EMPIRE: Advanced tool for nuclear reaction data evaluation

(EMPIRE version: 2.19beta, Lodi)

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http://www.nndc.bnl.gov/nndcscr/model-codes/empire-ii/

Developers

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Highlights

- broad range of energies (~1 keV - 200 MeV) and projectiles (n, p, ...)
- most important nuclear reaction models with ensured 'idiot proof' compatibility
- input parameter library (RIPL-2)
- recoils' spectra (emission and excitation energy correlations taken into account)
- ENDF-6 formatting (EMPEND)
- utility codes (ENDF-6 verification)

Highlights (cont.)

- automatic retrieval of experimental data from EXFOR
- interactive plots of experimental and calculated results
  - excitation functions
  - angular distributions
  - inclusive emission spectra for n, p, alphas, and gammas
  - double differential spectra

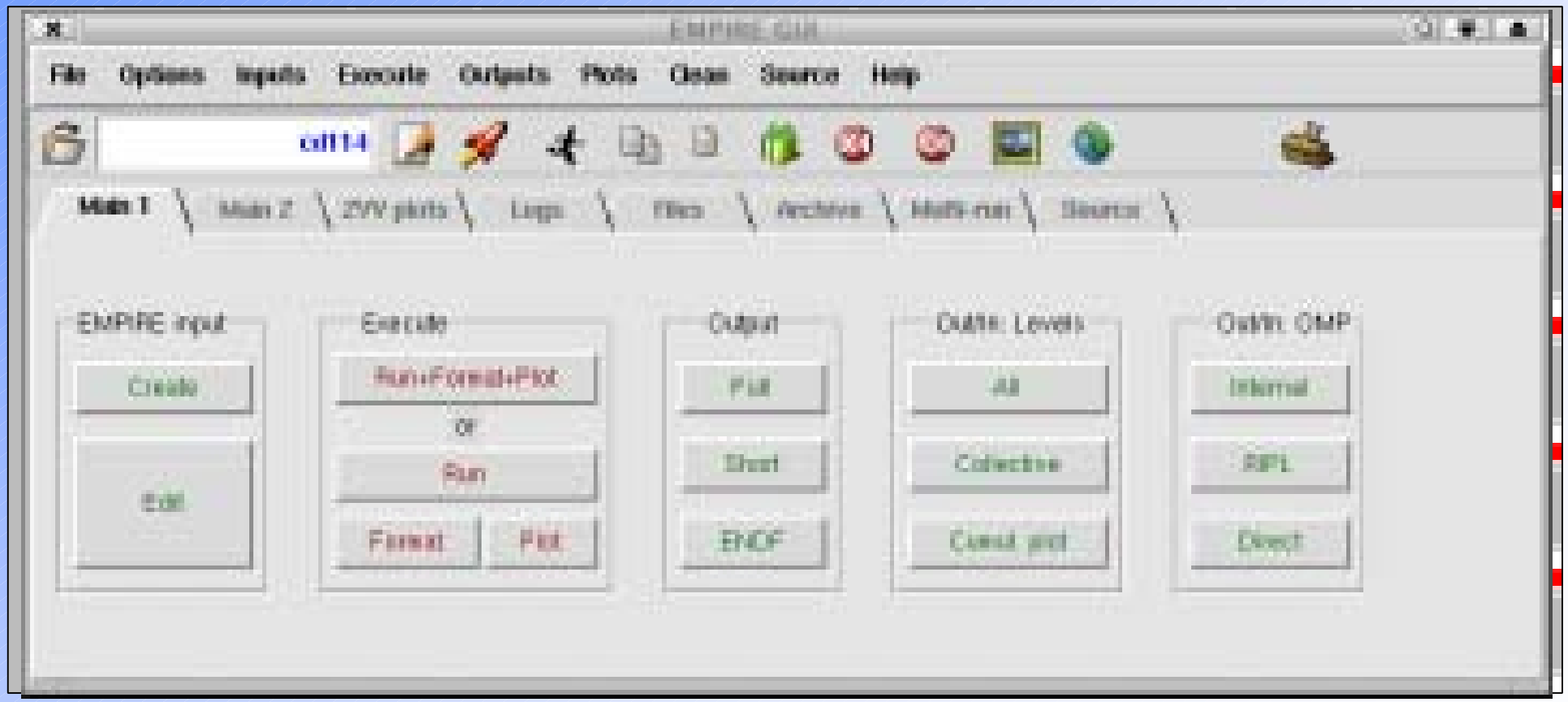
Reaction mechanisms

- spherical optical model (SCAT2), deformed (ECIS)
- Hauser-Feshbach model with full gamma-cascade and dynamical deformation effects
- HRTW (widths fluctuations)
- state of art fission channel (three-hump barrier)

