Indications of Deformation Along the N = 40 Isotones

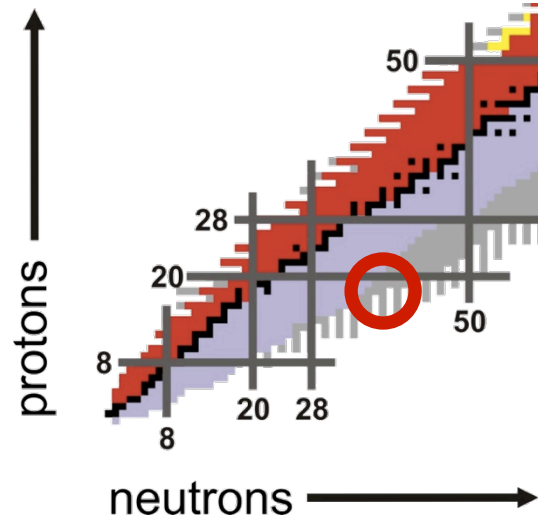
SN Liddick

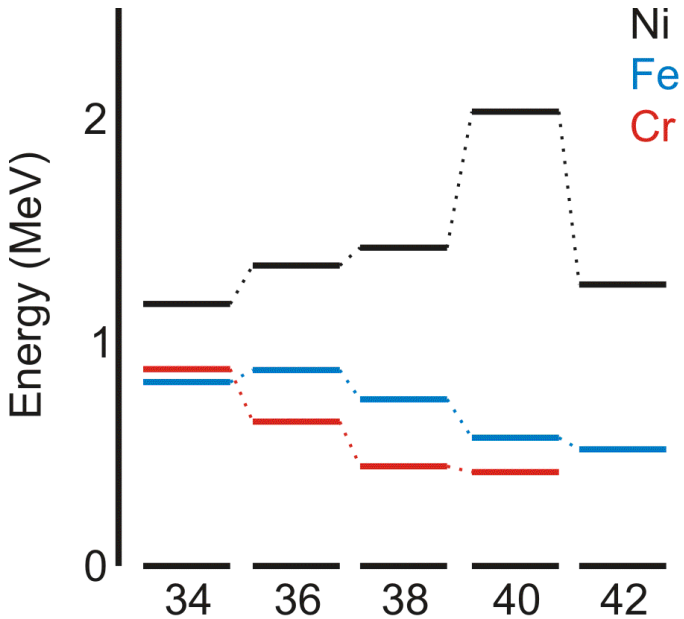
NS 2012

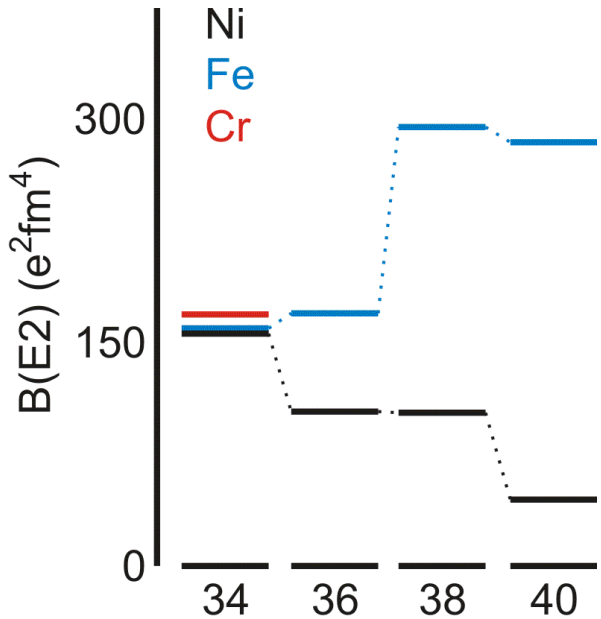
8/14/2012

N = 40

- Rapid development of collectivity as protons are removed from the $f_{7/2}$ single-particle state.
- Evidenced by drop in excitation energy of first 2^+ level in even-even nuclei and increase in B(E2) values.





