The time-dependent Hartree-Fock approach

$$i\hbar\frac{d}{dt}|\varphi_i(t)\rangle = \hat{h}[\rho]|\varphi_i(t)\rangle \quad \text{for } i = 1, 2 \cdots N$$

ex: vibrations induced by an external excitation

TDHF: *practical aspects*

TDHF calculations

Evolution operator $\left|\varphi_i(t)\right\rangle \neq \exp(-i\hat{h}t)\left|\varphi_i(0)\right\rangle$

because $\hat{h}[\rho(t)]$ **is time dependent**

We assume $\hat{h} \equiv Cst$ **between** t **and** $t+\Delta t$

$$\left|\varphi_i(t+\Delta t)\right\rangle \approx \exp\left[-i\,\tfrac{\Delta t}{\hbar}\,\hat{h}(t+\tfrac{\Delta t}{2})\right] \quad \left|\varphi_i(t)\right\rangle$$

TDHF: *practical aspects*

TDHF calculations

algorithm (order 2 Runge-Kutta)

$$\{|\varphi_1^{[n]}\rangle \cdots |\varphi_N^{[n]}\rangle\} \quad \Rightarrow \quad \rho^{[n]} \quad \Rightarrow \quad \hat{h}^{[n]} \equiv \hat{h}[\rho^{[n]}]$$

$$\Uparrow \qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad \Downarrow$$

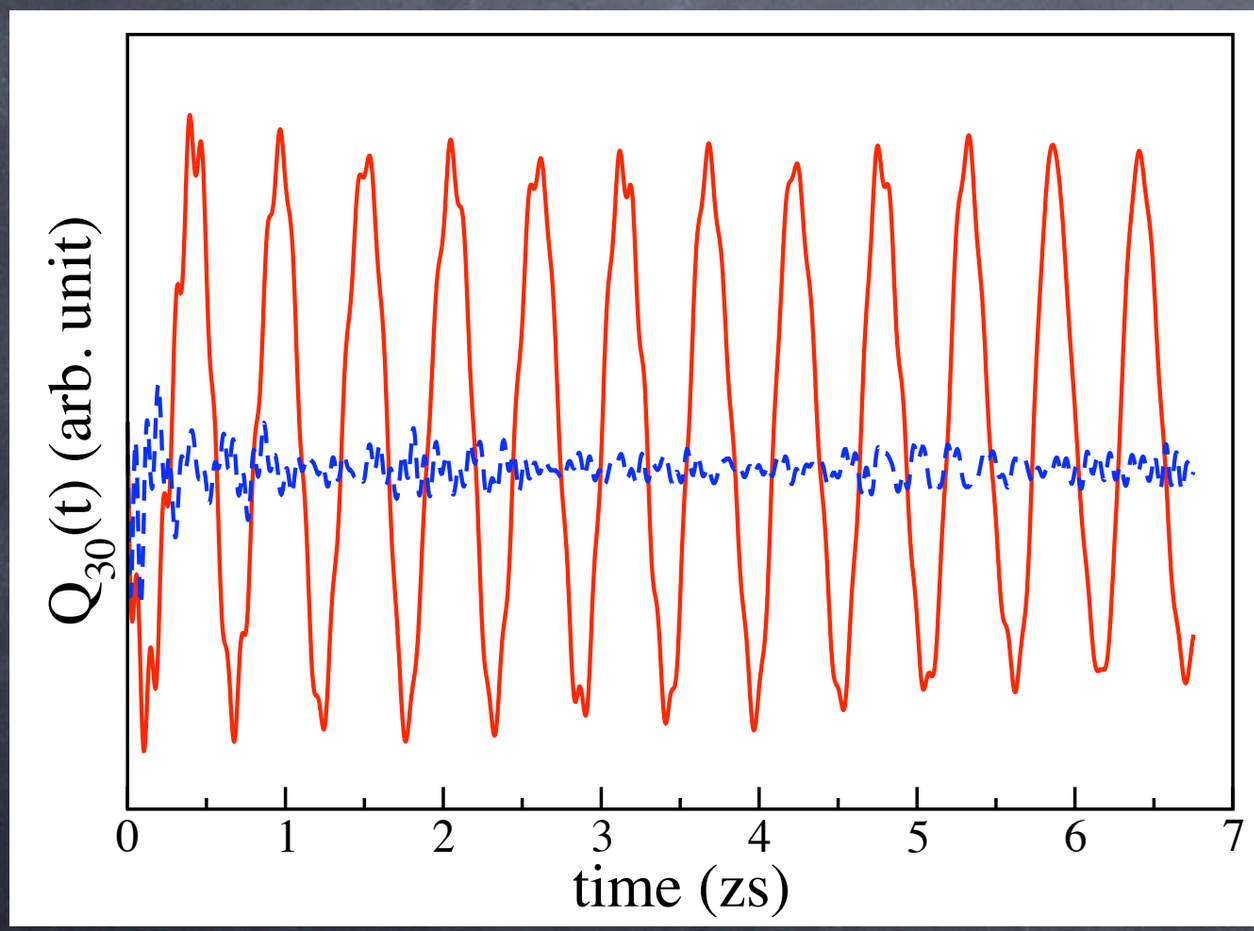
$$|\varphi_i^{[n+1]}\rangle = e^{-i\frac{\Delta t}{\hbar}\,\hat{h}^{[n+\frac{1}{2}]}}\,|\varphi_i^{[n]}\rangle \qquad\qquad |\tilde{\varphi}_i^{[n+1]}\rangle = e^{-i\frac{\Delta t}{\hbar}\,\hat{h}^{[n]}}\,|\varphi_i^{[n]}\rangle$$

