29th Geant4 Collaboration meeting
Four Point Sheraton Hotel, Catania, Italy

October 7-11, 2024

RAON Beam Simulation

2024. 10. 9

Kihyeon CHO (KISTI/UST)*
Kyungho KIM (KISTI)

* Presenter

Contents

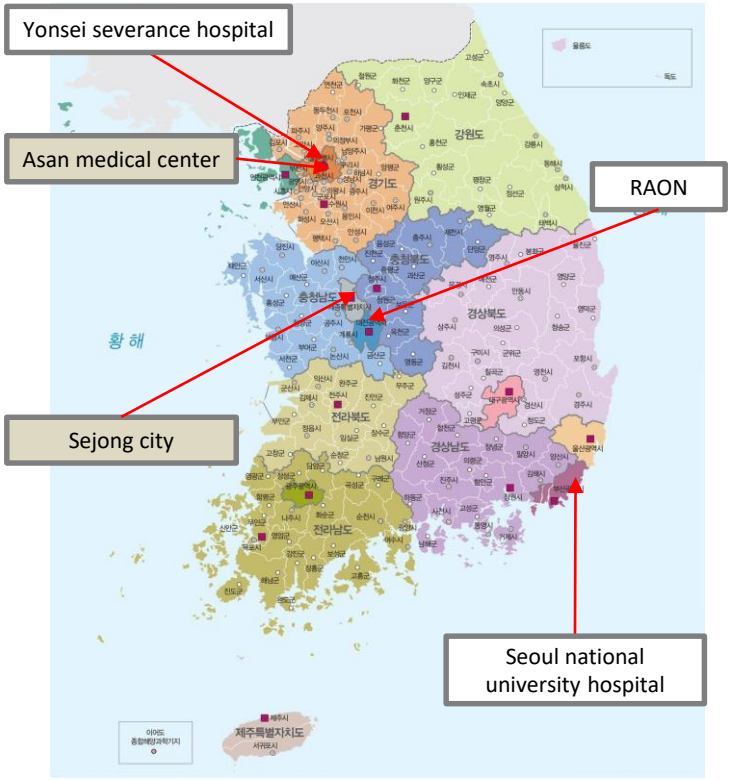
1. Introduction
2. Production of Secondary Particles
3. Collaboration with IBS for RAON
4. Summary

1. Introduction

Accelerators in Korea

- The last few years, there have seen a rise in the number of particle accelerators in Korea.
  - Confirmed
    - RAON, 2024 (Scientific)
    - Yonsei Severance hospital, 2023 (Medical)
    - Seoul national university hospital, 2025 (Medical)
  - Consideration
    - Asan medical center (Medical)
    - Sejong city (Medical)
  - .. And so on.
- However, there has been relatively little focus on accelerator-based study of secondary particles.

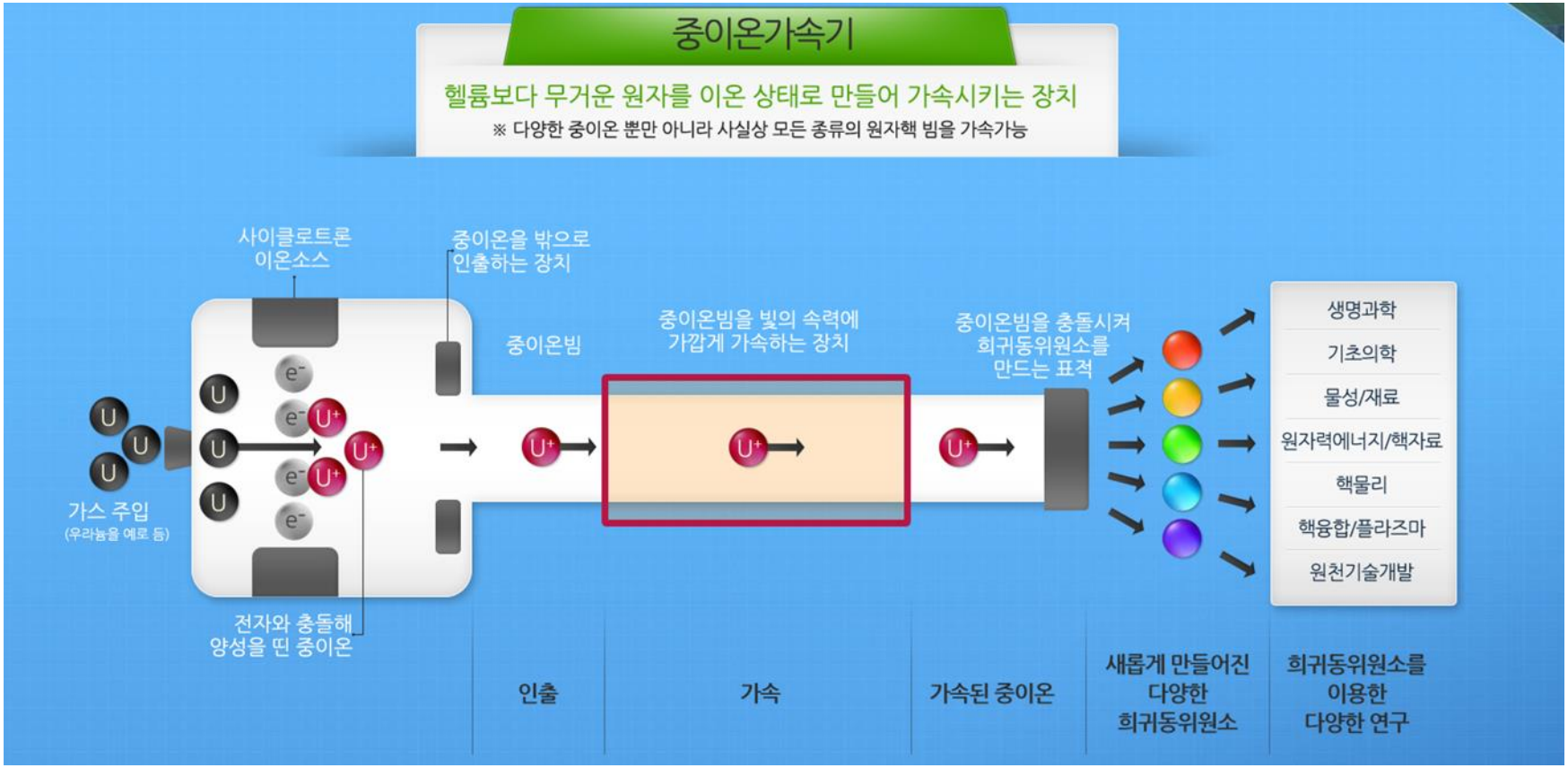
⇒ Need to study heavy ion beam simulation



