

*Nuclear Reaction Studies around the
Coulomb Barrier Energies at SINP*

Subinit Roy

Nuclear Physics Division

Saha Institute of Nuclear Physics

Major areas of research activity.....

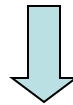
- ➔ Probing the fusion and scattering of $6,7\text{Li}$ isotopes on different target masses
 - * to understand the effect of breakup or breakup-like reactions on the process of fusion of these weakly bound nuclei,
 - * to investigate the breakup modified effective interaction controlling the collision,
 - * to understand the influence of breakup with decreasing Coulomb field of the target.

- ➔ Low energy transfer reaction studies to obtain the astrophysical S-factor for capture reaction in an indirect method
 - *estimation of ANC from the peripheral part of the reaction.

- ➔ Investigation of cluster states and its application to astrophysical problems.

Weakly bound stable nuclei are characterized by ...

*Features : dominant cluster structure,
ground state close to particle emission threshold*



Coupling to bound and continuum states to affect the dynamics

Breakup of weakly bound nuclei

*Induces new mode:
ICF*

Inhibits CF

*Induces new type of
threshold behavior for
interaction potential*

.... observed distinctly for collision with heavy targets.

1. Fusion and total alpha yield measurement for $6,7\text{Li}+159\text{Tb}$ around the barrier.

A. Mukherjee, M. Pradhan, et al.

- *Measurement carried out at **TIFR-BARC 14UD Pelletron Facility***
- *Fusion cross sections determined using the **Characteristic γ -ray detection** method*
- ***Total α -yield** and **elastic** measured in a separate experiment in the General Purpose Scattering Chamber*

Fusion of $6,7\text{Li}$ with deformed 159Tb primarily decay through neutron channels with negligibly small compound nuclear α decay



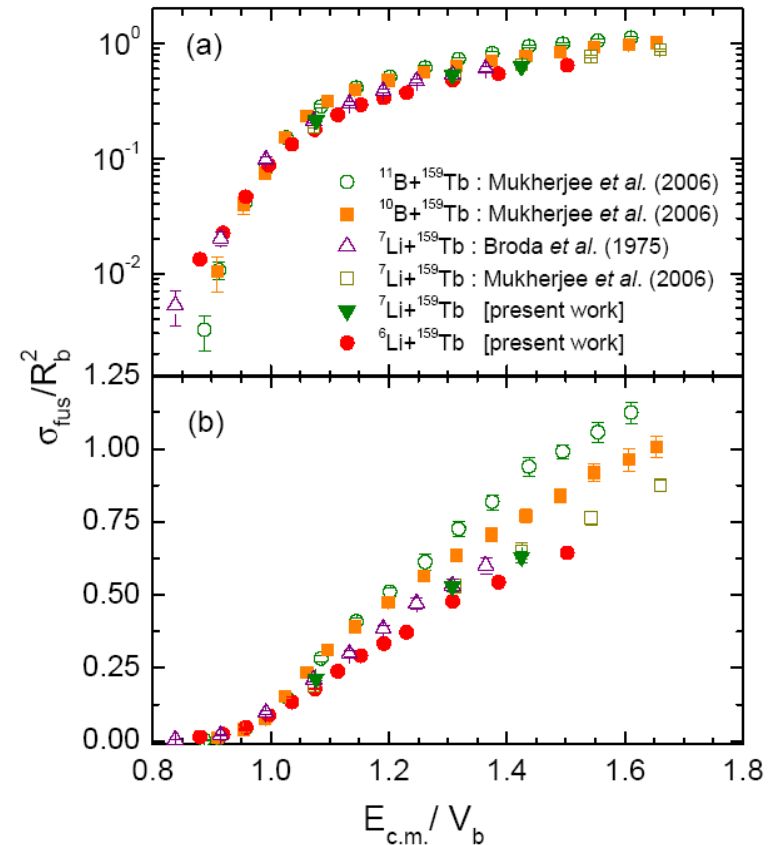
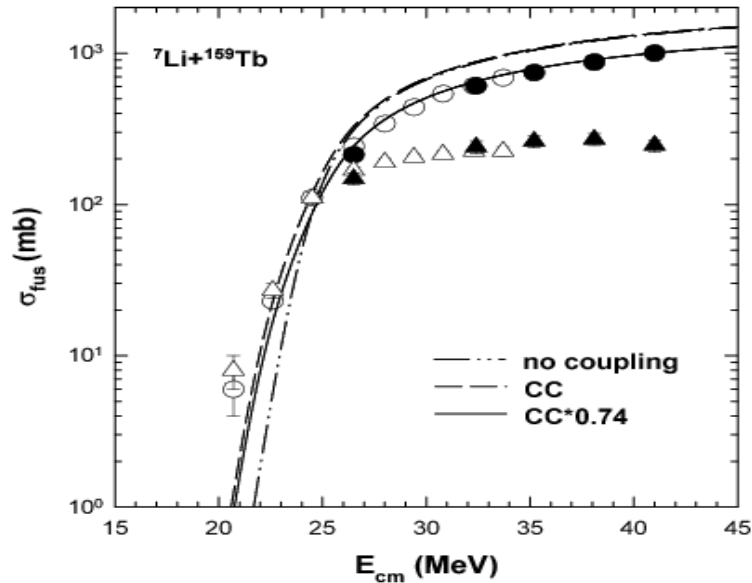
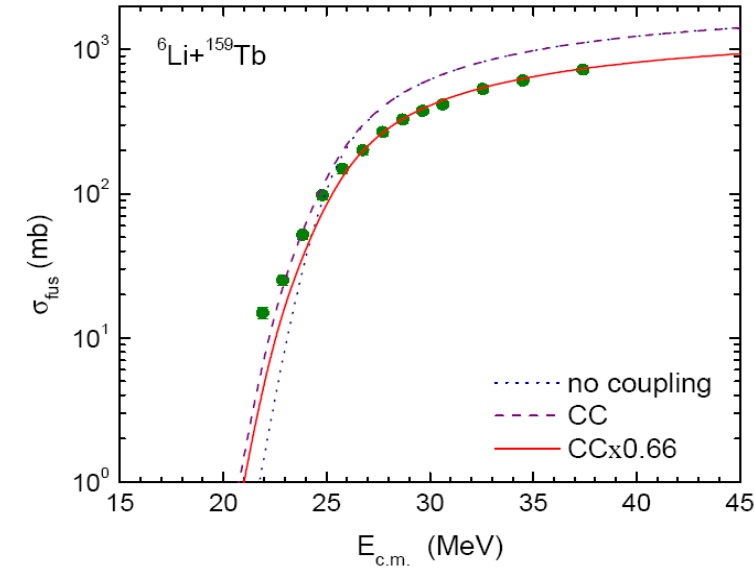
detection of dominant α -ICF possible