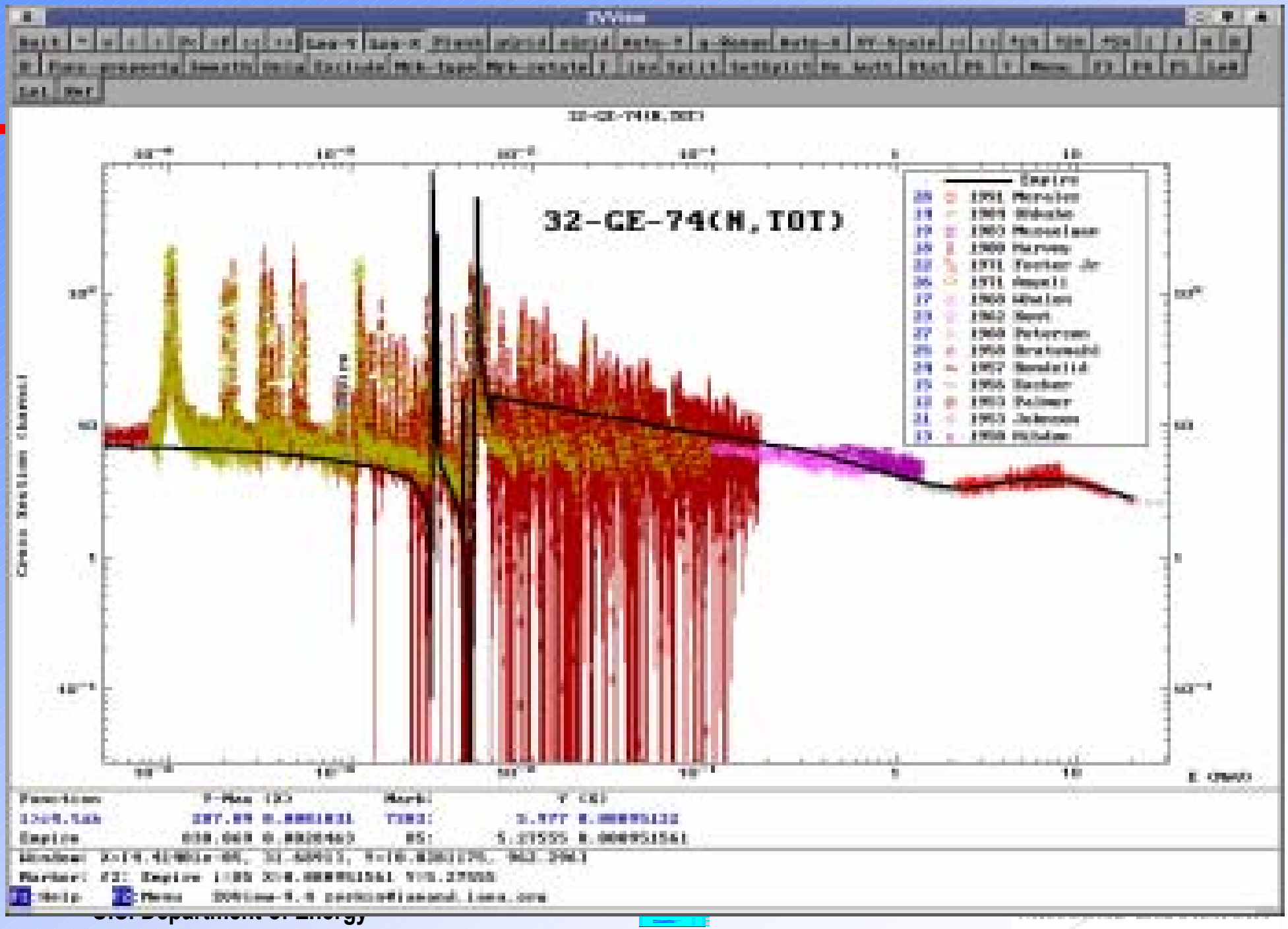
Reaction mechanisms (preequilibrium)

