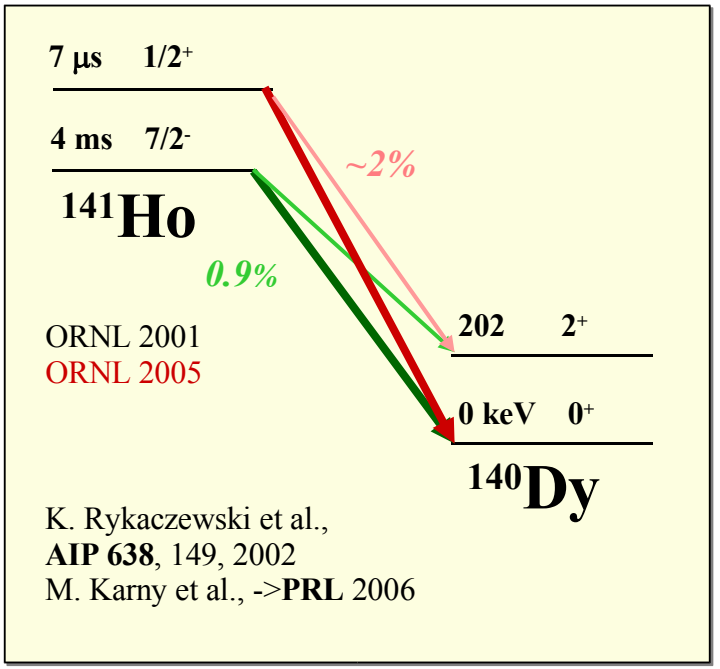
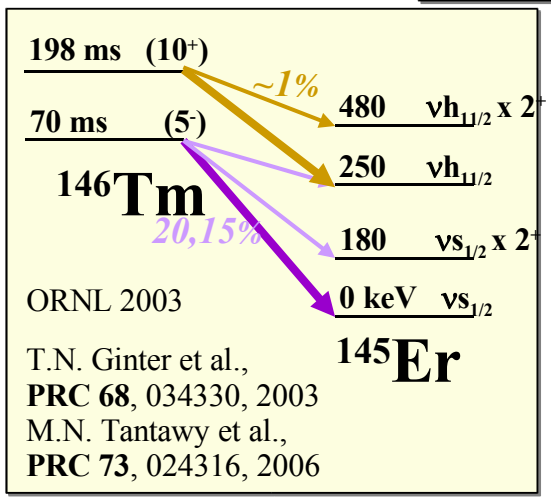
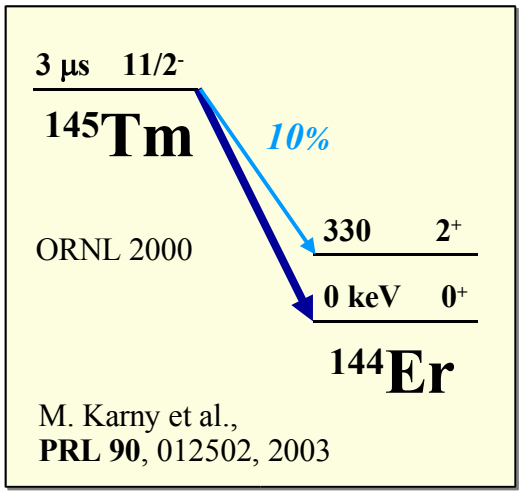
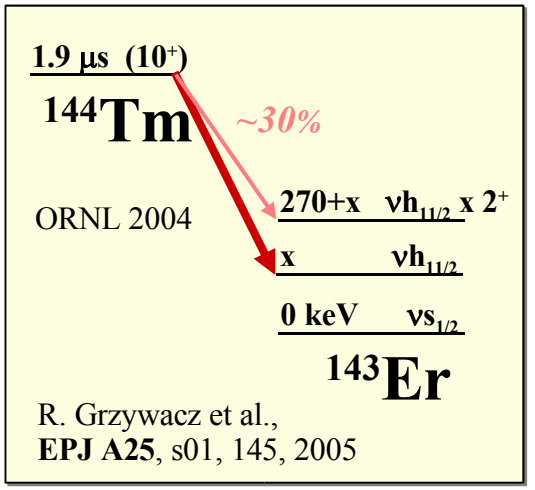
Discovery of the fine structure in proton emission from $^{141g.s,m}$Ho

Robert Grzywacz
University of Tennessee/ORNL









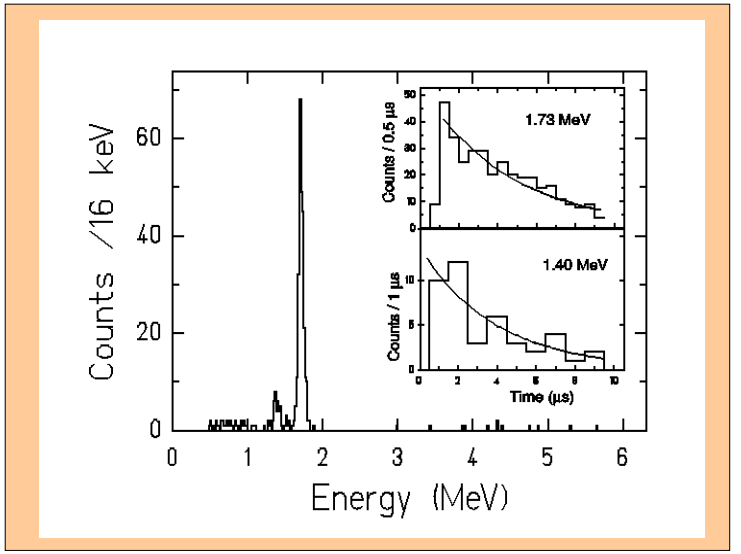
Nature of the nucleonic matter

Limits of nuclear existence & weakly-bound systems

Effects of proton/neutron asymmetry on nuclear properties

Proton decay studies at ORNL

hribf



M. Karny et al PRL

Ultrasensitive experimental method:

Direct observation of proton emitted from the nucleus

(proton energy and lifetime)

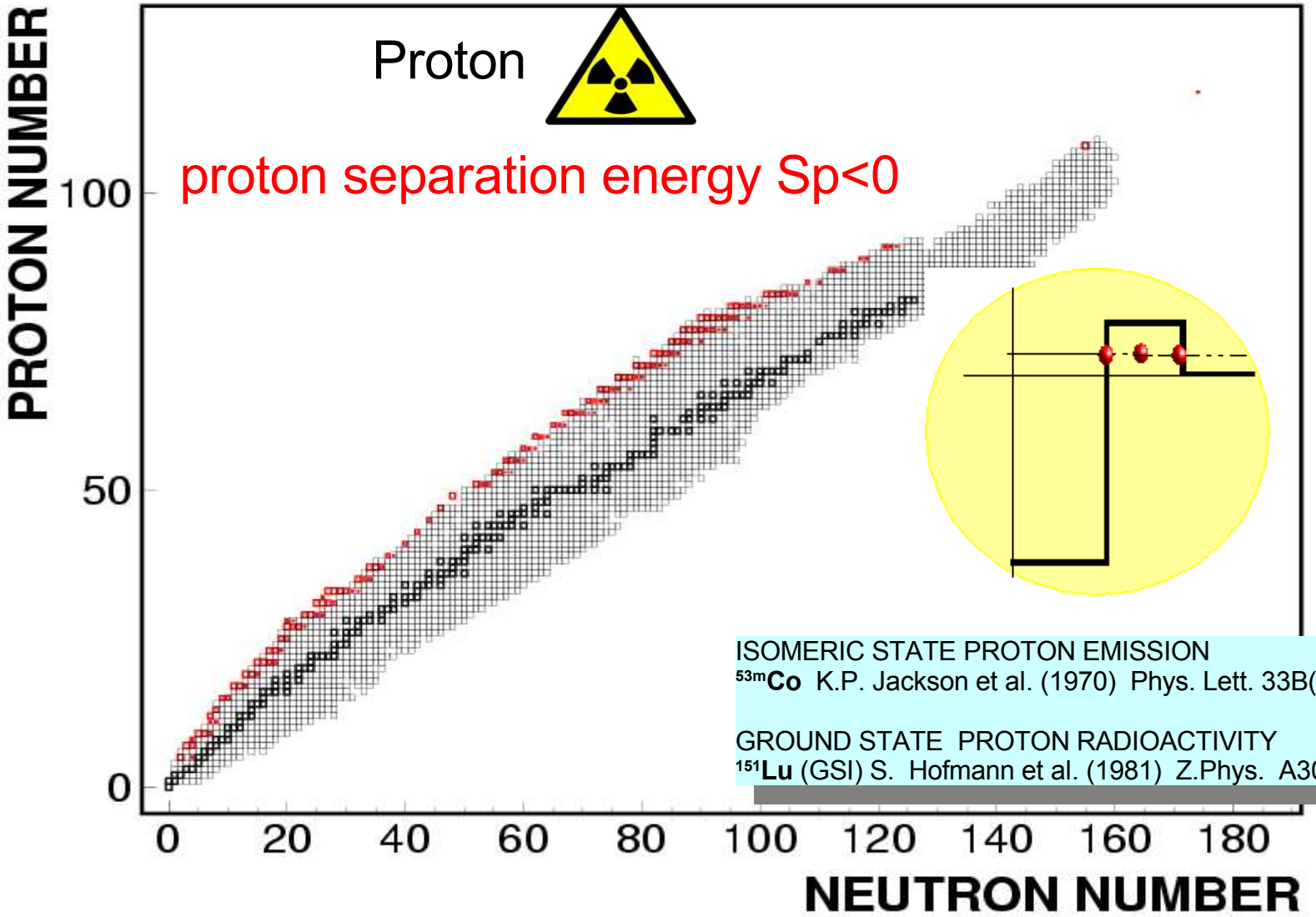
Usefull "general information" :

binding energies, lifetimes

Very successful program:

- short lived proton emitters (lifetimes ~1 μs)
- proton decay to excited nuclear states
- theoretical formalism for 3D-tunneling

Proton emitters - mapping the drip line



ISOMERIC STATE PROTON EMISSION
^{53m}**Co** K.P. Jackson et al. (1970) Phys. Lett. 33B(1970)281

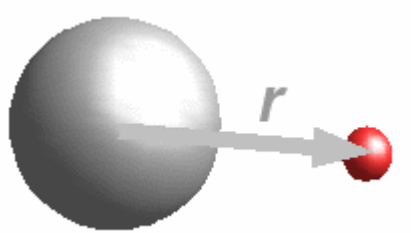
GROUND STATE PROTON RADIOACTIVITY
^{151}**Lu** (GSI) S. Hofmann et al. (1981) Z.Phys. A305(1982)111

VERY STRONG
ENERGY and L DEPENDENCE

$$10^{-22} < T_{1/2} < \infty$$

Fine structure in proton decay - a tool to study configurations

particle - core model



Hypothetical example (spherical)

$\pi d_{3/2} \otimes 0^+$ core

$\pi d_{3/2} \otimes 2^+$core

$\pi s_{1/2} \otimes 2^+$core

50%

$J^\pi=3/2^+$

(N,Z)

?

