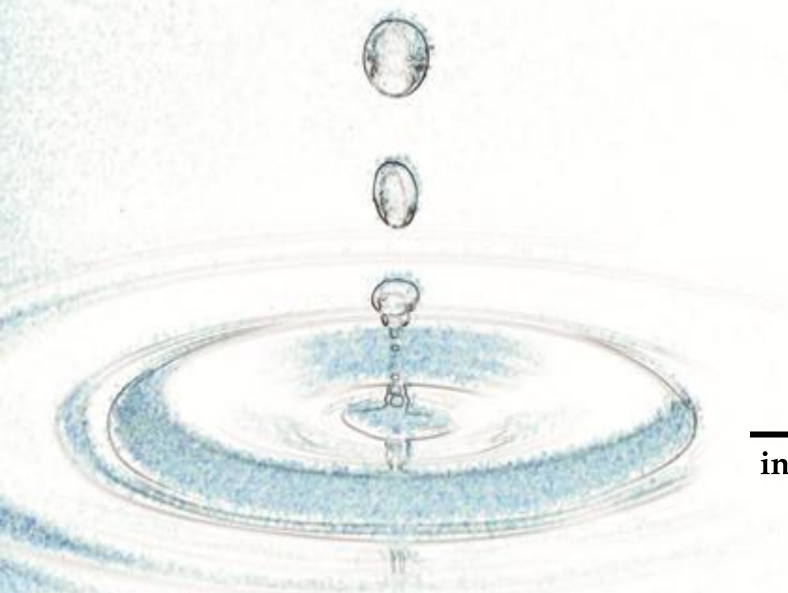
Monte-Carlo Simulations on the Detector Sensitivity to Cosmic-Ray nduced Neutron Showers



Markus Köhli

U. Schmidt
AG Dubbers

Physikalisches Institut
Ruprecht-Karls-Universität
Heidelberg

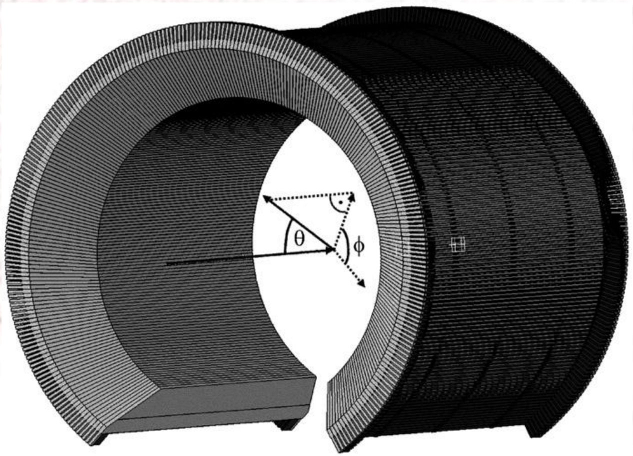
in collaboration with:

Martin Schrön

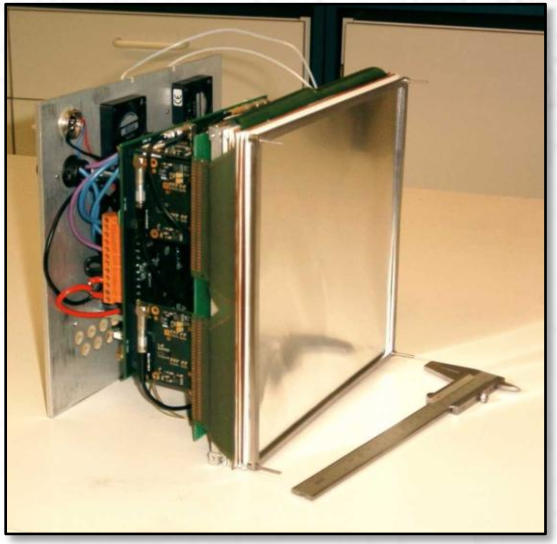
Helmholtz Center for
Environmental Research
Leipzig

