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Summary Report

3rd Research Coordination Meeting

Updating Photonuclear Data Library and Generating a Reference Database for Photon Strength Functions

IAEA Headquarters
Vienna, Austria

17 to 21 December 2018

Prepared by

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iThemba LABS
Cape Town, South Africa

Dan Filipescu
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and

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March 2019

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ABSTRACT

A summary is given of the 3rd Research Coordination Meeting (RCM) of the IAEA Co-ordinated Research Project (CRP) on Updating the Photonuclear Data Library and Generating a Reference Database for Photon Strength Functions. Participants presented their progress reports, reviewed the list of actions assigned at the previous meeting, agreed on the remaining task assignments necessary to achieve the goals of the CRP and agreed on the content and type of publication for the final CRP report. A summary of the presentations and discussions is presented in this report.

March 2019

Contents

1. Introduction

The CRP on Updating the Photonuclear Data Library and Generating a Reference Database for Photon Strength Functions (2016-2020) has two main objectives:

- Updating the IAEA Photonuclear Data Library released in 1999 [1.1]
- Generate a dedicated database for Photon Strength Functions

The CRP proposal and programme were based on the recommendations of the Consultants' Meeting held at the IAEA from 11 to 13 November 2013 [1.2].

Specific Objectives

The two objectives will be achieved by a series of activities listed below:

- Measurements,
- compilation of existing data,
- assessment / recommendation of data,
- evaluation of data (on the basis of models),
- dissemination (data library/database).

Progress of the activities and individual tasks assigned to the participants of the CRP are to be discussed and reviewed at three Research Coordination Meetings to ensure the goals of the CRP are achieved in a timely manner.

The 1st Research Coordination Meeting (RCM) of the CRP was held at the IAEA Headquarters, Vienna, from 4 to 8 April 2016. Sixteen CRP participants and advisers from 13 countries attended the meeting to review the CRP program and agree on additional actions required for the timely achievement of the objectives. The summary report of the meeting is available in Ref. [1.3].

The 2nd RCM was held at the IAEA Headquarters, Vienna, from 16 to 20 October 2017. The meeting was attended by 21 participants, including 3 advisors and 2 IAEA staff. Reports were given on the progress in all the individual and joint assignments, further actions were adopted and the preliminary outlines of the two final CRP technical reports on Updating the Photonuclear Data Library and Reference Database for Photon Strength Functions, respectively, were agreed. The summary report of the meeting is available in Ref. [1.4]

The 3rd RCM was held at the IAEA Headquarters, from 17 to 21 December 2018. The meeting was attended by 22 participants, including 3 advisors and the IAEA Scientific Secretary. The meeting began with the welcome address by the Head of the Nuclear Data Section, A. Koning. P. Oblozinsky (Slovakia) was elected chairman of the meeting, and D. Filipescu (Romania) and M. Wiedeking (South Africa) were elected rapporteurs. The preliminary agenda was adopted and the meeting continued with presentations from participants followed by extensive technical discussions on the programme of work and future action needs. Summaries of the presentations are given in Section 2, while the technical discussions are described in Section 3. A complete list of actions is given in Appendix 2. The Meeting Agenda and Participants list are available in Annexes 1 and 2, respectively. Links to the presentations are found in Annex 3.

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2. Summary of participants' presentations

2.1. Summary of The PHOENIX Collaboration, H. Utsunomiya

The goal of the PHOENIX Collaboration was to acquire new photonuclear data for the IAEA-CRP F41032 at the NewSUBARU synchrotron radiation facility in Japan. The collaboration was carried out with the University of Oslo (UiO), ELI-NP (later changed to IFIN-HH), Moscow State University (MSU), Shanghai Institute of Applied Nuclear Physics (SINAP), and Univérsity Libre de Bruxelle (ULB). The new data acquired are classified into two groups, (γ,xn) cross section data for 11 nuclei with 100% natural abundances at γ-ray energies from 1n threshold up to 40 MeV and (γ,n) cross section data for 21 enriched isotopes at energies below 2n thresholds. The (γ,xn) data were acquired mainly in collaboration with ELI-NP (IFIN-HH), MSU, and SINAP, while the (γ,n) data with UiO.

There are two experimental factors that have led to a success of the data acquisition; the laser Compton-scattering (LCS) γ-ray beam produced at the NewSUBARU facility and a new methodology of direct neutron-multiplicity sorting with a flat-efficiency neutron detector [1]. The LCS beam is quasi-monochromatic, energy-tunable, and, more importantly, energy- and flux-calibrated [2,3]. The new methodology which is free from the limitation of the ring-ratio technique originally developed at the Lawrence Livermore National Laboratory was used to measure (γ,xn) cross sections.

We have successfully acquired all the data as originally time-scheduled as follows. The institute which is responsible for the data reduction of (γ,xn) cross sections is shown in the parenthesis. The data reduction of (γ,n) cross sections is undertaken by UiO.

I. (γ,xn) data on 11 nuclei
   2015: 9Be(Konan), 208Bi(ELI-NP)
   2016: 89Y(MSU), 169Tm(ELI-NP), 197Au(Konan)
   2017: 59Co(MSU), 165Ho(ELI-NP), 181Ta(Konan)
   2018: 103Rh(MSU), 139La(Konan), 159Tb(ELI-NP)

II. (γ.n) data on 21 nuclei

2015: 89Y, 203Tl, 205Tl

2016: 13C, 58Ni, 60Ni, 61Ni, 64Ni, 137Ba, 138Ba, 185Re, 192Os

2017: 64Zn, 66Zn, 68Zn, 182W, 183W, 184W

2018: 156Gd, 157Gd, 158Gd, 160Gd

The data newly acquired in the PHOENIX Collaboration are evaluated by the JENDL, CNDC, and KAERI and compiled in the updated photonuclear data library published in 2020. The data are also used to supplement the (γ,γ') and the Oslo method data to construct the photon strength function and compiled in the reference database for photon strength functions published in 2020.

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2.2. Photoneutron reactions using direct neutron multiplicity sorting method, D. Filipescu

During 2015 – 2018, the IFIN-HH team participated as part of the Phoenix Collaboration (Konan University, IFIN-HH, Moscow State University, University of Oslo) in (g,xn) reaction cross-section measurements performed at the NewSUBARU facility at energies starting from the neutron threshold up to ~40 MeV.

The IFIN-HH team is responsible of developing a data analysis procedure to be used for obtaining absolute (g,xn), where x = 1, 2, 3, …, reaction cross sections. The procedure was validated on data obtained from full Geant4 simulations of the experiment. For this, the neutron source was generated using results of Monte Carlo statistical model calculations provided by Toshihiko Kawano.

The procedure was applied by the IFIN-HH team on ^{197}Au, ^{169}Tm, ^{89}Y (measured in 2016), ^{181}Ta, ^{165}Ho, ^{59}Co (measured in 2017), ^{139}La, ^{159}Tb and ^{103}Rh (measured in 2018). Details of the experimental and data analysis procedure were presented with focus on non-linearity correction of NaI photon spectra, multiple firing corrections and energy unfolding. Evaluations have been performed for the photon induced reactions on all nine nuclei using the EMPIRE statistical model code.

Evaluations of the experimental NewSUBARU data sets were performed. The experimental (γ, tot) and (γ, Sn) cross sections were deduced from the (γ, xn) partial cross sections, but, when comparing with the EMPIRE calculations, the fact that charged particles are not detected in the experiment was considered. Specifically, the experimental (γ, tot) cross section does not include contributions from (γ, p), (γ, α), etc. Consequently, when EMPIRE calculations were performed, charged-particle emission only cross sections were extracted from a preliminary EMPIRE calculation, and artificially added to the experimental (γ, tot) cross section. This so obtained (γ, tot) cross section was then fitted using SLO and SMLO functions. A second EMPIRE calculation was performed using the SLO/SMLO parameters resulting from the separate fit. In a few cases, this procedure was applied 2-3 times. The contribution of charged-particle emission only channels was found to be most significant for the two lightest nuclei from the set, ^{59}Co and ^{89}Y. The parameterization which fitted best the experimental cross sections was chosen, either the SLO or the SMLO one. The final fit parameters for the energy, width and magnitude of the Lorentzian functions were used as input for the EMPIRE evaluations.

Additionally, the average energy of the total neutron emission spectra for each irradiation point on each of the nine measured nuclei was presented. The values were obtained using the ring ratio method, which relies on the energy dependence of neutron detection efficiency of the individual neutron counter rings of the detection setup.

Results of the evaluation of photon-induced reaction cross-sections for ^{197}Au, ^{169}Tm, ^{89}Y, ^{181}Ta, ^{165}Ho, ^{59}Co, ^{139}La, ^{159}Tb and ^{103}Rh were presented.

2.3. Evaluation of partial and total photoneutron reactions cross sections using new objective physical data reliability criteria, V. Varlamov

Assigned work

In accordance with Scientific Scope of the Project the detailed working plan for the third year is the following:

1) The energy dependencies of multiplicity transitional functions Fi^{exp} and Fi^{theo}, the evaluated cross sections for partial reactions, and correspondent integrated cross sections will be obtained for energies by experimentall–theoretical method for ^{75}As, ^{78,82}Se, ^{140,142}Ce, ^{145,148}Nd, ^{160}Gd.
2) For selected nuclei (^{116}Sn, ^{139}La, ^{197}Au,) neutron emission spectra will be calculated in the frame of the CMPNR.
3) For all investigated nuclei ted evaluated cross sections will be compared with the results of modern photonuclear measurements carried out using various methods.
4) For nuclei investigated on the whole evaluated data will be prepared as ENDF files.
5) Recommendations for updating the IAEA Photonuclear Data Library will be formulated.

Additionally to the list of nuclei mentioned above ^{165}Ho was moved firstly from the CRP 1st year program of work to the 2nd and later to the 3rd one and ^{103}Rh was moved from the 2nd to the 3rd year program of work.

The results obtained

In accordance with Scientific Scopes of the Contract 20501 all 3 year working plans the experimental data for partial photoneutron reaction cross sections were analyzed using objective physical data reliability criteria [1–3] – neutron multiplicity transitional functions Fi^{exp} – for all nuclei included into the lists of 3 working plans – ^{63,65}Cu ([4], EXFOR – M0920) ^{75}As [5], ^{78,82}Se ([6], M0973), ^{80}Se ([4], M0920), ^{89}Y ([7,8], M0931), ^{103}Rh [9], ^{133}Cs ([3], M0922), ^{139}La ([10], M0970) ^{140,142}Ce ([11], M0972), ^{138}Ba ([3], M0922), ^{141}Pr ([12], M0938), ^{145,148}Nd ([13], M0971), ^{160}Gd[14], ^{165}Ho ([9], M0974), ^{186}W ([12], M0938), ^{197}Au ([1], M0798), ^{209}Bi ([3], M0922).

Additionally to the Contract program the analogous analysis of partial photoneutron reaction cross-section data reliability was carried out and new evaluated reliable data were obtained for ^{59}Co [15], ^{76}Se [6], ^{90,92}Zr [16], ^{98}Mo [17], ^{116}Sn [18], ^{153}Eu [19]. Those nuclei were chosen because many doubts in experimental data reliability, predominantly because the presence of many nefative values in the (γ, 1n) reaction cross sections.

The new evaluated cross sections for partial reactions (γ, 1n), (γ, 2n) and (γ, 3n) and also for total photoneutron reaction (γ, tot) = (γ, 1n) + (γ, 2n) + (γ, 3n) for all nuclei mentioned were obtained using experimentally–theoretical method [1–3] for all niclei mentioned [4–24]. Almoust all of obtained data were published and included into the international database EXFOR. Data for ^{75}As, ^{76,78,80,82}Se, ^{103}Rh, and ^{160}Gd were submitted to various journals.

For ^{209}Bi newly evaluated data additionally to the prevously evaluated once were obtained using new data for reaction σ(γ, Sn) measured in the NewSUBARU facility (Japan) using quasi-monochromatic laser Compton–scattering (LCS) *γ*–ray beams and the novel technique of direct neutron-multiplicity sorting with a flat–efficiency detector [20].

In accordance with Scientific Scope of the Contract 3 year working plans neutron emission spectra were calculated in the frame of the CMPNR for selected nuclei ^{116}Sn [21], ^{141}Pr [22], ^{181}Ta [23], ^{186}W [22], ^{197}Au [24], ^{208}Pb [23], ^{209}Bi [23].

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2.4. Update of the Photonuclear Cross Sections, Young-Sik Cho

(1) Photonuclear cross sections for ^{24,25}Mg, ^{40}Ca, ^{64}Zn, ^{80}Se and ^{93}Nb were evaluated, and the photonuclear data files have been created for 40 nuclides including ^{14}C, ^{75}As , ^{91,94}Zr, ^{115}In and ^{197}Au in ENDF-6 format.

(2) The photonuclear cross sections for ^{14}C have been updated (Fig. 1). Experimental data were collected from the EXFOR database. The TALYS code was used along with the automatic model parameter tuning system. The optical model parameters, the level density-related parameters, the GDR parameters and pre-equilibrium model parameters were adjusted mostly up to 30% of their default values to fit the calculated cross sections to the experimental data using the automatic tuning tool. The exciton model for the pre-equilibrium reaction, the Brink-Axel Lorentzian for the gamma-ray strength function, and the constant temperature+Fermi gas model for the level densities were used.

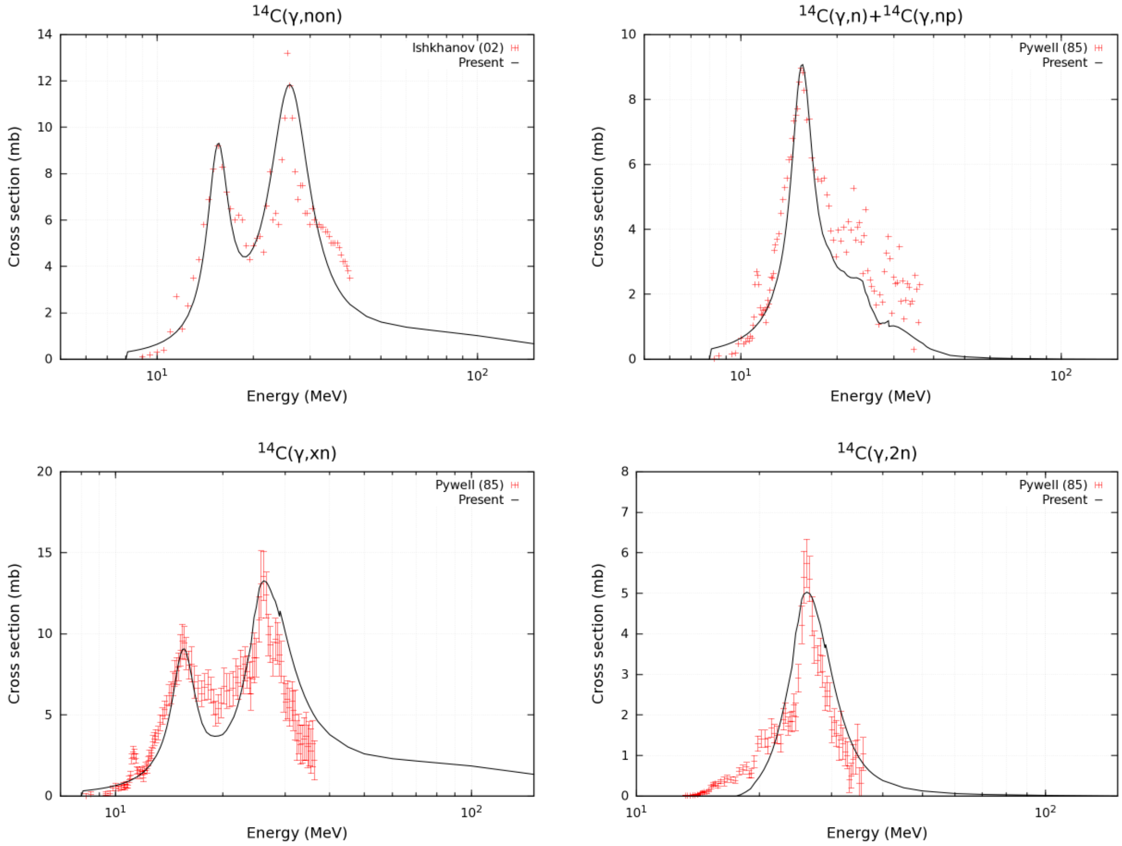

FIG. 1. Calculated cross sections compared with the experimental data for γ+^{14}C reaction.

