A NEW METHOD TO INCREASE THE COLD NEUTRON PRODUCTION IN LIQUID p-H_2 MODERATORS

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TABLE 2. HISTORICAL LIST OF COLD NEUTRON SOURCES AT RESEARCH REACTORS

Reactor, location	Country	Start	MW	Moderator	Reflector	Flux	Reactor status	Refs
BEPO, Harwell	UK	1956	6	LH_2	graphite	0.015	Under Decommissioning	[28]
BR-1, Mol	Belgium	1960	4	LH_2	graphite	0.02	Operational	[29]
DIDO, Harwell	UK	1960/ 1967	15/ 27	LH_2/ D_2	D_2O	2.3	Under Decommissioning	[30–31]
EL-3, Saclay	France	1962	17	LH_2/D_2	graphite	1.0	Decommissioned	[32–33]
SILOETTE, Grenoble	France	1964	0.1	LD_2	H_2O/Be	0.01	Decommissioned	[34–35]
FiR-1, Espoo	Finland	1964/ 1972	0.25	LH_2/ CH_4	graphite	0.1	Under Decommissioning	[36]
HERALD, Aldermaston	UK	1966	6	LH_2+D_2	Be	0.57	Decommissioned	[37]
AVOGADRO, Saluggia	Italy	1969	1	LC_3H_8	graphite	0.27	Decommissioned	[37]
FR-2, Karlsruhe	Germany	1969	44	LH_2	D_2O	1.0	Under Decommissioning	[38]
FRJ 2(1), Jülich	Germany	1969	23	LH_2	D_2O	2.5	Under Decommissioning	[39]

APR 1 8 1991

ANL/CP--72633

DE91 010594

Cold Moderators for Pulsed Neutron Sources

John M. Carpenter
Intense Pulsed Neutron Source
Argonne National Laboratory

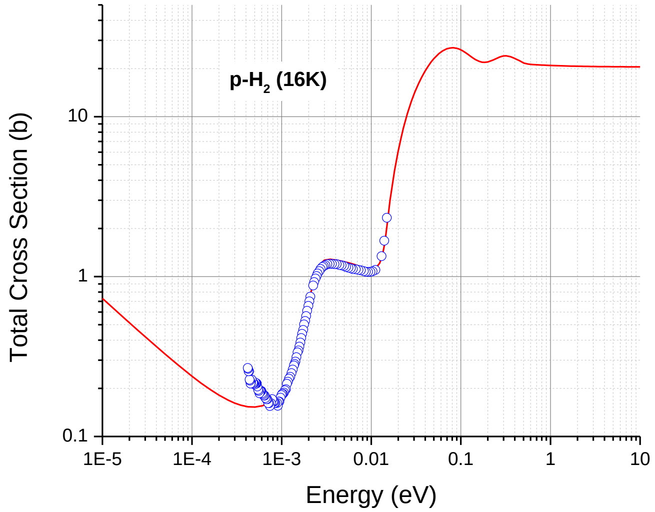
Workshop on Cold Neutron Sources
Held at LANL
Los Alamos, N.M.
March 5-7, 1990

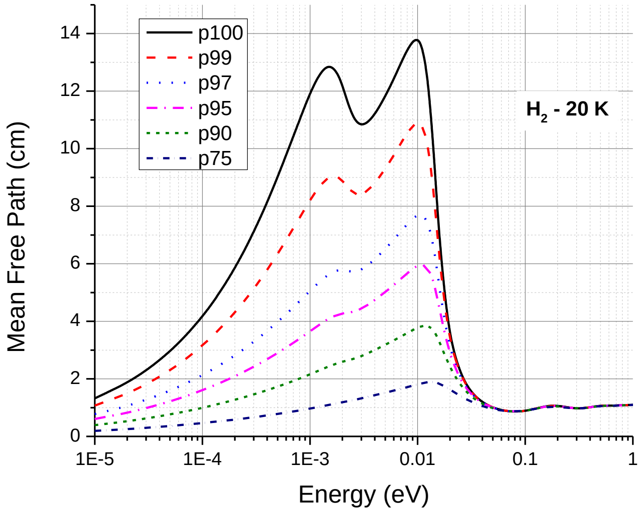
TABLE II

Cold Moderators at Pulsed Spallation Neutron Sources

Source	Designation, beams	Material	Tempera-ture (K)	Dimensions (cm)	Poisoning
IPNS	"C" 1,2,2',3	L-H_2	20.	10.x10.x7.6	none, grooved
IPNS	"F" 1-3,4-6	L-CH_4	110.	10.x10.x5.	0.5 mm Cd @ 1.7 cm
IPNS	"H" 1,2,3	L-CH_4	110.	10.x10.x5.	0.5 mm Cd @ 2.5 cm.
ISIS	N 4,5,6	L-H_2	35.	11.x12.x8.	none
ISIS	N 1-3, S 6-9	L-CH_4	100.	11.5x12.x4.5	none
KENS		S-CH_4	25.	12.x15.x5.	none
LANSCE		L-H_2	20.	12.x12.x7.	none
ZING-P'	"A"	L-H_2	20.	10.x7.6x5.	none

LIQUID p-H_2 : A STANDARD COLD NEUTRON MODERATOR MATERIAL

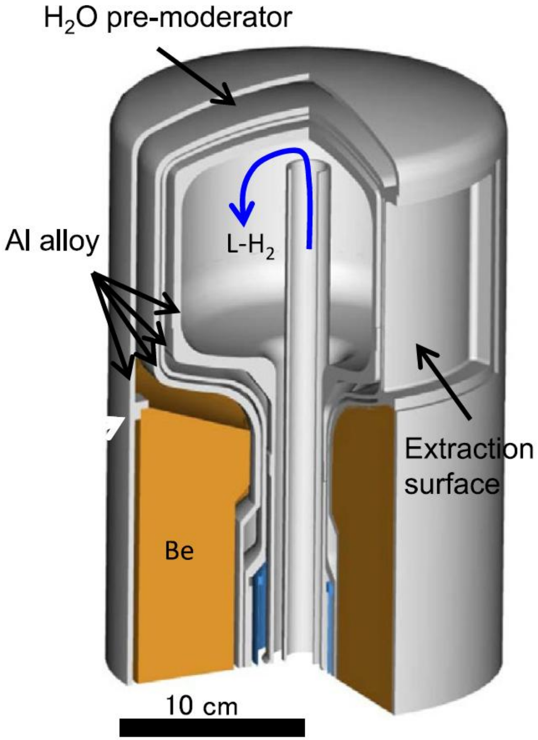




New Neutron Scattering Kernels for Liquid Hydrogen and Deuterium,
J.R. Granada, J.I. Márquez Damián and F. Cantargi, UCANS-VI, Xi'an, China (2016).

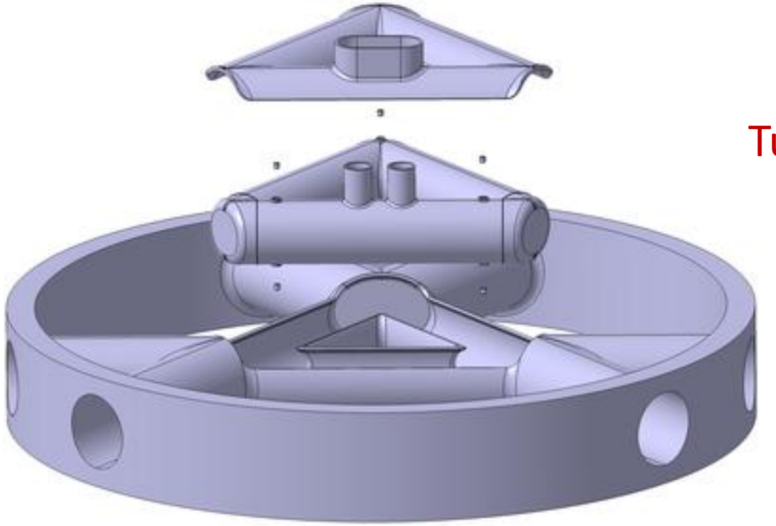
J.I. Márquez Damián, New Evaluations JEFF-3.3 Thermal Scattering Law Sublibrary (2018).
https://www.oecd-nea.org/dbdata/jeff/jeff33/tsl.html

Volume (JPARC)



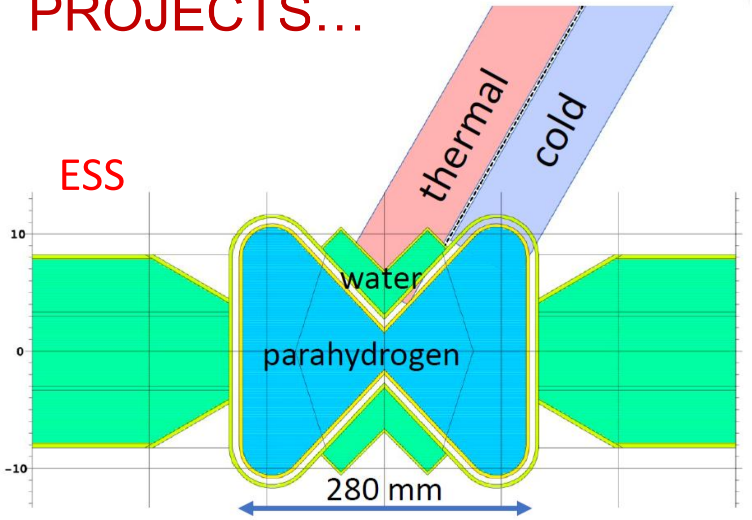
Flat (ESS)

Tube (SNS STS)

