

Neutron Transport Modelling with URANOS and Footprint Sensitivity

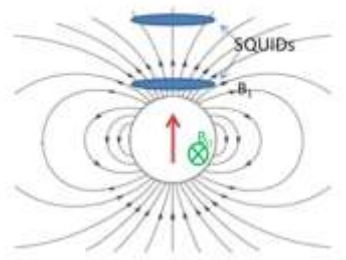
5th International COSMOS Workshop

Making Neutrons great again

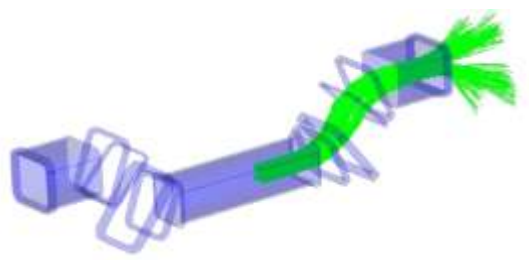




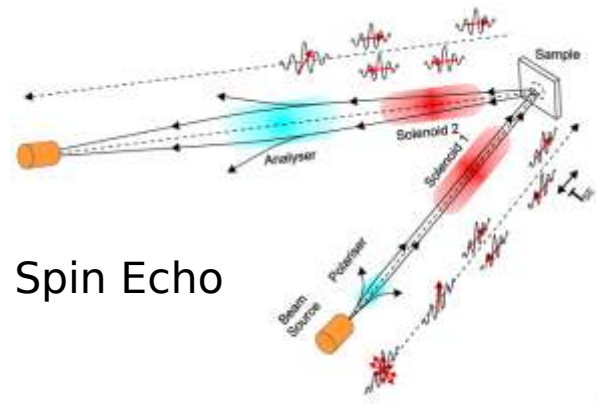
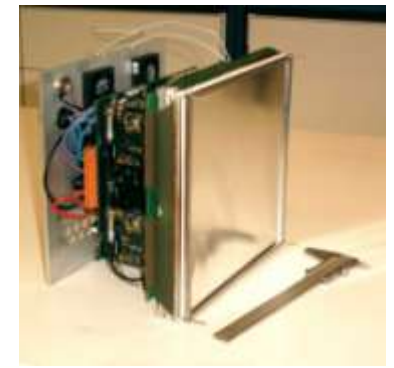
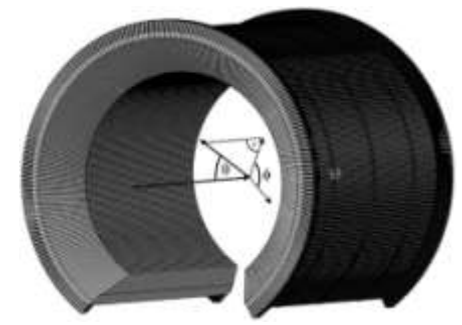
Helium-Xenon EDM [test of Lorentz invariance]



PERC and PERKEO [v_{ud} via neutron beta decay]



^{10}B Neutron Detectors [large area and high time resolution]



Spin Echo



RESEARCH ARTICLE Footprint characteristics revised for field-scale soil moisture monitoring with cosmic-ray neutrons

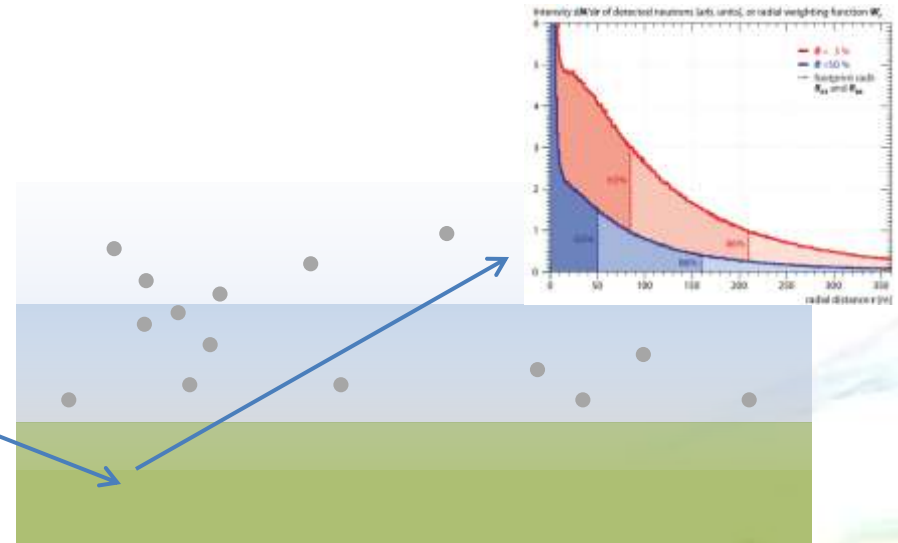
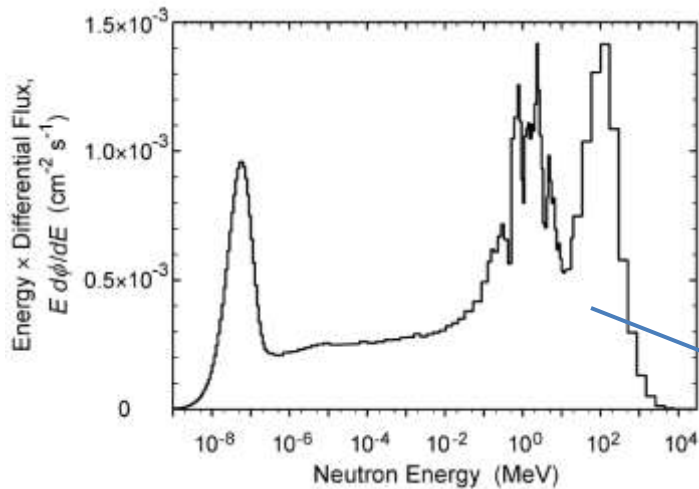
10.1002/2015WR017169

M. Köhli and M. Schrön contributed equally to this work.

Key Points:

- Neutron transport modeling revised

$$W_r(h, \theta) \approx \begin{cases} F_1 e^{-F_2 r} + F_3 e^{-F_4 r}, & r \leq 50 \text{ m} \\ F_5 e^{-F_6 r} + F_7 e^{-F_8 r}, & r > 50 \text{ m} \end{cases}$$





RESEARCH ARTICLE

10.1002/2015WR017169

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Key Points:

- Neutron transport modeling revised

Footprint characteristics revised for field-scale soil moisture monitoring with cosmic-ray neutrons

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WRR Paper 2015

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URANOS

Ultra Rapid Adaptable Neutron-Only Simulation
for Environmental Research



Physikalisches
Institut
**Heidelberg
University**



HELMHOLTZ
CENTRE FOR
ENVIRONMENTAL
RESEARCH – UFZ



URANOS

URANOS - The Cosmic Neutron Soil Moisture Simulator

URANOS

Simulate Pause Stop Clear

#neutrons: 59999500
maximum: 60000000



(1599/s)
-00:00:00

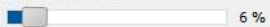
Refresh every 500 neutrons

Export

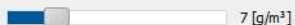
Physical Parameters Computational Parameters Detector Setup Export & Display

Layers are arranged in the vertical direction, representing different materials or 2D gridded patterns
Position z denotes the depth below surface (z=0) in [m]
Layers override topological presets

Soil Moisture [Vol%]



Air Humidity



Atmospheric depth [g/cm²]



Topological presets (water, land)

- None
- River, width [m]
- Coast at x [m]
- Island, diameter [m]
- Lake, diameter [m]

Layers

	Position	Height	Material	Matrix
1	-1000	920	11	
2	-80	30	11	
3	-50	48	11	
4	-2.5	0.5	11	
5	-2	2	11	
6	0	3	20	6.dat (450)

Load Minimal Config

-

+

Source Layer 2

Detector Layer 4

Ground Layer 6

Material Codes

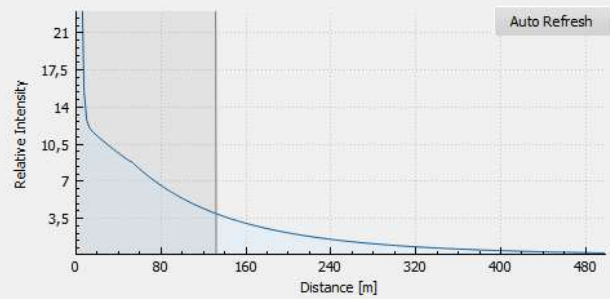
Use layer maps

View layer maps

Load

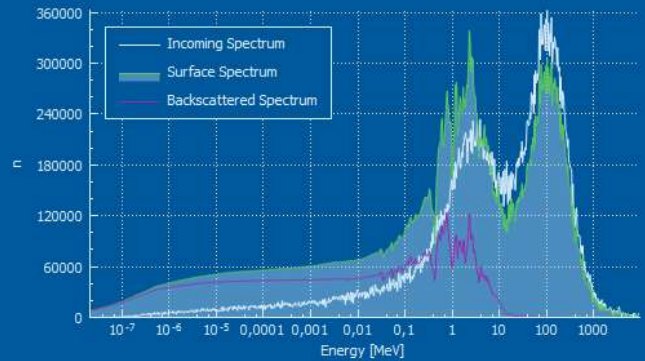
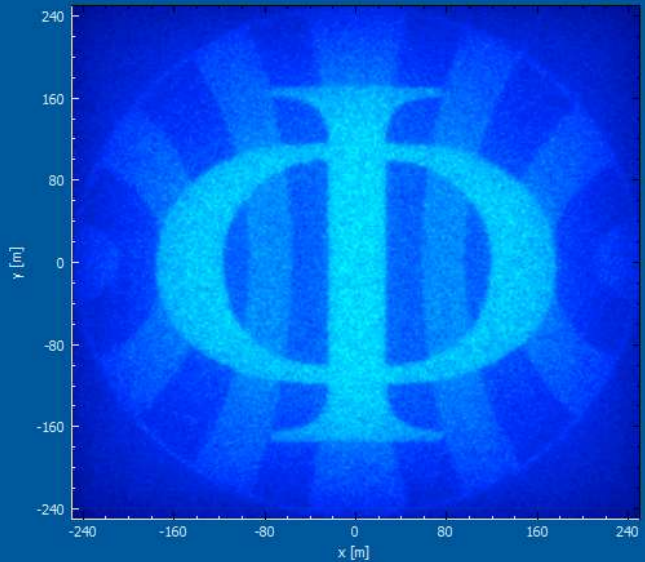
Save

Estimated Radial Neutron Distribution at Sea Level



Live: Birds-eye View & Spectra

Range View Spatial View





URANOS

URANOS - The Cosmic Neutron Soil Moisture Simulator

URANOS

Simulate

Pause

Stop

Clear

#neutrons: 59999500
maximum: 60000000



(1599/s)
-00:00:00

Refresh every 500 neutrons

Export

Physical Parameters Computational Parameters Detector Setup **Export & Display**

Specify the data to be printed to the output folder

- Epithermal Map
- Epithermal Data
- Intermediate Energy Map
- Intermediate Energy Data
- Fast Neutron Map
- Fast Neutron Data
- Selected Energy Map
- Selected Energy Data
- Travel Distance Graphs
- Log Y Axis
- Detector Distance Data
- Detector Layer Distance Data
- Write Detector Neutron Hits to File

Map drawing options

- Heat Map
- Heat Map Inverted
- Rainbow
- Gray Scale
- Deviation
- Dark Corona

Compress by Factor 2

PDF Output

Displayed energy window

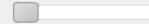
- 1 eV-1 keV
- 1 keV-1 MeV
- 1 MeV-20 MeV
- Detector Selection

Neutron Color Scheme

- Night
- Cold
- Polar
- URANOS

Color range: [0-204]

Lower bound:

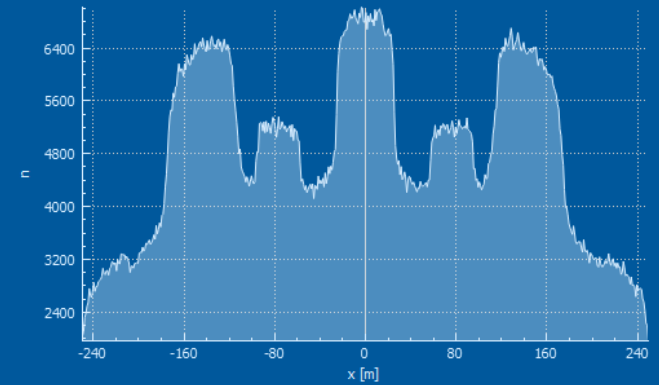


Upper bound:

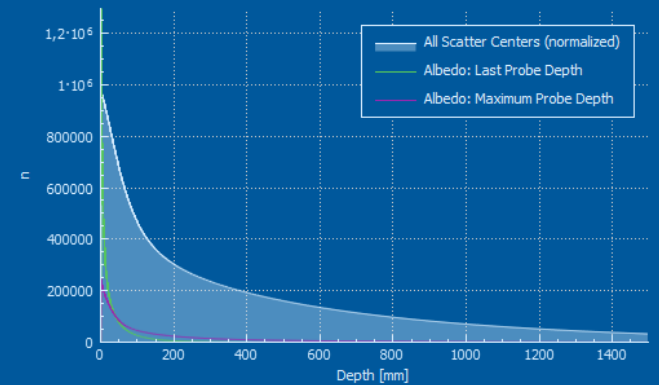


Live: Birds-eye View & Spectra Range View **Spatial View**

Profile view: horizontal slice along the x-axis



Depth of Interactions





URANOS

URANOS - The Cosmic Neutron Soil Moisture Simulator

URANOS

Simulate

Pause

Stop

Clear

#neutrons: 59999500
maximum: 60000000



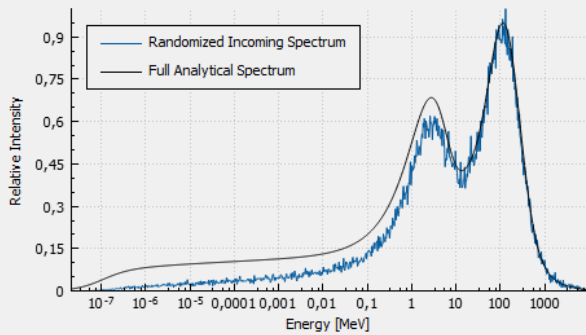
(1599/s)
-00:00:00

Refresh every 500 neutrons

Export

Physical Parameters Computational Parameters Detector Setup Export & Display

Generated neutrons are sampled from an incoming spectrum. URANOS uses the incoming-only part of the analytical spectrum by Sato et al. (2006)



View spectrum

Sampling magnitude:

10[^] 5

Cut-off rigidity [GeV]



use a Mean Basic Spectrum

The simulation domain can be cut to an area of interest for the sake of computational efficiency. Please adjust the source geometry accordingly.

