TRIUMF

Canada's national laboratory for particle and nuclear physics

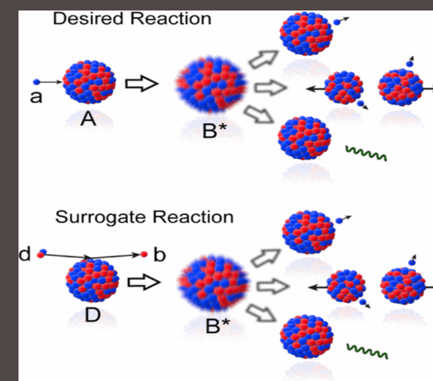
Laboratoire national canadien pour la recherche en physique nucléaire et en physique des particules

Ab initio many-body calculations of single nucleon transfer reactions
(Application to ^{7}Li(*d*,p)^{8}Li reaction)

INT Workshop
March 3, 2015
Seattle, US

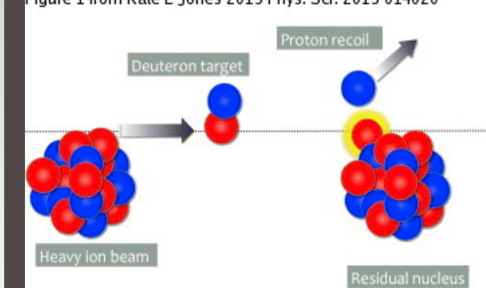
Reactions and structure of exotic nuclei
March 2 – March 13, 2015

Francesco Raimondi, TRIUMF



In collaboration with:
G. Hupin, P. Navrátil, S. Quaglioni

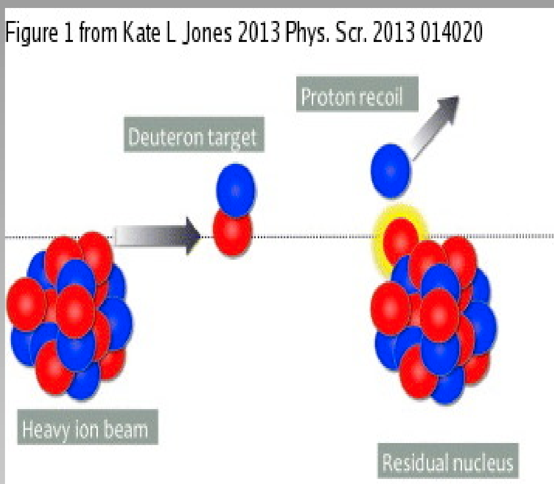
Figure 1 from Kate L Jones 2013 Phys. Scr. 2013 014020



Outline

- Motivations for *ab initio* study of transfer reactions
- Interest of ^{7}Li(d,p)^{8}Li reaction
- Results on the first resonance of ^{9}Be above d-^{7}Li threshold
- Recent progress on inclusion of 3N forces in transfer reaction (s-shell nuclei)
  (on behalf of: G. Hupin, P. Navrátil, S. Quaglioni)
- Conclusions

Deuteron-nucleus reaction: experimental motivations



(d,p) reaction in inverse kinematics

Intense experimental activity (now with exotic nuclei beams in RIB facilities):

- Structure and spectroscopy of nuclei (^{11}Be(d,p)^{12}Be at ISAC - TRIUMF)
- Nucleosynthesis and nuclear fusion applications (^{3}H(d,n)^{4}He reaction)
- Surrogate for (p/n) capture reactions (^{14}C(d,p)^{15}C as surrogate of ^{14}C(n, γ)^{15}C)

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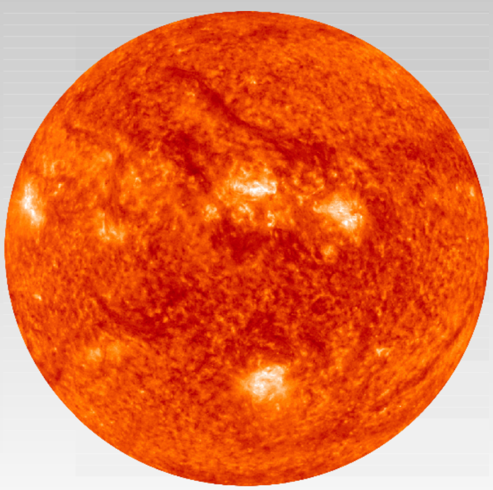
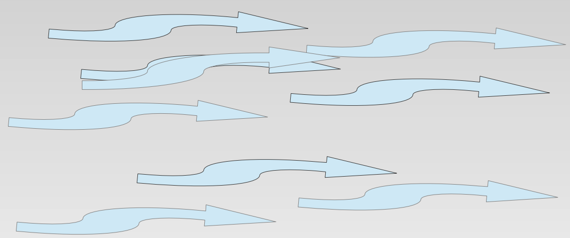
^{7}Li(*d*,p)^{8}Li transfer reaction

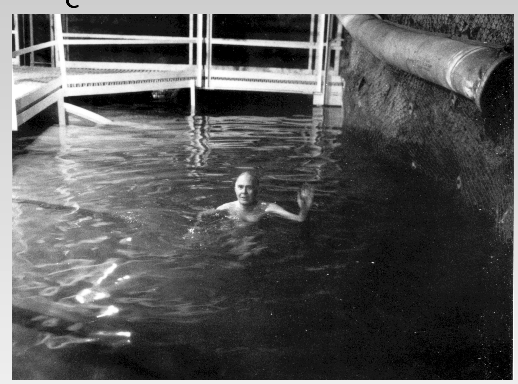
- Calibration reaction for astrophysical process: ^{7}Li(*d*,p)^{8}Li as target calibration for ^{7}Be(p,γ)^{8}B

Solar neutrino problem:





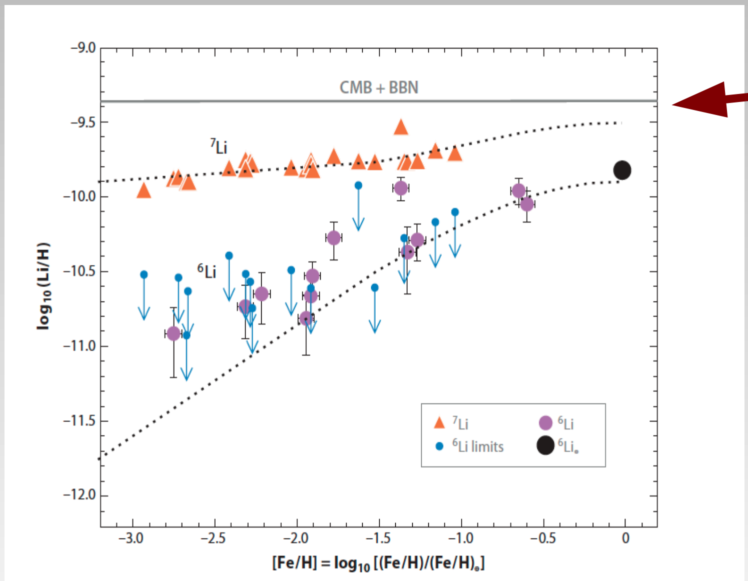
$\nu_e + {}^{37}Cl \rightarrow {}^{37}Ar + e^-$



R. Davis Jr takes a dip
At Homestake Mine (1971)

$^{7}Li(d,p)^{8}Li$ transfer reaction

- Calibration reaction for astrophysical process: $^{7}Li(d,p)^{8}Li$ as target calibration for $^{7}Be(p,\gamma)^{8}B$
- Possible mechanism of destruction of ^{7}Li in the context of baryon-inhomogeneus models of the primordial nucleosynthesis

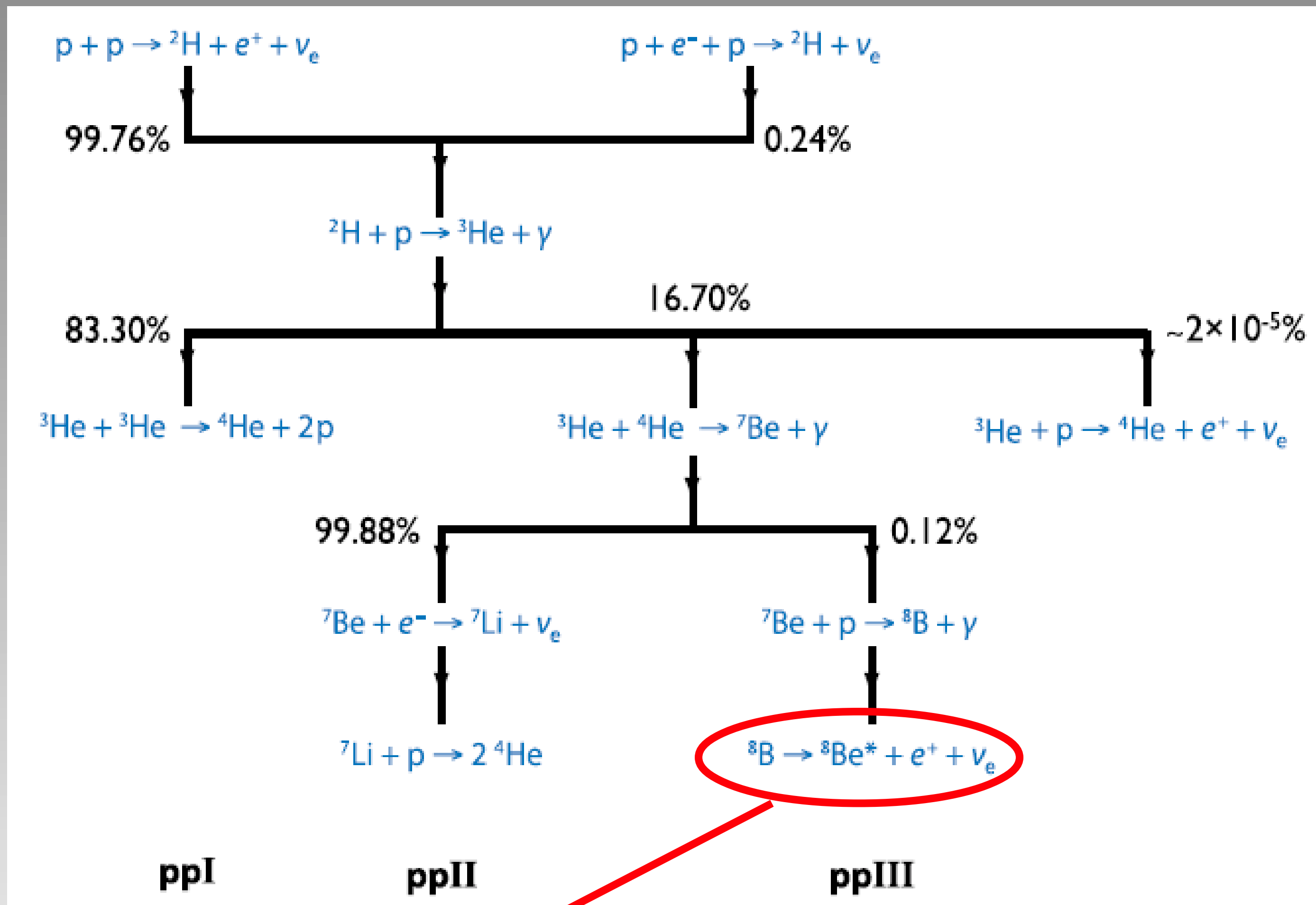


Primordial Lithium problem:

- 4-5σ discrepancy between observed and calculated (CMB+BBN) abundance of ^{7}Li
- Nuclear solution to the problem: d-^{7}Li destruction mechanism is ruled out (but only in a standard BBN scenario PRC 47, 2369 1993)

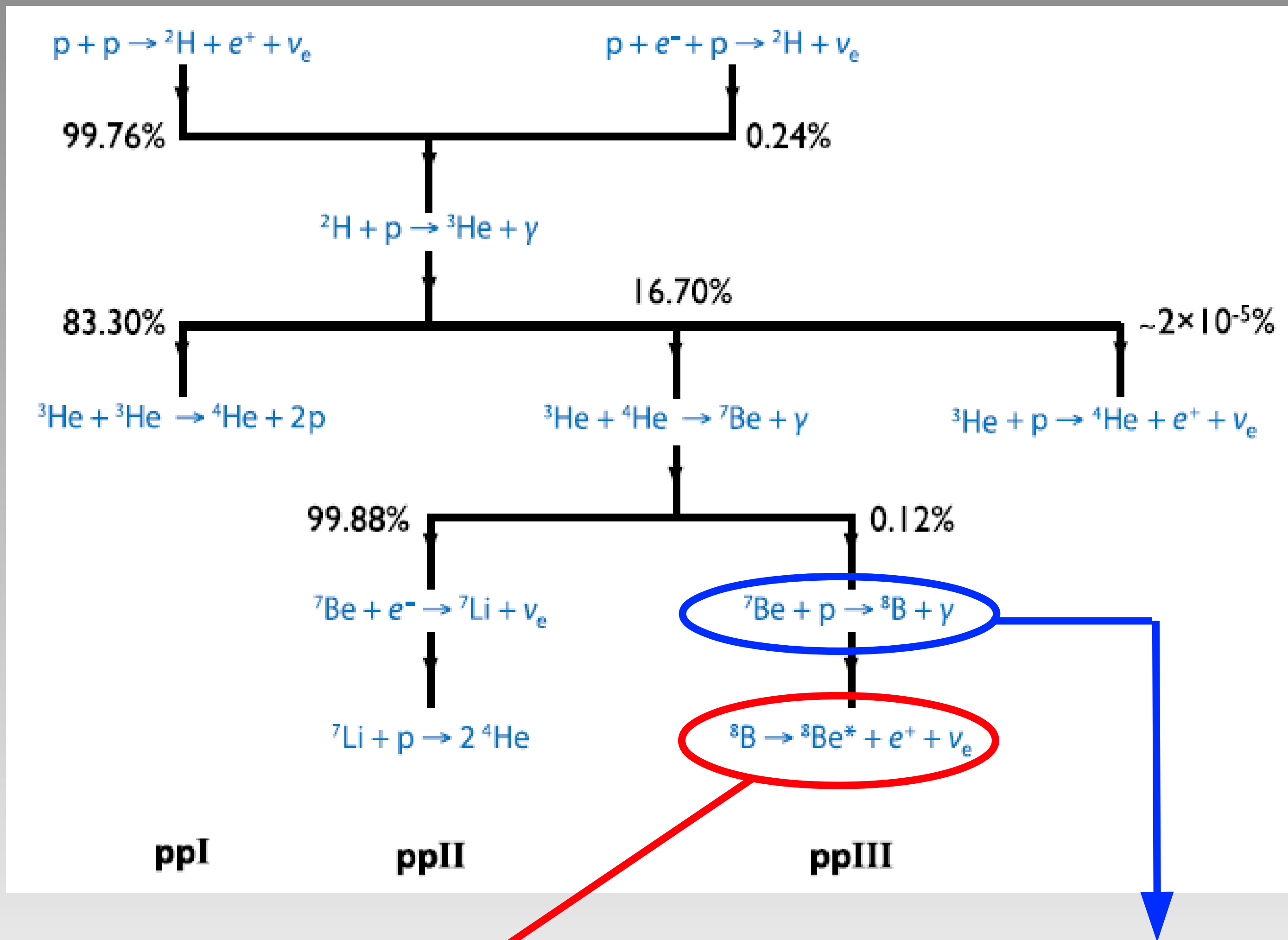
Annu Rev. Nucl. Part. Sci. 2011 61:47-68

Solar p-p chain



High-energy solar neutrinos
(E_ν up to 15 MeV)

Solar p-p chain



$S_{17}(0)$ crucial input to estimate solar neutrino flux

High-energy solar neutrinos (E_ν up to 15 MeV)

"Prudent conservative range" $S_{17}(0)$=20.8(2.1) eV b

(Rev Mod Phys 83, 1 (2011))

$^{7}Be(p,\gamma)^{8}B$ direct measurements

Solar fusion cross sections (Rev Mod Phys 70, 4, 1265 (1998))

- At low energy, it is an external, direct-capture process (Q=137.5 ± 1.2 KeV)

- Experimental uncertainties:
  - Need to be extrapolated to astrophysical relevant regime (E_p < 134 KeV)
  - ^{7}Be target is radioactive: Areal density of ^{7}Be difficult to estimate (required for normalization of the cross section)

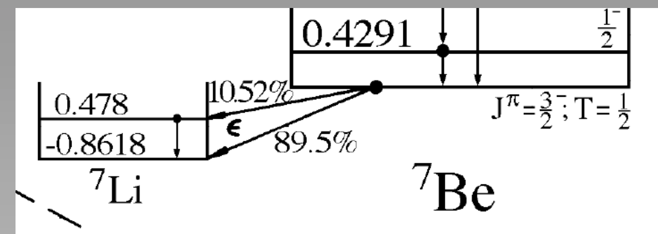
- Two possible strategies:
  - Direct: counting 478 KeV photons of $^{7}Li^{*}$ after ^{7}Be decay (Filippone 1983)
  - Indirect: measuring the $^{7}Li(d,p)^{8}Li$ yield on the resonance ($\Gamma \approx$ 0.2 MeV) at E_d = 0.78 MeV) (Kavanagh 1960, Parker 1966, Filippone 1982, Weissman 1998)

^{7}Li(d,p)^{8}Li calibration reaction (Normalization procedure)

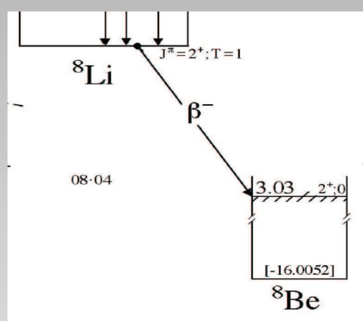
1) Buildup of ^{7}Li in ^{7}Be

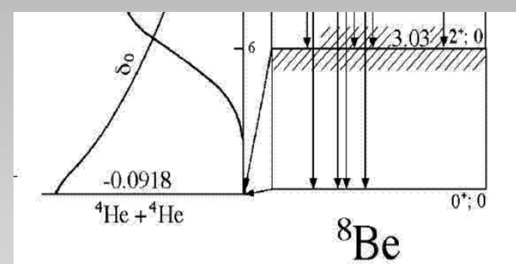
$$N_{^7Li}(t) = N_{^7Be}(0)(1 - e^{\lambda t}) + N_{^7Li}(0)$$

N_i areal density at time t



2) Counting ^{7}Li through the yield of (d,p) reaction





Beta-delayed alphas detected

3) Areal density of Li from total σ

$$\sigma(E_d) \sim \frac{Y_\alpha(E)\beta(^8Li)}{N_d N_{^7Li}(t)}$$

Y_α(E) α-particle yield

β(^{8}Li) depends on decay constant of ^{8}Li

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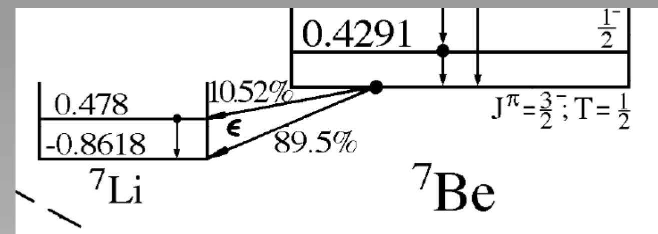

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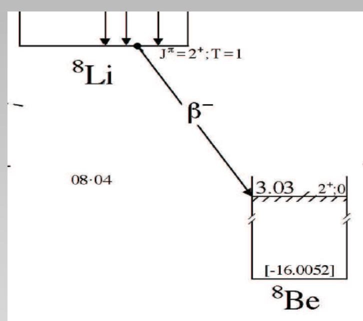

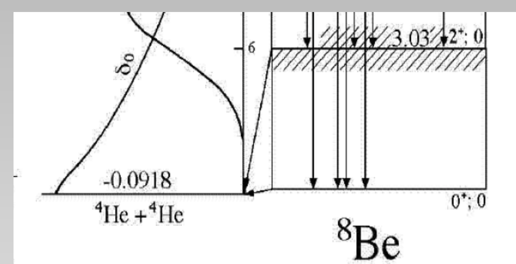

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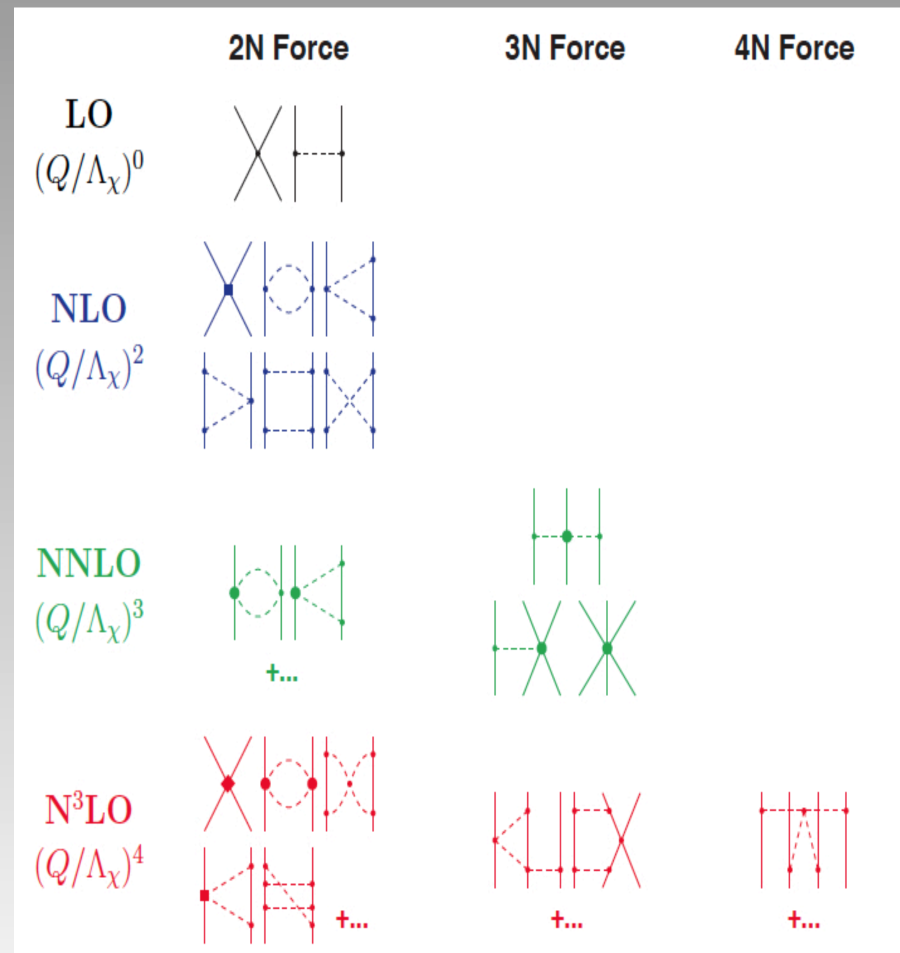
Ab initio calculation of transfer reactions: theoretical motivations

