Beam Simulations

Kihyeon Cho (KISTI) and Marc Verderi (LLR, N2P3)

May 18, 2026

2026 Joint Workshop of the FKPPN and TYL/FJPPN
Hamamatsu, Japan, May 18~21, 2026

Contents

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The French and Korean LIA teams

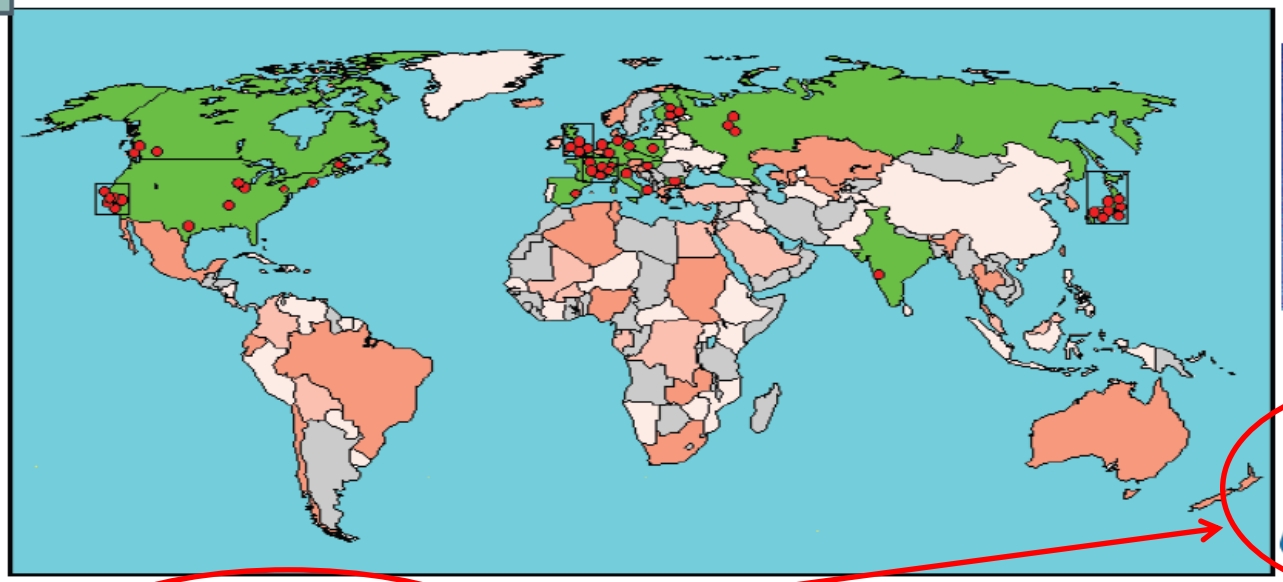
Members

- Korean Group
  - Kihyeon Cho (KISTI)
  - Kyungho Kim* (KISTI)

- French Group
  - Marc Verderi (LLR, IN2P3)
  - Davide Mancusi (CEA)

*Current address: Sungkyunkwan University

Geant4 Collaboration



TRIUMF

Lebedev

J.W.Goethe Universität

Collaborators also from non-member institutions, including
Budker Inst. of Physics
IHEP Protvino
MEPHI Moscow
Pittsburg University
Northeastern University
Wollongong University

Purpose of the Project

- To collaborate on beam simulations based on Geant4
- Initial motivation is for the RAON accelerator, IBS in Daejeon.
  - Proton, oxygen, xenon, and uranium beams of a few hundred MeV/u
  - RAON's first official experiment began (Jul. 8, 2024).
- Goal: Pre-verification through large scale computer simulation
  - To assess Geant4 performances in predicting isotope production
  - To provide the subject of the experiment (The first)
- Note that the study interest is not limited to the RAON accelerator.

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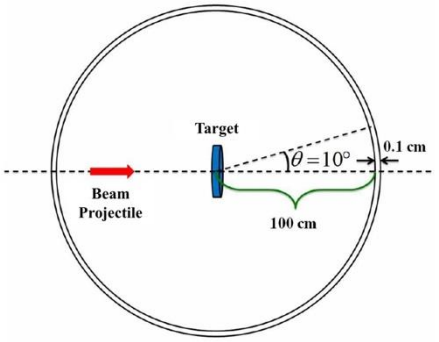
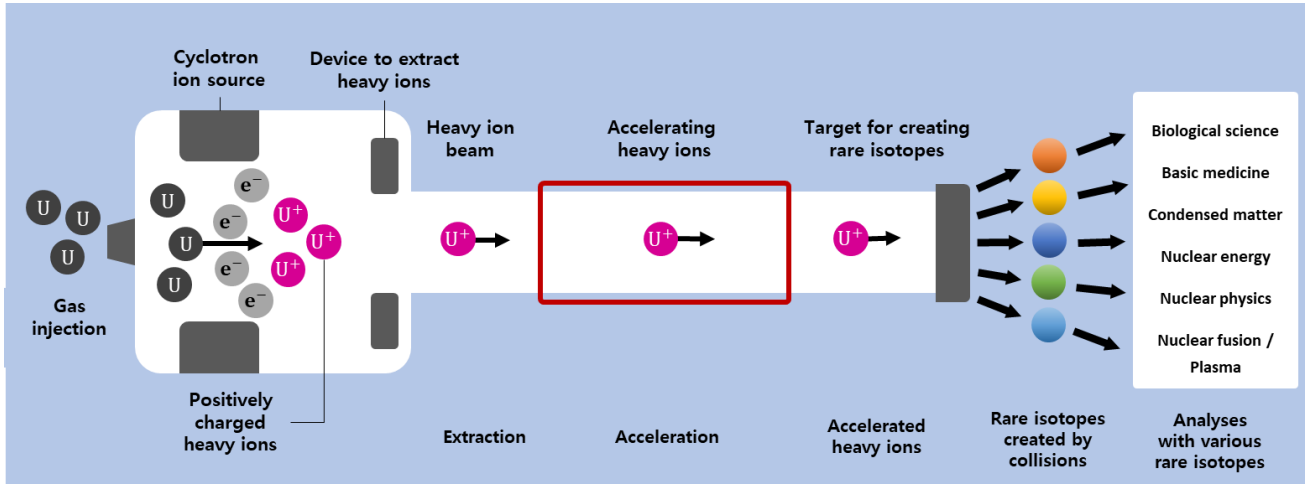
Group Activities

