Study of the shell structure and order-to-chaos transition in warm rotating nuclei with the radioactive beams of SPES

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SPES exotic beams for science

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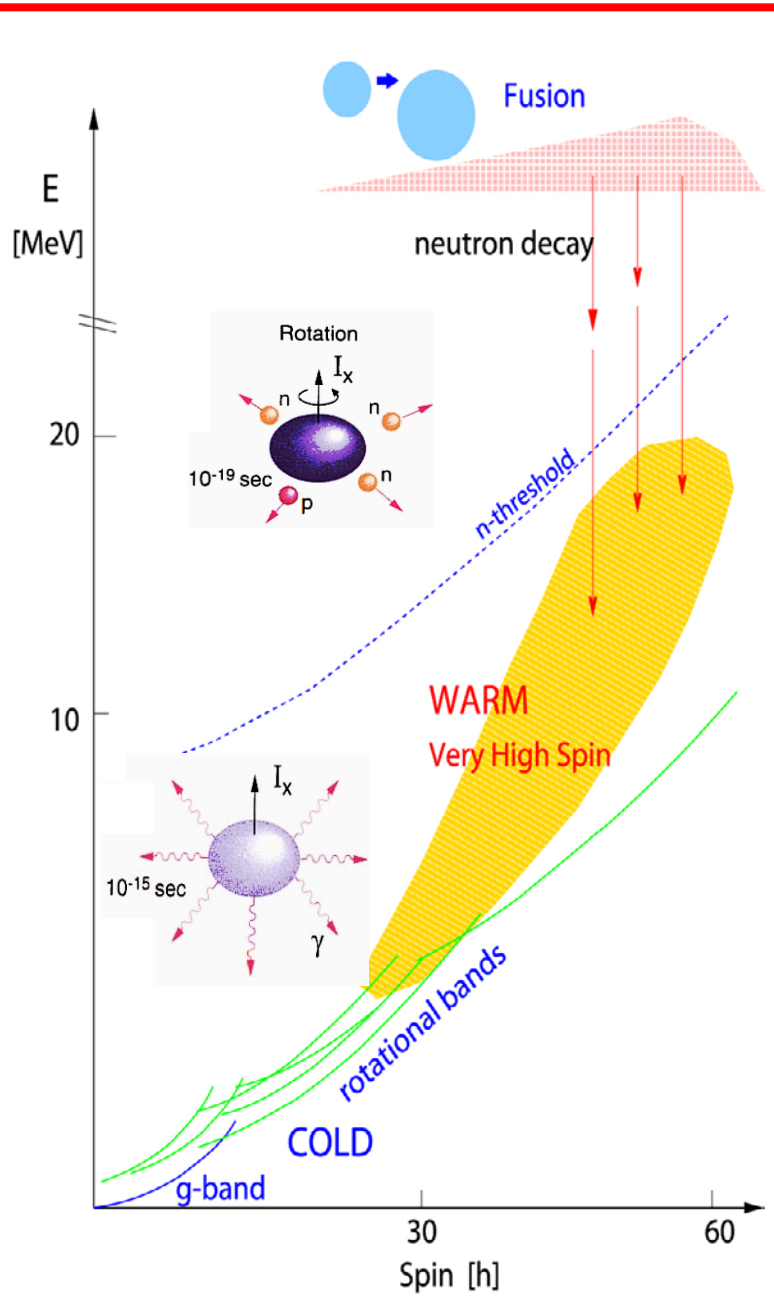
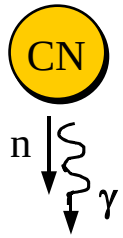
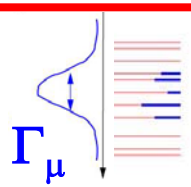
Outline:

- General introduction on warm rotating nuclei
- Specific properties of fusion-evaporation reactions induced by n-rich beams ➔ see also LOI by P. Bednarczyk
- topics to be addressed with exotic beams:
  - dependence of properties of warm rotating nuclei on T,I,N
  - order-to-chaos transition
- proposed reactions and requirements
- detection array
- conclusions