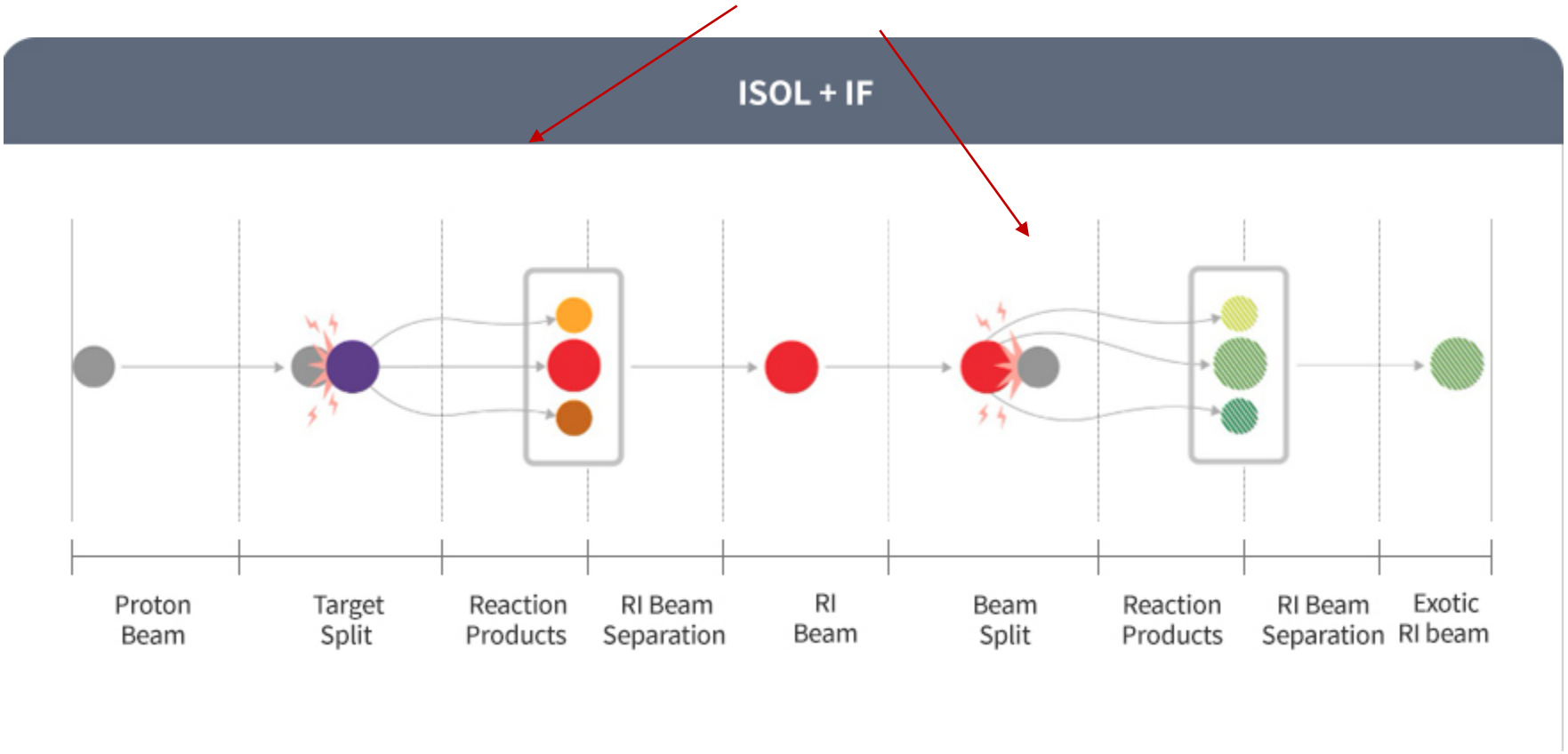
RAON

- RAON - **R**are isotope **A**ccelerator complex for **ON**-line experiments
- RAON accelerator
  - Proton, oxygen, xenon & uranium beams of a few 100MeV/u
  - Period:
    - 2011.12~2022.12: 1st Phase
    - 2022. 1~2025.12 : 2nd Phase R&D SCL2
    - 2024.5~ : First Experiment
- Goals of this study
  - To assess Geant4 performances in predicting isotope production
  - To use it to anticipate isotope natures and production yields
  - To foresee what measurements apparatus would be appropriate
- However, note that the study interest is not limited to the RAON.

