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Results of time-of-flight transmission measurements for ^{nat}Cu at a 25 m station of GELINA

Description of GELINA data to be stored in the EXFOR data base

Hyeong Il Kim
Carlos Paradela
Stefan Kopecky
Gery Alaerts
Andre Moens
Peter Schillebeeckx
Ruud Wynants

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Results of time-of-flight transmission measurements for ^{nat}Cu at a 25 m station of GELINA

H. I. Kim[a], C. Paradela[b], S. Kopecky[b], G. Alaerts[b], A. Moens[b], P. Schillebeeckx[b] and R. Wynants[b]

[a]Korea Atomic Energy Research Institute, Daejeon 34057, Republic of Korea

[b]European Commission, Joint Research Centre, B - 2440 Geel, Belgium

Contents

Abstract

Transmission measurements have been performed at the time-of-flight facility GELINA to determine neutron resonance parameters for ^{63}Cu and ^{65}Cu. The measurements have been carried out at a 25 m transmission station at a moderated neutron beam using a Li-glass scintillator with the accelerator operating at 800 Hz. This report provides the experimental details required to deliver the data to the EXFOR data library which is maintained by the Nuclear Data Section of the IAEA and the Nuclear Energy Agency of the OECD. The experimental conditions and data reduction procedures are described. In addition, the full covariance information based on the AGS concept is given such that nuclear reaction model parameters together with their covariances can be derived in a least squares adjustment to the data.

1 Introduction

To study the resonance structure of neutron induced reaction cross sections, neutron spectroscopic measurements are required which determine with a high accuracy the energy of the neutron that interacts with the material under investigation. To cover a broad energy range such measurements are best carried out with a pulsed white neutron source, which is optimized for time-of-flight (TOF) measurements [1].

The TOF-facility GELINA [2][3] has been designed and built for high-resolution cross section measurements in the resonance region. It is a multi-user facility, providing a white neutron source with a neutron energy range from 10 meV to 20 MeV. Up to 10 experiments can be performed simultaneously at measurement stations located between 10 m to 400 m from the neutron production target. The electron linear accelerator provides a pulsed electron beam with a maximum energy of 150 MeV, a peak current of 10 A and a repetition rate ranging from 50 Hz to 800 Hz. A compression magnet reduces the width of the electron pulses to about 2 ns [4]. The electron beam hits a mercury-cooled uranium target producing Bremsstrahlung and subsequently neutrons via photonuclear reactions [5]. Two water-filled beryllium containers mounted above and below the neutron production target are used to moderate the neutrons. By applying different neutron beam collimation conditions, experiments can use either a fast or a moderated neutron spectrum. The neutron production rate is monitored by BF_3 proportional counters which are mounted in the ceiling of the target hall. The output of the monitors is used to normalize the time-of-flight spectra to the same neutron intensity. The measurement stations are equipped with air conditioning to reduce electronic drifts in the detection chains due to temperature changes.

In this report results of transmission measurements carried out at GELINA with natural Cu metallic samples are described. To reduce bias effects due to e.g. dead time and background, the measurement and data reduction procedures recommended in Ref. [1] have been followed. The main objective of this report is to provide the information that is required to extract resonance parameters for ^{63}Cu and ^{65}Cu in a least squares adjustment to the data [1] using e.g. the resonance shape analysis code REFIT [6]. In the description of the data the recommendations resulting from a consultant’s meeting organized by the Nuclear Data Section of the IAEA have been followed [7].

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2 Experimental conditions

The transmission experiments were performed at the 25 m measurement station of flight path 2 with the accelerator operating at 800 Hz. The moderated neutron spectrum was used. A shadow bar made of Cu and Pb was placed close to the uranium target to reduce the intensity of the γ-ray flash and the fast neutron component. The flight path forms an angle of 9° with the direction normal to the face of the moderator viewing the flight path. The sample and detector were placed in a climatised room to keep them at a constant temperature of 20 $^{\circ}$C.

The partially thermalized neutrons scattered from the moderators were collimated into the flight path through evacuated aluminum pipes of 50 cm diameter with annular collimators, consisting of borated wax, copper and lead. A combination of Li-carbonate plus resin, Pb and Cu-collimators was used to reduce the neutron beam to a diameter of 15 mm at the sample position. The samples were placed at 9 m distance from the neutron source. Close to the sample position a ^{10}B overlap filter was placed to absorb slow neutrons from a previous burst. The impact of the γ-ray flash was reduced by a 5 mm Pb filter. Permanent S, Bi and Co black resonance filters were used to continuously monitor the background at 102 keV, 800 eV and 132 eV and to account for the impact of the sample on the background [1]. The neutron beam passing through the sample and filters was further collimated and detected by a 12.7 mm thick and 101 mm diameter NE905 Li-glass scintillator enriched to 95% in ^{6}Li. The scintillator was connected through a boron-free quartz window to a 127 mm EMI9823 KQB photomultiplier (PMT). The detector was placed at about 24.5 m from the neutron target.