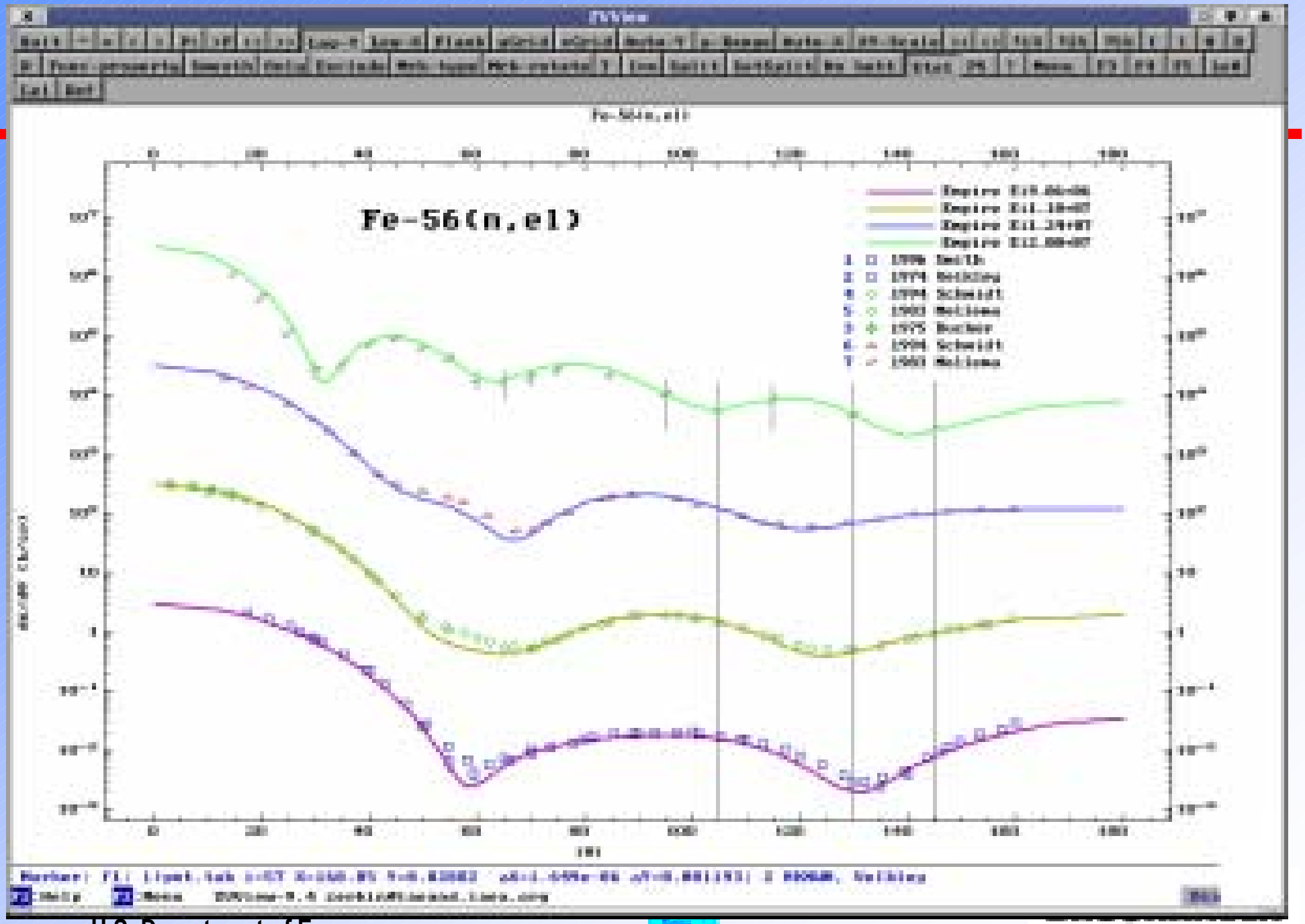
- Multistep Direct (ORION + TRISTAN)
- Multistep Compound with gamma-emission
- Exciton model (DEGAS & new module for cluster emission according to Harada (to be implemented))
- Monte Carlo preequilibrium (DDHMS)

