Does monopole pigmy resonance exist in ^{68}Ni?

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Low-energy dipole strengths may increase radiative neutron capture cross section and affect strongly r-process nucleosynthesis.

Pigmy dipole strength observed at much lower energy that IVGDR (Ex~15MeV)

Pigmy dipole strength is increased in neutron-rich nuclei.

oscillation between neutron skin and core?

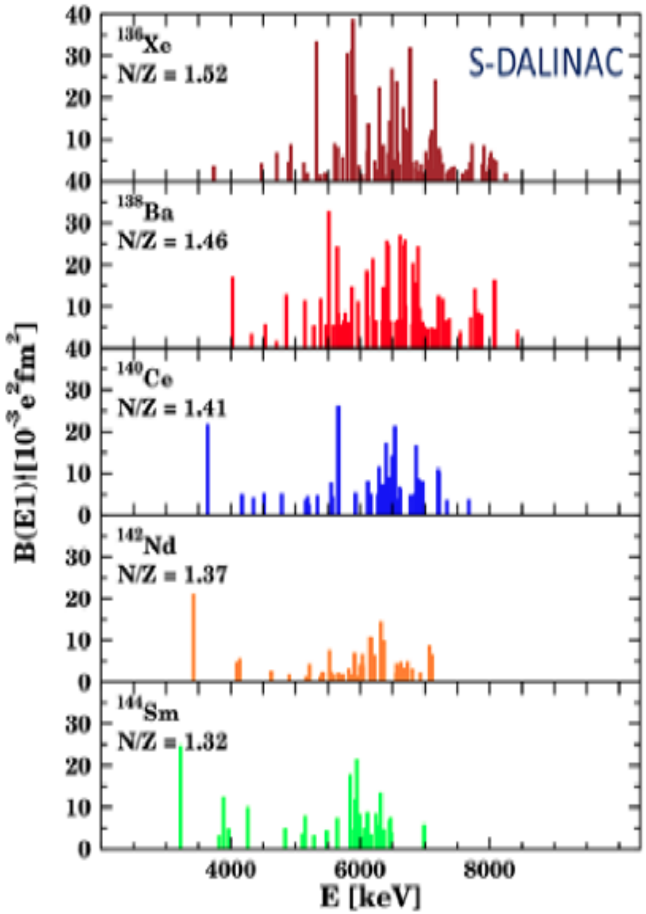
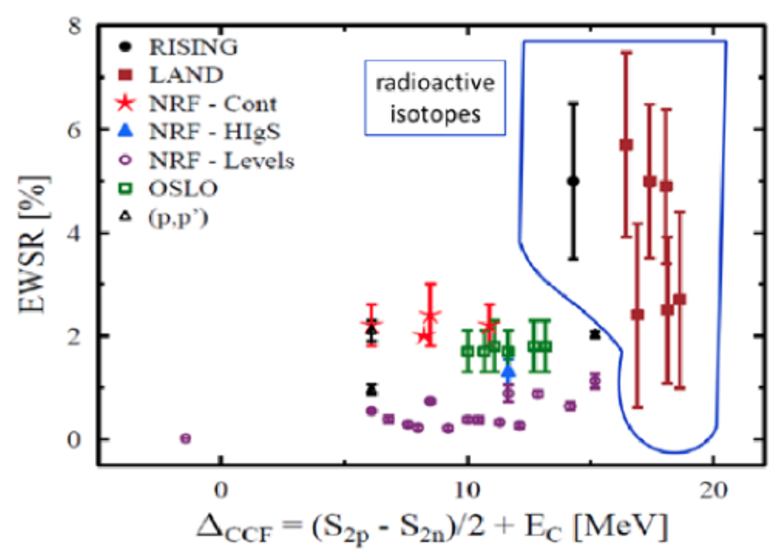


Figure 1: E1 strength distribution observed in discrete transitions to the groundstate in the stable even-even N=82 isotones (adapted from Refs. 14 and 15).

