Experimental Study of the $^{7}\mathrm{Be}(n, p_1)^{7}\mathrm{Li}^{*}$ Reaction for the Cosmological Lithium Problem

Shunki Ishikawa

PhD 1st year
Laboratory of Experimental Nuclear Physics
Department of Physics, Tohoku University

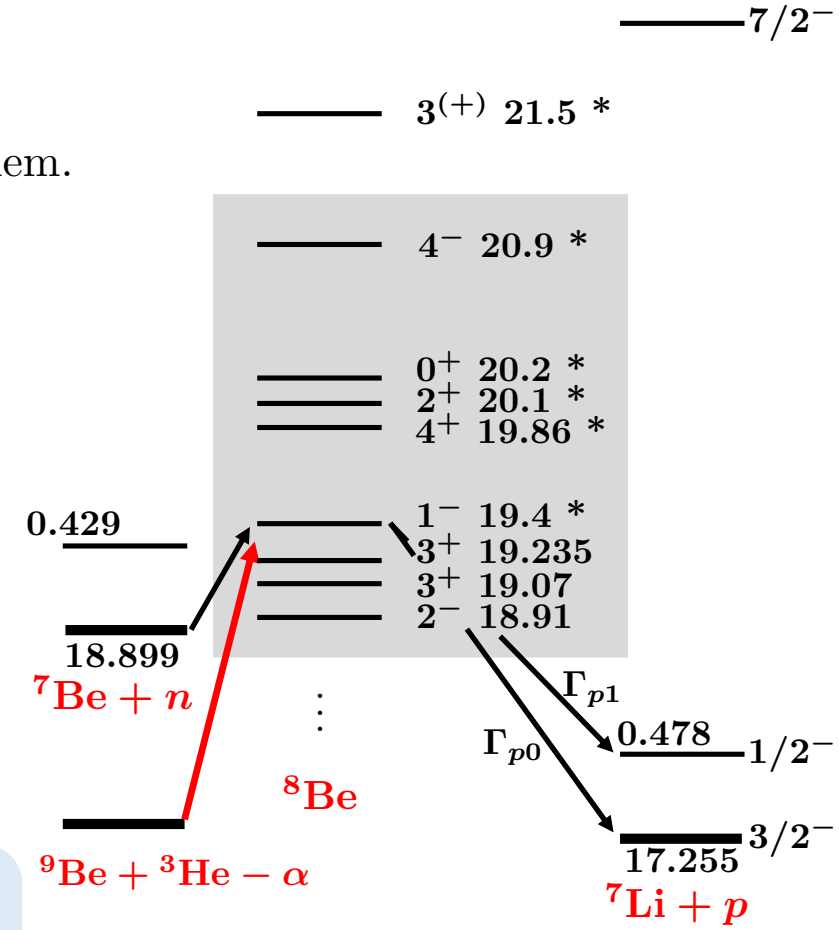
Motivation

- Big Bang Nucleosynthesis (BBN) model vs. observation
- Large discrepancy for ^{7}Li: Cosmological Lithium Problem
- Decrease in ^{7}Be abundance during BBN may solve the problem.
- Destruction: neutron induced reaction
  ^{7}Be$(n,p)^7$Li followed by ^{7}Li$(p,\alpha)^4$He
  - ⟶ direct measurement at low energy region (up to 2^-)
  - ⟶ inverse reaction measurement
  - ⇒ **^{7}Be$(n,p_1)^7$Li* was ignored!**
- Cross section (for a single level)

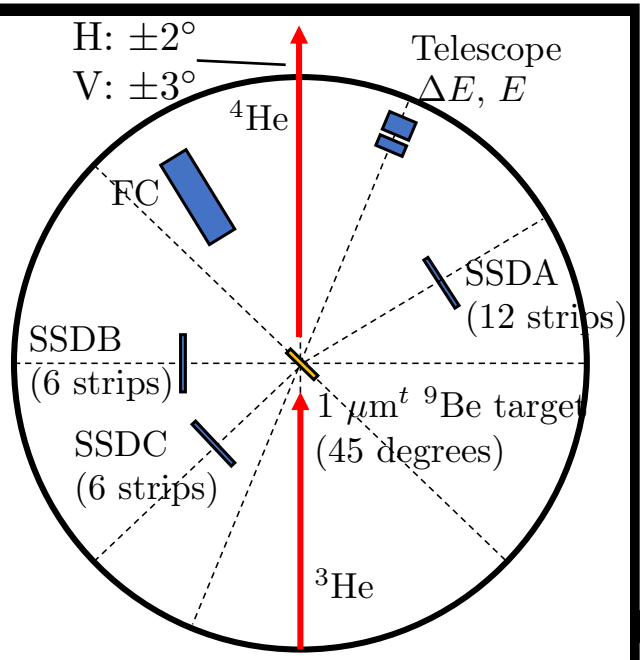
$$\sigma_{n,p}(E_n) = \frac{\pi}{k_n^2} g(J) \frac{\Gamma_n \Gamma_p}{(E_n - E_r)^2 + \Gamma^2/4}$$

