EIC RIKEN / U-Tokyo Collaboration Meeting

Host: Jim Yeck

February 3, 2025

EIC-Japan status
EIC project in Universities and RIKEN
International Quantum Physics Network

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Outline

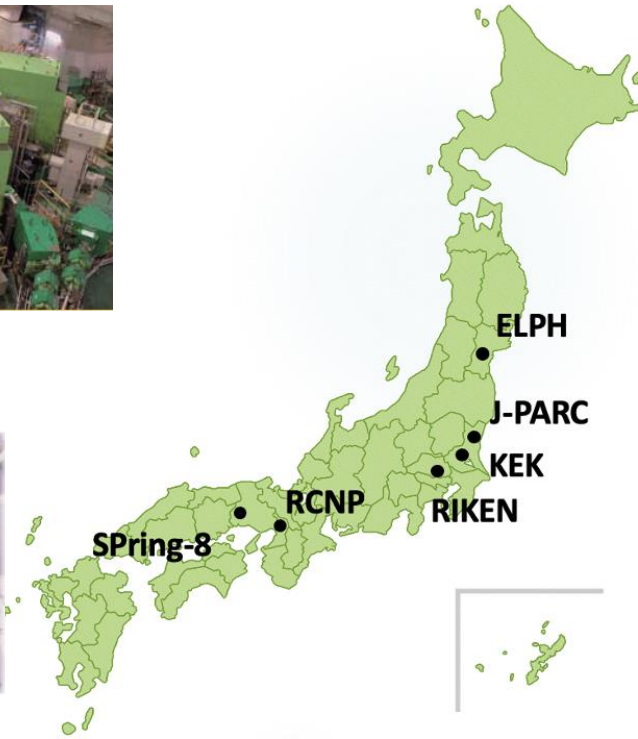
- Nuclear Physics in Japan
- Recent progress for EIC in Japan
  - MEXT expert committee meeting
  - RIKEN Fundamental Quantum Science
  - International Quantum Physics Network among Universities
- Status of Japanese institutes in ePIC Collaboration
- Contributions to ePIC

Nuclear Physics in Japan

- Low Energy Nuclear Physics
  - RIBF, RCNP
  - ~300 researchers
- Strangness and Hadron Physics
  - J-PARC, Spring-8, ELPH
  - ~200 researchers
- High Energy QCD Physics
  - LHC, RHIC, EIC
  - ~100 researchers
- Total ~ 600 researchers
  - High-energy ~ 900
  - Atomic energy society ~ 6500
  - Plasma & nuclear fusion ~ 1200

RIBF

RCNP

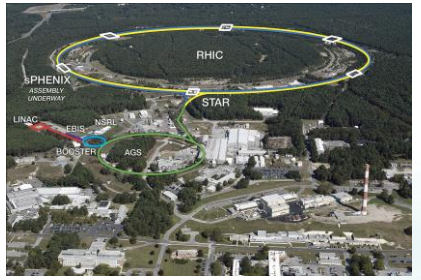


J-PARC

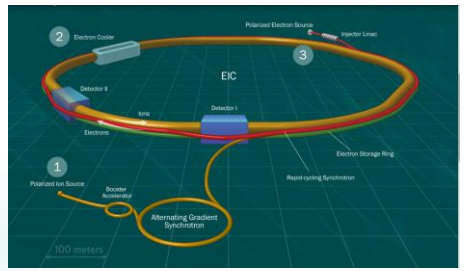
ELPH

LHC

RHIC



EIC



Building collaborative research system

- There are so many NP projects in Japan at many facilities (RIBF, J-PARC, LHC/RHIC, EIC) under the limitted resources (~600 researchers).

- It will be important to establish collaborative research system across the different fields to share resources across various projects, rather than having them monopolized by individual projects.

- EIC is the good opportunity to establish such system using broad scientific topics covering from low to high-energy nuclear physics and synergies with other facilities. EIC can contribute to the new quantum research opportunities (fundamental quantum science in RIKEN) and to develop international human resources in quantum era.

Workshops for EIC in FY24

- Three workshops and one JPS symposium related to EIC to attract more proples from other communities.
  - EIC physics from low to high-energy (~150 participants)
  - Topcial workshop for Short-range correlation (~60 partcipants)
  - Streaming readout XII (~90 partcipants)

https://indico2.riken.jp/event/5050/

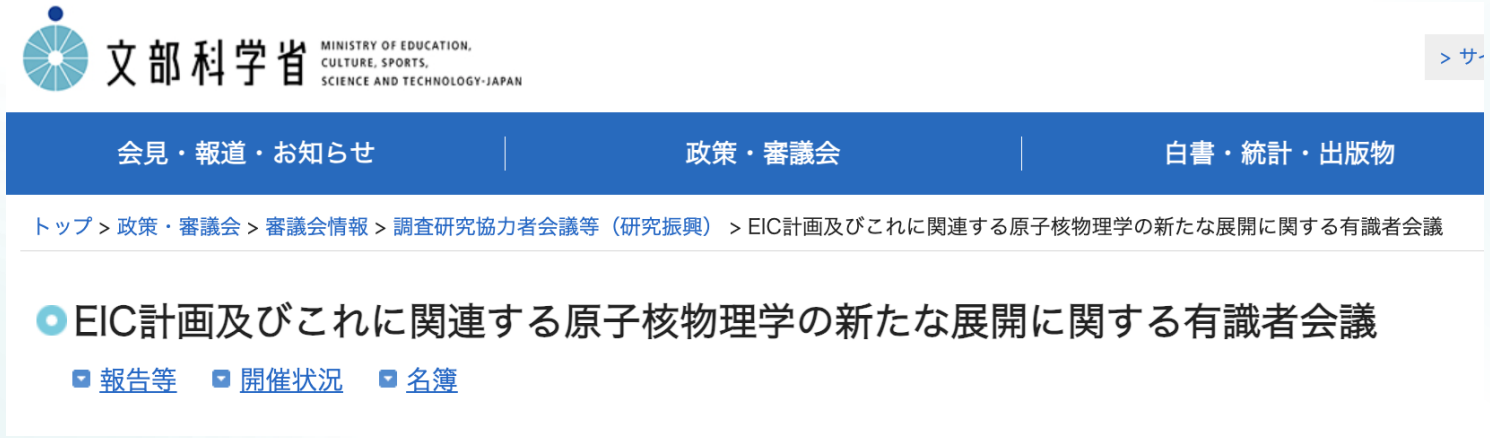
https://indico3.cns.s.u-tokyo.ac.jp/event/315/

https://indico.rcnp.osaka-u.ac.jp/event/2484/#b-2012-eic-eic

https://indico.bnl.gov/e/SRO-XII

EIC Expert Committee Meeting

- MEXT organized EIC Expert Committee Meeting.
  - “EIC project and related new developments in nuclear physics“



  - 10 committee members consist of physicists from nuclear physics, high-energy, fusion energy, and quantum computing.
  - Key questions addressed
    - Which new developments EIC can bring in entire NP community?
    - How the EIC and NP contributes to quantum science, fusion energies, etc?

