CENDL-3 and the Works Concerned

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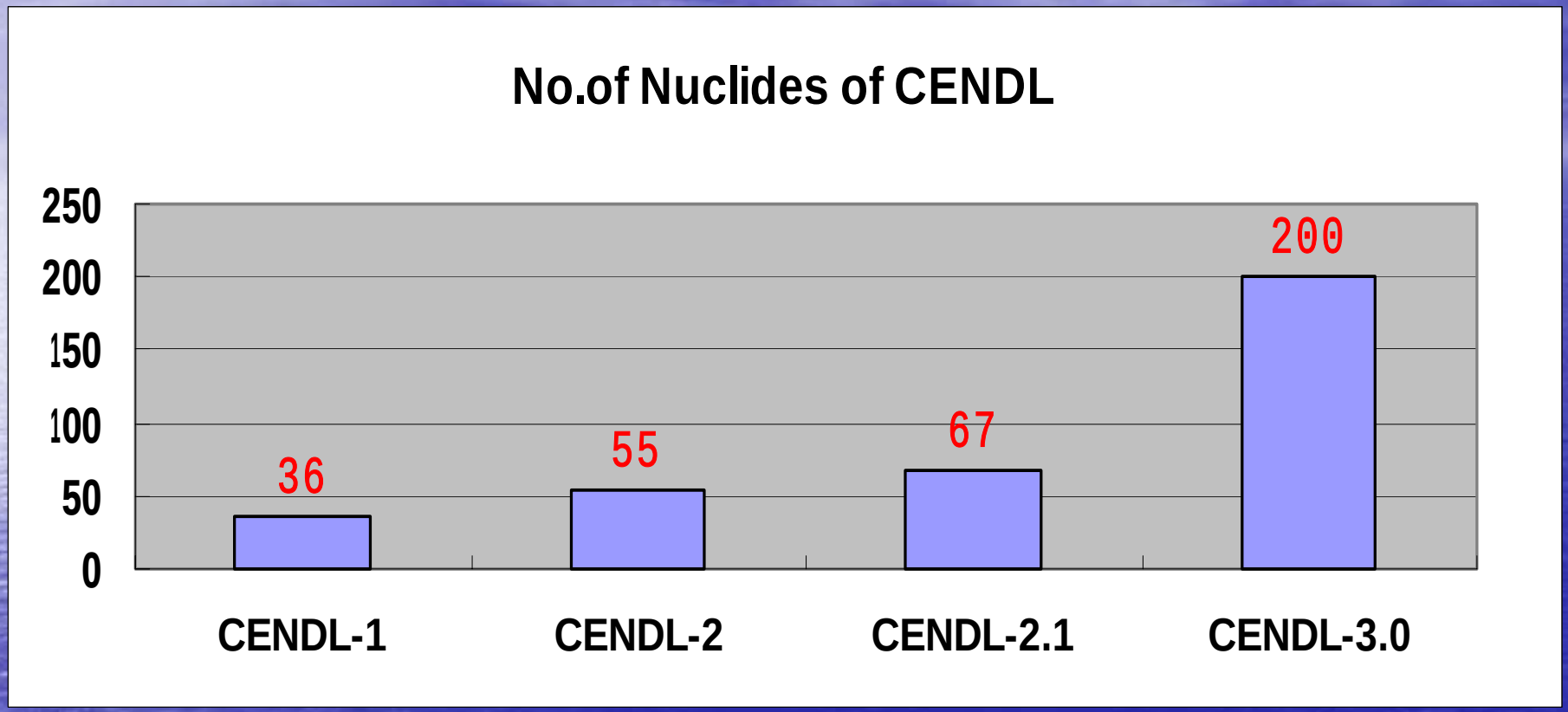
Abstract

Chinese Evaluated Nuclear Data Library third version (CENDL-3.0) contains the nuclear data evaluated works, which were performed during the period of 1995-2000 at China Nuclear Data Center (CNDC) in cooperation with China Nuclear Data Coordination Network (CNDCN), including the neutron data for about 200 nuclides in ENDF/B-6 format in energy region of 10^{-5}eV-20MeV. For most important nuclei the comparisons with other nuclear data libraries (ENDF, JENDL, BROND, JEF, et al.) have been performed, and the benchmark testing for the most important nuclei also have been done.

CNDC and CNDCN also have got a lot of progress in the fields of nuclear data theory study, model and code developments, and nuclear database establishment etc. The status of CENDL-3 and some progress of the nuclear data evaluation studies in the past several years will be introduced in this presentation.


No.of Nuclides of CENDL
250
200
150
100
50
0
36
55
67
200
CENDL-1
CENDL-2
CENDL-2.1
CENDL-3.0

I. CENDL-3 Library

1.1 The view of CENDL-3.0

CENDL-3.0 were started in 1995 and finished in 2000, which includes comprehensive data evaluations for all neutron reactions in the energy range from 10^{-5}eV to 20MeV for 200 nuclides, 133 nuclides are newly evaluated, and 67 nuclides are taken from CENDL-2.1.

The experimental data involved into the evaluations were taken from the EXFOR library, the literary indexed by CINDA and the experimental data measured in China domestically institutes and universities, which were evaluated carefully and corrected by using the new standard cross sections and decay data et al.

UNF series cods LUNF, UNF, SUNF, FUNF were used in the model calculations for the light elements, structural materials, fission products & medium elements, heavy elements and actinides, respectively. Most of the input model parameters are taken from the RIPL library and were adjusted based on the experimental information. APMN and APOM94 programs are used for optimal optical potential parameters automatically searching. ECIS95 is also involved for some model calculations.

