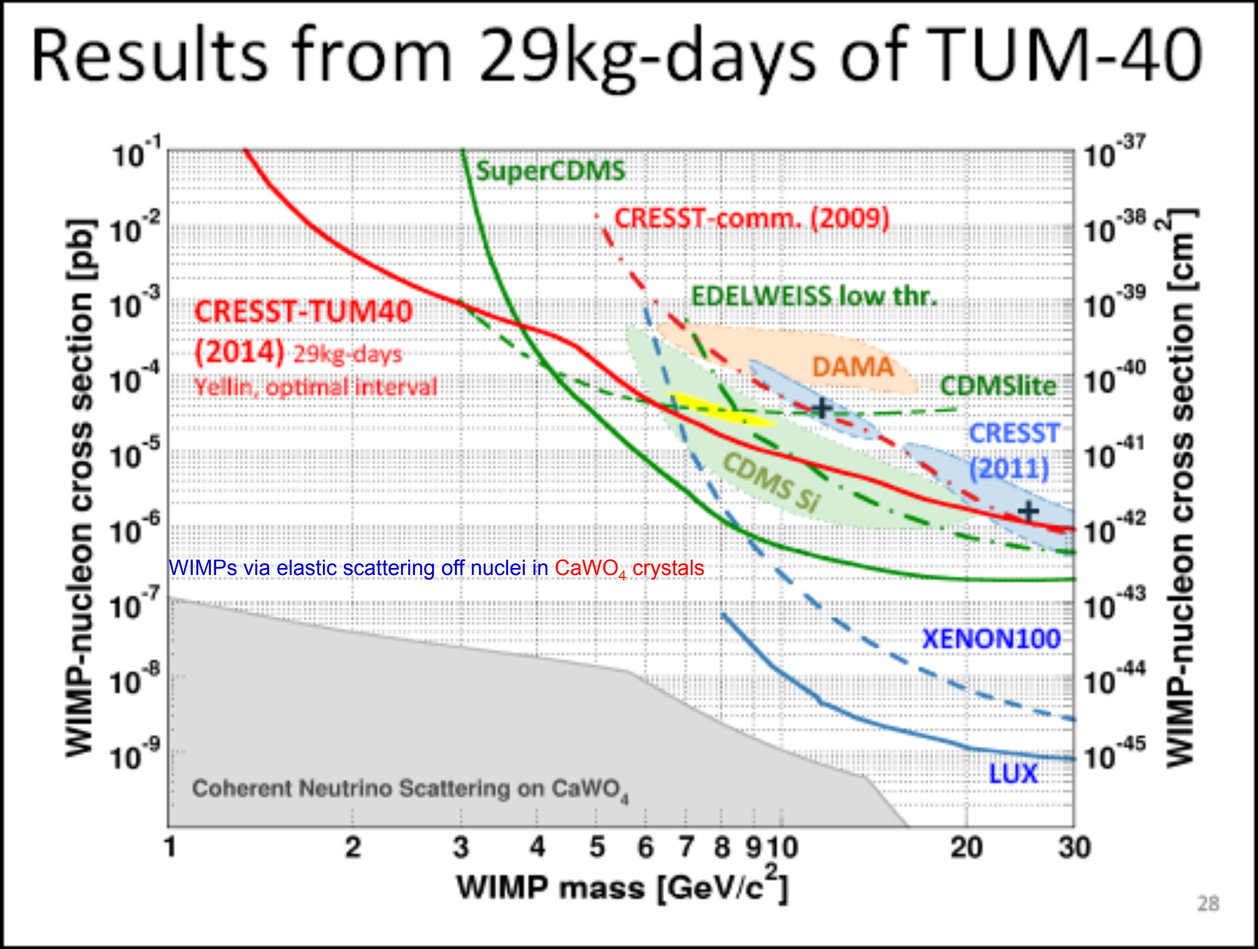
The annually modulating ~ keV scintillations observed in the DAMA/NaI and DAMA/Libra experiments might be due to dark matter - electron scattering. Such an explanation is now favoured given the stringent constraints on nuclear recoil rates obtained by LUX, SuperCDMS and other experiments. We suggest that multi-component dark matter models featuring light dark matter particles of mass ~ MeV can potentially explain the data. A specific example, kinetically mixed mirror dark matter, is shown to have the right broad properties to consistently explain the experiments via dark matter - electron scattering. If this is the explanation of the annual modulation signal found in the DAMA experiments then a sidereal diurnal modulation signal is also anticipated. We point out that the data from the DAMA experiments show a diurnal variation at around 2.3σ C.L. with phase consistent with that expected. This electron scattering interpretation of the DAMA experiments can potentially be probed in large xenon experiments (LUX, XENON1T,...), as well as in low threshold experiments (CoGeNT, CDEX, C4, ...) by searching for annually and diurnally modulated electron recoils.

arXiv:1407.4213v2 [hep-ph] 25 Aug 2014

News from CRESST

Results from the CRESST-II upgrade

Strauss at IDM2014



CRESST low-mass WIMP solution completely ruled out by new CRESST

Signals of CRESST II will be forget as earlier CDMS signals ！

1407.3146 [astro-ph.CO]; July 11

Results on low mass WIMPs using an upgraded CRESST-II detector

G. Angloher,[1] A. Bento,[2] C. Bucci,[3] L. Canonica,[3] A. Erb,[4,5] F. v. Feilitzsch,[4] N. Ferreiro Iachellini,[1] P. Gorla,[3] A. Gütlein,[6] D. Hauff,[1] P. Huff,[1] J. Jochum,[7] M. Kiefer,[1] C. Kister,[1] H. Kluck,[6] H. Kraus,[8] J.-C. Lanfranchi,[4] J. Loebell,[7] A. Münster,[4] F. Petricca,[1] W. Potzel,[4] F. Pröbst,[1,*] F. Reindl,[1,†] S. Roth,[4] K. Rottler,[7] C. Sailer,[7] K. Schäffner,[3] J. Schieck,[6] J. Schmaler,[1] S. Scholl,[7] S. Schönert,[4] W. Seidel,[1] M. v. Sivers,[4] L. Stodolsky,[1] C. Strandhagen,[7,‡] R. Strauss,[1] A. Tanzke,[1] M. Uffinger,[7] A. Ulrich,[4] I. Usherov,[7] M. Wüstrich,[1] S. Wawoczny,[4] M. Willers,[4] and A. Zöller[4]

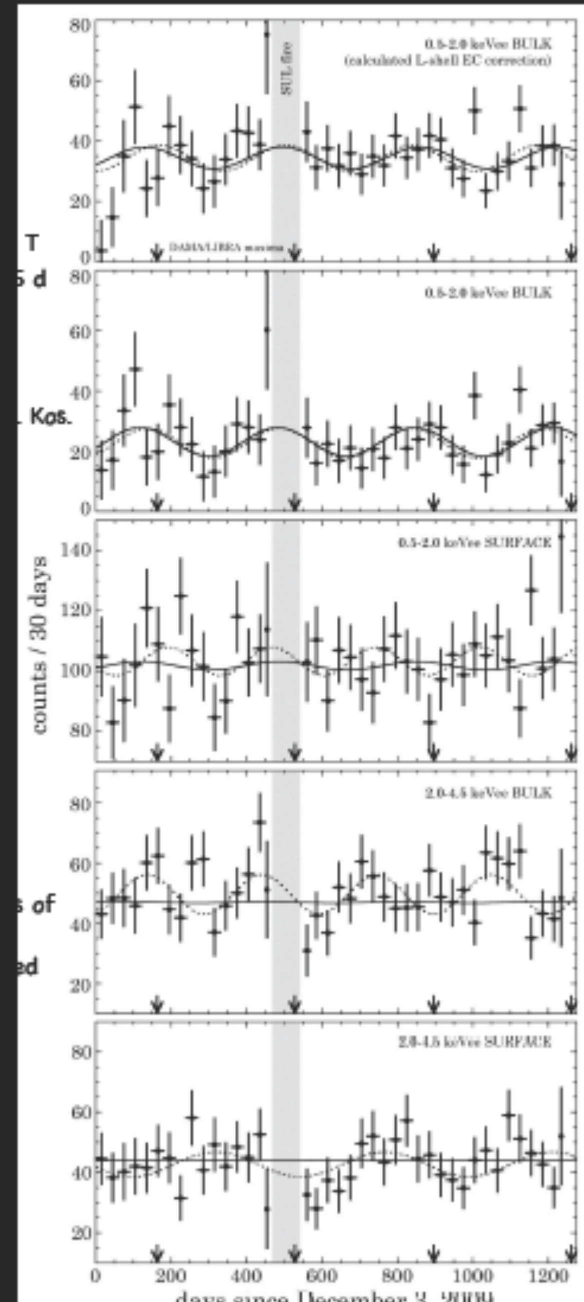
[1]*Max-Planck-Institut für Physik, D-80805 München, Germany*
[2]*Departamento de Fisica, Universidade de Coimbra, P3004 516 Coimbra, Portugal*
[3]*INFN, Laboratori Nazionali del Gran Sasso, I-67010 Assergi, Italy*
[4]*Physik-Department, Technische Universität München, D-85747 Garching, Germany*
[5]*Walther-Meißner-Institut für Tieftemperaturforschung, D-85748 Garching, Germany*
[6]*Institut für Hochenergiephysik der Österreichischen Akademie der Wissenschaften, A-1050 Wien, Austria and Atominstitut, Vienna University of Technology, A-1020 Wien, Austria*
[7]*Eberhard-Karls-Universität Tübingen, D-72076 Tübingen, Germany*
[8]*Department of Physics, University of Oxford, Oxford OX1 3RH, United Kingdom*

The CRESST-II cryogenic dark matter search aims for the detection of WIMPs via elastic scattering off nuclei in $CaWO_4$ crystals. We present results from a low-threshold analysis of a single upgraded detector module. This module efficiently vetoes low energy backgrounds induced by α-decays on inner surfaces of the detector. With an exposure of 29.35 kg live days collected in 2013 we set a limit on spin-independent WIMP-nucleon scattering which probes a new region of parameter space for WIMP masses below $3\,\mathrm{GeV}/c^2$, previously not covered in direct detection searches. A possible excess over background discussed for the previous run (from 2009 to 2011) is not confirmed.

CoGeNT made their data public

Annual modulation in 3.4 yr of CoGeNT

- Annual modulation exclusively at low energy and for bulk events.
- Best-fit phase consistent with DAMA/LIBRA
- Unoptimized frequentist analysis yields ~2.2σ preference over null hypothesis
- Modulation amplitude is 4-7 times larger than in the standard halo model



Collar (CoGeNT) at TAUP 2013

CoGeNT made their data public

CoGeNT decided to publish energy and time of their events

Independent groups reanalyzed the CoGeNT data

Pulse-shape discrimination of surface/bulk events

No significant modulation found

The CoGeNT region of interest results from a biased analysis, and has no statistical meaning.

Davis, McCabe, Boehm 1405.0495

The likelihood gets worse when including a WIMP component either as a standard halo or Sagittarius like stream

Bellis, Collar, Field, Kelso at IDM2014

CoGeNT made their data public

CoGeNT decided to publish energy and time of their events

Maximum Likelihood Signal Extraction Method Applied to 3.4 years of CoGeNT Data

C.E. Aalseth,[1] P.S. Barbeau,[2,*] J. Colaresi,[3] J.I. Collar,[2] J. Diaz Leon,[4] J.E. Fast,[1] N.E. Fields,[2] T.W. Hossbach,[1] A. Knecht,[4,†] M.S. Kos,[1,‡] M.G. Marino,[4,§] H.S. Miley,[1] M.L. Miller,[4,¶] J.L. Orrell,[1] and K.M. Yocum[3]
(CoGeNT Collaboration)

arXiv:1401.6234v1 24 Jan 2014

Maximum Likelihood Signal Extraction Method Applied to 3.4 years of CoGeNT Data

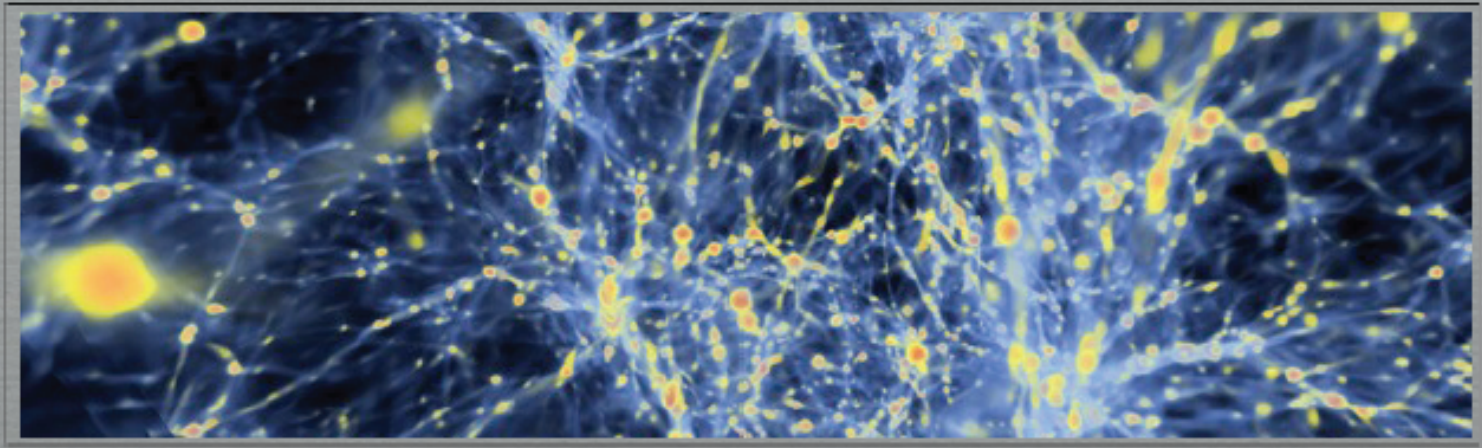
C.E. Aalseth,[1] P.S. Barbeau,[2,*] J. Colaresi,[3] J. Diaz Leon,[4] J.E. Fast,[1] T.W. Hossbach,[1] A. Knecht,[4,†] M.S. Kos,[1,‡] M.G. Marino,[4,§] H.S. Miley,[1] M.L. Miller,[4,¶] J.L. Orrell,[1] and K.M. Yocum[3]

arXiv:1401.6234v2 27 Jan 2014

The likelihood gets worse when including a WIMP component either as a standard halo or Sagittarius like stream

Bellis, Collar, Field, Kelso at IDM2014

CoGeNT leader



A CoGeNT Analysis

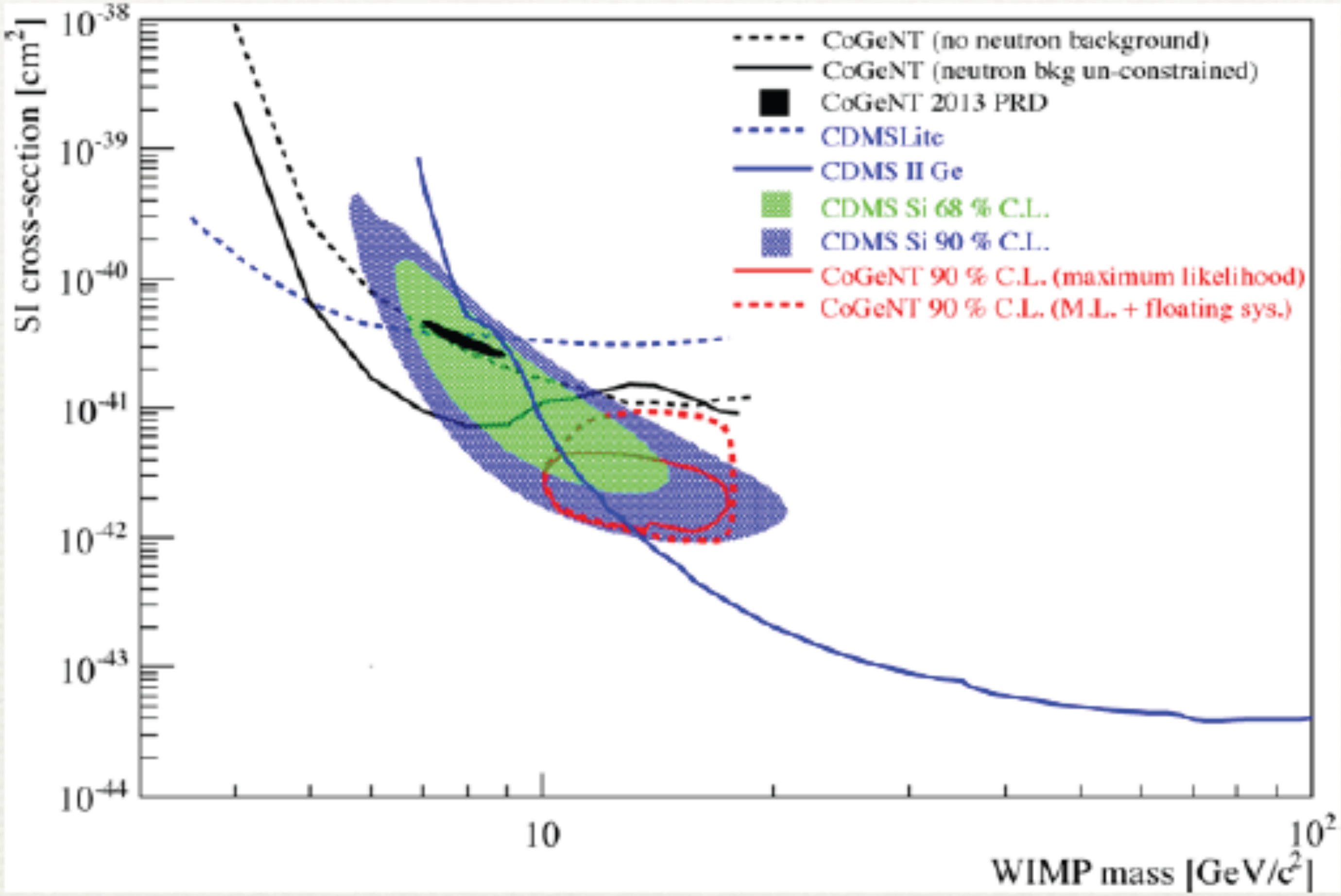
Jonathan Davis
(IPPP, Durham University)
in collaboration with Celine Boehm and Christopher McCabe

28th March 2014
Moriond Cosmology

Contact: j.h.davis@durham.ac.uk

Comparison of Results II

CoGeNT seem to disagree with themselves.

