DE LA RECHERCHE À L'INDUSTRIE

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STATUS OF THE UO2 MEASUREMENTS AT ILL FROM ROOM TO 900 K

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16-18 May 2017

Experimental programs

2010

⇒ Light and heavy water in IN5 and IN4 at ILL **in cold operating conditions**

- H20: 285 K, 290 K, 294 K, 300 K 302 K, 311 K, 323 K (P = 1bar)
- D20: 250 K (ice), 295 K, 296 K, 325 K

2015

⇒ Light and heavy water in IN6 and IN4 at ILL **in hot operating conditions**

- T = 300 - 540 K and P=1 - 600 bar

2016

⇒ Measurement of the double-differential neutron cross section of U in UO2 in IN6 and IN4 **from room temperature to Hot Full Power conditions**

- T = 294 K, 600 K et 900 K

2018

⇒ Measurement of the double-differential neutron cross section of U in UO2 up to 2000 K

Experimental programs

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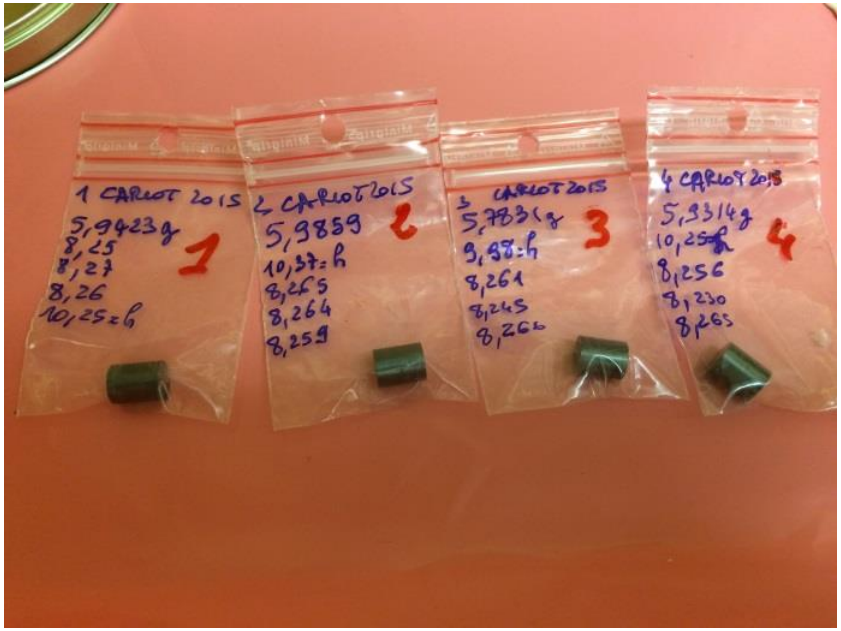
Objectives of the experimental program

- Experimental validation of the new NCSU evaluation
- Comparison MCNP/TRIPOLI calculations
- Recommendation of effective températures for PWR calculations

Sample preparation

Raw material ⇒ provided by the Fuel Studies Department (DEC, CEA Cadarache)*



	Pastille 1	Pastille 2	Pastille 3	Pastille 4
Masse (g)	5,9423	5,9859	5,7831	5,9314
Hauteur (mm)	10,25	10,37	9,98	10,25
diamètre (mm)	8,25	8,265	8,261	8,256

