# ENDFB VI Libraries with EGAF neutron capture data

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# Summary

- EGAF thermal neutron capture evaluations
- Completed Libraries of Light Nuclei –Testing
- Libraries Medium & Heavy Nuclei- Modeling the Quasi-Continuum

# Evaluated Gamma Ray Activation File (EGAF)

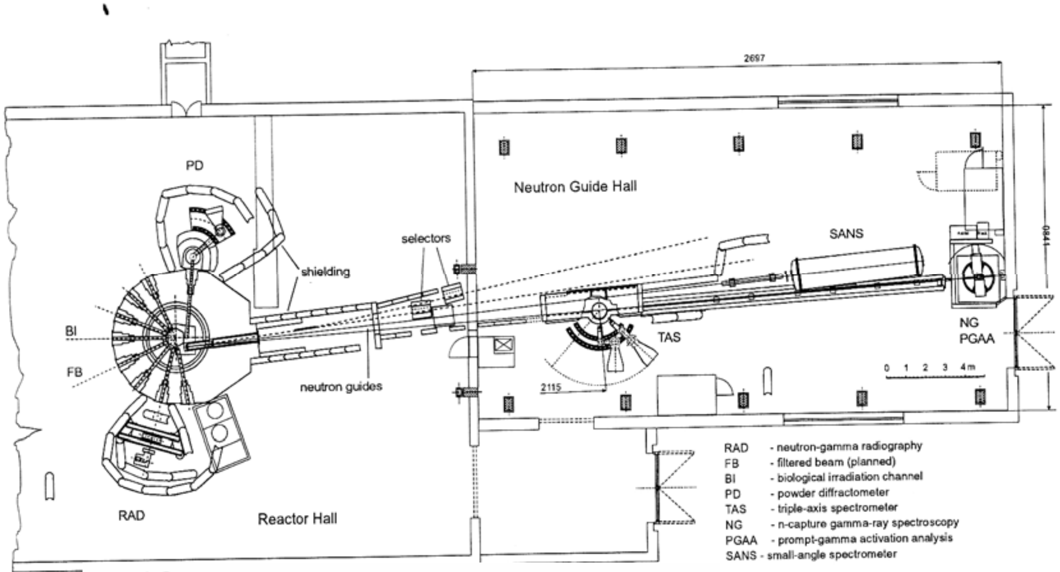
- Built Upon Previous literature compilations-ENSDF, Reedy& Frankle, Lone
- Measurements at the Budapest Reactor (G.L. Molnar, Zs. Revay, and T. Belgya)
- Evaluation with the IAEA CRP for a *Database of Prompt Gamma Rays from Slow Neutron Capture for Elemental Analysis* (R.B. Firestone, H.D. Choi, R.M. Lindstrom, G.L. Molnar, S.F. Mughabghab, R. Paviotti-Corcuera, Zs. Revay, A. Trkov, V. Zerkin, and C.M. Zhou)-On web
- Results

  Database of 35,000 γ-ray energies with absolute cross sections for Z=1-83,90,92

  New total radiative neutron capture cross sections for many elements

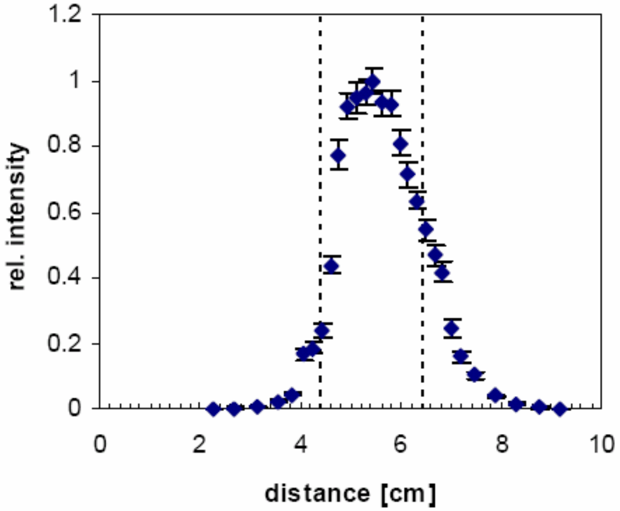
  New tests of statistical model parameters-see below

# Measurements: guided Neutron Beam




**Reactor and neutron guide hall.** The PGAA (capture gamma) station is located ≈30 m from the reactor wall.

Low BG environment




**Measured beam profile at target position**. Thermal neutron flux at the target position is $2\times10^{6}$ $cm^{-2}s^{-1}$.

