February 10th, 2025

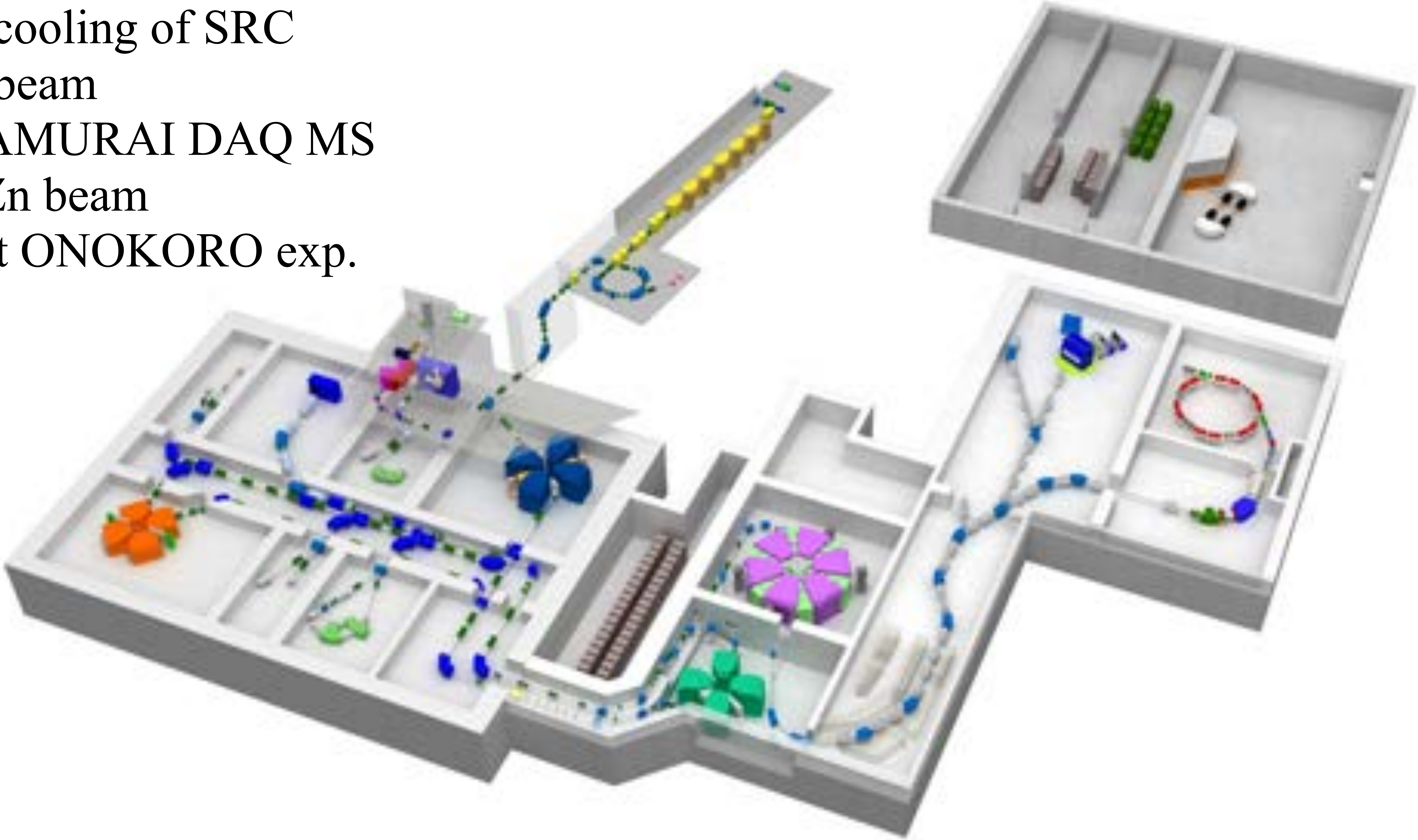
RIBF, SAMURAI and around

Tomohiro Uesaka
RIKEN Nishina Center for Accelerator-Based Science

RIBF

Tentative schedule for FY2025

- April— Start cooling of SRC
- mid of May — U beam
- end of May SAMURAI DAQ MS
- mid of June — ^{70}Zn beam
- end of June — 1st ONOKORO exp.



Demand for U beam is the largest.

SAMURAI accepted proposals

as of Jul. 2024

Done in 2024

Light-ion

^{40}Ar, ^{40}Ca

^{48}Ca

^{70}Zn

^{78}Kr

^{124}Xe

^{238}U

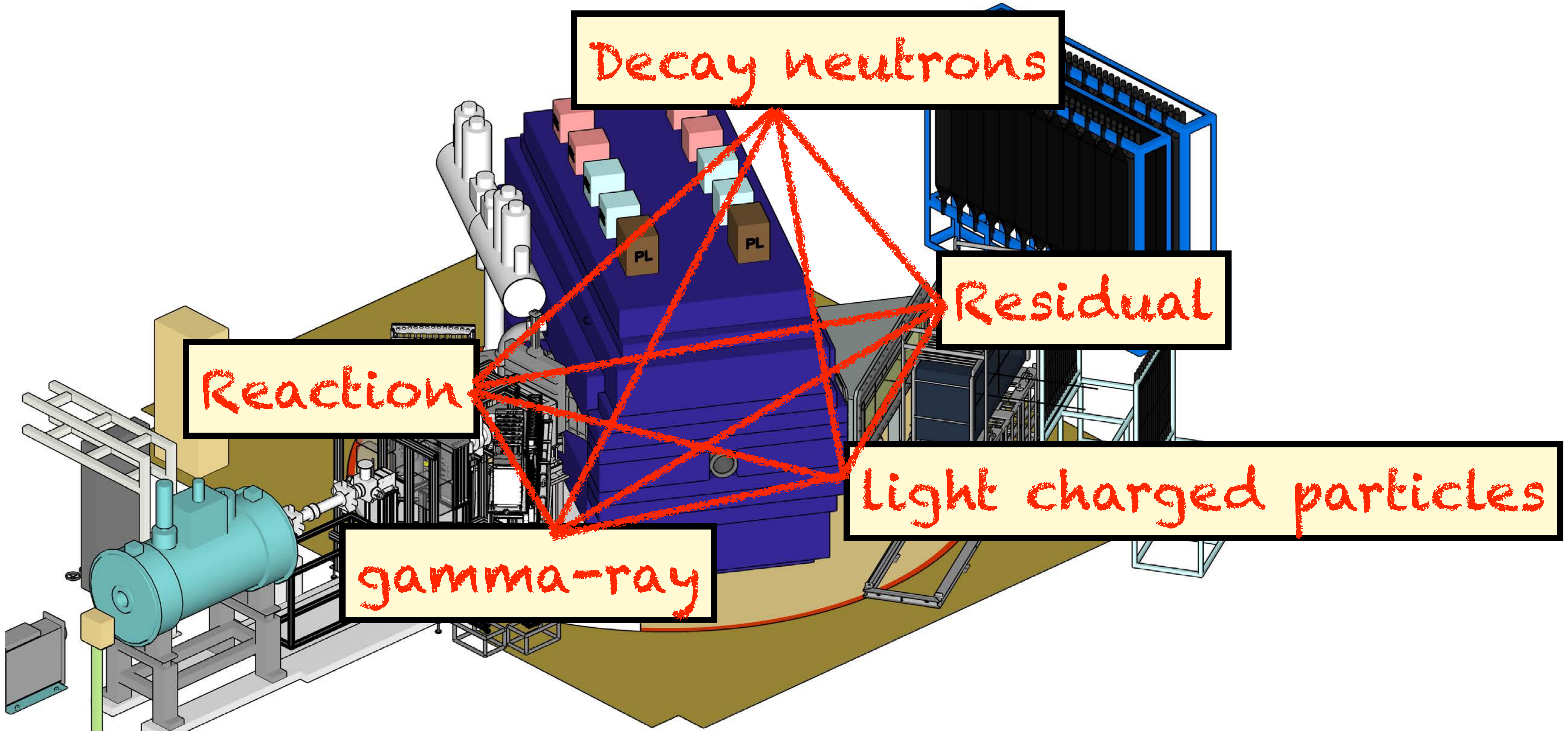
NP2312-SAMURAI73R1	Z. Xiao	Observation of the isovector reorientation effect of polarized deuteron and the constraint of nuclear symmetry energy	d_{pol} 190 MeV/u	4.0+0.5 days
NP2312-SAMURAI77	T. Uesaka	Comprehensive research of cluster formation in medium to heavy nuclei -- ONOKORO Project --	^{78}Kr, ^{124}Xe, ^{238}U, 345 MeV/u	(7 days)
NP2312-SAMURAI75R1	Y. Matsuda	Study of neutron single-particle states in carbon and calcium isotopic chains using (p,pn) reactions	^{48}Ca, SUP(70}Zn 345 MeV/u	6+0.5 days
NP2212-SAMURAI74	K. Miki	Correlations in multi-neutron systems	^{18}O 250 MeV/u	11 +0.5 days
NP2212-SAMURAI66R1	T. Nakamura	Determination of neutron capture reaction cross sections of Cd isotopes at N ≥ 82: Part 1	^{238}U, 345 MeV/u	(2.5 days)
NP2212-SAMURAI64R1	S. Kim	Reduction factor study at large isospin asymmetry using the (α,αp) reaction	^{18}O, SUP(40}Ar 345 MeV/u	(9.0 days)
NP2112-SAMURAI65	H. Liu	Search for the first excited 0^+ state in the doubly-magic nucleus ^{54}Ca	^{70}Zn 345 MeV/u	6.5 days
NP2112-SAMURAI69	A. Obertelli	Momentum distribution of deeply-bound nucleons	^{16}O, ^{48}Ca 345 MeV/u	9.5 days
NP2112-SAMURAI68	J. Gibelin	Search for $^{17,18}Be$	^{48}Ca 345 MeV/u	6.5 days
NP2012-SAMURAI55R1	T. Aumann	Determination of the nn scattering length from a high-resolution measurement of the nn relative-energy spectrum produced in the ^{6}He(p,pα)2n, t(p,2p)2n, and d(^{7}Li,^{7}Be)2n reactions	^{18}O 345 MeV/u	8.5 days
NP2012-SAMURAI57	T. Uesaka	Cluster and nucleon knockout reaction studies of neutron-rich calcium isotopes	^{70}Zn 345 MeV/u	4 days
NP2012-SAMURAI59	Y. Kondo	Invariant-mass spectroscopy in the vicinity of the possible doubly magic nucleus ^{28}O	^{48}Ca 345 MeV/u	10.5 days

