MONOPOLE OSCILLATIONS IN LIGHT NUCLEI WITH A MOLECULAR DYNAMICS APPROACH

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The AMD/FMD models

- AMD/FMD wave functions :

$$|\Phi(t)\rangle = \det_{kl}\left\{\exp\left[-\nu_k\left(\vec{r}_k - \frac{\vec{Z}_k}{\sqrt{\nu_k}}\right)^2\right]\chi_k(l)\right\}$$

$\vec{Z}_k = \sqrt{\nu_k}\vec{D}_k + \frac{i}{2\hbar\sqrt{\nu_k}}\vec{K}_k$ and χ_k contains the spin and isospin degree of freedom

- The time evolution of each Gaussian wave packet is given by :

$$\frac{d\vec{Z}_{k\sigma}}{dt} = -\frac{i}{\hbar}\sum_{l\tau} C^{-1}_{k\sigma,l\tau}\frac{\partial\mathcal{H}}{\partial\vec{Z}^*_{l\tau}}$$

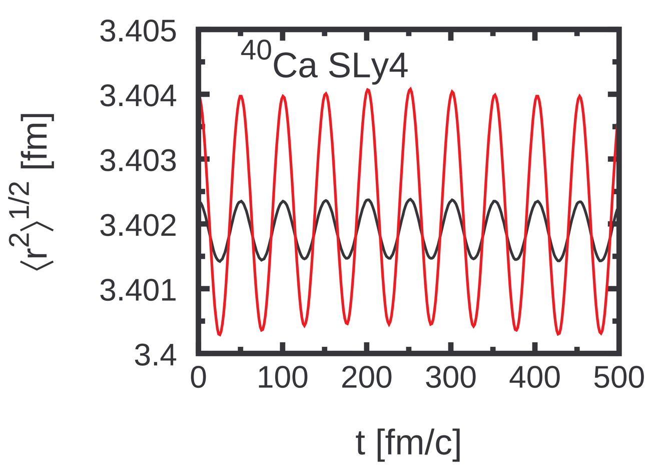
- Differences between AMD and FMD :
  – The width ν are dynamical variables for FMD and fixed for AMD
  – Stochastic equation of motion for the wave packet centroids Z in AMD case :

$$\frac{d}{dt}\vec{Z}_i = \left\{\vec{Z}_i, H\right\}_{PB} + \Delta\vec{Z}_i(t) + (\text{NN collisions})$$

  – Treatment of the center of mass motion

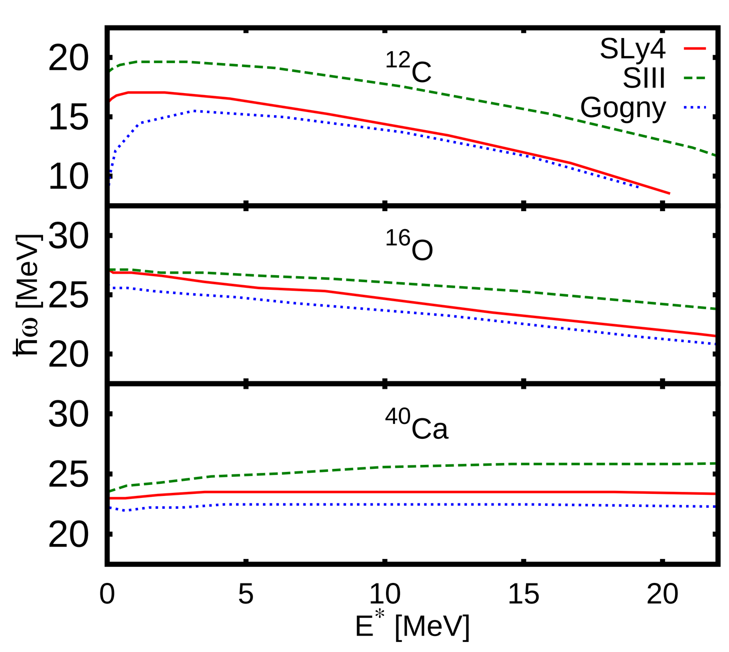
AMD/FMD for monopole vibrations

- The monopole vibrations can be found in doing an expansion of the nuclei
- The monopole vibrations can be seen in plotting the time evolution of $\langle r^2\rangle^{1/2}$



