“Time-Reversal Measurement of the p-Wave Cross Sections of the ^{7}Be(n,α)^{4}He Reaction for the Cosmological Li Problem”

T. Kawabata et. al., PRL 118, 052701 (2017)

05/26/2017

Lithium Problem

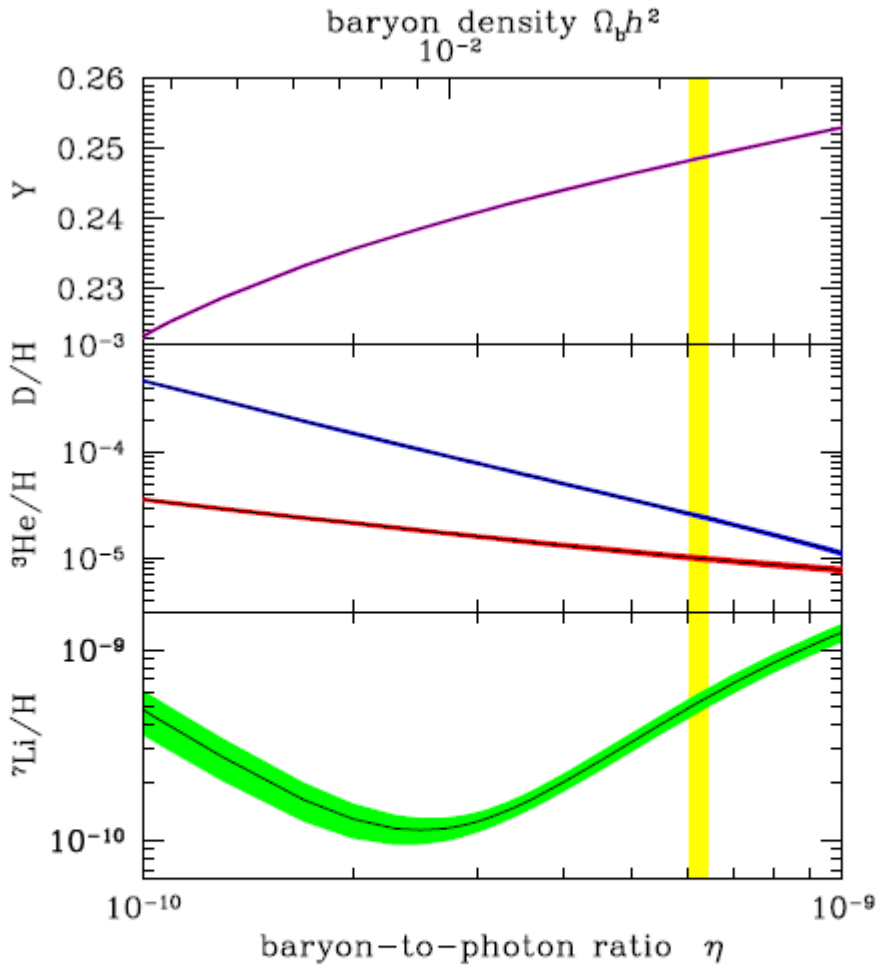
Usually, the term “Lithium problem” means , , ,

1. Mismatch of the abundance of ^{7}Li between observations and Big bang nucleosynthesis (BBN) theory estimation

2. Discrepancy of the ratio $^{7}Li/^{6}Li$ estimated from BBN

Big Bang Theory prediction of each abundance

^{4}He/H in mass →



From "The Primodal Lithium Problem" , Brian D. Firlds

Figure 2: BBN theory predictions for light nuclide abundances vs baryon-to-photon ratio η. Curve widths: 1σ theoretical uncertainties. Vertical band: WMAP determination of η.