RAON


중이온가속기
헬륨보다 무거운 원자를 이온 상태로 만들어 가속시키는 장치
※ 다양한 중이온 뿐만 아니라 사실상 모든 종류의 원자핵 빔을 가속가능
사이클로트론 이온소스
중이온을 밖으로 인출하는 장치
중이온빔
중이온빔을 빛의 속력에 가깝게 가속하는 장치
중이온빔을 충돌시켜 희귀동위원소를 만드는 표적
가스 주입
(우라늄을 예로 듬)
전자와 충돌해 양성을 띤 중이온
생명과학
기초의학
물성/재료
원자력에너지/핵자료
핵물리
핵융합/플라즈마
원천기술개발
인출
가속
가속된 중이온
새롭게 만들어진 다양한 희귀동위원소
희귀동위원소를 이용한 다양한 연구

RAON



- The first kind of facility having ISOL(Isotope Separation On-Line) and IF(In-flight) method combined

- To increase the rate of discovery of rare isotopes

RAON Science

Nuclear science

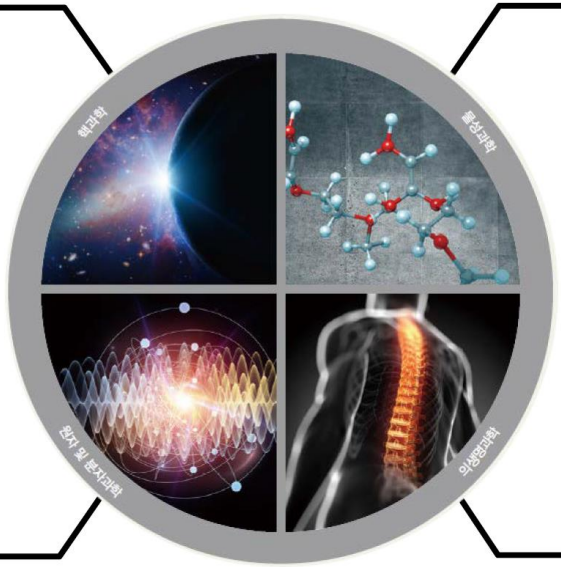
Origin of elements
Systematic search of new rare isotopes

- Chemical history of the universe
- Nuclear structure/reaction
- Nuclear data
- Nuclear theory

Material science

Microscopic structure and process study of various materials.

- Experimental technique with extreme sensitivity to probe deep inside materials
- New materials: nanostructured conductors, high T_c superconductor, etc



Atomic & Molecular science

Precision mass and radius measurements of rare isotopes

- Fundamental properties of nuclei: masses, moments, spins and radii
- Measurement of fundamental constants

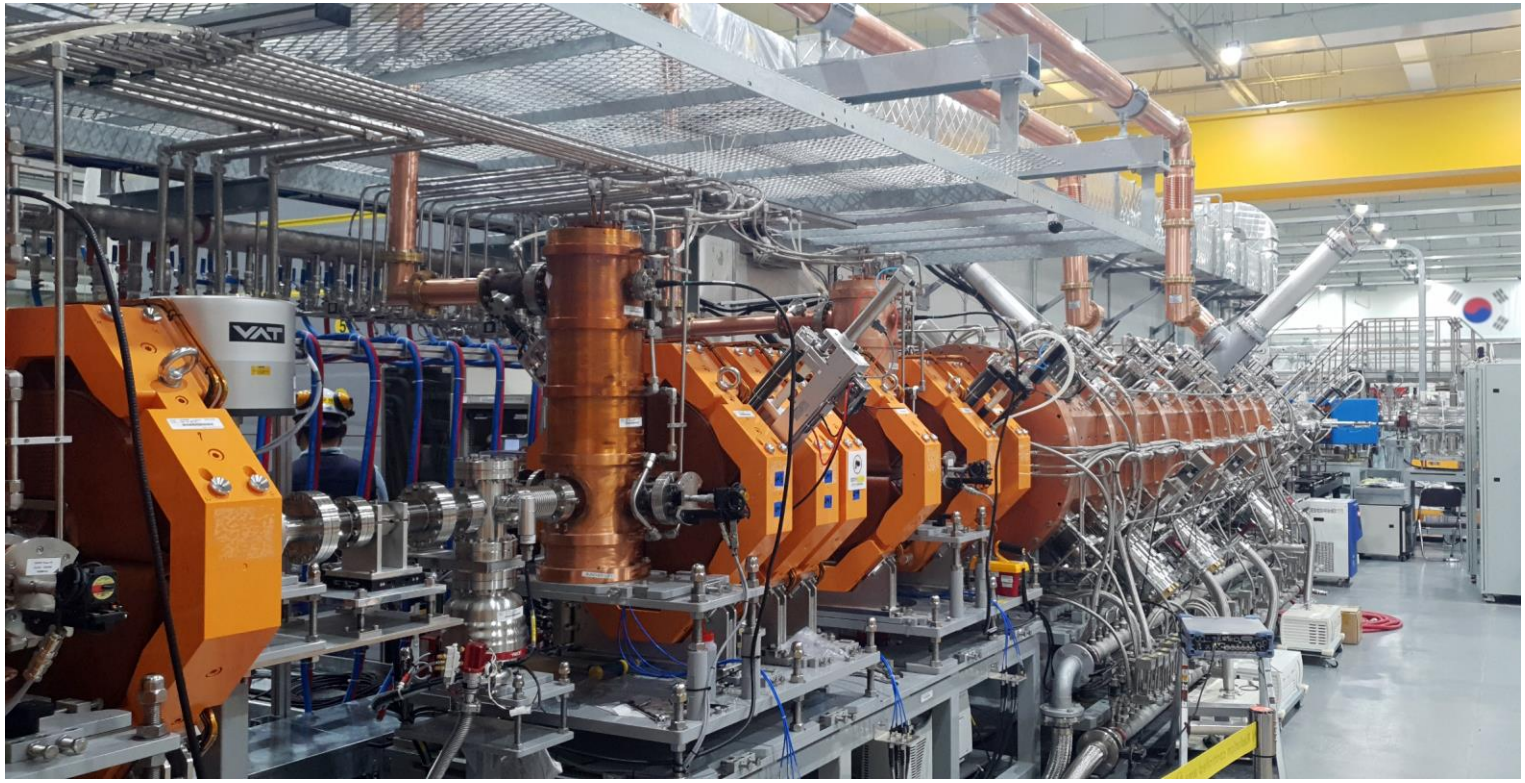
Medical & Bio science

Paradigm shift in medical/bio science with rare isotopes

- New cancer treatment
- New biotechnology in plant breeding

S. Jeong, P. Papakonstantinou, H. Ishiyama, Y. Kim, "A Brief Overview of RAON Physics," J. Korean Phys. Soc. 73 (2018) 516

