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Evaluation Work at KAERI

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3. **New Evaluation on n+^{182,183,184,186}W**

Background: Neutron Capture Gamma Ray Spectra

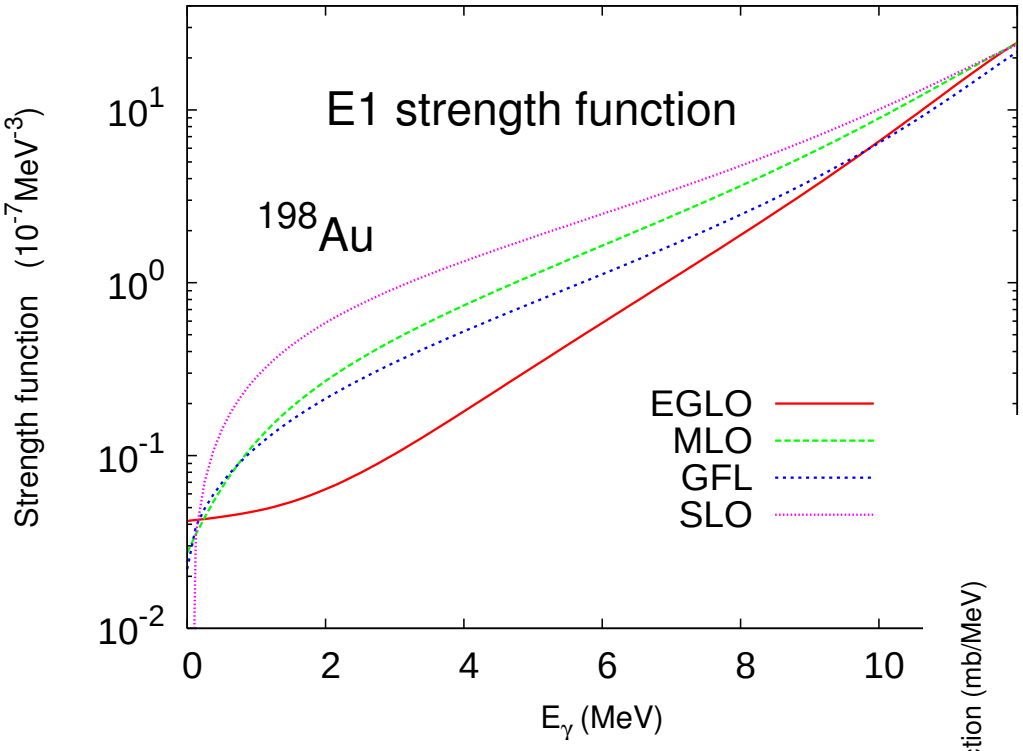
Calculation is based on
- Hauser-Feshbach statistical model
- **Gamma-ray strength function**
- Nuclear level densities

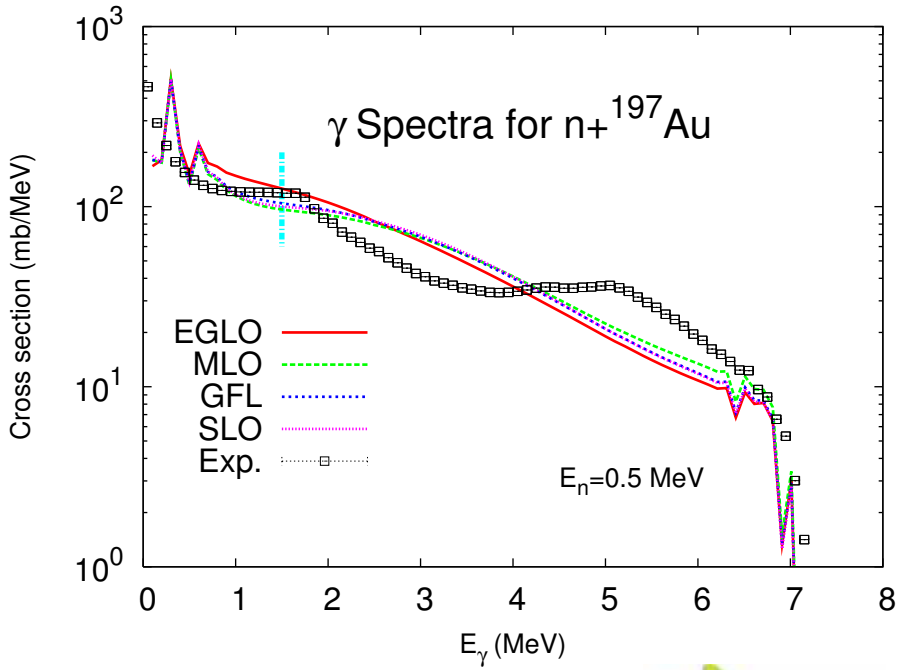
- ✓ **Photonuclear data for Giant Resonance**
  - ✓ Standard Lorentzian (SLO) :
  - ✓ Enhanced Generalized Lorentzian (EGLO)
    - ➢ Modified Lorentzian (MLO)
    - ➢ Generalized Fermi Liquid (GFL)

  ⇒ Insufficient to describe the gamma-ray strength function below nucleon binding energy

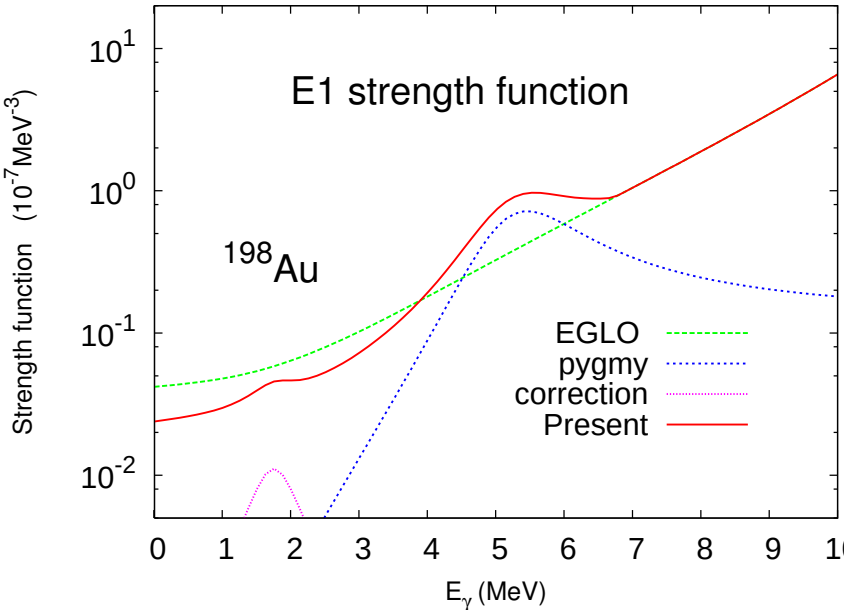
- ✓ **Measurements of Capture gamma-ray spectra**
  - ✓ Improve gamma-ray strength function
  - ✓ Reasonable estimation for gamma-ray spectra for nuclides with no experimental data.

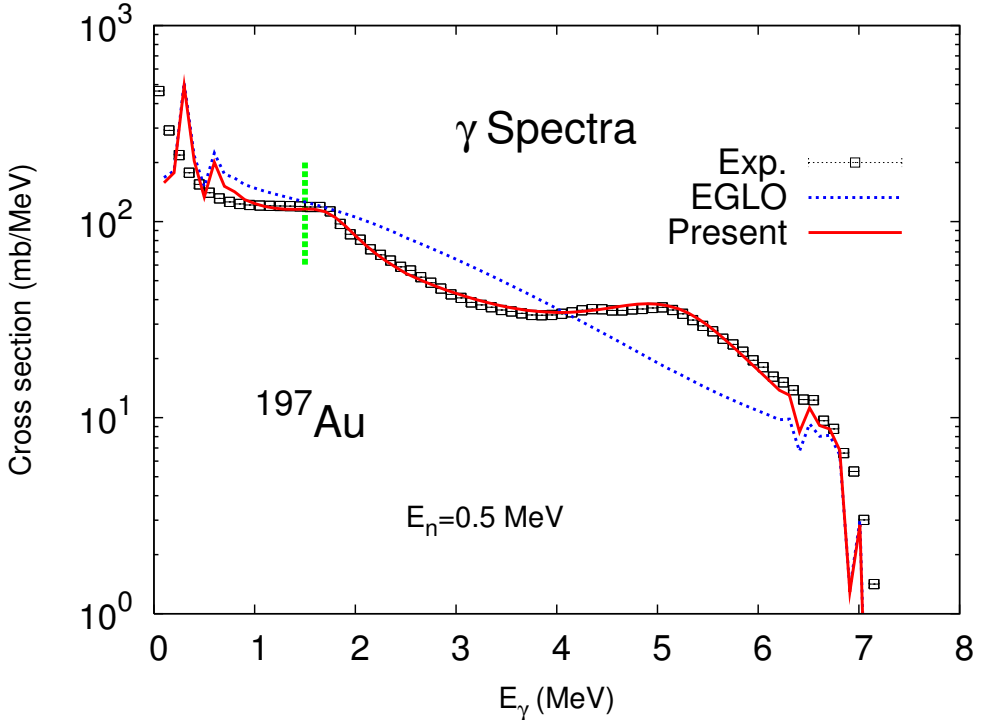
Gamma-ray Strength function & Spectrum



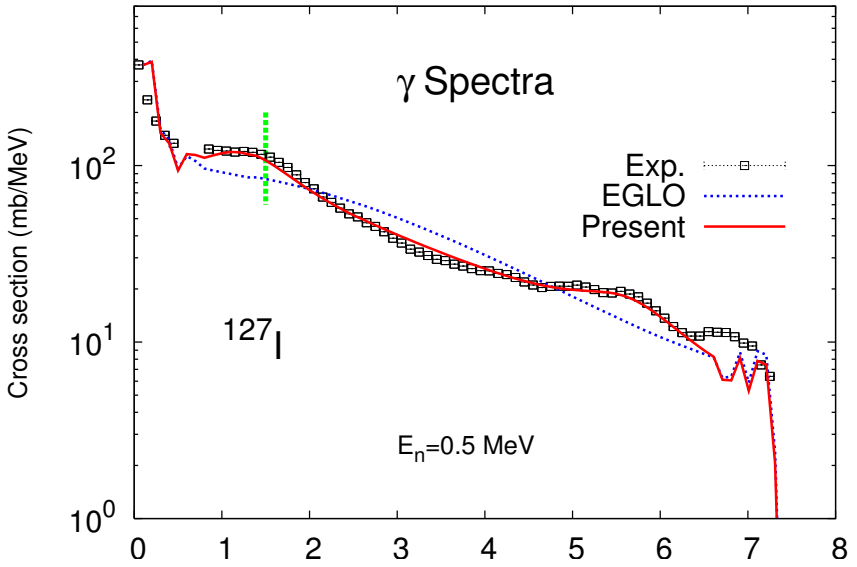


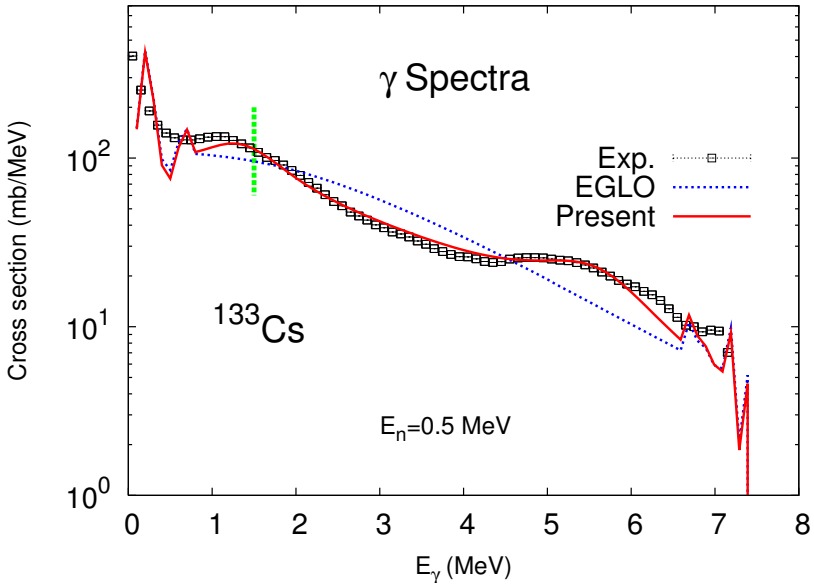
Pygmy Resonance

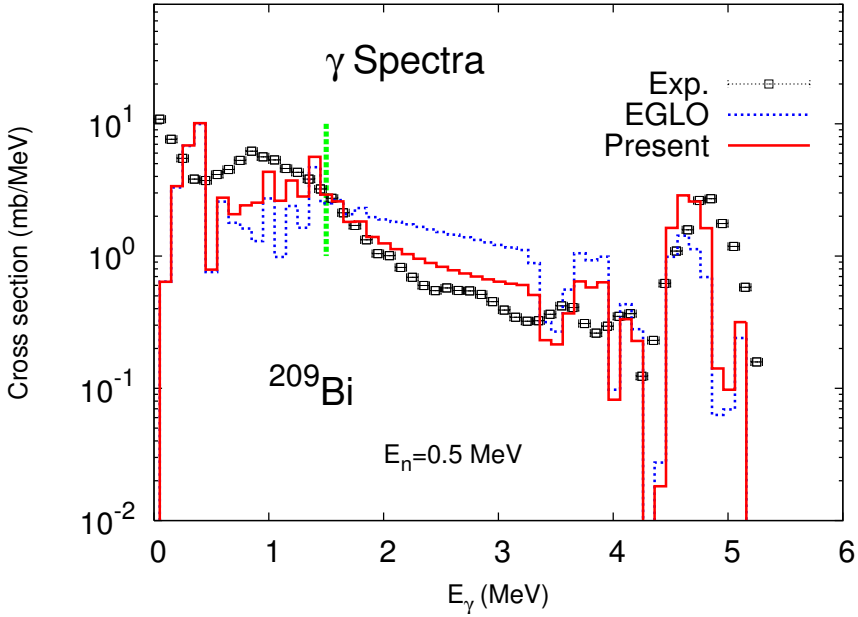




Neutron Capture Gamma-ray Spectra







Future Work

- More measurement for gamma-ray spectra
- Develop systematics for gamma-ray strength functions in low energy region: Similar to GDR parameters
- Improve nuclear data files for nuclides with no measurement

- Publication

Hyeong Il KIM, Mi Ja YI and Young-Ouk LEE,
" Evaluation of Neutron Capture Gamma-ray Spectra for ^{89}Y, ^{93}Nb, ^{127}I, ^{133}Cs, ^{141}Pr, ^{197}Au, ^{nat}Tl, and ^{209}Bi",
Journal of Nuclear Science and Technology,
Vol. 44, No.8, pp. 1117-1125, 2007