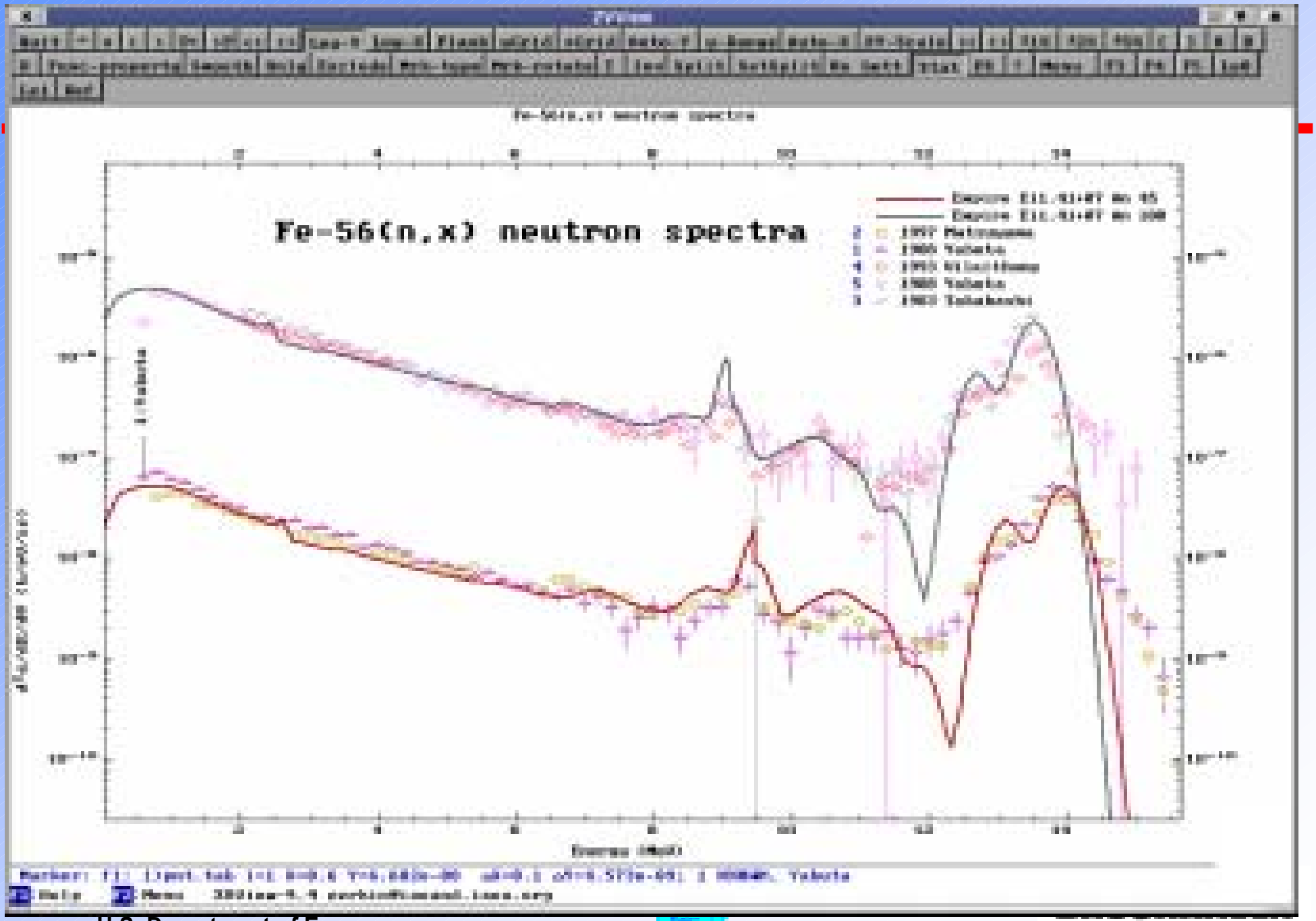
GUI (Main 1)


File
Options
Inputs
Execute
Outputs
Plots
Clean
Source
Help
Main 1
Main 2
2VV plots
Logs
Files
Archive
Multi-run
Source
EMPIRE input
Create
Edit
Execute
Run+Format+Plot
or
Run
Format
Plot
Output
Full
Short
ENDF
Out/In: Levels
All
Collective
Coarse grid
Out/In: OMP
Internal
RIPL
Direct

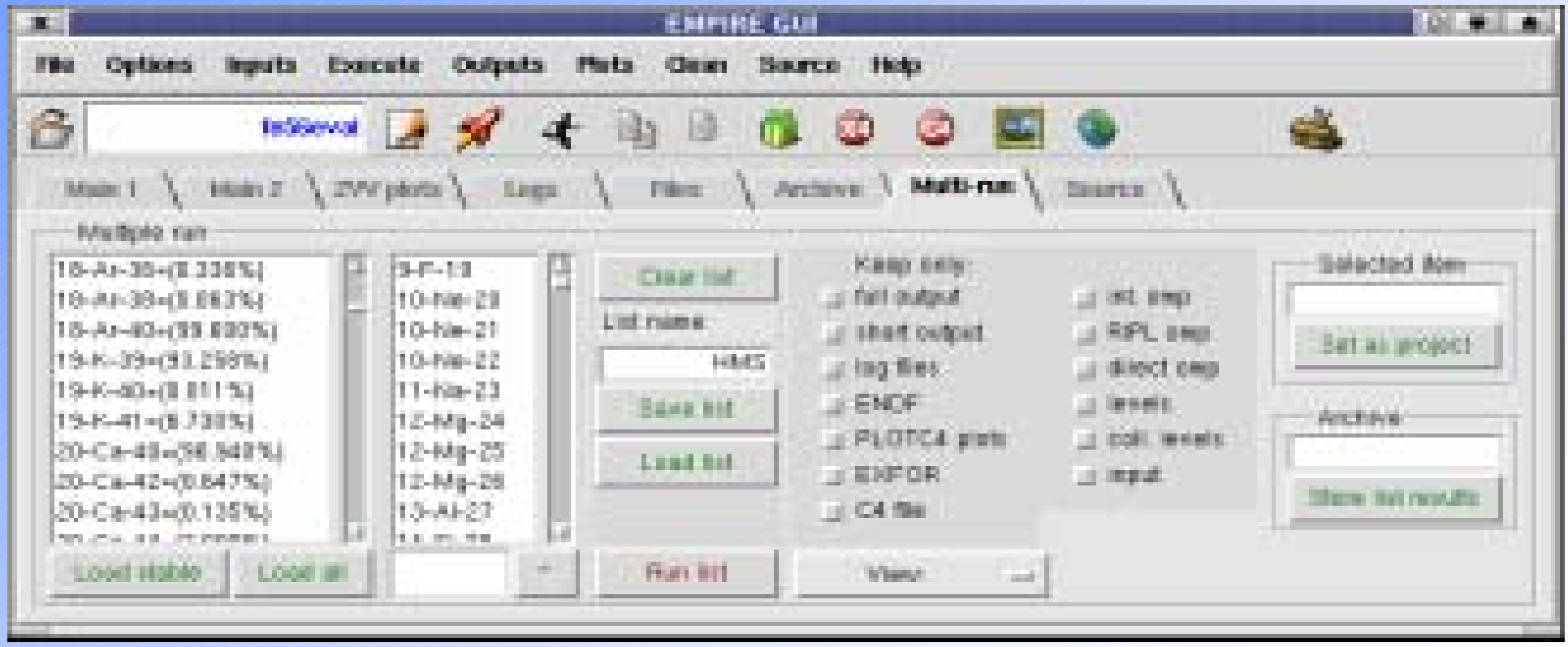
GUI (ZVV plots)


