united nations educational, scientific and cultural organization

international atomic energy agency

the **abdus salam** international centre for theoretical physics

ICTP 40th Anniversary

SMR.1555 - 37

**Workshop on
Nuclear Reaction Data and Nuclear Reactors:
Physics, Design and Safety**

16 February - 12 March 2004

WIMS Nuclear Data Libraries

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WIMS Nuclear data Libraries

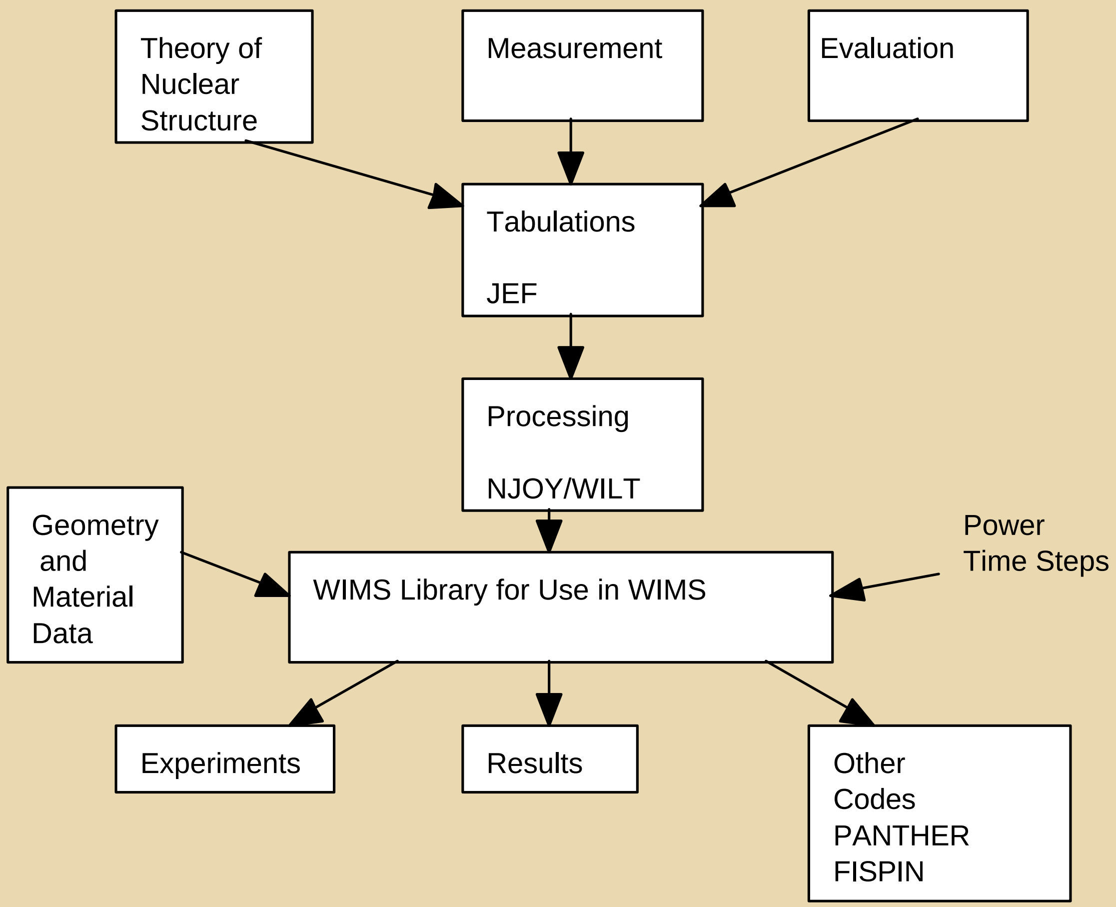
Nuclear Data Libraries

- Transport properties of nuclides tabulated on a library
- Library read from but never written to by WIMS
- Can be interpreted as table of probabilities
- WIMS treats problem as in Classical Mechanics
- Quantum effects are incorporated in the generation of the library

