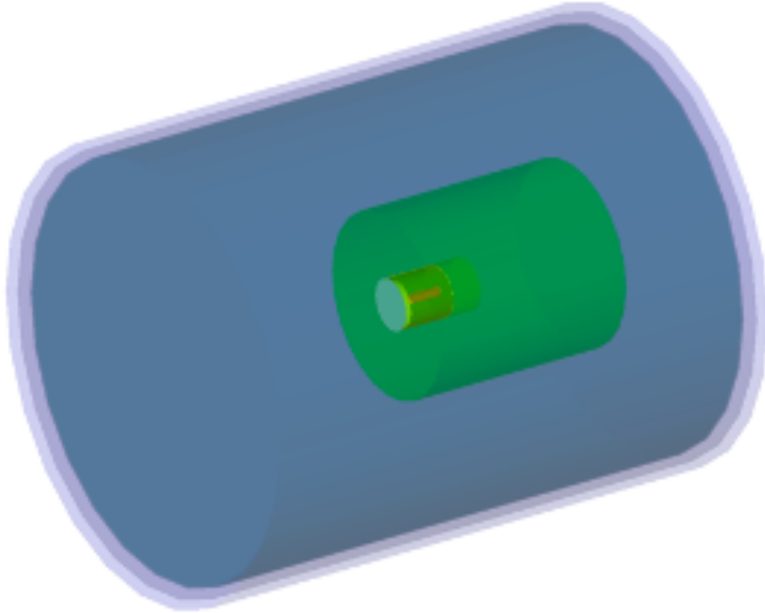
Cosmic Ray - Atmosphere interaction Simulation and Be-7 Production Rate Study

2025 CENuM WorkShop

PKNU SeungHoon LEE

2025.01.17

TimeTable



- Introduction
- Geant4 Simulation Setting
- Use Cosmic Ray Library(Cry_v1.7)
- Add the magnetic fields due to limitations of CRY
- Cross Section verification
- Measurement Data
- Comparison with Geant4 data
- Conclusion

Introduction

$$^{14}N + p \rightarrow {}^{7}Be + X$$
$$^{16}O + p \rightarrow {}^{7}Be + X$$

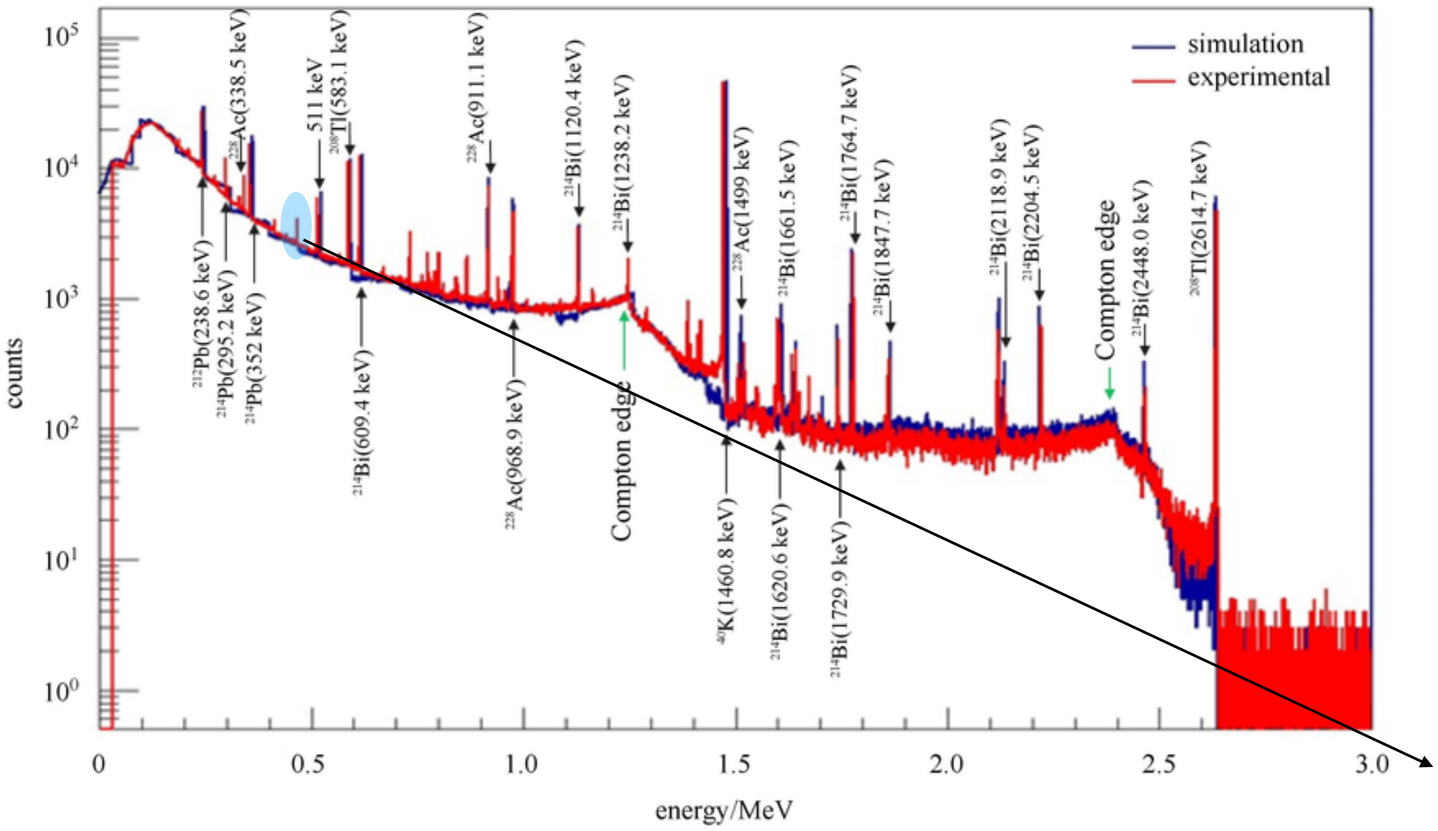
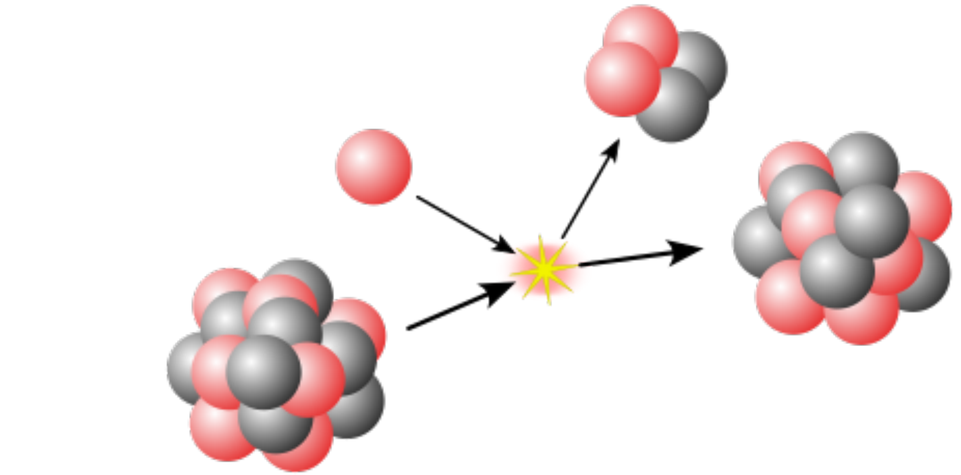
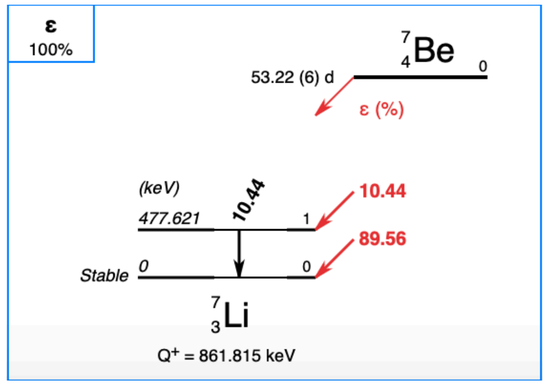
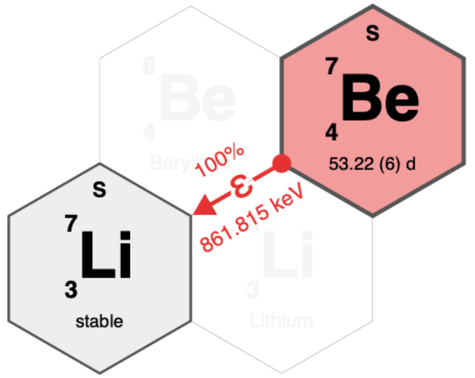


