Nov 11th, 2019
Magnificent CEvNS 2019

Topics from Tokyo workshop "Dark matter searches in the 2020s - At the crossroads of the WIMP"

Kentaro Miuchi
(Kobe University)

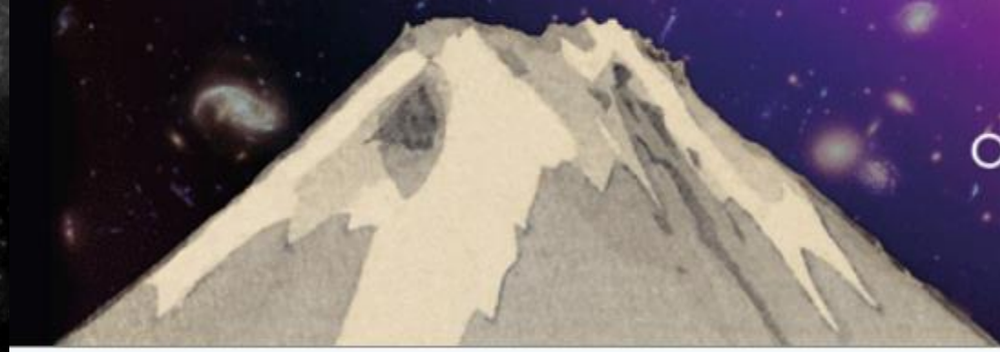
- Overview
- ν as a signal
- CEvNS BG

科研費
KAKENHI

Dark Matter searches in the 2020s

At the crossroads of the WIMP

Symposium on next-generation collider, direct, and indirect Dark Matter searches



11-13 November 2019
The University of Tokyo, Kashiwa Campus

https://indico.icrr.u-tokyo.ac.jp/event/259/overview

- starting tomorrow

- DM workshop
  - Collider + Direct + Indirect + Astro + Theory
  - 2 focused sessions

main message (would be) :
important to search for WIMPs down to (and beyond) the neutrino floor.
important to understand CEvNS

Focused Session: Neutrino Floor

Dr Kentaro Miuchi

The Neutrino Floor	*Prof. Kate Scholberg*
The University of Tokyo, Kashiwa Campus	16:30 - 17:00
Discussion of experimental approach to go beyond the neutrino floor in the WIMP search	*Dr Tatsuhiro Naka*
The University of Tokyo, Kashiwa Campus	17:00 - 17:30
Breaking through the neutrino floor	*Dr Ciaran O'Hare*
The University of Tokyo, Kashiwa Campus	

The University of Tokyo, Kashiwa Campus

Focused Session: Charged particles

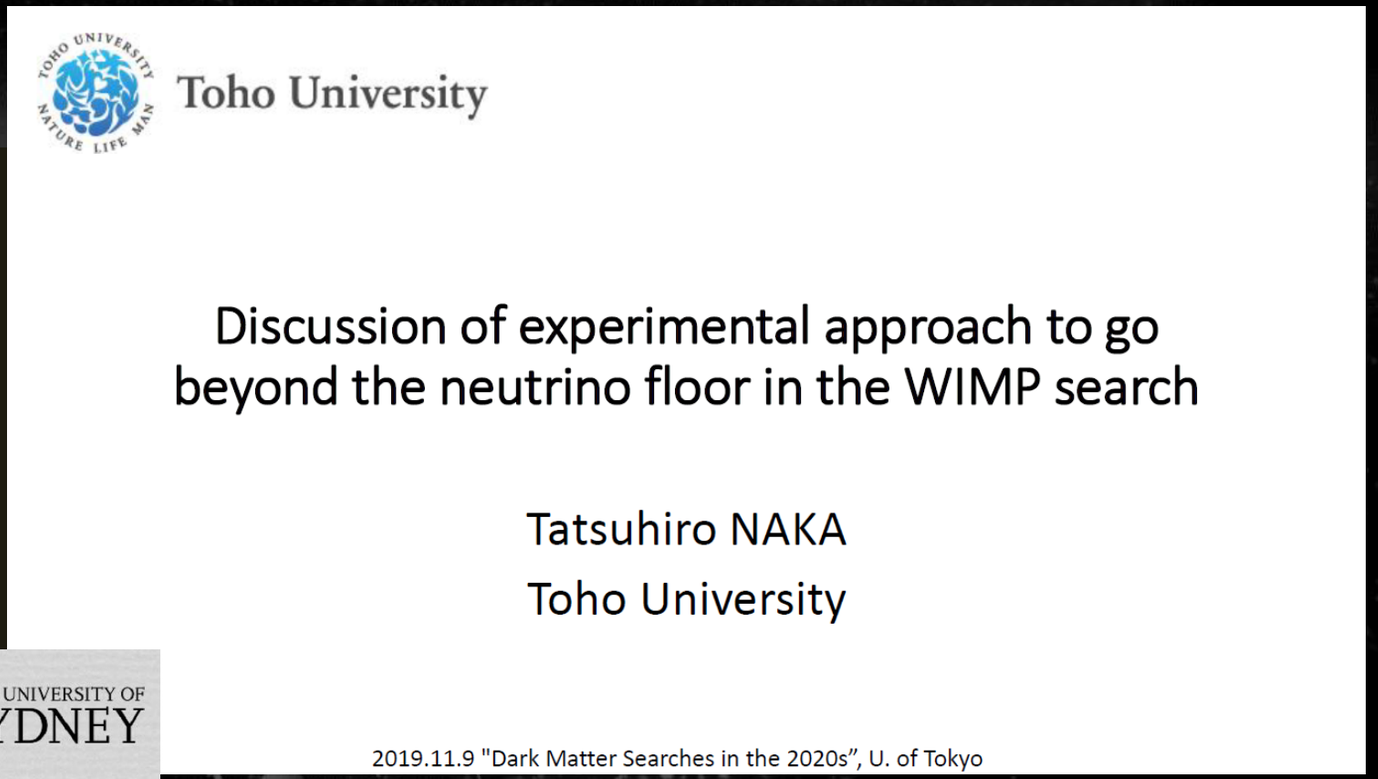
Dr Moritz Hütten

Recent Results and Dark Matter Search with CALET on the ISS	*Yoichi Asaoka*
The University of Tokyo, Kashiwa Campus	13:30 - 14:00
Propagation processes of cosmic rays	*Yutaka Ohira*
The University of Tokyo, Kashiwa Campus	14:00 - 14:30
Constraints on cosmic ray propagation and magnetic fields using gamma-ray observations	*Dr Rubén López-Coto*
The University of Tokyo, Kashiwa Campus	14:30 - 15:00

The University of Tokyo, Kashiwa Campus

Focused Session: Neutrino Floor

Dr Kentaro Miuchi



Nov 11th 16:30- (JST)
https://bluejeans.com/177369462

Neutrino Floor

- being mentioned from early stages
- became realistic in these 10 years

CYGNUS 2007

First Workshop on Directional Detection of Dark Matter

22-24 July 2007

Boulby Underground Laboratory, UK

Jocelyn Monroe	MIT	Neutrino backgrounds to dark matter searches
Tim Lawson	Sheffield	Alpha background in the DRIFT TPC