Transfer reactions from first principles:

- Inter-nucleon forces from chiral effective field theory:

1) Nucleons and pions as degrees of freedom
2) Based on QCD symmetries
3) Organized as low-momentum expansion
4) Hierarchy and consistency
5) Low energy constants fitted to 2- and 3-body systems
6) Evolution with SRG methods

Entem-Machleidt NN force at N^3LO (cutoff 500 MeV)



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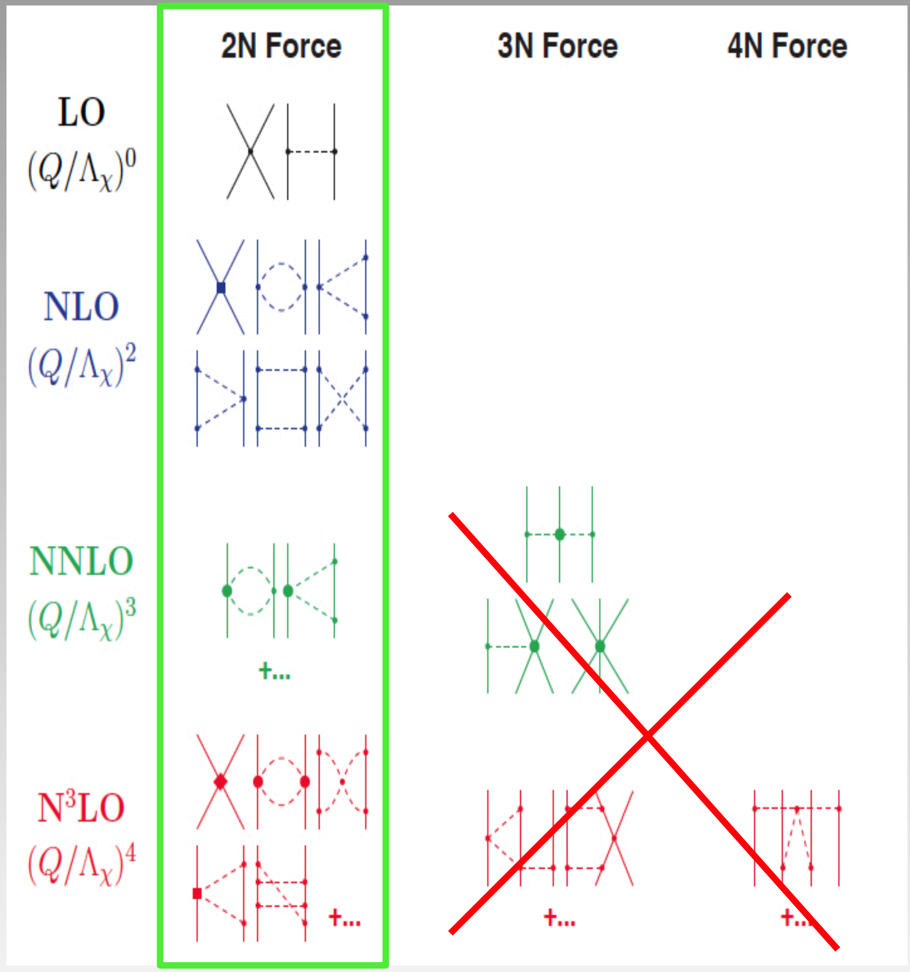
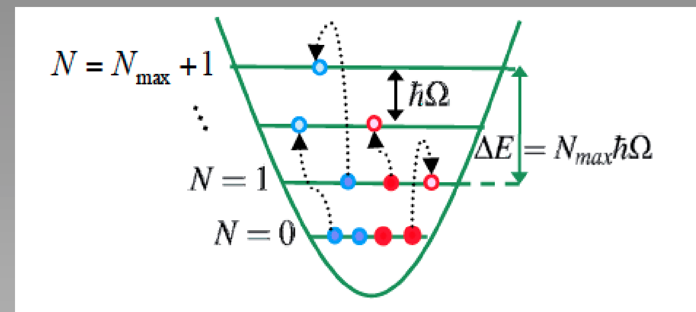


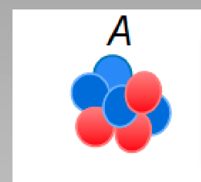
No-core shell model combined with the resonating group method (NCSM-RGM)

No-core shell model (NCSM):

- A-nucleon wave function expansion in the harmonic-oscillator (HO) basis
- Short- and medium-range correlations
- No continuum



$$\Psi^A = \sum_{N=0}^{N_{max}} \sum_i c_{Ni} \Phi^A_{Ni}$$



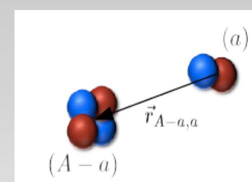
P. Navrátil at al. PRL **84**, 5728 (2000)

Resonating group method (RGM):

- Microscopic approach to describe the scattering of clusters
- Long range correlations (relative motion of clusters)

$$\Psi^{A-a,a} = \sum_\nu \int d\vec{r} \phi_\nu(\vec{r}) \mathcal{A} \Phi^{(A-a,a)}_{\nu\vec{r}}$$

$$\psi^{(A-a)}_{1\nu} \psi^{(a)}_{2\nu} \delta(\vec{r} - \vec{r}_{A-a,a})$$



K. Wildermuth, Y.C. Tang
A unified theory of the nucleus 1977

No-core shell model combined with the resonating group method (NCSM-RGM)

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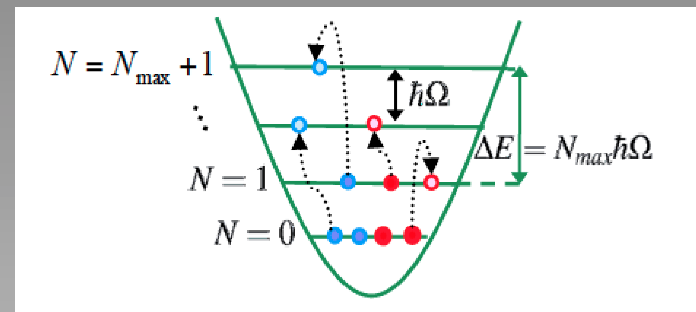

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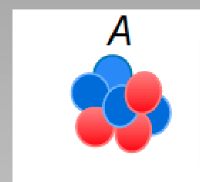

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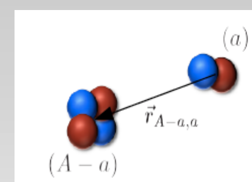
$$\psi_{1\nu}^{(A-a)} \psi_{2\nu}^{(a)} \delta(\vec{r} - \vec{r}_{A-a,a})$$

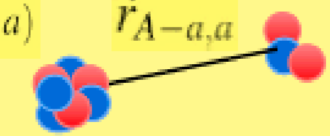


Ab initio NCSM/RGM: Combines both approaches
Ab initio nuclear Hamiltonian, consistent cluster wave functions,
correct asymptotic expansion, Pauli principle and translational invariance

The *ab initio* NCSM-RGM equation

- Ansatz: $\Psi^{(A)} = \sum_\nu \int d\vec{r}\, \varphi_\nu(\vec{r})\, \hat{\mathcal{A}}\, \Phi^{(A-a,a)}_{\nu\vec{r}}$

$(A-a)$ $\quad \vec{r}_{A-a,a}$ $\quad (a)$



$\psi^{(A-a)}_{1\nu}\, \psi^{(a)}_{2\nu}\, \delta(\vec{r} - \vec{r}_{A-a,a})$

eigenstates of $H_{(A-a)}$ and $H_{(a)}$ in the *ab initio* NCSM basis

- Many-body Schrödinger equation:

$$H\Psi^{(A)} = E\Psi^{(A)}$$

$T_{\rm rel}(r) + \mathcal{V}_{\rm rel} + \bar{V}_{\rm Coul}(r) + H_{(A-a)} + H_{(a)}$

realistic nuclear Hamiltonian

$$\sum_\nu \int d\vec{r} \left[\mathcal{H}^{(A-a,a)}_{\mu\nu}(\vec{r}\,', \vec{r}) - E\mathcal{N}^{(A-a,a)}_{\mu\nu}(\vec{r}\,', \vec{r}) \right] \varphi_\nu(\vec{r}) = 0$$

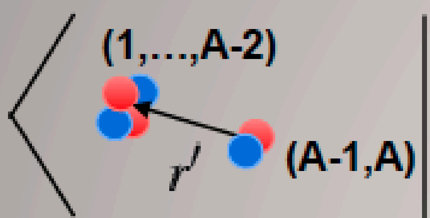
$\langle \Phi^{(A-a,a)}_{\mu\vec{r}\,'} | \hat{\mathcal{A}} H \hat{\mathcal{A}} | \Phi^{(A-a,a)}_{\nu\vec{r}} \rangle$

Hamiltonian kernel

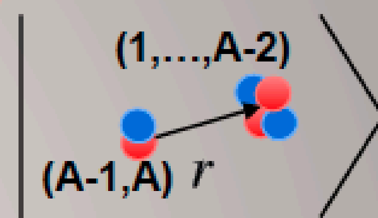
$\langle \Phi^{(A-a,a)}_{\mu\vec{r}\,'} | \hat{\mathcal{A}}^2 | \Phi^{(A-a,a)}_{\nu\vec{r}} \rangle$