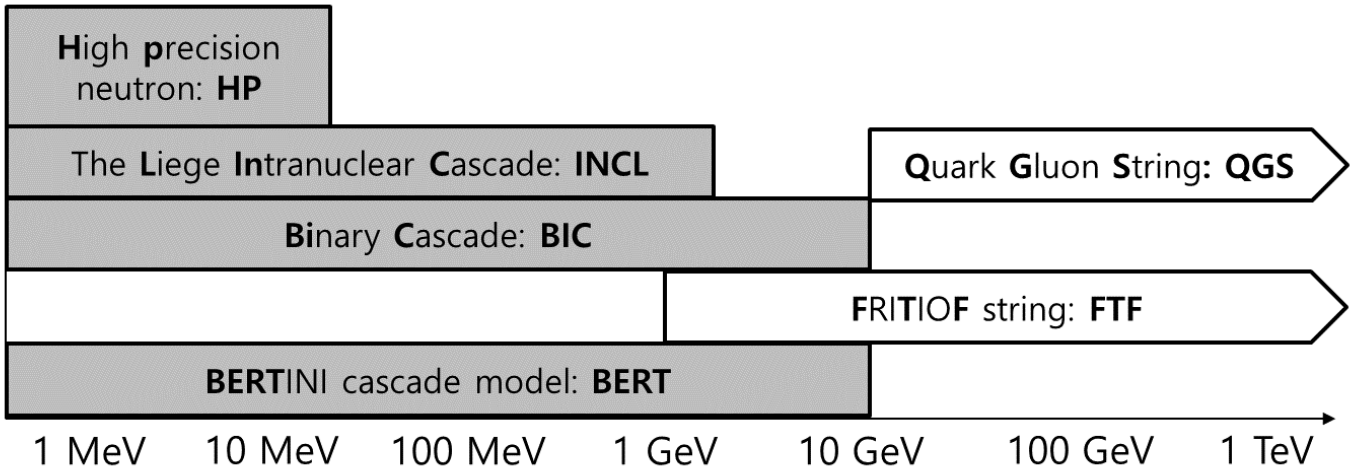

DANFYSIK
KoBRA
Korea Broad acceptance Recoil Spectrometer & Apparatus


VAT

2. Production of secondary particles

Physics List

- Considered physics list in Geant4
  - FTFP_BERT, FTFP_BERT_HP, FTFQGSP_BERT, QGSP_FTFP_BERT
  - FTF_BIC, QGSP_BERT, QGSP_BERT_HP, QGSP_BIC
  - FTFP_INCLXX, FTFP_INCLXX_HP, QGSP_INCLXX, QGSP_INCLXX_HP
  - Shielding

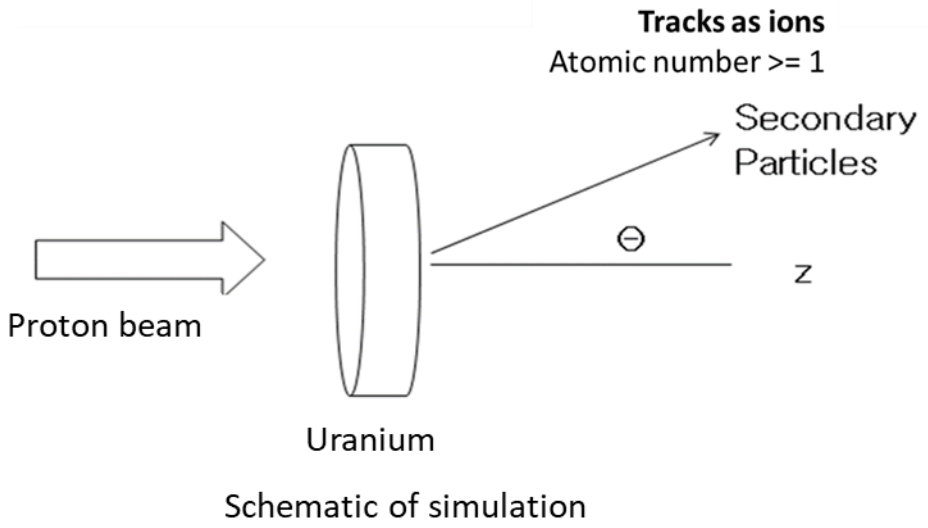


⇒ **Found "FTFP_INCLXX" for RAON**

K. Cho, Geant4 meeting (2023)

Conditions

- Conditions of experiments
  - Geant4 version: 11.0.2
  - 1 million events per each condition
  - FTFP_INCLXX