Background: New Evaluation on p+^{27}Al up to 150 MeV

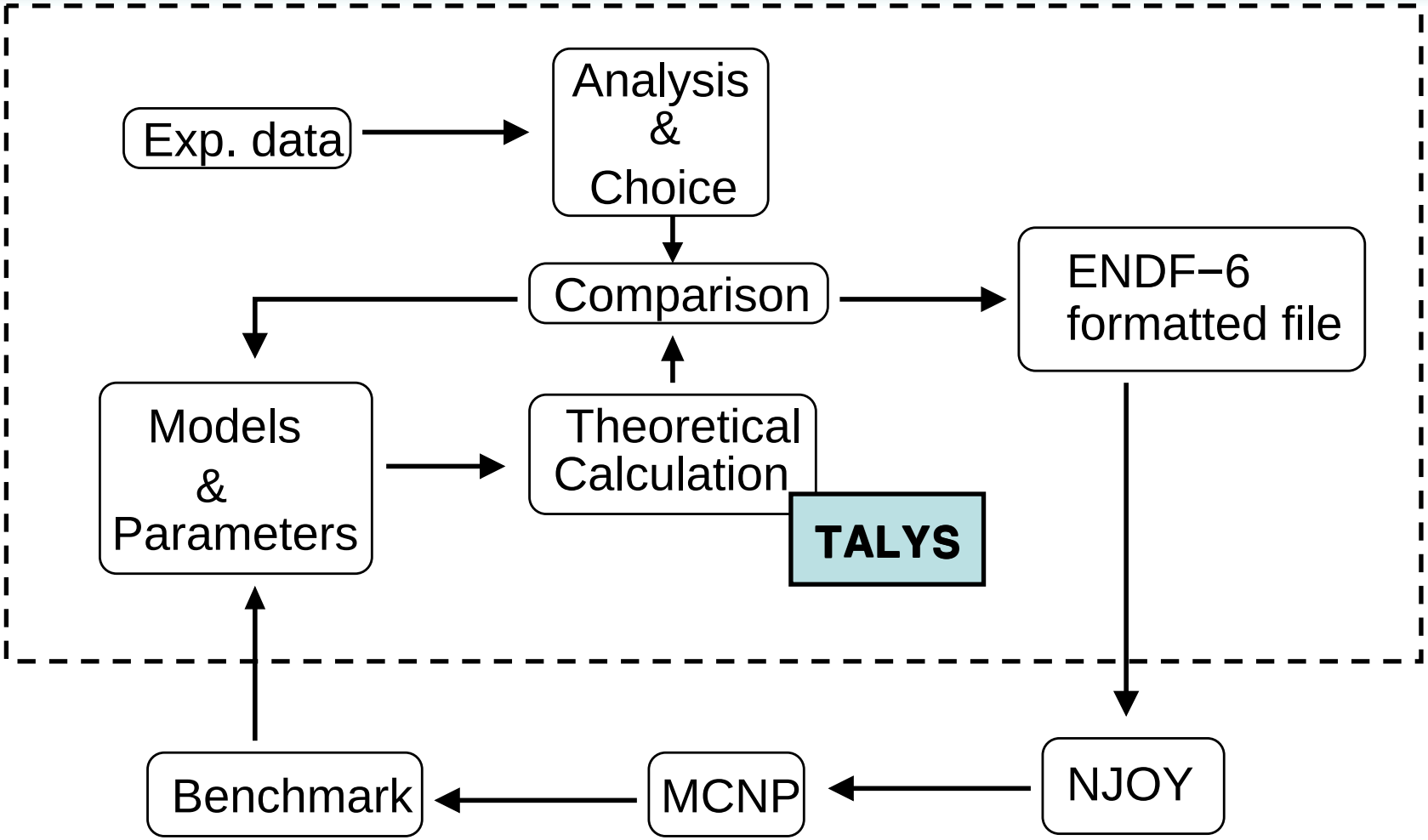
- Proton Accelerator Development Project (PEFP) requires **proton nuclear data with higher accuracy** relevant to the radiological safety and the accelerator and Beam unitization.

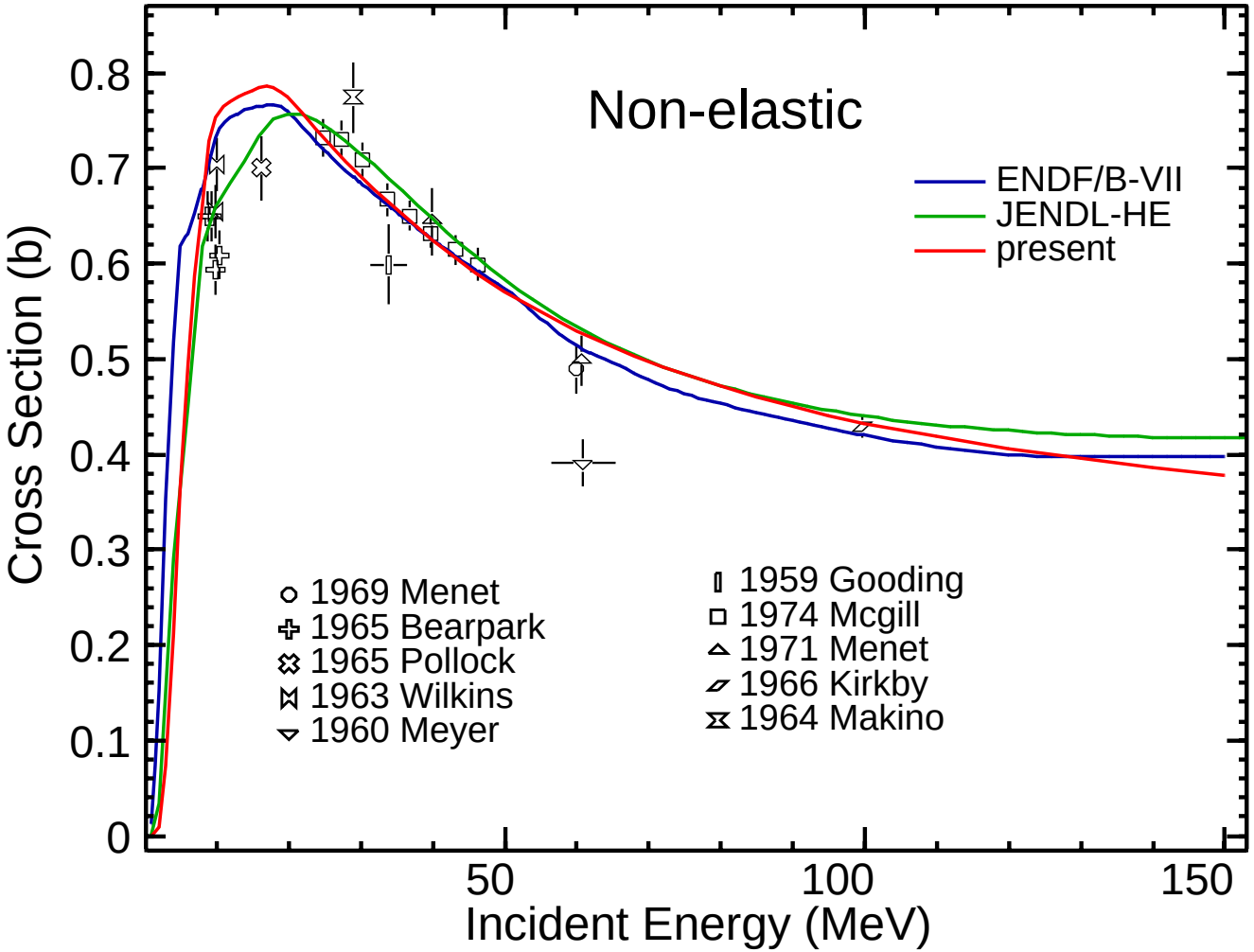
→ A complete set of cross sections, yield, energy spectra and angular distributions in order to be used in transport applications

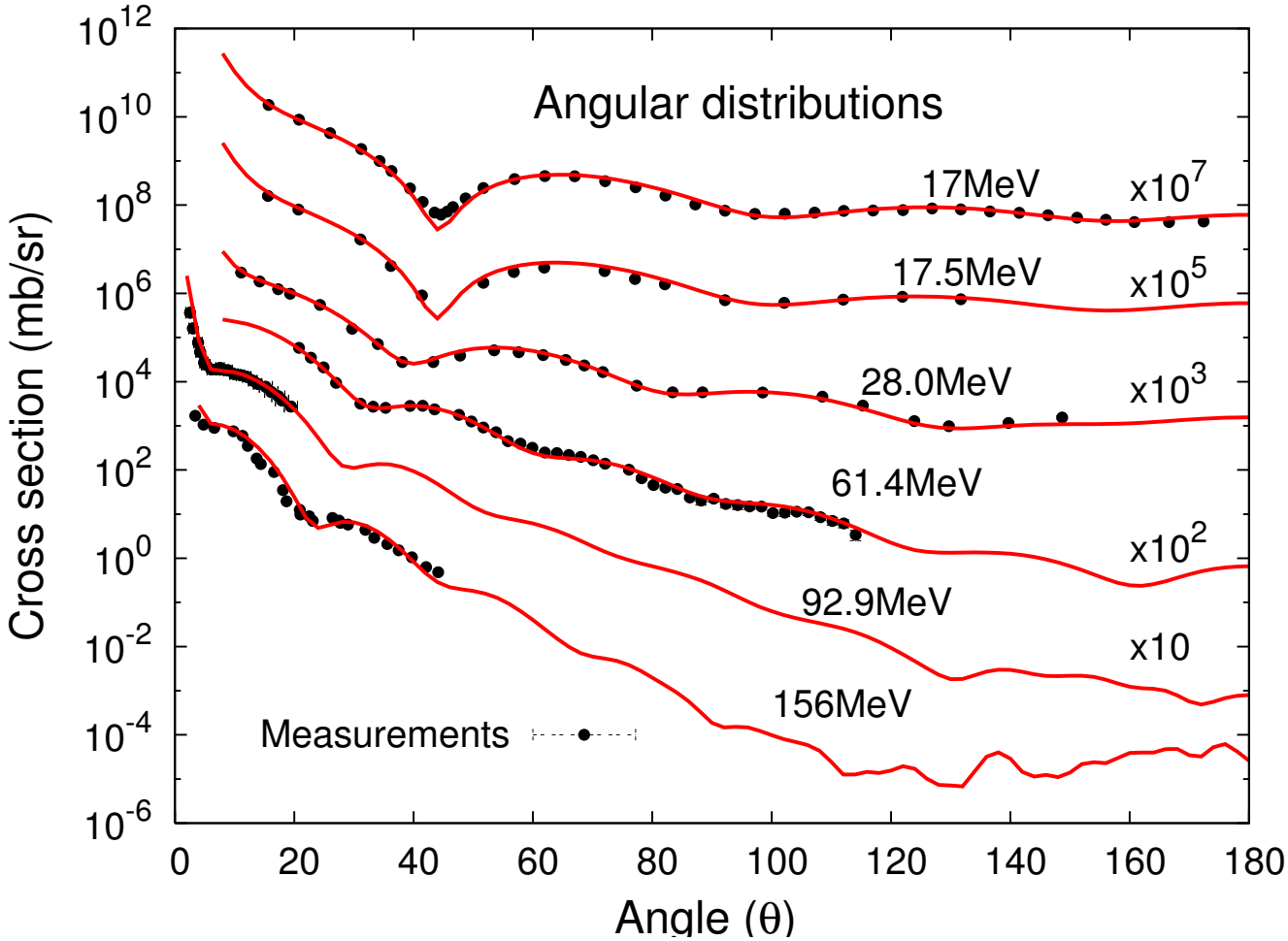
- ✓ **Evaluation of ^{27}Al for proton incident energy up to 150 MeV**
  - ✓ Al-27 in ENDF/B-VII : by M. Chadwick (LANL), 1997
  - ✓ Al-27 in JENDL–HE : by Y.O Lee (KAERI), 1998

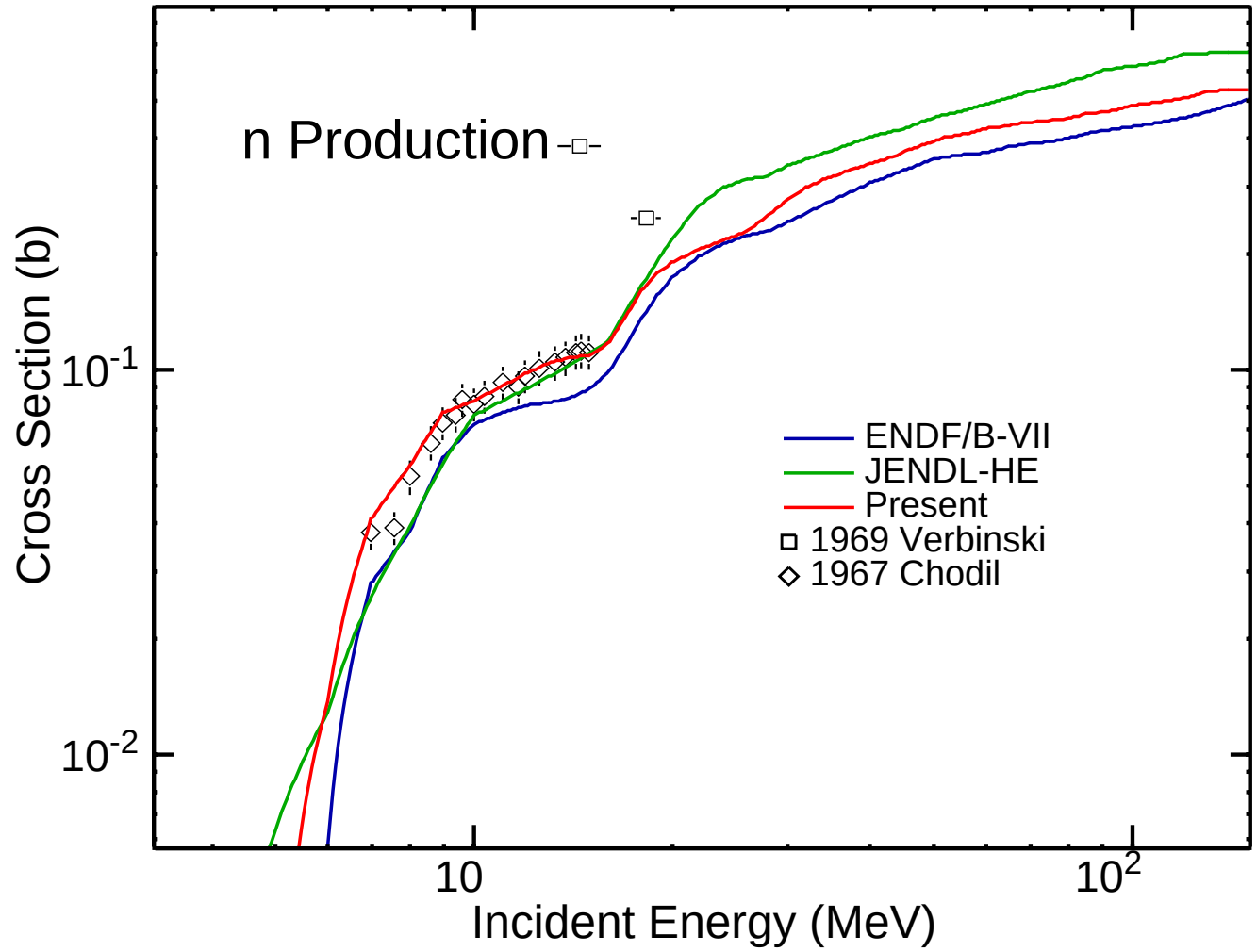
- ✓ **Up-to-date theories, models, measurements and evaluation methodologies were applied**

