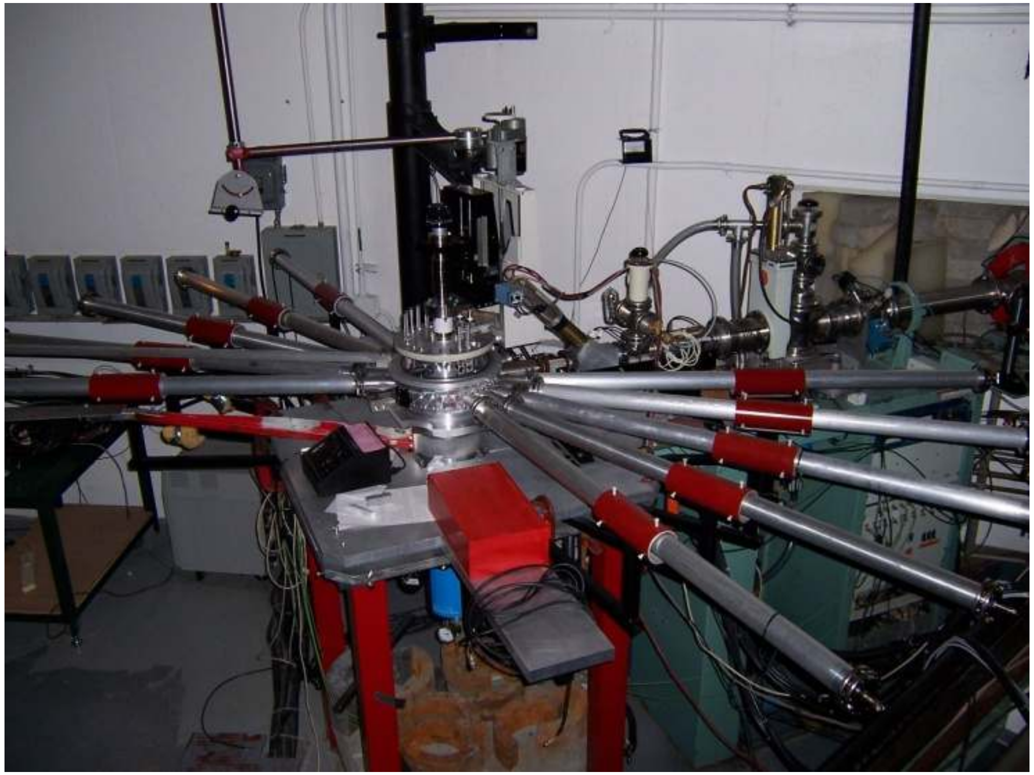
Level density of $^{59-64}$Ni isotopes from lithium induced reactions



Edwards Accelerator Laboratory, Ohio University

Total level density versus density of neutron resonances

Total level density
is needed for reaction cross section calculations and it is not well known experimentally

Neutron resonance density
is well known experimentally but in a very limited spin interval and for one parity

Can we do it well ?

Problems

- Neutron resonances are known in a very limited spin interval (1/2 for even-even targets, and typically 2-3 or 3-4 for others), and for one parity only.
- Number of neutron resonances consist of only 5-10 % of the total level density at Bn.

Assumptions:

1. Spin cutoff parameter :
2. Parity distribution

} are not well studied experimentally !!!

Conversion procedure is model dependent !!!

Modern computer codes (Empire, Talys, Gnash …)
use level densities systematics based neutron resonance spacings

1. Fermi-gas backshifted model
2. Gilbert Cameron model
3. Generalized superfluid model (Ignatuik)
4. "Empire-specific" level density used for ENDF evaluations

The list is not complete

The problem : these systematics do not work for predictions, they just provide many options available to describe existing experimental data. Some of them will definitely succeed for one experimental data, some for the others. The is no a single model which succeeds in describing all data.

Solution

1. If we want to describe nuclear reactions we should get level density information directly from nuclear reactions but not from neutron resonances with its uncertain way of conversion.

2. Level density systematics would need to be established on the basis of experimental data from nuclear reactions.

The level density from particle spectra of compound nuclear reactions

The concept:

$$d\sigma(E) \sim \sigma_C(E) \frac{T_{in}(E')\rho_f(E^*)}{\sum_i T_{out\,i}} dE$$

The problem :

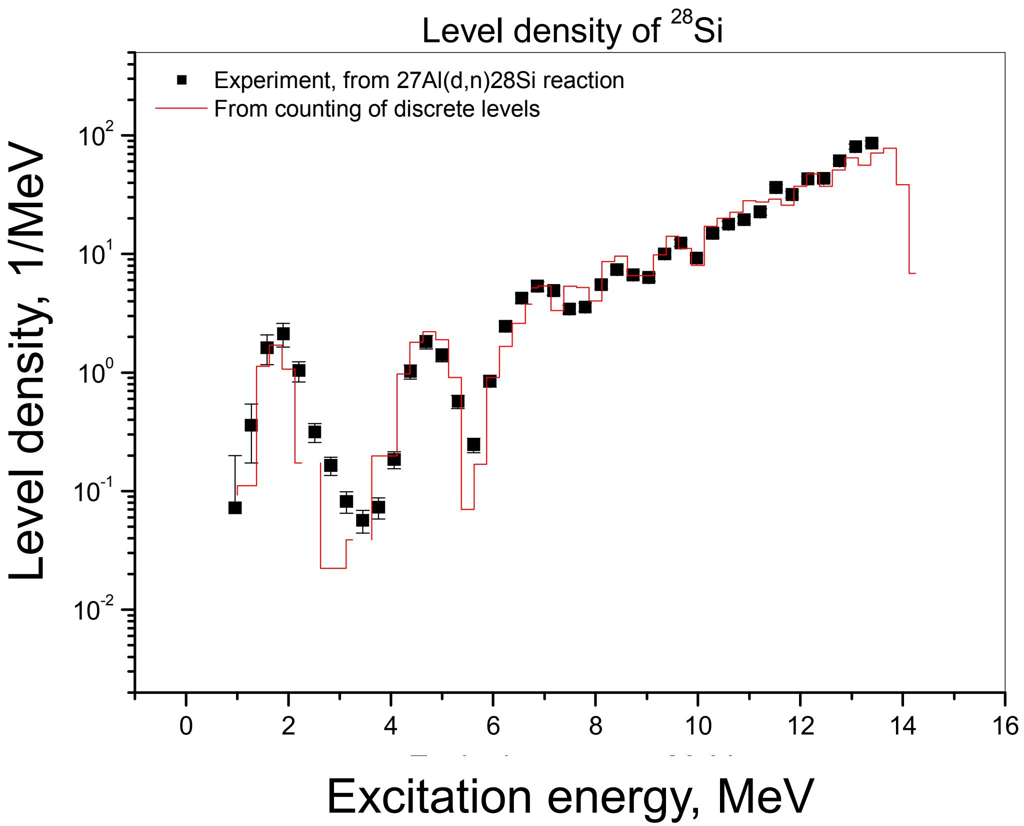
Make sure that the compound reaction mechanism dominates.

