TRIUMF

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Towards triples inclusion in dipole excitations

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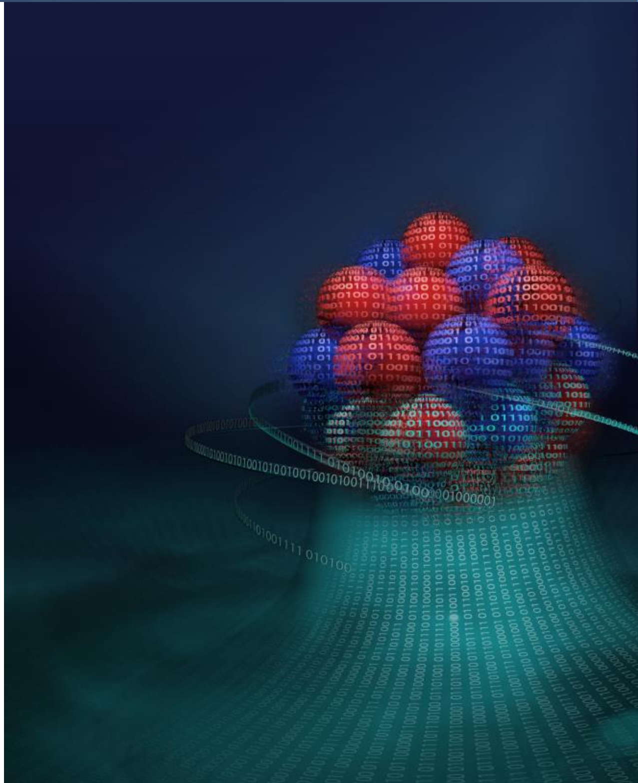
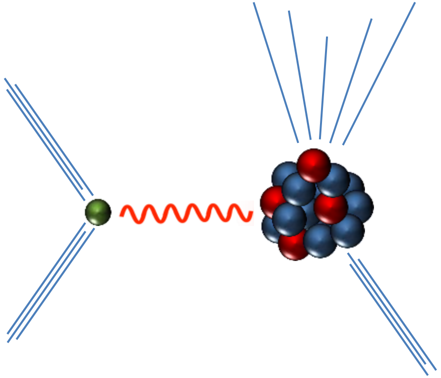
UBC a place of mind
THE UNIVERSITY OF BRITISH COLUMBIA

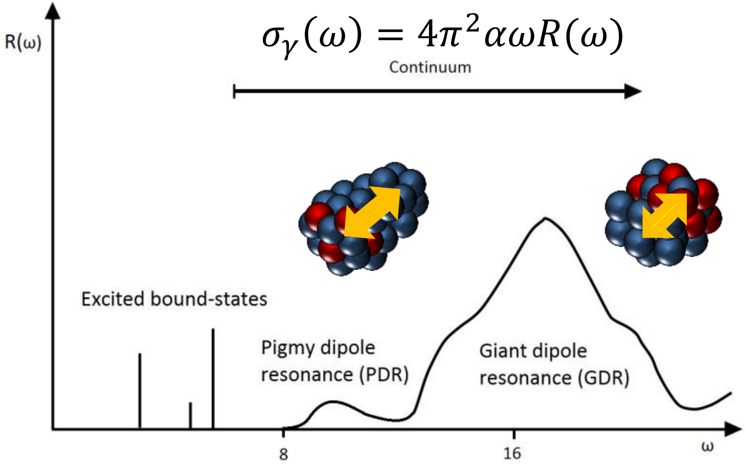


ORNL, conceptual art by LeJean Hardin and Andy Sproles

Collective modes: GDR and PDR



$$\sigma_\gamma(\omega) = 4\pi^2 \alpha \omega R(\omega)$$



Experiments with EM probes allow for a direct connection with theory:

- Small coupling constant (perturbative treatment)
- Transition matrix elements and cross section are directly related

- Focus on the response of the nucleus to an external dipole excitation
- Continuum region: dipole collective modes (PDR & GDR)