Basic Definitions

- 2 Major Processes
- Nuclear Processes - Quantum Mechanics
- Particle Migration and Multiplication - Classical Mechanics
- Both in WIMS- Library and Code

Processes in Reactor Physics



Data requirements - Reactions

- Cross Sections
- Resonance Parameters - Widths and Partial Widths
- Scatter Data $S(a, b)$
- Fission Spectra
- Delayed Neutron Data

Types of Reaction

- 4 Classes - Capture(Absorption), Transport, Scatter, Fission
- Capture Includes (n,gamma), (n,alpha), (n,p), (n,2n), plus others
- Down Scatter only above 4eV -Phonon model below 4eV
- Fission includes yield/fission and Spectrum

Nuclear Data Libraries

- Point Data - Monte Carlo
  -13,000 groups
- Group Data - Deterministic and Monte Carlo
  -69 and 172 groups

History of Nuclear Data Libraries

- Pre 1986 - United kingdom Nuclear Data Library (UKNDL)
- Files at either 0K or 300K
- Processing by many codes
- Further processing for important nuclides (U^{238} H in water)

History of Nuclear Data Libraries (cont)

- 1981 Data adjustment
- Graphite and H2O moderated experiments
- 1986 more adjustment
- 14 nuclides from JEF1
- Adjustment on resonance integral

Brief History

- First Library - WIMSD
  - designed for 1970’s
  - limited size
  - limited scope - P1 data for 4 nuclides
  - sequential structure
- Second Library - WIMSE
  - More general structure
  - size not limited - 1980’s machines
  - Sequential structure

Brief History

- Latest library - Datagram
  - Very general structure
  - Easy to extend
  - Random access structure
  - Photon and Neutron data
  - More reactions - (n,2n)
  - Branching ratios

JEF2 Library

- New WIMS library based on JEF
- Uses NJOY processing code

Structure of Data

- Up to 7 reactions for all nuclides
  - 1.Absorption
  - 2. Transport
  - 3. Scatter
  - 4. Fission plus yields
  - 5. Effective potential scatter $l \; s_{p}$
  - 6. Mean lethargy increase per collision x
  - 7. n,2n

Structure of Data

- Cross sections in 3 energy ranges
  - Fast 20 MeV to 9 keV
  - Resonance 9 keV to 4 eV
  - Thermal 4 eV to 0
- Can be a function of temperature
- At resonance energies - Table of resonance integral by temperature and potential scatter

Group Structures

	69 Groups	172 Groups
Fast	14	45
Resonance	13	47
Thermal	42	80

Production of Nuclear Data Library

- Convert data from tabulations to pointwise data
- Convert data to values at a given temperature
- Include corrections for the unresolved resonances
- Convert scattering data to scattering matrix
- Select nuclides to be represented on library

NJOY Functions

- RECONR - reconstruction of point energy variation of cross section
- BROADR - Doppler broadening of the resonance cross sections
- UNRESR - Shielding of data in the unresolved region
- THERMR - Generation of scattering data from phonon spectra

Resonance Reconstruction

- Single level Breit-Wigner representation (SLBW)
- Multilevel Breit-Wigner Representation (MLBW)
- Adler-Adler Representation (AA)
- Reich-Moore Representation (RM)
- Hybrid R-Function Representation (HRF)

Doppler Broadening (1)

- Increase in temperature broadens resonances
- Broader resonances have increased resonance integral
- Tabulate resonance integral against temperature

Doppler Broadening (2)

The effective cross section for a material at temperature T is defined to be that cross section that gives the same reaction rate for stationary target nuclei as the real cross section gives for the moving nuclei

Doppler Broadening (3)

$$r v \overline{s}(v,T) = \int dv' r \left|v - v'\right| s\left(\left|v - v'\right|\right) P(v',T)$$

$$P(v',T)\,dv' = \frac{a^{3/2}}{p^{3/2}} \exp\left(-a v'^{2}\right) dv'$$

$$a = \frac{M}{(2kT)}$$

Unresolved Resonances

- Difficult to distinguish between resonances
- Define shielding effect
- Choose a value for background scatter and shield using this

