Single-neutron states and the role of the $\nu g_{9/2}$ orbital in ^{71}Zn

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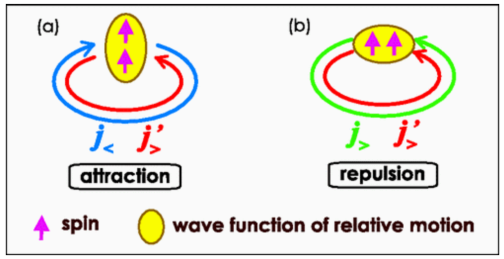
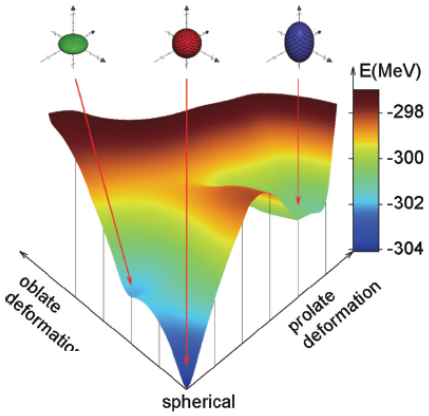
Outline

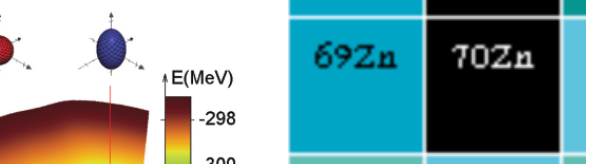
- The neutron-rich region around N = 40
- Transfer reactions between heavy-ions
- The case of ^{71}Zn: the GRETINA campaign at ANL
- Shell model interpretation
- Conclusions and future perspectives

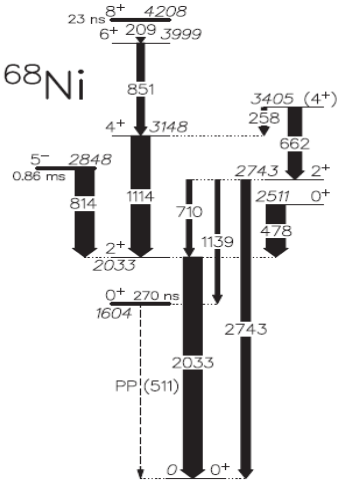
The neutron-rich region around N=40



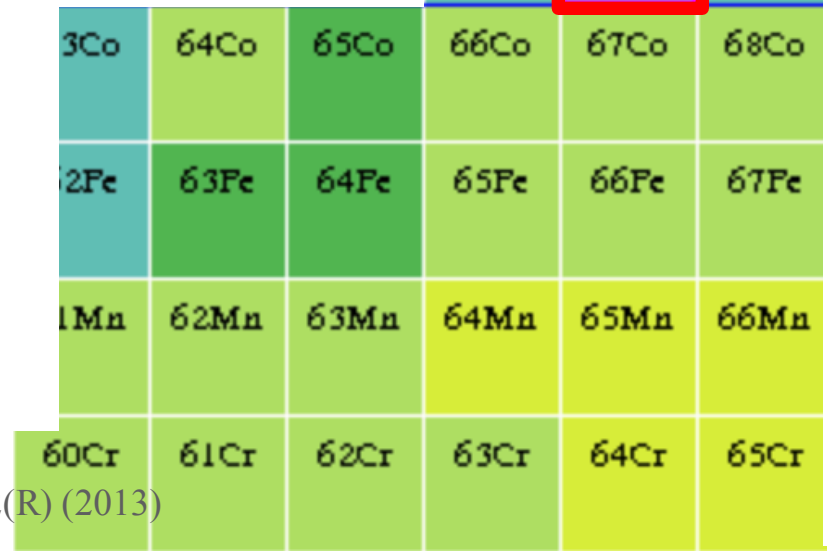
T. Otsuka *et al.*,
Phys. Rev. Lett
95, 232502 (2005)



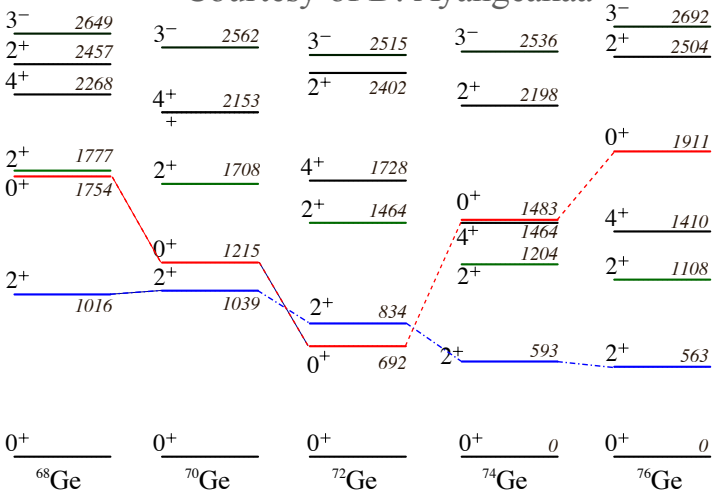


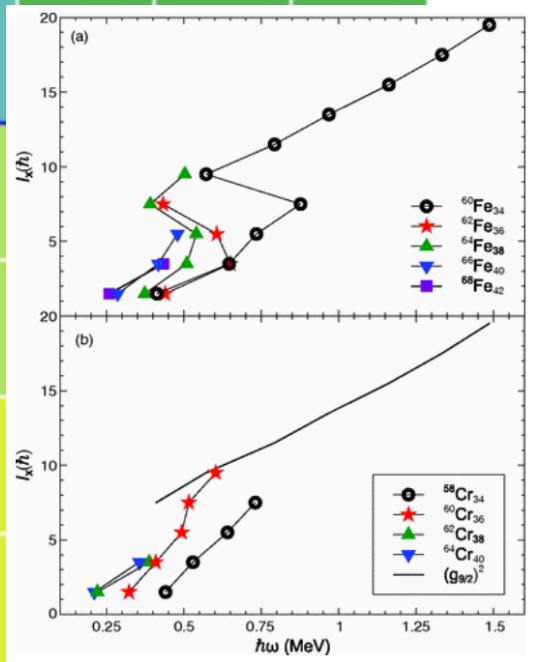


F. Recchia *et al.*,
Phys. Rev. C **88**, 041302(R) (2013)



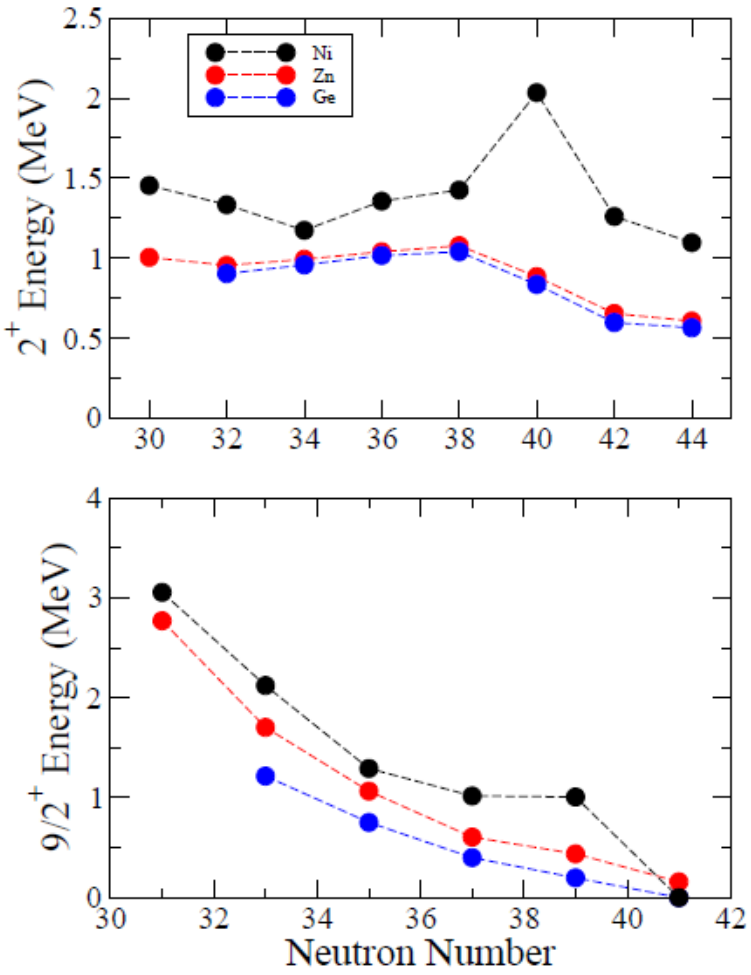
Courtesy of D. Ayangeakaa



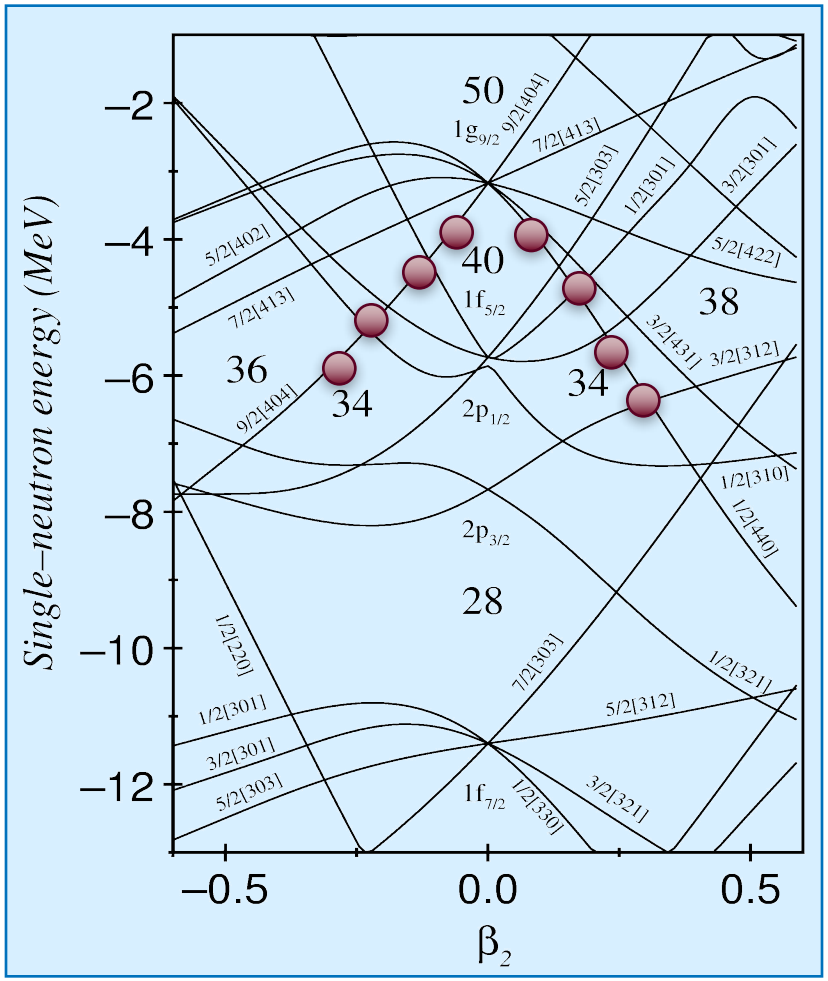


M.P. Carpenter *et al.*, Phys. Rev. C **87**, 041305(R) (2013)

