A next generation liquid xenon observatory for rare events

Kelsey C Oliver Mallory
Imperial College London
April 5th, 2022
Institute of Physics HEP & APP Annual Conference 2022

Imperial College London

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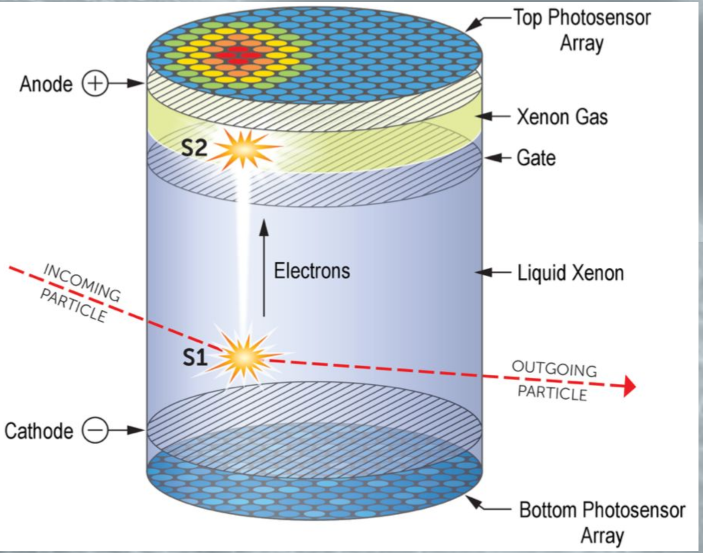

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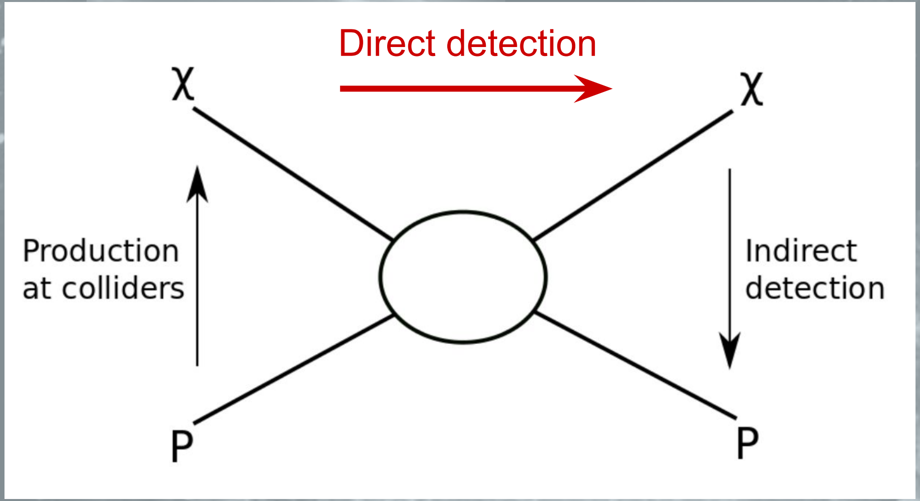

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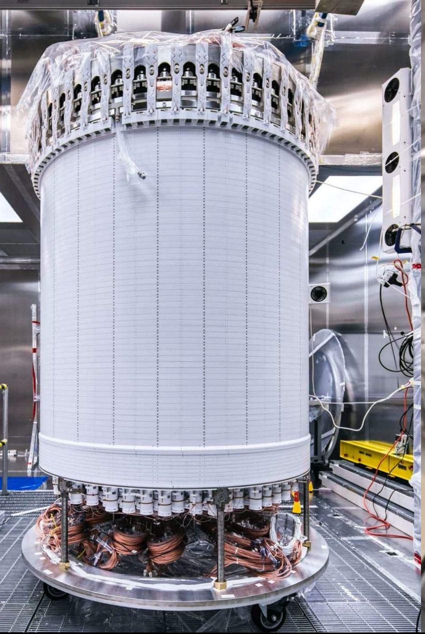
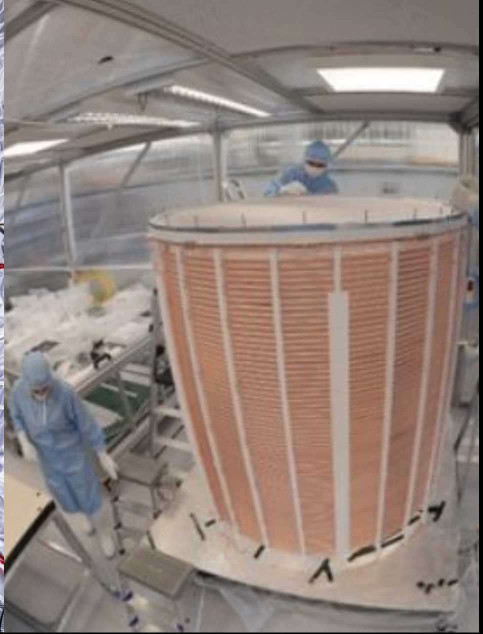
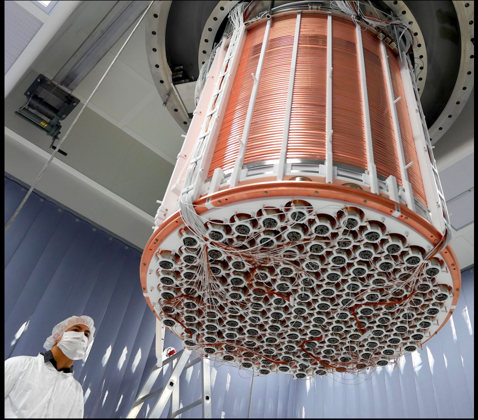
Dark matter and xenon: a timeline



