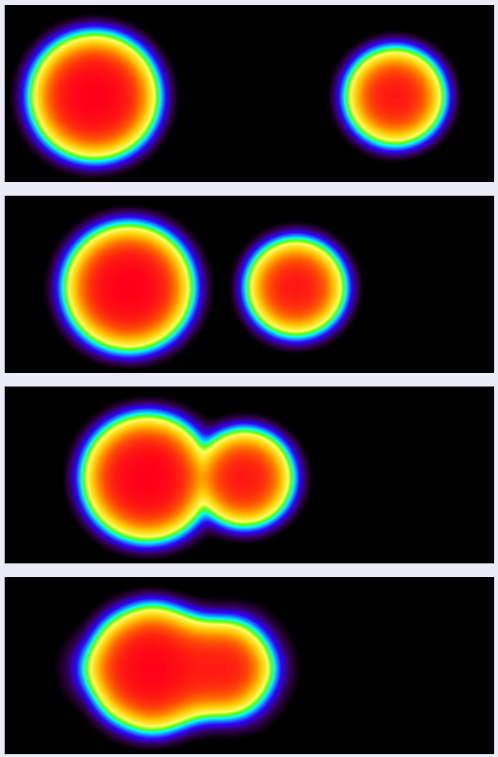
Assemblée génerale des theoriciens
de physique nucléaire 2013

Isovector and isoscalar giant quadrupole resonances in normal and superfluid nuclei



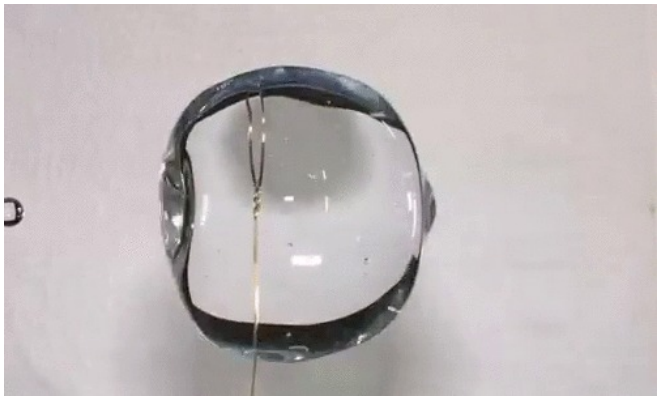
Guillaume SCAMPS

GANIL

December 18th 2013

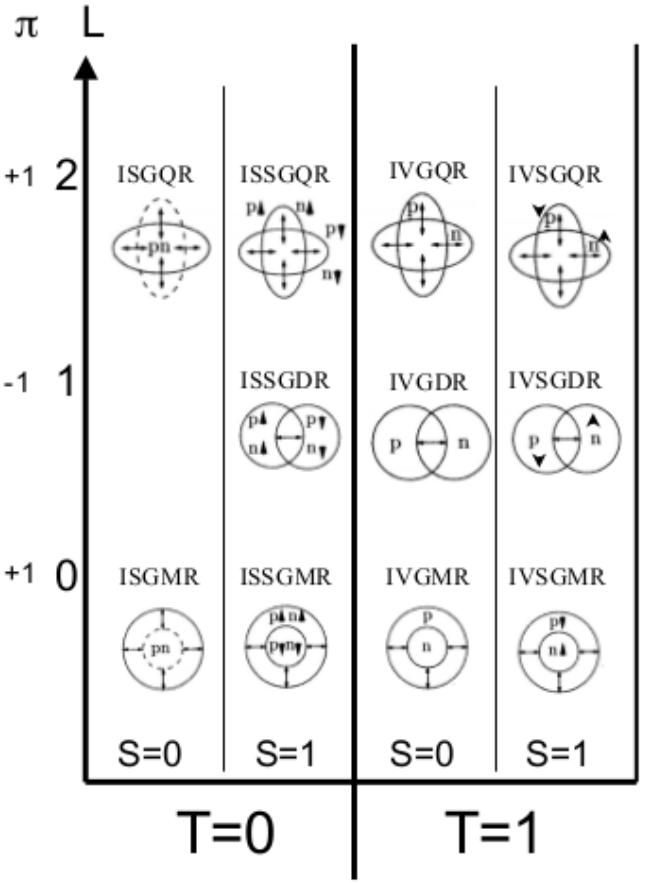
Collaboration : D. Lacroix, G. Bertsch, K. Washiyama, G.G. Adamian, N.V. Antonenko, V.V. Sargsyan

Giant resonances



Motivation

- Astrophysical interest
- Structure information (neutron skin, incompressibility,...)
- Constraint the interaction/functional
- Many-body problem challenge



Mean-field with pairing theory

TDHF / RPA

- Independent particle
- Initialisation : $\hat{h}_{MF} |\phi_i\rangle = \epsilon_i |\phi_i\rangle$
- Evolution :
  $i\hbar \frac{d\rho}{dt} = [h_{MF}, \rho]$

TDHFB / QRPA

- Pairing correlation
- Quasi-particles : $|\omega_\alpha\rangle = \begin{pmatrix} U_\alpha \\ V_\alpha \end{pmatrix}$
- Evolution :
  $i\hbar \frac{d|\omega_\alpha\rangle}{dt} = \begin{pmatrix} h & \Delta \\ -\Delta^* & -h^* \end{pmatrix} |\omega_\alpha\rangle$

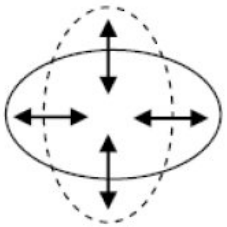
TDHF+BCS, S. Ebata et al. PRC 82 (2010)

- Based on TDHFB with the approximation : $\Delta_{ij} = \delta_{ij}\Delta_i$
- Evolution : $i\hbar \frac{d\phi_i}{dt} = (\hat{h}_{MF} - \epsilon_i)\phi_i$

$$i\hbar \frac{dn_i}{dt} = \Delta_i^* \kappa_i - \Delta_i \kappa_i^*$$

$$i\hbar \frac{d\kappa_i}{dt} = \kappa_i(\epsilon_i - \epsilon_{\bar{i}}) + \Delta_i(2n_i - 1)$$