E_p~700 keV

L=0

~600 keV

2^+

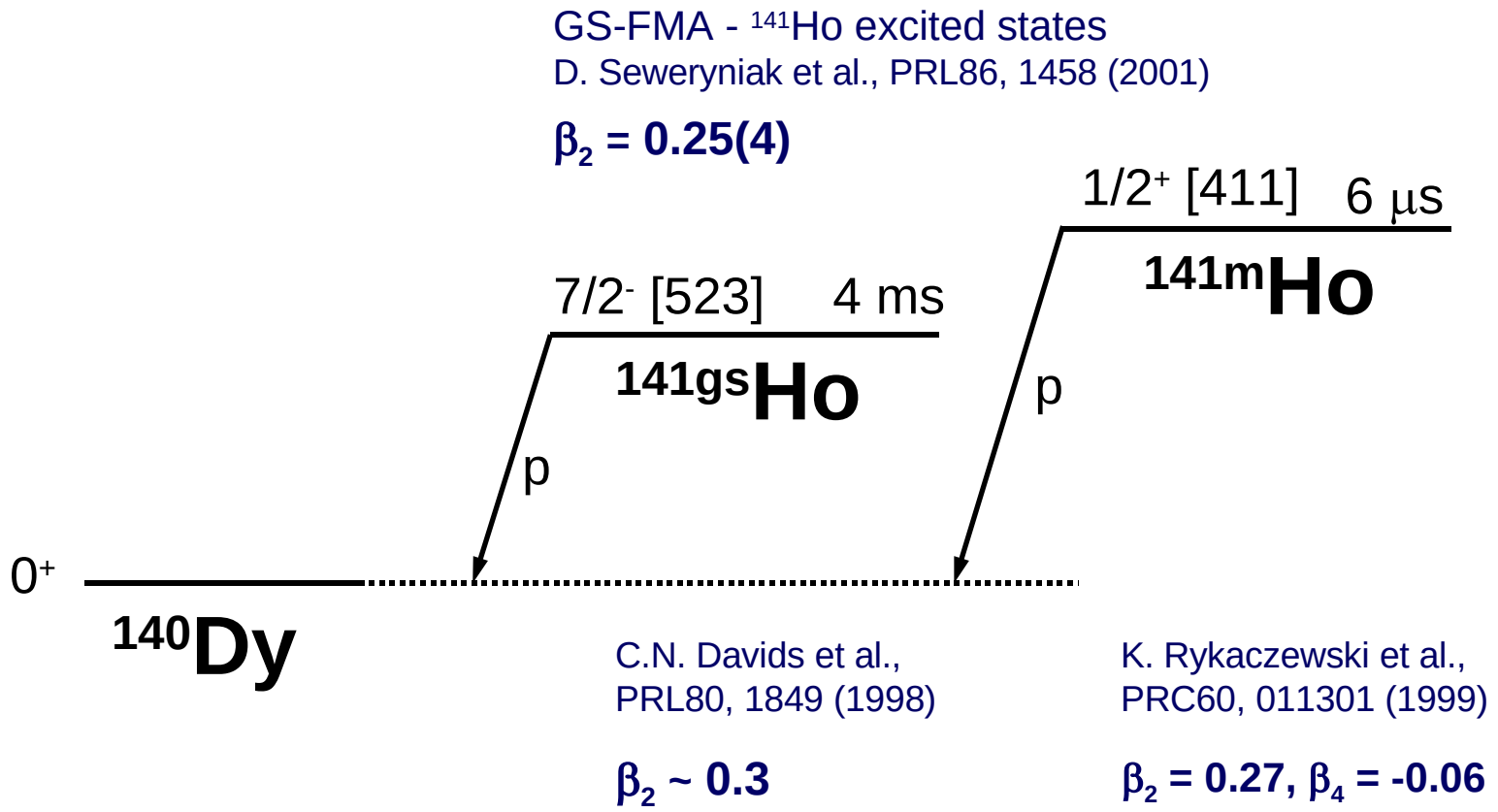
E_p~1100 keV

L=2

0^+

(N,Z-1)

Proton emission from highly deformed ^{141}Ho

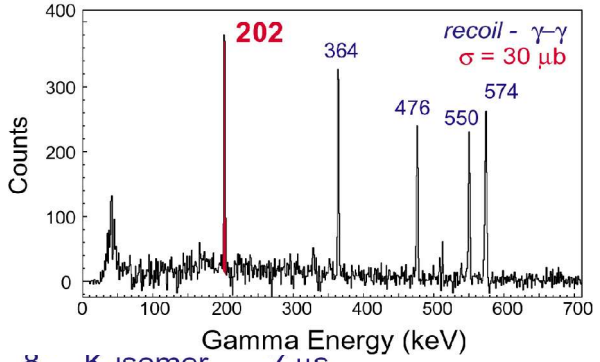


Benchmark nucleus for the particle-rotor model

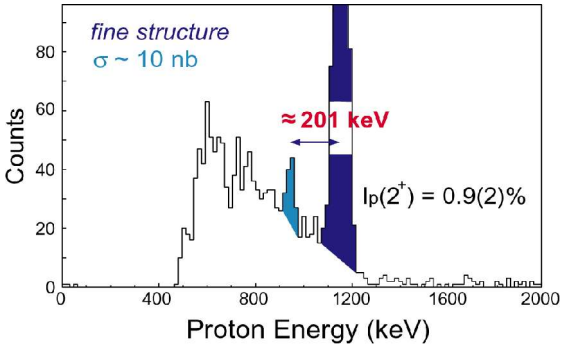
Test the model beyond g.s. to g.s. decay.