Warm rotating nuclei







$|\alpha\rangle=\Sigma_\mu X_\alpha^\mu |\mu\rangle$

Loss of Selection rules

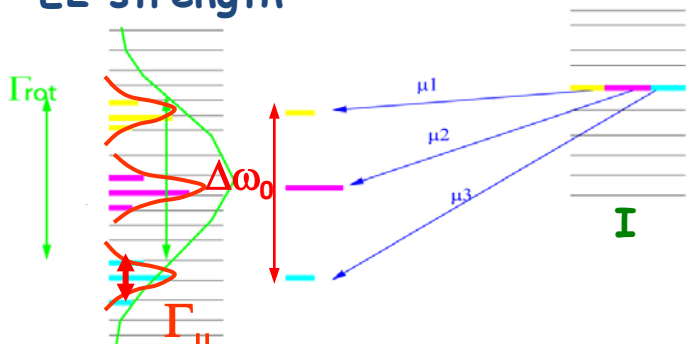
$|\alpha\rangle$

Compound Nucleus

Chaos

U ≈ 8 MeV

E2 strength

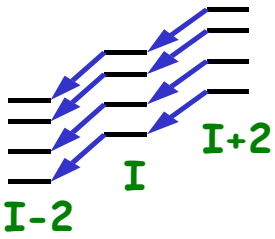


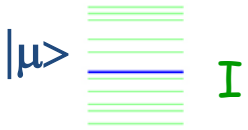
Rotational Damping

strongly interacting bands

U= 1-5 MeV

np-nh states





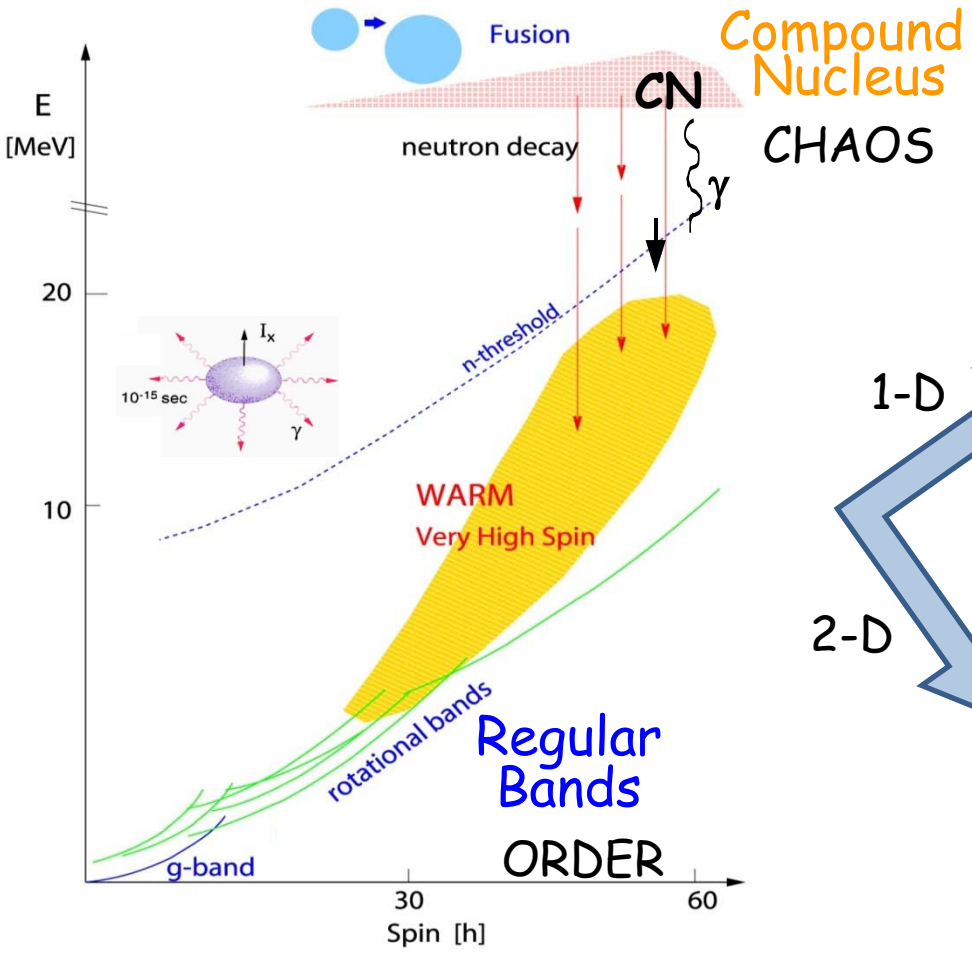
Selection rules (E,I,K,α, ...)

