

Mar 21, 2024

● JPS 2024春

# 暗黒物質直接探索の現状

身内賢太郎  
(神戸大学)

情報提供ありがとうございます

岸本さん(東北大) 石徹白さん(東北大)

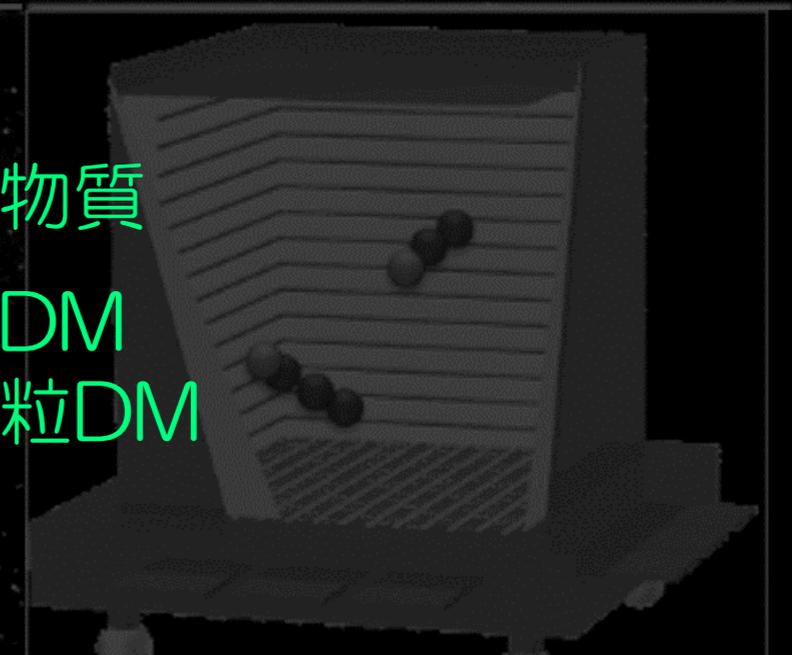
陳さん(東大ICEPP) 田島さん(京大) 安達さん(京大)

科研費  
KAKENHI

暗黒物質

波DM

粒DM



## 宇宙のダークマター直接探索の現状



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hamaguchi@phys.s.u-tokyo.ac.jp

see also

日本物理学会誌 第75巻  
(2020年) 第2号 68-76頁 交流

# 暗黒物質

基研研究会 素粒子物理学の進展2023

2023年8月28日-9月1日

開催方式: ハイブリッド

Aso workshop on Particle Physics and Cosmology 2023

Nov 12-15, 2023  
熊本県阿蘇市  
Asia/Tokyo timezone

Journal of Advanced Instrumentation in Science

JAIS-ID, 2023

Email address: miuchi@panda.kobe-u.ac.jp

Technical Report

## LaTeX Challenges for the directional dark matter direct detection

Kentaro Miuchi,<sup>1</sup>

<sup>1</sup>Department of Physics, Kobe University, Hyogo 657-8501, Japan.

<https://arxiv.org/abs/2309.13923>

to appear in JAIS

# • DM: seen in various scales in the universe

- @ galaxy: rotation curves (1970~)
- @ cluster of galaxies: collision of galaxy clusters (2007~)
- @ universe: CMB and other observations (2002~)

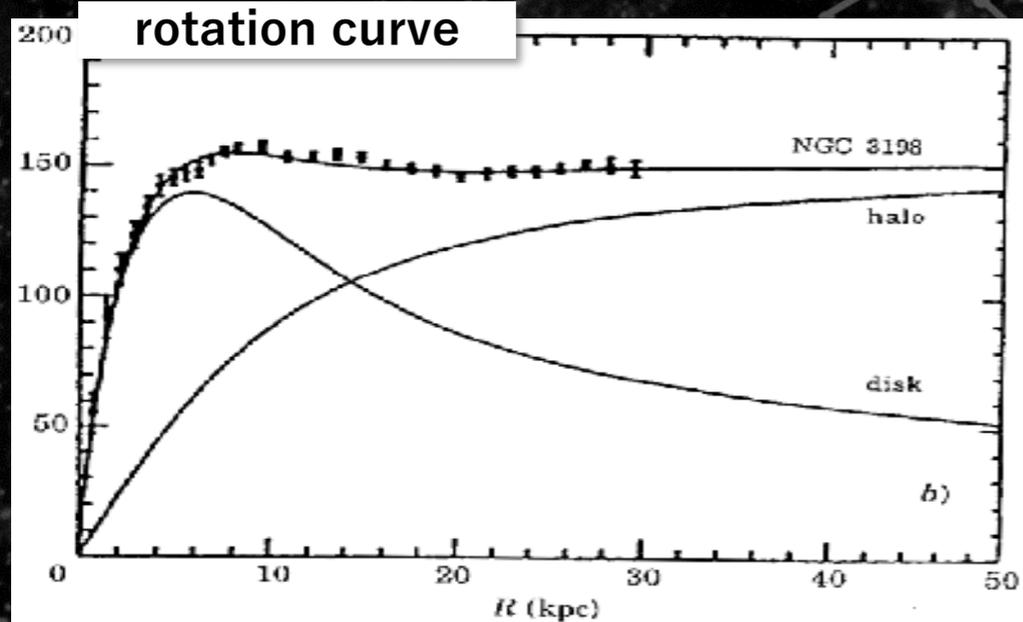
GR!



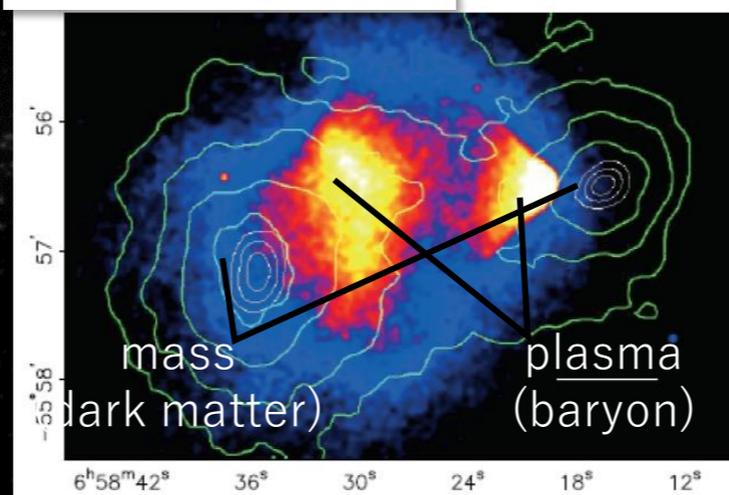
Gravitational Lens in Abell 2218

HST - WFPC2

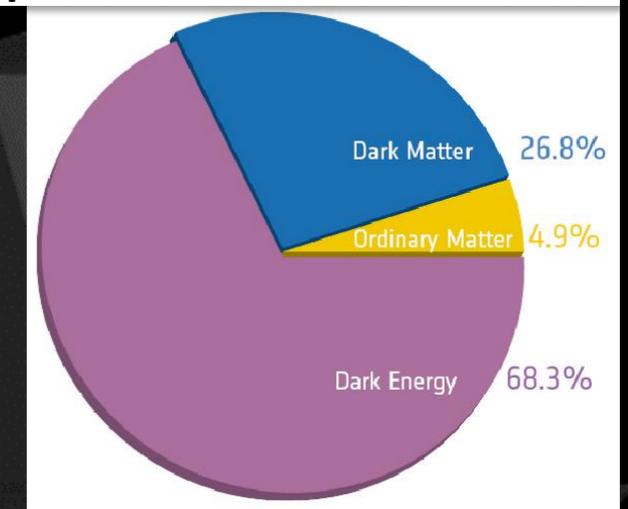
PF95-14 · ST ScI OPO · April 5, 1995 · W. Couch (UNSW), NASA



cluster collision



pie chart of the universe



Annu. Rev. Astron. Astrophys. 29(1991)409

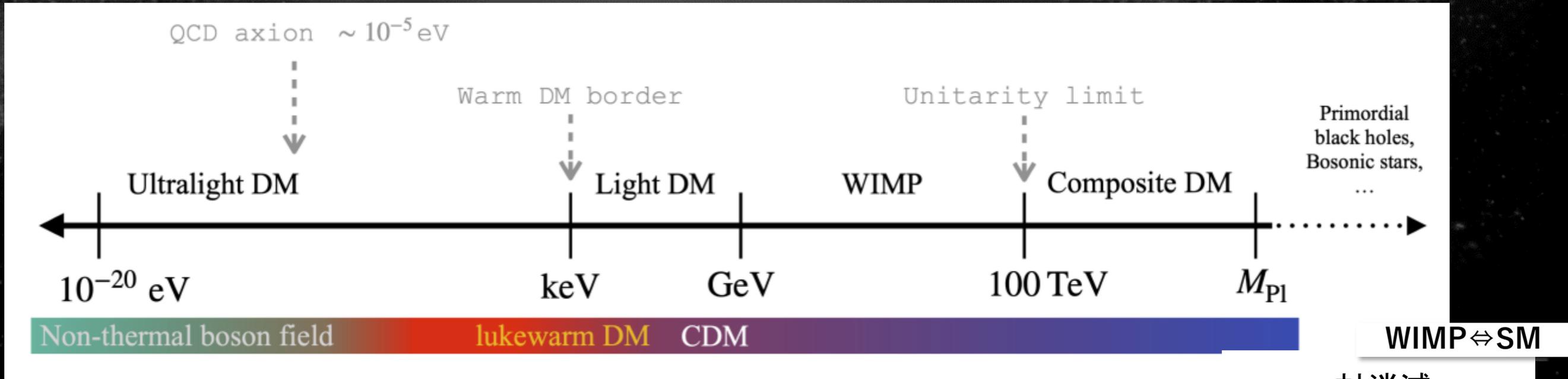
THE ASTROPHYSICAL JOURNAL, 648:L109-L113, 2006 September 10

Planck team

# DM候補

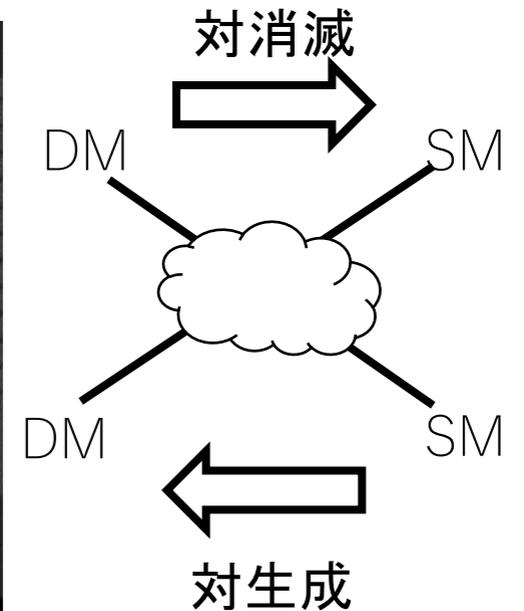
- 広大なdiscoveryスペース

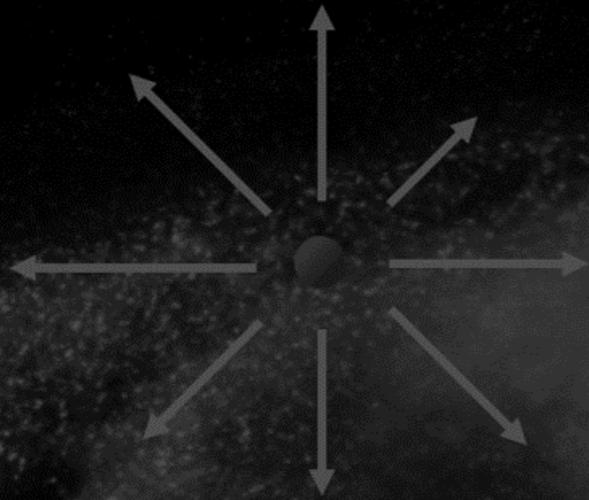
Symmetry 2021, 13(10), 1945;  
<https://doi.org/10.3390/sym13101945>



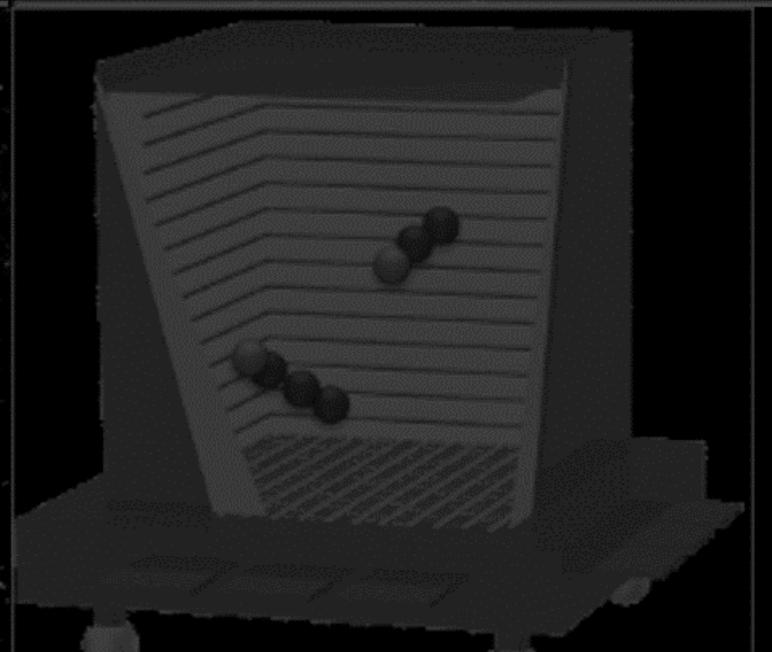
## • 本日のトーク

- 波状DM AXION (CP problem in QCD) など
- 粒子DM WIMPs (Weakly Interacting Massive Particles) など
- 国内の取り組みもあわせて 



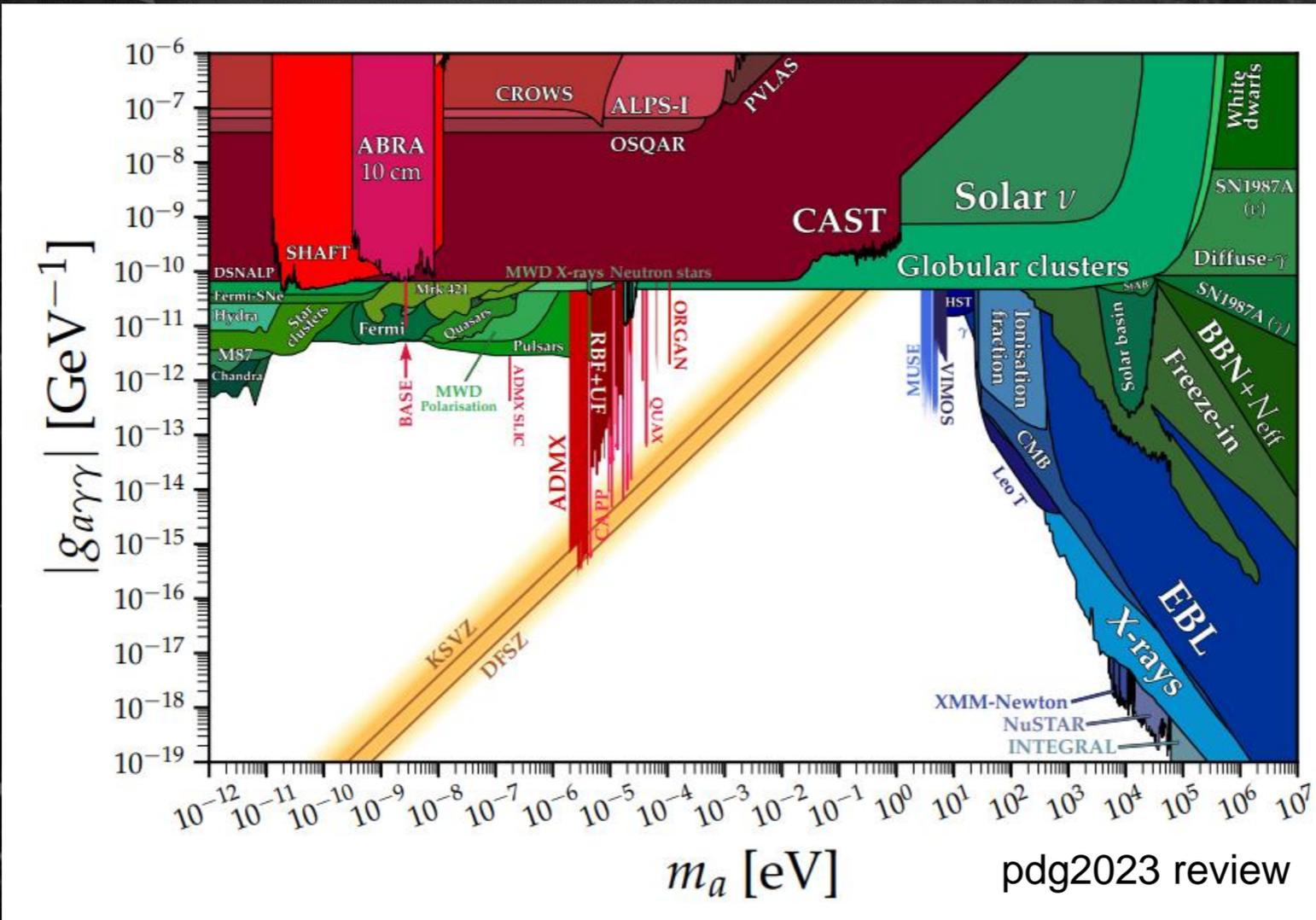


# 波DM (AXIONなど)



# • アクシオン/アクシオンの粒子

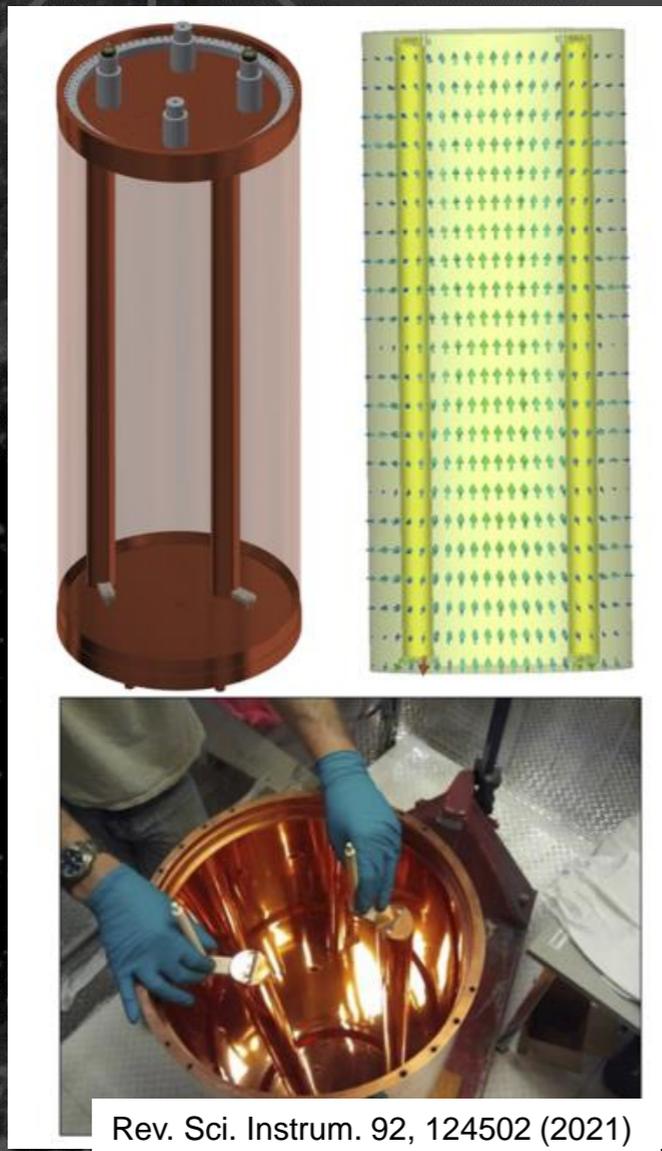
- QCDアクシオン：strong CP問題 質量とカップリングに関係
- アクシオンの粒子：超ひも 上記制限なし
- 光子（電子、核子）とのcoupling を探索