NP2012-SAMURAI63	W. Lynch	Study of density dependence of the symmetry energy with the measurements of charged pion ratio in heavy RI collisions (III)	$^{124,136}Xe$ 345 MeV/u	9.5 days
NP1912-SAMURAI53	H. Wang	Search for short-range correlated proton-neutron pair in neutron-rich nuclei	^{22}Ne 250 MeV/u	7.5 days
NP1812-SAMURAI43	A.Corsi	Shell evolution at Z =14 around ^{22}Si, mirror of the doubly magic ^{22}O	^{40}Ca 345 MeV/u	4.5 days
NP1812-SAMURAI44	H. Otsu	Cluster structure study on ground and excited states by means of HI-α invariant mass spectroscopy	^{22}Ne 250 MeV/u	5 days
NP1812-SAMURAI33R2	Z.Yang	Study on the cluster structure in light nuclei by using (p,pα) reaction on carbon isotopes $^{12,14,16,18,20}C$	^{48}Ca 345 MeV/u	5.5 days
NP1812-SAMURAI47	T. Nakamura	Multi-neutron 4n and 6n states in extremely neutron-rich nuclei beyond the neutron drip line	^{18}O 345MeV/u	5 days
NP1712-SAMURAI37R1	T. Aumann	Dipole response of the drip-line nuclei ^{24}O and ^{29}F	^{48}Ca 345MeV/u	6.5 days
NP1712-SAMURAI32R1	M. Sasano	Study of "Island of Asymmetric Fission"	^{238}U 345MeV/u	9 days
NP1612-SAMURAI40	T. Nakamura	Two-neutron correlation measurement for nuclei beyond the neutron drip line	^{48}Ca 345 MeV/u	8.5 days
NP1512-SAMURAI36	N.A. Orr	Search for ^{22}C (2^+), ^{21}B, ^{23}C and ^{25}N: Structure at and beyond the N=16 sub-shell closure	^{48}Ca 345MeV/u	Nov 2016, 3 days out of 6 days
NP1512-SAMURAI35	H.L. Crawford	Invariant Mass Measurement of ^{39}Mg at SAMURAI	^{48}Ca 345 MeV/u	2.5 days

SAMURAI Next

Best use of the large-acceptance capability of SAMURAI
Multidimensional data with guaranteed reliability
Platforms for reliable and quick data-analysis and simulation

Upgrades in
- **n-detection capabilities**
  - **LAMPS-NDA, HIME, Neolith, MNEUT**
- **Missing mass detectors**
  - **TOGAXSI**
  - **STRASSE**
  - **and future**
- **Data acquisition system**



Two new programs

1. RIKEN Fundamental Quantum Science Program (FQSP) and RIBF-EIC joint program under FQSP

2. TOPTIER Project between Korea and Japan

ONOKORO is one of the main activities in both programs

RIKEN

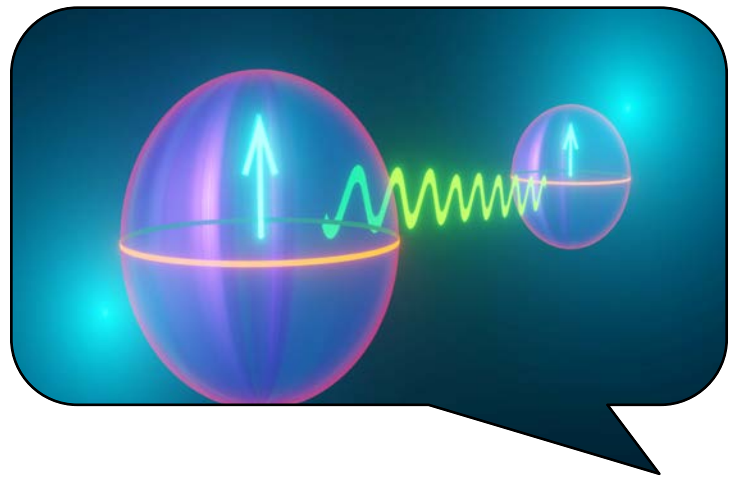
Fundamental Quantum Science Program

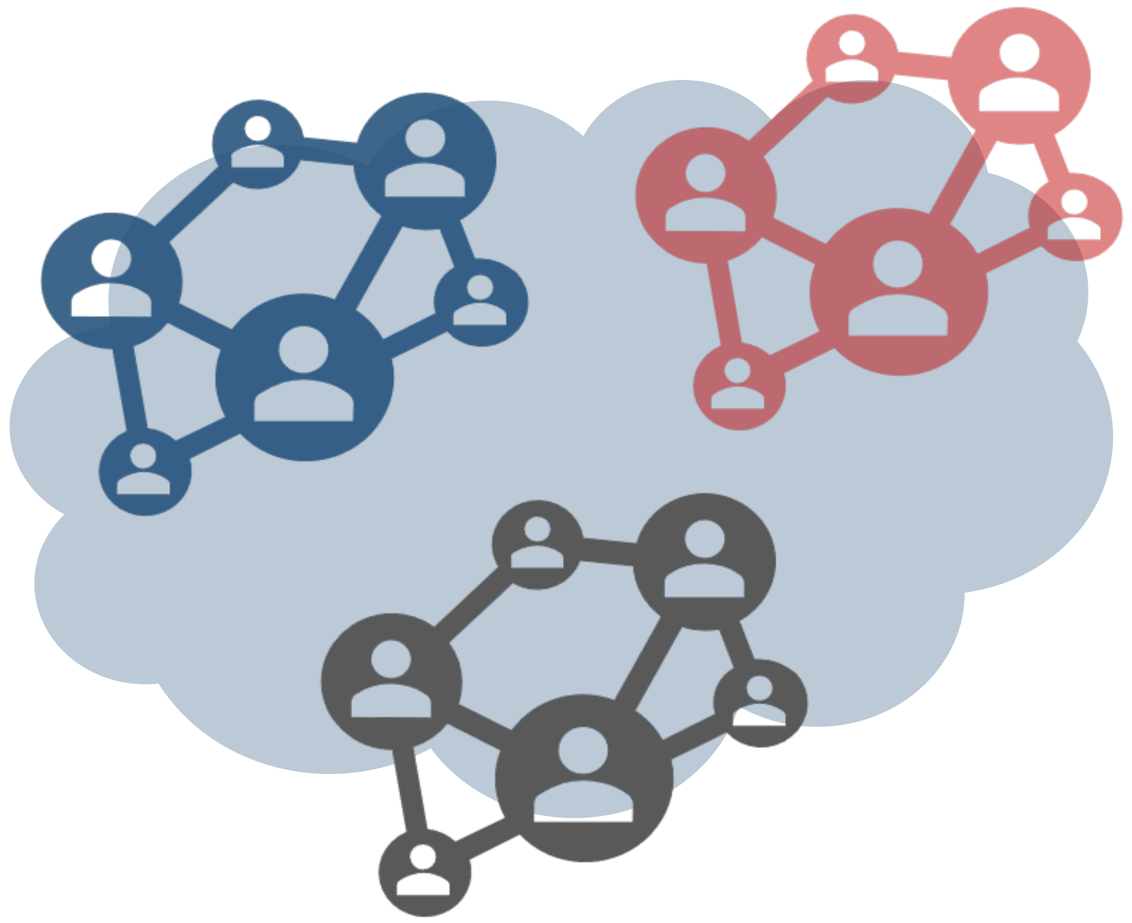
Courtesy of
N. Nagaosa

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.





