Prepared for the SG-31 meeting on 23/May/2012

Status of SG31

Meeting Nuclear Data Needs for Advanced Reactor Systems

Status of Capture Cross Sections on C, ^{56}Fe, ^{241}Am, ^{244}Cm

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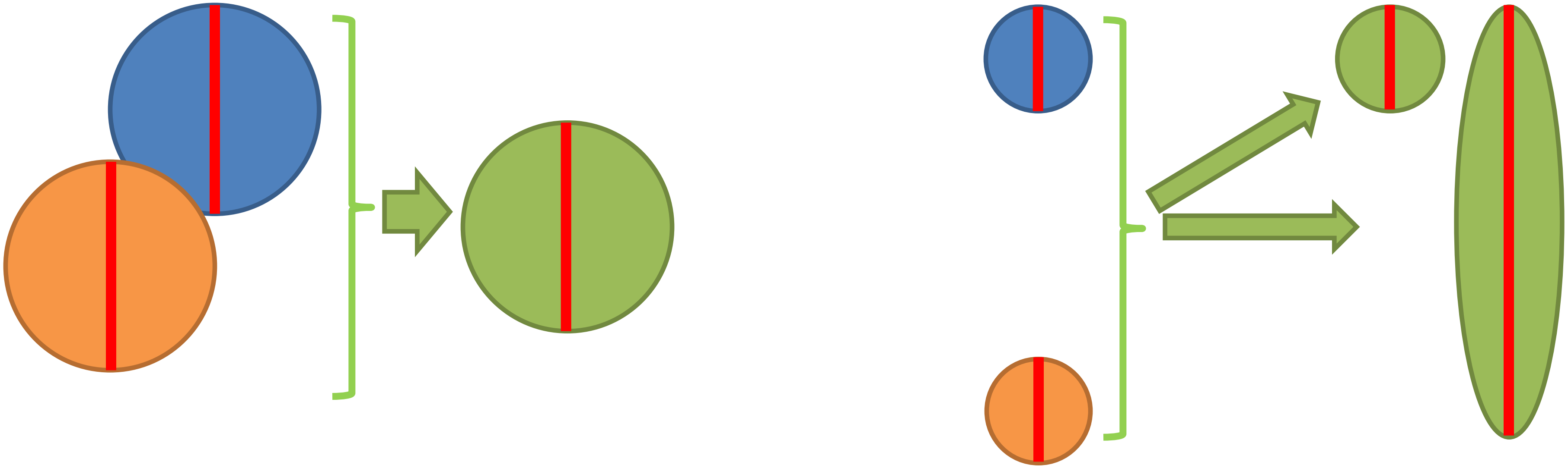
Precision to Accuracy

- Statistical Uncertainty
- Systematic Uncertainty
- Unrecognized Uncertainty
- **Importance of a double check or a triple check experiments**



Nuclear Data Requests From SG26

reactor	nucleus	reaction	range	initial	target L1	target N1	target N1B	lowE (eV)	highE (eV)
ADMAB (table 30)	Am241	capt	1.35MeV-0.454keV	8	2	2		4.54E+02	1.35E+06
GFR (table 28)	Am241	capt	183-2.03keV	8	3	3		2.03E+03	1.83E+05
SFR (table 26)	Am242m	capt	498-67.4keV	25	12	12	11	6.74E+04	4.98E+05
ADMAB (table 30)	Am243	capt	1.35MeV-0.454keV	10	2	2		4.54E+02	1.35E+06
ABTR (table 25)	B10	capt	498-183keV	15	14	11	9	1.83E+05	4.98E+05
LFR (table 29)	B10	capt	1.35MeV-2.03keV	15	2	2		2.03E+03	1.35E+06
SFR (table 26)	B10	capt	1.35MeV-9.12keV	15	4	3	3	9.12E+03	1.35E+06
VHTR (table 33)	C	capt	19.6-6.07MeV	20	7	7		6.07E+06	1.96E+07
VHTR (table 33)	C	capt	4-0.54eV	20	5	5		5.40E-01	4.00E+00
ADMAB (table 30)	Cm244	capt	498-9.12keV	20	6	6		9.12E+03	4.98E+05
ABTR (table 25)	Fe56	capt	183-2.03keV	12	8	6	5	2.03E+03	1.83E+05
ADMAB (table 30)	Fe56	capt	183-0.454keV	12	5	3		4.54E+02	1.83E+05
EFR (table 27)	Fe56	capt	2.03-0.454keV	12	8	5		4.54E+02	2.03E+03
LFR (table 29)	Fe56	capt	183-24.8keV	12	6	4		2.48E+04	1.83E+05
SFR (table 26)	Fe56	capt	183-0.454keV	12	5	4	3	4.54E+02	1.83E+05
EFR (table 27)	Ni58	capt	6.07-2.23MeV	15	9	5		2.23E+06	6.07E+06
ADMAB (table 30)	Np237	capt	498-0.454keV	6	3	3		4.54E+02	4.98E+05
PWR (table 34)	O	capt	6.07-2.23MeV	100	10	9		2.23E+06	6.07E+06
EFR (table 27)	O16	capt	6.07-2.23MeV	100	11	6		2.23E+06	6.07E+06

