A DETAILED MONTE CARLO ACCOUNTING OF RADIATION TRANSPORT IN THE BRAIN DURING BNCT

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A DETAILED MONTE CARLO ACCOUNTING

QUANTITATIVE *BOOKEEPING* OF

- NEUTRON COLLISIONS PER HISTORY
- CAPTURE FRACTION

BREAKDOWN INTO COMPONENTS

- H, C, N, O, Na, Mg, P, S, Cl, ...
- tumour, lens, nervous system, corpus colloseum, ...

MCNPX 2.5.0 SIMULATIONS

Table 1. Combinations of ^{10}B mass concentration specified in five independent simulations.

Simulation	^{10}B concentration (ppm)		
	B_B	B_T	B_R
S_I	0	0	0
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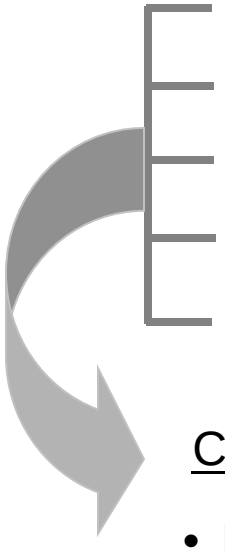
S_{IV}	15	50	10
S_V	10	30	10



COMPARE

- NEUTRON COLLISIONS PER HISTORY
- CAPTURE FRACTION

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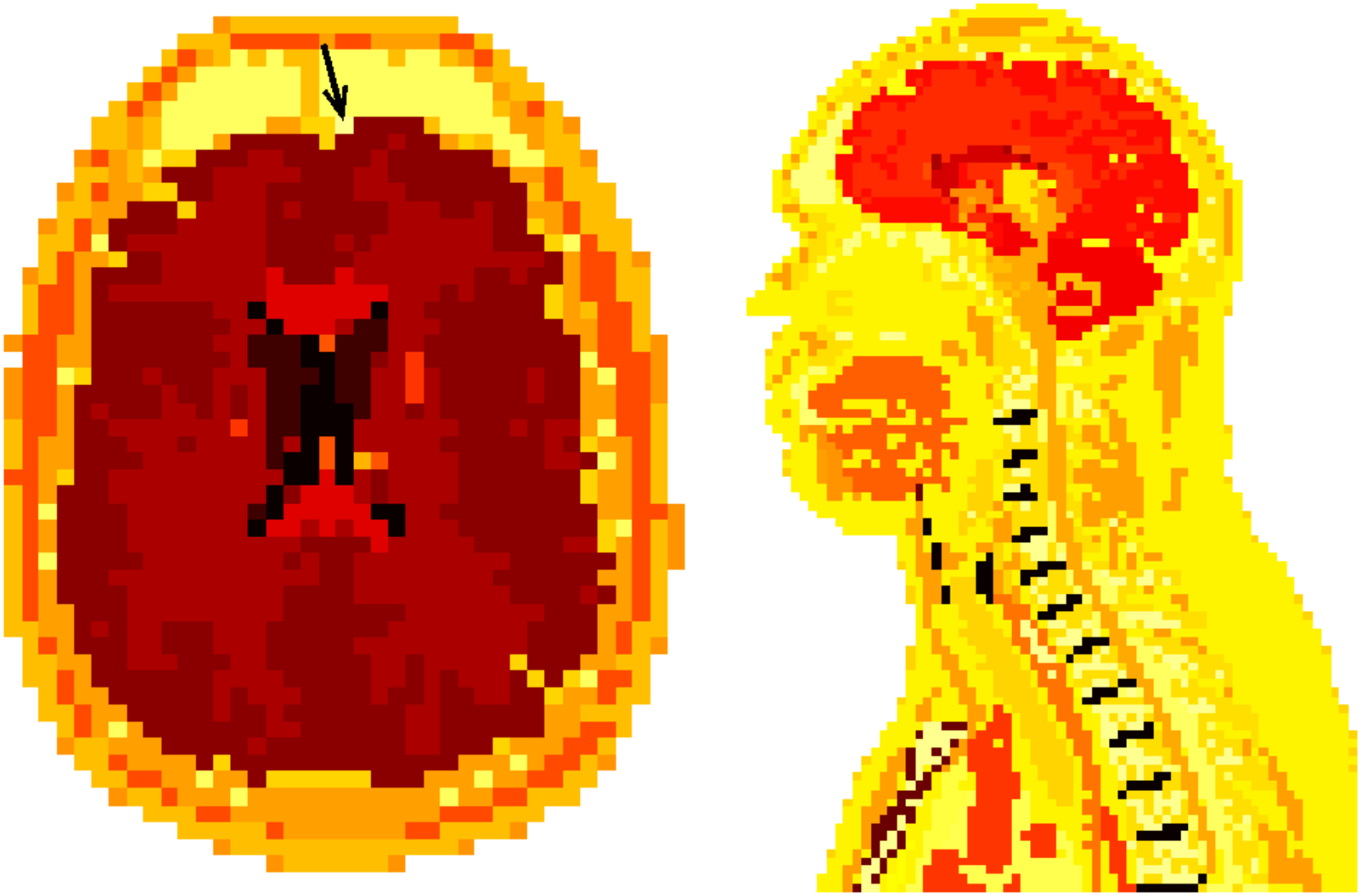
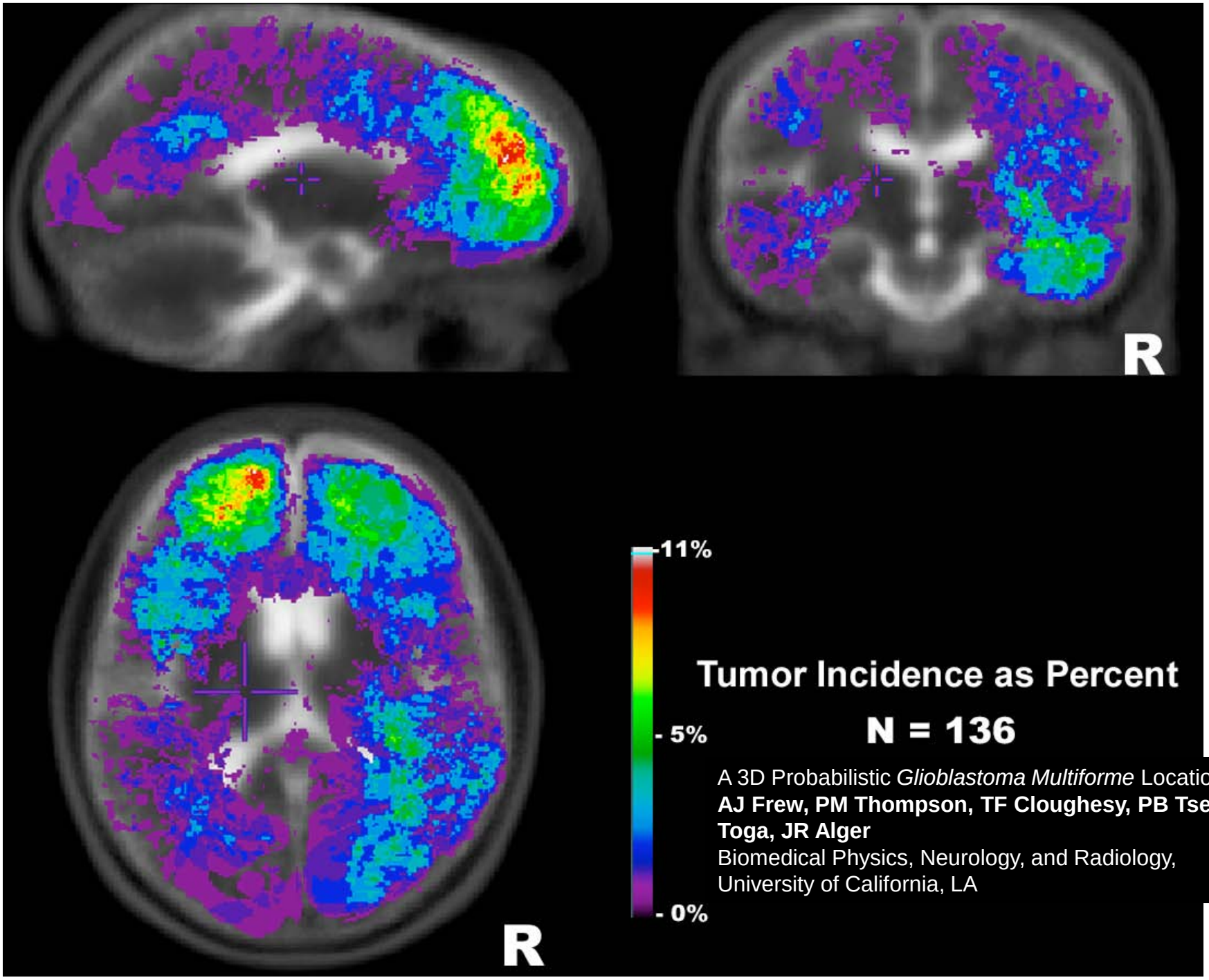
COMPARE

