Markus Köhli Martin Schrön Steffen Zacharias Ulrich Schmidt

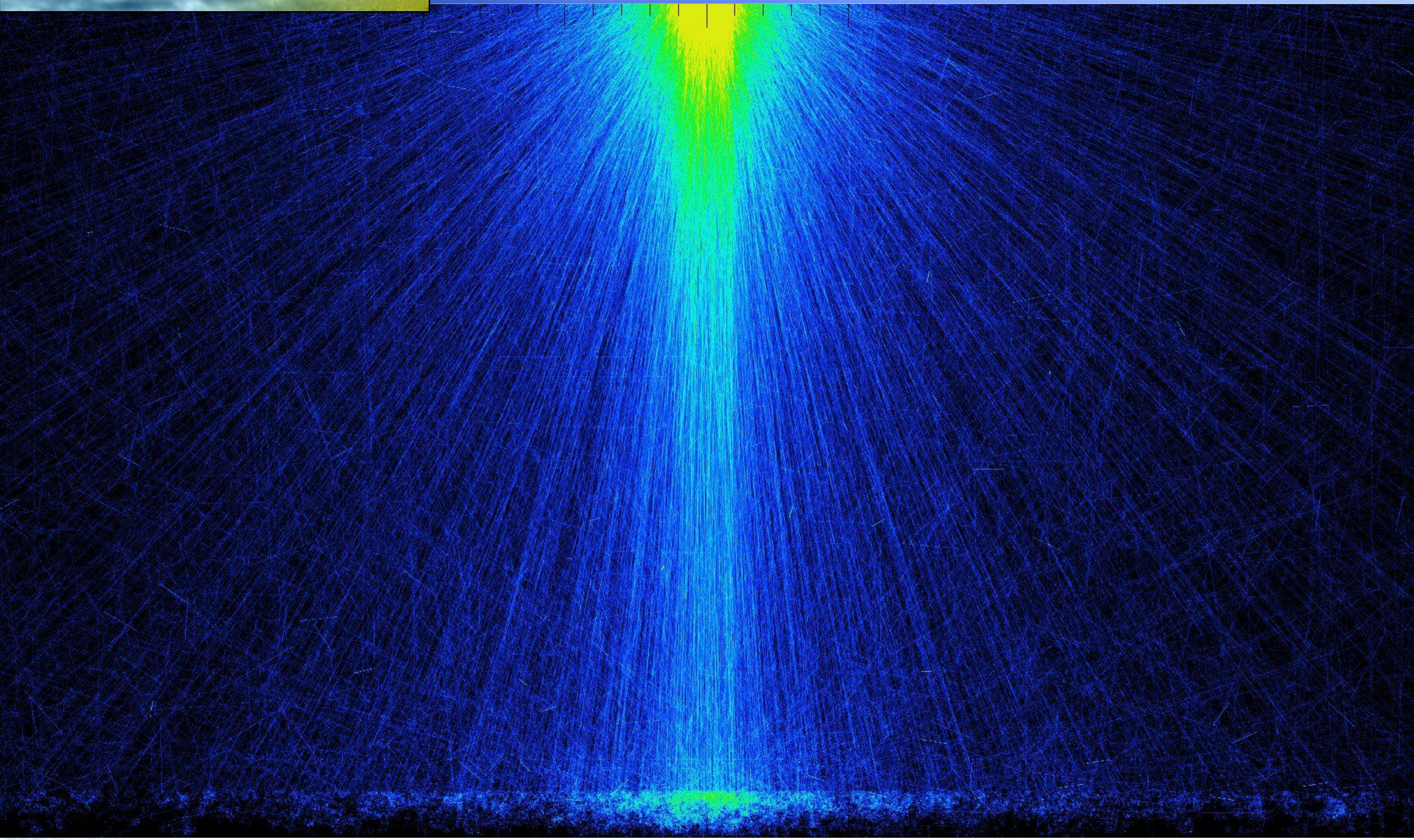
27.01.2021

URANOS
-
a novel
voxel engine Monte Carlo tool
for neutron transport studies

EURADOS Meeting

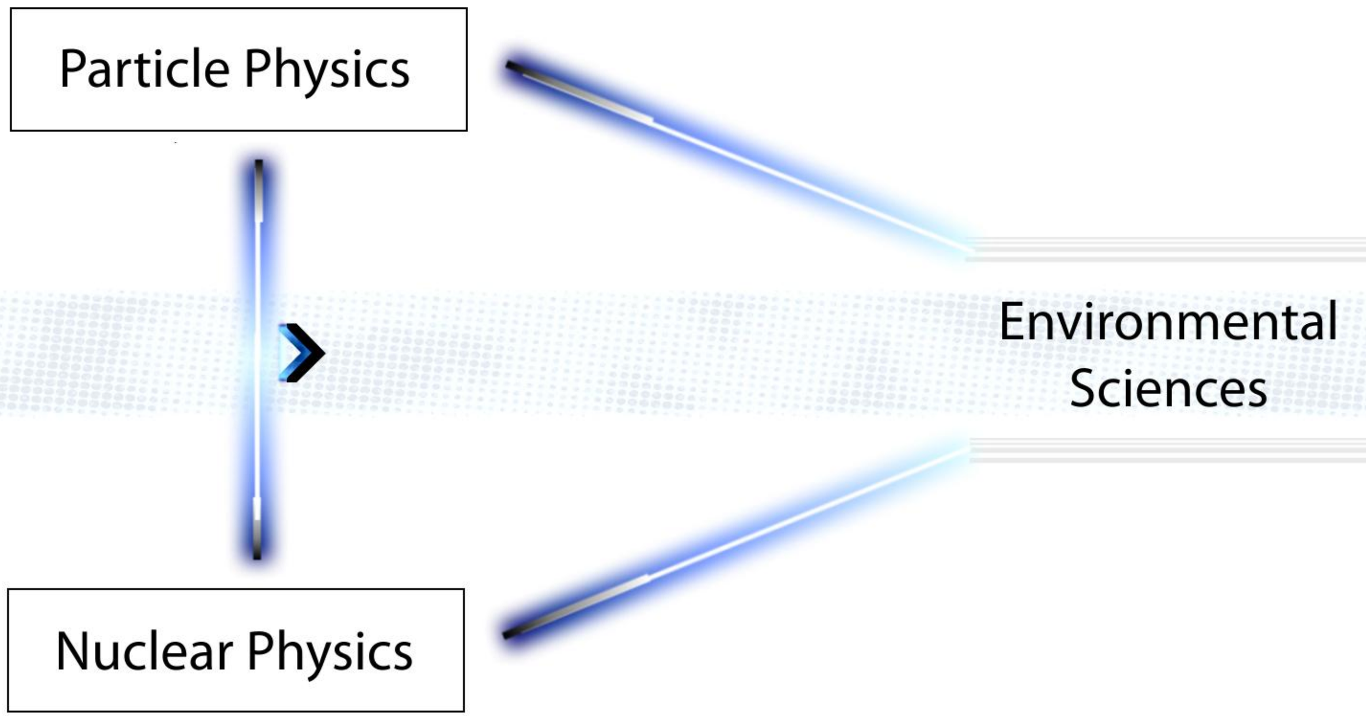
UNIVERSITÄT
HEIDELBERG
ZUKUNFT
SEIT 1386