Possible solutions:

1. Select appropriate reactions (beam species, energies, targets).
2. Measure the outgoing particles at backward angles
3. Compare reactions with different targets and incoming species leading to the same final nuclei

Experimental level densities measured at Edwards Lab. of Ohio University

Testing the technique with $^{27}Al(d,n)^{28}Si$



We used lithium induced reactions to get level density for the nickel isotopes:

$^{54}Fe(^{6}Li,p)^{59}Ni$

E_{Li}=15 MeV

$^{54}Fe(^{7}Li,p)^{60}Ni$

$^{56}Fe(^{6}Li,p)^{61}Ni$

$^{56}Fe(^{7}Li,p)^{62}Ni$

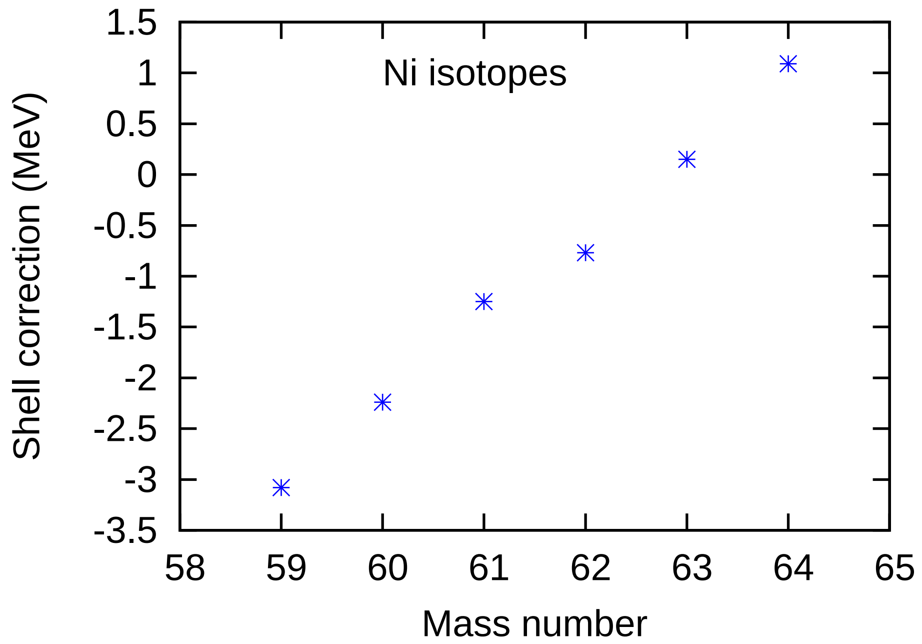
$^{58}Fe(^{6}Li,p)^{63}Ni$

$^{58}Fe(^{7}Li,p)^{64}Ni$

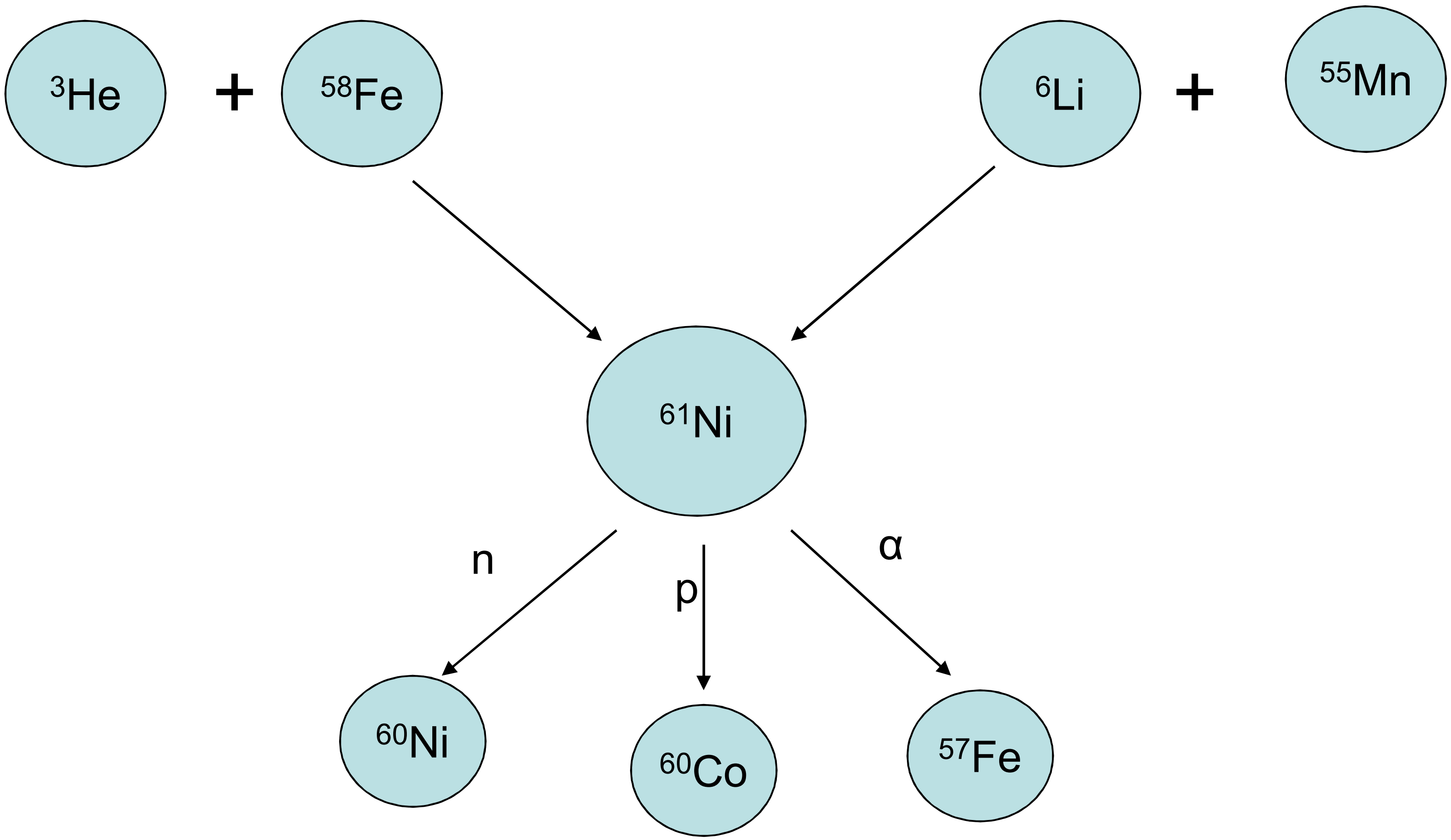
Shell correction

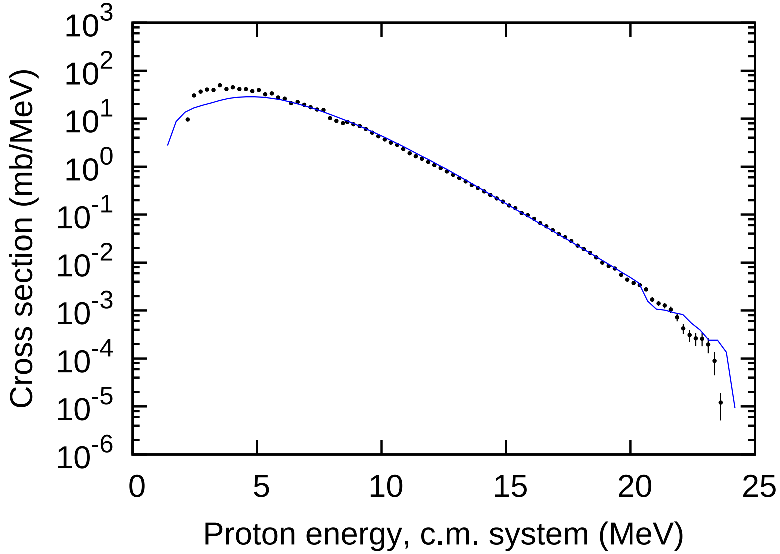
$$a = \tilde{a}(A)\left\{1 + \frac{\delta W(Z,A)}{U}[1 - \exp(-\gamma U)]\right\}$$