2.5. Evaluation of photonuclear data library by taking into account new experimental data and evaluation methodologies, N. Iwamoto

It was announced that JENDL/PD-2016 was released and available from Nuclear Data Center of JAEA [1]. The contribution to new IAEA photonuclear data library was summarized. The comparison figures between evaluated data of JENDL/PD-2016 and previous IAEA library were made for 164 isotopes and some of natural elements, together with experimental data. The new evaluations of 28 isotopes for Cl, Ar, Ti, V, Cr, Mn, Fe, Co, Ni, Cu were performed by the CCONE code so as to be replaced from JENDL/PD-2016. The 13 isotopes requested from IAEA were prepared in JENDL/PD-2016 (^{3}He, ^{6,7}Li, ^{10,11}B, ^{19}F, ^{160}Gd, and ^{237}Np) or newly evaluated by CCONE (^{45}Sc, ^{103}Rh, ^{139}La, ^{178}Hf, and ^{187}Re). The other 23 nuclides (Gd, Hf, Re and Hg isotopes, ^{50}V, ^{99}Tc, ^{180m}Ta, and ^{204}Pb) were additionally prepared. Those data were not included in the scope of the present CRP, but were evaluated for JENDL/PD-2016. For light nuclides the nuclear data of 33 isotopes from ^{2}H to ^{48}Ca can be taken from JENDL/PD-2016.

New nuclear data evaluations for ^{89}Y, ^{139}La and ^{159}Tb were carried out, on the basis of the photoneutron cross sections measured at NewSUBARU facility. The evaluated results were shown and compared with Varlamov's and other experimental data. For the data of ^{89}Y measured by Saclay and Livermore groups, Berman et al. [2] supported smaller cross sections of the Livermore group, which leads to large contradiction with the data of NewSUBARU facility above 21 MeV. In the present evaluations with the modified Lorentzian model (MLO1) for ^{139}La and ^{159}Tb as well as ^{89}Y, large Levinger parameters were needed to reproduce the data of NewSUBARU facility above 25 MeV.

The average energies of neutrons produced by the photon-induced reactions on ^{209}Bi were measured by Gheorghe et al. [3] as well as the (γ,1nx), (γ,2nx), (γ,3nx) and (γ,4nx) reaction cross sections. The nuclear data evaluation was performed by using their photoneutron cross sections. The average neutron energies derived from the present evaluation were compared with those of Gheorghe et al. The photon energy dependence below 8 MeV is almost the same as that of Gheorghe et al., in which the TALYS calculation showed that the average neutron energies were almost zero. The better reproducibility in the present evaluation may be attributed to the use of discrete levels for ^{208}Bi. This interpretation was explained by showing neutron emission spectra for different photon energies. The decay contribution to discrete levels of ^{208}Bi from ^{209}Bi was significant below photon energies of 10 MeV, above which the contribution of continuum level become increased. The (γ,2n) reaction contribution was found above 15 MeV. This is responsible for the rapid decrease of average emitted neutron energy between 14 and 15 MeV.

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2.6. Progress of photonuclear cross-sections evaluation from CNDC, R.R. Xu

Two reports by R. Xu and Y. Tian were presented during the 3rd RCM to introduce the modified evaluations of photonuclear data after 2018.06 and the PSF study at CNDC. All the responses to the questions and comments raised by experts during the last CM are presented.

1. Some points related to the photonuclear data (PD) calculations at CNDC are described:
    - In MEND-G calculation, our initio model parameters input for compound nuclei reaction are from empirical systematic formula, and Gilbert-Cameron-Cook-Ignatyuk, Su Zongdi modification;
    - There are not crucial rules in our parameter adjustments and set the range for the parameters. In our cases, our adjustments are less than 50% at maximum, and 20~30% variation from the initio input are normally;
    - The most sensitive parameters for the PD calculations are the level densities for the 1st, 2nd, 3rd neutron emission reaction, and pair energy correction are the secondary important to the calculation;

- The negative values of pair energy correction (△) appear in our evaluation, which indicate the particle pair will be formed in the excited nuclei and release energy.

2. The evaluation of the 12 nuclei assigned to CNDC follows the scheme in Fig.2. Based on the PD evaluations in June 2018, V-51 and Sn isotopes were re-evaluated and good agreements were obtained. Apart from that, all the other data were systematically compared with the results from the other groups, and the input and output files were submitted to IAEA at the same time.

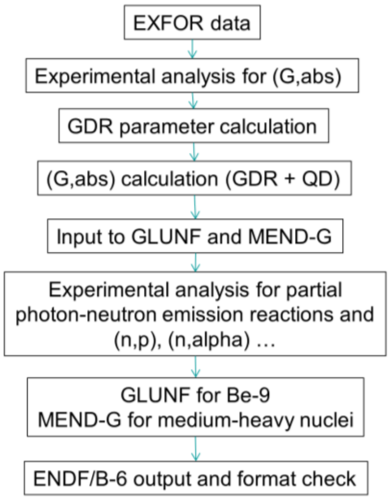

Fig. 2. Scheme of photonuclear data evaluation at CNDC.

3. The GDR parameters derived from (γ,absorption), (γ,1n) reactions of ^{23}Na - ^{235}U were systematically adjusted (see Tian's report).

2.7.Report on GDR parameters from CNDC, Tian Xao

Photonuclear data to extract Photon Strength Functions (PSF) and photonuclear cross sections are necessary for energy, safety, and medical applications as well as for nuclear physics and astrophysics.

We have constructed two kinds of systematic GDR parameters to describe the photoabsorption cross sections of medium-weight to heavy nuclei. The microscopic GDR parameters are based on the relativistic quasiparticle random phase approximation (RQRPA) calculation which is obtained with the NL3 interaction and separable pairing interaction. In order to reproduce experimental photoabsorption data, we add two parameters, one is the energy-dependence width parameter Γ in formula $\Gamma(\epsilon_\gamma) = \Gamma\sqrt{\epsilon/E_{E_1}}$, and another one is the strength parameter G. By adjusting the values of these two parameters to $G = 0.65$ and $\Gamma = 1.59$, we could reproduce the experimental photoabsorption cross-section as well as the MLO1 model which is recommended by RIPL-3. Our microscopic GDR parameters were used to calculate cross sections for spherical nuclei, which for the heavy nuclei were found to be lower than the experimental data.

A phenomenological GDR parameter set is suggested by using the simplify modified Lorentzian (SMLO) model with 16 parameters. We compare the calculated peak energy and the measured GDR energy for a broad range of nuclei (20≤A≤209). The GDR energies based on the SMLO calculations are in close agreement with the experimental data not just for spherical nuclei, but also for the deformed nuclei from medium to heavy masses. In the following table, we present the the GDR parameters obtained from this fit.

The quantities shown in the table are:

N: neutron number of the nucleus
A: mass number of the nucleus
E_r^1 and E_r^2 are the center energies of the first and second peaks
σ_r^1 and σ_r^2 are the cross sections of the first and second peaks
Γ_r^1 and Γ_r^2 are the widths of the first and second peaks
β_2 is the deformation parameter of the nucleus

When the deformation parameter $\beta_2 = 0$, namely there is no deformation, the first peak and second peak should coincide in the same single peak. But in our calculation, in order to use a uniform formula of GDR, we have assumed two peaks even for the spherical nucleus, by just separating the contributions from the one peak into two parts.

Table 1: Parameters of SMLO calculations.

model		A	E_r^1	σ_r^1	Γ_r^1	E_r^2	σ_r^2	Γ_r^2	χ^2	β_2
SMLO	0	1 12	1 5.75	2 31.23	4 .93	1 6	3 0.6	1 2.98	2. 0595	0 .018
SMLO	0	1 14	1 5.93	1 72.03	6 .75	1 5.93	7 2.4	4 .04	4. 5176	0
SMLO	0	1 16	1 5.67	6 4.94	4 .7	1 5.67	2 05.03	4 .7	7. 0882	0
SMLO	0	1 17	1 6.28	7 5.11	9 .23	1 5.67	1 81.32	4 .26	2. 5107	- 0.044
SMLO	0	1 18	1 5.62	4 5.94	2 .21	1 5.62	2 18.34	5 .6	6. 0457	0
SMLO	0	1 19	1 5.76	9 4.12	3 .81	1 5.76	1 58.6	6 .9	3. 4919	0
SMLO	0	1 20	1 5.5	2 02.5	6 .01	1 5.5	7 9.57	3 .15	3. 185	0
SMLO	0	1 22	1 5.44	4 8.95	2 .11	1 5.44	2 11.58	5 .98	5. 8085	0
SMLO	0	1 24	1 5.28	6 .01	2 0.89	1 5.28	2 69.53	4 .75	2. 473	0
SMLO	3	5 1	1 7.94	2 2.01	3 .39	1 9.54	5 2	8 .64	3. 5282	0 .1
SMLO	3	2 09	1 3.57	4 73.27	3 .6	1 3.47	5 6.73	1 2.94	0. 2004	- 0.008
SMLO	0	9 0	1 6.75	1 04.52	3 .69	1 7.26	1 16.58	4 .64	0. 4928	0 .035
SMLO	0	9 1	1 5.94	8 .02	1 0.55	1 6.68	1 76.7	4 .19	0. 1911	0 .053
SMLO	0	9 2	1 5.72	1 8.6	1 .07	1 6.45	1 55.52	5 .35	1. 6609	0 .053
SMLO	0	9 4	1 5.66	1 1.36	2 2.99	1 6.52	1 60.18	5 .2	0. 8812	0 .063
SMLO	0	9 6	1 4.78	7 0.81	5 .48	1 7.77	1 23.6	6 .02	11 .3488	0 .219
SMLO	4	1 80	1 3.18	3 21.59	5 .92	1 6.17	2 15.88	4 .32	0. 9097	0 .243
SMLO	4	1 82	1 3.02	3 32.59	3 .58	1 5.94	2 26.76	4 .13	15 .8411	0 .24
SMLO	4	1 83	1 2.98	3 28.6	3 .73	1 5.77	2 34.63	3 .95	0. 0081	0 .231
SMLO	4	1 84	1 2.95	3 23.3	4 .04	1 5.61	2 42.91	3 .77	5. 5927	0 .221
SMLO	4	1 86	1 2.83	3 24.15	3 .22	1 5.32	2 57.48	3 .51	4. 8312	0 .21

2.8. Review of photonuclear evaluations, T. Kawano

Kawano coordinated a review of photo-nuclear data files evaluated by CIAE, ELI-NP, JAEA, and KAERI, together with the evaluated experimental data by Varlamov. The review was performed by nuclear data library specialists of IAEA, JAEA, KAERI, and LANL, prior to this RCM, and Kawano assembled their review reports. Although the review reports were seriously considered as specialists' recommendations, further investigation was made by including all the evaluators as well as the NewSUBARU experimental data to achieve a consensus on which evaluated data files should be included in the IAEA photo-nuclear data library. This final process is still on the way, since some adjustments might be made for some evaluated data. The first version of the starter file will be prepared once all institutes finalized their evaluation process.

2.9. Summary of two presentations on compilation and assessment of experimental PSF data, M. Wiedeking

1) Compilation of Data

An overview of collected data sets was presented. A total of 130 data sets were collected from NRF, Oslo Method, (p,p') and Ratio/Chi^2 Methods are available. The compiled data so far contain, in some cases, re-measurements and re-analysis. Approximately 10 data sets are still outstanding. A discussing is necessary to identify which of the data sets need to be included in the final database, in particular the cases which have gone through a re-analysis.

2) Comparison and Assessment of Oslo and NRF data

For several nuclides, PSFs below the neutron-separation energy have been studied in NRF experiments at the bremsstrahlung facility ELBE as well as in light-ion induced reactions at the Oslo cyclotron lab (OCL). For these nuclides, the PSF data extracted from the different reactions were studied and an assessment was given.

Each data set was considered as an equally trustful set therefore none of the sets were given a larger weight than others. This was also applied in cases where more than one data set exists for either the NRF or for the Oslo method.

Therefore, the assessed PSF was created as an unweighted average of the values of all available data sets rather than a weighted average. On a case-to-case basis, we removed the outermost data points in the considered energy range were removed, for either NRF or Oslo data, if those points seemed to be unreliable, for example because of low statistics, or were regarded as approaching the limitations of the methods.

PSF data for 74Ge, 89Y, 139La, and 181Ta were considered in the assessment. A good agreement between NRF and OCL data was found for 74Ge and 181Ta. In the case of 139La, the PSFs from NRF and OCL experiments differ considerably in both shape and magnitude. Even though the origins of these discrepancies are not fully understood, an average PSF was still produced. The five lowest-energy points of the NRF data were not included in the averaging. Because of the large differences between the PSFs in the case of 139La, it was agreed that another independent experiment was necessary and plans are already underway.

While the Oslo Method includes both E1/M1 isoscalar and isovector components, the NRF method probes the isovector component exclusively. In view of this, an experiment at the K600 magnetic spectrometer at iThemba LABS using the (p,p´) and (α,α') reactions at zero degrees to the beam is planned, with the aim of investigating the isoscalar and isovector components of the E1 excitations in detail. These additional data are expected to help to disentangle the different components of the total dipole strength function.

In the case of 89Y, there are also differences in the shape and magnitude of the PSFs. An average PSF was produced for this case too.

To conclude: the adopted approach was to take a simple average of the strength functions when one has equal confidence in the different experimental results (and not the weighted average, because error bars do not necessarily reflect the confidence in the data). Data points lying at the limits of the validity of the methods or suffering from low statistics were removed. One of the major problems encountered is what errors to assign as simple error propagation will not reflect how well the different data sets agree.

2.10. Assessment of Experimental -Ray Strength Functions R. Schwengner

In nuclear-resonance-fluorescence (NRF) experiments, photoabsorption cross sections are deduced from intensity distributions that include resolved peaks as well as a quasicontinuum, determined as the intensity in a spectrum after subtraction of the background due to atomic processes in the target.

For the determination of the photoabsorption cross section the intensities of inelastic transitions have to be subtracted from the total intensity distribution. Furthermore, the remaining ground-state transitions have to be corrected for their branching ratios. The relative intensities of elastic and inelastic transitions can be estimated in simulations of statistical γ-ray cascades. Input quantities for these simulations are initial strength functions and level densities. The initial strength functions for E1, M1, and E2 radiation are Lorentz-shaped using parameters taken from the RIPL data base [1].

Absorption cross sections are determined in a number of iterations, in which the E1 input strength function is taken from the output of the preceding step. Level density parameters are taken from the compilation in Ref. [2]. The given uncertainties are taken into account in the simulations for the constant-temperature as well as the back-shifted Fermi gas model. The extreme limits of the resulting strength functions can be determined by combining strength functions obtained using the limits of the uncertainties given in Ref. [2]. This has been done for the cases of 89Y [3], 96Mo [4], and 139La [5] in the present uncertainty analysis. Error bars include statistical uncertainties and uncertainties of detector efficiencies, of photon flux as well as a 1σ deviation from the mean values in the individual simulations. In the present analysis, all combinations of upper and lower limits of the level-density parameters were applied. To determine the extreme lower and upper limits of the strength functions, the values with the greatest deviations from the means were combined. The results are shown in Figs. 1 – 3 and are compared with the data obtained in experiments at the Oslo cyclotron lab [6].

