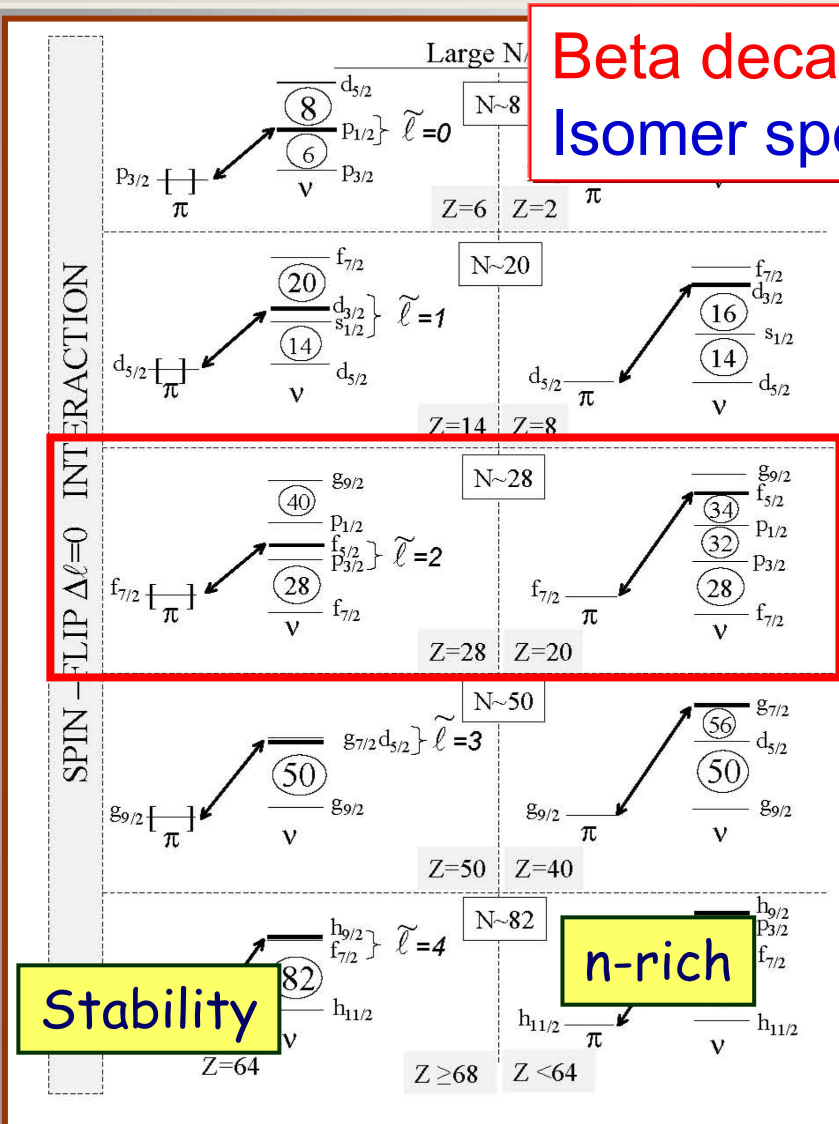
Beta decay in the region of 78Ni: Study of 74Ni through the beta decay of 74Co

Tommaso Marchi, E. Sahin, J. Valiente dobon, Giacomo de Angelis, B. Rubio etc.
Laboratori Nazionali di Legnaro – INFN, Italy

Beta decay of ^{75,77}Ni E. Sahin et al.

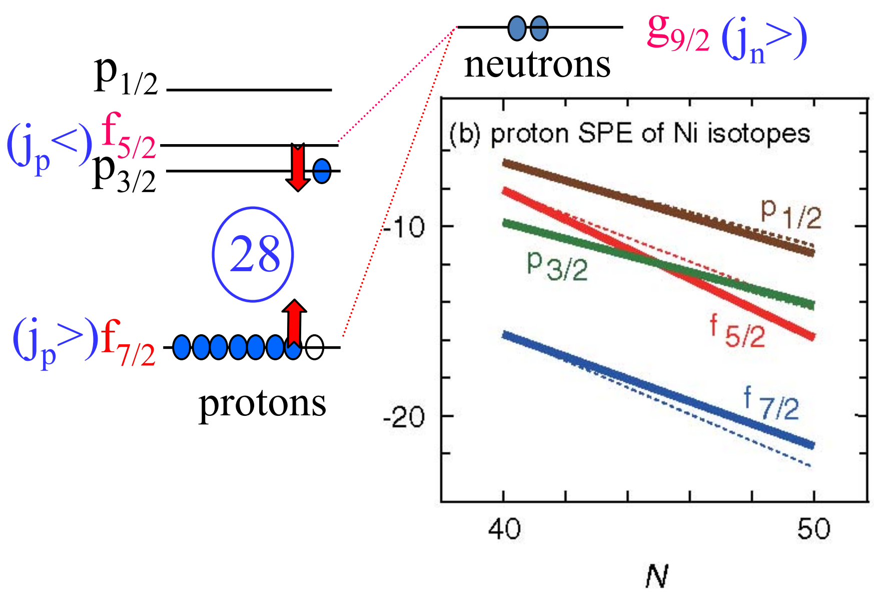
Isomer spectroscopy in ^{71}Kr F. Recchia et al.



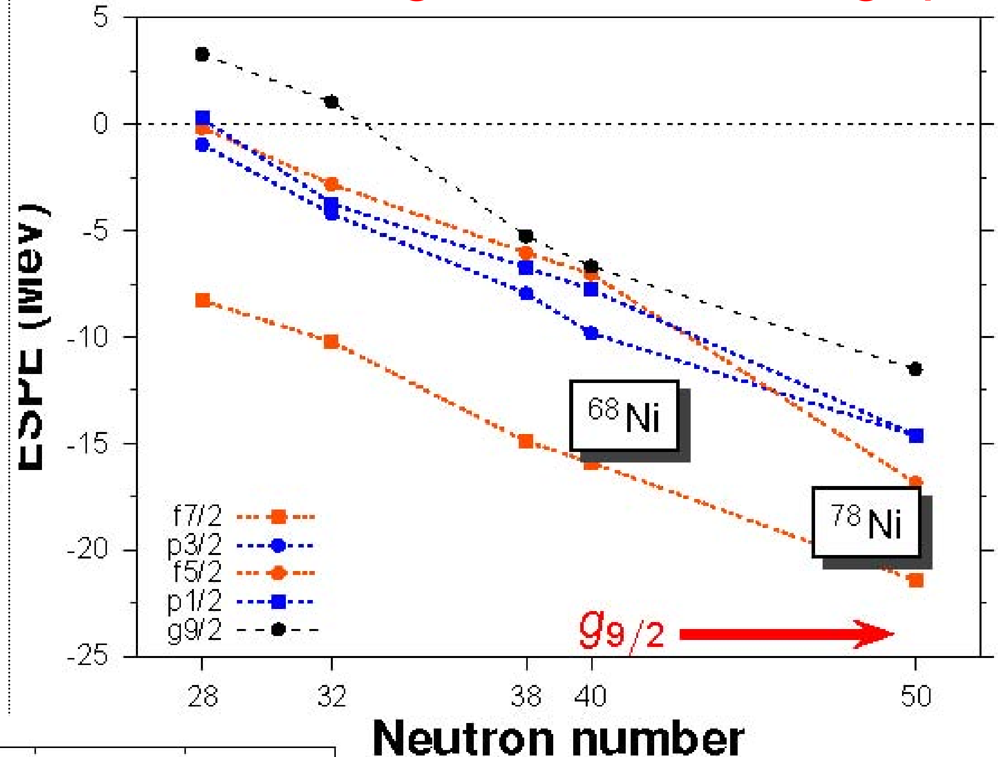
$\ell = 0$ **proton-neutron interaction** is shown for different regions of the chart of nuclides. By comparing the left and right hand sides of the Figure, the removal of protons induces a change in the spacing and possibly ordering of the neutron states. When this interaction is missing, the major Harmonic Oscillator shell gaps N = 8, 20, 40 are reduced to the benefit of **new subshell gaps at N = 6, 16, 32, 34.**

O.Sorlin, M.-G.Porquet, Prog.Part.Nucl.Phys. 61, 602 (2008)

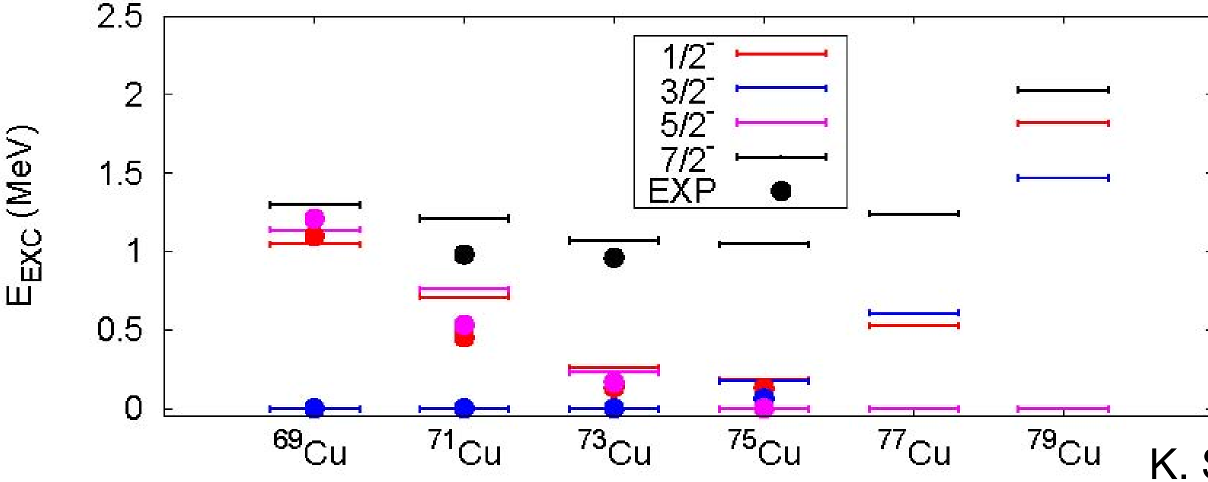
Erosion of the Z=28 proton Gap (from 6 MeV in ^{68}Ni to 5 MeV in ^{78}Ni)



Quenching of the Z=28 π gap?



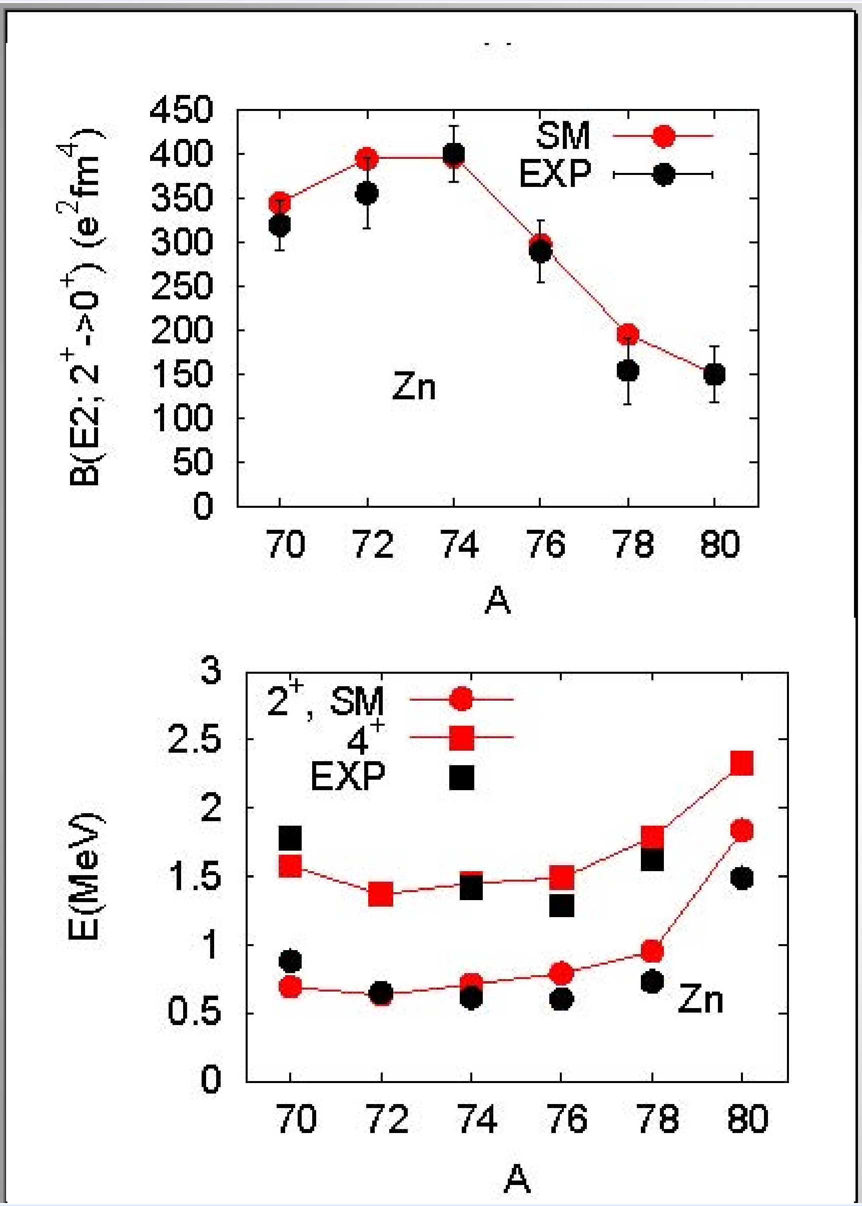
SM space $\pi f_{7/2}, f_{5/2}, p_{3/2}, p_{1/2}$ $\nu f_{5/2}, p_{3/2}, p_{1/2}, g_{9/2}$