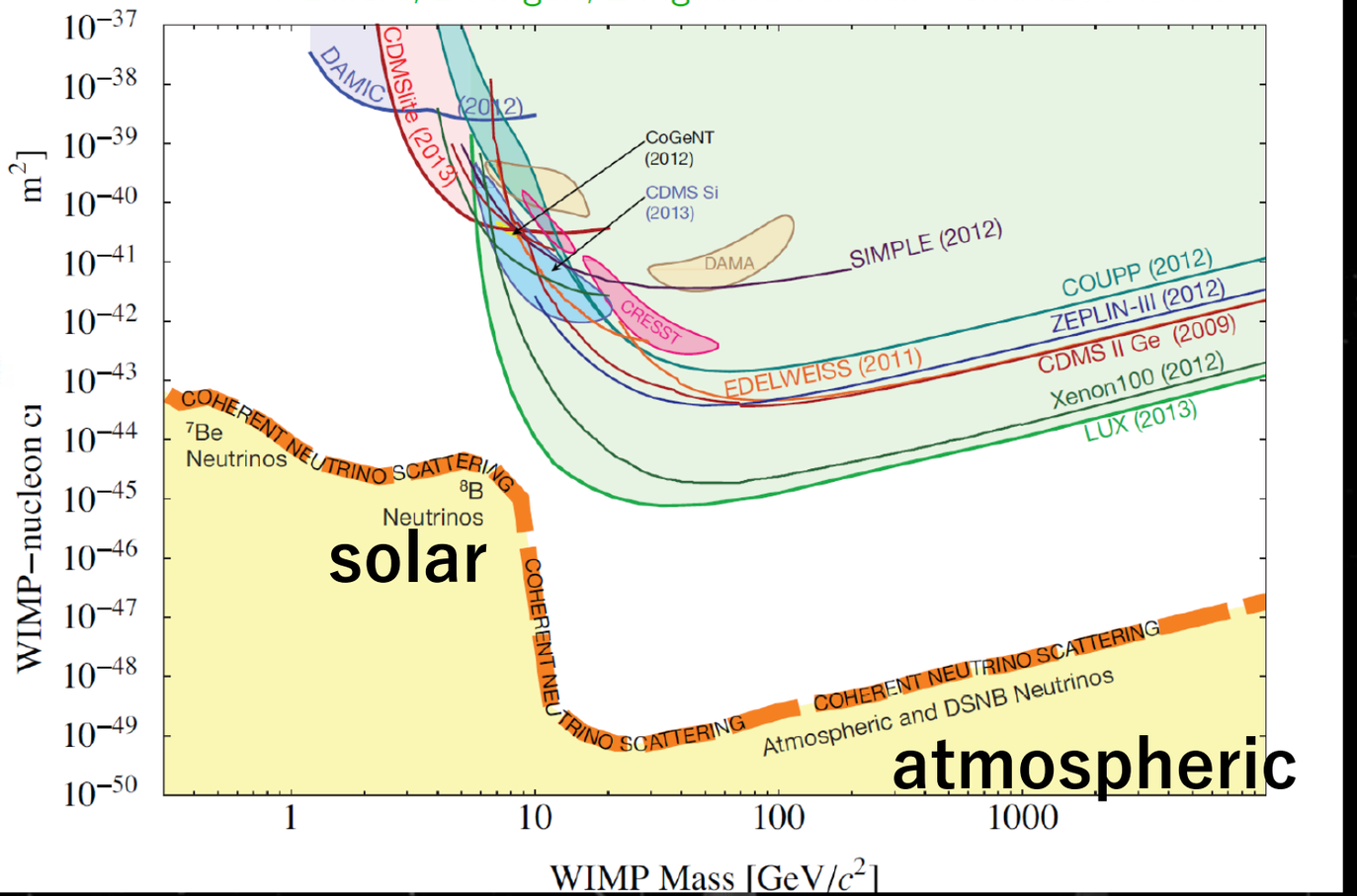
detectors

solar ^{8}B coherent neutrino scattering events per ton-year:

nucleus	total	T>2 KeV	T>5 KeV	T>10 KeV
^{12}C	235.7	191.8	104.1	36.0
^{19}F	378.0	204.1	88.8	13.3
^{40}Ar	804.8	231.4	21.0	<1.0
^{76}Ge	1495.0	111.5	<1.0	<1.0
^{132}Xe	2616.9	14.7	<1.0	<1.0

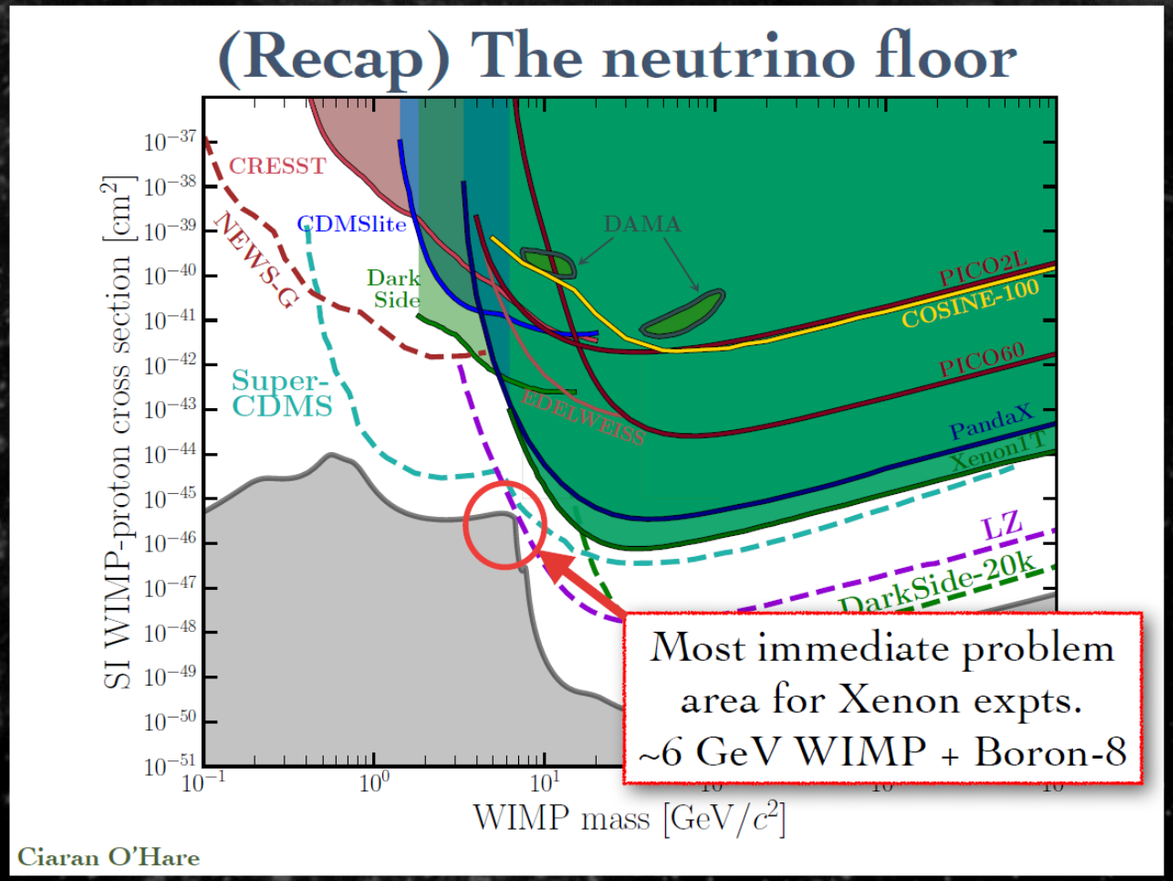
* current experimental recoil energy thresholds

