

Cosmic Background Neutrino Decay Search – COBAND Experiment –

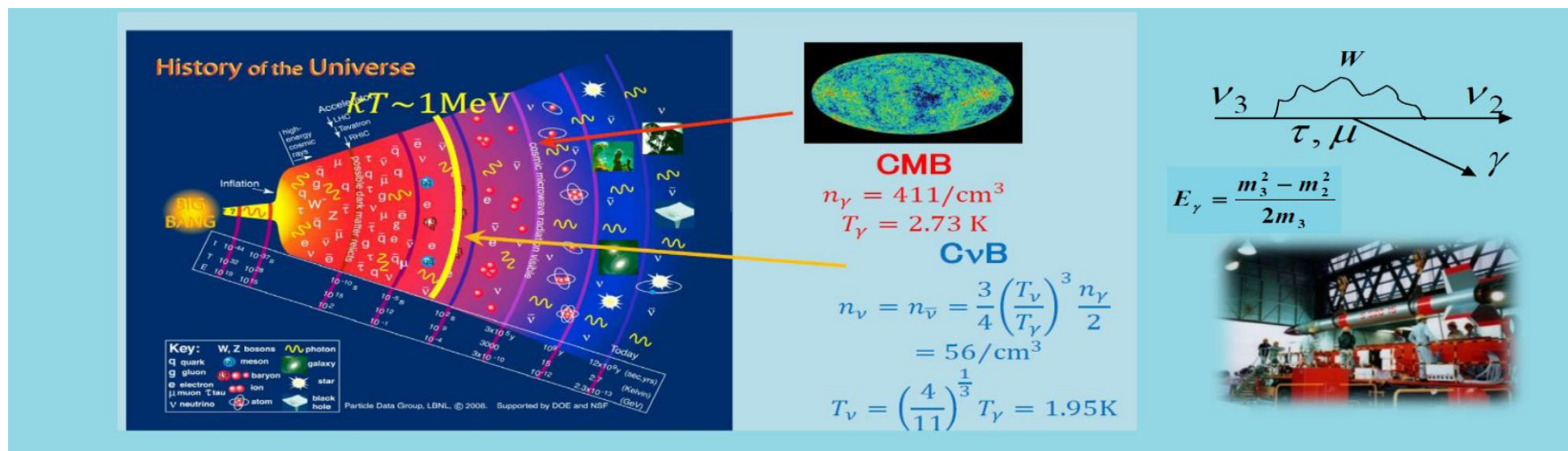
Continuous Spectral Measurement in Far-Infrared Region using STJ

Shin-Hong Kim (University of Tsukuba, TCHoU)
for COBAND collaboration

KNRC Seminar at Seoul National University



COBAND (COsmic Background Neutrino Decay) Collaboration



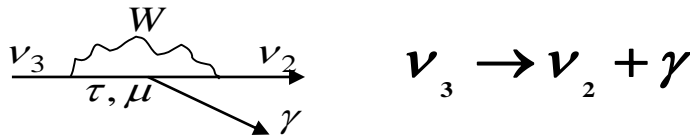
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 Y. Arai, I. Kurachi, M. Hazumi (KEK),
 T. Yoshida, M. Sakai, T. Nakamura (University of Fukui),
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 K. Kiuchi, S. Mima (RIKEN),
 H. Ishino, H. Kibayashi (Okayama University),
 S. Shiki, G. Fujii, M. Ukibe, M. Ohkubo (AIST),
 S. Kawahito (Shizuoka University),
 E. Ramberg, P. Ruvinov, D. Sergatskov (Fermilab),
 S.B. Kim (Seoul National University)



Motivation of Search for Cosmic Background Neutrino Decay

- Why three generations ? Why such mass hierarchy with large mass differences ?
Only neutrino masses are not measured . To determine the neutrino mass itself is an important subject.

Neutrino decay observation can determine the neutrino mass.

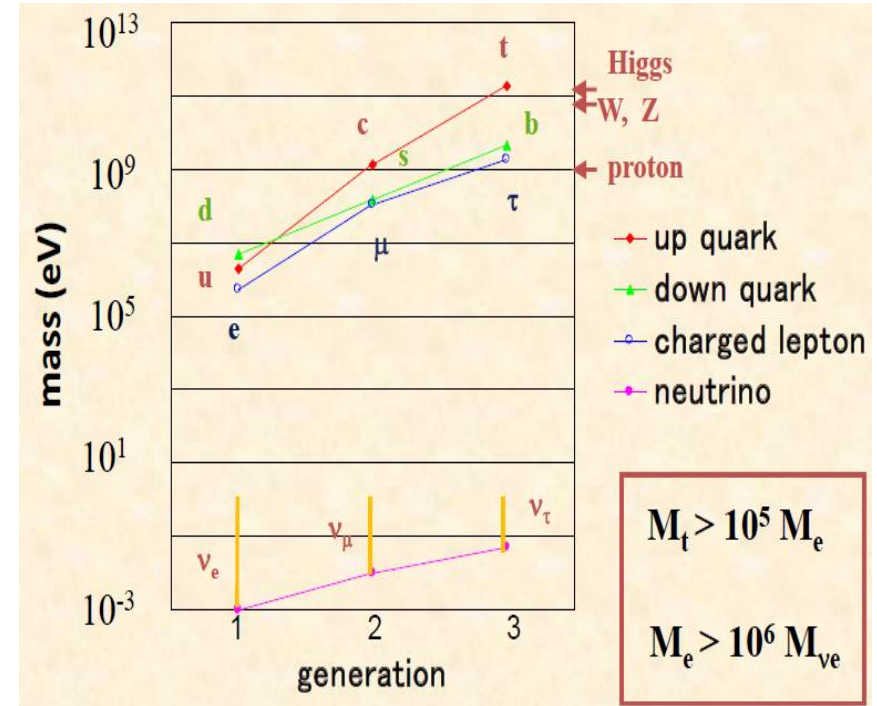


$$E_\gamma = \frac{m_3^2 - m_2^2}{2m_3} = \frac{\Delta m_{23}^2}{2m_3}$$

Using $\Delta m_{23}^2 = (2.43 \pm 0.09) \times 10^{-3} \text{ eV}^2$

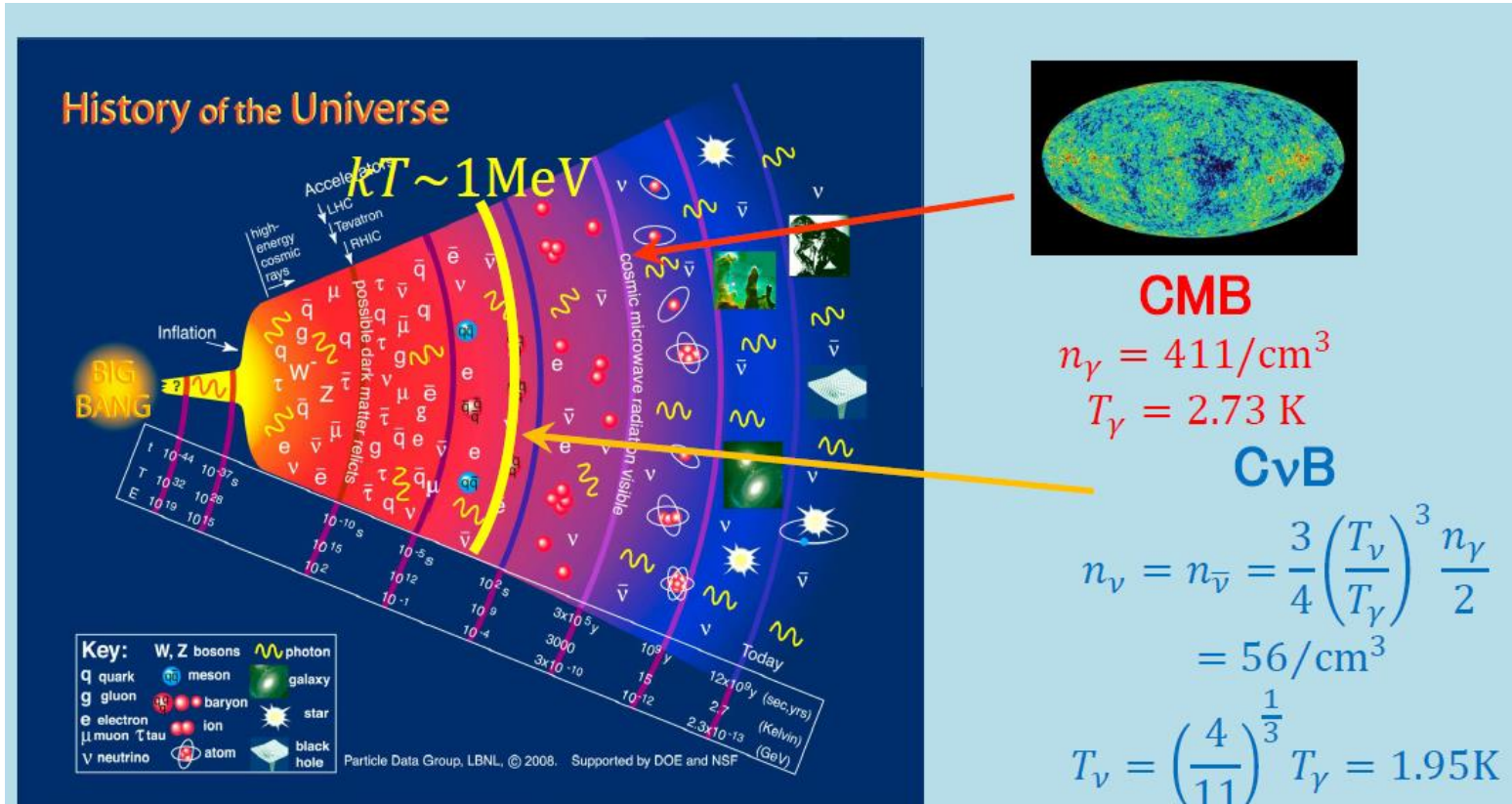
$E_\gamma = 10 \sim 25 \text{ meV}$ at ν_3 rest frame.

(Far - Infrared region $\lambda = 50 \sim 125 \mu$)



- As the neutrino lifetime is very long, we need use cosmic background neutrino to observe the neutrino decay. To observe this decay of the cosmic background neutrino means a discovery of the cosmic background neutrino predicted by cosmology.
- Left-Right symmetric model predicts the neutrino lifetime larger than 10^{17} year while the standard model predicts 2×10^{43} year.
Measured neutrino lifetime limit $\tau > 3 \times 10^{12}$ year.

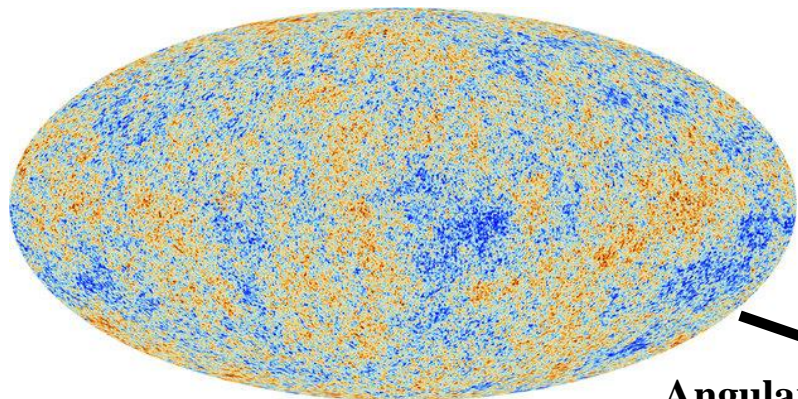
Big-Bang Cosmology and Cosmic Background Neutrino (CvB)



- A few seconds after Big Bang → Cosmic Background Neutrino (CvB) became free.
- 300,000 years after Big Bang → Cosmic Microwave Background (CMB) became free.

Large Scale Structure of the Universe and CvB

Temperature fluctuation of CMB
observed by Planck satellite



Angular
correlation
at high
temperature

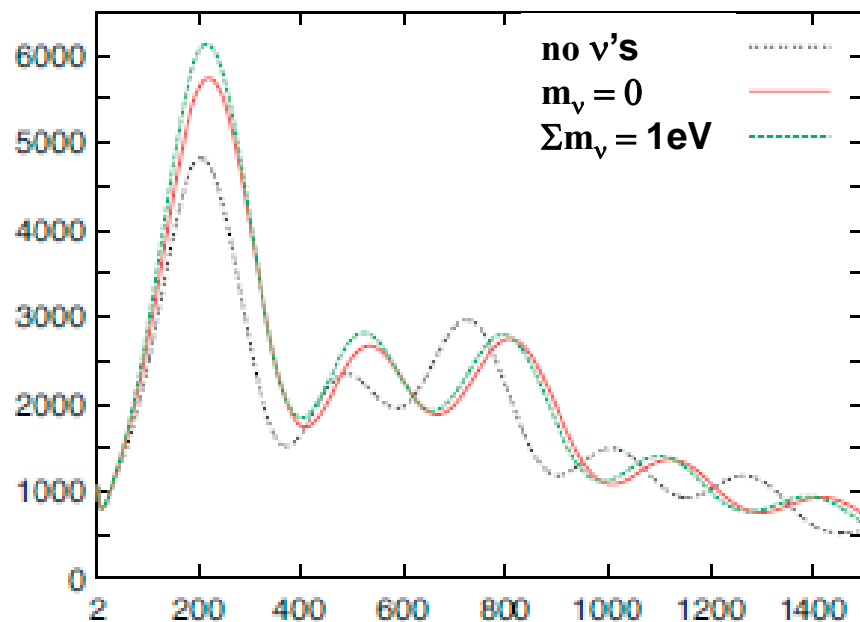
Decision Factor of Temperature
Fluctuation:

Dark matter, Dark energy, **Neutrino**



Matter density
or Large scale structure of the Universe

Theoretical prediction on Power
Spectra of the angular correlation of
the CMB temperature fluctuation
(depending on the neutrino mass)

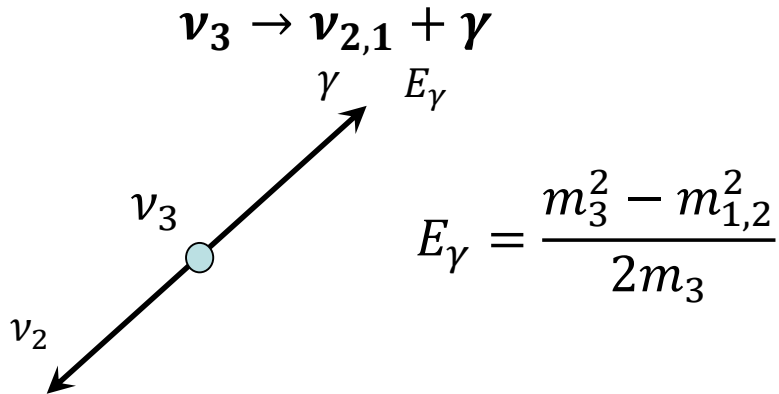


Large Angular scale($180^\circ / l$) Small
High Temperature = High Galaxy matter density
CvB exists → large angular correlation at high angle
higher neutrino mass → larger angular correlation
at high angle

Ref. J. Lesgourgues, S. Pastor Phys. Rep. 429 (2006) 307

Photon Energy from Neutrino Decay

Neutrino decay

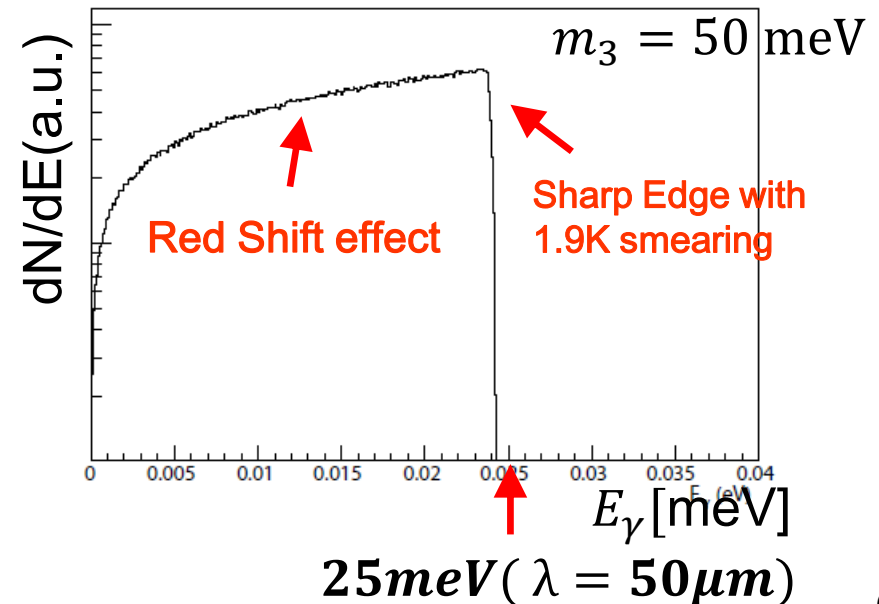
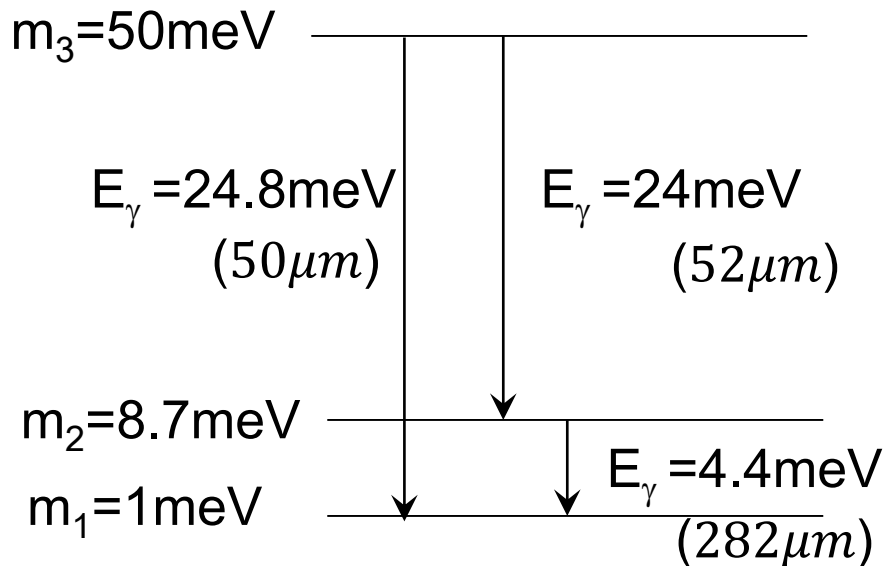


- Neutrino oscillation results
 - $|\Delta m_{23}^2| = |m_3^2 - m_2^2| \sim 2.4 \times 10^{-3} \text{ eV}^2$
 - $\Delta m_{12}^2 \sim 7.65 \times 10^{-5} \text{ eV}^2$
- Space observatory results
(Planck+WP+highL+BAO)
 - $\Sigma m_i < 0.23 \text{ eV}$

→ $50 \text{ meV} < m_3 < 87 \text{ meV}$

$E_\gamma = 14 \sim 24 \text{ meV}$ ($\lambda_\gamma = 51 \sim 89 \mu\text{m}$)