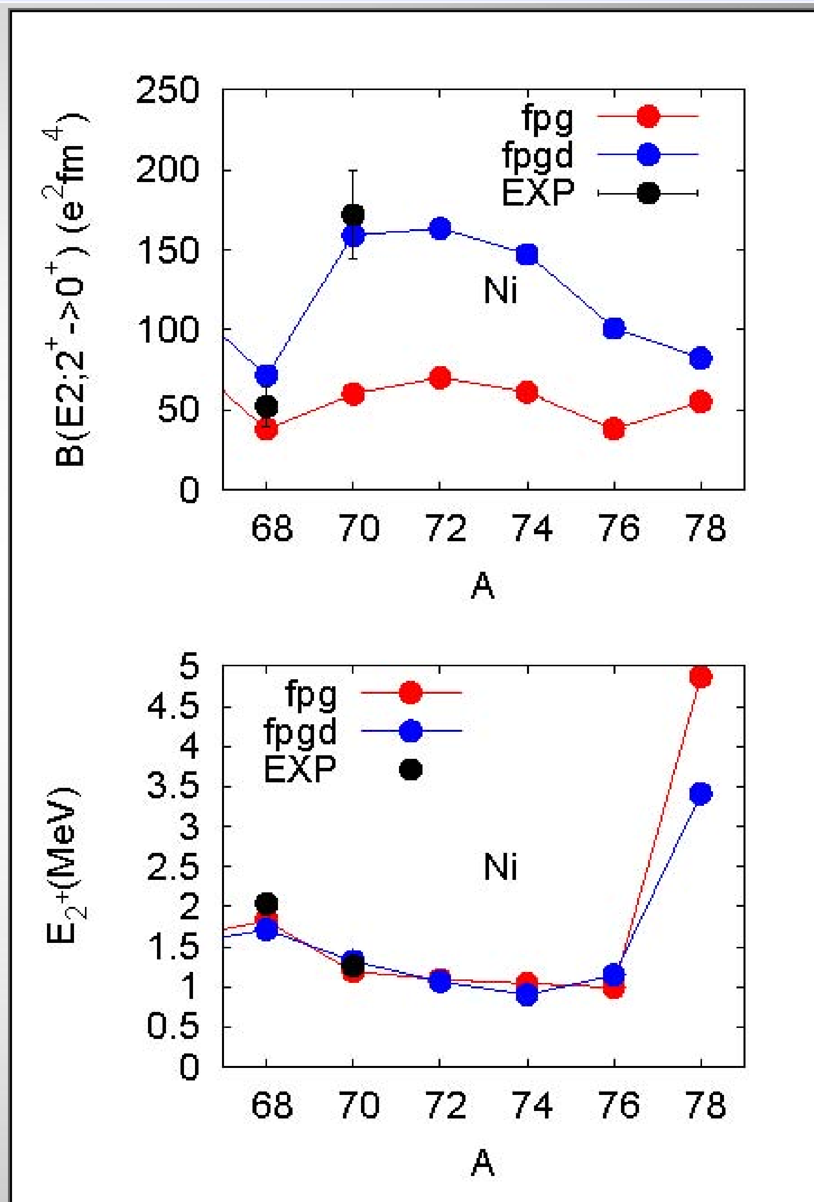


- Reduction of the proton $f_{5/2} - f_{7/2}$ gap when filling neutron $g_{9/2}$ orbital
- Crossing of proton $f_{5/2} - p_{3/2}$ orbitals in the mid-shell

K. Seija and F. Nowacki PRC81 (2010)

B(E2)'s n-rich Zn and Ni isotopes: Enhanced collectivity?

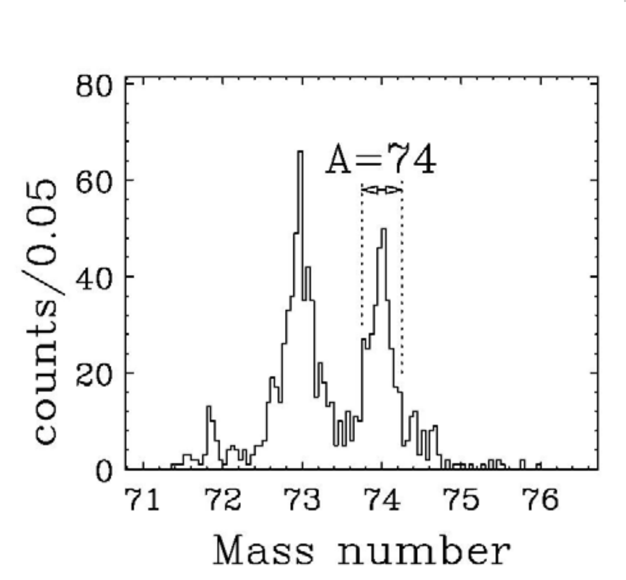




I. Stefanescu et al., PRL 100, 112502 (2008)

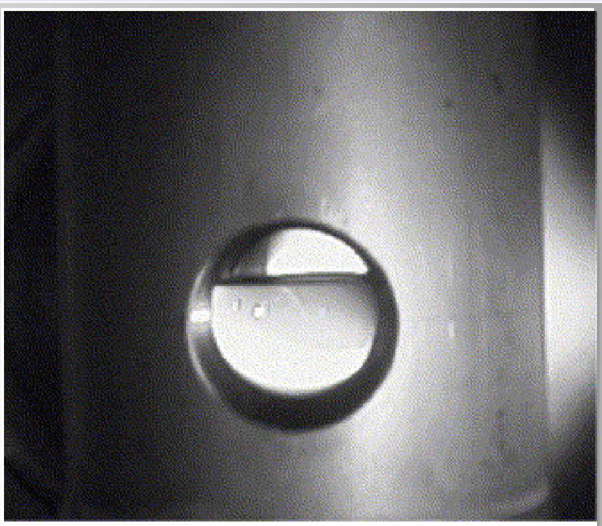
K. Sieja, 10th International Spring seminar on nuclear Physics, Vietri sul mare (Sa), Italy (2010).

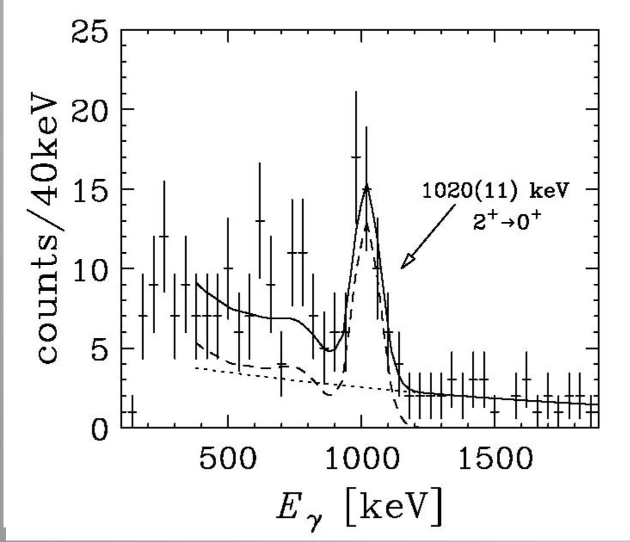
Proton inelastic scattering and Q-collectivity in ^{74}Ni



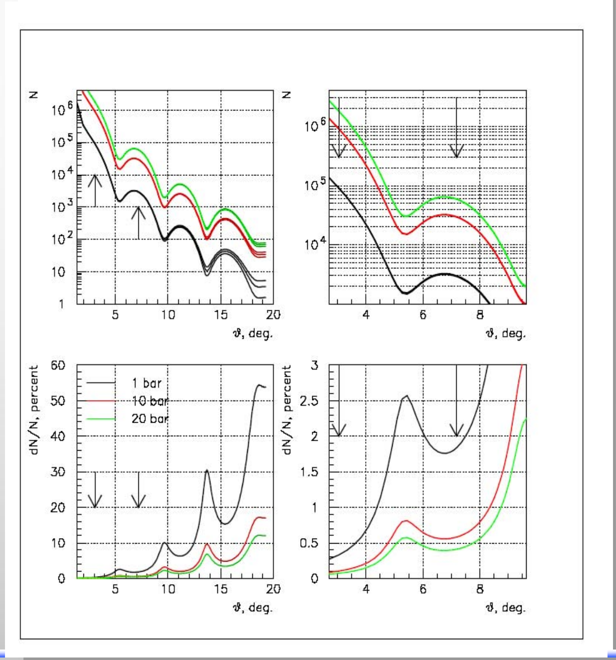
H. Ryuto *et al*,

NIM A 555, 1 (2005)