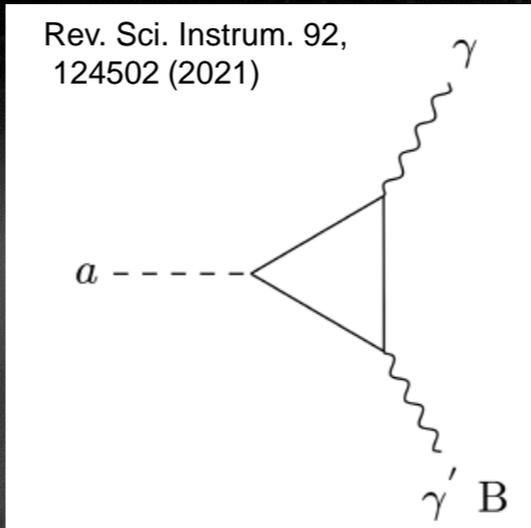
pdg2023 review

# キャビティーによる探索 (ADMX)

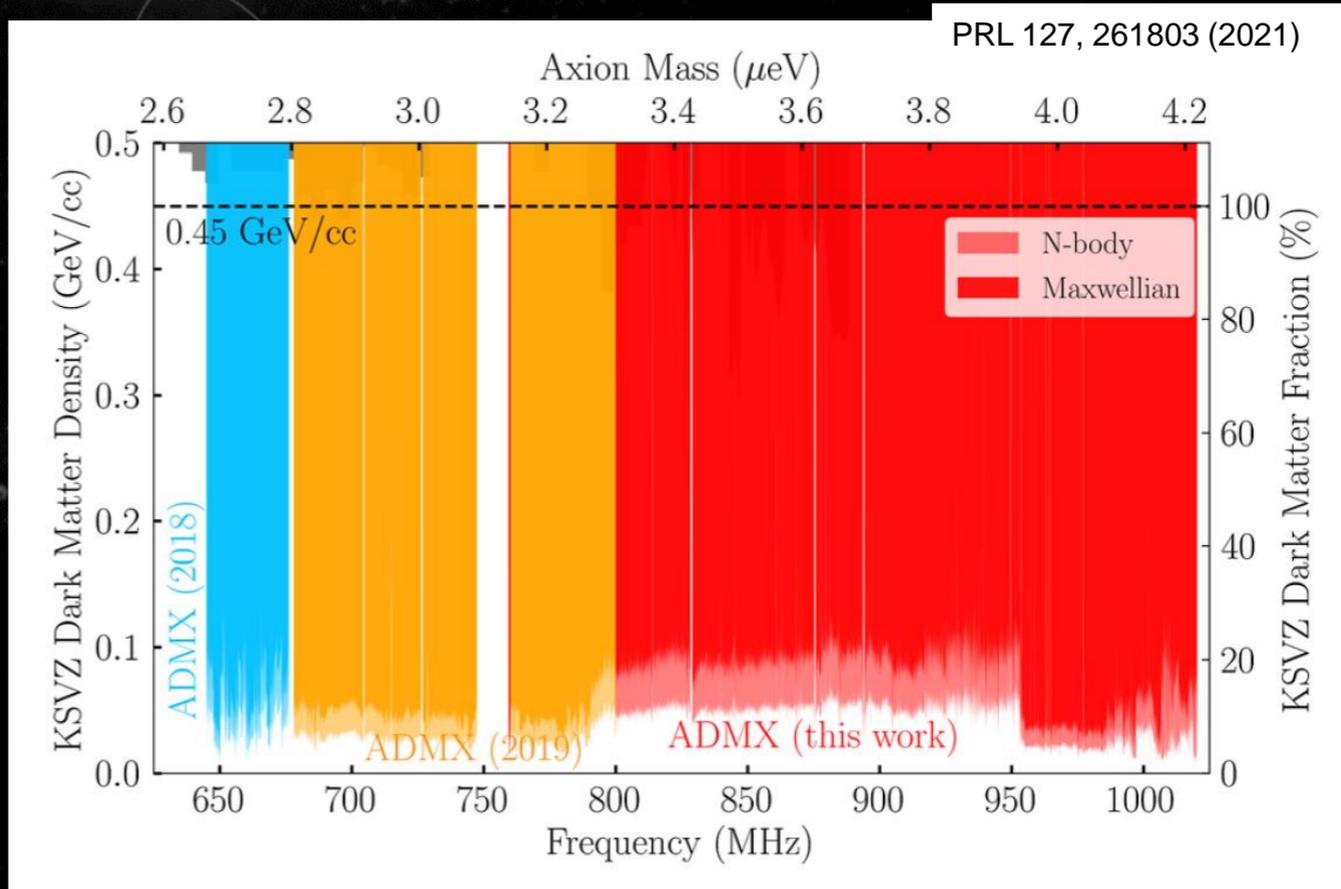
- 強磁場中で axion を光子に変換
- キャビティー・読み出しに工夫
- 理論の予言領域の探索を開始



Rev. Sci. Instrum. 92, 124502 (2021)



Rev. Sci. Instrum. 92, 124502 (2021)



# キャビティによる探索 (東北大)

- 形状の工夫
- テストrun開始

<https://www.lowbg.org/ugap/ws/am2023/slide/6-1.pdf>

## Wave-like dark matter

UGAP conference in Sendai on March 5<sup>th</sup>, 2024

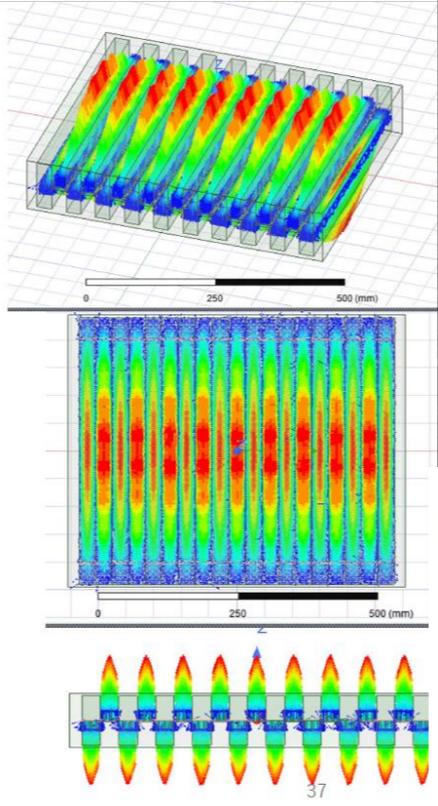
Y. Kishimoto  
RCNS, Tohoku University

### New ideas in the cavity

When we look  $G_{lmn} = \frac{(\int dV \vec{E} \cdot \vec{B}_0)^2}{|B^2|V \int dV E^2}$  carefully, the negative interference can avoid by  $dV$  in numerator.

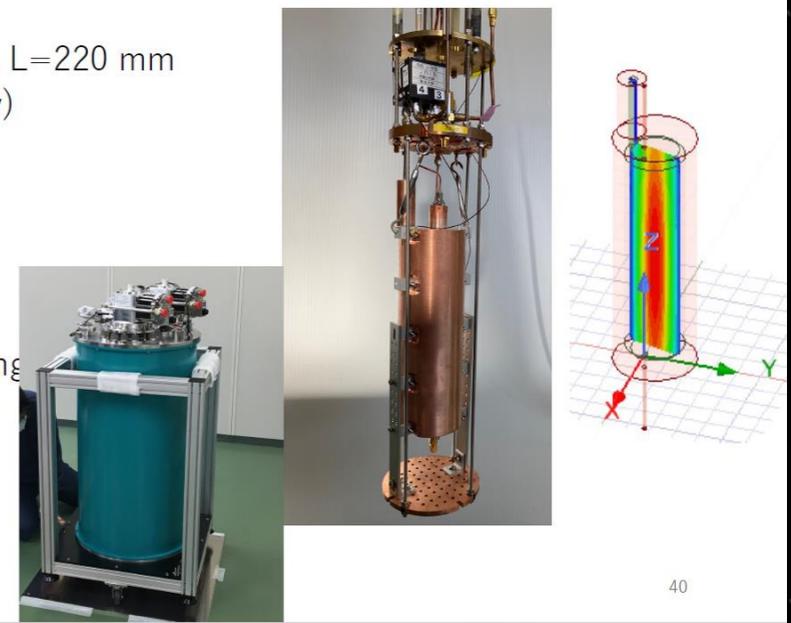
Large volume (H=100mm)

Smaller volume (H=10 mm)



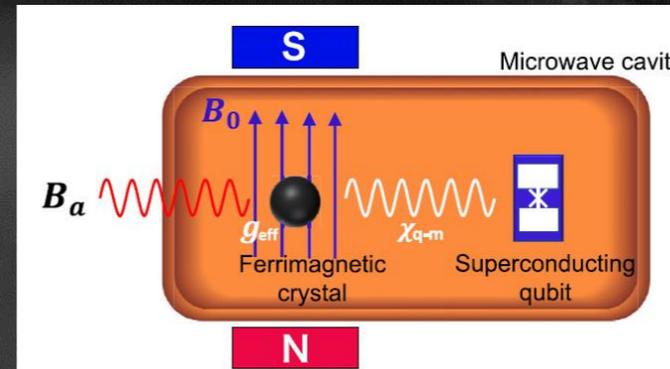
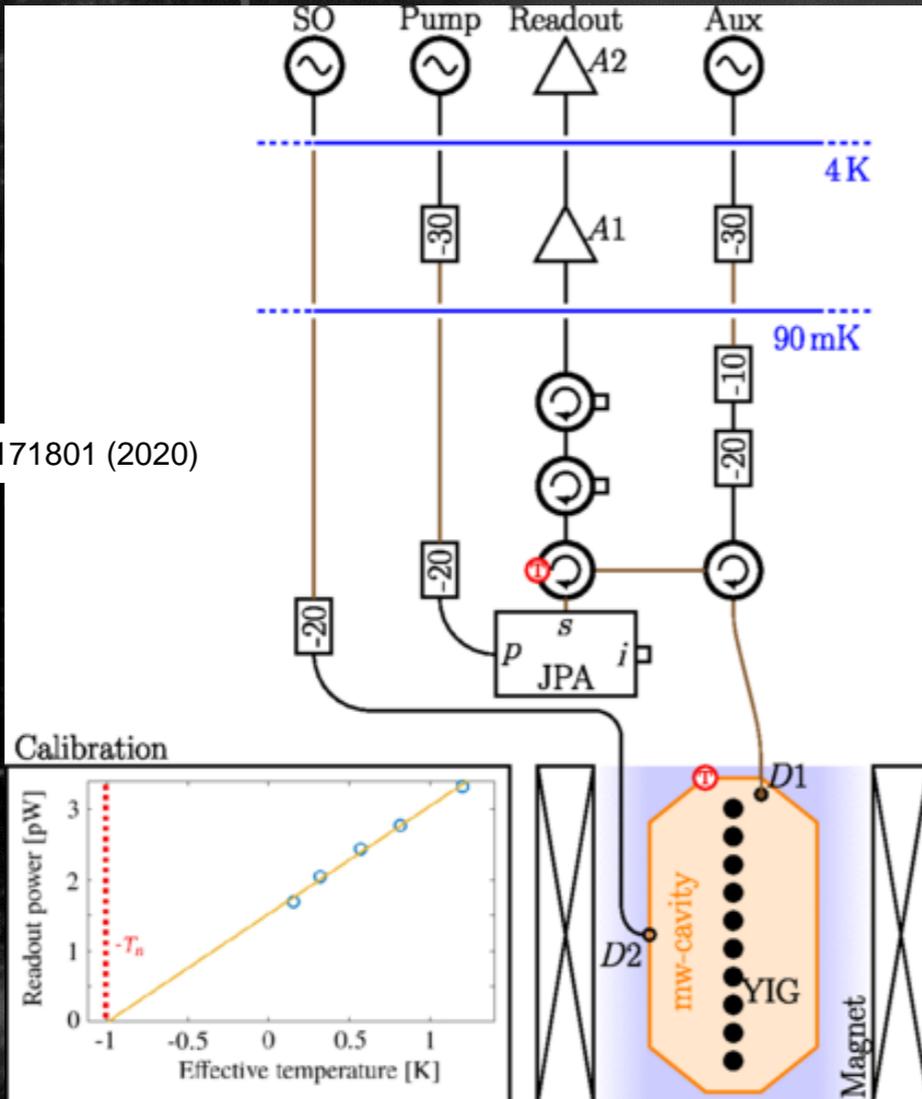
### Polit run system for axion search in Tohoku

- Magnet
  - Sample volume D=110mm, L=220 mm
  - Max B=9.1 T (2% uniformity)
- Simple cavity
  - $G = 0.686$
  - $V = 373 \text{ cm}^3$
  - $Q_L = 1.84 \times 10^4$
  - $f_R = 4,614.54 \text{ MHz}$  (No tuning)
  - Antenna coupling  $\beta = 2.04$
- Temperature
  - $T = 8.85 \text{ K}$
  - No load min.  $T = 3.8 \text{ K}$

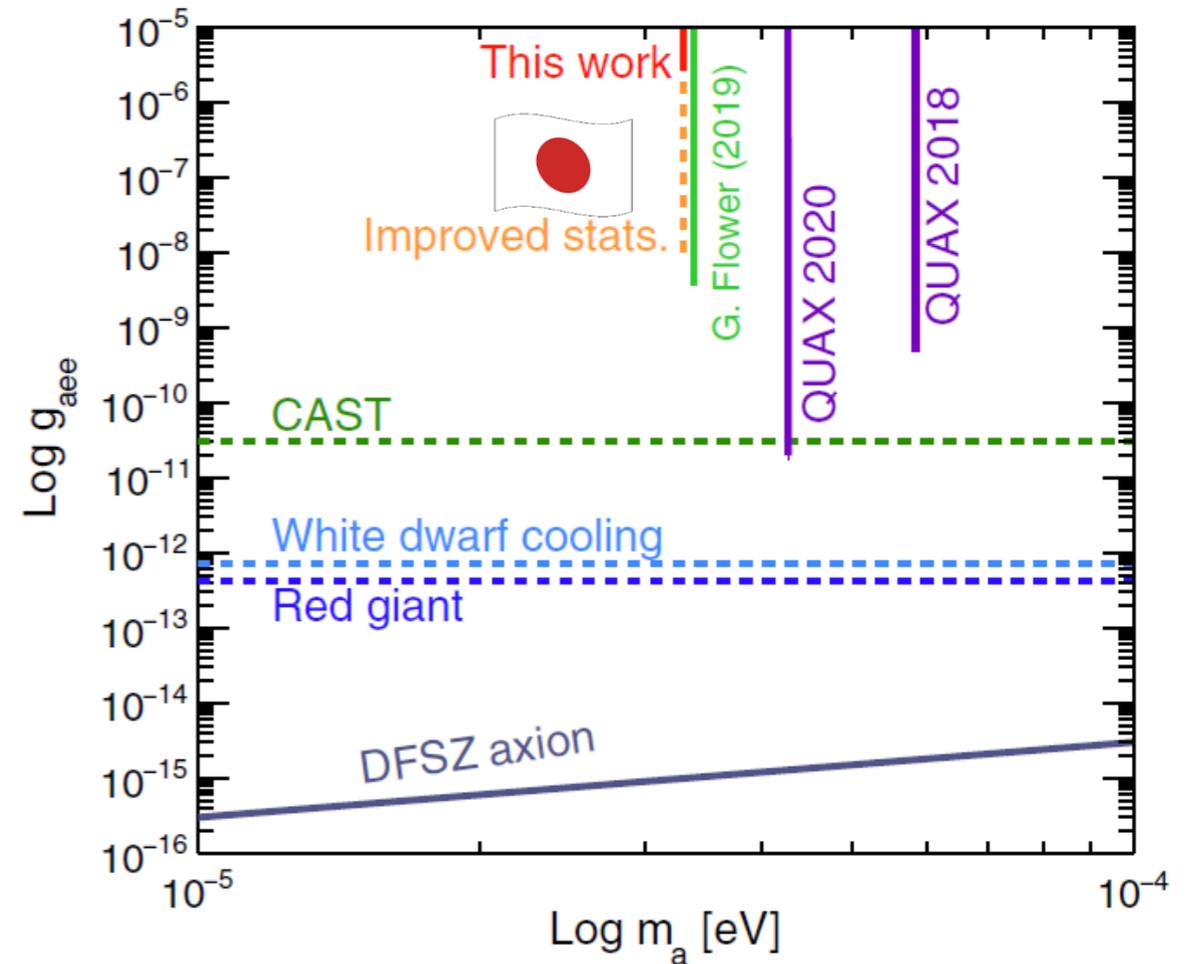


# マグノンによる探索

- axion-電子の反応
- マグノンとして検出
- QUAXによって先鞭
- 量子センサー開発用データで制限

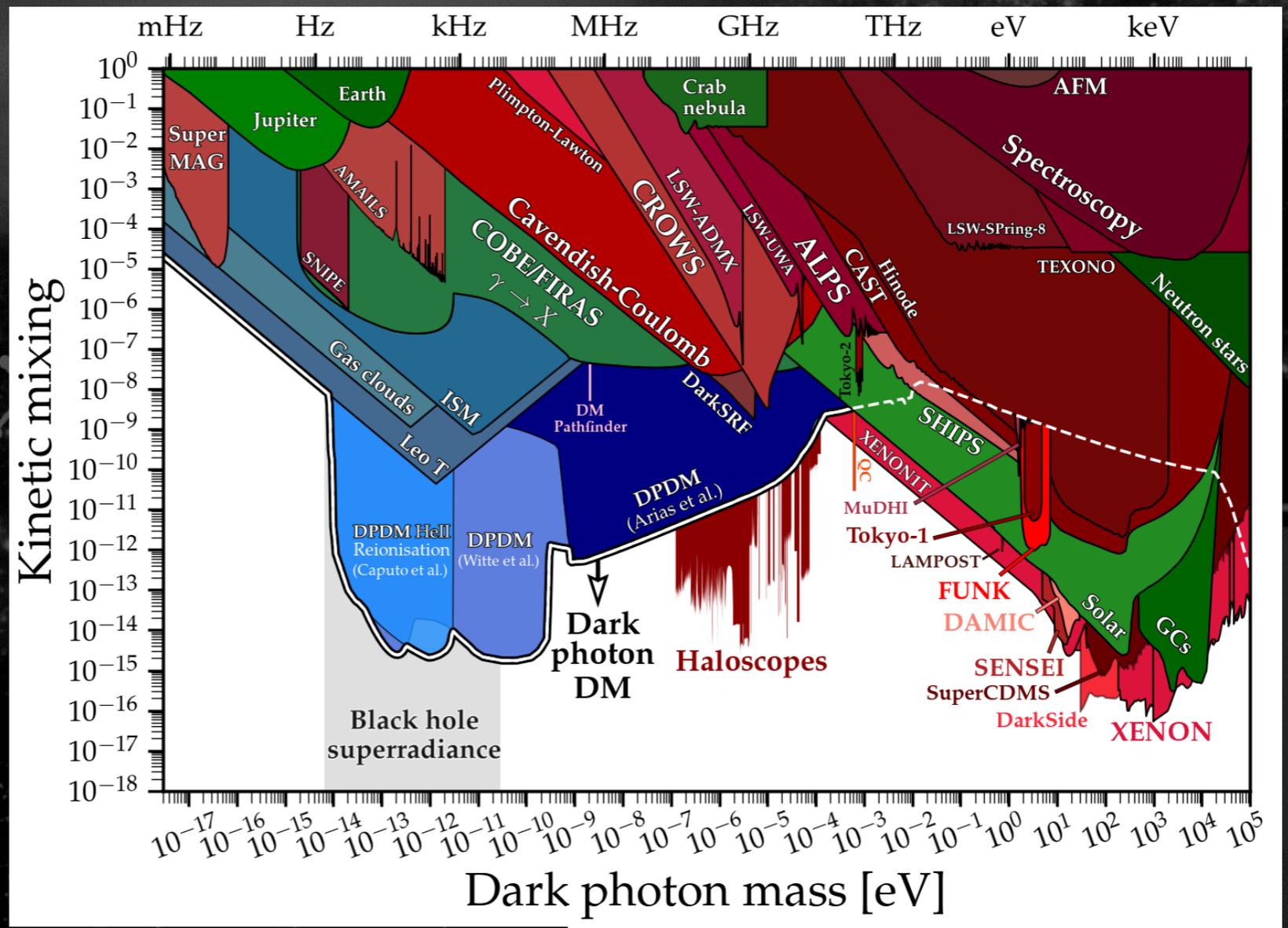


PRD **105**, 102004



# ダークフォトン

- U(1)対称性
- 光子とカップル
- 磁場不要



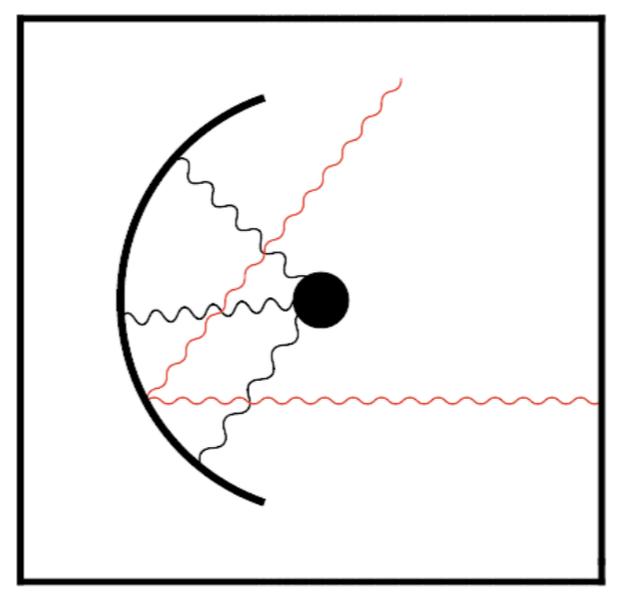
<https://github.com/cajohare/AxionLimits>

# ダークフォトン

- 金属面でダークフォトン→光子
- 面に垂直に放射→（焦点）にレシーバー
- DOSUE-RR (J, Kバンド)

