Measurements of thermal neutron data using a low-intensity pulsed neutron source

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ARGENTINA

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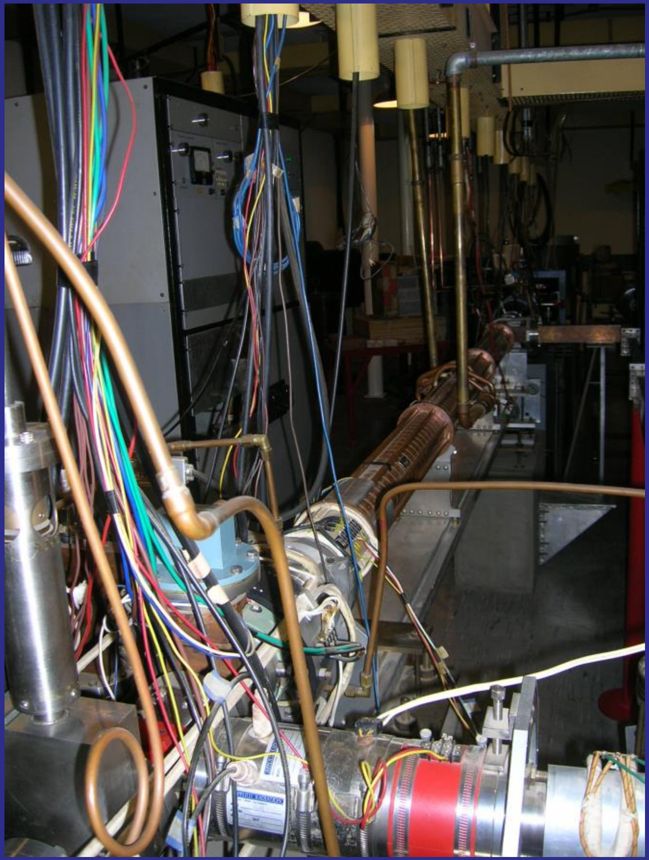
The Neutron Physics Department at Centro Atómico Bariloche was founded in 1969 by Hector Antunez , one of the alumni of the legendary neutron physics group at General Atomics in San Diego.

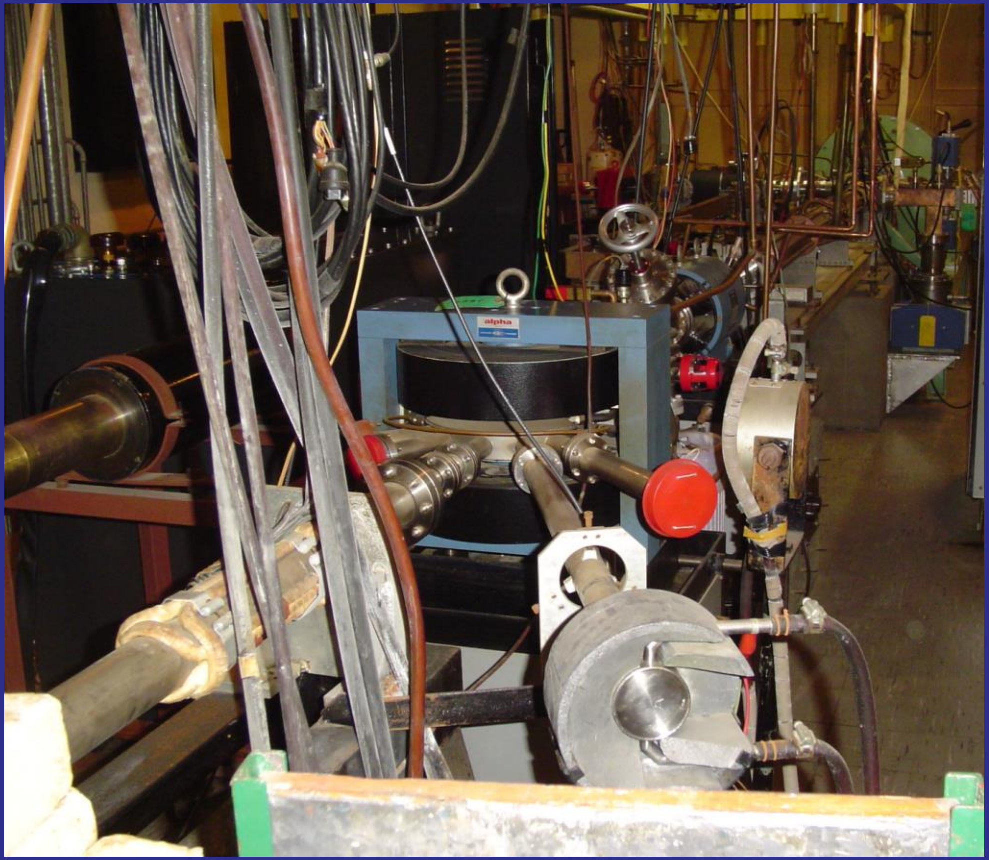
The group was created towards a small pulsed neutron source, a 25 MeV electron LINAC, similar to the accelerator at RPI.

Now we are 23 people (counting researchers, students and technical staff) working on neutron physics and applications to condensed matter research, materials science and nuclear engineering.

Our main current activity is the development of neutron scattering instruments for the forthcoming RA-10 reactor, which will be similar to the OPAL reactor that the Argentine company INVAP built in Australia.

BARILOCHE 25 MeV ELECTRON LINAC





Bariloche e-LINAC

Situated at the

Neutron Physics Department

(Centro Atómico Bariloche).

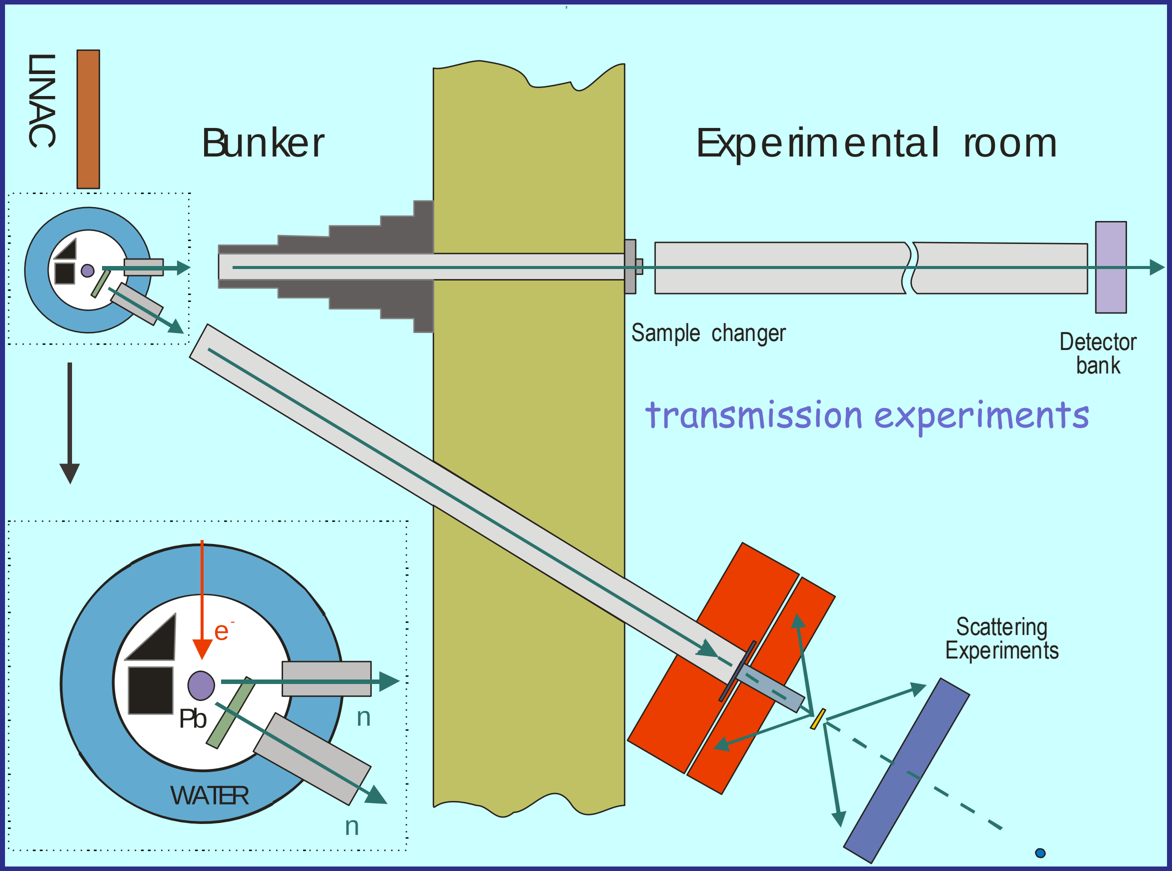
It started operation in 1969

It belongs to National Commission of Atomic Energy

Pulsed accelerator which uses a microwave of 2856 MHz to accelerate electrons upto 25 MeV