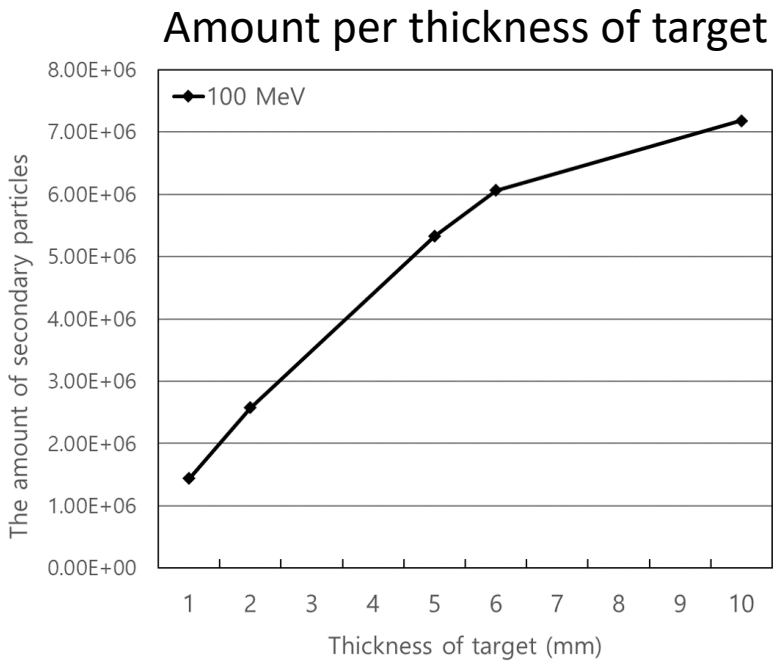


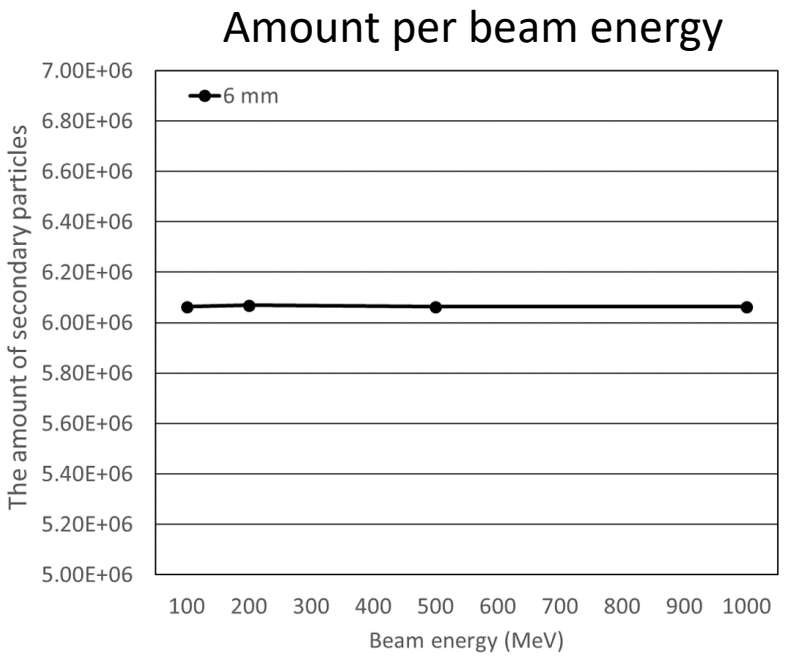
Schematic of simulation

Simulation	Geant4 Beam		Target	
	Particle	Energy (MeV/u)	Materials	Thickness (mm)
Proton → U	Proton	100, 200, 500, 1000	Uranium	6
Proton → U	Proton	100	Uranium	1, 2, 5, 6, 10