[1]unites g/100gU
234 U = 0.002+-.001

235 U = 0.300+-.008

236 U = 0.006+-.001

238 U = 99.692+-.010

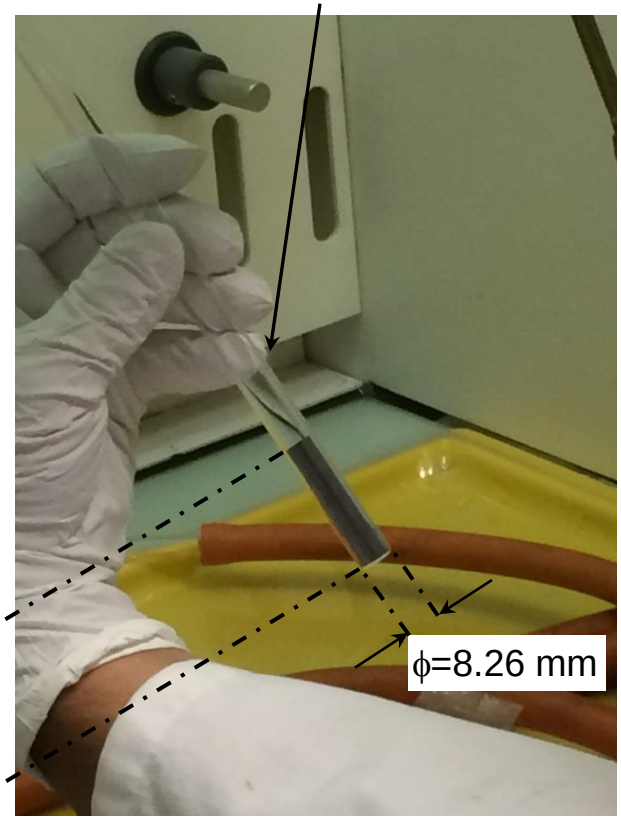
[2]unites g/100gUO2
U = 87.87+-0.04
at/at
O/U = 2.04+-0.01