The neutron-rich region around N=40



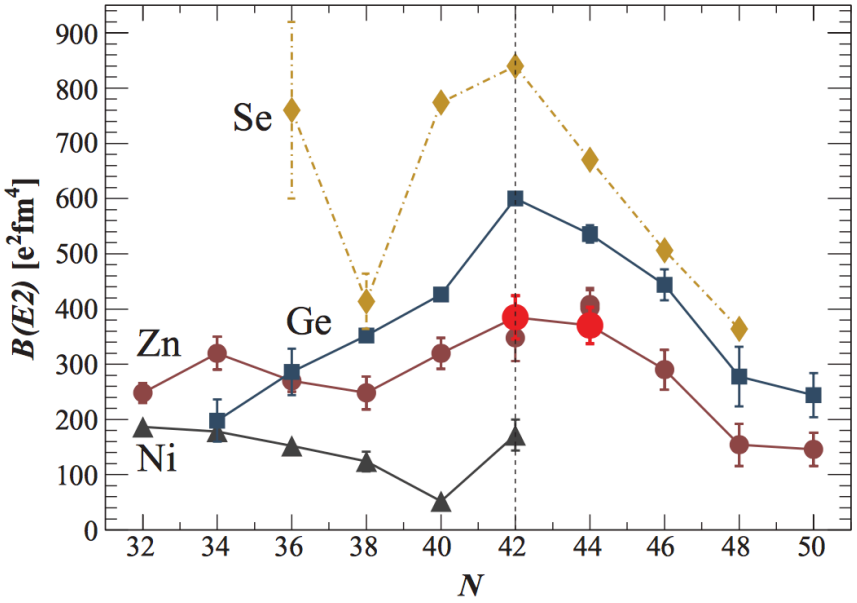
Disappearing of the
N=40 subshell gap



Onset of deformation driven by the
$\nu g_{9/2}$ orbital → collectivity

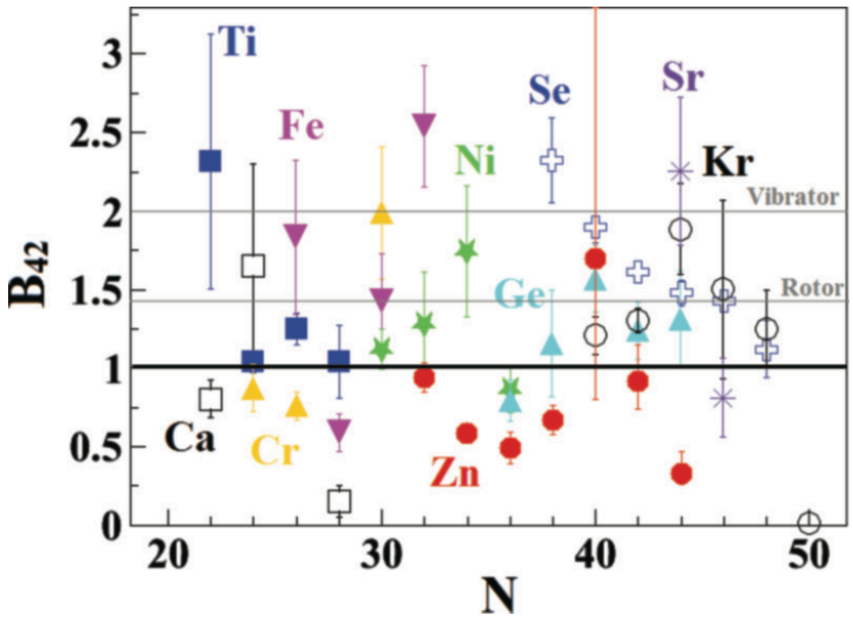
What happens in Zn isotopes?

M. Niikura *et al.*, Phys. Rev. C **85**, 054321 (2012)



Maximum of collectivity at
N=42 in Zn isotopes

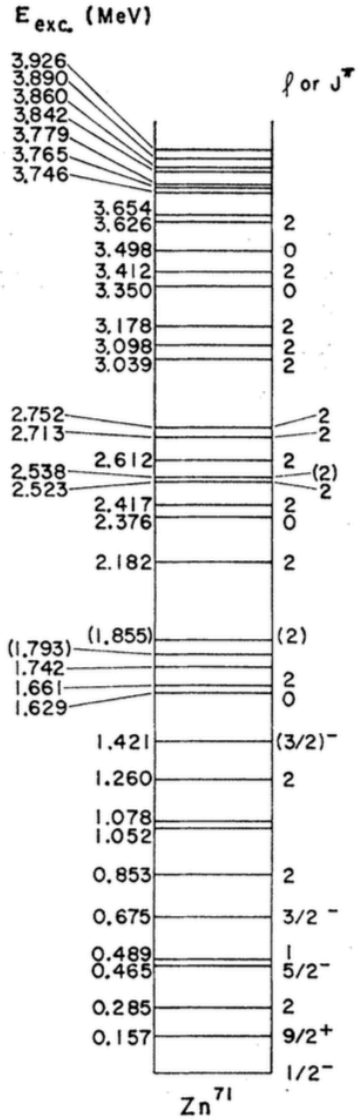
C. Louchart *et al.*, Phys. Rev. C **87**, 054302 (2013)

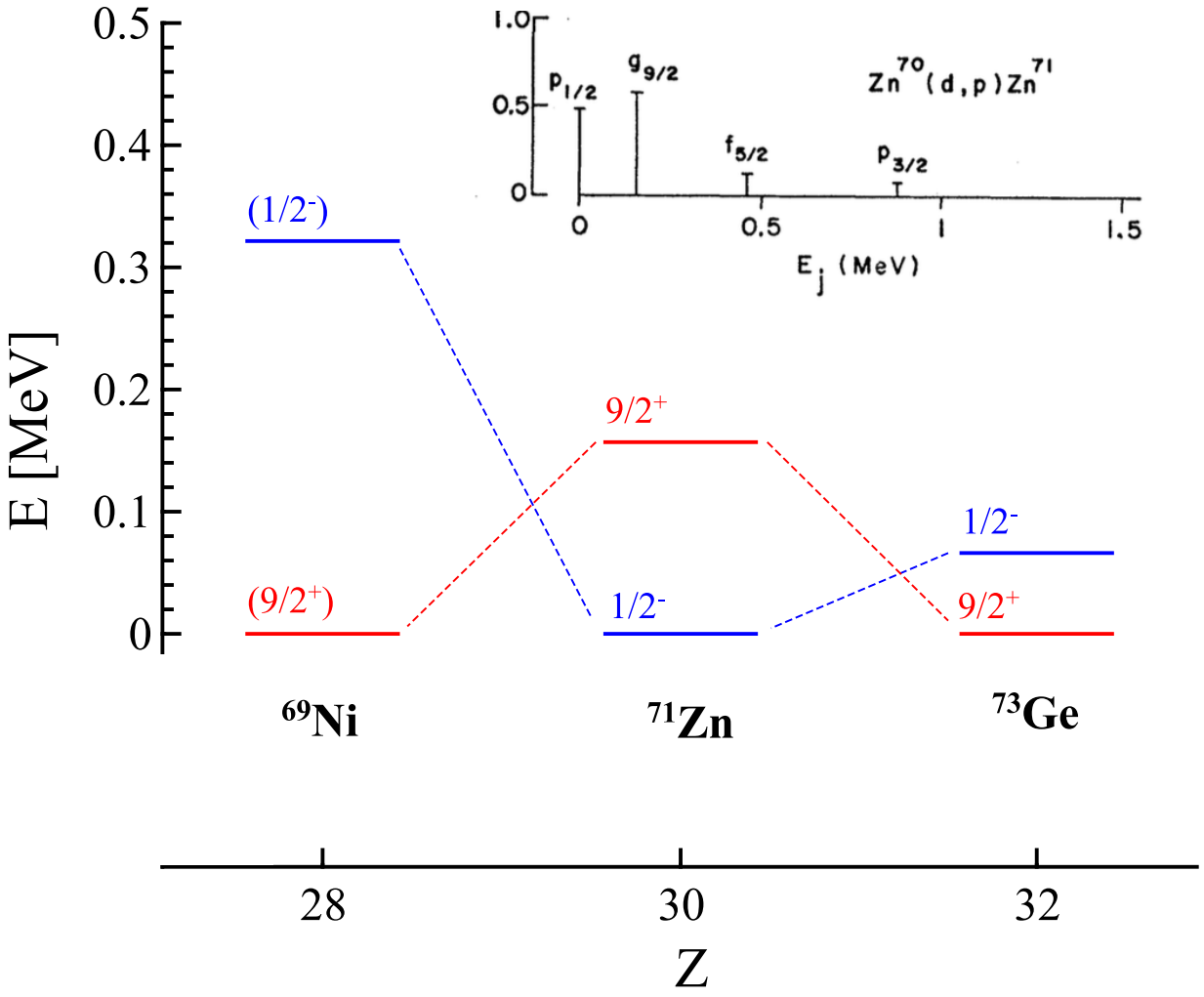


$B(E2; 4^+ \rightarrow 2^+)/B(E2; 2^+ \rightarrow 0^+)$
Single-particle character

odd-even Zn isotopes → single-particle *vs* collective excitations
(one-particle outside N = 40)