EIC Expert Committee Meeting

- 1st meeting (May, 2024):
  - Overview of EIC project, Japanese plans, and related developments in NP (T.G)
    - bTOF+ZDC+DAQ/Computing $30M, Human resources + travel : $30M
- 2nd meeting (June, 2024):
  - Current status of NP in Japan and expects for EIC (Prof. Takashi Nakano)
  - Scientific significance of the EIC and its effects to other fields (Prof. Tetsuo Hatsuda)
  - Homework of 1st meeting (T. G)
- 3rd meeting (July, 2024):
  - Discussion and summary for interim report

EIC Expert Committee Meeting

- **Summary of interim report (link)**
  - **EIC and New developments in nuclear physics**
    - ***Quantum physics has advanced understanding across different hierarchical scales (particles, nuclei, atoms, molecules, solids, cosmic systems). Challenges persist, requiring cross-scale comprehension. Nuclear physics serves as a pivotal discipline consolidating modern physics' fundamental concepts.***
    - ***By using EIC opportunities, NP aims to create "Multi-scale Quantum Dynamics Research" from quark to nucleus by integrating theory, experiments, and computational science to uncover universal quantum dynamics laws across hierarchical scales, including quantum resilience, emergent quantum many-body phenomena, and non-equilibrium quantum systems.***
    - ***This research is expected to contribute to Multi-scale Quantum Dynamics Research through advanced quantum understanding and to groundbreaking scientific discoveries, such as unraveling the origins of proton mass and spin, exploring potential new energy sources, and potentially advancing quantum computing technologies.***

EIC Expert Committee Meeting

- **Summary of interim report (link)**
  - **Recommendation**
    - ***In order to proactively promote the participation of Japanese universities and research institutes in the EIC and new developments in nuclear physics related to EIC, it is necessary for the Ministry of Education, Culture, Sports, Science and Technology to actively support the efforts of institutions in RIKEN and Universities and researchers.***

Fundamental Quantum Science Program

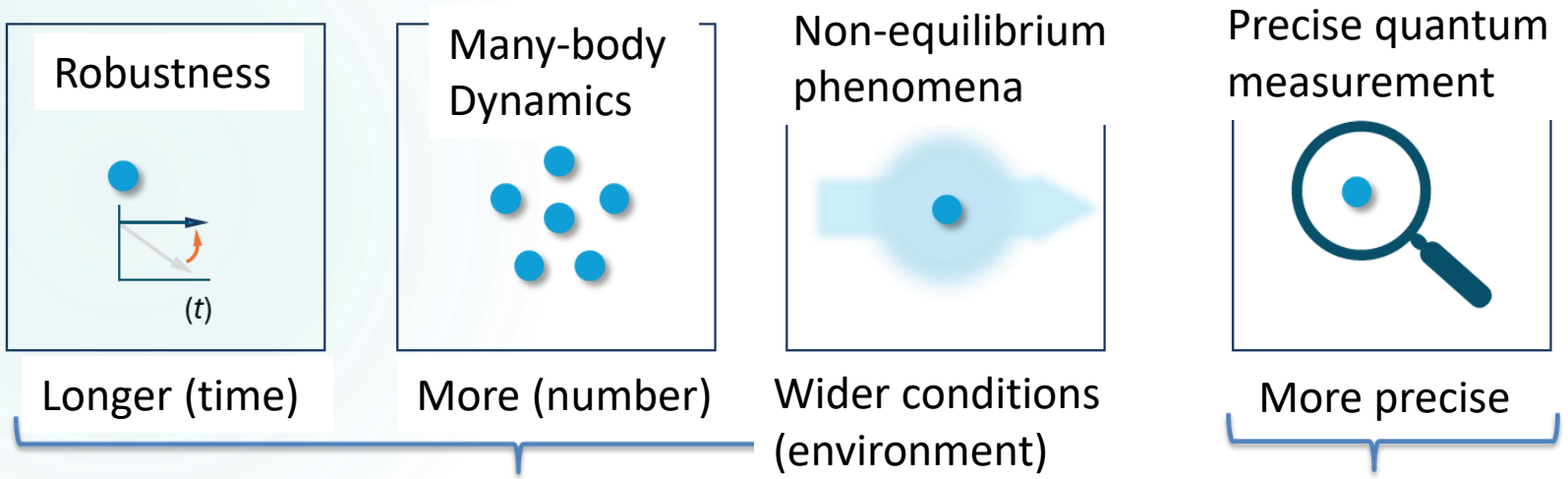
RIKEN launched fundamental quantum science program

https://www.riken.jp/en/research/labs/trip/fundament_qtm_sci/

Goal of FPQS

To become a world lead in quantum technology by the 2030s, RIKEN will utilize the EIC project to elucidate the fundamental principles of quantum mechanics and establish the active control of quantum systems.

