

Activities of D01 group

September 28th, 2026

Investigation of the Origin and Evolution of Matter
in the Universe by Extremely Rare Events (UGRP2026)

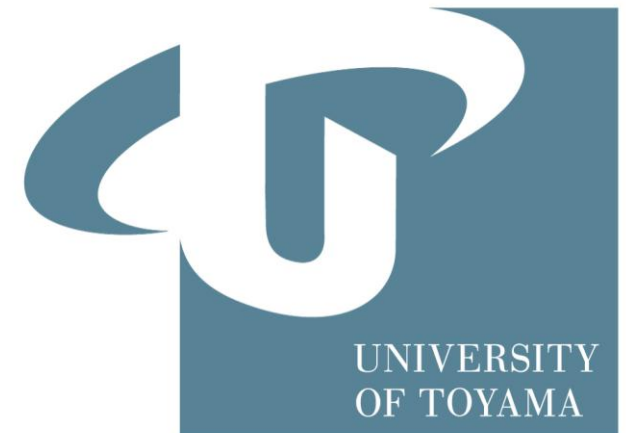
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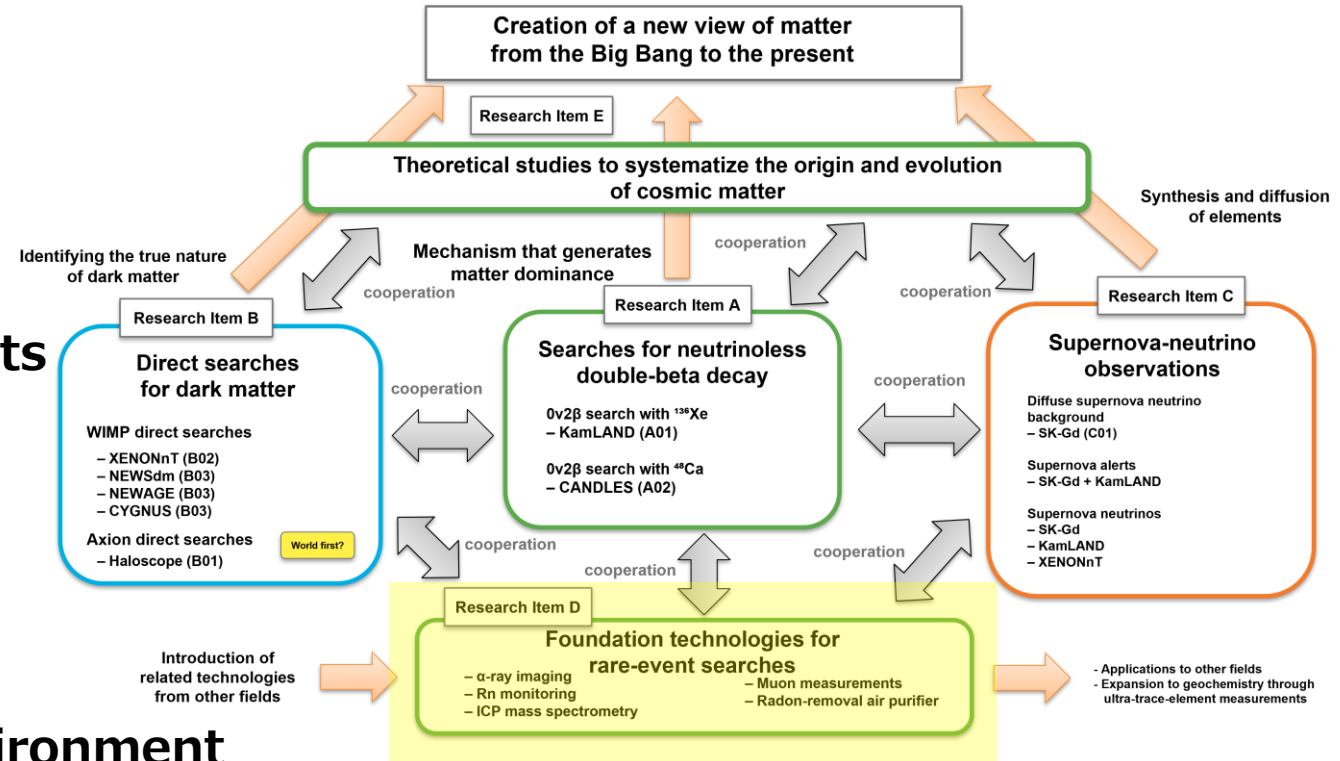
Deployment of Ultra-Low
Radioactivity Technology