32-CE-74(N,TOT)
Empire
1951 Mercier
1949 Bidwell
1963 Musselman
1969 Harvey
1971 Fowler Jr
1971 Angeli
1969 Whelan
1962 Hunt
1969 Peterman
1959 Brotzmann
1957 Randolph
1956 Barbour
1953 Palmer
1953 Johnson
1958 Nicholas
Cross Section (barns)
E (MeV)


Fe-56(n,el)


Fe-56(n,x) neutron spectra

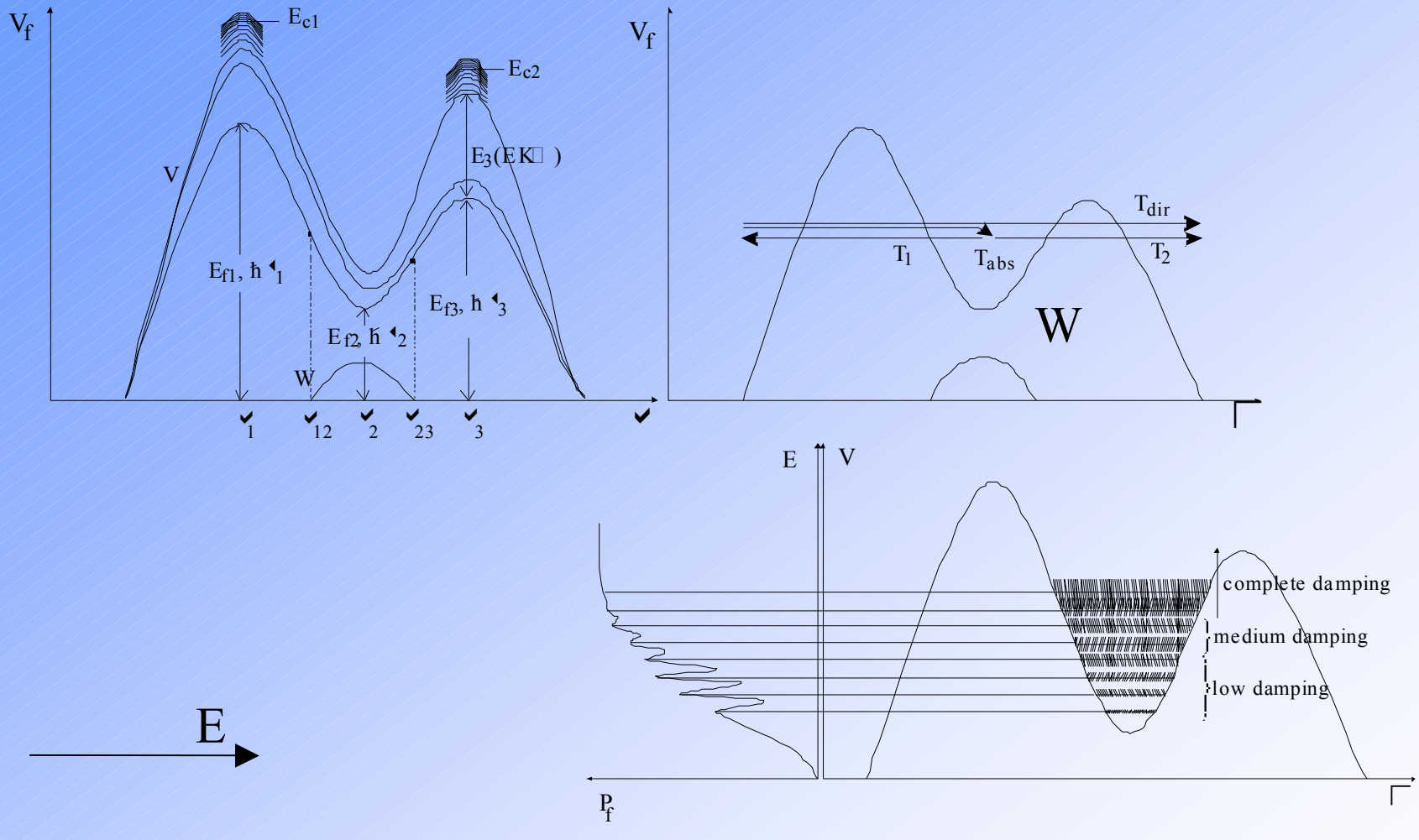
GUI (Multi-run)



