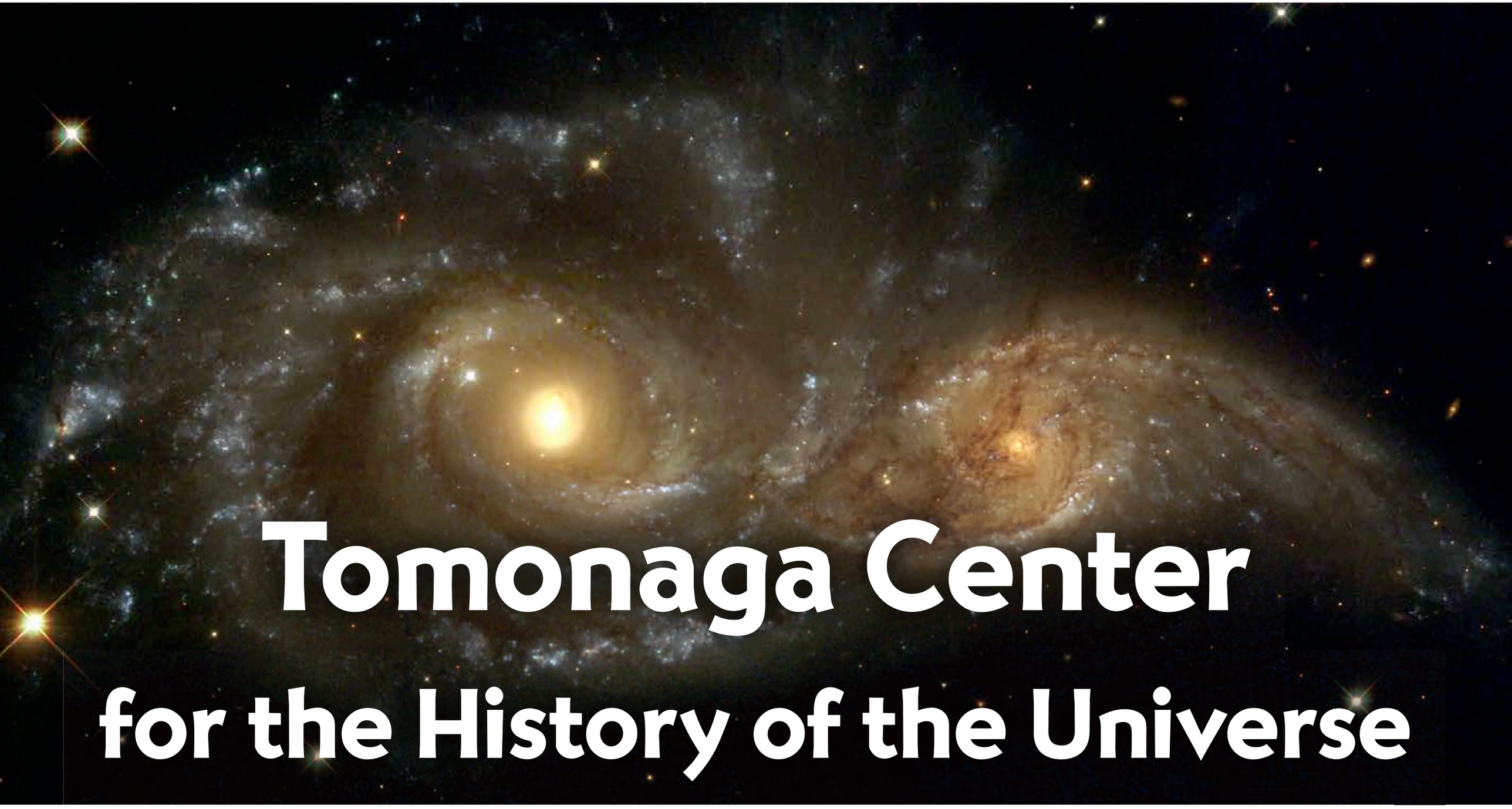
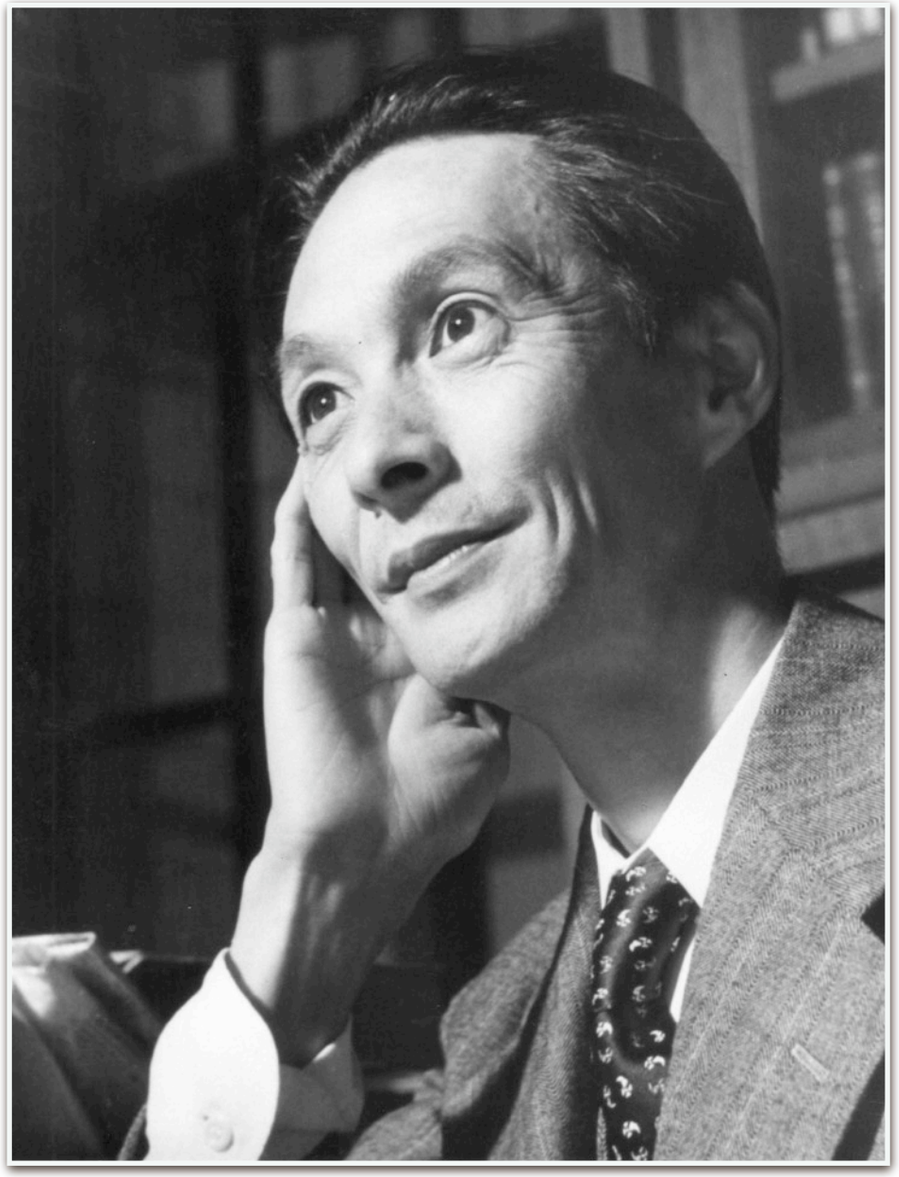
2019/05/20



Tomonaga Center for the History of the Universe

www.pas.tsukuba.ac.jp/~TCHoU/



Sin-Itiro Tomonaga

1906-1979

Basic contributions to the foundation of
- relativistic quantum field theory
- renormalization theory
- theory of collective motions

=> Nobel prize in Physics 1965
together with Julian Schwinger
and Richard Feynman
(2nd Nobel laureate from Japan)

A founder of physics institutes at Tsukuba.

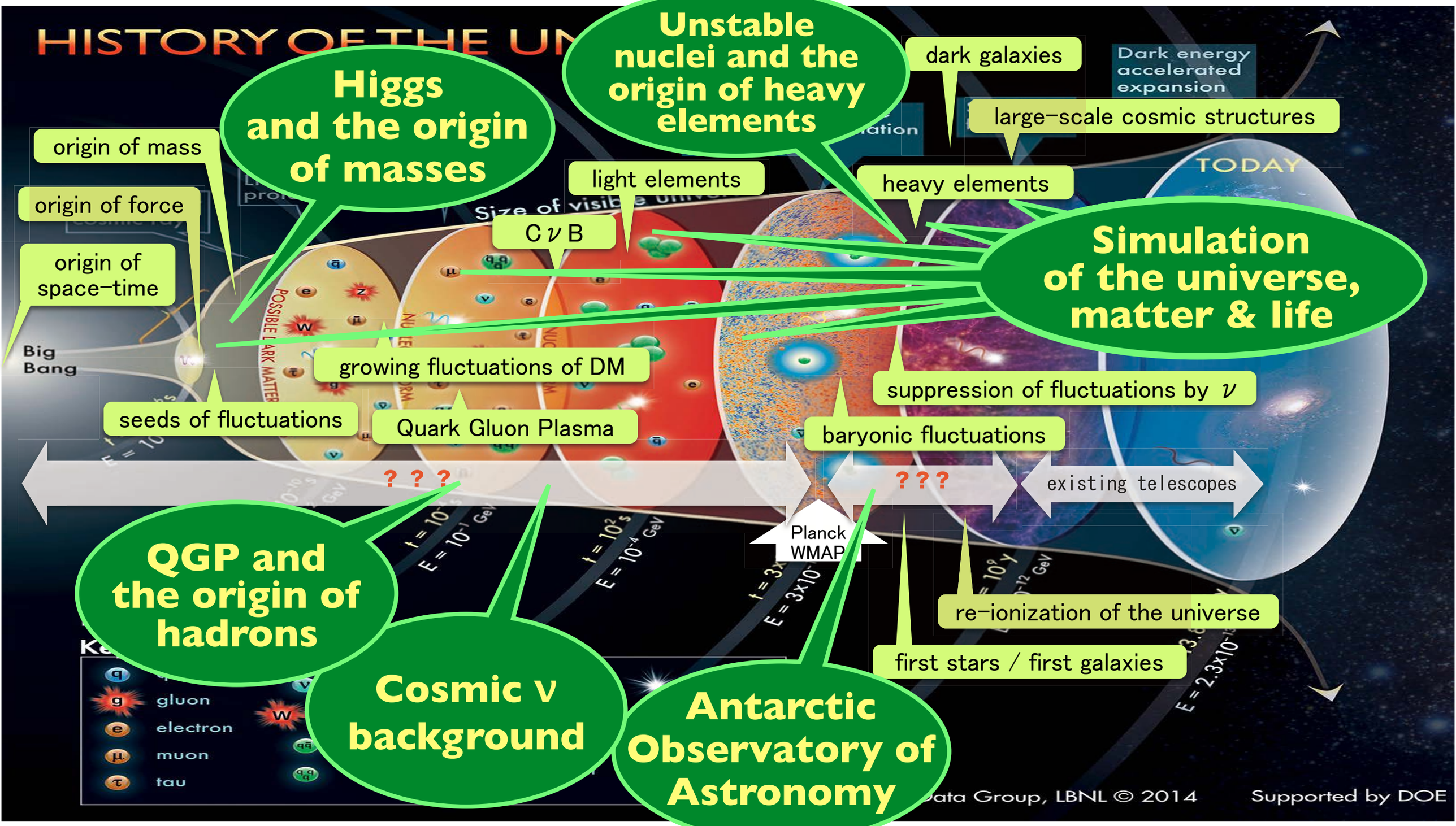
1941 Professor of the Tokyo Univ. of Literature and Science
works on relativistic QED and renormalization theory
1949 Professor of the Tokyo Univ. of Education
1956 President of the Tokyo Univ. of Education

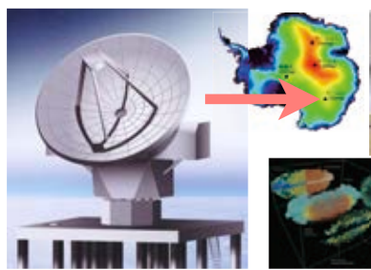
reorganized to found

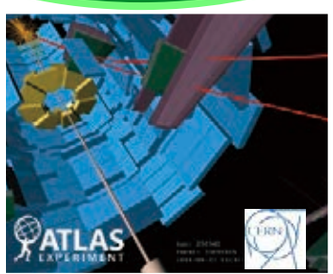
1973 Univ. of Tsukuba

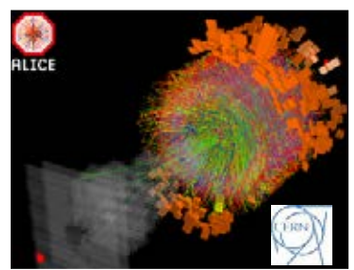
Standing exposition at the Tomonaga Memorial Room
in the University Gallery, Univ. of Tsukuba