LUX-ZEPLIN (LZ)
Present, 7t



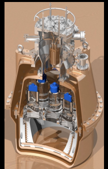
XENONnT
Present, 6t



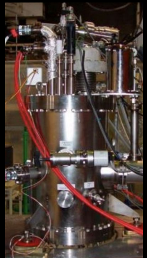
XENON1T
2017, 2 t

PANDAX-II
2016, 580 kg

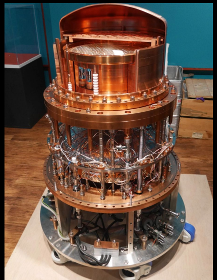
ZEPLIN-I
2005, 3.2 kg



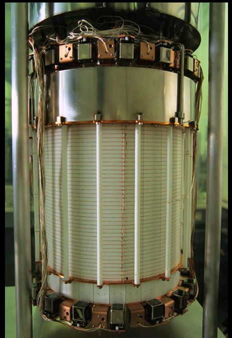
ZEPLIN-II
2007, 31 kg



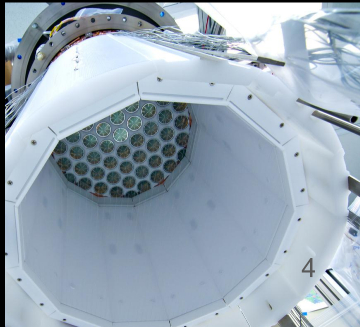
XENON10
2007, 15 kg



ZEPLIN-III
2008, 12 kg



XENON100
2010, 62 kg



LUX
2013, 250 kg

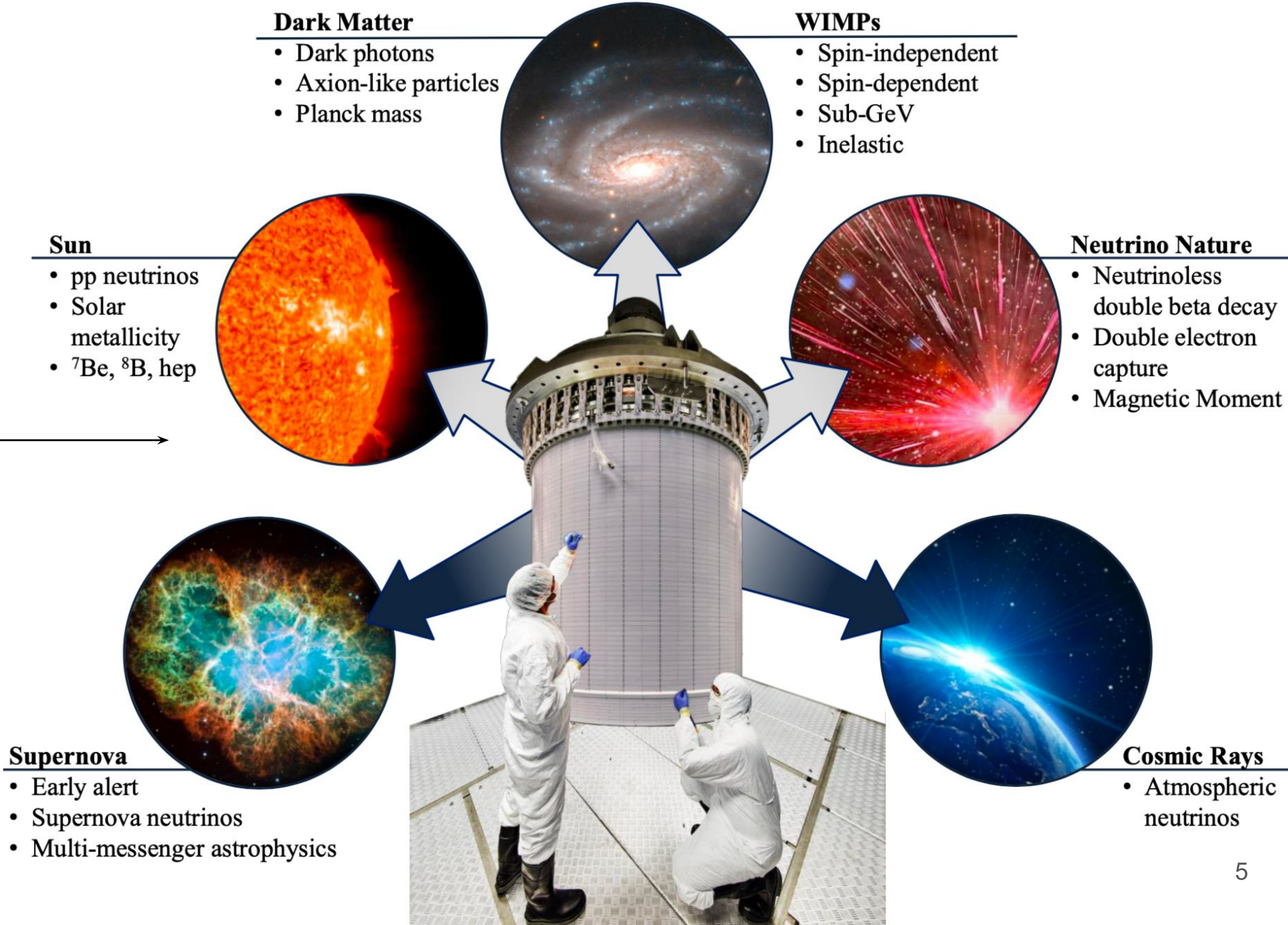
Massive

→ 50-100 tonnes

Yet compact

→ 2-4m height x diameter

Science



Memorandum of Understanding between members of the XENON/DARWIN and LUX-ZEPLIN collaborations towards a next generation liquid xenon experiment

More than 100 senior scientists from 16 countries signed MoU on July 6, 2021

XENON Dark Matter Project

DARWIN

Boulby Underground Laboratory

A potential host site is the Boulby Underground Laboratory

Feasibility study indicates technical viability

A challenge, but a great opportunity

FINAL REPORT

FEASIBILITY STUDY

FOR DEVELOPING THE BOULBY UNDERGROUND LABORATORY INTO A FACILITY FOR FUTURE MAJOR INTERNATIONAL PROJECTS

Supported by the STFC Opportunities Call 2019

H M Araújo[1], J Dobson[2], C Ghag[2], S Greenwood[3], V A Kudryavtsev[4], P Majewski[3], S M Paling[5], V Pěč[4], R Saakyan[2], P R Scovell[5], N Smith[6], and T J Sumner[1,*]