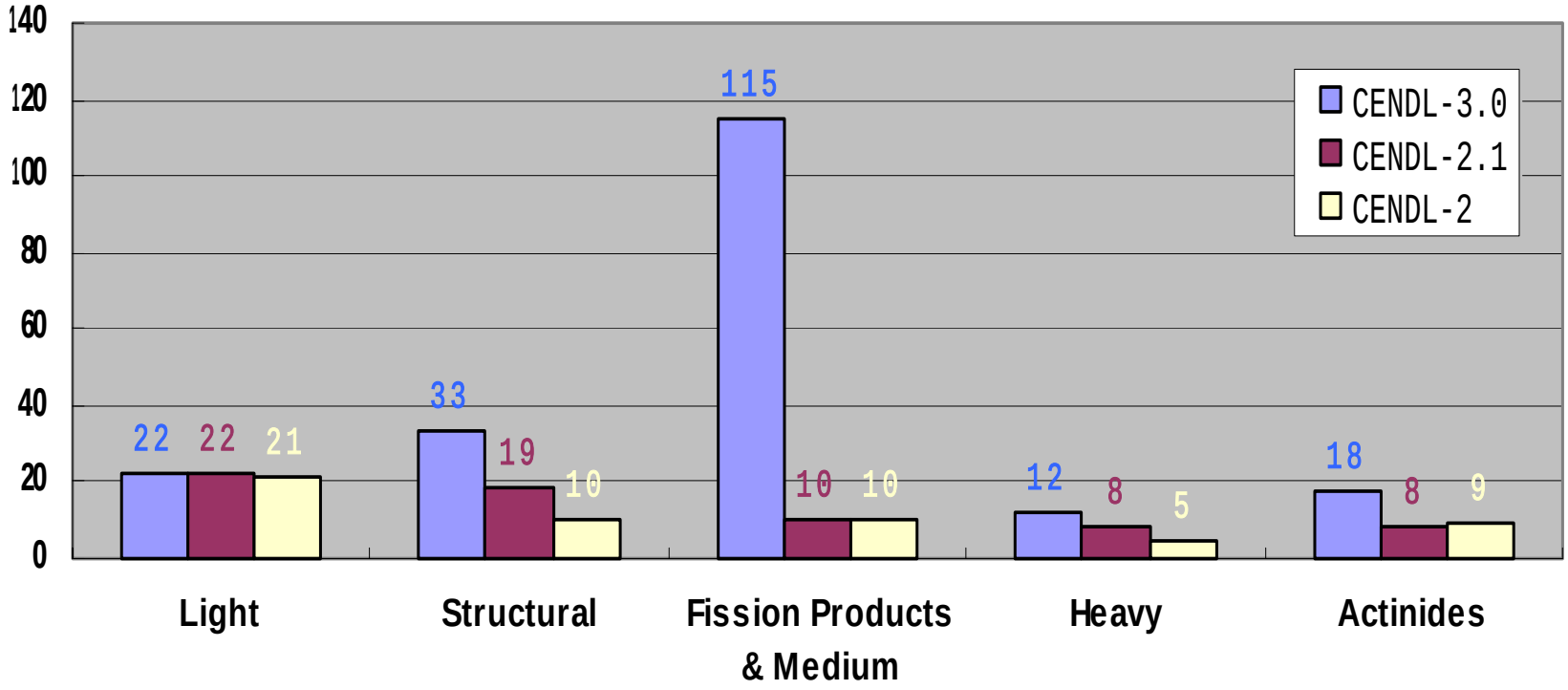
All evaluations were checked by using the ENDF facilities CHECKR, PHYCHE and FIZCON.

CENDL-3.0 was distributed inside of CNDCN and some users in China as an internal test version in 2001. After that some feedback information from benchmark testing and users has been received. These were considered in the re-evaluations for improving the data of the important nuclides, especially for the uranium and plutonium isotopes when the improvement is completed, a new version of CENDL-3.0 CENDL-3.1 will be released in the world.

Nucl.	Content
Light Elements	$^{1,2,3}H$, $^{3,4}He$, $^{6,7}Li$, ^{9}Be, $^{10,11}B$, ^{14}N, ^{16}O, ^{19}F, ^{23}Na, ^{nat}Mg, ^{27}Al, ^{nat}Si, ^{31}P, ^{nat}S, ^{nat}Cl, ^{nat}K, ^{nat}Ca
Structural Materials	^{nat}Ti, ^{nat}V, $^{50,52,53,54,nat}Cr$, ^{55}Mn, $^{54,56,57,58,nat}Fe$, ^{59}Co, $^{58,60,61,62,64,nat}Ni$, $^{63,65,nat}Cu$, ^{nat}Zn
Fission Products & Medium Elements	$^{69,71,nat}Ga$, $^{83,84,85,86}Kr$, $^{85,87,nat}Rb$, $^{88,89,90}Sr$, $^{89,91}Y$, $^{90,91,92,93,94,95,96,nat}Zr$, $^{93,95}Nb$, $^{95,97,98,100,nat}Mo$, ^{99}Tc, $^{99,100,101,102,103,104,105}Ru$, ^{103}Rh, $^{105,108}Pd$, $^{107,109,nat}Ag$, $^{113,nat}Cd$, $^{115,nat}In$, ^{nat}Sn, $^{121,123,nat}Sb$, ^{130}Te, ^{127}I, $^{124,129,131,132,134,135,136}Xe$, $^{133,134,135,137}Cs$, $^{130,132,134,135,136,137,138,nat}Ba$, ^{139}La, $^{140,141,142,144}Ce$, ^{141}Pr, $^{142,143,144,145,146,147,148,150,nat}Nd$, $^{147,148,149}Pm$, $^{144,147,148,149,150,151,152,154,nat}Sm$, $^{151,153,154,155,nat}Eu$, $^{152,154,155,156,157,158,160,nat}Gd$, ^{164}Dy
Heavy Elements	^{nat}Lu, ^{nat}Hf, ^{181}Ta, ^{nat}W, ^{197}Au, ^{nat}Hg, ^{nat}Ti, $^{204,206,207,207,nat}Pb$,
Actinides	$^{233,234,235,236,238,239}U$, ^{237}Np, $^{238,239,240,241,242}Pu$, $^{241,242}Am$, ^{249}Bk, ^{249}Cf

Table 1. The Nuclides of CENDL-3

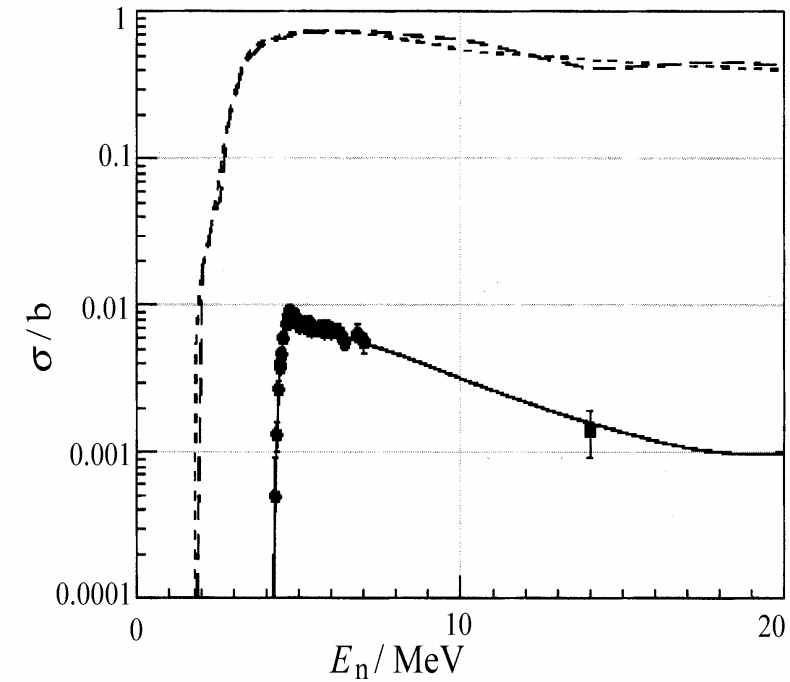
CONTENT OF CENDL- 3.0



1.2 The evaluation of CENDL-3

Light elements

Based on the updated experimental information, a series codes (LUNF) were developed for model calculations of ^{6,7}Li and ^{9}Be, mainly for double differential cross sections (MF-6). The full sets of neutron data, i.e. cross sections of all reactions, energy and angular distribution of