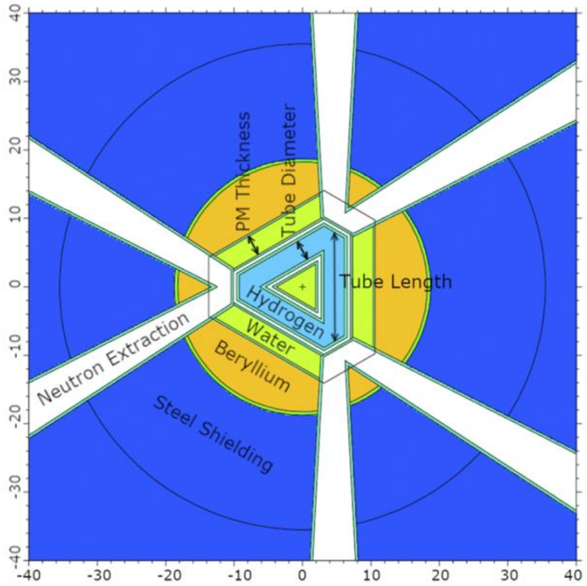


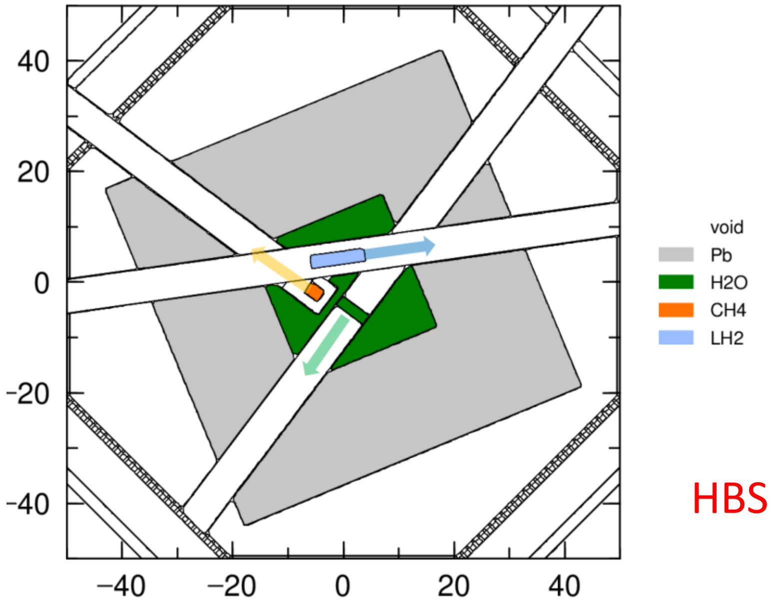
PROJECTS…

ESS



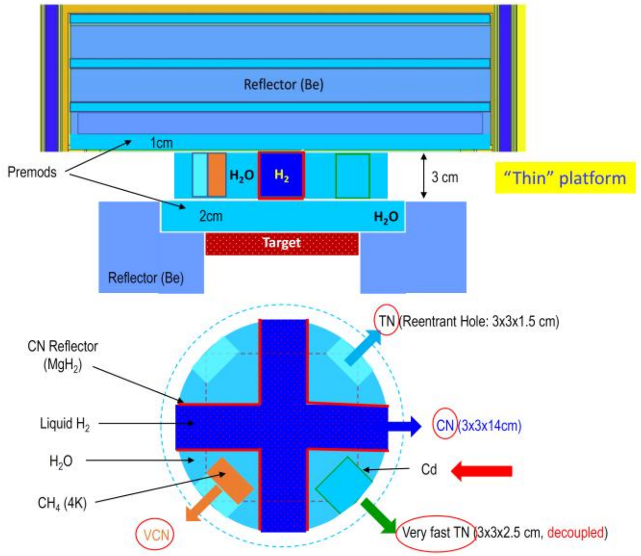
SNS
STS





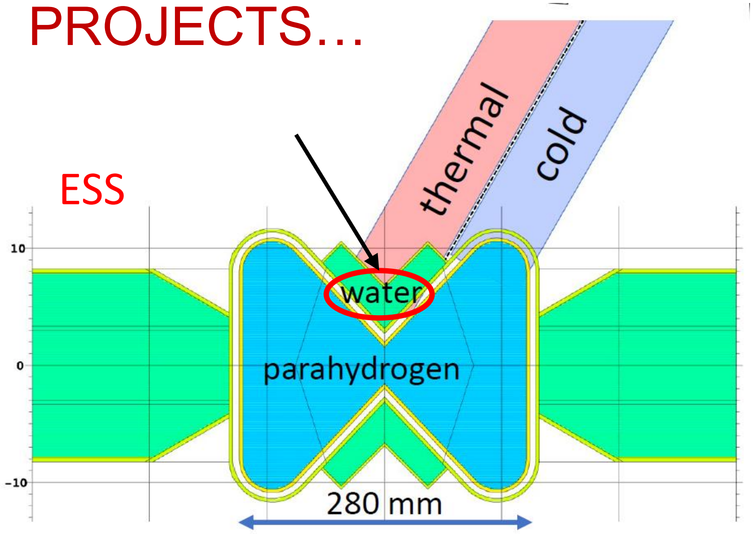
HBS

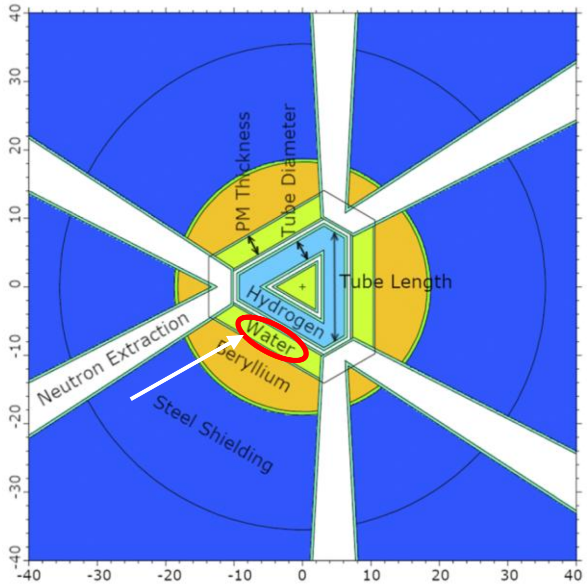
??



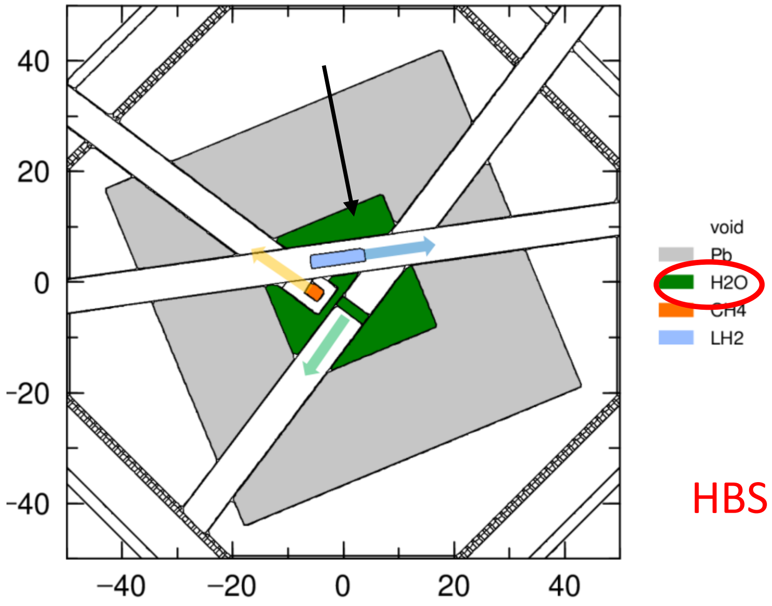
PROJECTS…

ESS

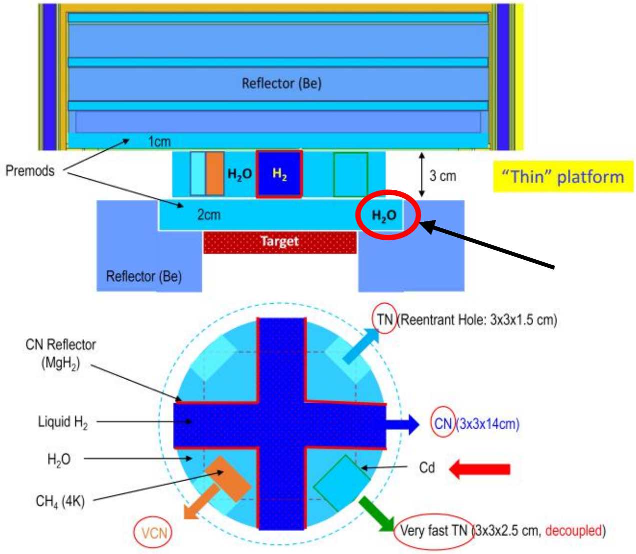




SNS
STS



HBS



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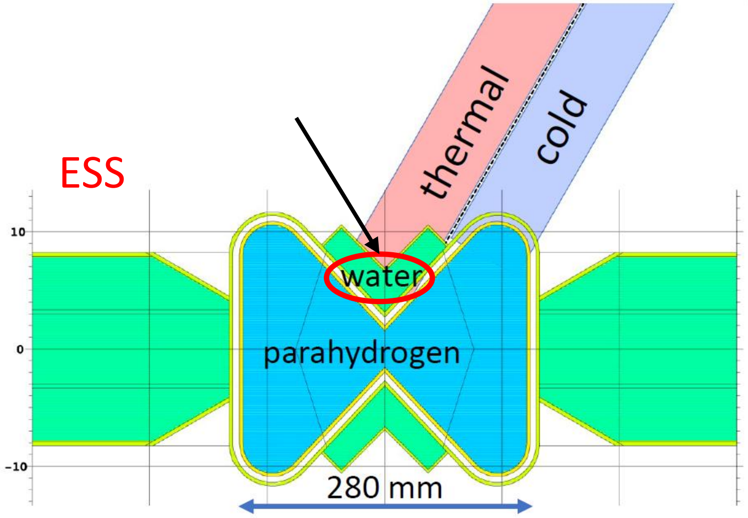
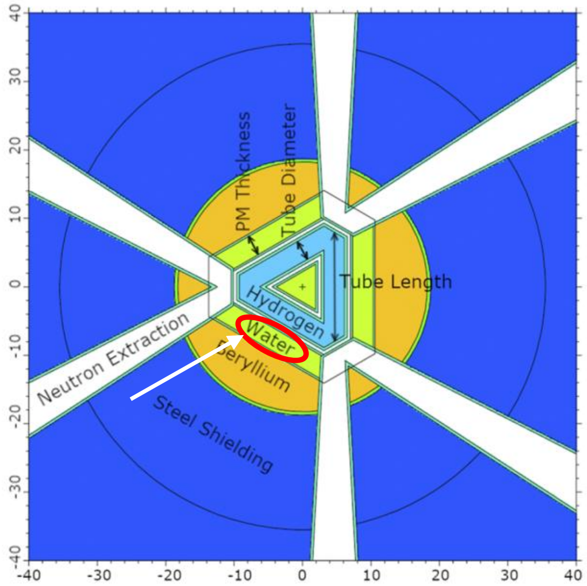
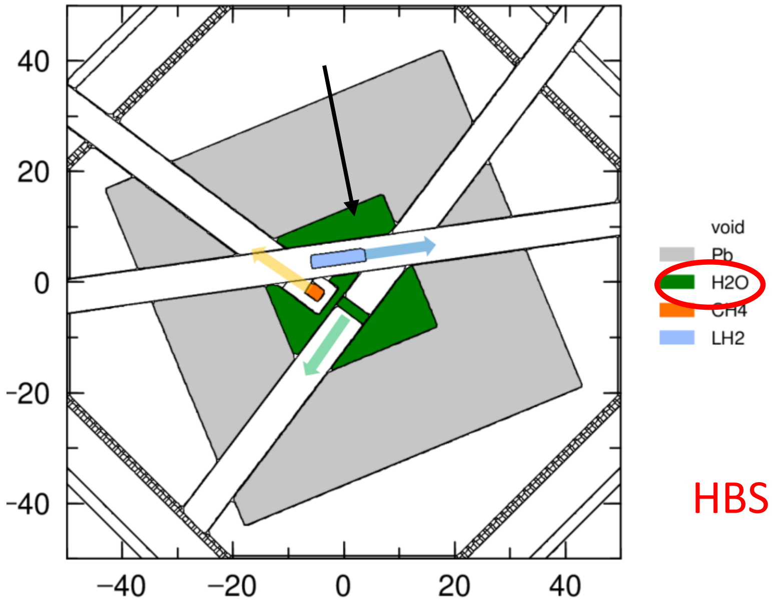
Is Water/p-H_2 the best neutronic combination for CN production?

