

# Beam simulation depending on physics lists

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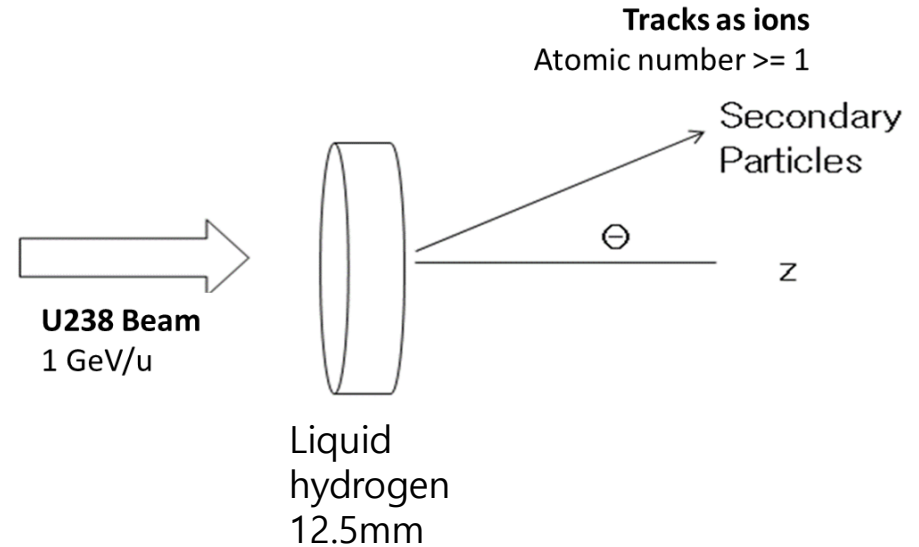
# Contents

1. Validation of physics lists
2. Production of secondary particle
3. Summary & Plan

# 1. Validation of physics lists

# Conditions

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



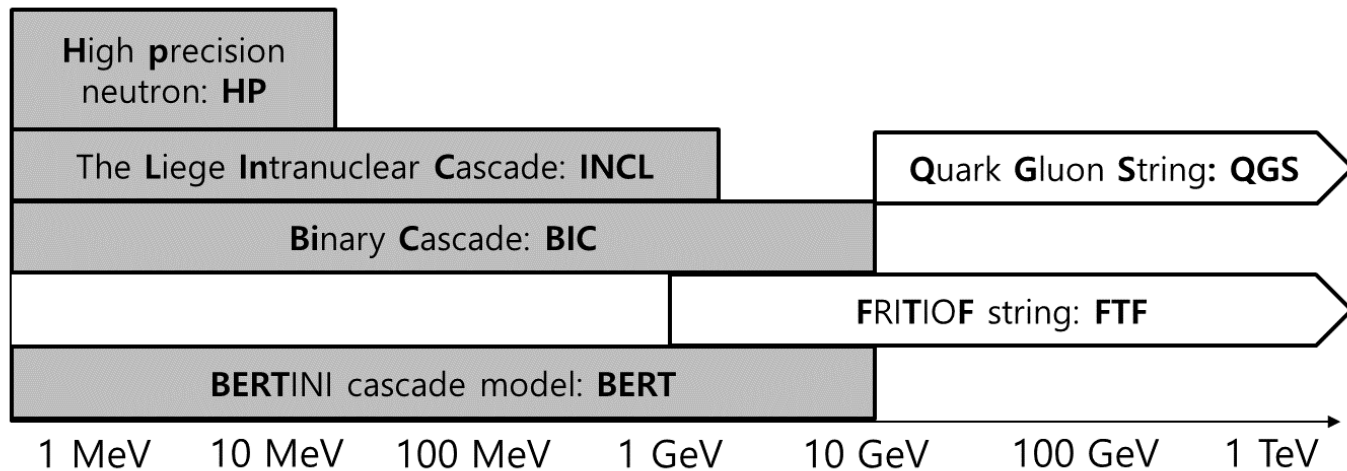
Schematic of simulation

Simulation	Geant4 Beam		Target	
	Particle	Energy (MeV/u)	Materials	Thickness (mm)
U → Liquid Hydrogen	U	1000	Liquid Hydrogen	12.5