Experimental Uncertainty on C(n, γ)

reactor	nucleus	reaction	range	initial	targetL1
VHTR (table 33)	C	capt	19.6-6.07MeV	20	7
VHTR (table 33)	C	capt	4-0.54eV	20	5

Below 100 eV, 1/v curve
Thermal cross section

Table 1 Neutron capture cross section of carbon at 0.0253 eV

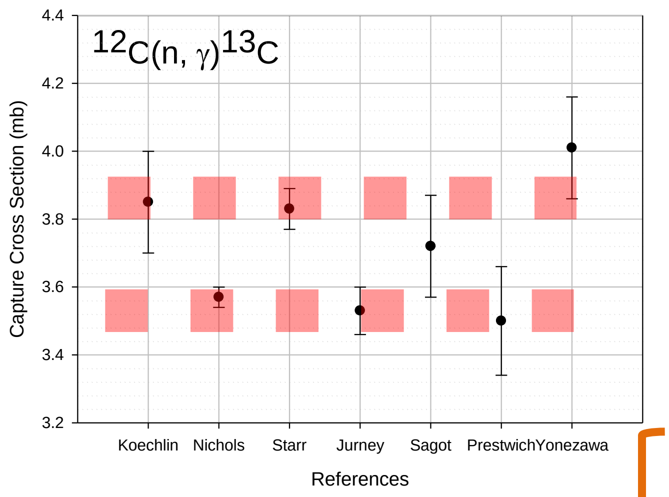
JENDL-4.0	JENDL-3.3	ENDF/B-VII.0	JEFF-3.1
3.85 mb	3.53 mb	3.36 mb	3.36 mb

+ 9 %

- 5 %

Firestone R.B et al.: Proc 2007 Int. Workshop on Compound- Nucleus Reactions and Related Topics, Yosemite 2007, p.26 (2007).

Experimental Uncertainty on C(n, γ) at thermal region



$^{12}C(n,\gamma)$ σ_0 Measurements

Reference	σ_0(mb)	Exp. Precision
Prestwich(1981)	3.50(16)	5 %
Jurney(1963)	3.53(7)	2 %
Nichols (1960)	3.57(3)	1 %
Sagot (1963)	3.72(15)	4 %
Starr (1962)	3.83(6)	2 %
Koechlin (1957)	3.85(15)	4 %
Yonezawa (2003)	4.01(15)	4 %
This work*	3.86(6) mb	
Mughabghab(2006)	3.53(7) mb	

2 % uncertainty
9 % discrepancy

* Average of measurements with various stoichiometric carbon compounds.