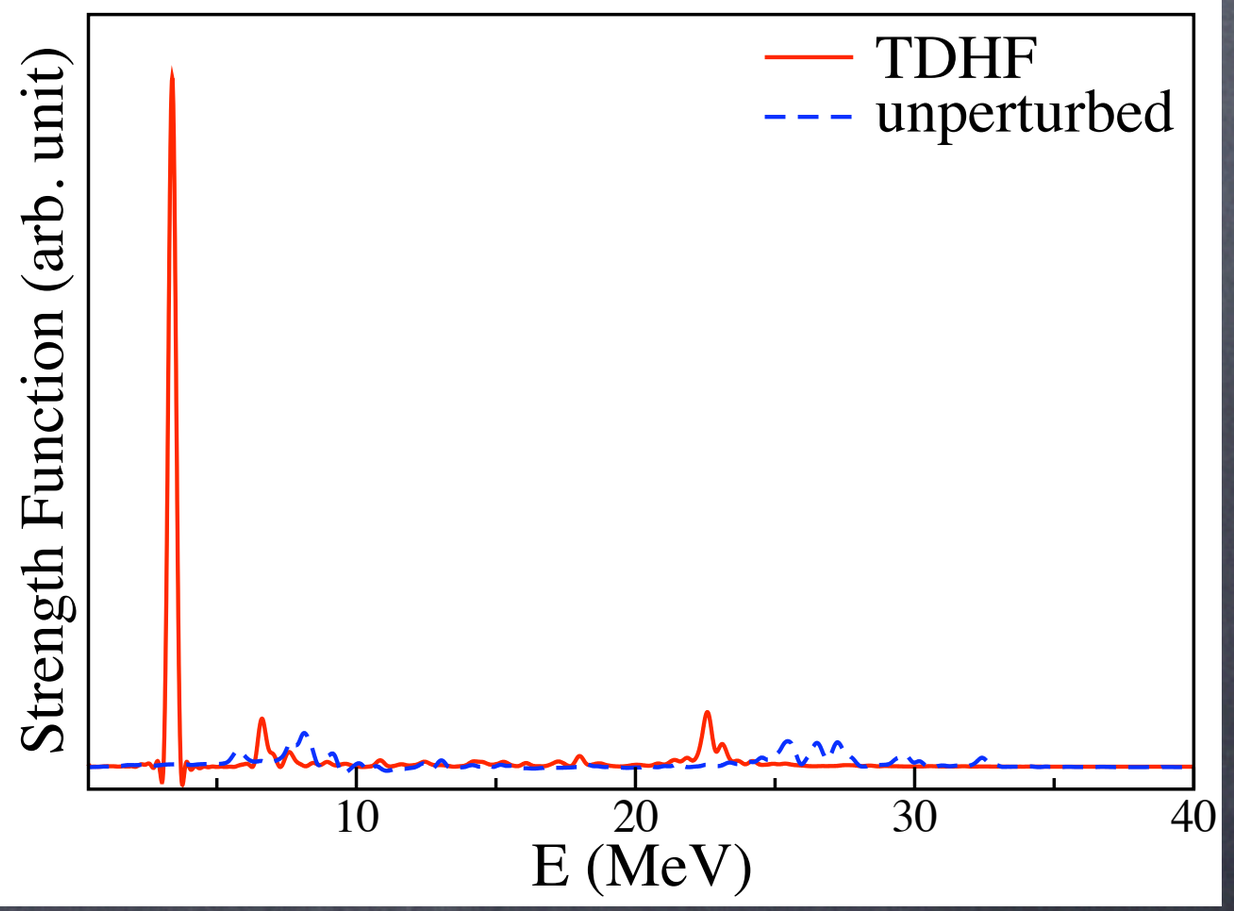
$$\Uparrow \qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad \Downarrow$$

$$\hat{h}^{\left[n+\frac{1}{2}\right]} \equiv \hat{h}\left[\rho^{\left[n+\frac{1}{2}\right]}\right] \quad \Leftarrow \quad \rho^{\left[n+\frac{1}{2}\right]} = \frac{\rho^{[n]}+\tilde{\rho}^{[n+1]}}{2} \quad \Leftarrow \quad \tilde{\rho}^{[n+1]}$$

Ex: octupole vibration in ^{208}Pb

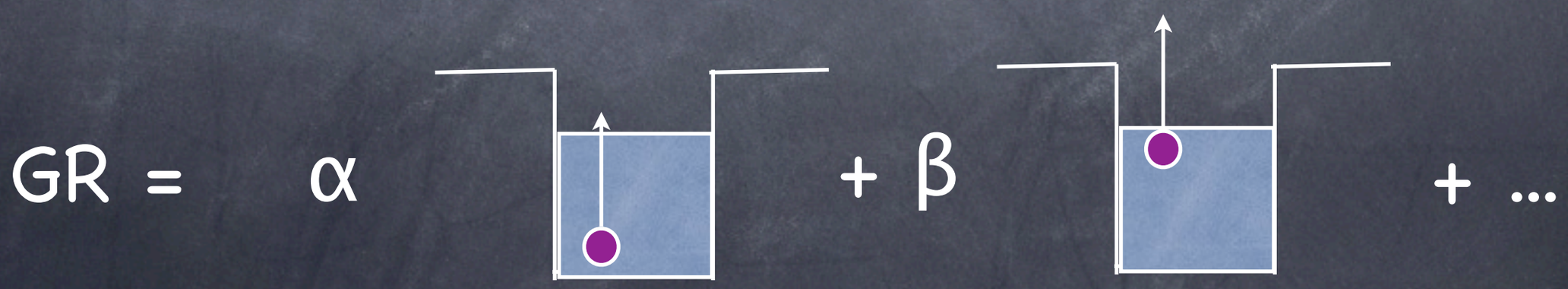
external excitation $\hat{V}_{ext}(t) = \varepsilon \hat{Q}_{30} \delta(t - t_0)$