Well collimated-reduced BG

# Cross Section Standardization

**Partial γ-ray cross sections were measured with absolute internal standards** including H, N, Cl, Au, Ti and S.

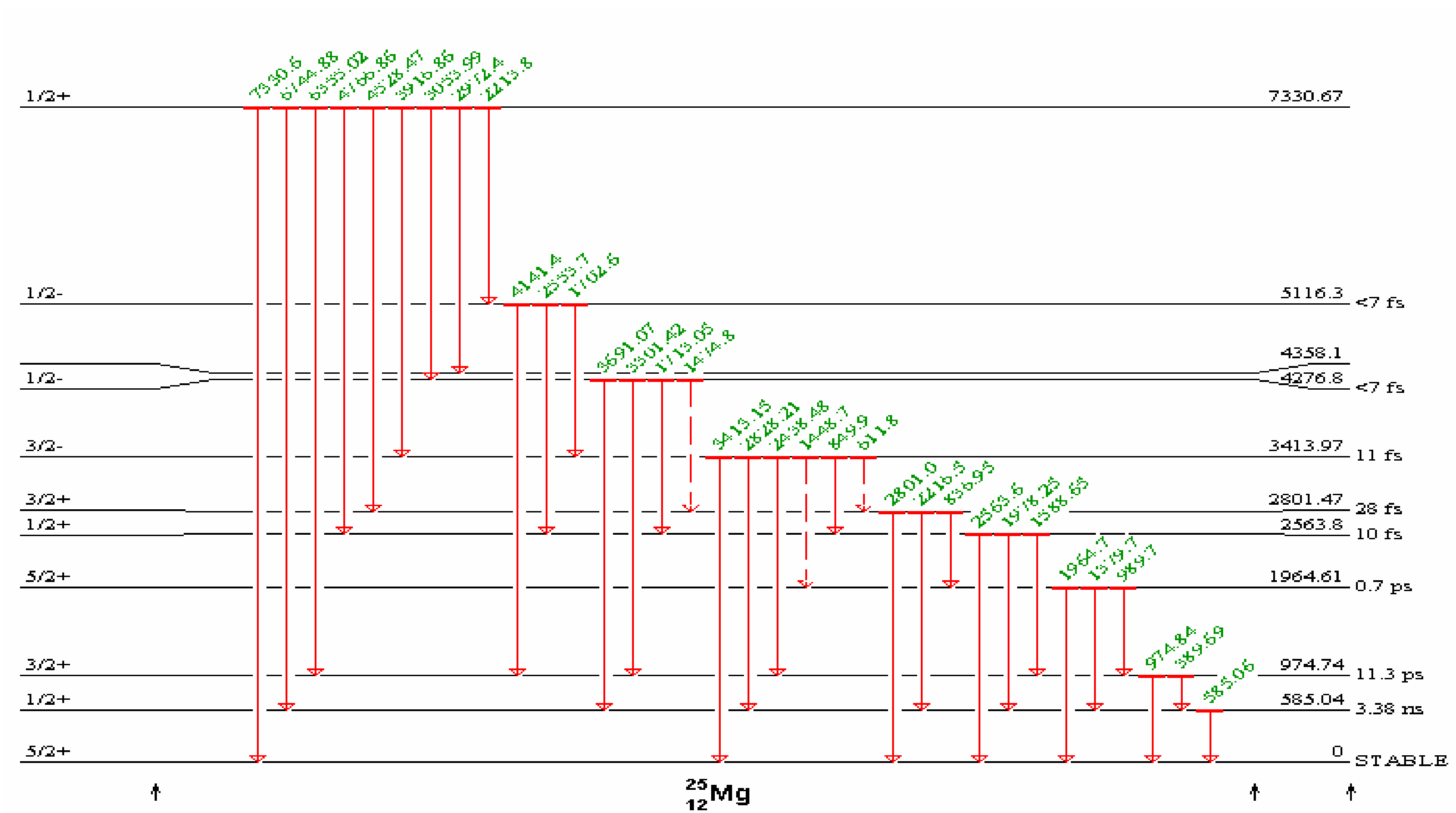
**Standardization with compounds** – high purity compounds with stable stoichiometry containing a standard element, e.g. NaCl.

**Standardization using homogeneous mixtures** – if no stoichiometric compounds were available, homogeneous mixtures, typically water solutions, were used.

**Very Well characterized targets allows measurement of absolute cross sections**

Low energy γ-ray data were corrected for attenuation in the sample.

# Gamma energies and cross sections constrained by level scheme-complete data sets for light nuclei Transition probability & energy in=out, all levels, allowing complete evaluation