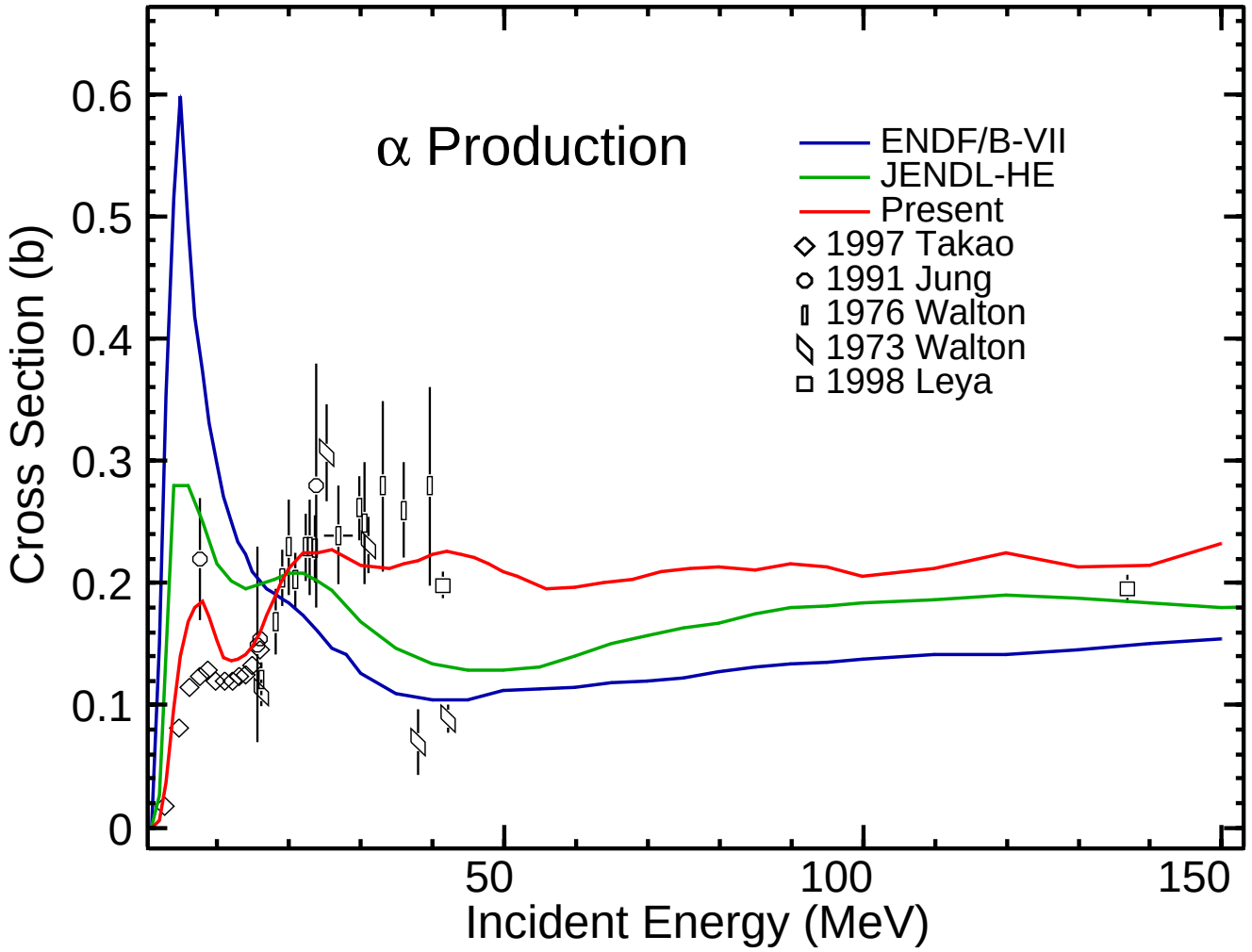
A procedure applied to p+Al Evaluation

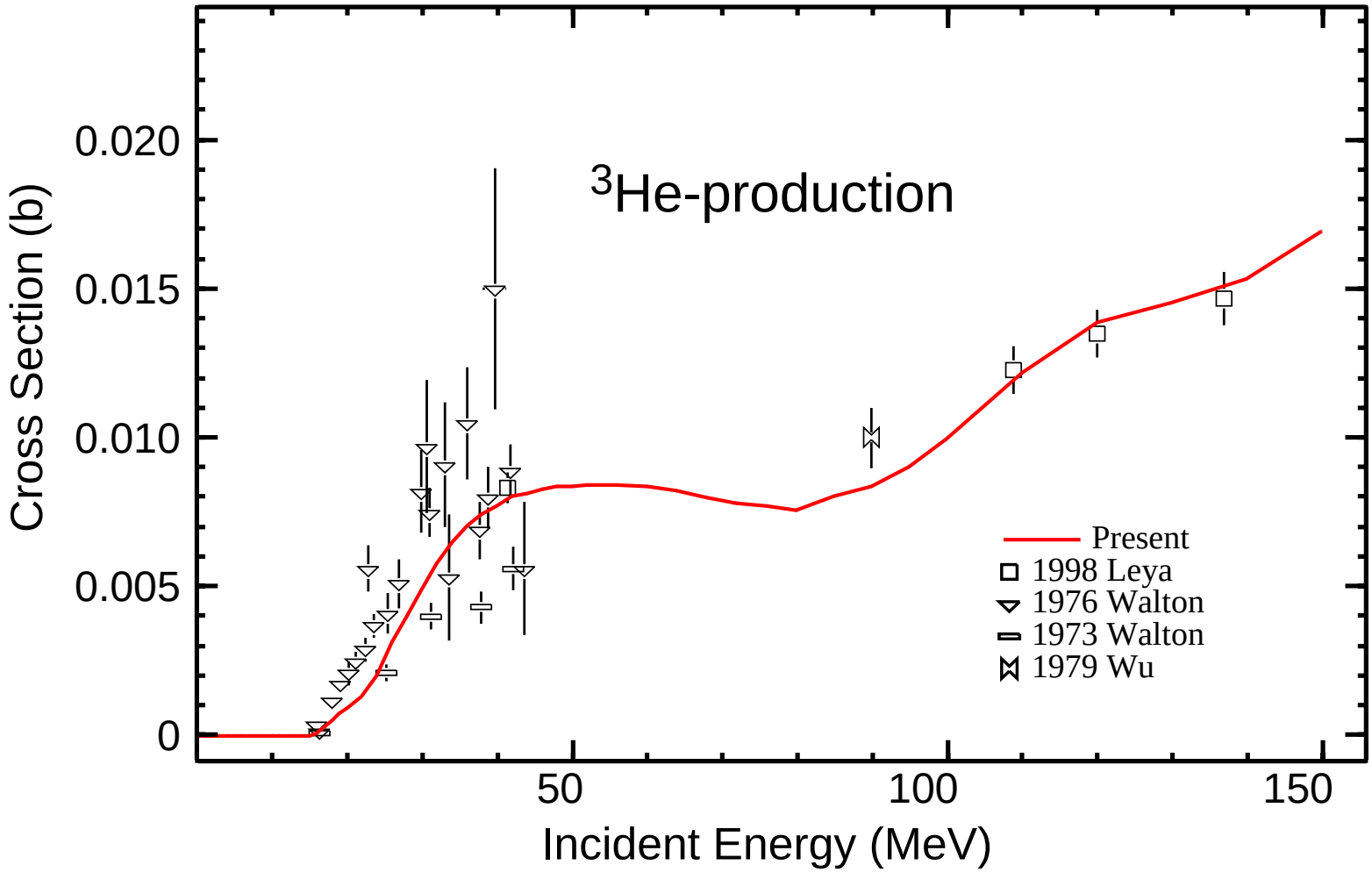


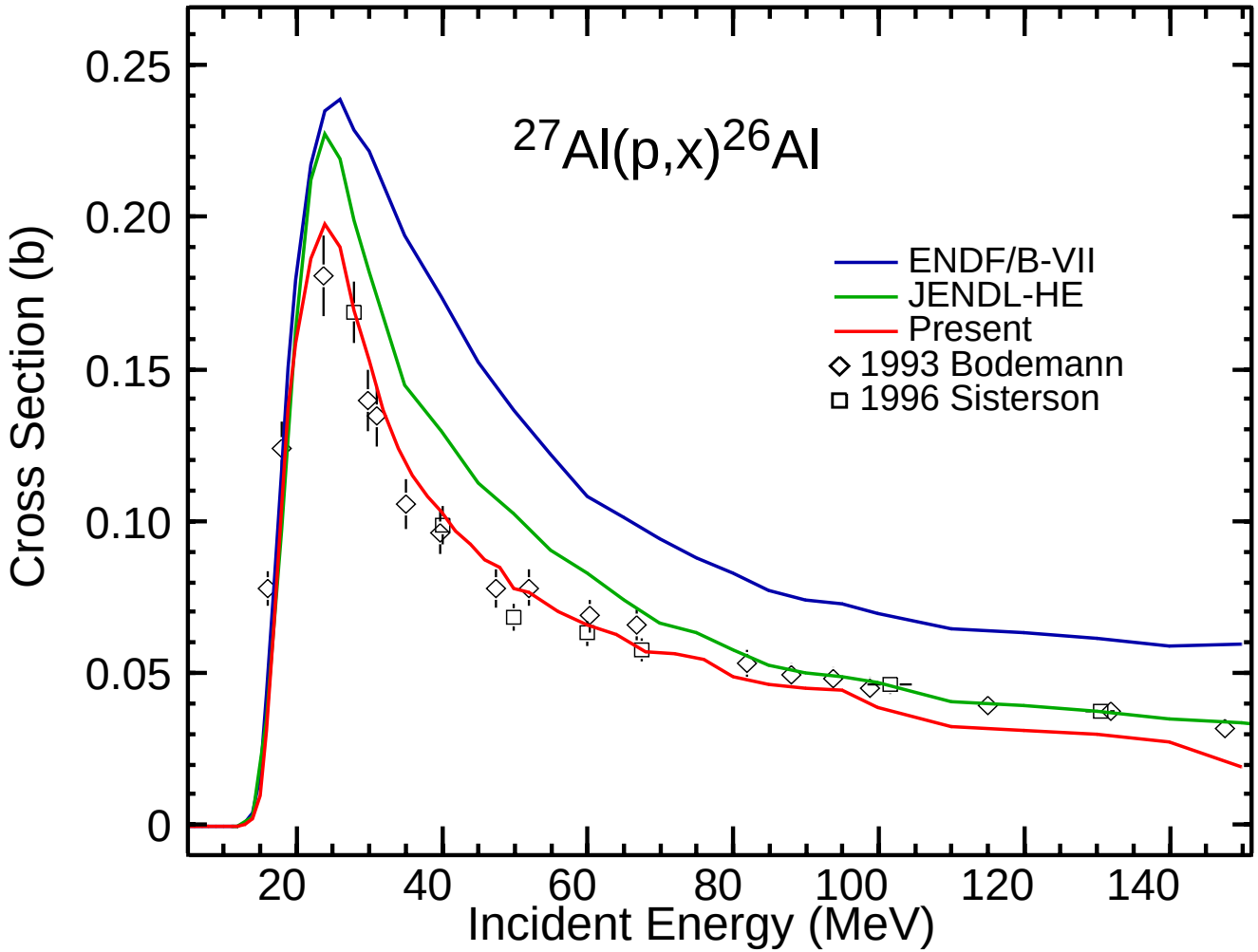

Non-elastic
Cross Section (b)
Incident Energy (MeV)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
50
100
150
ENDF/B-VII
JENDL-HE
present
1969 Menet
1965 Bearpark
1965 Pollock
1963 Wilkins
1960 Meyer
1959 Gooding
1974 Mcgill
1971 Menet
1966 Kirkby
1964 Makino

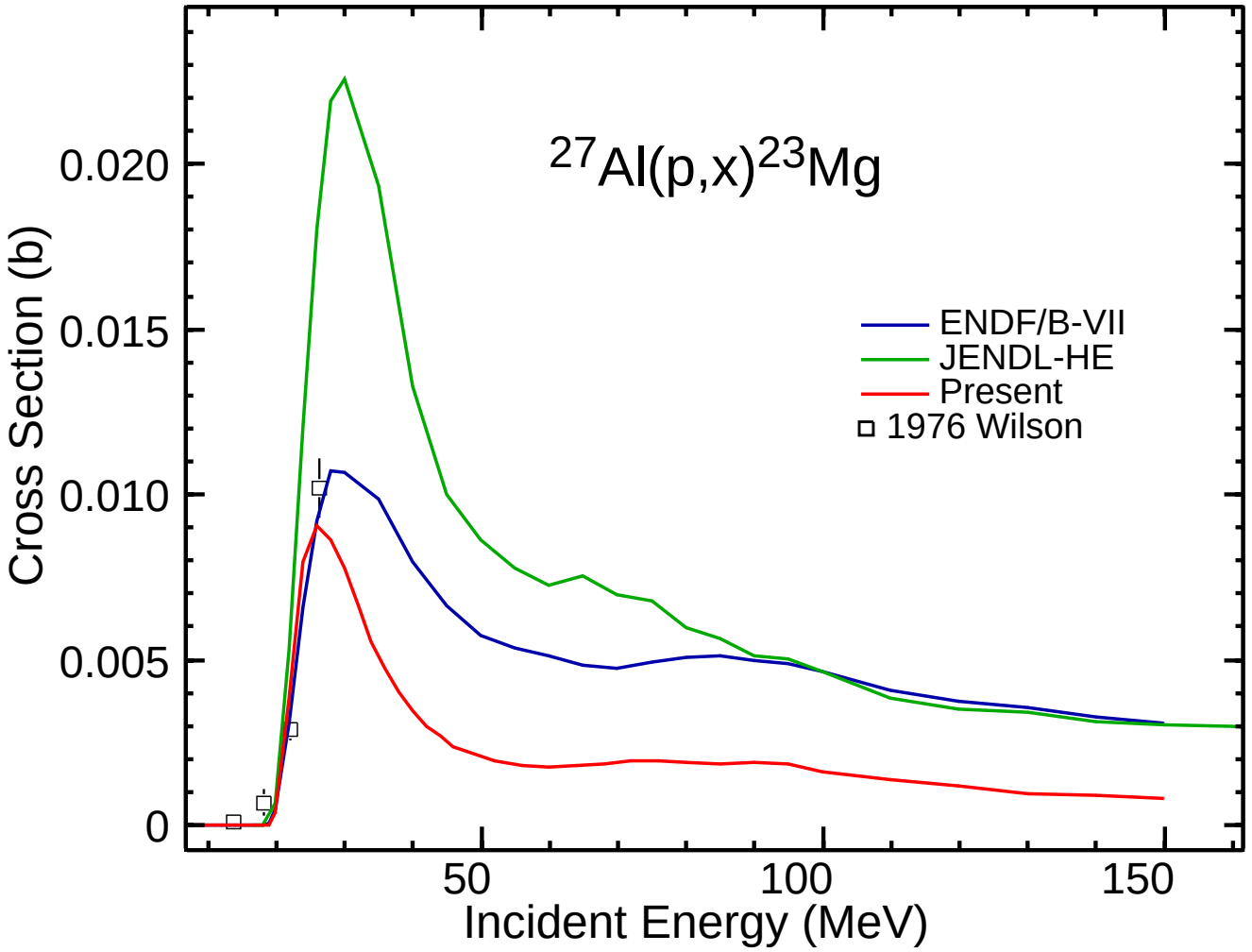

Angular distributions
17MeV
x10^7
17.5MeV
x10^5
28.0MeV
x10^3
61.4MeV
x10^2
92.9MeV
x10
156MeV
Measurements
Cross section (mb/sr)
Angle (θ)
10^12
10^10
10^8
10^6
10^4
10^2
10^0
10^-2
10^-4
10^-6
0
20
40
60
80
100
120
140
160
180