Photon energy distribution $\nu_3 \rightarrow \nu_2 + \gamma$



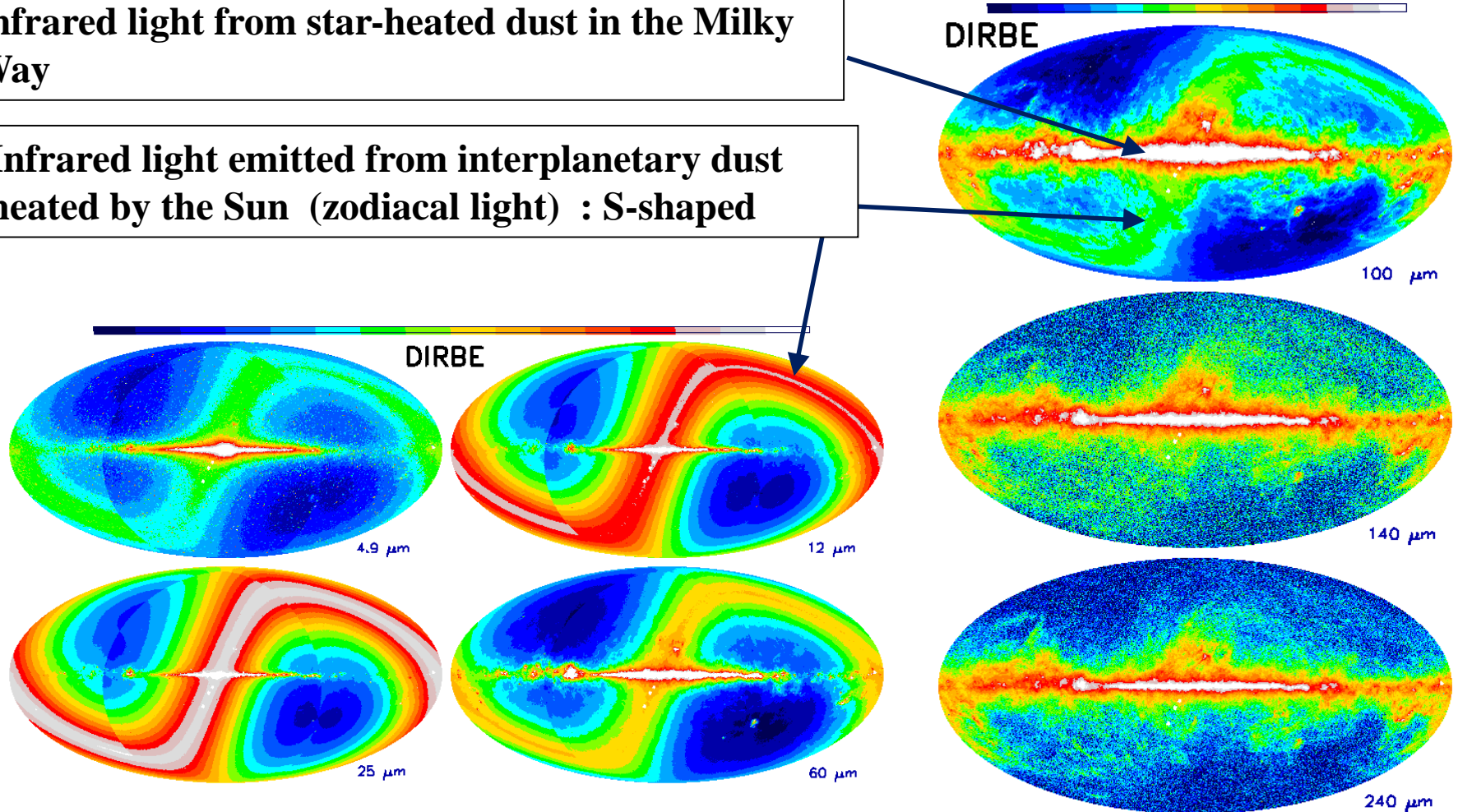
Cosmic Infrared Background Radiation

Cosmic Infrared Background Observation by COBE

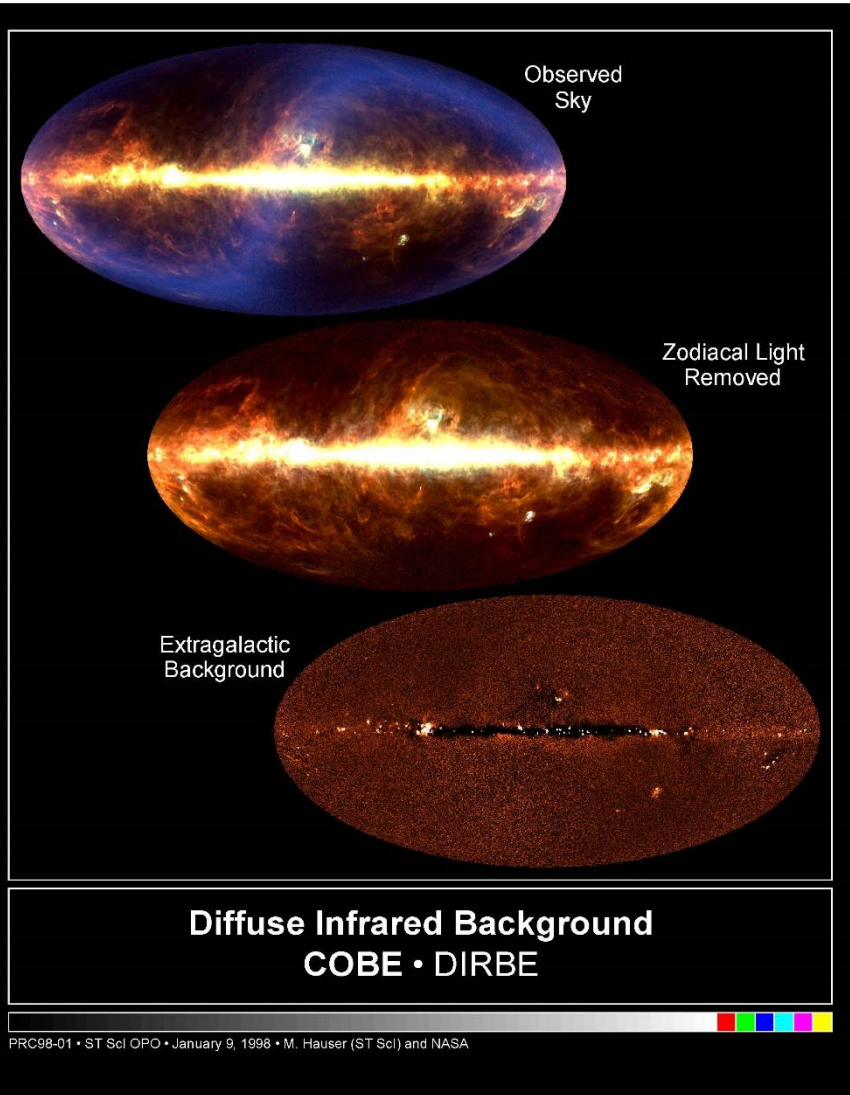
January 1998 (Press Release): COBE (Cosmic Background Explorer) announced the first observation of the cosmic infrared background (CIB)

Infrared light from star-heated dust in the Milky Way

Infrared light emitted from interplanetary dust heated by the Sun (zodiacal light) : S-shaped



Cosmic Infrared Background Observation by COBE



(Top)

Observed Sky at $\lambda = 60 \mu\text{m}$ (blue), $100 \mu\text{m}$ (green) and $240 \mu\text{m}$ (red).

Horizontal band corresponds to Infrared light from interstellar gas in the plane of our Milky Way Galaxy. The blue S-shaped region corresponds to Infrared light from interplanetary dust in the solar system called zodiacal emission.

(Middle)

After removing the zodiacal emission.

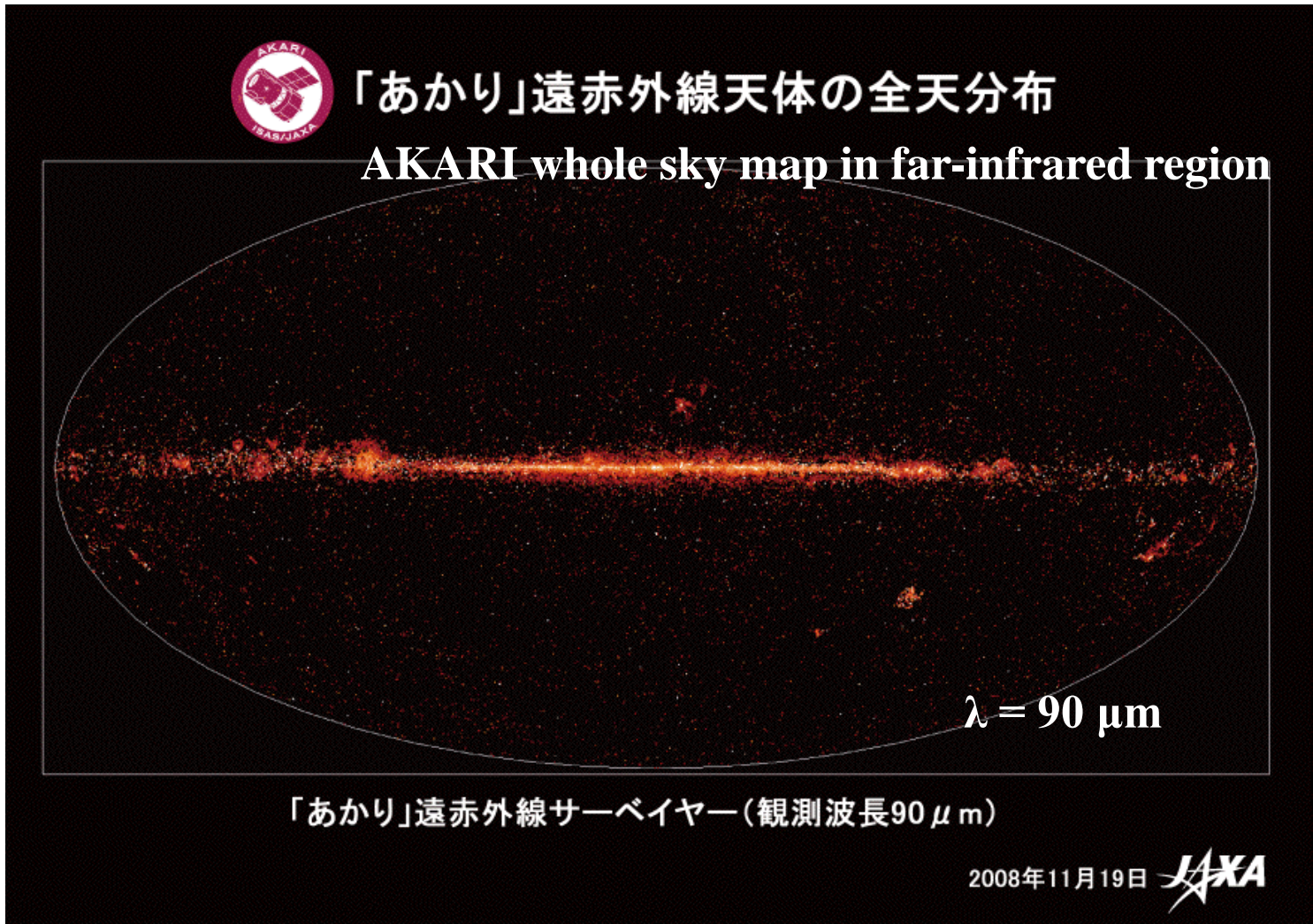
(Bottom)

After removing the infrared light from our solar system and Galaxy at $\lambda = 240 \mu\text{m}$.

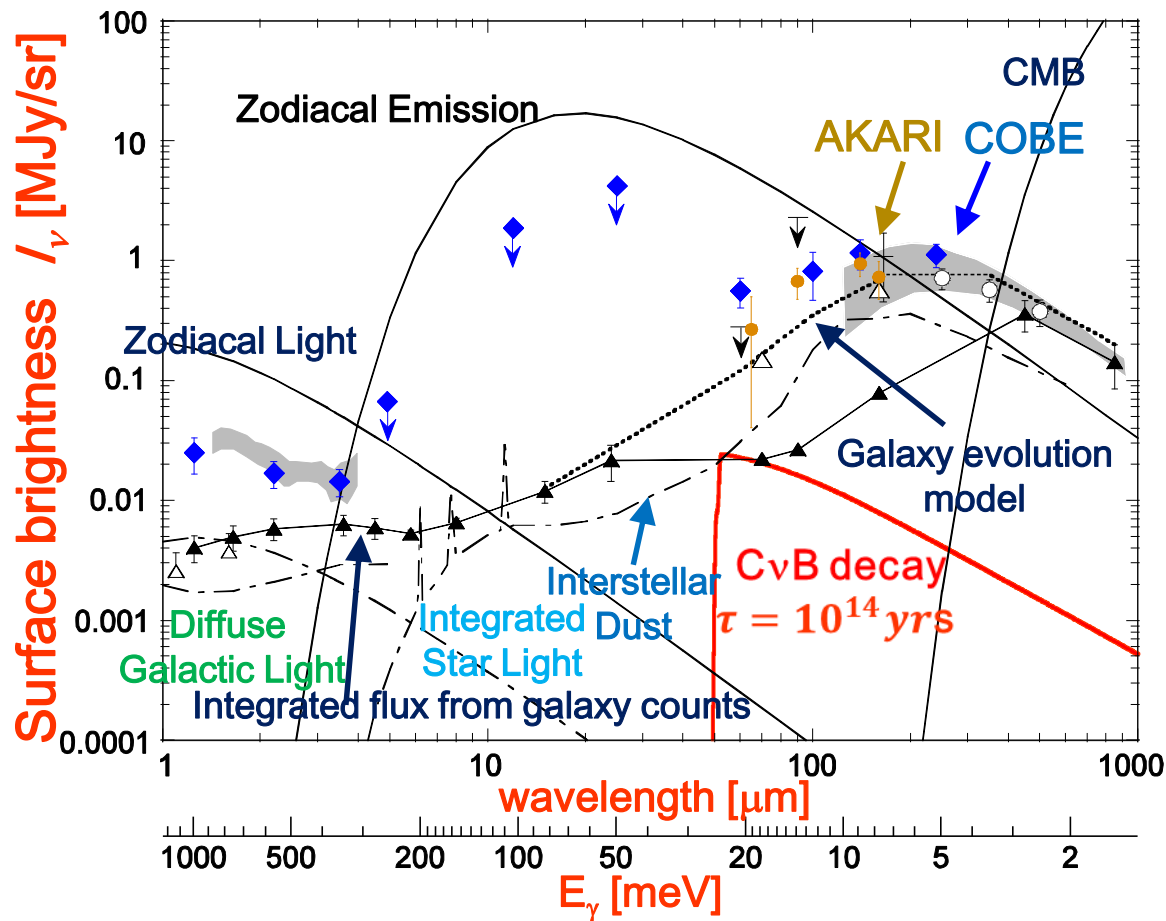
COBE announced that they observed the extragalactic residual infrared light called “Cosmic Infrared Background” at the 240 and 140 micrometer wavelength.

Cosmic Far-Infrared Background Observation by AKARI

November 2008 : AKARI (JAXA Infrared Imaging Satellite) observed 64,000 stars and galaxies at wavelengths of 65, 90, 140 and 160 μm . Made a whole sky map. They extracted CIB map from this observation.



Photon Energy Spectrum from Outer Space



CIB
measurements
(● AKARI,
◆ COBE)

There was an excess of the CIB measured by COBE and AKARI over the prediction by galaxy evolution model.

Sources at FIR: dusts of far galaxies or far blackhole, or CvB decay ?

Our paper published in JPSJ on Jan. 18th, 2012

Journal of the Physical Society of Japan **81** (2012) 024101

FULL PAPERS

DOI: [10.1143/JPSJ.81.024101](https://doi.org/10.1143/JPSJ.81.024101)

Search for Radiative Decays of Cosmic Background Neutrino using Cosmic Infrared Background Energy Spectrum

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(Received September 8, 2011; revised November 22, 2011; accepted December 1, 2011; published online January 18, 2012)

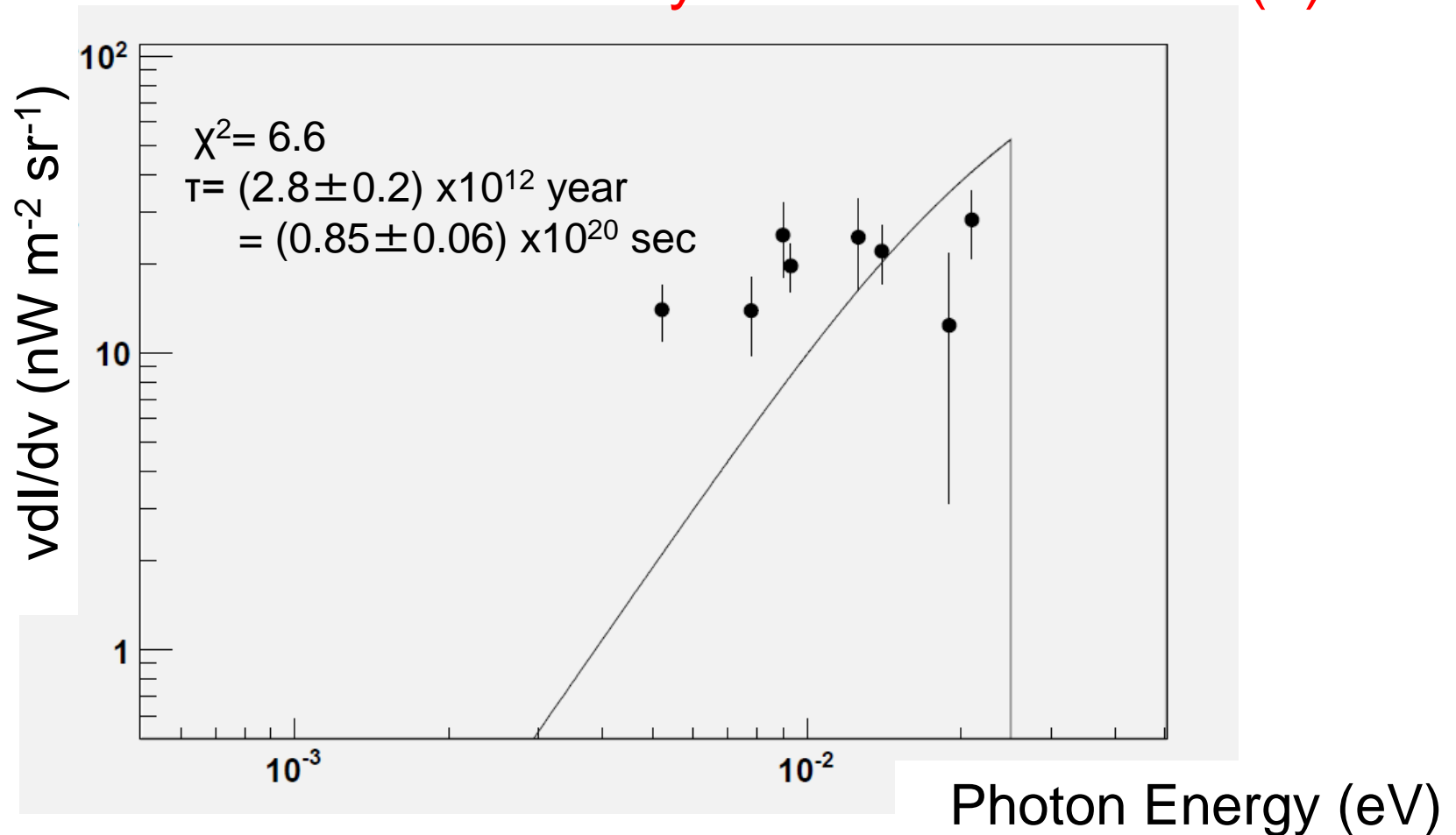
We propose to search for the neutrino radiative decay by fitting a photon energy spectrum of the cosmic infrared background to a sum of the photon energy spectrum from the neutrino radiative decay and a continuum. By comparing the present cosmic infrared background energy spectrum observed by AKARI and Spitzer to the photon energy spectrum expected from neutrino radiative decay with a maximum likelihood method, we obtained a lifetime lower limit of 3.1×10^{12} to 3.8×10^{12} years at 95% confidence level for the third generation neutrino ν_3 in the ν_3 mass range between 50 and 150 meV/ c^2 under the present constraints by the neutrino oscillation measurements. In the left-right symmetric model, the minimum lifetime of ν_3 is predicted to be 1.5×10^{17} years for m_3 of 50 meV/ c^2 . We studied the feasibility of the observation of the neutrino radiative decay with a lifetime of 1.5×10^{17} years, by measuring a continuous energy spectrum of the cosmic infrared background.