Electron pulses can be extended upto 2 μs, with a repetition frequency of 150 pps

It reaches its maximum neutron production operating at 100 pps (~ 10^{11} n/s) and 25 μA mean current



Neutrons are born as fast neutrons by means of the reaction (γ,n) in the Pb target

To get a thermal spectrum, 2 cm of a polyethylene moderator is used

To get a subthermal spectrum, 2 cm of mesitylene at 77K is used

Two lines are available: transmission experiments and scattering experiments

EDUCATION AND TRAINNING ACTIVITIES

• Neutron Die-away time as function of moderator dimensions and poisoning

• Neutron flux distribution through activation probes

•Total cross section measurements

•Resonances (thermal range)

• Neutron spectra determination by TOF

• Multiplication Factor of Fuel Assembly
(loss of coolant simulation)

RESEARCH ACTIVITIES

- Total Cross section measurements
(from subthermal to epithermal energies)

- Neutron Spectra measurements
(multiplicative and non-multiplicative systems)

- Neutron Diffraction

- Deep Inelastic Neutron Scattering (DINS)

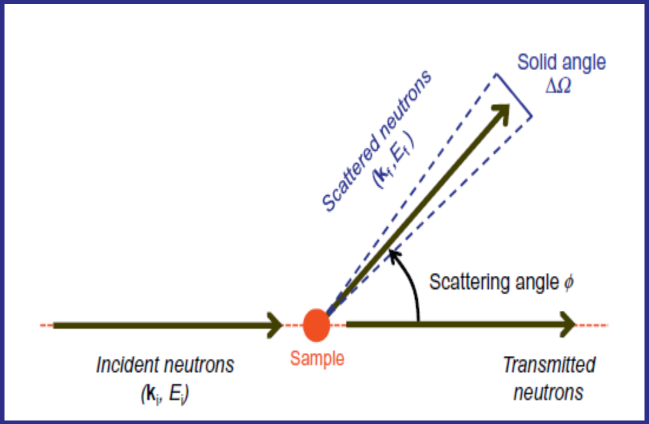
- Non-destructive determination of hydrogen content

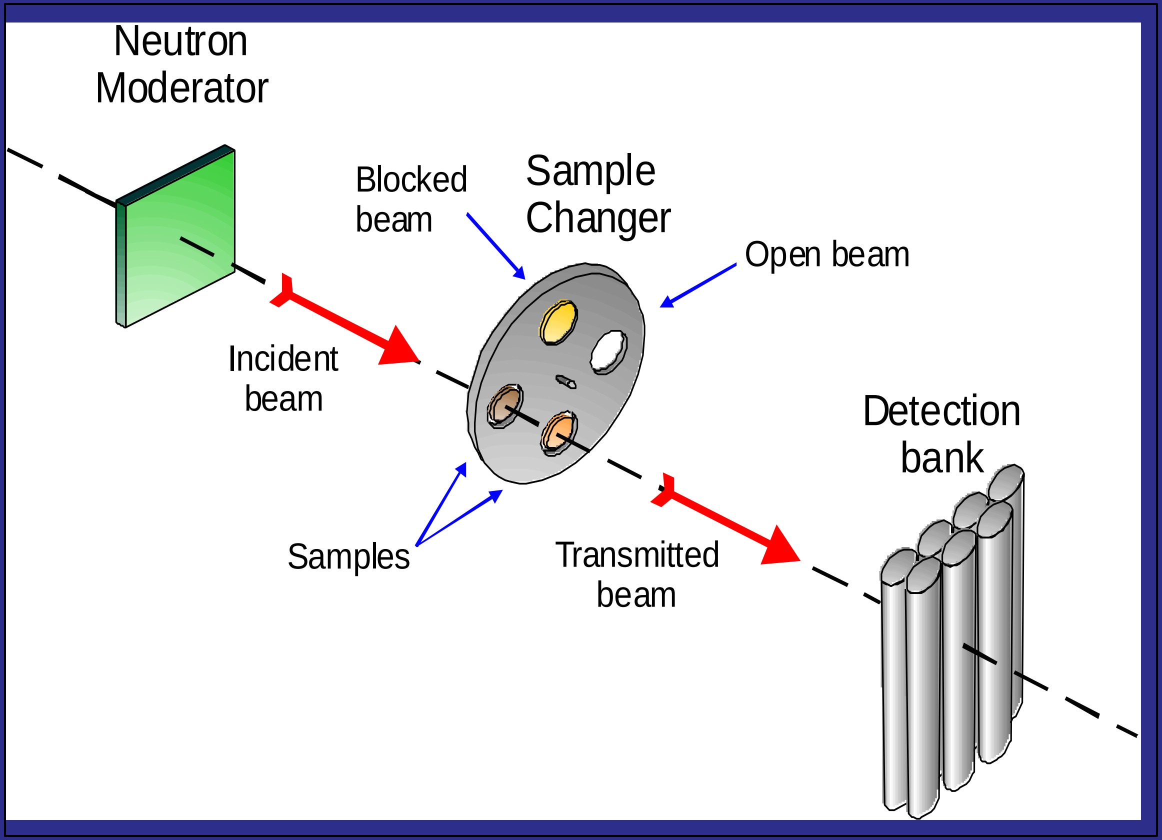
- Cryogenic Materials studies

- Complementary Techniques for Cargo Scanning

- Texture studies

Total Cross section measurements : transmission experiment





$$I = I_o e^{-\Sigma x}$$

$$Tr(E_0) = \frac{I}{I_0} = e^{-nd\sigma(E_0)}$$

Sample-in sample-out technique is used to minimize the effect of beam power fluctuations. It consists in inserting and removing the sample from the neutron beam every 20 min approximately.

$$Tr(E_0) = \frac{\dfrac{\phi_M(E_0)}{M_M} - \dfrac{\phi_{BG}(E_0)}{M_{BG}}}{\dfrac{\phi_{TL}(E_0)}{M_{TL}} - \dfrac{\phi_{BG}(E_0)}{M_{BG}}}$$

Measured spectra are normalized using the integral counts from a monitoring ^3He detector (M_M, M_{BG}, M_{TL})

Background is measured and subtracted from both the incident and the transmitted beam spectra

The neutron energy is determined by means of the time-of-flight technique.

The time of flight scale is corrected by the mean emission time of the moderator

Spectra are corrected by dead time effects from detectors and electronics

Technical Notes

The first paper, 1972

Total Neutron Cross Section of Mylar at Low Energies

C. Castro Madero, F. Kropff, and A. Oliva

Comisión Nacional de Energía Atómica
Centro Atómico Bariloche
San Carlos de Bariloche, Argentina

and

J. M. Neill

Gulf Radiation Technology
P. O. Box 608
San Diego, California 92112

Received June 30, 1972

ABSTRACT

The total neutron cross section of Mylar has been measured in the range 0.007 to 20 eV by the time-of-flight transmission method.

The total neutron cross section of Mylar ($C_{10}H_8O_4$) has been measured in the range 0.007 to 20 eV by the time-of-flight transmission method, using a 25 MeV Linac and a fansteel target as a pulsed neutron source. The objective of the measurement was to obtain cross sections which could be used to correct spectral data from time-of-flight systems employing Mylar windows, as is frequently the case. A 20-× 20-× 10-cm block of paraffin thermalized the neutrons and was viewed through an 8-cm-diam collimator leading to a 17-m evacuated flight path. A 12.5-cm-diam by 1.27-cm-thick ^{6}Li glass scintillator coupled to an EMI-9618R photomultiplier tube was employed as the detector at the end of the flight path.