From nuclei to stars

- Nuclear matter:

$$E(\rho,\delta) = E(\rho,0) + S(\rho)\delta^2 + o(\delta^4)$$

$$\rho = \rho_p + \rho_n$$

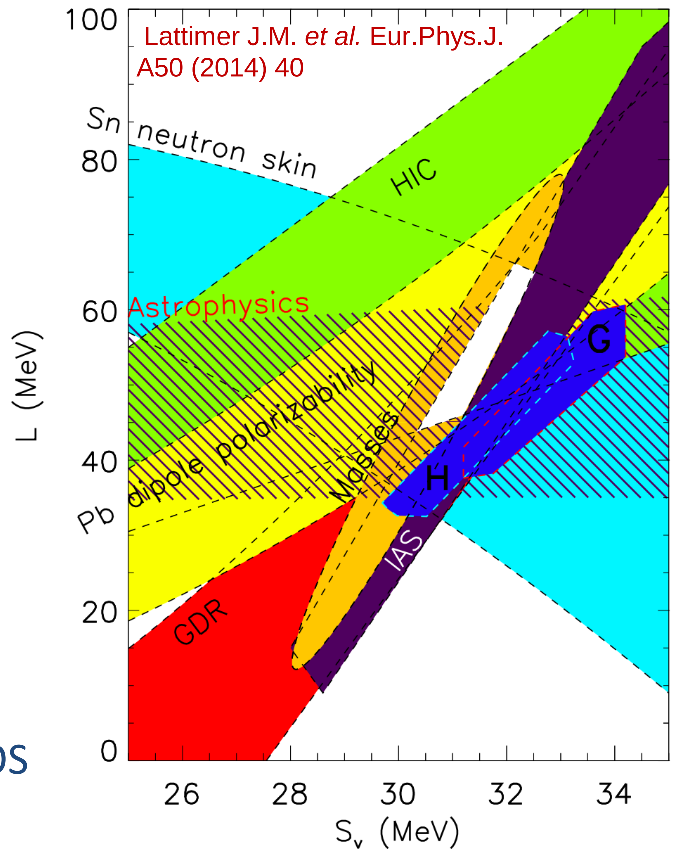
$$\delta = \frac{\rho_n - \rho_p}{\rho_p + \rho_n}$$

- Expand around saturation density:

$$S(\rho) = S_\mathrm{v} + \frac{L}{3\rho_0}(\rho-\rho_0) + \frac{K_{sym}}{18\rho_0^2}(\rho-\rho_0)^2 + \cdots$$

- S_v, L and K_{sym} can be related to finite-nuclei properties

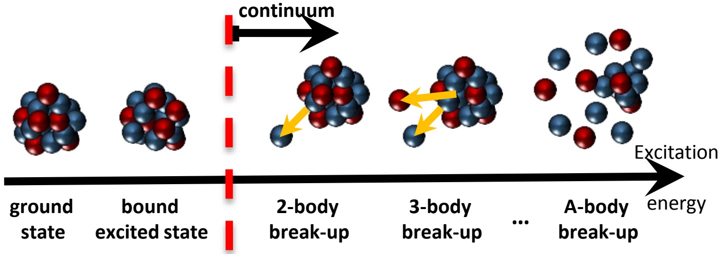
→ We cannot create neutron stars in a lab, but we can use nuclear observables to constrain the EOS

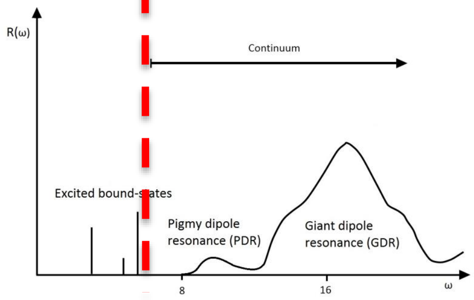


Challenges for an *ab initio* theory

$$\alpha_D = 2\alpha \int \frac{R(\omega)}{\omega} d\omega \qquad R(\omega) = \sum\!\!\!\!\!\!\!\int_f \left|\langle \Psi_f | D | \Psi_0 \rangle\right|^2 \delta(\omega - E_0 - E_f)$$

$|\Psi_f\rangle$ is a **many-body scattering state** and cannot be calculated explicitly → we use **integral transforms**





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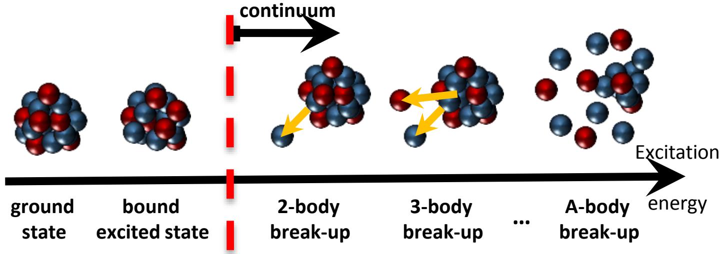
$$(\bar{H} - E_0 - z)|\tilde{\Psi}_R(z)\rangle = \bar{D}|0_R\rangle$$