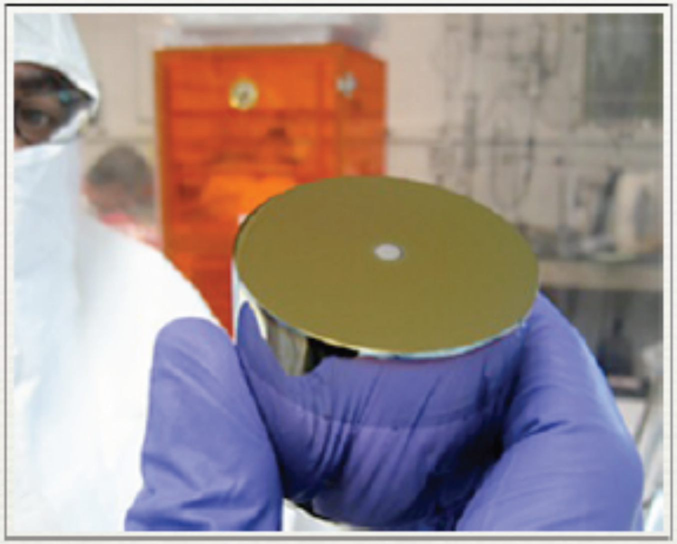


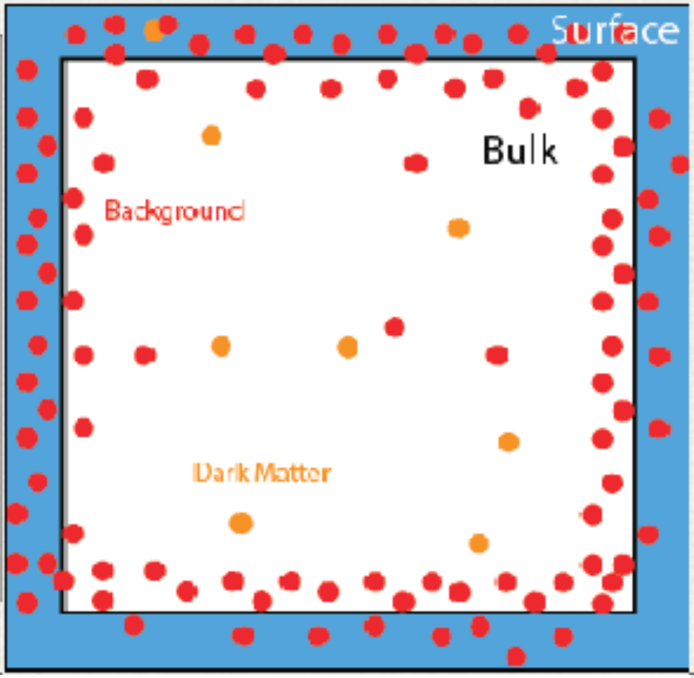
Aalseth et al., arXiv:1401.6234

backup slide

Conclusion

- CoGeNT is an experiment looking for Dark Matter nuclear recoils.
- The large surface event background rises at low energy, like a light DM recoil signal.
- Uncertainties in this background make a statistically-significant claim of DM detection difficult.
- **The CoGeNT region of interest results from a biased analysis, and has no statistical meaning.**





Thank You

清華大學
Tsinghua University

1405.0495 [hep-ph]; May 2

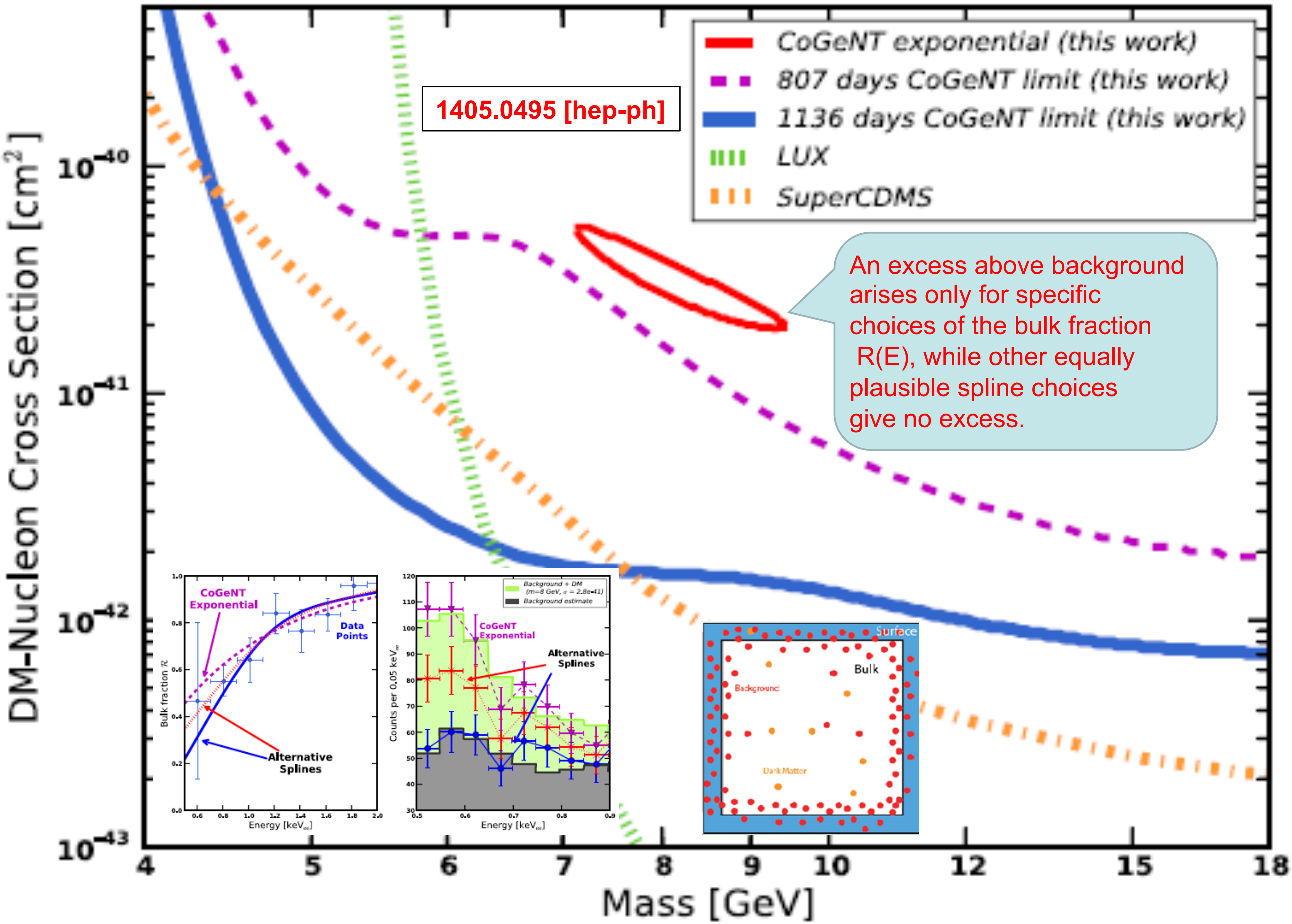
Quantifying the evidence for Dark Matter in CoGeNT data

Jonathan H. Davis,[1] Christopher McCabe,[1] and Céline Bœhm[1,2]

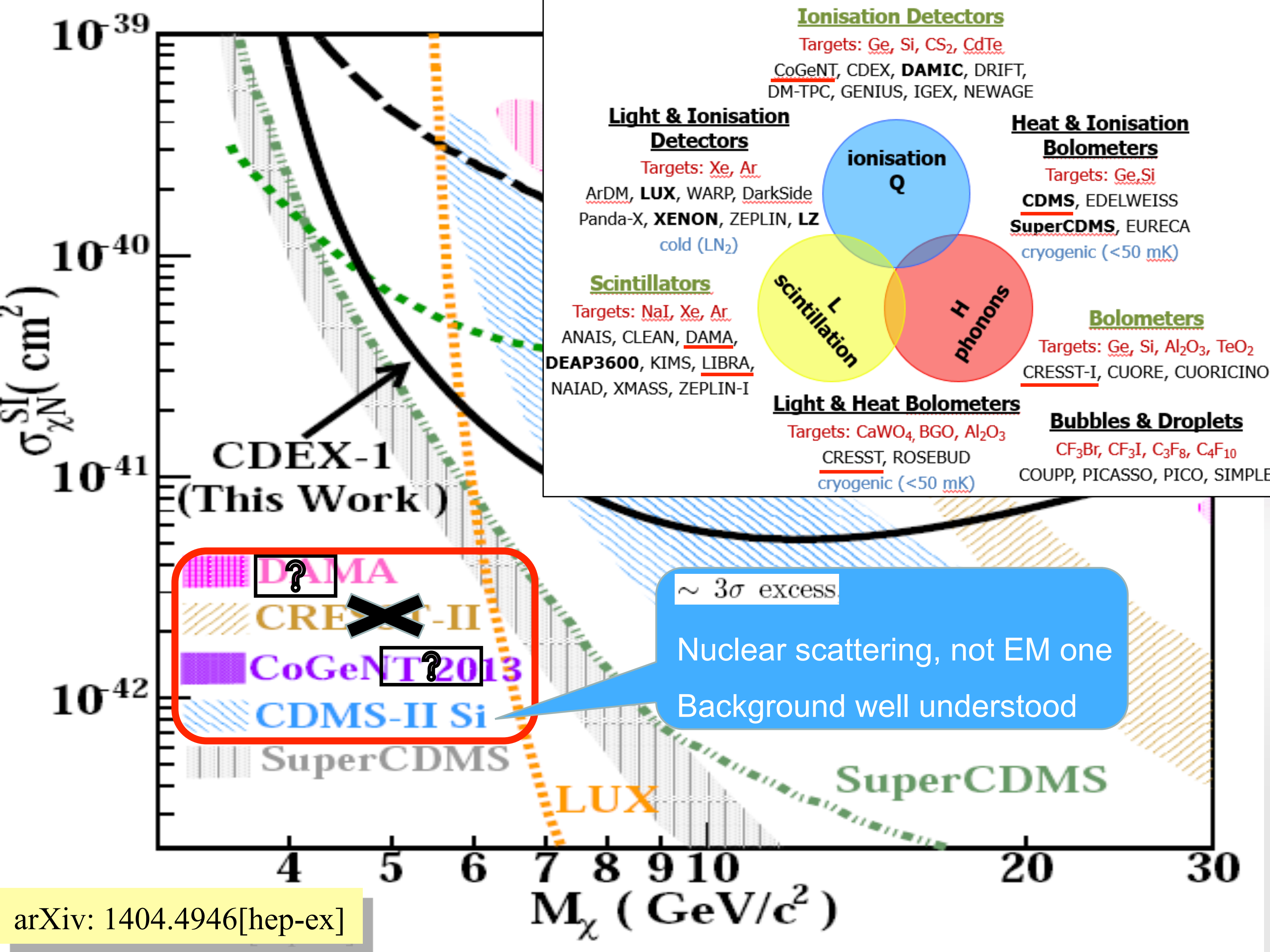
[1]*Institute for Particle Physics Phenomenology, Durham University, South Road, Durham, DH1 3LE, United Kingdom*
[2]*LAPTH, U. de Savoie, CNRS, BP 110, 74941 Annecy-Le-Vieux, France*

j.h.davis@durham.ac.uk, christopher.mccabe@durham.ac.uk, c.m.boehm@durham.ac.uk

We perform an independent analysis of data from the CoGeNT direct detection experiment to quantify the evidence for dark matter recoils. We critically re-examine the assumptions that enter the analysis, focusing specifically on the separation of bulk and surface events, the latter of which constitute a large background. This separation is performed using the event rise-time, with the surface events being slower on average. We fit the rise-time distributions for the bulk and surface events with a log-normal and Pareto distribution (which gives a better fit to the tail in the bulk population at high rise-times) and account for the energy-dependence of the bulk fraction using a cubic spline. Using Bayesian and frequentist techniques and additionally investigating the effect of varying the rise-time cut, the bulk background spectrum and bin-sizes. We conclude that the CoGeNT data show a preference for light dark matter recoils at less than 1σ.

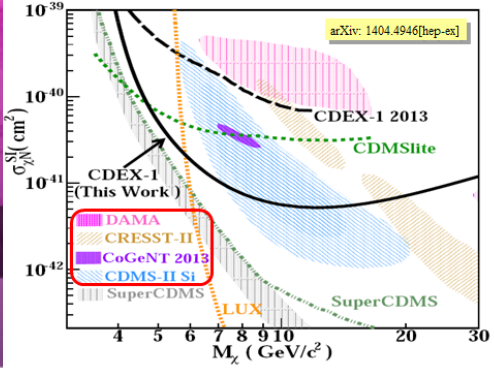


CoGeNT exponential (this work)
807 days CoGeNT limit (this work)
1136 days CoGeNT limit (this work)
LUX
SuperCDMS
1405.0495 [hep-ph]
An excess above background arises only for specific choices of the bulk fraction R(E), while other equally plausible spline choices give no excess.
DM-Nucleon Cross Section [cm^2]
Mass [GeV]
10^{-40}
10^{-41}
10^{-42}
10^{-43}
4
5
6
7
8
9
10
12
15
18
CoGeNT Exponential
Data Points
Alternative Splines
Bulk fraction $\mathcal{R}$
Energy [keV$_{ee}$]
Background + DM
Background estimate
Counts per 0.05 keV$_{ee}$
Surface
Bulk
Background
Dark Matter



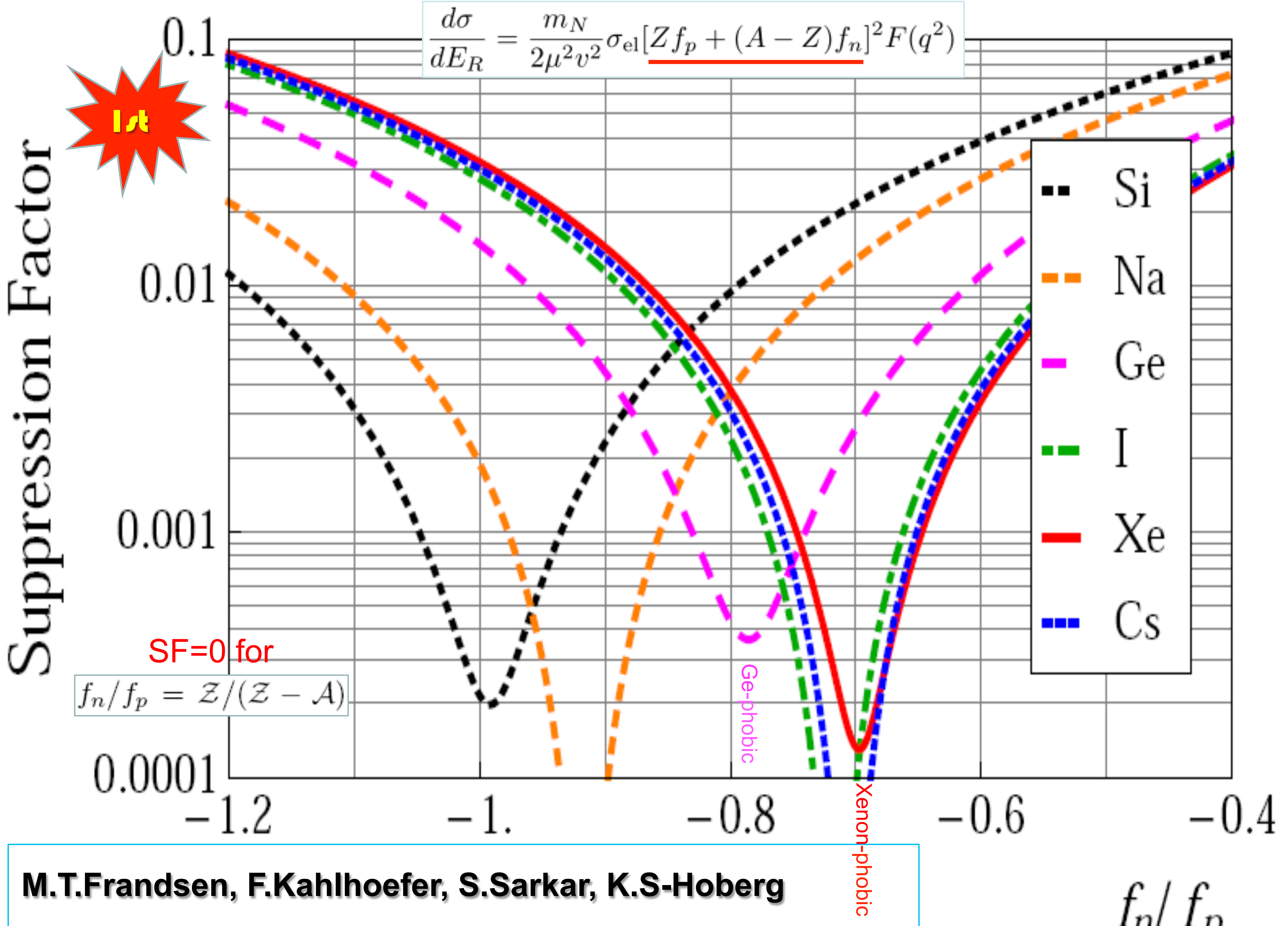
Ionisation Detectors
Targets: Ge, Si, CS_2, CdTe
CoGeNT, CDEX, DAMIC, DRIFT, DM-TPC, GENIUS, IGEX, NEWAGE
Light & Ionisation Detectors
Targets: Xe, Ar
ArDM, LUX, WARP, DarkSide
Panda-X, XENON, ZEPLIN, LZ
cold (LN_2)
Heat & Ionisation Bolometers
Targets: Ge,Si
CDMS, EDELWEISS
SuperCDMS, EURECA
cryogenic (<50 mK)
ionisation Q
L scintillation
H phonons
Scintillators
Targets: NaI, Xe, Ar
ANAIS, CLEAN, DAMA, DEAP3600, KIMS, LIBRA, NAIAD, XMASS, ZEPLIN-I
Bolometers
Targets: Ge, Si, Al_2O_3, TeO_2
CRESST-I, CUORE, CUORICINO
Light & Heat Bolometers
Targets: $CaWO_4$, BGO, Al_2O_3
CRESST, ROSEBUD
cryogenic (<50 mK)
Bubbles & Droplets
CF_3Br, CF_3I, C_3F_8, C_4F_{10}
COUPP, PICASSO, PICO, SIMPLE
CDEX-1 (This Work)
DAMA ?
CRE T-II
CoGeNT 2013 ?
CDMS-II Si
SuperCDMS
LUX
SuperCDMS
$\sim 3\sigma$ excess
Nuclear scattering, not EM one
Background well understood
10^{-39}
10^{-40}
10^{-41}
10^{-42}
$\sigma_{\chi N}^{SI}(cm^2)$
4 5 6 7 8 9 10 20 30
M_χ (GeV/c^2)
arXiv: 1404.4946[hep-ex]