KEYWORDS: neutrino radiative decay, neutrino mass, cosmic background neutrino, cosmic infrared background, COBE, AKARI, Spitzer

Search Region: $\lambda = 35 \sim 250 \mu\text{m}$ ($E_\gamma = 35 \sim 5 \text{ meV}$)

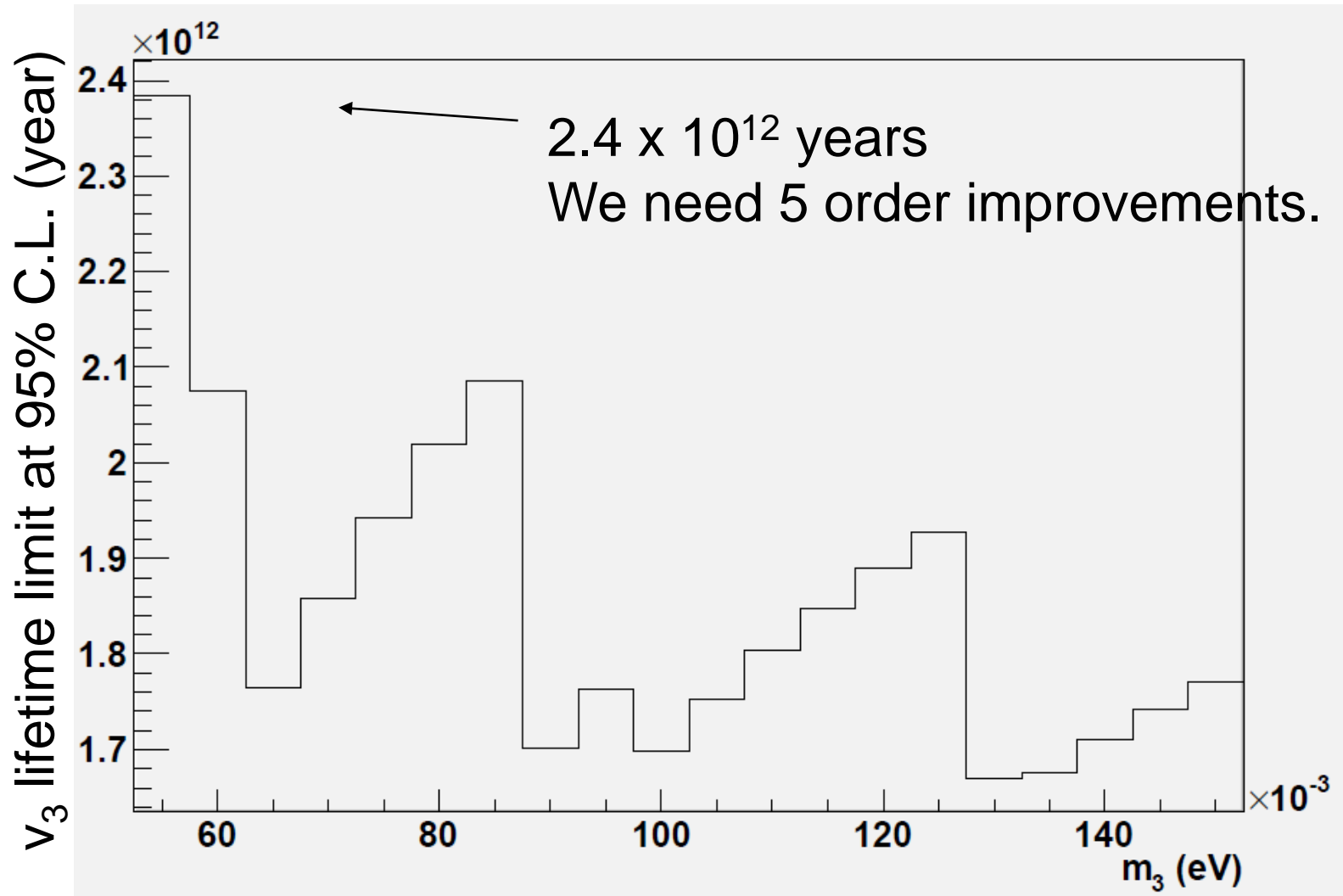
In Rocket experiment, $\lambda = 40 \sim 80 \mu\text{m}$ ($E_\gamma = 31 \sim 15 \text{ meV}$)

Lower Limit of Lifetime from the Energy Spectrum Fit the CIB measured by COBE and AKARI(1)



Using the CIB at 60, 100 (ApJ, 544, 81, 2000), 140, 240 μm (ApJ, 508, 25, 1998), 65, 90, 140, and 160 μm (arXiv:1002.3674, 2010), the photon energy spectrum from neutrino radiative decay gives a lifetime lower limit of $2.4 \times 10^{12} \text{ year}$ at 95% C.L. for $m_3 = 0.05\text{eV}$ and $m_2 = 0.01\text{eV}$.
(My calculation)

Lower Limit of Lifetime from the Energy Spectrum Fit to the CIB measured by COBE and AKARI(2)

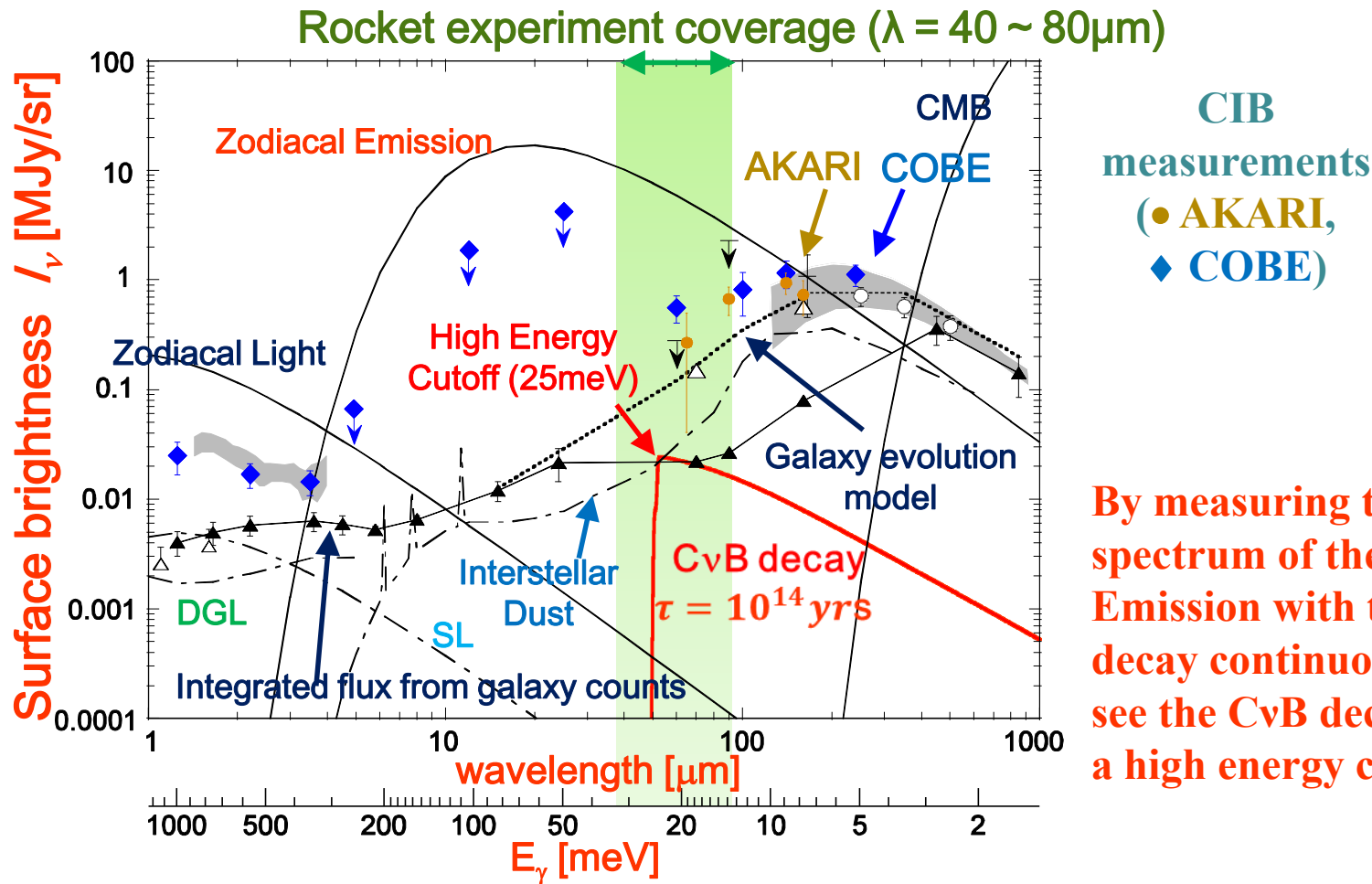


ν_3 mass (eV)

$$\Delta m_{23}^2 = 0.00243 \text{ eV}^2$$

Cosmic Background Neutrino Decay Search (COBAND)

Signal of Cosmic Background Neutrino Decay and its Backgrounds



By measuring the energy spectrum of the Zodiacal Emission with the CvB decay continuously, we can see the CvB decay signal as a high energy cutoff.

Requirements for the detector

- Continuous spectrum of photon energy around $E_\gamma \sim 25\text{ meV} (\lambda = 50\mu\text{m})$
- Energy measurement for single photon with better than 2% resolution for $E_\gamma = 25\text{ meV}$ to identify the sharp edge in the spectrum
- Rocket and/or satellite experiment with this detector

COBAND (COsmic BACKGROUND Neutrino Decay Search) Experiment

Rocket Experiment Plan: 5minutes data acquisition at 200 km height in 2019.
Improve the current limit of lifetime $\tau(\nu_3)$ by two orders of magnitude ($\sim 10^{14}$ years).

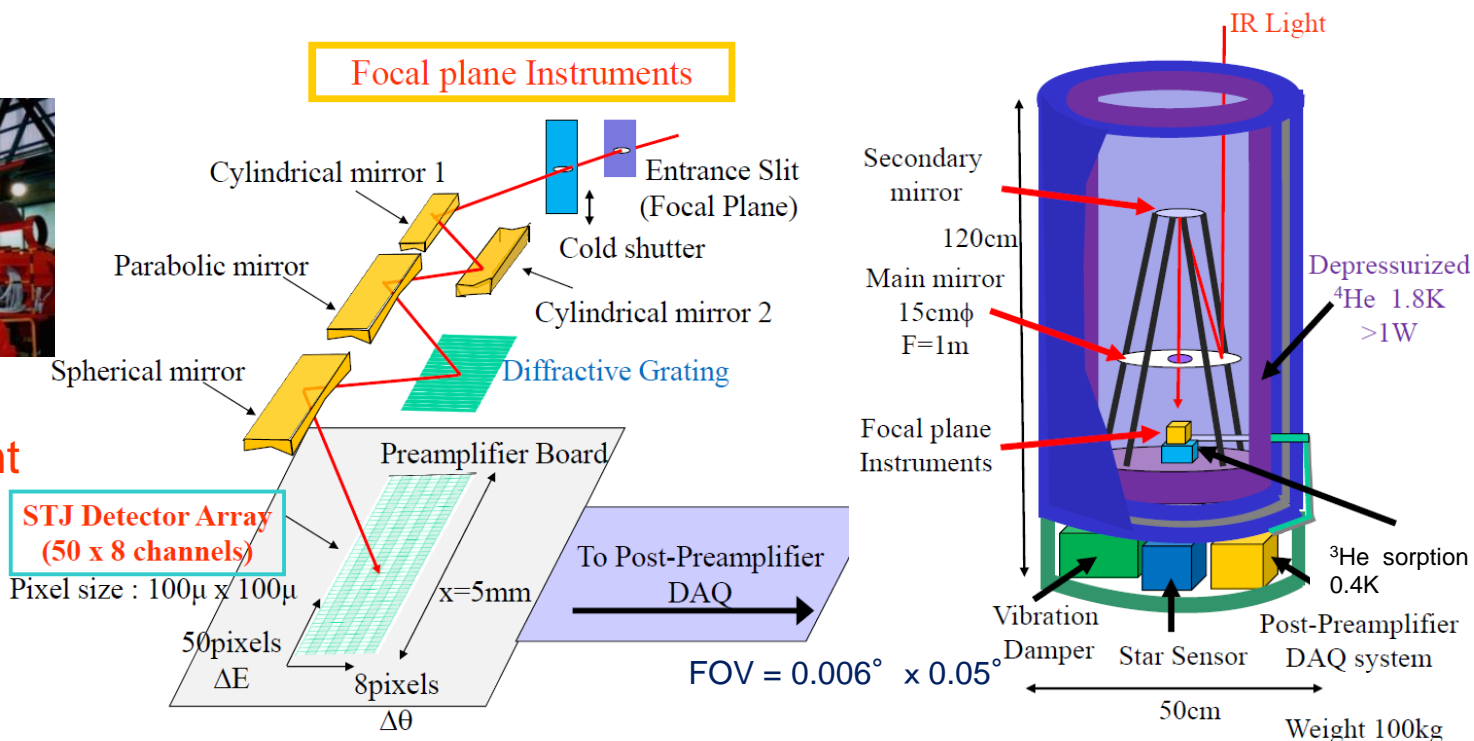
» Superconducting Tunneling Junction (STJ) detectors in development

> Array of 50 Nb/Al-STJ pixels with diffractive grating covering $\lambda = 40 - 80 \mu\text{m}$



JAXA Rocket
CIB Experiment

(Feb 2, 1992)



Satellite experiment after 2025 \rightarrow sensitivity of $\tau(\nu_3) \sim 10^{17}$ year

> STJ using Hafnium: Hf-STJ for satellite experiment (S. H. Kim et al. JPSJ 81,024101 (2012))

- $\Delta = 20\mu\text{eV}$: Superconducting gap energy for Hafnium
- $N_{\text{q.p.}} = 25\text{meV}/1.7\Delta = 735$ for 25meV photon: $\Delta E/E < 2\%$ if Fano-factor is less than 0.3

Zodiacal Emission

Thermal emission from the interplanetary dust cloud

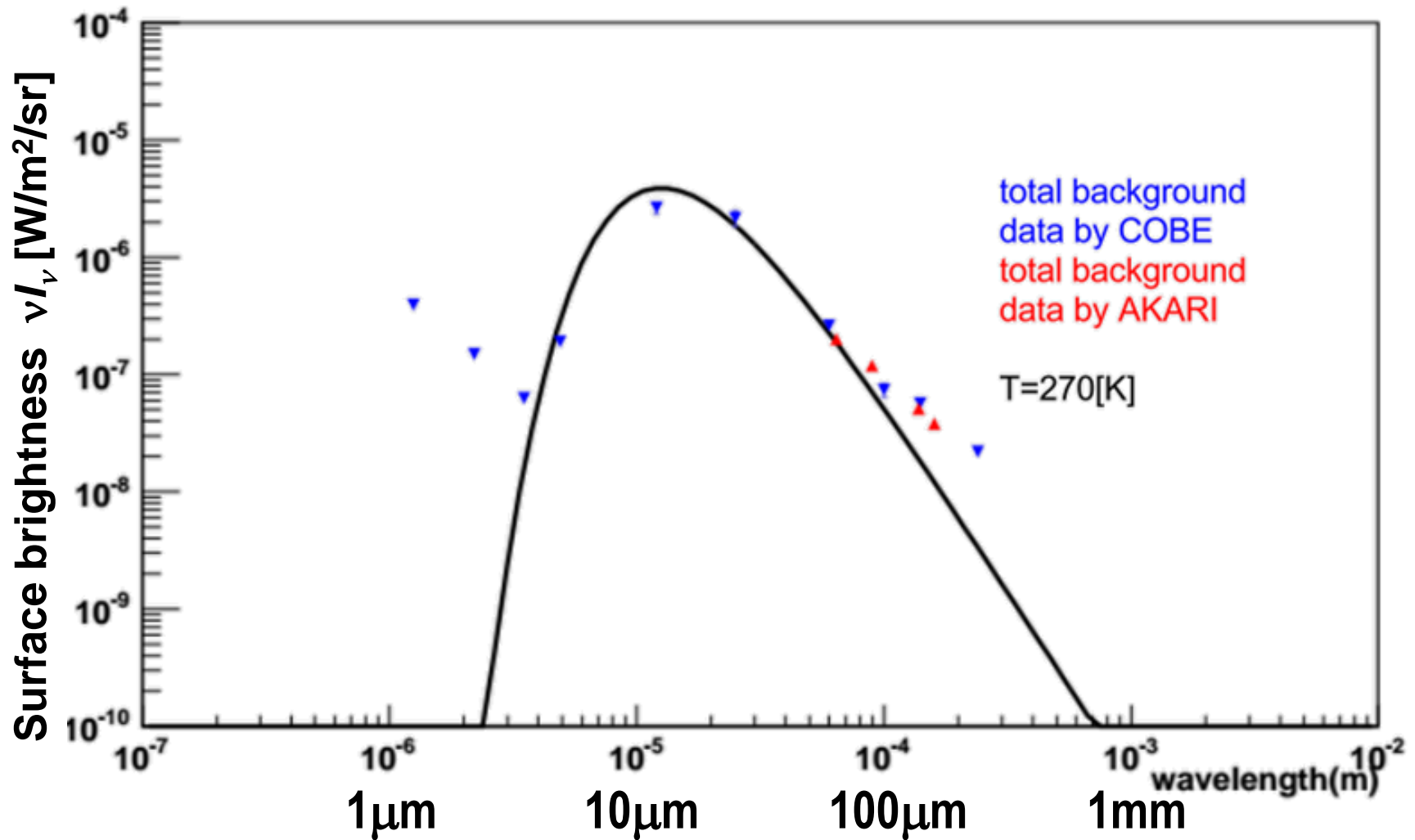
$$I_\nu = \frac{2h\nu^3}{c^2} \frac{1}{\exp(h\nu/kT) - 1} \\ \times A \left(\frac{\nu}{c} \times 10^{-5} \right)^B \text{ Wm}^{-2}\text{sr}^{-1}$$

$$T = 270\text{K}, A = 6 \times 10^{-8}, B = 0.3$$

$$h \text{ [Js]}, c \text{ [m/s]}, \lambda \text{ [m]}$$

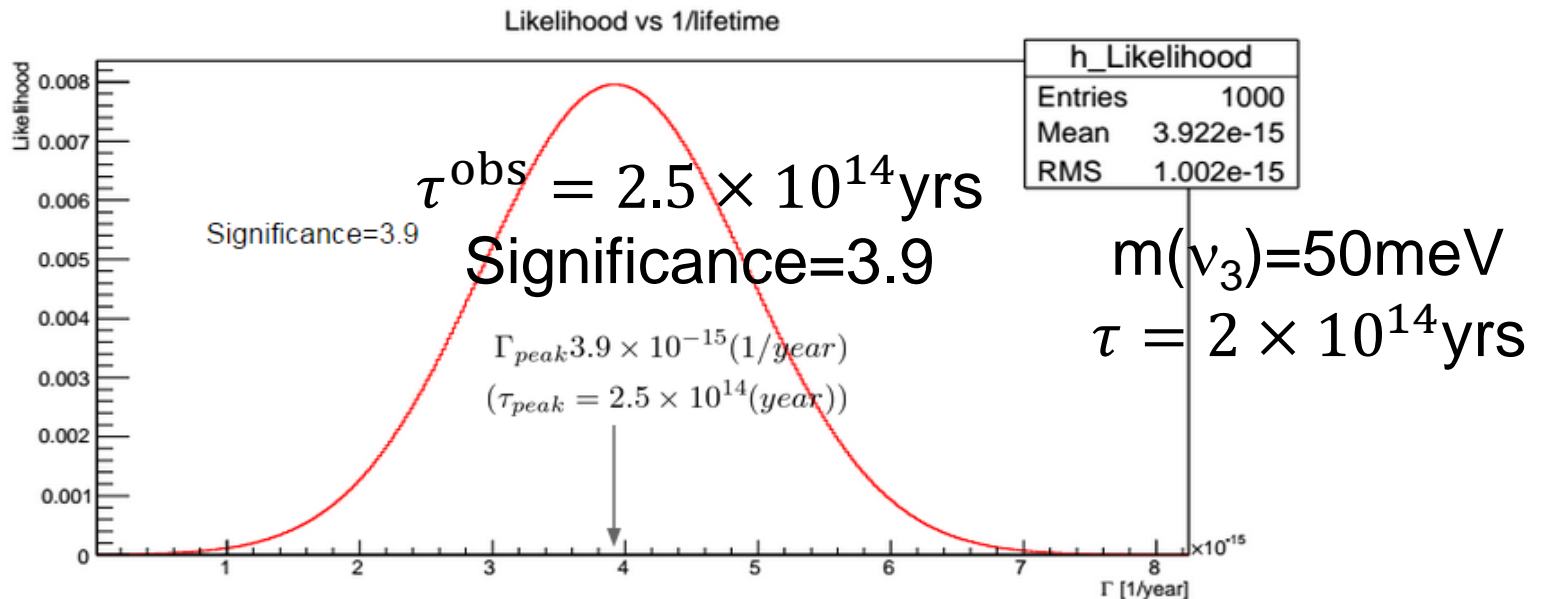
Zodiacal Emission(ZE) is overwhelmingly dominating. Here we consider only ZE as the background.