Giant Quadrupole Resonances



Initial excitation

$$|\Psi(0+)\rangle = e^{i\eta V(\mathbf{r})}|\Psi(0)\rangle$$

$$V(\mathbf{r},t) = -\eta F_{20}(\mathbf{r})\delta(t)$$

$$F_{20}(\mathbf{r}) = r^2 Y_{20}(\mathbf{r})$$

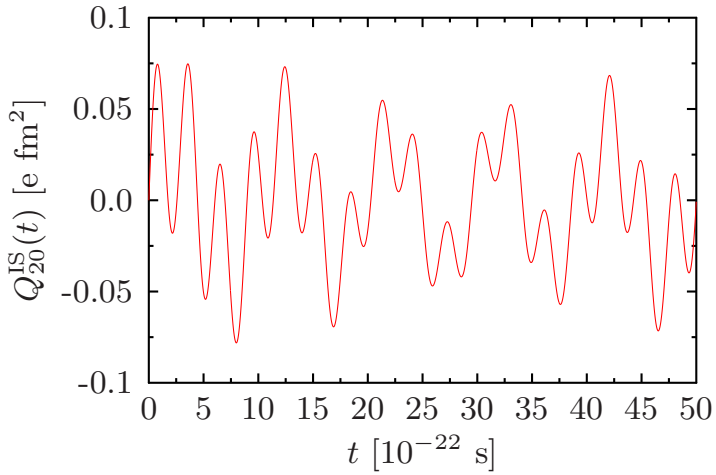
Computation of the strength function

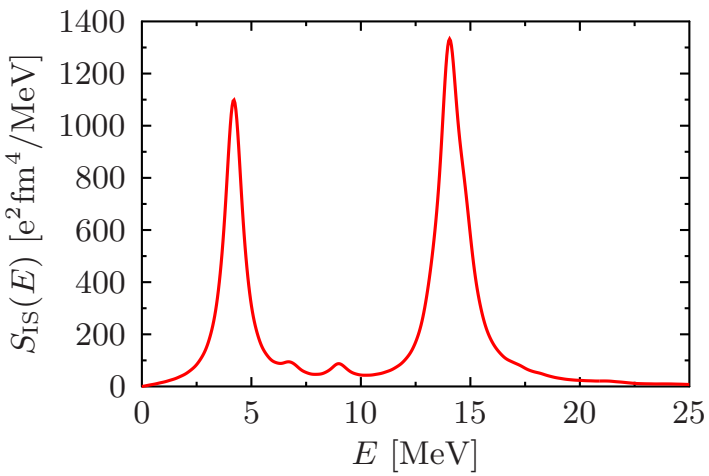
$$S(E) = \frac{-1}{\pi\ \eta}\mathrm{Im}[\mathcal{F}(\mathrm{E})]$$

With $\mathcal{F}(E)$ the Fourier transform of the function,

$$f(t) = \langle\Psi(t)|\hat{F}|\Psi(t)\rangle$$

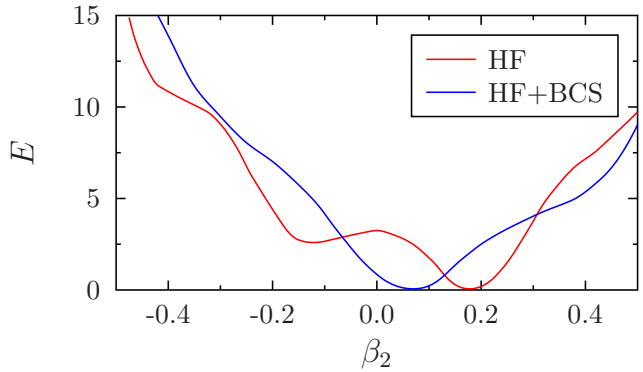
Ex : ^{132}Sn, G. Scamps and D. Lacroix PRC 88, 044310 (2013)

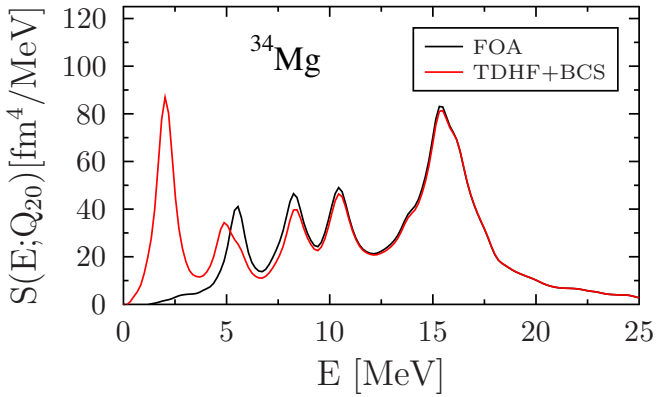




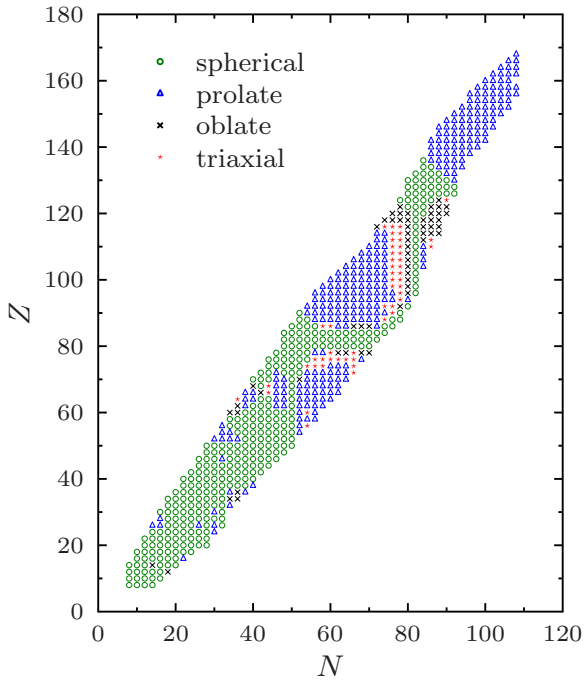
Global study with TDHF+BCS

Influence of pairing



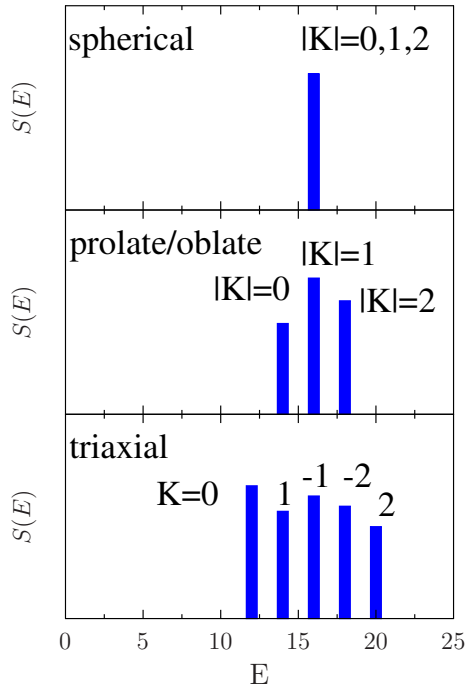


→Principal influence of pairing on the initial state



Goal of our study

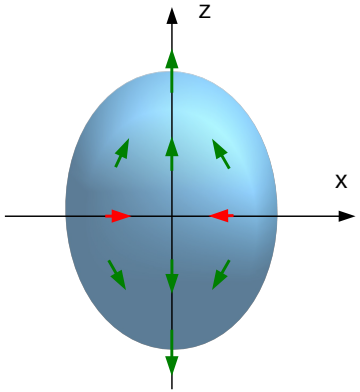
- Validate the TDHF+BCS approach
- Global study over all the chart