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June 25, 2021

Issue v1.0

OFFICIAL-SENSITIVE [COMMERCIAL]

Science with liquid xenon

White paper just released (arXiv:2203.02309) (particular thanks to Rafael Lang, Purdue)

~600 authors from 146 institutes

72 UK authors from 13 institutes

Details the breadth of physics enabled by a next-generation xenon observatory

arXiv:2203.02309v1 [physics.ins-det] 4 Mar 2022

A Next-Generation Liquid Xenon Observatory for Dark Matter and Neutrino Physics

J. Aalbers,[1,2] K. Abe,[3,4] V. Aerne,[5] F. Agostini,[6] S. Ahmed Maouloud,[7] D.S. Akerib,[1,2] D.Yu. Akimov,[8] J. Akshat,[9] A.K. Al Musalhi,[10] F. Alder,[11] S.K. Alsum,[12] L. Althueser,[13] C.S. Amarasinghe,[14] F.D. Amaro,[15] A. Ames,[1,2] T.J. Anderson,[1,2] B. Andrieu,[7] N. Angelides,[16] E. Angelino,[17] J. Angevaare,[18] V.C. Antochi,[19] D. Antón Martin,[20] B. Antunovic,[21,22] E. Aprile,[23] H.M. Araújo,[16] J.E. Armstrong,[24] F. Arneodo,[25] M. Arthurs,[14] P. Asadi,[26] S. Baek,[27] X. Bai,[28] D. Bajpai,[29] A. Baker,[16] J. Balajthy,[30] S. Balashov,[31] M. Balzer,[32] A. Bandyopadhyay,[33] J. Bang,[34] E. Barberio,[35] J.W. Bargemann,[36] L. Baudis,[5] D. Bauer,[16] D. Baur,[37] A. Baxter,[38] A.L. Baxter,[9] M. Bazyk,[39] K. Beattie,[40] J. Behrens,[41] N.F. Bell,[35] L. Bellagamba,[6] P. Beltrame,[42] M. Benabderrahmane,[25] E.P. Bernard,[43,40] G.F. Bertone,[18] P. Bhattacharjee,[44] A. Bhatti,[24] A. Biekert,[43,40] T.P. Biesiadzinski,[1,2] A.R. Binau,[9] R. Biondi,[45] Y. Biondi,[5] H.J. Birch,[14] F. Bishara,[46] A. Bismark,[5] C. Blanco,[47,19] G.M. Blockinger,[48] E. Bodnia,[36] C. Boehm,[49] A.I. Bolozdynya,[8] P.D. Bolton,[11] S. Bottaro,[50,51] C. Bourgeois,[52] B. Boxer,[30] P. Brás,[53] A. Breskin,[54] P.A. Breur,[18] C.A.J. Brew,[31] J. Brod,[55] E. Brookes,[18] A. Brown,[37] E. Brown,[56] S. Bruenner,[18] G. Bruno,[39] R. Budnik,[54] T.K. Bui,[4] S. Burdin,[38] S. Buse,[5] J.K. Busenitz,[29] D. Buttazzo,[51] M. Buuck,[1,2] A. Buzulutskov,[57,58] R. Cabrita,[53] C. Cai,[59] D. Cai,[39] C. Capelli,[5] J.M.R. Cardoso,[15] M.C. Carmona-Benitez,[60] M. Cascella,[11] R. Catena,[61] S. Chakraborty,[62] C. Chan,[34] S. Chang,[63] A. Chauvin,[64] A. Chawla,[65] H. Chen,[40] V. Chepel,[53] N.I. Chott,[28] D. Cichon,[66] A. Cimental Chavez,[5] B. Cimmino,[67] M. Clark,[9] R.T. Co,[68] A.P. Colijn,[18] J. Conrad,[19] M.V. Converse,[69] M. Costa,[50,51] A. Cottle,[10,70] G. Cox,[60] O. Creaner,[71] J.J. Cuenca Garcia,[41] J.P. Cussonneau,[39] J.E. Cutter,[30] C.E. Dahl,[72,70] V. D'Andrea,[73] A. David,[11] M.P. Decowski,[18] J.B. Dent,[74] F.F. Deppisch,[11] L. de Viveiros,[60] P. Di Gangi,[6] A. Di Giovanni,[25] S. Di Pede,[18] J. Dierle,[37] S. Diglio,[39] J.E.Y. Dobson,[11] M. Doerenkamp,[64] D. Douillet,[52] G. Drexlin,[75] E. Druszkiewicz,[69] D. Dunsky,[43] K. Eitel,[41] A. Elykov,[37] T. Emken,[19] R. Engel,[41] S.R. Eriksen,[76] M. Fairbairn,[77] A. Fan,[1,2] J.J. Fan,[34] S.J. Farrell,[78] S. Fayer,[16] N.M. Fearon,[10] A. Ferella,[73] C. Ferrari,[45] A. Fieguth,[13] A. Fieguth,[79] S. Fiorucci,[40] H. Fischer,[37] H. Flaecher,[76] M. Flierman,[18] T. Florek,[9] R. Foot,[35] P.J. Fox,[70] R. Franceschini,[80] E.D. Fraser,[38] C.S. Frenk,[81] S. Frohlich,[82] T. Fruth,[11] W. Fulgione,[45] C. Fuselli,[18] P. Gaemers,[18] R. Gaior,[7] R.J. Gaitskell,[34] M. Galloway,[5] F. Gao,[59] I. Garcia Garcia,[83] J. Genovesi,[28] C. Ghag,[11] S. Ghosh,[44] E. Gibson,[10] W. Gil,[41] D. Giovagnoli,[39,84] F. Girard,[5] R. Glade-Beucke,[37] F. Glück,[41] S. Gokhale,[85] A.de Gouvêa,[72] L. Gráf,[66] L. Grandi,[20] J. Grigat,[37] B. Grinstein,[86] M.G.D.van der Grinten,[31] R. Grössle,[41] H. Guan,[9] M. Guida,[66] R. Gumbsheimer,[41] C.B. Gwilliam,[38] C.R. Hall,[24] L.J. Hall,[43,40] R. Hammann,[66] K. Han,[87] V. Hannen,[13] S. Hansmann-Menzemer,[64] R. Harata,[88] S.P. Hardin,[9] E. Hardy,[89] C.A. Hardy,[79] K. Harigaya,[90,91] R. Harnik,[70] S.J. Haselschwardt,[40] M. Hernandez,[86] S.A. Hertel,[92] A. Higuera,[78] C. Hils,[82] S. Hochrein,[5] L. Hoetzsch,[66] M. Hoferichter,[93,94] N. Hood,[86] D. Hooper,[70,95] M. Horn,[96] J. Howlett,[23] D.Q. Huang,[14] Y. Huang,[48] D. Hunt,[10] M. Iacovacci,[67] G. Iaquaniello,[52] R. Ide,[88] C.M. Ignarra,[1,2] G. Iloglu,[9] Y. Itow,[88] E. Jacquet,[16] O. Jahangir,[11] J. Jakob,[13] R.S. James,[11] A. Jansen,[41] W. Ji,[1,2] X. Ji,[24] F. Joerg,[66] J. Johnson,[30] A. Joy,[19] A.C. Kaboth,[65,31] A.C. Kamaha,[48,97] K. Kanezaki,[98] K. 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Backgrounds