Four Mylar samples with neutron transmissions at ~10 eV ranging from 70 to 90% were used by placement in the middle of the flight path. Sample thicknesses were measured directly and by weighing to an accuracy of 0.5%. Two ^{235}U miniature fission chambers inside cadmium covered paraffin cubes located in the Linac cell monitored the neutron source from one run to another. Time-of-flight data were taken utilizing a 1024-channel (16 μsec each) Laben TV-60 encoder connected "on-line" to an IBM/360 model 44 computer. Backgrounds were measured in separate runs with suitable filters added to the sample location:

1. a filter opaque to thermal neutrons (a 3.5-cm-thick block of paraffin) to measure gamma-ray fluxes from the source
2. a filter opaque to thermal neutrons and source gamma-rays comprising item[1] above plus a 10-cm-thick lead brick.

Raw data were corrected for deadtime, mean emission time and backgrounds. The resulting spectral data were initially grouped into energy intervals of ~5%. Sample transmissions were corrected for in-scattering and multiple scattering. Each set of transmission data was smoothed using a least squares convolution factor method[1] and the statistical error values were then interpolated by Aitken's method to fixed energy values chosen to be 40 points per energy decade at equal lethargy intervals.

TABLE I

Total Neutron Cross Section of Mylar

E (eV)	Cross Section (b) at Energy:				
	$E \times 10^2$	$E \times 10^1$	$E \times 10^0$	$E \times 10^{-1}$	$E \times 10^{-2}$
0.9440		225.9	237.7	330.7	620.1
0.8913		226.0	238.7	337.5	627.2
0.8414		226.2	239.4	344.7	634.4
0.7943		226.3	240.1	352.4	641.8
0.7499		226.5	240.9	360.1	649.6
0.7079		226.8	241.6	367.3	658.5
0.6683		227.1	242.4	374.6	
0.6310		227.4	243.4	382.3	
0.5957		227.7	244.1	389.9	
0.5623		228.0	245.0	397.0	
0.5309		228.3	245.9	404.1	
0.5012		228.7	247.0	411.4	
0.4732		228.9	248.6	419.2	
0.4467		229.0	250.1	427.2	
0.4217		228.9	251.6	435.2	
0.3981		228.9	253.0	443.1	
0.3758		228.8	254.3	450.8	
0.3548		228.8	256.2	458.1	
0.3350		228.7	258.2	465.3	
0.3162		228.8	261.0	473.0	
0.2985		228.9	263.7	480.6	
0.2818		229.0	266.5	488.1	
0.2661		229.2	269.5	495.7	
0.2512		229.4	272.5	503.6	
0.2371		229.5	275.6	511.3	
0.2239		229.7	278.6	519.0	
0.2113	226.1	230.0	281.4	526.6	
0.1995	226.1	230.3	284.1	533.6	
0.1884	225.9	230.6	286.9	540.3	
0.1778	225.7	230.9	289.8	546.7	
0.1679	225.5	231.2	292.8	552.9	
0.1585	225.4	231.6	296.1	559.3	
0.1496	225.6	231.9	299.4	565.5	
0.1413	225.7	232.3	302.3	571.9	
0.1334	225.8	232.8	305.2	578.2	
0.1259	225.8	233.2	307.8	584.7	
0.1189	225.7	233.8	310.9	591.4	
0.1122	225.7	234.6	314.8	598.5	
0.1059	225.8	235.5	319.5	605.7	
0.1000	225.9	236.6	324.8	612.8	

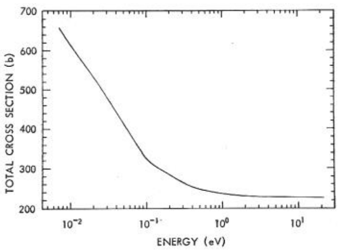


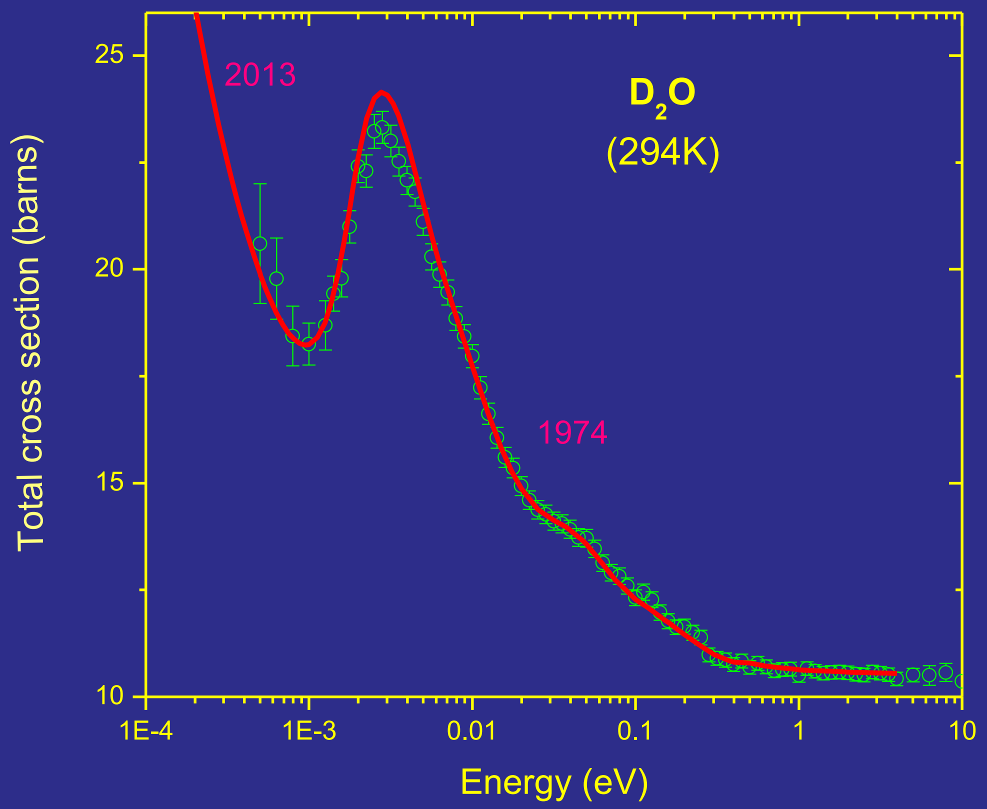
Fig. 1. Total cross section of Mylar.

The resulting data are presented in Table I and shown graphically in Fig. 1. These are a weighted average from 16 runs performed with the 4 samples. The errors are due mainly to inaccuracies in source monitoring and are better than 2%.

The result at 10 eV is in close agreement with the sum of the free atom cross sections 225.1 b.

[1] D. J. GORMAN, "A Computer Program for the Smoothing and Differentiation of Data from Multichannel Analyzers," UCRL-19903, University of California, Berkeley (1970).

First publication in EXFOR (1974)



"Experimental Neutron Data:

Sigma(E) of D2O in the thermal range".

F.Kropff, J.R.Latorre, J.R.Granada and C.Castro Madero

Nuclear Data Section, IAEA, EXFOR 30283 (1974)

“CAB models for water: A new evaluation of the thermal neutron scattering laws for light and heavy water in ENDF-6 format”

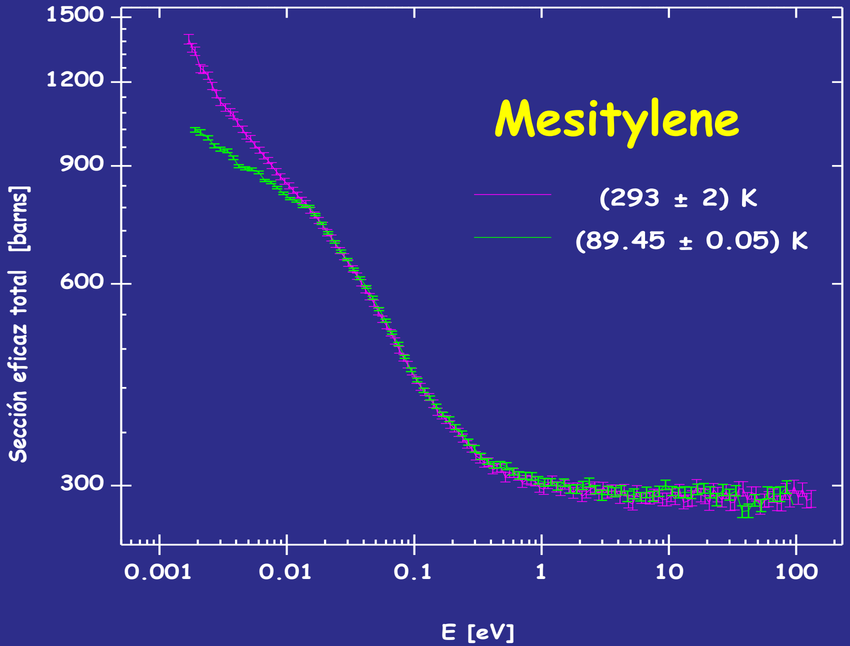
J.I. Marquez Damian, J.R. Granada, D.C. Malaspina..

