RELICS

REactor neutrino **LI**quid xenon
Coherent elastic **S**cattering

Reactor-based Axion Search using RELICS Liquid Xenon Detector

Yuehuan Wei
Sun Yat-sen University
On behalf of the RELICS collaboration

April 11-14, 2025

Workshop on Multi-front Exotic phenomena in Particle and Astrophysics (MEPA 2025)

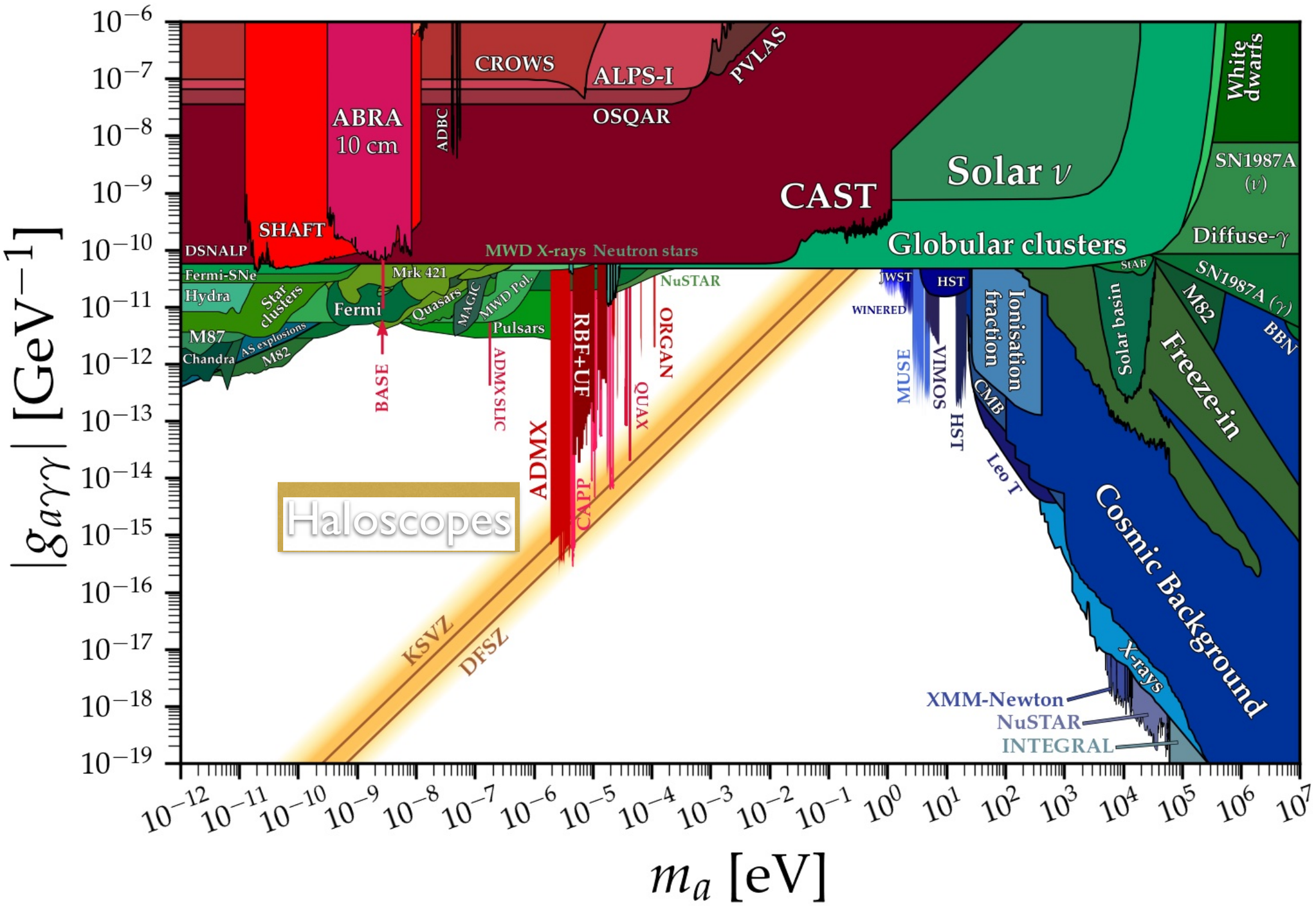
Axions and Axion-like Particles (ALPs)

- Proposed to solve the **strong CP problem** of Quantum Chromodynamics
- Well-motivated and thoroughly-studied **dark matter** candidate
- ALPs do not solve the strong CP problem.

实验类型	代表性实验
轴子暗物质晕望远镜 (Haloscopes)	ADMX、ABRACADABRA、CASPEr
太阳轴子望远镜 (Helioscopes)	CAST、IAXO
穿壁实验(LSW) (Light-Shining-Through-Walls)	ALPSII
干涉测量 (Interferometry)	ADBC、DANCE
暗物质直接探测实验 (Dark matter direct detection)	CDEX、PandaX、XENON

Status of axion searches

https://cajohare.github.io/AxionLimits/



Reactor axion searches

Volume 114B, number 1 PHYSICS LETTERS 15 July 1982

SEARCH FOR AXIONS IN THERMAL NEUTRON CAPTURE BY PROTONS

V.M. DATAR, C.V.K. BABA, M.G. BETIGERI and P. SINGH
Nuclear Physics Division, Bhabha Atomic Research Centre, Bombay 400 085, India

Received 28 April 1982

A search for axions at a 500 MW light water power reactor was performed. From the measured upper limit on the n + p → d + a cross section the "standard" axion is ruled out.

Volume 121B, number 2,3 PHYSICS LETTERS 27 January 1983

A SEARCH FOR AXIONS AT A POWER REACTOR

J.F. CAVAIGNAC, A. HOUMMADA, D.H. KOANG, B. OST, B. VIGNON, R. WILSON [1]
Institut des Sciences Nucléaires de Grenoble, IN2P3, 38026 Grenoble CEDEX, France
and
Y. DECLAIS, G. GIRARDI, H. DE KERRET, H. PESSARD and J.M. THENARD
Laboratoire d'Annecy le Vieux de Physique des Particules, IN2P3, Chemin de Bellevue, BP 909, 74019 Annecy le Vieux, France

Received 23 July 1982

PHYSICAL REVIEW LETTERS **124,** 211804 (2020)

New Directions for Axion Searches via Scattering at Reactor Neutrino Experiments

James B. Dent,[1] Bhaskar Dutta,[2] Doojin Kim
Kuver Sinha,[3] and Adri
[1]*Department of Physics, Sam Houston State Un*
[2]*Mitchell Institute for Fundamental Physics and Astronomy, Depar*
College Station, Texas
[3]*Department of Physics and Astronomy, University of*

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Axionlike particles searches in reactor experiments

D. Aristizabal Sierra,[a,b] V. De Romeri,[c] L.J. Flores[d] and D.K. Papoulias[e]

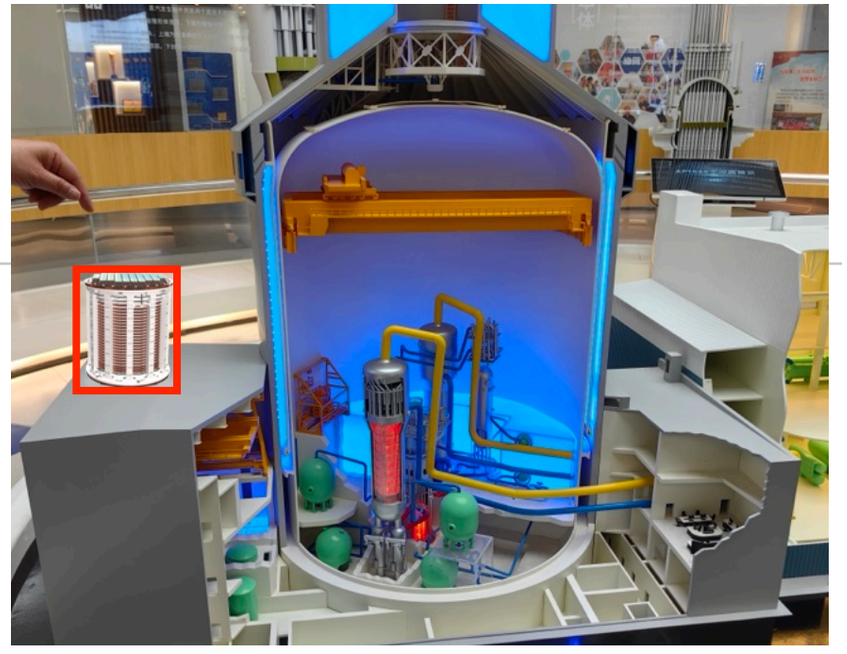
RELICS Collaboration 6 institutions, ~40 members

