Data on level densities from evaporation spectra experiments

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- What is the problem with current level density models used in reaction codes for data evaluations ?

- What needs to be done to improve level density modeling for data evaluations

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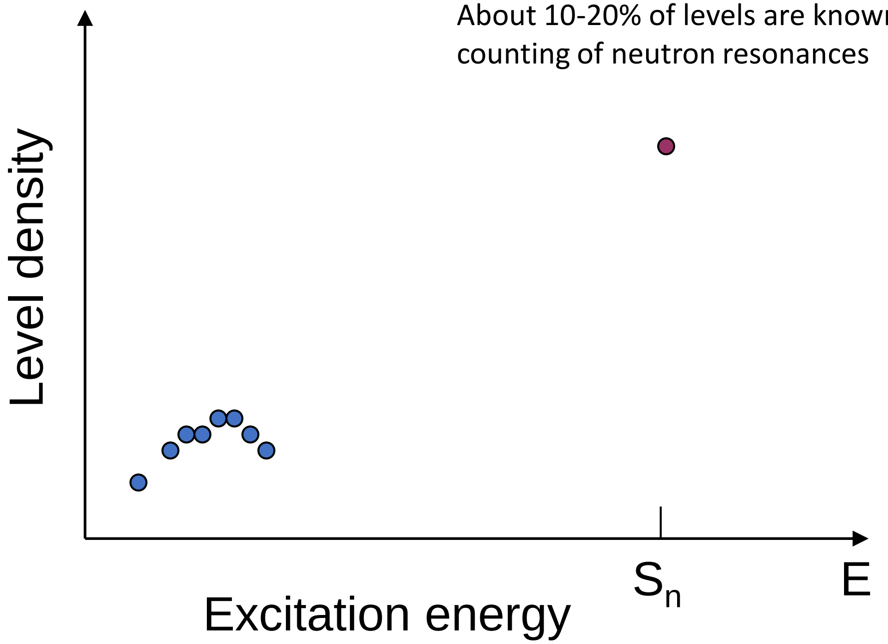
Source of uncertainties of current level density models

All current models rely on data on neutron s-wave neutron resonance spacings !!!

Neutron resonance spacings have very limited information about the nuclear level density

1) they are known at the neutron separation energy S_n only (about 7-10 MeV of excitation energy)
2) they are known in very limited spin interval (target spin I±1/2)