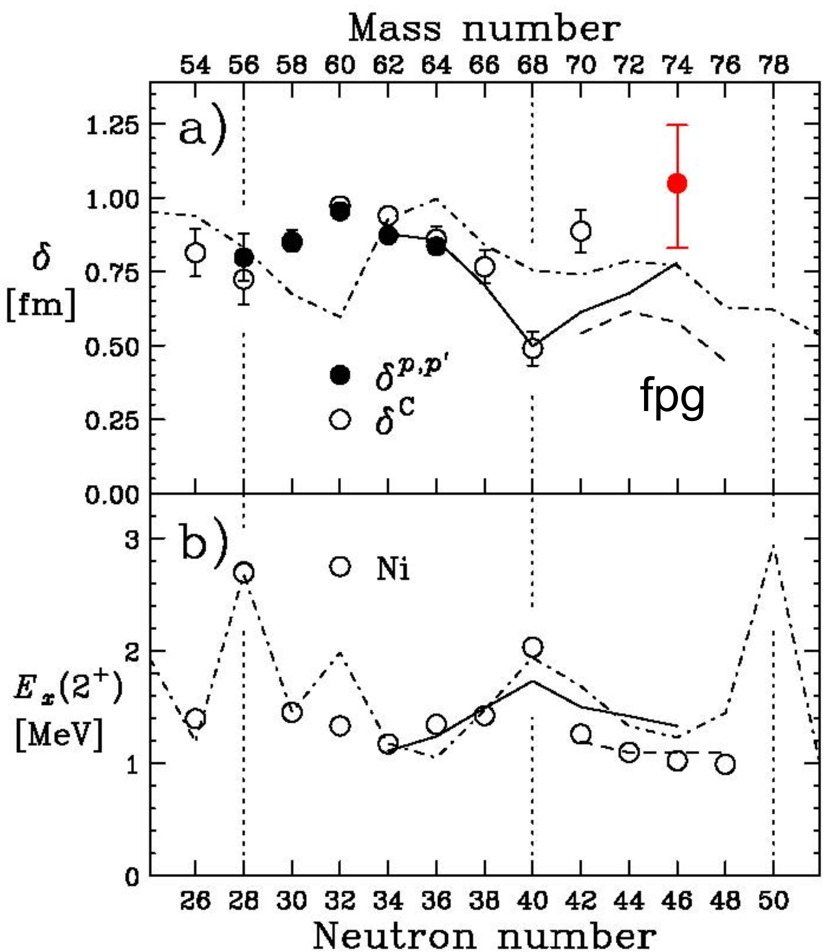


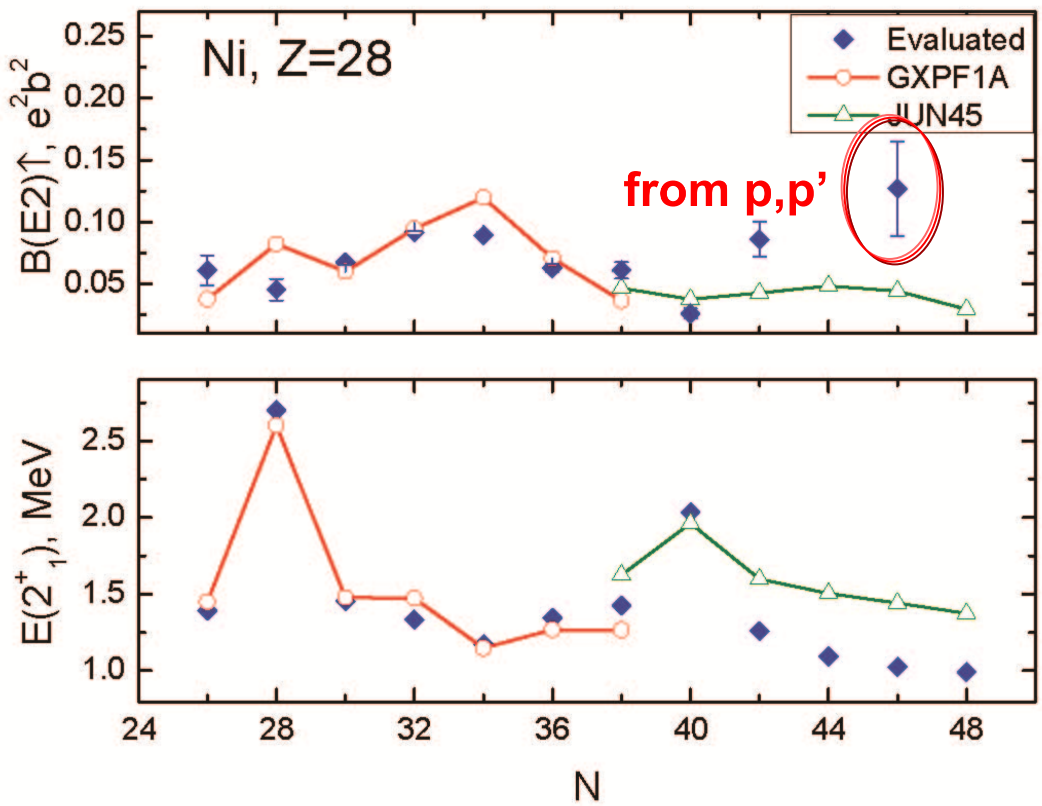
N. Aoi *et al*, Phys. Lett. B 602, 302 (2010)



Electromagnetic transition matrix elements: n-rich Ni isotop.

