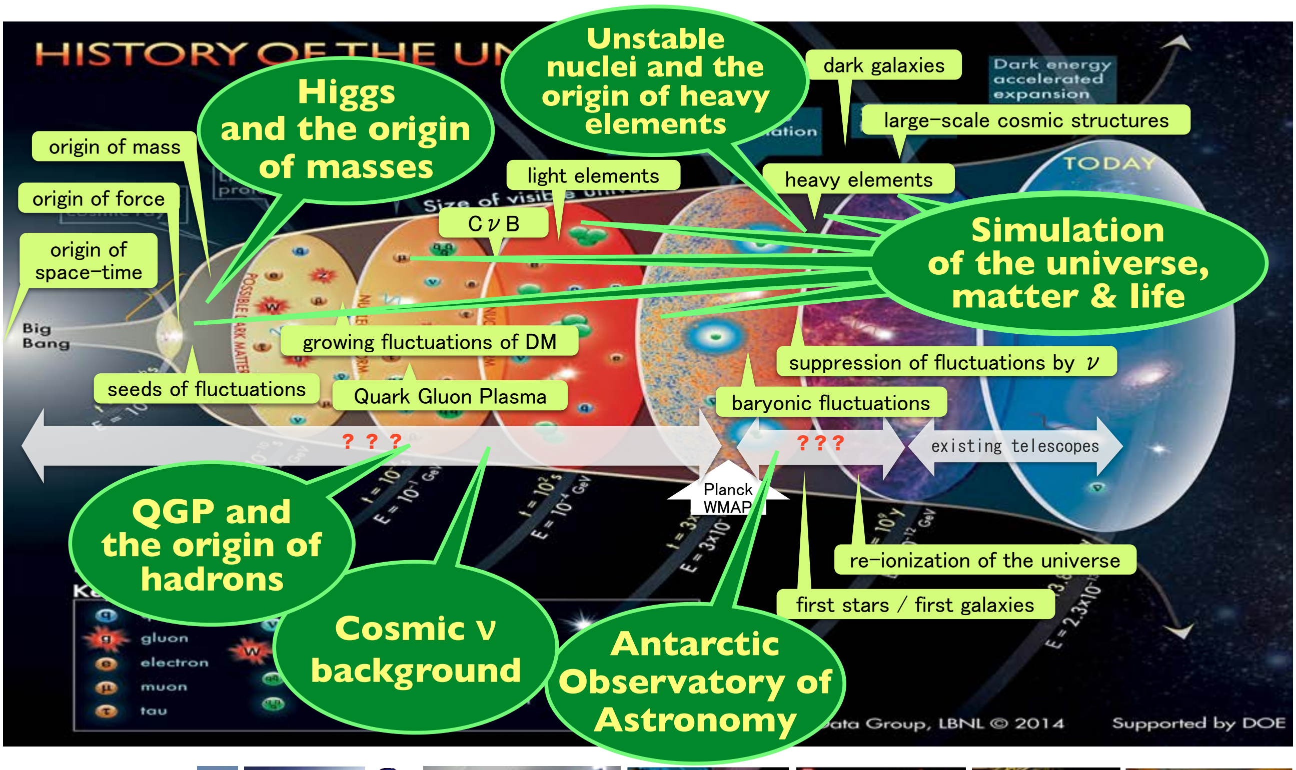
https://tchou.tomonaga.tsukuba.ac.jp/eng

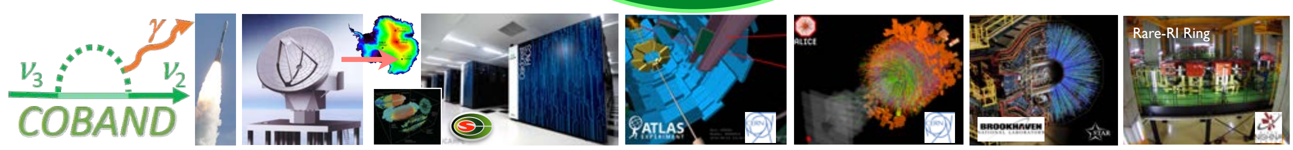
About the Tomonaga Center

Tomonaga Center for the History of the Universe (TCHoU) was founded in 2017 as a research center at the University of Tsukuba to clarify the genesis of the Universe as well as the origin of matter and life through construction of an integrated view of the History of the Universe.