Towards Clarification of the History of the Universe: Projects at Tsukuba



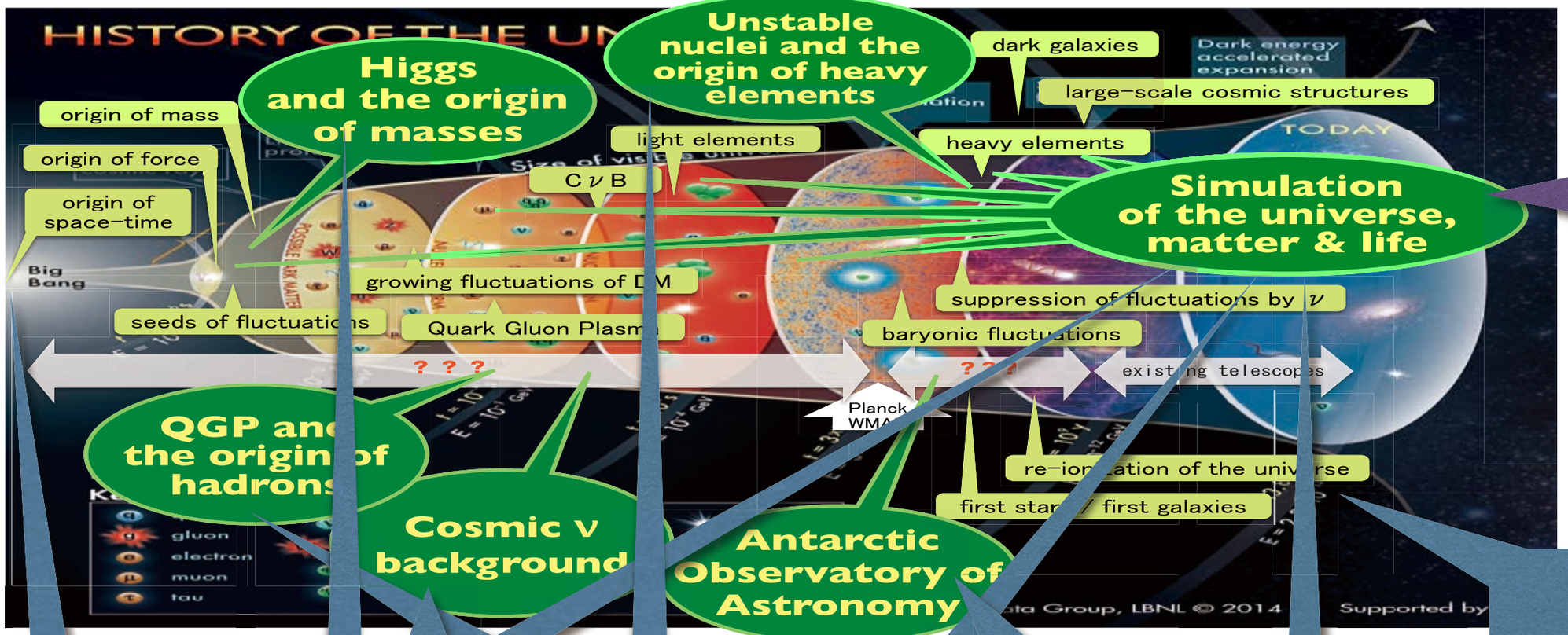




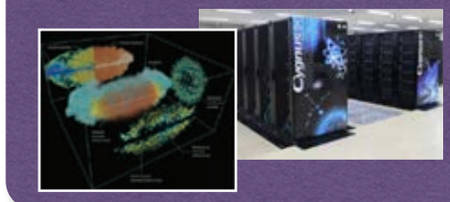


Tomonaga Center for the History of the Universe

to support and integrate these projects



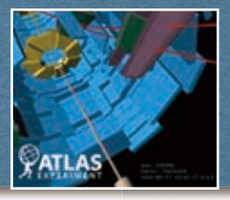
Center for Computational Sciences



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

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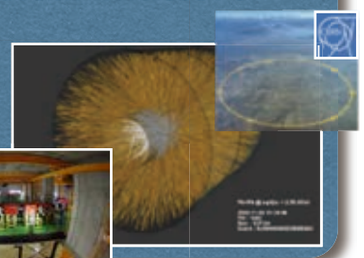


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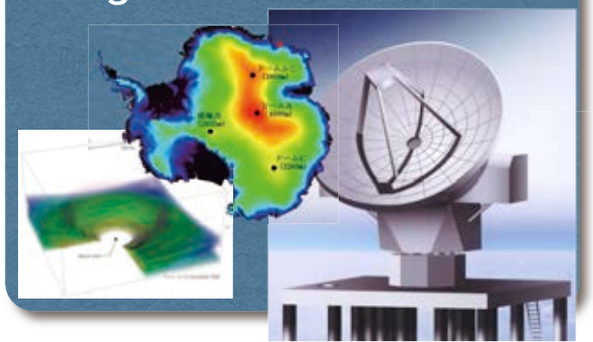
- Construction of Antarctic Observatory of Astronomy towards dark galaxies
- Simulation of universe and galaxies



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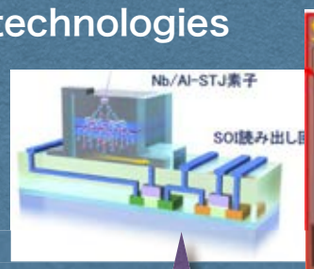

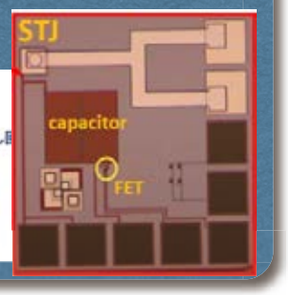

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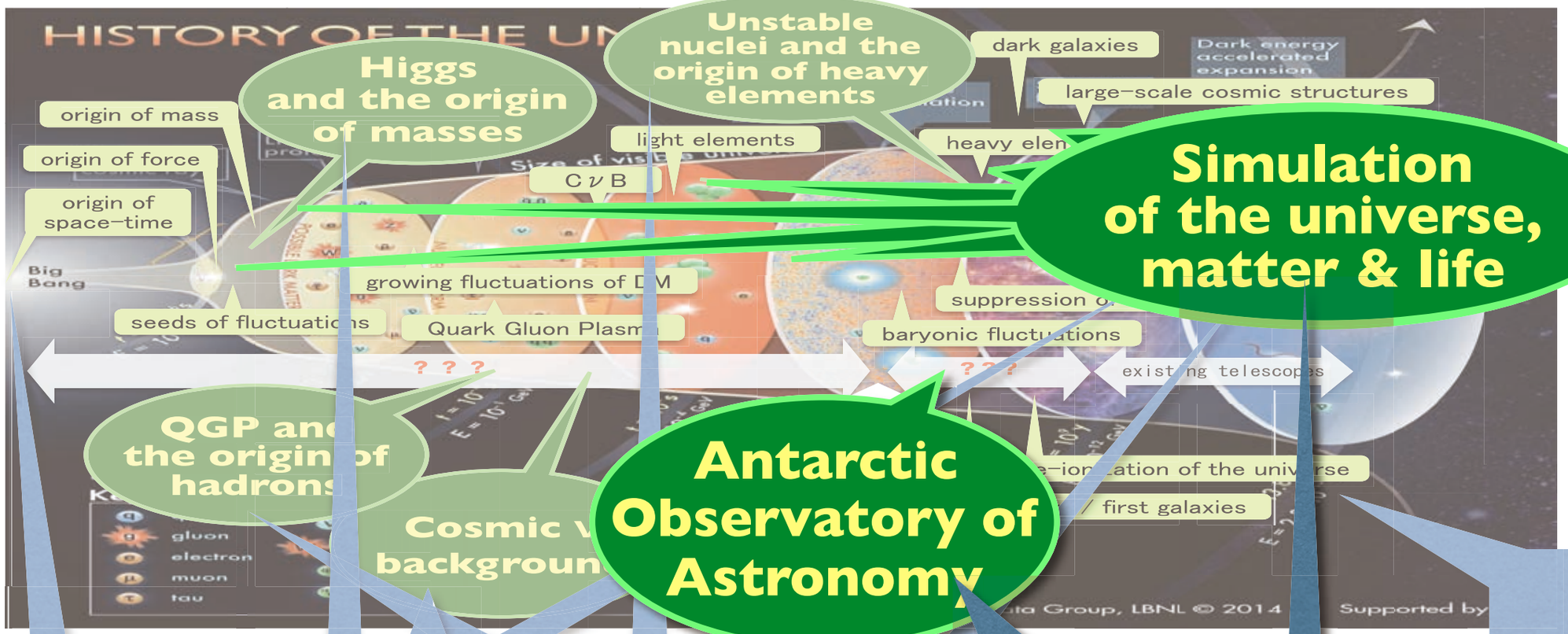
TIA-ACCELERATE, . . .

Tomonaga Center for the History of the Universe



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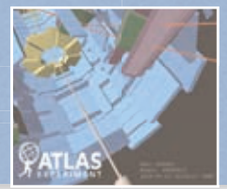

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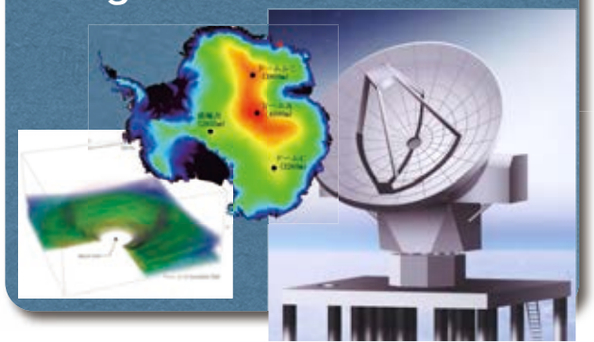

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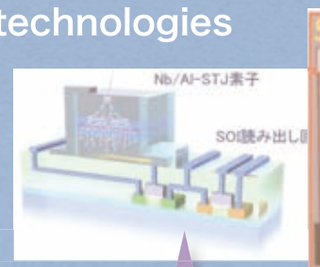
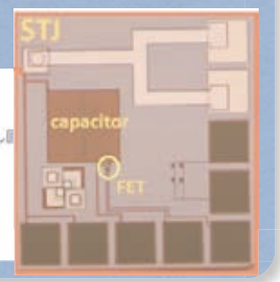


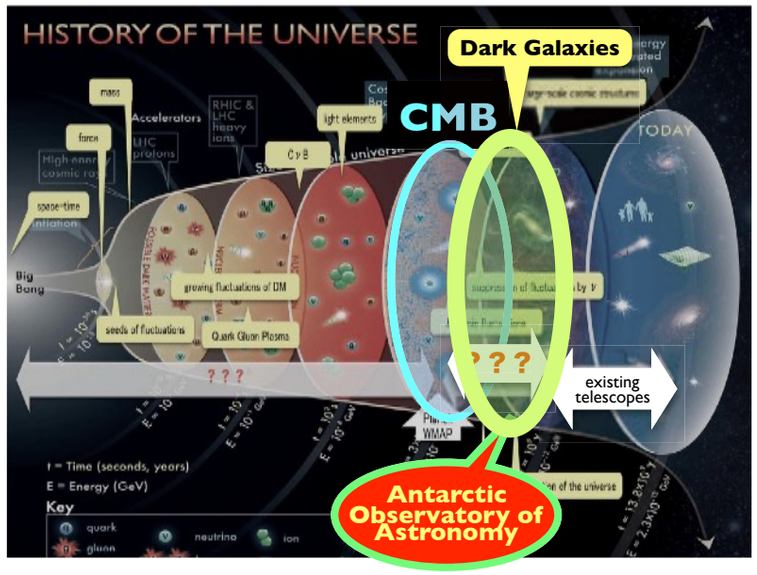


Tsukuba Research Center for Energy Materials Science

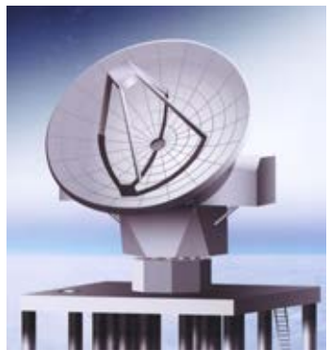
TIA-ACCELERATE, . . .