Enhanced collectivity in ^{74}Ni

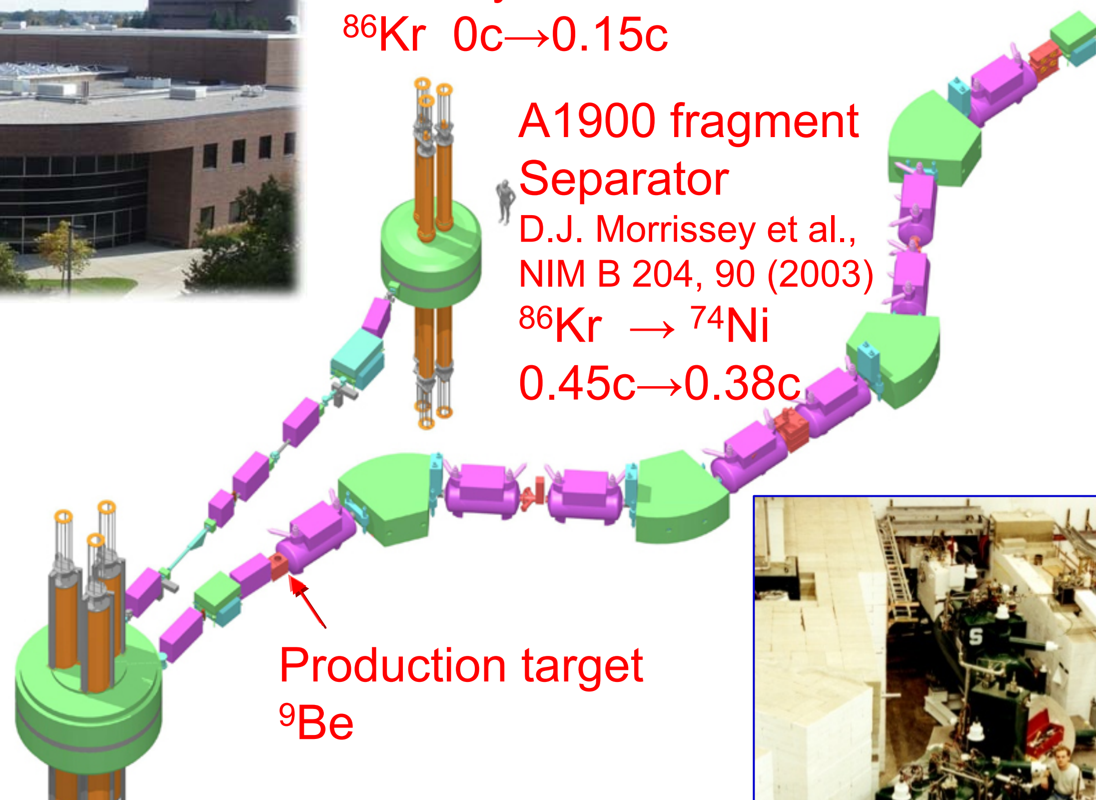


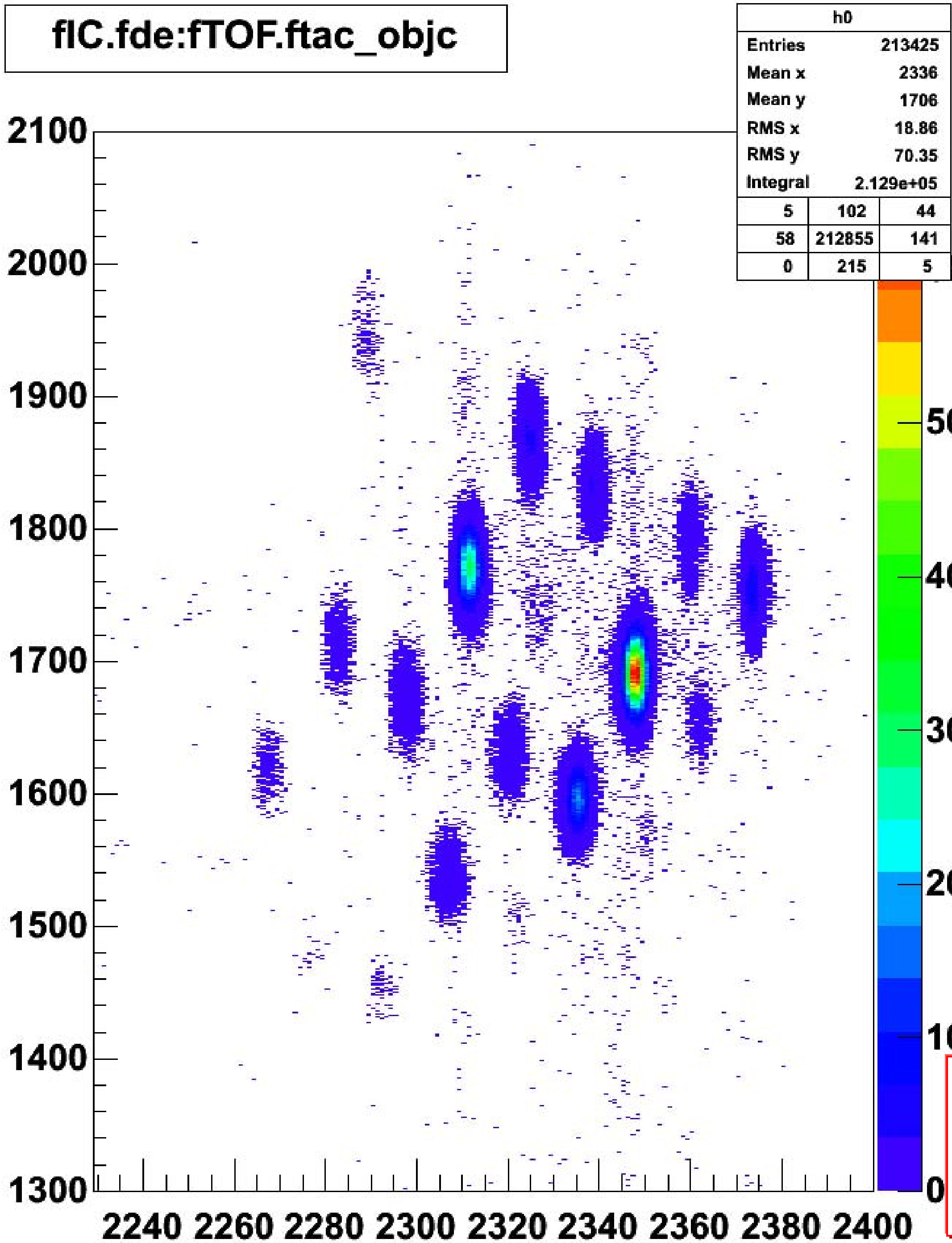


N. Aoi *et al*, Phys. Lett. B 602, 302 (2010)

B. Pritychenko et al., arXiv:1102.3365v2 (2011)

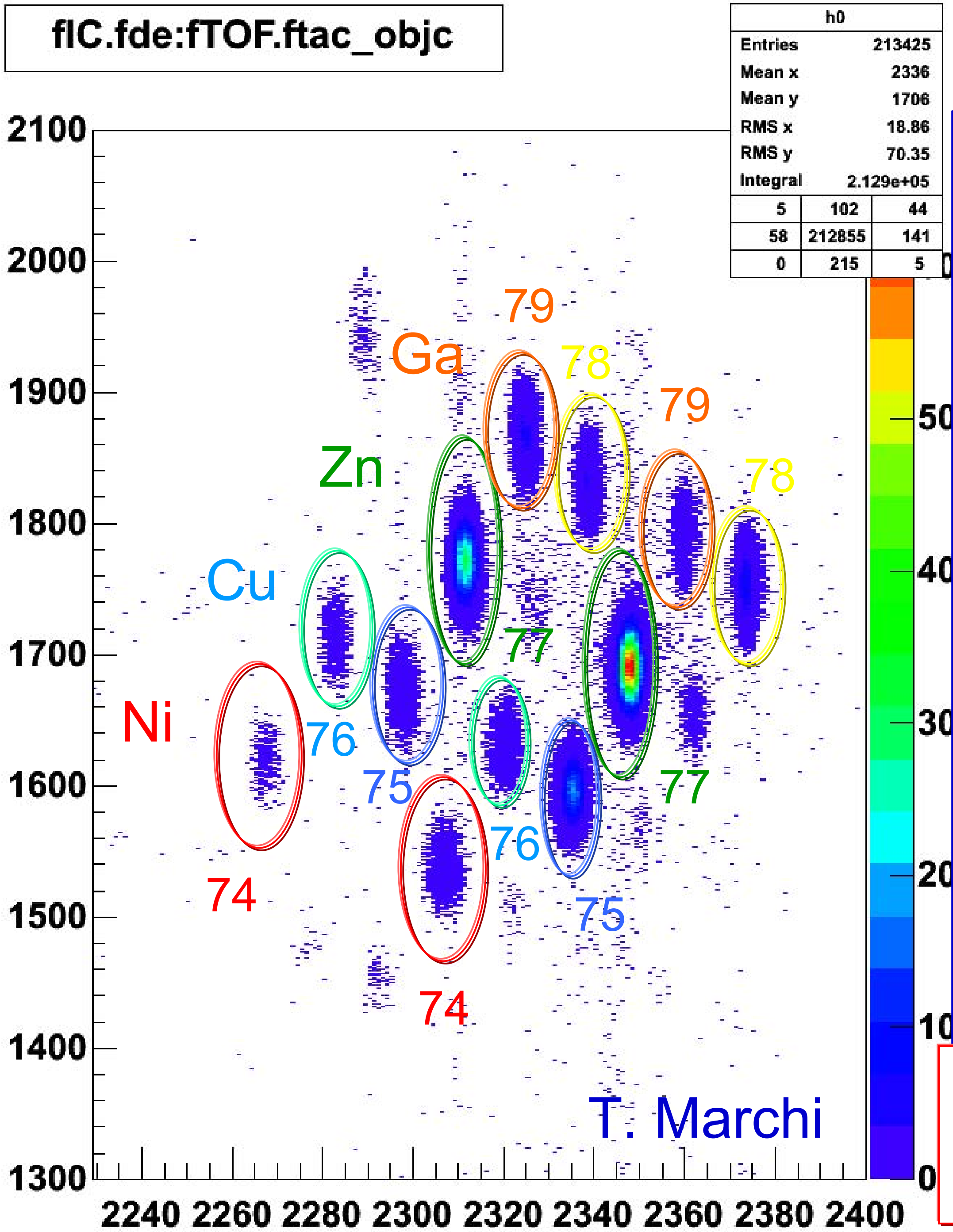
NSCL/Coupled Cyclotron Facility

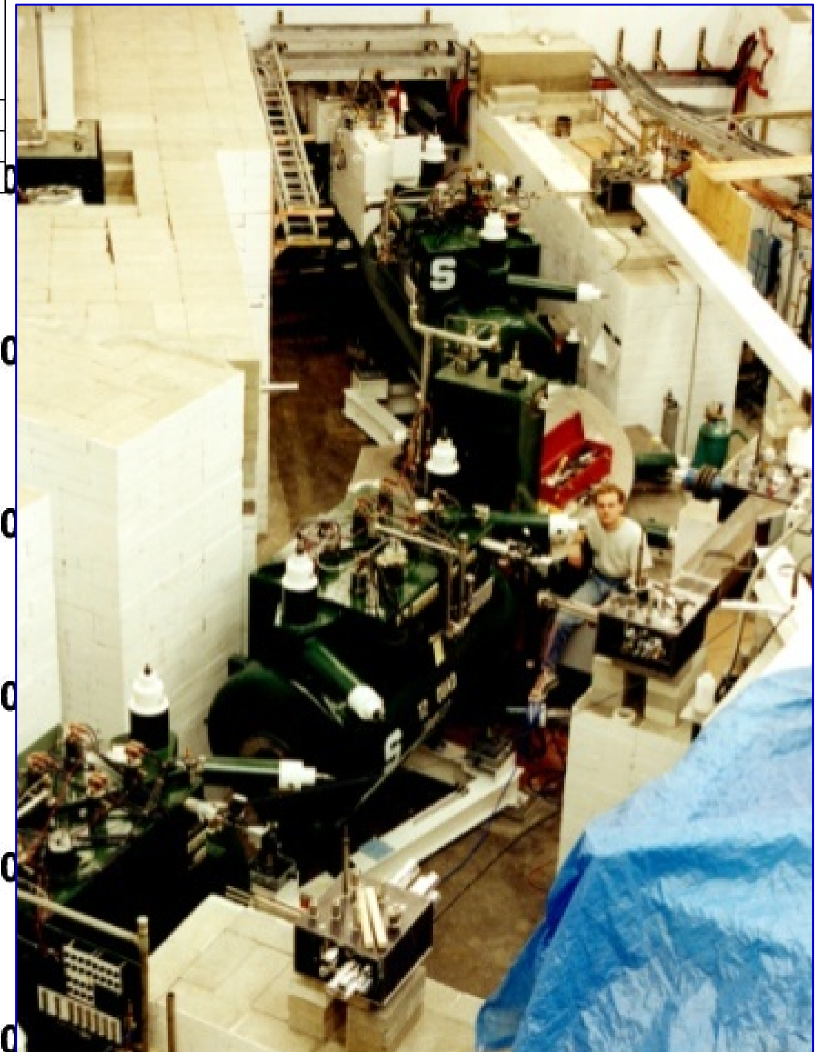




^{74}Ni 2 pps 27% yield.

24 10^{6} ^{74}Ni

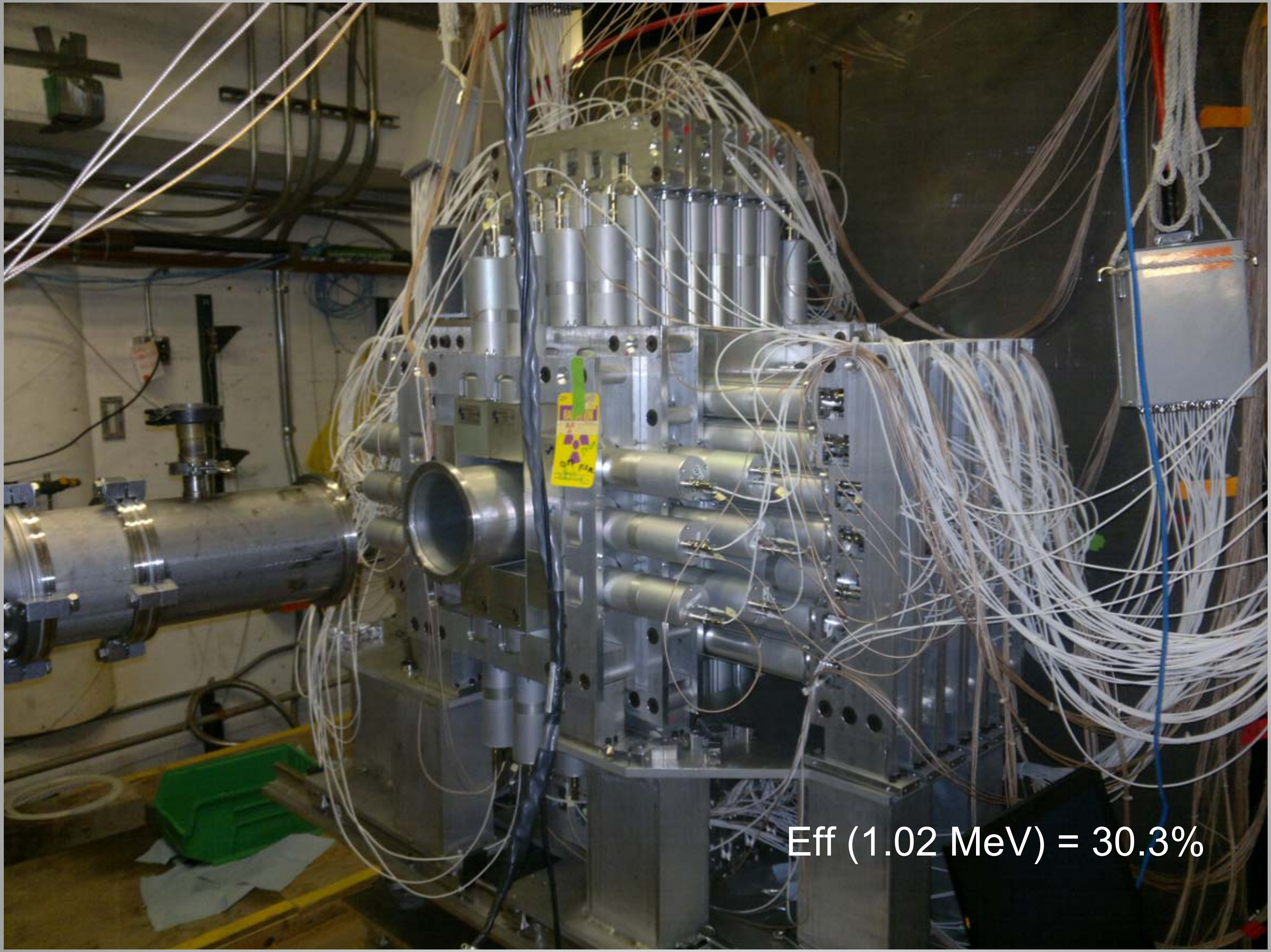


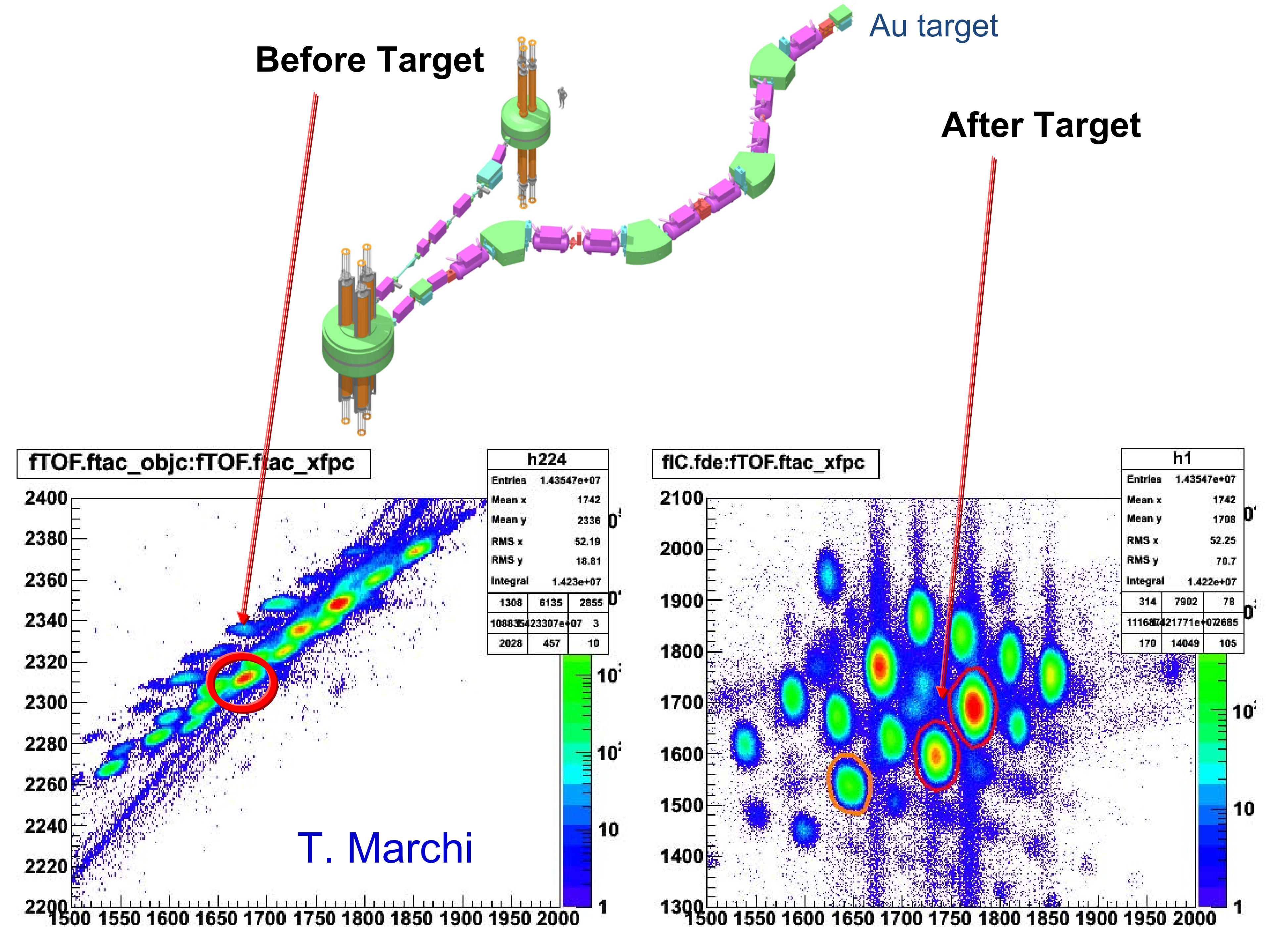


^{74}Ni 2 pps 27% yield.