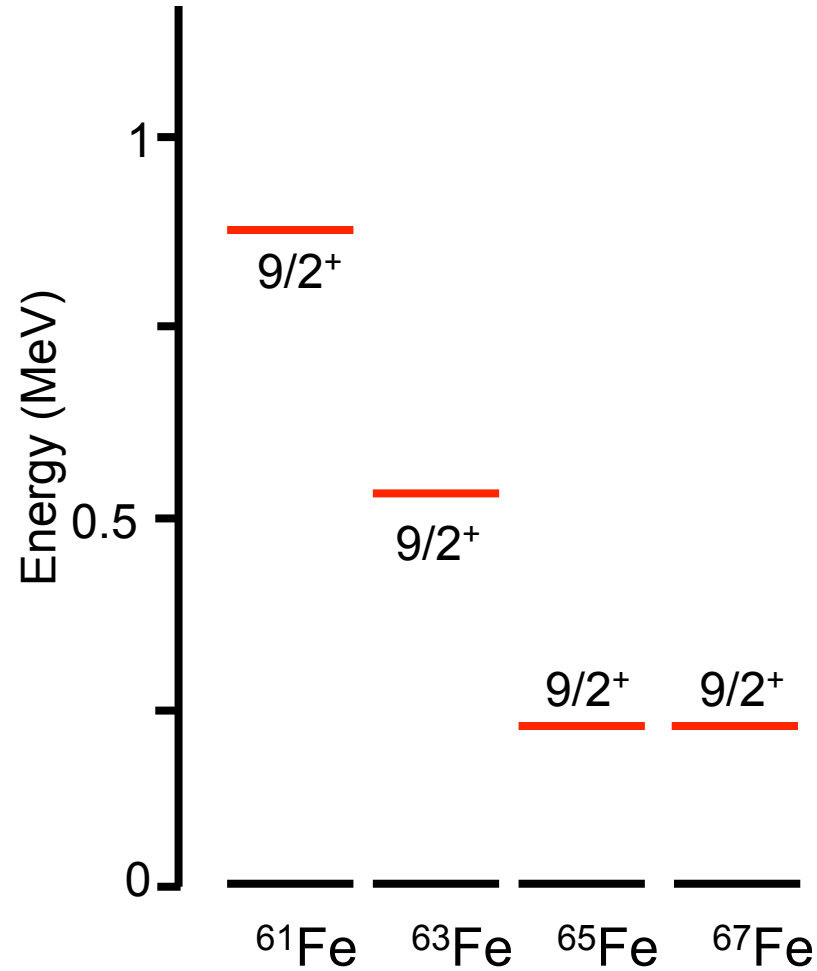


W. Rother *et al.*, PRL 106, 022502 (2011)
Gade *et al.*, PRC, 81, 051304 (2010)
M. Hannawald *et al.*, PRL 82, 1391 (1999)
S. Lunardi *et al.*, PRC 76, 034303 (2007)
O. Sorlin *et al.*, EPJA 16, 55 (2003); PRL 88, 092501 (2002)
A. Burger et al., PLB, 622, 29 (2005)

Neutron states

- Development of collectivity attributed to influence of neutron $g_{9/2}$ single-particle state
- Low-energy positive parity isomeric states in odd-A Fe isotopes.
- Positive parity band heads in odd-odd Mn isotopes.
- Significant occupation of neutron $g_{9/2}$ single-particle state starting at N = 36

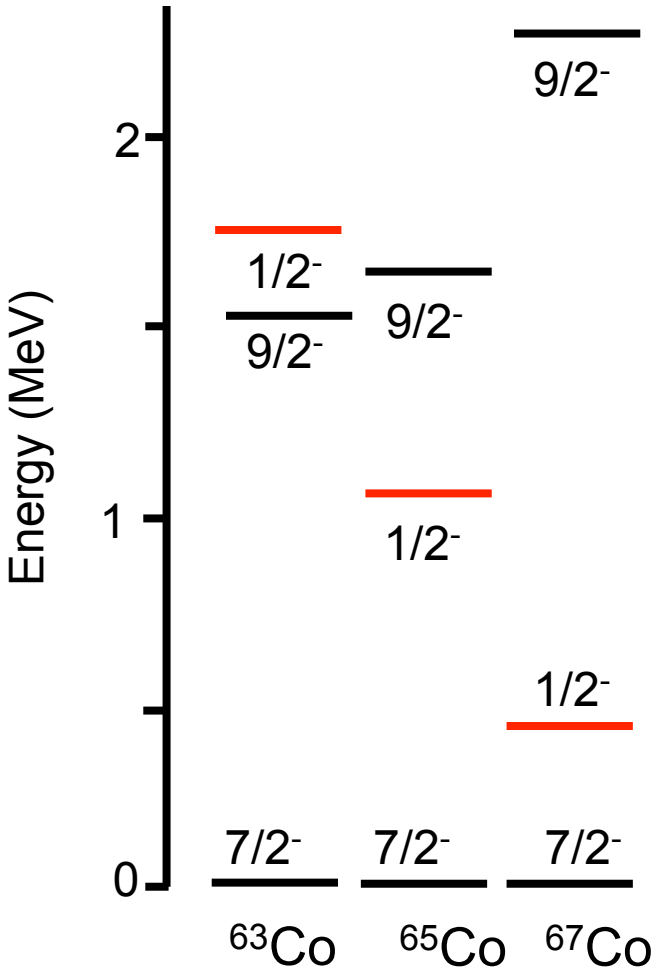
	$g_{9/2}$	$d_{5/2}$
$^{62}Fe_{36}$	0.95	0.12
$^{64}Fe_{38}$	2.0	0.27
$^{66}Fe_{40}$	3.22	0.51



R. Grzywacz *et al.*, PRL 81, 766 (1998)
R. Ferrer *et al.*, PRL, 81, 044318 (2010)
S. Lenzi *et al.*, PRC, 82, 054301 (2010)
S. Lunardi *et al.*, PRC 76, 034303 (2007)
M. Sawicka *et al.*, EPJA 16, 51 (2003)

