Report on Division for Experimental Studies Research high lights

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Division for Experimental Studies, KMI

2025.03.06

Kobayashi-Maskawa Institute
for the Origin of Particles and the Universe

Research at DIvision for Exp. Studies

New Particle Phenomena (accelerator)

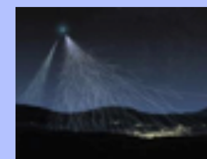
SuperKEKB/Belle II

Neutron

LHCf & RHICf

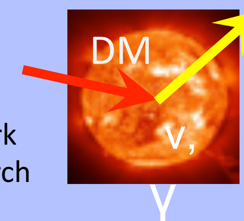
LHC-ATLAS

New astroparticle phenomena (non-accelerator)



Cosmic-ray and X-ray observations

Direct & Indirect Dark Matter search

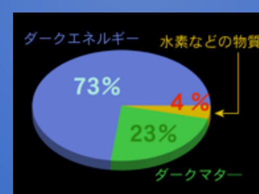


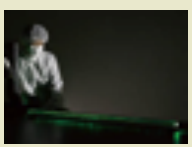
Mysteries of the Universe

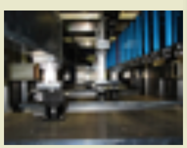
Why no anti-matter ?

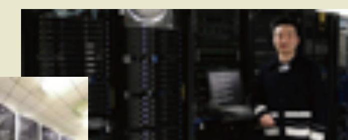
What is the dark matter ?

What is the dark energy ?









Technology development & Computing

Center for Theoretical Studies

Laboratories (KEK, CERN, Gransasso, JAXA, …)

Universities (Japanese, Abroad)

KMI recognized projects

ATLAS EXPERIMENT

Belle II

Neutron Optics and Physics

LHCf

NEWSdm

Xe XENON Dark Matter Project

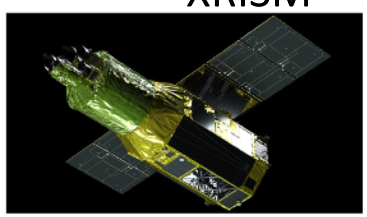
SUPER K

Hyper-K

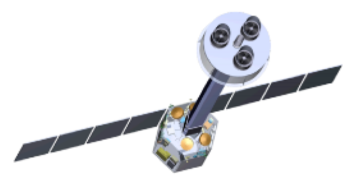
cta cherenkov telescope array

MWA MURCHISON WIDEFIELD ARRAY

XRISM

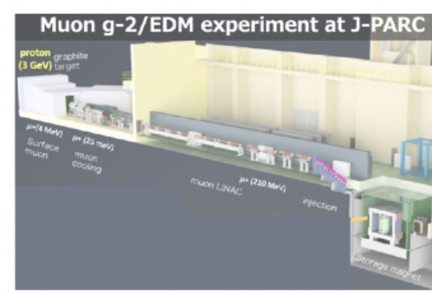


FORCE



Fermi Gamma-ray Space Telescope

DECIGO



Kobayashi-Maskawa Institute for the Origin of Particles and the Universe

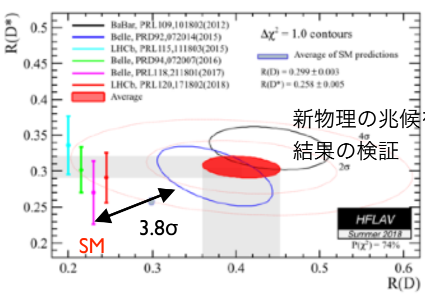
High Energy Physics at KMI

c チャームクォーク　b ボトムクォーク　τ タウレプトン

SuperKEKB/Belle II

- 小林-益川理論以外の対称性の破れの起源
- タウレプトンにおける対称性の破れの探究

KEK



新物理の兆候を示すB崩壊結果の検証

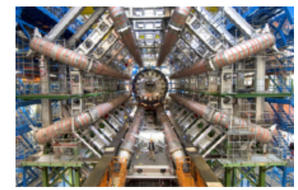
小林-益川理論（クォーク物理）

標準理論を超える新物理の発見

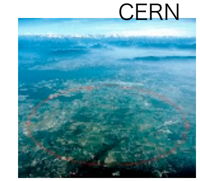
t トップクォーク　H ヒッグス

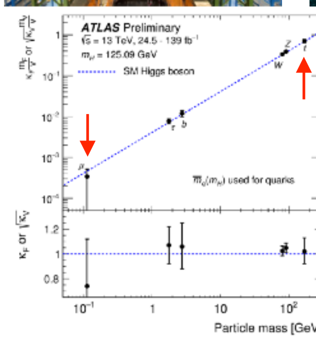
LHC-ATLAS

- トップ、ヒッグスの詳細な性質、対称性の破れ
- 新粒子直接探索（第2のヒッグスなど）



CERN

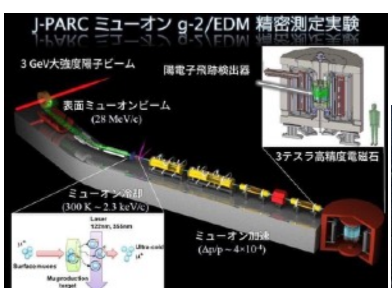




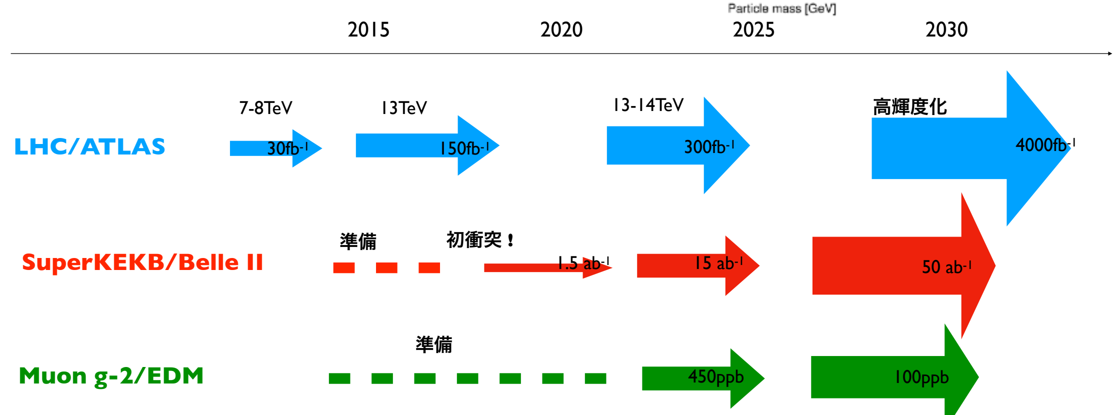
ヒッグス機構の検証
質量の起源（真空の相転移）を明らかにする

Muon g-2/EDM @ J-PARC

μ ミューオン



J-PARC

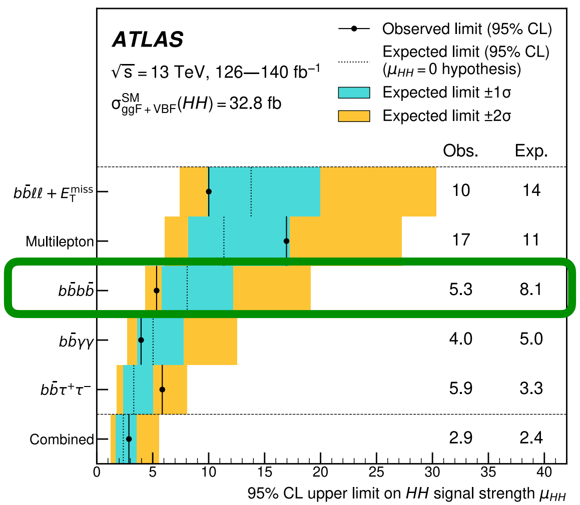


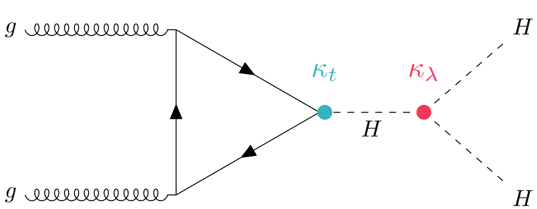
ATLAS physics achievements

KMI took leading roles in Higgs/SUSY analyses

Y. Horii, S. Izumiyama

Di-Higgs search with bbbb



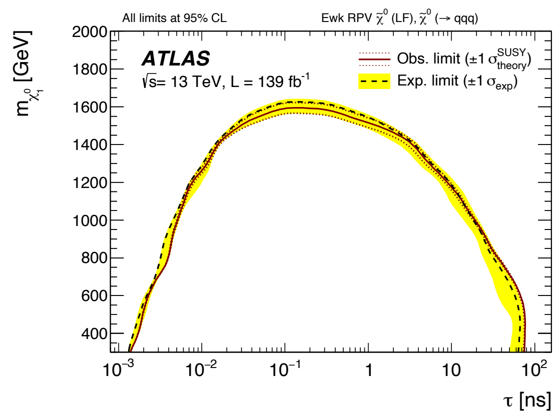


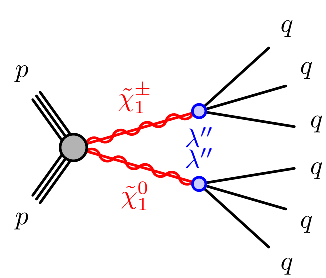
PRD 108, 052003 (2023)

PRL 133, 101801 (2024)

S. Hayashida, doctor's degree (2023)

Search for long-lived particles (electroweakino in RPV SUSY)

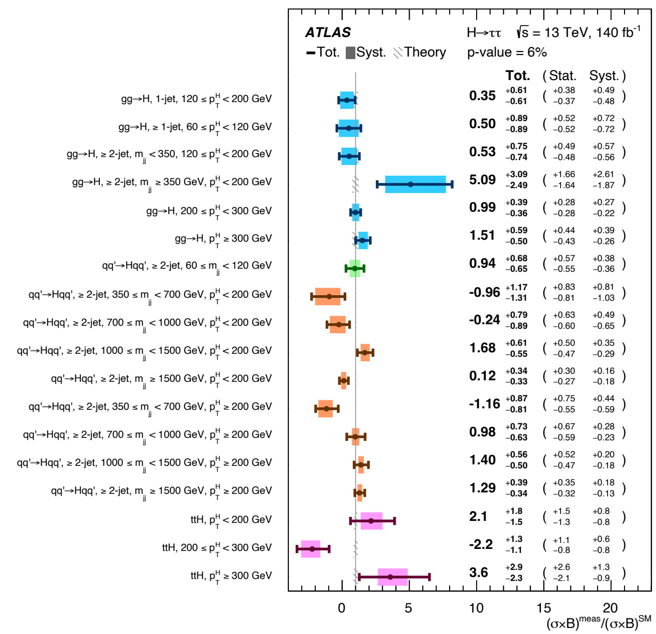




JHEP 06, 200 (2023)

M. Wakida, doctor's degree (2023)

H→ττ STXS measurement (focus on VBF H production)



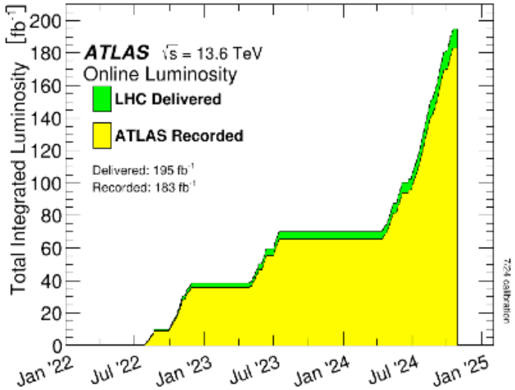
Accepted by JHEP

Y. Mitsumori, doctor's degree candidate (2025)

ATLAS muon trigger operation/upgrade

Operation S. Izumiyama: TGC Run Coordinator (from Feb. 2025)

- In 2023/24, KMI supported five travels of students (~400 days)
- TGC oncall shifts: 170 days
- Control room shifts: 20 x 8 hours
- Integrated luminosity: 183 fb^{-1}



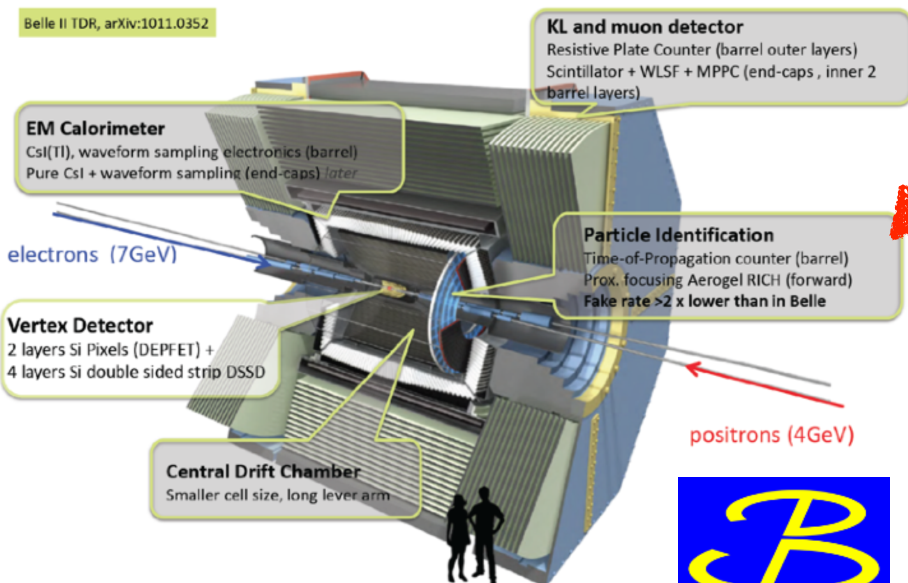
Upgrade Y. Horii: Muon Trigger Coordinator (from Jan. 2024)

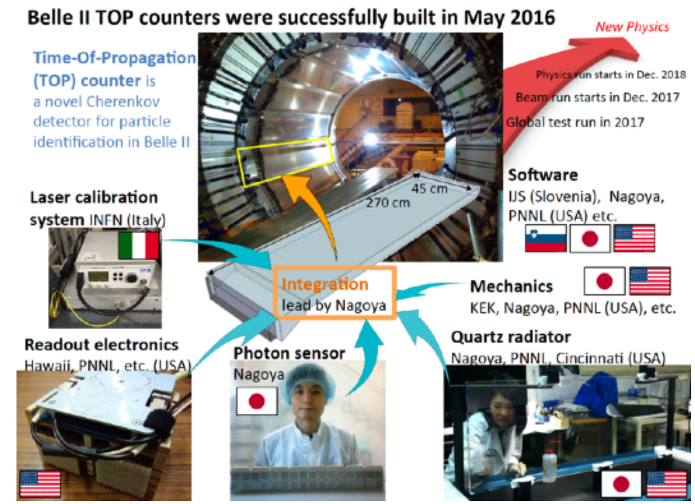
- To take full advantage of HL-LHC, a new trigger/readout system was designed and production is ongoing.
- KMI took a leading role in the development of electronics boards and fast muon tracking algorithm of the endcap muon trigger.
- Schematic of both frontend/backend boards provided from KMI

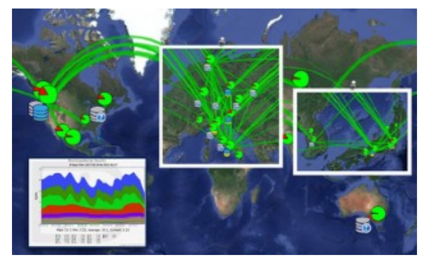
Frontend boards:
mass production (1540) and quality check completed.

