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Photoneutron cross sections for ^{59}Co: Systematic uncertainties of data from various experiments

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Abstract. Data on partial photoneutron reaction cross sections $(\gamma, 1n)$, $(\gamma, 2n)$, and $(\gamma, 3n)$ for ^{59}Co obtained in two experiments carried out at Livermore (USA) were analyzed. The sources of radiation in both experiments were the monoenergetic photon beams from the annihilation in flight of relativistic positrons. The total yield was sorted by the neutron multiplicity, taking into account the difference in the neutron energy spectra for different multiplicity. The two quoted studies differ in the method of determining the neutron. Significant systematic disagreements between the results of the two experiments exist. They are considered to be caused by large systematic uncertainties in partial cross sections, since they do not satisfy physical criteria for reliability of the data. To obtain reliable cross sections of partial and total photoneutron reactions a new method combining experimental data and theoretical evaluation was used. It is based on the experimental neutron yield cross section which is rather independent of neutron multiplicity and the transitional neutron multiplicity functions of the combined photonucleon reaction model (CPNRM). The model transitional multiplicity functions were used for the decomposition of the neutron yield cross section into the contributions of partial reactions. The results of the new evaluation noticeably differ from the partial cross sections obtained in the two experimental studies are under discussion.

1 Introduction

Most of the neutron yield, total and partial photoneutron reactions cross sections were obtained using quasi-monoenergetic annihilation photon beams at the National Lawrence Livermore Laboratory (USA) and the Centre d'Etudes Nucleaires de Saclay (France) [1–4].

To identify the reactions with different multiplicities, a method based on the assumption that the energy spectra of neutrons from $(\gamma, 1n)$, $(\gamma, 2n)$, and $(\gamma, 3n)$ reactions are noticeably different was employed in both laboratories. The multiplicity of detected neutron was determined from its kinetic energy measurement. Different neutron detectors were used, the paraffin-moderated 4π detector containing BF3 counters with the "ring-ratio method" at Livermore and the large 4π gadolinium-loaded liquid-scintillator at Saclay. Systematic discrepancies in partial photoneutron reaction cross sections among the experiments are significant. For 19 nuclei from ^{51}V to ^{238}U the cross sections for $(\gamma, 1n)$ reaction are noticeably larger at Saclay than at Livermore, and vice versa for $(\gamma, 2n)$ cross sections and disagreements approach $\sim$ 60–100% [5–9].

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It has been shown [8,9] that these disagreements originated from the procedures of neutron multiplicity sorting which were used to separate neutron counts into $1n$ and $2n$ events. For ^{181}Ta using additional data obtained with the activation method it was found [9] that Saclay $\sigma(\gamma, 2n)$ data are significantly underestimated (and correspondingly $\sigma(\gamma, 1n)$ overestimated) suggesting large systematic uncertainties in the analysis.

In order to resolve these problems a new experimental-theoretical method for evaluating the partial reaction cross sections was developed [10,11]. It is based on using the experimental neutron yield cross section $\sigma^{\mathrm{exp}}(\gamma, Sn)$, expressed as the sum of the partial cross sections $\sigma^{\mathrm{exp}}(\gamma, in)$, where i (equal to $1, 2, 3, \ldots$) denotes the neutron multiplicity, as

$$\sigma^{\mathrm{exp}}(\gamma, Sn) = \sigma^{\mathrm{exp}}(\gamma, 1n) + 2\sigma^{\mathrm{exp}}(\gamma, 2n) + 3\sigma^{\mathrm{exp}}(\gamma, 3n) + \ldots, \quad (1)$$

which is rather independent of the problem regarding the neutron multiplicity sorting because all detected neutrons are included.

To be rather free from the problem regarding the neutron-multiplicity sorting, the partial cross sections are evaluated in terms of theoretically estimated fraction of the partial cross section called "transitional neutron multiplicity function" $F_i^{\rm th}$ as

$$\sigma^{\rm eval}(\gamma,in) = F_i^{\rm th}\sigma^{\rm exp}(\gamma,Sn) = [\sigma^{\rm th}(\gamma,in)/\sigma^{\rm th}(\gamma,Sn)]\sigma^{\rm exp}(\gamma,Sn). \quad (2)$$

The $F_i^{\rm th}$ were calculated within the framework of CPNRM (combined photonucleon reaction model) [12,13] for the partial reactions (γ,in) with given neutron multiplicity $i = 1, 2, 3, \ldots$.

The CPNRM is based on the statistical approach and uses a combination of the preequilibrium exciton model and particle evaporation process to calculate probabilities of formation of specific final nuclei after absorption of a photon. It takes into account the deformation of nucleus and isospin splitting of its giant dipole resonance. The model is well tested for many medium and heavy nuclei.

