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Evaluations of the fast neutron cross sections of ^{28}Si including complete covariance information

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1. Abstract

A new evaluation of all important neutron cross sections of ^{28}Si was performed in the neutron energy range 1.75 - 20 MeV, that is for the whole energy range above the resonance region. The evaluation combines the results of nuclear model calculations and the complete existing experimental data base in order to obtain the most accurate description of the cross sections possible within our present knowledge. The evaluation was performed in the following way: The cross sections from the EFF - 2 file (results of model calculations) and their estimated covariances are used as prior information which is successively improved by adding experimental data and by applying Bayes' theorem to obtain the posterior information. For this process the code GLUCS was used. For some cross sections, not covered in EFF - 2, priors were taken from BROND and recent nuclear model calculations. As results we obtained evaluated cross sections and their covariances for a chosen set of 15 independent cross sections in a group structure of 31 neutron energy groups 0.2 - 1 MeV wide. The evaluated cross sections thus are the average cross sections over the respective energy group. Thus before use as evaluated data file, fine structure of the various cross sections has to be added whenever such fine structure has been established with sufficient accuracy. A final coupled set of evaluated cross sections and covariances was obtained by a last GLUCS run including the experimental data for "redundant" cross sections, that is all cross sections which can be expressed as sum or difference of the basic cross sections chosen for the evaluation. The results of our new evaluation agree with ENDF/B-VI and EFF - 2 within the uncertainties of these evaluations. Most of the uncertainties of our evaluated cross sections, however, are considerably smaller than those of ENDF/B-VI and the estimated uncertainties of EFF - 2

2. General evaluation procedure

The general principle of our evaluation is essentially the same as used in (*Vonach 92*). For a better understanding of this report we will give a short description of this procedure; it is shown schematically in Fig. 1. First we choose a set of non-redundant cross sections which give a complete and sufficiently detailed description of the interaction of fast neutrons with ^{28}Si as the subject of the evaluation. As the starting point we use the EFF - 2 evaluation and covariances, which we estimated for this evaluation in a similar way as we did previously for the EFF evaluations of the structural materials (*Tagesen 91*). This constitutes our prior knowledge of the neutron cross sections of ^{28}Si. Each type of cross sections is represented prior by a cross section vector T and its covariance matrix M. For some rare reactions, not contained in EFF - 2, we have used BROND and recent nuclear model calculations (*Bateman 99*) (see Section 3). Then Bayes' theorem was used to add successively the experimental data for the various ^{28}Si cross sections to the prior. This is done in the following way: If the data are described by a vector R with the covariance matrix V, application of Bayes' theorem results in the following relations for the improved cross sections T' and the covariances M'

$$T' = T + MG^{+} (GMG^{+} V)^{-1} (R - R_T) \qquad (1)$$

$$M' = M - MG^{+} (GMG^{+} + V)^{-1} GM \qquad (2)$$

where R_T presents the prior value interpolated at the point where R is given, G is the sensitivity matrix of the new experimental data relative to the prior data with the matrix elements $g_{ij} = \delta R_i/\delta T_j$, and the up scripts (+) and (-1) mean transpose and inverse operation respectively. One of the most important conditions for obtaining these formulae is an absence of correlations between the data vectors T and R. This condition is fulfilled as T was derived from nuclear model calculations and R are results of measurements.

From this procedure (depicted at the left side of Figure 1) we get a set of improved cross sections with much reduced uncertainties compared to the prior EFF - 2 values. Cross

sections for which no experimental data exist (e.g. $\sigma_{n,np}$, $\sigma_{n,n\ cont.}$) remain unchanged at this step. This procedure however does not use the complete experimental data base. In addition to cross section measurements for our basic cross sections there exist always additional measurements of so-called redundant cross sections, which are sums or differences of our basic, linearly independent cross sections (see Fig. 1 and Section 5.2). In order to also use this information in a final evaluation step (see right side of Figure 1) the results of our evaluations for the basic cross sections are used as a new improved prior and the data for the redundant cross sections are added as data for the corresponding sums or differences of basic cross sections in a final evaluation step again using Equ. 1 and 2.

Thus the evaluations proceed in the following steps:

1) Establishment of the prior data for all cross sections of interest.
2) Establishment of the experimental data base.
3) Calculation of the improved cross sections *T'* and covariances *M'* for all important cross sections for which data are available.
4) Further improvement of the evaluation by adding the information from all redundant cross sections in a final evaluation step applied to the joint cross section vector for all reaction types.

This leads to a final result of the evaluation in form of a cross section vector *T'* containing a complete set of independent cross sections and one large covariance matrix *M'* which can be subdivided into covariance matrices for the individual cross sections and covariance matrices between different cross section types (interreaction covariance matrices).

Technically this procedure is performed by means of the code GLUCS (*Hetrick 80*) which implements Equ. (1) and (2) and provides output on *T'* and *M'* directly in ENDF/B format. As modified recently (*Tagesen 94*) it can also be used for the constrained least squares adjustment of step 4 of our evaluation procedure.

There is, however, one important difference between this evaluation and our previous evaluations on structural materials (*Vonach 92, Tagesen 94*). In the ENDF - format covariances can only be assigned to group cross sections, that is to cross sections

averaged over the energy grid chosen for the covariances. In case of smooth excitation functions these group cross sections may well be approximated by the point cross sections at the respective group centers if the energy grid is suitably chosen. Thus in our previous evaluations we could use for the cross section vector *T* a set of point cross sections at the center of our energy groups and combine it with a covariance matrix *M* desribing the corresponding group cross sections. In this approximation it was also allowed to enter the measured cross sections (which in most cases are approximately point cross sections) directly into the evaluations.

In the present case of ^{28}Si all cross sections do show considerable irregular fluctuations up to quite high energies (see Fig. 2 -3) because of the low mass and correspondingly low level densitiy of this nucleus.

Therefore we decided to perform the ^{28}Si evaluation strictly in terms of group cross sections in a fixed energy grid. Accordingly both the evaluations chosen as priors and the experimental data base were transformed into group cross sections for the energy grid chosen for the evaluations. The details of this procedure will be described in Sections 3 and 4.

3. Establishment of the prior information for all cross sections of interest and choice of the scope and energy grid of this evaluation

Our basic set of non-redundant cross sections (from which all other cross sections can be derived as linear functions) is shown in Table 1. Most of the choices are obvious, the only important point is the amount of detail used to describe inelastic neutron scattering to discrete levels. Our starting point EFF - 2 contains cross sections for the excitation of 16 levels in ^{28}Si by inelastic neutron scattering; reliable experimental data, however, only exist for the 3 lowest energy levels and even for the second and third excited level are not resolved in most experiments at higher neutron energies. From these considerations we finally decided to describe inelastic neutron scattering by 4 cross sections (n,n_1), (n,n_{2-3}), (n,n_{4-16}), and (n,n_{cont}) (see Table 1).

As already mentioned the recent evaluation EFF - 2.4 completely based on nuclear model calculations was used for construction of the prior cross section vector *T* as far as possible. There are, hoever, a few exceptions as shown in Table 1:

1) The total cross section of silicon is covered by accurate measurements over the whole energy range of the evaluation 1.75 - 20 MeV. Therefore this cross section was entirely evaluated from the experimental data using one of the most recent measurements (*Larson 96*, which is identical to ENDF/B-VI) as prior.

2) The cross sections $\sigma_{n,d}$, $\sigma_{n,t}$, and $\sigma_{n,^3He}$ have not been included in the EFF - 2.4 evaluation. For completeness these reactions have to be included, therefore priors had to be selected from other sources. For $\sigma_{n,t}$ and $\sigma_{n,^3He}$ suitable priors could be taken from the BROND evaluation (*Manokhin 89*). For $\sigma_{n,d}$ evaluations do exist both in ENDF/B-VI and BROND. The results of these two evaluations, however, are completely incompatible with each other and with the existing data. Therefore we had to reject both of them and chose a recent model calculation of the Los Alamos group (M. Chadwick) as our prior (*Bateman 99*).

Covariances *M* for these prior cross sections were constructed by us in the following way:

Uncertainties for various cross sections as function of neutron energy were estimated from the deviations of the excitation functions from different evaluated cross section

libraries (ENDF/B-VI, JENDL - 3, BROND) from our chosen priors (*Tagesen 91*) and our experience on the accuracy of calculated cross sections for different reaction types gained within our evaluation work. As this necessarily is a rather qualitative method, these uncertainties were assigned rather conservatively, as may be seen e.g. from Figs. 5, 6 or 15. A triangular decrease of correlation with increasing distance in energy was assumed for all cross sections in order to describe the (positive) correlations between the cross section uncertainties at different neutron energies E_1 and E_2 (see discussion on page 6 in *Pavlik 91*). To prevent high rigidity of shape of the excitation functions at low energies a variable FWHM of the triangular decrease was calculated as

$$FWHM = (E_1 + E_2)/10. + 2.e+5 \text{ (eV)}$$

which results in FWHM ranging from ≈ 400 keV at 1 MeV up to ≈ 4 MeV at 20 MeV incident neutron energy for generating the off – diagonal elements of the covariances of our priors. Correlation coefficients between cross section uncertainties at the energies E_1 and E_2 were calculated according to the relation

$$\mathrm{cov}(\sigma_1\sigma_2) = \sqrt{Var(\sigma_1)\cdot Var(\sigma_2)}\cdot\frac{(FWHM - ABS(E_1 - E_2)}{FWHM} \qquad (3).$$

in case of ABS (E_1 - E_2) ≤ FWHM and zero otherwise

The energy range of the evaluation was chosen as 1.75 - 20 MeV, as there is an excellent new description of the resonance range up to 1.75 MeV, which is to be combined with this evaluation.

Within the energy range of the evaluation we chose the following 33 bin structure:

First bin	1.75 - 2 MeV
2 - 4 MeV	0.2 MeV bins
4 - 8 MeV	0.5 MeV bins
8 - 13 MeV	1.0 MeV bins
13 - 15 MeV	0.5 MeV bins
15 - 20 MeV	1.0 MeV bins

Thus the elements of our prior cross section vector *T* are the group cross sections for this selected bin structure for each of our basic cross sections. These group cross sections were derived from the evaluations used as priors by numerical integration of the respective excitation functions over the energy range of the bins using the interpolation laws given in the evaluation.

The covariance matrices *M* of the priors were directly constructed in our selected energy grid.

4. Establishment of the experimental data base including construction of covariance matrices for all data sets

We used the experimental data compiled in EXFOR (*Lemmel 86, McLane 88*) and supplemented them by very recent ones which were mostly obtained directly from the authors. A summary on these new data not used in any previous evaluation is given in Table 2. In addition to measurements on ^{28}Si we also used measurements on natural silicon for such cross sections for which the difference between ^{28}Si and ^{nat}Si is known to be small as is the case for σ_{tot}, σ_{non}, and σ_{el}. Additionally, in order to widen our data base, also some more complex cross sections like the γ - production cross section for the first 2^+ level were included in our data base as good measurements exist and accurate conversion procedures to basic cross sections, e.g. σ_{inel}, could be developed. Differential elastic and inelastic scattering cross sections measured over a sufficient angular range were used to derive the total elastic and inelastic scattering cross sections by means of fits with Legendre polynomials in those cases where the integrations had not been performed by the authors.

All data sets were critically reviewed, obviously wrong data were rejected. The accepted data were renormalized if necessary with regard to the used standard cross sections. In some cases renormalizations were also applied if comparisons of a data set with other data consistently have indicated the need for such renormalizations.

For the construction of the covariance matrices of the experimental data sets it is necessary to have detailed information on all uncertainty components of the measurements and the correlation of each component within the data set. As this information is not given for most of the experiments various approximations had to be used.

We assumed that the covariance matrix of total uncertainties can be split into two matrices of partial uncertainties:

1) a diagonal covariance matrix of partial uncertainties describing short-energy-range (SER) correlation properties such as statistical uncertainties due to a finite number of counts per channel;

2) a constant covariance matrix of partial uncertainties connected with properties which induce large-energy-range (LER) correlations, such as systematic uncertainties due to any normalization of the cross sections in order to get absolute values, to the determination of the number of nuclei in a sample, to geometrical sizes and distances and to sample self-absorption properties for the non-resonance energy region. This means we assume complete correlation over all energy groups for these long-range uncertainty components.

The magnitudes of the described two components were chosen according to the uncertainty information given by the authors, or in case of missing information they were estimated by the authors according to their experience about typical uncertainties at the time of the respective experiments. In a considerable number of cases we had to increase the uncertainties given by the authors on the basis of inconsistencies between different data sets (none of which could be excluded for obvious reasons) and our experience about the data uncertainties in different types of experiments at different times.

Only for the total cross sections it was necessary to use a third partial uncertainty matrix, describing so-called medium-energy range correlations (MER). For this covariance matrix the correlations between the uncertainties for different energy groups are described by a linear model of correlation propagation with a certain energy E_c (typical 2 MeV) within which the correlation decreases linearly from 100% to zero.

A summary on the data base prepared in this way is given in Tables 3 - 9. For each data set, accepted for the evaluation, the tables give the energy range of the experiment, the number of data points, the short- and long-range uncertainties assigned to the respective data set and in some cases information about special treatment of the data prior to the use in the evaluation. In some cases which required a more complicated pretreatment of the data, the tables refer to the following discussion in this section.

Finally all experimental data had to be transformed into group cross sections in the energy grid of our prior. This was done in the following way:

1) For suffiently "dense" cross section measurements (where the energy difference between neighboring data points was equal or smaller than the experimental

energy resulution) the group cross sections could be derived directly by numerical integration of the experimental excitation functions. The correlated uncertainty (LER) of the data is obviously not changed by this procedure, the random error (SER) gets very much reduced by this procedure in many cases. Unrealistically low values of the random error obtained in this way were therefore increased in a number of cases according to the judgement of the authors.

2) Single data points or data sets with widely separated points (compared to the energy resolution of the experiment) were only accepted for neutron energies above 4 MeV, as below this energy the amplitudes of the fluctuations are so large, that no useful information on the group cross section can be obtained from single point data. Above 4 MeV single point data were accepted as group cross sections for the energy group containing the data point after adding an additional random (SER) error component, the so-called fluctuation uncertainty. This takes into account that the measured cross section may deviate from the group cross section, because it may by chance coincide with either a fluctuation maximum or minimum. Fluctuation uncertainties of 10 and 5% were used in the energy region 4 - 10 MeV and 10 - 20 MeV respectively. While most experimental data could be transformed into group cross sections and corresponding covariances according to the general scheme described before, some special pretreatment was necessary for a part of the cross section types and some special data sets. In detail the following procedures were used:

1) (n,n_1): Inelastic scattering to the first level (E = 1.79 MeV).

As noted in Table 4 a number of data sets reporting only differential cross sections were integrated over angle using the code GPOLFIT (*Pavlik 90*). In addition it was noticed that some cross sections given in EXFOR as ^{28}Si cross sections are in fact cross sections referring to ^{nat}Si. Therefore all original papers were checked whether the cross sections refer to ^{28}Si or ^{nat}Si. Cross sections for ^{nat}Si were converted into ^{28}Si cross sections by multiplication with a factor $1/f_{28}$, f_{28} being the isotopic abundance of ^{28}Si.

In addition to direct measurements of (n,n_1) cross sections by neutron detection, also γ-production measurements for the $^{1}2^{+} \rightarrow$ g.s. transition were used in the energy range below the energy of the second excited level, where both cross sections must be equal. Differential γ-production cross section measured at 55 and 125 degrees were

transformed into total γ-production cross sections by simple multiplication with a factor 4π, as the angular distribution is expected to be of the form A + B P_2 (cos θ) and the Legendre polynomial P_2 has its zero points at 55° and 125°.

2) The cross sections for n,n_{2-3} were processed very similar. All data were checked for necessary renormalizations from ^{nat}Si to ^{28}Si and renormalized if necessary. In addition to the direct measurements of inelastic scattering the γ-production data of (*Dickens 70*) were also used. The 55° differential γ data for the transition depopulating the second and third level of ^{28}Si were multiplied by a factor of 4π, renormalized to ^{28}Si and added in order to be used as $\sigma(n,n_{2-3})$ values.

3) $\sigma n,n_{4-16}$

A value for this cross section was derived from the measurement of the secondary neutron emission spectrum from the interaction of 14 MeV neutrons with ^{nat}Si. This value was derived by integrating the secondary neutron spectrum over the neutron energy range 5 - 8 MeV corresponding to the excitation energy range 6 - 9 MeV, which extends from an energy intermediate between level 3 and 4 to the excitation energy of level 16 (8.9 MeV). No attempt was made to correct this value from ^{nat}Si to ^{28}Si, as this correction is probably small and rather difficult to calculate. Due to the difficulty in the exact determination of the energy range to be used in the integration and the possible errors due to the use of data ^{nat}Si a rather large uncertainty (15%) was assigned to this cross section.

4) σ_{inel}

Total inelastic cross sections were derived from γ-production measurements for the $^{1}2^{+} \rightarrow$ g.s. for deexcitation of the first excited level, as in even-even nuclei most of the γ-cascades depopulating excited levels proceed via the lowest 2^{+} level. Again differential γ-production cross sections measured at 55 or 125 degrees were converted into total γ-production cross sections by multiplication with 4π and renormalized from ^{nat}Si to ^{28}Si if necessary. In addition the cross sections were corrected for the effect of γ-transitions from higher levels, which bypass the first 2^{+} level. The value of the correction factor is 1.00 up to E_n = 6.28 MeV, the energy of the 4th level, as all lower levels decay completely via the $^{1}2^{+}$ level. At E_n = 7.5 and 9 MeV the correction factor

could be derived as 1.03 and 1.1 from the γ-production measurements of Dickens (*Dickens 70*). Based on this information the energy dependence of the correction factor was assumed as shown in Figure 2. An uncertainty of 5% was assigned to the correction factor in the energy range above 9 MeV.

5) (n,p) cross sections

The very old cross section measurements of *Mainsbridge 63* and *Marion 56* were renormalized by factors 0.53 respectively 0.61 to the new accurate activation measurement at PTB Braunschweig (*Mannhart 2000*) in the overlapping energy range 7-8 MeV. The data of *Anderson 63*, which only give partial (n,p) cross sections for excitation in the lowest 7 excited levels were converted to total (n,p) cross sections by summing over all partial cross sections and the energy range for this summation was restricted to a neutron energy range up to 8 MeV in order to ensure that the excitation of higher levels not contained in the Anderson data is negligible. In addition also these data were renormalized to *Mannhart 2000* in the energy region 7-8 MeV resulting in a renormalization factor of 0.73.

6) (n,α) cross sections

The only existing data sets *Mainsbridge 63* and *Anderson 63* are due to an experiment, in which a silicon surface barrier detector was used both as target and detector for the charged particles produced by neutron induced reactions in silicon. Thus (n,p) and (n,α) cross sections were measured simultaneously with the same efficiency, as both neutron fluence and target thickness are identical for proton and α-particle production. For this reason the (n,α) cross sections from *Mainsbridge 63* and *Anderson 63* were renormalized by the same factors 0.53 and 0.73 as described before for the (n,p) cross section. In addition for *Anderson 63* the partial (n, α_i) cross sections were converted into total (n,α) cross sections in the same way as described for the (n,p) case.

7) (n,p_{prod}) and (n,α_{prod})

The new proton and α-production cross sections from the Los Alamos group (*Batemann 99*) were converted into group cross sections for ^{28}Si in the following way:

a) First the cross sections were corrected for the contribution of the minor isotopes ^{29}Si and ^{30}Si using the ENDF/B-VI cross sections for these isotopes. For

protons in addition a correction was made for the contribution of low energy deuterons (E_d < 5 MeV) which could not be separated from the protons in that experiment. This correction was based on the measured cross sections for the production of deuterons above this detection limit and the results of model calculations in *Bateman 99* on the shape of the deuteron spectra.

b) The original proton and α-production cross sections in *Bateman 99* are given as group cross sections over relatively wide energy bins (2 MeV) not coinciding with the group structure of our evaluation. This structure is not changed by the correction for the influence of the minor Si-isotopes described before. Therefore it was necessary to convert the *Bateman 99* data to our group structure. For this purpose an excitation function was constructed by linear interpolation between the data points and the group cross sections needed for our energy grid were determined by numerical integration of this excitation fucntion within our energy groups. As the data of *Bateman 99* are group cross sections with bin width larger or equal to the distance of neighboring points, they automatically average over the cross section fluctuations and no fluctuation uncertainty had to be added. Because of the large bin width (2 MeV) the data were not used in the steeply rising part of the excitation function between threshold and 6 MeV for protons and threshold and 7 MeV for α-particles.

8) (n,d)

The measurement of the deuteron production cross section in *Bateman 99* is used as (n,d) cross section as the Q-values exclude contributions of (n,dn) or (n,dp) reactions below 20 MeV.

The group cross sections measured in *Bateman 99* were converted into group cross sections for our bin structure in the same way as described for the proton and α-particle production cross section.

9) Total cross sections

As a large number of high-resolution total cross sections exist with high density of points (compared to the energy resolution) all single point cross sections measured were excluded, their contribution would have been negligible due to the large fluctuation uncertainty. Some very old "dense" cross section measurements which strongly deviate from the consistent body of more recent experiments were also excluded. In addition the

target thickness and energy resolution of the measurements were checked wherever given. No need for correction for self-shielding effects was found in this survey.

5. Cross section evaluation

5.1. Evaluation of the cross sections for individual reactions

In the first evaluation step the experimental data for the basic cross sections were combined with the respective priors by means of the code GLUCS according to the general procedure described in Section two (see Fig. 1). This was done for the cross sections σ_{tot}, $\sigma_{n,n1}$, $\sigma_{n,n2\text{-}3}$, $\sigma_{n,n4\text{-}16}$, $\sigma_{n,p}$, $\sigma_{n,d}$ and $\sigma_{n,\gamma}$. For the cross sections $\sigma_{n,\gamma}$, $\sigma_{n,2n}$, $\sigma_{n,np}$, $\sigma_{n,n\alpha}$, $\sigma_{n,n\ cont.}$, $\sigma_{n,t}$, $\sigma_{n,^3He}$, $\sigma_{n,2p}$, and $\sigma_{n,\alpha}$ there are no experimental data; accordingly no improvement of the priors was possible in the first evaluation step.

5.2. Consistent joint evaluation of all cross sections

The cross sections σ_{inel}, σ_{non}, σ_{el}, $\sigma_{p,prod}$ and $\sigma_{\alpha\text{-}prod}$ summarized in Table 7-9 are "redundant" cross sections that is they are sums or differences of the basic cross sections chosen for our evaluation (see Table 1). They are connected to the basic cross sections by means of the relations

$$\sigma_{inel} = \sigma_{n,n_1} + \sigma_{n,n_{2-3}} + \sigma_{n,n_{4-16}} + \sigma_{n,n_{cont}} \tag{4}$$

$$\sigma_{non} = \sigma_{inel} + \sigma_{n,2n} + \sigma_{n,p} + \sigma_{n,np} + \sigma_{n,\alpha} + \sigma_{n,n\alpha} + \sigma_{n,d} + \sigma_{n,t} + \sigma_{n,\gamma} + \sigma_{n,^3He} + \sigma_{n,2p} \tag{5}$$

$$\sigma_{el} = \sigma_{tot} - \sigma_{non} \tag{6}$$

$$\sigma_{\alpha-prod} = \sigma_{n,\alpha} + \sigma_{n,n\alpha} \tag{7}$$

$$\sigma_{p-prod} = \sigma_{n,p} + \sigma_{n,np} \tag{8}$$

As the final step of the evaluation (see right side of Figure 1), an improved evaluation using the information contained in both our basic and redundant cross sections, was obtained in the following way: The redundant cross sections were added as "data" of sums or differences of basic cross sections, according to Equation 4 – 8, by using again the code GLUCS, based on Equation 1 and 2 (see Section 2). The posterior data derived in this way not only strictly fulfill the consistency relations (Equation 4 – 8) but are also considerably improved in quality as many of the redundant cross sections (e.g. σ_{non} or σ_{inel}) are known rather accurately and this accuracy is in part transferred to the basic

cross sections by means of the applied constrained least squares fit. Technically the accepted redundant cross sections (see Tables 7-9) of all types were added as one large data vector to the prior consisting of the coupled set of all basic cross sections in one GLUCS run.

Because of the conditions (4 – 8) and the consideration of all basic cross sections as one coupled set, the resulting correlation matrix now includes parts, which describe correlations between different energy intervals of different cross sections. In most cases these correlations are small (< 10%), in some cases however, e.g. between different partial inelastic cross sections, they are important and have to be taken into account.

6. Result of the evaluation

The main result of this evaluation is a complete but non-redundant set of complete cross sections (σ_{tot}, $\sigma_{n,2n}$, $\sigma_{n,n\alpha}$, $\sigma_{n,np}$, $\sigma_{n,n1}$, $\sigma_{n,n2\text{-}3}$, $\sigma_{n,n4\text{-}16}$, $\sigma_{n,n\ cont.}$, $\sigma_{n,\gamma}$, $\sigma_{n,p}$, $\sigma_{n,d}$, $\sigma_{n,t}$, $\sigma_{n,^3He}$, $\sigma_{n,2p}$, and $\sigma_{n,\alpha}$ averaged over the energy intervals listed on page 8) and their covariances in the energy interval 1.75 - 20 MeV. In addition to this, cross sections and covariances for σ_{el}, σ_{non} and σ_{inel} were obtained by expressing these cross sections as linear functions of the basic cross sections (see Equations 4-8). In Table 10 the final results of this evaluation, that is the group cross sections and their uncertainties, are listed.

These results are also presented in Fig. 3-20 and compared to the EFF-2 and ENDF/B-VI evaluations and to the experimental data base. Both ENDF/B-VI and EFF-2 cross sections were transformed into group cross sections corresponding to the energy intervals of this evaluation for this comparison. For clarity two figures are given for each cross section. The first one compares our new result to the prior (EFF-2) and to the experimental data; the second one compares our new evaluation to ENDF/B-VI. (For those cases where no ENDF/B-VI cross sections exist, of course only one figure is given.) For each evaluation both the evaluated cross sections and the "uncertainty bands" calculated from the respective covariance matrices are shown.

In these figures the progress, achieved in this evaluation, is immediately obvious. Our main conclusions are rather similar to those obtained in our previous evaluations for ^{56}Fe and ^{52}Cr (*Vonach 92, Pronyaev 95*):

1. Except for the total cross sections in the fluctuation region below 4 MeV, the results of this evaluation remain within the uncertainty limits of EFF-2 for all reaction types and energies. Thus our new evaluation, which is more accurate, confirms the validity of the estimations, concerning the uncertainties for the EFF-2 cross sections which were derived from the dispersion of recent evaluations for the establishment of the covariances of our priors (see Section 3).
2. Our new evaluation agrees with ENDF/B-VI within the uncertainties of both evaluations for all cross sections in the whole energy range with the exception of $\sigma_{n,d}$ and σ_{non} in a small energy range (6-9 MeV). The reason for the discrepancy in σ_{non} is

an overestimate of $\sigma_{n,p}$ and $\sigma_{n,\alpha}$ in this energy range by ENDF/B-VI caused erraneously by experimental data, which were renormalized in our evaluation as described in Section 4. The reason for the large discrepancy of our evaluation of $\sigma_{n,d}$ to ENDF/B-VI is not obvious. The ENDF/B-VI evaluation, however, contradicts both the existing experimental data and theoretical expectations, thus probably there is some error in this part of the ENDF/B-VI file for ^{28}Si.

3. The most important improvement of our new evaluation compared to both EFF-2 and ENDF/B-VI is certainly the considerable reduction of the cross section uncertainties in all energy ranges where accurate measurements exist. For the most important cross section σ_{tot} the uncertainties could be reduced by more than a factor of five compared to both EFF-2 and ENDF/B-VI over the whole energy range. A similar improvement compared to EFF-2 could be obtained for σ_{el} and $\sigma_{n,\alpha}$. Considerable improvements could also be obtained for most cross sections important for neutron transport (σ_{inel}, σ_{non}, $\sigma_{n,n1}$, $\sigma_{n,n2-3}$, $\sigma_{n,\alpha}$ and $\sigma_{n,p}$). Due to the large number of cross section measurements around E_n = 14 MeV our new evaluation gives especially low uncertainties in this energy region, which is especially important for fusion neutronics.

   Reduction of uncertainties could not only be obtained for these cross sections where accurate data were available, but also for a number of cross sections, where no direct measurements exist as $\sigma_{n,\alpha}$, $\sigma_{n,np}$, and $\sigma_{n,n\ cont}$ through the use of redundant cross sections as described in Section 5.2 (for example accurate $\sigma_{n,np}$ values could be derived from $\sigma_{n,p}$ and $\sigma_{n,p\text{-}prod}$ cross sections). Only for some reactions with very small cross sections and no data at all, e.g. $\sigma_{n,\gamma}$, $\sigma_{n,^3He}$, and $\sigma_{n,2p}$, it was not possible to obtain any improvement by our new evaluation. Most of these cross sections - with the exception of $\sigma_{n,\gamma}$ in the lower energy range - will however not be very important for applications and the present high cross section uncertainties may be tolerable for these cross sections. The capture cross sections in the lower MeV range, however, are of some importance for neutron transport calculations and are probably the point where new measurements are most urgently needed.