- NEUTRON COLLISIONS PER HISTORY
- CAPTURE FRACTION

IN MCNP/MCNPX NOMENCLATURE 'CAPTURE' INCLUDES *RADIATION CAPTURE* AND *ABSORPTION*

^{10}B ADDED TO A VOXEL (ORIGINALLY GRAY MATTER)

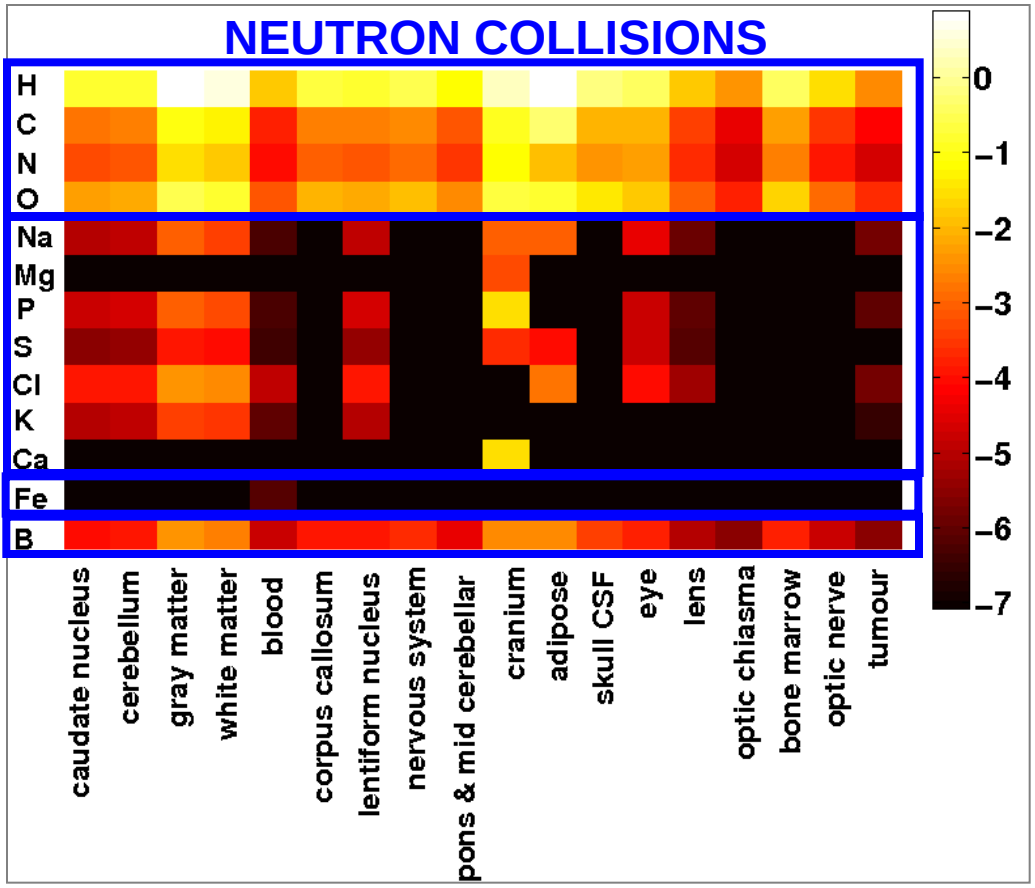




A 3D Probabilistic *Glioblastoma Multiforme* Location Atlas

AJ Frew, PM Thompson, TF Cloughesy, PB Tseng, AW Toga, JR Alger

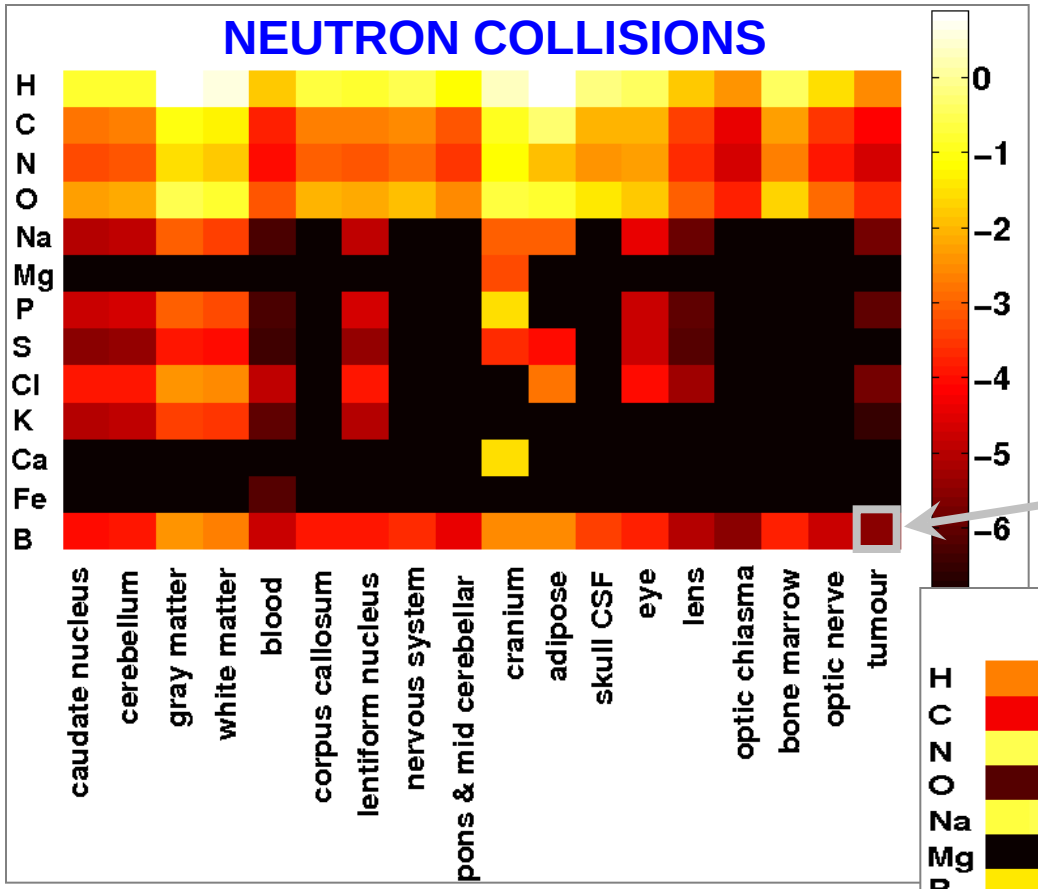
Biomedical Physics, Neurology, and Radiology, University of California, LA