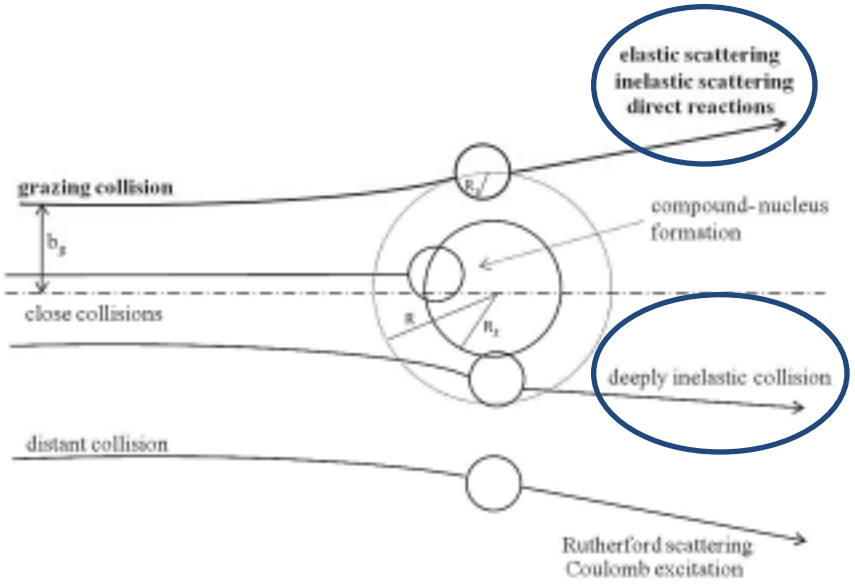
The case of ^{71}Zn



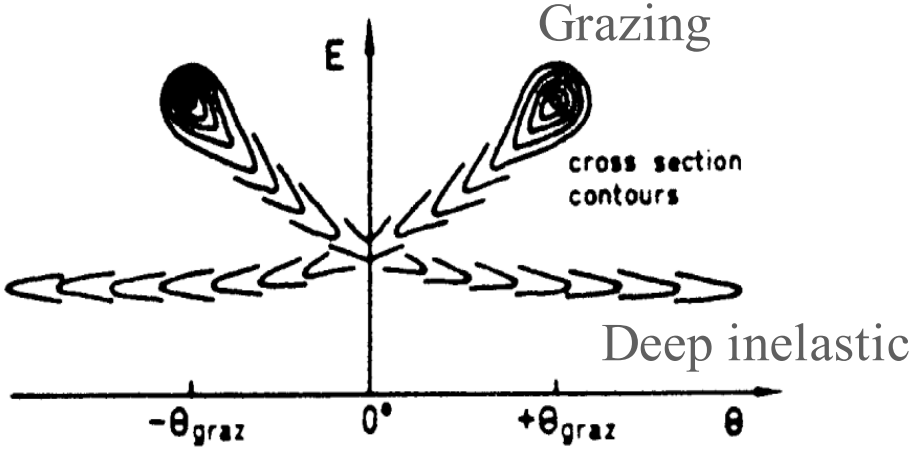


D. von Ehrenstein and J. P. Schiffer, Phys. Rev. **164**, 1374 (1967)

Heavy-ion transfer reactions

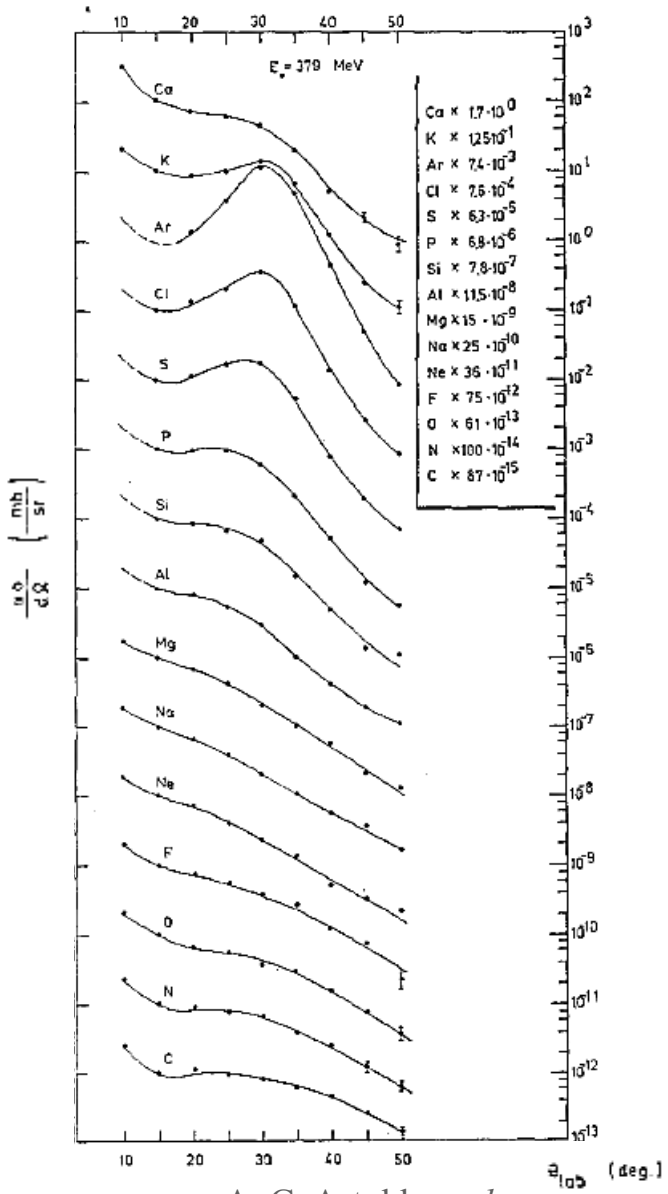


Transfer reactions



J. Wilczynski
Phys. Lett. B **47,** 484 (1973)

$^{40}Ar+^{232}Th$



A. G. Artukh *et al.*,
Nucl. Phys. A **215**, 91 (1971)

Heavy-ion transfer reactions

QUASI – ELASTIC REGIME

- Few degrees of freedom - binary process
- Spin selection in low-lying states
- Cross section governed by Optimum Q-value

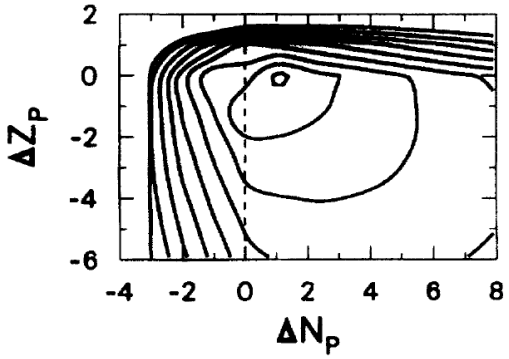
Multi-nucleon transfer

L. Corradi *et al.*,
JPG, **36,** 113101 (2009)

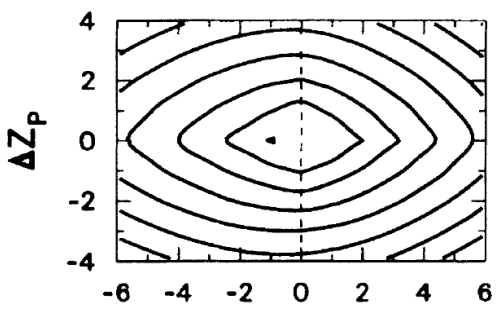
DEEP – INELASTIC COLLISIONS

- Many degrees of freedom
- High-spin and energy states
- Particles evaporation

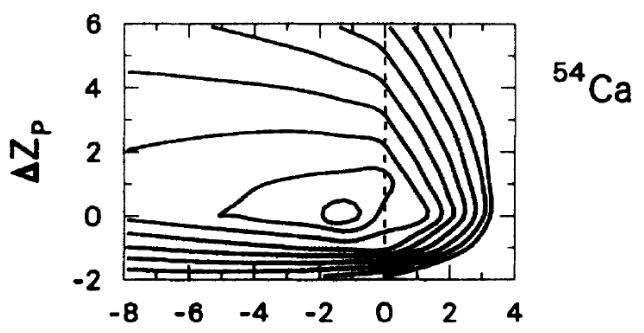
NEUTRON PICK UP
PROTON STRIPPING



SYMMETRIC DISTRIBUTION



PROTON PICK UP
NEUTRON STRIPPING

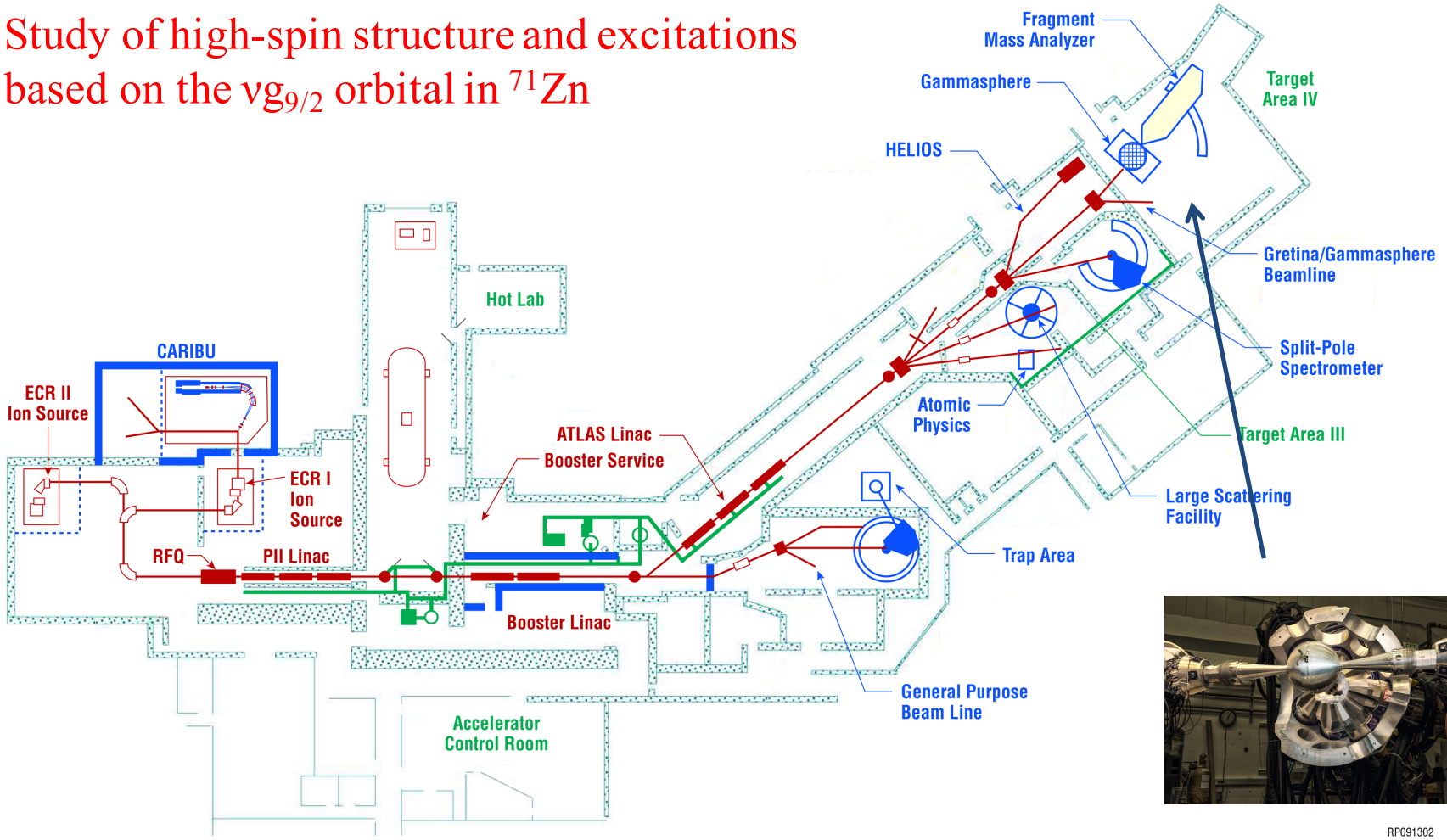


^{A}Ca+^{120}Sn @ E_{cm} = 150 MeV

C. H. Dasso *et al.*, Phys. Rev. Lett. **73**, 1907 (1994)

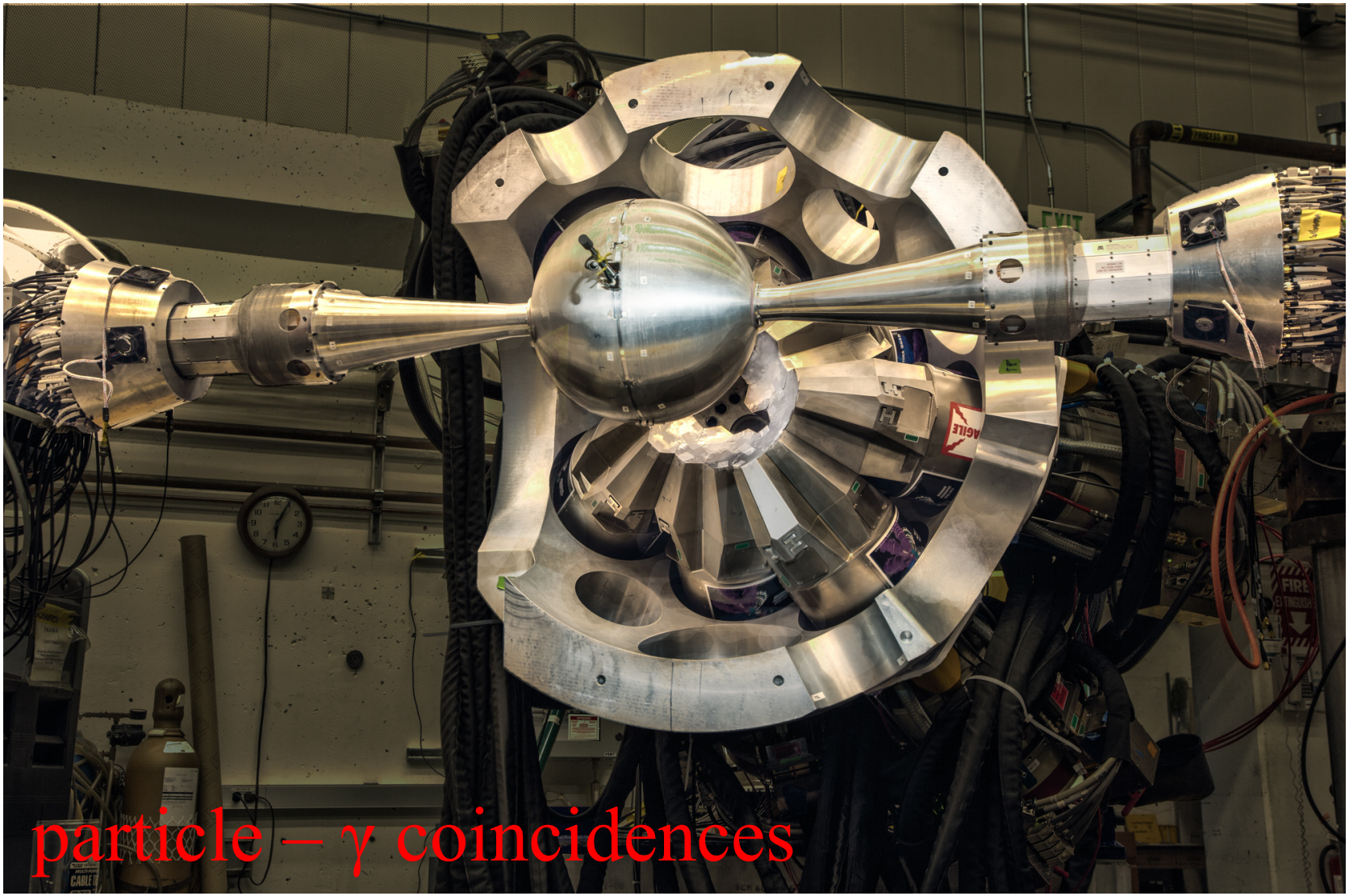
The $^{48}Ca+^{70}Zn$ experiment

- Test of heavy-ion transfer reactions with GRETINA
- Study of high-spin structure and excitations based on the $\nu g_{9/2}$ orbital in ^{71}Zn