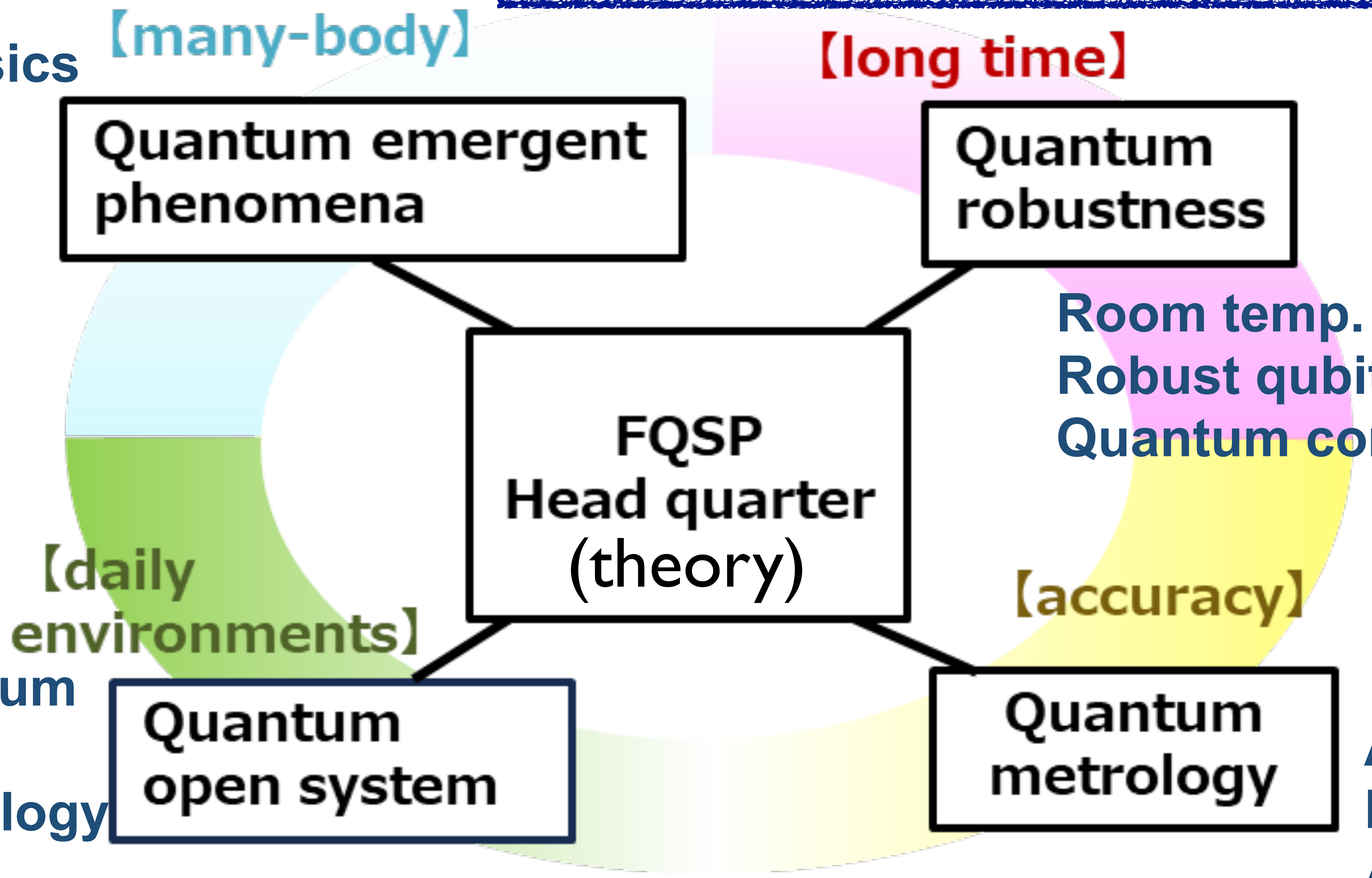
RIKEN Fundamental Quantum Science Program

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

Our activity is one of the main topics.

Nuclear physics
Many-body effects in solids

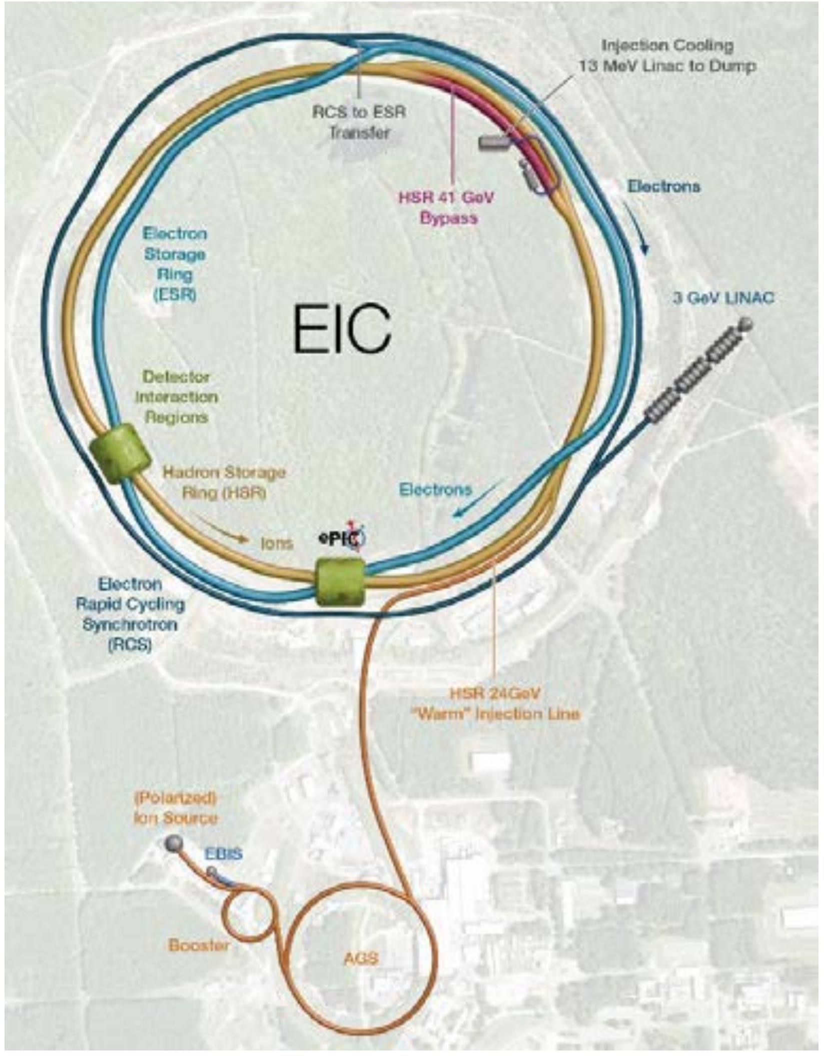


Room temp. SC
Robust qubits
Quantum computation

Non equilibrium phenomena
Quantum biology

Atomic clock
Nuclear clock
Anti-particle
TES

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



Synergy between RIBF and EIC

Physics

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)