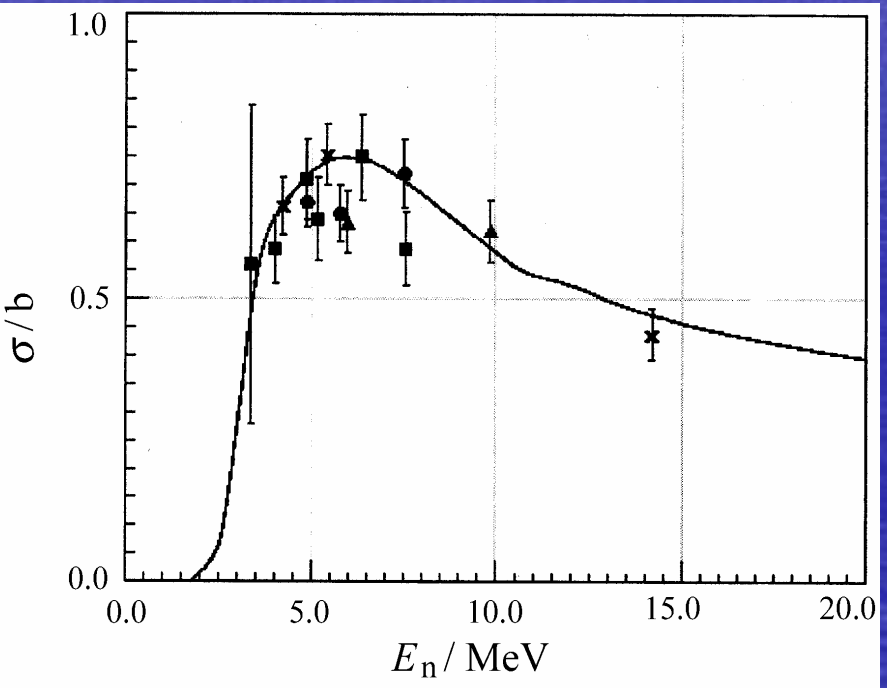


Fig. 1 ^{6}Li(n, n'γ) ^{6}Li total inelastic scattering reaction

Fig. 2 ^{6}Li(n, nd) ^{4}He reaction cross section

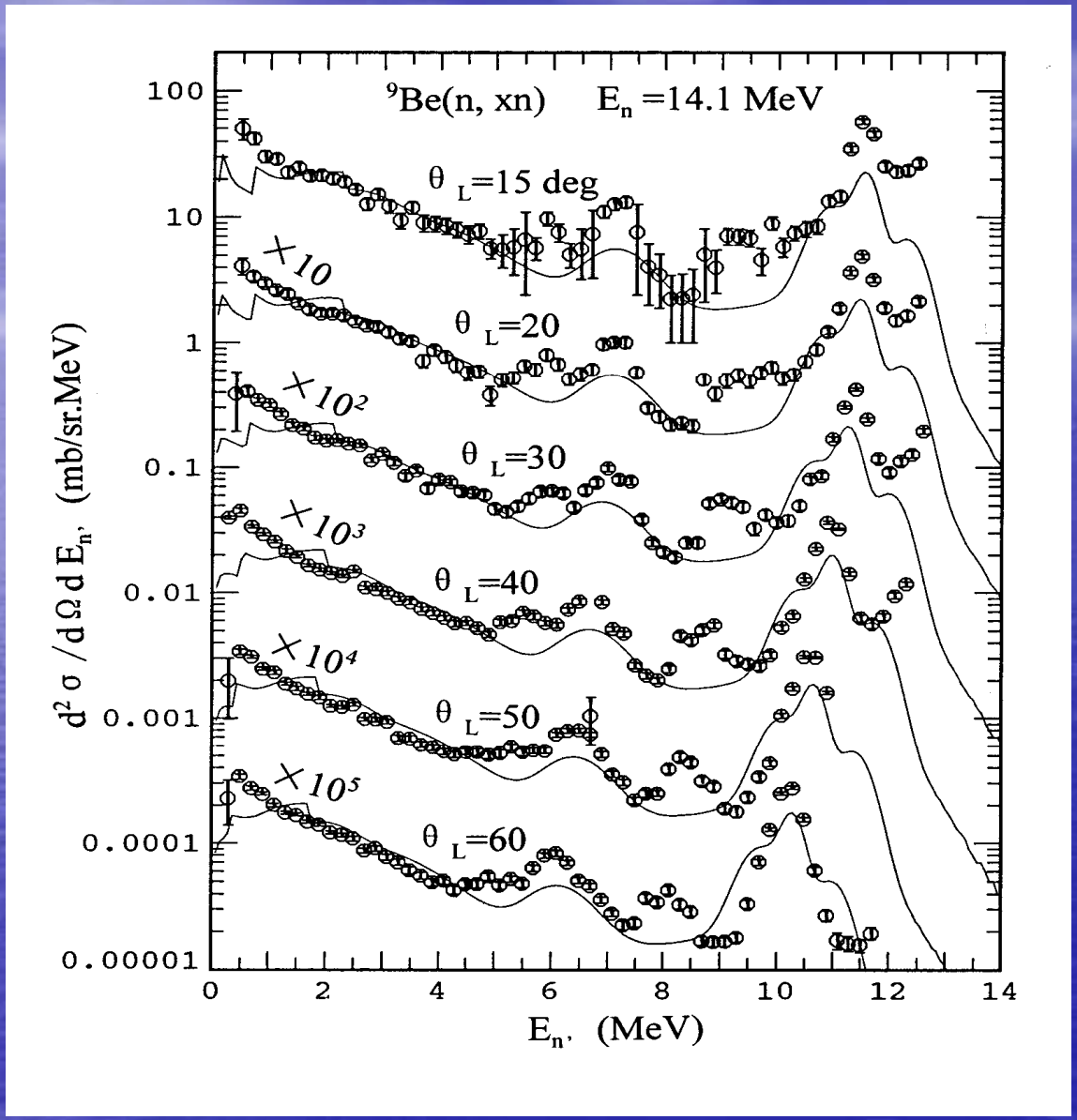


Fig.3 n + ^{9}Be DDX comparisons with exp. data

Structural materials

According to the MUP code used in the CENDL-2 evaluations and the new results of nuclear reaction theoretical studies, a new code UNF used for structural material and medium nuclides calculation was development. With the UNF code calculations and evaluation of new experimental data, the full neutron data set (γ-production data including) are provided in ENDF/B-6 format.

Comparing to CENDL-2, the main development of CENDL-3.0 for the structured materials is that in addition to the data of natural elements, the data of their isotopes were also included, and made the data consistent between the natural elements and their isotopes.