Why our Universe was bone and how it developed into the present state? Since its birth by the Big Bang, the Universe has experienced various drastic events. Because the Universe is not a stable object, we have to understand and explain the present state as a consequence of dynamical processes the Universe has experienced. Though many events in the History of the Universe have been clarified, still many pieces are missing to understand our Universe today.

At Tsukuba, five experimental projects in the area of astrophysics, particle physics, and nuclear physics were selected in the Master Plan 2017 of the Science Council of Japan as scientifically important projects to be pushed by the whole community, i.e., "Search for the decay from the cosmic neutrino background", "Study of the quark-gluon plasma phase by high-energy heavy ion collision experiment", "Antarctic Astrotelescope Project", "Heavy-elements science through improvement of RI Beam Factory", and "Particle experiments by the high-luminosity Large Hadron Collider (HL-LHC)". Based on close collaborations with the Center for Computational Science (CCS) that pushes forward the "Cosmo-Simulator Project -From the genesis of the Universe to the creation of life-", TCHoU connects these five projects to cast a new light on the missing pieces in the History of the Universe.

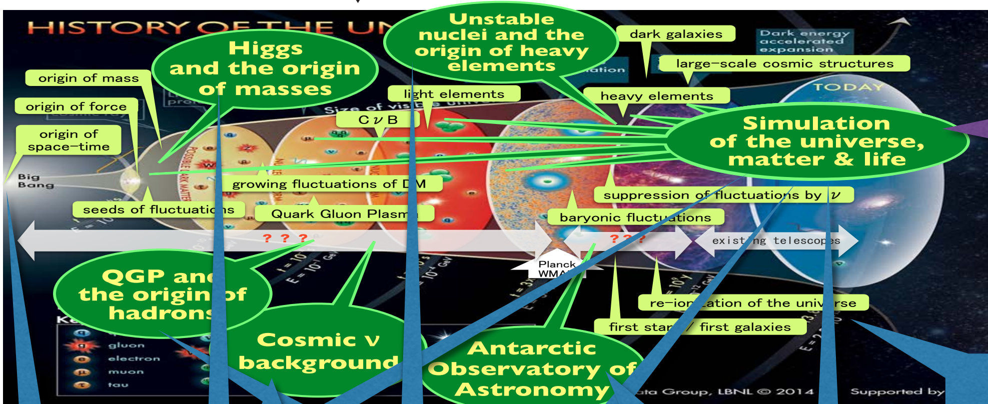




宇宙史研究センター
Tomonaga Center for the History of the Universe

- センター長・副センター長 / Director / Codirector
  - 運営協議会 / Steering Committee
  - 運営委員会 / Administration Committee
  - 構成員会議 / Research Member Meeting
  - 融合研究企画調整室 / Office for Integrated Researches
    - 計算科学研究センター (CCS)
    - 数理物質系 数理科学研究コア (RCMS)
    - エネルギー物質科学研究センター (TREMS)
- 南極天文学研究部門 / Div. of Antarctic Astronomy
- 素粒子構造研究部門 / Div. of Elementary Particles
- クォーク・核物質研究部門 / Div. of Quark Nuclear Matters
- 光量子計測器開発部門 / Div. of Photon and Particle Detectors

Tomonaga Center for the History of the Universe



Center for Computational Sciences

JICFuS　JCAHPC

Division of Elementary Particles

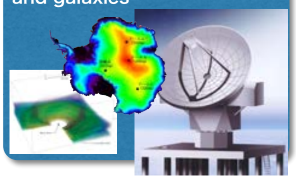
- Higgs precision study by ATLAS experiment
- Detection of cosmic neutrino background by COBAND experiment
- Theory of quantum gravity and superstrings

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

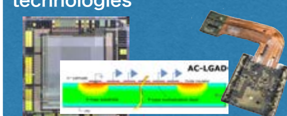
Division of Antarctic Astrophysics

- 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, . . .

