Study of the neutron Fermi surface of ^{68}Ni by using (d,p) and (p,d) reactions (E843)

Shumpei Koyama
GANIL

LISE Workshop 2022

29/03/2022

N=50 in neutron-rich Ni

^{78}Ni : Z=28 and N=50, “classical” magic numbers kept?

cf : Broken magic in ^{12}Be(N=8), ^{32}Mg(N=20), ^{44}S(N=28),…

Mass measurement around ^{78}Ni J. Hakala et al., PRL 101 52502 (2008)

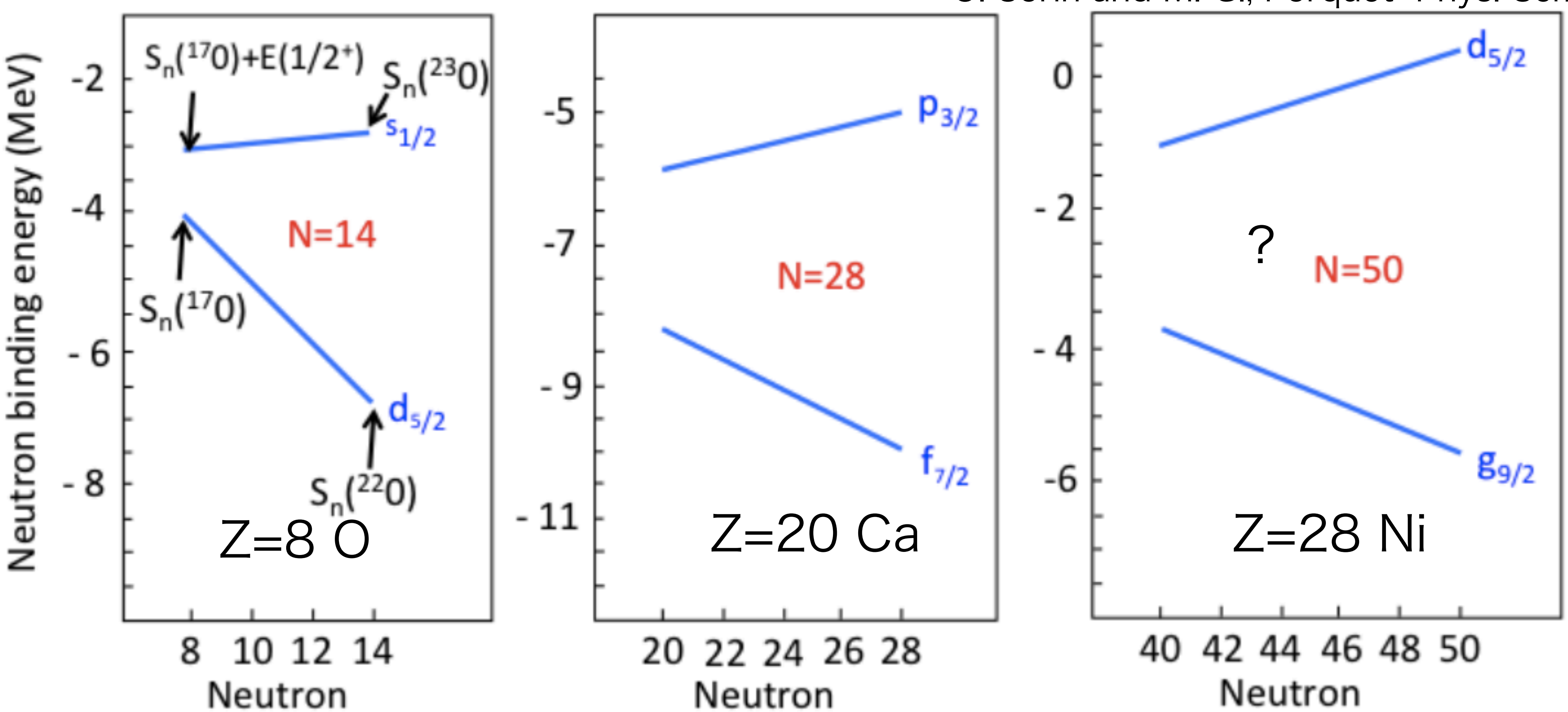
β-decay life time around ^{78}Ni Z. Y. Xu et al., PRL 113 032505 (2014)

High energy of 2^+_1 state of ^{78}Ni R. Taniuchi et al., Nature 569 53 (2019)

Doubly magic nuclei ^{78}Ni

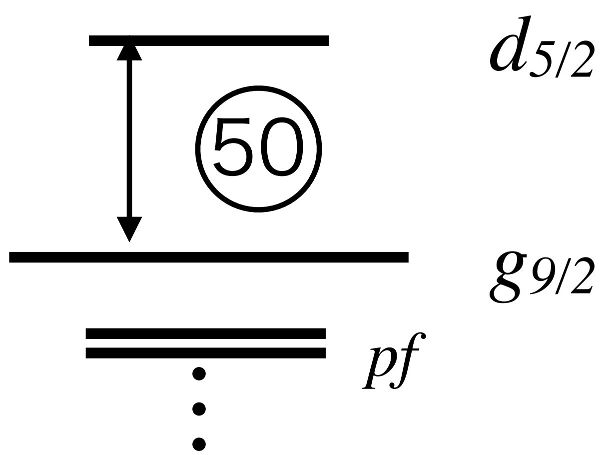
-> Detailed study of N=50 gap in Ni isotope

O. Sorin and M.-G., Porquet Phys. Scr. T152 014003



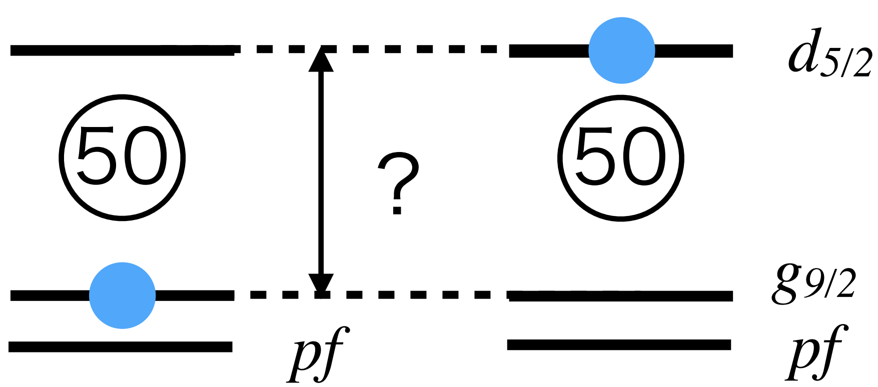
^{68}Ni : Starting point of N=50 gap at N=40