Backend boards:
final prototype fully tested

KMI/Nagoya at Belle II







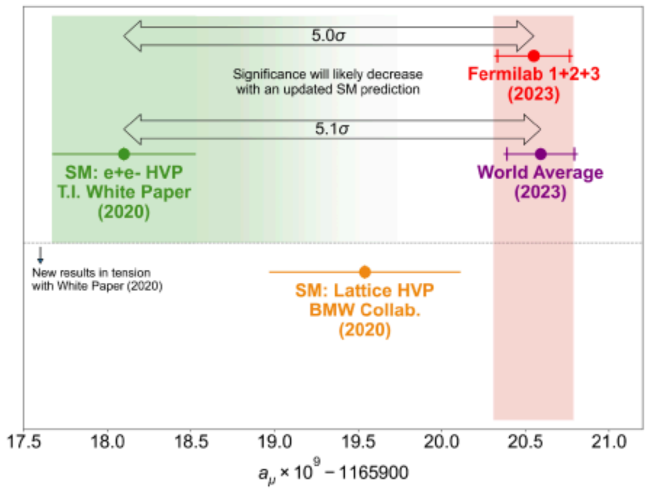
Nagoya group takes leading roles: Particle ID, Computing, Physics analyses

T.I was the spokesperson from June, 2019 to June 2023.

Flavor Anomalies

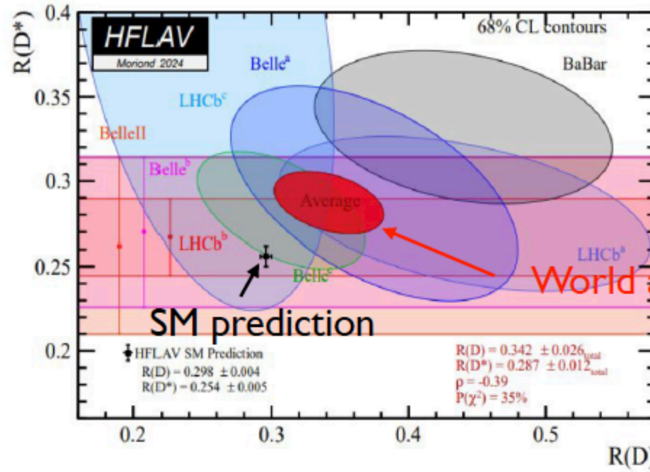
There is still no indication of physics Beyond the Standard Model (BSM) at LHC.
Flavor physics experiments play important roles.

“Muon g-2 anomaly”



“B anomalies”

e.g.; Test of lepton-flavor-universality w/ B semileptonic decays



$$R(D^{(*)}) = \frac{\mathcal{B}(\bar{B} \to D^{(*)}\tau^-\bar{\nu}_\tau)}{\mathcal{B}(\bar{B} \to D^{(*)}\ell^-\bar{\nu}_\ell)}$$

$$(\ell = e, \mu)$$

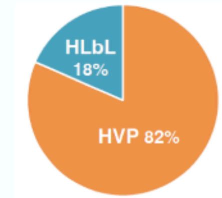
>3σ deviation

KMI/Naoya makes significant contributions to these topics.

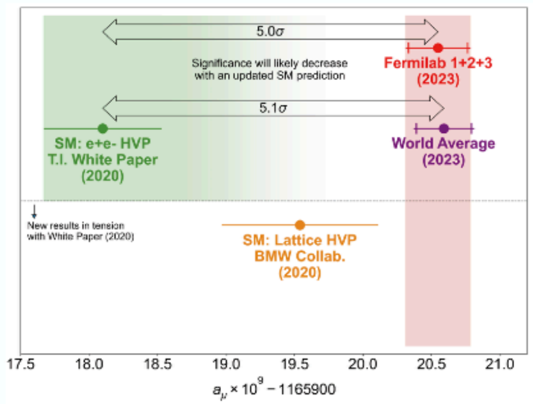
Two Ph.D.s

- **K. Kojima**: Search for lepton flavor universality violation in decays using hadronic tagging at the Belle II experiment
- **Y. Sue**: Precision measurement of the e+e- → π+π-π0 cross section using initial-state radiation

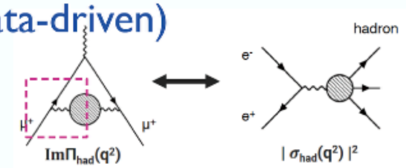
Reference SM Predictions

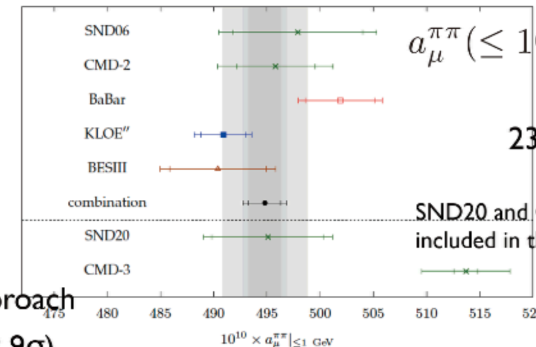


- Hadronic Vacuum Polarization (HVP) is the dominant error source.
- Tension between two approaches; Dispersive and Lattice



Dispersive approach (data-driven)





2308.04217

SND20 and CMD-3 are not included in the combination

T.I. White Paper (2020) takes this approach

Tension between BaBar and KLOE (2.9σ)

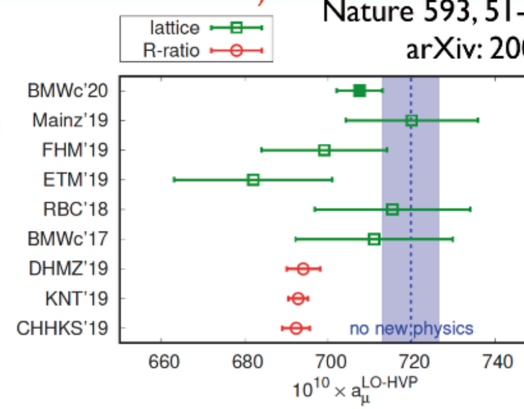
& more tension between CMD-3 (2.2/5.1σ w.r.t. BaBar/KLOE)

Lattice approach

Finite size, lattice spacing, large computing

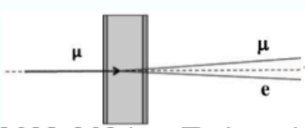
Recent lattice calculation (e.g.;BMW20) achieved comparable error and gives prediction closer to exp.

Nature 593, 51-55 (2021)
arXiv: 2002.12347



Another approach by MUonE

A new independent evaluation of a_μ^{HLO} by $\mu e \to \mu e$ differential cross section



Test runs in 2023-2024 → Technical proposal for 4-week run in 2025

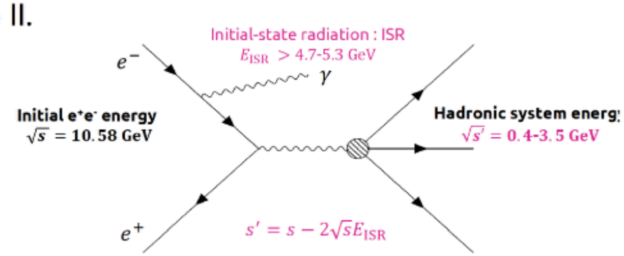
Eugenia Spedicato

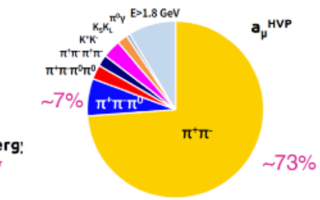
$e^+e^- \to \pi^+\pi^-\pi^0$ by Belle II

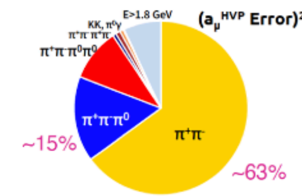
arXiv: 2404.04915

Yuki Sue

- e^+e^- cross-section measurement w/ ISR method in progress at Belle II.
  - Good trigger efficiency confirmed
- Released the first result for $e^+e^- \to \pi^+\pi^-\pi^0$ with 2.2% error
  - The largest uncertainty arises from the MC generator (1.2%)
- The results are about 2.5σ higher than BaBar and global fit.

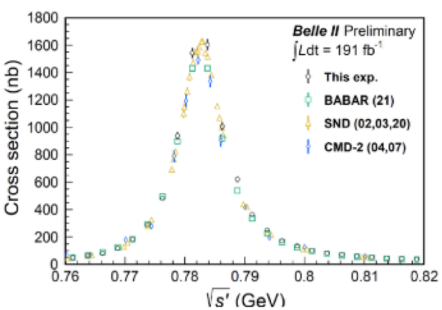


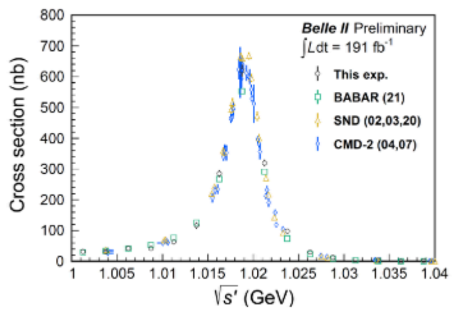


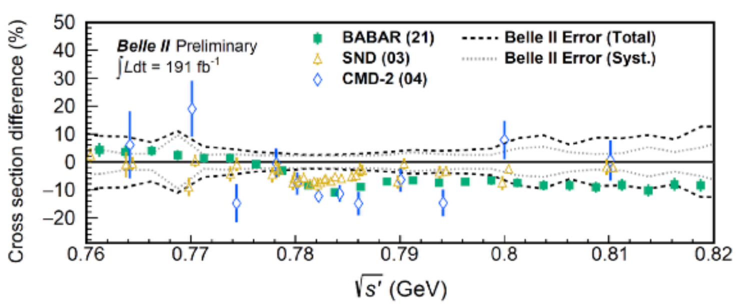


$$a_\mu^{LO,HVP,3\pi}(0.62\text{-}1.8\ \text{GeV}) = (48.91 \pm 0.25_{stat} \pm 1.07_{syst}) \times 10^{-10}$$

	$a_\mu(3\pi)\times10^{10}$	Difference$\times10^{10}$
BABAR alone [PRD104 11 (2021)]	45.86 ± 0.14 ± 0.58	3.2±1.3 (6.9%)
Global fit [JHEP08 208 (2023)]	45.91 ± 0.37 ± 0.38	3.0±1.2 (6.5%)







- Next: $e^+e^- \to \pi^+\pi^-$ w/ target precision: 0.5% of $a_\mu(2\pi)$

Belle II has joined this important community-wide activity

Stay Tuned!

Muon g-2 /EDM at J-PARC

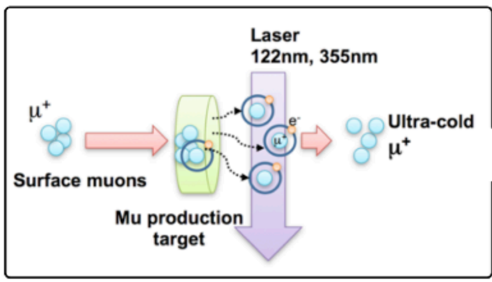
https://g-2.kek.jp

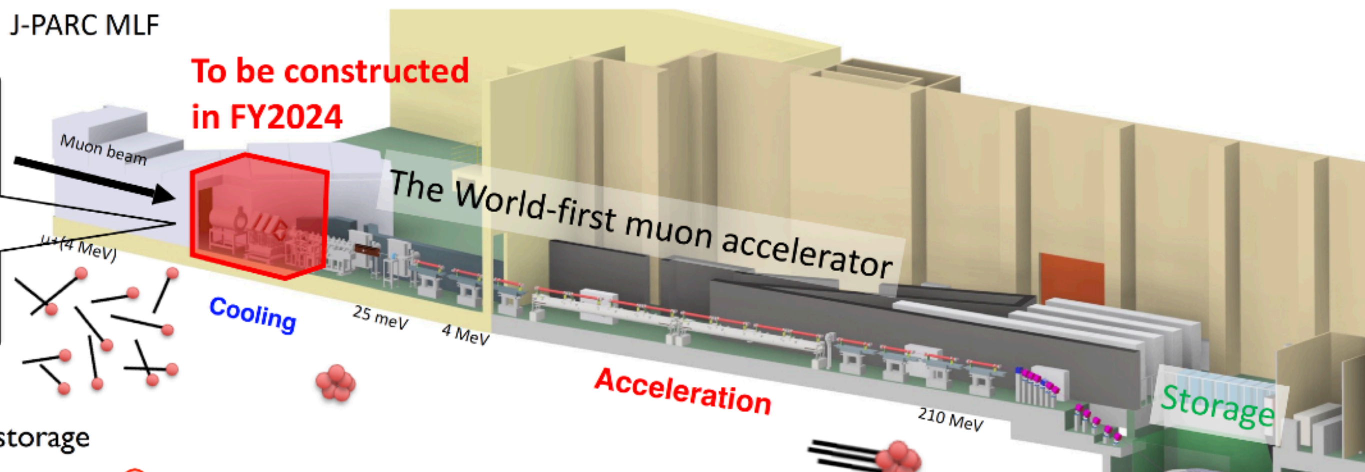
New approach to measure the muon g-2 and EDM at the J-PARC facility

Prog. Theor. Exp. Phys. 2019, 053C02 (2019)

- low emittance muon beam (1/1000) by cooling and re-acceleration
- no strong focusing (1/1000) & good injection efficiency (x10)
- Compact storage magnet (1/20)

⇒ *Independent measurement of g-2 to test BNL/FNAL results with different systematic uncertainty*





No focusing electrode (E=0) in the storage

$$\vec{\omega}_a + \vec{\omega}_\eta = -\frac{e}{m}\left[a_\mu \vec{B} - \underbrace{\left(a_\mu - \frac{1}{\gamma^2 - 1}\right)\frac{\vec{\beta}\times\vec{E}}{c}}_{=0} + \frac{\eta}{2}\left(\vec{\beta}\times\vec{B} + \underbrace{\frac{\vec{E}}{c}}_{=0}\right)\right]$$

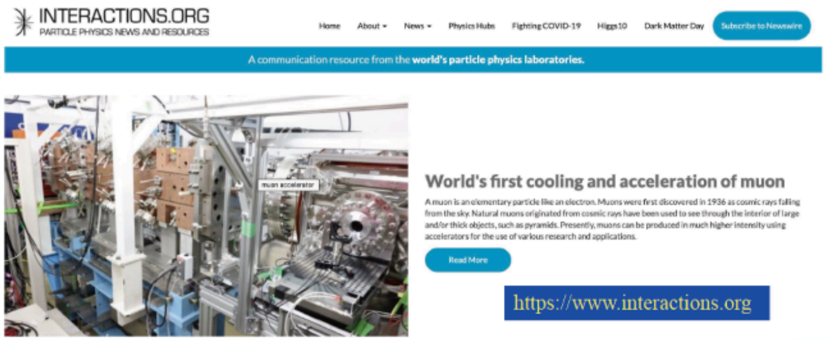
Aiming at data taking from 2028.

Expected sensitivity (2 year running)

	Δstat	Δsyst
g-2	450 ppb	70 ppb
EDM	1.5×10^{-21} e・cm	0.4×10^{-21} e・cm

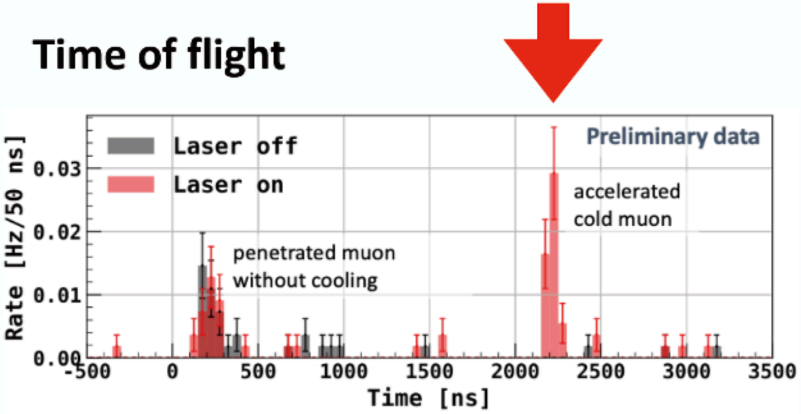
World-first Acceleration of Positive Muon!