Scattering Models

- Determined by the structure of the scattering material
- Free gas model - no interatomic binding
- Phonon model e.g. graphite
- Explicit structural model - all modes of oscillation

Scattering Law

$$S(a, b)$$

$$a = \frac{E' + E - 2m\sqrt{EE'}}{AkT}$$

$$b = \frac{E' - E}{kT}$$

Group Averaged Cross section

$$\int \sigma \phi dE / \int \phi dE$$

for absorption and fission

Group Averaged Cross Section

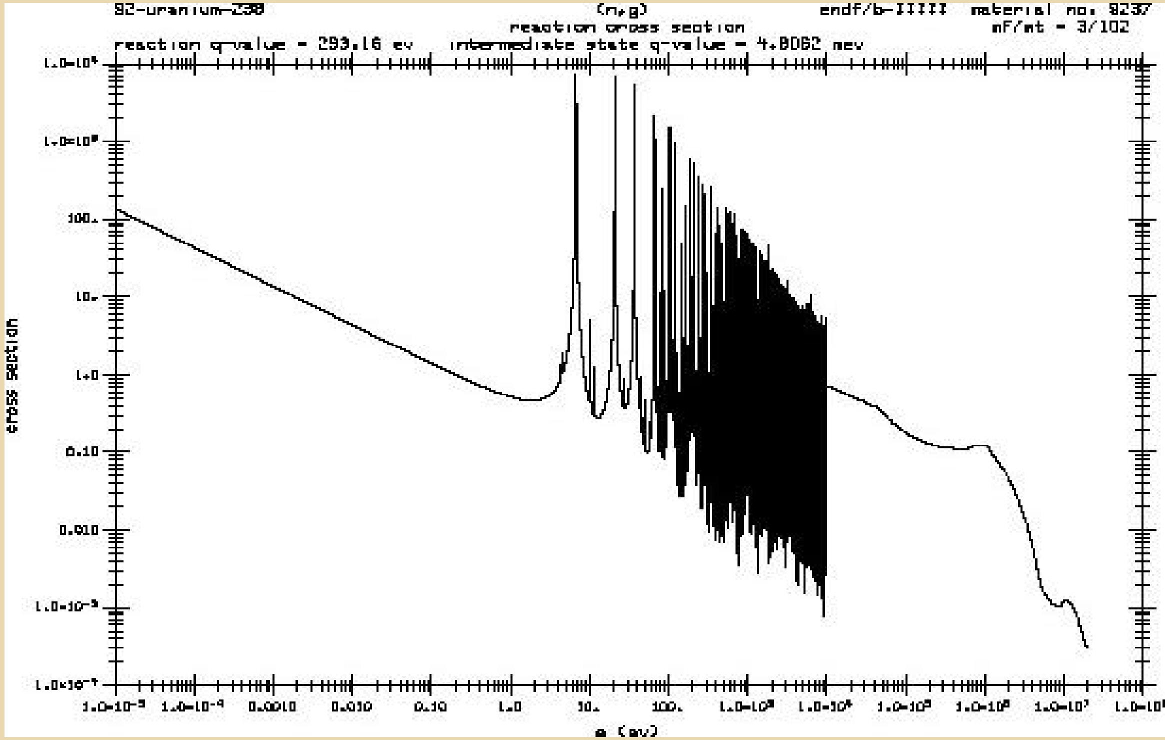
$$\int \int s(E' \to E) f(E') dE dE' / \int f(E') dE'$$

for scattering

Calculation of Flux

- Function of cross section
- Varies between energy ranges
- Input analytic solution
- Calculate effect of resonances