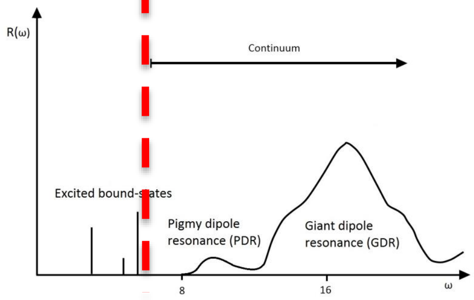
Bacca et *al*., Phys. Rev. Lett. 111, 122502 (2013)

Bacca S., M.M., et al., Phys. Rev. C 90, 064619 (2014)

$$|\tilde{\Psi}_R(z)\rangle = [R_0(z) + R_1(z) + R_2(z)]|0_R\rangle$$

$$\left.\begin{array}{l} \bar{D} = e^{-T} D e^{T} \\ \bar{H} = e^{-T} H e^{T} \end{array}\right\} \quad T = T_1 + T_2$$

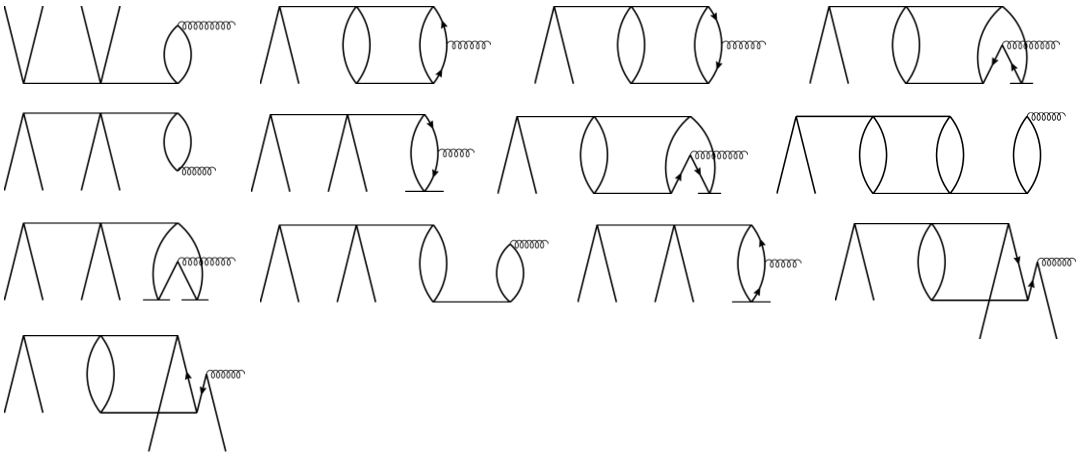




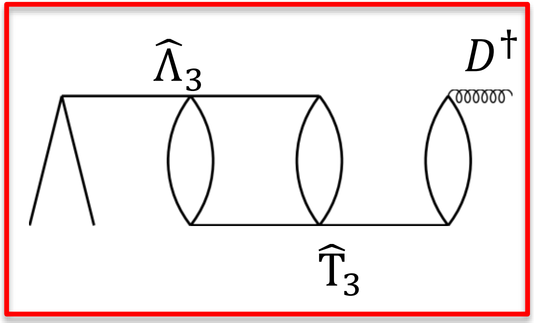
(Equivalently for left states: $\Lambda = \Lambda_1 + \Lambda_2$ and $L(z) = L_0(z) + L_1(z) + L_2(z)$)

Triples inclusion – CCSDT1 approximation

- Linearized triples for the ground state: $e^{T_1+T_2}+T_3$ and $\Lambda_1+\Lambda_2+\Lambda_3$
- Triples effects on excited states from linear triples (R,L)