Comparison of 7Li abundance with prediction

Corresponds to ^{7}Li/H →

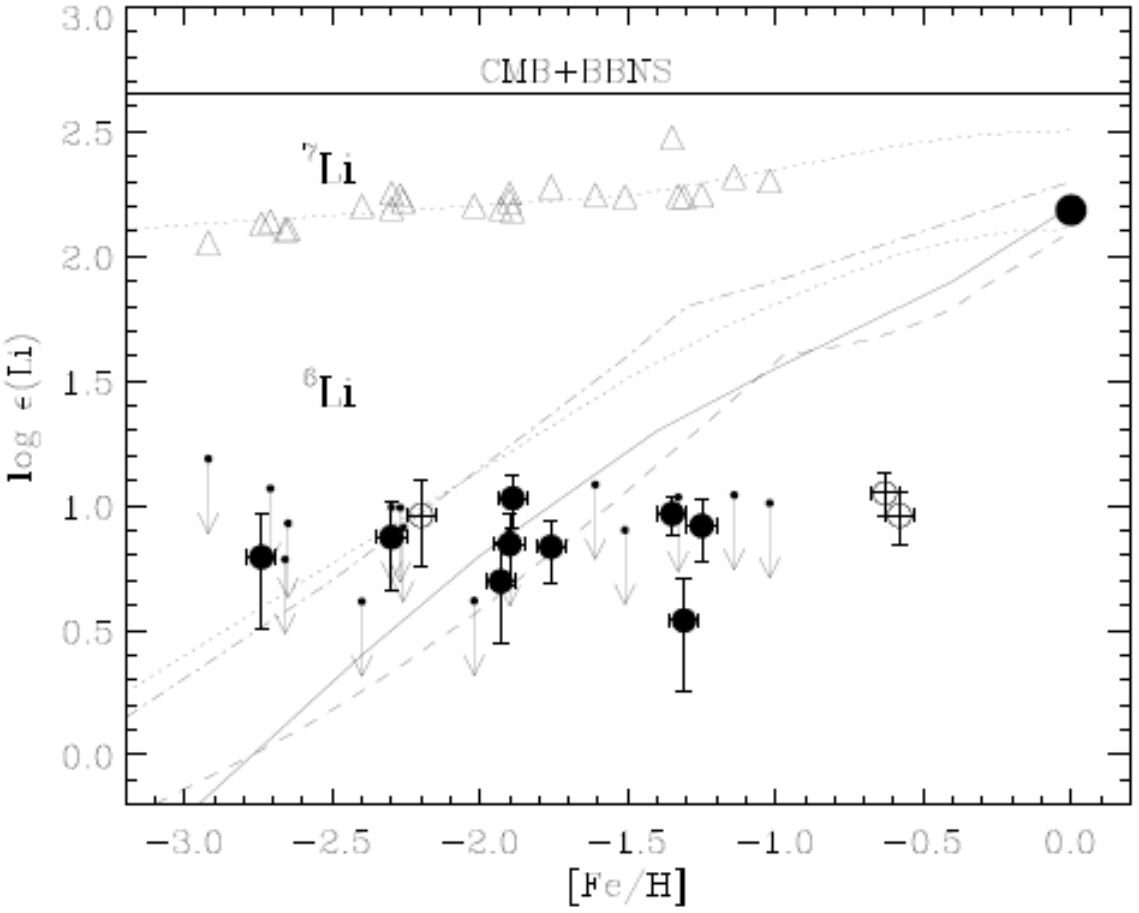


Figure 3: Lithium abundances in selected metal-poor Galactic halo stars, from (46) with permission. Fore each star, elemental Li = ^{6}Li + ^{7}Li is plotted at the star's metallicity [Fe/H] = $\log_{10}[(Fe/H)_{obs}/(\mathrm{Fe/H})_\odot]$. The flatness of Li vs Fe is the "Spite plateau" and indicates that the bulk of the lithium is unrelated to Galactic nucleosynthesis processes and thus is primordial. The horizontal band gives the BBN+WMAP prediction; the gap between this and the plateau illustrates the ^{7}Li problem. Points below the plateau show ^{6}Li abundances; the apparent plateau constitutes the ^{6}Li problem.