Fig . Experimental and simulated γ ray spectrum of detected background from unshielded HPGe detector







Introduction

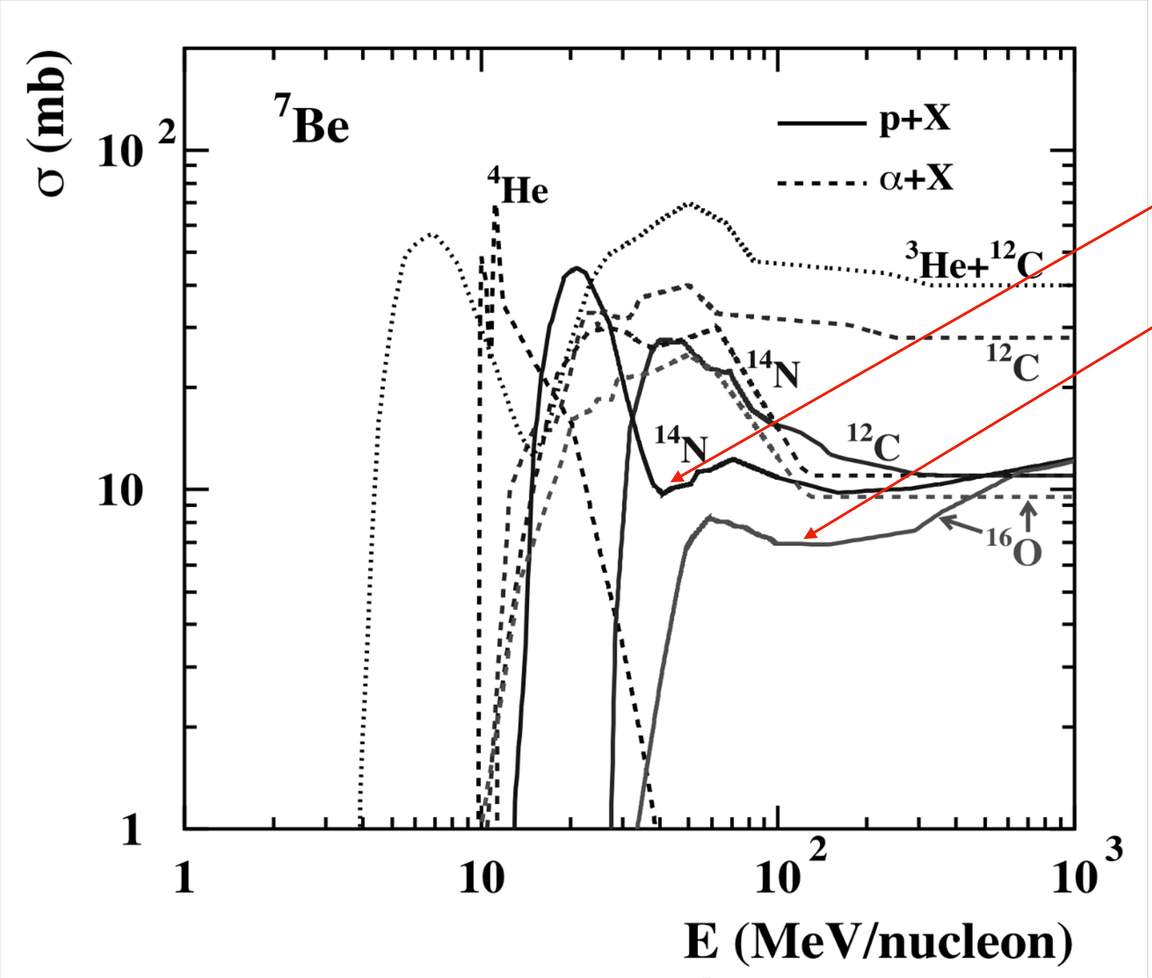
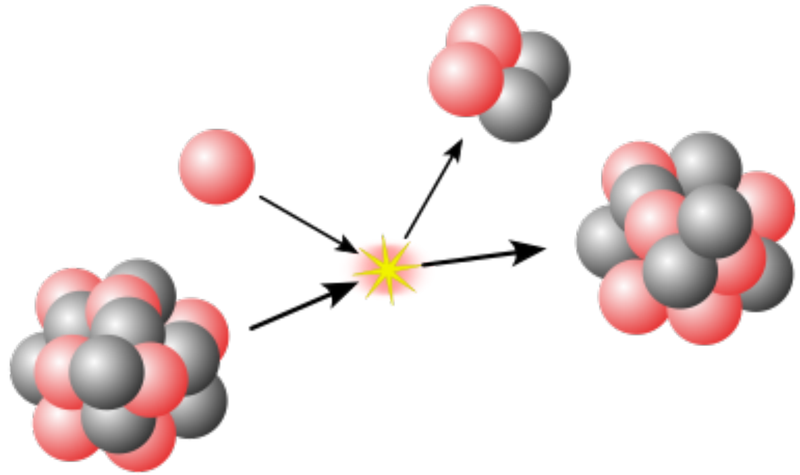
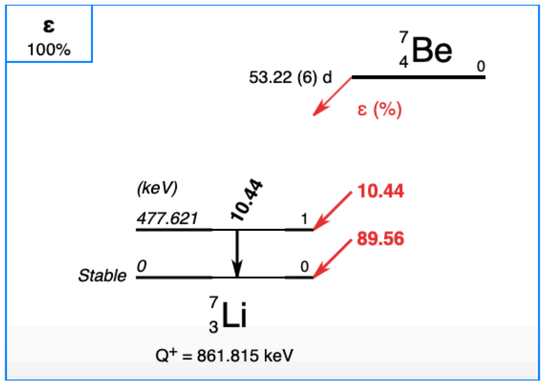
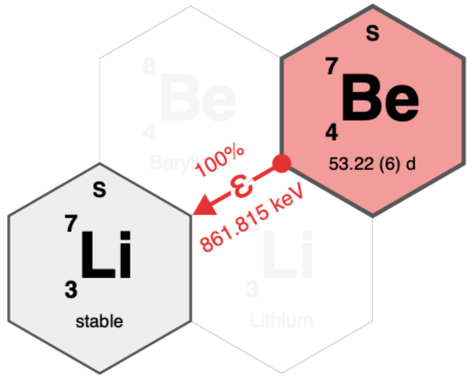