Four elements necessary to actively control quantum



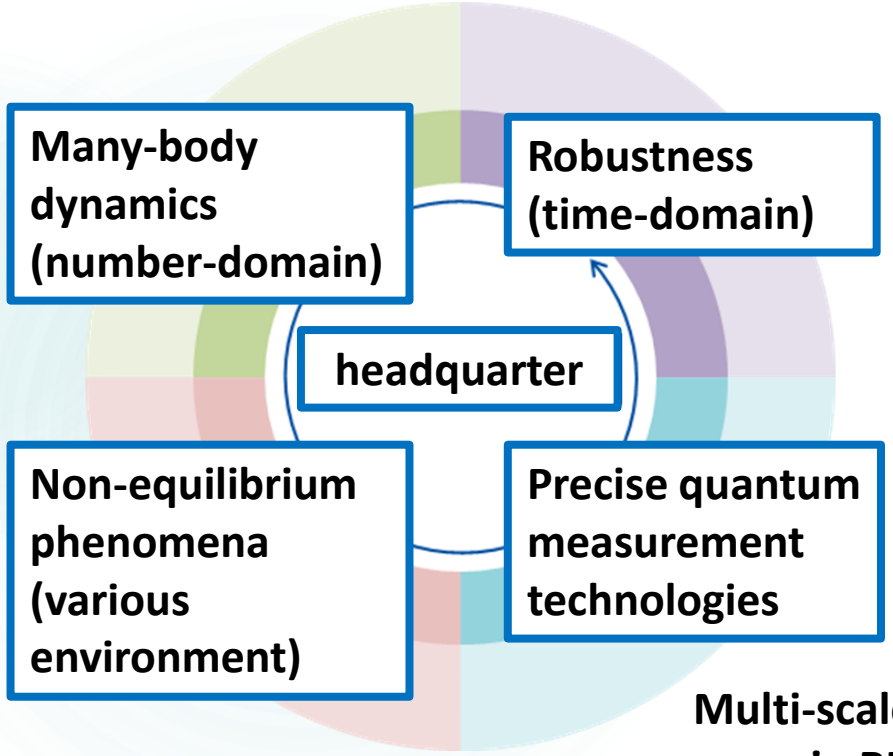
Eliminate constraints of time, number, and environment and connect to active control of quantum states

Applying the results toward new measurement technology

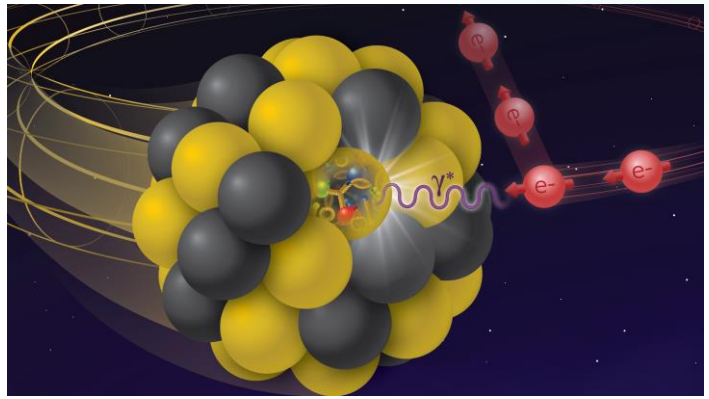
FY25 budget ~ $10M (shared by many research centers in RIKEN including Nishina Center – hosting EIC in RIKEN)

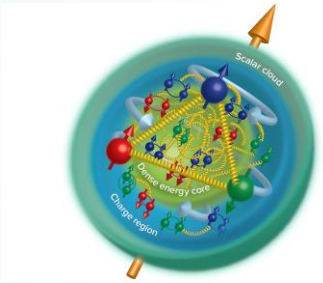
Fundamental Quantum Science Program

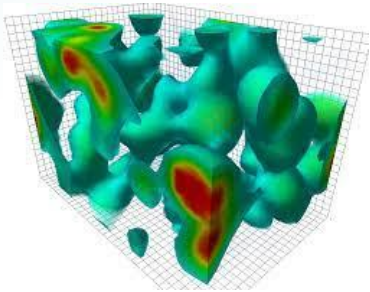
RIKEN FQSP
Exploration of fundamental quantum principles



Electron Ion Collider
elucidation of proton and nucleus (dynamical) structure







Multi-scale quantum dynamics joint research group in RIKEN Nishina Center (Uesaka, Gunji)
Interdisciplinary from RIBF to EIC

Fundamental Quantum Science Program

- RIKEN-BNL workshop on Fundamental Quantum Science
  - https://indico2.riken.jp/event/4944/
  - Quantum computing, Quantum information, Nuclear Physics

Makoto Gonokami, President, RIKEN (2022-)
He was President, University of Tokyo (2015-2021)

Quark-Nuclear Science Institute in U-Tokyo

Established in 2024 to lead EIC sciences in Japan

https://www.qnsi.s.u-tokyo.ac.jp/

読賣新聞オンライン

東大が「大型加速器」の研究拠点設置へ...国際共同研究を主導する若手研究者ら育成

2024/05/28 05:00

加速した粒子同士を衝突させて物質の構造などを解明する研究を強化するため、東京大が７月、新たな拠点を設置することがわかった。１兆分の１ミリレベルの原子核内部を観察できる米国の大型加速器「ＥＩＣ」の建設計画に日本が参加することを見据え、加速器を使った米国などとの共同研究を主導する人材を育成する。

東京大の加速器研究拠点の役割

東京大
クォーク・核物理研究機構 7月に設置
研究や人材育成で連携
理化学研究所や高エネルギー加速器研究機構、大阪大など
研究機会の提供
人材派遣
米ブルックヘブン国立研究所
新型加速器「EIC」 2032年に実験開始

新拠点は「クォーク・核物理研究機構」で、本郷キャンパス（東京都文京区）に事務局を設ける。研究者約１０人で７月から運用を始め、機構長には、中村哲教授（原子核物理学）が就く。

全ての物質は原子で構成され、中心部の原子核は陽子と中性子で出来ている。新拠点は、原子核内部の極微の世界の構造や性質、陽子などを構成する素粒子の一種クォークの研究を行う。

米エネルギー省傘下のブルックヘブン国立研究所（ニューヨーク州）は、粒子の衝突実験を行う大型加速器「ＥＩＣ」を建設する計画で、日本の文部科学省は今月１５日、計画に参加する方針を表明した。計画には２４か国が参加する見通しで、量子コンピューターなど先端技術の実用化にも貢献できると期待されている。

新型加速器「ＥＩＣ」が建設される米ブルックヘブン国立研究所＝同研究所提供

新拠点は、各国との共同研究を見据え、大型加速器を持つ理化学研究所や高エネルギー加速器研究機構のほか、大阪大など複数の国内大学とも連携する。ＥＩＣに派遣する若手研究者らの育成も進め、ＥＩＣが実験を始める２０３２年に向け、日本が国際研究を主導する体制を整える。

中村教授は「国際的な視点を持つ次世代のリーダーを輩出し、日本の研究力向上にも貢献したい」と話す。

Prof. Nakamura
Director of QNSI

In anticipation of Japan's participation in the EIC project in the United States, QNSI will develop human resources who will lead joint research with the United States and other countries using accelerators.