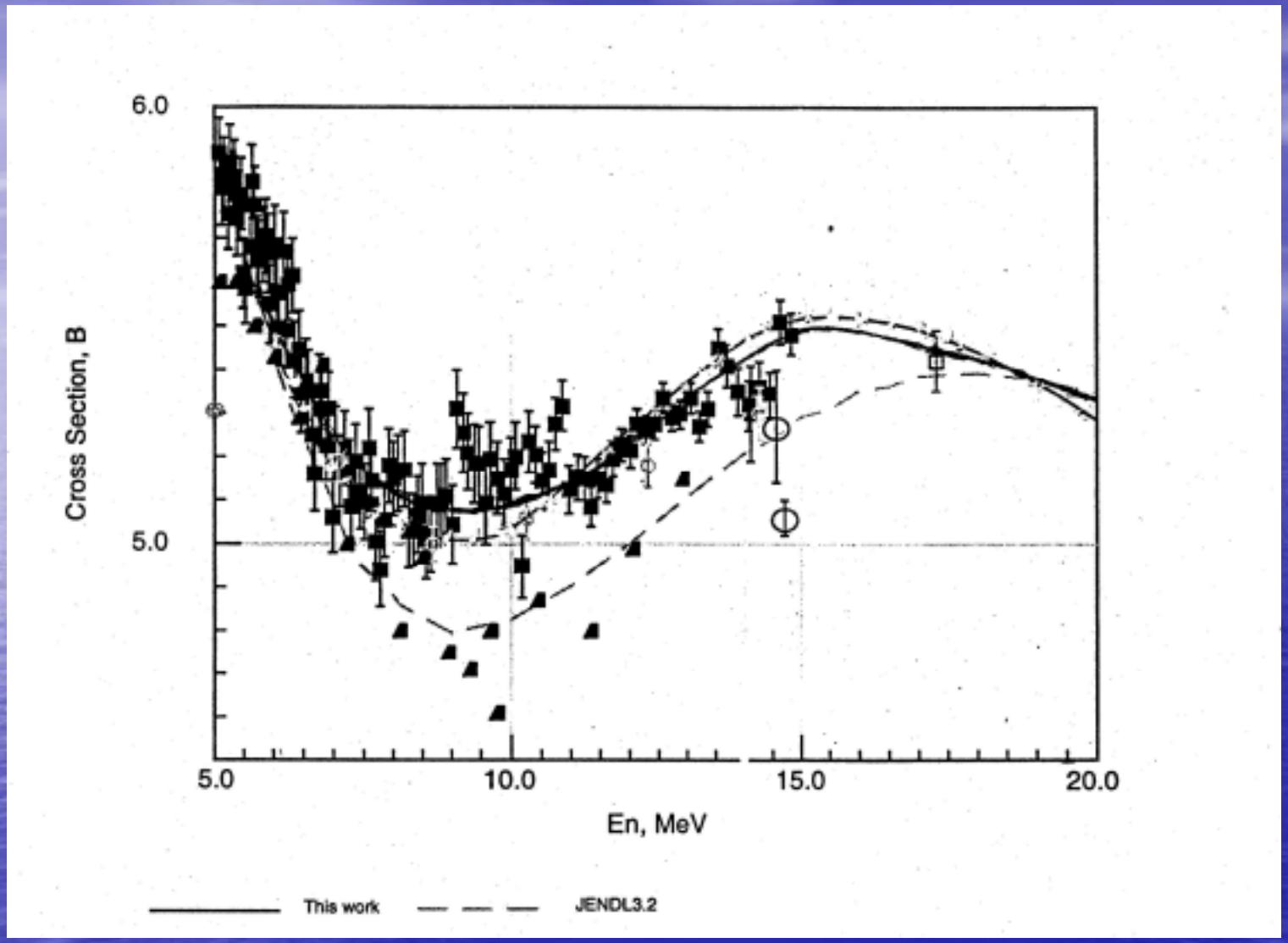


Fig.4 Evaluated total CS of n + ^{nat}W comparison with exp. data and JENDL3.2

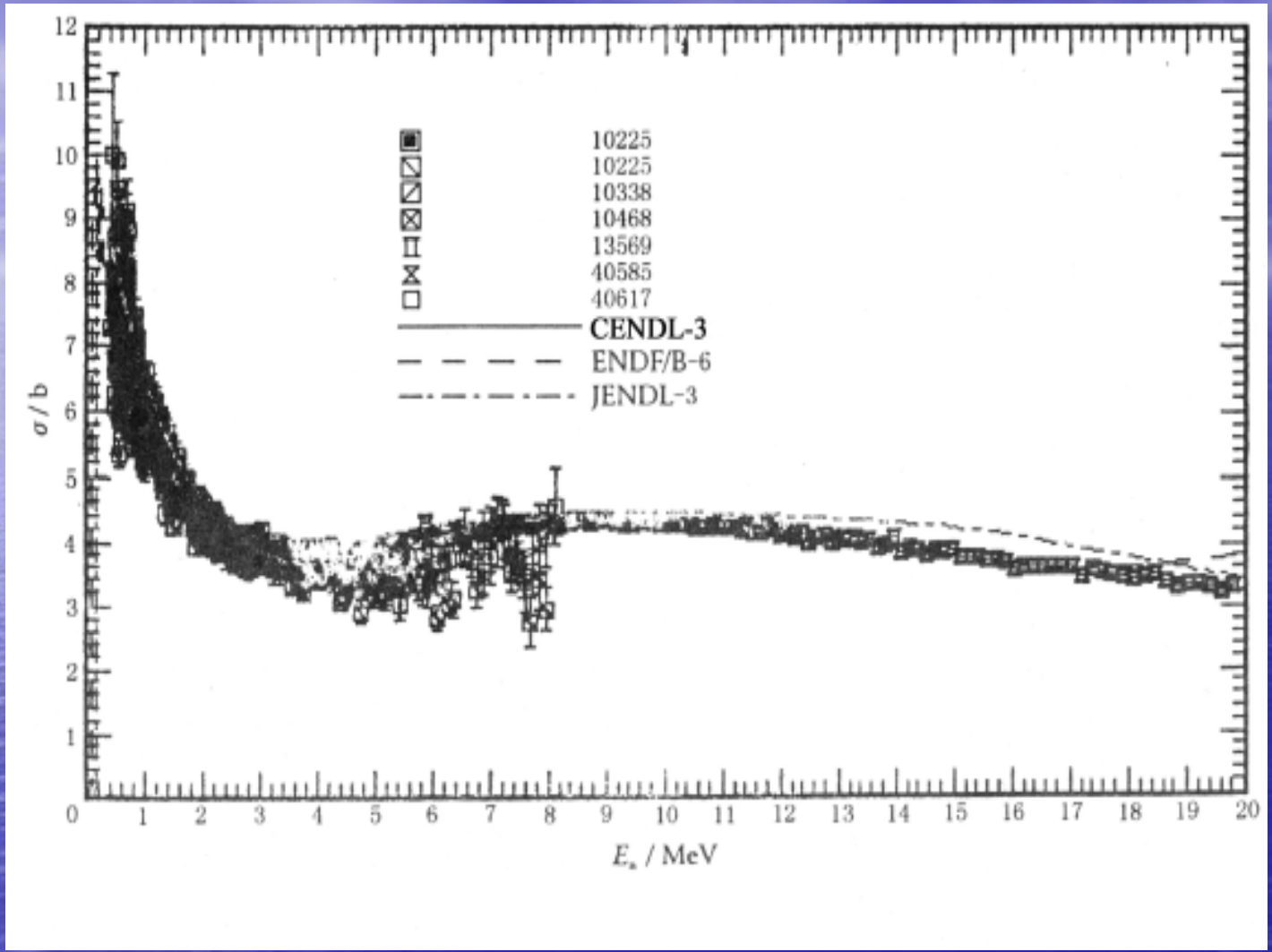


Fig 5. The evaluated total cross section of n + ^{90}Zr

Fission products

From MF-1 to MF-5 were provided in CENDL-3.0 for most fission products nuclides, MF-1 to MF-6 are variable for others. A code SUNF, the simple version of UNF, was developed for the model calculations of fission products nuclides. The data of 101 fission products nuclides were sent to join in the international comparison of FP and coordinated by WPEC Subgroup 21, and 38 of them were selected as the data file of release 7 of ENDF/B-VI.