Proton emission from deformed ^{141}Ho experimental data constrain the models

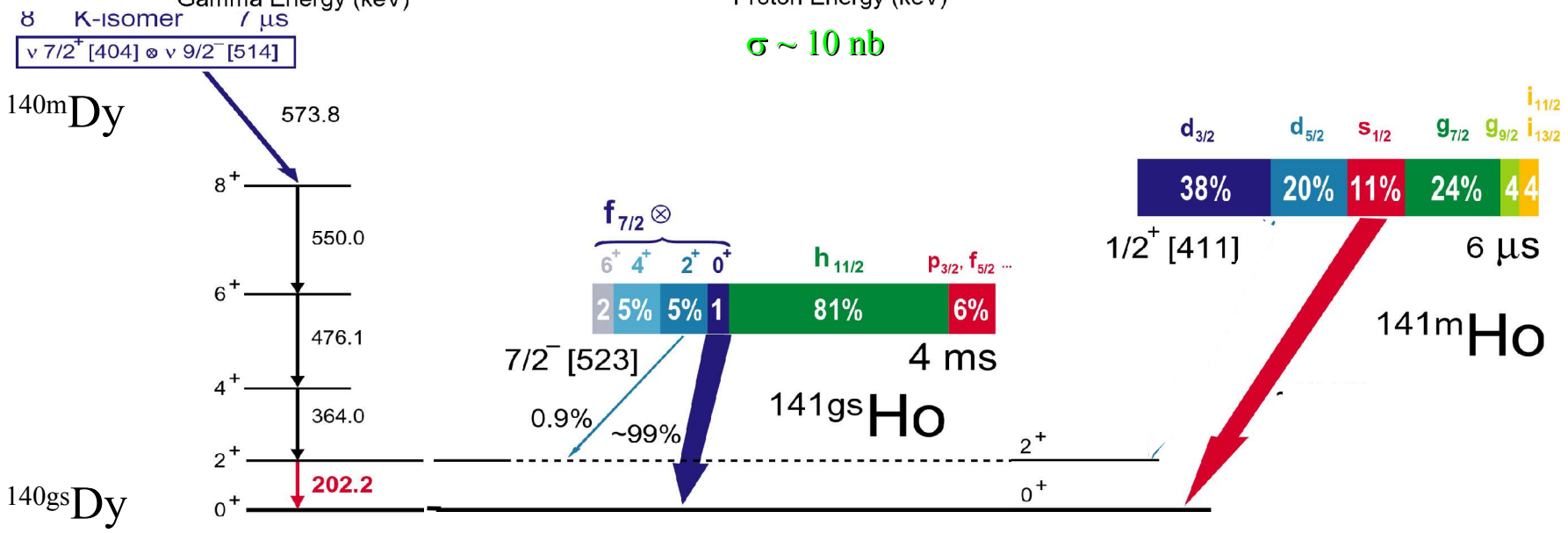
7 μs ^{140m}Dy isomeric decay



4 ms ^{141gs}Ho proton decay



σ ~ 10 nb



new isomer and ground state band; deformation of ^{140}Dy β_2 = 0.23-0.24

W. Krolas et al., PRC65, 031303 (2002)
D.M. Cullen et al., PLB529, 42 (2002)

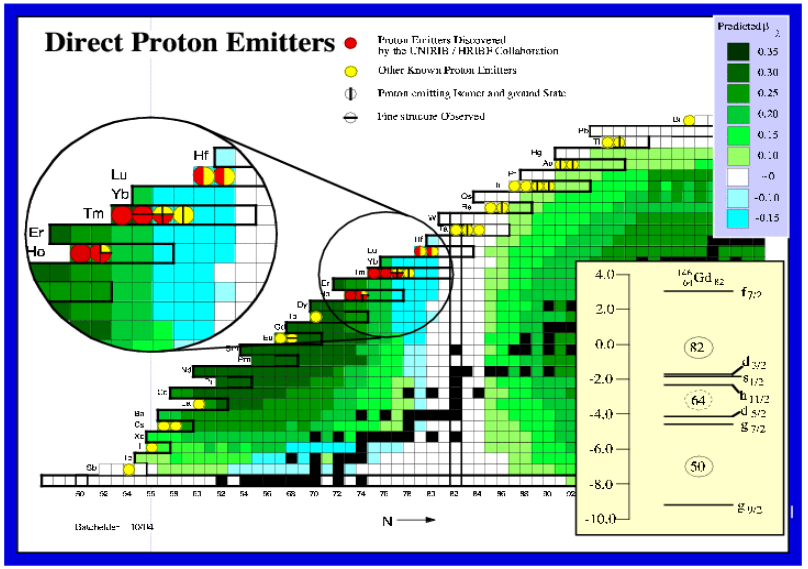
fine structure in proton decay, wave function of ^{141gs}Ho

K. Rykaczewski et al., AIP638, 149 (2002)

Deformed proton emitters :

- nuclear structure
- 3 dimensional (deformed) barrier

have to be taken into account



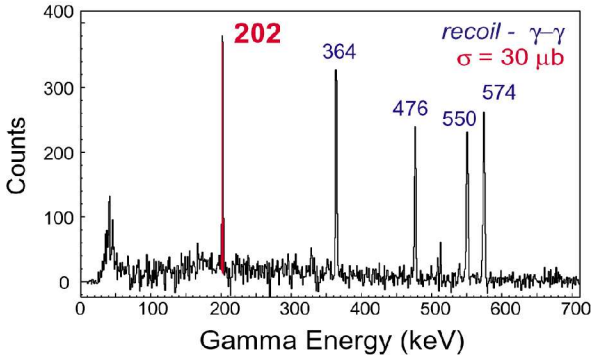
formalism correctly describing variety of cases