Exp. Discrepancy 15 %

Three Times larger than Exp. Precision

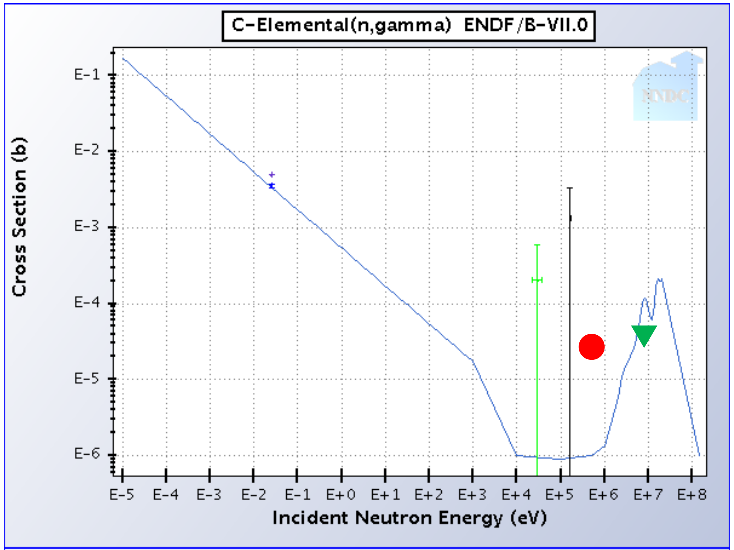
To cover the recent Exp.,

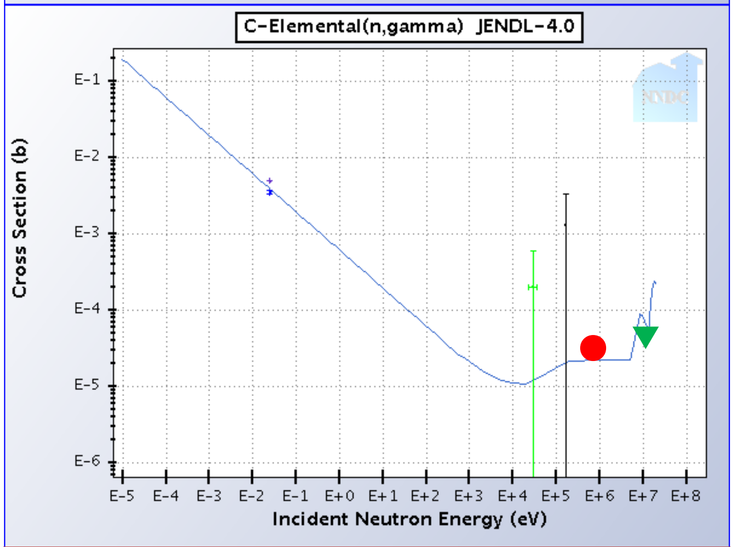
σ_0 3.50-0.16= 3.34 b
4.01+0.15=4.16 b
= 3.76+- 0.26 mb
(Uncertainty = 7 %)

A double check or a triple check experiments is required for 5 % accuracy.

Firestone R.B et al.: Proc 2007 Int. Workshop on Compound- Nucleus Reactions and Related Topics, Yosemite 2007, p.26 (2007).

Experimental Uncertainty on C(n, γ) at fast region





Discrepancy (factor ～20) between JENDL and ENDF

J,CNP,13,(2),97,1991 (CHN)

▼ 37.7±5.7 μb @ 9 MeV 15 % precision

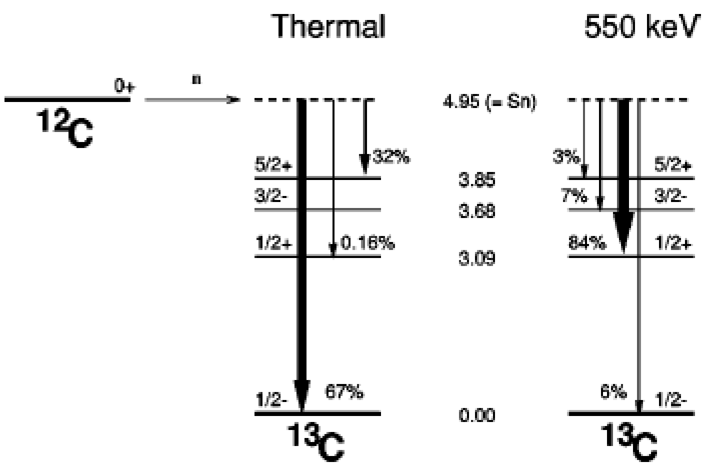
J,PR/C,35,393,8702 (USA)