One question may be the rather small uncertainties, resulting from our evaluation

because of possible correlations between our prior data and the added data sets. However, this objection is not valid, because the statistical weight of the priors becomes negligible, if the added data are much more accurate than the prior data, and this is exactly the situation which exists in those parts of our evaluation, where the uncertainties are very low.

Of course, as is the case with any evaluation of experimental data, the uncertainties of our results could be too small because of unrealistically low uncertainty estimates, given for the data or because of neglecting correlations between different data sets. As it has been discussed in the previous chapters, we accounted for such effects by increasing the uncertainty components, estimated by the authors in all cases, which seemed to be doubtful. The correlations between different data sets were checked and generally seemed to be small. Finally our uncertainty estimates are confirmed by the fact that in all evaluations of individual cross sections and in the final joint evaluation χ^2 values of about unity were obtained. According to our judgement, which is also based on our previous experience with evaluations of experimental data (*Pavlik 88, Wagner 90, Pavlik 91, Vonach 92*), the final uncertainties of the present evaluation are realistic effective standard deviations at the 1σ confidence level.

All correlation matrices for the uncertainties of the different reactions are positive definite. There are strong positive correlations between cross sections for neighboring energies, which decrease strongly with the energy difference between the considered points (see Figures 21 to 35).

For most applications concerning neutron transport and activation in fusion devices, the accuracy of the present evaluation will probably be sufficient. The weakest point is to our judgement the capture cross sections in the lower MeV range where data are almost completely missing and thus very large uncertainties have to be assigned to the calculated cross sections. A new accurate measurement of $\sigma_{n,\gamma}$ in the MeV range therefore seems to us the most urgent neutron data requirement for ^{28}Si.

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Table 1 Choice of priors for ^{28}Si

Reaction	Cross section	Covariance matrix
σ_{+}	exp. Larson 96	exp. uncertainties
$\sigma_{n,2n}$	EFF 2.4	new estimate
$\sigma_{n,n\alpha}$	EFF 2.4	new estimate
$\sigma_{n,np}$	EFF 2.4	new estimate
$\sigma_{n,n1}$	EFF 2.4	new estimate
$\sigma_{n,n2\text{-}3}$	EFF 2.4	new estimate
$\sigma_{n,n4\text{-}16}$	EFF 2.4	new estimate
$\sigma_{n,ncont}$	EFF 2.4	new estimate
$\sigma_{n,\gamma}$	EFF 2.4	new estimate
$\sigma_{n,p}$	EFF 2.4	new estimate
$\sigma_{n,d}$	new GNASH calc.	new estimate
$\sigma_{n,t}$	BROND	new estimate
$\sigma_{n,3He}$	BROND	new estimate
$\sigma_{n,\alpha}$	EFF 2.4	new estimate
$\sigma_{n,2p}$	EFF 2.4	new estimate

Table 2 Important new data sets not used in previous evaluations

1) Bateman 1999: Measurement of $\sigma_{n,prod}$, $\sigma_{n,\alpha prod}$ and $\sigma_{n,dprod}$ from threshold to 20 MeV published in Phys. Rev. **C60**, 064906 (1999), numerical cross sections obtained from author.

2) Mannhart 2000: Precision measurements of $\sigma_{n,p}$ from 8-14 MeV at PTB, Germany, data analysis completed in fall 2000, still unpublished data directly obtained from the author.

3) Schmidt 2000: Accurate measurements of σ_{el}, $\sigma_{n,n1}$, $\sigma_{n,n2}$, and $\sigma_{n,n3}$ from 8-14 MeV at PTB, Germany, data analysis completed 2000, still unpublished data directly obtained from the author.

4) Drosg 2000: γ-production measurements for the $^{1}2^{+} \rightarrow$ g.s. transition for E_n = 8.5 - 14 MeV performed at Los Alamos, data analysis completed in 2000, still unpublished data directly obtained from the author.

5) Fessler 2000: Measurement of $\sigma_{n,p}$ between 17 and 20 MeV, published as A. Fessler et al., Nucl.Sci.Eng. **134**, 171 (2000).

Table 3 Experimental data base for σ_T for ^{nat}Si

EXFOR Number	Reference	Sample Thick-ness (At/b)	E_n (MeV)	Number of data points	SER (%)	MER (%)	LER (%)
10047	Foster 71		2.26 - 14.89	243	2	1 - 2	1.0
10070	Schwartz 71	0.63 and 0.14	0.5 - 20	3454	1.5	0 - 2	1.0
10377	Perey 72		0.18 - 20	3693	1.5	1 - 5	1.0
11497	Carlson 67		4.5 - 14.31	506	2	0 - 3.7	2
12882	Larson 81	0.35	2 - 20	685	1.5	1 - 5	1.0
13569	Finley 93	1.02	5.3 - 20	474	1.5	0 - 3.6	1
20012	Cierjacks 68	0.24	0.5 - 20	5115	3	1.4 - 3.7	1.5
20171	Manero 70		3.34 - 5.1	63	2	0.5 - 4	1.5
20292	Tsukada 63		3.05 - 5.05	63	2	2.6 - 3.9	1.5
20480	Cabe 73	0.25	1.2 - 4.95	789	1.5	0 - 0.8	1.5
20973	Calvi 66		2.76 - 4.73	63	3	2 - 7	2
20978	Fasoli 63		5.42 - 8.53	123	2	0.6 - 8	2
22027	Martin 86	0.073	1.75 - 6.0	5522	1.5	1.7 - 4.8	1
10012	Grimes 69		4.75 - 14		1.5	1.7 - 3.3	2
22072	Weigmann 87	0.073	2.2 - 18.98	5148	1.5	0.6 - 3.6	1
ENDF/B-VI	Larson 96		1.75 - 20		1	0 - 6	1

Table 4 Experimental data base for $\sigma(n,n_1)$ for ^{28}Si

EXFOR Number	Reference	Particles detected	Correction applied	E_n (MeV)	Number of data points	SER (%)	LER (%)
10529	Perey 71	n	conv. to ^{28}Si	1.77 - 3.53	258	4	7
10784	Sullivan 79	γ		1.96 - 4.15	42	4	8
11188	Lind 61	γ		1.81 - 3.0	24	4	15
10235	Petitt 66	n		2.45 - 5.8	5	10	10
11579	Drake 69	n	conv. to ^{28}Si	4 - 7.5	4	7 - 8	7
21773	Haout 82	n		9.76 - 14.83	2	5 - 6.4	5
21046	Martin 68	n		5.95	1	10 total	
22113	Boerker 88	n		10.16	1	total	
10263	Brandenberger 72	n	int. diff. c.s. conv. to ^{28}Si	7.71 - 9.05	3	5	6
20343	Tanaka 70	n	int. diff. c.s.	4.81 - 8.03	4	5	7
10107	Kinney 70	n	conv. to ^{28}Si	5.44 - 8.56	4	7.3	7
10306	Obst 73	n	from graph conv. to ^{28}Si	9.8	1	8 total	
10384	Velkley 74	n	conv. to ^{28}Si	8.92	1	5 total	
12927	Howell 88	n	int. diff. c.s.	7.96 - 16.92	5	5	5
21984	Baba 85	n		14.2	1	7 total	
30456	Kliczewski 78	n	int. diff. c.s.	14.1	1	7 total	
21629	Yamanouti 77	n	int. diff. c.s.	21	1	7 total	
12125	Alarcon 86	n	int. diff. c.s.	21.7	1	7 total	
22128	Olsson 90	n		21.6	1	5 total	
	Schmidt 00	n		7.9 - 13.85	10	2	2

Table 5 Experimental data base for the $(n,n_{2\text{-}3})$ cross section of ^{28}Si

EXFOR Number	Reference	Particles detected	Correction applied	E_n (MeV)	Number of data points	SER (%)	LER (%)
10094	Dickens 70	γ	conv. to ^{28}Si	5.35 - 9.0	8	8	10
11579	Drake 69	n	conv. to ^{28}Si	6 - 7.5	3	5 - 8	7
21773	Haout 82	n	-	9.76	1	10 tot	
10107	Kinney 70	n	conv. to ^{28}Si	6.37 - 8.56	5	7 - 18	10
12882	Schmidt 00	n	-	7.9 - 13.85	10	3 - 5	2
20343	Tanaka 70	n	from graph	7.02 - 8.03	2	10	10

Table 6 Experimental data base for $\sigma_{n,p}$ for ^{28}Si

EXFOR Number	Reference	E_n (MeV)	Number of data points	Method	Correction applied	SER (%)	LER (%)
11274	Paul 53	14.5	1	active	s. text	23 total	
11552	Mainsbridge 63	5.06 - 8.42	120	p-det.	s. text	10	10
11567	Marion 56	4.4 - 8.08	39	active		10	10
20799	Robertson 73	14.78	1	active		5 total	
21115	Cohen 56	13.05 - 17.5	18	active		10	20
21999	Bahal 86	14.7	1	active		7 total	
20935	Anderson 63	5.86 - 9.12	573	p.det.	s. text	10	10
21846	Schantl 70	14.7	1	active		7 total	
22089	Ikeda 88	13.33 - 14.91	6	active		4	4
22187	Kawade 90	13.4 - 14.87	6	active		4	
22889	Pasquarelli 67	14.7	1	active	s. text	7 total	
30013	Mitra 66	14.8	1	active	s. text	6 total	
30263	Dresler 73	14.6	1	active		8 total	
30562	Nghoc 80	14.6	1	active		6 total	
30820	Csikai 86 a	13.4 - 14.83	7	active		4	4
30820	Csikai 86 b	13.84 - 14.71	5	active		4	4
40539	Shchebelov 77	14.8	1	active		5 total	
41240	Filatenkov 99	13.47 - 14.81	5	active		3	3
	Mannhart 00	6.9 - 14	19	active		3	3
	Fessler 00	17 - 20	4	active		3 - 9	4
11515	Ranakumar 68	14.4	1	active		8 total	

Table 7 Experimental data for σ_{el} for ^{nat}Si

EXFOR Number	Reference	E_n (MeV)	Correction applied	Number of data points	SER (%)	LER (%)
10107	Kinney 70	5.44 - 8.56		4	7	7
10235	Petitt 66	4 - 5.8		3	7	7
10306	Obst 73	9.8	from graph	1	7 total	
10348	Velkley 74	9		1	5 total	
11286	Clarke 64	14.1		1	10 total	
11579	Drake 69	4 - 7.5		4	4	7
12927	Howell 88	7.96 - 16.92	int. diff.c.s.	5	5	5
13125	Alarcon 86	21.7	s. text	1	8 total	
20343	Tanaka 70	4.81 - 8.03	int. diff.c.s.	4	5	7
21046	Martin 68	5.95	int. diff.c.s.	1	15 total	
21629	Yamanouti 77	21	s. text	1	7 total	
22048	Olsson 87	21.6	s. text	1	7 total	
22113	Boerker 88	10.16		1	5 total	
30456	Kliczewski 78	14.1	int. diff.c.s.	1	10 total	
10203	Brandenberger 73	7.71 - 9.05	int. diff.c.s.	1		7
	Schmidt 00	7.9 - 13.85		10	2	2

Table 8 Experimental data base for the total inelastic cross section for ^{28}Si

EXFOR Number	Reference	Type of experiment	E_n (MeV)	Number of data points	Correction applied	SER (%)	LER (%)
10397	Dickens 74	$\sigma(2^+ \rightarrow g.s.)$	1.83 - 9.7	715	conv. to ^{28}Si	5	12
10094	Dickens 70	$\sigma(2^+ \rightarrow g.s.)$	5.35 - 9.0	8	conv. to ^{28}Si	7	7
41138	Lychagin 92	$\sigma(2^+ \rightarrow g.s.)$	14.1	1		17 total	
40802	Benetskij 65	$\sigma(2^+ \rightarrow g.s.)$	14.0	1		16 total	
20886	Connell 75	$\sigma(2^+ \rightarrow g.s.)$	14.2	1		14 total	
	Drosg 00	$\sigma(2^+ \rightarrow g.s.)$	8.5 - 14.2	4		7	8
	Abbandano 73	$\sigma(2^+ \rightarrow g.s.)$	14.2	1		11 total	
	Zong Ren 79	$\sigma(2^+ \rightarrow g.s.)$	14.9	1		15 total	
	Hongyu 94	$\sigma(2^+ \rightarrow g.s.)$	14.9	1		10 total	
	Besotnij 80	$\sigma(2^+ \rightarrow g.s.)$	14.0	1		11 total	
	Drake 78	$\sigma(2^+ \rightarrow g.s.)$	14.2	1	conv. to ^{28}Si	12 total	

Table 9 Experimental data for the cross section $\sigma_{n,\alpha}$, $\sigma_{n,\alpha prod}$, $\sigma_{n,pprod}$, $\sigma_{n,d}$, $\sigma_{n,\gamma}$, $\sigma_{n,n4\text{-}16}$ for ^{28}Si and σ_{non} for ^{nat}Si

Type of reaction	EXFOR Number	Reference	Correction applied	E_n (MeV)	Number of data points	SER (%)	LER (%)
(n,α)	20935	Anderson 63	s. text	5.86 - 9.12	671	10	10
(n,α)	11552	Mainsbridge 63	s. text	5.42 - 8.42	109	10	10
(n,α_{prod})		Bateman 99	s. text	Thr. - 20	10	8	8
(n,p_{prod})		Bateman 99	s. text	Thr. - 20	12	8	10
(n,d)		Bateman 99	s. text	Thr. - 20	5	15 - 25	10
(n,γ)	20530	Rigaud 70		14.06	1	25 total	
(n,γ)	30532	Budnar 79		14.10	1	14 total	
nonel	40369	Flerov 56		14.7	1	6 total	
nonel	30758	Zhong 86		15	1	6 total	
$(n,n_{4\text{-}16})$	22075	Takahashi 88	s. text	14.1	1	15 total	

Table 10 Evaluated cross sections for neutron induced reactions on ^{28}Si

MT = 1 total cross section

Neutron energy (in MeV)	cross section (in barn)	std.dev. of sigma(E) (in barn)	std.dev. (in %)
1.7500E+00 - 2.0000E+00	3.4776E+00	2.954E-02	0.85
2.0000E+00 - 2.2000E+00	2.6921E+00	2.119E-02	0.79
2.2000E+00 - 2.4000E+00	2.5281E+00	1.835E-02	0.73
2.4000E+00 - 2.6000E+00	2.8676E+00	2.067E-02	0.72
2.6000E+00 - 2.8000E+00	2.5249E+00	1.691E-02	0.67
2.8000E+00 - 3.0000E+00	2.4972E+00	1.600E-02	0.64
3.0000E+00 - 3.2000E+00	2.4901E+00	1.616E-02	0.65
3.2000E+00 - 3.4000E+00	2.2822E+00	1.464E-02	0.64
3.4000E+00 - 3.6000E+00	2.2199E+00	1.417E-02	0.64
3.6000E+00 - 3.8000E+00	1.7566E+00	1.140E-02	0.65
3.8000E+00 - 4.0000E+00	2.1275E+00	1.441E-02	0.68
4.0000E+00 - 4.5000E+00	2.3093E+00	1.597E-02	0.69
4.5000E+00 - 5.0000E+00	2.5230E+00	1.680E-02	0.67
5.0000E+00 - 5.5000E+00	2.0796E+00	1.339E-02	0.64
5.5000E+00 - 6.0000E+00	2.1987E+00	1.497E-02	0.68
6.0000E+00 - 6.5000E+00	2.0615E+00	1.246E-02	0.60
6.5000E+00 - 7.0000E+00	1.8432E+00	1.114E-02	0.60
7.0000E+00 - 7.5000E+00	1.9603E+00	1.216E-02	0.62
7.5000E+00 - 8.0000E+00	2.0244E+00	1.290E-02	0.64
8.0000E+00 - 9.0000E+00	1.8725E+00	1.190E-02	0.64
9.0000E+00 - 1.0000E+01	1.8296E+00	1.185E-02	0.65
1.0000E+01 - 1.1000E+01	1.7852E+00	1.140E-02	0.64
1.1000E+01 - 1.2000E+01	1.7836E+00	1.239E-02	0.69
1.2000E+01 - 1.3000E+01	1.8233E+00	1.121E-02	0.61
1.3000E+01 - 1.3500E+01	1.8111E+00	1.182E-02	0.65
1.3500E+01 - 1.4000E+01	1.8292E+00	1.164E-02	0.64
1.4000E+01 - 1.4500E+01	1.7917E+00	1.119E-02	0.62
1.4500E+01 - 1.5000E+01	1.7718E+00	1.288E-02	0.73
1.5000E+01 - 1.6000E+01	1.7952E+00	1.404E-02	0.78
1.6000E+01 - 1.7000E+01	1.8266E+00	1.309E-02	0.72
1.7000E+01 - 1.8000E+01	1.8177E+00	1.343E-02	0.74
1.8000E+01 - 1.9000E+01	1.8484E+00	1.506E-02	0.81
1.9000E+01 - 2.0000E+01	1.8494E+00	1.748E-02	0.95

MT = 2 elastic cross section

Neutron energy (in MeV)	cross section (in barn)	std.dev. of sigma(E) (in barn)	std.dev. (in %)
1.7500E+00 - 2.0000E+00	3.3893E+00	2.9955E-02	0.88
2.0000E+00 - 2.2000E+00	2.4883E+00	2.3513E-02	0.94
2.2000E+00 - 2.4000E+00	2.1411E+00	2.7104E-02	1.27
2.4000E+00 - 2.6000E+00	2.4823E+00	2.8725E-02	1.16
2.6000E+00 - 2.8000E+00	2.2248E+00	2.2646E-02	1.02
2.8000E+00 - 3.0000E+00	2.0260E+00	2.8893E-02	1.43
3.0000E+00 - 3.2000E+00	2.0449E+00	2.9422E-02	1.44
3.2000E+00 - 3.4000E+00	1.7394E+00	3.3367E-02	1.92
3.4000E+00 - 3.6000E+00	1.7390E+00	3.1213E-02	1.79
3.6000E+00 - 3.8000E+00	1.3329E+00	2.7501E-02	2.06
3.8000E+00 - 4.0000E+00	1.5779E+00	3.6005E-02	2.28
4.0000E+00 - 4.5000E+00	1.7339E+00	3.5582E-02	2.05
4.5000E+00 - 5.0000E+00	1.7900E+00	4.2150E-02	2.35
5.0000E+00 - 5.5000E+00	1.3668E+00	3.7631E-02	2.75
5.5000E+00 - 6.0000E+00	1.4576E+00	3.2768E-02	2.25
6.0000E+00 - 6.5000E+00	1.2825E+00	3.3478E-02	2.61
6.5000E+00 - 7.0000E+00	9.8715E-01	3.1301E-02	3.17
7.0000E+00 - 7.5000E+00	1.0608E+00	3.1060E-02	2.93
7.5000E+00 - 8.0000E+00	1.0223E+00	2.8436E-02	2.78
8.0000E+00 - 9.0000E+00	9.1178E-01	2.6645E-02	2.92
9.0000E+00 - 1.0000E+01	8.0789E-01	2.6180E-02	3.24
1.0000E+01 - 1.1000E+01	7.3117E-01	2.1824E-02	2.98
1.1000E+01 - 1.2000E+01	7.2103E-01	2.5913E-02	3.59
1.2000E+01 - 1.3000E+01	7.5963E-01	2.6335E-02	3.47
1.3000E+01 - 1.3500E+01	7.4624E-01	4.8098E-02	6.45
1.3500E+01 - 1.4000E+01	7.8549E-01	2.7091E-02	3.45
1.4000E+01 - 1.4500E+01	7.6878E-01	2.5307E-02	3.29
1.4500E+01 - 1.5000E+01	7.7292E-01	3.0758E-02	3.98
1.5000E+01 - 1.6000E+01	8.4194E-01	4.9893E-02	5.93
1.6000E+01 - 1.7000E+01	9.0212E-01	4.0136E-02	4.45
1.7000E+01 - 1.8000E+01	9.0786E-01	5.8283E-02	6.42
1.8000E+01 - 1.9000E+01	9.4492E-01	5.5632E-02	5.89
1.9000E+01 - 2.0000E+01	9.2443E-01	3.1271E-02	3.38

MT = 3 nonelastic cross section

Neutron energy (in MeV)	cross section (in barn)	std.dev. of sigma(E) (in barn)	std.dev. (in %)
1.7500E+00 - 2.0000E+00	8.8264E-02	5.2726E-03	5.97
2.0000E+00 - 2.2000E+00	2.0376E-01	1.0425E-02	5.12
2.2000E+00 - 2.4000E+00	3.8698E-01	2.0166E-02	5.21
2.4000E+00 - 2.6000E+00	3.8532E-01	2.0256E-02	5.26
2.6000E+00 - 2.8000E+00	3.0006E-01	1.5293E-02	5.10
2.8000E+00 - 3.0000E+00	4.7120E-01	2.4334E-02	5.16
3.0000E+00 - 3.2000E+00	4.4524E-01	2.4808E-02	5.57
3.2000E+00 - 3.4000E+00	5.4276E-01	3.0187E-02	5.56
3.4000E+00 - 3.6000E+00	4.8089E-01	2.8016E-02	5.83
3.6000E+00 - 3.8000E+00	4.2369E-01	2.5188E-02	5.95
3.8000E+00 - 4.0000E+00	5.4961E-01	3.3198E-02	6.04
4.0000E+00 - 4.5000E+00	5.7539E-01	3.2318E-02	5.62
4.5000E+00 - 5.0000E+00	7.3305E-01	3.9258E-02	5.36
5.0000E+00 - 5.5000E+00	7.1281E-01	3.5687E-02	5.01
5.5000E+00 - 6.0000E+00	7.4114E-01	2.9991E-02	4.05
6.0000E+00 - 6.5000E+00	7.7905E-01	3.1704E-02	4.07
6.5000E+00 - 7.0000E+00	8.5605E-01	2.9962E-02	3.50
7.0000E+00 - 7.5000E+00	8.9946E-01	2.9377E-02	3.27
7.5000E+00 - 8.0000E+00	1.0021E+00	2.7333E-02	2.73
8.0000E+00 - 9.0000E+00	9.6072E-01	2.6131E-02	2.72
9.0000E+00 - 1.0000E+01	1.0217E+00	2.6256E-02	2.57
1.0000E+01 - 1.1000E+01	1.0540E+00	2.3294E-02	2.21
1.1000E+01 - 1.2000E+01	1.0626E+00	2.7152E-02	2.56
1.2000E+01 - 1.3000E+01	1.0637E+00	2.6435E-02	2.49
1.3000E+01 - 1.3500E+01	1.0649E+00	4.7337E-02	4.45
1.3500E+01 - 1.4000E+01	1.0437E+00	2.8003E-02	2.68
1.4000E+01 - 1.4500E+01	1.0229E+00	2.4801E-02	2.42
1.4500E+01 - 1.5000E+01	9.9888E-01	2.8323E-02	2.84
1.5000E+01 - 1.6000E+01	9.5326E-01	4.8320E-02	5.07
1.6000E+01 - 1.7000E+01	9.2448E-01	4.0415E-02	4.37
1.7000E+01 - 1.8000E+01	9.0984E-01	5.7258E-02	6.29
1.8000E+01 - 1.9000E+01	9.0348E-01	5.4457E-02	6.03
1.9000E+01 - 2.0000E+01	9.2497E-01	3.2447E-02	3.51

MT = 4 inelastic cross section

Neutron energy (in MeV)	cross section (in barn)	std.dev. of sigma(E) (in barn)	std.dev. (in %)
1.7500E+00 - 2.0000E+00	8.7522E-02	5.2596E-03	6.01
2.0000E+00 - 2.2000E+00	2.0307E-01	1.0419E-02	5.13
2.2000E+00 - 2.4000E+00	3.8634E-01	2.0164E-02	5.22
2.4000E+00 - 2.6000E+00	3.8472E-01	2.0254E-02	5.26
2.6000E+00 - 2.8000E+00	2.9949E-01	1.5291E-02	5.11
2.8000E+00 - 3.0000E+00	4.7066E-01	2.4332E-02	5.17
3.0000E+00 - 3.2000E+00	4.4470E-01	2.4807E-02	5.58
3.2000E+00 - 3.4000E+00	5.4220E-01	3.0186E-02	5.57
3.4000E+00 - 3.6000E+00	4.8031E-01	2.8014E-02	5.83
3.6000E+00 - 3.8000E+00	4.2308E-01	2.5187E-02	5.95
3.8000E+00 - 4.0000E+00	5.4898E-01	3.3196E-02	6.05
4.0000E+00 - 4.5000E+00	5.7306E-01	3.2313E-02	5.64
4.5000E+00 - 5.0000E+00	7.2766E-01	3.9248E-02	5.39
5.0000E+00 - 5.5000E+00	6.9177E-01	3.5639E-02	5.15
5.5000E+00 - 6.0000E+00	6.9848E-01	2.9848E-02	4.27
6.0000E+00 - 6.5000E+00	6.3985E-01	3.1202E-02	4.88
6.5000E+00 - 7.0000E+00	6.2462E-01	2.8903E-02	4.63
7.0000E+00 - 7.5000E+00	6.0120E-01	2.8068E-02	4.67
7.5000E+00 - 8.0000E+00	6.3484E-01	2.5922E-02	4.08
8.0000E+00 - 9.0000E+00	5.7730E-01	2.4060E-02	4.17
9.0000E+00 - 1.0000E+01	6.1232E-01	2.5318E-02	4.13
1.0000E+01 - 1.1000E+01	6.0439E-01	2.5484E-02	4.22
1.1000E+01 - 1.2000E+01	5.8200E-01	2.8861E-02	4.96
1.2000E+01 - 1.3000E+01	5.5433E-01	2.4741E-02	4.46
1.3000E+01 - 1.3500E+01	5.3893E-01	4.5331E-02	8.41
1.3500E+01 - 1.4000E+01	4.9072E-01	2.9820E-02	6.08
1.4000E+01 - 1.4500E+01	4.4763E-01	1.8213E-02	4.07
1.4500E+01 - 1.5000E+01	4.0946E-01	2.6657E-02	6.51
1.5000E+01 - 1.6000E+01	3.3913E-01	4.1072E-02	12.11
1.6000E+01 - 1.7000E+01	2.6991E-01	4.0326E-02	14.94
1.7000E+01 - 1.8000E+01	2.3196E-01	4.9471E-02	21.33
1.8000E+01 - 1.9000E+01	2.1293E-01	4.5463E-02	21.35
1.9000E+01 - 2.0000E+01	2.0535E-01	2.9589E-02	14.41

MT = 16 (n,2n) cross section

Neutron energy (in MeV)	cross section (in barn)	std.dev. of sigma(E) (in barn)	std.dev. (in %)
1.7000E+01	0.0000E+00	0.000E+00	0.00
1.8000E+01 - 1.9000E+01	4.7801E-04	4.155E-04	86.92
1.9000E+01 - 2.0000E+01	2.4430E-03	2.099E-03	85.92

MT = 22 (n,na) cross section

Neutron energy (in MeV)	cross section (in barn)	std.dev. of sigma(E) (in barn)	std.dev. (in %)
9.0000E+00	0.0000E+00	0.000E+00	0.00
1.0000E+01 - 1.1000E+01	1.7780E-09	8.889E-10	50.00
1.1000E+01 - 1.2000E+01	2.1253E-04	1.066E-04	50.15
1.2000E+01 - 1.3000E+01	2.5010E-03	1.254E-03	50.13
1.3000E+01 - 1.3500E+01	7.3603E-03	3.708E-03	50.38
1.3500E+01 - 1.4000E+01	1.1007E-02	5.603E-03	50.90
1.4000E+01 - 1.4500E+01	1.5133E-02	7.654E-03	50.58
1.4500E+01 - 1.5000E+01	2.1452E-02	1.073E-02	50.01
1.5000E+01 - 1.6000E+01	3.7638E-02	1.842E-02	48.93
1.6000E+01 - 1.7000E+01	6.5081E-02	2.885E-02	44.33
1.7000E+01 - 1.8000E+01	1.0173E-01	3.360E-02	33.03
1.8000E+01 - 1.9000E+01	1.3709E-01	3.183E-02	23.22
1.9000E+01 - 2.0000E+01	1.6509E-01	3.022E-02	18.31