Test of muon cooling + re-acceleration at MLF S2 beam line

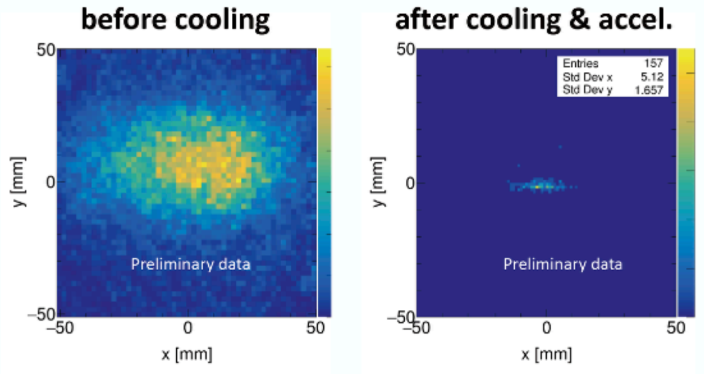


World first The experimental set up for muon cooling and acceleration at J-PARC. A beam of antimatter muons enters the apparatus from the right. Credit: J-PARC

Time of flight

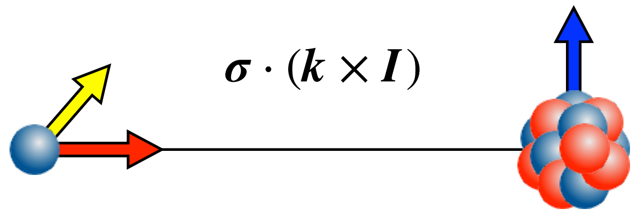


Beam profiles



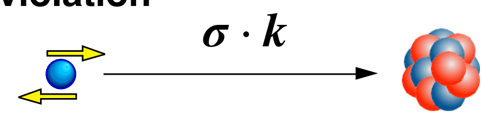
T-violation in compound nuclei

Enhanced symmetry violation appears
in neutron resonance capture reaction.



Statistical nature of
compound states

P-violation



In the case of ^{139}La,
P-violation is **10^6** times enhanced.

Determine enhancement factor **~10^6**
also for T-violation in ^{139}La

$$\Delta\sigma_{\mathrm{T}} = \kappa(J)\,\frac{W_{\mathrm{T}}}{W}\,\Delta\sigma_{\mathrm{P}}$$

$$\kappa = \underline{0.59 \pm 0.05}$$

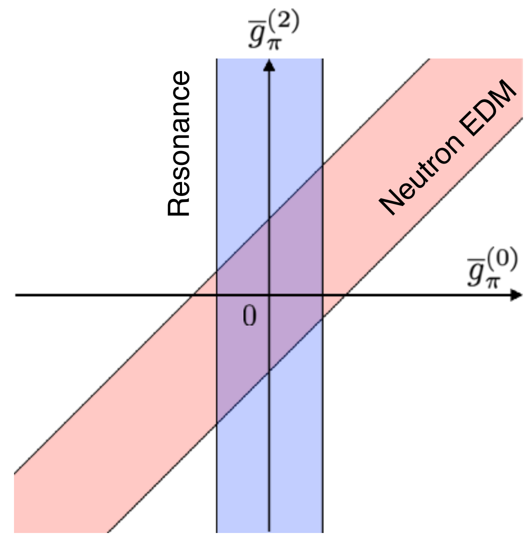
Target candidate search

^{139}La
T. Okudaira *et. al.* , Phys. Rev. C. 97 034622 (2018)
T. Yamamoto *et al.* Phys. Rev. C. 101, 064624 (2020)
T. Okudaira *et. al.* , Phys. Rev. C. 104, 014601(2021)
M. Okuizumi *et al.* Phys. Rev. C. accepted (2025)

^{117}Sn
J. Koga *et. al.*, Phys. Rev. C. 105, 05461 (2022)
S. Endo *et al.*, Phys. Rev. C.106 064601 (2022)

^{131}Xe
T. Okudaira et al. Phys. Rev. C 107, 054602 (2023)

Suggest discovery potential for T-violation
search competitive with neutron EDM



^{139}La resonance
30 days
at J-PARC

complementary

Neutron EDM
10^{-26} e cm

$$\frac{\Delta\sigma_{\mathrm{CP}}}{2\sigma_{\mathrm{tot}}} = \frac{-0.185[\mathrm{b}]}{2\sigma_{\mathrm{tot}}}\left(\bar{g}_\pi^{(0)} + 0.26\bar{g}_\pi^{(1)}\right)$$

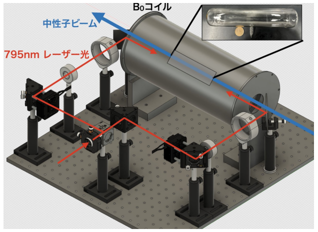
$$d_n \simeq 0.14\left(\bar{g}_\pi^{(0)} - \bar{g}_\pi^{(2)}\right)$$

R&D for T-violation search

Neutron beam polarization

^{3}He spin filter for eV neutrons is available now! P~80% at 0.75eV

In-situ system is also available.

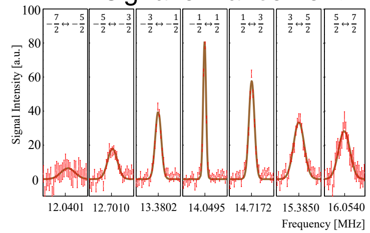


Target nuclei polarization

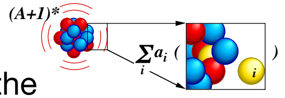
Dynamic nuclear polarization for ^{139}La with $LaAlO_3$ crystal

P_{La}→31.9%

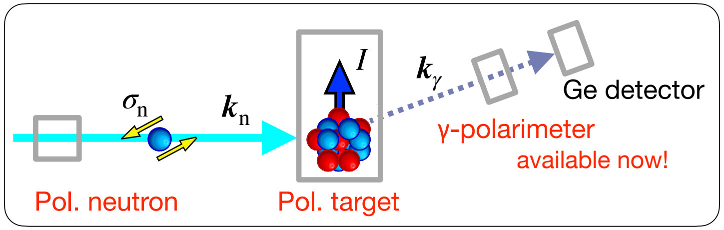
DNP signal enhancement



Many correlation terms of (n, γ) reaction can be used to study the statistical nature of compound states.



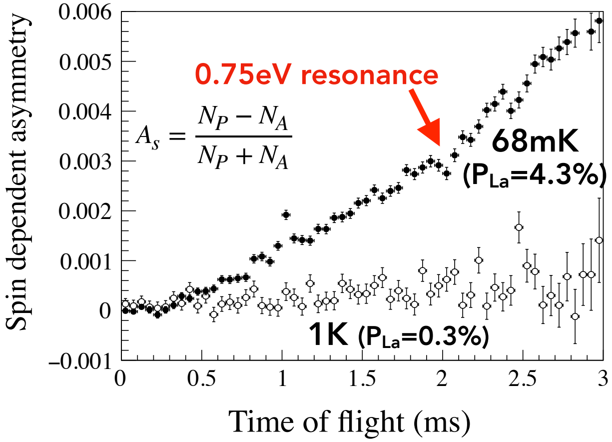
$$\frac{d\sigma}{d\Omega} = \frac{1}{2}\left\{a_0 + a_1\, \boldsymbol{k}_n \cdot \boldsymbol{k}_\gamma + a_2\, \boldsymbol{\sigma}_n \cdot (\boldsymbol{k}_n \times \boldsymbol{k}_\gamma) + a_3\left((\boldsymbol{k}_n \cdot \boldsymbol{k}_\gamma)^2 - \frac{1}{3}\right) + \cdots\right\}$$



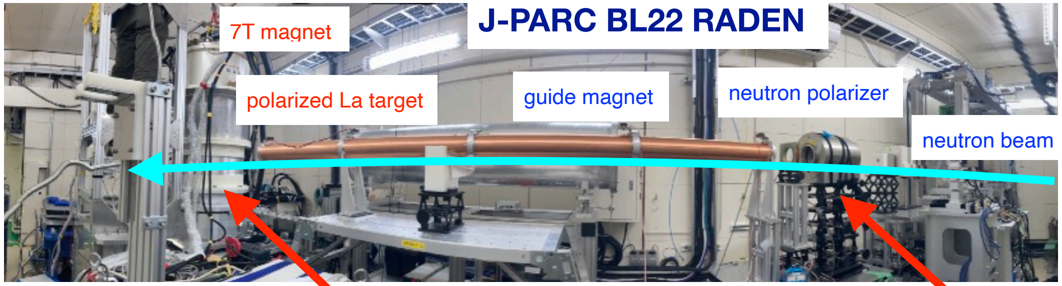
T. Yamamoto et. al., Phys. Rev. C101, 064624 (2020)
T. Okudaira et. al., Nucl. Instr. Meth. A977, 164301 (2020)
K. Ishizaki, et.al., Nucl. Instr. and Meth. A1020, 165845 (2021)
K. Ishizaki, et.al., Rev. Sci. Instrum. 95, 063301 (2024)
S. Endo et. al. Eur. Phys. J. A 60:166 (2024)

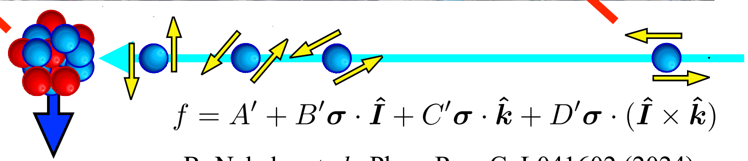
Demonstration of T-violation search

Asymmetry of absorption was observed.



T. Okudaira *et al*., Phys. Rev. C., 109, 044606 (2024)





$$f = A' + B'\boldsymbol{\sigma}\cdot\hat{\boldsymbol{I}} + C'\boldsymbol{\sigma}\cdot\hat{\boldsymbol{k}} + D'\boldsymbol{\sigma}\cdot(\hat{\boldsymbol{I}}\times\hat{\boldsymbol{k}})$$

R. Nakabe *et al*., Phys. Rev. C. L041602 (2024)

This asymmetry can be translated into an upper limit on CP violation.

Same order of nEDM with 10^{-19} e cm (~ first nEDM limit)

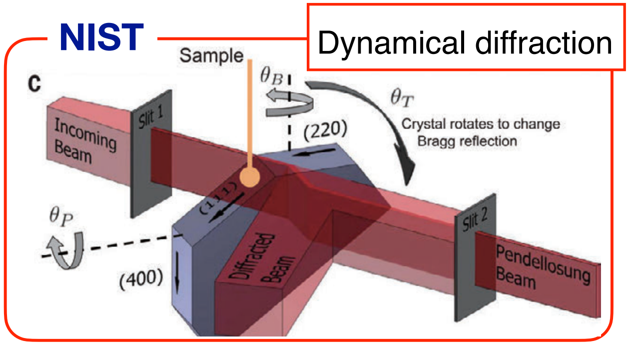
R. Nakabe, PhD thesis (2024)

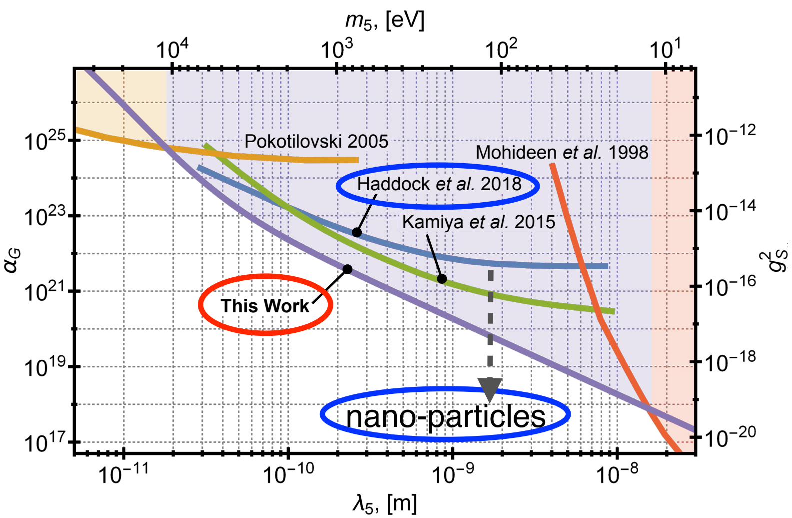
Unknown force search

Extra-dimension, Dark energy

New limit for Yukawa-type intermediate force

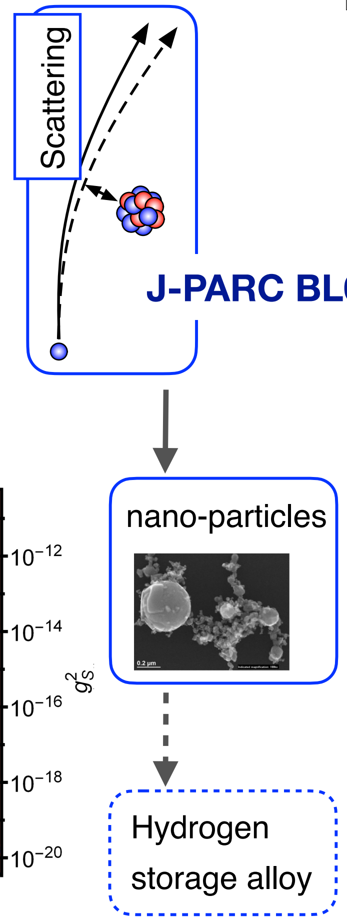
$$V(r) = -G_N \frac{mM}{r}(1 + \alpha\, e^{-r/\lambda})$$





C. C. Haddock, et al., Phys. Rev. D97, 062002 (2018)

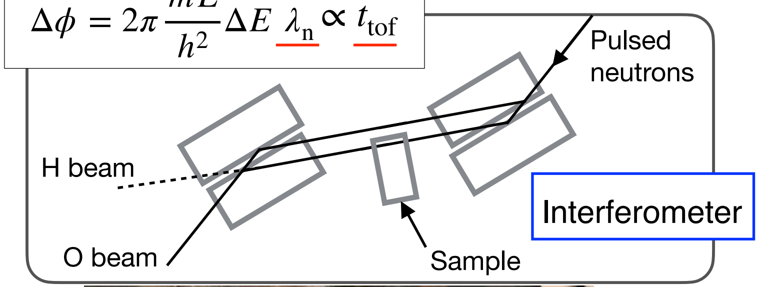
B. Heacock et. al., Science 373 6560 (2021)

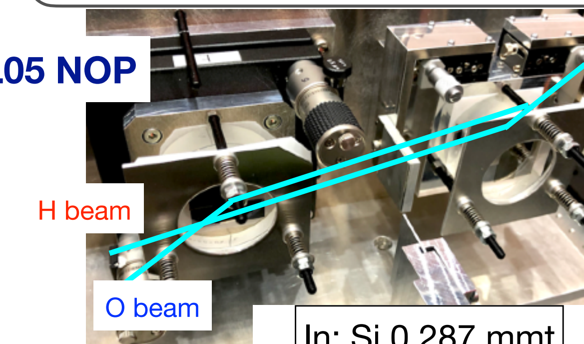


J-PARC BL05 NOP

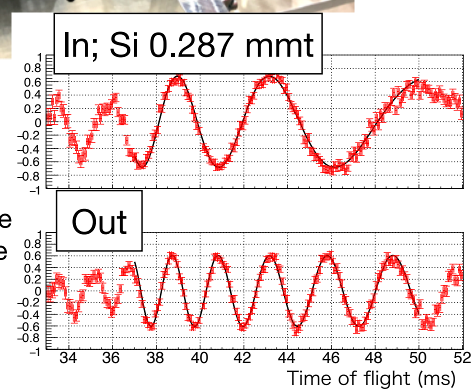
New interferometer with high precision

$$\Delta\phi = 2\pi \frac{mL}{h^2} \Delta E\ \lambda_n \propto t_{tof}$$





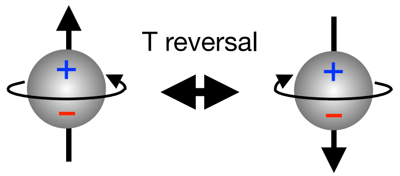
Phase-shift was observed due to refractive index of sample