COSMOS Workshop, 7th of May 2014

Neutron Detector Research in Heidelberg

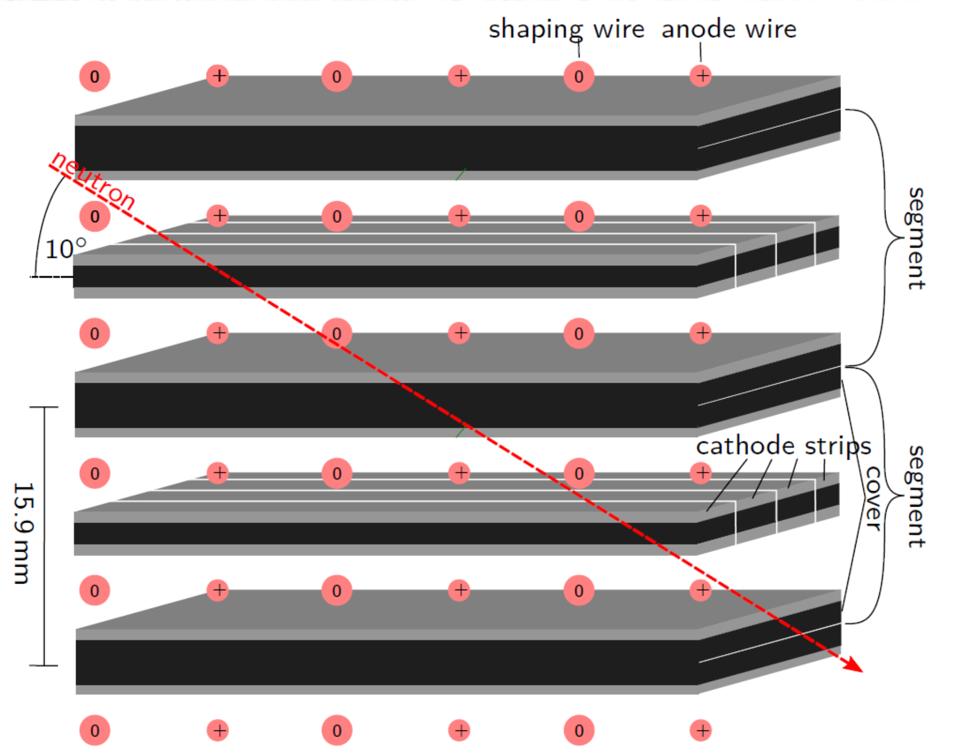


Large Area

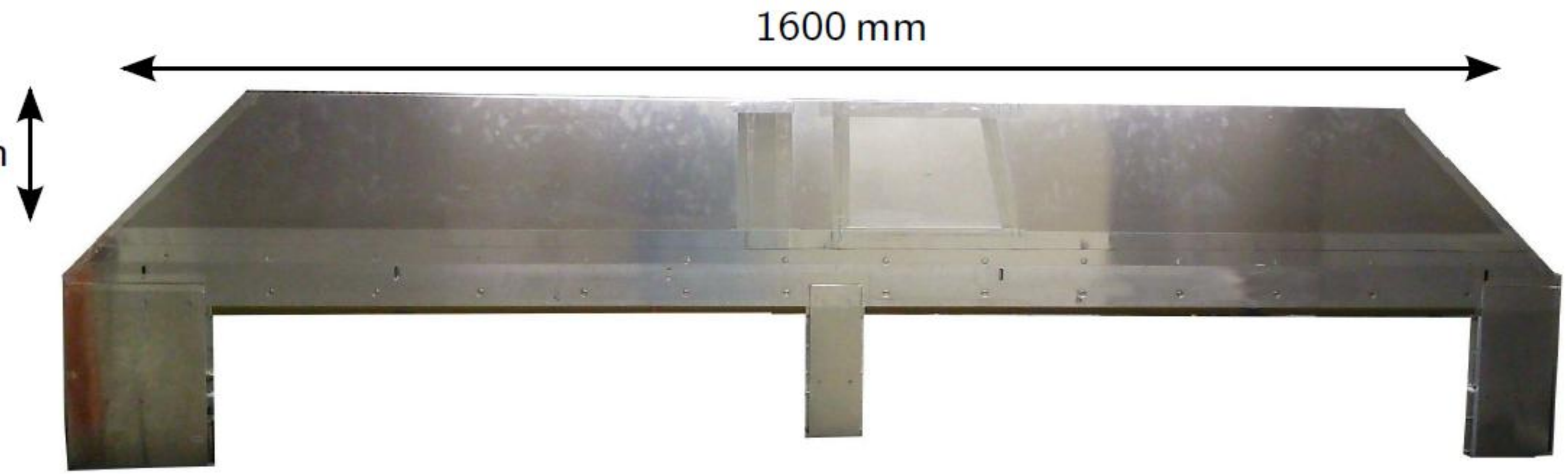


High Resolution

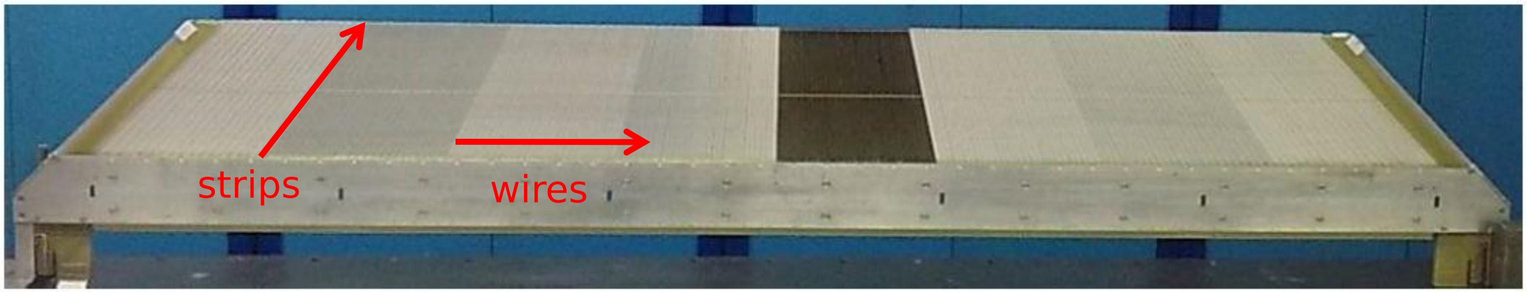
Stacked Solid State Detectors



Large Area Detector - Segment

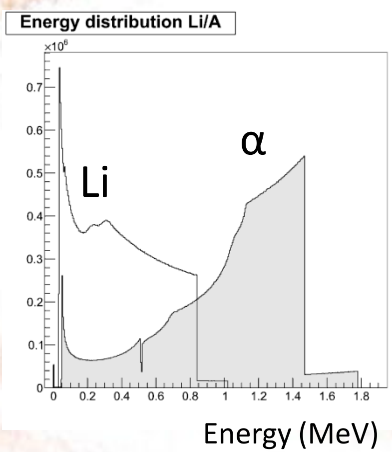


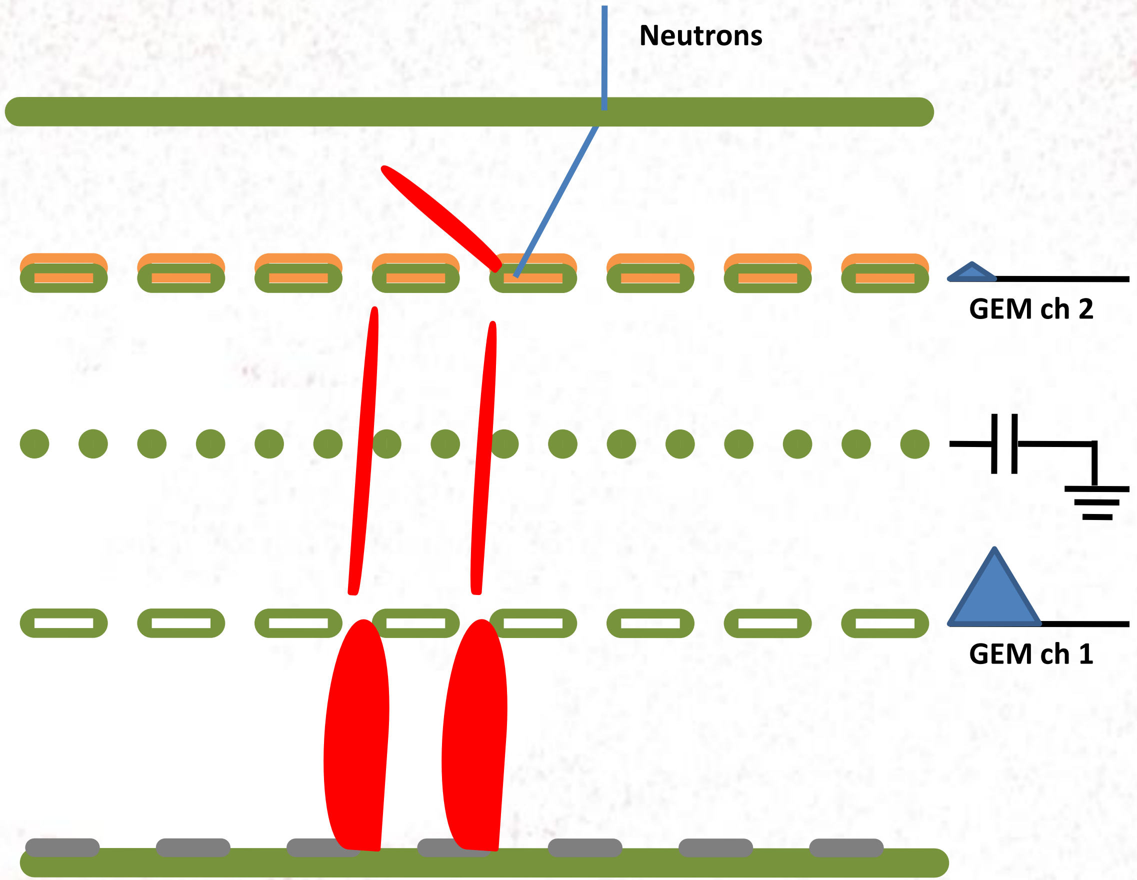
- With Cover



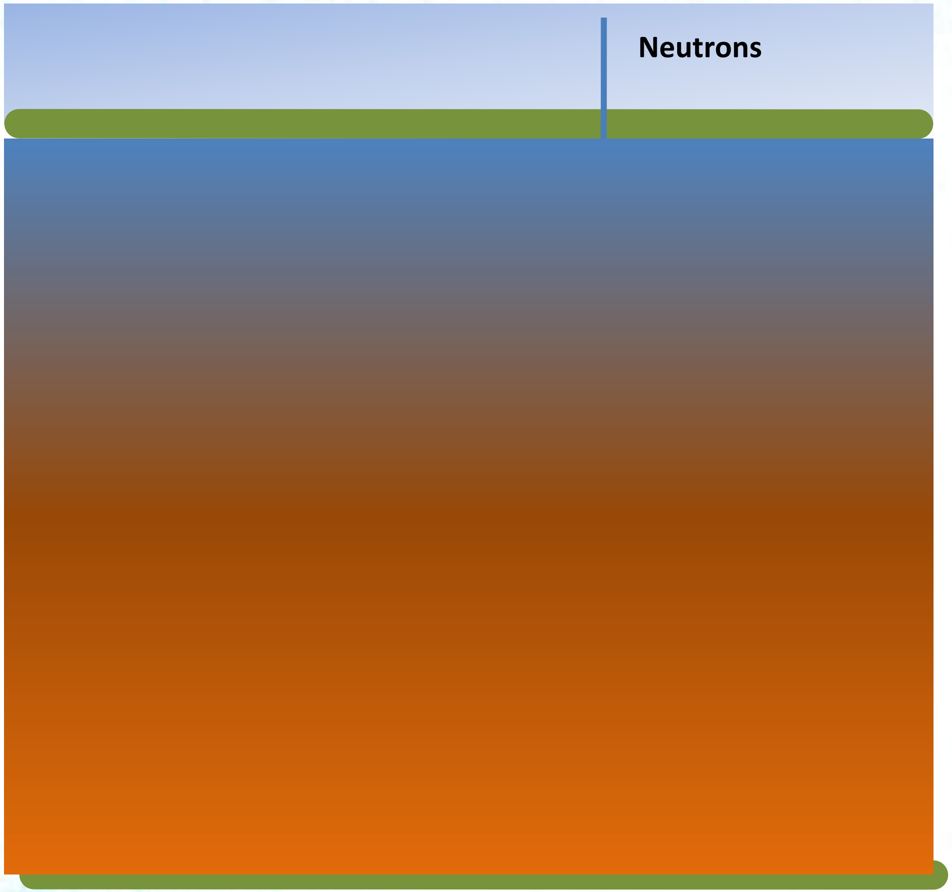
- Without Cover

Neutron Detector Simulation





Neutron Soil Simulation

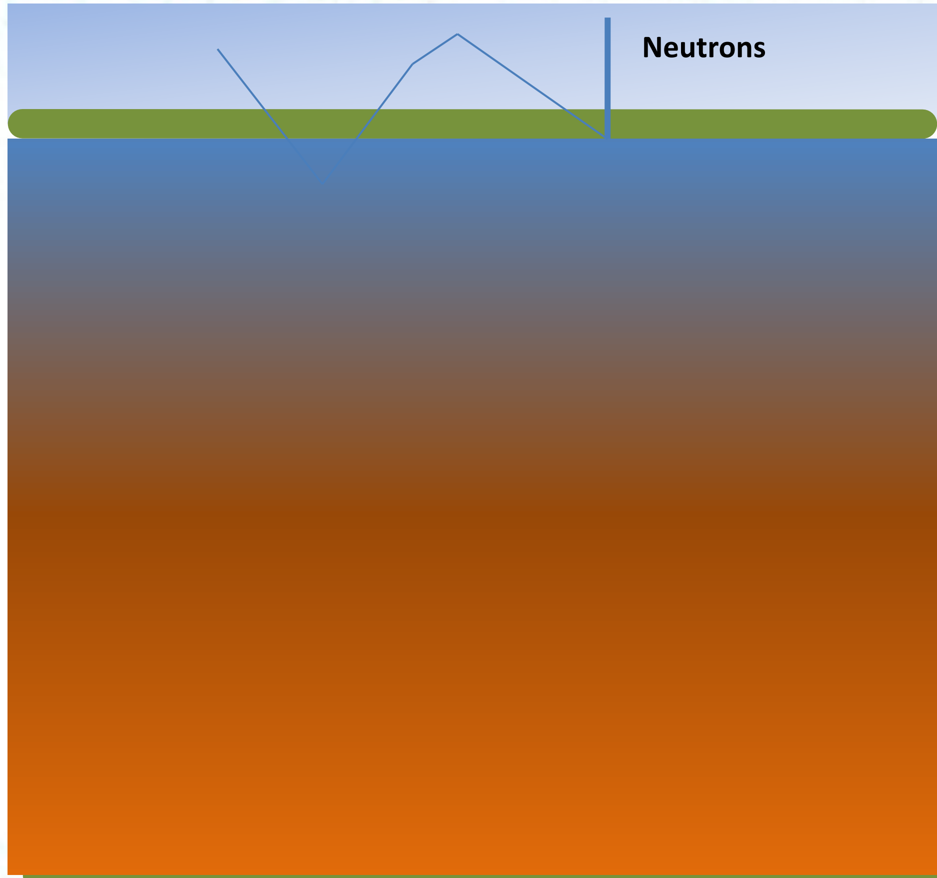


Neutron Soil Simulation

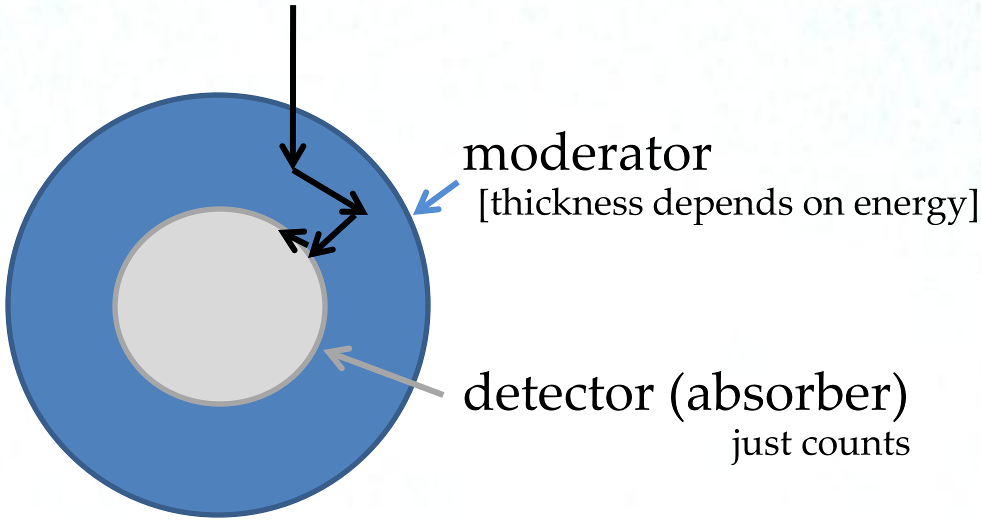
air
N_2 , O_2
biomass
H_2O + (CH_2)

water
H_2O

soil
SiO_2
Al_2O_3

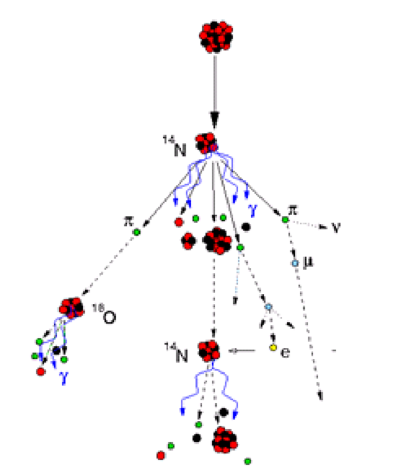


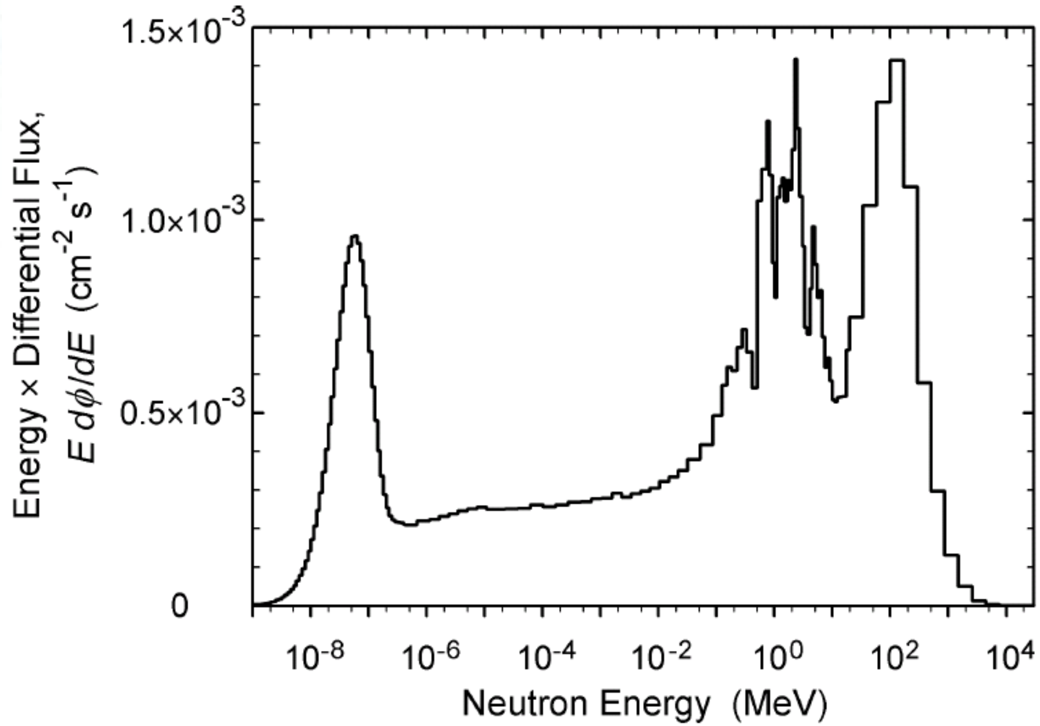
Why a Monte Carlo simulation?



(…with bad energy and angular resolution)

The cosmic neutron spectrum

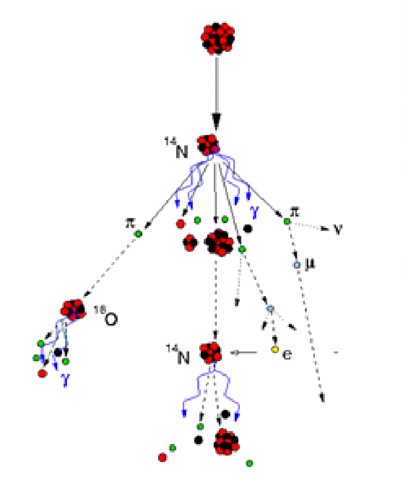


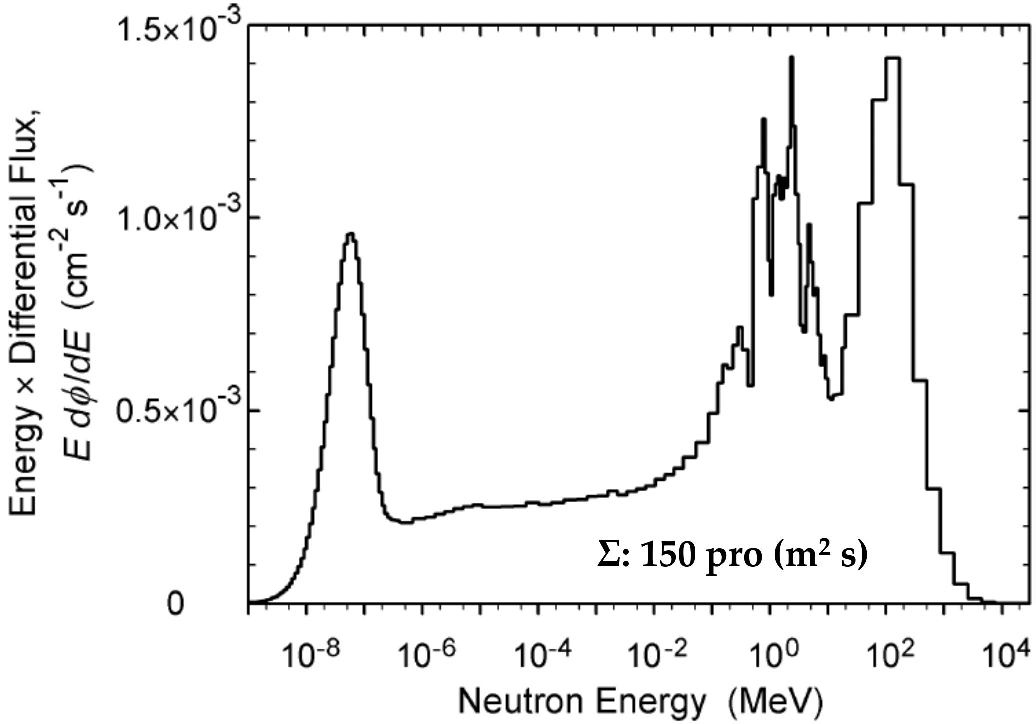


[1]

[1] Gordon, M.S.; Goldhagen, P.:, Measurement of the Flux and Energy Spectrum of Cosmic-Ray Induced Neutrons on the Ground, Nuclear Science, IEEE Transactions on, Vol 51, Issue 6 (2004)