Domain

Dimension: 500 m

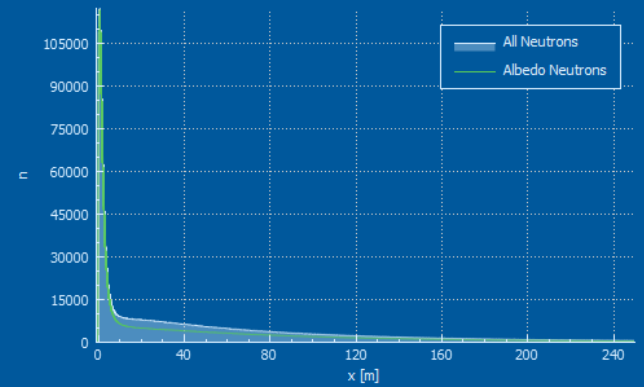
Source geometry

round Dimension: 250 m

quadratic

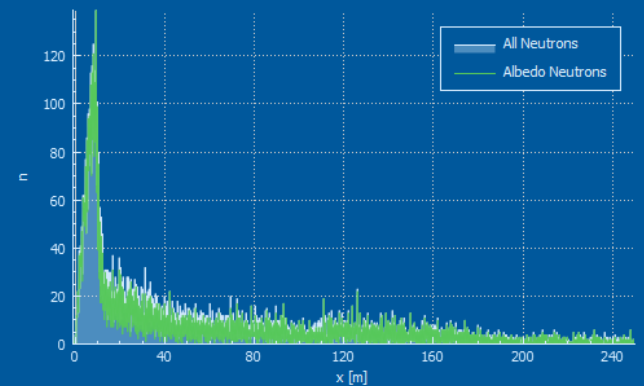
Live: Birds-eye View & Spectra Range View Spatial View

Range distribution of neutrons passing the surface



76% Neutrons with Soil Contact

Range distribution of detected neutrons



84% Neutrons with Soil Contact





Neat Examples





Land-Water Interface Simulation



[Movie Removed]