Fig . Cross Sections for the production of ^7Be

$$^{14}N + p \rightarrow {}^{7}Be + X$$
$$^{16}O + p \rightarrow {}^{7}Be + X$$







Geant4 Simulation Setting

- **PhysicsList**

Hadronic Process : QGSP_BIC_HP OR FTFP_BIC_HP, G4HadronElasticPhysics, G4IonElasticPhysics, G4IonPhysics

ElectroMagnetic Process : G4EmStandardPhysics_option4

SetCut Value : Proton = 0mm

Electron, positron, gamma = 0mm

G4ProductionCutsTable : 1 eV ~ 1 TeV

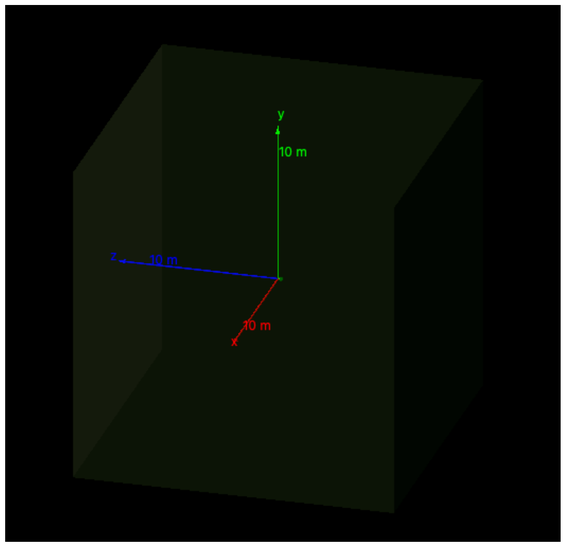
- **DetectorConstruction**

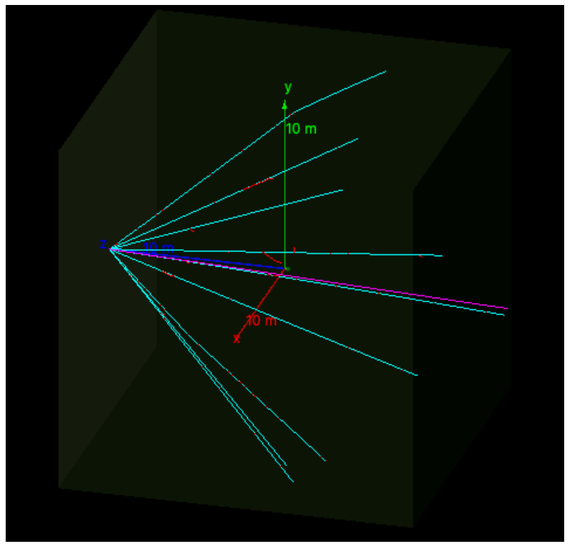
World size : 20m * 20m * 20m

World Material : G4_AIR

Density : $0.00120479\ g/cm^3$

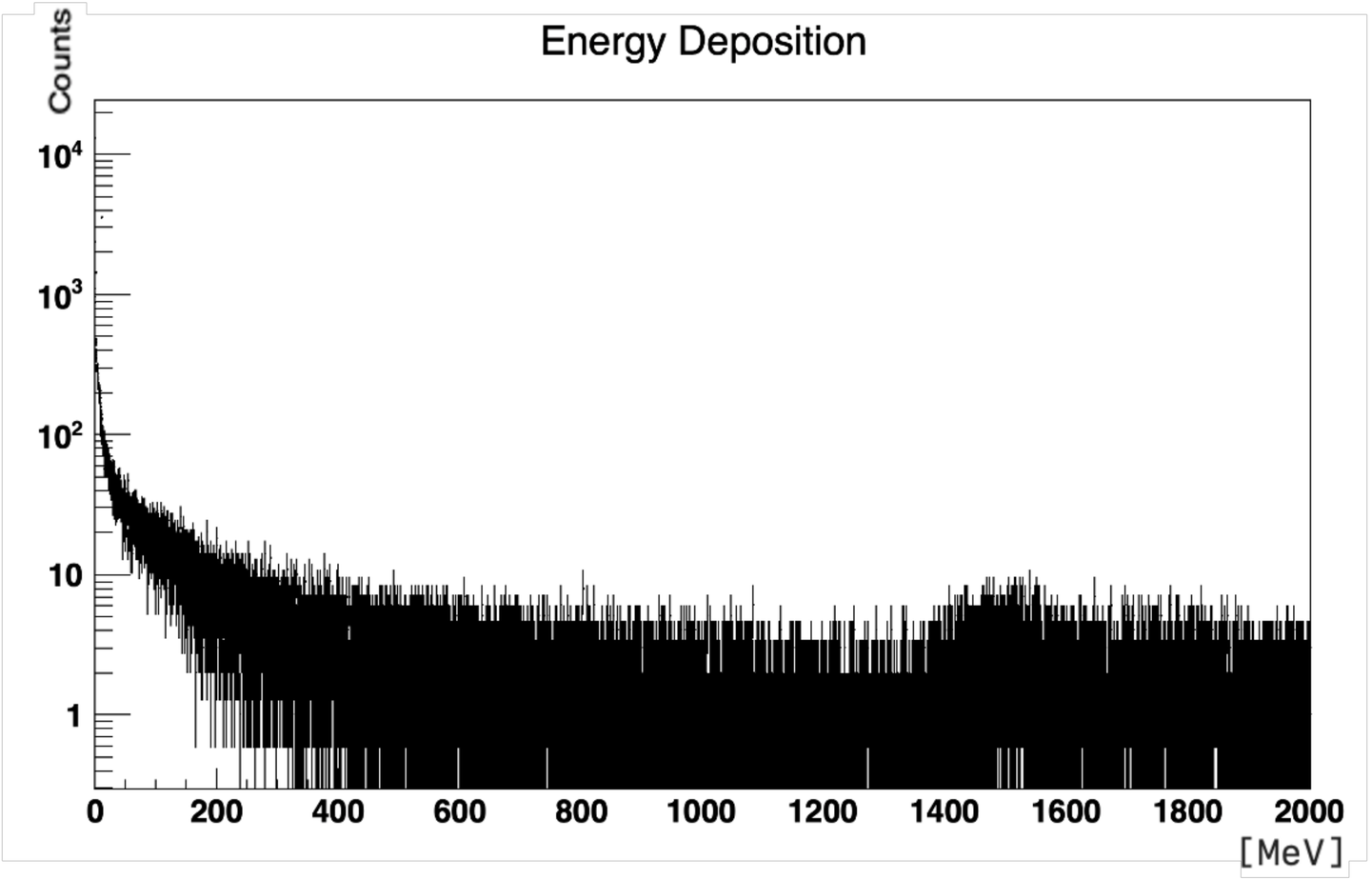
```
G4_AIR                      0.00120479       85.7
      6     0.000124
      7     0.755268
      8     0.231781
     18     0.012827
```





- **Then what about PrimaryGeneratorAction?**

Use Cosmic Ray Library(Cry_v1.7)