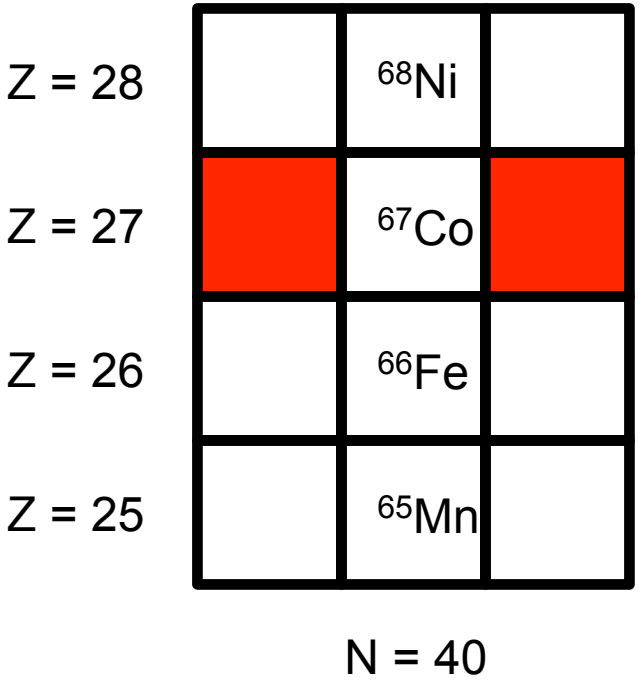
^{67}Co – proton states

- Proton intruder states observed in odd-A Co isotopes due to proton excitations across Z = 28
- 1/2- states identified in ^{65,67}Co from beta decay experiments
- Rapid drop in energy of the $1/2^-$ state as a function of neutron number
- Inferred deformation of ~0.3

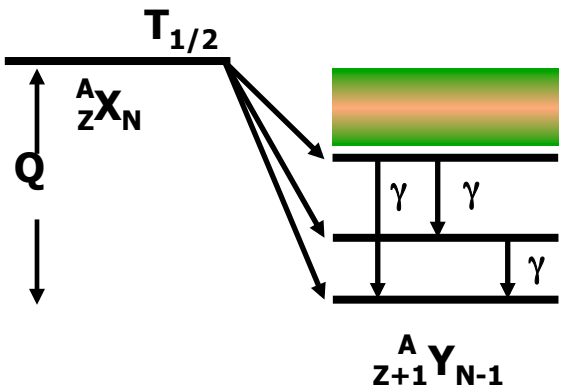


D. Pauwels, *et al.*, PRL 78, 041307 (2008)
F. Recchia, *et al.*, PRC 85, 064305 (2012)

^{66,68}Co

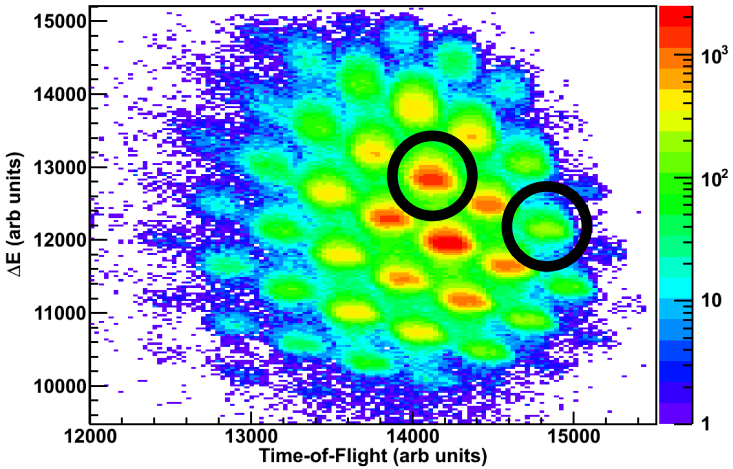


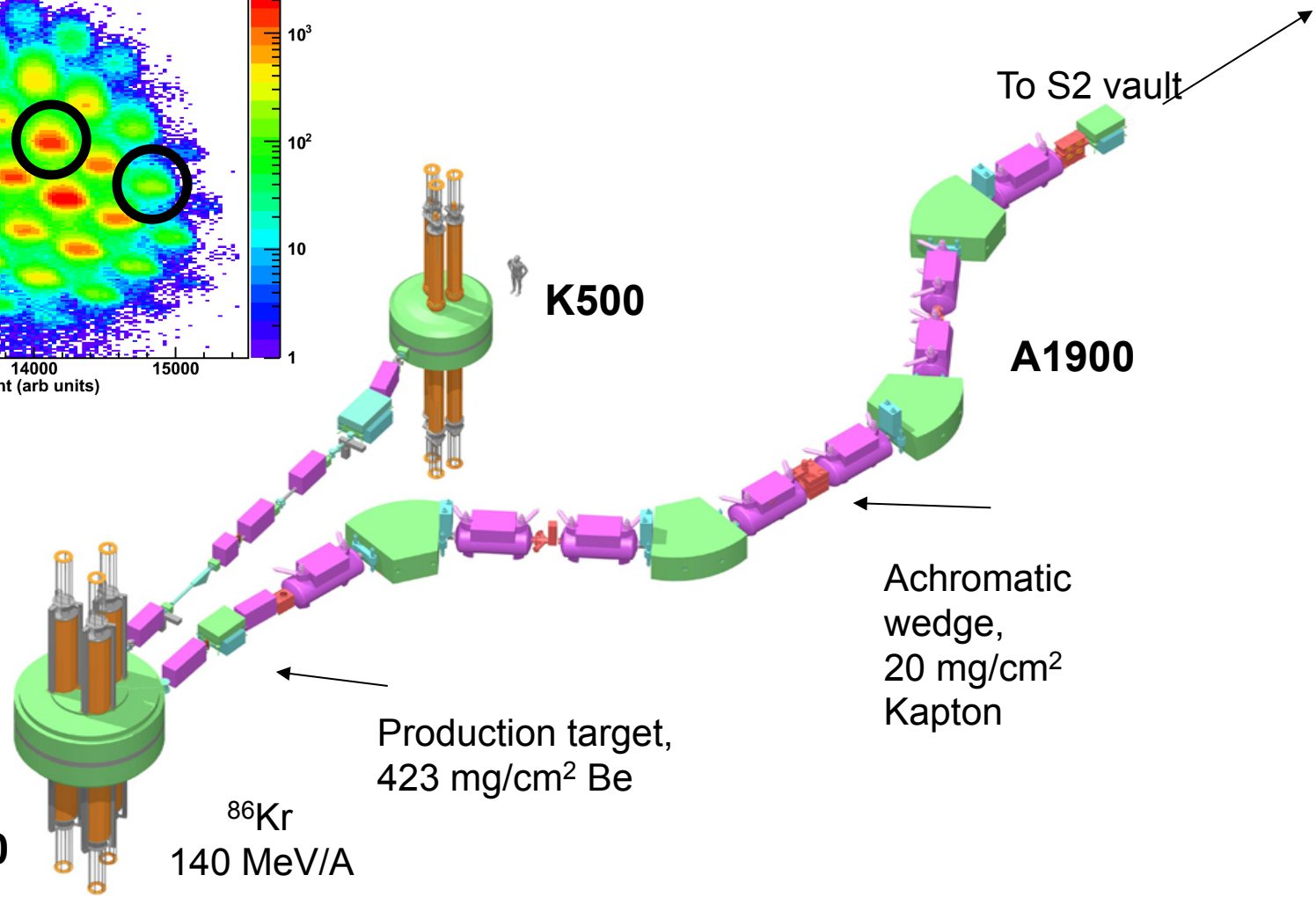
- Search neighboring odd-odd Co isotopes for states associated with neutron and protons intruder levels.
- Populate through beta decay of the respective Fe isotopes.