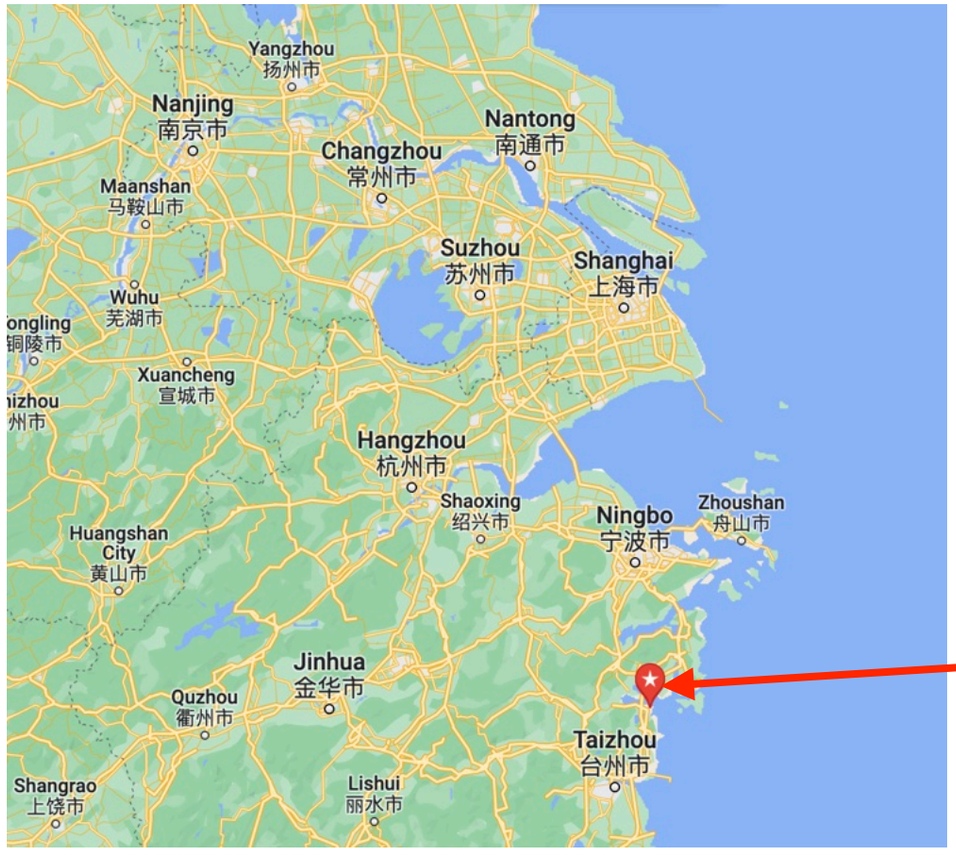
RELICS
REactor neutrino LIquid xenon Coherent elastic Scattering

香港中文大學（深圳）
The Chinese University of Hong Kong, Shenzhen

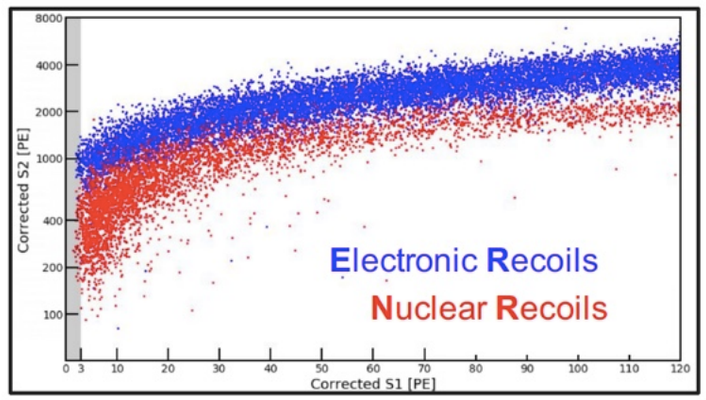
The site of RELICS Experiment

- Sanmen Nuclear Power Plant, Zhejiang Province
- Thermal Power ~3.4GW, baseline ~22m
- Neutrino flux ~1e14 ν/cm^2/s

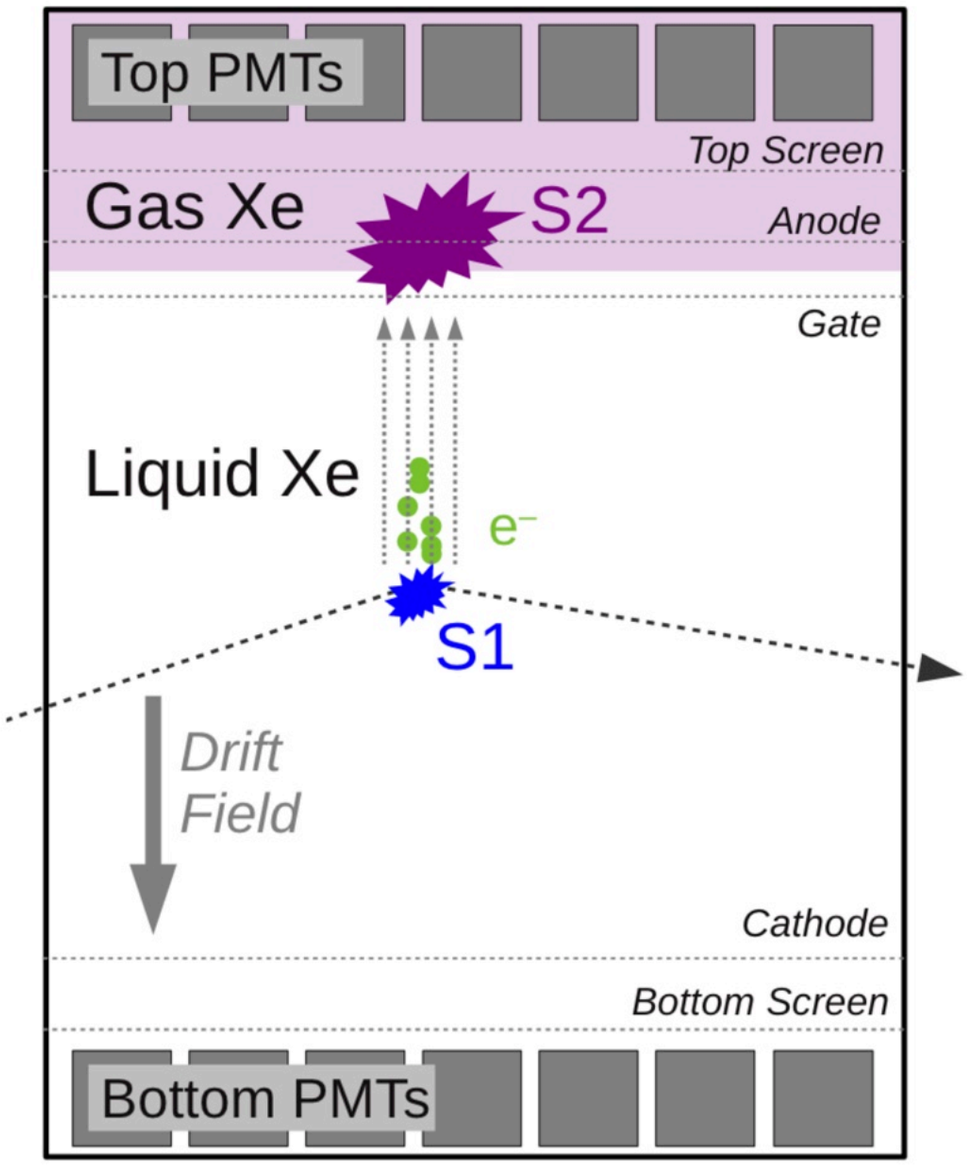


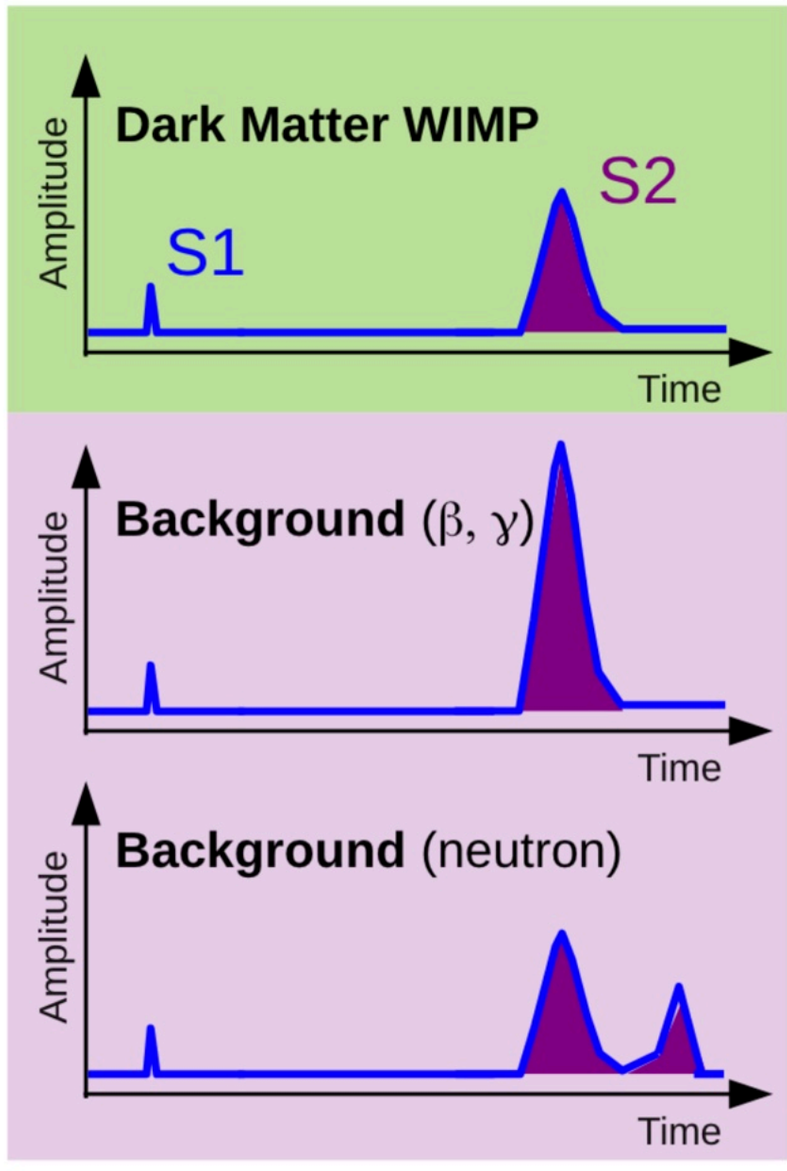


RELICS detection technology



Liquid Xenon Time Projection Chamber (LXeTPC)