- Option

Type of Particle : proton, neutron, electron, gamma, muon, pion

Altitude : 0m, 2100m, 11300m

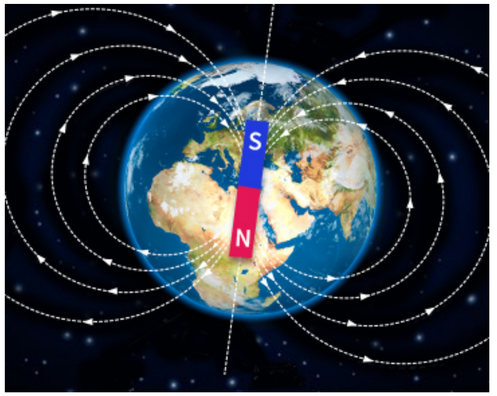
Latitude : 35.13408024

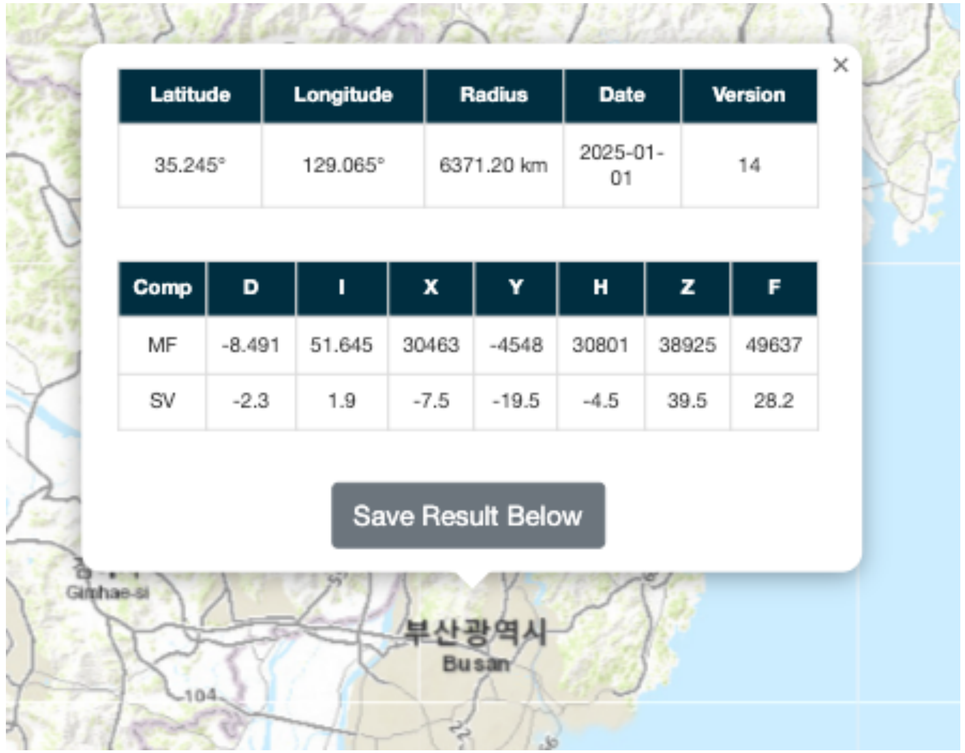
Date : 2007-01-01

Add the magnetic fields due to limitations of CRY

International Geomagnetic Reference Field

The International Geomagnetic Reference Field (IGRF) is a standard mathematical description of the Earth's main magnetic field. It is used widely in studies of the Earth's deep interior, crust, ionosphere, and magnetosphere. While this web page is hosted at NOAA/NCEI, the model itself is developed and maintained by the International Association of Geomagnetism and Aeronomy (IAGA).





	MF = Main Field	SV = Secular Variation
D = Declination	degrees east	arcmin/year
I = Inclination	degrees down	arcmin/year
X = North Intensity	nT	nT/year
Y = East Intensity	nT	nT/year
H = Horizontal Intensity	nT	nT/year
Z = Vertical Intensity	nT down	nT/year
F = Total Intensity	nT	nT/year

https://geomag.bgs.ac.uk/data_service/models_compass/igrf_calc.html

Production Cross section verification

$$^{14}N + p \rightarrow {}^{7}Be + X$$

$$\sigma_p = \frac{N_{^7Be}}{N_{proton} \times density \times thickness}$$

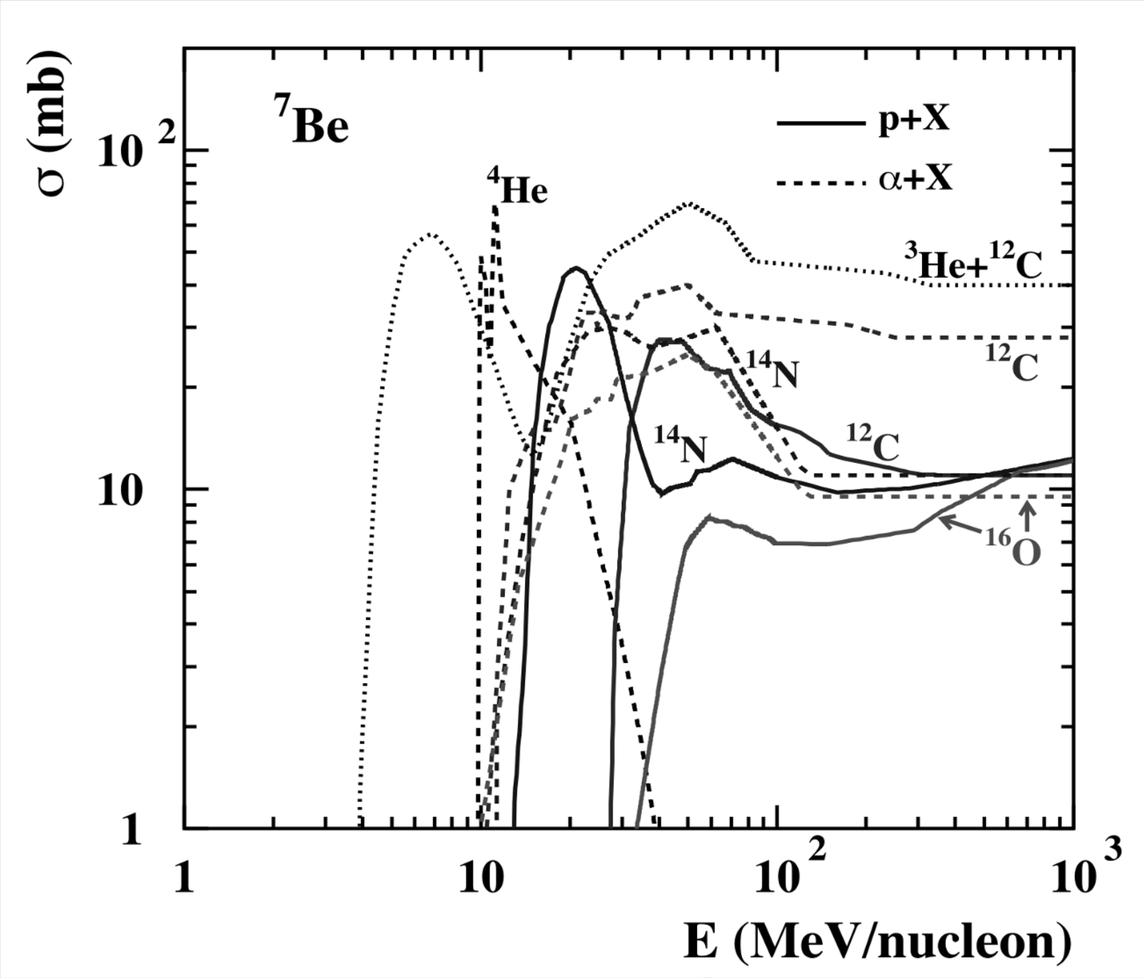


Fig . Cross Sections for the production of ^{7}Be

Number of proton beam	5,000,000
Target length(cm)	2000
density(g/cm^3)	0.000909938
NA(/mol)	6.022E+23
N (g/mol)	14
Energy (MeV)	1000
Cross section(mb)	10
Number of Production of Be-7	3914.033866