6.9±0.3 μb @ 9 MeV (n, γ_0) 5 % precision

J. PR/C, 57,2724, 1998 (JPN)

● 29±1 μb @ 0.55 MeV (n, $\gamma_{0+1+2+3}$) 3 % precision

JENDL-4 22 μb @ 0.55 MeV

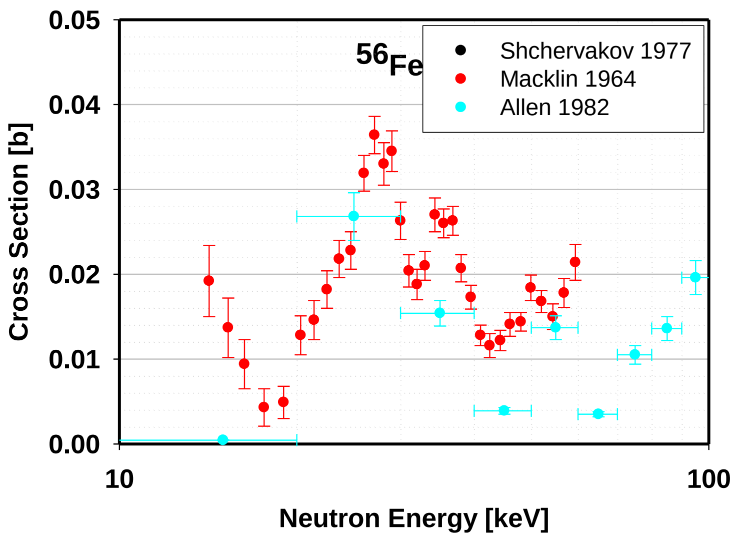


A double check or a triple check experiments is required for 5 % accuracy.

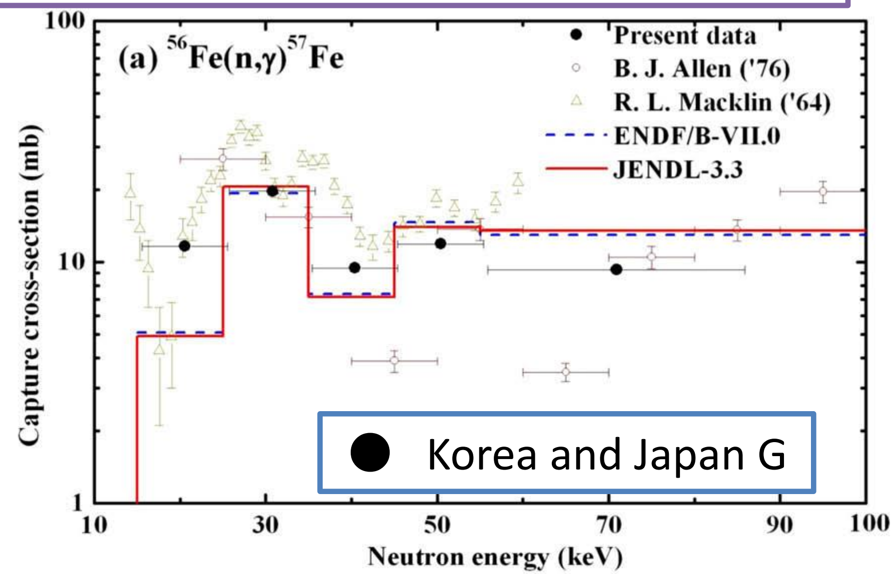
Experimental Uncertainty on $^{56}Fe(n, \gamma)$

reactor	nucleus	reaction	range	initial	targetL1
ABTR (table 25)	Fe56	capt	183-2.03keV	12	8
ADMAB (table 30)	Fe56	capt	183-0.454keV	12	5
EFR (table 27)	Fe56	capt	2.03-0.454keV	12	8
LFR (table 29)	Fe56	capt	183-24.8keV	12	6
SFR (table 26)	Fe56	capt	183-0.454keV	12	5

^{56}Fe: data before 2010



NIM/B,268,440,2010 → Uncertainty < 5 %
→ Precision < 5 %



Initial uncertainty on ^{56}Fe cap in SG-26 is too small.
Target uncertainty will be achieved using current technique.
A double check or a triple check should be done to guarantee the accuracy.

Experimental Uncertainty on $^{241}Am(n, \gamma)$: TOF data normalization

Weston et al. (1976) (0.01 eV – 370 keV) normalized to thermal cross section in ^{241}Am.

Reference	σ_0	I(0.369eV)	I(0.5eV)	I(0.5eV)/σ_0
JENDL-4.0	684.3 b		1588	2.32
Weston, 1976	582 b Normalization	1532 ± 92 b	1403 b Nakamura's calculation	2.41
Jandel, 2008	665 ± 33 b	-	1553 ± 7 b	2.34