ESS

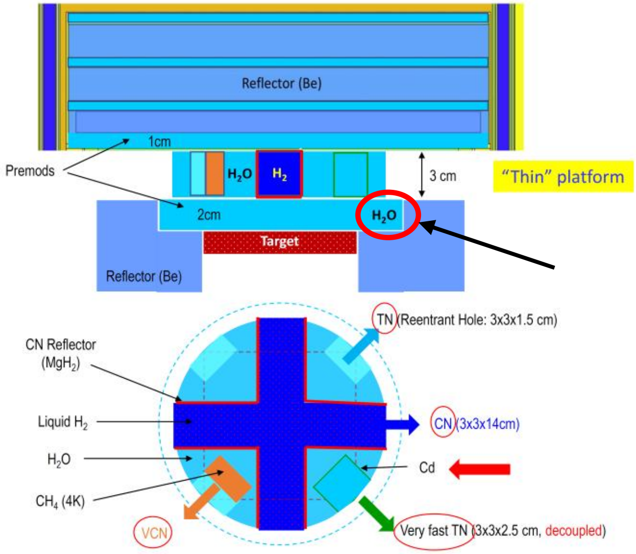




SNS
STS



HBS



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New Design of a Compact Cryogenic Neutron Moderator

J.R. Granada, F. Cantargi and J.I. Márquez Damián

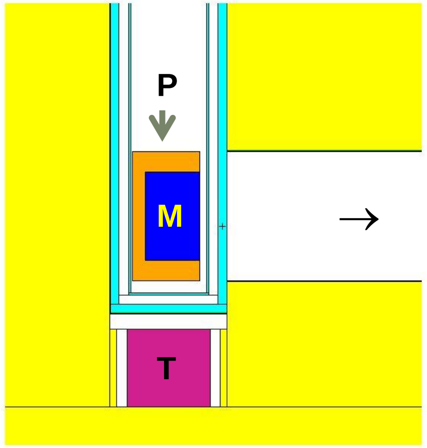
Neutron Physics Group

Centro Atómico Bariloche

Comisión Nacional de Energía Atómica

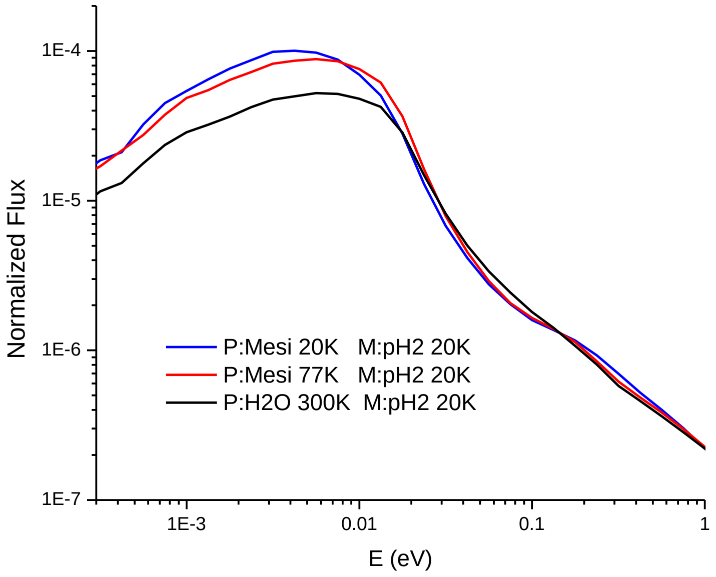
ARGENTINA

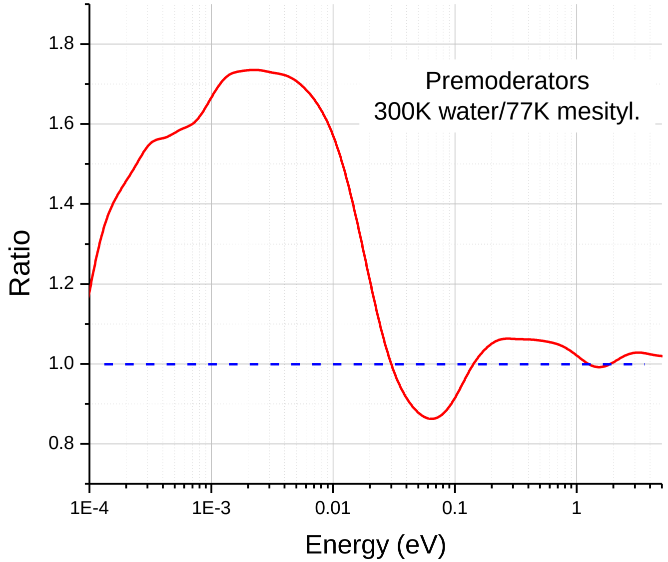
⇒ Effect of Premoderator Temperature on p-H_2 moderator

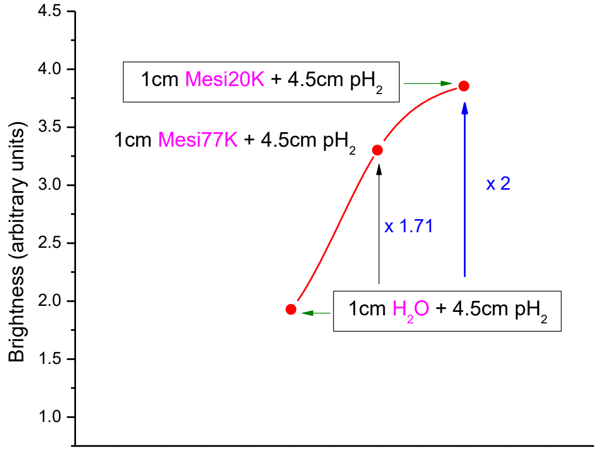


P: premoder.
1 cm thick
H_2O, C_9H_{12}

M: moderator
13x13 cm^2
4.5 cm thick
p-H_2 (20K)







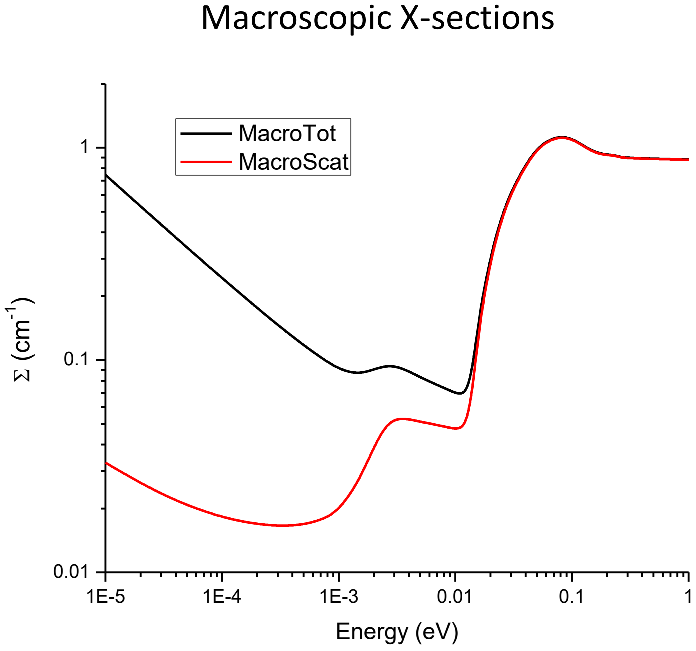
DEPENDENCE OF p-H_2 *CN* PRODUCTION

ON PREMODERATOR TEMPERATURE

1. The parent flux dependence on Premod temps.
2. Parent to Cold flux probability dependence on T.
3. Total gains and a way to achieve them

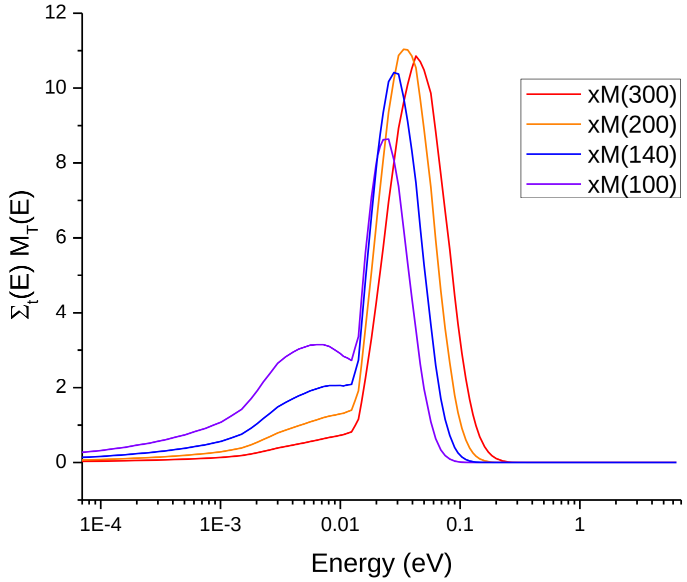
In what follows, I refer to “Moderator Height” meaning a normal dimension to the emission direction of the CN cell (the height of a slab, the thickness of a flat, or the diameter of a tube moderator)

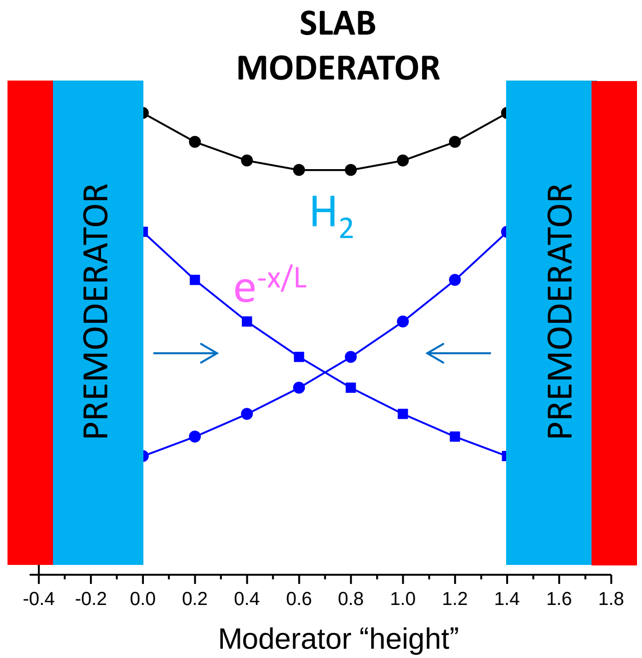
MAXWELLIAN AVERAGED MFP

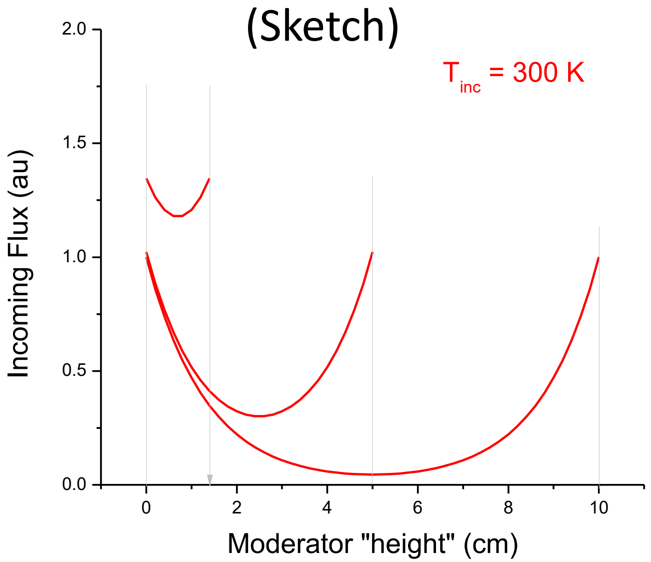


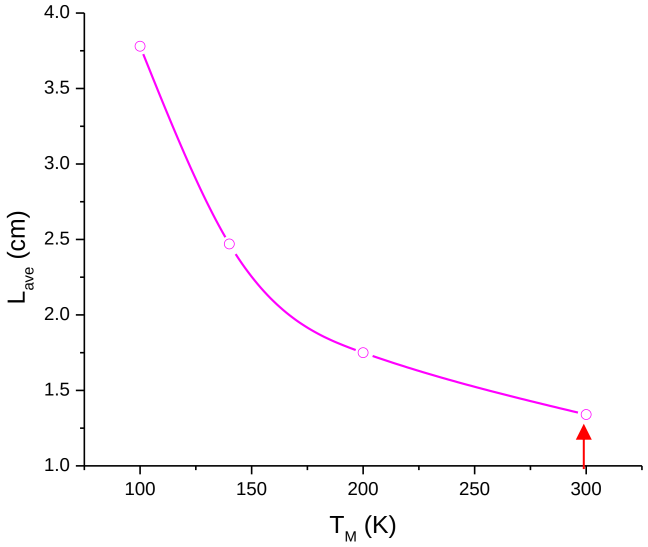
I use (normalized) Maxwellian distributions to represent the incoming flux from premoderators at different temperatures. The average MFP is then L_{ave} (T):