Reference : ^{7}Li abundance

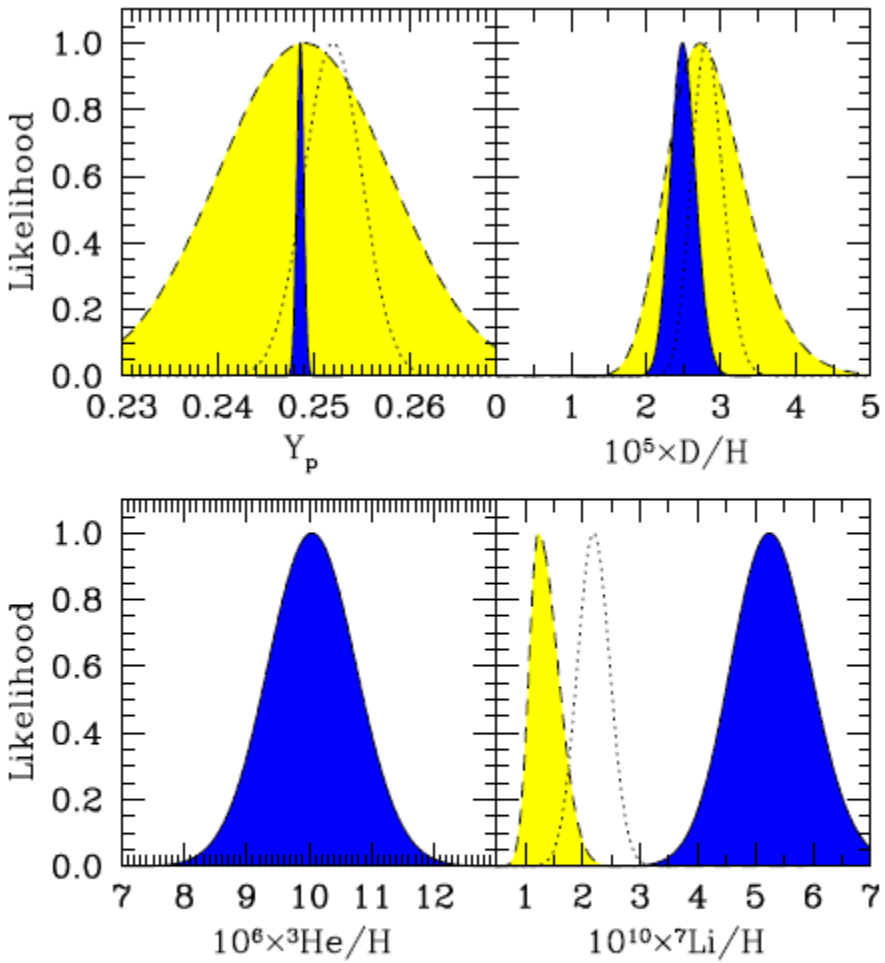


FIG. 4: *The theoretical and observational likelihood functions for* ^{4}He, *D/H,* ^{3}He*/H, and* ^{7}Li*/H. BBN results have been convolved with the WMAP determination of* η *and are shown as dark (blue) shaded area. The observational likelihoods are shown as light (yellow) shaded regions as well as alternative dotted curves. The data and distinctions are detailed in the text.*

