STEREO Update

Cary Rock / University of Tennessee, Knoxville

ORNL-UT N→N’ Meeting

February 16, 2023

Overview

- The analysis of the STEREO reactor simulation is not yet completed but we are close.

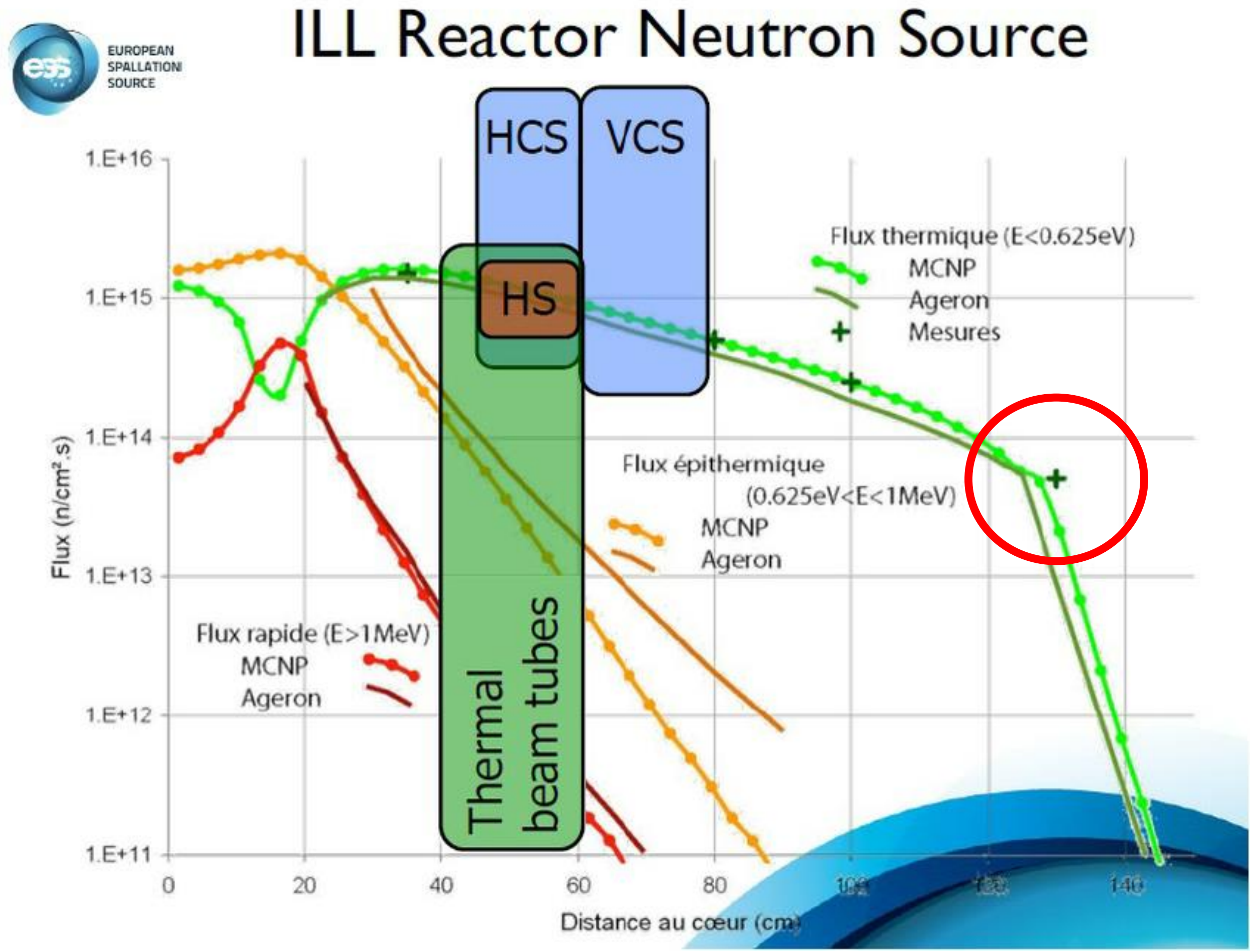
- Progress reported in several issues:

    1) Large Mixing Angle Exclusion in D_2O
    2) Update of Material Parameter Table
    3) Better Understanding the Scintillator
    4) Understanding B_4C Better

1) Large Mixing Angle Exclusion in D_2O Neutron Flux in the ILL Reactor

- MCNP-calculated and measured neutron flux in D_2O* agree to better than < 10? %

