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Hadrons Nuclei CRC 1660

# New Insights into Indirect Studies of the $\alpha(d,\gamma)^6Li$ Radiative Capture

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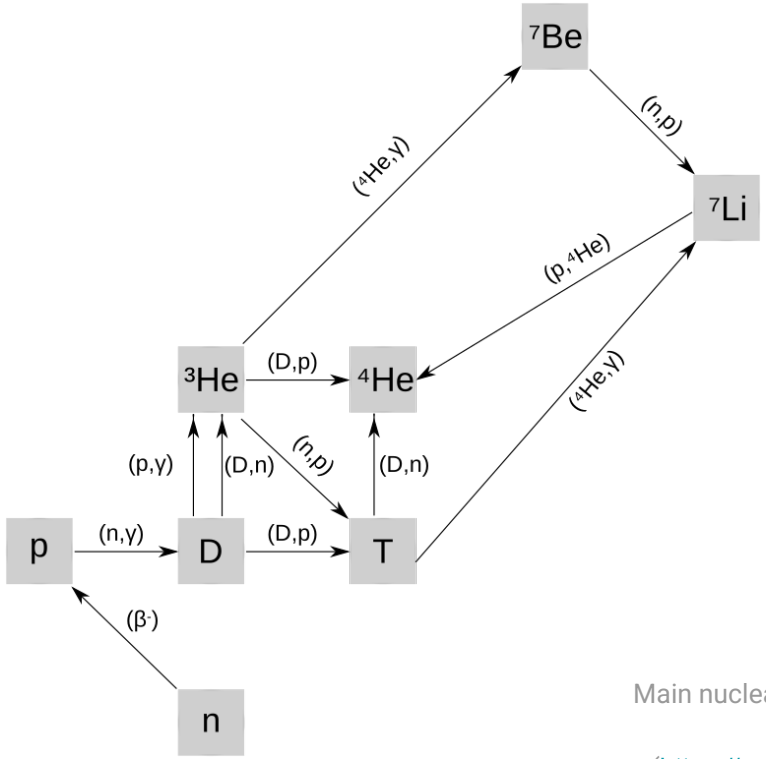
# Big Bang Nucleosynthesis: Capture Reactions




Main nuclear reaction chains for BBN. Adapted from Pamputt (https://creativecommons.org/licenses/by-sa/4.0/)