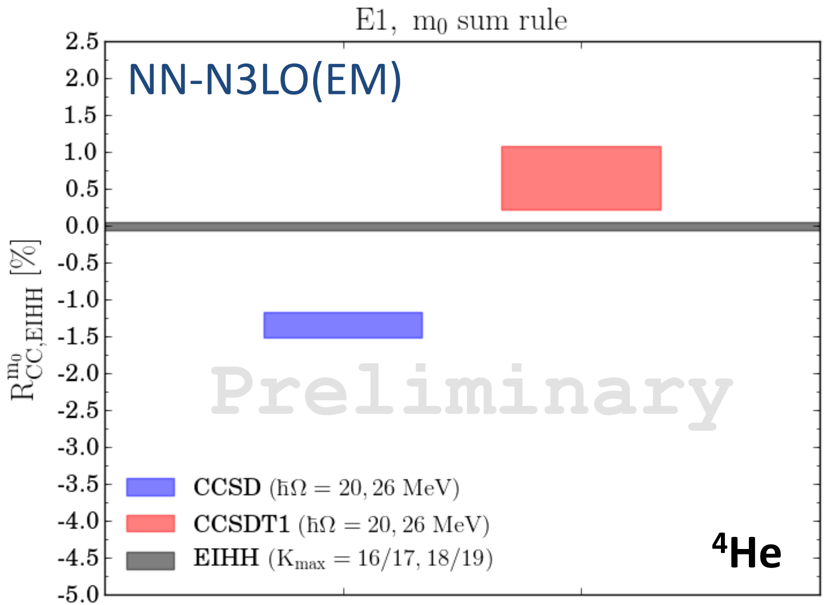


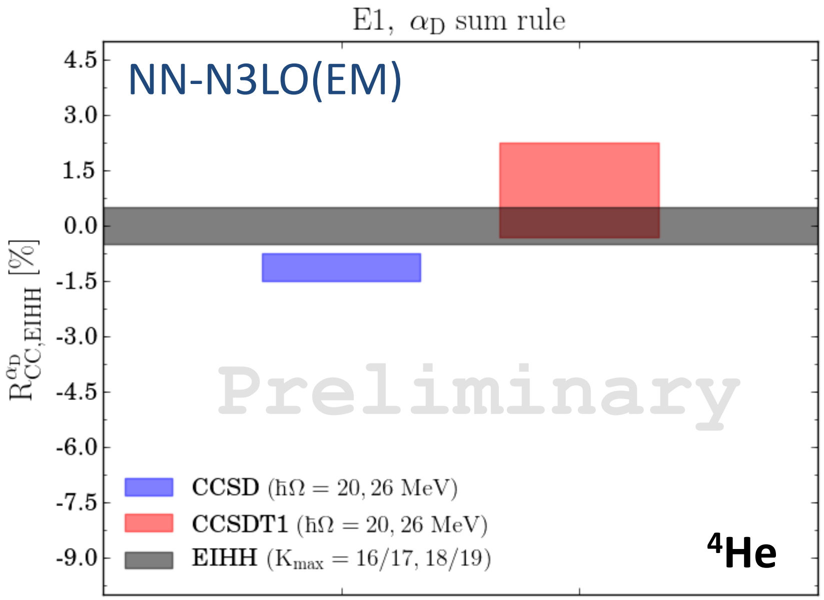
$$m_0 = \langle\phi_0|(1+\hat{\Lambda})\bar{D}^\dagger\bar{D}|\phi\rangle$$



New *1p1h* and *2p2h* contributions to dipole sum rules from $\hat{T}_3$ and $\hat{\Lambda}_3$