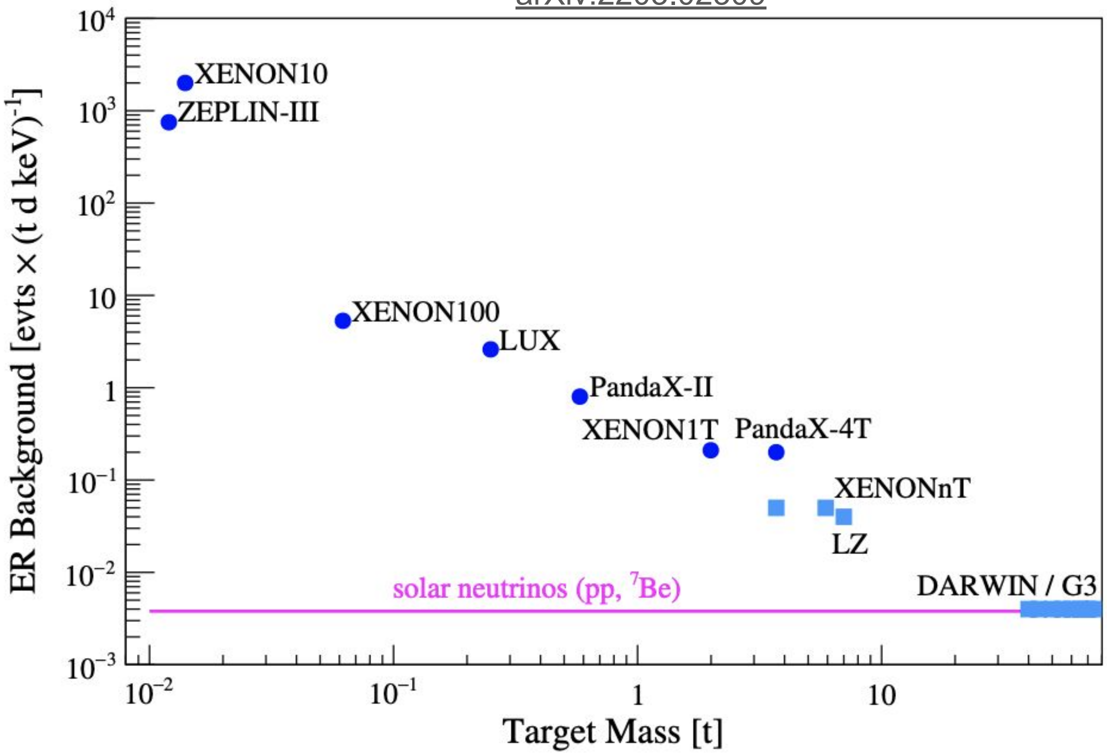
Goal is to be dominated by neutrino backgrounds

^{222}Rn challenging but there is R&D to fix it

^{85}Kr purity levels sufficient for next generation achieved

Self-shielding from γ-ray and neutron backgrounds

arXiv:2203.02309



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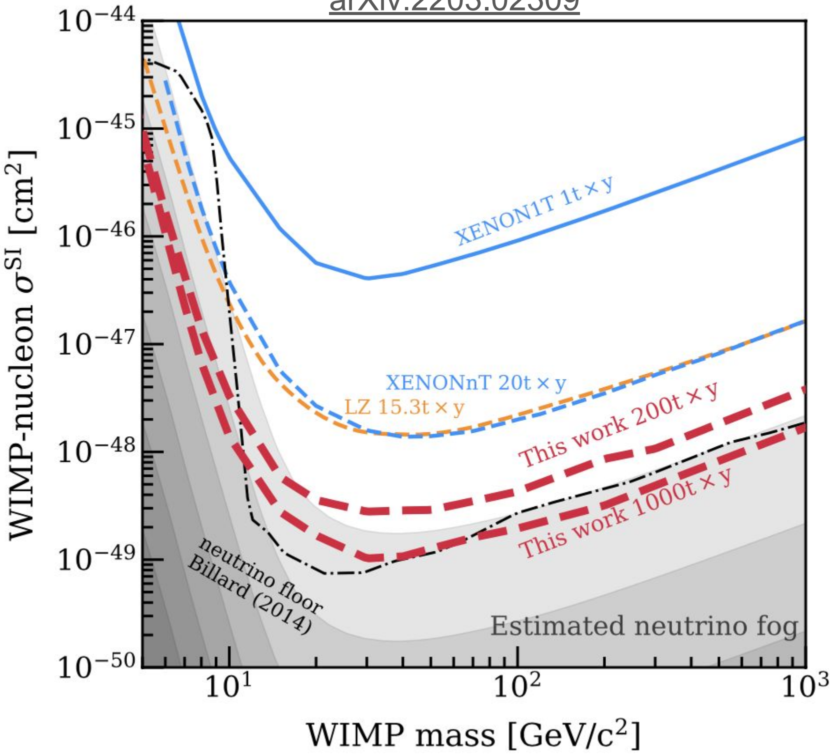