The cosmic neutron spectrum





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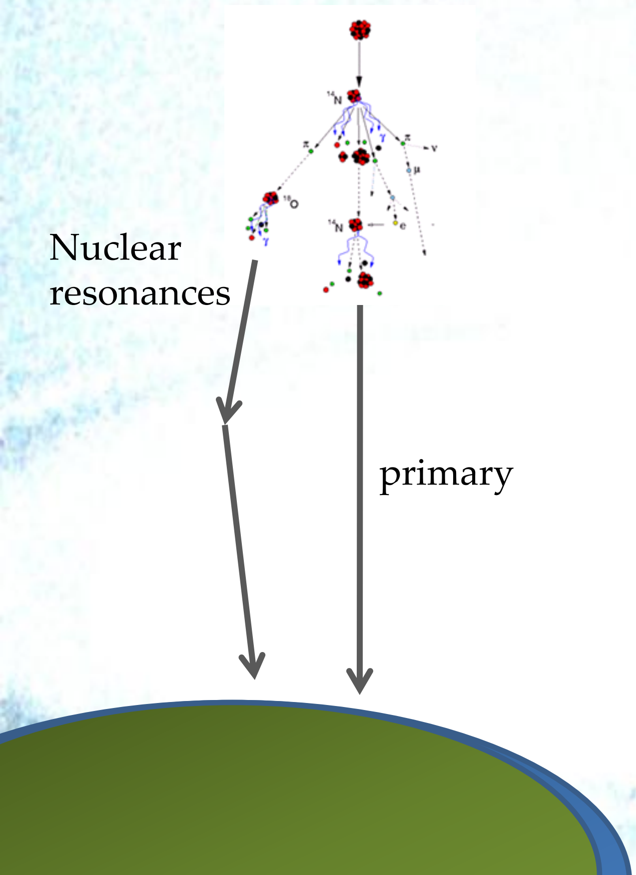
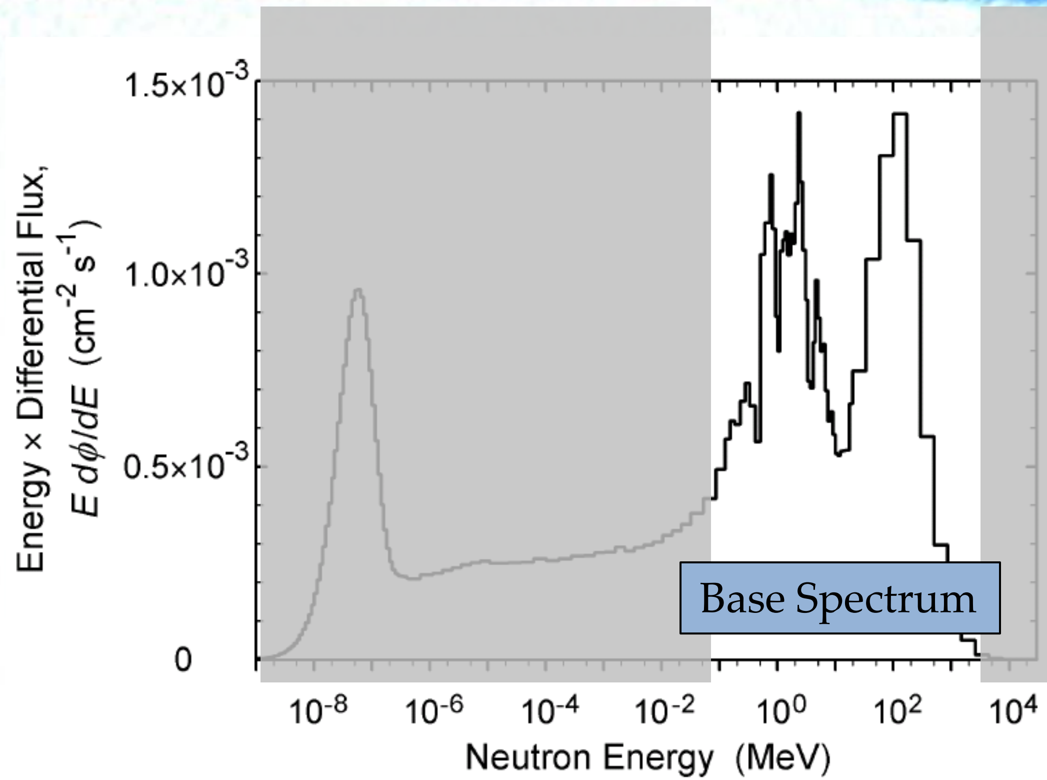
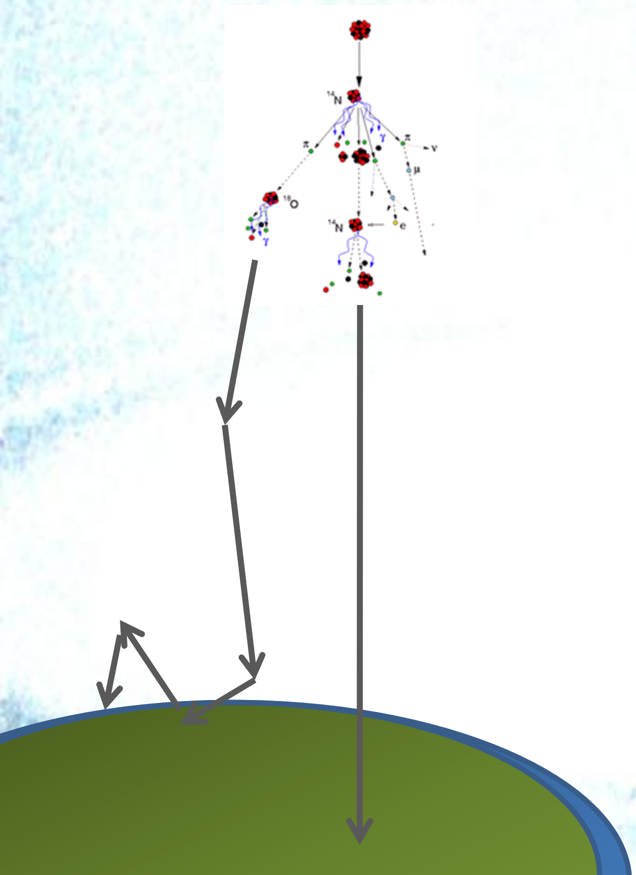
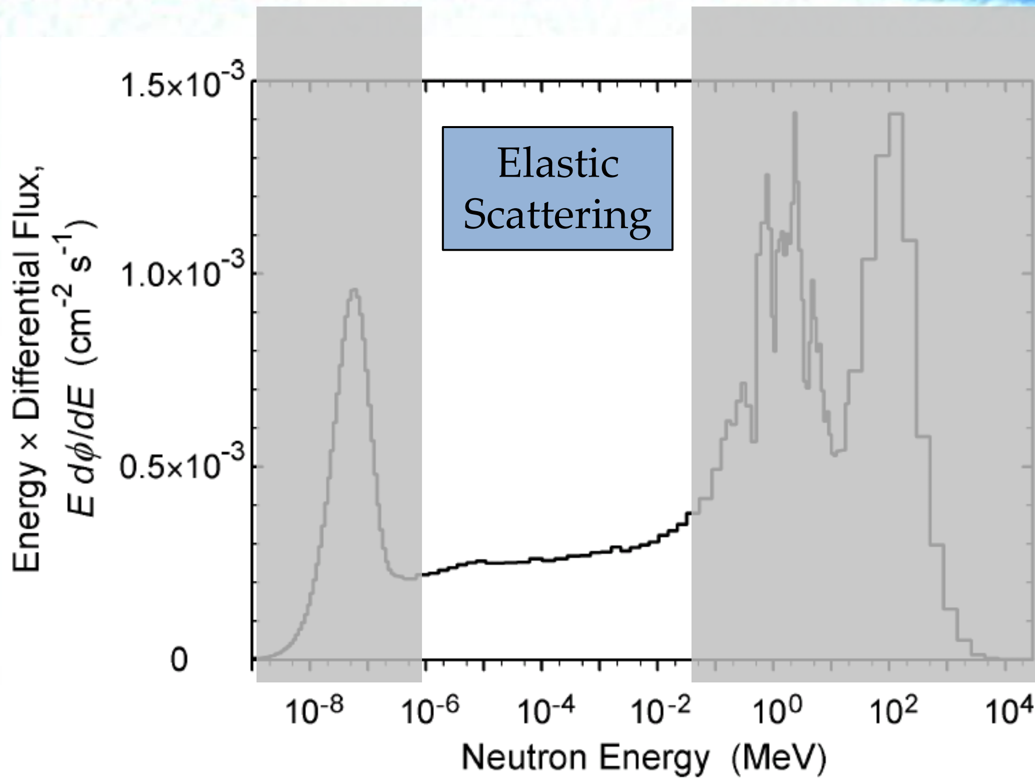
The cosmic neutron spectrum





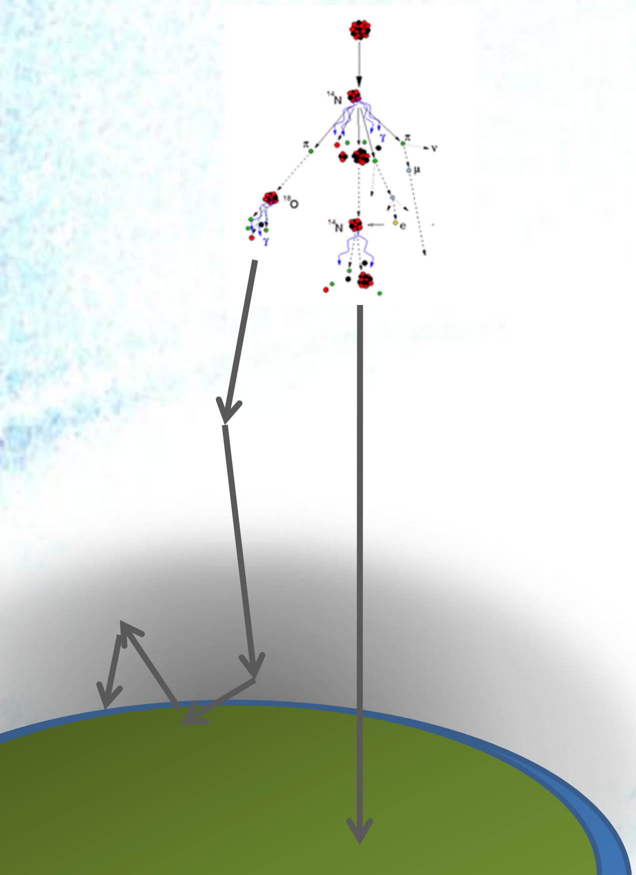
The cosmic neutron spectrum

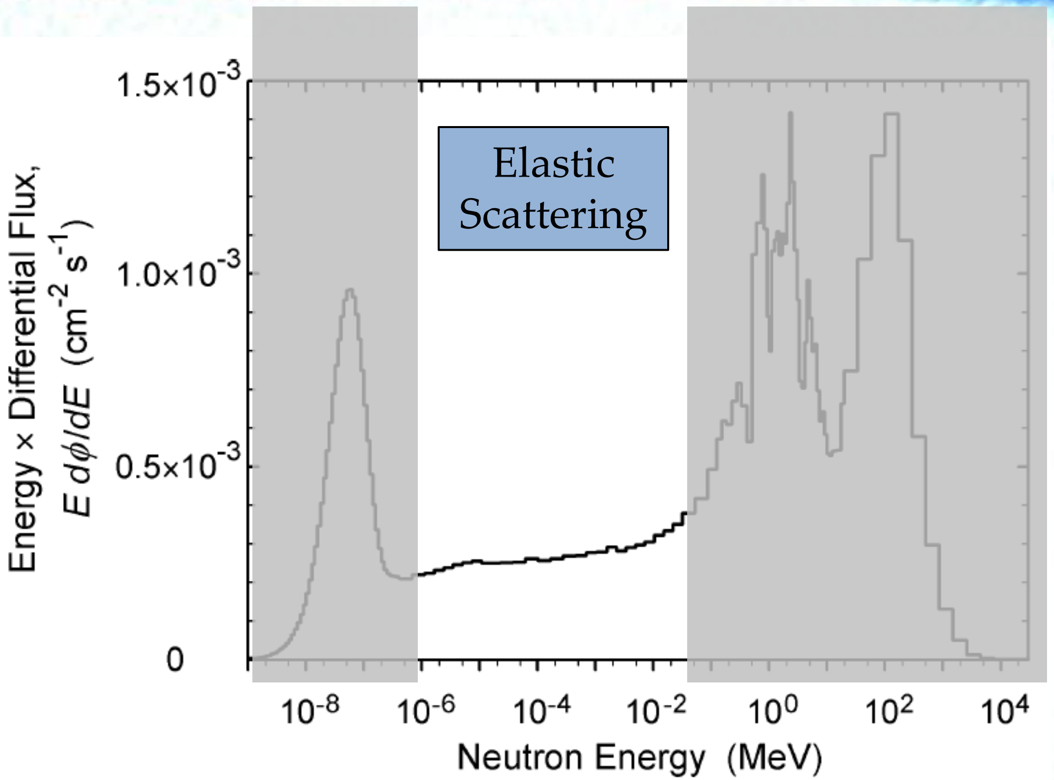




[1]

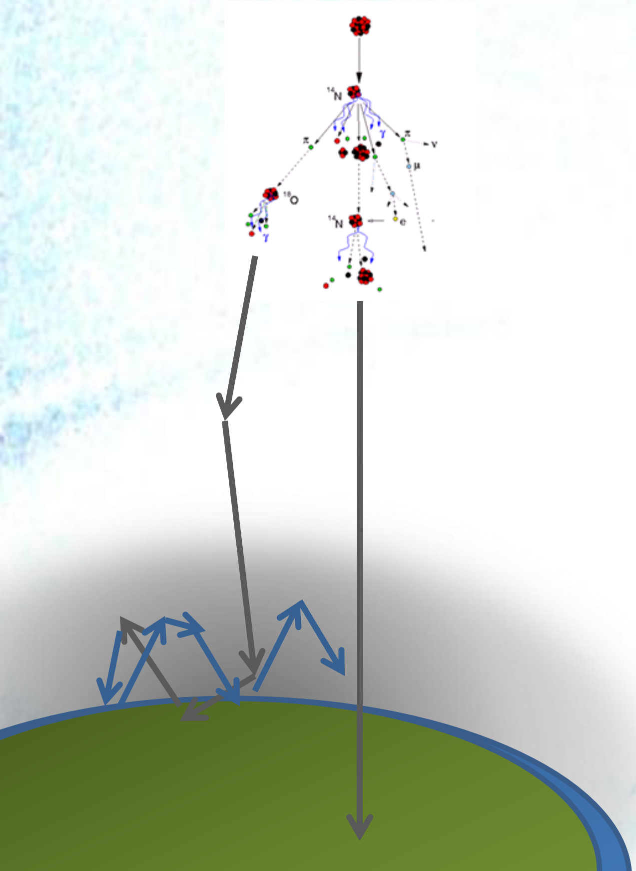
The cosmic neutron spectrum

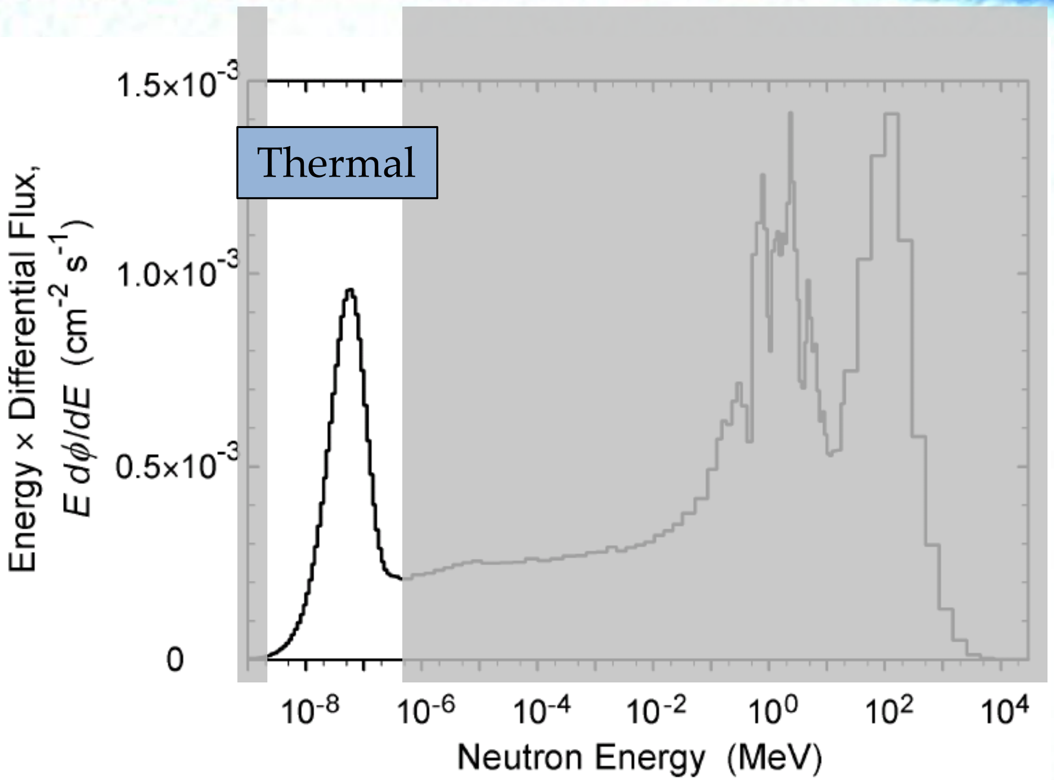




[1]