Benchmarks in ^{4}He

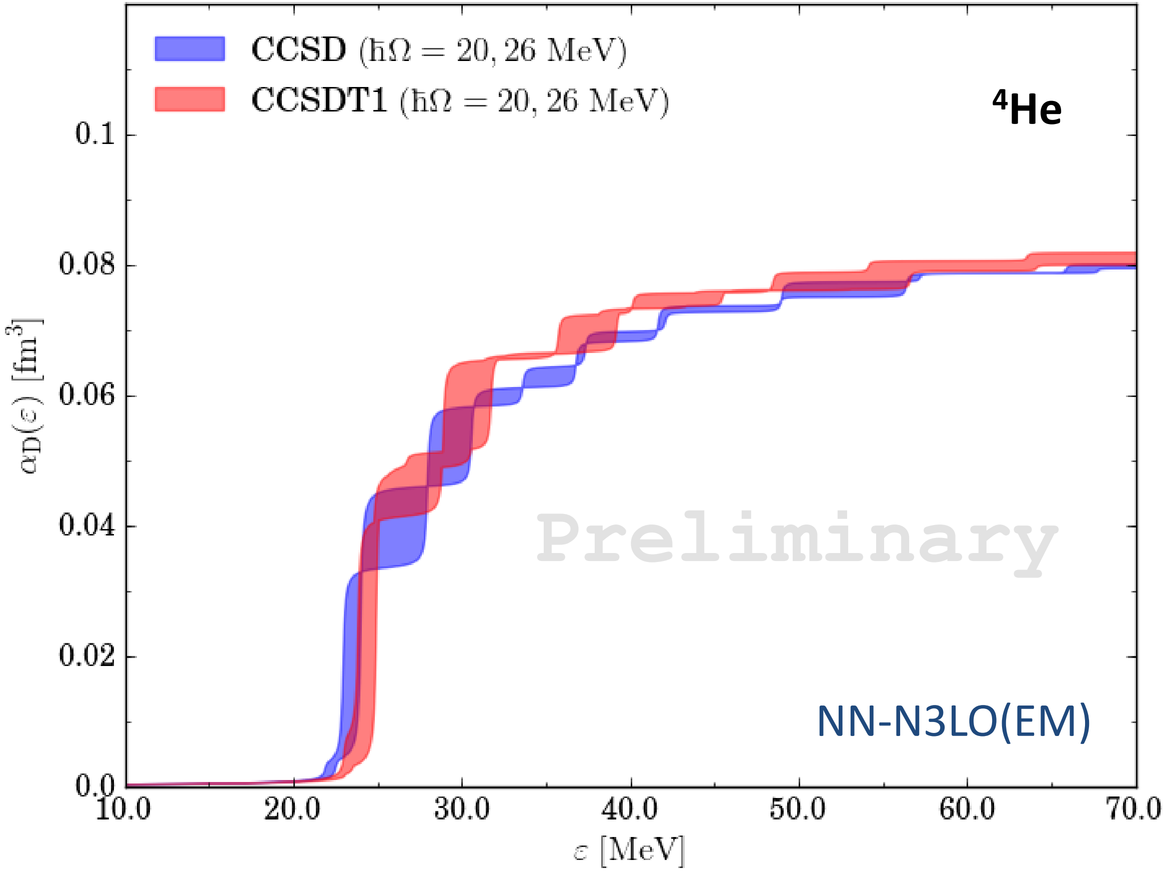




- The dipole strength (m_0) increases adding triples
- Polarizability also increases
- Coupled cluster results with triples are closer to EIHH

How about the strength distribution?

Strength distribution with CCSDT1



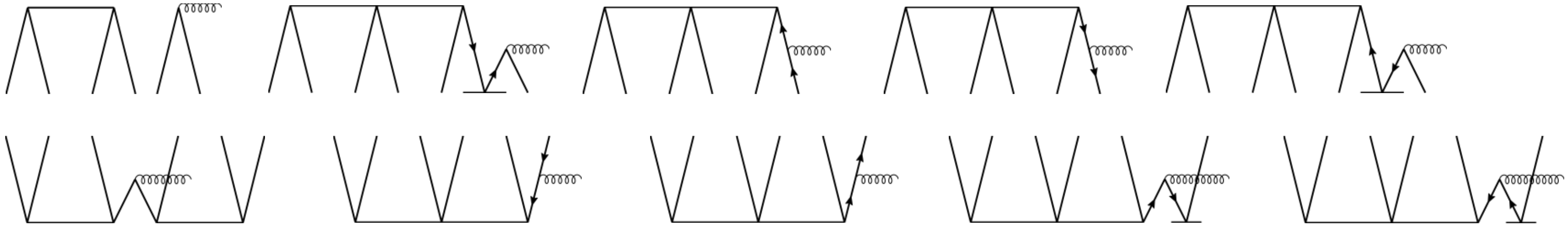
M.M. et *al.*, Phys. Rev. C 94, 034317 (2016)