For experimental data the ratios $F_i^{\rm exp}$ can be defined in analogy to eq. (2) to be equal to $\sigma^{\rm exp}(\gamma,in)/\sigma^{\rm exp}(\gamma,Sn)$. Those ratios allow one to investigate the systematic uncertainties in partial reactions cross sections. According to the definition, F_1 which is the ratio of $\sigma(\gamma,1n)$ to the sum $[\sigma(\gamma,1n)+2\sigma(\gamma,2n)+3\sigma(\gamma,3n)+\ldots]$ can never be larger than 1; analogously F_2 can never be larger than 0.5; correspondingly F_3 never can be larger than 0.33, and so on. It should be noted that F_i are the ratios of reaction cross sections and therefore should have positive values.

Therefore, the evaluation method by eq. (2) allows one to keep the competitions between partial reaction cross sections $\sigma^{\rm eval}(\gamma,in)$ in accordance with the theoretically calculated ratios $F_i^{\rm th}$ and to keep the correspondent sum $\sigma^{\rm eval}(\gamma,Sn)$ close to $\sigma^{\rm exp}(\gamma,Sn)$.

For isotopes ^{63,65}Cu, ^{80}Se, ^{91,94}Zr, ^{115}In, $^{112-124}$Sn, ^{133}Cs, ^{138}Ba, ^{159}Tb, ^{181}Ta, $^{186-192}$Os, ^{197}Au, ^{208}Pb, ^{209}Bi [7,10,11,14–19] it was shown that in many cases the experimental partial reaction cross sections are not reliable because they do not satisfy the proposed data reliability criteria. There are many:

1) negative values of $\sigma^{\rm exp}(\gamma,in)$ and correspondingly of $F_i^{\rm exp}$;
2) $F_i^{\rm exp}$ values larger than the upper limits mentioned above and corresponding unreliably large $\sigma^{\rm exp}(\gamma,in)$ values.

It was shown [7,20] also that the partial reaction cross sections evaluated by using $F_i^{\rm th}$ in accordance with eq. (2) for ^{181}Ta and ^{209}Bi nuclei agree with the corresponding experimental results obtained by using the activation method. In this method, alternative to the method of neutron multiplicity sorting, the direct identification of each partial reaction is based on the final nuclei. So if $F_i^{\rm exp}$ noticeably differ from $F_i^{\rm th}$ one has definite doubts in experimental data reliability.

It was shown [7,10,11,14–19] that the main reason of the disagreements between the partial reaction cross sections mentioned above might originate from the definite shortcomings of the neutron multiplicity sorting procedures. The dependence of neutron multiplicity on its energy is not direct and is very complicated.

Table 1. The energy thresholds B for various photonuclear reactions on ^{59}Co.

Reaction	Threshold B (MeV)
$(\gamma,1n)$	10.5
$(\gamma,1n1p)$	17.4
$(\gamma,2n)$	19.0
$(\gamma,2n1p)$	25.1
$(\gamma,3n)$	30.4

Two experiments for ^{59}Co carried out at Livermore [21, 22] are of great interest from the point of view of data reliability. The same reaction cross sections were studied in the two experiments using similar detectors (4π paraffin-moderated detector containing BF3 counters): in [21] the detector has 24 BF3 counters and its efficiency was 17% [23]; in [22] the detector has 48 BF3 counters and its efficiency was 29–49% [24]. However, the procedures for neutron multiplicity determination were quite different. In [21] "... the neutron counts were separated electronically as single, double, or triple counts during the gating interval. Statistical analysis was applied to the data, and the neutron counts recorded per beam pulse were correlated to the number of neutrons emitted per nuclear disintegration. The cross sections for the reactions $(\gamma,1n)$ and $(\gamma,2n)$ were then deduced". In [22] "... the partial photoneutron cross sections were determined by neutron multiplicity counting and the average neutron energies, and hence the neutron detector efficiencies, were obtained for each multiplicity and for each data point by the ring-ratio technique" [25].

We examined the results of both Livermore experiments [21,22] by the physical criteria of the data reliability, F_i ratios. Then the new reliable (free from the aforementioned shortcomings of experimental data) partial $(\gamma,1n)$, $(\gamma,2n)$, and $(\gamma,3n)$ reaction cross sections and the total photoneutron reaction cross section expressed as

$$\sigma(\gamma,{\rm tot}) = \sigma(\gamma,1n)+\sigma(\gamma,2n)+\sigma(\gamma,3n)+\ldots \quad (3)$$

were obtained using the experimental-theoretical method based on eq. (2).

2 Physical criteria of partial reaction cross sections reliability

The energy thresholds of various partial photonuclear reactions on ^{59}Co are presented in table 1.