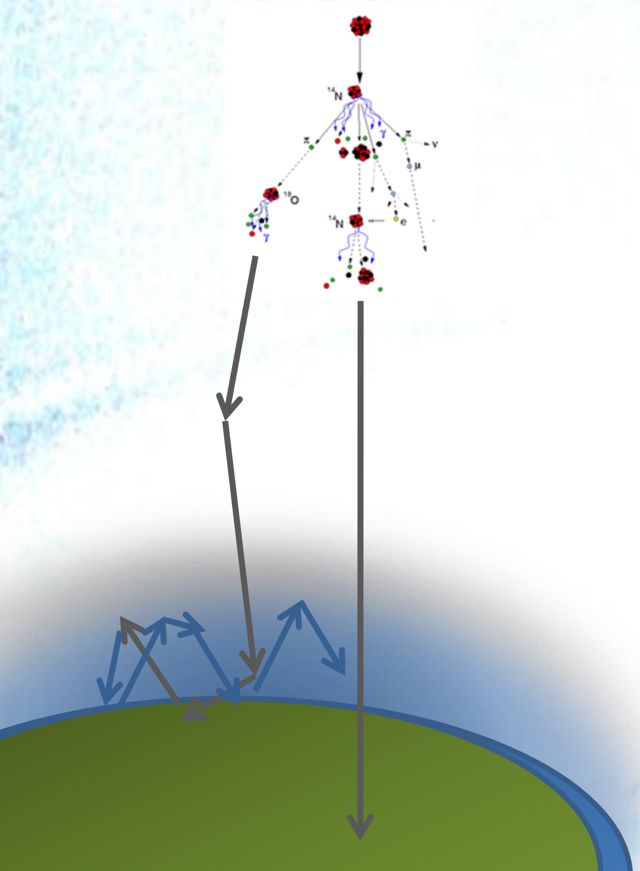
The cosmic neutron spectrum

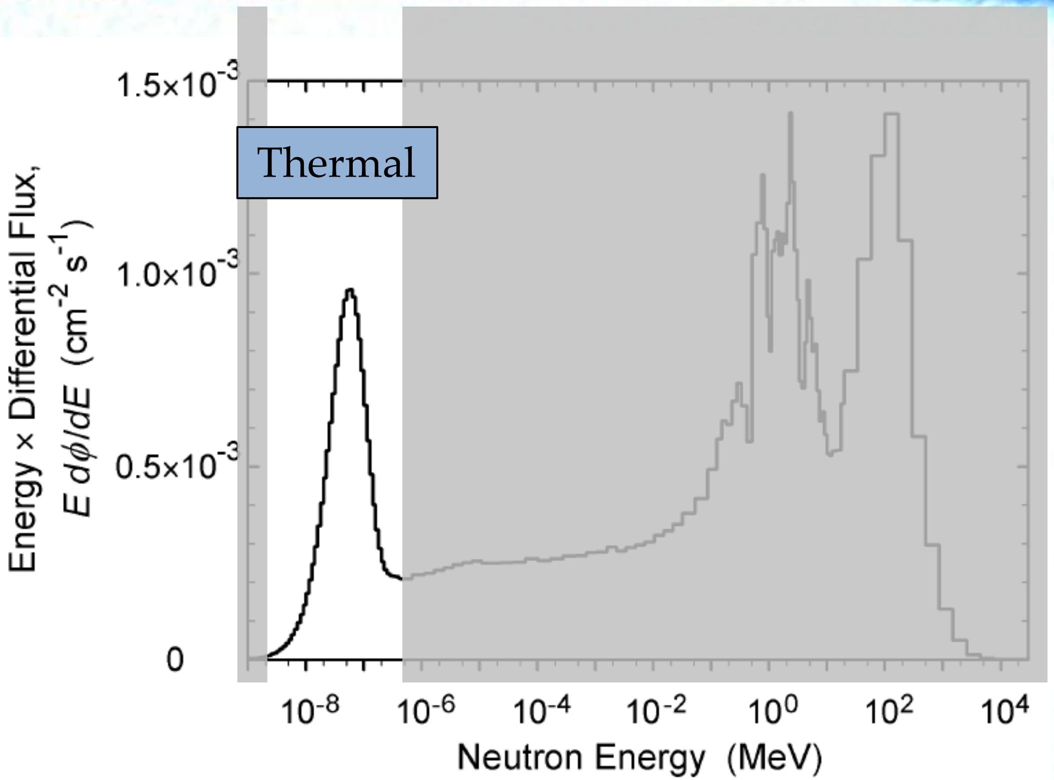




$$E = O(k_B \cdot 300K)$$

The cosmic neutron spectrum

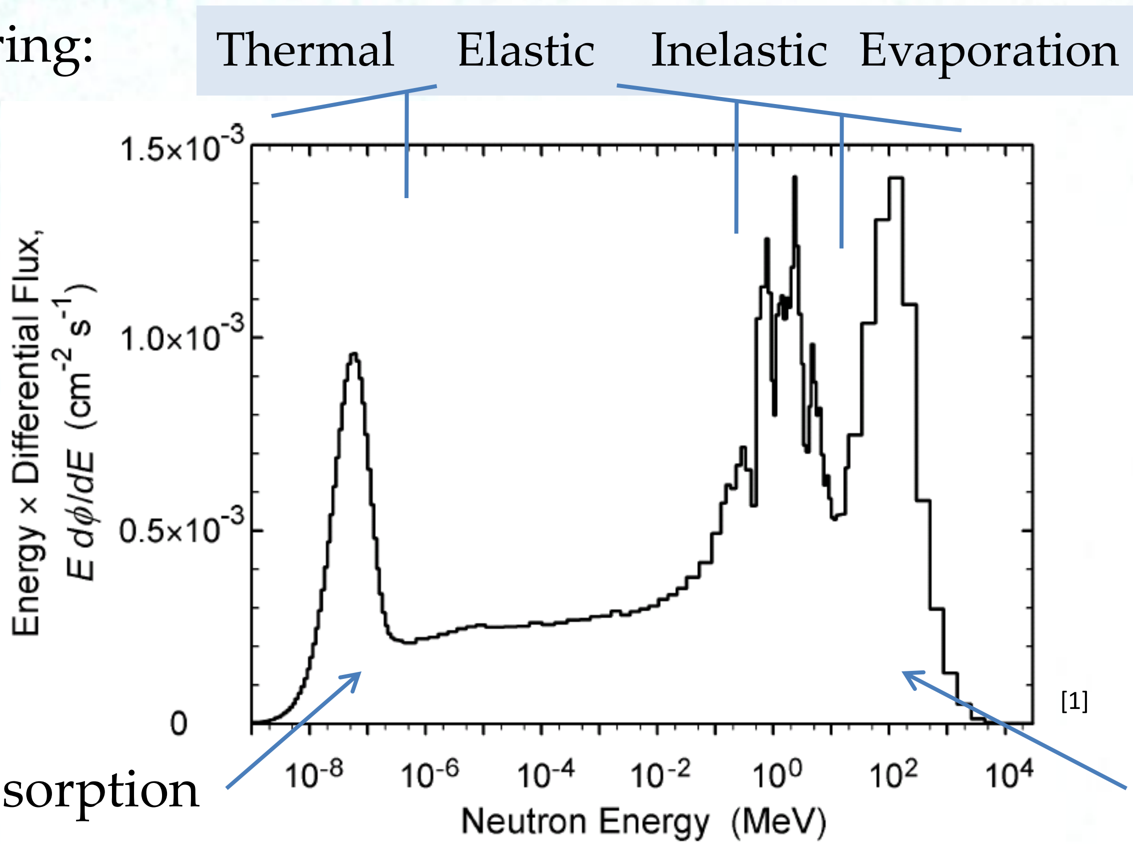




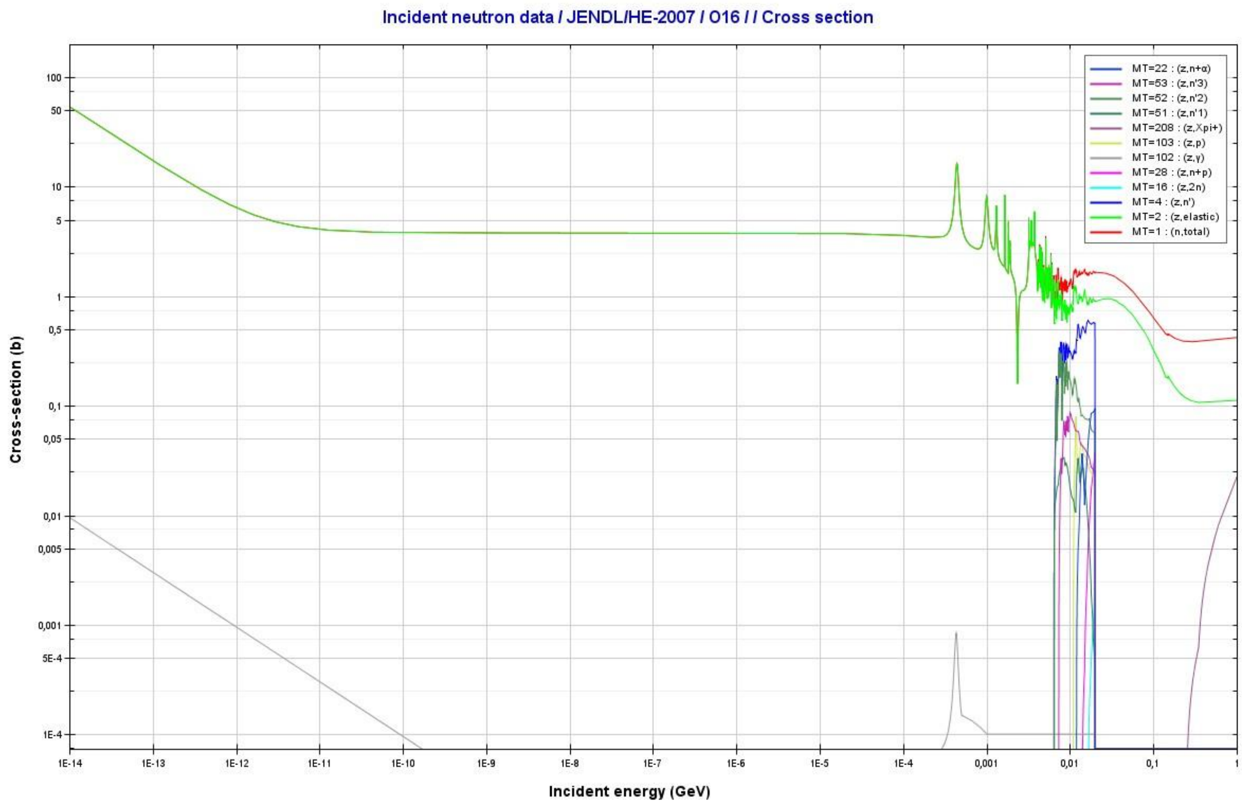
$E = O(k_B \cdot 300K)$

Important Reactions

Type of scattering:



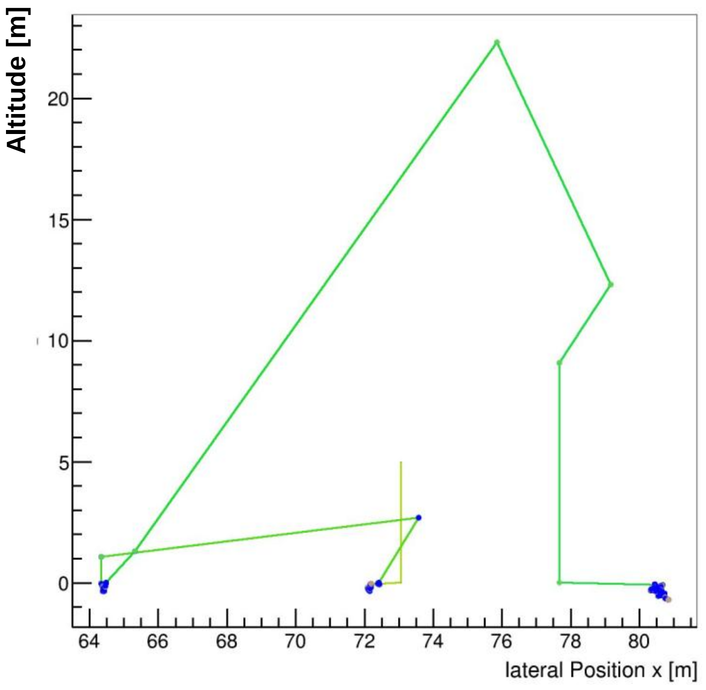
Example Cross Section



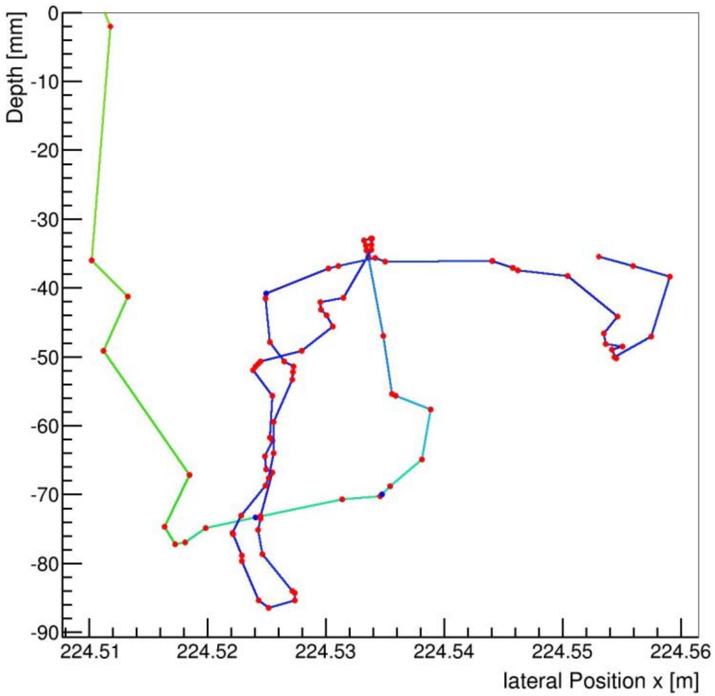
[JANIS 3.4]