Objective:
^{7}Be$(n,p_1)^7$Li* cross section using the inverse reaction data
⇒ **Experimental determination of Γ_{p1}/Γ_{p0} is required!**

We carried out the ^{9}Be$(^3$He$,\alpha)^8$Be$^*(p)^7$Li reaction measurement at 30 MeV to deduce the branching ratio for the resonance states of ^{8}Be at 18.91-20.1 MeV.



Experimental Setup 2

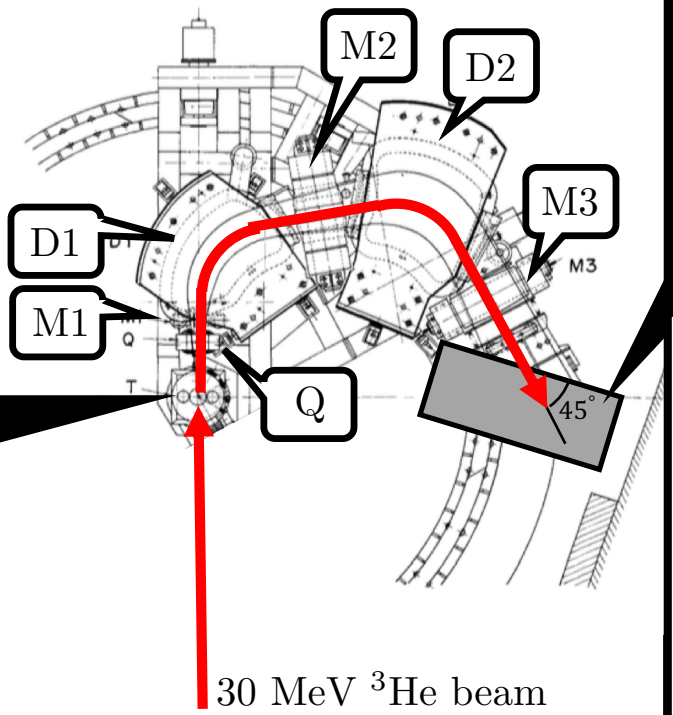


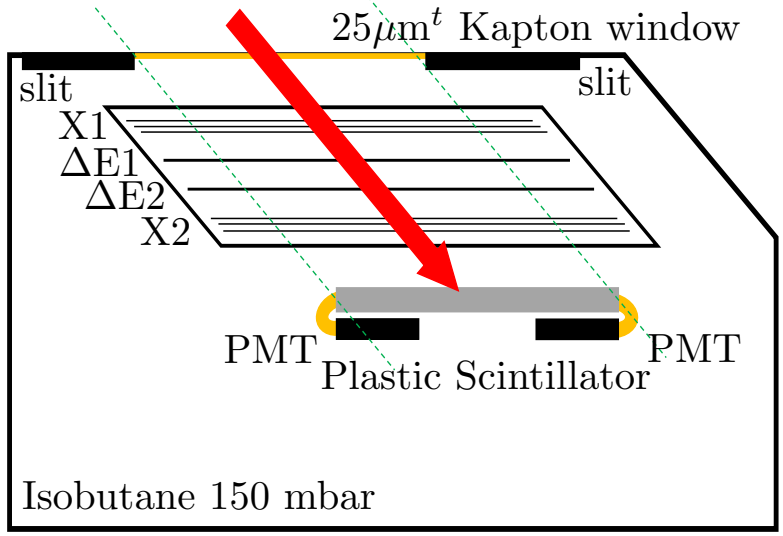
Target Chamber

- SSD: $60 \times 60 \times 0.3$ mm^3
- SSDA: 150 mm, 48-71°
- SSDB: 120 mm, 76-104°
- SSDC: 120 mm, 121-150°
- Telescope: 22.5°, 8 mmϕ
  ΔE : 0.15 mm^t, E : 3 mm^t