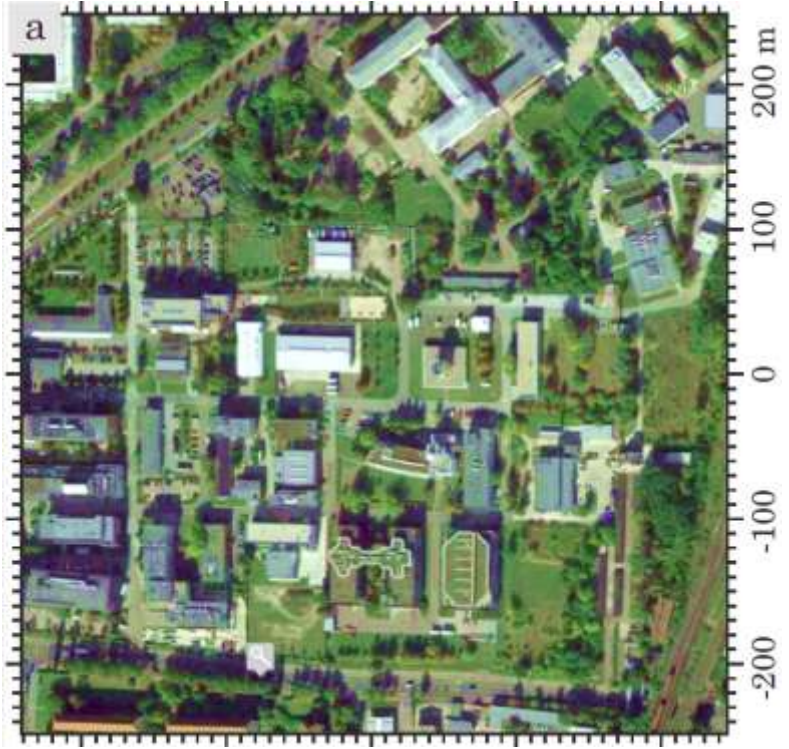
dry soil

water

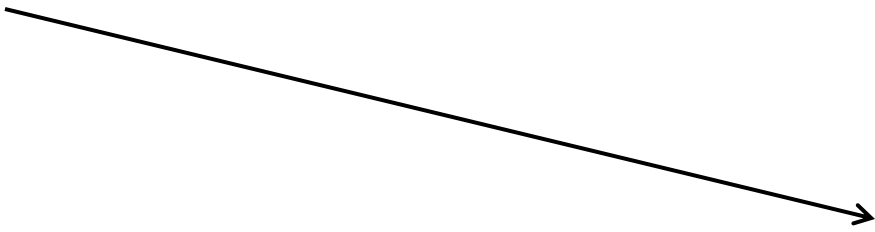




Inhomogeneous Terrain

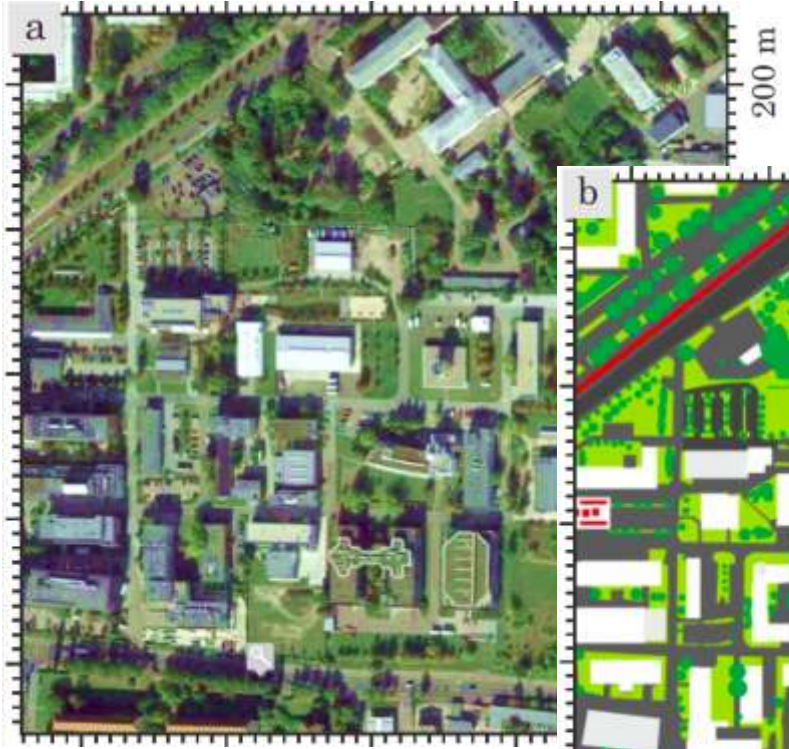


topography

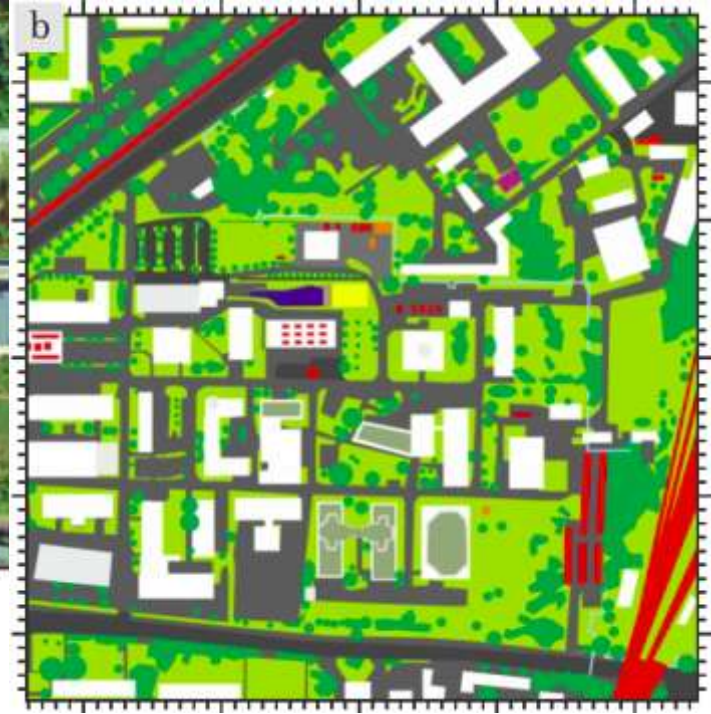




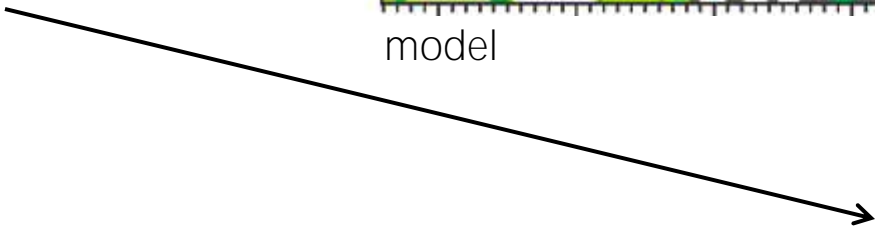
Inhomogeneous Terrain



topography

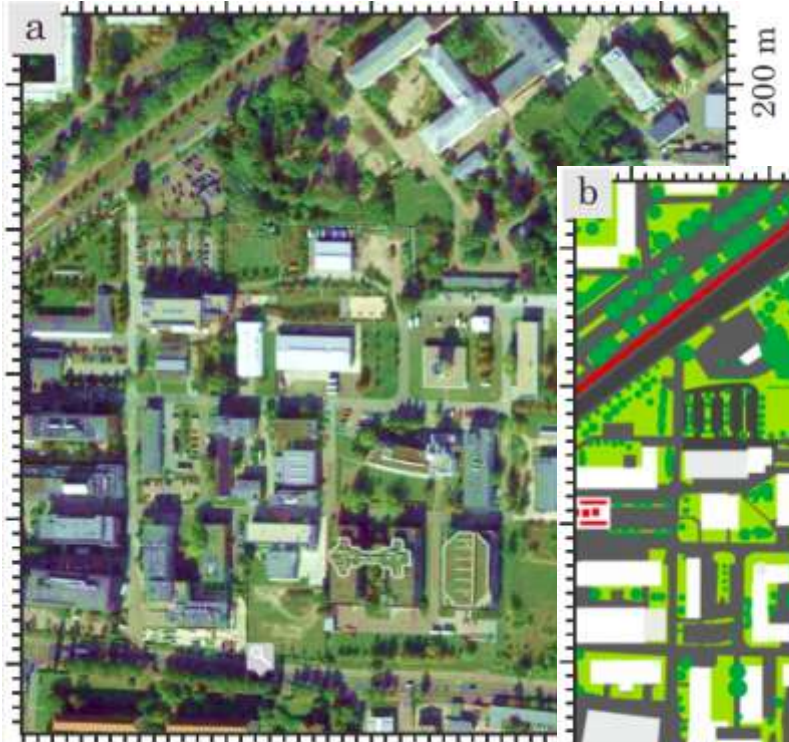


model

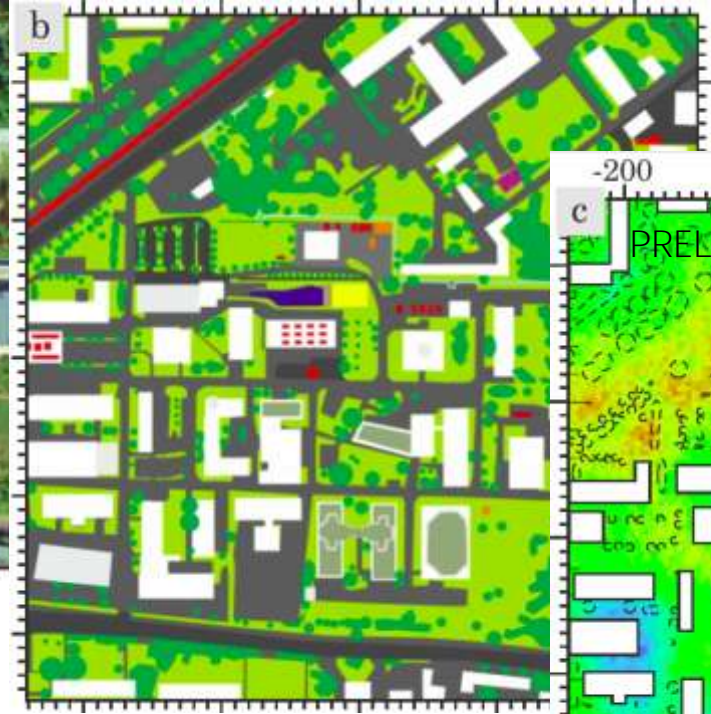




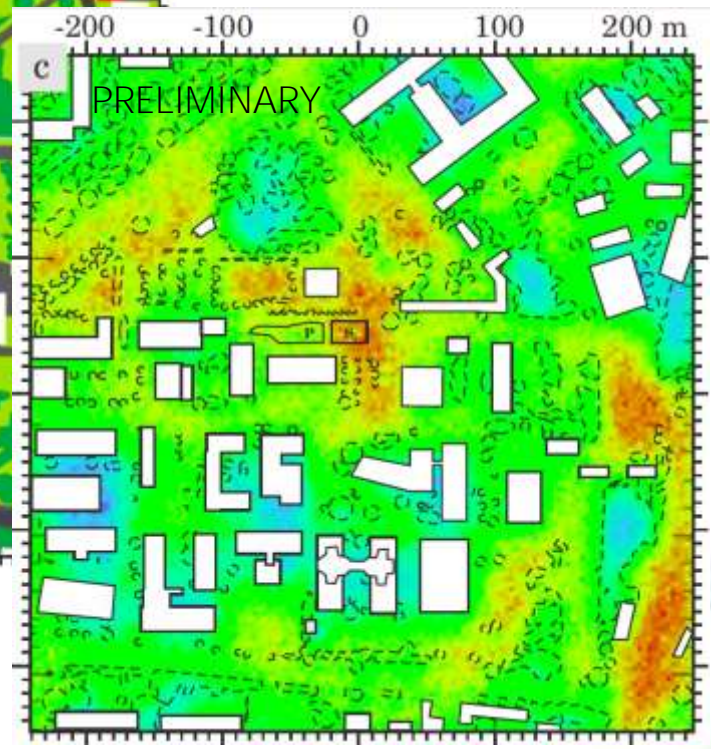
Inhomogeneous Terrain



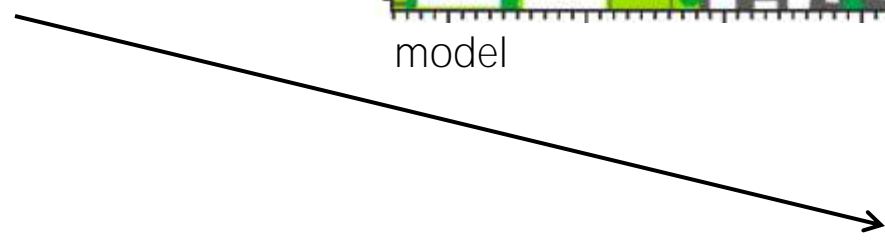
topography



model

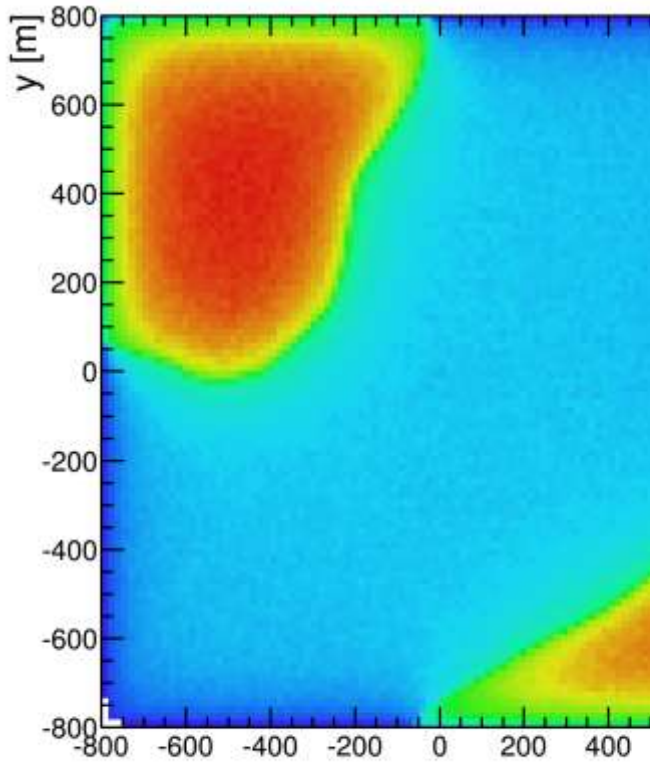


simulation

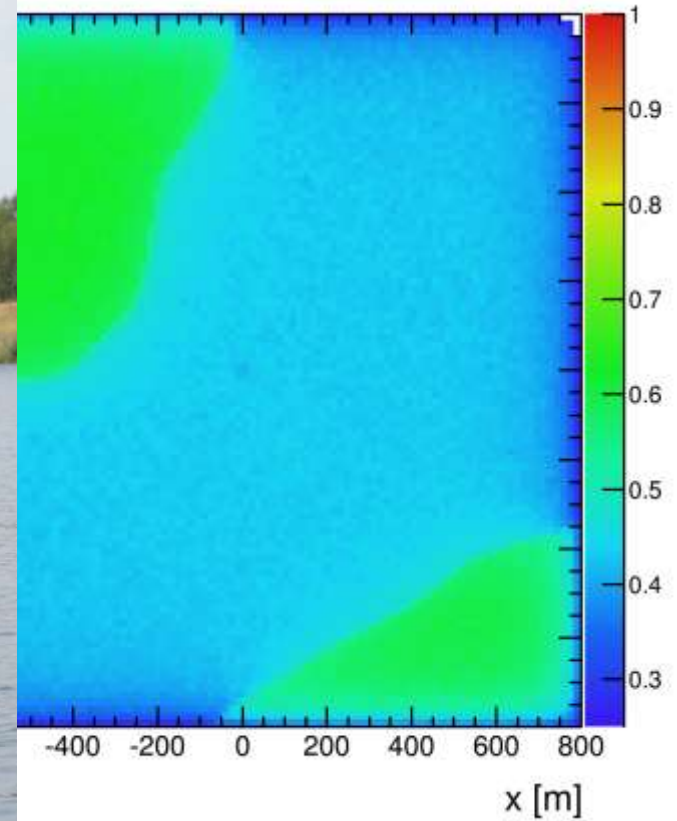




Buoy on a lake



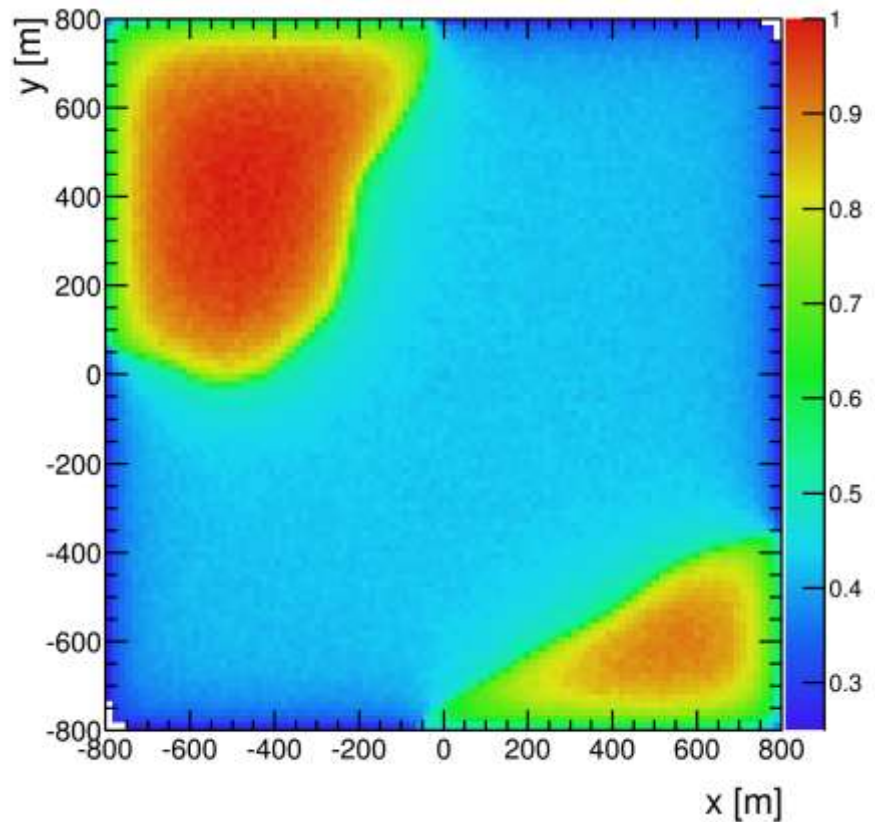
dry coast



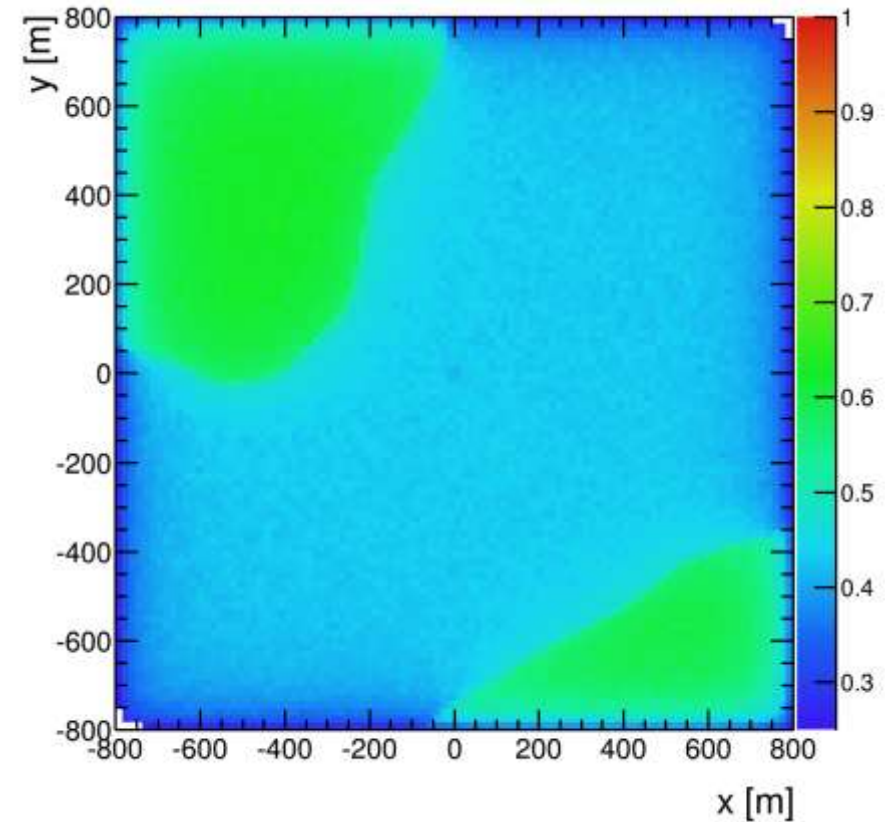
wet coast



Buoy on a lake