QNSI will also promote the training of young researchers for the EIC, and will establish a system in which Japan will lead international research at the EIC.

https://www.yomiuri.co.jp/science/20240528-OYT1T50039/

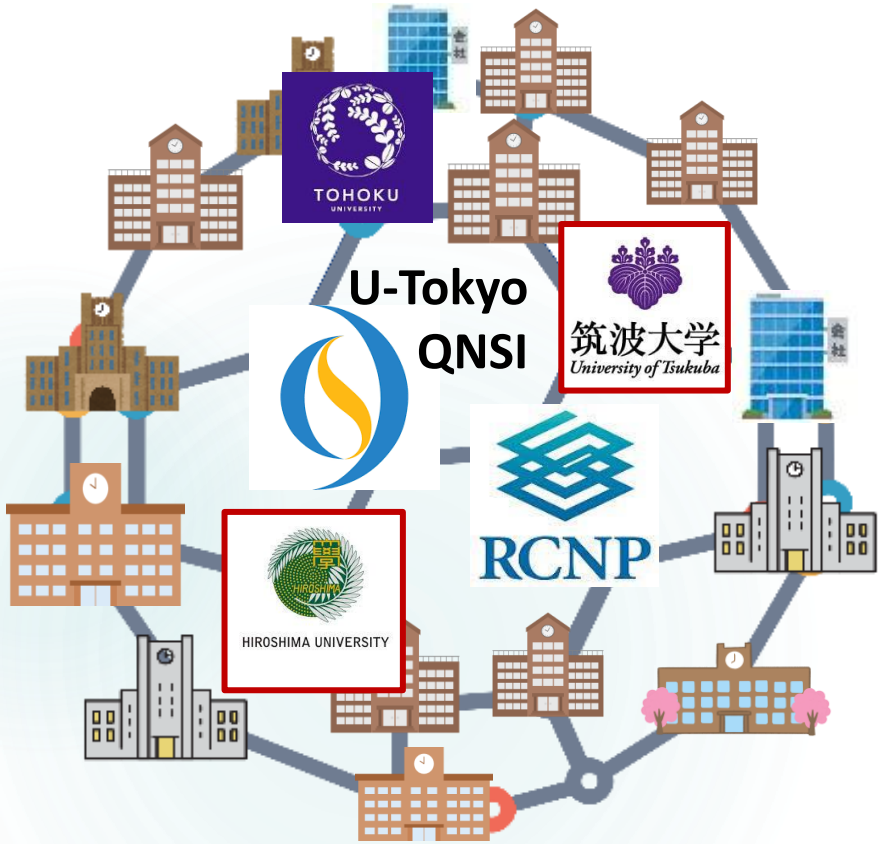
International Quantum Physics Network

U-Tokyo
QNSI

U-Osaka
RCNP
International Joint Usage and Research Center

- New network being built in 2025 among universities
- The primary objectives of the IQPN include:
  - Making network between universties to share resources, technologies, and expertizes and establishing an "All-Japan" framework
  - Leading major international projects such as EIC
  - Creating new international quantum science
  - Developing international young talents
- FY25 budget (~$1M) for U-Tokyo and U-Osaka.
  - ~2 new PIs dedicated for the EIC
- RIKEN + IQPN aims to advance the global leadership of nuclear physics and fundamental quantum science.

International Quantum Physics Network



EIC provides the opportunities to implement new research system in nuclear physics community in Japan.

- **FY26 proposal for budgetary requests:**
  - **Including Tohoku University, Tsukuba University, and Hiroshima University**
  - **Building oversea branches at BNL, JLab, and CERN and adding shareable infrastructures (beamline, large cleanrooms) in IQPN to accelerate:**
    - **Expanding International Collaborative Research such as EIC**
    - **Advancing standardization of technologies such as large-scale streaming data collection/analysis systems and semiconductor sensor technologies**
    - **Enhancing Research and Educational Infrastructure**
    - **Accelerating Interdisciplinary Collaboration and international research network**

Nuclear Physics Consortium

- Nuclear Physics Consortium (NPC) (>2009)
  - 10 institutes (21 people) from nuclear physics community participate in Belle(2) experiment as one cluster.
    - Contact person: Takashi Nakano (RCNP)
    - Leading efforts for exotic hadrons, fragmentation functions