Systematic of isoscalar and isovector giant quadrupole resonances in deformed nuclei

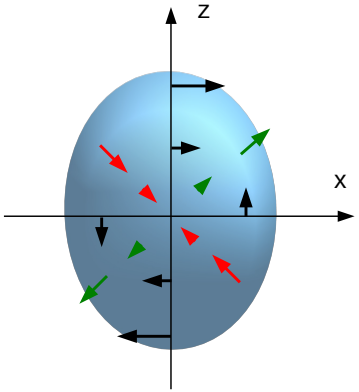
K=0

$$d^{K=0}_{z^2} = Y_{20} = \sqrt{\frac{5}{16\pi}}\,\frac{2z^2 - x^2 - y^2}{r^2}$$



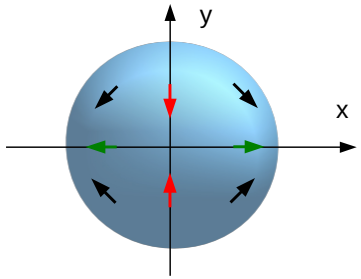
K=1

$$d^{|K|=1}_{xz} = \frac{Y_{2-1} - Y_{21}}{\sqrt{2}} = \sqrt{\frac{15}{4\pi}}\,\frac{xz}{r^2}$$



K=2

$$d^{|K|=2}_{x^2-y^2} = \frac{Y_{2-2} + Y_{22}}{\sqrt{2}} = \sqrt{\frac{15}{16\pi}}\,\frac{x^2 - y^2}{r^2}$$

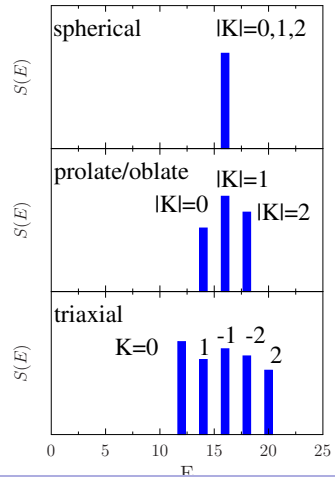


K=1

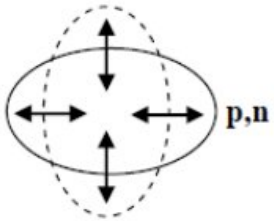
$$d^{|K|=1}_{yz} = \frac{i}{\sqrt{2}}\left(Y_{2-1} + Y_{21}\right) = \frac{1}{2}\sqrt{\frac{15}{\pi}}\,\frac{yz}{r^2}$$

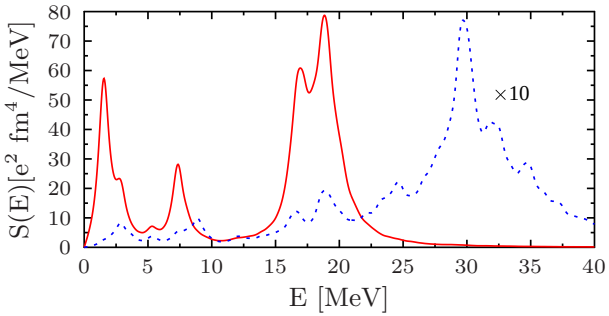
K=2

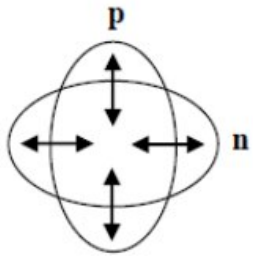
$$d^{|K|=2}_{xy} = \frac{i}{\sqrt{2}}\left(Y_{2-2} - Y_{22}\right) = \frac{1}{2}\sqrt{\frac{15}{\pi}}\,\frac{xy}{r^2}$$



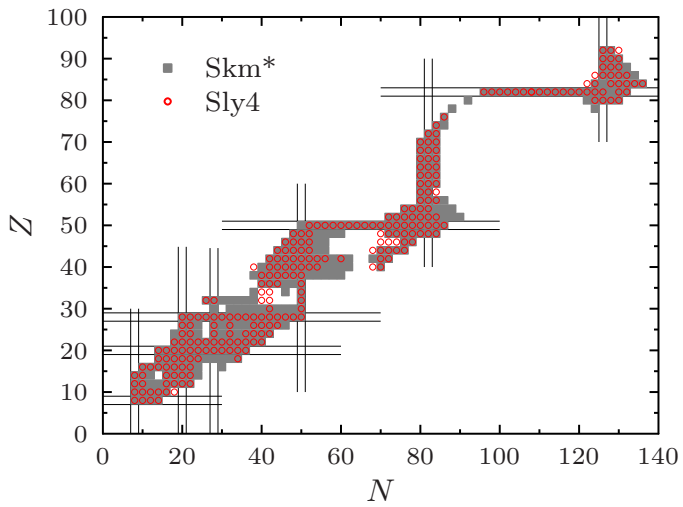
Systematic of isoscalar and isovector giant quadrupole resonances in spherical nuclei ($\sim$ 300 nuclei)