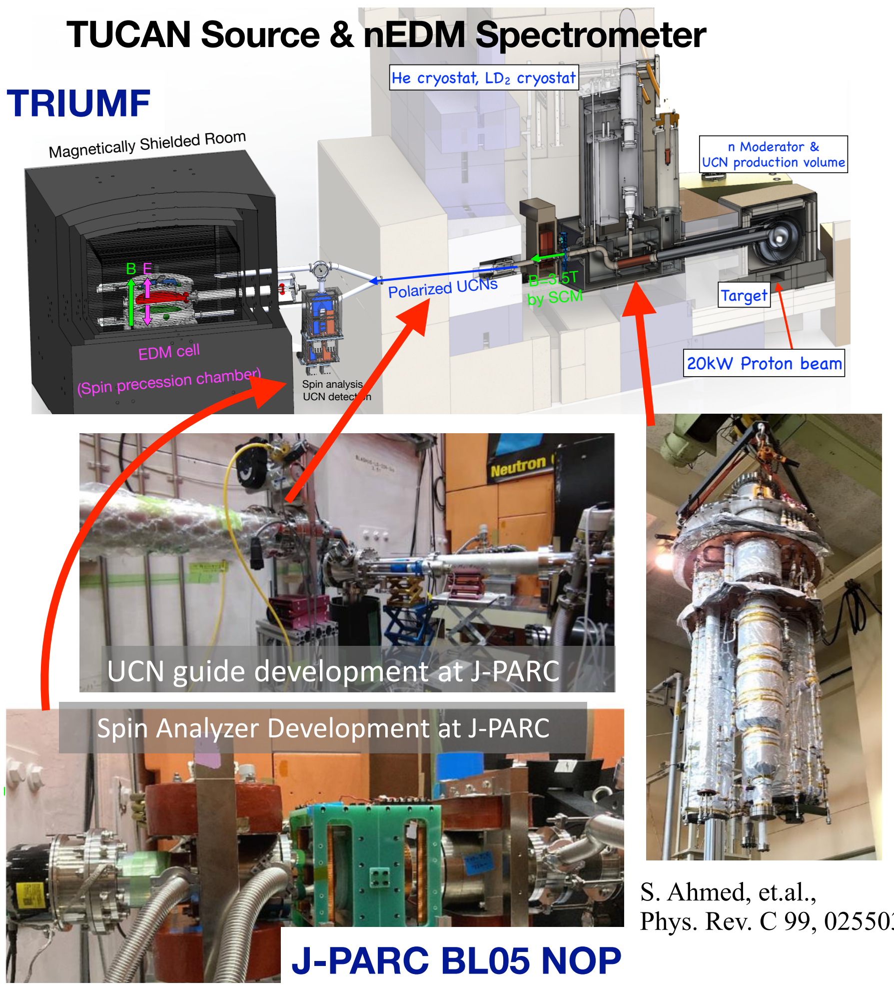
Precision measurements of neutron-nuclear scattering lengths were demonstrated.

T. Fujiie, et al., PRL 132, 023402 (2024)

Neutron EDM using high-flux UCNs

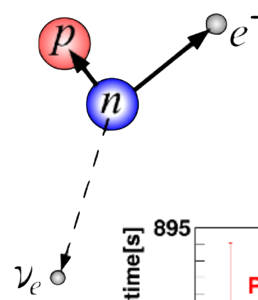


Permanent EDM signals
Time-reversal violation.

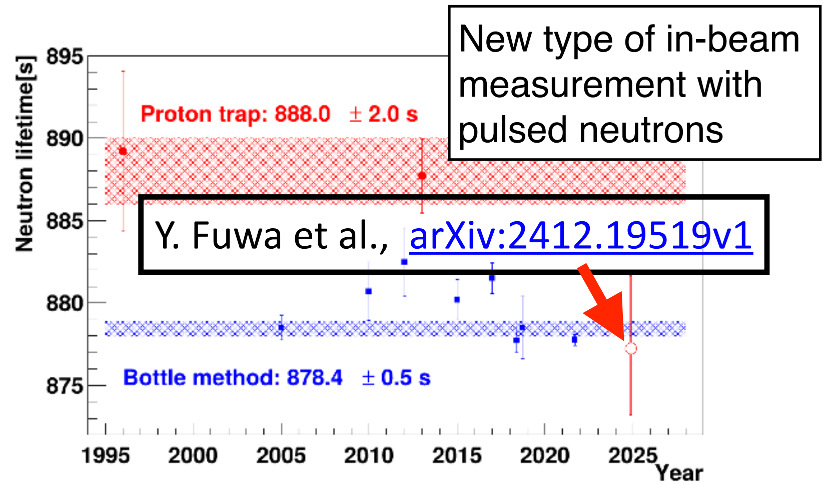


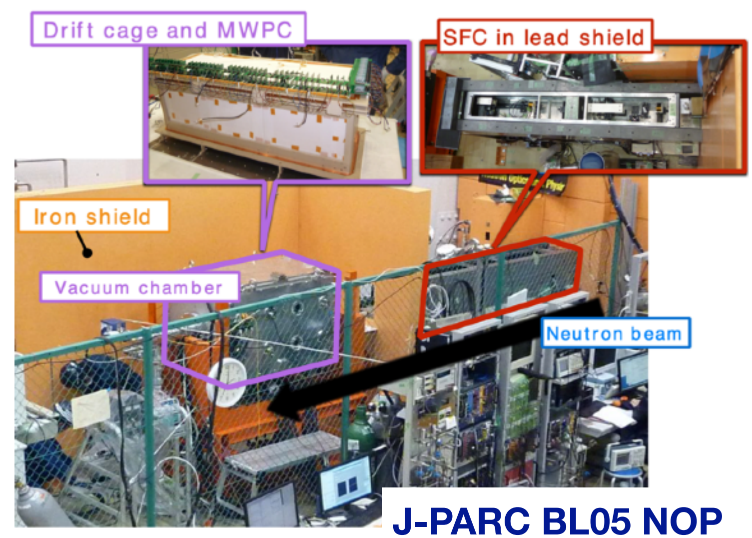
S. Ahmed, et.al.,
Phys. Rev. C 99, 025503 (2019)

Neutron Lifetime



CKM Unitarity check
Big Bang Nucleosynthesis
Decay to dark channel?





LHCf /RHICf ：Study VHECR interactions by colliders

Unique data for very forward production

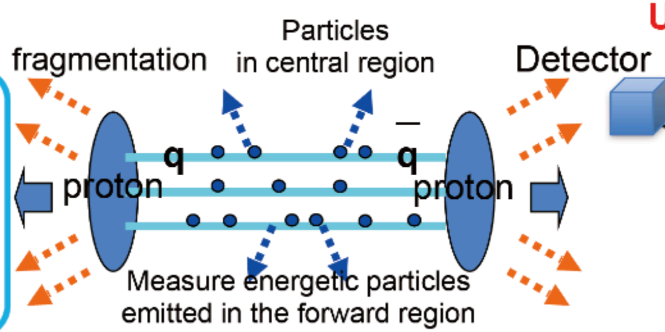
Y.Itow

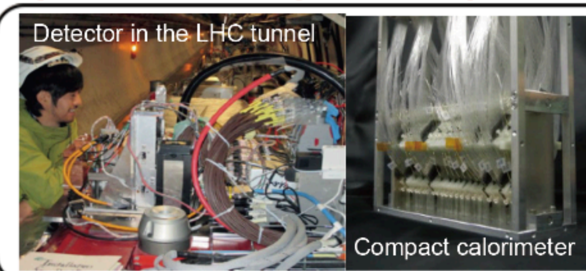
T.Sako

move 2024

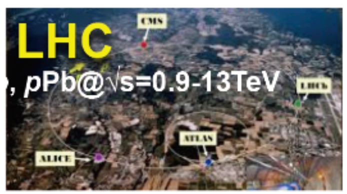
move 2017

H.Menjo

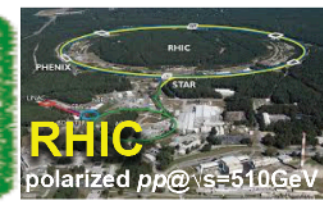




Supported by KMI for 15yrs
Connection to HECR/ν@ ICRR

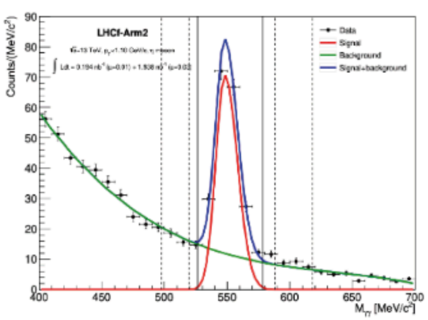


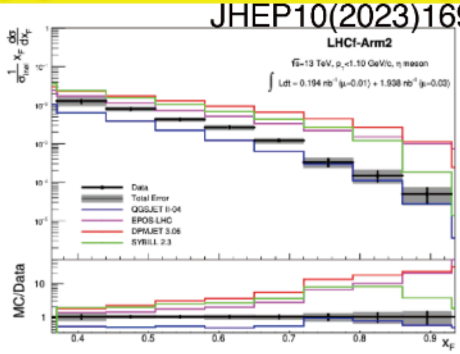
LHCf	RHICf
- pp@√s=14TeV (2022) - Light ions (p-O, O-O) (planed in 2025 Jun)	- p↑p↑@√s=510GeV (2017)



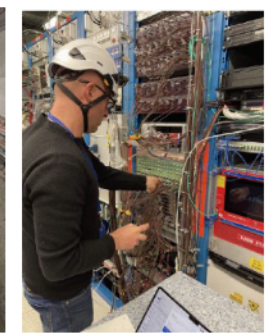
First very forwardηspectrum @ 13TeVpp

JHEP10(2023)169



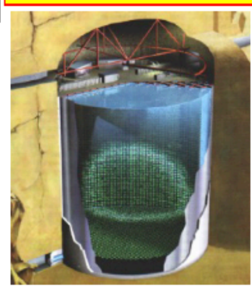


Preparation for LHC p-O 2025 Jun



Super-Kamiokande (SK-Gd) / Hyper-Kamiokande

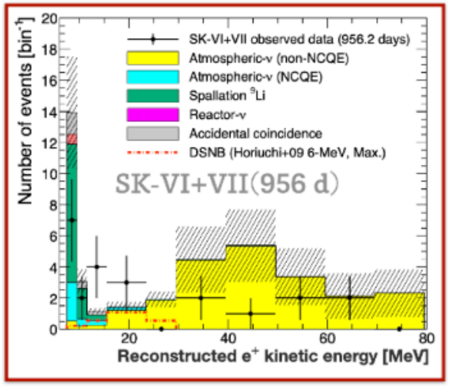
Super-Kamiokande

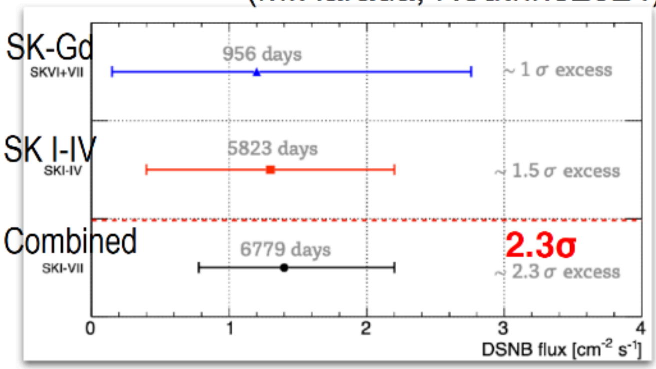


0.03% Gd-loaded
First DSNB result

- Diffuse SN signal search in SK-Gd

(M.Harada, Neutrino2024)

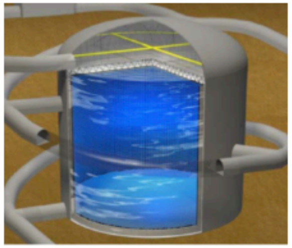




Y.Itow
(→ICRR, Nov2024)

H.Menjo

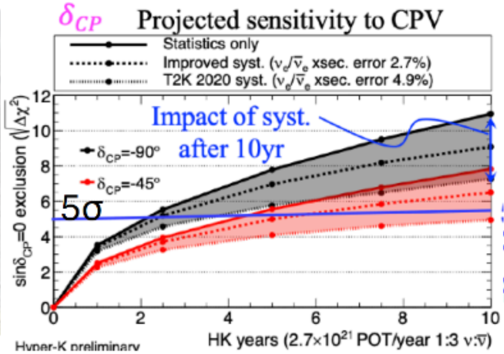
Hyper-Kamiokande



Construction on-going.
Aiming operation 2027.

- Hyper-K construction on-going

(S.Moriyama, Neutrino2024: © ICRR, Univ of Tokyo



M.Hartz
(TRIUMF/Victoria)
joins cross-appointed
professor (Mar 2025)

Direct Dark Matter Detection with the XENONnT

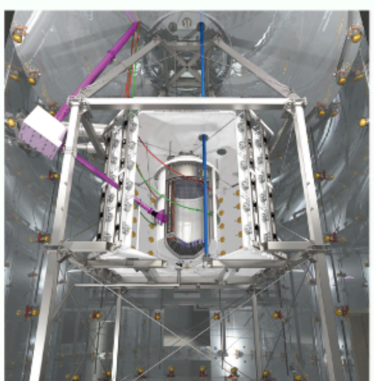
- Dual-phase TPC with 8.5 tonnes of liquid xenon
- Livetime: Science Run 0 (95.1 days) + Science Run 1 (186.5 days)
- Exposure: 3.1 ton-year
- Lowest electronic recoil BG ever achieved in a dark matter detector: ~5 times lower than in XENON1T
- Coherent elastic scattering of ^{8}B solar neutrino has been observed ("Neutrino Fog")
- New WIMP results with 3.1 ton-year exposure (paper submitted to PRL this Monday)



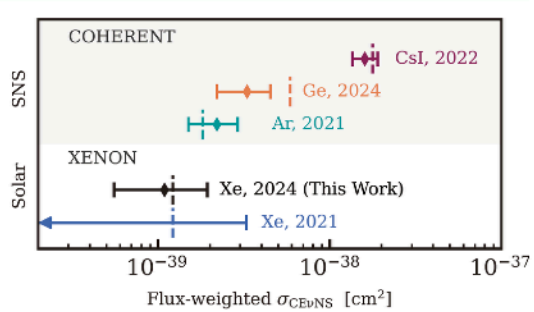
Phys. Rev. Lett. 133, 191002 (2024)
Featured in Physics & Editor's Suggestion

2409.17868 (PRL) 2502.18005 (PRL)