Regular Bands

mean field

U < 1 MeV

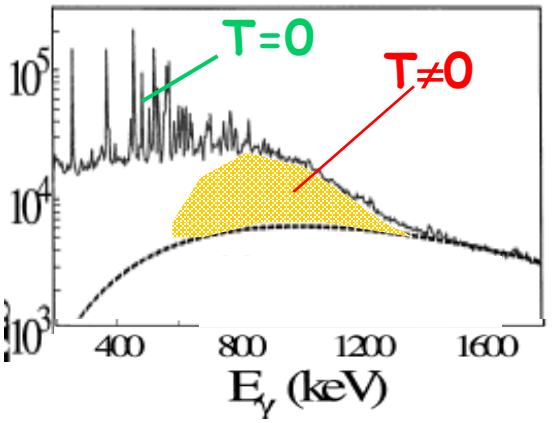
Collective Rotation: de-excitation spectra

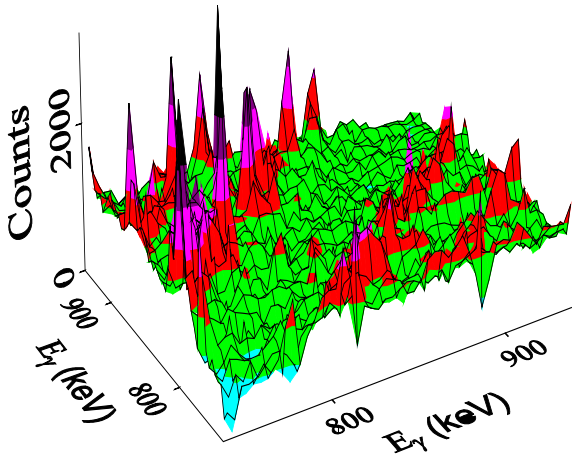


1-D

2-D

Quasi-Continuum emission
1-3 MeV γ-rays from
rotating warm nuclei



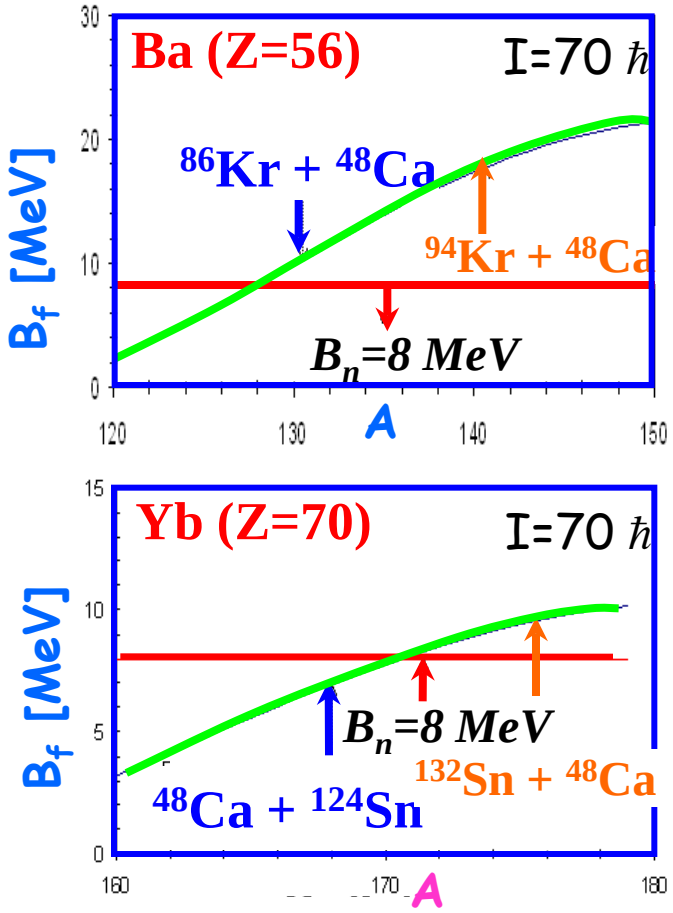


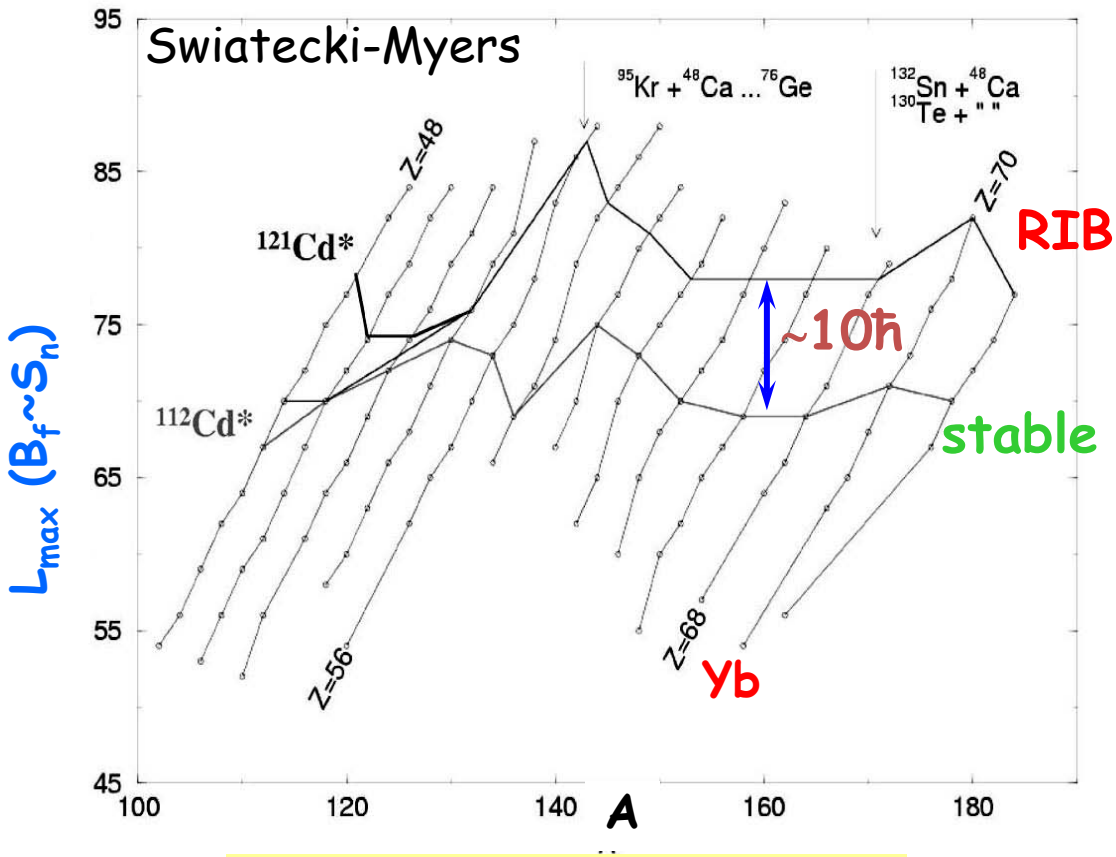
Exotic Beams: fusion-evaporation reactions ~5 MeV/A