Beam & target conditions for validation

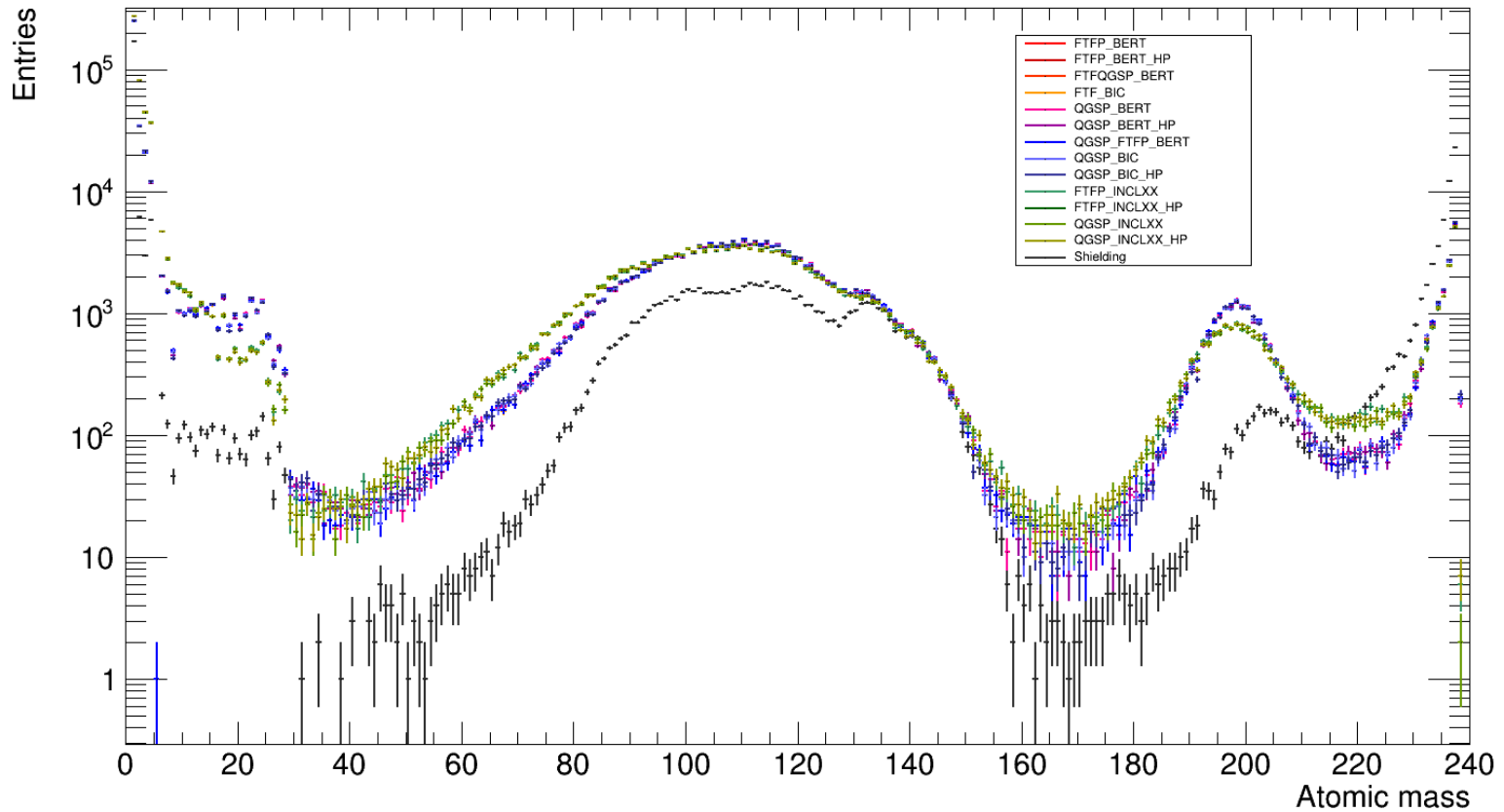
# Physics List

- 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



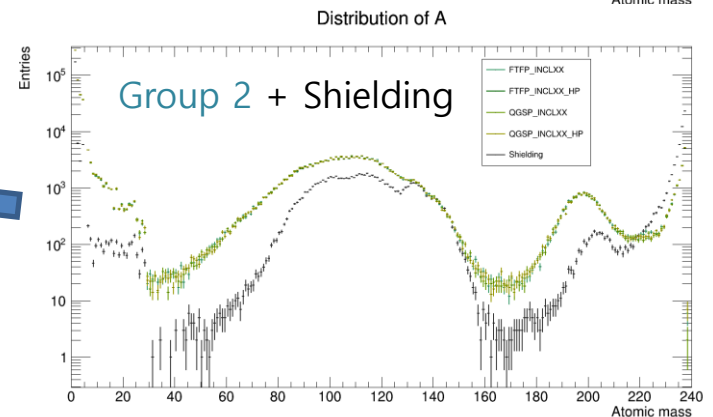
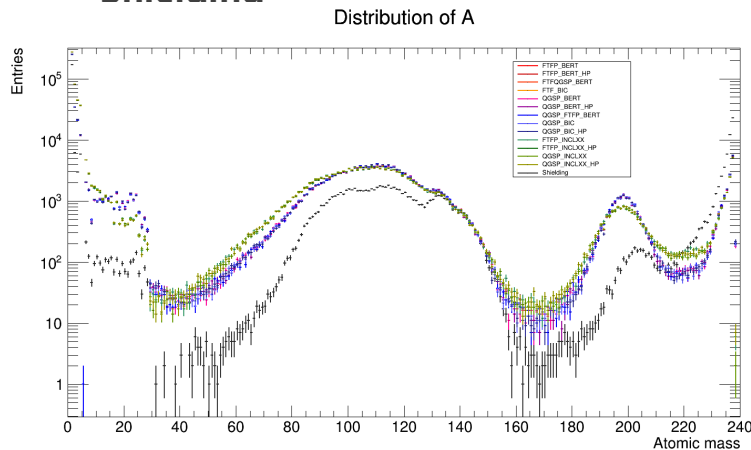
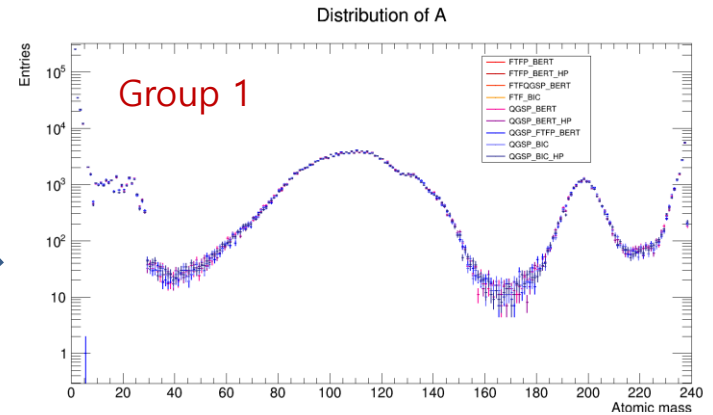
# Distribution: Atomic Mass