Members, Associates, Research Fellows

Director: Prof. F. Ukegawa　　**Codirector: Prof. N. Kuno**

Div. of Antarctic Astronomy　　**Chair: Prof. N. Kuno**

Members: Assi.Prof. T. Hashimoto, Assi.Prof. S. Honda

Associates: Prof. K. Sorai (Hokkaido U.), Prof. N. Nakai (Kwansei Gakuin U.), Prof. M. Seta (Kwansei Gakuin U.), Prof. Y. Kasai† (NICT), Asso.Prof. T. Nishibori† (JAXA), Asso.Prof. Y. Watanabe (Shibaura Inst. Tech.), Asso.Prof. H. Yajima (CCS), Asso.Prof. H. Matsuo (NAOJ)

Div. of Elementary Particles　　**Chair: Asso.Prof. Y. Takeuchi**

Members: Prof. N. Ishibashi, Prof. F. Ukegawa, Asso.Prof. G. Ishiki, Assi.Prof. K. Sato, Assi.Prof. T. Iida, Assi.Prof. S. Hirose, Assi.Prof. Y. Asano, Prof. S. Kim††

Associates: Prof. S. Matsuura† (Kwansei Gakuin U.), Asso.Prof. Y. Ikegami† (KEK), Prof. Y. Satoh (Fukui U.)

Div. of Quark Nuclear Matters　　**Chair: Prof. S. Esumi**

Members: Prof. A. Ozawa, Prof. T. Chujo, Assi.Prof. T. Niida, Assi.Prof. T. Nonaka, Prof. K. Kanaya††

Associates: Prof. Y. Kuramashi, Asso.Prof. K. Sasa, Assi.Prof. T. Moriguchi, Prof. T. Sugitate†† (Hiroshima U.), Prof. Y. Akiba† (RIKEN), Prof. M. Wakasugi† (Kyoto U.), Prof. S. Nagamiya (RIKEN), Asso.Prof. T. Gunji (U.Tokyo), Prof. K. Shigaki (Hiroshima U.), Prof. H. Sako (CA JAEA), Prof. T. Saito† (RIKEN), Asso.Prof. Y. Yamaguchi† (RIKEN), Asso.Prof. T. Yamaguchi† (Saitama U.), Asso.Prof. K. Ozawa† (KEK), Asso.Prof. M. Inaba† (Tsukuba U. of Tech.)

Res.Fellow: S. Sakai

Div. of Photon and Particle Detectors　　**Chair: Prof. A. Ozawa**

Members: Prof. S. Esumi, Prof. T. Chujo, Asso.Prof. Y. Takeuchi, Assi.Prof. K. Sato, Assi.Prof. S. Hirose, Assi.Prof. S. Honda, Prof. S. Kim††

Associates: Prof. E. Nishibori, Asso.Prof. S. Tomita, Asso.Prof. T. Kondo, Assi.Prof. K. Nakamura (KEK)

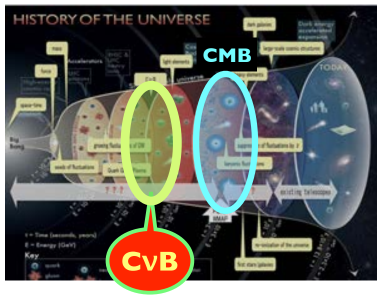
†) Visiting (Asso.) Prof., ††) Specially Appointed Prof., *) Research unit under IERL Program.