N=50 in neutron-rich Ni



N=50 gap energy in ^{68}Ni

$$= \ < E(d_{5/2}) > \ - \ < E(g_{9/2}) >$$



^{69}Ni g.s. ^{69}Ni 5/2$^+$

$< E(d_{5/2}) >$ $C^2S^+, {}^{69}\mathrm{Ni}\ E\mathrm{x}(d_{5/2})$

-> ^{68}Ni(d,p)^{69}Ni

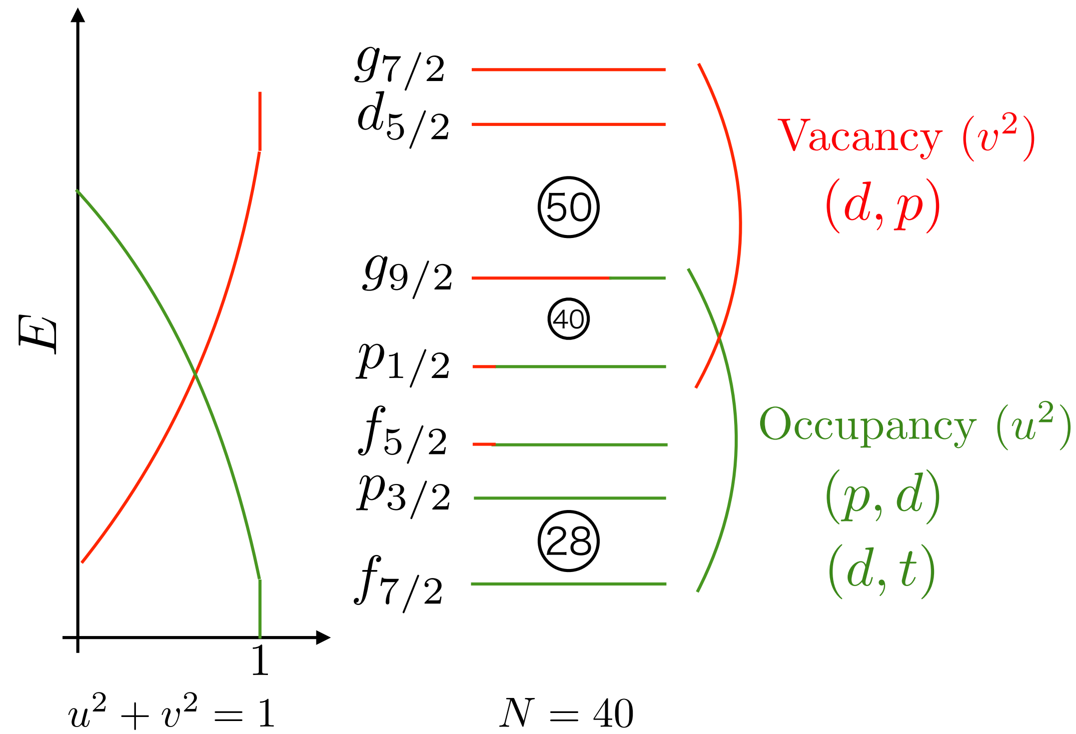
$< E(g_{9/2}) >$ $C^2S^+, {}^{69}\mathrm{Ni}\ E\mathrm{x}(g_{9/2})$

$C^2S^-, {}^{67}\mathrm{Ni}\ E\mathrm{x}(g_{9/2})$

-> ^{68}Ni(p,d)^{67}Ni

N=40 magicity in ^{68}Ni

^{68}Ni : pf-shell HO "closure" of N=40"