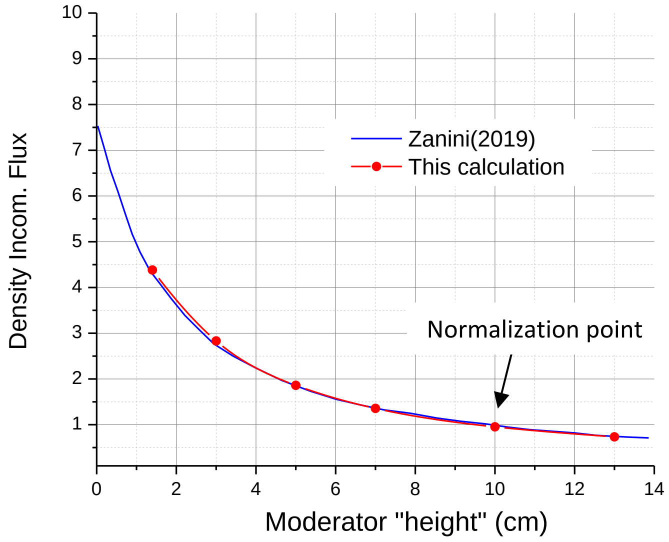
$$\Sigma_{ave}(T) = \int dE\, M_T(E)\, \Sigma_t(E) \Rightarrow L_{ave}(T) = 1/\Sigma_{ave}(T)$$



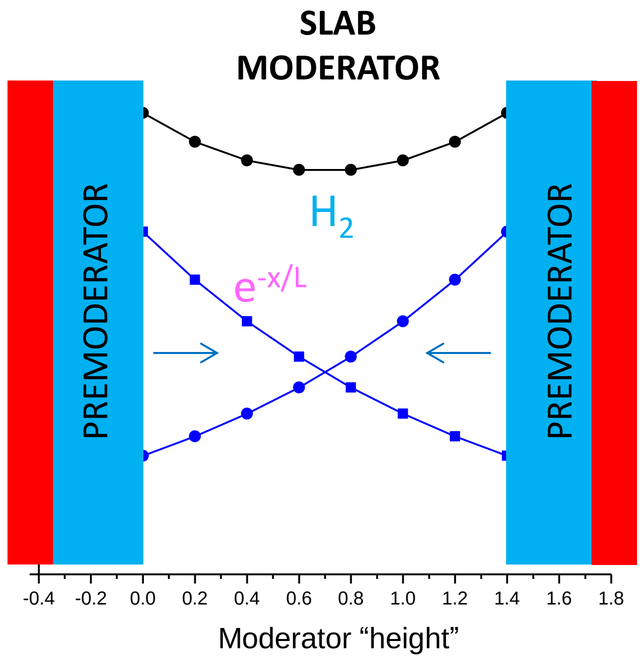


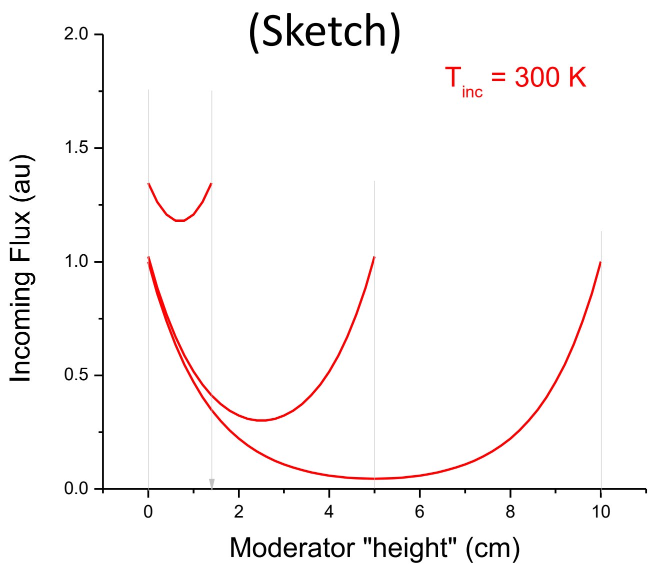


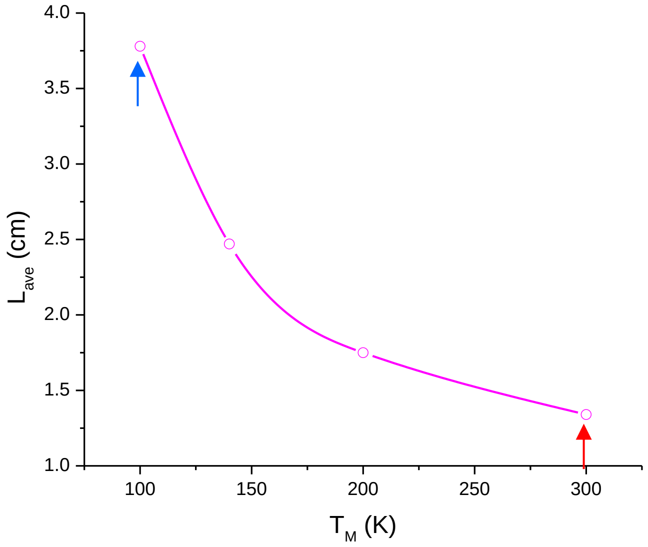


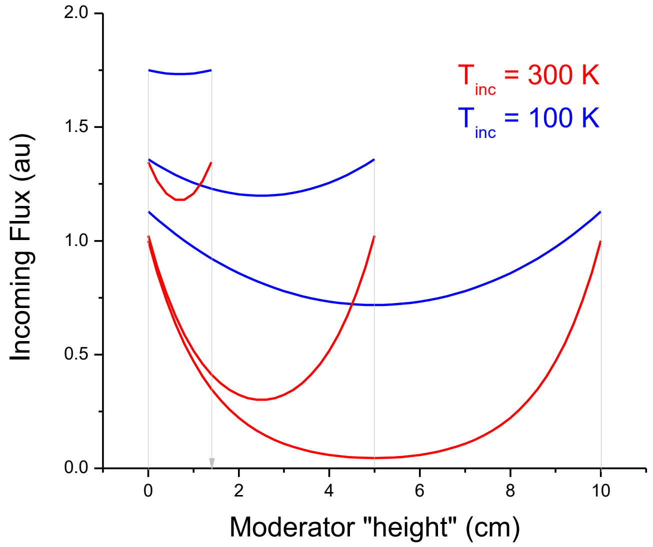


Zanini et al. Nuclear Inst. and Methods in Physics Research, **A 925** (2019) 33

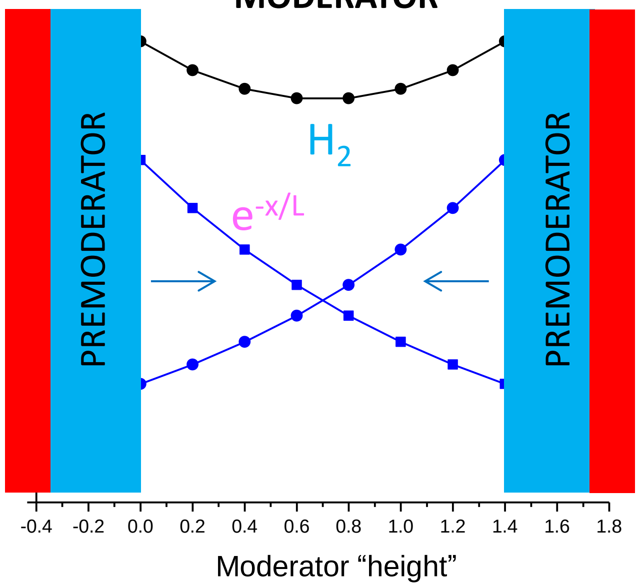

SLAB
MODERATOR
PREMODERATOR
PREMODERATOR
H_2
$e^{-x/L}$
-0.4 -0.2 0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8
Moderator “height”


(Sketch)
T_{inc} = 300 K
Incoming Flux (au)
Moderator "height" (cm)

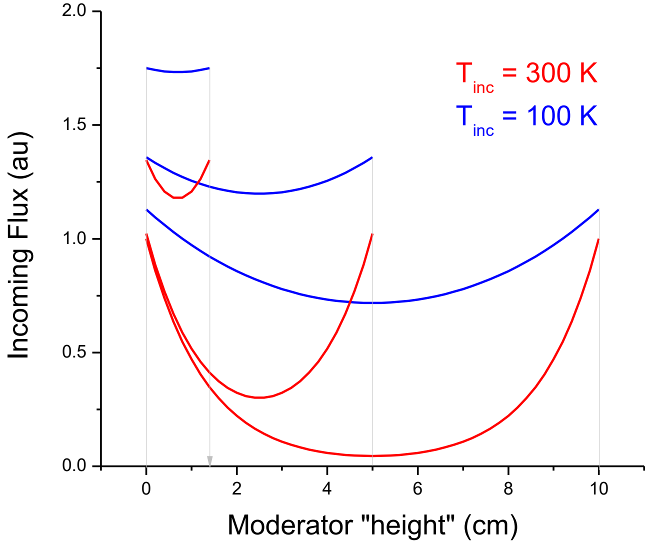

L_{ave} (cm)
T_M (K)

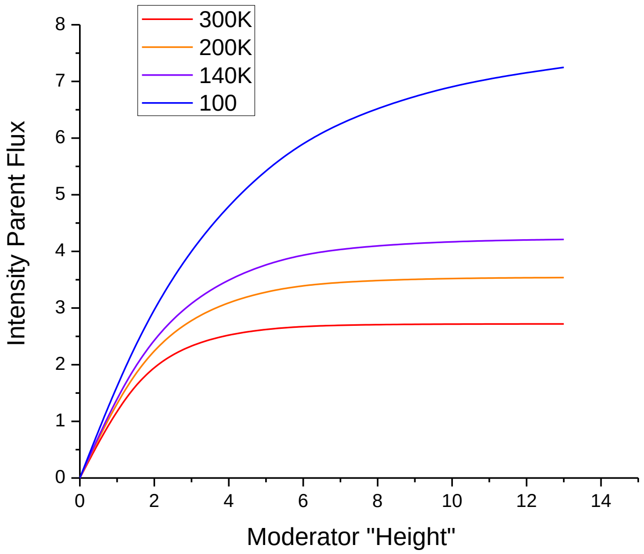

T_{inc} = 300 K
T_{inc} = 100 K
Incoming Flux (au)
Moderator "height" (cm)

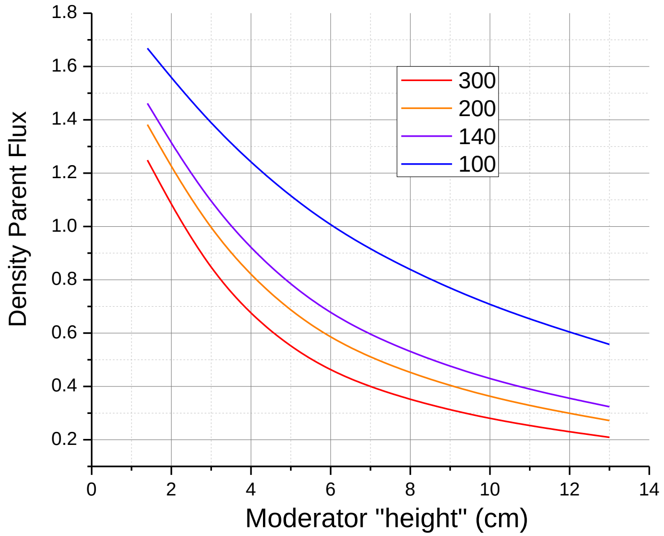
SLAB MODERATOR



(Sketch)