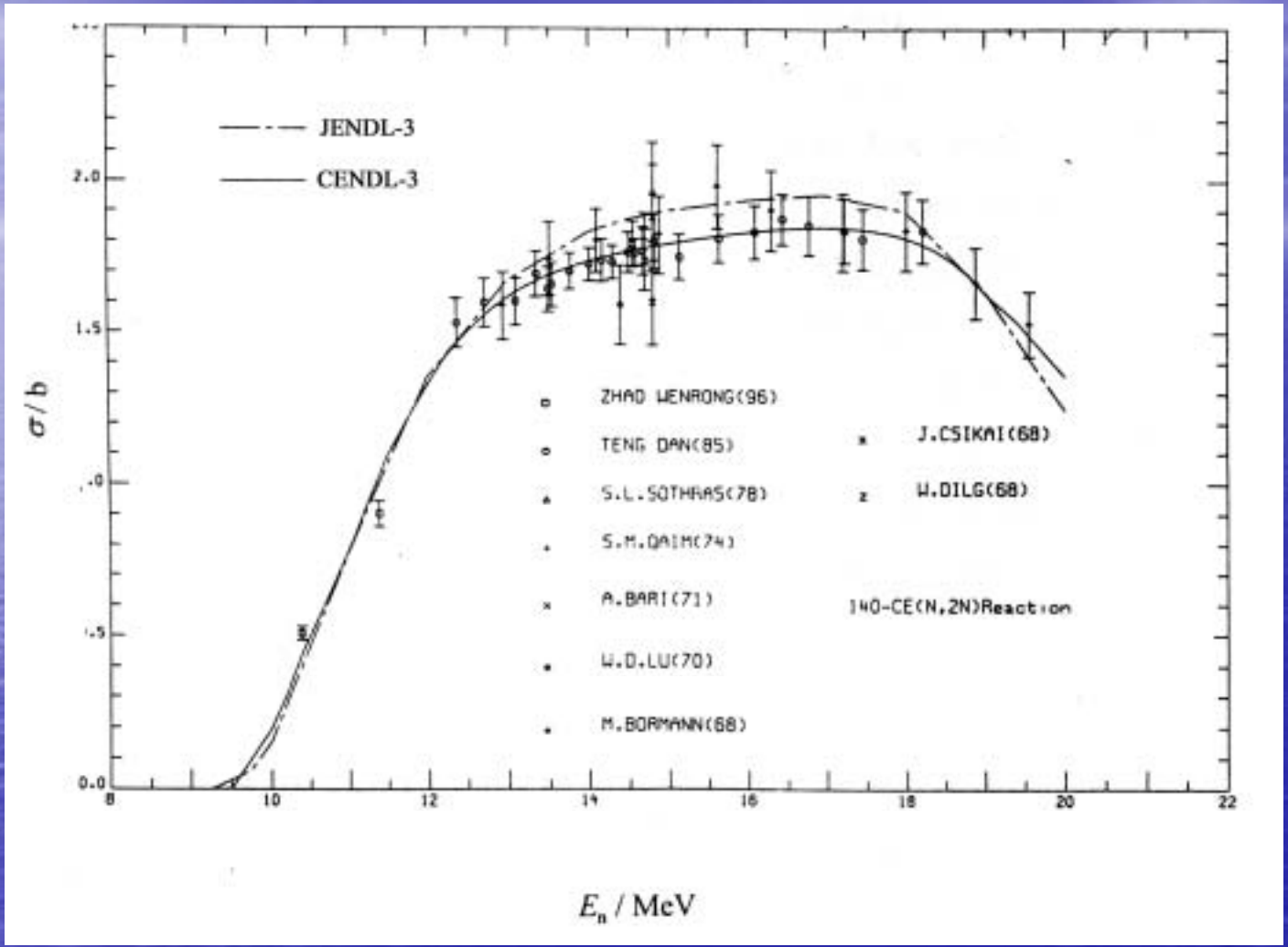


Fig.6 The evaluated (n,2n) reaction cross section of n + ^{140}Ce

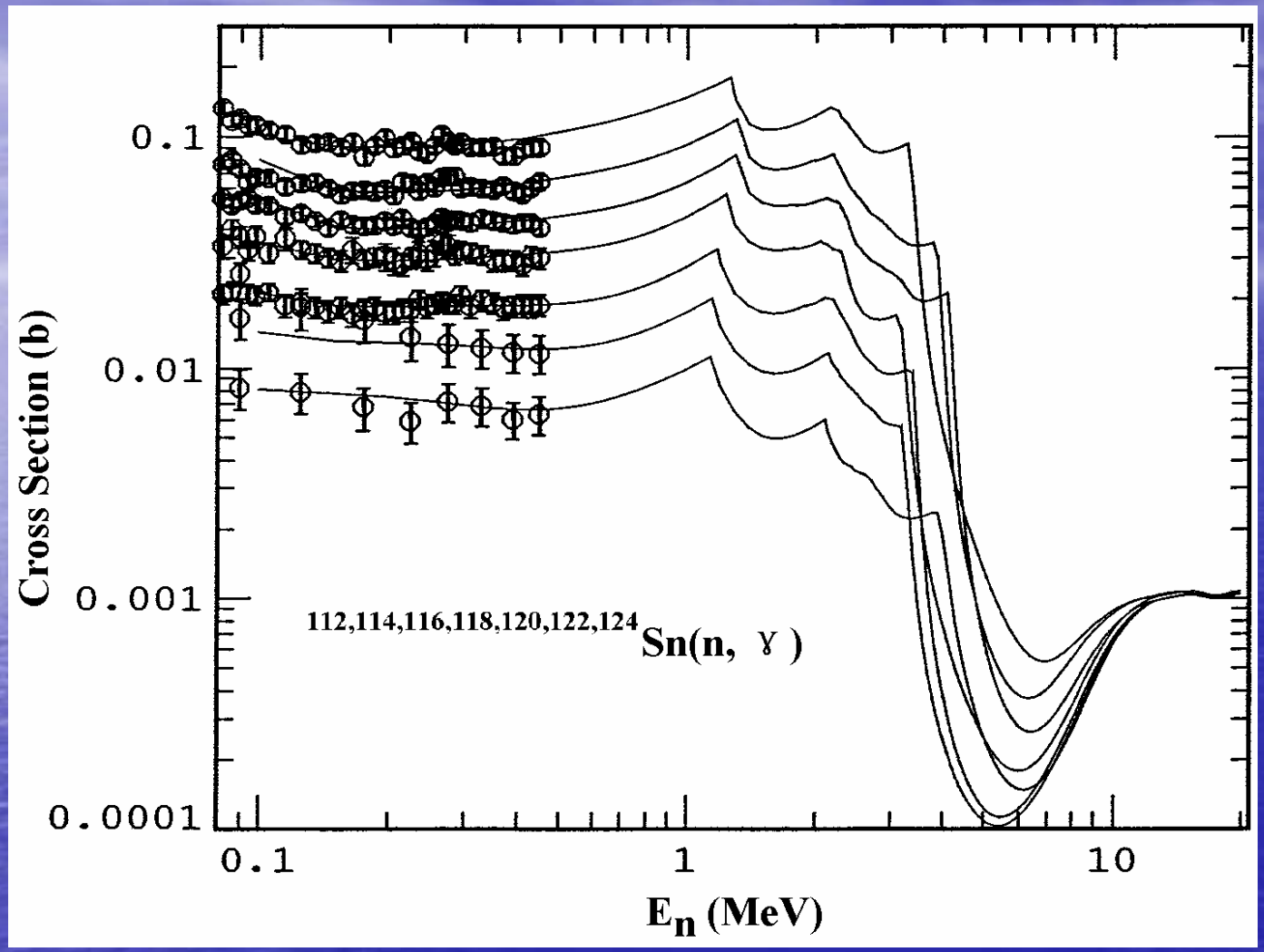


Fig.7 Sn (n, γ) reactions evaluations comparisons with exp. data

Actinides

On the basis of the model calculations with the code FUNF and adjusting the model parameters carefully, the new experimental data, 15 actinides were evaluated or re-evaluated. MF-1~6, 