Distribution of A



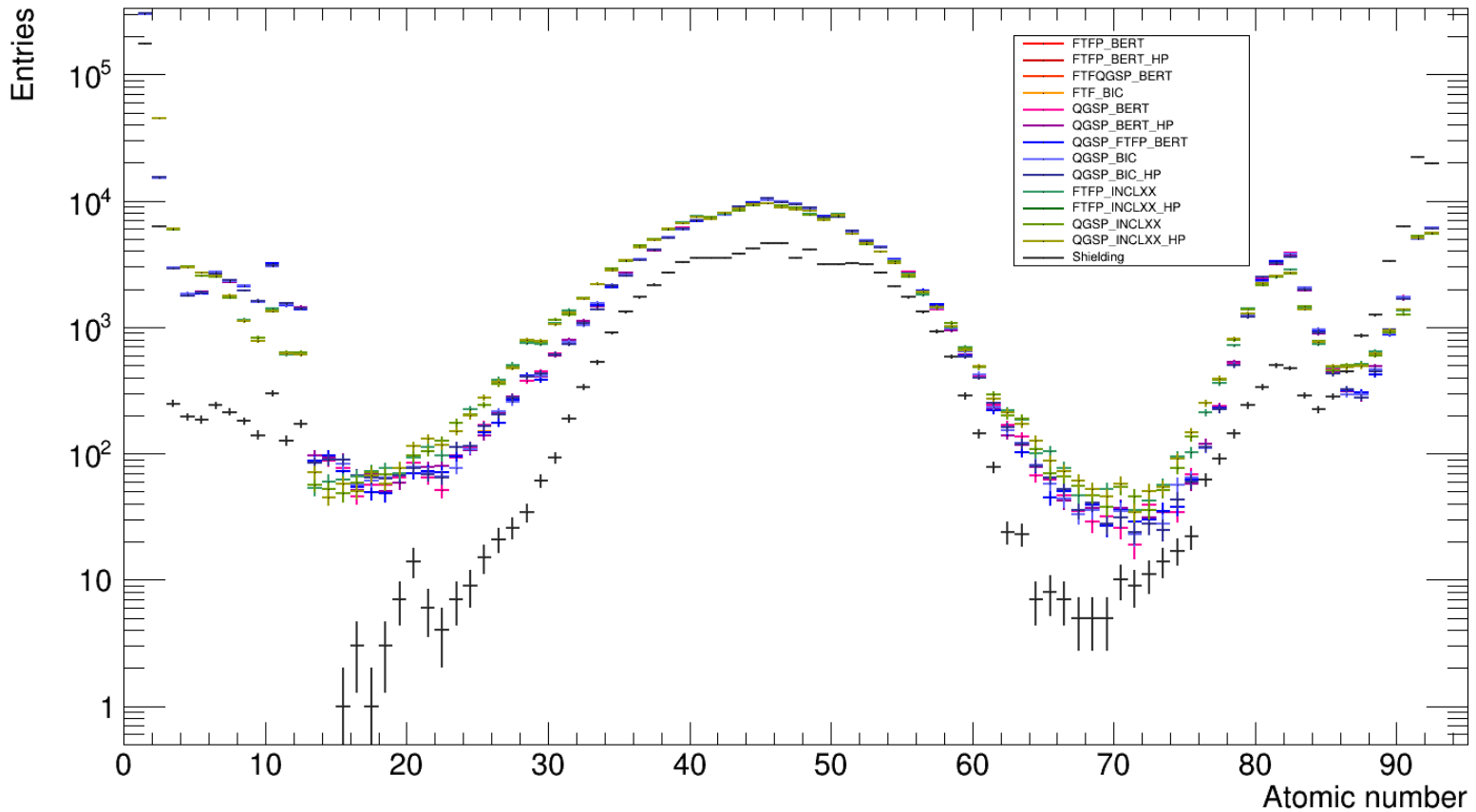
# Distribution: Atomic Mass

- PhysicsLists are separated to 3 group
  - Group 1: FTFP\_BERT, FTFP\_BERT\_HP, FTFQGSP\_BERT, FTF\_BIC, QGSP\_FTFP\_BERT, QGSP\_BERT, QGSP\_BERT\_HP, QGSP\_BIC, QGSP\_BIC\_HP
  - Group 2: FTFP\_INCLXX, FTFP\_INCLXX\_HP, QGSP\_INCLXX, QGSP\_INCLXX\_HP
  - Shieldina



# Distribution: Atomic Number

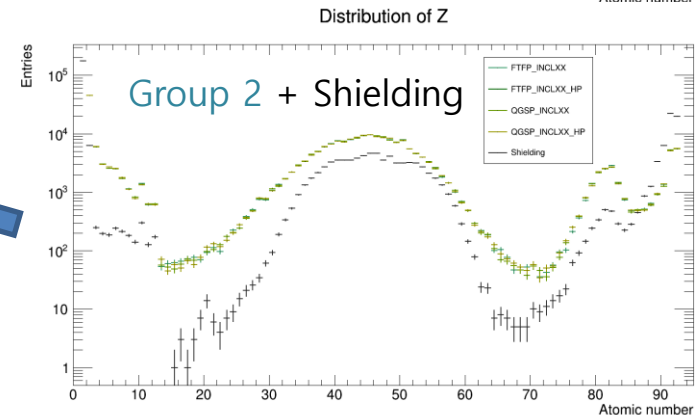
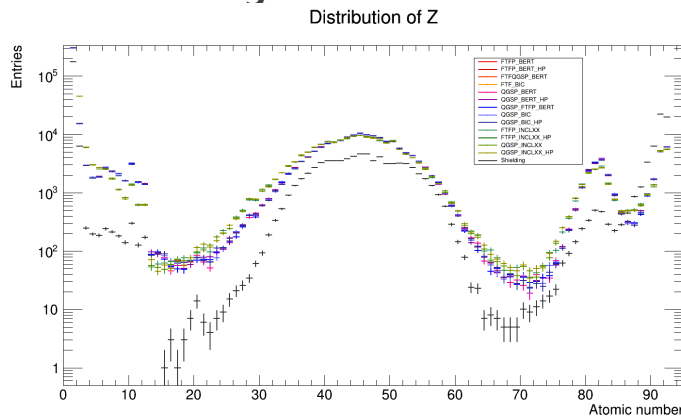
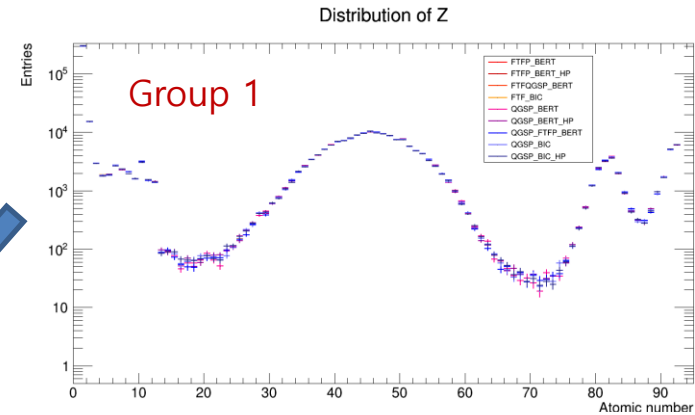
Distribution of Z





# Distribution: Atomic Number

- PhysicsLists are separated to 3 groups
  - Group 1: FTFP\_BERT, FTFP\_BERT\_HP, FTFQGSP\_BERT, FTF\_BIC, QGSP\_FTFP\_BERT, QGSP\_BERT, QGSP\_BERT\_HP, QGSP\_BIC, QGSP\_BIC\_HP
  - Group 2: FTFP\_INCLXX, FTFP\_INCLXX\_HP, QGSP\_INCLXX, QGSP\_INCLXX\_HP
  - Shielding