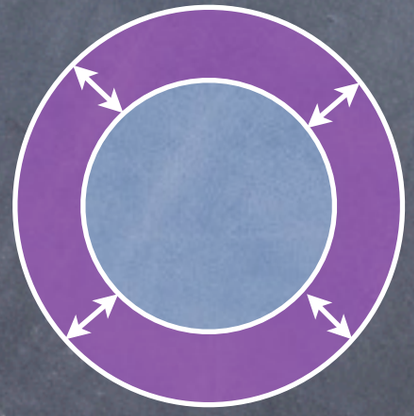
Giant resonances

- «very» Collective: almost all nucleons participate to the vibration
- high energy (typically 10 - 30 MeV)
- some nucleons are promoted into the continuum



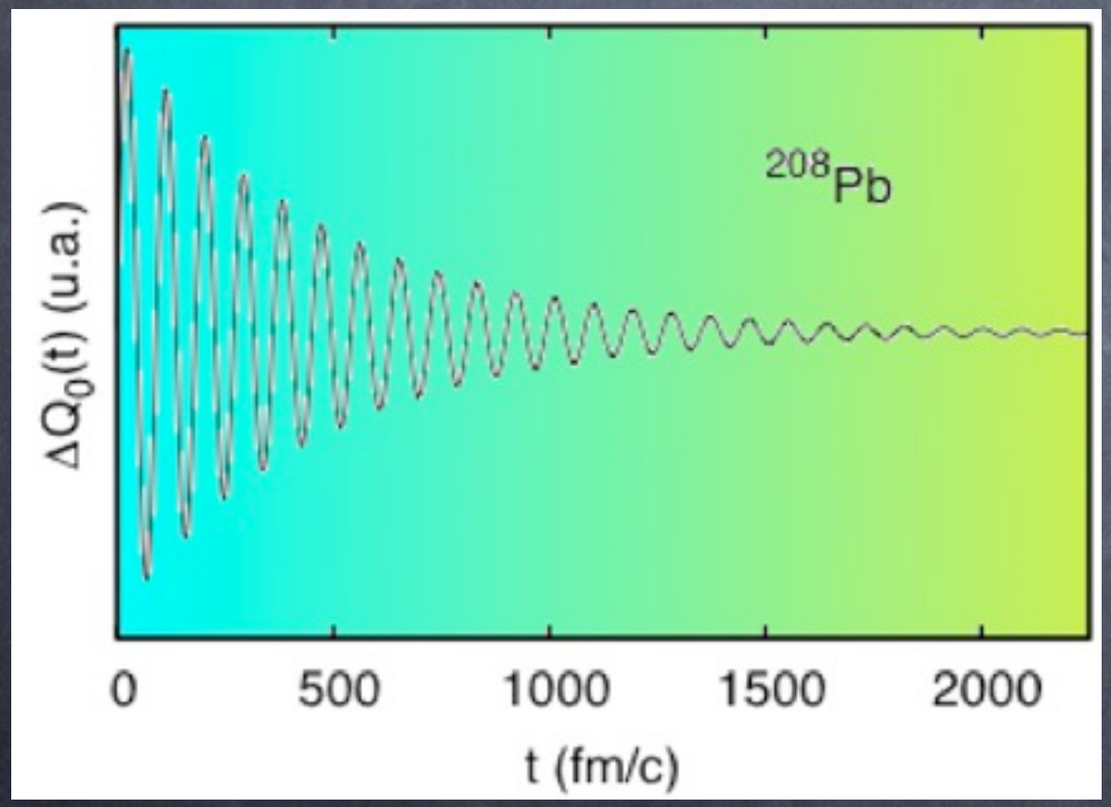
Giant resonances

- giant monopole resonance (breathing mode)



Giant resonances

- TDHF response to a monopole excitation



Giant resonances

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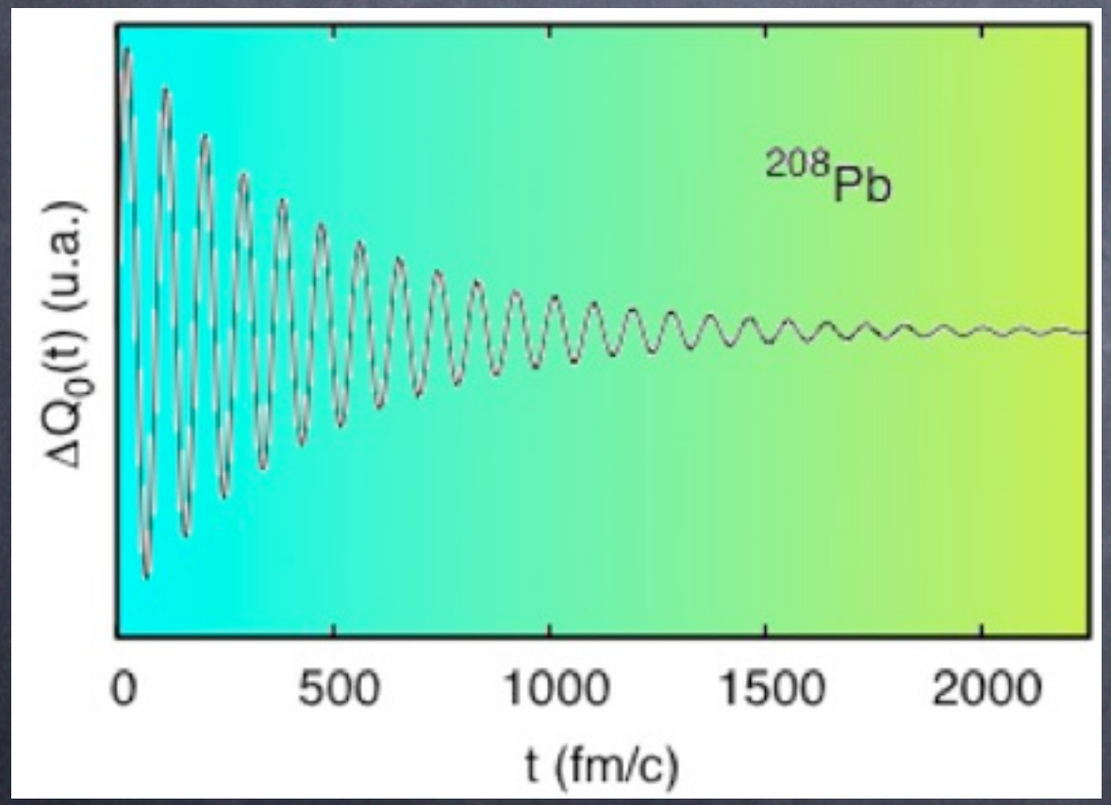