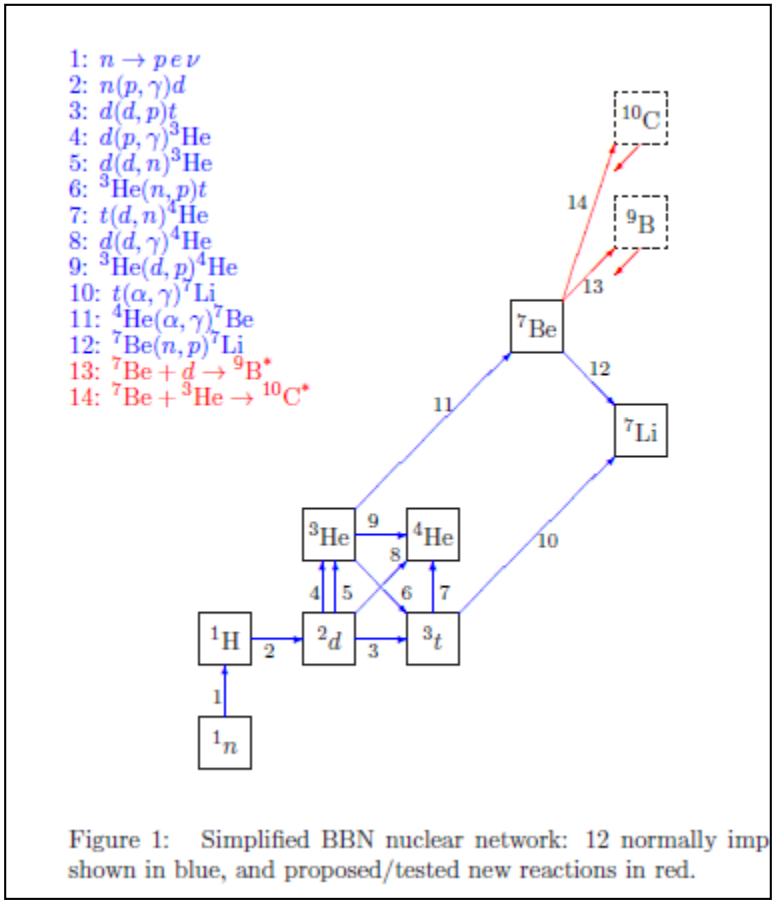


Figure 1: Simplified BBN nuclear network: 12 normally imp
shown in blue, and proposed/tested new reactions in red.

Motivation

From a view of nuclear physics, nuclear-reaction rates involved in the BBN theory should be examined. The main process of the ^{7}Li production in the BBN is the electron-capture decay of ^{7}Be, which is synthesized in the $^3\mathrm{He}(^4\mathrm{He},\gamma)^7\mathrm{Be}$ reaction. Direct measurements of the cross section for the $^3\mathrm{He}(^4\mathrm{He},\gamma)^7\mathrm{Be}$ reaction were extensively carried out in the past by several groups, and uncertainties in this thermonuclear reaction rate are now very small. There is no room to modify the ^{7}Be production rate to solve the lithium problem [7].

Recently, it was pointed out that the ^{7}Li abundance will be greatly reduced in the BBN calculation if the destruction rate of ^{7}Be is enhanced. One of the candidate channels to destruct ^{7}Be is the $^7\mathrm{Be}(n,\alpha)^4\mathrm{He}$ reaction.

^{7}Be$(n,\alpha)^{4}$He Reaction and the Cosmological Lithium Problem: Measurement of the Cross Section in a Wide Energy Range at n_TOF at CERN