Dieter Horns et al JCAP04(2013)016

<https://conference-indico.kek.jp/event/236/contributions/4356/>



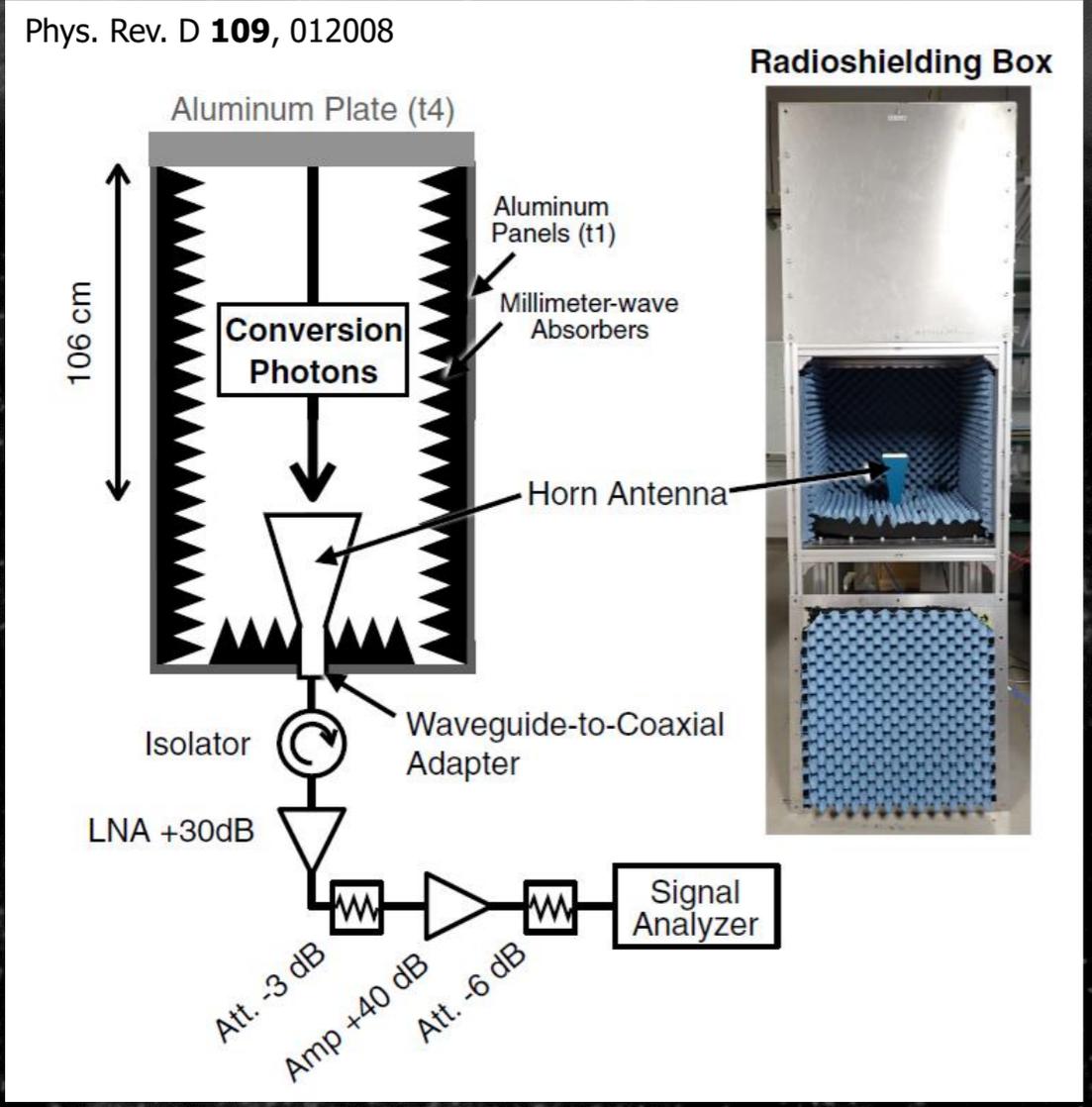
波動的な性質を持つ  
軽いダークマターの探索実験の  
現状と展望

アンテナを用いた

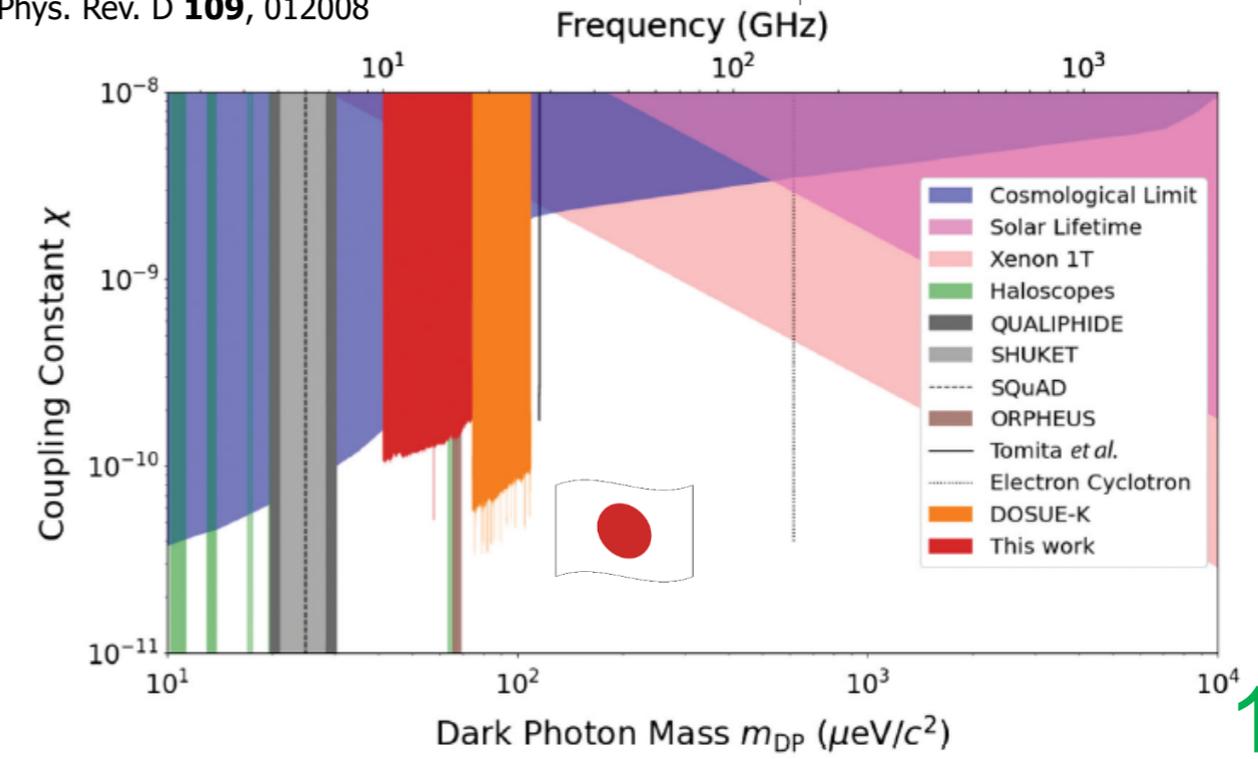
安達俊介 (京大)

2023.12.23 @ KEK, 素粒子物理学の今と未来

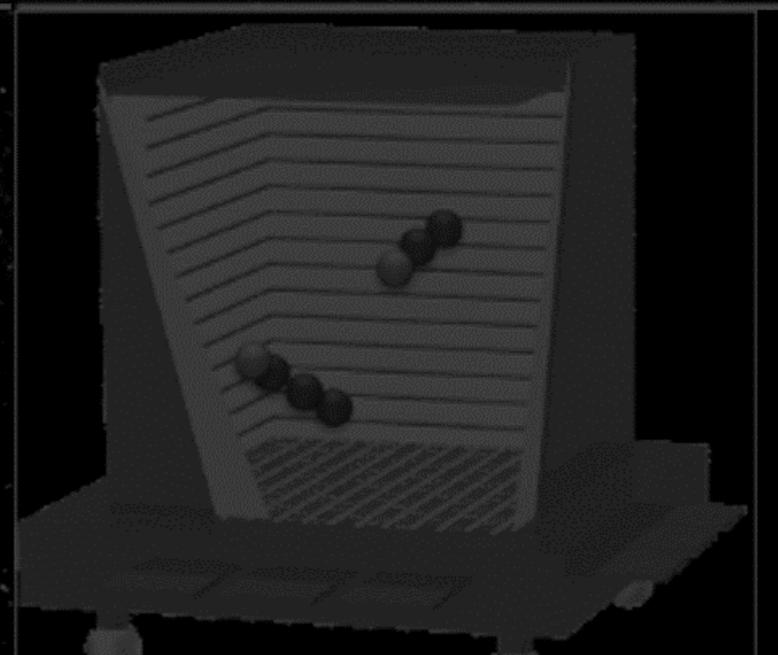
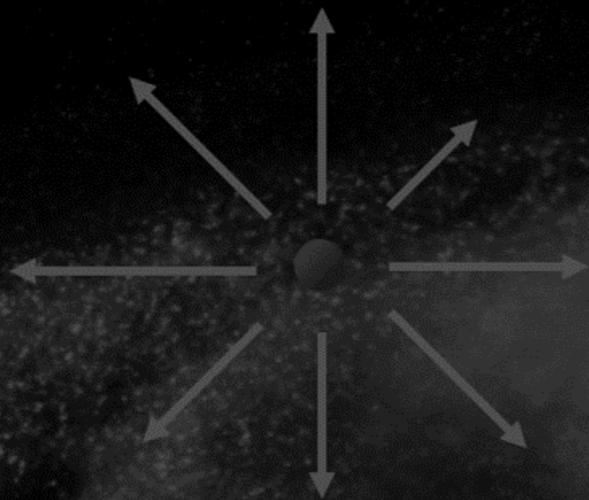
電波望遠鏡  
(10GHz-1THz)  
の技術ですぐできる



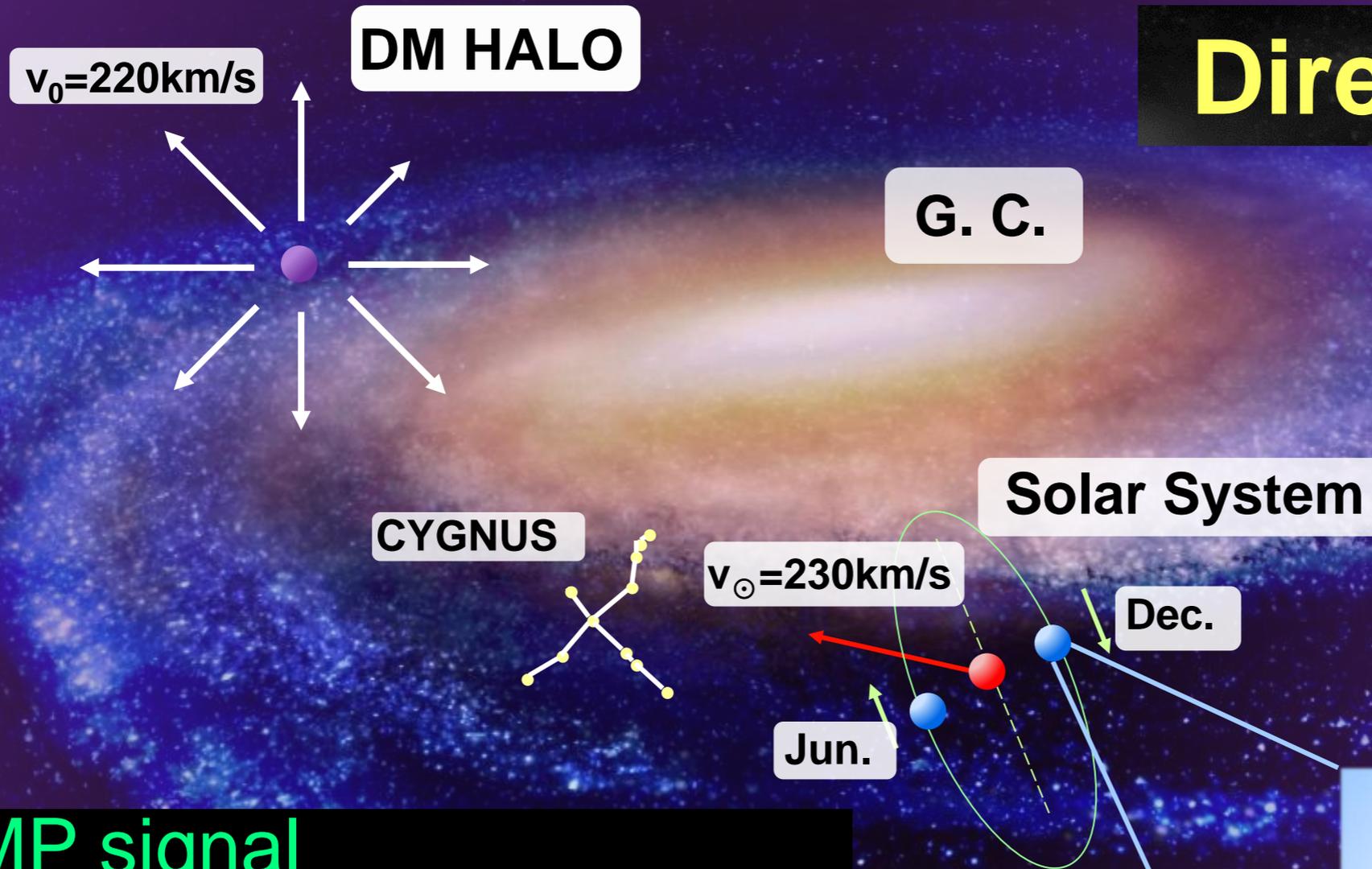
Phys. Rev. D **109**, 012008



# 粒DM (WIMPなど)

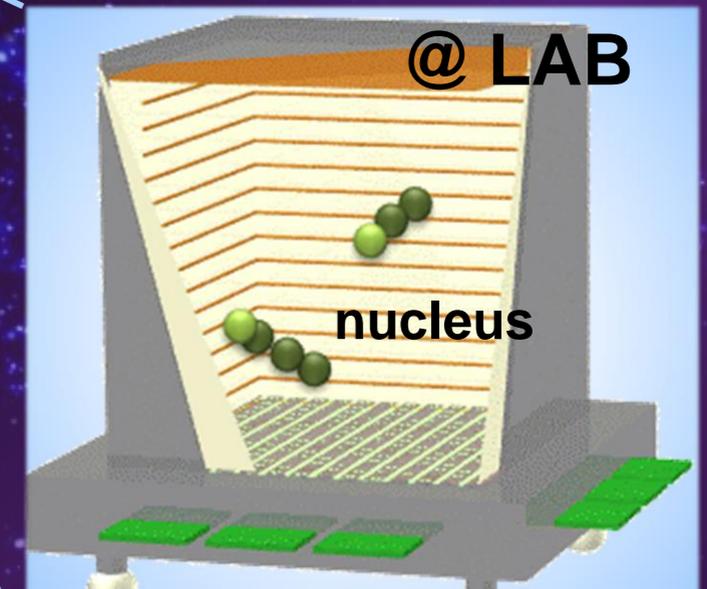


# Direct Detection



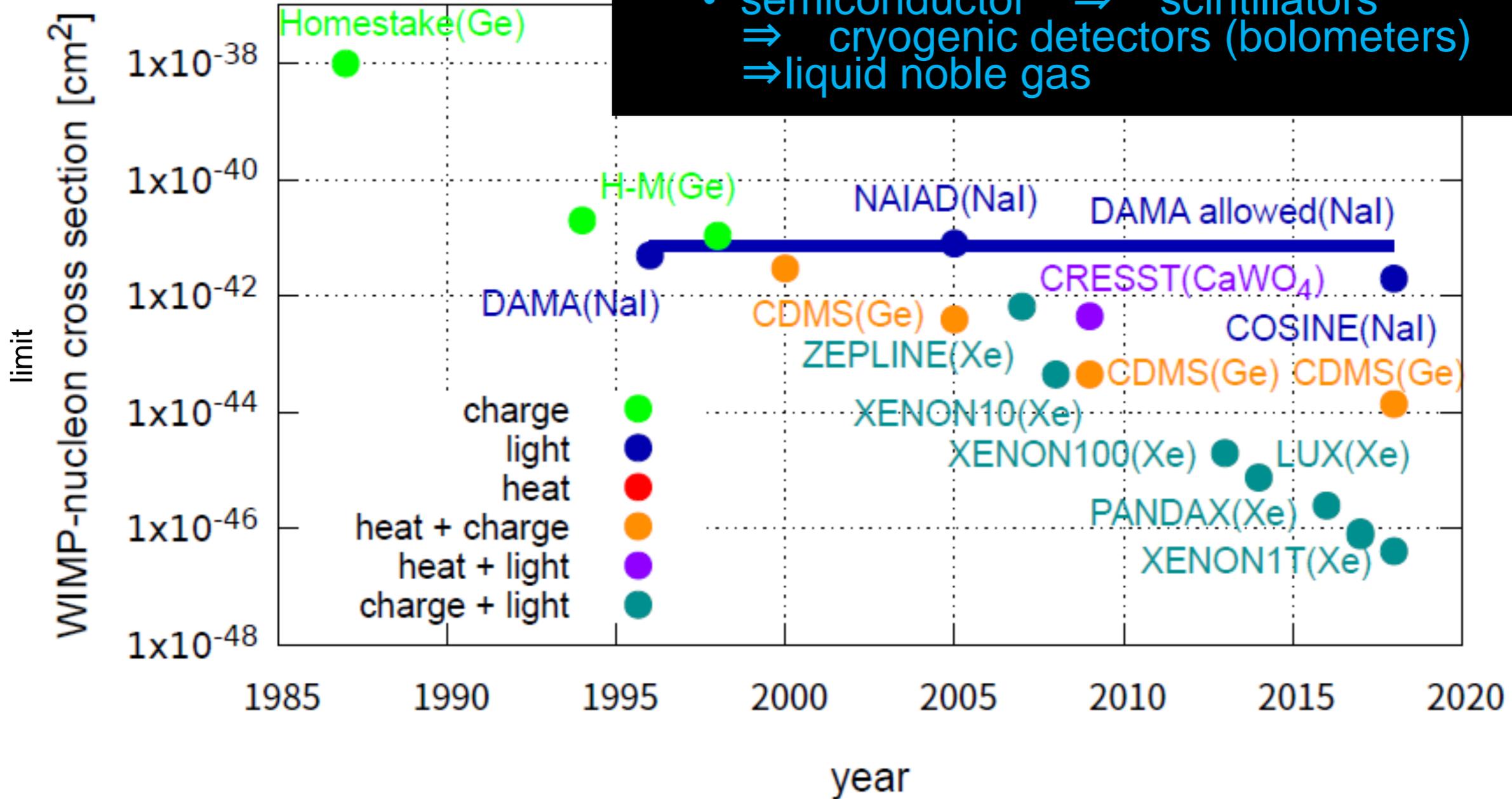
## • WIMP signal

- nuclear recoil: elastic scattering
- energy
- nucleus dependence
- seasonal modulation
- direction



# History

## Direct search history



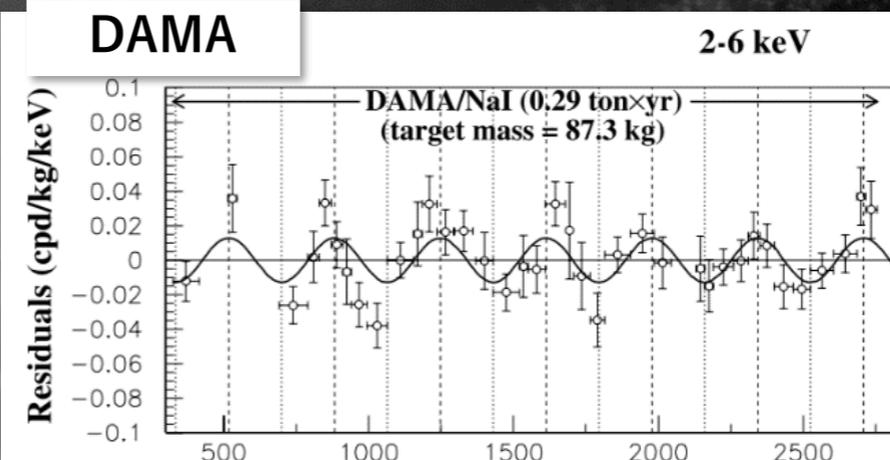
## • leading technologies

- semiconductor  $\Rightarrow$  scintillators
- $\Rightarrow$  cryogenic detectors (bolometers)
- $\Rightarrow$  liquid noble gas

# • DAMA (NaI)

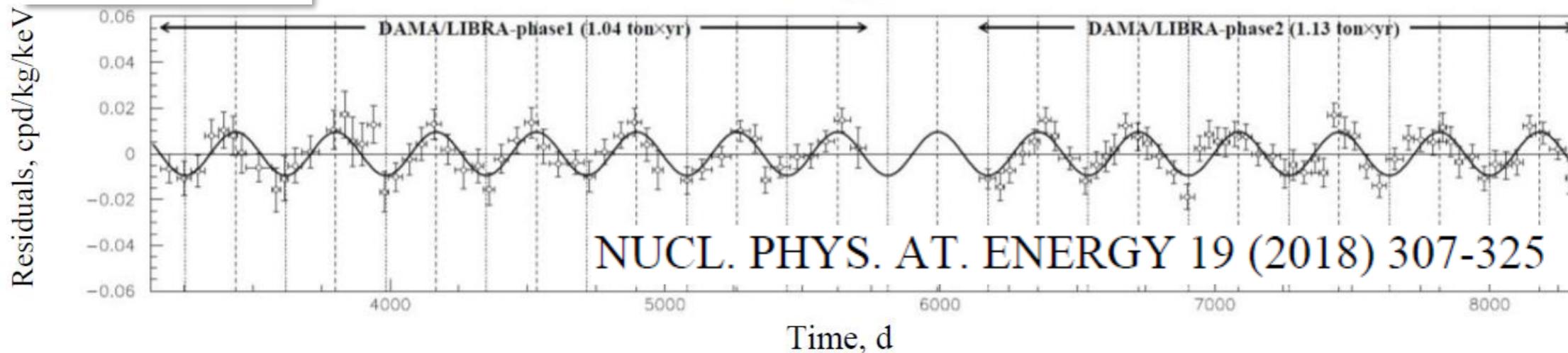
- 250kg NaI scintillators
- Annual modulation were reported : 1998~
- Latest 2.46 ton year  $12.9 \sigma$
- SOMETHING is detected