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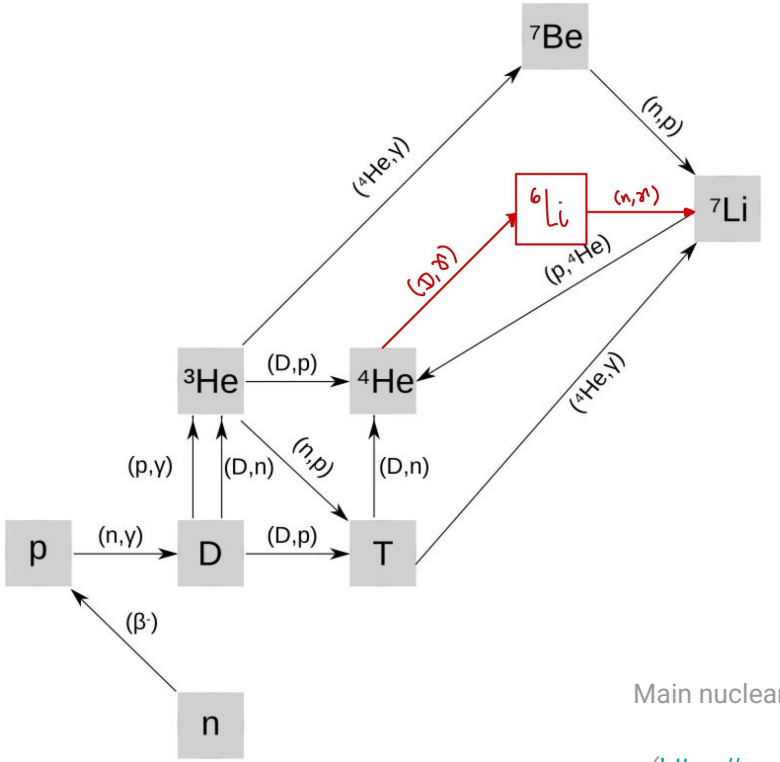
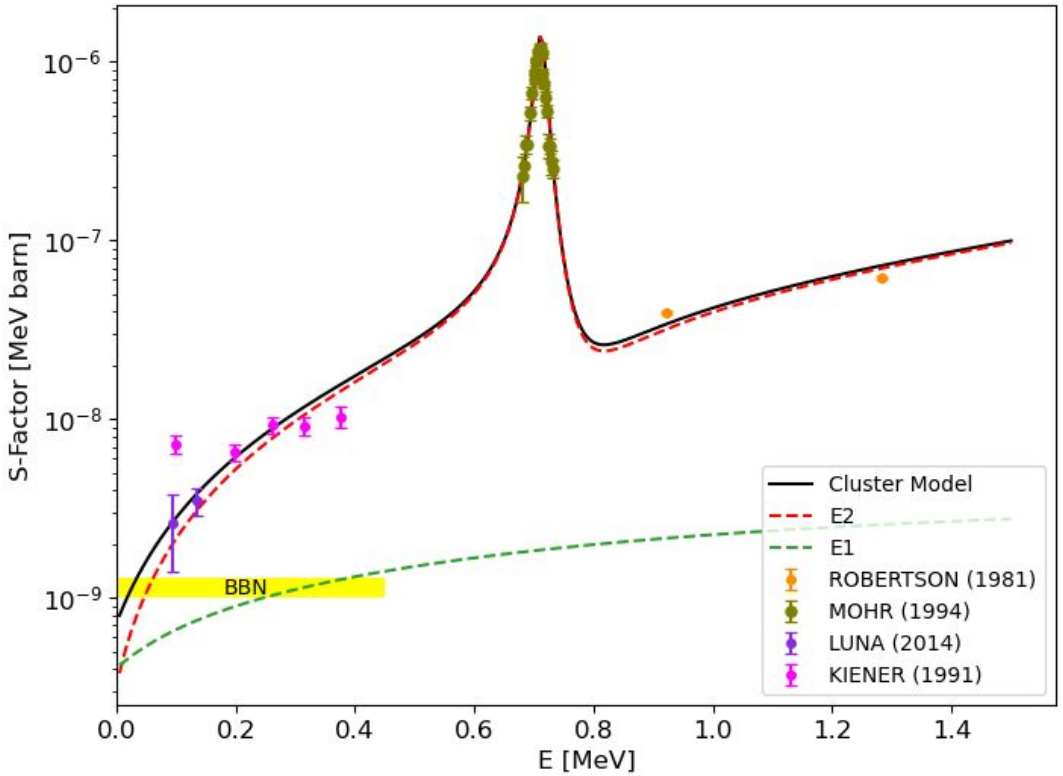



Main nuclear reaction chains for BBN. Adapted from Pamputt (https://creativecommons.org/licenses/by-sa/4.0/)

# All measurements of the α(d,γ)$^{6}$Li astrophysical S-factor




Robertson *et al.*, PRL, **47**, 1867 (1981).
Mohr *et al.*, PRC, **50**, 1543 (1994).
LUNA, PRL, **113**, 042501 (2014).