Stable beams: fission limits the maximum angular momentum of the nucleus

N-rich beams: fission barrier increases with N

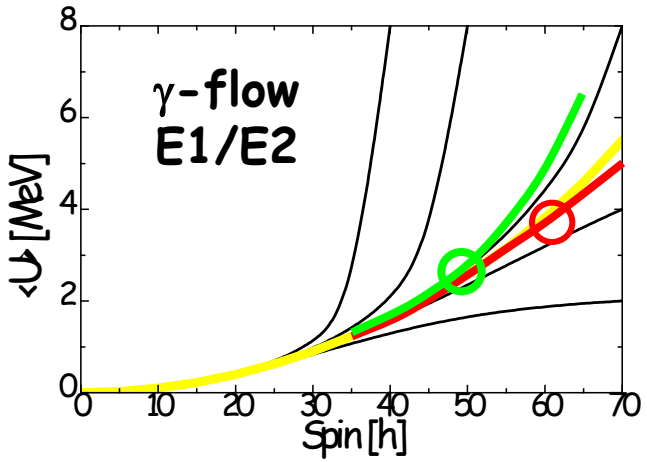
population of larger angular momenta





P.Fallon ActaPhys.Pol.B36(2005)1003

Exotic Beams:
Dependence of rotational damping width Γ_{rot} on T and I

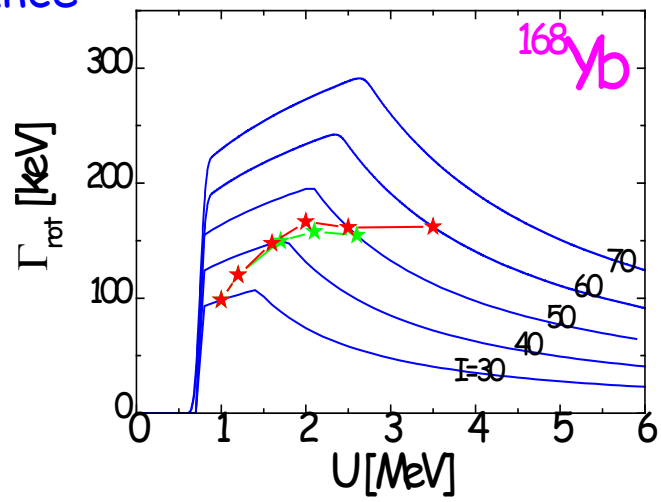


Døssing, Vigezzi, NPA587(1995)13.