清華大學
Tsinghua University



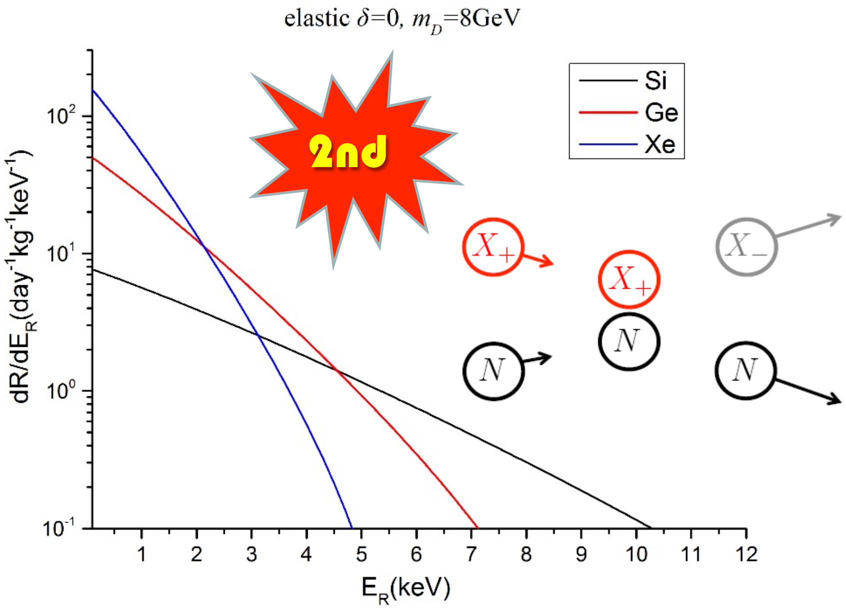
Outline

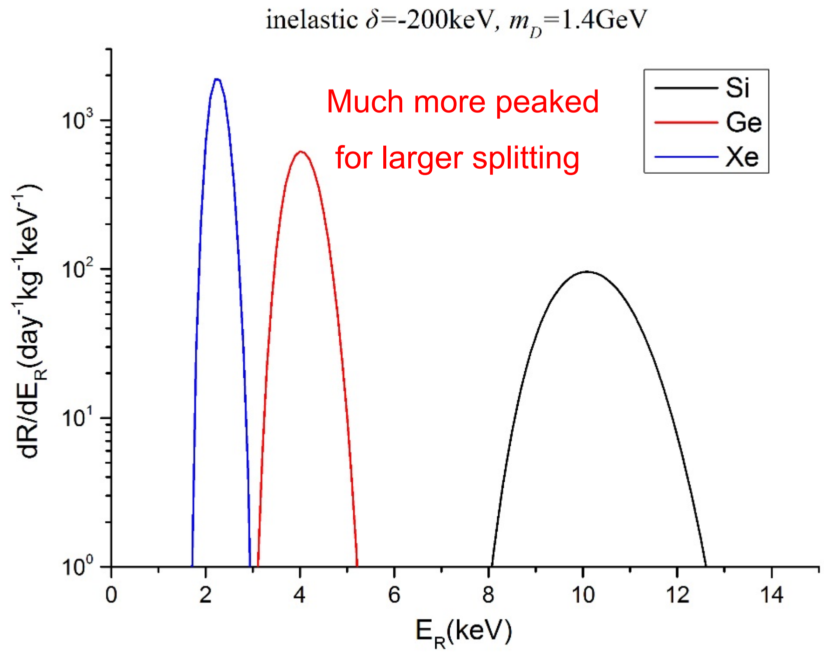
- Motivation & Status
- Three old Exps: DAMA；CRESST；CoGeNT
- Reconcilation Methods ✓
- Latest Result
- Theoretical Models

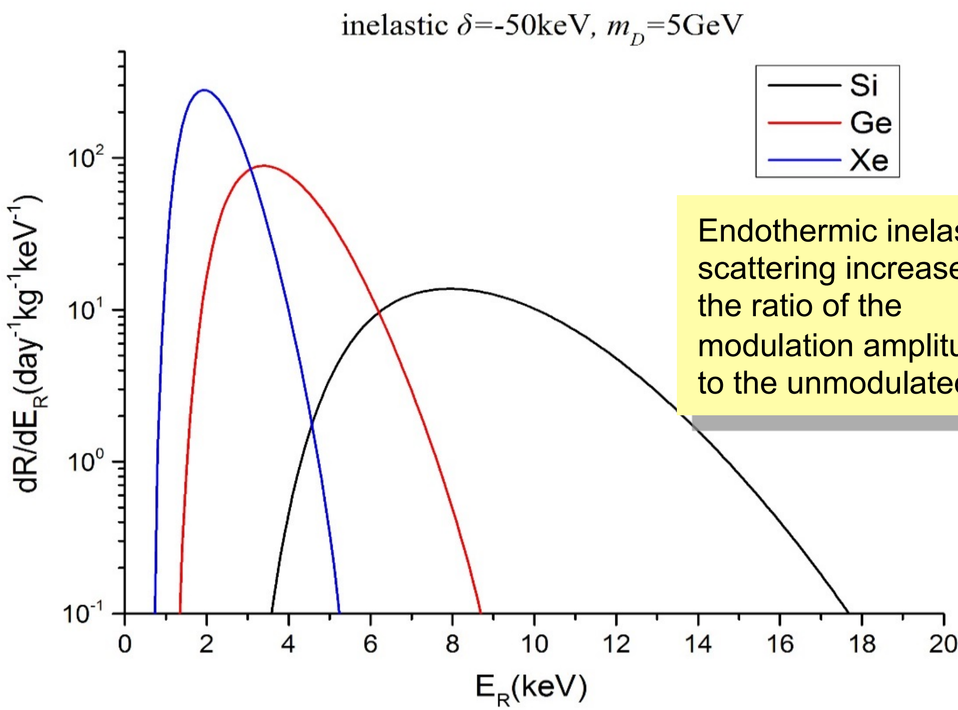


M.T.Frandsen, F.Kahlhoefer, S.Sarkar, K.S-Hoberg

JHEP 1109, 128 (2011)







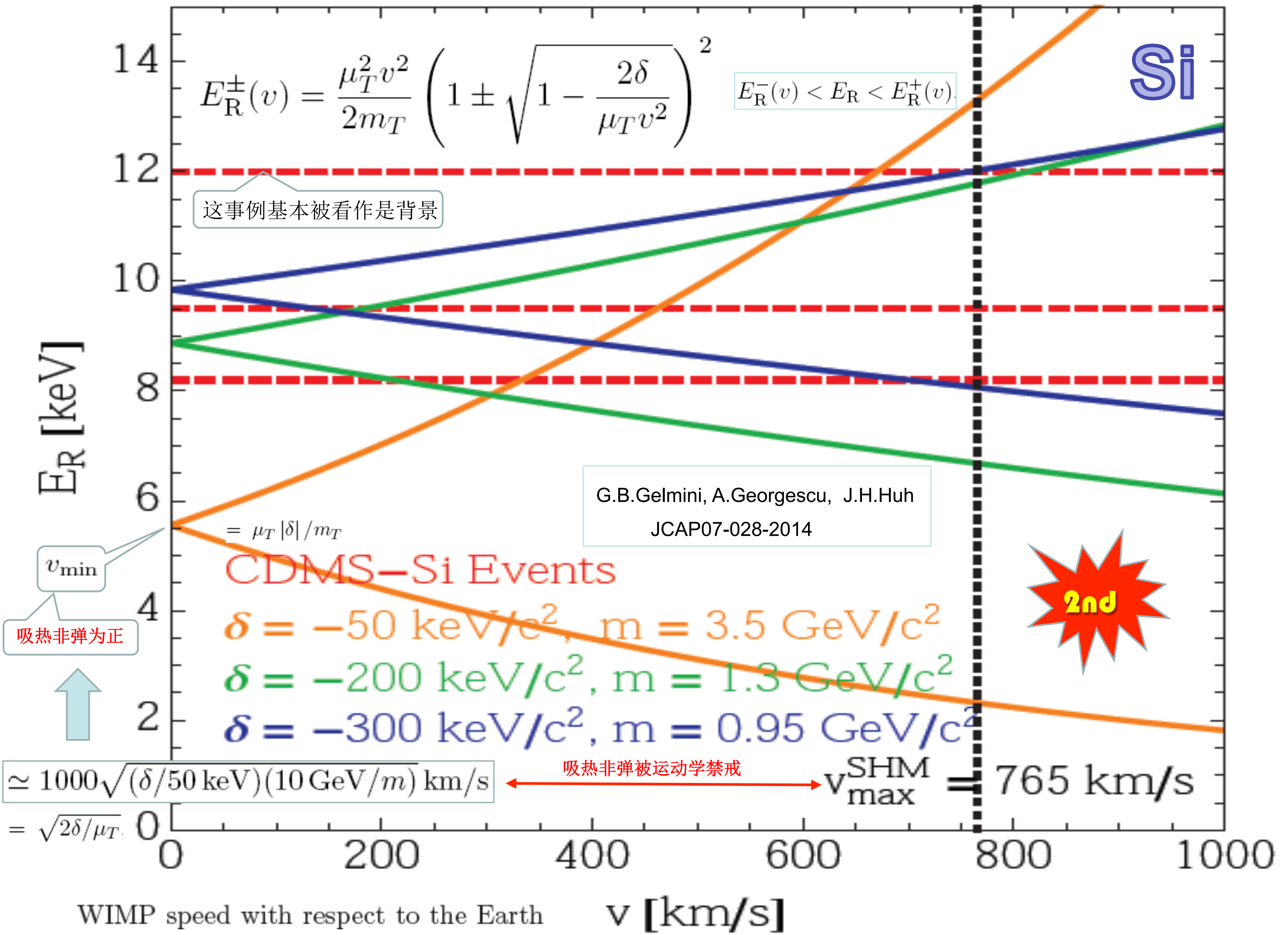
Endothermic inelastic scattering increases the ratio of the modulation amplitude to the unmodulated rate

- ES is exponential spectrum
- IS limit in special region
- Larger δ, more separation

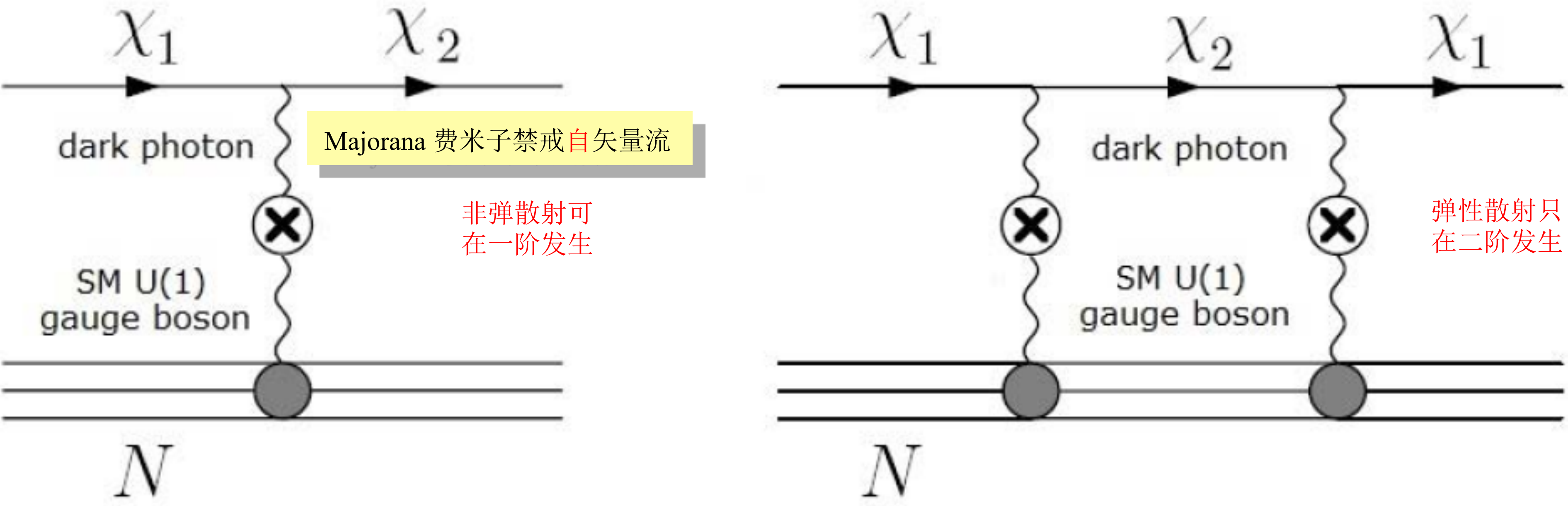
Endothermic prefer heavy nucleon

Exothermic prefer light nucleon

But reduce relative modulation amplitude



$E_R^{\pm}(v) = \frac{\mu_T^2 v^2}{2m_T}\left(1 \pm \sqrt{1 - \frac{2\delta}{\mu_T v^2}}\right)^2$
$E_R^-(v) < E_R < E_R^+(v)$
Si
这事例基本被看作是背景
G.B.Gelmini, A.Georgescu, J.H.Huh
JCAP07-028-2014
$= \mu_T |\delta| / m_T$
v_{min}
吸热非弹为正
CDMS−Si Events
$\delta = -50$ keV/c², m = 3.5 GeV/c²
$\delta = -200$ keV/c², m = 1.3 GeV/c²
$\delta = -300$ keV/c², m = 0.95 GeV/c²
2nd
$\simeq 1000\sqrt{(\delta/50\,\mathrm{keV})(10\,\mathrm{GeV}/m)}$ km/s
$= \sqrt{2\delta/\mu_T}$
吸热非弹被运动学禁戒
$v_{max}^{SHM} = 765$ km/s
E_R [keV]
WIMP speed with respect to the Earth
v [km/s]



Majorana 费米子禁戒自矢量流

非弹散射可在一阶发生

弹性散射只在二阶发生

$$\kappa V_\nu \partial_\mu F_{\mu\nu}$$

Brian Batell, Maxim Pospelov Adam Ritz

Phys.Rev. D79 (2009) 115019

散射被压低 { 弹性 / 吸热散射被

非弹散射禁戒

动能<质量差

只剩下放热散射

$$\chi_2 \to \chi_1 \nu\bar{\nu} \qquad \Gamma_\nu \simeq 3\times 10^{-53}\ \text{GeV} \times \frac{\alpha'}{\alpha}\left(\frac{\kappa}{10^{-3}}\right)^2 \left(\frac{\Delta m}{100\ \text{keV}}\right)^9 \left(\frac{100\ \text{MeV}}{m_V}\right)^4$$

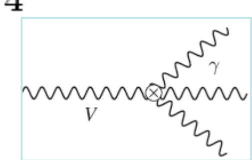
mediated by $V-Z$ mixing.

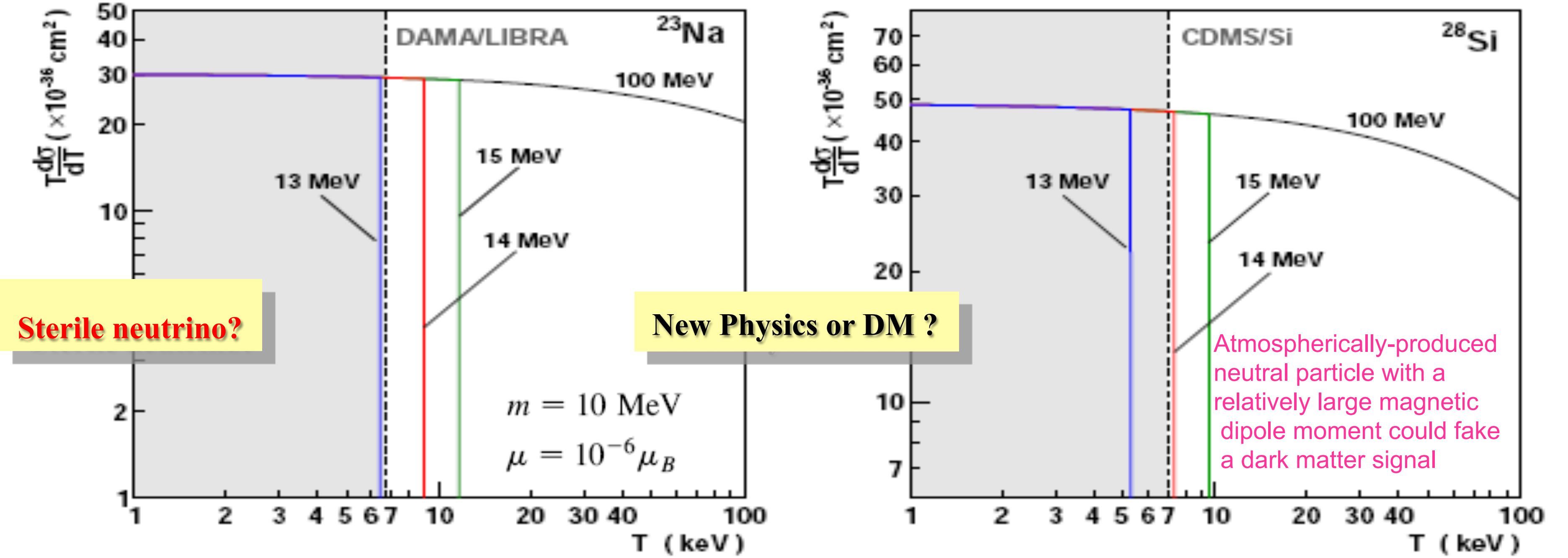
inverse age of the Universe $\quad \tau_U^{-1} \simeq 1.5\times 10^{-42}\ \text{GeV}$

2nd

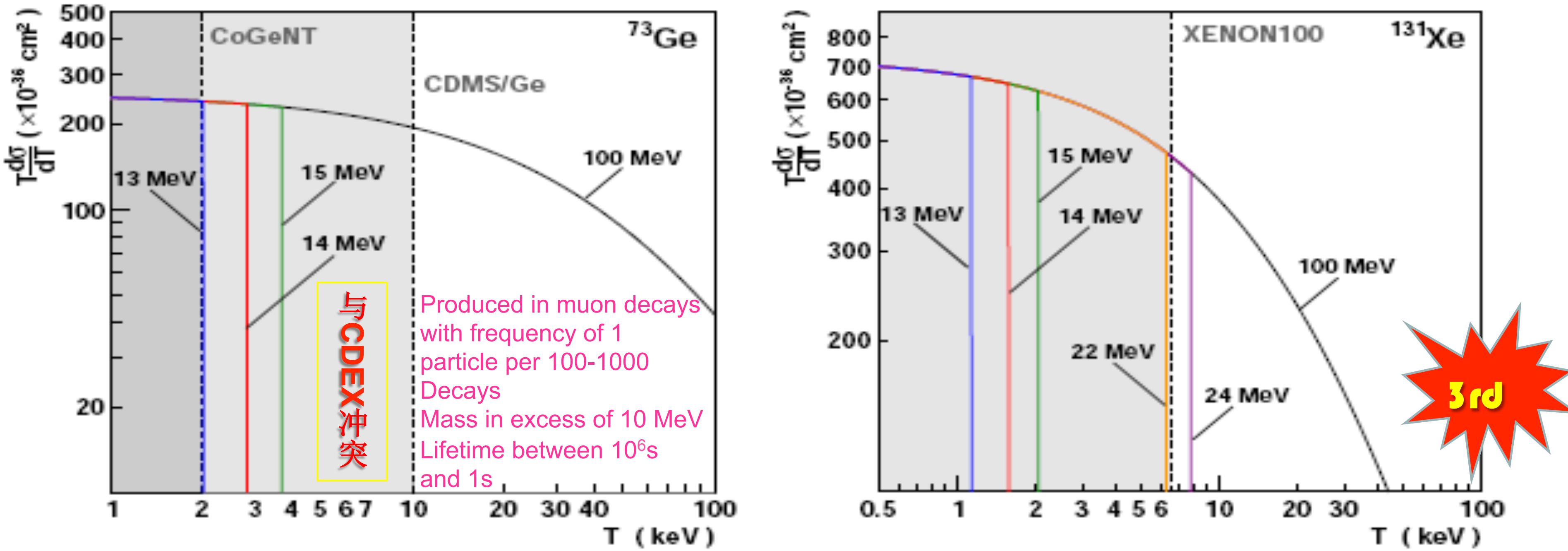
$$\Gamma_{\chi_2\to\chi_1+3\gamma} \lesssim 4\times 10^{-47}\ \text{GeV} \times \left(\frac{\kappa}{10^{-3}}\right)^2 \left(\frac{\Delta m}{100\ \text{keV}}\right)^{13} \left(\frac{100\ \text{MeV}}{m_V}\right)^4$$

mediated by the virtual production of an e^+e^- pair.