2025/04

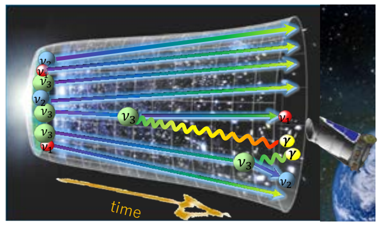
The name of the "Tomonaga Center" is from Dr. Sin-Itiro Tomonaga, the second Nobel Laureate from Japan, who made fundamental contributions in constructing relativistic quantum field theories, the renormalization theory, theory of collective motions, etc. and also a founder of the physics institute at Tsukuba.

Sin-Itiro Tomonaga
1906 – 1979
(Tomonaga Memorial Room, Univ. Tsukuba)

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.

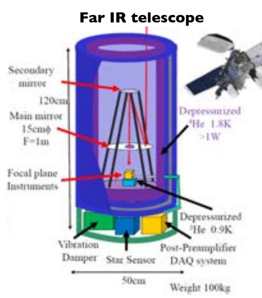


☆ COBAND Project: exploration of CνB by rocket and satellite experiments

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.)



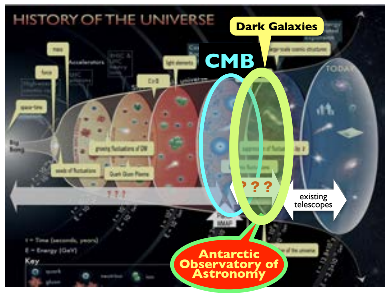
Step 2: Satellite experiment

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

Development of SOI-STJ detectors.

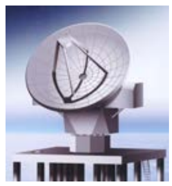
Operation at extreme low temperatures confirmed.
(Nagata et al., 2009).

Antarctic Observatory of Astronomy



- Present Universe is in an ionized plasma state. On the other hand, it was neutral 0.3 Bi. years ago as the CMB is observable.
  <= Ionization due to UV radiation from the stars.
- Existing telescopes could identify only 30% of required stars/galaxies.
  Remaining 70% -- "dark galaxies" -- should be found in the deep space.
- To understand the formation of galaxies, stars, and life, it is indispensable to clarify the ionization mechanism.

☆ Deep-space exploration by THz Telescope at Antarctica



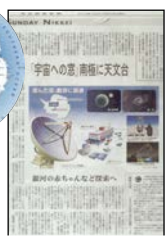
Step 1: 10m THz Telescope

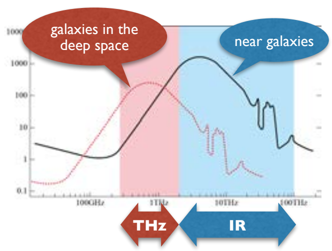
Due to the expansion of the Universe, lights from the deep-space are in the THz range, which are dumped by the water vapor in the atmosphere.

=> **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: New Dome Fuji (3800m, Japan)





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.

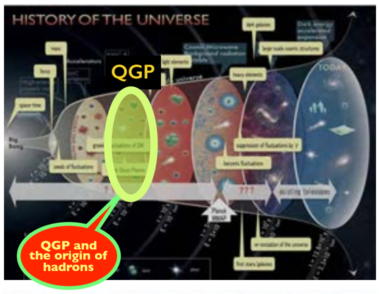
Planned site: New Dome Fuji (3800m, Japan)

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.

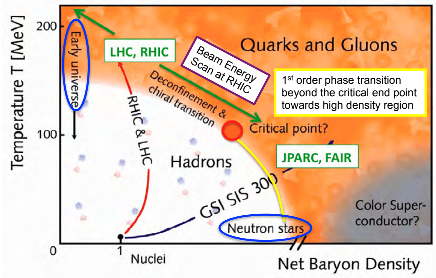
=> Initial condition for the evolution of ordinary elements.