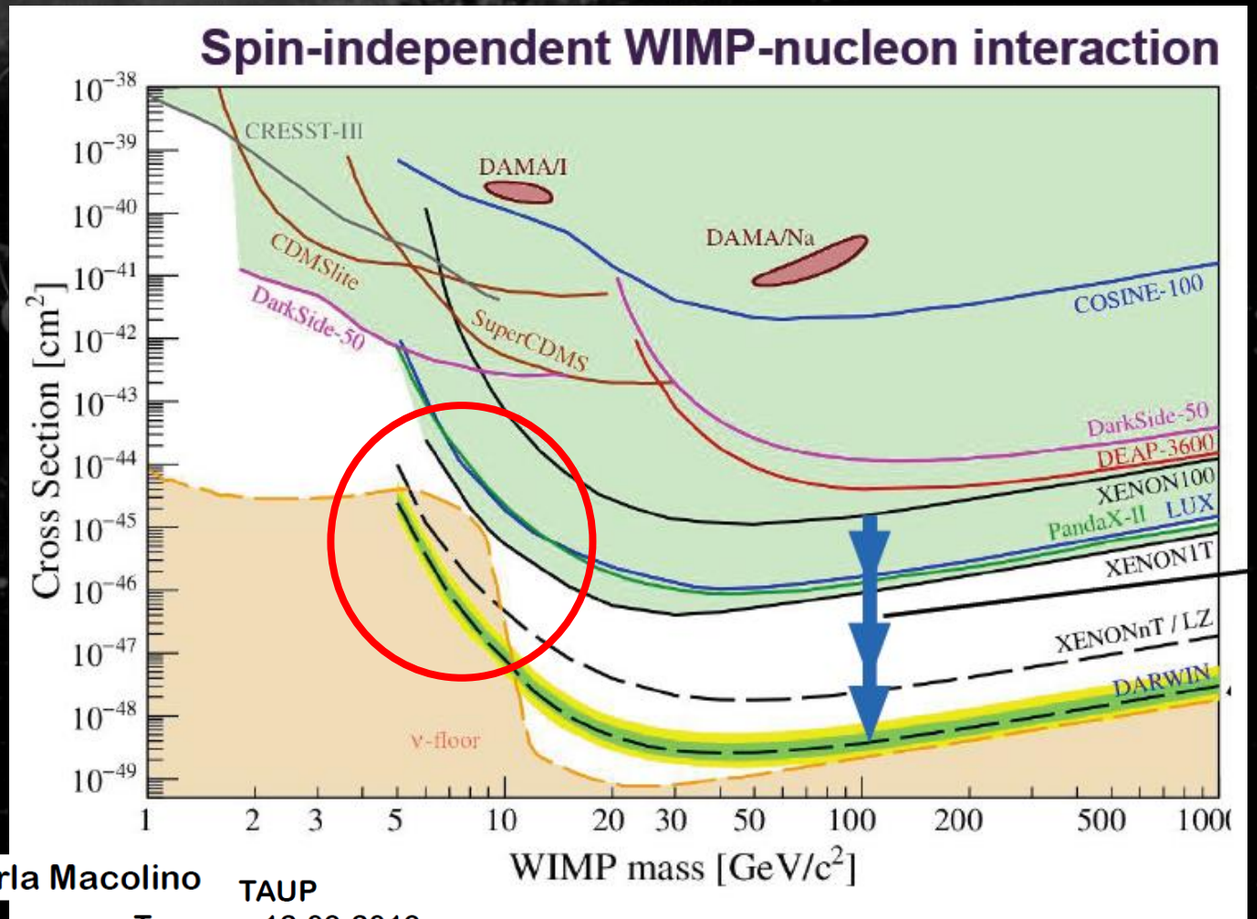
J Billard, L Strigari, E Figueroa-Feliciano arXiv:1307.5458



Neutrino Floor: Magnificent background

- Upcoming Xe detectors start to hit ^{8}B shoulders
- Future detectors are approaching atmospheric floor





The Neutrino Floor

Kate Scholberg, Duke University
Dark Matter Searches in the 2020's
November 11, 2020

How well do we know where the neutrino floor is?

$$\text{Rate} \propto \text{Flux} \otimes \text{Cross section}$$

Solar flux known to ~% level... others not so much...

CEvNS xscn predicted at **few % level in SM**...

K. Scholberg
DM in 2020s

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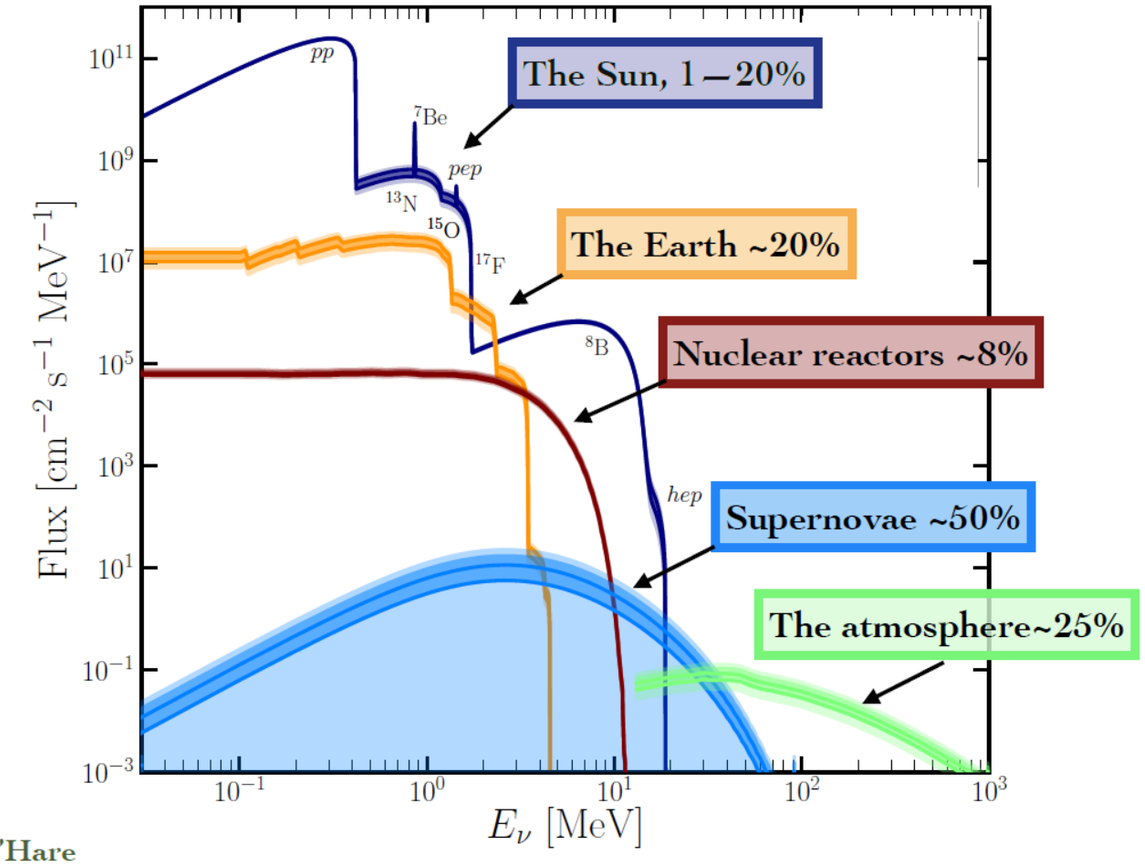
(Recap) Neutrino fluxes + Uncertainties