Technology

1. High-speed data acquisition system

2. Silicon tracker

Topics connecting RIBF and EIC

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

π-atom spectroscopy and chiral symmetry

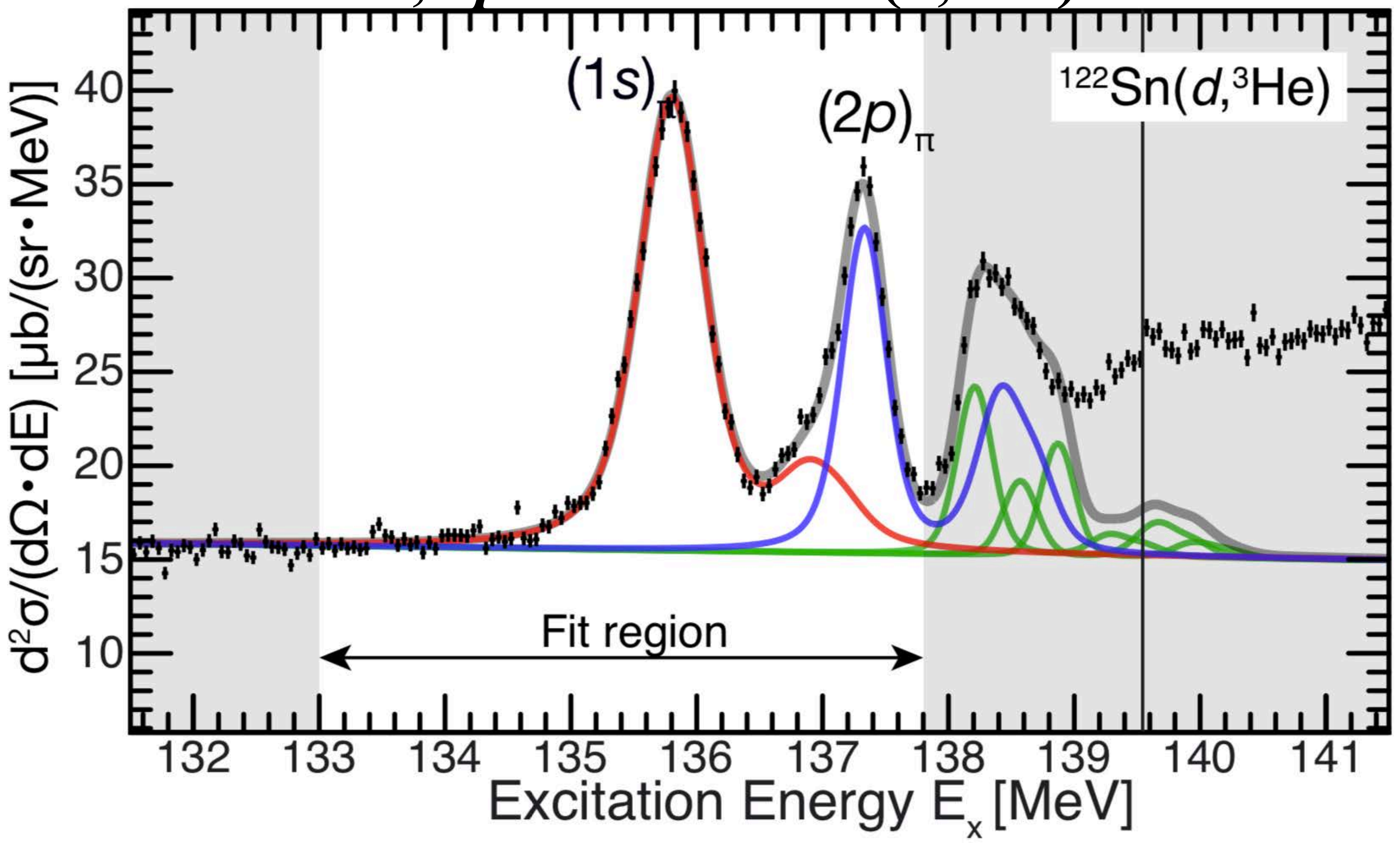
T. Nishi, K. Itahashi et al.,
Nature Physics 19, 788 (2023).

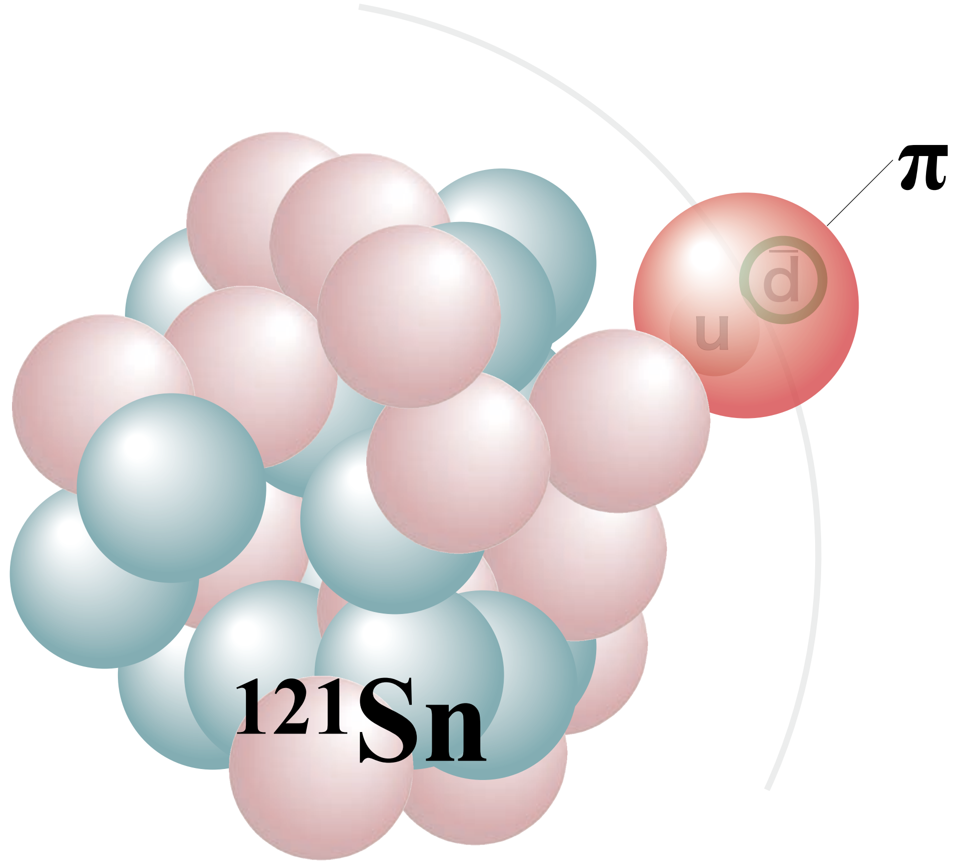
nature physics

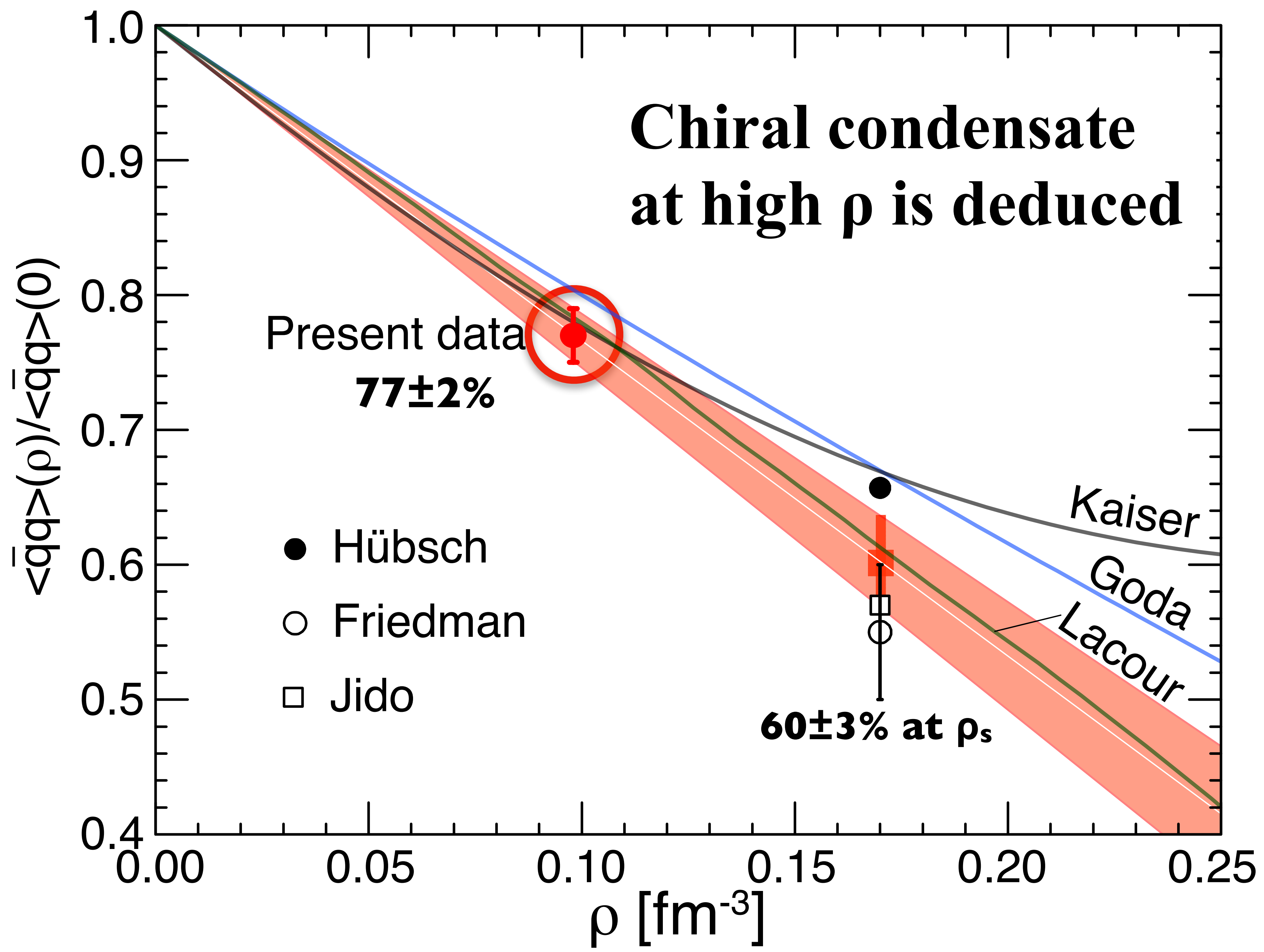
Article https://doi.org/10.1038/s41567-023-02001-x