HELMHOLTZ
CENTRE FOR
ENVIRONMENTAL
RESEARCH – UFZ



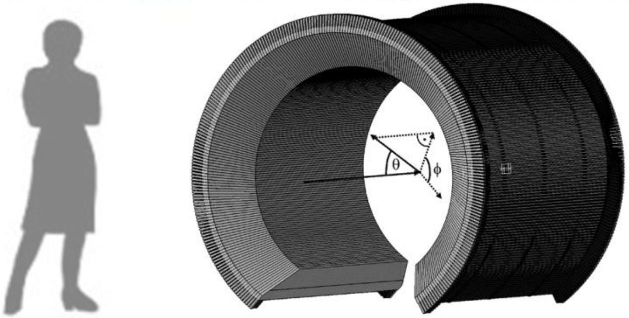
URANOS - origins

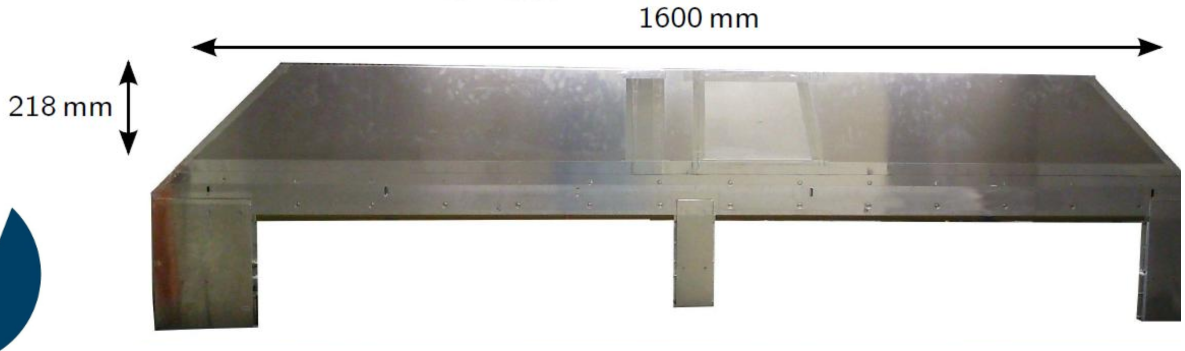
- an interdisciplinary spin-off

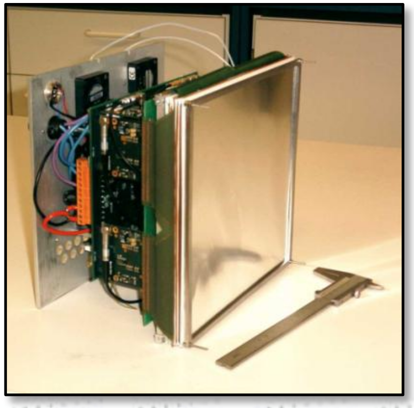


Heidelberg Neutron Detectors

The JALOUSIE system



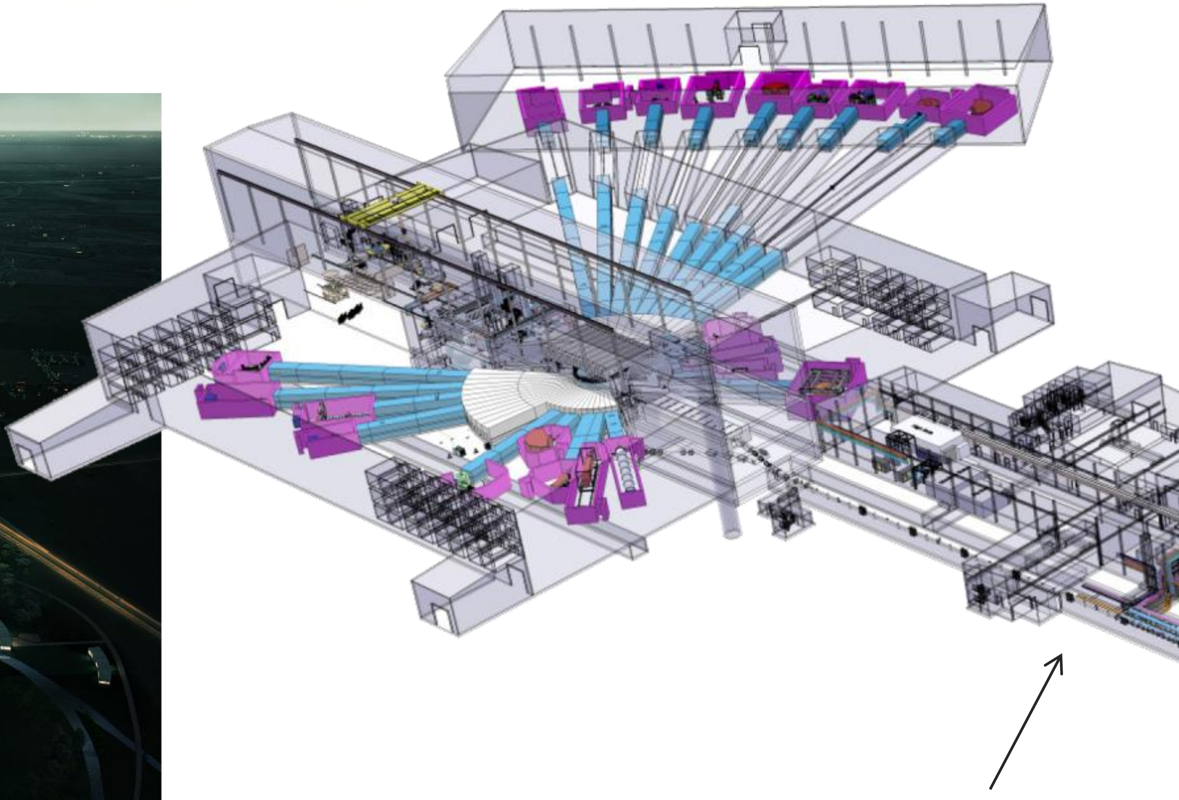




The CASCADE detector

ESS Detectors

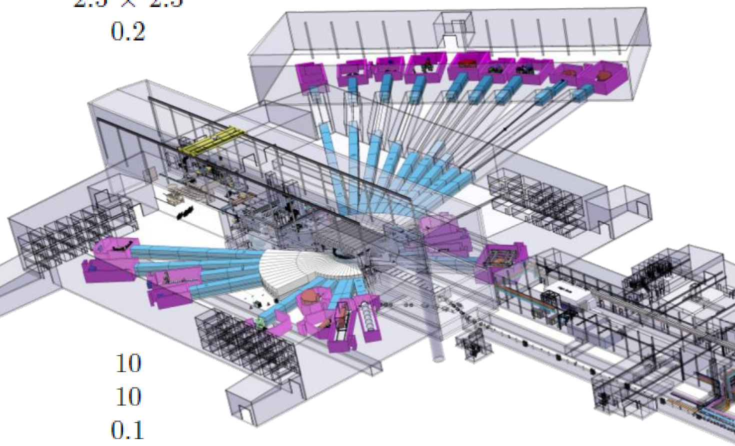
ESS TDR 2013
Lund, Sweden



Linear Accelerator
2 GeV
3 ms Pulse
62.5 mA

ESS Instrumentation

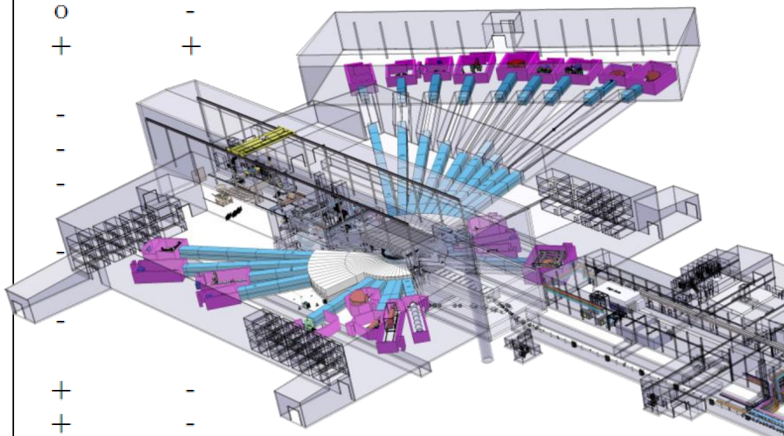
Instrument	Detector area [m²]	Wavelength range [Å]	Time resolution [μs]	Spatial resolution [mm]
Multi-purpose imaging	0.5	1 - 20	1	0.001 - 0.5
General purpose polarised SANS	5	4 - 20	100	10
Broad-band small sample SANS	14	2 - 20	100	1
Surface scattering	5	4 - 20	100	10
Horizontal reflectometer	0.5	5 - 30	100	1
Vertical reflectometer	0.5	5 - 30	100	1
Thermal powder diffractometer	20	0.6 - 6	< 10	2×2
Bi-spectral powder diffractometer	20	0.8 - 10	< 10	2.5×2.5
Pulsed monochromatic powder diffractom.	4	0.6 - 5	< 100	2×5
Material science & engineering diffractom.	10	0.5 - 5	10	2
Extreme conditions instrument	10	1 - 10	< 10	3×5
Single crystal magnetism diffractometer	6	0.8 - 10	100	2.5×2.5
Macromolecular diffractometer	1	1.5 - 3.3	1000	0.2
Cold chopper spectrometer	80	1 - 20	10	
Bi-spectral chopper spectrometer	50	0.8 - 20	10	
Thermal chopper spectrometer	50	0.6 - 4	10	
Cold crystal-analyser spectrometer	1	2 - 8	< 10	