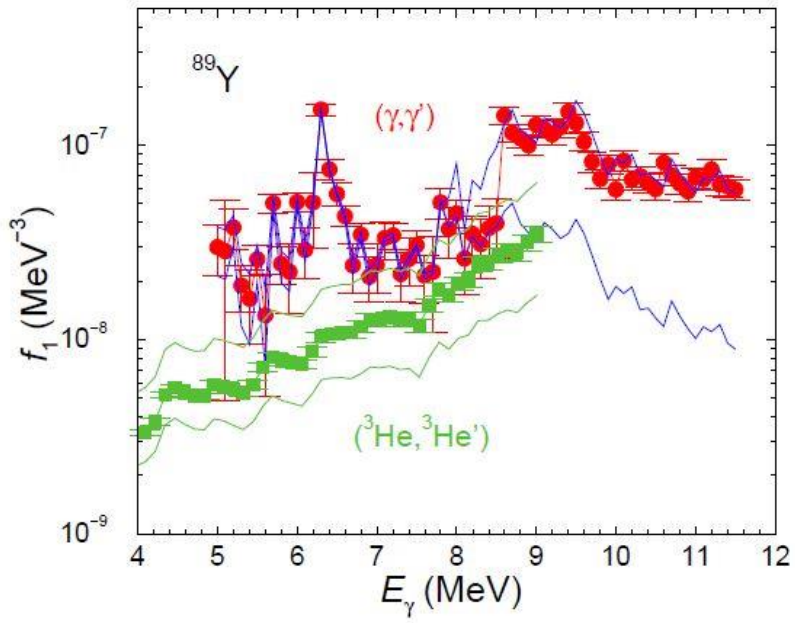

FIG. 1. *Strength functions deduced from (γ,γ') data of ^{89}Y (red circles). Maximum uncertainties obtained from applying extreme limits of level densities in the simulations of γ-ray cascades are shown as blue lines. Oslo data are shown for comparison (green boxes), also with extreme uncertainty limits (green lines).*

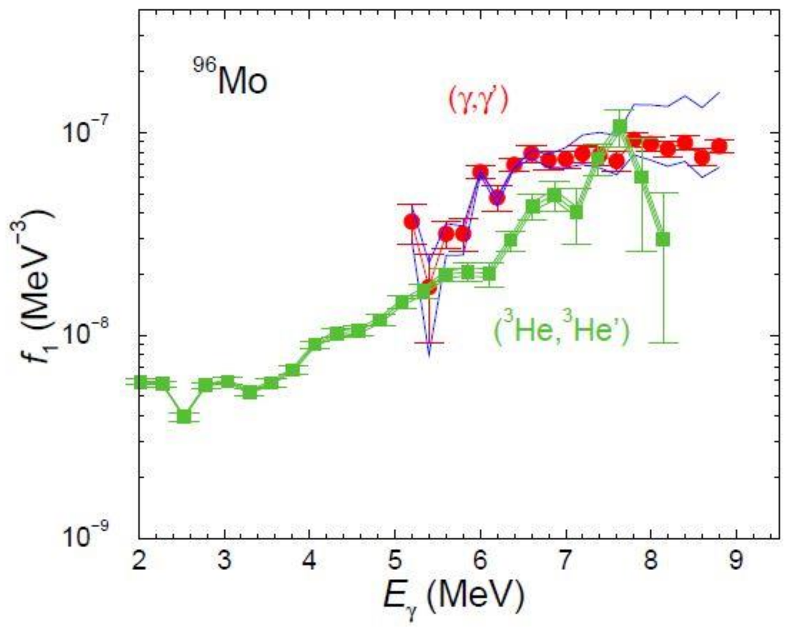

FIG. 2. *As Fig. 1 but for ^{96}Mo.*

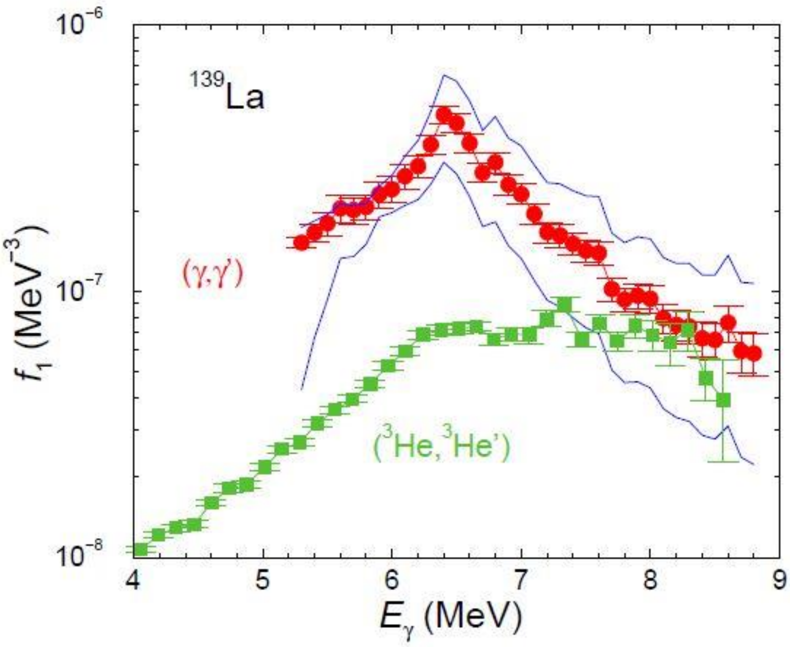

FIG. 3. *As Fig. 1 but for ^{139}La.*

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2.11. Revision and Update of Experimental Gamma-ray Strength Functions Derived from the Discrete Neutron Resonance Capture, J. Kopecky

Since the 1960s, neutron capture measurements in discrete resonances – *Discrete Resonance Capture (DRC)* – have been used primarily as a spectroscopy tool to study initial and final states or the product nuclide. In some cases, the behaviour of the gamma strength of different multipole radiation was also investigated giving insight into gamma ray de-excitation at energies below the reaction threshold and how it connects to the photonuclear tail of the Giant Dipole Resonance (GDR). DRC data are also used in the absolute normalization of Average Resonance Capture (ARC) measurements.

Laboratories involved in *DRC* type of measurements were ORNL, LNL and BNL in the US, Chalk River in Canada and at UKAEA Harwell, JINR Dubna and IRM Geel in Europe. The most recent measurements have been carried out in Dubna and Geel during the second half of the nineteen eighties. The pioneering group with the largest data production was the Neutron Physics Group at BNL which published the first comprehensive collection of DRC data [1]. The main output of this work was a data set of binned model dependent k(E1, M1) or S(E1) strength function values, averaged not only over measured resonances, but also over a number of gamma transitions in order to increase the averaging power, often limited due to the small number of resonances. The first survey was published by C. McCullagh et al. in 1981 [2]. This database was later taken over by ECN in the frame of the BNL/ECN collaboration.

Several updates of this ECN/BNL database have been performed since [1,2] with the most recent revision being published recently [3]. In this latest work, the earlier DRC measurements were newly processed into the average strength function format, both as partial (for isolated gamma transitions - for the first time), and binned format (transitions in a gamma energy window) for 57 nuclides from ^{20}F up to ^{240} Pu. Several DRC nuclides include enough resonances and may be used to form a new extended and comprehensive database of PSF using combined data from both DRC and ARC measurements. This work is already in progress and a comprehensive publication will be produced as a result.

More details about the new ATLAS f(L) DRC database can be found in [3].

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2.12. Deconvolution of the Photon Strength Function, R. B. Firestone

There are significant differences between the photon strength function described in this Coordinated Research Project (CRP) and traditional g-ray strength analysis by the nuclear structure community. The standard definition of g-ray strength was derived by Blatt and Weisskopf [1] as

$$B(EL)\downarrow = \frac{\Gamma_\gamma(EL)\cdot L[(2L+1)!!]^2}{8\pi(L+1)e^2b^L}\left(\frac{\hbar c}{E_\gamma}\right)^{2L+1} = \frac{C(EL)\Gamma_\gamma(EL)}{E_\gamma^{2L+1}} = C(EL)\cdot f_\gamma(EL)$$

$$B(ML)\downarrow = \frac{\Gamma_\gamma(ML)\cdot L[(2L+1)!!]^2}{8\pi(L+1)\mu_N{}^2b^{L-1}}\left(\frac{\hbar c}{E_\gamma}\right)^{2L+1} = \frac{C(ML)\Gamma_\gamma(ML)}{E_\gamma^{2L+1}} = C(ML)\cdot f_\gamma(ML)$$

where

$$B(E1)\downarrow = \Gamma_\gamma(E1)\frac{9.56\times10^3}{E_\gamma^3}\ \mathrm{MeV}^{-2}$$

$$B(E2)\downarrow = \Gamma_\gamma(E2)\frac{1.24\times10^8}{E_\gamma^5}\ \mathrm{MeV}^{-4}$$

$$B(M1)\downarrow = \Gamma_\gamma(M1)\frac{8.64\times10^7}{E_\gamma^3}\ \mathrm{MeV}^{-2}$$

This differs from the definition of photon strength [2]

$$F_{E1}^{(\gamma,n)}(E_\gamma)\uparrow = \frac{\sigma_\gamma(\mathrm{E_x})}{3\pi^2\hbar^2\mathrm{c}^2\mathrm{E}_\gamma} = \frac{\Gamma_{\mathrm{E1}}^{(\gamma,\mathrm{n})}}{\mathrm{D}\cdot\mathrm{E}_\gamma^3} = \frac{\rho(E_x,J^\pi)\cdot\Gamma_{E1}^{(\gamma,n)}}{E_\gamma^3} = \frac{\rho(E_x,J^\pi)\cdot B(E1)\uparrow}{C(E1)}$$

which is the product of level density and g-ray strength. Photon strength was defined to describe photonuclear data which is uniquely determined by a Standard Lorentzian (SLO) fit to the giant dipole resonance (GDR) for E1 transitions [3,4].

In recent years there has been an attempt to compare reaction photon strength data measured at the Oslo cyclotron and elsewhere with photonuclear data. These attempts are problematic because the level densities populated in reactions are much higher than in photonuclear data, M1 and E2 transition strengths become more significant despite having no expected SLO dependence, and the photon strength must be corrected for transition direction by the equation

$$B(\sigma L)\uparrow = \frac{(2J_f+1)}{(2J_i+1)} B(\sigma L)\downarrow$$

despite the fact the reaction spin distribution is seldom known. The product of level density and g-ray strength is not a fundamental quantity that can be investigated systematically. Instead it is better to deconvolute the photon strength function by removing the better-known level density component and concentrating on the fundamental g-ray strength component.

I have shown that the level density component for photonuclear data can be calculated using HFB level densities [5]. Removing this from the photonuclear photon strength leads to a nearly continuous g-ray strength function which decreases rapidly with increasing energy. Evidence of the GDR is nearly imperceptible in the photonuclear g-ray strength function. In the case of Oslo reaction data, the level density is experimentally determined and the g-ray strength can be extracted by dividing the photon strength by the level density. In the case of the ^{92,94,95,96,97,98}Mo isotopes, although an absolute normalization is not possible, there clearly are both low and high energy upbends in the g-ray strength with respect to a simple E_γ^3 dependence while for ^{57}Fe no such upbend is observed.

A database of g-ray strengths from thermal, resonance, and average resonance (ARC) neutron capture has be prepared based on the Evaluated Gamma-ray Activation File (EGAF) [6] and the ENSDF [7] database. The thermal and resonance data are binned to give average g-ray strengths and corrected for unobserved transitions assuming a Porter-Thomas distribution [8]. These data provide direct measurements of the E1, M1, and E2 g-ray strength independent of level density. For comparison with photon strength measurements these data have been multiplied by the level density at the neutron separation energy, S_n. This normalization is only valid for comparisons near S_n. An example was shown for ^{57}Fe indicating that the total (n,g) photon strength is in good agreement with Oslo (^{3}He,^{3}He') data down to $E_\gamma \approx 4\ MeV$, and that that E1 photon strength is in good agreement with the SLO model down to $E_\gamma \approx 1\ MeV$.

The global systematics E1, M1, and E2 g-ray strengths were investigated for even-N, even-Z; odd-N, odd-Z; and even-N, odd-Z nuclei. Despite a large scatter in the values due to nuclear structure effects, a robust, previously unreported A^{-3} dependence in g-ray strength was observed for all cases. The origin of this mass dependence is unknown.

The final neutron capture g-ray database will be provided to the IAEA Nuclear Data Section after additional checking and the addition of error bars to the g-ray strengths. An additional ≈210 capture g-ray data sets will be provided to the photon strength database for this IAEA CRP.

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2.13. Updating Photonuclear Data Library and Phenomenological Photon Strength Functions, V. A. Plujko

In the report, the results are presented on several items: 1) the preparation of the database for electric dipole photon strength functions of photoexcitation (PSF) from the total photo-neutron/ photo-absorption cross-sections, 2) extension of analytical expressions for PSF with energy-dependent widths [1-2] to high gamma-ray energies (above ~ 30 MeV), 3) redetermination of the temperature dependence of width for simplified version of the modified Lorentzian (SMLO) approach, and 4) the quantitative comparison between different Lorentzian–type PSF models of photoexcitation for even-even nuclei.

Experimental data for photoabsorption cross-section above neutron separation energies (S_n) from EXFOR database [3] do not include contribution of the cross-section from gamma-gamma channels. This contribution is very large at gamma-ray energies below $S_n + \Delta\varepsilon$, where $\Delta\varepsilon$ is a small positive energy below the threshold of the photo-reaction with emission of two neutrons or, in some cases, other reactions with large cross-sections; typically $\Delta\varepsilon$ < 1.5 MeV. The absence of this contribution leads to incorrectly small values of the photon strength functions extracted from photodata in above mentioned gamma-ray energy range.

The specific intervals $\Delta\varepsilon$ for every nucleus were calculated using simulations of the photo cross-sections by the nuclear reaction code TALYS 1.6 [4,5]. These intervals were found from the condition of ten percent contribution of the cross-section from gamma-gamma transitions to total photoabsorption cross-section. Data files for electric dipole PSF were prepared with systematic uncertainty less than 10%. The PSF values in the gamma-energy range from S_n to $S_n + \Delta\varepsilon$ were kept in readme-files.

A new version of the energy- and temperature- dependent width, $\Gamma_j(\varepsilon_\gamma, T)$, for SMLO approach was tested. Namely, the following expression was used for the width of the PSF shape $\Gamma_j(\varepsilon_\gamma, T) = \Gamma_{r,j}(\varepsilon_\gamma + 4\pi^2 T^2 / E_{r,j}) / E_{r,j}$, where index j enumerates normal modes of the giant dipole resonance (GDR) excitation with resonance energy $E_{r,j}$ and width $\Gamma_{r,j}$. The linear dependence on the energy comes from the inverse -dependence of the average squared matrix element in the transitions of the 1 particle - 1 hole states to 2 particles - 2 holes states. The quadratic temperature dependence originates from the expression for width within the Fermi liquid theory. Theoretical E1 PSF within SMLO&SLO models were calculated for 8980 nuclei for photon energies from interval 0.1-30 MeV with $\Delta\varepsilon_\gamma = 0.1$ MeV at the nuclear temperatures *T*= 0.0-2 MeV with the temperature differences $\Delta T = 0.2$ MeV. In these calculations recommended experimental values of the GDR parameters were used from new Atlas of the GDR parameters [2] and their systematics.

Intensive studies of the photoabsorption in middle-weight to heavy nuclei also demonstrated that the photoabsorption cross-sections at the low-energy tail of the GDR can be better described with allowance for increasing dependence of the width $\Gamma(\varepsilon_\gamma)$ on gamma-ray energy (see [1,2] for references therein). However, if the width increases with energy steadily, the energy-weighted sum rule for E1 transitions (EWSR) is violated due to overestimation of the values of corresponding PSF at the gamma-ray energies >~ 30 MeV. The new model (SMLOc) with constant width $\Gamma_j(\varepsilon_\gamma, T) = \Gamma_j(E_{r,j}, T)$ after the GDR energy $E_{r,j}$ is considered with correct behaviour of the EWSR.