The TOF of the detected neutron was derived from the time difference between the stop signal T_s, obtained from the anode impulse of the PMT, and the start signal T_0, given at each electron burst. This time difference was processed with a multi-hit fast time coder with a 0.5 ns time resolution [8]. The TOF and the pulse height of each detected event were recorded in list mode using a multi-parameter data acquisition system developed at the EC-JRC [9]. Each measurement was subdivided in different cycles. Only cycles for which the ratio between the total counts in the transmission detector and in the neutron monitor deviated by less than 0.5 % were selected. The dead time of the detection chain t_d = (3135 ± 10) ns was derived from a spectrum of the time-interval between successive events. The maximum dead time correction was less than 20 %. In Ref. [1], it has been demonstrated that uncertainties for such dead time corrections are very small and can be neglected. All measurements were performed with natural Cu metallic discs. The main characteristics of the samples are reported in Table 1. The areal density of the natural samples was derived from a measurement of the weight and the area with an uncertainty better than 0.1 %. The area was determined by an optical surface inspection with a microscope system from Mitutoyo [9]. The isotopic composition of the natural samples was taken from Ref. [10].

ID	Thickness /mm	Mass/g	Area/cm2	Areal Density (at/b)
1	0.125	5.25 ± 0.01	50.2771 ± 0.0003	(9.8868 ± 0.0005) x 10^{-4}
2	0.25	11.11 ± 0.01	50.2971 ± 0.0009	(2.0936 ± 0.0001) x 10^{-3}
3	0.7	31.39 ± 0.01	50.3060 ± 0.0007	(5.9143 ± 0.0002) x 10^{-3}
4	20	669.30 ± 0.01	38.5269 ± 0.0013	(1.6463 ± 0.0001) x 10^{-1}

Table 1 Characteristic of each sample. Each areal density n_d was calculated by mass and area.

3 Data reduction

The AGS code [12], developed at the EC-JRC, was used to derive the experimental transmission from the TOF-spectra. The code is based on a compact formalism to propagate all uncertainties starting from uncorrelated uncertainties due to counting statistics. It stores the full covariance in formation after each operation in a concise, vectorized way. The use of the AGS concept has been recommended in a consultants' meeting organized by the IAEA [7][6] to report TOF cross section data in the EXFOR data library [13][14].

3.1 Experimental transmission

The experimental transmission T_{exp} as a function of TOF was obtained from the ratio of a sample-in measurement C_{in} and a sample-out measurement C_{out}, both corrected for their background contributions B_{in} and B_{out}, respectively:

$$T_{exp} = N\frac{C_{in} - K_{in}B_{in}}{C_{out} - K_{out}B_{out}}, \tag{3.1}$$

The TOF spectra (C_{in}, C_{out}, B_{in}, B_{out}) were corrected for losses due to the dead time in the detector and electronics chain. All spectra were normalized to the same TOF-bin width structure and neutron beam intensity. The latter was derived from the response of the BF_3 beam monitors. To avoid systematic effects due to slow variations of both the beam intensity and detector efficiency as a function of time, data were taken by alternating sample-in and sample-out measurements in cycles of about 900 seconds each. Such a procedure reduces the uncertainty on the normalization to the beam intensity to less than 0.25 %. This uncertainty was evaluated from the ratios of counts in the ^{6}Li transmission detector and in the flux monitors. To account for this uncertainty the factor N= 1.0000 ± 0.0025 was introduced in Eq. (3.1). The background as a function of TOF was approximated by an analytic expression applying the black resonance technique [1]. The factors K_{in} = 1.00 ± 0.02 and K_{out} = 1.00 ± 0.015 in Eq. (3.1) was introduced to account for systematic effects due to the background model. Its uncertainty was derived from a statistical analysis of the difference between the observed black resonance dips and the estimated background [15]. This uncertainty is only valid for measurements with at least two fixed black resonance filters in the beam [1].