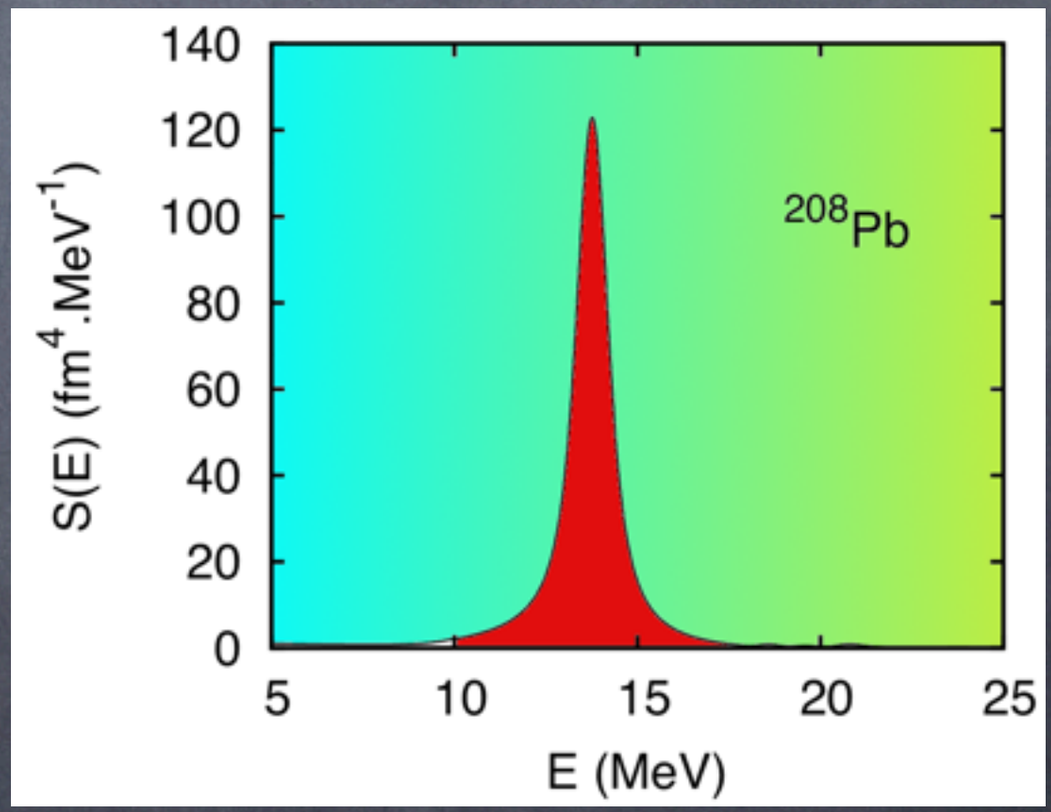

Giant resonances

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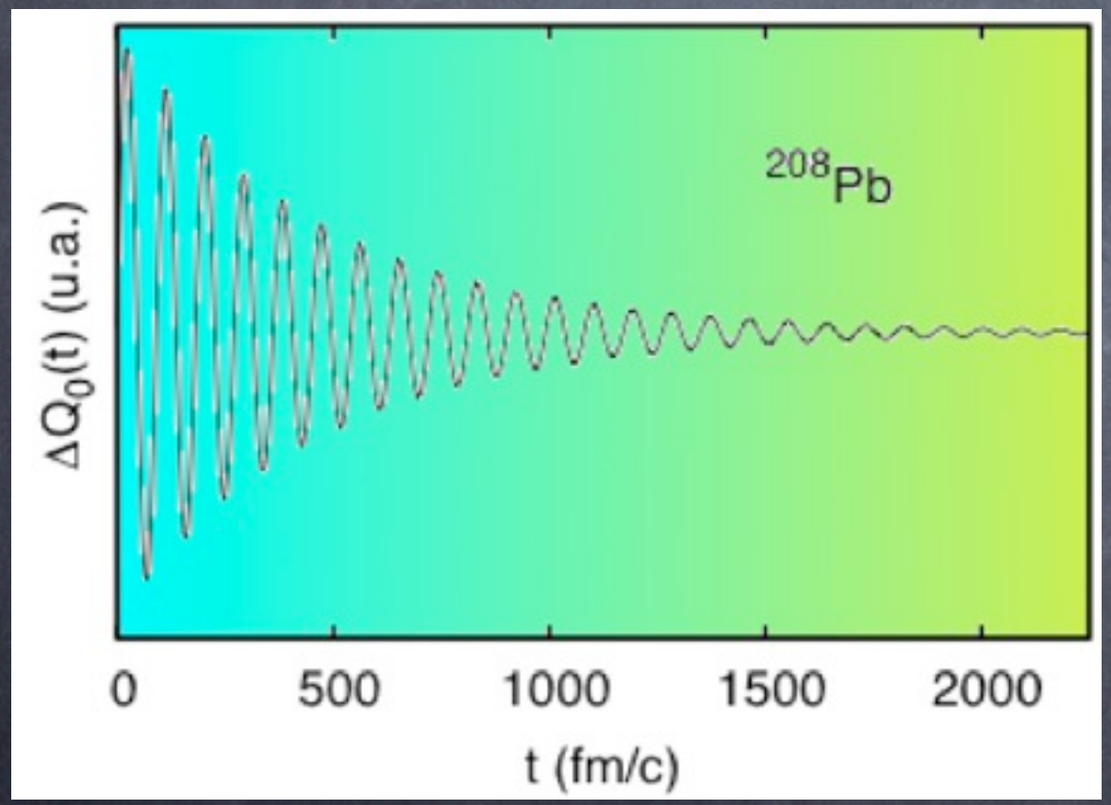
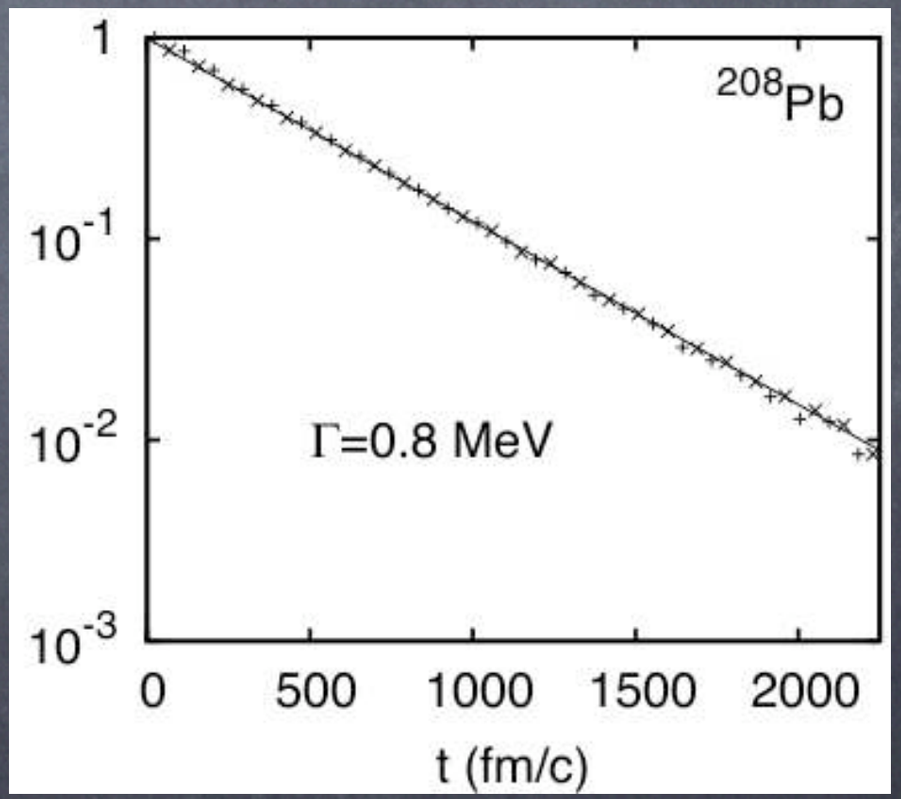
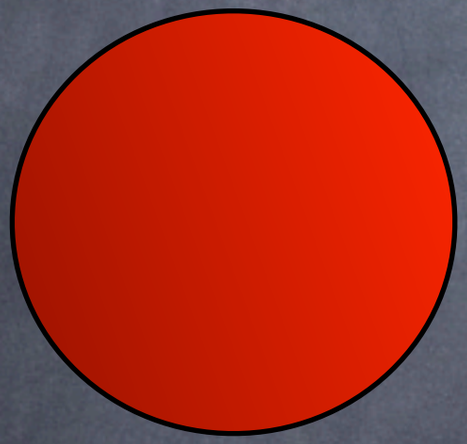




Giant resonances