v^2 $(g_{9/2}) = 1$

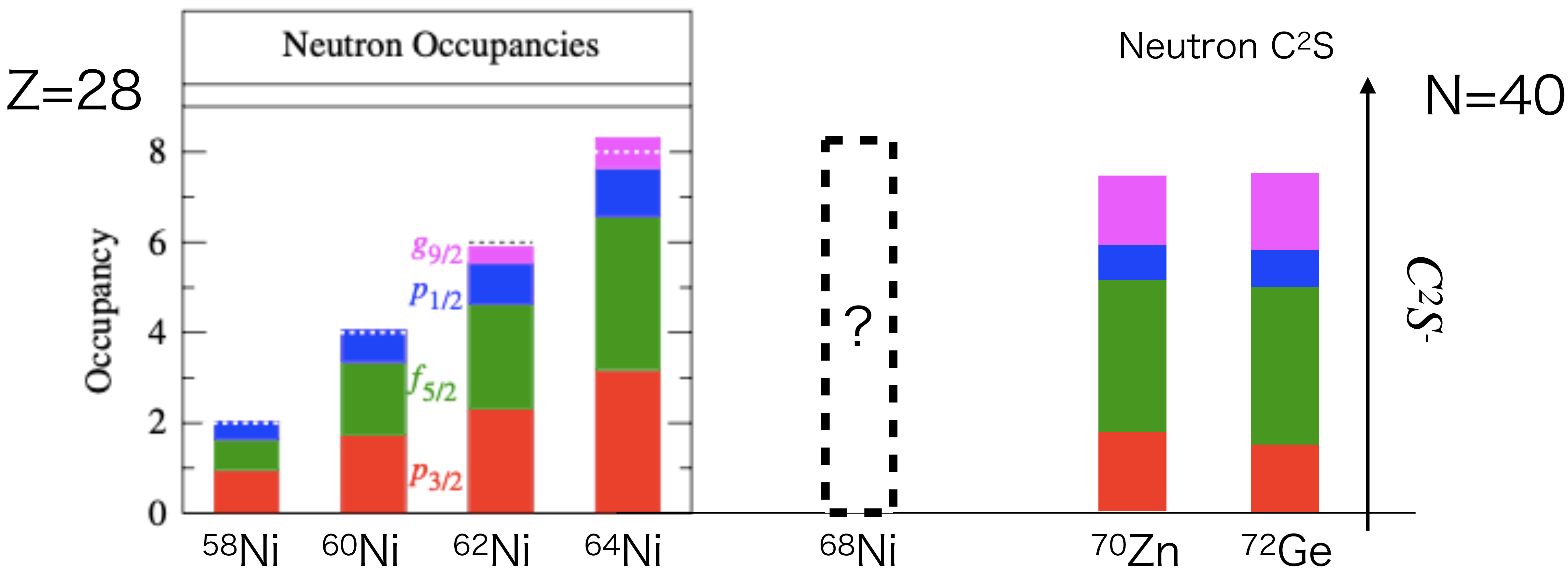
$(p_{1/2}, p_{3/2}, f_{5/2}) = 0$

-> ^{68}Ni$(d,p)^{69}$Ni C^2S^+

u^2 $(g_{9/2}) = 0$

$(p_{1/2}, p_{3/2}, f_{5/2}) = 1$

-> ^{68}Ni$(p,d)^{67}$Ni C^2S^-

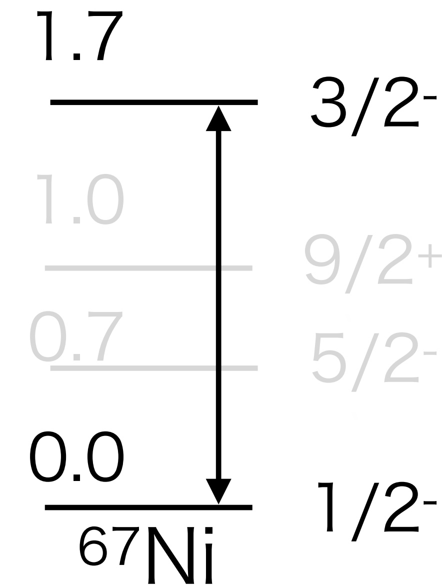


J. P. Schiffer et al., PRL 108 22501

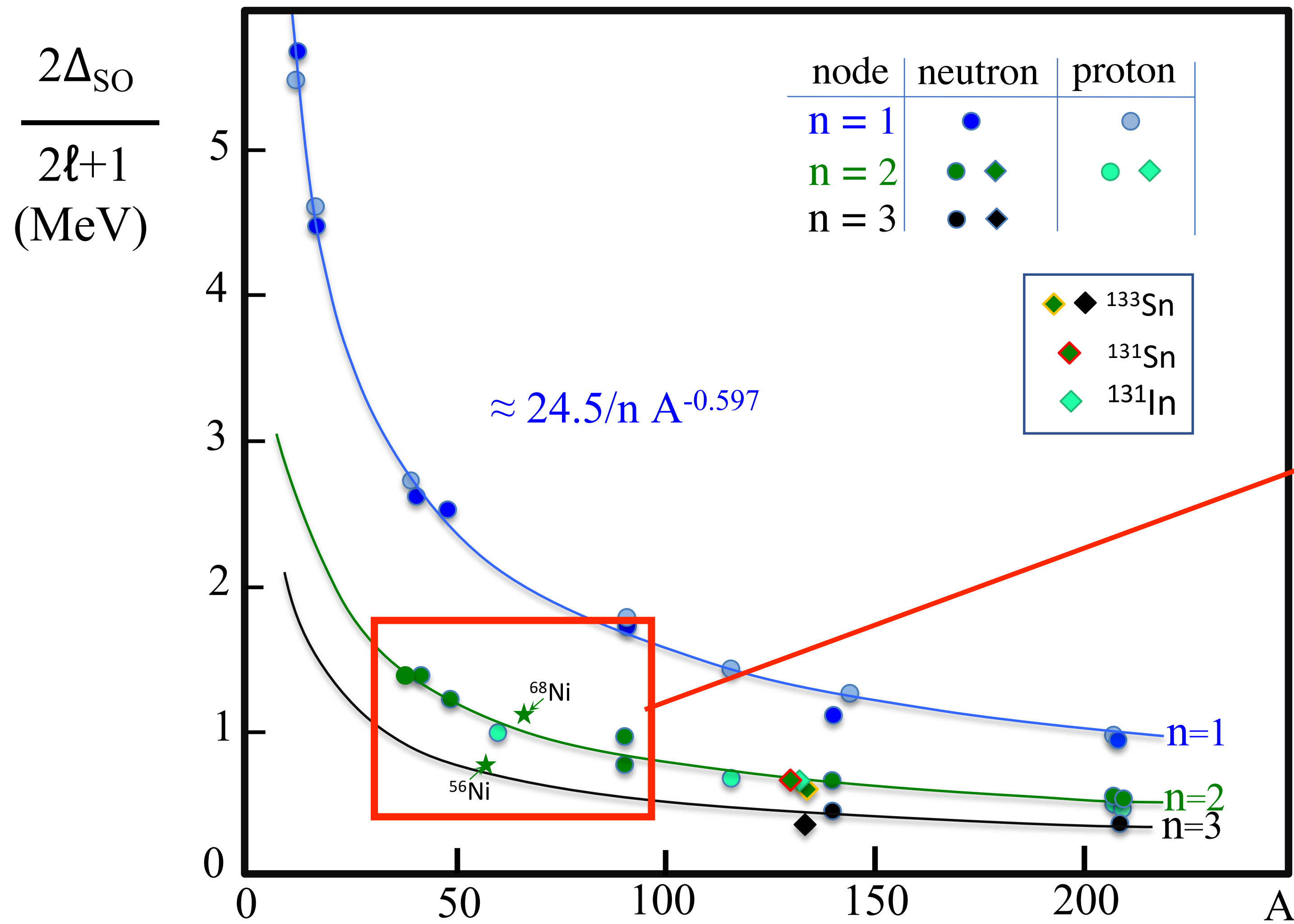
^{70}Zn(p,d) L. C. McIntyre, PR 152 1013

^{72}Ge(p,d) R. Fournier et al., NPA 202 1

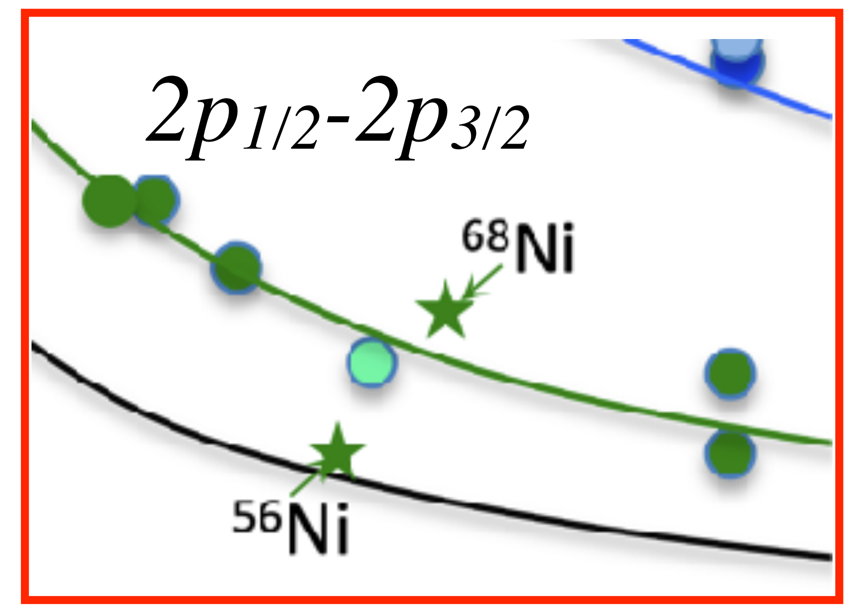
SO splitting



J. Diriken et al, PRC 91 054321



O. Sorlin et al, PLB 809 135740



Inverse trend of *2p* SO splitting from ^{56}Ni to ^{68}Ni?