MT = 28 (n,np) cross section

Neutron energy (in MeV)	cross section (in barn)	std.dev. of sigma(E) (in barn)	std.dev. (in %)
1.1000E+01 - 1.2000E+01	0.0000E+00	0.000E+00	0.00
1.2000E+01 - 1.3000E+01	2.6492E-04	1.133E-04	42.78
1.3000E+01 - 1.3500E+01	1.9615E-02	6.704E-03	34.18
1.3500E+01 - 1.4000E+01	5.2858E-02	1.413E-02	26.72
1.4000E+01 - 1.4500E+01	9.7674E-02	1.856E-02	19.00
1.4500E+01 - 1.5000E+01	1.2647E-01	2.048E-02	16.19
1.5000E+01 - 1.6000E+01	1.8218E-01	2.560E-02	14.05
1.6000E+01 - 1.7000E+01	2.3220E-01	2.579E-02	11.11
1.7000E+01 - 1.8000E+01	2.7051E-01	2.888E-02	10.68
1.8000E+01 - 1.9000E+01	3.0077E-01	3.401E-02	11.31
1.9000E+01 - 2.0000E+01	3.3966E-01	2.699E-02	7.95

MT = 51 (n,n‘1) cross section

Neutron energy (in MeV)	cross section (in barn)	std.dev. of sigma(E) (in barn)	std.dev. (in %)
1.0000E-11 - 1.7500E+00	0.0000E+00	0.000E+00	0.00
1.7500E+00 - 2.0000E+00	8.7522E-02	5.260E-03	6.01
2.0000E+00 - 2.2000E+00	2.0307E-01	1.042E-02	5.13
2.2000E+00 - 2.4000E+00	3.8634E-01	2.016E-02	5.22
2.4000E+00 - 2.6000E+00	3.8472E-01	2.025E-02	5.26
2.6000E+00 - 2.8000E+00	2.9949E-01	1.529E-02	5.11
2.8000E+00 - 3.0000E+00	4.7066E-01	2.433E-02	5.17
3.0000E+00 - 3.2000E+00	4.4470E-01	2.481E-02	5.58
3.2000E+00 - 3.4000E+00	5.4220E-01	3.019E-02	5.57
3.4000E+00 - 3.6000E+00	4.8031E-01	2.801E-02	5.83
3.6000E+00 - 3.8000E+00	4.2308E-01	2.519E-02	5.95
3.8000E+00 - 4.0000E+00	5.4898E-01	3.320E-02	6.05
4.0000E+00 - 4.5000E+00	5.7306E-01	3.231E-02	5.64
4.5000E+00 - 5.0000E+00	7.2766E-01	3.925E-02	5.39
5.0000E+00 - 5.5000E+00	6.1616E-01	3.621E-02	5.88
5.5000E+00 - 6.0000E+00	5.9509E-01	2.998E-02	5.04
6.0000E+00 - 6.5000E+00	5.1606E-01	3.195E-02	6.19
6.5000E+00 - 7.0000E+00	4.5924E-01	3.003E-02	6.54
7.0000E+00 - 7.5000E+00	4.0321E-01	2.813E-02	6.98
7.5000E+00 - 8.0000E+00	3.7563E-01	1.704E-02	4.54
8.0000E+00 - 9.0000E+00	2.9455E-01	1.084E-02	3.68
9.0000E+00 - 1.0000E+01	2.2532E-01	9.736E-03	4.32
1.0000E+01 - 1.1000E+01	1.5979E-01	5.673E-03	3.55
1.1000E+01 - 1.2000E+01	1.4723E-01	6.484E-03	4.40
1.2000E+01 - 1.3000E+01	1.3219E-01	7.330E-03	5.54
1.3000E+01 - 1.3500E+01	1.2807E-01	1.877E-02	14.65
1.3500E+01 - 1.4000E+01	1.1808E-01	1.681E-02	14.23
1.4000E+01 - 1.4500E+01	1.1175E-01	3.352E-03	3.00
1.4500E+01 - 1.5000E+01	1.1104E-01	1.611E-02	14.51
1.5000E+01 - 1.6000E+01	1.0499E-01	1.742E-02	16.59
1.6000E+01 - 1.7000E+01	9.7220E-02	5.526E-03	5.68
1.7000E+01 - 1.8000E+01	9.4132E-02	2.374E-02	25.22
1.8000E+01 - 1.9000E+01	9.2563E-02	2.299E-02	24.83
1.9000E+01 - 2.0000E+01	9.3578E-02	5.297E-03	5.66

MT = 91 (n,n'cont) cross section

Neutron energy (in MeV)	cross section (in barn)	std.dev. of sigma(E) (in barn)	std.dev. (in %)
8.0000E+00 - 9.0000E+00	0.0000E+00	0.000E+00	0.00
9.0000E+00 - 1.0000E+01	4.8211E-03	2.159E-03	44.78
1.0000E+01 - 1.1000E+01	6.6893E-02	2.503E-02	37.42
1.1000E+01 - 1.2000E+01	1.3872E-01	3.092E-02	22.29
1.2000E+01 - 1.3000E+01	1.9036E-01	3.455E-02	18.15
1.3000E+01 - 1.3500E+01	2.2035E-01	4.161E-02	18.89
1.3500E+01 - 1.4000E+01	2.1361E-01	3.214E-02	15.05
1.4000E+01 - 1.4500E+01	1.9782E-01	2.251E-02	11.38
1.4500E+01 - 1.5000E+01	1.8330E-01	3.029E-02	16.52
1.5000E+01 - 1.6000E+01	1.4683E-01	3.862E-02	26.31
1.6000E+01 - 1.7000E+01	1.0337E-01	4.005E-02	38.75
1.7000E+01 - 1.8000E+01	7.7507E-02	4.178E-02	53.90
1.8000E+01 - 1.9000E+01	6.2357E-02	3.711E-02	59.51
1.9000E+01 - 2.0000E+01	5.2709E-02	2.630E-02	49.89

MT = 102 (n,cap) cross section

Neutron energy (in MeV)	cross section (in barn)	std.dev. of sigma(E) (in barn)	std.dev. (in %)
1.0000E-11 - 1.7500E+00	0.0000E+00	0.000E+00	0.00
1.7500E+00 - 2.0000E+00	7.4235E-04	3.712E-04	50.00
2.0000E+00 - 2.2000E+00	6.8633E-04	3.431E-04	50.00
2.2000E+00 - 2.4000E+00	6.4060E-04	3.203E-04	50.00
2.4000E+00 - 2.6000E+00	6.0133E-04	3.007E-04	50.01
2.6000E+00 - 2.8000E+00	5.6739E-04	2.838E-04	50.02
2.8000E+00 - 3.0000E+00	5.3735E-04	2.688E-04	50.03
3.0000E+00 - 3.2000E+00	5.3475E-04	2.675E-04	50.02
3.2000E+00 - 3.4000E+00	5.5780E-04	2.790E-04	50.02
3.4000E+00 - 3.6000E+00	5.8076E-04	2.904E-04	50.00
3.6000E+00 - 3.8000E+00	6.0286E-04	3.014E-04	49.99
3.8000E+00 - 4.0000E+00	6.2491E-04	3.123E-04	49.98
4.0000E+00 - 4.5000E+00	6.6123E-04	3.303E-04	49.95
4.5000E+00 - 5.0000E+00	7.1103E-04	3.548E-04	49.90
5.0000E+00 - 5.5000E+00	7.4035E-04	3.688E-04	49.82
5.5000E+00 - 6.0000E+00	7.4902E-04	3.728E-04	49.77
6.0000E+00 - 6.5000E+00	7.5628E-04	3.764E-04	49.77
6.5000E+00 - 7.0000E+00	7.6370E-04	3.797E-04	49.72
7.0000E+00 - 7.5000E+00	7.2512E-04	3.610E-04	49.78
7.5000E+00 - 8.0000E+00	6.5260E-04	3.252E-04	49.83
8.0000E+00 - 9.0000E+00	5.9133E-04	2.958E-04	50.02
9.0000E+00 - 1.0000E+01	5.7743E-04	2.880E-04	49.87
1.0000E+01 - 1.1000E+01	6.1339E-04	3.046E-04	49.67
1.1000E+01 - 1.2000E+01	6.7571E-04	3.357E-04	49.68
1.2000E+01 - 1.3000E+01	7.0751E-04	3.393E-04	47.95
1.3000E+01 - 1.3500E+01	6.9380E-04	2.846E-04	41.02
1.3500E+01 - 1.4000E+01	6.5364E-04	2.084E-04	31.89
1.4000E+01 - 1.4500E+01	6.1221E-04	7.269E-05	11.87
1.4500E+01 - 1.5000E+01	5.9294E-04	1.874E-04	31.60
1.5000E+01 - 1.6000E+01	5.7276E-04	2.478E-04	43.26
1.6000E+01 - 1.7000E+01	5.6053E-04	2.767E-04	49.36
1.7000E+01 - 1.8000E+01	5.5822E-04	2.800E-04	50.15
1.8000E+01 - 1.9000E+01	5.4045E-04	2.697E-04	49.90
1.9000E+01 - 2.0000E+01	5.0107E-04	2.498E-04	49.85

MT = 103 (n,p) cross section

Neutron energy (in MeV)	cross section (in barn)	std.dev. of sigma(E) (in barn)	std.dev. (in %)
3.8000E+00 - 4.0000E+00	0.0000E+00	0.000E+00	0.00
4.0000E+00 - 4.5000E+00	1.5976E-03	5.667E-04	35.47
4.5000E+00 - 5.0000E+00	4.5051E-03	9.021E-04	20.02
5.0000E+00 - 5.5000E+00	1.7691E-02	1.653E-03	9.34
5.5000E+00 - 6.0000E+00	3.5344E-02	3.281E-03	9.28
6.0000E+00 - 6.5000E+00	1.1020E-01	5.954E-03	5.40
6.5000E+00 - 7.0000E+00	1.7614E-01	8.045E-03	4.57
7.0000E+00 - 7.5000E+00	2.0859E-01	8.389E-03	4.02
7.5000E+00 - 8.0000E+00	2.3398E-01	9.362E-03	4.00
8.0000E+00 - 9.0000E+00	2.2577E-01	1.043E-02	4.62
9.0000E+00 - 1.0000E+01	2.3167E-01	9.140E-03	3.95
1.0000E+01 - 1.1000E+01	2.4733E-01	1.111E-02	4.49
1.1000E+01 - 1.2000E+01	2.6293E-01	9.158E-03	3.48
1.2000E+01 - 1.3000E+01	2.8108E-01	1.189E-02	4.23
1.3000E+01 - 1.3500E+01	2.8134E-01	6.586E-03	2.34
1.3500E+01 - 1.4000E+01	2.7749E-01	6.983E-03	2.52
1.4000E+01 - 1.4500E+01	2.5287E-01	5.965E-03	2.36
1.4500E+01 - 1.5000E+01	2.3802E-01	4.352E-03	1.83
1.5000E+01 - 1.6000E+01	2.0614E-01	8.741E-03	4.24
1.6000E+01 - 1.7000E+01	1.8891E-01	8.627E-03	4.57
1.7000E+01 - 1.8000E+01	1.6451E-01	7.904E-03	4.80
1.8000E+01 - 1.9000E+01	1.3573E-01	2.364E-02	17.42
1.9000E+01 - 2.0000E+01	1.0550E-01	5.861E-03	5.56

MT = 104 (n,d) cross section

Neutron energy (in MeV)	cross section (in barn)	std.dev. of sigma(E) (in barn)	std.dev. (in %)
9.0000E+00 - 1.0000E+01	0.0000E+00	0.000E+00	0.00
1.0000E+01 - 1.1000E+01	1.0141E-05	4.999E-06	49.30
1.1000E+01 - 1.2000E+01	2.8795E-03	1.392E-03	48.34
1.2000E+01 - 1.3000E+01	6.5302E-03	3.128E-03	47.90
1.3000E+01 - 1.3500E+01	9.5448E-03	4.282E-03	44.87
1.3500E+01 - 1.4000E+01	1.1758E-02	4.894E-03	41.63
1.4000E+01 - 1.4500E+01	1.4182E-02	5.261E-03	37.10
1.4500E+01 - 1.5000E+01	1.6659E-02	5.390E-03	32.35
1.5000E+01 - 1.6000E+01	2.2400E-02	4.927E-03	21.99
1.6000E+01 - 1.7000E+01	3.0043E-02	5.862E-03	19.51
1.7000E+01 - 1.8000E+01	3.6777E-02	6.661E-03	18.11
1.8000E+01 - 1.9000E+01	4.2498E-02	7.244E-03	17.05
1.9000E+01 - 2.0000E+01	4.7902E-02	7.617E-03	15.90

MT = 105 (n,t) cross section

Neutron energy (in MeV)	cross section (in barn)	std.dev. of sigma(E) (in barn)	std.dev. (in %)
1.1000E+01 - 1.2000E+01	0.0000E+00	0.000E+00	0.00
1.2000E+01 - 1.3000E+01	5.8204E-06	5.238E-06	89.99
1.3000E+01 - 1.3500E+01	1.4849E-05	1.336E-05	90.01
1.3500E+01 - 1.4000E+01	2.0867E-05	1.878E-05	90.01
1.4000E+01 - 1.4500E+01	2.6884E-05	2.420E-05	90.02
1.4500E+01 - 1.5000E+01	3.2897E-05	2.962E-05	90.04
1.5000E+01 - 1.6000E+01	4.1923E-05	3.775E-05	90.04
1.6000E+01 - 1.7000E+01	5.4134E-05	4.858E-05	89.74
1.7000E+01 - 1.8000E+01	1.3095E-04	1.170E-04	89.35
1.8000E+01 - 1.9000E+01	4.0459E-04	3.600E-04	88.98
1.9000E+01 - 2.0000E+01	7.8187E-04	6.930E-04	88.63

MT = 106 (n,3He) cross section

Neutron energy (in MeV)	cross section (in barn)	std.dev. of sigma(E) (in barn)	std.dev. (in %)
1.2000E+01 - 1.3000E+01	0.0000E+00	0.000E+00	0.00
1.3000E+01 - 1.3500E+01	4.9498E-06	4.455E-06	90.00
1.3500E+01 - 1.4000E+01	6.2996E-06	5.670E-06	90.01
1.4000E+01 - 1.4500E+01	7.8493E-06	7.065E-06	90.01
1.4500E+01 - 1.5000E+01	9.5988E-06	8.640E-06	90.01
1.5000E+01 - 1.6000E+01	1.1998E-05	1.080E-05	90.02
1.6000E+01 - 1.7000E+01	1.7001E-05	1.530E-05	89.99
1.7000E+01 - 1.8000E+01	2.2507E-05	2.025E-05	89.97
1.8000E+01 - 1.9000E+01	2.9016E-05	2.610E-05	89.95
1.9000E+01 - 2.0000E+01	3.9030E-05	3.510E-05	89.93

MT = 107 (n,a) cross section

Neutron energy (in MeV)	cross section (in barn)	std.dev. of sigma(E) (in barn)	std.dev. (in %)
2.7485E+00 - 2.8000E+00	0.0000E+00	0.000E+00	0.00
2.8000E+00 - 3.0000E+00	0.0000E+00	0.000E+00	0.00
3.0000E+00 - 3.2000E+00	6.1971E-07	3.099E-07	50.00
3.2000E+00 - 3.4000E+00	1.8591E-06	9.295E-07	50.00
3.4000E+00 - 3.6000E+00	3.0986E-06	1.549E-06	50.00
3.6000E+00 - 3.8000E+00	4.3380E-06	2.169E-06	50.00
3.8000E+00 - 4.0000E+00	5.5776E-06	2.789E-06	50.00
4.0000E+00 - 4.5000E+00	7.1889E-05	3.590E-05	49.94
4.5000E+00 - 5.0000E+00	1.7308E-04	9.753E-05	56.35
5.0000E+00 - 5.5000E+00	2.6049E-03	1.229E-03	47.17
5.5000E+00 - 6.0000E+00	6.5707E-03	7.242E-04	11.02
6.0000E+00 - 6.5000E+00	2.8241E-02	2.415E-03	8.55
6.5000E+00 - 7.0000E+00	5.4530E-02	4.540E-03	8.33
7.0000E+00 - 7.5000E+00	8.8941E-02	5.563E-03	6.25
7.5000E+00 - 8.0000E+00	1.3259E-01	8.247E-03	6.22
8.0000E+00 - 9.0000E+00	1.5706E-01	1.244E-02	7.92
9.0000E+00 - 1.0000E+01	1.7714E-01	1.386E-02	7.83
1.0000E+01 - 1.1000E+01	2.0168E-01	1.534E-02	7.60
1.1000E+01 - 1.2000E+01	2.1387E-01	1.656E-02	7.74
1.2000E+01 - 1.3000E+01	2.1825E-01	1.659E-02	7.60
1.3000E+01 - 1.3500E+01	2.0736E-01	1.717E-02	8.28
1.3500E+01 - 1.4000E+01	1.9919E-01	1.692E-02	8.49
1.4000E+01 - 1.4500E+01	1.9478E-01	1.692E-02	8.69
1.4500E+01 - 1.5000E+01	1.8618E-01	1.575E-02	8.46
1.5000E+01 - 1.6000E+01	1.6514E-01	2.285E-02	13.84
1.6000E+01 - 1.7000E+01	1.3768E-01	2.869E-02	20.84
1.7000E+01 - 1.8000E+01	1.0348E-01	3.334E-02	32.22
1.8000E+01 - 1.9000E+01	7.2306E-02	3.220E-02	44.53
1.9000E+01 - 2.0000E+01	5.5871E-02	2.702E-02	48.37

MT = 111 (n,2p) cross section

Neutron energy (in MeV)	cross section (in barn)	std.dev. of sigma(E) (in barn)	std.dev. (in %)
1.3500E+01 - 1.4000E+01	0.0000E+00	0.000E+00	0.00
1.4000E+01 - 1.4500E+01	1.5750E-12	1.417E-12	90.00
1.4500E+01 - 1.5000E+01	5.6390E-10	5.075E-10	90.00
1.5000E+01 - 1.6000E+01	7.8985E-07	7.112E-07	90.05
1.6000E+01 - 1.7000E+01	2.4403E-05	2.198E-05	90.08
1.7000E+01 - 1.8000E+01	1.6292E-04	1.468E-04	90.10
1.8000E+01 - 1.9000E+01	6.9881E-04	6.298E-04	90.12
1.9000E+01 - 2.0000E+01	1.8320E-03	1.649E-03	89.99

MT = 851 (n,n‘2-3) cross section

Neutron energy (in MeV)	cross section (in barn)	std.dev. of sigma(E) (in barn)	std.dev. (in %)
4.7843E+00 - 5.0000E+00	0.0000E+00	0.000E+00	0.00
5.0000E+00 - 5.5000E+00	7.5613E-02	9.037E-03	11.95
5.5000E+00 - 6.0000E+00	1.0339E-01	1.101E-02	10.65
6.0000E+00 - 6.5000E+00	1.2379E-01	1.131E-02	9.14
6.5000E+00 - 7.0000E+00	1.3633E-01	1.068E-02	7.83
7.0000E+00 - 7.5000E+00	1.2000E-01	9.355E-03	7.80
7.5000E+00 - 8.0000E+00	1.2243E-01	6.864E-03	5.61
8.0000E+00 - 9.0000E+00	1.0255E-01	5.000E-03	4.88
9.0000E+00 - 1.0000E+01	9.4433E-02	4.598E-03	4.87
1.0000E+01 - 1.1000E+01	7.5851E-02	3.265E-03	4.31
1.1000E+01 - 1.2000E+01	4.9592E-02	2.887E-03	5.82
1.2000E+01 - 1.3000E+01	4.6407E-02	2.772E-03	5.97
1.3000E+01 - 1.3500E+01	3.6120E-02	5.138E-03	14.22
1.3500E+01 - 1.4000E+01	3.2004E-02	2.263E-03	7.07
1.4000E+01 - 1.4500E+01	3.0424E-02	4.798E-03	15.77
1.4500E+01 - 1.5000E+01	2.6992E-02	6.732E-03	24.94
1.5000E+01 - 1.6000E+01	2.2187E-02	8.108E-03	36.54
1.6000E+01 - 1.7000E+01	2.1777E-02	1.076E-02	49.41
1.7000E+01 - 1.8000E+01	2.2118E-02	1.048E-02	47.37
1.8000E+01 - 1.9000E+01	2.2144E-02	1.018E-02	45.99
1.9000E+01 - 2.0000E+01	2.2506E-02	9.945E-03	44.19

MT = 852 (n,n‘4-16) cross section

Neutron energy (in MeV)	cross section (in barn)	std.dev. of sigma(E) (in barn)	std.dev. (in %)
6.0000E+00 - 6.5000E+00	0.0000E+00	0.000E+00	0.00
6.5000E+00 - 7.0000E+00	2.9051E-02	8.319E-03	28.64
7.0000E+00 - 7.5000E+00	7.7992E-02	2.007E-02	25.73
7.5000E+00 - 8.0000E+00	1.3678E-01	2.742E-02	20.05
8.0000E+00 - 9.0000E+00	1.8020E-01	2.598E-02	14.42
9.0000E+00 - 1.0000E+01	2.8775E-01	2.640E-02	9.17
1.0000E+01 - 1.1000E+01	3.0186E-01	3.118E-02	10.33
1.1000E+01 - 1.2000E+01	2.4646E-01	3.359E-02	13.63
1.2000E+01 - 1.3000E+01	1.8537E-01	2.844E-02	15.34
1.3000E+01 - 1.3500E+01	1.5439E-01	3.120E-02	20.21
1.3500E+01 - 1.4000E+01	1.2703E-01	2.287E-02	18.01
1.4000E+01 - 1.4500E+01	1.0764E-01	1.427E-02	13.26
1.4500E+01 - 1.5000E+01	8.8127E-02	1.743E-02	19.78
1.5000E+01 - 1.6000E+01	6.5125E-02	1.780E-02	27.33
1.6000E+01 - 1.7000E+01	4.7539E-02	1.920E-02	40.39
1.7000E+01 - 1.8000E+01	3.8200E-02	1.710E-02	44.76
1.8000E+01 - 1.9000E+01	3.5868E-02	1.574E-02	43.87
1.9000E+01 - 2.0000E+01	3.6561E-02	1.505E-02	41.18

Fig. 1 ^{28}Si evaluation-flow chart.

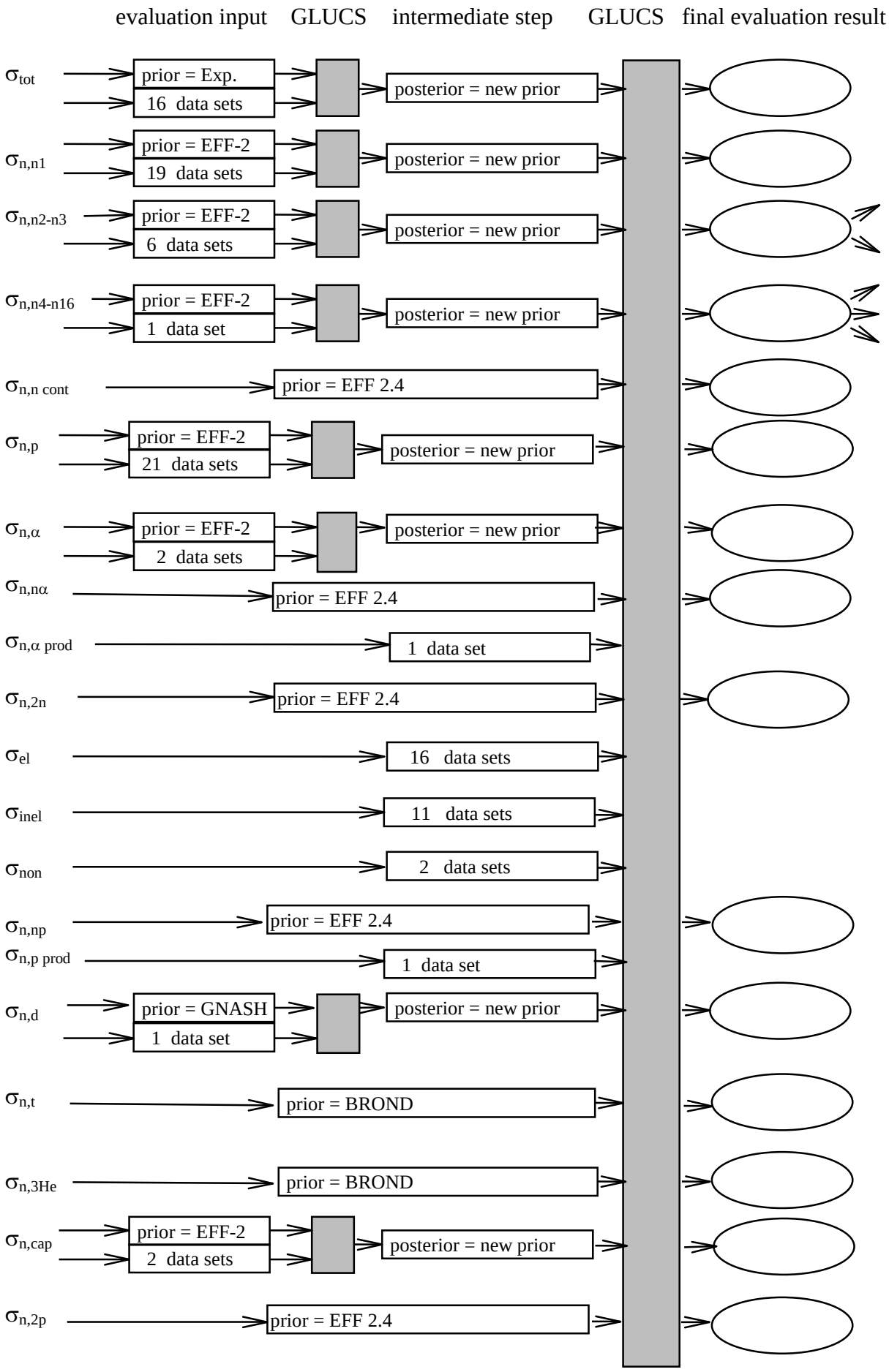


Fig. 2 Correction factor for conversion of σ ($2_1^+ \rightarrow$ g.s.) to σ_{inel}

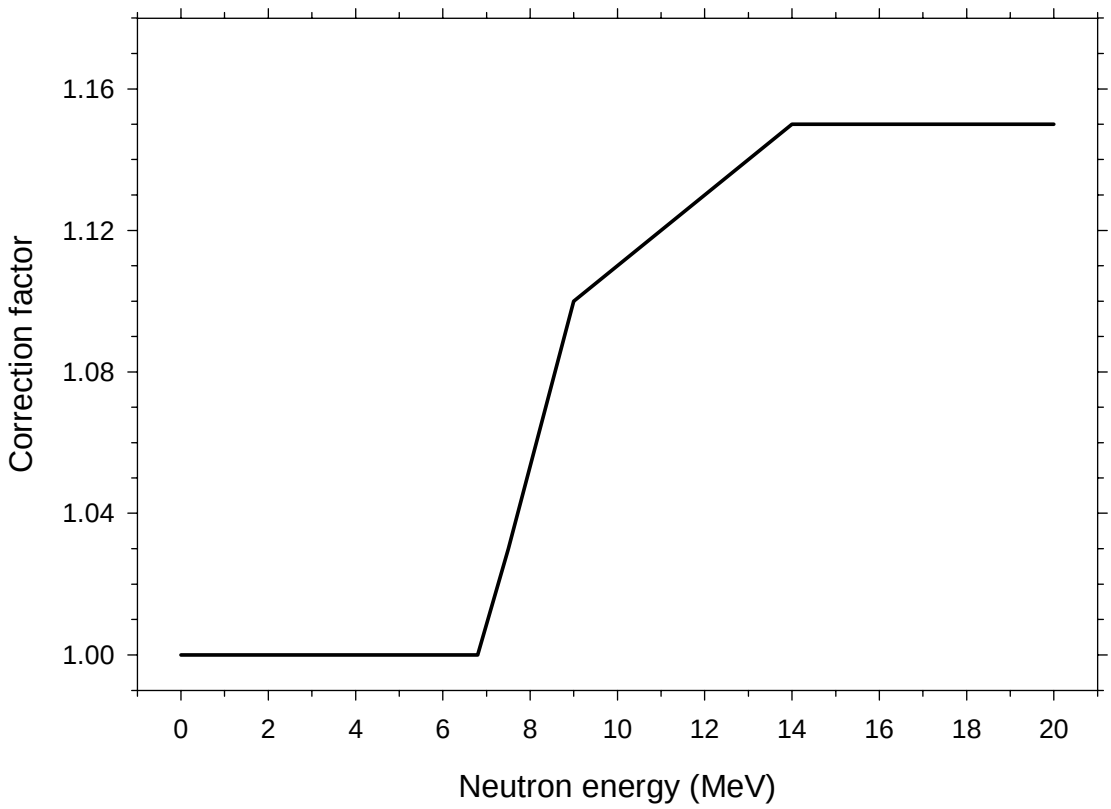
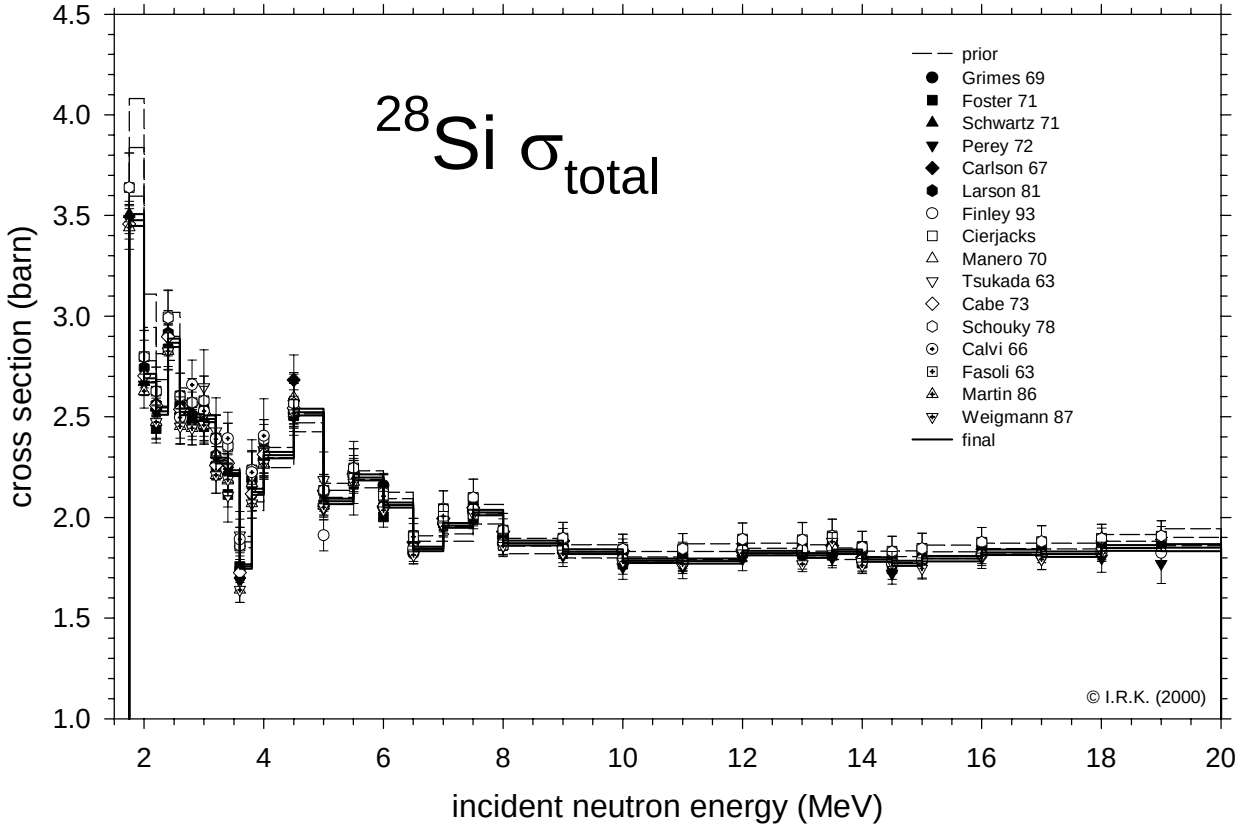