Vibrational spectroscopy	1	0.4 - 5	< 10	
Backscattering spectrometer	0.3	2 - 8	$<$	
High-resolution spin echo	0.3	4 - 25	100	10
Wide-angle spin echo	3	2 - 15	100	10
Fundamental & particle physics	0.5	5 - 30	1	0.1
Total	**282.6**			



ESS TDR 2013

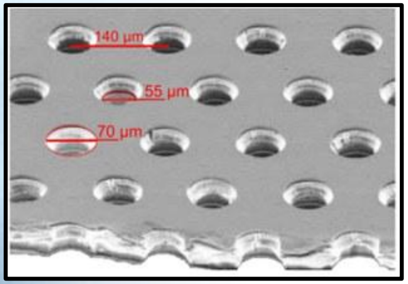
ESS Instrumentation

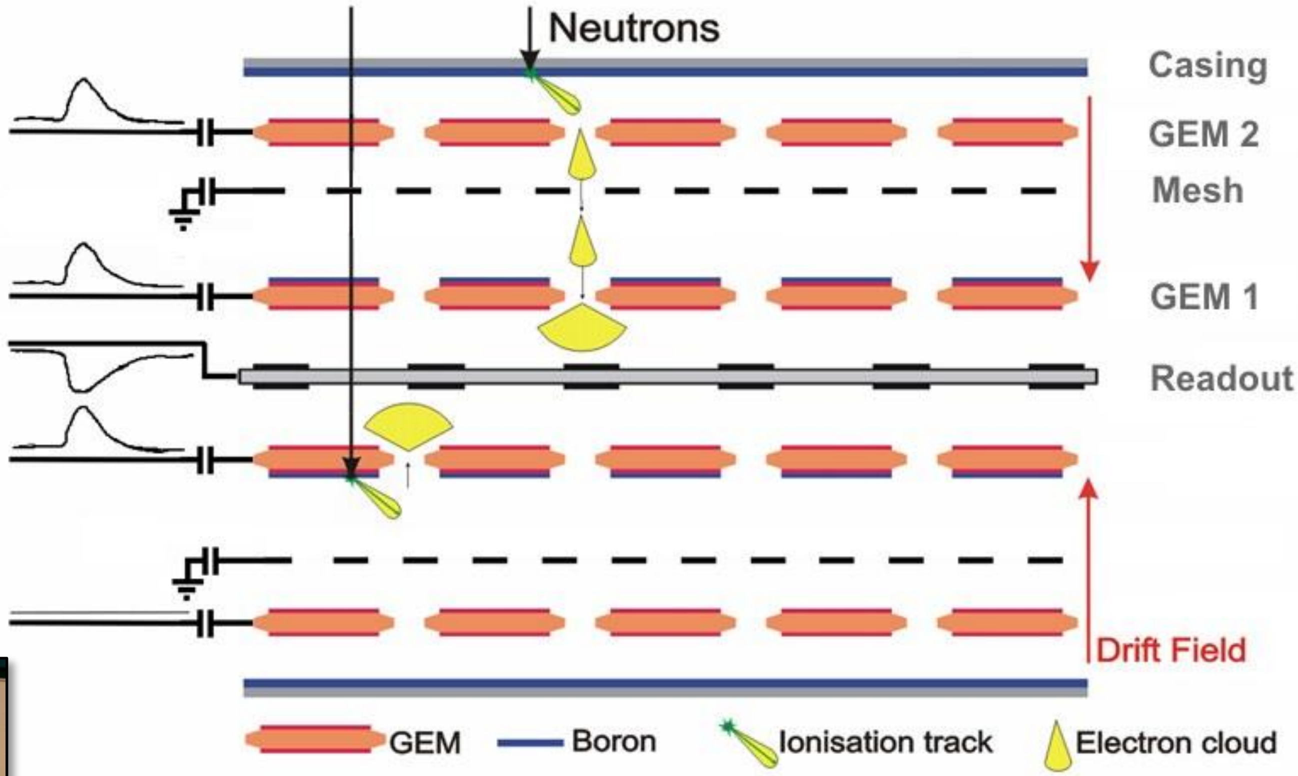
Instrument	Detector technology						
	^{10}B thin films		Scintillators		^{3}He	Micropattern	
	⊥	∥	WSF	Anger		Rate	Resolution
Multi-purpose imaging	-	-	-	-	-	o	+
General purpose polarised SANS	o	+	-	+	o	+	-
Broad-band small-sample SANS	o	+	-	+	-	+	-
Surface scattering	o	+	-	+	o	+	-
Horizontal reflectometer	-	o	-	+	+	o	-
Vertical reflectometer	-	o	-	+	+	o	-
Thermal powder diffractometer	o	+	+	-	-	o	-
Bi-spectral powder diffractometer	o	+	+	-	-	o	-
P-M powder diffractometer	o	+	+	-	-	o	-
MS engineering diffractometer	o	+	+	-	-	o	-
Extreme conditions diffractometer	o	+	+	-	-	o	-
Single crystal diffractometer	o	+	+	-	-	o	-
Macromolecular diffractometer	-	o	o	o	-	+	+
Cold chopper spectrometer	+	o	o	-	-	-	[illegible]
Bi-spectral chopper spectrometer	+	+	o	-	-	-	[illegible]
Thermal chopper spectrometer	+	+	+	-	-	-	[illegible]
Cold crystal analyser spectrometer	-	o	-	+	+	-	[illegible]
Vibrational spectrometer	-	o	-	o	+	[illegible]	[illegible]
Backscattering spectrometer	-	o	-	+	+	-	[illegible]
High-resolution spin echo	-	o	-	o	+	+	-
Wide-angle spin echo	-	o	-	o	+	+	-
Fundamental & particle physics	-	-	-	-	+	+	+