Andreas Zilges[1,a] and Deniz Savran[2,3]



Measurement of the isoscalar monopole response in the neutron-rich nucleus ^{68}Ni

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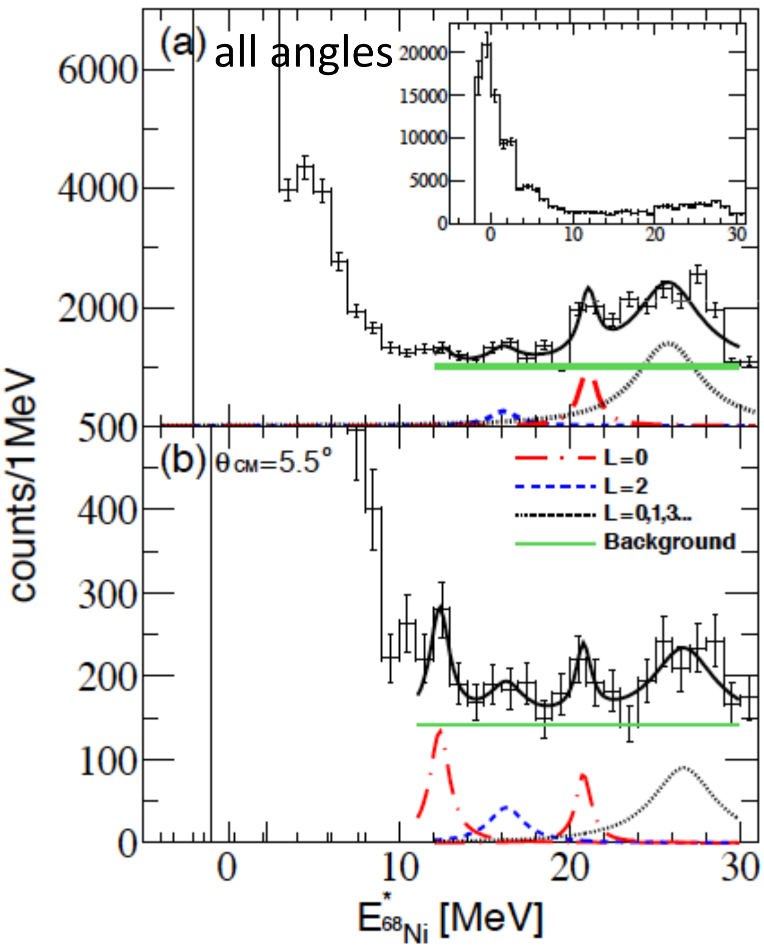
PRL113, 032504(2014)

alpha scattering at 50A MeV in inverse kinematics with the active target MAYA at GANIL



Low-energy monopole

ISGMR

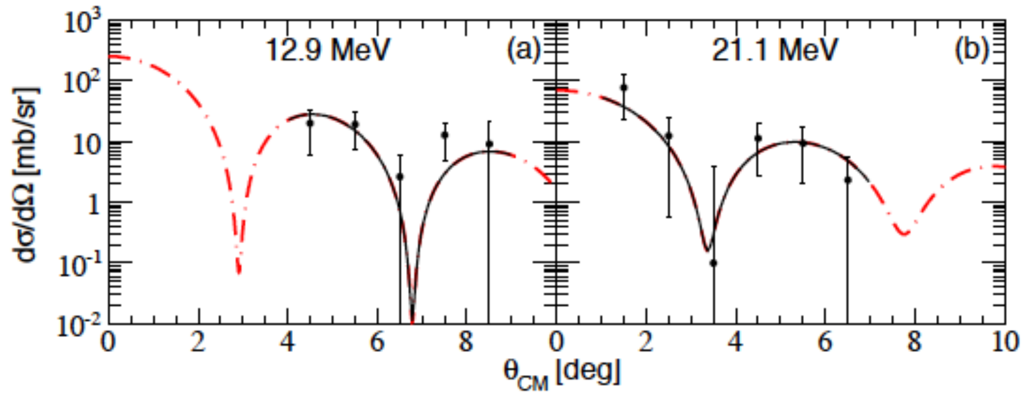


FIG. 3. (Color online) Angular distributions for the modes located at 12.9 MeV (a) and 21.1 MeV (b). The black solid line corresponds to the fit based on DWBA calculation using microscopic RPA predictions with isoscalar $L = 0$ multipolarity. Theses predictions are represented in red dot-dashed line.