Antarctic Observatory of Astronomy

- Present Universe is ionized. On the other hand, it was neutral 0.3 Bi. years ago as the CMB is observable. To understand the formation of galaxies, stars, and life, it is important to clarify the ionization mechanism.
- Ionization must be caused by UV radiations from stars.
- However, only 30% of required stars/galaxies are visible with present telescopes. Remaining 70% -- "dark galaxies" -- should be found in the deep space.



Deep-space exploration by THz telescope at Antarctica



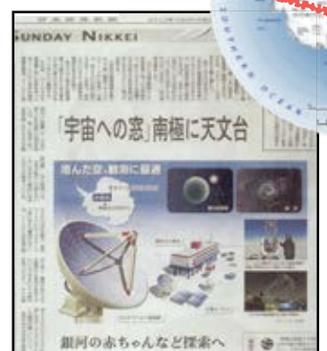
Step 1: 10m THz telescope

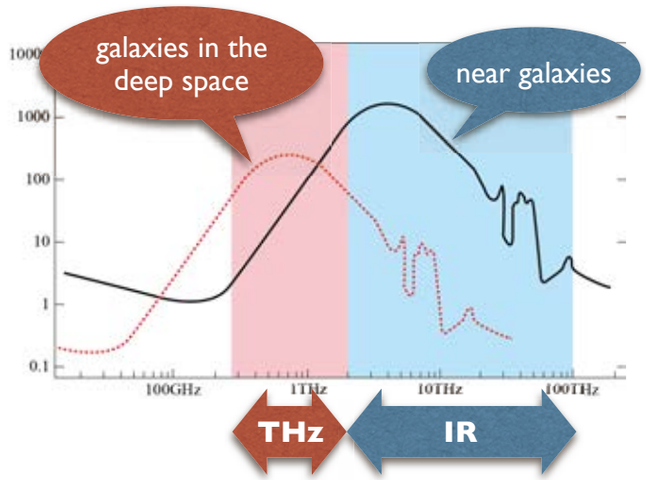
The Hubble expansion makes lights from the deep-space in the THz range, which are usually dumped by the water vapor in the atmosphere.

=> Antarctica with its extremely low humidity is the only place on the Earth where THz waves are observable.

Wide angle survey up to 12.6 Bi. years ago by 10m telescope. Recommendation by SCAR (2010). Combining with the IR observation by the rocket/satellite experiment of the cosmic neutrino background project, we clarify the whole spectrum to determine the character and distance of dark galaxies.

Planned site: Concordia Station (3233m, built by France and Italy)





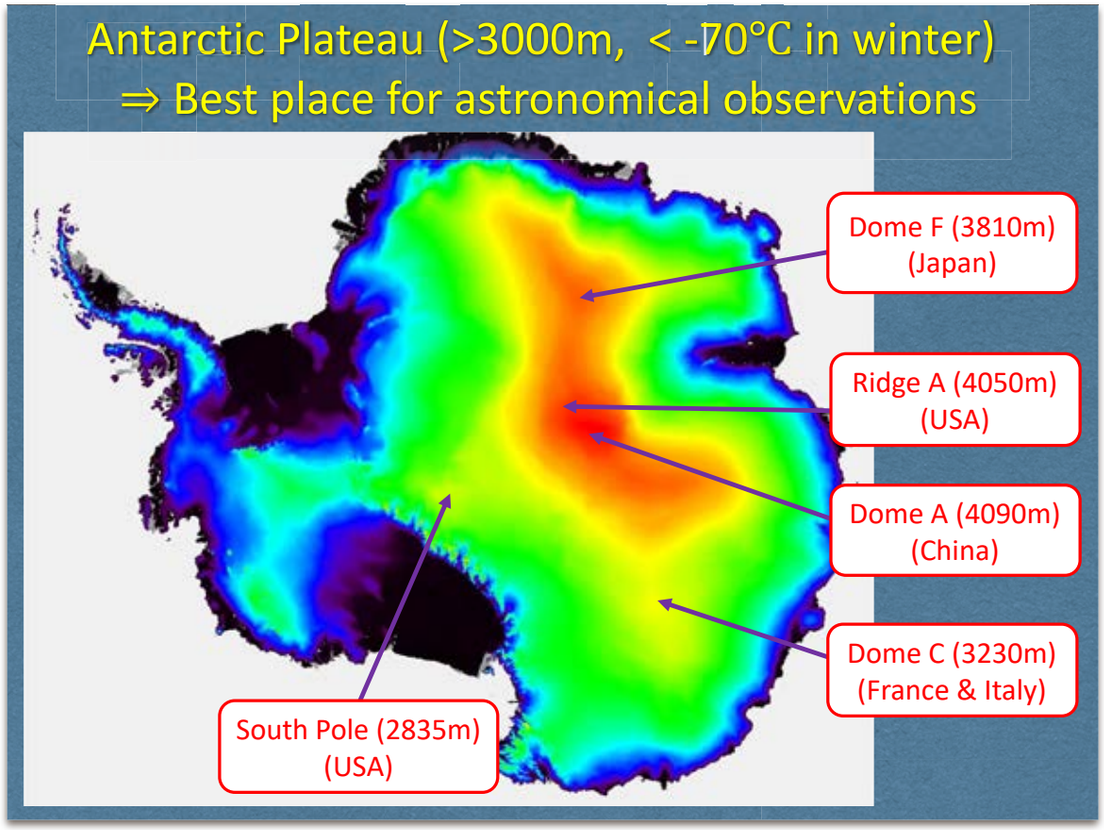
Step 2: 30m THz telescope

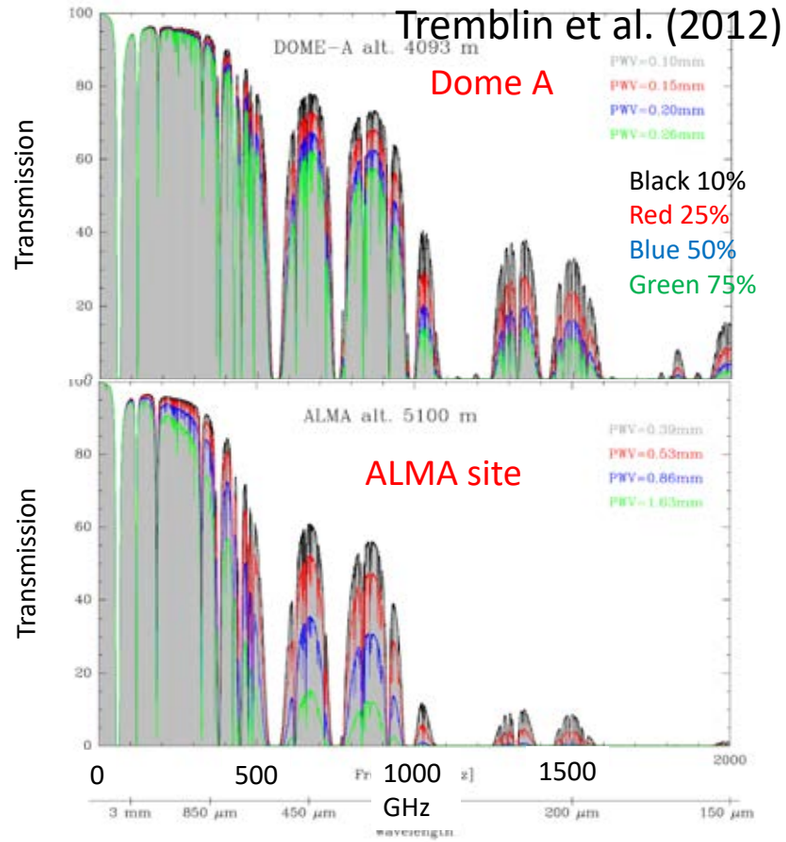
Survey up to 13.6-13.7 Bi. years ago.

=> Direct observation of first stars and galaxies.

Based on the experience of 10m telescope.

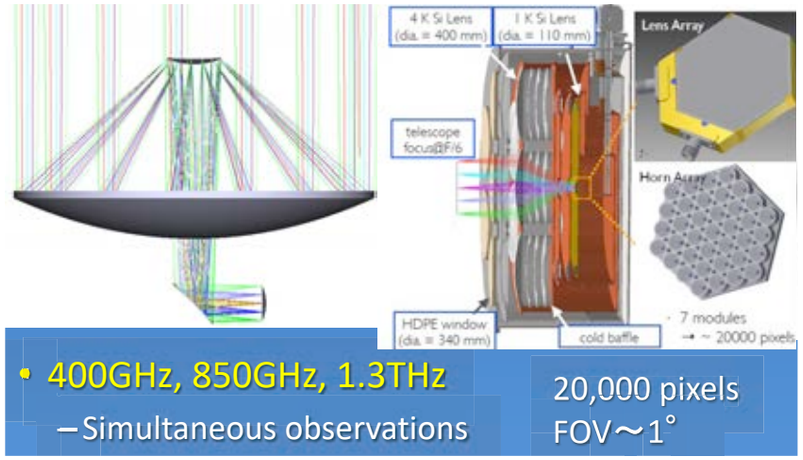
Planned site: New Dome Fuji (3800m, NiPR)



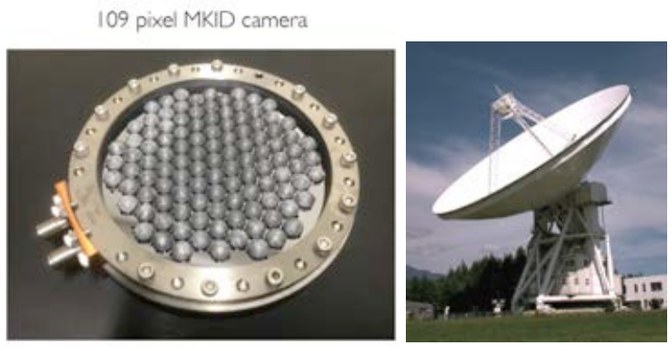


Step 0:

- **development of wide-field MKID camera (Microwave Kinetic Inductance Detector)**

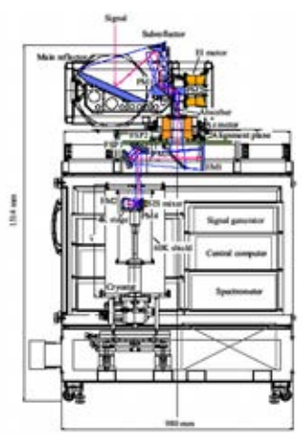


MKID camera at NAOJ 40m



- **test observation at Dome C with 30cm radio telescope**

Equipped with a 0.5 THz SIS receiver.
Can be assembled by 4 persons by hand.
=> Galactic plan survey in CO(4-3) and [CI].



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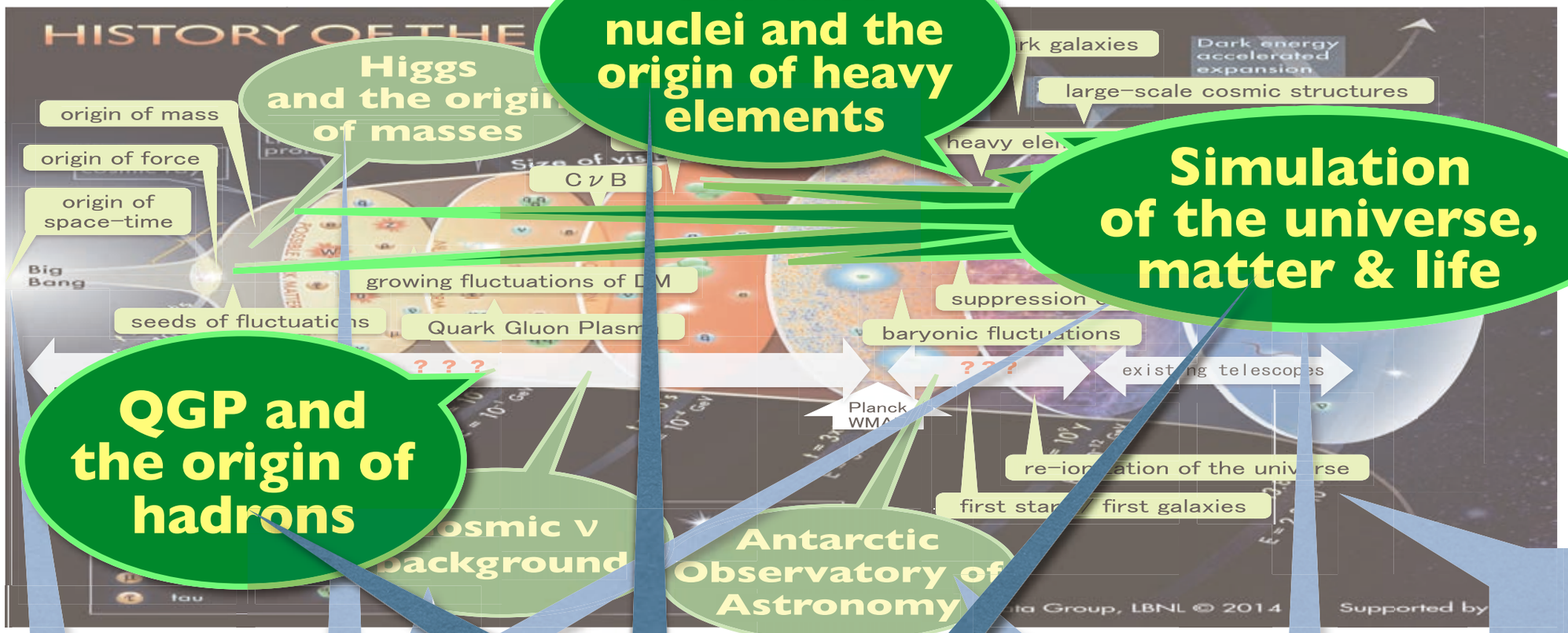