12~15 were included for important actinides (i.e. U, Pu isotopes), and MF-1~5 for others. The file number and nuclides were extended comparing with the pervious version of CENDL, and the results of the benchmark testing have been considered during the evaluation process.

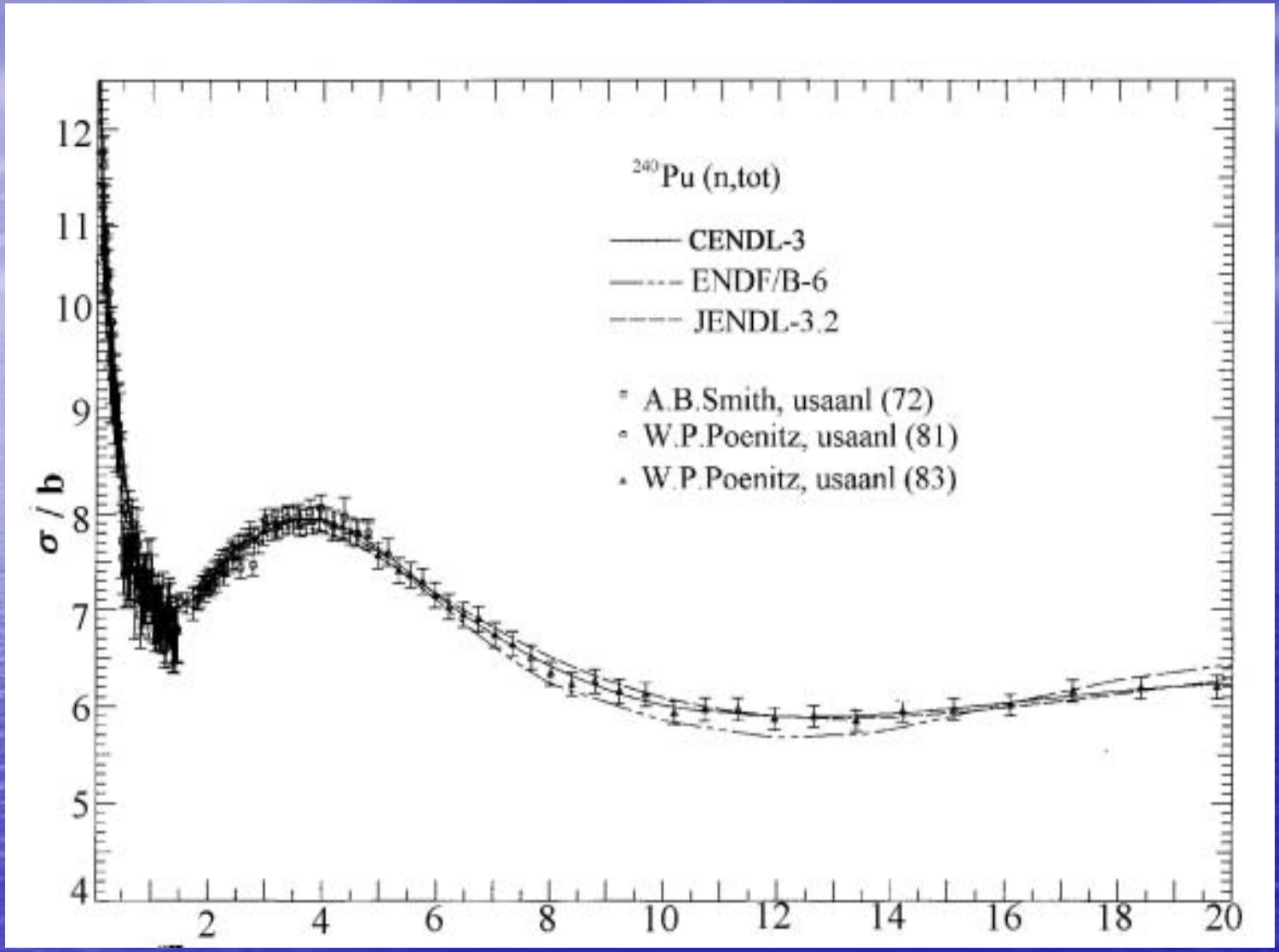


Fig.8 ^{240}Pu (n, tot) evaluations comparisons with exp. data and other libraries