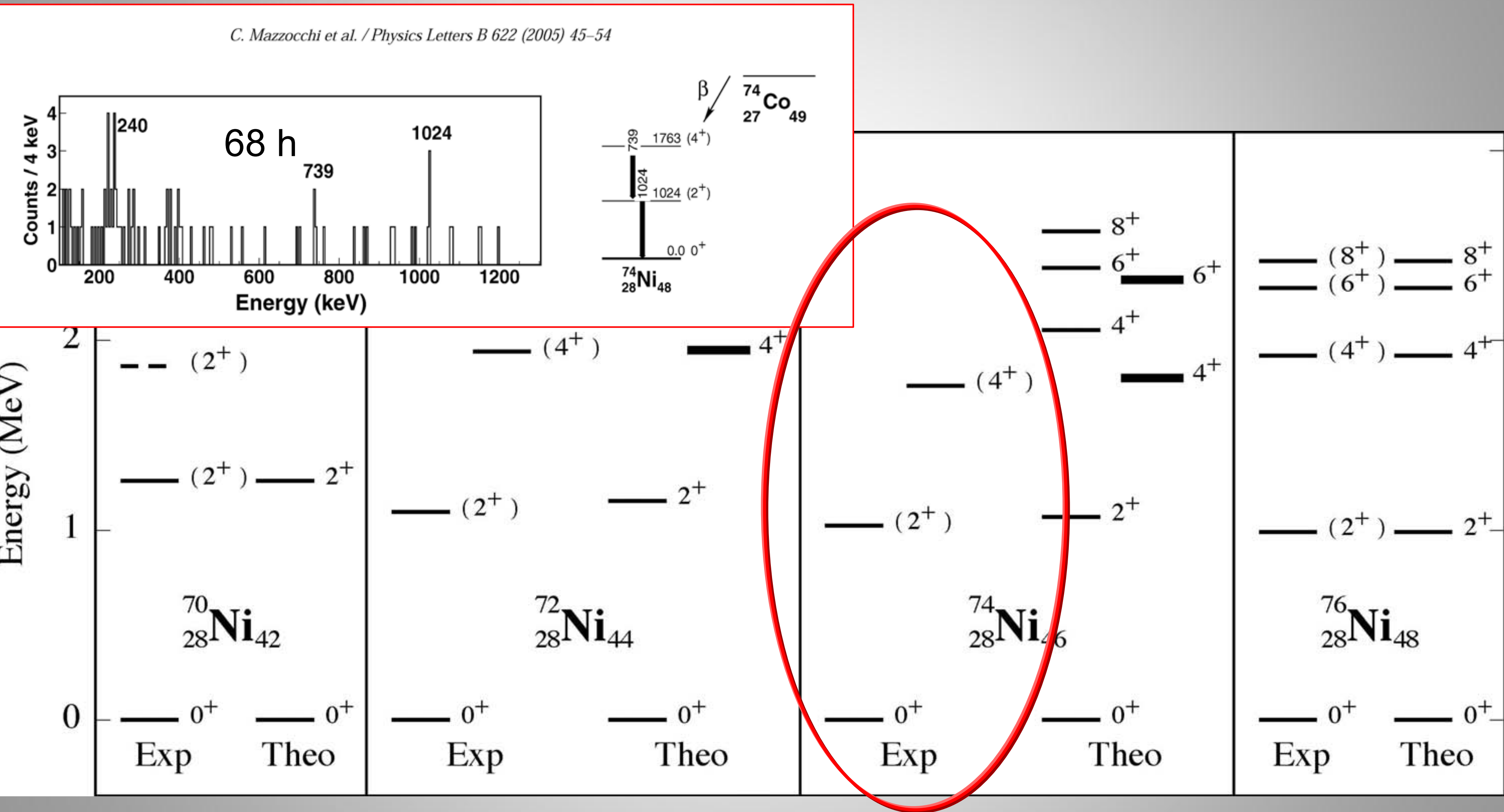
24 10^{6} ^{74}Ni

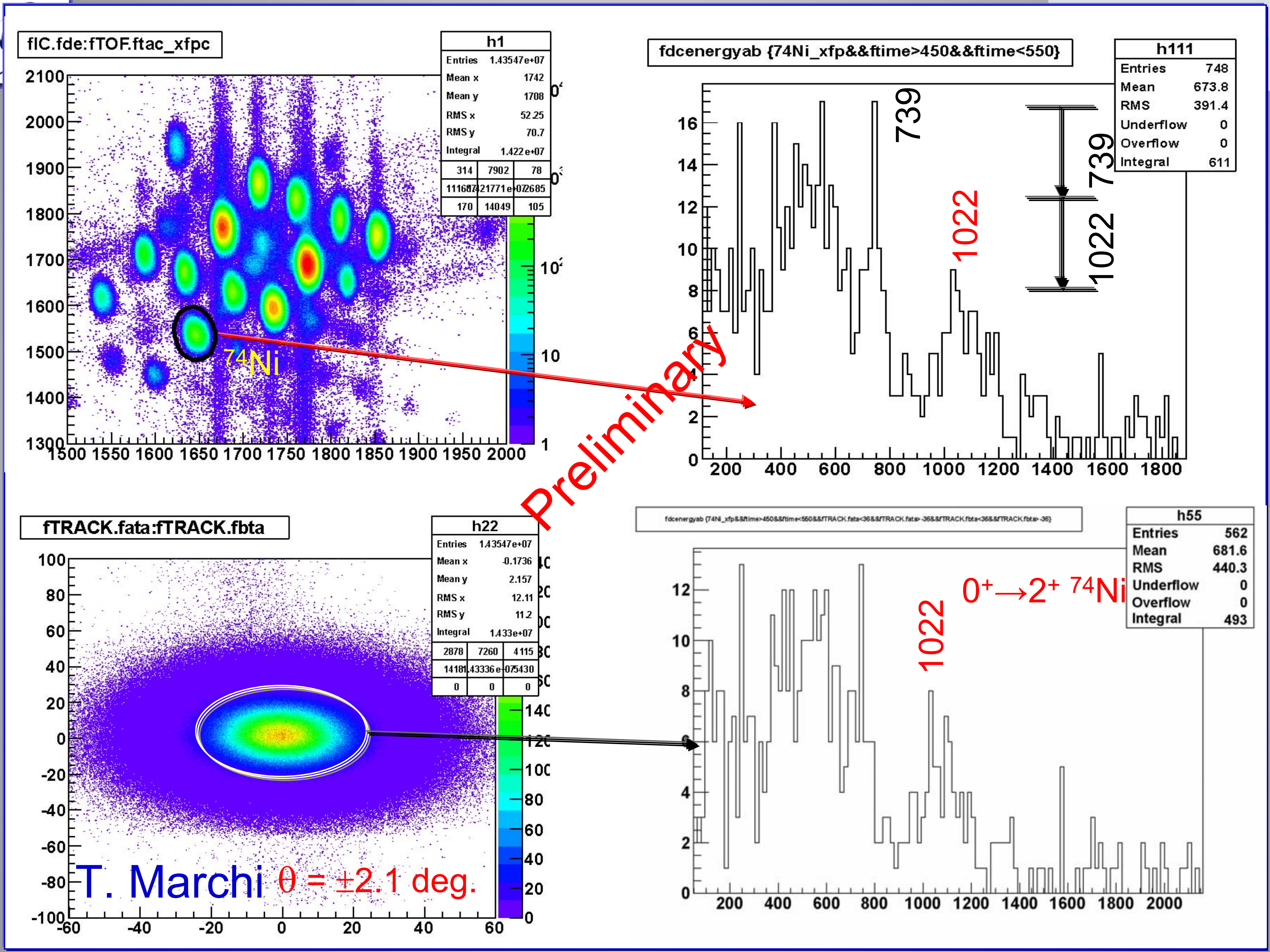
Intermediate energy Coulomb excitation in 74Ni with CAESAR




Au target
Before Target
After Target
fTOF.ftac_objc:fTOF.ftac_xfpc
h224
Entries 1.43547e+07
Mean x 1742
Mean y 2336
RMS x 52.19
RMS y 18.81
Integral 1.423e+07
T. Marchi
fIC.fde:fTOF.ftac_xfpc
h1
Entries 1.43547e+07
Mean x 1742
Mean y 1708
RMS x 52.25
RMS y 70.7
Integral 1.422e+07

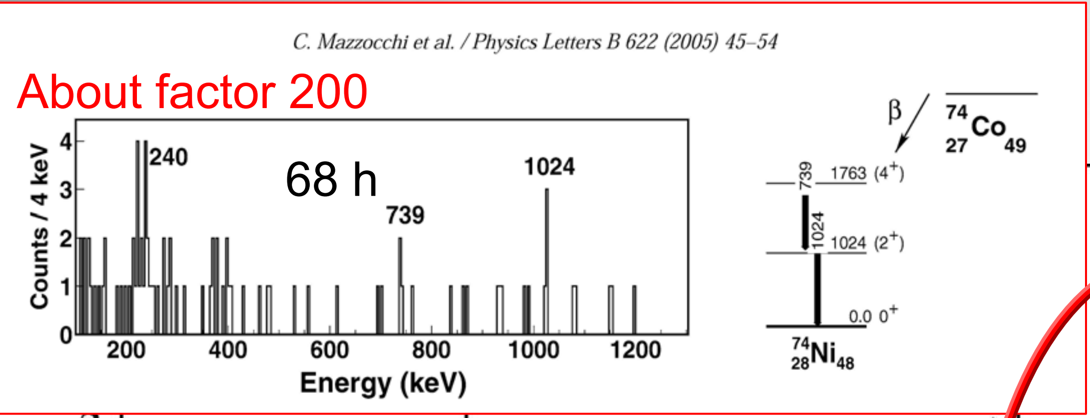
Beta decay study of ^{54}Co in ^{74}Ni



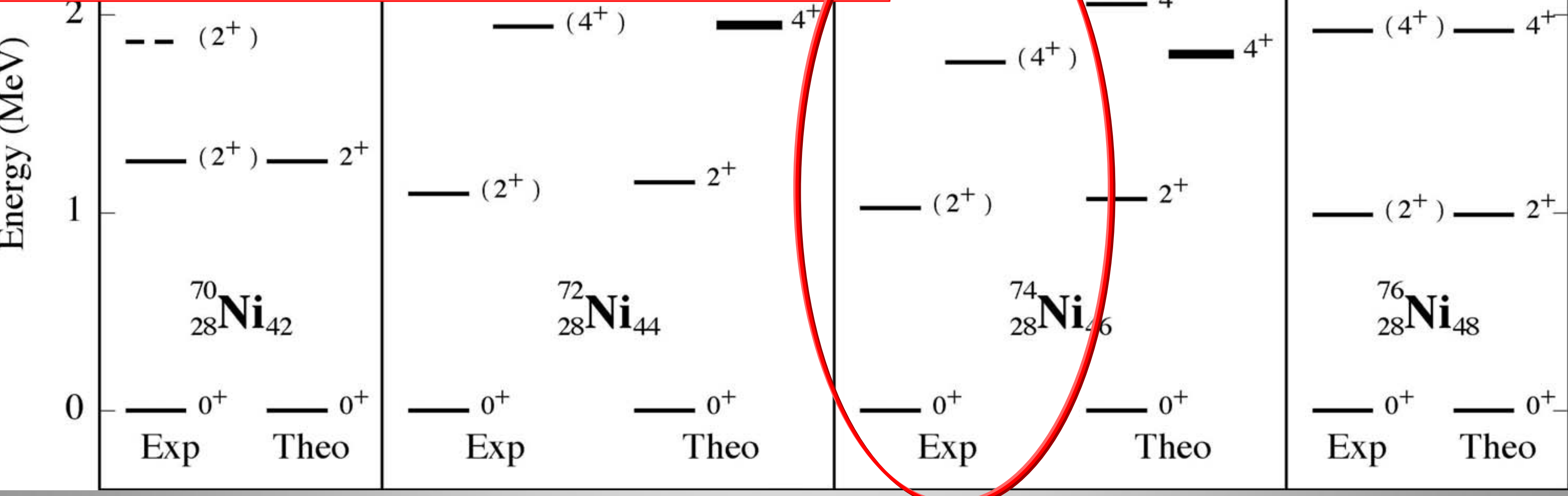


fIC.fde:fTOF.ftac_xfpc
h1
Entries 1.43547e+07
Mean x 1742
Mean y 1708
RMS x 52.25
RMS y 70.7
Integral 1.422e+07
74Ni
fdcenergyab {74Ni_xfp&&ftime>450&&ftime<550}
h111
Entries 748
Mean 673.8
RMS 391.4
Underflow 0
Overflow 0
Integral 611
739
1022
Preliminary
fTRACK.fata:fTRACK.fbta
h22
Entries 1.43547e+07
Mean x -0.1736
Mean y 2.157
RMS x 12.11
RMS y 11.2
Integral 1.433e+07
h55
Entries 562
Mean 681.6
RMS 440.3
Underflow 0
Overflow 0
Integral 493
0+→2+ 74Ni
T. Marchi
θ = ±2.1 deg.