(Kadmensky, Davids, Nazarewicz, Kruppa, Ferreira, Maglione, Hagino)

B.Barmore et al. Phys. Rev.C62(2000)054315
H. Esbensen, C. Davids Phys. Rev. C63(2000)014315
L.S. Ferreira, E. Maglione PRL 86(2001) 1721
G. Fiorin et al. PRC67(2003)054302
A. Kruppa, W. Nazarewicz ,Phys. Rev.C69(2004)054311

Fine structure in proton emission from deformed ^{141m}Ho - predictions (constrained model)

7 μs ^{140m}Dy isomeric decay



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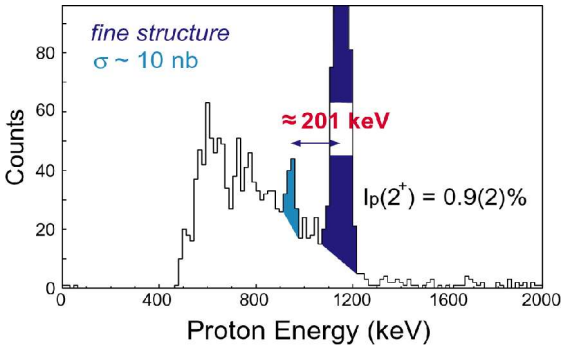
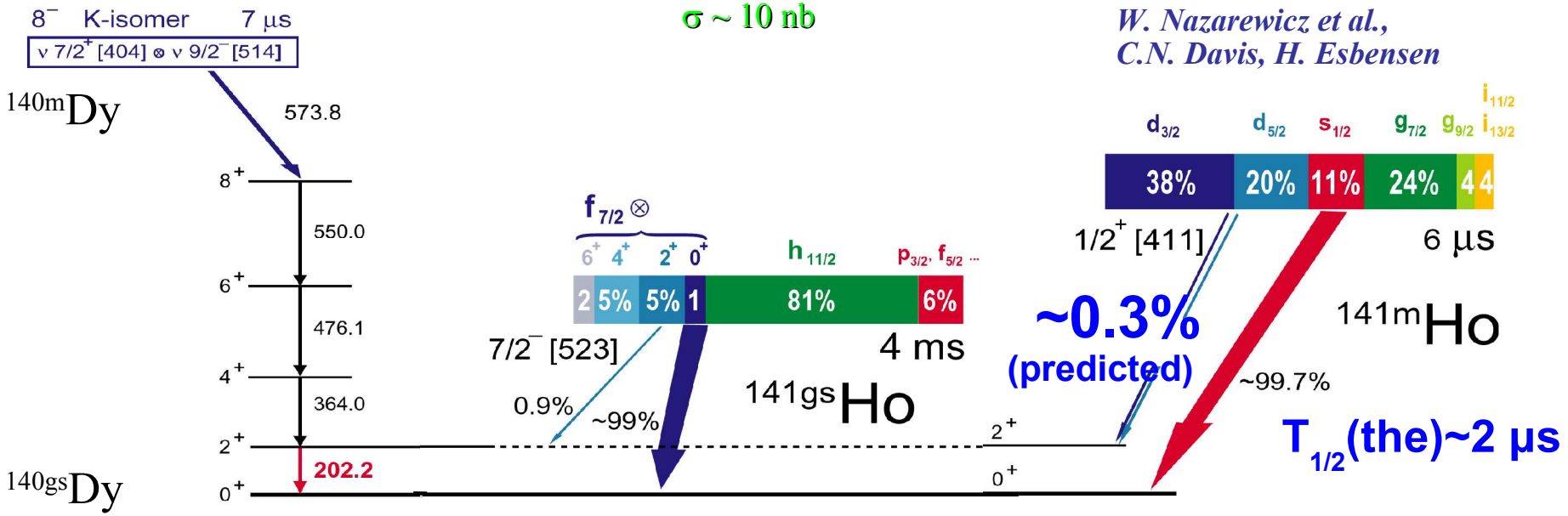


σ ~ 10 nb

W. Nazarewicz et al.,
C.N. Davis, H. Esbensen



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fine structure in proton decay, wave function of ^{141gs}Ho

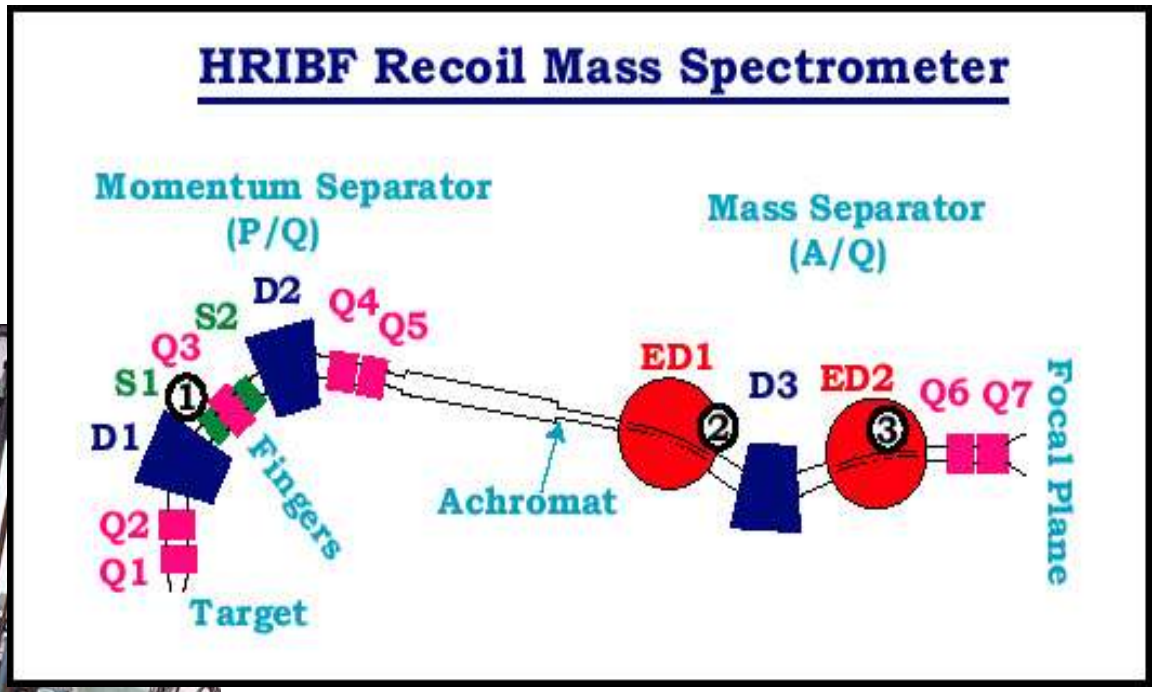
K. Rykaczewski et al., AIP638, 149 (2002)

