Spectroscopy of fission fragments

Maggie Hellström

for the GSI-FRS Isomer Collaboration

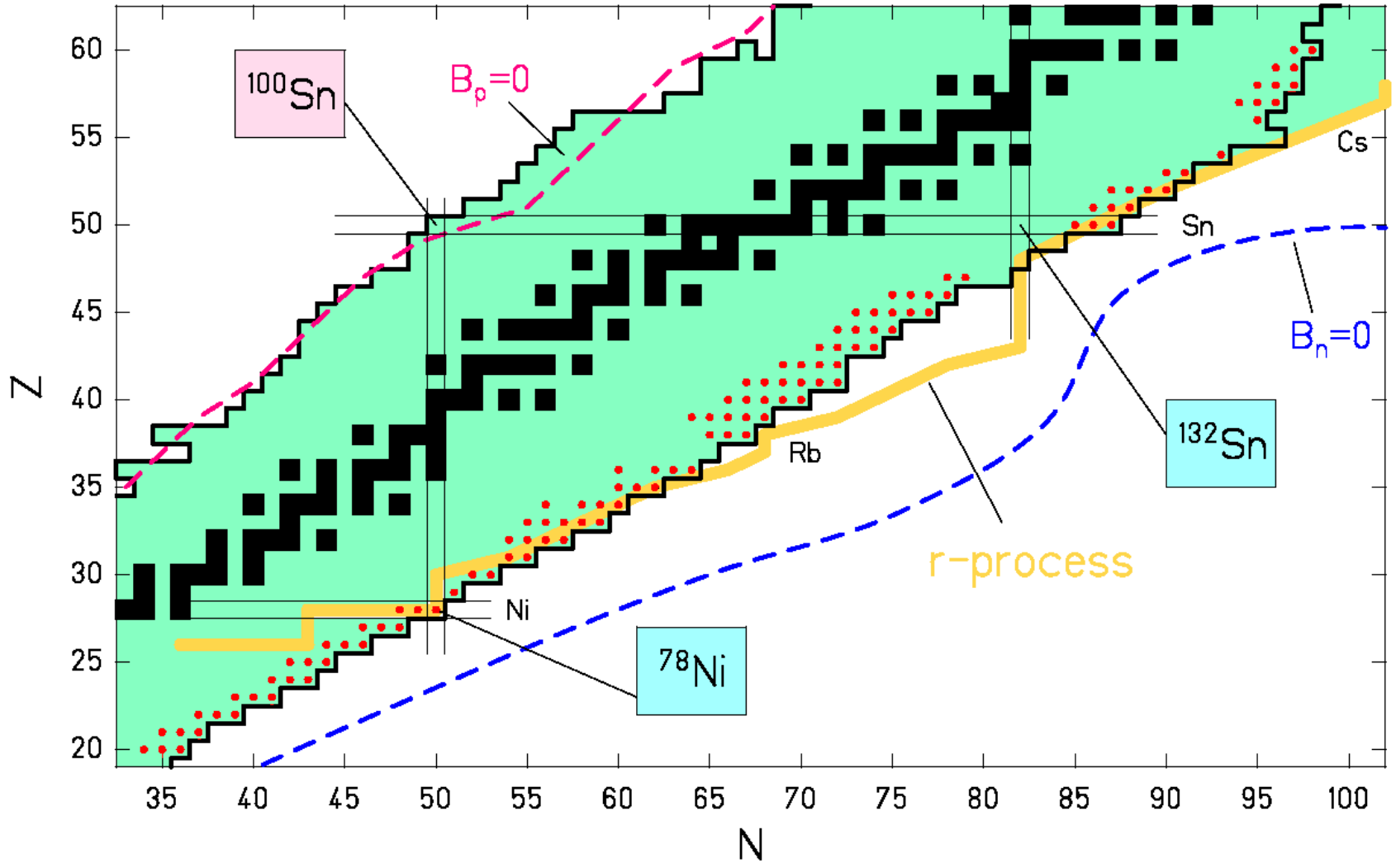
Nuclear structure of very n-rich nuclei:

- specific questions
- “realistic” calculations

Isomer population as a reaction mechanism probe:

- angular momentum, excitation energy
- (influence of kinematics on rates and isomeric ratios)

The Bermuda DCSN triangle...



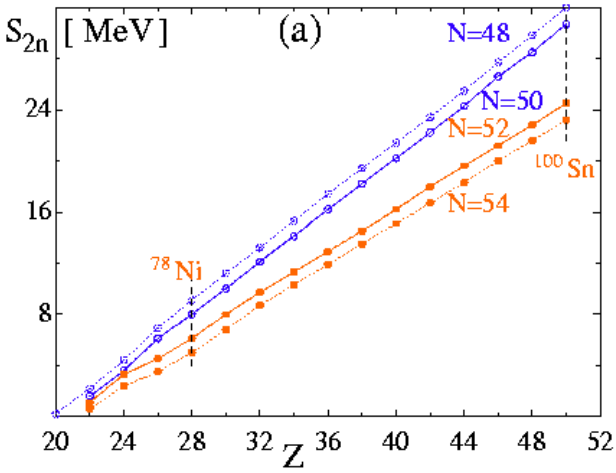
The ^{132}Sn region: many questions!

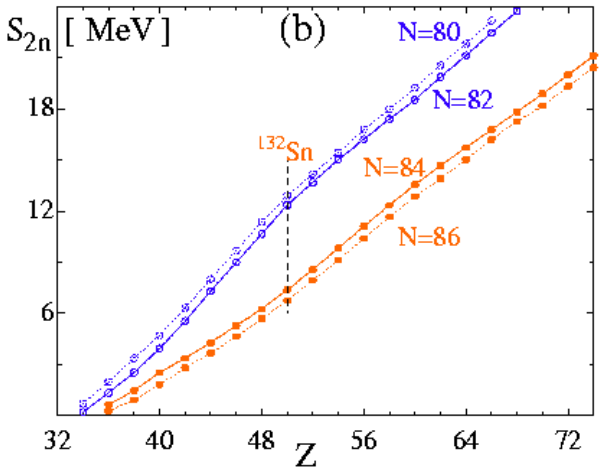
- Persistence of the N=82 shell gap?
- Location of single-particle levels?
- Softening of neutron potential surface? (spin-orbit splitting)
- Excitation energies of 2^+ (4^+, 6^+,…) states in ^{130,132}Cd, ^{136,138}Sn, ^{138,140}Te?
- Trend of proton level monopole shifts?
- Spectroscopic factors – mostly unknown!
- Onset of collectivity?