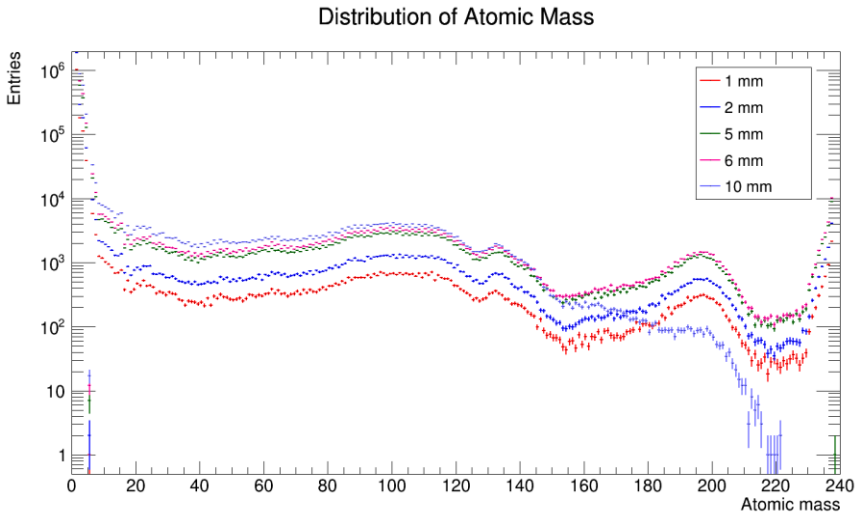
Beam & target conditions for validation

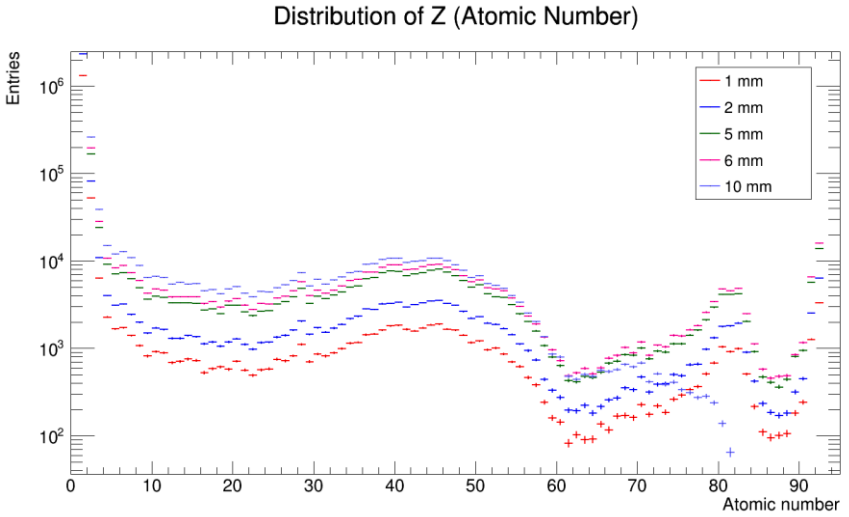
Amount of Secondary Particles

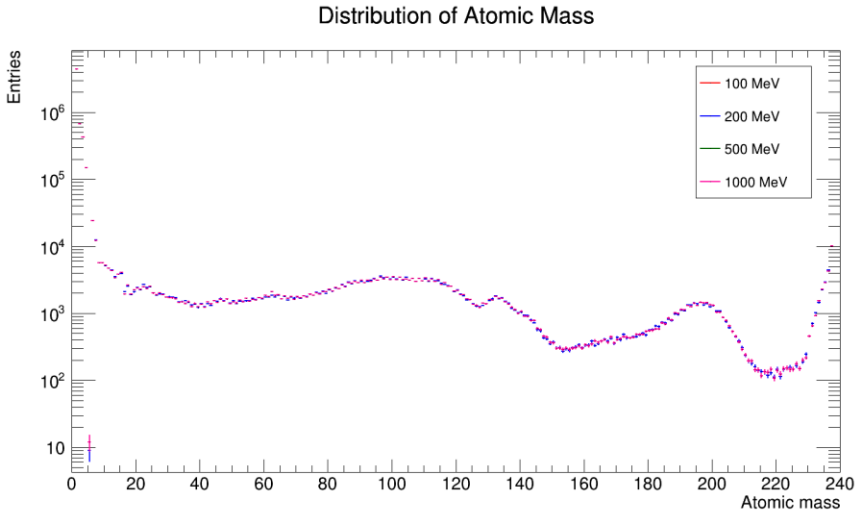


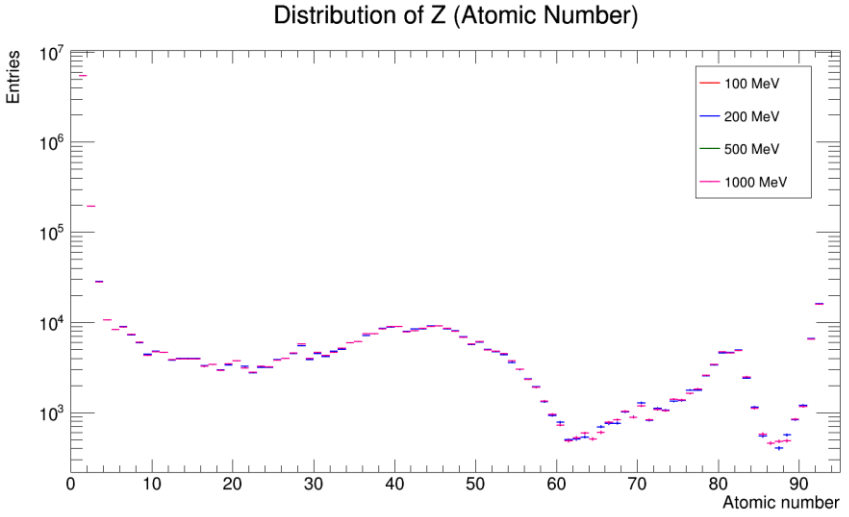


Amount of Secondary Particles





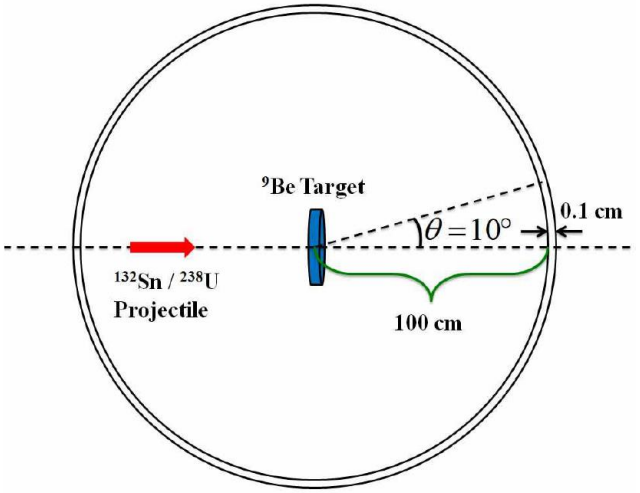




3. Collaboration with IBS for RAON

Sn132/U238 beam

- Sn132/U238 collides to Be target.
- Ion counting condition
  - Escaped from Be target
  - Travel 100cm from target
  - Forward direction with θ < 10°

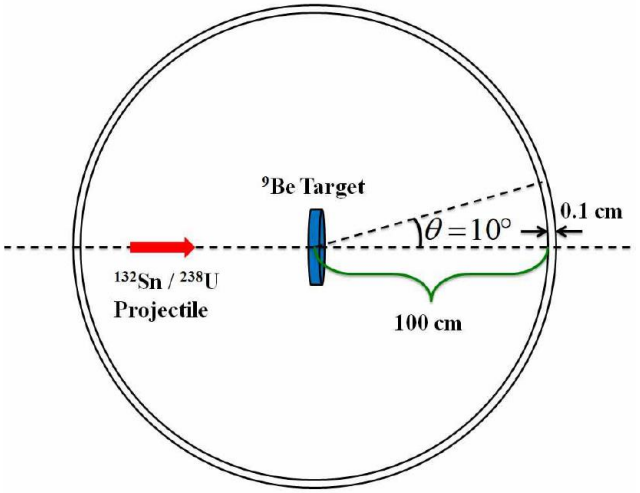


Simulation	Geant4 Beam		Target	
	Particle	Energy (MeV/u)	Materials	Thickness (mm)
Sn → Be	Sn132	200	Beryllium	1 ~ 10 mm (1mm step)
U → Be	U238	200		

Beam & target conditions for KoBRA simulation

Simulation Conditions

- Sn132/U238 collides to Be target.
- Conditions of experiments
  - Geant4 version: 11.0.2
  - 100,000 events per each condition
  - PhysicsList: FTFP_INCLXX

