International Atomic Energy Agency

Progress in TOF Spectra Compilation

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IAEA Nuclear Data Section

in collaboration with

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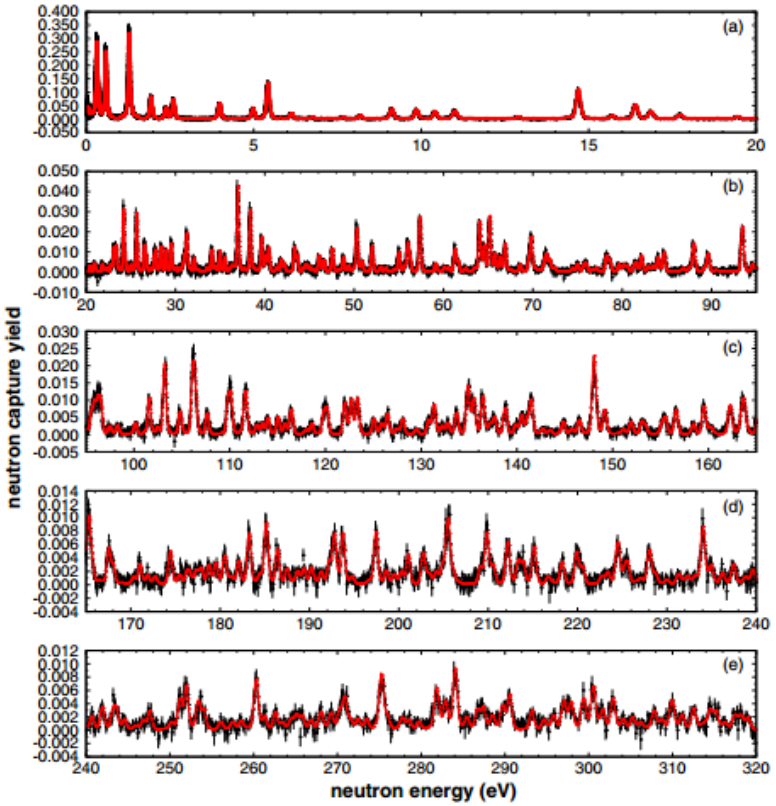
Oscar Cabellos (NEA Data Bank)

Compilation of TOF Spectra - Background

- Archiving of energy dependent data sets for future resonance analysis (e.g., simultaneous fitting of transmission and capture yield)
- Not tabulated in publications.
- Not for digitization (~10000 points, input for least-square analysis)
- Submission of data by authors is essential.



^{241}Am(n,γ) capture yield-
K. Fraval et al., PRC89(2014)044609

Consultant's Meeting (October 2013, Vienna)

International Atomic Energy Agency
Nuclear Data Services
提供核数据组，原子能机构

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Links
Nuclear Data Services
Nuclear Data Section
NRDC Network
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EXFOR

EXFOR Data in Resonance Region and Spectrometers' Response Function

(Consultants' Meeting, 8 to 10 October 2013, IAEA Headquarters, Vienna, Austria)

Background

Neutron-induced reaction cross section data in the resonance region are important for many fields of science and technology. Regarding nuclear energy applications such data are needed for analysis of nuclear criticality safety, advanced fuel cycle developments, nuclear safeguards applications, nuclear waste managements, etc. There are very few experimental facilities worldwide providing data in the resonance region: GELINA (IRMM, Belgium), J-PARC (Japan), n_TOF (CERN), ORELA (Oak Ridge, USA), RPI (NY, USA), each with its own characteristics. All facilities employ accelerators for production of neutrons in a broad energy range and data are obtained by transmission and capture measurements by time-of-flight method. Proper analysis of the data in the resonance region (total, capture, fission cross sections, and time-of-flight spectra) requires knowledge of response functions of the complete target to detector set-up.

The IAEA Nuclear Data S
library in collaboration with
Data Centres (NRDC). Data
of the EXFOR database. Ho
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of such experiments for an
observables available in a f
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resolution function) in orde

Documentation
NIM A618 (2010) 54
NIM A555 (2005) 329
NIM A489 (2002) 346
NDS 113 (2012) 3054
JNST 7 (2012) P11002
KPS 59 (2011) 1314
NIM A736 (2014) 66
Memo CP-D/772

Codes
SAMMY
REFIT

Templates
Template TOF

Major Facilities Providing TOF Spectra

- **Major facilities providing TOF spectra for resonance analysis:**
  - n_TOF (2ZZZCER)
  - GELINA (2ZZZGEL)
  - RPI (1USARPI)
  - ORELA (1USAORL)
  - Some other TOF facilities providing point-wise neutron-induced cross sections in the resonance regions (*e.g.*, J-PARC, LANSCE).