Continuum coupling is properly accommodated in the response function (coordinate space solutions)

Unperturbed Green's function

$$G^{(0)}(\vec{r},\vec{r}';\omega)=\sum_{i\in occupied}\varphi_i^*(\vec{r})\left\langle\vec{r}\left|\frac{1}{\omega+i\eta-h_0+\varepsilon_i}-\frac{1}{\omega-i\eta+h_0+\varepsilon_i}\right|\vec{r}'\right\rangle\varphi_i(\vec{r}')$$

where $\varphi_i(\vec{r})$ and ε_i are the HF single particle wave function and energy

$$h_0\varphi_i(\vec{r})=\varepsilon_i\varphi_i(\vec{r})$$

RPA Green's function is given by

$$G^{\mathrm{RPA}}=G^{(0)}+G^{(0)}\frac{\delta v}{\delta\rho}G^{\mathrm{RPA}}=(1-G^{(0)}\frac{\delta v}{\delta\rho})^{-1}G^{(0)}$$

Strength function

$$S(E)=\sum_n\left|\langle n\,|\,f(\vec{r})\,|\,0\rangle\right|^2\delta(E_n-E_0-E)$$

$$=\frac{1}{\pi}\int d\vec{r}_1\int d\vec{r}_2 f^*(\vec{r}_1)\,\mathrm{Im}\{G(\vec{r}_1,\vec{r}_2;\omega)\}f\ (\vec{r}_2)$$

$f(r)=\frac{1}{\sqrt{4\pi}}\sum_i r_i^2$ for isoscalar monopole strength.

The inverse operator equation can be solved as

$$\left\langle \vec{r} \left| \frac{1}{h_0 - \varepsilon_i \pm \omega - i\eta} \right| \vec{r}' \right\rangle = \sum_{ljm} Y^*_{ljm}(\hat{r},\sigma) Y_{ljm}(\hat{r}',\sigma) g_{lj}(r,r')$$

where

$$g_{lj}(r,r') = -\frac{2m^*(r)}{\hbar^2} \frac{1}{W(u,v)} u(r_<) v(r_>) \qquad \begin{cases} r_< = r, r_> = r' \text{ if } r < r' \\ r_< = r', r_> = r \text{ if } r \geq r' \end{cases}$$

and

$$(h_0 - \varepsilon_i \pm \omega) \begin{pmatrix} u \\ v \end{pmatrix} = 0$$

where u (v) is the regular (irregular) solution at the origin and u (v) behaves like a standing (outgoing) wave at infinity.

Continuum coupling is properly accommodated in the response function (coordinate space solutions)

Questions and Answers

1) Sharp resonance with the width of 1MeV exists for the monopole response near the threshold?

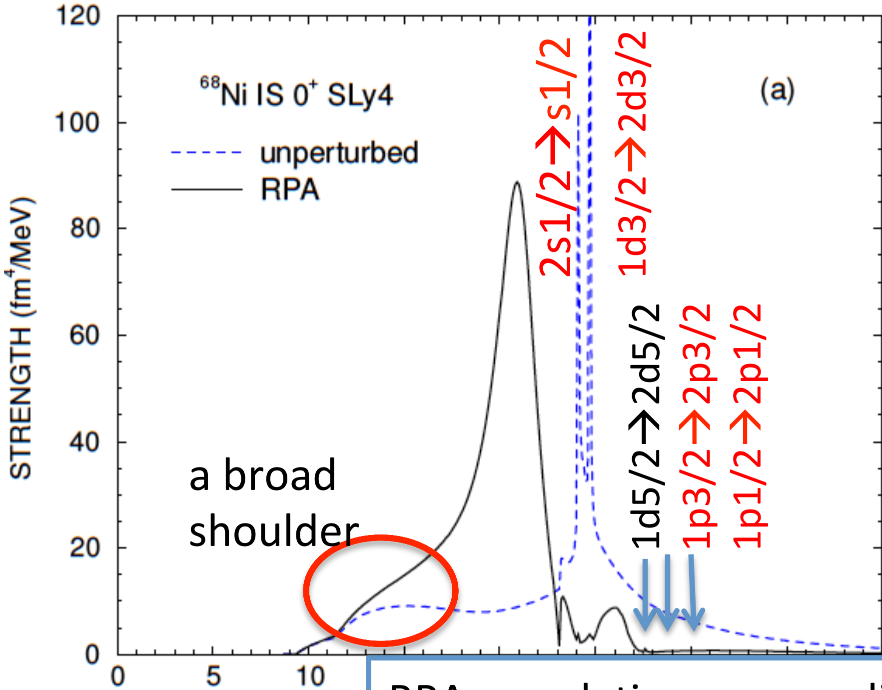
The answer is NO!