The time-of-flight (t) of a neutron creating a signal in the neutron detector was determined by the time difference between the start signal (T_0) and the stop signal (T_s):

$$\mathrm{t} = (T_s - T_0) + t_0, \tag{3.2}$$

with t_0 a time-offset which was determined by a measurement of the γ-ray flash. The flight path distance L = 24.328 m, i.e. the distance between the centre of the moderator viewing the flight path and the front face of the detector, was derived previously from results of transmission measurements for ^{238}U using the (6.673 ± 0.001) eV resonance of ^{238}U as a reference. The parameters of this resonance have been evaluated by Derrien et al. [16].

3.2 Background Correction

The background contribution for the transmission measurements was approximated by an analytical function applying the black resonance technique [1]. The analytical function was a sum of a time independent and three time dependent components:

$$B(t) = b_0 + b_1 e^{-\lambda_1 t} + b_2 e^{-\lambda_2 t} + b_3 e^{-\lambda_3 (t+t_0)}, \tag{3.3}$$

The parameter b_0 is the time independent contribution. The first exponential is due to the detection of 2.2 MeV γ-rays resulting from neutron capture in hydrogen present in the moderator. The second exponential originates predominantly from neutrons scattered inside the detector station. The third one is due to slow neutrons from previous accelerator cycles. This contribution was estimated by an extrapolation of the TOF-spectrum at the end of the cycle. The parameter t_0 is related to the operating frequency of the accelerator, i.e. t_0 = 1.25 ms for 800 Hz. The time dependence of the background was derived from the results of measurements with the 20 mm thick Cu sample and verified with measurements using a 3 mm thick Au sample [15]. The dead time corrected sample-out and sample-in TOF-spectra together with the background contributions resulting from the measurements with the 20 mm thick ^{nat}Cu sample and a Co and Na filter are shown in Figures. 1 and 2, respectively. The contributions of the different background components illustrate that the smallest contribution results from overlap neutrons.

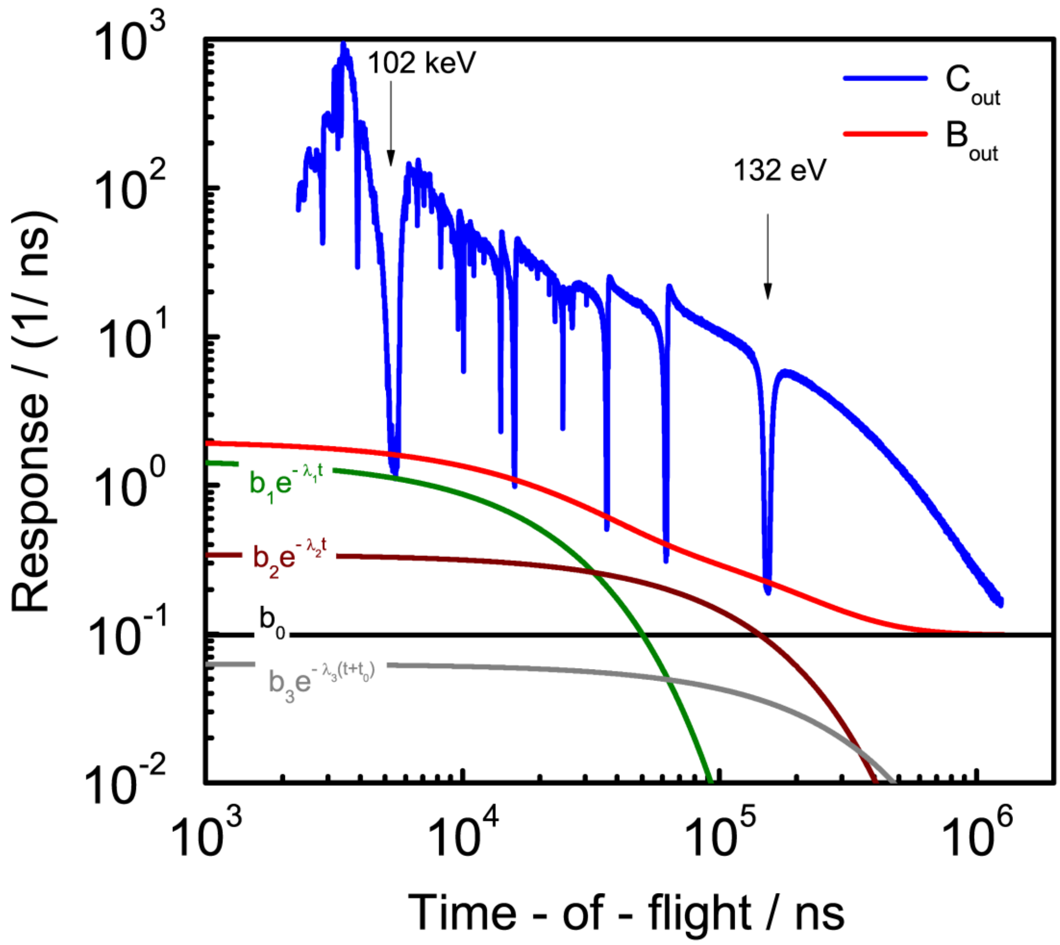

Figure 1 TOF spectrum without sample (C_{out}) in the beam together with the total background (B_{out}) and its different components.