- **NDS and NEA DB continue compilation for GELINA and n_TOF.**

- **NNDC continues compilation for RPI and ORELA.**

n_TOF

- n_TOF (Emmeric Dupont) monitors dissemination status since June 2015. He collects data and also review EXFOR entries.

- Now we usually receive numerical data without delay after final publication.

  ***Examples*:**

  ^{238}U(n,γ) C6D6 by Mingrone et al. (EXFOR 23234): Compiled in December 2016 and published in March 2017.)

  ^{25}Mg(n,γ) C6D6 by Massimi et al. (EXFOR 23327): Compiled in March 2017 and published in May 2017.)

- EXFOR is *complete* for (n,f) and (n,cp) data sets finalized / published by n_TOF.

Retroactive compilation of n_TOF (n,γ) data sets

There is also a major progress in retroactive compilation of (n,γ) capture yields finalized / published by n_TOF many years ago.

***Examples*:**

- ^{209}Bi(n,γ) C6D6 by Domingo-Pardo et al. (EXFOR 22944): Published in August 2006 and compiled in February 2017.
- ^{207}Pb(n,γ) C6D6 by Domingo-Pardo et al. (EXFOR 22946): Published in Nov. 2006 and compiled in April 2017.
- ^{90,94,96}Zr(n,γ) C6D6 by Tagliente et al. (EXFOR 23329, 23330, 23331): Published in March 2008 and July+Nov. 2011, and compiled in March 2017.

Reprocessing of Raw Data for EXFOR Compilation

From: emmeric.dupont@cea.fr [mailto:emmeric.dupont@cea.fr]
Sent: Thursday, 16 March 2017 11:43
To: OTSUKA, Naohiko <N.Otsuka@iaea.org>; Oscar.Cabellos@oecd.org
Cc: Giuseppe Tagliente <Giuseppe.Tagliente@ba.infn.it>
Subject: n_TOF C6D6 capture data for Zr-90,94,96

Dear Naohiko and Oscar,

Thanks to Pino (in Cc) I'm pleased to forward you the yields of the capture reaction on Zr-90,94,96 isotopes measured during n_TOF Phase-I. Well, I don't want to make a long story too short, but you have to know at least that the reduced data are no longer available and that Pino kindly agreed to process the yields again starting from the raw data stored at CERN!

!!

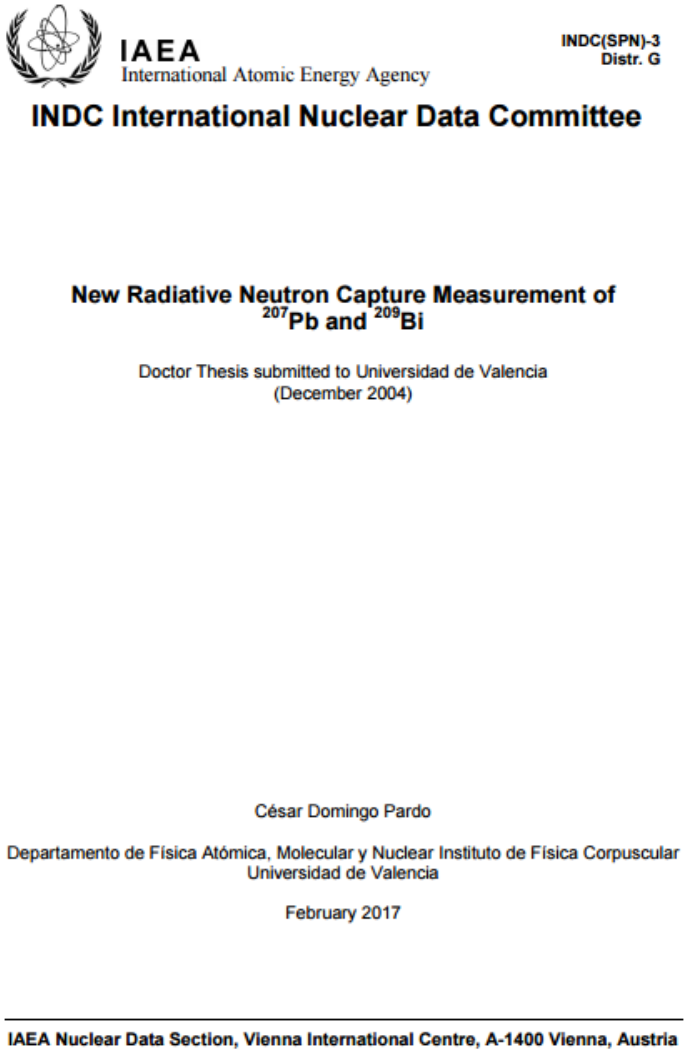
You will find attached three files:

- Zr90_v2_highres_Normalized4SAMMY_full_range_4EXFOR.txt with data published in PRC 77 (2008) 035802
- Zr94_v1_highres_Normalized4SAMMY_full_range_4EXFOR.txt with data published in PRC 84 (2011) 015801
- Zr96_v3_highres_Normalized4SAMMY_full_range_4EXFOR.txt with data published in PRC 84 (2011) 055802

These files share the same characteristics:

- The energy values (in eV) correspond to the middle of the bins

Reproduction of n_TOF Thesis as INDC Report



IAEA
International Atomic Energy Agency

INDC(SPN)-3
Distr. G

INDC International Nuclear Data Committee

New Radiative Neutron Capture Measurement of ^{207}Pb and ^{209}Bi

Doctor Thesis submitted to Universidad de Valencia
(December 2004)

César Domingo Pardo

Departamento de Física Atómica, Molecular y Nuclear Instituto de Física Corpuscular
Universidad de Valencia

February 2017

IAEA Nuclear Data Section, Vienna International Centre, A-1400 Vienna, Austria

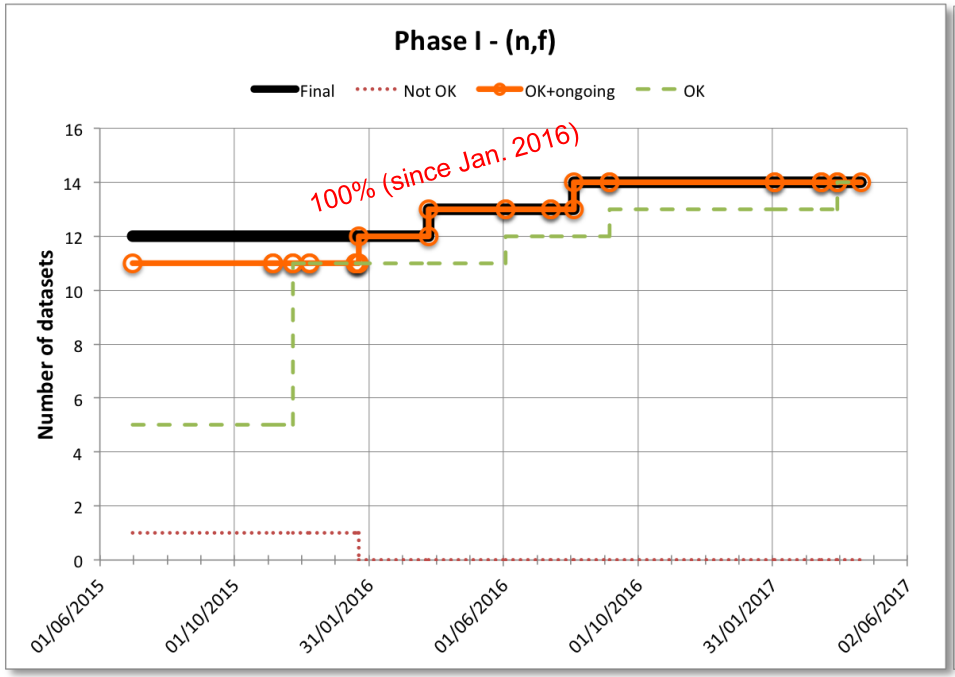
- Publication of the thesis as an INDC report.
- Addition as a secondary reference in EXFOR.
- Guaranteed access for future EXFOR users.

