Resonance excitation in ^{7}Be + d reaction to study the cosmological lithium problem

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Introduction

The ^{7}Li abundance anomaly is a long-standing problem [1]. Recent observations of metal-poor halo stars and the high precision measurement of the baryon-to-photon ratio of the Universe by WMAP demands a deeper thought on the ^{7}Li abundance anomaly. The predicted abundance is higher by a factor of 2-3 than that observed in metal-poor halo stars. A possible nuclear physics solution to the problem is that if ^{7}Be is destroyed more quickly in the early universe than was previously thought, less would be available to decay to ^{7}Li, reducing the predicted big bang nucleosynthesis (BBN) abundance [2]. There have been some efforts to explore a purely nuclear physics solution to the ^{7}Li problem [3–6], however the results were contradictory. It has been proposed that a resonant enhancement of the ^{7}Be(d,p)2α reaction could resolve the cosmological lithium problem [3]. The objective of the present work is to study the unresolved ^{7}Li abundance anomaly by carrying out experiments that destroy the rare isotope ^{7}Be, the main source of ^{7}Li. In our upcoming experiment (IS 554) at CERN-HIE-ISOLDE, using a 35 MeV ^{7}Be beam, we plan to measure the (d,p) reaction with the silicon detector array T-REX. The higher beam energy, for the first time, would allow us to measure higher excitation energies in ^{8}Be and a wider angular coverage would help in improved cross-section measurements without assuming isotropy done in earlier works.

Result and Discussion

We have carried out extensive Geant4 simulations for the above experiment. The T-REX [7] is a compact detector configuration of 4 sets of ΔE, E detectors and are named CD and Barrel detectors. To study the destructive channel of ^{7}Be we plan to use a 35 MeV ^{7}Be on CD_2 target. The Fig. 1 shows a typical Geant4 simulation considering two excited state at 10 MeV and 20 MeV in addition to the ground state in ^{8}Be. The energy resolution of T-REX would be sufficient for particle identification in this experiment. It is apparent from the Fig. 1 that, we can not detect anything in the region 75° to 100° due to the geometric position of target ladder and detectors.

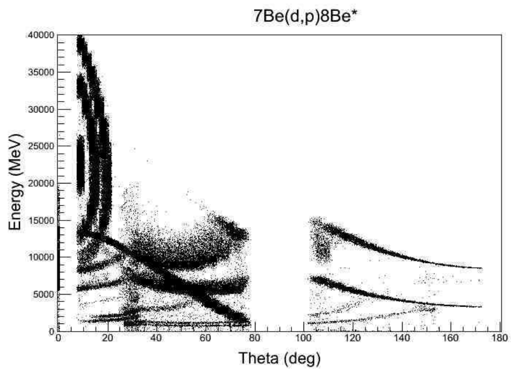

FIG. 1: Geant4 simulation for the reaction ^{7}Be(d,p)^{8}Be*.

The relevant finite range distorted wave Born approximation (DWBA) calculations using the code FRESCO [8] have been carried out. The optical model (OM) parameters and the spectroscopy factors were used from ref [9, 10]. The predicted angular distributions for several excited states of ^{8}Be are

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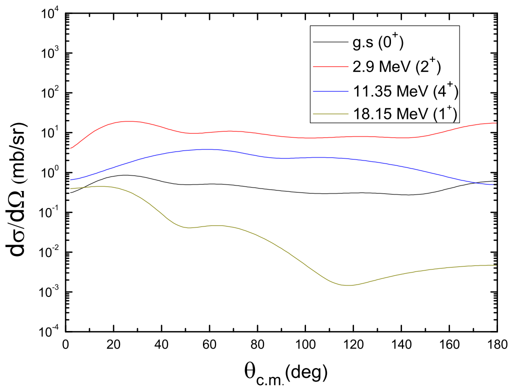

FIG. 2: Predicted proton angular distributions for the reaction ^{7}Be(d,p)^{8}Be* by FRESCO.

shown in Fig. 2.

Direct experimental determination of the above reaction rates might either support/refute a nuclear physics solution to the lithium problem. Other effects may include astrophysical effects, new effects (beyond standard BBN model) or a combination of all. Thus a serious and thorough evaluation of all possible nuclear physics aspects of primordial lithium production is urgent in order to determine whether the lithium problem truly points to new fundamental physics.

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References

[1] S. G. Ryan, *et al.*, Astrophys. **J. 530**, L57 (2000).
[2] A. Coc *etal.*, Astrophys. J. **600**, 544 (2004).
[3] R. H. Cyburt *et al.*, Int. J. Mod. Phys. **E 21**, 1250004 (2012).
[4] C. Angulo *et al.*, Astrophys. J. **630**, L105 (2005).
[5] P. D. O'Malley *et al.*, Phys. Rev. **C 84**, 042801(R) (2011).
[6] R. W. Kavanagh *et al*, Nucl. Phys. **18**, 492 (1960).
[7] V. Bildstein *et al.*, Eur. Phys.J. **A 48**, 85 (2012).
[8] I. J. Thompson, Comput. Phys. Rep. **7**, 167 (1988) .
[9] H. G. Bingham *et al.*, Nucl. Phys. **A 173**, 265 (1971) ; J. P. Schiffer *et al.*, Phys. Rev **C 164**, 1274 (1967).
[10] J. L. Schoonover., Nucl. Phys, **A 176**, 567 (1971).