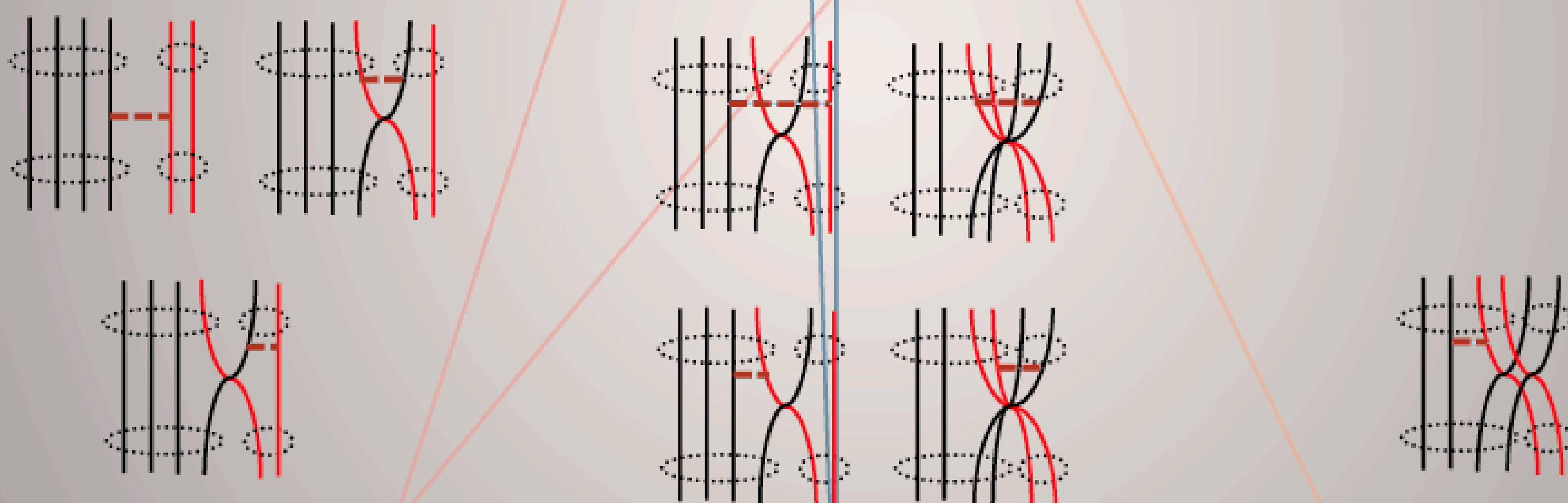
Norm kernel

The deuteron projectile: Hamiltonian kernel



$$\begin{aligned}&2(A-2)V_{A-1,A-2}(1-P_{A-1,A-2})-2(A-2)V_{A,A-2}\hat{P}_{A-2,A-1}\\&-2(A-2)(A-3)V_{A,A-3}(1-\hat{P}_{A,A-3})\hat{P}_{A-2,A-1}\\&-2(A-2)(A-3)V_{A-1,A-3}\hat{P}_{A-2,A-1}\\&+(A-2)(A-3)(A-4)V_{A-1,A-4}\hat{P}_{A-2,A}\hat{P}_{A-3,A-1}\end{aligned}$$

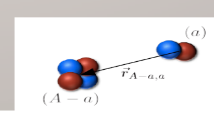
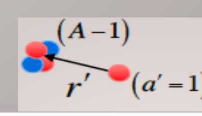




$${}_{SD}\left\langle \psi^{(A-2)}_{\mu_1}\middle| a^+ a \middle| \psi^{(A-2)}_{\nu_1}\right\rangle_{SD}$$

$${}_{SD}\left\langle \psi^{(A-2)}_{\mu_1}\middle| a^+ a^+ a\, a \middle| \psi^{(A-2)}_{\nu_1}\right\rangle_{SD}$$

$${}_{SD}\left\langle \psi^{(A-2)}_{\mu_1}\middle| a^+ a^+ a^+ a\, a\, a \middle| \psi^{(A-2)}_{\nu_1}\right\rangle_{SD}$$

... and 'offdiagonal' coupling kernels $<$  $|V\hat{P}|$  $>$

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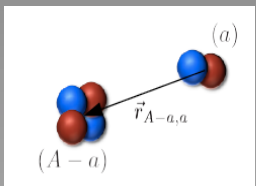
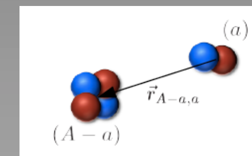
Three-body density Hamiltonian kernel



$$\left\langle \Phi^{J^\pi T}_{k'_{ab}} \right| \left(V_{A,A-4} \hat{P}_{A-2,A-1} \hat{P}_{A-3,A} \right) \left| \Phi^{J^\pi T}_{k_{ab}} \right\rangle$$



$$\underbrace{{}_{\mathrm{SD}}\langle A{-}2\alpha' | \hat{a}^\dagger_{\beta_{A-4}} \hat{a}^\dagger_a \hat{a}^\dagger_b \hat{a}_{b'} \hat{a}_{\beta'_{A-3}} \hat{a}_{\beta'_{A-4}} | A{-}2\alpha \rangle_{\mathrm{SD}}}_{\text{Three-body density matrix}} \; \underbrace{{}_a\langle \beta_{A-4}, a' | V_{A,A-4} | \beta'_{A-4} \beta'_{A-3} \rangle_a}_{\text{Two-body potential}}$$

- Number of three-body matrix elements increases fast with basis size
- Optimized numerical algorithm: On-the-fly calculation of the needed three-body matrix elements for a given target nucleus in the m-scheme

Memory size issue in kernels computation

Dimension of the RGM kernels affects the calculation:

- Memory of a node could be insufficient to handle kernels files
- R-matrix solver is slowed down by the reading-in of huge kernel files

Three different 'representations' of the three-body kernels:

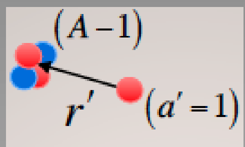
1) ${}_{SD}\langle A{-}2\,\alpha_1' I_1' M_1' T_1' M_{T_1}' | \hat{a}^\dagger_{\beta_{A-4}} \hat{a}^\dagger_{n_a\ell_a j_a m_{j_a} \frac{1}{2} m_{t_a}} \hat{a}^\dagger_{n_b\ell_b j_b m_{j_b} \frac{1}{2} m_{t_b}} \hat{a}_{n_b'\ell_b' j_b' m_{j_b'}' \frac{1}{2} m_{t_b'}'} \hat{a}_{\beta'_{A-3}} \hat{a}_{\beta'_{A-4}} | A{-}2\,\alpha_1 I_1 M_1 T_1 M_{T_1} a\rangle_{SD}$

2) $\left\langle \Phi^{J^\pi T}_{k'_{ab}} \right| \left(V_{A,A-4} \hat{P}_{A-2,A-1} \hat{P}_{A-3,A} \right) \left| \Phi^{J^\pi T}_{k_{ab}} \right\rangle$

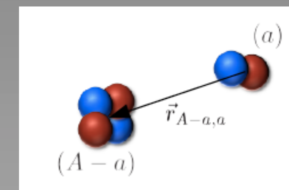
3) $\left\langle \Phi^{J^\pi T}_{\nu' r'} \right| \left(V_{A,A-4} \hat{P}_{A-2,A-1} \hat{P}_{A-3,A} \right) \left| \Phi^{J^\pi T}_{\nu r} \right\rangle$

Nmax (single-channel *d*-^{4}He)	1) # 3-body density matrix	2) # Kernels in SD-basis	3) # Kernels in physical basis
2	$\sim 10^5$	$\sim 10^2$	20
4	$\sim 10^7$	$\sim 10^3$	70
6	$\sim 10^9$	$\sim 10^4$	167
8	$\sim 10^{10}$	$\sim 10^5$	325

Coupling Hamiltonian kernel



$$\left\langle \Phi^{J^\pi T}_{k'_a} \right| \left(V_{A-3,A-2}\hat{P}_{A-2,A} \right) \left| \Phi^{J^\pi T}_{k_{ab}} \right\rangle$$



$${}_{SD}\langle A-1\alpha'|\hat{a}^\dagger_{\beta_{A-3}}\hat{a}^\dagger_b\hat{a}^\dagger_a\hat{a}_{\beta'_{A-2}}\hat{a}_{\beta'_{A-3}}|A-2\alpha\rangle_{SD}\;{}_a\langle\beta_{A-3},a'|V_{A-3,A-2}|\beta'_{A-3}\beta'_{A-2}\rangle_a$$

"Not-diagonal" density matrix

Two-body potential

(A-2,2) mass partition in the entrance channel
(A-1,1) mass partition in the exit channel

- Inclusion of coupling kernel describing the dominant channel in a (*d*,p/n) transfer reaction

< d,^{7}Li | ^{9}Be > & < p,^{8}Li | ^{9}Be > cluster overlaps

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$N_{max} = 6$

- Understand cluster structure of ^{9}Be

Cluster overlaps from NCSM eigenstates

$$g(r) = < \Psi^{(A)} | \mathcal{A} \Psi^{(A-a)} \Psi^{(a)} \delta_{r, r_{A,A-a}} >$$

Large overlap of mass partitions considered with compound nucleus in the 5/2^{+} partial wave

< ^{9}Be | p + ^{8}Li > E_{thr} = -37.60 MeV

$J^{\pi}T$	E (^{9}Be) [Mev]	(2s,l)	S
$(3/2^{+}1/2)_{5}$	4.49	(3,0)*	0.356
$(5/2^{-}1/2)_{6}$	3.87	(5,1)*	0.052
$(5/2^{+}1/2)_{4}$	3.46	(5,0)	0.593

< ^{9}Be | d + ^{7}Li > E_{thr} = -38.16 MeV

$J^{\pi}T$	E (^{9}Be) [MeV]	(2s,l)	S
$(1/2^{-}1/2)_{4}$	2.98	(1,0)*	0.140
$(5/2^{-}1/2)_{6}$	4.43	(5,0)*	0.153
$(5/2^{+}1/2)_{4}$	3.46	(5,1)	0.371

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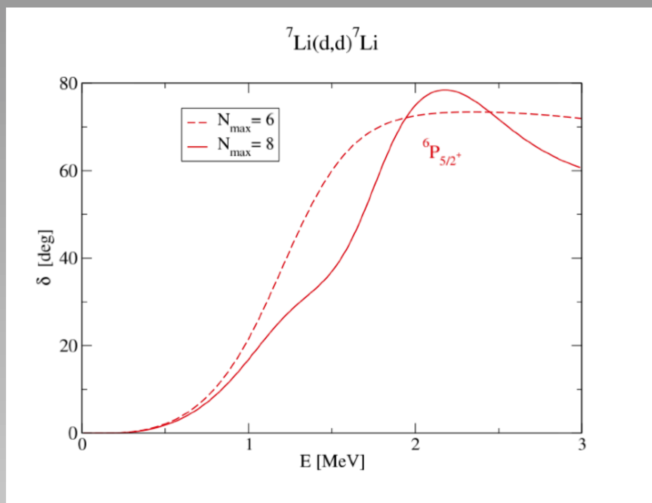
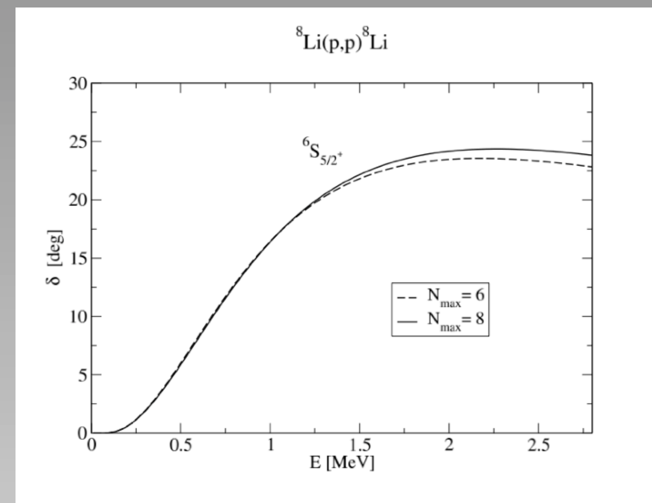
Phase shifts analysis (NCSM-RGM)