Chiral symmetry restoration at high matter density observed in pionic atoms

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



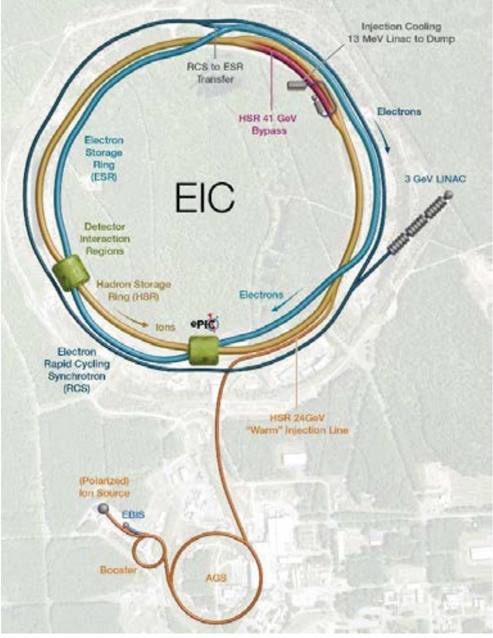




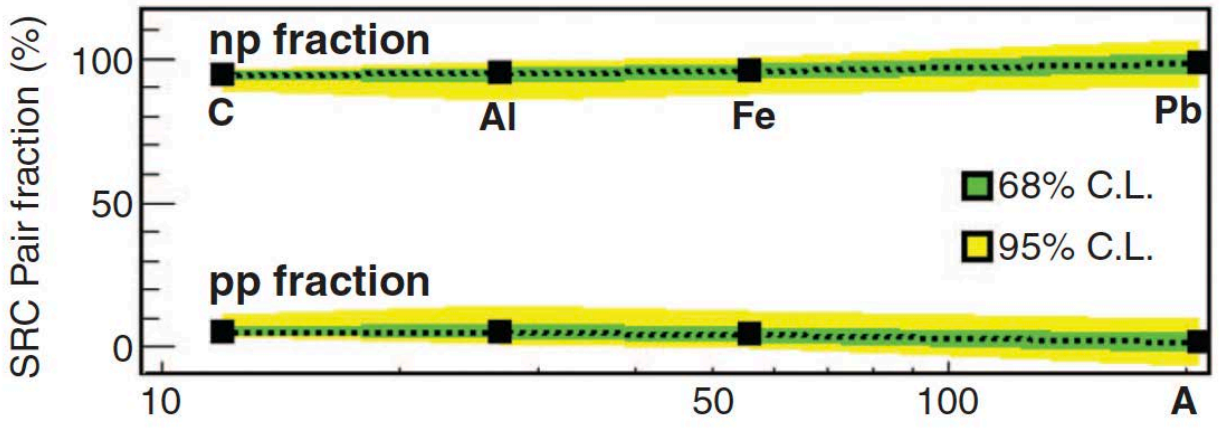
How can we understand consistently the origin of mass in terms of partial restoration of the chiral symmetry breaking and that to be revealed at EIC?

Topics connecting RIBF and EIC

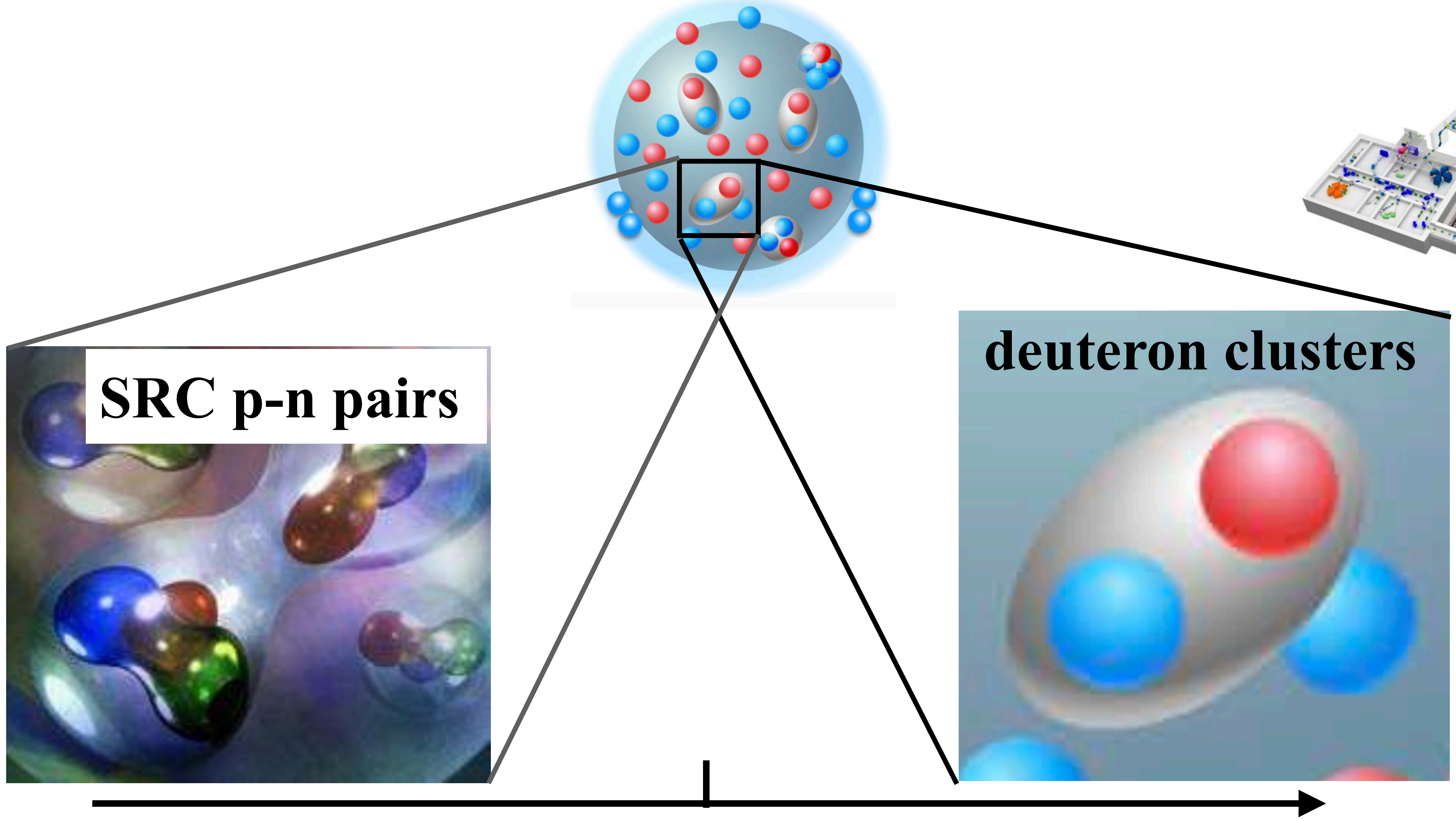
2. Properties of proton-neutron pairs at different resolutions/environment



O. Hen et al., Science 364



hints to understand the EMC effect



small p-n distance

quark-gluon dynamics

Proton radius (~0.8 fm)