Zodiacal Emission



Discovery Potential for Neutrino Decay

1. Create a pseudo-data for ND and ZE expectation on assumption of ν_3 mass and lifetime: $N_{\text{obs}}(m^{\text{true}}, \Gamma^{\text{true}})$
2. Calculate expected distribution of ND+ZE on assumption of ν_3 mass and lifetime: $N_{\text{exp}}(m, \Gamma)$
3. Calculate likelihood of the pseudo-data as a function of the decay width for each neutrino mass
4. Obtain the most probable decay width and its significance



Sensitivity to Neutrino Decay

Parameters in the rocket experiment simulation

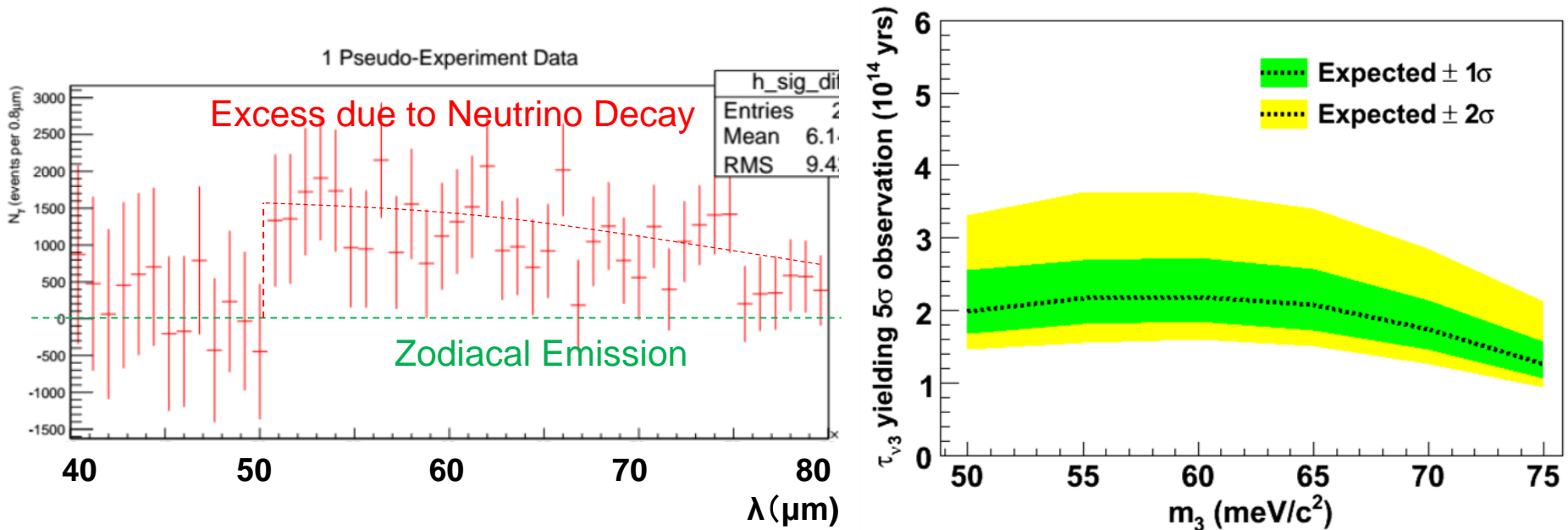
telescope diameter: 15cm

50-column (λ : 40 μm – 80 μm) \times 8-row array

Viewing angle per single pixel: 100 μrad \times 100 μrad

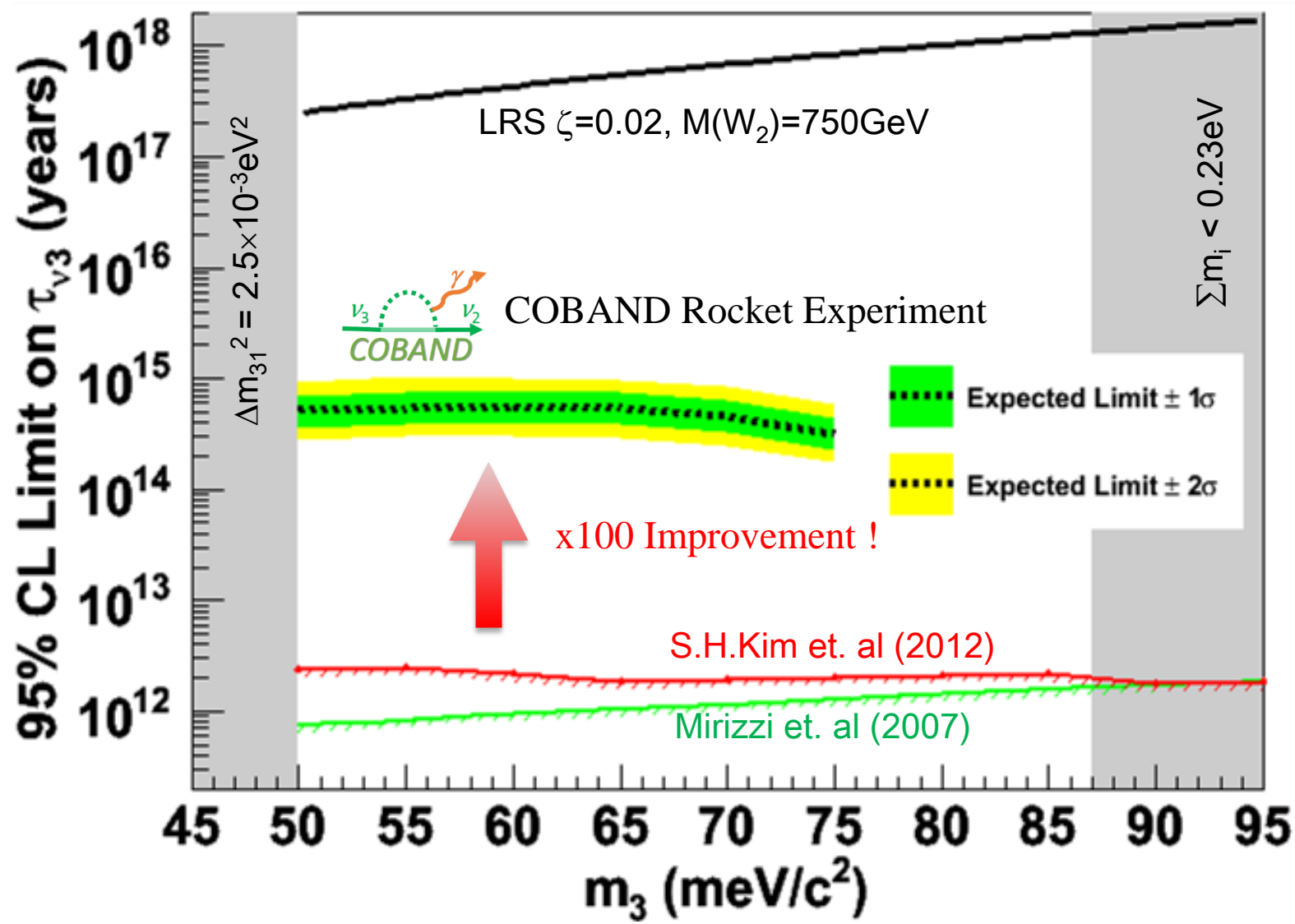
Measurement time: 200 sec.

Photon detection efficiency: 100%



- If ν_3 lifetime were 2×10^{14} yrs, the signal significance is at 5 σ level

COBAND Experiment Sensitivity to Neutrino Decay



Requirement for the photon detector in COBAND rocket experiment

- Sensitive area of $100\mu\text{m} \times 100\mu\text{m}$ for each pixel
- High detection efficiency for a far-infrared single-photon in $\lambda = 40\mu\text{m} \sim 80\mu\text{m}$
- Dark count rate less than 300Hz (expected real photon rate)

$$\rightarrow \text{NEP} = \epsilon_{\gamma} \sqrt{2f_{\gamma}} \sim 1 \times 10^{-19} \text{ W} / \sqrt{\text{Hz}}$$

(Noise Equivalent Power) , where ϵ_{γ} is a photon energy and f_{γ} is a photon rate.

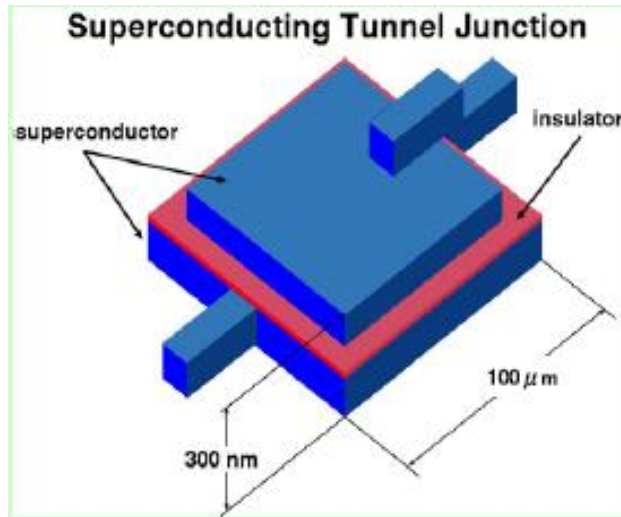
We are trying to achieve $\text{NEP} \sim 10^{-19} \text{ W} / \sqrt{\text{Hz}}$ by using

- Superconducting Tunneling Junction detector
(leakage current per pixel $< 100\text{pA}$)
- Cryogenic amplifier readout

R&D Status of Superconducting Tunnel Junction Detector for COBAND experiment

STJ (Superconducting Tunnel Junction) Detector

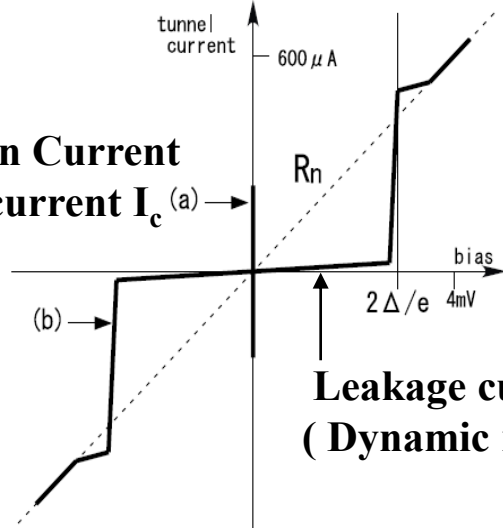
Superconductor / Insulator / Superconductor Josephson Junction



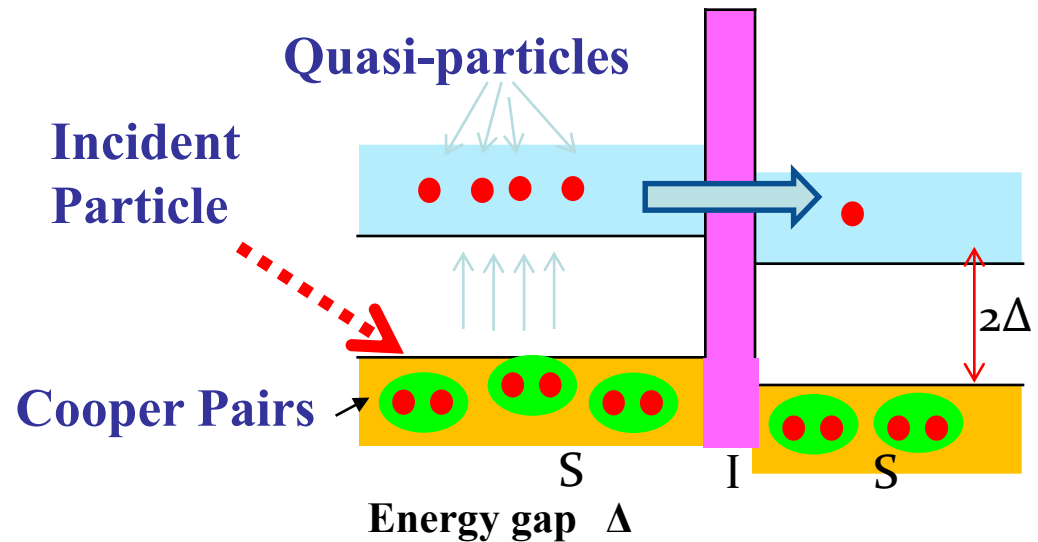
At the superconducting junction, quasi-particles over their energy gap go through tunnel barrier by a tunnel effect. By measuring the tunnel current of quasi-particles excited by an incident particle, we measure the energy of the particle.

current-voltage (I-V) curve for STJ

Josephson Current
Critical current I_c (a) →



Leakage current
(Dynamic resistance R_d in $|V| < 2\Delta/e$)



Material	$T_c(K)$	$\Delta(meV)$
Niobium	9.20	1.550
Aluminum	1.14	0.172
Hafnium	0.13	0.021

STJ Energy Resolution

STJ Energy Resolution

$$\sigma_E = \sqrt{1.7\Delta(FE)}$$

Using Hf as a superconductor,

$$\sigma_E / E = 1.7\% \quad \text{at } E = 25\text{meV}$$

Δ : Band gap energy

F: Fano factor (= 0.2)

E: Incident particle energy

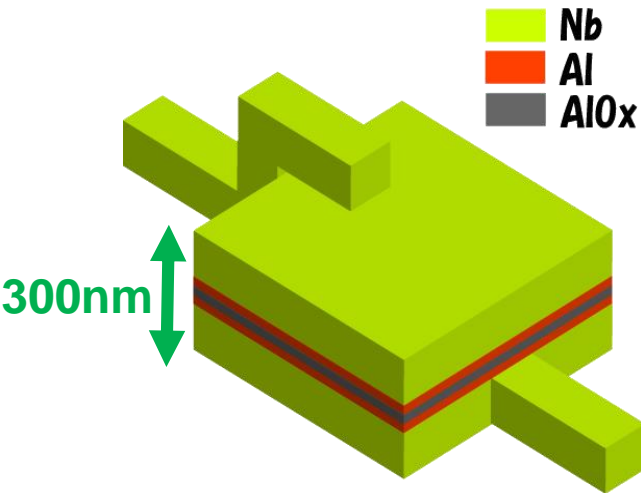
Material	$T_c(K)$	$\Delta(\text{meV})$
Niobium	9.20	1.550
Aluminum	1.14	0.172
Hafnium	0.13	0.021

Tc : Critical Temperature

Operation is done at a temperature around 1/10 of Tc

We reported that Hf-STJ worked as a STJ in 2011.

Nb/Al-STJ Photon Detector



Number of Quasi-particles in Nb/Al-STJ

$$N_q = G_{Al} E_0 / 1.7 \Delta$$

G_{Al} : Trapping Gain in Al (~10)

E_0 : Photon Energy

Δ : E-Gap in superconductor

For 25meV single photon

$$N_q = 10 \frac{25 \text{ meV}}{1.7 * 0.57 \text{ meV}} = 250 \text{ e}$$

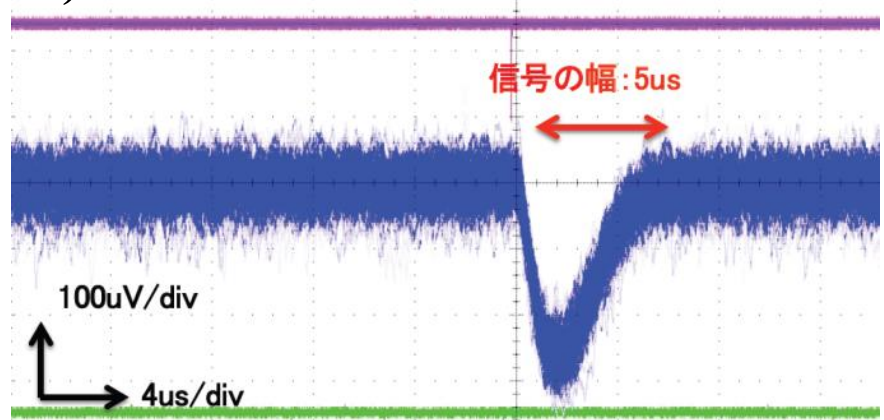
Back tunneling Effect → Trapping Gain

Quasi-particles near the barrier can mediate Cooper pairs, resulting in true signal gain

- Bi-layer fabricated with superconductors of different gaps $\Delta_{Nb} > \Delta_{Al}$ to enhance quasi-particle density near the barrier
- Nb(200nm)/Al(70nm)/AlOx/Al(70nm)/Nb(100nm)

$$\Delta_{Nb/Al} = 0.57 \text{ meV}$$

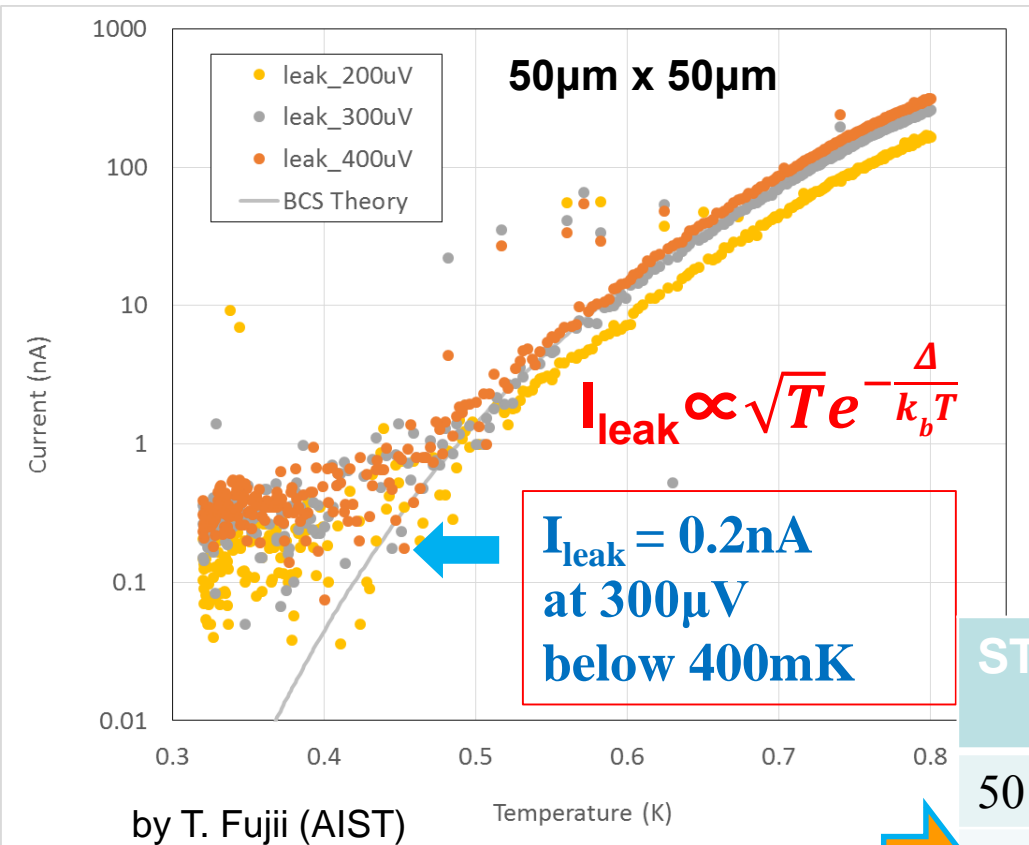
Response of Nb/Al-STJ to visible laser light pulse ($\lambda=465\text{nm}$) at 350mK



Leakage Current of Nb/Al-STJ

- Leakage current I_{leak} is required to be below 0.1nA to detect a single far-infrared photon ($\lambda = 40 - 80\mu\text{m}$).

Temperature Dependence of Leakage Current



In 2014,
AIST group joined us and produced
Nb/Al-STJ with AIST CRAVITY
processing system.
Leakage current has satisfied our
requirement of 0.1nA .

