Evaluation test cases proposed for discussion during the NSDD Meeting

A. Negret

Case 1 - Proton decay from 58Cu to 57Ni

The previous evaluation of 57Ni contains the following datasets:

^{57}Ni Levels

T: from (^{3}He,α) and (p,d), (pol p,d).
See ^{58}Ni(p,d),(d,t),(^{3}He,α) for (pol p,d) and (pol d,t) results.

Cross Reference (XREF) Flags

A	^{57}Cu β^{+} decay	E	^{58}Ni(p,d) E=121 MeV	I	^{58}Ni(γ,n), (e,e′n) res
B	^{58}Ni(pol p,d), (pol d,t),	F	^{58}Ni(^{3}He,α) E=130-217 MeV	J	^{58}Ni(γ,nγ′)
C	^{59}Ni(p,t) E=40 MeV	G	^{58}Ni(^{3}He,$\alpha\gamma$), (pol p,dγ)	K	^{2}H(^{56}Ni,p)
D	^{54}Fe(α,n), (α,nγ), (^{6}Li,t)	H	^{40}Ca(^{20}Ne,2pnγ)		

While scanning for new papers I encountered two papers discussing the proton decay from an excited state in 58Cu: 2002Ru09 and 1998Ru01 (figure from 2002Ru09):

