February 3rd, 2025

Nishina-center's vision on FQSP and EIC

Tomohiro Uesaka
RIKEN Nishina Center for Accelerator-Based Science

RIKEN Nishina center for Accelerator-Based Science

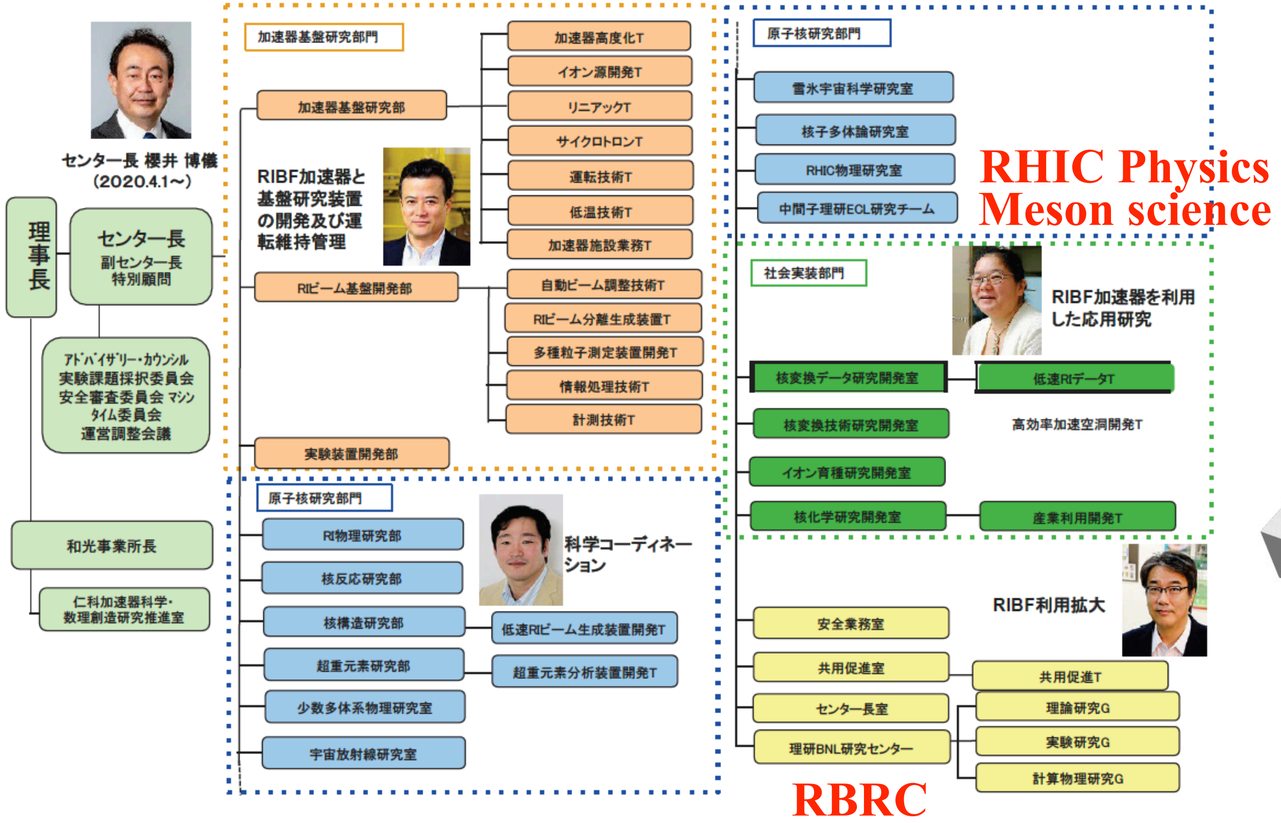
3 divisions

Accelerator division (3 groups+12 teams)

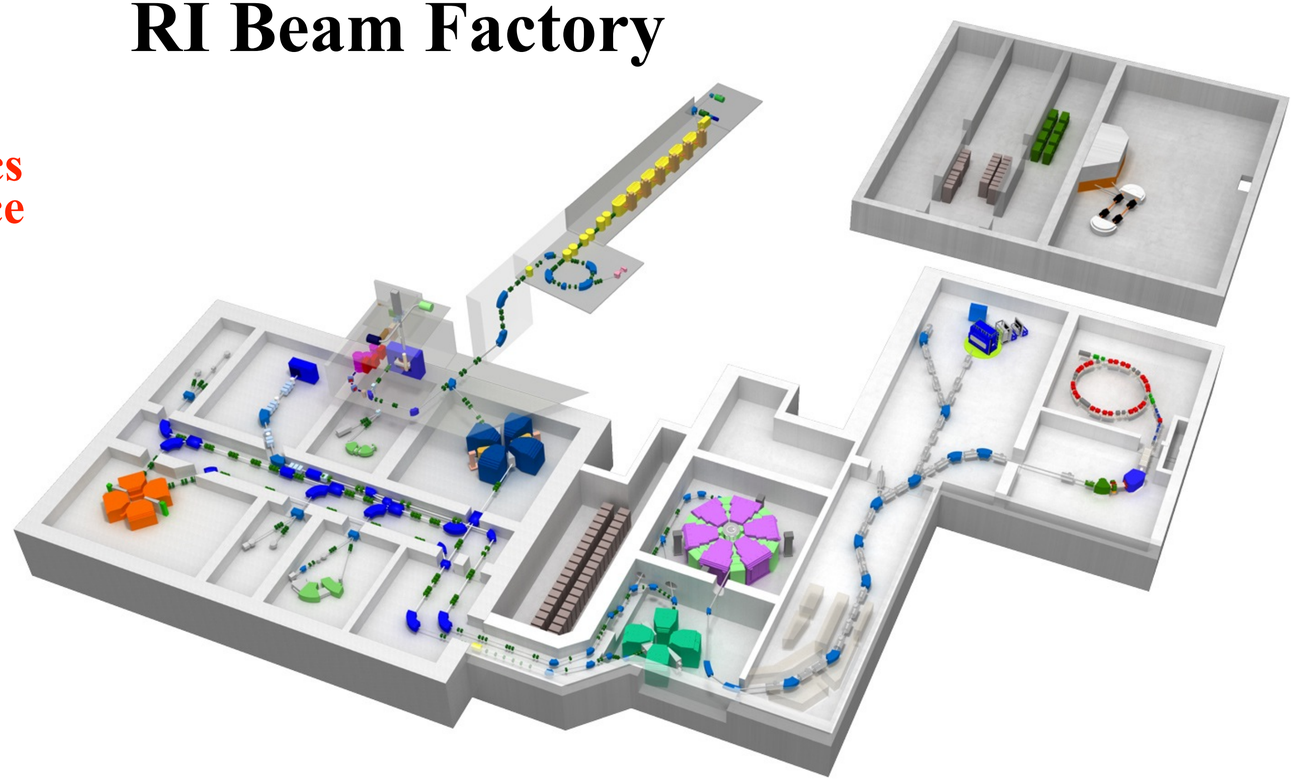
Nuclear science division (11 groups + 2 teams)