Eur. Phys. J. C (2008) 56: 333–355  
DOI 10.1140/epjc/s10052-008-0662-y



## DAMA/LIBRA

2 - 6 keV



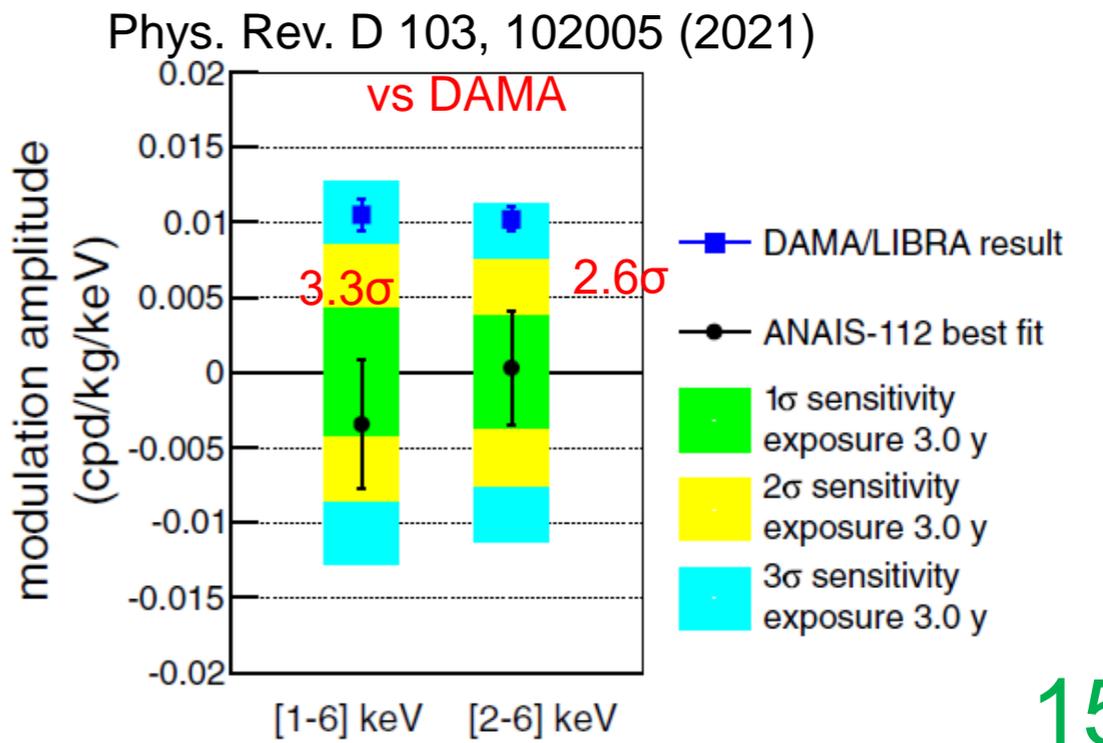
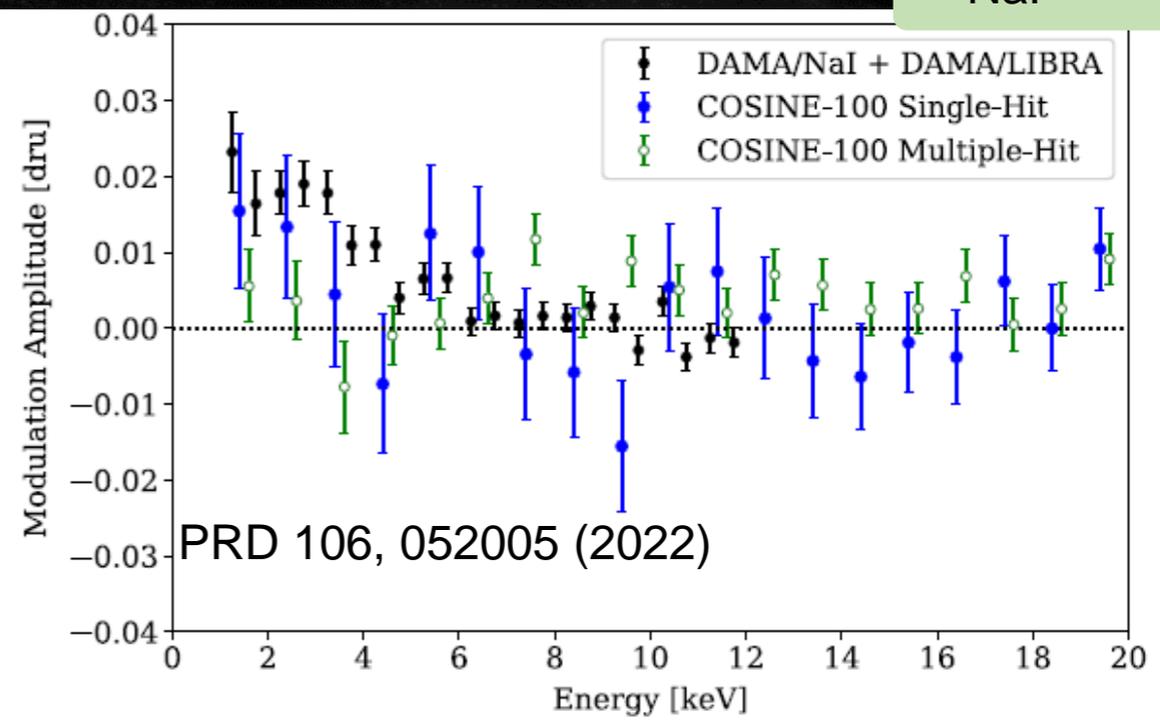
No BG explains this modulation

No natural DM model explains, either...

# Other NaI detectors

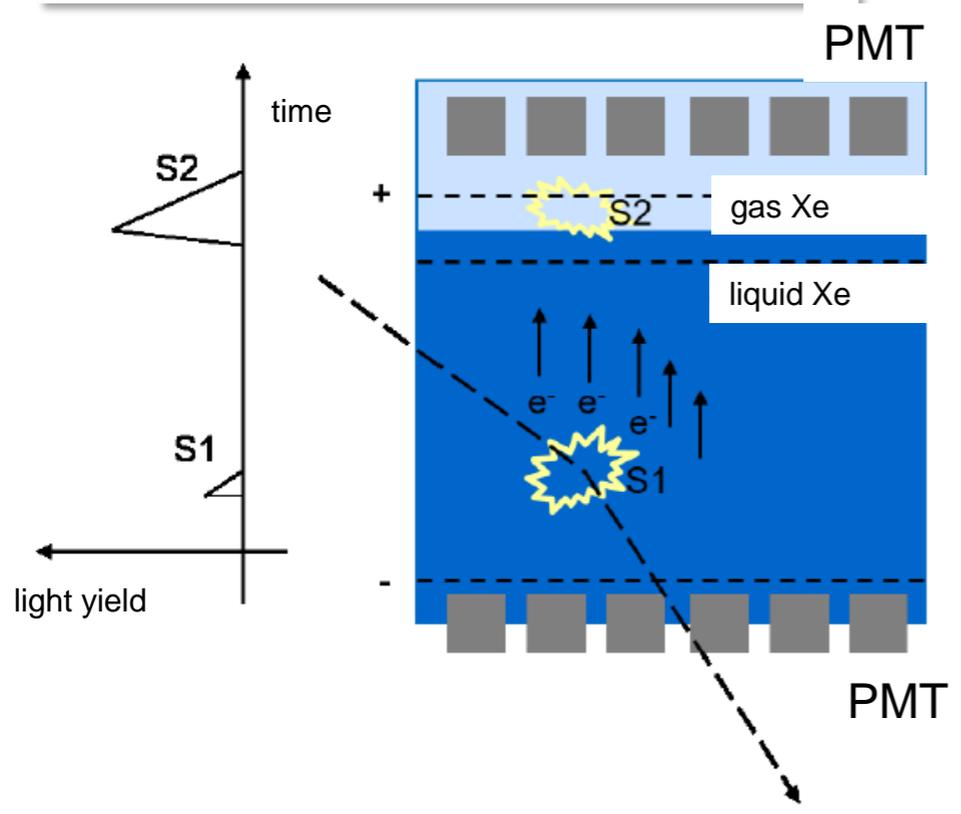
- COSINE (~100kg):
  - 3 years' measurement completed
  - Consistent with null and DAMA.
  - upgrading (low threshold, mass X2)
- ANAIS (112kg)
  - 3 years' measurement
  - incompatible with DAMA
  - 2 more years to test by  $5\sigma$
- SABRE
  - North and South inpreparation
- PICOLON
  - Pure crystal 
- COSINUS
  - bolometer technique

Need to be stay tuned.

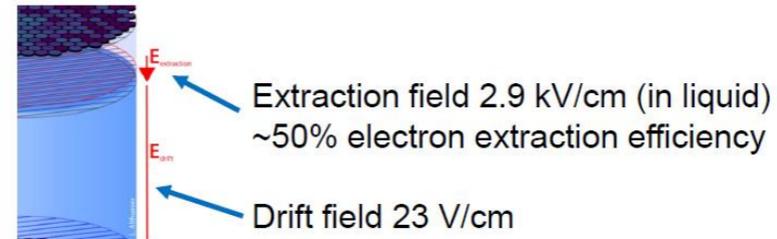


- Liquid Xe/Ar : double-phase (liquid+gas)
- XENONnT, LZ, PandaX-II (Xe) , DARKSIDE(Ar)
- Several 100kg ~ 1 ton
- z position can be known
- Electron background can be discriminated

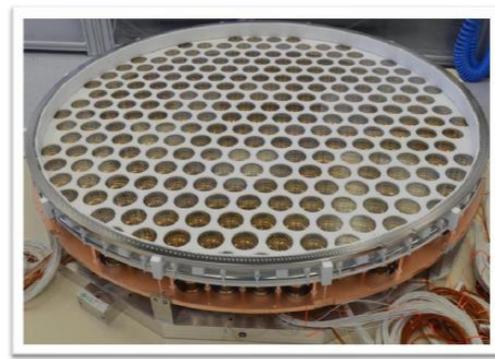
Double phase detector principle



Time projection chamber



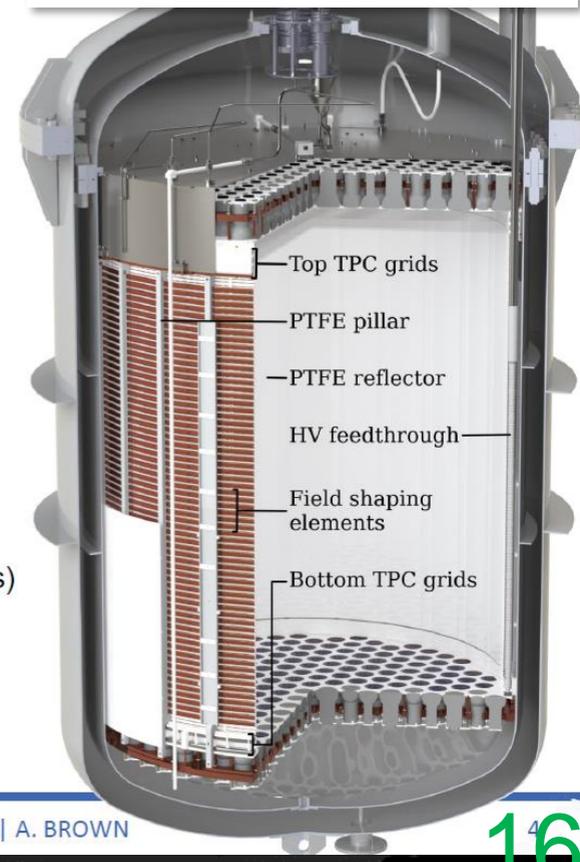
5.9 tonnes Xe in TPC  
8.5 t total



Hamamatsu R11410-21  
3-inch photomultiplier tubes (PMTs)

477 out of 494 PMTs operational

XENON nT detector



• XENONnT

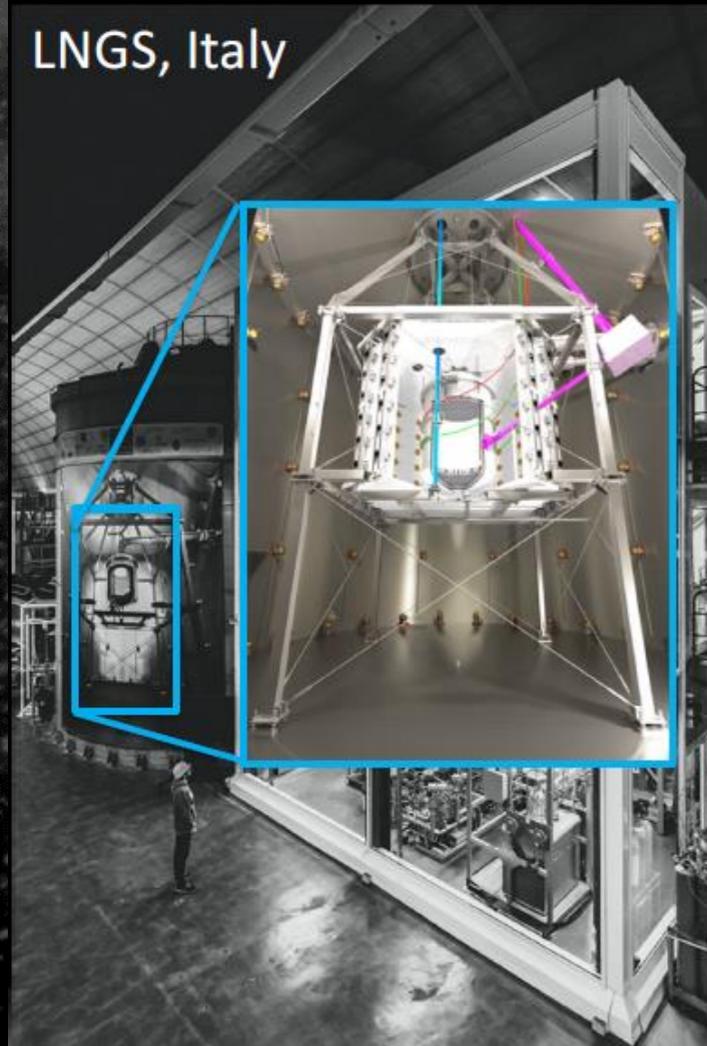
# Upgrade from XENON1T to XENONnT

<https://doi.org/10.48550/arXiv.2402.10446>

- LXe time projection chamber (enlarged)
  - 5.9 t LXe active (3 x XENON1T)
- Liquid xenon purification (new)
  - Faster purification (>> XENON1T)
- Neutron veto (new)
  - Cherenkov neutron veto (68% eff. with pure water, 87% with planned Gd-loaded water)
- Radon distillation column (new)
  - Reducing Rn-originated BG (<1/10 x XENON1T)



Japanese contributions

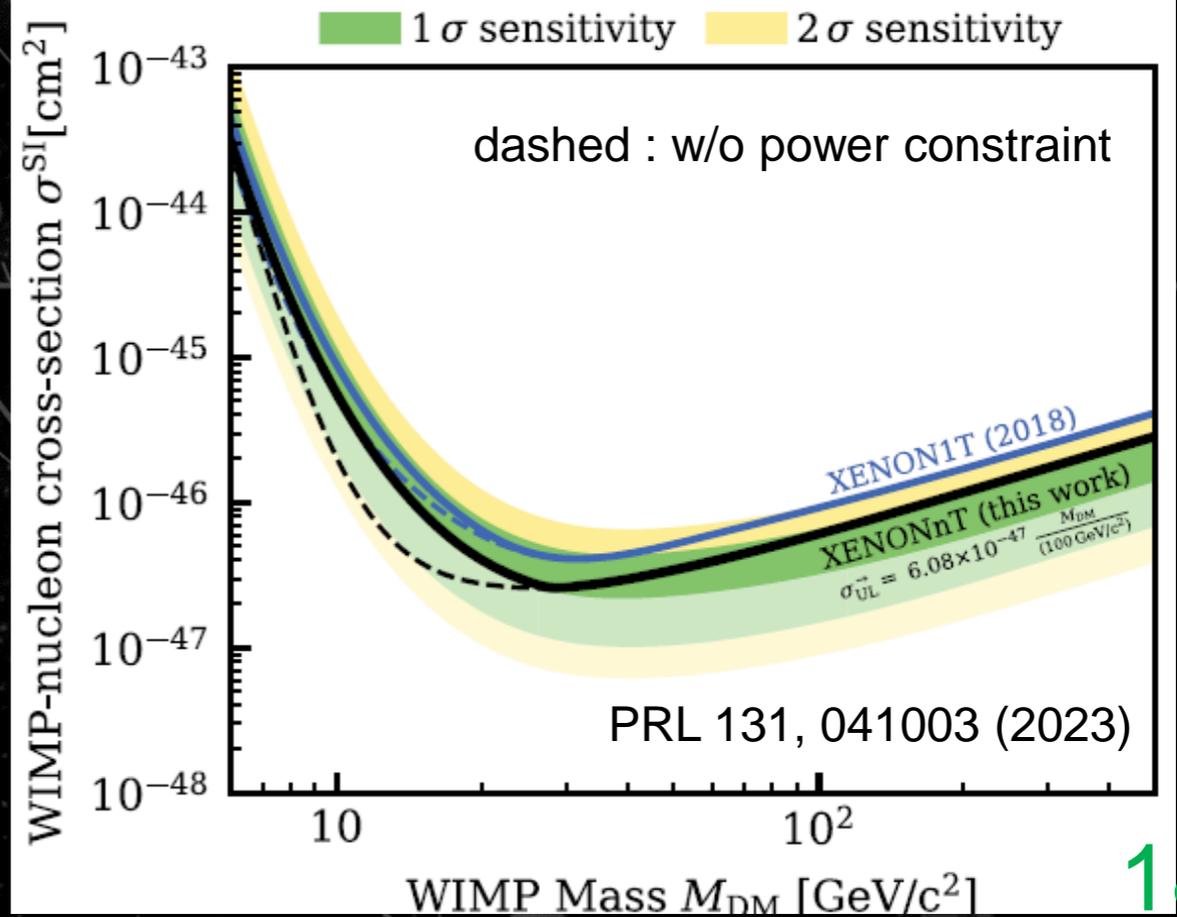
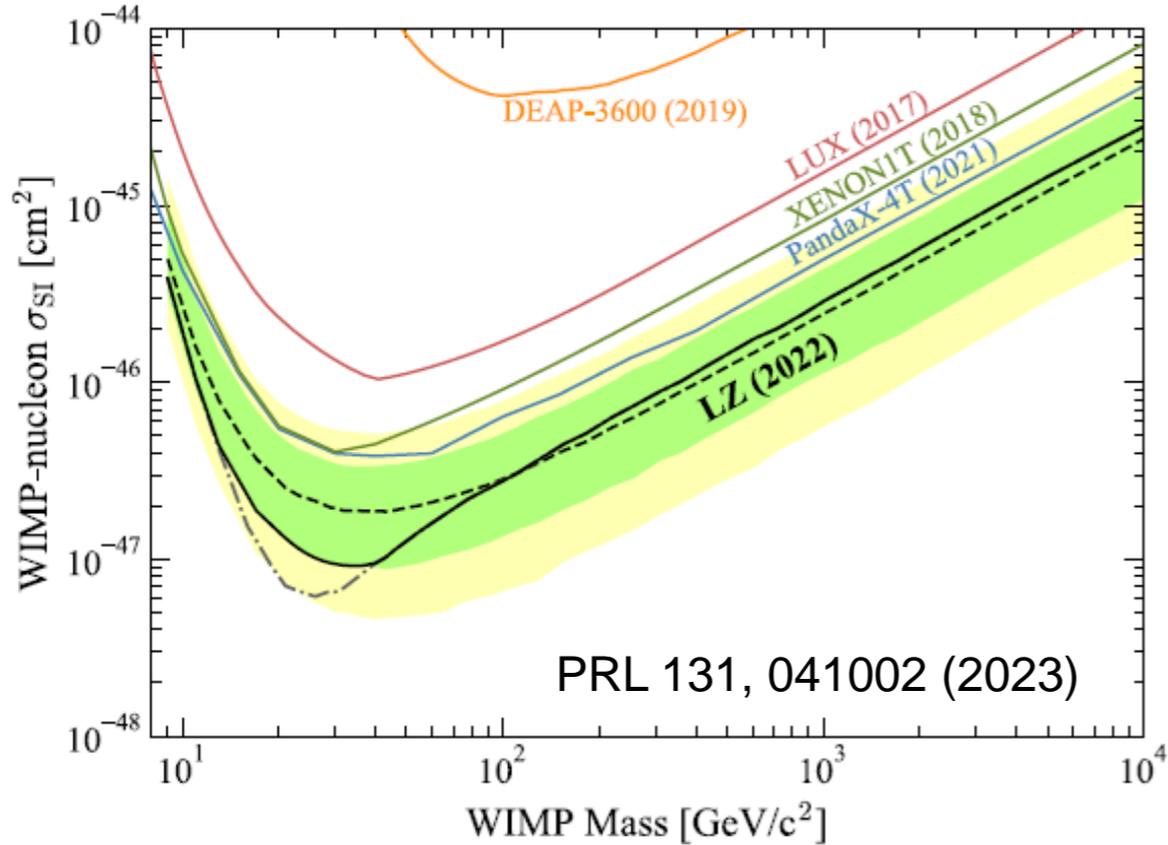


地下から解き明かす宇宙の歴史と物質の進化  
Unraveling the History of the Universe and Matter Evolution with Underground Physics

ICRR Institute for Cosmic Ray Research University of Tokyo  
DMNet  
IPMU Kavli Institute for the Physics and Mathematics of the Universe

最新結果

- LZ : 0.9 ton · year       $9.2e-48 \text{ cm}^2$  for 36 GeV WIMPs
- XENON : 1.1 ton · year  $2.6e-47 \text{ cm}^2$  for 28 GeV WIMPs  
(blind analysis + power constraint limit setting)