- decay by nucleon emission



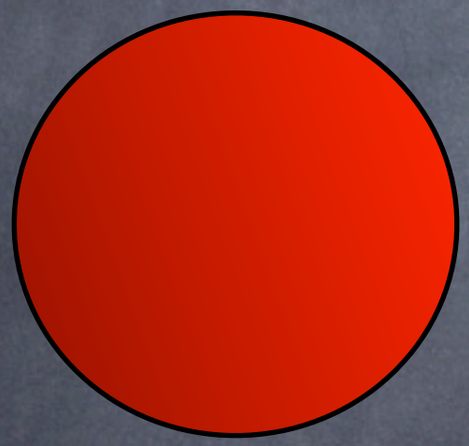
nucleus

emitted
nucleon

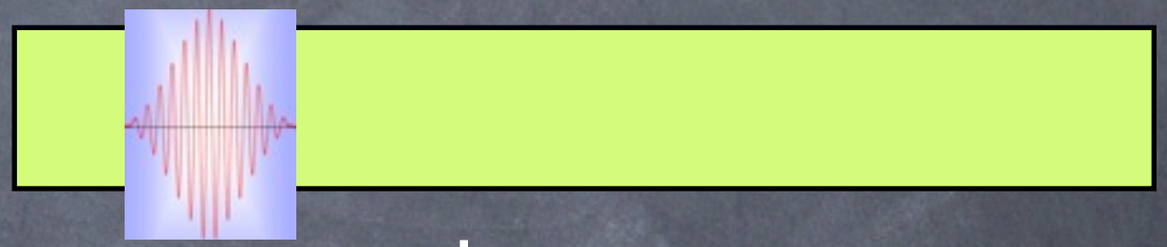
detector
(Fourier transform)

Giant resonances

- decay by nucleon emission



nucleus



detector
(Fourier transform)