Fig. 3 Total cross section and comparison with ENDF/B-VI



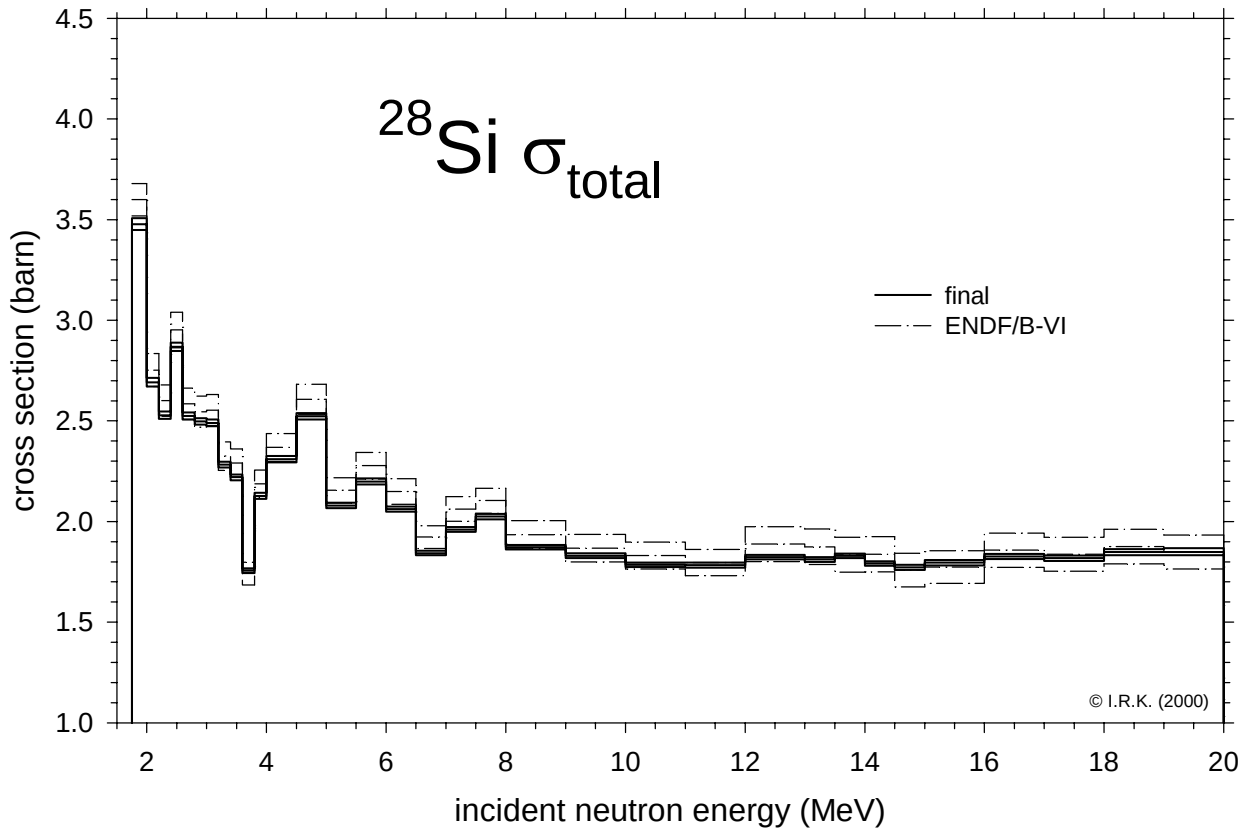
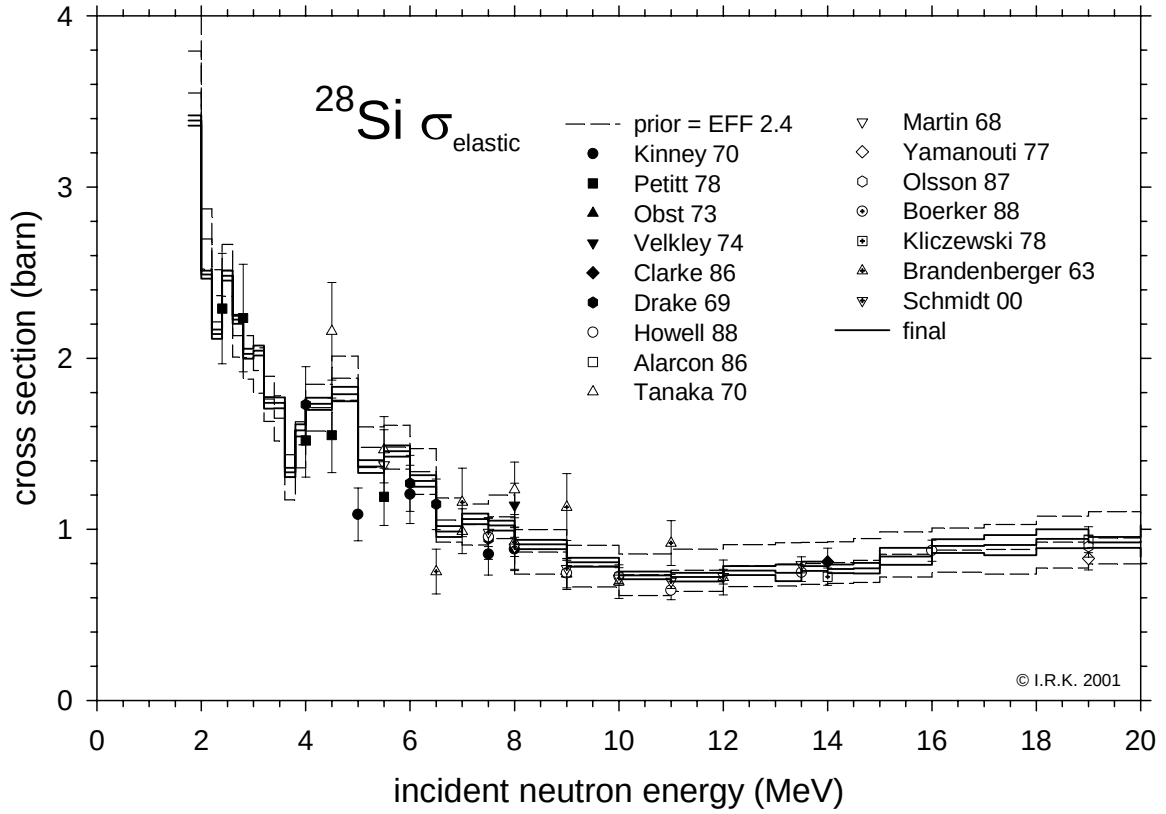


Fig. 4 Elastic cross section and comparison with ENDF/B-VI



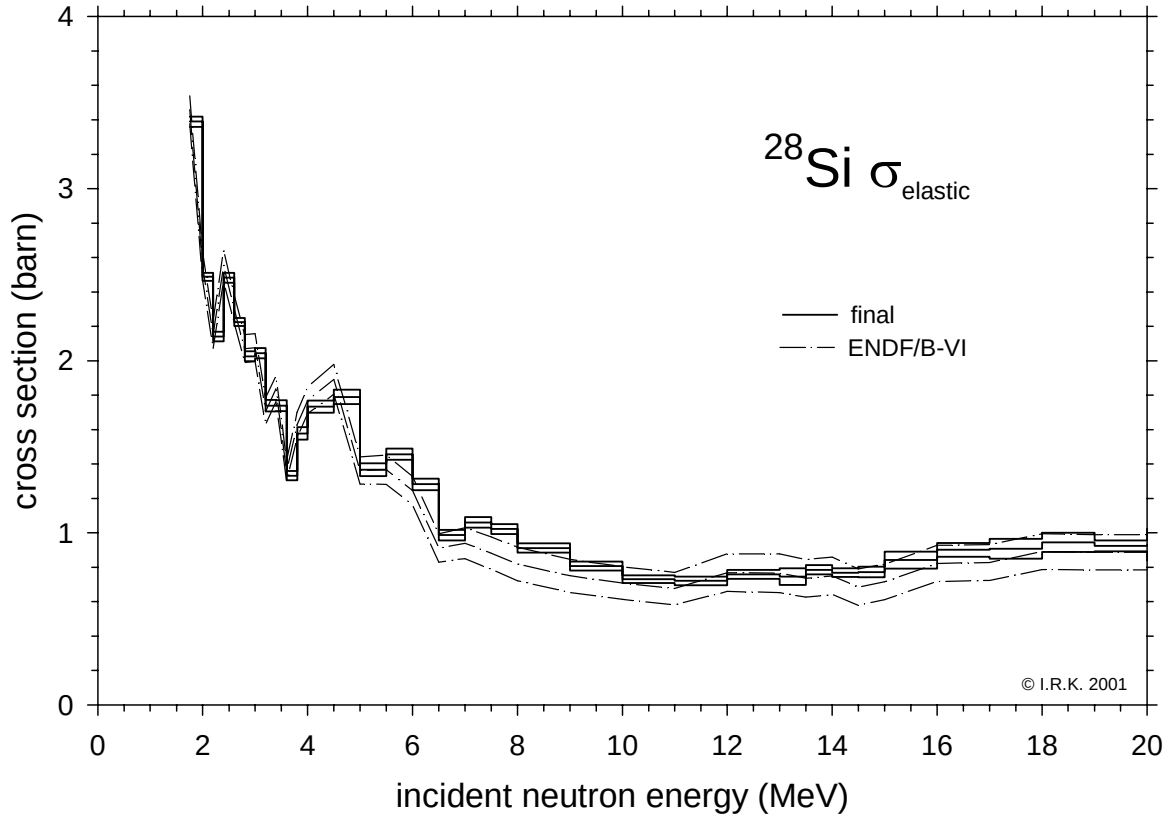
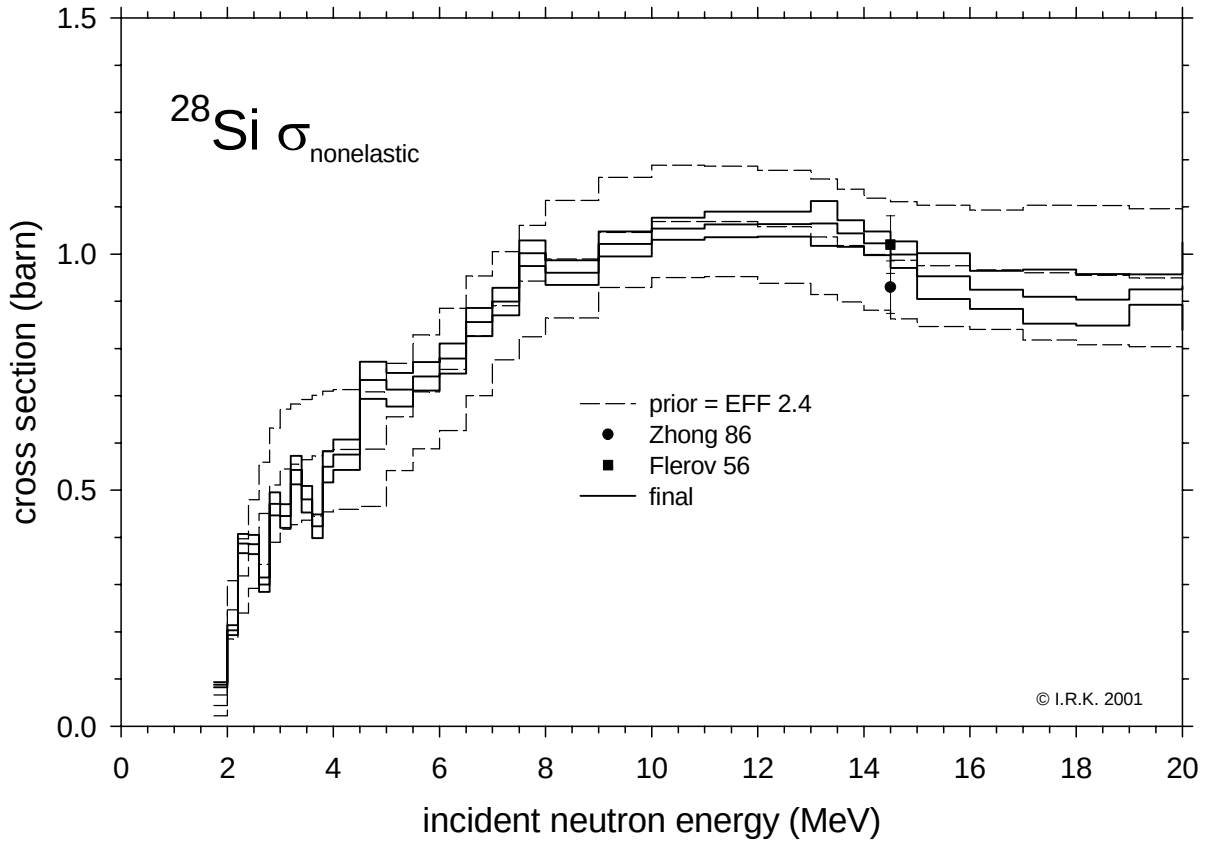


Fig. 5 Nonelastic cross section and comparison with ENDF/B-VI



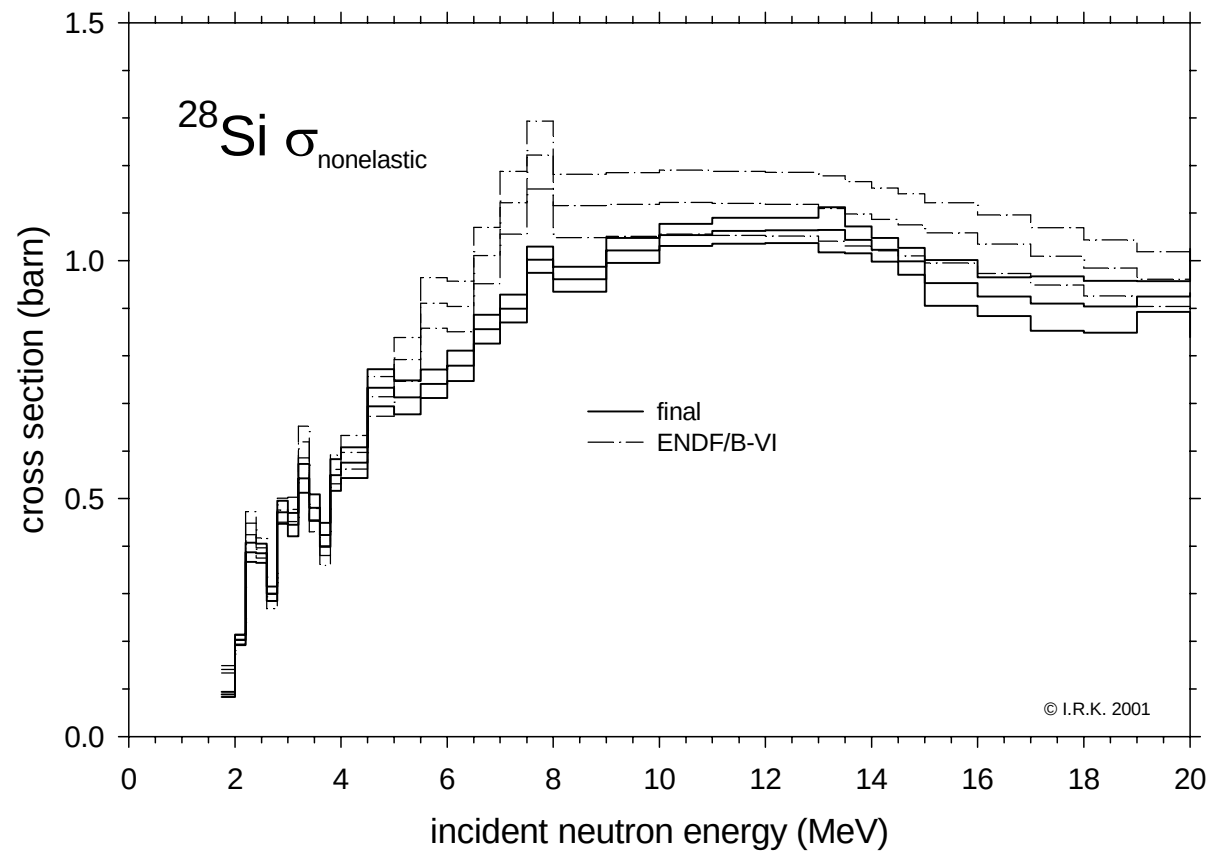
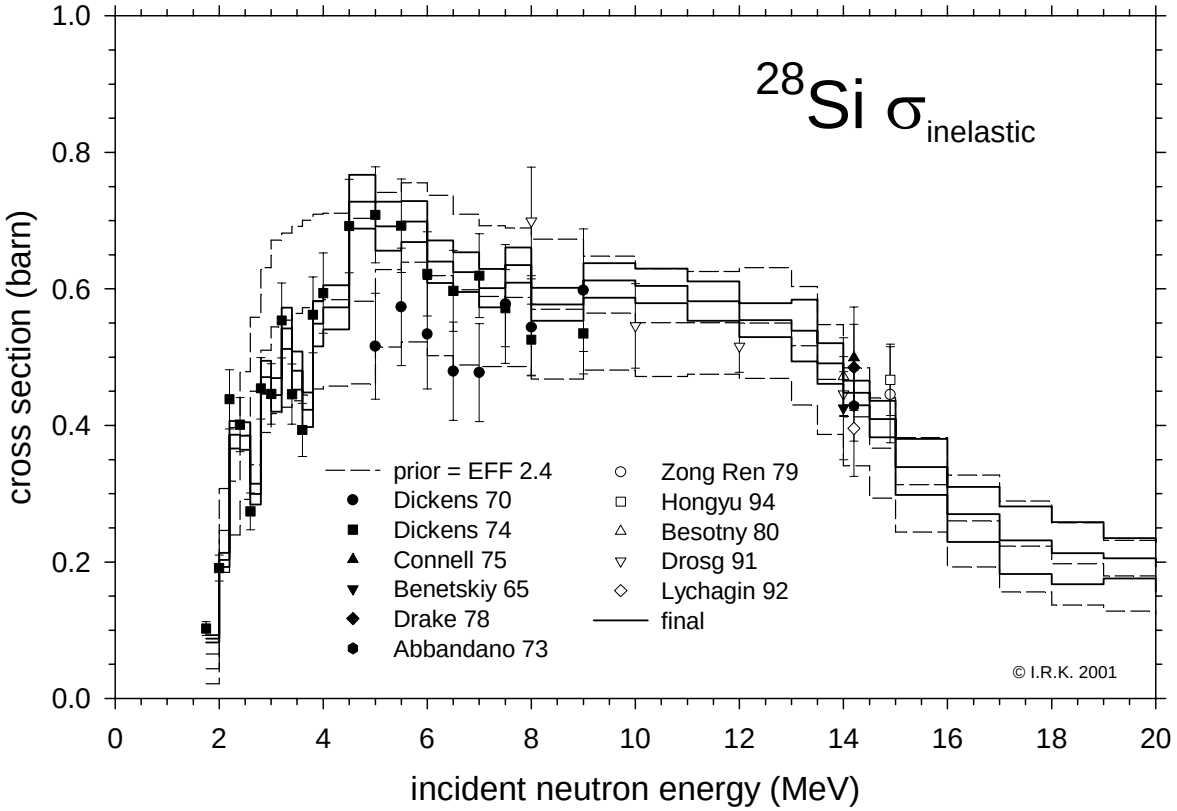


Fig. 6 Inelastic cross section and comparison with ENDF/B-VI



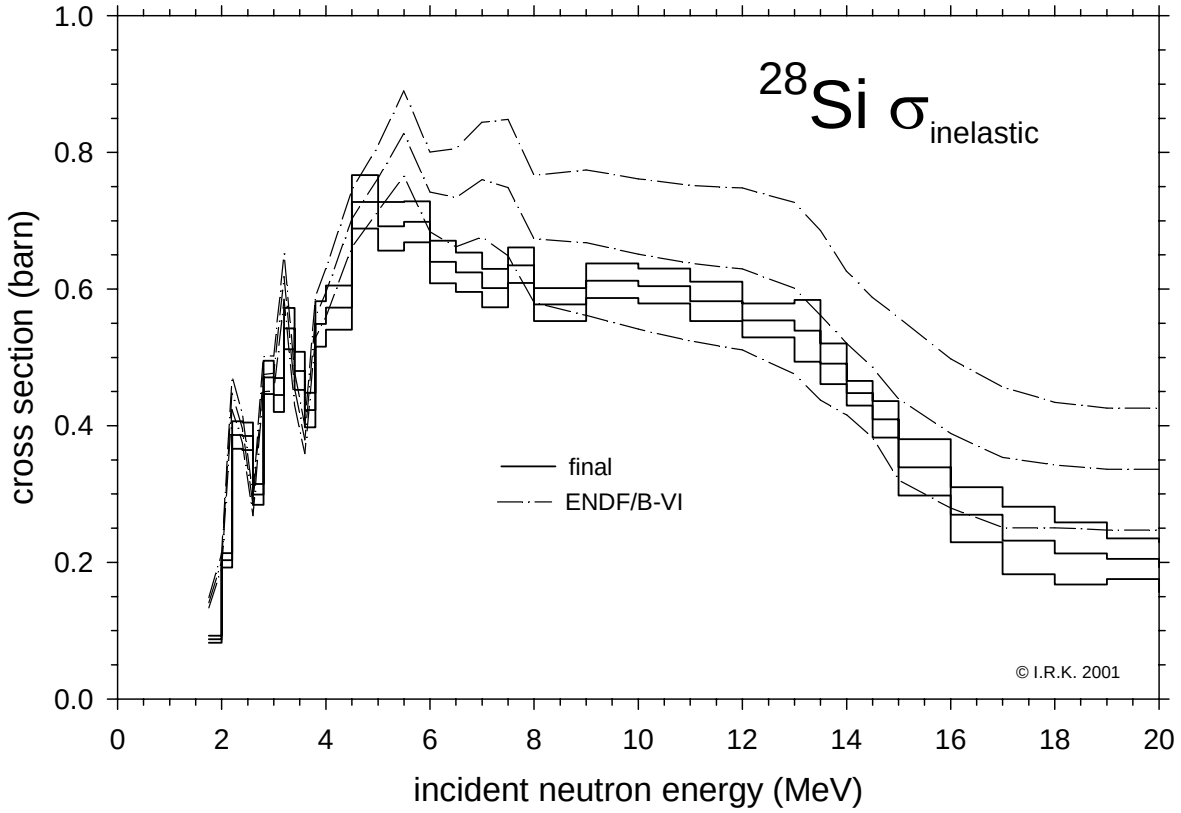
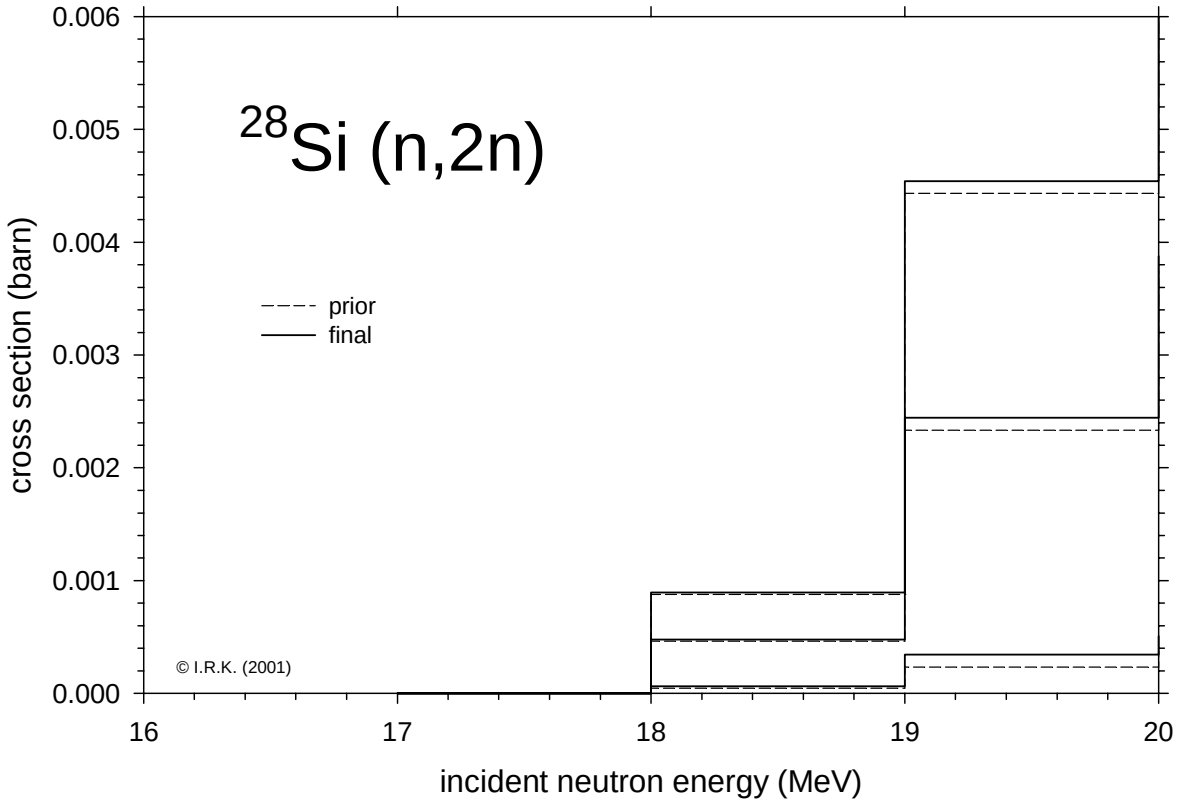