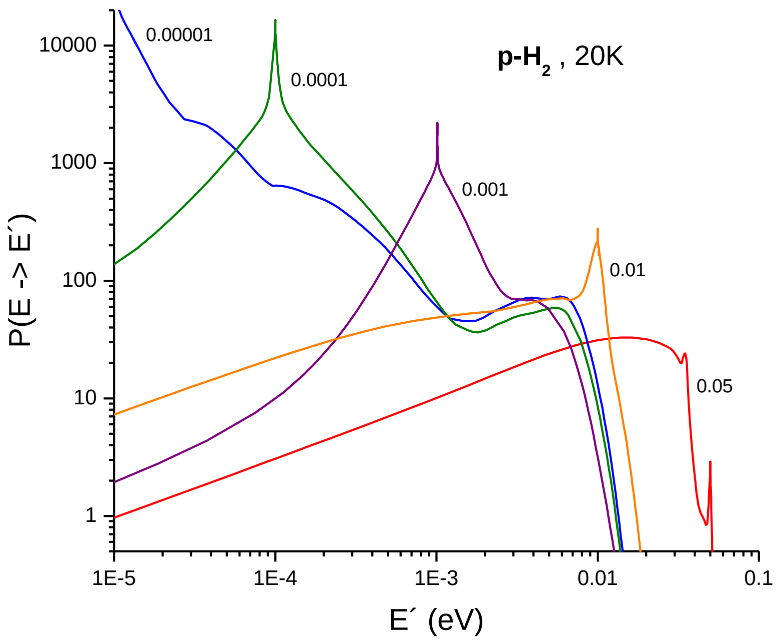






PROBABILITY OF *CN* PRODUCTION

Energy-transfer kernels



"*Cold*" group : $E' \leq 5$ meV

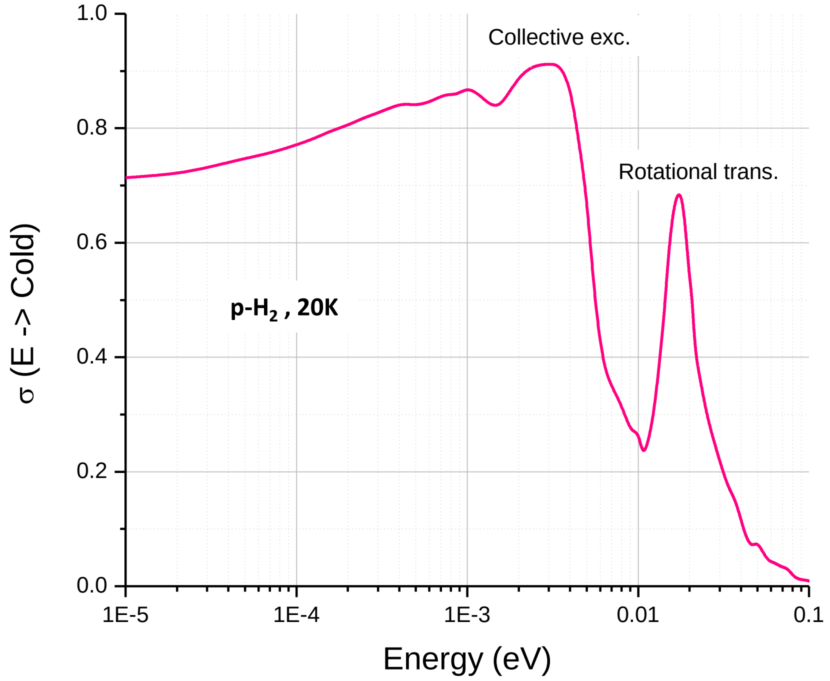
$$\sigma(E \rightarrow \text{"Cold"}) = \int_{Cold} dE' \, \sigma(E) P(E \rightarrow E')$$

TWO-ENERGY GROUPS, SINGLE COLLISION MODEL

Probability Cold Neutron Production: $\Sigma_{1\rightarrow2}$

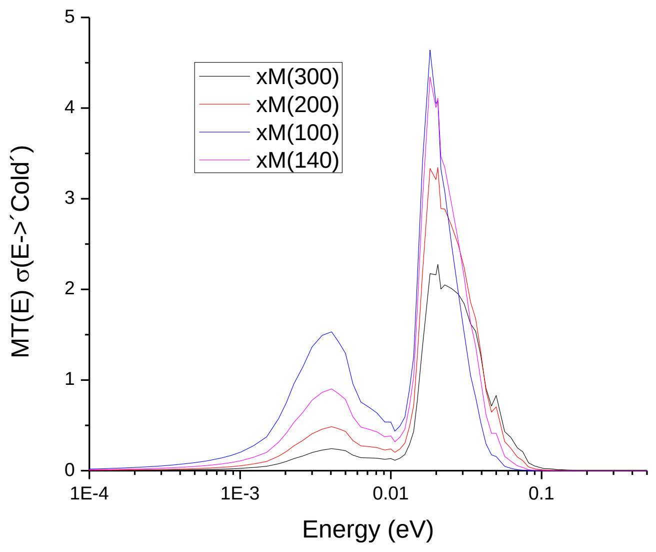
Reaction Rate: $dR_{1\rightarrow2}(x) = \Phi_1(x) \, . \, \Sigma_{1\rightarrow2} \, dx$

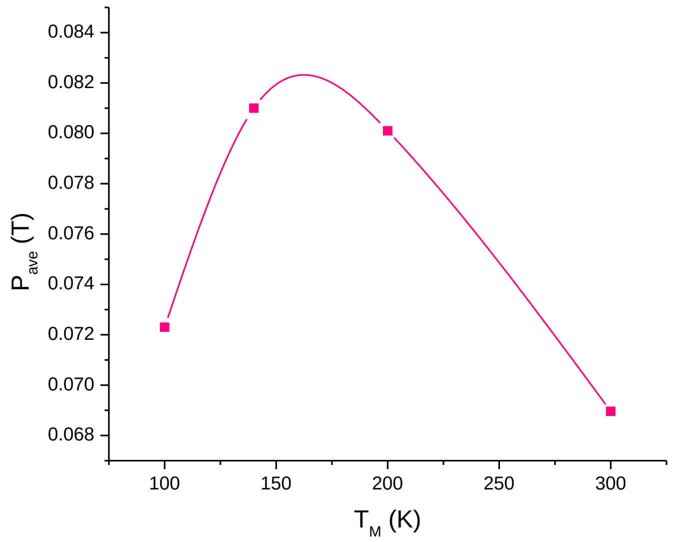
Brightness: $dR_{1\rightarrow2}(x)/dx = \Phi_1(x) \, . \, \Sigma_{1\rightarrow2}$



Again, I use Maxwellian distributions to represent the incoming flux from premoderators at different temperatures. The average probability for CN generation is then

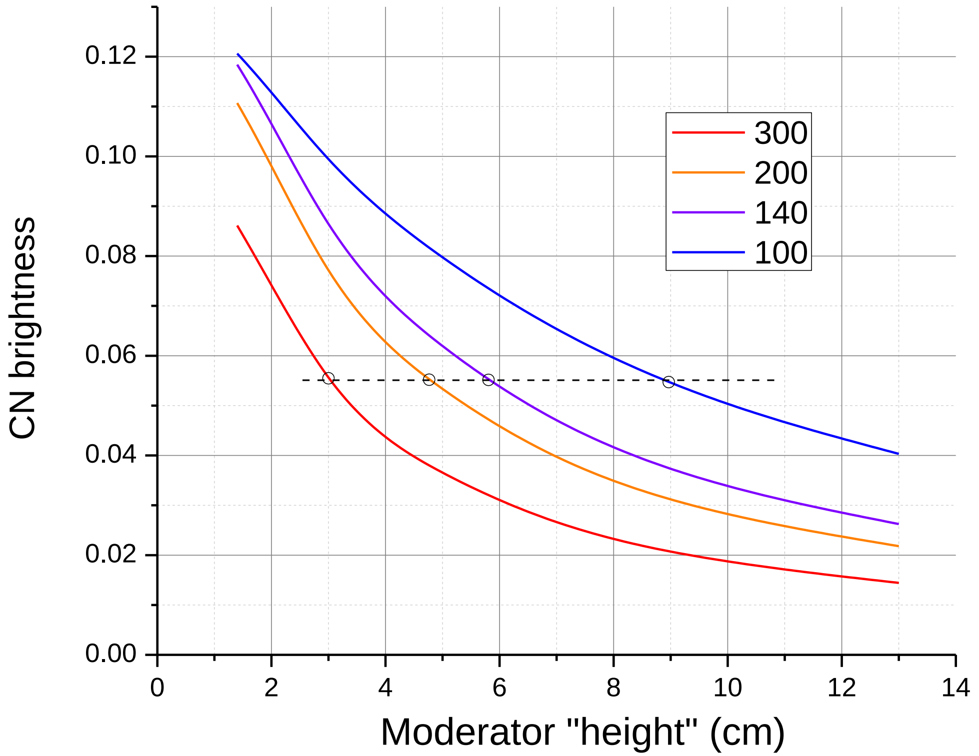
$$P_{ave}(T) = \int dE\, M_T(E)\, \sigma(E \rightarrow \text{"Cold"})$$





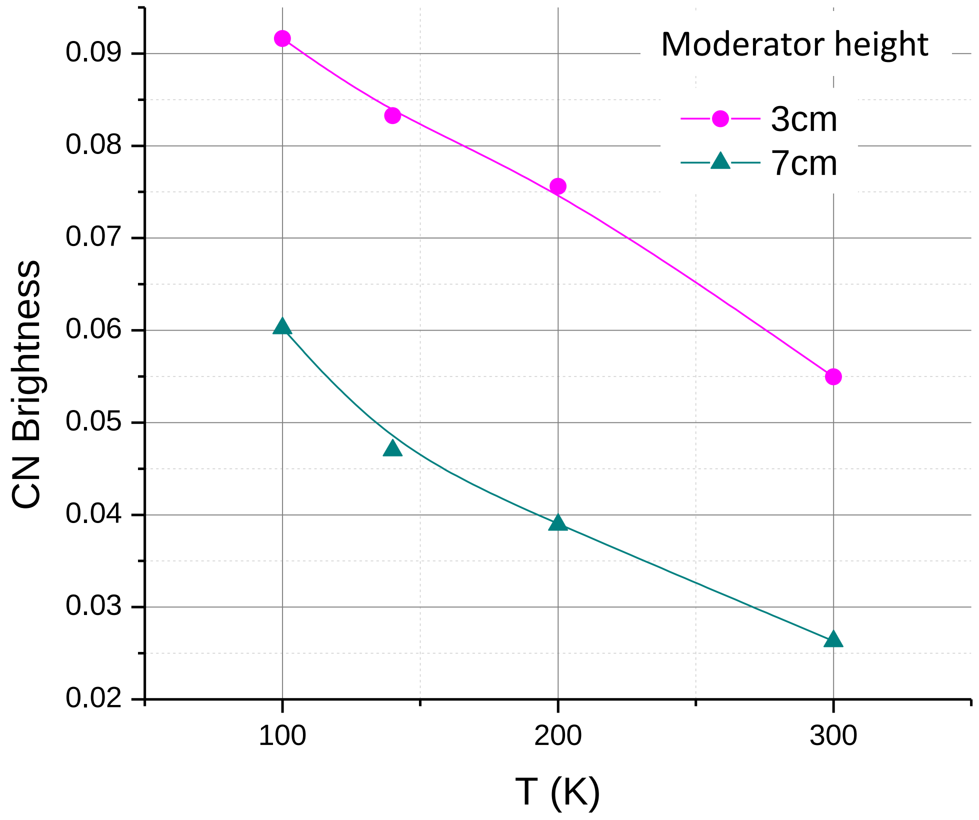
Effective Densities for different Maxwellian temperatures