Giant resonances

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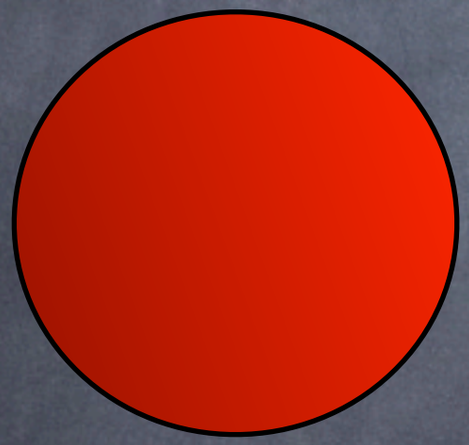
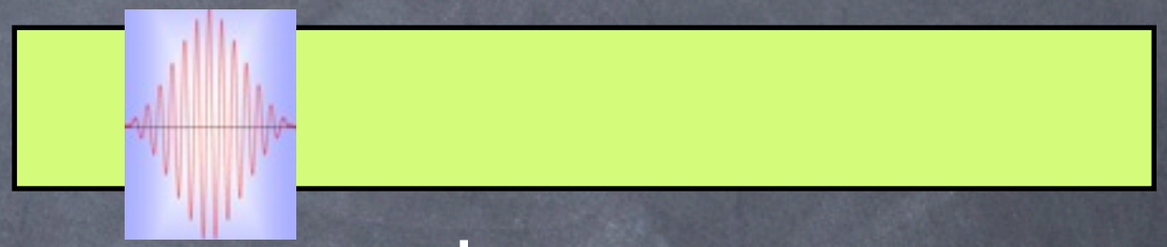
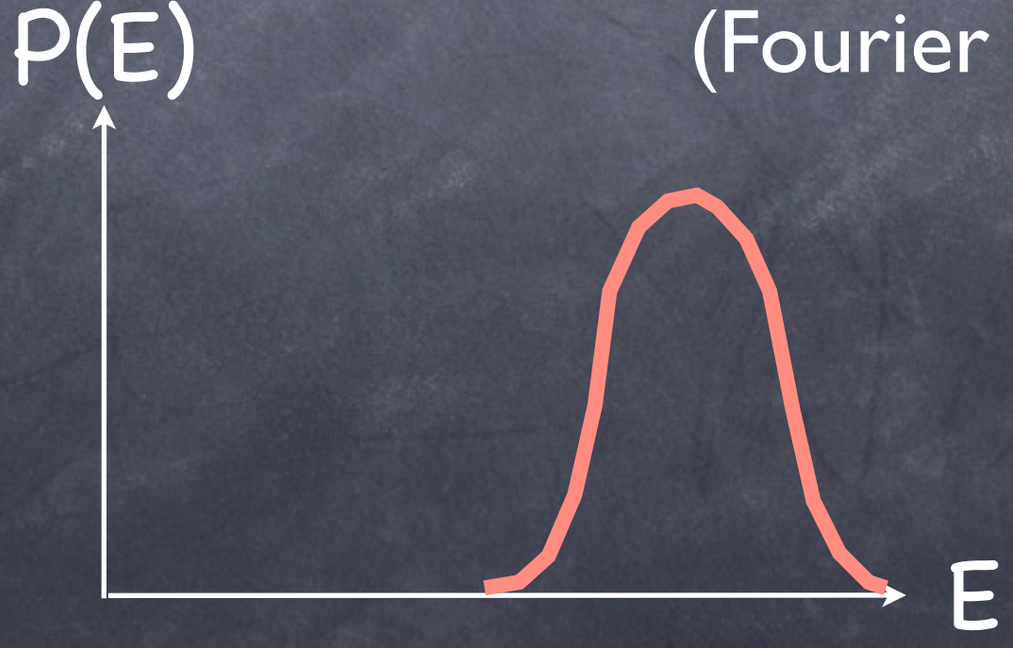


nucleus

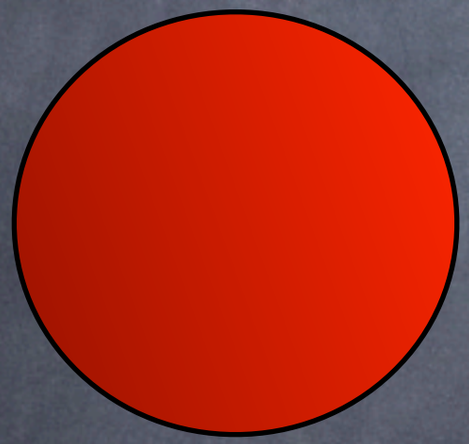


detector
(Fourier transform)