Analysis of the partial wave phase shifts: spin and parity (J^π) of the resonance

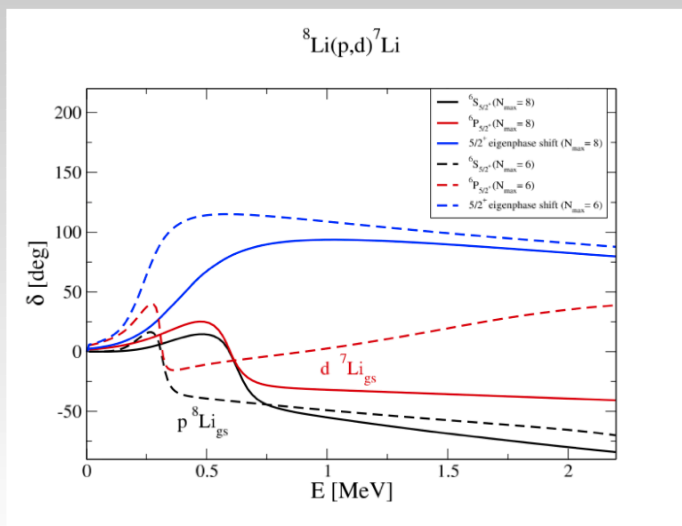


$J^\pi = 5/2^+$

dominant resonance at low energy



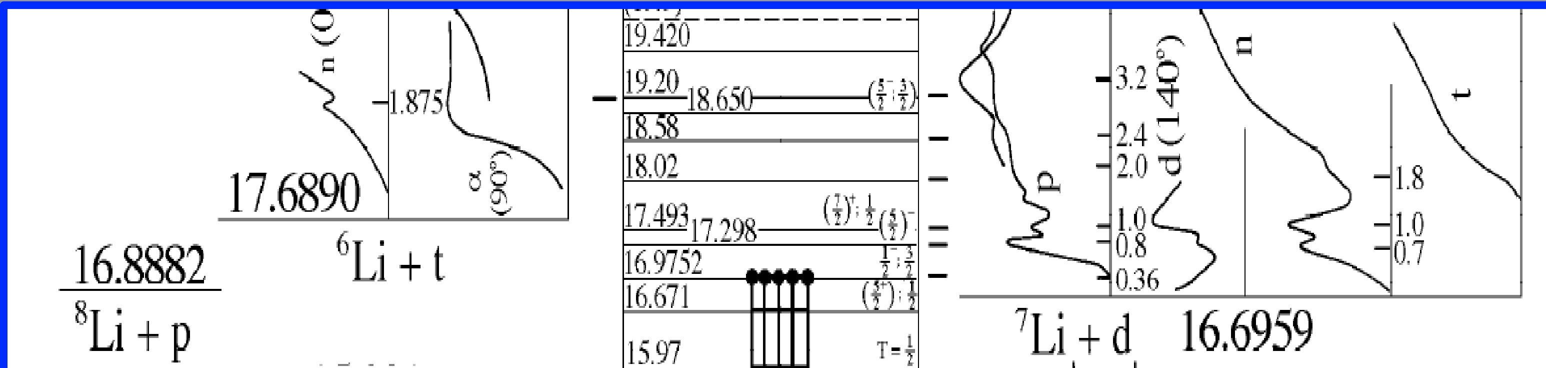
Effect of the coupling: contribution from 'offdiagonal' elements of the collision matrix



Eigenphase shifts convey informations on all the matrix elements of the collision matrix

Spin-parity assignment of 0.78 MeV resonance of ^{9}Be

^{9}Be spectrum above *d*-^{7}Li threshold



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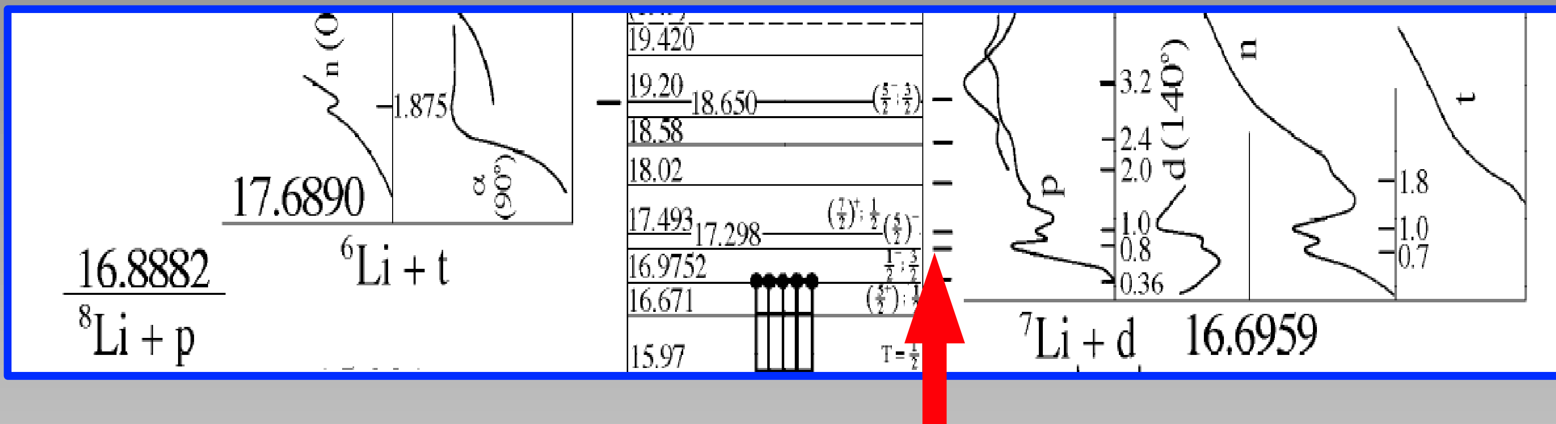


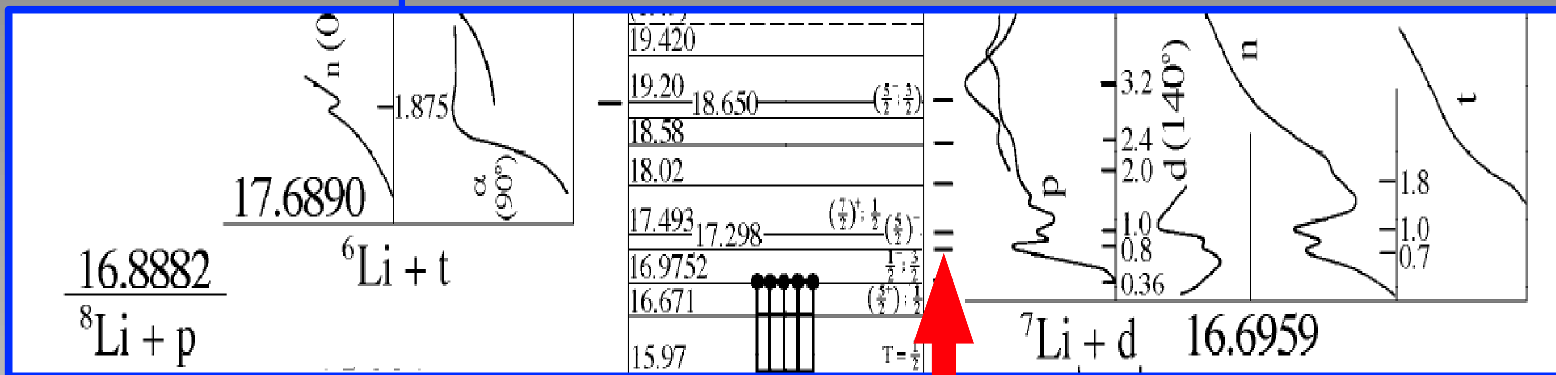
Low peak in the experimental total cross section:

E(5/2^{-})~0.78 MeV above the threshold

(Uncertain spin-parity assignment)

Spin-parity assignment of 0.78 MeV resonance of ^9Be

^{9}Be spectrum above *d*-^{7}Li threshold



Low peak in the experimental total cross section:
E(5/2$^-$)~0.78 MeV above the threshold
(Uncertain spin-parity assignment)

LE JOURNAL DE PHYSIQUE — TOME 33, MAI-JUIN 1972, PAGE 485

Classification
Physics Abstracts
12.13 — 12.37

CONTRIBUTION A L'ÉTUDE EXPÉRIMENTALE DE LA RÉACTION ^{7}Li(dα)^{5}He A BASSE ÉNERGIE

J. DECHARGE
CEA, Centre d'Etudes de Limeil, BP nº 27, 94-Villeneuve-Saint-Georges, France

et G. SURGET (*), G. BRUNO, M. Y. DECHARGE
CEA, Centre de Bruyères-le-Châtel, BP nº 61, 92-Montrouge, France
(*Reçu le 17 août 1971, révisé le 24 novembre 1971 et le 21 janvier 1972*)

E(~17.3 MeV) --> 3/2$^-$

Z. Physik 243, 126—131 (1971)
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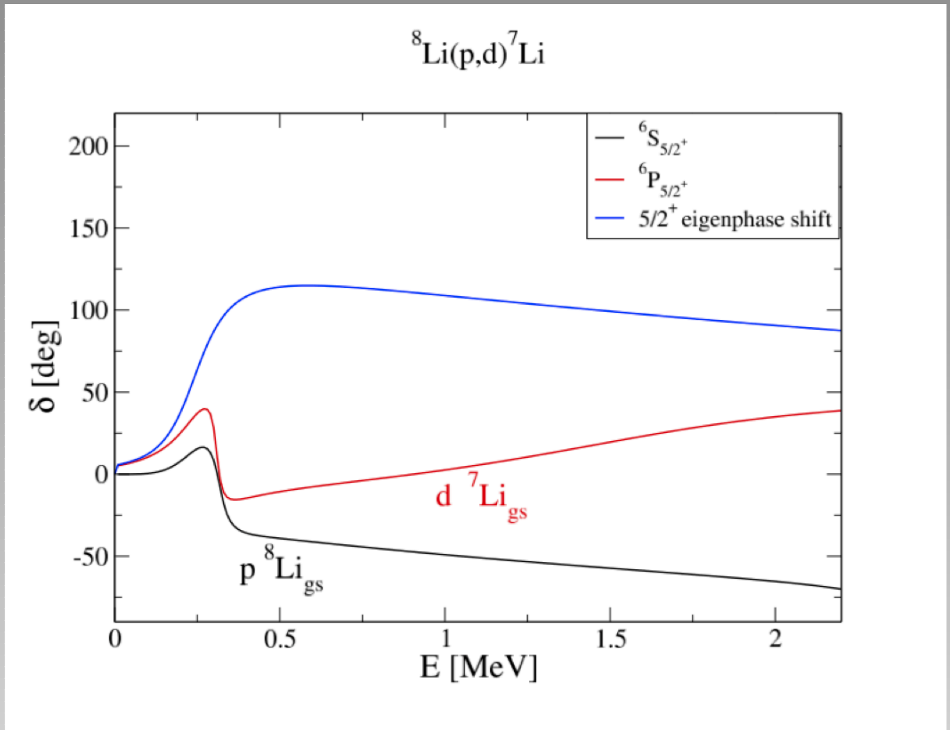
Die Reaktion ^{7}Li$(d,\alpha)^5$He im Energiegebiet von 0,6 bis 2,0 MeV