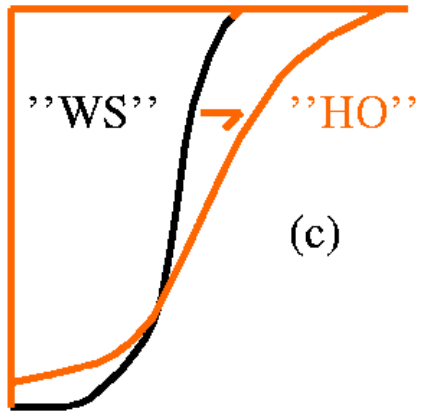
and, related to this

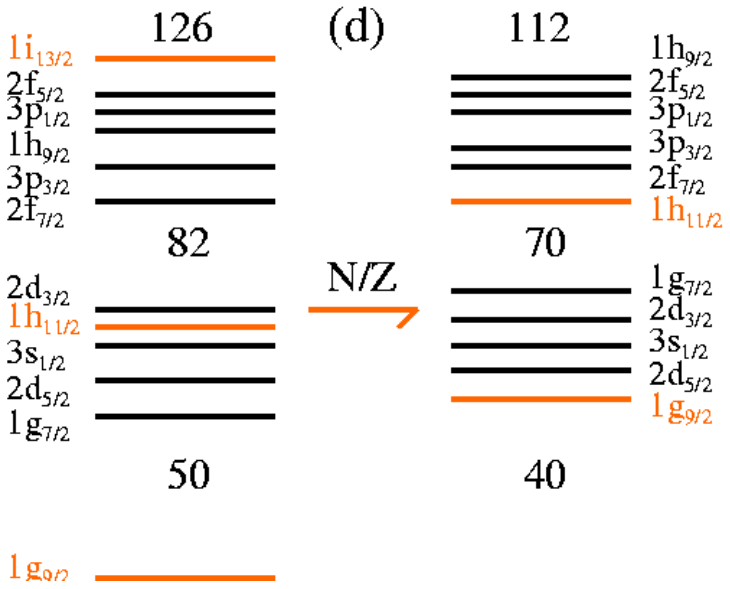
- Implications for the r-process?

Shell quenching for large N !?





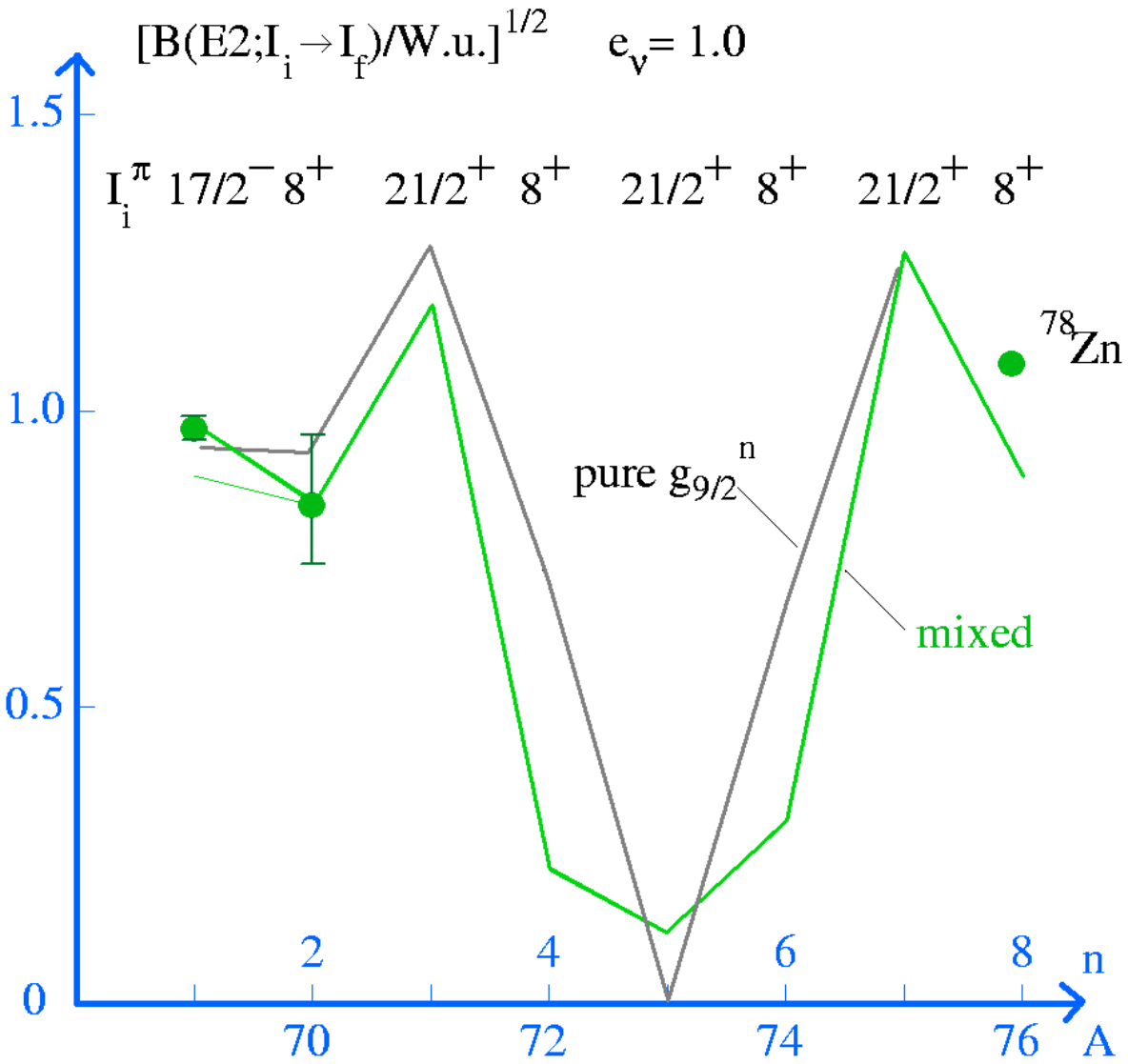




Taken from the GSI Future Facility Report (2001)