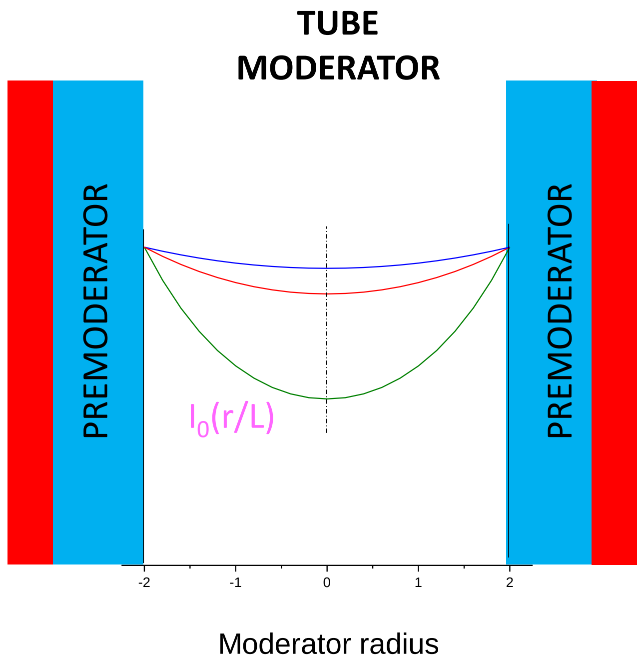
SLAB MODERATOR



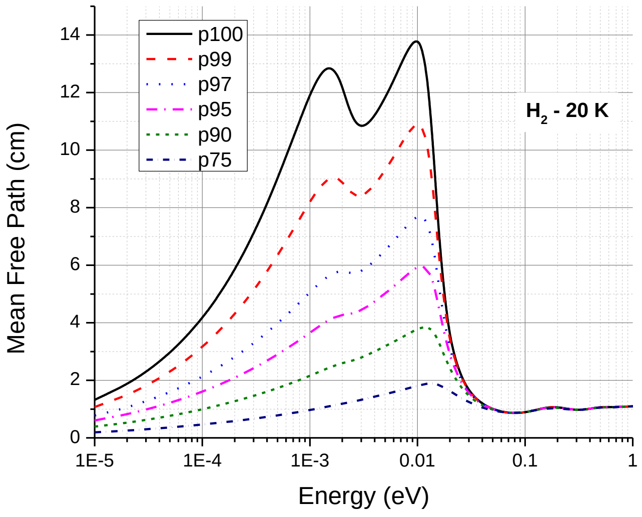
CN Production = $P_{ave}(T)\ N[\phi_{parent}(T)]$

Dependence of CN Brightness with different Maxwellian temperatures

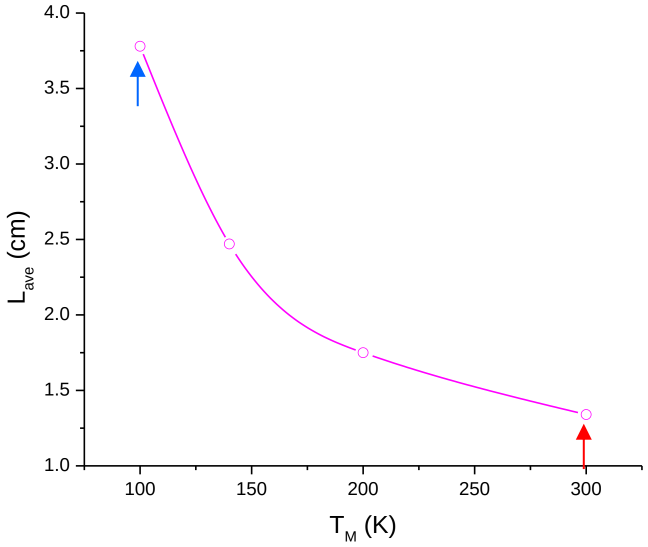




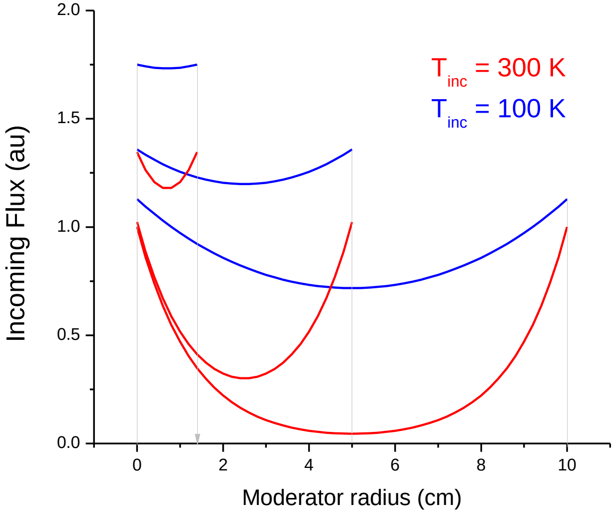
TUBE
MODERATOR
PREMODERATOR
PREMODERATOR
$I_0(r/L)$
-2
-1
0
1
2
Moderator radius



p100
p99
p97
p95
p90
p75
H_2 - 20 K
Mean Free Path (cm)
Energy (eV)
0
2
4
6
8
10
12
14
1E-5
1E-4
1E-3
0.01
0.1
1



L_{ave} (cm)
T_M (K)
1.0
1.5
2.0
2.5
3.0
3.5
4.0
100
150
200
250
300



T_{inc} = 300 K
T_{inc} = 100 K
Incoming Flux (au)
Moderator radius (cm)
0.0
0.5
1.0
1.5
2.0
0
2
4
6
8
10

International Collaboration on Advanced Neutron Sources (ICANS XXII)

ICANS XXII Oxford 2017

27–31 March 2017, Saïd Business School, University of Oxford, UK

Preliminary Thermal Neutron Scattering Kernel for Liquid Ethane

J.R. Granada[1], F. Cantargi[1] and J.I. Márquez Damián [1,2]

[1]Neutron Physics Department and Instituto Balseiro, Centro Atomico Bariloche, CNEA, Argentina and [2]CONICET, Argentina

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CENTRO ATÓMICO BARILOCHE

A "TUNABLE" PREMODERATOR:

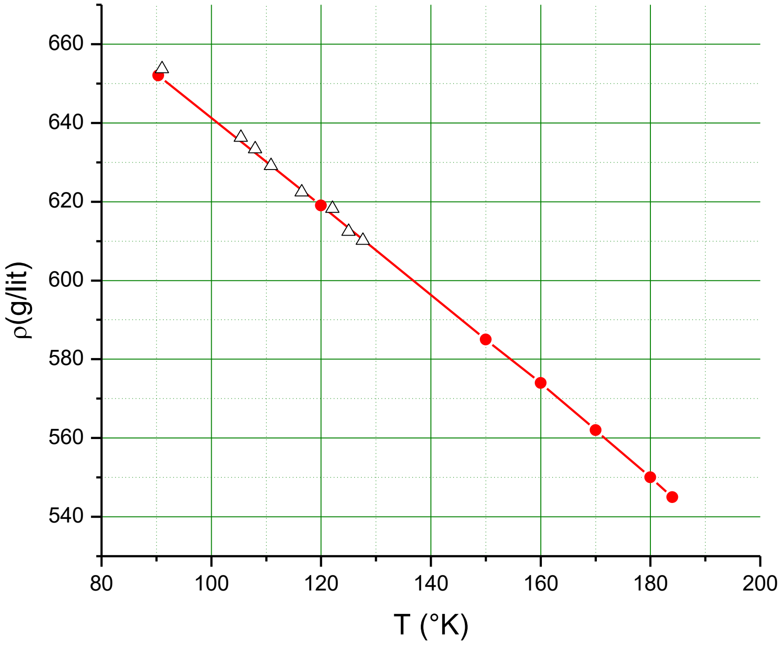
LIQUID ETHANE

EPJ Web of Conferences **146**, 13003 (2017) DOI: 10.1051/epjconf/201714613003

ND2016

Preliminary scattering kernels for ethane and triphenylmethane at cryogenic temperatures

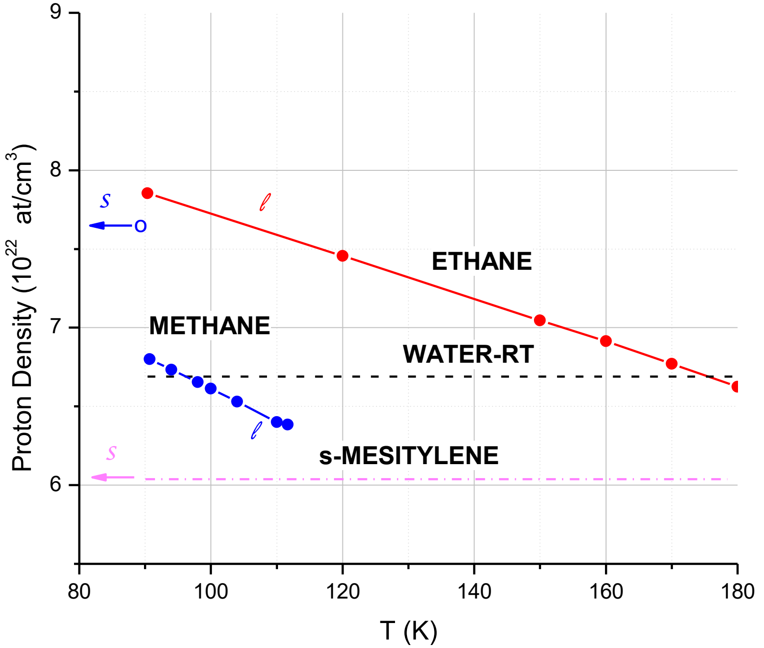
F. Cantargi[a], J.R. Granada, and J.I. Márquez Damián



http://www.engineeringtoolbox.com/ethane-thermal-properties-d_1761.html

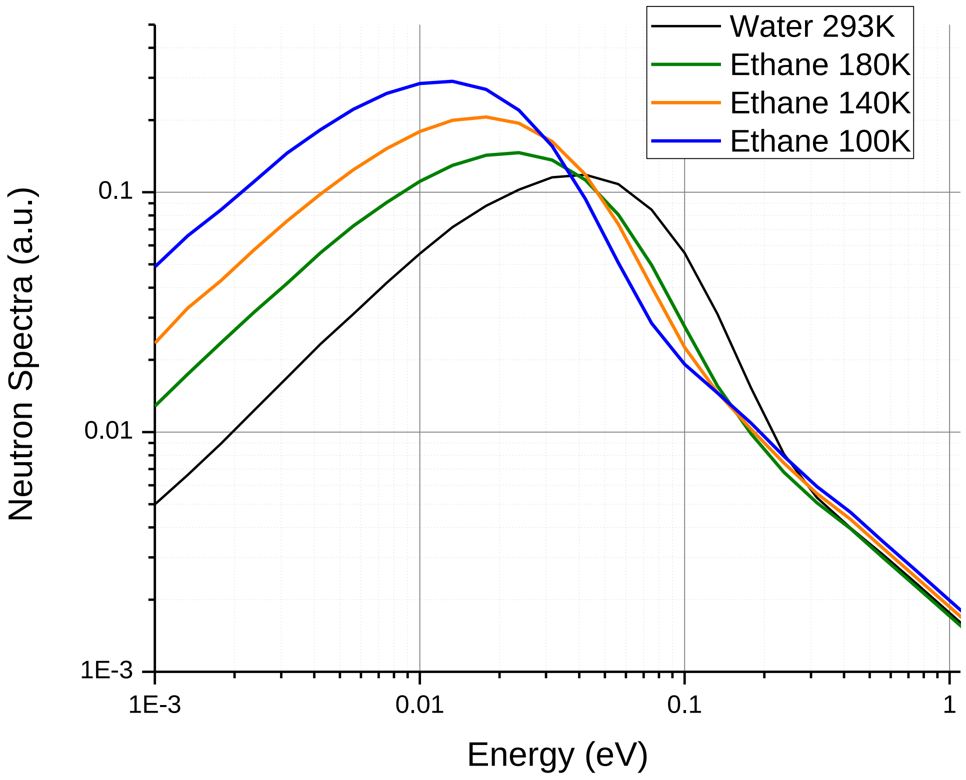
Liquid Ethane exists over a large temperature range…