predicted fine structure in proton decay of ^{141m}Ho

Experimental systems

$$^{54}_{26}Fe_{28}(290\,MeV\,@\,35\,pnA)+^{92}_{42}Mo_{50}\rightarrow{}^{146}_{78}Er^{*}_{68}\xrightarrow{p4n}{}^{141m}_{67}Ho_{74}$$

RMS
large MCP,Si box - DSSD - SiLi



RMS
large acceptance spectrometer
for the fusion-evaporation residues
excellent suppression of primary beam
C.J. Gross et al. NIM A450(2000)12

REAL-TIME DIGITAL SIGNAL PROCESSING (XIA-DGF)

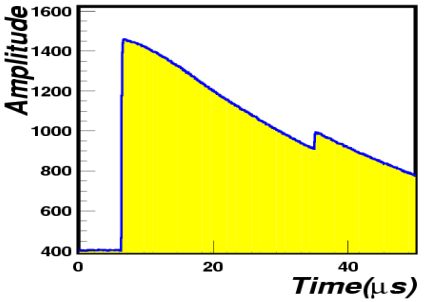
60 MB/s/channel

Analog Digital

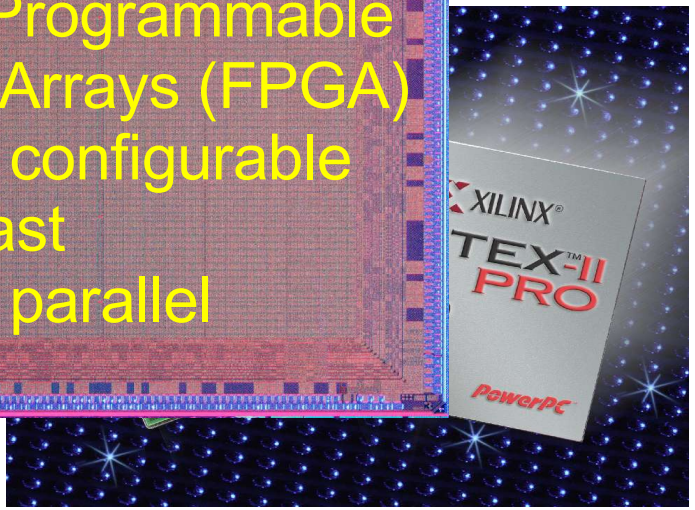
DET

sampling ADC
(40 MHz-100 MHz)
total system load 5.8 GB/s

Selective
triggering
0.3Mb/s



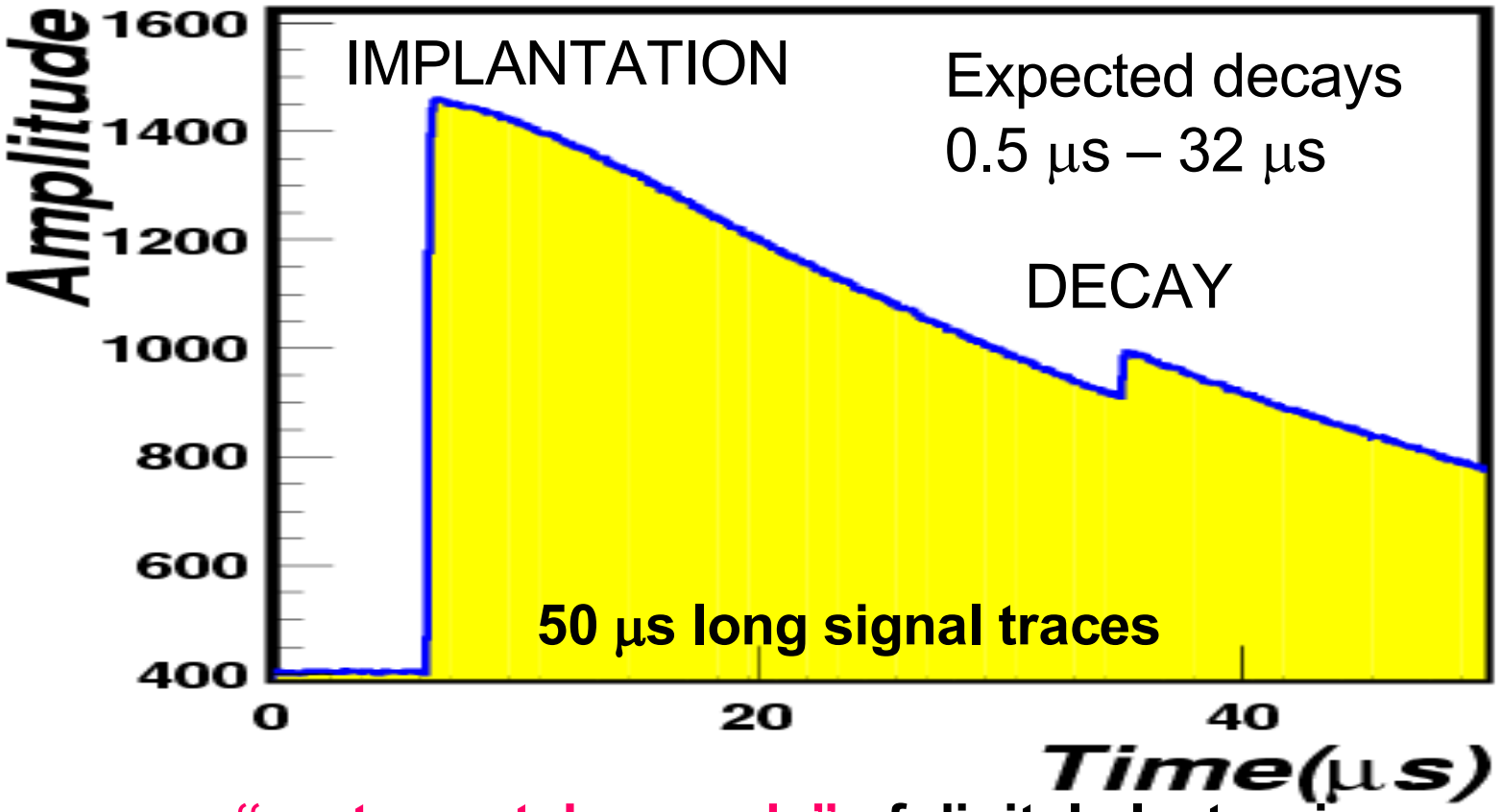
Field Programmable
Gate Arrays (FPGA)
highly configurable
very fast
highly parallel



Electronic signals processing

PROBLEM:
OVERLAPPING PULSES

$E_{implant}$ ~ 20-30 MeV
E_{decay} ~1-2 MeV

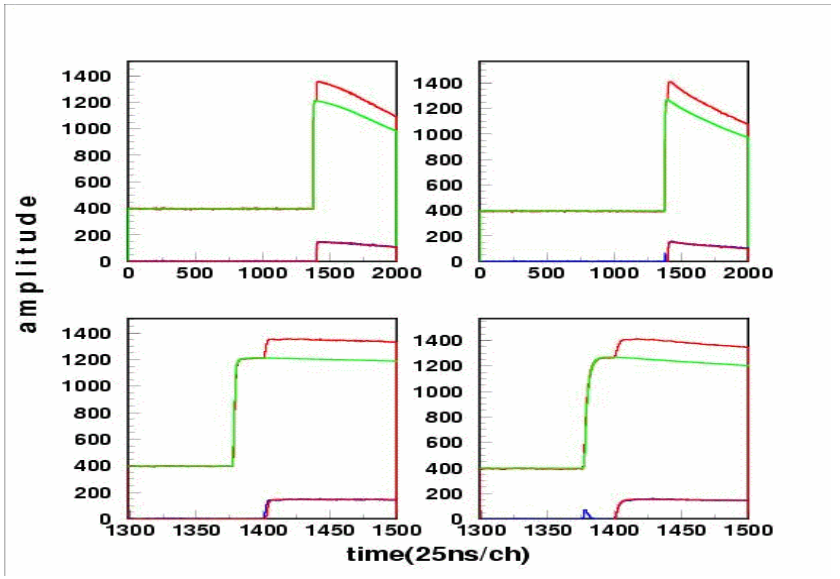


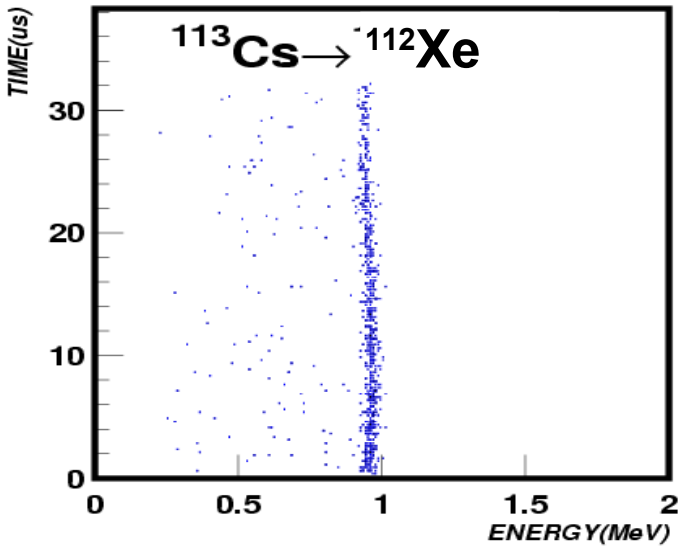
"proton catcher mode" of digital electronics