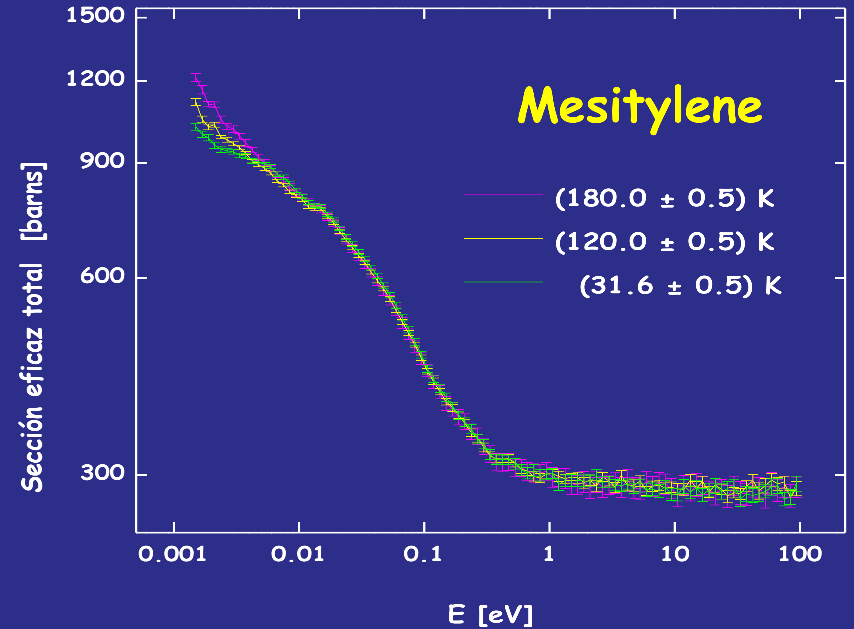
Annals of Nuclear Energy, 65, 280, 2014.

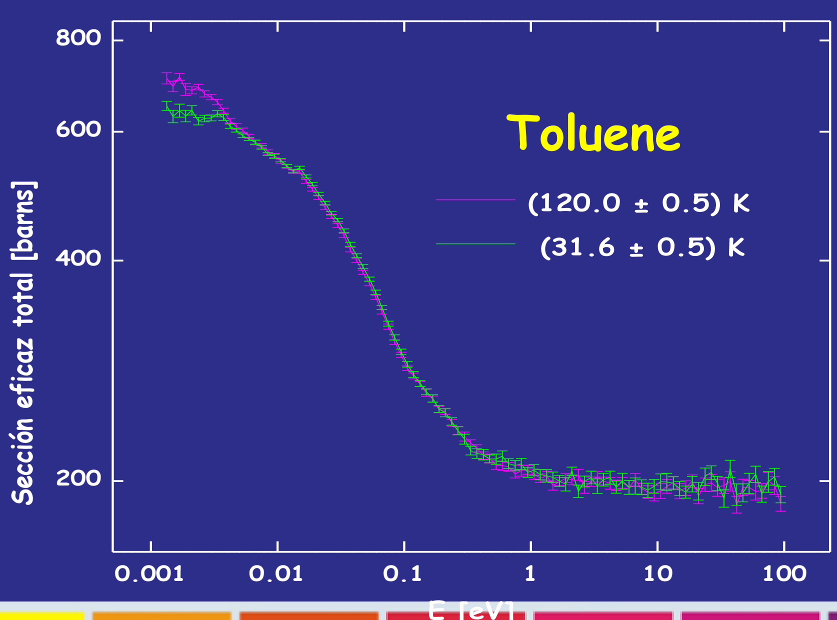
For low temperature measurements we have a cryostat where the sample is placed inside and cooled down to the desire temperature . The lowest temperature that we can reach is 32K

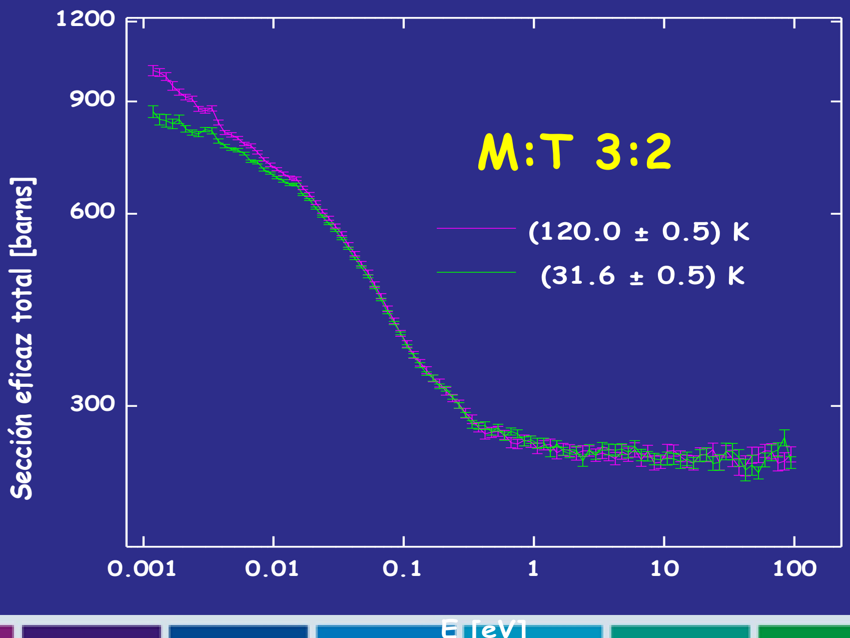
The temperature is constantly controlled by two thermoresistances placed on both sides of the sample holder

Cold moderators materials: mesitylene, toluene and mixes


Mesitylene
(293 ± 2) K
(89.45 ± 0.05) K
Sección eficaz total [barns]
1500
1200
900
600
300
0.001
0.01
0.1
1
10
100
E [eV]


Mesitylene
(180.0 ± 0.5) K
(120.0 ± 0.5) K
(31.6 ± 0.5) K
Sección eficaz total [barns]
1500
1200
900
600
300
0.001
0.01
0.1
1
10
100
E [eV]


Toluene
(120.0 ± 0.5) K
(31.6 ± 0.5) K
Sección eficaz total [barns]
800
600
400
200
0.001
0.01
0.1
1
10
100
E [eV]


M:T 3:2
(120.0 ± 0.5) K
(31.6 ± 0.5) K
Sección eficaz total [barns]
1200
900
600
300
0.001
0.01
0.1
1
10
100
E [eV]

EXFOR data: http://www-nds.iaea.org/EXFOR/31578.002
Data retrieved from the EXFOR database version of May 05, 2015.