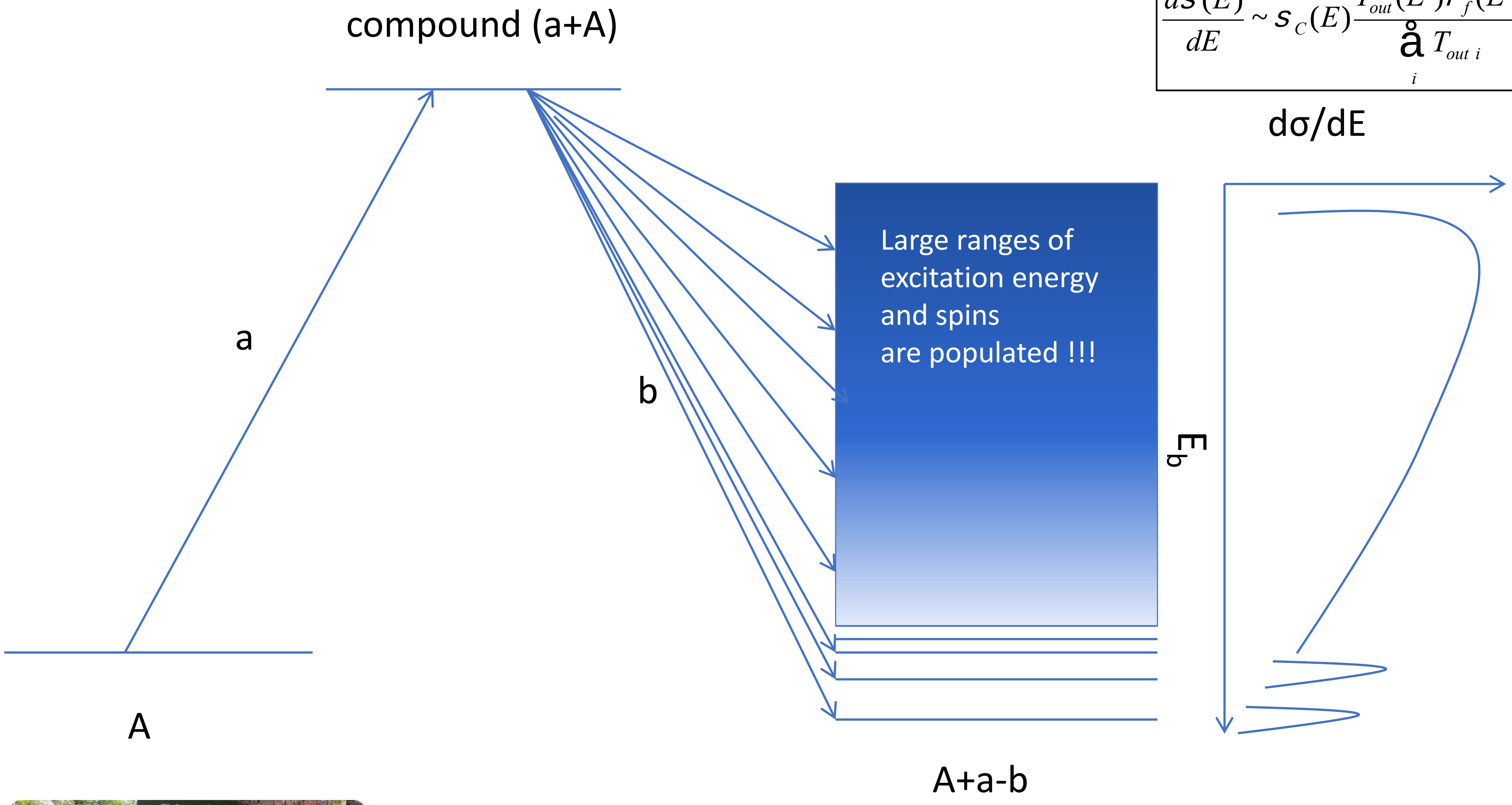
About 10-20% of levels are known from counting of neutron resonances



Neutron resonance data are very limited to constrain level density models !!!