Quantitative comparison between Lorentzian –type PSF models of photoexcitation and experimental data was performed for the 88 even-even isotopes. The following analytical expressions for PSF were used [1,2,6,7]: Standard Lorentzian (SLO), Enhanced generalized Lorentzian model (EGLO), SMLO, SMLOc and Triple Lorentzian model (TLO). On average, the SMLO and SMLOc were determined as the most suited model for E1 transitions at gamma-ray energies till 30 MeV within criterion of minimal value of f rms deviation factor, and a least-square value.

This work is partially supported by the IAEA through the CRP on Updating the Photonuclear Data Library and generating a Reference Database for Photon Strength Functions (#F41032).

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2.14. Microscopic description of the photon strength function: S. Goriely

As detailed in the first and second RCM in 2016 and 2017, the HFB+QRPA method based on the Gogny D1M interaction have been applied to calculate the E1 and M1 photoabsorption strength functions for a large set of nuclei [1]. To reproduce experimental data, some phenomenological corrections were included to take the effects beyond the standard 1p-1h QRPA excitations, the coupling between the single-particle and low-lying collective phonon degrees of freedom, as well as the damping of the collective motions into account. These effects have been included systematically, as simple energy or mass dependent expressions of the energy shift and width of the Lorentzian function used to fold the QRPA strength [1]. As far as the photoexcitation strength function is concerned, the QRPA strength is complemented by a low-energy component inspired from the shell model for both the E1 and M1 strength. More specifically, the D1M+QRPA+0lim strength function is expressed as

$$f_{E1}(\varepsilon_\gamma) = f_{QRPA}(\varepsilon_\gamma) + f_0\, U / [1+\exp(\varepsilon_\gamma - \varepsilon_0)] \qquad (1)$$

$$f_{M1}(\varepsilon_\gamma) = f_{QRPA}(\varepsilon_\gamma) + C \exp(-\eta\, \varepsilon_\gamma) \qquad (2)$$

where f_{QRPA} is the D1M+QRPA strength at a photon energy ε_γ, U (in MeV) is the excitation energy of the initial state and $f_0=10^{-10}$ MeV^{-4}, ε_0=3MeV, C, η=0.8MeV^{-1} are free parameters adjusted on the shell model results and Oslo data. In addition, a careful recent analysis of multi-step cascade (MSC) and multiplicity distribution (MD) spectra obtained from radiative neutron captures helped us to adjust the parameter C [2]. Such a study showed that the D1M+QRPA+0lim model could globally reproduce satisfactorily the MSC and MD spectra provided C=10^{-8} MeV^{-3} for A>105 and C=3 10^{-8} exp(-4β_2) MeV^{-3} for A≤105, where β_2 is the quadrupole deformation parameter (cf Krticka's report). The deformation dependence is also inspired from shell model results.

In the meantime, as agreed upon at the 2d RCM, a phenomenological model of M1 strength has been developed [3]. On the basis of experimental and theoretical information on the M1 strength function, inspired both from axially deformed QRPA and SM calculations, simple Lorentzian-type expressions were derived to determine systematically the dipole strength in order to update former RIPL-3 prescriptions with a special emphasis on new expressions for the M1 spin-flip and scissors mode. Supplemented by the E1 SMLO model developed by V. Plujko, the new M1 model was tested on experimental data collected by the present CRP. The resulting model is referred to as SMLO.

The D1M+QRPA+0lim and SMLO models for both the E1 and M1 strength has been extensively tested on data related to the dipole strength function and that will be made available in the present CRP. These include

- photoneutron and photoabsorption data for about 120 nuclei sensitive to the dominant E1 PSF in the GDR region;
- photoneutron data above the neutron threshold for about 46 nuclei sensitive to the dominant E1 PSF;
- ARC and DRC data in the 5-8 MeV region for about 50 nuclei separately for the E1 and M1 modes;
- integrated $M1$ strength from photon scattering experiments for about 47 nuclei in the 2-4 MeV region;
- Oslo data for the total dipole strength below S_n for about 60 nuclei; the data are sensitive to the adopted NLD model;

- NRF data for the total dipole strength below S_n for about 21 nuclei; the data are sensitive to the adopted NLD model;
- MSC and MD spectra for the total dipole strength below S_n for about 21 nuclei and about 4 resonances per nucleus; the data are sensitive to the adopted NLD model (cf Krticka's report);
- thermal neutron capture spectra for the total dipole strength below S_n for 5 nuclei; the data are sensitive to the adopted NLD model (cf Belgya's report);
- Average radiative width $\langle\Gamma_\gamma\rangle$ for the total dipole strength below S_n for about 230 nuclei; the data are sensitive to the adopted NLD model;
- Maxwellian-averaged radiative capture cross sections at 30 keV for the total dipole strength below S_n for about 240 nuclei; the data are sensitive to the adopted NLD model.

Experimental, SMLO and D1M+QRPA+0lim strengths have been compared and the corresponding comparisons will be included in the final CRP publication. Some of them can already be found in Refs. [1-3].

Finally, SMLO and D1M+QRPA+0lim PSF predictions have been compared for the E1, M1 and E1+M1 strengths for 6200 nuclei with 8≤Z≤110 lying between the proton and neutron driplines. The PSF are found to be impressively similar even close to the driplines. Both model predictions have also been used to estimate the 30 keV MACS. Globally, deviations smaller than a factor of 2 are obtained. These comparisons will be included in the final CRP report on the Photon Strength Function.

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[2] M. Krictka, S. Goriely, S. Hilaire, S. Péru, S. Valenta, Phys. Rev. C (submitted) (2019).

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2.15. DICEBOX simulations to validate input PSFs, M. Krticka

1. The comparison of predictions made by the DICEBOX code with the D1M+QRPA+0lim and SMLO models the coincidence spectra from resonance neutron capture measured with the DANCE detector was shown. Sensitivity to several different parameters, that can hardly be restricted from other experimental data, has been checked for the D1M+QRPA+0lim model. Specifically, sensitivity of simulations to the smearing width of the M1 PSF, that is applied to the PSF from the D1M+QRPA calculations. It was found that the smearing width should be smaller than about 1 MeV. Further, we checked the sensitivity to the low-energy limit of the E1 PSF, to the size of the low-energy M1 PSF and to the level density. The sensitivity to the E1 PSF is relatively small as the proposed limits of the E1 PSF in the model are not very different. Contrary to this, substantial sensitivity has been found to the M1 PSF limit and to the level density model. A systematics of the low-energy limit for M1 PSF has been proposed. All these checks, together with a comparison of the predictions with the Enhanced General Lorentzian model for E1 PSF and the spin-flip model for M1 PSF – the model recommended by RIPL-3, are a part of the paper that we submitted recently to the Physical Review C.
2. The comparison of predictions made by the DICEBOX code with models based on the "Oslo recommended data" with the coincidence spectra from resonance neutron capture

measured with the DANCE detector was shown for 96,98Mo isotopes. It was repeated that there are several problems related to the definition of models that should be used in simulations. Namely, the main problem is the extrapolation of the PSF models to the low energies (below about 1.5 MeV) a division of the PSF to the E1 and M1 part. Different extrapolations and divisions yield rather different predictions. This issue was already discussed on the previous CRP meeting.

3. A brief comparison of predictions for the singles gamma-ray spectrum from thermal neutron capture on 195Pt measured at Budapest with the D1M+QRPA+0lim and SMLO models has been presented. Tests of different low-energy M1 limits and to different level-density models have been shown. The sensitivity was found to be relatively small. A first comparison for 114Cd has been also shown.
4. Finally, the current status of dissemination of the code DICEBOX was reported. This Fortran code, that allows simulation of gamma cascades with all the fluctuations expected within the statistical model (mainly the Porter-Thomas distribution), is now available to public via the IAEA web page. Specifically, there is a source code, which does not require any external libraries, a manual and a few examples available on the web page.

2.16. Thermal capture singles spectra for validating PSFs, T. Belgya

All of the radiative capture gamma-ray measurements shown here were made at the cold neutron beam facilities of the Budapest Research Reactor [1] on enriched samples. In the case of ^{242}Pu(n,γ)^{243}Pu measurement extensive subtraction of backing, instrumental background and the Pu covering Ti spectra were necessary. In the other cases, they were negligible. Following the unfolding (detector response correction) and detector efficiency corrections pure full energy gamma-ray spectra were obtained [2]. Applying the internal calibration, spectra of partial gamma-ray production cross sections were obtained. Using the energy weighted sum rule [3]

$$\sigma_0 = \sum_{E_i}^{B_n} \frac{E_i \sigma_{\gamma,i}}{B_n},$$

the thermal capture cross section σ_0 can be determined for the target nuclei. Here, B_n is the binding energy of the daughter nuclei, E_i is the gamma-ray energy and $\sigma_{\gamma,i}$ is their partial cross section. Multiplicity M was calculated by dividing the sum of the partial cross sections with σ_0. These quantities characteristic for the radiative capture process which are also an important measure for the models that are describing the decay process. In Table 1., experimental capture cross section the and multiplicity values are given.

Table 1 Measured and literature data

Target	σ_0 (b) this work	σ_0 (b) literature	Daughter	Multiplicity this work
^{72}Ge	1.13(6)	0.9(1)	^{73}Ge	3.0(2)
^{73}Ge	18.7(5)	14.7(4)	^{74}Ge	5.1(1)
^{77}Se	36(4)	42(4)	^{78}Se	3.6(2)
^{113}Cd	21660(360)	20615(400)	^{114}Cd	4.1(1)
^{242}Pu	18.2(6)	18.5(5)	^{243}Pu	3.9(4)

For the validation of the recommended microscopic D1M-QRPA global model [4] simulation were performed with the BITS (Bin Type Statistical simulation) program for ^{72}Ge(n,γ)^{73}Ge, ^{73}Ge(n,γ)^{74}Ge, ^{77}Se(n,γ)^{78}Se, ^{113}Cd(n,γ)^{114}Cd and ^{242}Pu(n,γ)^{243}Pu nuclei to describe the low lying decay-scheme intensities and the decay gamma-ray spectra. For this reason, a new interface was written to calculate the NLDs and PSFs that are given in table format. Values from the tables were interpolated at energies when the calculation required. Other than that, the program works the usual way. The input data were obtained from Stephan Goriley [4], [5]. Typical running time is around 2-3 minutes. Results were presented in the talk that was given at the 3rd RCM meeting. In general, it can be stated that the agreement between the simulation based on the D1M-QRPA model and the experimental spectra are rather good taking in to the account that no adjustment was made on the minimal values of the PSFs' parameters [4].

In cases where two possible capture spins can be excited the contribution weights can be obtained from the from the evaluated capture cross section can be obtained from EXFOR database. Adding up them by weighting with these values gives the final result. For example, in case of ^{113}Cd the first strong 1^+resonance has almost 100% contribution to the capture cross section thus we expect that the calculated and experimental running sum of decay probabilities should almost overlap. The matching also means that the model is able to describe the multiplicity within uncertainty. As it can be seen in Fig. 1 that in fact this is the case, while in the case of pure 0^+ contribution the calculated running sum of decay probabilities are considerably below the experimental one. As it is shown in Fig. 2.

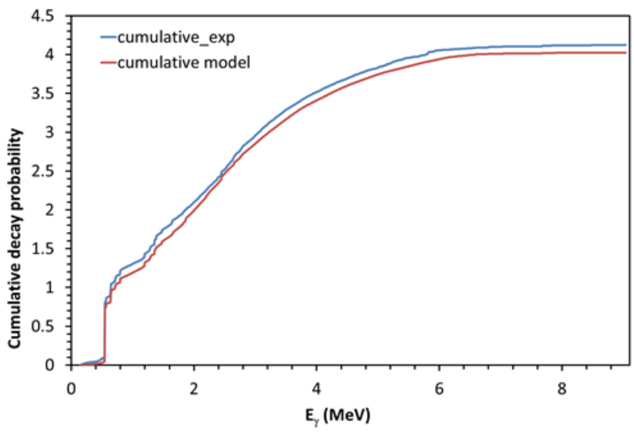

Fig. 1 *The calculated and measured cumulative sum of decay probability for pure 1^+ contribution to the cold neutron radiative capture in ^{114}Cd. The calculated multiplicity is M = 4.02.*

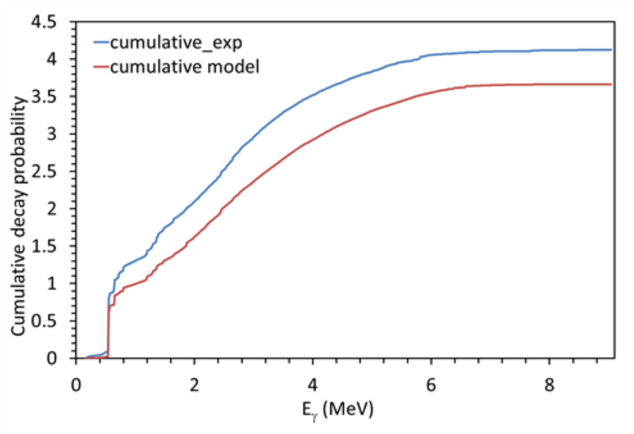

Fig. 2 *The calculated and measured cumulative sum of decay probability for pure 0^+ contribution to the cold neutron radiative capture in ^{114}Cd. The calculated multiplicity is M = 3.66.*

Beside these results the performance of Triple Lorentzian PSFs [6] for E1 were calculated and also shown as drawings with experimental data collected in this CRP for a number of nuclei in the 0-30 MeV energy region. Since the TLO requires nuclear shape parameters of γ and β_2, these were taken from the calculations of Möller et al. [7], [8] and Delaroche [9]. The results are shown at the web site of https://www-nds.iaea.org/CRP-photonuclear/index_3RCM.html.

References

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2.17. Gamma strength function measurements at the Oslo Cyclotron, S. Siem

A progress report on the Oslo group's contribution to the photonuclear database was presented. The data were collected via inverse-Compton scattering experiments at Spring-8 in Japan. The experimental setup and analysis methods have been covered in the presentations by H. Utsunomiya (Sect. 2.1) and D. Filipescu (Sect. 2.2).

For the measurements Oslo has been responsible for, data have already been published for the following nuclei: Ni-60, Ni-61, Ni-64, Ni-58, Dy-162, Dy-163 and data have been analyzed and papers submitted for: Tl-203, Tl-205, Y-89.Results will soon be submitted for publication for the following nuclei: Os-192, Re-185, Ba-138, Ba-137, W-184, W-183, W-182, Zn-68, Zn-66, Zn-64. All these data have now been delivered to the IAEA database. For the last nuclei: Gd-156, Gd-157, Gd-158, Gd-160, the data analysis is expected to be finished in March

2019. For Ni-60, the photonuclear data were compared to the photon strength functions obtained with the Oslo method and the two data sets were found to match very nicely.

The Oslo method is a technique which allows for the simultaneous extraction of the Nuclear Level Density (NLD) and Photon Strength functions (PSF) from particle-gamma coincidence data. This method probes the PSF below the neutron separation energy S_n. A short presentation of the Oslo method was given, the method has been presented in more detail at the earlier CRP meetings. Until recently all the experiments have been performed at the Oslo Cyclotron Laboratory (OCL) using proton, deuteron, 3He or alpha beams on isotopic enriched self-supporting targets. Particle-gamma coincidences were measured with the particle-telescope system SiRi and the NaI(Tl) scintillator array CACTUS. Since the last CRP meeting the CACTUS detector array has been replaced with 30 large volume LaBr3 detector in an array called OSCAR, which has much better energy and time resolution. The efficiency is also increased and combined with new digital electronics we can now collect 10 times as much data per hour. For all the data obtained with the Oslo method that have been submitted to the IAEA database so far, the emitted gamma-rays were measured with the CACTUS array, consisting of 28 collimated 5 inches by 5 inches NaI(Tl) detectors with a 15(1)% efficiency at $E\gamma$ = 1332.5 keV. The energy of the charged particles was measured with the Silicon Ring (SiRi) particle-detector array consisting of 8 ΔE - E silicon detectors (130μm thin front and 1550μm thick back detector) where the ΔE detectors are segmented in 8 giving in total a system of 64 detectors used for particle identification and determination of excitation energy.