…and it has a very large protonic density

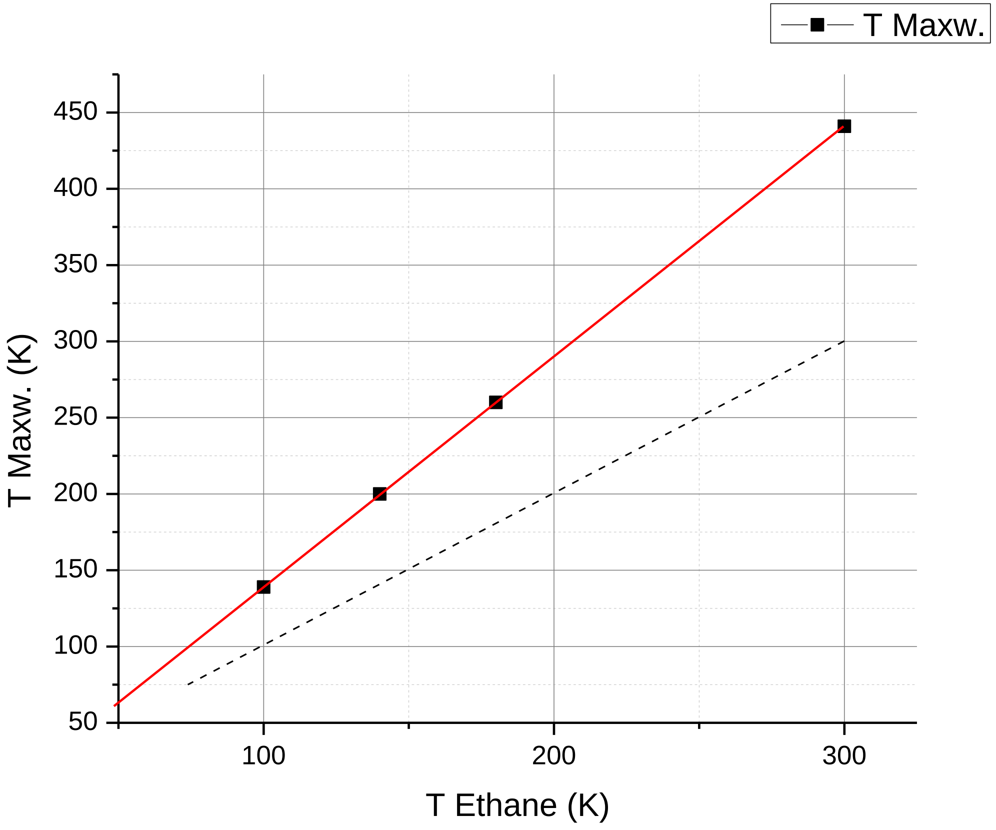


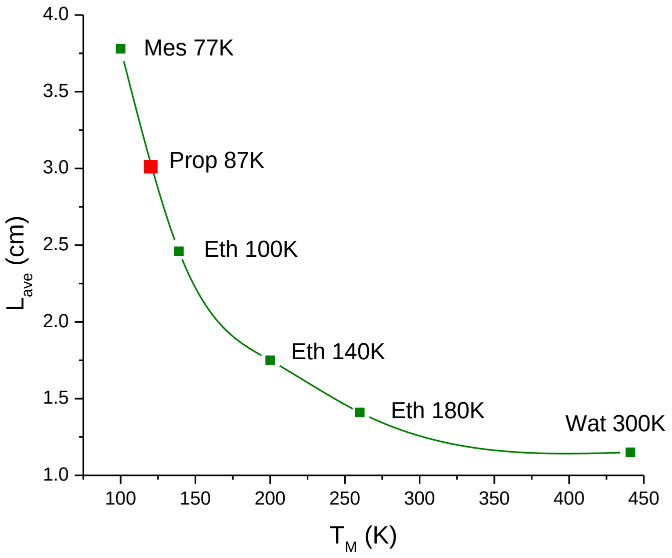
http://www.engineeringtoolbox.com/ethane-thermal-properties-d_1761.html

Neutron spectra for a potential premoderator material

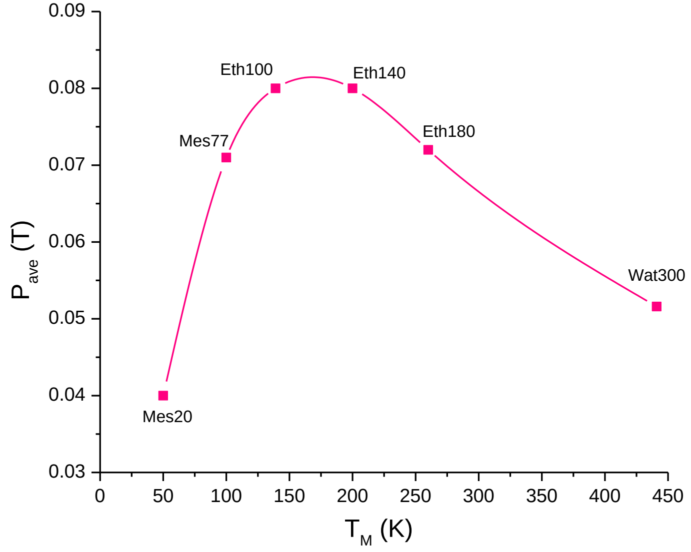


Effective temperature of liquid premods over the temperature range of interest

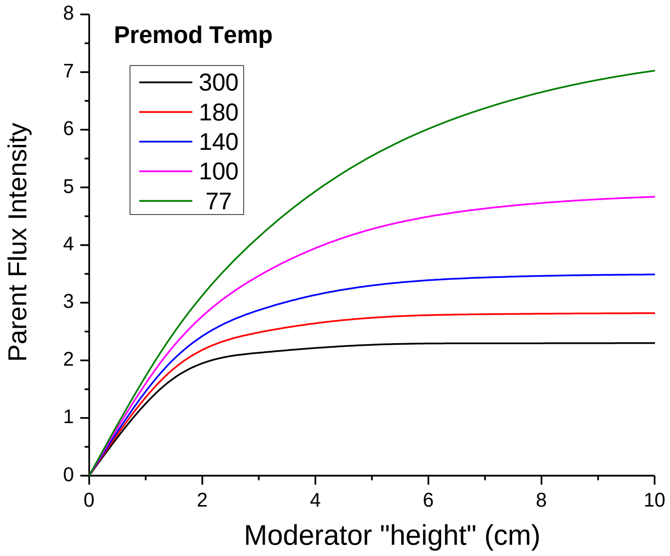




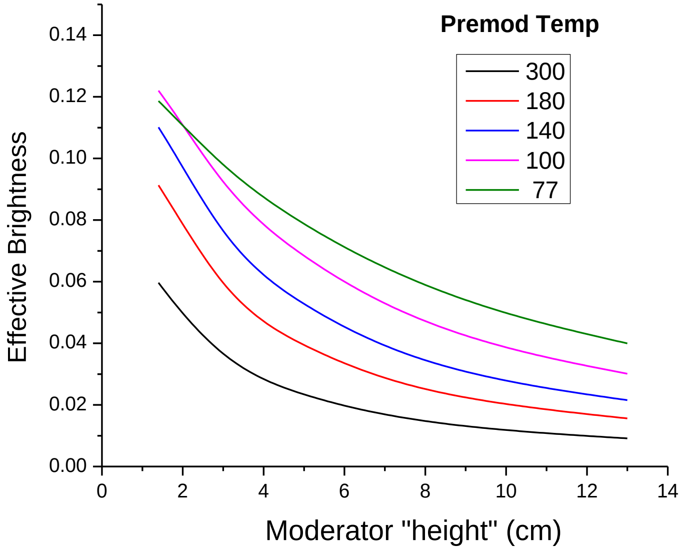
4.0
3.5
3.0
2.5
2.0
1.5
1.0
L_{ave} (cm)
Mes 77K
Prop 87K
Eth 100K
Eth 140K
Eth 180K
Wat 300K
100
150
200
250
300
350
400
450
T_M (K)



0.09
0.08
0.07
0.06
0.05
0.04
0.03
P_{ave} (T)
Eth100
Eth140
Mes77
Eth180
Wat300
Mes20
0
50
100
150
200
250
300
350
400
450
T_M (K)



Premod Temp
300
180
140
100
77
Parent Flux Intensity
0
1
2
3
4
5
6
7
8
0
2
4
6
8
10
Moderator "height" (cm)



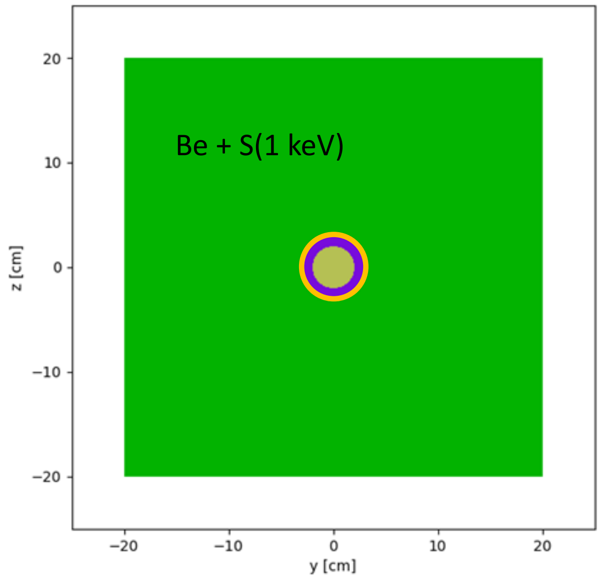
Premod Temp
300
180
140
100
77
Effective Brightness
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0
2
4
6
8
10
12
14
Moderator "height" (cm)