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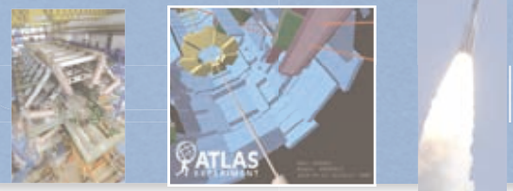

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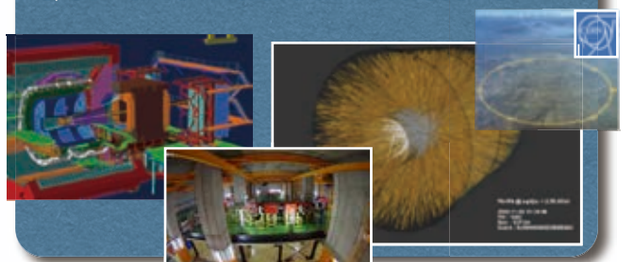

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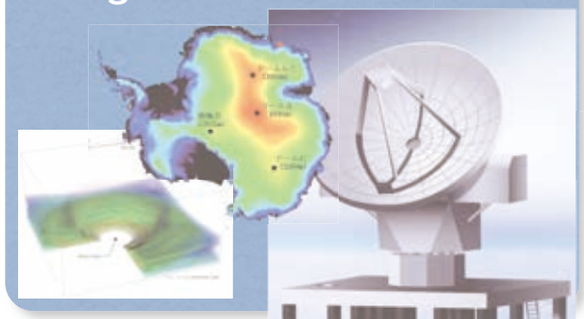

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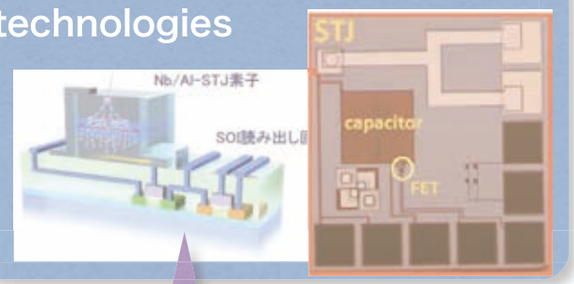


Tsukuba Research Center for Energy Materials Science

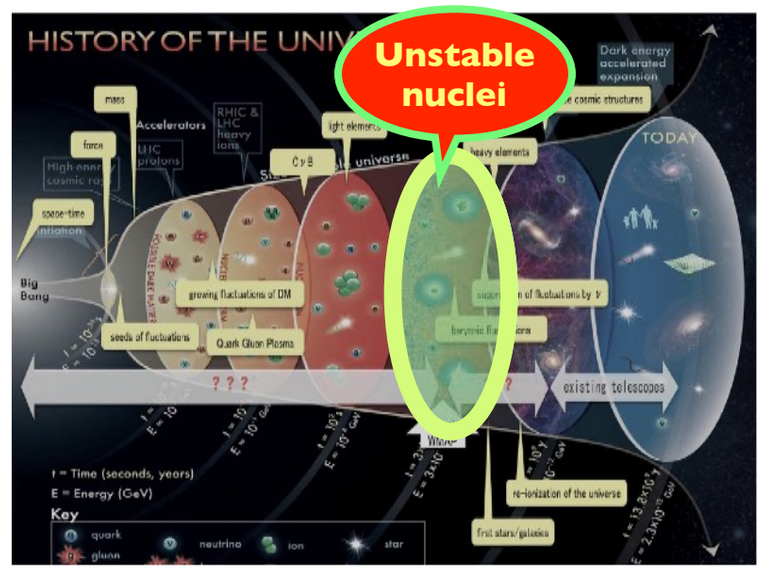
TIA-ACCELERATE, . . .

Study of Unstable Nuclei

Origin of heavy elements in the Universe:

Super-nova explosions after the formation of first stars and galaxies around 13 Bi. years ago, merger of neutron stats, etc.

Important to understand the reaction processes of unstable nuclei (r-process, s-process).



Rare RI-Ring @ RIKEN/RIBF
in operation since Mar. 2015

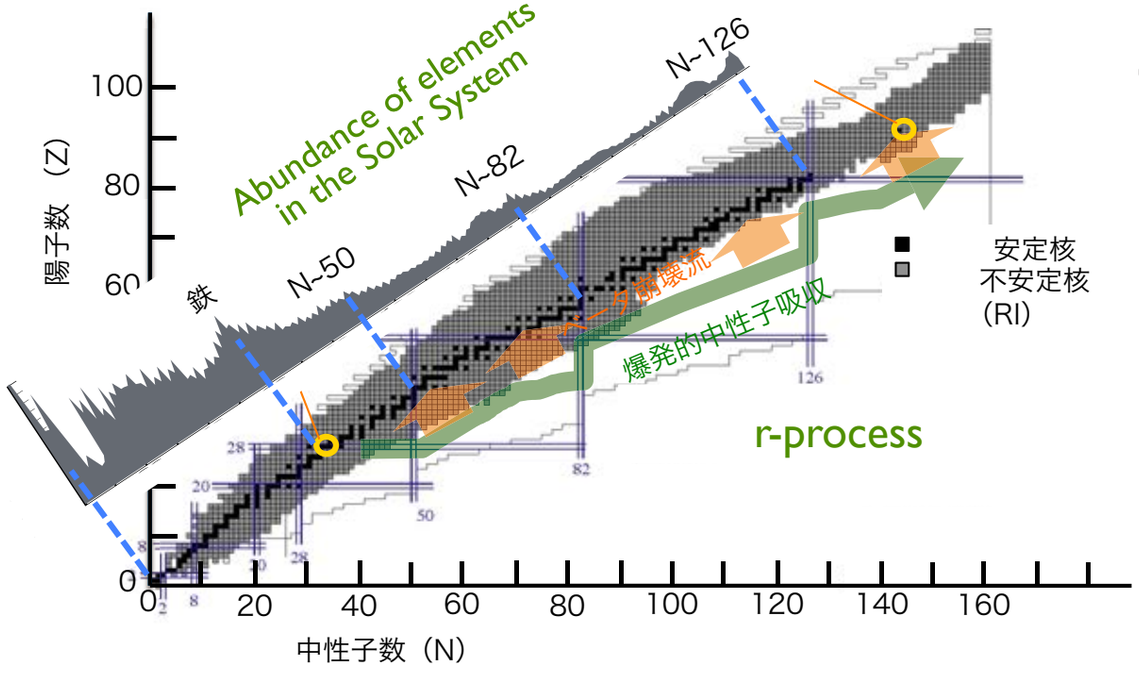
Study of unstable nuclei using heavy-ion accelerators

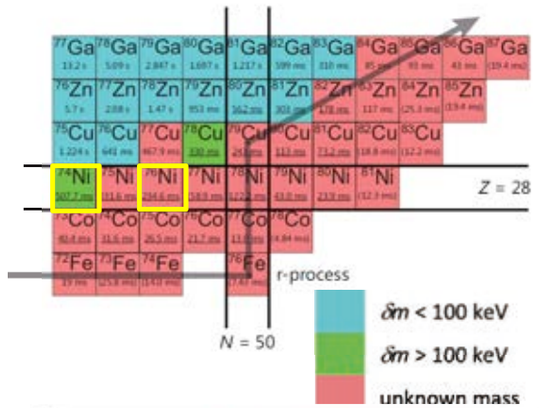
Measure masses and lifetimes of unstable nuclei by Rare RI-Ring at the RI Beam Factory (RIBF) of RIKEN, and obtain the reaction rates for the r-process.

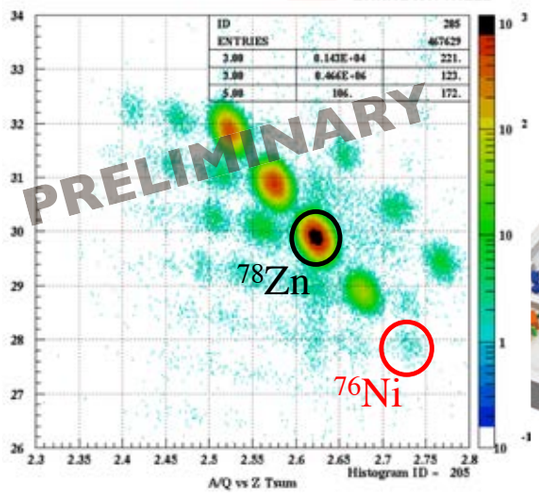
1st step: Study at N≈50 (Ni-region) <= 1st run in Nov. 2018

2nd step: N≈82 (Sn-region) <= 1st run in Nov. 2018

3rd step: N≈126





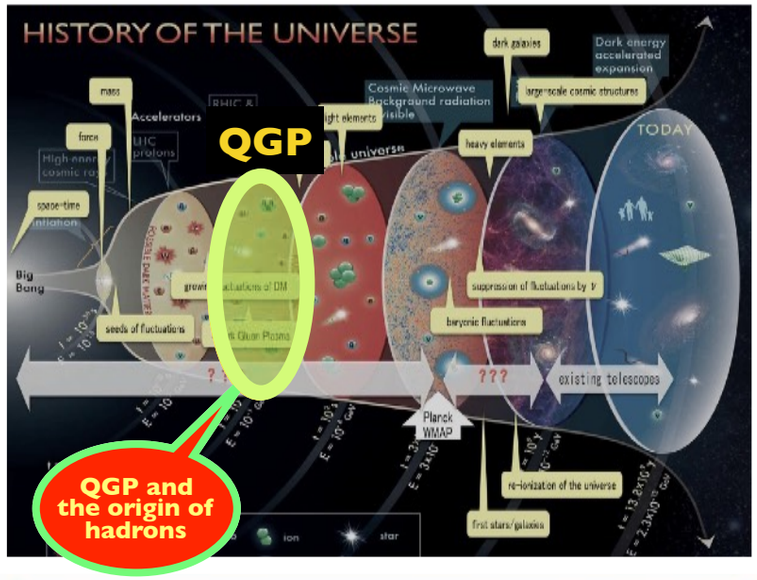


Clarification of Quark and Nuclear Matters

- 10^{-4} sec after Big Bang: phase transition from quark matter (quark-gluon plasma: QGP) to ordinary matter of hadrons/ nucleons

It is the most recent particle-level phase transition of our Universe.

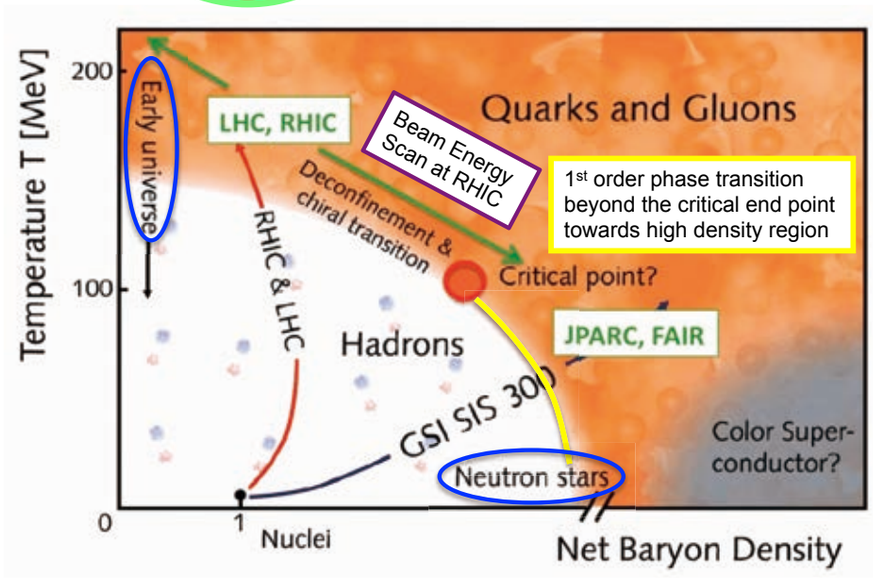
=> Initial condition for the evolution of ordinary elements.