The angular resolution is $\Delta\vartheta$ = 2 degrees and the solid angle coverage is ≈ 6%. The SiRi detector system can be placed in forward or backward angles with respect to the beam direction, covering scattering angles from 40 to 54 degrees or 126 to 140 degrees respectively in the laboratory frame. The excitation energy of the final nucleus is obtained from the energy of the emitted charged particles and the kinematics of the reaction and the particle gamma coincidence data are sorted into a matrix with excitation energy E_x versus gamma energy.

Recently, the Oslo method has been extended to allowed for the study of the NLD and PSF in more neutron-rich nuclei, either via the analysis of experimental data following beta-decay, the so-called beta-Oslo method or for experiments using inverse kinematics, both methods also resulting in a coincidence matrix with excitation energy E_x versus gamma energy which is the starting point of the Oslo method analysis.

For each excitation energy bin, the gamma spectra are unfolded utilizing the response functions of the detectors. From the unfolded gamma-ray spectra, the distribution of primary gamma-rays was obtained for each excitation energy bin by means of an iterative subtraction technique, known as the first-generation method. The main assumption of this procedure is that the gamma-decay routes from a given excitation energy are independent on whether it was populated directly in the reaction, or through gamma-decay from above-lying states.

From the primary gamma-ray spectrum the NLD and PSF are extracted with a χ^2-method giving the unique solution of the functional shape of the NLD and PSF. The extraction is limited to the E_γ and the excitation energy region of the primary gamma-ray matrix where the decay is assumed to be statistical.

The NLD and PSF are normalized to other known experimental data to retrieve the correct slope and absolute value, and this is the part of the analysis which introduces the biggest uncertainties.

In the presentation various tests of the validity of the generalized Brink-Axel hypothesis were presented. For example, for the case of $^{64,65}Ni$ (L. Crespo Campo et al. Phys. Rev. C 98, 054303 (2018)). Here we looked at the effect on the extracted PSF of excluding or including direct decay to the ground state. Also, the extracted PFS as a function of initial or as a function of final excitation energy have been compared to show that the Brink-Axel hypothesis seems to be valid in the excitation region used for the Oslo method analysis.

Finally, a discussion on how the uncertainty analysis is done in the Oslo method analysis was presented. A new method decomposing the different contributions to the uncertainty for the case of ^{89}Y case (G.M. Tveten et al submitted to PRC 2019) was presented, with this method one can easier see which component which is dominant. The challenge for assessing and recommending the PSF data in the IAEA database, is that the method that is used to treat the uncertainties, represented by an upper and lower limit, has been evolving with time. It would have been more ideal if the uncertainties for all the datasets had been analyzed in the same way. However, re-visiting and re-analyzing all the old data measured before 2012, would be a very time-consuming job.

A compilation of all the published NLD and PSF data measured at the Oslo Cyclotron can be found on the webpage (https://www.mn.uio.no/fysikk/english/research/about/infrastructure/OCL/nuclear-physics-research/compilation/).

All the Oslo method data have been submitted to the IAEA database.

3. Technical Discussion

The technical discussions were held in two parallel sessions from Wednesday to Thursday, on Updating the Photonuclear Data (PD) Library and the Reference Database for Photon Strength Functions (PSF), respectively. The group responsible for updating the PD library re-visited all the photonuclear cross-section evaluations while the group charged with generating the PSF database discussed the assessment of experimental data, global models and validation, and then proceeded to drafting the final report on PSF. Details of the discussions held in both sessions are summarized in the following sections.

From the 2nd RCM, it was already decided that there would be two separate final papers describing the work of the CRP: one on Updating the Photonuclear Data Library, and the other on Reference Database for Photon Strength Functions. It was agreed that the leading authors and coordinators of the two papers would be S. Goriely and T. Kawano, respectively.

During the joint session on Friday, the publication journals and deadlines for preparation and submission of the papers were discussed in more detail. It was agreed that since the work carried out during the CRP was a joint effort, all of the participants would be co-authors on both papers. Order of authors on each paper: primary author and then the contributors to that paper in alphabetical order. Following that the authors from the other CRP paper are included alphabetically.

It was decided that the PSF final paper would be submitted to the European Physical Journal A while the Updating the Photonuclear Data Library paper would be submitted for publication in Nuclear Data Sheets.

3.1. Updating the Photonuclear Data Library

3.1.1. Review of photonuclear data evaluations

Can evaluators include unpublished data in their evaluations? In that case, the experimental data will be marked as "private communication", and once they have been published and uploaded on EXFOR, the reference will be updated provided the data have not changed significantly. If the data have changed and could lead to a different evaluation, then preferable, the evaluation will be revised to take into account the new data.

Deuteron: it was confirmed that the exsiting JAEA evaluation has taken into account the new data of Hara et al, Phys. Rev. D 68 (2003) 072001.

Light elements: Li, Be, C. In the previous IAEA PD library these evaluations were produced by CNDC. In this CRP, CNDC has only provided Be-9, however, as the Chinese data centre is working on other light elements as well, they will also provide those evaluation for the PD library: Li-6,7, B-10,11, C-12, N-14, O16.

The updated IAEA PD library is extended up to energies of 200 MeV. An important question that needs to be addressed is how will the previous 1999 IAEA PD library evaluations which were up to 150 MeV be extended to 200 MeV if the recommendation is to keep them in the library.

The evaluations of Re-187 and Hf isotopes, which were requested for medical applications (photoproduction of medical radionuclides) and are new in the library, were performed by JAEA and were adopted.

A complete list of the evaluations and recommendations of the review committee is given in Appendix 1.

3.1.2. Photonuclear Data Library Report

A final review of the updated evaluations will be conducted and the selection of evaluations to be included in the PD will be finalized at a second review meeting to be organized by the IAEA (Dimitriou).

To be able to process the data files and prepare the data library, and also to make the final review, all pending evaluations should be sent to the IAEA (cc to T. Kawano) by the 31st January 2019.

Action on PD evaluators: to submit their evaluated data in ENDF-6 format to the IAEA by 31st January.

A preliminary draft of the final report will be prepared for the IAEA review meeting for further discussions. After that, an abstract and tentative report will be submitted to Nuclear Data Sheets editor, to initiate the publication procedure.

Estimated deadline for submitting draft paper: 30 April 2019
Deadline for submitting paper: 31st May 2019.

3.2. Reference Database for PSFs

3.2.1. Assessment of experimental PSFs

Recommendation of experimental data is straightforward when only one data set exists. In cases where PSF data have been extracted from multiple different techniques, such as the Oslo method or NRF, then the data have to be assessed by taking into account the random and systematic uncertainties including the model dependencies. The methods that use normalizations to the total density or radiative strength provided by models need to be carefully assessed by considering all the uncertainties arising from these models and how they contribute to the total uncertainty budget. In the absence of an uncertainty analysis, it is difficult to make a recommendation due to lack of sufficient information. An exception to this is when a given data set is an outlier in which case it can be discarded. The proposal to produce unweighted averages of the PSFs extracted by the various methods was discussed in detail. Such an approach would only be valid if these methods were independent. However, due to the fact that either method uses models of level densities or normalization to D_0 average resonance spacings or the total radiative widths, they are not independent but correlated through these models and normalizations. A possible solution in cases where a full uncertainty analysis is not available or possible, is to rely on the global models for the recommended PSF. This should be made clear in the final CRP report,

3.2.2. Compilation of experimental data

The following items were discussed:

1) Data that have not been published yet should not be included in the database or in the final CRP report.

2) Extracted PSF data points at energies near the neutron threshold or the Quasi-Deuteron threshold where they may not correspond to the true values of the strength function should be discarded from the data files. The information that such data have been measured could be provided in the readme file. The NRF data files have already been revised to respect these cut-offs.

3) A series of (p,γ) measurements aimed at studying the PSF was performed in the 1970-80s. Several of these published papers include PSF data in graphical form. About 600 such articles were retrieved and checked (T. Belgya, M. Krticka, M. Wiedeking) to see whether the data are suitable to be included in the data base. Out of these, 39 contain suitable data in graphs. These graphical data will be digitized and prepared in preliminary PSF data files for further checking.
Action on IAEA (Dimitriou): to digitize the graphs and provide preliminary data files for checking. Readme files should be prepared by T. Belgya, M. Krticka, M. Wiedeking.

4) ARC/DRC data: A combined ARC and DRC PSF database will be produced. In general ARC data will be recommended and, when not available, DRC data. In any case, the final recommended value will be included in the data file. If in doubt, this will be reflected in the readme file.
Action on J. Kopecky: to provide combined ARC and DRC data file by mid-January.

5) Final data format: Data may depend on different theoretical (model dependent) uncertainties. Having separate files for upper, recommended, lower data may be inconvenient for the user because downloading three files instead of only one can complicate things. All this information will be included in one file with the same info as previously. When the uncertainties are asymmetric, the following format will be used

E, dE, f1, dF1+, df1-

Action on IAEA (Dimitriou): to merge files in the new and correct format.

6) Final data files to be included:
Action on M. Wiedeking: to provide La and Ta data and readme files by mid-January. Action on S. Siem: to provide data and readme files on Dy, Ni, Ge, Ge beta Oslo by mid-January.

7) Thermal neutron capture (n,g): data for about 200 nuclei will be provided in the same format as the other data described in (5).
Action on R. Firestone: to provide data and assessment of individual transitions by mid-January with emphasis on thermal neutron capture.

3.2.3. Atlas of GDR parameters

The new (γ,n) data from the PHOENIX collaboration should be sent to V. Plujko for inclusion in the GDR tables. The table of GDR parameters has been published in Atomic Data and Nuclear Data Tables (2018), but that table does not include all the recent data. The table will be updated for this CRP and sent to everyone (by March when the data will be finalized).
Also, the recommendations in the GDR Atlas should be consistent with the recommendations of the evaluators of the photonuclear cross-section data. The results of the photonuclear data evaluation should be shared with V. Plujko and conversely, the new Atlas should be sent to the evaluators.

Action on IAEA (Dimitriou): to send (g,n) and (g,xn) measurements from PHOENIX collaboration to V. Plujko to update the Atlas of GDR parameters.

Action on IAEA (Dimitriou): to provide photonuclear data evaluations to V. Plujko for consideration in production of GDR parameters Atlas.

Action on V. Plujko: to provide updated table by March 2019.

3.2.4. PSF final publication

Contributors to the PSF final paper discussed the contents of the PSF final report and agreed to work on the sections in order to produce a complete version by the end of the meeting.

The coordinator of the preparation of the report, S.Goriely, gave an overview of the status and reminded the co-authors of their responsibilities.

The format of reference citations was clarified: last name of author and two digits for the year. If there is more than one paper of the same author in a given year then add a,b,c, etc

The sections on Recommendation of PSF data and uncertainty analysis of PSF data could be merged into one section. Data sets that have not been published should not be included in the figures. In cases where a full uncertainty analysis is not available, the conclusion could be that there is not sufficient information to make a recommendation. Alternatively, if experimental data are not available or only partial data covering a limited energy range are available, the recommendation could be to use global models.

For thermal neutron capture, R. Firestone suggested he could prepare another comparison with Oslo and NRF data, in addition to ^{57}Fe, but with uncertainties included.

In cases where data exist from all methods, a figure should be included, e.g. for ^{74}Ge.

The section on compilation of PSF data should comprise a concise description or account of which data are available, for which nuclei, which methods have been used, how uncertainties are treated, etc. Also, how the data have been processed in the data files, e.g. cut-off's at the low and high-energy thresholds.

Sections 5 and 6 are merged.

Some important deadlines were set:

- first complete draft for PSF publication – S. Goriely needs all the contributions by 31 January.
- second draft of PSF paper 28 February.
- Draft ready for submission 31 March.

3.3. Miscellaneous

The List of Actions from the 2nd RCM was reviewed and the following recommedations / amendments were made (# of action is taken from 2nd RCM report):

- Action item 14 (from RCM2): All PSF data to be sent to IAEA by 15 January 2019 (M. Wiedeking)
- New Action on IAEA (Dimitriou): The PSF data files will be converted to correct format by the IAEA.
- New Action on R. Firestone: for thermal capture data, uncertainties need to be included and files need to be created. To be delivered by end of January 2019.
- Action 17: actual validation tests will be included in the final report by 15 January 2019.
- Action 20: M. Wiedeking and M. Krticka to include part of the ^{56}Fe analysis in report possibly under Methods (TBD).
- Action 21: withdrawn
- Action 22: withdrawn with the remark that this method can be used with recommended PSFs model.
- Action 25: R. Firestone can produce possible spin dependence in his analysis of gamma strengths. He will provide his conclusions when they become available.
- Action 26: lead to a new Action on IAEA: to provide the new PSF data to theorists by 16 January 2019.
- Action 32: lead to a new Action on S. Goriely: to provide QRPA and SMLO tables to T. Kawano by 15 January 2019.
- Action 33: done for MSC data (for more nuclei than listed). For TSC results will be provided by 15 January 2019.
- Action 34: The list of nuclei for which this validation has been done has changed. T. Belgya has already results using the QRPA PSFs for 78Se, 74,73Ge, Cd114, Pu242, while Th233 is in progress.
- Action 36: PSF web interface to be distributed by end of April 2019.

The complete updated List of Actions is found in Appendix 2.

4. Summary

The 3rd RCM of the CRP on Updating the Photonuclear Data Library and Generating a Reference Database for Photon Strength Functions was held from 17 to 21 December 2018 at the IAEA Headquarters in Vienna.

The meeting was attended by all the CRP members and advisors. The program included presentations of progress reports and discussions on technical issues regarding measurements, compilation, evaluation and theoretical calculations. The task assignments were reviewed and additional actions were adopted to ensure that the updated photonuclear data library and new reference database of photon strength functions are produced in a timely manner.

In addition to the technical discussions, participants also worked on the final technical publications and agreed on the publisher and tentative submission.

The importance of acknowledging the CRP effort in presentations and relevant publications was stressed once again. Particularly in presentations and publications of work done within the CRP, the following wording should be used:

“This work was performed within the IAEA CRP on Updating the Photonuclear Data Library and Generating a Reference Database for Photon Strength Functions (F410 32)”.