- The Korean and French teams
  - ⇒ Developed Geant4 R&D within the Geant4 collaboration
  - ⇒ Contributions to the Geant4.11.4 release (Dec. 5, 2025)
- The Korean group
  - ⇒ Large scale computational simulations for RAON experiments
- The French group
  - ⇒ Developing an ultra-thin beam profiler
  - ⇒ Developing the "event biasing" in Geant4
  - ⇒ Developing the INCLXX Geant4 model





Face to Face Meeting

1) Date: Feb. 6~7, 2025

2) Place: Pohang Accelerator Laboratory, Pohang, Korea

3) Participants: 9 persons

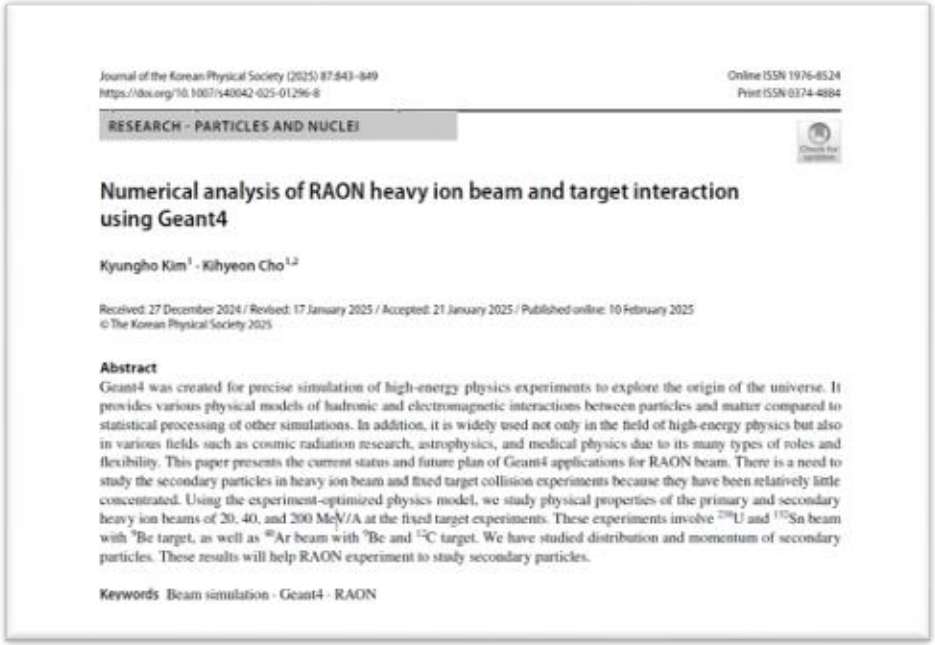
- Kihyeon Cho, Kyungho Kim (KISTI), Sebastien Incerti, Hoang Tran (IN2P3), Makoto Asai (Jefferson lab), Soon Yung Jun (Fermilab), Luis S. Pico (Lund University), Se Byeong Lee (NCC), Garam Han (PAL)

4) Aim:

- To attend the Geant4 Tutorial and present our recent developments
- To promote our activities and improve collaboration on Geant4 beam simulations

2 Papers

1. Numerical analysis of RAON heavy ion beam and target interaction using Geant4
   - Authors: Kyungho Kim and Kihyeon Cho (KISTI)
   - J. Korean Phys. Soc. 87, 843 (2025).
2. Nuclear Theory in the KISTI-6 supercomputer era
   - Authors: Kyungho Kim and Kihyeon Cho (KISTI)
   - J. Subatomic Part. Cosmol. 3, 8 (2025).



Journal of the Korean Physical Society (2025) 87:843–849
https://doi.org/10.1007/s40042-025-01296-8

Online ISSN 1976-8524
Print ISSN 0374-4884

RESEARCH - PARTICLES AND NUCLEI

Numerical analysis of RAON heavy ion beam and target interaction using Geant4

Kyungho Kim[1] · Kihyeon Cho[1,2]

Received: 27 December 2024 / Revised: 17 January 2025 / Accepted: 21 January 2025 / Published online: 10 February 2025

Abstract

Geant4 was created for precise simulation of high-energy physics experiments to explore the origin of the universe. It provides various physical models of hadronic and electromagnetic interactions between particles and matter compared to statistical processing of other simulations. In addition, it is widely used not only in the field of high-energy physics but also in various fields such as cosmic radiation research, astrophysics, and medical physics due to its many types of roles and flexibility. This paper presents the current status and future plan of Geant4 applications for RAON beam. There is a need to study the secondary particles in heavy ion beam and fixed target collision experiments because they have been relatively little concentrated. Using the experiment-optimized physics model, we study physical properties of the primary and secondary heavy ion beams of 20, 40, and 200 MeV/A at the fixed target experiments. These experiments involve ^{238}U and ^{132}Sn beam with ^{9}Be target, as well as ^{40}Ar beam with ^{9}Be and ^{12}C target. We have studied distribution and momentum of secondary particles. These results will help RAON experiment to study secondary particles.