Fig. 7 (n,2n) cross section and comparison with ENDF/B-VI



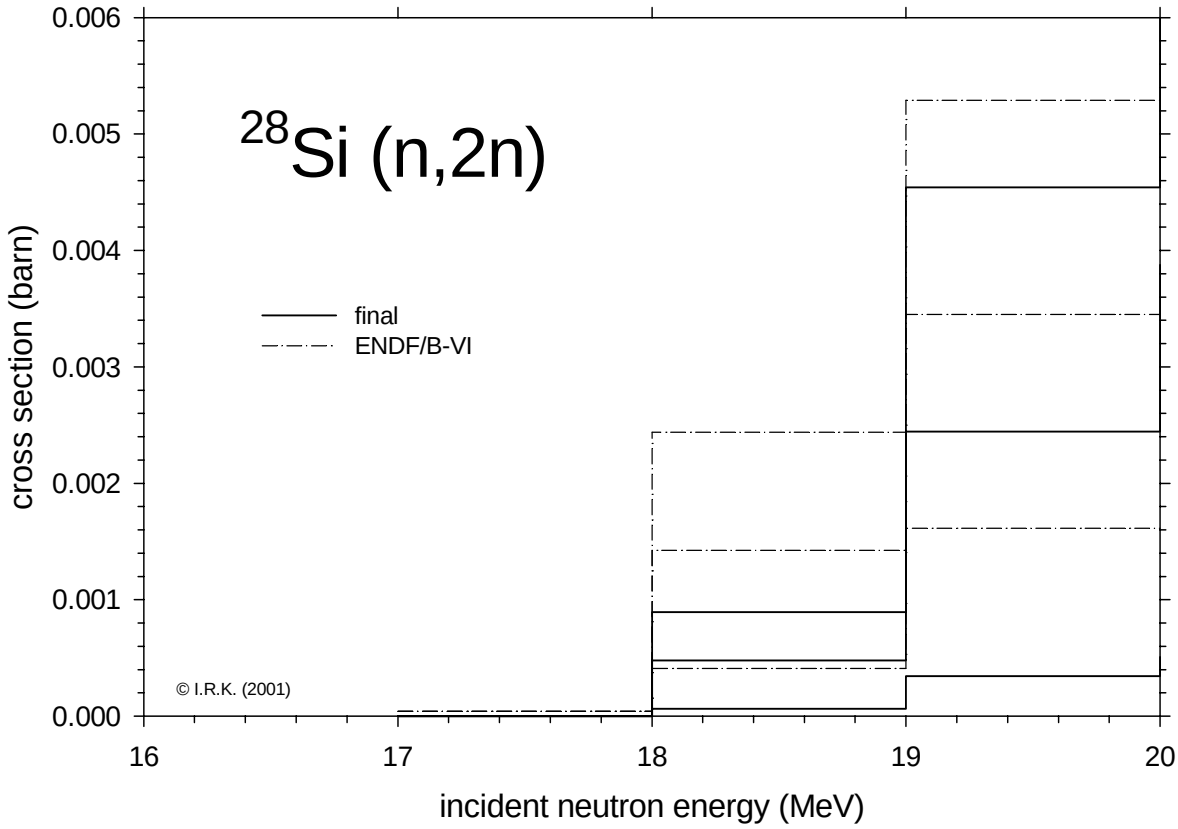
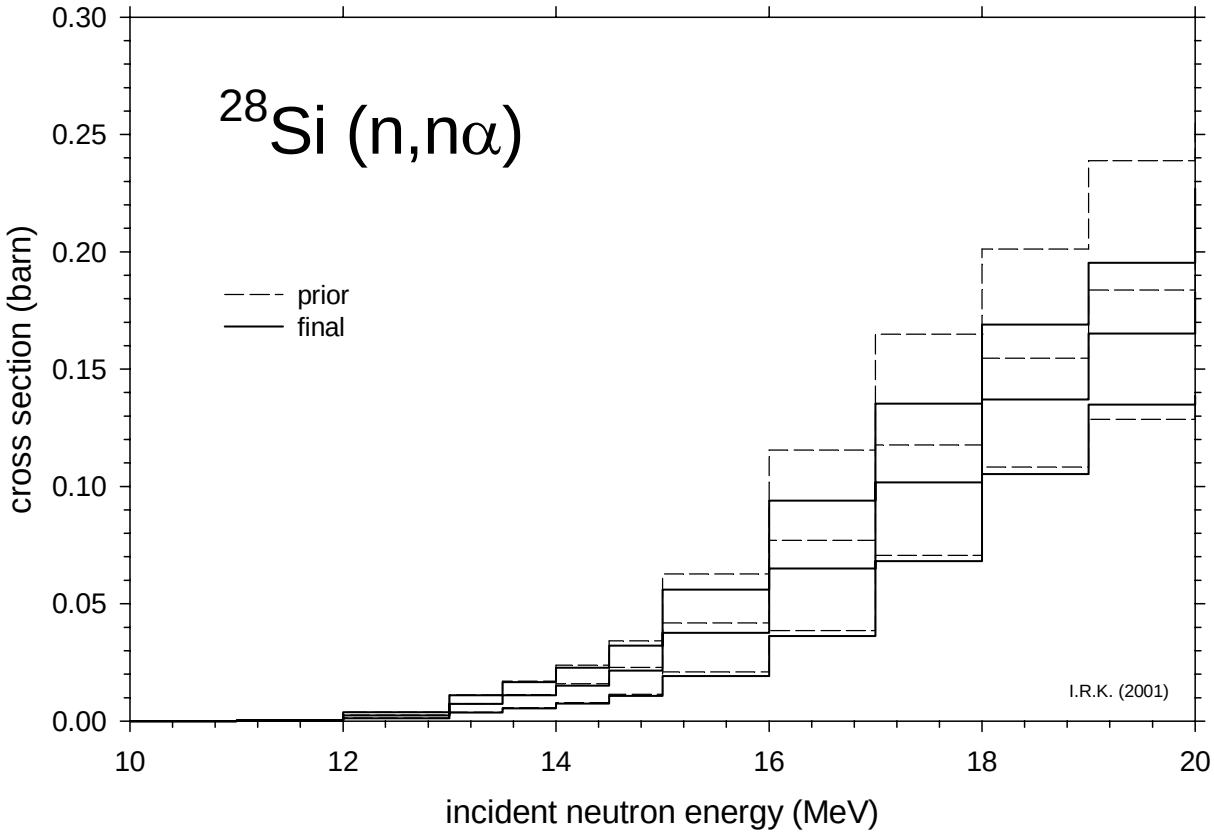


Fig. 8 (n,nα) cross section and comparison with ENDF/B-VI



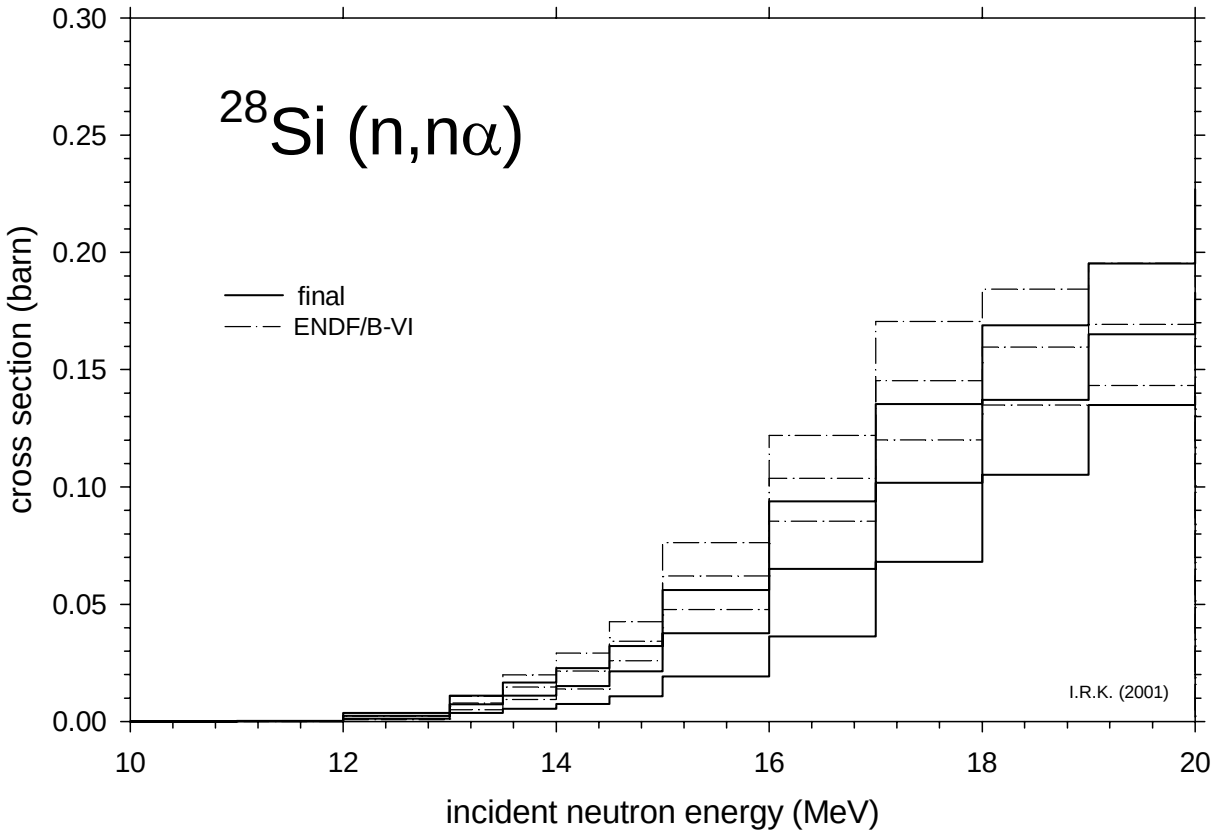
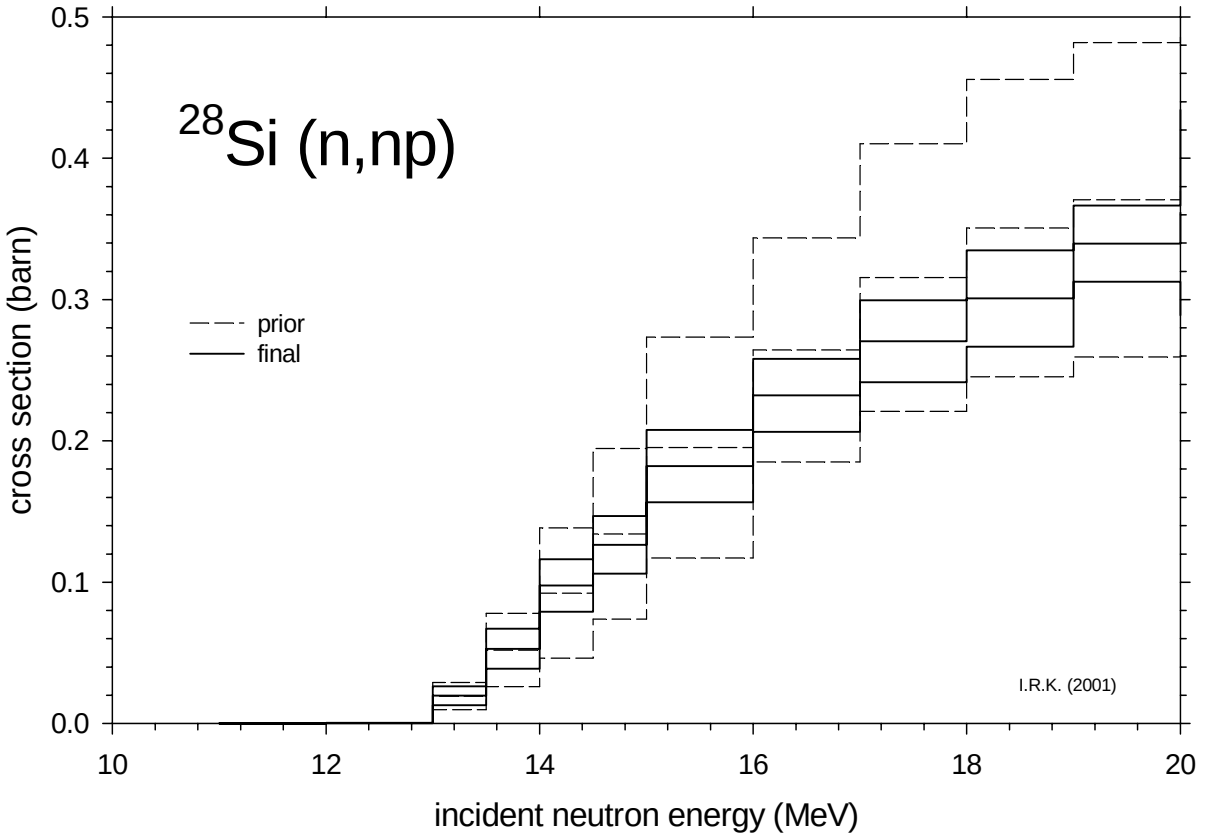


Fig. 9 (n,np) cross section and comparison with ENDF/B-VI



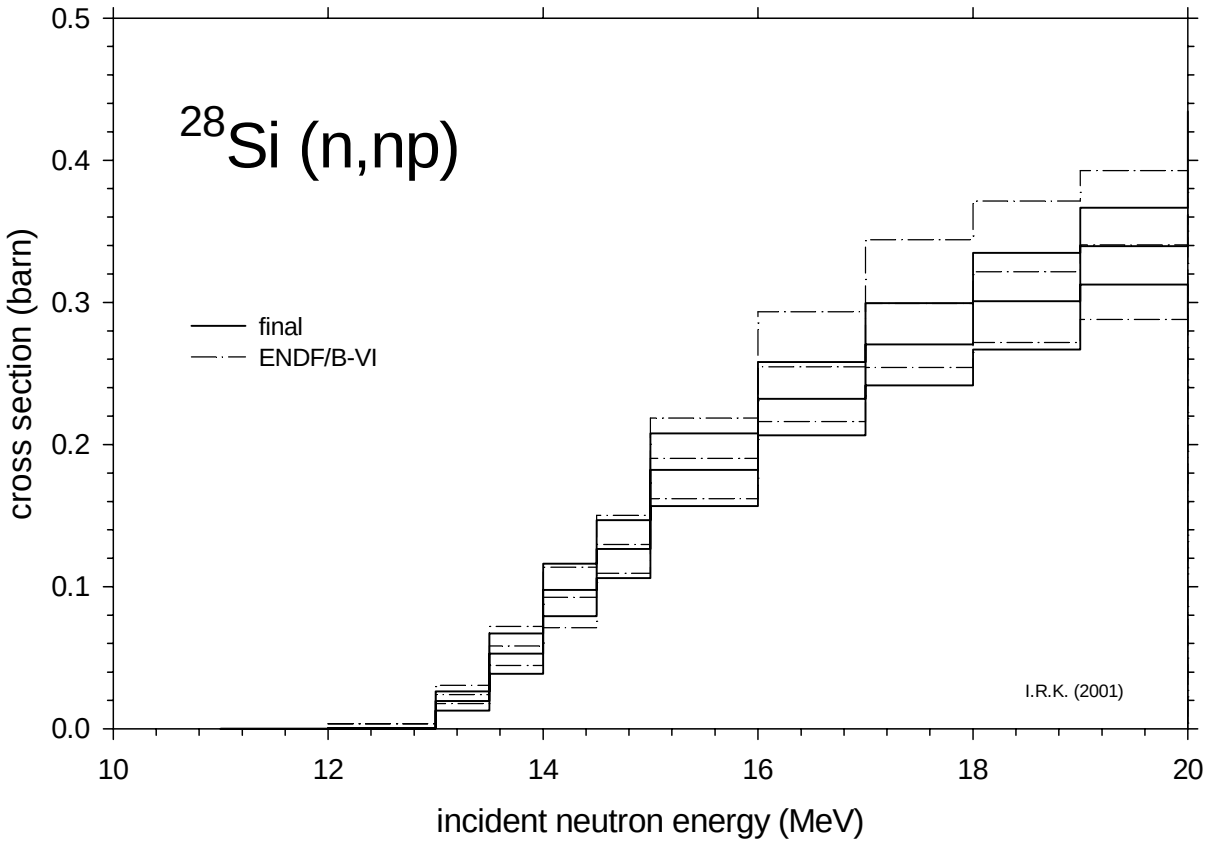
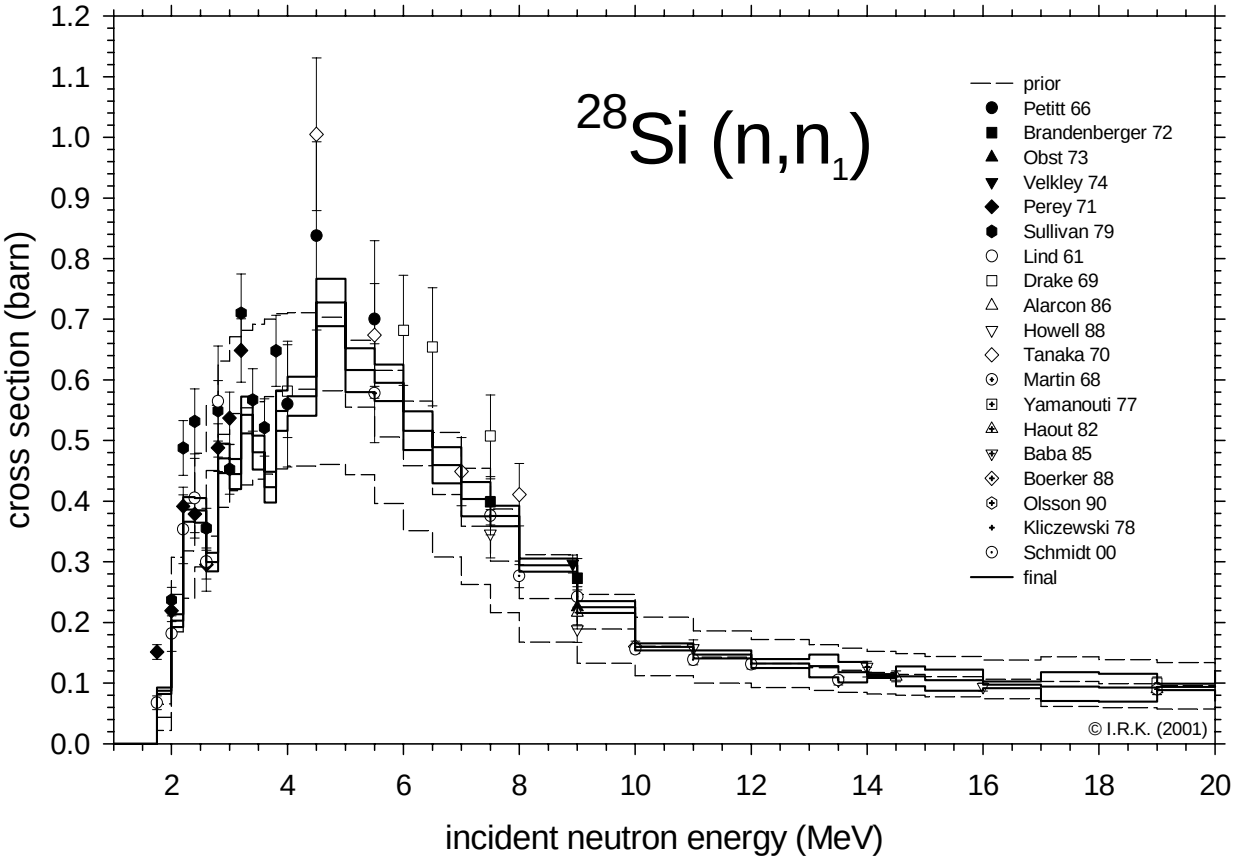


Fig. 10 (n,n_1) cross section and comparison with ENDF/B-VI



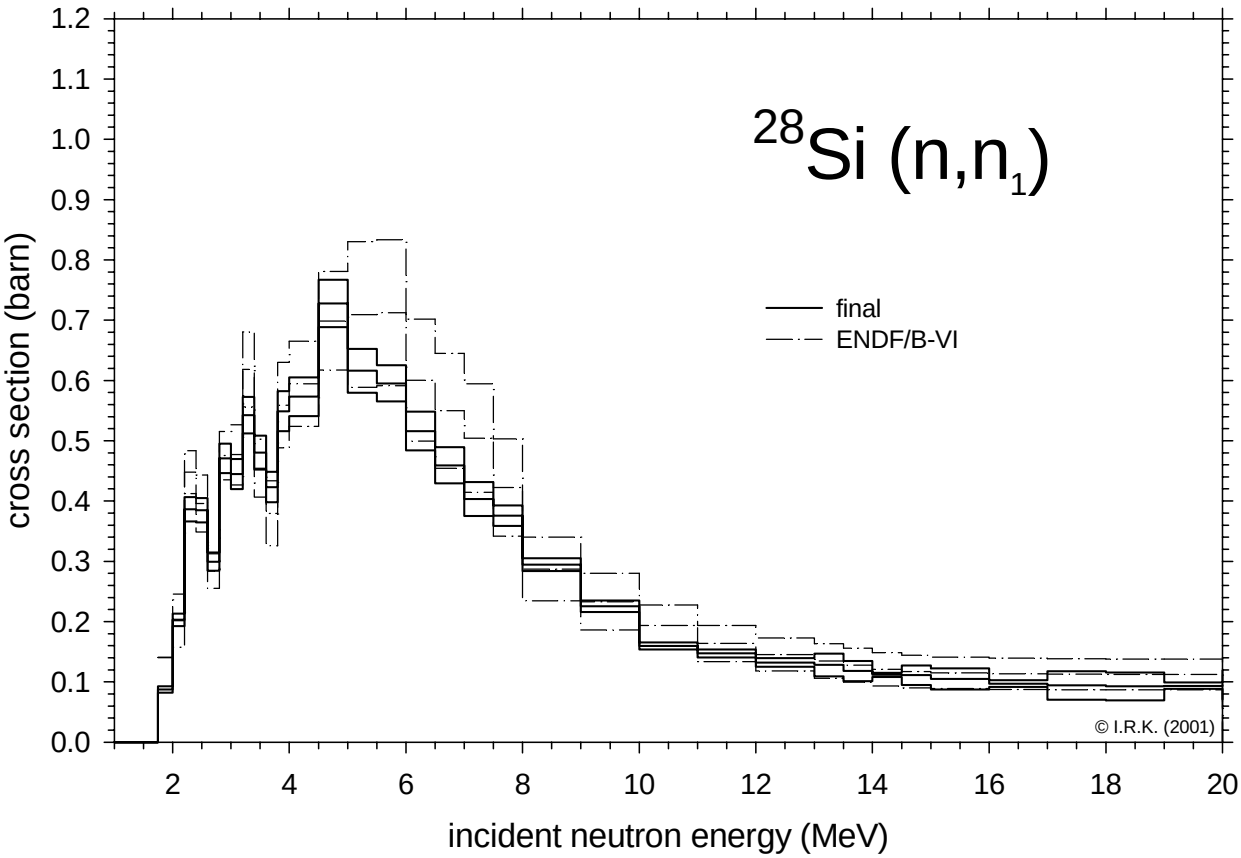
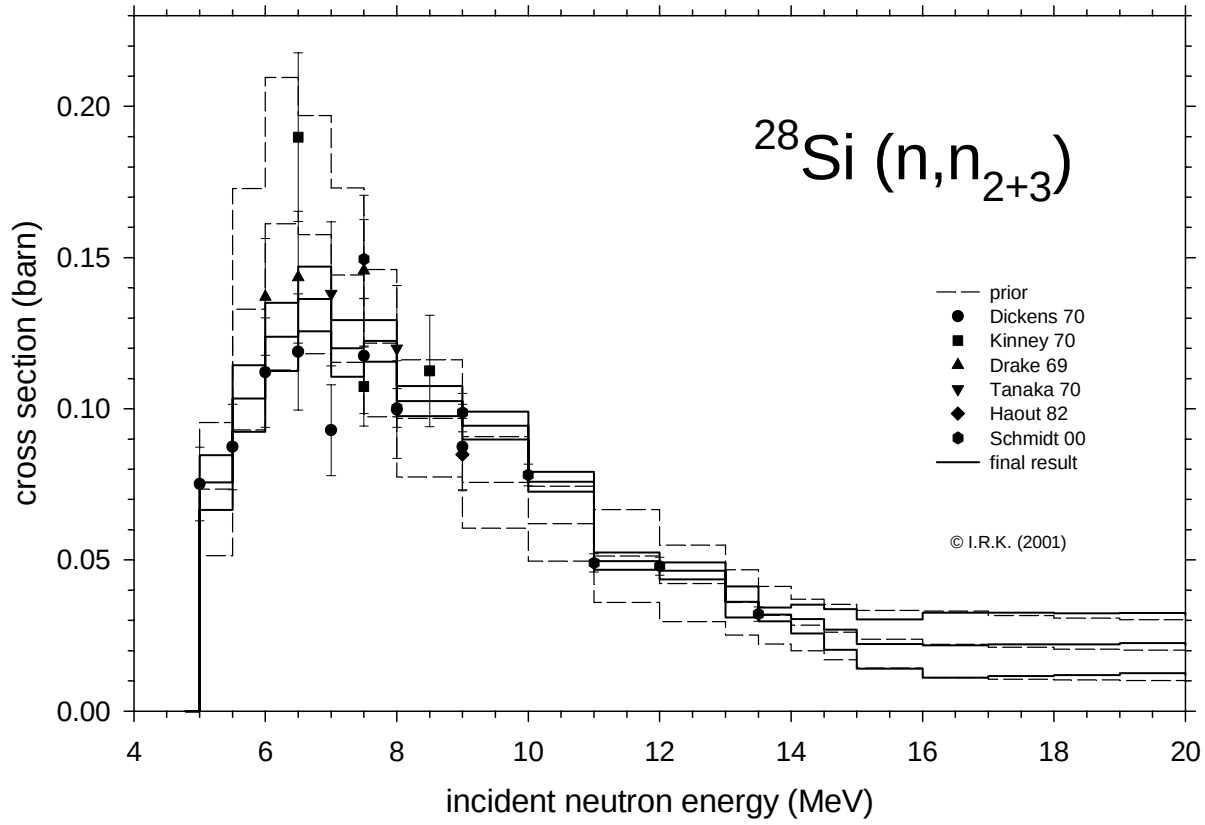