Production Cross section verification

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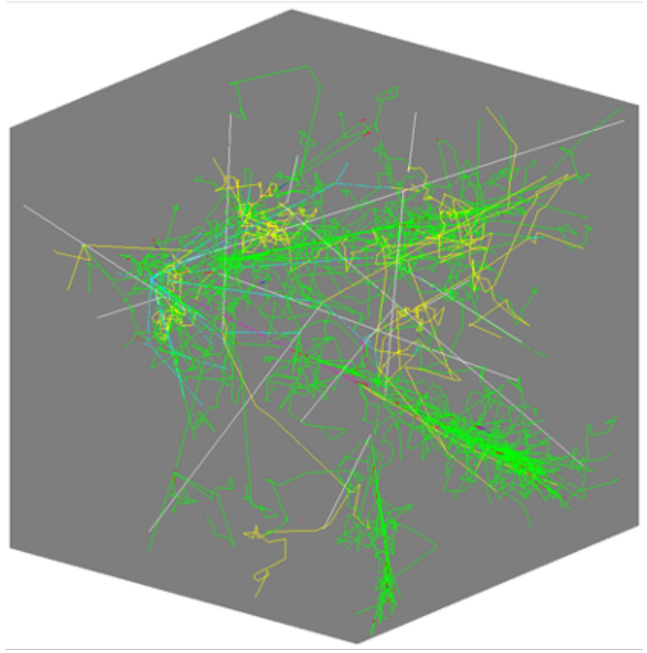

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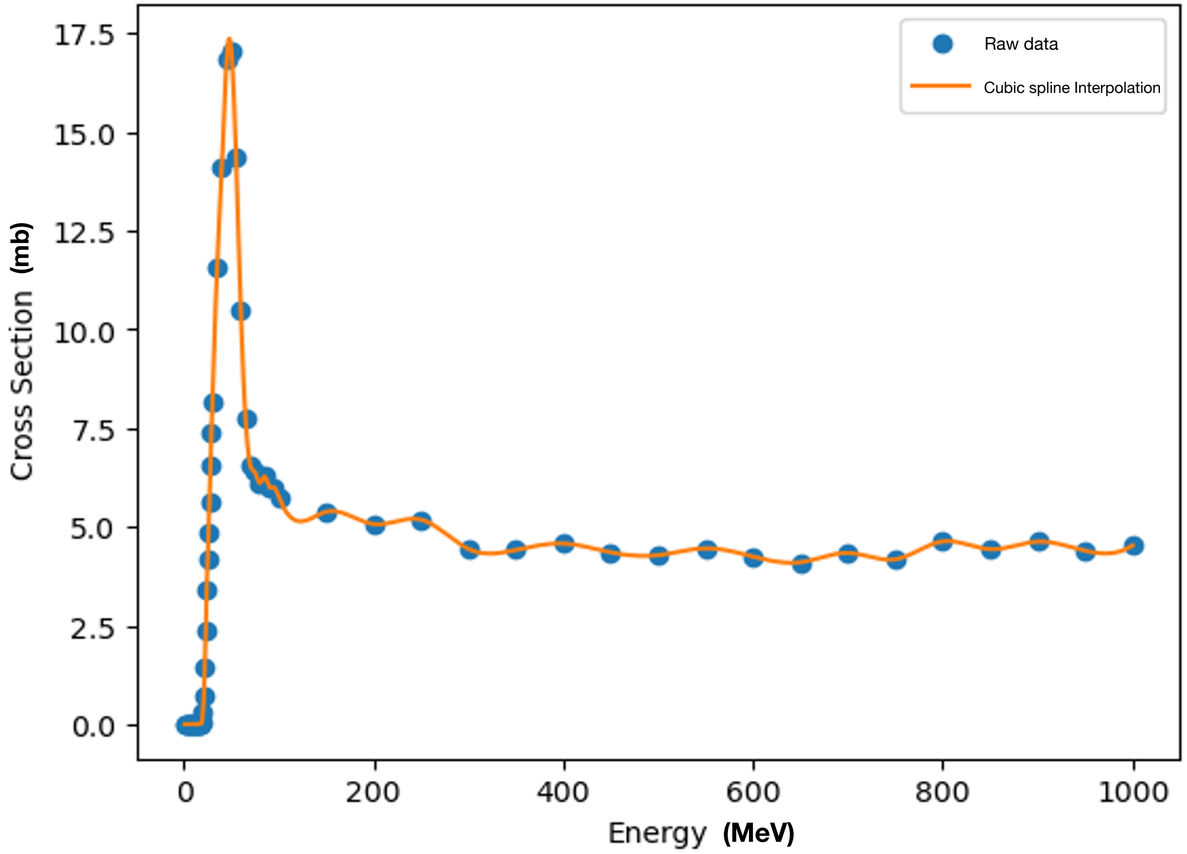
density(g/cm^3)	0.000909938
NA(/mol)	6.022E+23
N (g/mol)	14
Number of Production of Be-7	1943
Energy (MeV)	1000
Cross Section(mb)	4.964188013