Suppression of CF:

6Li (1.47 MeV) – 34%

7Li (2.45 MeV) – 26 %

Magnitude and onset of suppression function of breakup threshold

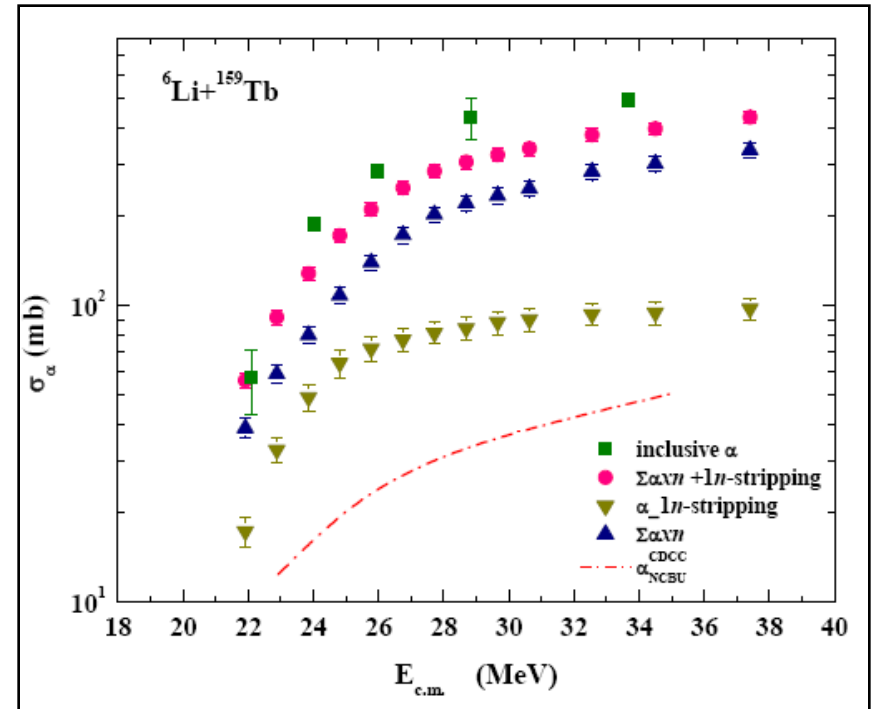
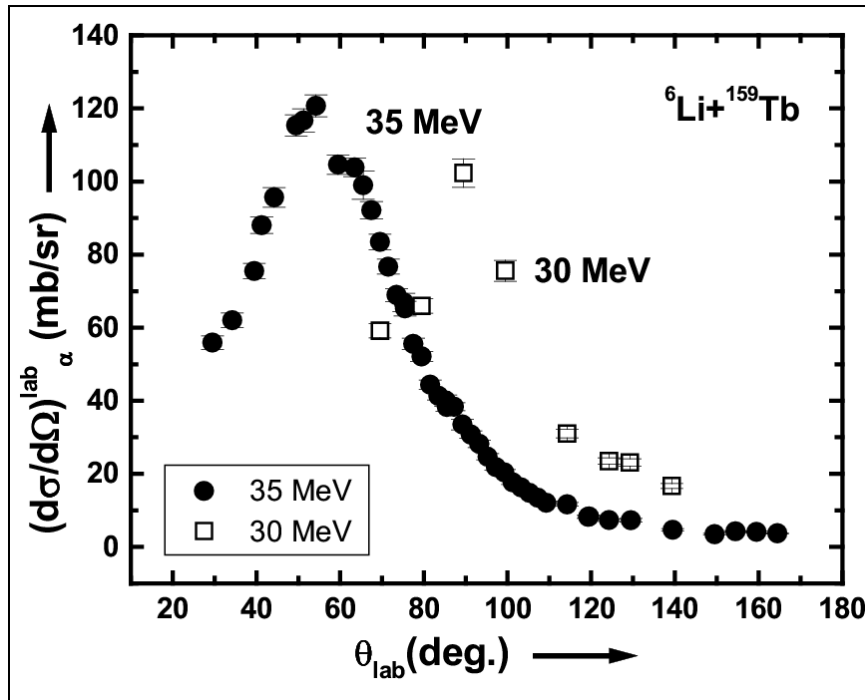


M.K. Pradhan *et al.*, PRC 83, 064606 (2011)

Inclusive α -angular distribution \longrightarrow Increasing forward angle peaking with increasing incident energy

Dominating direct reaction contribution but BU seems to be insufficient

1n-stripping producing $5\text{Li} \rightarrow \alpha + p$, found to be a major contributor



A. Mukherjee and M.K. Pradhan, *Pramana* 75, 99 (2010)
(Conf. Proc.)

*How the coupling to the continuum evolves around the barrier
with decreasing target mass and energy?*

For lower mass targets



*Reduced influence of Coulomb
field at near barrier energies*

Experimental difficulty



ICF contribution small +
ICF and CF can not be separated

Measurement provides Total Fusion (TF): $\sigma_{TF} = \sigma_{CF} + \sigma_{ICF}$

Does BU affect the σ_{TF} ?