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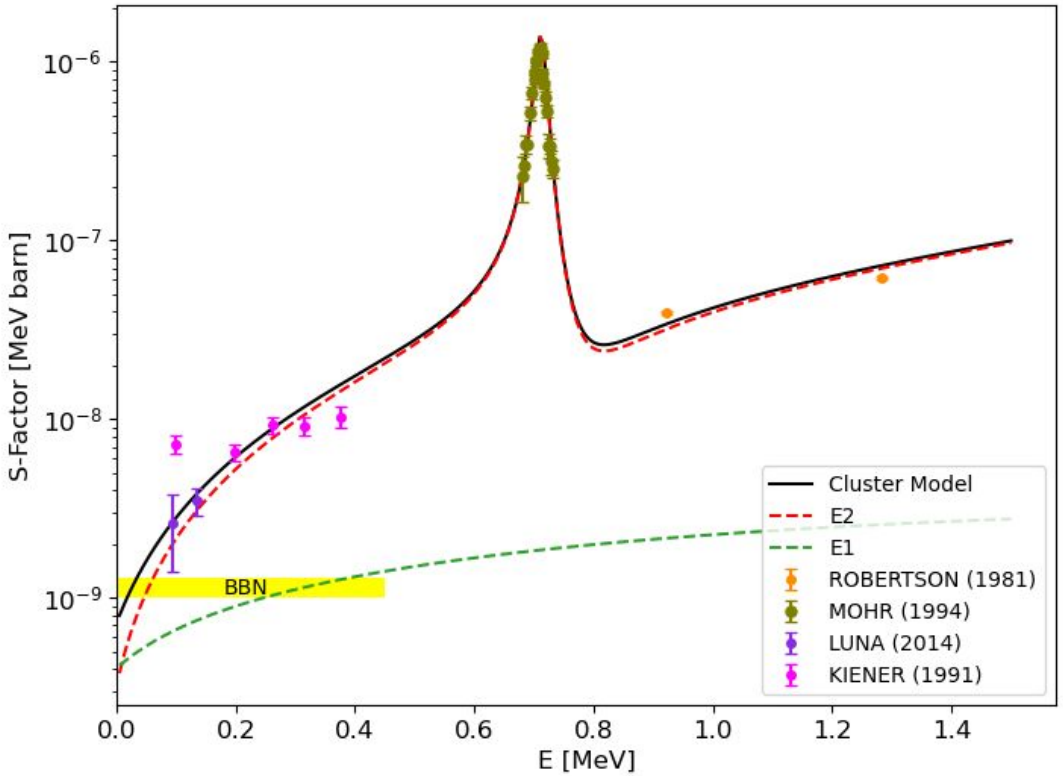


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# $^{6}$Li breakup on $^{208}$Pb: Indirect method for nuclear astrophysics

**Coulomb dissociation for astrophysics:** proposed by Baur, Bertulani and Rebel.

Baur *et al*., NPA, **458**, 188-204 (1986).
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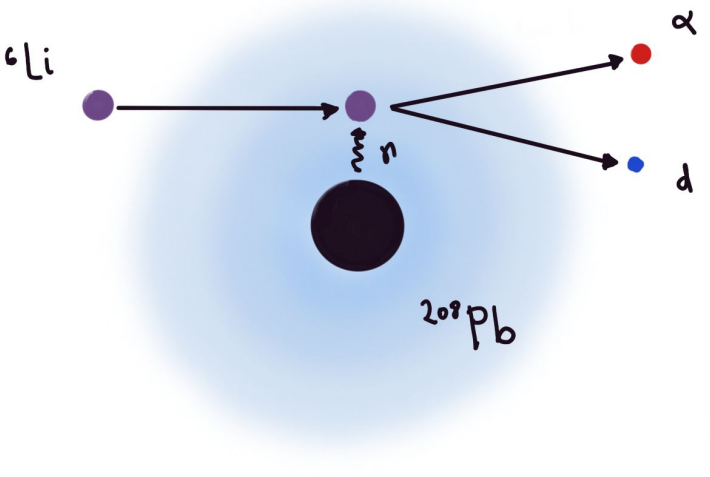