MAJOR ELEMENTS

MINOR ELEMENTS

TRACE ELEMENT INTRODUCED BY BNCT

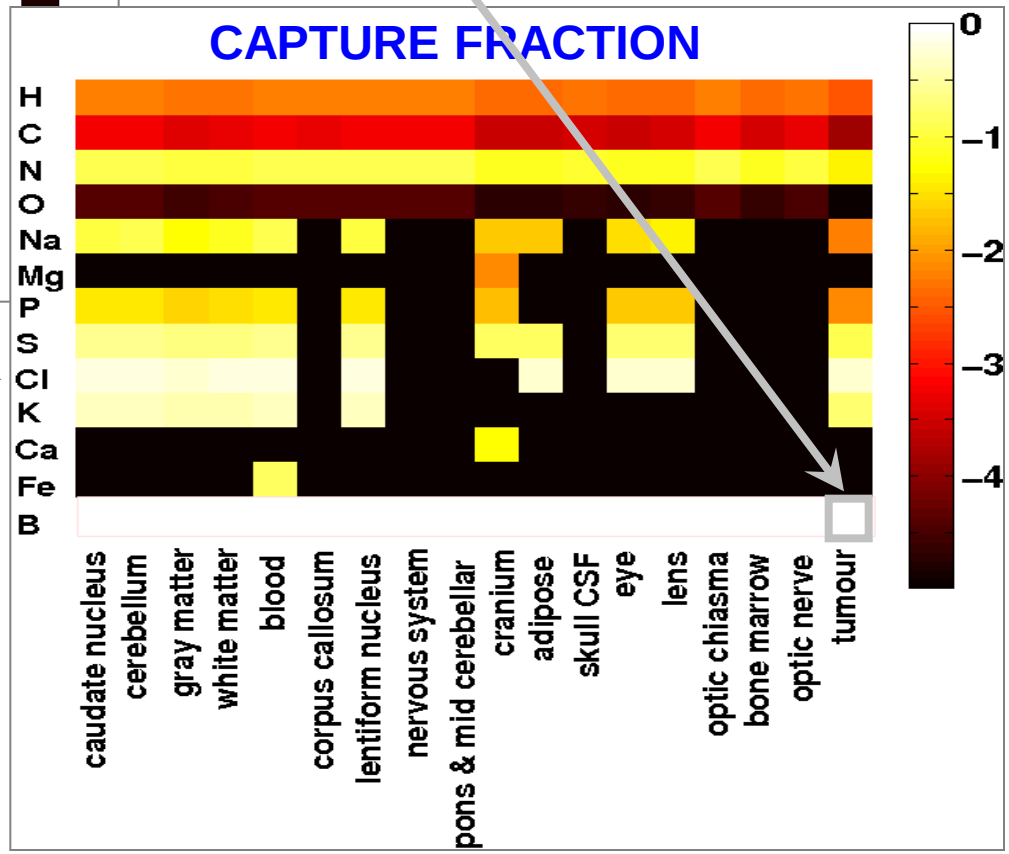


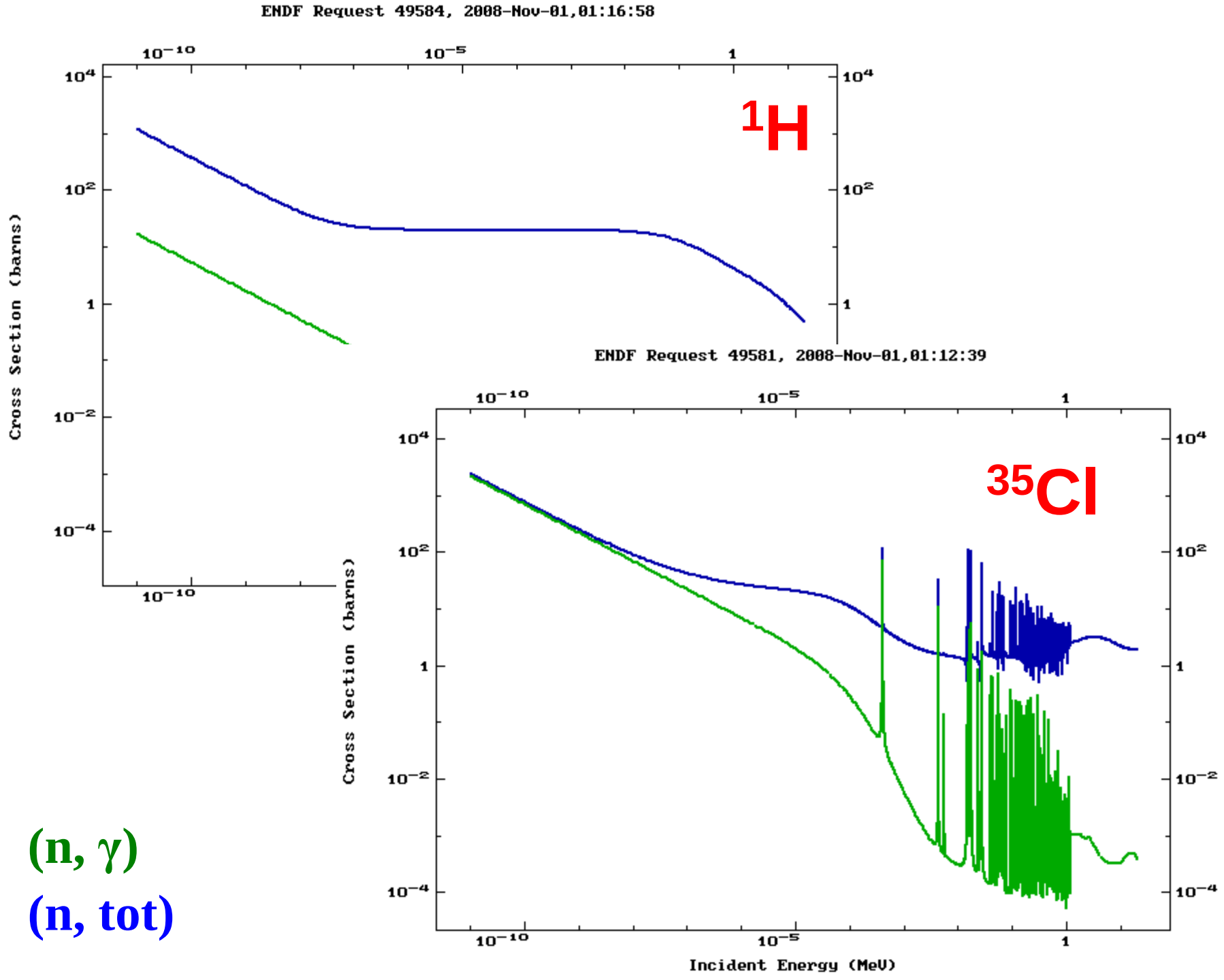
IF BNCT WERE AS NICE AND CLEAN AS

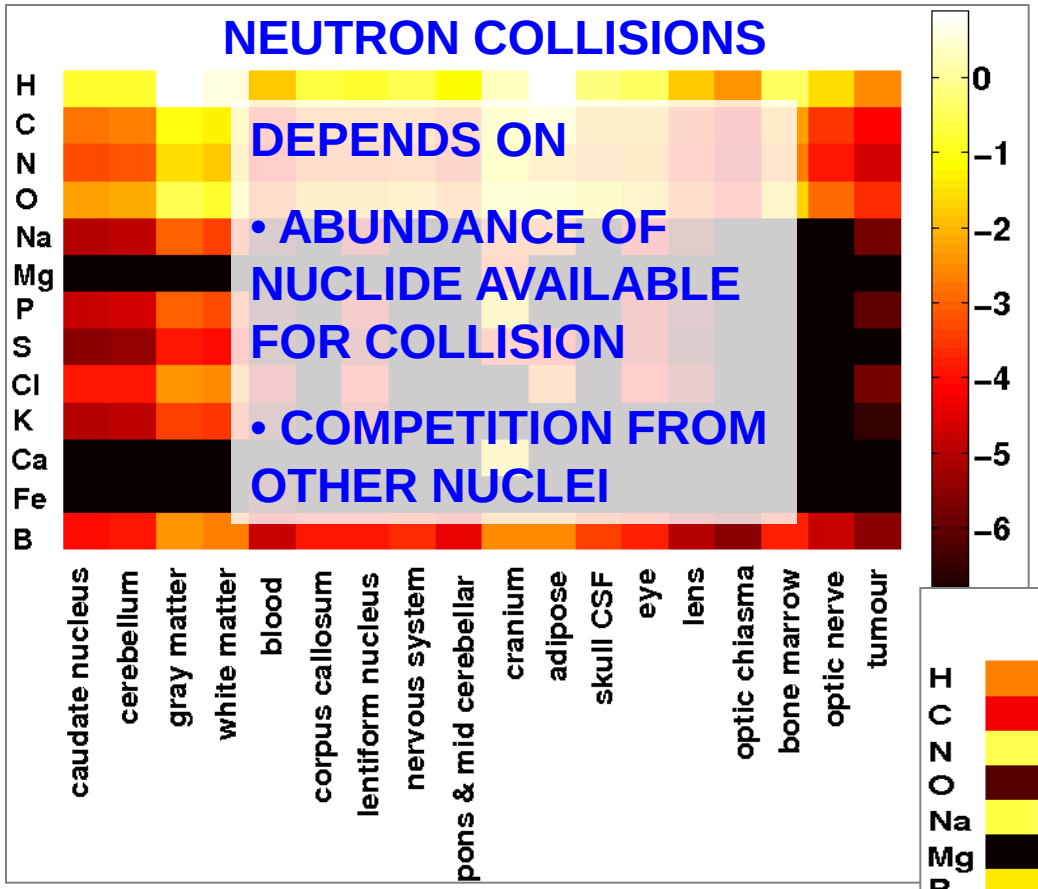
$$^{10}B + n \rightarrow {}^{7}Li + \alpha$$