A. Bueno, M. Masip, P. Sánchez-Lucas, N. Setzer **Phys.Rev. D88 (2013) 073010**

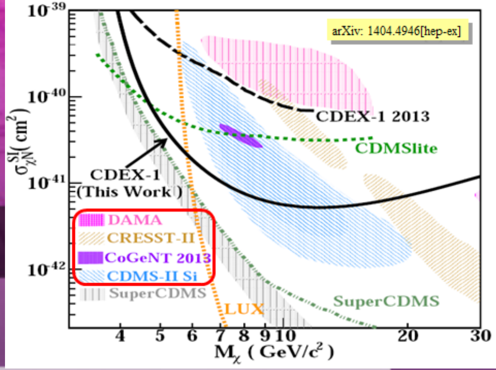


Other Possible effects

- channeling effect
- quenching factor
- velocity distribution；astrophysics
- form factors：nuclear；particle
- ……

清華大學
Tsinghua University

Outline



- Motivation & Status
- Three old Exps: DAMA；CRESST；CoGeNT
- Reconciliation Methods
- Latest Result ✓
- Theoretical Models

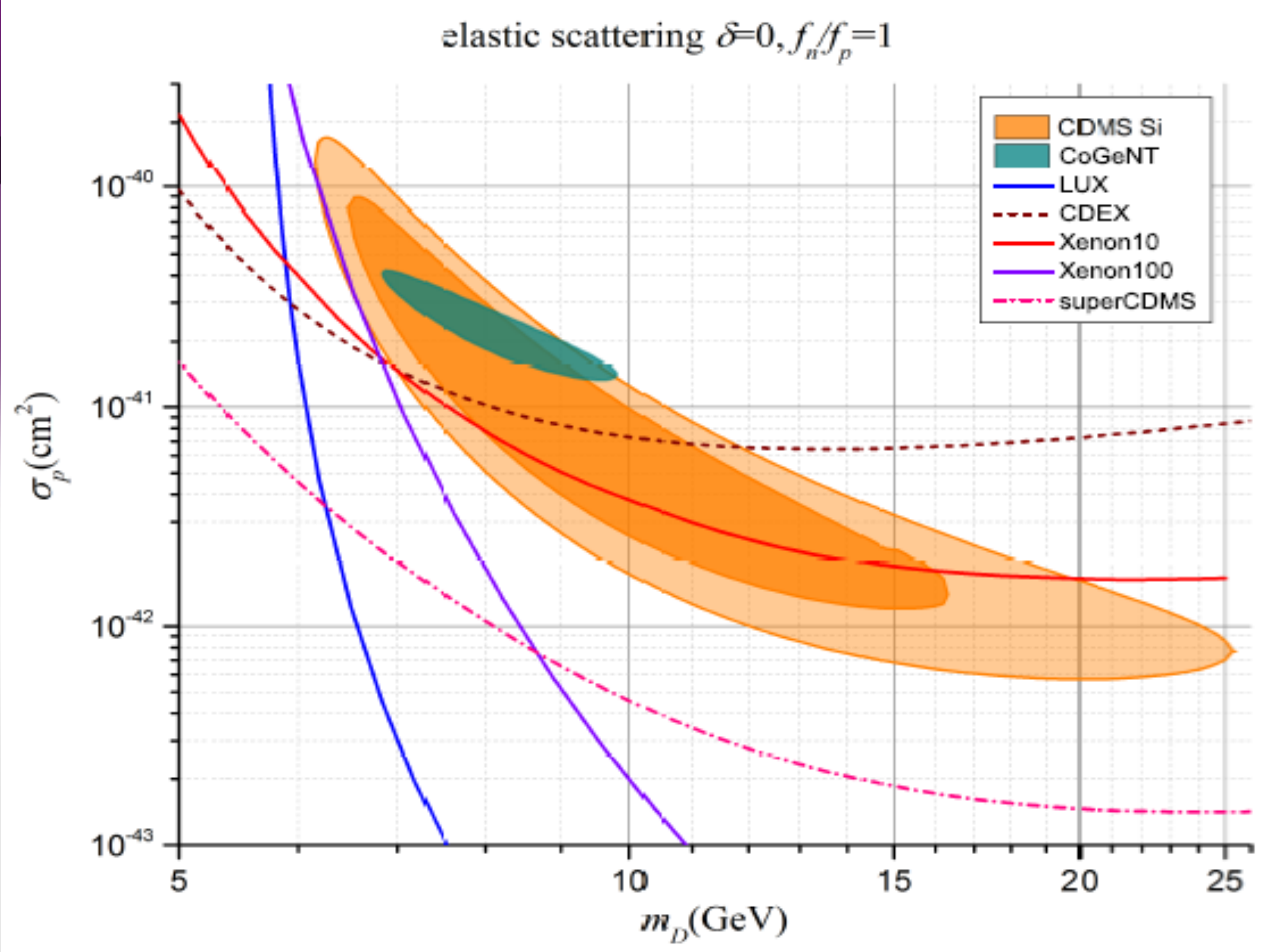
arXiv: 1404.6043

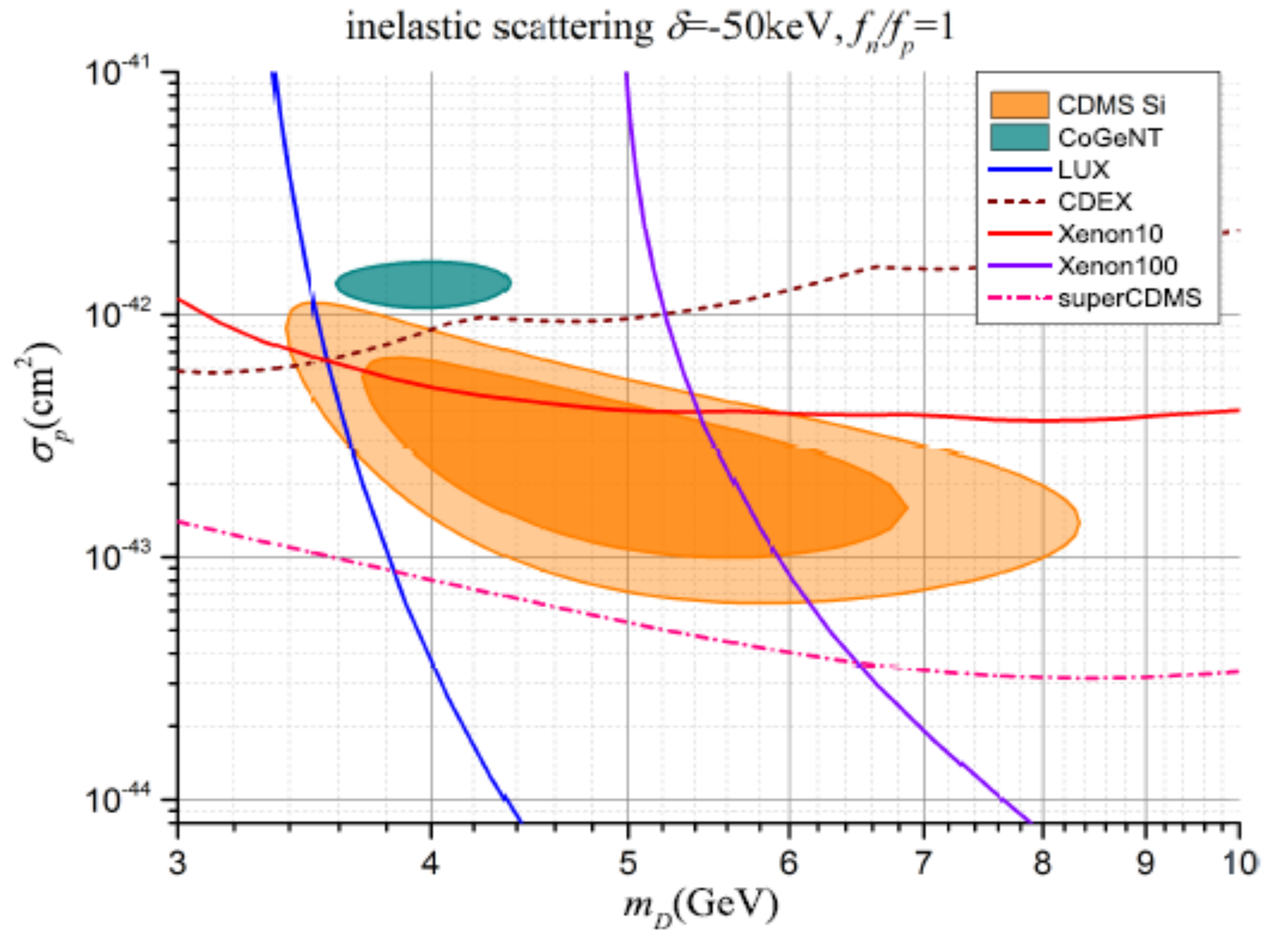
no new particle **Our Result** in combined with CDEX Data

Exothermic isospin-violating dark matter after SuperCDMS and CDEX

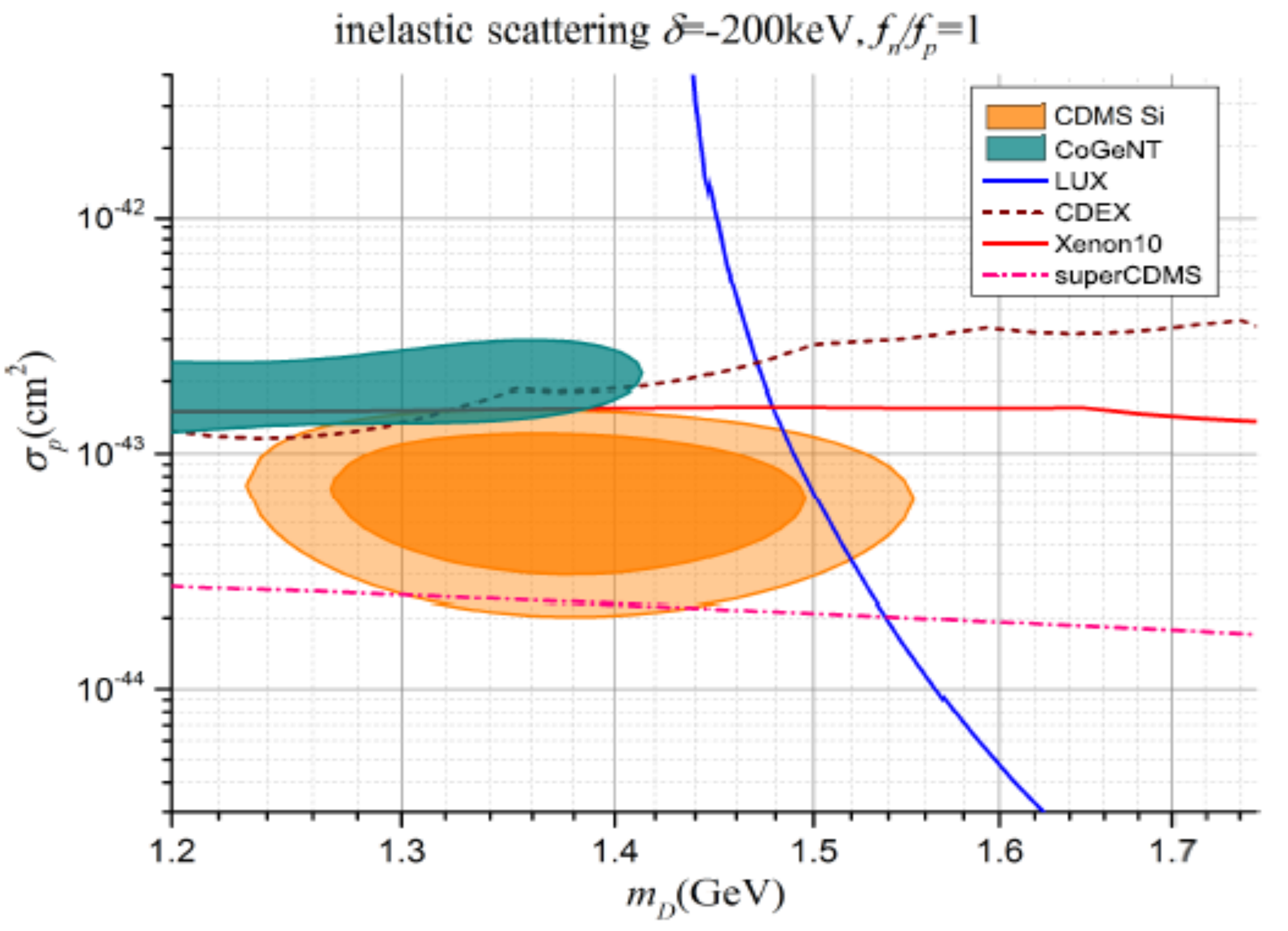
Nan Chen[1]* and Qing Wang[1,2,3]†
[1] *Department of Physics, Tsinghua University, Beijing 100084, P. R. China*
[2] *Center for High Energy Physics, Tsinghua University, Beijing 100084, P. R. China*
[3] *Collaborative Innovation Center of Quantum Matter, Beijing 100084, P. R. China*

Wei Zhao[4], Shin-Ted Lin [5], Qian Yue[4], and Jin Li[4]
[4] *Key Laboratory of Particle and Radiation Imaging (Ministry of Education) and Department of Engineering Physics, Tsinghua University, Beijing 100084, P. R. China*
[5] *College of Physical Science and Technology, Sichuan University, Chengdu 610064, P. R. China*

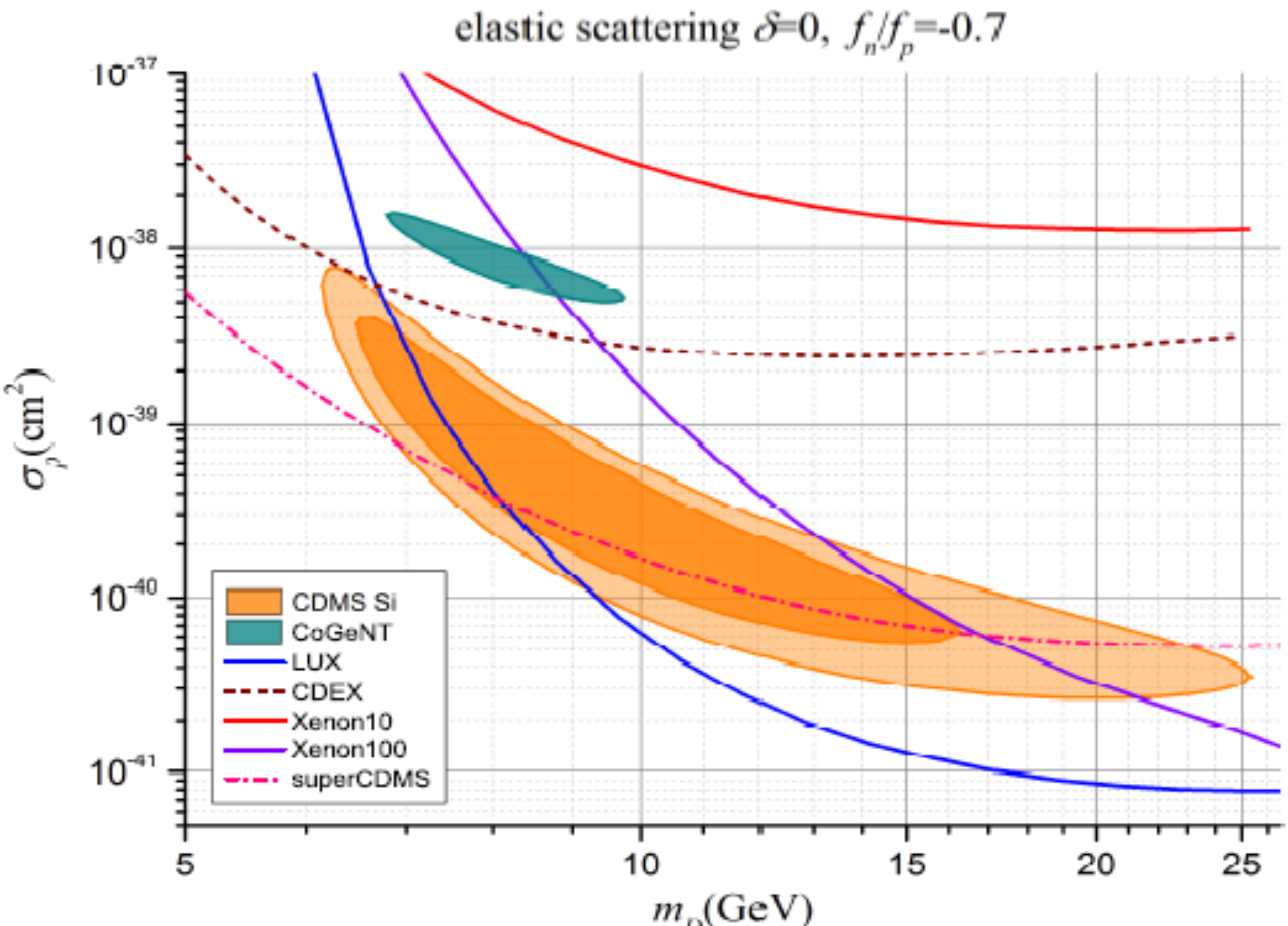

elastic scattering δ=0, f_n/f_p=1
CDMS Si
CoGeNT
LUX
CDEX
Xenon10
Xenon100
superCDMS
10^{-40}
10^{-41}
10^{-42}
10^{-43}
σ_p(cm^2)
5
10
15
20
25
m_D(GeV)