M. Barbagallo, et. al., PRL 117, 152701 (2016)

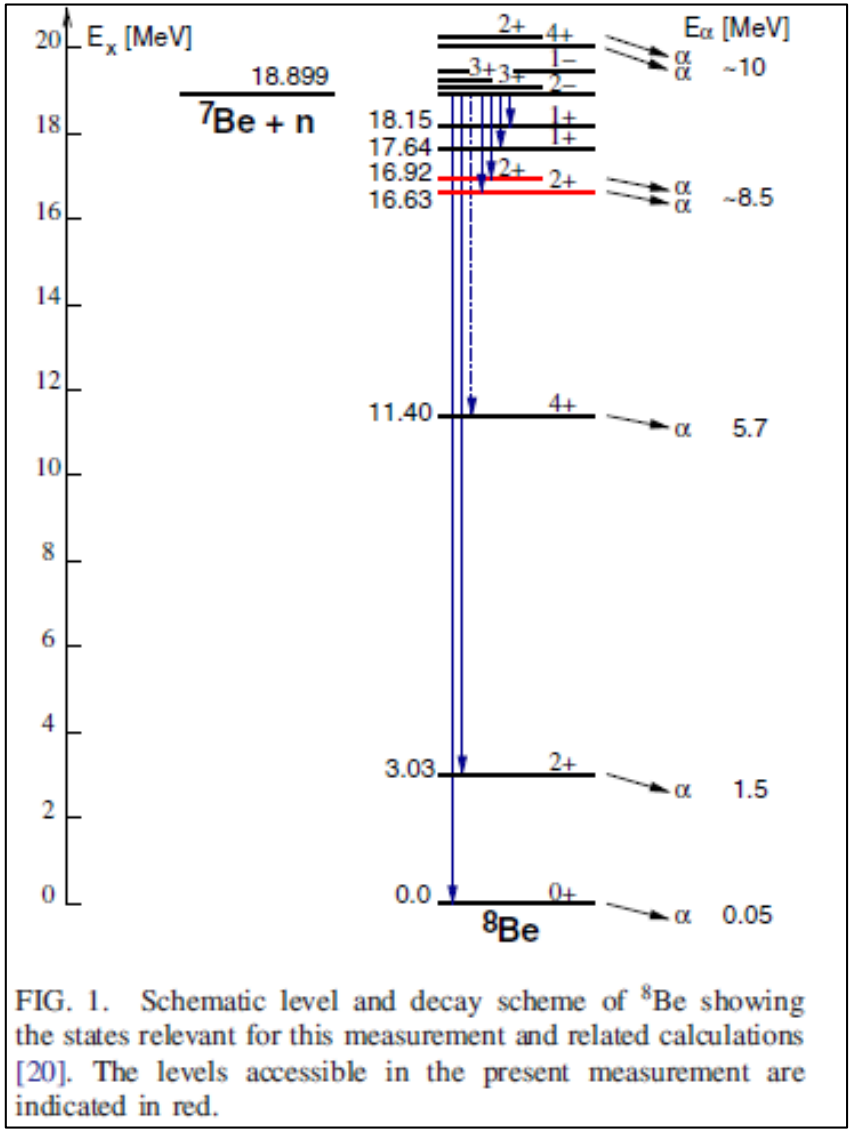


FIG. 1. Schematic level and decay scheme of ^{8}Be showing the states relevant for this measurement and related calculations [20]. The levels accessible in the present measurement are indicated in red.

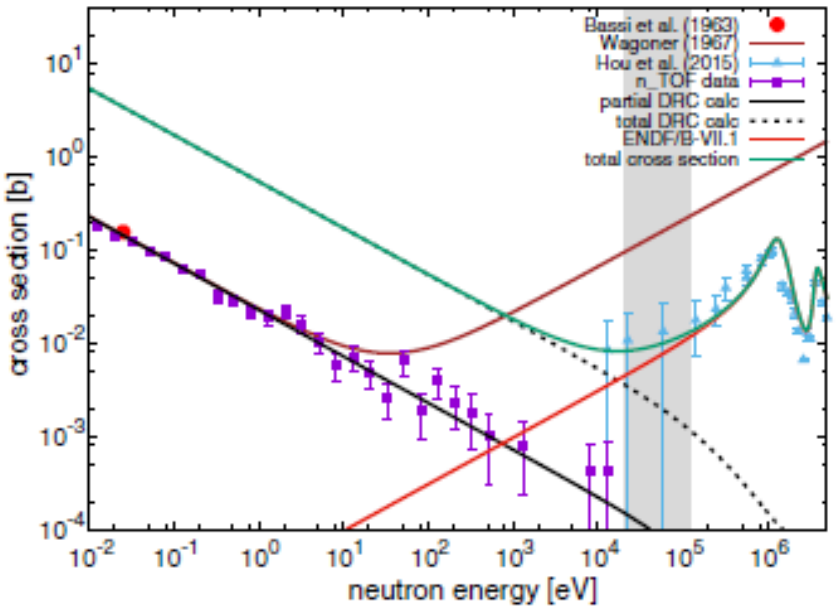


FIG. 3. The partial ^{7}Be$(n,\gamma\alpha)$ cross section measured at n_TOF between 10 meV and 10 keV (blue squares), compared with the result of Bassi *et al.* [12] at thermal energy (red circle). The solid