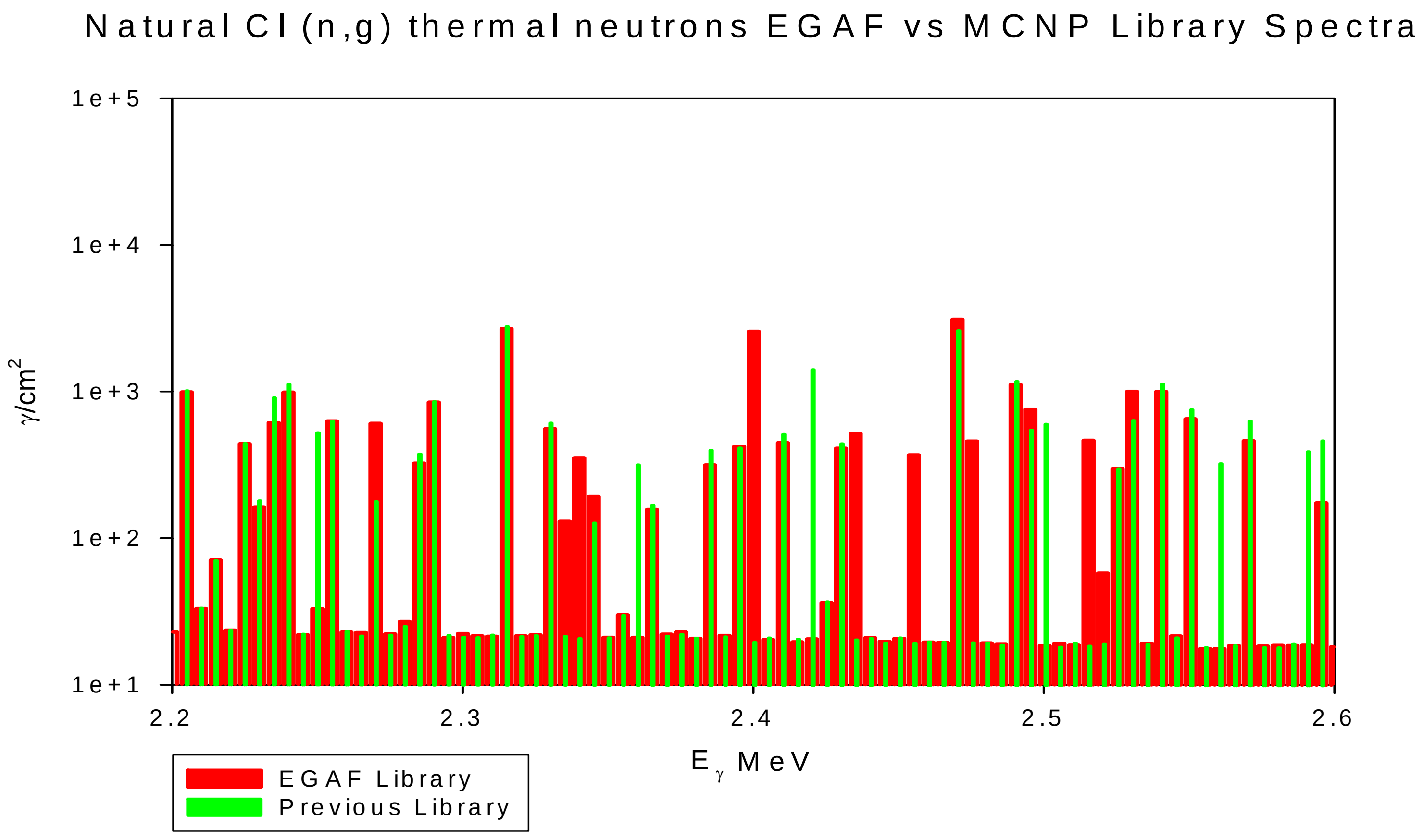
# 18 Libraries of Light Nuclei completed to date

| Z | Library | A | %NA | b | # Gammas |
|---|---|---|---|---|---|
| 1 | H | 1 | 99.9844 | 0.33 | 1 |
| 1 | D | 2 | 0.01557 | 0.00 | 1 |
| 3 | Li | 6 | 7.589 | 0.04 | 3 |
| 3 | Li | 7 | 92.411 | 0.05 | 3 |
| 4 | Be | 9 | 100 | 0.01 | 12 |
| 5 | B | 10 | 19.82 | 0.50 | 9 |
| 5 | B | 11 | 80.18 | 0.01 | 9 |
| 6 | C | 12 | 98.892 | 0.00 | 6 |
| 7 | N | 14 | 99.6337 | 0.08 | 60 |
| 8 | O | 16 | 99.7628 | 0.00 | 4 |
| 11 | Na | 23 | 100 | 0.53 | 233 |
| 12 | Mg | nat | | 0.06 | 283 |
| 13 | Al | 27 | 100 | 0.23 | 291 |
| 14 | Si | 28 | 92.2297 | 0.18 | 54 |
| 15 | P | 31 | 100 | 0.17 | 202 |
| 16 | S | nat | | 0.53 | 470 |
| 17 | Cl | 35 | 75.771 | 45.55 | 383 |
| 17 | Cl | 37 | 24.229 | 0.43 | 77 |