schematic β decay

NSCL


15000
14000
13000
12000
11000
10000
ΔE (arb units)
12000
13000
14000
15000
Time-of-Flight (arb units)
10^3
10^2
10
1


To S2 vault
K500
A1900
Achromatic wedge, 20 mg/cm^2 Kapton
Production target, 423 mg/cm^2 Be
^{86}Kr
140 MeV/A
K1200

NSCL Beta Counting System + SeGA

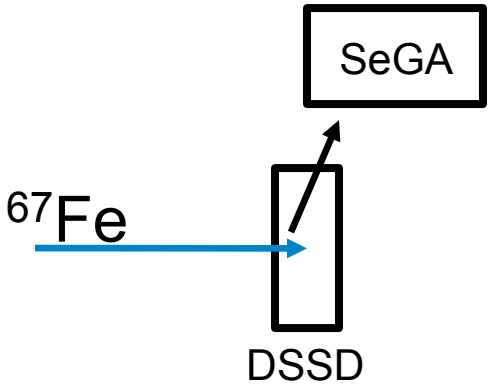
- Beta-decay apparatus allows the correlation of exotic ion implants with their subsequent decays on an event-by-event basis

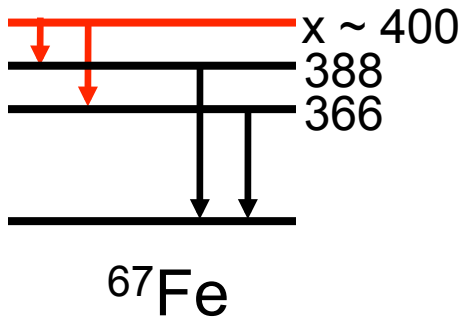
- DSSD: 40 front strips and 40 perpendicular back strips segment detector into 1600 pixels
- Surrounding the BCS, 16 detectors from the MSU Segmented Germanium Array (SeGA) . Efficiency ~ 7% at 1 MeV
- All detectors instrumented with digital data acquisition system (DDAS)

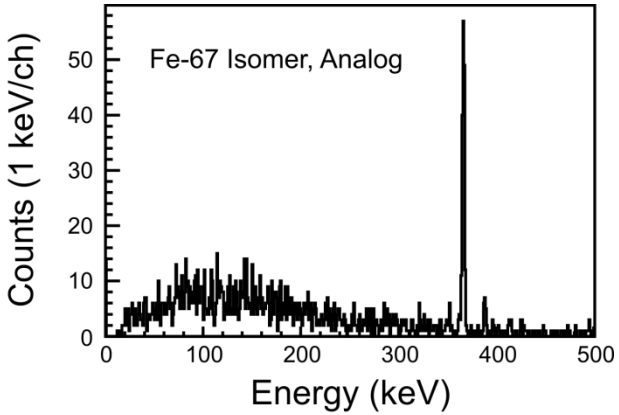
Prisciandaro *et al.*, NIM A505, 140 (2003)