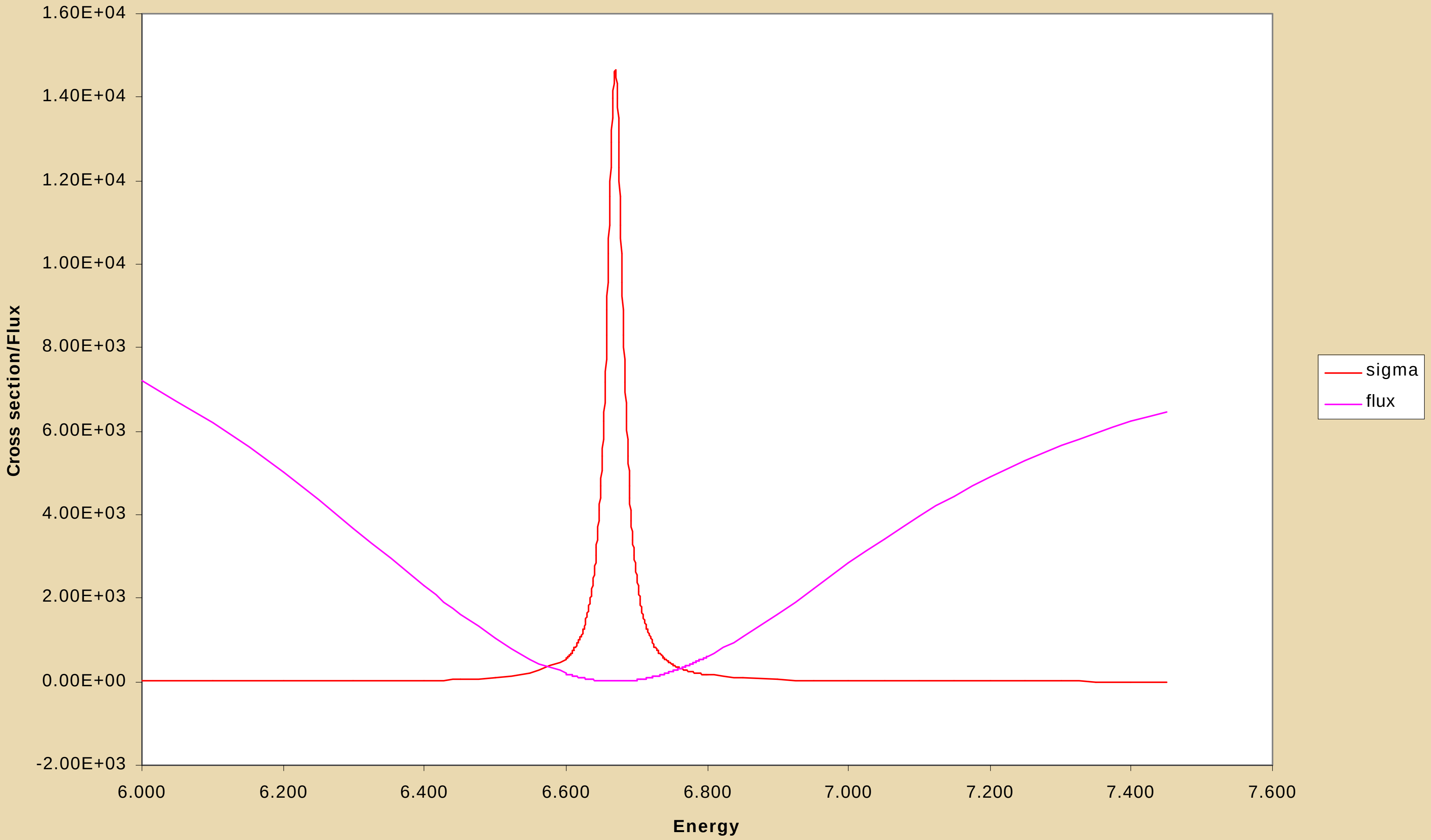
U238 Capture Cross Sections