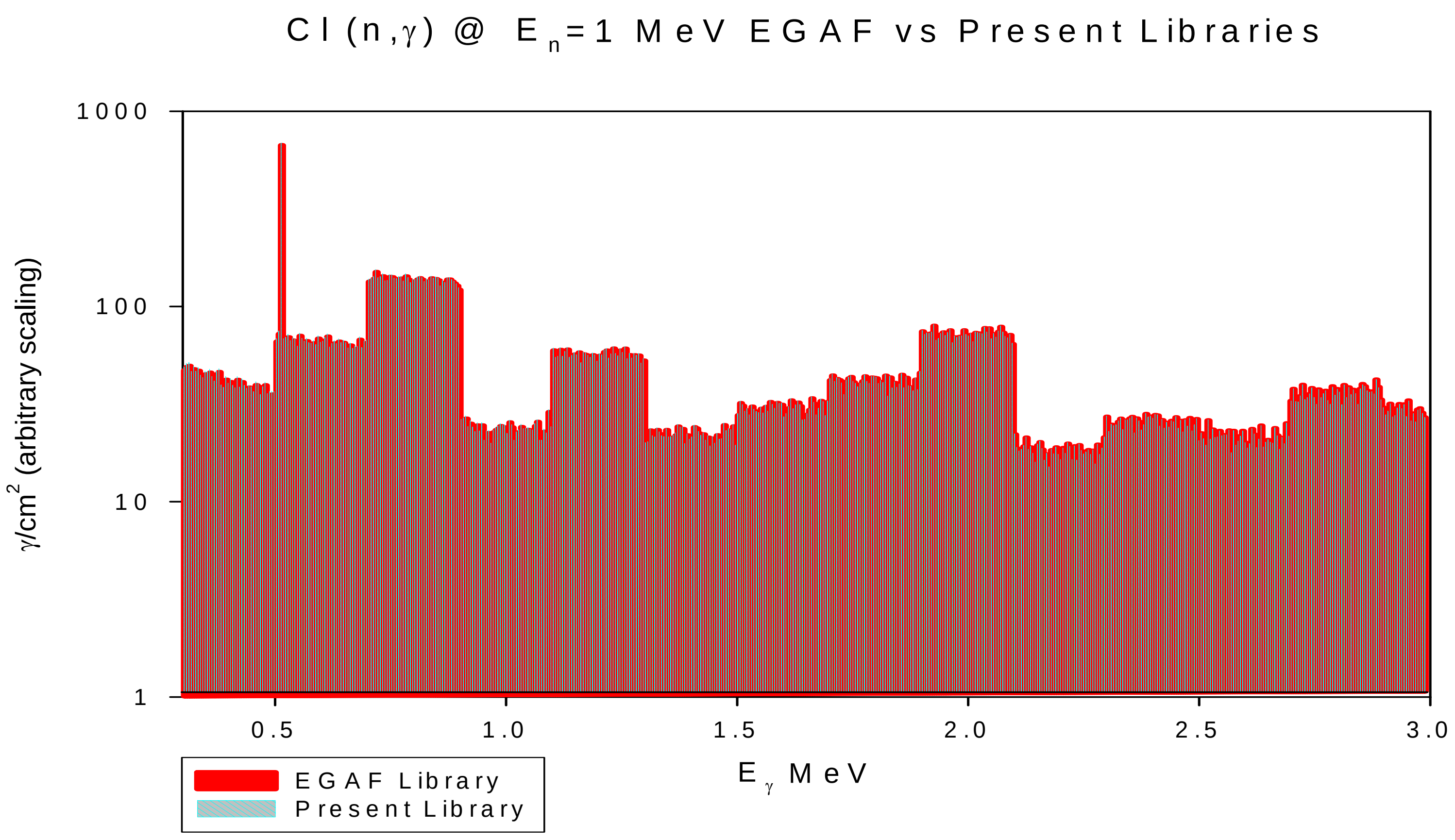
# Library modifications

- Primarily File 12 (&14 if present) MT 102
- File 15 left unchanged, thermal continuum=0
- All measured lines and cross sections included for completeness, >thermal dependencies unchanged
- Yields were normalized to conserve total decay energy vs Q value, typically < 1%
- Prepro and NJOY used to process libraries for testing in transport codes
- Psyche, Physor, Checkr, -minor errors found