Social implementation division (4 groups + 2 teams)

RBRC, safety, user-liaison . . .

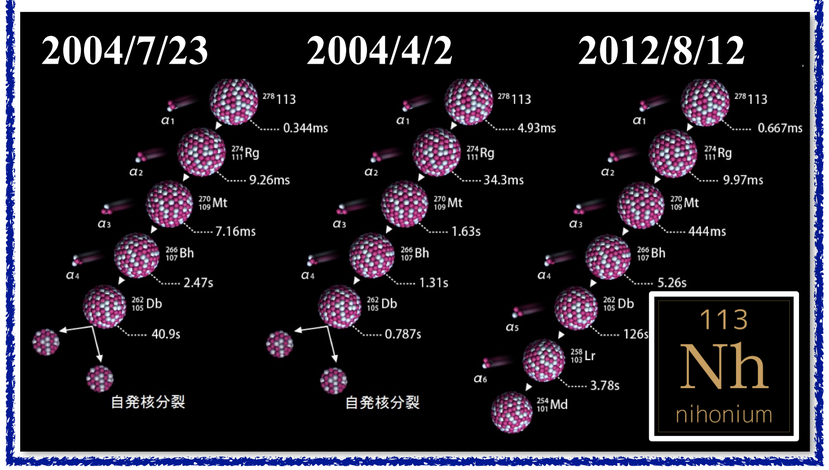


RI Beam Factory

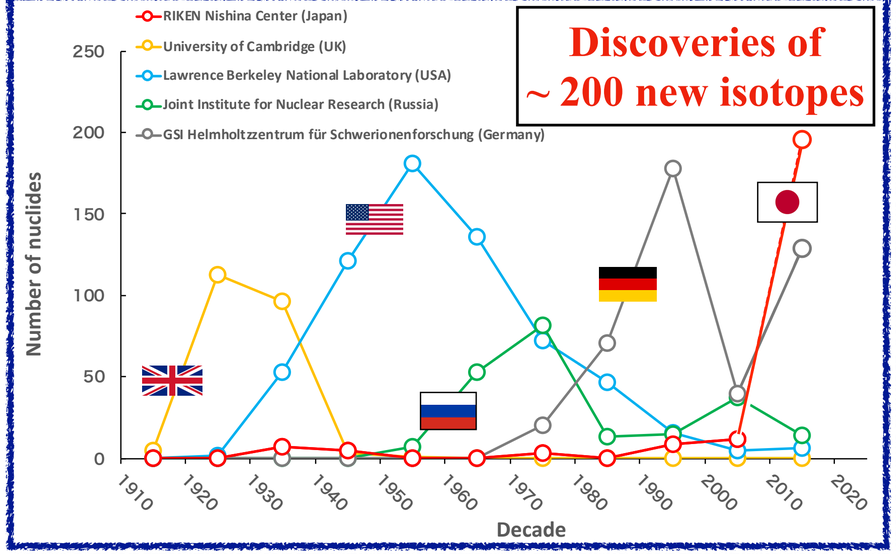


Selected Achievements at RIBF

Discovery of Nihonium (Z=113)

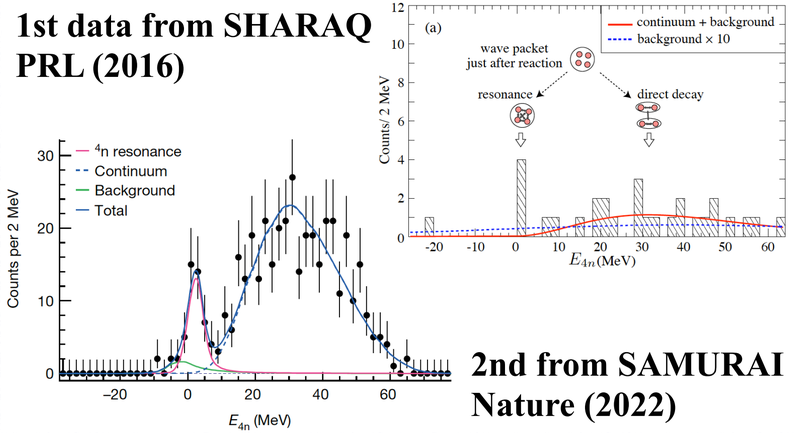


Discoveries of ~ 200 new isotopes



Discovery of tetraneutron

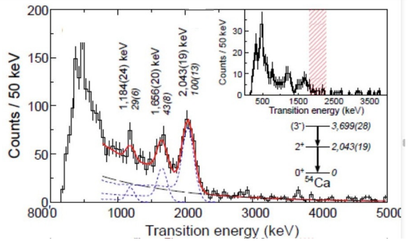
1st data from SHARAQ
PRL (2016)