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Approximately 1/2 times

Number of proton beam	5,000,000
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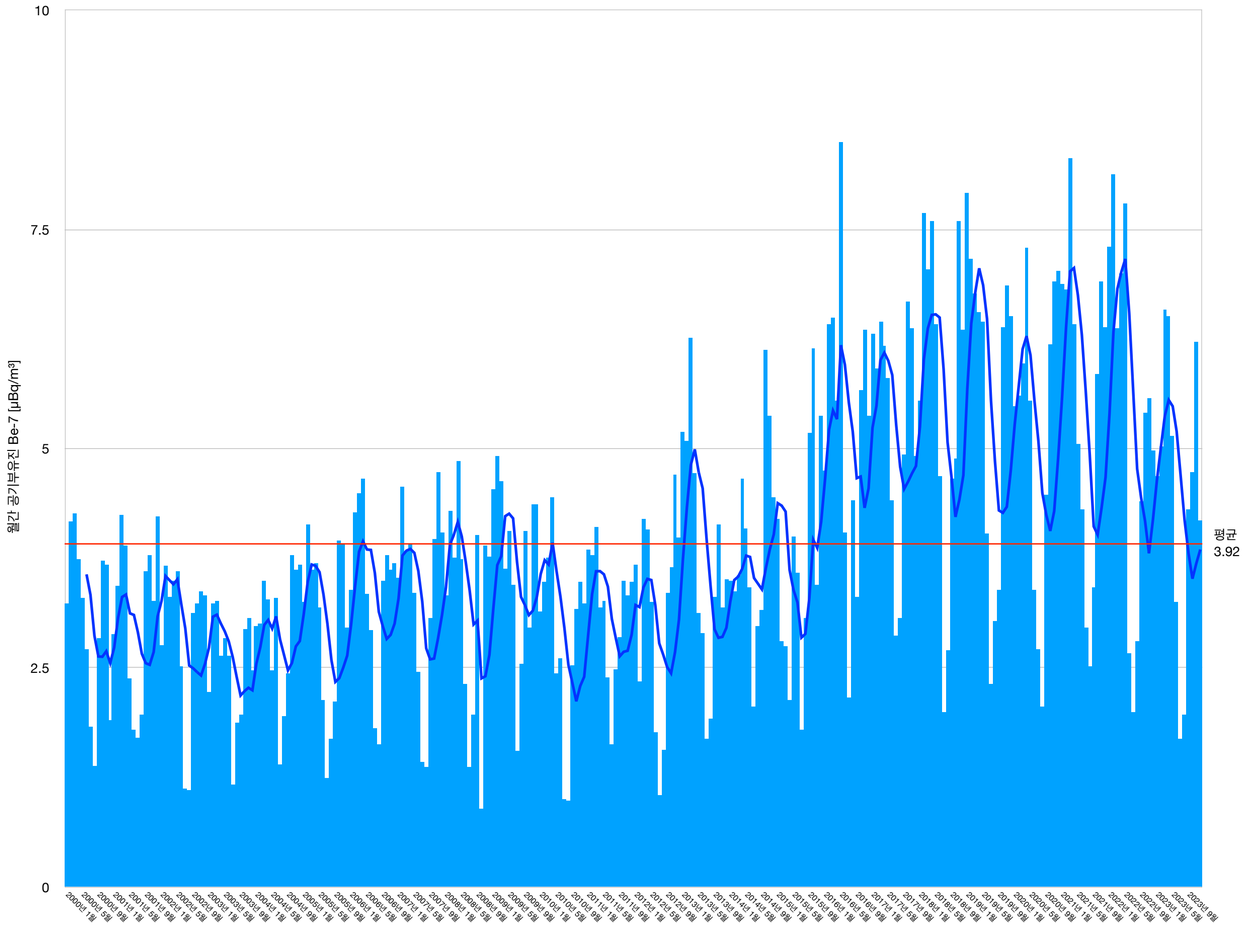
density(g/cm^3)	0.000909938
NA(/mol)	6.022E+23
N (g/mol)	14
Number of Production of Be-7	1943
Energy (MeV)	1000
Cross Section(mb)	4.964188013

Measurement data



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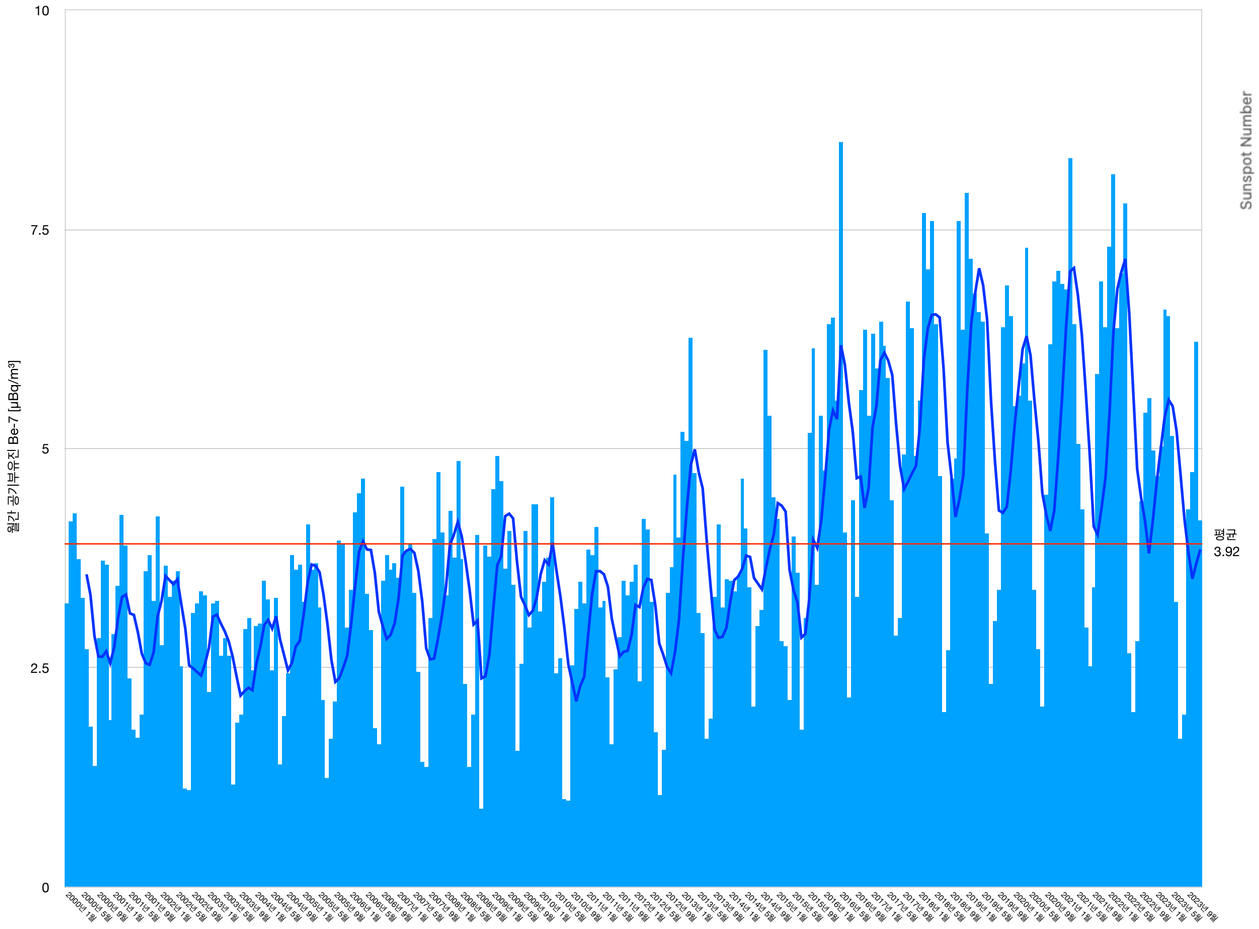
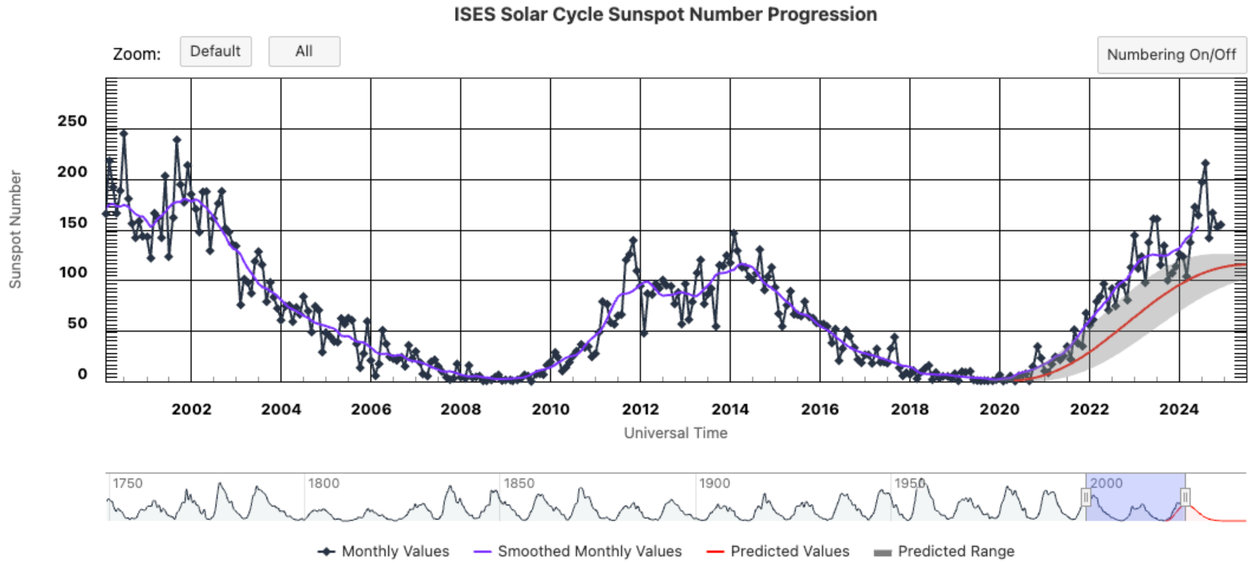