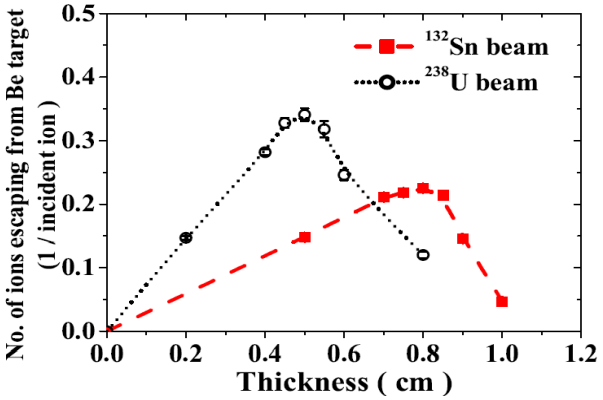


Simulation	Geant4 Beam		Target	
	Particle	Energy (MeV/u)	Materials	Thickness (mm)
Sn → Be	Sn132	200	Beryllium	1 ~ 10 mm (1mm step)
U → Be	U238	200		

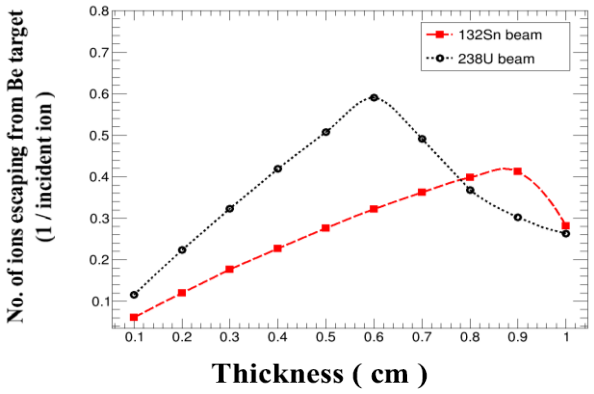
Beam & target conditions for KoBRA simulation

Results

- Amount of events
  - Thin target: penetrate the target
  - Thick target: ions cannot escape from target
  - What is the best target thickness for given condition?
- Comparison with previous study [NIMB349 (2015]
  - Different version (10.0 vs. 11.02)
  - Different physics list (FTF_BIC vs. FTFP_INCLXX)
  - Similar shape but different 'maximum number of ions'