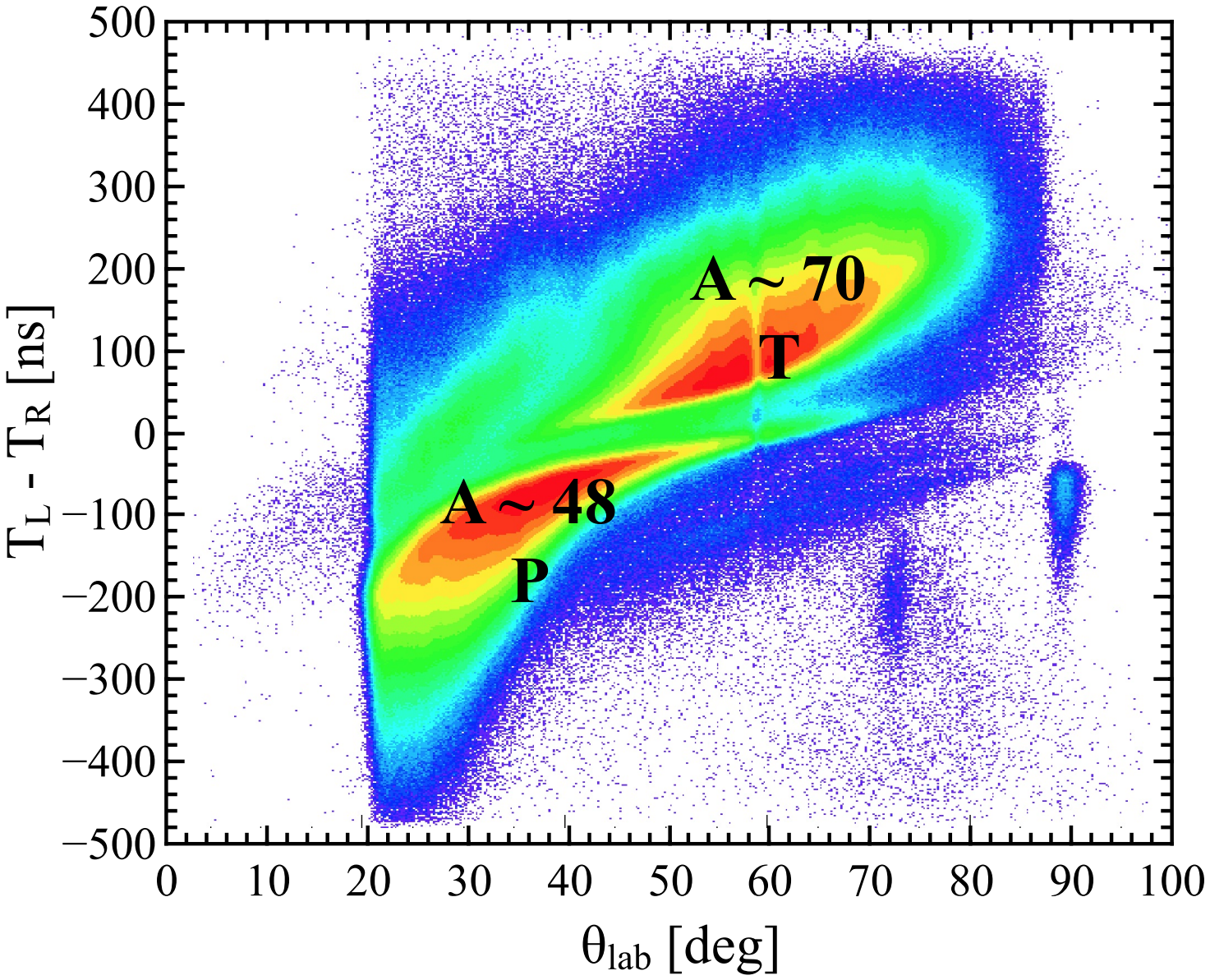


$^{48}Ca+^{70}Zn \rightarrow {}^{47}Ca+^{71}Zn$ @ 170 MeV (30 % above C.B.)

The GRETINA+CHICO2 setup @ ANL



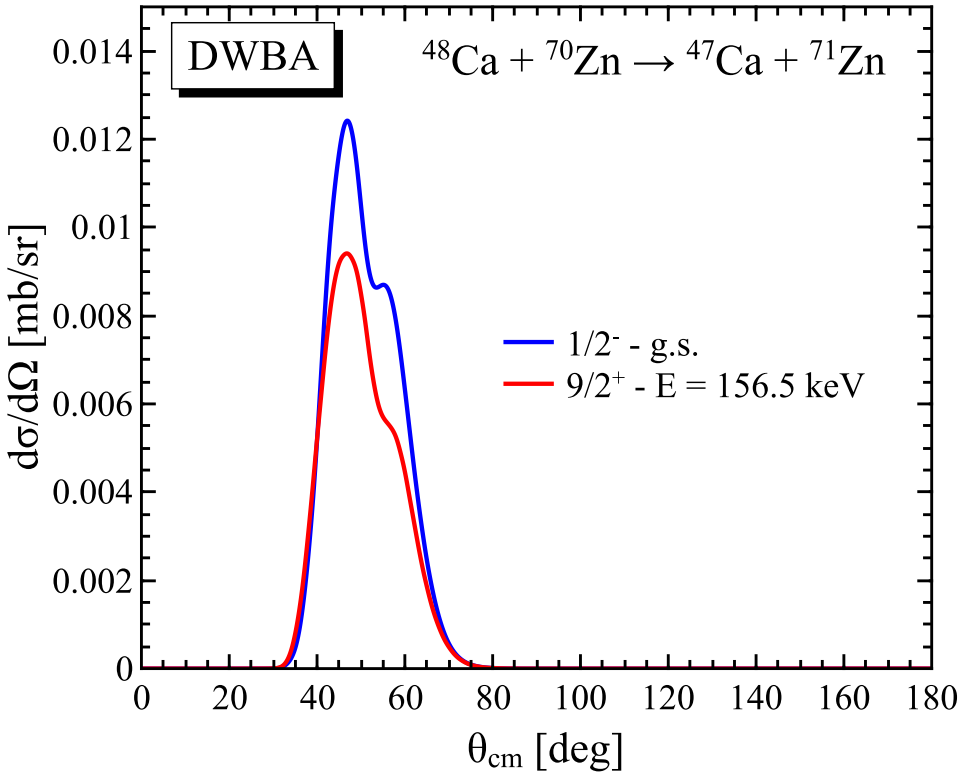
Particles spectrum



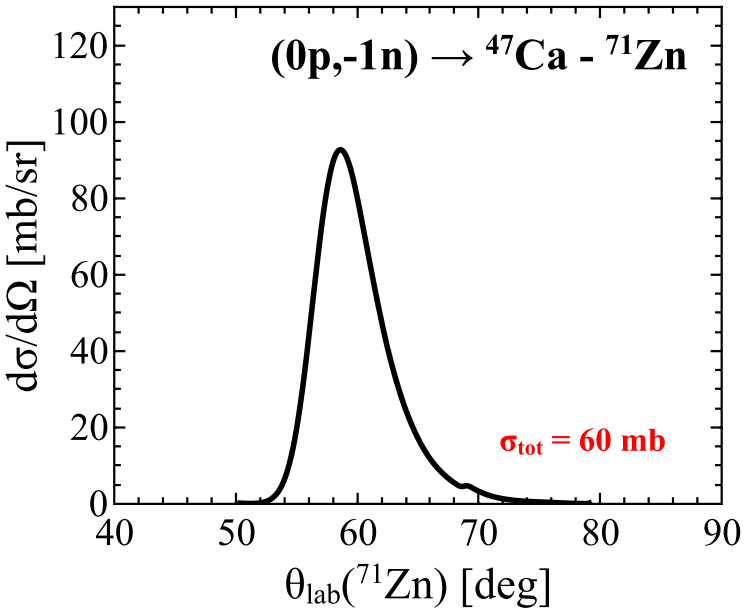
- $\gamma\gamma_{PP}$
- $\gamma\gamma_{TT}$
- $\gamma\gamma_{PT}$