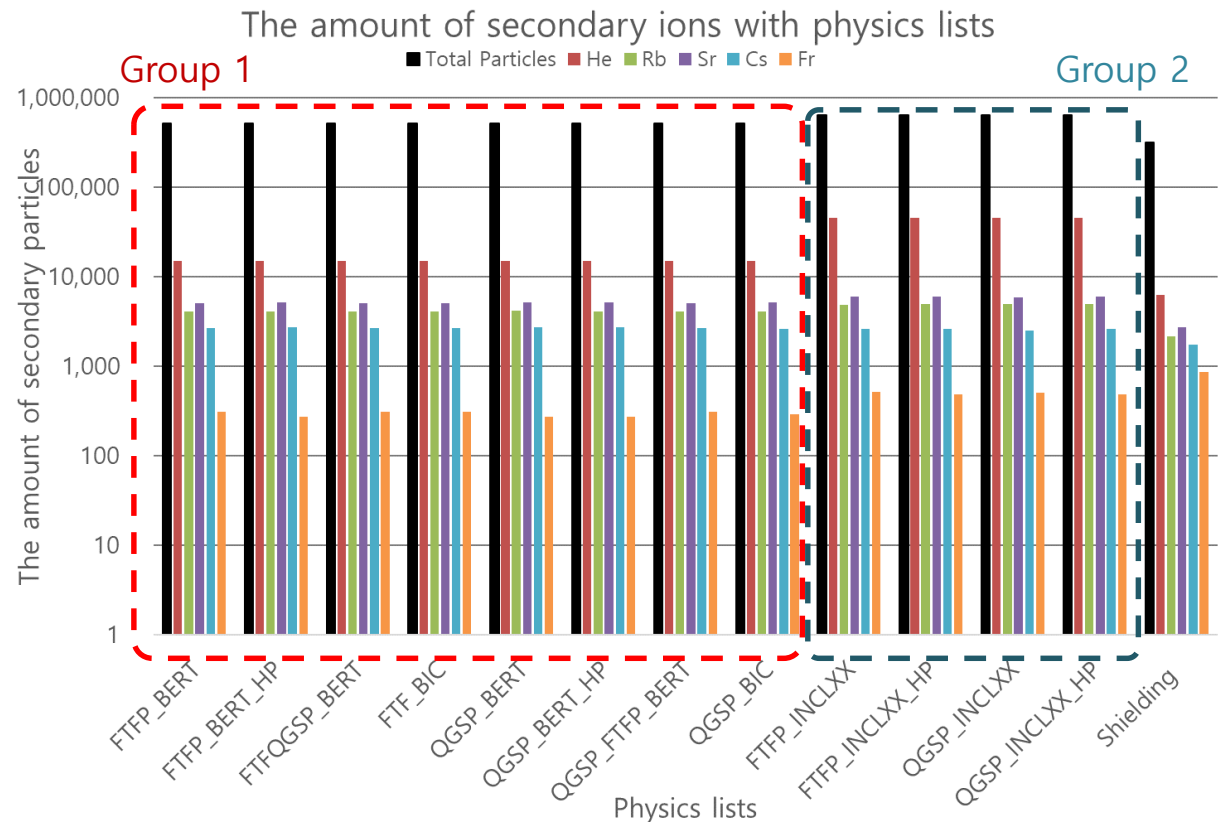


# Finding the Best Physics List

- The best physics list for studying heavy-ion beam simulation
  - 1) Created secondary ions
  - 2) Validation compared with experiment
  - 3) Cost-effective CPU time

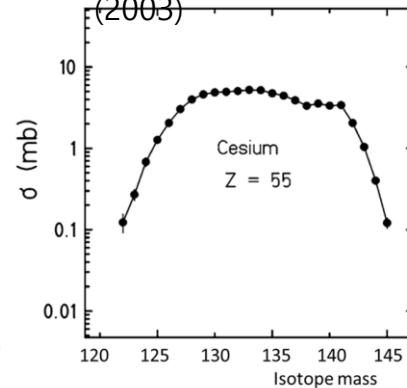
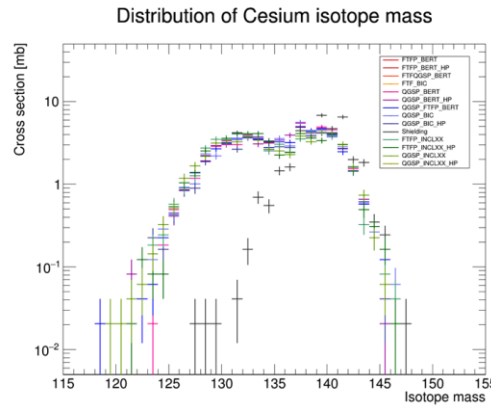
# 1) Created Secondary Ions

- Group 2 physics list take more secondary ions.
  - Abundant statistics for analysis compared with group 1 lists.

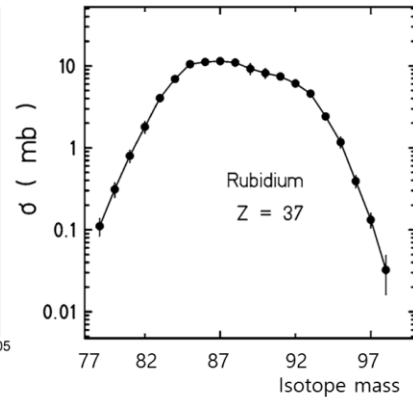
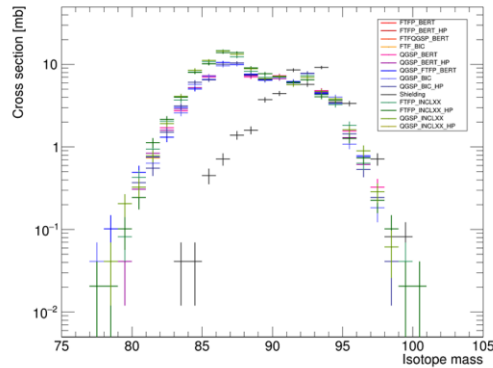