Ciaran O'Hare

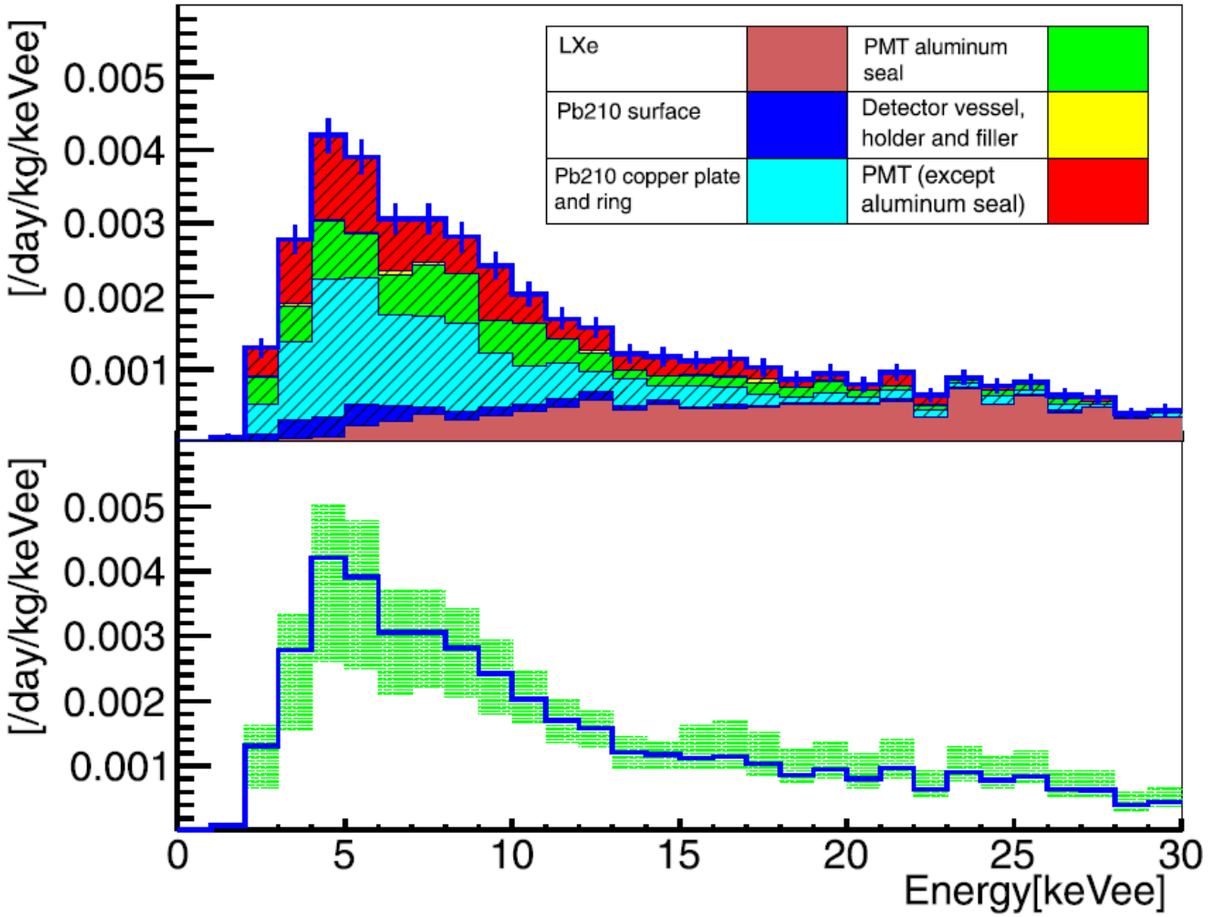
Kentaro Miuchi

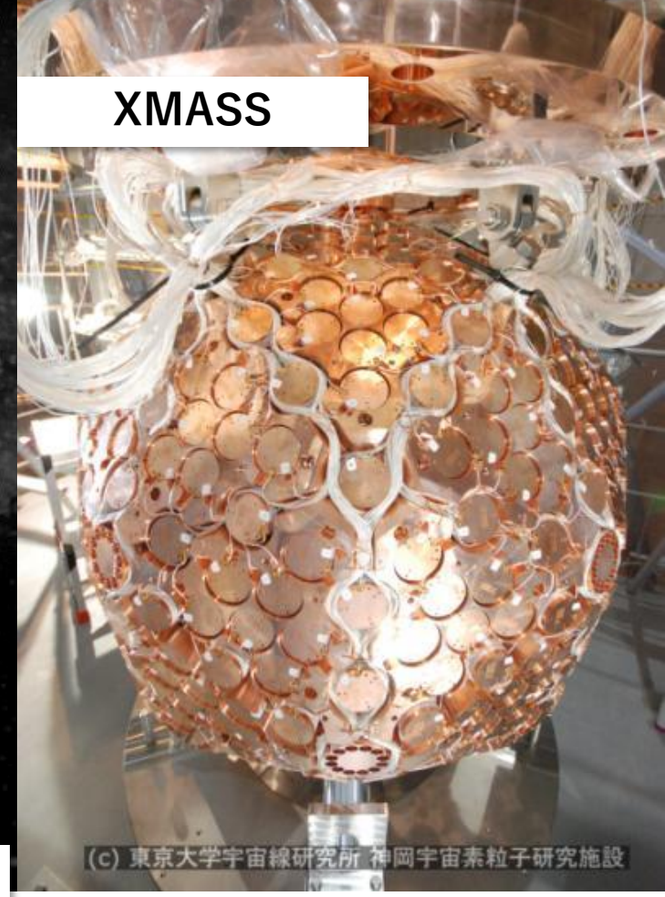
- BG subtraction: XMASS's case
  - intensive BG study
  - WIMP upper limits are the size of the systematic error

A direct dark matter search in XMASS-I

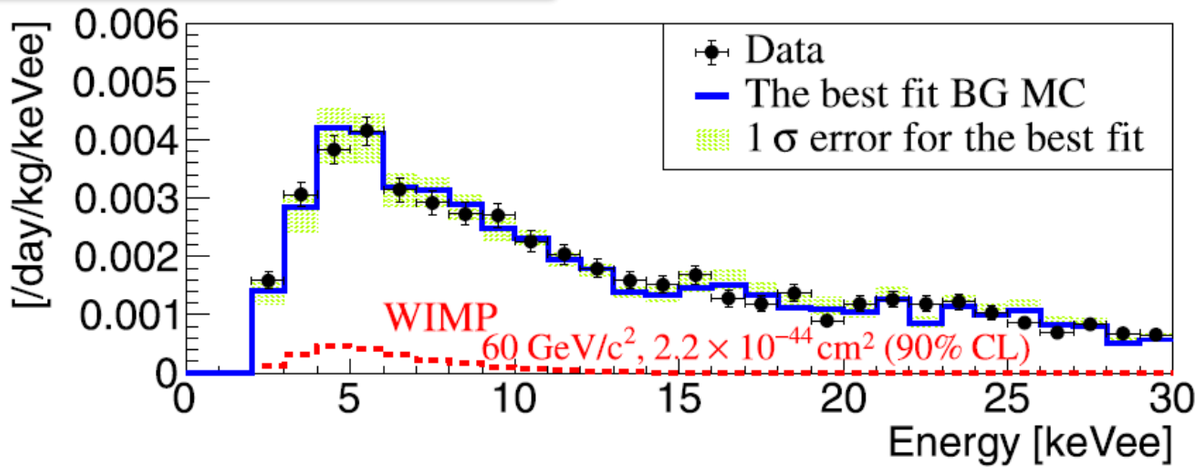
XMASS Collaboration *

Physics Letters B 789 (2019) 45–53





WIMP upper limits



But what if there's BSM physics?