Weakly Interacting Massive Particles

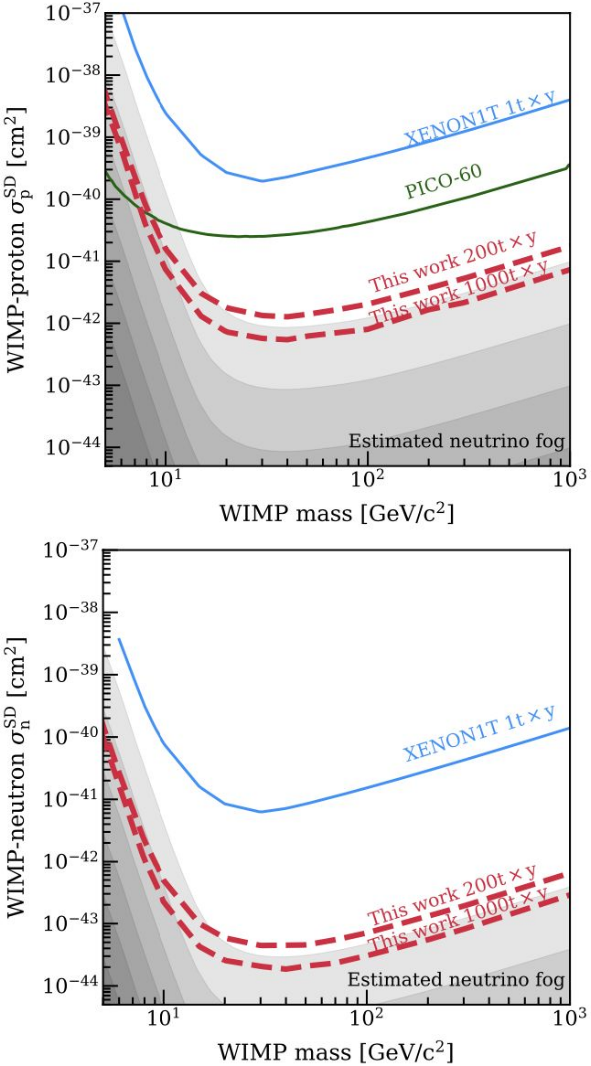
Spin independent interactions

Chase WIMPs to the neutrino floor!