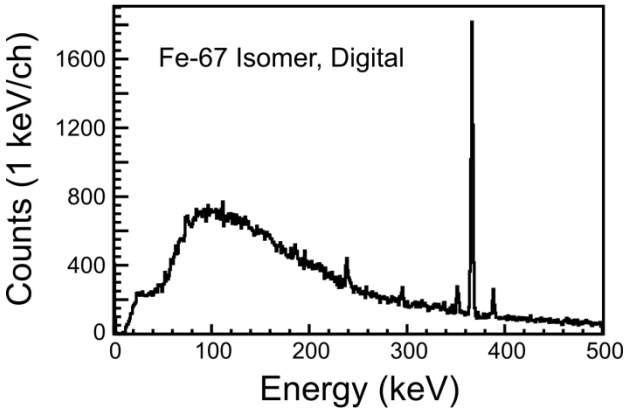
BCS and DDAS

Isomeric state

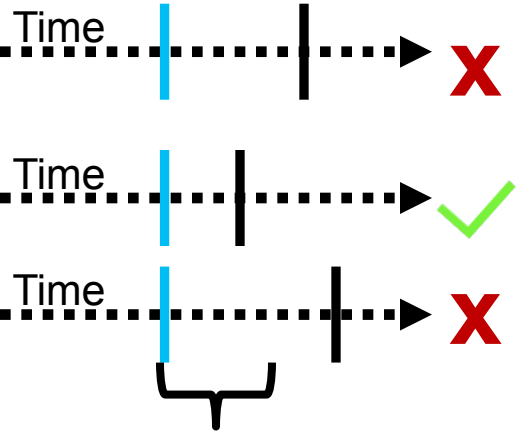




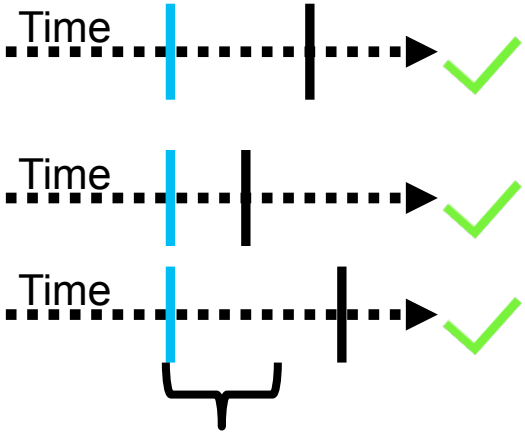




Analog

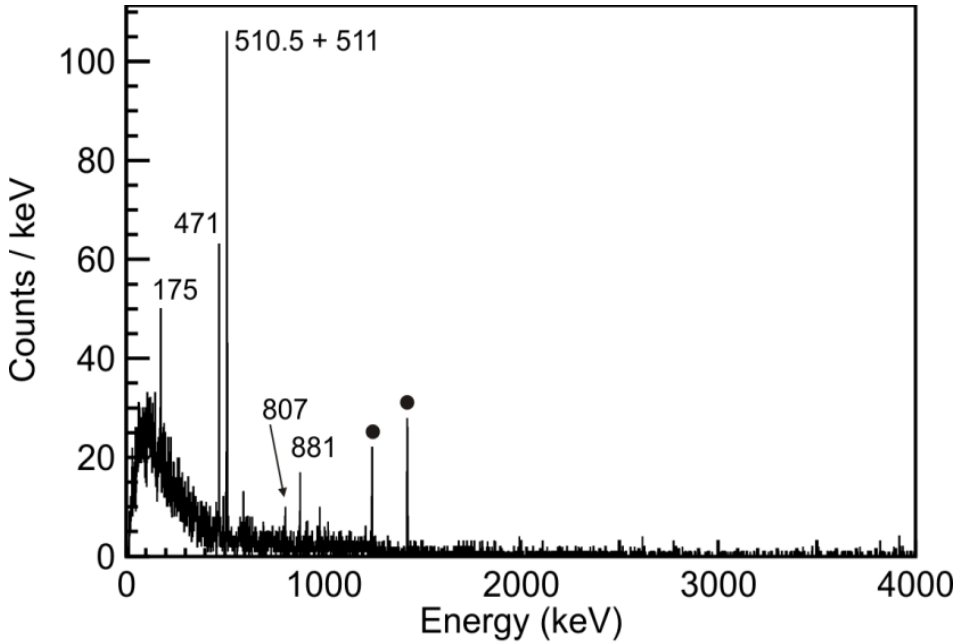


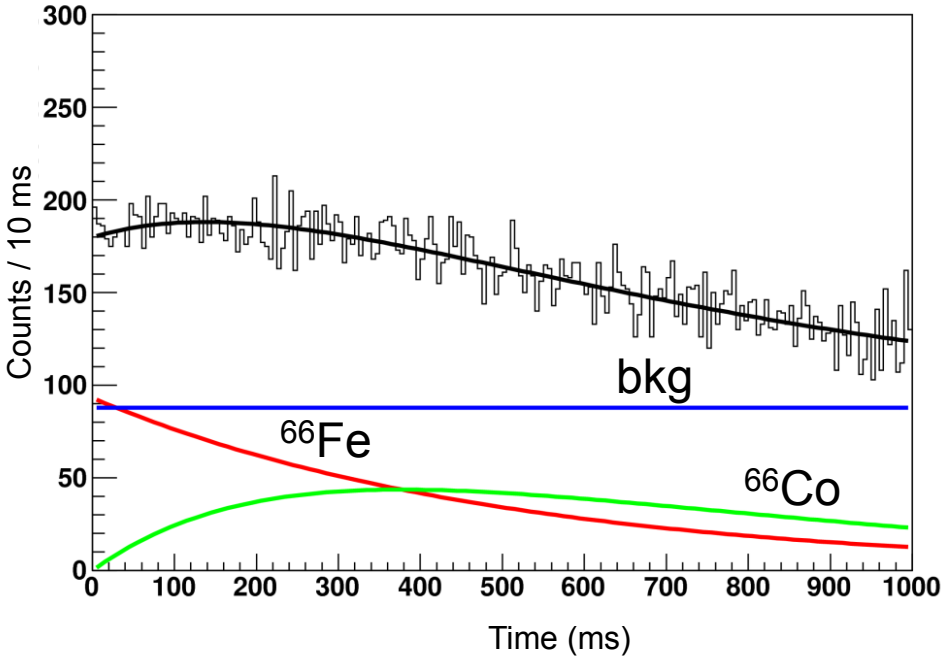
Digital



- Unique acquisition modes increases the sensitivity to longer lived isomeric states