It is important to underline that:

– in wide energy regions $\sigma(\gamma,1n)$ is the sum $[\sigma(\gamma,1n)+\sigma(\gamma,1n1p)]$ and $\sigma(\gamma,2n)$ is the sum $[\sigma(\gamma,2n)+\sigma(\gamma,2n1p)]$ as can be understood from table 1;
– the partial reaction cross sections determined in both experiments [21,22] were used for extracting the total photoneutron reaction cross section in eq. (3) and the neutron yield cross section in eq. (1).

The experimental cross sections for ^{59}Co [21,22] are presented in fig. 1. One can see that $\sigma(\gamma, Sn)$ obtained in the both experiments are very close to each other below 25 MeV and start deviating significantly above 25 MeV (fig. 1(a)). At the same time there are (figs. 1(b), (c)) noticeable disagreements between the partial reaction cross sections $\sigma(\gamma, 1n)$ and $\sigma(\gamma, 2n)$ obtained in the experiments [21,22] at energies higher than about 21 MeV. Those disagreements indicate that significant systematic uncertainties are presented at least in one or generally in both the experimental results. The corresponding disagreements are very clear in the ratios F_i presented in fig. 2.

Since B_{1n1p} is smaller than B_{2n} (table 1) the $(\gamma, 1n1p)$ channel is opened in the energy region for the $(\gamma, 1n)$ reaction, and therefore both the results with the corresponding theoretical ratio $F_1^{\rm th}$ obtained with (solid curve) and without (dotted curve) the contribution from the $1n1p$ emission are shown in fig. 2(a). As was pointed out before the $(\gamma, 1n1p)$ reaction could be an important source of unknown systematic uncertainties of the detected neutron multiplicity determination procedure. One important possible source of ambiguity in this case is that the sharing of nuclear excitation energy between neutron and proton is similar to that for two neutrons in the reaction $(\gamma, 2n)$ but the multiplicity of outgoing neutron in the reaction $(\gamma, 1n1p)$ is 1 but in the reaction $(\gamma, 2n)$ is 2.

One can see that the reason for the disagreements between the two versions of $F_1^{\rm exp}$ based on the two experiments [21,22], respectively, presented in fig. 2 and for corresponding disagreements between $\sigma(\gamma, 1n)$ and $\sigma(\gamma, 2n)$, presented in fig. 1, is very clear. In [21] many neutrons from the reaction $(\gamma, 1n1p)$ were erroneously interpreted as those from the reaction $(\gamma, 2n)$. In [7,14–19] it was pointed out that if $\sigma(\gamma, 1n)$ is the sum $[\sigma(\gamma, 1n)+(\gamma, 1n1p)]$ that could distort noticeably the dependence of neutron multiplicity on the energy.

One can see in fig. 2 that there are neither negative values nor values larger than the upper limit 1 in $F_1^{\rm exp}$ and 0.5 in $F_2^{\rm exp}$ obtained in both experiments [21,22]. At the same time $F_1^{\rm exp}$ of refs. [21,22] are in agreement with both versions of $F_1^{\rm th}$ and $F_2^{\rm exp}$ of refs. [21,22] are in agreement with both versions of $F_2^{\rm th}$ only for low energies up to ~ 21 MeV. At higher energies $F_1^{\rm exp}$ of ref. [21] (filled triangles) are noticeably lower than the two versions of $F_1^{\rm th}$ and decrease down to values near 0 at energy ~ 26 MeV. $F_2^{\rm exp}$ of ref. [21] are noticeably higher than the two versions of $F_2^{\rm th}$ and increase up to values close 0.5 at energy ~ 26 MeV also. It can be concluded that because of the significant systematic uncertainties at energies $\sim$ 21–26 MeV the data [21] are not reliable.

The situation is noticeably different for the results of experiment [22]. In the energy range $\sim$ 21–26 MeV generally $F_1^{\rm exp}$ within errors is systematically lower than $F_1^{\rm th}$ (fig. 2(a)) including the contribution of the reaction $(\gamma, 1n1p)$. At the same time $F_2^{\rm exp}$ (open triangles) is systematically higher than $F_2^{\rm th}$ (fig. 2(b)) obtained in the same version. At higher energies $F_i^{\rm exp}$ look like oscillating (within the errors but with large amplitudes) around $F_i^{\rm th}$.