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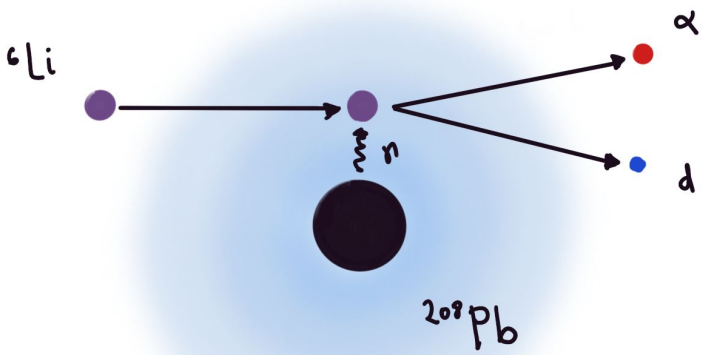
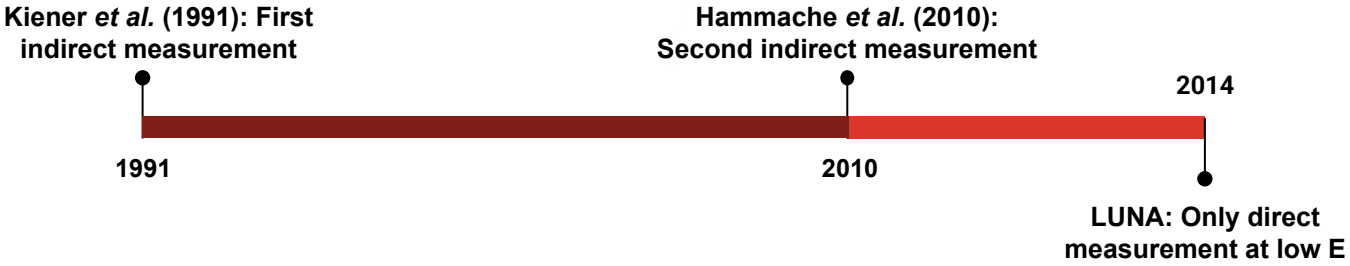
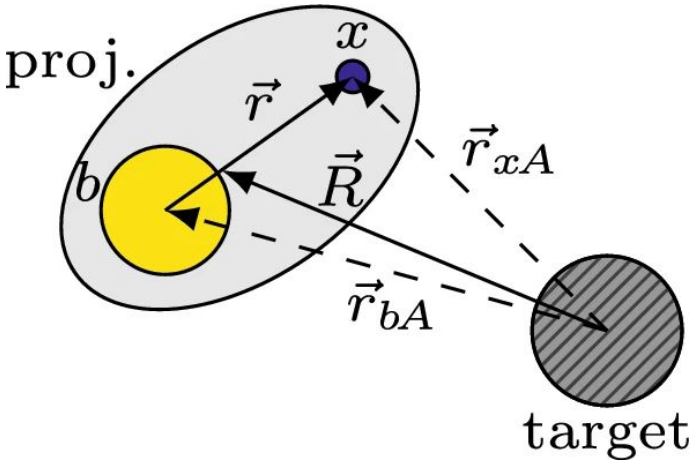


# $^{6}$Li breakup on $^{208}$Pb: The breakup reaction model

$^{6}\text{Li} + {}^{208}\text{Pb} \rightarrow \text{d} + \alpha + {}^{208}\text{Pb}$




From Moro *et al,* EPJA, **61**, 47 (2025).

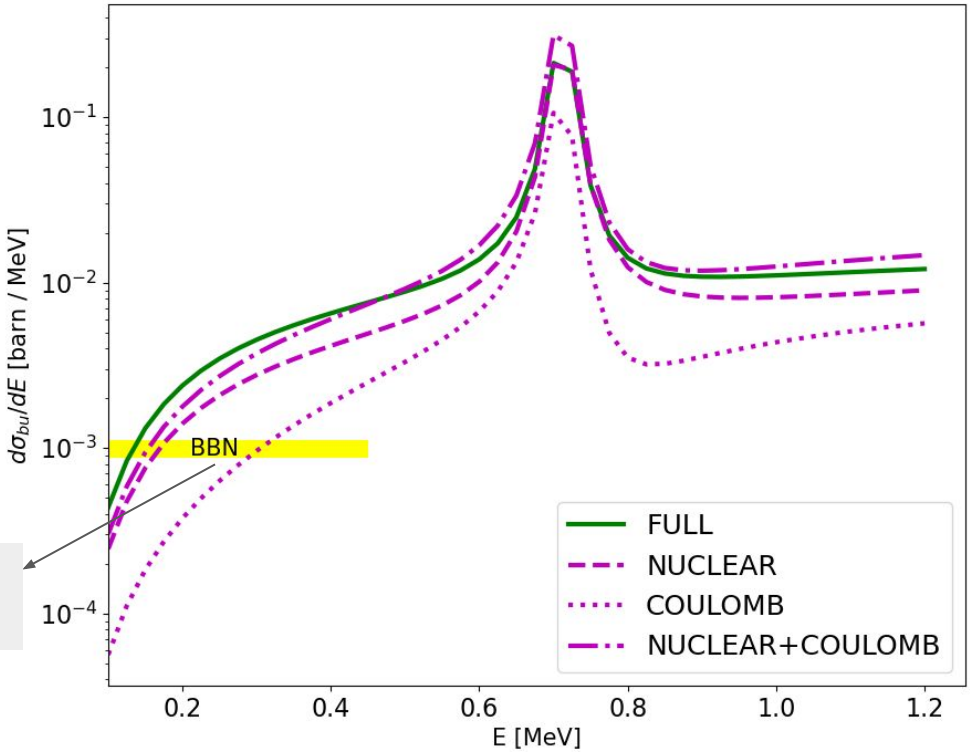
$$H = H_{\text{proj}} + T_{\vec{R}} + U_{bA}(\vec{r}_{bA}) + U_{xA}(\vec{r}_{xA})$$