2) Spin-orbit splitting of the states near the threshold will be disappeared ?
(E. Yuksel et al., Eur. Phys. J. A49, 124(2013))

The answer is NO!

3) Threshold strength proportional to $(E-E_{threshold})^{l+1/2}$ appears in neutron-rich nuclei.

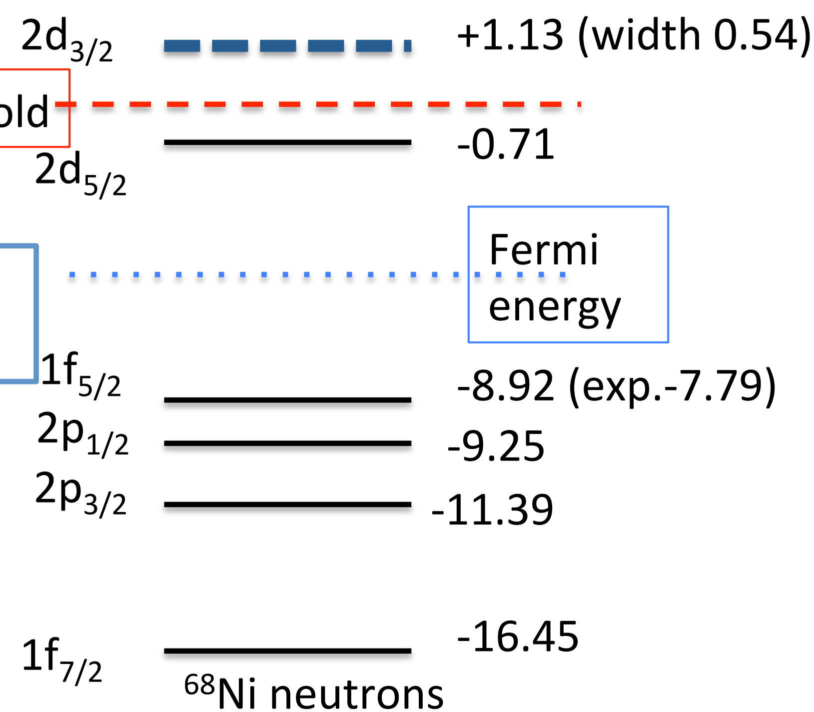
The answer is YES!