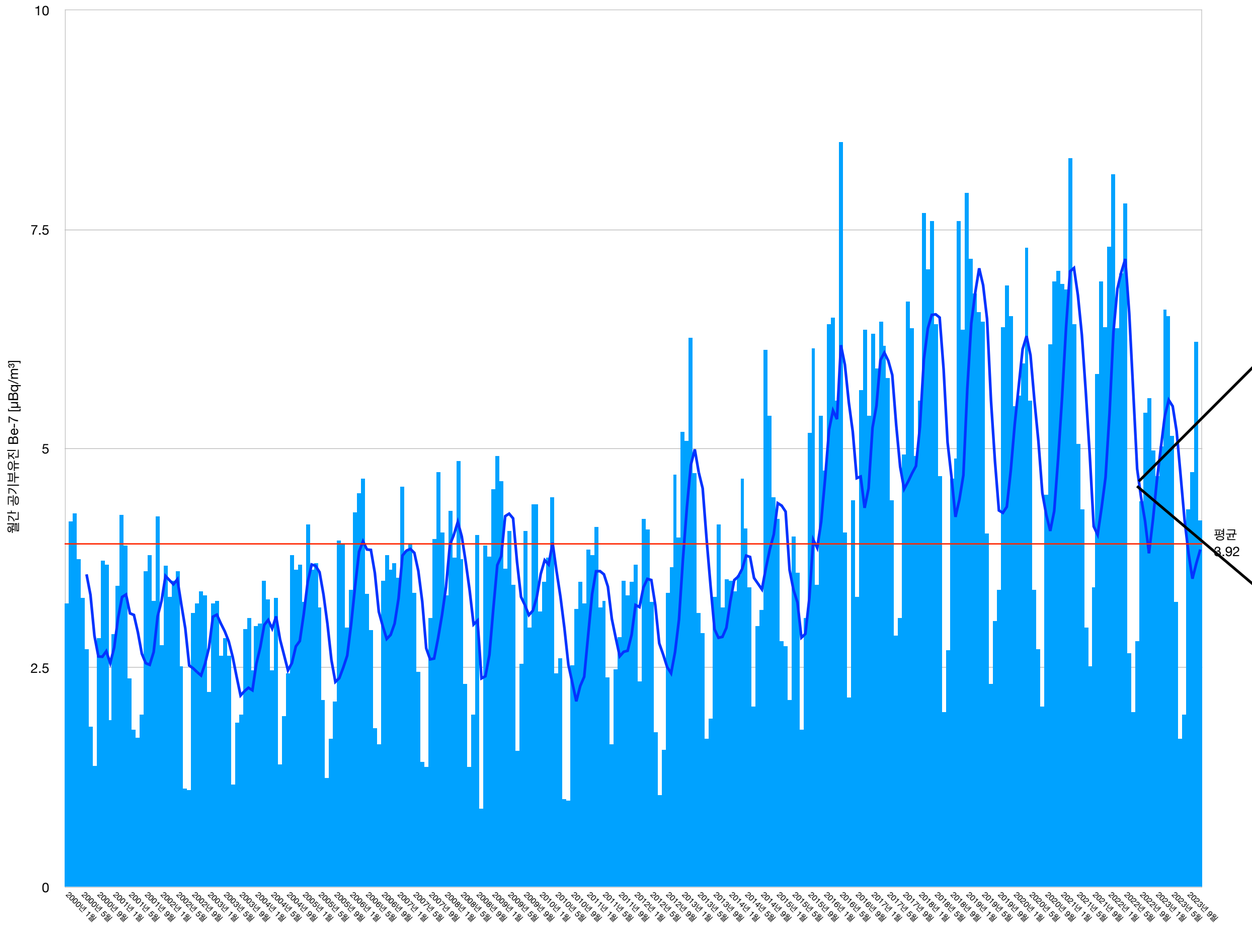
- Cause of Variation

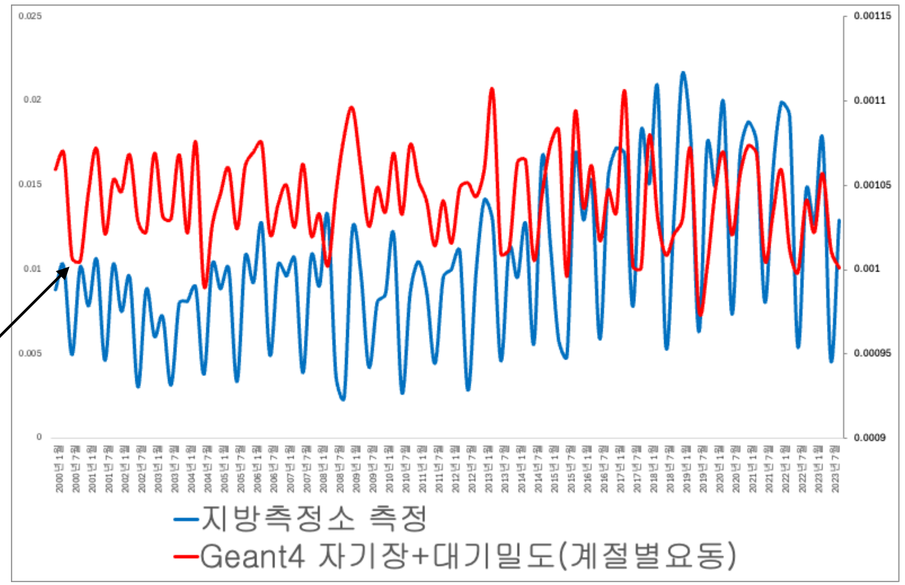
1. Solar activity and cosmic ray intensity