Fig. 11 (n,n_{2+3}) cross section and comparison with ENDF/B-VI



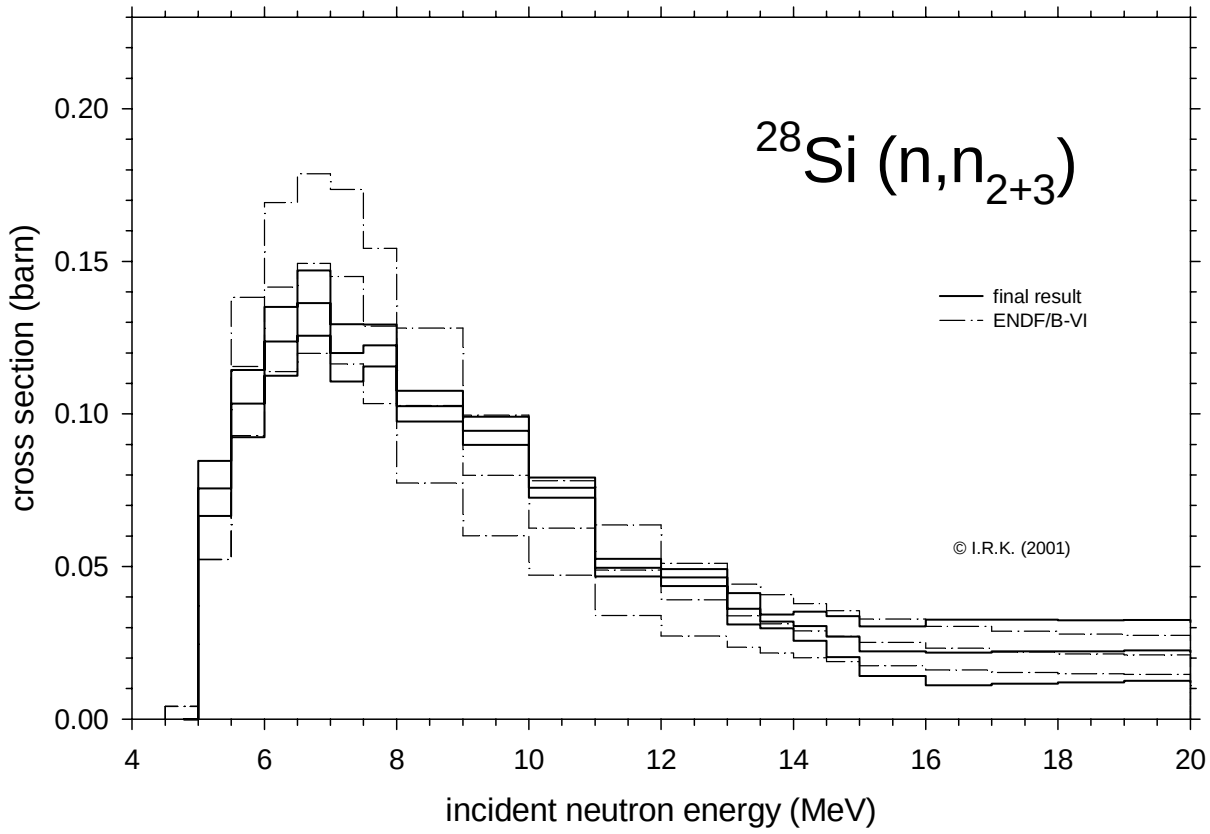
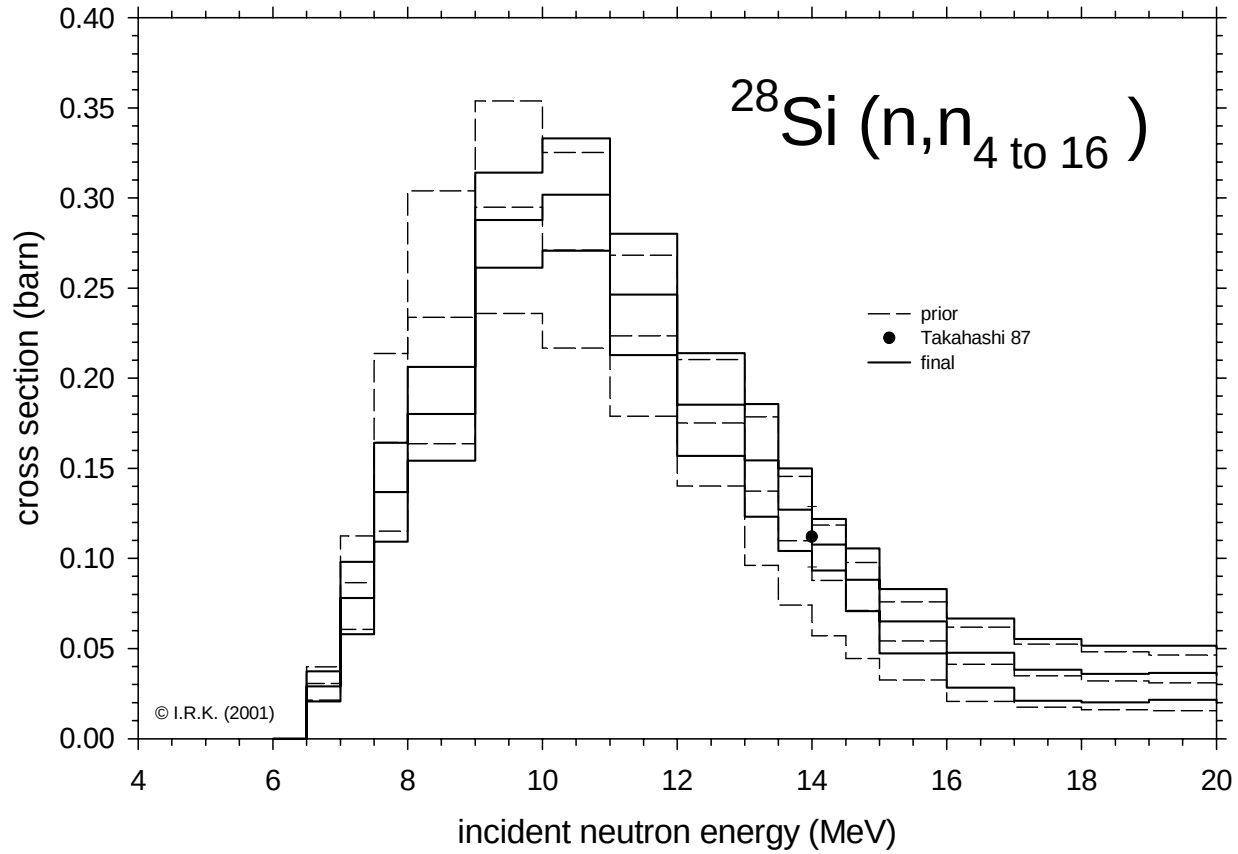


Fig. 12 $(n,n_{4+..+16})$ cross section and comparison with ENDF/B-VI



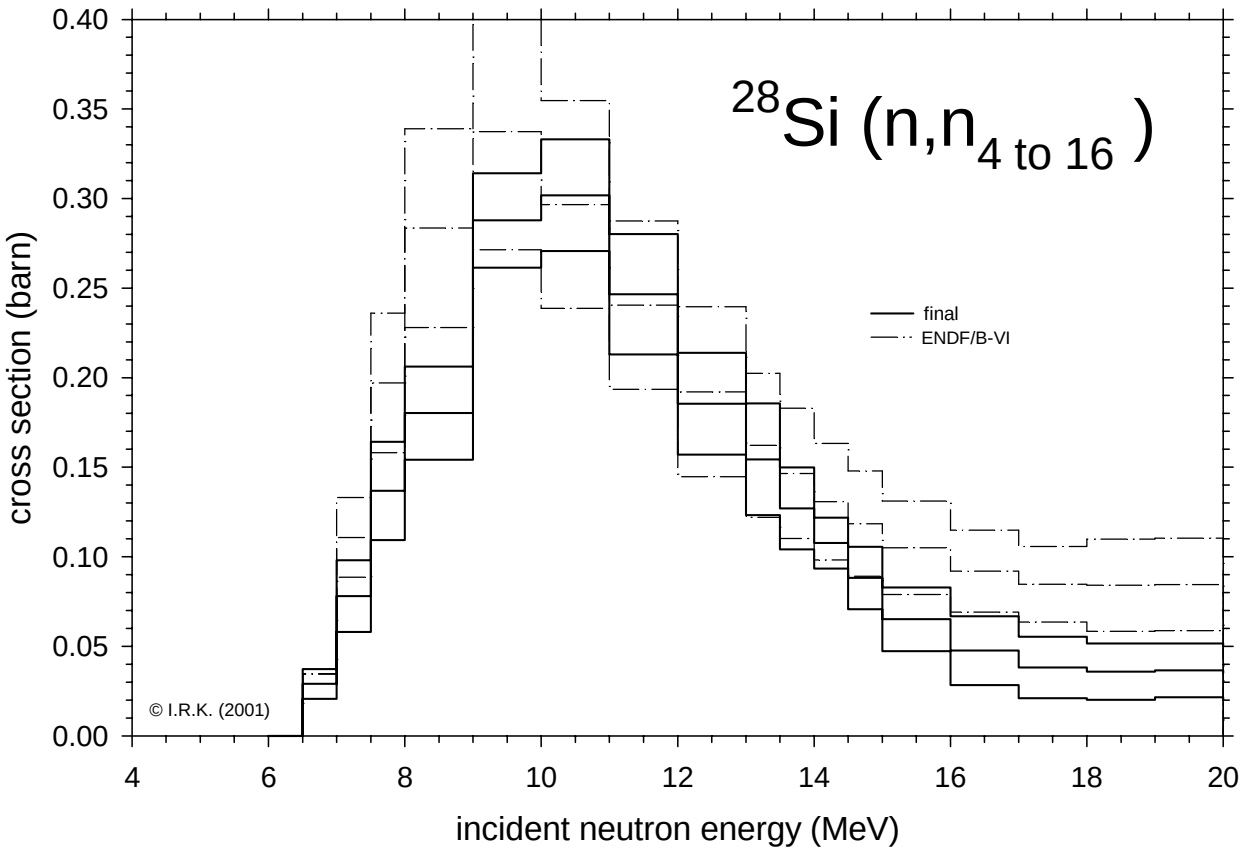
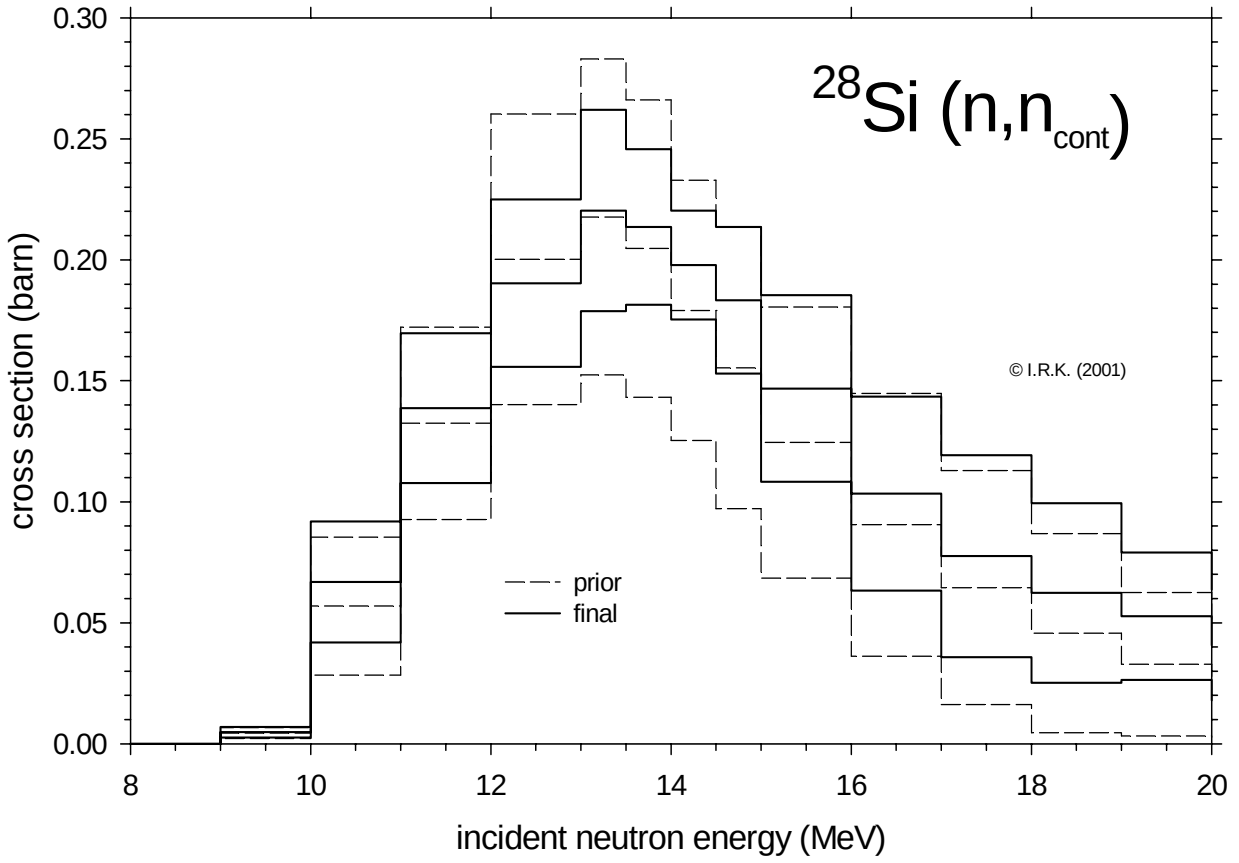


Fig. 13 (n,n_{cont}) cross section and comparison with ENDF/B-VI



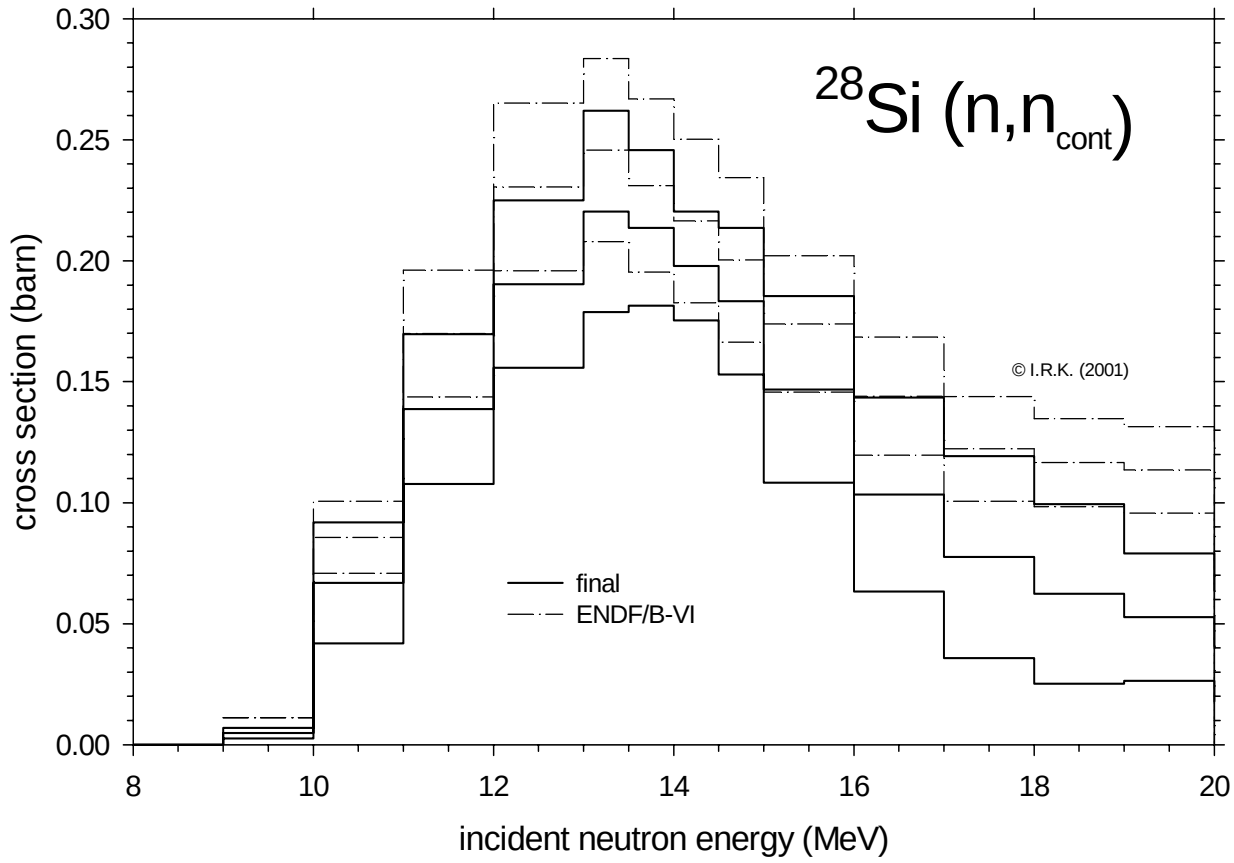
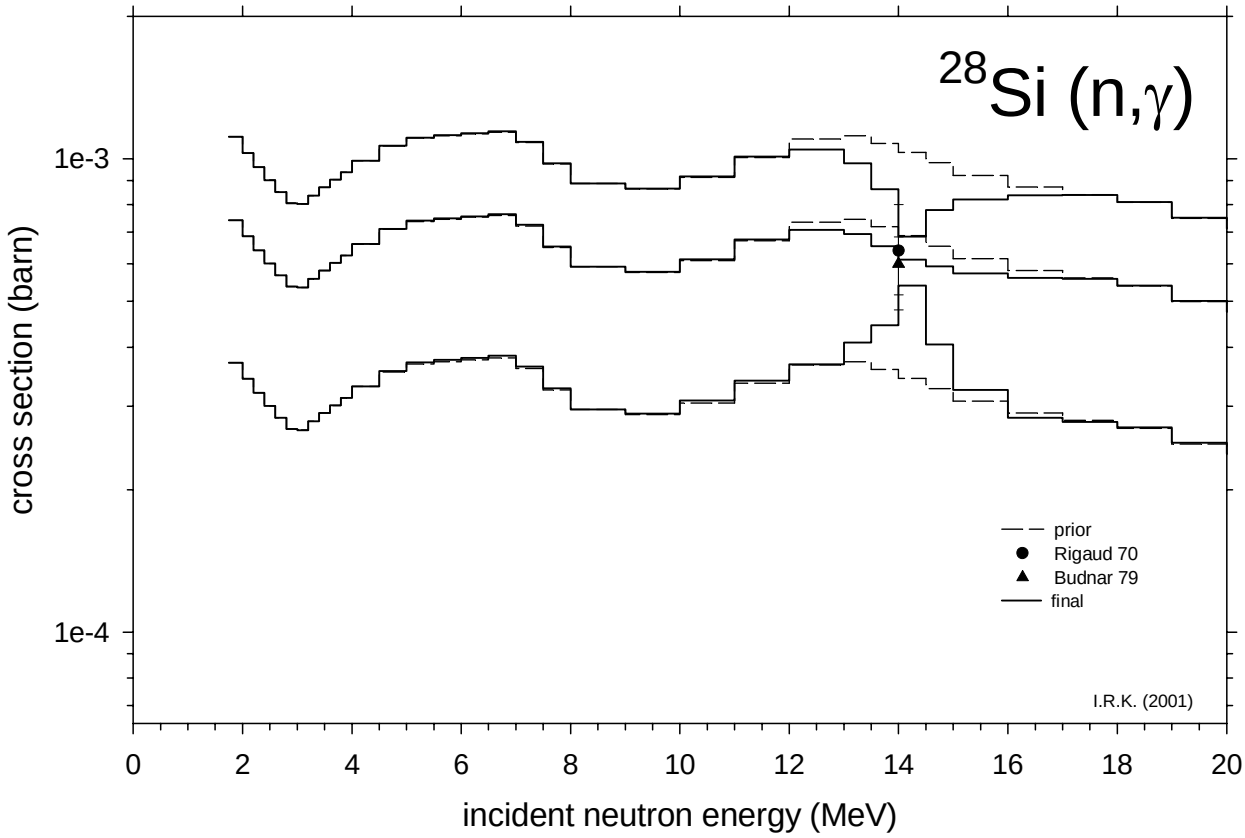


Fig. 14 (n,γ) cross section and comparison with ENDF/B-VI



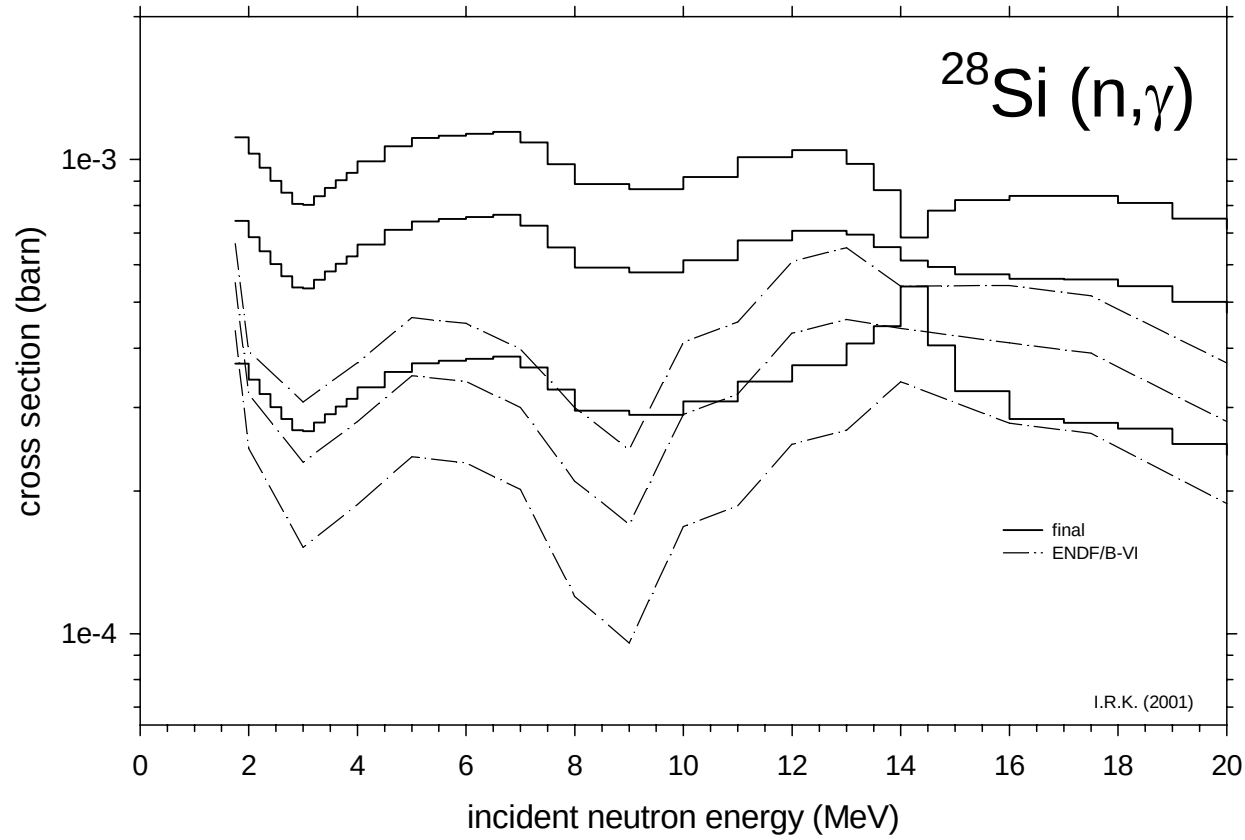
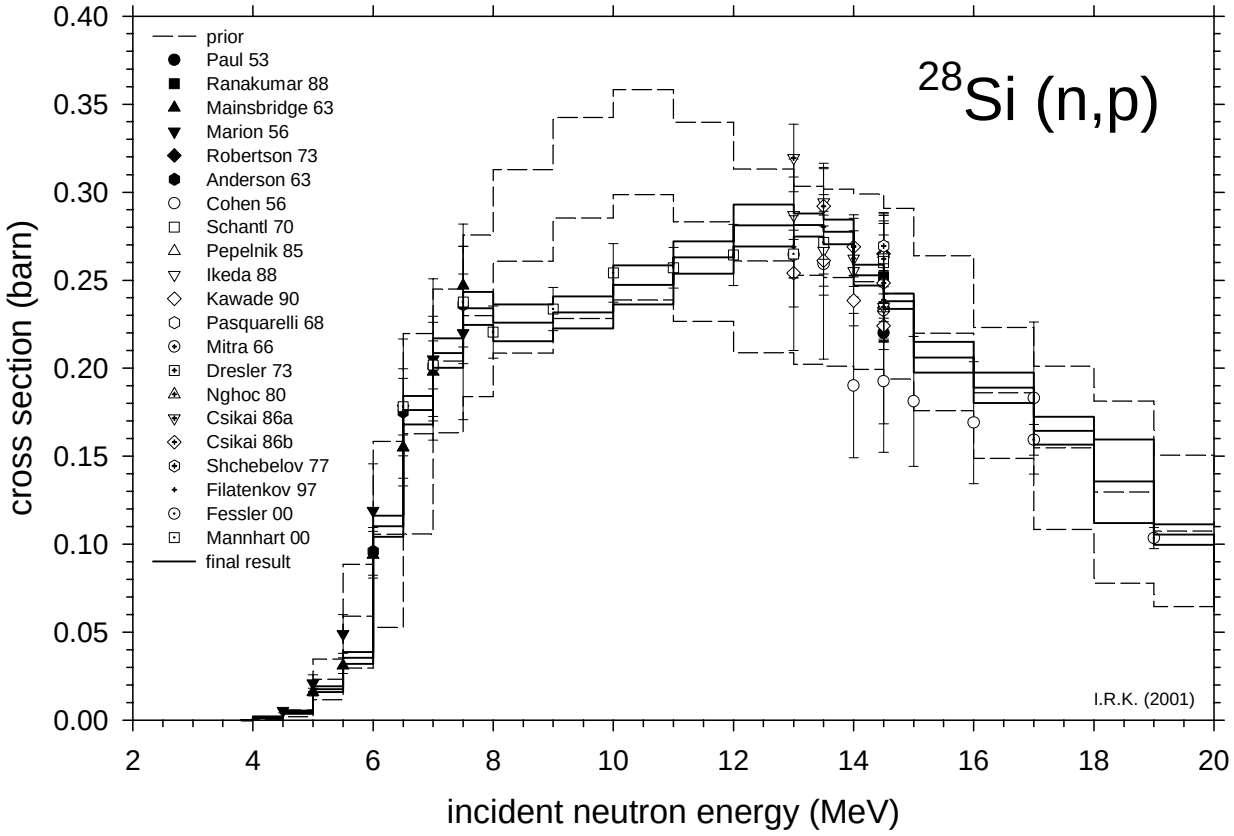


Fig. 15 (n,p) cross section and comparison with ENDF/B-VI



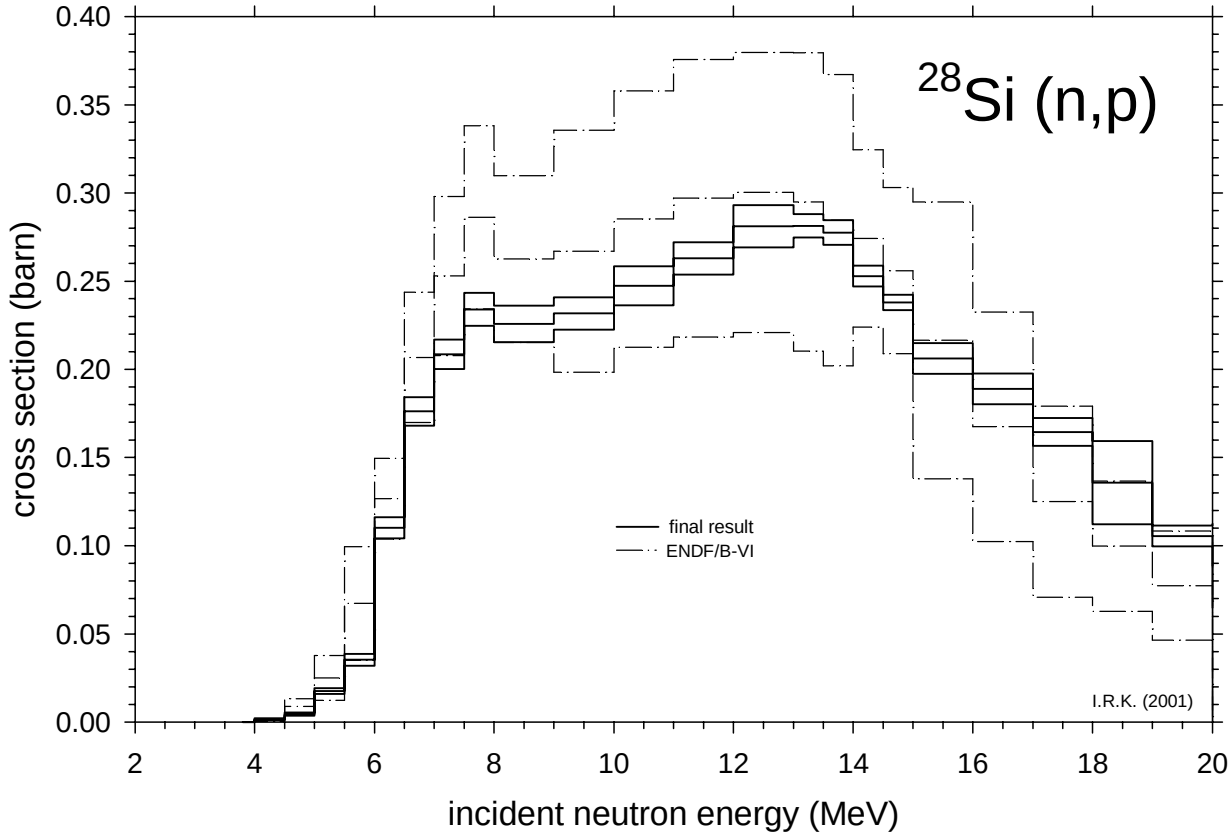
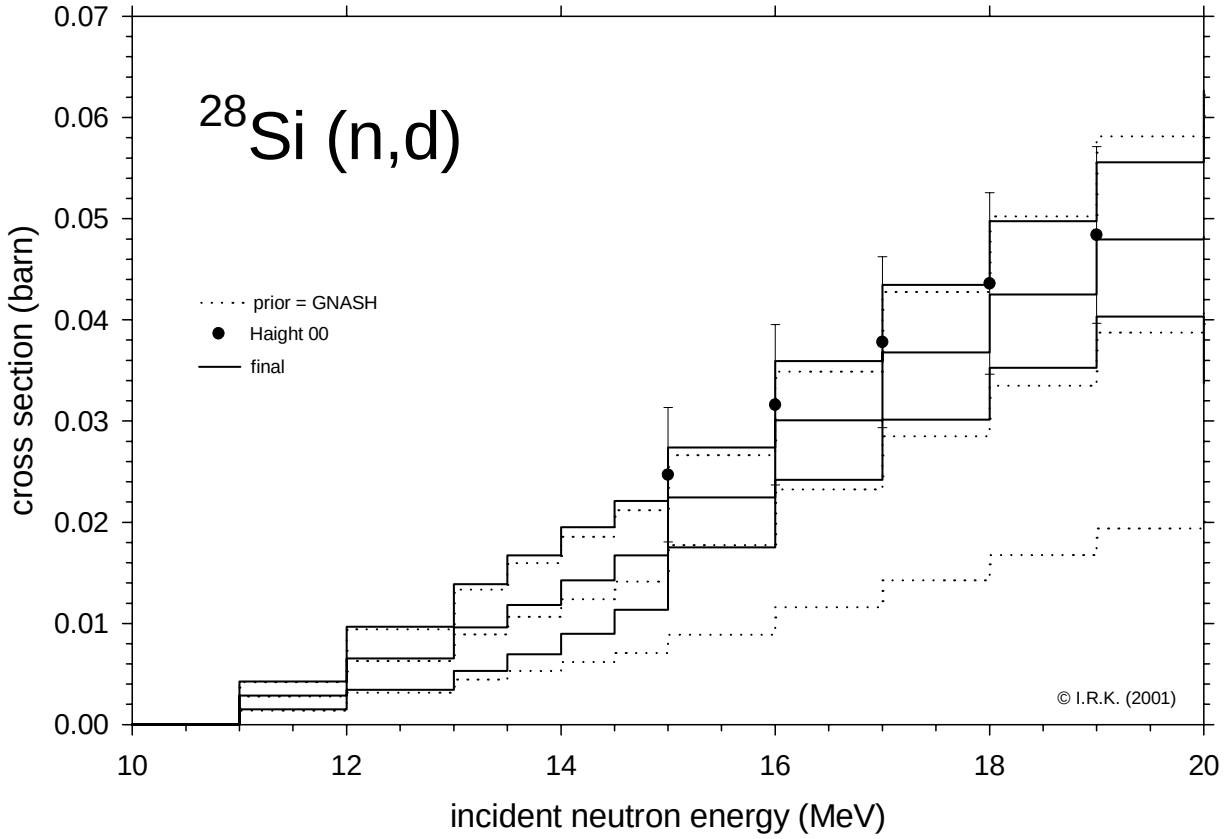