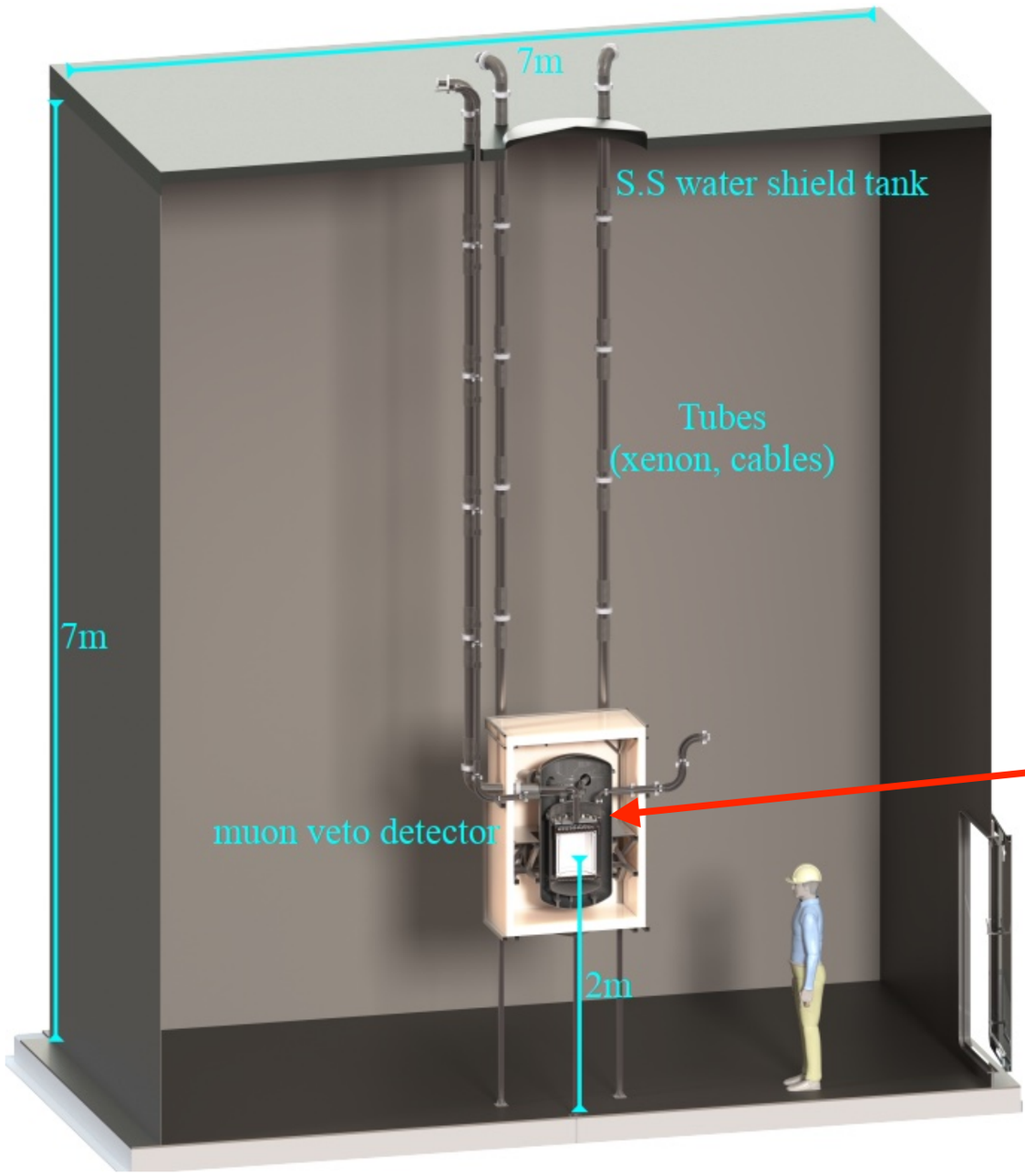


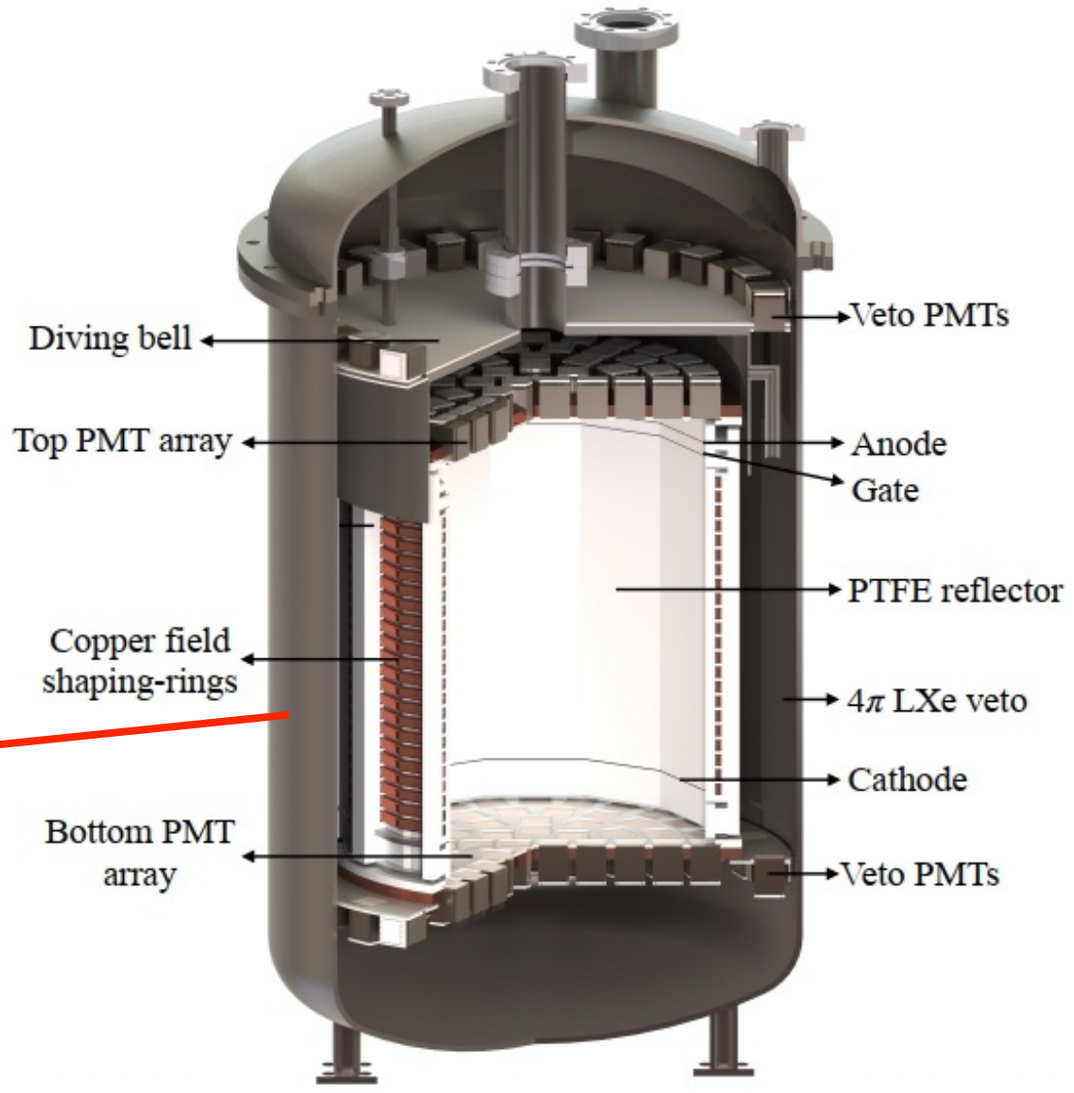
- ✦ Low-threshold
- ✦ Low-background
- ✦ Large-mass

Same as the PandaX, XENON, LZ Dark Matter Experiments..