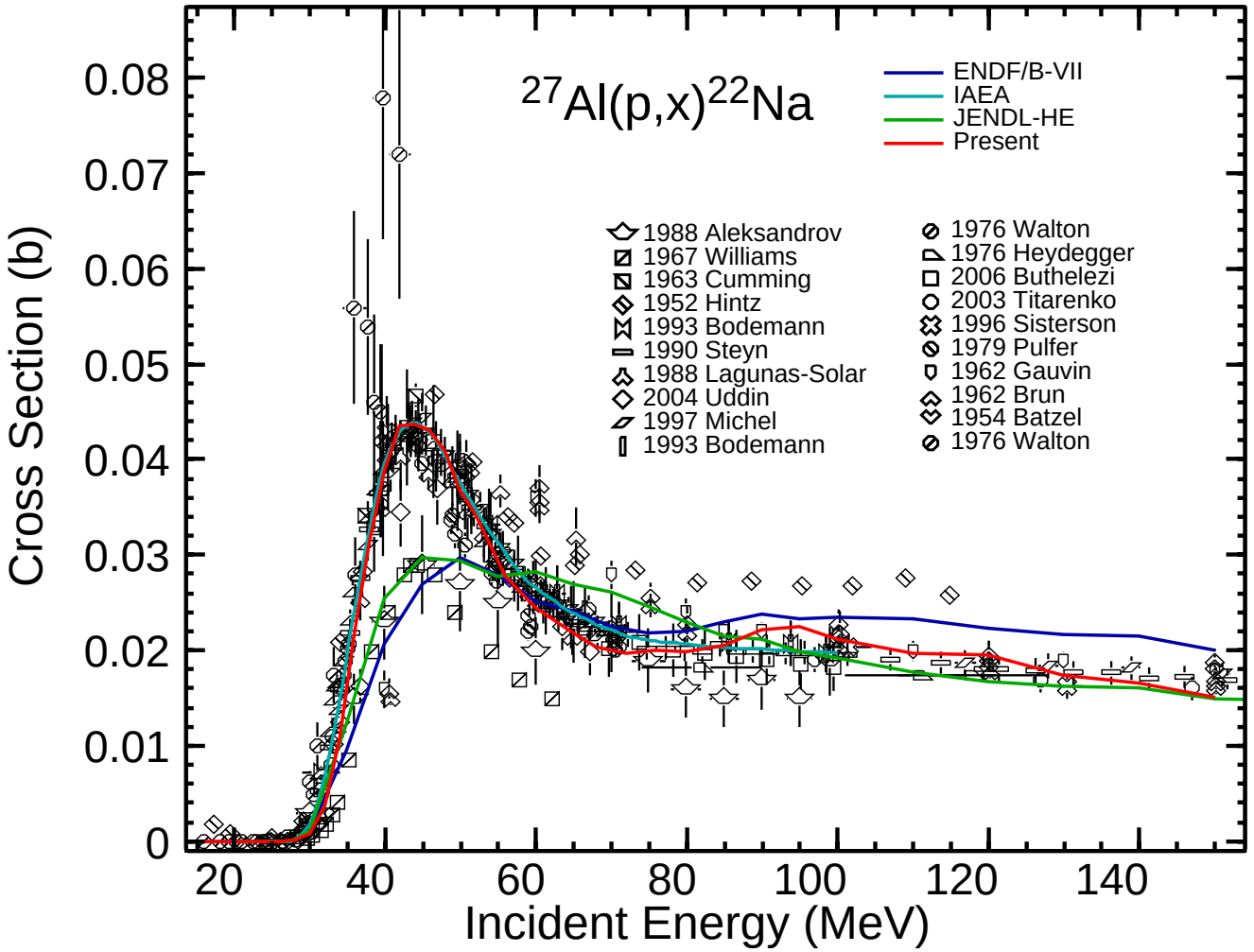

n Production
Cross Section (b)
10^{-1}
10^{-2}
10
10^{2}
Incident Energy (MeV)
ENDF/B-VII
JENDL-HE
Present
1969 Verbinski
1967 Chodil

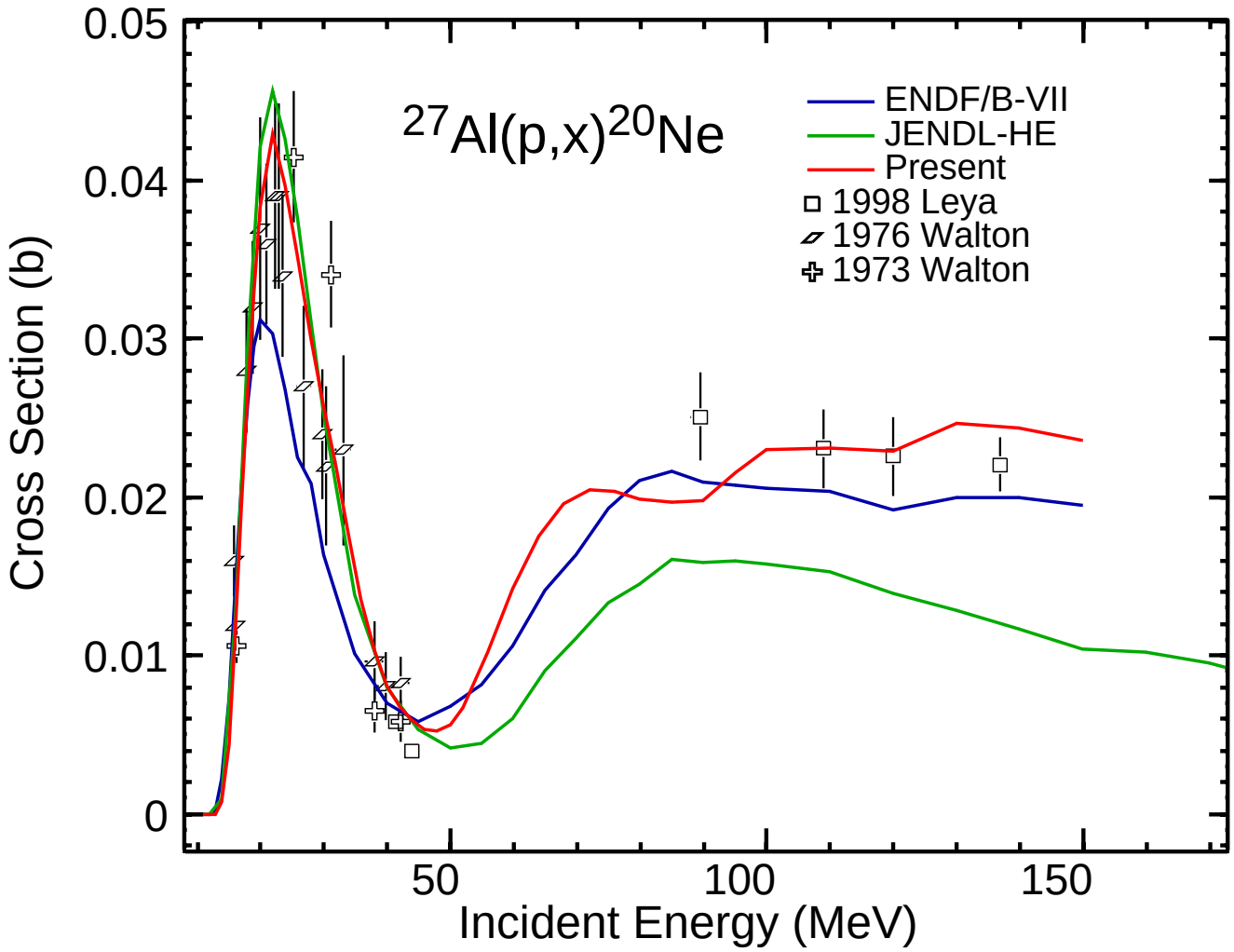

α Production
ENDF/B-VII
JENDL-HE
Present
1997 Takao
1991 Jung
1976 Walton
1973 Walton
1998 Leya
Cross Section (b)
0
0.1
0.2
0.3
0.4
0.5
0.6
50
100
150
Incident Energy (MeV)

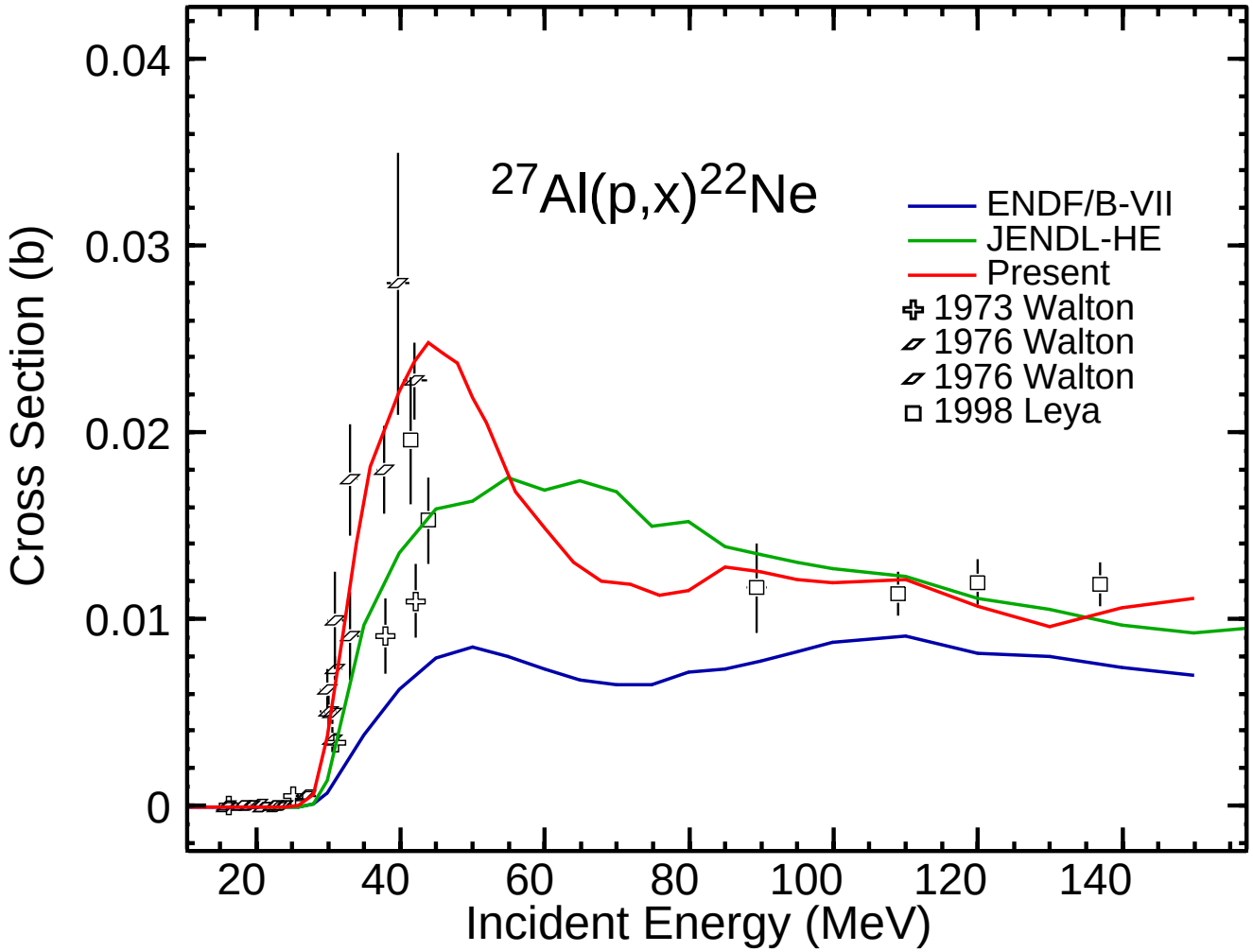

^{3}He-production
Cross Section (b)
0.020
0.015
0.010
0.005
0
50
100
150
Incident Energy (MeV)
Present
1998 Leya
1976 Walton
1973 Walton
1979 Wu


^{27}Al(p,x)^{26}Al
ENDF/B-VII
JENDL-HE
Present
1993 Bodemann
1996 Sisterson
Cross Section (b)
Incident Energy (MeV)
0
0.05
0.10
0.15
0.20
0.25
20
40
60
80
100
120
140

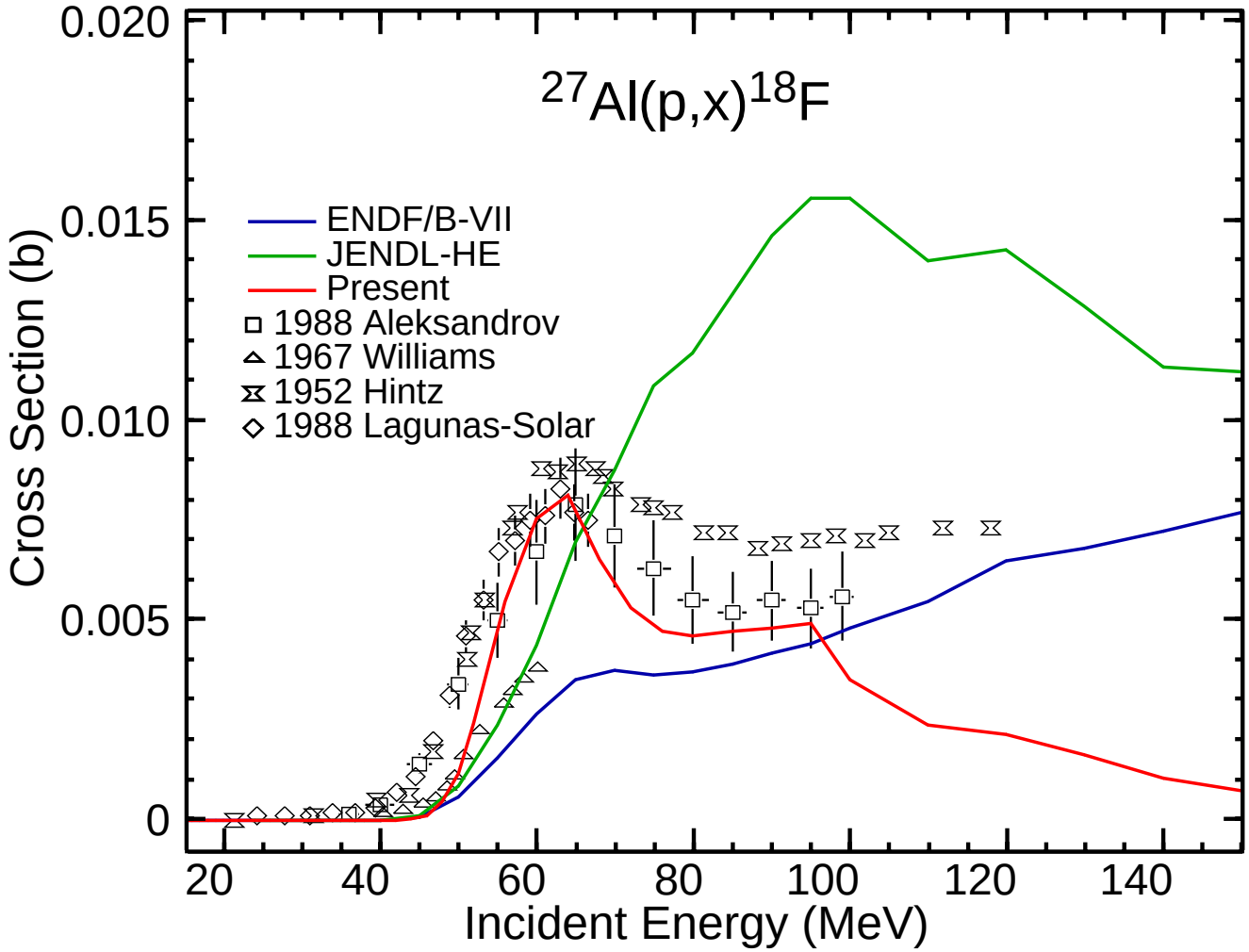

^{27}Al(p,x)^{23}Mg
Cross Section (b)
0.020
0.015
0.010
0.005
0
50
100
150
Incident Energy (MeV)
ENDF/B-VII
JENDL-HE
Present
1976 Wilson