Keywords Beam simulation · Geant4 · RAON

Journal of Subatomic Particles and Cosmology 3 (2025) 100060

Contents lists available at ScienceDirect

Journal of Subatomic Particles and Cosmology

journal homepage: https://www.sciencedirect.com/journal/journal-of-subatomic-particles-and-cosmology

ELSEVIER

Full length article

Nuclear theory in the KISTI-6 supercomputer era

Kyungho Kim[a], Kihyeon Cho[a,b,*]

[a] Korea Institute of Science and Technology Information, Daejeon 34141, Republic of Korea
[b] University of Science and Technology, Daejeon 34113, Republic of Korea

ARTICLE INFO

Keywords:
Nuclear theory
Supercomputer
Large-scale science
Nucleus structure

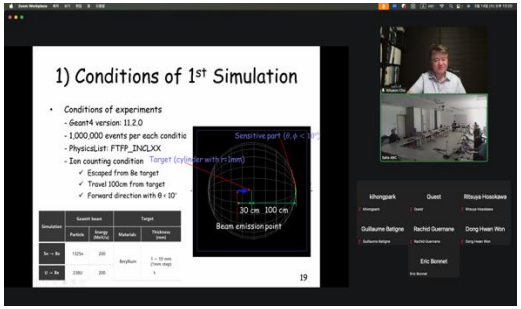
ABSTRACT

Supercomputers have enabled us to challenge previously unimaginable calculations. In the area of nuclear theory, various microscopic or elementary research methods are being attempted to understand the interactions of the nucleons. Using the KISTI-5 supercomputer of 25.7 PFLOPS (Floating point Operations Per Second) at the Korea Institute of Science and Technology Information (KISTI), we have done grand challenge programs of using 1500 node exclusively for nuclear theory. We introduce a few research experiences of them on nucleus constraint, neutron drip line, and Rare isotope Accelerator complex for ON-line experiment (RAON) beam simulation. Since large-scale science requires deep learning and big data processing, the architecture of supercomputing requires heterogeneous computing in traditional CPU evolutionary computing. Therefore, the KISTI-6 supercomputer of heterogeneous computing will be installed at the KISTI in 2025. This paper shows what can be done for nuclear theory with the KISTI-6 supercomputer in near future. The dynamic and transport properties of neutron star crust level may be solved. Beyond discovery will be able to brought by the KISTI-6 supercomputer.

3 Conference talks

1. 2025 Joint workshop of TYL/FJPPN and FKPPN

- Date: May 14, 2025
- Location: Nantes, France
- Talk title: Beam Simulations
- Presenters: Kihyeon Cho and Marc Verderi



2. 2025 Korean Society for Computational Science and Engineering Spring Meeting

- Date: May 14, 2025
- Location: Seoul, South Korea
- Talk title: Particle Physics in the KISTI-6 Supercomputing Era
- Presenter: Kihyeon Cho

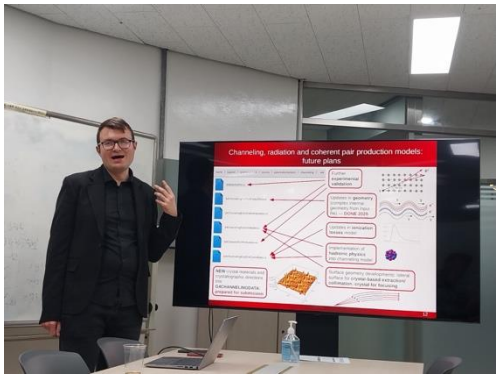
3. The 26th International Conference on Accelerators and Beam Utilizations (ICABU2025)

- Date: Nov. 13, 2025
- Location: Pohang, South Korea
- Talk title: Prospects for RAON Experiments with the KISTI-6 Supercomputer
- Presenter: Kihyeon Cho

Meeting Organization

Geant4 seminar

- Title: Geant4 Activities in Europe
- Speaker: Dr. Alexei Sytov
- Date: Nov. 4, 2025
- Location: KISTI, Daejeon, Korea
- Participants: 6 persons



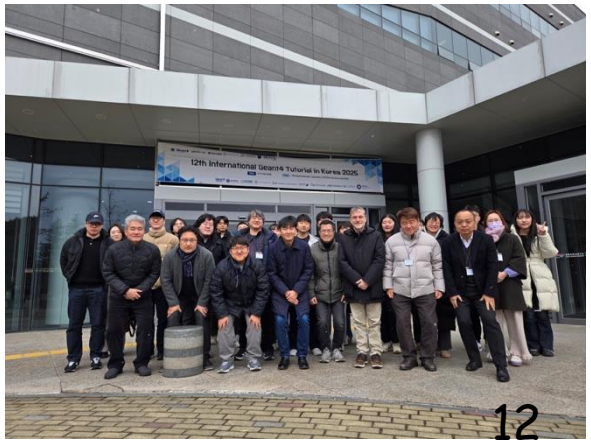
12th Int'l Geant4 Tutorial in Korea 2025

- Date: Feb. 2~7, 2025
- Location: Pohang Accelerator Laboratory, Pohang, Korea
- Aim:

  - Tutorials for users already familiar with previous Geant4 versions

  - To have bidirectional information exchanges between Geant4 team and Korean users