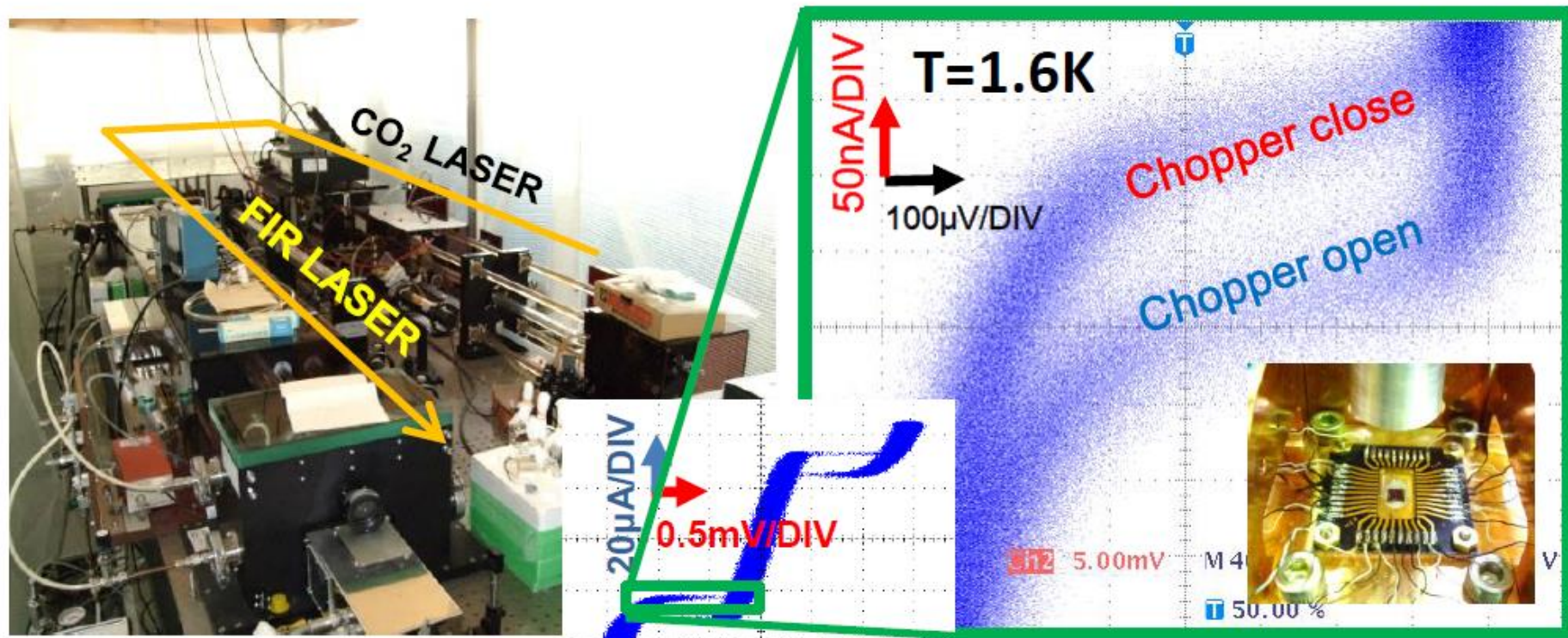


STJ size	# of samples	I_{leak} at 0.3mV
50 x 50 μm^2	18	224 \pm 29 pA
20 x 20 μm^2	7	39 \pm 13 pA
10 x 10 μm^2	20	14 \pm 7 pA

Test Results of Nb/Al-STJ with Far-Infrared laser

Far-Infrared Laser at University of Fukui
($\lambda=57.2\mu\text{m}$)

Nb/Al-STJ Response to Far-Infrared Laser

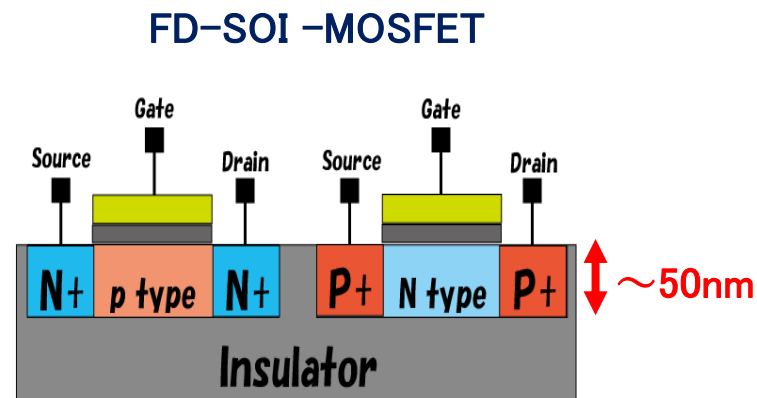


- 20μm-square Nb/Al-STJ made at AIST CRAVITY system
- Laser light was turned on and off with a chopper at a frequency of 200Hz. Measured the change of the I-V curve between the laser on and off to be 50~100nA in current.

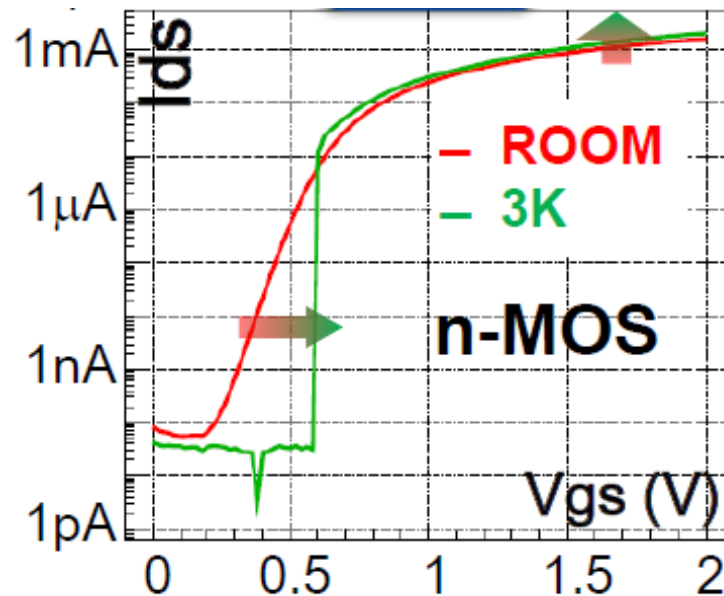
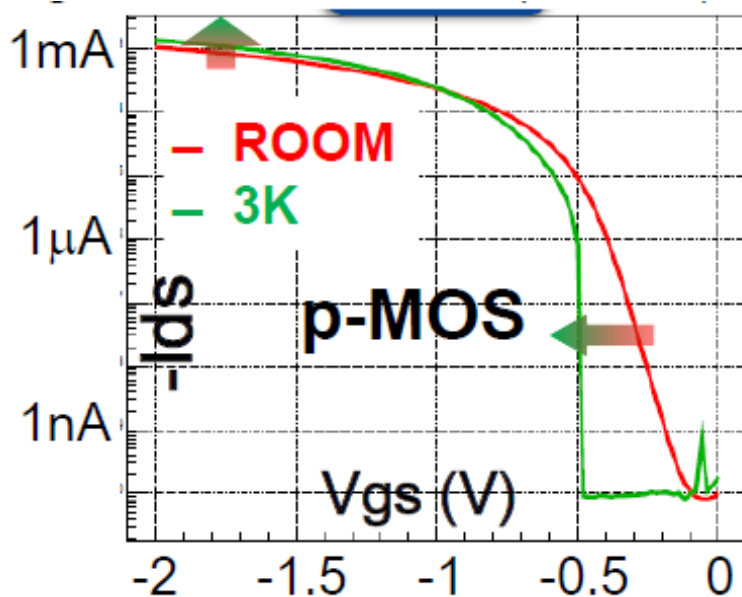
R&D Status of SOI Cryogenic Preamplifier for STJ

FD-SOI-MOSFET at Cryogenic Temperature

FD-SOI (Fully Depleted Silicon-On-Insulator) device was proved to operate at 4K by a JAXA/KEK group (AIPC 1185,286-289(2009)). It has the following characteristics: low-power consumption, high speed, easy large scale integration and suppression of charge-up by high mobility carrier due to thin depletion layer($\sim 50\text{nm}$).



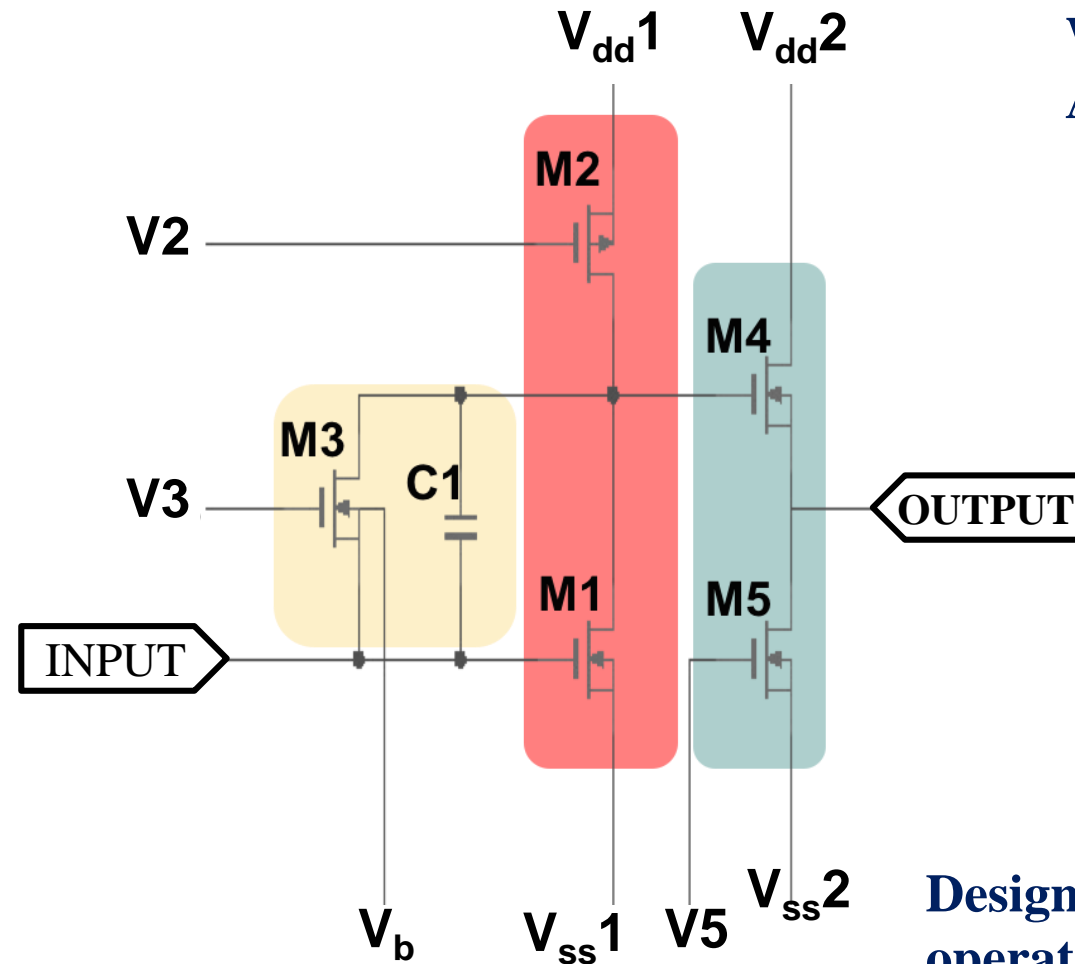
I_{ds} - V_{gs} Curve of $W/L=10\mu\text{m}/0.4\mu\text{m}$ at $|V_{ds}| = 1.8\text{V}$



Both p-MOS and n-MOS show excellent performance at 3K and below.

SOI Cryogenic Amplifier

SOI-STJ4 (the 4th prototype)



We updated the SOI cryogenic Amplifier for Nb/Al-STJ.

Amplification

Replace the resistance by a SOIFET as a current source (M2).

Feedback

Use the feedback between the drain and the gate of M1 to apply a stable bias voltage (M3).

Buffer

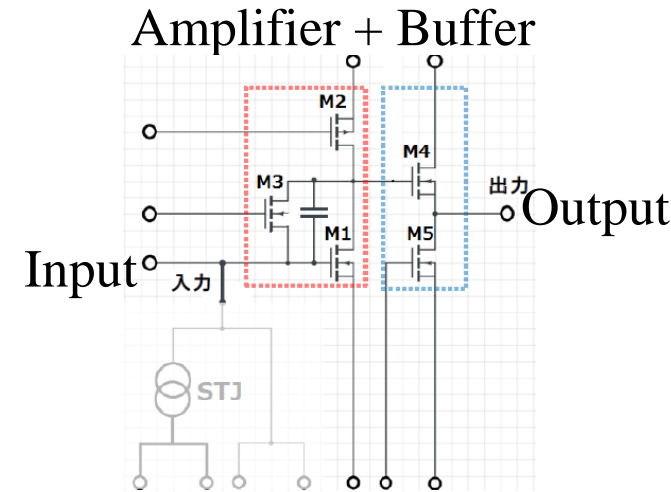
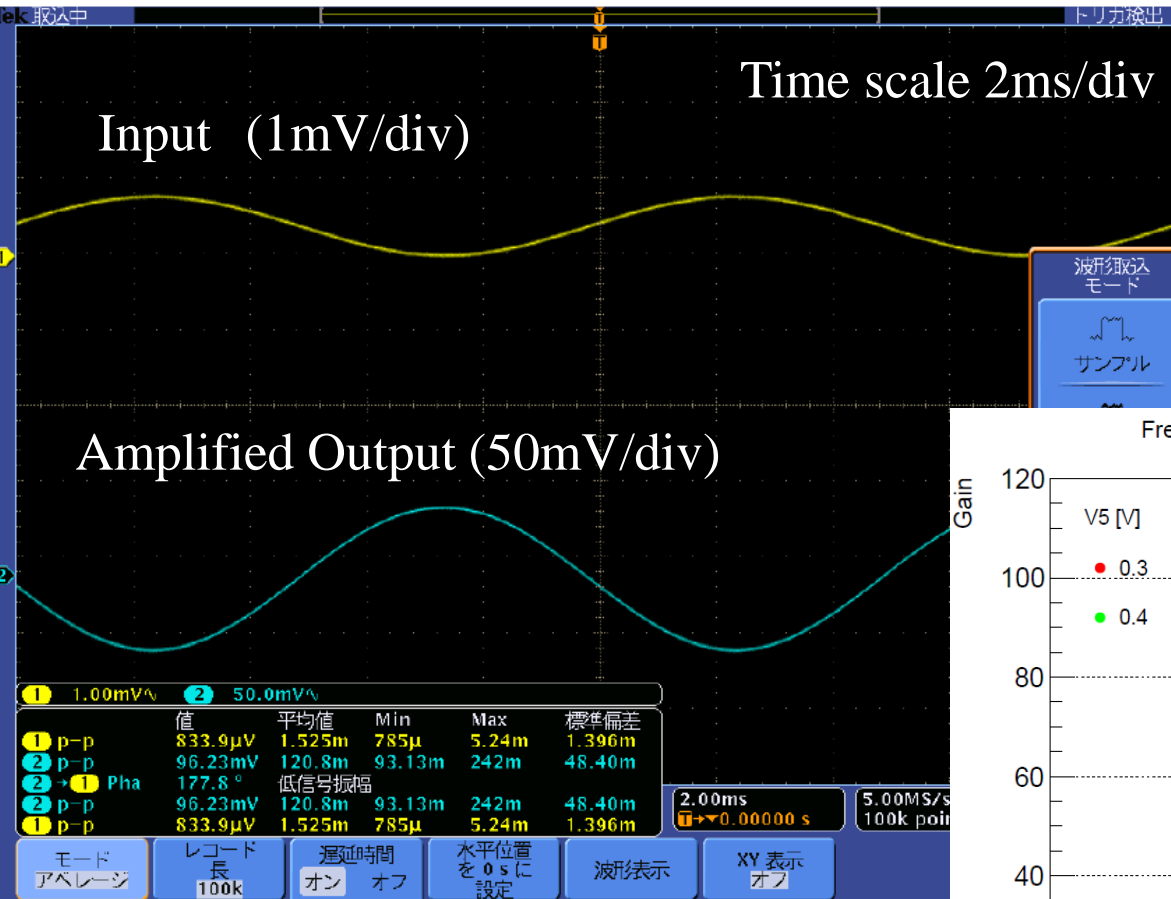
Add the follower to reduce the output impedance (M4 and M5).

Designed the ratio (W/L) to set the operation power consumption below $120\mu\text{W}$.

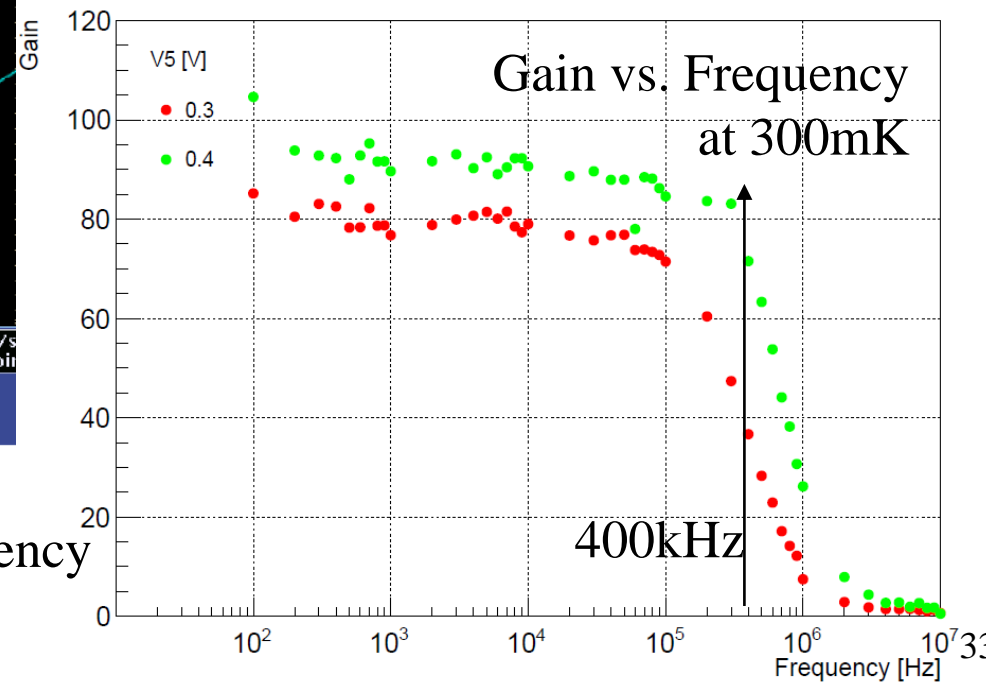
This SOI amplifier board was made by LAPIS semiconductor company.