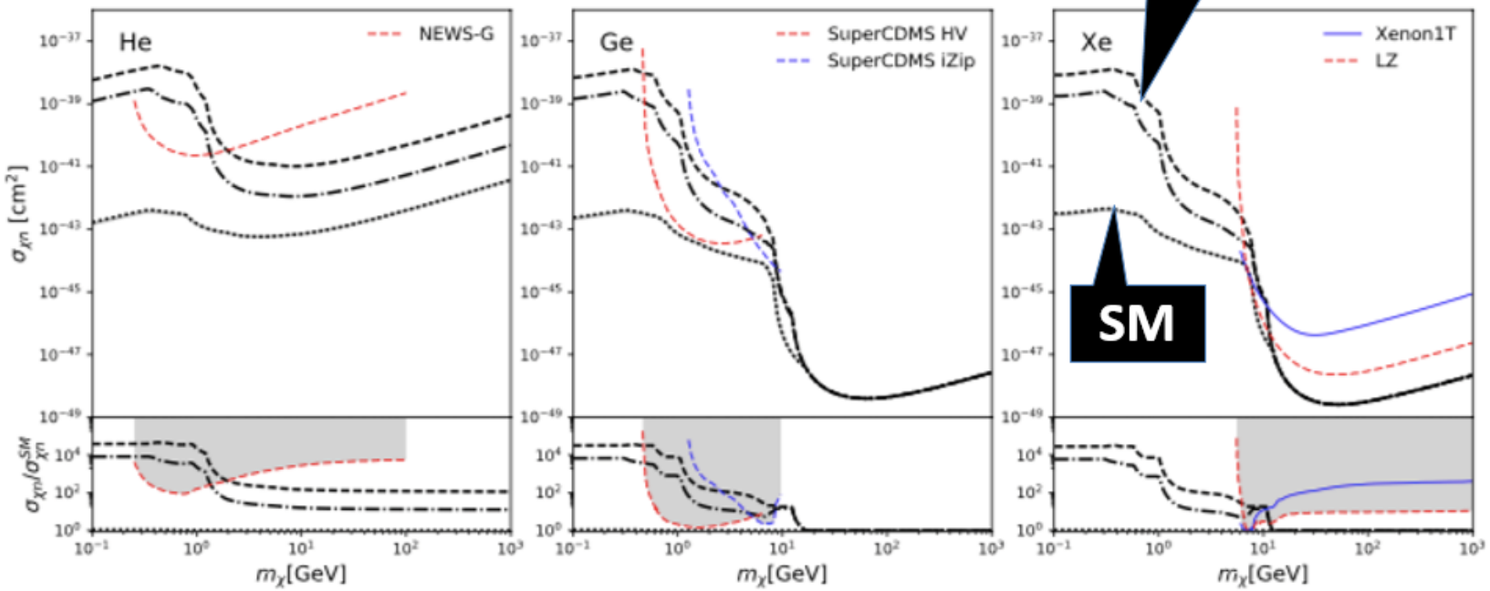
Non-standard interactions could raise

How high is the neutrino floor?

C. Bœhm[a,b], D.G. Cerdeño[c], P.A.N. Machado[d], A. Olivares-Del Campo[c], E. Perdomo[e] and E. Reid[c]

Published 21 January 2019 • © 2019 IOP Publishing Ltd and Sissa Medialab
Journal of Cosmology and Astroparticle Physics, Volume 2019, January 2019

New scalar mediator in the neutrino sector



We need to *measure* CEvNS!

K. Scholberg
DM in 2020s
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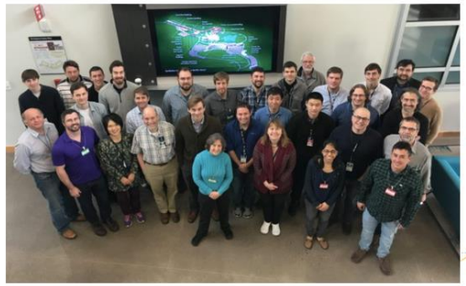
The COHERENT collaboration

http://sites.duke.edu/coherent



~90 members,
21 institutions
4 countries

arXiv:1803.09183v2

ENERGY Office of Science · NSF · KICP · NASA · CNEC

COHERENT · SNS Spallation Neutron Source · Oak Ridge National Laboratory · Duke University · TUNL · Indiana University · Sandia National Laboratories · The University of Tennessee Knoxville · Los Alamos National Laboratory · NC State University · University of Washington · The University of Chicago · NM State · MPPI · UF University of Florida The Foundation for The Gator Nation · KAIST · North Carolina Central University · Carnegie Mellon University · Tufts University · Virginia Tech · Laurentian University Université Laurentienne · University of South Dakota

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- We expect good progress in CEvNS measurement!

Centre for Dark Matter Particle Physics

THE UNIVERSITY OF SYDNEY

Breaking through the neutrino floor

Ciaran O'Hare
University of Sydney

How to break through the neutrino floor

5 methods, increasing effectiveness

1. Detect *a lot* of events
2. Improve neutrino flux measurements
3. Use annual modulation
4. Have multiple target nuclei
5. Use directional detectors

C. O'hare
DM in 2020s

~~Method 1: Detect a lot of events~~

~~Method 2: Improve neutrino flux measurements~~

~~Method 3: Use annual modulation~~

Method 4: Use multiple targets

This helps too, but only substantially for SD interactions, and still requires a lot of events

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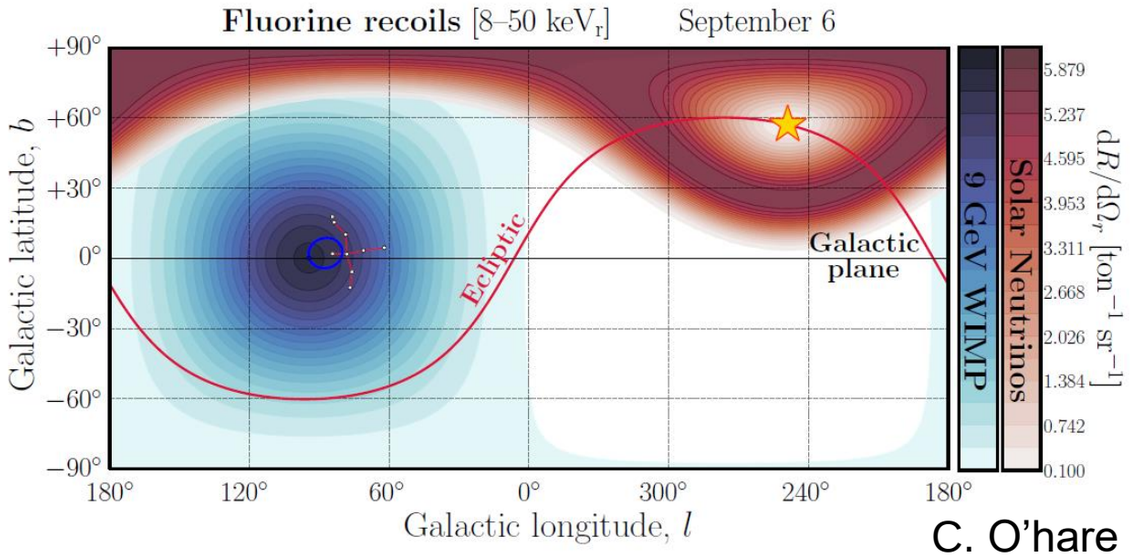
Nothing mimics dark matter, including solar neutrinos