**Dynamical Eikonal Approximation (DEA)**: fully-dynamical, quantum mechanical framework.

Baye *et al,* PRL, **95**, 082502 (2005).

# $^{6}$Li breakup on $^{208}$Pb: 150 A MeV with DEA model

Hammache *et al.*, PRC, **82**, 065803 (2010).




Nuclear-dominated breakup.

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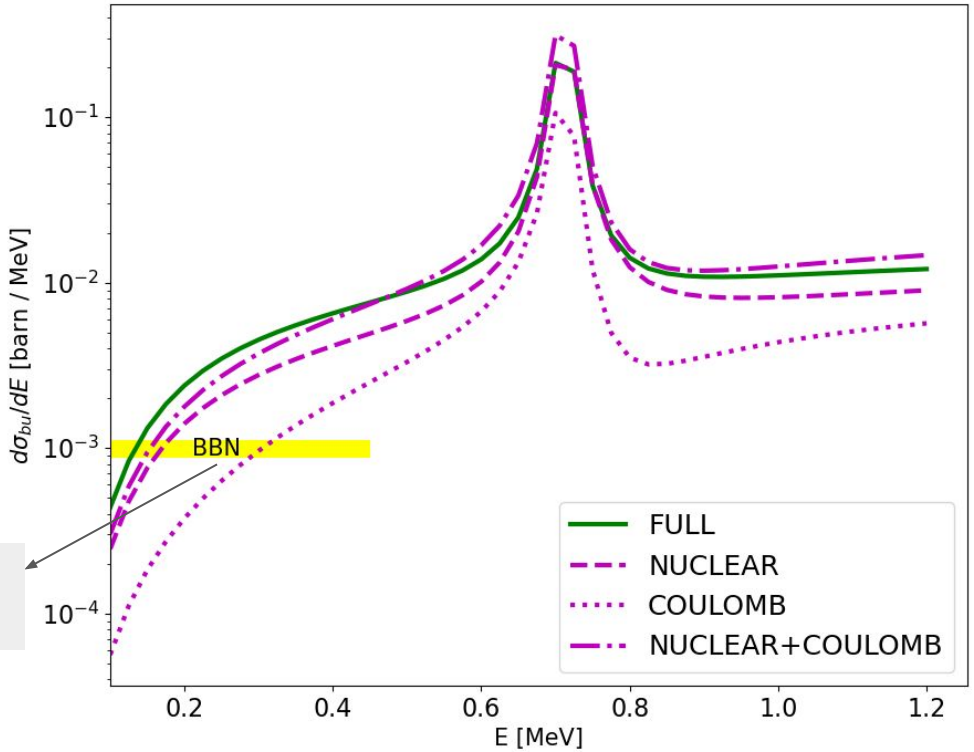
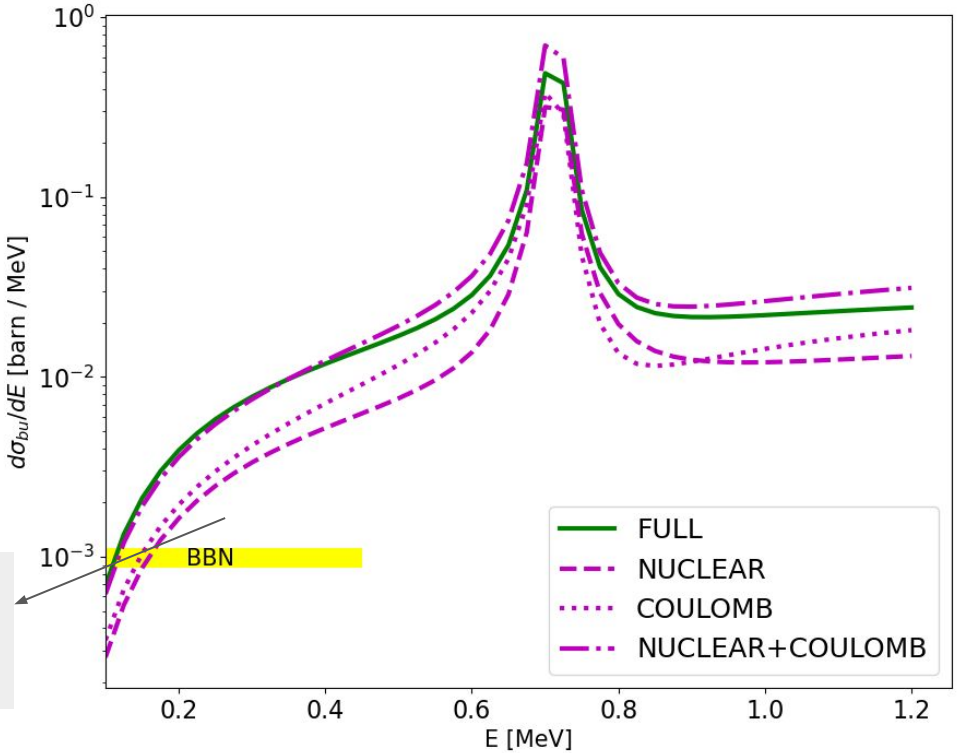