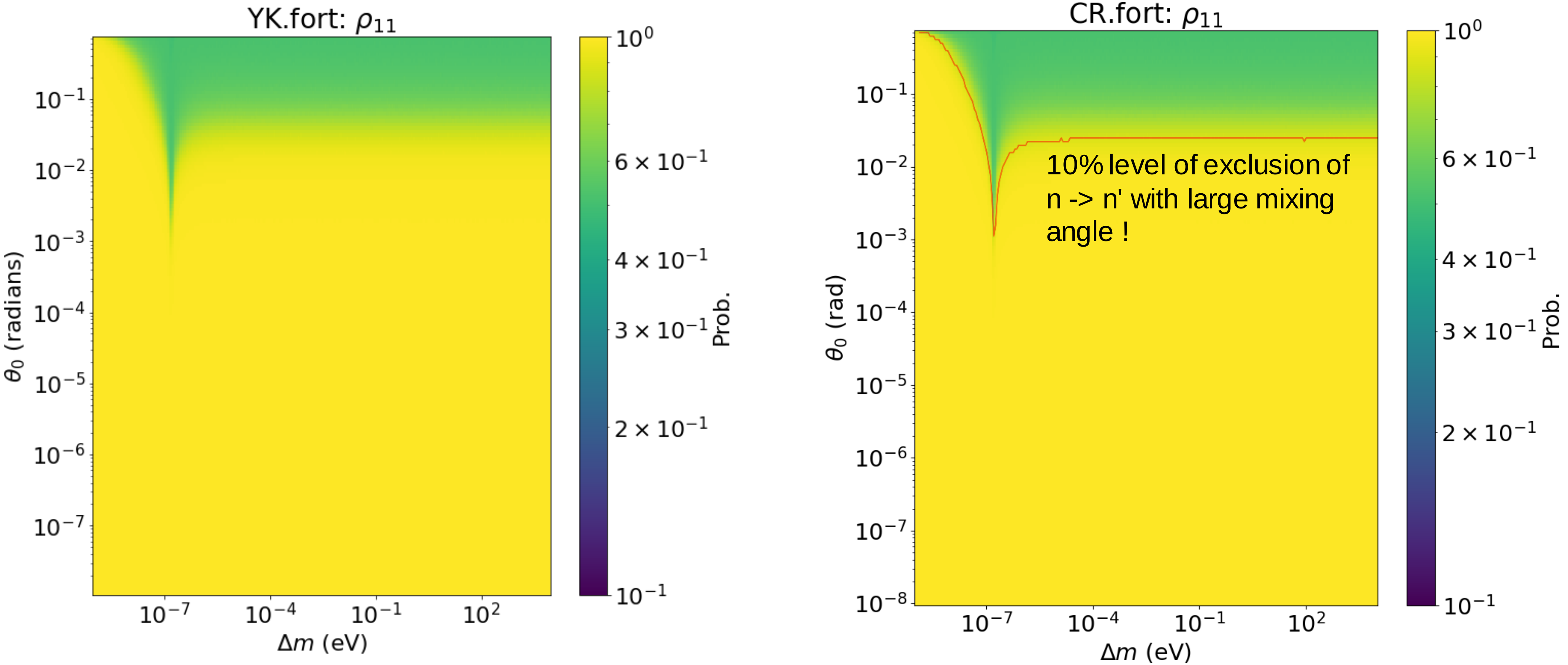
- Will take 10% as an uncertainty of the flux measurements that would be giving max space for disappearance effect



* Figure Source: S.G. Arutunian et al., "Thermal Neutron flux monitors based on a vibrating wire", *Nucl. Inst. Meth.*, **797**, (2015)