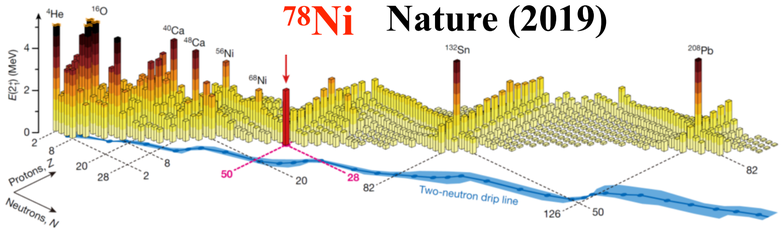


2nd from SAMURAI
Nature (2022)

Evolution of nuclear magicity far from the stability line

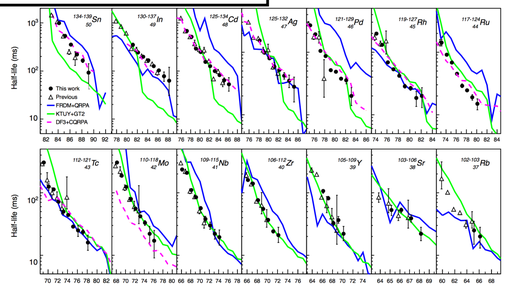
N=34,
Nature
(2013)





Data crucial for understanding the origin of heavy elements

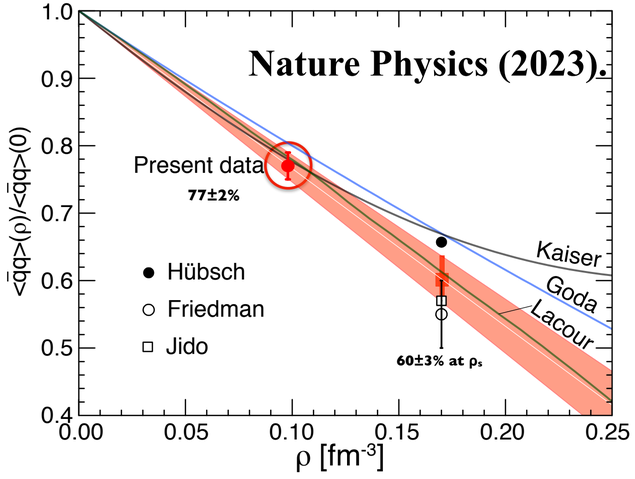
Lifetime
PRL (2015) etc.



Mass
PRL (2023) etc.

P_{xn}, PRL (2022)

Partial restoration of chiral symmetry observed in pionic atoms

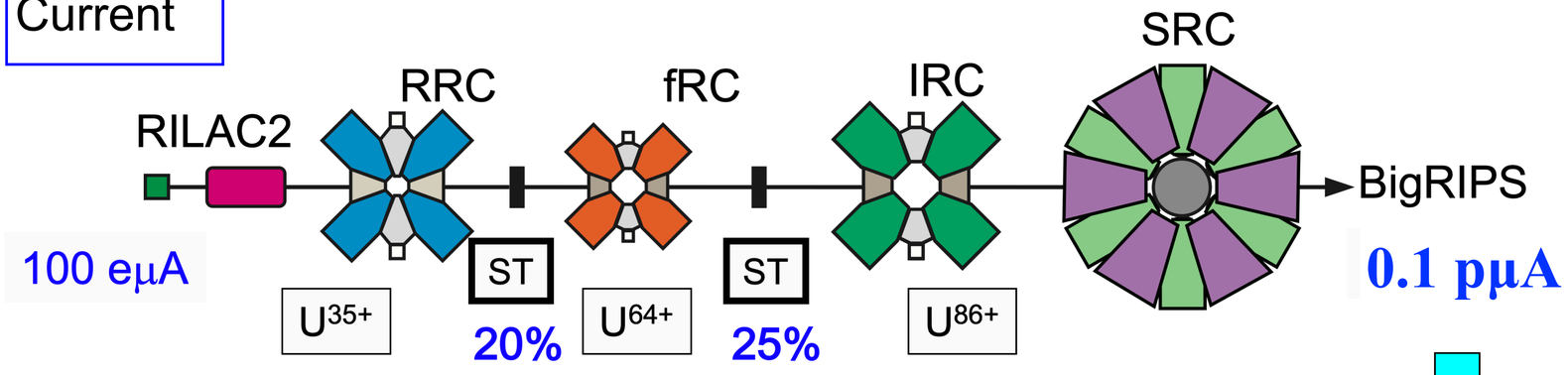


RIBF Upgrade Plan

Intensity upgrade (x20) through introduction of novel “Charge stripper rings”