$$\delta W(Z,A) = M_{\exp}(Z,A) - M_{\mathrm{LDM}}(Z,A,\beta)$$

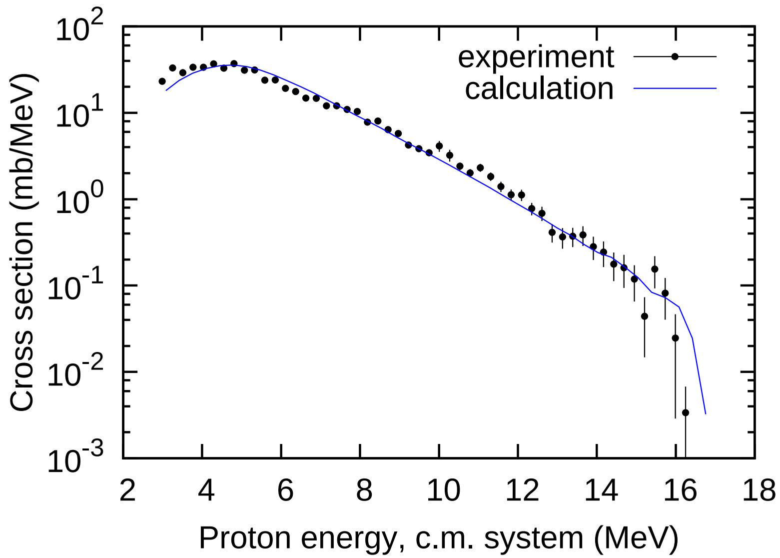


Reactions with ^{6}Li and ^{3}He



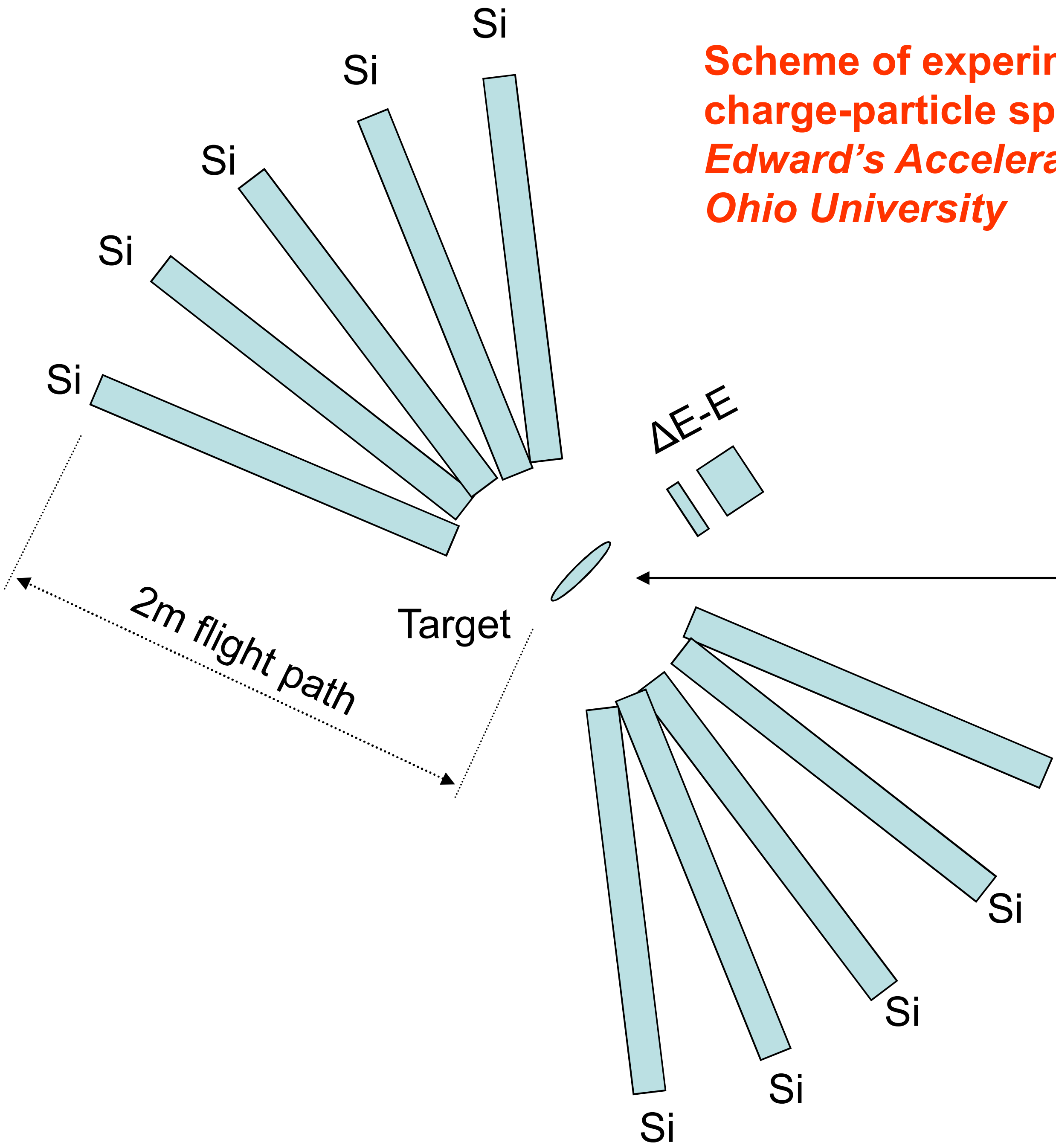


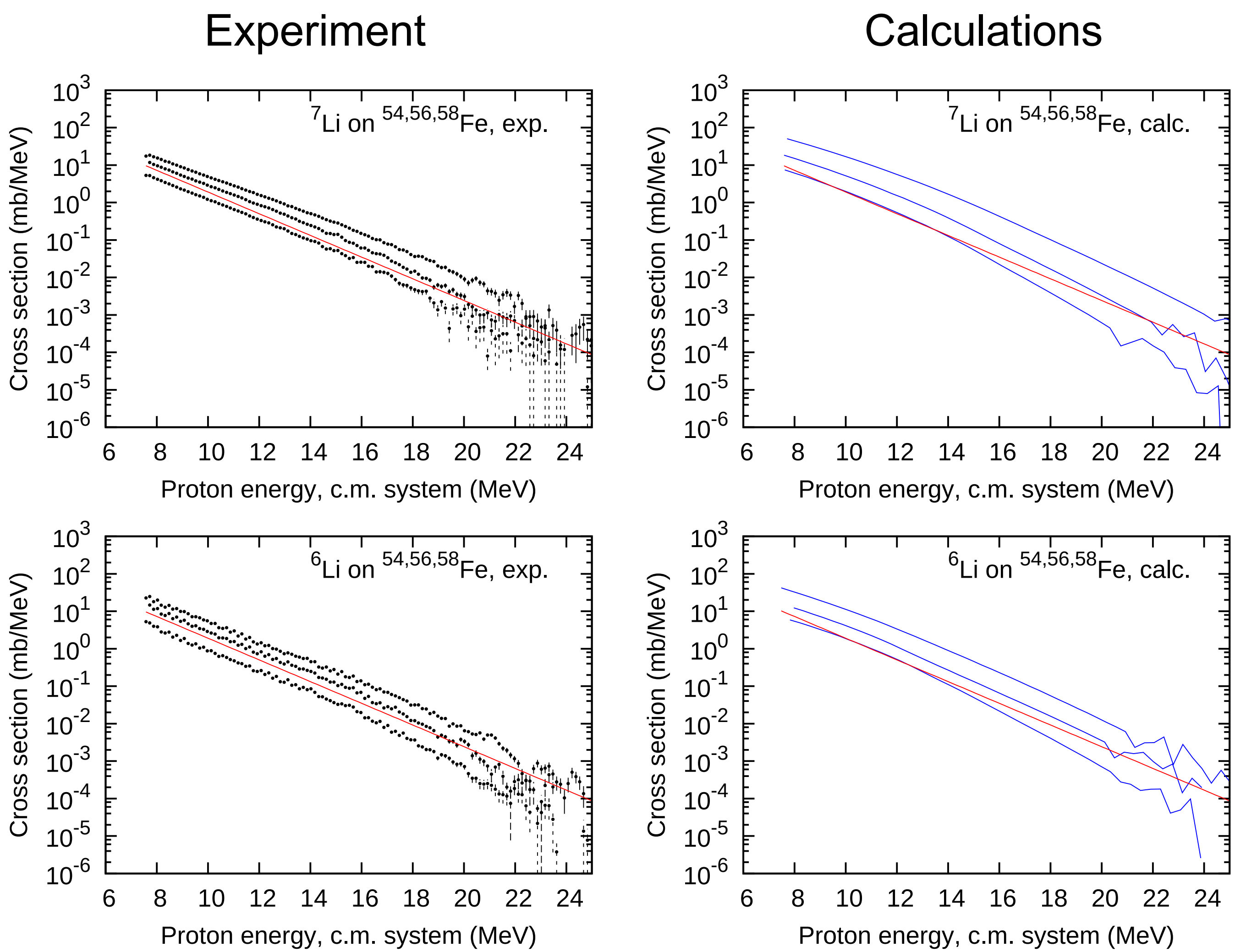
$^{6}Li + ^{55}Mn$, E_{6Li}=15 MeV



$^{3}He + ^{58}Fe$, E_{3He}=10 MeV

Scheme of experimental set-up for charge-particle spectra measurements
Edward's Accelerator Lab,
Ohio University