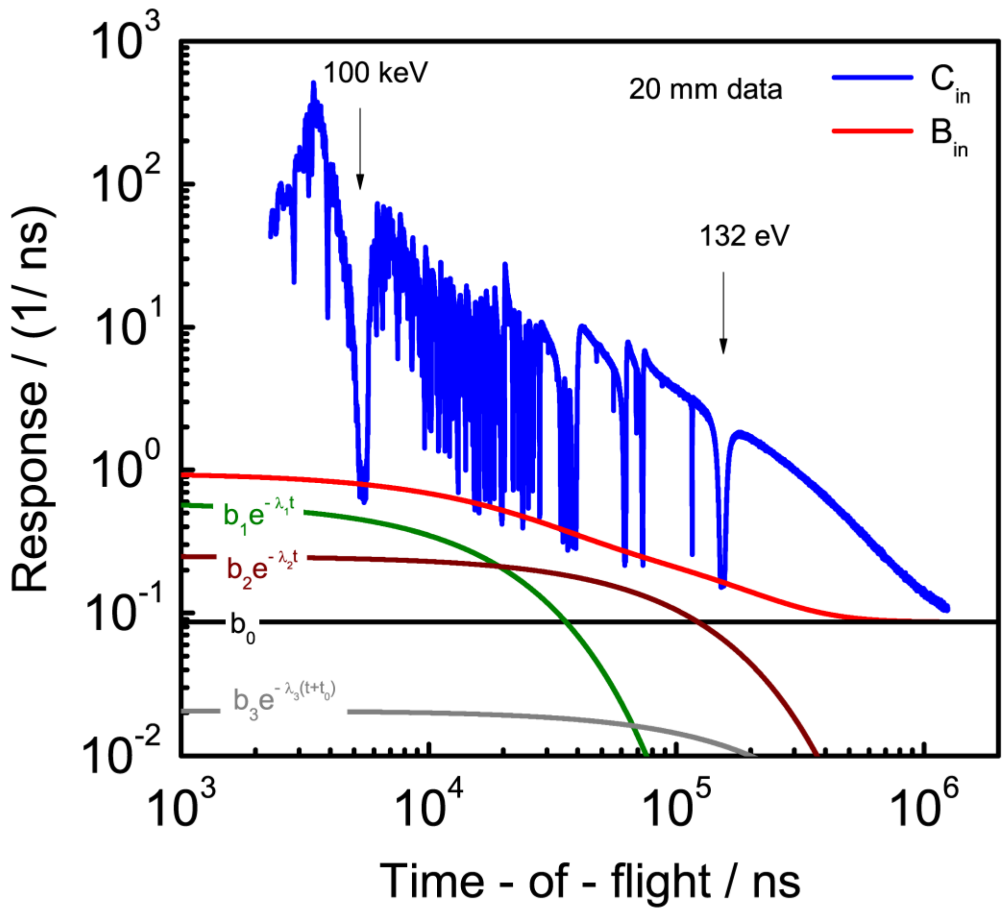

Figure 2 The same as Figure 1, but for sample-in (C_{in}) measurements.

4 Results

To derive the experimental transmission and propagate both the correlated and uncorrelated uncertainties the AGS code was used [12]. The AGS (Analysis Of Geel Spectra) code, developed at the EC-JRC, was used to derive the experimental yield. The code is based on a compact formalism to propagate all uncertainties starting from uncorrelated uncertainties due to counting statistics. It stores the full covariance information after each operation in a concise, vectorized way. The AGS formalism results in a substantial reduction of data storage volume and provides a convenient structure to verify the various sources of uncertainties through each step of the data reduction process. The concept is recommended by the Nuclear Data Section of the IAEA [7] to prepare the experimental observables, including their full covariance information, for storage into the EXFOR data library [13][17].