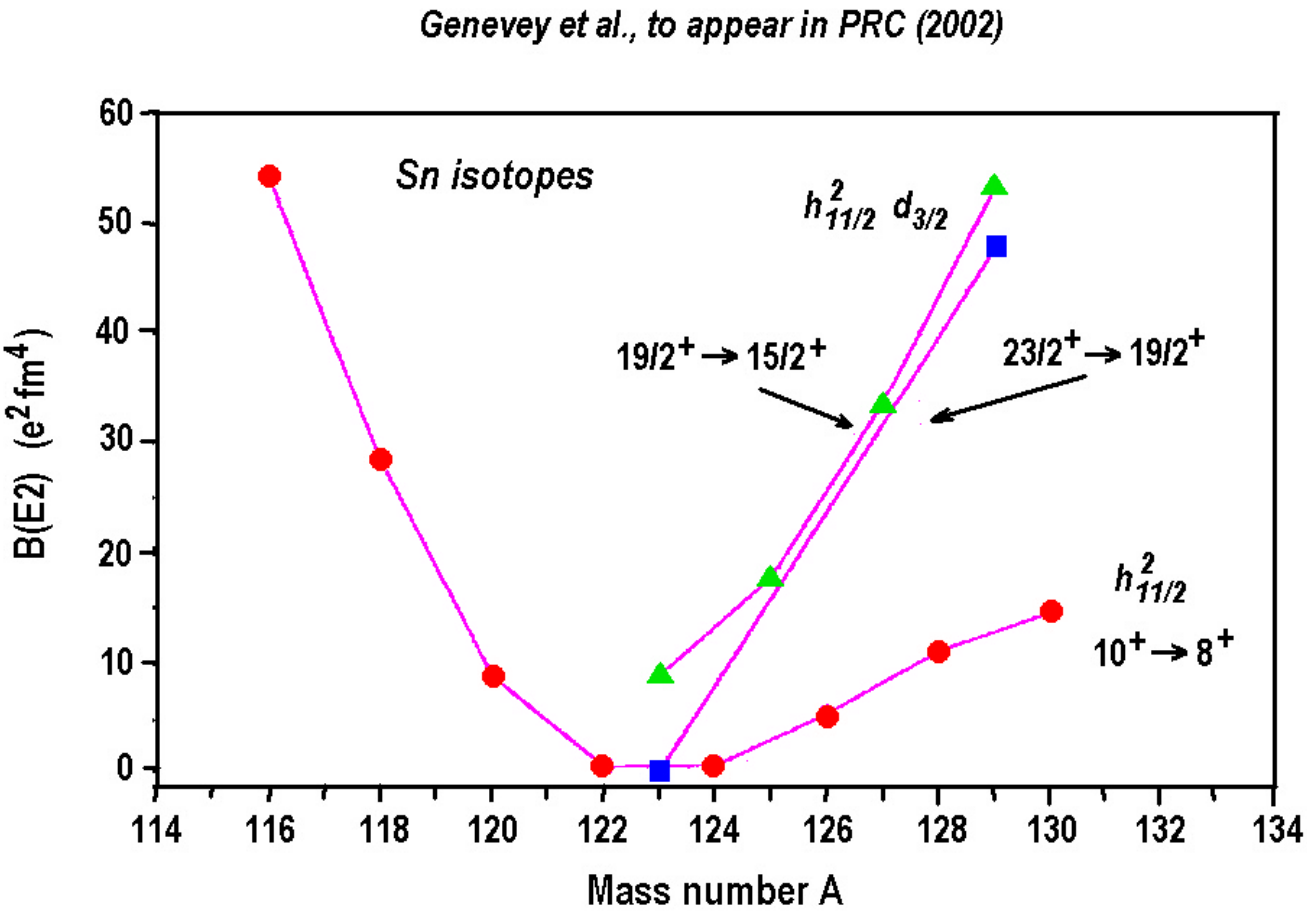
Seniority isomers – typical behavior

E2 transitions in N>40 nickel isotopes

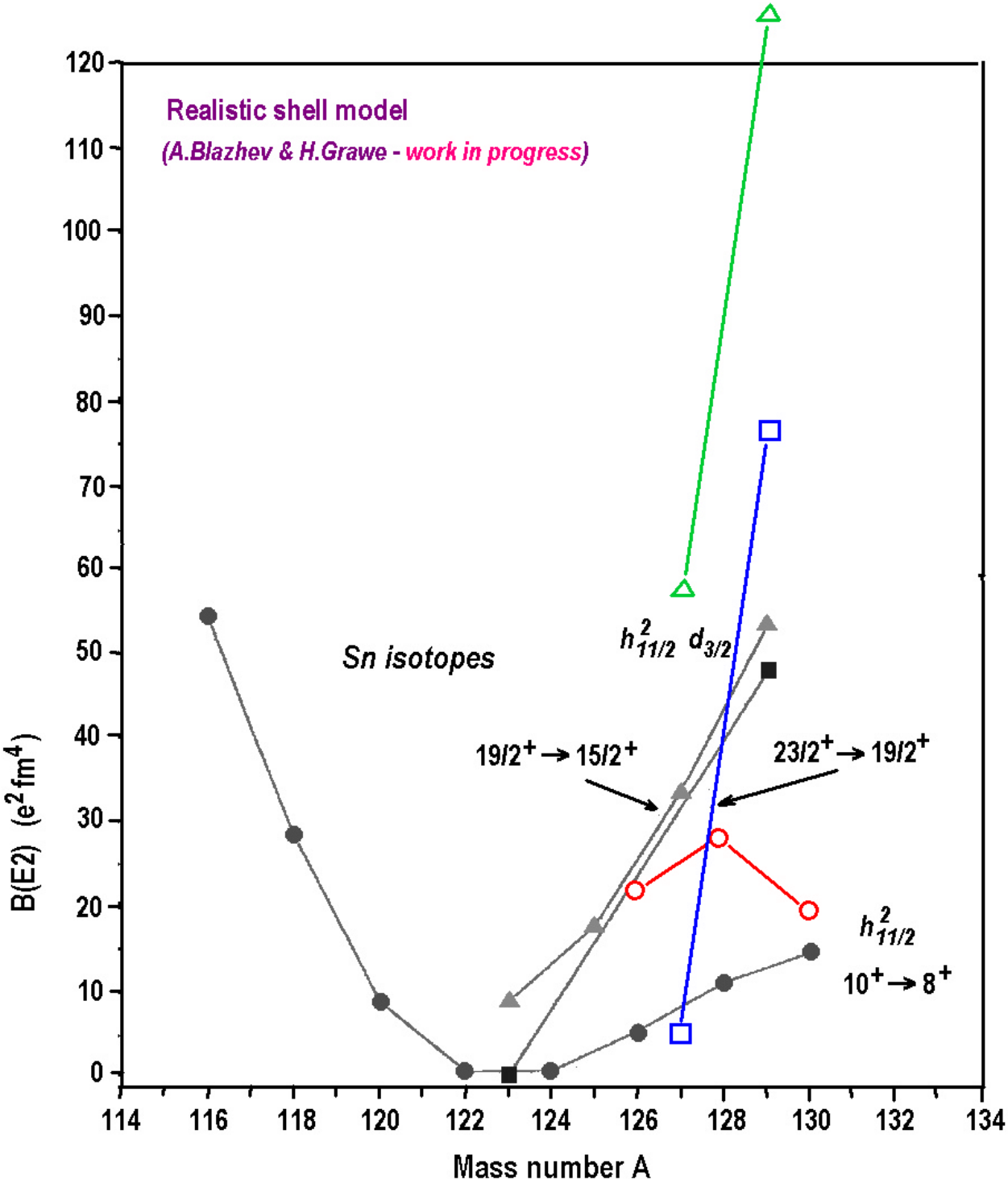