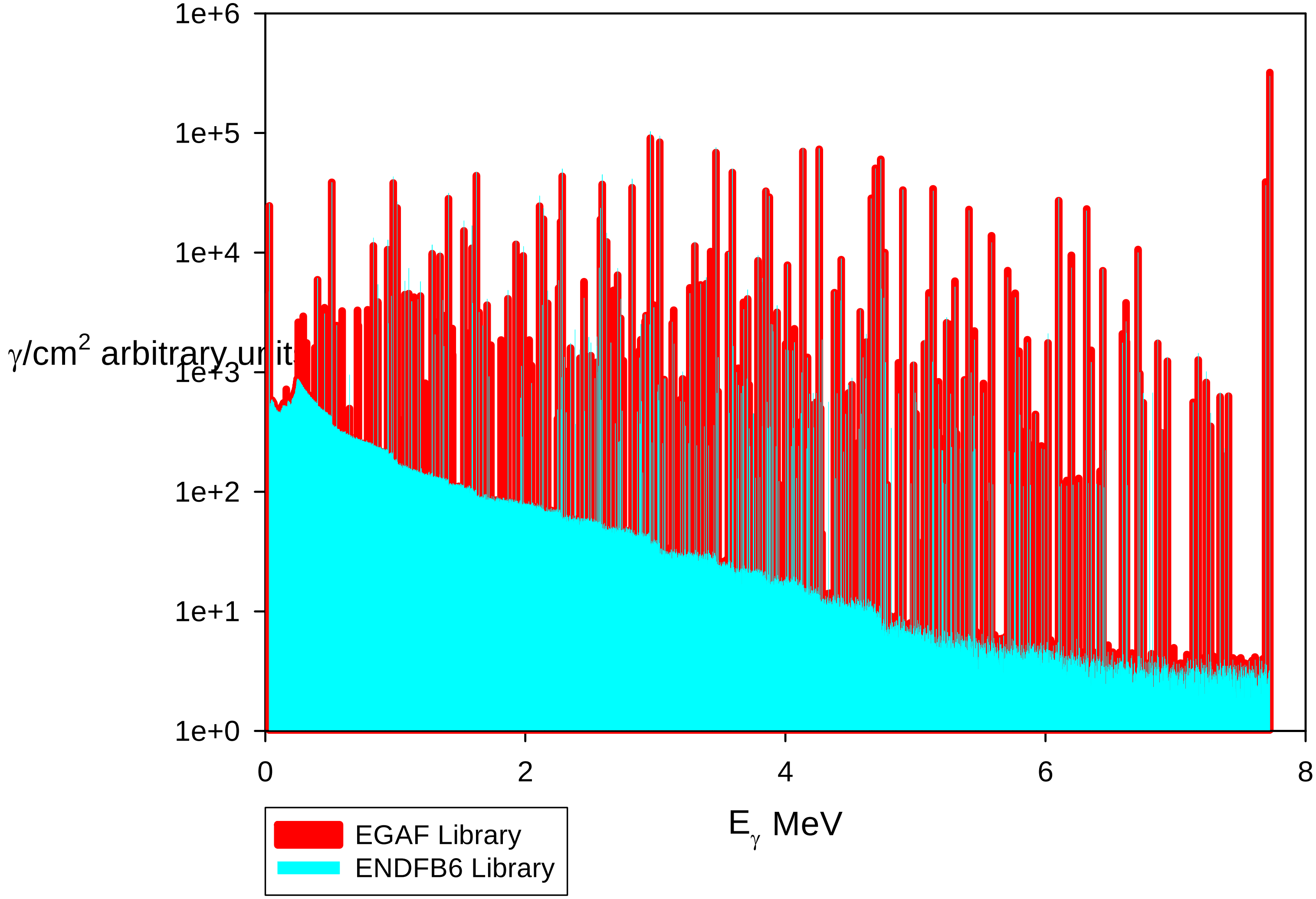
# Library Comparison-Thermal Neutrons->Cl MCNP: ENDFB6 vs EGAF



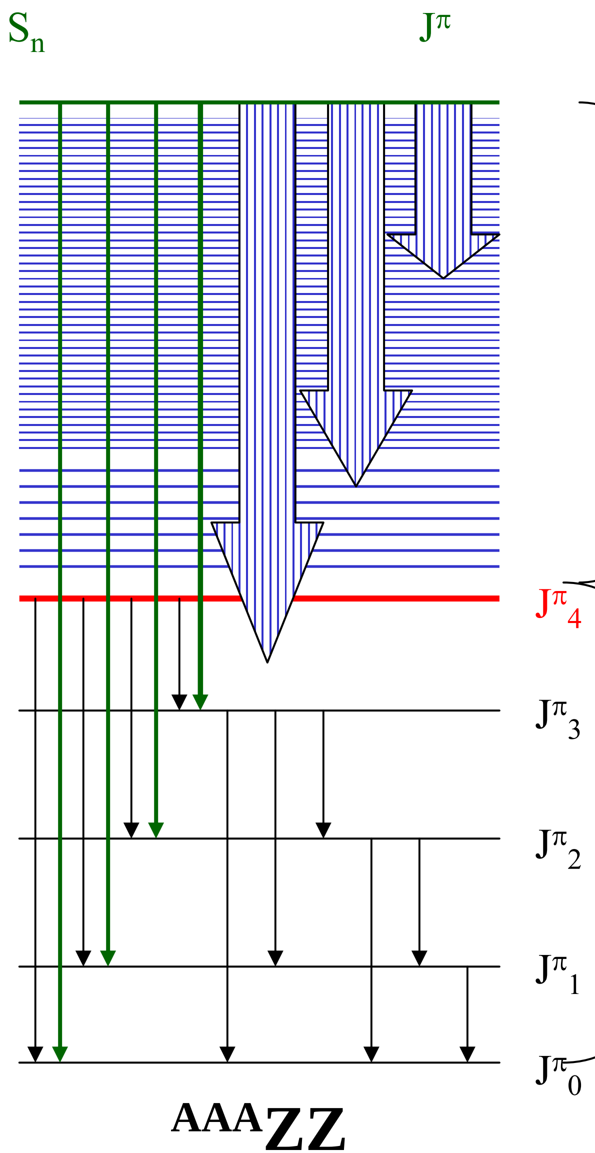
# Library Comparison-1 MeV->Cl



# 27Al(n,g) comparison MCNP ENDFB6 vs EGAF Libraries-thermal Neutrons



# In Medium-Heavy Nuclei the Cascade is modeled with the DiceBox/Casino Statistical model




- Thermal neutron capture state energy and $J^\pi$ value(s) are taken from experiment if known.

