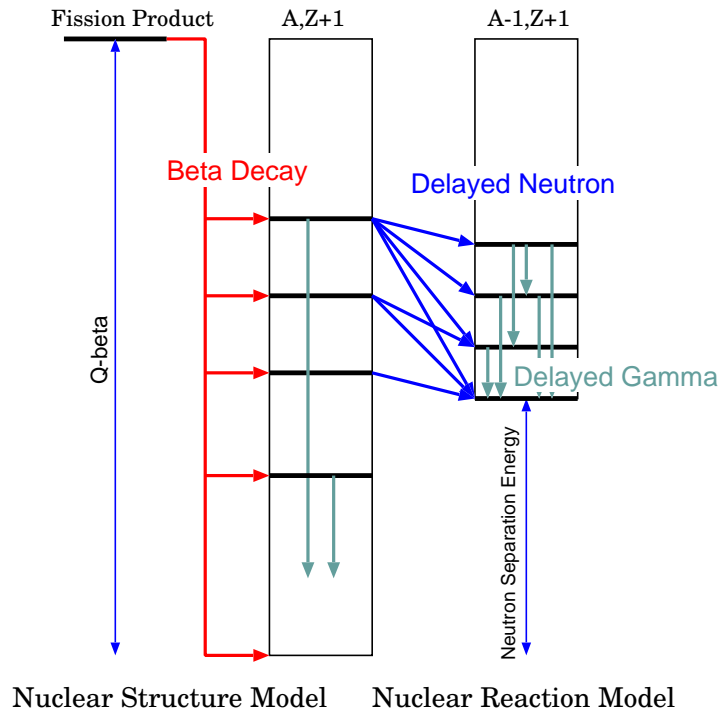


Beta-Delayed Neutron Spectra

T. Kawano, P. Möller, W.B. Willson
T-16, LANL

β -Delayed Neutron

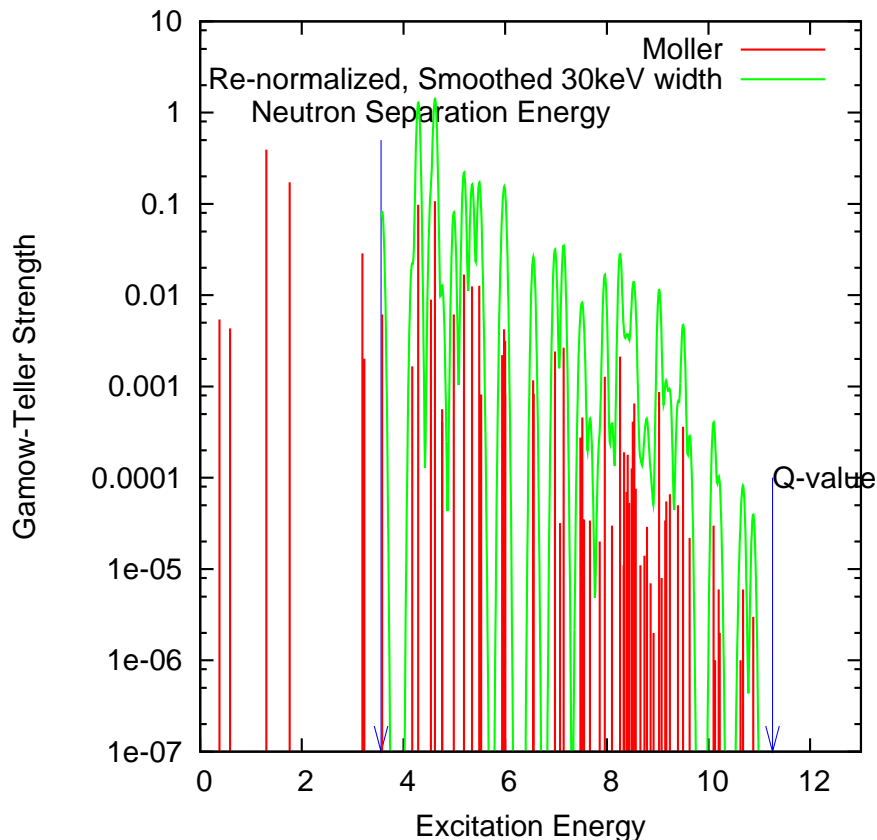


- Once fission takes place, two fission fragments (FF) emit prompt neutrons and γ -rays, and they de-excite to their ground state.
- Some fragments β -decay to more stable nuclei, and they can emit a delayed neutron if the final state excitation energy is higher than the neutron separation energy.