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- Overview of D01 group
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- Research topic and results
 - 1) Ultra-trace radionuclide analysis
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 - 4) Background estimation for future dark matter search
- Summary



Overview of the D01 group

■ Objectives

- Further develop **broadly applicable ultra-low-radioactivity techniques** by combining expertise from underground experiments, other research fields, and industry.
 - 1) Operate, improve, and deploy **high-sensitivity screening systems**.
 - 2) Improve and characterize environments **for next-generation rare-event searches**.
 - 3) **Introduce techniques from other fields** and expand their applications.
 - Radon removal using silver zeolite
 - Ultra-trace radioactivity analysis using novel chemical-separation methods
- **Deploy these techniques across experiments** within and beyond the Transformative Research Area **to advance rare-event searches**.

Our group

■ Members and topics

- Four researchers with complementary expertise in low-background techniques.
- **Apply low-background assay techniques** to a wide range of experiments to advance rare-event searches.

Yasuo TAKEUCHI
(Project leader)



- Overall coordination
- Radon removal with silver zeolite
→ **Next talk**
- Collaborative research and applications in the medical field

Aya SAKAGUCHI



- Mass spectrometry with ICP-MS
- Applications to Earth science

Yuuki NAKANO



- Radon measurement in Gd-loaded water
- Cosmic-ray muons in underground environment
- Muon-nucleon reaction

Hiroshi ITO



- α -particle imaging
- Neutron detection in underground environment

Collaborations with other research projects

	Main topics	Specific topics	Collaborating group/projects
Takeuchi Nakano	Silver zeolite	Radon removal from air	C01, A01, B03, Medical applications
		Radon removal from CF ₄ gas	B03
		Xenon adsorption from air	A01, B02, Publicly offered research
		Removal of impurities from xenon (Ar, Kr, Rn, H ₂ O, O ₂)	B02
		Water removal from liquid scintillator	A01
Sakaguchi	Mass spectrometry	BIS	A01
		CaF ₂	A02
		PTFE	B02
Nakano Takeuchi	Radon assay	Radon measurement in Gd-loaded water	C01
		Radon emanation from detector materials	B02
Ito	α -particle imaging	Analysis of detector materials	B03
		Impurities in scintillator crystals	Industry
Nakano	Cosmic-ray muons	Muon-nucleus reactions	C01
		Cosmic-ray muons in underground environments	A01, B02, B03, C01

Collaborative studies with groups outside this transformative research area are also on-going.

Related poster presentations

Category	Poster No.	Research Group	Presenter	Title
Zeolite / Noble gas	P05	D01	Yuya Inaba	Temperature dependence of Rn adsorption performance by silver zeolite in air and noble gases.
Zeolite / Radon / Hyper-K	P08	D01	Hiroto Bambara	Development of the Radon Removal System Using Silver Zeolite for Hyper-Kamiokande
Zeolite / Radon	P10	D01	Hiyori Nishimura	Study of Radon Adsorption Performance of Silver Zeolites
Zeolite / Xe adsorption	P39	A01/D01	Yoshihito Gando	Formulation of Copper-Ion-Exchanged Zeolites for Xenon Enrichment
Super-K calibration	P13	C01/D01	Shinya Aoyama	Evaluation of the stability of the energy scale using decay electrons detected in Super-Kamiokande
Super-K muons	P14	C01/D01	Tomoaki Tada	Measurement of the kaon-to-pion ratio for the atmospheric neutrino using the cosmic-ray muon data in Super-Kamiokande
Super-K Gd related	P02	C01/D01	Mao Nishigami	Neutron Detection Efficiency Evaluation in the Super-Kamiokande Gd Phases
Dark matter	P24	D01/B03	Kaede Furukawa	Estimation of background events induced by solar neutrinos in fluorine-based dark matter detectors

Results in P14 and P24 are briefly presented in my talk.

Ultra-trace radionuclide analysis as a cross-cutting activity

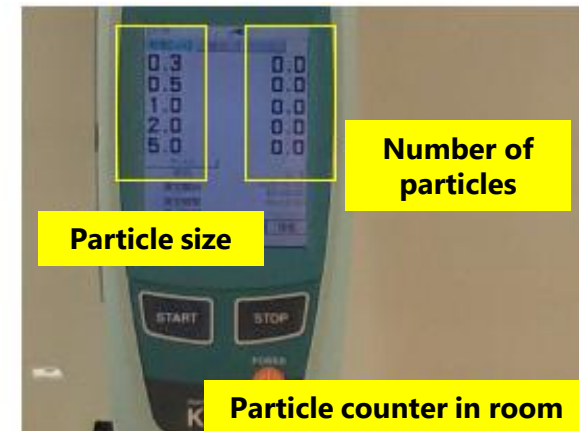


■ Demand for material screening

- Various particle-physics experiments **require material screening**.
- **Target materials and radionuclides differ** among experiments.
- We support these experiments by **developing appropriate analytical methods**.