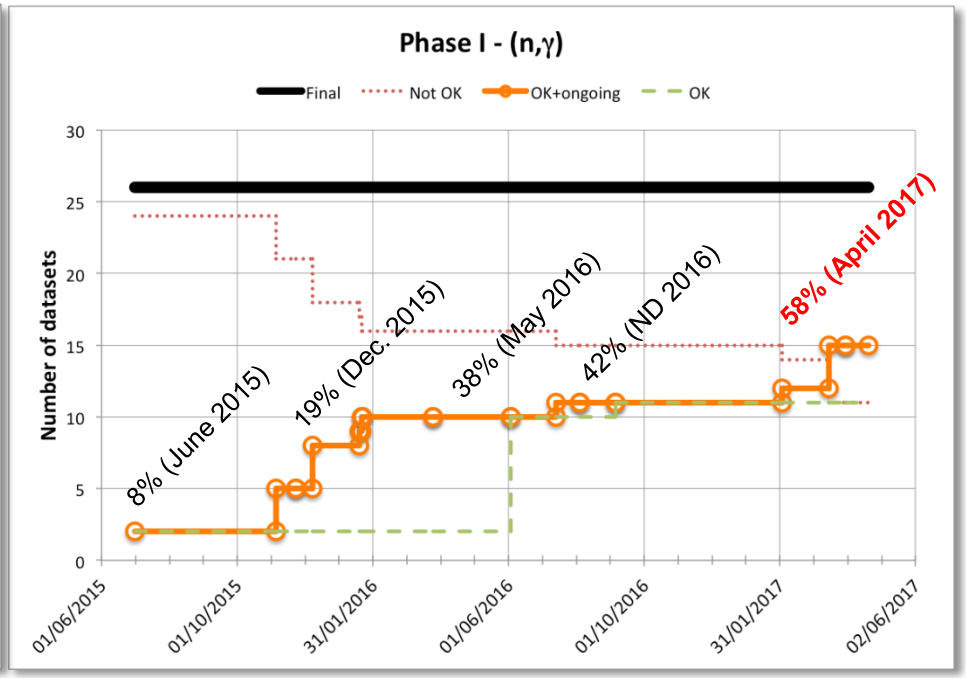
This is an option not only for n_TOF experiments but for any EXFOR related theses as long as the authors permit reproduction.
(Another example: INDC(FR)-73 for EXFOR 23114)

STATUS OF DATA DISSEMINATION

Progress in data dissemination

- n_TOF monitoring of the dissemination status since June 2015 (https://twiki.cern.ch/NTOFPublic/DataDissemination)





Slide presented by Emmeric Dupont (April 2017)

EXFOR Coverage for n_TOF Point-wise Data

As of	Phase I experiments (2001-2004)		Phase II experiments (2009-2012)	
	Capture	Fission	Capture	Fission
NRDC 2016	38%	100%	25%	100%
NRDC 2017	**62%**	100%	**71%**	100%

GELINA

- Cd transmission entry (S. Kopecky+ 2009, EXFOR 23077)
  - *A milestone for TOF spectrum compilation in EXFOR*

- Intensive EXFOR compilation of TOF spectra available agreed with GELINA in 2015.

- Hyeong-Il Kim (KNDC) created 6 entries for ^{238}U (his own work), ^{197}Au, ^{nat}Ce, ^{nat}W, ^{nat,63,65}Cu in 2016.

GELINA EXFOR Entries Prepared by H.I. Kim

Entry	Subent	Target	Quantity	primary reference	En min	En max	points
23302	1			J,EPJ/A,52,170,2016			
	2	^{238}U	average capture cross section		3.5 keV	80 keV	27
	3	^{238}U	LSQ capture cross section		3 keV	8.5 MeV	16
	4	^{238}U	Resonance parameter		6.674 eV	1.211 keV	108
	5	^{238}U	kT=25.3 keV qMACS				1
	6	^{238}U	capture yield		3.5 eV	1.2 keV	16108
	7	^{238}U	capture yield		150 eV	1.2 keV	10229
	8	^{238}U	capture yield		3.5 eV	1.2 keV	22252
23253	1			J,EPJ/A,50,124,2014			
	2	^{197}Au	average capture cross section		3.5 keV	84 keV	
23322	1		general description	R,EUR-28223,2016			
	2	^{nat}Ce	transmission		300 eV	200 keV	32399
	3	^{nat}Ce	transmission		300 eV	200 keV	32399