Test Results of the SOI Cryogenic Amplifier

Input and Amplified Output

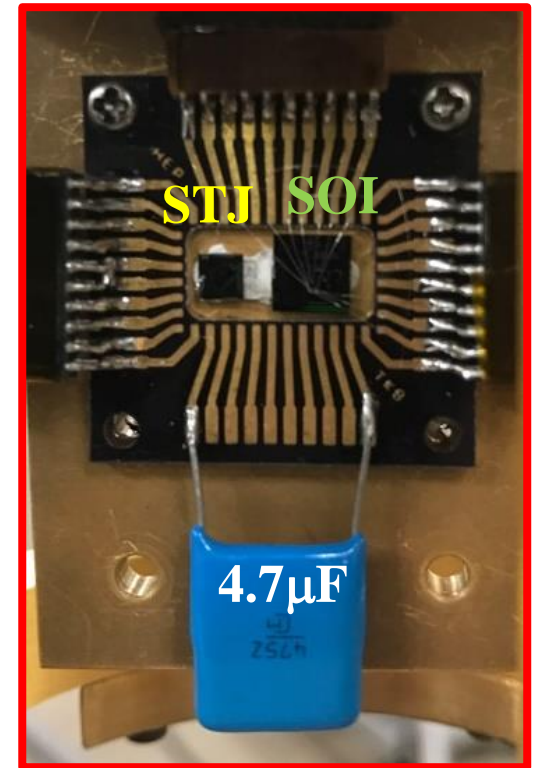
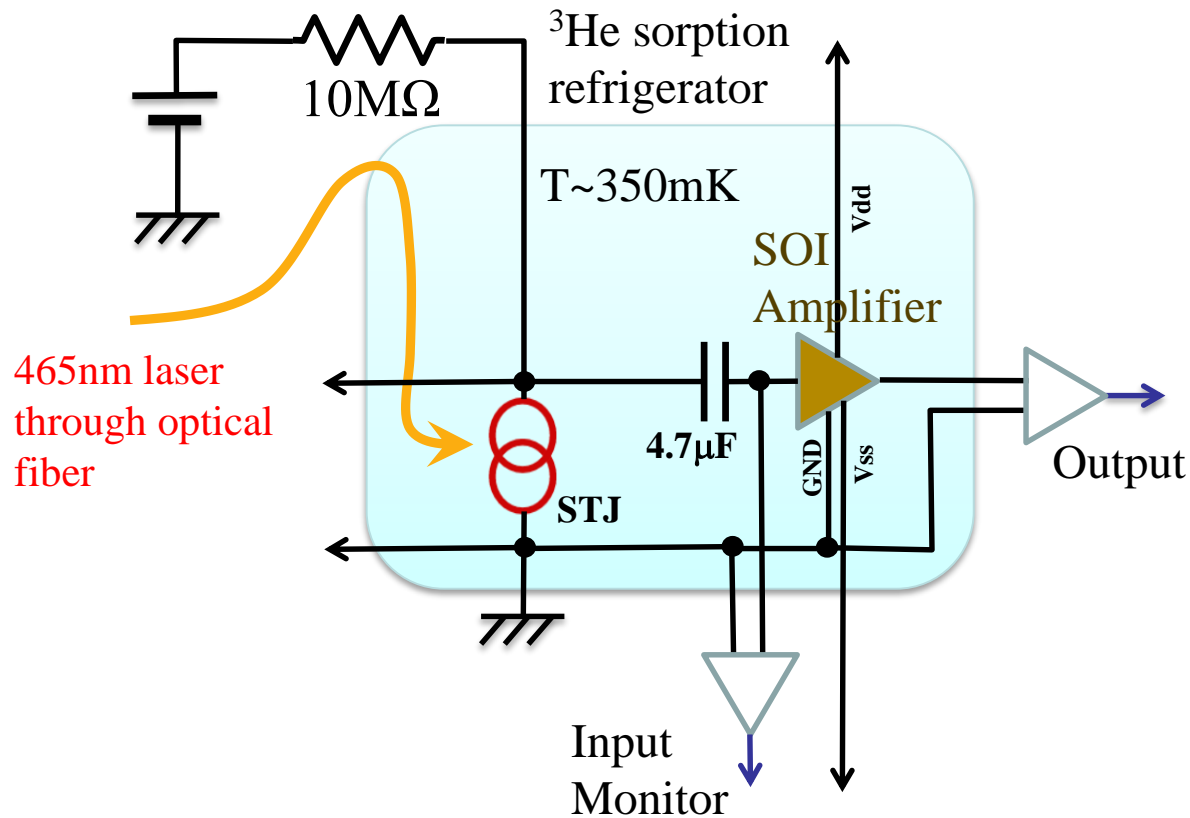


Frequency characteristic of cold amplifier(SOISTJ4) at 300mK



Gain of 80 was achieved for a signal frequency up to 400kHz signals at 300mK.

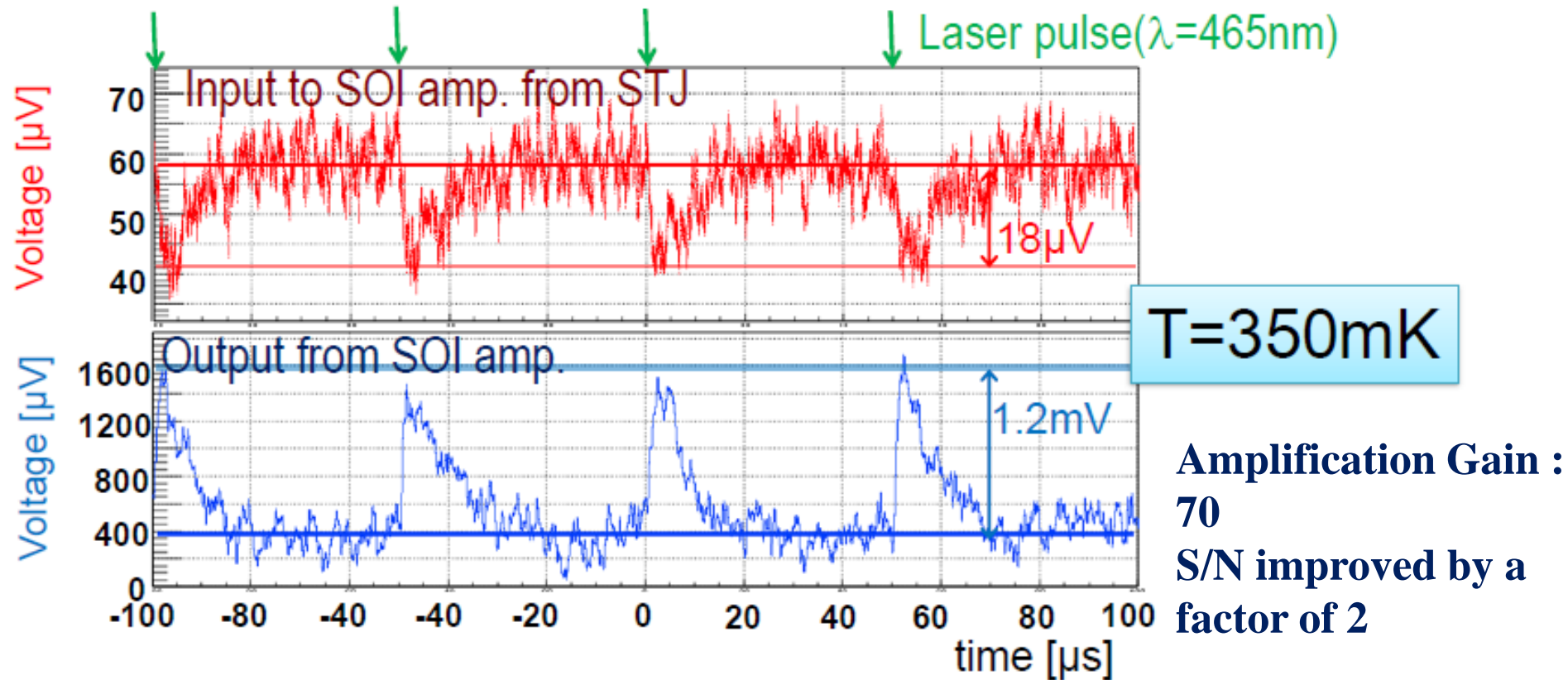
Setup of STJ Signal Amplification with the SOI Cryogenic Amplifier



- $20\mu\text{m}$ -square Nb/Al-STJ with SOI-STJ4 amplifier through $4.7\mu\text{F}$ capacitance.
- Input impedance of the SOI amplifier is about $20\text{k}\Omega$.
 - **STJ operation at a constant current mode.**
 - STJ bias cable capacitance is around 1nF : $Z=160\Omega$ for $1\mu\text{s}$ signal.

STJ signal amplified with the SOI cryogenic preamplifier

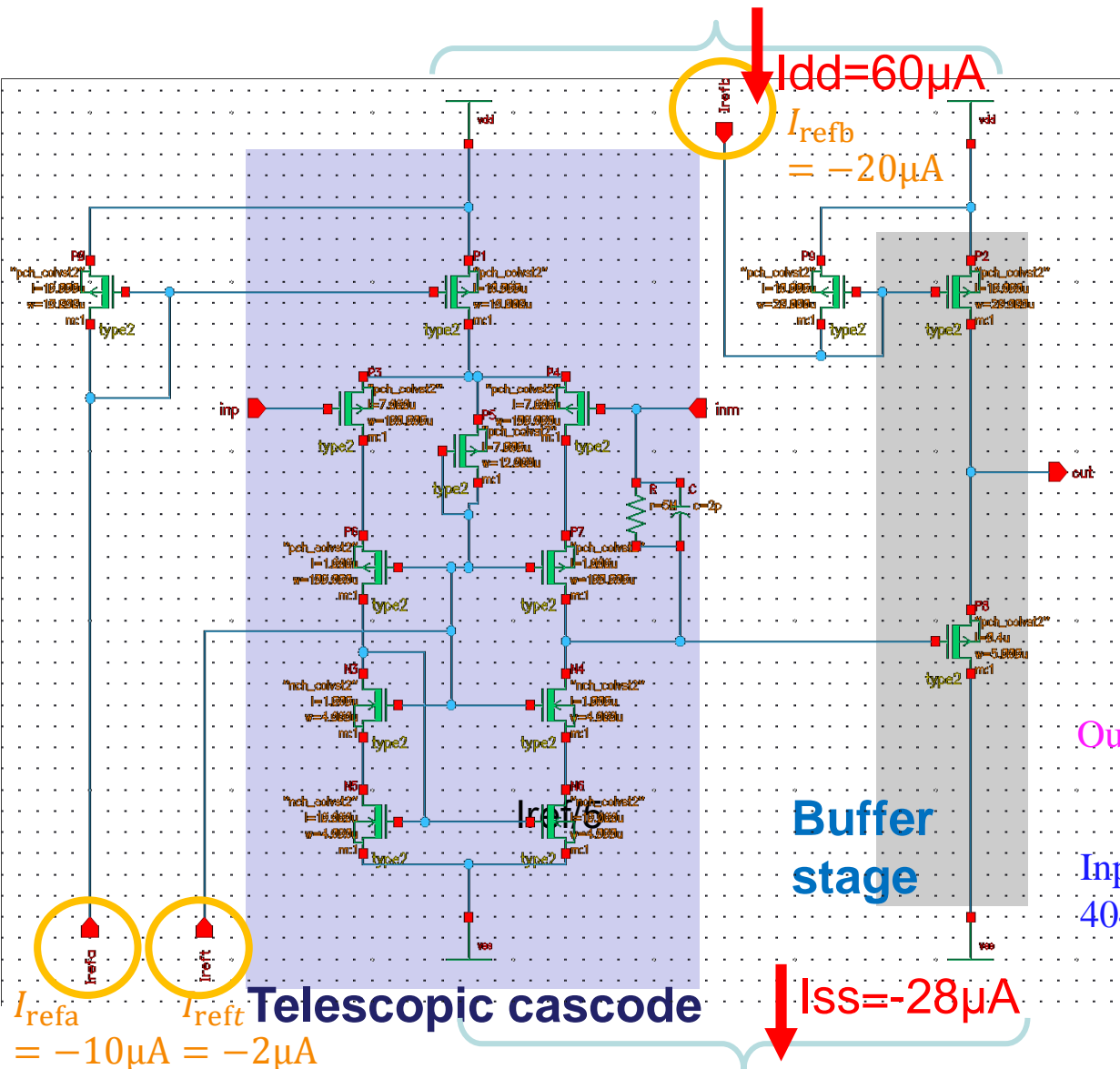
Nb/Al-STJ laser light response signal was amplified with this SOI cryogenic preamplifier at 350mK.



Development of the SOI cryogenic preamplifier is now moving to the stage of the final design for COBAND experiment.

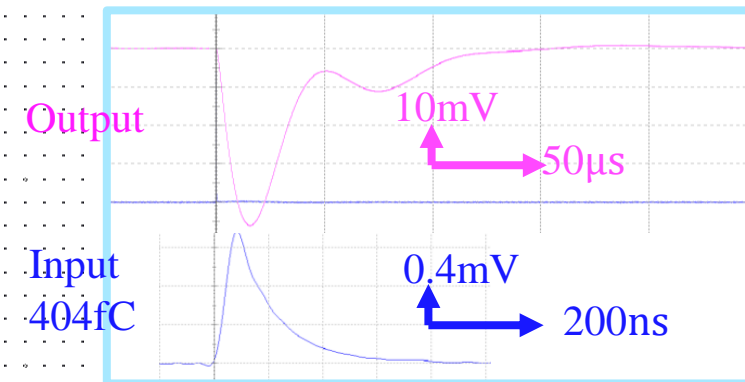
Charge Amp. Circuit for STJ (SOI-STJ5 design)

- telescopic cascode differential amplifier
- Feedback $C(2\text{pF}) \times R(5\text{M}\Omega) = 10\mu\text{s}$
- Power consumption $\sim 150\mu\text{W}$



This cryogenic charge amplifier test is underway.

Working at 3K



Next cryogenic charge amplifier was designed with a higher gain.

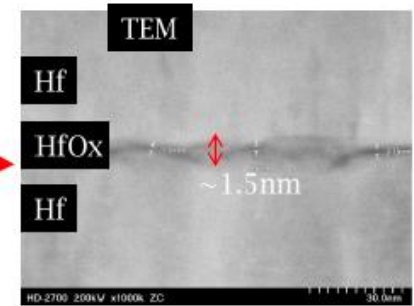
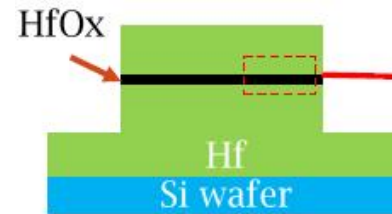
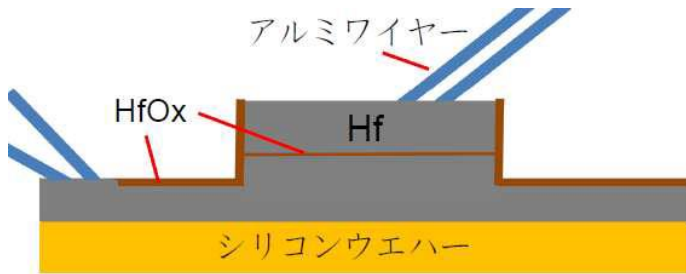
R&D Status of Hf-STJ

R&D Status of Hf-STJ

Goal: Measure energy of a single far-infrared photon for neutrino decay search experiment within 2% energy resolution.

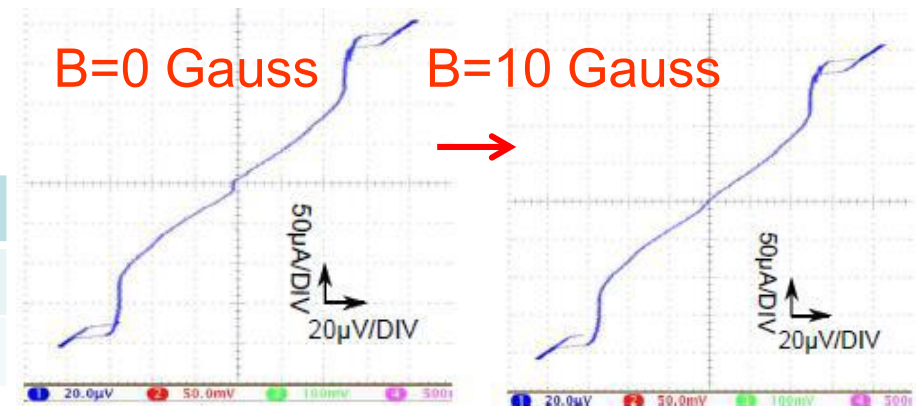
Micro-calorimeter: Hf-STJ can generate enough quasi-particles from cooper pair breakings to achieve 2% energy resolution for photons with $E_\gamma = 25\text{meV}$.

Direct wire bonding on Hf layer



I-V curve of Hf-STJ ($100 \times 100 \mu\text{m}^2$)

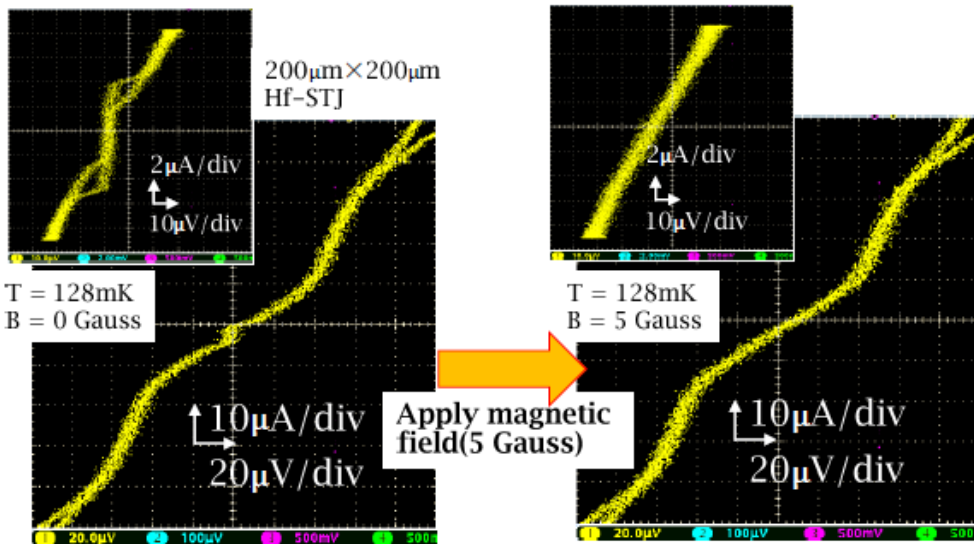
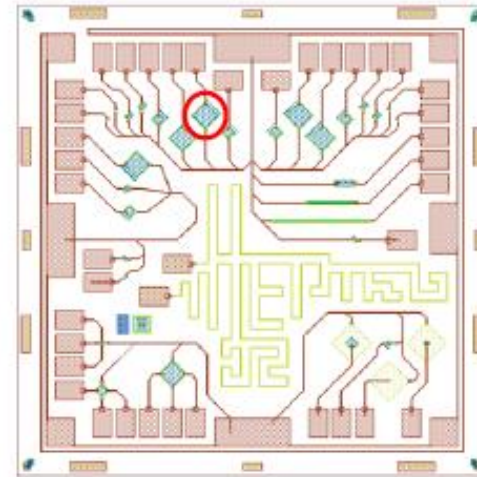
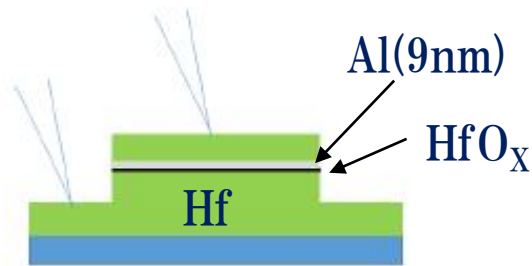
- $T \sim 40\text{mK}$, $I_c = 10 \mu\text{A}$, $R_d = 0.6 \Omega$



STJ size	# of samples	R_d
$200 \times 200 \mu\text{m}^2$	3	$0.22 \pm 0.01 \Omega$
$100 \times 100 \mu\text{m}^2$	3	$0.60 \pm 0.10 \Omega$

Results of Hf/Al-STJ R&D

In 2016, we made a thin aluminum layer (9nm) on the HfO layer (1-2 nm) to improve the insulation of the HfO_x layer. Hf/Al/HfO_x/Hf-STJ



$$I_{\text{leak}} = 5 \mu\text{A at } 10 \mu\text{V.}$$

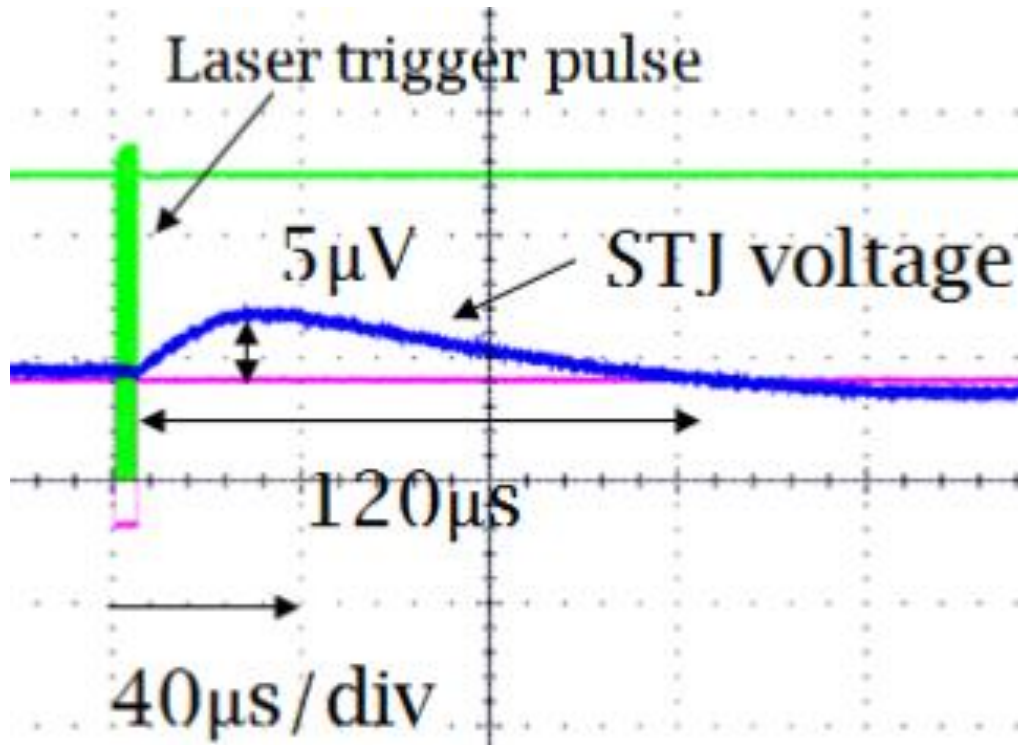
$$R_d = 2 \Omega$$

Dynamic Resistance was improved by a factor of 15 in Hf/Al/HfO_x/Hf-STJ.