Precedent experiment & result

Experiment

- Beam line in RCNP (Osaka, Japan)
- Using inverse reaction $^{4}\mathrm{He}(\alpha, n)^{7}\mathrm{Be}$
- Target He (gas) irradiated by He beam with energy of ~40 MeV
- Scattered neutron is measured by liquid scintillation counter

Neutron Energy spectrum

The spectrum is obtained from liquid scintillator (BC-501A).
(neutron vs gamma event selection is necessary …..)

Subtraction of empty target run

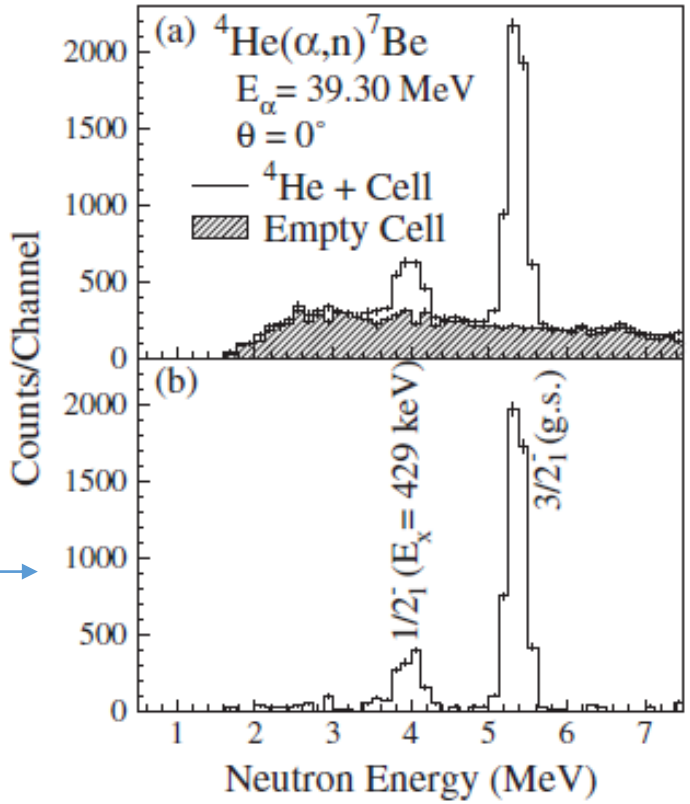


FIG. 1. Neutron energy spectra in the $^4\mathrm{He}(\alpha, n)^7\mathrm{Be}$ reaction measured at $E_\alpha = 39.30$ MeV and $\theta_{\mathrm{lab}} = 0°$. (a) Open and hatched spectra were taken using the He gas-filled and empty cells, respectively. (b) Background-free spectrum obtained by subtracting the background spectrum taken from the empty-cell measurement.