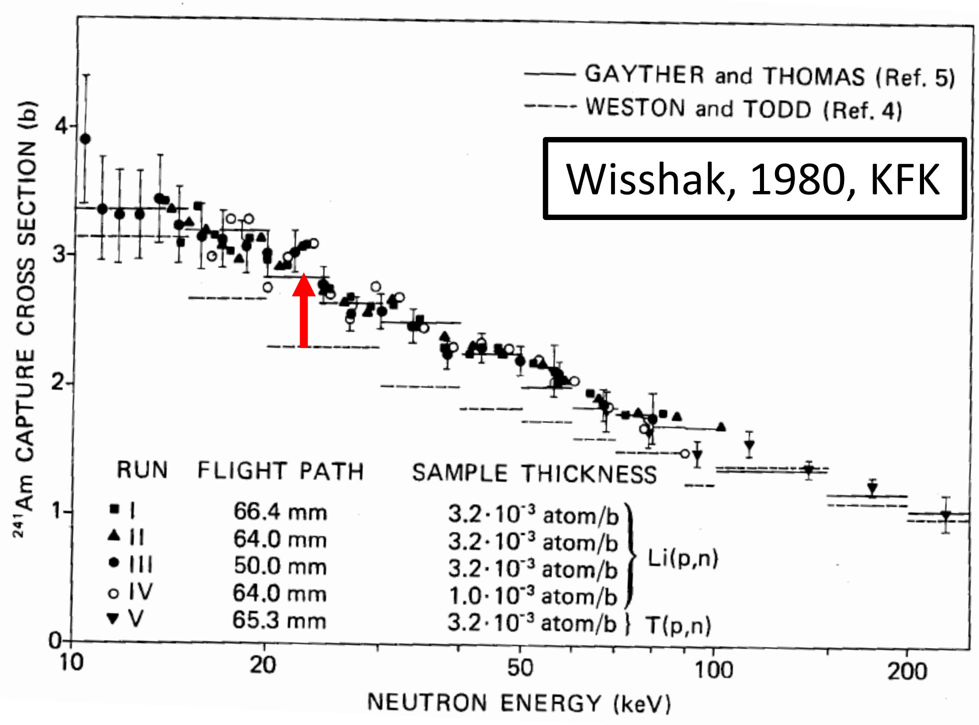
Agree within 3%

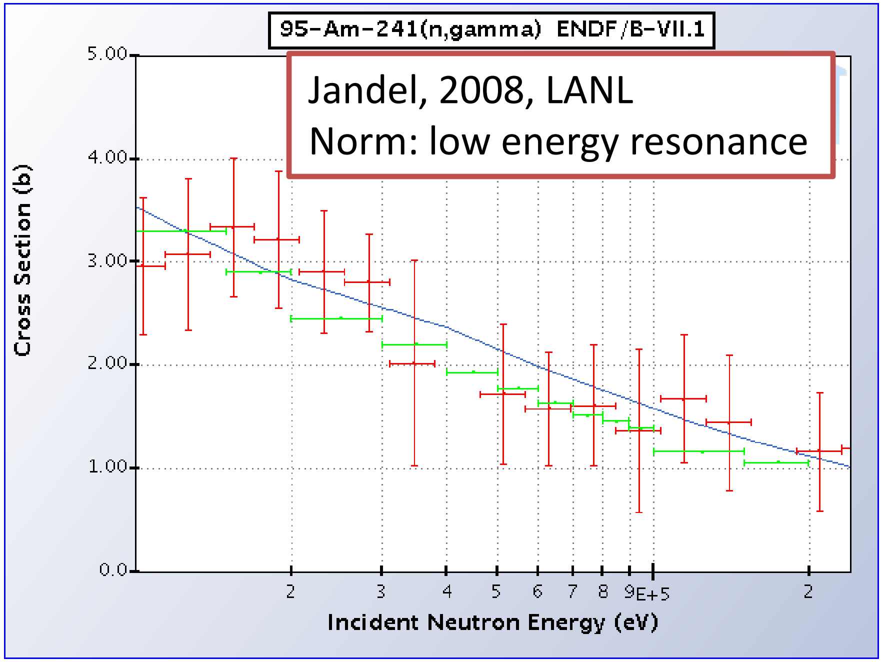
TOF data are sometimes normalized at thermal cross section or low energy resonances. Therefore, these data are important to reduce uncertainty of cross sections at higher energy.

Discrepancies will be reduced by careful evaluations.

Some standard cross sections, Au(n, γ) or $^{10}B(n, \alpha\gamma)$ etc., are also sometimes used for normalization. For measurements at high energy region with precision < 3 %, these data's accuracy need to be improved.