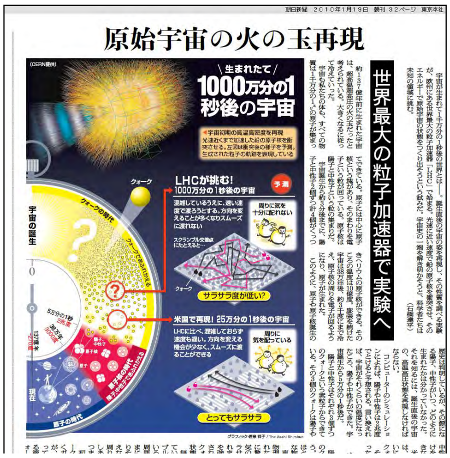


☆ High-energy heavy-ion collision experiments

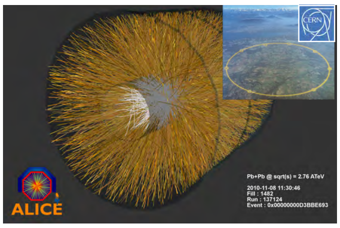
Create QGP on the earth by mankind ("Little Bang").

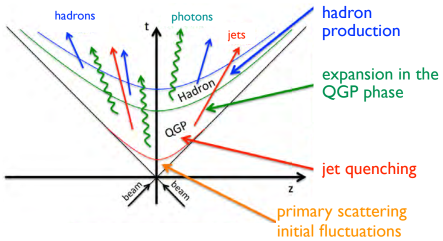
=> Clarify the nature of the phase transition and the quark nuclear matters (fluctuations, expansion, transition temperature, viscosity, etc.) around the transition temperature.





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





Study of Higgs Particle and Search for New Particles

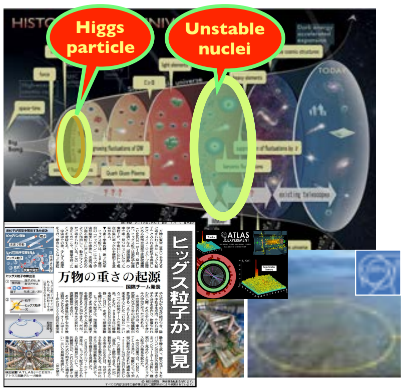
- 10^{-10} sec after Big Bang: Higgs phase transition, particles get masses.
- Clarification of the nature of the Higgs particle(s): the number of Higgs particles, decay to dark matter particles, self-coupling

=> **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).

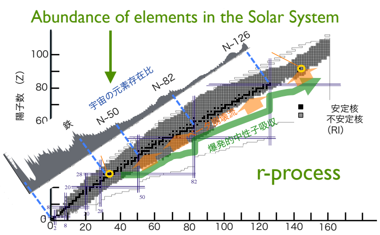
- Exploration of super-symmetric particles, extra dimensions, etc.

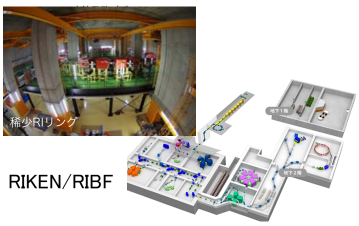
=> **Origin of force, origin of space-time**



☆ ATLAS experiment at CERN/LHC

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





RIKEN/RIBF

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).

☆ Study of unstable nuclei using heavy-ion accelerators

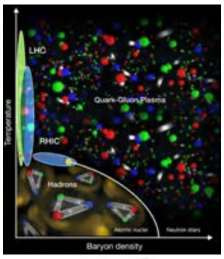
Measure masses and lifetimes of unstable nuclei by Rare RI-Ring at the RI Beam Factory (RIBF) of RIKEN, and obtain the reaction rates for the r-process.