-Above $\mathbf{E_{crit}}$ a complete level scheme is generated as a discretization of an assumed level density formula $\rho(E,J^\pi)$ and a corresponding photon strength function $S(E_\gamma)$ model.

-Transitions have partial widths that also follow the Porter-Thomas distribution

-Below $\mathbf{E_{crit}}$, all transition probabilities are taken from experiment (EGAF).

# DiceBox parameter scans

$$\langle \Gamma_{ab} \rangle = \Sigma_{XL} \, (E_a - E_b)^{2L+1} \, S_\gamma^{XL} (E_a - E_b) \, / \, \rho(E_a)$$

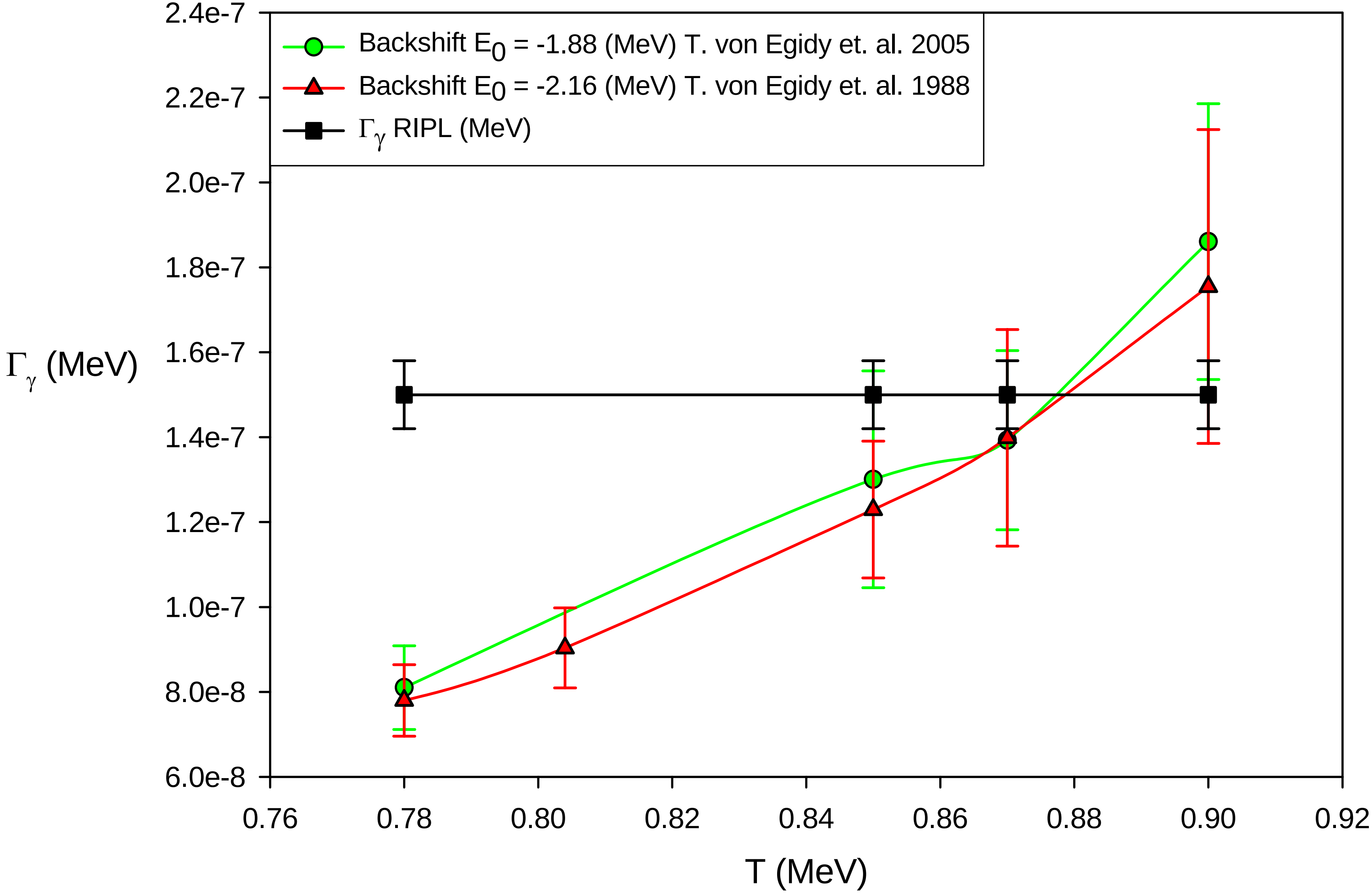
XL= multipolarity that contributes

- Input parameters from many sources, RIPL, Von Egidy (Constant T level density), etc.
- Strength function used is from experience:
  Blend of KMF-BA below 10 MeV
- Scans in $E_{crit}$ did not have a large effect
- Level Density model was chosen by predicted $\Gamma_{tot}$ vs experimental $\Gamma_{tot.}$ No strong affect on discrete spectrum, does affect continuum shape