Experimental Uncertainty on $^{241}Am(n, \gamma)$





The discrepancy is solved by renormalization for En < 80 keV.

Vanpraet, 1986, IRMM
Norm: low energy resonance
Uncertainty:
Statistical: 0.5 %
Background: 5 %
Normalization and Flux: 5 %

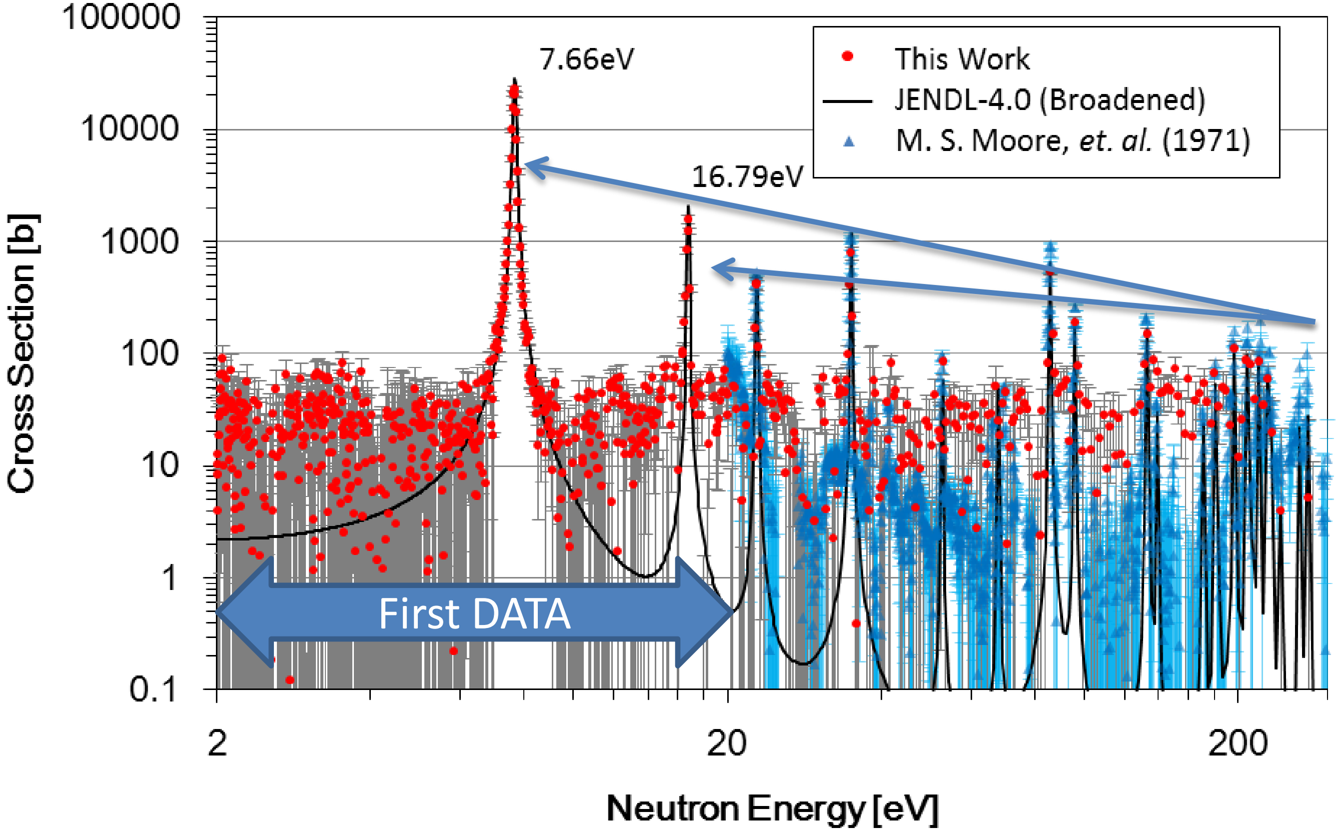
Experimental Uncertainty on $^{244}Cm(n, \gamma)$

A. Kimura (JAEA), *et. al*, JKPS, 59, 1828-1831, (2011)

J. Nucl. Sci. Technol., *to be published.*

Only one neutron-capture cross-section data of ^{244}Cm (n,γ) was reported in 1969.