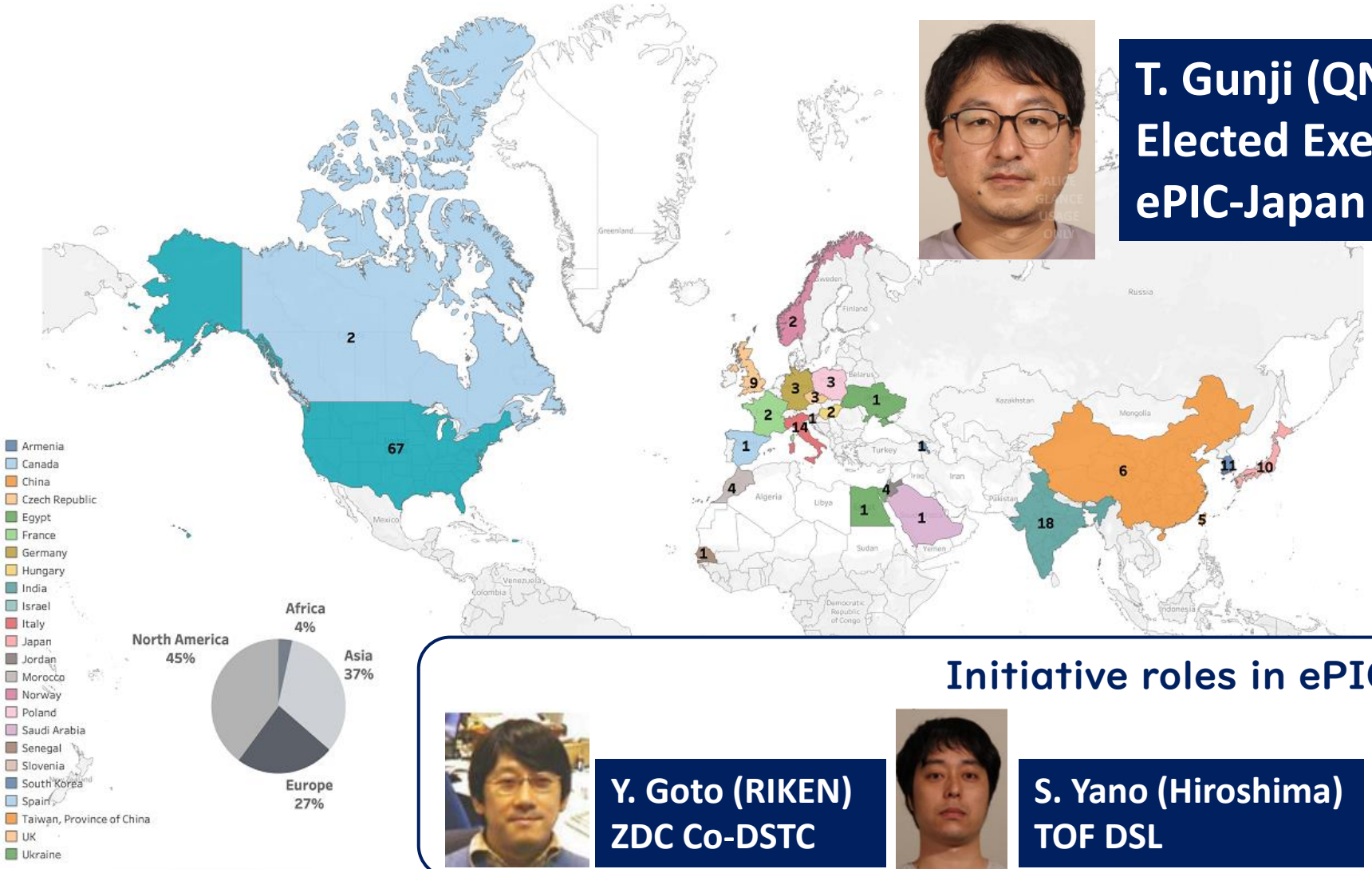
- In NP community in Japan, size of each institute is very small.
- This type of participation through consortium will be helpful for small groups to join and pursue the science at EIC/ePIC.

Japan in ePIC Collaboration

ePIC Institutions
173

ePIC Countries
25

ePIC World Region
4



T. Gunji (QNSI/CNS U-Tokyo), Elected Executive Board member ePIC-Japan CC representative

11 Japanese institutes

Initiative roles in ePIC

Y. Goto (RIKEN) ZDC Co-DSTC

S. Yano (Hiroshima) TOF DSL

R. Seidl (RIKEN) Semi-Inclusive PWG

Japan in ePIC Collaboration

11 Japanese institutes with different research backgrounds

Nucleon structure
(COMPASS/AMBER, RHIC, SeaQuest, SpinQuest)

山形大学 YAMAGATA UNIVERSITY

RIKEN NiSHiNA CENTER — RIKEN Nishina Center for Accelerator-Based Science

NIHON UNIVERSITY

High-Energy particle physics
(ZEUS@HERA, ATLAS@LHC)

SHINSHU UNIVERSITY

KOBE UNIVERSITY

Heavy-Ion Physics
((s)PHENIX@RHIC, ALICE@LHC)