Theory Developed

- β -decay rate : Q_β from Möller mass model (FRDM); decay matrix element $\langle f | \beta_{GT} | i \rangle$ from (Möller) QRPA model
- neutron and γ emission range : statistical Hauser-Feshbach model
- nuclear structure data are taken from ENSDF

Data Smoothing and Re-normalization



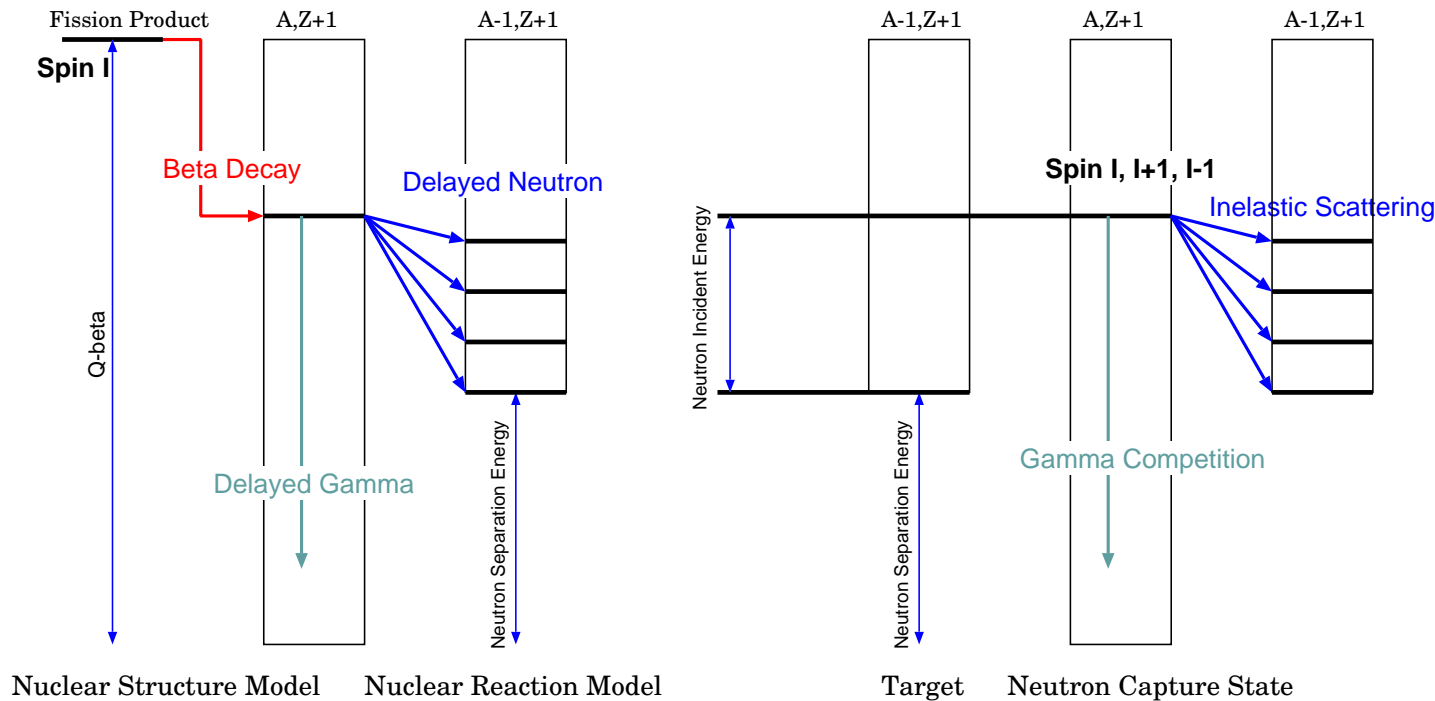
- Moller's calculation includes pairs of (E_x, b) , where E_x is the excitation energy of the daughter nucleus, and b is the branching ratio to the state.
- The strength distribution is smoothed by a Gaussian with the width Γ of 30 keV (empirical value),
- and the total strength is re-normalized by including the transitions to the state having the higher energy than the neutron separation energy S_b .

$$\rho(E) \propto \sum_i b^{(i)} \exp \left\{ -\frac{[E_x^{(i)} - (E + S_b)]^2}{2\Gamma^2} \right\}, \quad 0 \leq E \leq Q_\beta - S_b \quad (1)$$