# 2) Validation compared with experiments

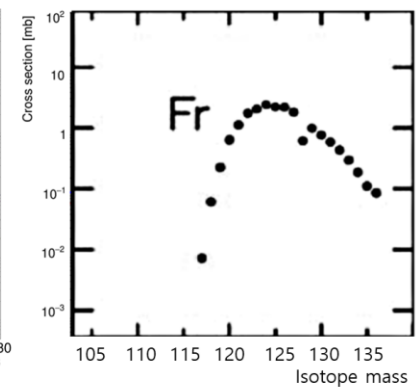
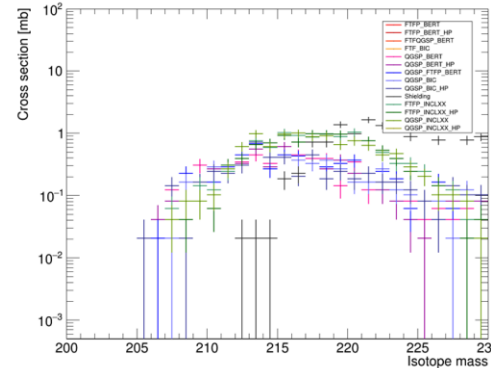
M. Bernas et al., Nucl. Phys. A 725, 213 (2003)



Distribution of Rubidium isotope mass



Distribution of Francium isotope mass



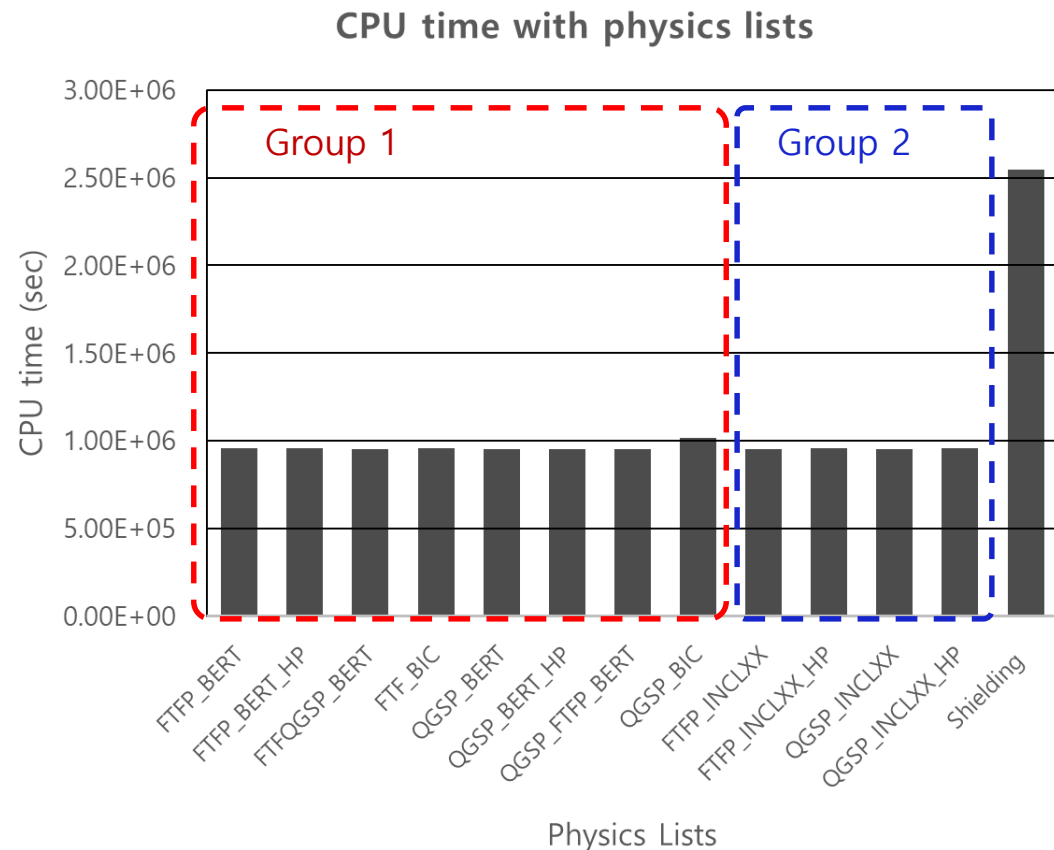
M. Bernas et al., Nucl. Phys. A 725, 213 (2003)

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

# 3) Cost effective CPU time

- Excluding 'Shielding' for our suitable list (due to long runtime)
- Others look same.
  - Any physics list (except Shielding) would be OK.
- What would be the best?