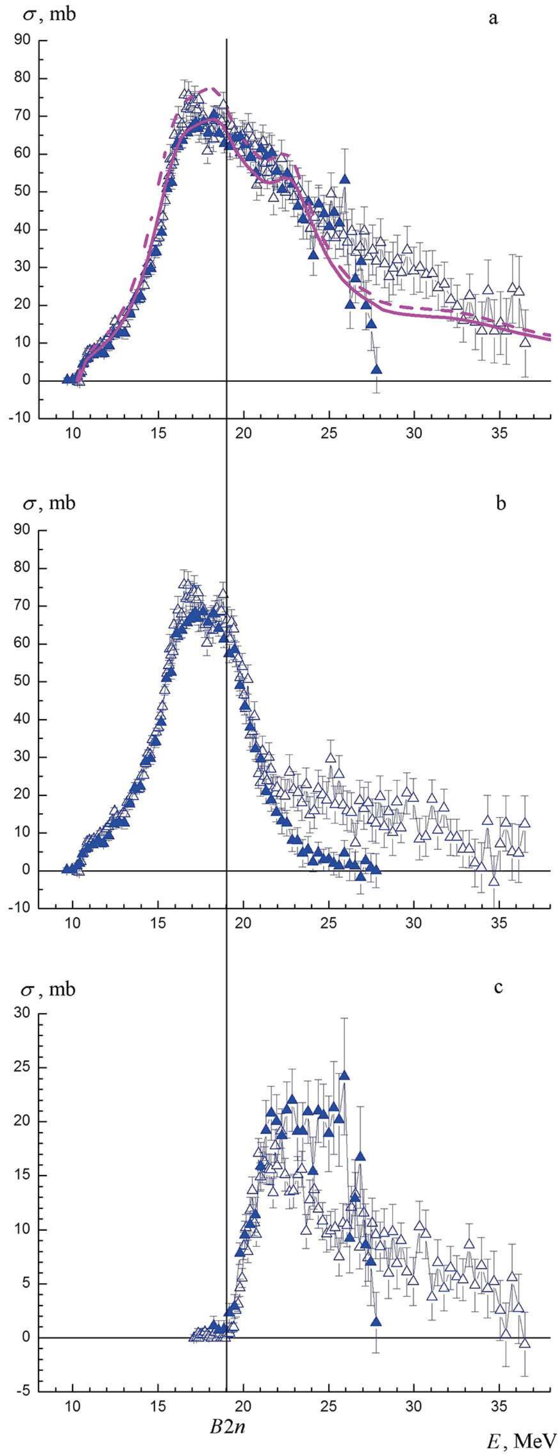

Fig. 1. The comparison of the neutron yield and partial cross sections for ^{59}Co ([21]: filled triangles and [22]: open triangles, [12,13]: lines, initial: dotted, corrected: solid, see later): (a) $\sigma(\gamma, Sn)$, (b) $\sigma(\gamma, 1n)$, (c) $\sigma(\gamma, 2n)$.

Large uncertainties prevent detailed discussion on the dependence of $F_2^{\rm exp}$ on the contribution of $\sigma(\gamma, 2n1p)$ which in accordance with the results of calculations in the CPNRM increase systematically from $B_{2n1p} = 25.1$ MeV (table 1) up to value ~ 4 mb at 35.0 MeV.