Magnetic Spectrometer ENMA

- Q-M-D-M-D-M ststem
- $(x|x) = 1.7$
- $(x|\delta) = 12.6$ cm/%

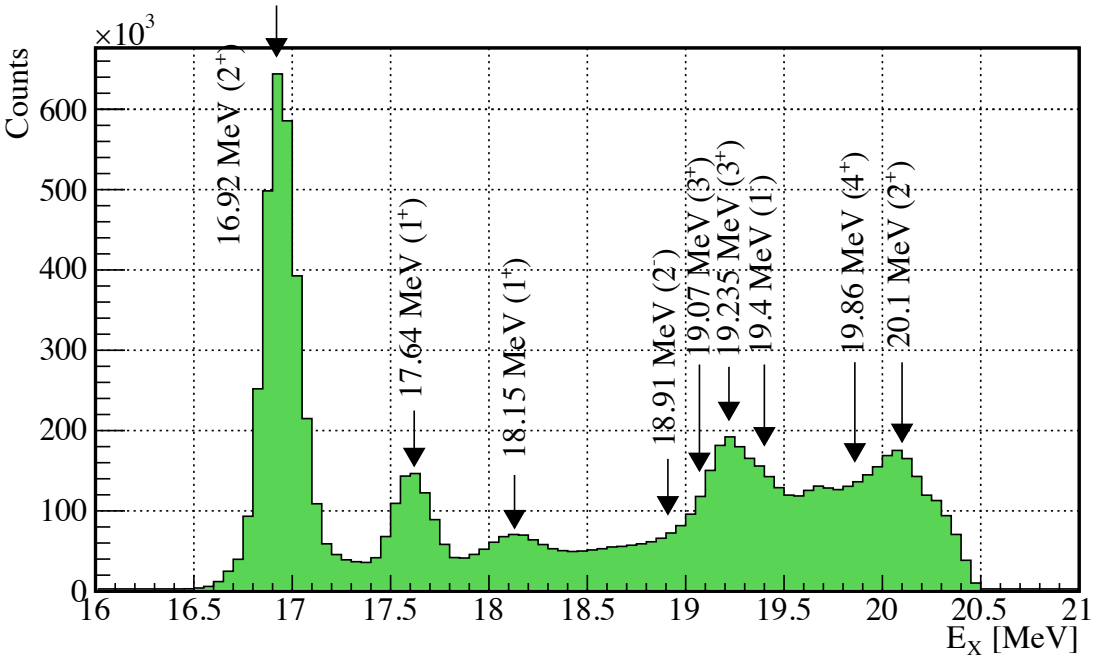


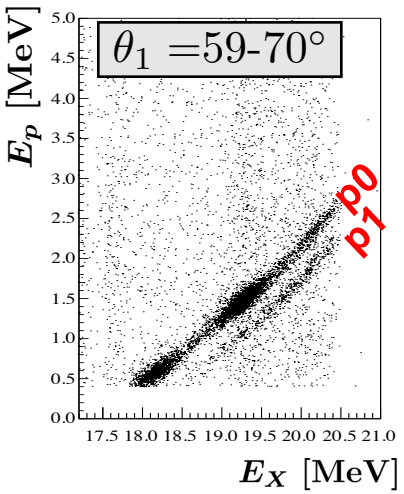


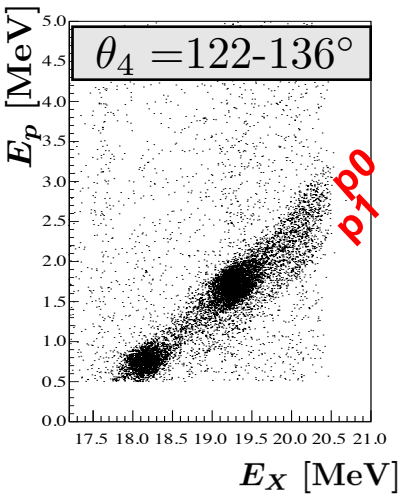
Focal Plane Chamber

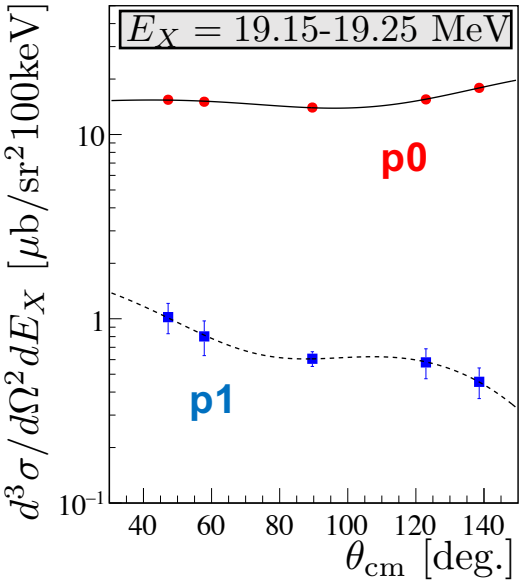
- X1 (1.17 m): 3×NiCr wire(15 μmϕ),2.2 kΩ
- X2 (1.17 m): 3×NiCr wire(15 μmϕ),2.2 kΩ
- ΔE1, ΔE2: Au-W wire(25 μmϕ)
- Plastic Scintillator+2×PMT
- HV:
  Cathode=-800 V
  X1=950 V, X2=950 V
  ΔE1=750 V, ΔE2=750 V

Experimental Data









- Excitation energy spectrum of ^{8}Be at FP
- σ=80 keV (E_x = 16.92, 17.64 MeV)
- Decay protons measured in coincidence
- Angular distribution in the rest frame of ^{8}Be
- Angle-integrated differential cross section obtained by fitting with

$$\left(\frac{d^3\sigma}{d\Omega^2 dE_X}\right)_{cm} = \sum_{L=0}^{3} A_L P_L(\cos\theta_p^{cm})$$