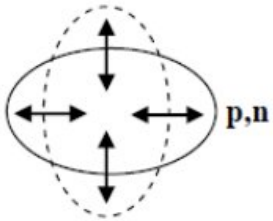


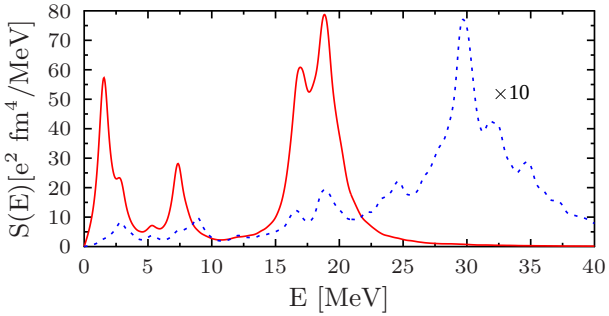
spherical nuclei

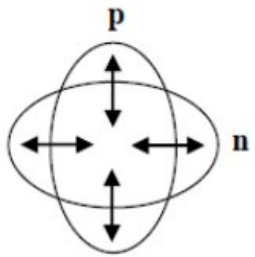


G. Scamps and D. Lacroix, Phys. Rev. C 88, 044310 (2013)

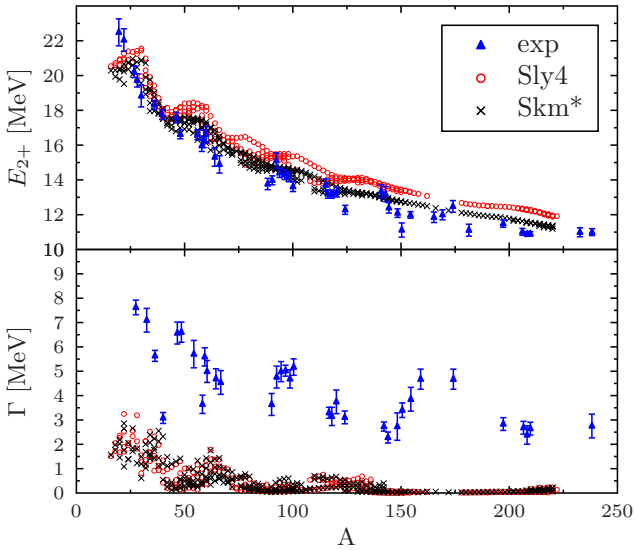
Systematic of isoscalar and isovector giant quadrupole resonances in spherical nuclei ($\sim$ 300 nuclei)