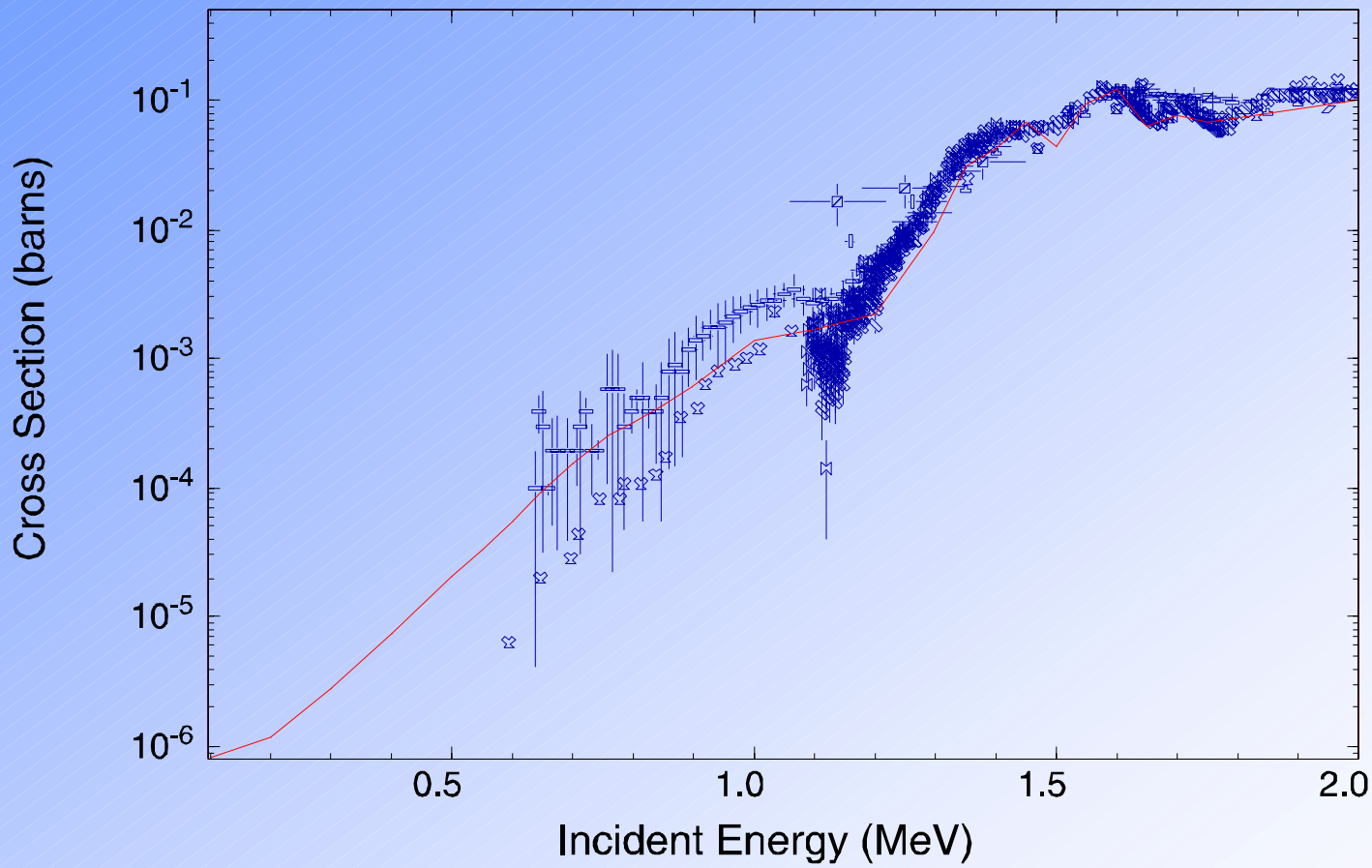
Recent developments (2.19 Lodi)