Beta decay study of ^{54}Co in ^{74}Ni



^{86}Kr 350 MeV/A 30 pnA
Target: 5000 micron Be
F1 wedge: 2000 mg/cm2 Al
2° target: ^{208}Pb (degrader)
^{74}Co 250 MeV/A 0.5 pps



Shell structure around ^{78}Ni: Beta decay studies of neutron-rich $^{75,77}Cu$

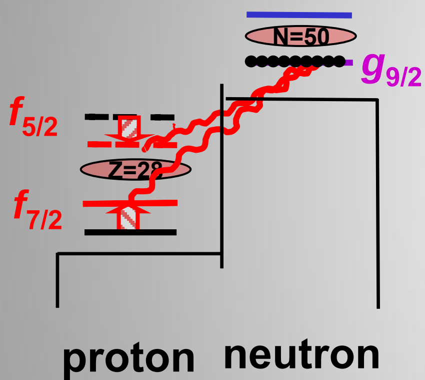
E. Sahin, V. Modamio

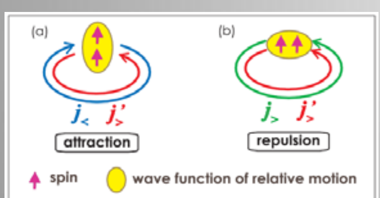
Laboratori Nazionali di Legnaro, LNL, Italy

Cu Isotopes

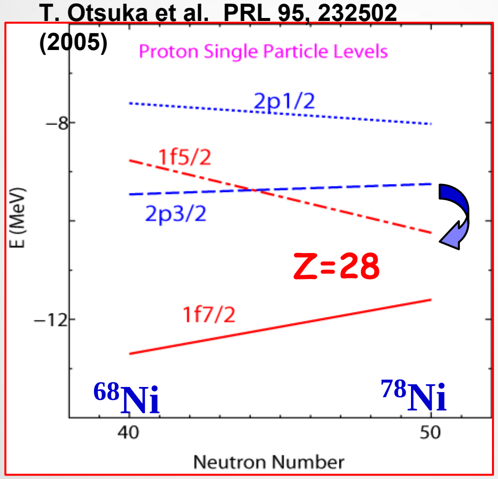
Inversion of the ($\pi f_{5/2}$-$\pi p_{3/2}$) effective single-particle states

$$V^{T}_{j_1,j_2} = \frac{\sum_J (2J+1)\langle j_1\, j_2|V|j_1\, j_2\rangle_{JT}}{\sum_J (2J+1)}$$





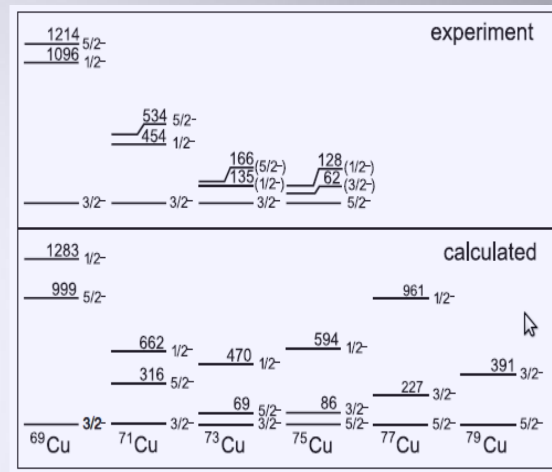
T. Otsuka et al. PRL 95, 232502 (2005)



neutrons in $g_{9/2}$

Inversion of the single particle orbitals

Particle-hole excitations across the shell gap (Z=28)



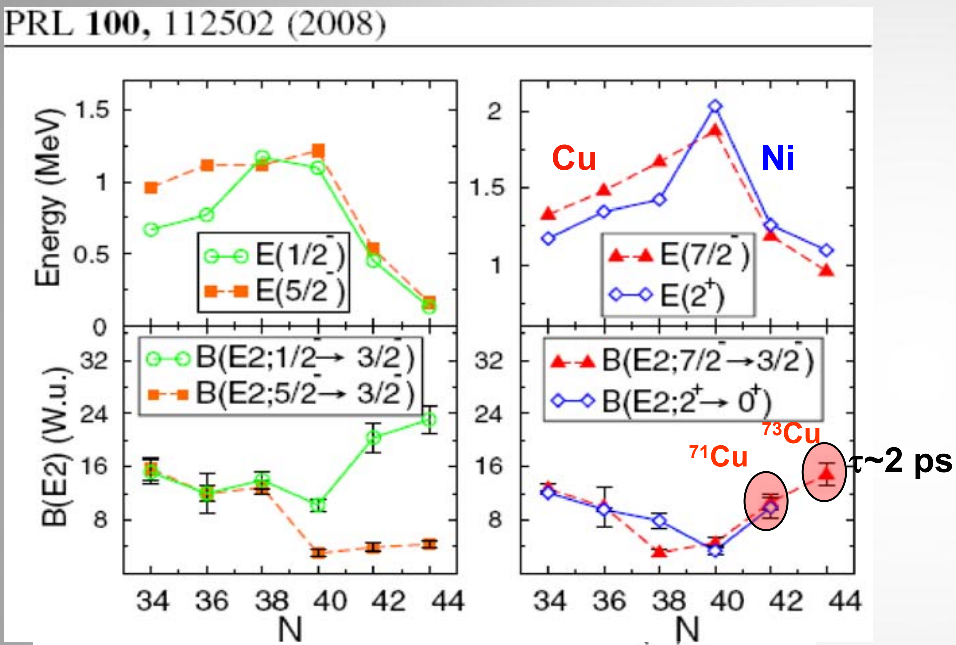
Nuclear spin and magnetic moment measurements @ ISOLDE proved the inversion

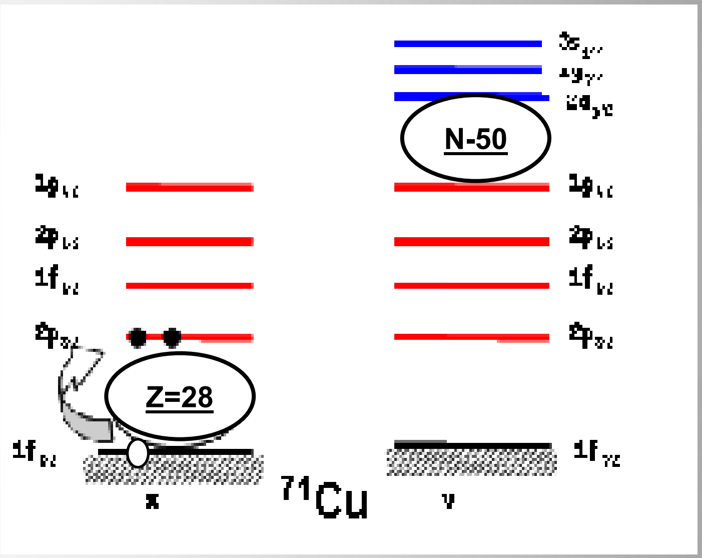
K.T. Flanagan et. al, PRL 103, 142501 (2009)

SM Calculations: B. A. Brown and A. F. Lisetskiy

Various attempts to characterize the excited states in Cu isotopes are ongoing

Coulomb excitation with radioactive beams at REX-ISOLDE





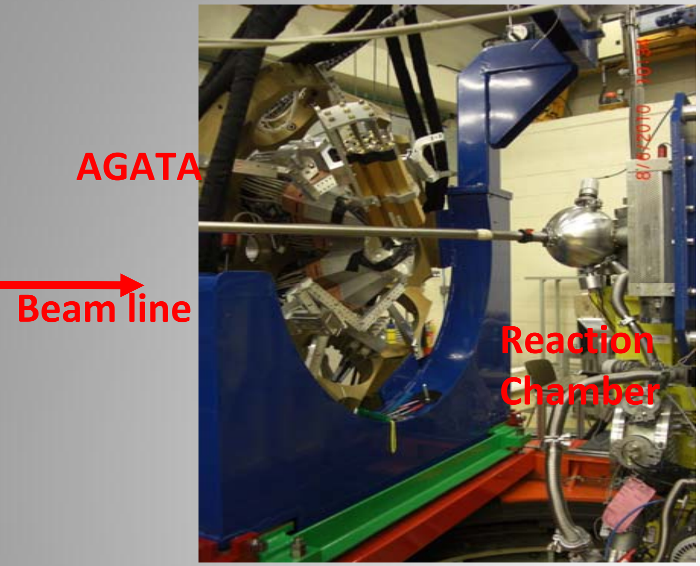
B(E2) values are essential in order to characterize the levels.

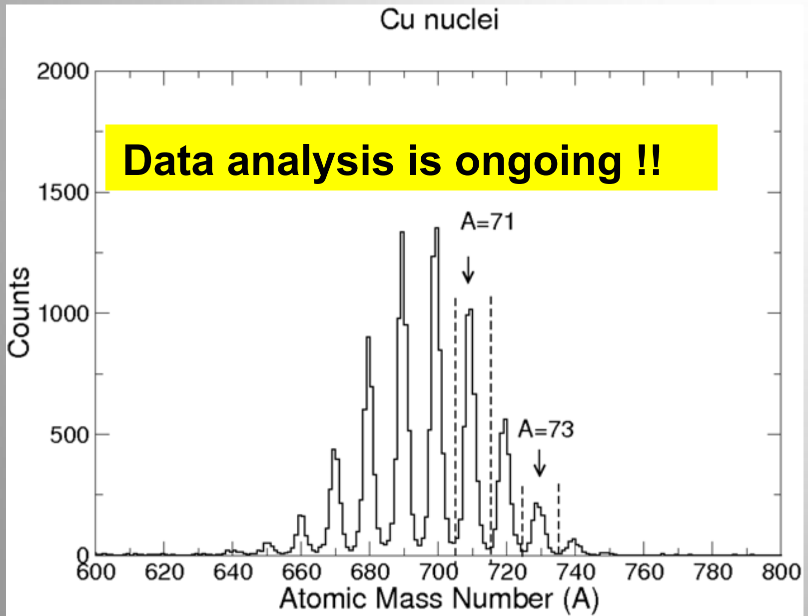
Single-particle excitations across the Z=28 shell gap will provide the information on the Z=28 shell gap size and therefore, its evolution.

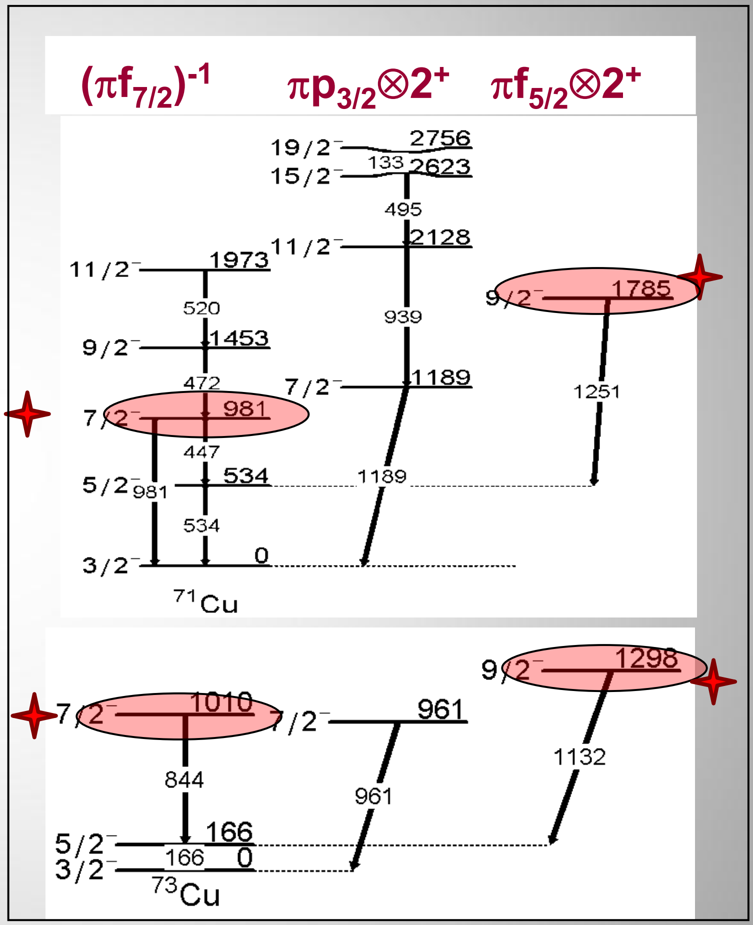
LEGNARO: AGATA Demonstrator coupled to PRISMA (at 55°) + Köln Plunger

Experiment Performed in middle June 2010 Multi-nucleon transfer reactions

$^{76}Ge + ^{238}U$ @ $E(^{76}Ge)=577$ MeV







: Levels to measure Lifetimes!