RELICS detector

- ✦ 7x7x7m³ water shield to suppress cosmic-ray neutrons induced background
- ✦ 4π plastic scintillator muon veto detector with veto efficiency of 99%





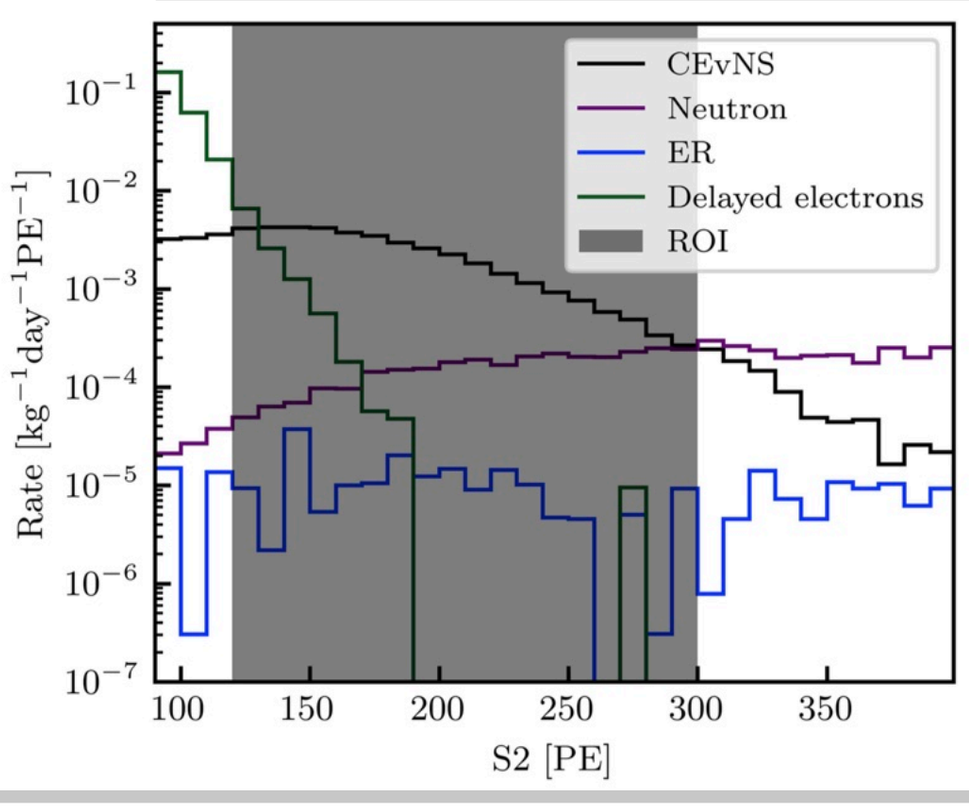
RELICS experiment and CEvNS study

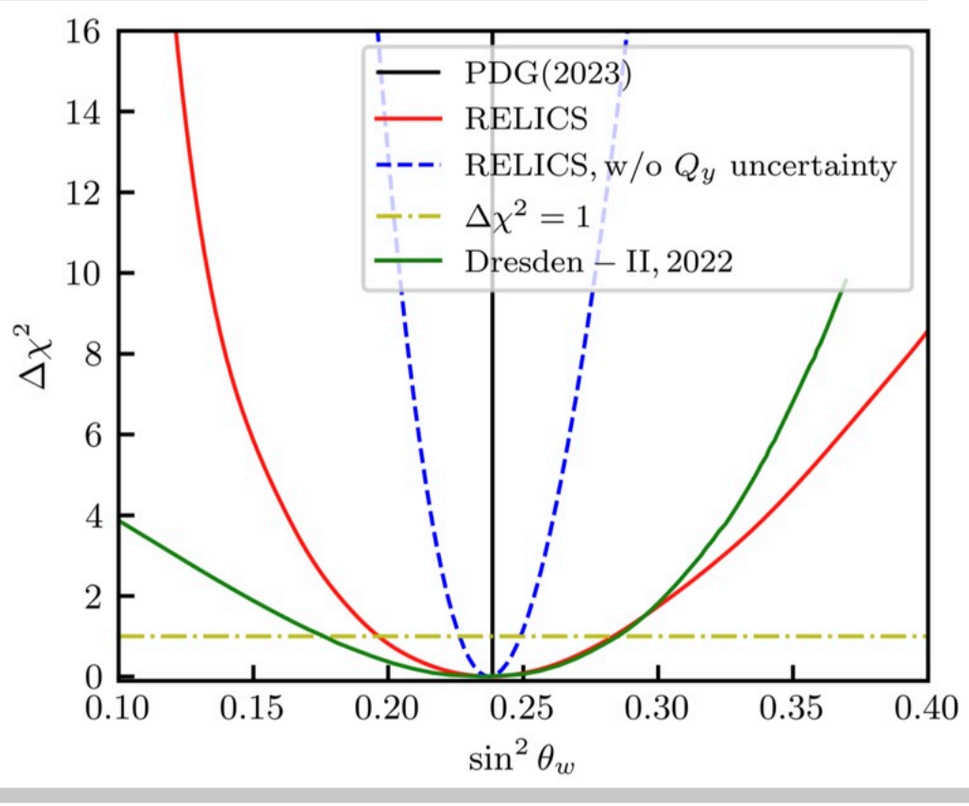
PHYSICAL REVIEW D **110,** 072011 (2024)

Reactor neutrino liquid xenon coherent elastic scattering experiment

Chang Cai,[1] Guocai Chen,[2] Jiangyu Chen,[3] Rundong Fang,[4] Fei Gao,[1,*] Xiaoran Guo,[5,6] Jiheng Guo,[4] Tingyi He,[7,‖] Chengjie Jia,[1,‡] Gaojun Jin,[2] Yipin Jing,[1,¶] Gaojun Ju,[2] Yang Lei,[1] Jiayi Li,[1] Kaihang Li,[1] Meng Li,[2] Minhua Li,[2] Shengchao Li,[8] Siyin Li,[8] Tao Li,[2] Qing Lin,[5,6] Jiajun Liu,[9] Minghao Liu,[1] Sheng Lv,[2] Guang Luo,[9] Jian Ma,[1] Chuanping Shen,[2] Mingzhuo Song,[1] Lijun Tong,[5,6] Xiaoyu Wang,[8] Wei Wang,[3,9] Xiaoping Wang,[4,10] Zihu Wang,[2] Yuehuan Wei,[3,†] Liming Weng,[2] Xiang Xiao,[9] Lingfeng Xie,[1] Dacheng Xu,[1,§] Jijun Yang,[8] Litao Yang,[11] Long Yang,[2] Jingqiang Ye,[7] Jiachen Yu,[5,6] Qian Yue,[11] Yuyong Yue,[3] Bingwei Zhang,[2] Shuhao Zhang,[1] Yifei Zhao,[1] and Chenhui Zhu[6]

(RELICS Collaboration)



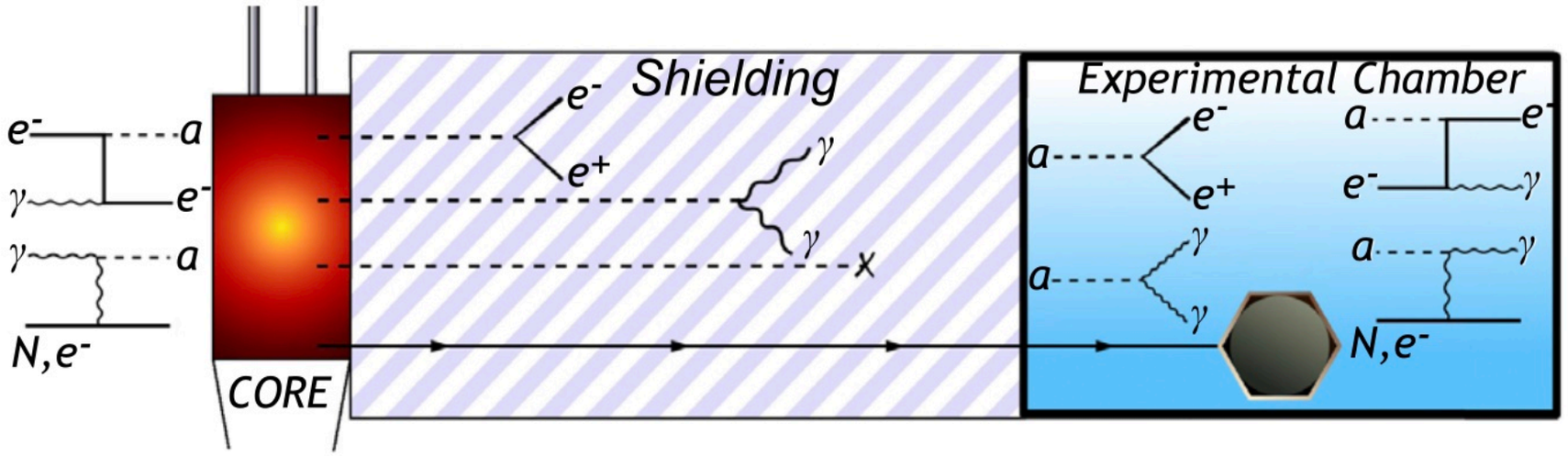


Reactor axion searches

PHYSICAL REVIEW LETTERS **124,** 211804 (2020)