Appendix 1
List of reviewed photonuclear data evaluations

Nuclides	**IAEA1999**	**2016-2018**	**newer**	**Recommend**	**Decision**	**Note**	discussion
H-2	JAEA	JAEA		IAEA	IAEA	no difference between IAEA and JENDL/PD-2016	newer Utsunomiya data (Hara 2003) agree
H-3							
He-3		JAEA		JAEA	JAEA	only available	
Li-6		JAEA	CNDC	JAEA	JAEA	only available	CNDC data will be available by the end of this year: Yamagata data in 2017 are also available
Li-7		JAEA	CNDC	JAEA	JAEA	only available	
Be-9	CNDC	CNDC/JAEA		CNDC	CNDC	relatively better reproduce (g,xn) and (g,abs)	
B-10		JAEA	CNDC	JAEA	JAEA	only available	
B-11		JAEA	CNDC	JAEA	JAEA	only available	
C-12	LANL	JAEA	CNDC	reserved	reserved	IAEA(LANL) evaluation is not correctly plotted (see attached)	to be considered, keep IAEA or newer
C-13	KAERI	JAEA		JAEA	JAEA	better reproduced (g,xn)	
C-14		KAERI		KAERI	KAERI	only available	KAERI preliminary, finalized by the end of this year
N-14	JAEA	JAEA	CNDC	JAEA	JAEA	Better reproduced all channels	wait CNDC new evaluation
N-15	KAERI	JAEA		JAEA	JAEA	better reproduced (g,xn)	
O-16	LANL	JAEA	CNDC	reserved	reserved	IAEA(LANL)'s (g,nx) should be compared to (g,n) measurement (see attached)	to be discussed

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O-17	KAERI	JAEA		reserved	reserved	IAEA(KAERI)'s (n+np) and 2n+2np should be compared to measurements (see attached)	to be discussed, JENDL 1n might be too high (exp data are 1nx)
O-18	KAERI	JAEA		IAEA	IAEA	better reproduced (g,abs), again IAEA's (g,n+np) etc should be compared (see attached)	
F-19		JAEA		JAEA	JAEA	only available	
Na-23	KAERI	JAEA		IAEA	IAEA	better reproduced (g,xn), again IAEA's n+np and 2n+2np should be compared to measurement (see attached)	
Mg-24	KAERI	JAEA		IAEA	IAEA	better reproduced proton emission which is major channel, again IAEA's (g,n+np) should be compared to measurement (see attached)	
Mg-25	KAERI	JAEA		IAEA	IAEA	IAEA's (n+np+2(2n)) and (n,np) should be compared to measurements (see attached)	
Mg-26	KAERI	JAEA		IAEA	IAEA	IAEA's (n+np+2(2n)) and (n,np) should be compared to measurements (see attached)	

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Al-27	LANL	JAEA		reserved	reserved	IAEA's (g,2n+2np) should be compared to measurement (see attached)	
Si-27	KAERI	JAEA/JAEA(new)		IAEA	IAEA	IAEA reproduced available measurements (see attached)	
Si-28	KAERI	JAEA		IAEA	IAEA	IAEA's (g,n+np) should be compared (see attached)	
Si-29	KAERI	JAEA		IAEA	IAEA	IAEA's (g,abs) reproduced well measurement (see attached)	
Si-30	KAERI	JAEA		reserved	IAEA	JAEA gives better prediction, but proton emission is too small which underestimated for the energies where proton emission becomes dominant. Again IAEA's n+p, 2n+p etc should be compared to measurements	keep IAEA
S-32	KAERI	JAEA		IAEA	IAEA	IAEA reproduced available measurements, again IAEA's n+np should be compared (see attached)	
S-33	KAERI	JAEA		IAEA	IAEA	no data. IAEA's evaluation adopted	

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						GDR and other parameters from S-34	
S-34	KAERI	JAEA		IAEA	IAEA	IAEa reproduced proton emission 9major channel) well, again IAEA's n+np+2n, n+2n+np, n+np should be compared (see attached)	
S-36	KAERI	JAEA		IAEA	IAEA	no data. IAEA's evaluation adopted GDR and other parameters from S-34	
Cl-35	KAERI	JAEA/JAEA(Dec2018)		IAEA	JAEA (new)	IAEA's n+np should be compared to measurement (see attached)	JAEA Dec2018
Cl-37	KAERI	JAEA/JAEA(Dec2018)		IAEA	JAEA (new)	IAEA adopted Cl-nat's model and parameters (see attached)	JAEA Dec2018
Ar-36	KAERI	JAEA/JAEA(Dec2018)		IAEA	JAEA (new)	IAEA adopted Ar-40's model and parameters (see attached)	JAEA Dec2018
Ar-38	KAERI	JAEA/JAEA(Dec2018)		IAEA	JAEA (new)	IAEA adopted Ar-40's model and parameters (see attached)	JAEA Dec2018
Ar-40	KAERI	JAEA/JAEA(Dec2018)		IAEA	JAEA (new)	IAEA reconstructed ref. since (g,n) bump above 22 actually comes from (g,2n) (see attached)	JAEA Dec2018
K-39	KAERI	JAEA		IAEA	JAEA	no data. IAEA's evaluation adopted GDR and other parameters from K-nat (see attached)	JENDL/PD-2016 adopted, which includes Iwamoto's new CCONE evaluation

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K-40	KAERI	JAEA		IAEA	JAEA	no data. IAEA's evaluation adopted GDR and other parameters from K-nat (see attached)	JENDL/PD-2016 adopted, which includes Iwamoto's new CCONE evaluation
K-41	KAERI	JAEA		IAEA	JAEA	no data. IAEA's evaluation adopted GDR and other parameters from K-nat (see attached)	JENDL/PD-2016 adopted, which includes Iwamoto's new CCONE evaluation
Ca-40	LANL	JAEA		JAEA	JAEA	JAEA reproduced (g,1p) well	
Ca-42	KAERI	JAEA		IAEA	IAEA	IAEA reproduced (g,sn), theonly data available.	
Ca-43	KAERI	JAEA		IAEA	IAEA	no data. IAEA's evaluation adopted GDR and other parameters from Ca-40 (see attached)	
Ca-44	KAERI	JAEA		JAEA	JAEA	JAEA reproduced better (g,sn)	
Ca-46	KAERI	JAEA		IAEA	IAEA	no data. IAEA's evaluation adopted GDR and other parameters from Ca-40 (see attached)	
Ca-48	KAERI	JAEA		JAEA	JAEA	JAEA reproduced better (g,n) and (g,2n)	
Sc-45		JAEA/JAEA(Dec2018)		JAEA(new)	JAEA (new)	only evaluation	
Ti-46	KAERI	JAEA/JAEA(Dec2018)		JAEA(new)	JAEA (new)	well repproduced peak around 18 MeV in (g,n)	JAEA Dec2018

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Ti-47	KAERI	JAEA/JAEA(Dec2018)		IAEA	JAEA (new)	no data	JAEA Dec2018
Ti-48	KAERI	JAEA/JAEA(Dec2018)		JAEA(new)	JAEA (new)	better reproduced available measurements	JAEA Dec2018
Ti-49	KAERI	JAEA/JAEA(Dec2018)		JAEA(new)	JAEA (new)	consistant evalauation with Ti-48 is assumed	JAEA Dec2018
Ti-50	KAERI	JAEA/JAEA(Dec2018)		IAEA	JAEA (new)	Pywell's data is (g,n+np+2n) which is well reproduced by IAEA (see attached)	JAEA Dec2018
V-50		JAEA(new)		JAEA(new)	JAEA (new)	only available	
V-51	CNDC	CNDC/JAEA/JAEA(Dec2018)		JAEA(new)	JAEA (new)/ CNDC	Better reproduced neutron emissions	JAEA Dec2018, but CNDC will reconsider Fultz correction
Cr-50	CNDC	CNDC/JAEA/JAEA(Dec2018)		CNDC	CNDC	better reproduced GDR shoulder of 1n emission	2n cross section seems to be too small
Cr-52	CNDC	CNDC/JAEA/JAEA(Dec2018)		JAEA(new)	JAEA (new)	two-Lorenzian seems reasonable based on available measurements	
Cr-53	CNDC	CNDC/JAEA/JAEA(Dec2018)		IAEA	IAEA	no data	JAEA Dec2018, but CNDC will revisit absorption cross section
Cr-54	CNDC	CNDC/JAEA/JAEA(Dec2018)		IAEA	IAEA	no data	JAEA Dec2018, but CNDC will revisit absorption cross section
Mn-55	KAERI	JAEA/JAEA(Dec2018)		IAEA	JAEA (new)	IAEA gives overall agreement including (g,3n) (see attached)	JAEA Dec2018
Fe-54	JAERI	JAEA/JAEA(Dec2018)		JAEA(new)	JAEA(new)	(g,2n) looks reasonable	JAEA Dec2018

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Fe-56	JAERI	JAEA/JAEA(Dec2018)		JAEA(new)	JAEA (new)	surprisingly no data for Fe-56	JAEA Dec2018
Fe-57	KAERI	JAEA/JAEA(Dec2018)		IAEA	JAEA (new)	no data	JAEA Dec2018
Fe-58	KAERI	JAEA/JAEA(Dec2018)		IAEA	JAEA (new)	JAEA 2n shape looks strange, better to have a new calc.	JAEA Dec2018
Co-59	KAERI	ELI-NP/JAEA(new)		IAEA	JAEA (new)/ELI	JAEAL 2n too low, ELI data not available	Put JAEA Dec2018 for now, then ELI-NP, try to produce final ENDF6 by the end of Jan.
Ni-58	JAERI	JAEA/JAEA(Dec2018)		IAEA	JAEA (new)	new ALICE calc. absorption too high	
Ni-60	KAERI	JAEA/JAEA(Dec2018)		IAEA	JAEA (new)	new ALICE calc. absorption too high	
Ni-61	KAERI	JAEA/JAEA(Dec2018)		IAEA	JAEA (new)	considering too high abs. cross section of 58,60Ni	
Ni-62	KAERI	JAEA/JAEA(Dec2018)		IAEA	JAEA (new)	ditto	
Ni-64	KAERI	JAEA/JAEA(Dec2018)		IAEA	JAEA (new)	ditto	
Cu-63	LANL	JAEA/ KAERI/JAEA(Dec2018)		JAEA(new)	JAEA (new)	well reproduce all exp. data	JAEA Dec2018
Cu-65	JAEA	JAEA/ KAERI/JAEA(Dec2018)		JAEA(new)	JAEA (new)	well reproduce all exp. data	JAEA Dec2018
Zn-64	JAEA	JAEA/KAERI(missed)		JAEA	JAEA/ KAERI	1n looks 40% low, but CCONE better than ALICE. Maybe photo-	JENDL/PD-2016, but KAERI data are also available. We will check it later

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						abs will be too large if 1n is fitted	
Zn-66	KAERI	JAEA		JAEA	JAEA	well reproduce all exp. data	JENDL/PD-2016
Zn-67	KAERI	JAEA		JAEA	JAEA	ditto	JENDL/PD-2016
Zn-68	KAERI	JAEA		JAEA	JAEA	ditto	JENDL/PD-2016
Zn-70	KAERI	JAEA		JAEA	JAEA	1n looks 30% low, but considering systematics of Zn isotopes	JENDL/PD-2016
Ge-70	KAERI	JAEA		JAEA	JAEA	well reproduce all exp. data	JENDL/PD-2016
Ge-72	KAERI	JAEA		JAEA	JAEA	ditto	JENDL/PD-2016
Ge-73	KAERI	JAEA		JAEA	JAEA	ditto	JENDL/PD-2016
Ge-74	KAERI	JAEA		JAEA	JAEA	ditto	JENDL/PD-2016
Ge-76	KAERI	JAEA		JAEA	JAEA	ditto	JENDL/PD-2016
As-75		KAERI		KAERI	KAERI	reproduce experimenta data well	KAERI
Se-76		KAERI		KAERI	KAERI	reproduce experimenta data well	KAERI
Se-78		KAERI		KAERI	KAERI	reproduce experimenta data well	KAERI
Se-80		KAERI		KAERI	KAERI	reproduce experimenta data well	KAERI
Se-82		KAERI		KAERI	KAERI	reproduce experimenta data well	KAERI
Sr-84	KAERI	JAEA		JAEA	JAEA	well reproduce all exp. data	JENDL/PD-2016
Sr-86	KAERI	JAEA		JAEA	JAEA	ditto	JENDL/PD-2016
Sr-87	KAERI	JAEA		JAEA	JAEA	ditto	JENDL/PD-2016
Sr-88	KAERI	JAEA		JAEA	JAEA	ditto	JENDL/PD-2016

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Sr-90	KAERI	JAEA		JAEA	JAEA	no data, but considering systematics of Sr	JENDL/PD-2016
Y-89		ELI-NP/JAEA(Dec2018)			JAEA (new)		JAEA Dec2018, then replaced by ELI-NP data when available (end of Jan)
Zr-90	KAERI	CNDC/JAEA		CNDC	CNDC	all evaluations reasonablly good	CNDC
Zr-91	CNDC	KAERI/CNDC/JAEA		KAERI	KAERI	all evaluations reasonablly good, but KAERI slightly better	KAERI
Zr-92	CNDC	CNDC/ JAEA		CNDC	JAEA	the same quality	JAEA, because it follows Utsunomiya
Zr-93	KAERI	JAEA		JAEA	JAEA	no data, but considering systematics of Zr	
Zr-94	KAERI	CNDC/KAERI/ JAEA		KAERI	KAERI	the same quality, but KAERI is slightly better	KAERI
Zr-96	CNDC	CNDC/JAEA		CNDC	JAEA	considering other Zr isotopes	JAEA, because it follows Utsunomiya
Nb-93	KAERI	JAEA/KAERI(missed)		JAEA	JAERI	well reproduce all exp. data	KAERI
Nb-94	KAERI	JAEA		JAEA	JAEA	no data, but considering Nb93 eval	JENDL/PD-2016
Mo-92	KAERI	JAEA		JAEA	JAEA	well reproduce all exp. data	JENDL/PD-2016
Mo-94	KAERI	JAEA		JAEA	JAEA	ditto	JENDL/PD-2016
Mo-95	KAERI	JAEA		JAEA	JAEA	no data, but considering systematics of Mo	JENDL/PD-2016
Mo-96	KAERI	JAEA		JAEA	JAEA	well reproduce all exp. data	JENDL/PD-2016

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Mo-97	KAERI	JAEA		JAEA	JAEA	no data, but considering systematics of Mo	JENDL/PD-2016
Mo-98	KAERI	JAEA		JAEA	JAEA	well reproduce all exp. data	JENDL/PD-2016
Mo-100	KAERI	JAEA		JAEA	JAEA	ditto	JENDL/PD-2016
Rh-103		ELI-NP/JAEA			JAEA	data not yet available	keep JENDL/PD2016, then we will see new files by both ELNPI and JAEA
Pd-102	KAERI	JAEA		JAEA	JAEA	well reproduce all exp. data	JENDL/PD-2016
Pd-104	KAERI	JAEA		JAEA	JAEA	ditto	JENDL/PD-2016
Pd-105	KAERI	JAEA		JAEA	JAEA	ditto	JENDL/PD-2016
Pd-106	KAERI	JAEA		JAEA	JAEA	ditto	JENDL/PD-2016
Pd-107	KAERI	JAEA		JAEA	JAEA	ditto	JENDL/PD-2016
Pd-108	KAERI	JAEA		JAEA	JAEA	only abs. data but considering other isotopes	JENDL/PD-2016
Pd-110	KAERI	JAEA		JAEA	JAEA	well reproduce all exp. data	JENDL/PD-2016
Ag-107	KAERI	JAEA		JAEA	JAEA	well reproduce all exp. data	JENDL/PD-2016
Ag-108	KAERI	JAEA			?	JENDL data not found	JENDL/PD-2016
Ag-109	KAERI	JAEA		JAEA	JAEA	xn looks high, but data are natural	JENDL/PD-2016
Cd-106	KAERI	JAEA		JAEA	JAEA	although KAERI data are OK in general, but JAEA looks better	JENDL/PD-2016
Cd-108	KAERI	JAEA		JAEA	JAEA	although KAERI data are OK in general, but JAEA looks better	JENDL/PD-2016

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Cd-110	KAERI	JAEA		JAEA	JAEA	although KAERI data are OK in general, but JAEA looks better	JENDL/PD-2016
Cd-111	KAERI	JAEA		JAEA	JAEA	although KAERI data are OK in general, but JAEA looks better	JENDL/PD-2016
Cd-112	KAERI	JAEA		JAEA	JAEA	although KAERI data are OK in general, but JAEA looks better	JENDL/PD-2016
Cd-113	KAERI	JAEA		JAEA	JAEA	although KAERI data are OK in general, but JAEA looks better	JENDL/PD-2016
Cd-114	KAERI	JAEA		JAEA	JAEA	although KAERI data are OK in general, but JAEA looks better	JENDL/PD-2016
Cd-116	KAERI	JAEA		JAEA	JAEA	although KAERI data are OK in general, but JAEA looks better	JENDL/PD-2016
In-115		KAERI			KAERI		KAERI
Sn-112	KAERI	CNDC/JAEA		JAEA	JAEA/ CNDC	unphysical bump below threshold in CNDC	CNDC reevaluate all Sn isotopes
Sn-114	KAERI	CNDC/JAEA		JAEA	JAEA/ CNDC	(g,2n) of CNDC might be too big comparing with other Sn isotopes	
Sn-115	KAERI	CNDC/JAEA		JAEA or IAEA	JAEA/ IAEA/ CNDC	no exp.	
Sn-116	KAERI	CNDC/ KAERI/JAEA		JAEA	JAEA/ CNDC	good agreement with exp.; no new KAERI, MSU data	
Sn-117	KAERI	CNDC/ JAEA		JAEA	JAEA/ CNDC	good agreement with exp.; no MSU data	