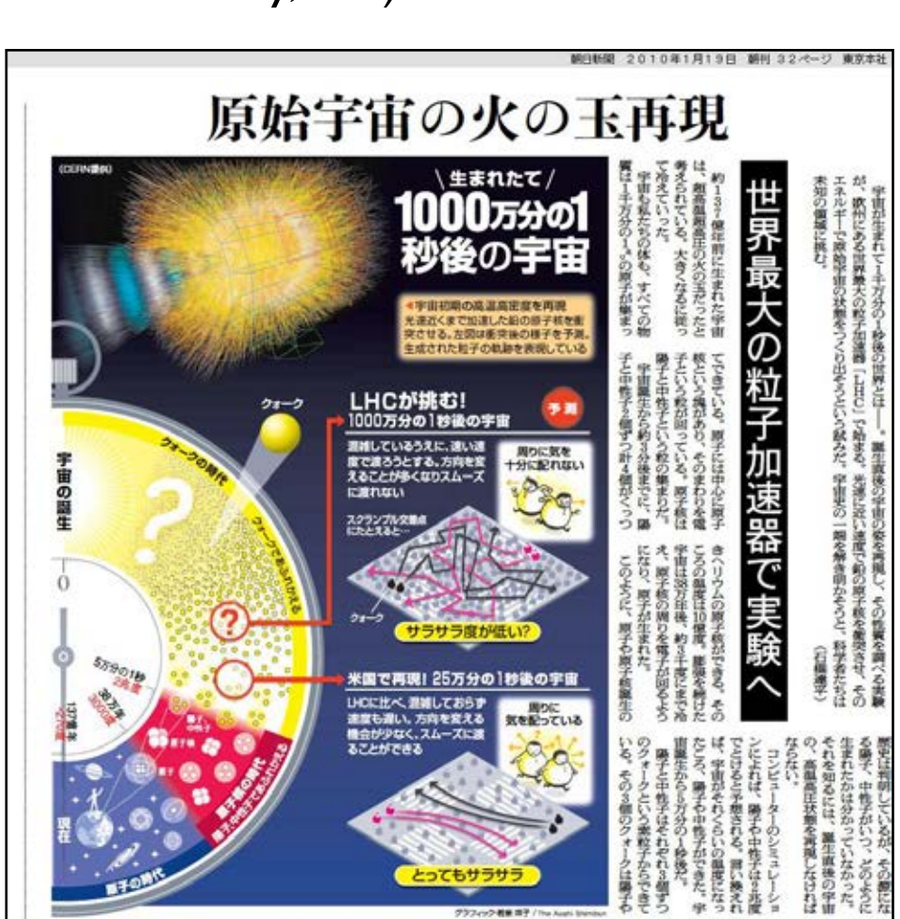


High-energy heavy-ion collision experiments

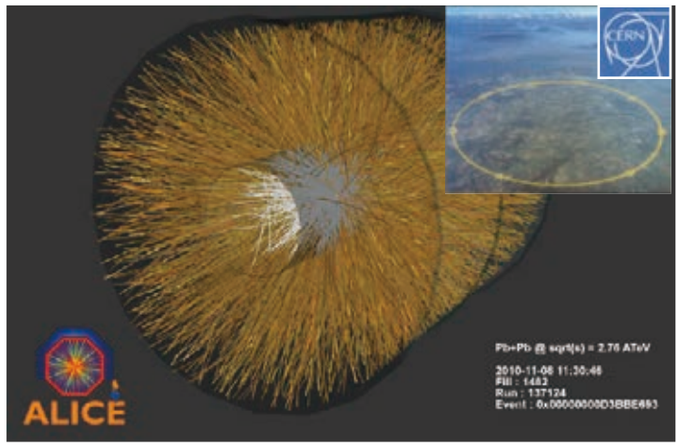
Create QGP on the earth by mankind ("Little Bang").

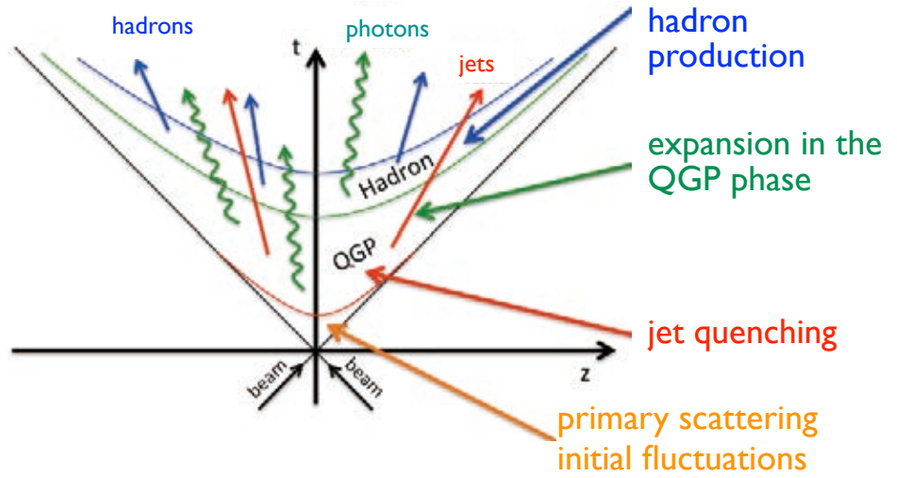
=> Clarify the nature of the phase transition and the quark nuclear matters (fluctuations, expansion, transition temperature, viscosity, etc.) around the transition temperature.





The Univ. of Tsukuba is pushing forward the RHIC experiment at BNL and the ALICE experiment at CERN.





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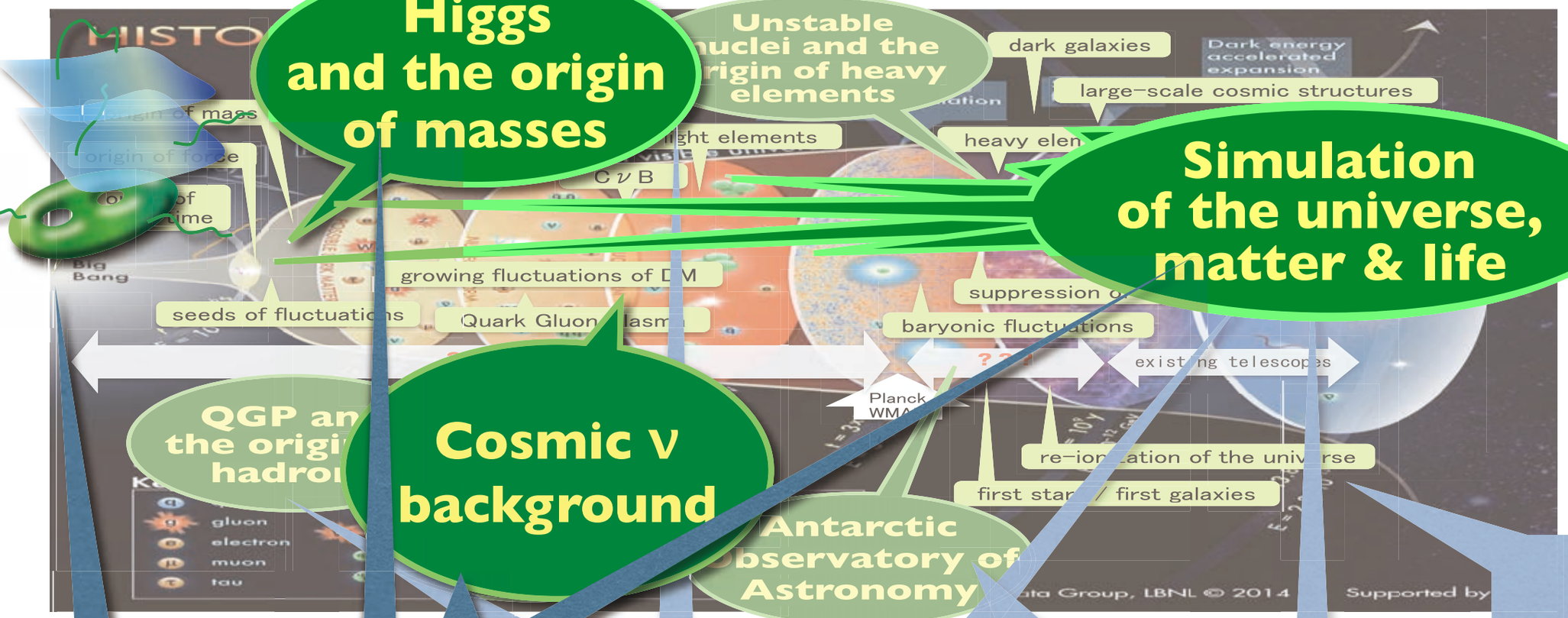

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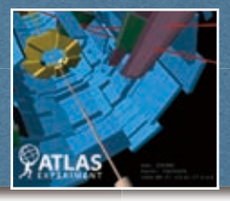

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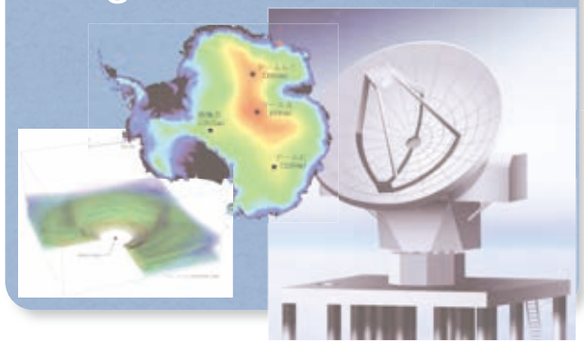

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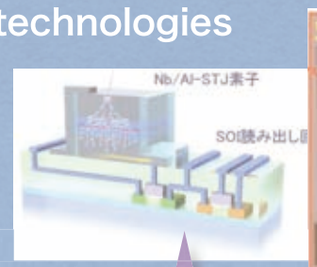
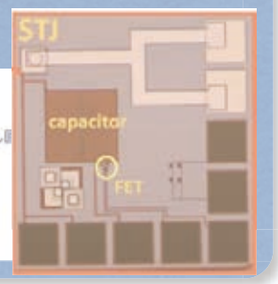




Tsukuba Research Center for Energy Materials Science

TIA-ACCELERATE, . . .

Exploration of Cosmic Neutrino Background

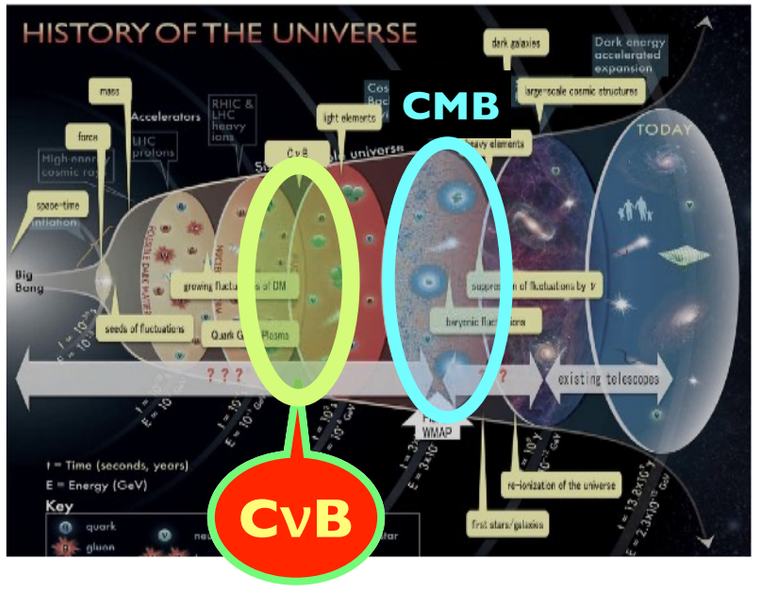
- Few seconds after Big Bang → Cosmic Neutrino Background (**CνB**)

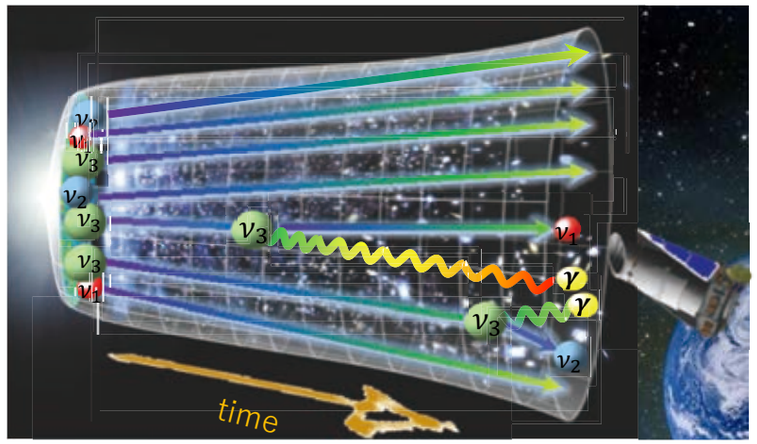
  300,000 years after BB → Cosmic Microwave Background (**CMB**)

- Discovery of CνB means the first direct observation of the cosmic era before CMB, => clarification of the initial condition for the formation of galaxies and large-scale structures of the Universe.