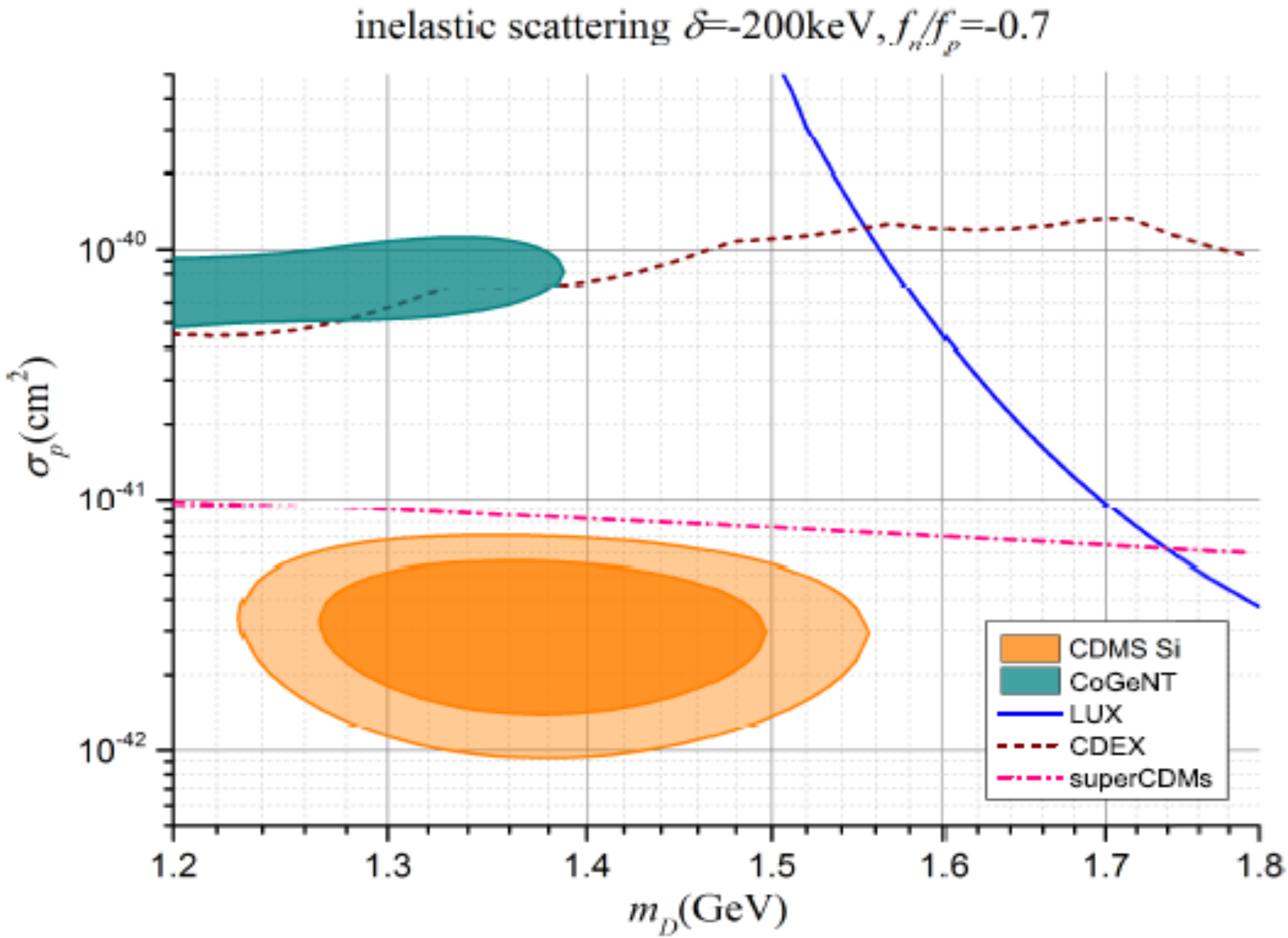
inelastic scattering δ=-50keV, f_n/f_p=1
CDMS Si
CoGeNT
LUX
CDEX
Xenon10
Xenon100
superCDMS
10^-41
10^-42
10^-43
10^-44
σ_p(cm^2)
3
4
5
6
7
8
9
10
m_D(GeV)



inelastic scattering δ=-200keV, f_n/f_p=1
CDMS Si
CoGeNT
LUX
CDEX
Xenon10
superCDMS
10^{-42}
10^{-43}
10^{-44}
σ_p(cm^2)
1.2
1.3
1.4
1.5
1.6
1.7
m_D(GeV)



elastic scattering δ=0, f_n/f_p=-0.7
10^{-37}
10^{-38}
10^{-39}
10^{-40}
10^{-41}
$\sigma_p(\mathrm{cm}^2)$
5
10
15
20
25
m_D(GeV)
CDMS Si
CoGeNT
LUX
CDEX
Xenon10
Xenon100
superCDMS



inelastic scattering δ=-200keV, f_n/f_p=-0.7
σ_p(cm^2)
10^{-40}
10^{-41}
10^{-42}
1.2
1.3
1.4
1.5
1.6
1.7
1.8
m_D(GeV)
CDMS Si
CoGeNT
LUX
CDEX
superCDMs

Journal of Cosmology and Astroparticle Physics
An IOP and SISSA journal

Dark Matter as a Trigger for Periodic Comet Impacts

Lisa Randall and Matthew Reece
Department of Physics, Harvard University, Cambridge, MA, 02138

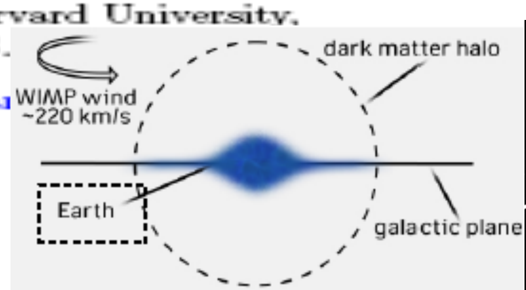
1403.0576; Mar 3

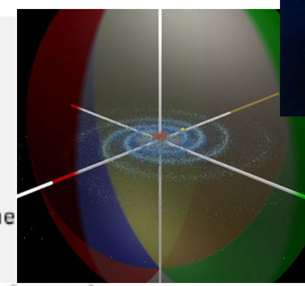
Exothermic double-disk dark matter

Matthew McCullough[a] and Lisa Randall[b]

[a]Center for Theoretical Physics, Massachusetts Institute of Technology,
Cambridge, MA, 02139 U.S.A.
[b]Department of Physics, Harvard University,
Cambridge, MA, 02138 U.S.

E-mail: mccull@mit.edu, ra





Last year…

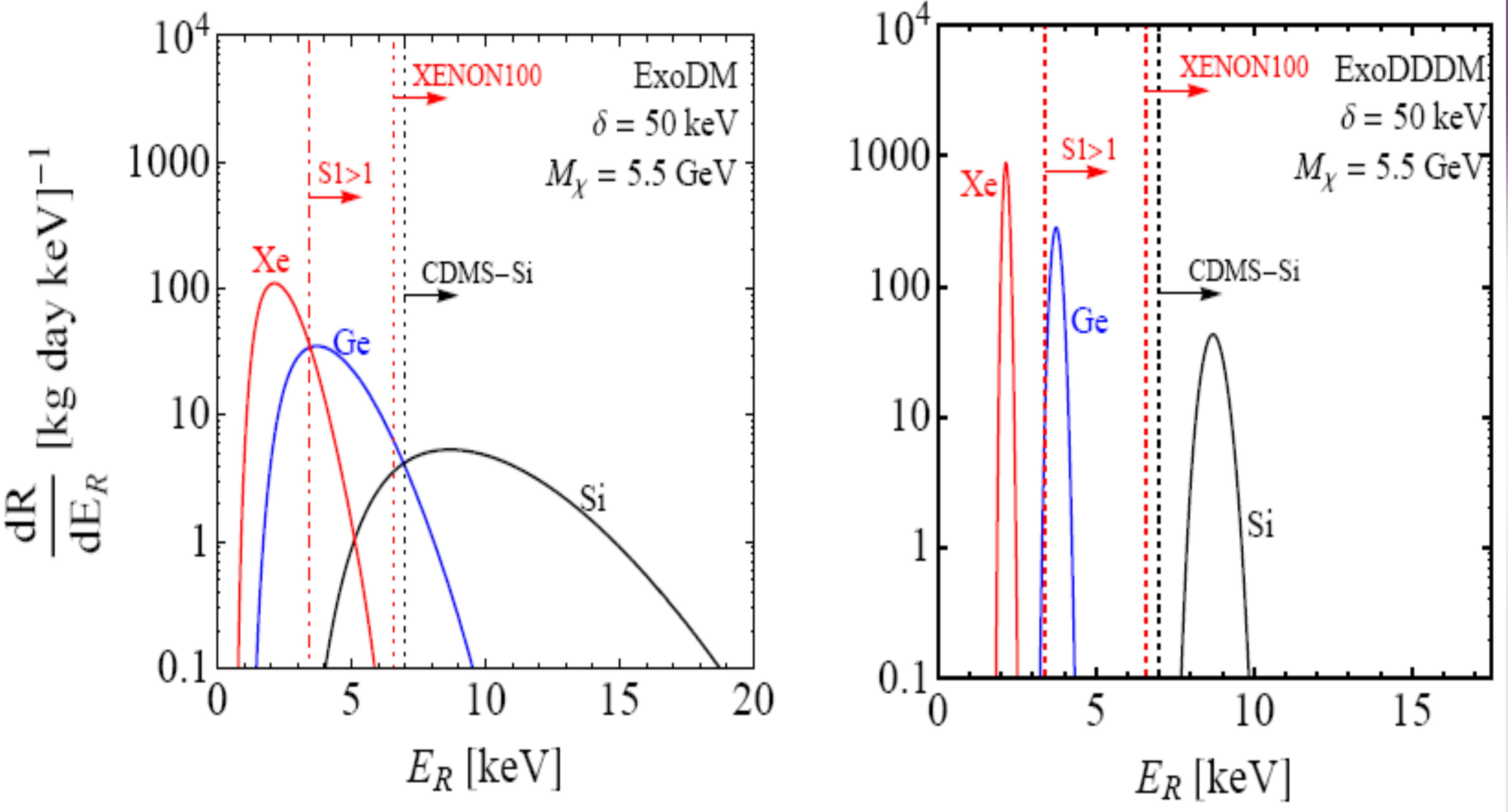
Received July 30, 2013
Accepted October 10, 2013
Published October 29, 2013

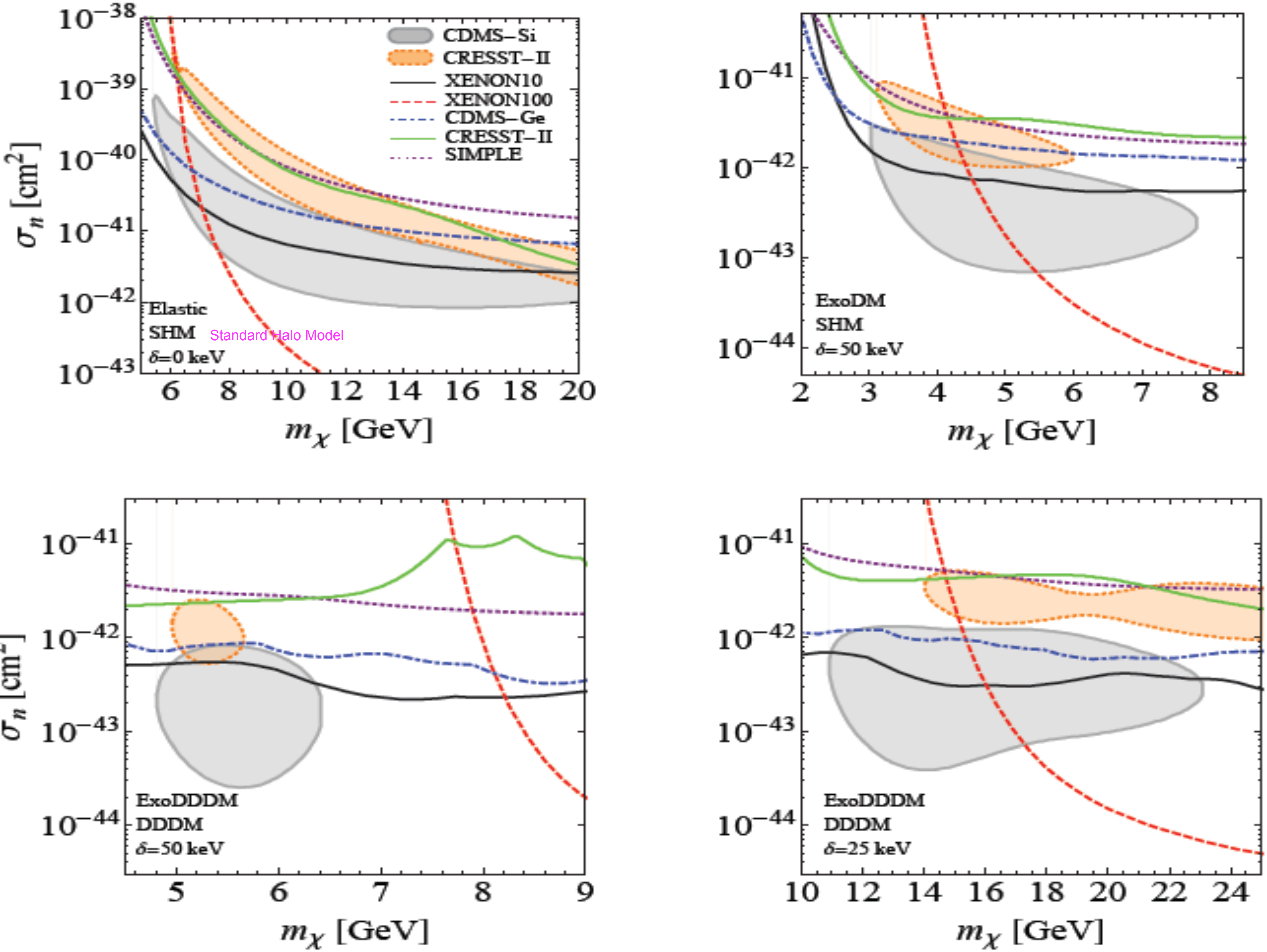
Abstract. If a subdominant component of dark matter (DM) interacts via long-range dark force carriers it may cool and collapse to form complex structures within the Milky Way galaxy, such as a rotating dark disk. This scenario was proposed recently and termed "Double-Disk Dark Matter" (DDDM). In this paper we consider the possibility that DDDM remains in a cosmologically long-lived excited state and can scatter exothermically on nuclei (ExoDDDM). We investigate the current status of ExoDDDM direct detection and find that ExoDDDM can readily explain the recently announced $\sim 3\sigma$ excess observed at CDMS-Si, with almost all of the 90% best-fit parameter space in complete consistency with limits from other experiments, including XENON10 and XENON100. In the absence of isospin-dependent couplings, this consistency requires light DM with mass typically in the $5-15$ GeV range. The hypothesis of ExoDDDM can be tested in direct detection experiments through its peaked recoil spectra, reduced annual modulation amplitude, and, in some cases, its novel time-dependence. We also discuss future direct detection prospects and additional indirect constraints from colliders and solar capture of ExoDDDM. As theoretical proof-of-principle, we combine the features of exothermic DM models and DDDM models to construct a complete model of ExoDDDM, exhibiting all the required properties.

Keywords: dark matter theory, dark matter detectors, dark matter experiments

ArXiv ePrint: 1307.4095

JCAP10(2013)058


10^4
1000
100
10
1
0.1
XENON100
ExoDM
δ = 50 keV
M_χ = 5.5 GeV
S1>1
Xe
Ge
CDMS−Si
Si
dR/dE_R [kg day keV]^−1
0
5
10
15
20
E_R [keV]
10^4
1000
100
10
1
0.1
XENON100
ExoDDDM
δ = 50 keV
M_χ = 5.5 GeV
S1>1
Xe
Ge
CDMS−Si
Si
0
5
10
15
E_R [keV]



CDMS–Si
CRESST–II
XENON10
XENON100
CDMS–Ge
CRESST–II
SIMPLE
Elastic
SHM
Standard Halo Model
δ=0 keV
ExoDM
SHM
δ=50 keV
ExoDDDM
DDDM
δ=50 keV
ExoDDDM
DDDM
δ=25 keV
σ_n [cm^2]
m_χ [GeV]

清華大學
Tsinghua University

Our work
arXiv: 1404.6043
April， 24

arXiv: 1404.7484
May， 2

Journal of Cosmology and Astroparticle Physics
An IOP and SISSA journal

Direct detection of light “Ge-phobic” exothermic dark matter

Graciela B. Gelmini, Andreea Georgescu and Ji-Haeng Huh

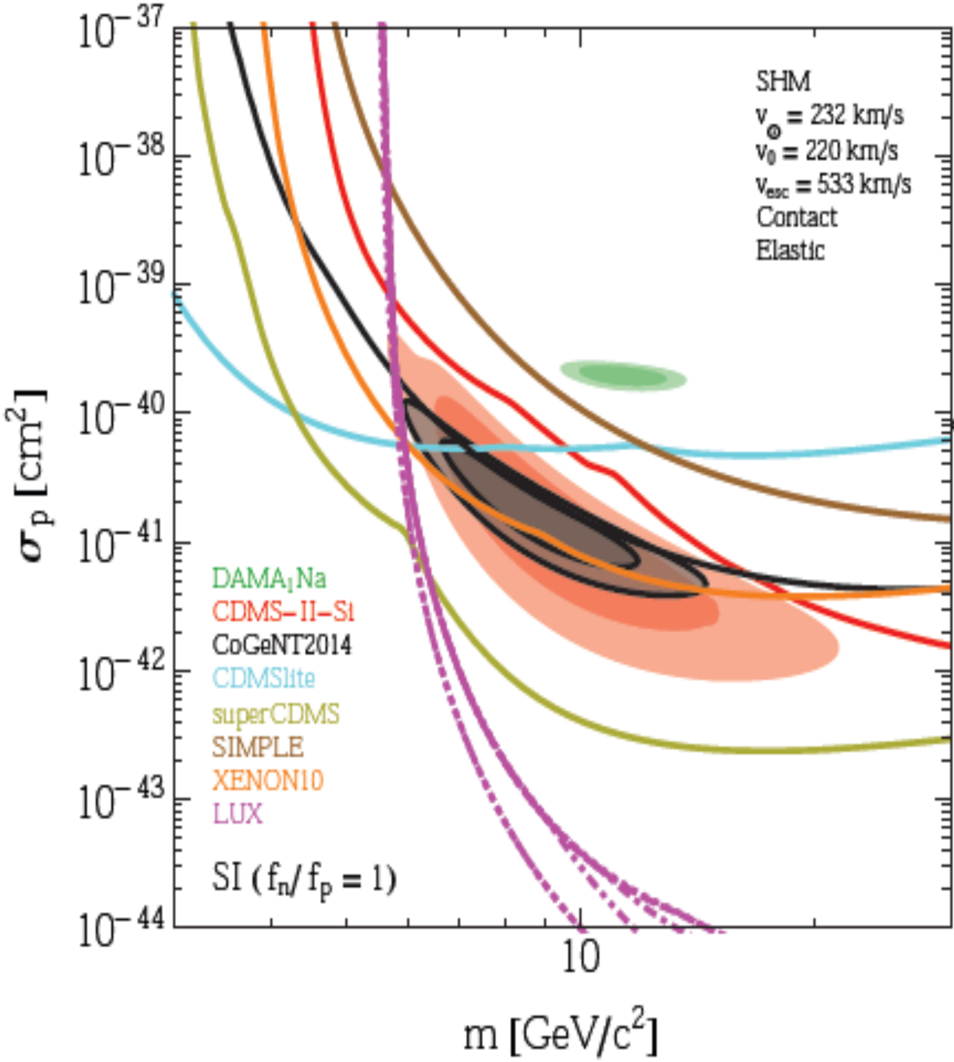
Department of Physics and Astronomy, UCLA,
475 Portola Plaza, Los Angeles, CA, 90095 U.S.A.