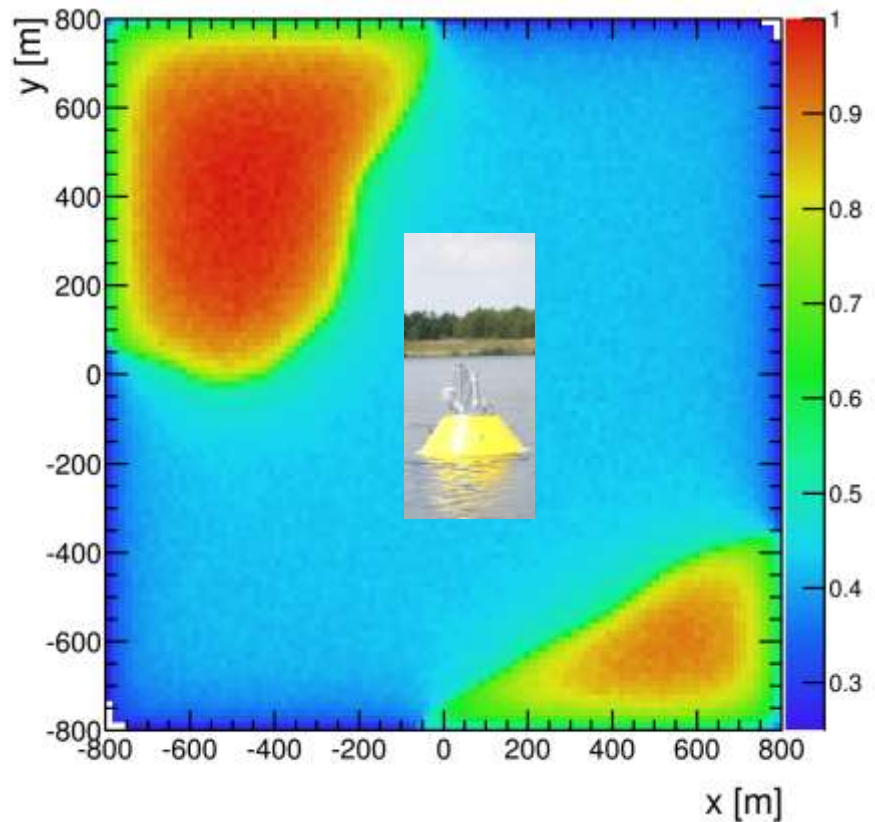
dry coast



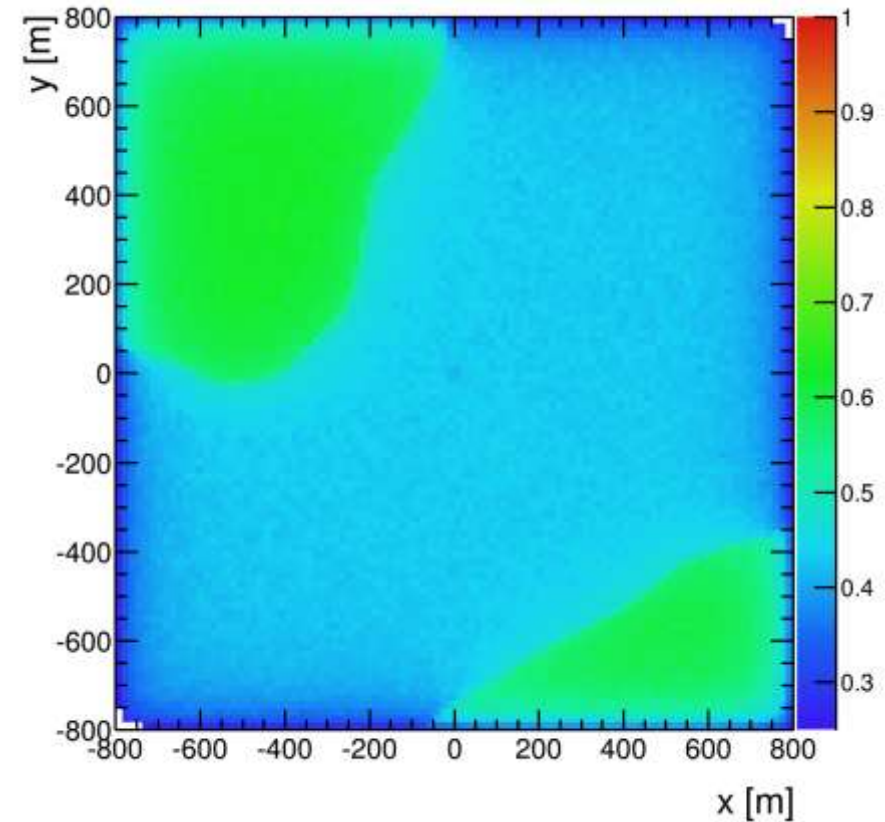
wet coast



Buoy on a lake



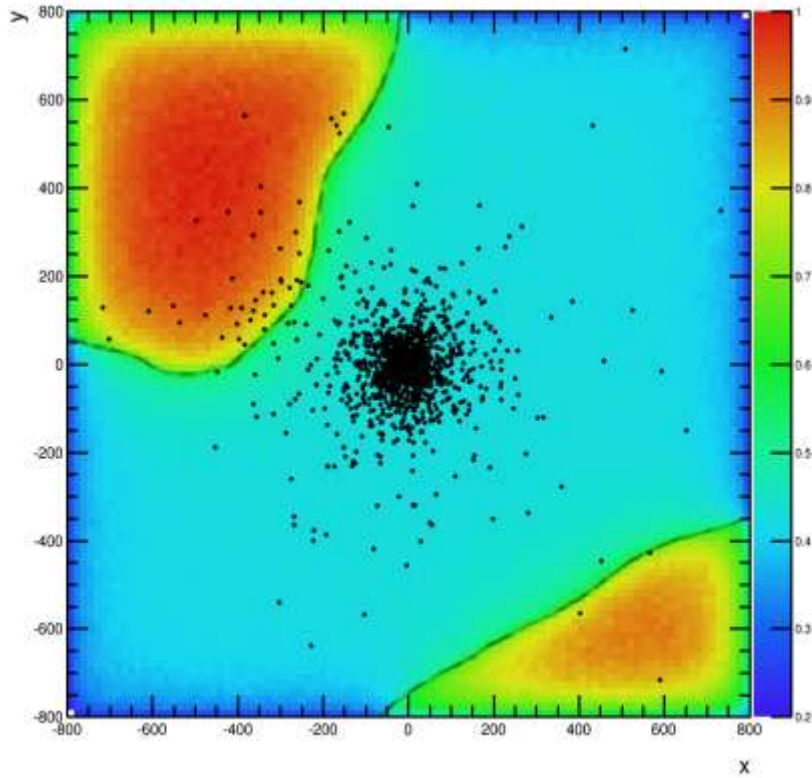
dry coast



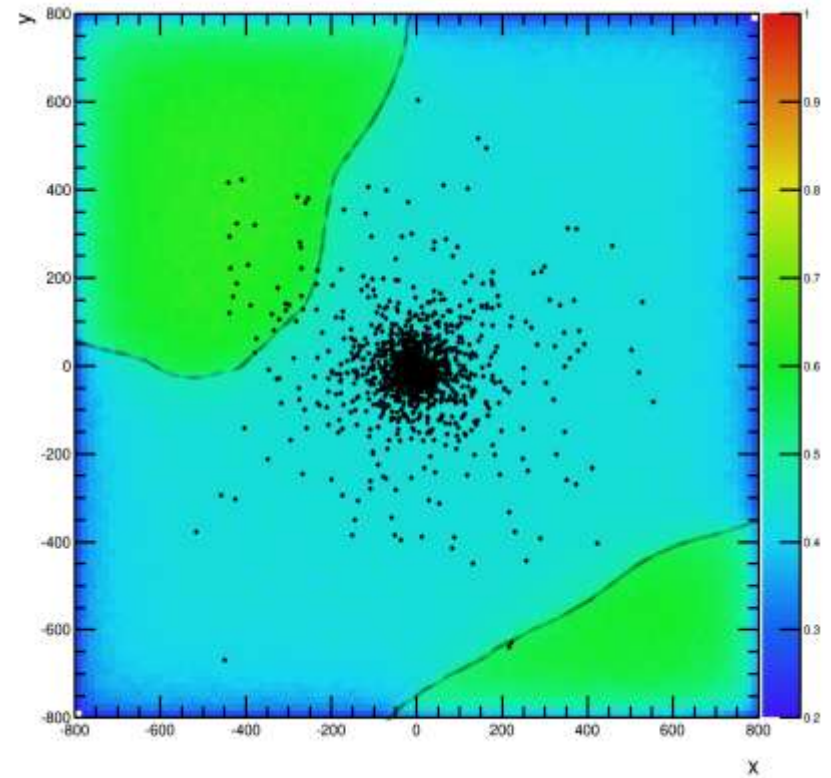
wet coast



Buoy on a lake



dry coast



wet coast



Lemon trees in Valencia

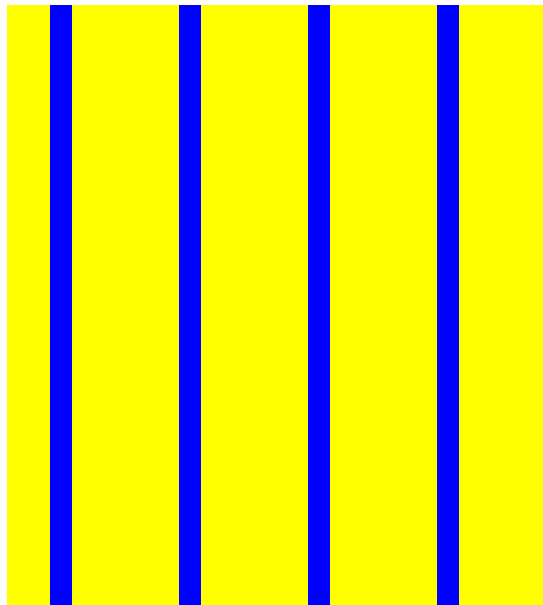




Irrigation control

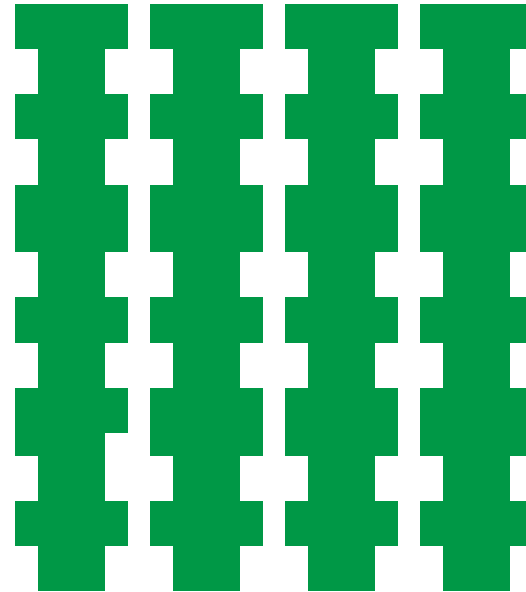
Lemon trees in Valencia

soil layer



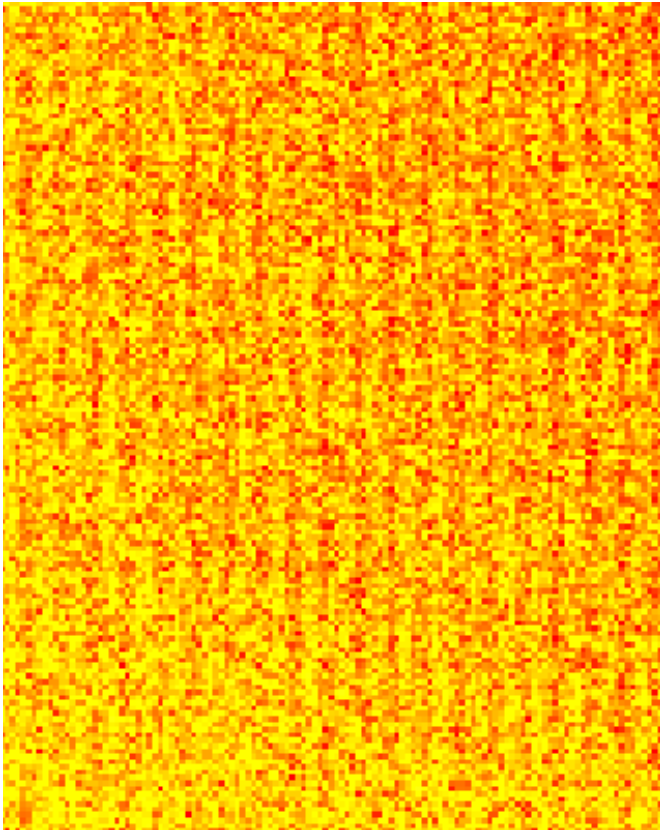
5m + 1m

plant gas layer





Lemon trees in Valencia



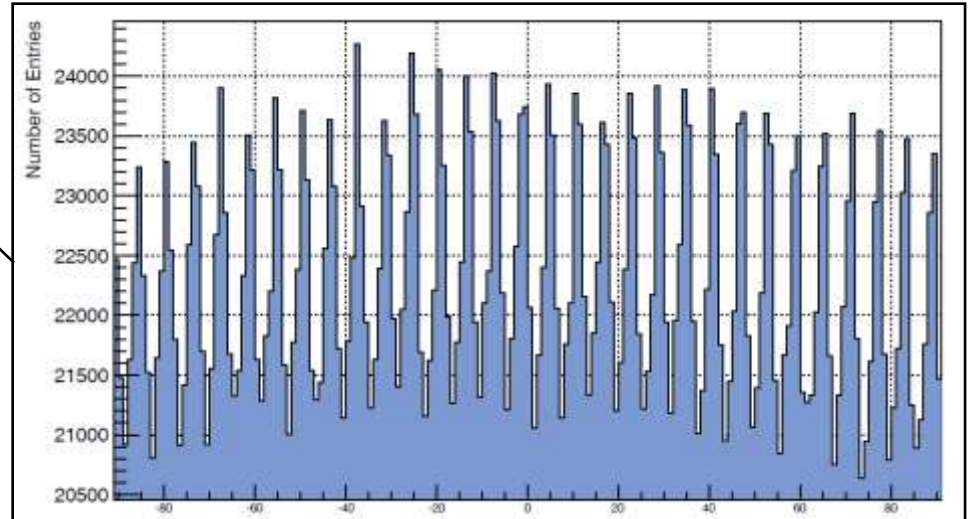
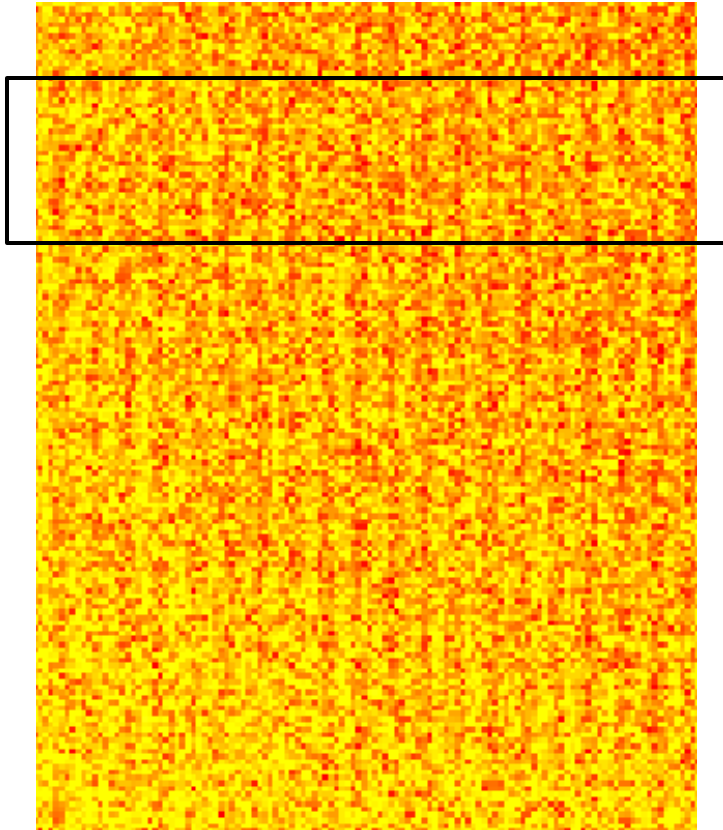
top view



Irrigation control

Lemon trees in Valencia

profile view



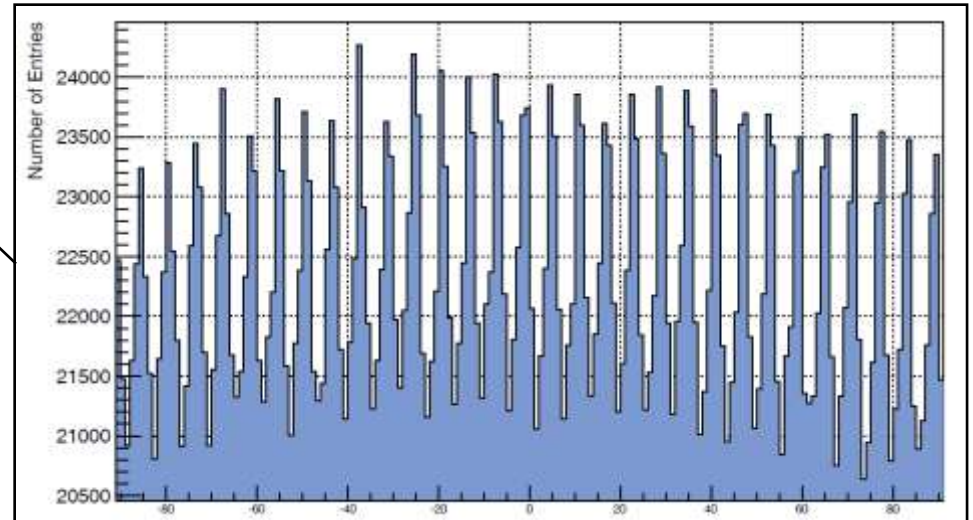
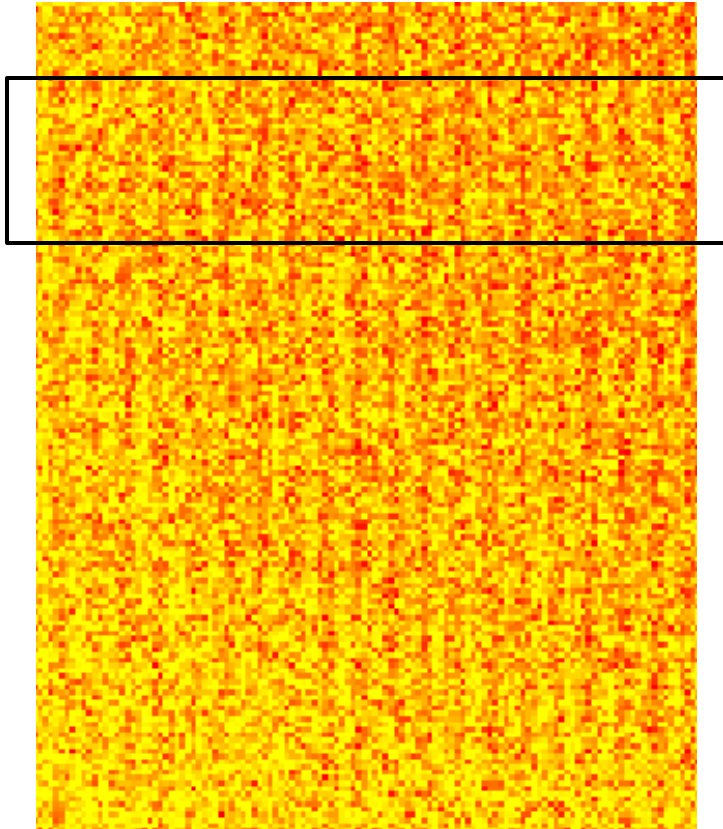
top view