Solar neutrino electron scattering

^{8}B, HEP, diffuse supernovae, atmospheric coherent neutrino-nucleus scattering

^{136}Xe double beta decay

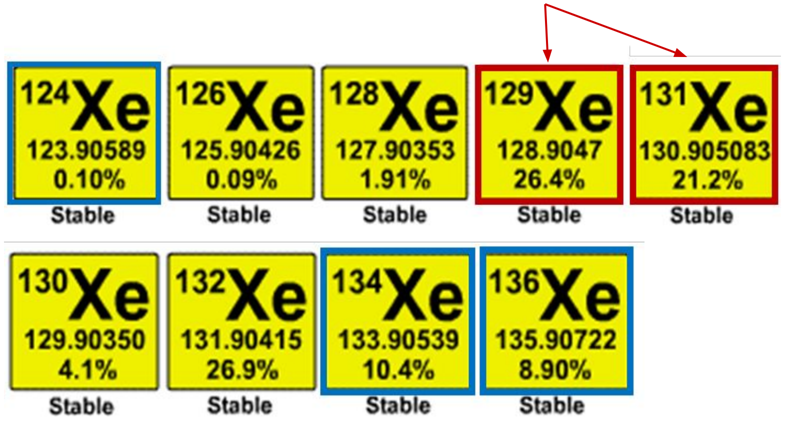


arXiv:2203.02309

Weakly Interacting Massive Particles

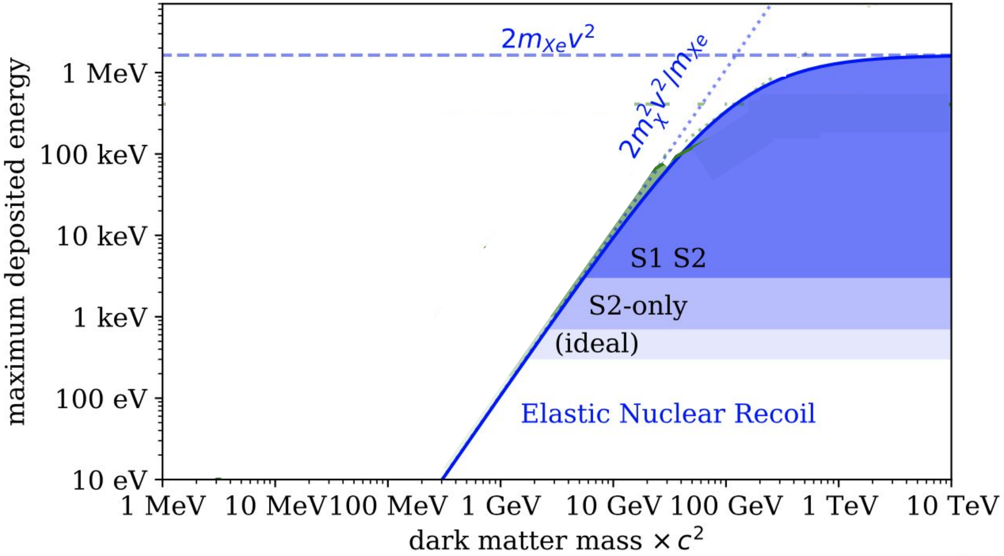
Spin dependent interactions

Unpaired neutrons

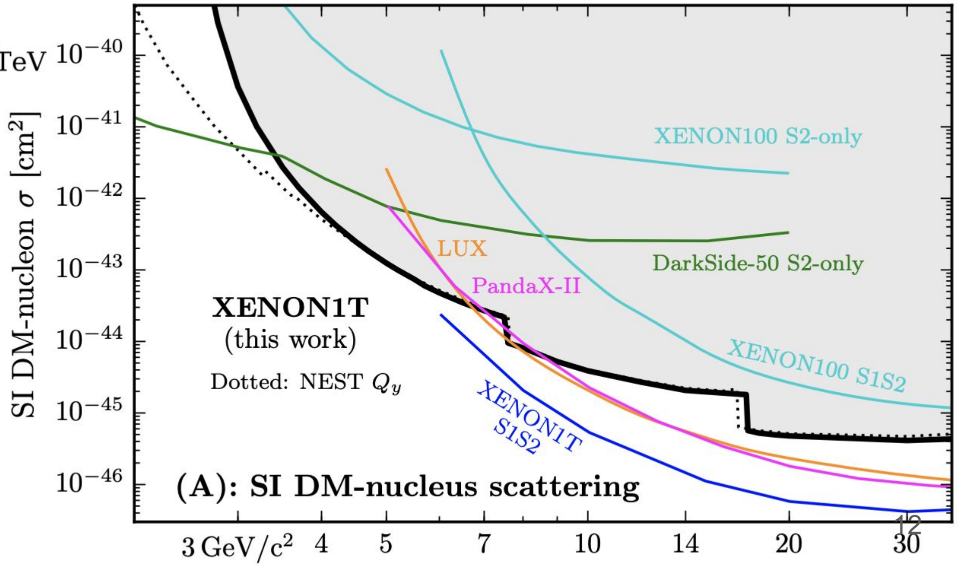


Light WIMPs

arXiv:2203.02309



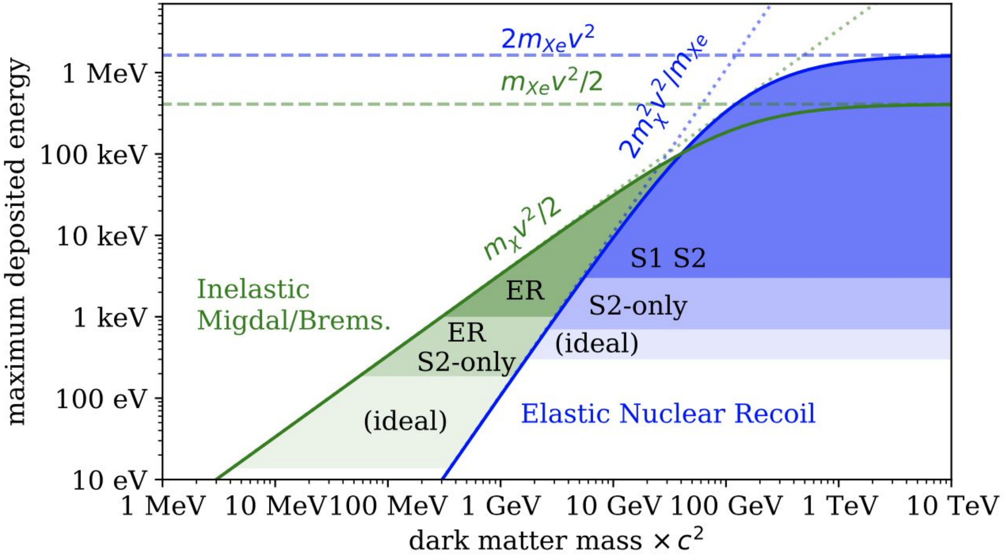
Phys. Rev. Lett. 123, 251801



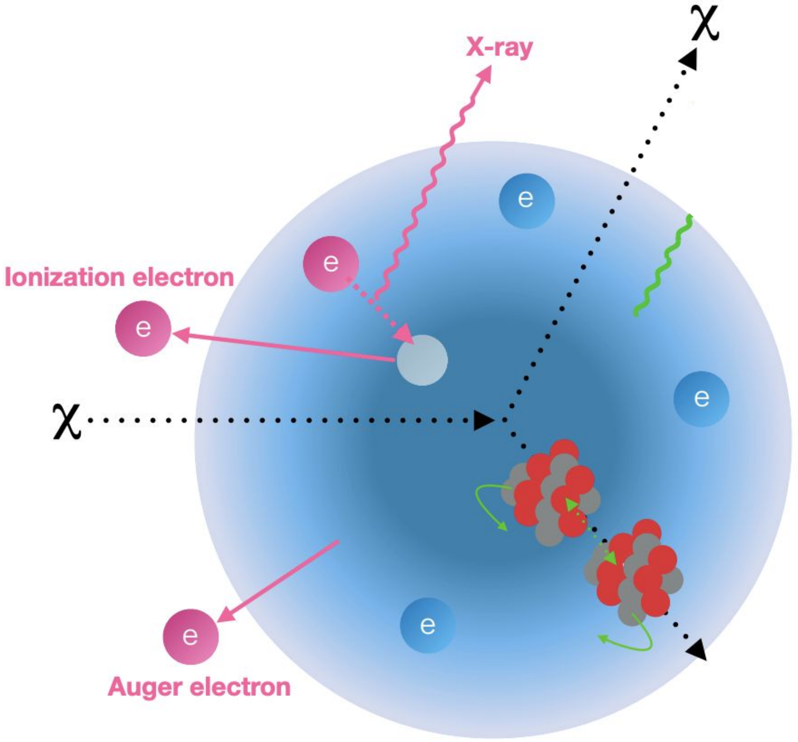
Scintillation agnostic

m_χ ~ few GeV

arXiv:2203.02309



Light WIMPs



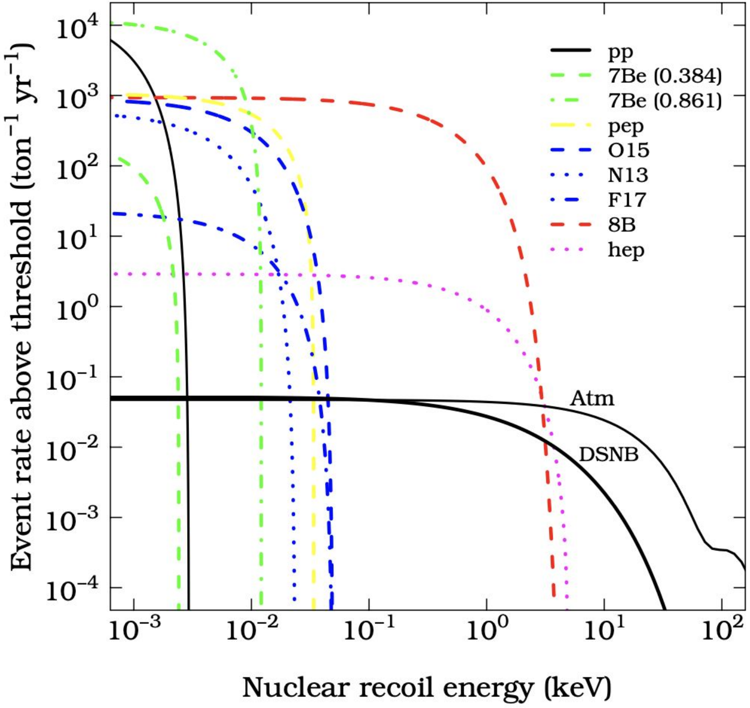
Migdal effect

m_χ ~ few-hundred MeV

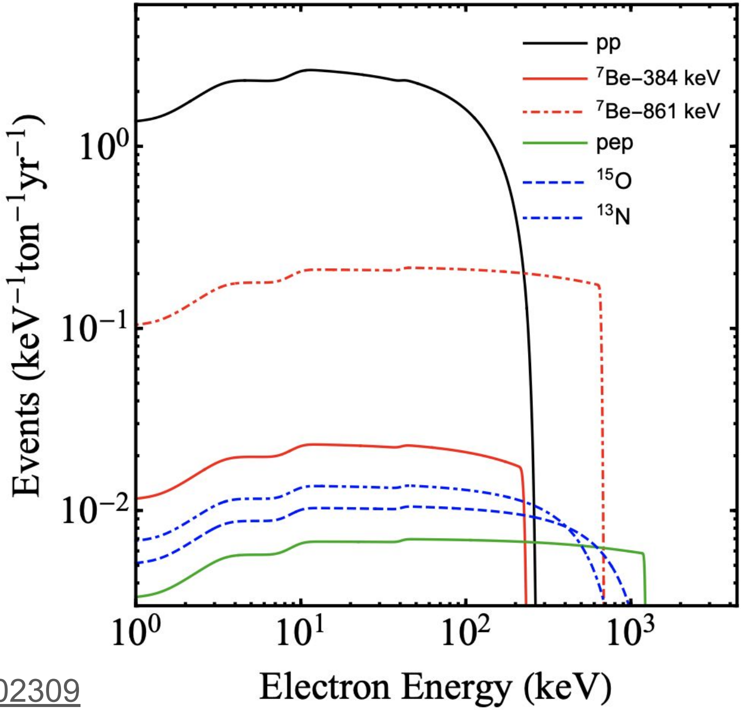
arXiv:1907.12771

Astrophysical neutrinos

^{8}B solar neutrinos
→ ready for supernova neutrinos