1) Large mixing-angle n→n' oscillations can reduce flux by >10%

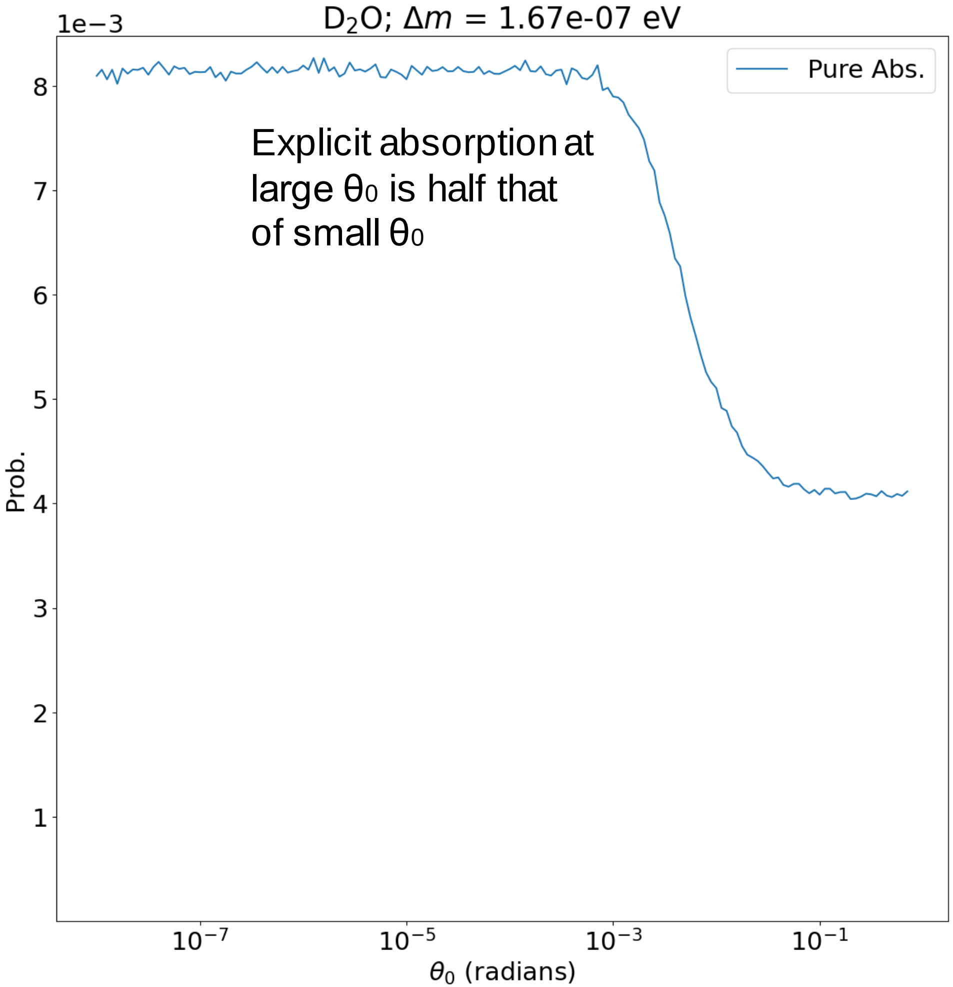
Cross check of Calculation with D_2O – 105 cm, 117 el. sc. Events (λ_{sc} = 2.2 cm)



1) Large mixing-angle n→n' oscillations can reduce flux by >10%

D_2O Comparison at Fixed Δm vs. θ_0

- Absorption at small angles is 8 x 10^{-3} which is close to the direct absorption calculation from absorption for ordinary neutrons
- At large mixing angles θ_0 > 0.01 radians, absorption is factor of 2 lower due to spending ~50% of the time in the state



2) Update of Material Parameter Table

Parameters of Included Material Layers

	Material	Thickness (m)	V (eV)	W_abs (eV)	El. scatt. length (m)	Diffusion Steps
1	D2O	1.05	1.659E-07	2.959E-15	2.041E-02	126.7
2	Aluminum-27	0.03	5.412E-08	1.008E-12	1.104E-01	1
3	H2O	1.5	-1.461E-08	1.610E-12	2.703E-03	1402.9
4	AISI 304 Stainless	0.05	9.135E-07	9.270E-11	2.219E-03	54
5	Heavy Concrete	1.18	3.959E-07	8.040E-09	1.135E-03	2041
6	Air	1.5	1.198E-10	5.756E-15	1.881E+01	1
7	Lead	0.05	8.072E-08	4.081E-13	3.664E-03	32
8	Air	1.5	1.198E-10	5.756E-15	1.881E+01	1
9	Lead	0.1	8.072E-08	4.081E-13	3.664E-03	66
10	Air	1.062	1.198E-10	5.756E-24	1.881E+01	1
11	PE	0.1	-1.694E-13	3.771E-26	7.570E+01	1
12	Lead	0.1	8.072E-08	4.081E-13	3.664E-03	66
13	Air	1.5	1.198E-10	5.756E-24	1.881E+01	1
14	Soft iron	0.01	2.089E-07	1.574E-11	1.014E-02	2
15	B4C covering	0.008	1.992E-07	6.101E-09	1.373E-02	2
16	Lead lining	0.1	8.072E-08	4.081E-13	2.729E-02	66
17	5% borated PE	0.147	1.390E-07	5.594E-09	1.894E-02	17
18	Mu-metal	0.0015	3.461E-08	4.039E-12	4.445E-02	1
19	Acrylic (PMMA)	0.024	-1.989E-08	6.024E-13	4.844E-03	10
20	GC Scintillator	0.369	8.419E-09	1.675E-12	1.688E-03	553
21	Acrylic (PMMA)	0.024	-1.990E-08	2.150E-09	4.844E-03	10
22	Gd-doped Scintillator	0.369	8.503E-09	2.613E-11	1.678E-03	556