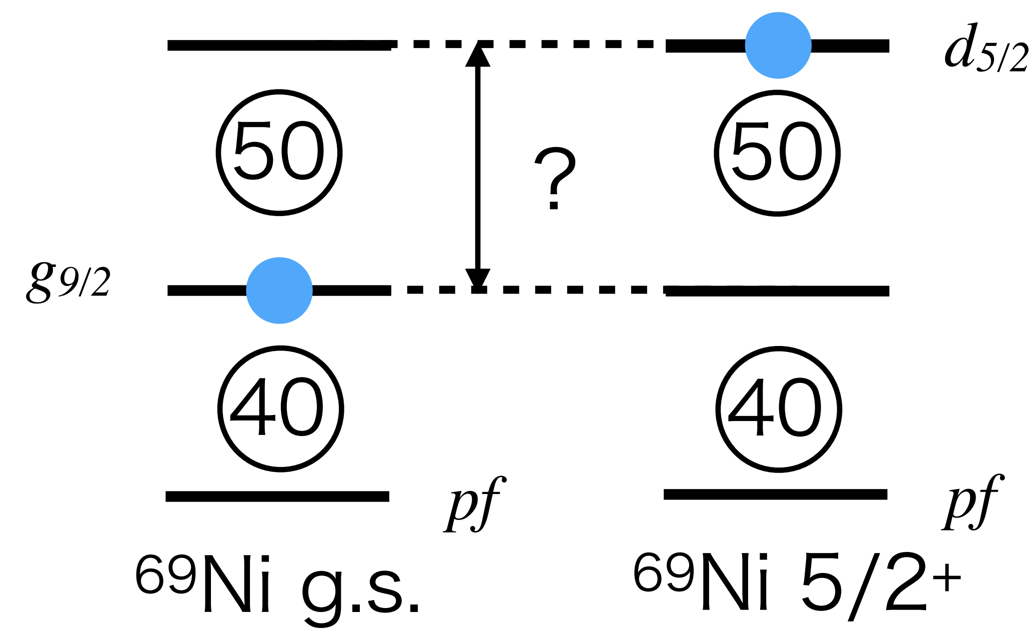
Spectroscopic info. of particle and hole states of *pfg*-shells

^{68}Ni(*d*,*p*)^{69}Ni ^{68}Ni(*p*,*d*)^{67}Ni

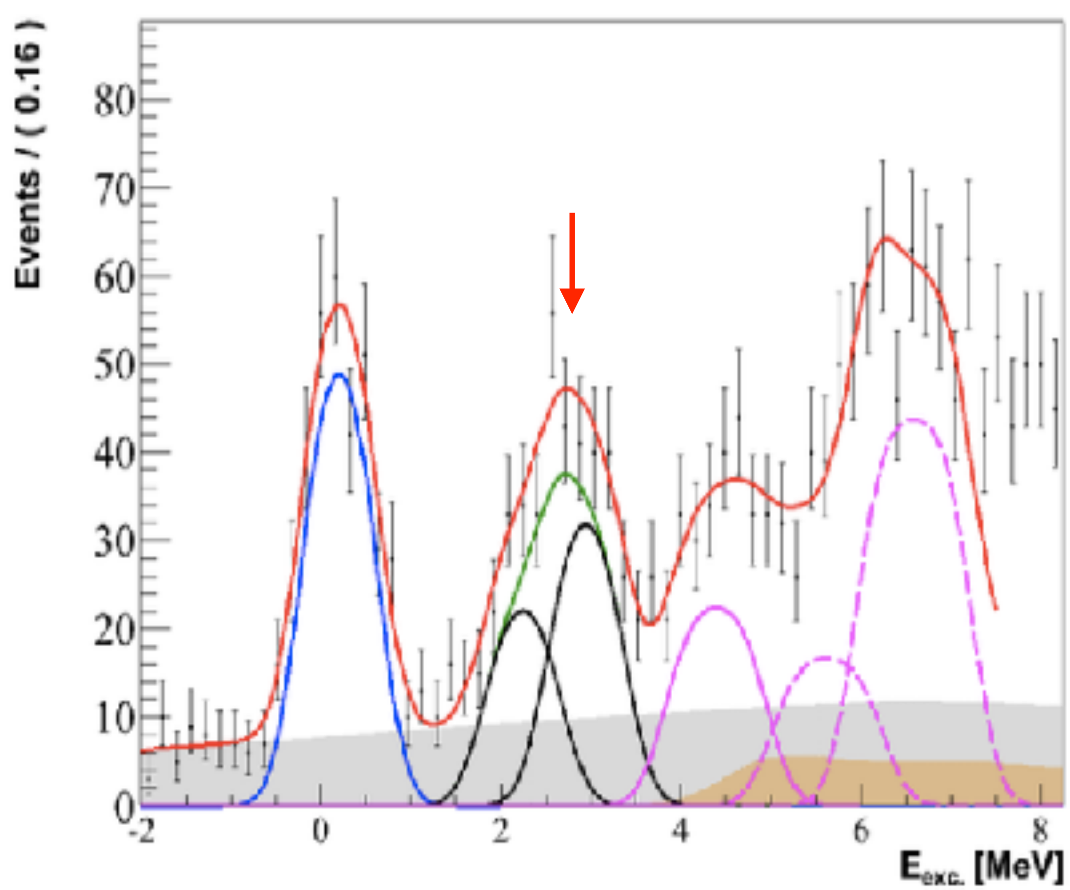
^{68}Ni(d,p)^{69}Ni

Shell gap of N=50 at N=40 nucleus ^{68}Ni

- Excitation energy of $d_{5/2}$ state(s) in ^{69}Ni
- C^2S^+ of $g_{9/2}$ and $d_{5/2}$ states