Response of Hf-STJ to Laser Pulse Light

Hf/Al/HfO_x/Hf-STJ

Visible light laser ($\lambda = 465\text{nm}$) 10Hz duration



Response speed ($120\mu\text{s}$) is slower than Nb/Al-STJ response speed (around a few μs).

Improvement of Hf-STJ Leakage Current

- Hf-STJ was proved to work as a photon detector.
- To satisfy our leakage current requirement for COBAND experiment, we need decrease the leakage current of Hf-STJ.

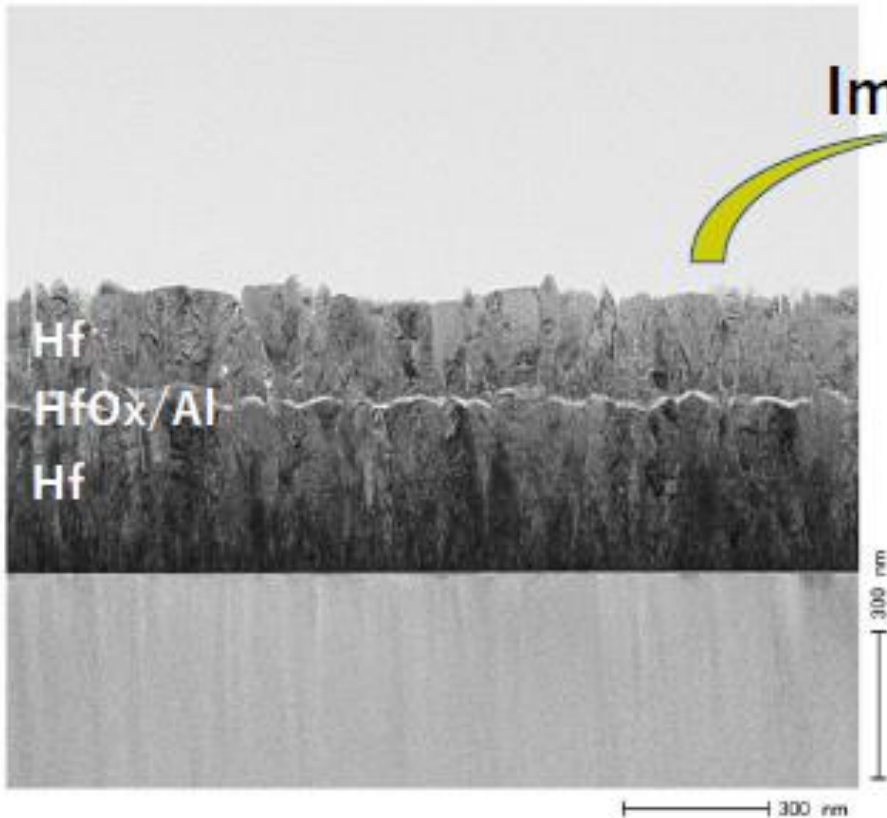
We are working on this improvement by the following methods:

- Optimize the Hf sputtering conditions to make Hf surface smoother. Because the imperfect insulator layer causes high leakage current.
- Downsize Hf-STJ. Because the leakage current is proportional to the junction size.

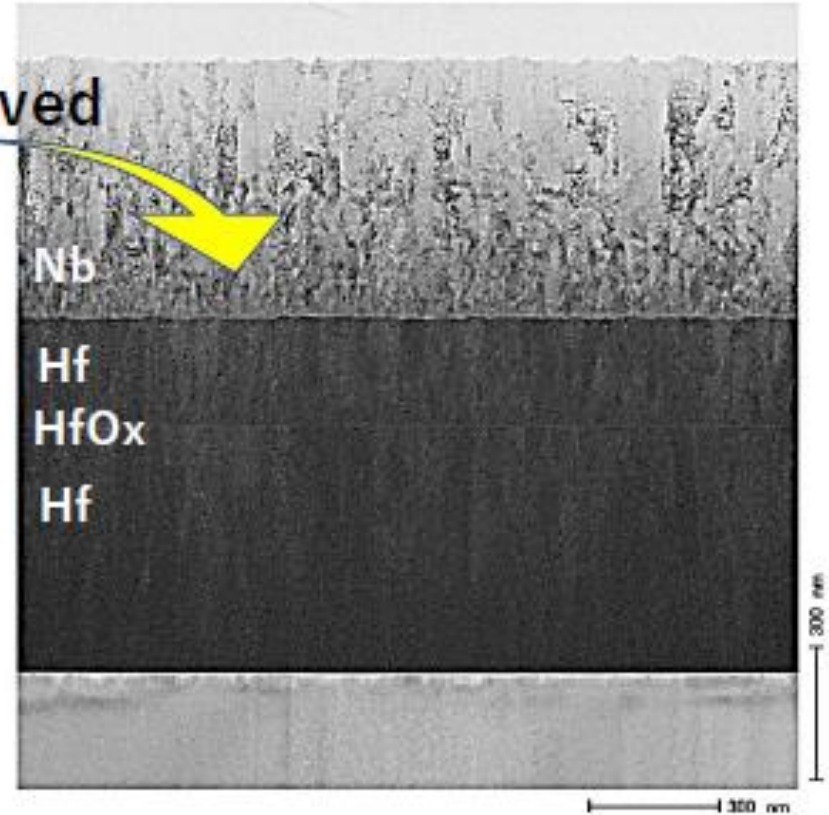
Improvement of Hf Surface Smoothness

We improved the Hf surface smoothness by optimizing the Hf sputtering parameters.

Old sputtering condition
Ar 2.0Pa, 80W



New sputtering condition
Ar 0.5Pa, 50W



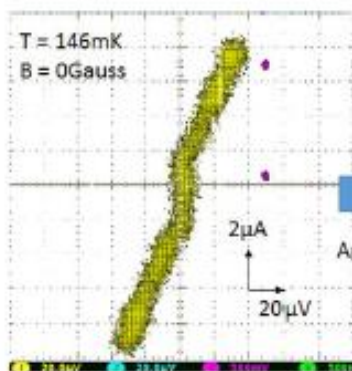
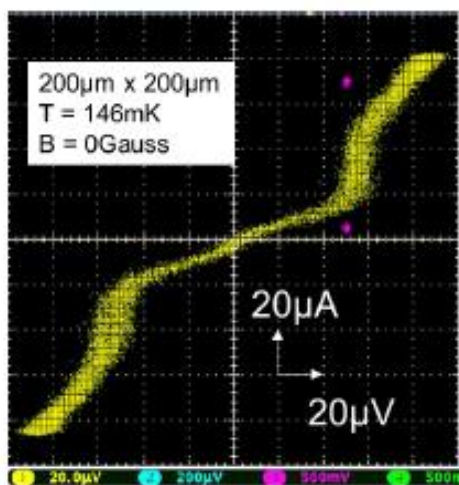
Improved



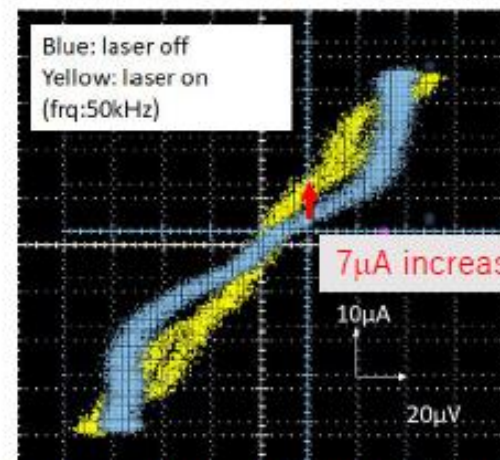
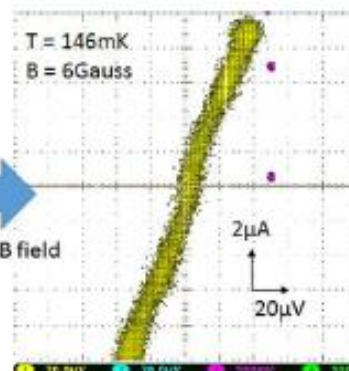
Hf-STJ with Improved Smoothness

200 μ square Hf-STJ with improved smoothness. Wire bonding readout line.

- Josephson current is 2 μ A.
- Effective energy gap $\Delta = 25\mu$ eV.
- Leakage current at 20 μ V is 7 μ A.



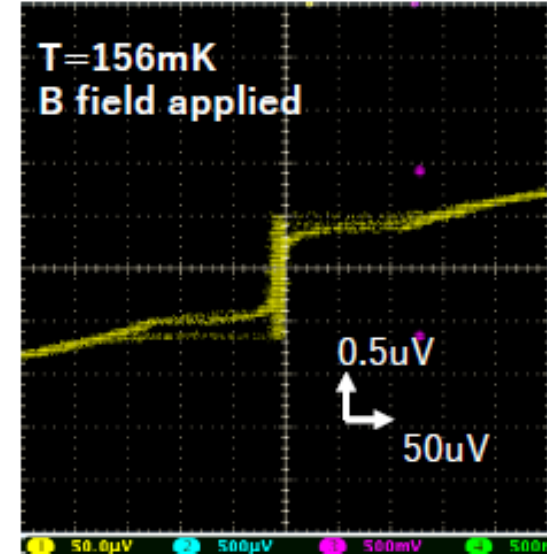
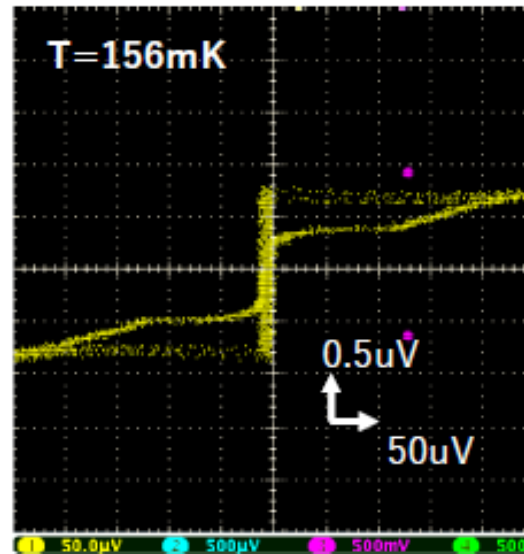
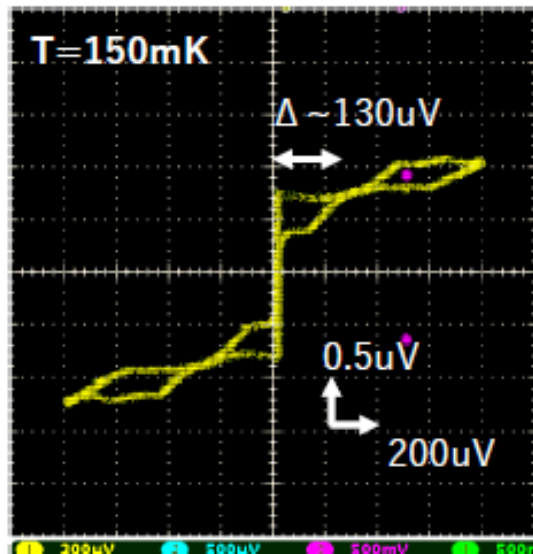
Apply B field



Small-size Hf-STJ with improved smoothness

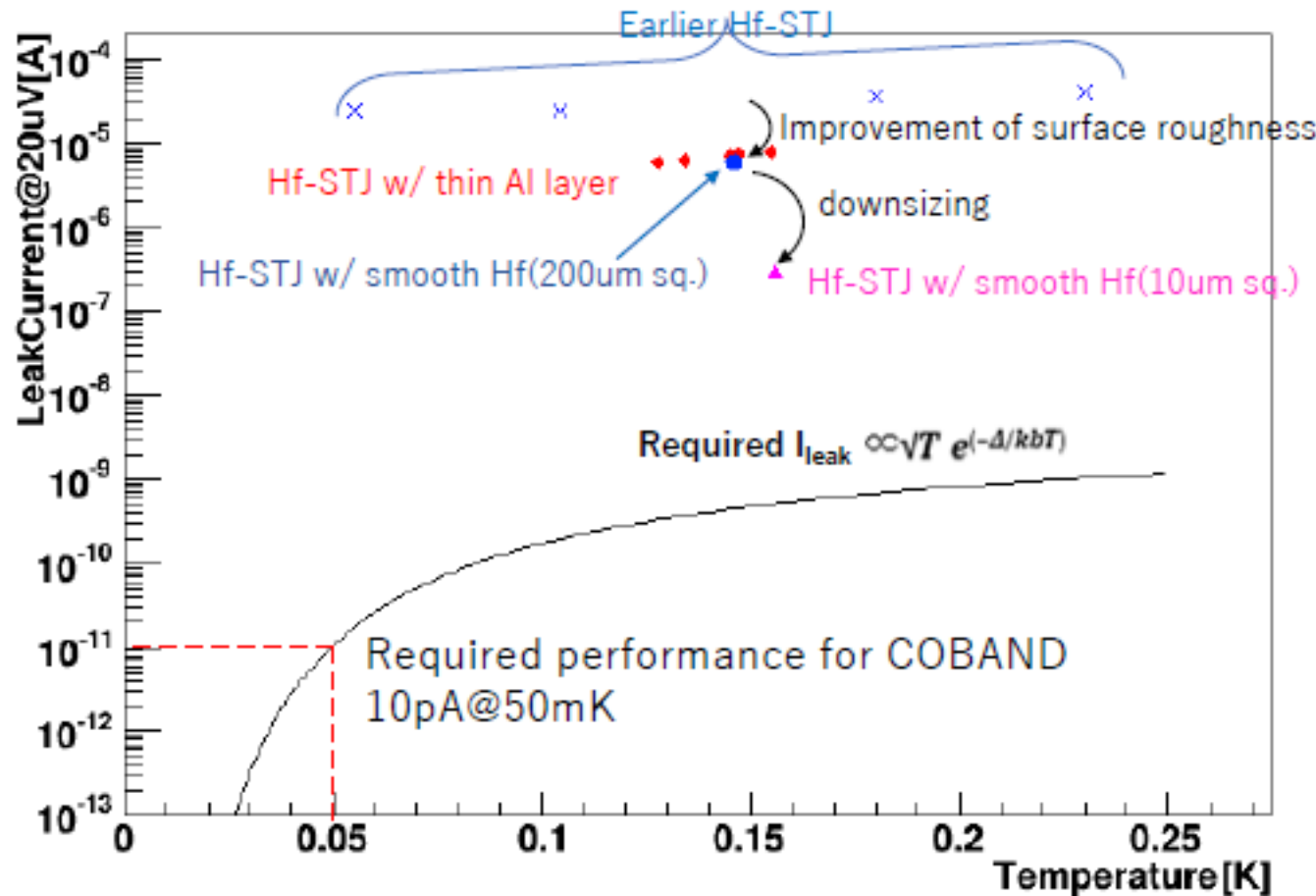
10 μ -square Hf-STJ. Signal line was made by sputtered Nb line not by wire bonding.

- Josephson current is 0.7 μ A.
- Effective energy gap $\Delta = 130\mu\text{eV}$.
- Leakage current at 20 μV is 0.3 μA (1/24 of 200 μ -square Hf-STJ).



Leakage Current of Hf-STJ

- Hf/Al/HfO_x/Hf-STJ reduced the leakage current to one-tenth.
- Hf-STJ with smooth Hf layer reduced the leakage current to one-tenth.
- Small size Hf-STJ (10 μ-square) reduced the leakage current to 1/24.

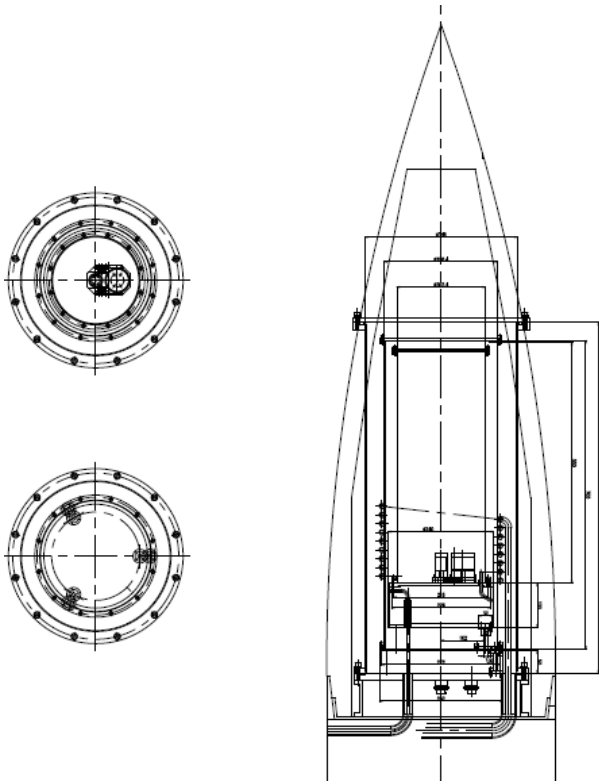


We are working on the study on downsizing of Hf-STJ.

We plan to decrease the operation temperature using another better dilution refrigerator.

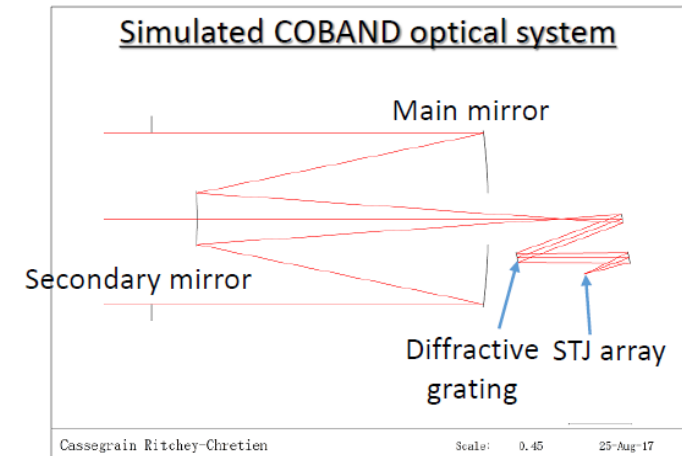
Prototype of Cryostat for the Rocket Experiment

In April 2017, a prototype of the cryostat for the rocket experiment was made. This is a ^3He sorption 0.3K refrigerator inside of ^4He depressurized 1.8K refrigerator. (For now it does not have a ^3He sorption 0.3K refrigerator inside yet.)



Made by Jeck Tohri company.

We are working on the simulation study on the optics in order to make a final design of COBAND optical system.