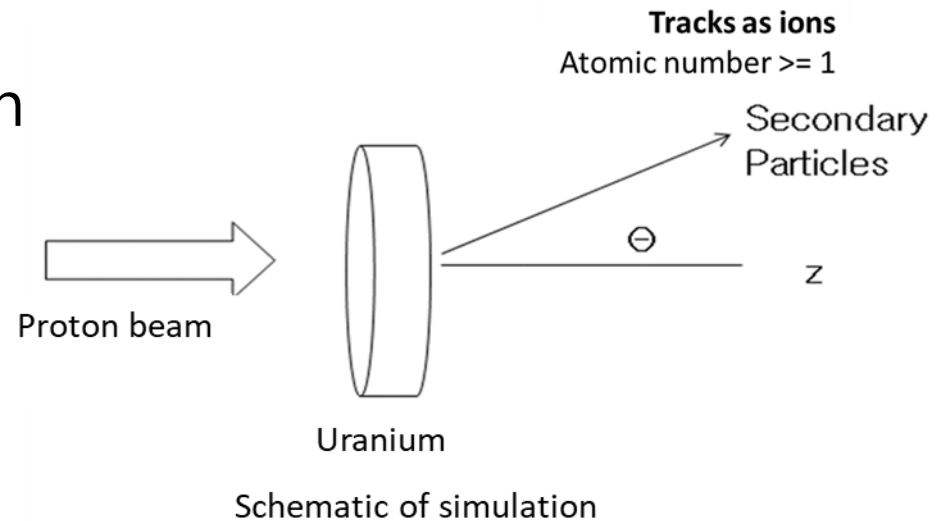
=> **FTFP\_INCLXX(\_HP)**



## 2. Production of secondary particles

# Conditions

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

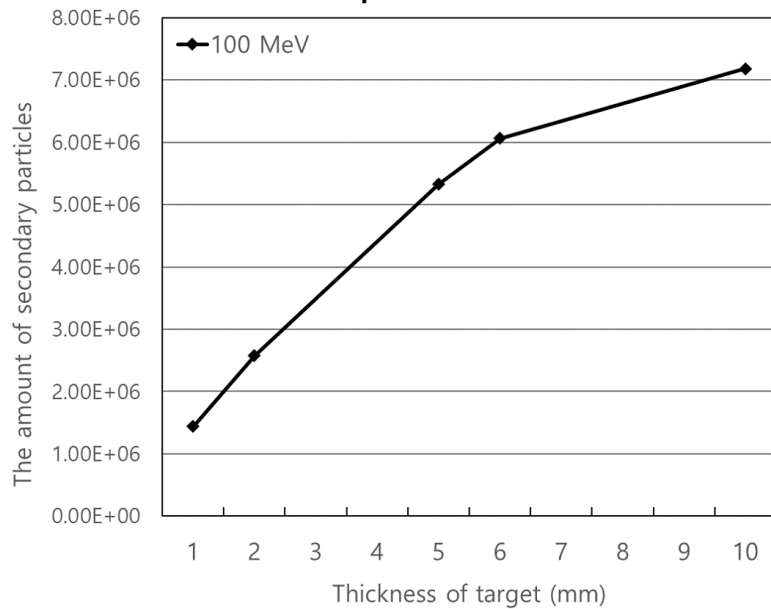


Simulation	Geant4 Beam		Target	
	Particle	Energy (MeV/u)	Materials	Thickness (mm)
Proton $\rightarrow$ U	Proton	100, 200, 500, 1000	Uranium	6
Proton $\rightarrow$ U	Proton	100	Uranium	1, 2, 5, 6, 10