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What is elastic scattering length in light water?

Properties of Common Neutron Moderators [3]

	Neutron scattering cross section (σ_s) in barns	Neutron absorption cross section (σ_s) in barns
Light water (H_2O)	49 ? Per molecule ?	0.66 2 Abs xs
Heavy water (D_2O)	10.6	0.0013 2 Abs xs
Graphite (C)	4.7	0.0035

$$\lambda_{sc}(H2O) = \frac{1}{\Sigma} = 0.61\ cm$$

[3] https://www.academia.edu/es/56422446/Bryan_Jeff_C_Introduction_to_nuclear_science_CRC_Press
[4] https://web.archive.org/web/20220617100504/https://www.ncnr.nist.gov/staff/hammouda/distance_learning/chapter_9.pdf - pg. 11

λ_{sc} (H_2O)= 0.27 cm

Neutron scattering lengths and cross sections [*]

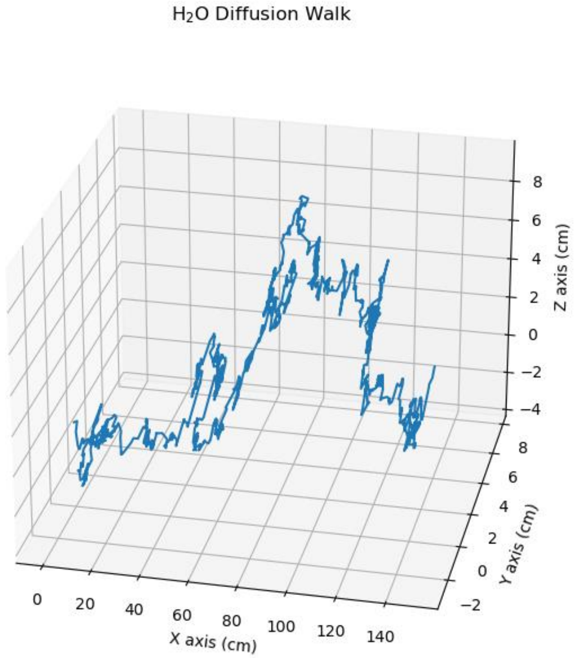
Isotope	conc	Coh b	Inc b	Coh xs	Inc xs	Scatt xs	Abs xs
H	---	-3.7390	---	1.7568	80.26	82.02	0.3326
1H	99.985	-3.7406	25.274	1.7583	80.27	82.03	0.3326
2H	0.015	6.671	4.04	5.592	2.05	7.64	0.000519
O	---	5.803	---	4.232	0.0008	4.232	0.00019
C	---	6.6460	---	5.551	0.001	5.551	0.0035

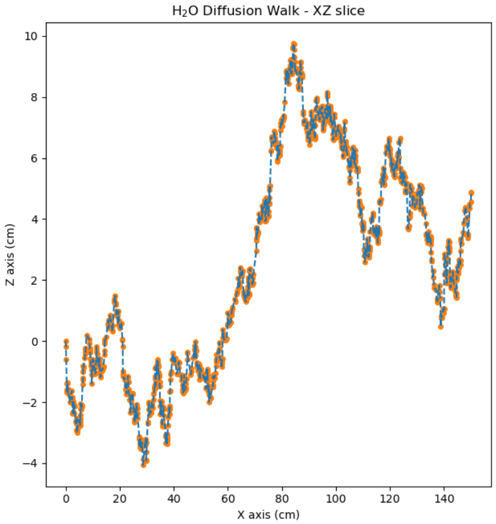
$$\lambda_{sc}(H2O) = \frac{1}{\Sigma} = 0.18\ cm$$