Previous experiment



M. Moukkaddam., Phd thesis

^{68}Ni beam of 24.8 MeV/u

2.6 mg/cm^2 CD_2 target

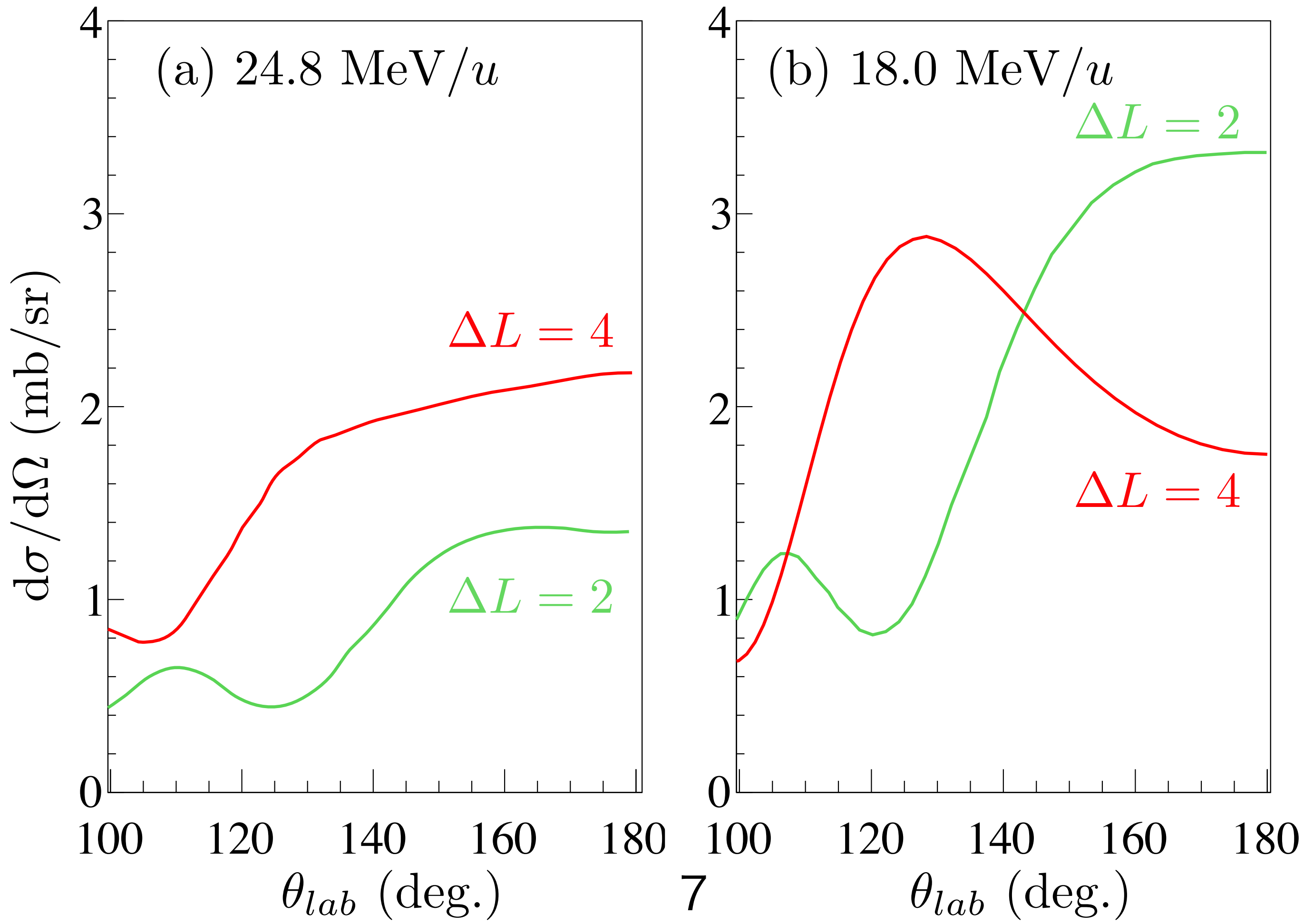
Candidate(s) of $d_{5/2}$ state(s) at 2.5 MeV, but J^π not concluded

-> Determine Ex of $d_{5/2}$ state(s)

Conclude J^π assignment from angular distribution

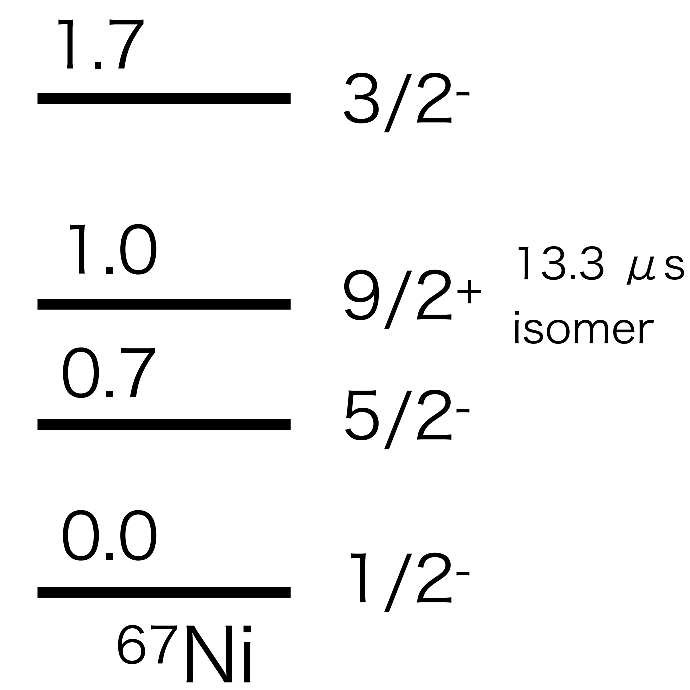
Up grade for ^{68}Ni(d,p)^{69}Ni

- Use lower energy ^{68}Ni beam of 18 MeV/u
  - Clear difference for ΔL=2 and ΔL=4
  - Larger cross section for ΔL=2
- Higher efficiency MUGAST setup
- ZDD system to obtain cleaner spectrum
- Gamma-ray coincidence
- Thin CD_2 target for better Ex resolution