From $\langle r^2\rangle^{1/2}$ Vs t, the frequency $\hbar\omega$ can be extracted as function of :
- The nuclei (N,Z)
- The interaction (difference between Gogny, SLy4, and SIII ?)
- The excitation energy E*
- The width parameter ν for the AMD case
- The amplitude $\Delta\langle r^2\rangle^{1/2} = \left(\text{Max}(\langle r^2\rangle^{1/2}) - \text{Min}(\langle r^2\rangle^{1/2})\right)/2$

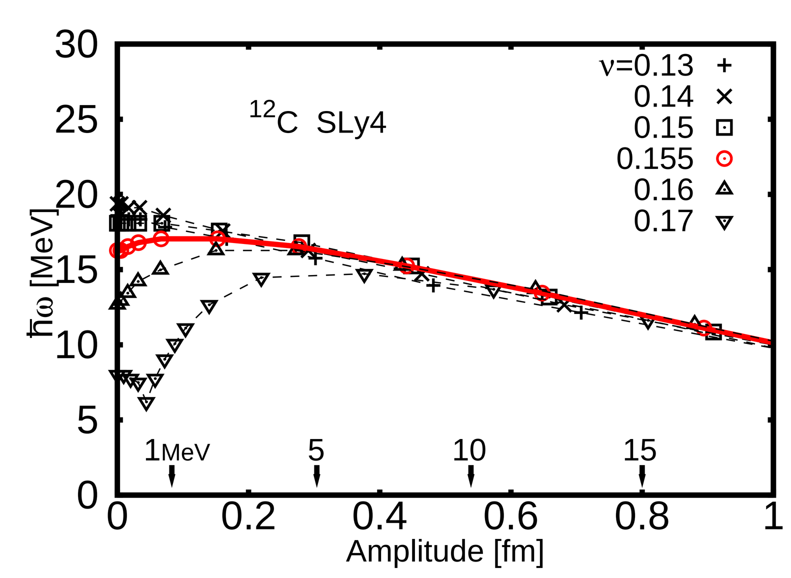
Frequencies of the monopole vibrations for a wide range of energie

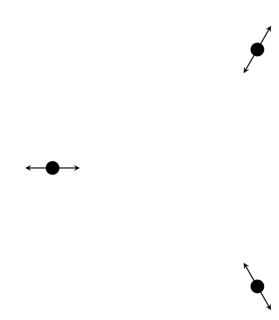


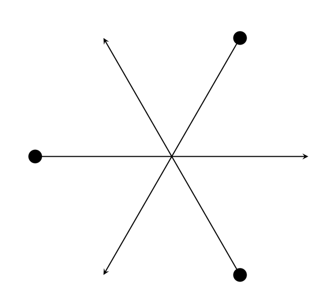
- The table shows the physical frequencies where $E^* \simeq \hbar\omega$
- The results are in good agreement with TDHF/RPA for ^{40}Ca with SLy4 :
  - $\hbar\omega$(TDHF) = 22.1MeV
  - $\hbar\omega$(RPA) = 21.5MeV
- $\hbar\omega$ increase with the incompressibility
  K_∞(Gogny) = 228MeV
  K_∞(SLy4) = 229.9MeV
  K_∞(SIII) = 355.4MeV
- The second frequency is more affected by K_∞ for the FMD case

$\hbar\omega$ [MeV]	AMD SLy4	AMD SIII	AMD Gogny	FMD SLy4	FMD SIII
^{12}C	13.0	15.5	12.8	14.4 & 25.2	16.3 & 31.4
^{16}O	21.6	23.5	21.0	22.3 & 24.7	23.7 & 30.6
^{40}Ca	23.3	26.0	22.3	21.5	26.8

Influence of the width degree of freedom (AMD case)