The format in which the numerical data will be stored in the EXFOR data library is illustrated in Tables B.1, B.2, B.3 and B.4 in the Appendix. The data include the full covariance information based on the AGS concept. The total uncertainty and the uncertainty due to uncorrelated components are reported, together with the contributions due to the normalization and background subtraction. Applying the AGS concept described in Ref. [12], the covariance matrix V of the experimental transmission can be calculated by:

$$V = U_u + S(\eta)S(\eta)^T, \tag{4.1}$$

where U_u is a diagonal matrix containing the contribution of all uncorrelated uncertainty components. The matrix S is contains the contribution of the components $\eta = \{N, K_{in}, K_{out}\}$ creating correlated components. The uncertainty due to the dead time correction can be neglected.

The experimental details, which are required to perform a resonance analysis on the data, are summarized in Appendix A1, A2, A3 and A4. The information given is based on the recommendations resulting from a consultant's meeting organized by the NDS-IAEA [7].

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Appendix

A. SUMMARY OF EXPERIMENTAL DETAILS

A. 1 Experiment description (ID 1)

1. Main Reference		[1][2]
2. Facility	GELINA	[3]
3. Neutron production		
Neutron production beam	Electron	
Nominal average beam energy	100 MeV	
Nominal average current	30 μA	
Repetition rate (pulses per second)	800 Hz	
Pulse width	2 ns	
Primary neutron production target	Mercury cooled depleted uranium	
Target nominal neutron production intensity	3.4 $\times 10^{13}$ s^{-1}	
4. Moderator		
Primary neutron source position in moderator	Above and below uranium target	
Moderator material	2 water filled Be-containers around U-target	
Moderator dimensions (internal)	2 x (14.6 cm x 21 cm x 3.9 cm)	
Density (moderator material)	1 g/cm^2	
Temperature (K)	Room temperature	
Moderator-room decoupler (Cd, B, …)	None	
5. Other experimental details		
Measurement type	Transmission	
Method (total energy, total absorption, …)	Good transmission geometry	[4][5]
Flight Path length (m) (moderator centre-detector front face)	L = 24.328 m	
Flight path direction	9° with respect to normal of the moderator face viewing the flight path	
Neutron beam dimensions at sample position	15 mm in diameter	
Neutron beam profile	-	
Overlap suppression	$^{10}B_4C$ overlap filter (^{10}B: 8E-3at/b)	
Other fixed beam filters	S, Bi, Co, Pb (5 mm)	
6. Detector		
Type	Scintillator (NE905)	
Material	Li-glass	
Surface Dimensions	101 mm diameter	
Thickness (cm)	12. 7 mm	
Distance from samples (cm)	127 mm	
Detector(s) position relative to neutron beam	In the beam	
Detector(s) solid angle	-	
7. Sample		
Type (metal, powder, liquid, crystal)	Metal	
Chemical composition	^{nat}Cu (100 at %)	
Sample composition (at/b)	^{nat}Cu (9.8868 ± 0.0005) 10^{-4} at/b	
Temperature	20 ℃	

	Sample mass (g)	(5.25 ± 0.01) g	
	Geometrical shape (cylinder, sphere, …)	cylinder	
	Surface dimension	(5027.71 ± 0.03) mm^2	
	Nominal thickness (mm)	0.125 mm	
	Containment description	None	
	Additional comment	63.17 at % ^{63}Cu, 30.83 at % ^{65}Cu	
8.	**Data Reduction Procedure**		[5][6]
	Dead time correction	Done (< factor 1.2)	
	Back ground subtraction	Black resonance technique	
	Flux determination (reference reaction, …)	-	
	Normalization	1.000 ± 0.0025	
	Detector efficiency	-	
	Self-shielding	-	
	Time-of-flight binning	Zone length / bin width: 16384 / 1 ns 10240 / 2 ns 8192 / 4 ns 8192 / 8 ns 6144 / 16 ns 6144 / 32 ns 4096 / 64 ns 4096 / 128 ns 1024 / 256 ns 1024 / 512 ns	
9.	**Response function**		
	Initial pulse	Normal distribution, FWHM = 2 ns	
	Target / moderator assembly	Numerical distribution from MC simulations	[7][8]
	Detector	Analytical function defined in REFIT manual	[9]