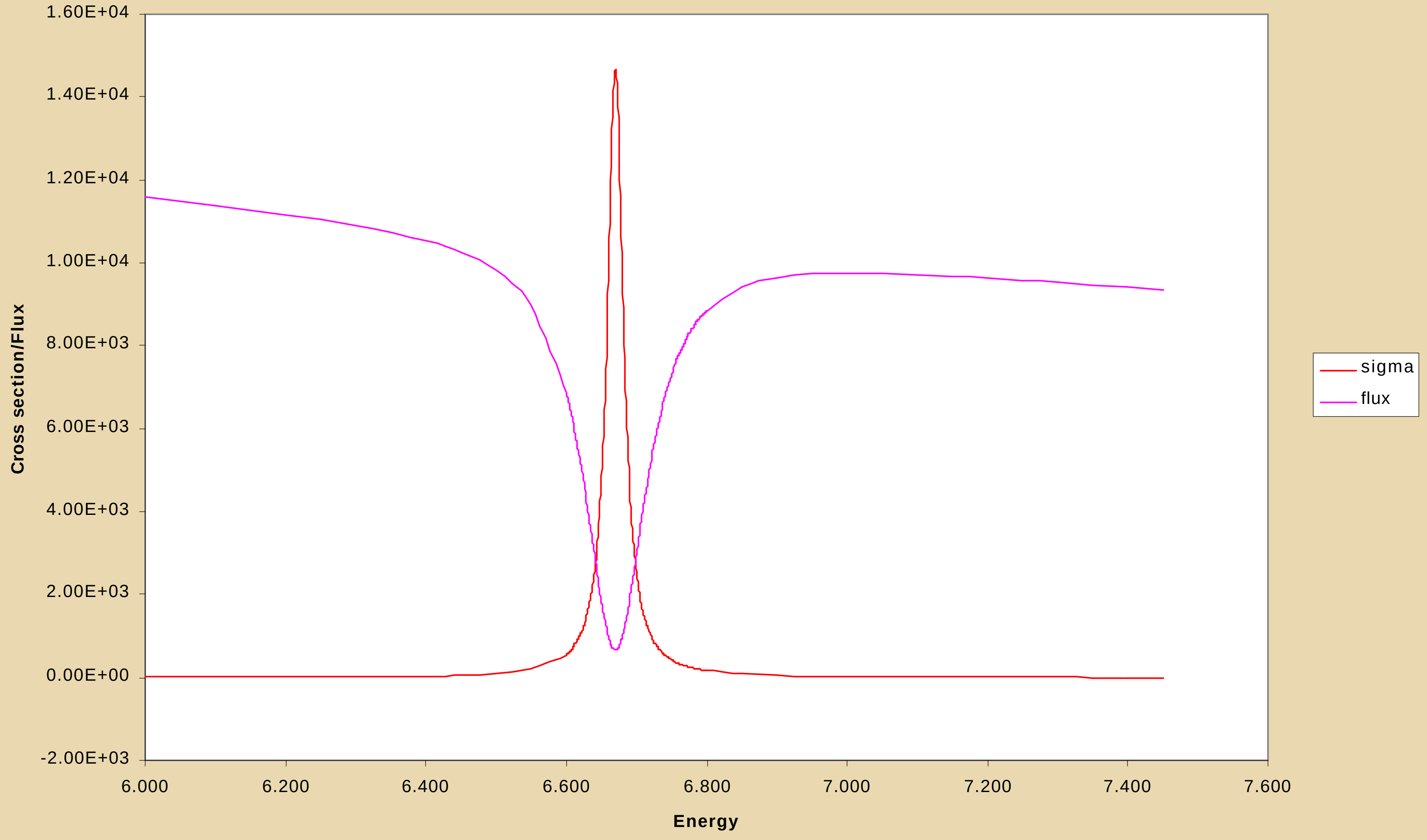
Cross Section

e (eV)