New Directions for Axion Searches via Scattering at Reactor Neutrino Experiments

James B. Dent,[1] Bhaskar Dutta,[2] Doojin Kim,[2] Shu Liao,[2] Rupak Mahapatra,[2]
Kuver Sinha,[3] and Adrian Thompson[2]
[1]*Department of Physics, Sam Houston State University, Huntsville, Texas 77341, USA*
[2]*Mitchell Institute for Fundamental Physics and Astronomy, Department of Physics and Astronomy, Texas A&M University, College Station, Texas 77845, USA*
[3]*Department of Physics and Astronomy, University of Oklahoma, Norman, Oklahoma 73019, USA*

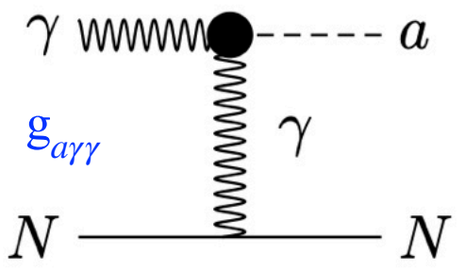


Abundant photons are produced and interact with the fuel materials (^{235}U) …

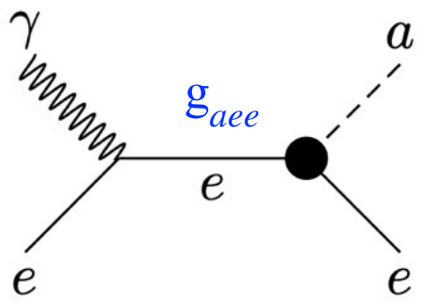
Reactor axion: **production** and **detection**

Axion can interact with SM particles with weakly $g_{a\gamma\gamma}$, g_{aee}, g_{ann} couplings…

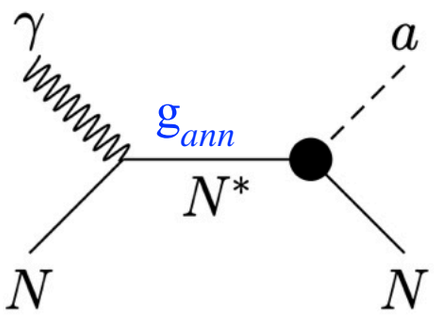
Primakoff photon-ALP conversion



Compton-like scattering



Nuclear de-excitation

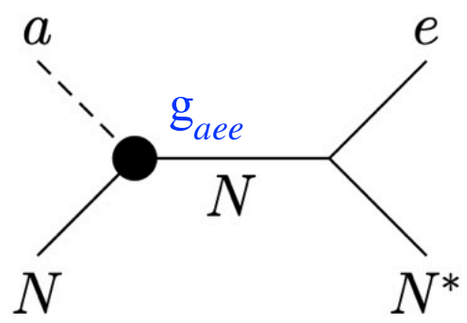


Inverse Primakoff

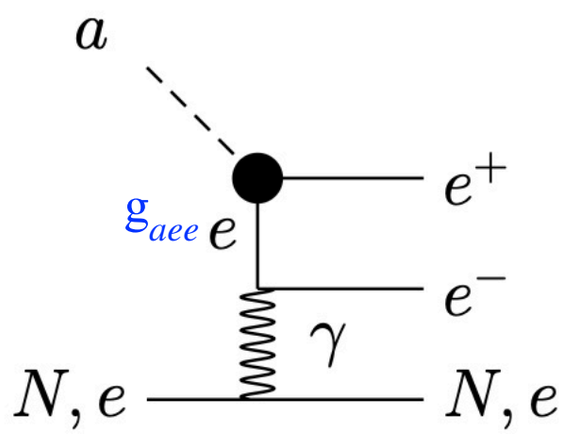
Inverse Compton-like

Nuclear excitation

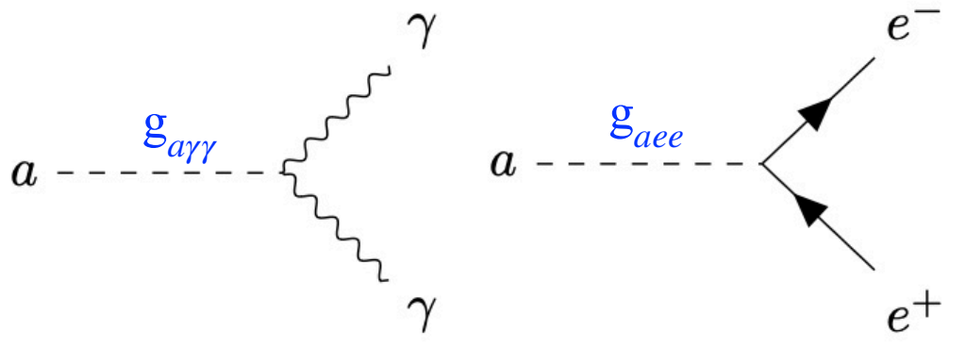
Axio-electric process



e-pair production



Axion decay
(photon, electrons-positron pairs)



Reactor axion: production and detection

Only the production and detection processes through the same ALP-SM coupling are considered to minimize the ALP assumptions.

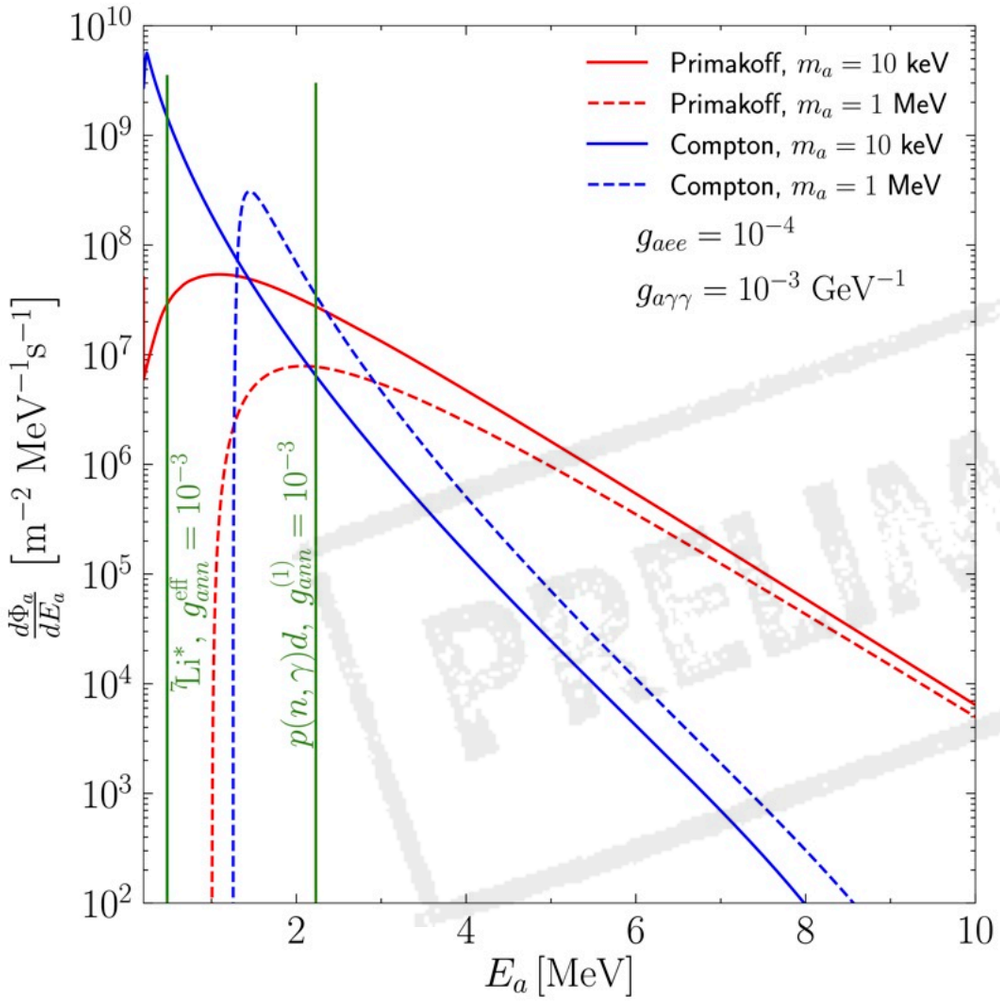
Production	Detection	Couplings
★ Primakoff	• inverse Primakoff • decay to diphoton	$g_{a\gamma\gamma}$
★ Compton-like	• inverse Compton-like • axio-electric • e-pair production • decay to e-pair	g_{aee}
Nuclear de-excitation		$g_{a\gamma\gamma} \cdot g_{ann}$ $g_{aee} \cdot g_{ann}$