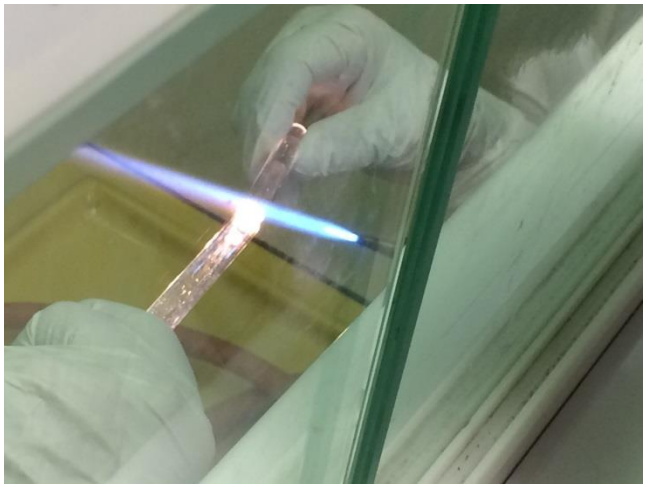
[7]unites g/100gUO2
H2O = 0.08+-0.02

* Special thanks to G. Carlot, L. Desgrange, G. Jomard, G. Philippe

Sample preparation at ILL

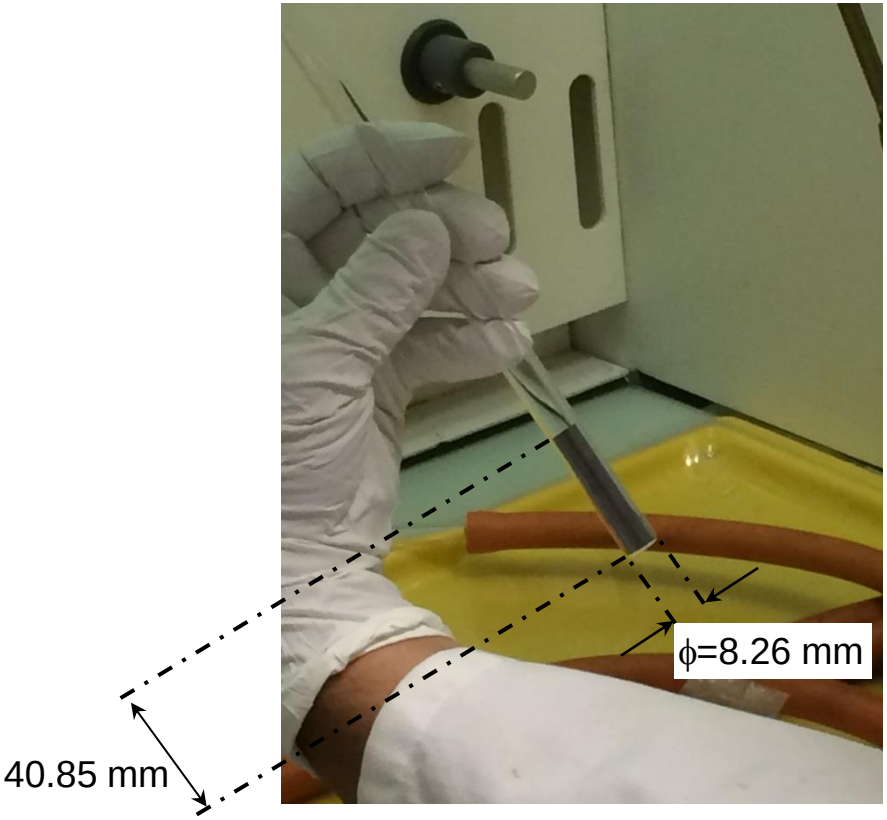
Standard quartz tube
ϕ_{int}=9 mm, ϕ_{ext}=11 mm, e=1 mm





Sample sealed under vacuum
(P. Mouveau)

Sample preparation at ILL



Sample holder in Vanadium
e=50μm 99.8-99.9%
(F. Marchal)

Spectrometer IN4

Sample	Neutron energie	Temperature	Time	Run
UO2	111,9 meV (0,855 A)	290,15 K (17°C)	12h	88121-88144
	111,9 meV (0,855 A)	591,15 K (318°C)	12h31min	88146-88171
	111,9 meV (0,855 A)	901,8 K (628,65°C)	12h	88174-88197
	66.4 meV (1,11 A)	902,15 K (629°C)	7h46min	88198-88213
	111,9 meV (0,855 A)	296,15 K (23°C)	3h57min	88257-88264
	66.4 meV (1,11 A)	296,15 K (23°C)	2h46min	88265-88270
Vanadium	66.4 meV (1,11 A)	288,18K (15°C)	1h30min	88396-88398
	111,9 meV (0,855 A)	287,15K (14°C)	4h02min	88399-88407
Dummy	111,9 meV (0,855 A)	290,15K (17°C)	6h	88468-88479
	111,9 meV (0,855 A)	598,15K (326°C)	6h	88482-88493
	111,9 meV (0,855 A)	905,15K (632°C)	6h	88496-88507
	66.4 meV (1,11 A)	905,15K (632°C)	3h	88508-88513
	66.4 meV (1,11 A)	306,15K→297,15K 33°C→24°C	4h58min	88542-88551

Two energies

- 66 meV
- 112 meV

Three temperatures

- T=300 K
- T=600 K
- T=900 K

Spectrometer IN6

Sample	Neutron energie	Temperature	Time	Run
UO2	3 meV (5,12 A)	336,15K→324,15K (63°C→51°C)	20h	189008 - 189048
	3 meV (5,12 A)	584,15K (311°C)	7h	189049-189062
	3 meV (5,12 A)	888,15K (615°C)	6h	189064-189075
	3 meV (5,12 A)	306,15K→302,15K (33°C→29°C)	12h30min	189233-189257
	3 meV (5,12 A)	587,15K 314°C	6h30min	189259-189271
	3 meV (5,12 A)	890,15K (614°C)	12h30min	189272-189296
Vanadium	3 meV (5,12 A)	304,55K (31,4°C)	2h30min	189094-189098
Dummy	3 meV (5,12 A)	302,68K (29,53°C)	18h	189101-189136
	3 meV (5,12 A)	594,15K (321°C)	15h	189138-189167
	3 meV (5,12 A)	598K (324,85°C)	18h	189169-189204