■ Development of analytical methods

- Ultra-trace radionuclide analysis for refractory and high-matrix samples.
- Development of clean analytical techniques for low-background measurements.
 - **Construct the clean room** for that purpose.



Current status and future prospect



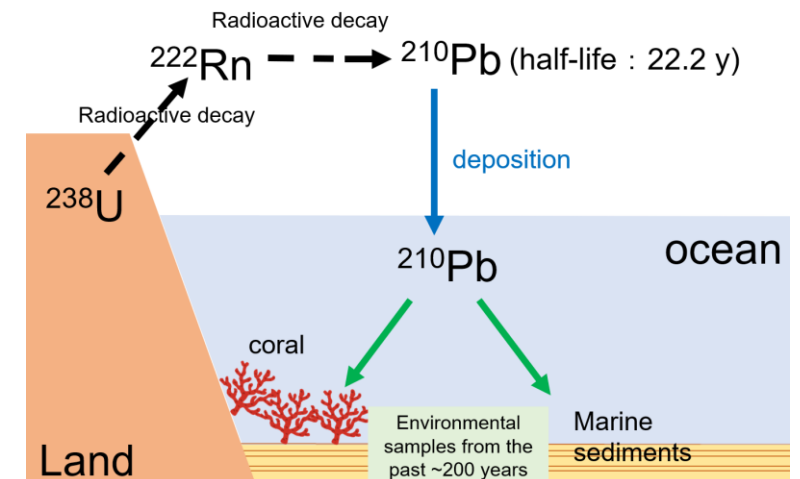
■ Material screening

- We collaborate with other particle-physics experiments to **develop and perform ultra-trace radionuclide analyses for material screening.**

Experiments (group)	Target materials and radionuclides
KamLAND (A01)	U and Th analysis and purification of PEN films and bis-MSB
CANDLES (A02)	U and Th analysis and purification of CaF_2 materials and CaF_2 itself
Dark matter activity (B01)	U and Th analysis in fluoropolymer
Pikachu (Publicly offered research)	^{40}K analysis in GAGG crystal