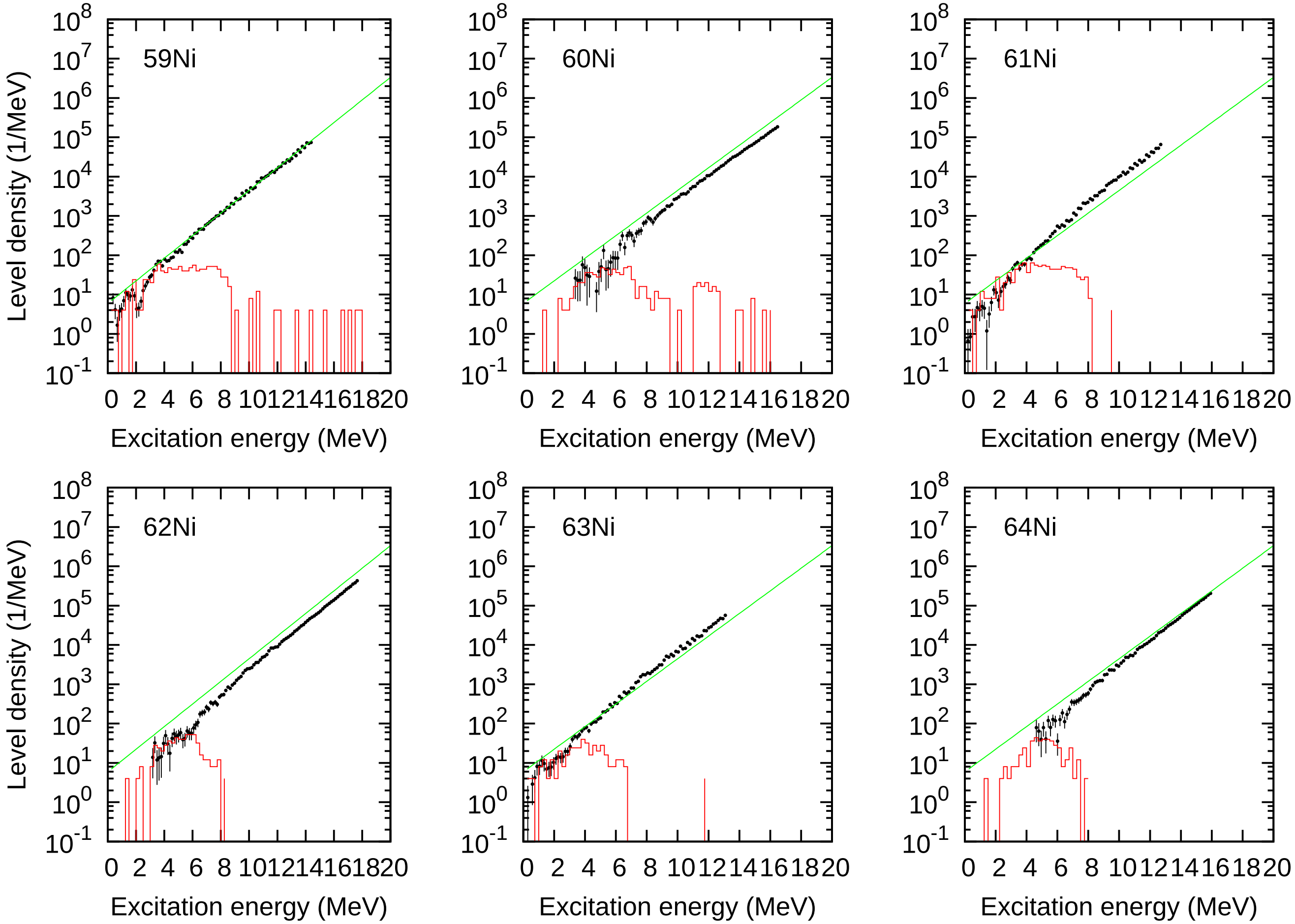




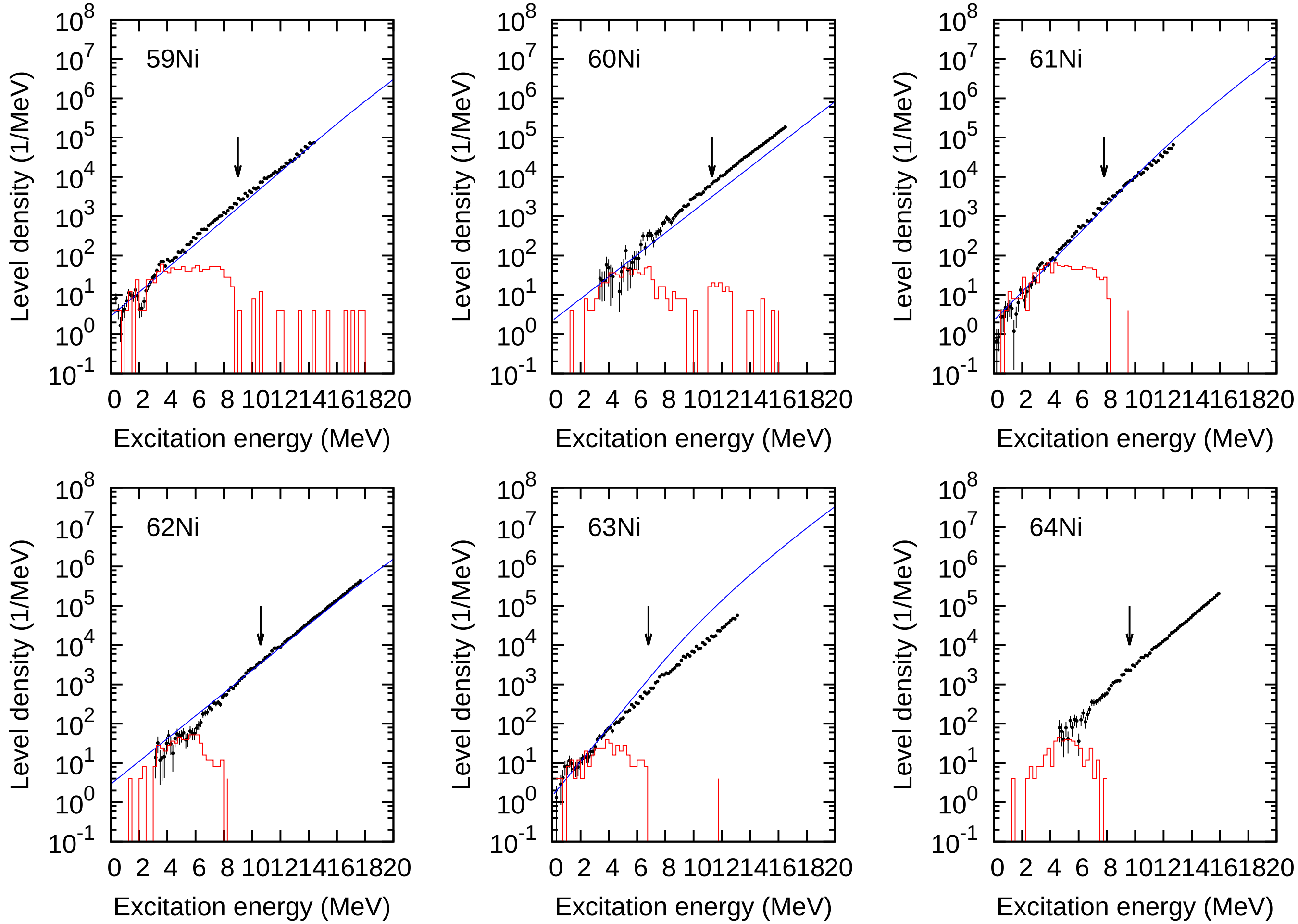
Experiment
Calculations
7Li on 54,56,58Fe, exp.
7Li on 54,56,58Fe, calc.
6Li on 54,56,58Fe, exp.
6Li on 54,56,58Fe, calc.
Cross section (mb/MeV)
Proton energy, c.m. system (MeV)