Irrigation control

Lemon trees in Valencia

profile view



- ~2.5% change for
- 10% soil moisture base
- 10% - 50% in the irrigation channel

top view

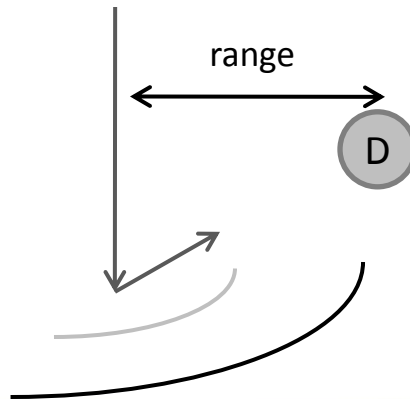


Local Effects



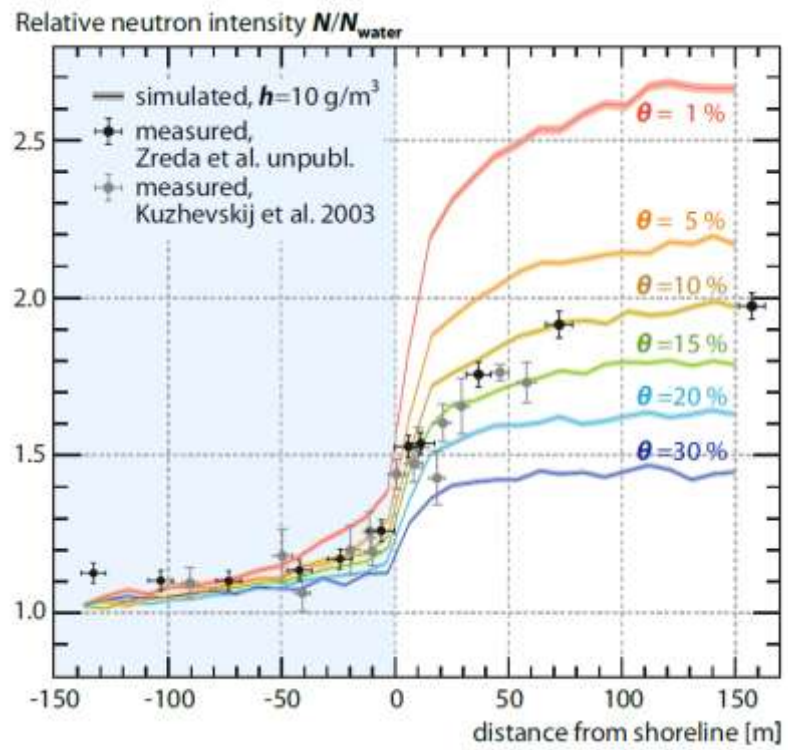
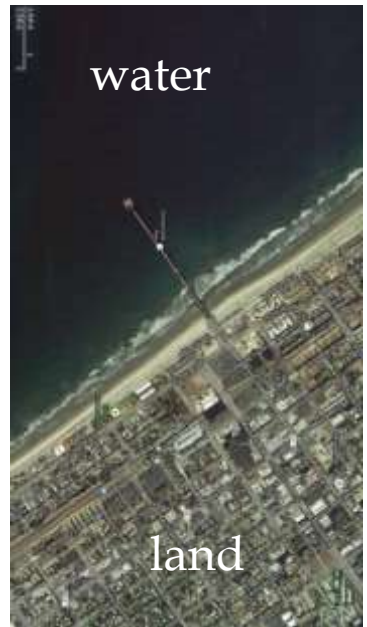
How far do reflected neutrons travel?

[Movie Removed]





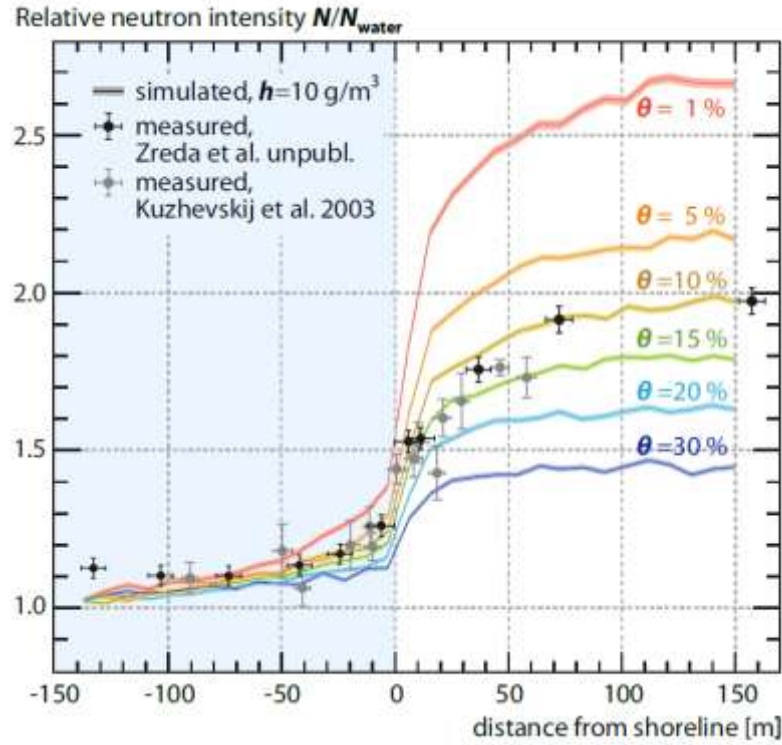
Coastal Transect



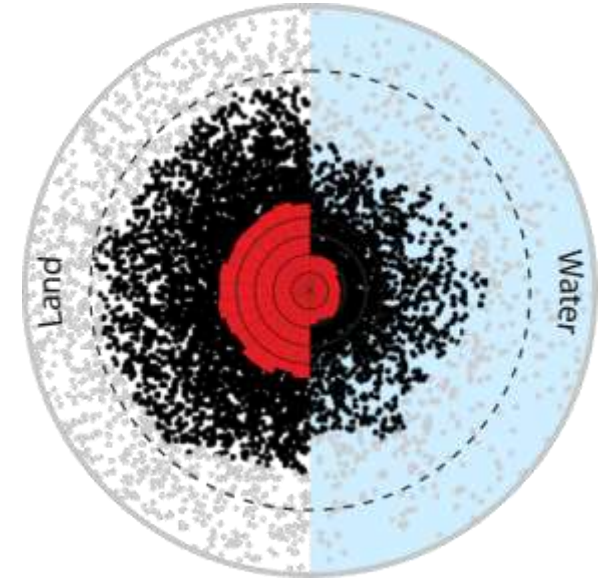
water land



Coastal Transect



water land

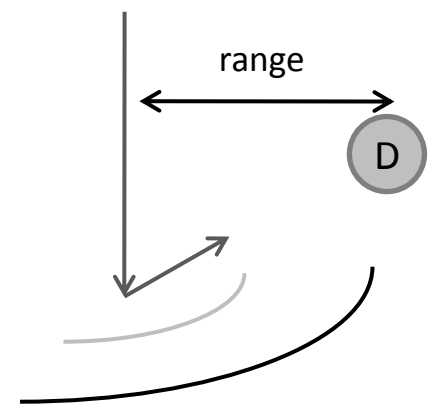
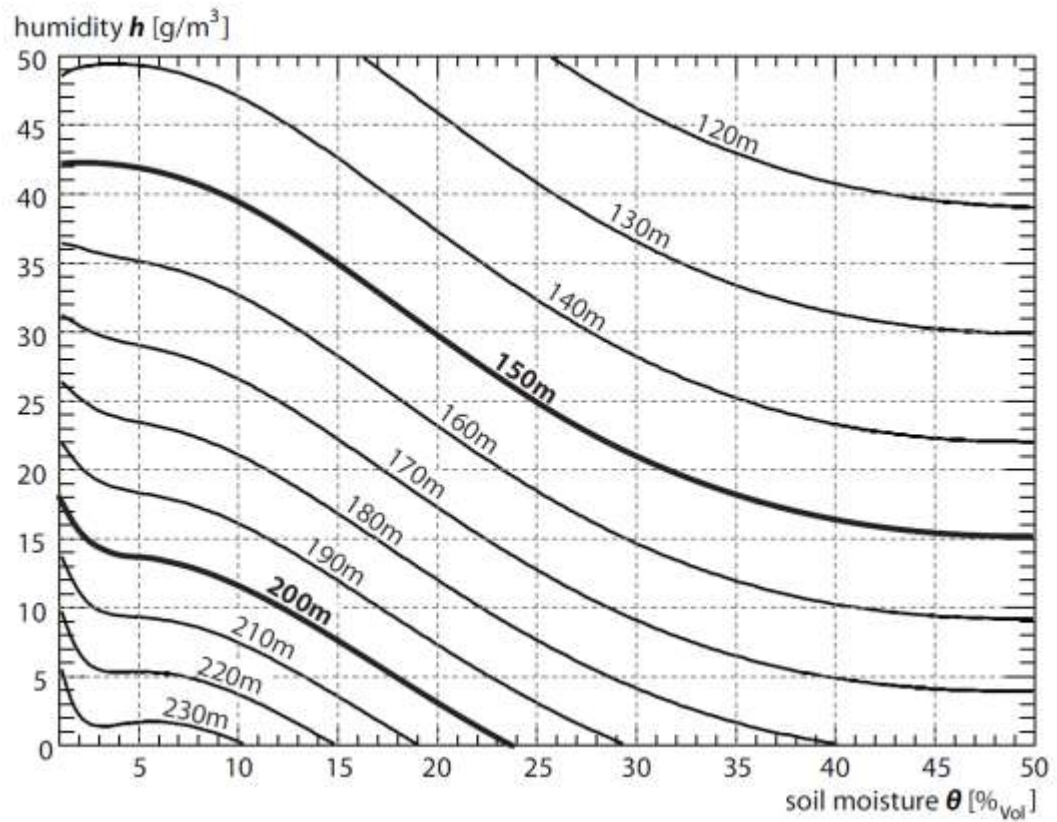


- Detected neutron origins (first contact to soil)
- Closest 86% of neutron origins for each 12° sector
- Neutron intensity for each 12° sector [arb. units]
- Footprint $R_{5\sigma}(5\text{g/m}^3, 5\%) = 210\text{m}$ for homogeneous soil



The Footprint in 2015

How far do reflected neutrons travel?



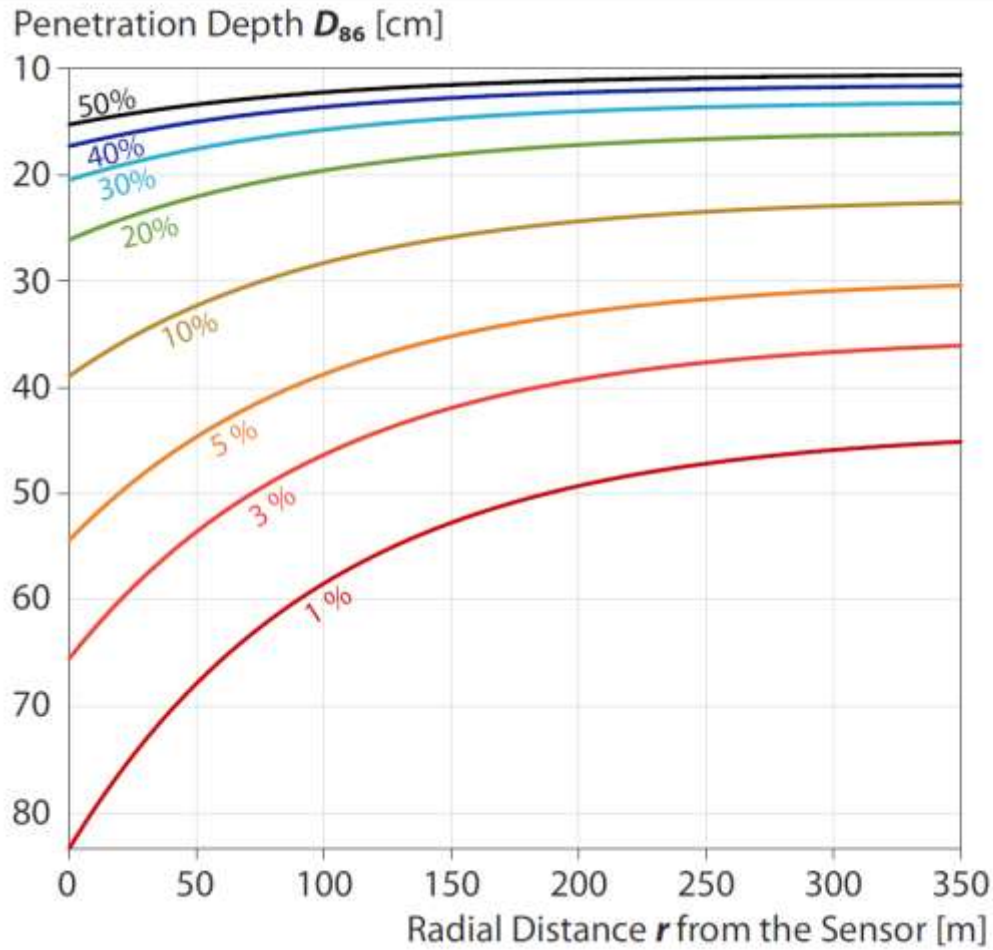
Köhli et Schrön et al.

Footprint characteristics revised for field-scale soil moisture monitoring with cosmic-ray neutrons

Water Resources Research, 51, 5772-5790



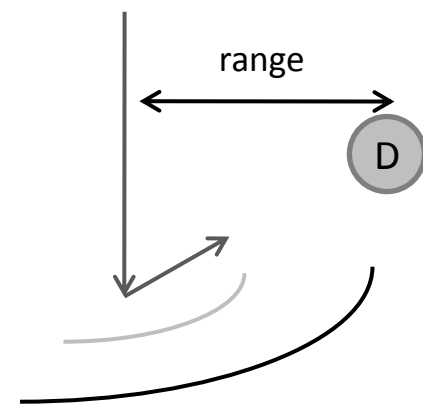
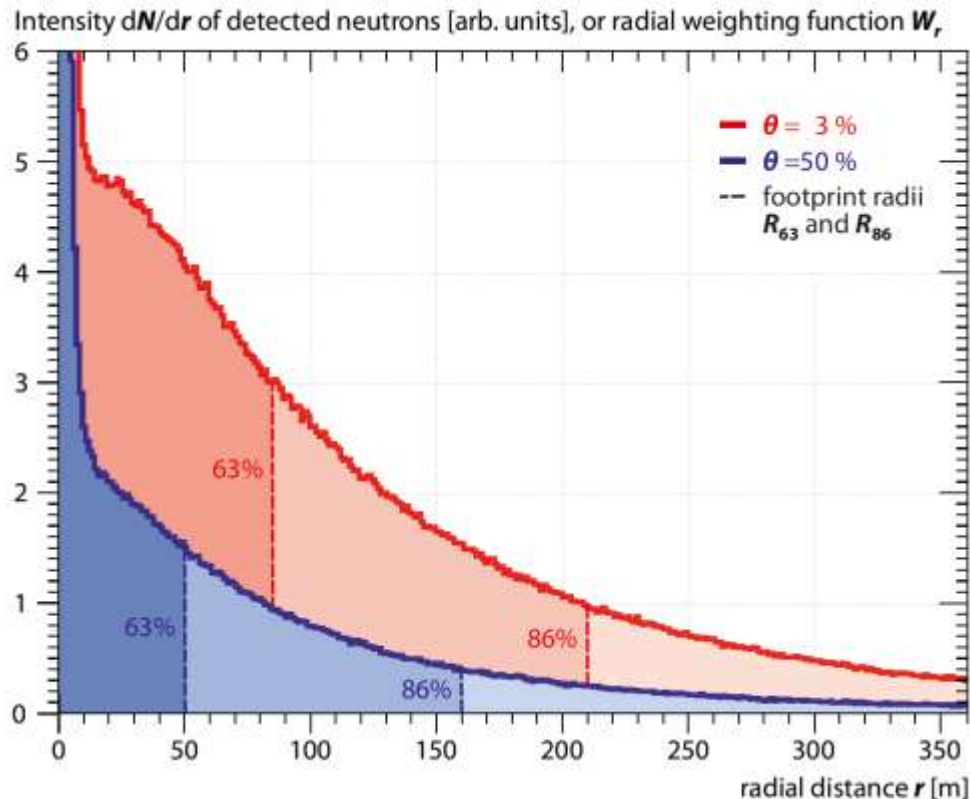
Penetration Depth





The Footprint in 2015

How far do reflected neutrons travel?