Search by
Entry: 31578
Authors:
F. Cantargi
J.J. Blostein
L. Torres
J.R. Granada

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ENTRY         31578001    20060714    20070213    20070209        3121
SUBENT        31578001    20060714    20070213    20070209        3121
BIB                 16          50
TITLE       Thermal neutron cross section of liquid and solid
            mesitylene
AUTHOR      (F.Cantargi,J.J.Blostein,L.Torres,J.R.Granada)
INSTITUTE   (3ARGCAB,3ARGCIN)
            #(3ARGCAB Inst.Balseiro y Centro Atomico Bariloche, Bariloche, Argentina
            #,3ARGCIN) Consejo Nac. de Invest. Cientificas y Tec. (CONICET), Argentina
REFERENCE   (J,NIM/B,248,340,2006)
            #(J,NIM/B,248,340,2006) Jour: Nucl. Instrum. Methods in Physics Res., Sect.B, Vol.248, p.340 (2006), Netherlands
            #+      #URL=http://dx.doi.org/10.1016/j.nimb.2006.04.161
            #+      #NSR=2006CA18 #DOI=10.1016/j.nimb.2006.04.161
            #+      #Title=Thermal neutron cross section of liquid and solid mesitylene
            #+      #Authors=F.Cantargi, J.J.Blostein, L.Torres, J.R.Granada
FACILITY    (LINAC,3ARGCAB)  25 MeV Electron LINAC based pulsed
            neutron source  at Centro Atomico Bariloche (Argentina)
            #(LINAC Linear accelerator
            #,3ARGCAB) Inst.Balseiro y Centro Atomico Bariloche, Bariloche, Argentina
SAMPLE      A commercial mesitylene ( 1,3,5-trimethylbenzene
            C6H3(CH3)3, 98.8% in purity) is liquid  at (293+-2) K
            and solid at (89.45+-0.05) K were used. Density is
             (0.896+-0.01) g/cm3 and thickness is (0.214+-0.002)cm.
              The mesitylene sample was supplied by ALDRICH
DETECTOR    (PROPC)  The detector bank consisted of seven 3He
            proportional counters (10 atm  filling press., 15.24cm
            active length, 2.54 cm diam.) placed at (827.2+-0.5)cm
            from the thermal neutron source, as determined
            by the use of well known  absorption resonances
            #(PROPC) Proportional counter
INC-SOURCE  A lead target and a slab shaped (4x21x21) cm3
            polyethylene moderator  were employed to obtain a
            thermal neutron spectrum. The sample was  placed at
            about 360 cm from the neutron source in a separate
            room  shielded by 100 cm thick concrete wall.
METHOD      (TOF) flight path =(827.2+-0.5)cm.
             The  sample-in sample-out method was used.
             Standard normalized transmission measurement.
            #(TOF) Time-of-flight
MONITOR     The experimental data were normalized in the free-atom
            region to the cross section value of 288.63 barn for
            the molecule unit.
PART-DET    (N) neutrons
MONIT-REF   (,S.F.Mughabghab,B,NEUT.CS 1A,,1981) S.F. Mughabghab,
            etc. Neutron Cross Sections, Neutron Resonance
            Parameters and Thermal Cross Sections, Part A,
            Z = 1-60, 1, Academic Press, New York, 1981.
ERR-ANALYS  (ERR-S) Quoted errors are only due to statistics.
             The observed spectra were normalized using the
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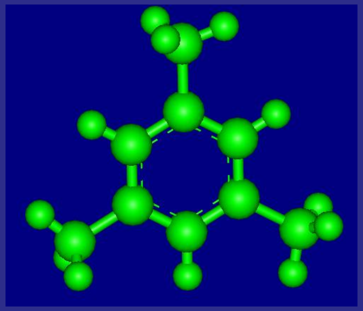
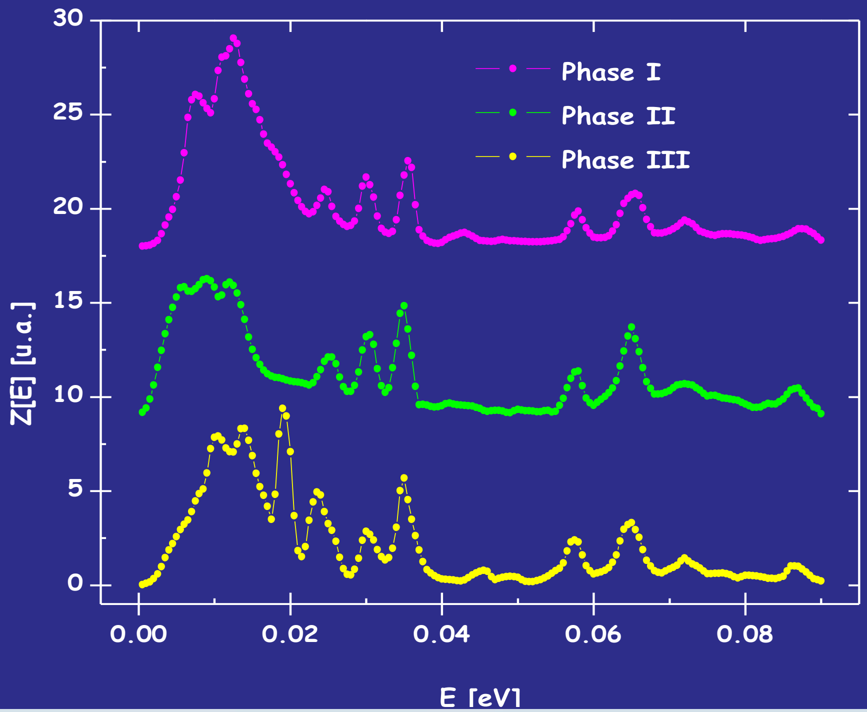
MESITYLENE

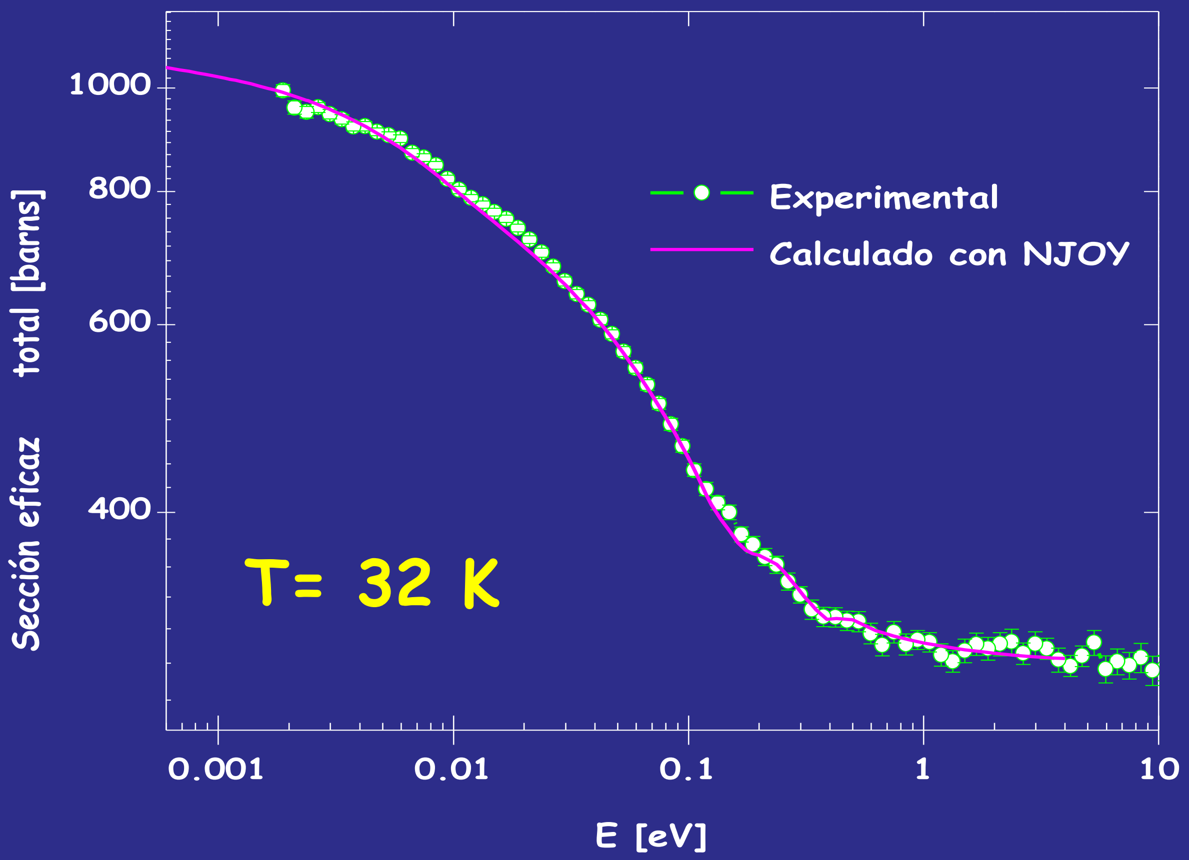
Experimental information [Natkaniec et al., Proceedings of ICANS XVI, 2003]	$h\nu_1$= 0.12 eV (Ring breathing)	$h\nu_2$= 0.17 eV (C-H stretching in CH_3)	$h\nu_3$= 0.37 eV (C-H stretching in the ring)
ω_{cont} = 0.252	ω_1 = 0.1505	ω_2 = 0.341	ω_3 = 0.2565



$$\omega^i_{mesitylene} = \frac{9}{12}\omega^i_{methane} + \frac{3}{12}\omega^i_{benzene}$$