H.Grawe, private communication

Experimental B(E2) values

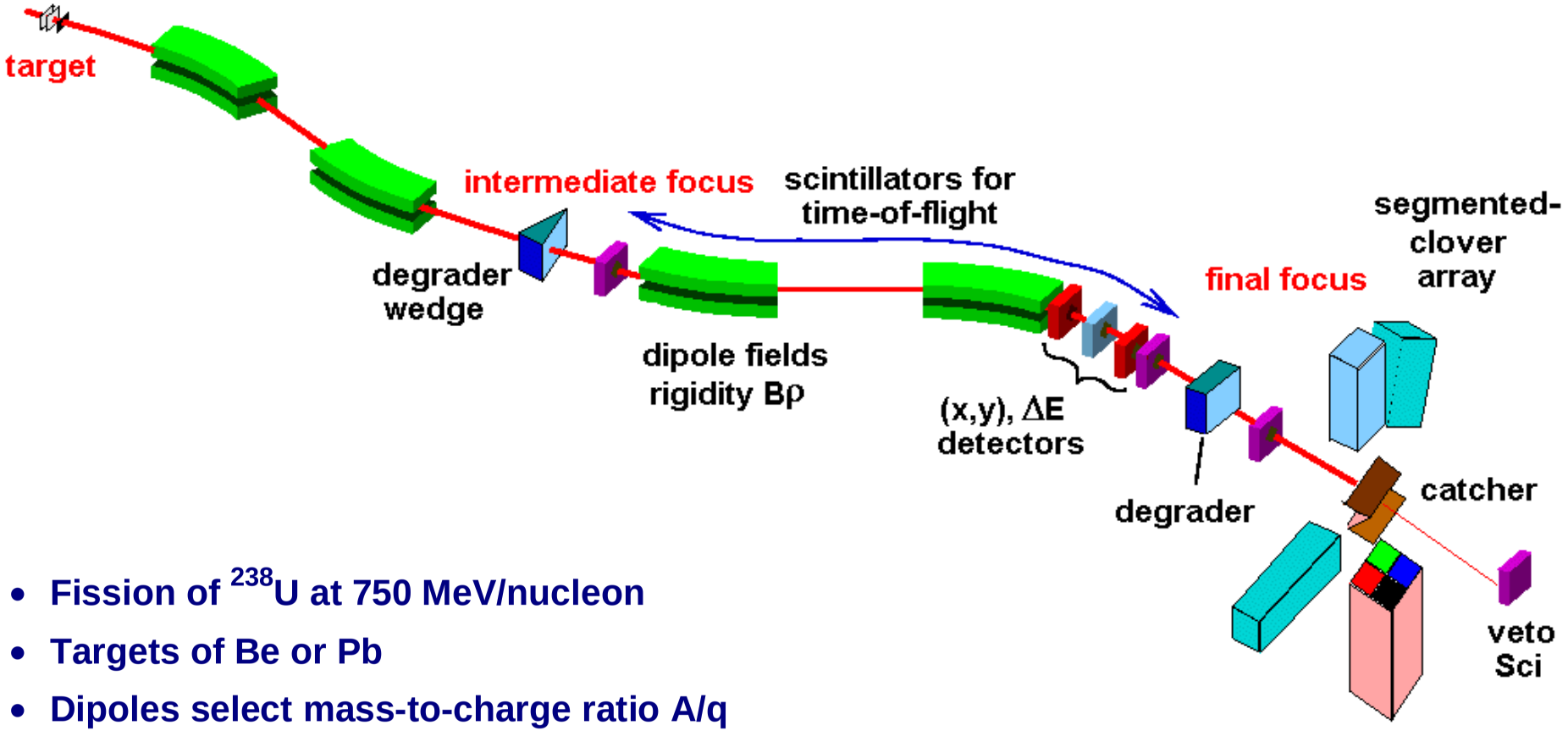


... and compared to theory...