2. Fusion and elastic scattering measurements for $6,7\text{Li}+28\text{Si}$ around the barrier.

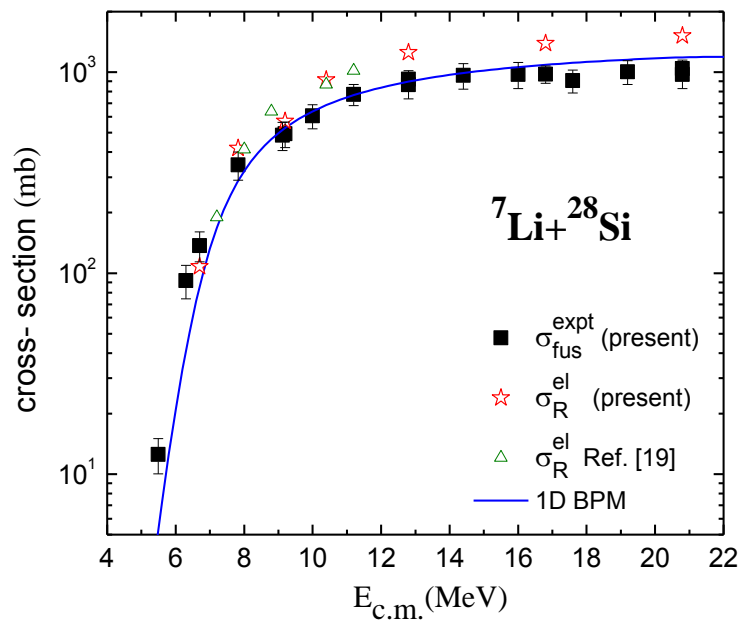
H.Majumdar, P.Basu, M.Sinha, et al.

- *Measurements carried out at **TIFR-BARC Pelletron Facility** for above barrier energies, and at **3 MV IOP Pelletron Facility** for sub-barrier energies*
- *Fusion cross sections measured using the **Characteristic γ - ray detection** method*
- *Elastic scattering and singles α angular distributions measured at **IUAC 15UD Pelletron Facility***

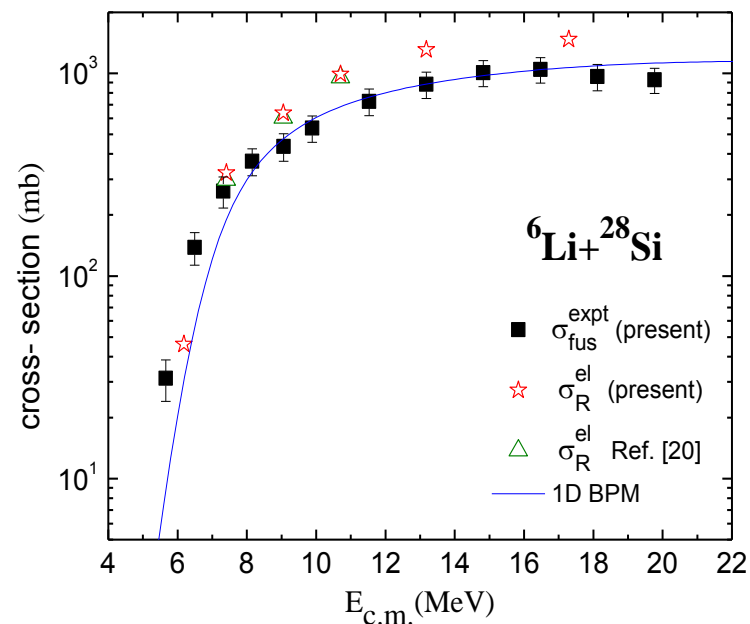
Fusion cross sections determined using both Characteristic γ -ray detection and decay α detection techniques.

- σ_{TF} for $V_B \leq E \leq 2V_B$ matched well with 1DBPM predictions
- σ_{TF} for $E \geq 2V_B$ data shows declining trend for both 6,7Li
- σ_{TF} for $E \leq V_B$ data shows enhancement for both 6,7Li