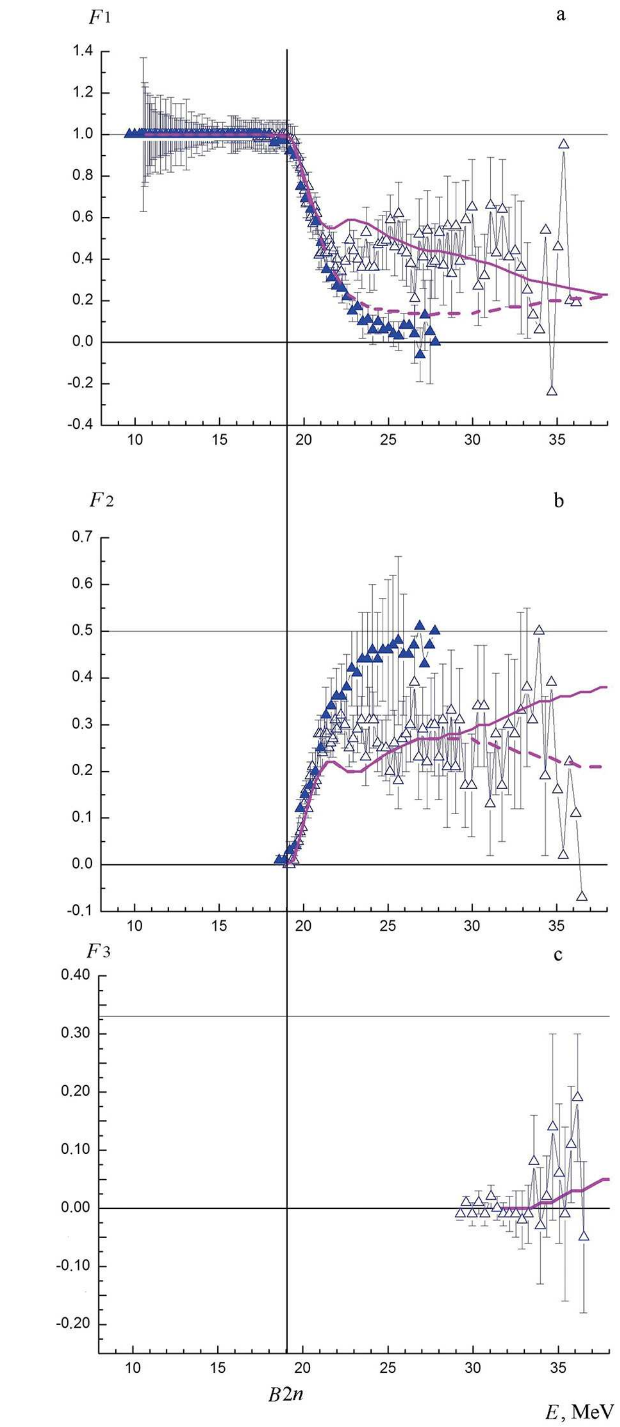

Fig. 2. The comparison of the experimental ([21]: filled triangles, [22]: open triangles) and the theoretical ([12,13]: lines (solid: with $(\gamma, 1n1p)$ and $(\gamma, 2n1p)$ contributions, dotted: without those)) ratios F_1 (a) and F_2 (b) and F_3 ((c), solid line: reaction $(\gamma, 3n)$ for ^{59}Co).

On the basis of comparison of the results presented in figs. 1 and 2 one can conclude that for ^{59}Co the procedures of the neutron multiplicity sorting used in [21,22] did not give reliable data. Therefore evaluation of the partial reaction cross section using the experimental-theoretical method described above and discussed in refs. [7,10,11, 14–19] is of interest.

3 The new evaluated partial and total photoneutron reaction cross sections for ^{59}Co

As was mentioned above the developed method for evaluation of the reliable partial photoneutron reaction cross sections in eq. (2) requires the following conditions to be satisfied:

– the competitions of evaluated partial reaction cross sections $\sigma^{\text{eval}}(\gamma, in)$ are described by the ratios of the cross sections calculated theoretically in the CPNRM;
– the corresponding sum $\sigma^{\text{eval}}(\gamma, Sn)$ is close to $\sigma^{\text{exp}}(\gamma, Sn)$.

Since $\sigma^{\text{exp}}(\gamma, Sn)$ [21] was measured only up to the energy $\sim$ 27.78 MeV the cross section $\sigma^{\text{exp}}(\gamma, Sn)$ [22] was used as an initial reference for the evaluation procedure. For a better agreement between $\sigma^{\text{exp}}(\gamma, Sn)$ [22] and $\sigma^{\text{th}}(\gamma, Sn)$ [12,13] for energies up to $E^{\text{int}} = 21$ MeV the latter was slightly corrected (shifted to higher energies by 0.15 (17.27–17.12) MeV and multiplied by 0.90 (458.98/512.49)). The initial data (dashed line) and the corrected $\sigma^{\text{th}}(\gamma, Sn)$ data (solid line) are presented in fig. 1(a). The corresponding energies at the center of gravity $E^{\text{c.g.}}$ and integrated cross section σ^{int} data are presented in table 2.

The ratios F_i^{th} in eq. (2) were obtained using the corrected $\sigma^{\text{th-corr}}(\gamma, Sn)$ and corresponding $\sigma^{\text{th-corr}}(\gamma, in)$. Evaluated cross sections $\sigma^{\text{eval}}(\gamma, 1n)$, $\sigma^{\text{eval}}(\gamma, 2n)$, $\sigma^{\text{eval}}(\gamma, 3n)$, and $\sigma^{\text{eval}}(\gamma, \text{tot})$ for ^{59}Co are presented in fig. 3. The corresponding integrated cross section data are presented in table 3. In accordance with the data from fig. 2 evaluated cross sections disagree noticeably with the data of [22] and disagree significantly with the data of [21]. In accordance with F_1 energy dependence, $\sigma^{\text{exp}}(\gamma, 1n)$ of [22] is systematically lower than $\sigma^{\text{eval}}(\gamma, 1n)$ in the energy range $\sim$ 19–28 MeV and the integrated cross sections (correspondingly, $(568.20 - 337.70 = 230.50)$ and $(597.46 - 337.96 = 259.50)$ MeV mb) differ by 13%.

At the same time in this energy range $\sigma(\gamma, 2n)$ [22] is systematically larger than $\sigma^{\text{eval}}(\gamma, 2n)$ and the integrated cross sections (correspondingly, 100.72 and 78.59 MeV mb) differ by 28%. As was pointed out for F_2 increase (fig. 2) the reason could be an erroneous addition of some neutrons from the reaction $(\gamma, 1n1p)$.