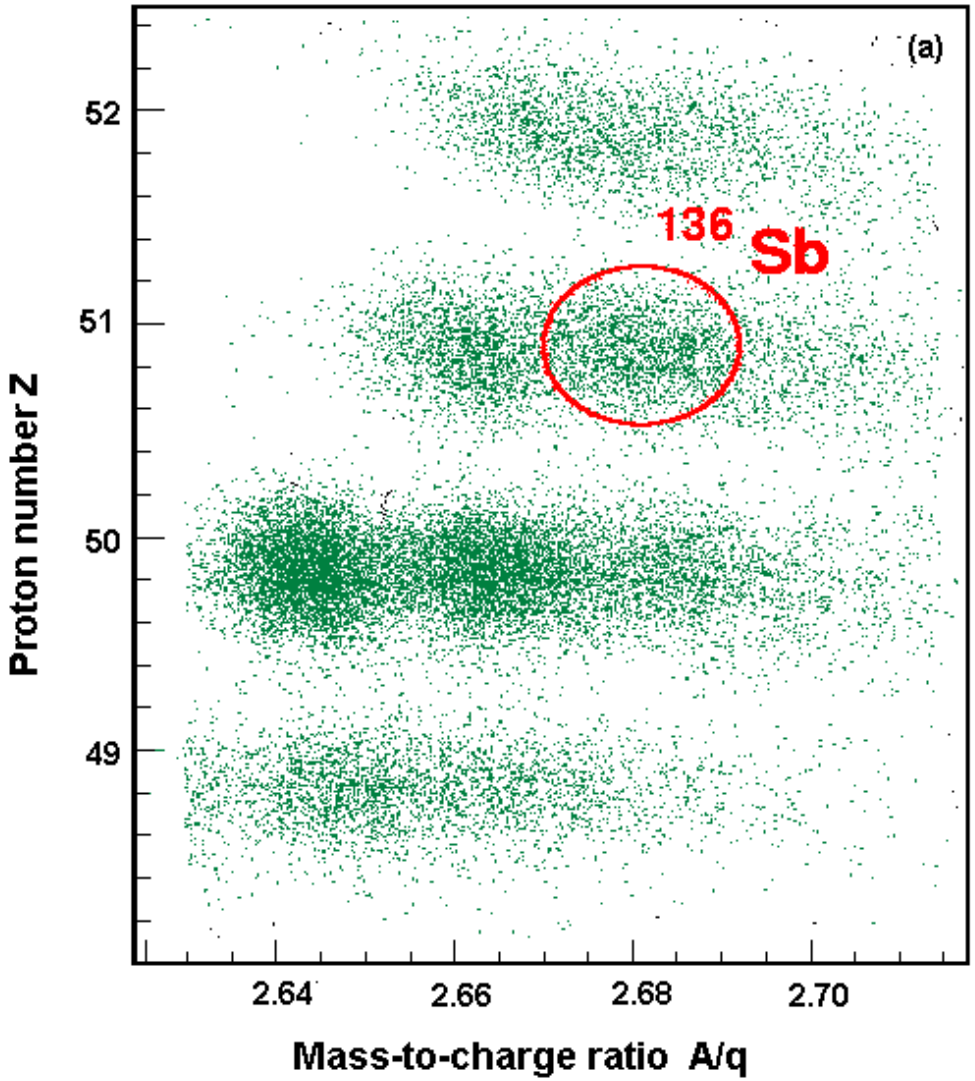
- interaction from ^{88}Sr (works well at ^{100}Sn)
- “scaled” to ^{132}Sn region
- full model space
- neutron effective charge = 1.0

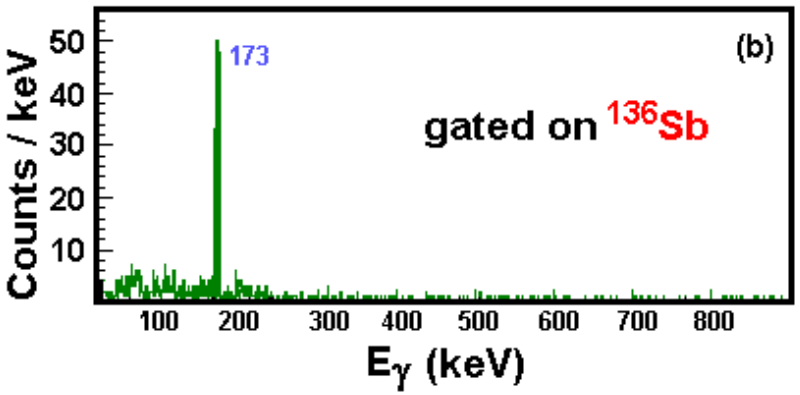
Isomer experiments at the GSI fragment separator FRS