20B JPY project

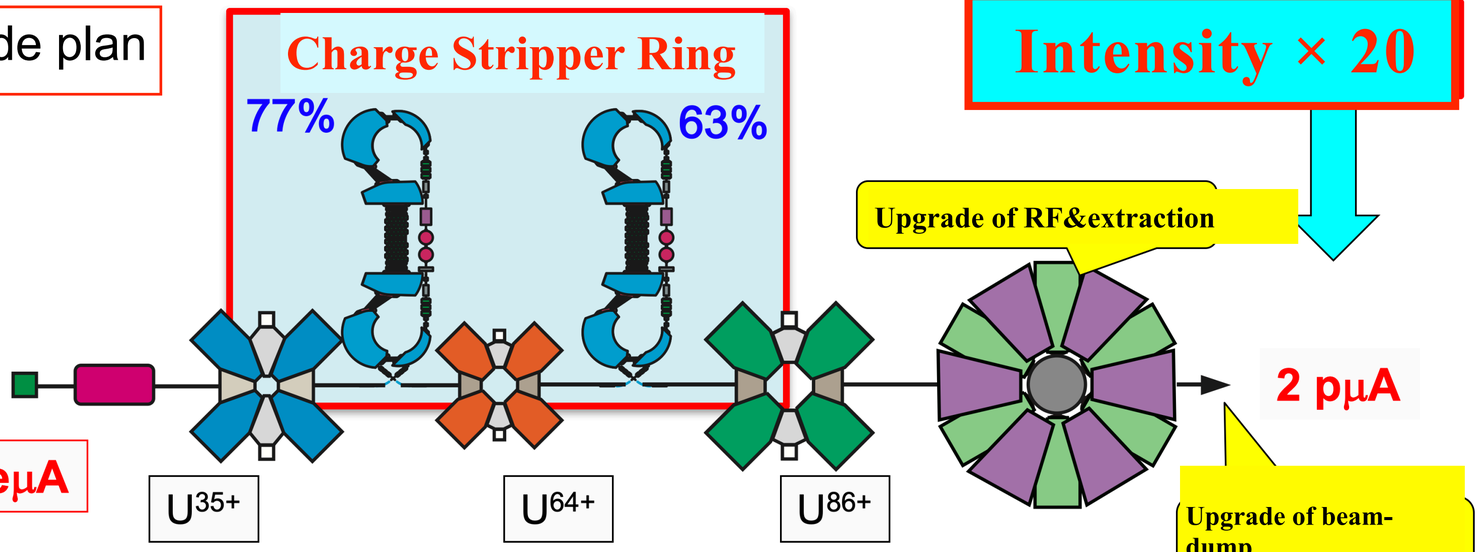
Current



100 eμA

0.1 pμA

Upgrade plan



300 eμA

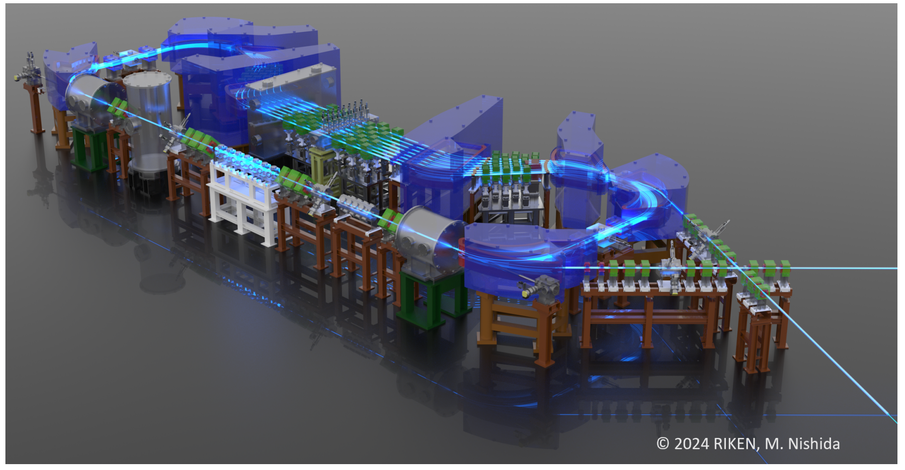
Intensity × 20

Upgrade of RF&extraction

2 pμA

Upgrade of beam-dump
& config of BigRIPS

Charge stripper ring



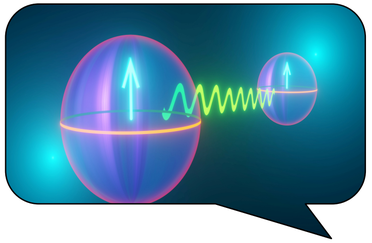
Fundamental Quantum Science Program

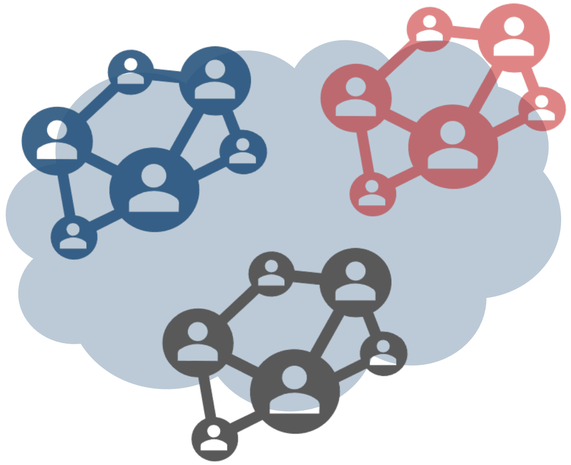
Courtesy of
N. Nagaosa

Outline

April 2024 ~

- **Expanding forefront** of quantum science and technology but the deep understanding of the basic principles is still lacking.
- Return to the **fundamentals of quantum science** and **develop research from a mid- to long-term perspective**.
- **Invite top-class researchers** by creating an open and secure research environment and implementing flexible personnel policies.
- Promote research and human resource exchange with **workshops and visitor programs as core measures**.
- **Build a flexible organizational structure** with steady and hearty connections not bound by traditional organizational forms.