Nuclear-dominated breakup.

Nuclear-Coulomb interferences at all energies.

# $^{6}$Li breakup on $^{208}$Pb: 26 A MeV with DEA model

Kiener *et al.*, PRC, **44**, 1543 (1991).

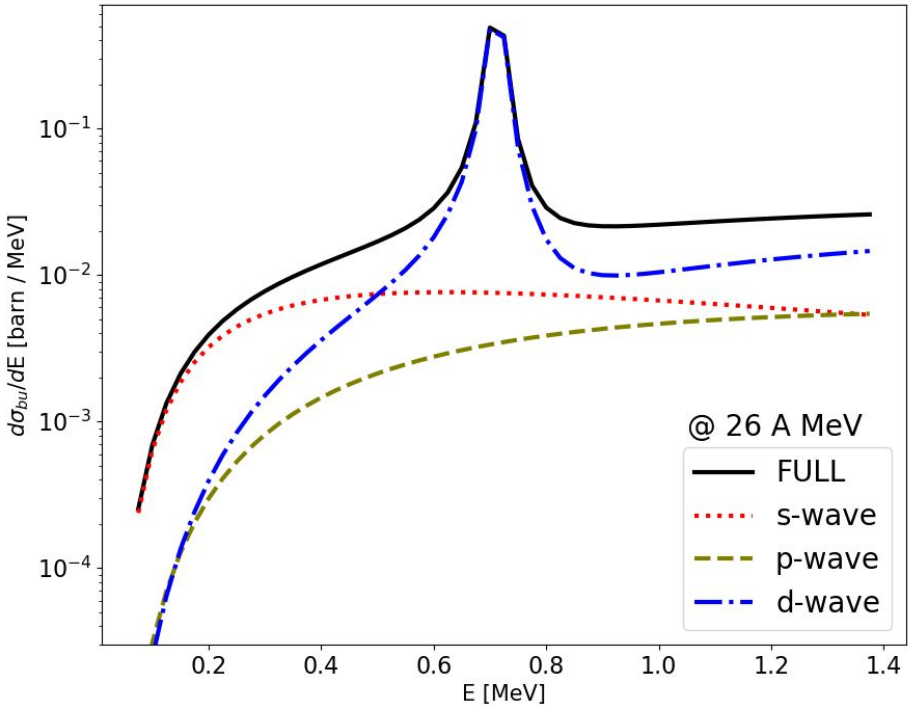



Comparable Coulomb and Nuclear contributions.

Nuclear-Coulomb interferences at all energies.