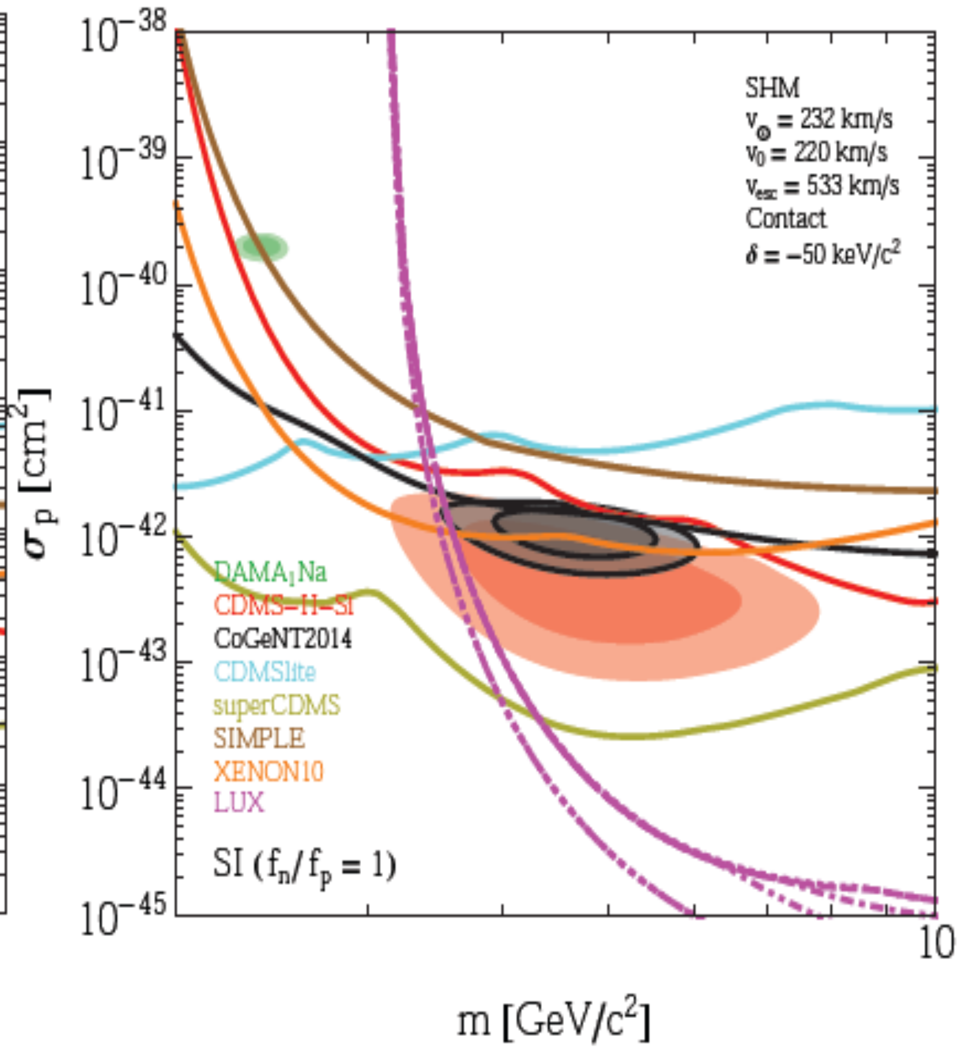
E-mail: gelmini@physics.ucla.edu, a.georgescu@physics.ucla.edu, jhhuh@physics.ucla.edu

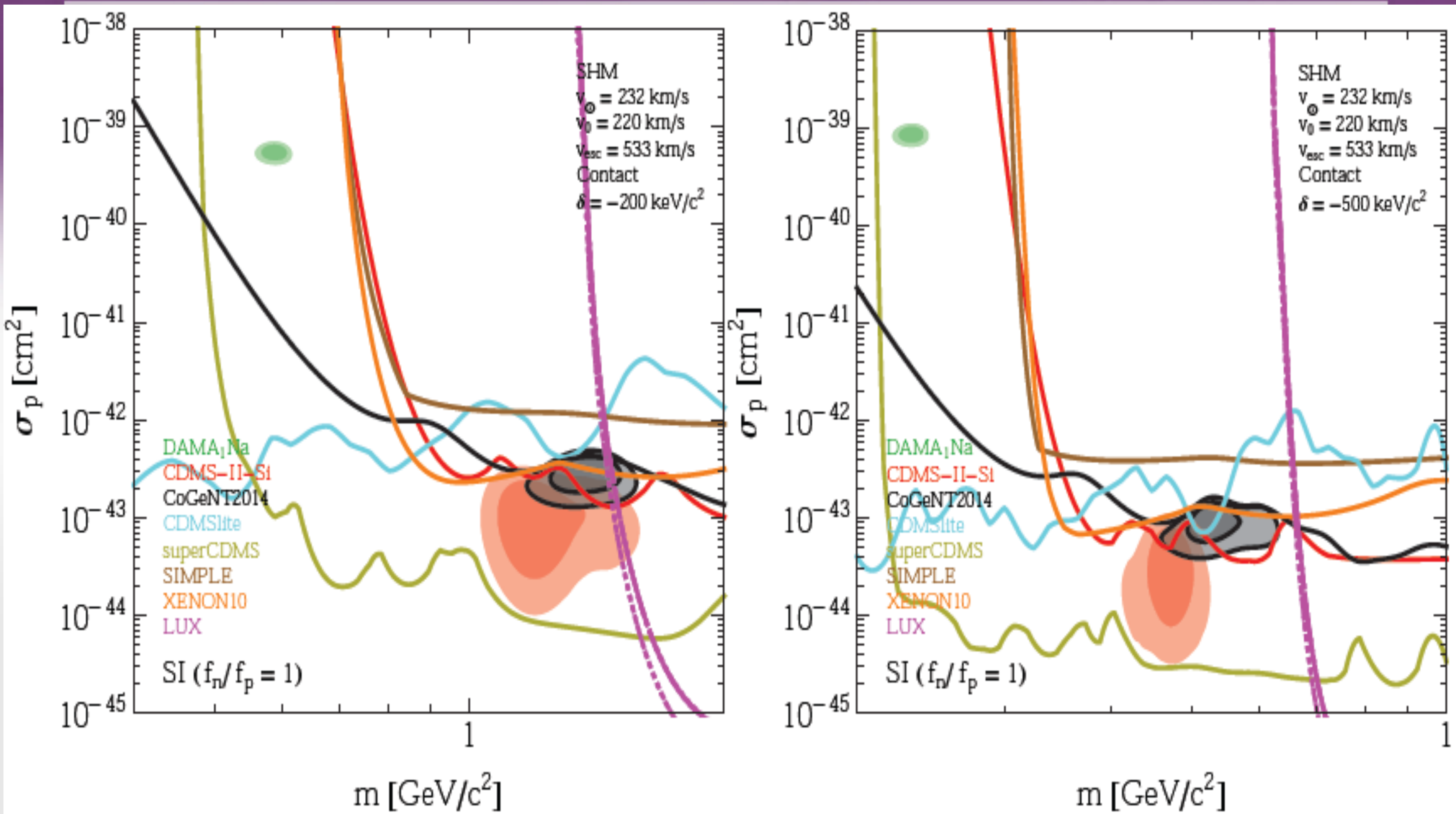
Received May 2, 2014
Accepted June 17, 2014
Published July 15, 2014

Abstract. We present comparisons of direct dark matter (DM) detection data for light WIMPs with exothermic scattering with nuclei (exoDM), both assuming the Standard Halo Model (SHM) and in a halo model — independent manner. Exothermic interactions favor light targets, thus reducing the importance of upper limits derived from xenon targets, the most restrictive of which is at present the LUX limit. In our SHM analysis the CDMS-II-Si and CoGeNT regions become allowed by these bounds, however the recent SuperCDMS limit rejects both regions for exoDM with isospin-conserving couplings. An isospin-violating coupling of the exoDM, in particular one with a neutron to proton coupling ratio of −0.8 (which we call “Ge-phobic”), maximally reduces the DM coupling to germanium and allows the CDMS-II-Si region to become compatible with all bounds. This is also clearly shown in our halo-independent analysis.

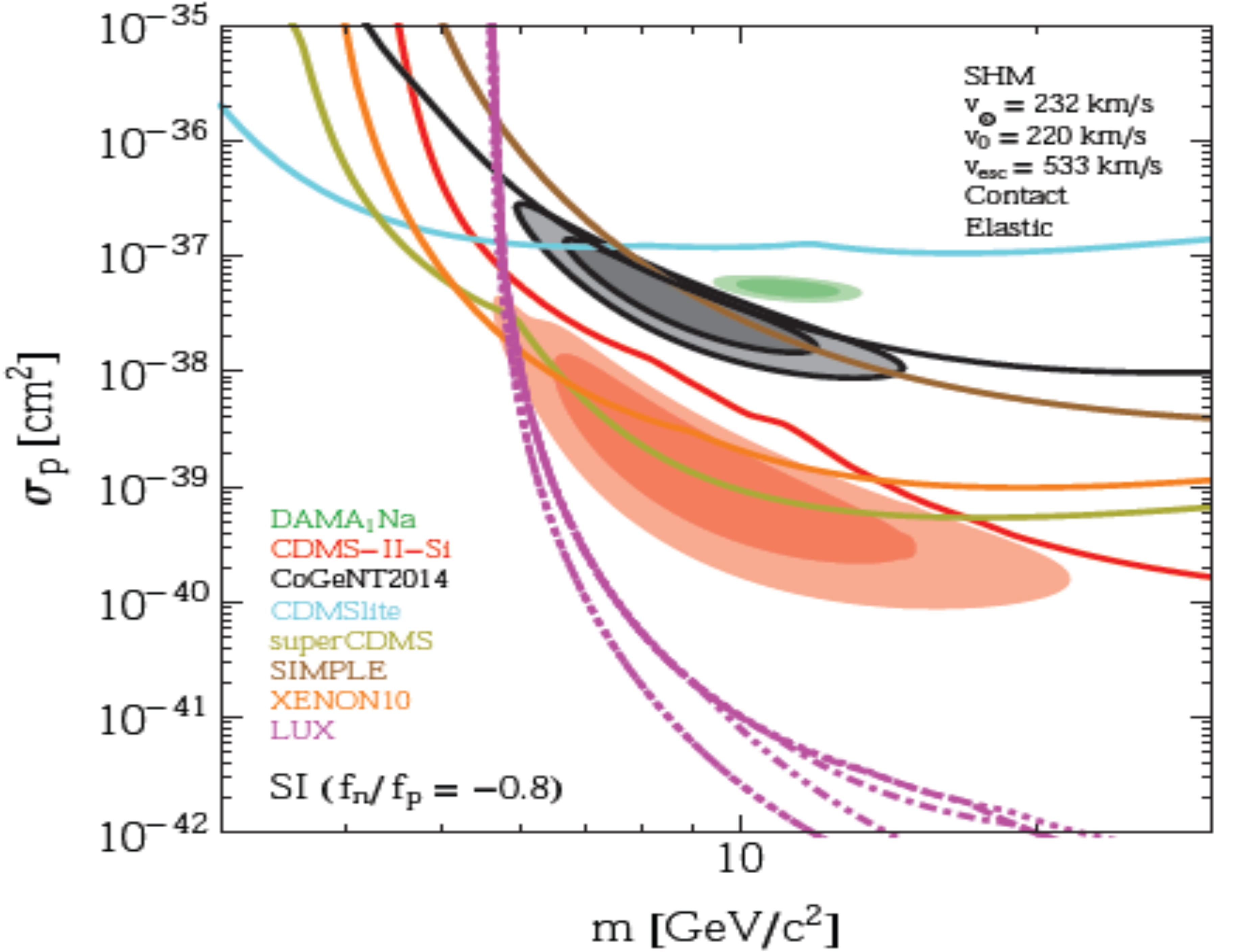
JCAP07(2014)028


SHM
$v_\odot$ = 232 km/s
v_0 = 220 km/s
v_{esc} = 533 km/s
Contact
Elastic
DAMA$_I$Na
CDMS−II−Si
CoGeNT2014
CDMSlite
superCDMS
SIMPLE
XENON10
LUX
SI (f_n/f_p = 1)
σ_p [cm^2]
m [GeV/c^2]
10^{-37}
10^{-38}
10^{-39}
10^{-40}
10^{-41}
10^{-42}
10^{-43}
10^{-44}
10

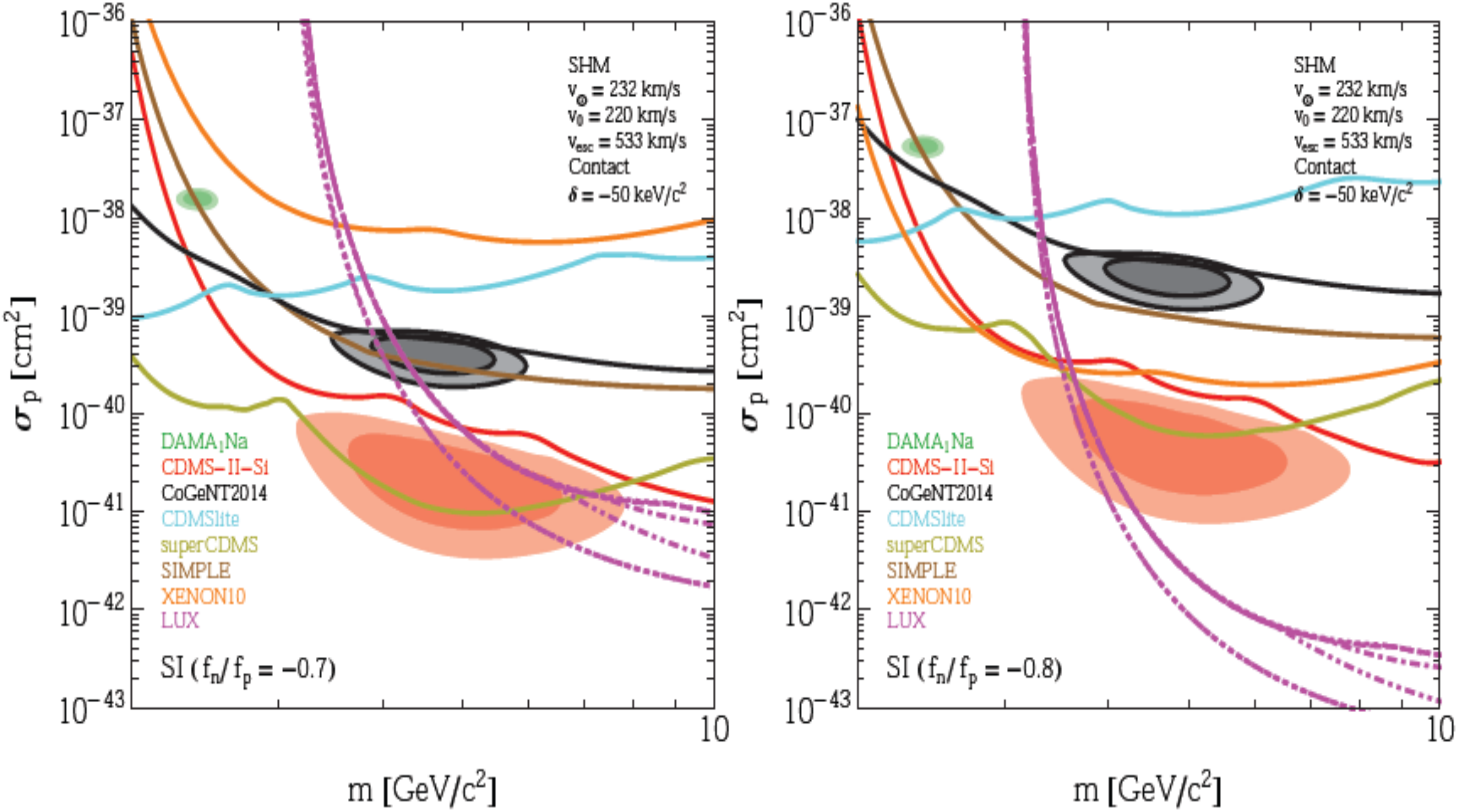

SHM
$v_\odot$ = 232 km/s
v_0 = 220 km/s
v_{esc} = 533 km/s
Contact
δ = −50 keV/c^2
DAMA$_I$Na
CDMS−II−Si
CoGeNT2014
CDMSlite
superCDMS
SIMPLE
XENON10
LUX
SI (f_n/f_p = 1)
σ_p [cm^2]
m [GeV/c^2]
10^{-38}
10^{-39}
10^{-40}
10^{-41}
10^{-42}
10^{-43}
10^{-44}
10^{-45}
10