Example Paths

Neutron scattered off the ground

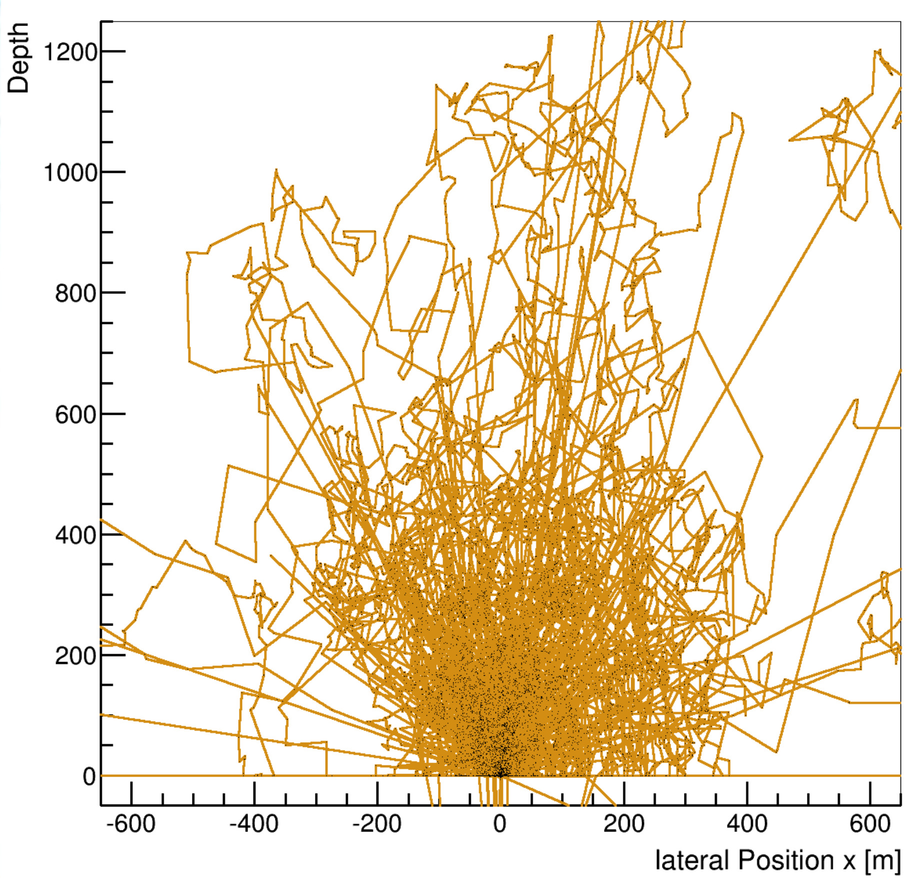


Neutron scattered in water



color: hue scaled by logarithmic energy of the neutron

Example Paths



900 Neutrons scattered off the ground into air

Neutron analytical spectrum

Analytical Functions to Predict Cosmic-Ray Neutron Spectra in the Atmosphere

Tatsuhiko Sato[a,1] and Koji Niita[b]

[a] Japan Atomic Energy Agency (JAEA) and [b] Research Organization for Information Science and Technology (RIST), Ibaraki, Japan

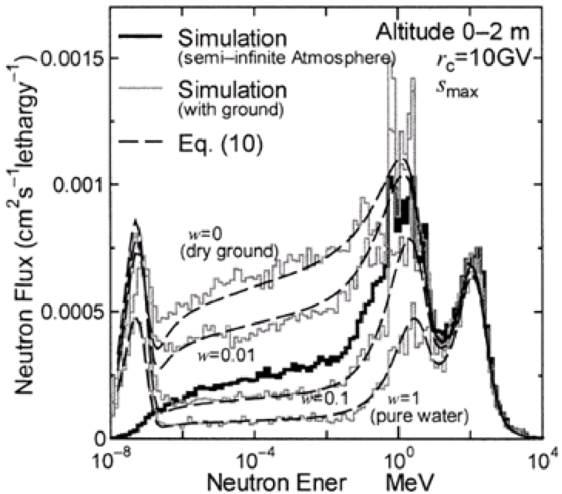
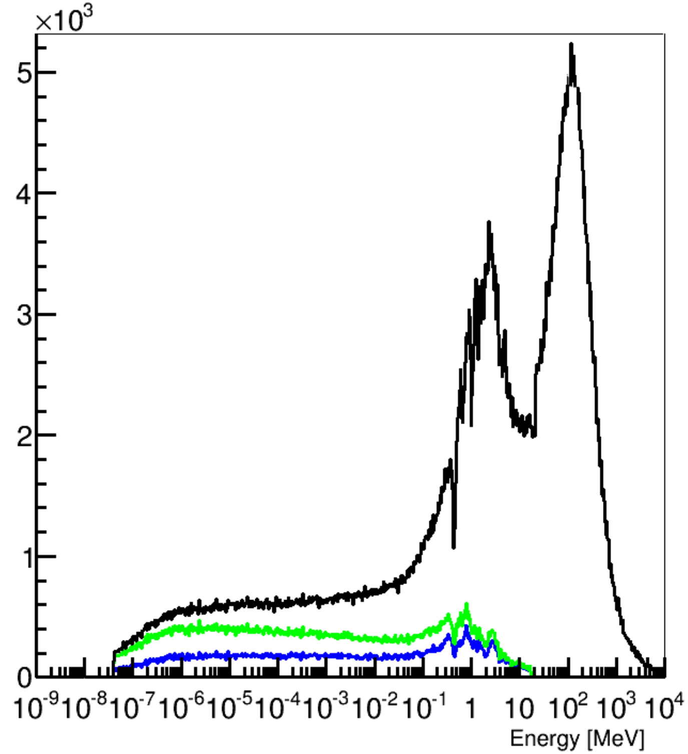


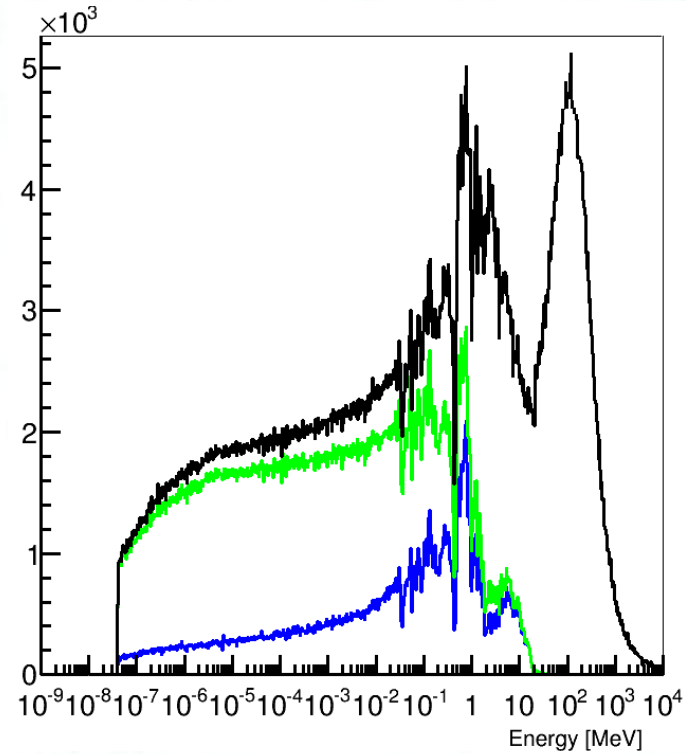
FIG. 9. Calculated neutron spectra at the ground level in comparison with the corresponding spectrum in the semi-infinite atmosphere.

Neutron spectra examples

100 % water



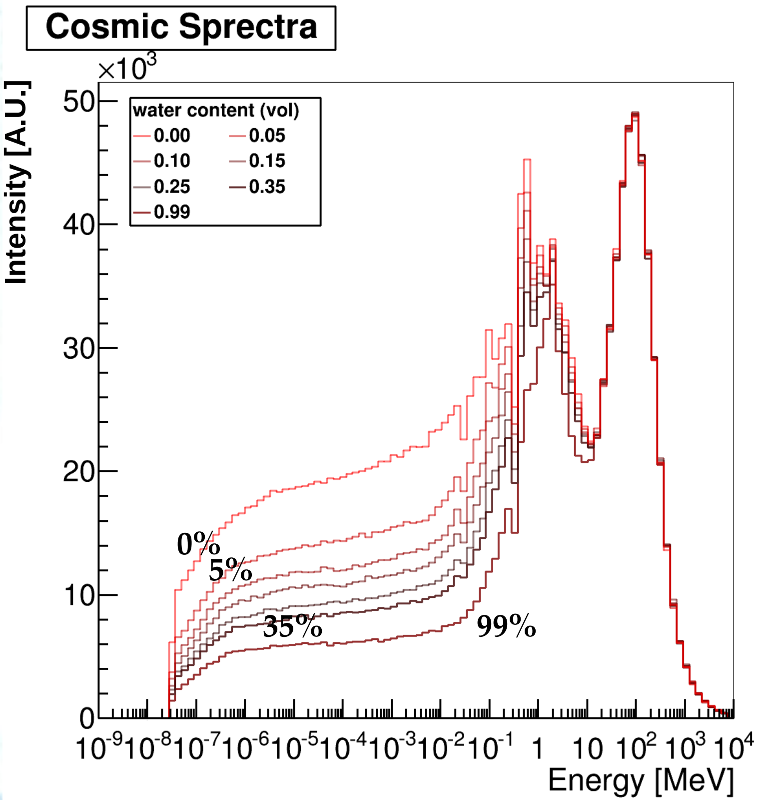
0 % water

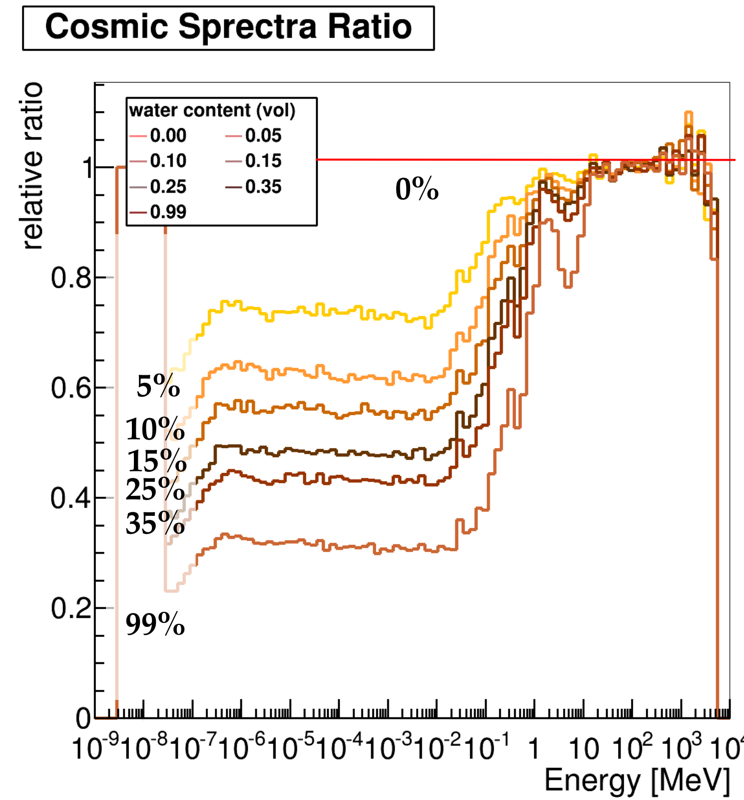


Reverse engineered fom Sato and Niita (Rev.)

Neutron spectra for soil of different moisture

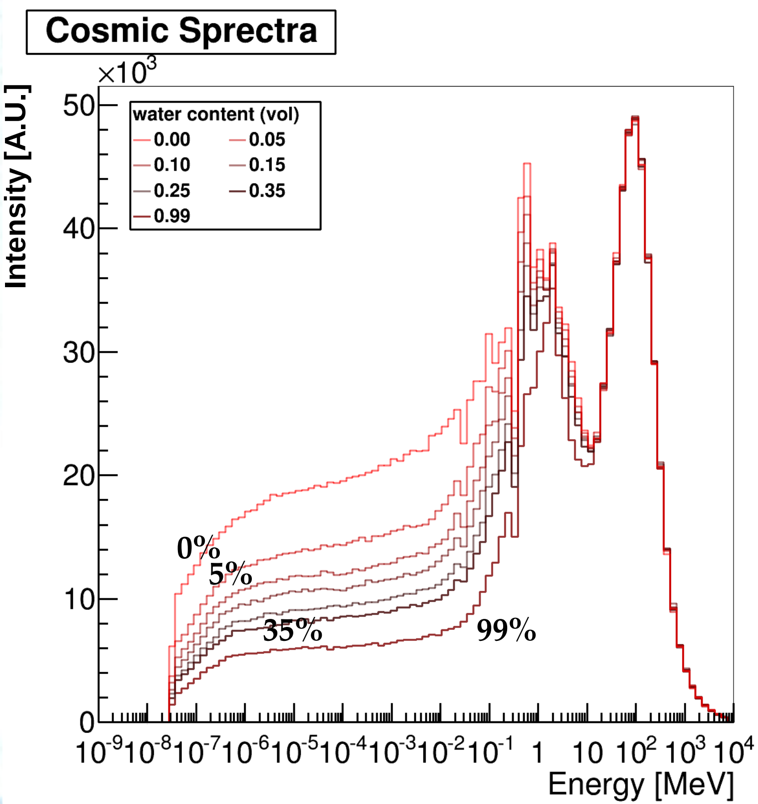
(with thermal neutron cutoff)