Energy : 3 meV

Three temperatures

- T=300 K
- T=600 K
- T=900 K

Data analysis

```
$Rev::          $  $Date::            $                                1 0  0     0
1.480000+2 2.360058+2          -1          0           0           1  48 1451     1
0.000000+0 0.000000+0           0          0           0           6  48 1451     2
1.000000+0 5.000000+0           0          0          12           8  48 1451     3
0.000000+0 0.000000+0           0          0          31           3  48 1451     4
U(UO2)     LEIP LAB    EVAL-OCT16 J.L. Wormald, Y. Zhu, A.I. Hawari  48 1451     5
                       DIST-                                         48 1451     6
----ENDF/B-VIII.beta3 MATERIAL   48                                  48 1451     7
-----THERMAL NEUTRON SCATTERING DATA                                 48 1451     8
------ENDF-6 FORMAT                                                 48 1451     9
Temperatures = 296 400 500 600 700 800 1000 1200 K                   48 1451    10
                                                                     48 1451    11
Background                                                           48 1451    12
-------                                                              48 1451    13
This library was produced by the Low Energy Interaction Physics      48 1451    14
(LEIP) group at NC State University. The inelastic scattering        48 1451    15
thermal scattering law data for UO2 were developed using             48 1451    16
ab-initio lattice dynamics methods [1,2]. The LEAPR module           48 1451    17
from the NJOY code system was used to produce File 7 MT=2 and 4      48 1451    18
for U in UO2 and O in UO2. Modifications to the LEAPR module were    48 1451    19
made to calculate the coherent elastic cross-section for UO2 [3].    48 1451    20