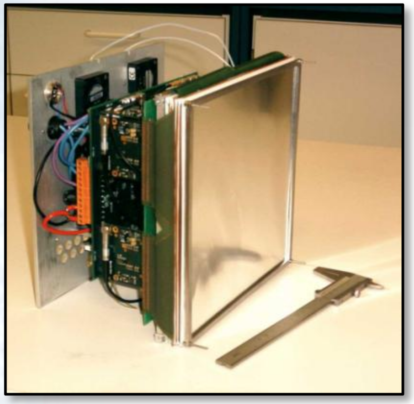


ESS TDR 2013

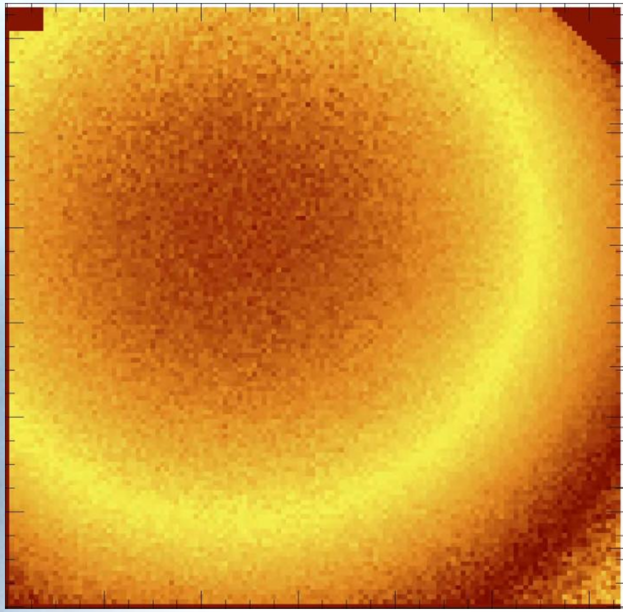
Heidelberg Neutron Detectors

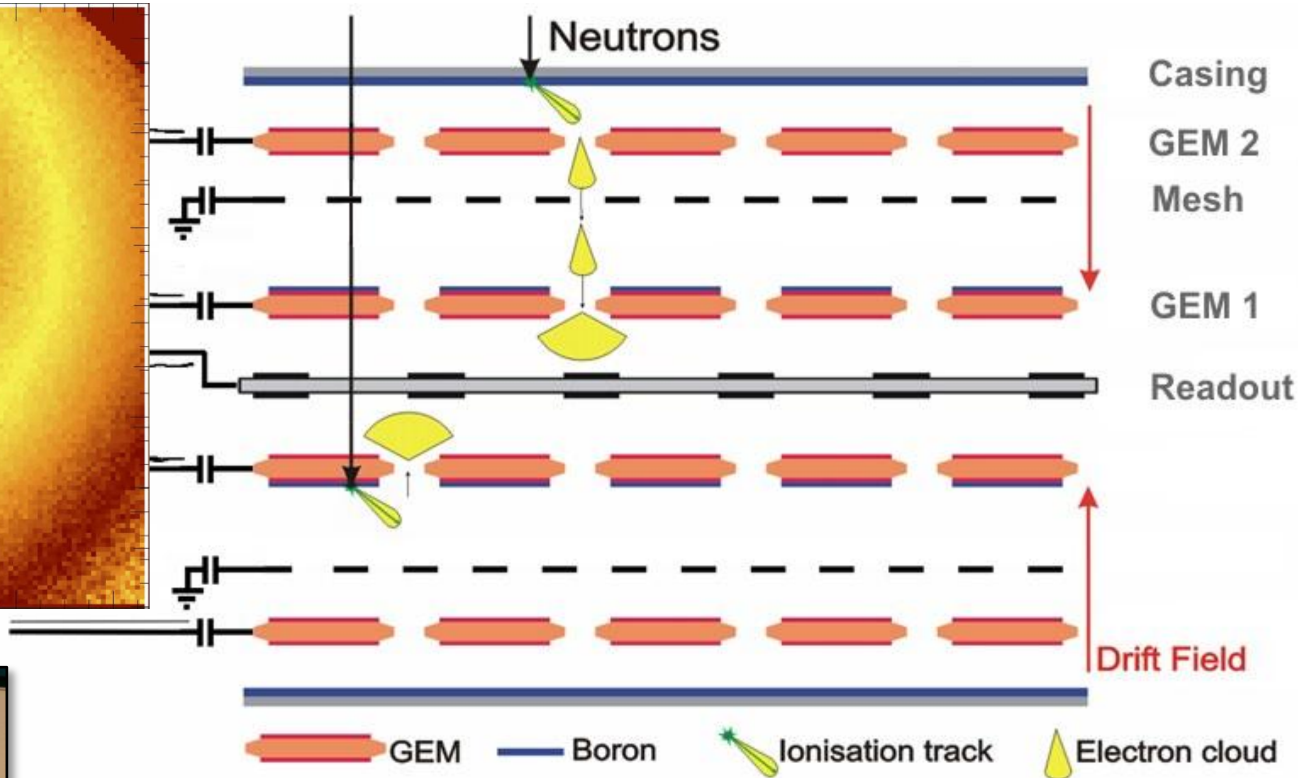






Heidelberg Neutron Detectors





URANOS concepts

- written in C++

```
if (detectorEnergyModel2->Eval(TMath::Log10(energy)) > r.Rndm() )
{
    detectorRealisticallyHitted = true; layerRealisticallyHitted = true;
}
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URANOS concepts

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if (detectorEnergyModel2->Eval(TMath::Log10(energy)) > r.Rndm() )
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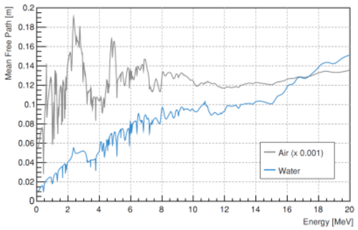
- written in C++

- linked against ENDF data bases