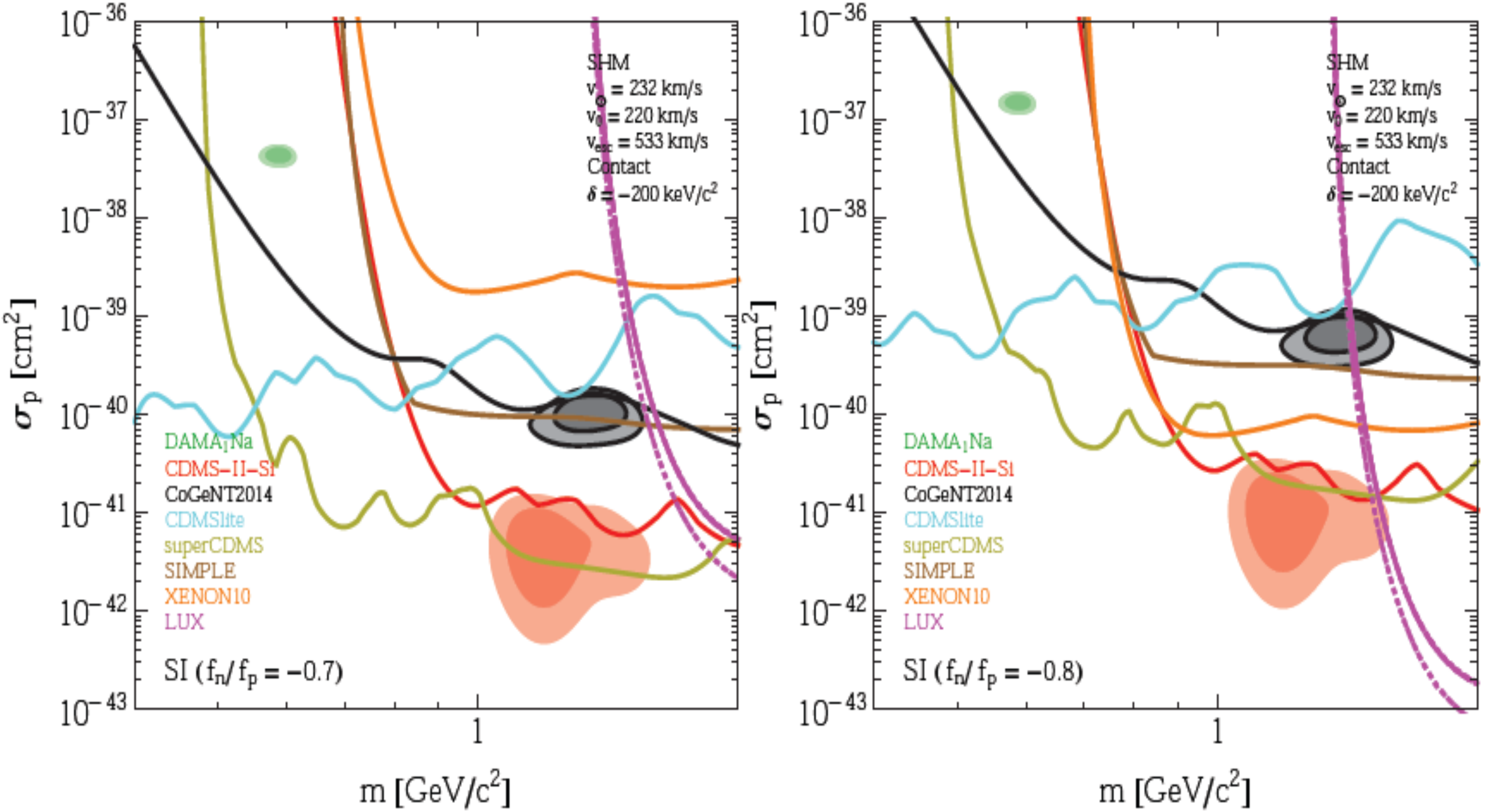


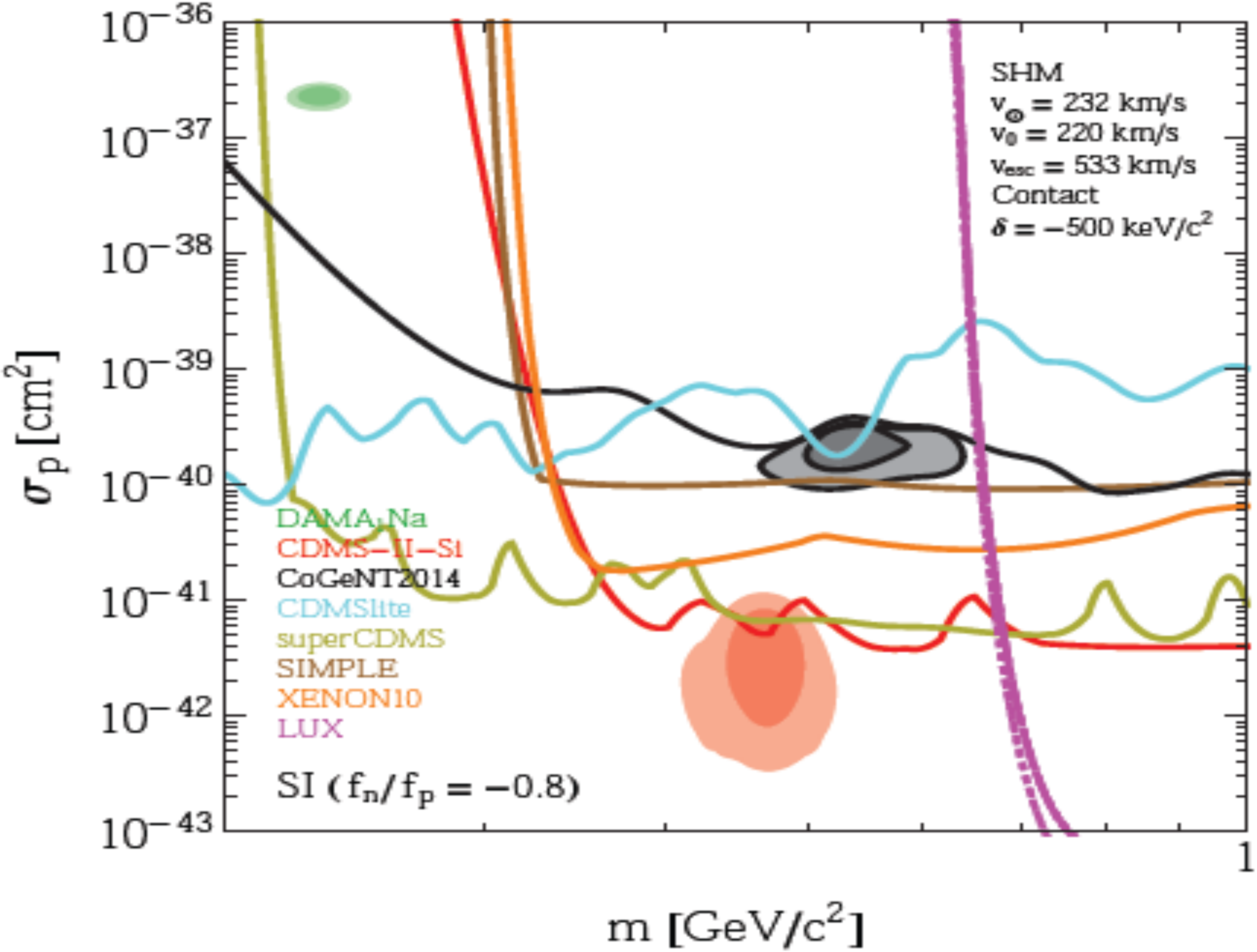
10^{-38}
10^{-39}
10^{-40}
10^{-41}
10^{-42}
10^{-43}
10^{-44}
10^{-45}
σ_p [cm^2]
SHM
$v_\odot$ = 232 km/s
v_0 = 220 km/s
v_{esc} = 533 km/s
Contact
$\delta = -200$ keV/c^2
DAMA$_I$Na
CDMS−II−Si
CoGeNT2014
CDMSlite
superCDMS
SIMPLE
XENON10
LUX
SI (f_n/f_p = 1)
1
m [GeV/c^2]
10^{-38}
10^{-39}
10^{-40}
10^{-41}
10^{-42}
10^{-43}
10^{-44}
10^{-45}
σ_p [cm^2]
SHM
$v_\odot$ = 232 km/s
v_0 = 220 km/s
v_{esc} = 533 km/s
Contact
$\delta = -500$ keV/c^2
DAMA$_I$Na
CDMS−II−Si
CoGeNT2014
CDMSlite
superCDMS
SIMPLE
XENON10
LUX
SI (f_n/f_p = 1)
1
m [GeV/c^2]



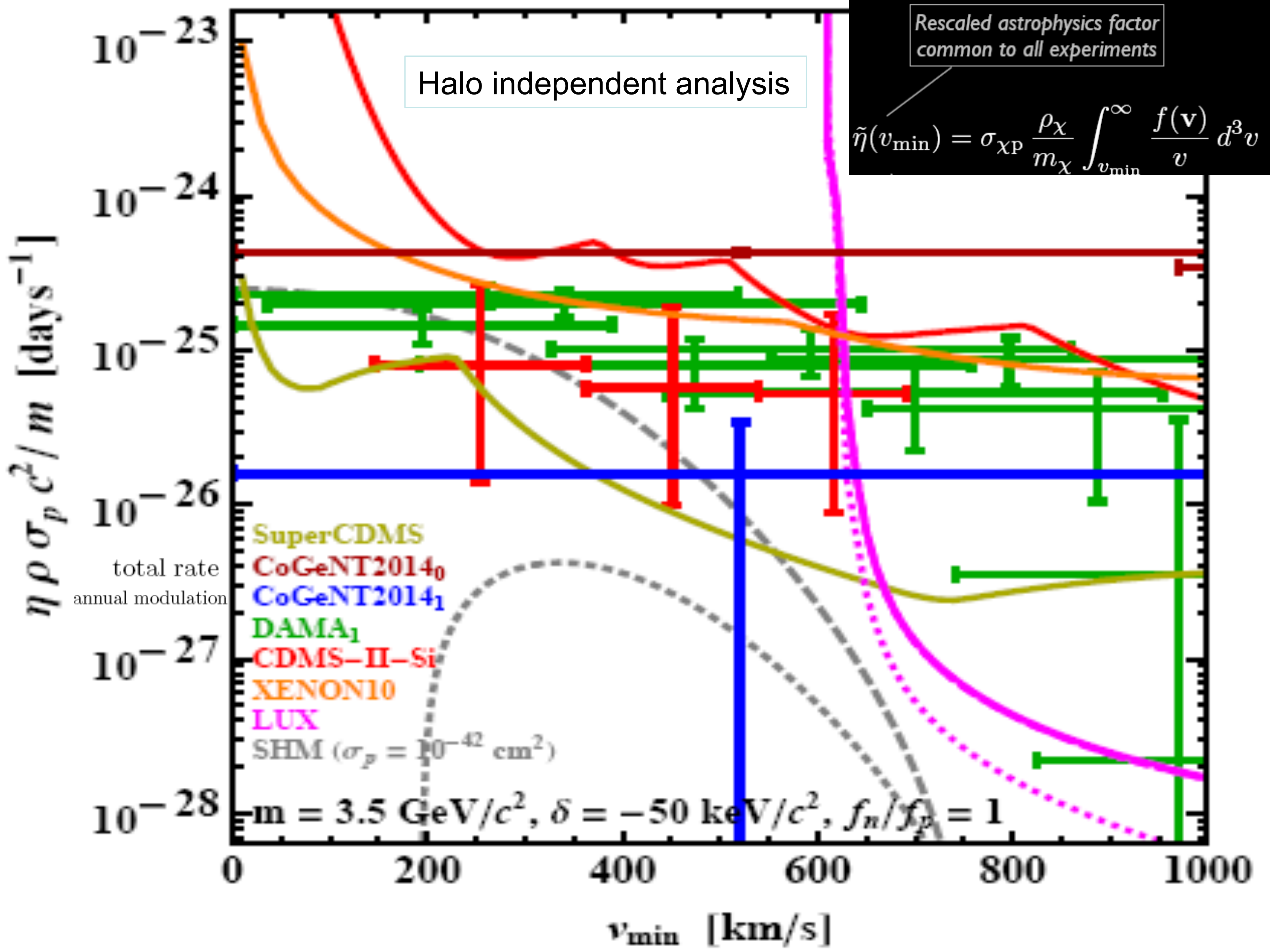
SHM
v⊕ = 232 km/s
v0 = 220 km/s
vesc = 533 km/s
Contact
Elastic
DAMA I Na
CDMS-II-Si
CoGeNT2014
CDMSlite
superCDMS
SIMPLE
XENON10
LUX
SI (fn/fp = -0.8)
σp [cm2]
m [GeV/c2]
10-35
10-36
10-37
10-38
10-39
10-40
10-41
10-42
10


SHM
$v_\odot = 232$ km/s
$v_0 = 220$ km/s
$v_{esc} = 533$ km/s
Contact
$\delta = -50$ keV/c^2
DAMA$_I$Na
CDMS−II−Si
CoGeNT2014
CDMSlite
superCDMS
SIMPLE
XENON10
LUX
SI ($f_n/f_p = -0.7$)
SI ($f_n/f_p = -0.8$)
σ_p [cm^2]
m [GeV/c^2]
10
10^{-36}
10^{-37}
10^{-38}
10^{-39}
10^{-40}
10^{-41}
10^{-42}
10^{-43}

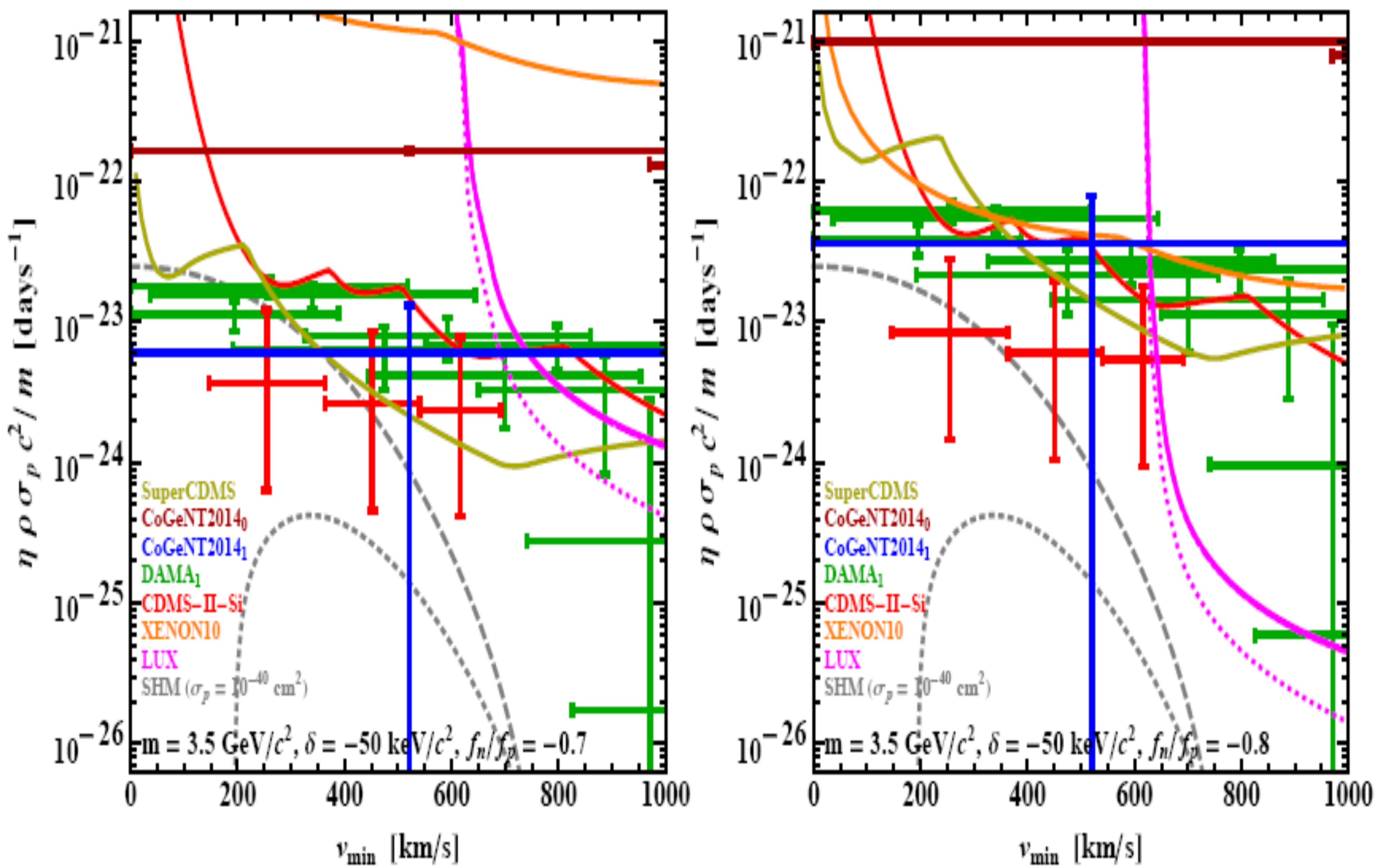

SHM
$v_\odot$ = 232 km/s
v_0 = 220 km/s
v_{esc} = 533 km/s
Contact
δ = −200 keV/c²
DAMA$_I$Na
CDMS−II−Si
CoGeNT2014
CDMSlite
superCDMS
SIMPLE
XENON10
LUX
SI (f_n/f_p = −0.7)
SI (f_n/f_p = −0.8)
σ_p [cm²]
m [GeV/c²]
10^{-36}
10^{-37}
10^{-38}
10^{-39}
10^{-40}
10^{-41}
10^{-42}
10^{-43}
1

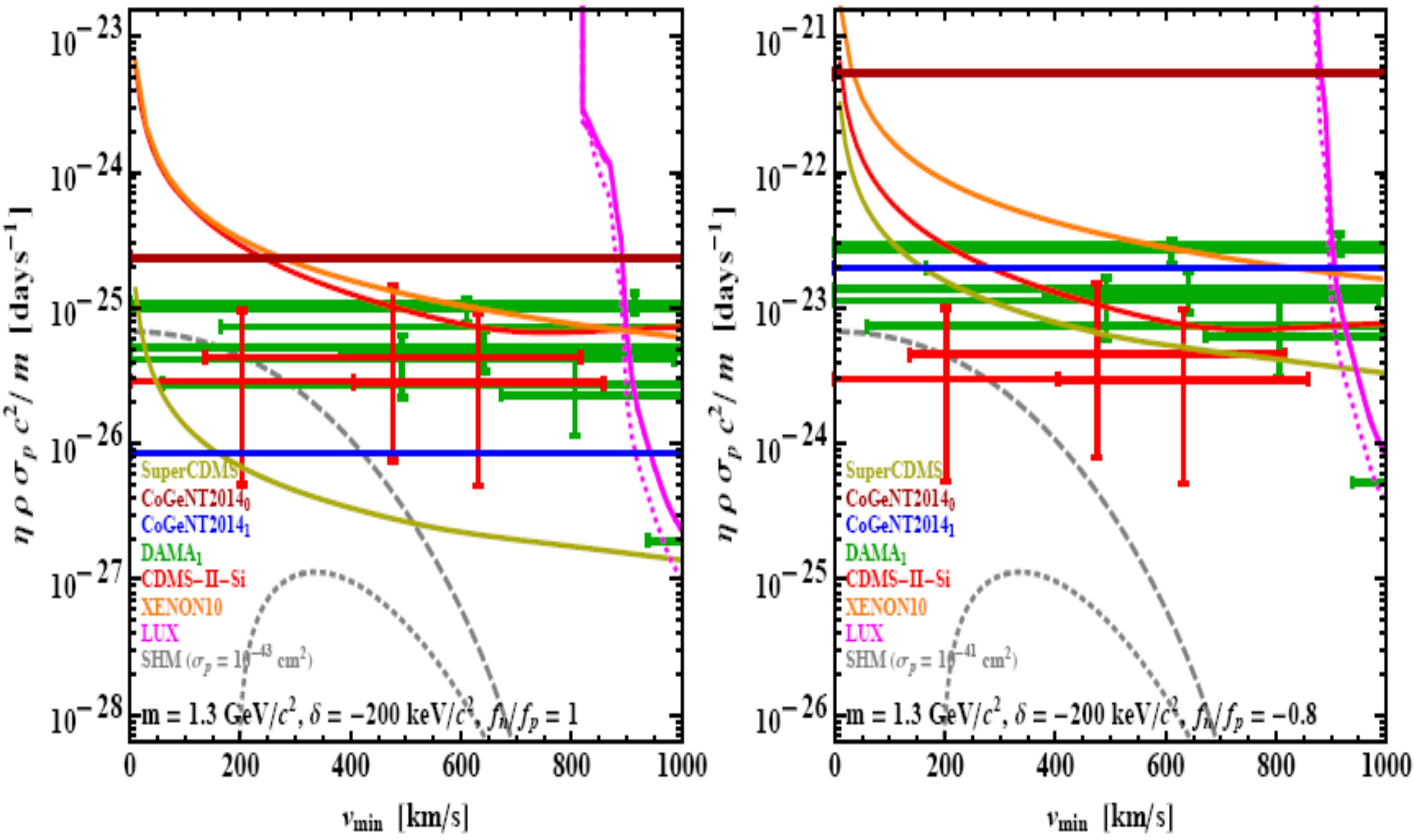


10^{-36}
10^{-37}
10^{-38}
10^{-39}
10^{-40}
10^{-41}
10^{-42}
10^{-43}
σ_p [cm^2]
SHM
$v_\oplus$ = 232 km/s
v_0 = 220 km/s
v_{esc} = 533 km/s
Contact
$\delta = -500$ keV/c^2
DAMA$_1$Na
CDMS−II−Si
CoGeNT2014
CDMSlite
superCDMS
SIMPLE
XENON10
LUX
SI ($f_n/f_p = -0.8$)
1
m [GeV/c^2]