Experimental level densities

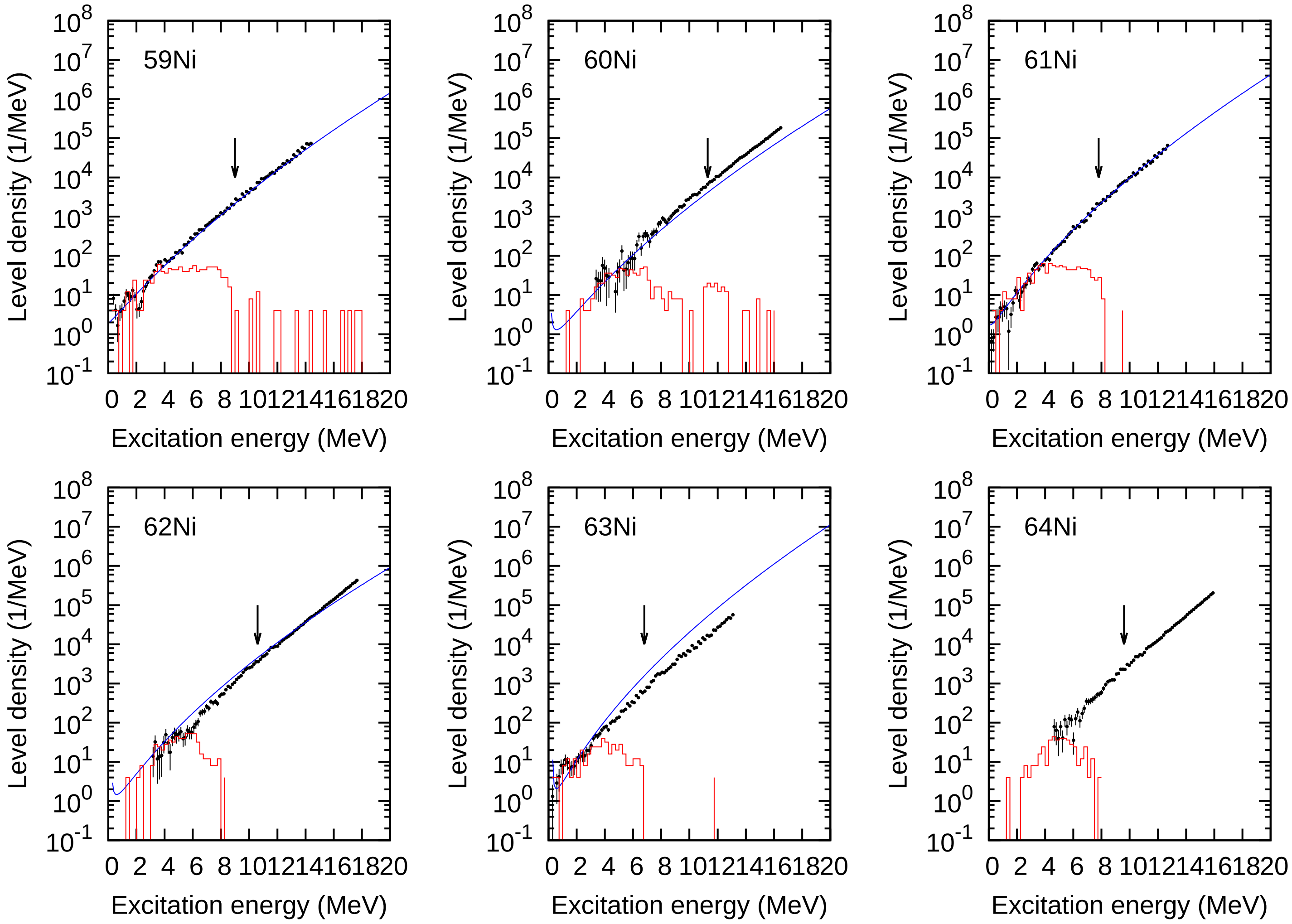
green line is a reference line



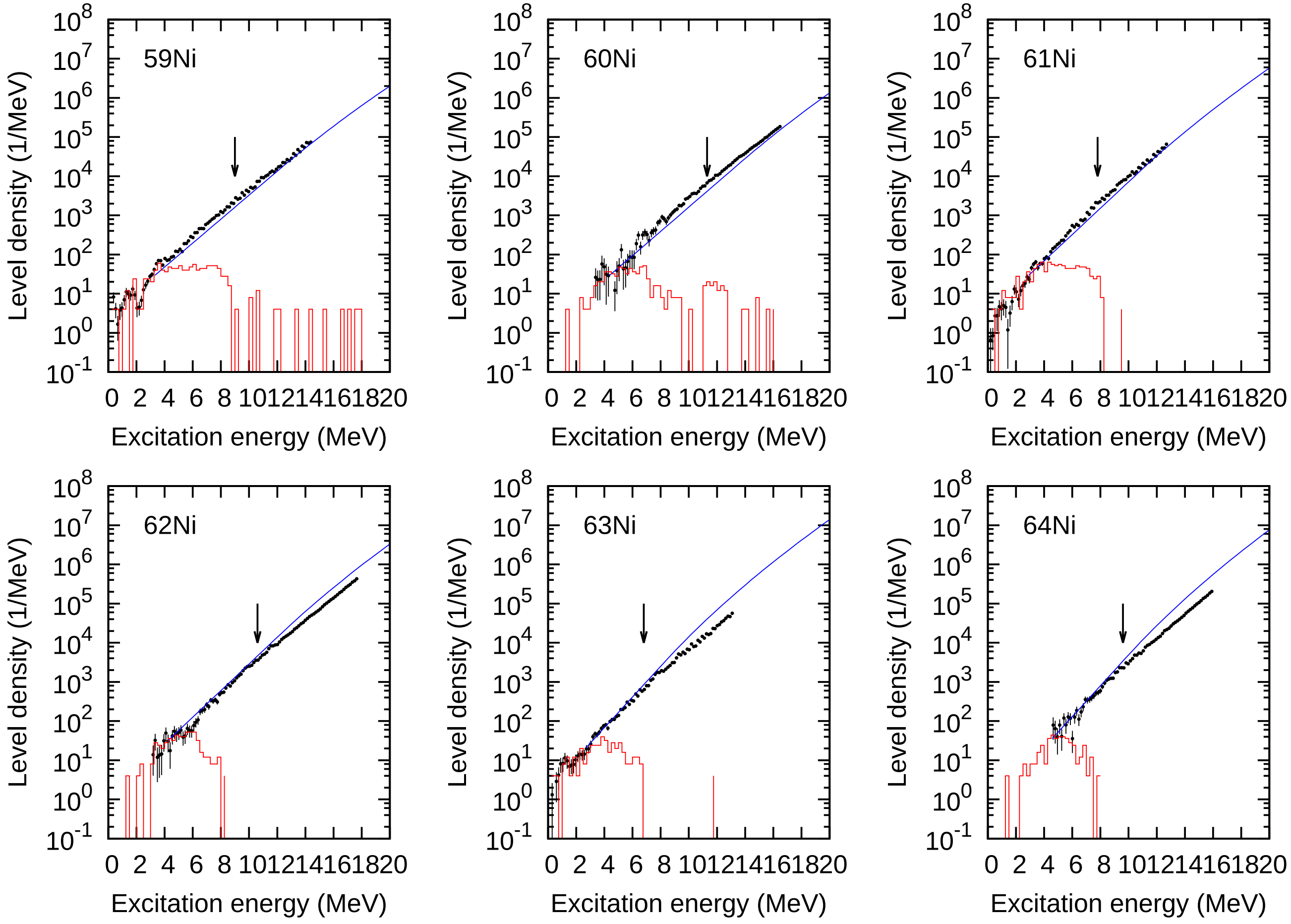
Line is Gilbert Cameron model with parameters from RIPL-3, based on neutron resonance data