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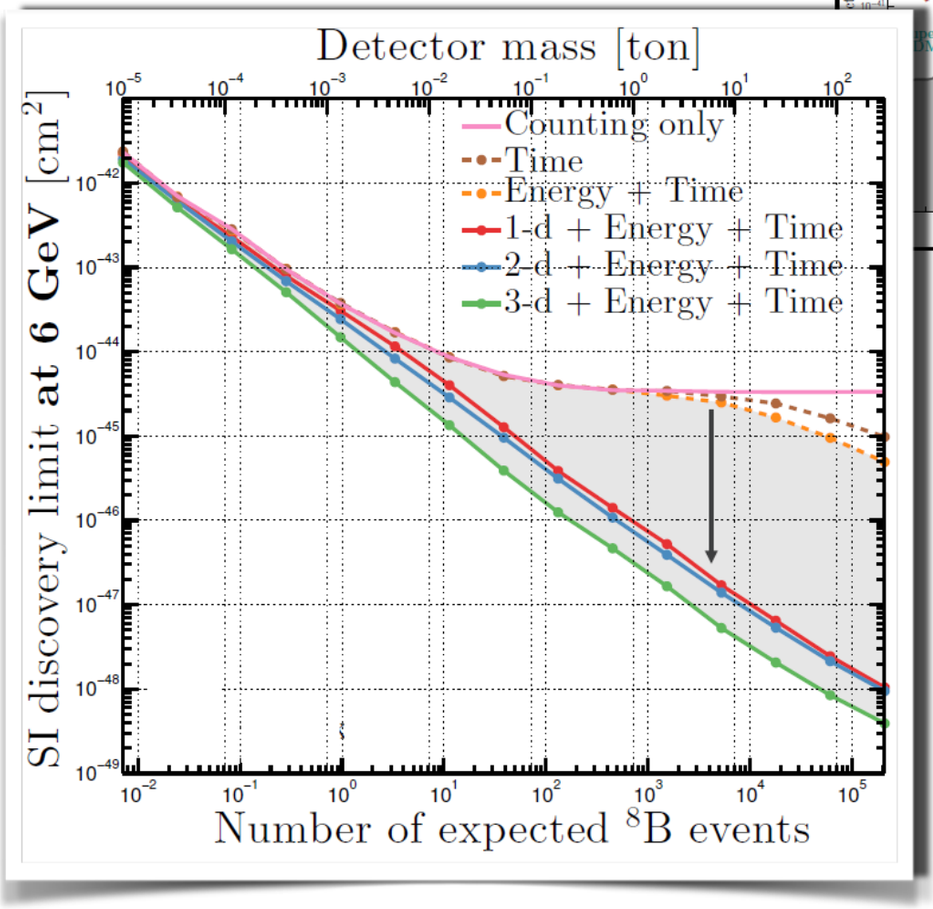
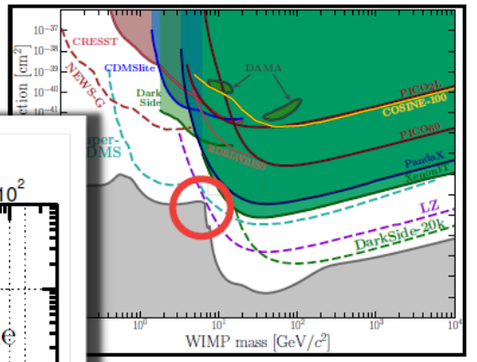
Comparing methods: Solar





Directionality powerful for subtracting Solar neutrinos

C. O'hare
DM in 2020s

Kentaro Miuchi

- We are not afraid of the floors

Toho University

Discussion of experimental approach to go beyond the neutrino floor in the WIMP search

Tatsuhiro NAKA
Toho University

2019.11.9 "Dark Matter Searches in the 2020s", U. of Tokyo

Current project using the detector already demonstrated direction sensitivity

Direct tracking

Gaseous target

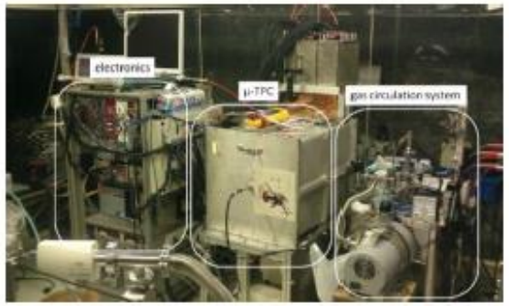
- DRIFT
- NEWAGE
- MIMAC
- D^3

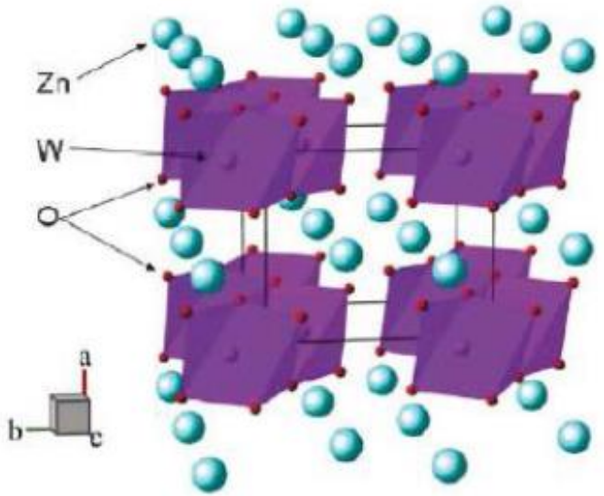
Solid target

- NEWSdm

Indirect direction information

- ZnWO3



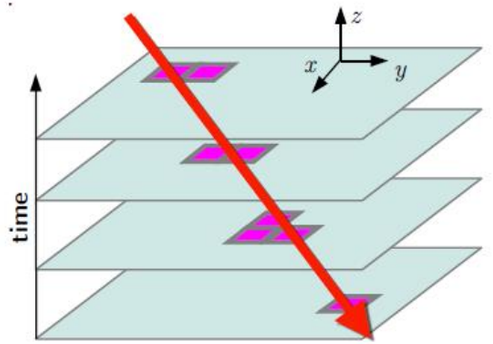


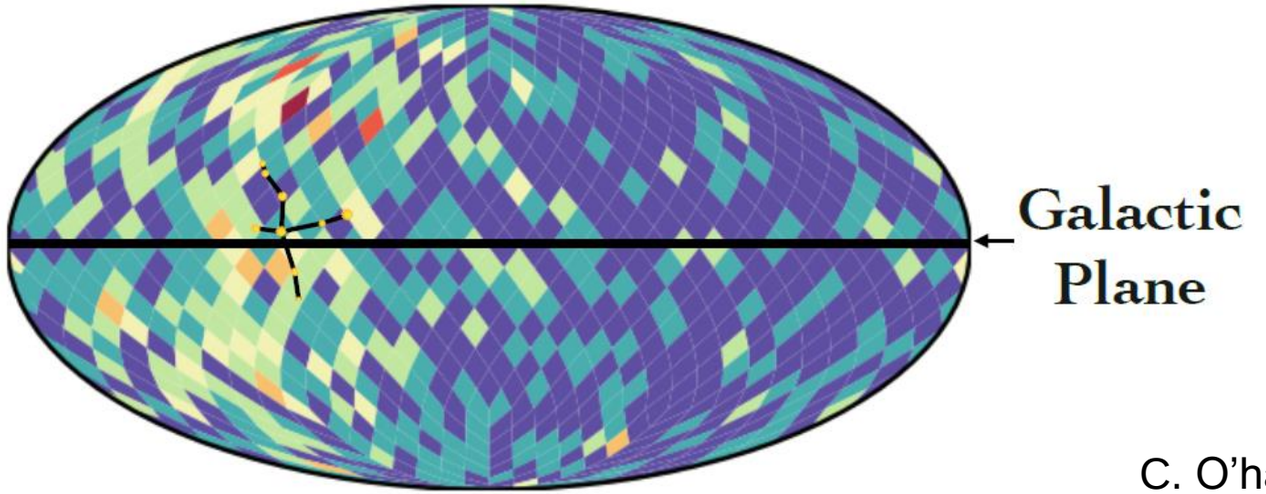
- Gas TPCs

Measuring the full track: 3D readout

All recoils are 3D **vectors** and are time-tagged so can be reoriented in the Galactic frame:

$$\hat{\mathbf{q}} = \sin\theta\cos\phi\hat{\mathbf{x}} + \sin\theta\sin\phi\hat{\mathbf{y}} + \cos\theta\hat{\mathbf{z}}$$