XENONnT Detector

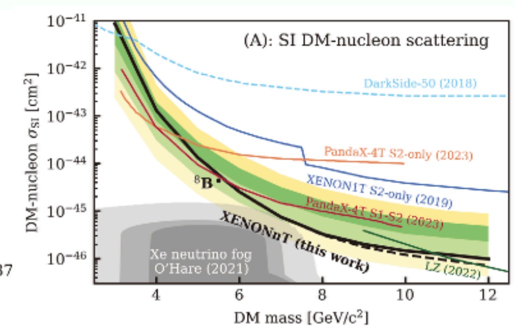


CEvNS Results

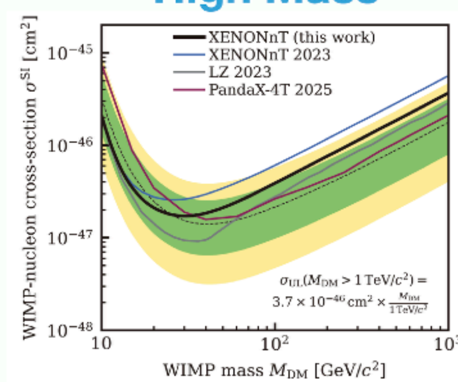


WIMP Results

Low Mass



High Mass

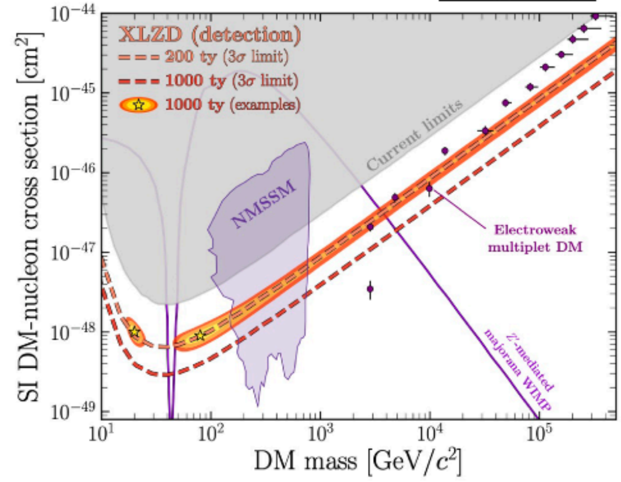


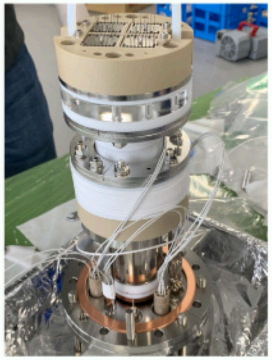
R&Ds for the XLZD Experiment @ Nagoya

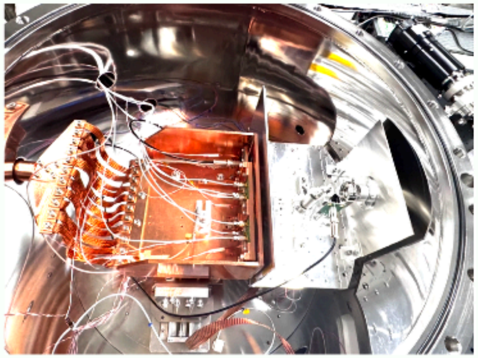
- Towards the future 60-80 t scale experiment (XLZD), we are developing new low-BG techniques such as low-noise SiPM, hybrid photosensor, and hermetic LXe TPC

- We have establised two dedicated cryogenic setups for local R&Ds
  - Currently operating the hermetic LXe TPC with ~7 kg of xenon
  - Recently characterized the peformance of SiPMs at low-temperature

2410.17137



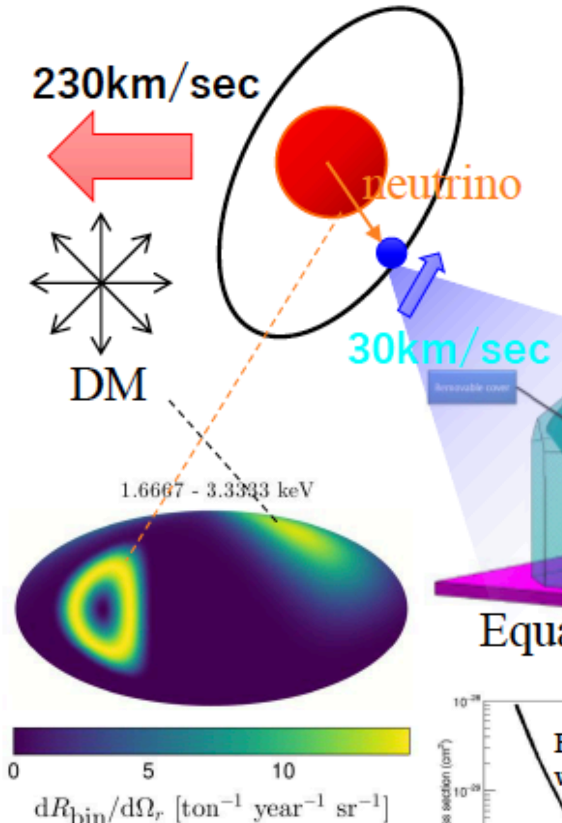




NEWSdm

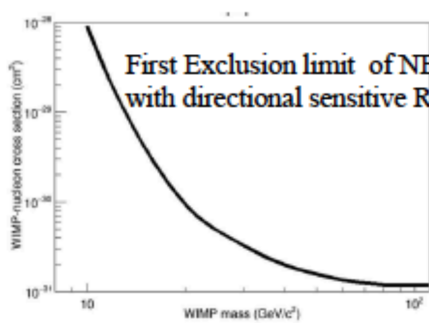
Nuclear Emulsions for WIMP Search -directional measurement

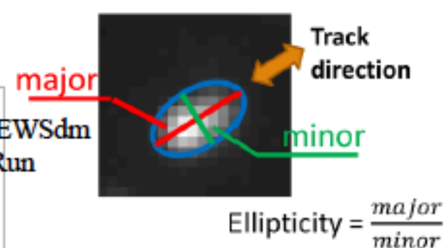
Super-resolution nuclear emulsion and sub-micron tracking



1602.03781(2016)

Equatorial mount

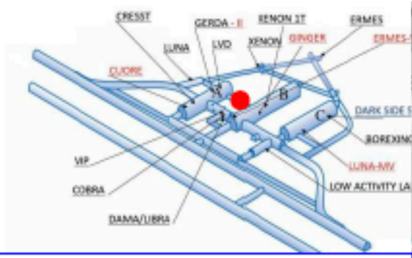




Direct dark matter search with directional sensitivity

high speed & high resolution readout System by optical microscope

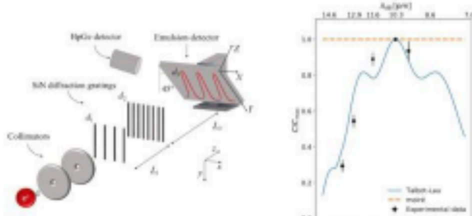
NEWSdm technology and collaboration



LNGS underground lab in Italy

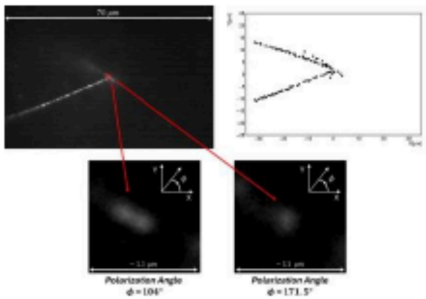
emulsion production facility

QUPLAS / AIABE
high precision antimatter measurement



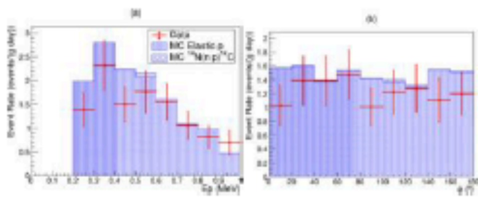
10.1016/j.nima.2019.163019

FOOT/DAMON
measurement of target fragmentation for medical application



10.1016/j.nima.2024.170006

environmental neutron measurement
at "low energy" and "directionality"



10.1103/PhysRevC.107.014608

high resolution & wide range analysis

WIMP signal | Higher energy signal e.g., boosted DM | Proton recoil or alpha

2D reconstructed | 3D reconstructed

NEWSdm

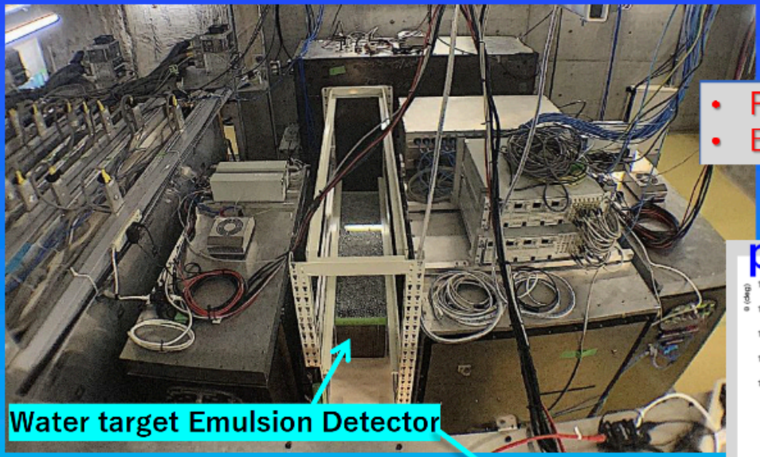
low BG R&D toward >kg scale detector are ongoing

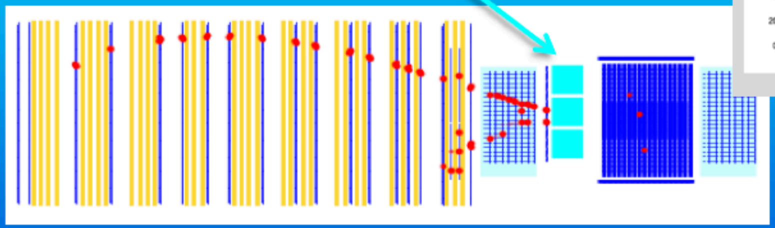
NINJA experiment

NINJA

Neutrino Interaction research with Nuclear emulsion and J-PARC Accelerator

- Precise measurement of ν_μ-nucleus CC cross-sections in Sub-Multi GeV region
- Electron neutrino cross-section measurement, Sterile neutrino search



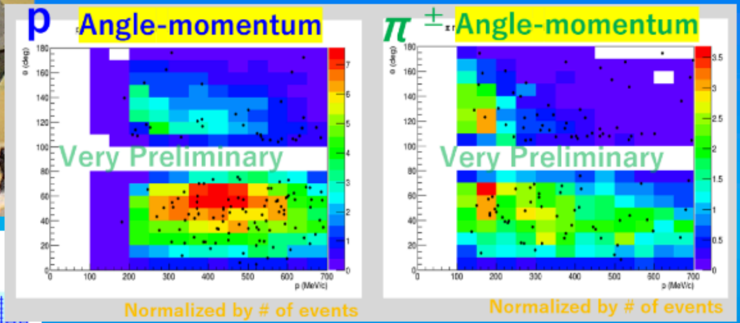


E71a : 2019 Nov. – 2020 Feb.
E71b : 2023 Nov. – 2024 Feb.
E71c : 2025 Nov. – (plan)

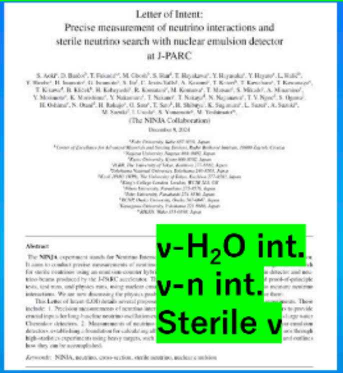
Total : 10^{21} POT

ν beam exposure (2nd Physics Run) is done!

Some Physics results (Preliminary)



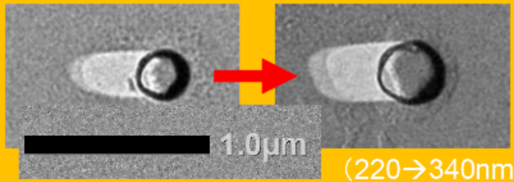
LOI for next NINJA physics



ν-H_2O int.
ν-n int.
Sterile ν

Technical improvements

①Refreshable large crystal emulsion

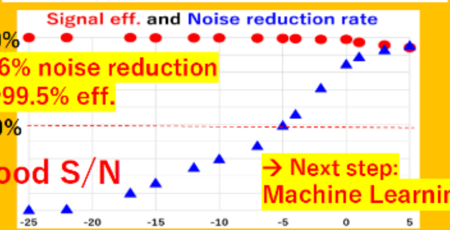


(220→340nm)

Good Efficiency for ν experiments

②New Track Ranking

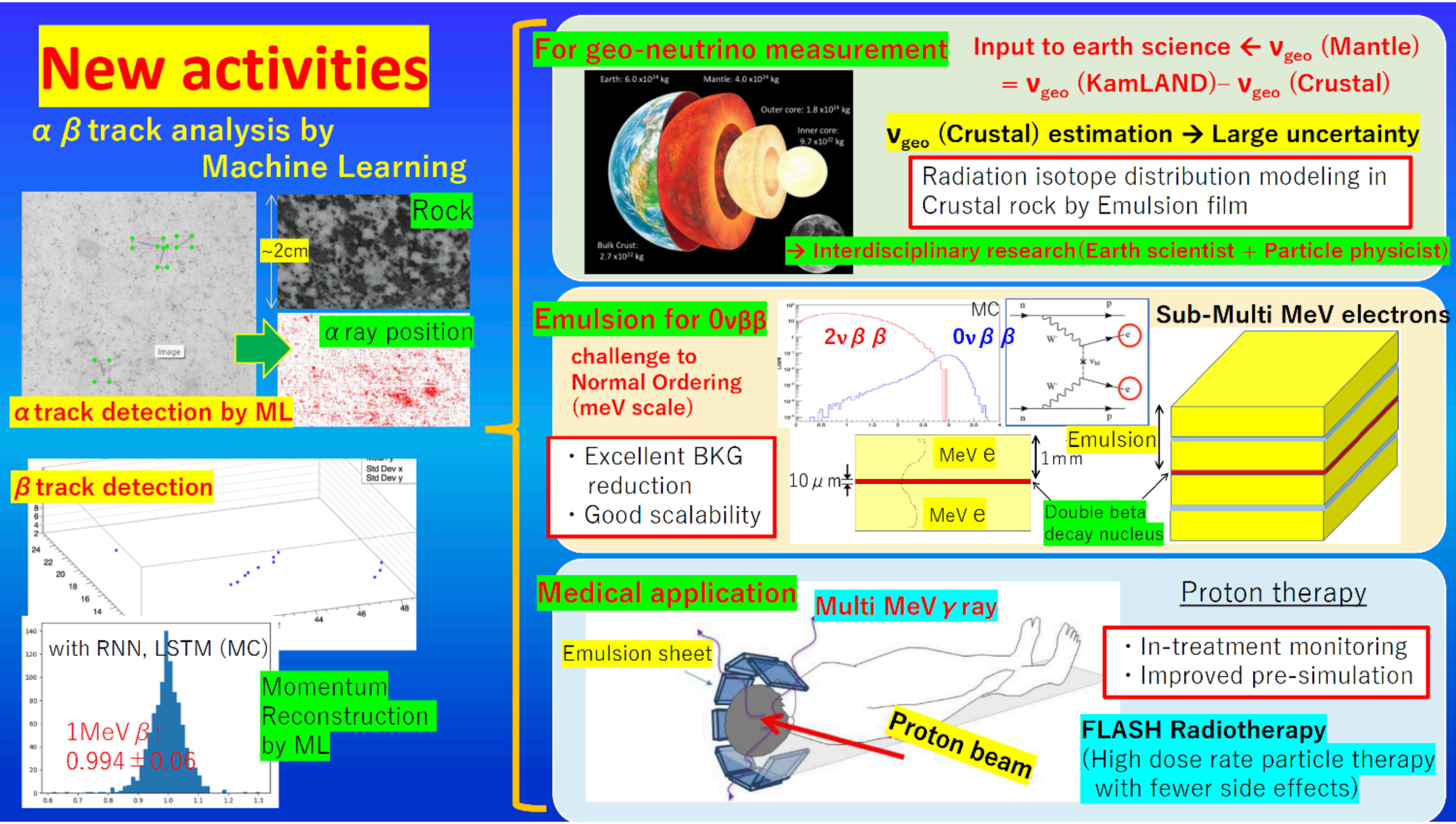
Image analysis
→ 3 new selection parameters



→ 56% noise reduction @99.5% eff.