E. Friedland und I. Venter
Physics Department, University of Pretoria, South Africa

Eingegangen am 25. Januar 1971

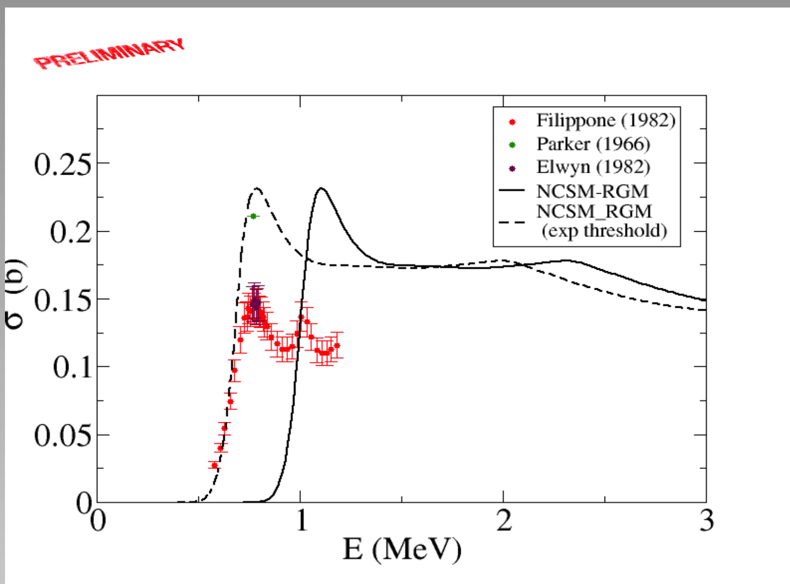
E(~17.3 MeV) --> 3/2$^+$,5/2$^+$,7/2$^+$

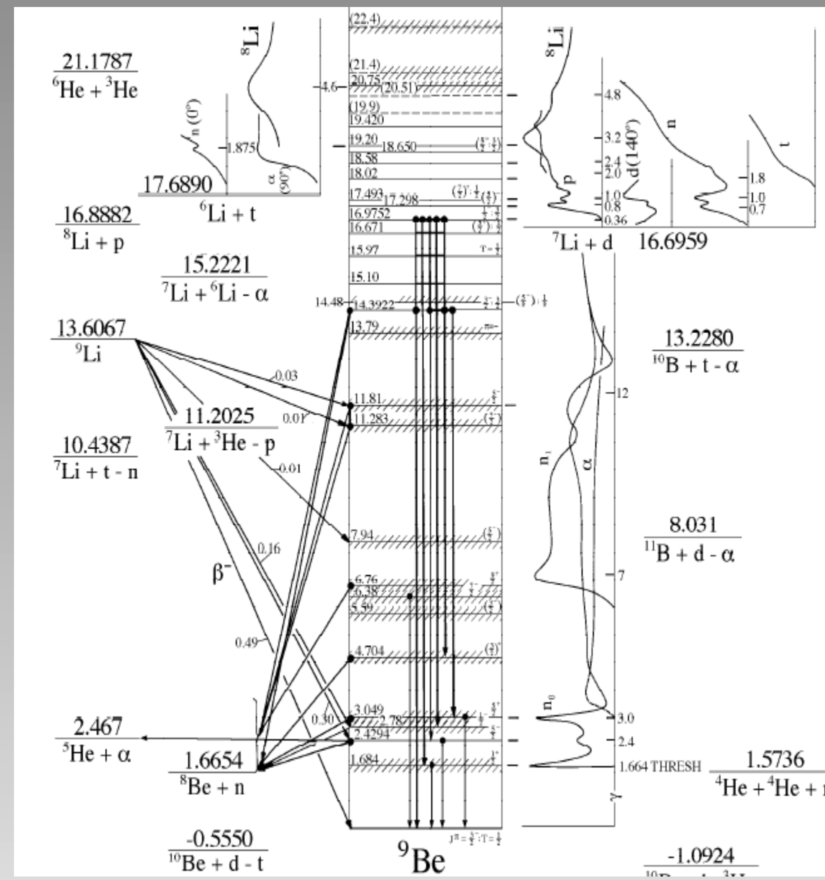
Reaction mechanism



$d - {}^{7}Li$ (p wave) → ${}^{9}Be$ ($5/2^{+}$) → $p - {}^{8}Li$ (s wave)

^{7}Li(d,p)^{8}Li scattering results (NCSM-RGM)



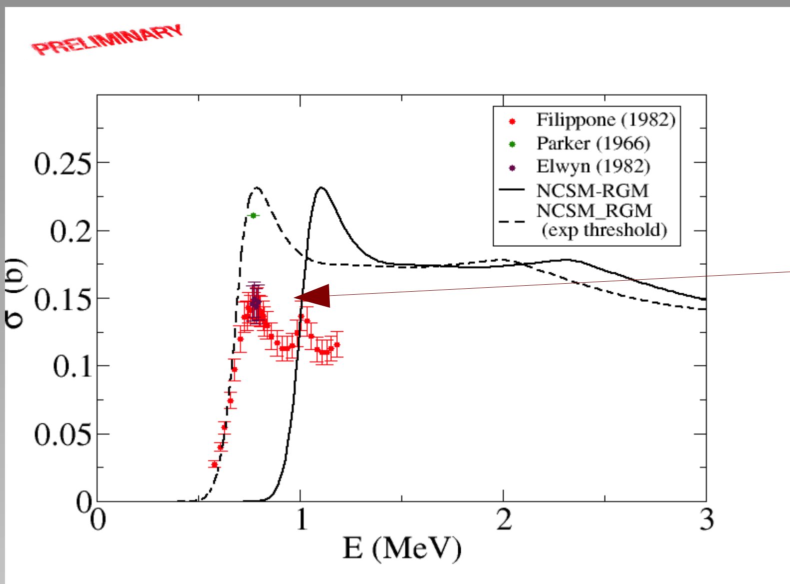


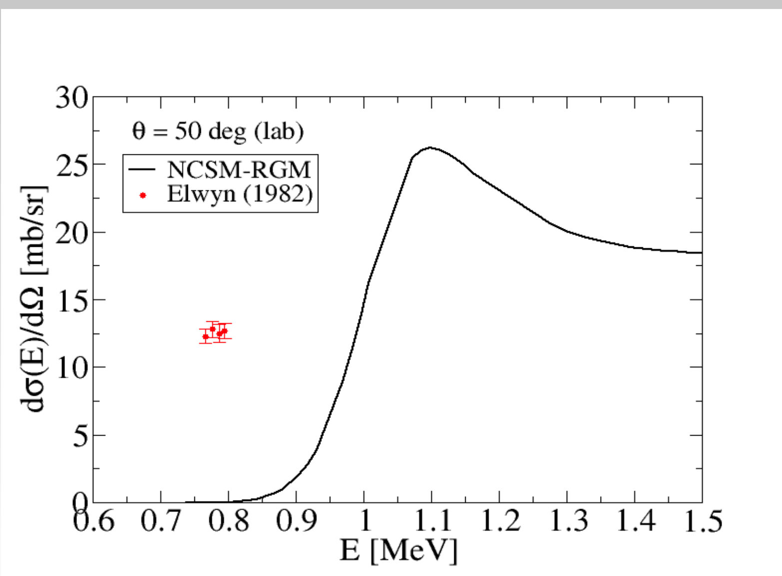
Included channels:
(1) p, ^{8}Li (2) d, ^{7}Li (3) coupling (d,p)
(4) virtual breakup of d

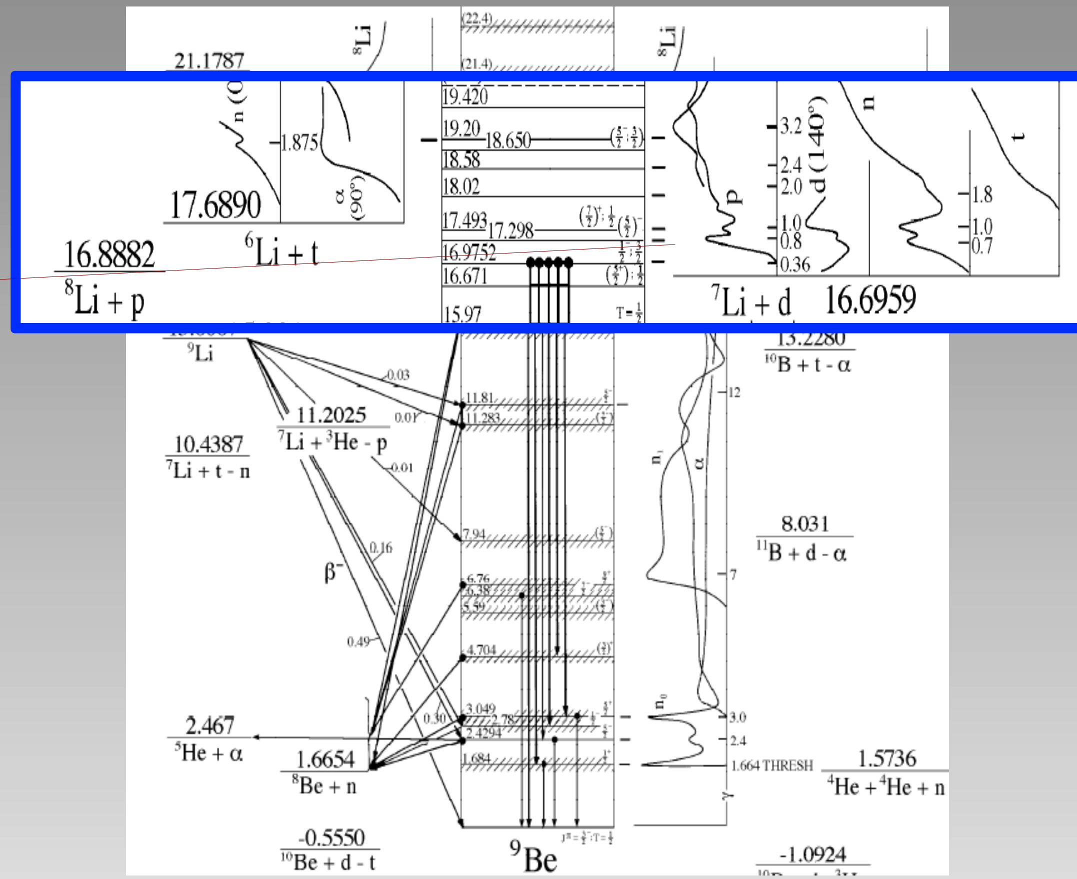
Not-included channels: (1)^{8}Be, n (2) ^{6}Li, t