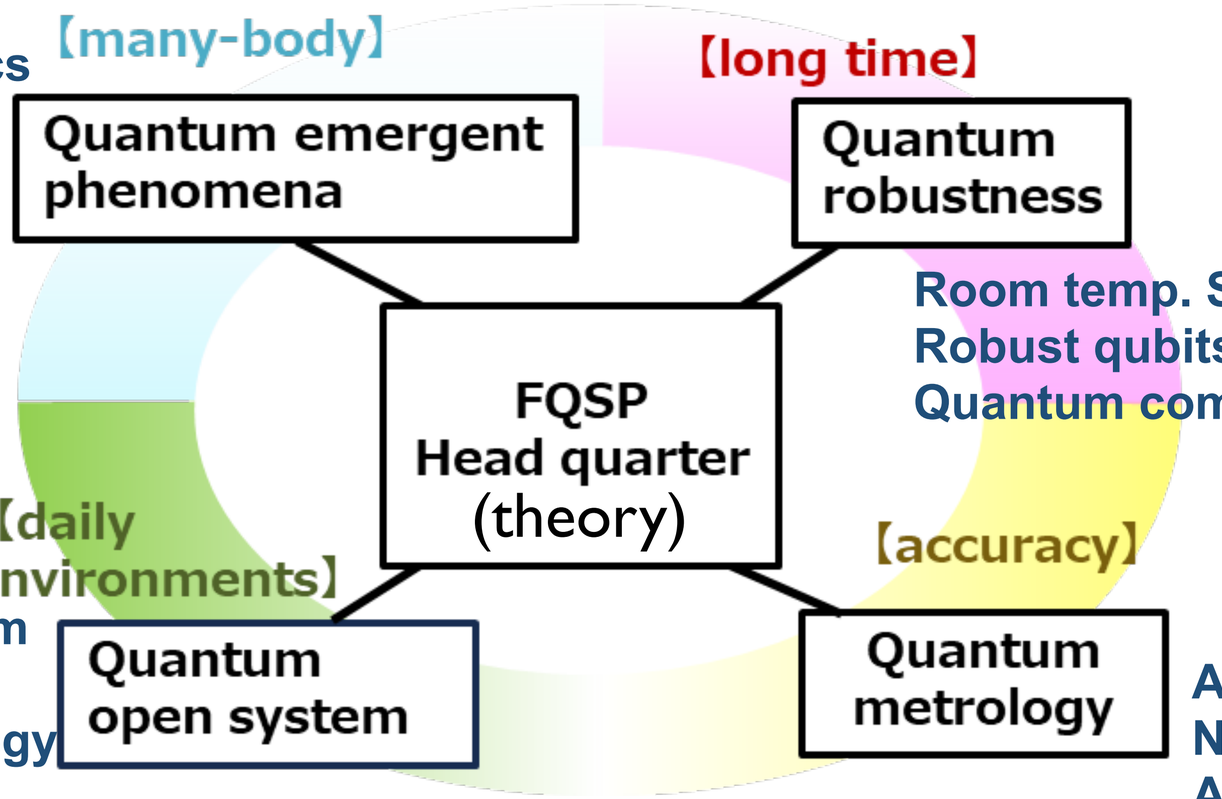




RIKEN Fundamental Quantum Science Program

Courtesy of
N. Nagaosa

Unified principles of quantum science in multi-scales of energy and length.
Interaction between "system" and "environment"
Offers collaboration platform for both experiments and theory in RIKEN



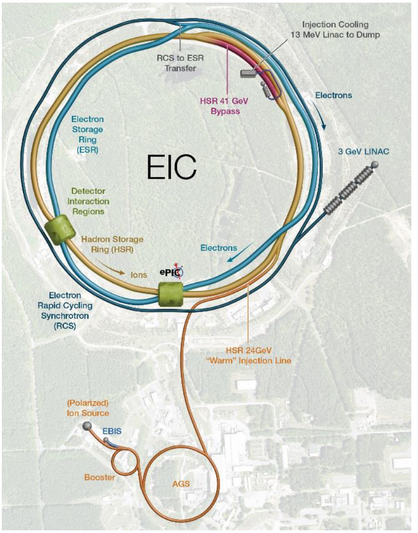
Nuclear physics
Many-body effects in solids

Non equilibrium phenomena
Quantum biology

Room temp. SC
Robust qubits
Quantum computation

Atomic clock
Nuclear clock
Anti-particle
TES

Electron Ion Collider
(Elucidation of the structure, including the dynamic motion within the nucleus)

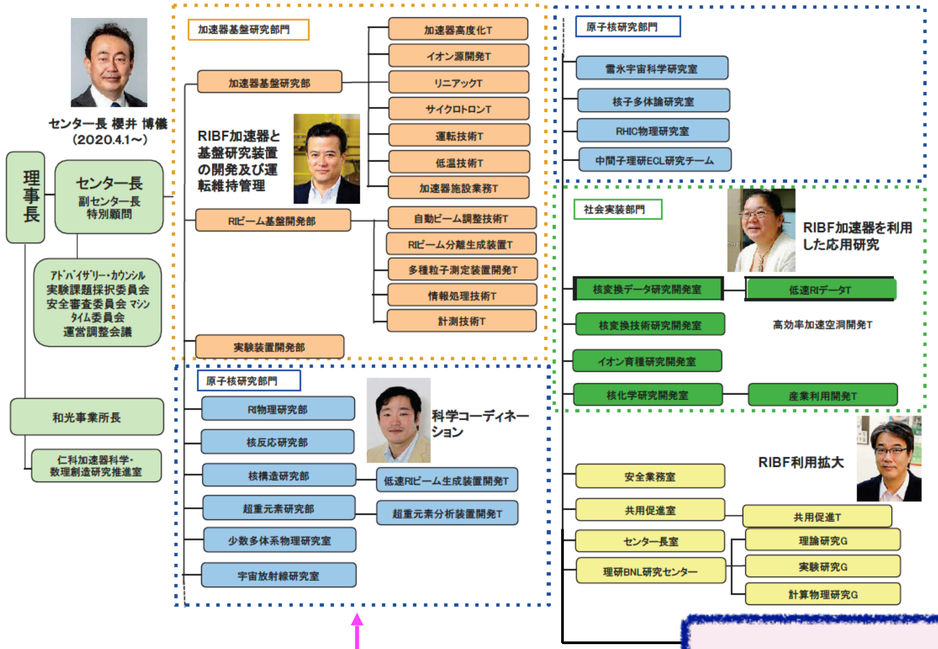


Nishina's recognition on synergies with FQSP and EIC

- **Nuclear physics deals with finite quantum systems of stongly-interacting particles. Their nature can be revealed with a renewed quantum viewpoints to be established in FQSP.**
  Scopes and directions of FQSP fit well with those of Nishina's activities.