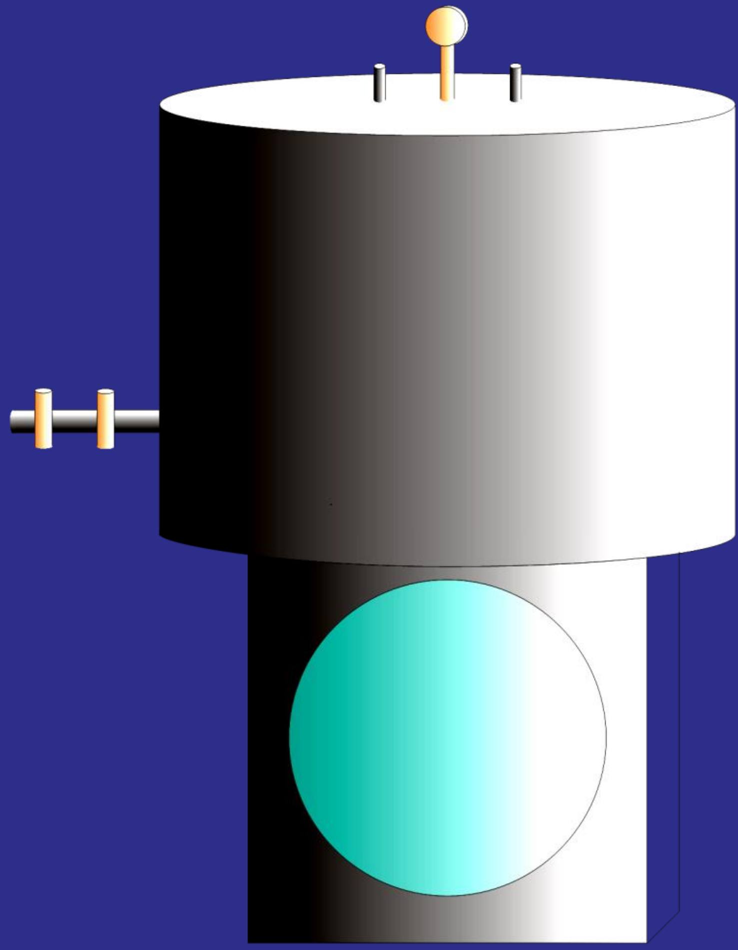


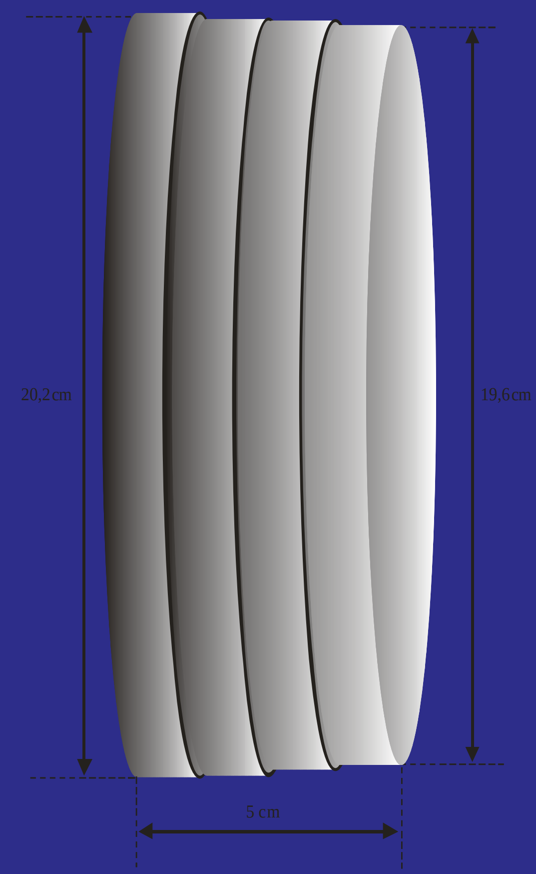
MESITYLENE



	continuum	$h\nu_1$= 0.12 eV	$h\nu_2$= 0.17 eV	$h\nu_3$= 0.37 eV
Optimized	ω_{cont} = 0.188	ω_1 = 0.170	ω_2 = 0.310	ω_3 = 0.332

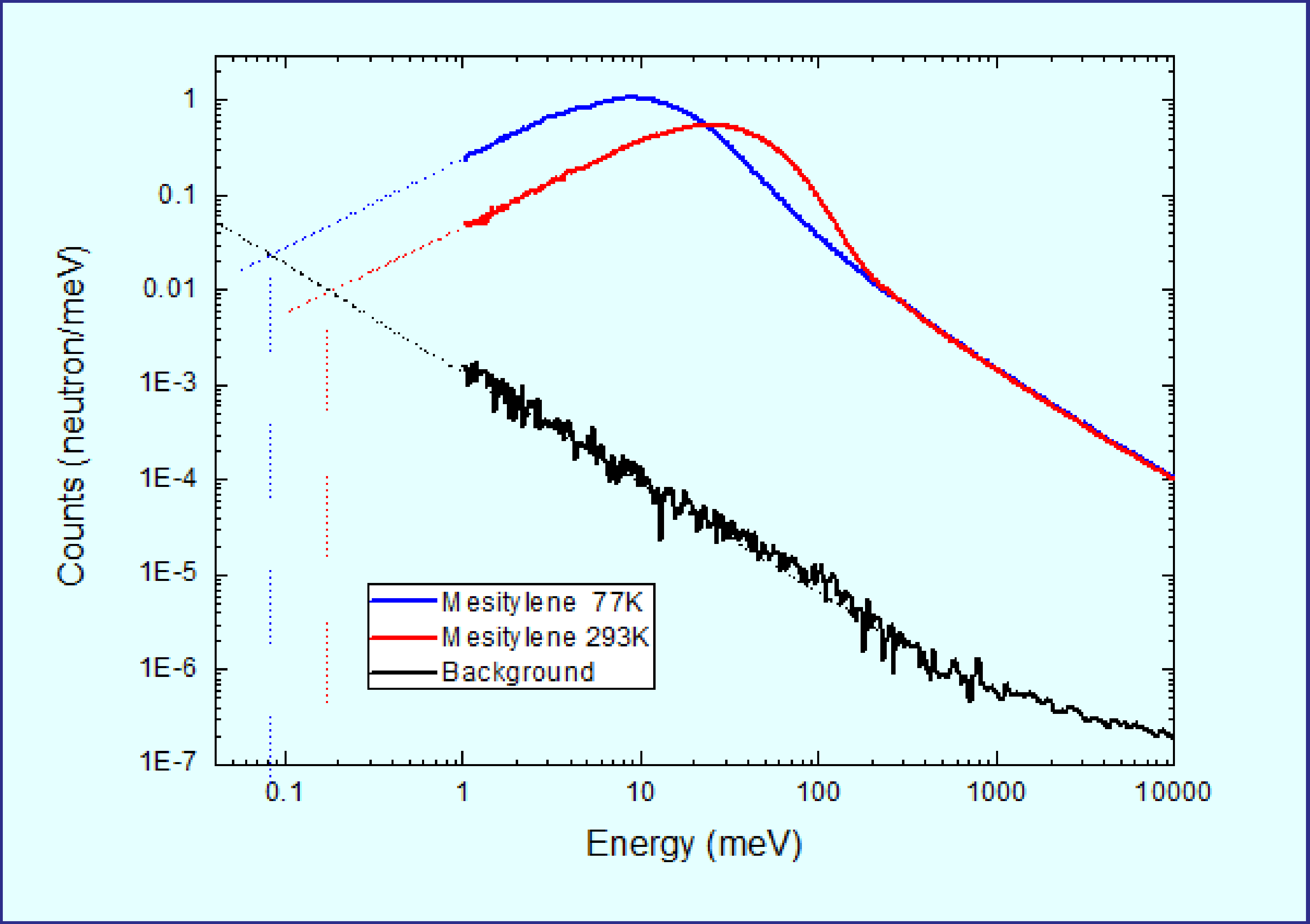
A SOLID MESITYLENE BASED COLD NEUTRON SOURCE