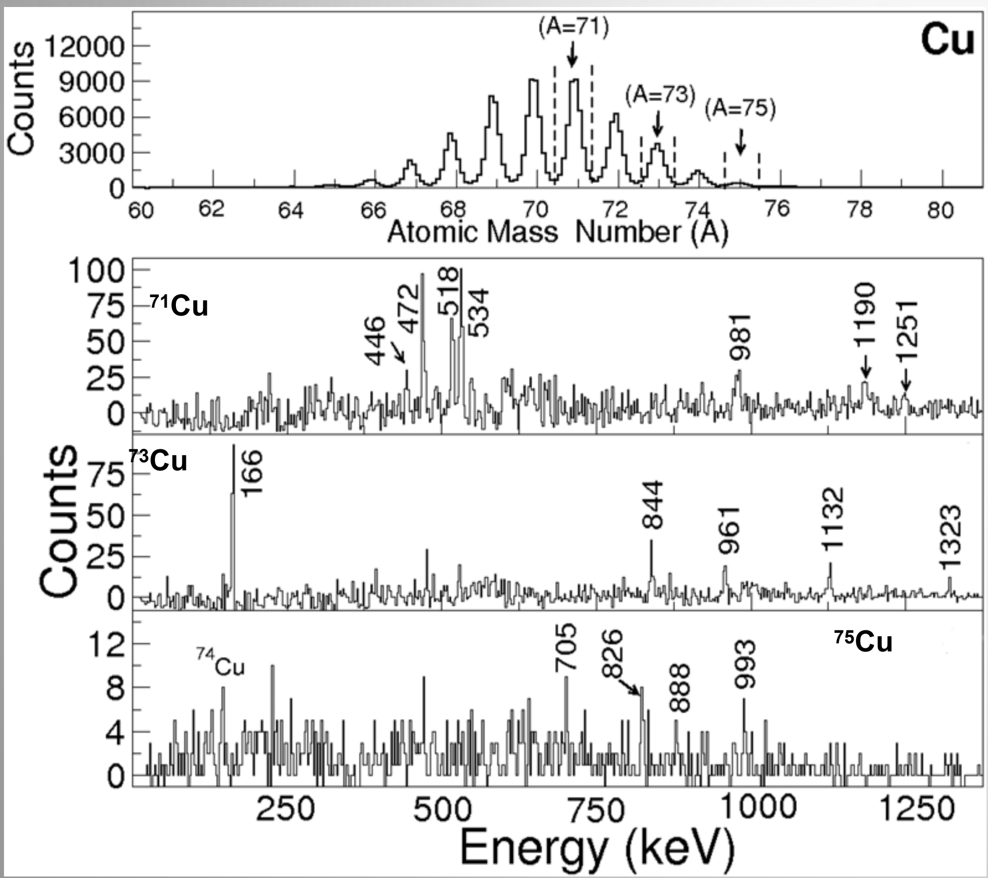
Present Proposal aims:

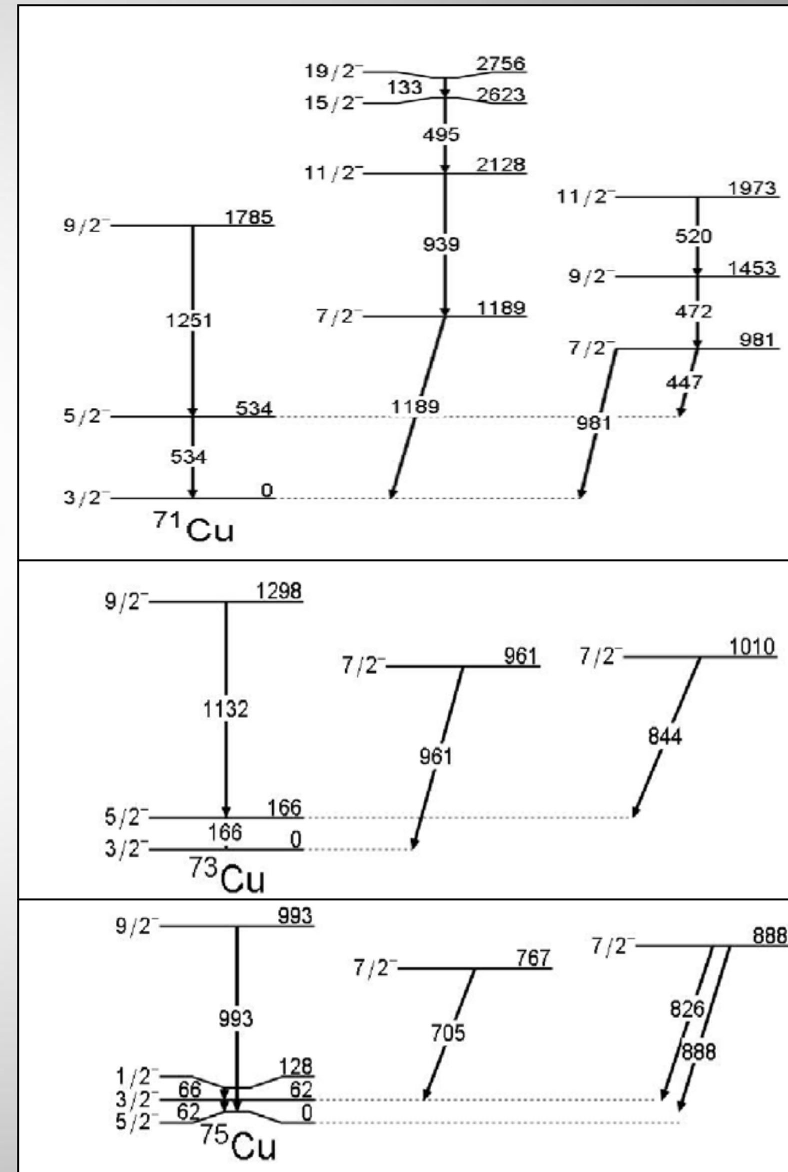
Identification of the excited states in ^{75,77}Cu via beta decay of ^{75,77}Ni

Information from our past experimental studies at Legnaro (^{71,7375}Cu):

^{82}Se + ^{238}U @ 515 MeV CLARA-PRISMA

$\Theta_{PRISMA}=\Theta_{Grazing}=64^{\circ}$ Multi-nucleon transfer reactions





Proposed Experiment
BigRIPS + E(U)RICA

Beta decays of ^{75,77}Ni to ^{75,77}Cu

Measured Beta-decay half lives

$T_{\beta}(^{75}Ni)$= 344 ms
$T_{\beta}(^{77}Ni)$= 128 ms

P.T. Hosma et al., Phys. Rev. Lett. 94, 112501 (2005)

Primary Beam: ^{86}Kr @ 350 MeV/A I_{Beam}=30 pnA

Production rate at the target position :

N(^{75}Ni)= 14x10^4 ppday (Transmission: 79%)

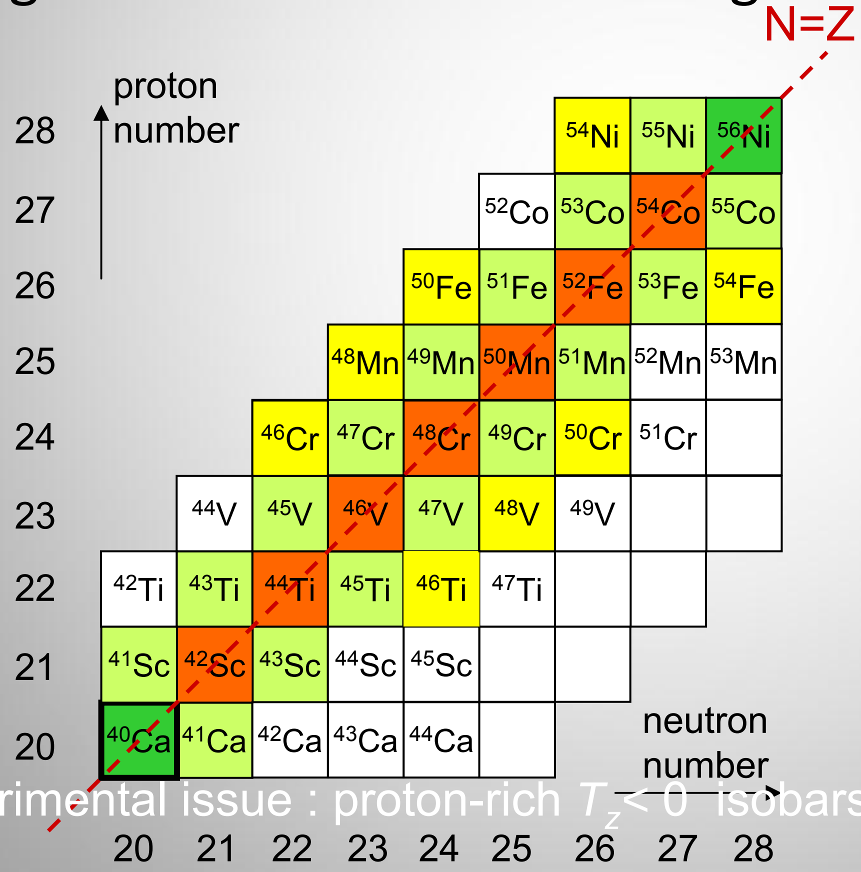
N(^{77}Ni)= 3500 ppday (Transmission: 80%)

Isomer spectroscopy: ^{71}Kr

Spokepersons: F. Recchia, J. Valiente Dobon, E. Sahin, C. Ur, S. Lunardi, J. Eberth, B. Rubio, B. Wadsworth, G. de Angelis, …

The isospin symmetry in the $f_{7/2}$

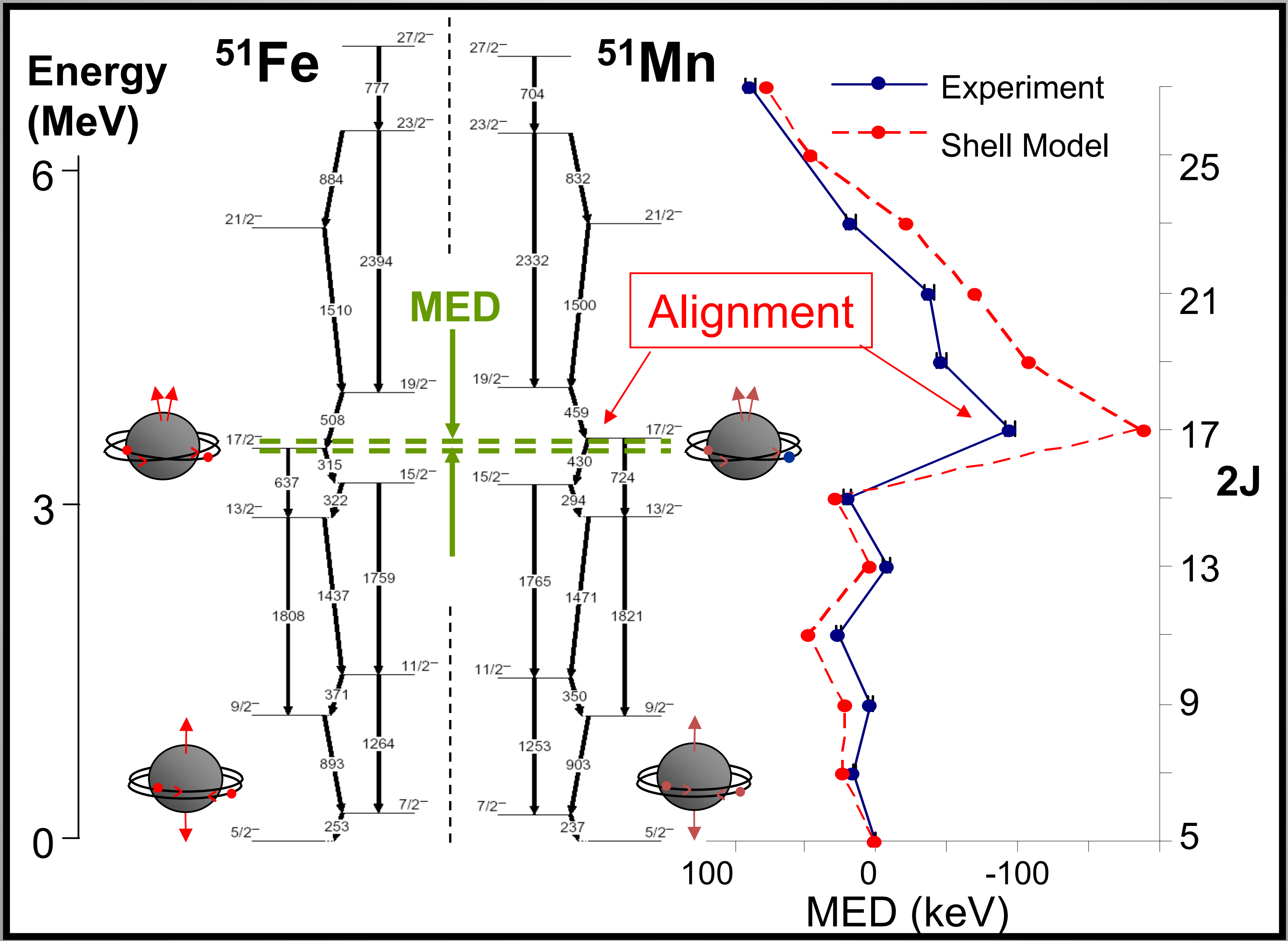
- Isospin symmetry manifest better along the N=Z nuclei
- Coulomb Energy Differences CED, difference in excitation energies between isobaric analog states.