■ Application to Earth science

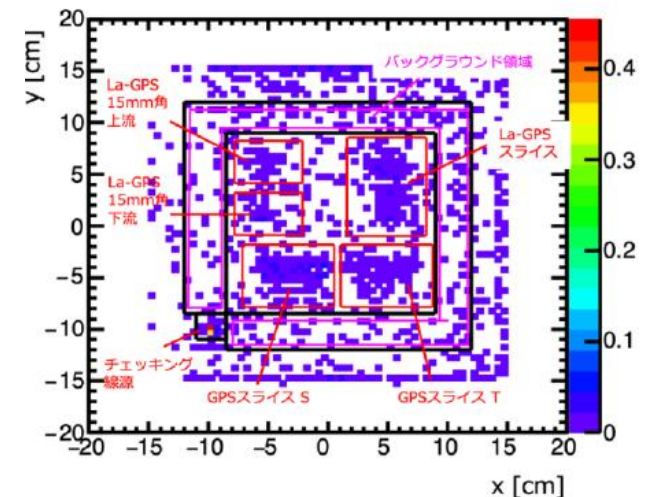
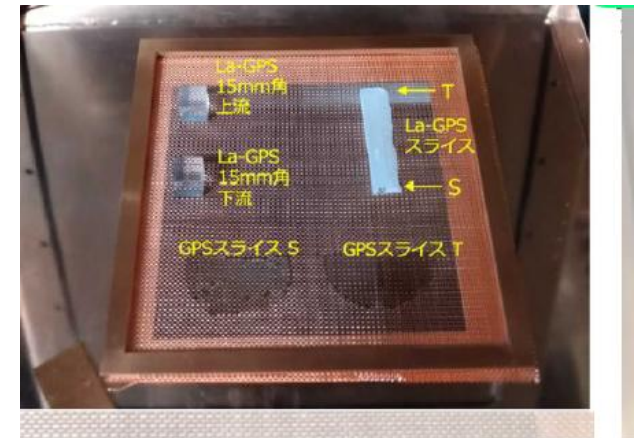
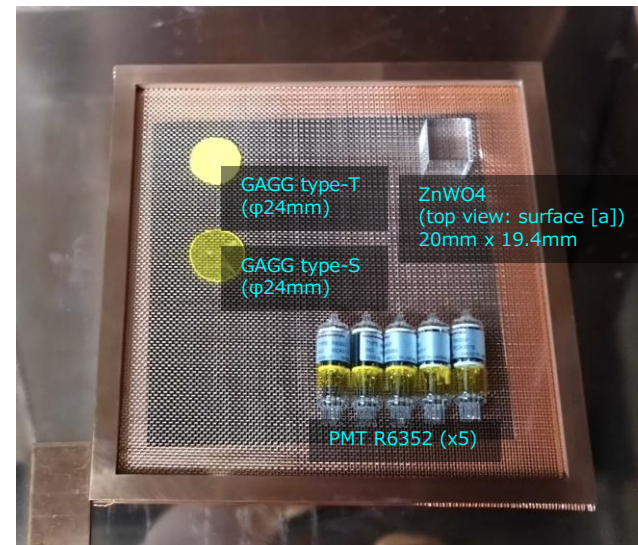
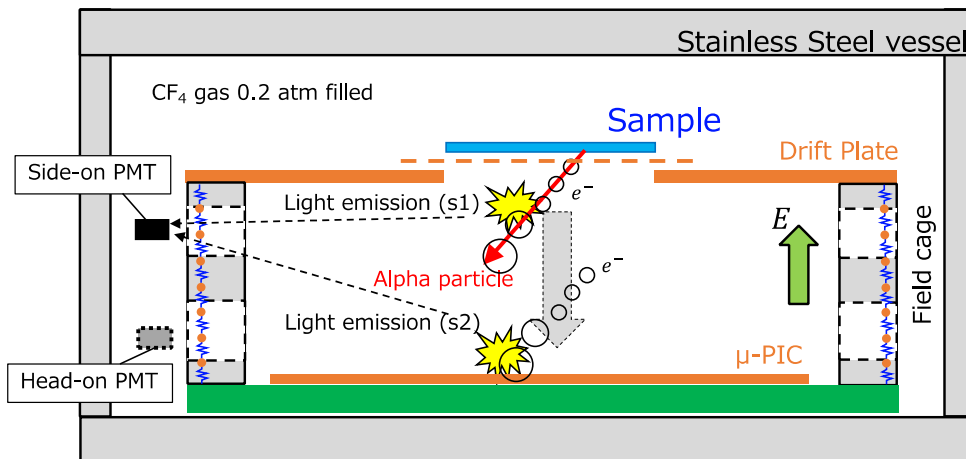
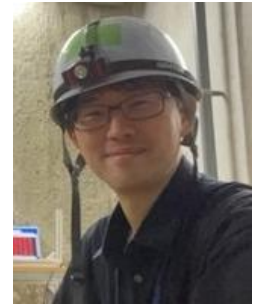
- Develop AMS-based method for **ultra-trace ^{210}Pb analysis** for **dating environmental samples.**
- The developed method will be **extended to a wider range of environmental samples.**



α -particle imaging

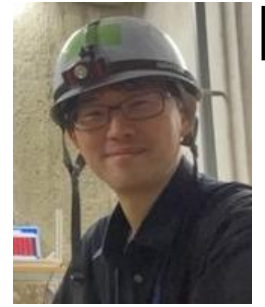
■ AICHAN detector

- Development of a gas TPC for low-background **surface radioactivity assay**.
→ α -particle track emitted from sample surface are measured using a μ -PIC.
- Detection limit of 2.4×10^{-3} **a/hour/cm²** (90% C.L., one month).
- Sample assays for a broad range of experimental groups.
→ Scintillator crystals (GAGG, ZnWO₄), PMTs, etc.
- This technique is very useful for **detector material screening**.