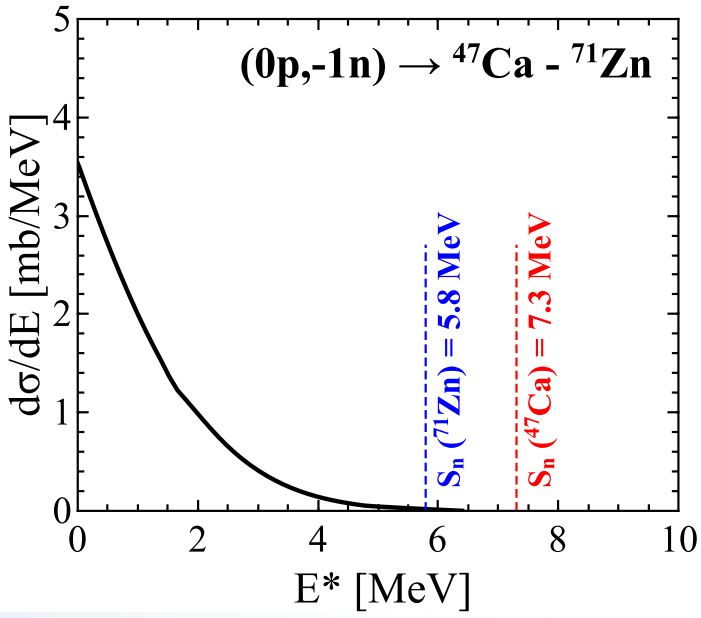
The ^{48}Ca+^{70}Zn heavy-ion reaction

@ 170 MeV

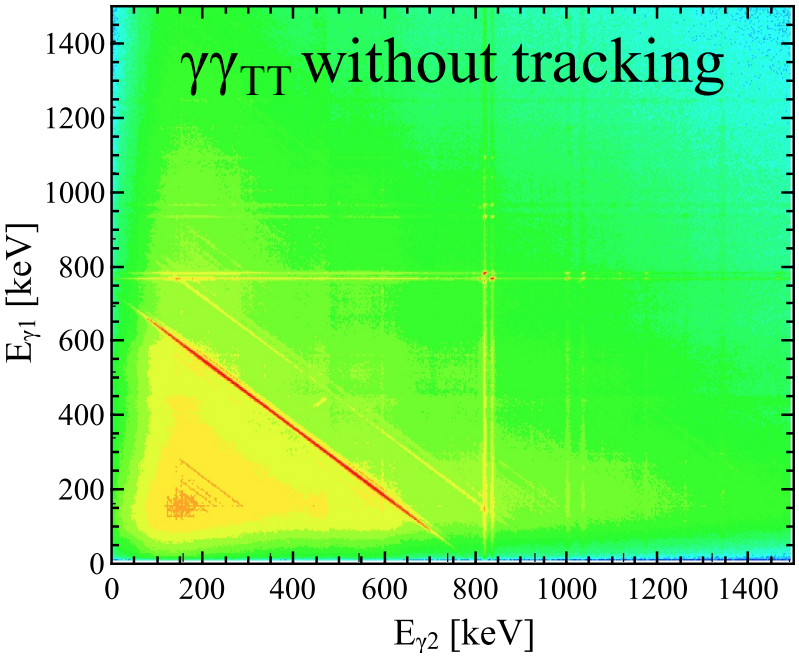


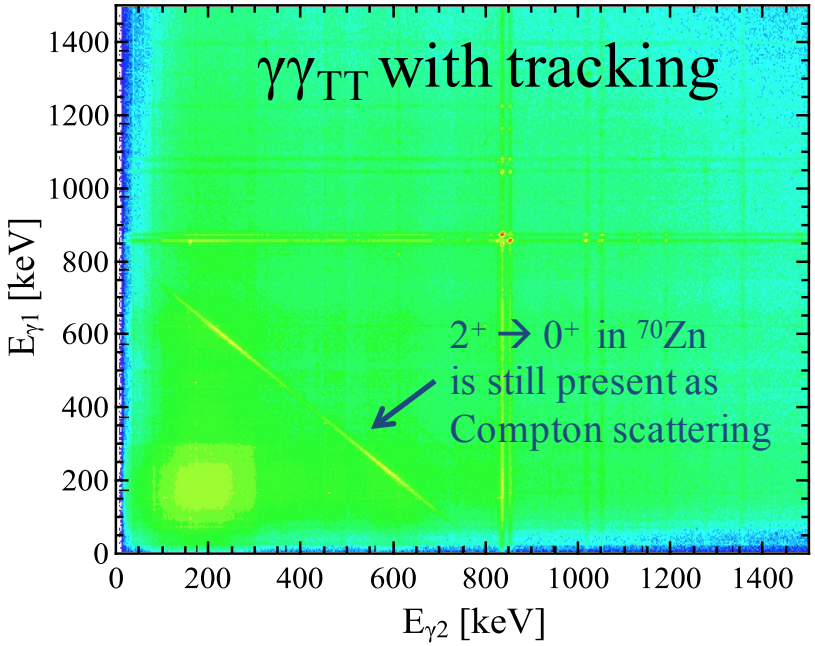
GRAZING calculations

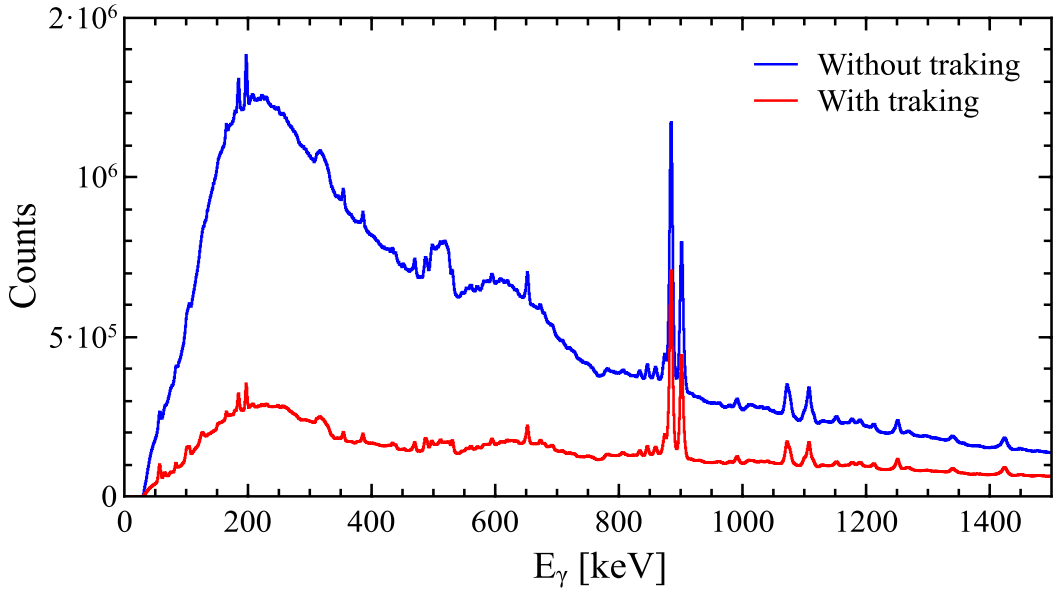




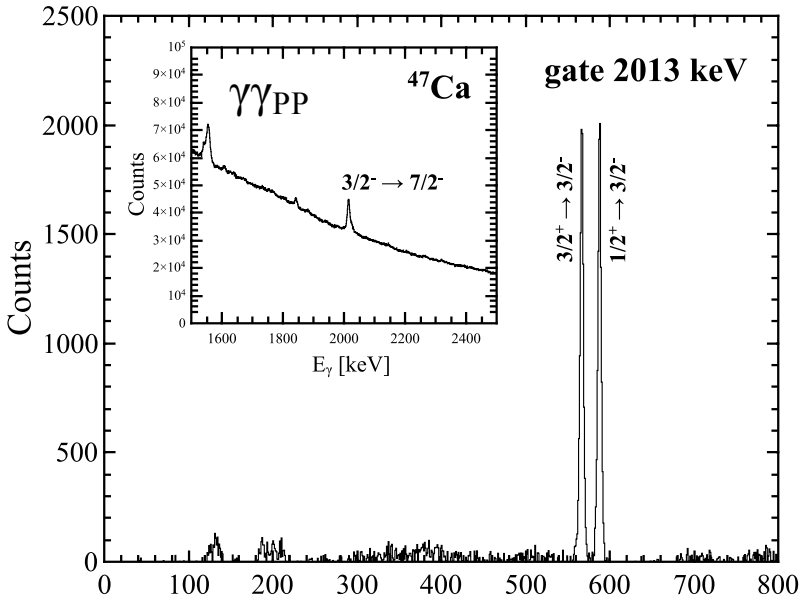
γ spectra

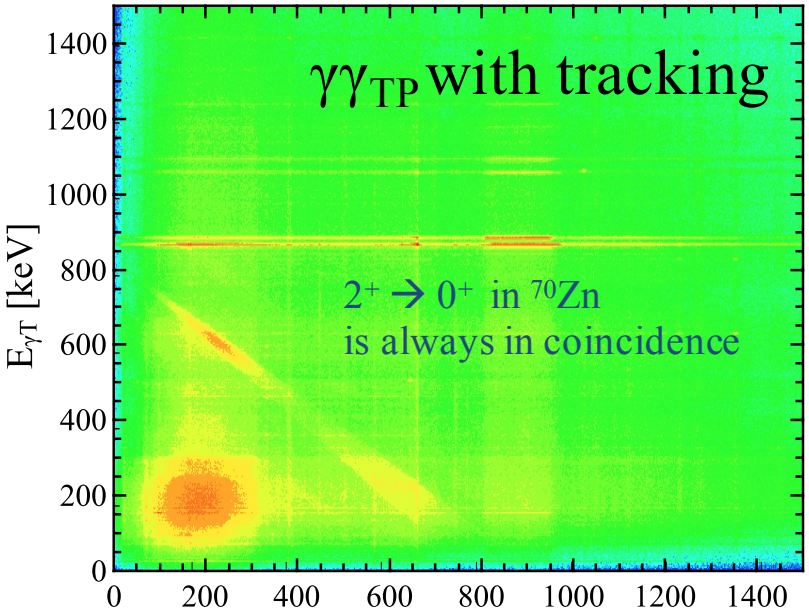

γγTT without tracking
Eγ1 [keV]
Eγ2 [keV]
0
200
400
600
800
1000
1200
1400

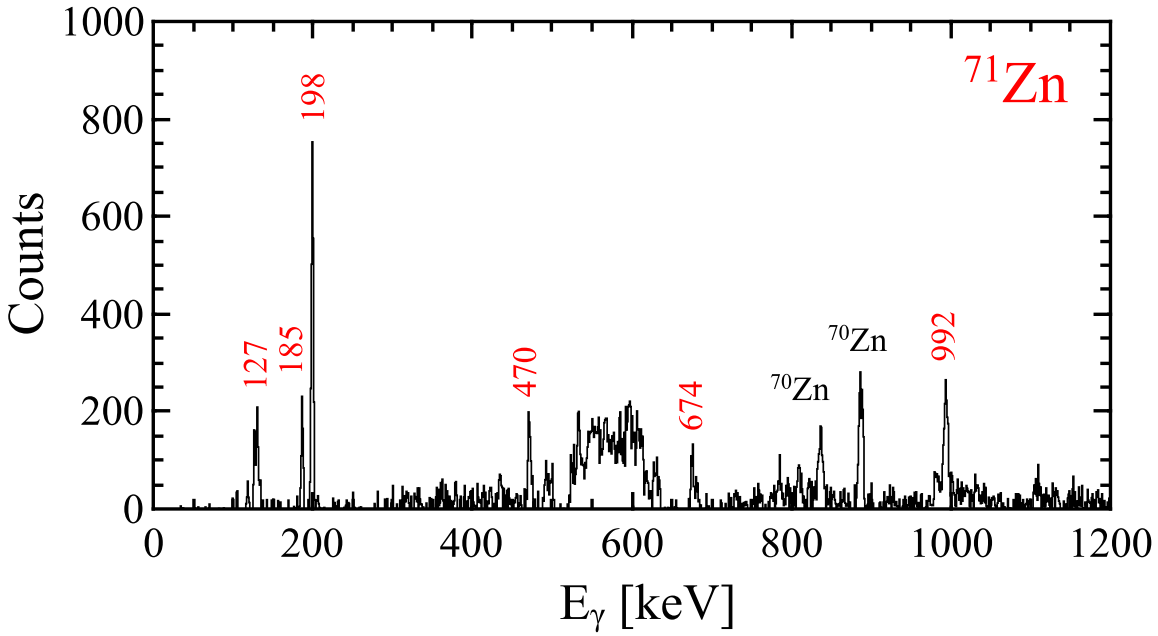

γγTT with tracking
2+ → 0+ in 70Zn
is still present as
Compton scattering
Eγ1 [keV]
Eγ2 [keV]
0
200
400
600
800
1000
1200
1400


Without traking
With traking
Counts
Eγ [keV]
0
5·10^5
10^6
2·10^6
0
200
400
600
800
1000
1200
1400

γ spectra


gate 2013 keV
$\gamma\gamma_{PP}$
^{47}Ca
3/2⁻ → 7/2⁻
3/2⁺ → 3/2⁻
1/2⁺ → 3/2⁻
Counts
E_γ [keV]