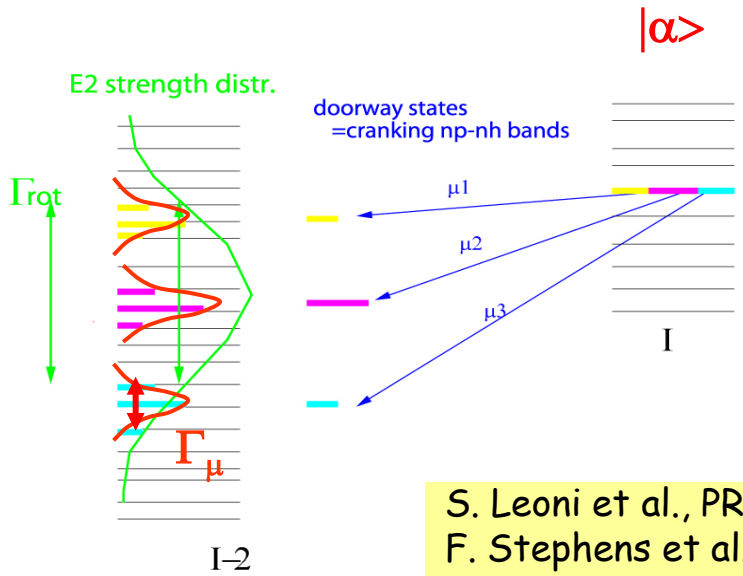
Temperature dependance

Stable: $^{48}Ca+^{124}Sn$

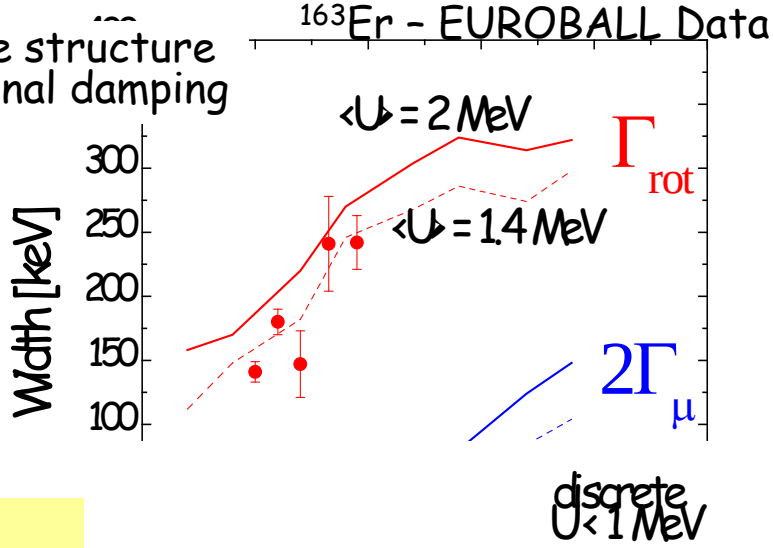
SPES: $^{132}Sn+^{48}Ca$



Spin dependance



fine structure
of rotational damping



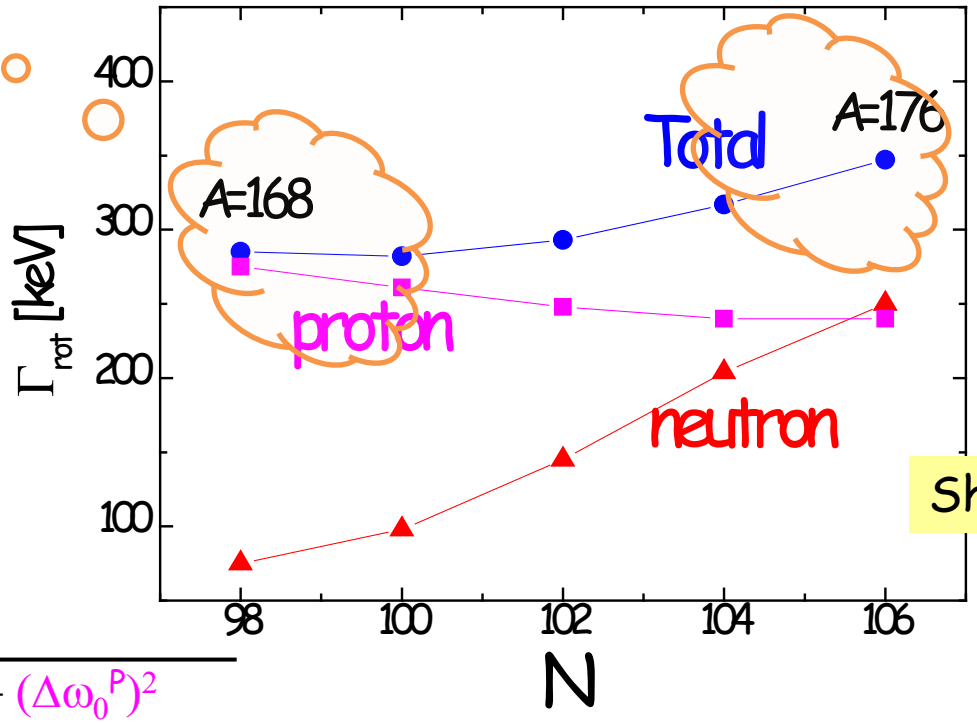
S. Leoni et al., PRL93(2004)022501
F. Stephens et al., PRL88(2002)142501
M. Matsuo et al., PLB465(1999)1