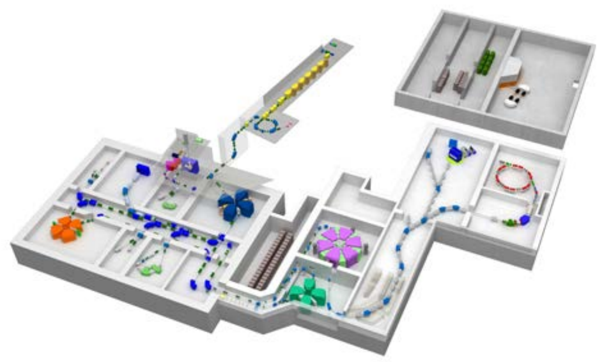
large p-n distance

nucleon-meson dynamics

200M JPY requested

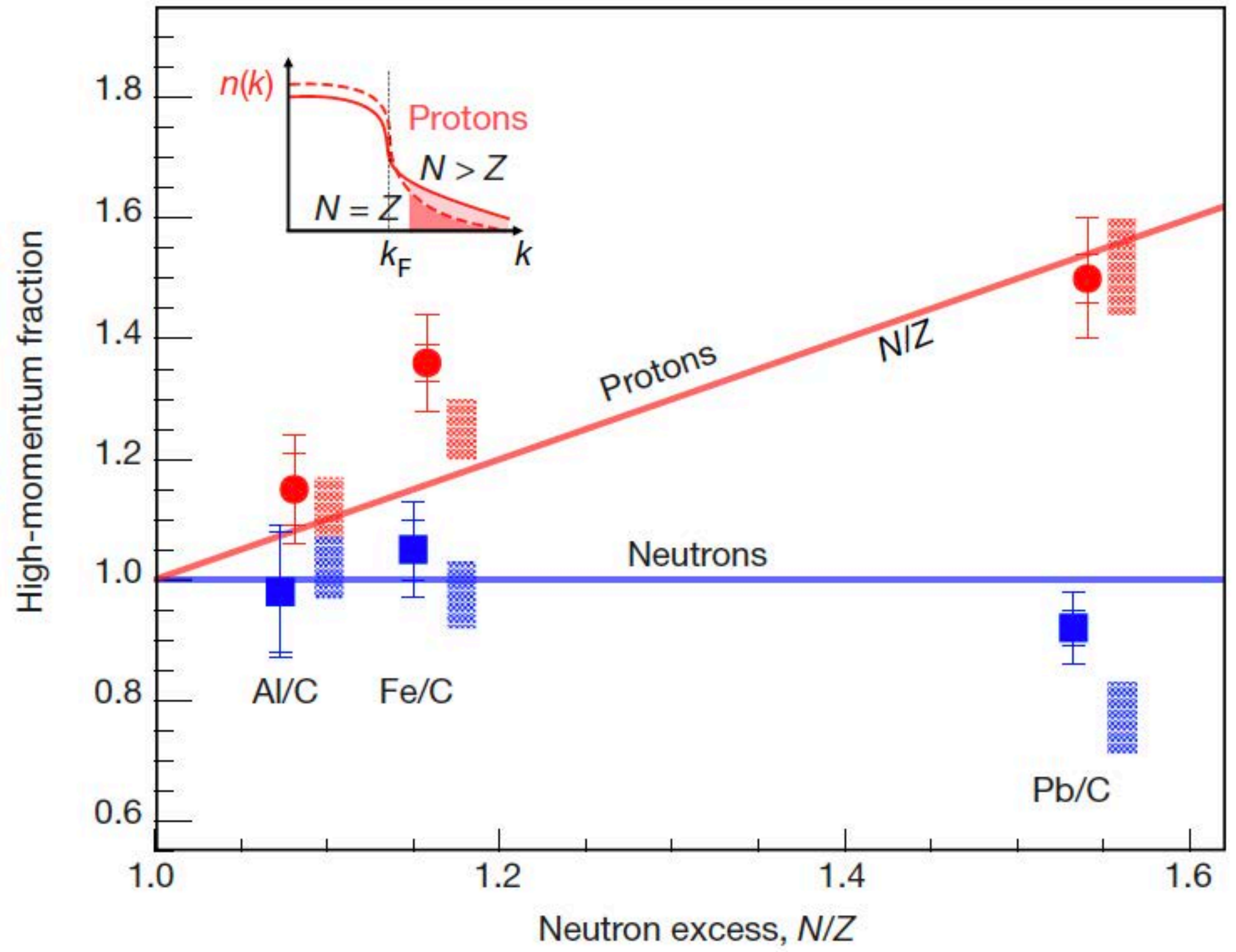
Si tracker

DAQ



Isospin dependence of p-n correlation

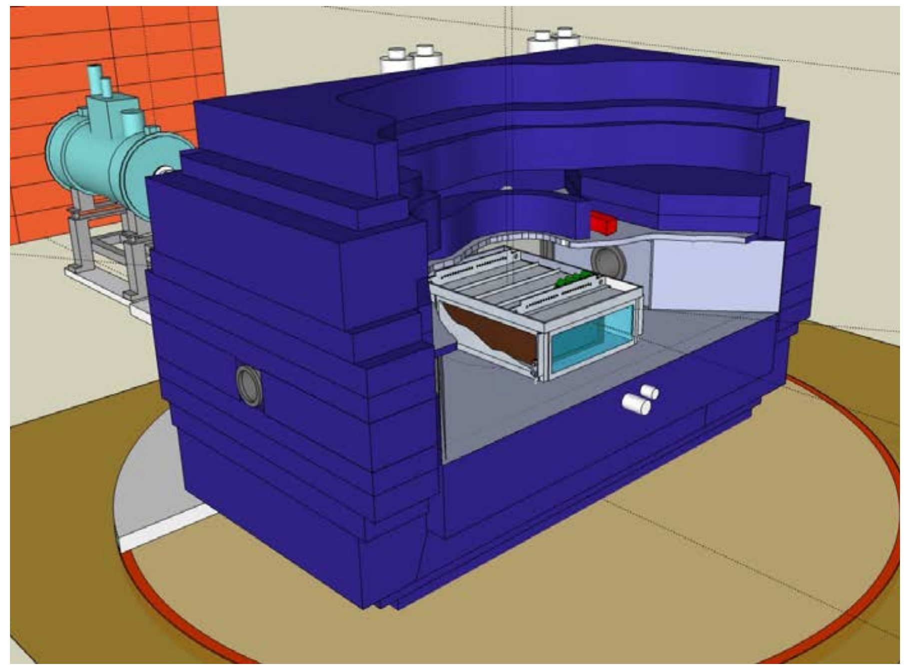
M. Duer et al., Nature 560

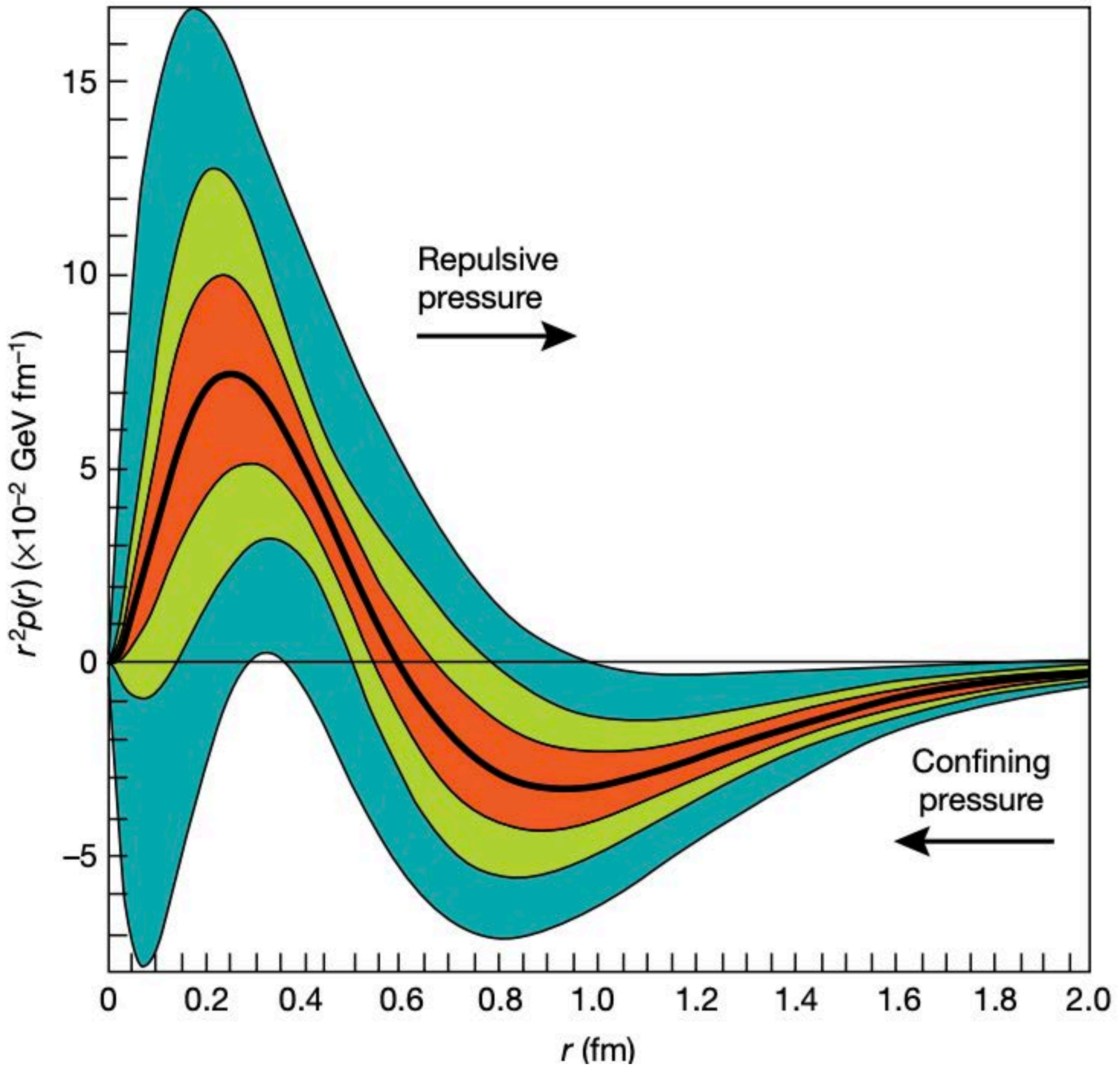


Topics connecting RIBF and EIC

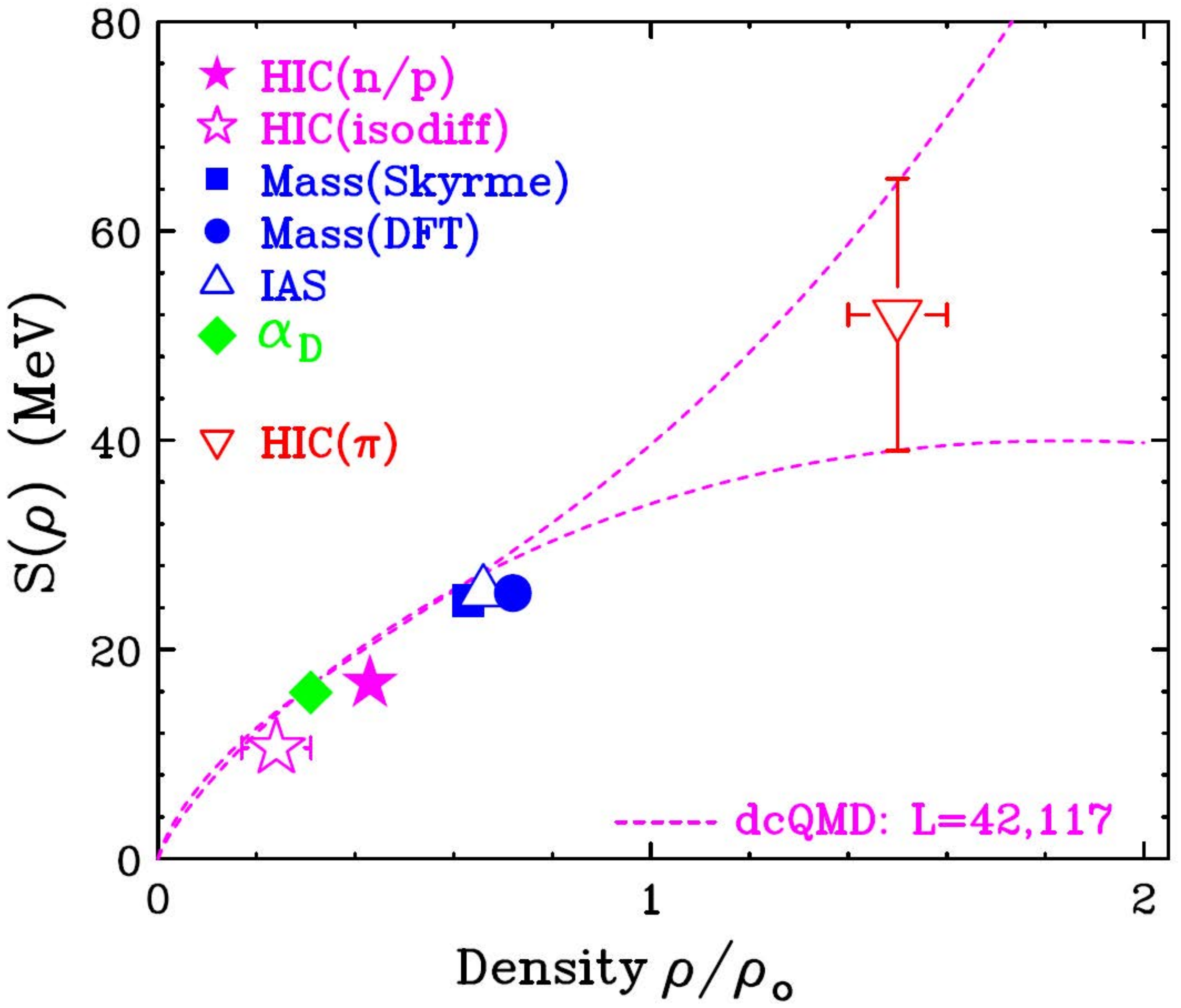
3. Mechanism that prevents matter from collapsing (equation of state)

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.



TOP-Tier platform In Extreme Rare isotope science(TOPTIER)

2024 IRIS Rare Isotope

ibS 기초과학연구원 Institute for Basic Science

World-class Research Results

Establishment of International Collaboration Center

RAON
극한 희귀동위원소 국제협력 사업단

RIKEN NiSHiNA CENTER
RIKEN 니시나센터 협력 사업팀

Top-tier Level New Researcher

Differentiated and Challenging Research Topics