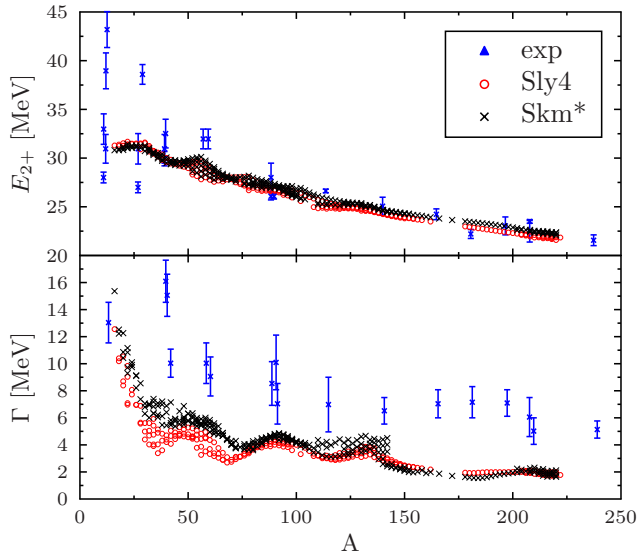




ISGQR

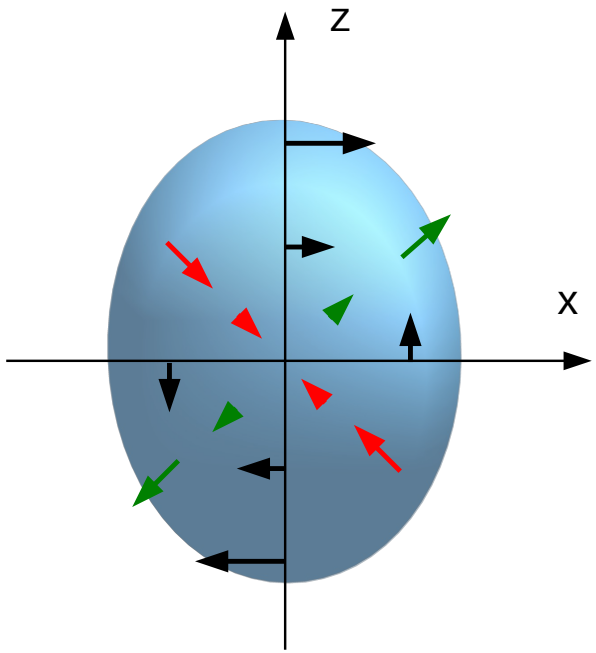


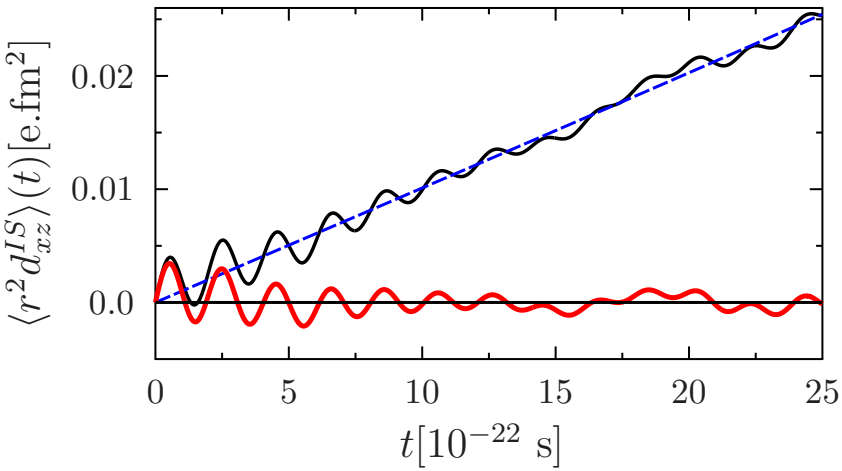
IVGQR

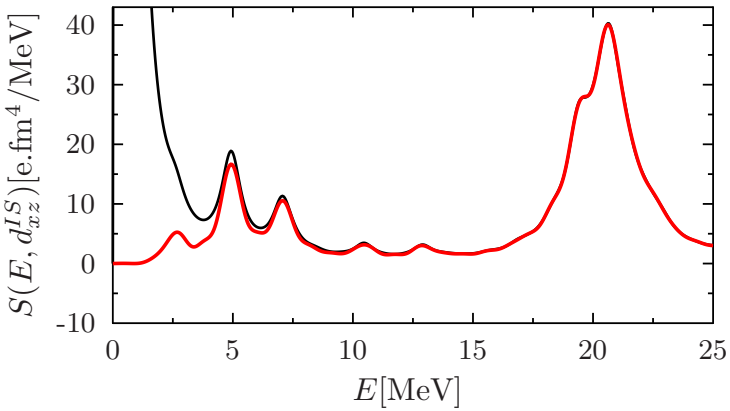


G. Scamps and D. Lacroix, Phys. Rev. C 88, 044310 (2013)

Spurious rotation with |K|=1



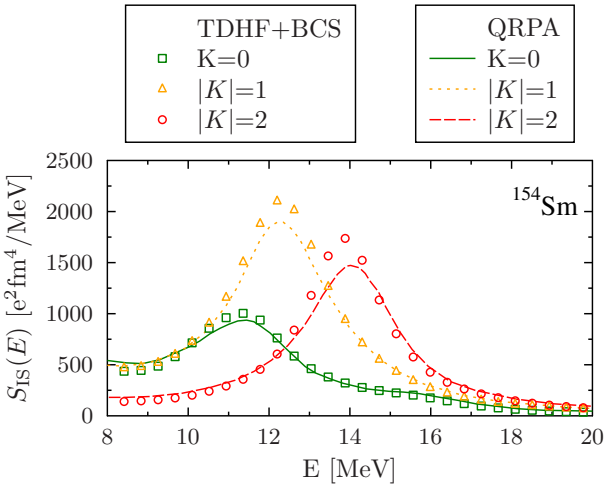




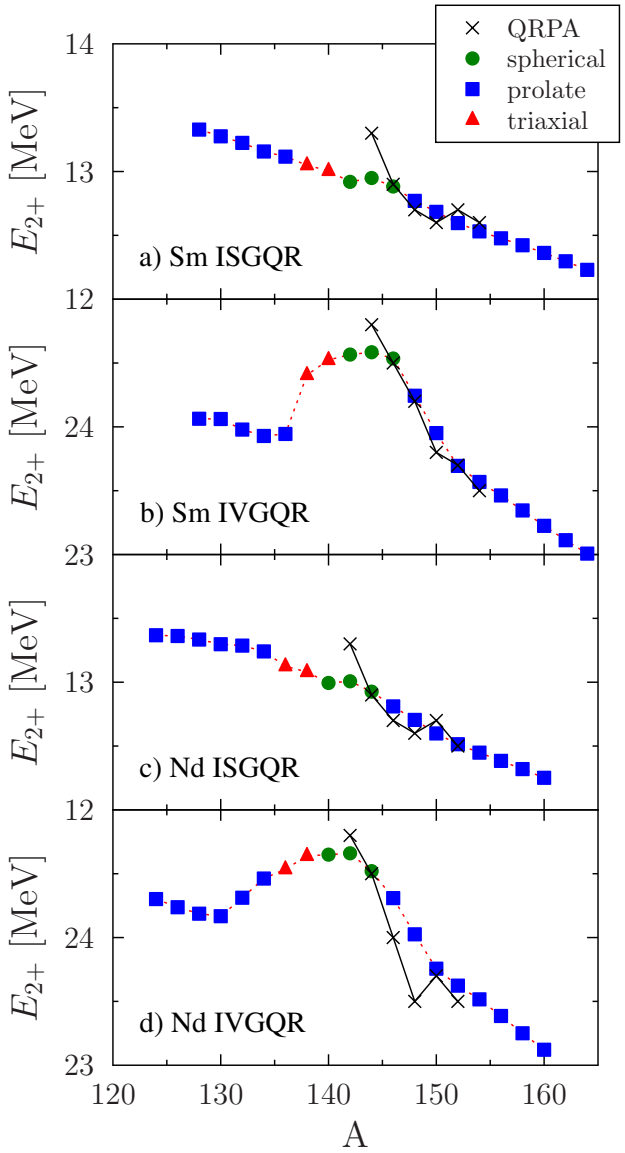
Conclusion

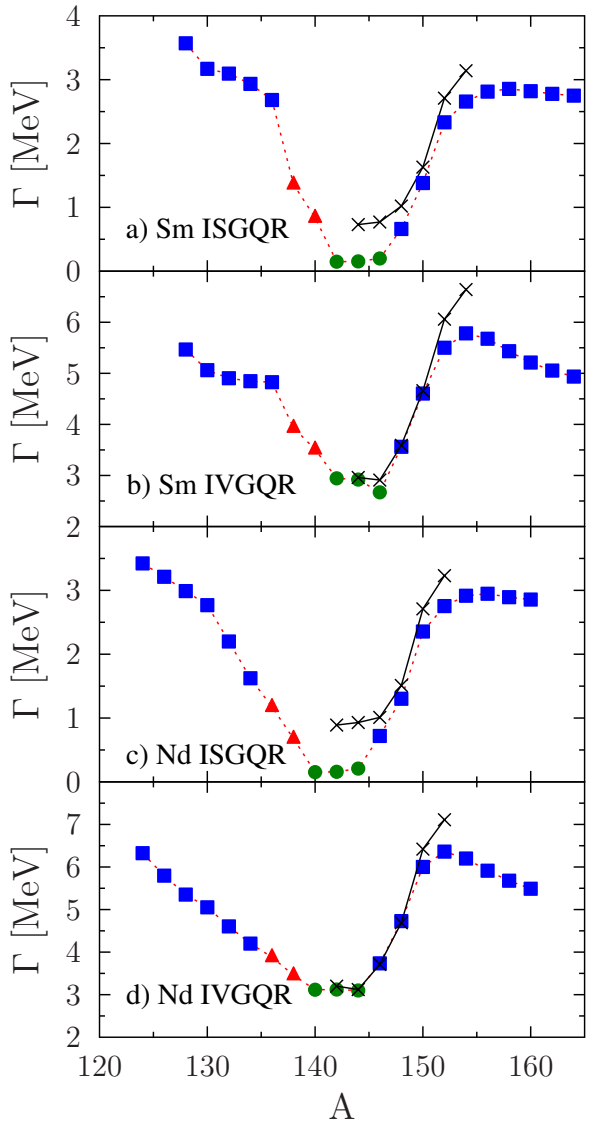
- Simple and efficient method
- No effect on the high energy peaks