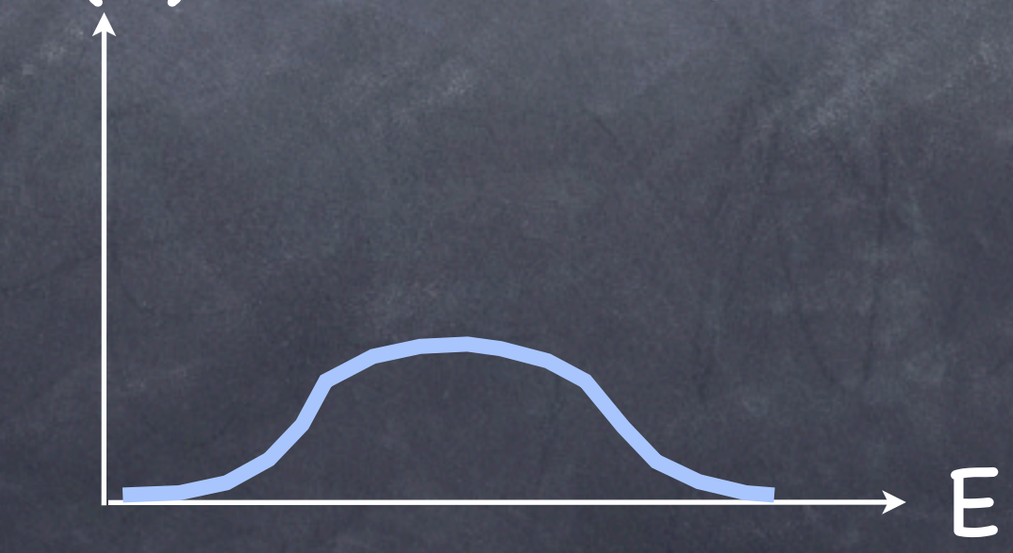
Giant resonances

- decay by nucleon emission



nucleus

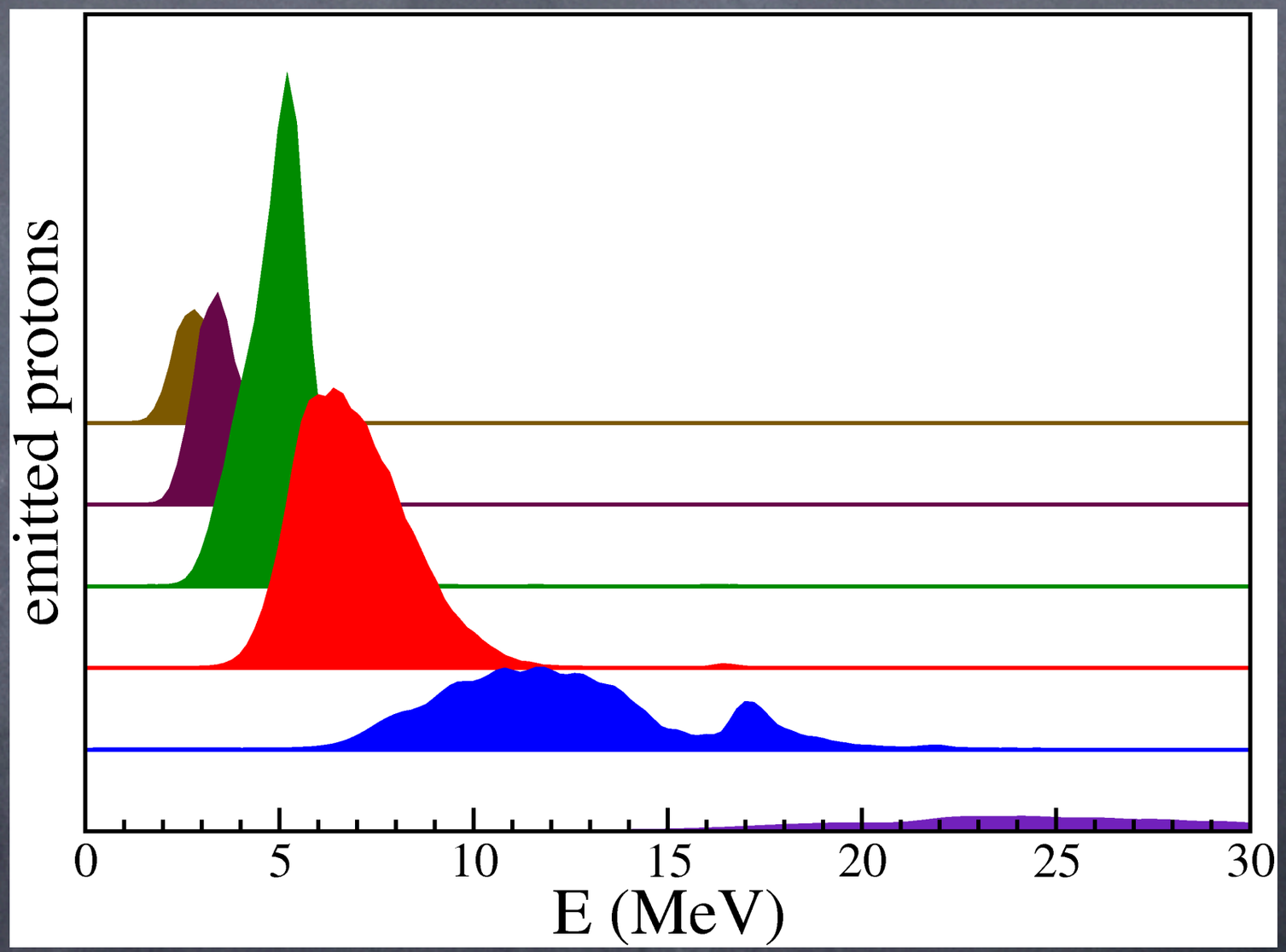
detector
(Fourier transform)



Giant resonances

Decay of a Giant resonance

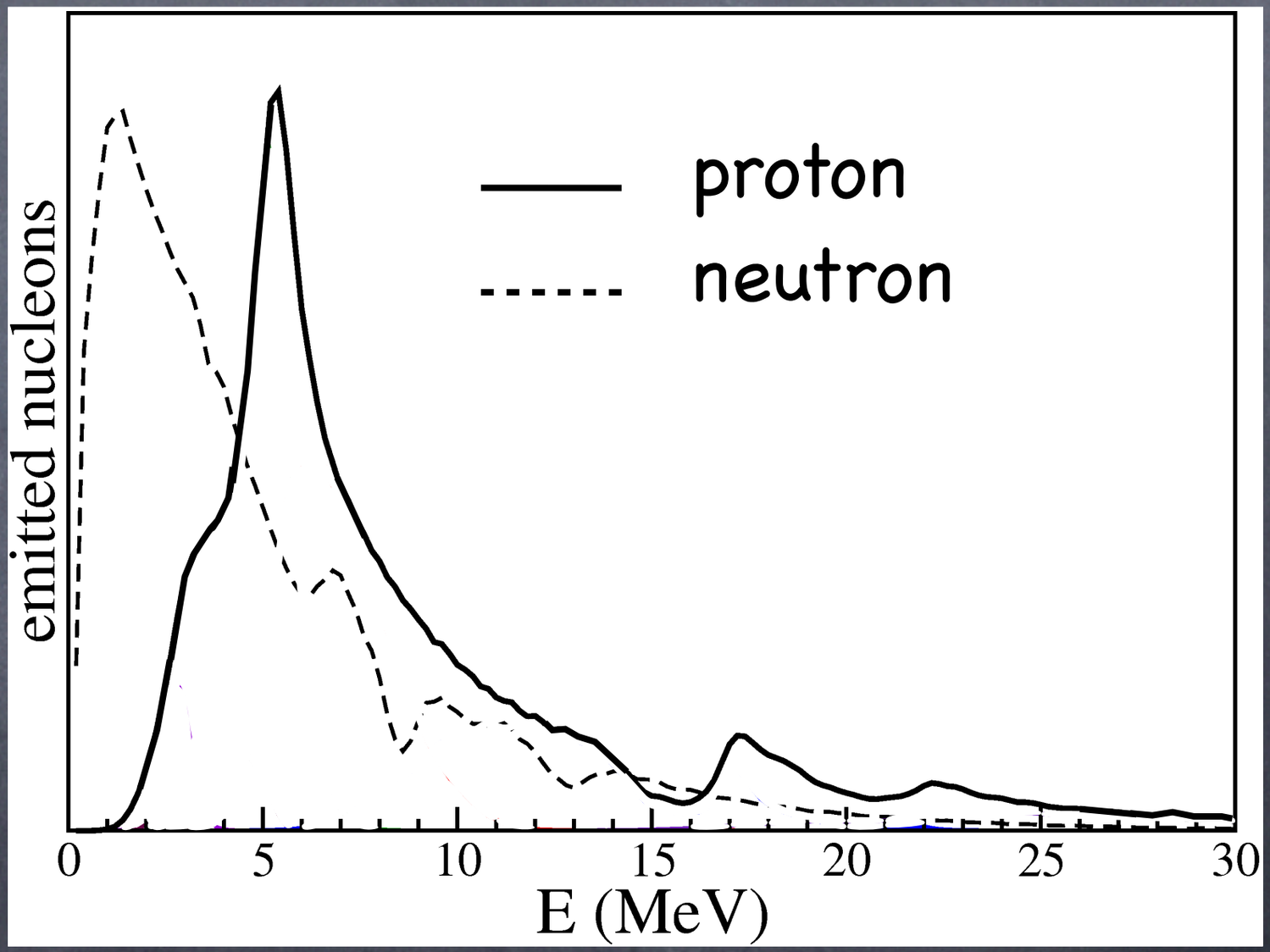
(IVGMR in ^{40}Ca)