- **EIC has strong research and technical synergies with those at RIBF.**
  By combining researches at RIBF and EIC (together with those at J-PARC and other facilities), we can challenge the physics that connects quark-gluon and nucleon-meson hierarchies.

Nishina's new organization



Fundamental Quantum Science Program (FQSP)
HQ (Naganaga, Kawakami, Aoki),
Research at other centers

collaboration

Collaboration within Nishina Center

Multi-Scale Quantum Dynamics (MSQD) Joint Group
January 2025 —

Director: Uesaka (in charge of RIBF-EIC and other management)
Deputy Director to be appointed (in charge of EIC)

EIC: TOF, ZDC, DAQ Development

RIBF-EIC: silicon tracker, DAQ, neutron detector
Tracking Germanium Development
(Concurrently from existing Nishina groups)

collaboration

QNSI
University of Tokyo

High energy QCD

Quark many-body systems

Nucleon many-body systems

Topics connecting RIBF and EIC

1. The origin of nucleon mass and nature of the QCD vacuum

2. Properties of proton-neutron pairs at different resolutions/environment

3. Mechanism that prevents matter from collapsing (equation of state)

and more

Topics connecting RIBF and EIC

1. The origin of nucleon mass and nature of the QCD vacuum

π-atom spectroscopy and chiral symmetry

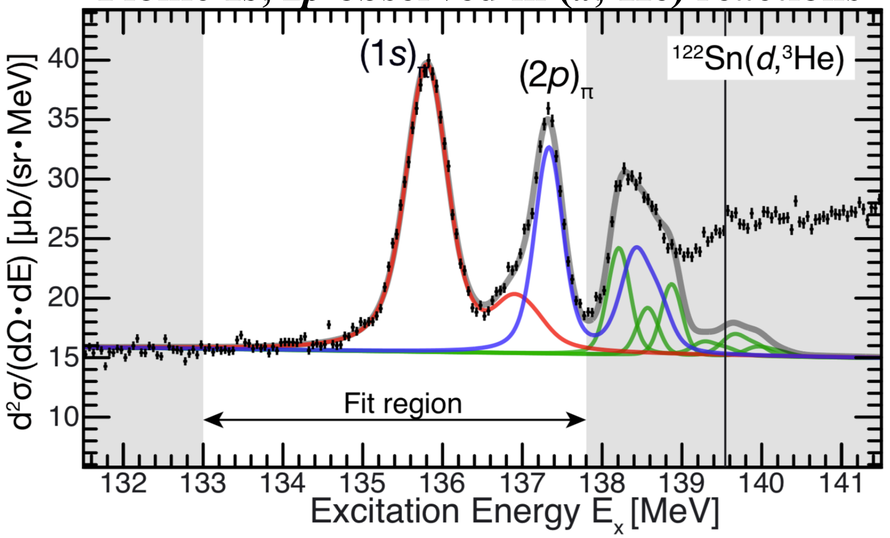
T. Nishi, K. Itahashi et al.,
Nature Physics 19, 788 (2023).

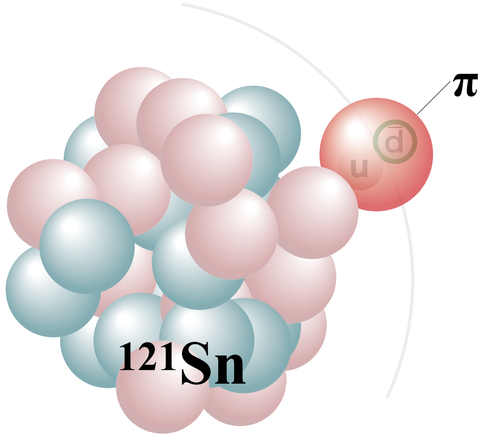
nature physics

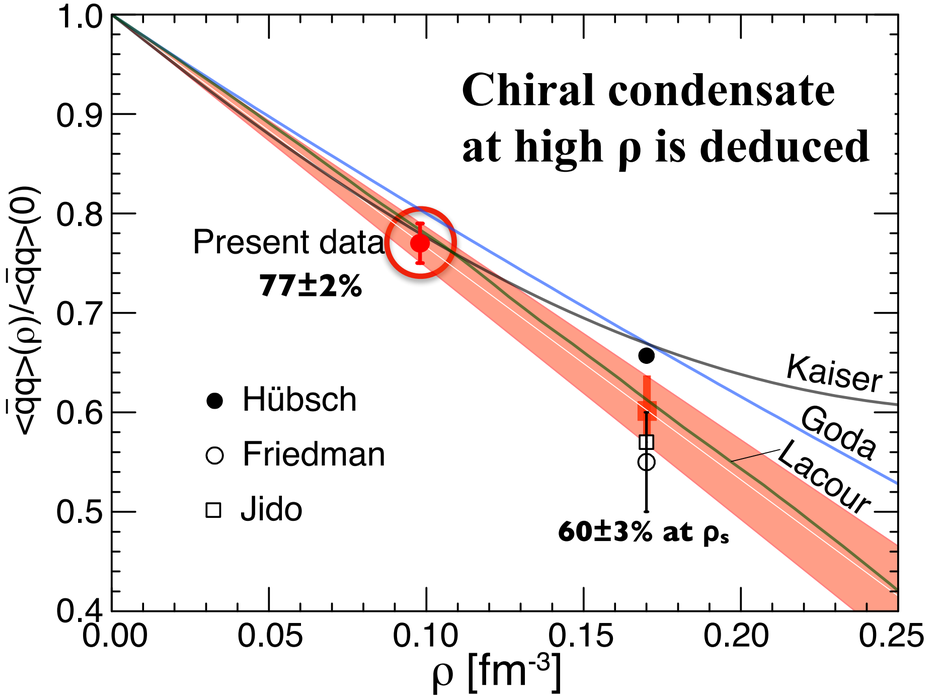
Article https://doi.org/10.1038/s41567-023-02001-x