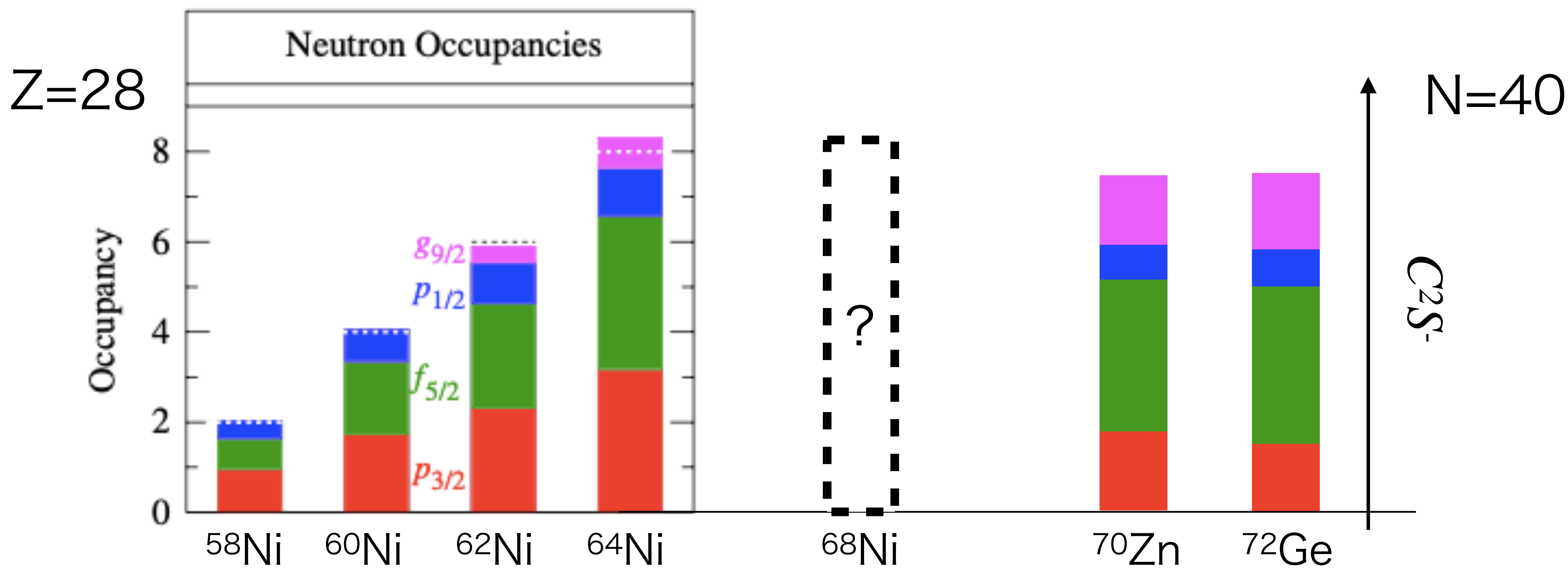


^{68}Ni(p,d)^{67}Ni

- ^{68}Ni : magicity of N=40
- $g_{9/2}$ already appears from ^{62}Ni
- Also in N=40 isotopes ^{70}Zn and ^{72}Ge