- A large amount of CνB of about 100/cm^3 is expected.

  This enables us a high precision observation of the neutrino decay, and thus provides us with the only way to directly measure the absolute value of neutrino masses, which play an essential role in the development of cosmic fluctuations together with the effects of dark matter and dark energy.





★ COBAND Project: exploration of CνB by rocket and satellite experiments

Precision measurements of far IR photons from neutrino decays.

- **Step 1: Rocket experiment** : take data for 5 min. at 200 km high.

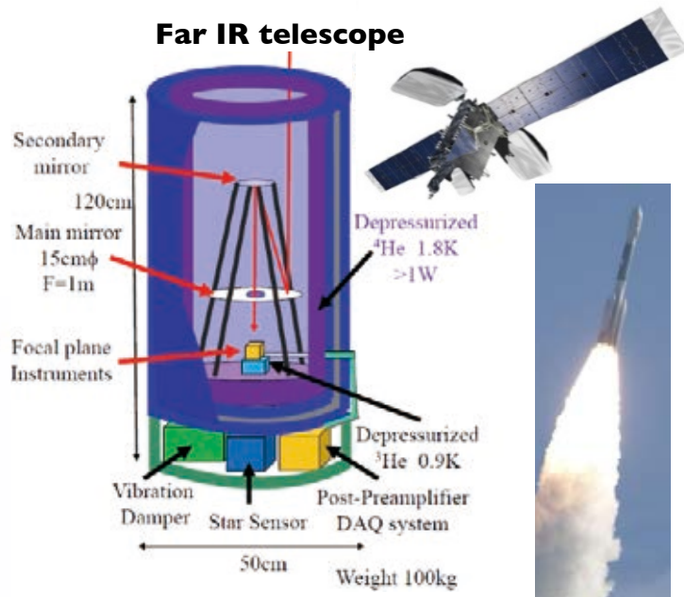
  Determine the life of the neutrino if it is shorter than 10^{14} years.
  (cf. current lower bound = 3×10^{12} years.)

- **Step 2: Satellite experiment**

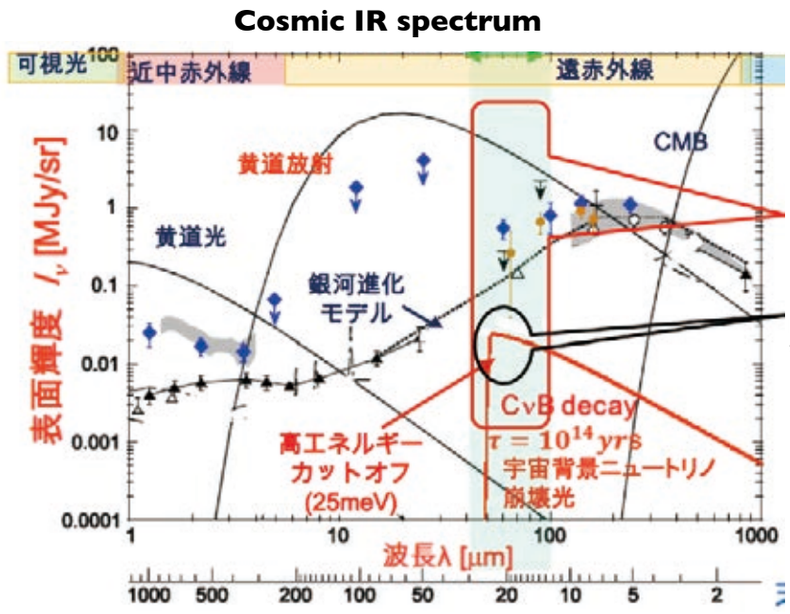
  Determine the life of the neutrino if it is shorter than 10^{17} years.

- **Development of SOI-STJ detectors.**

  Operation at extreme low temperatures confirmed.
  (Nagata et al., 2009).



- Far IR photons from neutrino decays



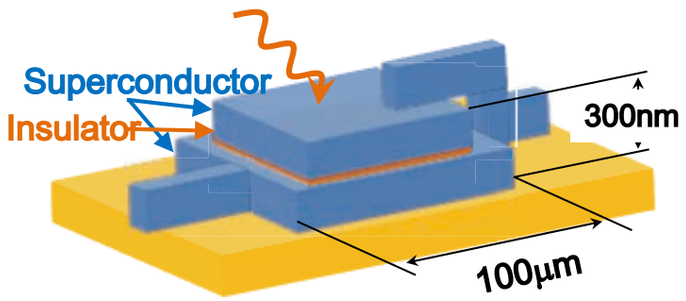
continuous background spectrum

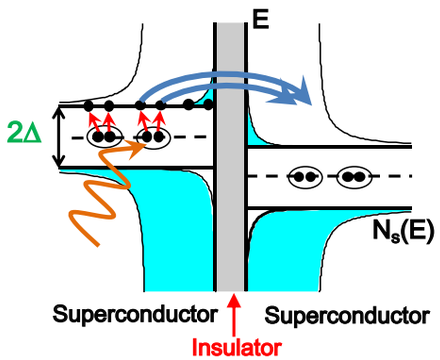
neutrino decay signal with a sharp cut-off

The signal is expected to be sharp, but hidden in a huge background.

=> Need high resolution and high sensitivity.

- Detectors based on superconducting tunneling junction (STJ)

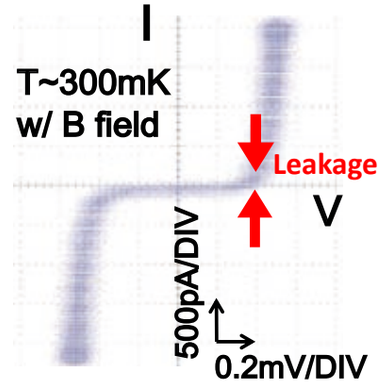




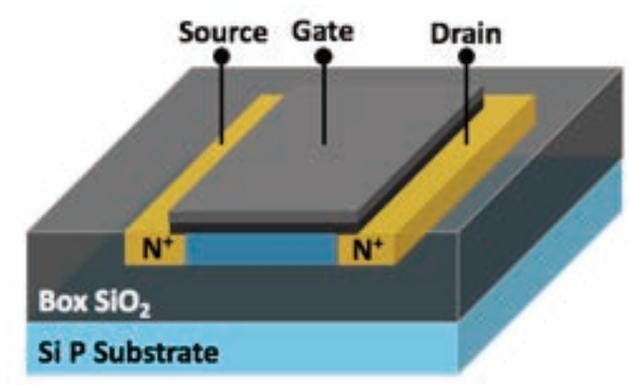
	Si	Nb	Al	Hf
Tc[K]		9.23	1.20	0.165
Δ[meV]	1100	1.550	0.172	0.020

- ◆ Nb/Al-STJ for the 1st step
- ◆ Hf-STJ for the 2nd step

Nb/Al-STJ

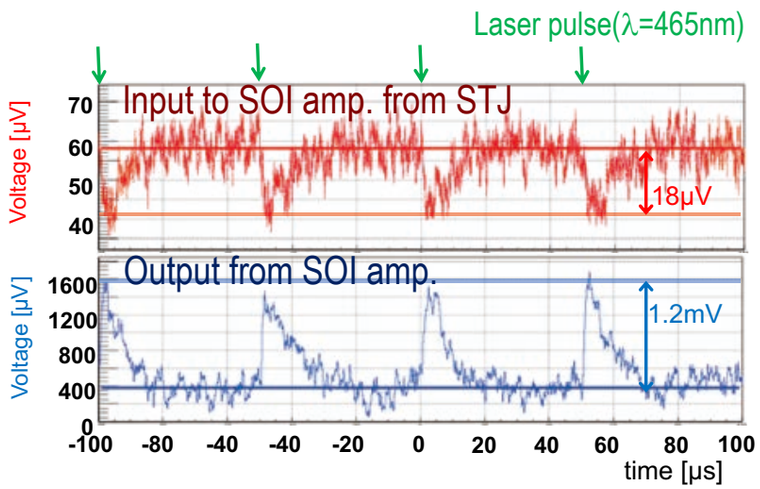


- Amplifier that operates at these low temperatures



FD-SOI-MOSFET

Combining them ...



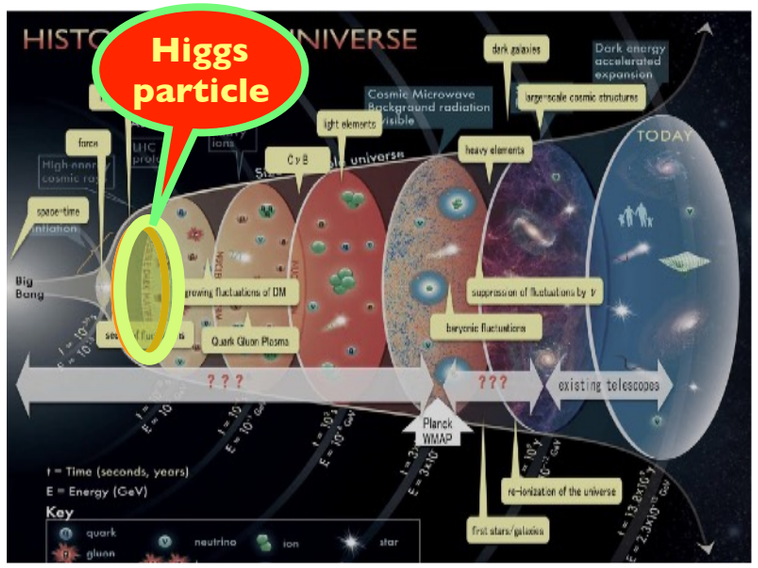
Study of Higgs Particle and Search for New Particles

- 10^{-10} sec after Big Bang: Higgs phase transition, particles get masses.
- Clarification of the nature of the Higgs particle(s): the number of Higgs particles, decay to dark matter particles, self-coupling

  => **Origin of mass, direct search for the dark matter**

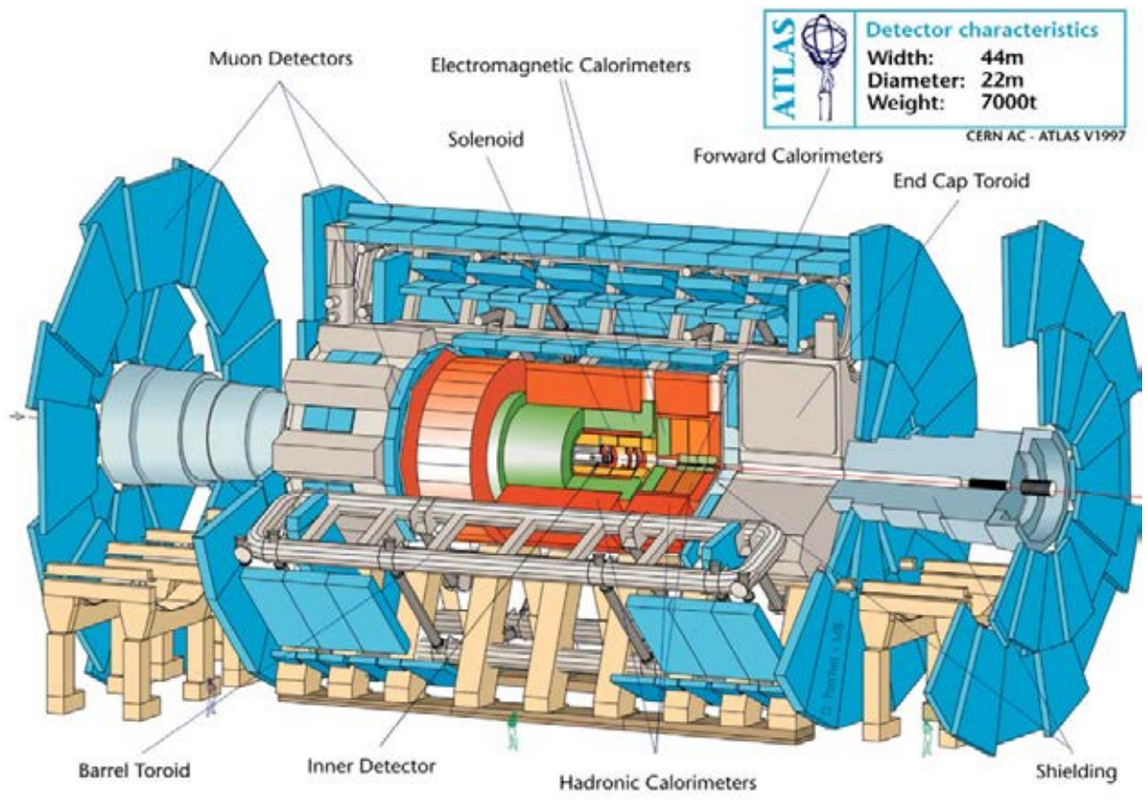
  towards physics beyond the standard model, critical test of the principles of particle physics (gauge symmetry, renormalizability).
- Exploration of super-symmetric particles, extra dimensions, etc.