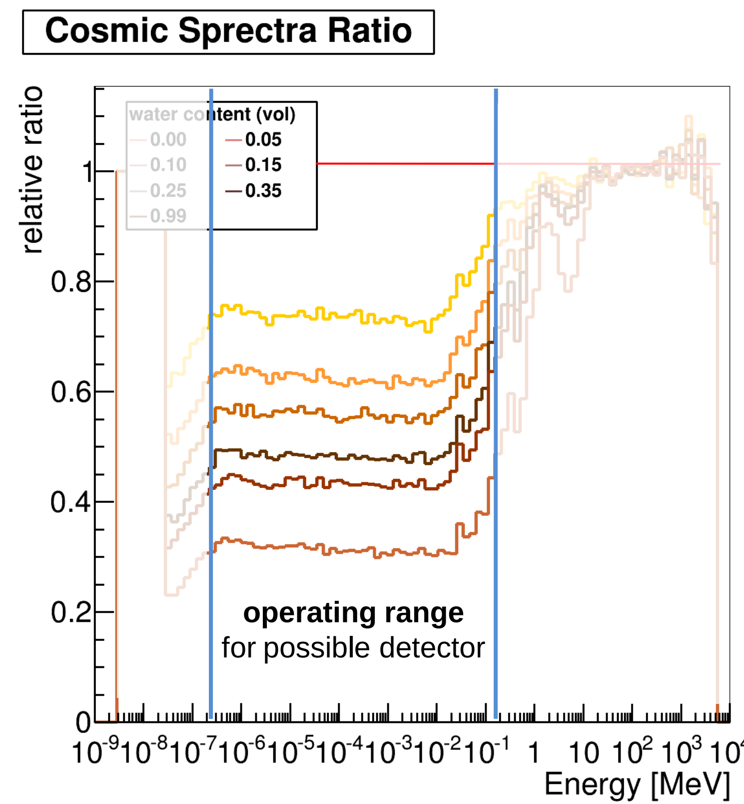




Neutron spectra for soil of different moisture

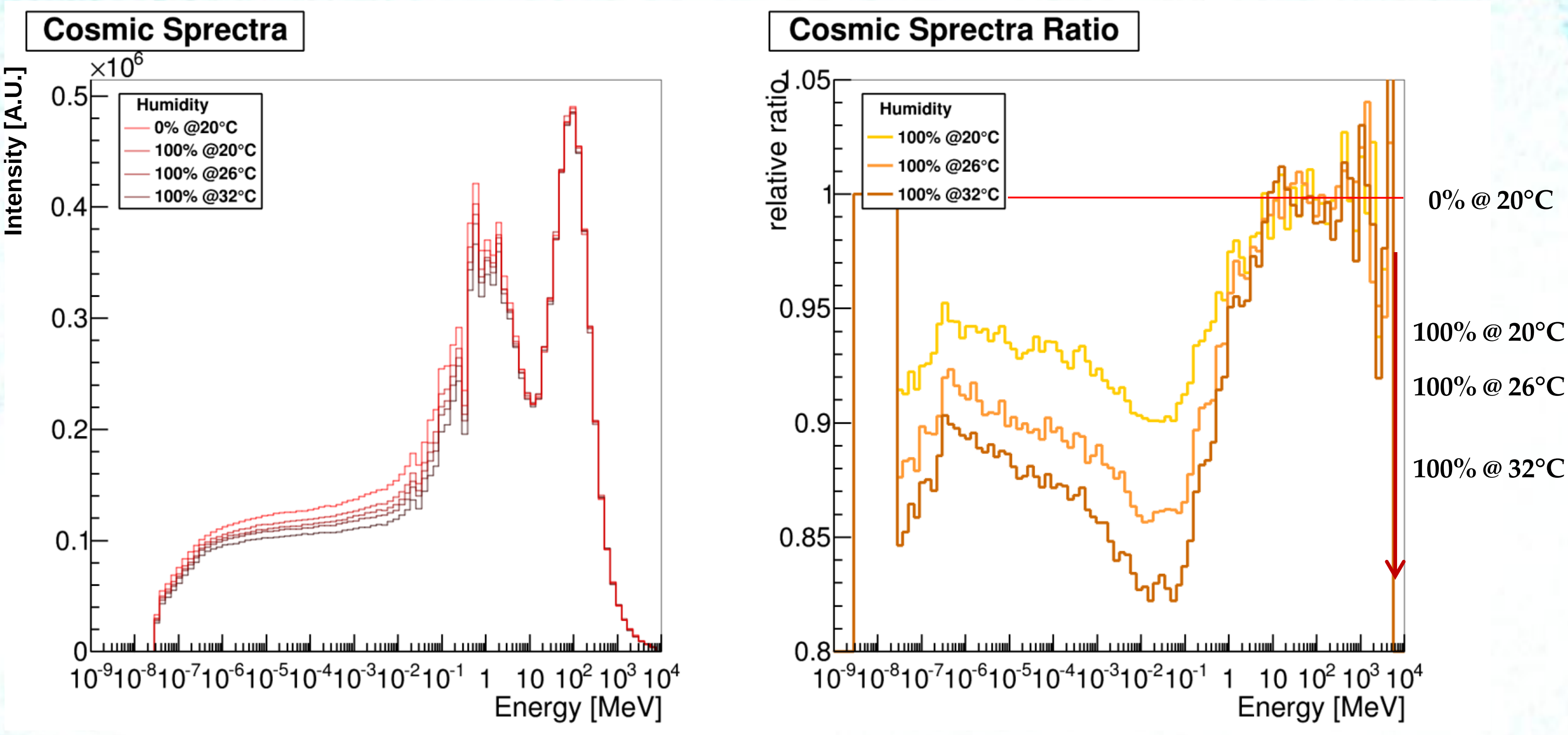
(with thermal neutron cutoff)





Neutron spectra for different humidities

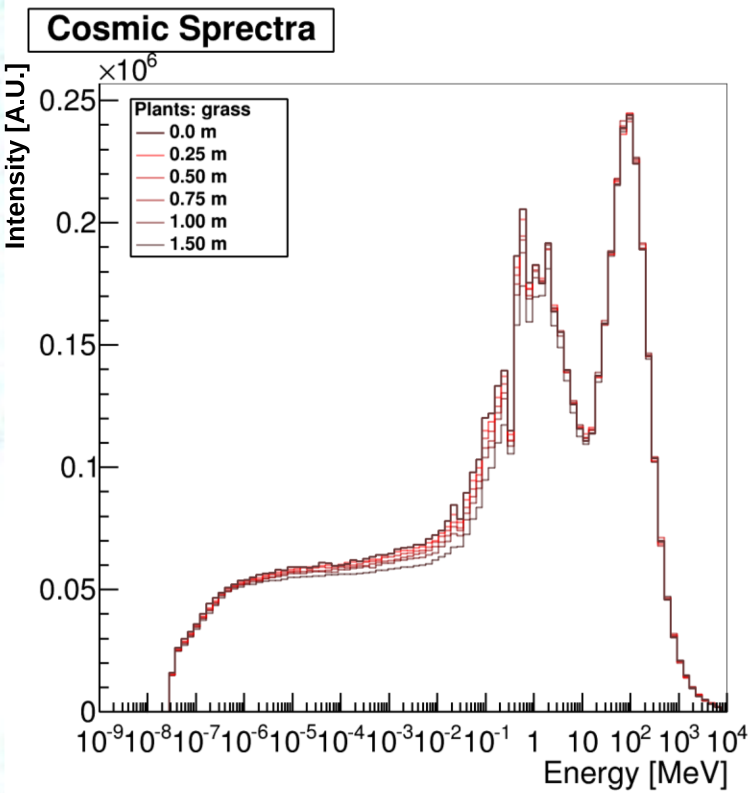
(with thermal neutron cutoff)

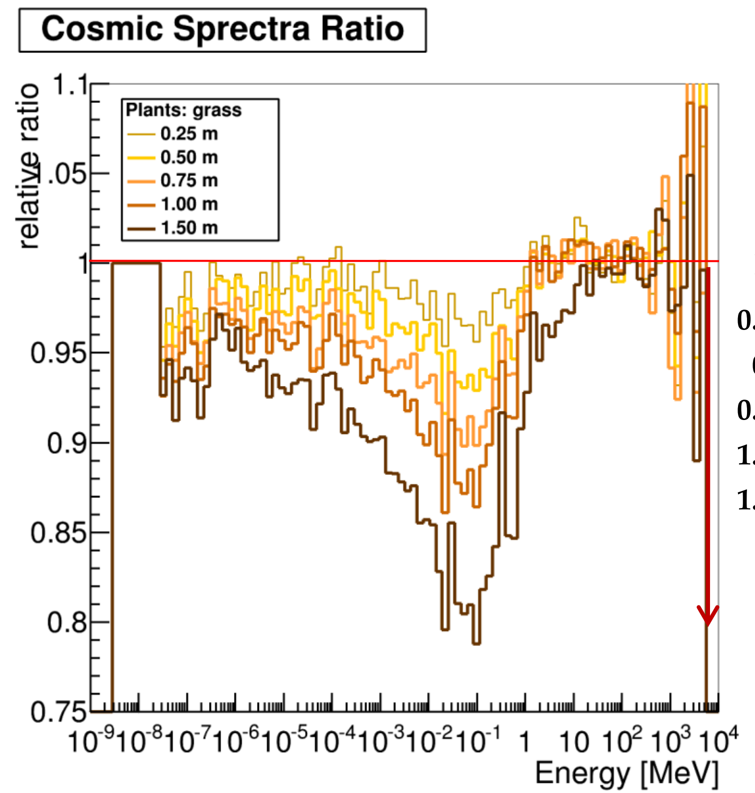


10% vol moisture

Neutron spectra for different plant heights

(with thermal neutron cutoff)





No plants

0.25 m plants

0.5 m plants

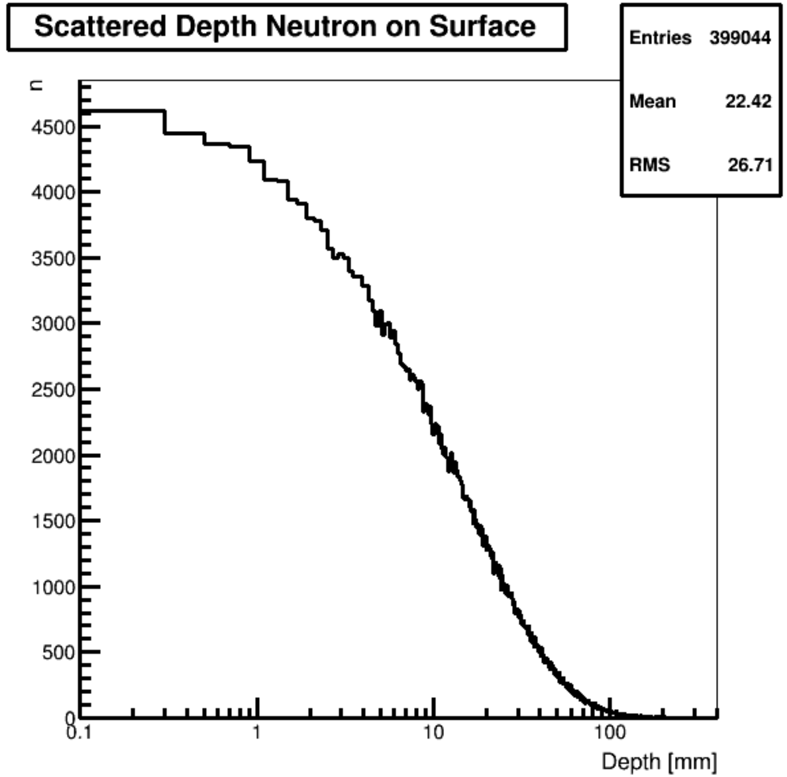
0.75 m plants

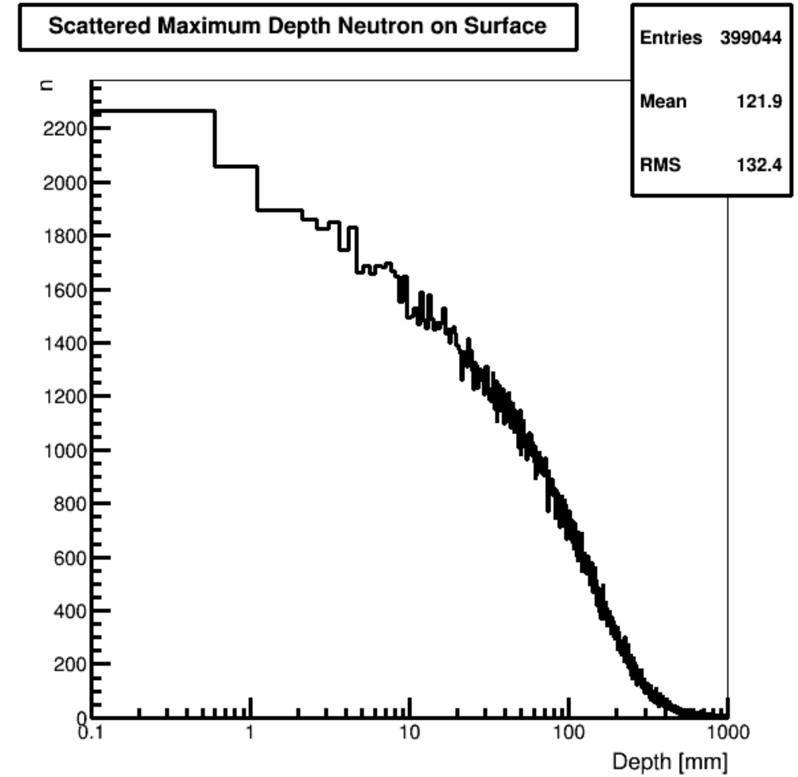
1.00 m plants

1.50 m plants

10% vol moisture

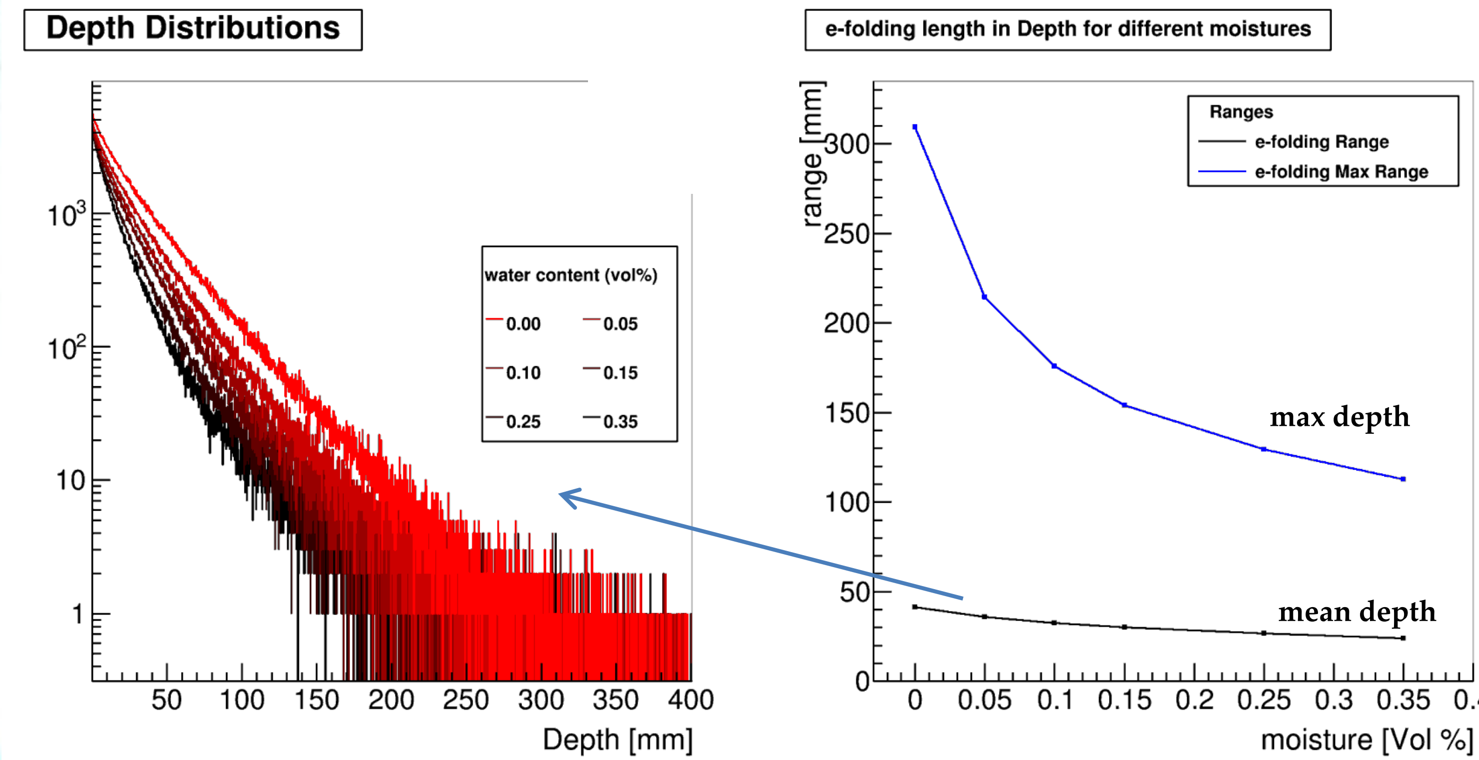
Depth distribution of the cosmic neutron probe