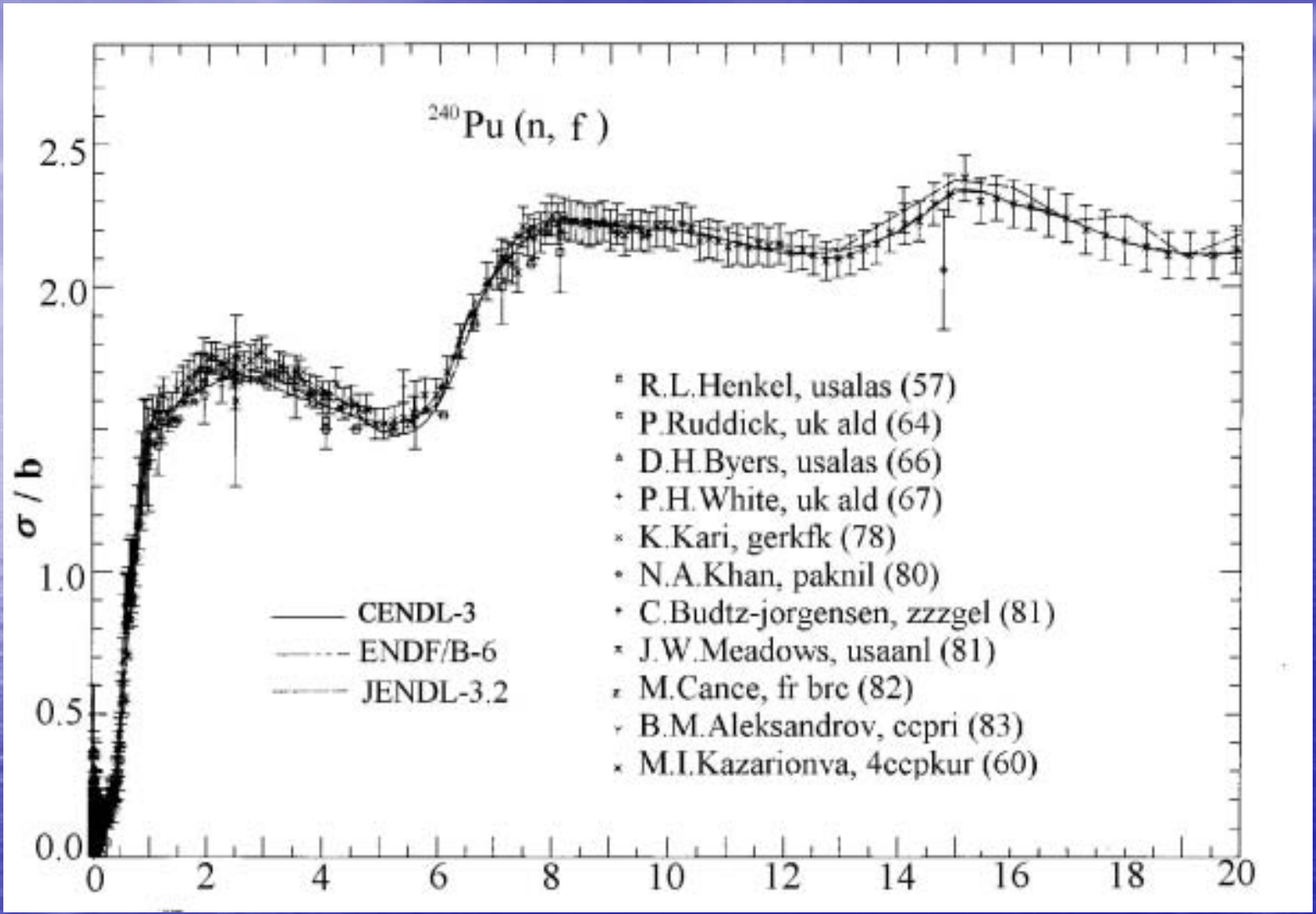


Fig.9 ^{240}Pu (n, f) evaluations comparisons with exp. data and other libraries

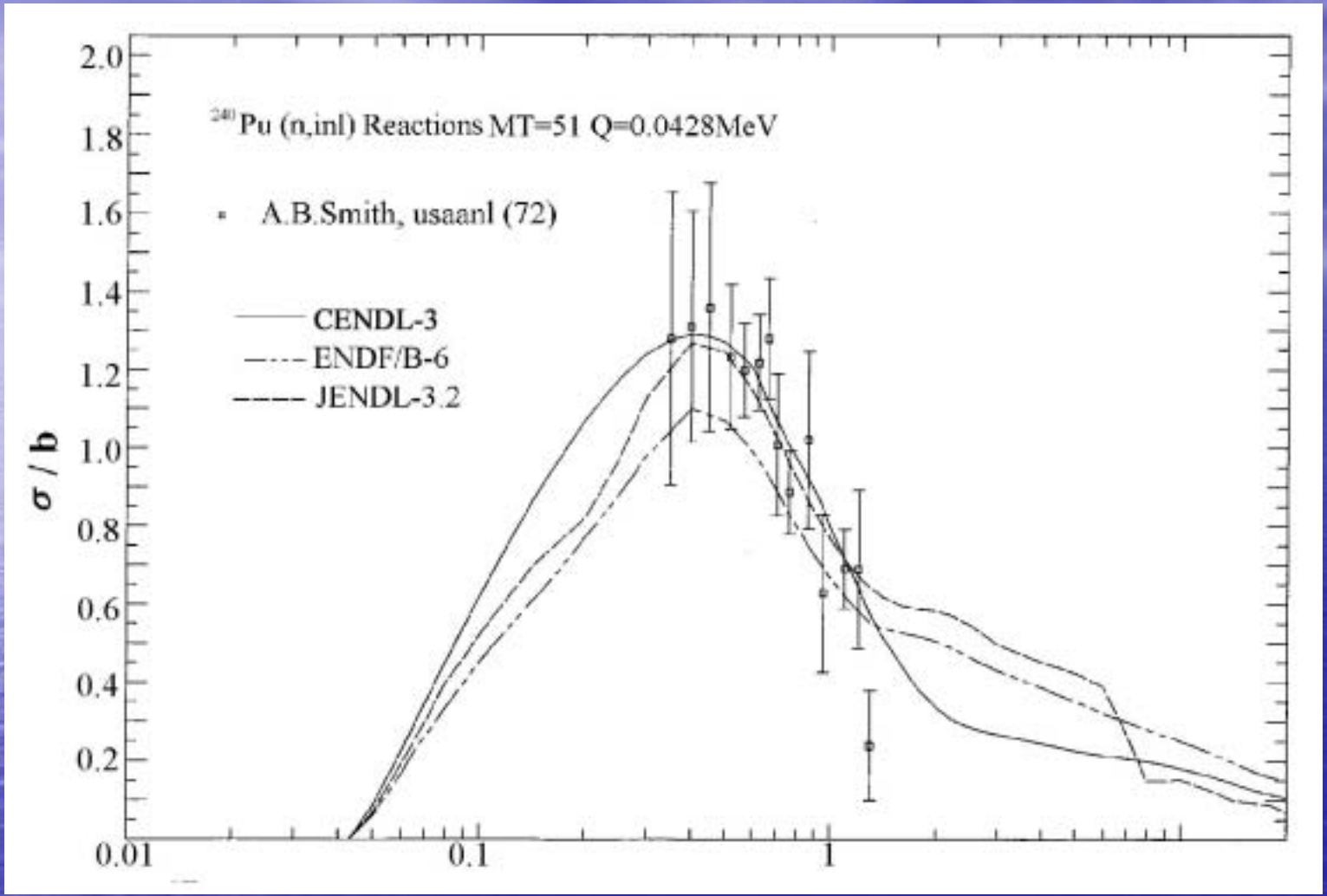


Fig.10 ^{240}Pu (n, inl) (MT=51) comparisons with exp. data and other libraries

1.3 The benchmark testing of CENDL-3.0

In order to test the reliability of the data from CENDL-3.0, benchmark testing for some important nuclides of CENDL-3.0 has been done, the calculations and analyses of benchmarks were done with Monte Carlo code MCNP and transformation codes. The data processing was carried out by using the internationally used code system NJOY97. The results were compared with ENDF/B6, JENDL and JEF-2.2 validated CENDL-3.0 to identify the source of the discrepancies with the experimental results.

Table 1 and 2 show the results of calculation with different libraries K_{eff} of ^{233}U and ^{238}U as the examples.

Assembly	Experiment	CENDL-3.0	ENDF/B-VI	JENDL-3.2
233U Jezebel	1.000(～0.001)	0.99822	0.99235	1.01460
233U-F-002a	1.000(～0.001)	0.99518	0.99544	1.00799
233U-F-002b	1.000(～0.001)	0.99583	0.99943	1.00959
233U-F-003a	1.000(～0.001)	0.99474	0.99755	1.01168
233U-F-003b	1.000(～0.001)	0.99523	0.99989	1.00929
233U-F-004a	1.000(～0.001)	1.00715	1.00494	1.01747
233U-F-004b	1.000(～0.001)	1.00808	1.00940	1.01721
233U-F005a	1.000(～0.001)	0.99951	0.99409	1.00852
233U-F-005b	1.000(～0.001)	1.00204	0.99803	1.00763
Flattop-23	1.000(～0.001)	0.99218	1.00146	1.01140
Averaging	1.000(～0.001)	0.99882	0.99926	1.01154

Table 2. The Calculations of K_{eff} for ^{233}U Benchmarks

Assembly	CENDL-3.0	JEF-2	JENDL-3.2	ENDF/B-6
TRX-1	0.9975	0.9952	0.9901	0.9908
TRX-2	0.9998	0.9972	0.9920	0.9924
BAPL-UO_2-1	1.0010	1.0020	0.9975	0.9952
BAPL-UO_2-2	1.0003	1.0014	0.9972	0.9951
BAPL-UO_2-3	1.0007	1.0014	0.9976	0.9960

Table 3. The Calculations of Keff for ^{238}U Benchmarks of Thermal Reactor

1.4 Conclusion

1. CENDL-3.0 was finished in 2000, and it has been improved since then. CENDL-3.1 is be preparing for its release.
2. Nuclides and data files of CENDL-3.1 were increased and extended compared with CENDL-2.1.
3. All evaluations performed based on the new experimental data and model calculations carefully. They were improved compared with CENDL-2.1.
4. The data of the most important nuclides were validated by the benchmark testing. Some of them are better than other evaluated libraries according to the results of the benchmark testing .

II. Progresses on nuclear data evaluations

2.1 Nuclear reaction model study

The model was improved and completed for 1p shell light nuclides, which contains the dynamics and kinematics of nuclear reactions.

A method to set up file-6 of light nuclei for evaluated neutron data in ENDF/B-6 format below 20 MeV has been established and the energy balance was strictly considered. This method has been used in the calculation of n +^{12}C.

The possibility of ^{5}He emission has been investigated in the light nuclear reactions, and the formulation for calculating of the ^{5}He emission was developed. Also the double differential cross sections of ^{5}He emission, as well as the spectra of neutron and alpha particle from the breakup of ^{5}He, were set up and used in the series codes of LUNF.