This is directly confirmed by the differences

$$\Delta\sigma_1(\gamma, 1n) = \sigma^{\text{eval}}(\gamma, 1n) - \sigma^{\text{exp}}(\gamma, 1n), \quad (4)$$

$$-\Delta\sigma_2(\gamma, 2n) = \sigma^{\text{exp}}(\gamma, 2n) - \sigma^{\text{eval}}(\gamma, 2n) \quad (5)$$

between the experimental and the evaluated cross sections for $(\gamma, 1n)$ and $(\gamma, 2n)$ reactions correspondingly, presented in fig. 4 in comparison with the calculated [12,13] $\sigma^{\text{th}}(\gamma, 1n1p)$.

Table 2. The energies at the center of gravity $E^{\text{c.g.}}$ (MeV) and the integrated cross sections σ^{int} (MeV mb) obtained for the experimental [22] and the evaluated data for ^{59}Co.

	$E^{\text{c.g.}}$	σ^{int}	$E^{\text{c.g.}}$	σ^{int}
Energy range	$E^{\text{int}} = 21.00\,\text{MeV}$		$E^{\text{int}} = 27.78\,\text{MeV}$	
Experiment [21]	17.33 ± 0.43	440.87 ± 2.55	19.86 ± 0.88	722.78 ± 6.49
Experiment [22]	17.27 ± 0.34	458.98 ± 2.07	19.97 ± 0.67	761.28 ± 5.22
Theory, initial	17.12 ± 1.09	512.49 ± 7.78	19.53 ± 0.81	800.48 ± 8.44
Theory, corrected	17.27 ± 1.10	459.08 ± 6.96	19.68 ± 0.81	717.02 ± 7.55

Table 3. The integrated cross sections σ^{int} (MeV mb) of the evaluated cross sections of various reactions on ^{59}Co in comparison with the experimental data [21,22].

Reaction	Evaluation	Experiment	
		[22]	[21]
$E^{\text{int}} = B_{2n} = 19.00\,\text{MeV}$			
$(\gamma, Sn)^{(a)}$	338.42 ± 1.57	338.42 ± 1.57	327.76 ± 1.88
(γ, tot)	337.96 ± 4.96	338.06 ± 1.56	326.95 ± 1.86
$(\gamma, 1n)$	337.96 ± 4.77	337.70 ± 1.56	325.80 ± 1.83
$E^{\text{int}} = 27.78\,\text{MeV}$			
$(\gamma, Sn)^{(a)}$	761.28 ± 5.22	761.28 ± 5.22	723.11 ± 6.49
(γ, tot)	676.05 ± 7.43	668.92 ± 5.07	587.71 ± 5.44
$(\gamma, 1n)$	597.46 ± 7.15	568.20 ± 4.80	452.31 ± 4.12
$(\gamma, 2n)$	78.59 ± 2.04	100.72 ± 1.64	135.17 ± 3.54
$E^{\text{int}} = 36.50\,\text{MeV}$			
$(\gamma, Sn)^{(a)}$	967.16 ± 10.18	967.16 ± 10.18	
(γ, tot)	804.09 ± 9.02	807.86 ± 9.38	
$(\gamma, 1n)$	655.22 ± 8.03	653.00 ± 8.68	
$(\gamma, 2n)$	138.09 ± 4.10	150.42 ± 3.38	
$(\gamma, 3n)$	0.77 ± 0.13	4.46 ± 1.05	

(a) The experimental cross section [22] which is the initial data for evaluation procedure (2).

One can see that the calculated cross section of the $(\gamma, 1n1p)$ reaction is very close to the difference (4) between evaluated and experimental cross sections of the $(\gamma, 1n)$ reaction and at the same time is relatively close to the difference (5) between experimental and evaluated cross sections of the $(\gamma, 2n)$ reaction. It means that many neutrons assigned to the $(\gamma, 2n)$ reaction are from the $(\gamma, 1n1p)$ reaction.

So it could be concluded that the main reason of noticeable disagreements between the experimental [21,22] and the evaluated data is unreliable sorting of many neutrons between the reactions with multiplicities 1 and 2.

There is very interesting disagreement between the experimental [22] and the evaluated data at energies lower and higher than $E \sim 30\,\text{MeV}$ (near B_{3n}). It looks as additional confirmation for unreliable sorting of neutrons between reactions with multiplicities 2 and 3. Unfortunately there is not enough experimental information for convincing discussion of the reliability of $(\gamma, 3n)$ reaction cross section.

So the results obtained could directly confirm the conclusion of ref. [7] that the main reason of disagreements under discussion is a very complex and indirect relationship between neutron energy and multiplicity.