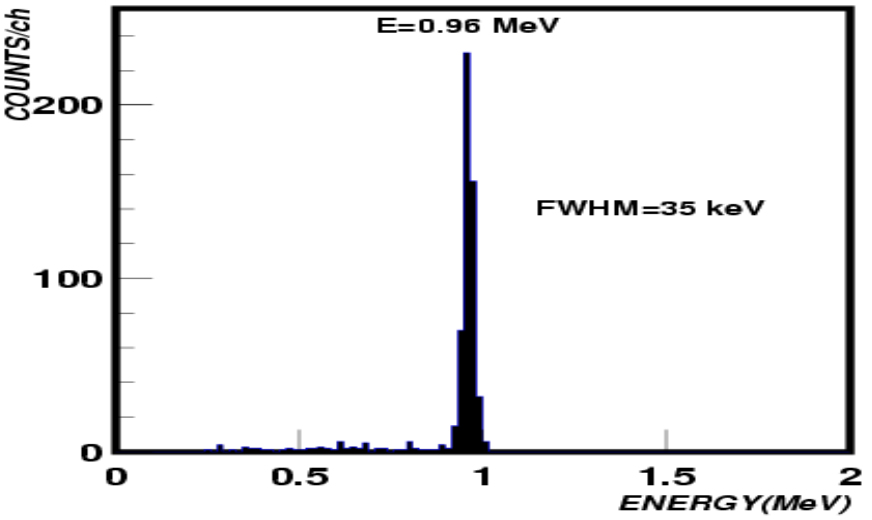
H. Hubbard-Nelson,M. Momayezi, W.K. Warburton NIM A422(1999) 41
R.Grzywacz, NIM B204(2003) 649

Resolution improvements:

New method of data analysis:
“matching shape” (RG)
“gain match algorithm”
(D. Simpson + RG)
Improved resolution
FWHM ~ 35 keV vs 75 keV







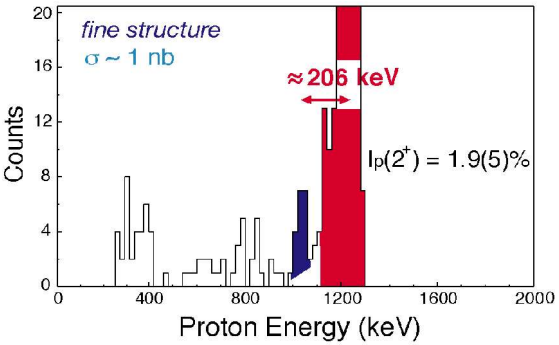
Fine structure in proton emission from deformed ^{141m}Ho experimental result

Observed large branching ratio

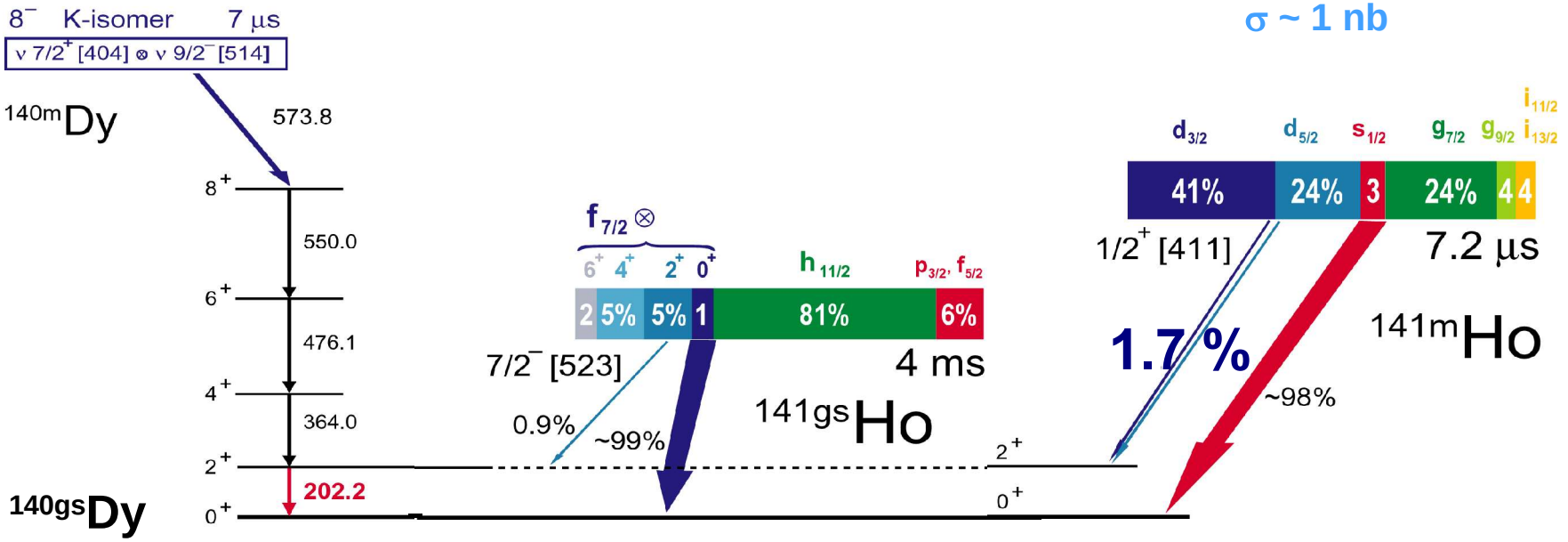
I_p(exp)=1.7% vs I_p(the)=0.3%

The "knobs" e.g. triaxiality, spin-orbit...

7.2 μs ^{141m}Ho proton decay



σ ~ 1 nb



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fine structure in proton decay, wave function of ^{141m}Ho

M. Karny et al., RIB133 exp, 2005
to be published

Proton emission from deformed ^{141,141m}Ho

Benchmark nucleus for the particle rotor model
Multiple HRIBF contribution
"Tour de force" for the HRIBF DSP system
New experimental information
I_p(exp)=1.7% vs I_p(the)=0.3%

Revision of the theoretical description