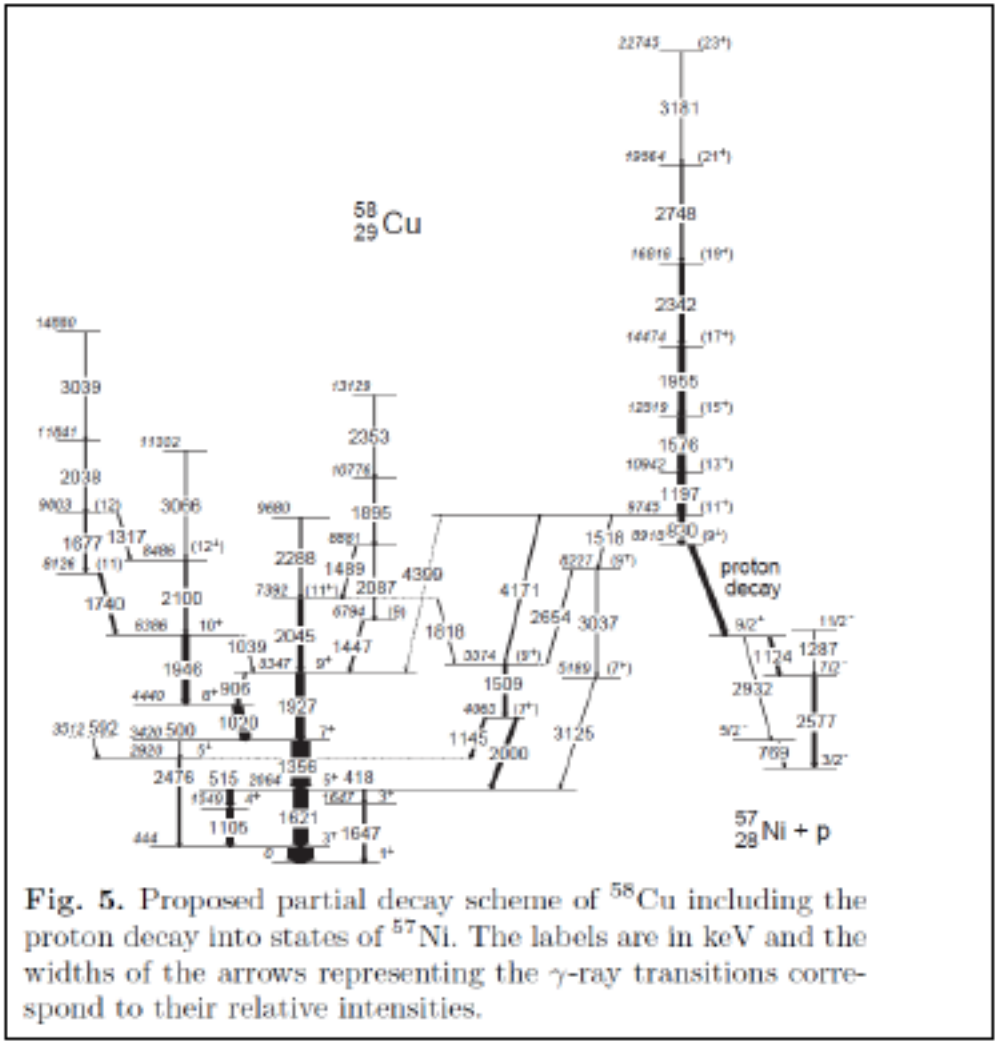

Fig. 5. Proposed partial decay scheme of ^{58}Cu including the proton decay into states of ^{57}Ni. The labels are in keV and the widths of the arrows representing the γ-ray transitions correspond to their relative intensities.

So I created a new dataset for this decay mode:

^{58}Cu p decay 2002Ru09,1998Ru01

Parent: ^{58}Cu: E=8916.9 *11*; $J^{\pi}=(9^+)$; $T_{1/2}=0.22$ ps *7*; Q(p)=6044.0 *13*; %p decay>93

^{58}Cu-Q(p): calculated from 2012Wa38 and the Adopted Levels, Gammas for ^{58}Cu.

^{58}Cu-$T_{1/2}$: from the Adopted Levels, Gammas for ^{58}Cu.

2002Ru09: ^{58}Cu populated through the ^{28}Si(^{36}Ar,αpn) reaction at 148 MeV. Target enrichment 99.1%. Measured γ-γ, and γ-γ-particle coincidences using the Gammasphere array consisting of 86 Compton-suppressed Ge detectors, 20 liquid-scintillator neutron detectors, the Microball array consisting of CsI detector elements and 4 ΔE-E silicon telescopes. Prompt proton decay occurs from the (9^+), 8916.9-keV state in ^{58}Cu that represents the bandhead of a rotational band formed in the well-deformed second minimum of the nuclear potential to the $9/2^+$, 3701-keV excited states in the spherical daughter nucleus ^{57}Ni.

1998Ru01: ^{58}Cu populated through the ^{28}Si(^{36}Ar,αpn) reaction at 136 MeV. Measured γ-γ, γ-γ-γ and γ-γ-particle coinc. using the Gammasphere array, the 4π CsI ball Microball and 15 liquid scintillator neutron detectors.

^{57}Ni Levels

E(level)†	Jπ‡	Comments
0	$3/2^-$	
769.0 9	$5/2^-$	
2577.1 9	$7/2^-$	
3701.1 *10*	$9/2^+$	Prompt proton decay occurs 100% towards this level with the emission of 2302(4)-keV protons. This value is calculated from 2012Wa38 and the Adopted Levels, Gammas for ^{58}Cu and ^{57}Ni. Prompt proton energy was measured as 2290 *20* keV with a resolution of 280 keV (2002Ru09).

† from 2002Ru09.

‡ from Adopted Levels, Gammas unless noted otherwise.

γ(^{57}Ni)

E_γ	E_i(level)	J_i^π	E_f	J_f^π
769	769.0	$5/2^-$	0	$3/2^-$
1124	3701.1	$9/2^+$	2577.1	$7/2^-$
2577	2577.1	$7/2^-$	0	$3/2^-$
2932	3701.1	$9/2^+$	769.0	$5/2^-$

But then I discovered another paper referring to proton decay from Gamow Teller states in 58Cu: 2003Ha43

Physics of Atomic Nuclei, Vol. 67, No. 9, 2004, pp. 1742–1749. From Yadernaya Fizika, Vol. 67, No. 9, 2004, pp. 1769–1776.