국제공동연구 国際共同研究

정보교환 情報交換

인력 교류 人材交流

협력 거점 協力拠点


Dr. Taeksu Shin

ibS 기초과학연구원 Institute for Basic Science

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Prof Seonho Choi

고려대학교 KOREA UNIVERSITY
Prof. Jung Keun Ahn

KAERI 한국원자력연구원 Korea Atomic Energy Research Institute
Dr. Do Heon Kim


Director H. Sakurai

RIKEN NiSHiNA CENTER

Center for Nuclear Study The University of Tokyo
Director Y. Sakemi

WNSC KEK Wako Nuclear Science Center
Director Y. Watanabe

TOPTIER Subproject 3

LAMPS-NDA

~7.5MJPY/year (10 years)+ RIKEN fund 8MJPY/year (5 years)

GOALS

Better constrain the equation of state of the pure neutron matter

Explore the "non-uniform" picture of nuclear matter

Understand nucleon-nucleon (in particular *p*-*n*) correlations on a wide scale

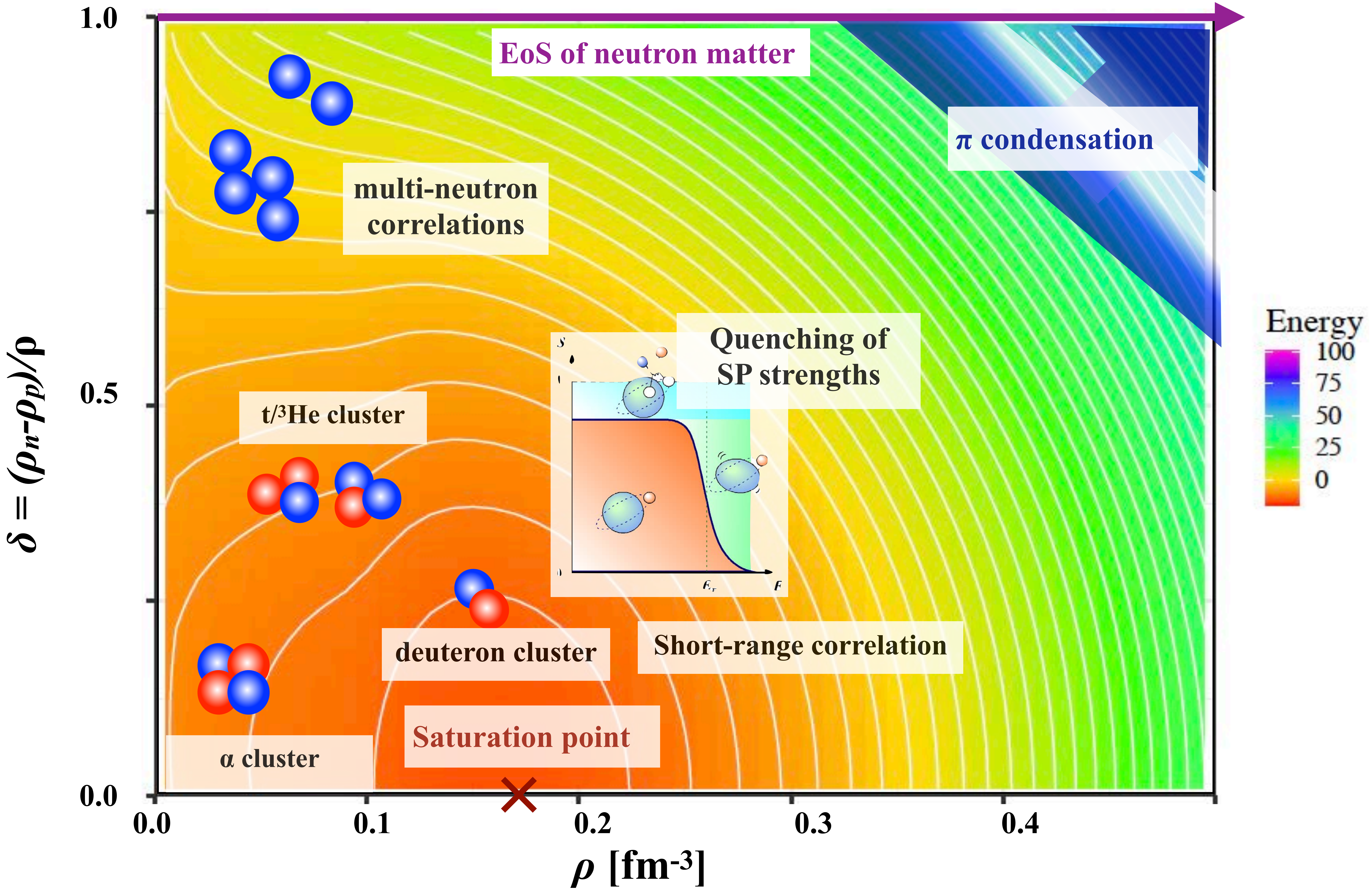
Capture signs of multi-neutron correlation beyond the drip-line