^{27}Al(p,x)^{22}Na
ENDF/B-VII
IAEA
JENDL-HE
Present
1988 Aleksandrov
1967 Williams
1963 Cumming
1952 Hintz
1993 Bodemann
1990 Steyn
1988 Lagunas-Solar
2004 Uddin
1997 Michel
1993 Bodemann
1976 Walton
1976 Heydegger
2006 Buthelezi
2003 Titarenko
1996 Sisterson
1979 Pulfer
1962 Gauvin
1962 Brun
1954 Batzel
1976 Walton
Cross Section (b)
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
20
40
60
80
100
120
140
Incident Energy (MeV)

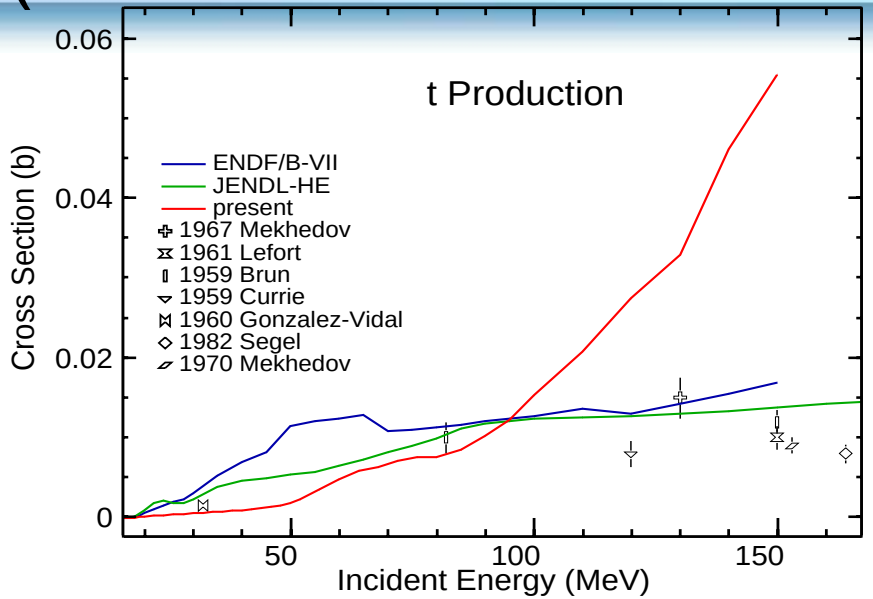

^{27}Al(p,x)^{20}Ne
ENDF/B-VII
JENDL-HE
Present
1998 Leya
1976 Walton
1973 Walton
Cross Section (b)
Incident Energy (MeV)
0.05
0.04
0.03
0.02
0.01
0
50
100
150

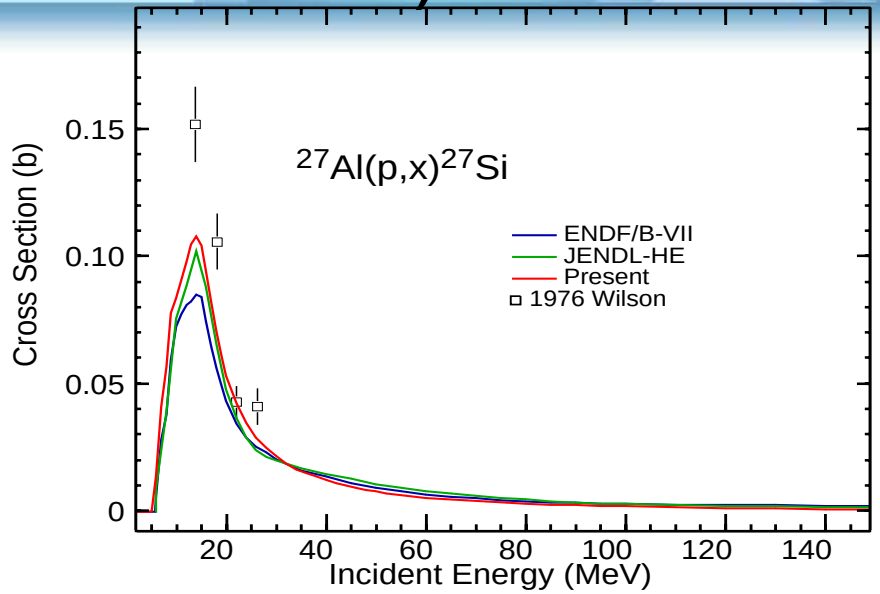

^{27}Al(p,x)^{22}Ne
ENDF/B-VII
JENDL-HE
Present
1973 Walton
1976 Walton
1976 Walton
1998 Leya
Cross Section (b)
0.04
0.03
0.02
0.01
0
20
40
60
80
100
120
140
Incident Energy (MeV)

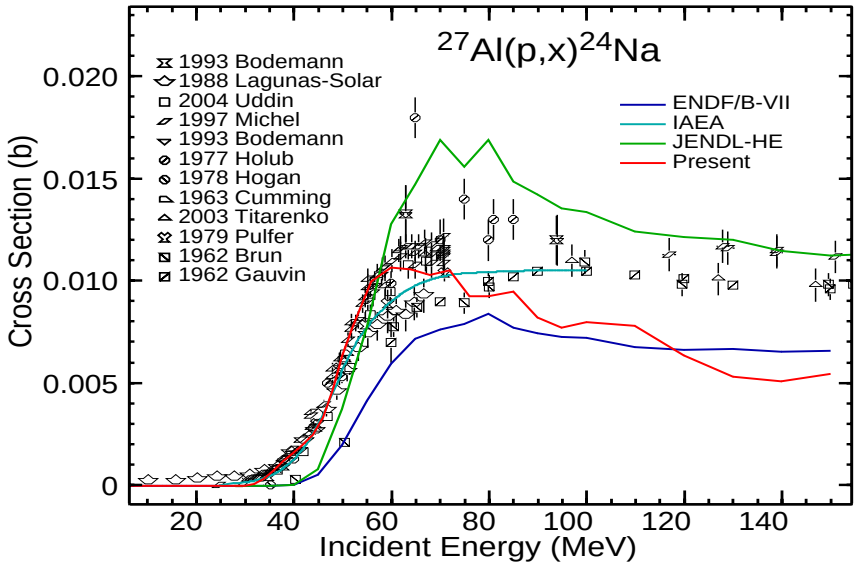
More measured points required

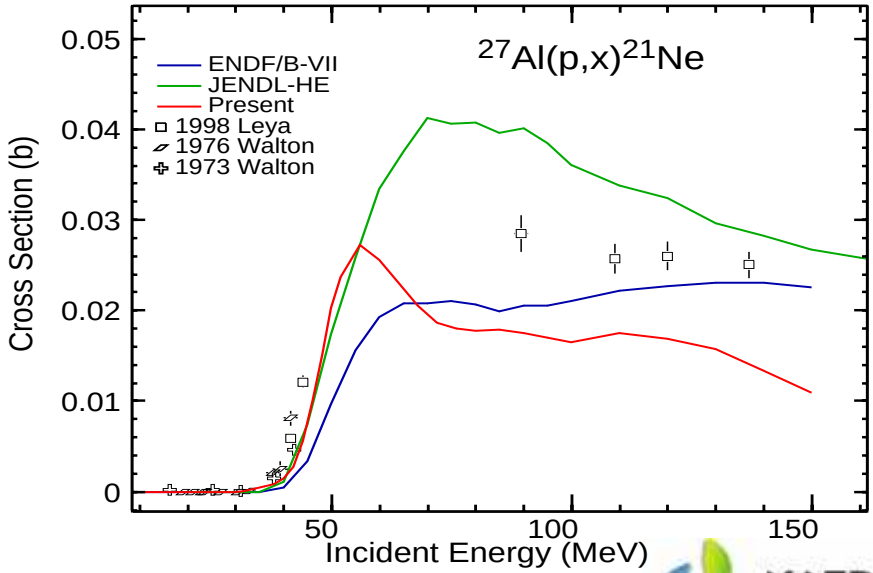


Calculated channels in question (measurement or reaction model ?)







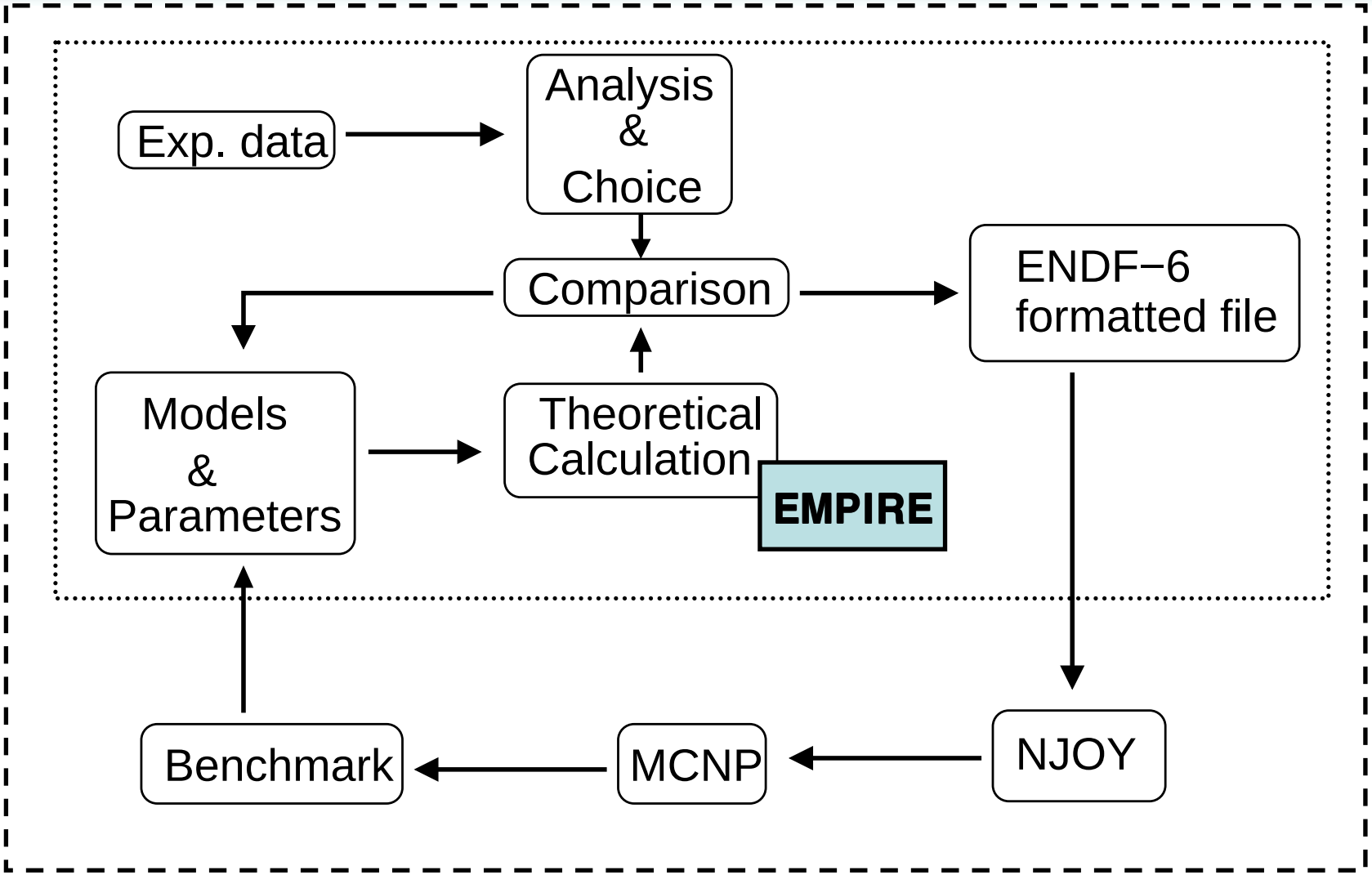


New Evaluation on Neutron Induced Reactions for $^{182,183,184,186}W$

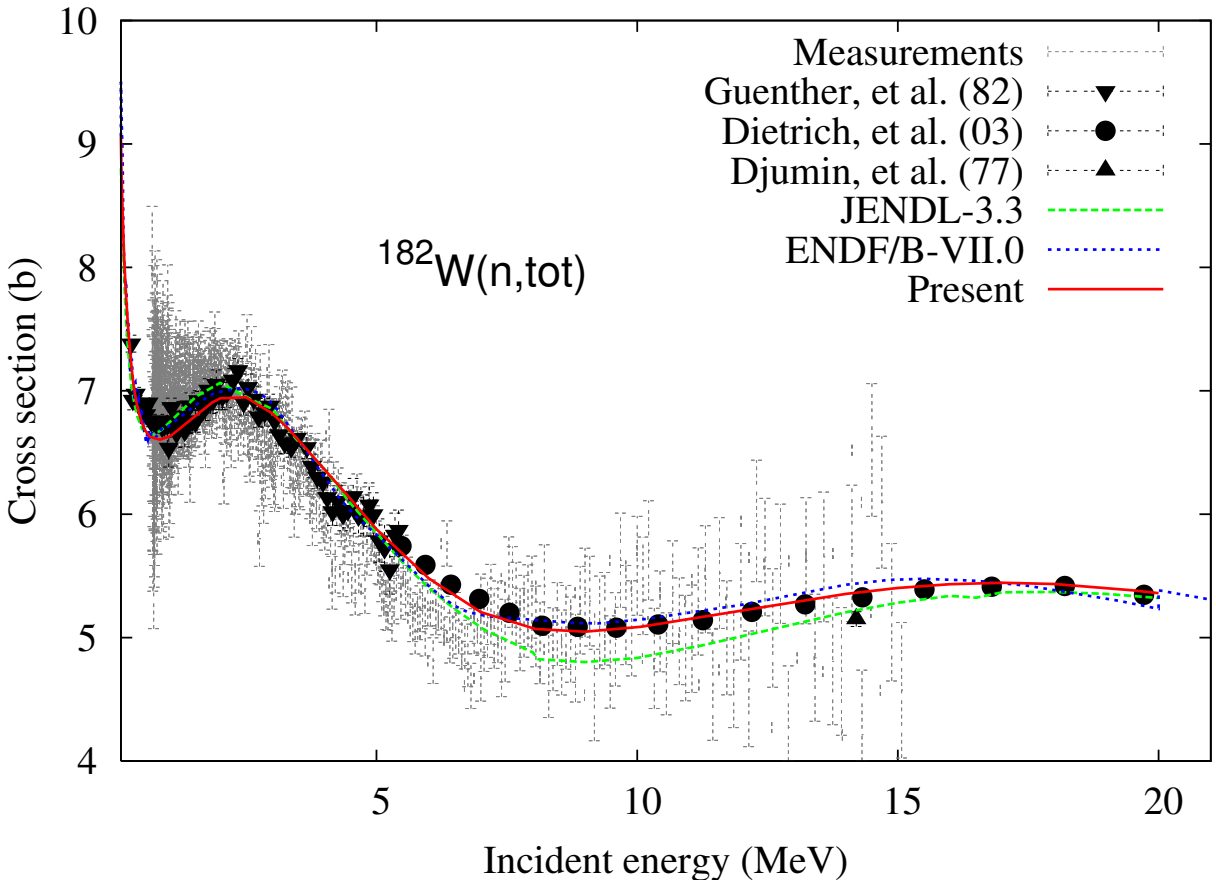
- Tungsten as a prime candidate of plasma facing materials (PFM) has to withstand heat and particle fluxes from the plasma in the environment of a fusion system.
- Existing libraries such as ENDF/B-VII, JEFF-3.1 and JENDL-3.3 **failed to reproduce the measured data**
- The integral tests of neutron production from the existing libraries showed **remarkable discrepancies** with leakage neutron measurements of OKTAVIAN.