ONLY 2 PIXELS SHOULD LIGHT UP

INDEED CAPTURE CROSS-SECTIONS FOR ^{35}Cl AND ^{37}Cl ARE HIGH

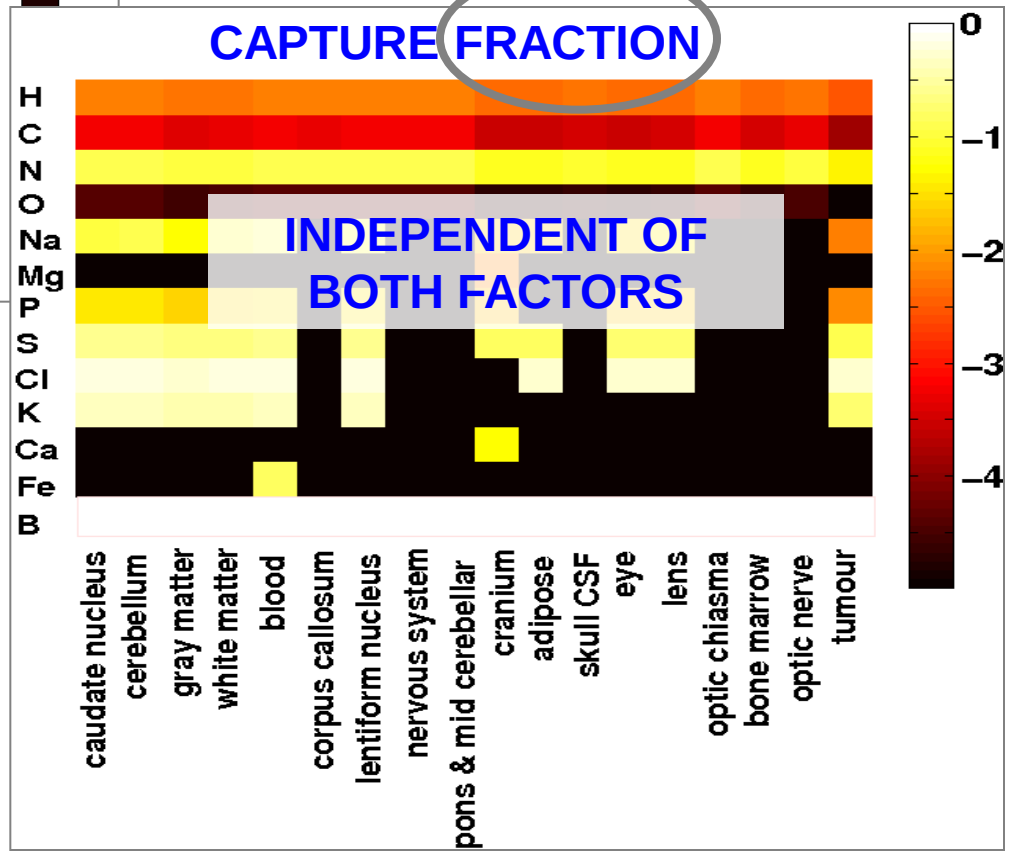



ENDF Request 49584, 2008-Nov-01,01:16:58
1H
ENDF Request 49581, 2008-Nov-01,01:12:39
35Cl
Cross Section (barns)
Incident Energy (MeV)
(n, γ)
(n, tot)