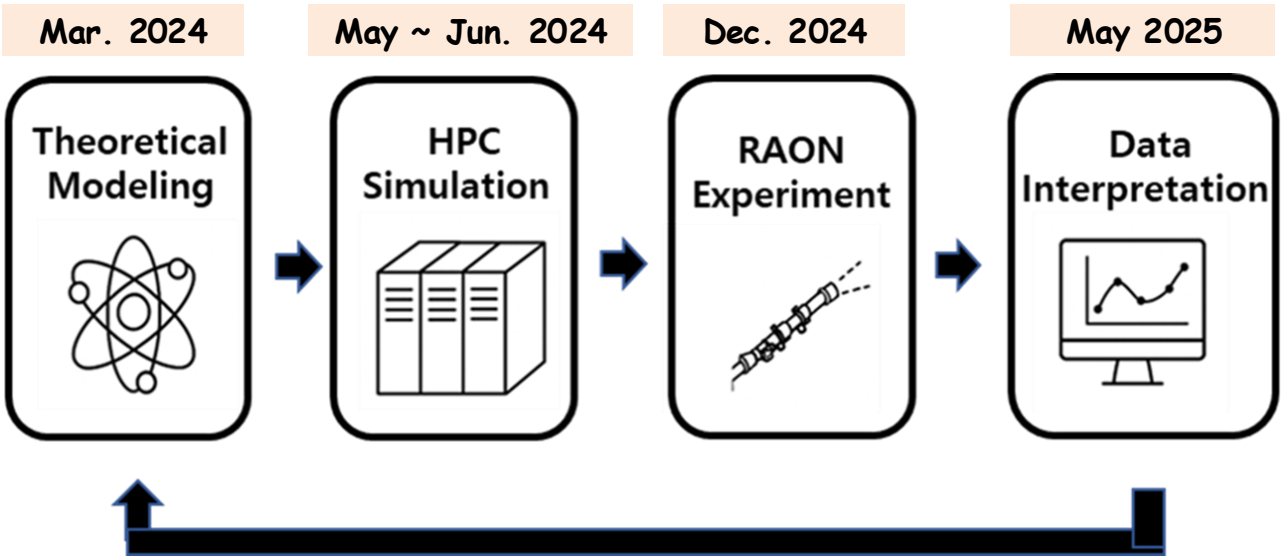
- Participants: over 50 persons



Korean Group Activity

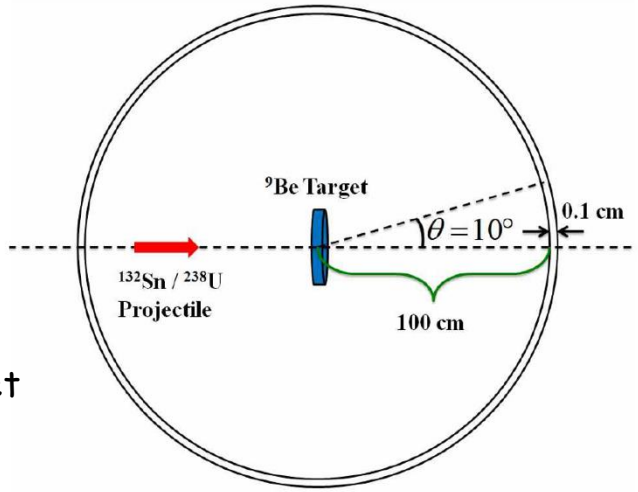
RAON Simulation

- **Large scale computational simulations for RAON experiments**
- IBS, KISTI
- 350 accounts: 1,500 exclusive nodes allocated for two months (May 1 ~ June 30, 2024)
- Pre-verification through large scale supercomputing simulations
  ⇒ Providing candidate isotopes for the RAON experiment (The first)

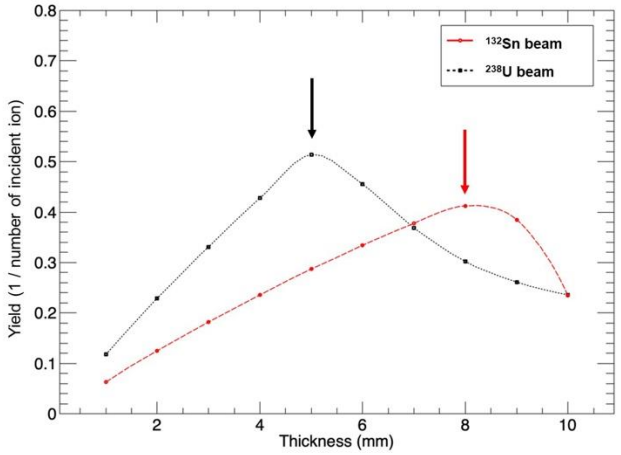


1. Heavy Ion beam Interaction using Geant4

- Conditions of experiments
  - Geant4 version: 11.2.0
  - 1,000,000 events for each condition
  - PhysicsList: FTFP_INCLXX
  - Ion counting condition
    - Escaped from Be target
    - Propagated 100cm downstream from the target
    - Forward direction with θ < 10°