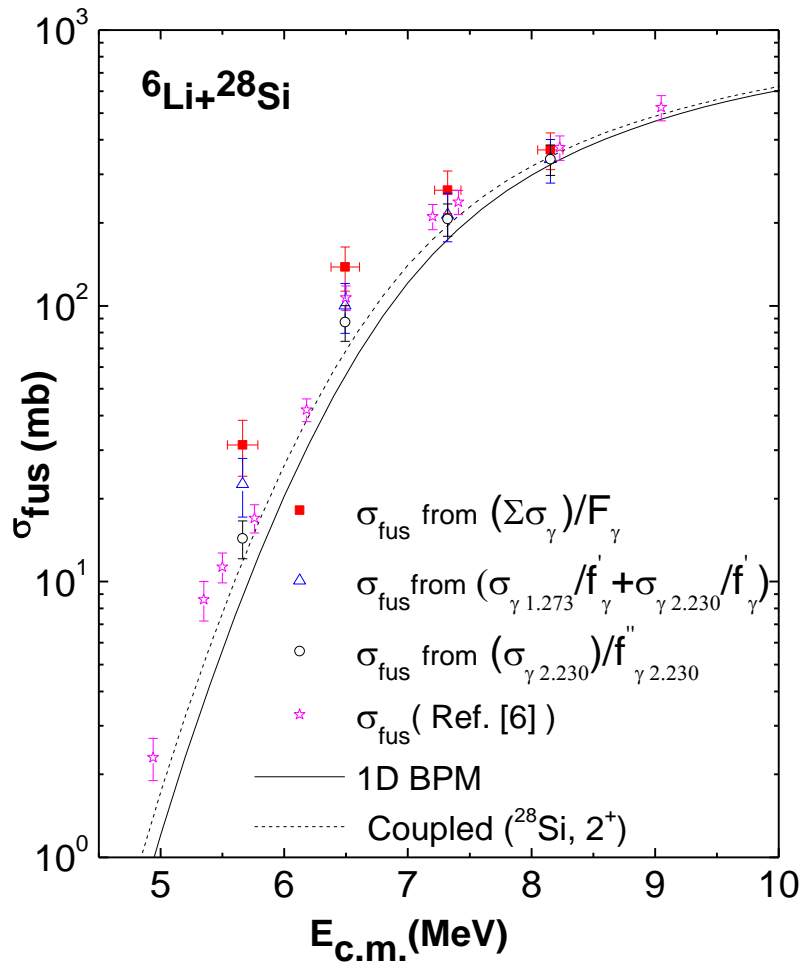
Nucl. Phys. A 805 (2008) 425



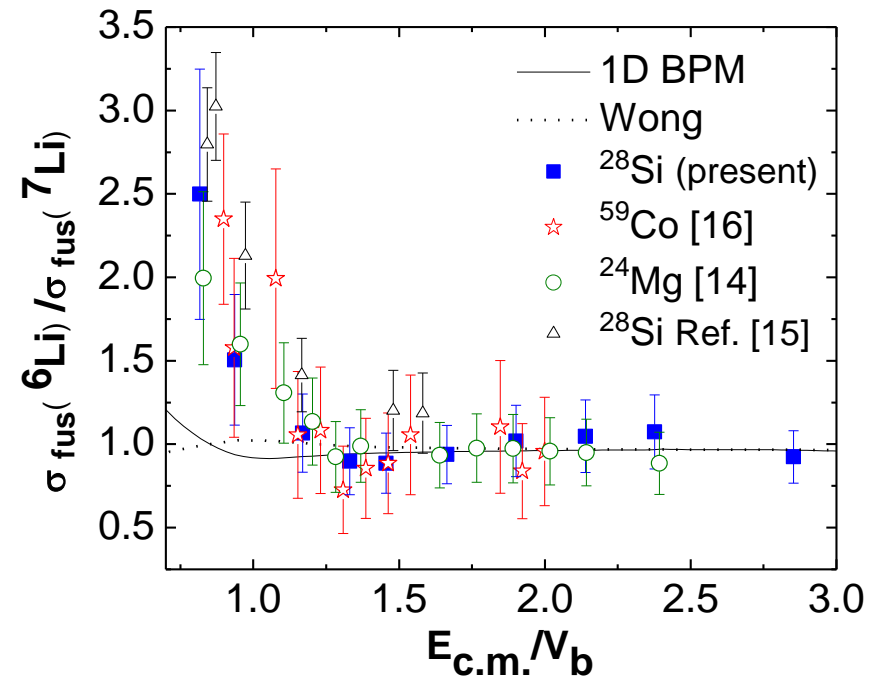
Eur. Phys. J. A 44, 403 (2010)



Collective excitation of ^{28}Si not enough!



Comparison of enhancements shows
 ^{6}Li enhancement > ^{7}Li enhancement



[16] C. Beck et al., Phys. Rev. C 67, 054602 (2003).

[14] M. Ray et al., PR C 78, 064617 (2008).

[15] A. Pakou et al., Eur. Phys. J. A 39, 187 (2009)