J. Diriken et al, PRC 91 054321



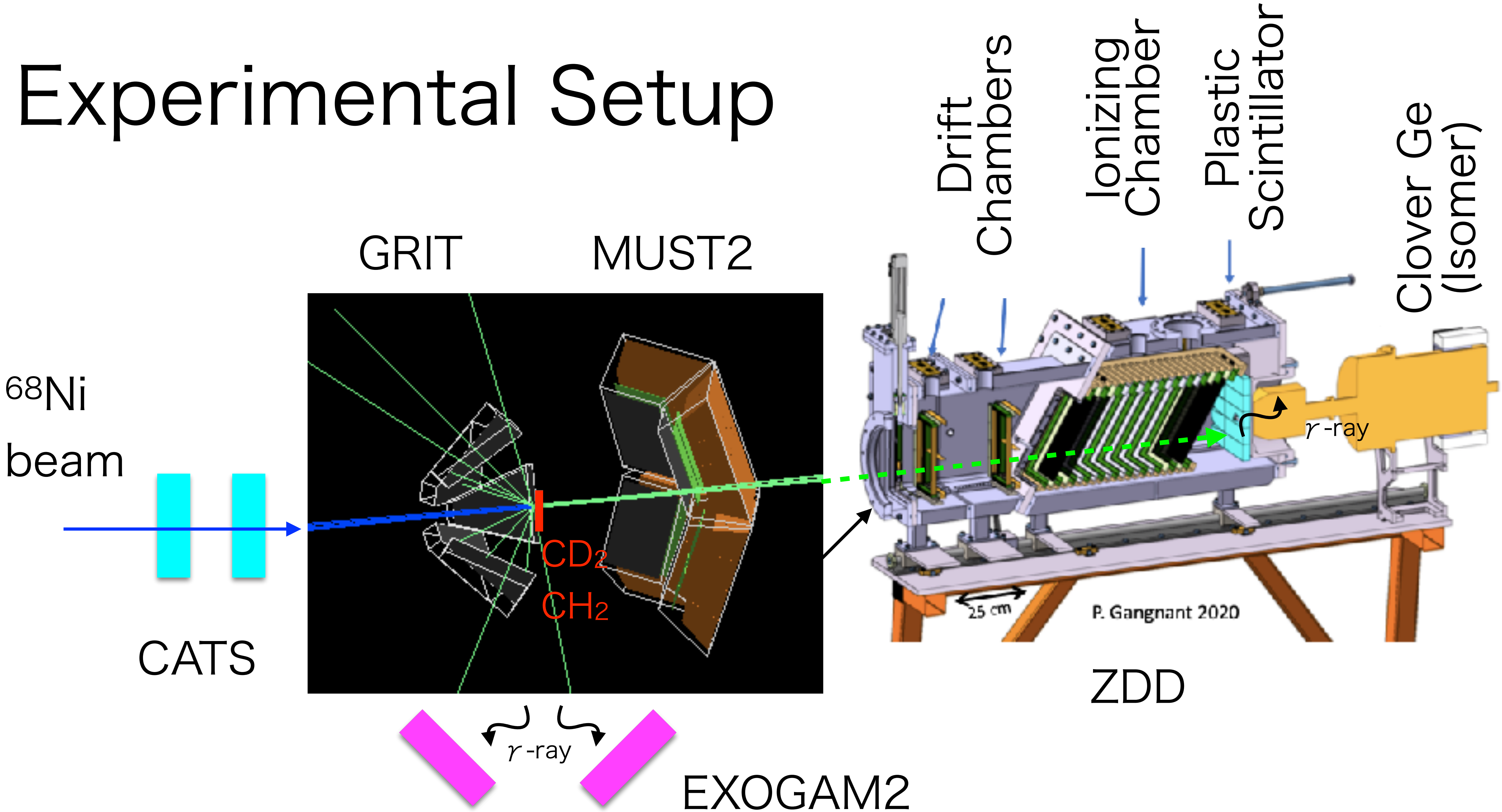
J. P. Schiffer et al., PRL 108 22501

8 8

^{70}Zn(p,d) L. C. McIntyre, PR 152 1013

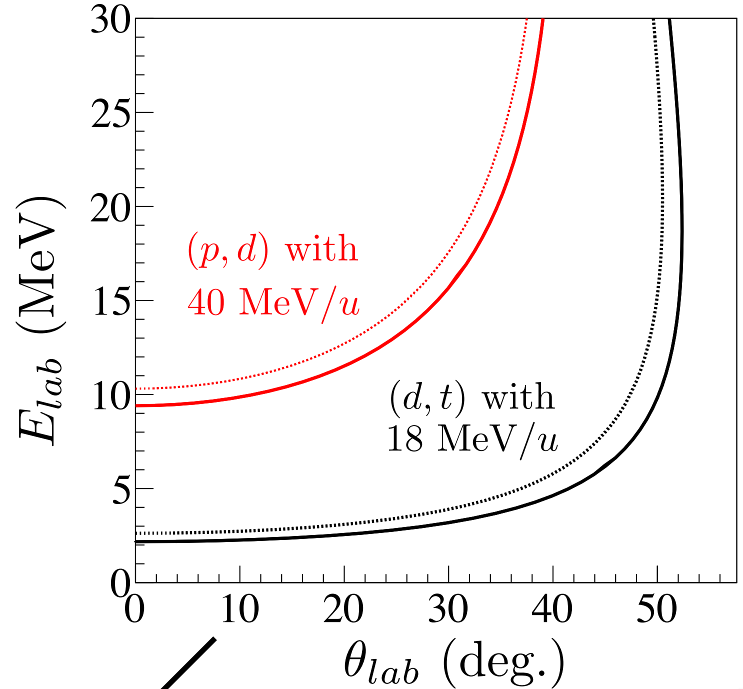
^{72}Ge(p,d) R. Fournier et al., NPA 202 1

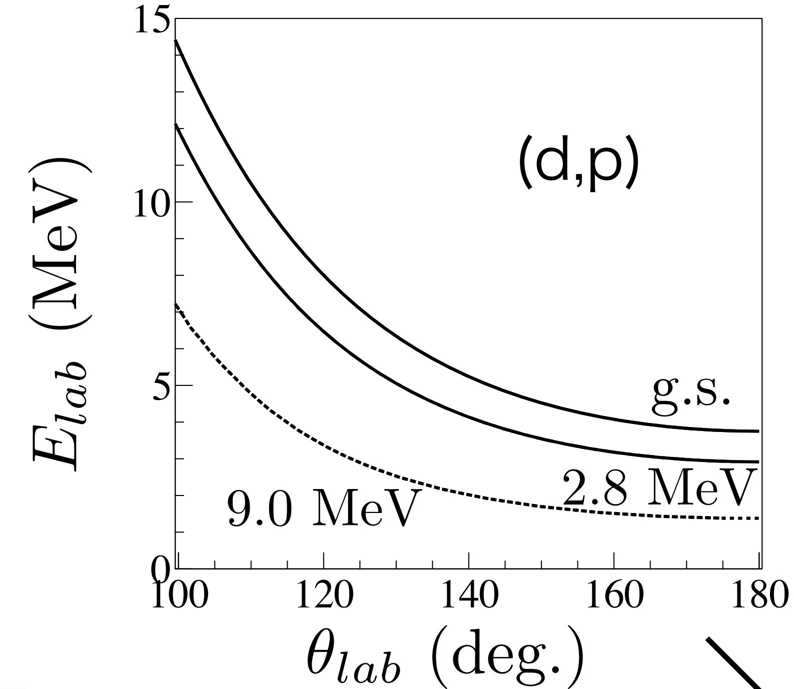
Experimental Setup

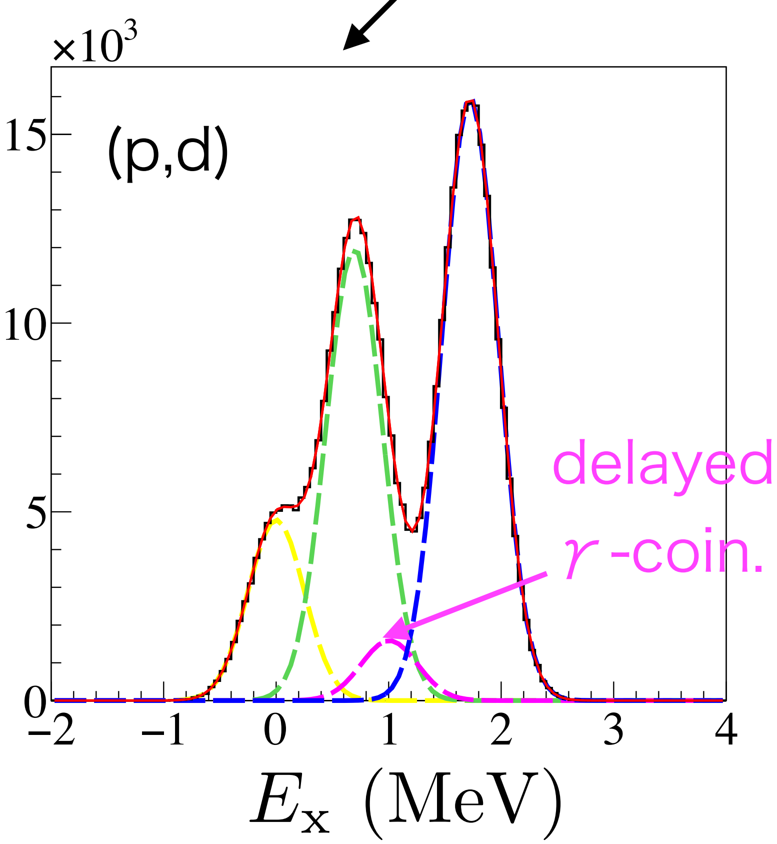


- ^{68}Ni secondary beam from LISE spectrometer and CD_2/CH_2 target
- Beam profile by 2 CATS detectors
- Recoil particle kinematics by GRIT and MUST2
- Prompt γ-ray energy by EXOGAM2
- Ejectile profile by ZDD (DS + IC + Plastic + Ge)