Further development

p. 10

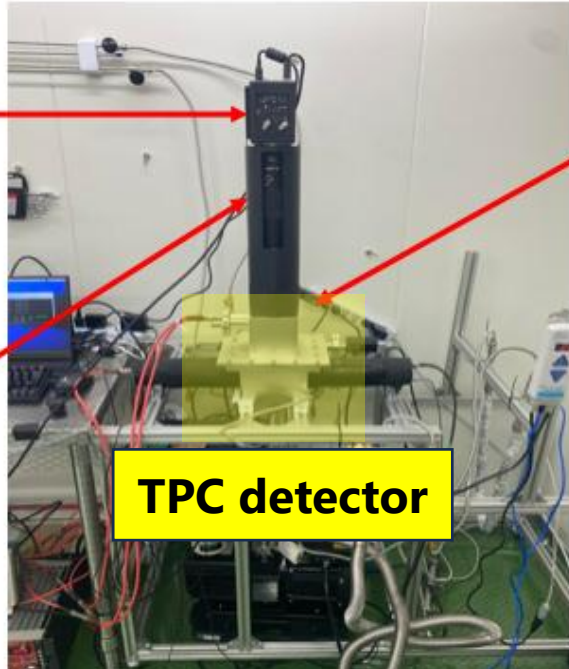


■ α -particle track imaging

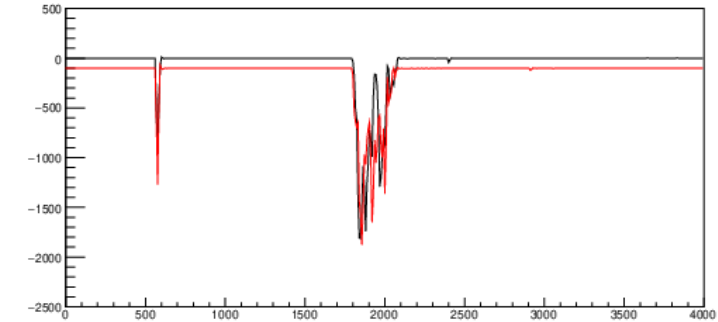
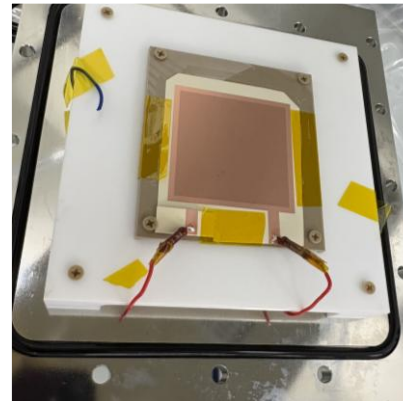
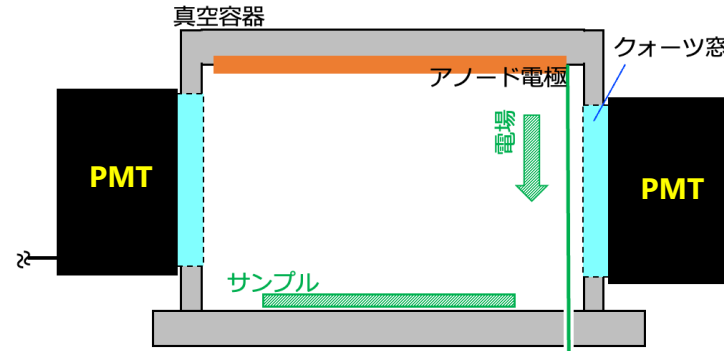
- Introducing the CMOS camera and PMTs for **imaging the α -particle track**.
→ **Scintillation emission** from TPC filling gas, CF_4 .
- Further upgrade of detector sensitivity is expected (10^{-4} **$\alpha/\text{hour}/\text{cm}^2$**).