3. Threshold behaviour of interaction potential for $6\text{Li} + 58,64\text{Ni}$

S. Roy, M.Biswas, et al.

Energy variation of interaction potential around the barrier

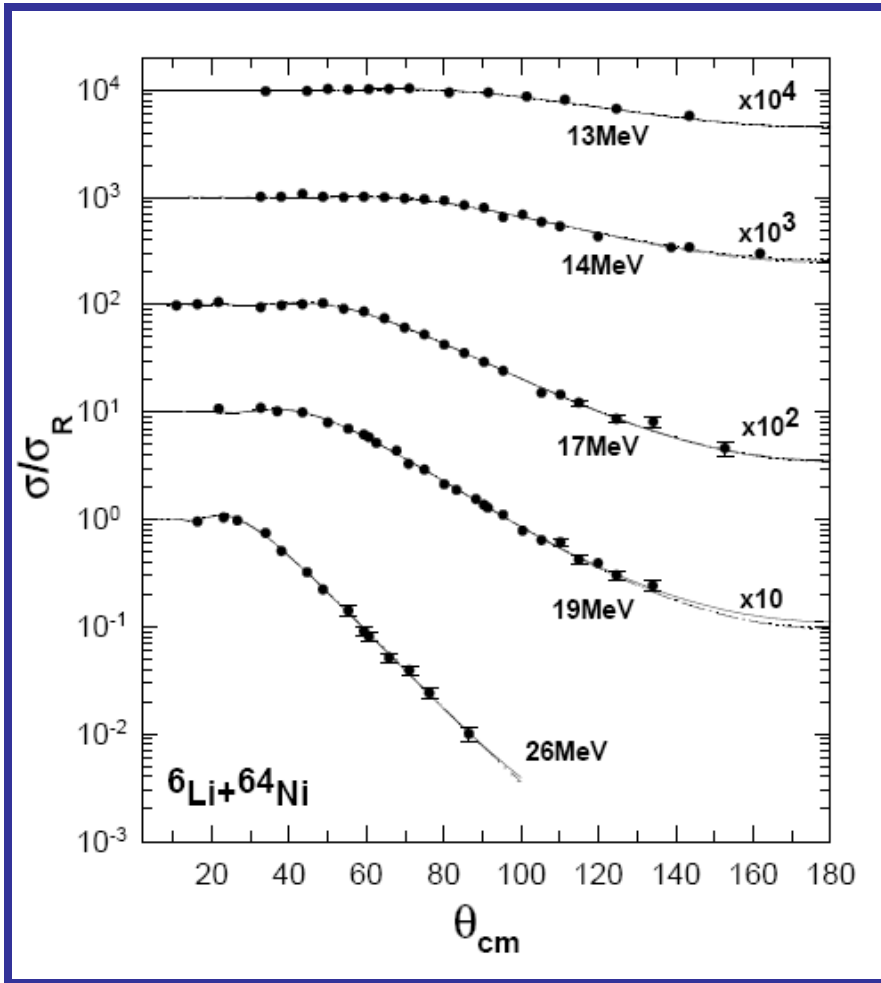
→ Complimentary probe for the effect of b.u. of projectile

Does the interaction potential show normal Threshold Anomaly (TA) or the new Breakup modified Threshold Anomaly (BTA)?

Measured elastic angular distributions for $6\text{Li}+64\text{Ni}$ system at TIFR-BARC Pelletron Facility for several incident energies around the barrier.

Extracted energy dependence of potential for $6\text{Li}+64\text{Ni}$ compared with the same for $6\text{Li}+58\text{Ni}$ elastic data

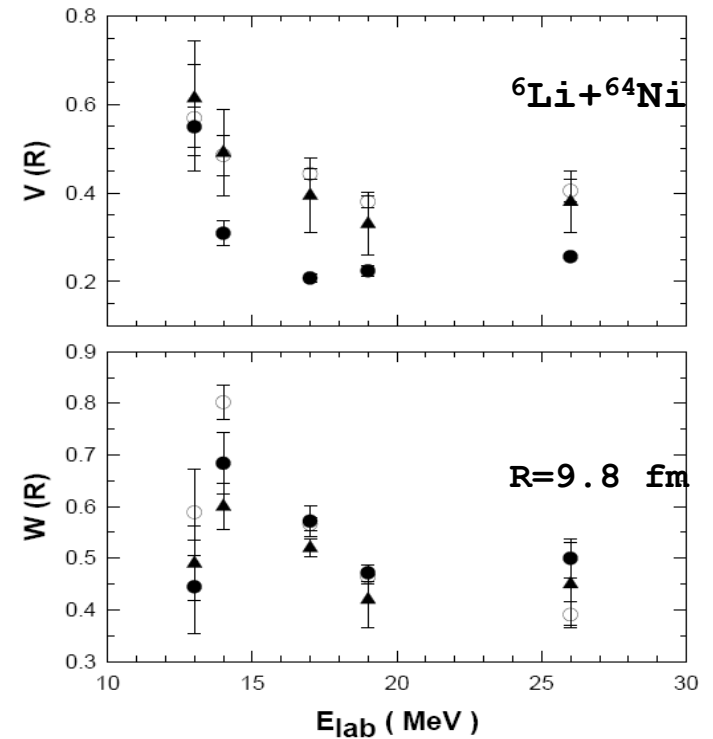
Near Threshold behaviour of interaction potential