Giant resonances

Decay of a Giant resonance

(IVGMR in ^{40}Ca)

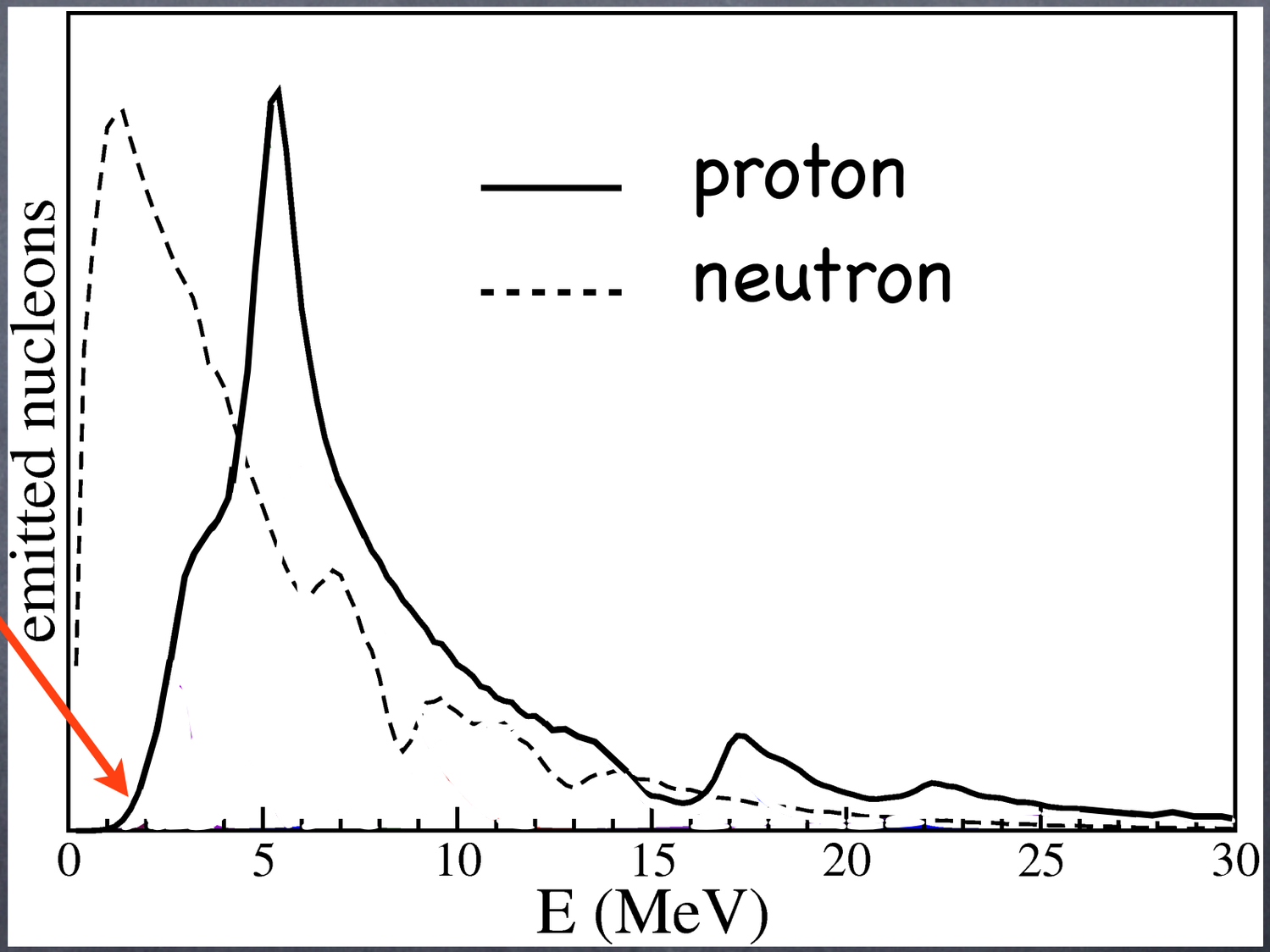


Giant resonances

Decay of a Giant resonance

(IVGMR in ^{40}Ca)

Coulomb barrier



Giant resonances

Decay of a Giant resonance

(IVGMR in ^{40}Ca)

Coulomb barrier