✓ **Up-to-data theories, models, measurements and evaluation methodologies were applied**

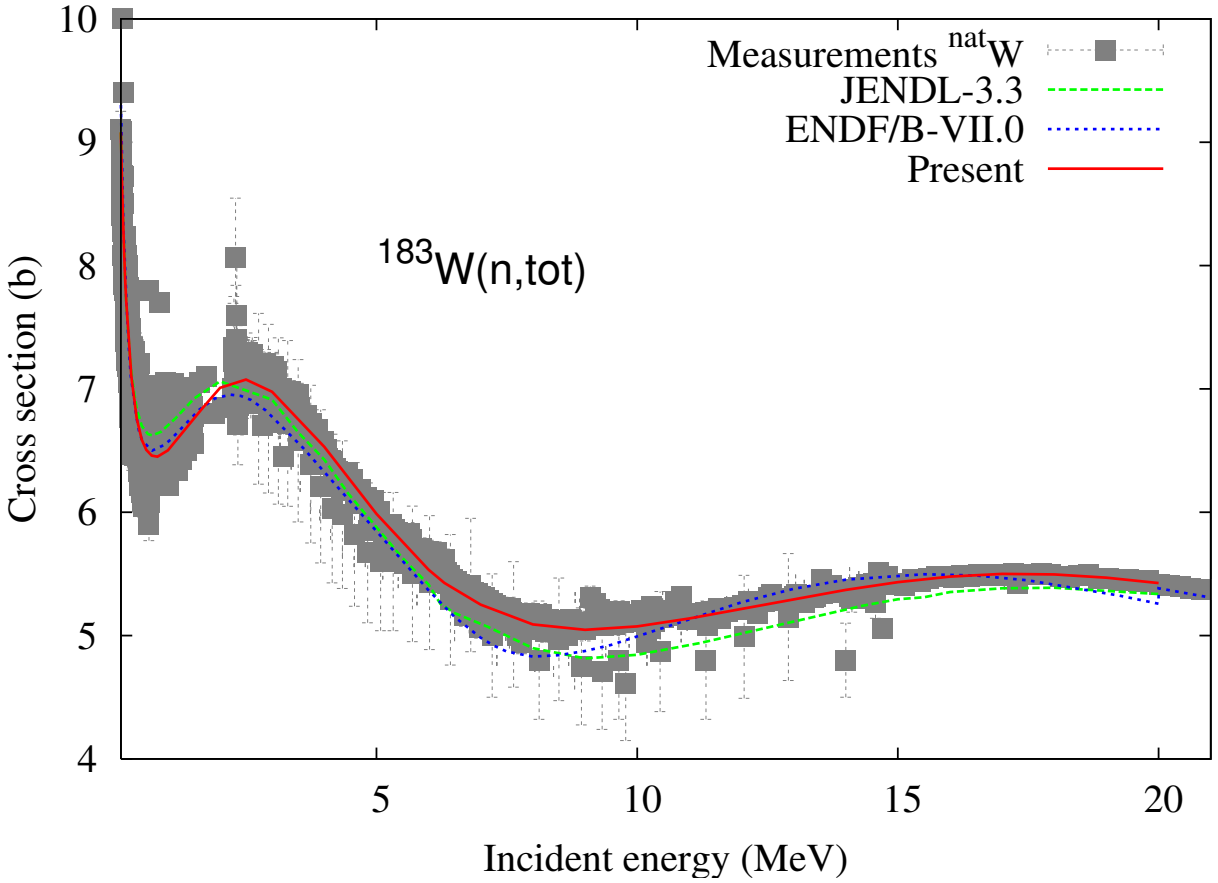
A procedure applied for n+W evaluation



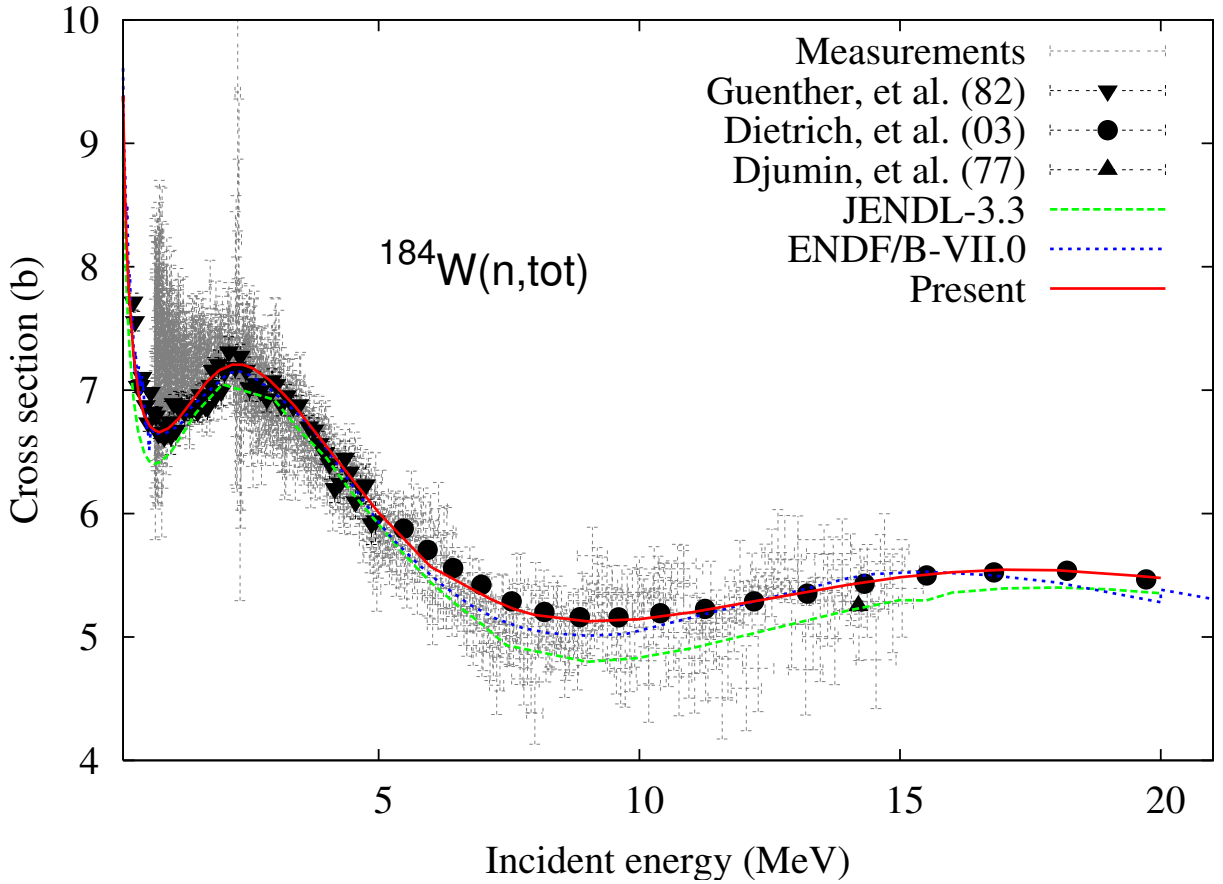
Total Cross Section for ^{182}W



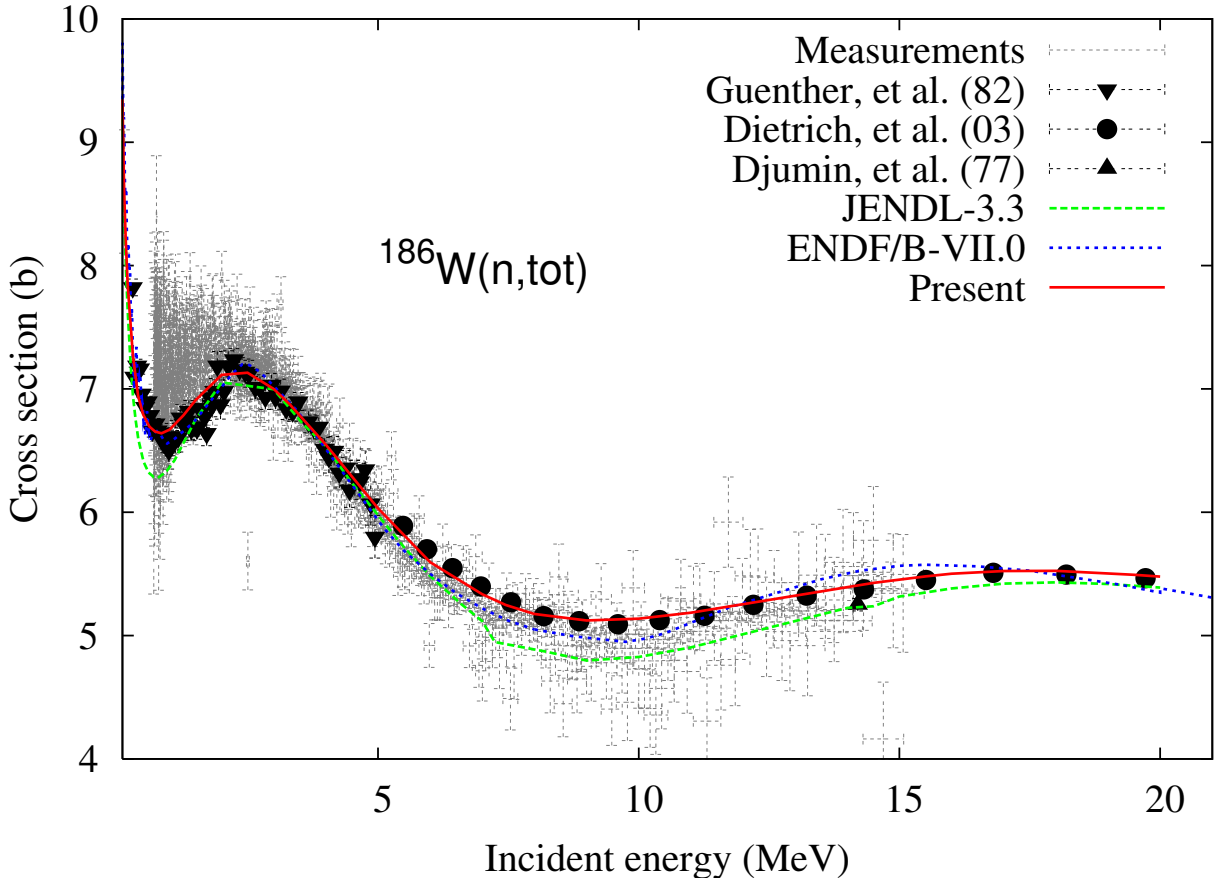
Total Cross Section for ^{183}W



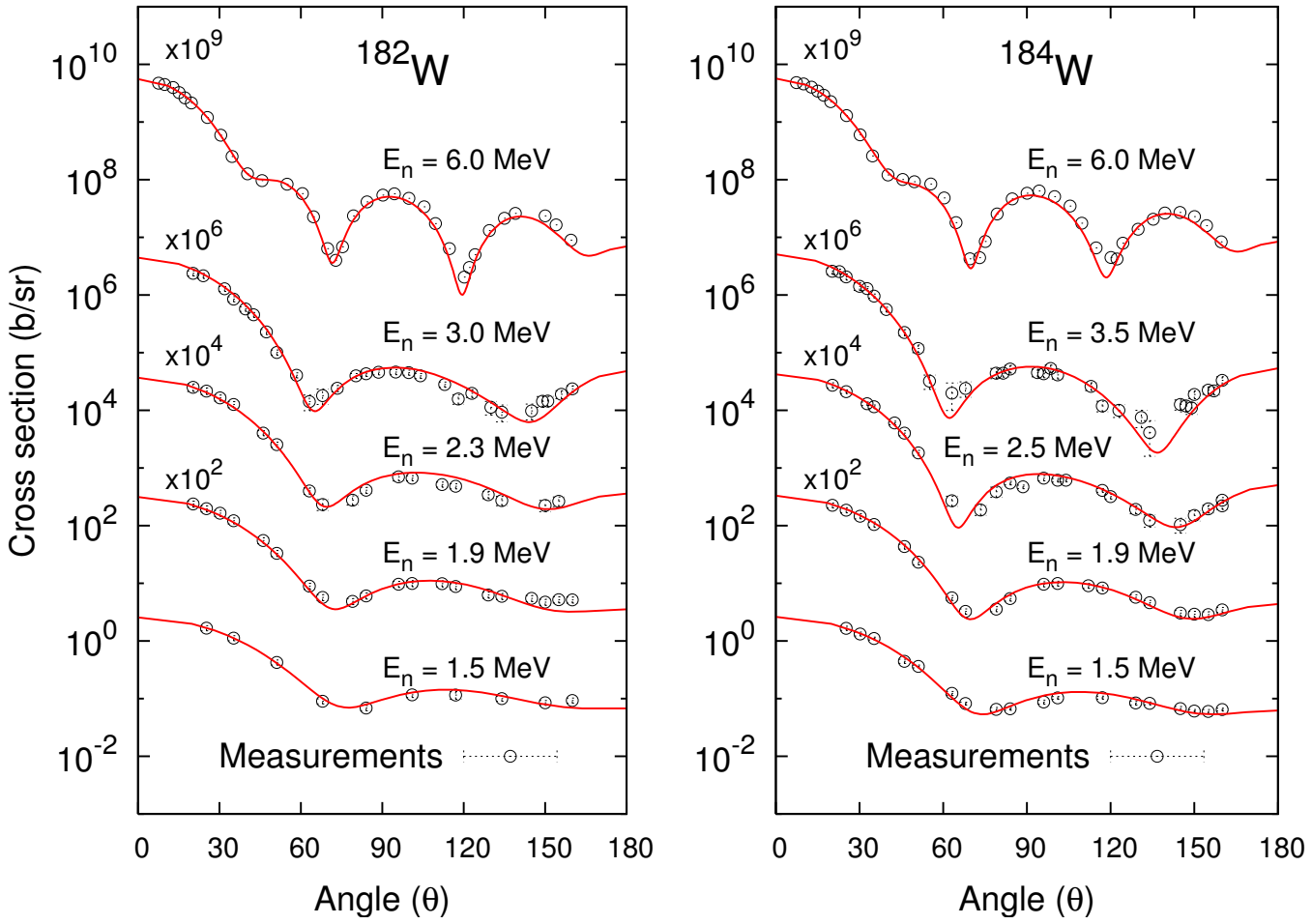
Total Cross Section for ^{184}W



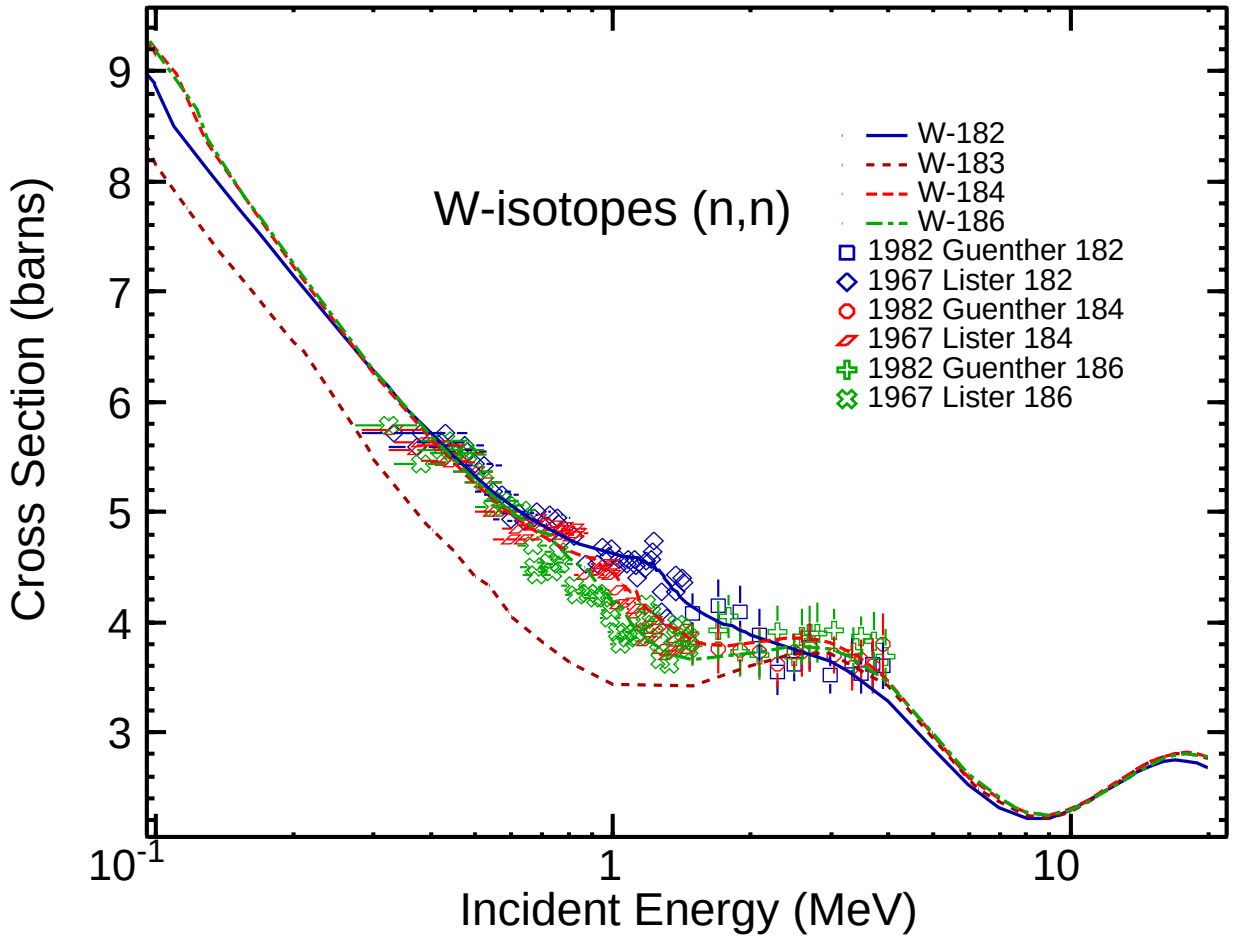