Nucl. Phys. A802 (2008) 67

Measured angular distributions fitted with three model potentials

Solid bullet – Phen, Open bullet – folded
 Solid triangle – hybrid

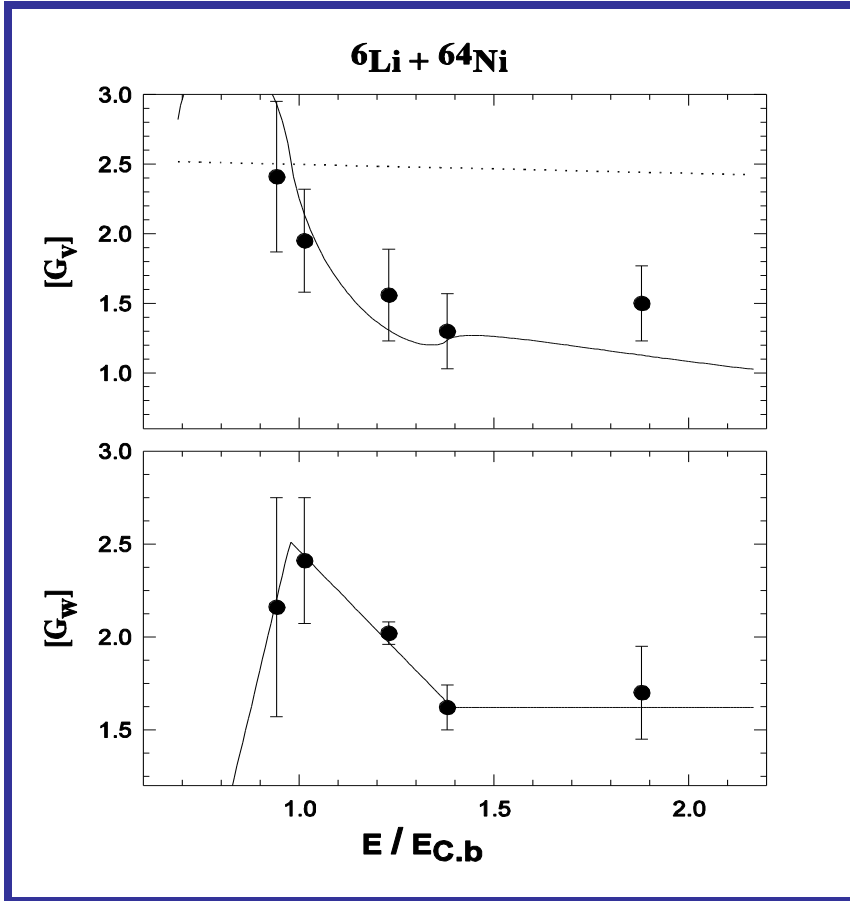


Barrier V_B is no more the threshold

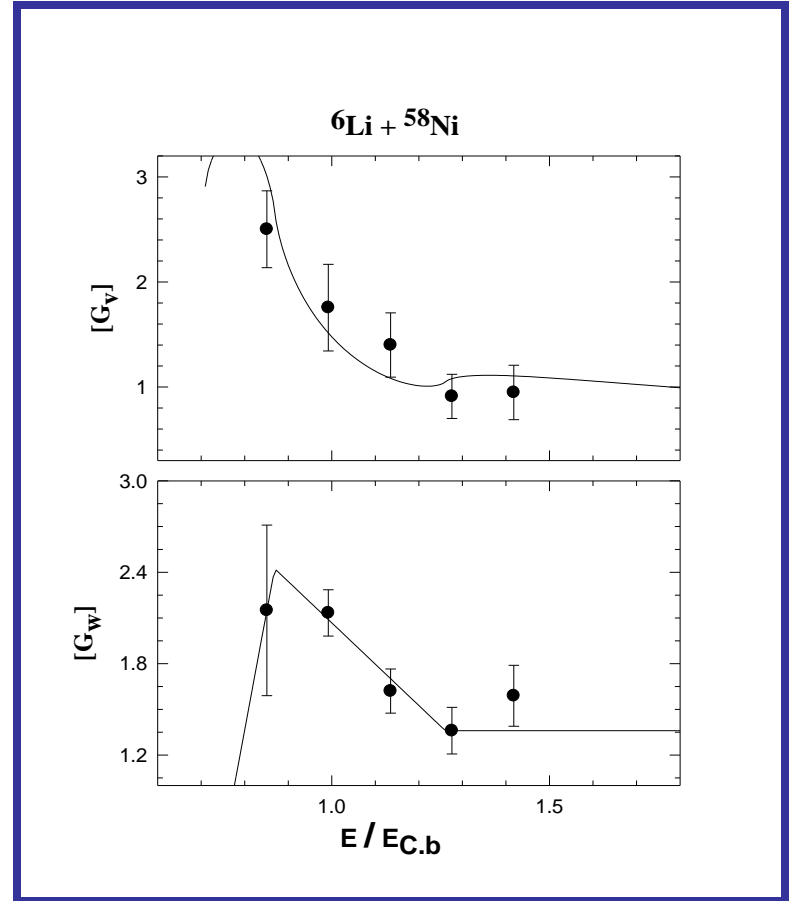


Evidence of BTA.

Connectivity through dispersion relation ..