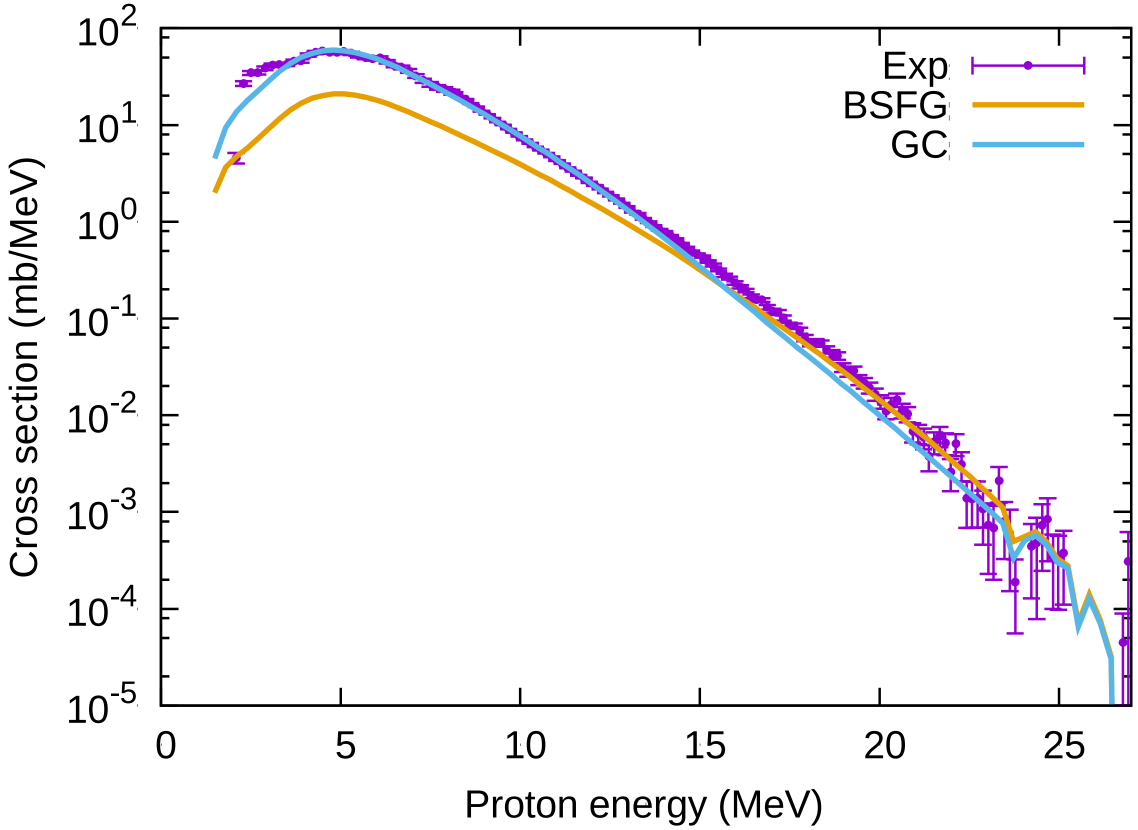
Level densities from evaporation spectra measurements

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



Proton evaporation from ^{7}Li induced reactions

$^{7}Li + ^{54}Fe \longrightarrow ^{60}Ni + p$

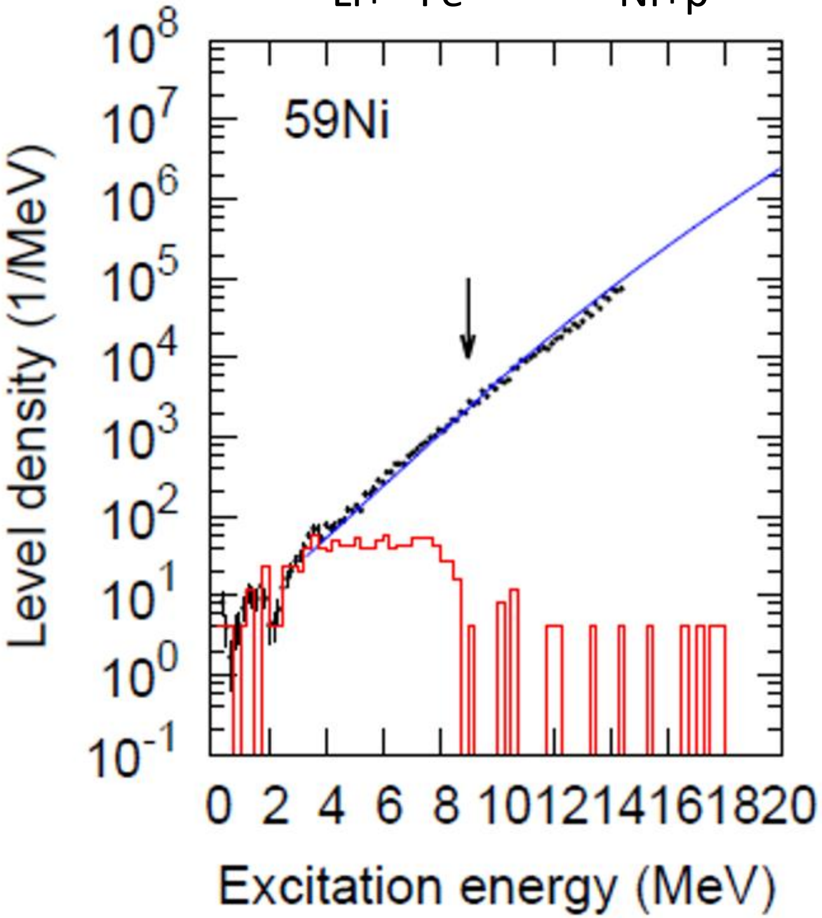


Back shifted Fermi-gas Model (BSFG)
Gilbert and Cameron Model (GC)