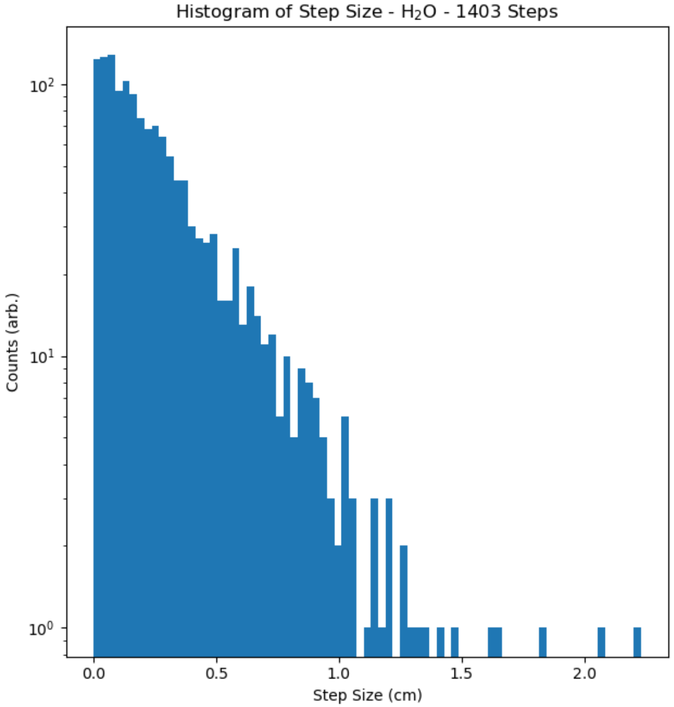
[*] https://www.ncnr.nist.gov/resources/n-lengths/list.html

Plots of H2O Diffusion

Method of Determining number of Scattering Events







3) Better Understanding the Scintillator

- Two types of liquid scintillator
- 36 cm LS (gamma catcher)

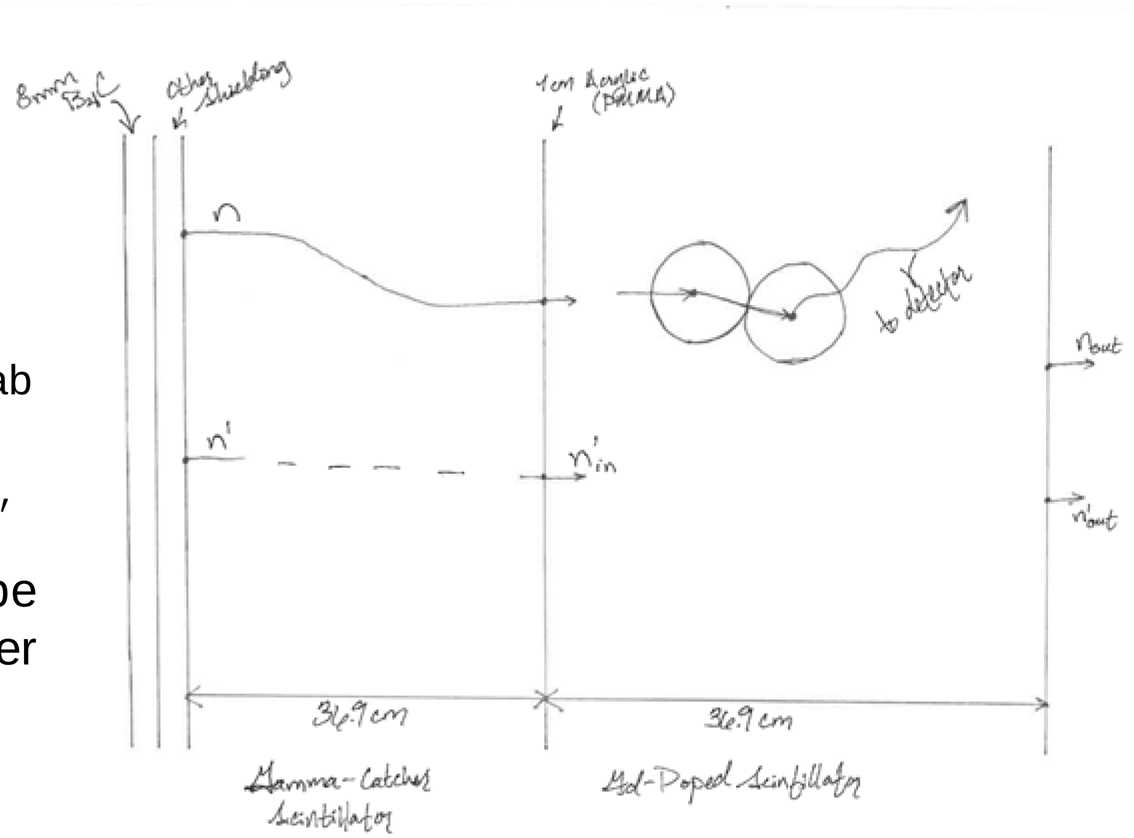
  + 6 × 36 cm LS with Gd

– Otherwise almost identical LS composition.