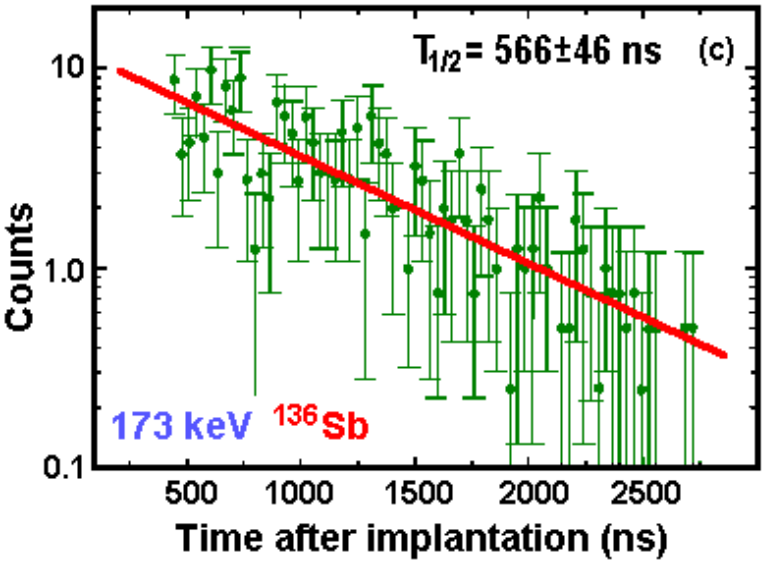


- Fission of ^{238}U at 750 MeV/nucleon
- Targets of Be or Pb
- Dipoles select mass-to-charge ratio A/q
- Wedge degrader adds selectivity through energy loss
- Event-by-event identification of reaction product (A,Z)
- <u>Total</u> time of flight ≈400 nanoseconds