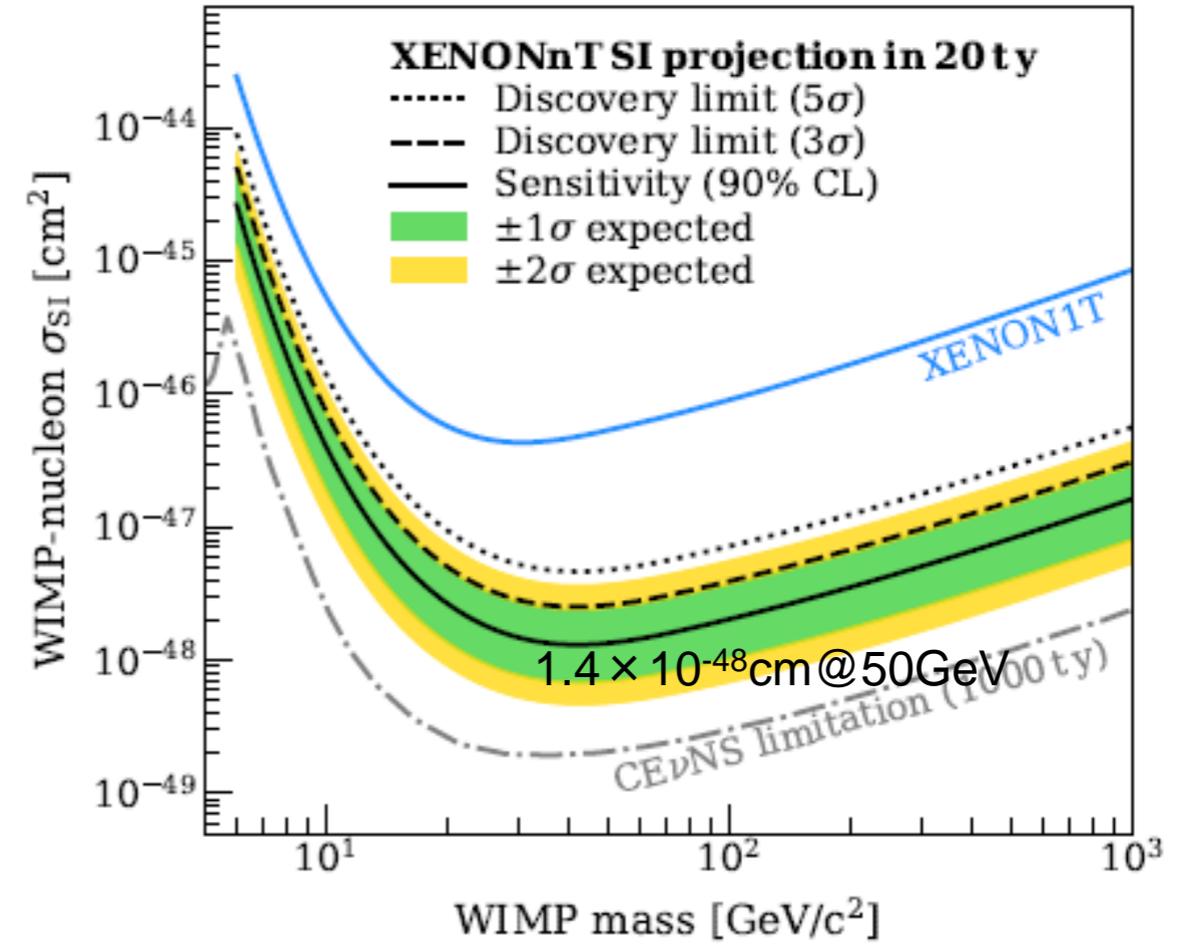
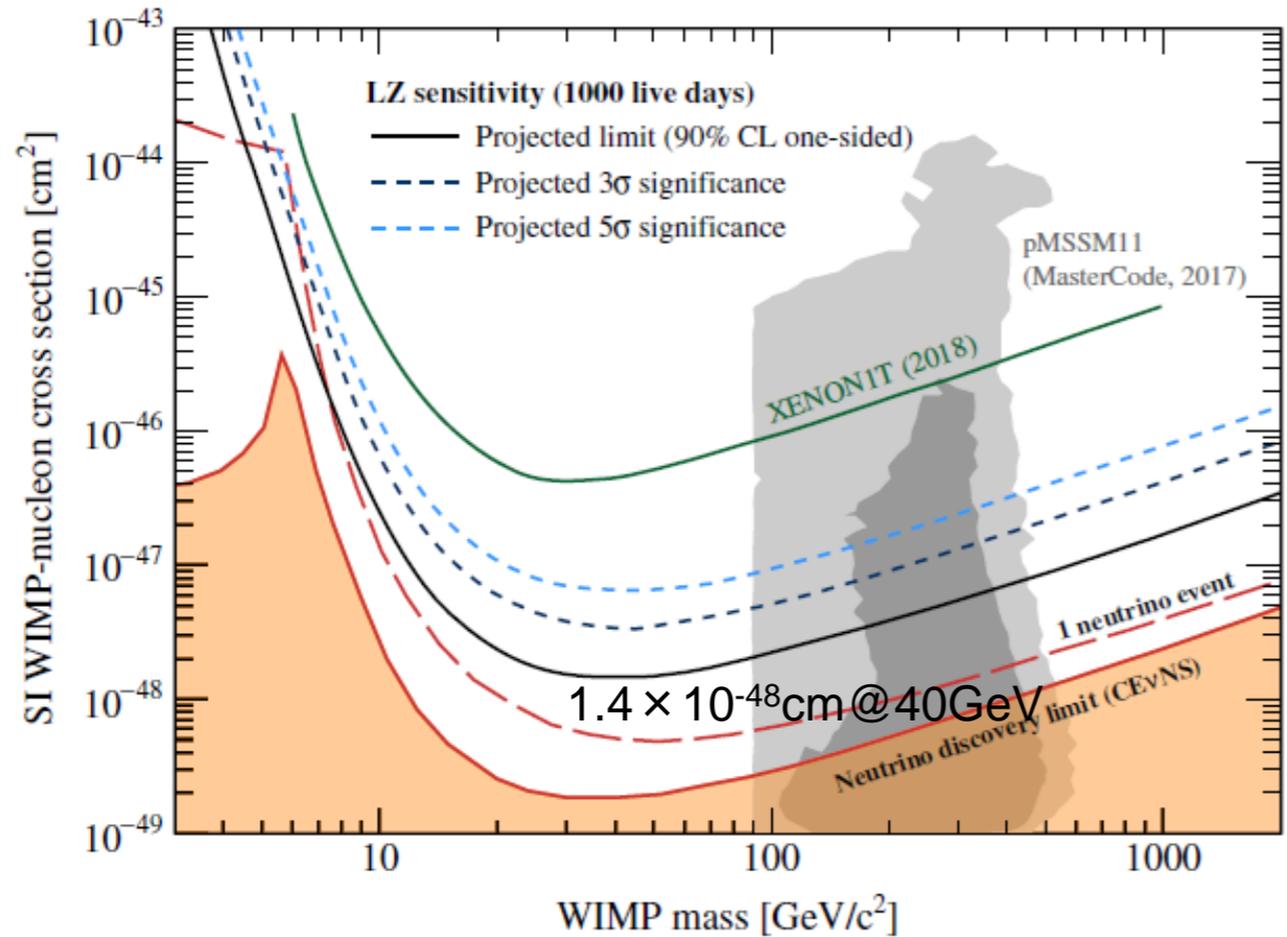


• 今後

- 5年程度の観測 → SUSY領域
- その後 XLZD (XENON+LZ+DARWIN) などさらに大型化  
: ニュートリノFOG

arXiv:2007.08796v1

PHYS. REV. D **101**, 052002 (2020)



# 低質量WIMP: MIGDAL効果

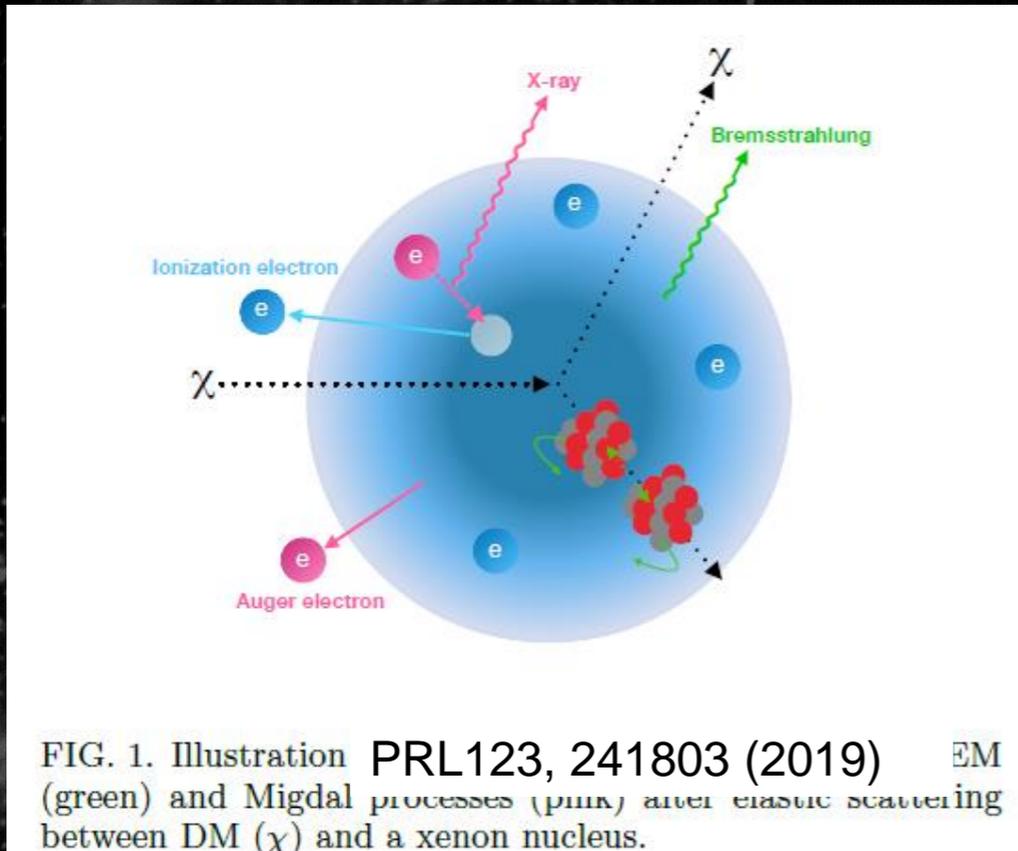
## MIGDAL効果

- 原子核反跳時に稀に電子が放出される
- A. B. Migdalによって計算 J. Phys. USSR 4 (1941) 449
- 伊部さん等によってDM探索を念頭にしたreformulation JHEP03(2018) 194
- 通常の検出器が低質量( $< 1\text{ GeV}$ )に感度

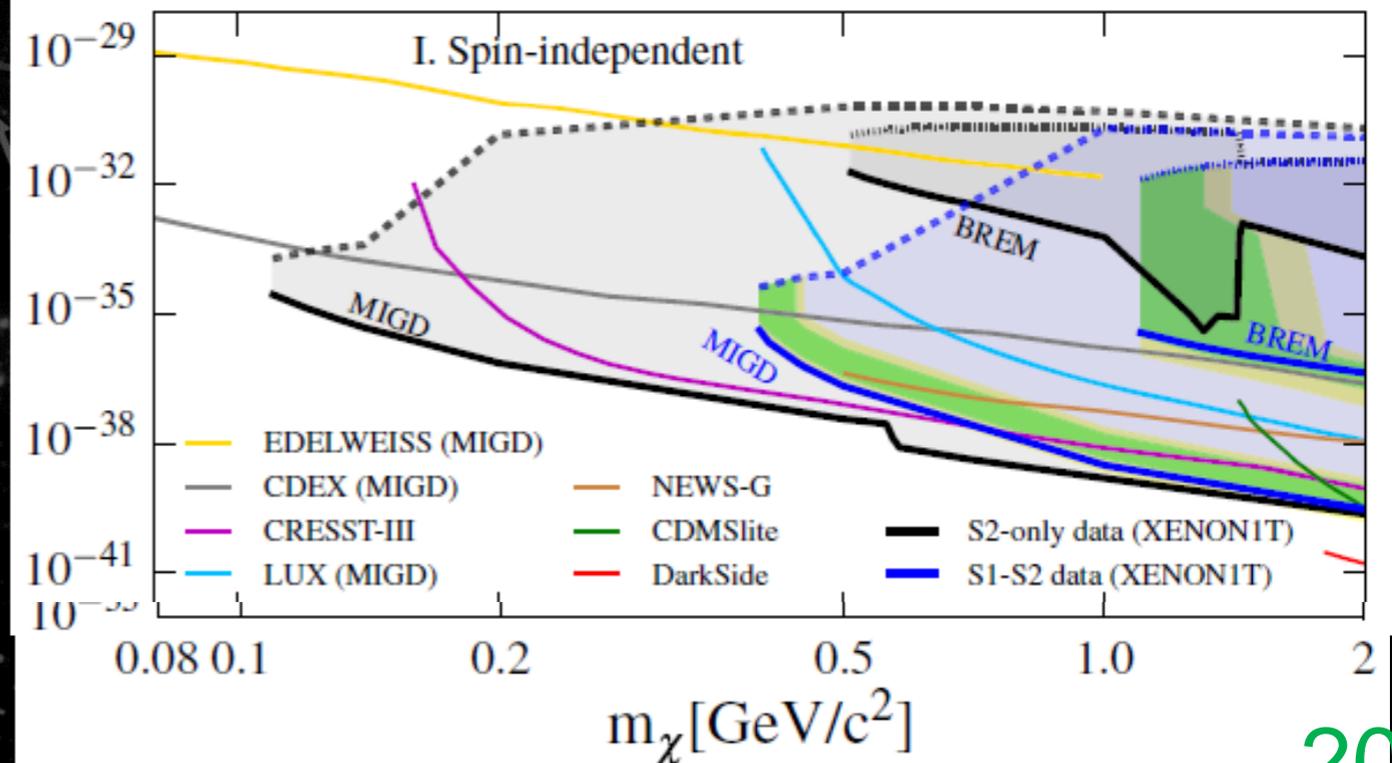
Migdal effect in dark matter direct detection experiments

Masahiro Ibe,<sup>a,b</sup> Wakutaka Nakano,<sup>a</sup> Yutaro Shoji<sup>a</sup> and Kazumine Suzuki<sup>a</sup>

JHEP03(2018) 194



PRL123, 241803 (2019)



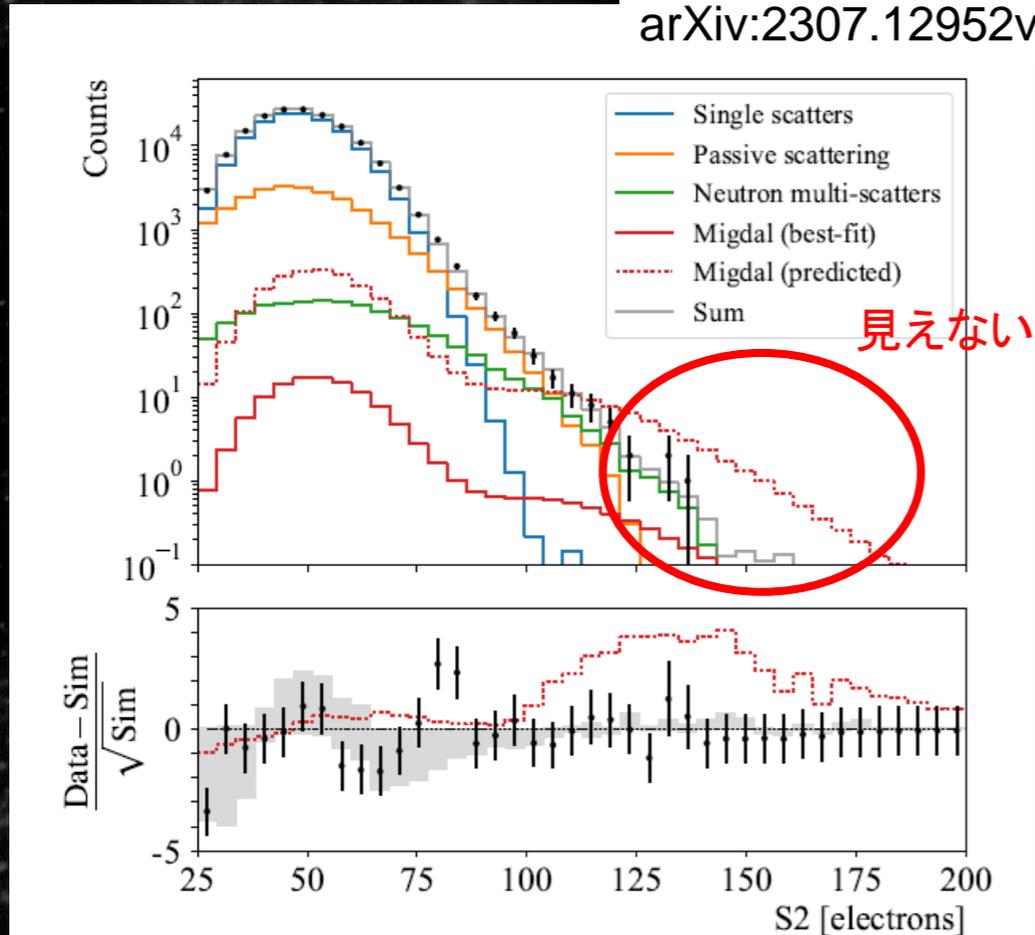
# • MIGDAL効果「自体」の確認 (液体キセノン)

- 原子核反跳に伴うMIGDAL効果は実験的に未確認
- 2相式キセノン検出器
- 14MeV中性子 → 7keV nuclear recoil **S2超過事象を探す**
- 2グループが報告 観測されず/見えた

Search for the Migdal effect in liquid xenon with keV-level nuclear recoils

J. Xu,<sup>1,\*</sup> D. Adams,<sup>2</sup> B. Lenardo,<sup>3,†</sup> T. Pershing,<sup>1</sup> R.L. Mannino,<sup>1</sup> E. Bernard,<sup>1</sup> J. Kingston,<sup>4,1</sup> E. Mizrachi,<sup>5,1</sup> J. Lin,<sup>6</sup> R. Essig,<sup>2</sup> V. Mozin,<sup>1</sup> P. Kerr,<sup>1</sup> A. Bernstein,<sup>1</sup> and M. Tripathi<sup>4</sup>

arXiv:2307.12952v1



## Migdal Search in the LUX-ZEPLIN Dark Matter Experiment

Jeanne Bang, Austin Vaitkus, Chen Ding  
On behalf of the LZ Collaboration

UCLA Dark Matter 2023  
03/31/2023

Background-Only talk at UCLA DM2023

Observe a 3.4  $\sigma$  excess in data in  $Y'$  in region of high S/B

— SS — IE+CSU  
— MSU2 — Bkg Only  
— MSU3 + LZ DD Migdal Data

Preliminary Result reports Event Data and Background only in this Green Shaded Region ( $Y' > 0.42$ )

Model fits in this plot are Bkg only - signal lines not shown

Source	Number of events in $Y' > 0.42$	
<b>Observed Data Events</b>	<b>23</b>	
BG Model Prediction	SS	0.3 +/- 0.1 (sys.)
	MSU2	4.9 +/- 0.1 (sys.)
	MSU3	2.4 +/- 0.1 (sys.)
	IE+CSU	2.0 +/- 0.2 (sys.)
<b>Total BG Model Predicted</b>	<b>9.6 +/- 0.5 (sys.)</b>	
<b>Significance versus BG-only Model Poiss(<math>n \geq 23   \mu = 9.6 + 0.5</math>)</b>	<b>3.4 <math>\sigma</math></b>	

見えた

# Migdal確認 (ガス) : MIRACLUE/MIGDAL

- ガス検出器
- 原子核反跳+電子信号
- 中性子照射試験を始めている

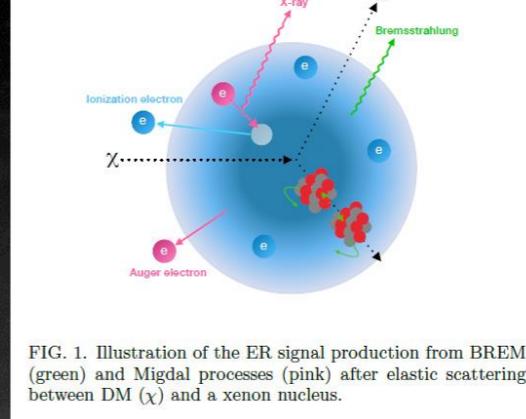


FIG. 1. Illustration of the ER signal production from BREM (green) and Migdal processes (pink) after elastic scattering between DM ( $\chi$ ) and a xenon nucleus.