Comparison with QRPA



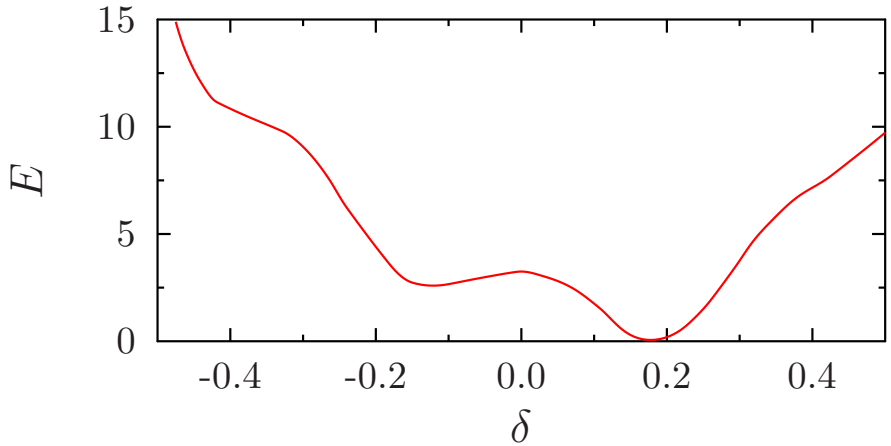
K. Yoshida and T. Nakatsukasa, Phys. Rev. C 88, 034309 (2013)

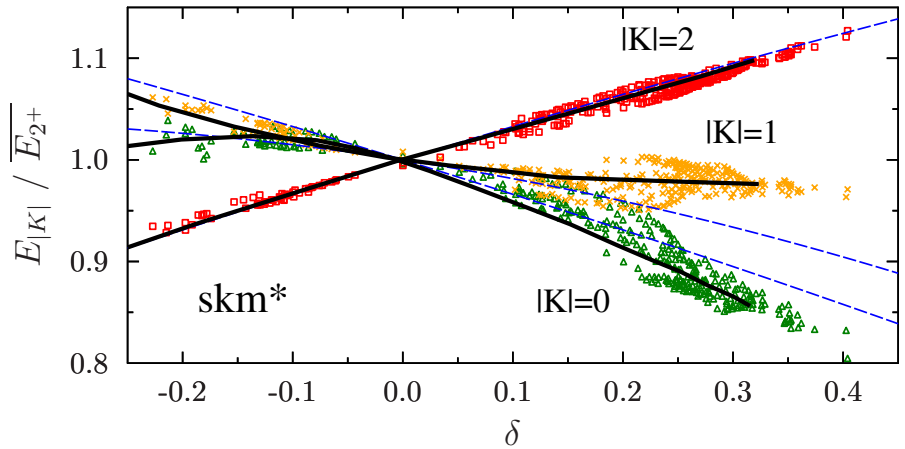




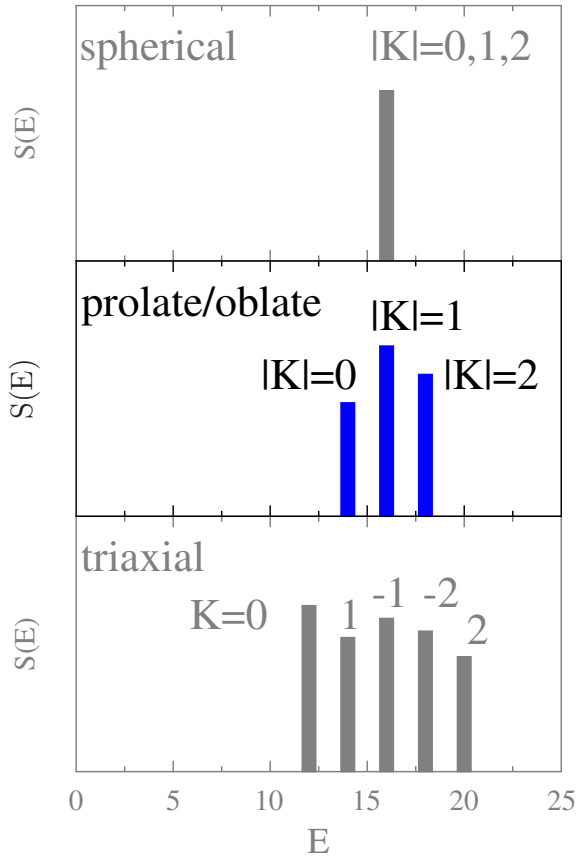
Conclusion : Very good agreement between TDHF+BCS and QRPA

Effect of axial deformation





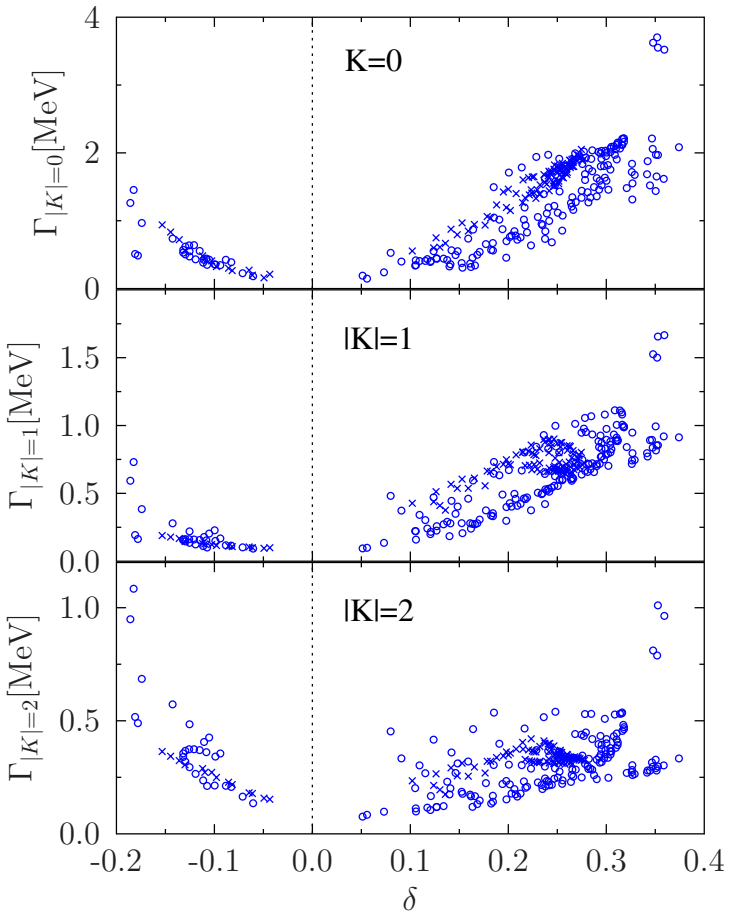
$$\delta = \frac{3Q_0}{4A\langle r \rangle}$$