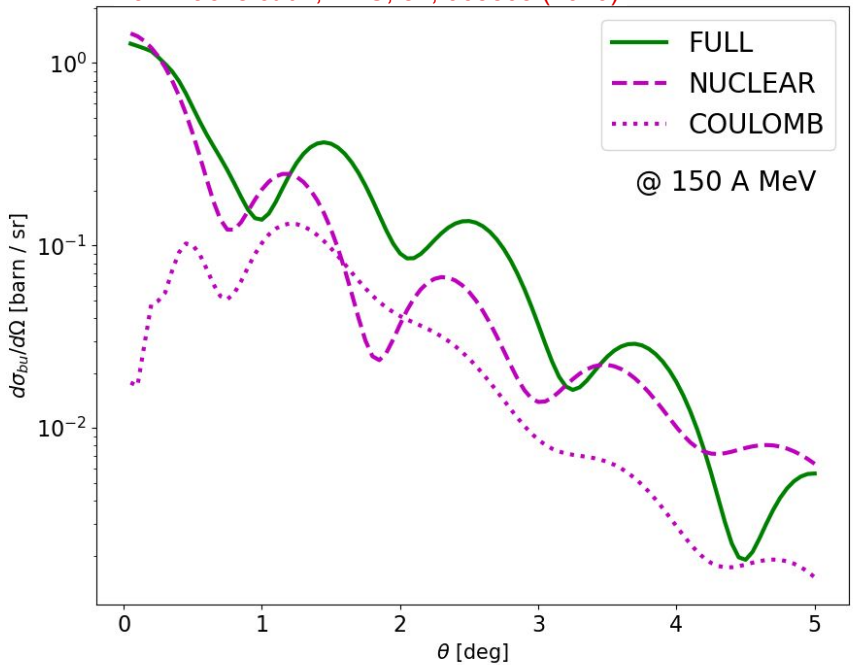
# $^{6}$Li breakup on $^{208}$Pb: Partial-wave decomposition

- It is essential to assess the contribution of different partial waves to the breakup process.
- An s-wave contribution dominates the BBN energy range of interest; it arises from both Coulomb and nuclear processes.
- The same s-wave dominance holds for the breakup reaction at 150 A MeV.



# $^{6}$Li breakup on $^{208}$Pb: Angular Distribution

Hammache *et al.*, PRC, **82**, 065803 (2010).