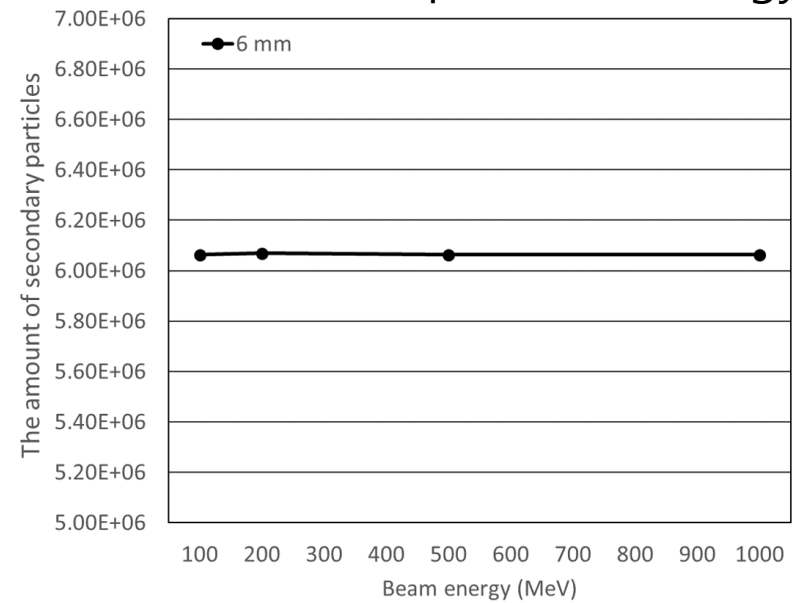
Beam & target conditions for validation

# Amount of Secondary Particles

Amount per thickness of target



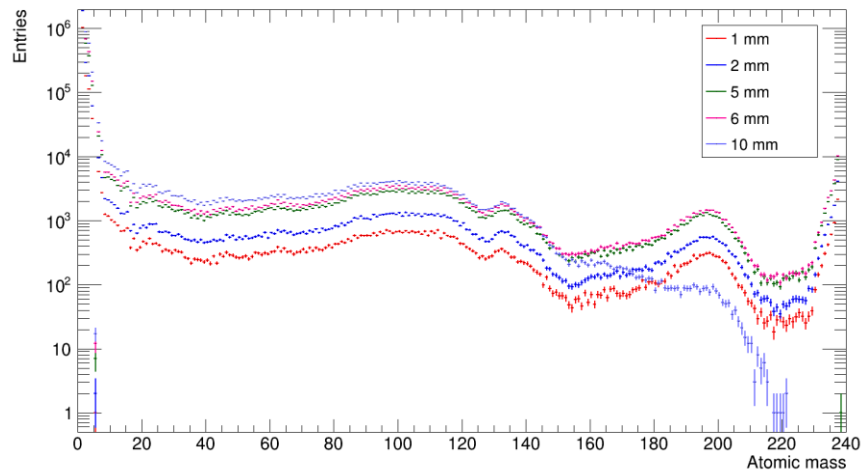
Amount per beam energy



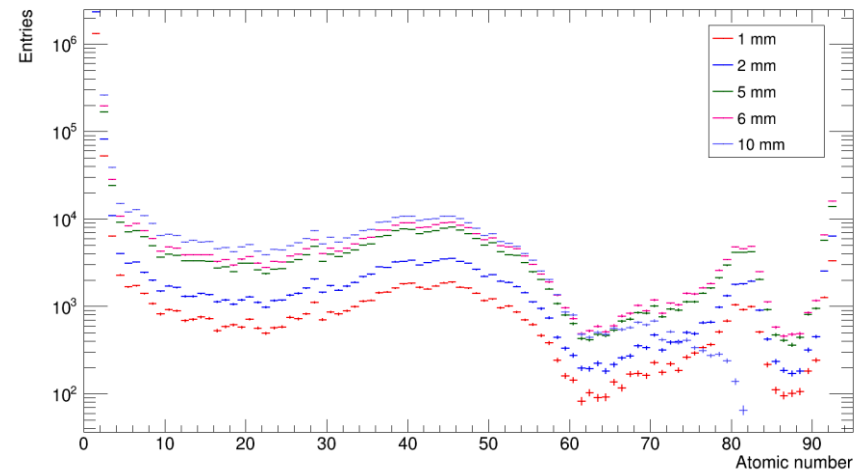


# Amount of Secondary Particles

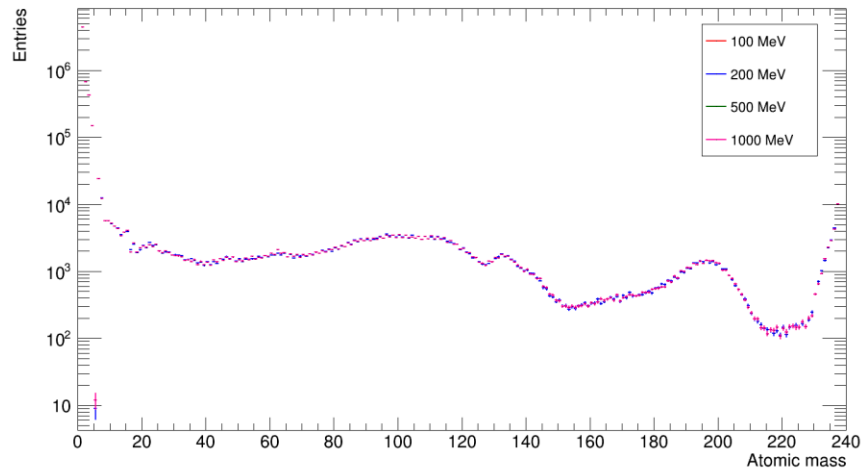
Distribution of Atomic Mass



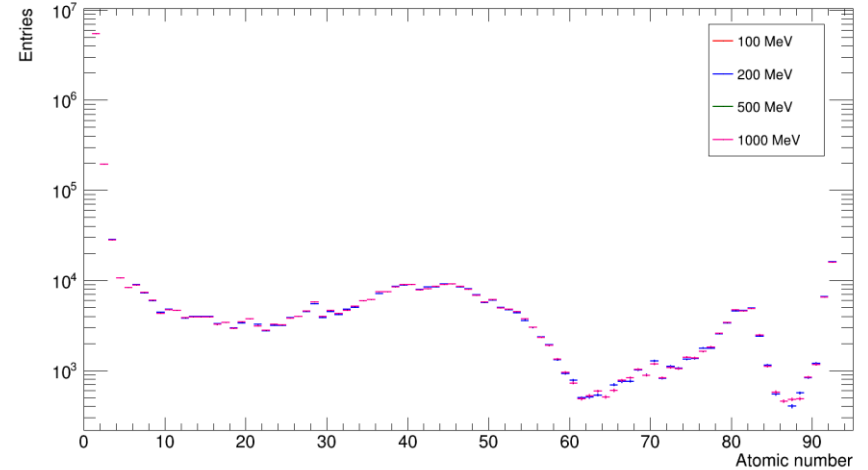
Distribution of Z (Atomic Number)