Fig. 16 (n,d) cross section and comparison with ENDF/B-VI



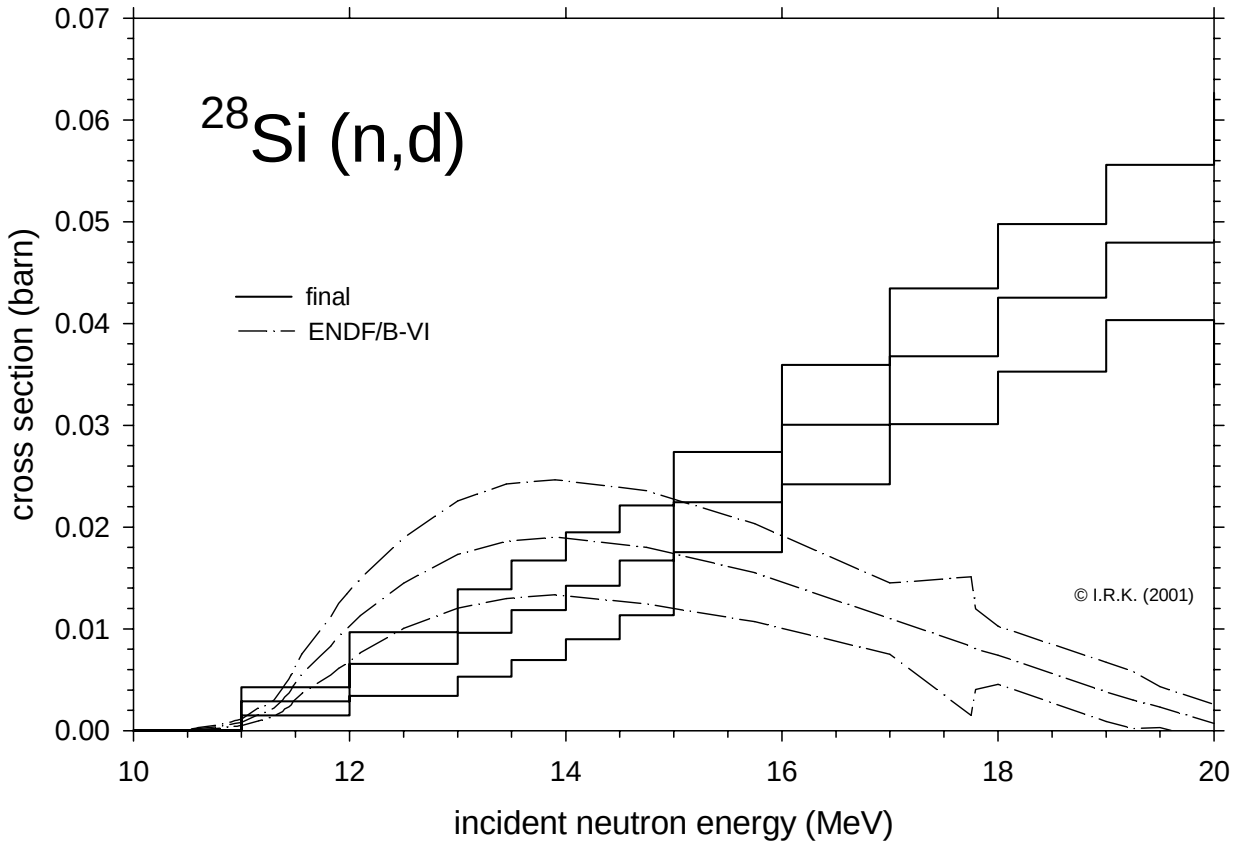


Fig. 17 (n,t) cross section

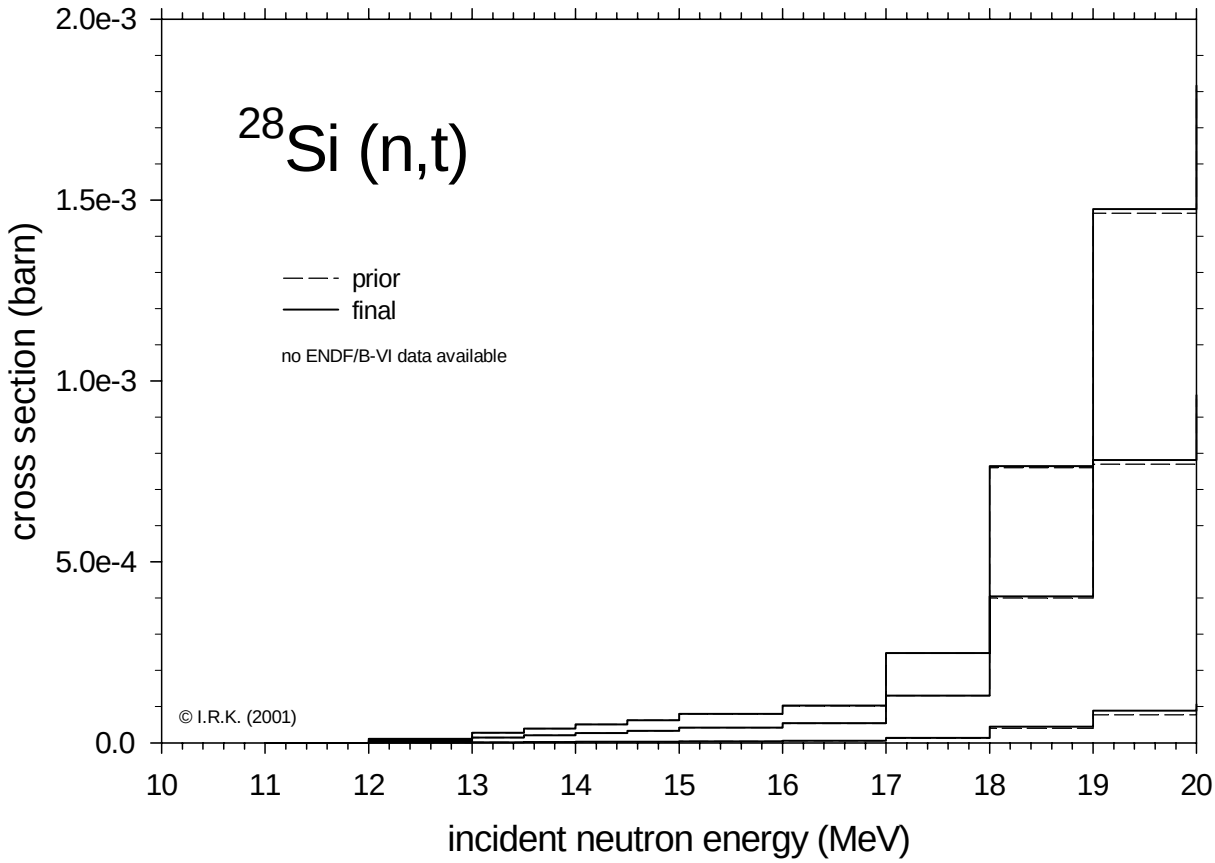


Fig. 18 (n,^{3}He) cross section

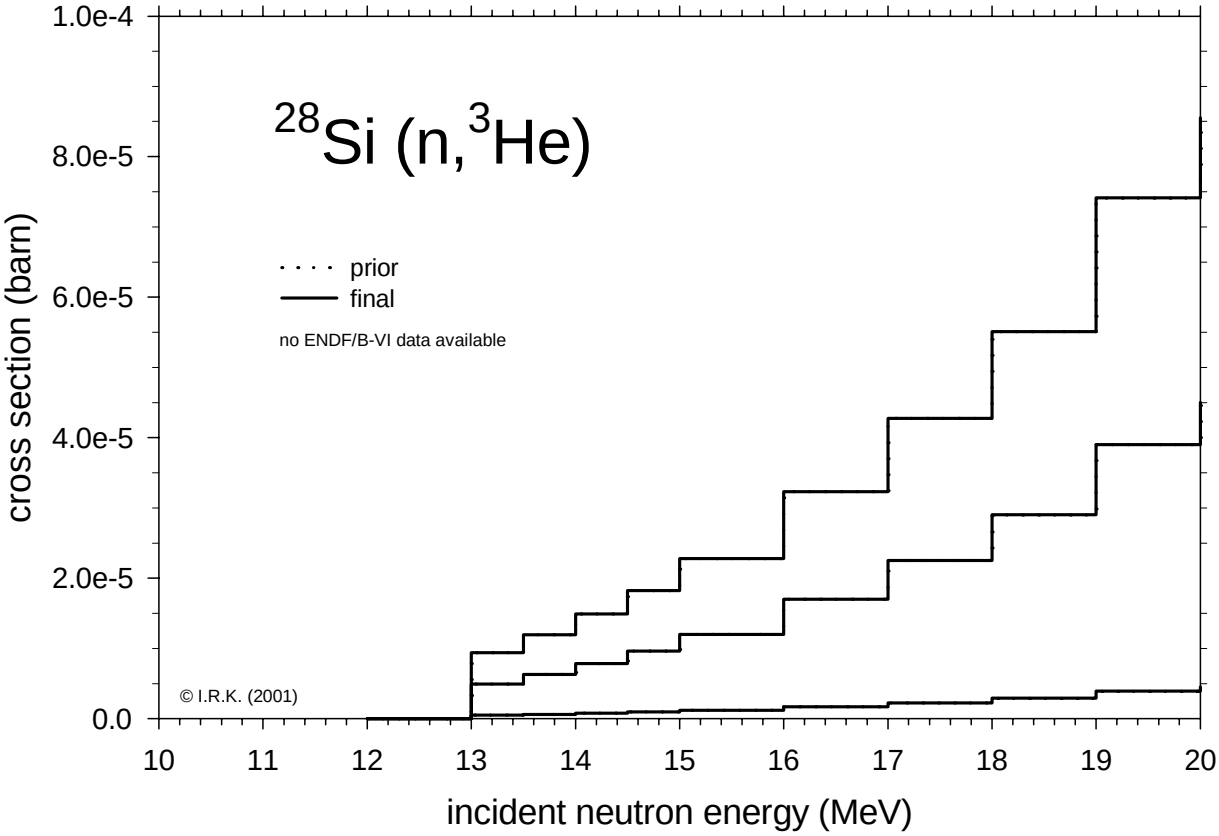
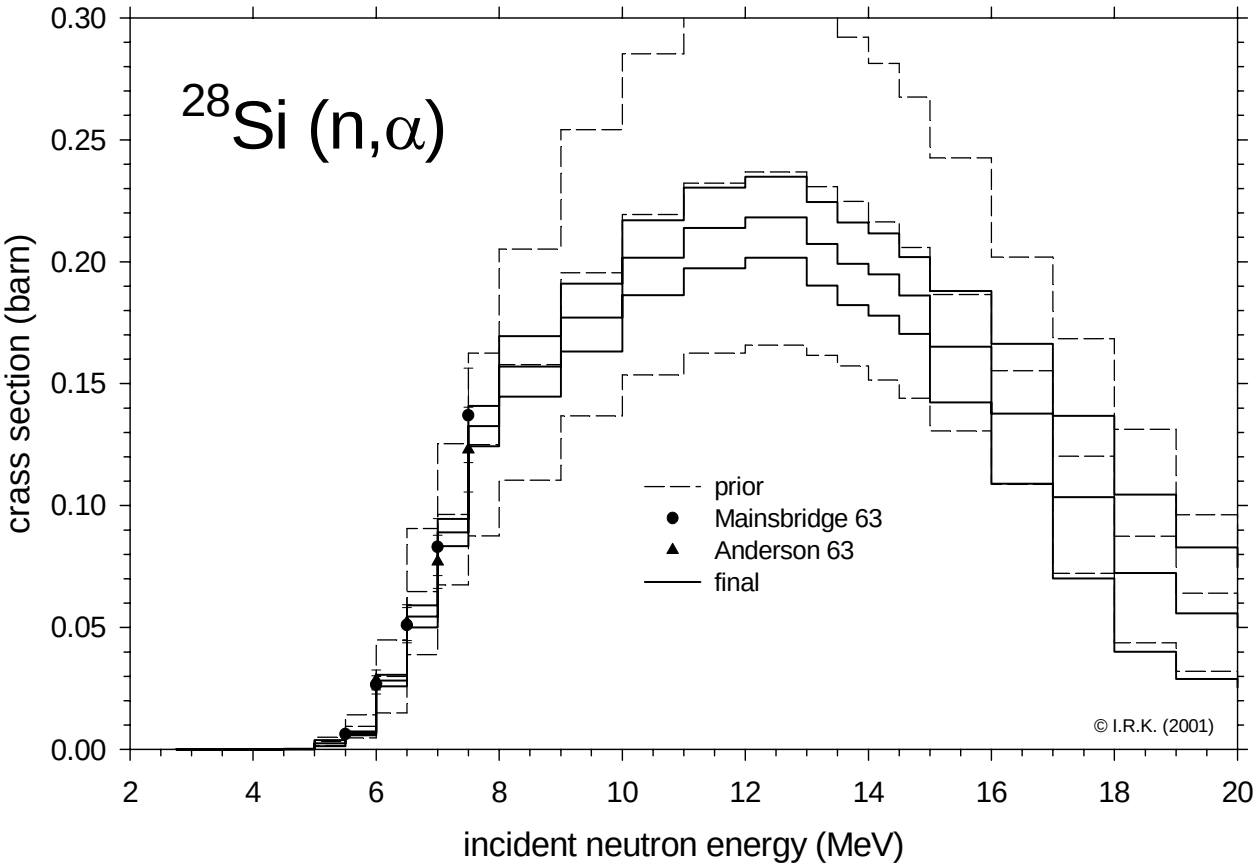