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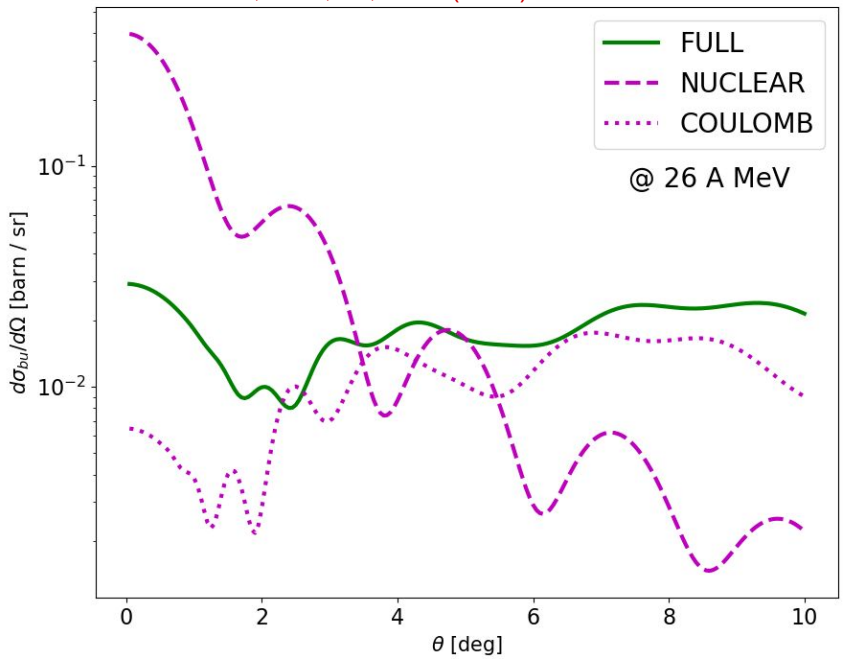
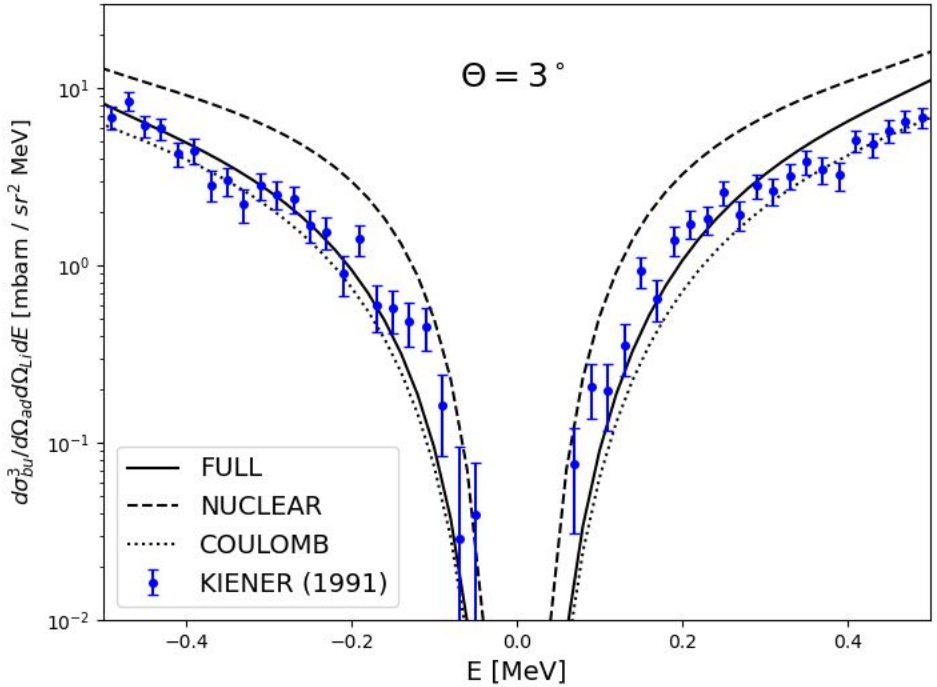


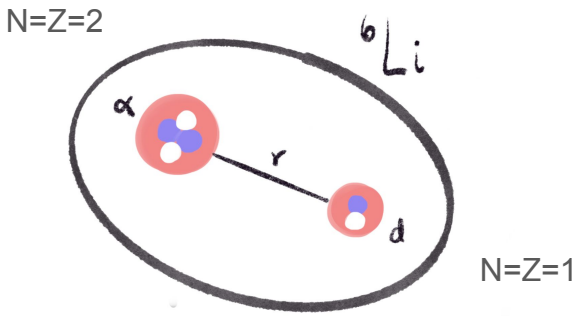
# $^{6}$Li breakup on $^{208}$Pb: Comparison with Kiener *et al.* (1991)

- Kiener et al. (1991) measured the triple differential breakup cross section at forward angles $\theta < 6^{o}$ .
- Our calculations confirm that the measurements at $\theta = 3^{o}$ are consistent with breakup including nuclear contributions.
- The S-factor, inferred from the data at $\theta = 3°$, is enhanced by additional nuclear breakup and s-wave contributions.



# $^{6}$Li breakup on $^{208}$Pb: Coulomb breakup suppression

Imprint of the nuclear structure into the reaction dynamics




- The Coulomb field of the heavy target accelerates both N=Z clusters equally.
  → No tidal force to induce the dissociation.

- Broader implications for the application of this indirect method for reactions with N=Z nuclei.
  ie. $^{12}C(\alpha,\gamma)^{16}O$

# Conclusions and Outlook

- We performed a theoretical analysis of the breakup of $^{6}$Li onto a heavy target with astrophysical motivation.
- Our results show that Coulomb breakup of $^{6}$Li is heavily influenced by the nuclear interaction with the target.
- Insights into the discrepancy between direct and indirect measurements at low energy:
  - Kiener *et al.* (1991) measurements included nuclear breakup contributions.
  - s-wave contributions enhance the cross section at BBN energies.
- Advancing alternative indirect methods for nuclear astrophysics is important:
  - Electron-induced dissociation: @MESA, the new electron accelerator at JGU.

Thank you