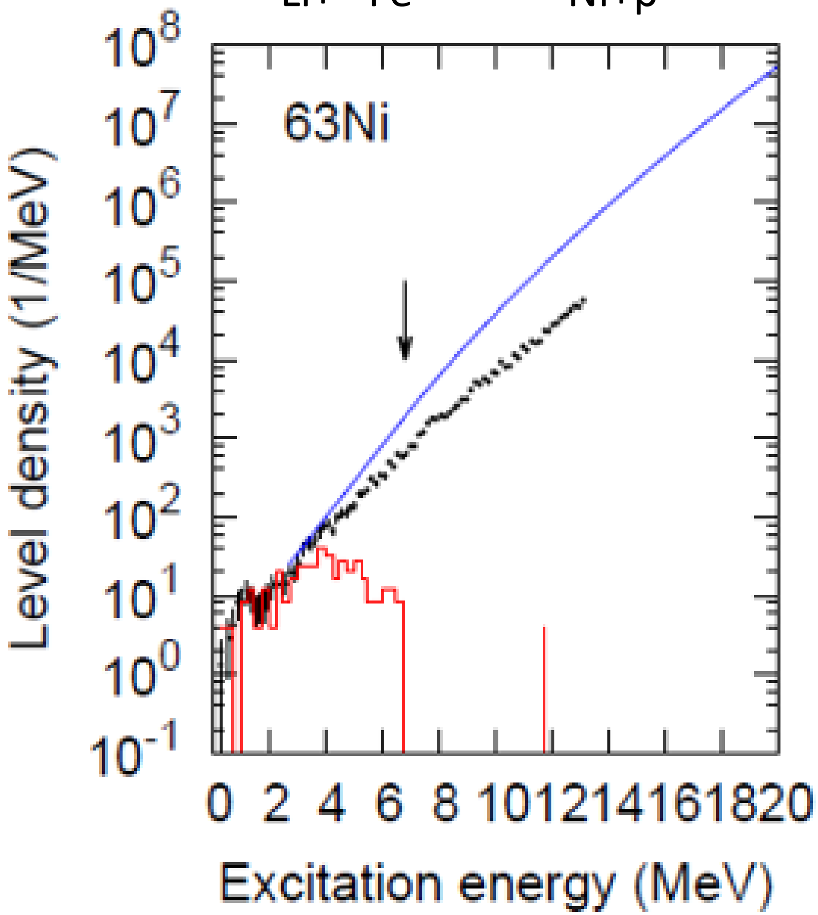
parameters from RIPL3

Comparison of level densities obtained from particle evaporation technique with the Fermi-gas model constrained by neutron resonance data