Center for Nuclear Study
The University of Tokyo

University of Tsukuba

National University Corporation
Tsukuba University of Technology

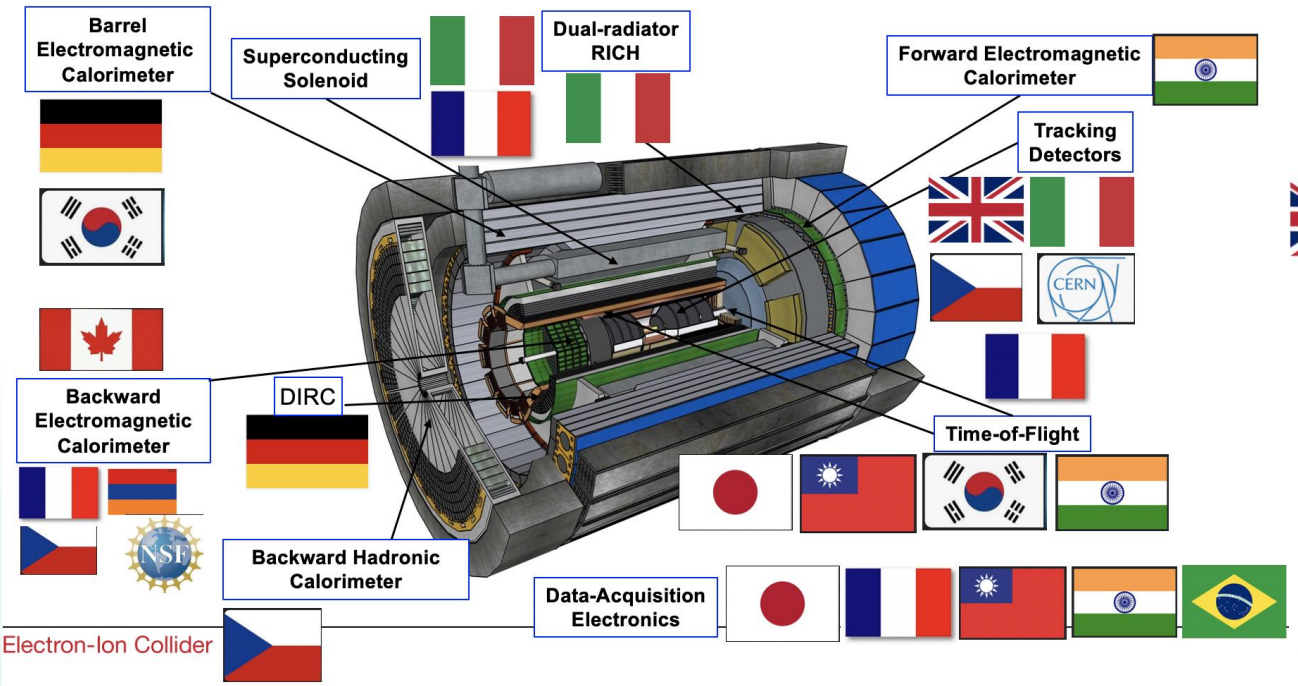
国立大学法人
奈良女子大学
Nara Women's University

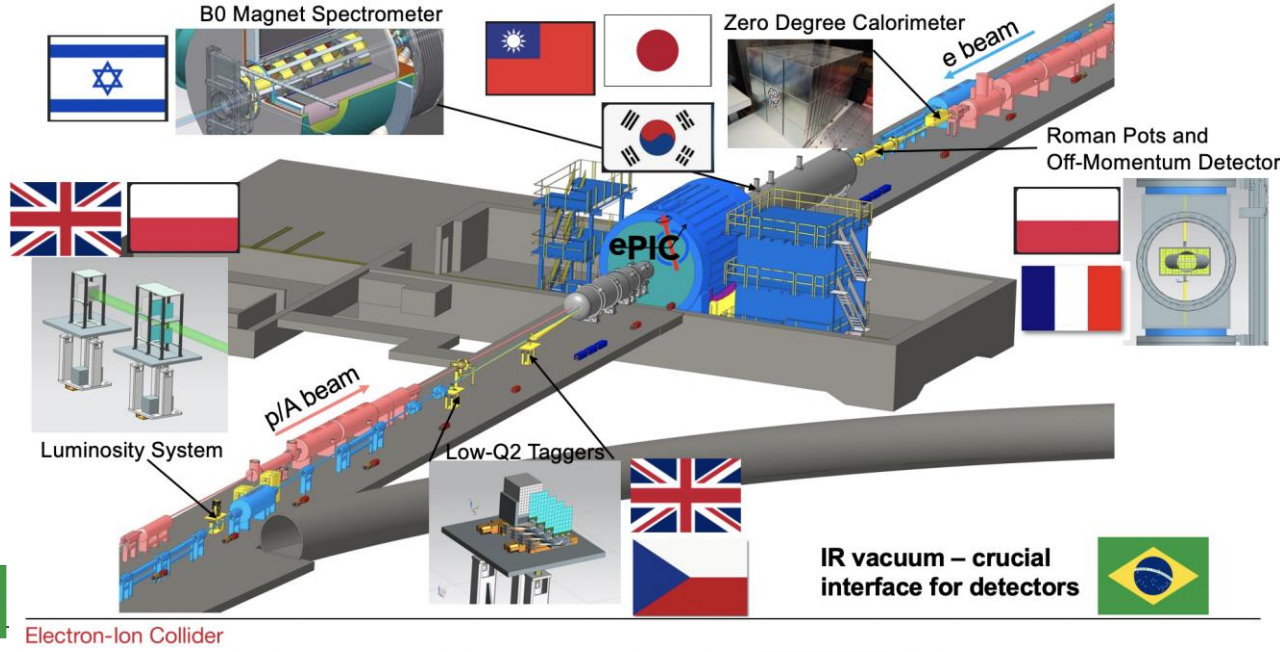
HIROSHIMA UNIVERSITY

Department of Physics,
Graduate School of Science and Faculty of Science,
Tohoku University

We will try to invite low-energy and hadron physics community to join ePIC.

Japanese contributions to ePIC



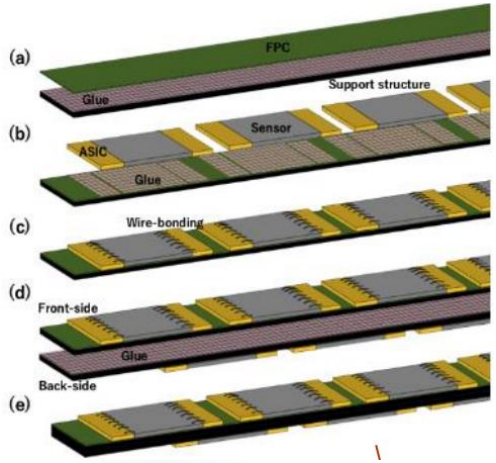


Japan is going to make in-kind contributions to:

- Barrel Time-of-Flight (bTOF)
- Zero-Degree Calorimeter (ZDC)
- Streaming DAQ (echelon0, DAM) and Computing (echelon2)

bTOF activities and plans in Japan

- ~$2M requested for FY25
- List of items for R&D and engineer runs
  - AC-LGAD Sensor
    - Mini-production of current baseline sensors
    - New sensors with different strip geometry
    - New sensors with double metal layer
  - Readout
    - ASIC R&D : Join effors with FNAL+OMEGA
    - Discrete amplifier boards :UC Santa-Cruz
  - FPC design and prototyping
  - Module (sensor + ASIC integration) and mini-ladder
  - Full chain readout (Service Hybrid, DAM)
- Building several sites for R&D and construction
  - wire-bonder, probe station, laser system, scope, etc

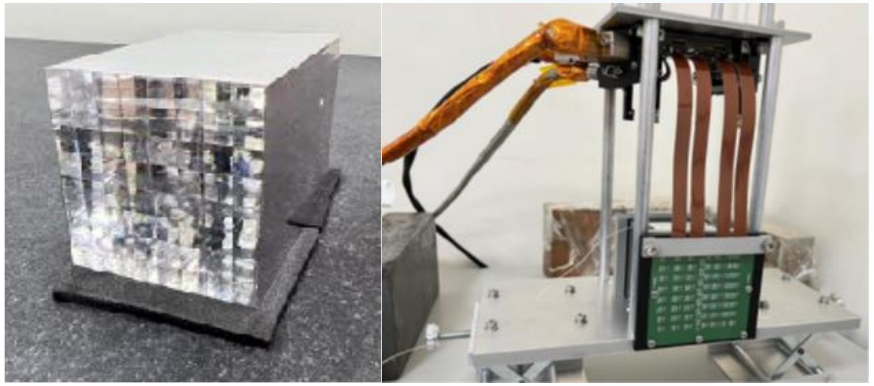


ZDC activities and plans in Japan

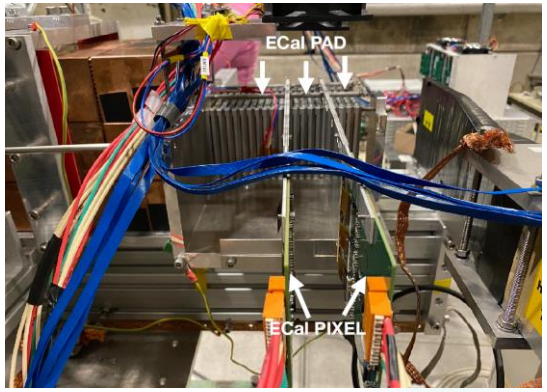
- ~$0.5M requested for FY25
- List of items for R&D and engineering runs
  - Crystal EM calorimeter with Taiwan group
    - Prototype made by Taiwan group
    - Test beam at RARiS in Tohoku Univ.
  - Hadron calorimeter with UC Riverside group
    - Fe + SiPM on plastic scintillator tile
  - Combined readout test
    - Readout electronics development
  - W+Si layer for future upgrade
    - Collaboration with ALICE-FoCal-E
    - Test beam and irradiation test
  - Simulation studies
    - $\Lambda \rightarrow n\pi^0$ detection by calorimeter imaging with W+Si
    - Low energy photon detection by crystal