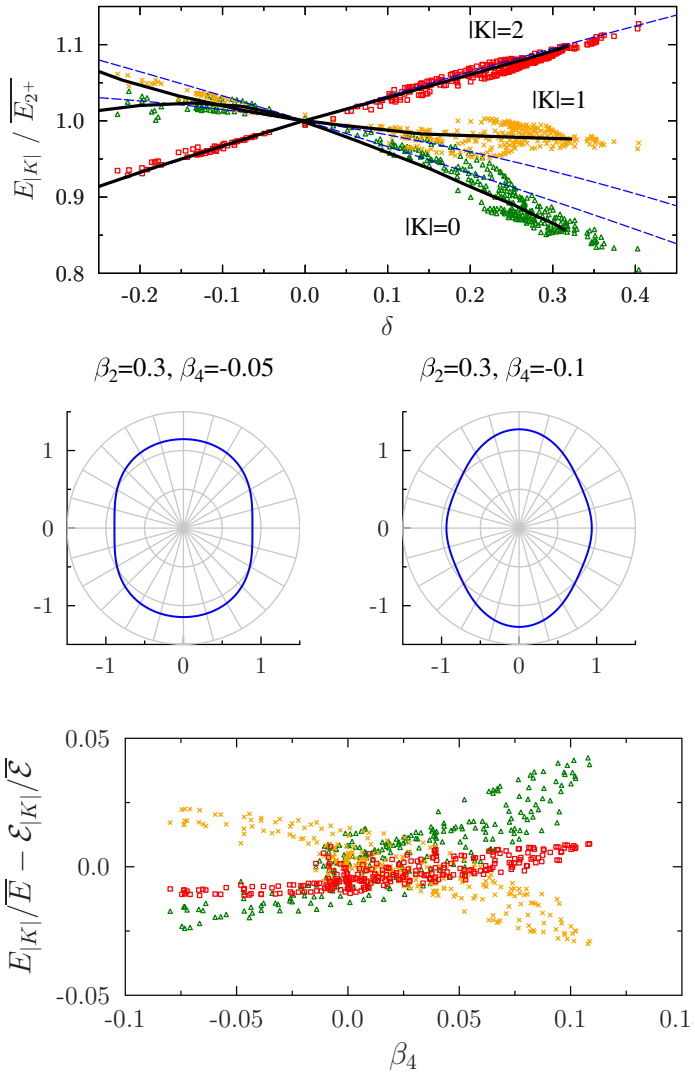
S. Nishizaki and K. Ando, Prog. of Theo. Phys. 73, 4 (1985).