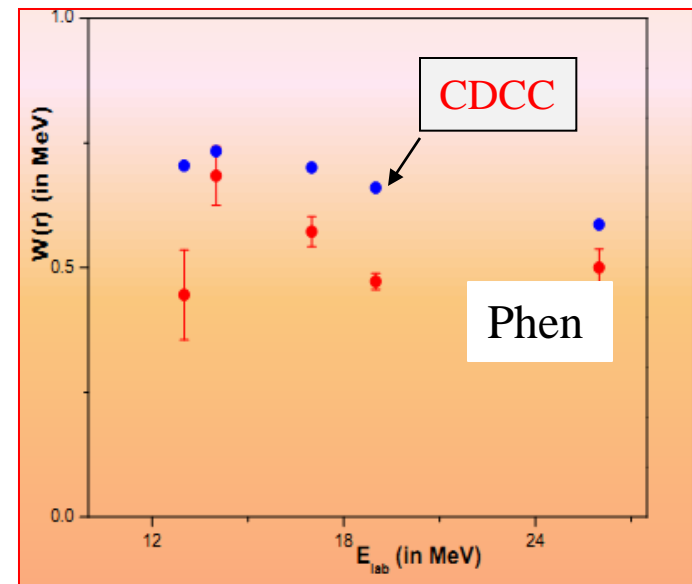
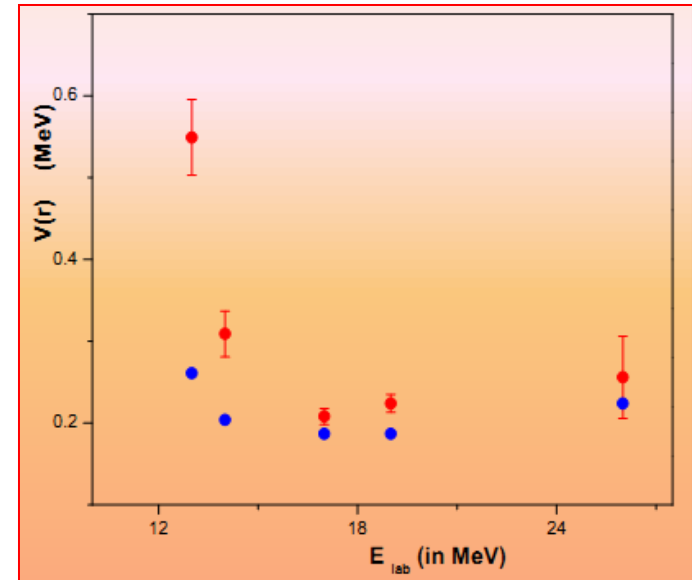
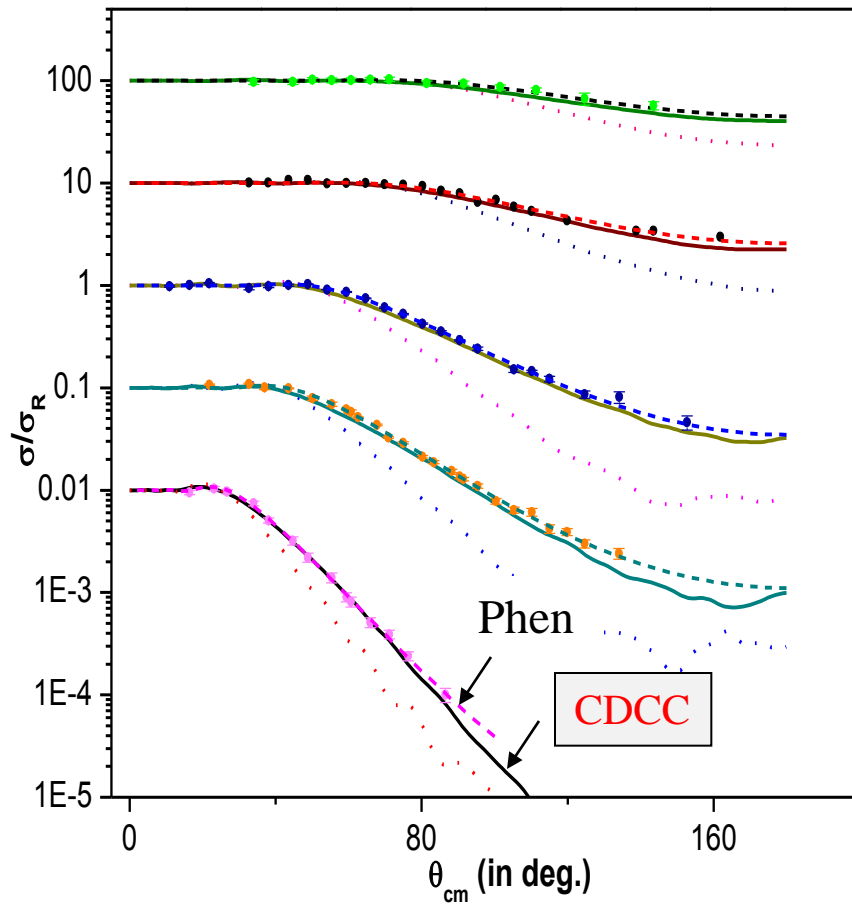
Nucl. Phys. A802 (2008) 67



The prediction of b.u. coupling.....

Coupling to b.u. continuum results ..

CDCC calculation (solid line)

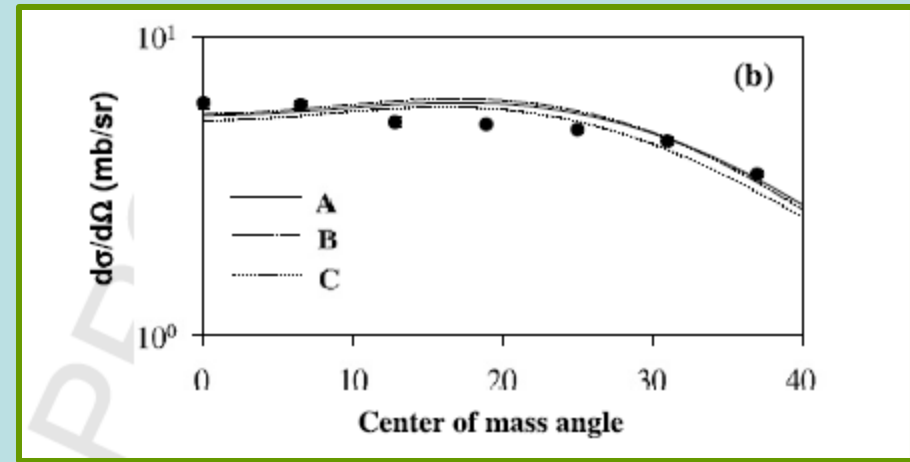


4. Alpha transfer reaction $^{12}\text{C}(^6\text{Li},d)^{16}\text{O}^*$ at 9 MeV

- Estimation of Asymptotic Normalization Constant (ANC)

C. Basu and S. Adhikari

- Reanalyzed the alpha transfer reaction $^{12}\text{C}(^6\text{Li},d)^{16}\text{O}^*$ at 9 MeV
- Systematic Finite Range DWBA calc. performed. ANC-s for 6.92 MeV (2^+) and 7.12 MeV (1^-) sub-threshold states extracted.
- Potential dependence of extraction of Spec. Factor/ ANC found to be minimum near grazing angle.
- Even at 9 MeV, nuclear potential contribution can not be neglected. Sub-Coulomb transfer study needed.