1st step: Study the reason for the peak at N≈50;

2nd step: N≈82; 3rd step: N≈126

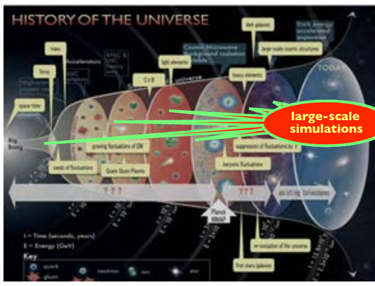
Theoretical investigations of Universe, Matter, and Life

Large-scale simulation of Universe and Matter

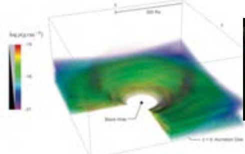


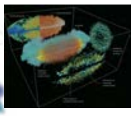
Under a close collaboration with the **Center for Computational Science (CCS)**, carry out simulations on the Universe, matter, and life to clarify the origin of their generation and structure formation. Combine the latest results of theoretical and experimental studies.

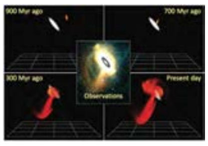
- **Determination of fundamental parameter of Nature**
- **Phase structure and equation of state of QCD at finite temperature and density**

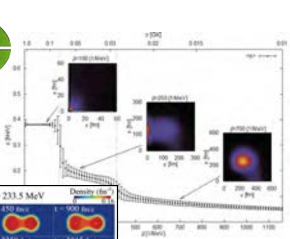


=> Genesis of matter at 10^{-6} sec, inner structure of neutron stars, dark matter





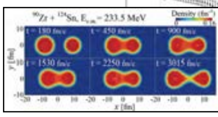




- **Nucrear reactions**
- **Unstable nuclei**
- **r-process**

=> Light and heavy elements in the Universe

- **Dark Matter, large-scale structure of the Universe**
- **Formation and collision of galaxies**
- **Black hole and gravitational wave**
- **Chemical evolution of the Universe**

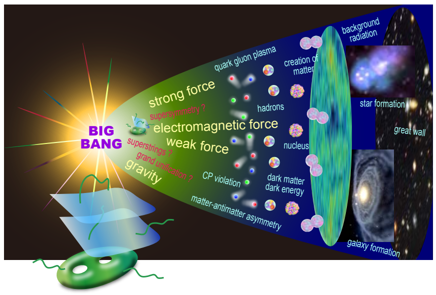


=> Origin of structures of the Universe, origin of organic molecules and life

Super-string and super-gravity theories

Investigations of the string theory towards quantum theory of gravity and unified theory of particles.

=> Origin of the space-time, origin of particles and forces.



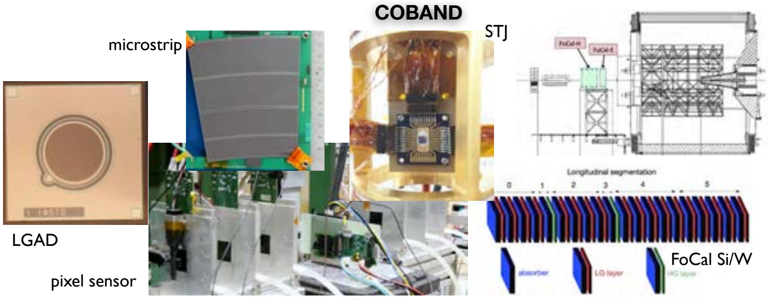
Division for Development of Photon and Particle Detectors

Advanced detectors enabling new physics measurements

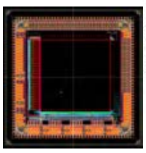
Advanced detectors based on new technologies promote and enable measurements in various physics area beyond the current limitations. The Division supports R&D of new detectors for the projects of TCHoU and develops innovative detectors in the framework of TIA activities.