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if (detectorEnergyModel2->Eval(TMath::Log10(energy)) > r.Rndm() )
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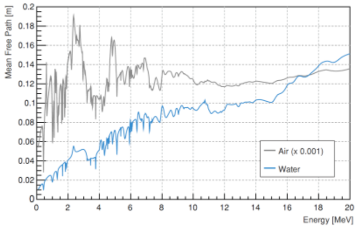
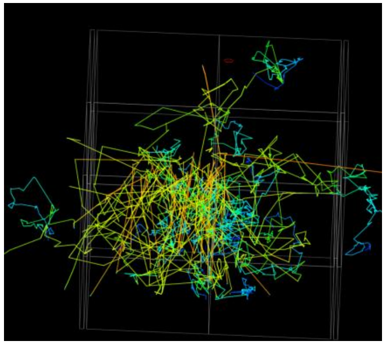


- Ray-Casting



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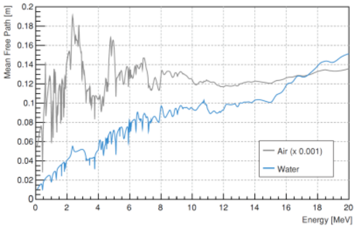

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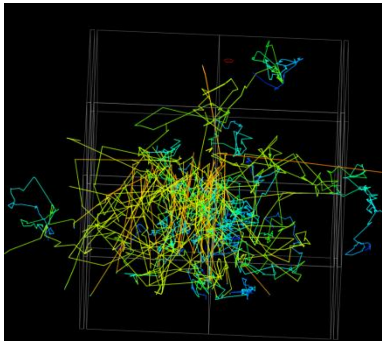
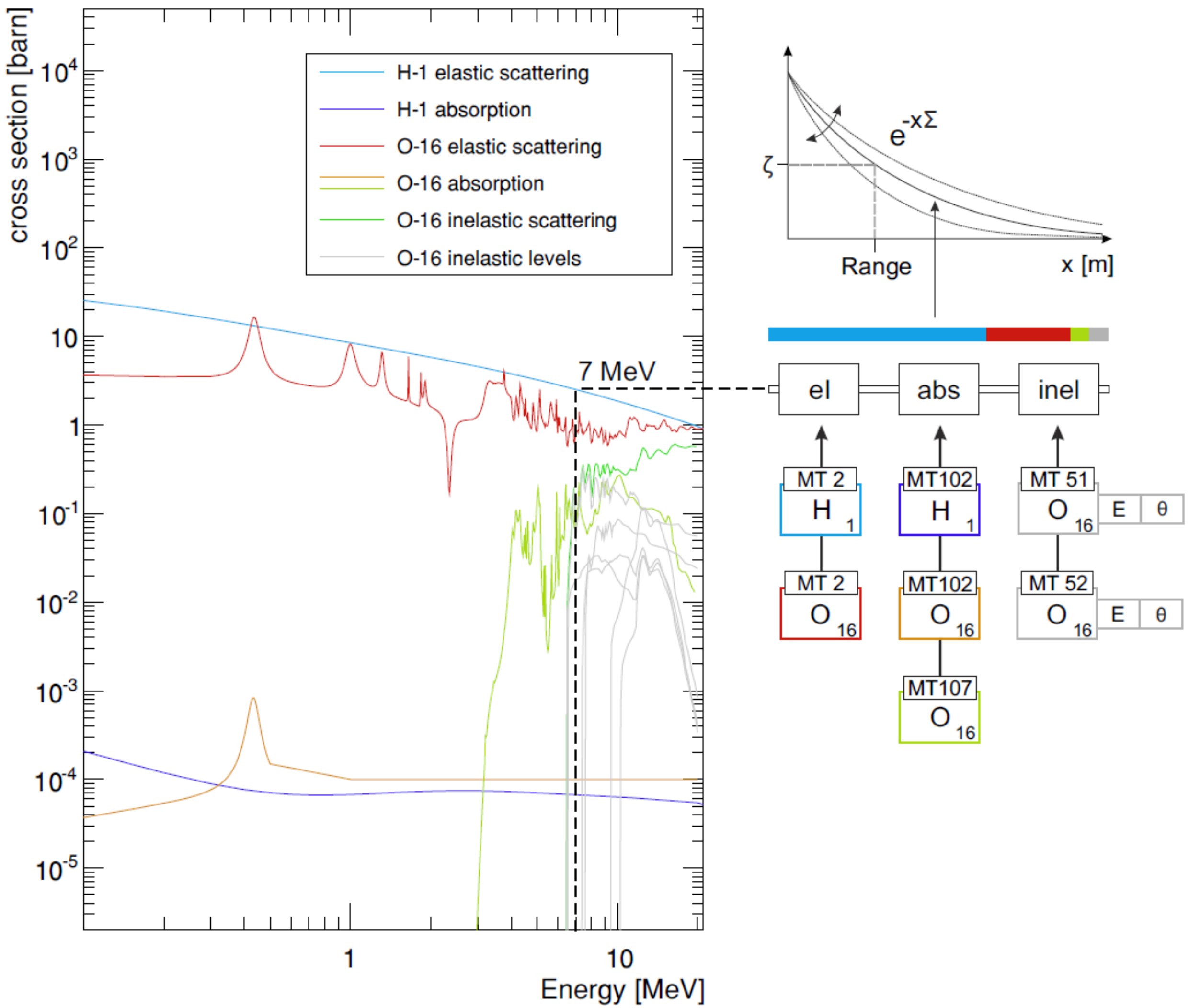


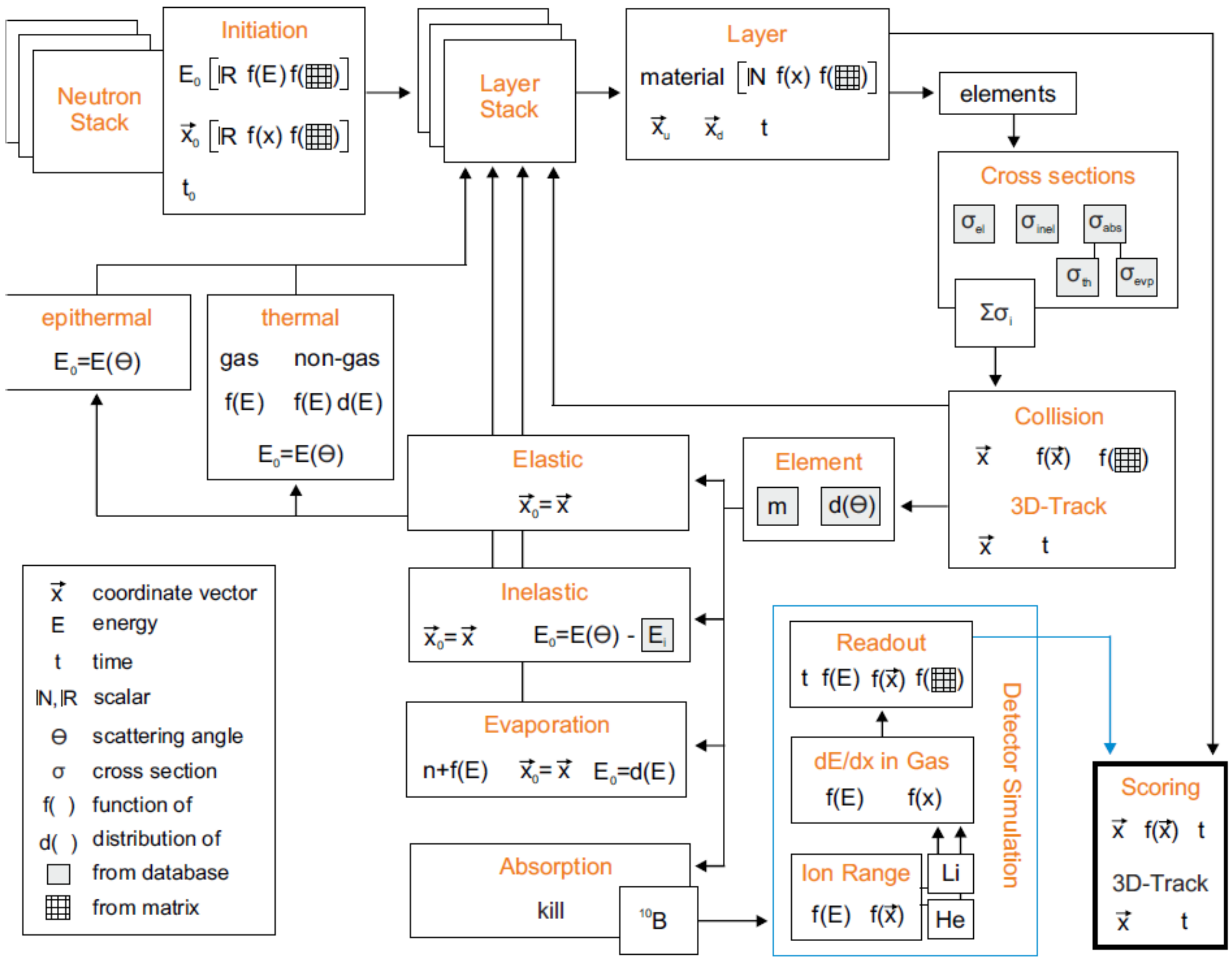
- Voxel Engine

Markus Köhli
Physikalisches Institut Heidelberg University
UFZ Leipzig
Physikalisches Institut University of Bonn

URANOS Buildup



URANOS Buildup



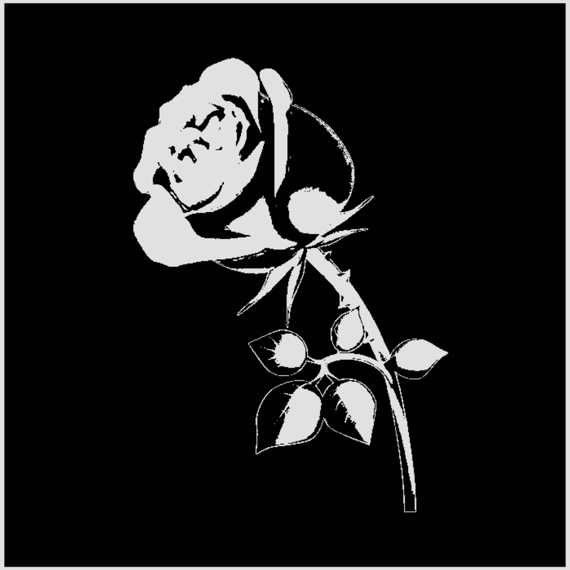
MCNP input file