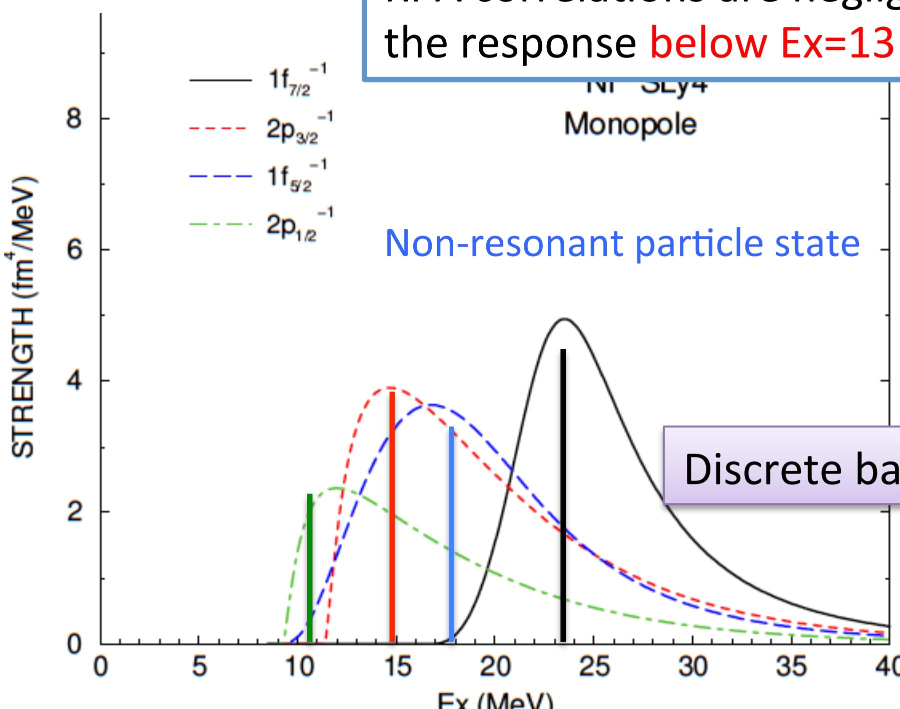
Red: proton p-h configuration

Black: neutron p-h configuration

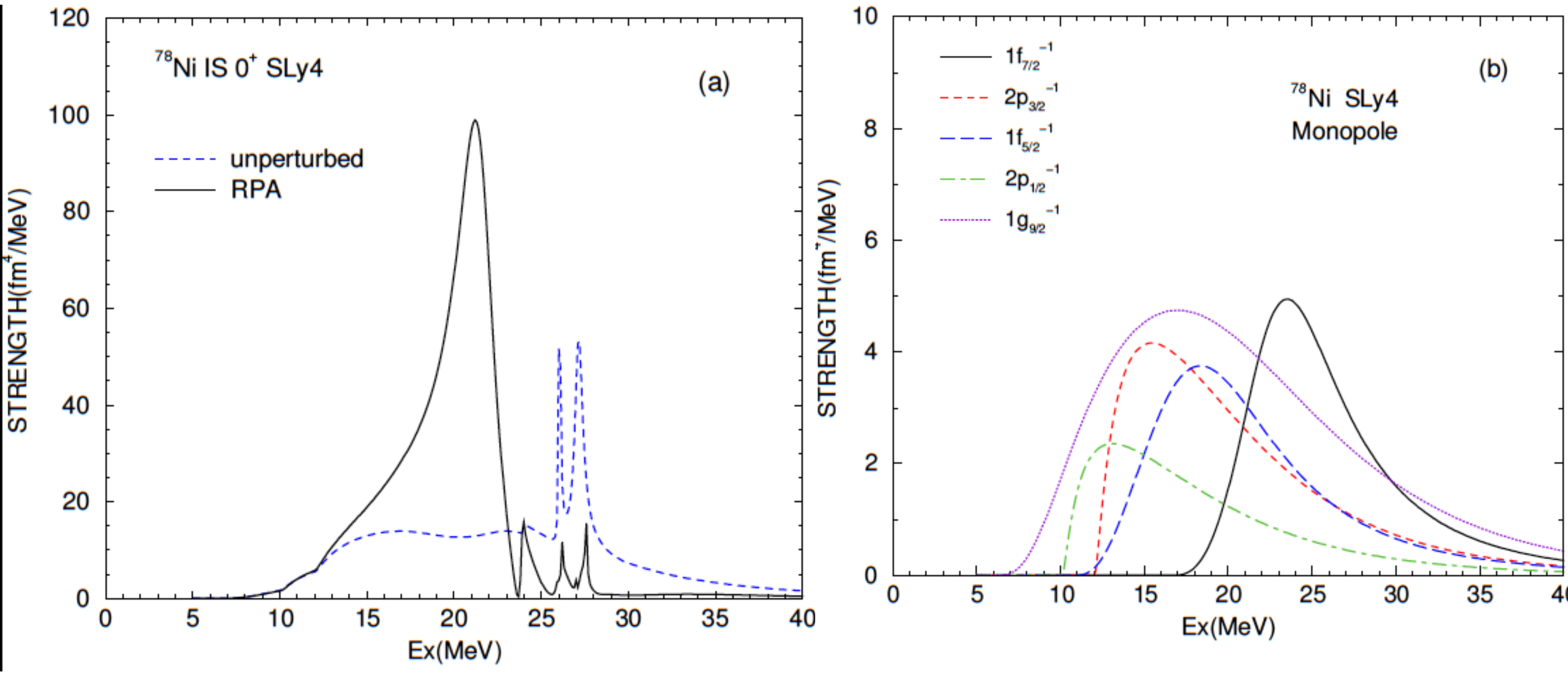
There is no unperturbed p-h states below Ex=20MeV, in which particle is either a bound or resonant state