RELICS: axion flux and recoil spectrum

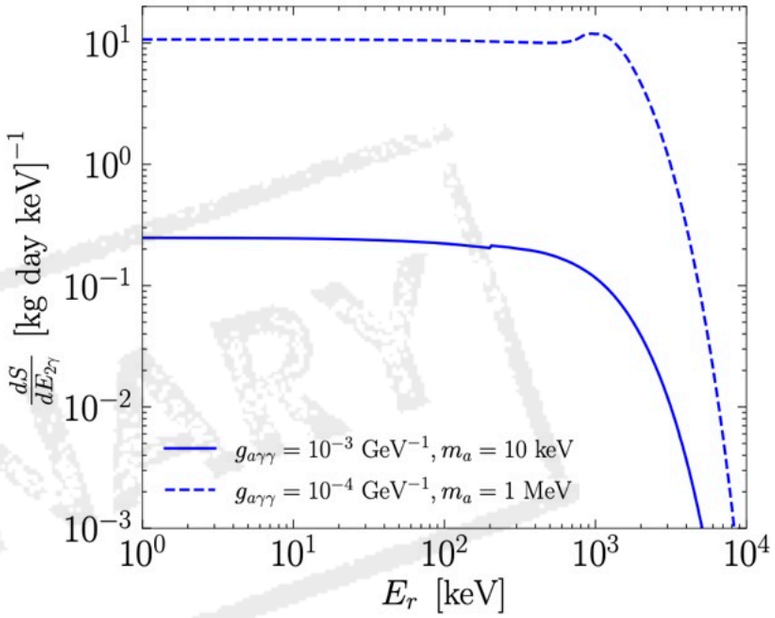
Axion flux @SanMen site

Electronic recoil energy spectrum

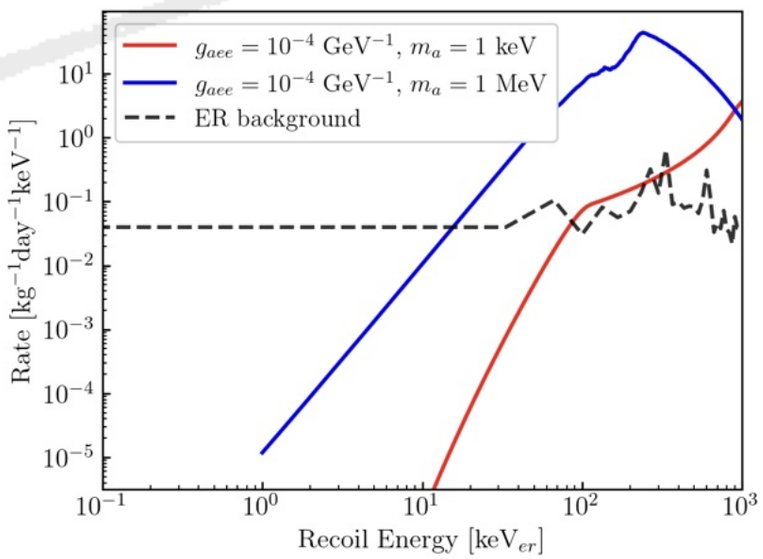
production



detection

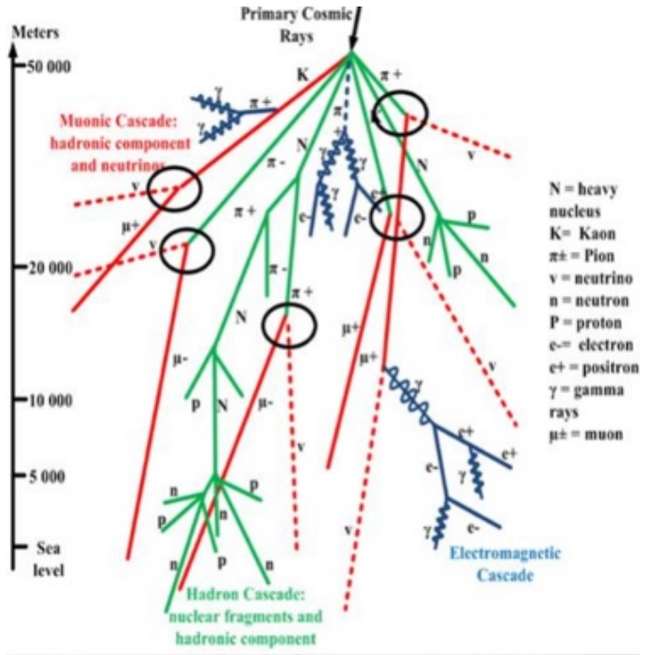


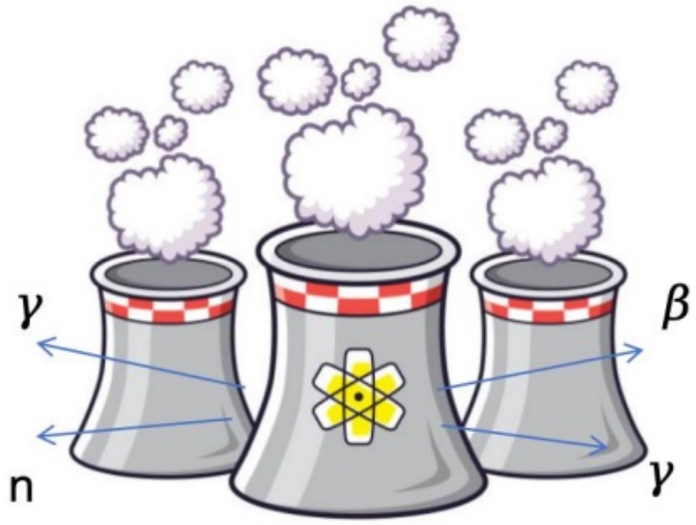
Axion-photon coupling $g_{a\gamma\gamma}$