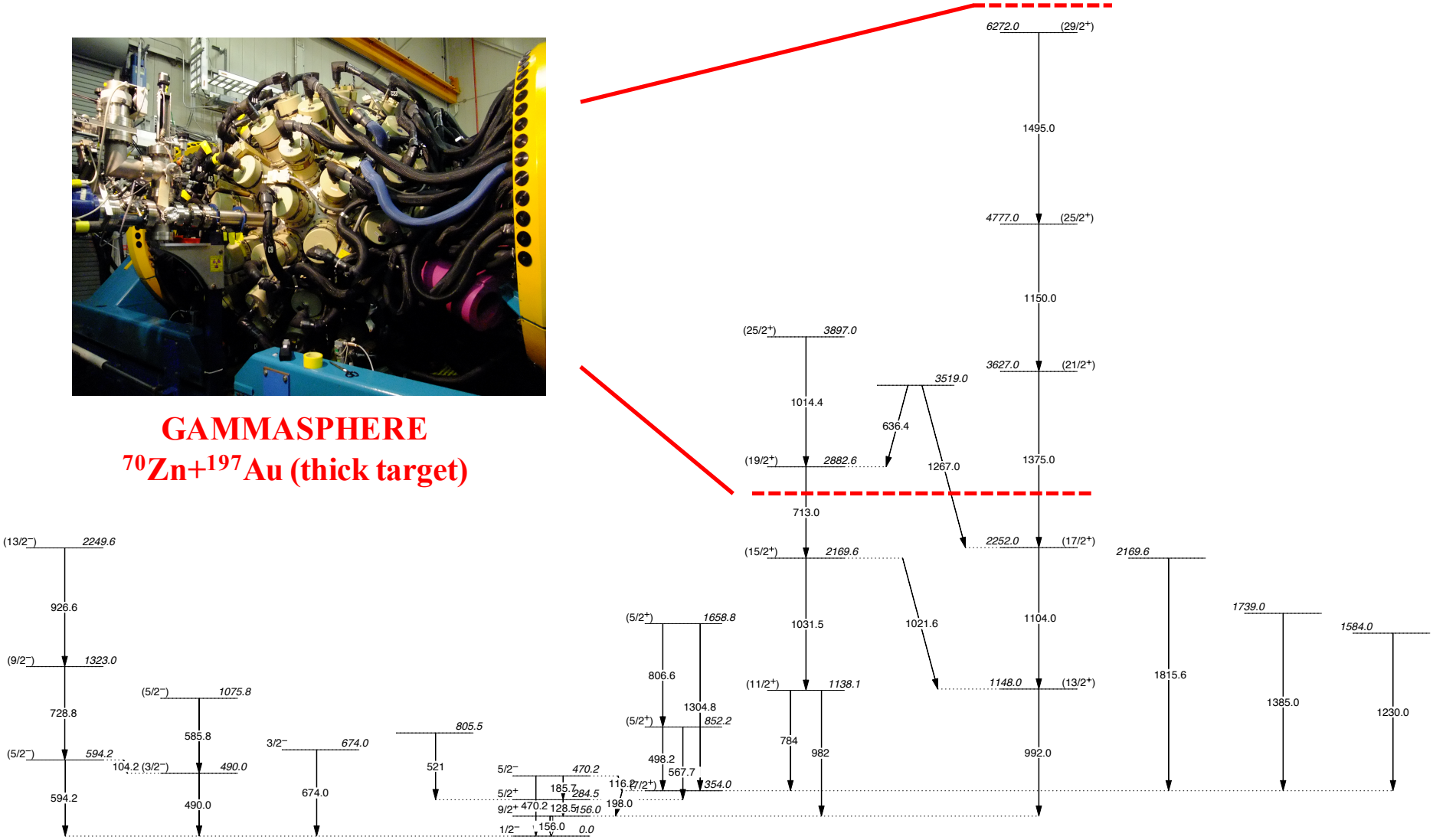

$\gamma\gamma_{TP}$ with tracking
2⁺ → 0⁺ in ^{70}Zn
is always in coincidence
$E_{\gamma T}$ [keV]


^{71}Zn
198
127
185
470
674
^{70}Zn
^{70}Zn
992
Counts
E_γ [keV]

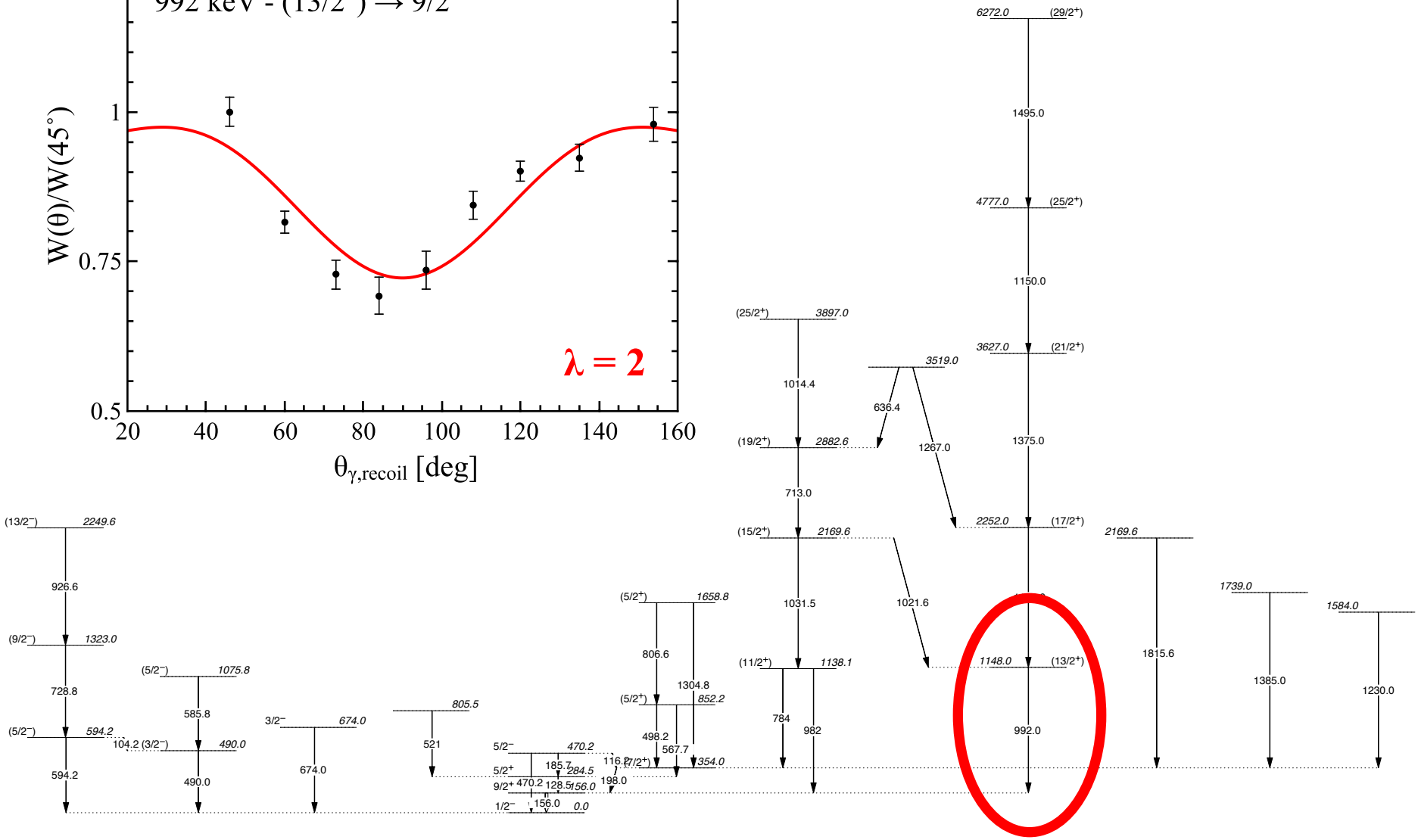
^{71}Zn level scheme and γ decay

GAMMASPHERE

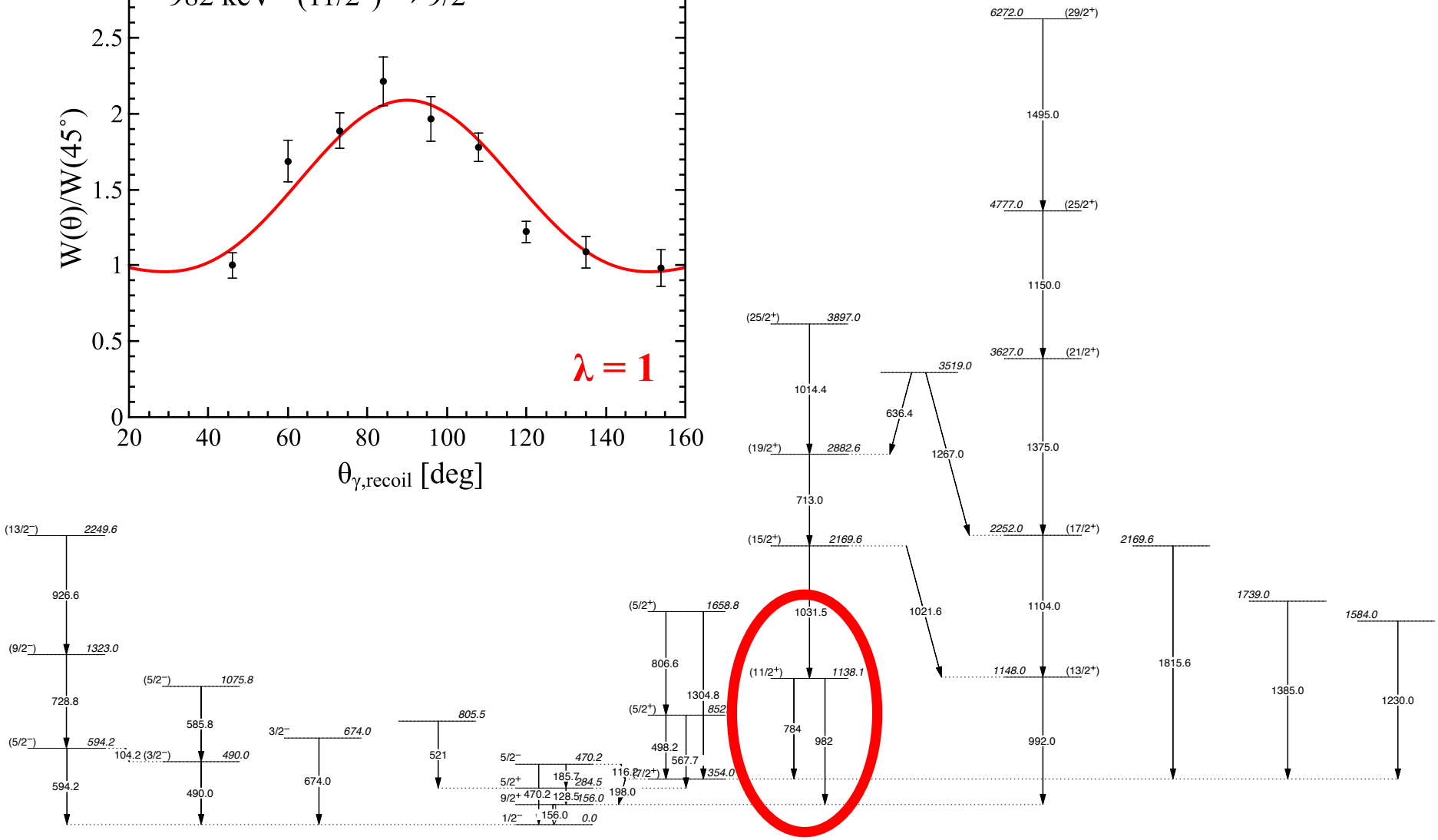
^{70}Zn+^{197}Au (thick target)



^{71}Zn level scheme and γ decay



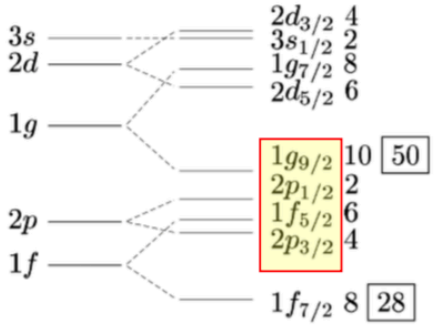
^{71}Zn level scheme and γ decay



Comparison with theory

A. Brown, unpublished

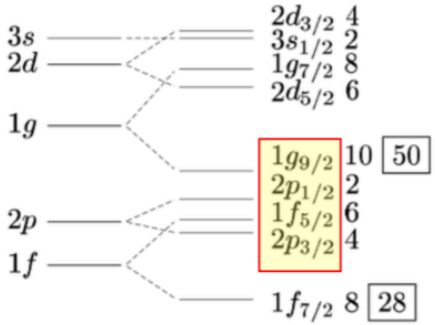
jj44b



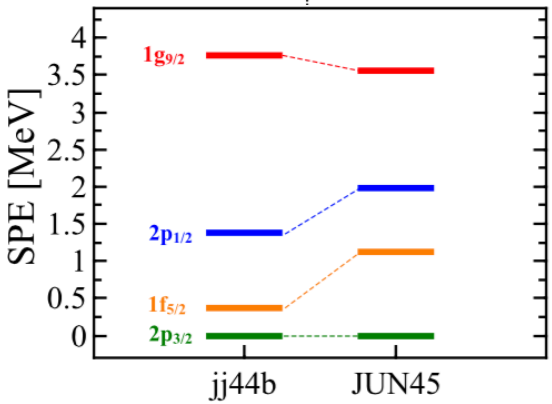
- ^{56}Ni core
- 600 binding energies and excitation energies
- Z = 28-30 and N = 48-50