Total Level width compared to RIPL values after known feedings modeled.
Constant T model generally fit better than Bethe model with 2 outliers:

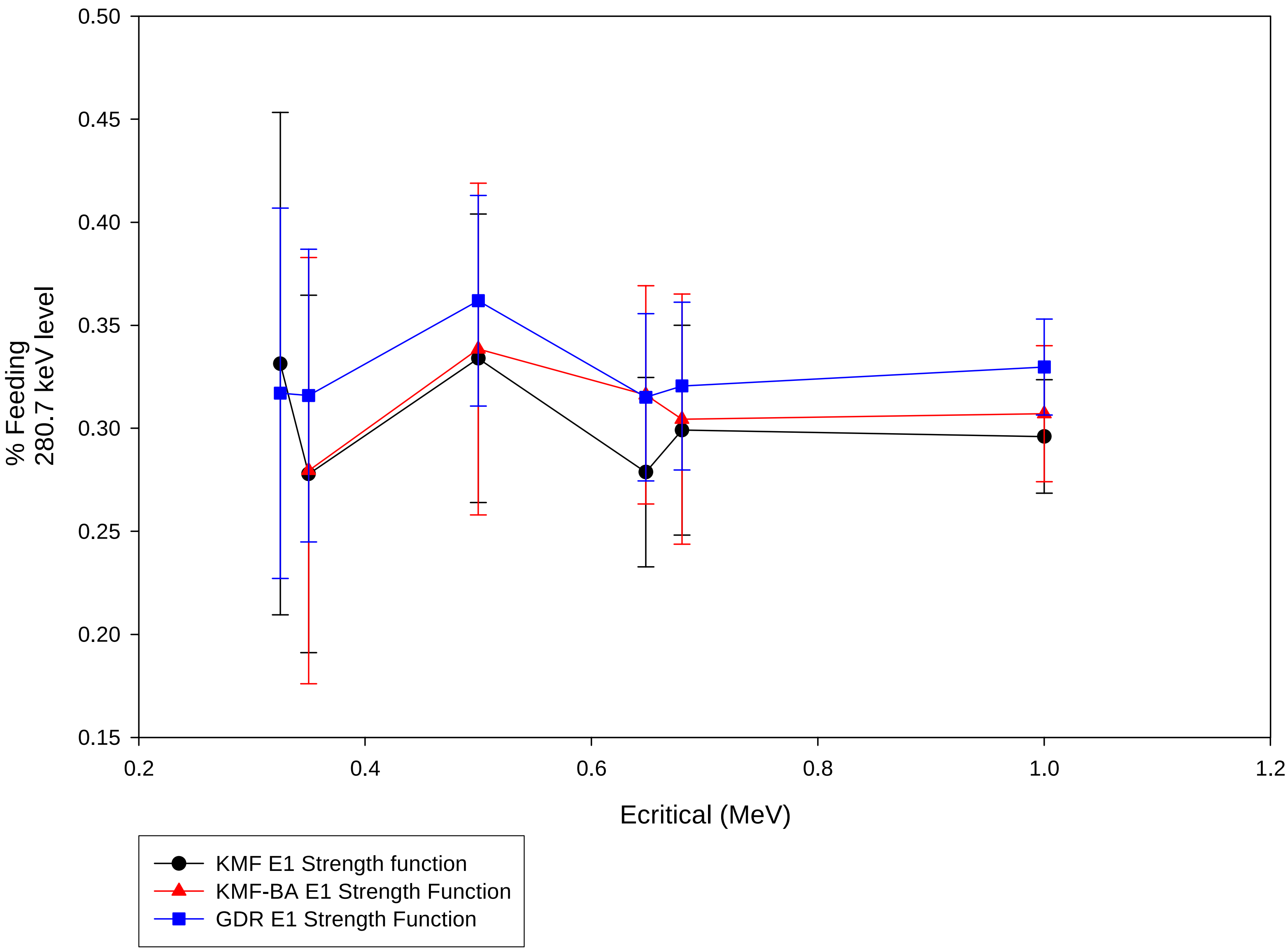
| C. N. | Density Model | $\Gamma_\gamma$ % Discrepancy |
|---|---|---|
| $^{103}Pd$ | Const. T (Von Egidy) | 3.02 |
| | BSFG | 74.20 |
| $^{105}Pd$ | Const. T | 39.75 |
| | BSFG | 3.70 |
| $^{106}Pd$ | Const. T | 10.11 |
| | BSFG | 78.80 |
| $^{107}Pd$ | Const. T | 14.81 |
| | BSFG | 34.35 |
| $^{109}Pd$ | Const. T | 39.50 |
| | BSFG | 248.77 |
| $^{111}Pd$ | Const. T | 16.93 |
| | BSFG | 38.88 |
| | | |
| | | |