A. 2 Experiment description (ID 2)

1.	**Main Reference**		[1][2]
2.	**Facility**	GELINA	[3]
3.	**Neutron production**		
	Neutron production beam	Electron	
	Nominal average beam energy	100 MeV	
	Nominal average current	30 μA	
	Repetition rate (pulses per second)	800 Hz	
	Pulse width	2 ns	
	Primary neutron production target	Mercury cooled depleted uranium	
	Target nominal neutron production intensity	3.4×10^{13} s^{-1}	
4.	**Moderator**		
	Primary neutron source position in moderator	Above and below uranium target	
	Moderator material	2 water filled Be-containers around U-target	
	Moderator dimensions (internal)	2 x (14.6 cm x 21 cm x 3.9 cm)	
	Mass	H_2O	
	Temperature (K)	Room temperature	

	Moderator-room decoupler (Cd, B, …)	None	
5.	**Other experimental details**		
	Measurement type	Transmission	
	Method (total energy, total absorption, …)	Good transmission geometry	[4][5]
	Flight Path length (m) (moderator centre-detector front face)	L = 24.328 m	
	Flight path direction	9° with respect to normal of the moderator face viewing the flight path	
	Neutron beam dimensions at sample position	15 mm in diameter	
	Neutron beam profile	-	
	Overlap suppression	$^{10}B_4C$ overlap filter (^{10}B: 0.02 at/b)	
	Other fixed beam filters	S, Bi, Co, Pb (5 mm)	
6.	**Detector**		
	Type	Scintillator (NE905)	
	Material	Li-glass	
	Surface Dimensions	101 mm diameter	
	Thickness (cm)	12. 7 mm	
	Distance from samples (cm)	127 mm	
	Detector(s) position relative to neutron beam	In the beam	
	Detector(s) solid angle	-	
7.	**Sample**		
	Type (metal, powder, liquid, crystal)	Metal	
	Chemical composition	^{nat}Cu (100 at %)	
	Sample composition (at/b)	^{nat}Cu (2.0936 ± 0.0001) 10^{-3} at/b	
	Temperature	20 ℃	
	Sample mass (g)	(11.11 ± 0.01) g	
	Geometrical shape (cylinder, sphere, …)	cylinder	
	Surface dimension	(5029.71 ± 0.09) mm^2	
	Nominal thickness (mm)	0.25 mm	
	Containment description	None	
	Additional comment	63.17 at % ^{63}Cu, 30.83 at % ^{65}Cu	
8.	**Data Reduction Procedure**		[5][6]
	Dead time correction	Done (< factor 1.2)	
	Back ground subtraction	Black resonance technique	
	Flux determination (reference reaction, …)	-	
	Normalization	1.000 ± 0.0025	
	Detector efficiency	-	
	Self-shielding	-	
	Time-of-flight binning	Zone length / bin width: 16384 / 1 ns 10240 / 2 ns 8192 / 4 ns 8192 / 8 ns 6144 / 16 ns 6144 / 32 ns 4096 / 64 ns 4096 / 128 ns 1024 / 256 ns 1024 / 512 ns	
9.	**Response function**		
	Initial pulse	Normal distribution, FWHM = 2 ns	

Target / moderator assembly	Numerical distribution from MC simulations	[7][8]
Detector	Analytical function defined in REFIT manual	[9]

A. 3 Experiment description (ID 3)

1. Main Reference		[1][2]
2. Facility	GELINA	[3]
3. Neutron production		
Neutron production beam	Electron	
Nominal average beam energy	100 MeV	
Nominal average current	30 μA	
Repetition rate (pulses per second)	800 Hz	
Pulse width	2 ns	
Primary neutron production target	Mercury cooled depleted uranium	
Target nominal neutron production intensity	3.4×10^{13} s^{-1}	
4. Moderator		
Primary neutron source position in moderator	Above and below uranium target	
Moderator material	2 water filled Be-containers around U-target	
Moderator dimensions (internal)	2 x (14.6 cm x 21 cm x 3.9 cm)	
Mass	H_2O	
Temperature (K)	Room temperature	
Moderator-room decoupler (Cd, B, …)	None	
5. Other experimental details		
Measurement type	Transmission	
Method (total energy, total absorption, …)	Good transmission geometry	[4][5]
Flight Path length (m) (moderator centre-detector front face)	L = 24.328 m	
Flight path direction	9° with respect to normal of the moderator face viewing the flight path	
Neutron beam dimensions at sample position	15 mm in diameter	
Neutron beam profile	-	
Overlap suppression	$^{10}B_4C$ overlap filter (^{10}B: 8E-3 at/b)	
Other fixed beam filters	S, Bi, Co, Pb (5 mm)	
6. Detector		
Type	Scintillator (NE905)	
Material	Li-glass	
Surface Dimensions	101 mm diameter	
Thickness (cm)	12. 7 mm	
Distance from samples (cm)	127 mm	
Detector(s) position relative to neutron beam	In the beam	
Detector(s) solid angle	-	
7. Sample		
Type (metal, powder, liquid, crystal)	Metal	
Chemical composition	^{nat}Cu (100 at %)	