β -Delayed Neutron Emission

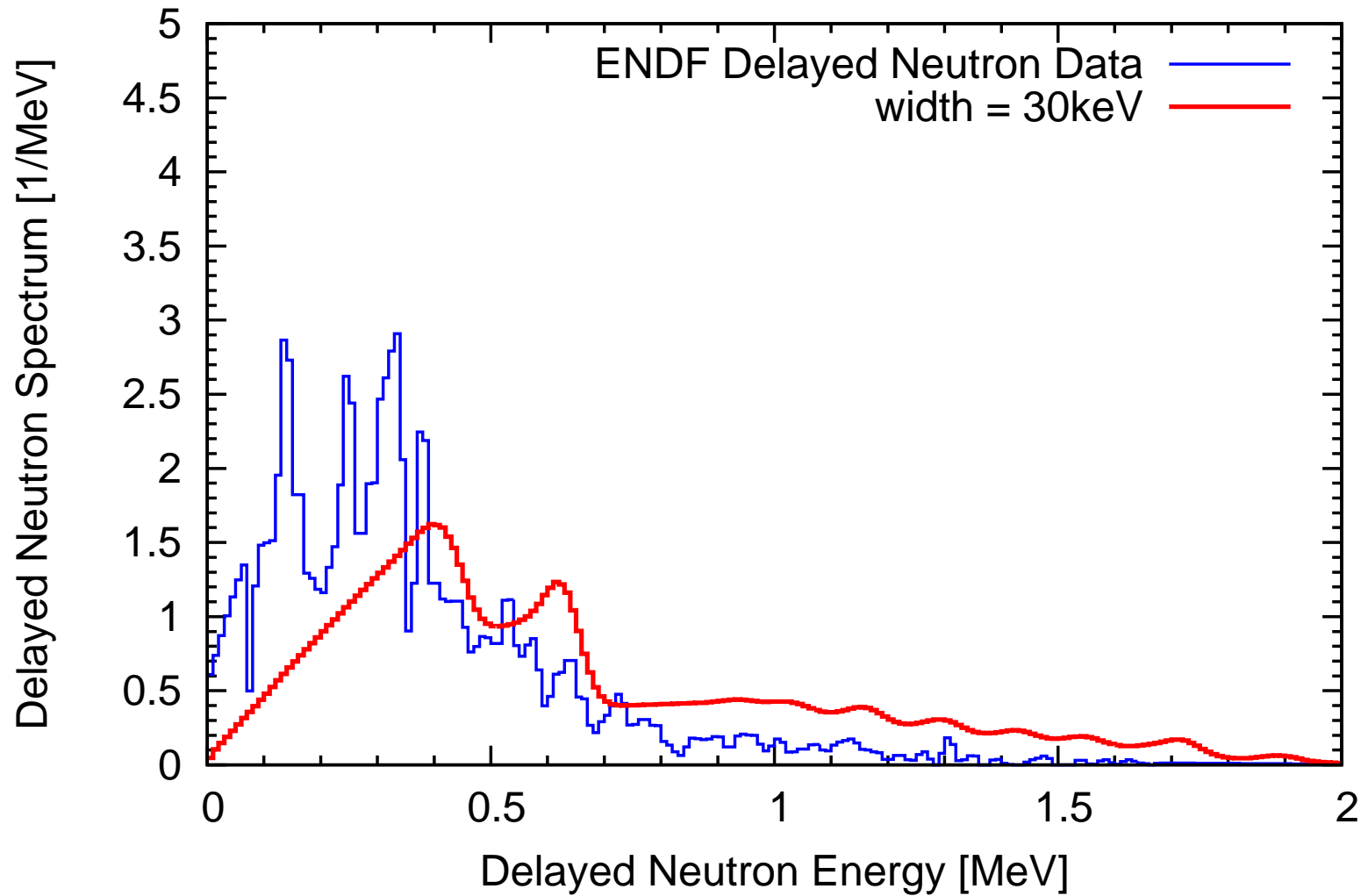
Neutron emission from the daughter nucleus

- We assume that the excited state after β -decay is a compound state, having a fixed J value, $|I - 1| \leq J \leq I + 1$, where I is the spin of precursor.
- Neutron and γ -ray emissions are calculated with the statistical Hauser-Feshbach theory (modified CoH code).
- The γ -ray emission competition is included, except for the $(n, \gamma n)$ process.