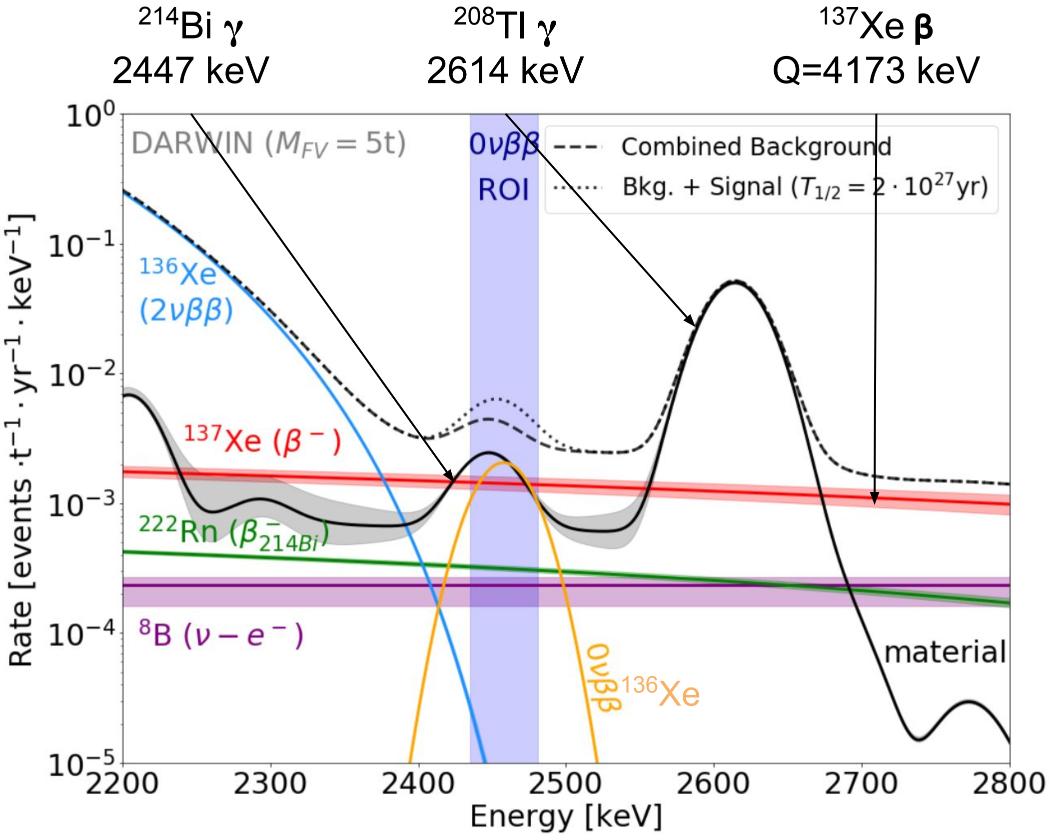


pp solar neutrinos
300 t×yr→ new solar physics

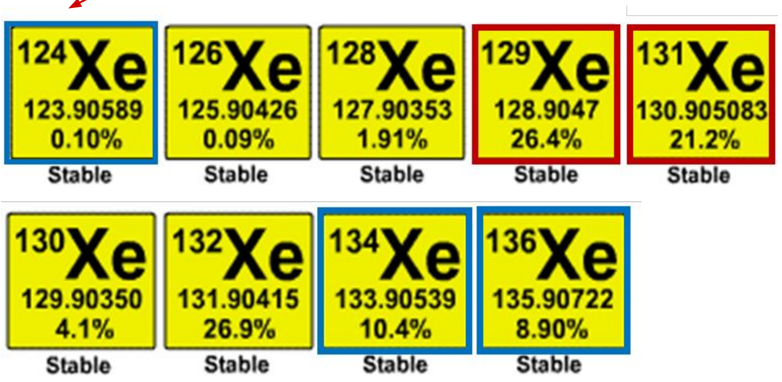


arXiv:2203.02309

Promising isotopes



Double electron capture



Neutrinoless double beta decay

arXiv:2003.13407

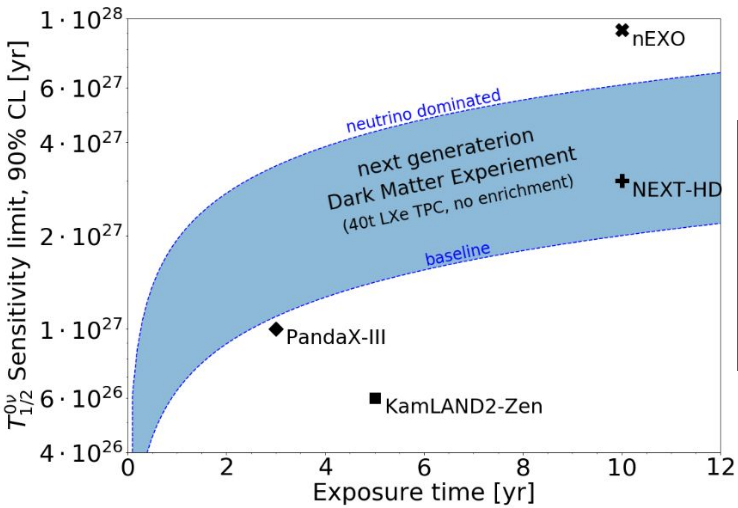
^{136}Xe neutrinoless double beta decay

γ-ray backgrounds from detector components and external environment

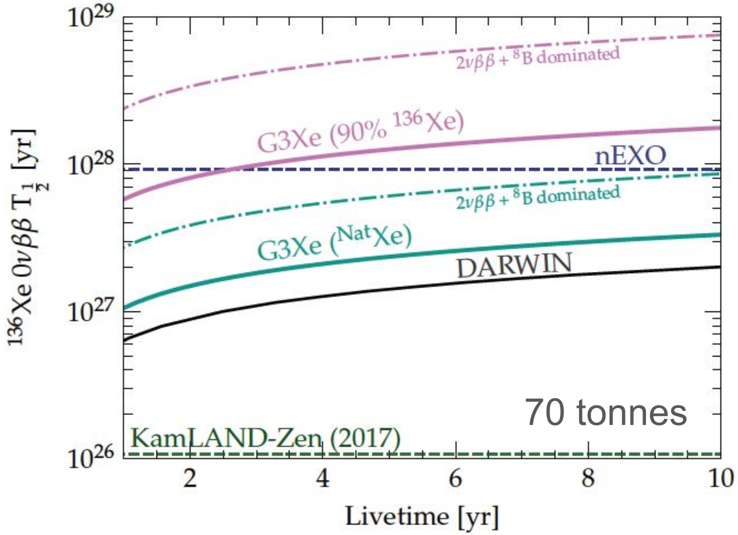
- ^{208}Tl 2614 keV → impact strongly mitaged by 1% **σ**/E
- ^{214}Bi 2447 keV → impact mitigated by self shielding of larger detector

^{137}Xe from neutron capture and cosmogenic activation

With major investment in controlling backgrounds (beyond DM needs) could match nEXO sensitivity



arXiv:2003.13407



Xenon Futures R&D Programme

UK has started the R&D phase towards a G3 experiment

Exploring SiPM readout for γ-ray and radon background reduction

Advanced radioassay techniques and cold radon emanation (Xinran Liu, Apr 5th, 12:15)

Attempting observation of the Migdal effect from nuclear recoils (Tim Marley, Apr 4th, 15:15)

University of BRISTOL

The University Of Sheffield.

Science & Technology Facilities Council
Rutherford Appleton Laboratory

KING'S College LONDON

UNIVERSITY OF LIVERPOOL

Imperial College London

UCL

UNIVERSITY OF OXFORD

ROYAL HOLLOWAY UNIVERSITY OF LONDON

THE UNIVERSITY of EDINBURGH

Additional Slides

Dual-phase Xe time projection chamber

S1: prompt scintillation

S2: ionization signal, electrons drifted upward and extracted into the gas phase region to create secondary scintillation

3D position reconstruction