DEPENDS ON RELATIVE CROSS-SECTIONS FOR THE GIVEN NUCLIDE

$$\frac{capture}{elastic + inelastic + capture}$$



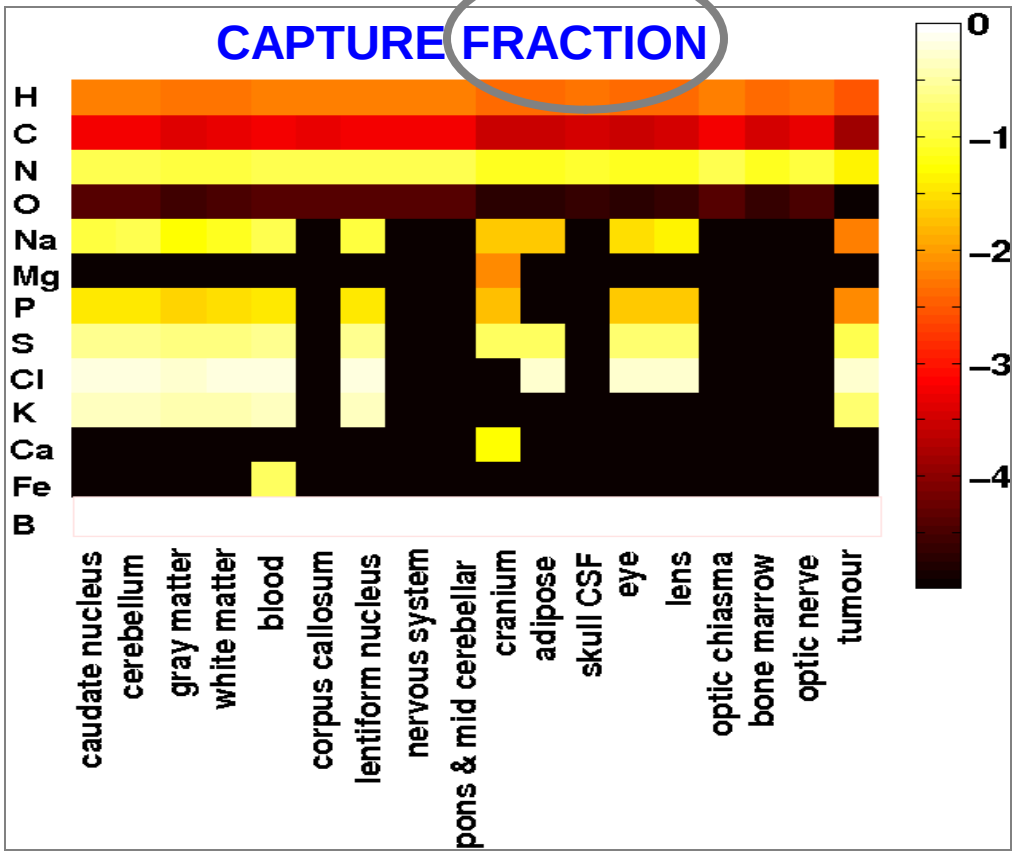
IF THIS WERE THE ONLY DEPENDENCE

DEPENDS ON RELATIVE CROSS-SECTIONS FOR THE GIVEN NUCLIDE

$$\frac{capture}{elastic + inelastic + capture}$$

1. **WE WOULDN'T NEED MONTE CARLO… CAN CALCULATE FROM CROSS-SECTIONS**

2. **CAPTURE FRACTION OF CARBON WOULD BE CONSISTENT WHETHER IN CEREBELLUM, OPTIC NERVE OR TUMOUR**



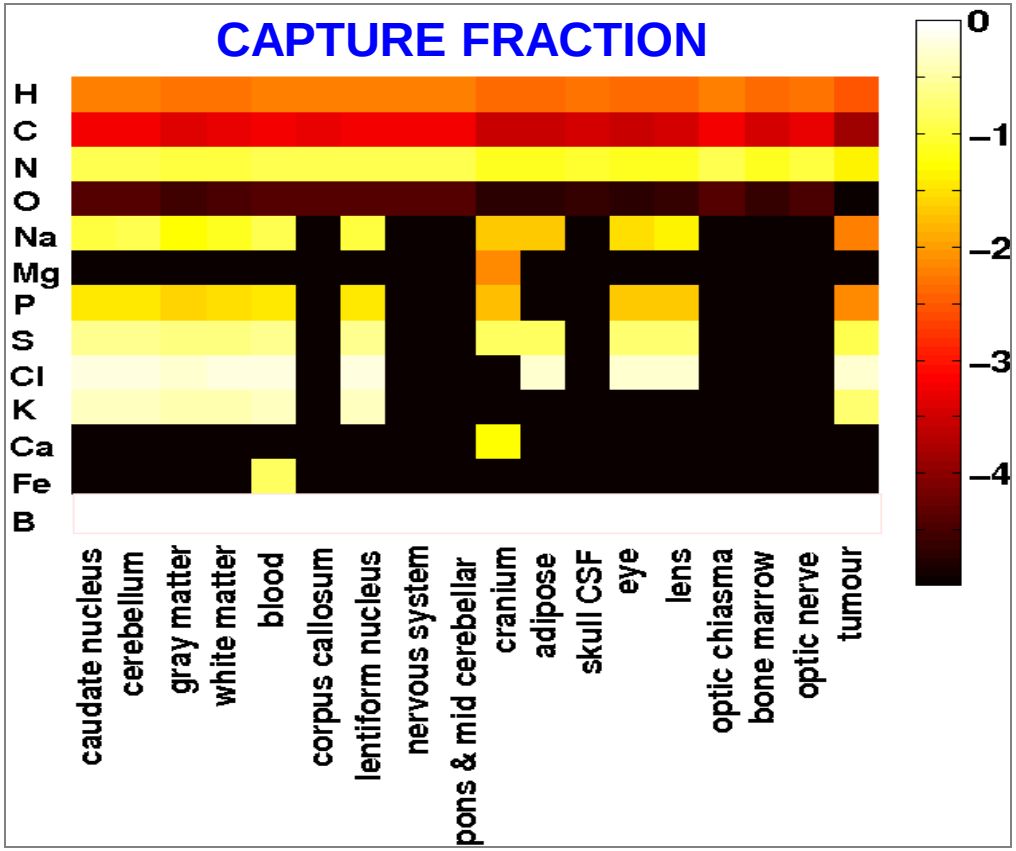
THE SAME NUCLIDE CAUSES DIFFERENT RADIATION EFFECTS IN DIFFERENT TISSUES ➔ DESIGN OF TARGETTED DRUGS