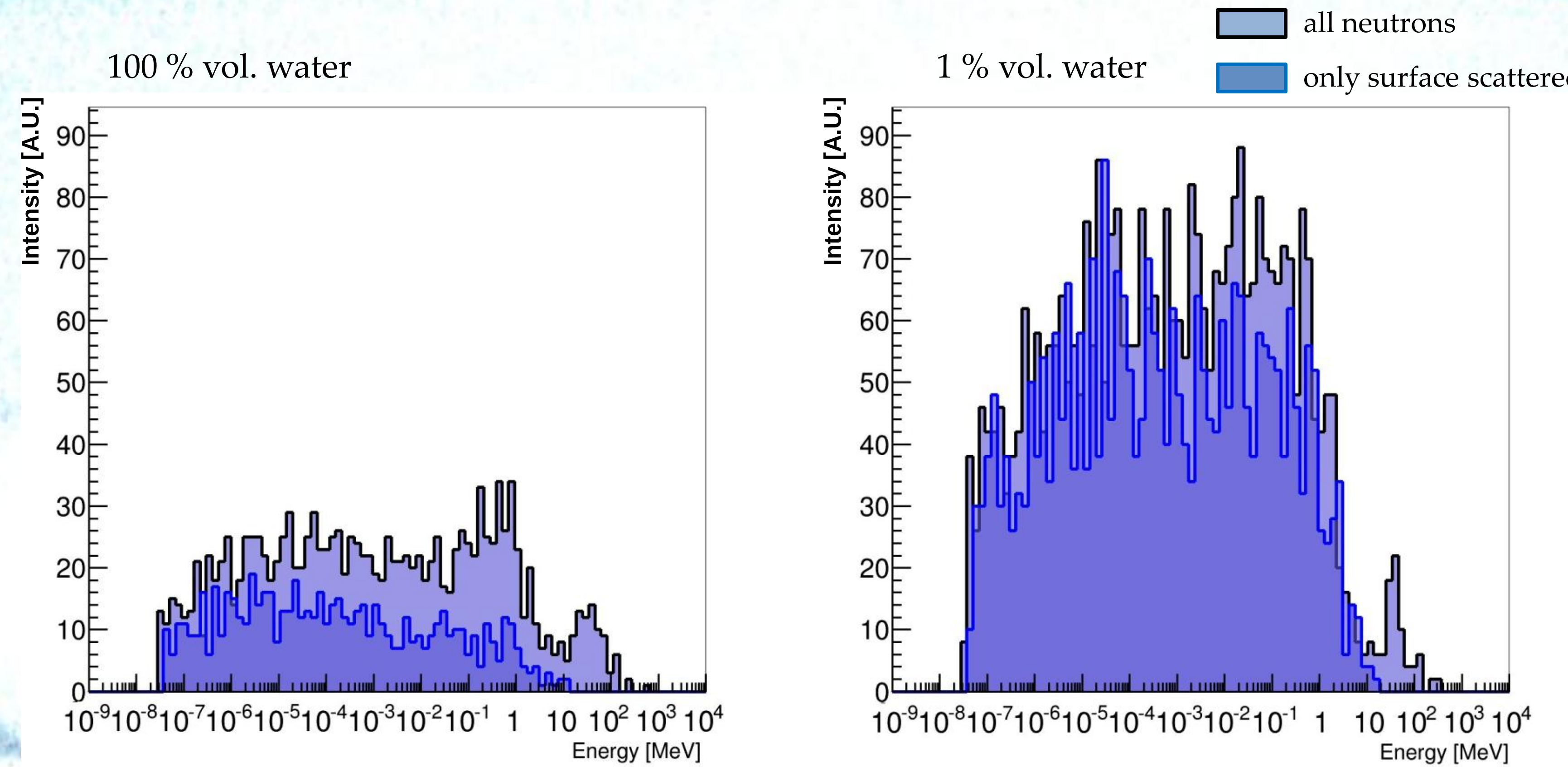


10% vol moisture

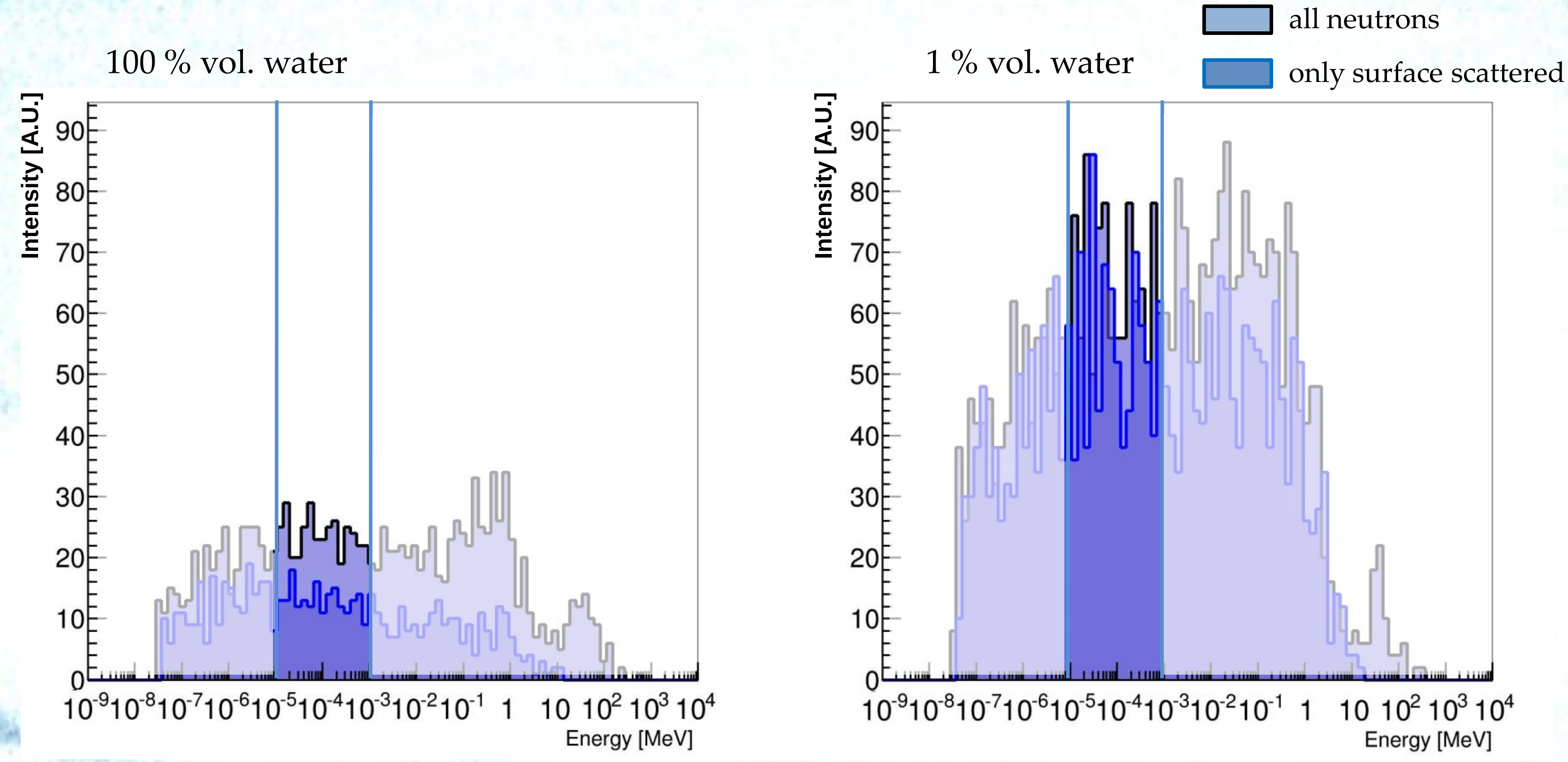
Depth distribution of the cosmic neutron probe