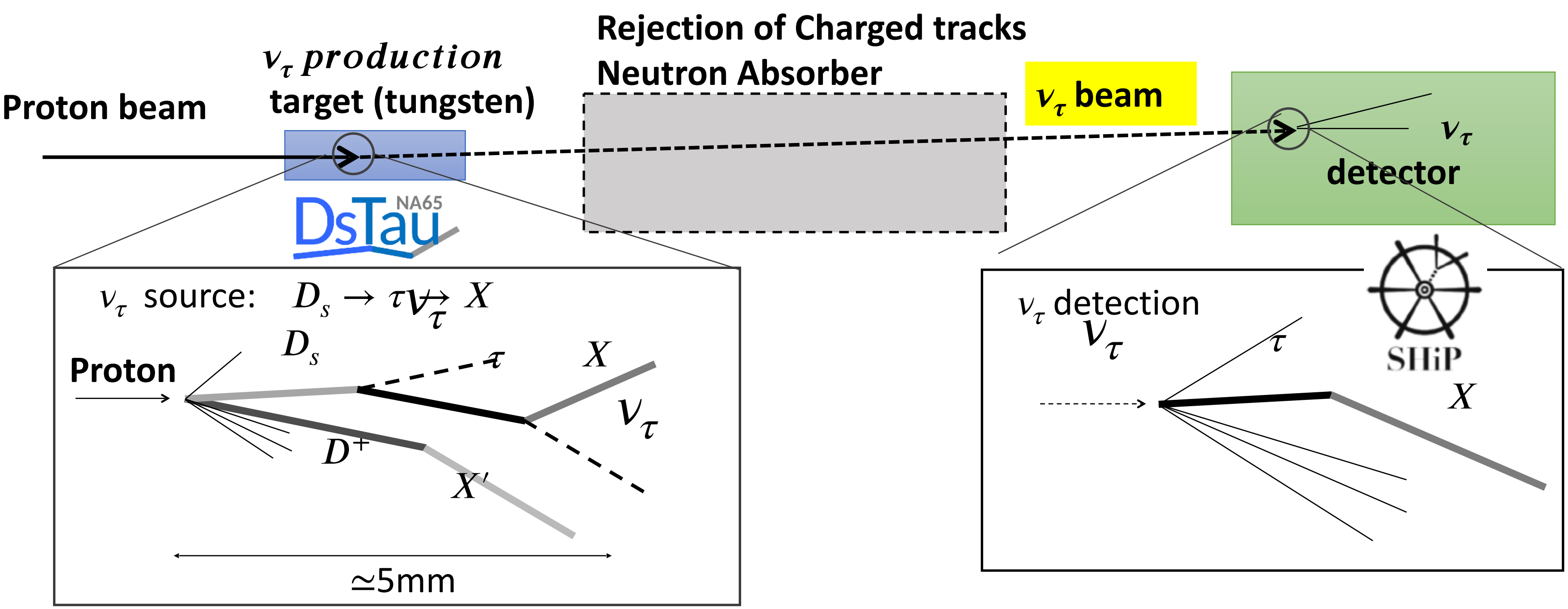
Good S/N

→ Next step: Machine Learning



New activities
α β track analysis by Machine Learning
Rock
~2cm
α ray position
α track detection by ML
β track detection
with RNN, LSTM (MC)
1MeV β : 0.994 ± 0.06
Momentum Reconstruction by ML
For geo-neutrino measurement
Earth: 6.0 x10^24 kg
Mantle: 4.0 x10^24 kg
Outer core: 1.8 x10^24 kg
Inner core: 9.7 x10^22 kg
Bulk Crust: 2.7 x10^22 kg
Input to earth science ← ν_geo (Mantle)
= ν_geo (KamLAND)– ν_geo (Crustal)
ν_geo (Crustal) estimation → Large uncertainty
Radiation isotope distribution modeling in Crustal rock by Emulsion film
→ Interdisciplinary research(Earth scientist + Particle physicist)
Emulsion for 0νββ
challenge to Normal Ordering (meV scale)
・Excellent BKG reduction
・Good scalability
MC
2νβ β
0νβ β
Sub-Multi MeV electrons
MeV e
MeV e
1mm
10 μ m
Emulsion
Double beta decay nucleus
Medical application
Multi MeV γ ray
Emulsion sheet
Proton beam
Proton therapy
・In-treatment monitoring
・Improved pre-simulation
FLASH Radiotherapy
(High dose rate particle therapy with fewer side effects)

Concept of tau neutrino experiment -cross section (etc.) measurement -



ν_τ production study: DsTau

- **No data of Ds differential production cross-section**
- **Larger ~50% uncertainty of ν_τ flux**
- **Detecting 1000 Ds -> tau -> X events**
- **Reduce the uncertainty to 10%**

ν_τ detection: SHiP etc.

- 9 $\boldsymbol{\nu_\tau}$ detected by DONuT (bam $\boldsymbol{\nu_\tau}$). 33% statistical error
- 10 $\boldsymbol{\nu_\tau}$ detected by OPERA (Oscillated $\boldsymbol{\nu_\tau}$)
- SHiP ~ 10000 events a few % statistical error

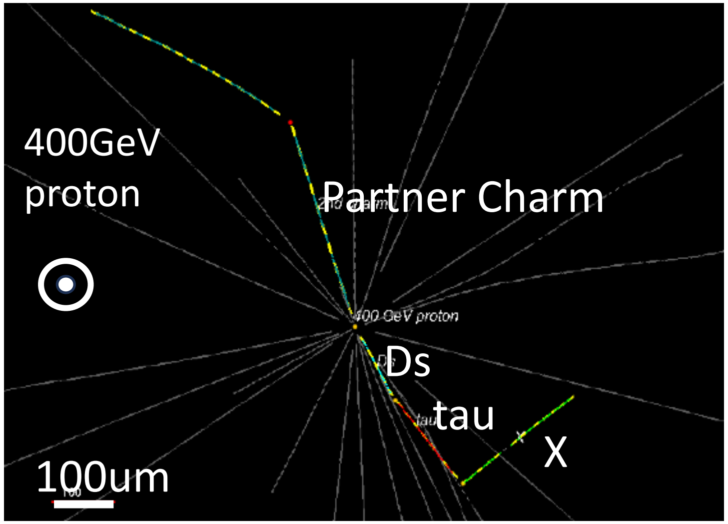
DsTau activities

- 2021-2023 CERN-SPS 400 GeV proton irradiated to Emulsion chamber.
  - In total 2.04 x 10^8 p-tungsten (molybdenum) interactions are accumulated in the detectors.
  - For the exposures, emulsion films were produced at Nagoya University and assembled at CERN with plastic spacers and tungsten (molybdenum) plates.
- A paper appear soon, accepted by EPJC, arXiv:2411.05452v1 discussing proton-tungsten interaction features and report its interaction length.
- Ds->tau->X signal event search

  Several candidates events are found in subsample of 1.9 x 10^6 p-tungsten interaction.

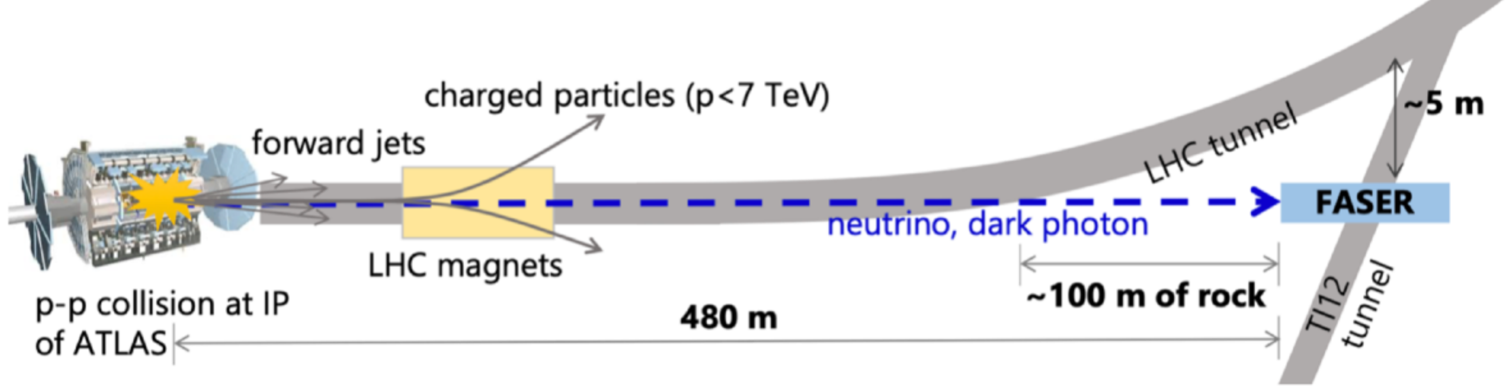
  Detailed analysis is on going

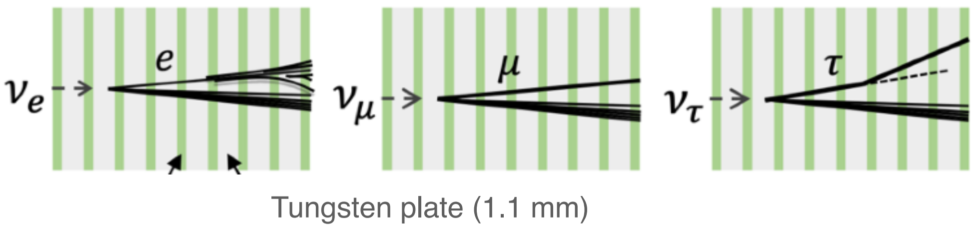
Proton Exposure runs	Detector Modules	Used Emulsion films area (m^2)	Integrated Module number	Integrated Accumulated proton-W(Mo) interactions (x 10^8)
Pilot run 2018	¼ x 30 = 7.5	49	7.5	0.19
Physics run 2021	**17**	**110**	**24.5**	**0.61**
Physics run 2022	**17**	**110**	**41.5**	**1.04**
Physics run	**40**	**260**	**81.5**	**2.04**



A Ds -> tau -> X associating p-tungsten interaction candidate found in preliminary analysis.
The display is from beam direction view.

FASERν

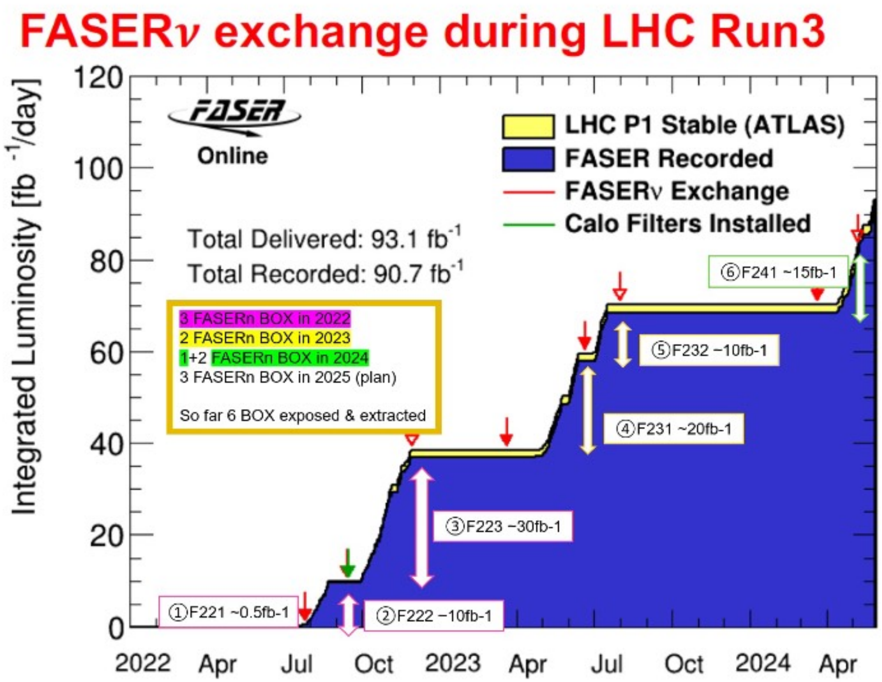




- Emulsion-based detector
  - 730 × [tungsten (1.1 mm thickness) + emulsion film]
  - 250 mm × 300 mm, 1 m long, 1.1 tons (220 X_0)
  - Install (exchange) emulsions 3 times a year

- ν flavor identified with topological/kinematical info

- Global reconstruction with FASER spectrometer
- Muon charge identification (ν_μ)

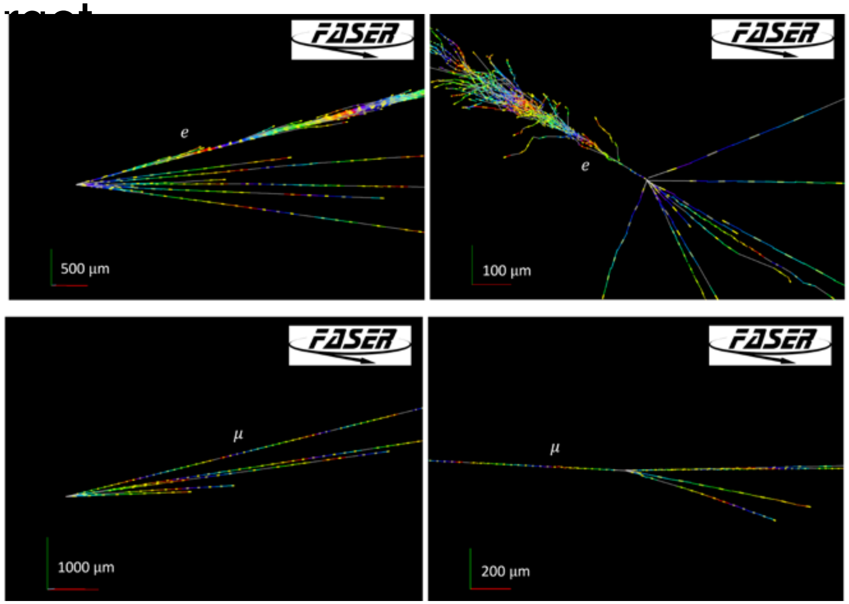


PHYSICAL REVIEW LETTERS 133, 021802 (2024)

Editors' Suggestion | Featured in Physics

First Measurement of ν_e and ν_μ Interaction Cross Sections at the LHC with FASER's Emulsion Detector

First cross section measurement at TeV energy region using 9.5 fb^{-1} and 128.6 kg target

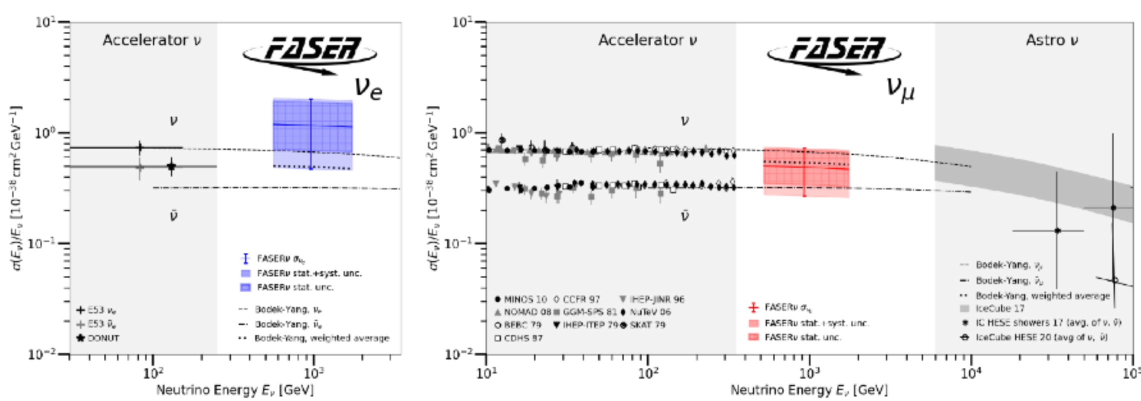


4 νe CC found in ECC

$\sigma(\nu e + N)/E = 1.2^{-0.8}_{-0.7} \times 10^{-38}\ \mathrm{cm^2/GeV}$

8 νμ CC found in ECC

$\sigma(\nu\mu + N)/E = 0.5 \pm 0.2 \times 10^{-38}\ \mathrm{cm^2/GeV}$

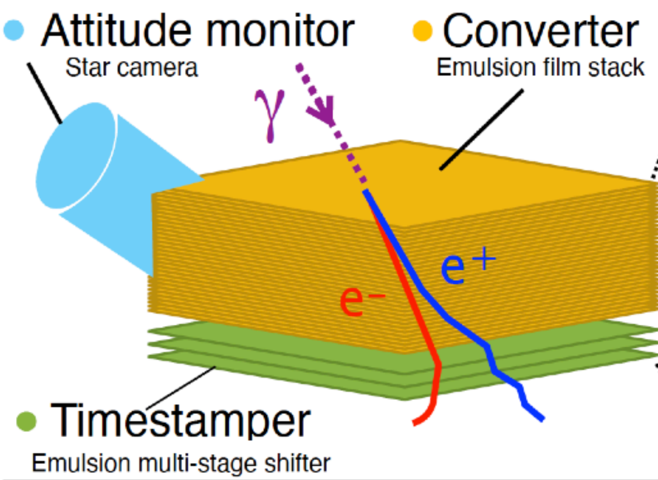


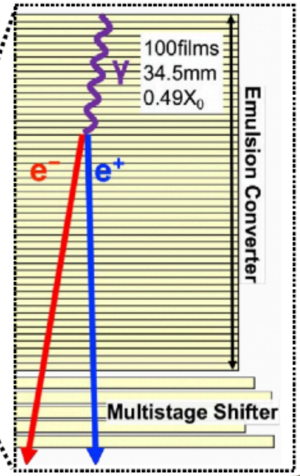
GRAINE Project

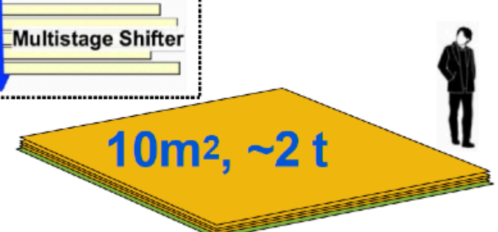
Gamma-Ray Astro-Imager with Nuclear Emulsion

Aichi U. of Edu., Gifu U., Kobe U., Nagoya U., Okayama U. of Sci. (PI: Shigeki AOKI, Kobe U.)