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Sn-118	KAERI	CNDC/JAEA		JAEA	JAEA/ CNDC	better agreement with Utsunomiya data of (g,1n)	
Sn-119	KAERI	CNDC/JAEA		JAEA	JAEA/ CNDC	better agreement with Utsunomiya data of (g,1n)	
Sn-120	KAERI	CNDC/JAEA		JAEA or IAEA	JAEA/ IAEA/ CNDC	similar quality	
Sn-122	KAERI	CNDC/JAEA		JAEA	JAEA	good agreement with exp.	
Sn-124	KAERI	CNDC/JAEA		JAEA or IAEA	JAEA/ IAEA/ CNDC	similar quality	
Sb-121	KAERI	JAEA		JAEA	JAEA	although KAERI data are OK in general, but JAEA looks better	JENDL/PD-2016
Sb-123	KAERI	JAEA		JAEA	JAEA	although KAERI data are OK in general, but JAEA looks better	JENDL/PD-2016
Te-120	KAERI	JAEA		JAEA	JAEA		JENDL/PD-2016
Te-122	KAERI	JAEA		JAEA	JAEA		JENDL/PD-2016
Te-123	KAERI	JAEA		JAEA	JAEA		JENDL/PD-2016
Te-124	KAERI	JAEA		JAEA	JAEA		JENDL/PD-2016
Te-125	KAERI	JAEA		JAEA	JAEA		JENDL/PD-2016
Te-126	KAERI	JAEA		JAEA	JAEA		JENDL/PD-2016
Te-128	KAERI	JAEA		JAEA	JAEA		JENDL/PD-2016
Te-130	KAERI	JAEA		JAEA	JAEA		JENDL/PD-2016
I-127	KAERI	JAEA			JAEA		JENDL/PD-2016
I-129	KAERI	JAEA			JAEA		JENDL/PD-2016
Cs-133	KAERI	KAERI/ JAEA		KAERI	KAERI	better reproduction	KAERI better

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Cs-135	KAERI	JAEA		JAEA	JAEA	new calculation	JENDL/PD-2016
Cs-137	KAERI	JAEA		JAEA	JAEA	new calculation	JENDL/PD-2016
Ba-138		KAERI			KAERI		KAERI, Utsunomiya has newer data
La-139		ELI-NP/JAEA(Dec2018)			JAEA (new)/ELI		JENDL(Dec2018), then compare with ELI-NP new calculation when available
Ce-140		KAERI			KAERI		KAERI
Ce-142		KAERI			KAERI		KAERI
Pr-141	KAERI	JAEA		JAEA	JAEA	new calc. and (g,3n) consistent with Fi value	JENDL/PD-2016
Nd-142		KAERI			KAERI		KAERI, then try fitting NewSUBARU data
Nd-143		KAERI			KAERI		ditto
Nd-144		KAERI			KAERI		ditto
Nd-145		KAERI			KAERI		ditto
Nd-146		KAERI			KAERI		KAERI
Nd-148		KAERI/ELI-NP			KAERI		KAERI, since all isotopes are done by KAERI. also good agreement with NewSUBARU data near threshold
Nd-150		KAERI			KAERI		KAERI
Sm-144	KAERI	JAEA		KAERI	JAEA (new)/ KAERI	JAEA abs. cross section too low	KAERI, then Iwamoto will reconsider the 0.8 factor
Sm-147	KAERI	JAEA		KAERI	KAERI		
Sm-148	KAERI	JAEA		KAERI	KAERI	JAEA abs. cross section too low	
Sm-149	KAERI	JAEA		KAERI	KAERI		

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Sm-150	KAERI	JAEA		KAERI	KAERI	JAEA abs. cross section too low	
Sm-151	KAERI	JAEA		KAERI	KAERI		
Sm-152	KAERI	JAEA		KAERI	KAERI	JAEA abs. cross section too low	
Sm-154	KAERI	JAEA		KAERI	KAERI	JAEA abs. cross section too low	
Eu-153		KAERI			KAERI		KAERI
Gd-160		JAEA		JAEA	JAEA	reasonable	JENDL/PD-2016
Tb-158	KAERI	JAEA			JAEA		JENDL/PD-2016
Tb-159	KAERI	KAERI/JAEA/ELI-NP/JAEA(Dec2018)		KAERI(Capote) JAEA or KAERI (Iwamoto)	KAERI/ JAEA (new)/ELI	better 3n (Capote), both agree well with exp. (Iwamoto)	KAERI, then Iwamoto, Filipescu, Cho will finalize evaluations by including newSubaru data
Ho-165	KAERI	ELI-NP/JAEA			JAEA (new)/ELI		JAEA/PD2016, then wait Iawamot's new calc. and Filipescu's final calc.
Tm-169		ELI-NP			ELI		ELI-NP whenever available
Lu-175		KAERI		KAERI	KAERI	good agreement with exp.	KAERI
Hf-174		JAEA(Dec2018)			JAEA(new)		JAEA Dec2018
Hf-176		JAEA(Dec2018)			JAEA(new)		JAEA Dec2018
Hf-177		JAEA(Dec2018)			JAEA(new)		JAEA Dec2018
Hf-177		JAEA(Dec2018)			JAEA(new)		JAEA Dec2018
Hf-178		JAEA(Dec2018)			JAEA(new)		JAEA Dec2018

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Hf-179		JAEA(Dec2018)			JAEA(new)		JAEA Dec2018
Hf-180		JAEA(Dec2018)			JAEA(new)		JAEA Dec2018
Ta-181	JAEA	KAERI/JAEA/ELI-NP		JAEA or IAEA	JAEA/ IAEA/ KAERI	both data agree well with exp.; new KAERI seems slight overestimation for (g,xn)	JAEA/PD2016, then wait Iawamoto, Cho's new calc. and Filipescu's final calc.
W-180	CNDC	CNDC/JAEA		?	CNDC	no exp.	CNDC
W-182	JAEA	CNDC/JAEA		JAEA	CNDC	only abs. data but considering other isotopes	CNDC
W-183	CNDC	CNDC/JAEA		?	CNDC	no exp.	CNDC
W-184	LANL	CNDC/JAEA		JAEA	CNDC	2n looks too high	CNDC
W-186	JAEA	CNDC/JAEA		JAEA	CNDC	good agreement with exp.	CNDC, since Berman data were remormalized in JENDL by factor of 1.09, which was questioned by Varlamon
Re-185		JAEA(Dec2018)			JAEA (new)		JAEA Dec2018, then add Oslo data
Re-187		JAEA(Dec2018)			JAEA (new)		JAEA Dec2018
Os-186		KAERI		KAERI	KAERI	good agreement with exp.	KAERI
Os-188		KAERI		KAERI	KAERI	good agreement with exp.	KAERI
Os-189		KAERI		KAERI	KAERI	good agreement with exp.	KAERI
Os-190		KAERI		KAERI	KAERI	good agreement with exp.	KAERI

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Os-192		KAERI		KAERI	KAERI	good agreement with exp.	KAERI, then add Oslo data
Au-197	KAERI	ELI-NP/KAERI/JAEA			KAERI/ JAEA (new)/ELI		KAERI, then we will wait updates by Cho, Iwamoto, and Filipescu
Pb-206	LANL	JAEA		IAEA	JAEA		JENDL/PD2016
Pb-207	LANL	JAEA		IAEA	JAEA		JENDL/PD2016
Pb-208	LANL	KAERI/JAEA		IAEA	JAEA	KAERI a bit high, LAEA 2n too low	JENDL/PD2016, although KAERI data also in good shape, except KAERI data do not fission; JENDL reproduces Berman, while KAERI preferred Saclay data without correction
Bi-209	CNDC	CNDC/ELI-NP/KAERI/JAEA/JAEA(Dec2018)		KAERI	KAERI	reproduce Gheorghe's new data well. However, there are uncertainties for (g,1n) and (g,2n) around (g,2n) threshold energy.	KAERI reproduces 4n
Th-232	BOFOD	JAEA		JAEA	JAEA	need to check the fission data, which were adopted above 15 MeV	fission cross section concerned in the 20 MeV region (model code issue). Cadwell data prefered by Iwamoto.
U-233	BOFOD	JAEA		JAEA	JAEA		
U-234	BOFOD	JAEA		JAEA	JAEA		
U-235	BOFOD	JAEA		JAEA	JAEA		We want new measurements around 15 MeV
U-236	BOFOD	JAEA		JAEA	JAEA		

Appendix 1
List of reviewed photonuclear data evaluations

U-238	BOFOD	JAEA		JAEA	JAEA		
Np-237		JAEA		JAEA	JAEA	fission cross section well reproduced	Veyssiere data reproduced this time, could be too low?
Pu-238	BOFOD	JAEA		JAEA	JAEA		
Pu-239	BOFOD	JAEA		JAEA	JAEA		
Pu-241	BOFOD	JAEA		JAEA	JAEA		

Appendix 2

List of Actions – updated at 3rd RCM, 17-21 December 2018

No	Action	Responsible	Deadline	Update
1	Prepare a preliminary list of top priority nuclides for which photonuclear data are important for applications.	Dimitriou (IAEA), Kawano	Preliminary list:12/2016 Complete list: 2nd RCM **Preliminary list prepared to be included in report.** **Complete list: 3nd RCM – in progress**	Done Additional isotopes evaluated by JENDL (Hf, Re) For the rest in the list JENDL-2016.ext will be compared with TENDL (Iwamoto) Then recommendation will be made
2	Collect the new measurements when they are ready for publication and submit to Dimitriou (IAEA) for distribution among evaluators and inclusion in the EXFOR database	Utsunomiya, Filipescu Siem	Continuous **Au, Tm, Y in 07/2018** **Os, Re, Ba, Ni in 12/2017** **^{13}C 3rd RCM**	Done for Ni, Dy, Tl, Bi, Be, Tb, La, Ho, Tm, Au, Ta Remaining : Os, Re, Ba, Co, Rh, Y , W, Zn: end of January Gd , ^{13}C: end of March
3	Investigate the completeness of the EXFOR database with respect to photonuclear cross-section data (with special emphasis on data published in the periods after 2000 and before 1975).	Dimitriou (IAEA)	06/2017 **Ongoing**	

Appendix 2

List of Actions – updated at 3rd RCM, 17-21 December 2018

3b	Missing NSR references: compile list of priorities for photonuclear and for (γ,γ') publications (based on CINDA search)	Varlamov, Schwengner	03/2018	Done (12 new photonuclear data publications included)
4	Send references of published photonuclear data to Dimitriou (IAEA) for inclusion in EXFOR. In case of data corrected by evaluators, data (and references) should be sent to IAEA with additional explanations about corrections.	Cho, Xu, Varlamov, Kawano, Iwamoto, Filipescu, Firestone	Continuous – **evaluators should search in NSR, private communication, and/or google**	Continuous
5	Provide Dimitriou (IAEA) with the list of EXFOR entries of available corrected photo-neutron cross-section data for ^{91,94}Zr, ^{115}In, ^{116}Sn, ^{159}Tb, ^{181}Ta, ^{197}Au, ^{208}Pb targets.	Varlamov	After 1st RCM (05/2016)- completed **Continuous for regular updates.**	Continuous
6	Provide new corrected data on ^{63,65}Cu, ^{133}Cs, ^{141}Pr, ^{80}Se, ^{89}Y, ^{138}Ba to Dimitriou (IAEA) for distribution to CRP evaluators. In general: provide new corrected data as they become available to the IAEA for distribution among CRP evaluators.	Varlamov	09/2016 - **completed** **Continuous for regular updates.**	Continuous
7	Coordinate the sensitivity study on the F_i correction factors and report on the conclusions.	Kawano	09/2016 (ND2016)- **completed**	To be included in final paper

Appendix 2

List of Actions – updated at 3rd RCM, 17-21 December 2018

7b	Evaluation on ^{209}Bi to explore model dependencies on evaluation and send results to Kawano	Cho, Xu, Varlamov, Kawano, Iwamoto, Filipescu	03/2018 Has to precede review meeting (week 1 or 2 07/2018).	Done
8	Explore the effect of over-enhancement of absorption of incident photon flux into 1p1h states for two test cases (one light and one heavy nucleus). Discussion with code developers will take place at the ND 2016 meeting and the results will be disseminated among all the CRP evaluators.	Kawano	ND2016- **completed** **To be included in the final report**	To be included in final report
9	**S**end plots with comparisons of new JAEA and existing IAEA Photonuclear Data Library evaluations to Dimitriou (IAEA) for uploading on the CRP web site.	Iwamoto	12/2016- **postponed to 02/2018** **To be distributed to evaluators by N. Iwamoto**	To be distributed by Iwamoto
9b	Compare with Varlamov evaluation for ^{91}Zr, ^{159}Tb, ^{197}Au		11/2017- Done	Done
10	Organize the first meeting of the Photonuclear Evaluation Committee to review the first round of evaluations.	Dimitriou (IAEA)	In 2017/before 2nd RCM – **postponed to week 1 or 2 07/2018** **Done in June 2018**	Second meeting in Q1 2019 to finalize and check starter file

Appendix 2

List of Actions – updated at 3rd RCM, 17-21 December 2018

11	The Atlas of GDR parameters will be updated.	Varlamov, Plujko	When new evaluated photonuclear data become available- **completed**	Continuous-will adopt recommendations of evaluators (Dimitriou to provide information to Plujko within 1 week)
11b	Provide additional column of cross section values at the declared GDR peak energies The PSF obtained from the recommended data from this Atlas will be labeled accordingly		Additional column: 01/2018 01/2018	Done
12	Photon Strength Functions (PSF) will be extracted from the total photo-neutron/ photo-absorption cross section and also compared with models. • QRPA calculations • TSE **List of nuclei and energy grid to be sent to Schwengner** • TLO tables	Plujko Goriely Plujko Plujko Schwengner	2nd RCM: preliminary data received draft received 07/2018 10/2017 07/2018	Done for QRPA and SMLO Not for TSE TLO done (Belgya)
12b	Look at nuclei where (g,1n) has been used to extract GDR PSF. PSF will be corrected close to Sn.	Plujko/Dimitriou Plujko	01/2018 01/2018	Done by Plujko and Schwengner
13	Propose a preliminary web interface for the photonuclear data library.	Dimitriou (IAEA)	2nd RCM – ongoing See action 36	To be completed by March 2019

Appendix 2

List of Actions – updated at 3rd RCM, 17-21 December 2018

14	Send the collected experimental PSF data to Dimitriou (IAEA) in a simple format	Wiedeking	Continuous- Preliminary files sent	Cut-off date for final report: 15 January 2019
14b	Resend new corrected PSF experimental datafiles (include cols with stat. errors, upper and lower limits) to Dimitriou (IAEA)		Corrected files will be resent by end of 02/2018.	Resend final versions of datafiles to be included in database (15 January 2019)
14c	Circulate program that creates datafiles in the required format. Key words need to be defined and added to files.	Dimitriou (IAEA)/Belgya	01/2018 01/2018	No need- corrections will be done by IAEA
15	Send the collected transition strength data to Dimitriou (IAEA) in a simple format in separate files (B(M1), B(E1)….) - Provide separate compilation ^{57}Fe comparison with Oslo data ARC	Firestone Firestone Kopecky	10/2018 – 02/2018 Completed	Data need to be updated (uncertainty analysis) and individual files need to be created – by end of January
16	Send samples of the format of the experimental PSF data files to the CRP participants.	Dimitriou (IAEA)	10/2016 - Completed	Done
17	Explore possibility of extracting/validating relative PSF from thermal capture spectra.	Belgya	Completed	Done – actual tests will be included in the final report (15 January 2019)
17b	Prepare a detailed report for inclusion in summary.		11/2017	See above