Experimental issue : proton-rich $T_z < 0$ isobars very weakly populated

M.A. Bentley and S.M Lenzi Prog. Part. And Nucl. Phys. 59 (2007) 497

Isospin symmetry in collective structures



D.D. Warner et al., Nature Physics 2 (2006) 311

Beyond the $f_{7/2}$ shell: ^{67}As – ^{67}Se

PRL 103, 052501 (2009) PHYSICAL REVIEW LETTERS week ending 31 JULY 2009

Coherent Contributions to Isospin Mixing in the Mirror Pair ^{67}As and ^{67}Se

R. Orlandi,[1,*] G. de Angelis,[1] P. G. Bizzeti,[2] S. Lunardi,[3] A. Gadea,[1,†] A. M. Bizzeti-Sona,[2] A. Bracco,[4] F. Brandolini,[3] M. P. Carpenter,[5] C.J. Chiara,[6,‖] F. Della Vedova,[1] E. Farnea,[3] J.P. Greene,[5] S.M. Lenzi,[3] S. Leoni,[4] C.J. Lister,[5] N. Mărginean,[3,‡] D. Mengoni,[3] D.R. Napoli,[1] B.S. Nara Singh,[7] O.L. Pechenaya,[6,§] F. Recchia,[1] W. Reviol,[6] E. Sahin,[1] D.G. Sarantites,[6] D. Seweryniak,[5] D. Tonev,[8] C. A. Ur,[3] J.J. Valiente-Dobón,[1] R. Wadsworth,[7] . Wiedemann,[9] and S. Zhu[5]

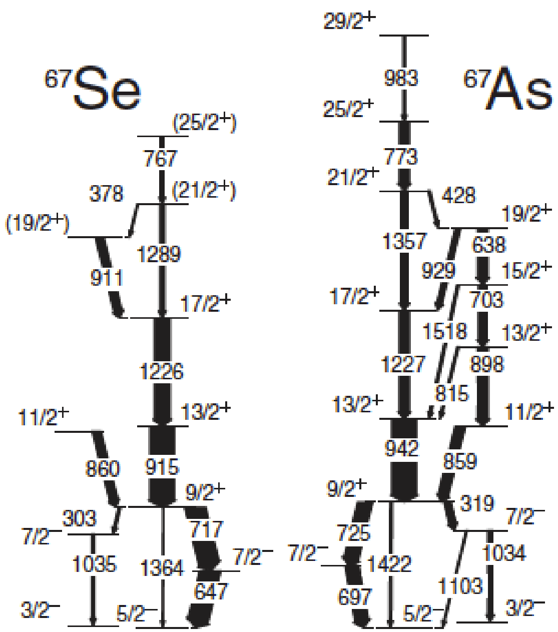


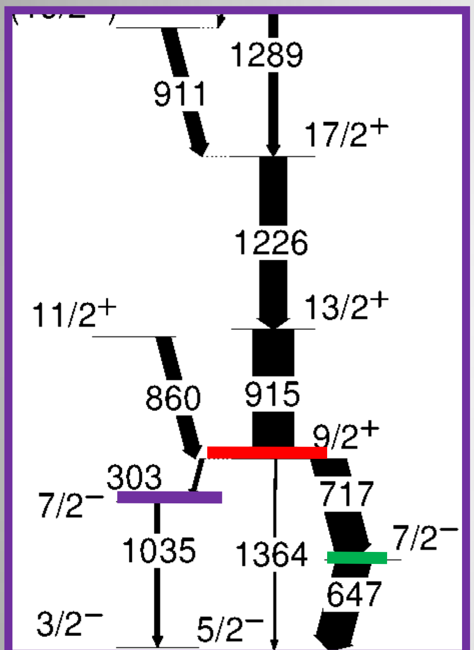
FIG. 1. Proposed partial level schemes for (left) ^{67}Se [16] and (right) ^{67}As determined from the present data. The energy labels are given in keV and the widths of the arrows are proportional to the relative intensities of the γ rays. Spin and parity assignments in ^{67}Se are based on symmetry considerations and on the measured ADO ratios (see text).

If isospin is conserved, the E1 transitions in mirror nuclei should have the same strength.

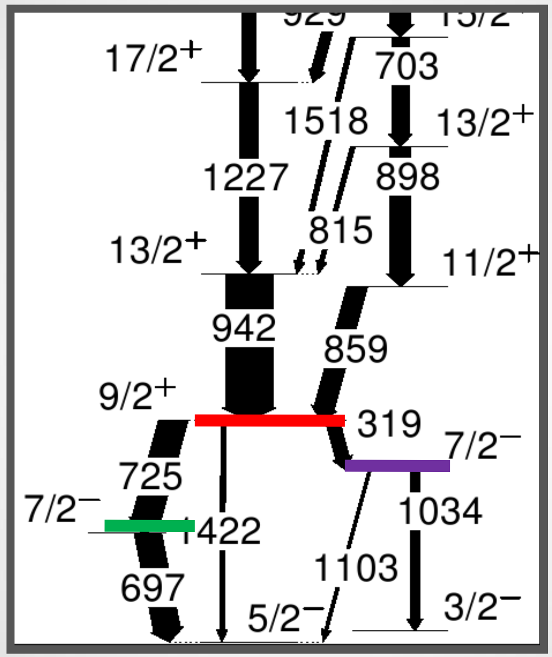
R. Orlandi et al., PRL103, 052501 (2009)

Measured B(E1)

^{67}Se



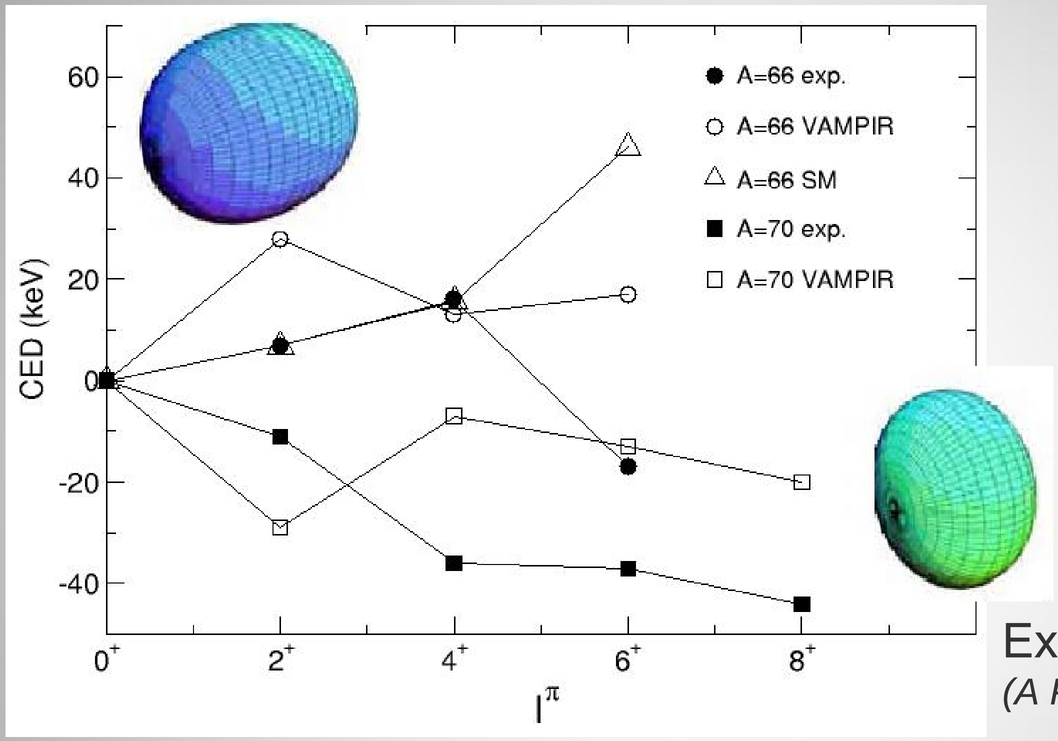
^{67}As



- Two pairs of $9/2^+ \rightarrow 7/2^-$ analogue transitions
- To determine B(E1)
  - branching ratios
  - lifetime of 9/2+ state
  - multipolarities and mixing ratios

Energy (KeV)	B(E1) (10^{-6} wu)	B(E1) (10^{-6} wu)	Energy (KeV)
717	0.4(4)	1.4(4)	725
303	<1.4(9)	8.3(2.4)	319

Shape effects in CED: breaking of the isospin symmetry?

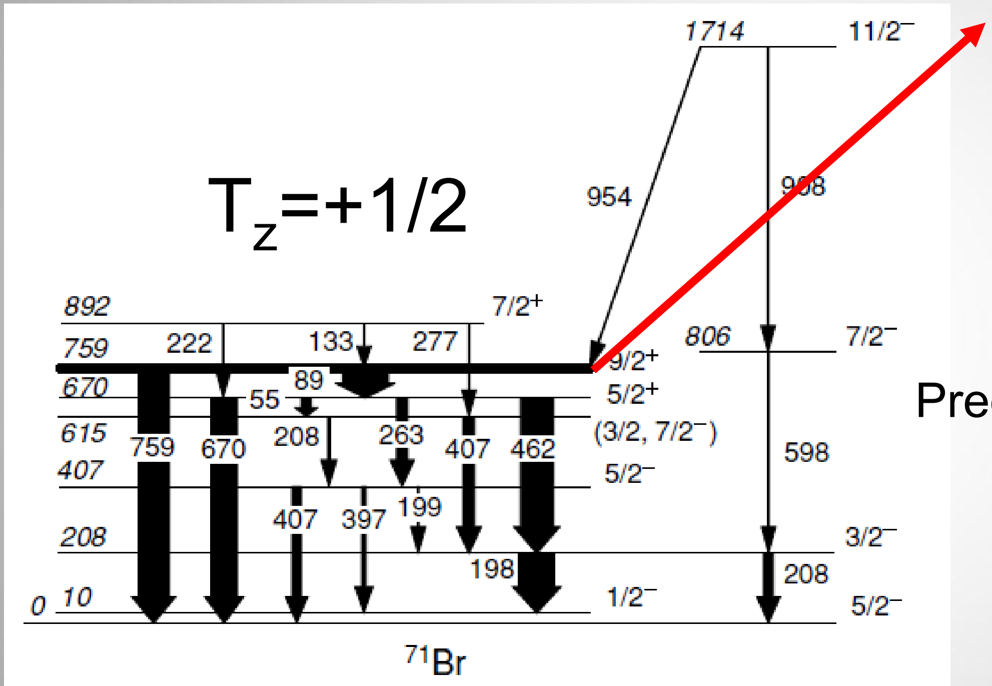


- ^{70}Se is predominantly oblate GS *(J. Ljungvall et al., PRL100 102502 (2008))*
- ^{70}Br is predominantly prolate GS

Excited VAMPIR Model
(A Petrovici et al NPA483, 317 (1988))

- Beyond mean-field approach with symmetry projection
- Successfully used to describe analogue states in mass 70 region, Petrovici et al., Nucl Phys A728, 396 (2003)
- Takes into account: Oblate/ prolate shape co-existence and n-p pairing correlations in both the T=0 and T=1 channels
- Calculations performed using the isospin symmetric G matrix based on Bonn A potential and Coulomb interaction between the valence protons.

Characterize the $9/2^+$ transition in ^{71}Kr



τ = 33ns isomer in ^{71}Br

Predicted τ ~ 100ns isomer in ^{71}Kr

- measurement of the decay branches in ^{71}Br and ^{71}Kr

S.M. Fischer et al., PRC72, 024321 (2005)

Possible beam time request

- Beam ^{78}Kr - 30pnA - 345MeV/nucleon (not in the list)
- Setting ^{71}Kr
- Be primary target 2g/cm^2
- BigRIPS fragment separator
- EURICA eff ~10%
- Nine-layer double-sided silicon-strip detector (DSSSD) PRL106, 052502 (2011)
- Production ~1500pps ^{71}Kr
- Isomeric ratio 10%
- 5 days → 3 10^5 gamma