Structure of the Gamow–Teller Resonance in ^{58}Cu Studied via the Proton- and γ-Decay Measurements*

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Abstract—The Gamow–Teller (GT) states in ^{58}Cu have been studied by ^{58}Ni(^{3}He, $t+p$) and ^{58}Ni(^{3}He, $t+\gamma$) coincidence experiments at $E(^3\mathrm{He}) = 450$ MeV and $\theta = 0°$. Proton emissions from the GT states in ^{58}Cu to the hole states in ^{57}Ni have been observed with solid-state detectors in coincidence with high-energy tritons measured with a magnetic spectrometer. For the first time, γ-ray emissions from the excited states in ^{58}Cu and in ^{57}Ni, following the ^{58}Ni(^{3}He, $t+p$) reaction at intermediate energies, have also been observed in coincidence with tritons. The wave functions of the $T = 1$ and $T = 2$ GT states with the $f_{7/2}^{-1}$ neutron–hole configuration are inferred to be strongly coupled to $2p$–$2h$ configurations, making fragmented GT strengths in ^{58}Cu.

The issue:

So “Proton decay of 58Cu” occurs also from the GT states (2003Ha43). The issue discussed in 2003Ha43 is interesting: they use a ^{3}He beam and they detect tritons with the Grand Raiden spectrometer at RCNP. They also detect protons and gammas in coincidence with protons so they can discuss the decay of the Gamow Teller states in 58Cu via proton and gamma decay.

But then what is the difference between “proton decay” (as discussed in 2003Ha43) and a normal reaction with an additional proton in the exit channel?

My opinion/solution:

My interpretation was, despite the discussion from 2003Ha43, that this second case is not “Proton decay” but simply a 58Ni(3He, tp)57Ni reaction. So I added an additional dataset that has no discussion about “Proton decay”:

^{58}Ni(^{3}He,tpg) 2004Fu25,2003Ha43

The ^{3}He beam was accelerated to E=450 MeV using the Ring Cyclotron of RCNP, Osaka in achromatic mode. Measured tp and tγ coincidences using the Grand Raiden magnetic spectrometer for tritons (FWHM=250 keV), silicon detectors for protons and Ge detectors for γ. Deduced the structure of the GT resonance in ^{58}Cu. Statistical model calculations using the Hauser-Feshbach formalism with the CASCADE code.

^{57}Ni Levels

E(level)	J^{π}	Comments
0	$(3/2^{-})$	
769	$(5/2^{-})$	
1112	$(1/2^{-})$	
2443	$(5/2^{-})$	
2578	$(7/2^{-})$	T=1/2

$\gamma(^{57}$Ni)

E_{γ}	E_i(level)	J_i^{π}	E_f	J_f^{π}
769	769	$(5/2^{-})$	0	$(3/2^{-})$
1112	1112	$(1/2^{-})$	0	$(3/2^{-})$
2443	2443	$(5/2^{-})$	0	$(3/2^{-})$
2578	2578	$(7/2^{-})$	0	$(3/2^{-})$

Case 2 – <u>Including references that have minimal information</u>

I got the following note from the reviewer of 57Mn:

Should 2008LuZZ be included?

Adopted Levels, Gammas

was

$Q(\beta^-)$=2695.6 *15*; S(n)=8646.0 *15*; S(p)=9490.2 *16*; $Q(\alpha)$=−8060 *3* 2017Wa10
S(2n)=15916.5 *15*, S(2p)=22920 *100* (2017Wa10).
Ref. ^{57}Mn activity identified by 1954Co26 in ^{57}Fe(n,p) reaction using high-energy neutrons, followed by measurements of half-life from γ and β emissions, and β-ray end-point energy. Later studies of ^{57}Mn decay: 1974Ti01, 1969Wa12.
Atomic mass measurements using Penning-trap system: 2012He13, 2012Na15, 2005Gu37, 2005Gu27.
Nuclear structure (theory): 2016Pe01: self-consistent tilted axis cranking, covariant density functional approach for bands.