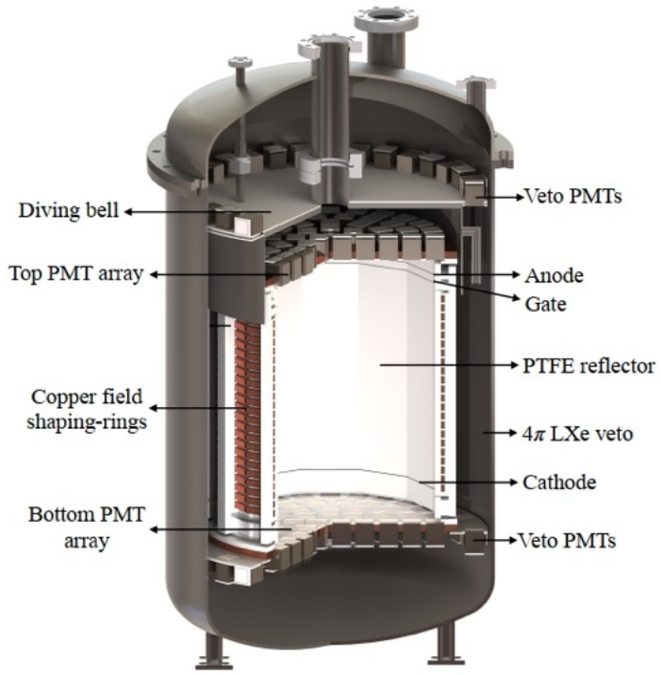


Axion-electron coupling g_{aee}

RELICS background sources







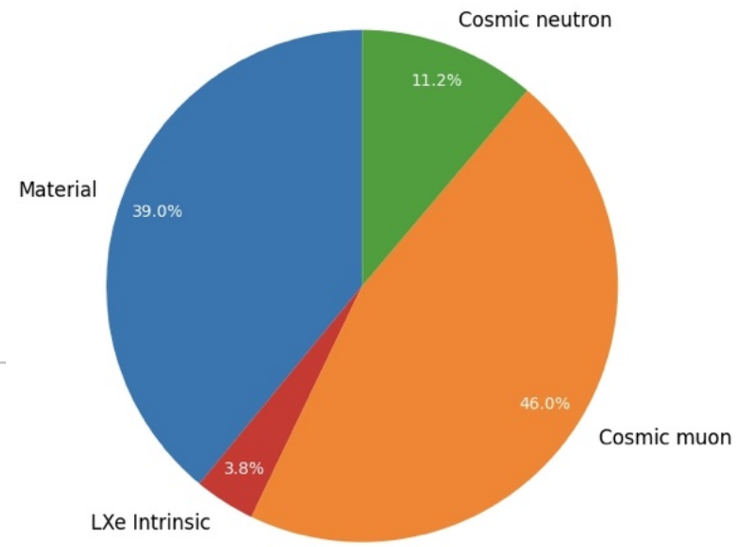
Cosmic muons
Cosmic neutrons

neutron, γ from
Reactor, environment

neutron, γ from
detector materials

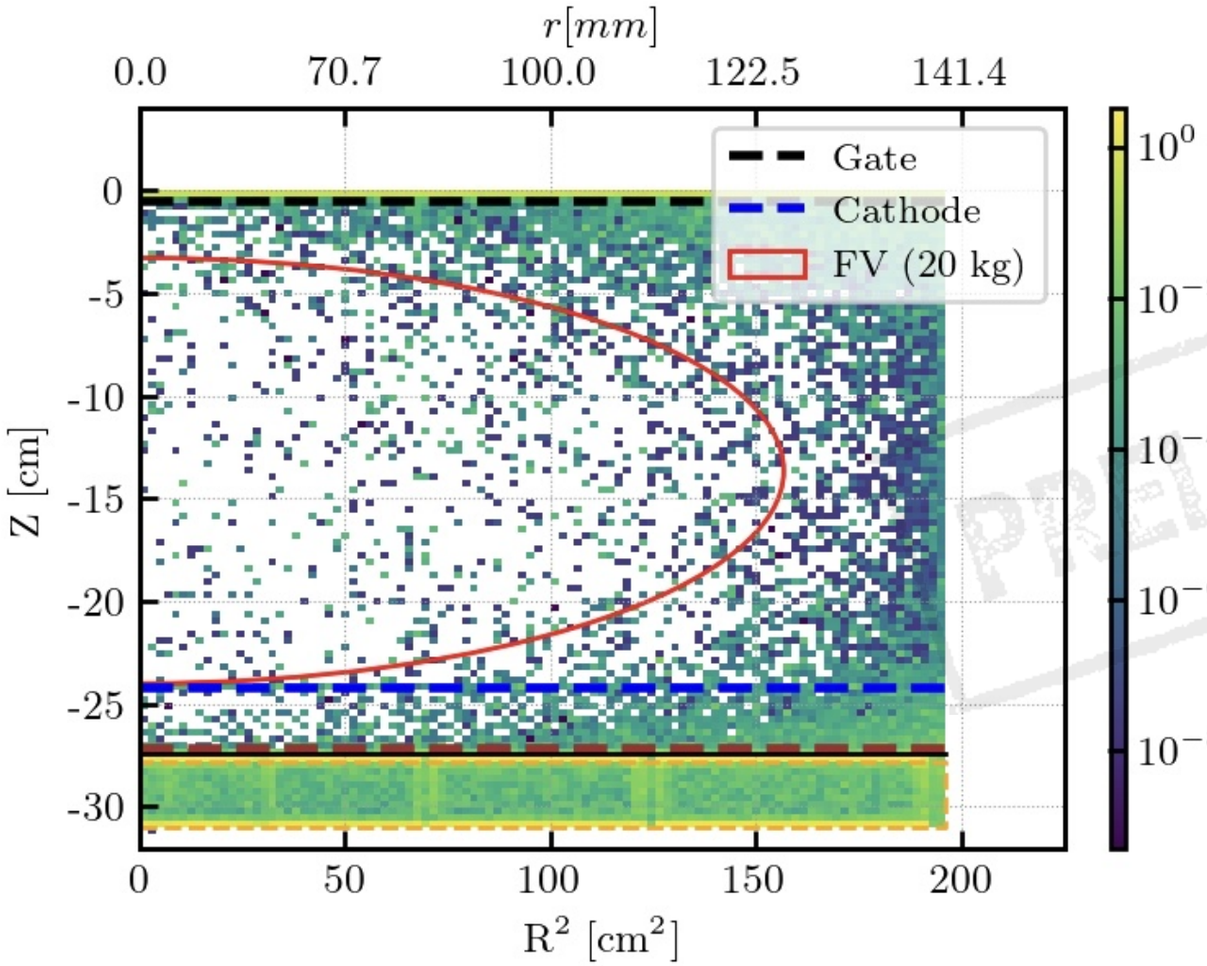
[0, 20] keV

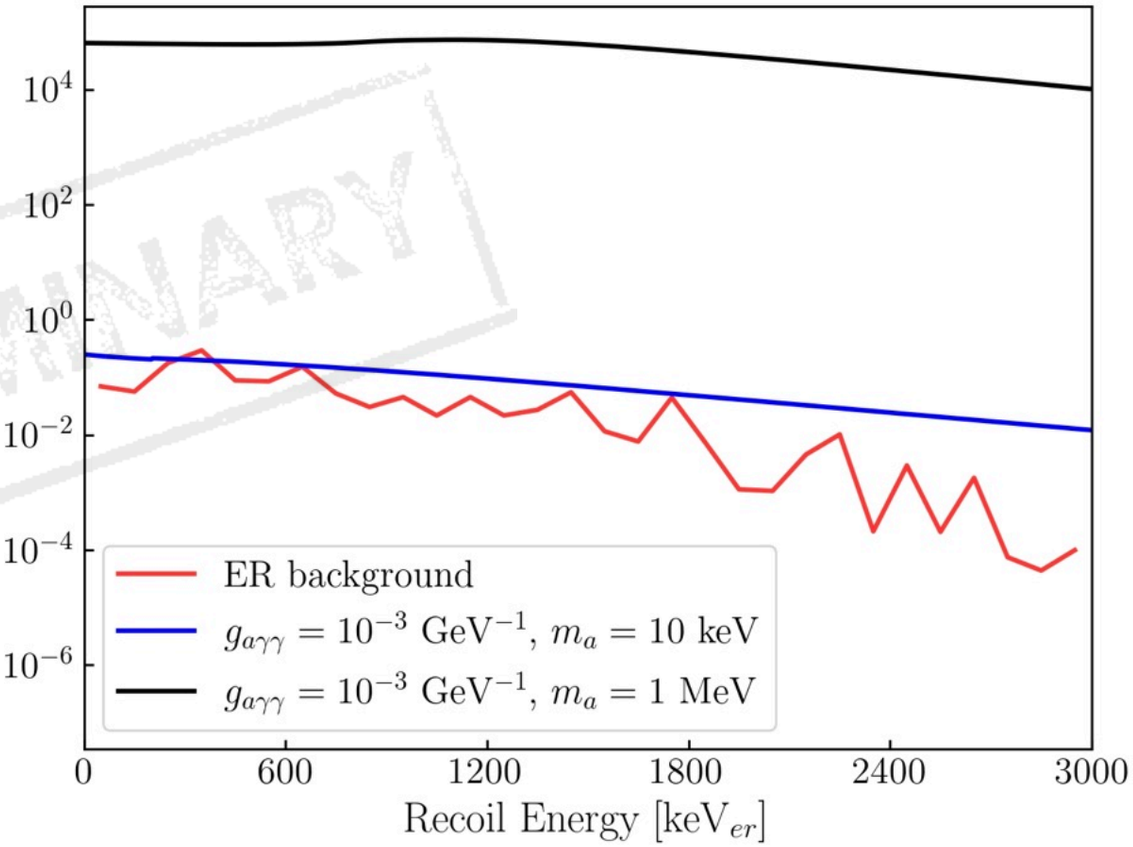
RELICS backgrounds



Geant4 simulations

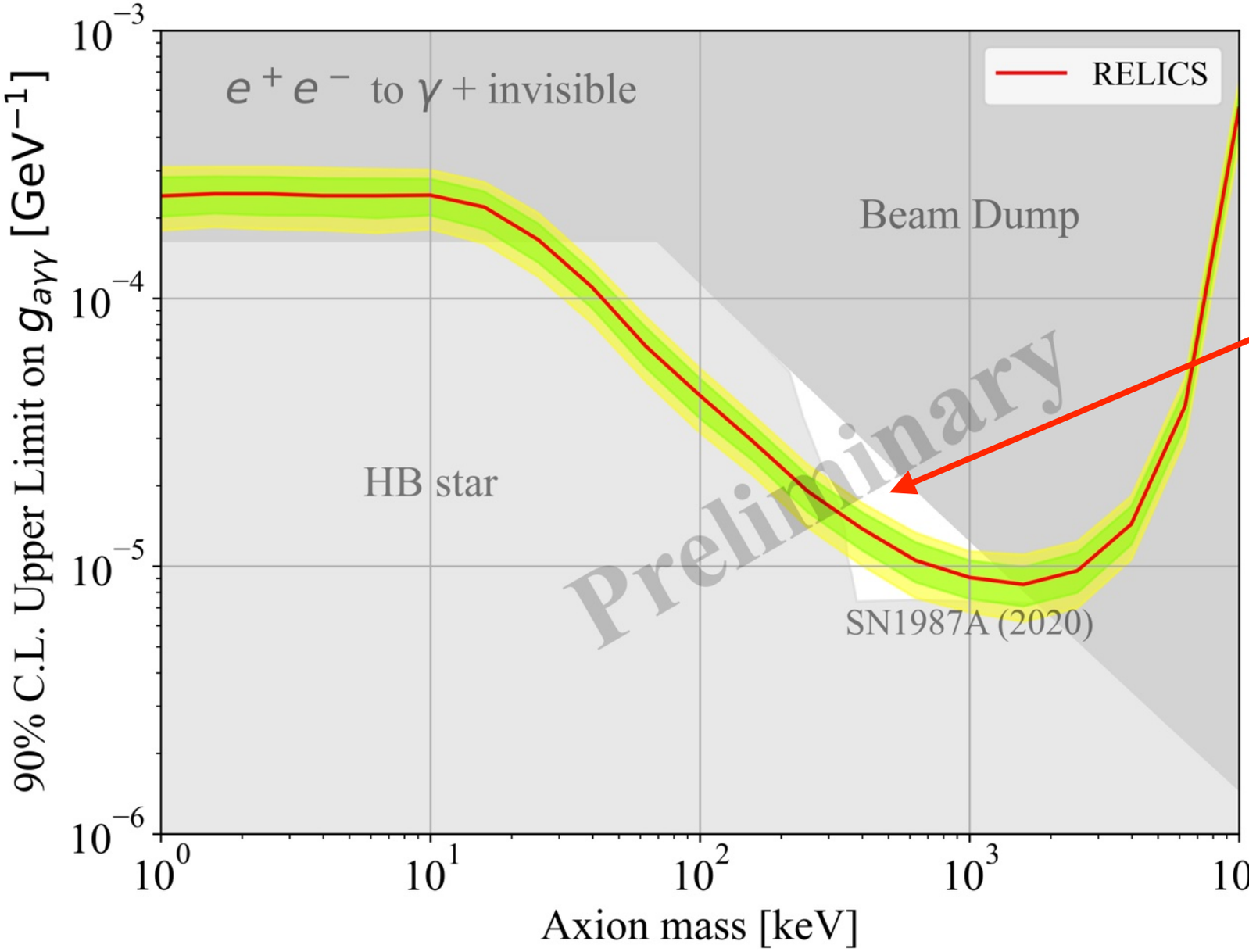
[0, 20] keV





RELICS sensitivity on axion-photon coupling

20 kg•year exposure



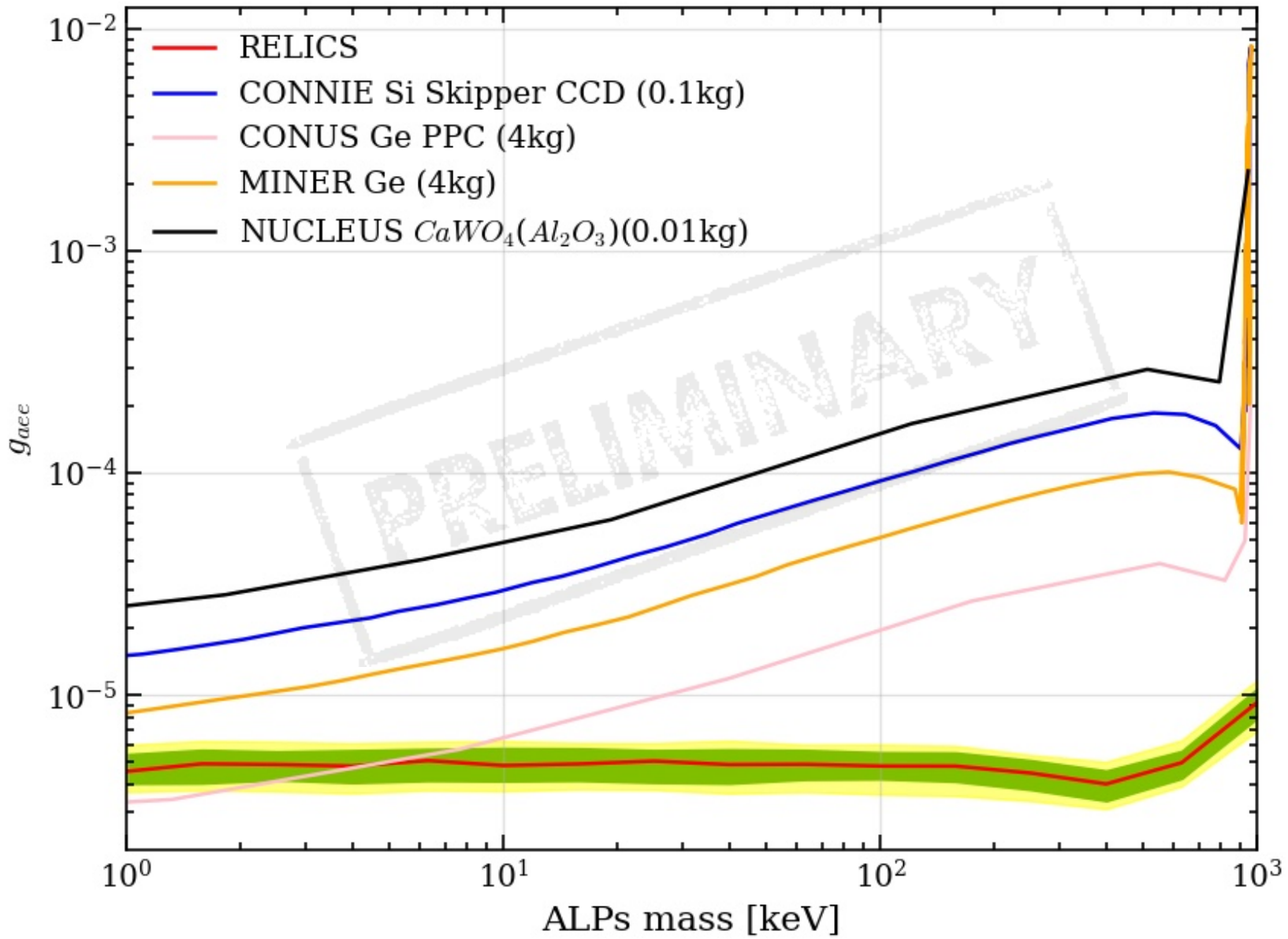
Exploring / Closing the Cosmological Triangle

which was previously accessible only through model-dependent cosmological arguments!