In fig. 5 the neutron energy spectra calculated in the CPNRM [12,13] for various ^{59}Co excitation energies are presented. One can see that when the excitation energy increases the part of high energy neutrons also increases. But all spectra peaked at energies between $\sim 1\,\text{MeV}$ and $\sim 2\,\text{MeV}$. It suggests complicated correlation between neutron kinetic energy and its multiplicity.

In fig. 3 one can see that the evaluated cross sections noticeably deviate from the experimental ones. It means that many physical effects based on those partial reaction cross section data should be re-analyzed and/or reestimated. The most important effects include, first of all, the competition between direct and statistical processes in the excitation and decay of highly excited nuclear Giant Dipole Resonance (GDR) states, secondly the relationship between the components of the GDR configuration and isospin splitting, and thirdly the exhaustion of the dipole sum rule.

4 Summary and conclusions

The results of two experiments [21,22] for the determination of the partial photoneutron reaction cross sections for ^{59}Co carried out at Livermore using different modifications of the method of photoneutron multiplicity sorting were discussed in detail. New objective physical criteria for the ratios $F_i = \sigma(\gamma, in)/\sigma(\gamma, Sn)$ based on the experimental neutron yield cross section $\sigma^{\text{exp}}(\gamma, Sn)$, which is rather independent from the neutron multiplicity sorting problem and F_i^{th} of the theoretical CPNRM, were used to analyze systematic uncertainties present in the experimental cross sections.

It was convincingly shown before [7,10,11,14–19] that definite systematic uncertainties of neutron multiplicity sorting method were the reason for noticeable disagreements between the partial photoneutron reactions cross sections obtained in various laboratories. The data evaluated by this method using $\sigma^{\text{exp}}(\gamma, Sn)$ and F_i^{th} agree with the experimental results obtained by using the activation method [7,20,26].

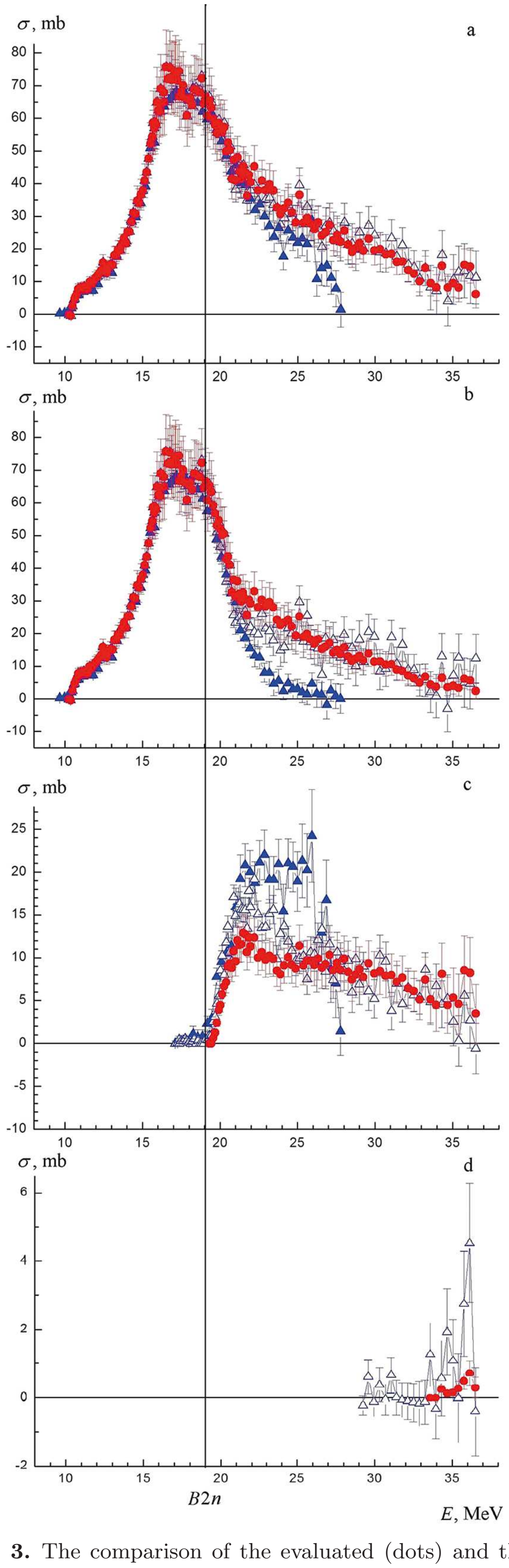

Fig. 3. The comparison of the evaluated (dots) and the experimental ([21]: filled triangles and [22]: open triangles) photoneutron reaction cross sections for ^{59}Co: (a) $\sigma(\gamma, \mathrm{tot})$, (b) $\sigma(\gamma, 1n)$, (c) $\sigma(\gamma, 2n)$, (d) $\sigma(\gamma, 3n)$.