^{57}Mn Levels

Cross Reference (XREF) Flags

A	^{57}Cr β^- decay (21.1 s)	E	^{55}Mn(t,p)
B	^{14}C(^{48}Ca,p4nγ)	F	^{57}Fe(n,pγ)
C	^{48}Ca(^{13}C,p3nγ),(^{15}N,α2nγ)	G	^{58}Fe(d,^{3}He)
D	^{54}Cr(α,p),(α,pγ)		

Here is 2008LuZZ. This is a conference proceeding, an overview of the PRISMA-CLARA experime
Legnaro:

Spectroscopy of Neutron-rich Nuclei of the A≈60 region populated through binary heavy-ion collisions

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Abstract.

Neutron-rich nuclei of the mass $A = 60$ region (from V to Fe) have been studied through multi-nucleon transfer reactions by bombarding a ^{238}U target with beams of ^{64}Ni and ^{70}Zn. Unambiguous identification of prompt γ rays belonging to each nucleus has been achieved by using the efficient gamma-array CLARA coupled to the large-acceptance magnetic spectrometer PRISMA installed at the Legnaro National Laboratories. With the new data, the existence of the N=32 sub-shell closure has been corroborated through the study of odd V isotopes, whereas a new region of deformation appears for neutron-rich Fe nuclei close to N=40. The results obtained for all these nuclei are compared with shell model calculations which reproduces quite well the experimental data also for the most neutron-rich nuclei when excitations from the *fp* shell into the upper $g_{9/2}$ orbital are allowed.

Keywords: γ-ray spectroscopy. Neutron-rich nuclei. Shell-model calculations.
PACS: 21.10.-k, 21.10.Re, 21.60.Cs, 23.20.Lv, 27.40.+e

The only reference to 57Mn in 2008LuZZ says that the first excited level is at 83 keV while discussing systematics and general Shell Model calculations. It is not clear if the value cams from their experiments or not:

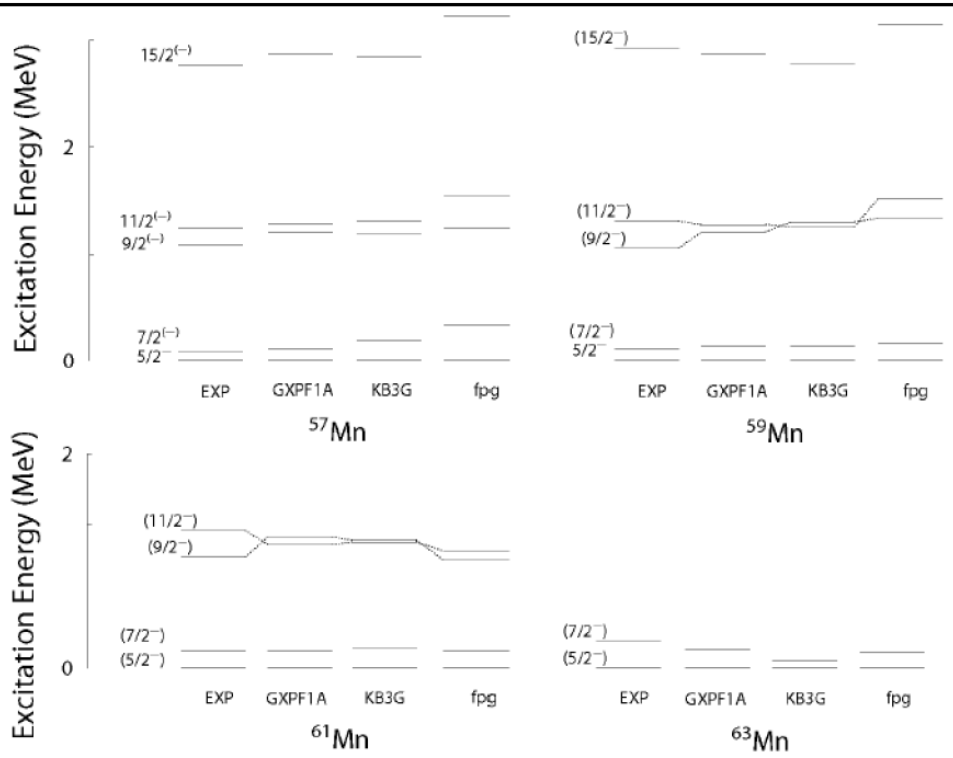

FIGURE 3. Comparison of the experimental level schemes of the ^{57,59,61,63}Mn nuclei with the results of large-scale shell model calculations using various effective interactions.