WHAT
BACK-OF-THE-ENVELOPE
CALCULATIONS
CAN'T TELL US

SCREENING EFFECTS

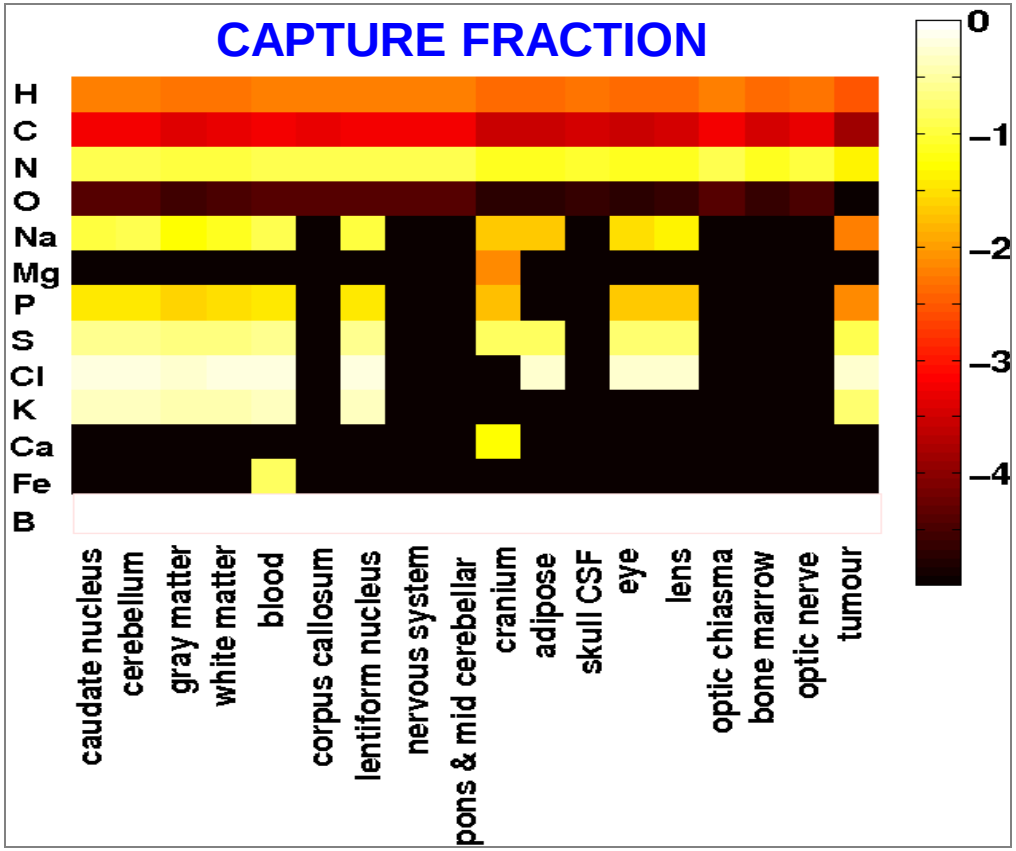
DUE TO EVENTS UPSTREAM OF THE PARTICLE'S RANDOM WALK

ie the neutron's experience prior to meeting a particular nuclide at a given location



PRODUCED CAPTURE GAMMA-RAYS AS HIGH AS 6.49, 9.28, 7.93, 8.64, 8.58, 7.77 MeV …

HIGHER THAN CONVENTIONAL RADIOTHERAPY'S PEAK @ 6 MeV (18 MV mode)!



Thermal Neutron Capture Gammas — Target Nucleus ^{10}B

Target Nucleus= ^{10}B

Strongest transition Eγ=4444.00+-2.00 keV %Iγunknown

Eγ (keV)	ΔEγ (keV)	Iγ/Iγ(max) (%)	Δ(Iγ/Iγ(max))
2120.00	0.00	4.6	0.21
2295.00	2.00	15.3	4.67
2534.00	2.00	23.0	3.26
4444.00	2.00	100.0	6.53
4711.00	2.00	38.4	2.35
5019.00	0.00	3.0	0.14
6739.00	2.00	29.2	2.05
7006.00	2.00	83.0	6.00
8916.00	2.00	23.0	3.26
11447.00	2.00	9.	1.60

^{10}B ITSELF PRODUCED UP TO 11.447 MV CAPTURE GAMMA-RAYS

HIGHER THAN CONVENTIONAL RADIOTHERAPY'S PEAK @ 6 MeV (18 MV mode)!

INTRODUCING ^{10}B INTO THE BODY DECREASES THE NUMBER OF NEUTRON COLLISIONS WITH MAJOR & MINOR ELEMENTS, MOST NOTABLY IN BLOOD. NEUTRONS COLLIDE WITH ^{10}B INSTEAD. A PRE-INJECTION PATIENT WOULD HAVE HAD MORE NEUTRON COLLISIONS & BACKGROUND DOSE.

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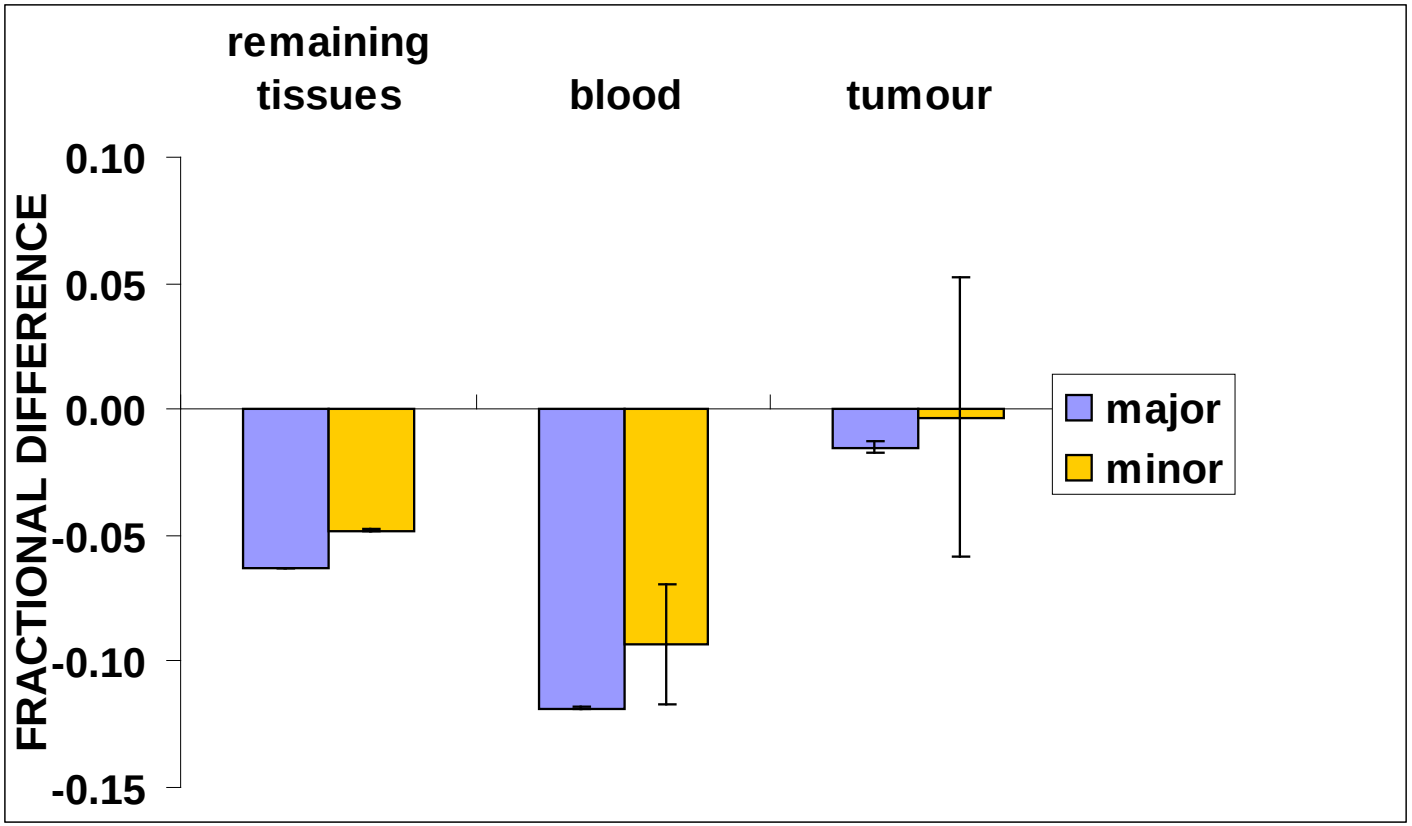