RIKEN, Kobe Univ., Shinshu Univ.,
Yamagata Univ., Nihon Univ.,
U. Tsukuba, Tsukuba U. Tech

Crystal prototype for test beam



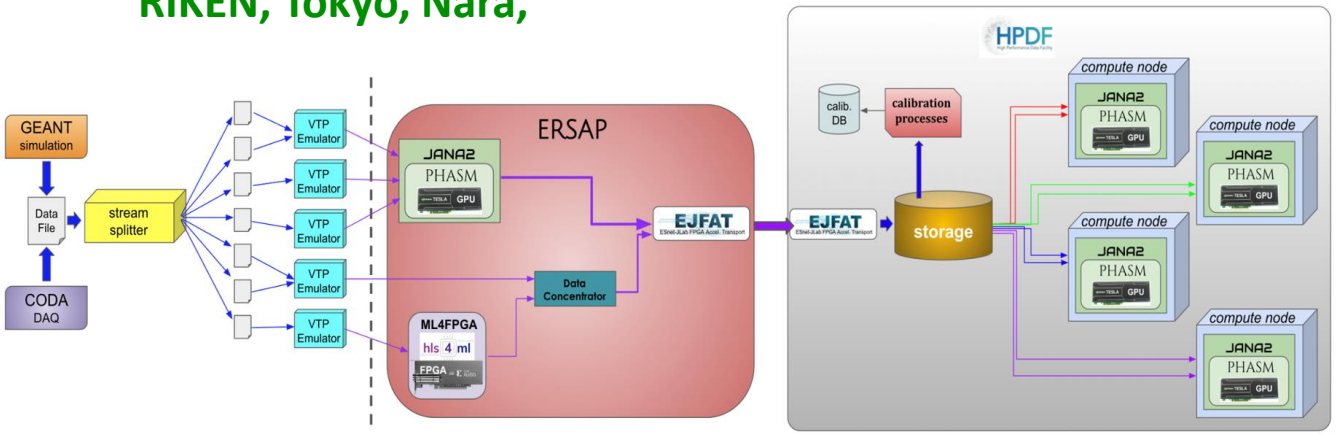
W+Si layer for ALICE-FoCal-E



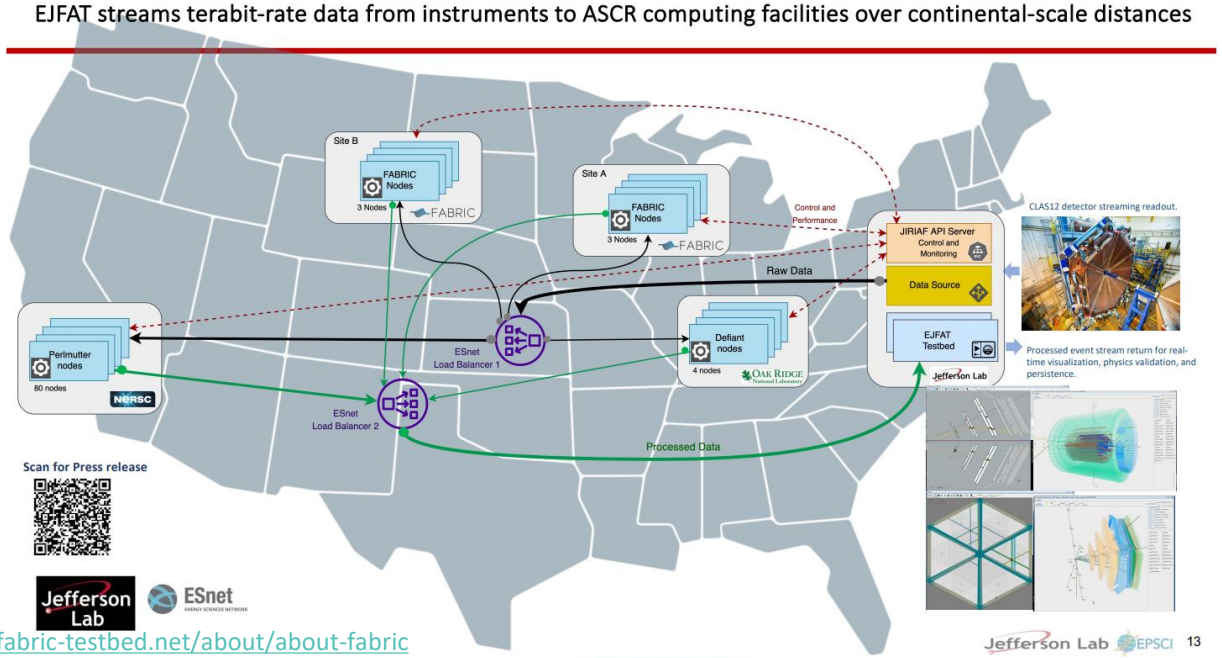
SRO activities and plans in Japan

- ~$0.7M requested for FY25
  - Computing servers, hardware accelerators, DAM, network, infrastructures
- List of items to be done in FY25
  - Prototyping
  - Workflow orchestration
  - Realtime data distribution from US to Japan using FSNet and FABRIC network
  - Porting reconstruction routines in the framework (runnable with AI, GPU, FPGA)
- Start sending people to JLab or BNL
- Cooperation with SPADI-Alliance in Japan

RIKEN, Tokyo, Nara,



EJFAT streams terabit-rate data from instruments to ASCR computing facilities over continental-scale distances