Total Cross Section for ^{186}W



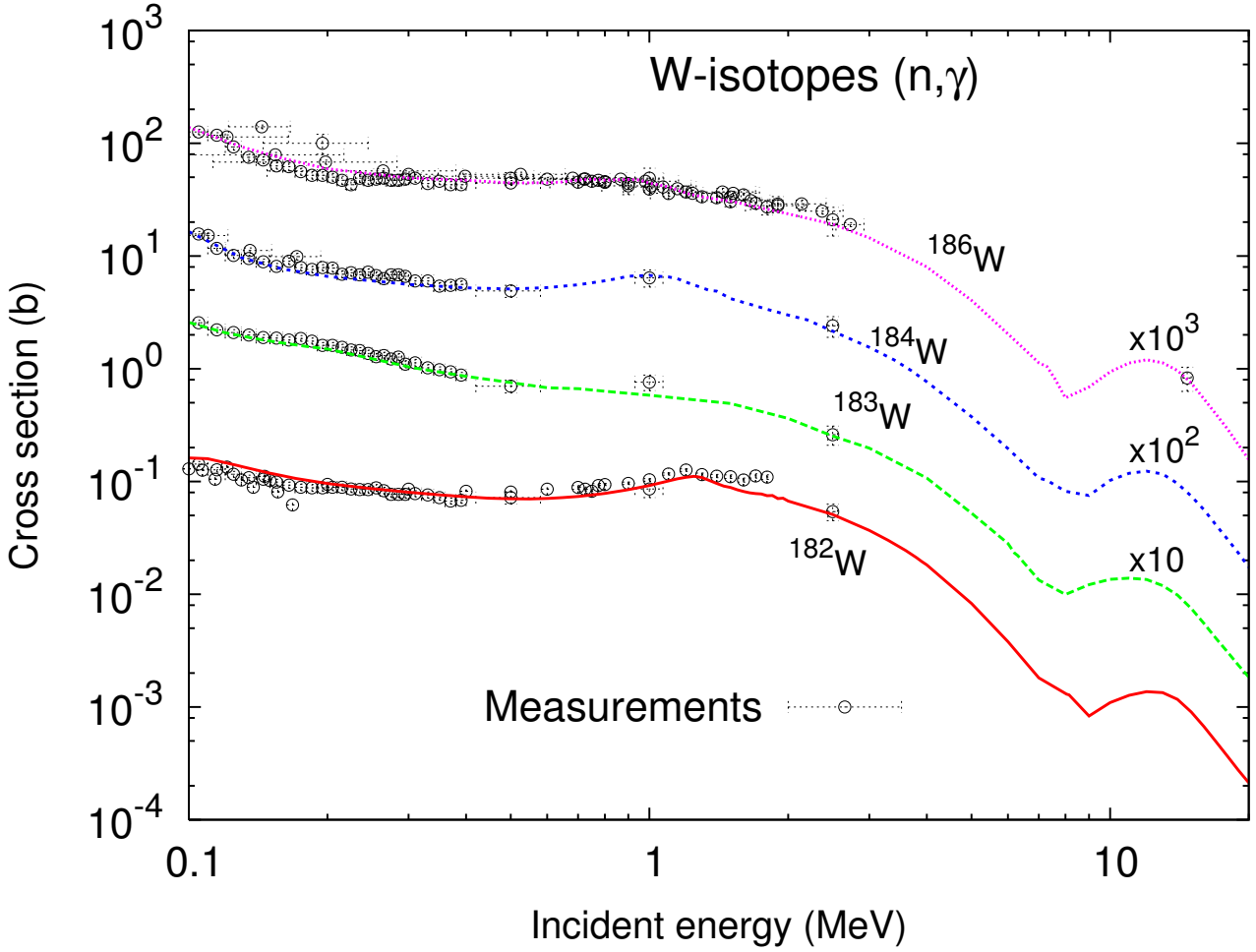
Angular Distributions of Elastic Scattering for $^{182,184}W$



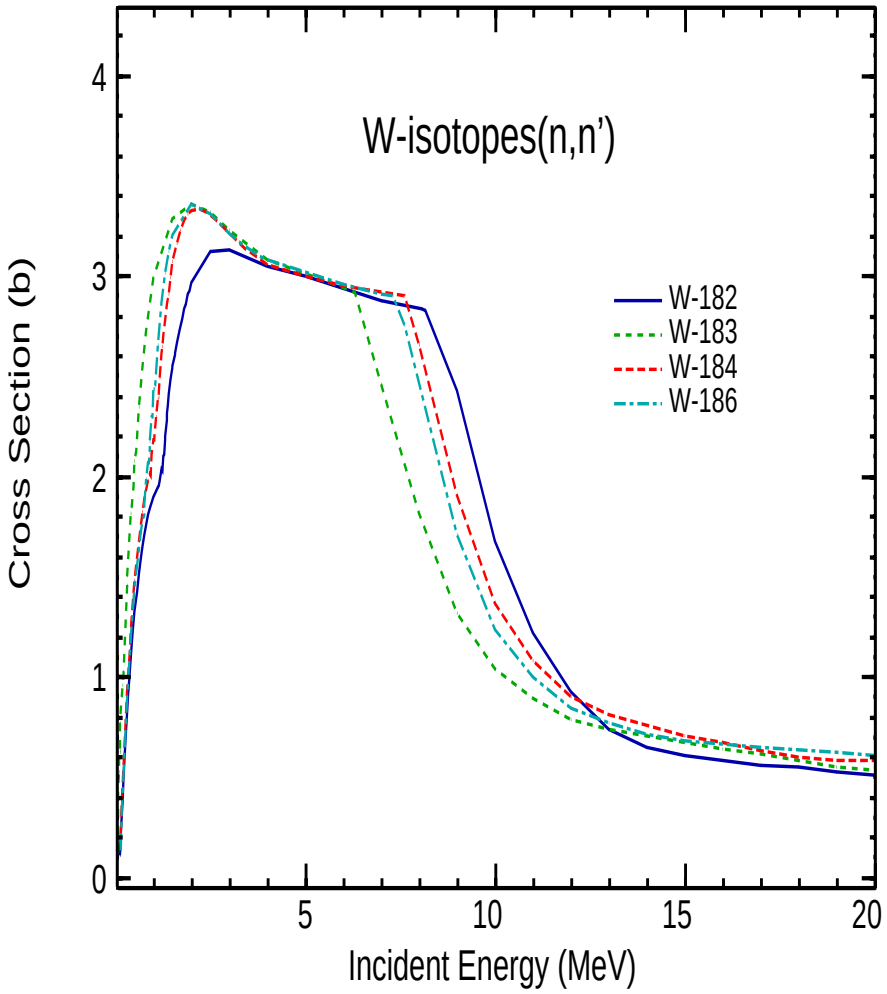
(n,n) cross sections for $^{182,183,184,186}W$



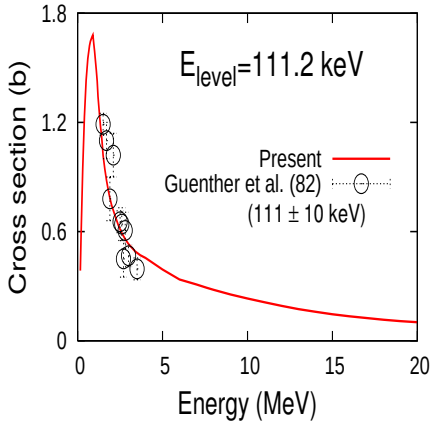
(n,g) cross sections for $^{182,183,184,186}W$

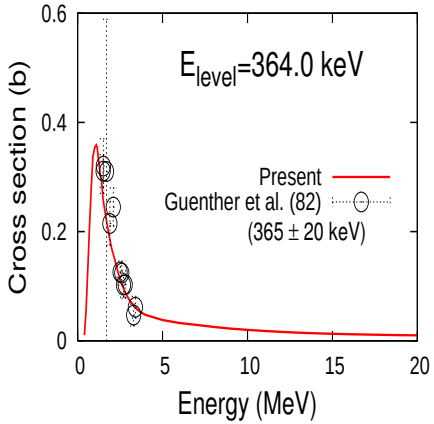


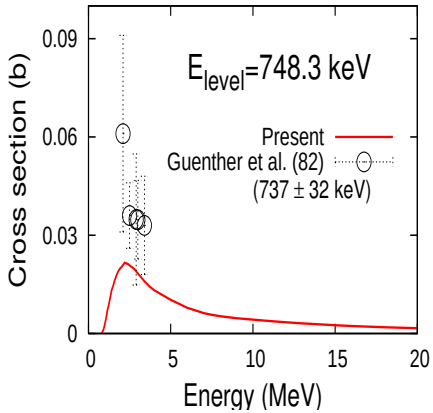
(n,n') cross sections for $^{182,183,184,186}W$