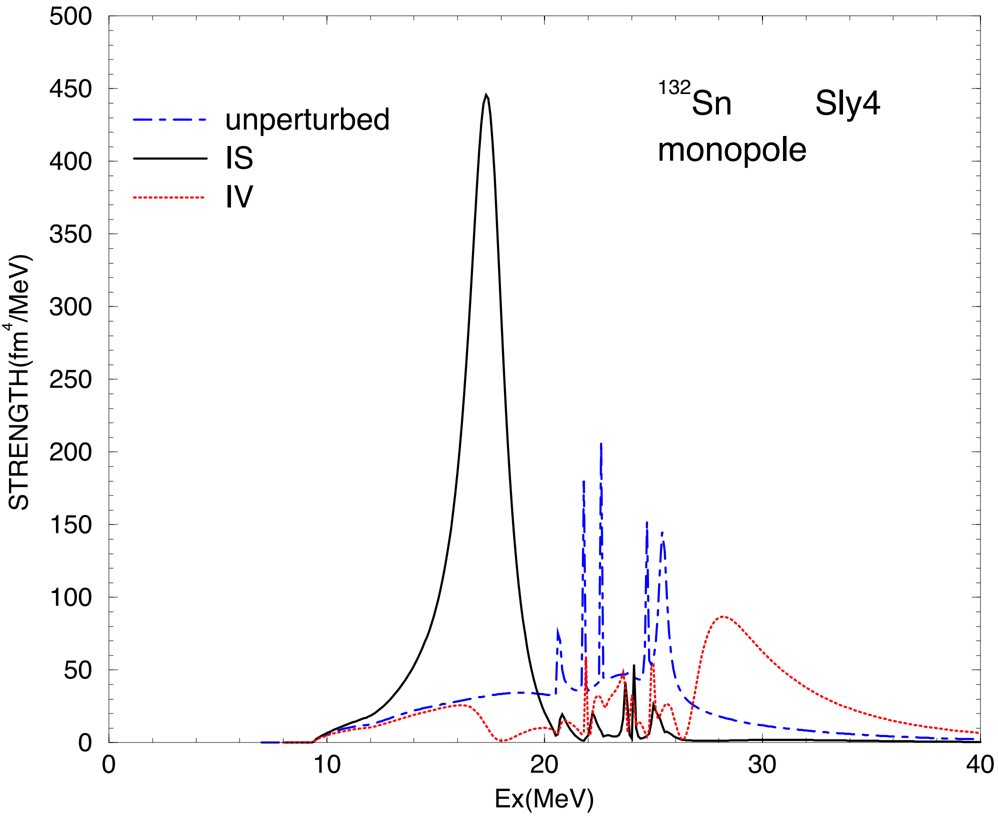
RPA correlations are negligible for the response below Ex=13MeV



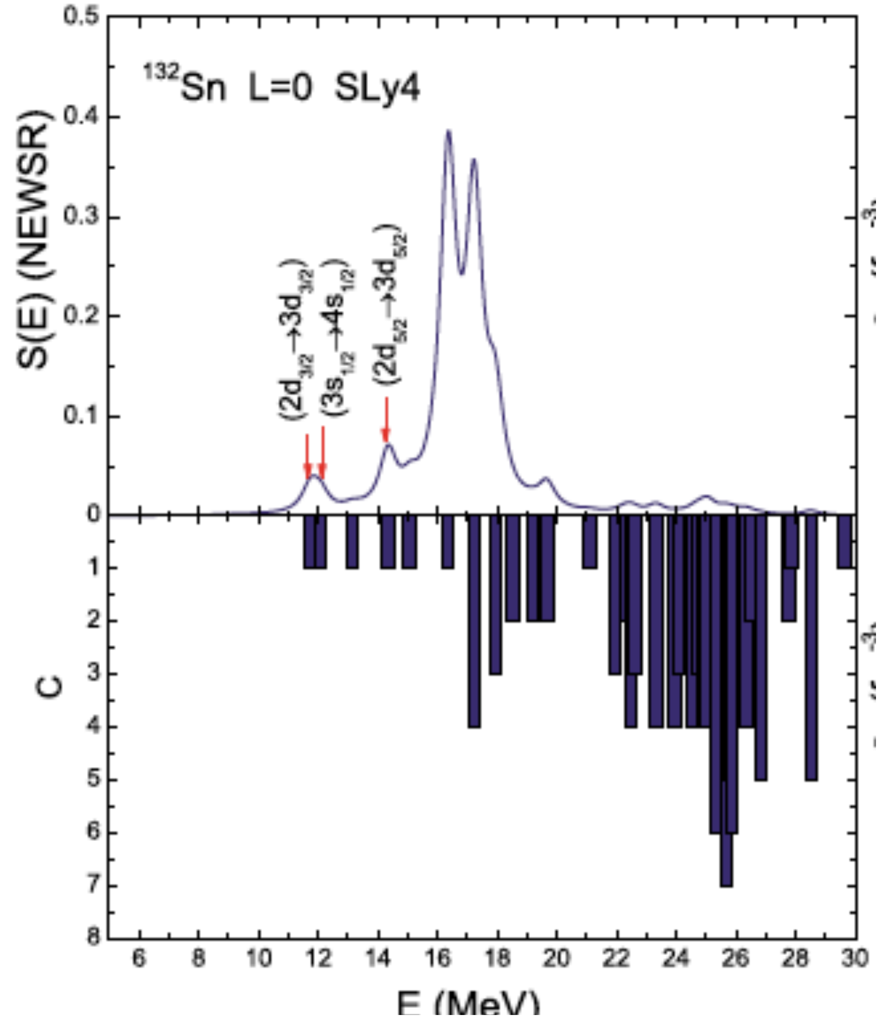
Phys. Rev. C90, 031302(R) (2014)