^{66}Fe beta decay



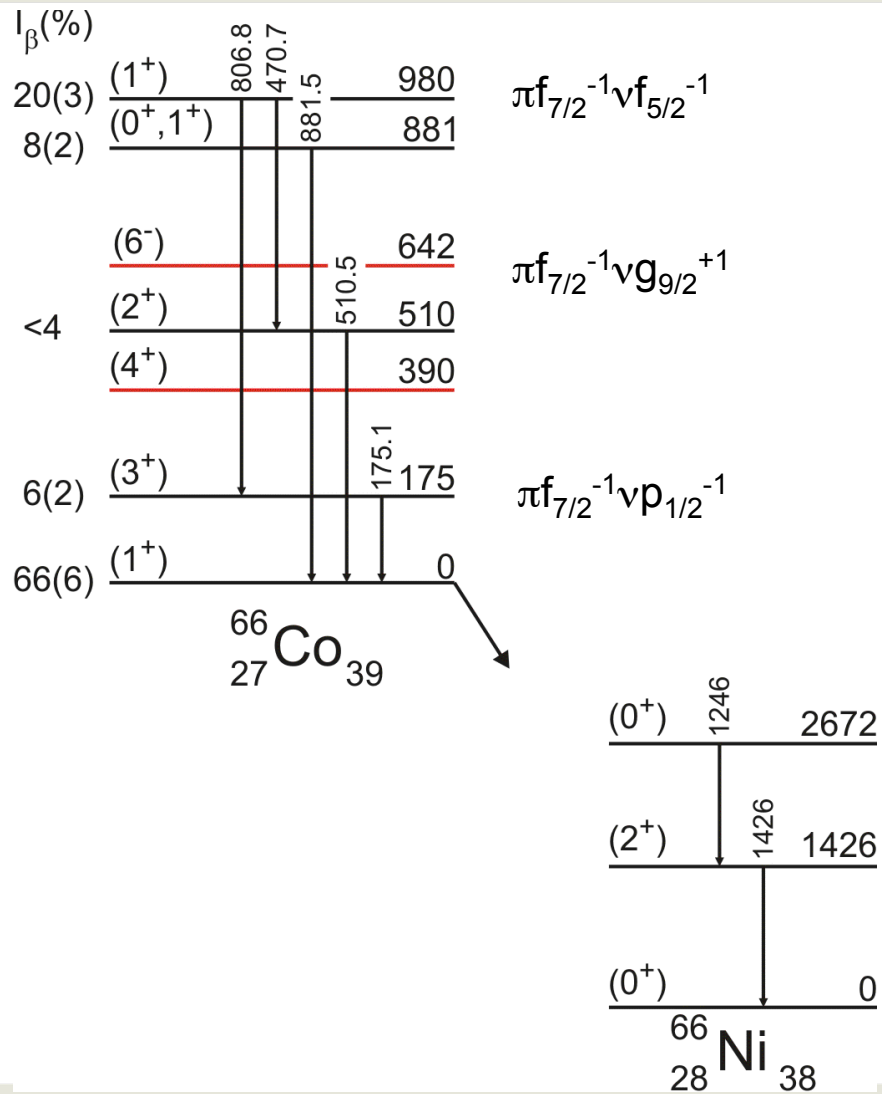


- ^{66}Fe $t_{1/2}$ – 351(6) ms

E (keV)	I (%)	E (keV)	I (%)
175.1	6(2)	806.8	5(2)
470.7	15(3)	881.5	8(3)
510.5	14(2)		