2.2 Covariance study

A code EXPOV for evaluating the covariance matrix of experimental data was developed. The covariance data are output in ENDF/B-6 format. The code together with the spline fitting code SPC for multi-sets of correlative data was used to practically evaluate the covariance data for $^{58,60,61,62,64,nat}Ni$, $^{63,65,nat}Cu$ and ^{27}Al and the reasonable results have been got.

A program RAC based on the R matrix theory for calculating covariance data of light nuclide was developed. The program has been tentatively used to calculate the covariance data for $^{6,7}Li$ and $^{10,11}B$, ^{16}O the reasonable results have been got for the cross sections up to 5 MeV. The calculated data and their covariance data for ^{6}Li, ^{10}B have been accepted internationally as standard data of light nuclide.

Also a code has been developed for calculating the covariance data of structural material nuclides based on the statistical theory, including optical model, Hauser-Feshbach and preequilibrium emission model. The code has been used to calculate the covariance data of Ni, Cu and their isotopes in ENDF/B-6 format.

2.3 The systematic study of fission yield data

Based on the mass distribution data up to 200 MeV measured by Zoller, the systematic on dependence of chain yield on incident neutron energy for each mass number A was studied. And also the systematics of mass distribution on mass A and incident neutron energy was investigated by using 5 (or 3) Gaussian model. The calculated results could reproduce the experimental data used well. The investigation also shows that the correlation between the parameters of the systematic and the yields calculated with the systematics is quite complicated and, in general, is quite strong.

2.4 The study on the dependence of yield on energy

Taken some typical important fission products from $^{235,\ 238}U$ fission, and the dependences of fission yield on incident neutron energy were studied. The covariance data were also evaluated based on each set of experimental data and the correlation among the data due to the systematical error, such as fission rate (or normalization), detector efficiency, decay data etc., was taken into account in the fitting and the covariance matrix was obtained as a fit result. The results show that the data for most of product nuclides can be fitted with a linear function. But for some special product nuclides , the data have to be fitted with a spline function.

2.5 Nuclear structure and decay data

CNDC has taken permanent responsibility for evaluating and updating NSDD for A=51, and 195-198 mass chain. The data have been revised using available experimental decay and reaction data for mass chain A=197, and are being updated for mass chain A=196. Updated evaluation of A=197 has been sent to NNDC, USA and will be published in NDS in 2004. The evaluations of mass chain A=52-56 were being updated at Jilin University. The decay data of ^{233}U were being evaluated on the basis of the new measured data.

Thank you for your attention !
Comments and suggestion welcome !