M. Honman et al., PRC **80**, 064323 (2009)

JUN45

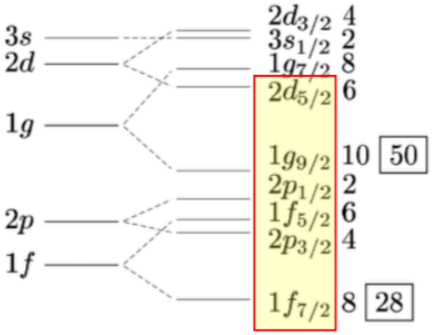


- ^{56}Ni core
- 400 binding energies and excitation energies
- Z = 28-32 and N = 46-50
- No Ni and Cu isotopes



Y. Tsunoda *et al.*, PRC **89**, 031301(R) (2014)

MCSM

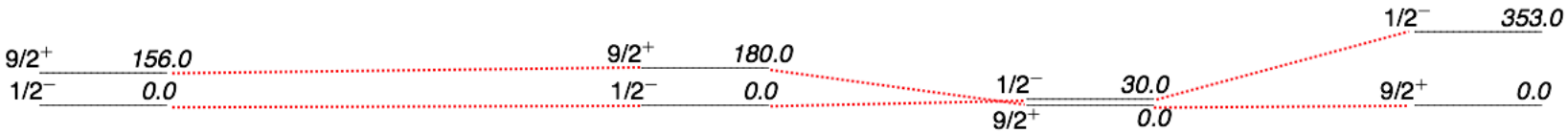


- ^{40}Ca core
- A3DA interaction*:
  - TBMEs for *pf* shell from GXPF1A
  - TBMEs related to $g_{9/2}$ from JUN45
  - Other TBMEs from G-matrix effective interaction using the chiral N3LO interaction
  - Core-polarization included perturbatively
  - Adjusted single-particle energies and monopole interaction to reproduce nuclei in the $pfg_{9/2}$ shells