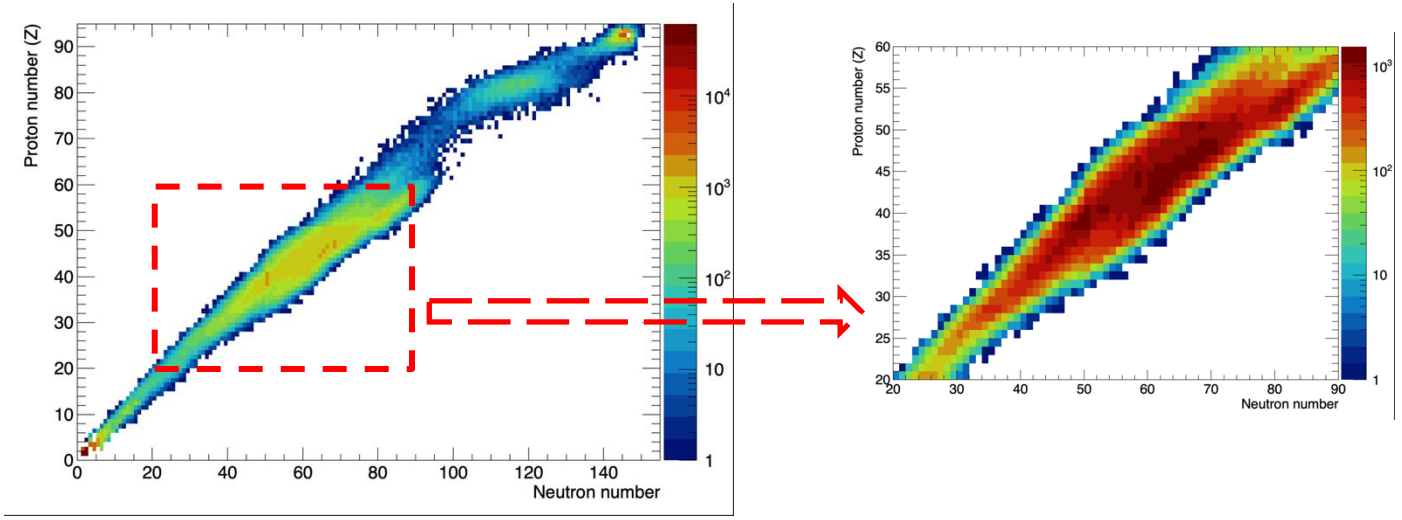


Simulation	Geant4 beam		Target	
	Particle	Energy (MeV/u)	Materials	Thickness (mm)
Sn → Be	Sn132	200	Beryllium	1 ~ 10 mm (1mm step)
U → Be	U238	200		



2D Distributions (U beam, 5mm Be target)

- With event generation optimized thickness
  - U beam for 5mm Be target

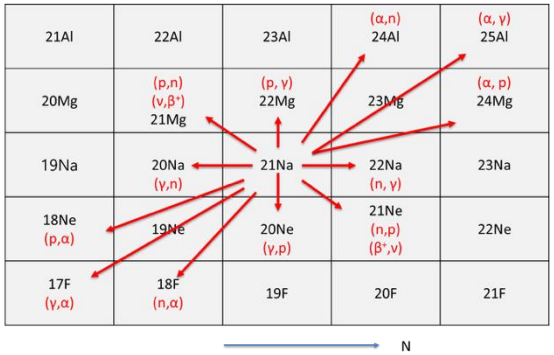


2. Supercomputing-Assisted Nuclear Structure

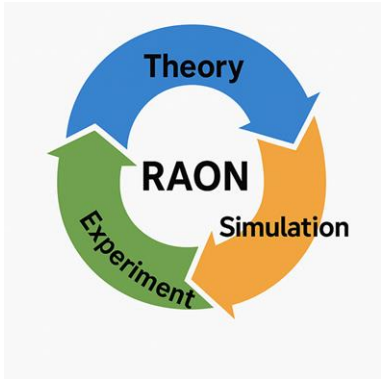
- **Nurion** was utilized to perform precise microscopic and *ab initio* nuclear structure calculations of rare isotopes.

- The computation successfully **predicted the nuclear structure of Sodium-21 (^{21}Na)** based on first-principles nuclear theory.

Theory-Simulation-Experiment



- ^{21}Na, Ab initio prediction (May~Jun. 2024)
- RAON CLS (Collinear Laser Spectroscopy) Experiment (Dec. 2024)
- Results were reported in INPC2025 (2025.5)



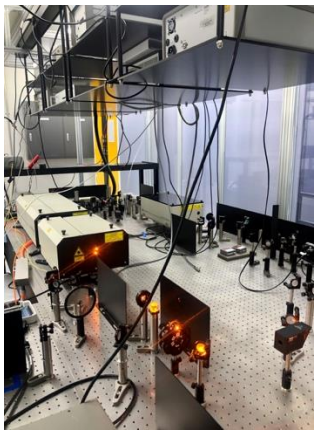
Proposal for an Experiment

Title of Experiment	Fusion-fission studies in the ^{20}Ne+^{197}Au reaction at 10 MeV/nucleon		
Application Area	☒Nuclear Physics ☐Energy ☐Medicine ☐Industry ☐Environment ☐Other Applications		
Experimental Devices	☒KoBRA ☐MMS ☐CLS ☐Cyclotron		
Available Beam	KoBRA	☐ ^{40}Ar (10~20 MeV/u)	
		☒ ^{20}Ne (10~20 MeV/u)	
	MMS	☐ $^{20-25}$Na (~20 keV)	
		☐ ^{26}Al (~20 keV)	
	CLS	☐ $^{20-25}$Na (~20 keV)	
		☐ ^{26}Al (~20 keV)	
	Cyclotron	☐ Proton (40 MeV)	☐ Proton (70 MeV)
Beam Time Unit*	☒ 1 BTU ☐ 2 BTU ☐ _____		
Beam Requests	Beam	Energy (MeV/u)	Intensity (pnA)
	^{20}Ne	10	1.5

* 1 BTU = 8 hours

☐ Spokesperson

Name	Zeren Korkulu



The 29th International Nuclear Physics Conference (INPC 2025)

INPC 2025 May 25-30, 2025 DCC, Daejeon, Korea

Contribution ID: 566 Type: **Contributed Oral Presentation**

Nuclear Charge Radius Measurement for Neutron-deficient Na Isotopes

Tuesday, May 27, 2025 11:00 AM (15 minutes)

We report on precision measurement of the isotope shifts of neutron-deficient sodium isotopes to determine their nuclear charge radii, with a specific emphasis on ^{21}Na. Precise determination of the nuclear charge radius allows for accurate calculation of the charge radius difference, ΔR_c, between ^{21}Na and its mirror nucleus ^{21}Ne. This difference provides critical constraints on the nuclear symmetry energy slope, L, and is also correlated with a correction term of the Ft value essential to the unitarity test of the Cabibbo-Kobayashi-Maskawa (CKM) matrix.