GELINA EXFOR Entries Prepared by H.I. Kim

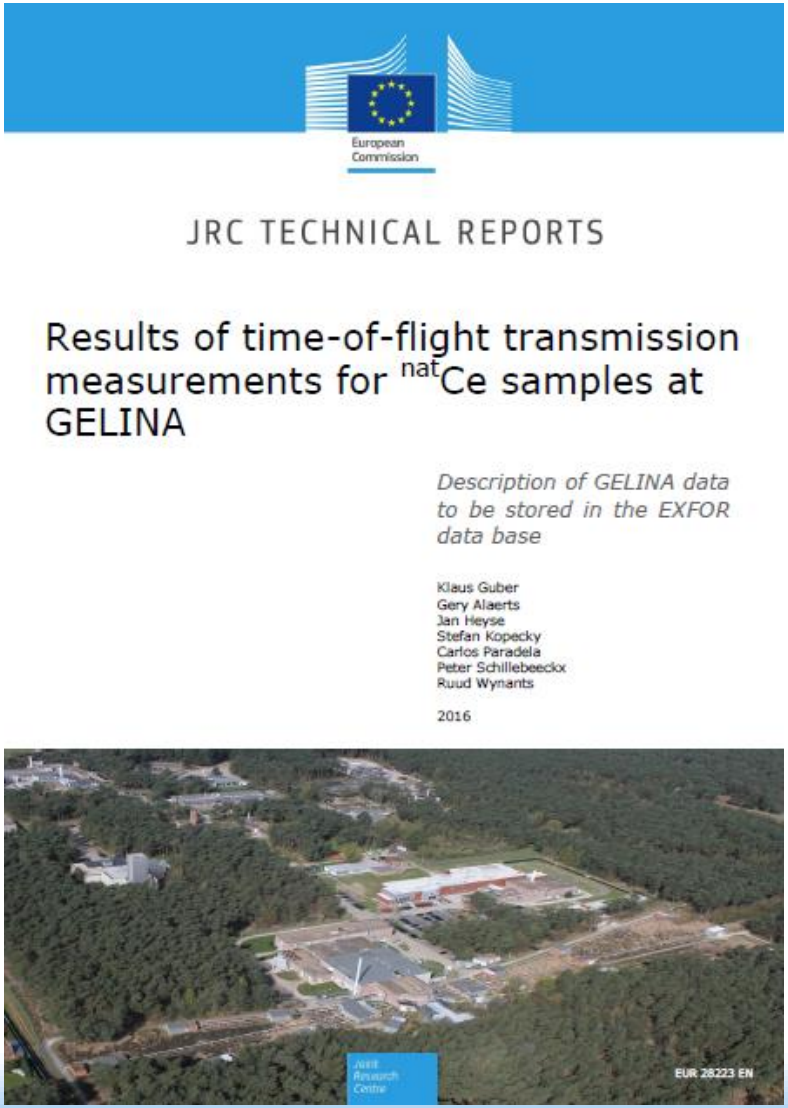
Entry	Subent	Target	Quantity	primary reference	En min	En max	points
23323	1		general description	J. EPJ/P,129,58,2014			
	2	^{nat}W	transmission		8.20 eV	2260 eV	31516
23324	1		general description	J,NIM/A,767,364,2014			
	2	^{nat}Cu	transmission		150 eV	90 keV	37673
	3	^{nat}Cu	transmission		150 eV	90 keV	37673
	4	^{nat}Cu	transmission		150 eV	90 keV	37673
	5	^{nat}Cu	transmission		150 eV	90 keV	37673
23325	1		general description	R,EUR-26479,2013			
	2	^{63}Cu	transmission		150 eV	90 keV	21528
	3	^{63}Cu	transmission		150 eV	90 keV	21528
	4	^{63}Cu	transmission		150 eV	90 keV	21528
	5	^{65}Cu	transmission		150 eV	90 keV	21528
	6	^{65}Cu	transmission		150 eV	90 keV	21528
	7	^{nat}Cu	transmission		150 eV	90 keV	21528

TOF Spectra in AGS Vectors (EXFOR 23302.006)

```
REACTION    (92-U-238(N,G)92-U-239,,RYL)
…
ERR-ANALYS Standard uncertainties at 1 standard deviation.
           (ERR-T) Total uncertainty
           (ERR-1,,,U) Uncorrelated uncertainty due to counting statistics
           (ERR-2,,,F) Correlated uncertainty due to background of capture, Bw (3%)
           (ERR-3,,,F) Correlated uncertainty due to background of flux, Bphi (3%)
           (ERR-4,,,F) Normalisation factor, Nc (1.5%)
…
```