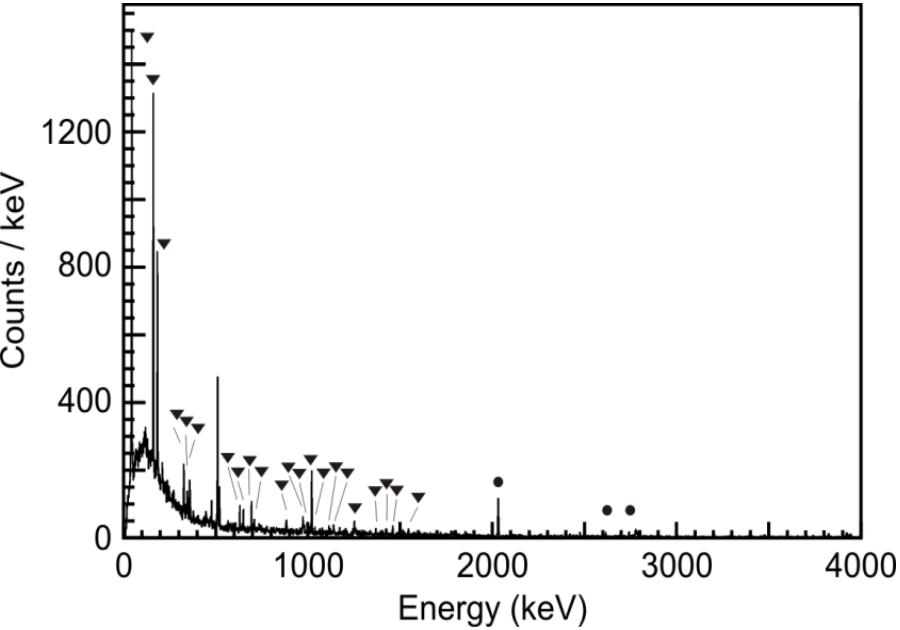
^{66}Co level scheme

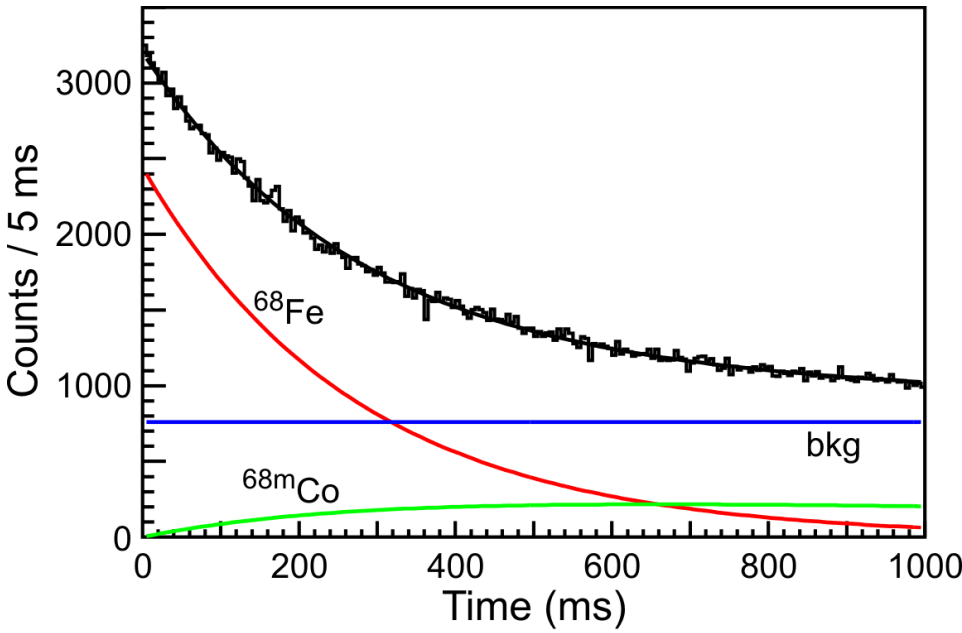
- Level scheme with absolute branching ratios
- High-spin isomeric states in ^{66}Co not observed in beta decay.
- ^{66}Co ground state likely 1^+.
- Reassignment of ^{66}Co ground state consistent with beta decay of ^{66}Co into ^{66}Ni.



W. Darcy et al., NPA 170, 253 (1971)
W.F. Mueller et al., PRC, 61, 054308 (2000)
R. Grzywacz *et al.*, PRL 81, 766 (1998)