M. S. Moore *et.al*. , Physical Review C, 3, 1656 (1971).

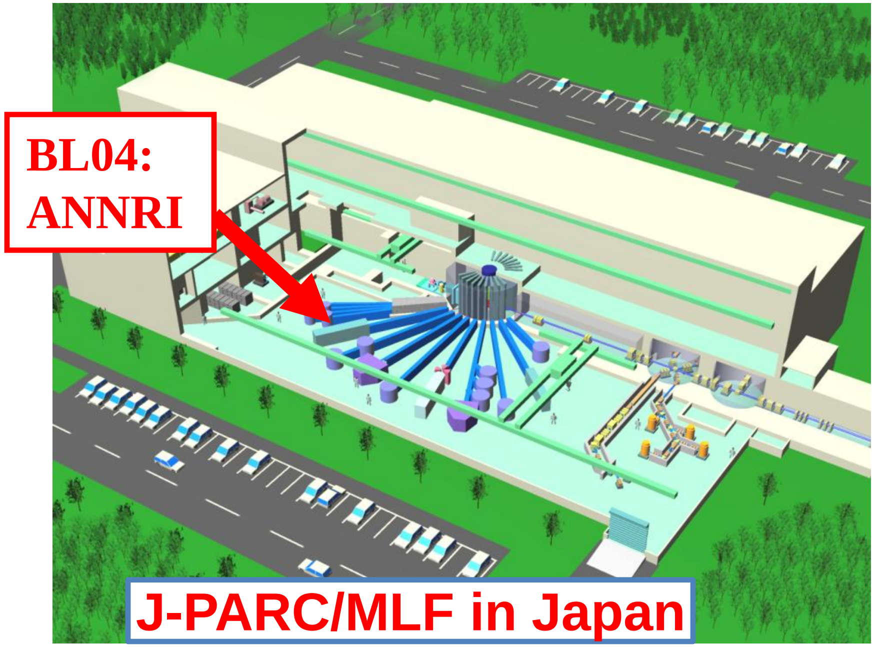


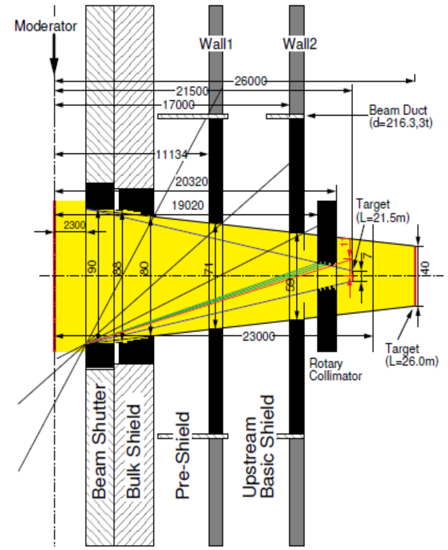
The results of the resonance peaks under 20 eV are also the first experimental results in the world!

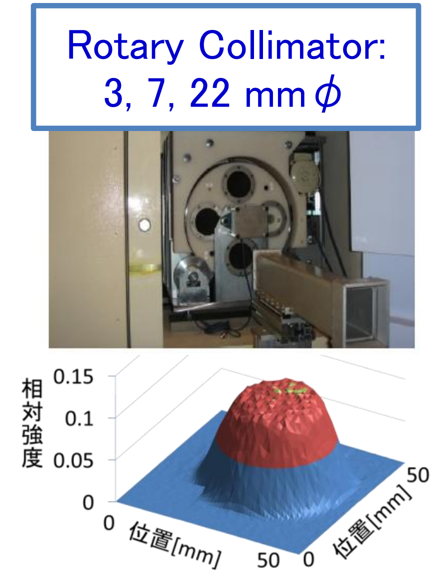
The previous measurement was performed using the nuclear explosion "Physics 8" as a pulsed neutron source in 1969.