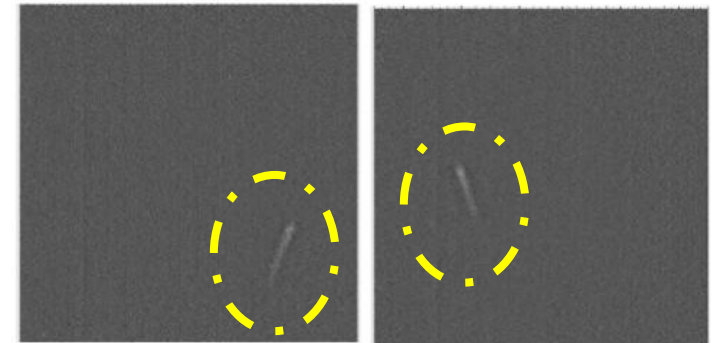
Hamamatsu
photronics
C13440-20CU



TPC detector



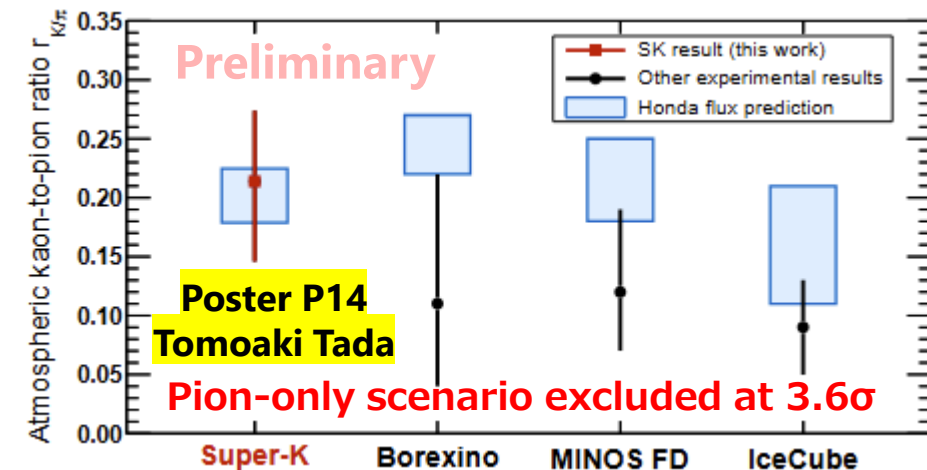
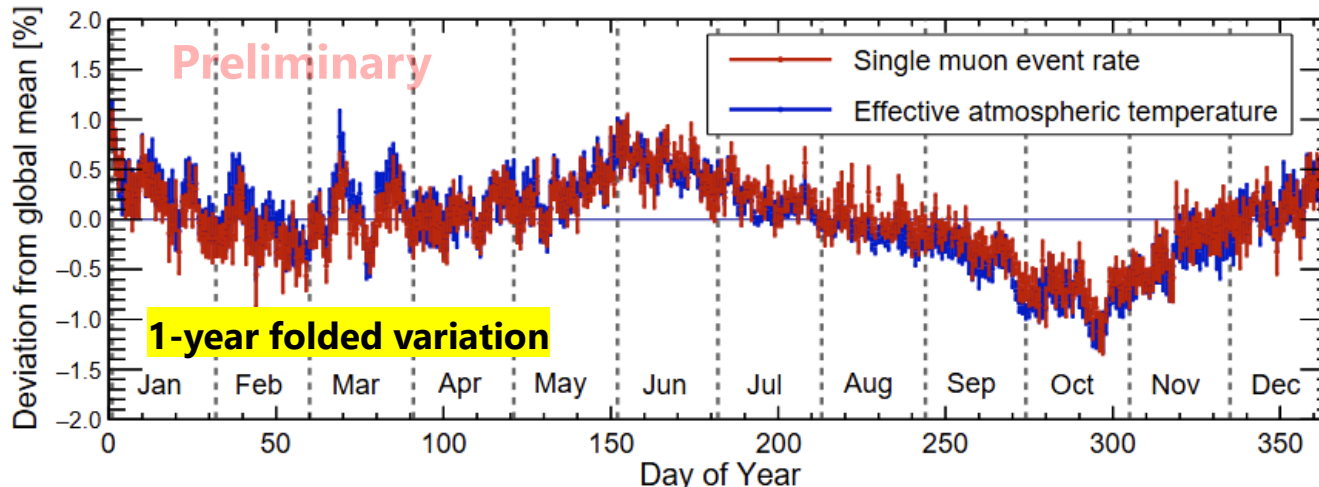
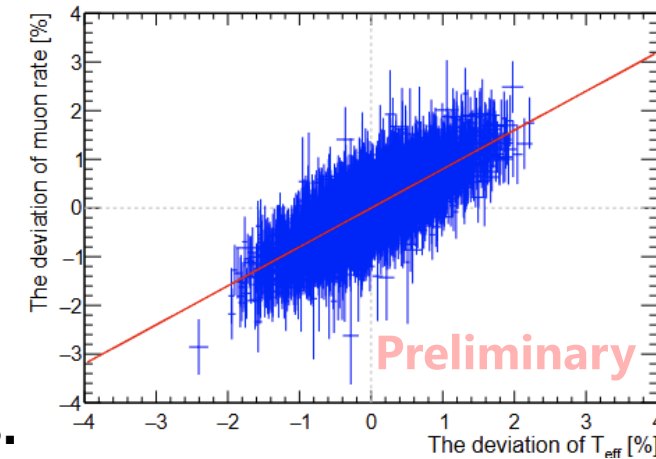
Successfully detecting
 α -particle track



Kaon-to-pion ratio from muon modulation^{p. 11}

■ Muon flux at underground

- Muon flux varies with atmospheric temperature.
 - Pions and kaons have different decay lengths in the atmosphere, leading to different sensitivities to atmospheric temperature.
- 10 years of Super-Kamiokande data shows correlated variations.
 - We determine pion-to-kaon ratio $r_{K/\pi} = 0.21^{+0.07}_{-0.06}$.
- Provides a new constraint on atmospheric-neutrino flux simulations.