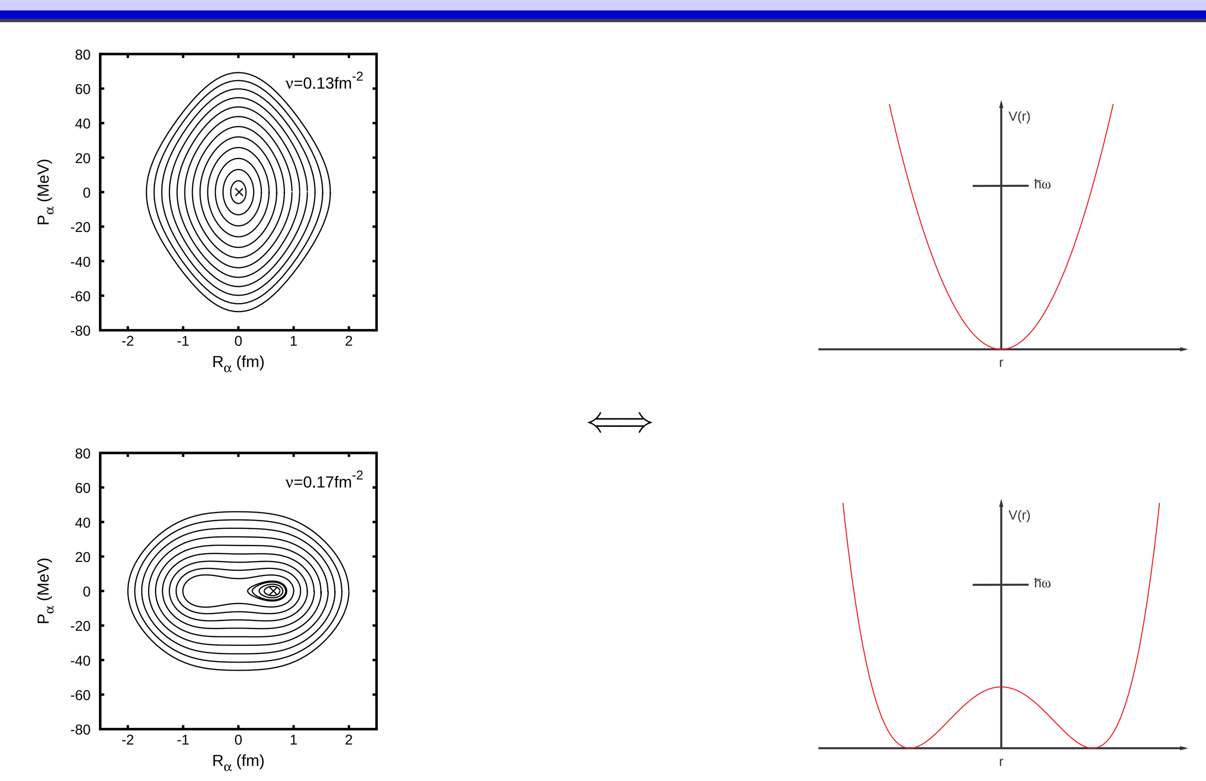



small vibrations


crossing

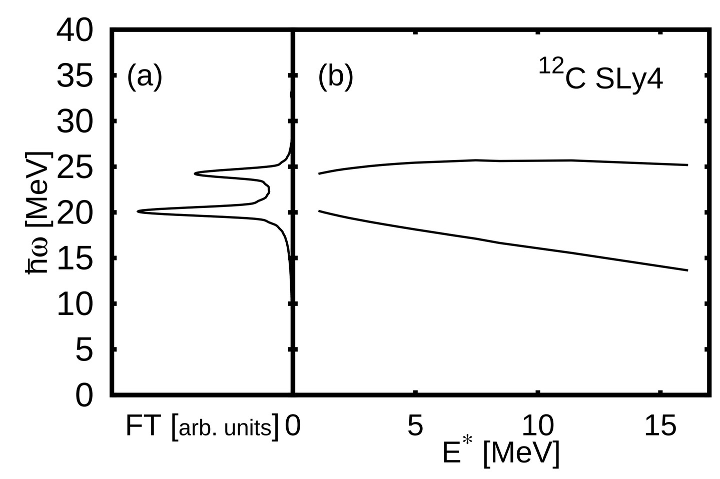
- The ^{12}C is taken as an example (same behavior for ^{16}O and ^{40}Ca)
- The frequency of the monopole vibration depends of $\Delta\langle r^2\rangle^{1/2}$, E* and ν
- The most optimal ground states for ^{12}C is the case for $\nu = 0.155$ fm^{-2}
- Two types of regimes : small vibrations and crossing of α clusters