Per convention, MAT=48 and ZA=148 are used for U in UO2.             48 1451    21
                                                                     48 1451    22
References                                                           48 1451    23
----------                                                           48 1451    24
1. A.I. Hawari, et al "Ab Initio Generation of Thermal Neutron       48 1451    25
   Scattering Cross Sections," Proceedings of PHYSOR 2004: The       48 1451    26
   Physics of Fuel Cycles and Advanced Nuclear Systems ---           48 1451    27
   Global Developments (2004).                                       48 1451    28
2. J.L. Wormald, A.I. Hawari "Ab Initio Generation of Thermal        48 1451    29
   Scattering Law for Uranium Dioxide," Transactions of the          48 1451    30
   American Nuclear Society, v 115 (2016)                            48 1451    31
3. Y. Zhu, A.I. Hawari, "Implementation of a Generalized Coherent    48 1451    32
   Elastic Scattering Formulation for Thermal Neutron Scattering     48 1451    33
   Analysis," Proceedings of ICNC 2015: 35th International           48 1451    34
   Conference on Nuclear Criticality Safety (2015)                   48 1451    35
                              1         451          38           0  48 1451    36
                              7           2        1305           0  48 1451    37
                              7           4       46810           0  48 1451    38
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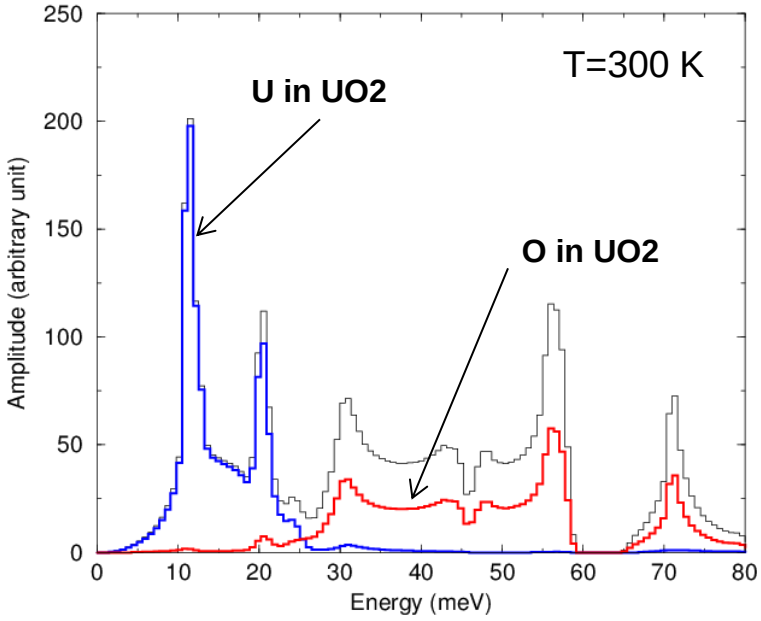
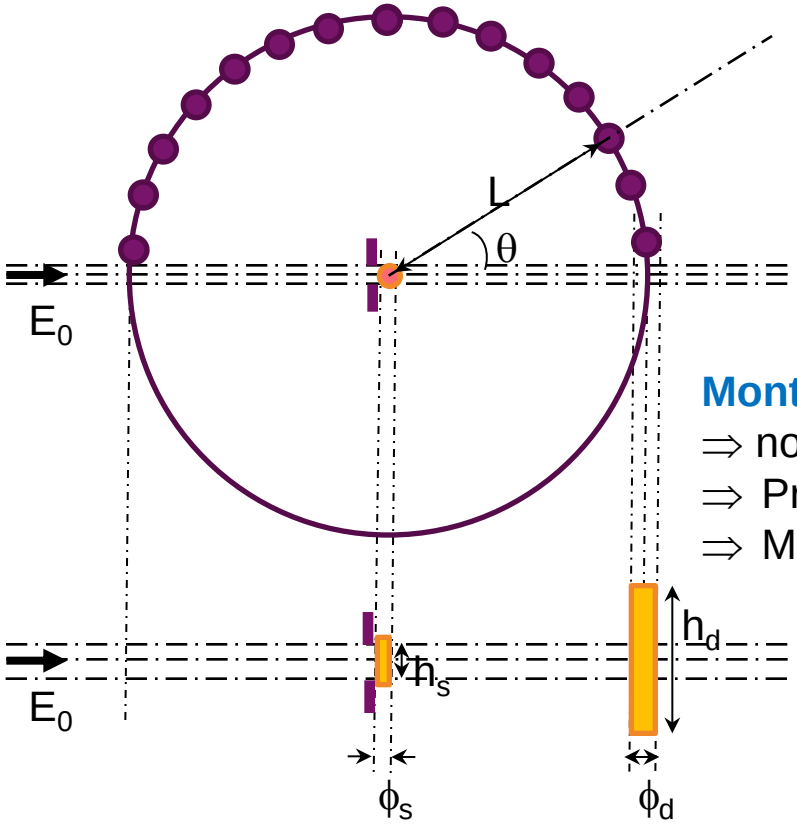
New TSL file from NCSU



Data analysis



Monte-Carlo simulation with TRIPOLI4

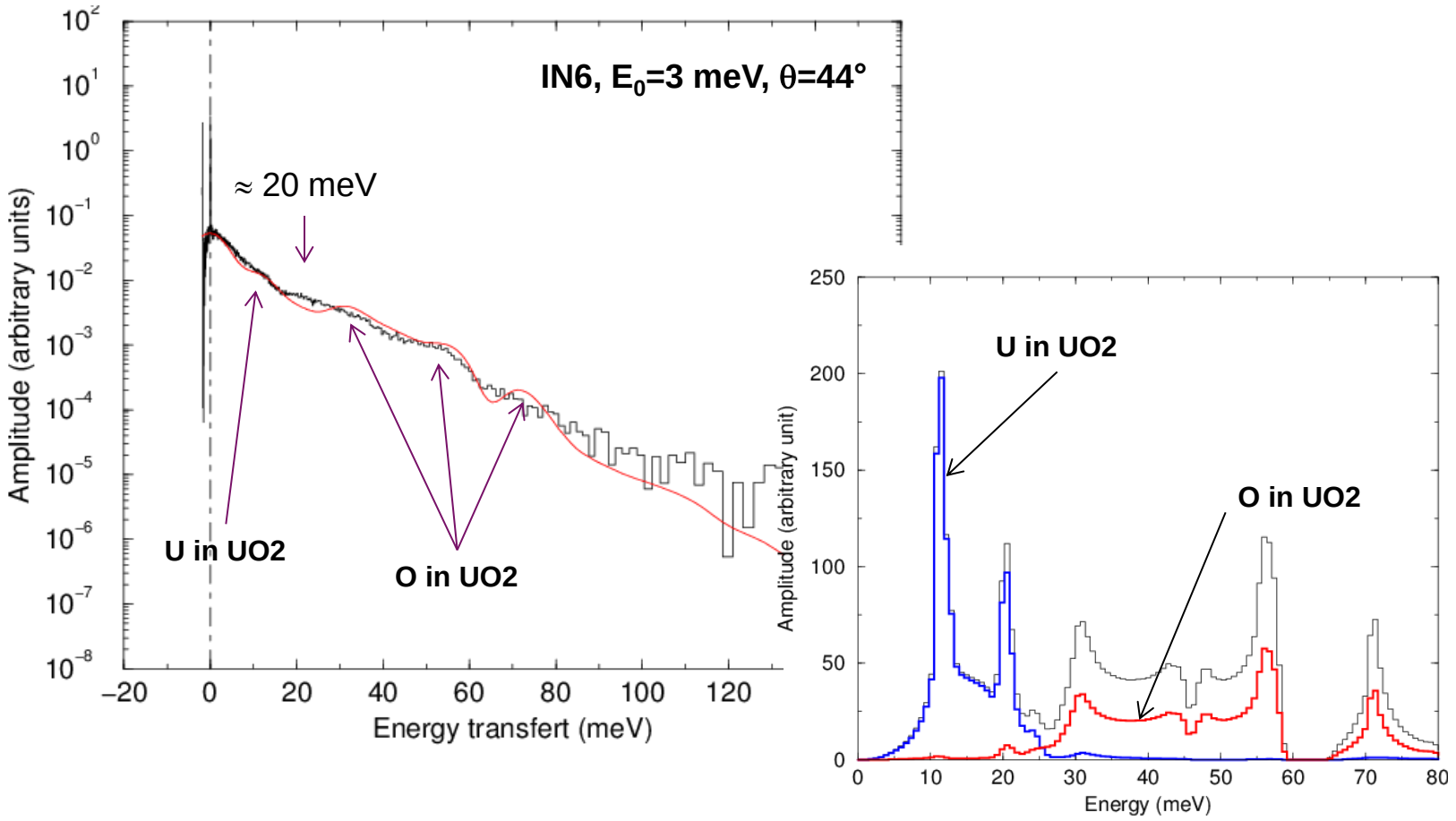
⇒ not yet possible !!!

⇒ Problems with the processing of the TSL library of U in UO2