Chiral symmetry restoration at high matter density observed in pionic atoms

Pionic 1*s*, 2*p* observed in (*d*,^{3}He) reactions



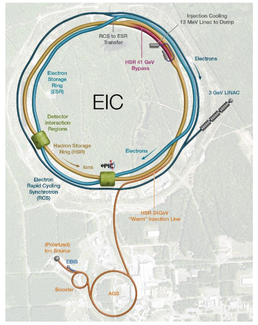


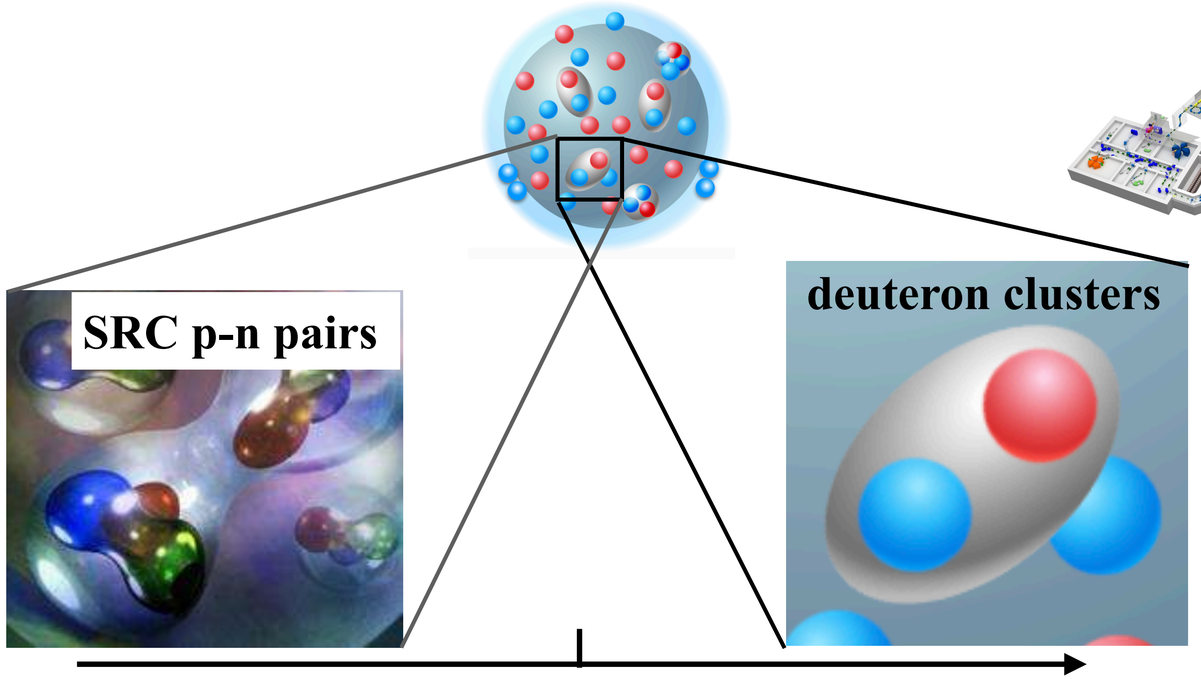


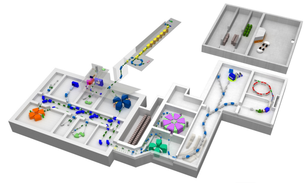
How can we understand consistently the origin of mass in terms of partial restoration of the chiral symmetry breaking and that to be revealed at EIC?

Topics connecting RIBF and EIC

2. Properties of proton-neutron pairs at different resolutions/environment

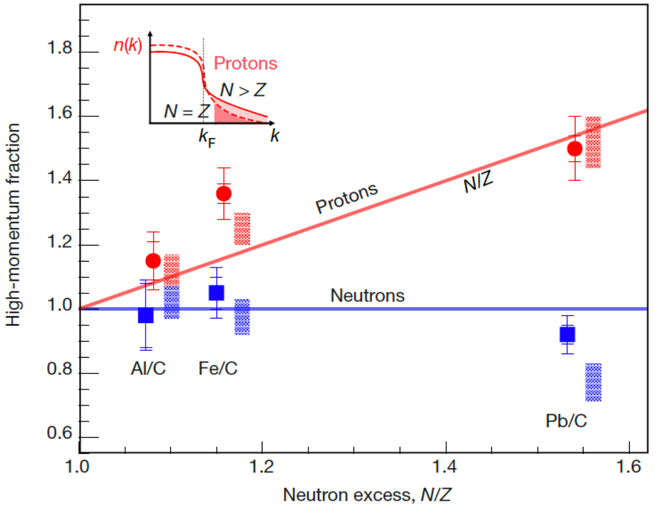




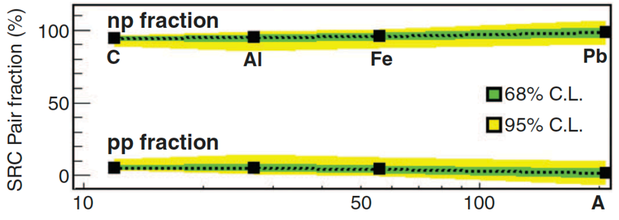


Isospin dependence of p-n correlation

M. Duer et al., Nature 560



O. Hen et al., Science 364



hints to understand the EMC effect

small p-n distance

quark-gluon dynamics

Proton radius (~0.8 fm)