MIGDAL

PTEP(2020)ptaa162

## Detection capability of Migdal effect for argon and xenon nuclei with position sensitive gaseous detectors

Kiseki D. Nakamura<sup>1</sup>, Kentaro Miuchi<sup>1</sup>, Shingo Kazama<sup>2</sup>, Yutaro Shoji<sup>3</sup>, Masahiro Ibe<sup>4,5</sup>, and Wakutaka Nakano<sup>6</sup>

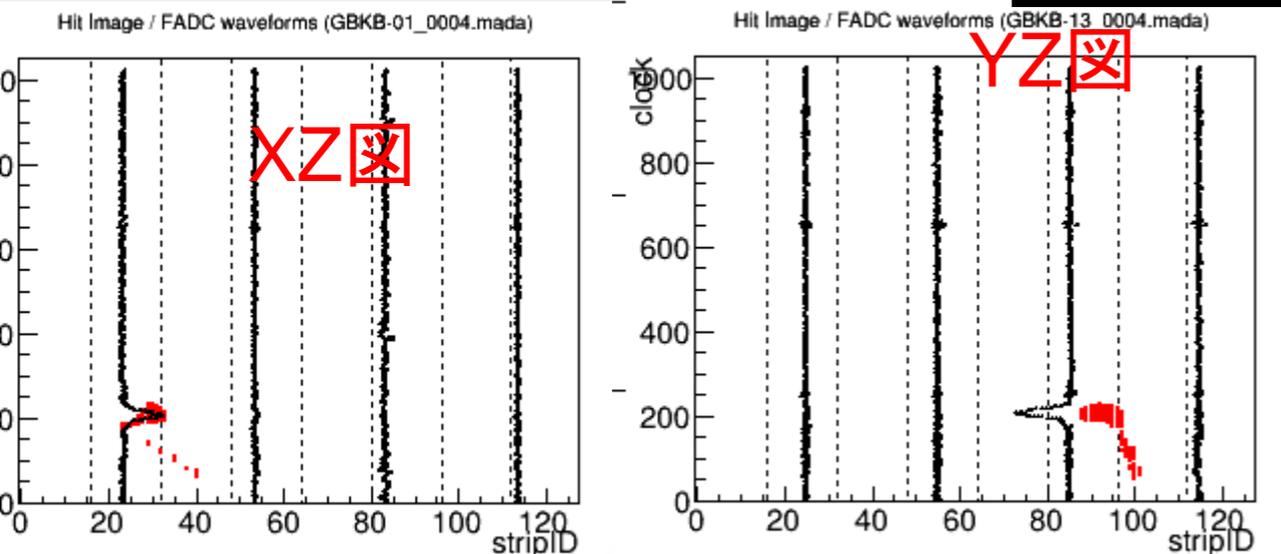
Astroparticle Physics 151 (2023) 102853

## The MIGDAL experiment: Measuring a rare atomic process to aid the search for dark matter

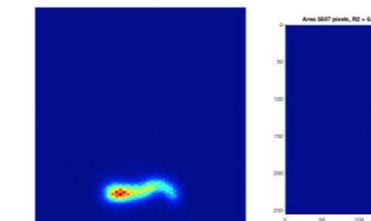
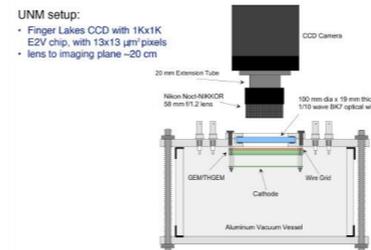
H.M. Araújo<sup>a,\*</sup>, S.N. Balashov<sup>b</sup>, J.E. Borg<sup>a</sup>, F.M. Brunbauer<sup>c</sup>, C. Cazzaniga<sup>d</sup>, C.D. Frost<sup>d</sup>, F. Garcia<sup>e</sup>, A.C. Kaboth<sup>f</sup>, M. Kastriotou<sup>d</sup>, I. Katsioulas<sup>g</sup>, A. Khazov<sup>b</sup>, H. Kraus<sup>h</sup>, V.A. Kudryavtsev<sup>i</sup>, S. Lilley<sup>d</sup>, A. Lindote<sup>j</sup>, D. Loomba<sup>k</sup>, M.I. Lopes<sup>j</sup>, E. Lopez Asamar<sup>jl</sup>, P. Luna Dapica<sup>d</sup>, P.A. Majewski<sup>b,\*</sup>, T. Marley<sup>a,b</sup>, C. McCabe<sup>m</sup>, A.F. Mills<sup>k</sup>, M. Nakhostin<sup>a,b</sup>, T. Neep<sup>g</sup>, F. Neves<sup>j</sup>, K. Nikolopoulos<sup>g</sup>, E. Oliveri<sup>c</sup>, L. Ropelewski<sup>c</sup>, E. Tilly<sup>k</sup>, V.N. Solovov<sup>j</sup>, T.J. Sumner<sup>a</sup>, J. Tarrant<sup>n</sup>, R. Turnley<sup>d</sup>, M.G.D. van der Grinten<sup>b</sup>, R. Veenhof<sup>c</sup>

身内20aV1-4

Ar + 電子 候補

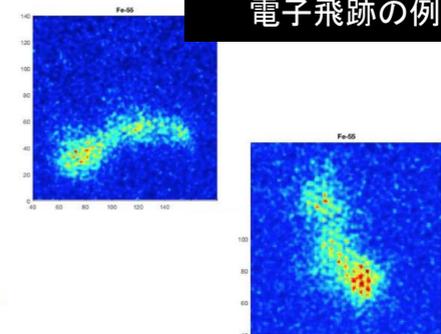


## O-TPC at UNM (from D. Loomba) 2D reconstruction



- 25-35 Torr CF4
  - 2THGEMs ( $\sigma > 0.7$  mm)
  - Imaging area  $\sim 1.9$ cm x 1.9cm
  - 4x4 on-chip binning
- Data acquired using following sources:
- Fe-55 (5.9 keV x-rays)
  - Co-60 ( $\gamma$ 's)
  - DD neutron generator ( $\sim 2.2$  MeV n's +  $\gamma$ 's)

電子飛跡の例



# • Spin-dependent WIMP探索

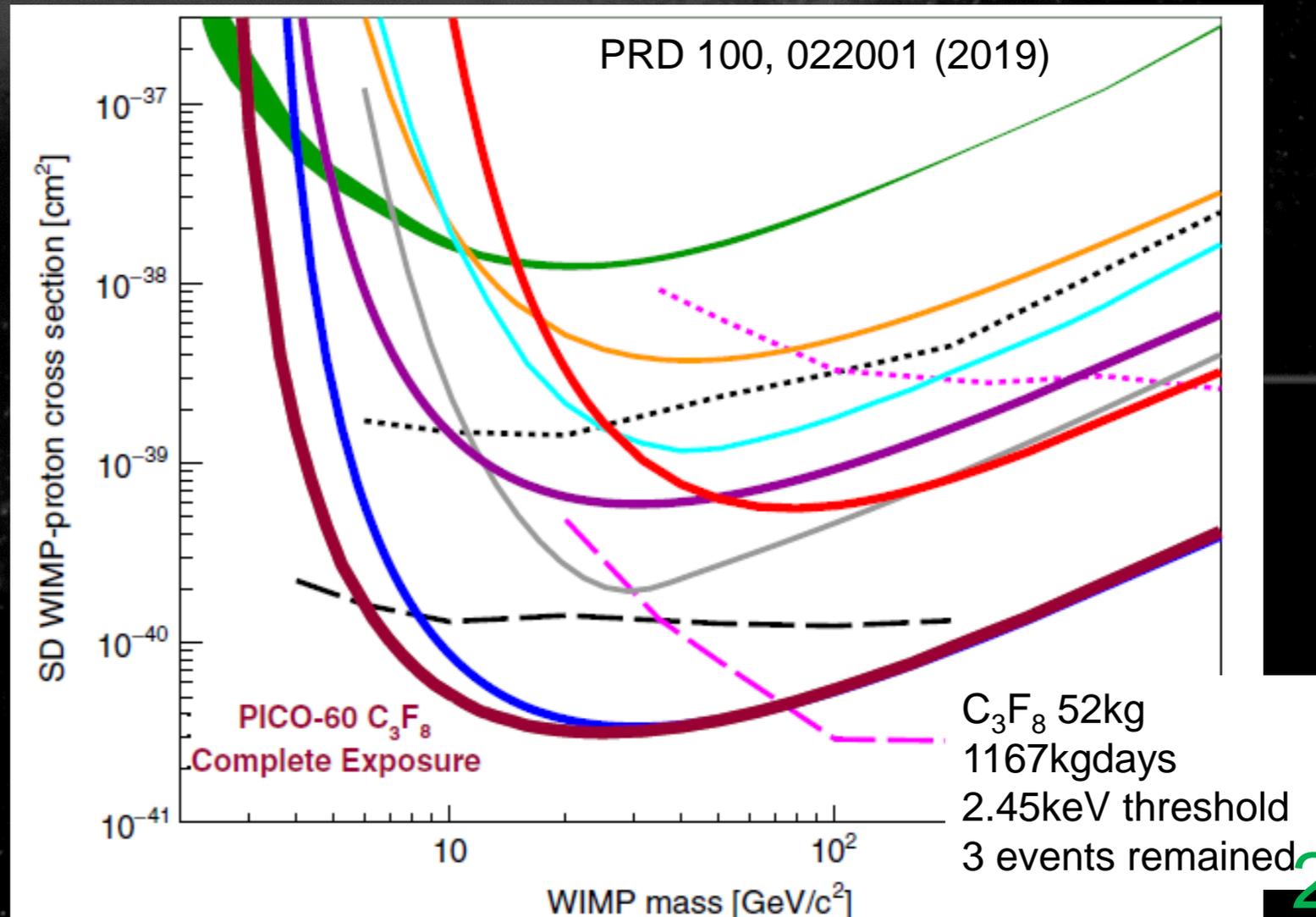
## • PICO

- Superheated chamber
- Threshold-type detector
- Best SD sensitivity

### PICO Results and Future Plans

Hugh Lippincott, Fermilab  
for the PICO Collaboration  
EDU 2017

How many bubbles can you count?



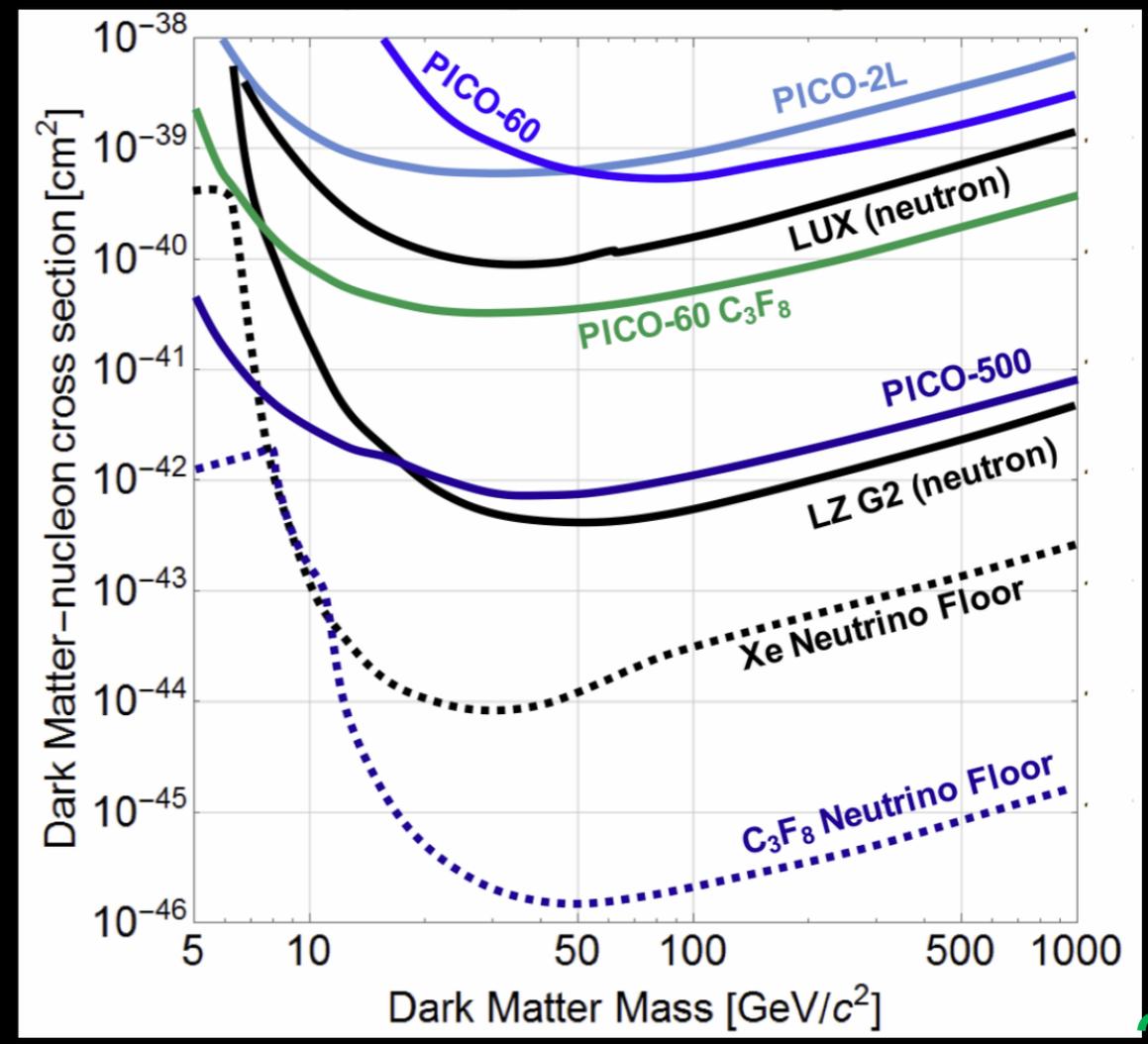
- Fluorine advantage
  - SD search
  - different “Neutrino floor” from xenon

Isotope	$J$	Abundance(%)	$\mu_{\text{mag}}$	$\lambda^2 J(J + 1)$	unpaired nucleon
$^1\text{H}$	1/2	100	2.793	0.750	proton
$^7\text{Li}$	3/2	92.5	3.256	0.244	proton
$^{11}\text{B}$	3/2	80.1	2.689	0.112	proton
$^{15}\text{N}$	1/2	0.4	-0.283	0.087	proton
$^{19}\text{F}$	1/2	100	2.629	0.647	proton
$^{23}\text{Na}$	3/2	100	2.218	0.041	proton
$^{127}\text{I}$	5/2	100	2.813	0.007	proton
$^{133}\text{Cs}$	7/2	100	2.582	0.052	proton
$^3\text{He}$	1/2	$1.0 \times 10^{-4}$	-2.128	0.928	neutron
$^{17}\text{O}$	5/2	0.0	-1.890	0.342	neutron
$^{29}\text{Si}$	1/2	4.7	-0.555	0.063	neutron
$^{73}\text{Ge}$	9/2	7.8	-0.879	0.065	neutron
$^{129}\text{Xe}$	1/2	26.4	-0.778	0.124	neutron
$^{131}\text{Xe}$	3/2	21.2	0.692	0.055	neutron
$^{183}\text{W}$	1/2	14.3	0.118	0.003	neutron

## PICO Results and Future Plans

Hugh Lippincott, Fermilab  
for the PICO Collaboration  
EDU 2017

### Scaling to PICO-500

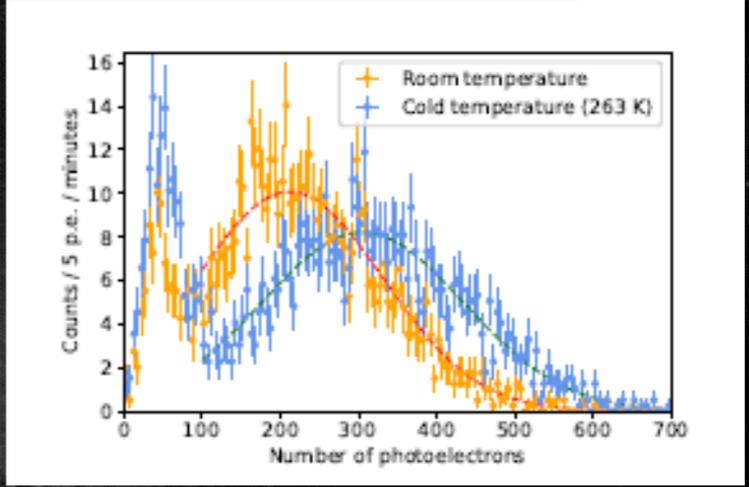


- フッ素使ってエネルギーもとりたい。  
 : 液化CF<sub>4</sub>シンチレータの開発

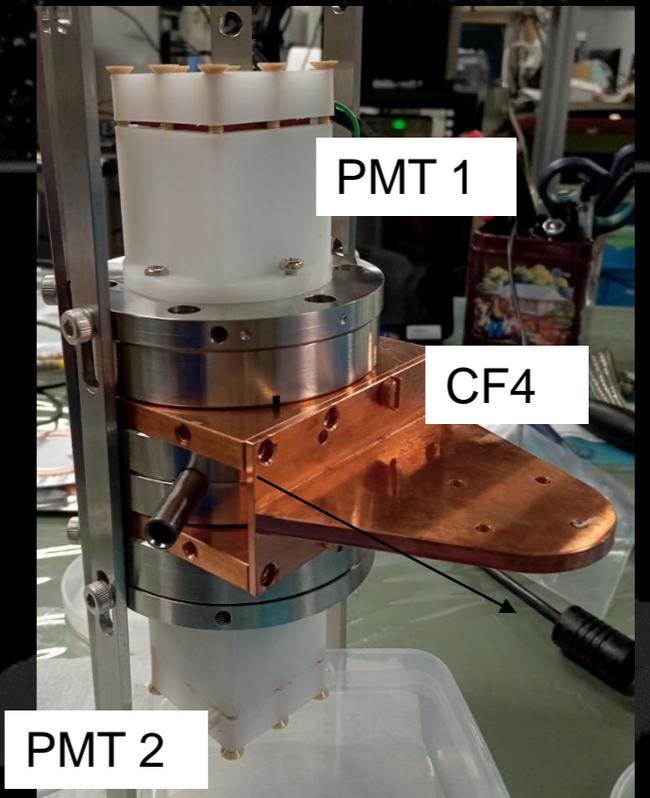
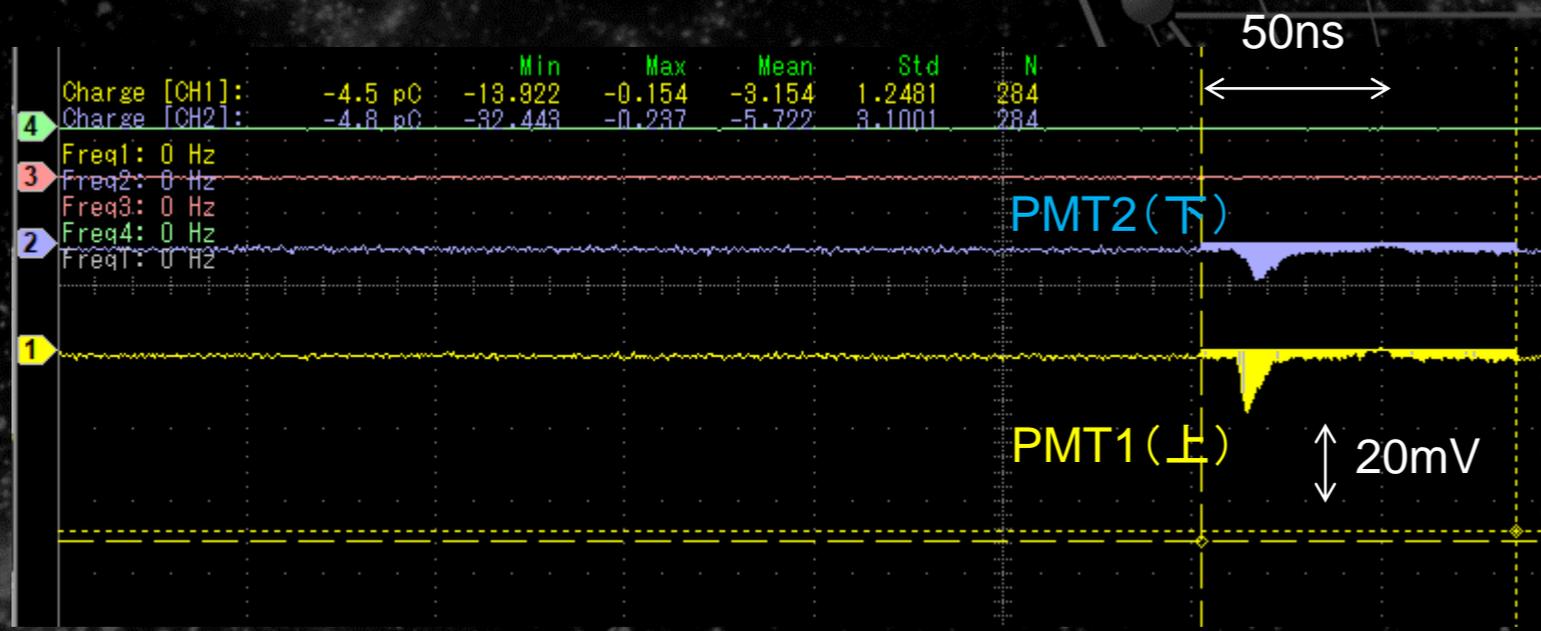


- 2021年論文 冷却CF<sub>4</sub>ガスの発光 (増光)

Scintillation light increase of carbontetrafluoride gas at low temperature  
 2021 JINST 16 P12033  
 K. Mizukoshi,\* T. Maeda, Y. Nakano,<sup>1</sup> S. Higashino and K. Miuchi



- 2023年実験 液化CF<sub>4</sub>の発光確認



• 低質量WIMP

• Bolometers

• Low energy threshold  $\Rightarrow$  low mass DM

Latest results of CRESST-III's search for sub-GeV/c<sup>2</sup> dark matter

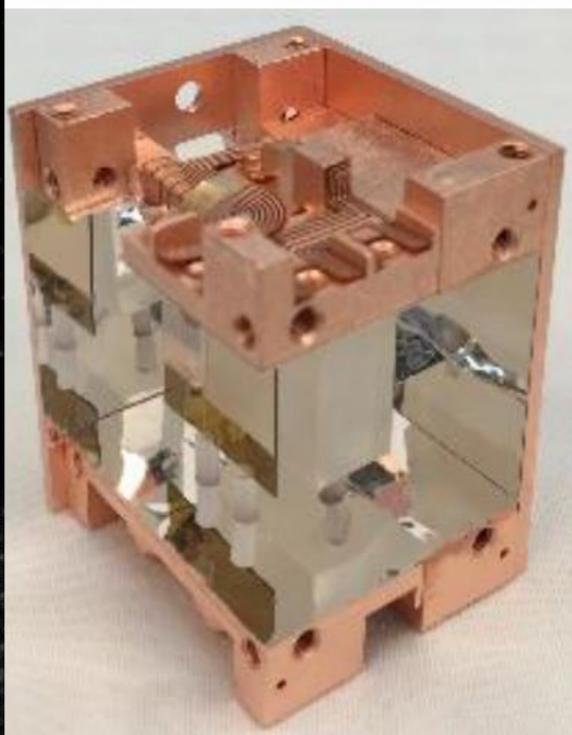
Holger Kluck

on behalf of the CRESST collaboration

16th International Conference on Topics in Astroparticle and Underground Physics (TAUP2019)