Exotic Beams:
Dependence of rotational damping width on N

Accessible with stable beams

Need for n-rich beams

Yb isotopes



$^{132}Sn + ^{48}Ca \rightarrow ^{176}Yb + 4n$

$^{130}Sn + ^{48}Ca \rightarrow ^{174}Yb + 4n$

Shell structure effects

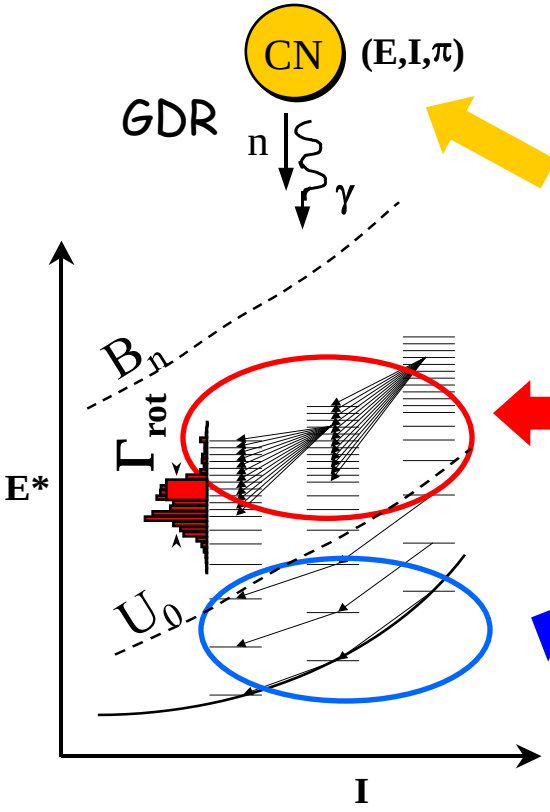
$$\Gamma_{rot} = 2(2\Delta\omega_0)$$

$$\Delta\omega_0 = \sqrt{(\Delta\omega_0^N)^2 + (\Delta\omega_0^P)^2}$$

Expected increase of Γ_{rot} (~25%) with N number, mainly driven by neutrons

M. Matsuo et al., PLB465(1999)1

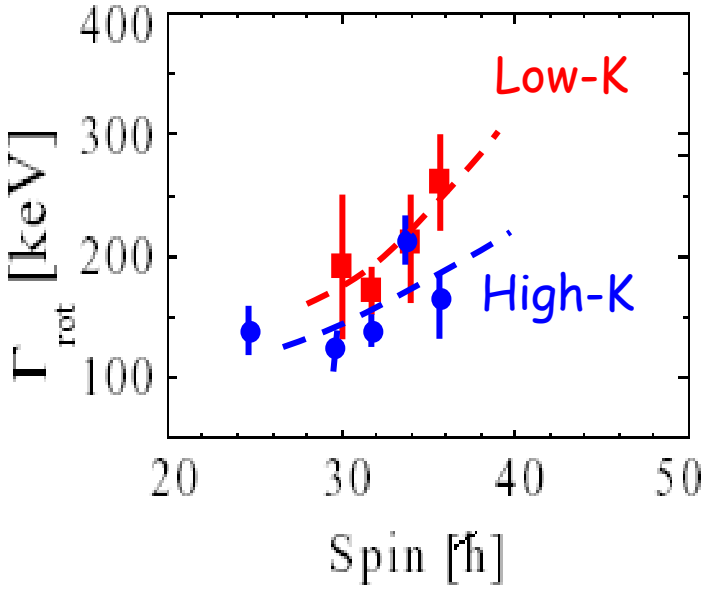
Order-to-chaos transition: Selection rules on K quantum number