Cross section

Angular distribution

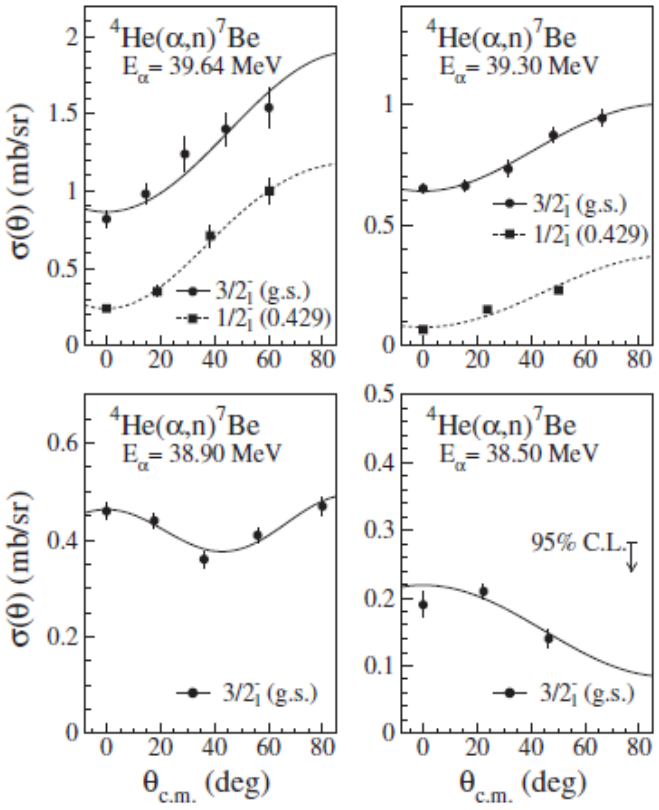


FIG. 2. Angular distribution of the differential cross sections for the ^{4}He$(\alpha, n)^7$Be reaction. The solid circles and squares show the differential cross sections for the ground and first excited states in ^{7}Be, respectively. The solid and dashed lines are series of the even-order Legendre polynomials to fit the experimental data.

Total cross section

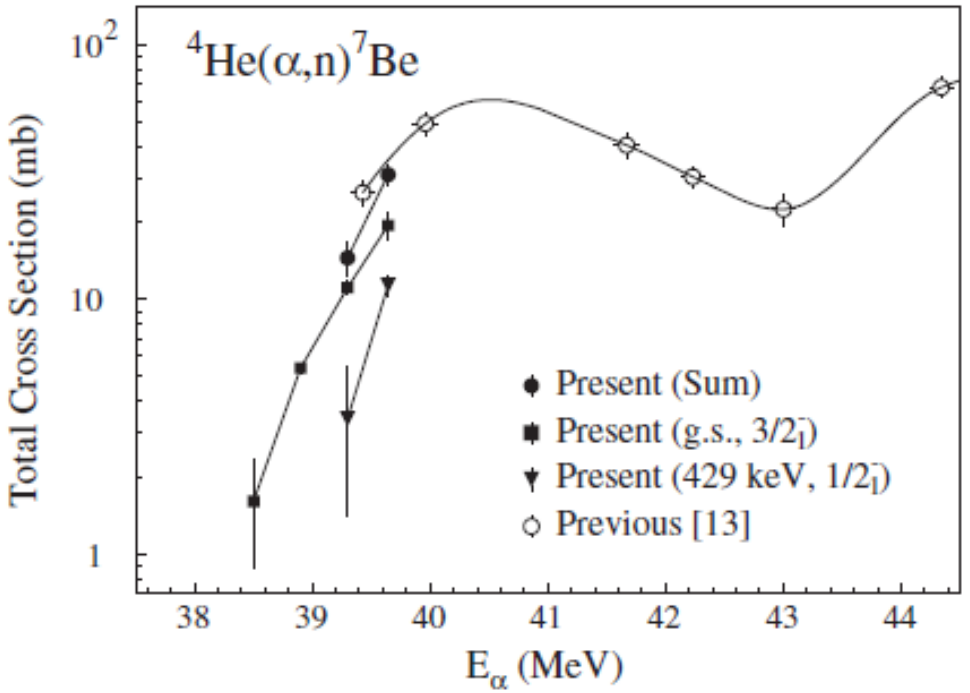


FIG. 3. Measured total cross sections of the ^{4}He$(\alpha, n)^7$Be reaction for the ground (solid squares) and first excited (solid triangles) states. The sum of the two states is shown by solid circles. Previous results from Ref. [13] are shown by the open circles. The solid lines interpolating the data points are drawn for a guide to the eye.