Appendix 2

List of Actions – updated at 3rd RCM, 17-21 December 2018

18	Model-dependent uncertainty analysis will be performed on both the NRF and Oslo method for the test case of ^{89}Y. The analysis will be done for ^{96}Mo instead of ^{89}Y.	Schwengner, Siem	12/2016 - postponed to 03/2018	Done for both ^{89}Y, ^{96}Mo and ^{139}La (to be included in the report)
18b	Oslo will provide upper/lower uncertainties for ^{96}Mo	Siem	03/2018	Done
19	Existing NRF and Oslo data for will be further assessed with uncertainty analysis. **^{139}La uncertainty analysis** **PSF data will be recommended with error bars for ^{74}Ge, ^{181}Ta.** **Consider ^{89}Y, ^{92}Mo, ^{94}Mo after the complete analysis on ^{96}Mo.** **Provide recommended PSF for which more than one data set exists.**	Schwengner, Siem, Wiedeking. Schwengner Schwengner, Siem, Wiedeking. Schwengner, Siem, Wiedeking Wiedeking, Siem, Schwengner	By 2nd RCM – partially done, extended to 3rd RCM 07/2018 By 3rd RCM 08/2018 08/2018	Done
20	PSF shape extracted from the Oslo and Ratio methods will be compared for ^{74}Ge similarly to the case of ^{95}Mo.	Wiedeking, Krticka.	by 2nd RCM-completed	
20b	For ^{56}Fe instead of above		by 09/2018	Done – to be considered for the report

Appendix 2

List of Actions – updated at 3rd RCM, 17-21 December 2018

21	Validation of the assessed and recommended PSF will be performed by Multi-Step Cascade method for the cases of ^{98}Mo including a full uncertainty analysis of Nuclear Level Density models.	Krticka	2nd RCM	Method requires too many assumptions for a definite conclusion to be drawn
21b	Assessment of uncertainties will be explored.		01/2018	See above
22	Compatibility of thermal capture & Oslo PSF data for the case of ^{196}Pt will be checked.	Krticka/Belgya	Completed	Same as #21 Conclusion is that this method can be used with recommended model PSFs
22b	Sensitivity check on level density for ^{114}Cd ^{196}Pt	 Belgya Krticka	 10/2017 11/2017	Done for model PSFs and NLDs
23	Compatibility between recommended PSF at low energies and the extracted one from photonuclear data will be studied as soon as corresponding data become available. This action is incorporated in Action 27. See below	Plujko, Siem	See 27	See 27
24	An update on the available experimental evidence for the multipolarity of the low-energy upbend will be given at the 2nd RCM.	Wiedeking	Completed	Done
25	The spin dependence of PSF-related observables will be investigated.	Firestone	2nd RCM – extended to 01/2018	To be done by Rick in his analysis of gamma strengths

Appendix 2

List of Actions – updated at 3rd RCM, 17-21 December 2018

26	Experimental PSF data will be made available to theorists (Goriely, Plujko) as soon as they are submitted to IAEA.	Dimitriou (IAEA)	Continuous	16 January 2019
27	The following global models of PSFs (E1, M1, total) will be adjusted to recommended (experimental) strength functions: HFB+QRPA SLO/SMLO	Goriely Plujko	completed completed	Done
27b	Modification of SMLO model to reproduce low-energy PSF data. M1 contributions required (see 29 and 37)	Plujko Goriely	06/2018 3rd RCM	Done
28	Shell model calculations of M1 PSF in relation with the upbend and the scissors mode will be explored.	Schwengner	2nd RCM - completed	Done
29	Empirical prescription for M1 PSF, including spin-flip & scissors, will be provided together with the RIPL E1 parameterization (tables of parameters).	Kawano	2nd RCM-completed for scissors mode Tables to be submitted by 01/2018	Done
30	Comparisons between existing global models and experimental PSF extending to energies below the neutron threshold will be performed This action is incorporated in Action 12 and 27	Plujko, Goriely	2nd RCM	Done

Appendix 2

List of Actions – updated at 3rd RCM, 17-21 December 2018

31	Comparison between global empirical and microscopic prescriptions (for E1 and M1 SF) will be provided for all nuclei across the nuclear chart.	Plujko, Goriely	3rd RCM – revised to 10/2018	Done
32	Validation of the different adjusted PSF models on experimental (n,γ) cross sections and <Γ_γ> data will be performed when data are available.	Kawano, Goriely.	After 2nd RCM – extended to 3rd RCM	Done Provide QRPA and SMLO tables to Kawano (15 january 2019)
33	Validation of adjusted PSF models on other available Two-Step Cascade (TSC) and Multi-Step Cascade (MSC) data: ^{155,156,157,158,159}Gd (MSC & TSC), ^{96,98}Mo (MSC & TSC), ^{239}U (MSC) (availability of data for other nuclides will be checked) For QRPA For modified SMLO (see 27)	Krticka	 02/2018 09/2018	Done for MSC data (more nuclei than listed) For TSC: to be done by 15 January 2019 Done
34	Validation of adjusted PSF models on single spectra from thermal capture for ^{78}Se, ^{114}Cd, ^{233}Th, ^{239}U, ^{196}Pt.	Belgya	09/2018	Done with QRPA for ^{78}Se, ^{73,74}Ge, ^{114}Cd, ^{242}Pu, ^{233}Th (in progress),
35	A first demonstration of the new DICEBOX software package will be made at the 2nd RCM and a first version of the package will be made available from the IAEA web site. Agreement preparation	Krticka Dimitriou (IAEA)	12/2017- postponed to 01/2018 01/2018	Done

Appendix 2

List of Actions – updated at 3rd RCM, 17-21 December 2018

36	Prepare a proposal for the PSF database web interface for presentation to and approval by the CRP.	Dimitriou (IAEA), Firestone, Belgya	2nd RCM - preliminary version 04/2018 Final version 3rd RCM	PSF interface to be distributed by March 2019 (by IAEA)
37	Proposal to improve the M1 systematics within the Lorentzian approach for spin-flip and scissors mode.	Goriely/Kopecky	06/2018	Done
New on 21-12-2018				
38	Provide final ARC+DRC data files	Kopecky	15 January 2019	
39	Check (p,g) publications for relevant data and submit references to IAEA	Mathis, Milan, Tamas	7 January 2019	
40	IAEA to prepare the (p,g) PSF datafiles	IAEA	15 January 2019	
41	Re-visit $^{16,17}O$ photonuclear evaluation ^{12}C Cr-isotopes	Iwamoto Xu	31st January 2019	
42	NewSUBARU data need to be considered in the evaluations	Evaluators	31 January 2019	
43	Some recommendations postponed	Reviewers	31st December 2018	
44	Distribute templates and guidelines for figures and text for submission to Nuclear Data Sheets for photonuclear paper	IAEA	31st Dec.	
45	Samples figures sent back to IAEA for checking of quality (IAEA to send to Oblozinsky) for photonuclear paper			

Appendix 2

List of Actions – updated at 3rd RCM, 17-21 December 2018

46	PSF paper: complete first draft		31st January 2019	
47	2nd draft of PSF paper		28 February 2019 (deadline for final submission 31st March)	
48	1st preliminary draft of photonuclear paper-		28 February 2019	
49	2nd complete draft of photonuclear paper		30 April 2019 (deadline for submission June 2019)	

Appendix 3

Outline of the final pulication on “Photon Strength Functions”

To be submitted for publication in European Physical Journal A.

1. **Introduction (coordinator: Dimitriou/Goriely)**
2. **Experimental methods (coordinator: Krticka – 7 p)**
    - NRF (Schwengner)
    - Oslo method (Siem)
    - Ratio and χ^2 method (Wiedeking)
    - DRC/ARC data (Kopecky)
    - Photonuclear data (Plujko)
    - Inelastic (p,p’) & partial reaction cross section (Wiedeking/Krticka)
    - Additional methods for PSF comparisons
        - Thermal n-capture (Belgya/Firestone)
        - Multi-step cascade (Krticka)
        - Average radiative width (Goriely)
        - MACS (Goriely)
3. **Assessment of PSF from experiments (coordinator: Wiedeking 10 p)**
    - Compilation of PSF (Wiedeking)
        - NRF (Schwengner)
        - Oslo (Siem)
        - Photodata (Plujko)
        - DRC/ARC data (Kopecky)
        - Others: Ratio and χ^2 method & (p,p’) & (p,γ) (Wiedeking)
        - individual transitions in thermal capture data (Firestone/Krticka)

    → Include figs with (g,n), Oslo, NRF, ARC, (p,p’) data for a few cases (Goriely)
    - Uncertainty analysis on test cases
        - NRF (Schwengner)
        - Oslo (Wiedeking/Siem)
    - recommendation experimental PSF
        - NRF vs Oslo
4. **PSF models (coordinator: Goriely – 10 p)**
    - Introduction (Goriely)
    - Phenomenological models E1 & M1 (Plujko/Goriely)
    - Mean-Field + QRPA models E1 & M1 (Goriely)
5. **Comparison between experimental and models (coordinator: Goriely - 10p)**
    - Comparison with NRF data (Goriely)
    - Comparison with integrated M1 data (Goriely)
    - Comparison with Oslo data (Goriely)
    - Comparison with DRC/ARC data (Goriely)
    - Comparison with photodata(Goriely)
    - Comparison with (p,p’) and (p,g) data (Goriely)
    - Comparison with thermal n-capture spectra (Belgya)
    - Comparison with Multi-step cascade spectra (Krticka)
    - Comparison with average radiative width (Goriely)

   - Comparison with radiative n-capture at 30 keV (Goriely)
6. **Comparison between models for experimentally unknown nuclei (coordinator: Goriely - 3p)**
   - Comparison of E1, M1 and E1+M1 PSF
   - Comparison of MACS
7. **Final database (coordinator: Dimitriou - 5p)**
8. **Final recommendations (coordinator: Goriely/Dimitriou 2p)**
9. **Conclusions**

Appendix 4

Outline of the paper on "Photonuclear Data Library"

The outline will be quite similar to the CRP IAEA-TECDOC-1178 (2000) and will be submitted to Nuclear Data Sheets

1. **Introduction (coordinator: Dimitriou – 3p)**
2. **Available experimental data (coordinator: Varlamov - 10p): Filipescu, Utsunomiya, Varlamov**
3. **Nuclear models (coordinator: Kawano – 15p):** models in codes used for the evaluation (Iwamoto, Xu, Kawano, Capote)
    - General description of models
    - Specifics of codes used
    - Fi correction functions
4. Evaluation
    a. **Evaluation by experimental data (Varlamov)**
    b. **Evaluation by models (coordinator: Kawano – 20p):**
        - General Evaluation methodology
        - Special cases:
        - Parameter values to be included in Annex
    - CNDC (Xu): GLUNF, MEND-G
    - KAERI (Cho): TALYS
    - JAEA (Iwamoto): CCONE
    - IFIN-HH (Filipescu): EMPIRE
5. **Content of the Library (coordinator: Kawano – 5p)**
6. **Database web interface (coordinator: Dimitriou – 3p)**
7. **Conclusions**
8. **Annex: GDR atlas (Plujko – only new data)**

Note:

- Main text will be published with the atlas of GDR parameters either in the paper or as a supplement paper.
- Extensive figures with comparisons to be published in INDC(NDS) report or made available on IAEA web page

3rd Research Coordination Meeting (RCM) of the CRP on

Updating the Photonuclear Data Library and Generating a Reference Database for Photon Strength Functions

IAEA Headquarters, Vienna, Austria
17-21 December 2018
Meeting Room M4

Adopted AGENDA

Monday, 17 December

08:30 - 09:00 **Registration** (IAEA Registration desk, Gate 1)

09:00 - 09:30 **Opening Session**

Welcoming address (Arjan Koning, Section Head)
Election of Chairman and Rapporteur
Adoption of Agenda
Administrative matters

09:30 - 12:30 **Reports by participants**

1. Photonuclear experiments: PHOENIX collaboration
   a. Measurements by Konan Univ.: H. Utsunomiya
   b. Measurements by IFIN-HH: D. Filipescu
   c. Measurements by Moscow State Univ.: V.V. Varlamov

2. Photonuclear cross section evaluations:
   a. Minutes/recommendations of CM on Review of Photonuclear Cross-section evaluations, 25-27 June 2018: P. Dimitriou
   b. Results of review of photonuclear evaluations: T. Kawano
   c. Reports by evaluators on new developments since CM:
      i. Cho
      ii. Iwamoto
      iii. Xu
      iv. Varlamov
      v. Filipescu

12:30 – 14:00 ***Lunch***

14:00 – 18:00 **Reporting session (cont'd)**

Coffee breaks as needed

Tuesday, 18 December

09:00 - 12:30 **Reports**

1. Compilation of Photon Strength Functions (PSF): M. Wiedeking
2. Assessment of experimental PSF:
   a. R. Schwengner,

   b. S. Siem,
   c. Joint assessments: R. Schwengner, S.Siem, M. Wiedeking
3. ARC and DRC PSFs, J. Kopecky
4. Deconvolution of PSFs, R. Firestone
5. Modelling of PSFs:
   a. V. Plujko
   b. S. Goriely
   c. T. Belgya
6. Validation of model PSFs:
   a. M. Krticka, S. Goriely, V. Plujko
   b. T. Belgya, S. Goriely
7. Dicebox, M. Krticka
8. PSF database: P. Dimitriou, All

12:30 – 14:00 Lunch

14:00 – 18:00 Reporting (cont'd)

Coffee breaks as needed

19:00 Dinner at a restaurant (see separate information)

Wednesday, 19 December

09:00 - 12:30 Round Table Discussion

Topics for discussion

1. Selection of evaluations for Updated Photonuclear Data Library
2. Atlas of GDR parameters
3. Total Atlas (ARC and DRC)
4. Recommended PSF experimental data
5. Global models of PSF
6. Validation of models and exp. Data
7. Databases
8. Final publications

12:30 – 14:00 Lunch

14:00 – 18:00 Round table discussion (cont'd)

Coffee breaks as needed

Thursday, 20 December

09:00 - 12:30 Drafting of Final Publications

1. Group 1: Photonuclear Data Library

2. Group 2: Photon Strength Functions

Note: The groups can be split into sub-groups depending on the needs. This can be decided at the meeting.)

12:30 – 14:00 Lunch

14:00 – 18:00 Drafting of Final Publications (cont'd)

Coffee breaks as needed

Friday, 21 December

09:00 - 12:00 Drafting of the meeting summary report

Coffee break as needed

12:30 Closing of the meeting

3rd Research Coordination Meeting on
"Updating Photonuclear Data Library and Generating a Reference Database for Photon Strength Functions"
IAEA, Vienna, Austria
17-21 December 2018

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Links to Presentations

#	Author	Title	Link
1	P. Dimitriou	CM on Photonuclear cross sections	PDF
2	H. Utsunomiya	Progress report on the PHOENIX* Collaboration	PDF
3	D. Filipescu	Photoneutron reactions using direct neutron multiplicity sorting method	PDF
4	V. Varlamov	Evaluation of partial and total photoneutron reactions cross sections using new objective physical data reliability criteria	PDF
5	N. Iwamoto	Evaluation results from JENDL	PDF
6	Y-S. Cho	Update of the Photonuclear Cross Sections	PDF
7	R. Xu	The Status of PD evaluations at CNDC (Contract 20466)	PDF
8	T. Yuan	A Study of Giant Dipole Resonance Parameters from Photoabsorption Cross Sections	PDF
9	T. Yuan	Comparison	PDF
10	V. Plujko	Updating Photonuclear Data Library and Phenomenological Photon Strength Functions	PDF
11	S. Goriely	Theoretical determination of the E1-M1 strength	PDF
12	j. Kopecky	Gamma-ray strength functions (discrete resonance experiments)	PDF
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Group Photo

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