$^{6}Li+^{54}Fe \rightarrow ^{59}Ni+p$



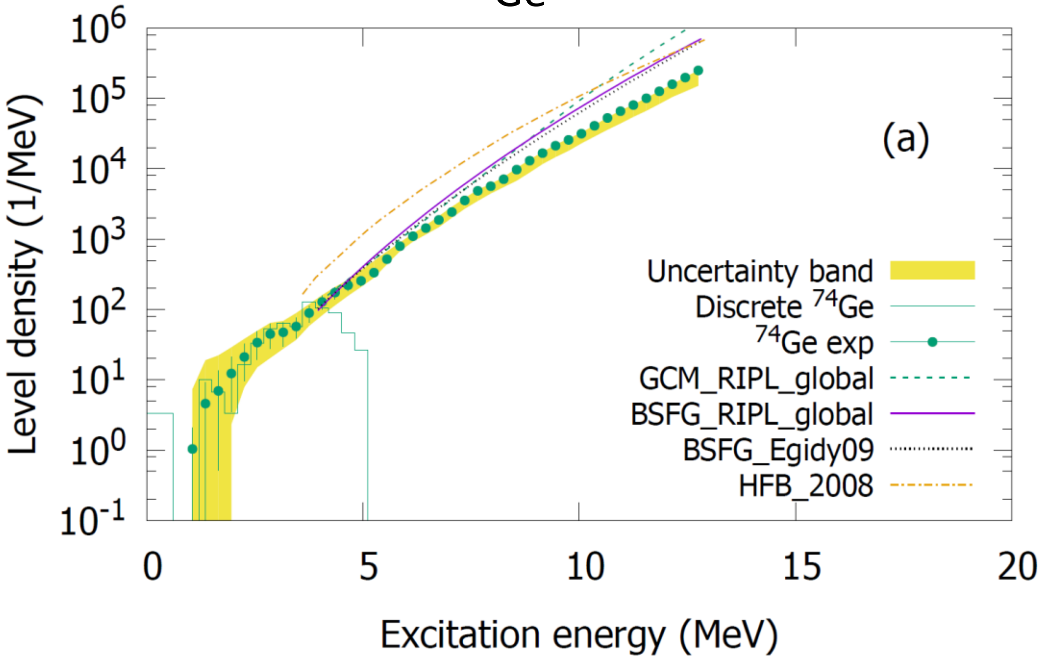
$^{7}Li+^{57}Fe \rightarrow ^{63}Ni+p$



A.V. Voinov et al, EPJ Web of Conference, 21, 05001(2012)

Evidence of deviation of data from evaporation spectra from models based on neutron resonance spacing data

^{74}Ge



A.V. Voinov et al, PRC 99, 054609 (2019)

^{56}Fe

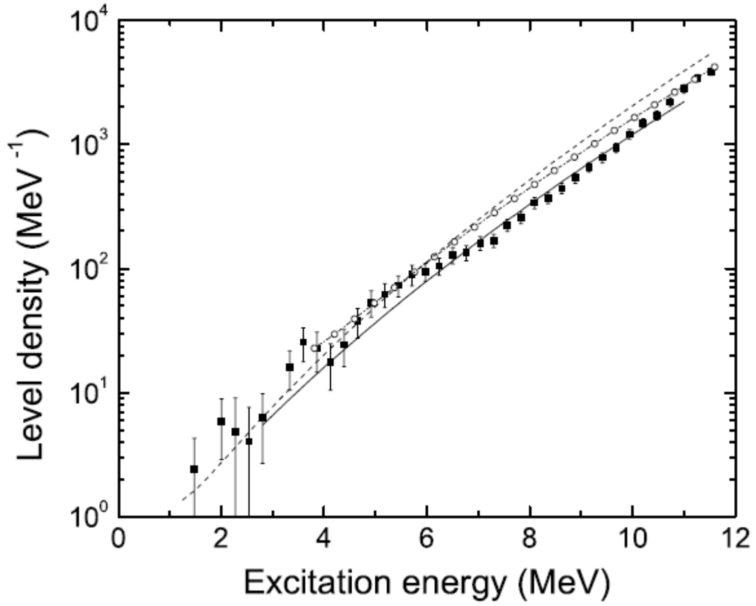


FIG. 4. NLD extracted from neutron evaporation spectra (full circles) compared to Fermi-gas (dashed) and microscopical model (open circles) calculations. Full line shows the fit to the data.