^{136}Sb data from GSI

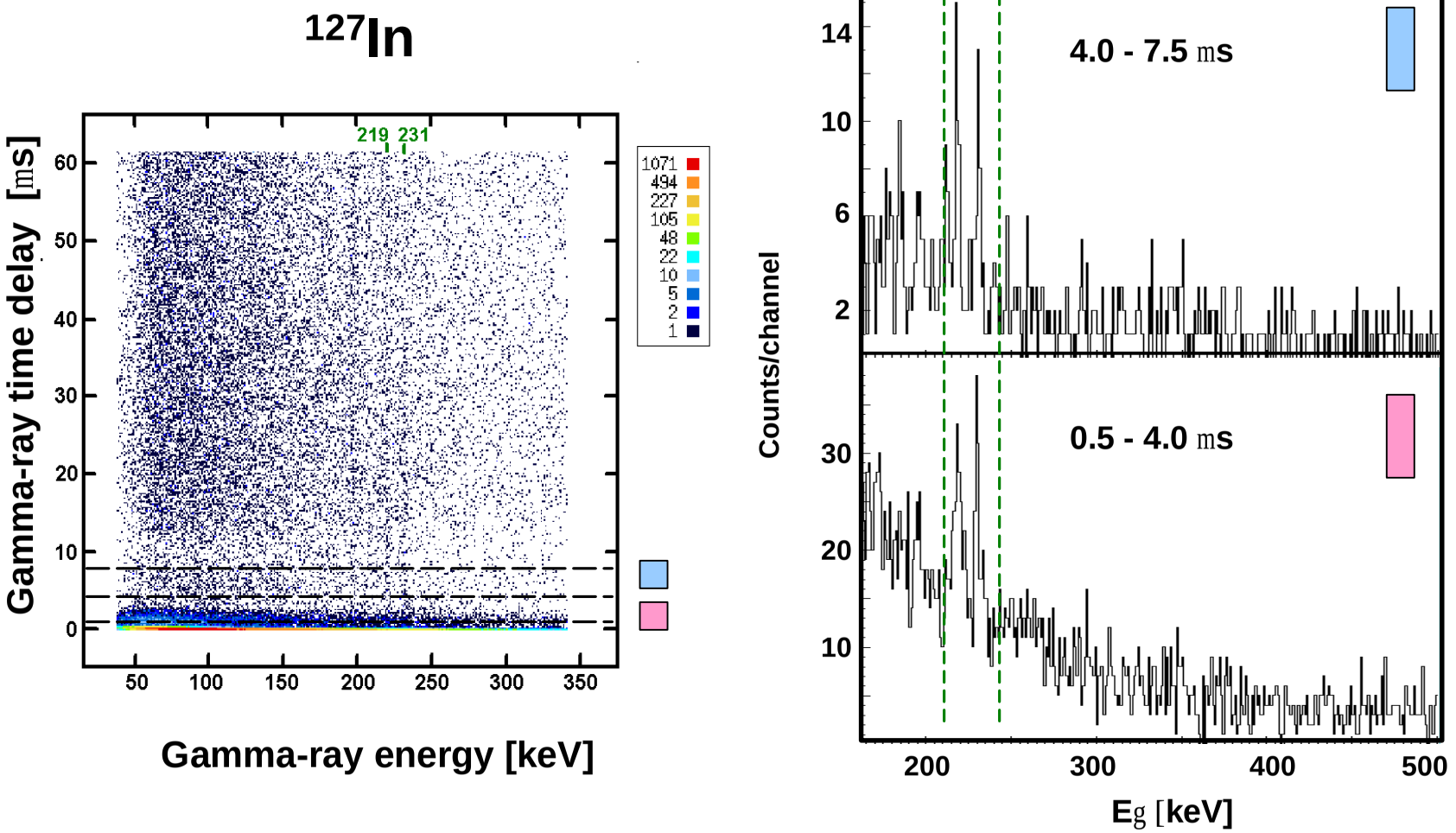






M.N.Mineva *et al.*, EPJ A11 (2001) 9

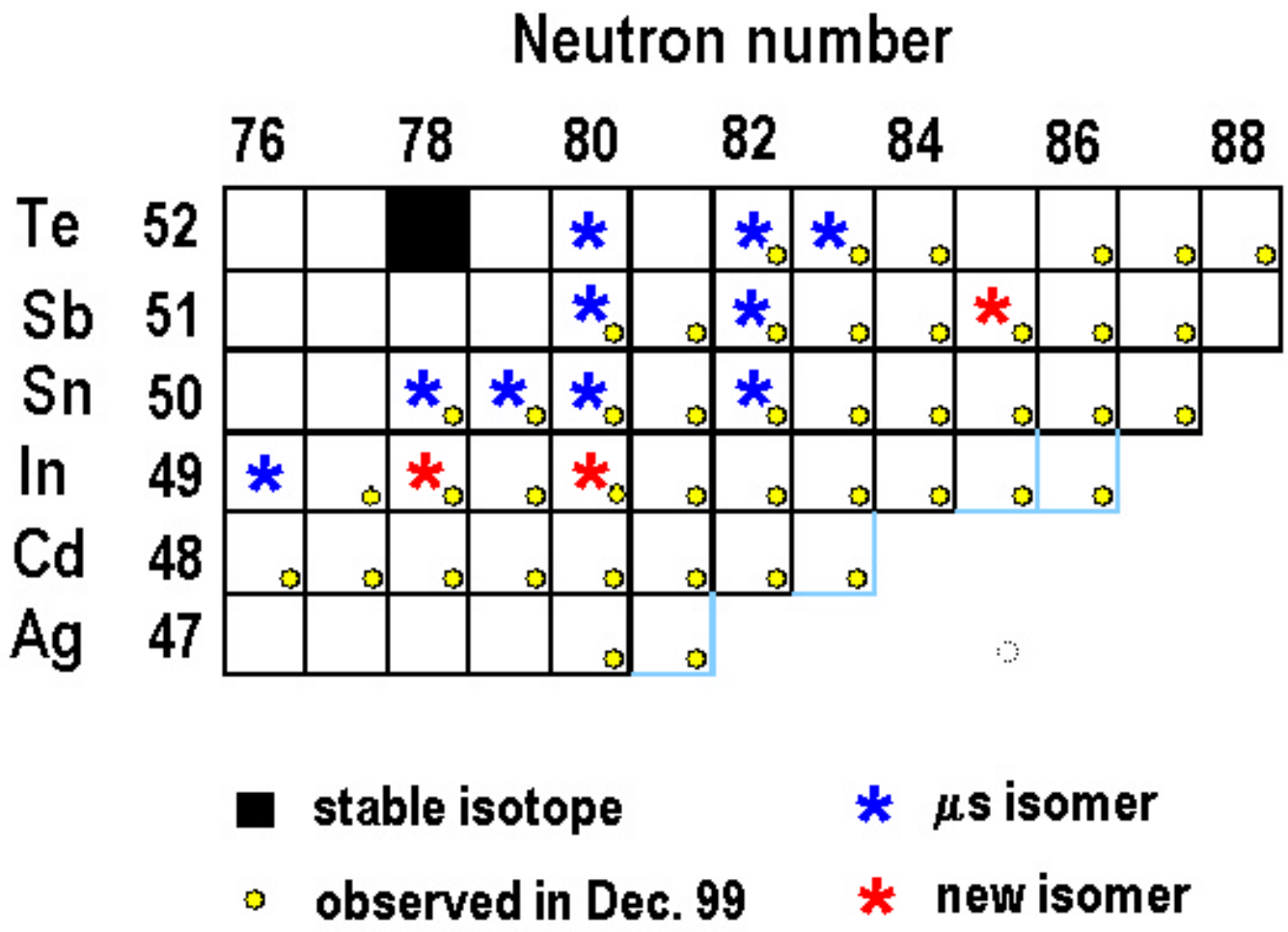
Preliminary ^{127}In data from GSI



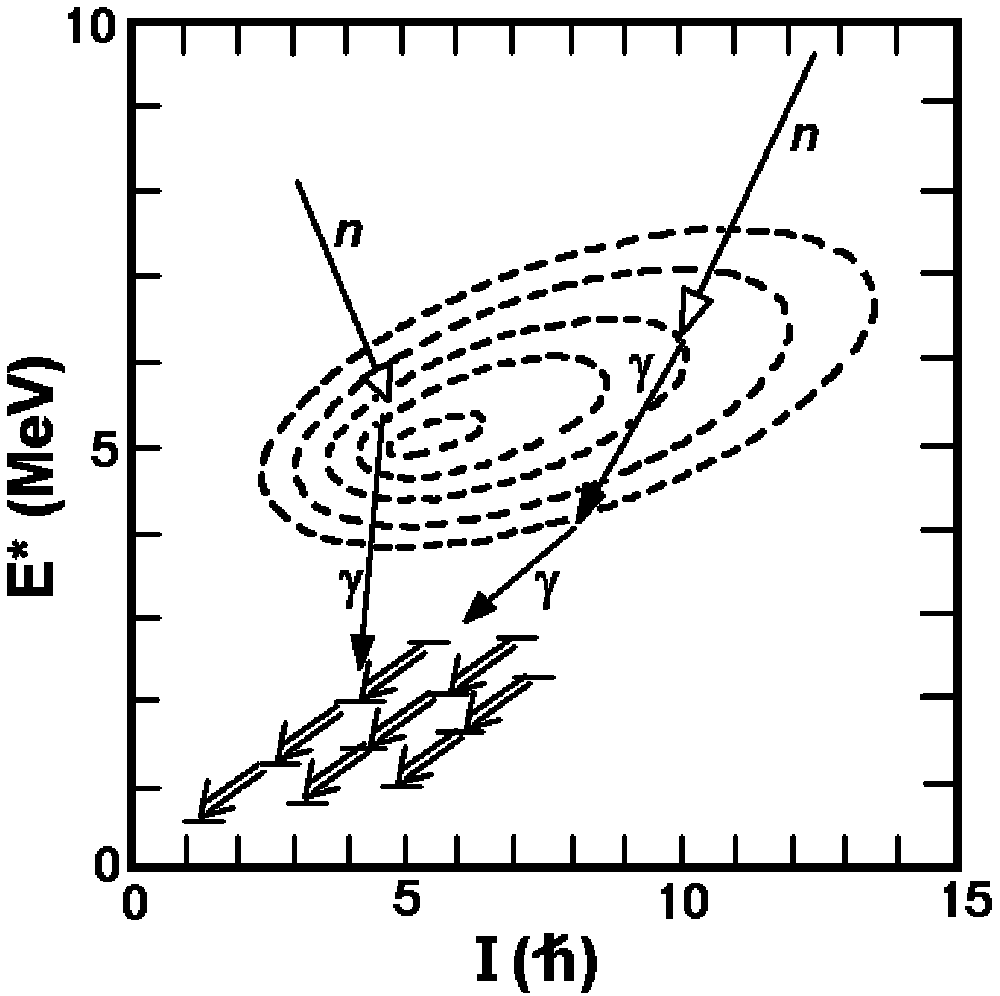
M.N. Mineva et al., GSI experiment December 1999