EN	TOF-MIN	TOF-MAX	DATA	ERR-T	ERR-1	ERR-2	ERR-3	ERR-4
EV	NSEC	NSEC	NO-DIM	NO-DIM	NO-DIM	NO-DIM	NO-DIM	NO-DIM
3.501	499968	500096	.001018	.007551	.0041841	-0.006286	-2.718e-6	1.528e-5
3.503	499840	499968	.001774	.007583	.0042189	-0.0063	-4.75e-6	2.662e-5
3.505	499712	499840	.004423	.007591	.0042107	-0.006316	-1.193e-5	6.634e-5
3.506	499584	499712	.002119	.007539	.0041944	-0.006265	-5.692e-6	3.179e-5
3.508	499456	499584	.006625	.007415	.0041481	-0.006145	-1.777e-5	9.938e-5
3.51	499328	499456	.006378	.007458	.0041562	-0.006191	-1.709e-5	9.567e-5
3.512	499200	499328	.006912	.007361	.0041143	-0.006103	-1.851e-5	.0001037
3.514	499072	499200	.003434	.007437	.0041275	-0.006186	-9.167e-6	5.151e-5
3.515	498944	499072	.006013	.007424	.004135	-0.006165	-1.602e-5	9.02e-5
3.517	498816	498944	.004244	.007539	.0041992	-0.006261	-1.135e-5	6.366e-5
3.519	498688	498816	.004974	.007509	.004181	-0.006237	-1.33e-5	7.46e-5
3.521	498560	498688	.001106	.007418	.0041106	-0.006175	-2.942e-6	1.659e-5
3.523	498432	498560	-0.001017	.007534	.0041811	-0.006267	2.717e-6	-1.526e-5
3.524	498304	498432	.000962	.007499	.0041577	-0.00624	-2.567e-6	1.443e-5
3.526	498176	498304	.002477	.007422	.0041091	-0.00618	-6.593e-6	3.716e-5
3.528	498048	498176	.006016	.007305	.0040566	-0.006074	-1.608e-5	9.024e-5
3.53	497920	498048	.005343	.007406	.0040963	-0.00617	-1.433e-5	8.015e-5
3.532	497792	497920	-0.00015	.007461	.0041365	-0.00621	4.01e-7	-2.25e-6
3.534	497664	497792	-0.001106	.007495	.0041573	-0.006236	2.969e-6	-1.659e-5
3.535	497536	497664	.003577	.007562	.0042205	-0.006275	-9.674e-6	5.365e-5
3.537	497408	497536	.001442	.007606	.004196	-0.006344	-3.914e-6	2.163e-5

Detailed Documentation (K. Guber+, EUR-28223)



A. SUMMARY OF EXPERIMENTAL DETAILS

1.	**Main Reference**		[1,2]
2.	**Facility**	GELINA	[3]
3.	**Neutron production**		
	Neutron production beam	Electron	
	Nominal average beam energy	100 MeV	
	Nominal average peak current	55 μA	
	Repetition rate (pulses per second)	800 Hz	
	Pulse width	1 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)	
	Density (moderator material)	1 g/cm^3	
	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]
	Flight Path length (m) (centre moderator – detector front face)	L = 47.669(4) m	
	Flight path direction	9° with respect to normal of the moderator face viewing the flight path	
	Neutron beam dimensions at sample position	45 mm in diameter	
	Neutron beam profile	-	
	Overlap suppression	^{10}B overlap filter (8×10^{-3} at/b)	
	Other fixed beam filters	Co, W, Pb (16 mm)	
6.	**Detector**		
	Type	Scintillator (NE912)	
	Material	Li-glass	
	Surface Dimensions	151.6 mm diameter	
	Thickness (cm)	6.35 mm	
	Detector(s) position relative to neutron beam	In the beam	
7.	**Sample**		
	Type (metal, powder, liquid, crystal)	Metal	
	Chemical composition	^{nat}Ce (88.450% ^{140}Ce, 11.114 % ^{142}Ce; 0.251 % ^{138}Ce; 0.185 ^{136}Ce)	
	Sample composition (at/b)	^{nat}Ce (5.534 ± 0.025) 10^{-3} at/b and ^{nat}Ce (28.713 ± 0.025) 10^{-3} at/b	
	Temperature	22°C	
	Sample mass (g)	34.975 g and 187.954 g	
	Geometrical shape (cylinder, sphere, ...)	Cylinder	

Summary

n_TOF

- Newly finalized and published data are received without delay.
- Significant progress in retroactive compilation of capture yields.

GELINA

- Intensive compilation created 6 new entries done in 2016. (They have been already in EXFOR Master.)