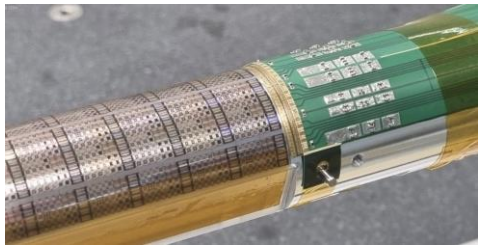


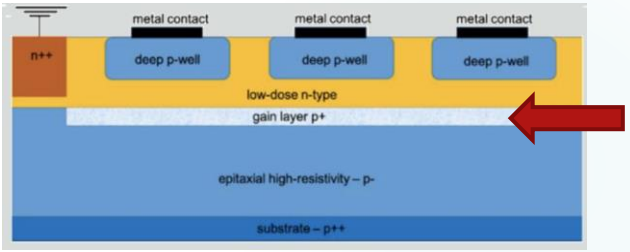
https://portal.fabric-testbed.net/about/about-fabric

Further technology developments

- **EIC is a good opportunity to develop and deploy new technologies.**
  - **Will bring benefits to the entire community (RIBF, J-PARC) and societies.**

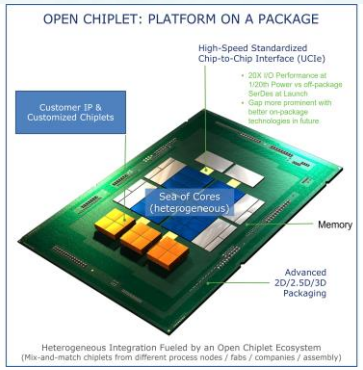
4D CMOS pixel sensors
(more fine pixel size, radiation tolerance, CMOS with gain layer, large size sensor)

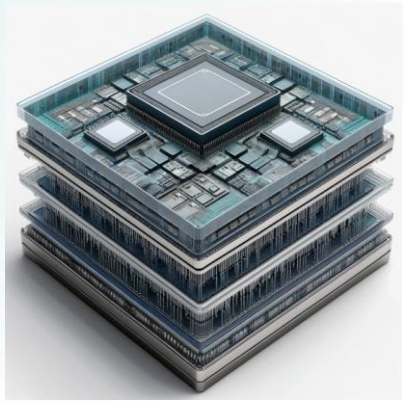




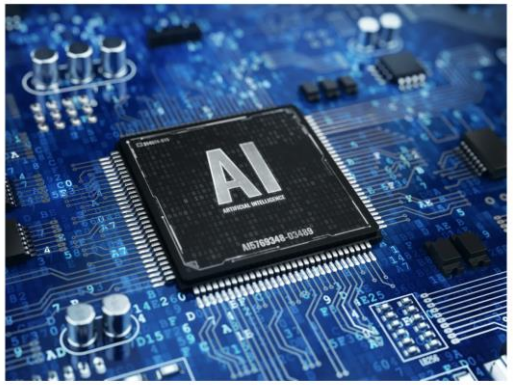
https://www.3dcad-data.com/blog/7133

High-density circuit packaging (ex, si-interposer, chiplet, 3D circuit)



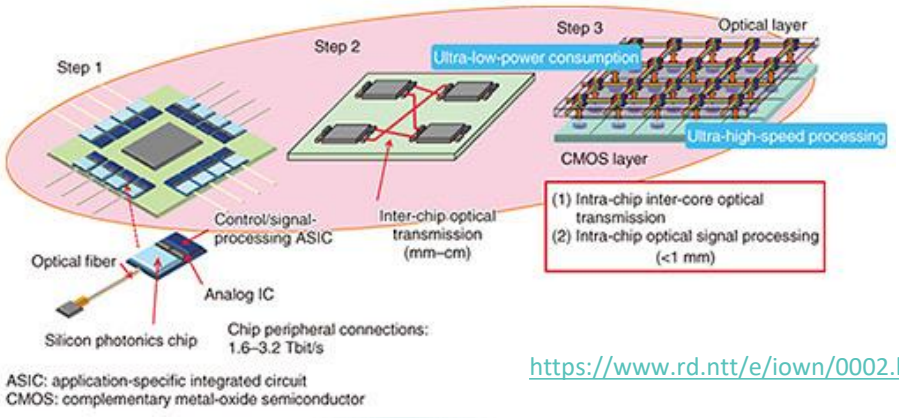


Edge processing technologies (ex, AI chip)



(Image credit: Synopsys)

High bandwidth and low power data transmission (ex, all photonics)



https://www.rd.ntt/e/iown/0002.html

EIC-school in FY25

- We plan to organize an international EIC school in **March 2026 (3/2/2026–3/13/2026) at Yukawa Institute for Theoretical Physics (YITP), Kyoto University**.
  - **Kazuhiro Watanabe (Tohoku University), Yoshimasa Hidaka (Kyoto University)**
- **Dedicated to the EIC theories (currently no EIC theory community in Japan – missing young talents)**
- **Invited lectures**
  - **Zhongbo Kang (University of California, Los Angeles, USA): Transverse Momentum Dependent distributions**
  - **Yong Zhao (Argonne National Laboratory, USA): Large Momentum Effective Theory**
  - **Yoshitaka Hatta (Brookhaven National Laboratory, USA): Generalized Parton Distributions**
  - **Anna Stasto (Penn State University, USA): Small-x Physics**
  - **Iain Stewart (Massachusetts Institute of Technology, USA): Soft Collinear Effective Theory**
  - **Constantia Alexandrou (The Cyprus Institute and University of Cyprus, Cyprus): Hadron structure from Lattice QCD**
- **Started discussion to have another school (both for experiment + theory).**
  - **Morning: plenary for both experiment + theory**
  - **Afternoon: hands-on session (ePIC simulation, pQCD/lattice calculation)**

Summary

- There are lots of process to promote EIC project in Japan NP community.
  - Workshops to attract more people from other communities
  - Fundamental Quantum Science and Multi-scale dynamics research from quarks to nucleus in RIKEN using EIC opportunities
  - International Quantum Physics Network (IQPN) framework to promote “All-Japan” framework to drive international science collaboration like EIC/ePIC.
  - IQPN + RIKEN work together to drive quantum science and related technologies from nuclear physics using EIC opportunities.
- Japan plans to contribute key detector constructions (bTOF and ZDC) and streaming DAQ/Computing. Budgetary requests for FY25 made to lead detector R&D and engineering runs. Waiting for the results.