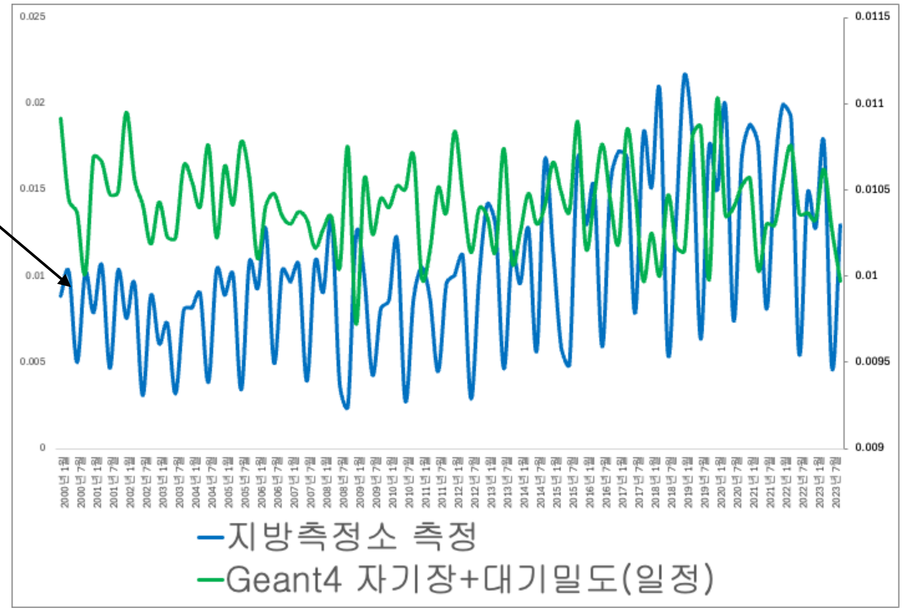
2. Climatic conditions (precipitation, seasonal atmospheric circulation)

3. Measurement errors and sampling process

Comparison with Geant4 data







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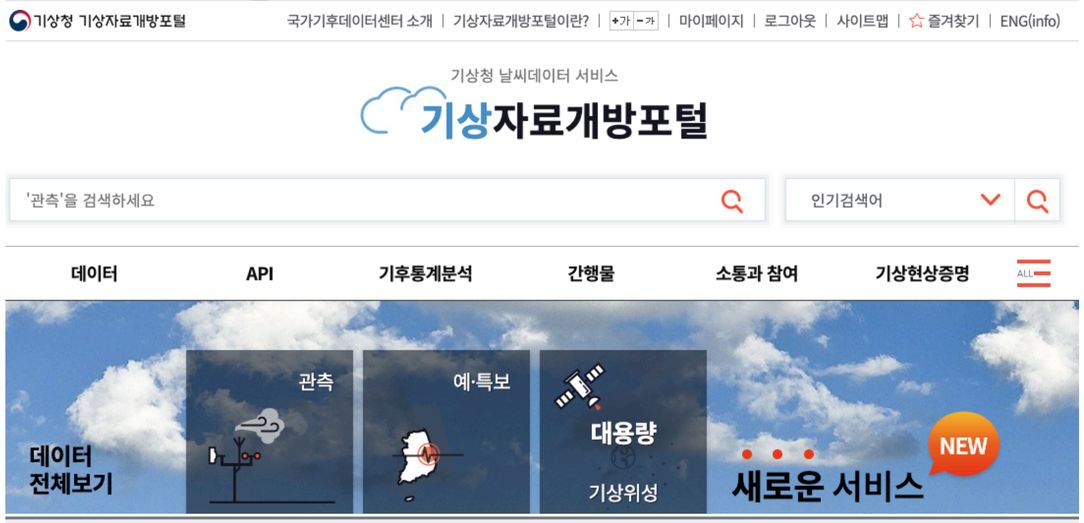


지점	시간	평균기온(℃)	평균현지기압(hPa)
부산(159)	2023-01	3.8	1013.2
부산(159)	2023-02	6.8	1014.4
부산(159)	2023-03	12.3	1010.5
부산(159)	2023-04	14.6	1005.8
부산(159)	2023-05	17.9	1004.8
부산(159)	2023-06	22.5	999.8
부산(159)	2023-07	25.5	1001
부산(159)	2023-08	27.8	997.6
부산(159)	2023-09	24.5	1004.2
부산(159)	2023-10	18.3	1009.3

→

지점	지점명	일시	평균기온(°C)	평균현지기압(hPa)
159	부산	2000. 1. 1.	4.2	1014.5
159	부산	2000. 2. 1.	3.2	1011.7
159	부산	2000. 3. 1.	9.1	1008.5
159	부산	2000. 4. 1.	13.2	1004.2
159	부산	2000. 5. 1.	17.3	1002.3
159	부산	2000. 6. 1.	20.4	1000
159	부산	2000. 7. 1.	25.3	998.6
159	부산	2000. 8. 1.	26.7	1001.4
159	부산	2000. 9. 1.	21.9	1003.7
159	부산	2000. 10. 1.	18.2	1010
159	부산	2000. 11. 1.	12.1	1013.9
159	부산	2000. 12. 1.	7.3	1013.7
159	부산	2001. 1. 1.	2.7	1012.6
159	부산	2001. 2. 1.	5.7	1013.4
159	부산	2001. 3. 1.	9.6	1005.9
159	부산	2001. 4. 1.	15	1007
159	부산	2001. 5. 1.	19	1002.2
159	부산	2001. 6. 1.	21.6	999.7
159	부산	2001. 7. 1.	26	1000.2

https://data.kma.go.kr/data/grnd/selectAsosRltmList.do?pgmNo=36

Conclusion

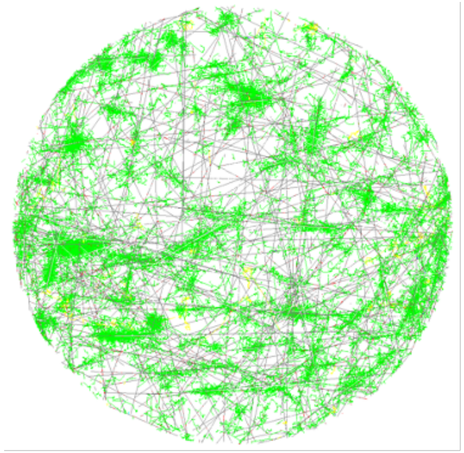
- The comparison between the ^{7}Be production yield obtained through Geant4 simulations and the experimental data revealed that the simulation exhibited periodicity similar to the experiment due to the seasonal variations in atmospheric density.

- Some discrepancies are believed to stem from the lack of consideration for abnormal weather anomalies and changes in solar activity in the simulation.

- To enhance the realism of the simulation, it is necessary to incorporate meteorological data and solar activity indices.

- By addressing these factors, it will be possible to achieve more accurate predictions of Be production yield and develop a simulation model that aligns more closely with real-world conditions.

THANK YOU



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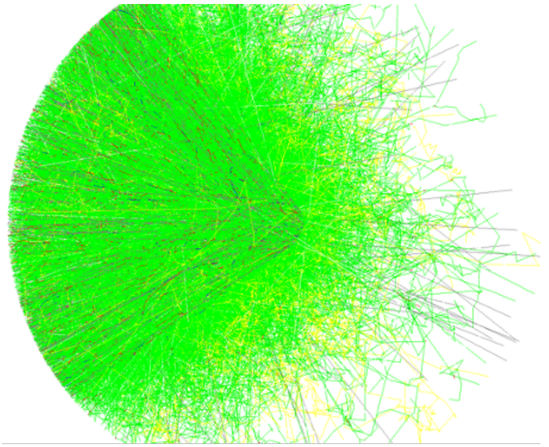

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