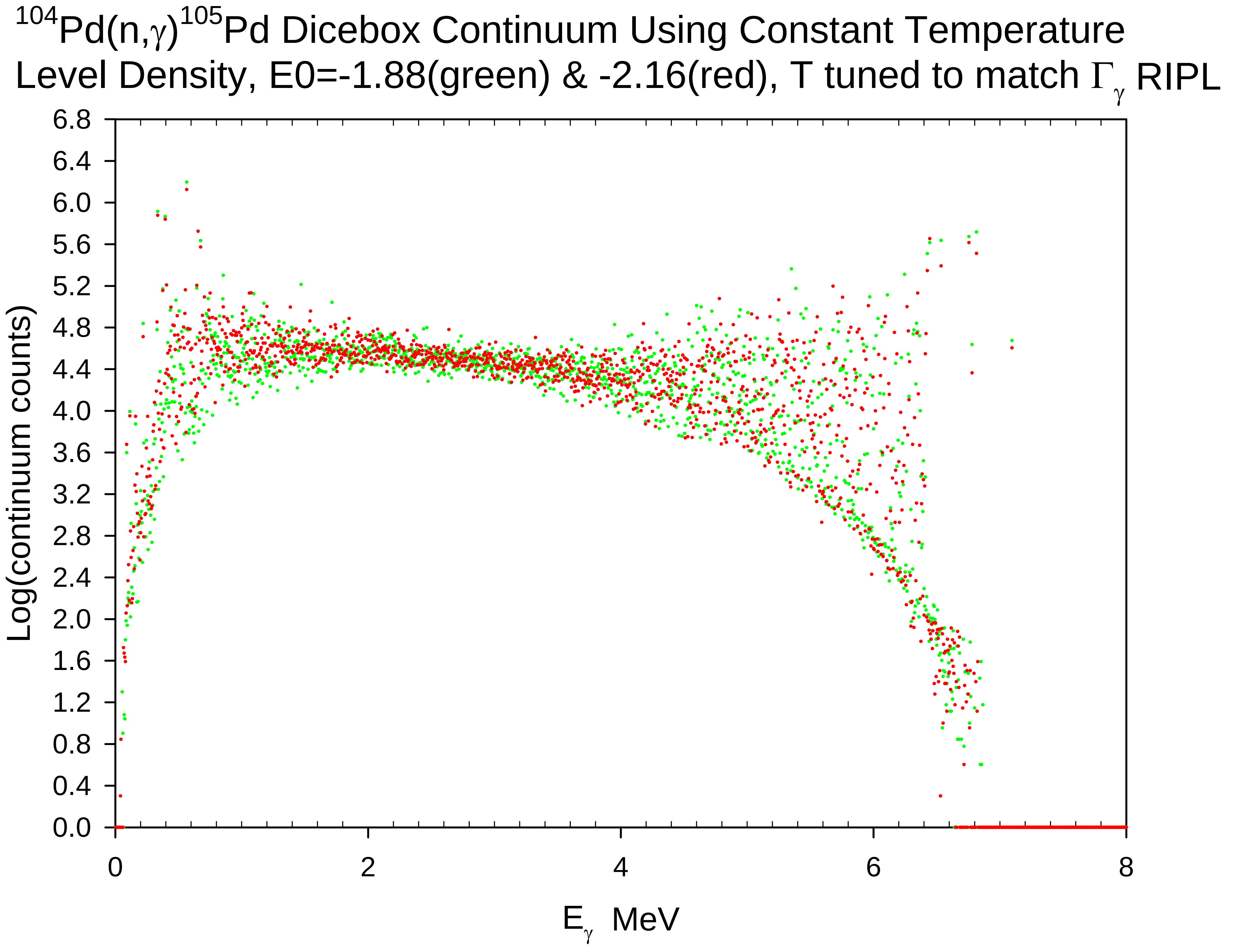
$^{104}Pd(n_{th},\gamma)^{105}Pd$ $\Gamma_\gamma$ vs Nuclear Temperature using Constant Temp Level Density Model in DiceBox w/2 Backshifts & RIPL



$^{104}$Pd(n,g)

% Cascade Feeding of 280.7 keV level vs Ecritical
KMF, KMF-BA, and GDR E1 Strength functions





$^{104}$Pd(n,γ)$^{105}$Pd Dicebox Continuum Using Constant Temperature Level Density, E0=-1.88(green) & -2.16(red), T tuned to match $\Gamma_\gamma$ RIPL
Log(continuum counts)
6.8
6.4
6.0
5.6
5.2
4.8
4.4
4.0
3.6
3.2
2.8
2.4
2.0
1.6
1.2
0.8
0.4
0.0
0
2
4
6
8
$E_\gamma$ MeV

# Conclusion

- Light Nuclei with EGAF data undergoing testing, can be built from $0^o$ libraries
- Libraries of Medium to Heavy Nuclei (Pd) in process, using DiceBox/Casino for quasi-continuum up to KeV neutron energies
- Plan to use Empire-II for higher neutron energies