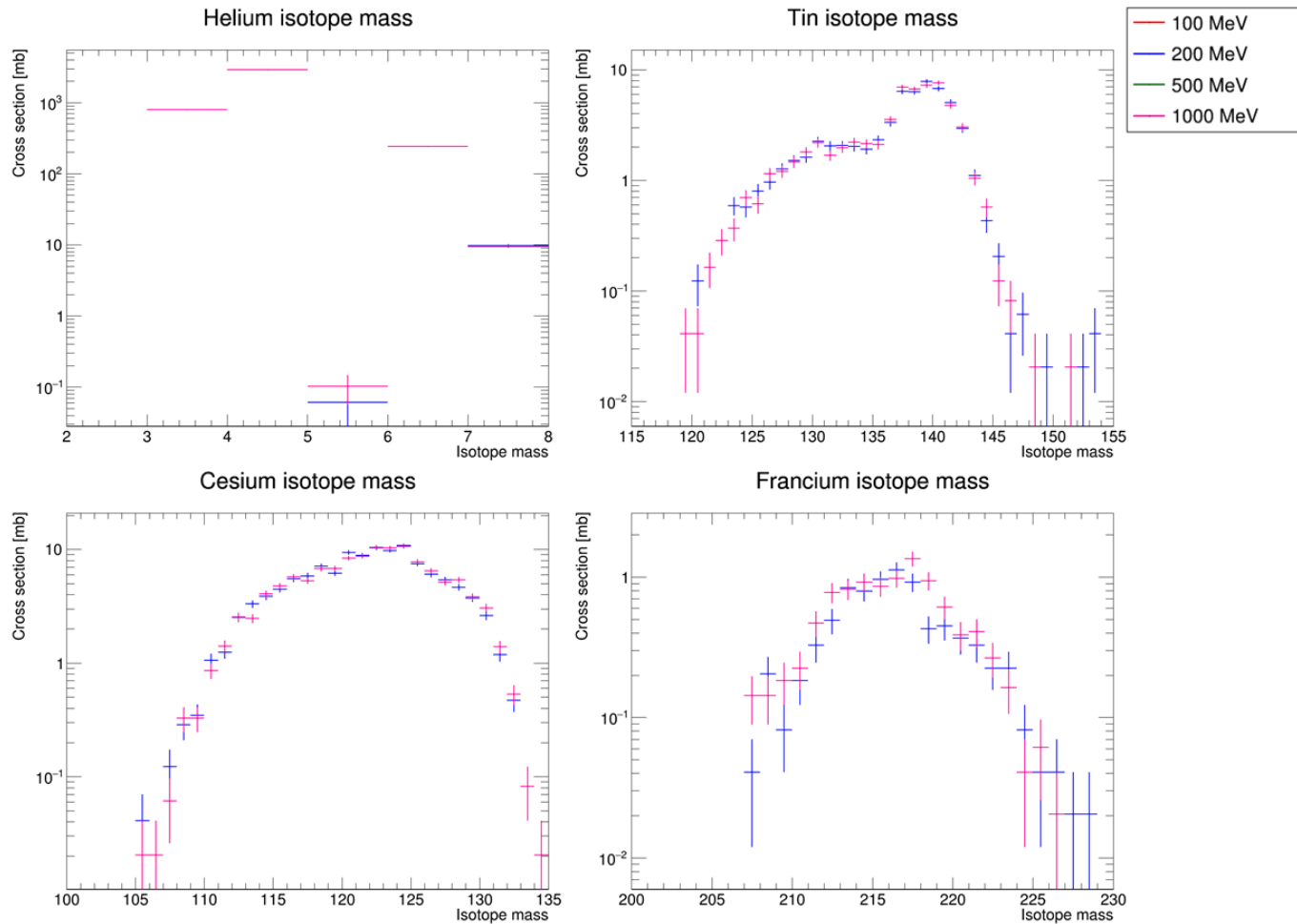
Distribution of Atomic Mass



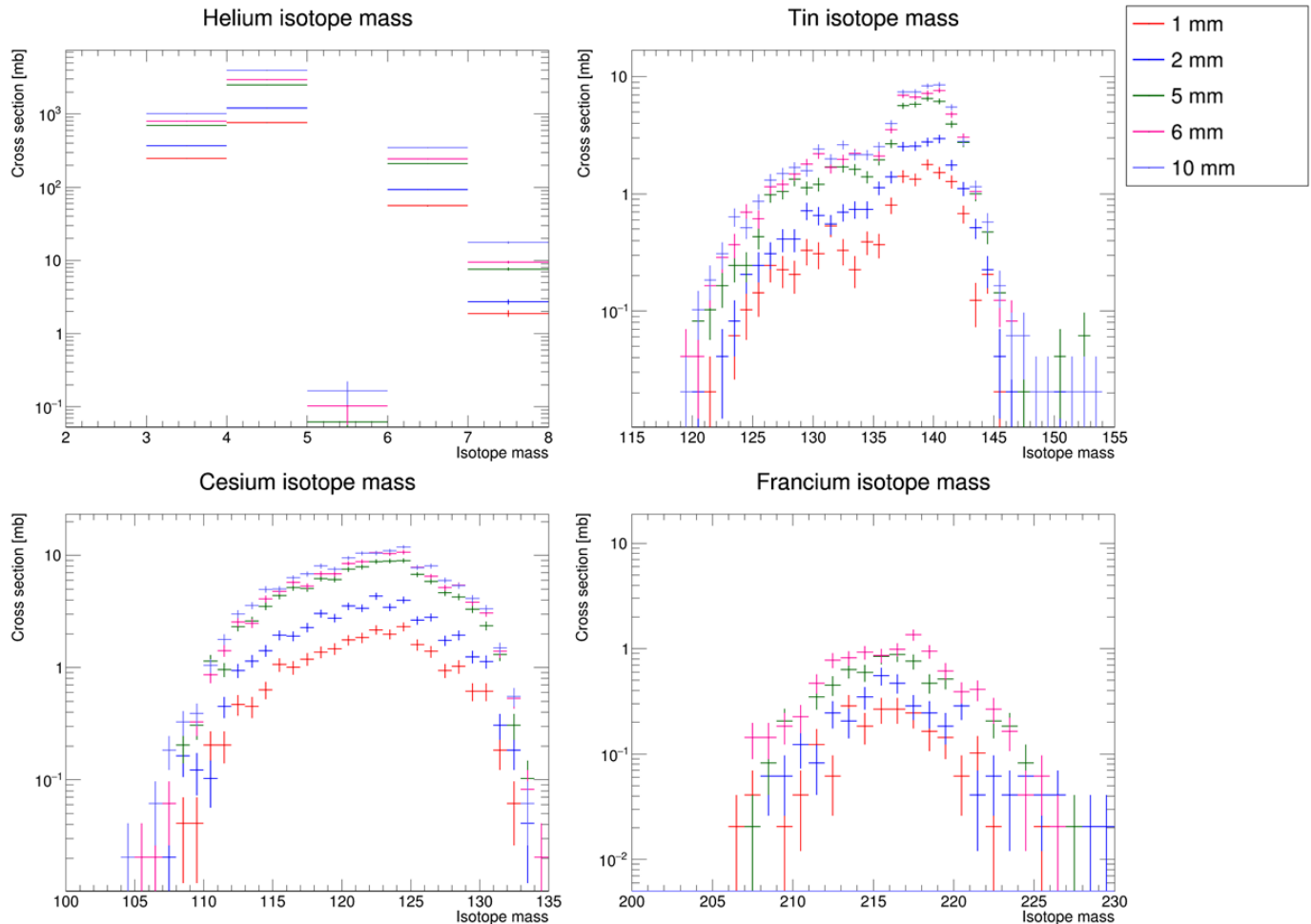
Distribution of Z (Atomic Number)



# Amount of Specific Isotopes (Energy)



# Amount of Specific Isotopes (Thickness)



# 3. Summary & Plan

1. We studied heavy ion beam simulation on WGeant4.
  - We found the optimized physics lists among Geant4 reference physics lists.
  - The most optimized physics list is FTFP\_INCL++(\_HP).
2. Next, we will test  $^{132}\text{Sn}/^{238}\text{U}$  beam emission to  $^9\text{Be}$  target with various target thickness => RAON experiment

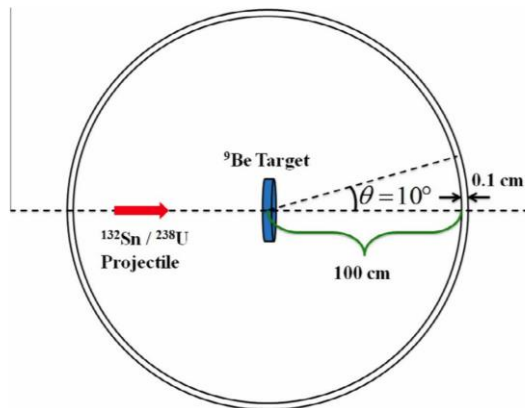
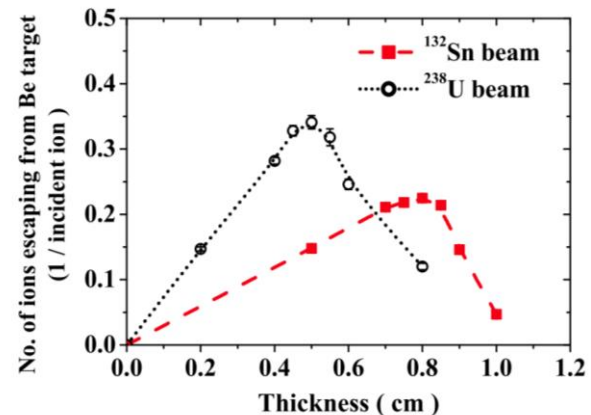


Fig. 9. Schematic diagram of the simulation setup.



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

# Acknowledgement

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