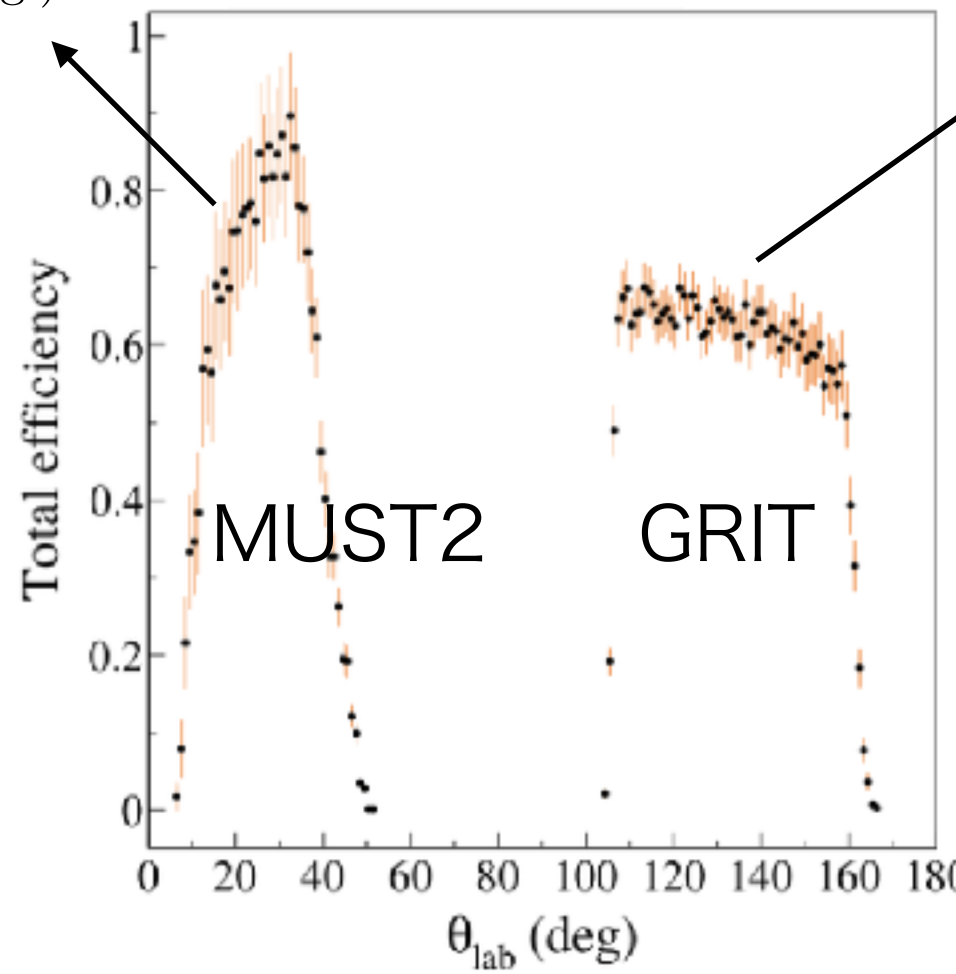
Recoil particle detection

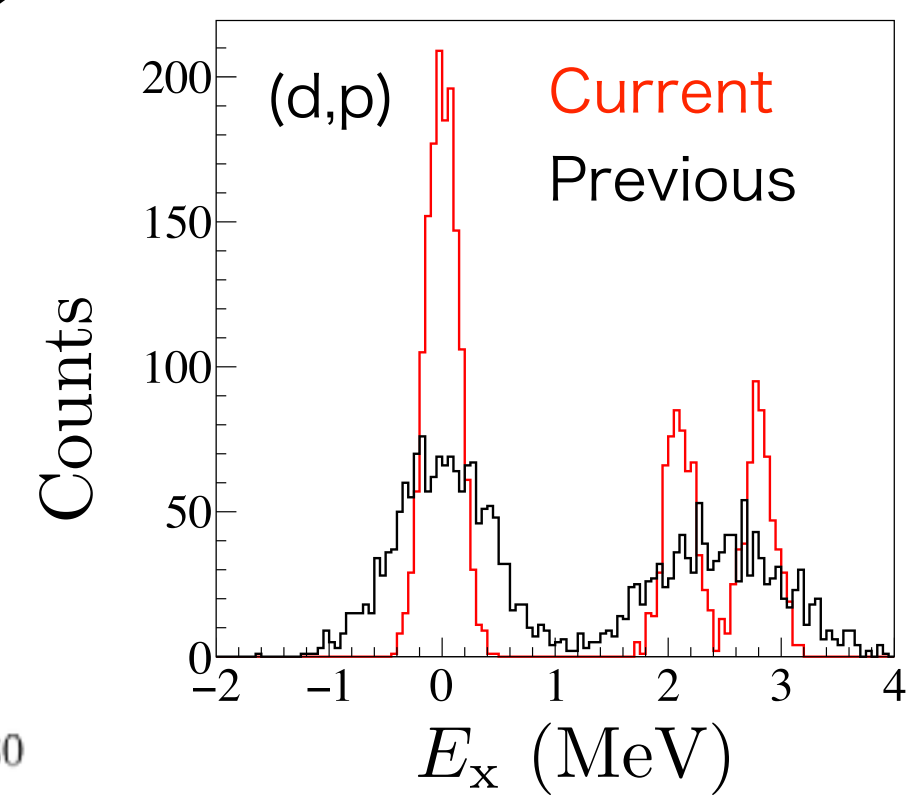






σ (Ex) = 0.25 MeV





σ (Ex) = 0.14 MeV

Yield estimation and BT request

Set1 18 MeV/u ^{68}Ni & 0.5 mg/cm^2 CD_2 for (d,p)

Set2 40 MeV/u ^{68}Ni & 5 mg/cm^2 CH_2 for (p,d)

- 15 UTs for ^{68}Ni(d,p)^{69}Ni (set1)
  -> ~ 1000 counts for g.s. and $d_{5/2}$ state(s)
- 8 UTs for ^{68}Ni(p,d)^{67}Ni (set2)
  -> ~ 500 counts for $g_{9/2}$ isomeric state
- 1 UT for 5^- isomeric state in ^{68}Ni beam
- 5 (3+2) UTs for tuning (from TAC report)

Beam time request

In total, 24 (physics) + 5 (tuning) = 29 UTs

Collaborators

S. Koyama*, D.Mengoni**, O. Sorlin**, M. Assié, M. Balogh,
D. Beaumel, Y. Blumenfeld, S. Bottoni, D. Brugnara, L. Caceres,
E. Clement, G. De Angelis, G. De France, N. De Séréville, C. Diget,
B. Fernandez Dominguez, F. Galtarossa, A. Goasduff, A. Gottardo,
J. Ha, F. Hammache, D. S. Harrouz, O. Kamalou, A. Lemasson,
A. Laird, S. Lenzi, S. Leoni, M. Moukaddam, D. R. Napoli, M. Niikura,
J. Pellumaj, R. M. Pérez Vidal, K. Rezynkina, T. Roger, M. Sedlak,
I. Stefan, C. Stodel, D. Suzuki, J. C. Thomas, J. J. Valiente Dobon,
L. Zago, I. Zanon, G. Zhang

Summary

- We propose to the experiment of ^{68}Ni by neutron adding and removal reactions to investigate the N=50 gap at N=40, neutron magicity of N=40 and SO splitting of pfg-shells in ^{68}Ni.
- We will re-measure the ^{68}Ni(p,d)^{69}Ni reaction for spectroscopy of the neutron particle states with upgraded setup, slow-downed beam, new detectors and thin target.
- We also will measure the ^{68}Ni(p,d)^{67}Ni reaction for the neutron hole state as a complimentary study.
- MUGAST@LISE setup planned in 2023 will be used.
- 24 UTs are requested for the physics measurement and 5 UTs for the tuning, in total 29 UTs.