We conducted collinear laser spectroscopy (CLS) measurements at the RAON facility using the CLaSsy setup. ^{21}Na was produced at the ISOL facility using a 70 MeV proton beam from a cyclotron impinging on the SiC target. The ^{21}Na beam was accelerated to 20 keV and delivered to the CLaSsy beamline as a 10 Hz bunched beam through the Radio Frequency Quadrupole-Cooler Buncher (RFQ-CB). The bunched ^{21}Na ion beam was neutralized in a charge exchange cell and subsequently interacted with a 589-nm laser beam. Fluorescence light from the D_1 transition line of ^{21}Na was detected using a photomultiplier tube (PMT), and its hyperfine spectra were obtained by scanning the voltage applied to the ion beam. Data acquisition was synchronized with the bunched beam to enhance the signal-to-background ratio. Both collinear and anti-collinear methods were employed to enhance ion kinetic energy precision. From these measurements, we achieved improved precision of isotope shifts of ^{21}Na in determining its nuclear charge radius. This study can be extended to perform precise measurements of nuclear symmetry energy and conduct unitarity tests of the CKM matrix for other isotopes with similar masses.

Primary authors: WON, Junho (CENS, IBS); HA, Jeongsu (CENS, IBS); KIM, Yung Hee (CENS); Dr AHN, Sunghoon(Tony) (Center for Exotic Nuclear Studies, Institute for Basic Science); AHN, Deuk Soon (Center for Exotic Nuclear Studies, IBS); CHEKHOVSKA, Anastasiia (Institute for Basic Science); Dr CHAVAN, Vivek (Center for Exotic Nuclear Studies, IBS); GU, Gyoungmo (Sungkyunkwan University); HAHN, Kevin Insik (Center for Exotic Nuclear Studies, IBS); HUH, Jangyong (CENS (Center for Exotic Nuclear Studies), IBS (Institute of Basic Science)); KIM, Dahee (Center for exotic nuclear studies, Institute Basic Science); Dr KIM, Dong Geon (IBS/IBS); KIM, Jung Bog (korea national university of education); KIM, Sunji (Institute for Basic Science); KIM, Young Suk (IBS, IBS); KORKULU, Zeren (IBS, CENS); KWAK, Donghyun; LEE, Jinho; LEE, Jung Woo (Center for Exotic Nuclear Studies, Institute for Basic Science); Ms LIM, Chaeyoung (IBSInstitute for Basic Science) / Korea University); PARK, Joochun (Jason) (CENS, IBS); Dr PARK, Sung Jong; PYEUN, Seong Jae (RISP, IBS); SON, CHANGWOOK (Institute for Basic Science); Mr SON, Yonghyun (Center for Exotic Nuclear Studies, IBS); SONG, Jaehyun (IBS, IBS); STUHL, Laszlo (CENS, IBS); TSHOO, Kyoungho (RISP/IBS); YU, Hoon (Republic of Korea Air Force Academy); YIM, Hee-Joong (IBS)

Presenter: WON, Junho (CENS, IBS)

Session Classification: Parallel Session

Track Classification: Fundamental Symmetries and Interactions in Nuclei

"Nuclear Charge Radius Measurement for Neutron-deficient Na Isotopes", Contributed Oral, INPC 2025, Daejeon, Korea.
PDF abstract available via IBS Indico System (Indico)

News Coverage

KISTI's Nurion Supercomputer Meets IBS' RAON Accelerator. (2025.06.22)

전자신문 | etnews

과학 과학

KISTI 슈퍼컴 '누리온', 중이온가속기 실험 정밀 예측...국제 학계 주목

발행일 : 2025-06-20 10:00

라온 전경

한국과학기술정보연구원(KISTI·원장 이식) 국가슈퍼컴퓨터 5호기 '누리온'이 기초과학연구원(IBS) 중이온가속기연구소의 중이온가속기 '라온' 실험 정밀 예측을 지원, 세계 핵물리학계 주목을 받고 있다.

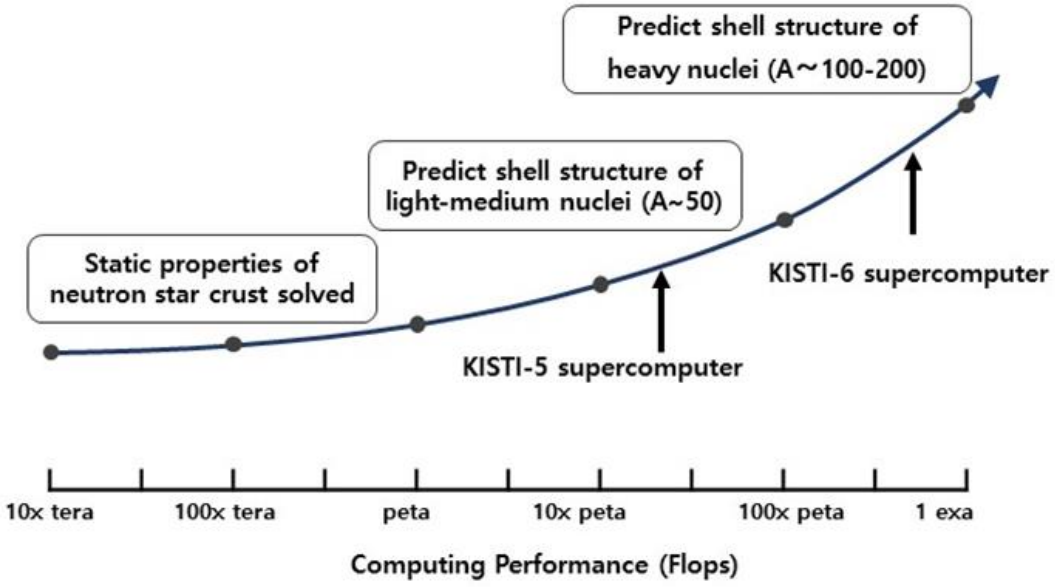
KISTI에 따르면 라온은 가속시킨 중이온을 표적에 충돌시켜 새로운 희귀동위원소를 생성하는 장치다. 지난해 7월부터 본격 가동했다.