⇒ MCNP input in preparation

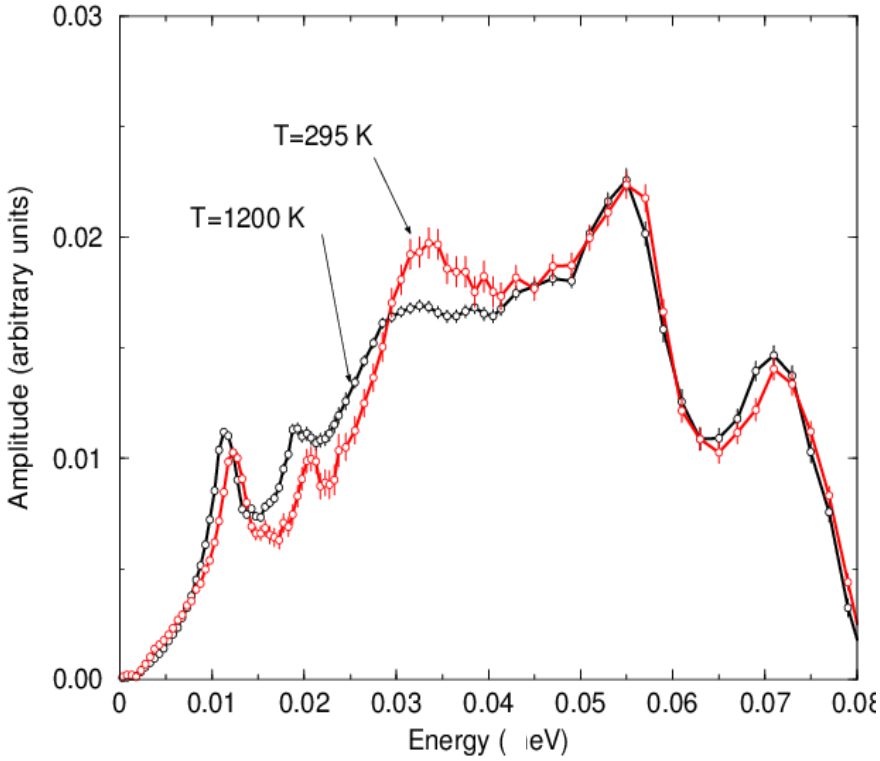
Double differential cross section at room temperature

⇒ simple comparison with ddxs calculated with the S(α,β) established by NCSU

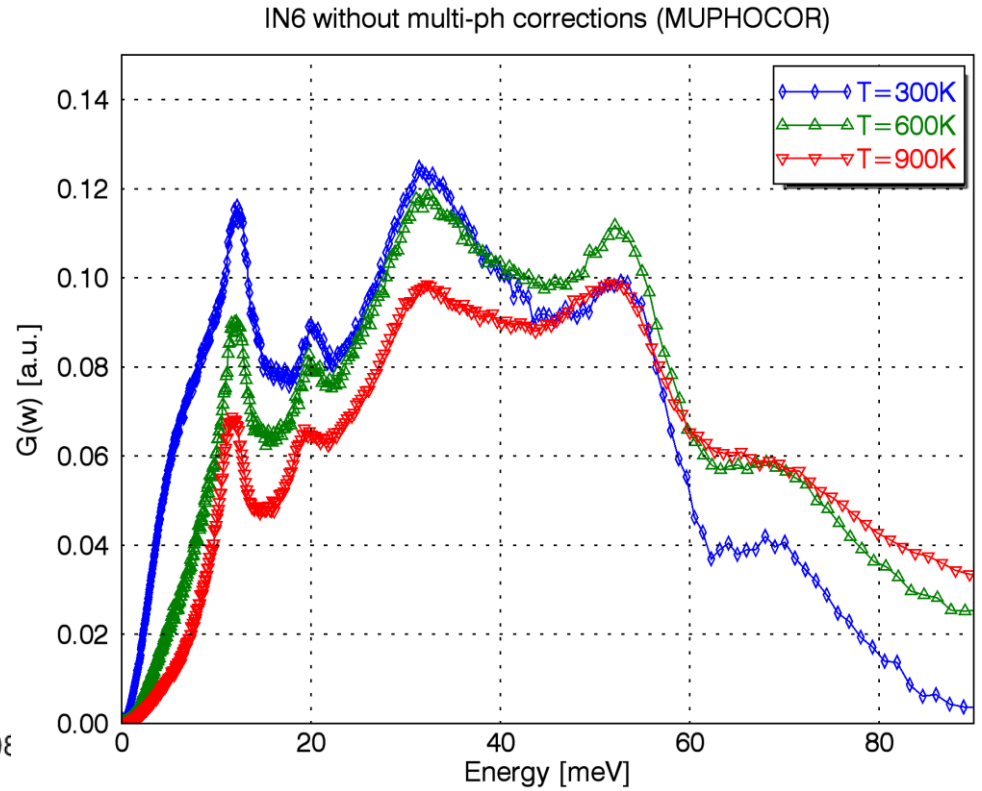


Experimental density of states of UO2

Comparison with data from J. Pang (Phys. Rev. B89, 115132, 2014)



Neutron-weighted phonon density of states of UO2 (J. Pang)



Density of states of UO2 extracted from the IN6 data by J. Ollivier, ILL

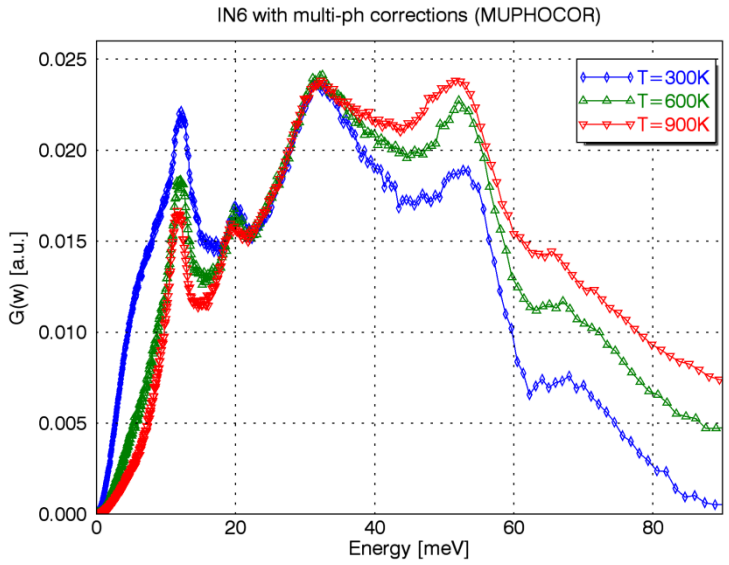
Next experimental program (2018)

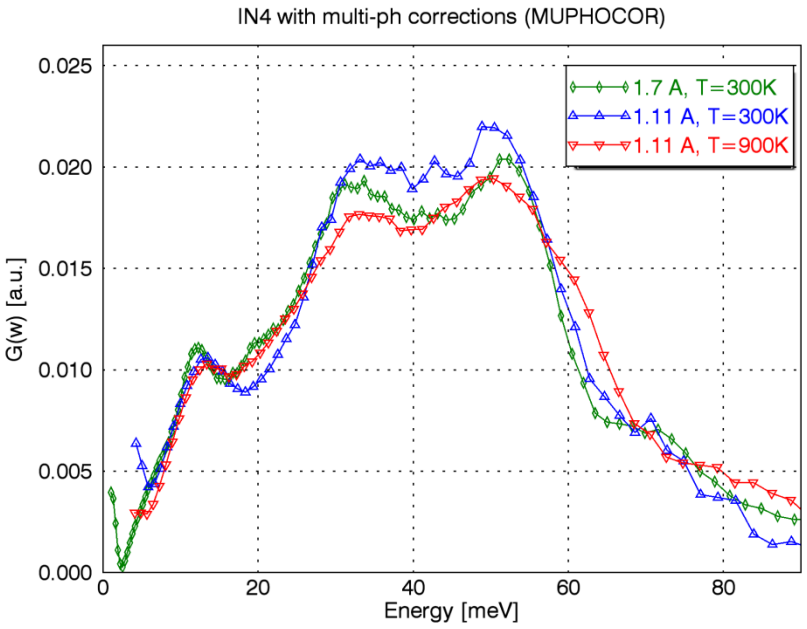
Measurement of the double-differential neutron cross section of U in UO2 up to 2000 K

- Main problem ⇒ sealed tubes are needed
- Strong efforts from JRC-Karlsruhe (**R. Caciuffo**) and ILL (**A. Filhol**) to find a solution ⇒ laser welding (Nb or Mo tubes)

Any suggestions are welcome !

Back up slides





Back up slides