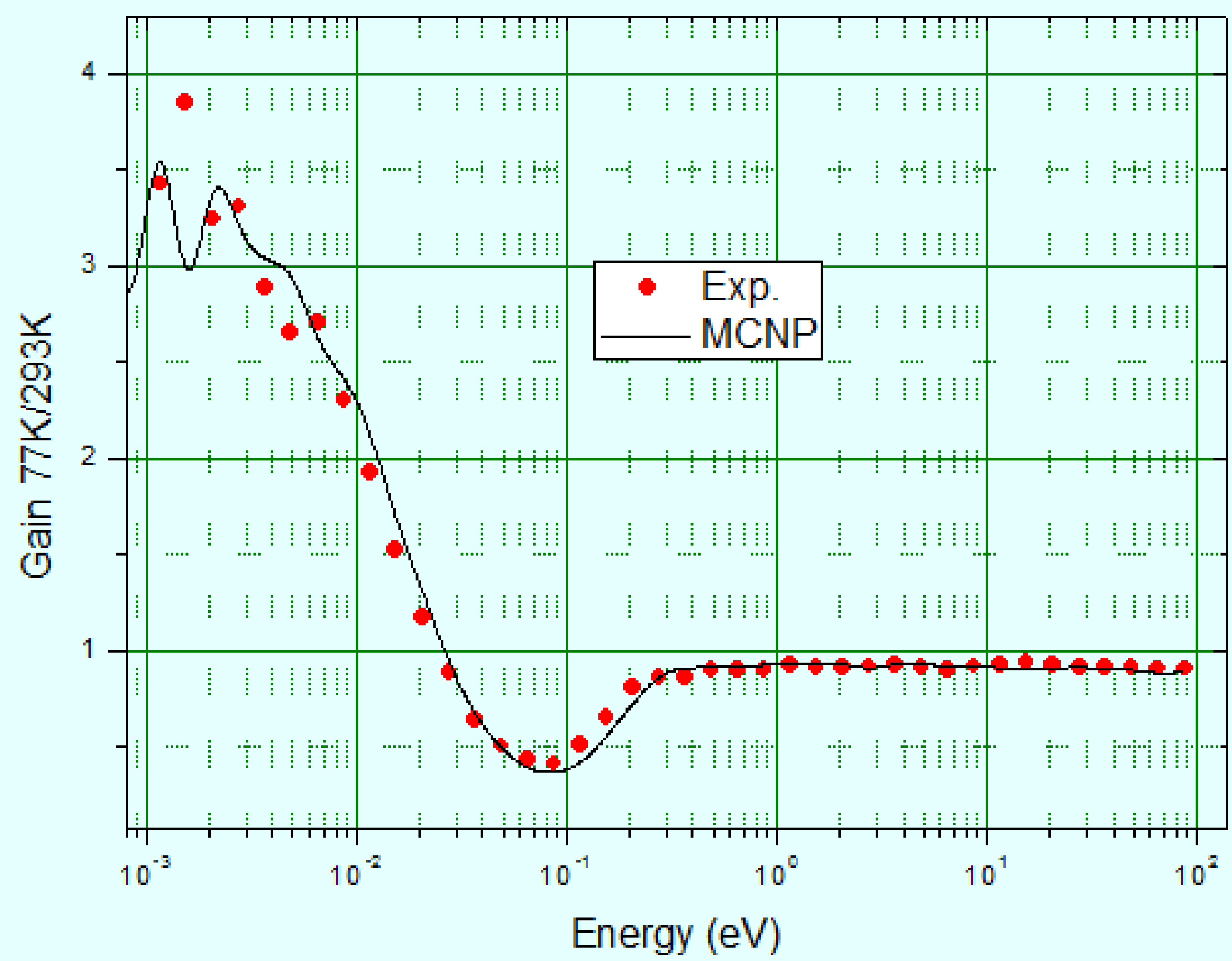


73 cm total height; 50 cm diameter; 38 cm moderator height.

Stainless steel. Zircaloy-4 windows



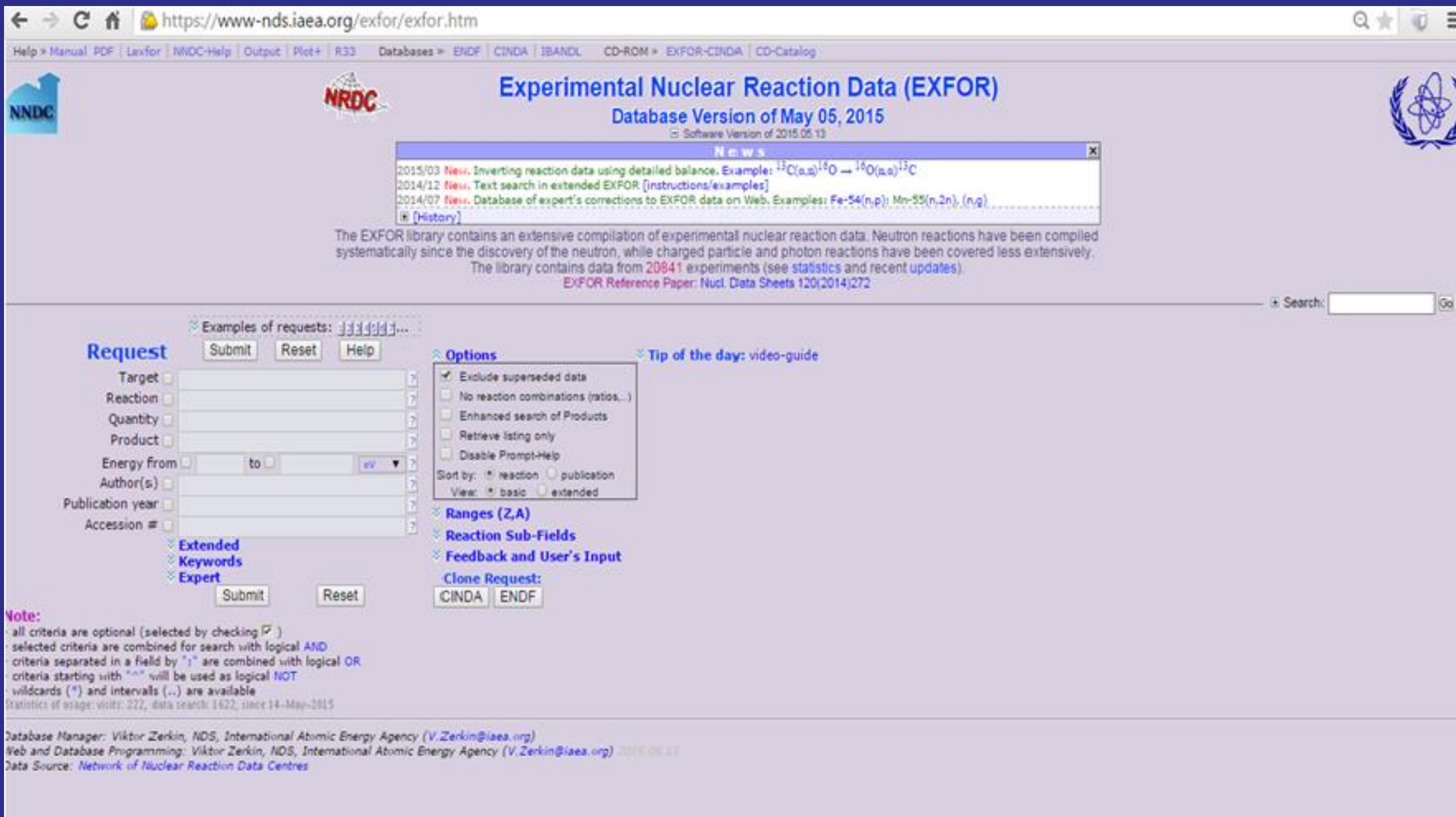
Counts (neutron/meV)
1
0.1
0.01
1E-3
1E-4
1E-5
1E-6
1E-7
0.1
1
10
100
1000
10000
Energy (meV)
Mesitylene 77K
Mesitylene 293K
Background



Exp.
MCNP
Gain 77K/293K
Energy (eV)
4
3
2
1
10^{-3}
10^{-2}
10^{-1}
10^{0}
10^{1}
10^{2}

EXFOR

https://www-nds.iaea.org/exfor/exfor.htm



Throughout these 45 years, the LINAC has enabled the development of many activities:

- Research and development in basic science and nuclear engineering
- Technological innovation in the field of nuclear energy
- Training of human resources specialized in the area of neutronics
- Transfer and development in other fields related to new technologies

It also supported

- the realization of 39 MSc theses and 20 PhD dissertations.
- the contribution of 46 datasets to EXFOR, mostly total cross sections transmission measurements (Institution 3ARGCAB: e-LINAC + RA-6 reactor).
- Evaluation of thermal scattering libraries through:
  - Transmission total cross section measurements.
  - Neutron spectrum measurements.