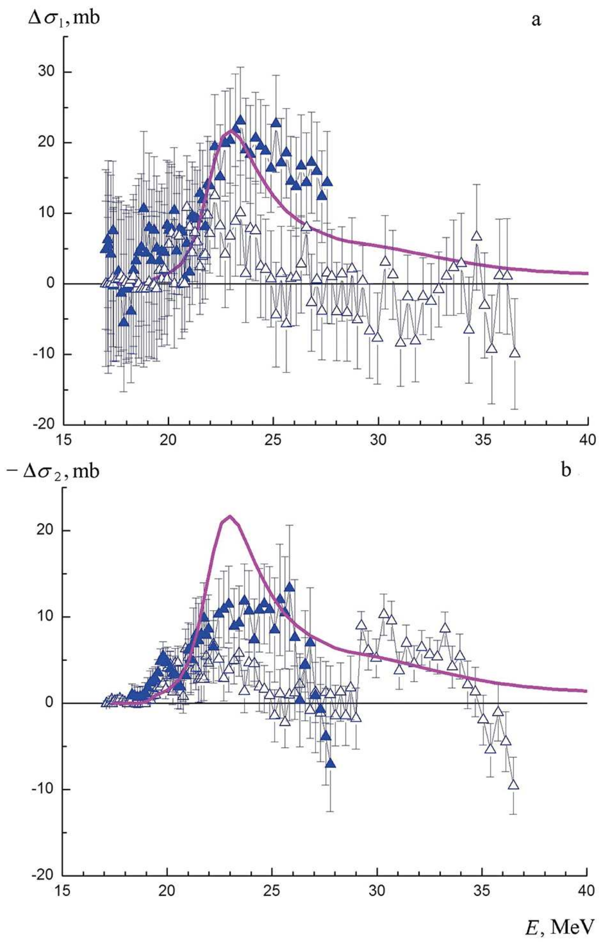

Fig. 4. The comparison of the differences $\Delta\sigma$ ((4), (5)) between the experimental ([21]: filled triangles and [22]: open triangles) and the evaluated data for $(\gamma, 2n)$ reaction with data calculated in model ([12,13]: line) for reaction $(\gamma, 1n1p)$.

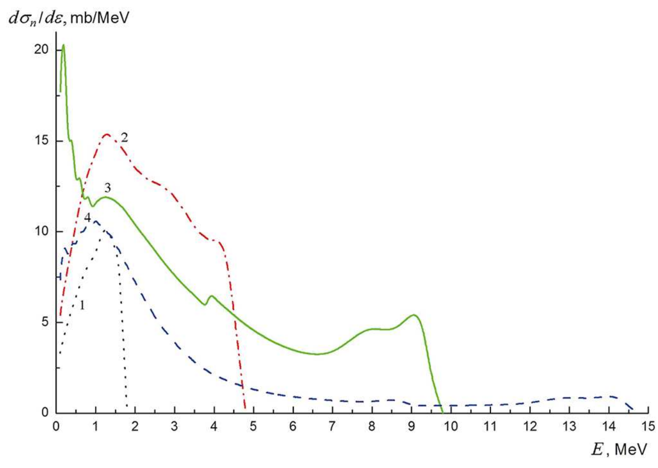

Fig. 5. The comparison of the photoneutron energy spectra calculated [12,13] for different ^{59}Co excitation energies $E^{\mathrm{exc}} = 12\,\mathrm{MeV}$ (line 1), $15\,\mathrm{MeV}$ (line 2), $20\,\mathrm{MeV}$ (line 3), $25\,\mathrm{MeV}$ (line 4).

It was shown that for ^{59}Co the significant disagreements between two experimental data under discussion [21,22] were the results of erroneous sorting of neutrons between various partial reactions, typically the $(\sigma, 2n)$ and $(\sigma, 1n1p)$ reactions. Typically it was the erroneous identification of large amount of neutrons from the $(\gamma, 1n1p)$ reaction as those from the $(\gamma, 2n)$ reaction.

The experimental-theoretical method for evaluating the partial reaction cross sections [7,10,11,14–19] was used for determination of new cross sections for the $(\gamma, 1n)$ and $(\gamma, 2n)$ reactions (which in reality are the summed reactions $(\gamma, 1n) + (\gamma, 1n1p)$ and $(\gamma, 2n) + (\gamma, 2n1p)$, correspondingly) on ^{59}Co satisfied the objective physical criteria of data reliability. Correspondingly new reliable data were evaluated for total photoneutron reaction cross section (3).

Newly evaluated cross sections noticeably disagree with data of both experiments [21,22] and therefore a discussion of underlying physics is needed.

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