이에 발맞춰 김영만 IBS 희귀 핵 연구단 박사 그룹과 조기현 KISTI 첨단과학컴퓨팅센터 박사 그룹이 공동 연구팀을 꾸렸다. 누리온 거대규모 전산 모사로 라온 실험 타당성을 검증하고, 누리온 1500노드를 전용 할당받아 라온 주요 미래 실험 주제를 제안하는 연구를 수행했다.

YouTube

RAON with KISTI-6 supercomputer

- A GPU-based 600-PF supercomputer will be launched in fall 2026.
- It will enable exascale, AI-accelerated research for high-precision nuclear simulations ($A \approx 100$–200) as well as Geant4.



French Group Activity

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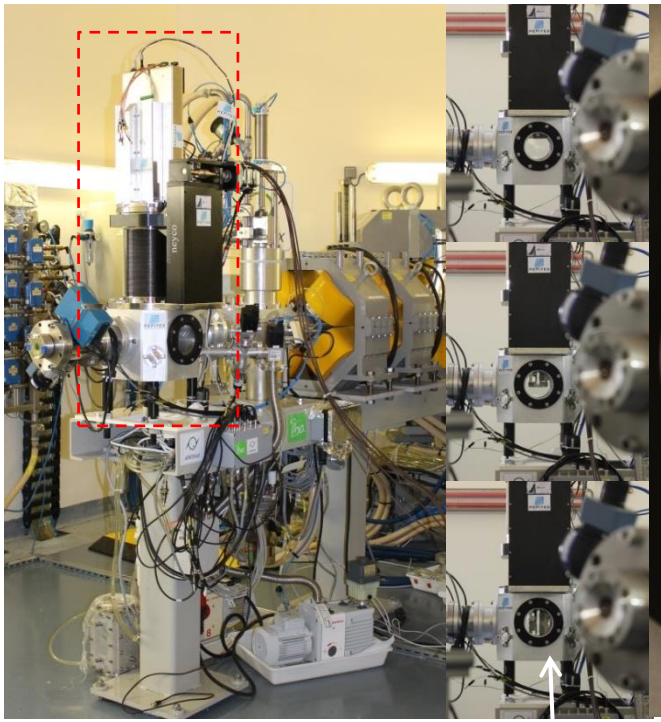
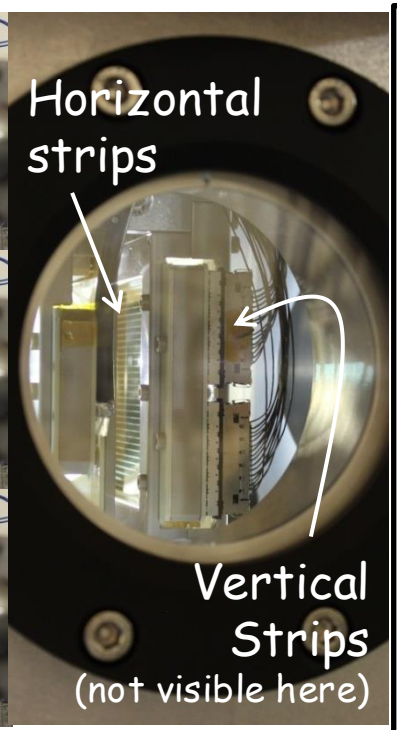
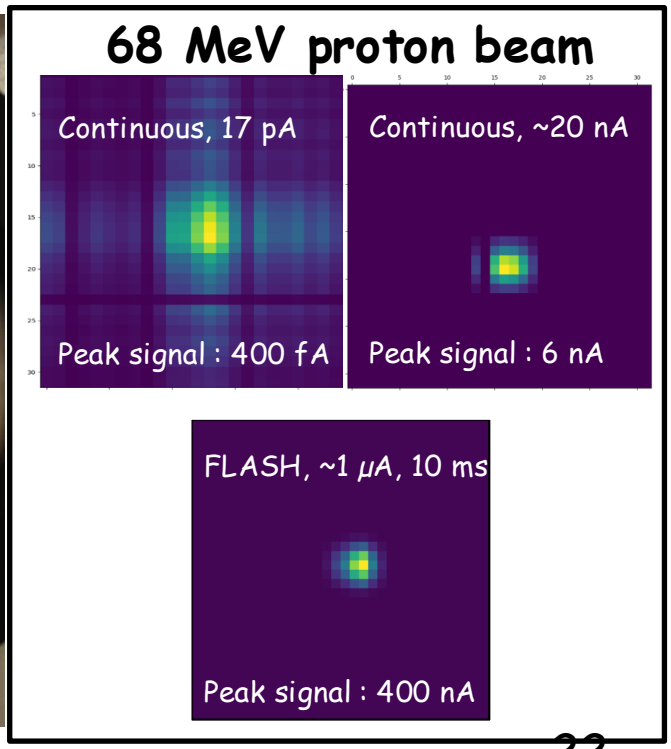
French group activity (1/3)

- Ultra-thin beam profiler (10 μm water equivalent), SEE*-based
  - Initially motivated by medical needs
- First monitor installed at ARRONAX** in May 2022 (ANR Grant)
  - Designed for continuous beams
  - But works with FLASH ones (SEE phenomenon very linear)