Development of PPDs in close linkage with other TCHoU divisions

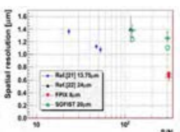
Developments of silicon semiconductor devices for ATLAS and ALICE detector upgrades, STJs for COBAND project, and detectors for other TCHoU projects are pushed forward by the Division with exchanging knowledge and expertise. (For details, visit corresponding project pages.)



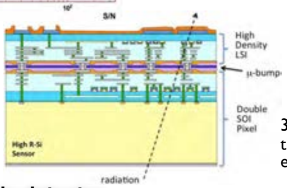
Innovative detectors in TIA



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

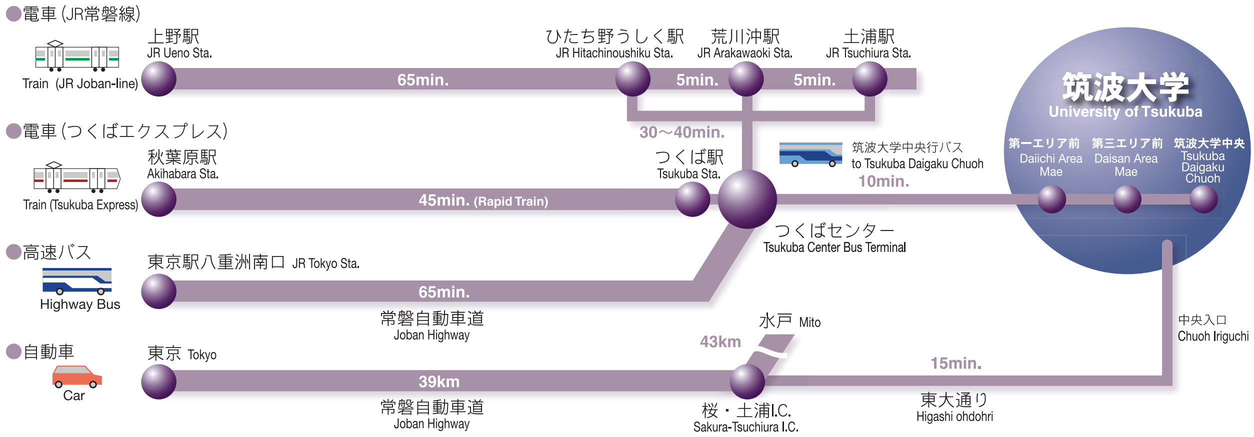
Rad-hard detector R&D

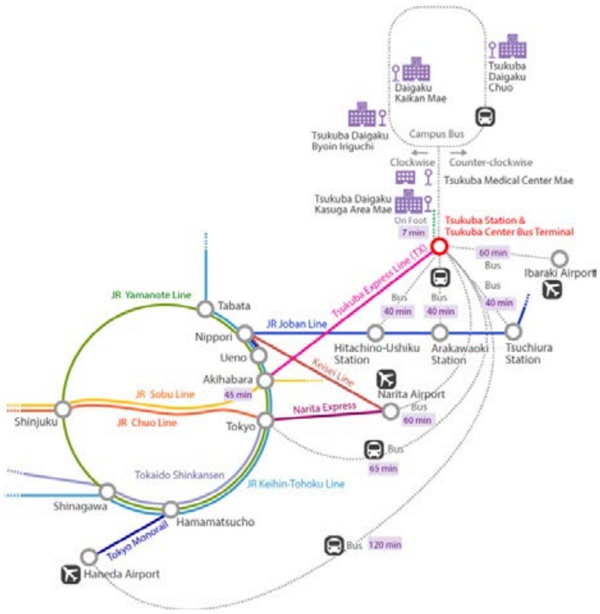
TIA (Tsukuba Innovation Arena) brings together the potentials and resources of five organizations in the Tsukuba area. The Sensor & Imaging Square of TIA is organized for developments of advanced detectors to create new scientific fields and industries.

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.

大学へのアクセス Access to University of Tsukuba





Tomonaga Center for the History of the Universe

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