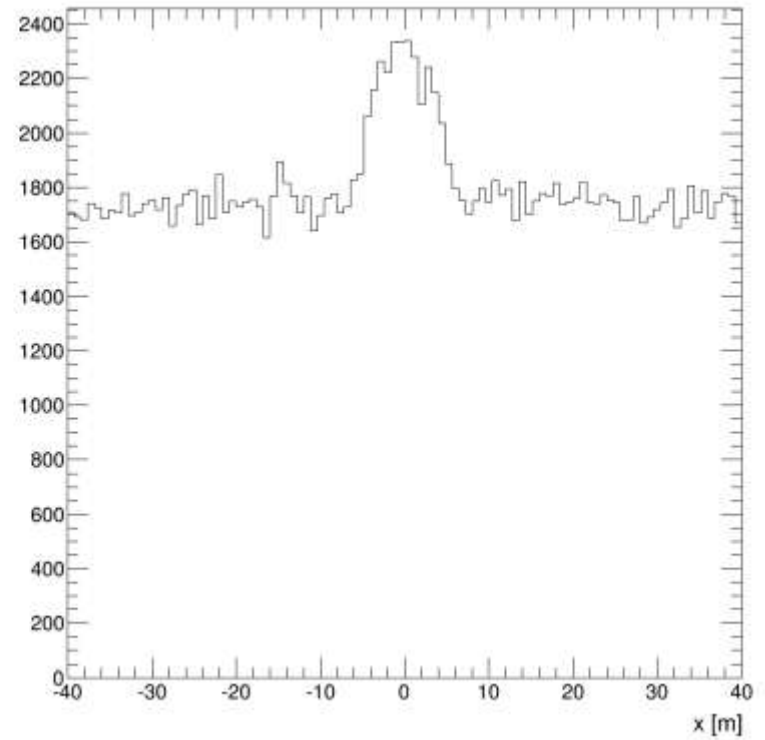
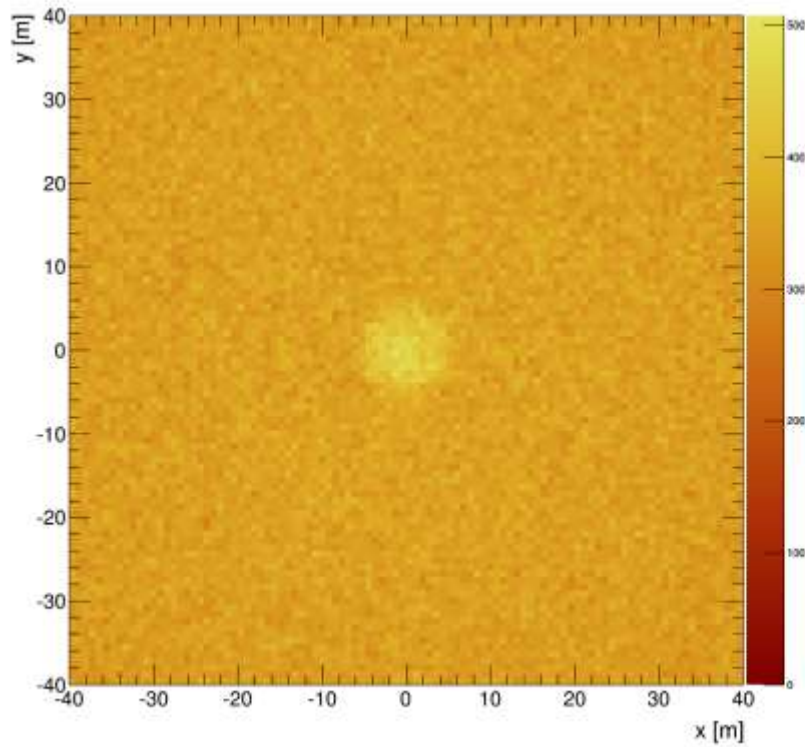
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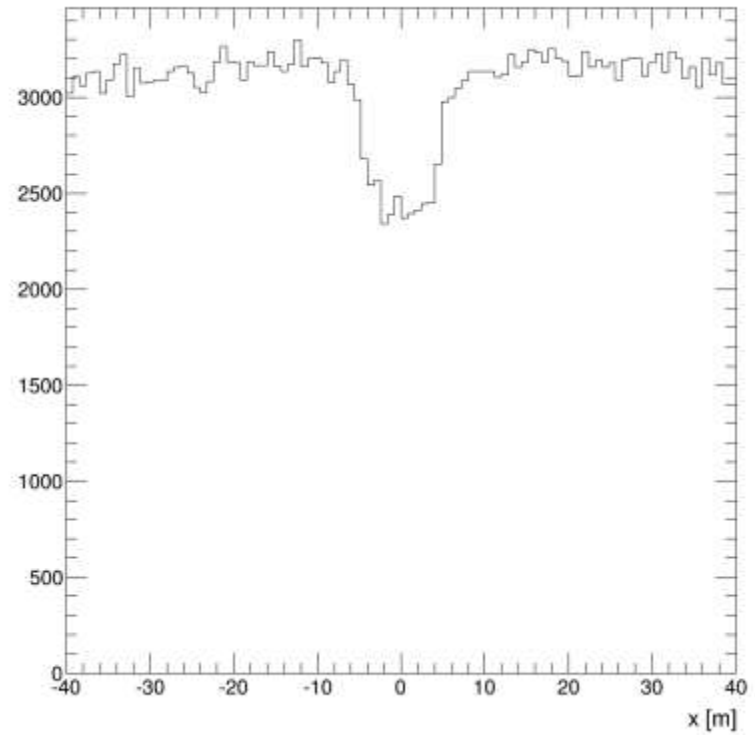
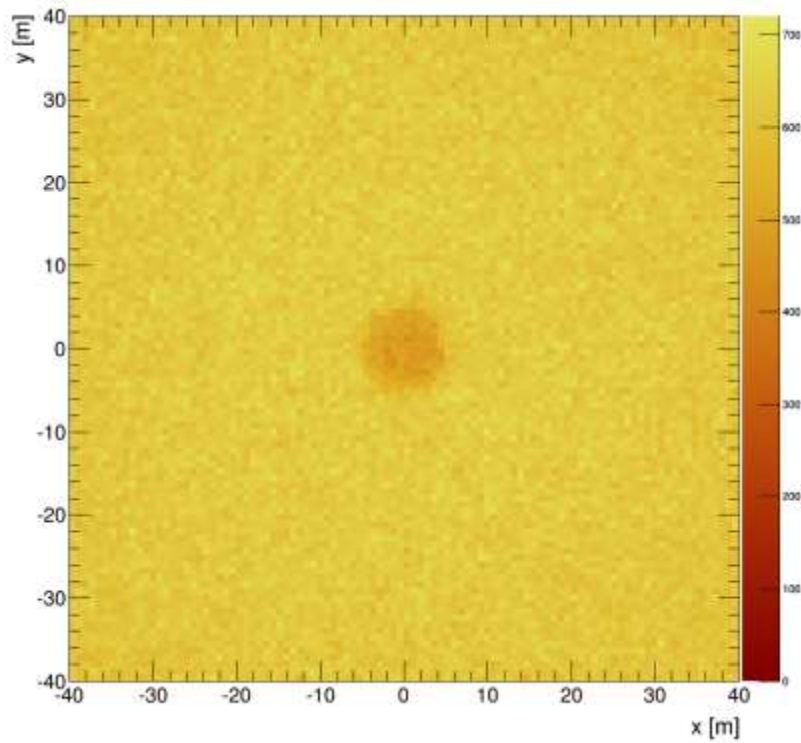


Island Transect



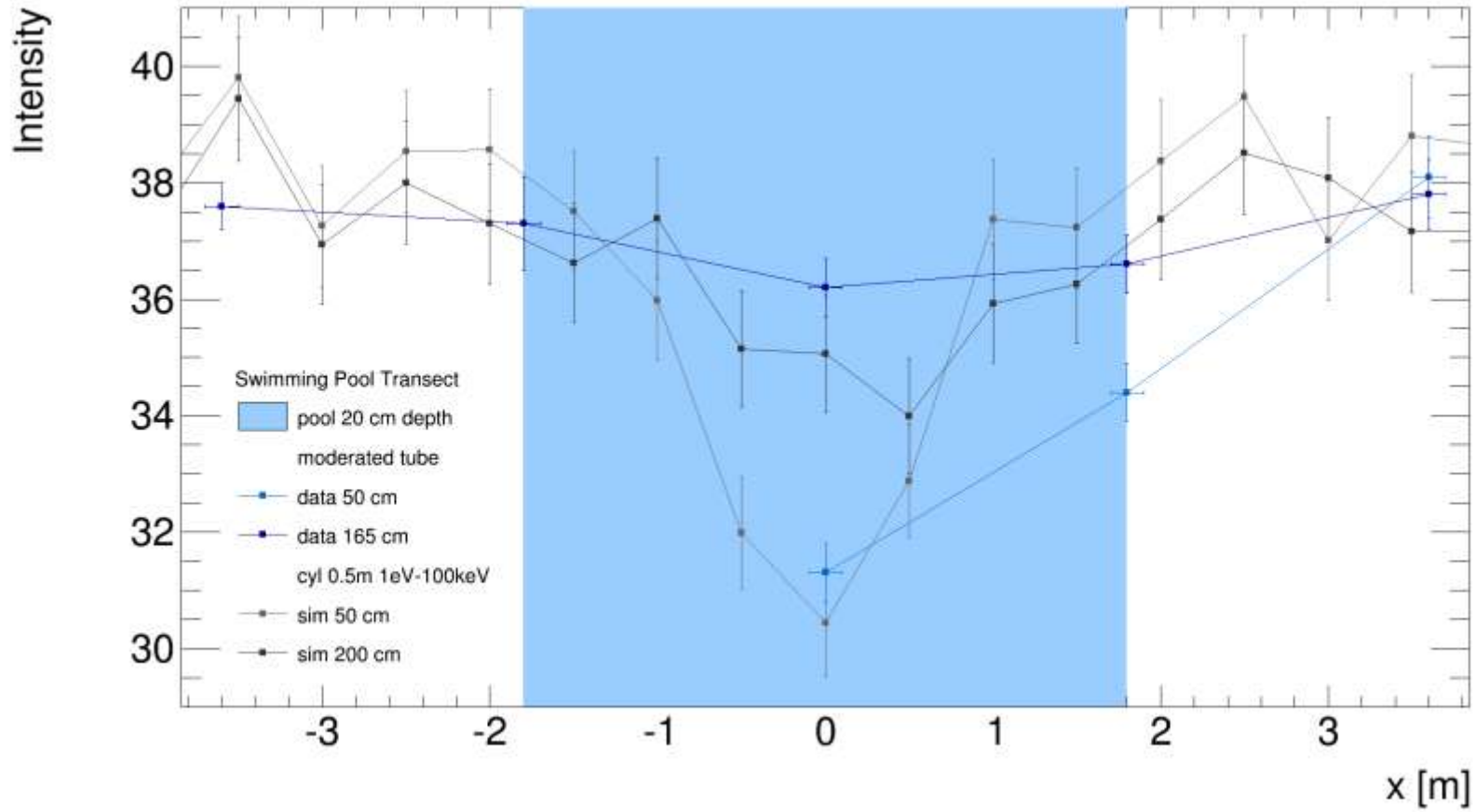


Lake Transect



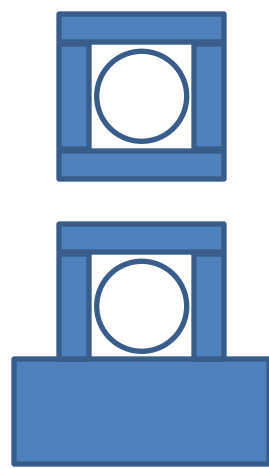
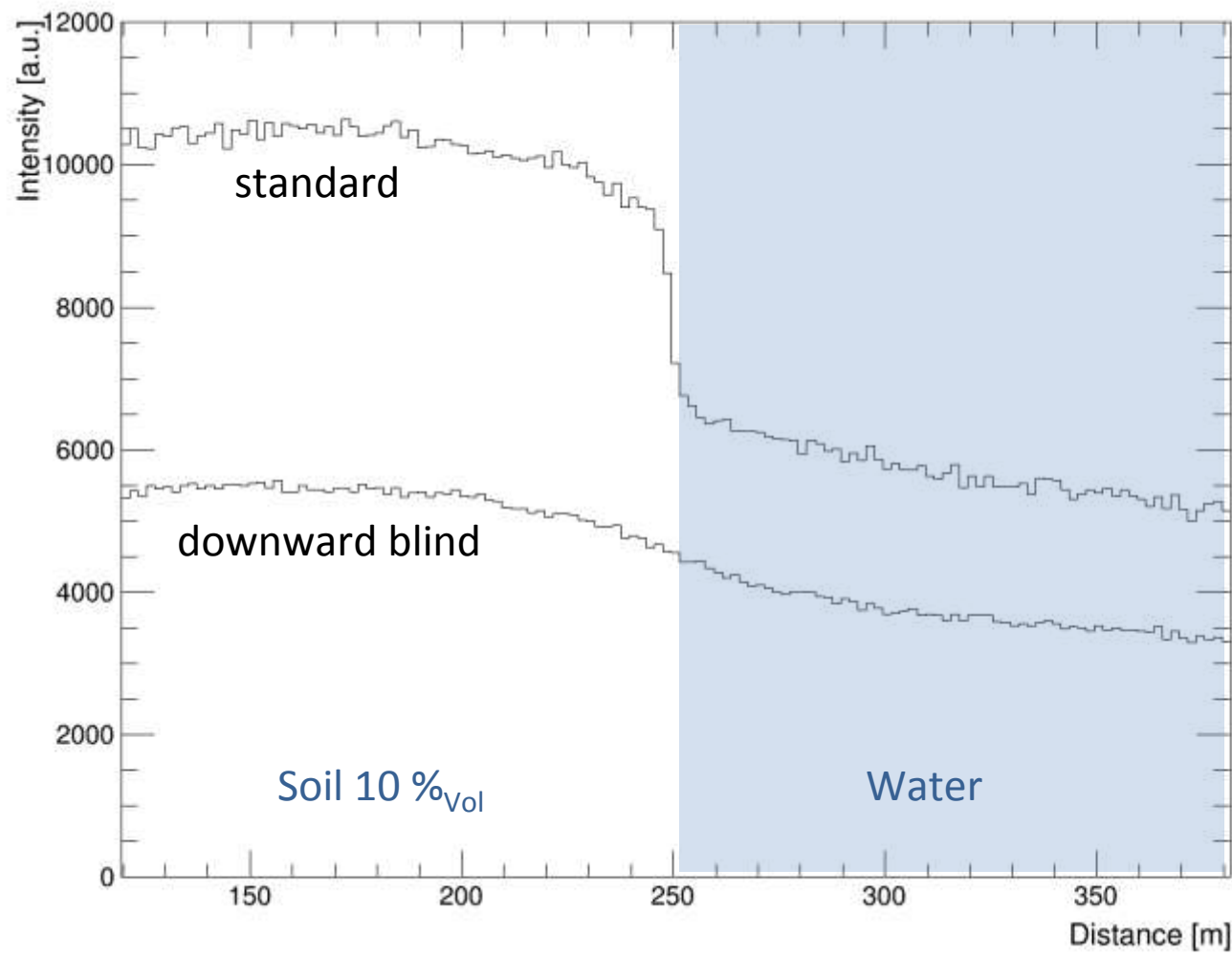