- merging resonance parameters into the final ENDF file
- GUI assisted OMP fitting
- exciton model for cluster emission (Harada) (to be implemented)
- new algorithm for calculation of exclusive spectra
- new fission channel (including optical model for fission through three-hump barrier)

Optical Model for fission



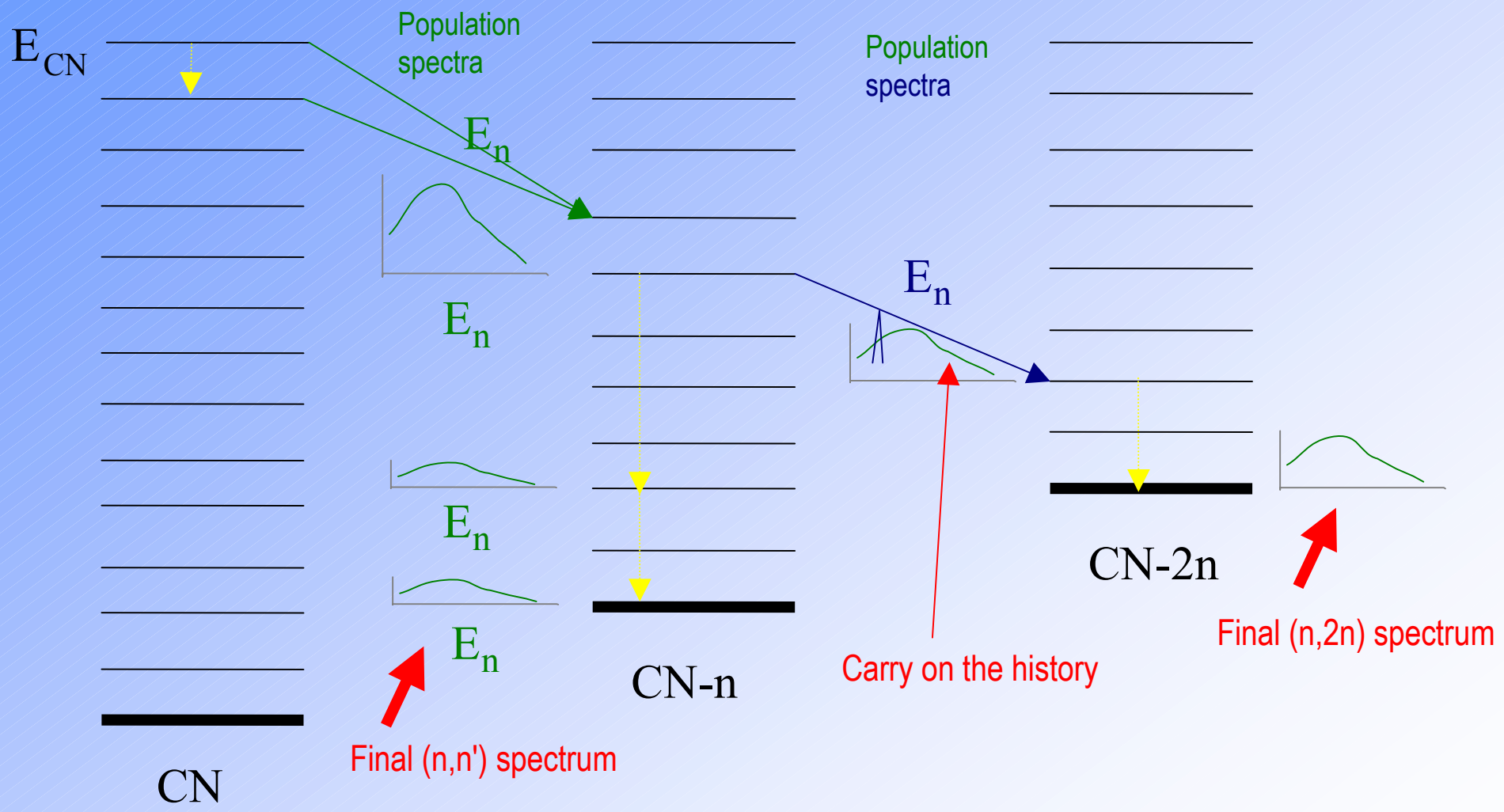
Fission cross sections on 232-Th calculated with sub-barrier effects (preliminary results)