DETECTOR: Balloon-borne Emulsion Telescope







	Fermi LAT	GRAINE
Angular Res. @ 100MeV	6.0 °	(x 6) 1.0 °
@ 1GeV	0.90 °	(x 9) 0.1 °
Polarization Sentivitity	—	Yes
Effective Area @ 100MeV	0.25 m²	(x 8) 2.1 m² *
@ 1GeV	0.88 m²	(x 3) 2.8 m² *

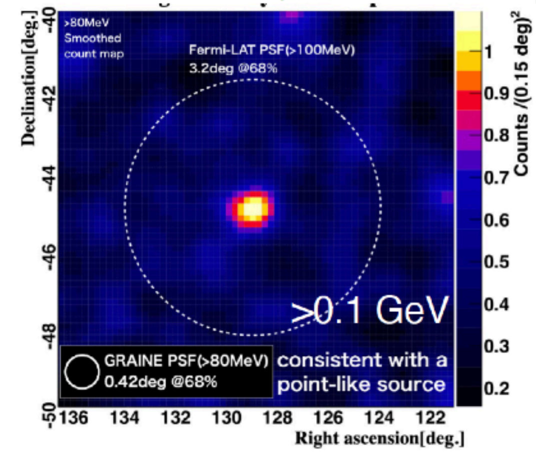
High-angular resolution
Polarization sensitive
Large aperture area

* $10m^2 \times \varepsilon_{trans} \times \varepsilon_{conv} \times \varepsilon_{det}$

DEMONSTRATION

✓ Imaging of Vela pulsar

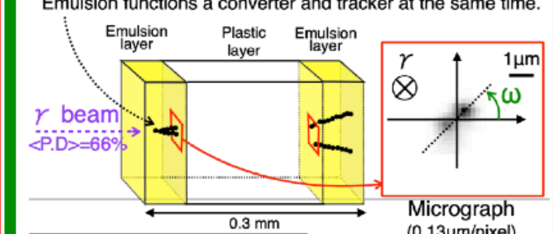
S.Takahashi et al. ApJ. 960 (2023) 47

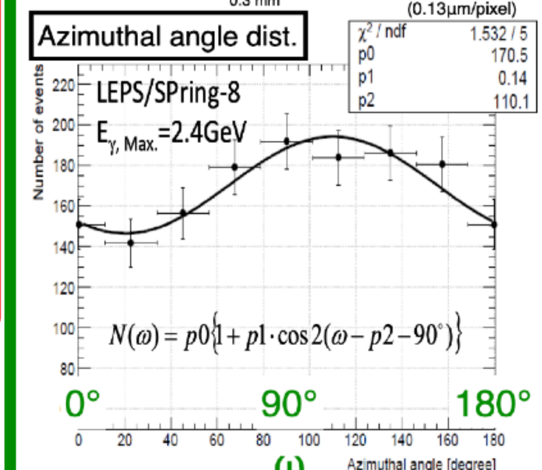


✓ Beam Test of Polarization

K. Ozaki, et al., NIM A 833 (2016)165

Emulsion functions a converter and tracker at the same time.





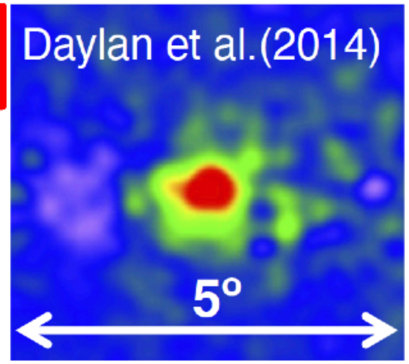
S.Takahashi et al. NIMA 620, 192 (2010) · H.Rokujo et al. NIMA 701, 127 (2013) · S.Takahashi et al. PTEP 2015 043H01 · K.Ozaki et al. JINST 10 (2015) P12018 · S.Takahashi et al. PTEP 2016, 073F01 · K. Ozaki, et al., NIM A 833 (2016)165 · H. Rokujo et al. PTEP 2018, 063H01 · S.Takahashi et al. Adv. Space Res. 62 (2018) 2945 · H. Rokujo et al. JINST 14 (2019) P09009 · Y. Nakamura et al. PTEP 2021,123H02 · M.Oda et al. PTEP. 2022 113H03 · S.Takahashi et al. ApJ. 960 (2023) 47 · Y.Nakamura et al. Astropart. Phys.165 (2025) 103055

Scientific Targets
in Alice Springs Experiment

GRAINE is expected to provide unique and impactful science that cannot be achieved by current and future satellite missions.

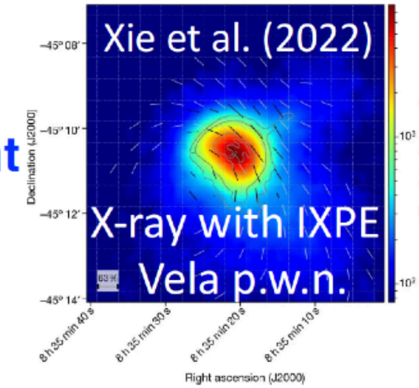
Galactic Center

Precise meas. of G.C. “GeV excess” w/ the world's highest angular res. (0.1°)

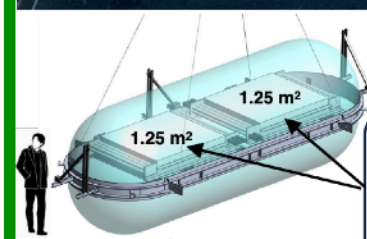


Vela Pulsar

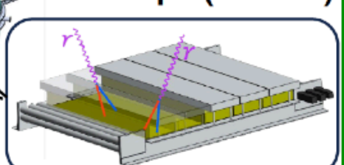
The first significant pioneering obs. of polarization in the 0.1-GeV band.



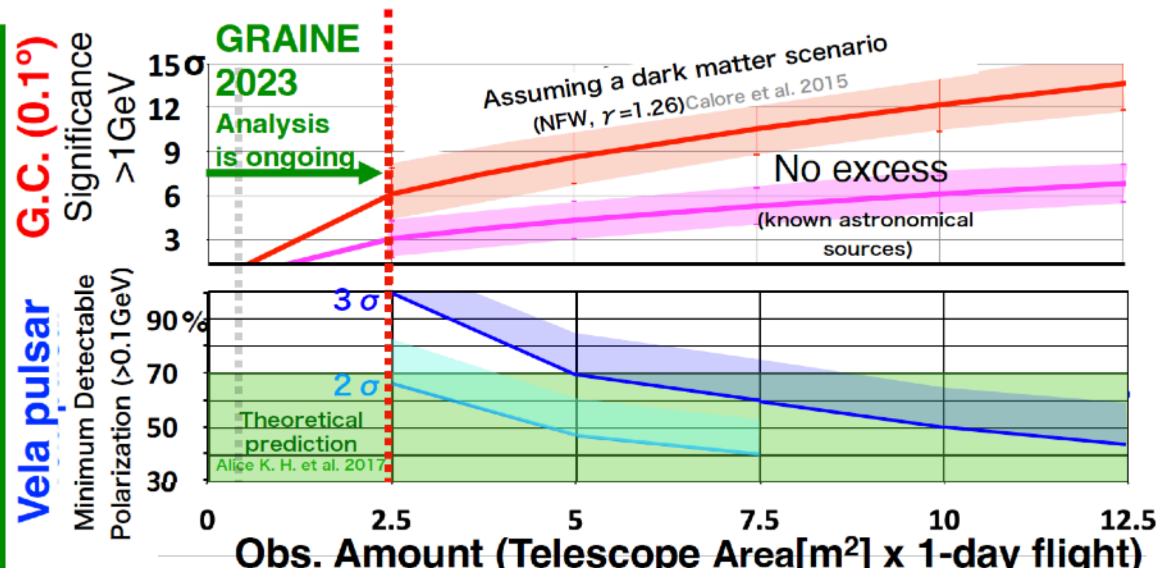
GRAINE2023 model payload

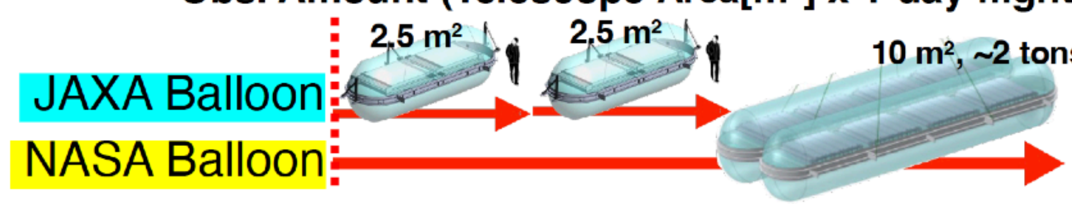


Unitized emulsion telescope (1.25 m²)



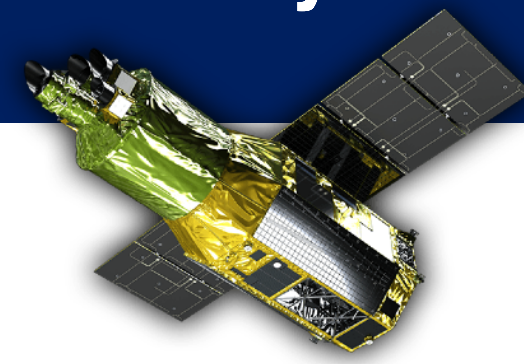
2.5 m², ~700 kg





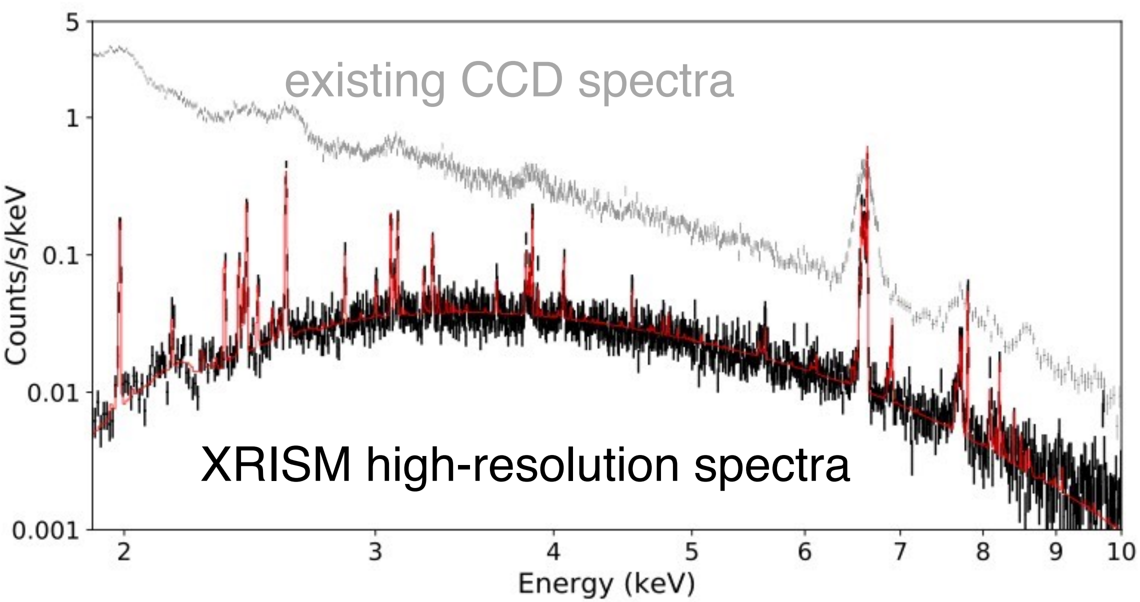
Larger aperture area & repeated balloon flights

High-energy X-ray astrophysics and X-ray/MeV detector developments

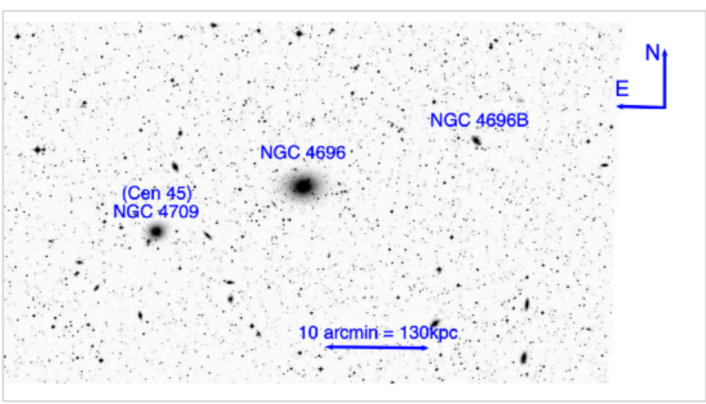


XRISM (X-Ray Imaging and Spectroscopy Mission)

A JAXA-lead X-ray astronomy satellite, developed with NASA and ESA, launched in 2023. It focuses on super high resolution spectroscopy. First papers are coming out.