Manganese isotopes

The level schemes of the odd-even Mn isotopes here proposed (see Fig. 3) are based on the systematics of the lighter isotopes above $N = 28$ (^{55,57}Mn). The deduced trend of the level schemes is therefore similar: a low-lying $5/2^- - 7/2^-$ doublet (whose separation increases from 83 keV in ^{57}Mn to 248 KeV in ^{63}Mn), a $9/2^- - 11/2^-$ doublet one MeV higher and (in the case of ^{59}Mn) the $15/2^-$ state 1.6 MeV above the $11/2^-$ level.

For the odd-even Mn isotopes, we have performed shell-model calculations in the full *fp* shell using the code ANTOINE. Here, two different effective interactions (GXPF1A [13], KB3G [14]), have been used to calculate the energy levels of the Mn

The issue:

Should 2008LuZZ be included? To which extent should we include references that have only a very tiny connection to the structure certain nucleus and do not bring new information.

My opinion/solution:

2008LuZZ does not bring any new information regarding the structure of 57Mn. I did not include it in the evaluation of 57Mn.

I should note, however, that I used 2008LuZZ in the evaluation of the neighboring nucleus 57V. In that case it is clear that the level energies were measured at Legnaro:

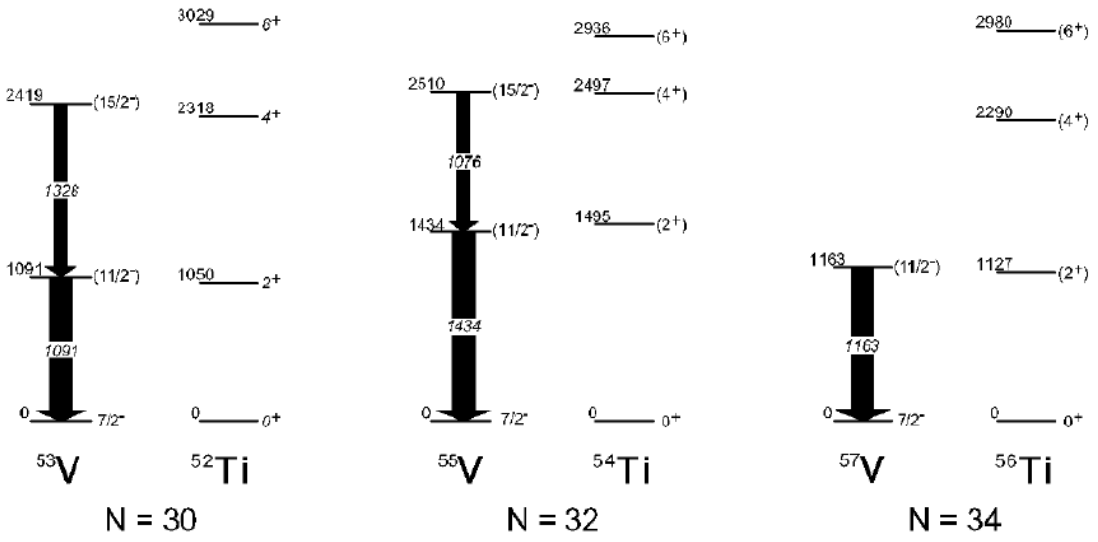

FIGURE 2. Level schemes of ^{53}V, ^{55}V and ^{57}V from the data of the present experiment, compared with the corresponding states of the titanium nuclei taken from Refs. [10, 11].