Sample composition (at/b)	^{nat}Cu (5.9143 ± 0.0002) 10^{-3} at/b	
Temperature	20 ℃	
Sample mass (g)	(31.39 ± 0.01) g	
Geometrical shape (cylinder, sphere, …)	cylinder	
Surface dimension	(5030.60 ± 0.07) mm^2	
Nominal thickness (mm)	0.7 mm	
Containment description	None	
Additional comment	63.17 at % ^{63}Cu, 30.83 at % ^{65}Cu	
8. Data Reduction Procedure		[5][6]
Dead time correction	Done (< factor 1.2)	
Back ground subtraction	Black resonance technique	
Flux determination (reference reaction, …)	-	
Normalization	1.000 ± 0.0025	
Detector efficiency	-	
Self-shielding	-	
Time-of-flight binning	Zone length bin width 16384 1 ns 10240 2 ns 8192 4 ns 8192 8 ns 6144 16 ns 6144 32 ns 4096 64 ns 4096 128 ns 1024 256 ns 1024 512 ns	
9. Response function		
Initial pulse	Normal distribution, FWHM = 2 ns	
Target / moderator assembly	Numerical distribution from MC simulations	[7][8]
Detector	Analytical function defined in REFIT manual	[9]

A. 4 Experiment description (ID 4)

1. Main Reference		[1][2]
2. Facility	GELINA	[3]
3. Neutron production		
Neutron production beam	Electron	
Nominal average beam energy	100 MeV	
Nominal average current	30 μA	
Repetition rate (pulses per second)	800 Hz	
Pulse width	2 ns	
Primary neutron production target	Mercury cooled depleted uranium	
Target nominal neutron production intensity	3.4 $\times 10^{13}$ s^{-1}	
4. Moderator		
Primary neutron source position in moderator	Above and below uranium target	
Moderator material	2 water filled Be-containers around U-target	

	Moderator dimensions (internal)	2 x (14.6 cm x 21 cm x 3.9 cm)	
	Mass	H_2O	
	Temperature (K)	Room temperature	
	Moderator-room decoupler (Cd, B, …)	None	
5.	**Other experimental details**		
	Measurement type	Transmission	
	Method (total energy, total absorption, …)	Good transmission geometry	[4][5]
	Flight Path length (m) (moderator centre-detector front face)	L = 24.328 m	
	Flight path direction	9° with respect to normal of the moderator face viewing the flight path	
	Neutron beam dimensions at sample position	15 mm in diameter	
	Neutron beam profile	-	
	Overlap suppression	$^{10}B_4C$ overlap filter (^{10}B: 8E-3 at/b)	
	Other fixed beam filters	S, Bi, Co, Pb (5 mm)	
6.	**Detector**		
	Type	Scintillator (NE905)	
	Material	Li-glass	
	Surface Dimensions	101 mm diameter	
	Thickness (cm)	12. 7 mm	
	Distance from samples (cm)	127 mm	
	Detector(s) position relative to neutron beam	In the beam	
	Detector(s) solid angle	-	
7.	**Sample**		
	Type (metal, powder, liquid, crystal)	Metal	
	Chemical composition	^{nat}Cu (100 at %)	
	Sample composition (at/b)	^{nat}Cu (1.6463 $\pm$ 0.0001) 10^{-1} at/b	
	Temperature	20 ℃	
	Sample mass (g)	(669.30 $\pm$ 0.01) g	
	Geometrical shape (cylinder, sphere, …)	cylinder	
	Surface dimension	(3852.69 $\pm$ 0.13) mm^2	
	Nominal thickness (mm)	20 mm	
	Containment description	None	
	Additional comment	63.17 at % ^{63}Cu, 30.83 at % ^{65}Cu	
8.	**Data Reduction Procedure**		[5][6]
	Dead time correction	Done (< factor 1.2)	
	Back ground subtraction	Black resonance technique	
	Flux determination (reference reaction, …)	-	
	Normalization	1.000 $\pm$ 0.0025	
	Detector efficiency	-	
	Self-shielding	-	
	Time-of-flight binning	Zone length / bin width: 16384 / 1 ns 10240 / 2 ns 8192 / 4 ns 8192 / 8 ns 6144 / 16 ns 6144 / 32 ns 4096 / 64 ns 4096 / 128 ns 1024 / 256 ns 1024 / 512 ns	