Insertion in beam

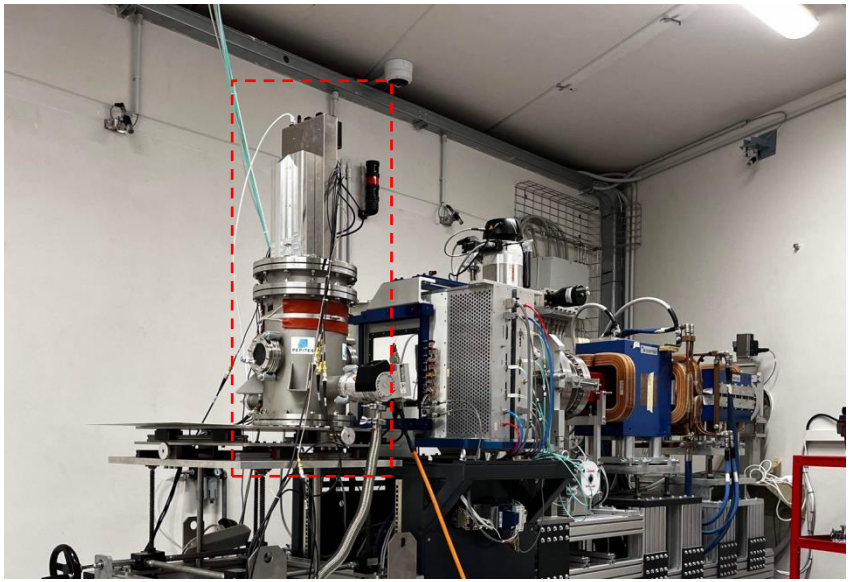




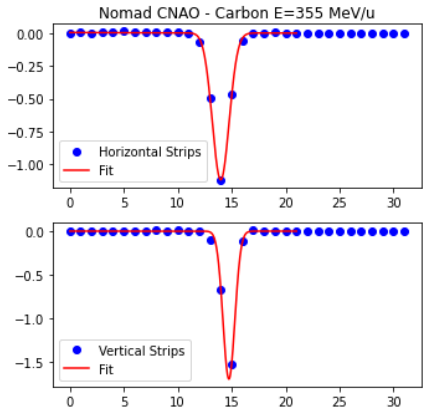
*SEE: Secondary Electron Emission
**ARRONAX: Accelerator for Research in Radiochemistry and Oncology at Nantes Atlantique

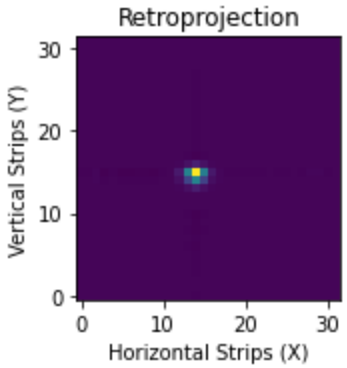
French group activity (2/3)

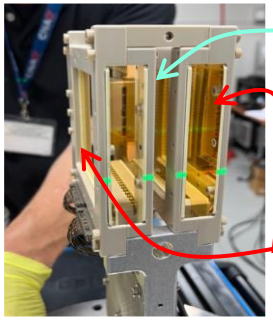
- A second monitor, a "nomad" copy of the ARRONAX one, is used @ CNAO (Pavia, Italy) to assess the possibility to use an adapted PEPITES.
  - Constraint : monitor 6.5 m from the patient → need low WET !



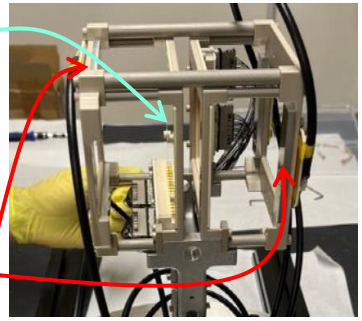
First carbon ions measured by PEPITES (Nov. 2023)







Keep strip planes. Replace anode planes by off axis electrodes



- Second test beam in Sept. 2024 : used "off axis" collection anodes to go from 10 µm WET to 5 µm WET : still works !

- 3rd PEPITES work : try to adapt to laser-plasma beams… (challenging)

French group activity (3/3)

- Development of "event biasing" techniques in Geant4
  - Expect to provide biasing functionalities at the level of other existing simulation packages
    - With the advantage of Object Oriented technologies: the user can extend the functionalities, not only use them.
  - Revised and uniformized existing Geant4 techniques
  - And provided flexible framework to extend to other techniques:
    - Biasing of physics process interaction law
    - Biasing in final state production
    - Both
  - Development was released in Geant4 version 11.4 (Dec. 5, 2025).

- Development of the Liège cascade model INCLXX of Geant4

Summary

- Scientific Activities
  - Geant4 R&D within the Geant4 collaboration
  - Beam simulation and detector optimization
  - Supercomputing-assisted nuclear structure for RAON

- Outreach & Collaboration
  - 2026 Geant4 Collaboration meeting (Bordeaux, France, Oct. 2026)
  - 13th International Geant4 Tutorial (Daejeon, Korea, Nov. 2026)

⇒ To advance common scientific goals with the KISTI-6 supercomputer and the RAON experimental program

Acknowledgement

- Kyungho Kim, Youngman Kim, Young Ho SONG, Ik Jae SHIN and Myungkuk Kim

- This research is supported by the major institutional R&D program, KISTI (K26L1M2C3). This study was also supported by National Supercomputing Center with supercomputing resources including technical support (KSC-2022-CHA-0003, KSC-2023-CHA-0005, KSC-2024-CHA-0001 and KSC-2025-CHA-0004).

Thank you.