The continuum response of ^{78}Ni is the same as ^{68}Ni, except $1g_{9/2} \rightarrow$ continuum

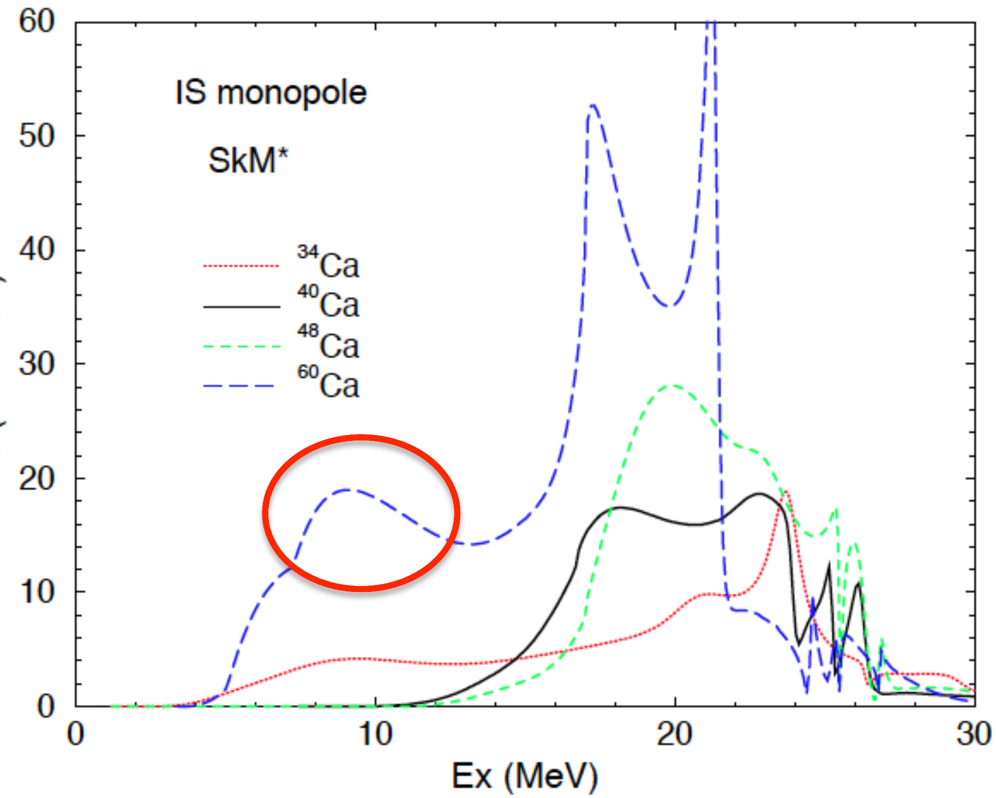


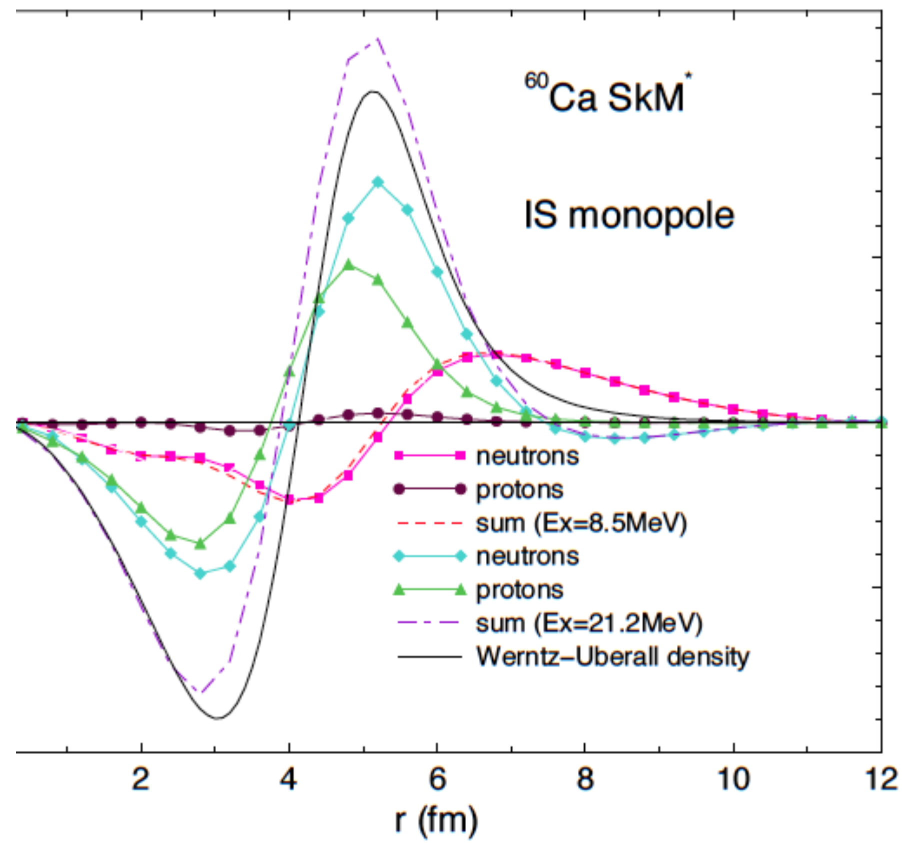
Continuum RPA: no smearing.



E. Yuksel et al.,Eur.Phys.J. A49, 124(2013)
RPA with discretized basis with smearing the strength

I. Hamamoto, H. Sagawa and X. Z. Zhang
Phys. Rev. C56, 3121(1997)

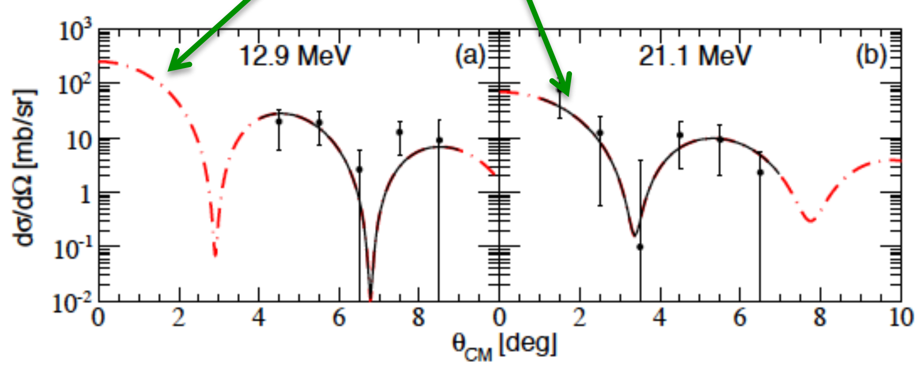




A broad bump appears as an oscillation of neutron skim against the core in ^{60}Ca.

Summary

1) Threshold continuum strength as a broad shoulder appears the monopole response less than Ex=15MeV in a neutron-rich nucleus ^{68}Ni.
2) No resonance state appears below E_x<20MeV.
3) Spin-orbit splitting should be discussed using resonance states.
4) Theoretically the proper treatment of the continuum effect is extremely important for the monopole excitations in neutron-rich nuclei.
5) To measure the cross sections at the forward angles is desperately needed to assign the monopole strength and excluding other multipoles.



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