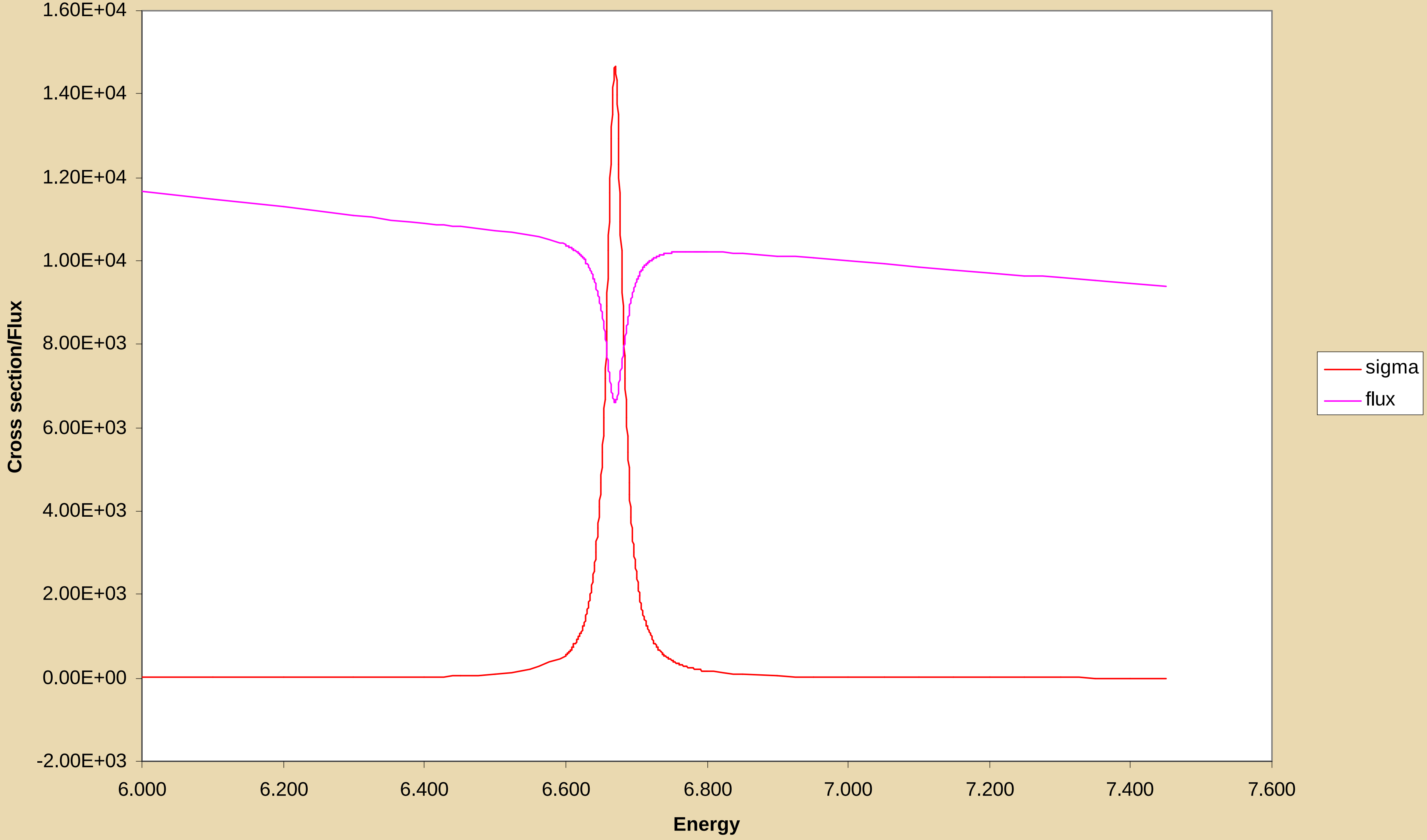
Fully Shielded



Medium Shielding



Low Shielding



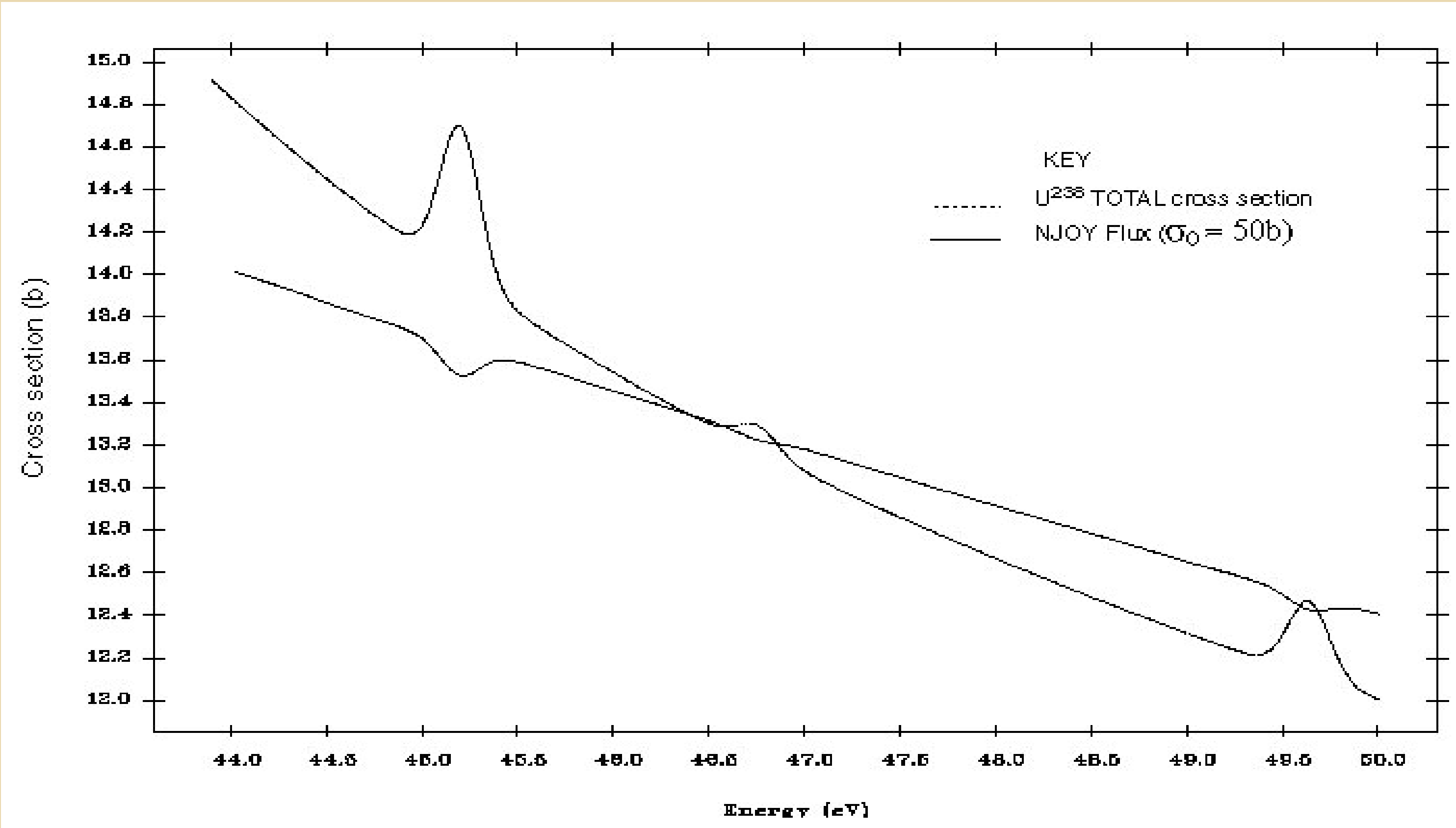
Resonance Flux Solution

- Homogeneous mixture of Hydrogen and Nuclide
- Calculate flux from slowing down equations
- Above 500eV use Bondorenko flux
- Carry out for range of effective scatter cross sections