Line is Fermi-gas model with parameters from RIPL-3, based on neutron resonance data

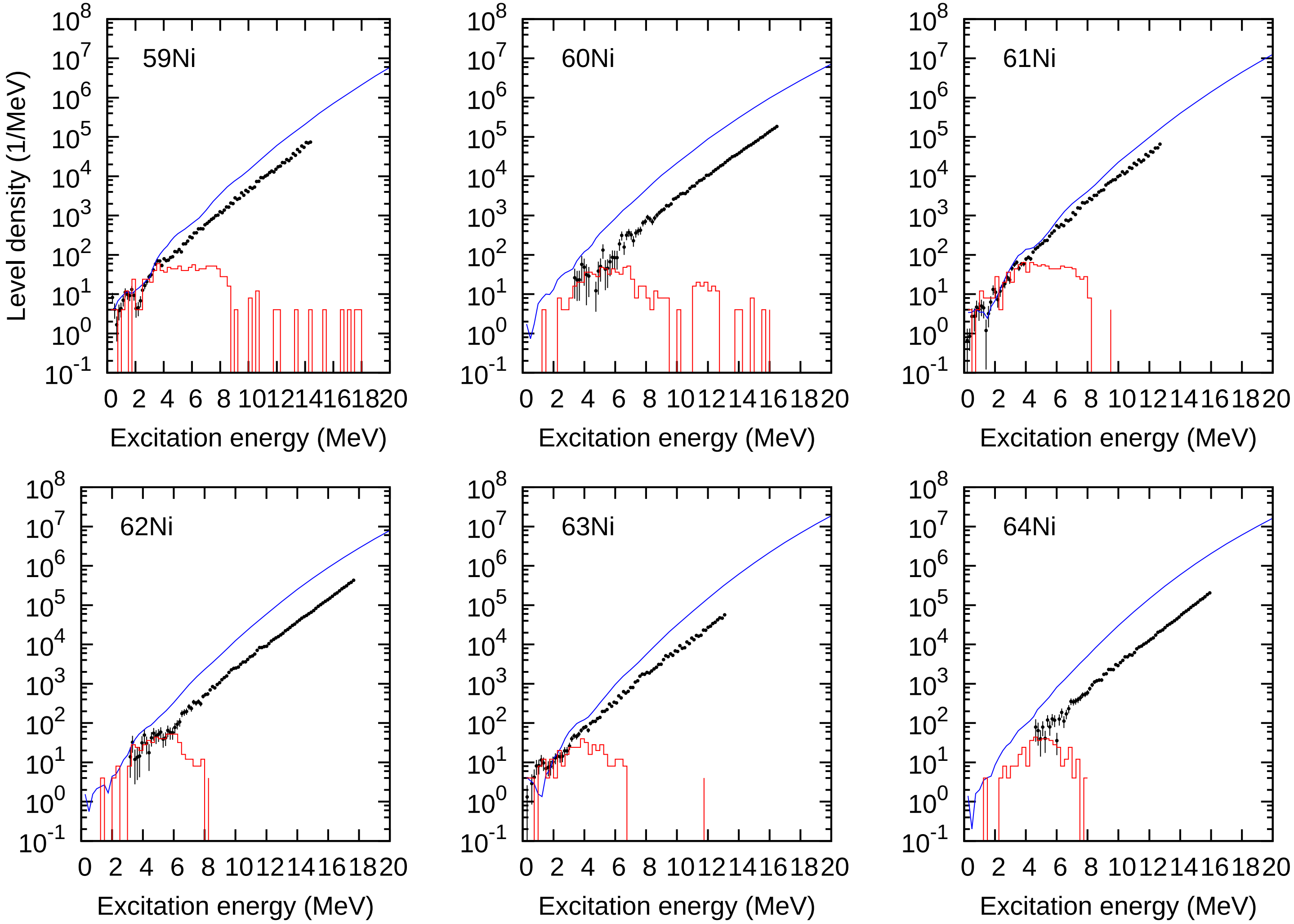


Line is Gilbert-Cameron model, global parameterization from Empire code



Line is microscopic calculations

S.Goriely, S.Hilaire, A.J.Koning, Phys.Rev. C 78, 064307 (2008)



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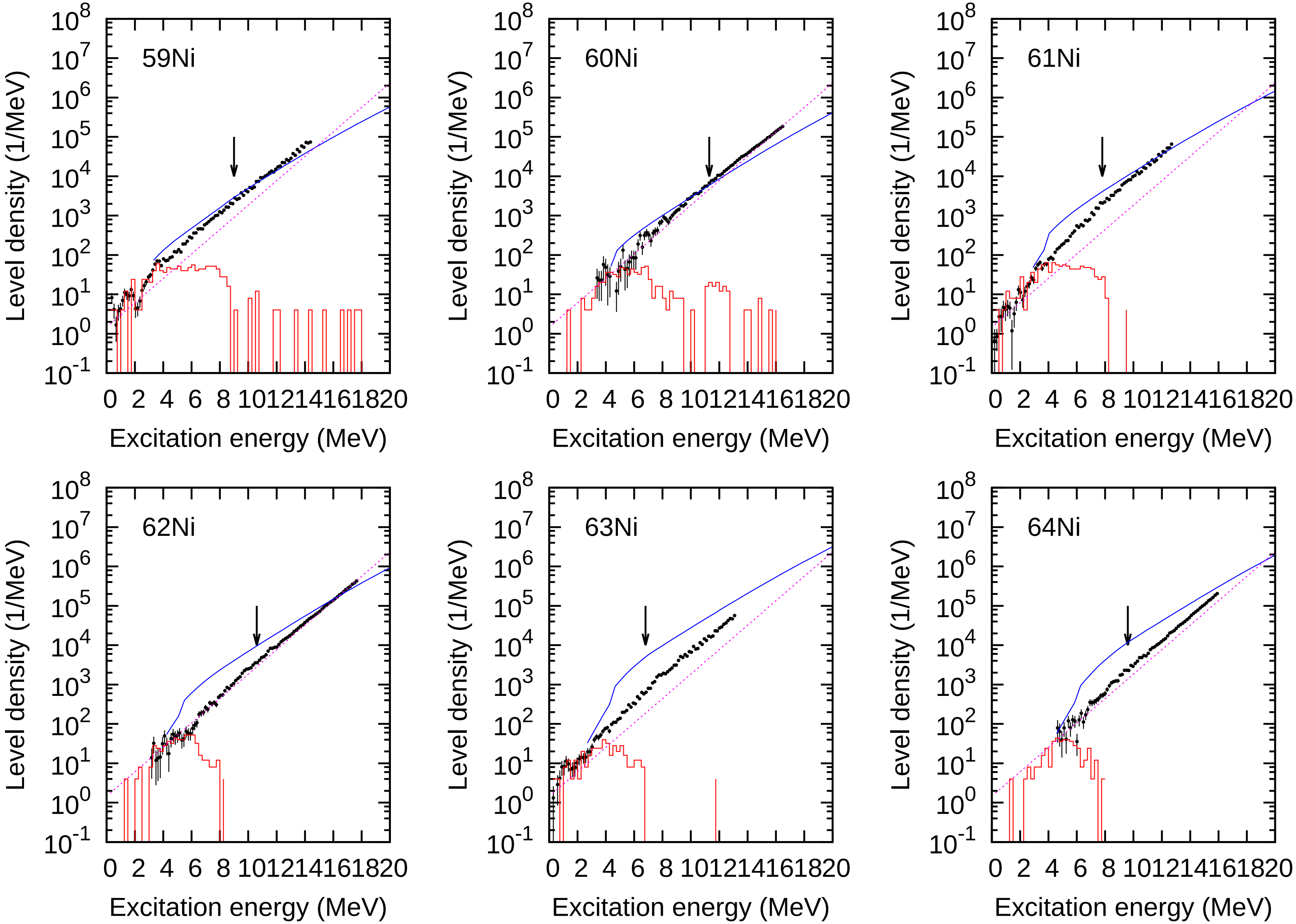
ENDF/B-VII.0: Next Generation Evaluated Nuclear Data Library for Nuclear Science and Technology