NCSM-RGM calculations with chiral N^{3}LO NN potentials (SRG λ=2.02 fm^{-1})
4 eigenstates of ^{8}Li, 2 eigenstates of ^{7}Li and 5 pseudostates of deuteron
Preliminary: Nmax=6, hΩ=20 MeV

^{7}Li(d,p)^{8}Li scattering results (NCSM-RGM)







Lowest peak in the experimental total cross section:
(E(5/2$^-$)~0.8 MeV above the threshold)

(Uncertain spin-parity assignment)

TRIUMF

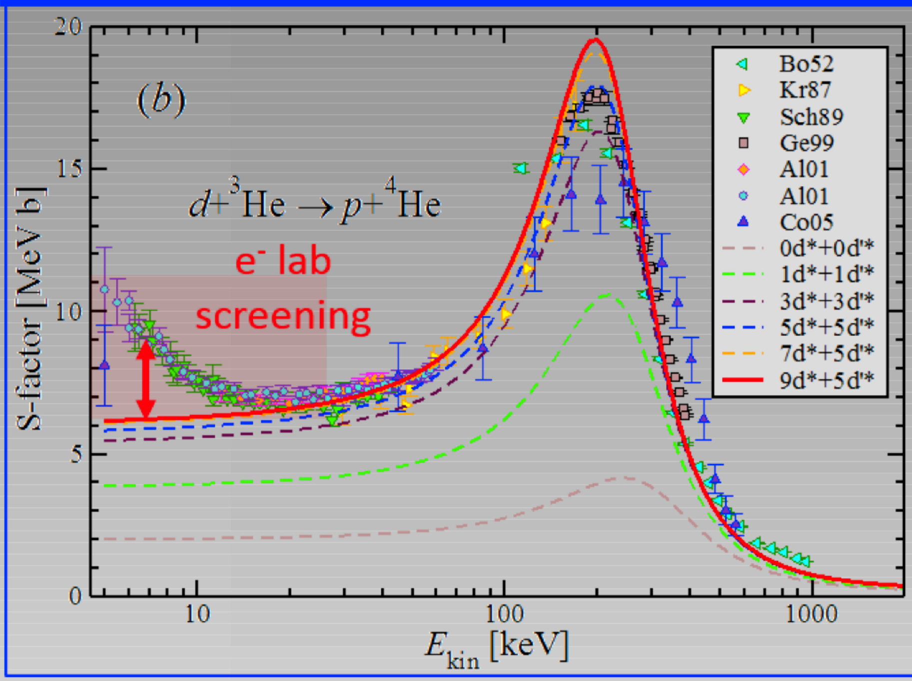
$^{3}H(d,n)^{4}He$ fusion with 3N forces

Recent progress on inclusion of 3N forces in transfer reactions (s-shell nuclei)

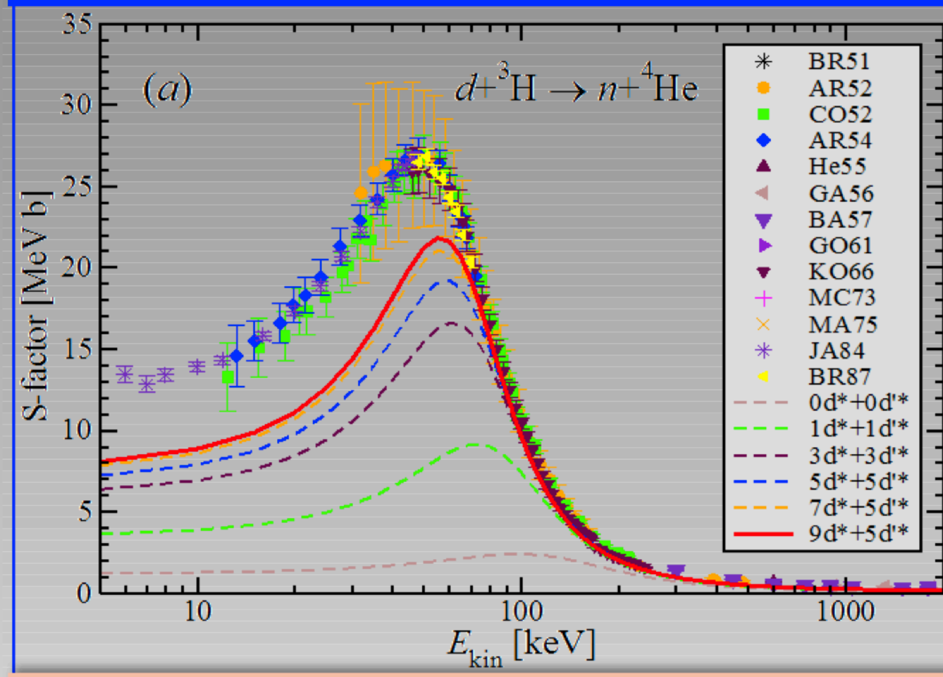
G. Hupin (CEA DAM, Bruyères-le-châtel),
P. Navrátil (TRIUMF, Vancouver),
S. Quaglioni (LLNL, US)

TRIUMF First step towards *ab initio* calculation transfer reactions (Navrátil, Quaglioni PRL108, 2012)

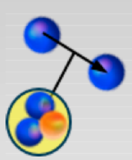
^{3}He(*d*,*p*)^{4}He astrophysical S-factor



^{3}H(*d*,*n*)^{4}He astrophysical S-factor



NCSM/RGM results for the ^{3}He(*d*,*n*)^{4}He astrophysical S-factor compared to beam-target measurements.



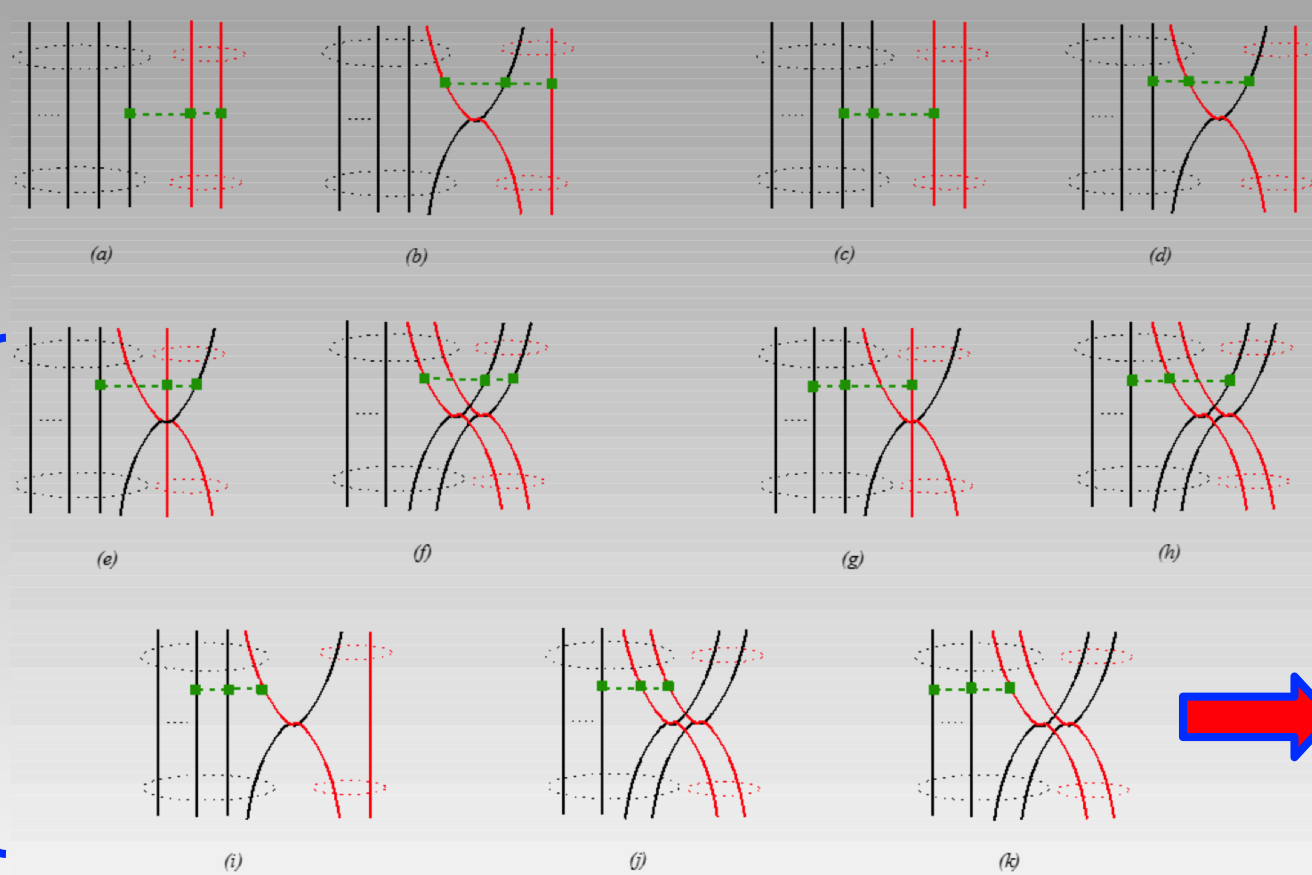
Deuterium breakup:

Calculated S-factors converge with the inclusion of virtual breakup of the Deuterium, obtained by means of excited $^3S_1$-$^3D_1$(d^*) and $^3D_2$(d'^*) pseudostates

Incomplete nuclear ineraction: Requires 3N forces (SRG-induced + “real”)

Including 3N force into the description of deuteron-nucleus scattering

$$\left\langle \Phi^{J^{\pi}T}_{\nu' r'} \middle| \hat{A}_{\nu'} V^{NNN} \hat{A}_{\nu} \middle| \Phi^{J^{\pi}T}_{\nu r} \right\rangle = \left\langle \underset{(a'=2)}{\overset{(A-2)}{\vec{r}\,'}} \middle| V^{NNN} \left(1 - \sum_{i=1}^{A-2} \sum_{k=A-1}^{A} \hat{P}_{ik} + \sum_{i<j=1}^{A-2} \hat{P}_{iA-1} \hat{P}_{jA} \right) \middle| \underset{(a=2)}{\overset{(A-2)}{\vec{r}}} \right\rangle$$