C. O'hare
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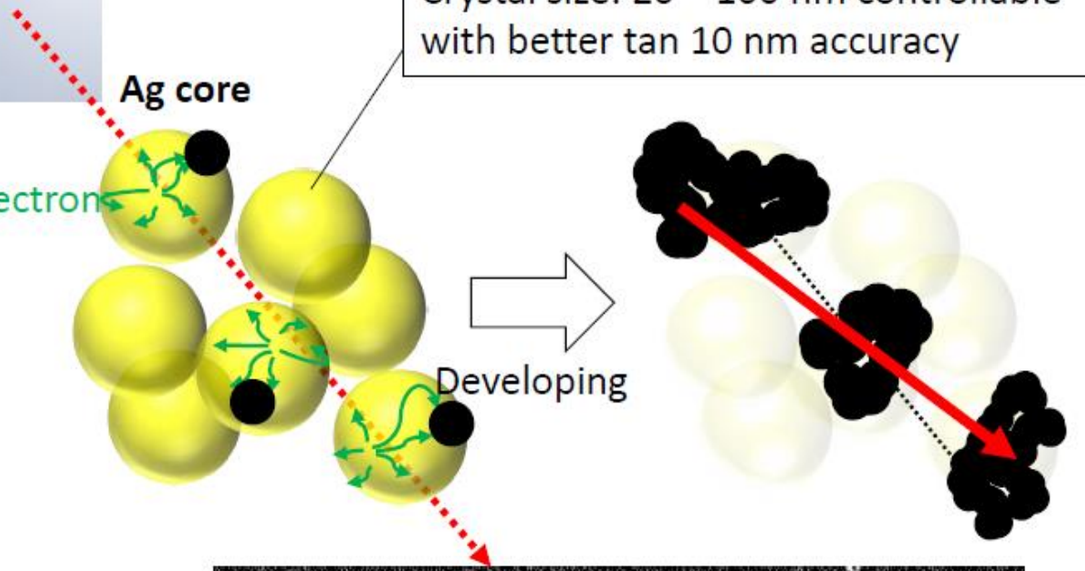
K. Scho
DM in 2

- see Neil's talk

• Nuclear Emulsion

Super-fine Grained Nuclear Emulsion [Nano Imaging Tracker : NIT]

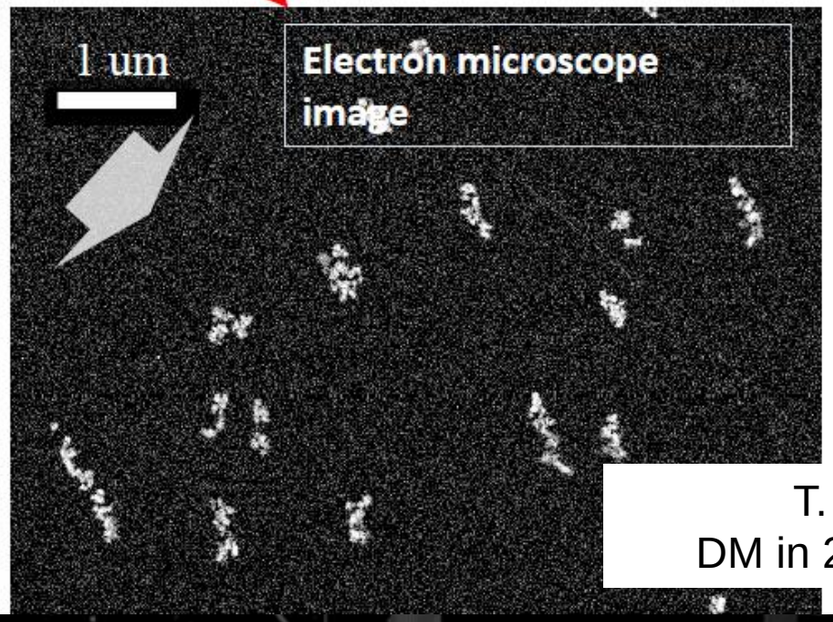


Elemental composition of NIT

	Mass fraction	Atomic Fraction
Ag	0.44	0.10
Br	0.32	0.10
I	0.019	0.004
C	0.101	0.214
O	0.074	0.118
N	0.027	0.049
H	0.016	0.410
S, Na + others	~ 0.001	~ 0.001

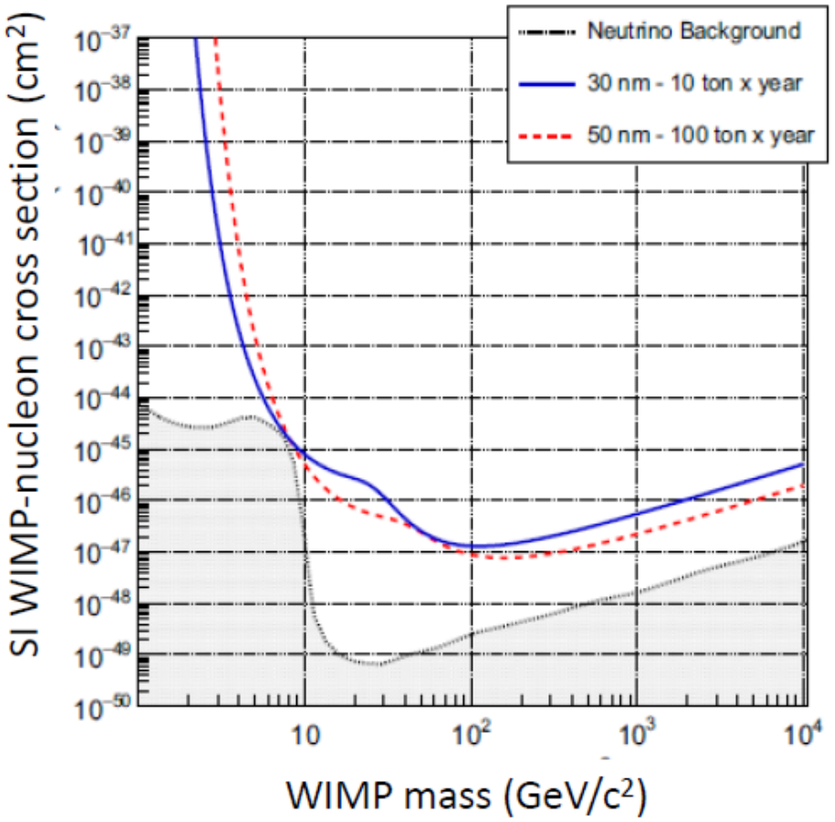
For high-mass DM s

For low-mass DM



T. Naka
DM in 2020s

Toward neutrino floor



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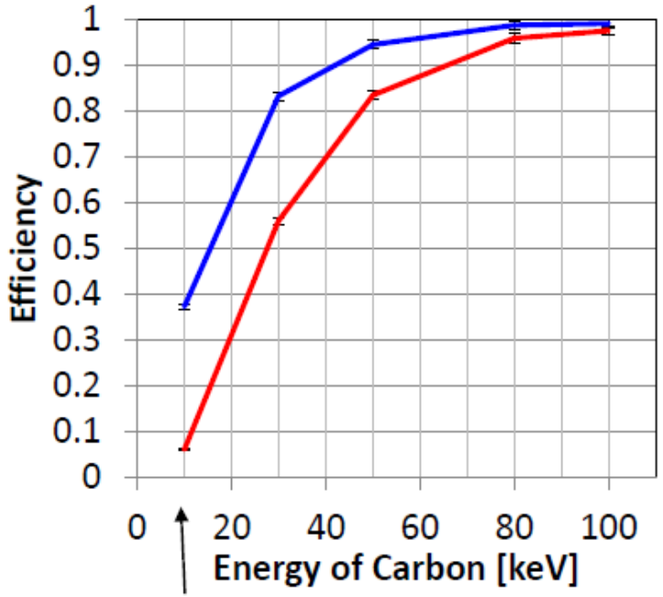
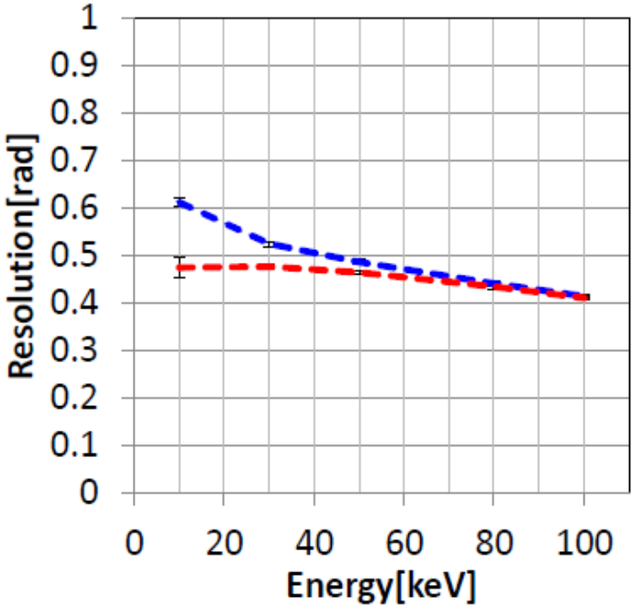
Simulation for NIT device intrinsic potential