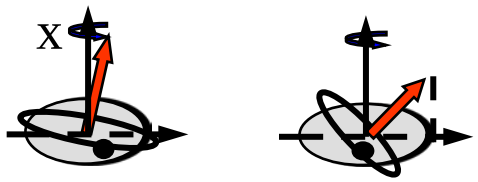
Compound nucleus: **CHAOTIC** regime, remaining quantum numbers **E, I, π**

Rotational Damping: High level density + residual interaction **SELECTION RULES???**

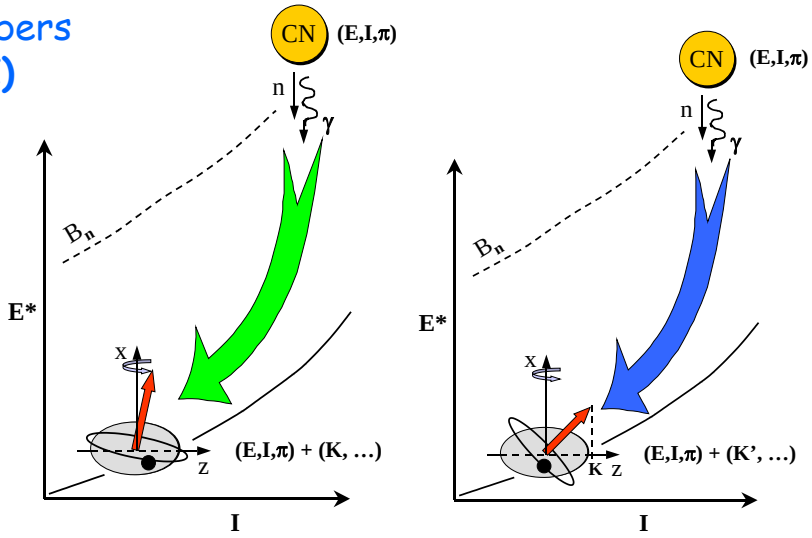
Regular decay: transitions follow **SELECTION RULES** of quantum numbers **(K,α π, E, I)**



Comparative Study of γ-decay flow gated by Low-K and High-K bands



with statistical methods



SPES Beams: proposed reactions

Γ_{rot} dependence on T, I and N

$^{132}Sn + ^{48}Ca \rightarrow ^{176}Yb+4n$

$^{130}Sn + ^{48}Ca \rightarrow ^{174}Yb+4n$

Order-to-caos transition

$^{136}Te + ^{48}Ca \rightarrow ^{180}Hf+4n$

beam intensities ≈ 10^8 pps

one order of magnitude less than presently available with stable beams, 1 pnA. i.e. ~10^9 pps.

E_{beam} ~ 5 MeV/u

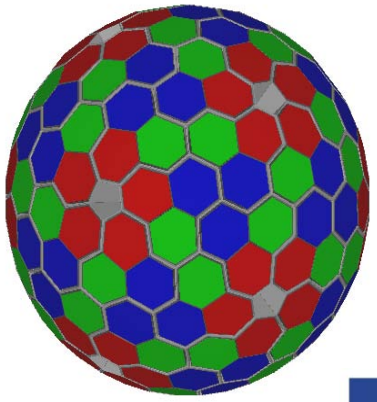
I ~ 70 ħ

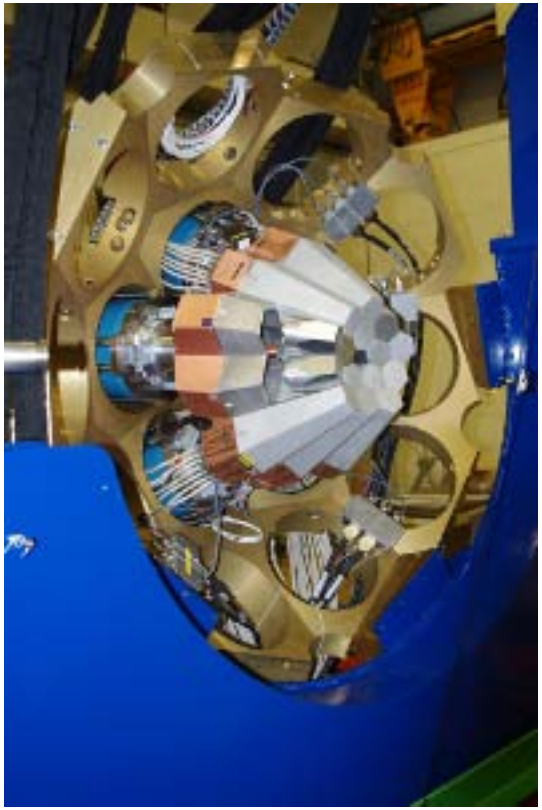
U ~ 2 MeV

Proposed array

Need for a 4π γ array:

Ge Ball (AGATA) + $LaBr_3$ scintillators





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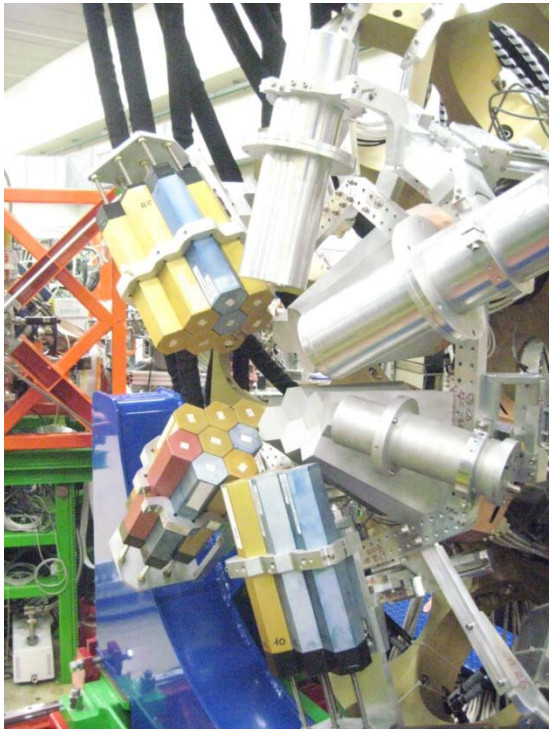
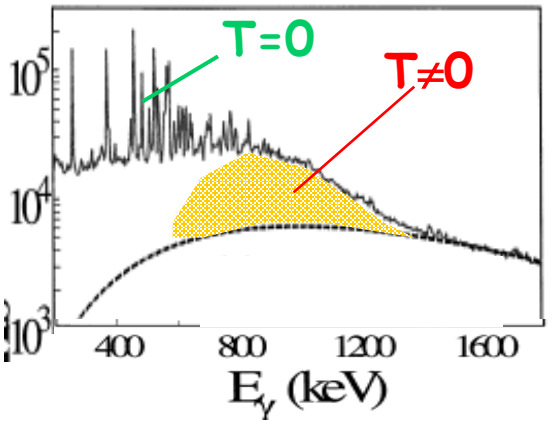


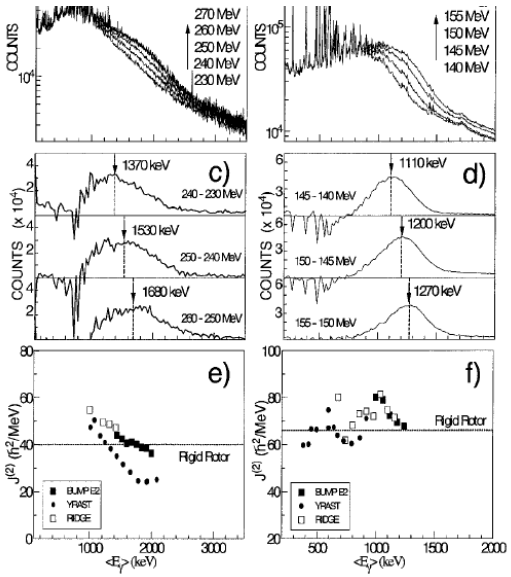
High-efficiency array could compensate low beam intensities

1D analysis

With expected 1st operation beam currents (~ 10^8) only analysis of 1D spectra will be feasible

➔ Chance to study first fundamental information as measurement of damping width





S. Frattini et al., PRL83(1999)5234

Conclusions and perspectives

- fusion-evaporation reactions induced by n-rich beams of SPES :
  - higher fission barrier
  - chance to reach larger angular momenta and internal energies

- study of warm rotating nuclei with n-rich beams of SPES:
  - Γ_{rot} dependence on Temperature/Spin
  - Γ_{rot} dependence on neutron number

  } Yb chain A=168-176

  - order-to-chaos transition → ^{180}Hf
- Requirements: E_{beam} ~ 5 MeV/u

I_{BEAM} ~ 10^9 pps

- 4π γ array: AGATA + $LaBr_3$:
  improved efficiency compensate lower I_{beam}

Proposed reactions:

^{132}Sn + ^{48}Ca --> ^{176}Yb+4n

^{130}Sn + ^{48}Ca --> ^{174}Yb+4n

^{136}Te + ^{48}Ca --> ^{180}Hf+4n

} Feasible at 1st operation of SPES