Exclusive spectra in EMPIRE-2.19

- ENDF/B-6 format requires **exclusive** spectra for each reaction
- Reaction codes calculate **inclusive** spectra
- EMPIRE-2.18 used 'no gammas before particle emission' approximation for spectra deconvolution => possibility of negative spectra at higher incident energies
- New method developed for EMPIRE-2.19 follows evolution of 'population spectra' through the cascade => exact, no limitation on number of emissions

Exclusive spectra in EMPIRE-2.19

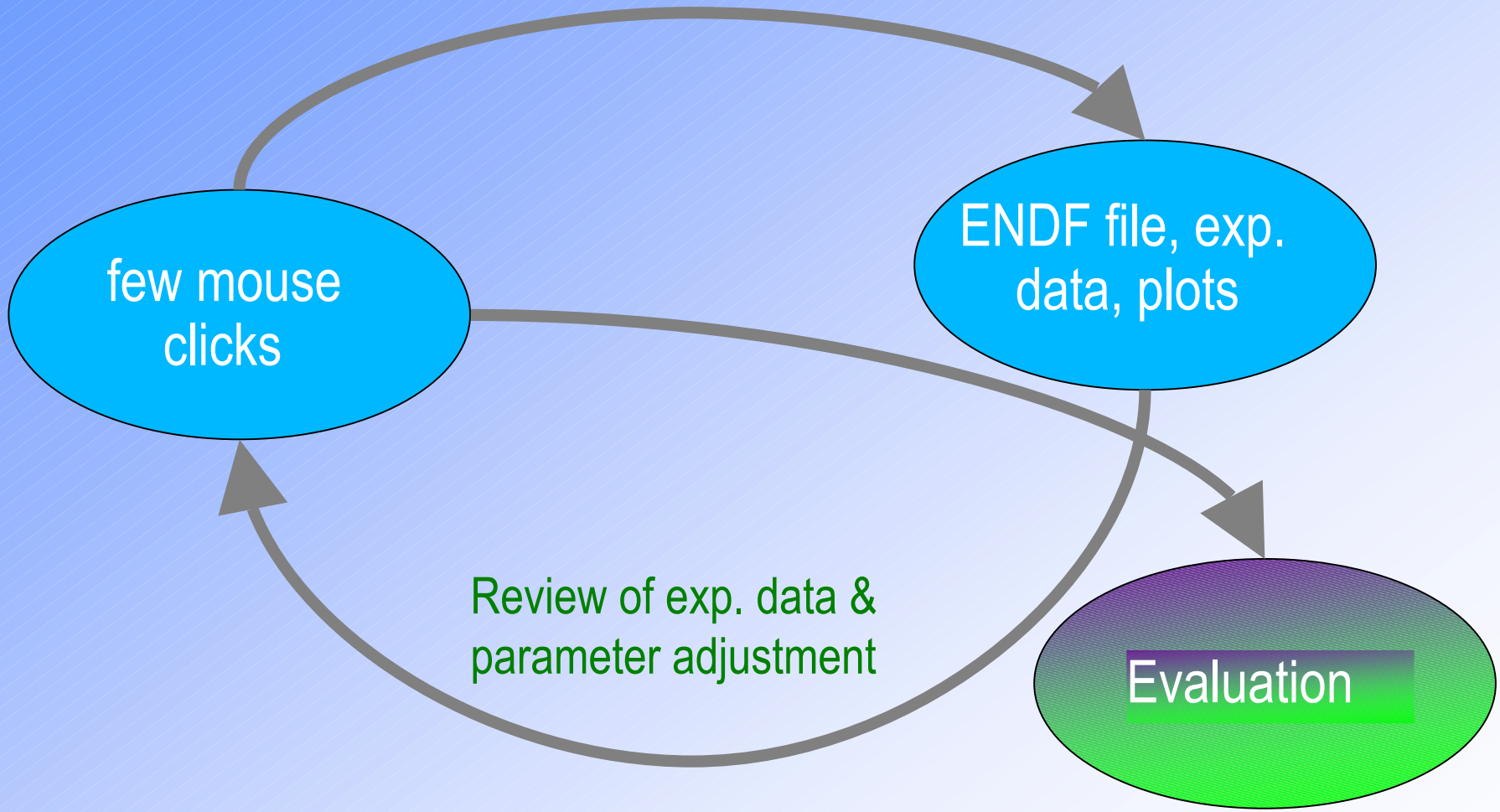


Conclusions

EMPIRE-II is a comprehensive tool for evaluation of nuclear reactions:

- complete set of nuclear models
- extensive library of input parameters based on RIPL-2
- GUI
- experimental data retrieval and plotting
- utility codes for ENDF formatting and file verification

Result


few mouse clicks
ENDF file, exp. data, plots
Review of exp. data & parameter adjustment
Evaluation