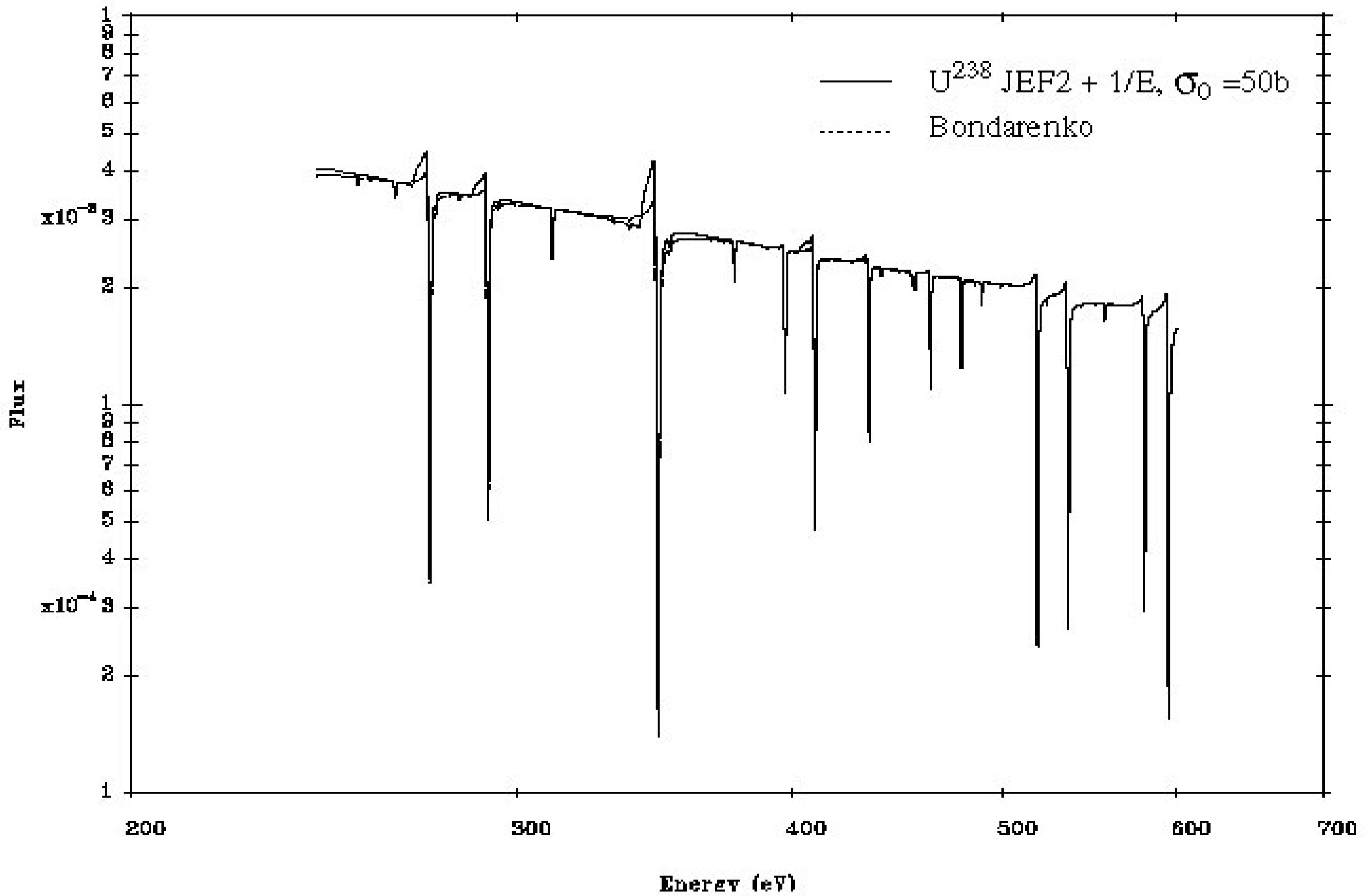
Tabulation of resonance Integrals

- Carry out calculations for range of S_p
- The potential scatter is scatter cross section outside resonances
- Tabulate results of resonance integral against potential scatter

U^{238} Total Cross Section & Flux



Flux from Bondarenko & NJOY



Interpolation

- Normally linear with temperature
- Exceptions at resonance energies
- Temperature as $\sqrt{T}$
- Potential scatter more complex
- Depends on ratio of RI to infinite dilute Value
  - 1/ s_p for values >0.95
  - 1/ $\sqrt{s_p}$ for values >0.8
  - Log (s_p) for values > 0.5
  - $\sqrt{s_p}$ for values < 0.5
- Required for Doppler and Shielding