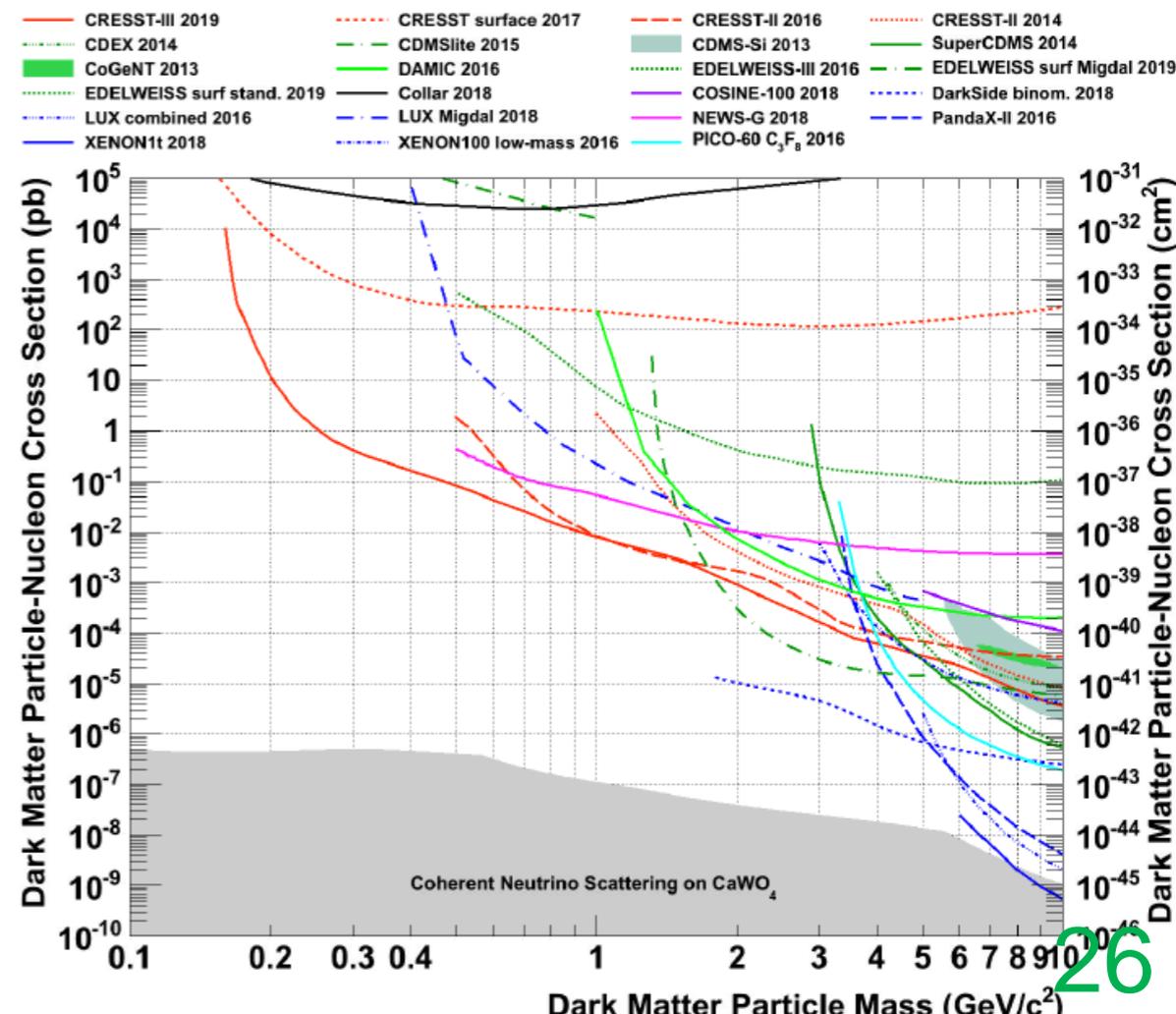
CRESST-III detector

CRESST-III result



- May 2016: 10 CRESST-III modules installed
- Jul 2016 – Feb 2018: data taking (80% blinded, 20% training set)
- Detector A  $\rightarrow$  lowest nuclear recoil threshold so far: **30.1 eV**
- Target crystal mass: 23.6g
- Gross exposure: 5.6 kg d

• [arXiv:1904.00498]

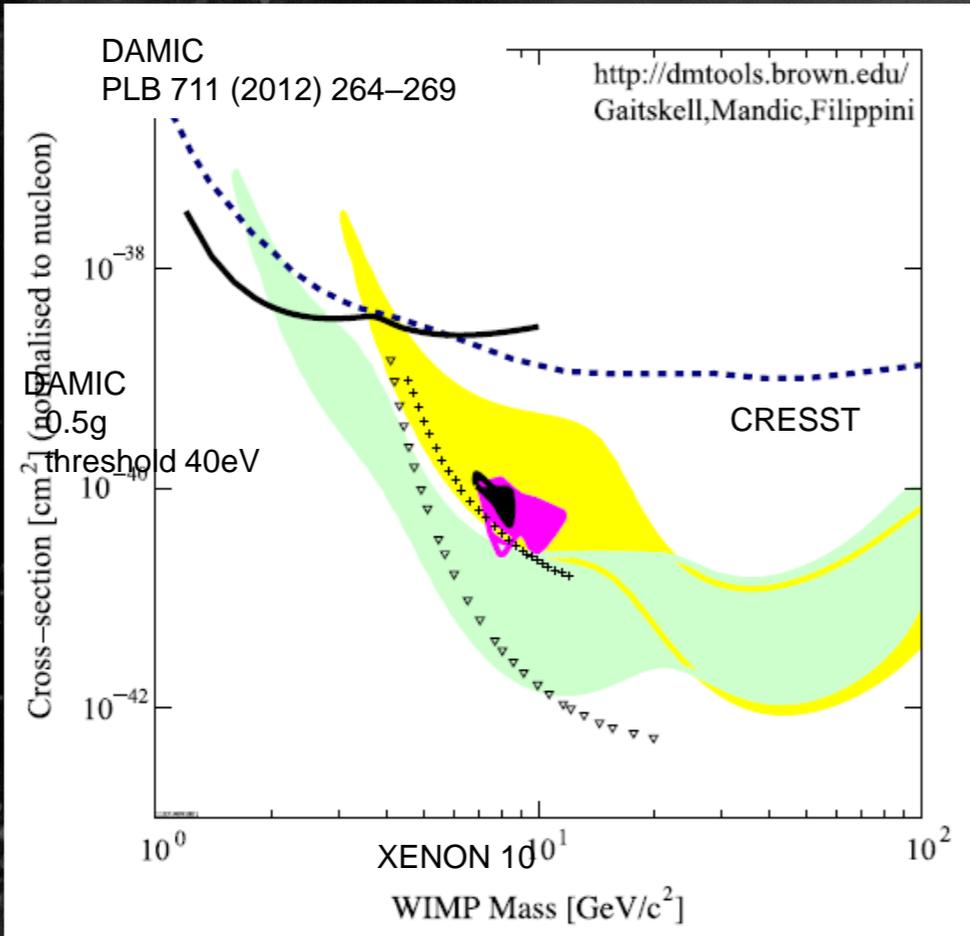


• CCD

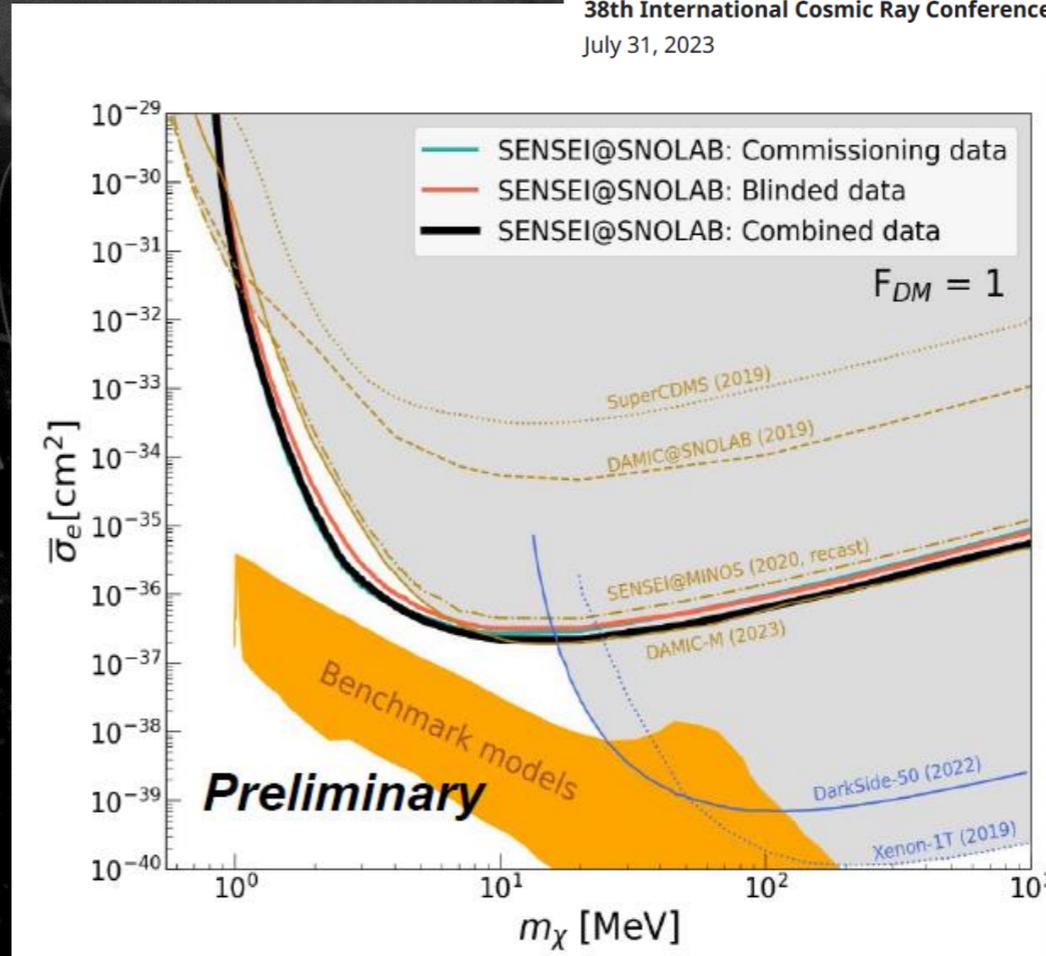
- DAMIC
  - pioneer of low threshold
- SENSEI
  - skipper CCD
  - sensitive to single electron
  - DM-electron channel and other

arXiv:2007.15622v1

PRL 125, 171802 (2020)



A. M. Botti\* for the SENSEI collaboration  
38th International Cosmic Ray Conference, Nagoya  
July 31, 2023



# 超電導体・量子技術

- TES (transition edge sensor), KID (kinetic inductance detector), MMC (metallic-magnetic calorimeter), nanowire...
- KID 開発
  - アルミニウムの細線をCaF<sub>2</sub>ウエハ上に形成
- 今後：“ Kamioka CryoLab “で低温complex  
→ 21aV1-7 石徹白

## PTEP

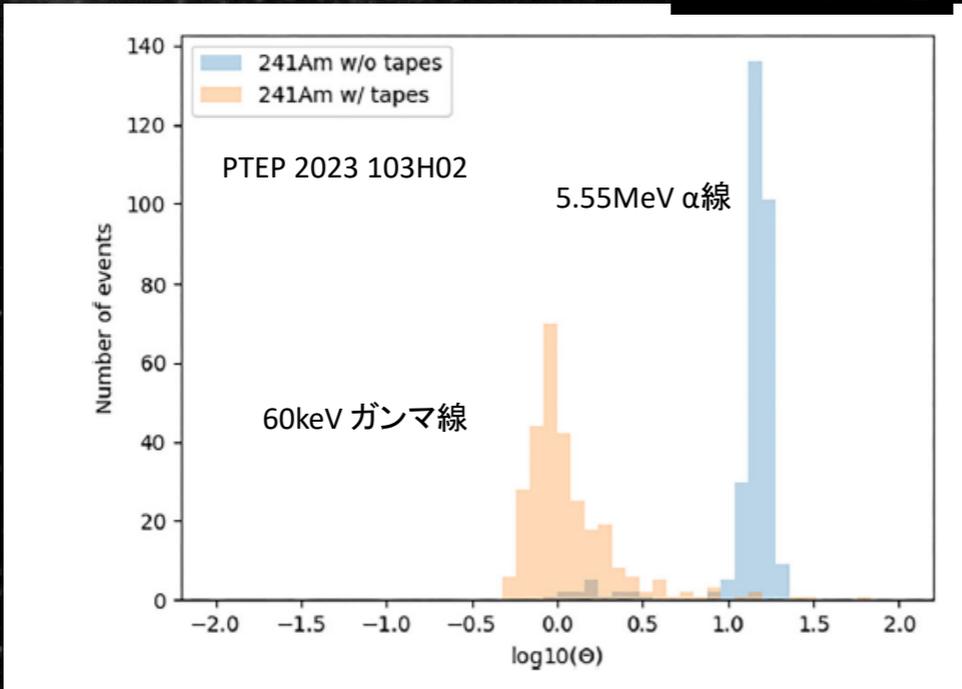
Prog. Theor. Exp. PTEP 2023 103H02

### Kinetic inductance detectors on calcium fluoride substrate for astroparticle physics

K. Ishidoshiro<sup>1,2,\*</sup>, T. Kobayashi<sup>3</sup>, K. Hosokawa<sup>4</sup>, Y. Kawamura<sup>3</sup>, Y. Kamei<sup>1,5</sup>, S. Mima<sup>5,6</sup>, C. Otani<sup>7,8</sup>, A. A. Suzuki<sup>1</sup>, M. Zulfakri<sup>9</sup>, and T. Taino<sup>3</sup>



KIDの動作検証



## Kamioka CryoLab

21aV1-7 石徹白

### Low BG dilution refrigerator (DR) at Kamioka for integration of quantum sensing and low BG technology

#### Quantum sensing

##### Cryogenic system

- ~0.1 K with refrigerator

##### Superconducting device

- MKID, TES, ...
- Fabrications
- Chain tests

##### RF/readout electronics

- 5G/6G technologies
- Quantum limited amplifier



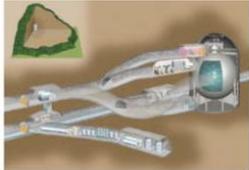
meets



#### Low background

##### Underground facility at the Kamioka mine

- Protecting system from cosmic-ray

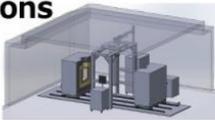


##### Low environmental radiation

- Understanding impacts of radio activities
- Low radio activities in materials
- Shielding system from radio activities

##### Low systematic fluctuations

- Low thermal noise
- Low vibration



# 超電導体・量子技術 (continued)

## 量子ビット

- キャビティの読み出し
- 直接励起

渡邊香凜: 21pT3-6, 中園寛: 21pT3-7

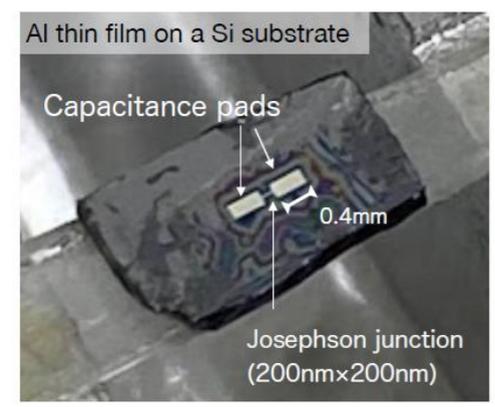
[https://conference-indico.kek.jp/event/236/contributions/4348/attachments/3270/4481/IPNS\\_20231222\\_quantum\\_schen.pdf](https://conference-indico.kek.jp/event/236/contributions/4348/attachments/3270/4481/IPNS_20231222_quantum_schen.pdf)

## 量子技術の素粒子実験への応用

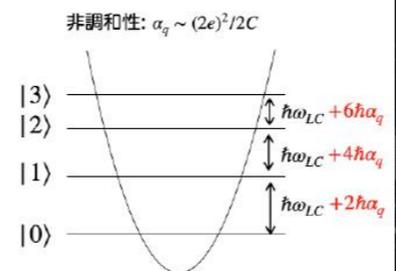
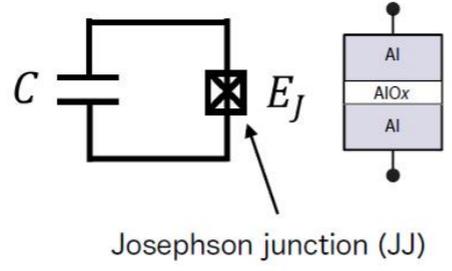
陳詩遠 (東大ICEPP)

2023.12.22 IPNS workshop 素粒子物理の今と未来

### 超伝導量子ビット = キンキンに冷えた非線形LC回路



$$\mathcal{H}_q \sim \hbar\omega_q a^\dagger a + \frac{\hbar\alpha_q}{2} a^\dagger a^\dagger a a$$



<https://arxiv.org/pdf/2311.10413.pdf>

### Quantum Enhancement in Dark Matter Detection with Quantum Computation

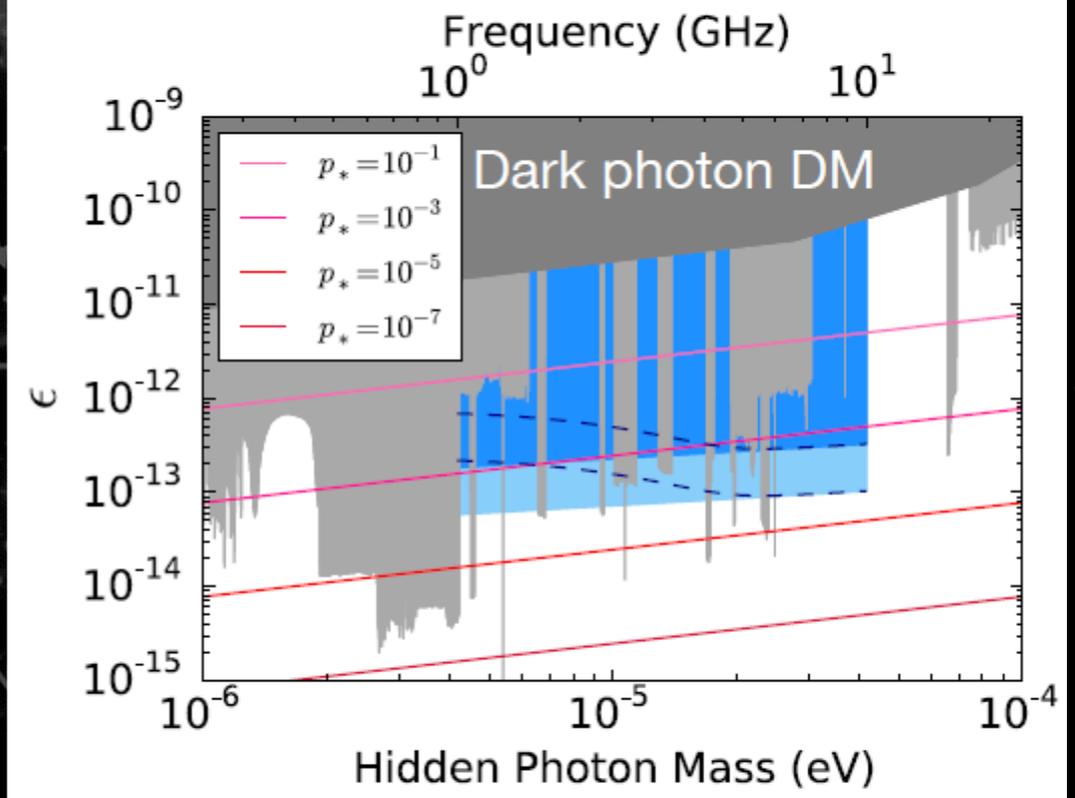
Shion Chen,<sup>1</sup> Hajime Fukuda,<sup>2</sup> Toshiaki Inada,<sup>1</sup> Takeo Moroi,<sup>2,3</sup> Tatsumi Nitta,<sup>1</sup> and Thanaporn Sichanugrist<sup>2,\*</sup>

<sup>1</sup>International Center for Elementary Particle Physics (ICEPP),  
The University of Tokyo, Tokyo 113-0033, Japan

<sup>2</sup>Department of Physics, The University of Tokyo, Tokyo 113-0033, Japan

<sup>3</sup>QUP (WPI), KEK, Tsukuba, Ibaraki 305-0801, Japan

Chen, Fukuda, Inada, Moroi, Nitta, Thanaporn  
PRL 131, 211001 (2023)



Dark blue:  $n_q=1$  @1mK

Light blue:  $n_q=100$  @1mK

点線: 30mK

$N_{\text{try}} \sim O(10^4)$

• さらに：理論面からのあおりinputは重要！

2 イオンの量子もつれを用いた軽い暗黒物質探索

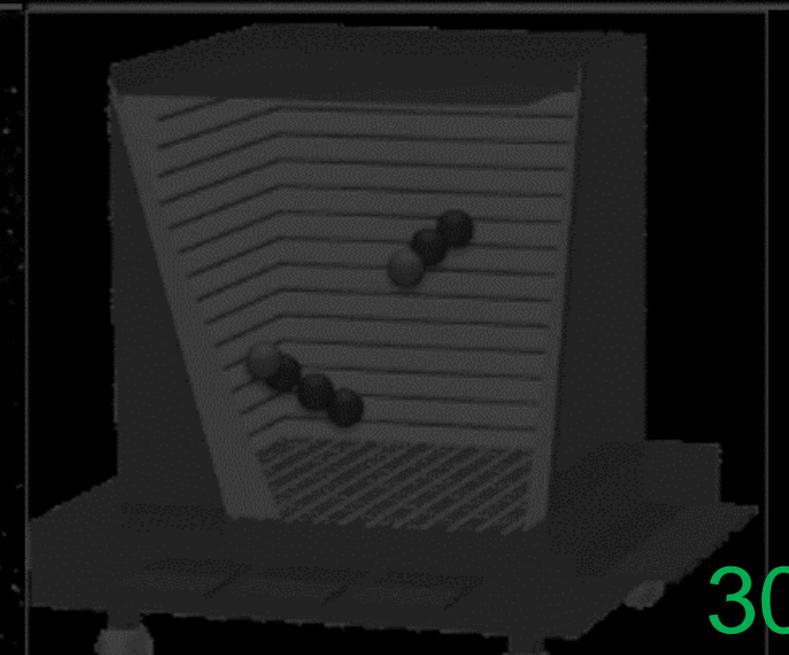
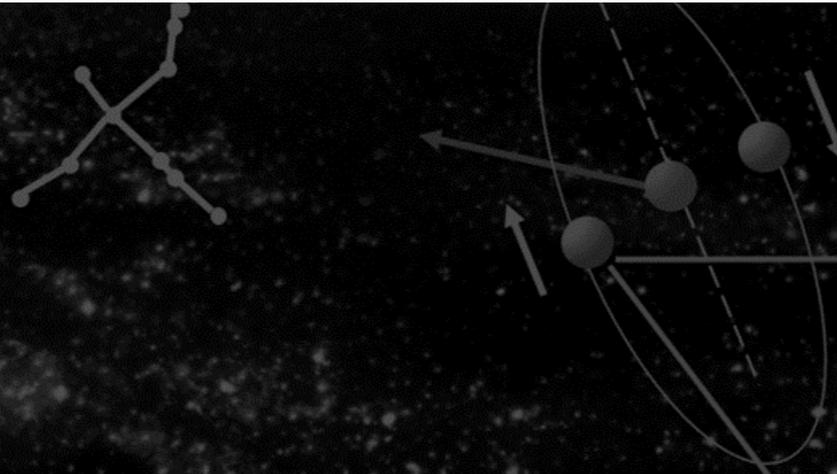
QUP<sup>A</sup>, 高工研<sup>B</sup>, 総研大<sup>C</sup>