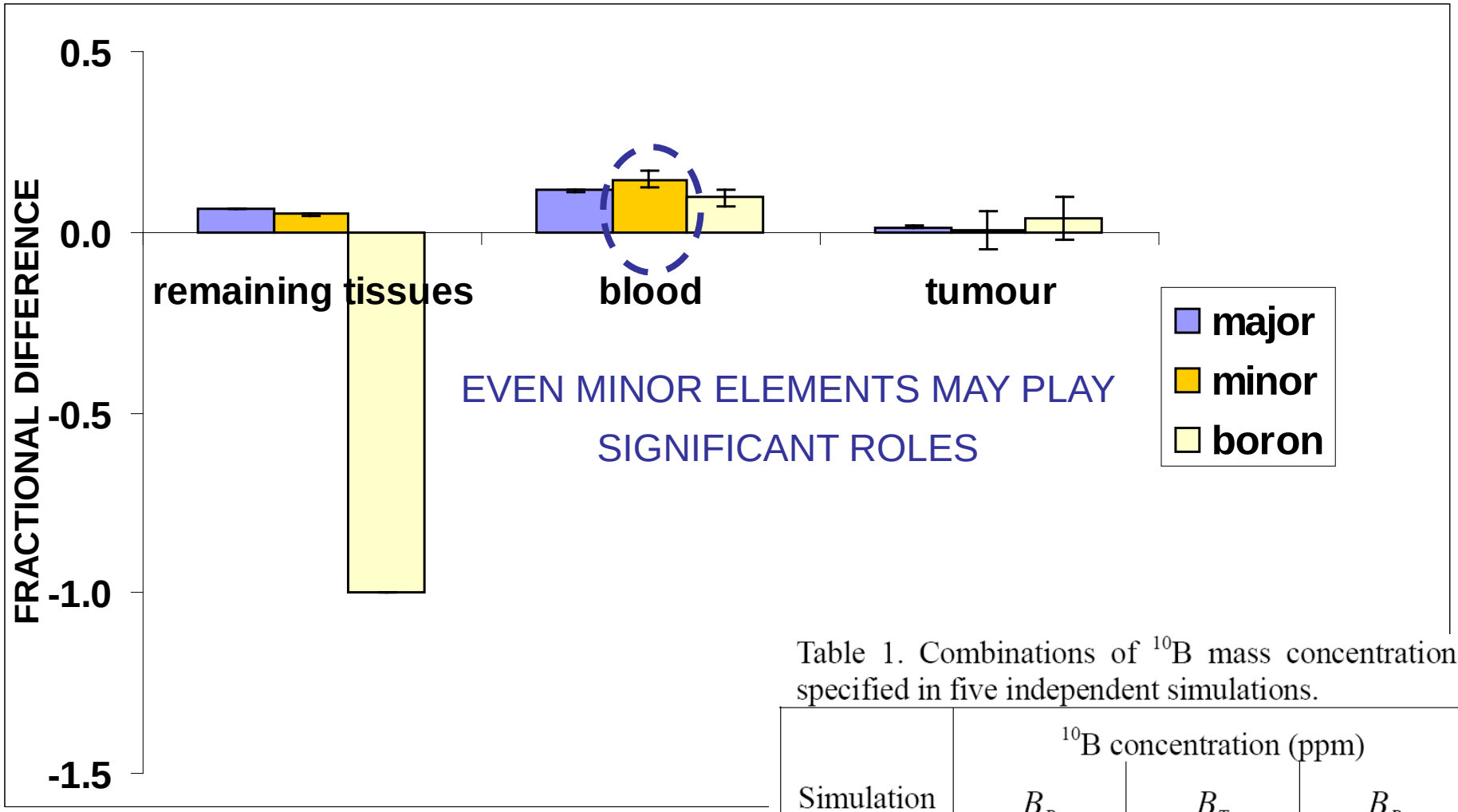

IF WE COULD ACHIEVE B_R=0 THERE WOULD BE INCREASED NEUTRON COLLISIONS WITH OTHER ELEMENTS ELSEWHERE, NOTE LARGER EFFECT FROM MINOR ELEMENTS IN BLOOD.