@ Barcelona, July 2024

Korea: J.K. Ahn, Y.J. Kim, H.S. Lee, C.S. Lee, J.W. Lee, B. Hong, Aram Kim, Sunji Kim + Director Office + Students (S.H. Choi, Rishav, 2 new students + 4 PhD candidates / M.K. Lee, + 5 PhD candidates)

Japan: T. Uesaka, T. Isobe, M. Sasano, Y. Kubota, Y. Kondo, S. Koyama, H. Otsu (RNC), K. Miki (Tohoku), T. Nakamura, K. Sekiguchi (Science Tokyo), J. Zenihiro, M. Dozono (Kyoto), S. Ota, J. Tanaka (RCNP), Y. Maeda (Miyazaki) ++

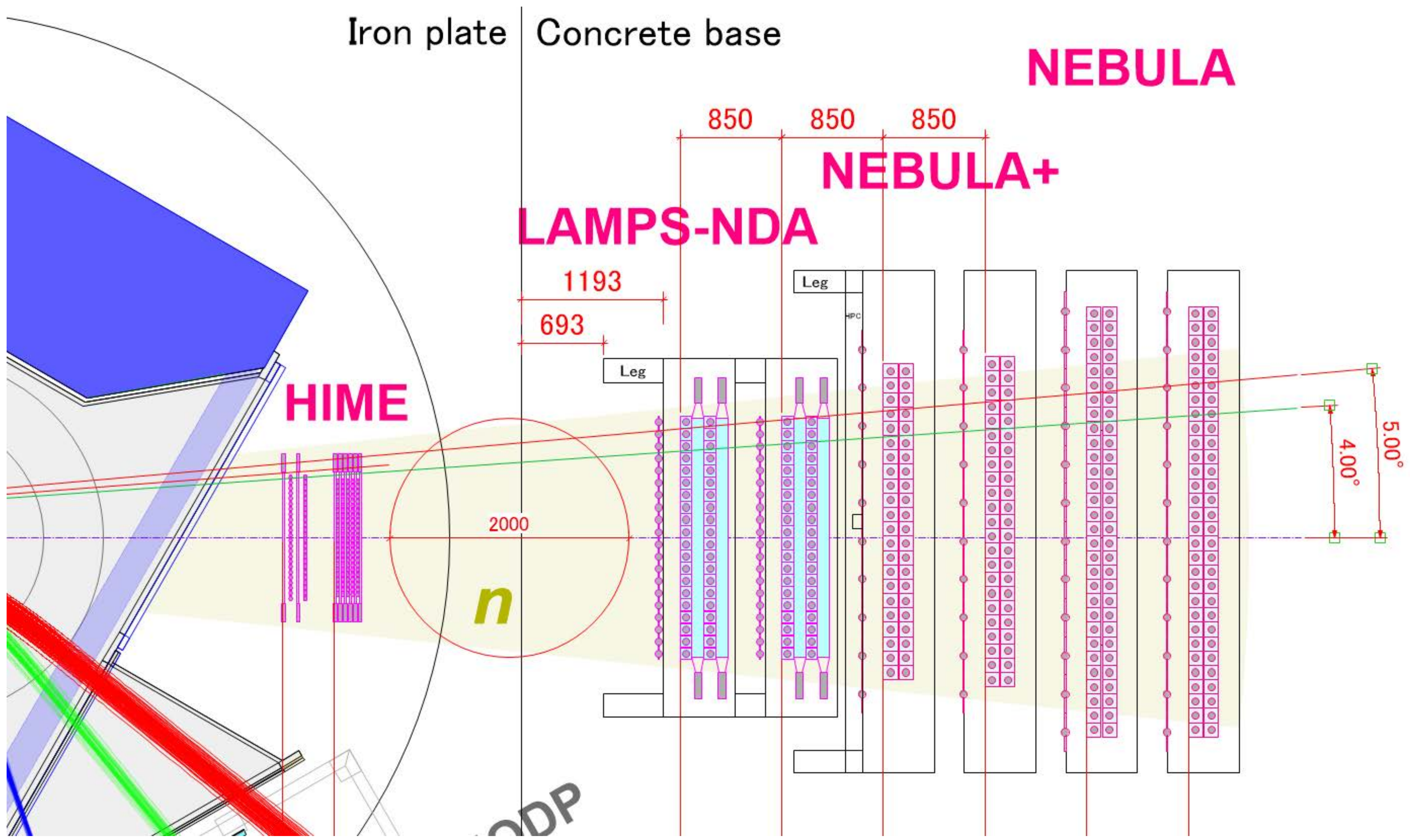
Multifaceted aspects of nuclear matter



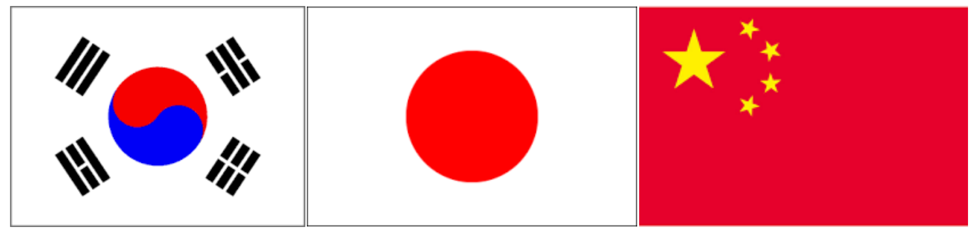
LAMPS-NDA@SAMURAI

LAMPS-NDA
"10×10×200 cm³"
× 160 bars

Y.J.Kim, J.W.Lee



Simulation by Siwei Huang (PKU)
w/ K. Miki and Y. Kondo



4n

E_{rel} [MeV]	Efficiency [%]	Gated eff. [%]	Resolution (FWHM) [MeV]	Crosstalk [%]
HIME + NEBULA				
1	2.1	2.1	0.24	13
2	1.7	1.7	0.34	15
3	1.2	1.2	0.43	17
5	0.65	0.65	0.60	22
HIME + NDA(4 dp) + NEBULA				
1	4.2	3.9	0.27	12
2	3.5	3.1	0.37	14
3	2.7	2.3	0.47	17
5	1.4	1.2	0.63	24

6n

E_{rel} [MeV]	Efficiency [%]	Gated eff. [%]	Resolution (FWHM) [MeV]	Crosstalk [%]
HIME + NEBULA				
1	0.15	0.15	0.29	30
2	0.16	0.16	0.38	31
3	0.14	0.14	0.45	31
5	0.08	0.08	0.76	34
HIME + NDA(4 dp) + NEBULA				
1	0.40	0.35	0.31	28
2	0.44	0.38	0.44	28
3	0.39	0.33	0.57	30
5	0.24	0.20	0.77	36

with LAMPS-NDA, we can challenge the world-first 6-neutron detection experiments

^{8}He(p,3p)6n

^{11}Li(p,3p)^{9}H→6n + t