伊藤飛鳥<sup>A, B</sup>, 北野龍一郎<sup>B, C</sup>, 中野湧天<sup>B</sup>, ○高井峻聖<sup>B, C</sup>

3 Light Dark Matter Search with Nitrogen-Vacancy Centers in Diamonds

UC Berkeley, QUP<sup>A</sup>, 京大化研<sup>B</sup>, 東北大理<sup>C</sup>

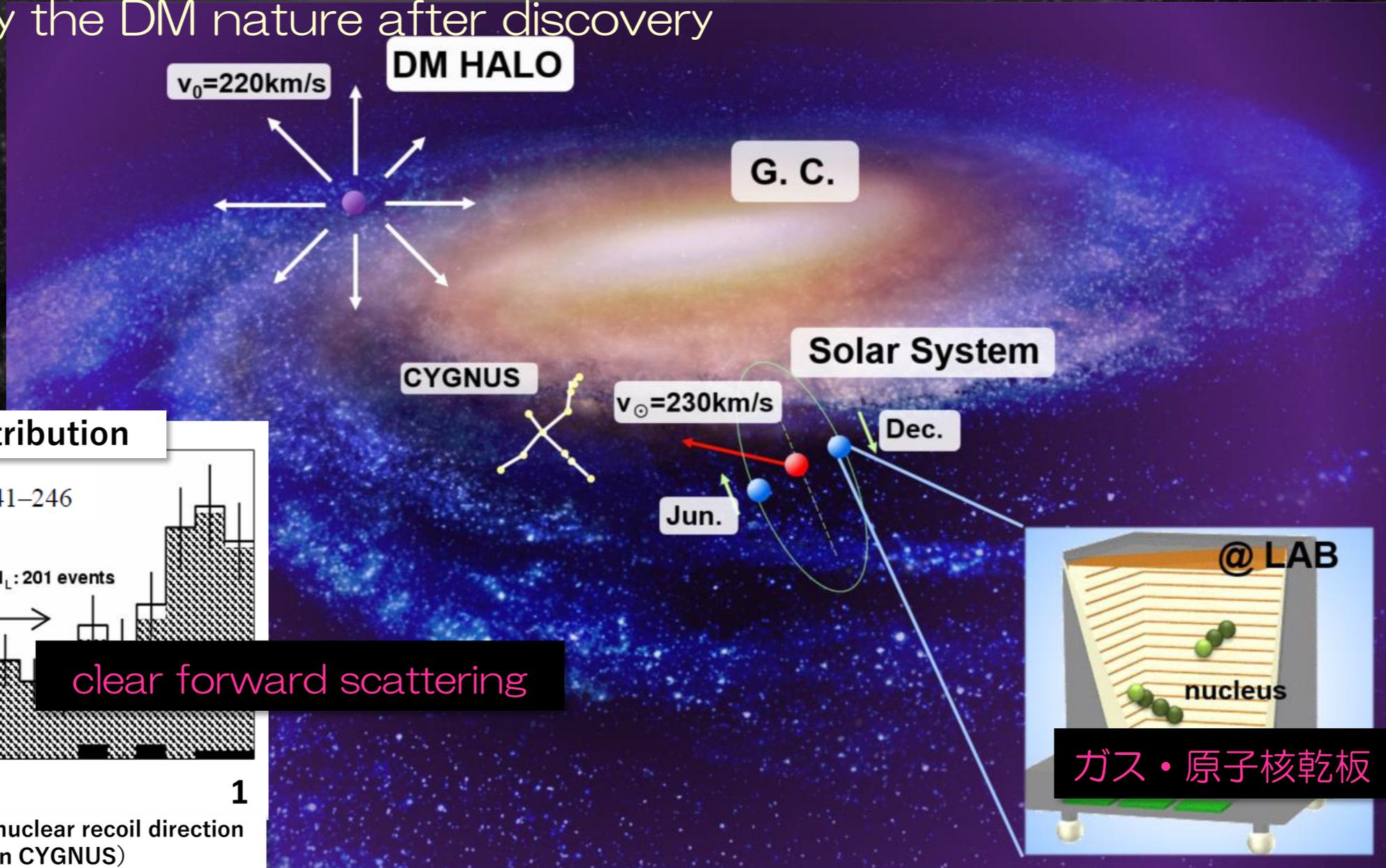
千草颯, 羽澄昌史<sup>A</sup>, Ernst David Herbschleb<sup>B</sup>, 水落憲和<sup>B</sup>, ○中山和則<sup>C</sup>



# Directional search

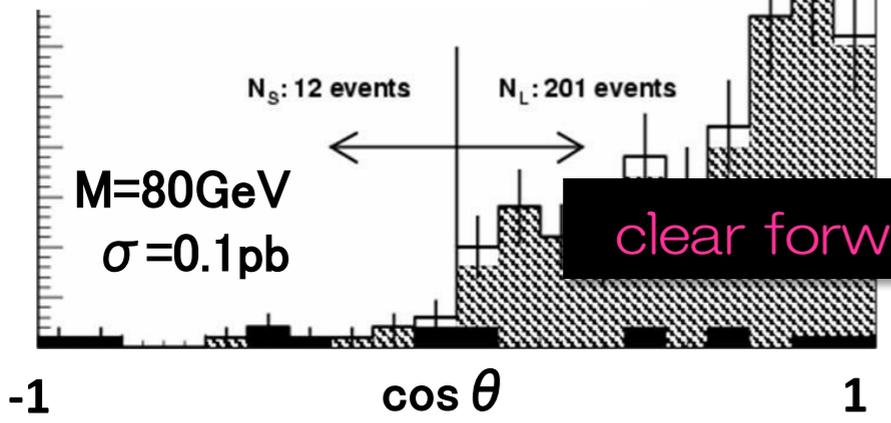
## Concept: "CYGNUS"

- More robust evidence than annual modulation
- Study the DM nature after discovery



### expected angular distribution

Physics Letters B 578 (2004) 241-246



clear forward scattering

( $\theta$  : angle between the nuclear recoil direction and constellation CYGNUS)

• ガス (NEWAGE) 

- 3D tracking
  - $\mu$ -PIC
  - SKYMAP
- $CF_4$  gas
  - High spatial resolution
  - Spin-Dependent search

• Proposal

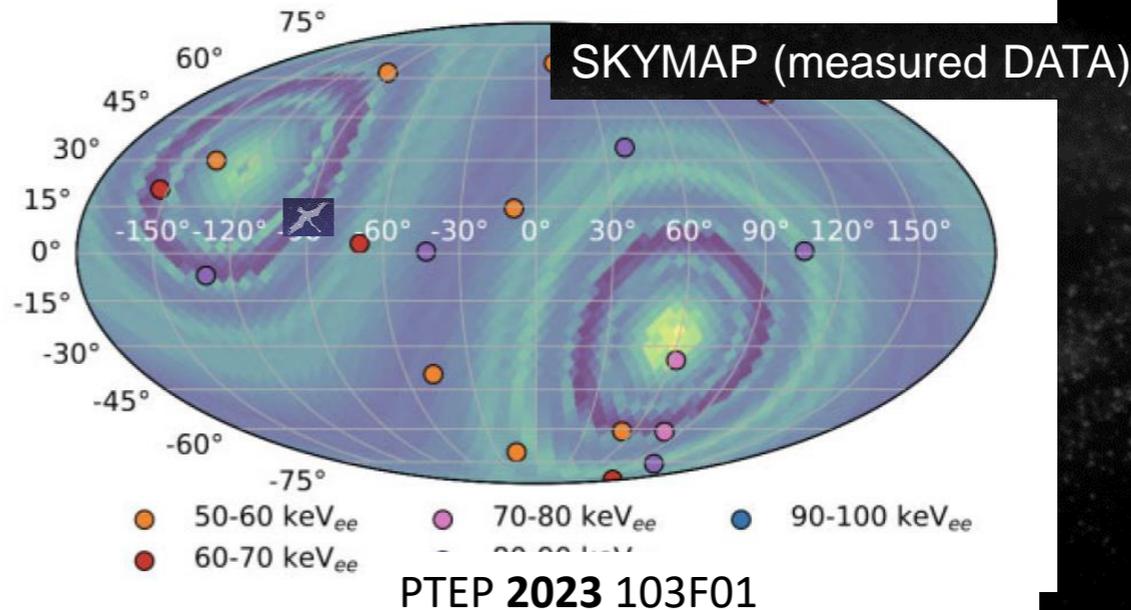
PLB 578 (2004) 241

• First directional search

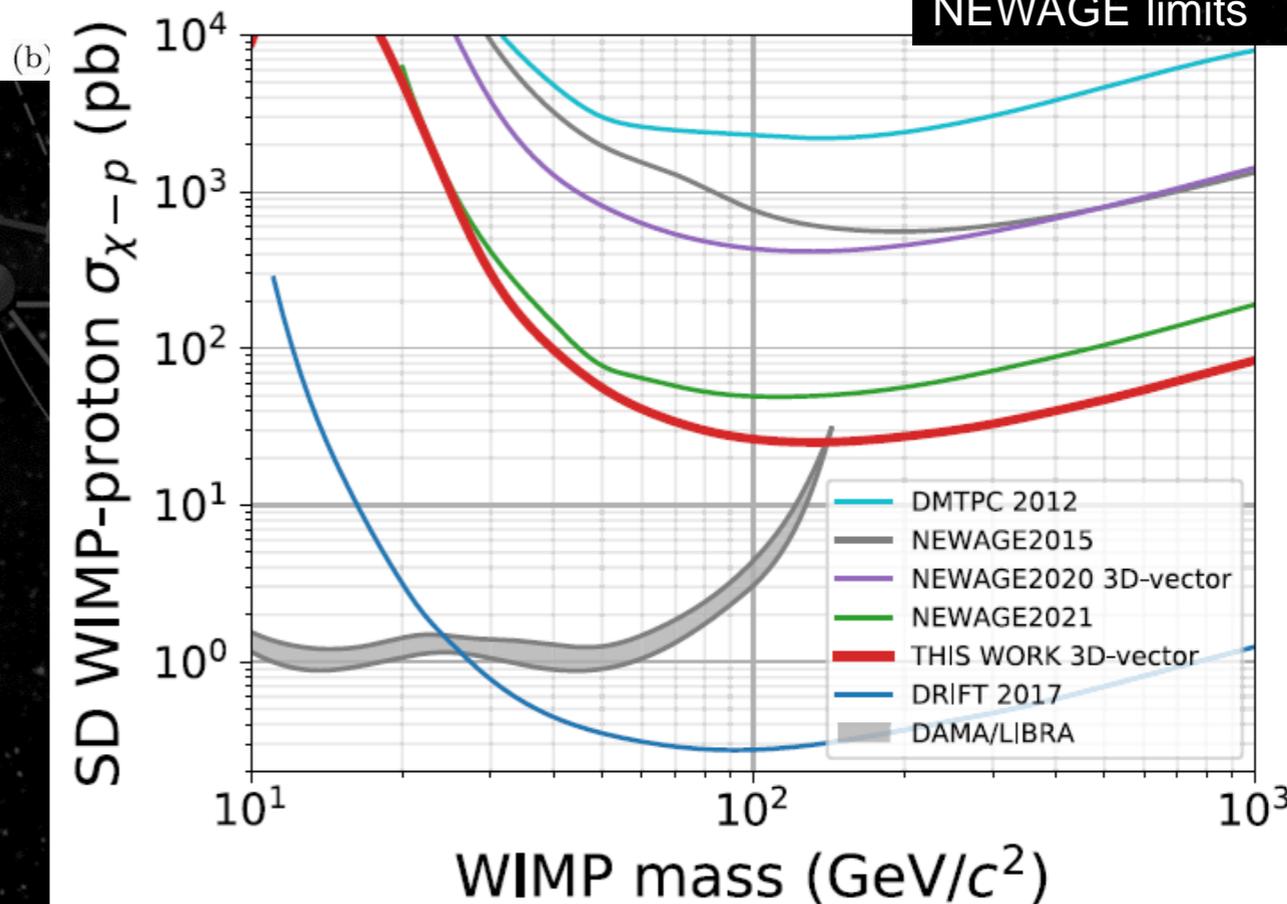
PLB 654 (2007) 58

• Underground measurements

PLB 686 (2010) 11, PTEP (2015) 043F01S,  
PTEP (2020) ptaa147, PTEP 2023 103F01



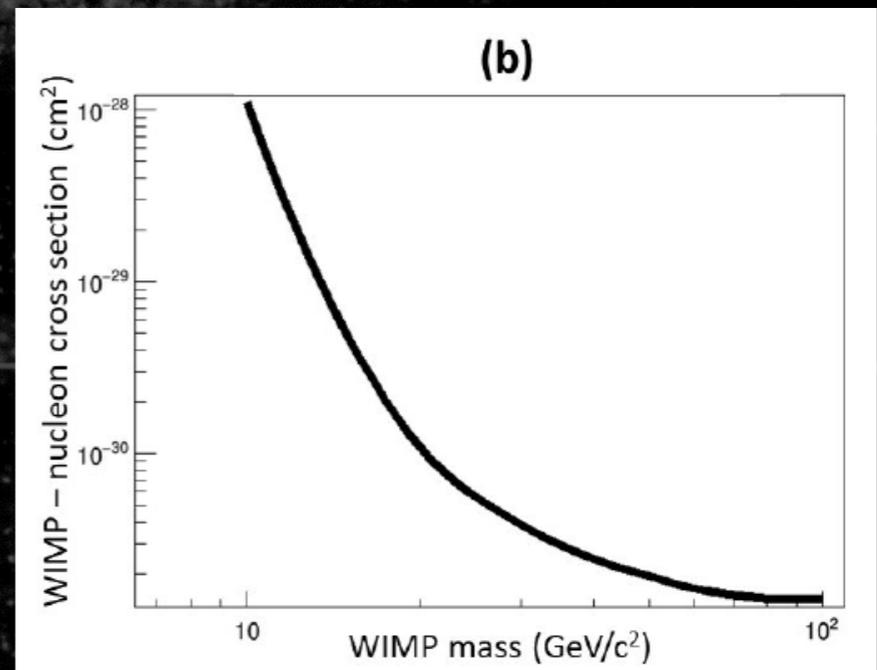
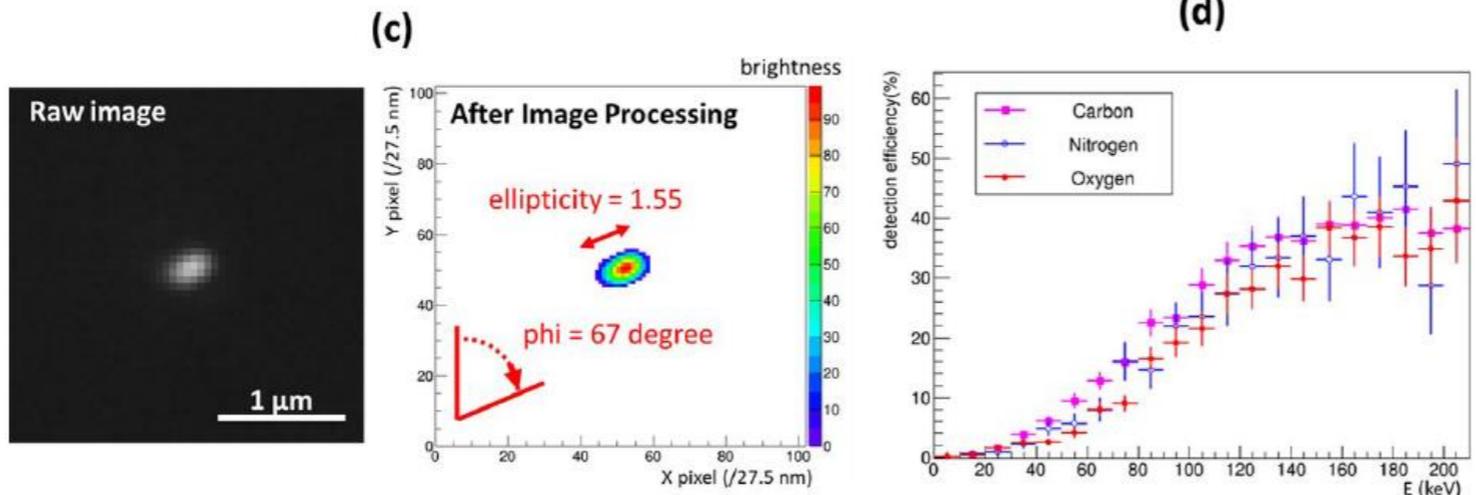
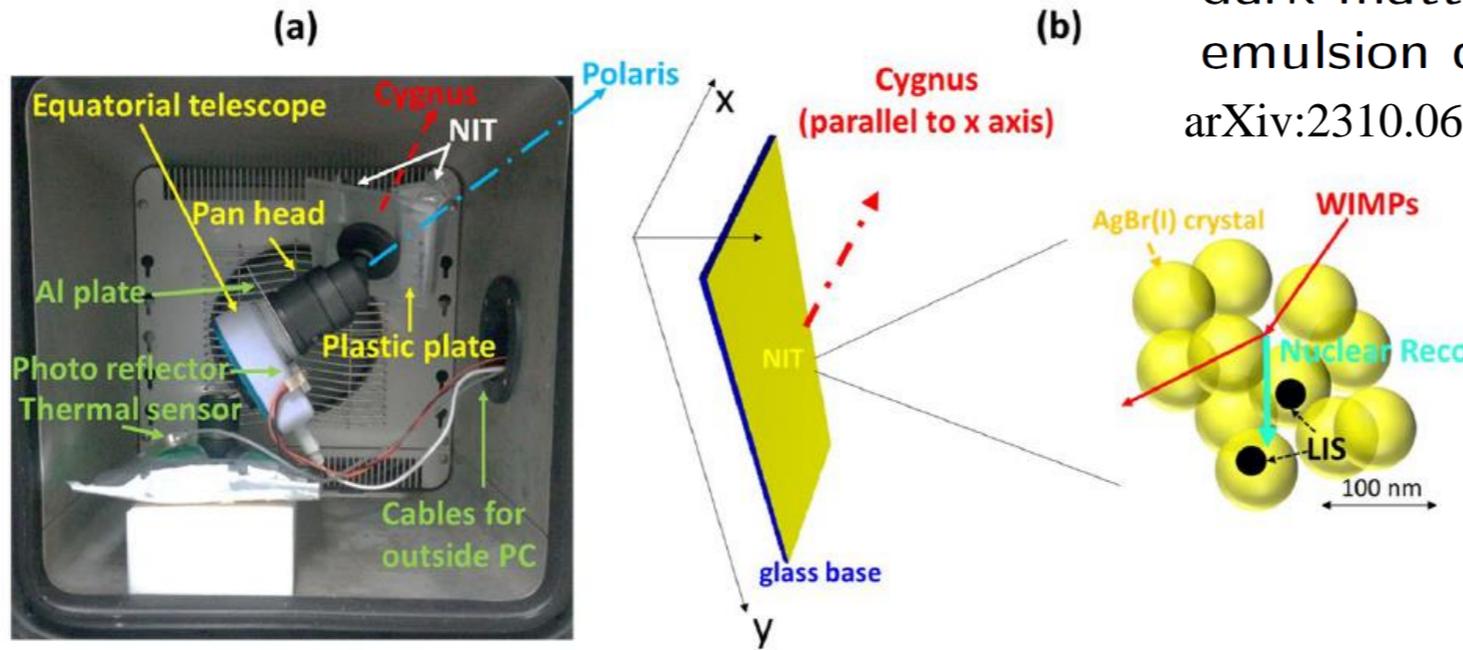
方向感度





- 原子核乾板 (NEWSdm)
- First direction-sensitive result

First direction sensitive search for dark matter with a nuclear emulsion detector at a surface site  
arXiv:2310.06265



# • まとめ

- 暗黒物質 波? 粒?
- 新旧多くの実験が行われている
- 日本のactivityも高い
- 実験・理論のコネクションは今後も重要

## 令和X(20XX)年度 基盤研究 (DM) 研究計画調書

この分野はこうやって育ってきた

令和XX年XX月XX日  
1版

### 新規

研究種目	基盤研究 (DM)	応募区分	一般
小区分			
研究課題名	新技術による暗黒物質探索検出器開発		

(概要)

宇宙の暗黒物質の正体解明は重要な課題です。私の持つ最新の技術を使うと今までに探索されていないフェーズスペースの暗黒物質を探索することが可能になります。まずは少額の予算で検出器として使えることを実証し、その後必要に応じて低バックグラウンド化や大型化を行うことで比較的安価かつ速やかに暗黒探索実験を行うことができます。

K You

量子技術をつかった軽い暗黒物質探索実験の提案についての科研費書類の概要を200字程度で書いてください。

ChatGPT

この科研費書類は、量子技術を活用し、軽い暗黒物質の探索を行う実験を提案する。我々は、量子干渉や量子状態制御を用いて、暗黒物質の微弱な相互作用を検出する手法を開発する。この実験では、高感度な検出器や冷却技術を組み合わせ、地下施設での実施を想定する。暗黒物質の探索において、量子技術の革新的な応用が可能性を秘めており、その成果は基礎物理学の理解や宇宙論の発展に大きな貢献を期待する。

これは実験的な成果は何も出せないけど。