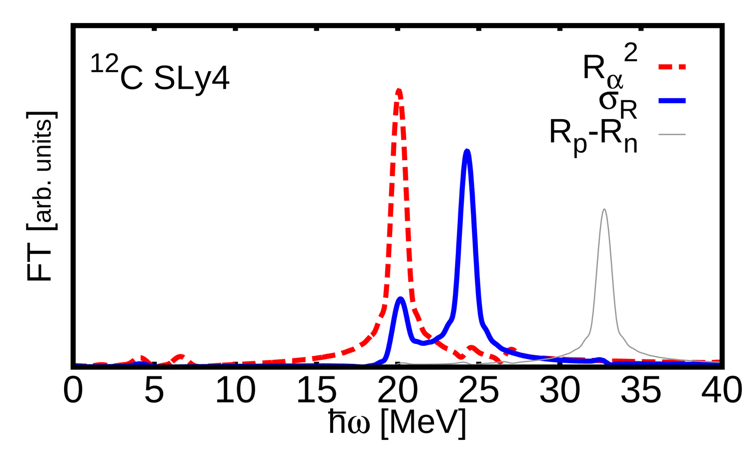
Motion of the Gaussian wave packets in the phase space



- Only one type of monopole vibrations for the wide widths
  $\Longrightarrow$ The frequencies decrease gradually with the amplitude
  $\Longrightarrow$ Potential with a single minimum
- Transition between two types of monopole vibrations for the narrow widths
  $\Longrightarrow$ The frequencies behave as if we have a potential with two minimums

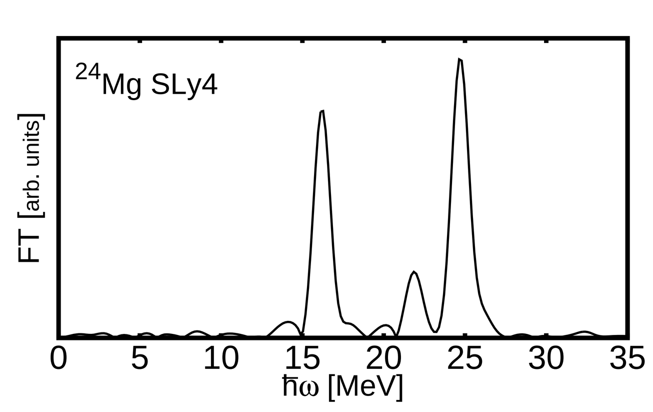
Influence of the width degree of freedom (FMD case)





- A second frequency appears for the FMD case
- There is only one regime : The crossing type
- $\sigma_R = \langle\Phi_\alpha|\hat{r}^2|\Phi_\alpha\rangle = \sum_{i=1}^4 \frac{3|a_i|^2}{2\Re(a_i)}$ where a_i is the dynamical width degree of freedom
- One frequency comes from the motion of the centroids
- The width degree of freedom contains the two frequencies
- The Isovector mode which is slightly exited

Other example with FMD



- Several frequencies can appear if the nuclei are light and structurally clusterized
- Example with ^{24}Mg : Three frequencies ($\hbar\omega$ = 16, 22 and 25.5 MeV)
- These three frequencies are seen to correspond with 3Be, 2Be+2α and 6α

Summary

- We studied the frequencies of the monopole vibrations for a wide range of amplitudes
- Interplay between the cluster structures and the monopole vibrations
- Only one mode is accessible for the AMD cases and a second frequency appears for the FMD cases because of the width degree of freedom
- http ://arxiv.org/abs/1006.3267 Submitted to Phys. Rev. C
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