9. Response function		
Initial pulse	Normal distribution, FWHM = 2 ns	
Target / moderator assembly	Numerical distribution from MC simulations	[7][8]
Detector	Analytical function defined in REFIT manual	[9]

B. Data format

Column	Content	Unit	Comment
1	Energy	eV	Relativistic relation using a fixed flight path length (L = 24.328 m)
2	t_l	ns	
3	T_h	ns	
4	T_{exp}		Transmission
5	Total Uncertainty		
6	Uncorrelated uncertainty		Uncorrelated uncertainty due to counting statistics
7	AGS-vector (K_{in})		Background with sample (u_{Kin}/K=2 %)
8	AGS-vector (K_{out})		Background without sample (u_{Kout}/K=1.5 %)
9	AGS-vector (N)		Normalization (u_N/N = 0.25 %)

Comments from the authors:

- The AGS concept was used to derive the experimental transmission

$$T_{exp} = N\frac{C_{in} - K_{in}B_{in}}{C_{out} - K_{out}B_{out}},$$

  and to propagate the uncertainties, both the uncorrelated due to counting statistics and the uncertainty due to the normalization and the background contributions.

- The quoted uncertainties are standard uncertainties at 1 standard deviation

B.1 DATA (ID 1)

E/ eV	t_l / ns	t_h / ns	Y_{exp}	u_t	AGS			
					u_u	S_{in}	S_{out}	N
89964.037	5864	5865	0.98191	0.02641	0.02628	0.00037	-0.00049	0.00245
89933.36	5865	5866	1.00389	0.02714	0.02701	0.00038	-0.00051	0.00251
1151.259	51836	51840	0.98847	0.02336	0.02321	0.00049	-0.00065	0.00247
1151.081	51840	51844	0.99819	0.02374	0.0236	0.0005	-0.00067	0.0025
150.141	143536	143552	0.99726	0.02139	0.0212	0.00083	-0.00111	0.00249
150.107	143552	143568	0.99469	0.02144	0.02125	0.00084	-0.00112	0.00249

B.2 DATA (ID 2)

E/ eV	t_l / ns	t_h / ns	Y_{exp}	u_t	AGS			
					u_u	S_{in}	S_{out}	N
89964.037	5864	5865	1.02163	0.03017	0.03005	0.00039	-0.00055	0.00255
89933.36	5865	5866	0.98199	0.02933	0.02922	0.0004	-0.00053	0.00245
1151.259	51836	51840	1.02641	0.02611	0.02597	0.00049	-0.00069	0.00257
1151.081	51840	51844	0.99661	0.02511	0.02497	0.00048	-0.00064	0.00249
150.141	143536	143552	0.97584	0.0225	0.02232	0.00081	-0.00106	0.00244
150.107	143552	143568	1.0021	0.02304	0.02286	0.00081	-0.0011	0.00251

B.3 DATA (ID 3)

E/ eV	t_l / ns	t_h / ns	Y_{exp}	u_t	AGS			
					u_u	S_{in}	S_{out}	N
89964.037	5864	5865	0.91021	0.02896	0.02886	0.00037	-0.00046	0.00228
89933.36	5865	5866	0.96452	0.03073	0.03063	0.00038	-0.0005	0.00241
1151.259	51836	51840	0.93197	0.02525	0.02513	0.00046	-0.00059	0.00233
1151.081	51840	51844	0.97295	0.02628	0.02616	0.00047	-0.00062	0.00243
150.141	143536	143552	0.93019	0.0227	0.02254	0.00077	-0.00097	0.00233
150.107	143552	143568	0.95247	0.02325	0.02309	0.00078	-0.00101	0.00238

B.4 DATA (ID 4)

E/ eV	t_l / ns	t_h / ns	Y_{exp}	u_t	AGS			
					u_u	S_{in}	S_{out}	N
89964.037	5864	5865	0.23639	0.00857	0.00855	0.0002	-0.00013	0.00059
89933.36	5865	5866	0.22376	0.00815	0.00813	0.00019	-0.00012	0.00056
1151.259	51836	51840	0.40504	0.01122	0.01117	0.00031	-0.00026	0.00101
1151.081	51840	51844	0.40986	0.01138	0.01132	0.00031	-0.00026	0.00102
150.141	143536	143552	0.30715	0.00842	0.00836	0.00057	-0.00032	0.00077
150.107	143552	143568	0.29788	0.00819	0.00813	0.00057	-0.00031	0.00074

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