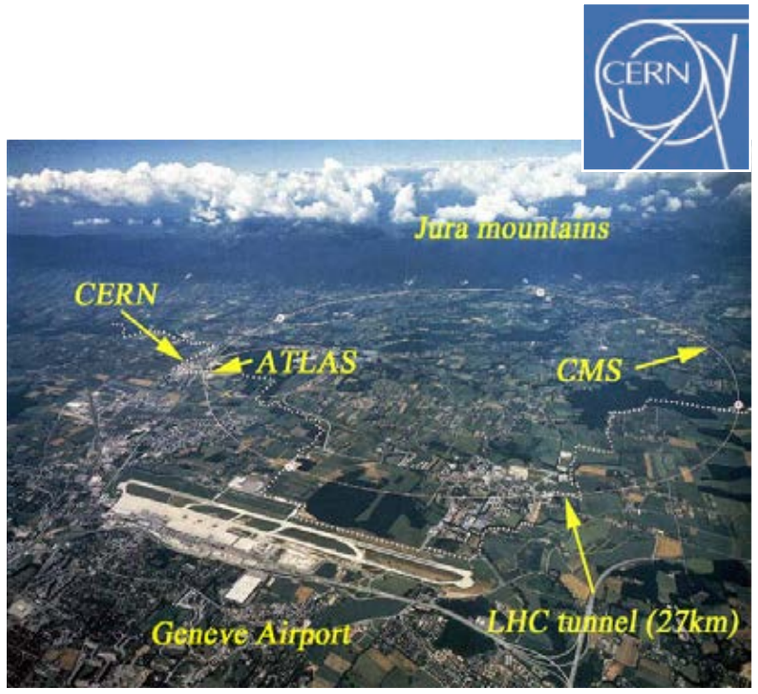
  => **Origin of force, origin of space-time**

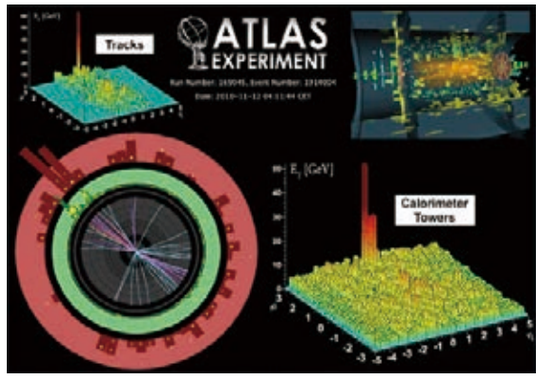


ATLAS experiment at CERN/LHC

Development of high-resolution detectors by the silicon micro strip sensor.



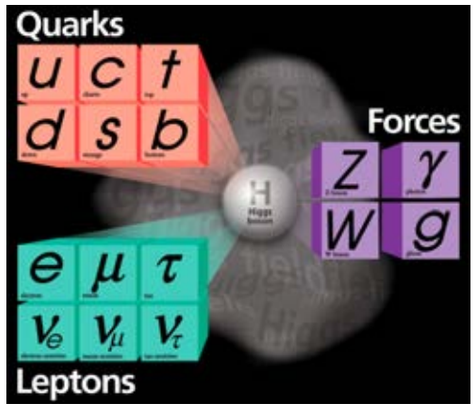




Detailed studies of the Higgs particle :

- **Higgs discovery in 2012**

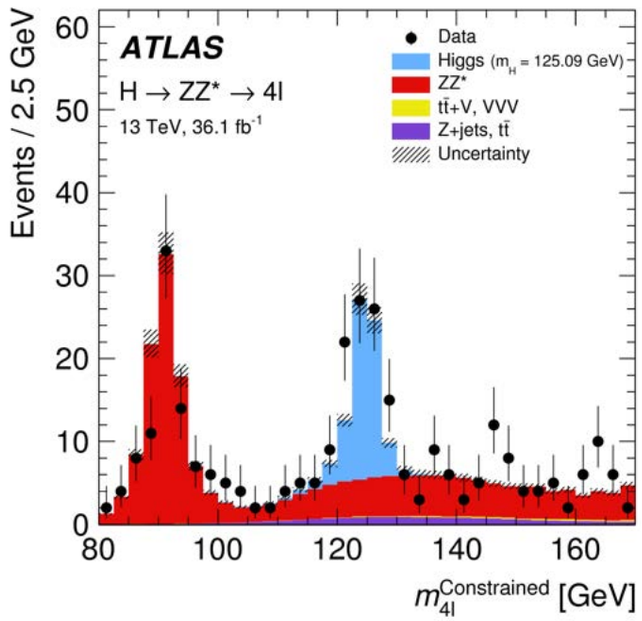
  Nobel prize in 2013 (theorists)

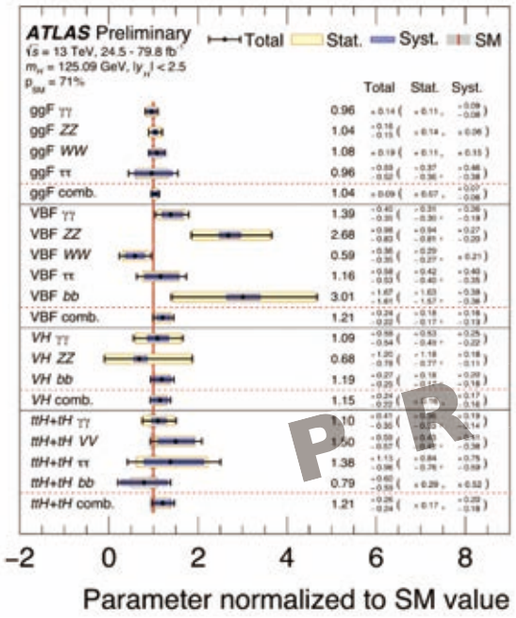


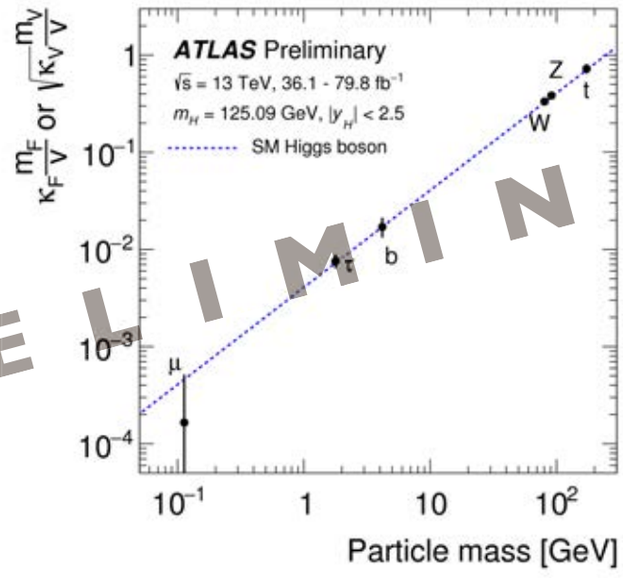
Higgs : a different kind of particle

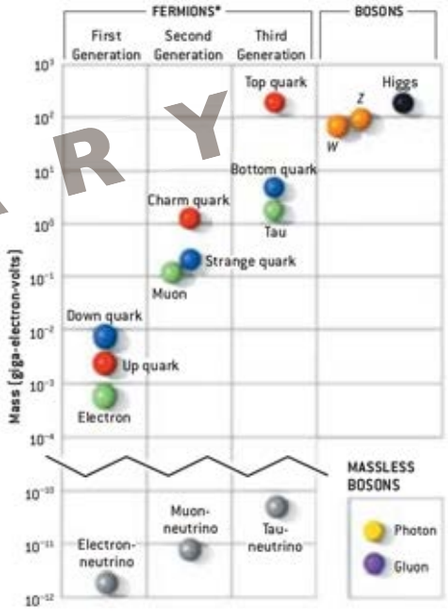
- Neither matter particle, nor a force carrier
- Gives mass to other particles
- New meaning to vacuum

Do the properties agree with theory?
e.g. the couplings to each particle



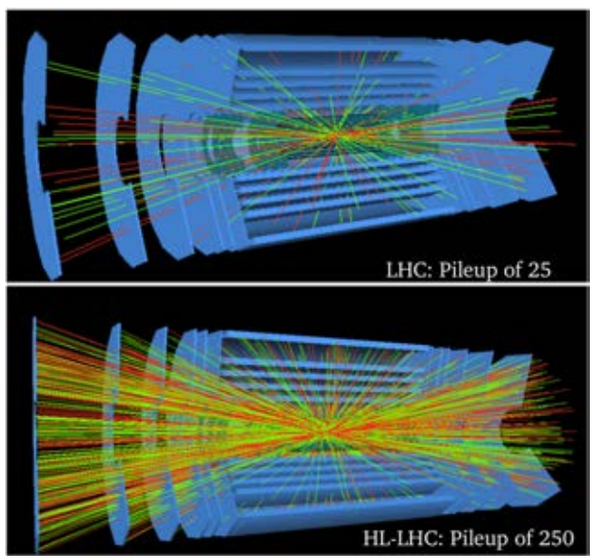






Upgrade for the High-Luminosity LHC

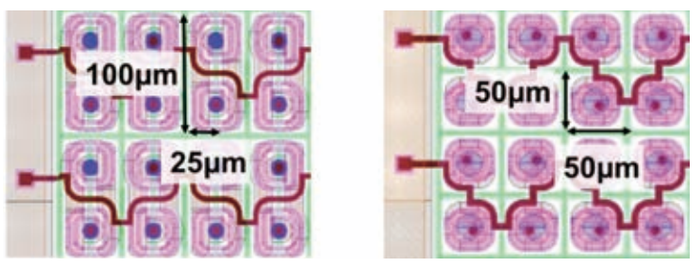
mid 2020s ➜ New particles/phenomena/laws beyond the standard theory?