Halo independent analysis
Rescaled astrophysics factor common to all experiments
$\tilde{\eta}(v_{\min}) = \sigma_{\chi p} \frac{\rho_\chi}{m_\chi} \int_{v_{\min}}^{\infty} \frac{f(\mathbf{v})}{v} d^3v$
$\eta \rho \sigma_p c^2 / m$ [days^{-1}]
10^{-23}
10^{-24}
10^{-25}
10^{-26}
10^{-27}
10^{-28}
SuperCDMS
total rate
CoGeNT2014$_0$
annual modulation
CoGeNT2014$_1$
DAMA$_1$
CDMS−II−Si
XENON10
LUX
SHM ($\sigma_p = 10^{-42}$ cm^2)
m = 3.5 GeV/c^2, $\delta = -50$ keV/c^2, $f_n/f_p = 1$
0
200
400
600
800
1000
$v_{\min}$ [km/s]


$\eta \, \rho \, \sigma_p \, c^2 / m$ [days^{-1}]
SuperCDMS
CoGeNT2014$_0$
CoGeNT2014$_1$
DAMA$_1$
CDMS–II–Si
XENON10
LUX
SHM ($\sigma_p = 10^{-40}$ cm^2)
m = 3.5 GeV/c^2, δ = −50 keV/c^2, f_n/f_p = −0.7
v_{min} [km/s]
$\eta \, \rho \, \sigma_p \, c^2 / m$ [days^{-1}]
SuperCDMS
CoGeNT2014$_0$
CoGeNT2014$_1$
DAMA$_1$
CDMS–II–Si
XENON10
LUX
SHM ($\sigma_p = 10^{-40}$ cm^2)
m = 3.5 GeV/c^2, δ = −50 keV/c^2, f_n/f_p = −0.8
v_{min} [km/s]


SuperCDMS
CoGeNT2014₀
CoGeNT2014₁
DAMA₁
CDMS–II–Si
XENON10
LUX
SHM (σp = 10⁻⁴³ cm²)
m = 1.3 GeV/c², δ = −200 keV/c², fn/fp = 1
SHM (σp = 10⁻⁴¹ cm²)
m = 1.3 GeV/c², δ = −200 keV/c², fn/fp = −0.8
η ρ σp c²/ m [days⁻¹]
vmin [km/s]
0
200
400
600
800
1000

arXiv:1405.0364v2 [astro-ph.CO] 26 Aug 2014

JCAP08(2014)060

A systematic halo–independent analysis of direct detection data within the framework of Inelastic Dark Matter

Our work
arXiv: 1404.6043
April，24

Stefano Scopel,[a] Kook-Hyun Yoon[b]

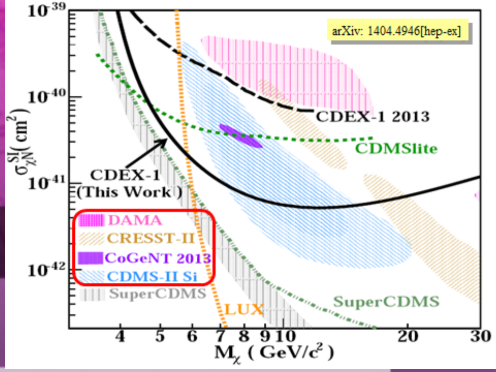
Department of Physics, Sogang University, Seoul 121-742, South Korea

E-mail: scopel@sogang.ac.kr, koreasds@naver.com

Abstract. We present a systematic halo–independent analysis of available Weakly Interacting Massive Particles (WIMP) direct detection data within the framework of Inelastic Dark Matter (IDM). We show that, when the smallest number of assumptions is made on the WIMP velocity distribution in the halo of our Galaxy, it is possible to find values of the WIMP mass and the IDM mass splitting for which compatibility between present constraints and any of the three experiments claiming to see a WIMP excess among DAMA, CDMS-*Si* and CRESST can be achieved.

清華大學
Tsinghua University

Outline



- Motivation & Status
- Three old Exps: DAMA；CRESST；CoGeNT
- Reconciliation Methods
- Latest Result
- Theoretical Models ✓

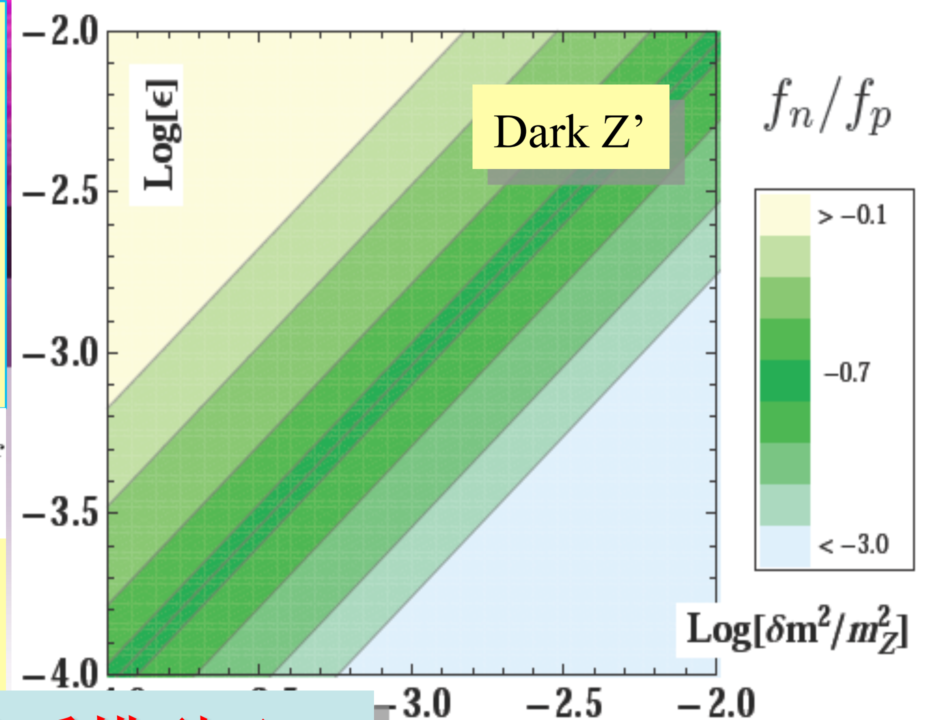
M.T.Frandsen,F.Kahlhoefer,J.M.Russell, C.McCabe,M.McCullough,K.S.Hoberg **PRD84,041301(2011)**第一

X.Gao,Z.Kang and T.Li,**JCAP 1301,021(2013)**第三

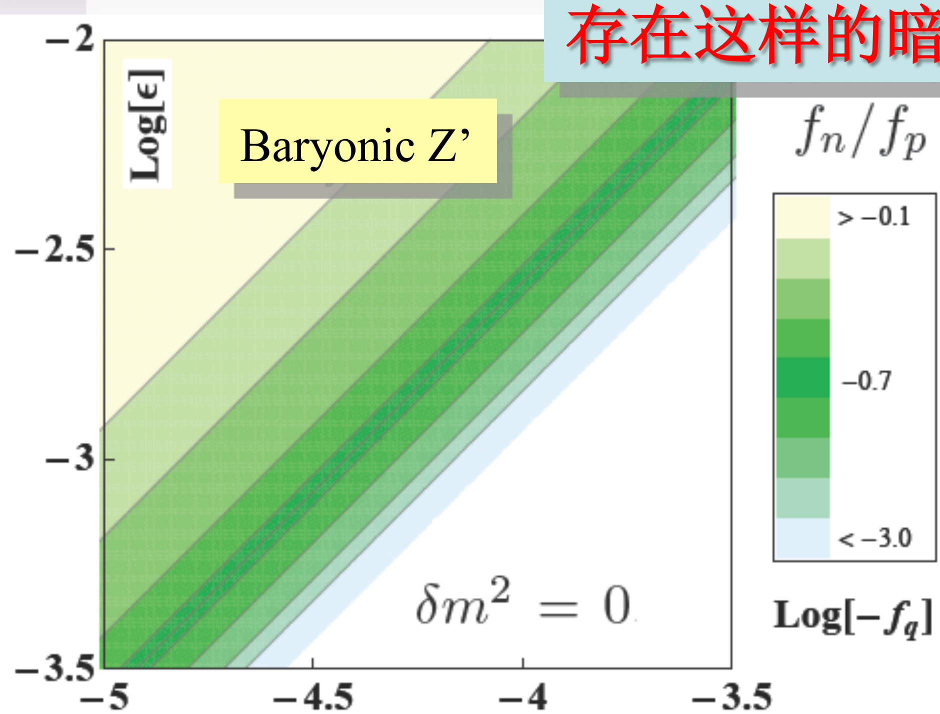
J.M.Cline, A.R.Frey, **PRD84,075003 (2011)**第四

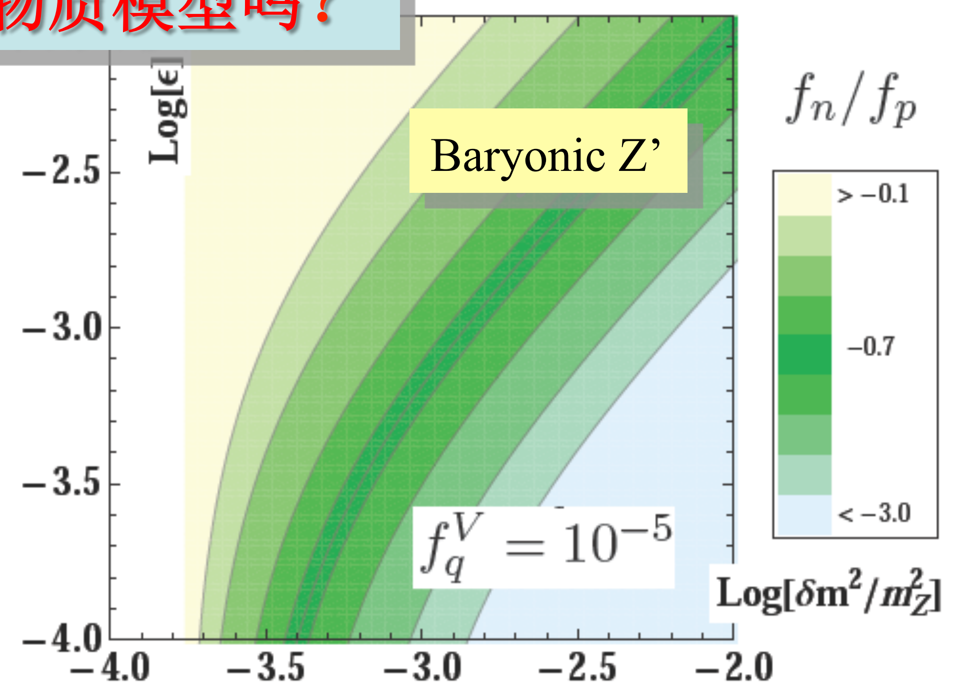
$$-\frac{1}{2}\sin\epsilon\,\hat{B}_{\mu\nu}\hat{X}^{\mu\nu}+\delta m^2\hat{Z}_\mu\hat{X}^\mu-\sum_f f_f^{V}\hat{X}^\mu\bar{f}\gamma_\mu f$$

M.T.Frandsen, F.Kahlhoefer, S.Sarkar, K.S-Hoberg **JHEP 1109, 128 (2011)**; **1107.2118** 没指出非弹文章第二



存在这样的暗物质模型吗？





PHYSICAL REVIEW D **82**, 063512 (2010)

暗物质复杂结构的自然延伸

No ISV

Exothermic dark matter

Peter W. Graham,[1] Roni Harnik,[2] Surjeet Rajendran,[3] and Prashant Saraswat[1]

[1]*Department of Physics, Stanford University, Stanford, California 94305, USA*

[2]*Theoretical Physics Department, Fermilab, Batavia, IL60510, USA*

[3]*Center for Theoretical Physics, Laboratory for Nuclear Science and Department of Physics, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139, USA*

(Received 2 June 2010; published 9 September 2010)

We propose a novel mechanism for dark matter to explain the observed annual modulation signal at DAMA/LIBRA which avoids existing constraints from every other dark matter direct detection experiment including CRESST, CDMS, and XENON10. The dark matter consists of at least two light states with mass ~few GeV and splittings ~5 keV. It is natural for the heavier states to be cosmologically long-lived and to make up an $\mathcal{O}(1)$ fraction of the dark matter. Direct detection rates are dominated by the exothermic reactions in which an excited dark matter state downscatters off of a nucleus, becoming a lower energy state. In contrast to (endothermic) inelastic dark matter, the most sensitive experiments for exothermic dark matter are those with light nuclei and low threshold energies. Interestingly, this model can also naturally account for the observed low-energy events at CoGeNT. The only significant constraint on the model arises from the DAMA/LIBRA unmodulated spectrum but it can be tested in the near future by a low-threshold analysis of CDMS-Si and possibly other experiments including CRESST, COUPP, and XENON100.

DOI: 10.1103/PhysRevD.82.063512

PACS numbers: 95.35.+d

1105.3734

May 18,2011,吸热

RAPID COMMUNICATIONS

PHYSICAL REVIEW D **84,** 041301(R) (2011)

On the DAMA and CoGeNT modulations

Mads T. Frandsen,* Felix Kahlhoefer, John March-Russell, Christopher McCabe, Matthew McCullough, and Kai Schmidt-Hoberg

Rudolf Peierls Centre for Theoretical Physics, University of Oxford, Oxford OX1 3NP, United Kingdom

(Received 6 July 2011; published 24 August 2011)

DAMA observes an annual modulation in their event rate, as might be expected from dark matter scatterings, while CoGeNT has reported evidence for a similar modulation. The simplest interpretation of these findings in terms of dark matter-nucleus scatterings is excluded by other direct detection experiments. We consider the robustness of these exclusions with respect to assumptions regarding the scattering and find that isospin-violating inelastic dark matter helps alleviate this tension and allows marginal compatibility between experiments. Isospin violation can significantly weaken the XENON constraints, while inelasticity enhances the annual modulation fraction of the signal, bringing the CoGeNT and CDMS results into better agreement.

DOI: 10.1103/PhysRevD.84.041301 PACS numbers: 95.35.+d

CoGeNT non-modulation excess result published in April 1,2014

Journal of Cosmology and Astroparticle Physics
An IOP and SISSA journal

Origins of the isospin violation of dark matter interactions

Xin Gao,[a] Zhaofeng Kang[a] and Tianjun Li[a,b]

[a]Key Laboratory of Frontiers in Theoretical Physics,
Institute of Theoretical Physics, Chinese Academy of Sciences,
Beijing 100190, P.R. China
[b]George P. and Cynthia W. Mitchell Institute for Fundamental Physics,
Texas A&M University,
College Station, TX 77843, U.S.A.

E-mail: gaoxinbnu@gmail.com, zhaofengkang@gmail.com, tli@itp.ac.cn

Received September 4, 2012
Revised November 6, 2012
Accepted December 12, 2012
Published January 21, 2013

JCAP01(2013)021

Abstract. Light dark matter (DM) with a large DM-nucleon spin-independent scattering cross section and moreover proper isospin violation (ISV) $f_n/f_p \approx -0.7$ may provide a way to understand the confusing DM direct detection results. Further using the stringent astrophysical and collider constraints, we systematically investigate the origin of ISV first via general operator analyses and further via specifying three types of mediators: a light Z' from chiral $U(1)_X$, an approximate spectator Higgs doublet (It can explain the $W + jj$ anomaly simultaneously) and color triplets. In addition, although Z' from an exotic $U(1)_X$ mixing with $U(1)_Y$ generates only $f_n = 0$, we can combine it with the conventional Higgs to achieve the proper ISV. As a concrete example, we propose the $U(1)_X$ model where the $U(1)_X$ charged light sneutrino is an inelastic DM, which dominantly annihilates to light dark states such as Z' with sub-GeV mass. The model can consistently (with other DM direct detection results) and safely interpret the recent GoGeNT annual modulation result.

Keywords: dark matter theory, dark matter detectors

ArXiv ePrint: 1107.3529

July 18,2011；v2 title changed；吸热

清華大學
Tsinghua University

PHYSICAL REVIEW D **84**, 075003 (2011)

1108.1391

Sep 19,2011

主要讨论弹性和吸热

为完备顺带讨论放热

Minimal hidden sector models for CoGeNT/DAMA events

James M. Cline[1,*] and Andrew R. Frey[2,†]

[1]*Physics Department, McGill University, Montreal, QC, H3A2T8, Canada*

[2]*Department of Physics and Winnipeg Insitute for Theoretical Physics, The University of Winnipeg, Winnipeg, MB, R3B2E9, Canada*

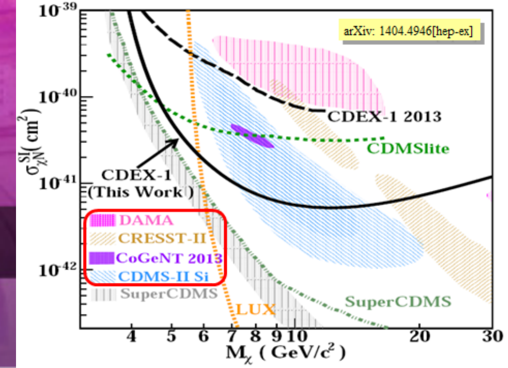
(Received 15 August 2011; published 3 October 2011)

Motivated by recent attempts to reconcile hints of direct dark matter detection by the CoGeNT and DAMA experiments, we construct simple particle physics models that can accommodate the constraints. We point out challenges for building reasonable models and identify the most promising scenarios for getting isospin violation and inelasticity, as indicated by some phenomenological studies. If inelastic scattering is demanded, we need two new light gauge bosons, one of which kinetically mixes with the standard model hypercharge and has mass <2 GeV, and another which couples to baryon number and has mass $6.8 \pm^{0.1}_{0.2}$ GeV. Their interference gives the desired amount of isospin violation. The dark matter is nearly Dirac, but with small Majorana masses induced by spontaneous symmetry breaking, so that the gauge boson couplings become exactly off-diagonal in the mass basis, and the small mass splitting needed for inelasticity is simultaneously produced. If only elastic scattering is demanded, then an alternative model, with interference between the kinetically mixed gauge boson and a hidden sector scalar Higgs, is adequate to give the required isospin violation. In both cases, the light kinetically mixed gauge boson is in the range of interest for currently running fixed target experiments.

DOI: 10.1103/PhysRevD.84.075003 PACS numbers: 95.35.+d, 12.60.Cn

清華大學
Tsinghua University

Summary



- CRESST already kill itself **No DM**

Exp measurement ←

- DAMA may or may not be explained by Atm μ & Solar ν **No DM**

or explained by electron scattering or atom neutral particle

Exp measurement ←

- CoGeNT analysis is questioned **No DM**

Contradic with CDEX result!

or explained by atom neutral particle

- CDMS II-Si ISV+Exothermic Inelastic Scatting **DM**

or explained by atom neutral particle

Suppress modulation strongly，conflict with DAMA、CoGeNT


谢 谢