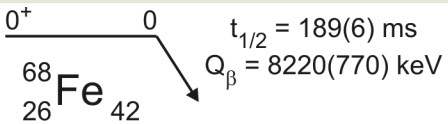
^{68}Fe beta decay



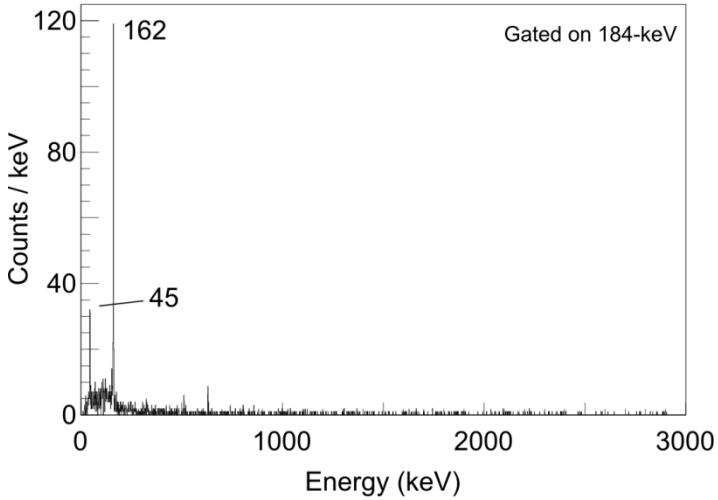


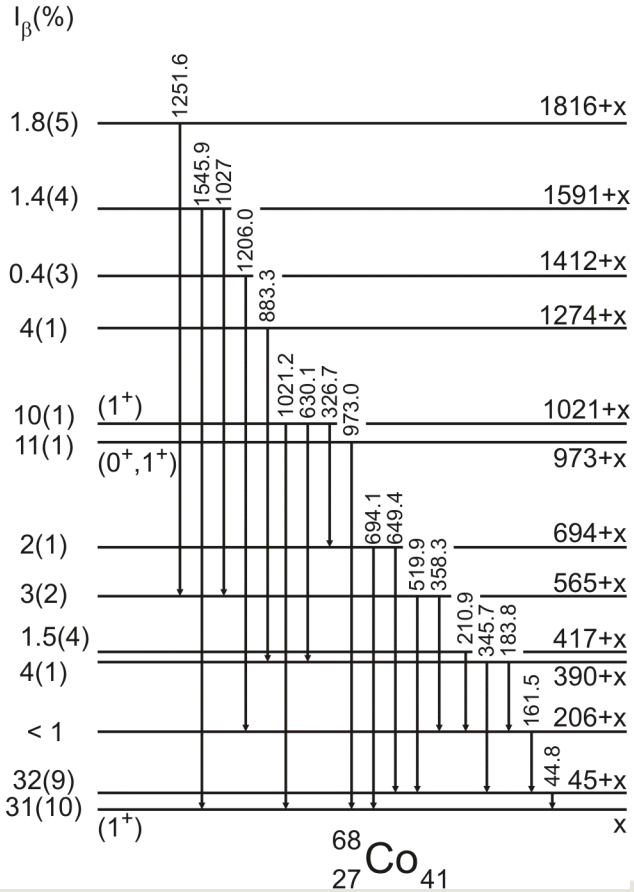
- Fe beta decay data into the Co isotopes.
- Only feed low-spin isomeric state in Co based on absence of transitions from decay of ^{68}Co 7^- state
- Total of 23 transitions observed and attributed to decay of ^{68}Co.
- ^{68}Fe $t_{1/2}$ – 189(6) ms

^{68}Co level scheme

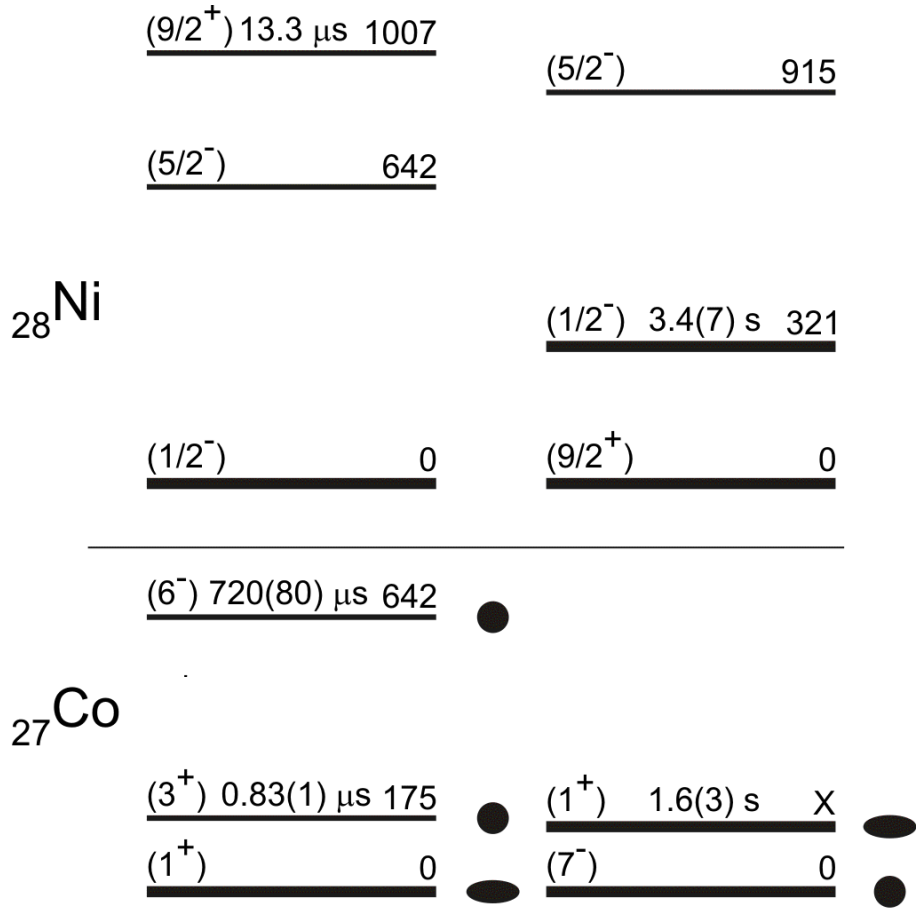


- ^{66}Co ground state likely 1^+.
- Reassignment of ^{66}Co ground state consistent with beta decay of ^{66}Co into ^{66}Ni.
- Infer electron conversion coefficient for 45-keV transition





N = 39,41 isotones



SN Liddick *et al.*, PRC, 85, 014328 (2012)

Summary

- Inferred presence of deformed and spherical states from the low-energy level schemes of odd-odd Co isotopes compared to neighboring nuclei
- Expect intruder configurations to dominate ground states of lower Z, N = 40 isotones.
- Further experimental data would aid in making tentative spin and parity assignments.

Collaborators

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  - H.L. Crawford
- Leuven
  - I.G. Darby
  - M.M. Rajabali
- MSU
  - S. Ilyushkin
- ORNL
  - K. Rykaczewski
- UTK
  - A. Ayres
  - A. Bey
  - C.R. Bingham
  - L. Cartegni
  - R. Grzywacz
  - M. Madurga
  - D. Miller
  - S. Padget
  - S. Paulauskas