To cope with the hostile environment

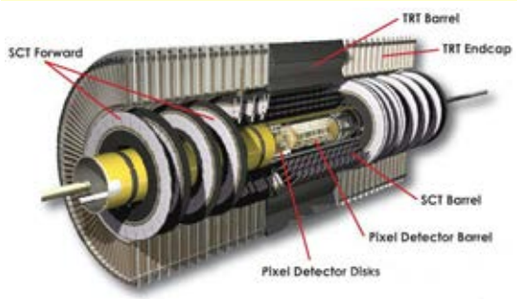
- **Many more particles produced**
- **Higher radiation level**

New pixel detector designs being developed

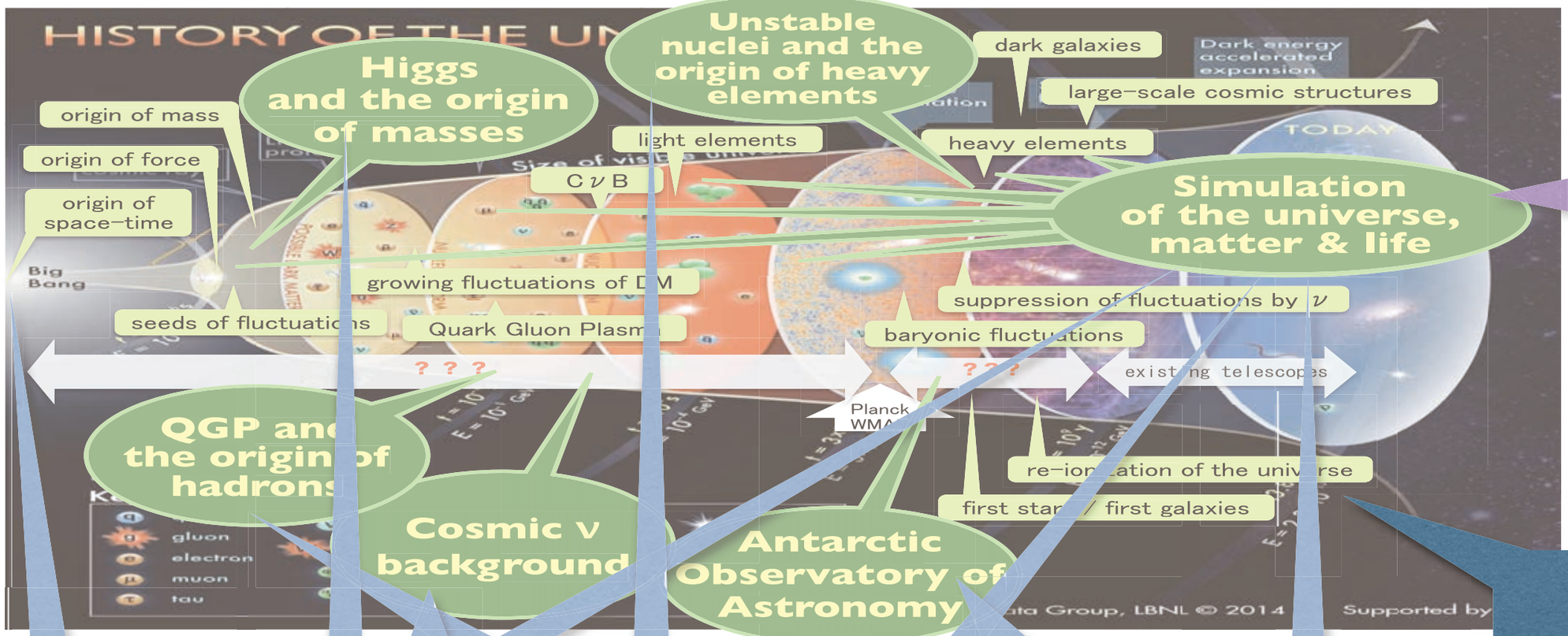


Beam tests at DESY and other places

Existing ATLAS inner tracking detector



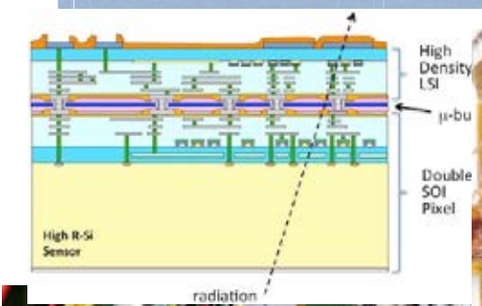
Tomonaga Center for the History of the Universe



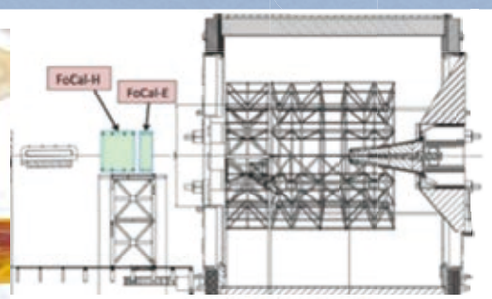
Center for Computational Sciences

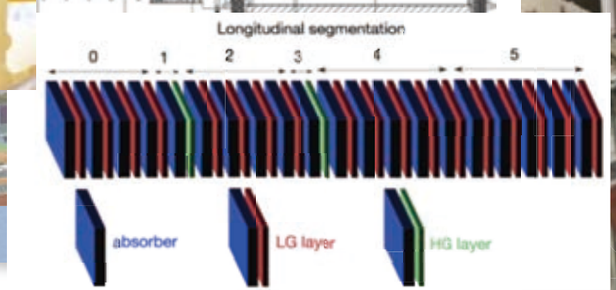
JICFuS JCAHPC

Division of Elementary Particles

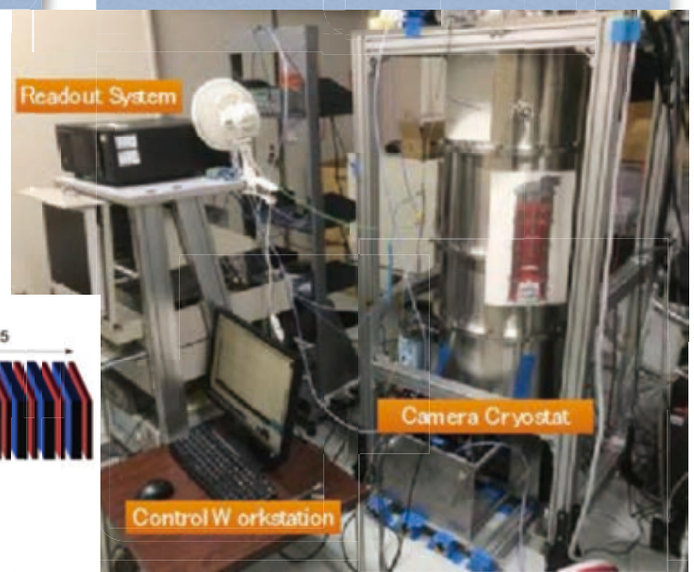


Division of Quark Nuclear Matters



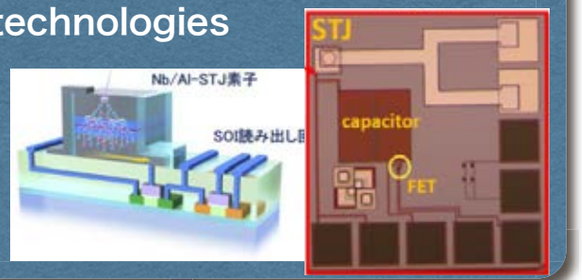


Division of Antarctic Astrophysics



Division of Photon and Particle Detectors

• Development of PPD by superconducting and SOI technologies



Tsukuba Research Center for Energy Materials Science

TIA-ACCELERATE, . . .

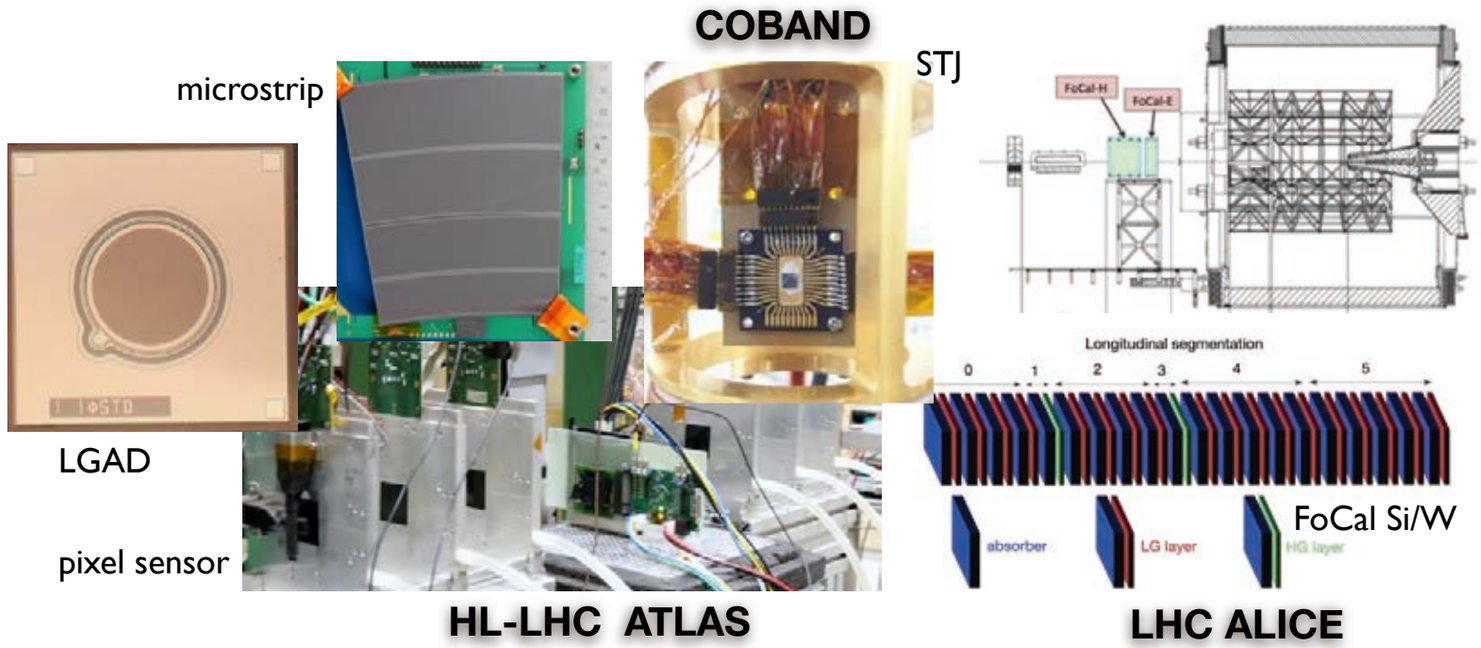
Division for Development of Photon and Particle Detectors

Advanced detectors enabling new physics measurements

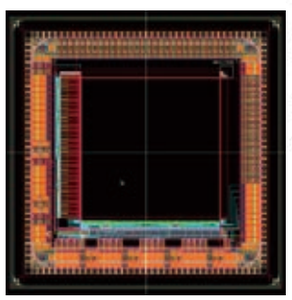
Advanced detectors based on new technologies promote and enable measurements in various physics area beyond the current limitations. The Division supports R&D of new detectors for the projects of TCHoU and develops innovative detectors in the framework of TIA activities.

Development of PPDs in close linkage with other TCHoU divisions

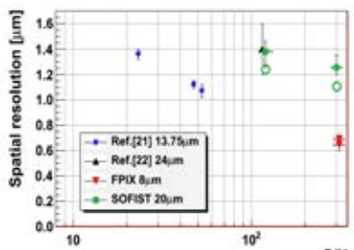
Developments of silicon semiconductor devices for ATLAS and ALICE detector upgrades, STJs for COBAND project, and detectors for other TCHoU projects are pushed forward by the Division with exchanging knowledge and expertise.



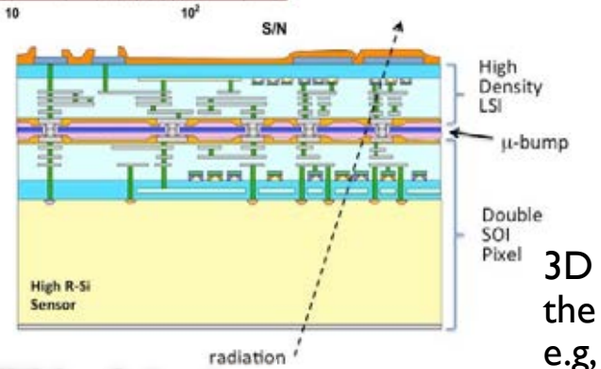
Innovative detectors in TIA



VLSI design

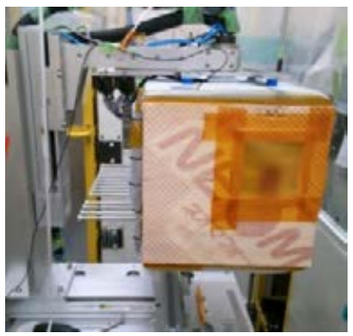


World-best spatial resolution 0.65mm achieved in 2017



SOI monolithic detector

3D stacking enhances the sensor capability, e.g, for ILC experiment



Rad-hard detector R&D

TIA (Tsukuba Innovation Arena) brings together the potentials and resources of five organizations in the Tsukuba area. The Sensor & Imaging Square of TIA is organized for developments of advanced detectors to create new scientific fields and industries.

Innovative monolithic pixel detectors are being realized by the SOI technology. Design and fabrication of VLSI are made in collaboration with KEK and VDEC (U Tokyo). 3D stacking using μ-bumps enables further enhancement of the sensor capability.

The projects for STJs and imaging of massive objects (muon-radiography) are also included in the Square.

Tomonaga Center for the History of the Universe

Mission:

- construction of an integrated view on the History of the Universe
- by clarifying key processes in the dynamical evolutions of the Universe
- thru interdisciplinary and international cooperations of particle-, nuclear- and astro-physics