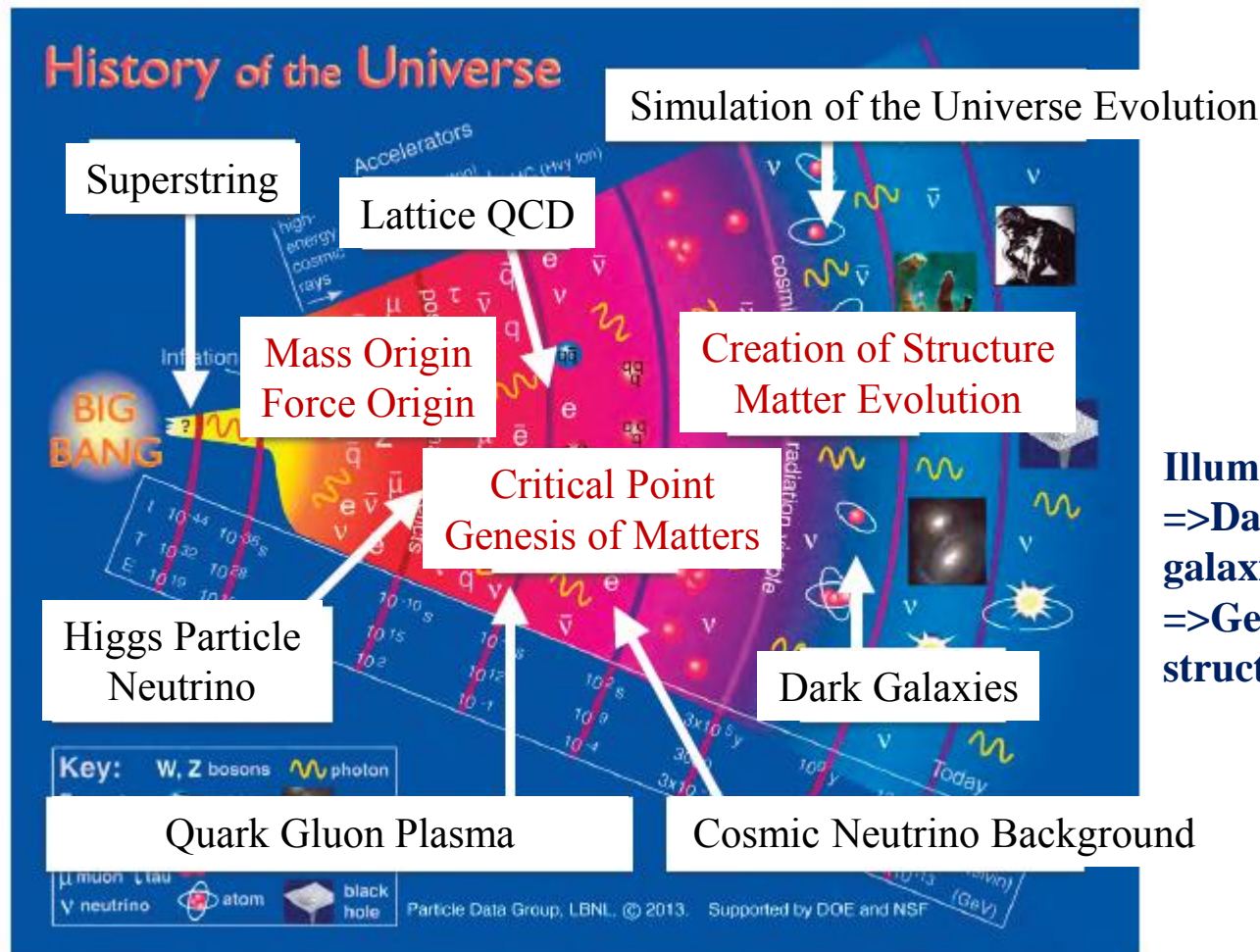


We will test Nb/Al-STJ inside of this cryostat with far-infrared(50μ) photon beam at Fukui this winter.

Research Core for the History of the Universe

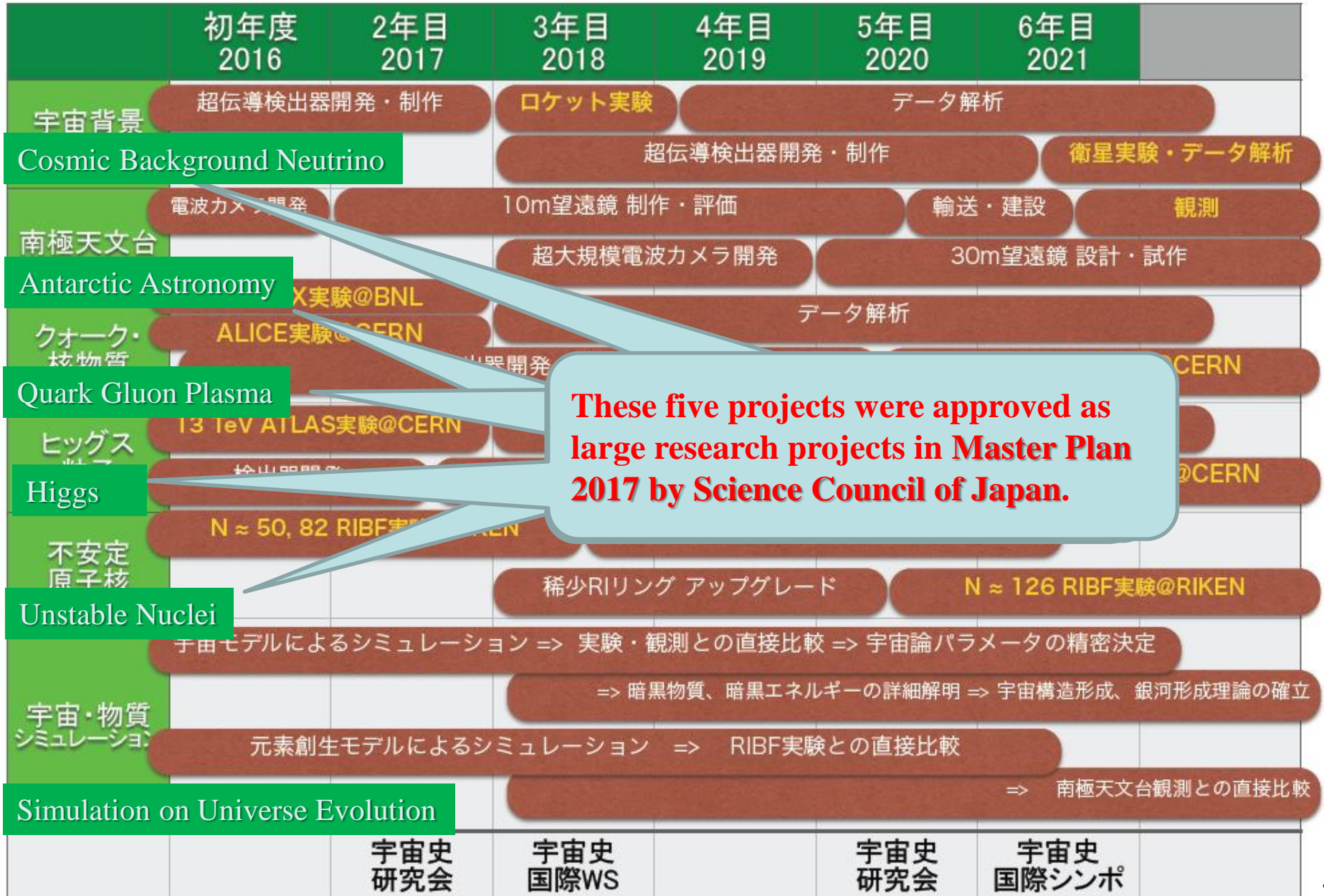
under Center for integrated Research in Fundamental Science and Engineering,
University of Tsukuba (founded on Sep. 1, 2014)

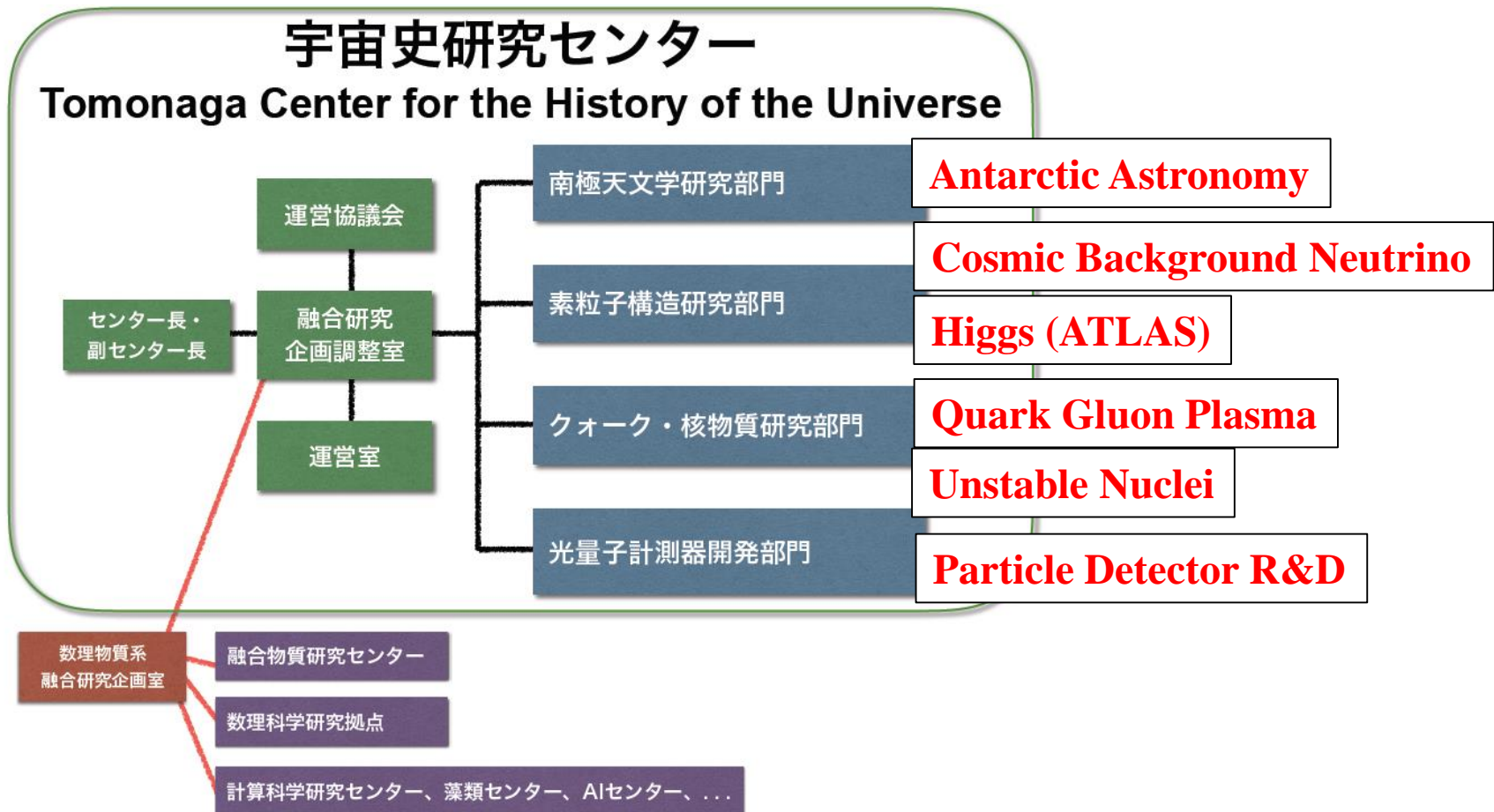
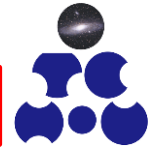
Mission: coordinate the studies in elementary particles, quark nuclear matters and astrophysics to construct an integrated view of the History of the Universe.



Illuminate the “Darkness”:
=>Dark matter, Dark energy , Dark galaxies
=>Genesis of matters, creation of structure and their evolution

Schedule of Projects on the History of the Universe

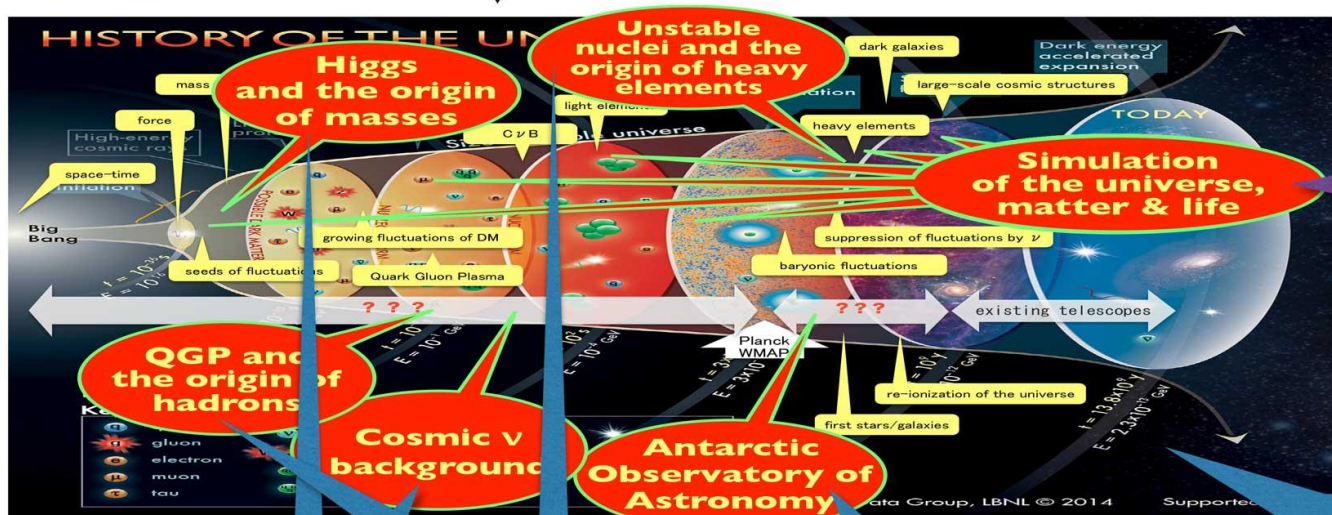






Tomonaga Center for the History of the Universe

From Oct. 2017

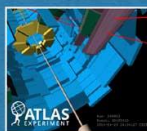


Center for Computational Sciences

JICFuS JCAHPC

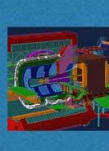
Division of Elementary Particles

- Higgs precision study by ATLAS experiment
- Detection of cosmic neutrino background by COBAND experiment
- Theory of quantum gravity and superstrings



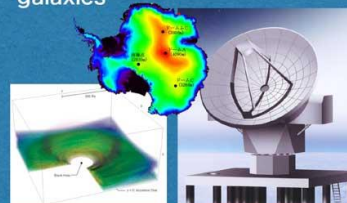
Division of Quark Nuclear Matters

- QGP study by ALICE and STAR experiments
- Study of unstable nuclei by RI-beam factory
- QCD simulations towards QGP and nuclear matters



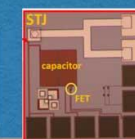
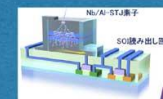
Division of Antarctic Astrophysics

- Construction of Antarctic Observatory of Astronomy towards dark galaxies
- Simulation of universe and galaxies



Division of Photon and Particle Detectors

- Development of PPD by superconducting and SOI technologies

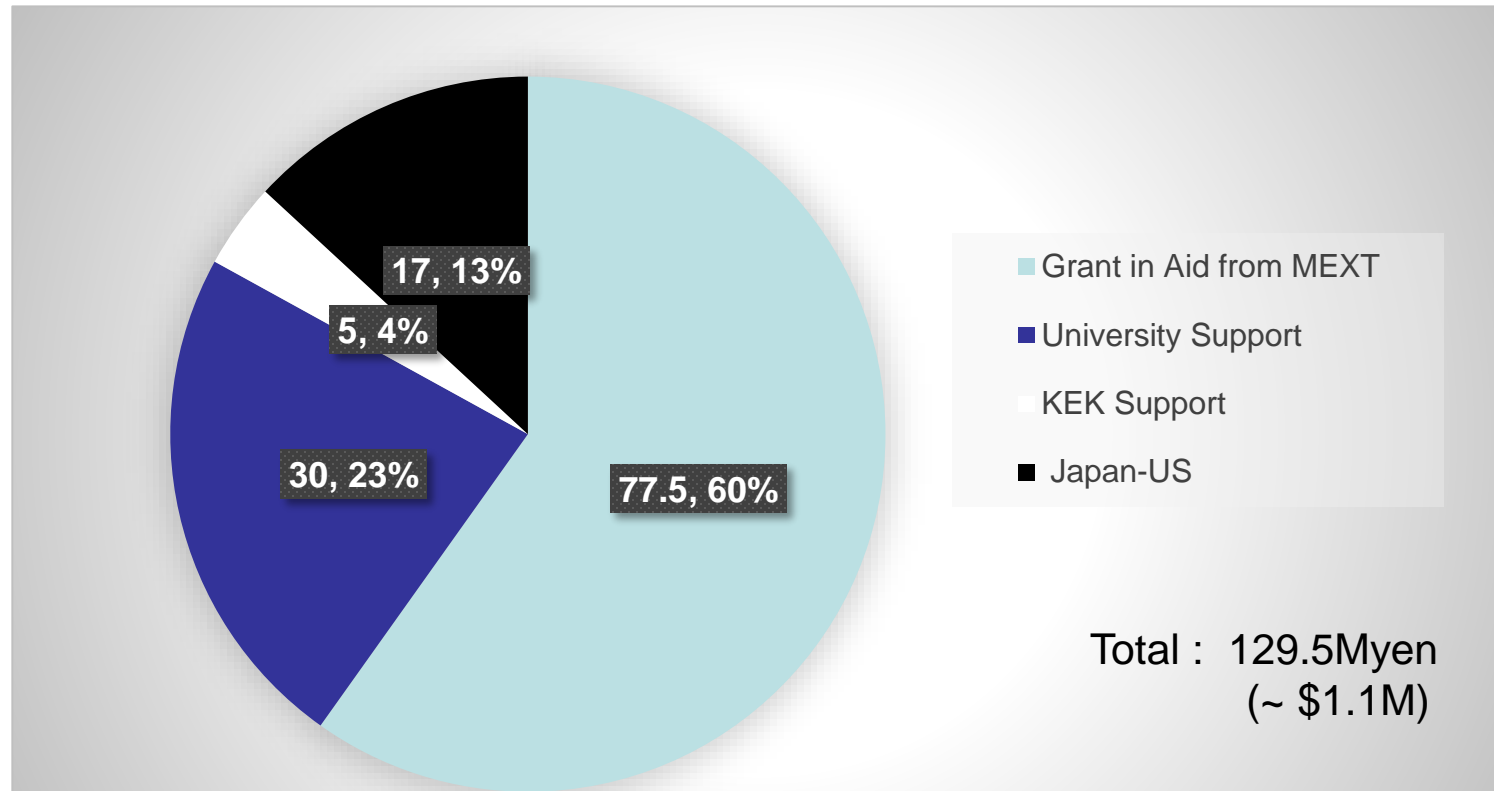


Tsukuba Research Center for Energy Materials Science

TIA-ACCELERATE, ...

**Approved for October 2017 to March 2022 (10,500kYen/year).
Budget for Postdocs, Detector R&D and travel expenses.**

R&D Budgets for the COBAND in the period of JFY2013-2017



Grant in Aid “Neutrino” from MEXT	R&D of Superconducting Infrared Detector for Neutrino Decay Experiment	JFY2013—2017	77.5 MYen
University Support	³ He Sorption Refrigerator	JFY2013—2017	30.0 MYen
KEK Support	Cooperative Project of University of Tsukuba and KEK	JFY2013-2016	5.0 MYen
Japan-US Project	Neutrino Decay Search Experiment Cooperative	JFY2012-2014	17.0 MYen

Summary

- R&D of STJ detectors and the design of the COBAND rocket experiment are underway.
 - Nb/Al-STJ satisfied our requirement for leakage current less than 100pA.
 - Cryogenic amplifier with the SOI technology worked at 300mK.

We have succeeded in amplifying the STJ signal with the SOI cryogenic amplifier.

 - **Hf-STJ signal for visible laser light was observed.**
- Many applications of the STJ detector as
 - a single photon detector in the far-infrared range,
 - a very low energy particle detector,
 - X-ray energy measurement with very higher energy resolution and so on.