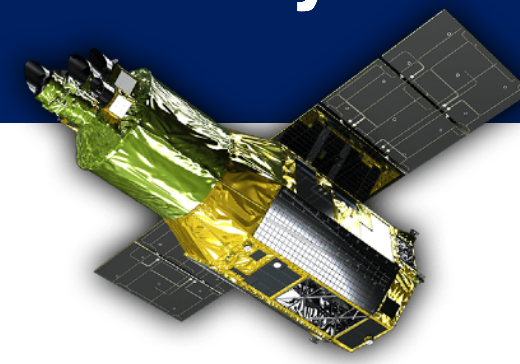


Optical image



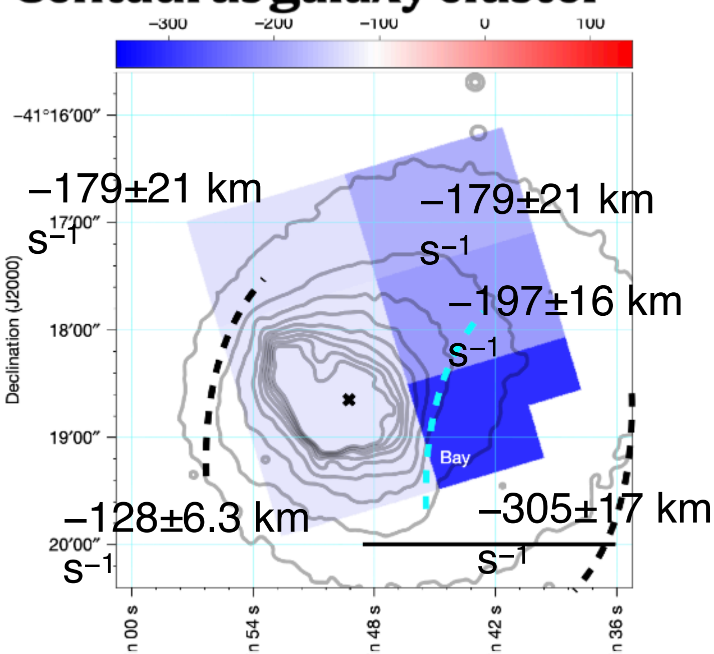
2023-25 Achievements

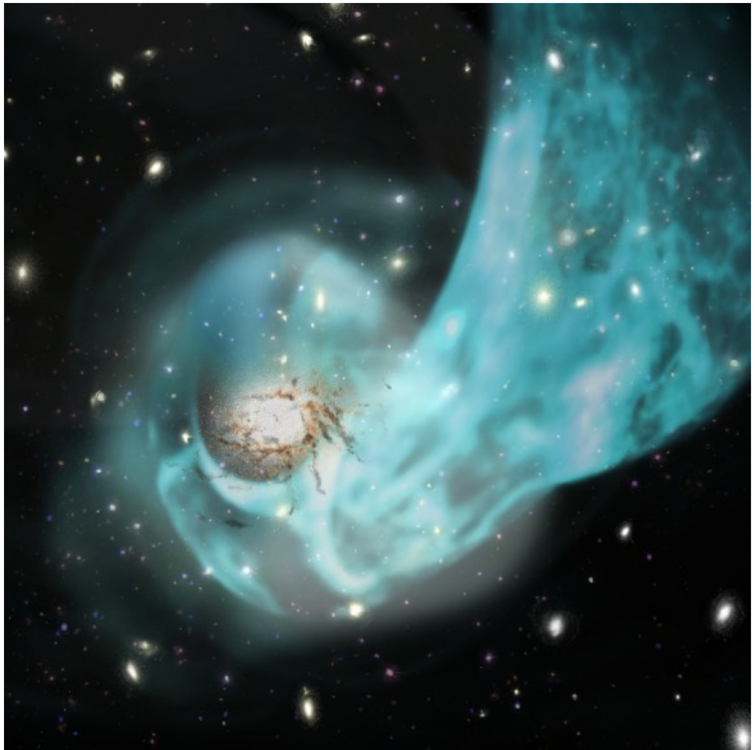
High-energy X-ray astrophysics and X-ray/MeV detector developments



Nature, Article, Published: 12 February 2025

The bulk motion of gas in the core of the Centaurus galaxy cluster





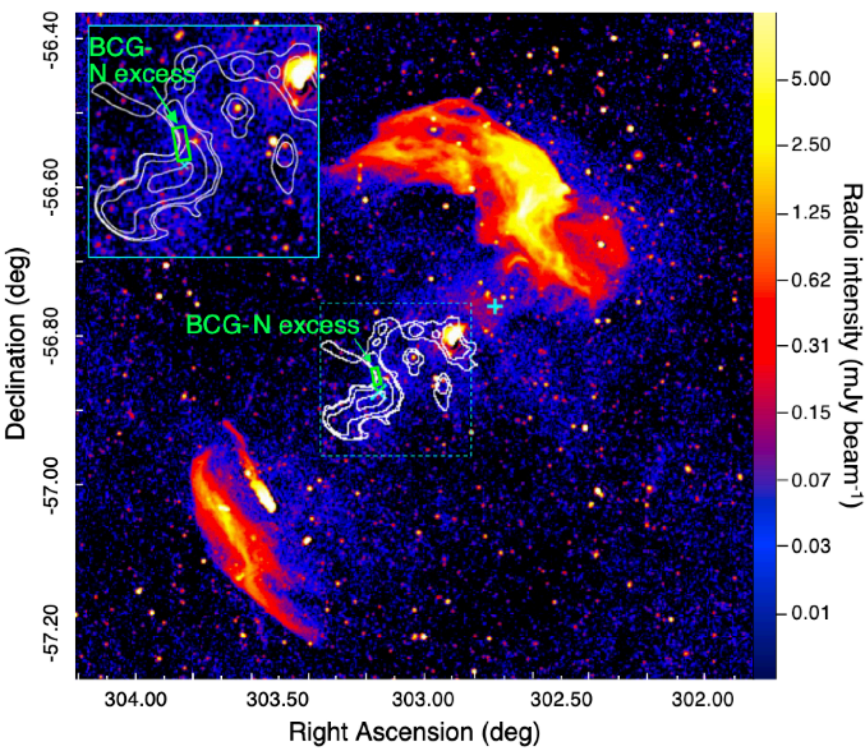
Hot gas is moving compare to the galaxy. Looks like faster to the so

→ "Sloshing" is taking place.

High-energy X-ray astrophysics and X-ray/MeV detector developments

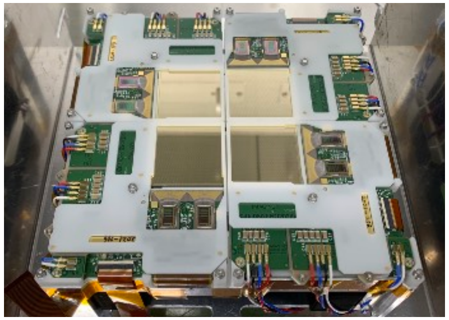
X-ray observation of merging cluster of galaxies

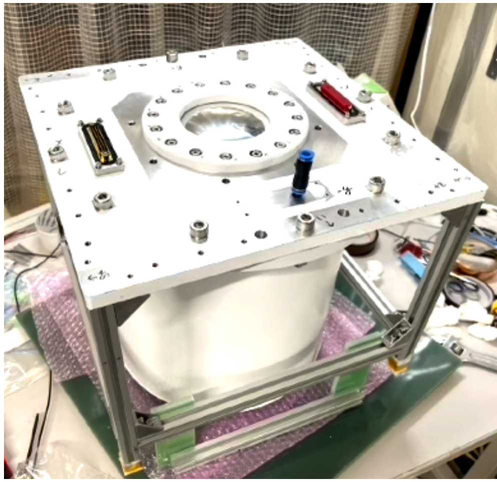
"Indications of an offset merger in Abell 3667", Omiya, Nakazawa + 2024



Si/CdTe hard X-ray/MeV detector development "miniSGD"

"Development of miniSGD"
Okuma, Nakazawa et al. 2023





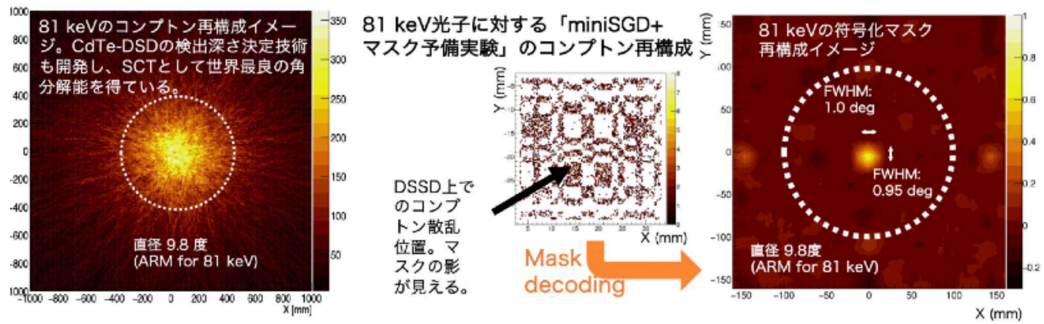
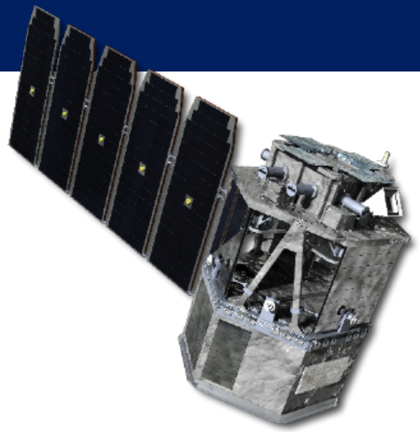


図 5: miniSGD+符号化マスク予備実験による撮像結果。

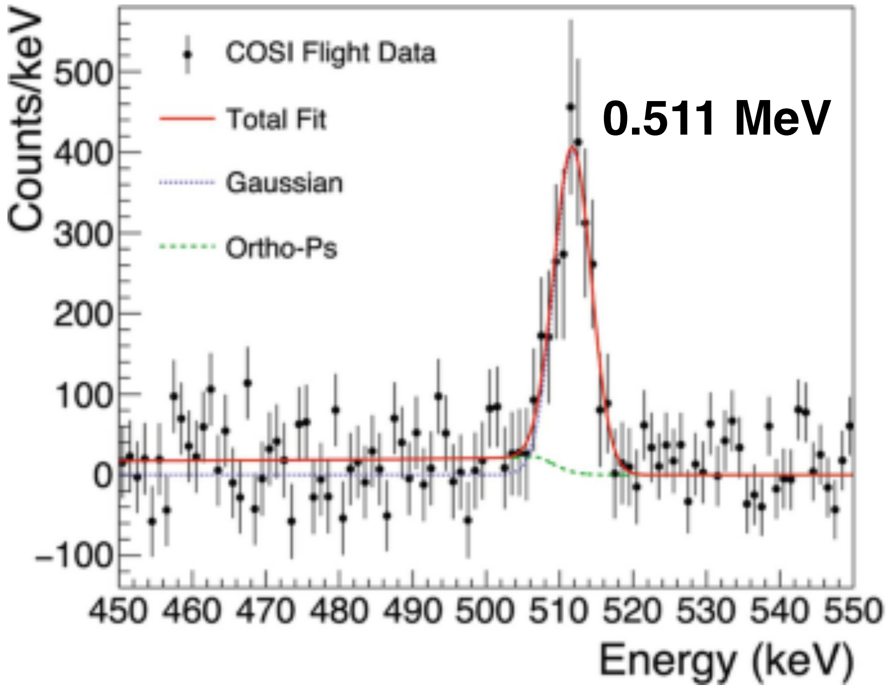
2023-25 Achievements

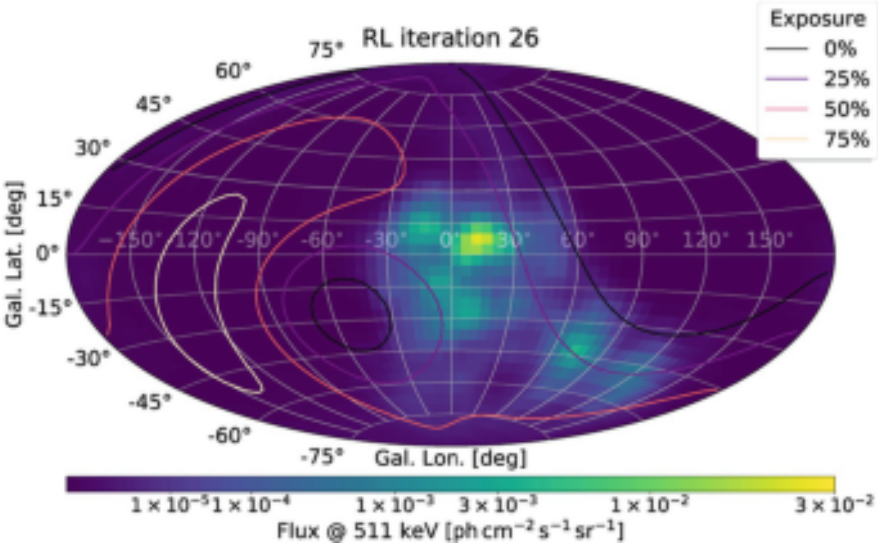
High-energy X-ray astrophysics and X-ray/MeV detector developments



COSI (Compton Spectrometer and Imager)

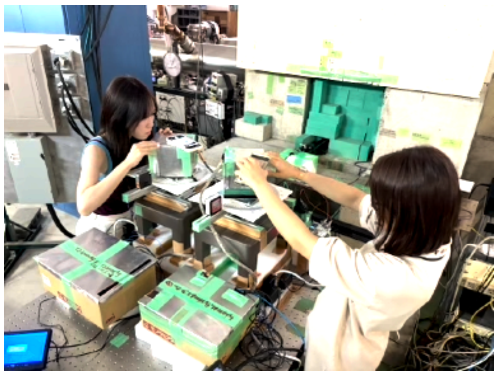
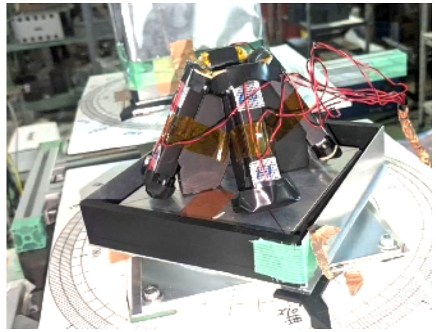
A NASA-SMEX mission to be launched on 2027, to "revive the MeV astronomy" after 27 years of gap.

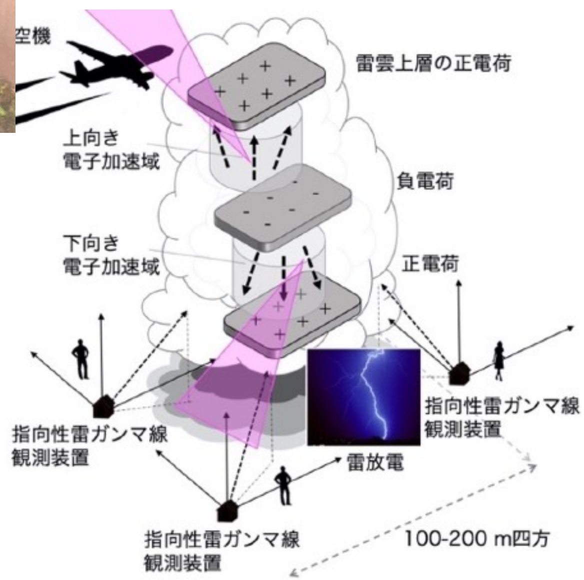


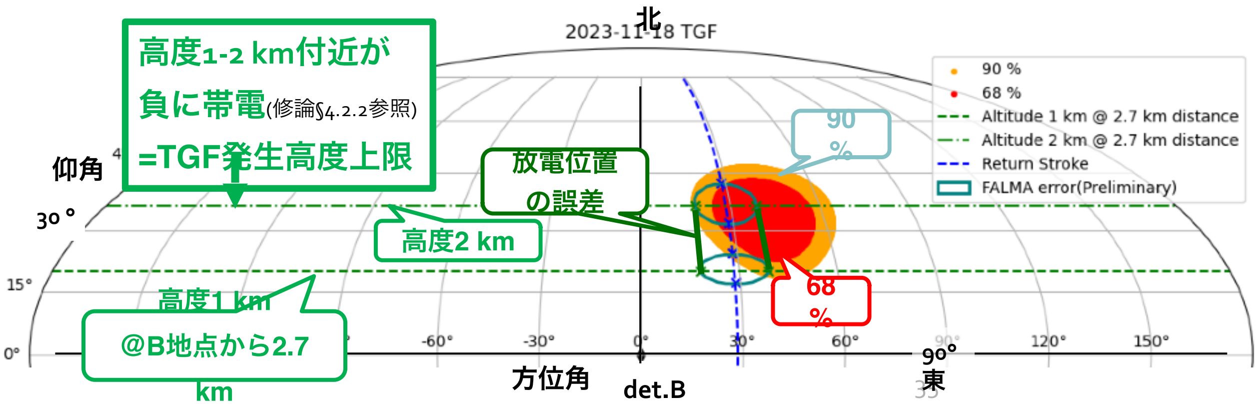


2023-25 Achievements

Thundercloud gamma rays





Gamma rays from lightning flash are direct evidence of a newly identified MeV-electron acceleration mechanism in nature. We detected its acceleration origin by novel "TGF imager".