- STEREO result is referred to the first LS(Gd) slab for n detection. Detected ↘

$$P_{after}(n) = P_{before} - \color{red}{abs.signal} + P_{n' \to n} - P_{n \to n'}$$

Absorbed signal is what is detected and will be compared to STEREO's stated 3.1×10^{-11} per initial neutron produced in the reactor



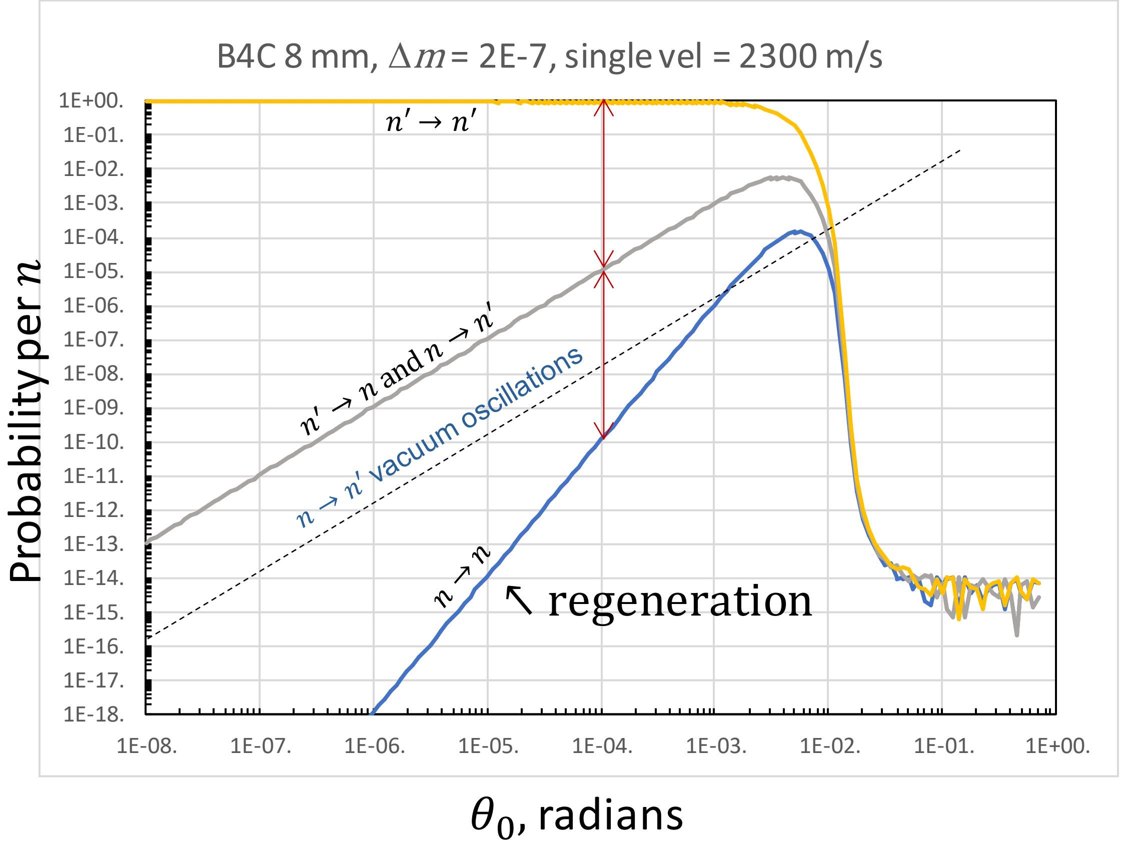
4) Better Understanding B4C
8mm B4C

- For consistency's sake, a check was made at fixed velocity v = 2300 m/s

- It was assumed no elastic scattering for 8mm B4C ($\lambda_{el} = 1.3$ cm)

- Δm = 2.0E-7 eV, in resonance

- YK and CR had consistent numbers.



Presence of possible elastic scattering for neutrons with fixed velocity doesn't change significantly the overall character of absorption