```
File  Edit  Options  Buffers  Tools  Help

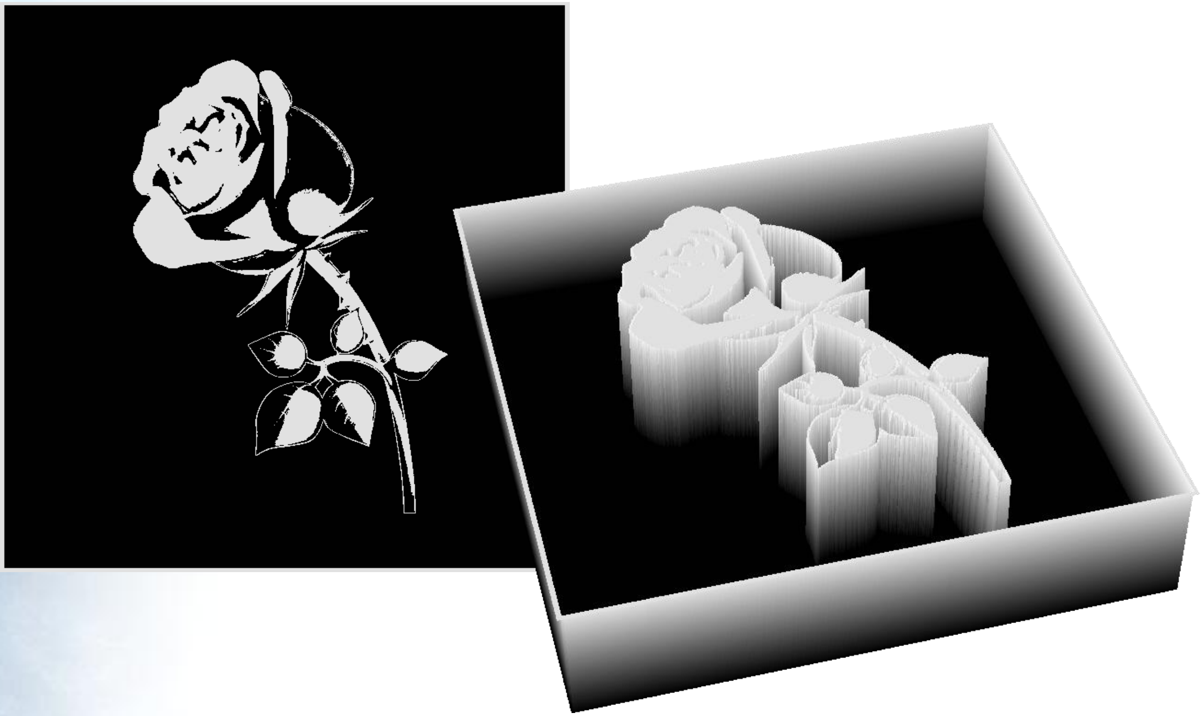
-*-mcnpgen-*- Pd-103 photon source,H2O phant filled w/cubes,1 cube has a sphere
c Cell Cards
1 1 -10. -1 2 -3              $ sr-90 source in silver foil
2 10 -2.7 -2 4 -3             $ Al filter
3 2 -8.02 -6 20 -5 (1:3:-4)   $ SS encapsulation
4 2 -8.02 -8 6 -7             $ SS rod
10 0 -20 21 -22 23 -24 25 fill=1       $ large water box
c 11 4 -1.0 -32 33 -34 35 -30 31 u=1 lat=1  $ water cubes
11 4 -1.0 -32 33 -34 35 -30 31 u=1 lat=1 fill=-1:1 -1:1 -1:1 &
        2 1 25r                             $ water cubes
12 3 -1.293e-3 -90 u=2                 $ air sphere inside cube
13 2 -8.02 90 u=2                     $ SS surrounding sphere inside cube
90 3 -1.293e-3 -100 -21                     $ air below box
91 3 -1.293e-3 -100 -20 21 (22:-23:24:-25)  $ air around box
92 3 -1.293e-3 -100 20 #1 #2 #3 #4          $ air outside src/rod
100 0 100                                     $ bounding region