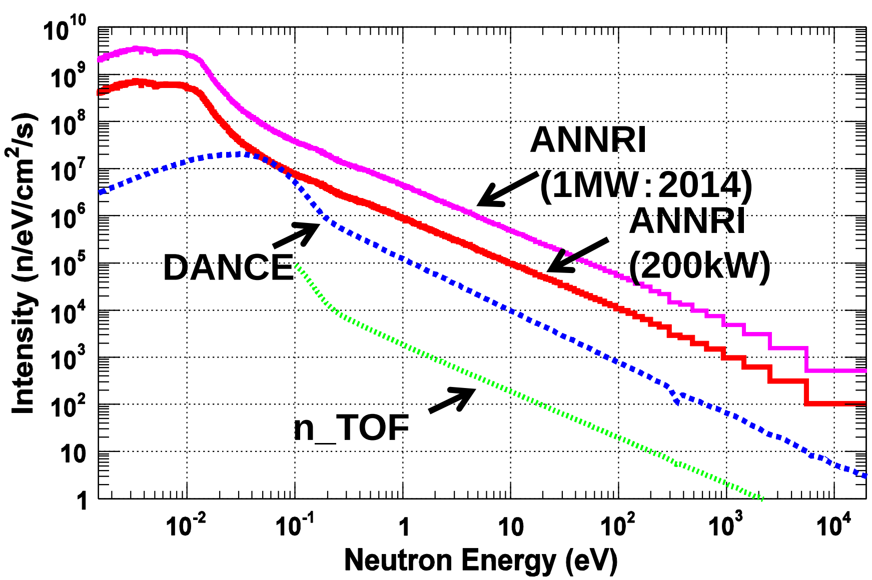
Uncertainties < 6 % for peak cross sections

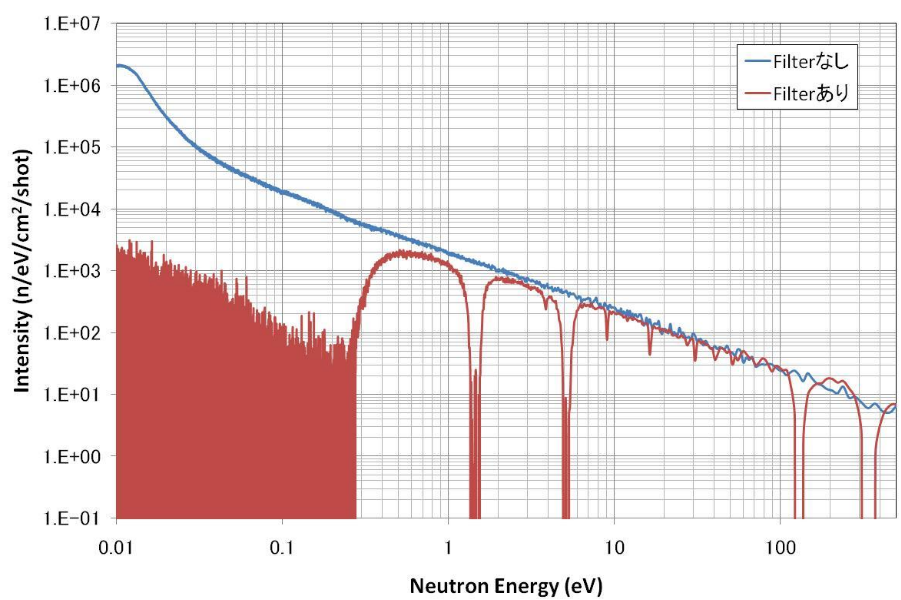
TOF data: background and statistics











Nuclear Data Requests From SG26

reactor	nucleus	reaction	range	initial	Comments To initial in SG-26	target L1	Comments To target accuracy in SG-26
ADMAB (table 30)	Am241	capt	1.35MeV-0.454keV	8	Reasonable for E < 80 keV	2	Very Challenging Need Standard < 1%
GFR (table 28)	Am241	capt	183-2.03keV	8	Reasonable for E < 80 keV	3	Challenging Need Standard < 2%
VHTR (table 33)	C	capt	19.6-6.07MeV	20	Under Estimation	7	Achievable DCE is recommended
VHTR (table 33)	C	capt	4-0.54eV	20	Over Estimation	5	Achievable DCE is recommended
ADMAB (table 30)	Cm244	capt	498-9.12keV	20	Under Estimation	6	Challenging but Achievable
ABTR (table 25)	Fe56	capt	183-2.03keV	12	Under Estimation	8	Achievable DCE is recommended
ADMAB (table 30)	Fe56	capt	183-0.454keV	12	Under Estimation	5	Achievable DCE is recommended
EFR (table 27)	Fe56	capt	2.03-0.454keV	12	Under Estimation	8	Achievable DCE is recommended
LFR (table 29)	Fe56	capt	183-24.8keV	12	Under Estimation	6	Achievable DCE is recommended
SFR (table 26)	Fe56	capt	183-0.454keV	12	Under Estimation	5	Achievable DCE is recommended

DCE: double check experiment