Fig. 19 (n,α) cross section and comparison with ENDF/B-VI



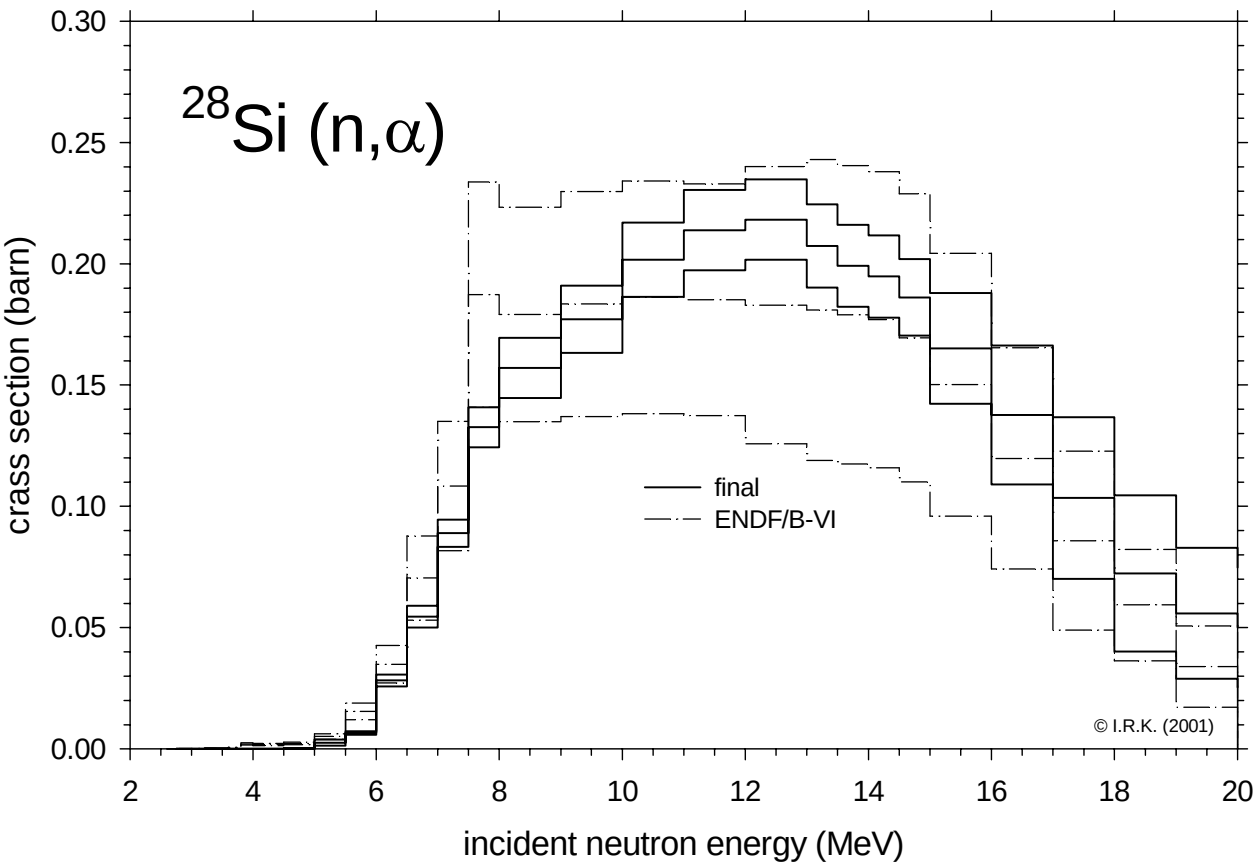


Fig. 20 (n,2p) cross section

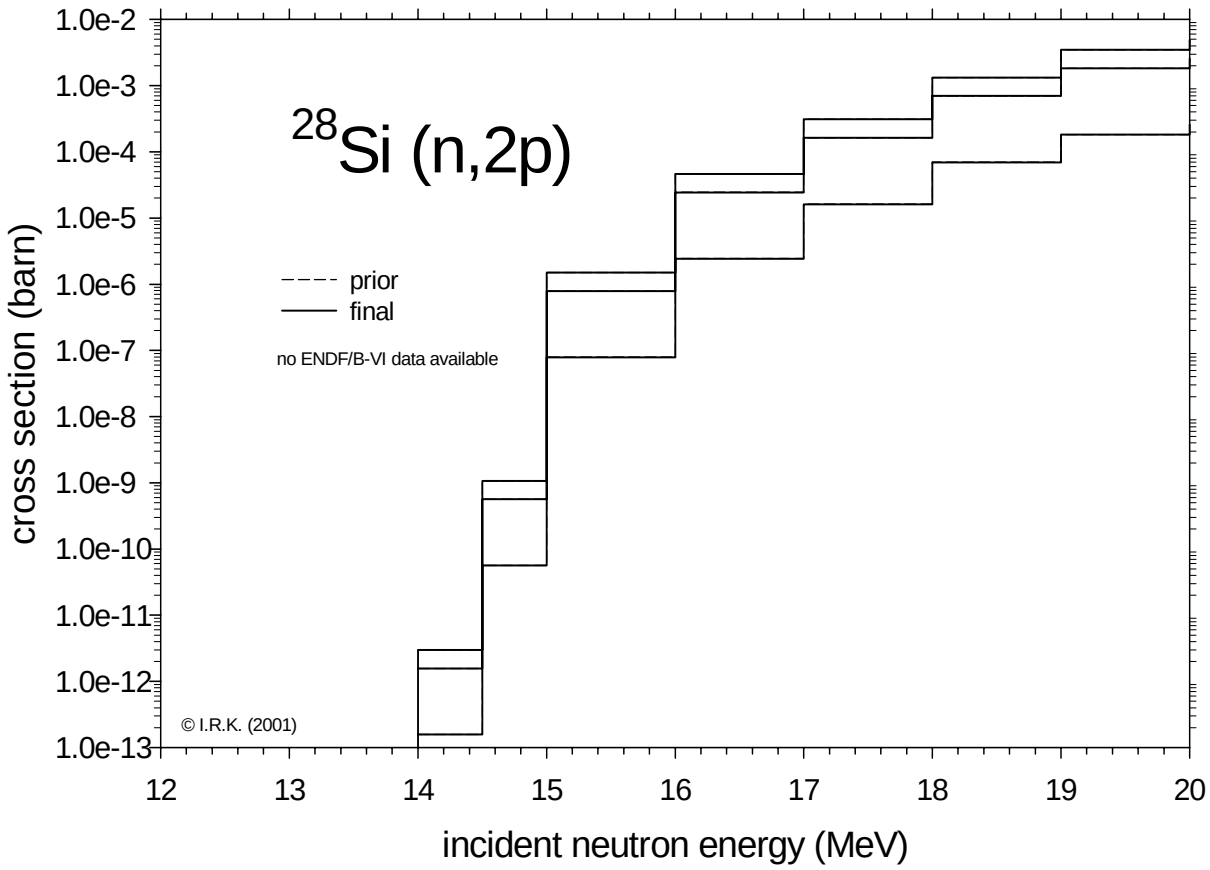


Fig. 21 Correlation matrix for the total cross section

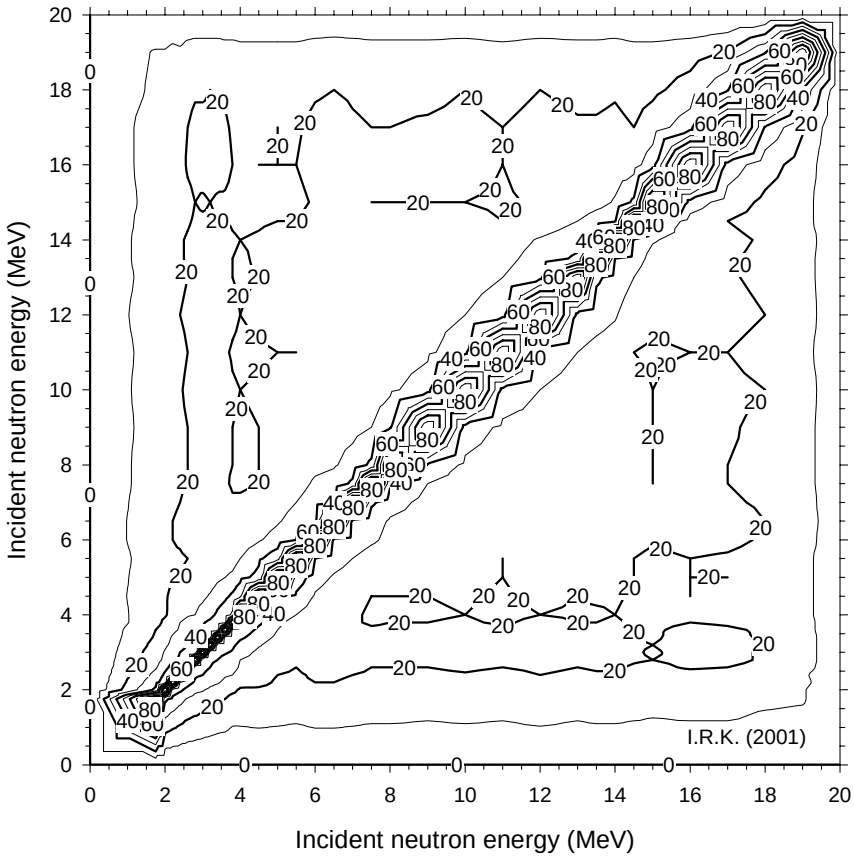


Fig. 22 Correlation matrix for the (n,2n) cross section

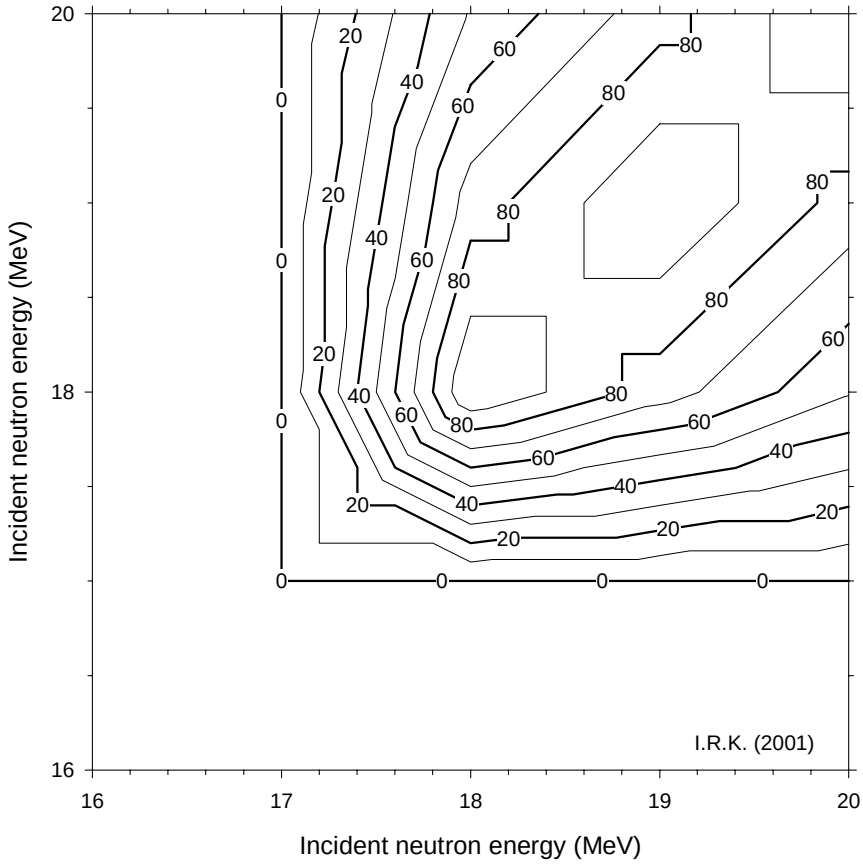


Fig. 23 Correlation matrix for the (n,nα) cross section

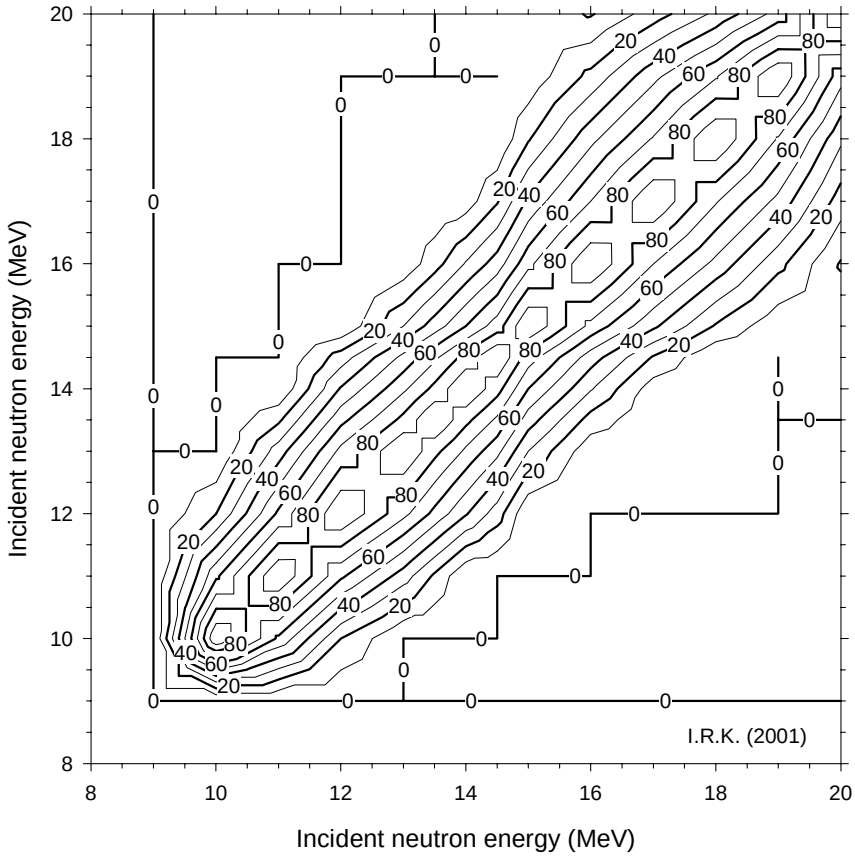


Fig. 24 Correlation matrix for the (n, np) cross section

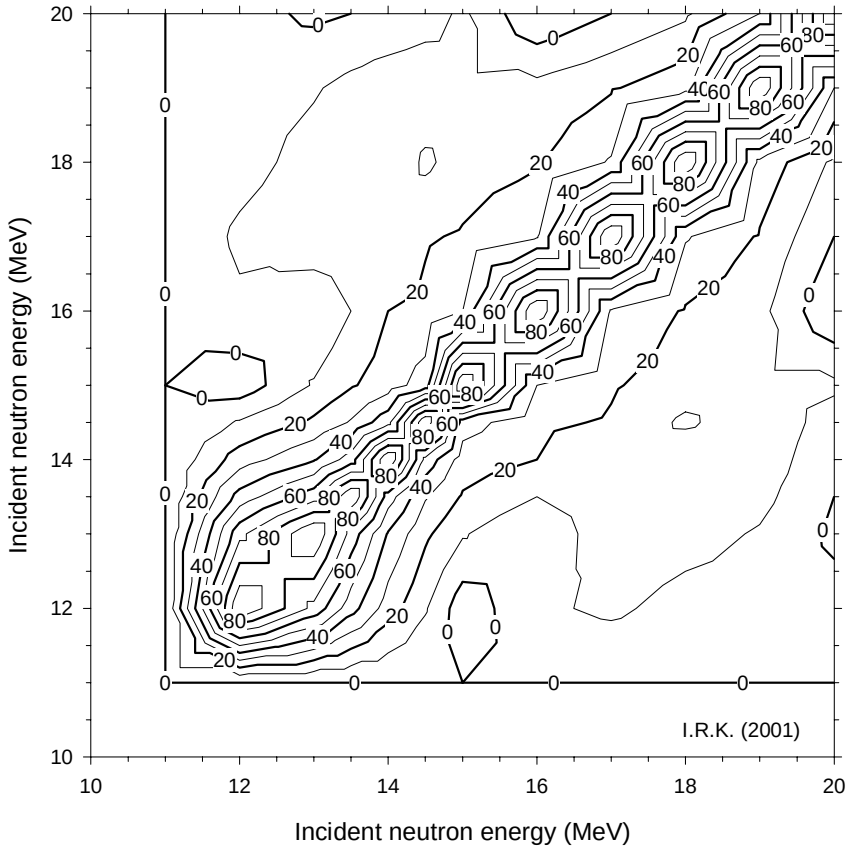


Fig. 25 Correlation matrix for the (n, n_1) cross section

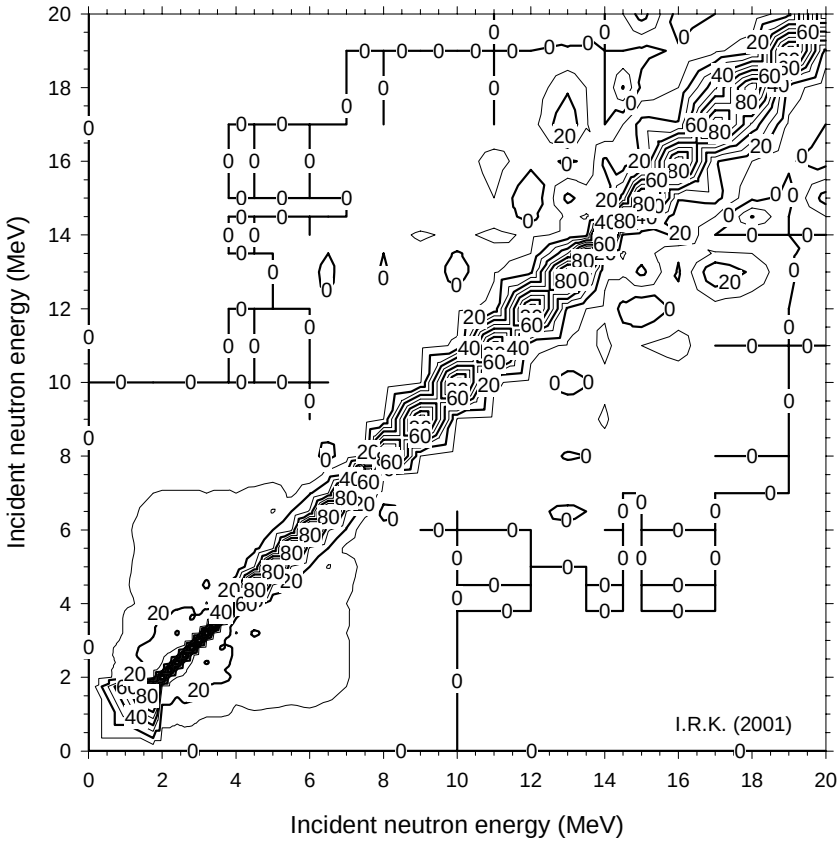


Fig. 26 Correlation matrix for the (n, n_{2+3}) cross section

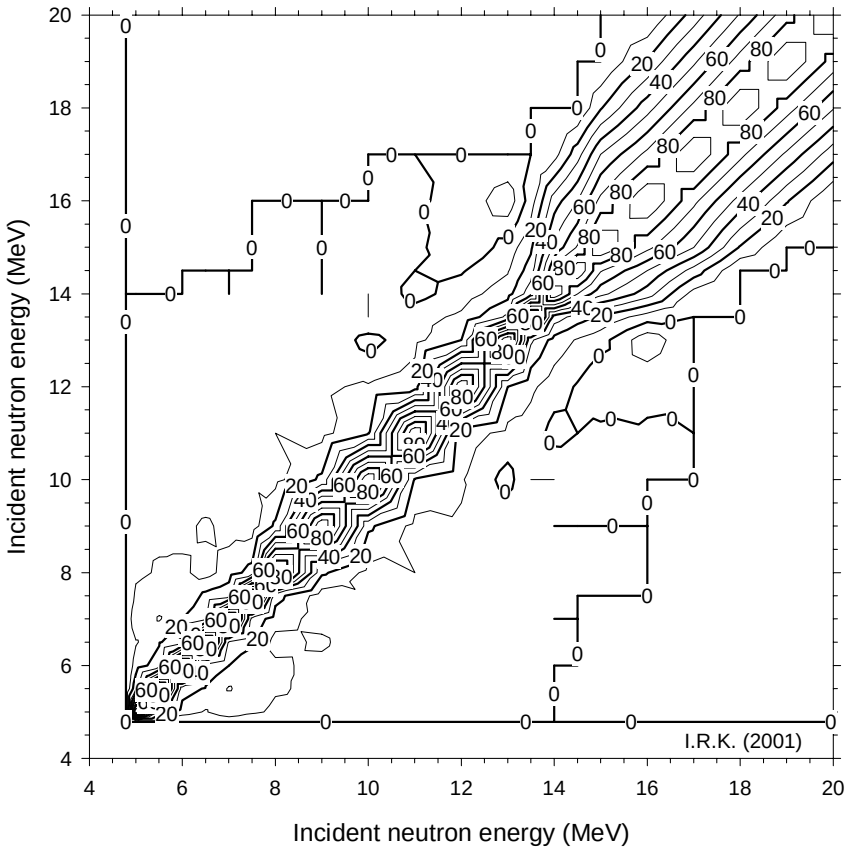


Fig. 27 Correlation matrix for the (n, $n_{4+..+16}$) cross section

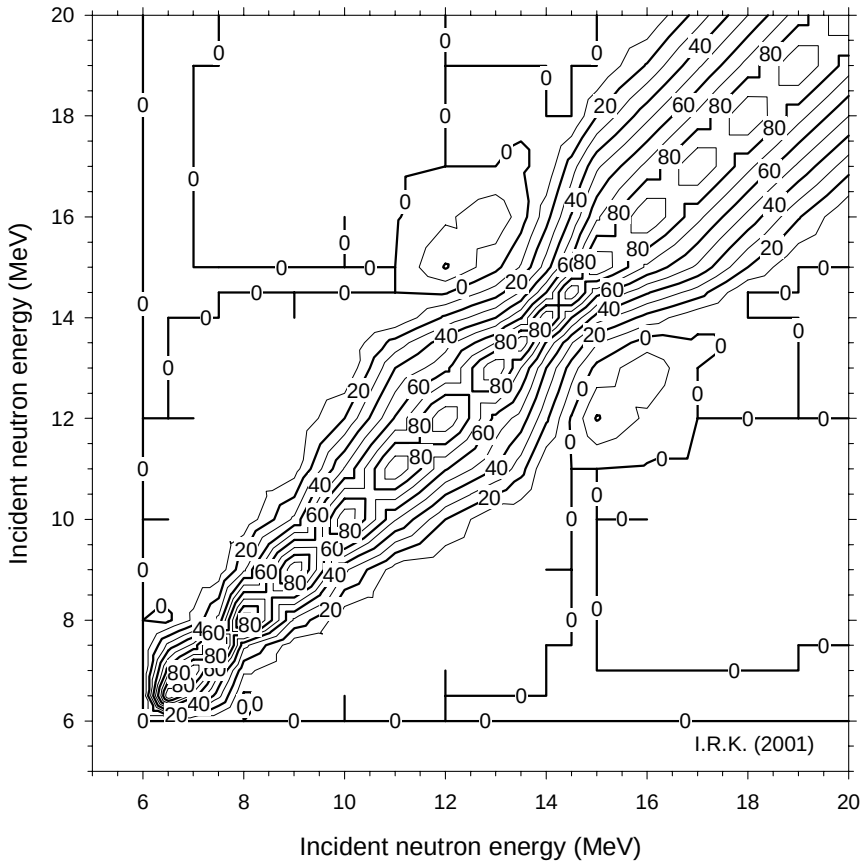


Fig. 28 Correlation matrix for the (n, n_{cont}) cross section

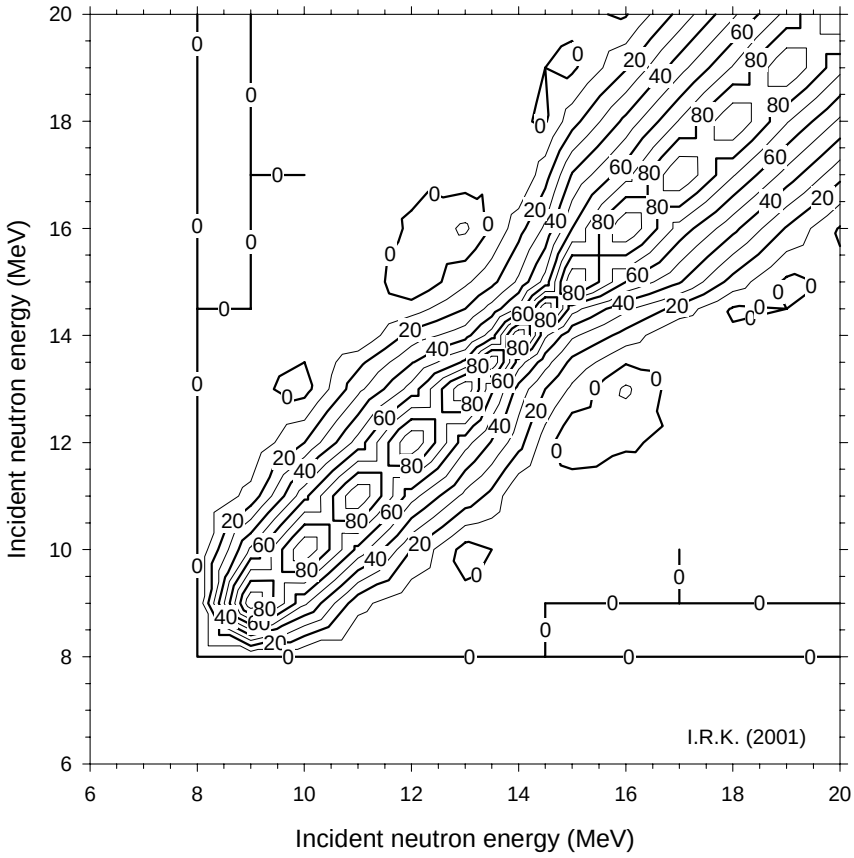


Fig. 29 Correlation matrix for the (n, nγ) cross section

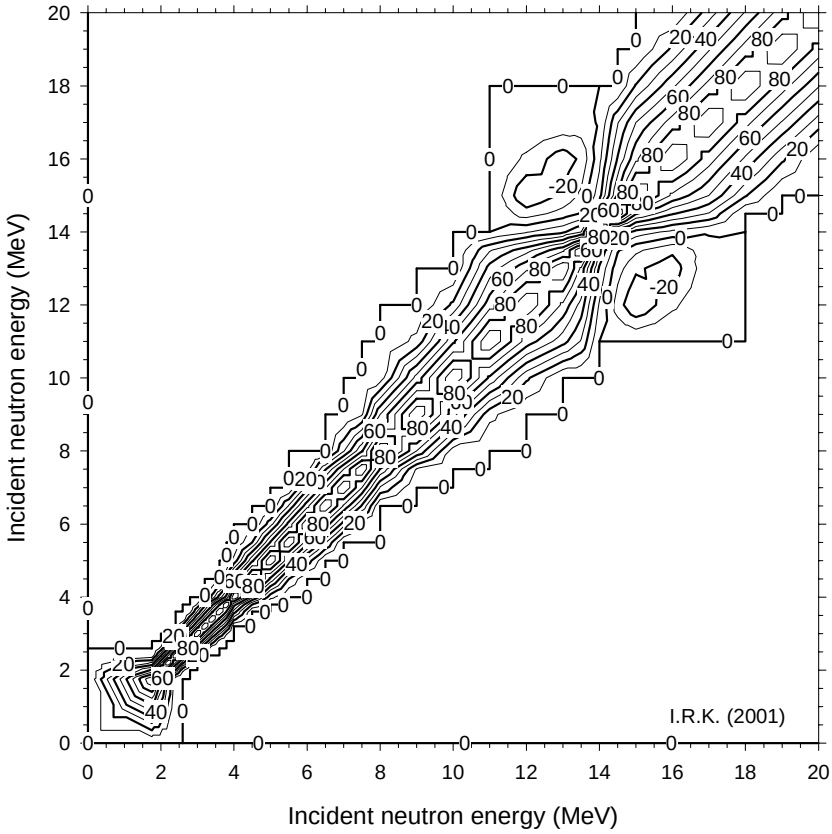


Fig. 30 Correlation matrix for the (n, p) cross section

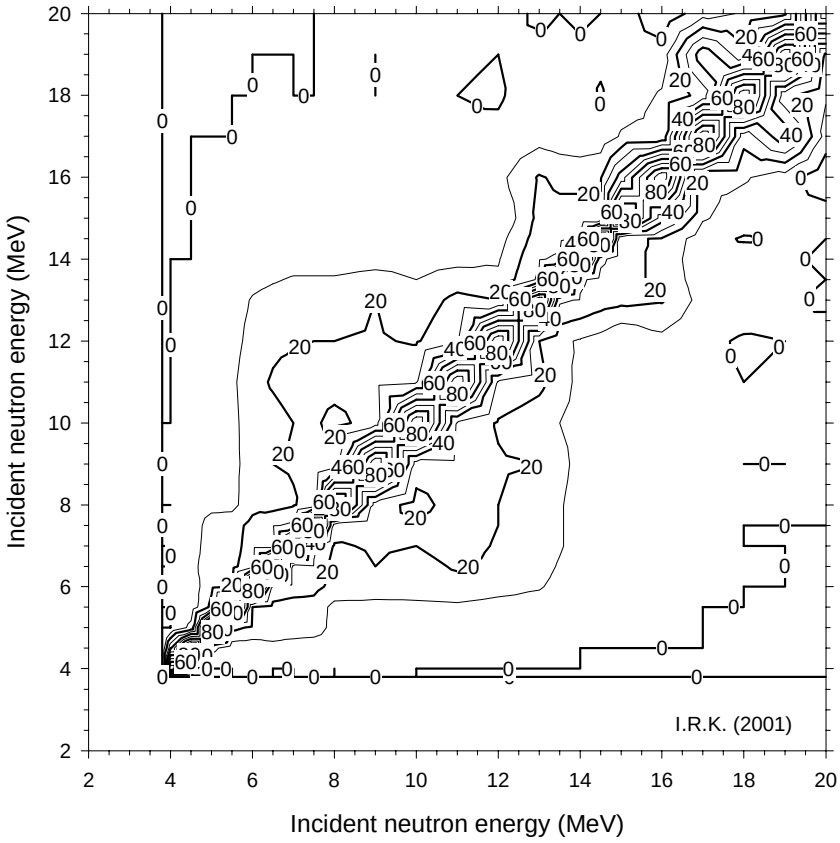


Fig. 31 Correlation matrix for the (n, d) cross section

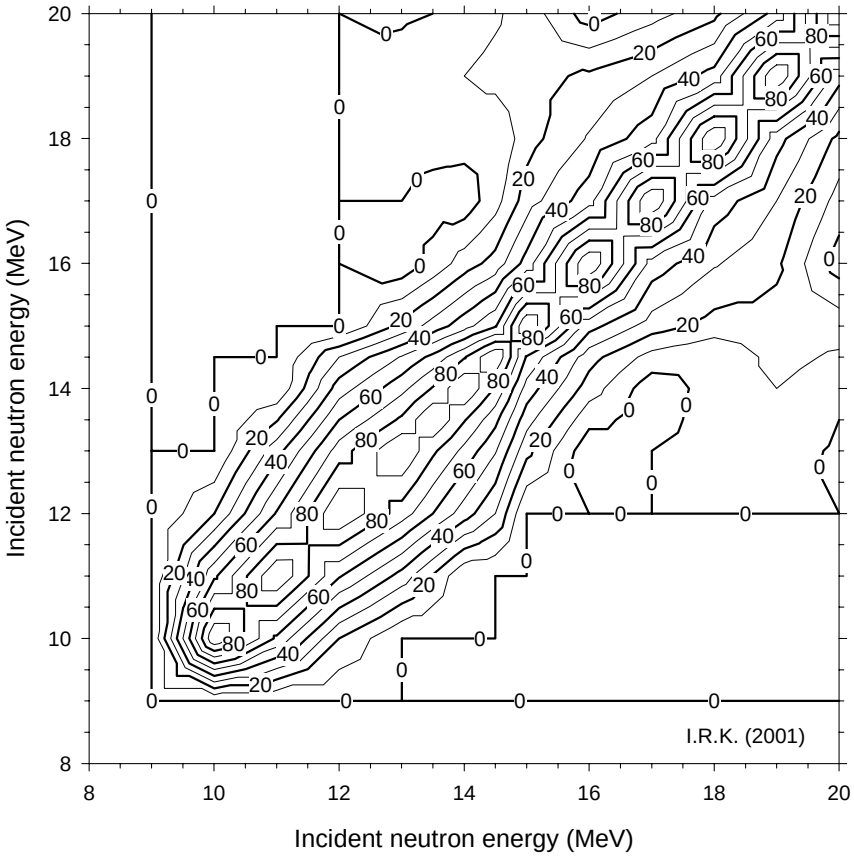


Fig. 32 Correlation matrix for the (n, t) cross section

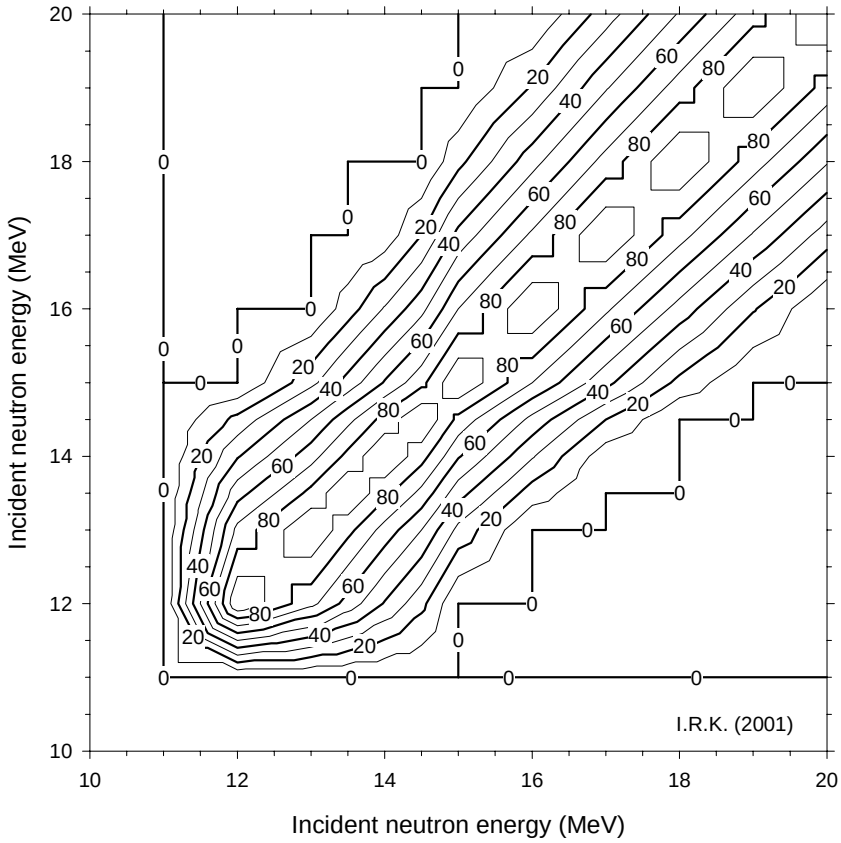


Fig. 33 Correlation matrix for the (n, ^{3}He) cross section

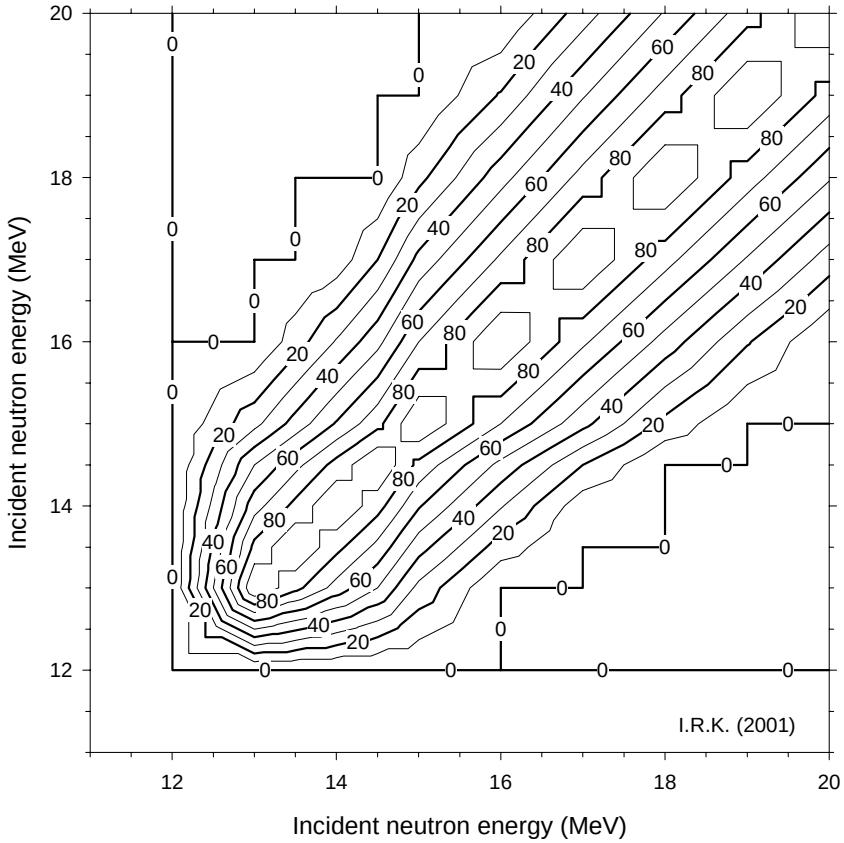


Fig. 34 Correlation matrix for the (n, α) cross section

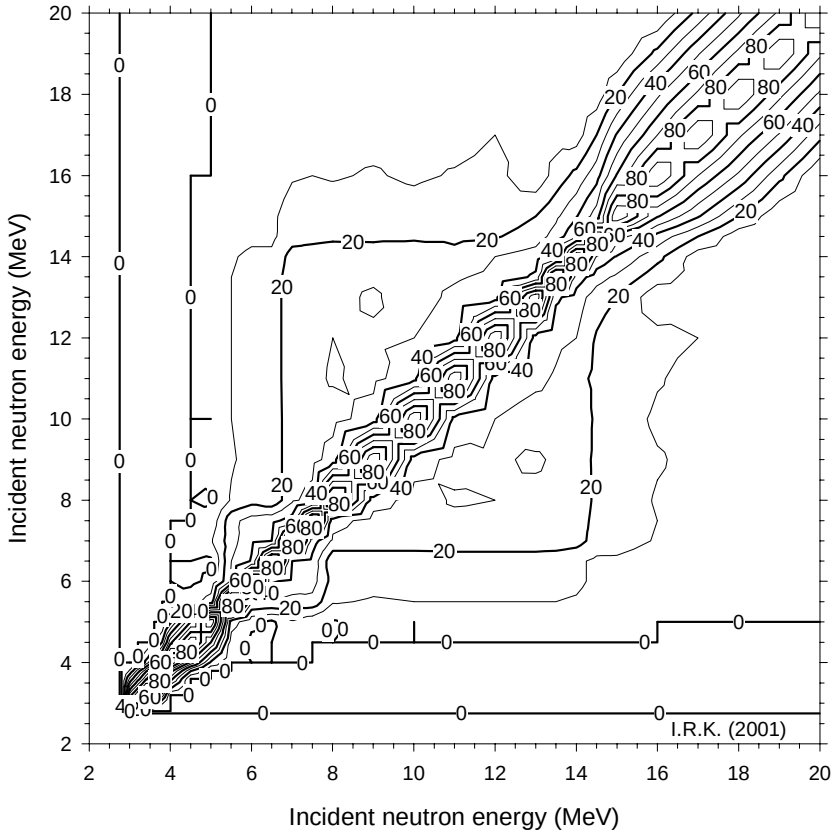
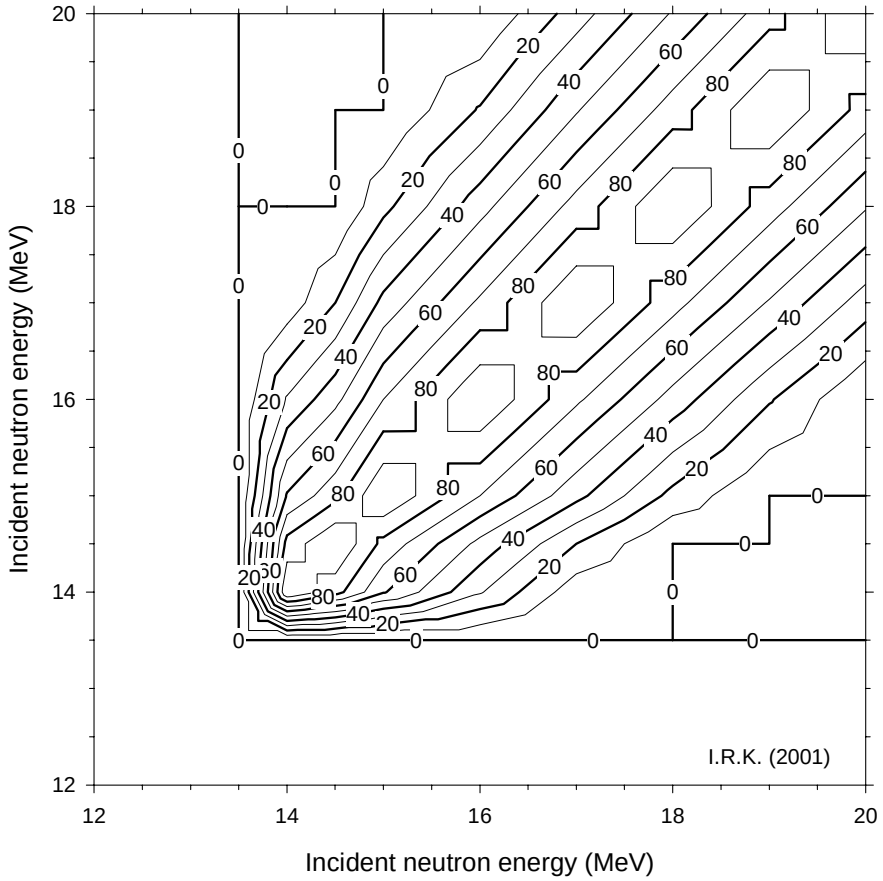


Fig. 35 Correlation matrix for the (n, 2p) cross section



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