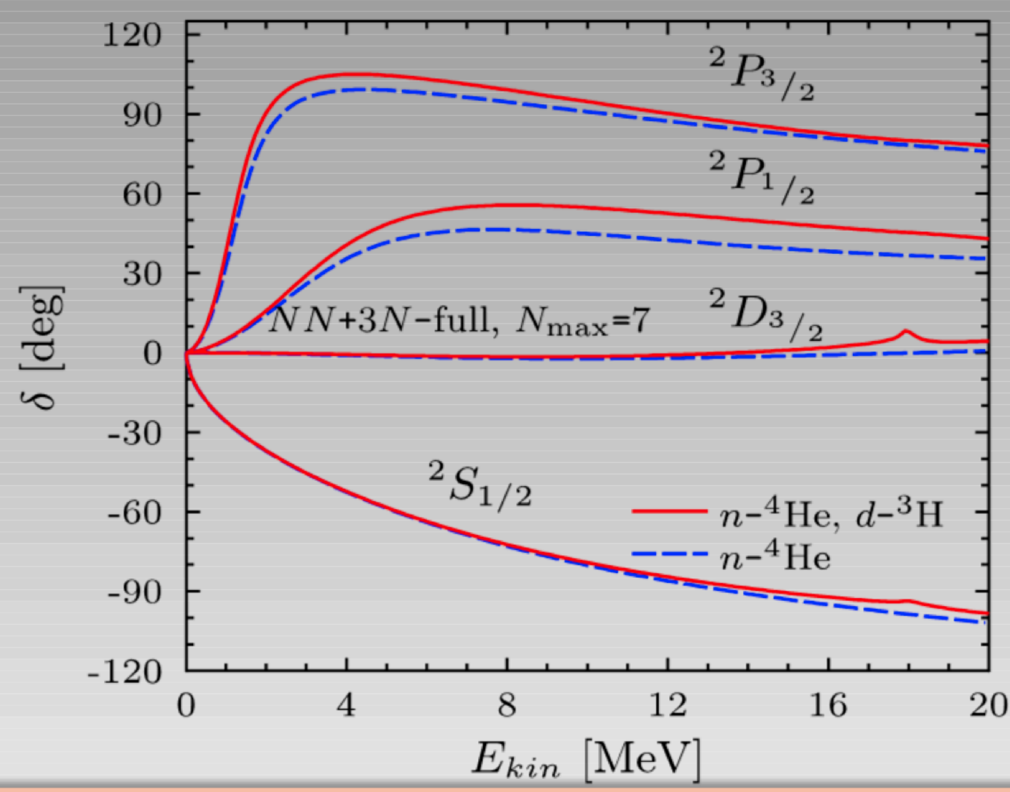
Direct {(a)–(d)}

Exchange {(e)–(k)}

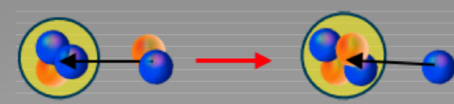
→ Four body density

NCSM-RGM calculation of transfer reaction $^3H(d,n)^4He$ with 3N forces

n-^{4}He with the d-^{3}H channel with the chiral two- and three-nucleon force (preliminary)



n+^{4}He(g.s.) phase shifts with NN+3N potential, λ=2.0 fm^{-1}, <u>no ^{5}He eigenstates</u>, with/o coupling to d-t.



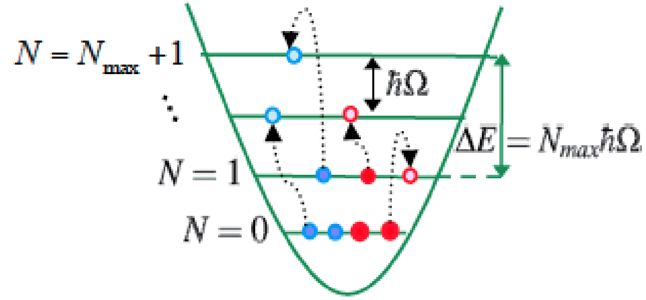
^{4}He fusion

- Perspective to provide accurate t(d,n)^{4}He fusion cross-section for the effort toward earth-based fusion energy generation
- The d-t transfer is known to be very sensitive to the spin-orbit and tensor part of the nuclear interaction

- 7 diagrams (+ exchange) arising from the coupling of n-α with d-t through the three-nucleon force.
- Next step: Coupling to the compound ^{5}He eigenstates

No-core shell model with continuum

- No-core shell model (NCSM)
  - *A*-nucleon wave function expansion in the harmonic-oscillator (HO) basis
  - short- and medium range correlations
  - Bound-states, narrow resonances



- NCSM with Resonating Group Method (NCSM/RGM)
  - cluster expansion
  - proper asymptotic behavior
  - long-range correlations

S.Baroni, P. Návratil, S.Quaglioni
PRL 110, 022505 (2013)

The most efficient:
No-Core Shell Model with Continuum (NCSMC)

NCSM eigenstates

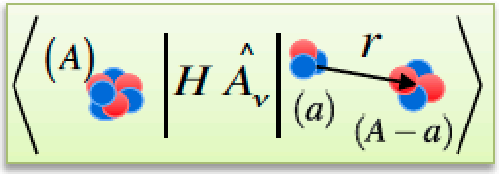
NCSM/RGM channel states

$$\Psi^{(A)} = \sum_{\lambda} c_{\lambda} \left|^{(A)}, \lambda\right\rangle + \sum_{\nu} \int d\vec{r}\, \gamma_{\nu}(\vec{r})\, \hat{A}_{\nu} \left| \vec{r}, (A-a), (a), \nu \right\rangle$$

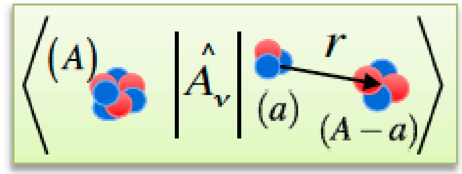
Unknowns

Coupled NCSMC equations

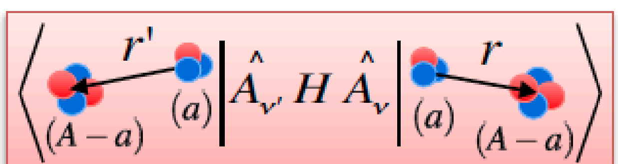
$E_\lambda^{NCSM} \; \delta_{\lambda\lambda'}$

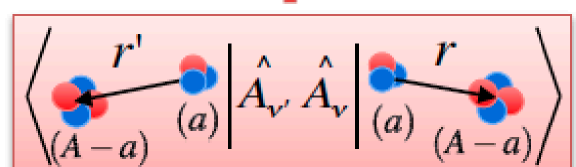


$\delta_{\lambda\lambda'}$



$$\begin{pmatrix} H_{NCSM} & h \\ h & H_{RGM} \end{pmatrix} \begin{pmatrix} c \\ \gamma \end{pmatrix} = E \begin{pmatrix} 1_{NCSM} & g \\ g & N_{RGM} \end{pmatrix} \begin{pmatrix} c \\ \gamma \end{pmatrix}$$



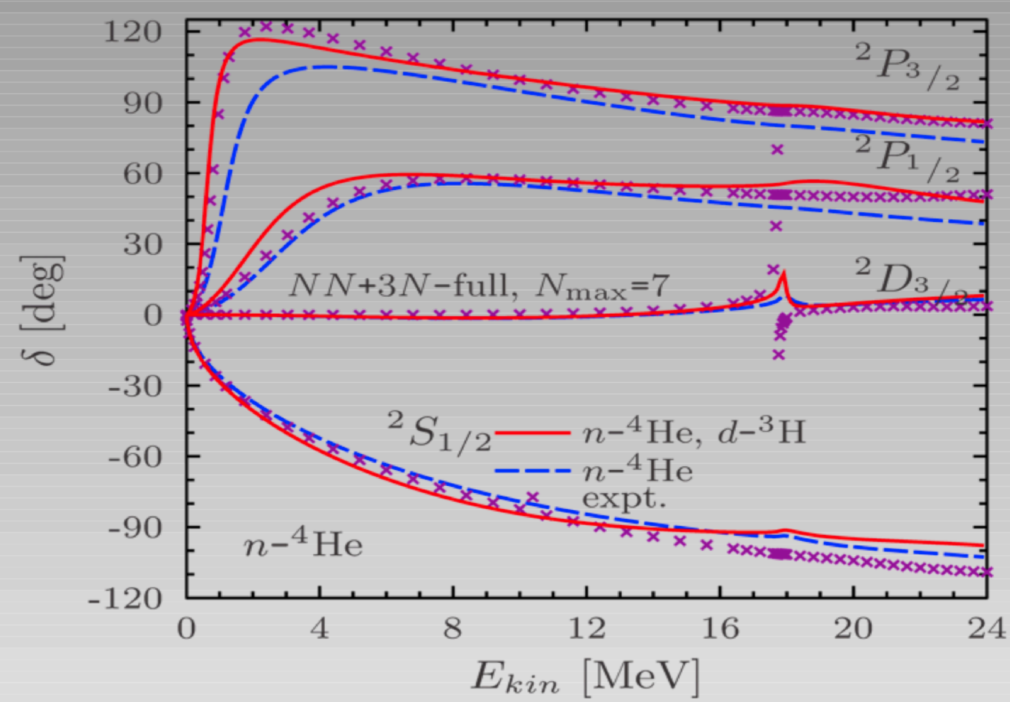


Scattering matrix (and observables) from matching solutions to known asymptotic with microscopic *R*-matrix on Lagrange mesh

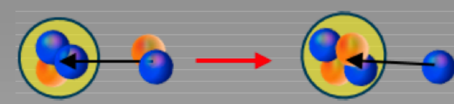
NCSMC calculation of transfer reaction $^{3}H(d,n)^{4}He$ with 3N forces

TRIUMF

^{4}He fusion with NCSMC and the chiral two- and three-nucleon force (preliminary)



n+^{4}He(g.s.) phase shifts with NN+3N potential, λ=2.0 fm^{-1}, with eigenstates of 5He.



^{4}He fusion

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- The d-t transfer is known to be very sensitive to the spin-orbit and tensor part of the nuclear interaction

- Preliminary, small N_{MAX}= 7

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Conclusions & Perspectives

First application of the NCSM-RGM for deuteron-projectile and p-shell nucleus as target:

- Inclusion of the “elastic” and coupling channel in the description of transfer reactions

Analysis of the ^{9}Be resonances above *d*-^{7}Li threshold:

- Discussion of the spin-parity assignment of 0.78 MeV resonance

NCSM/RGM and NCSMC results on *d*-t and *d*-^{3}He transfer reaction with 3N force

To be done:

- Complete the calculation (Nmax=8) of the ^{7}Li(*d*,p)^{8}Li transfer reaction in NCSM-RGM and NCSMC
- Include 3N force also for p-shell nuclei

TRIUMF

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Thank you