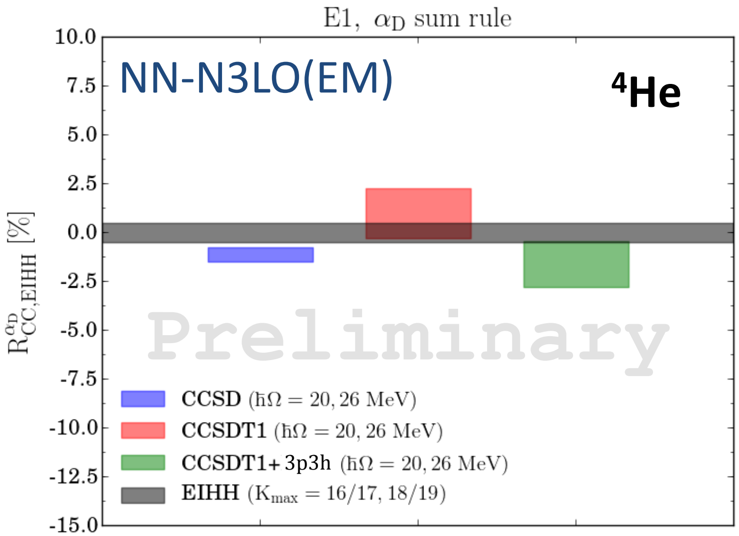
$$\alpha_D(\varepsilon) = 2\alpha \lim_{\Gamma\to 0} \int^{\varepsilon} \frac{L(\sigma,\Gamma)}{\sigma} \mathrm{d}\sigma$$

$$\alpha_D(\varepsilon) = 2\alpha \int^{\varepsilon} \frac{R(\omega)}{\omega} \mathrm{d}\omega$$

Outlook

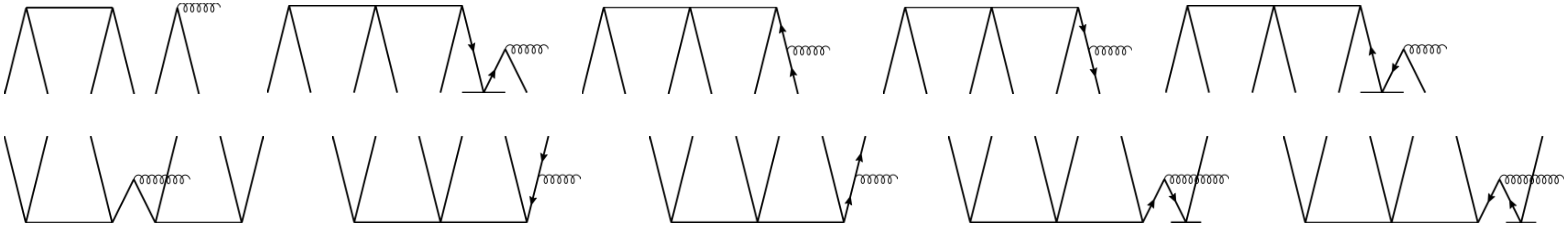
3p3h contr.

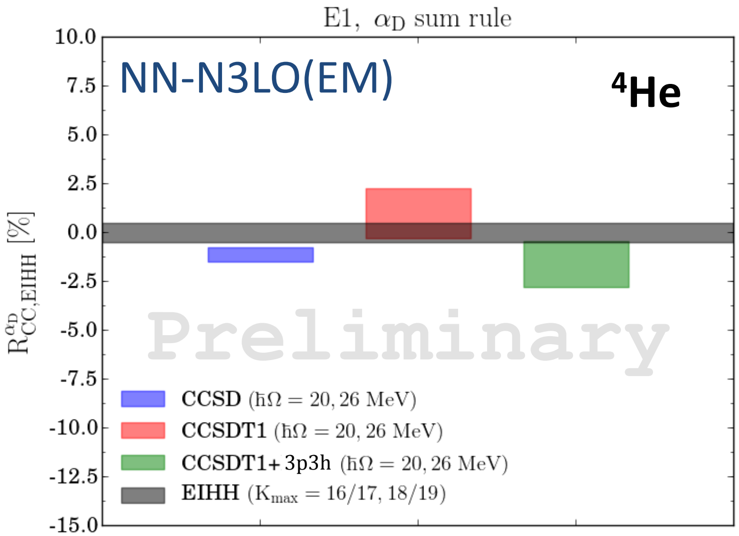




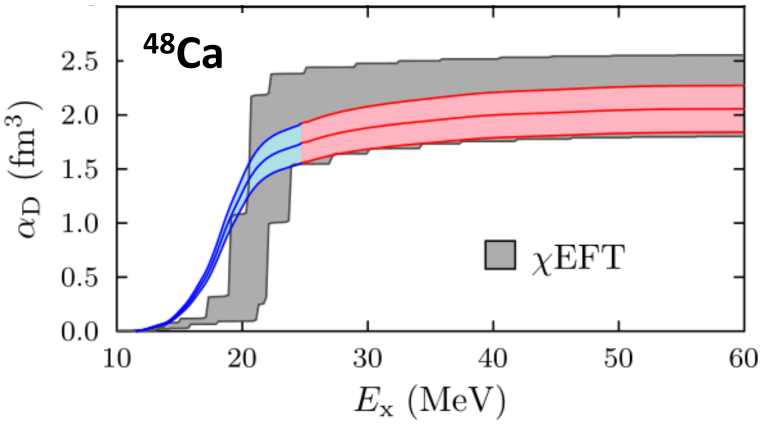
Outlook

3p3h contr.