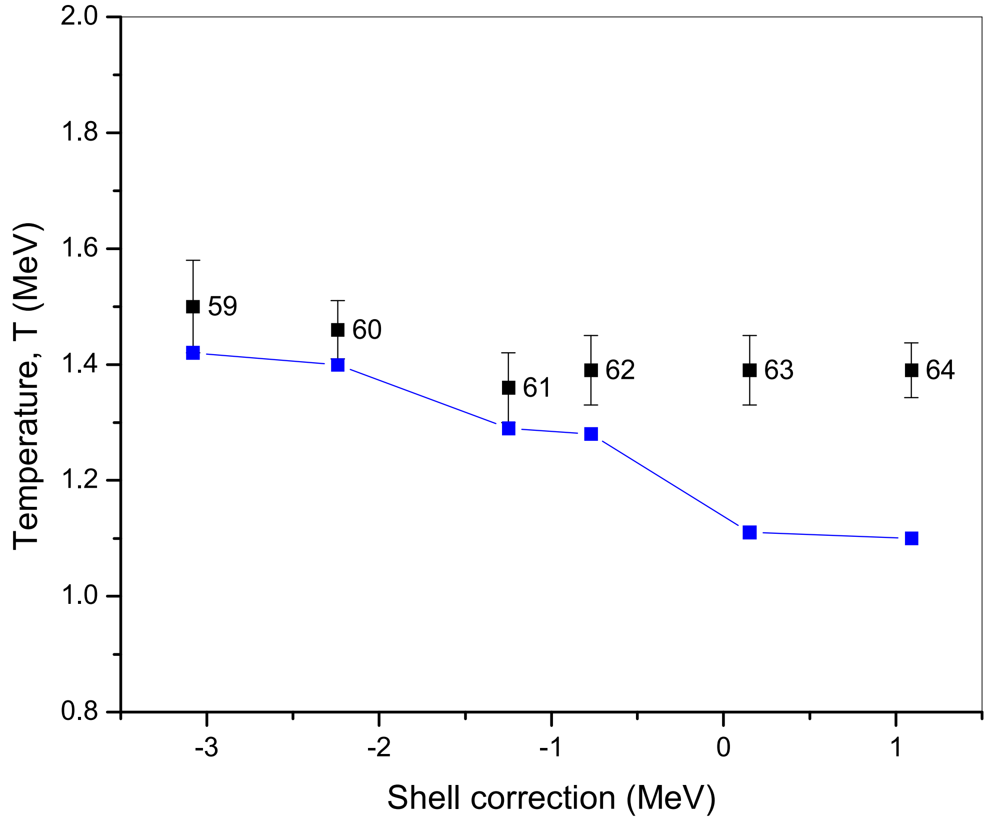
M.B. Chadwick,[1] P. Obložinský,[2*] M. Herman,[2] N.M. Greene,[6] R.D. McKnight,[3] D.L. Smith,[3] P.G. Young,[1] R.E. MacFarlane,[1] G.M. Hale,[1] S.C. Frankle,[1] A.C. Kahler,[1,12] T. Kawano,[1] R.C. Little,[1] D.G. Madland,[1] P. Moller,[1] R.D. Mosteller,[1] P.R. Page,[1] P. Talou,[1] H. Trellue,[1] M.C. White,[1] W.B. Wilson,[1] R. Arcilla,[2] C.L. Dunford,[2] S.F. Mughabghab,[2] B. Pritychenko,[2] D. Rochman,[2] A.A. Sonzogni,[2] C.R. Lubitz,[4] T.H. Trumbull,[4] J.P. Weinman,[4] D.A. Brown,[5] D.E. Cullen,[5] D.P. Heinrichs,[5] D.P. McNabb,[5] H. Derrien,[6] M.E. Dunn,[6] N.M. Larson,[6] L.C. Leal,[6] A.D. Carlson,[7] R.C. Block,[8] J.B. Briggs,[9] E.T. Cheng,[10] H.C. Huria,[11] M.L. Zerkle,[12] K.S. Kozier,[13] A. Courcelle,[14] V. Pronyaev,[15] S.C. van der Marck[16]

Apart from a few evaluations for which the standard Gilbert-Cameron approach was adopted, most of the evaluations performed with EMPIRE employed level densities that are specific to the EMPIRE code. The formal-

Test of Empire-specific level density model



The slope of level density function can be parameterized by temperature T from exp((E-E0)/T)



Black points – experiment

Blue points – prediction based on neutron resonance data

Conclusion

- Experimental level density for Ni isotopes does not depend on neutron number (or shell correction) the way it is predicted from systematics based on neutron resonance data

- Level density for nuclear reaction calculations needs to be obtained from nuclear reactions, not from neutron resonance spacings.

Collaborators:

S. Grimes
C. Brune
T. Massey
A. Schiller

Edwards Accelerator Laboratory,
Department of Physics and Astronomy, Ohio University