Comparison with the other result/theoretical estimation

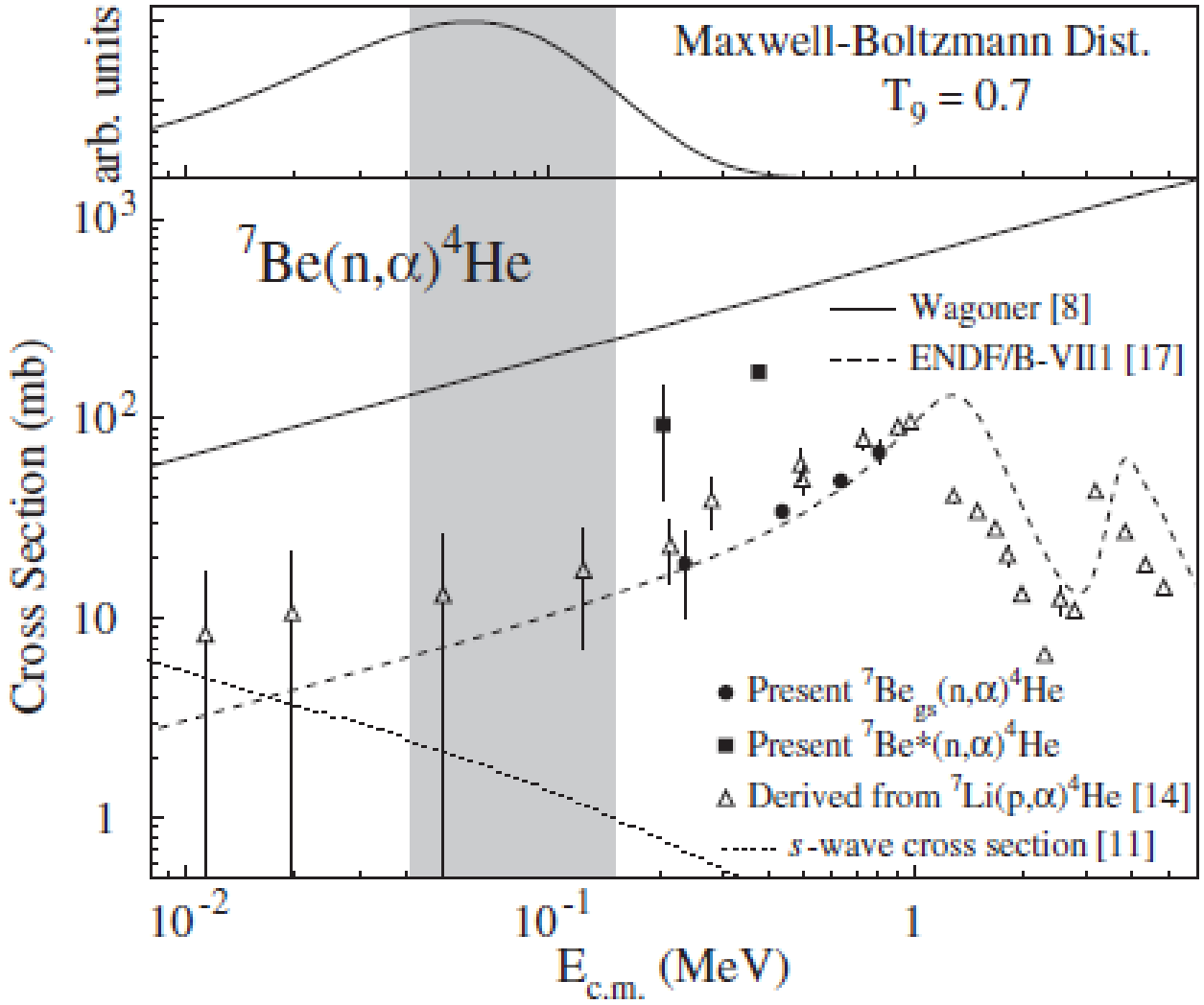


FIG. 4. Measured total cross sections for the ^{7}Be$(n,\alpha)^4$He reaction on the ground (solid circles) and first excited (solid squares) states. The cross sections for the first excited state are