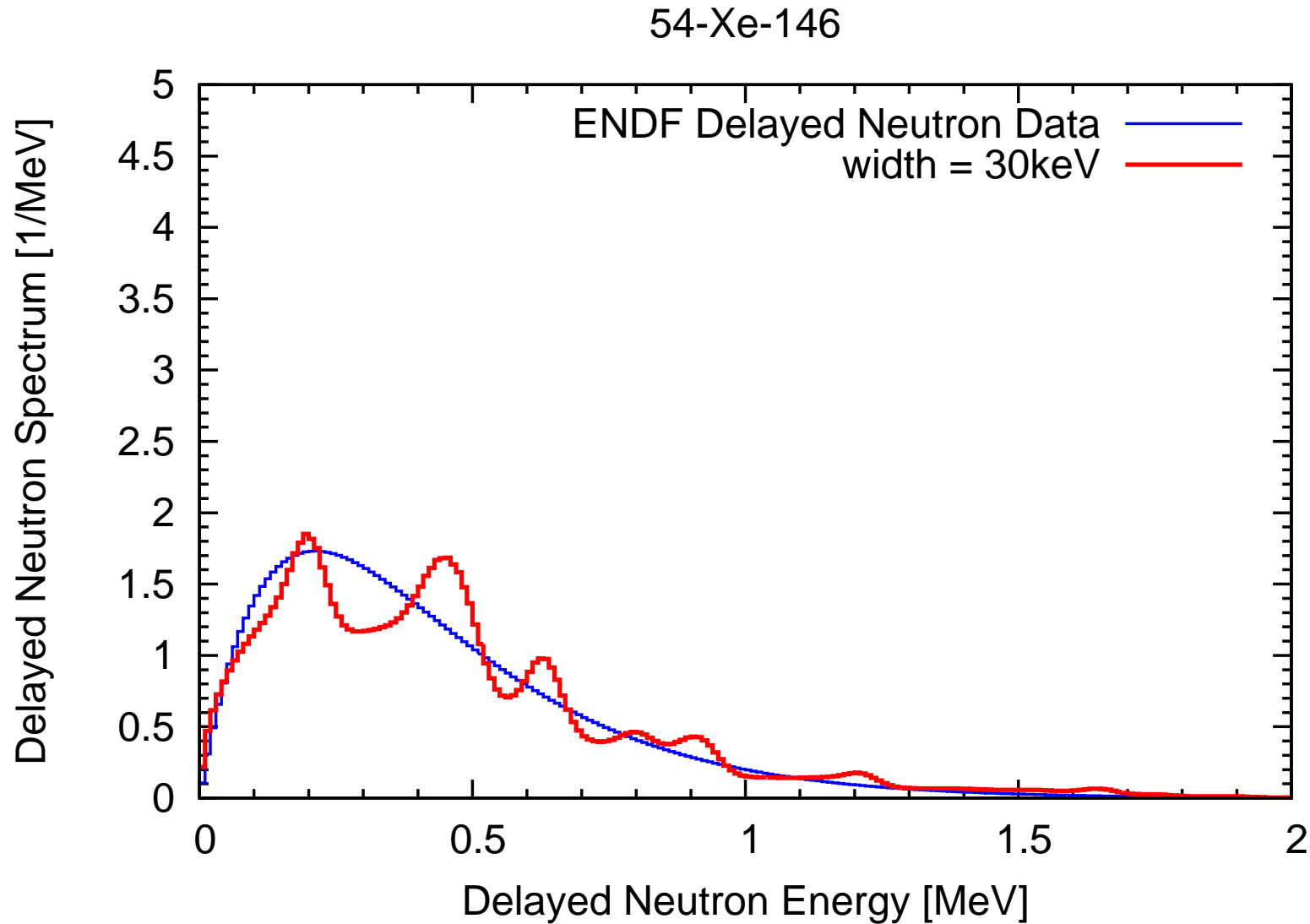


Beta-Delayed Neutron Spectra

31-Ga-81



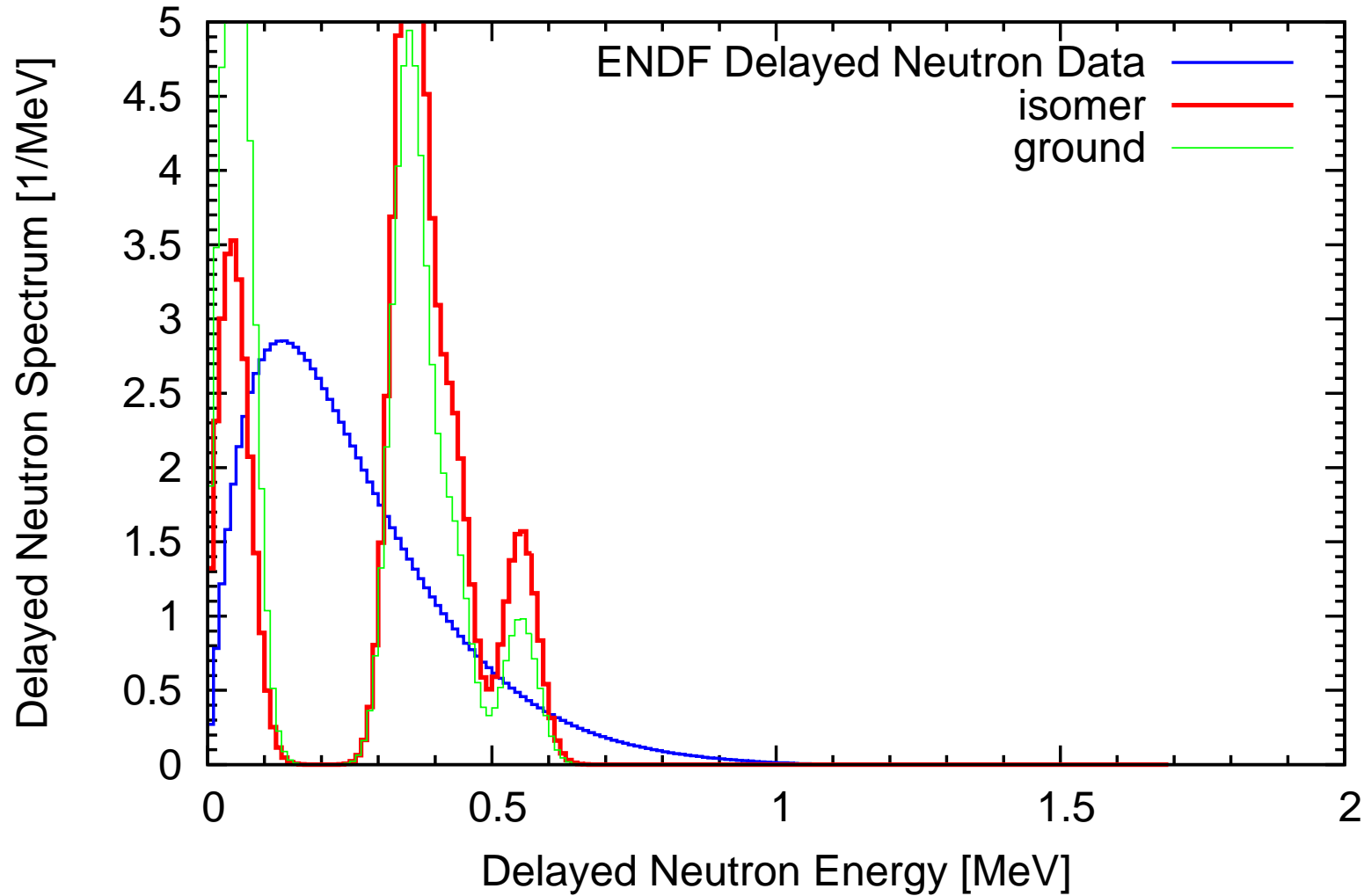
Beta-Delayed Neutron Spectra, cont'd



ENDF decay library gives a simple evaporation spectrum.

Beta-Delayed Neutron Spectra, Isomer

39-Y-97m



Number of Calculated Spectra

Total Calculations	
ground state	264
isomer	7
total	271

Adopted from ENDF	
based on experimental data	36
$Q_\beta \leq S_n$ cases	13
total	49

Plans, etc

- 271 – 49 = 222 data are newly evaluated.
- The calculated delayed neutron spectra, which are purely theoretical predictions, agree with those evaluations in the ENDF decay-data library that are based on experimental data.
- The delayed- γ calculations in progress
 - A new code CGM (Calculation of Gamma Multiplicity)
- The same technique can be applied to calculate the β -delayed fission process.