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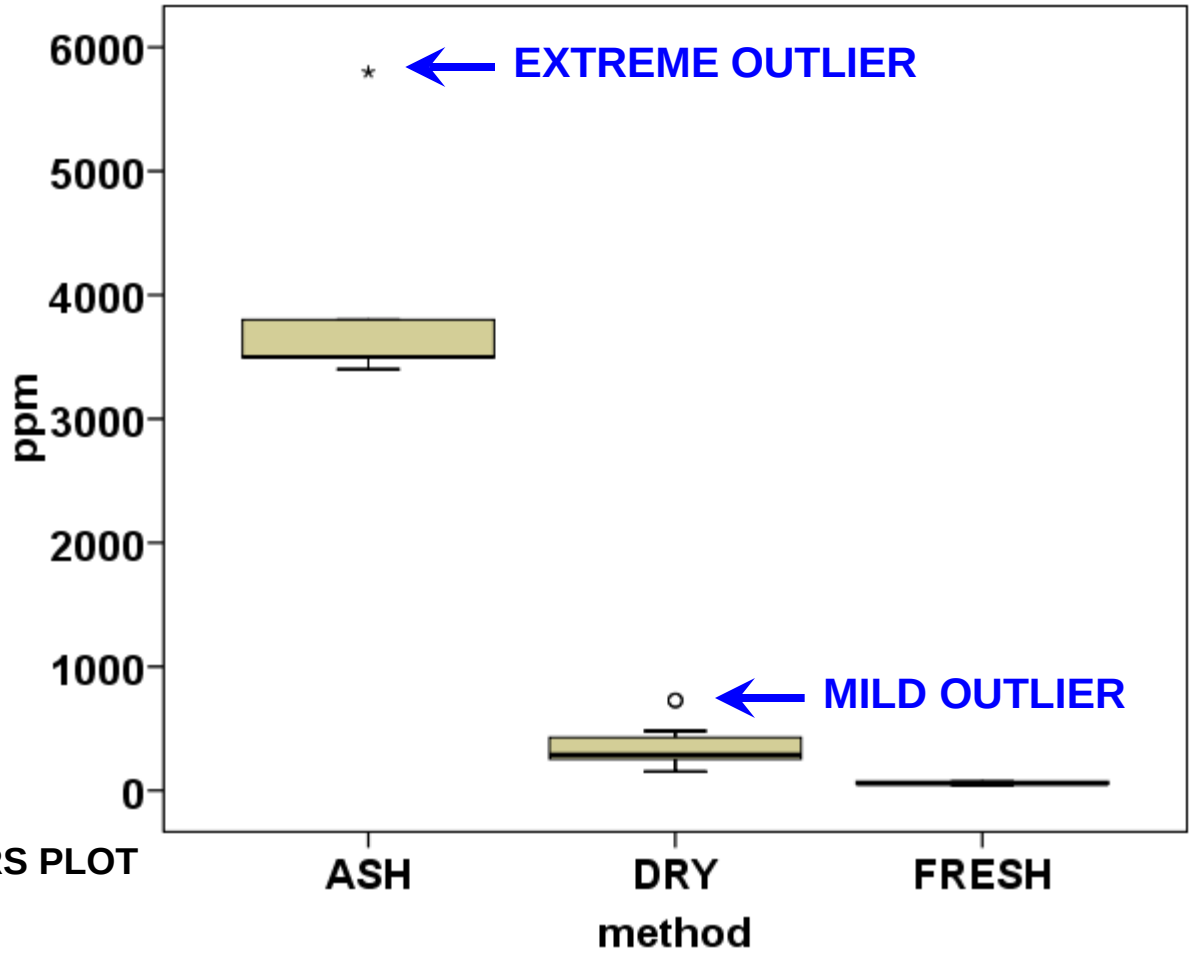
UNCERTAINTIES DUE TO LIMITED DATA ON ELEMENTAL COMPOSITION



BOX / WHISKERS PLOT

IRON IN BRAIN

Data extracted from Iyengar *The Elemental Composition of Human Tissues and Body Fluids* Verlag Chemie (Weinheim) 1978

INCREASING ^{10}B UPTAKE IN TUMOUR LEADS TO NEGLIGIBLE PROTECTION TO 'HEALTHY' TISSUES.

'HEALTHY' TISSUES SUFFERED NEUTRON COLLISIONS BEFORE THE NEUTRONS REACHED THE TUMOUR.

SCREENING EFFECTS NEGLIGIBLE.

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NEGLIGIBLE DIFFERENCE EXCEPT

FOR INCREASED NEUTRON

COLLISIONS DUE TO ^{10}B IN BLOOD.

NO MASKING OF TUMOUR &

REMAINING TISSUES WAS DETECTED.

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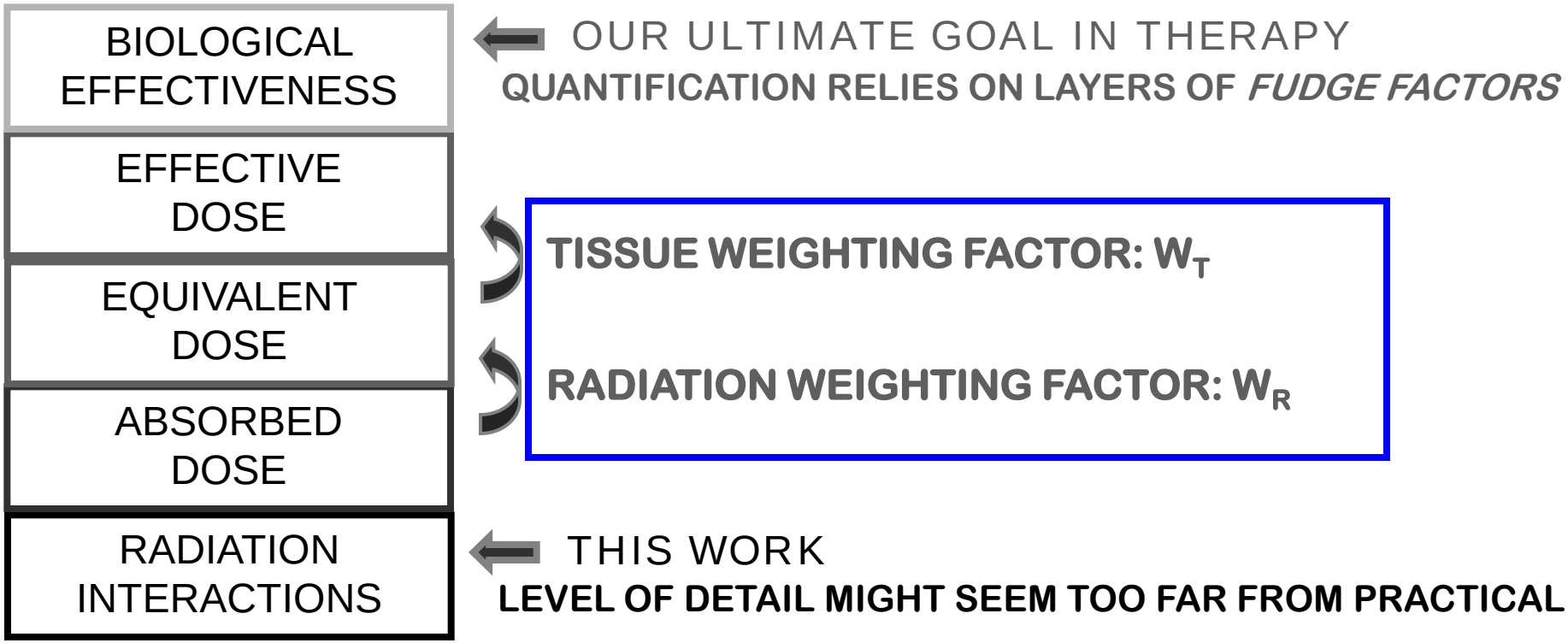

ICRP KEEPS CHANGING ITS MIND

THE NEED TO REDUCE W_R=5

WHEN NEUTRONS INTERACT, CONTRIBUTION FROM SECONDARY PHOTONS INCREASES WITH DECREASING NEUTRON ENERGY

$$E = \sum_T w_T \sum_R w_R D_{T,R}$$

E = EFFECTIVE DOSE

W_T = TISSUE WEIGHTING FACTOR

W_R = RADIATION WEIGHTING FACTOR

$D_{T,R}$ = AVERAGE ABSORBED DOSE

FOR THERMAL NEUTRONS

- **ICRP PUBLICATION 60 (1991)** $W_R = 5$
- **ICRP RECOMMENDATIONS 2005** $W_R = 1$
- **ICRP PUBLICATION 103 (2008)** $W_R = 2.5$

ICRP KEEPS CHANGING ITS MIND

QUESTIONS

1. **DO WE FEEL INCREASINGLY CONFIDENT THAT WE ARE INCREASINGLY CORRECT?**

2. **DOES IT SIMPLY SHOW THAT WE SIMPLY DO NOT KNOW?**

DRAMATIC CHANGES	FOR THERMAL NEUTRONS
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