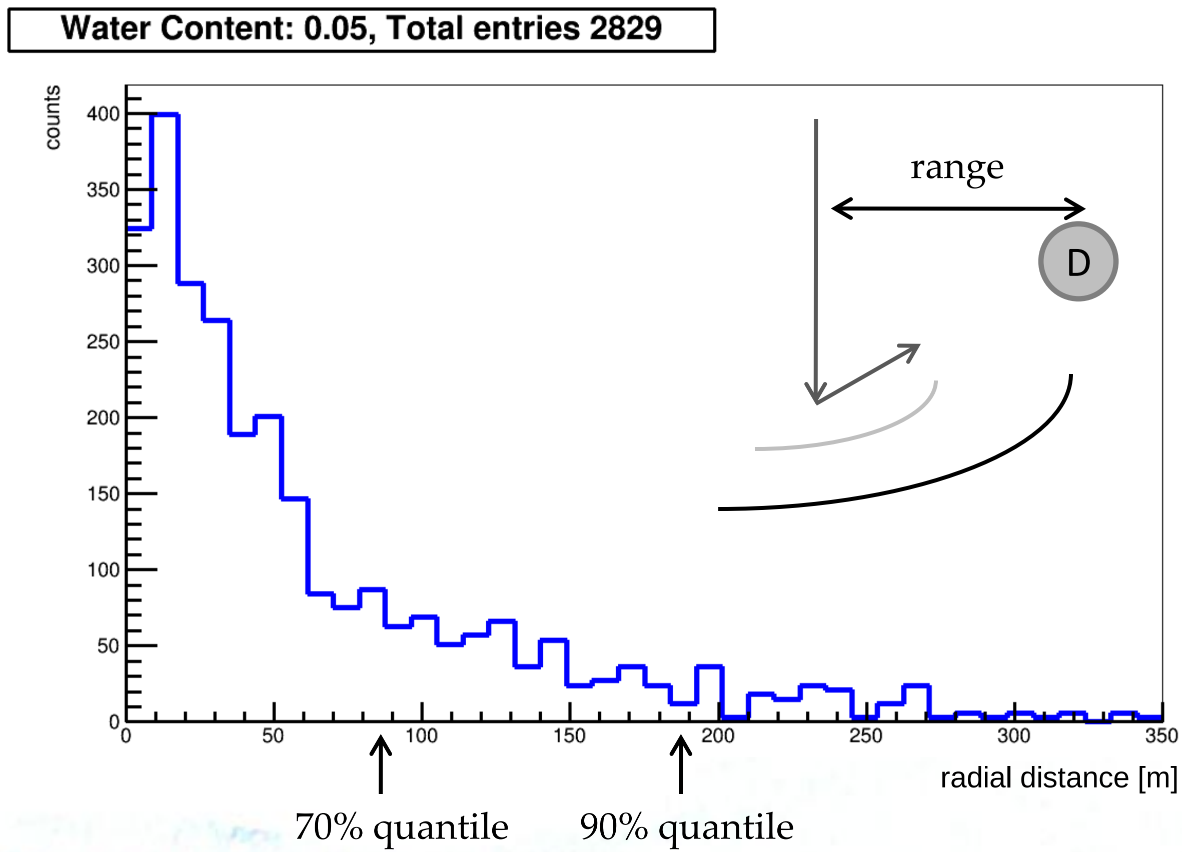
Neutron spectra of a simulated Detector



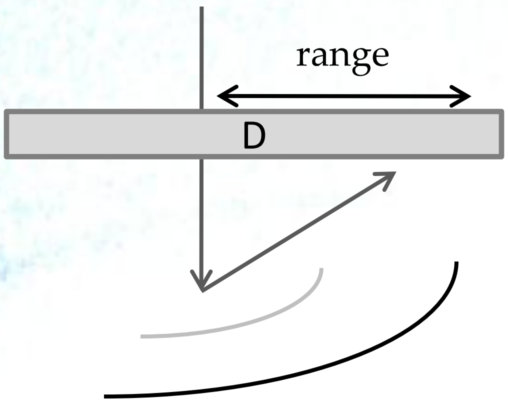
Neutron spectra of a simulated Detector

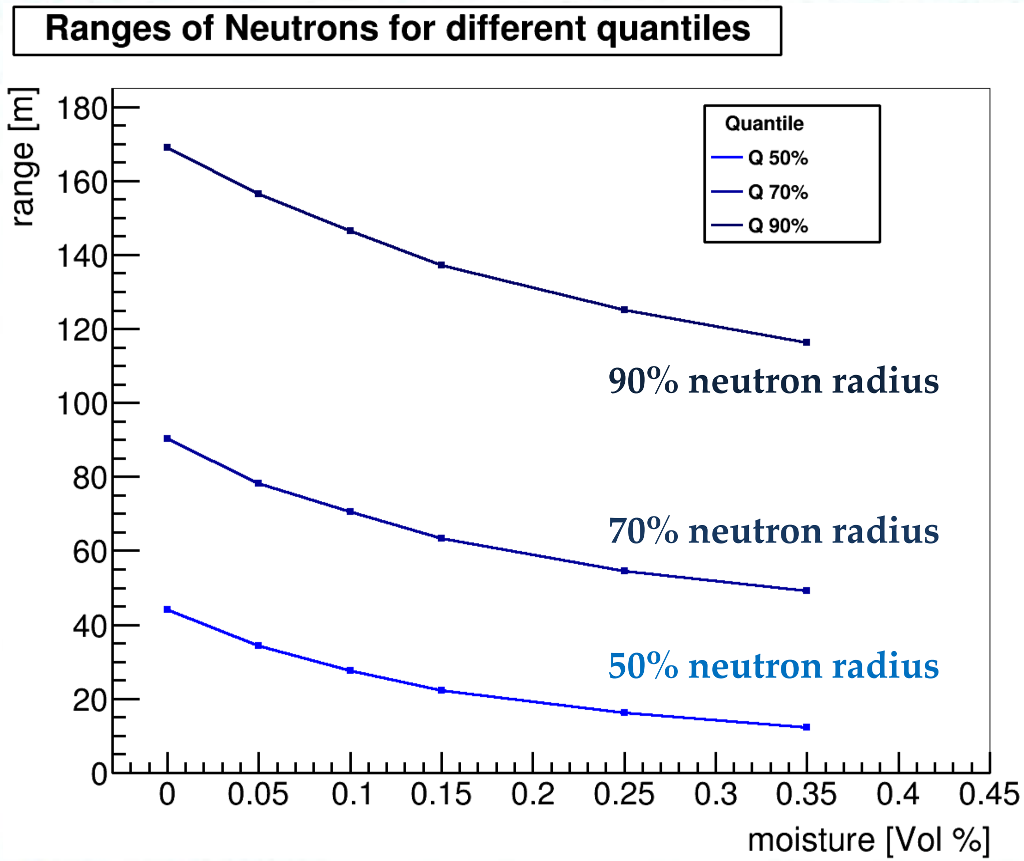


Range distribution of scattered neutrons

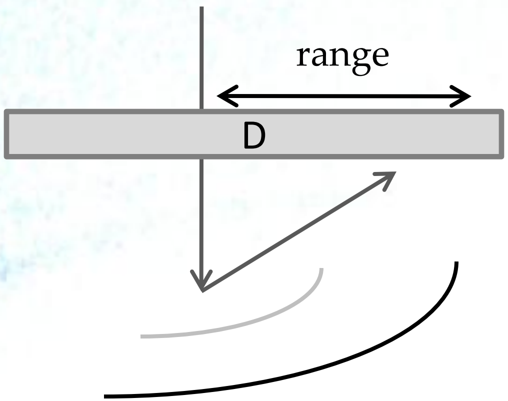


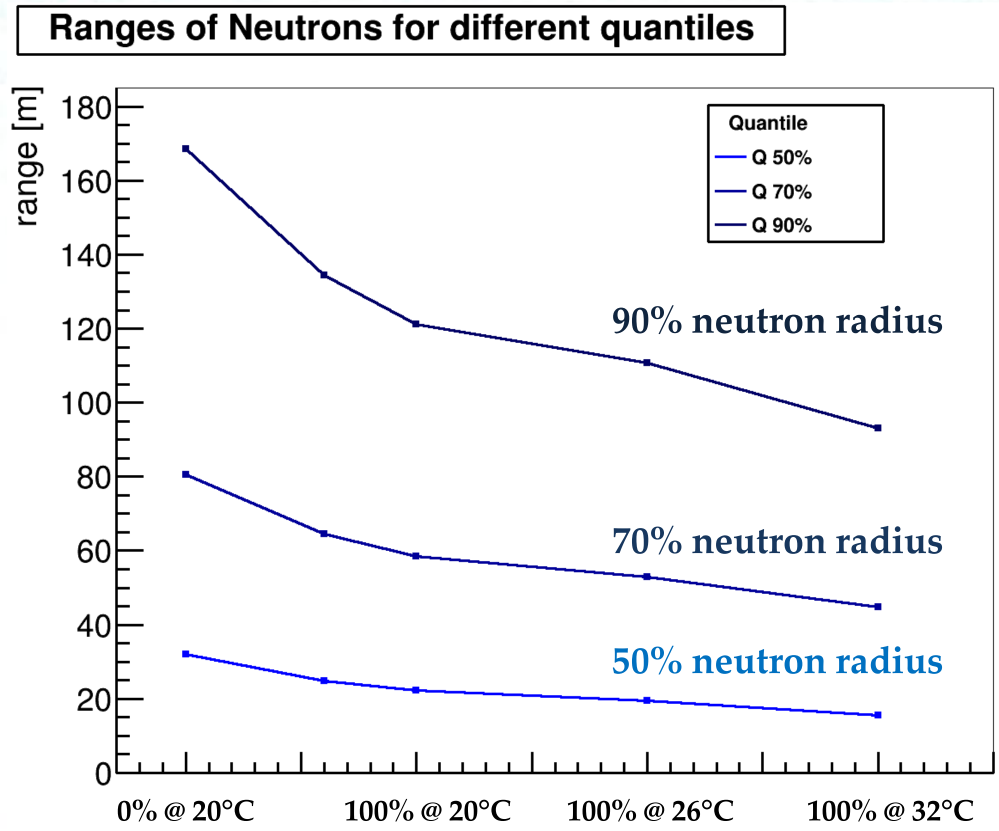
Range of the cosmic neutron probe



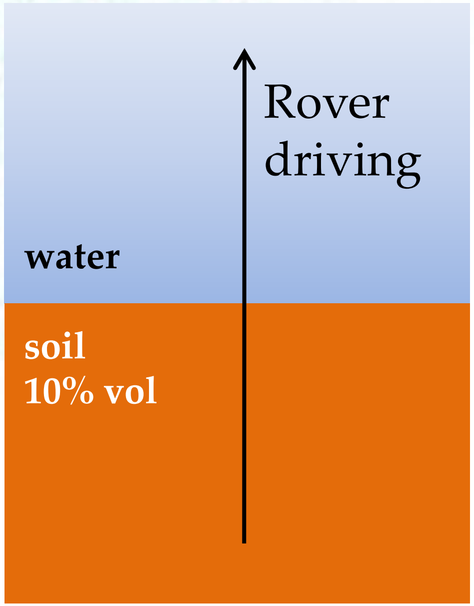


Range of the cosmic neutron probe

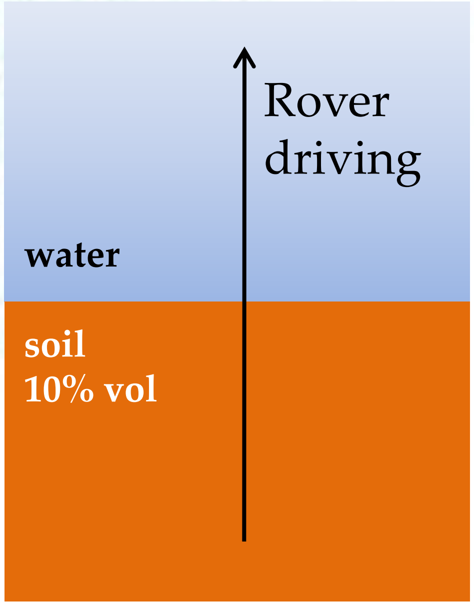


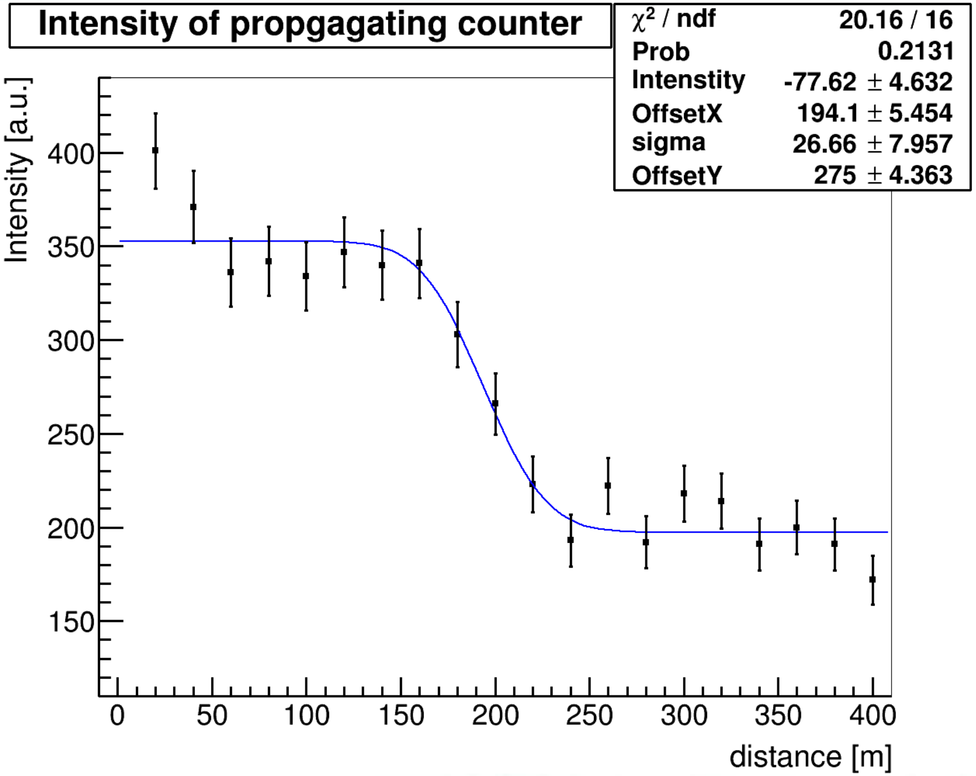


Test: Detector propagating over interface



Test: Detector propagating over interface





Concluding...

[Boron solid state detectors may be an alternative]

[Tailor the detector for the optimal neutron energy range]

Monte Carlo Simulations should be used to model geometries to answer some of this week's questions

Actual results in disagreement with established

Like:

footprint varies with soil moisture

2e-folding footprint is approximately 150 m

Monte-Carlo Simulations on the Detector Sensitivity to cosmic ray induced neutron showers

- fin-

open for discussion

Markus Köhli

U. Schmidt
AG Dubbers

Physikalisches Institut
Ruprecht-Karls-Universität
Heidelberg

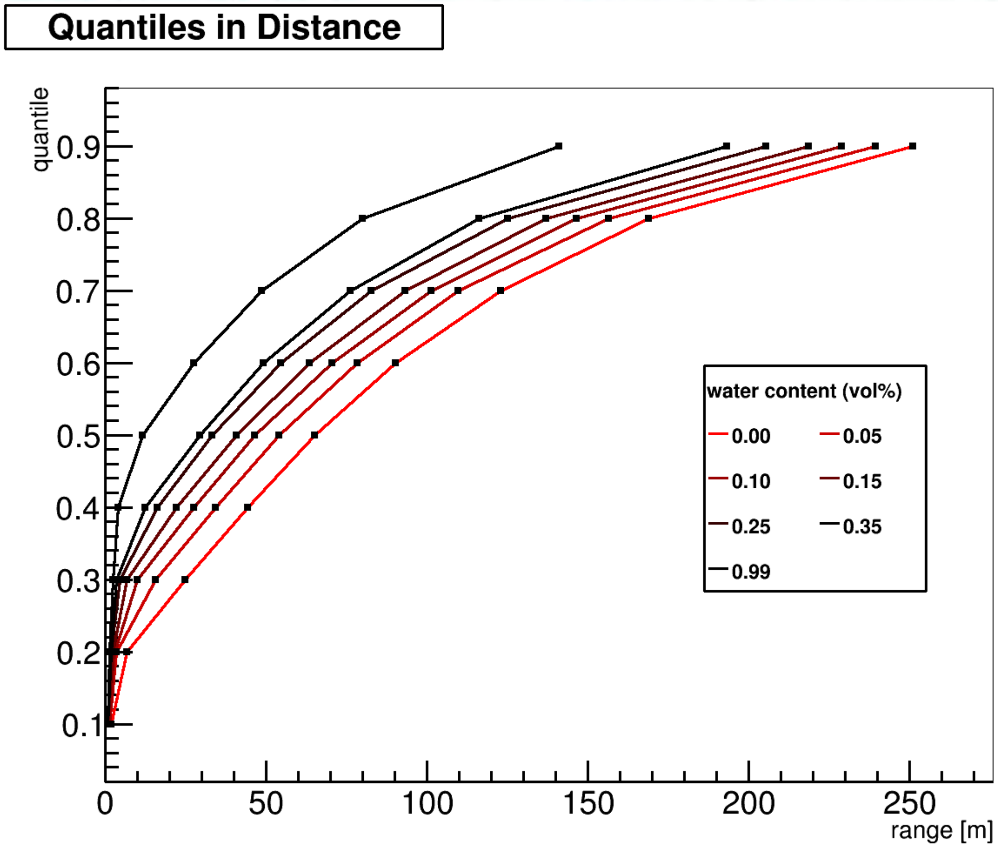
in collaboration with:

Martin Schrön

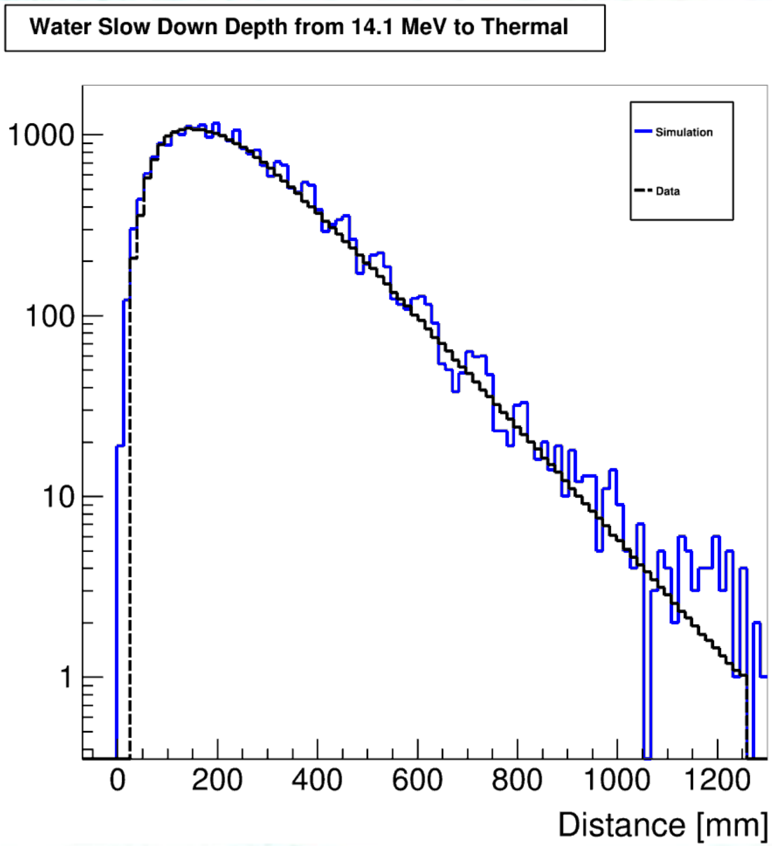
Helmholtz Center for
Environmental Research
Leipzig

Backup Slides

Range-quantiles of neutrons for different moistures



Intensity distribution of a neutron source in water



Data:

Caswell, R.S. et al: *Attenuation of 14.1 MeV Neutrons in water*
Nuclear Sci. and Eng. 2, 143 (1957)