Complex aspects of the influence of axial deformation

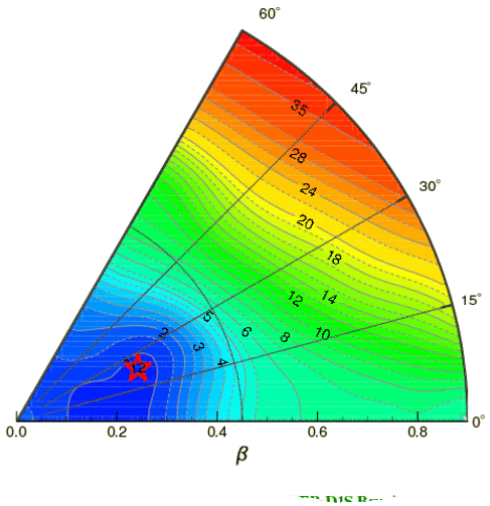
Width of the K components

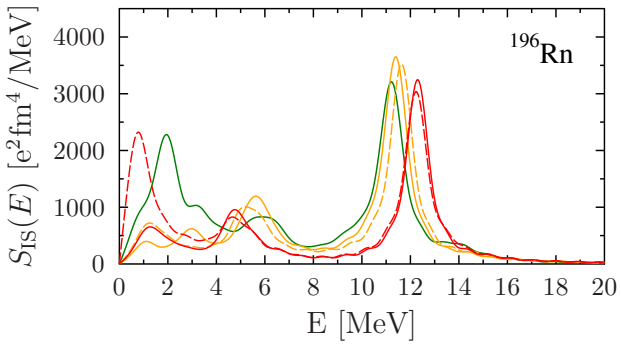


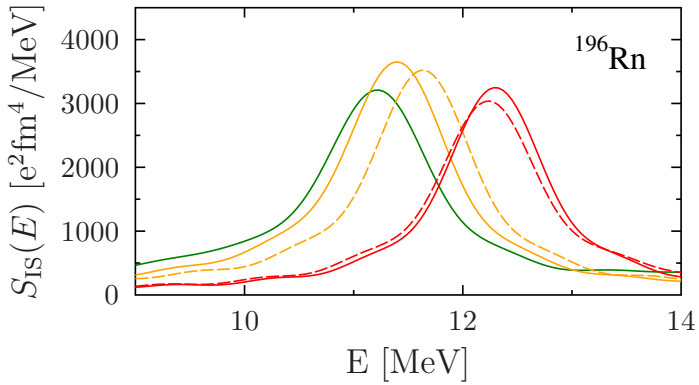
Higher multipolarity

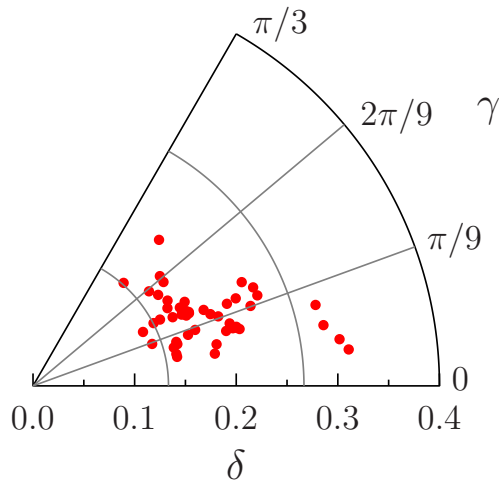


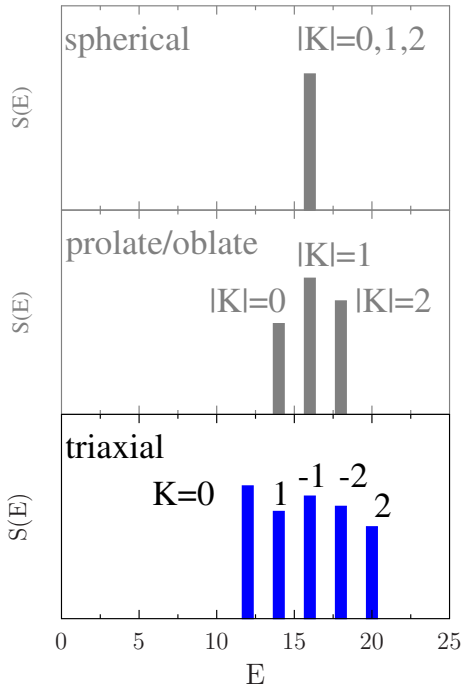
Effect of triaxial deformation

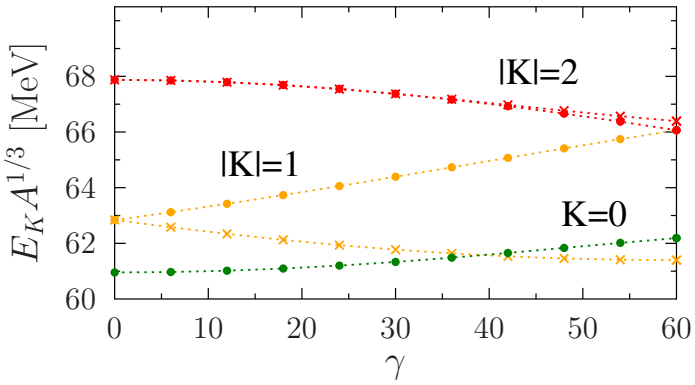


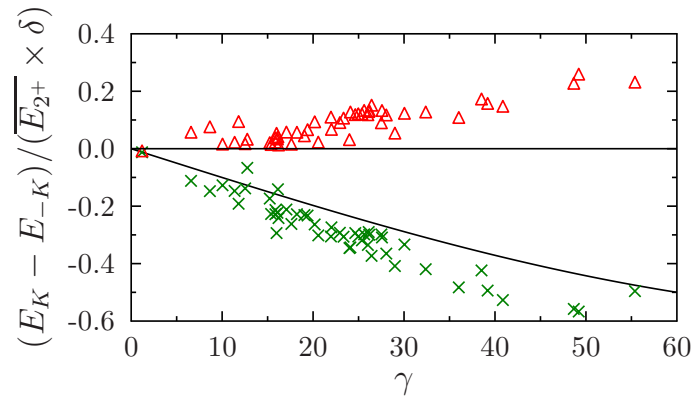












Conclusions and Outlook

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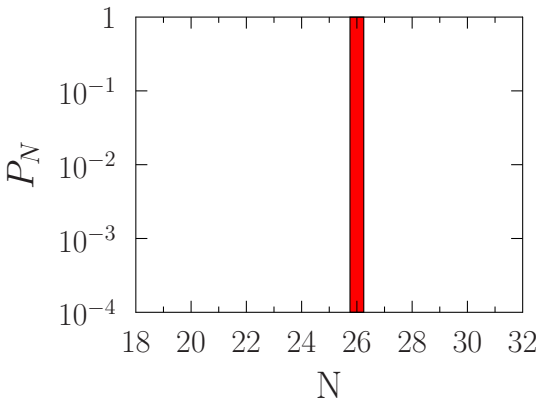
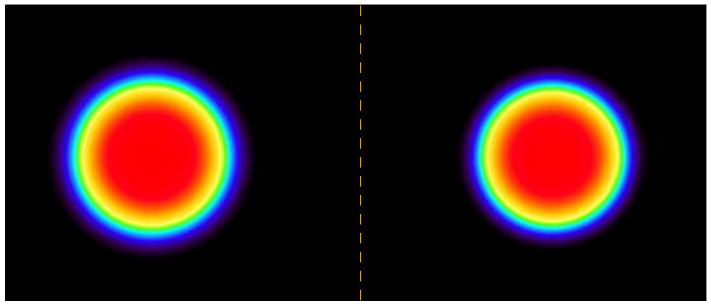
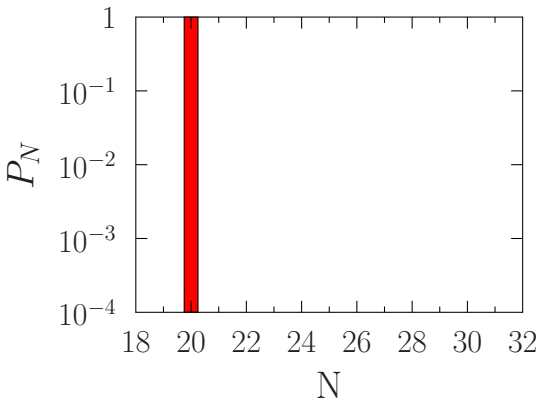
- TDHF+BCS is comparable to QRPA
- Good comprehension of the effect of deformation on giant quadrupole resonances (article in preparation)

Other study with TDHF+BCS : Transfer/fusion reaction







G. Scamps and D. Lacroix, PRC 87, (2013)

Outlook : Understanding of the width of the GQR

- Stochastic mean-field dynamics including pairing
- Time dependent density matrix
- Time dependent multi-determinant methods

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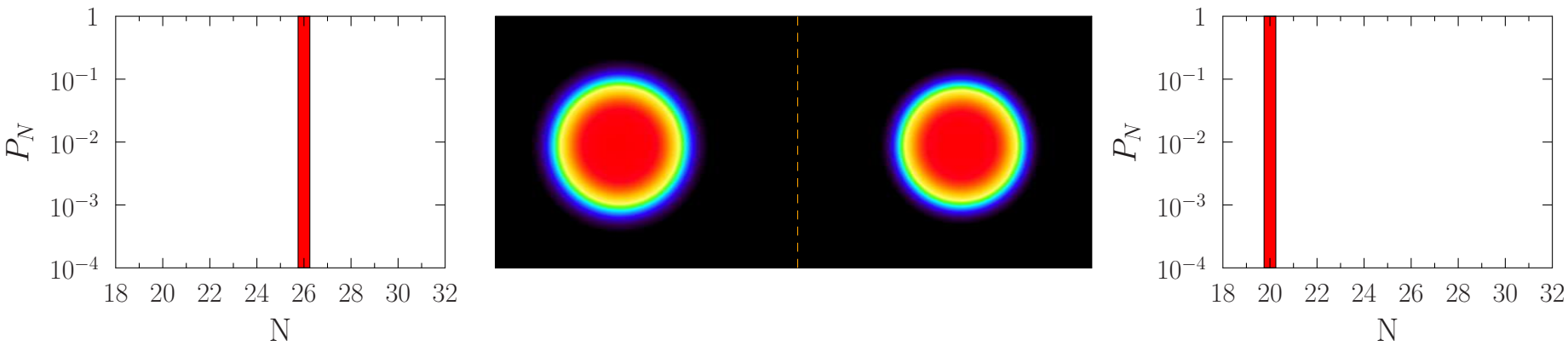

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Thank You !