RELICS sensitivity on axion-electron coupling

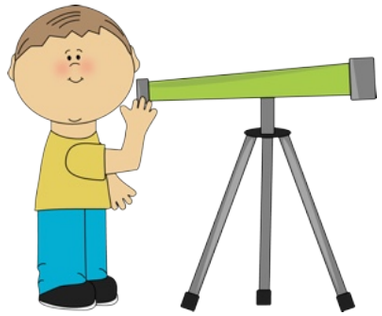
20 kg•year exposure

Ref: PRL 124, 211804 (2020)

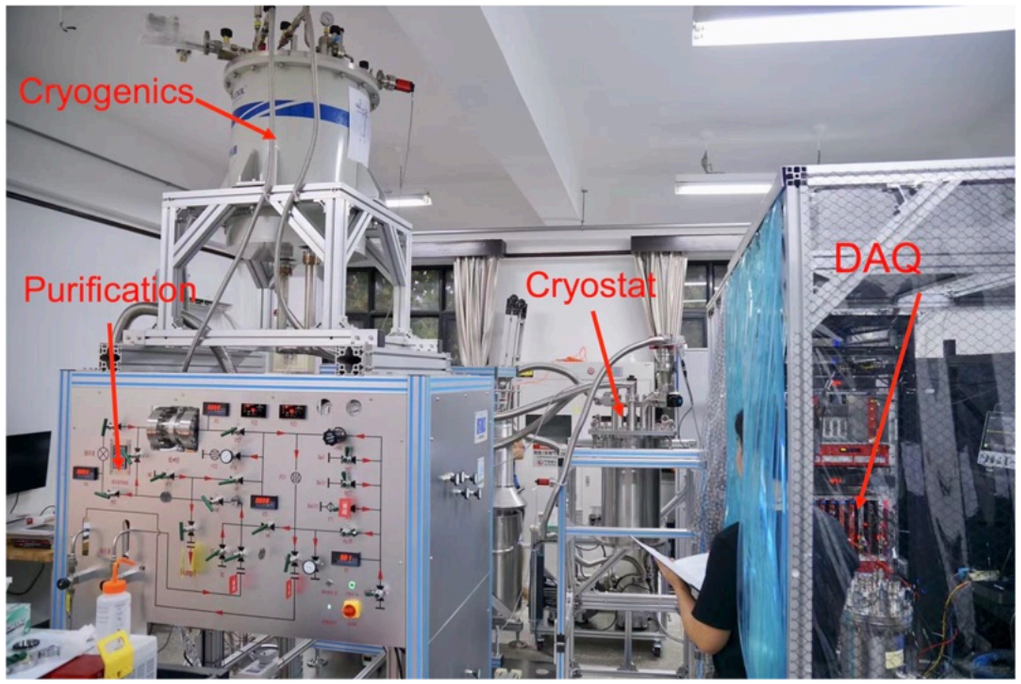


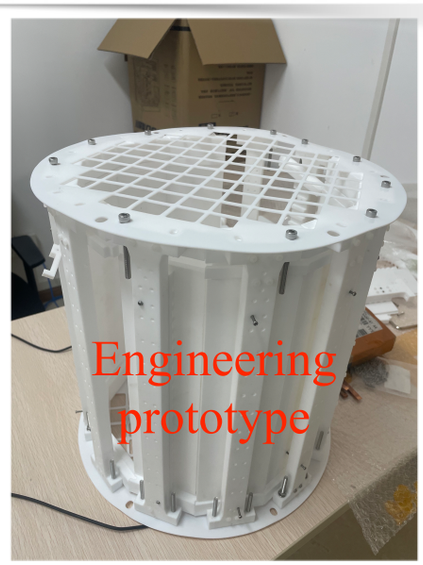
Summary

Outlook



- 2025: detector construction
- 2026: data taking …





1. **RELICS is a low threshold, low background LXeTPC detector planned to run at sea level.**

2. **RELICS has rich physics:**
   - **precise measurement of reactor neutrinos**
   - **competitive in the search for axions, which can explore or close the Cosmological Triangle.**

3. **High application value of nuclear safety.**


Thanks