J. Birkhan, M.M. et *al.*, arXiv:1611.07072 (2016)



- Effect of triples on heavier nuclei?
- Response function with triples?

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Thank you!

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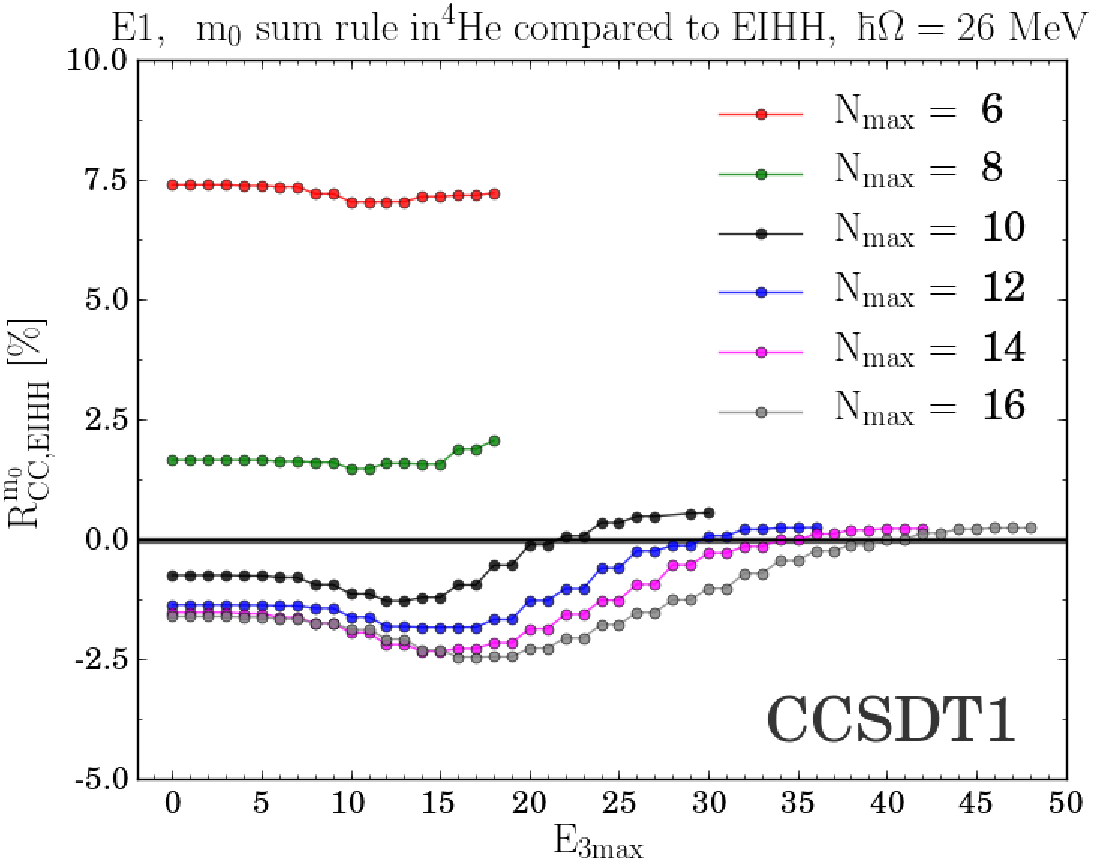
SUMMARY…

… come to see my poster!!

Backup


E1, m0 sum rule in 4He compared to EIHH, ħΩ = 26 MeV
10.0
7.5
5.0
2.5
0.0
-2.5
-5.0
0
5
10
15
20
25
30
35
40
45
50
E3max
R^m0 CC,EIHH [%]
Nmax = 6
Nmax = 8
Nmax = 10
Nmax = 12
Nmax = 14
Nmax = 16
CCSDT1