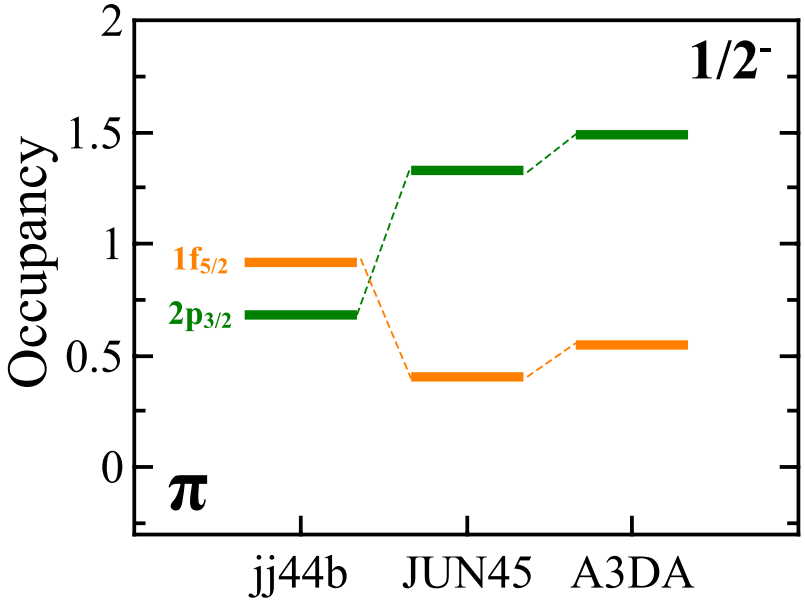
*unpublished

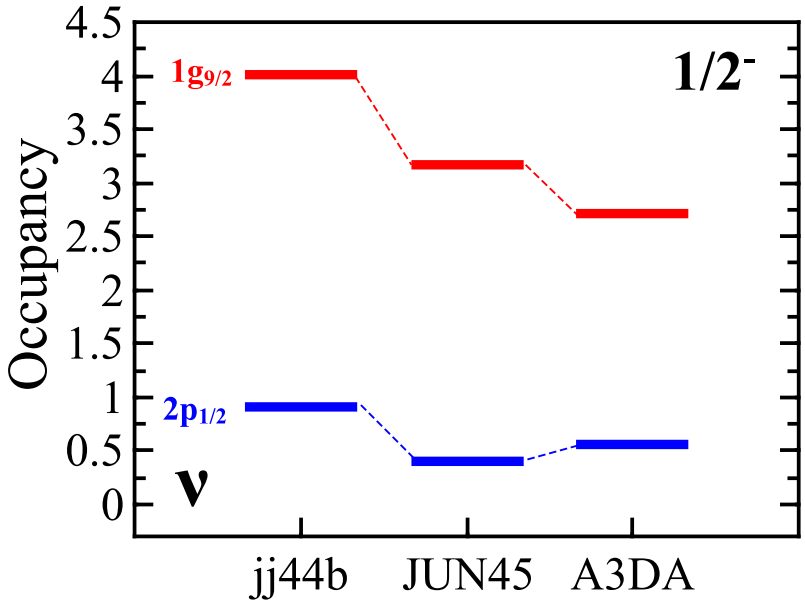
Calculations: Y. Tsunoda and T. Otsuka

Ground state

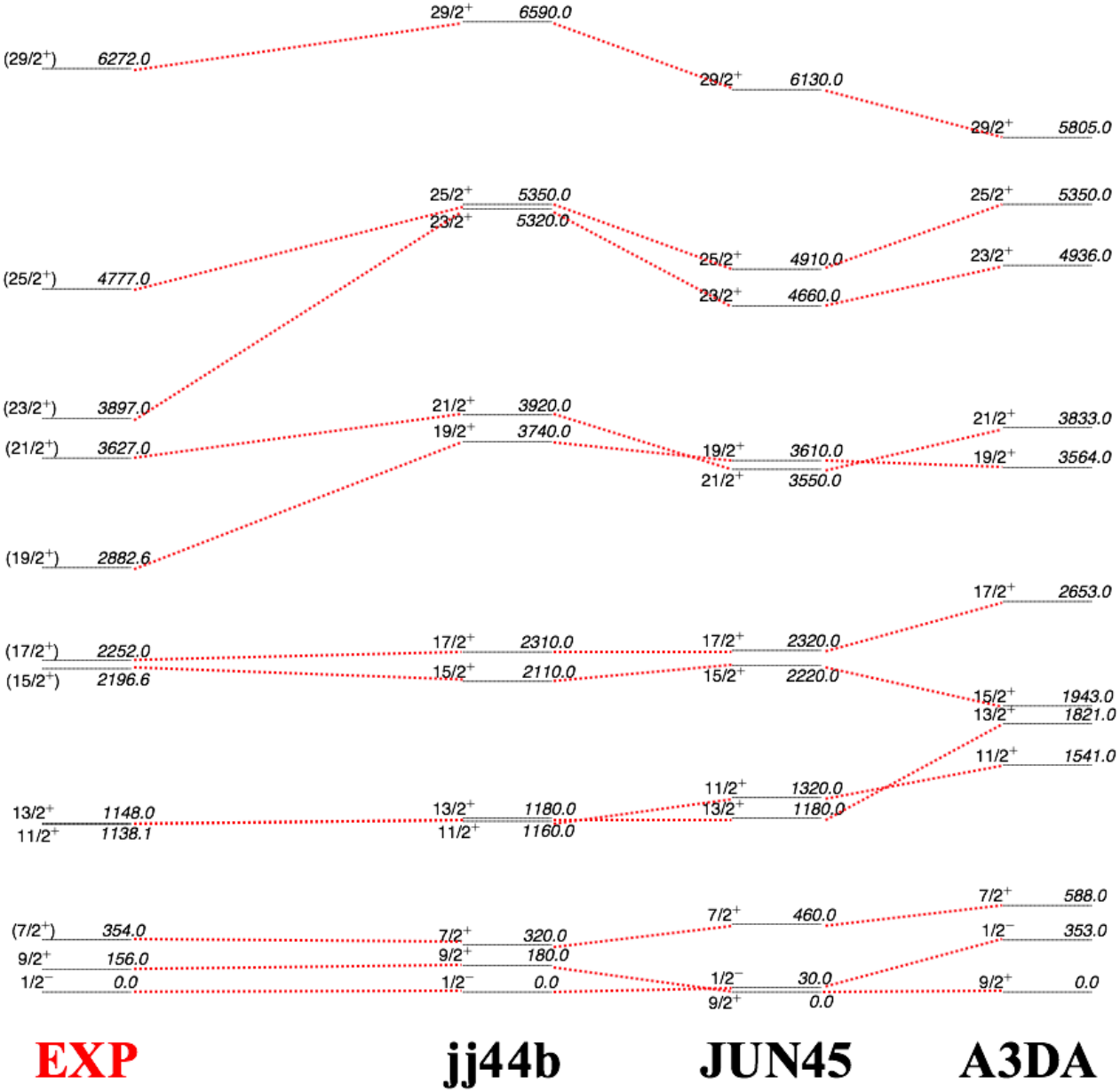


EXP **jj44b** **JUN45** **A3DA**





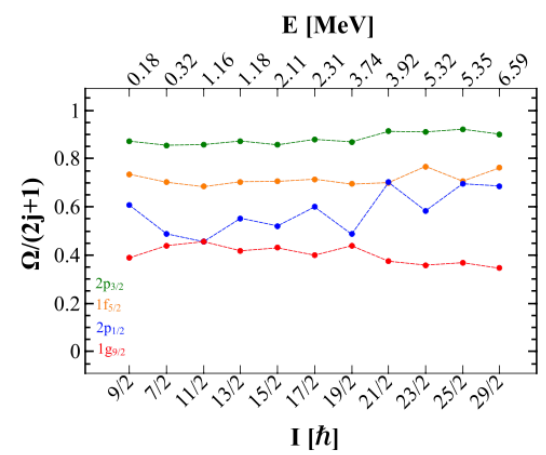
Band built on the $\nu g_{9/2}$ orbital

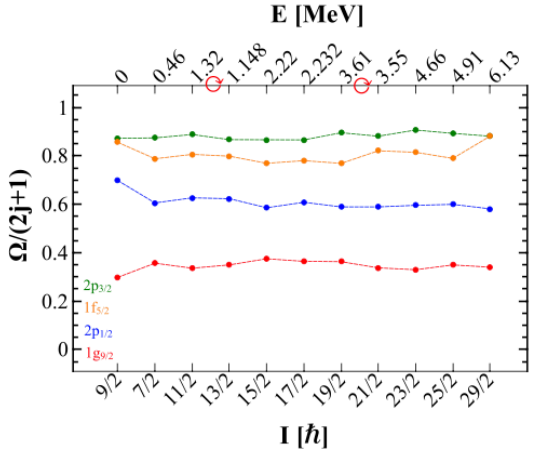


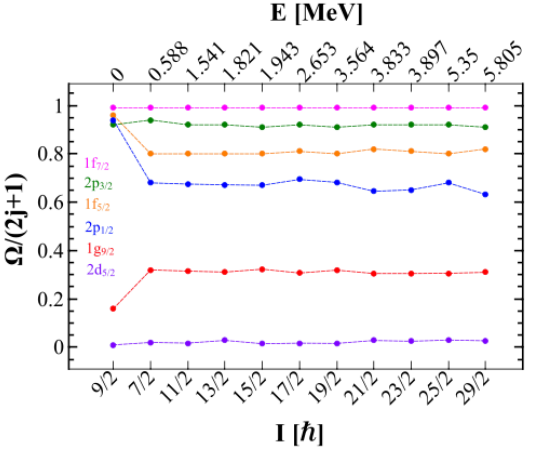
Band built on the $\nu g_{9/2}$ orbital

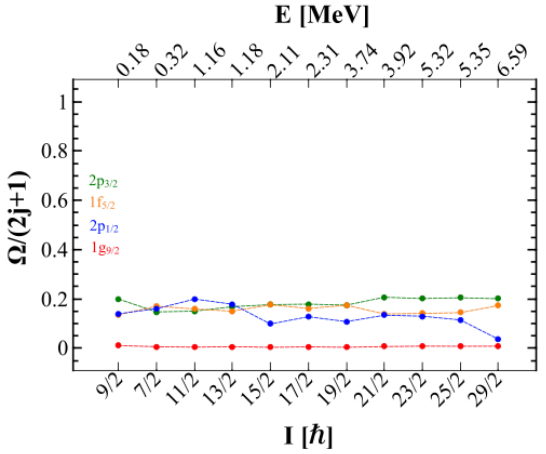
NEUTRONS

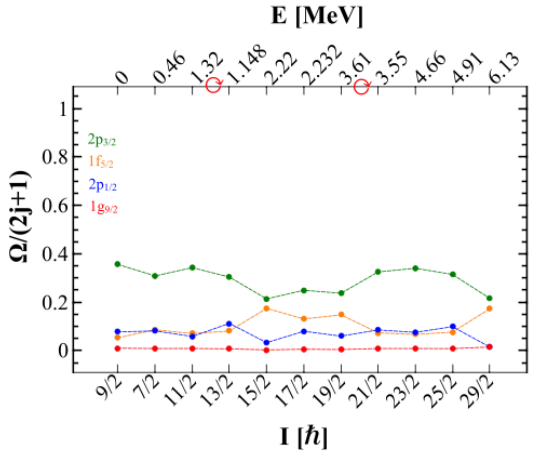
PROTONS

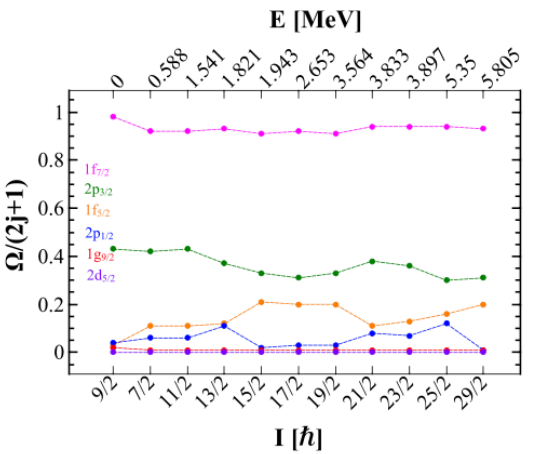






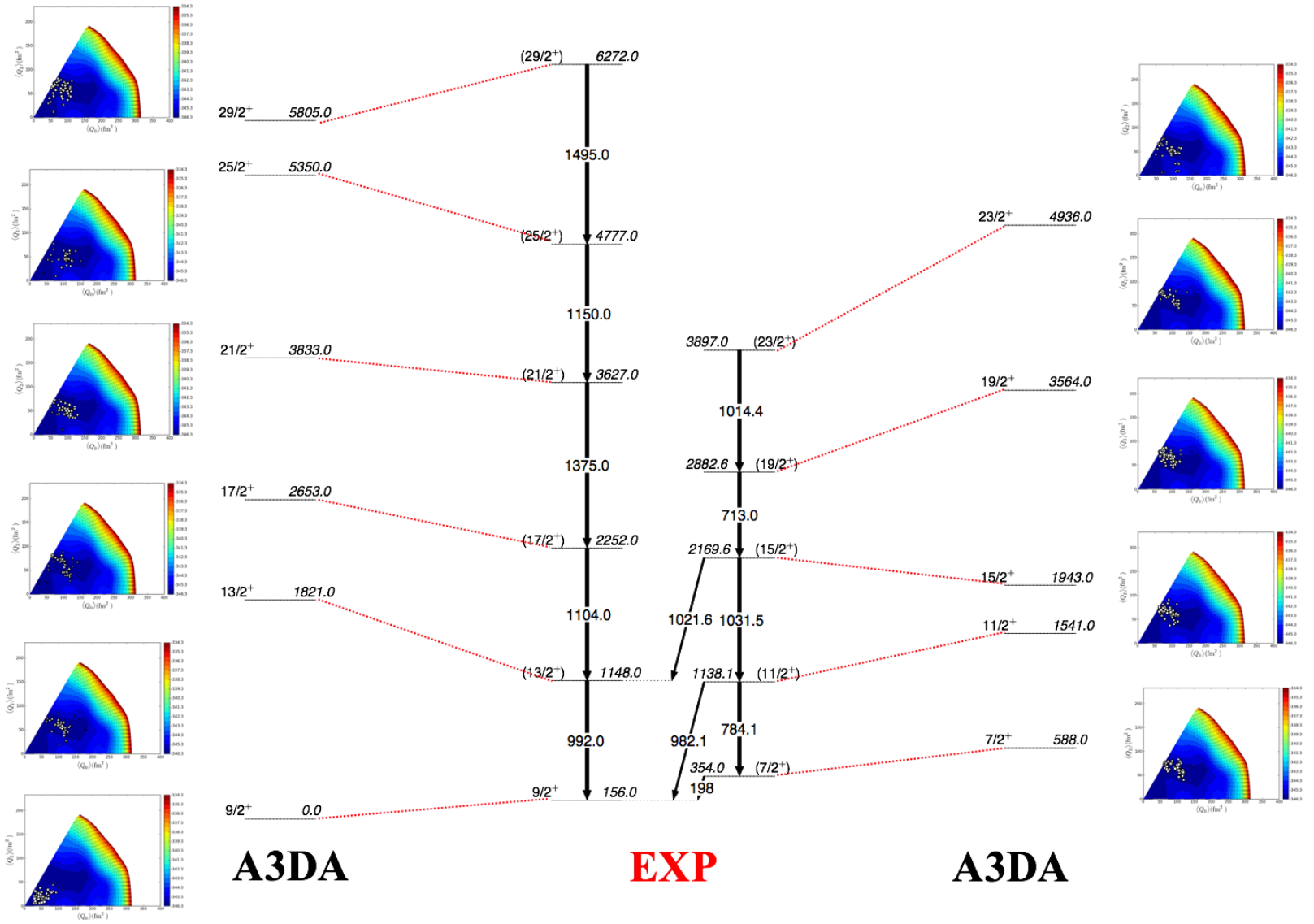




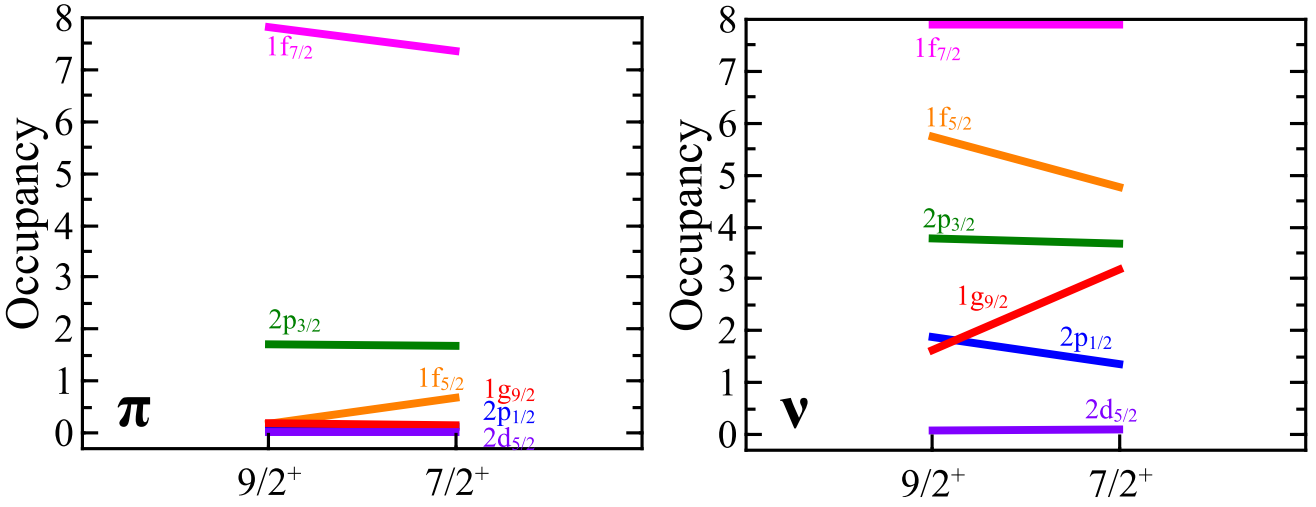


jj44b | **JUN45** | **A3DA**

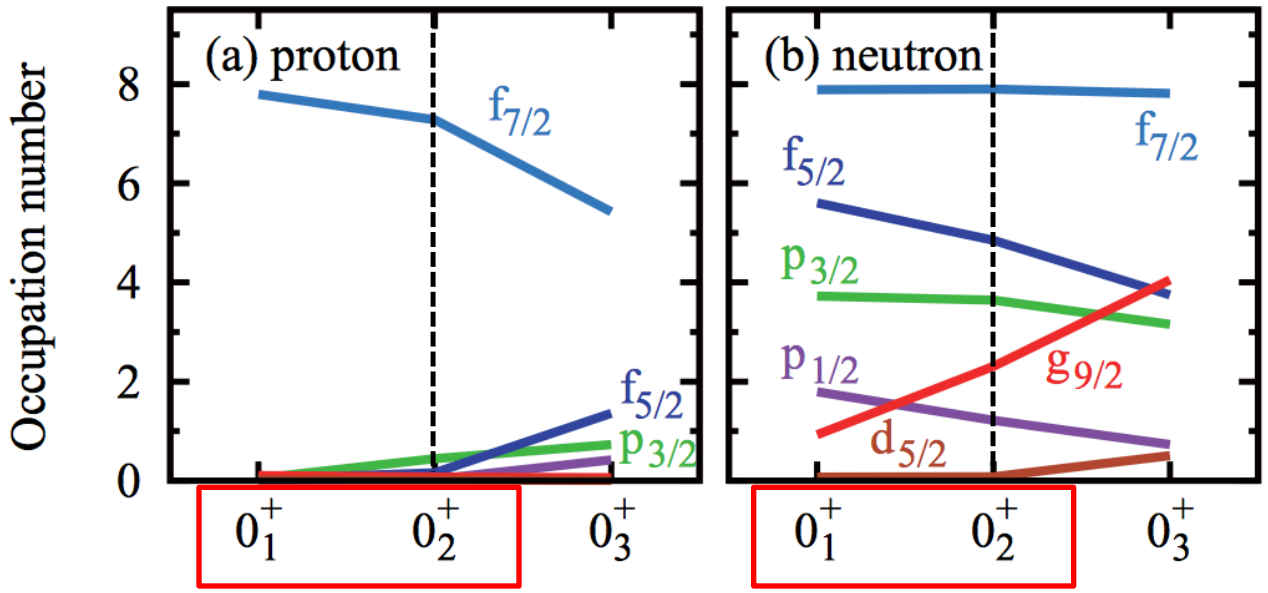
Band built on the $\nu g_{9/2}$ orbital



Band built on the $\nu g_{9/2}$ orbital



^{71}Zn



^{68}Ni [1]

(1) Y. Tsunoda *et al.*, PRC **89**, 031301(R) (2014)

Conclusions

- Heavy-ion transfer reactions with GRETINA and CHICO2 @ ANL
- Good setup to perform γ spectroscopy studies of n-rich nuclei (with RIB's)
- The case of ^{71}Zn
- $1/2^-$ ground state due to large occupancy of $\pi f_{5/2}$ orbital
- Observation of non-collective bands built on the $\nu g_{9/2}$ orbital
- Oblate shape stabilized by neutrons
- Transition to prolate shape "blocked"
- Similar configuration of 0_2^+ in ^{68}Ni

Collaboration

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Thank you!

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