FINAL REMARKS

With the e-LINAC, we have contributed to CNEA´s mission of transmitting to society the benefits of the peaceful uses of nuclear energy and its associated techniques, as well as promoting research on neutronics.

Bariloche e-LINAC is the ONLY operating pulsed neutron source in the Southern Hemisphere, small in neutron flux, but huge for the training of many generations that worked and grew up towards it.

Although a low intensity pulsed neutron source is clearly not competitive with an accelerator orders of magnitude more intense, for most of the possible applications, it is nevertheless very useful to test ideas and the ensuing methods born from the successful ones. This is particularly true for total cross section measurements.

Cross section modeling

WHO WE ARE: THERMAL SCATTERING NUCLEAR DATA GROUP AT CENTRO ATOMICO BARILOCHE

Rolando Granada
Scattering theory and advanced neutron sources

Florencia Cantargi
Cold moderator materials and neutron filters

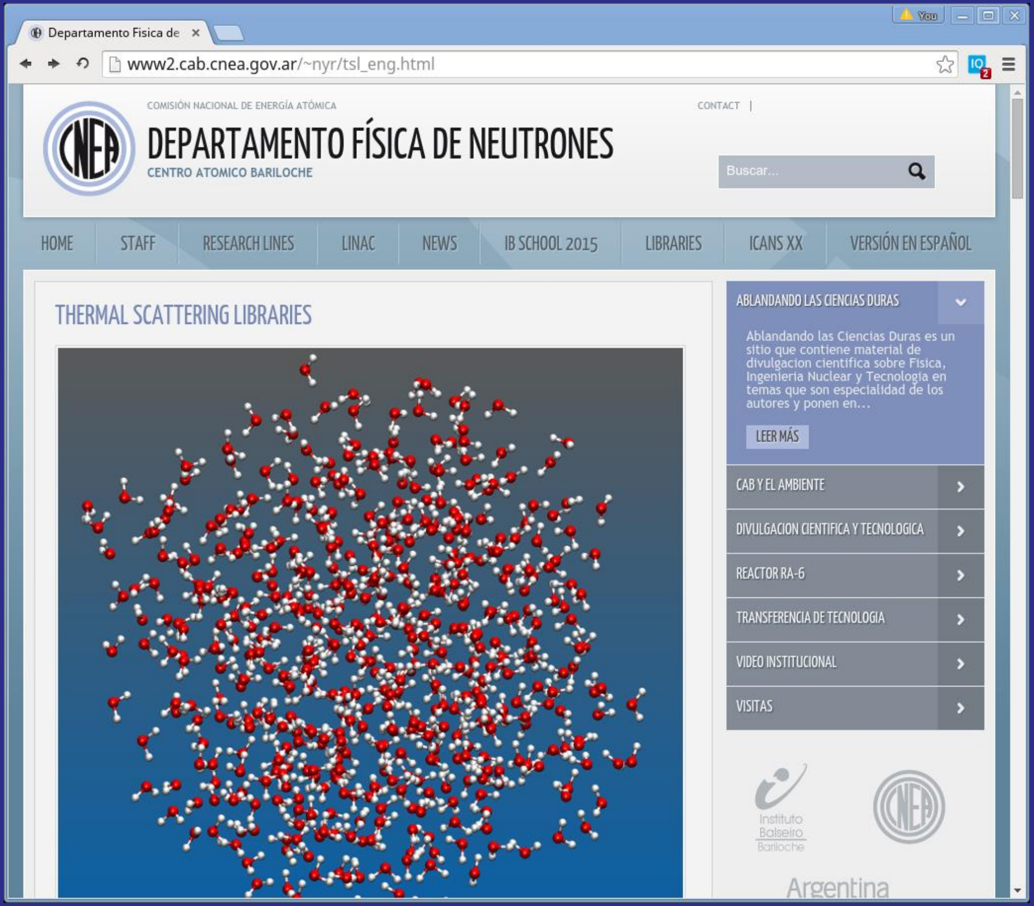
Ignacio Marquez
Nuclear reactor applications and benchmarking

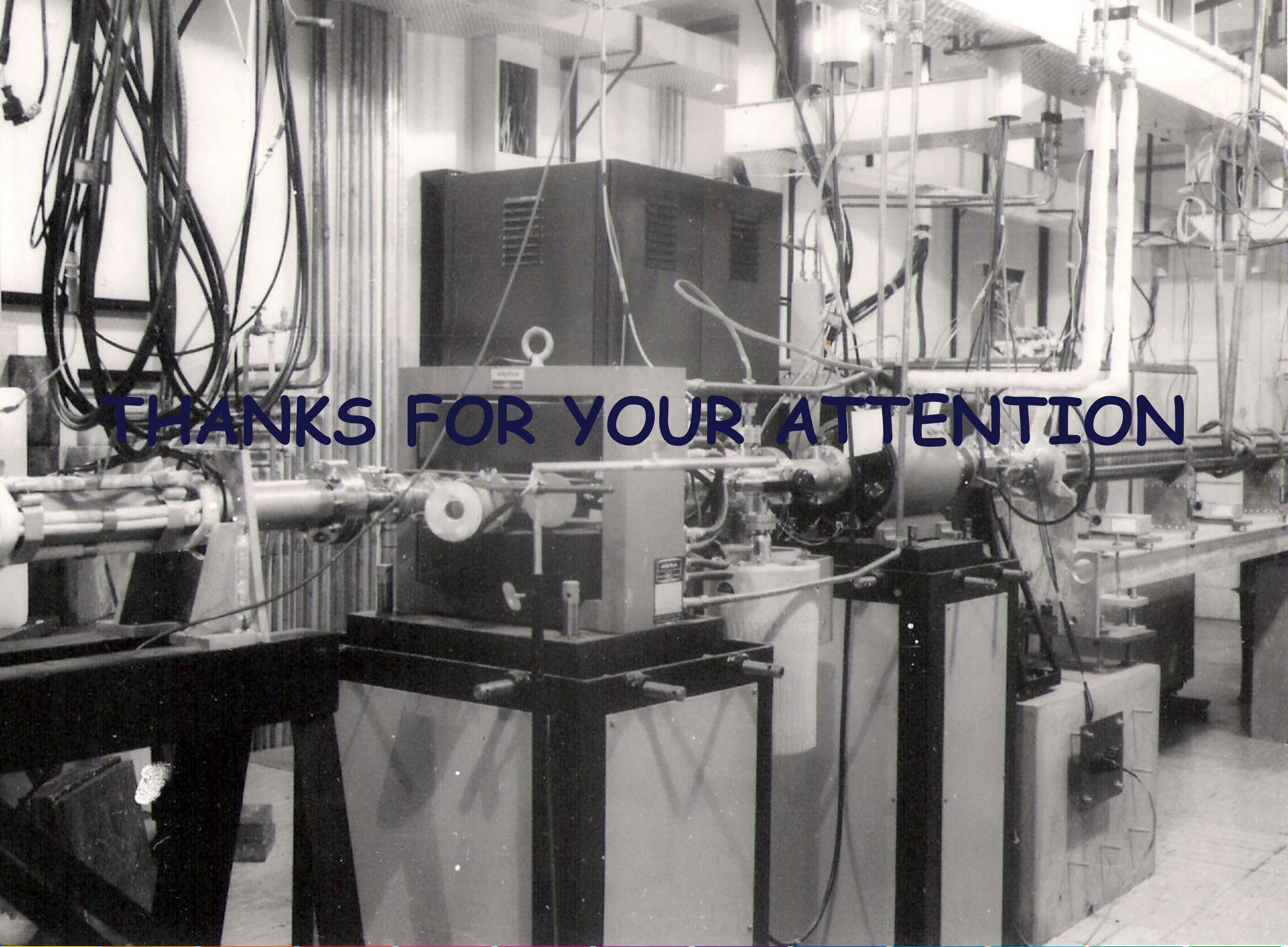
Past members:

- Monica Sbaffoni (currently at IAEA),
- Victor Gillette (currently at University of Sharjah, U.A.E).

Our cross section libraries are available in ENDF-6 and ACE format in the webpage of the Neutron Physics Department

http://www2.cab.cnea.gov.ar/~nyr/tsl_eng.html





THANKS FOR YOUR ATTENTION