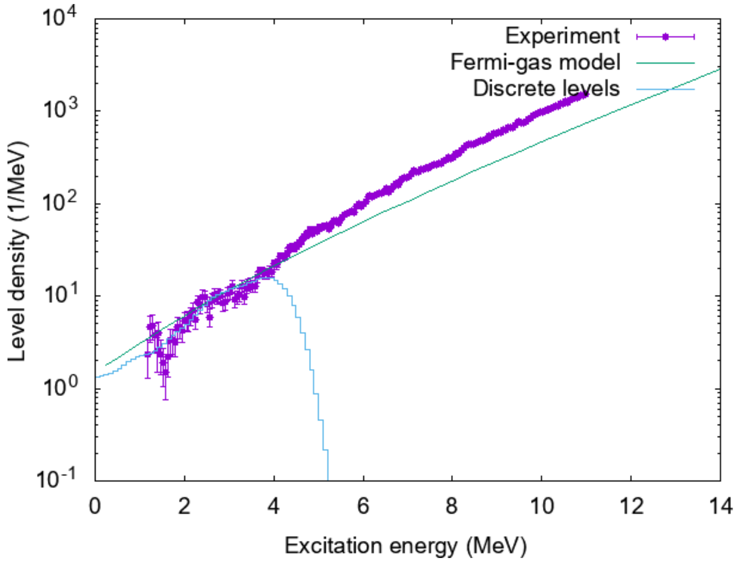
A.V. Voinov et al, PRC, 74, 014314 (2006)

Level density of chlorine isotopes $^{35,36,37}Cl$

It is important for neutron reaction data evaluations for applications in Molten Salt Reactors which use chloride salt for cooling (in collaboration with LANL).

For neutron energies higher than few MeV, the level density input is important for modeling

Level density of ^{36}Cl (preliminary !)



Experiment at Edwards Lab:

20 MeV $^{12}C + ^{24,25,26}Mg \longrightarrow ^{35,36,37}Cl + p$

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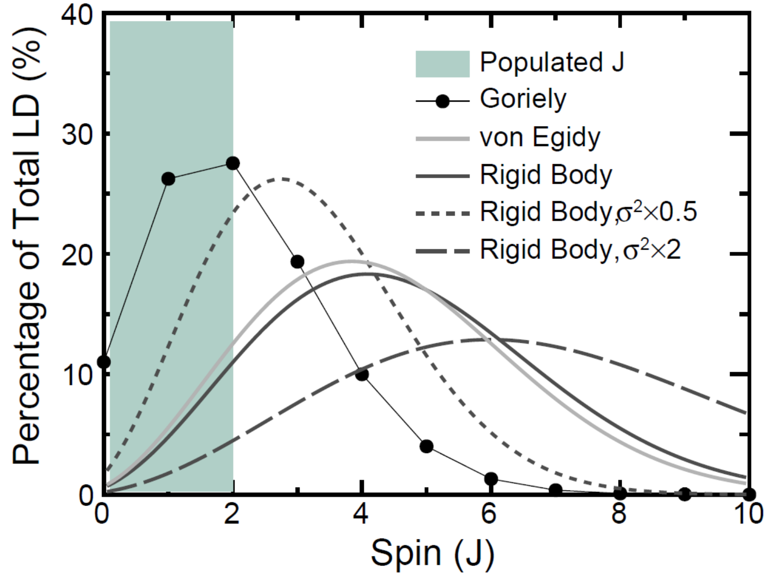
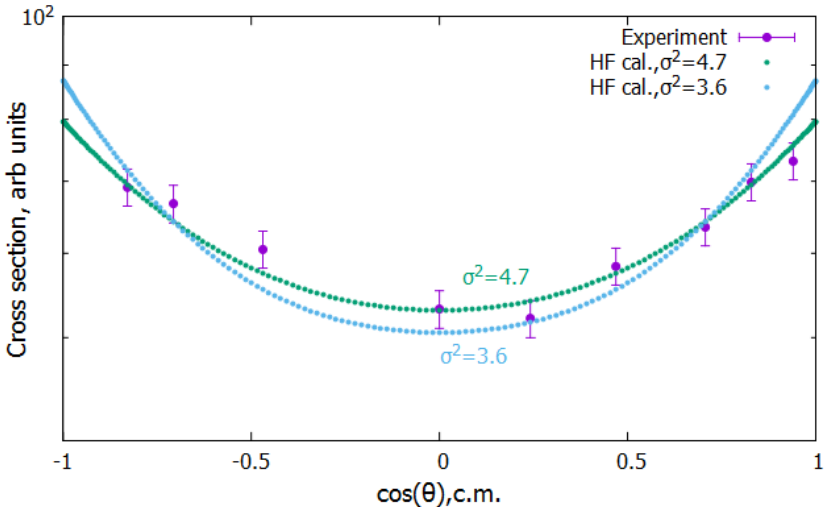
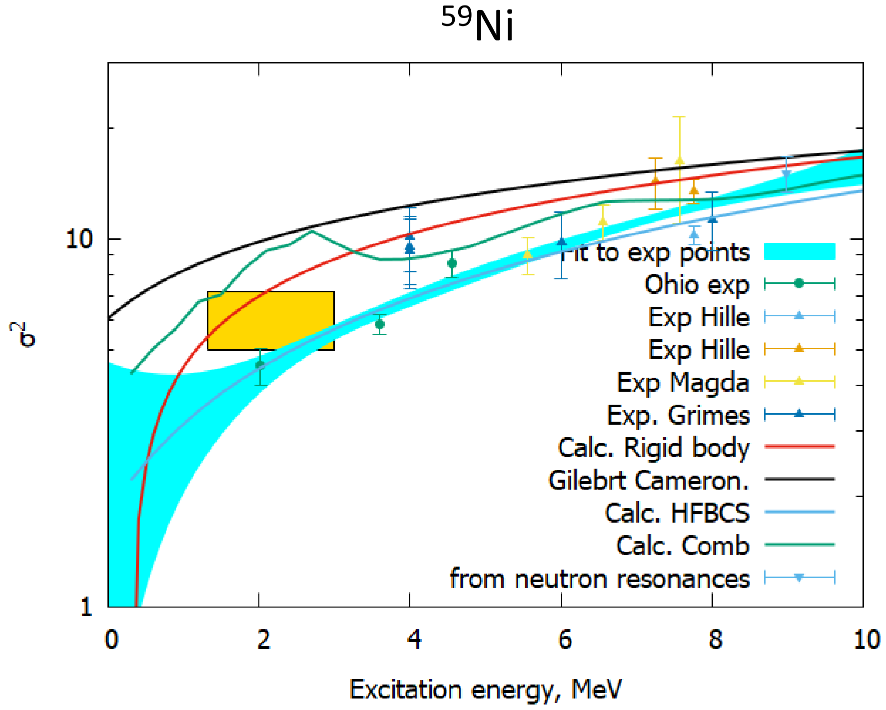
Angular distributions constrain the spin-distribution



$$\rho(U,J) = \rho(U)\cdot\frac{2J+1}{2\sigma^2}\exp\left[-\frac{(J+0.5)^2}{2\sigma^2}\right]$$

$^{56}Fe(\alpha,n)^{59}Ni$ angular distribution measurements allows us to determine the spin cutoff parameter





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A. V. Voinov, WANDA 2023

Conclusion

1. Particle evaporation technique allows studying nuclear level density in larger spin and excitation energy intervals compared to neutron resonance data. It is completely independent method to study nuclear level density

2. Results are consistent with neutron resonance models for some of the nuclei and have a large disagreement with others. Understanding the reason of disagreement can improve accuracy of level density modeling.

More data are needed to look for systematic regularities

1. Collect and evaluate literature data on level densities obtained from particle evaporation experiments. (about 100 data are available including about 30 measured at Edwards Lab, Ohio University) Create level density data base. Find physics regularities, use them to constrain level density models
2. Make more measurements of particle evaporation from compound nuclear reactions, possible reactions: (a,n), (d,n), (^{6,7}Li,p), (^{12}C,p), etc. Beam energy ~3-5 MeV/A. Possibility to extend this technique to radioactive beam facilities.

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