Branching ratio of muon capture reaction

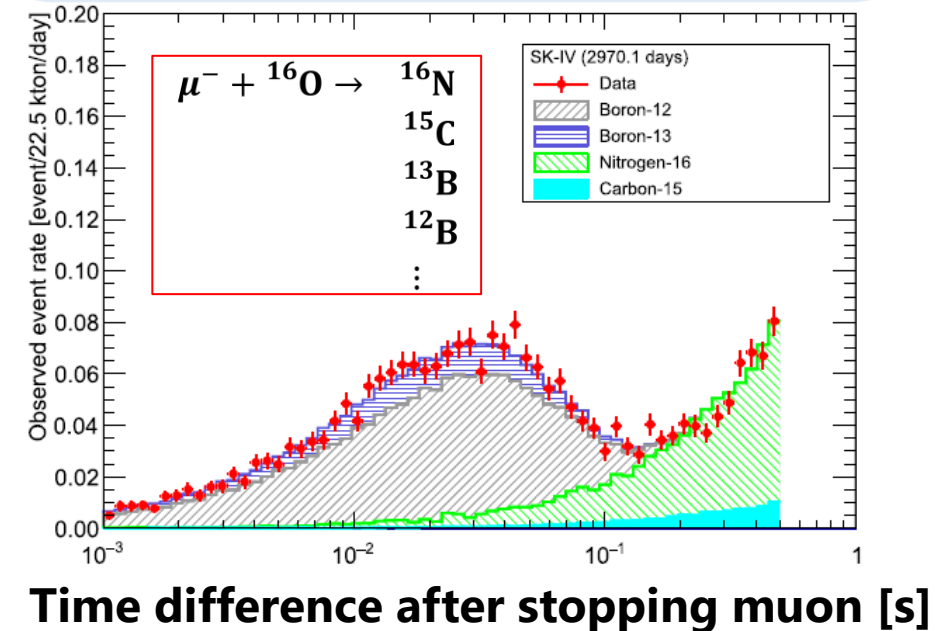
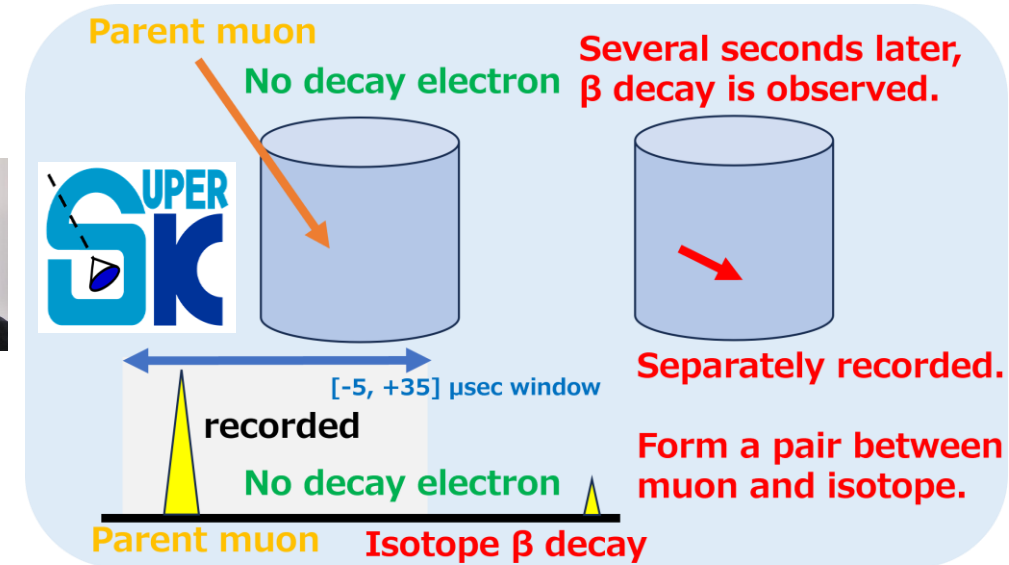
■ Production of unstable isotopes

- **Negative muons are captured** by detector material.
- **Unstable isotopes are produced.**
- Super-Kamiokande measured the branching ratio.