35 nm C : 10 keV
Br : 45 keV
Ag : 55 keV



☑ 10 ton production : special machine optimized this device is required (more simple system : current machine is over speck)

☑ High scanning speed machine is needed (current highest machine in the nuclear emulsion field is 1 ton/y)

☑ under discussing whether light emission information from NIT

- anisotropic crystals

$ZnWO_4$

- Proposed by ADAMO Group in 2011
- Reported 40-50 % anisotropy response for MeV alpha particle

Eur. Phys. J. C (2013) 73:2276
DOI 10.1140/epjc/s10052-013-2276-2

THE EUROPEAN PHYSICAL JOURNAL C

Regular Article - Experimental Physics

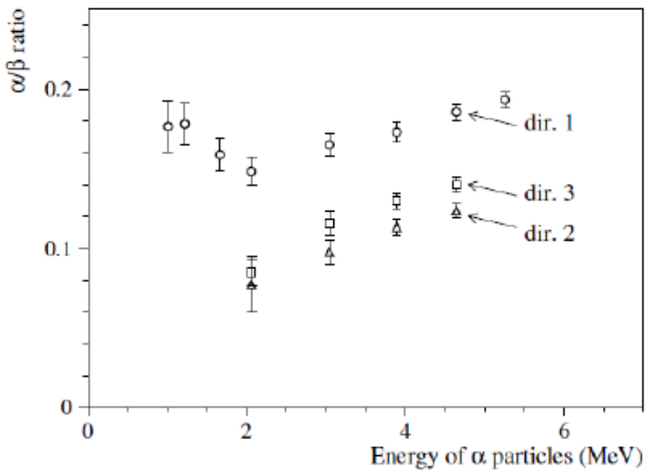
On the potentiality of the $ZnWO_4$ anisotropic detectors to measure the directionality of Dark Matter

F. Cappella[1], R. Bernabei[2,3,a], P. Belli[3], V. Caracciolo[4], R. Cerulli[4], F.A. Danevich[5], A. d'Angelo[1,6], A. Di Marco[2,3], A. Incicchitti[6], D.V. Poda[5], V.I. Tretyak[5]

Table 2 Quenching factors for O, Zn and W ions with energy 5 keV for different directions in $ZnWO_4$ crystal. Systematic uncertainties are estimated on the level of 20 % using data of [90]

Ion	Quenching factor		
	dir. 1	dir. 2	dir. 3
O	0.235	0.159	0.176
Zn	0.084	0.054	0.060
W	0.058	0.037	0.041

perpendicular to (010): dir1
(001): dir2
(100): dir3



ADAMO group
Reported α/β ratio of 55% anisotropic response

Eur. Phys. J. C (2013) 73:2276

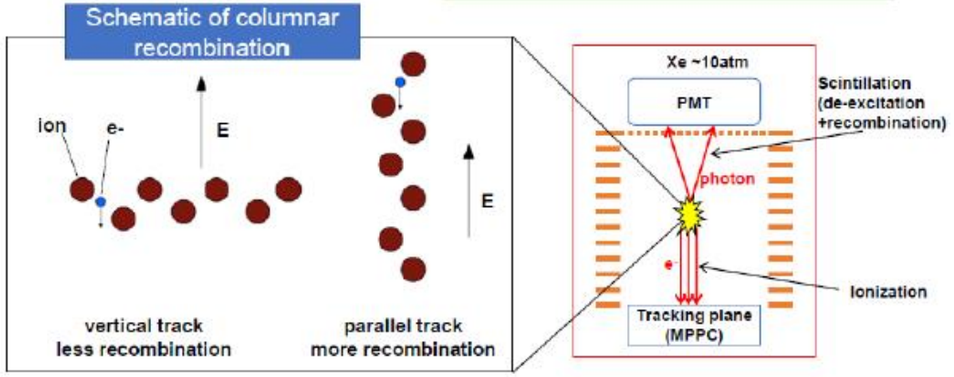
Current active groups
1. Italian Group (ADAMO)
2. Japanese Group (Prof. Sekiya *et al.*)

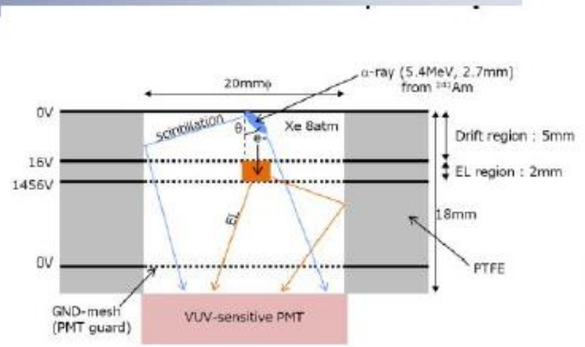
- and more…

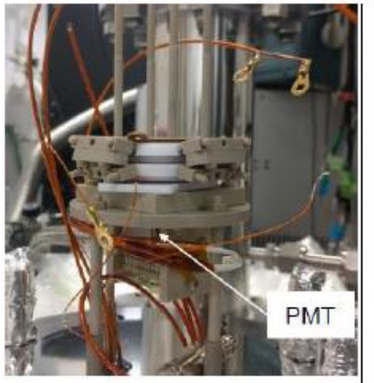
T. Naka
DM in 2020s

New idea and current effort for demonstration

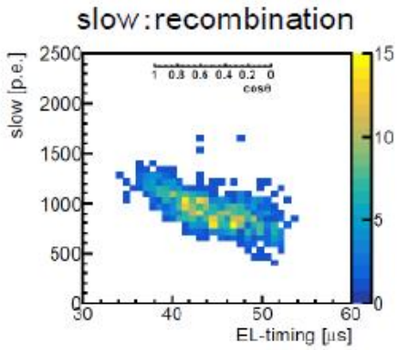
D. Nygren J Phys. Conf. Ser. 460 (2013) 012006

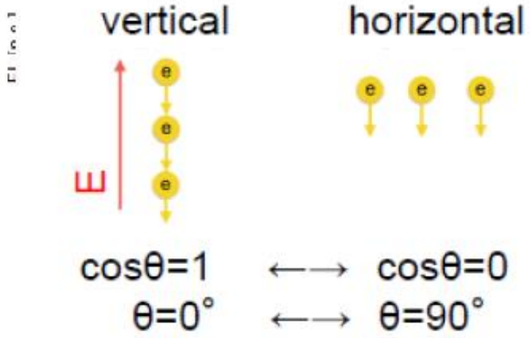






2018 J. Inst. 13 P07015





Columner recombination

- Recombination efficiency of ionized electrons should have dependence on relative direction between track and electric field
- Time profile of scintillation emission (especially slow component) should be affected

⇒ Directional search is possible if this effect would be confirmed in low-energy nuclear recoil

8 atom Xe gus

Observed angular dependence due to Colamnur recombination

20 % difference @alpha particle (~ MeV)

SUMMARY

- We have a magnificent CEvNS BG
- Several approaches are discussed
- Directionality is helpful