All isotopes implanted in the S4 catcher (3 settings)

M.N. Mineva *et al.*, GSI experiment December 1999



Angular momentum “production” in low-E* fission

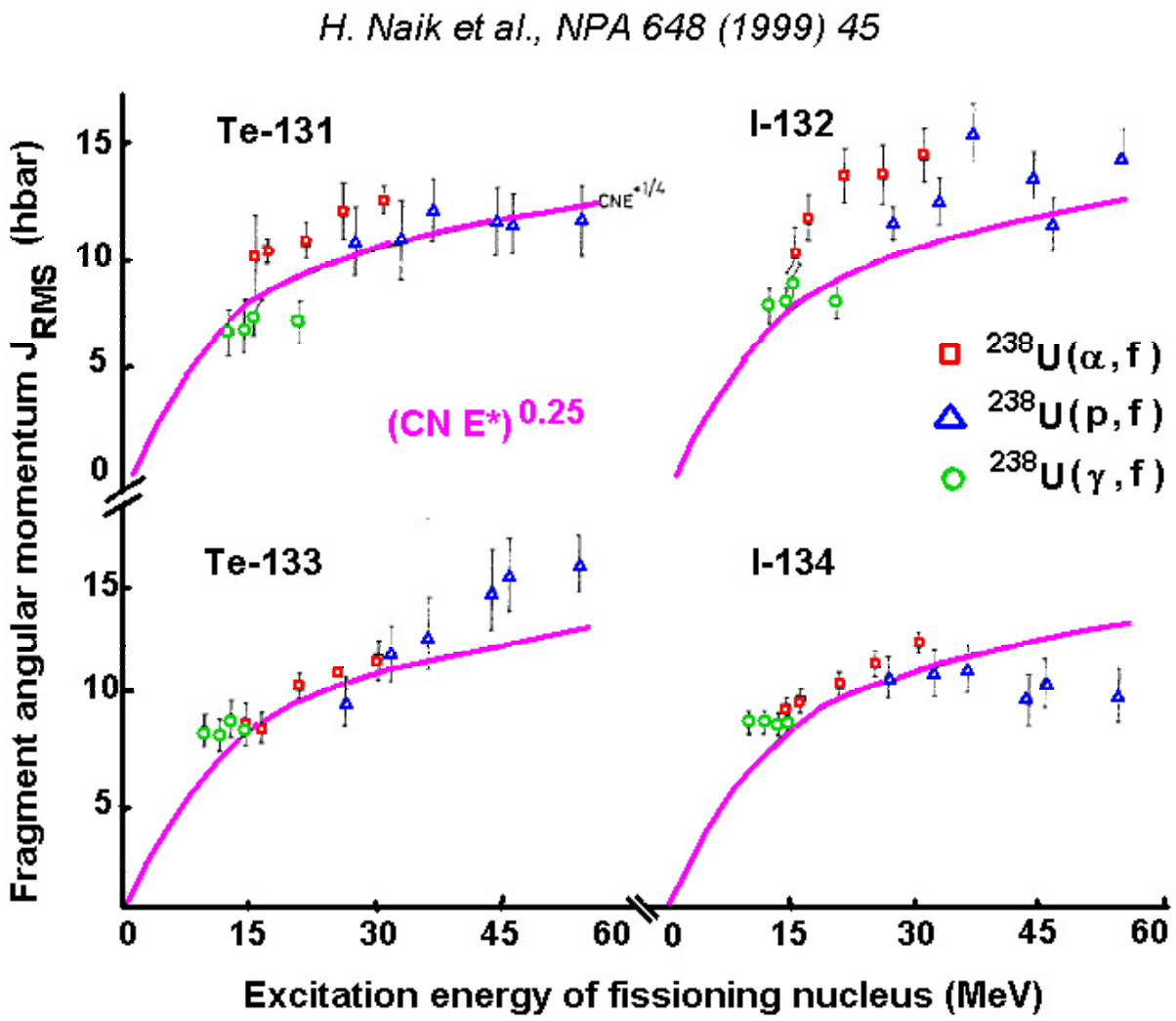


What do we know about fission???

- thermal-neutron induced fission (^{235}U)
  - low E* (asymmetric mass distribution)
- spontaneous fission (^{252}Cf)
  - also relatively low E*
- particle-induced fission (p, d,...)
  - higher E* ($\rightarrow$ symmetric distributions)
- in-flight fission ???
  - high projectile energy, **BUT**
  - peripheral interaction target-projectile
  - target Z determines process:
    - high-Z: electromagnetic – low E*
    - low-Z: nuclear – higher E*

Figure from Ahmad and Phillips, Rep. Prog. Phys. ***58*** *(1995) 1415*

Fission fragment angular momentum:
a-, p- and g-induced fission



Summary and outlook

- Empirical shell model calculations have reached a “limit”, realistic interactions are needed
- Models must be able to reproduce transition rates – level energies are not enough! (spectroscopic factors!)
- Isomer spectroscopy offers a new possibility to study the structure of nuclei far from stability – information also on intermediate levels!
- Several new isomeric decays in nuclei near doubly magic ^{132}Sn have been detected after projectile fission of ^{238}U @ 750 AMeV - ^{136}Sb, ^{127}In and ^{129}In (Dec. 1999)
- Investigations of kinematics and isomeric ratio dependence on production mechanism (Dec. 2001)
- Summer 2002 – spectroscopy of ^{130}Cd and ^{136}Sn, possibly also ^{76}Ni !?