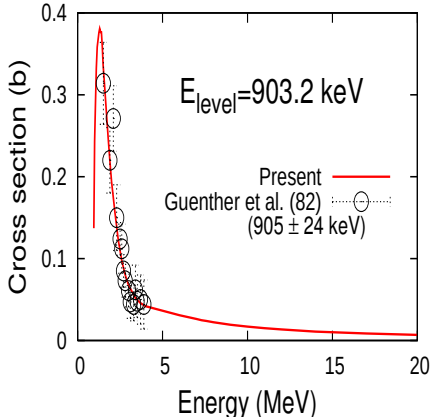


Inelastic scattering for ^{184}W

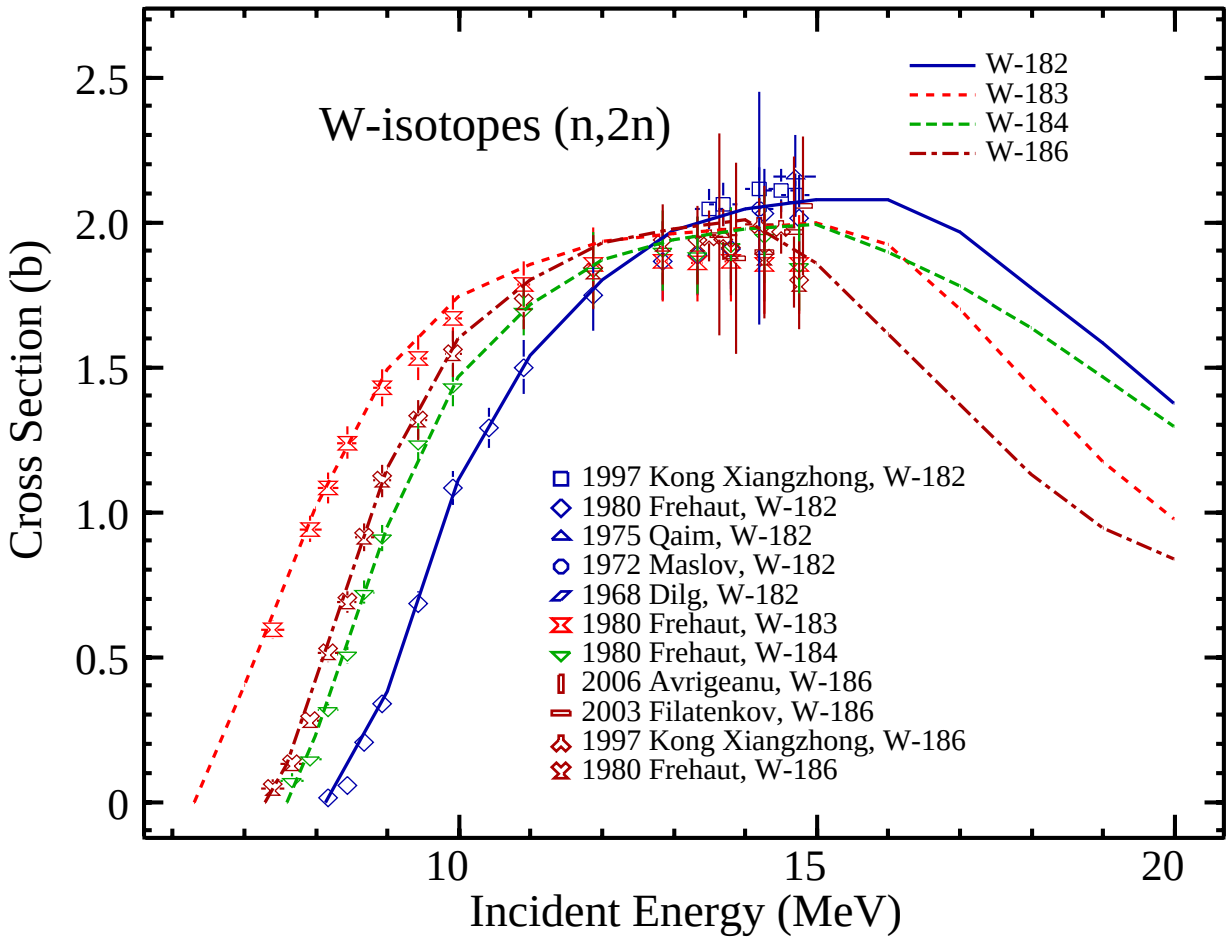




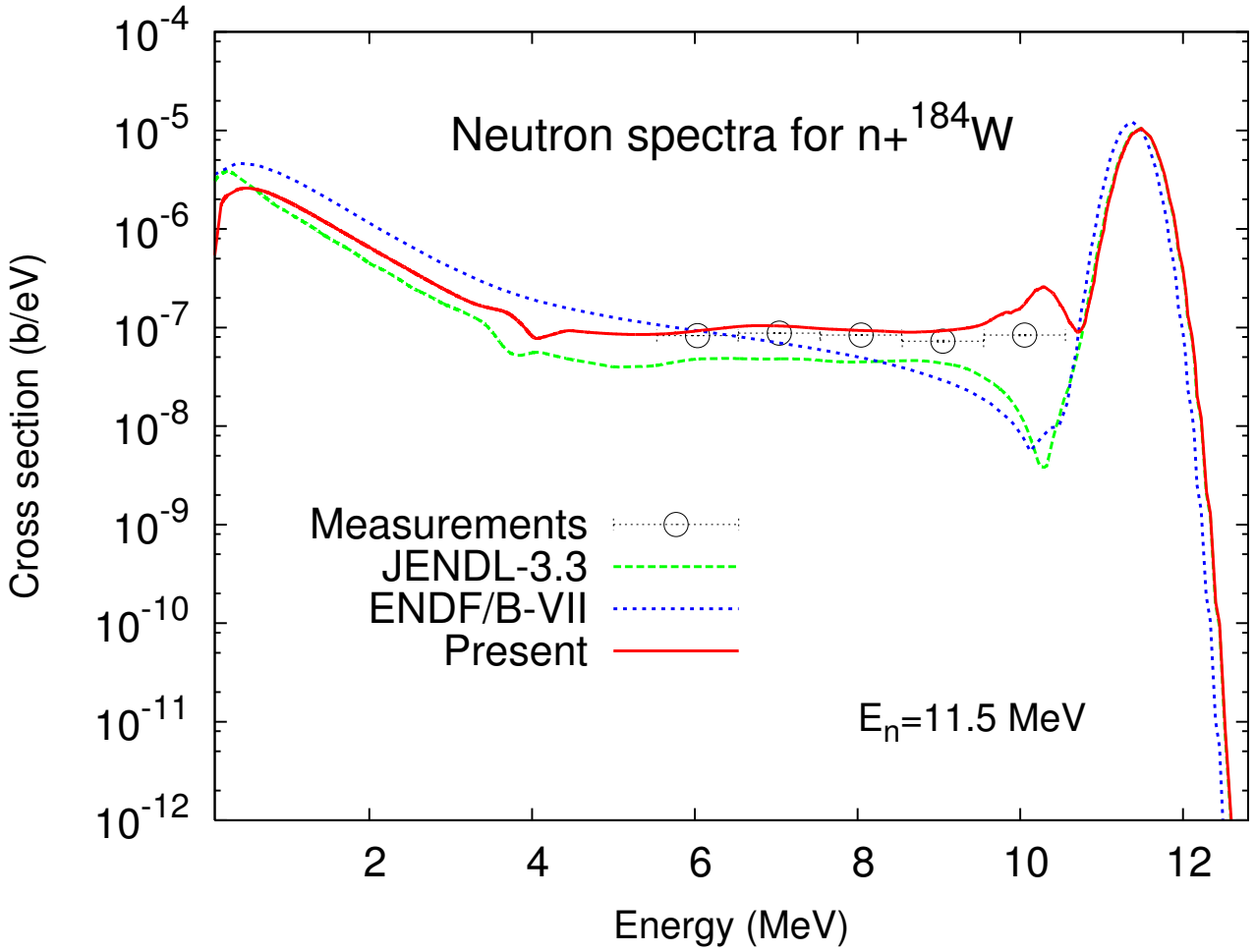




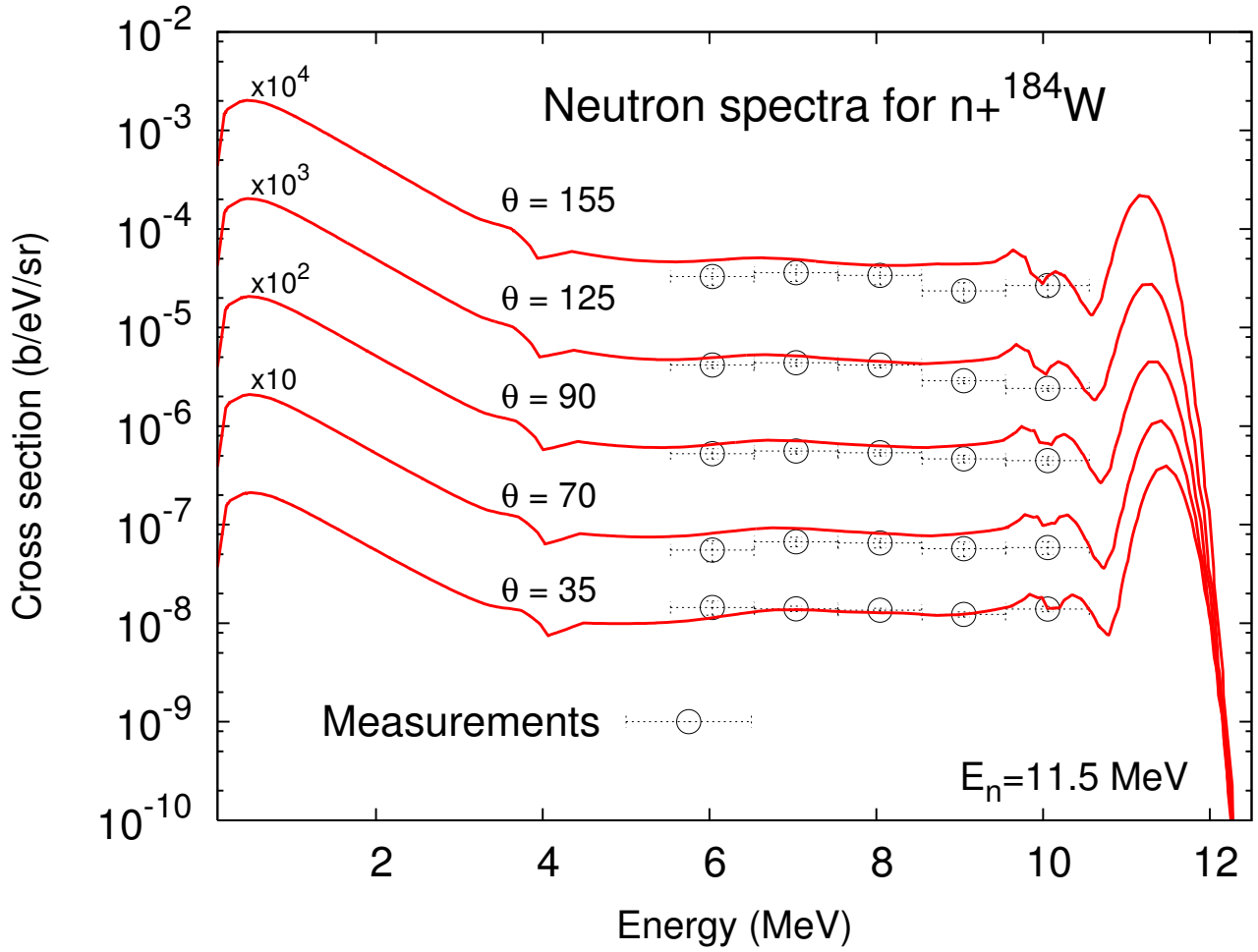
(n,2n) cross sections for $^{182,183,184,186}W$



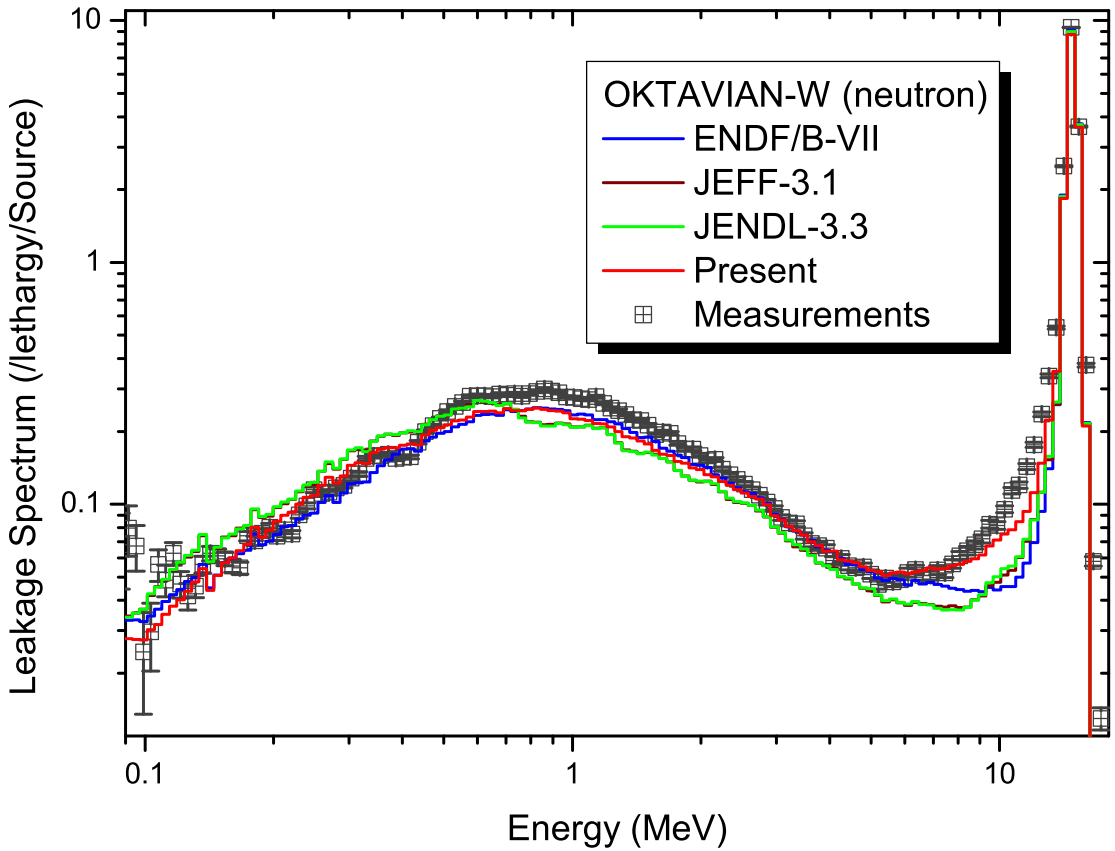
Angle-Integrated Neutron spectra for ^{184}W



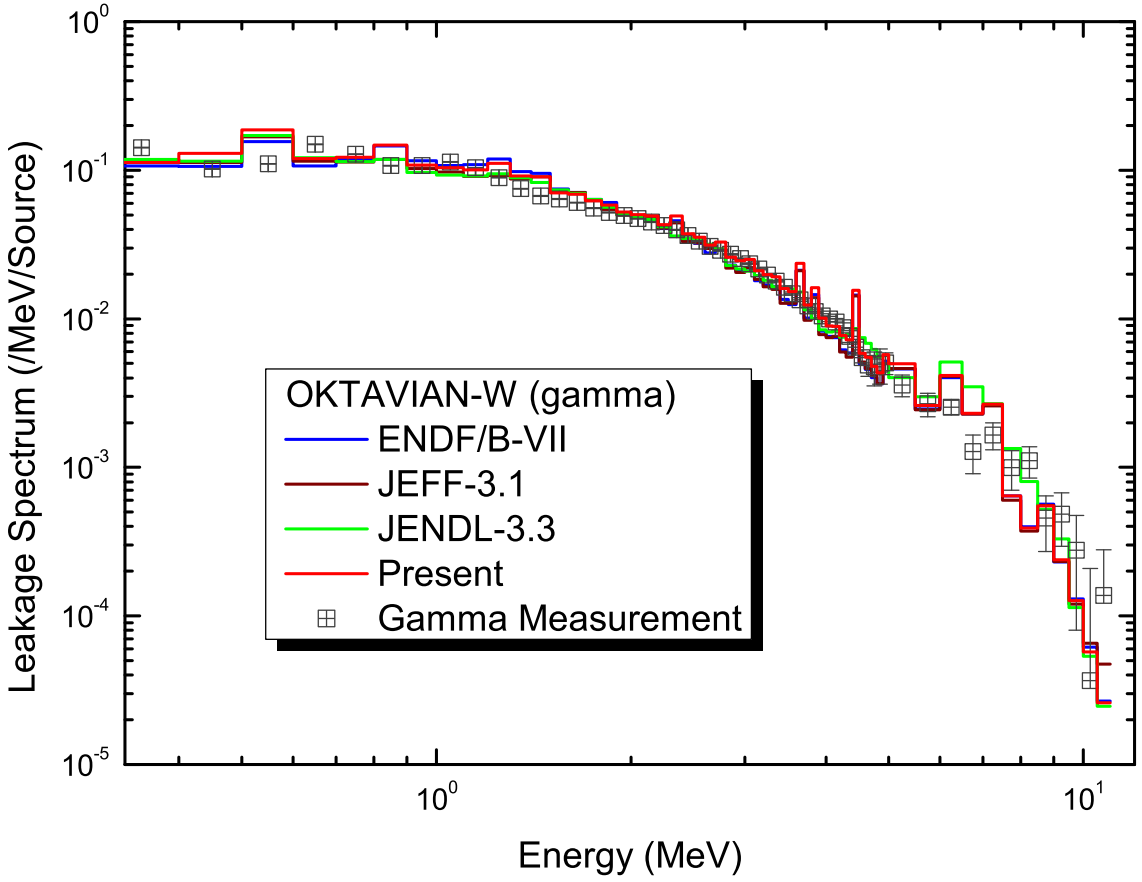
Energy-Angle Neutron spectra for ^{184}W



Integral Tests: Neutron Leakage



Integral Tests: Gamma Leakage



Summary

- **Neutron Capture Gamma Ray Spectra** ^{89}Y, ^{93}Nb, ^{127}I, ^{133}Cs, ^{141}Pr, ^{197}Au, ^{nat}Tl, ^{209}Bi with new Gamma-ray strength functions in low energy region

- **Proton induced nuclear data accurately evaluated for Al-27** in the energy region up to 150 MeV.

- **neutron cross sections for ^{182,183,184,186}W** evaluated in the neutron energies from 0.1 MeV to 20 MeV resolving discrepancies between calculations and measurements of several fusion shielding benchmarks