Cross Sections and Resonance Fit

- Resonance fit with

$$f(E) = \sum_r A P_l(E) V(E)$$

where,

$$P_l(E) = \frac{\rho(E)}{F_l(\rho(E),\eta(E))^2 + G_l(\rho(E),\eta(E))^2}$$

and

V: Convolution of Gaussian and Lorentzian

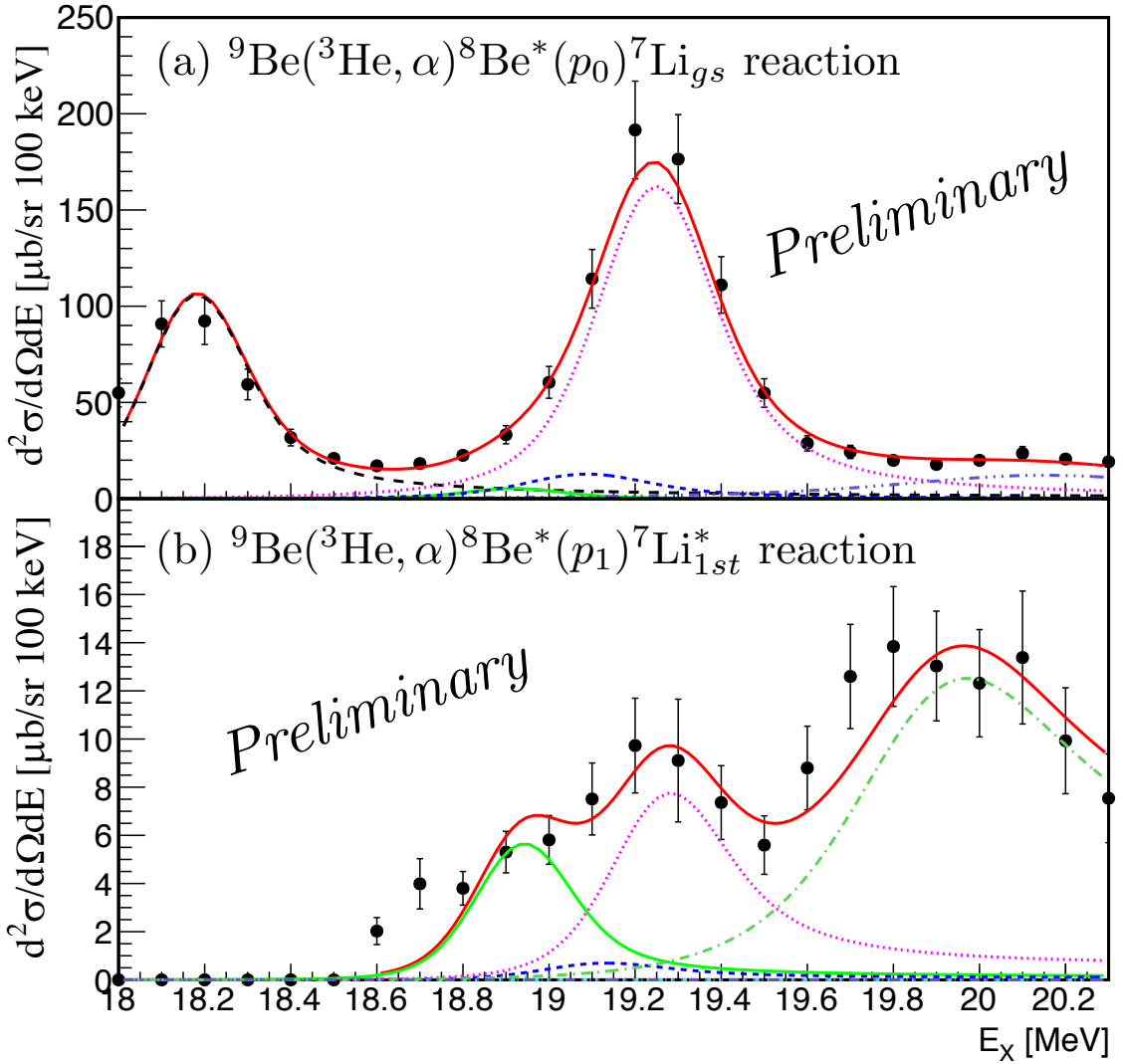
- The branching ratio

$$\Gamma_{p1}/\Gamma_{p0} = (A' P_l'(E_x))_{p1} / (A P_l(E_x))_{p0}$$

- Resonances considered:

E_x =18.91, 19.07, 19.235, 19.86, 20.1 MeV and E_x =18.15 MeV for (a)

- The resonance energies are fixed, while widths are allowed to vary within the uncertainties from NNDC library.



Summary

- In order to approach the $^{7}\mathrm{Be}(n, p_1)^{7}\mathrm{Li}^{*}$ reaction cross section, we performed the $^{9}\mathrm{Be}(^{3}\mathrm{He}, \alpha)^{8}\mathrm{Be}^{*}(p)^{7}\mathrm{Li}$ reaction measurement to deduce the Γ_{p1}/Γ_{p0} ratio for each of the resonant states of ^{8}Be.
- Succeeded in measuring the $^{7}\mathrm{Li}^{*} + p_1$ events for a wide excitation energy range of ^{8}Be for the first time!