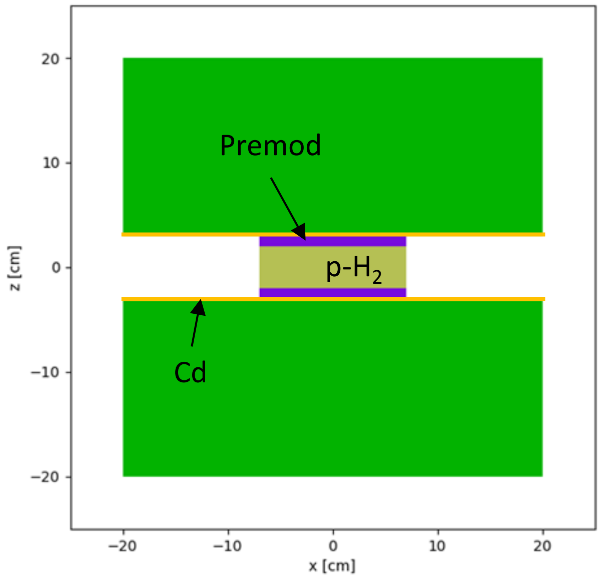
SIMULATIONS

CASE 1: PIPE CONFIGURATION

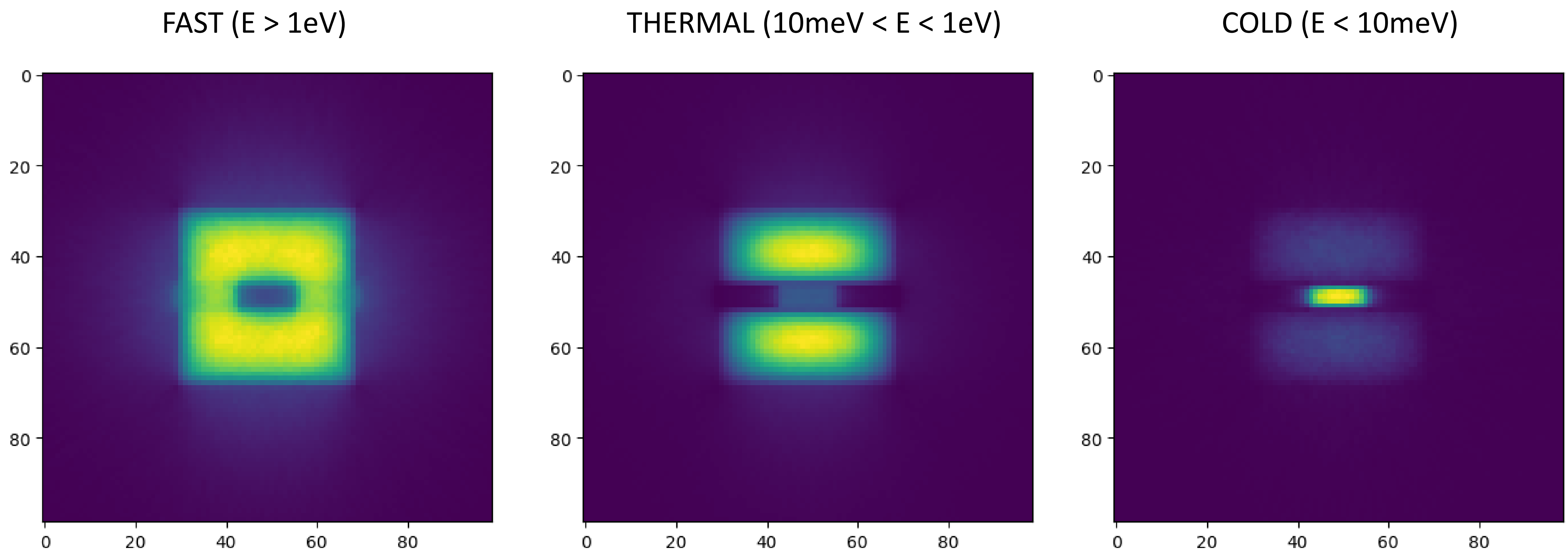
- Berillium cube with a distributed fast (1 keV, isotropic) neutron source
- Central hole lined with 2 mm Cd decoupler
- A 14 cm long pipe moderator with 99% para-H_2 (of variable radius), surrounded by a cylindrical layer of premoderator (of variable thickness)

TUBE

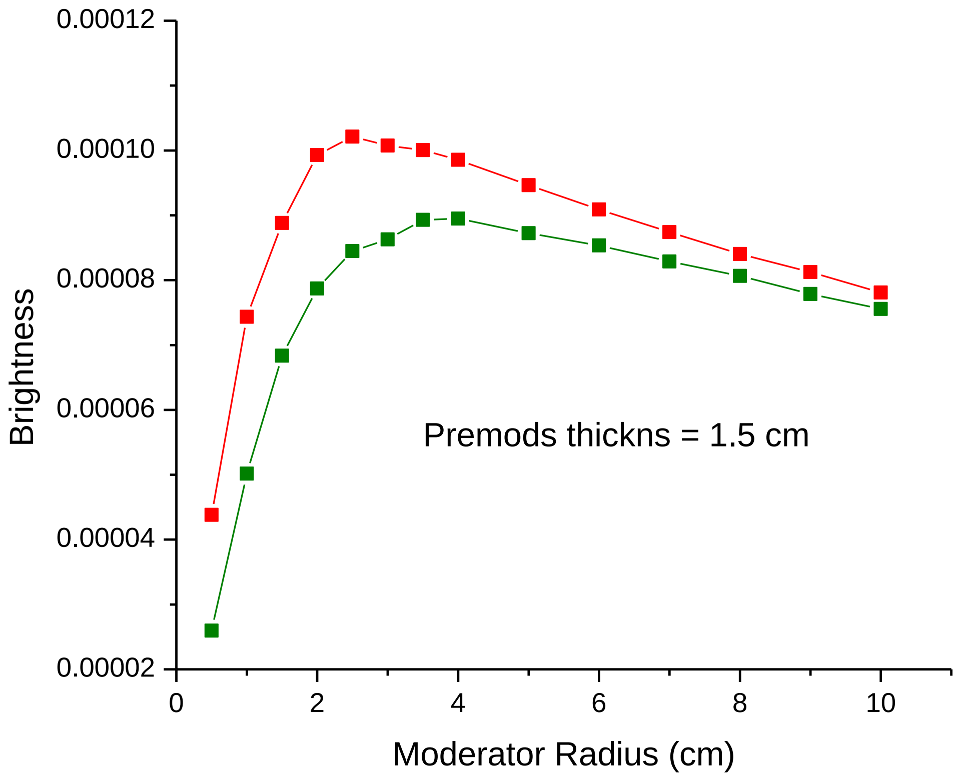




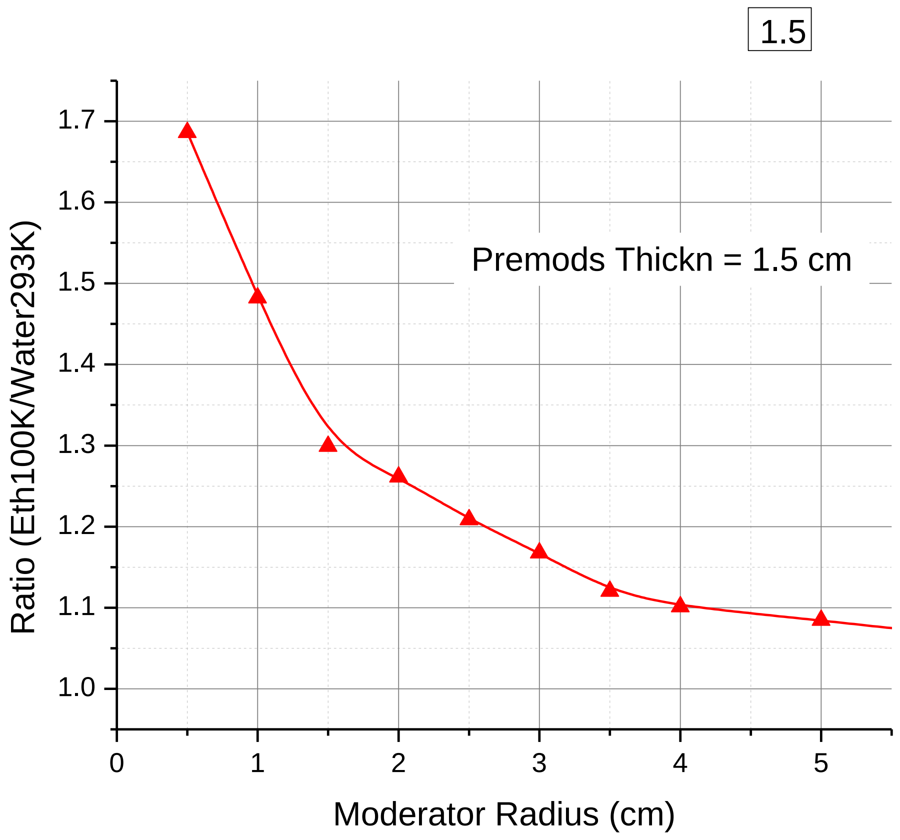
FLUX DISTRIBUTIONS



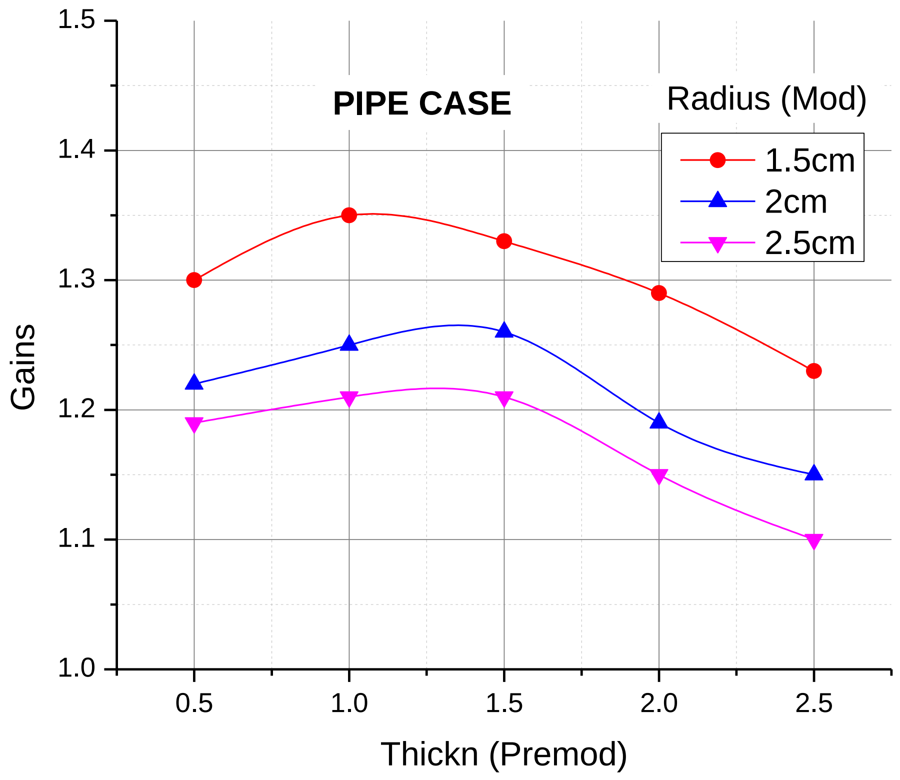
Typical result of CN brightness simulations with RT water (green) and ethane 100 K (red) premoderators with 1.5 cm thickness in this example.



The ratio of the above curves represents the gains in CN brightness when Ethane 100 K is used as premoderator instead of Water 293 K (both with 1.5 cm thickness).



For typical moderator radii the gains as a function of premoderator thicknesses are shown in the figure below. The gains are the ratios of the CN fluxes when Ethane 100K or Water 293K are used as premoderators.



CONCLUSIONS

1. The presented concept involves the production of brightness enhancement in p-H2 moderators by changing the premoderator temperature
2. Basic calculations on a toy configuration were done using integral cross sections, and average magnitudes were employed to describe the relevant processes
3. A potential premoderator material able to cover a wide temperature range has been discussed.
4. Simulations were performed on an idealized tube configuration, that support the conceptual ideas on CN flux enhancement.
5. It is shown by the simulations that gains in the emerging CN flux of the order of 30% or more can be achieved in typical configurations by using cold premoderators instead of water.

THANKS FOR YOUR ATTENTION!