Local Swimming Pool Effects





Transect with Shielding



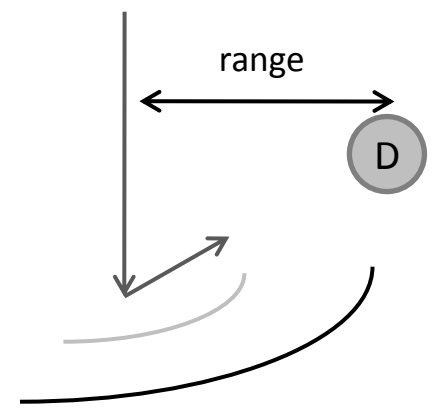
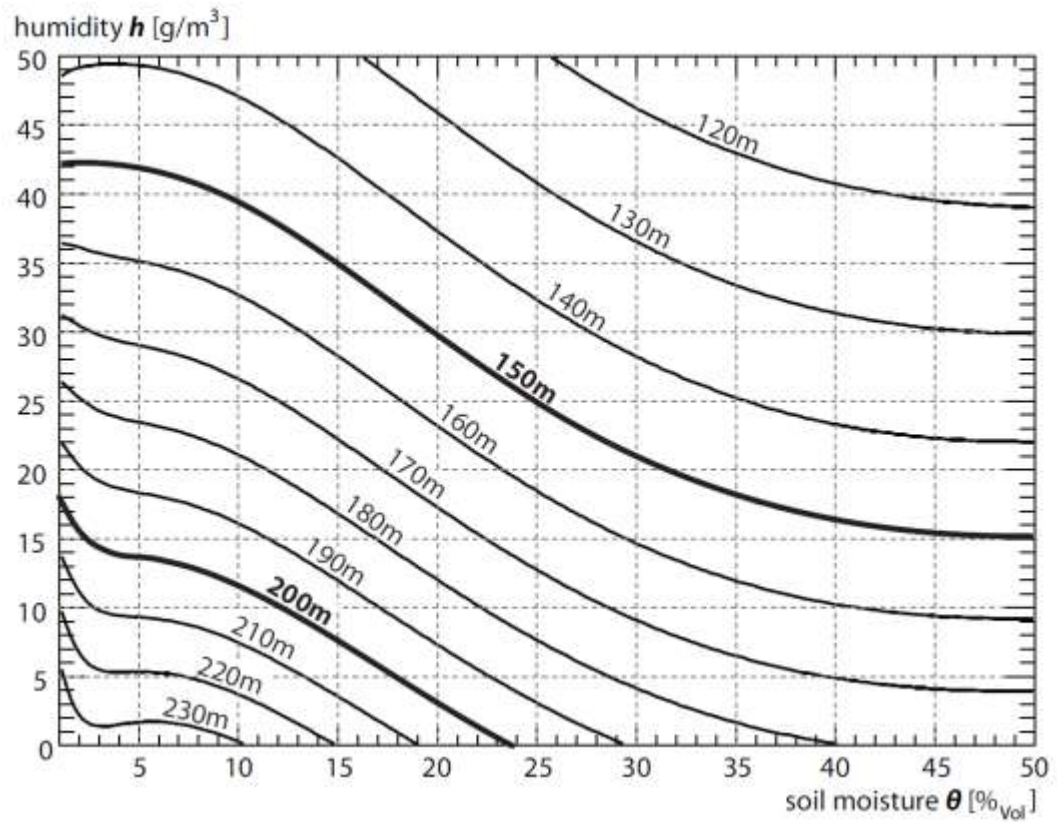


The Footprint



The Footprint in 2015

How far do reflected neutrons travel?



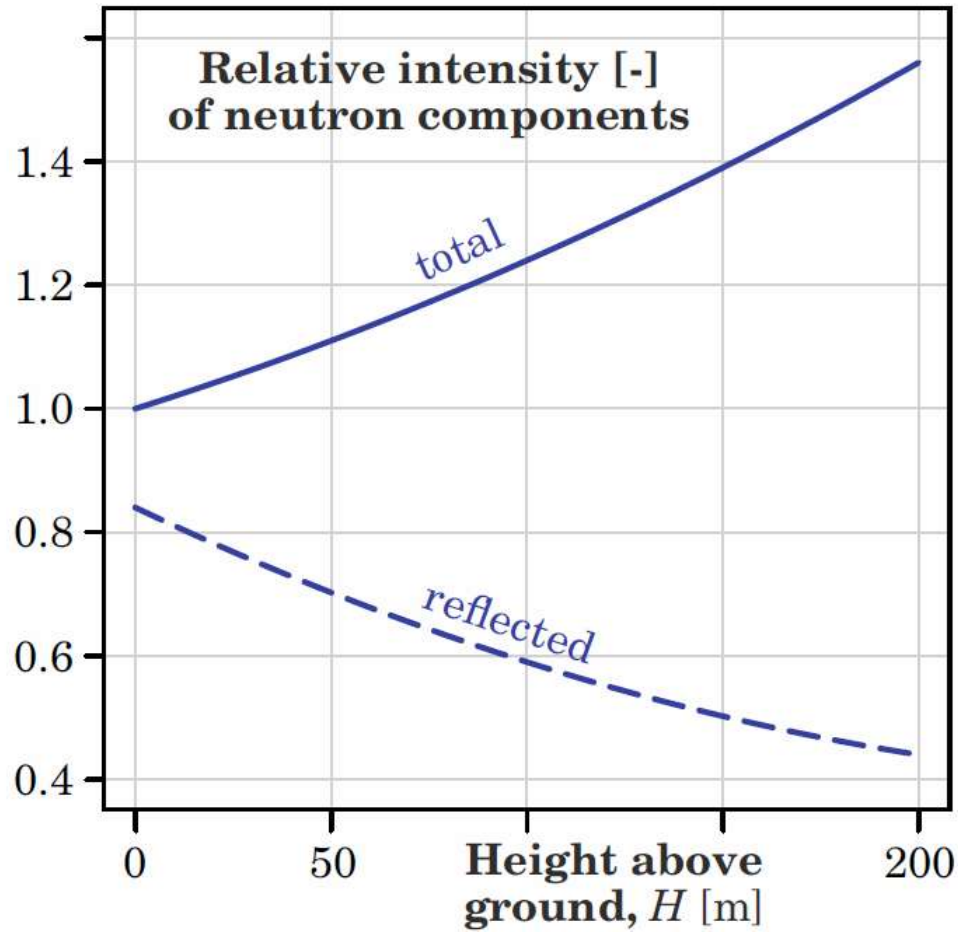
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Footprint characteristics revised for field-scale soil moisture monitoring with cosmic-ray neutrons

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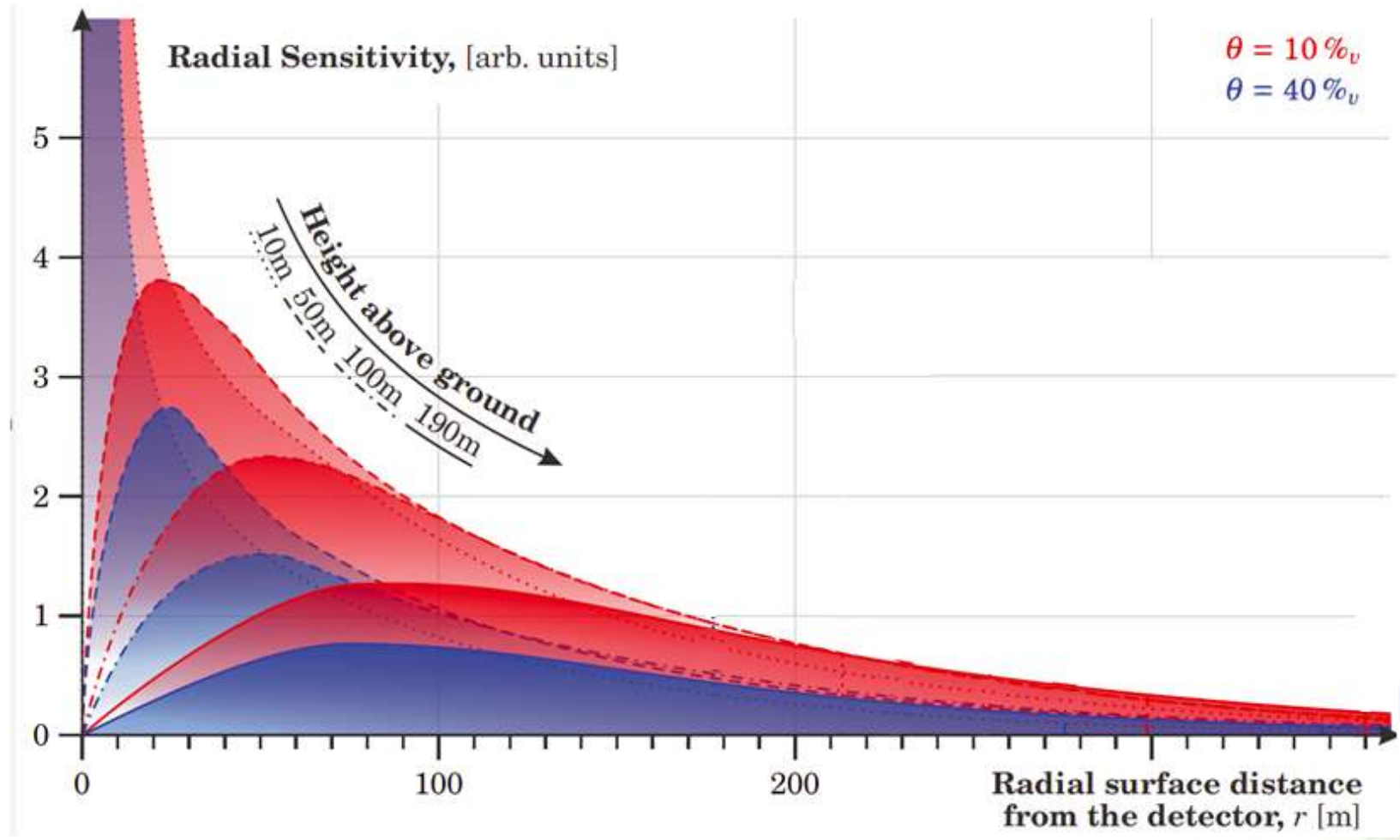