- $\sim 5\%$ increase in the cross section due to the p_1 channel at the 3^{+}(19.235 MeV) resonance.
- p_1 is dominant at the 4^{+}(19.86 MeV) resonance. (However, it will not give much effect)
- The $^{7}\mathrm{Be}(n, p_1)^{7}\mathrm{Li}^{*}$ reaction cross section may not solve the lithium problem?
- Need to improve the statistical accuracy.

TOHOKU UNIVERSITY

GPPU GRADUATE PROGRAM ON PHYSICS FOR THE UNIVERSE

宇宙創成物理学
国際共同大学院

Collaborators

S. Ishikawa[1], N. Iwasa[1], S. Kubono[2], K. Asada[1], D. Guru[1], S. Hayakawa[3], K. Hirose[4], T. Kawabata[5], K. Kominato[1], H. Makii[4], M. Matsuda[4], S. Nishimura[2], K. Nishio[4], R. Orlandi[4], and T. Sakakibara[1]

[1]Department of Physics, Tohoku University, Miyagi 980-8578, Japan
[2]RIKEN Nishina Center, Saitama 351-0198, Japan
[3]Center for Nuclear Study, University of Tokyo, RIKEN Campus, Saitama 351-0198, Japan
[4]Japan Atomic Energy Agency, JAEA, Ibaraki 319-1195, Japan
[5]Research Center for Nuclear Physics, Osaka University, Osaka 567-0047, Japan