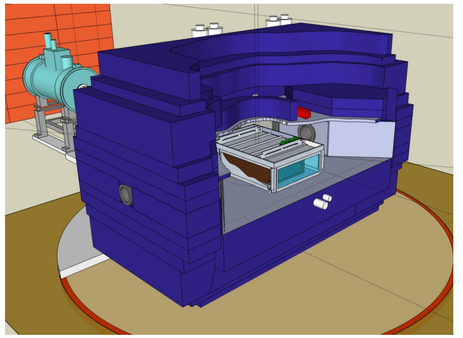
large p-n distance

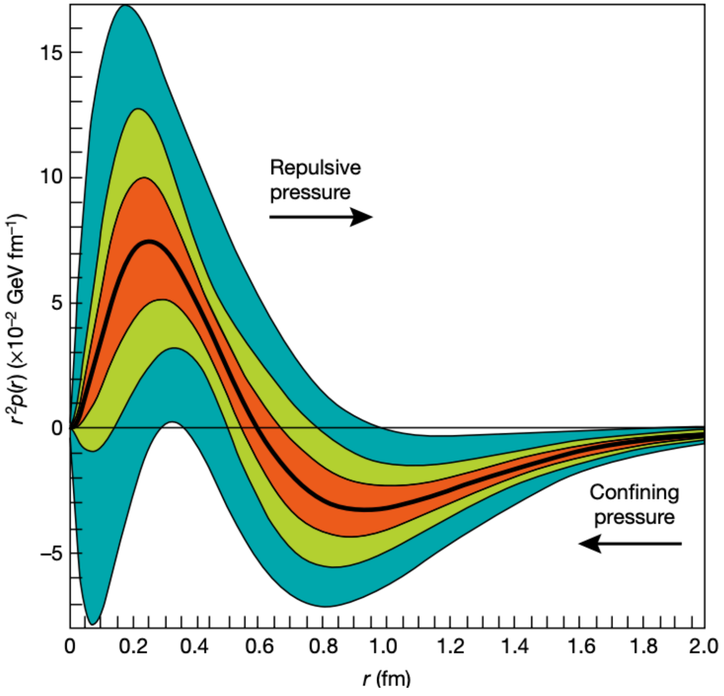
nucleon-meson dynamics

Topics connecting RIBF and EIC

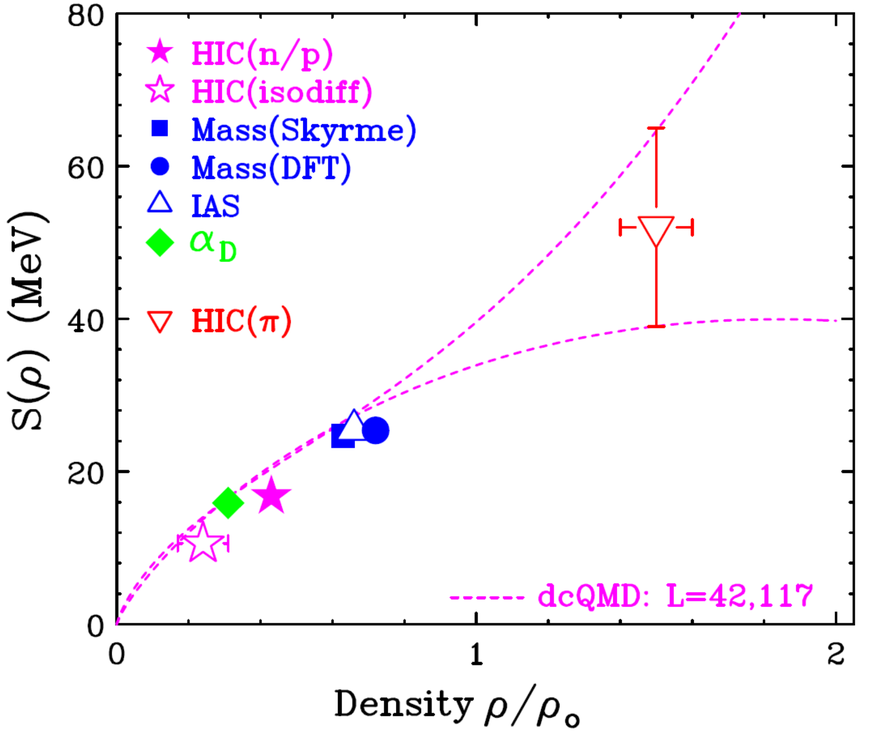
3. Mechanism that prevents matter from collapsing (equation of state)

Why can heavy neutron stars avoid collapsing?
Why can hadrons avoid collapsing?
How do changes of hadron properties in a high-density matter affect the equation of state?





Visualization of hot-spots on the 1.4 solar mass Pulser J0030+0451.



We are excited to initiate novel research programs by contributing to EIC and by connecting it to RIBF activities.
More topics to come.
I hope the BNL-RIKEN collaboration serves as a main body to lead the programs at both facilities.

RIKEN FQSP can be an excellent framework to shed new light on nuclear physics and to develop quantum science using new discoveries from nuclear physics.