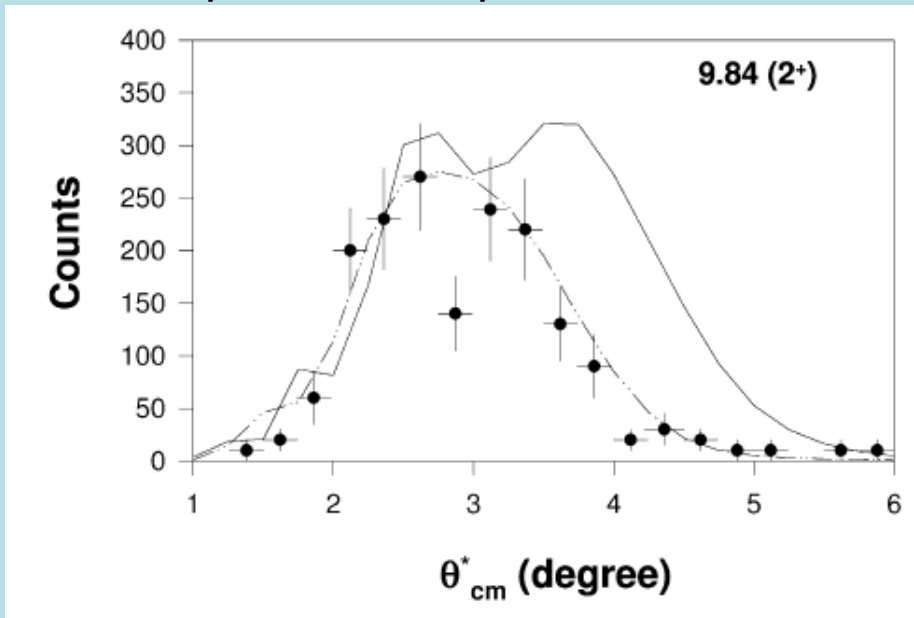
Sucheta Adhikari and Chinmay Basu, Phys. Lett. B 704, Issue 4 (2011) 308

5. Spectroscopic properties of alpha cluster states of ^{16}O

- Applications in Nuclear Astrophysics

C. Basu and S. Adhikari

Alpha breakup of $^{16}\text{O} \rightarrow \alpha + ^{12}\text{C}$



α Spectroscopic Factor/
Asymptotic Normalization
Constant (ANC) determined
from CDCC analysis
of breakup data from the 9.84
MeV (2⁺) resonance state.

Sucheta Adhikari and Chinmay Basu, Physics Letters B 682, Issue 2 (2009) 216

6. Resonant particle spectroscopy

C. Basu and S. Adhikari

$^{12}\text{C}(^{18}\text{O}, ^{14}\text{Ca})^{12}\text{C}$

$E(^{18}\text{O}) = 94.5 \text{ MeV}$

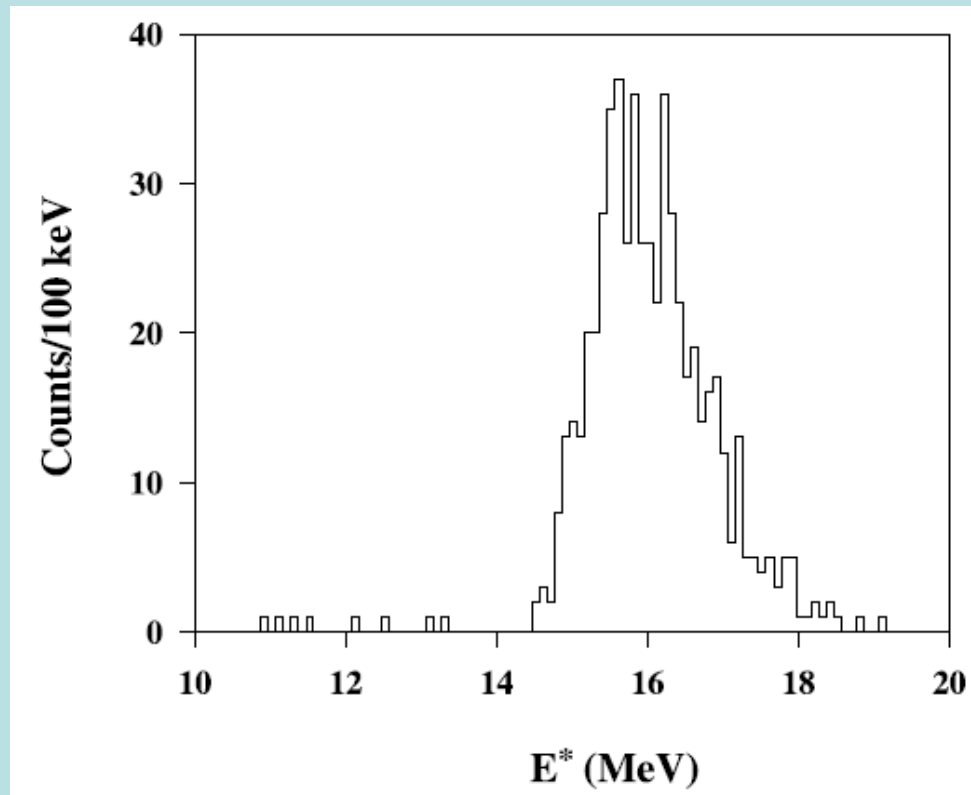
(TIFR-BARC) Pelletron

Conclusions:

Alpha cluster states of ^{18}O in higher energy region $E_\alpha > 14 \text{ MeV}$ observed.

A 5^- spin for 15.8 MeV state assigned instead of 1^- .

Measured alpha-cluster spectrum of ^{18}O



S. Adhikari, C. Basu et al., Int. Jour. Mod. Phys. E 18 No.9 (2009) 1917

THANK YOU.