The Elevated Footprint



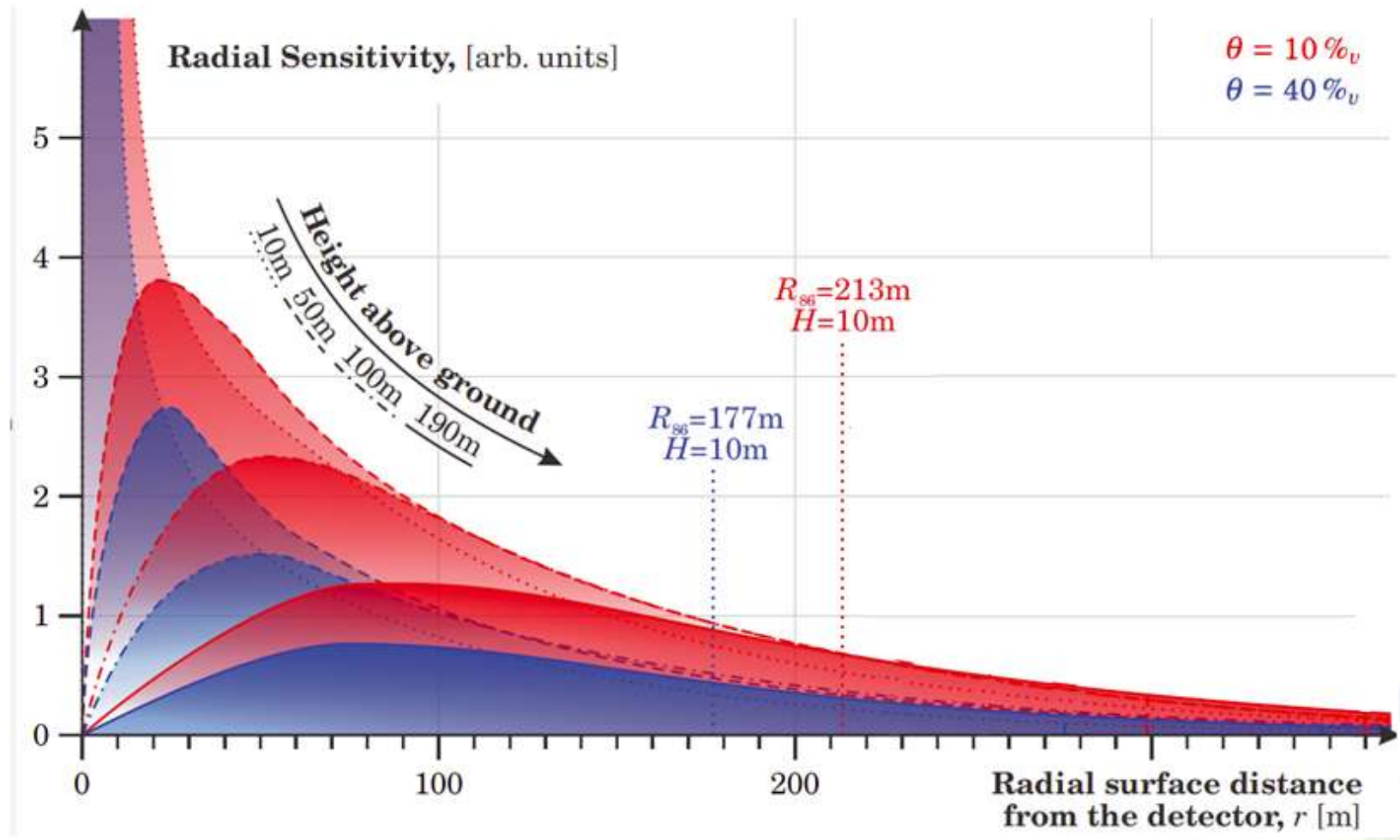


The Elevated Footprint



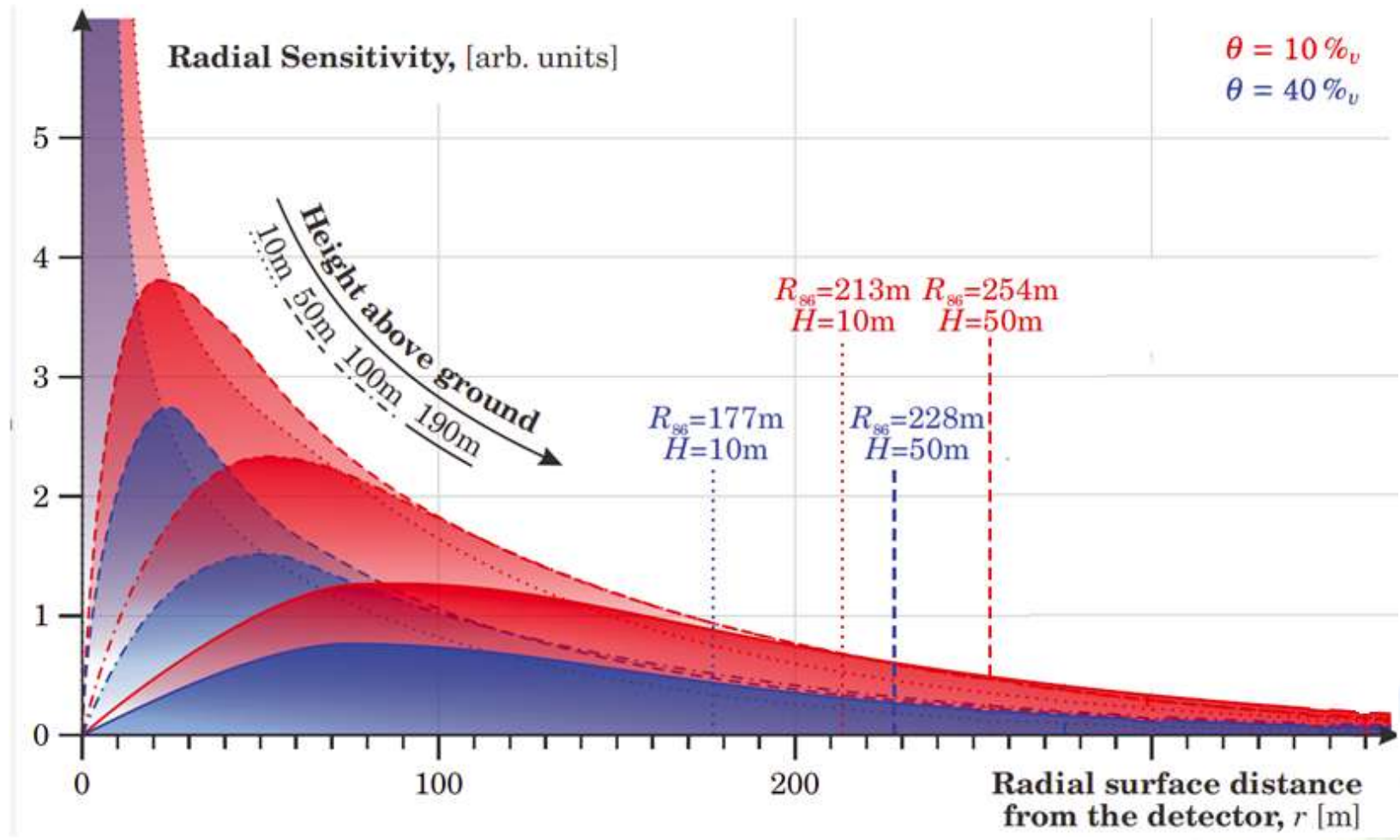


The Elevated Footprint



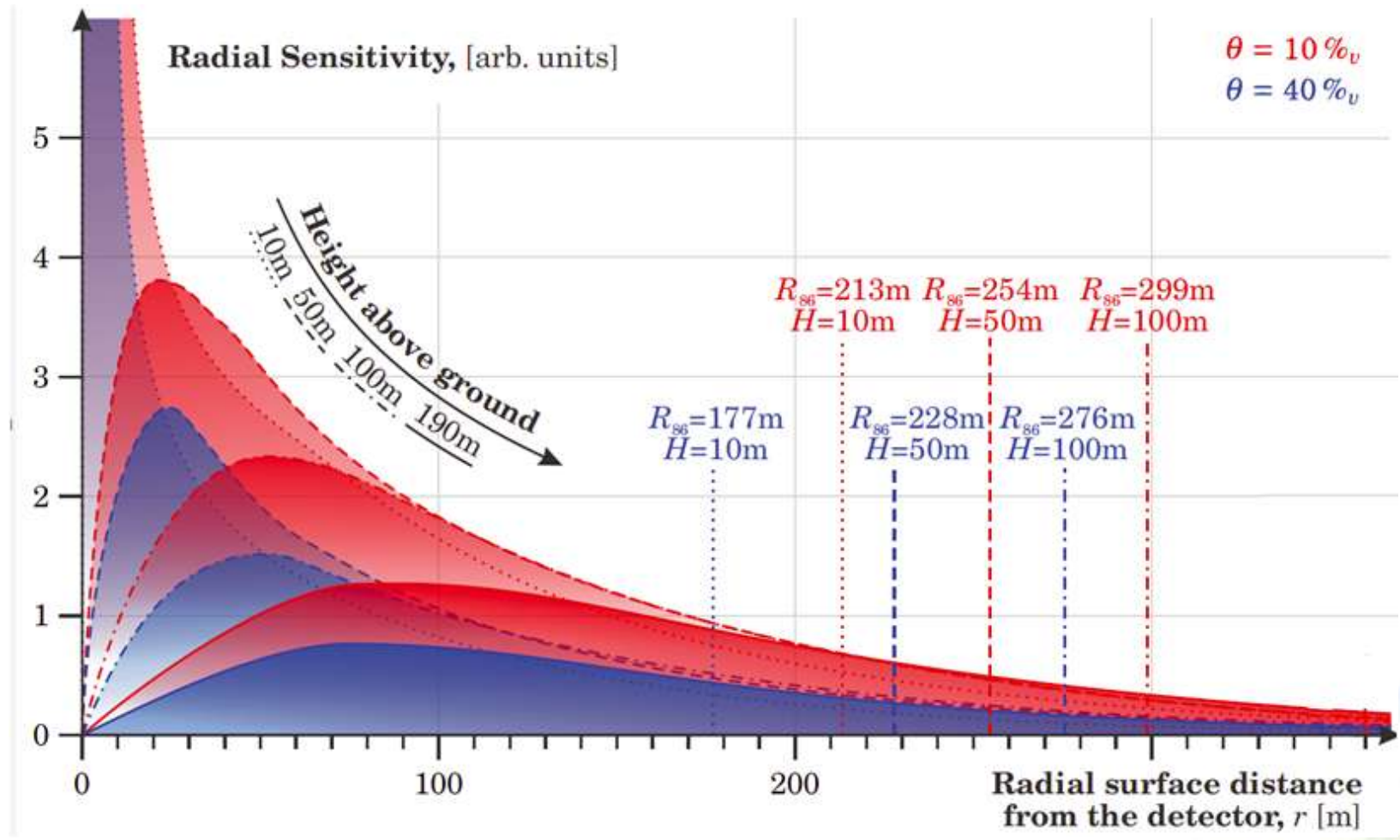


The Elevated Footprint



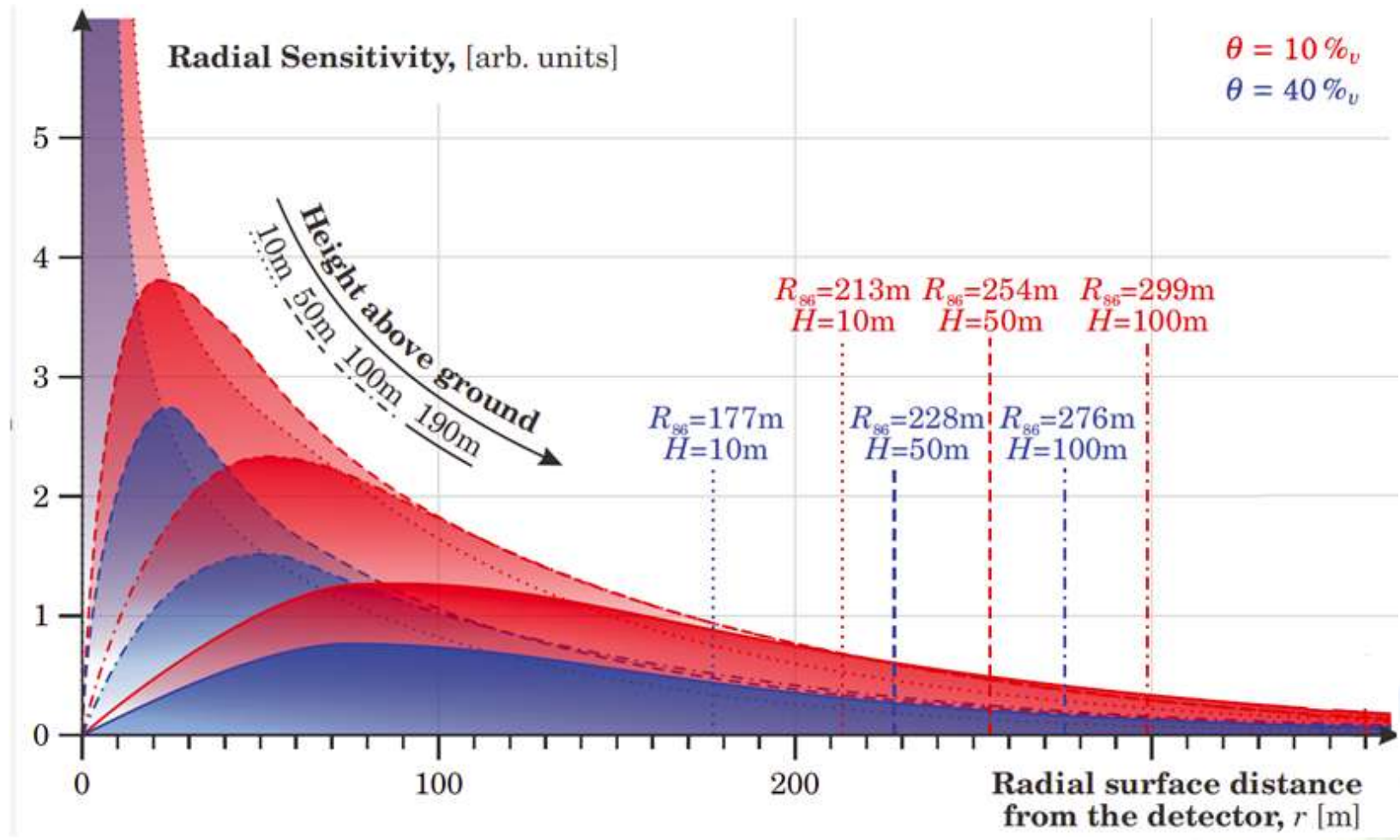


The Elevated Footprint





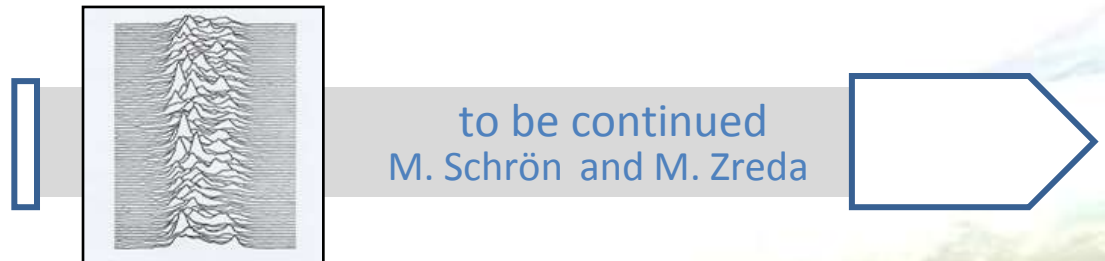
The Elevated Footprint





■ Cosmic-Ray Neutron Detection

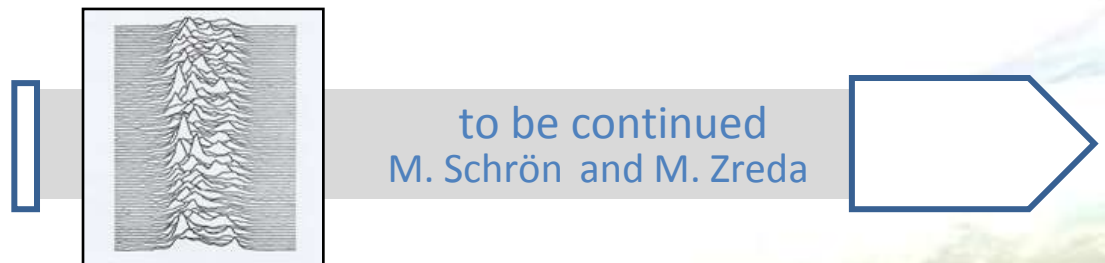
- can be understood by Monte-Carlo transport modelling





■ Cosmic-Ray Neutron Detection

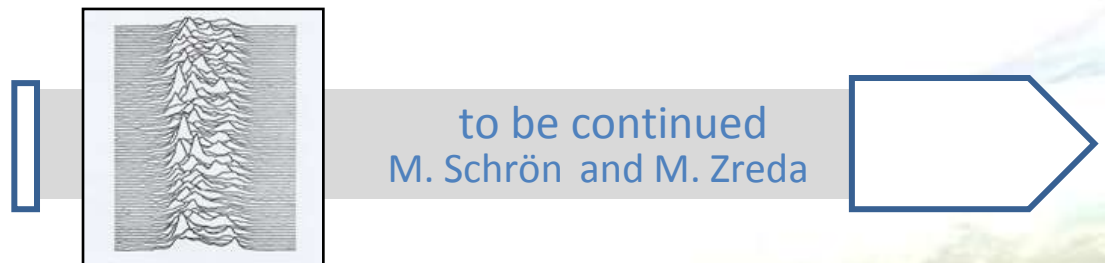
- can be understood by Monte-Carlo transport modelling
- road effect, small scale variations, inhomogeneous soil moisture patterns can be explained





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■ URANOS Community Version: **Now available!**
(and in development)