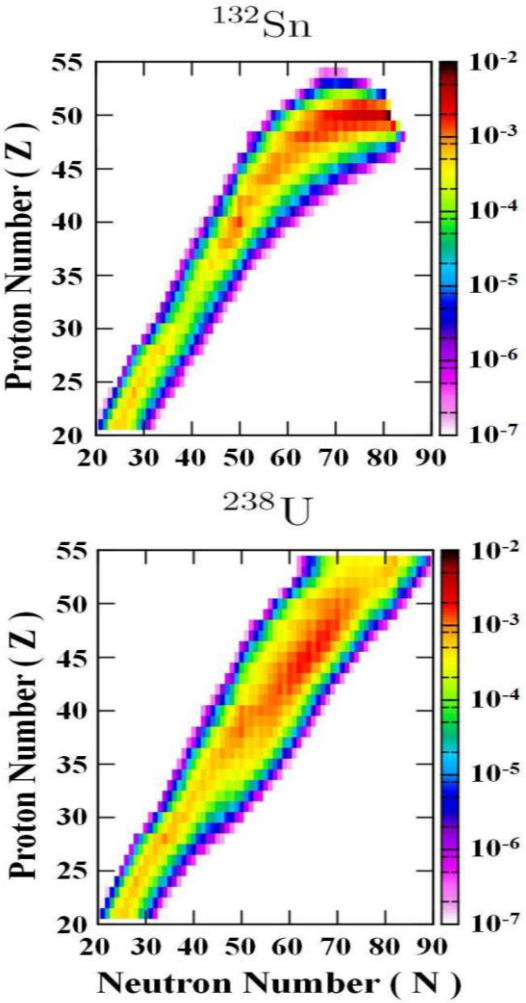


J. W. Shin *et al.*, NIM B 349, 221 (2015)

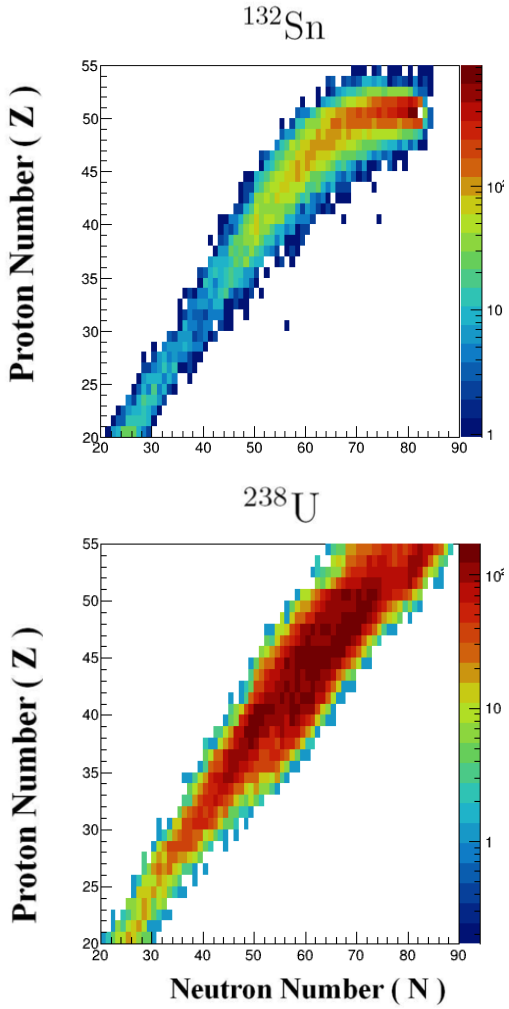


This work

Isotopic Production Yields



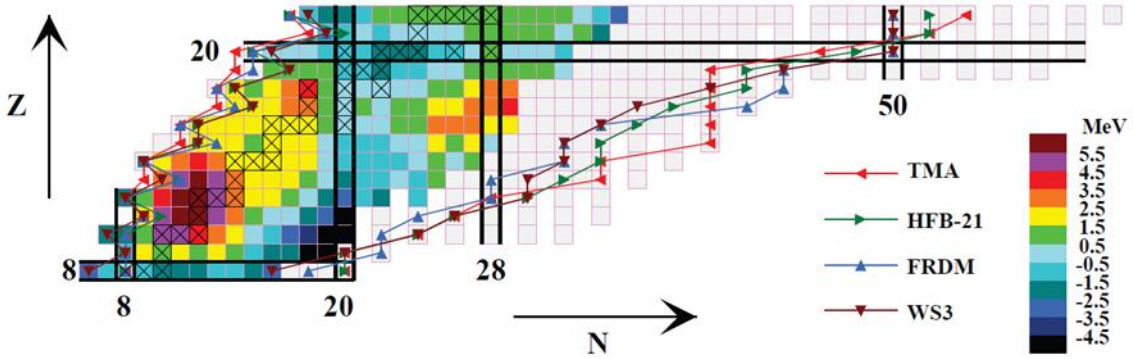
J. W. Shin *et al.*, NIM B 349, 221 (2015)



This work

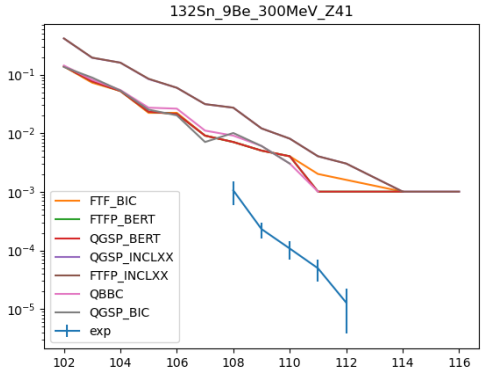
Neutron-excessive nuclide

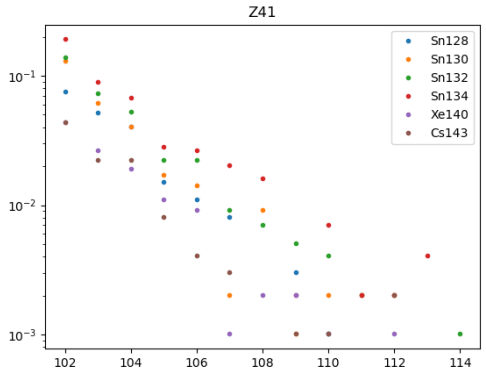
- Rare-isotope production to study Neutron-excessive nuclide



- Various beam, target and energy
- Sn(128, 130, 132, 134), Xe140 beam

Example)





Y. Song

4. Plan

- RAON experiment plan
  - To see the generation of nuclides near 34Si
    by colliding a 40Ar (20 MeV/u) beam with the C target
  - Not only for the total cross section,
    but also momentum distribution of the final nuclei

X.H. Zhang *et al.*, PRC85, 024621 (2012)

- If Geant4 can explain these experimental results,
  or if it can be improved to explain the experimental results

⇒ To update the experiments

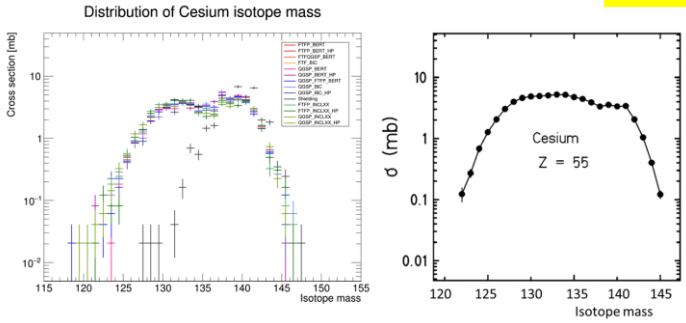
Acknowledgement

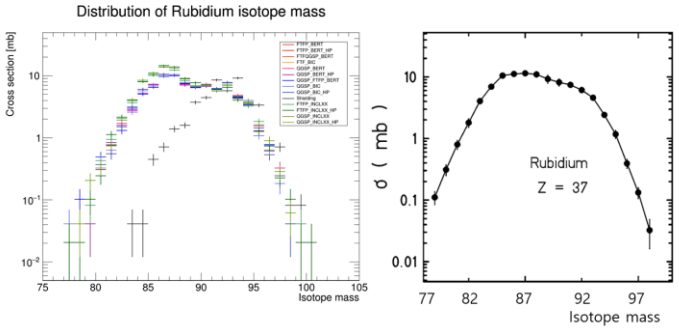
- The major institutional R&D program of KISTI (No. K-24-L02-C04-S01) and National Supercomputing Center with supercomputing resources including technical support.

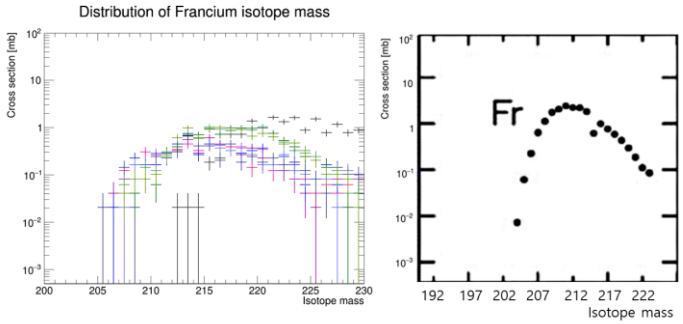
Thank you.

Isotope Distribution

M. Bernas, et al., Nucl. Phys. A 725, 213 (2003).







M. Bernas, et al., Nucl. Phys. A 725, 213 (2003).

J. Taieb, et al. Nucl. Phys. A 724, 413 (2003).

– **FTFP_INCLXX**