Isotopes	Branching ratio [%]	Other measurement [%]	Geant 4 [%]	PHITS [%]	FLUKA [%]
^{16}N	9.0 ± 0.1	11 ± 1	12.0	0.5	5.52
^{15}C	0.6 ± 0.1	--	0.7	0.19	0.67
^{12}B	0.98 ± 0.18	--	7.6	1.16	4.41
^{13}B	0.14 ± 0.12	--	--	0.02	0.0088

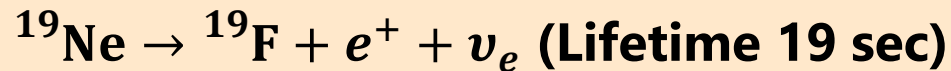
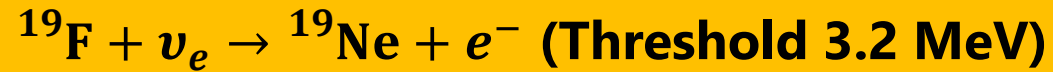
- ^{16}N is the world-leading precision at present.
- ^{15}C , ^{12}B , and ^{13}B are the first measurements.
- Helpful to update the muon capture reaction rate in simulations and background modeling.



Solar-neutrino background in fluorine-based dark matter detector

■ Fluorine

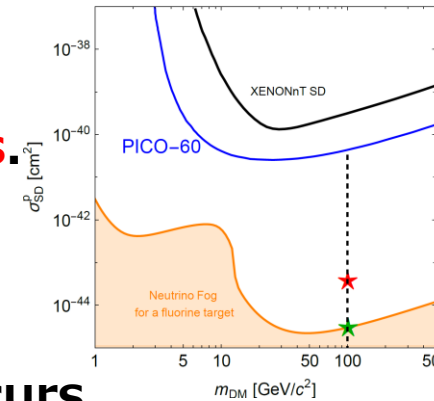
- Promising target for **spin-dependent DM searches**.
→ Large Landa factor: $\sigma_{\chi-N}^{SD} \propto \lambda^2 J(J+1)$.
- **Solar neutrino absorption reaction on ^{19}F also occurs.**



→ Mimic dark matter signals?

■ Results

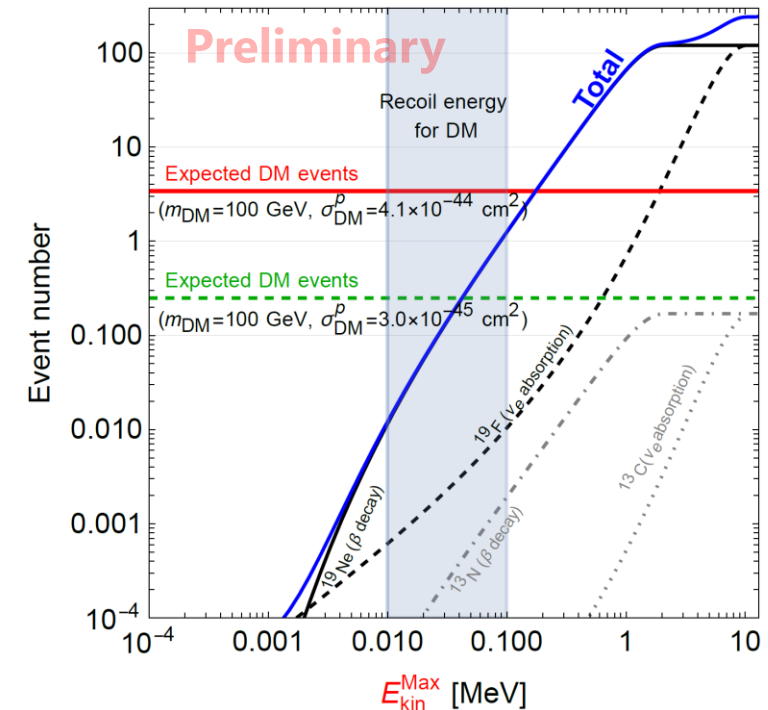
- **Solar-neutrino reactions become a relevant background** at sensitivities $\sim 10^{-3}$ below the current limit.
- Assuming 58 ton of (liquid) CF_4 and 1 year operation.
- Delayed-coincidence technique may reduce this background.



Poster P24
Kaede Furukawa



Exposure: CF_4 58 ton, Observation time: 1 yr



Summary

- Develop and deploy complementary **low-background techniques for rare-event searches**.
- **Silver-zeolite-based radon removal** is being developed for low-background gas purification, including the Hyper-Kamiokande air-purification system.
- **Ultra-trace radionuclide analysis** and **α -particle imaging** are developed for material screening.
- **Cosmic-ray muon** studies provide new inputs for **atmospheric-neutrino simulations** and **muon-capture background modeling**.
- **Solar-neutrino interactions may become a relevant background** for future high-sensitivity fluorine-based dark-matter searches.
- We will **further develop these techniques** and **expand collaborations** with other experiments and new research fields.