c SURFACE CARDS
1 pz .03574                           $ source top plane
2 pz .03074                           $ source bottom plane
3 cz .475                             $ source outer radius
4 pz .00574                             $ Al filter bottom plane
5 cz .525                        $ SS encapsulation outer radius
6 pz 1.4                         $ SS encapsulation top plane
7 cz .2                                  $ rod outer radius
8 pz 2.4                                 $ rod top plane
20 pz 0.                         $ large box top plane
21 pz -1.2                       $ large box bottom plane
22 px .6                         $ large box xmax
23 px -.6                        $ large box xmin
24 py .6                         $ large box ymax
25 py -.6                        $ large box ymin
30 pz -.4                           $ cube top plane
31 pz -.8                           $ cube bottom plane
32 px .2                            $ cube xmax
33 px -.2                           $ cube xmin
--:--  sampl          (Mcnpgen)--L29--C0--Top------------------------------------
```

URANOS voxel engine

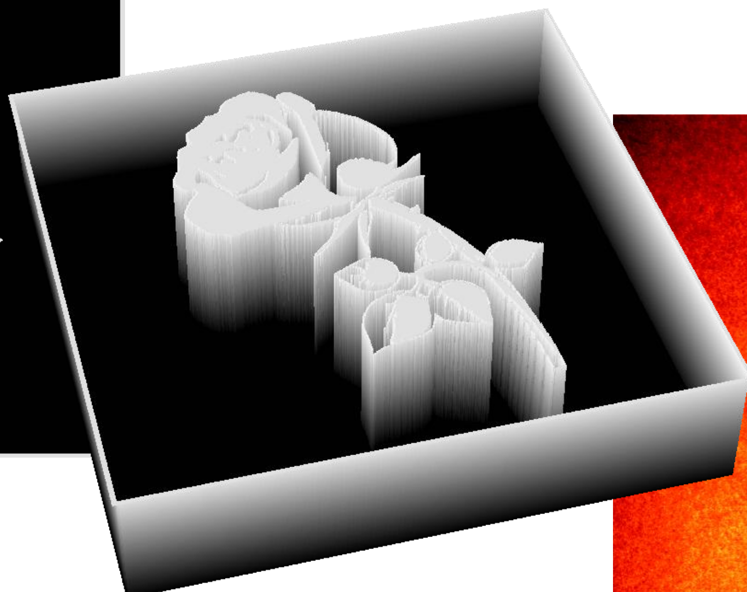


URANOS voxel engine



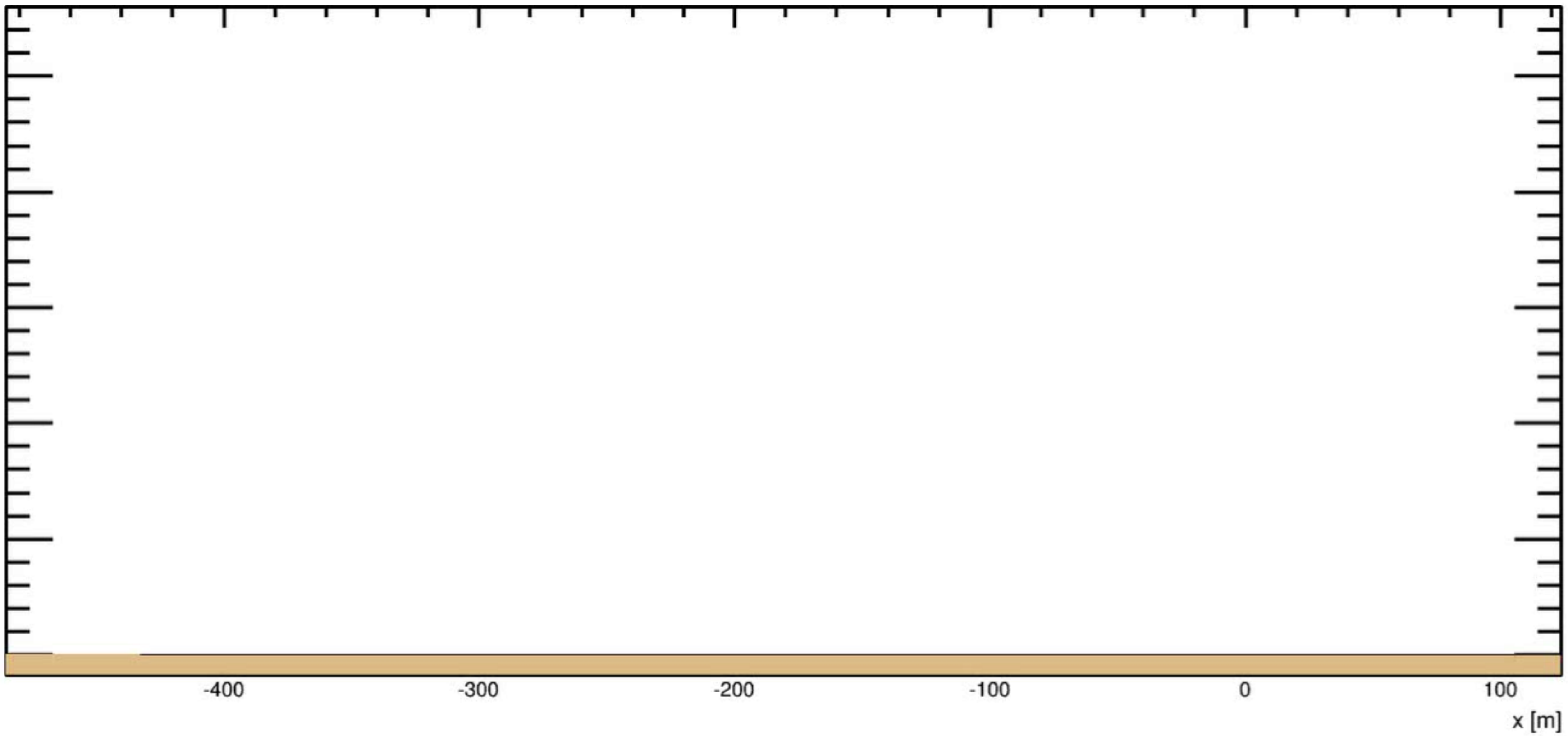
polyethylene rose in a box

URANOS voxel engine

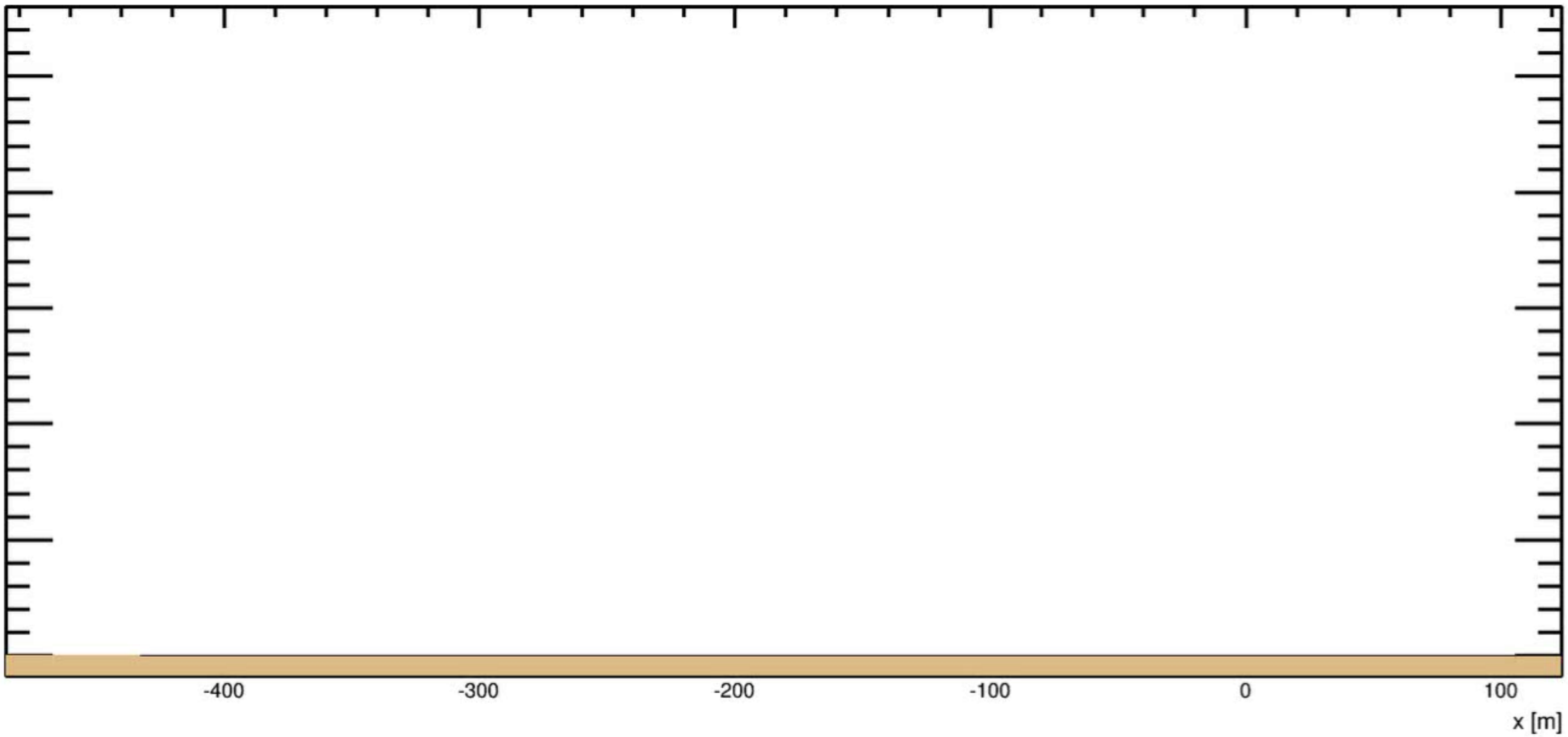


polyethylene rose in a box

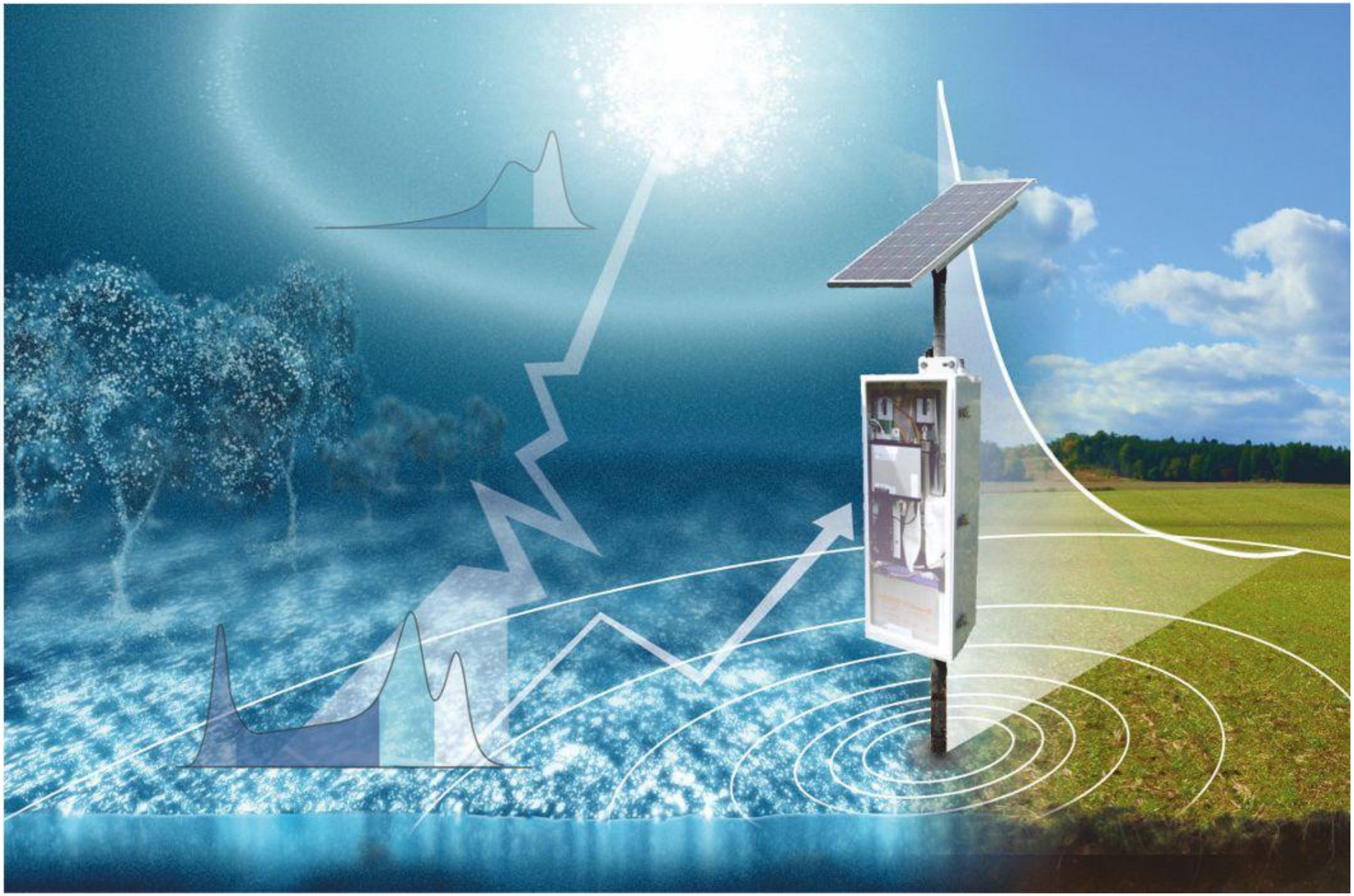
Neutron Animation (Evaporation)



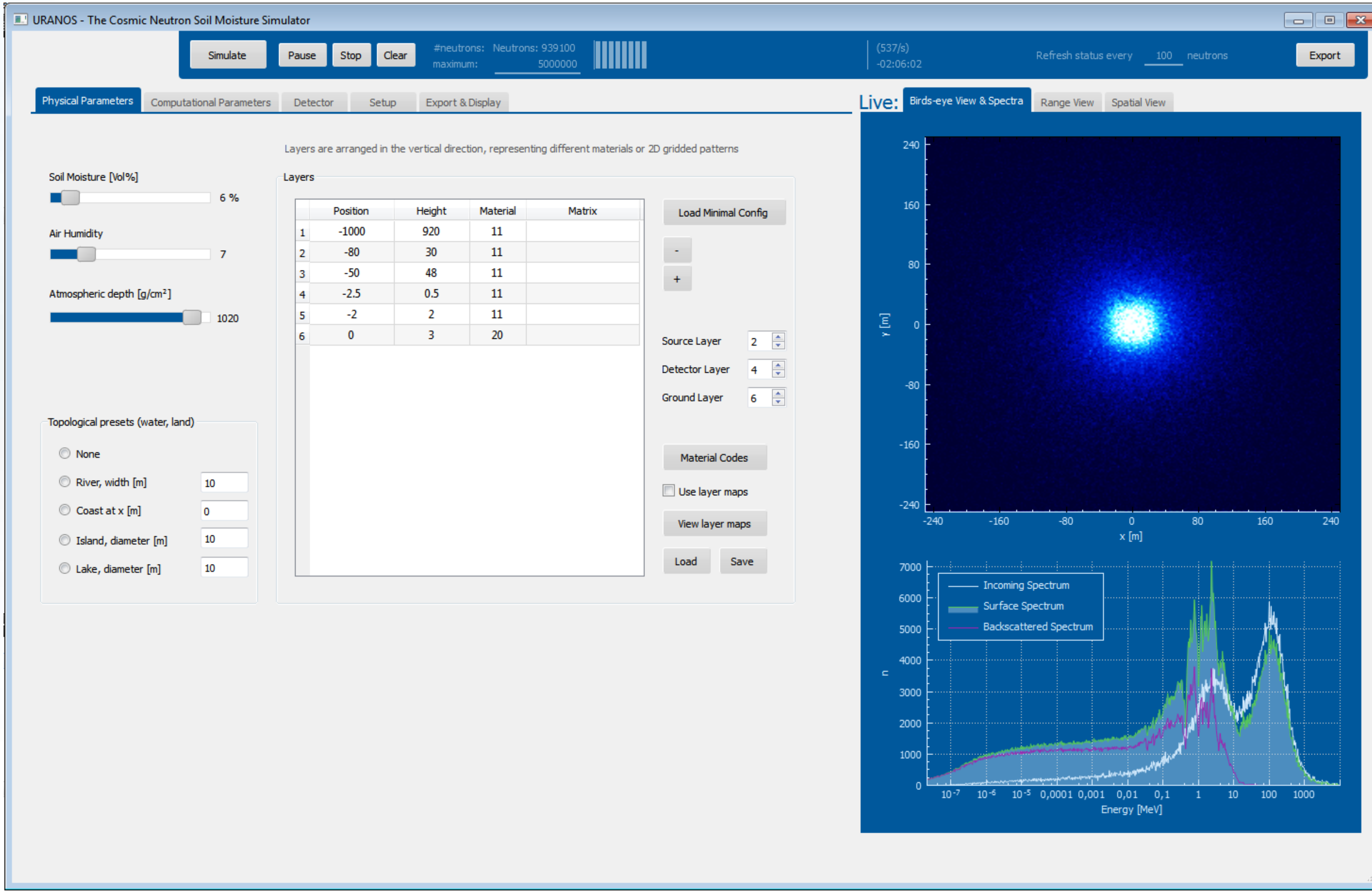
Neutron Animation (D-T)



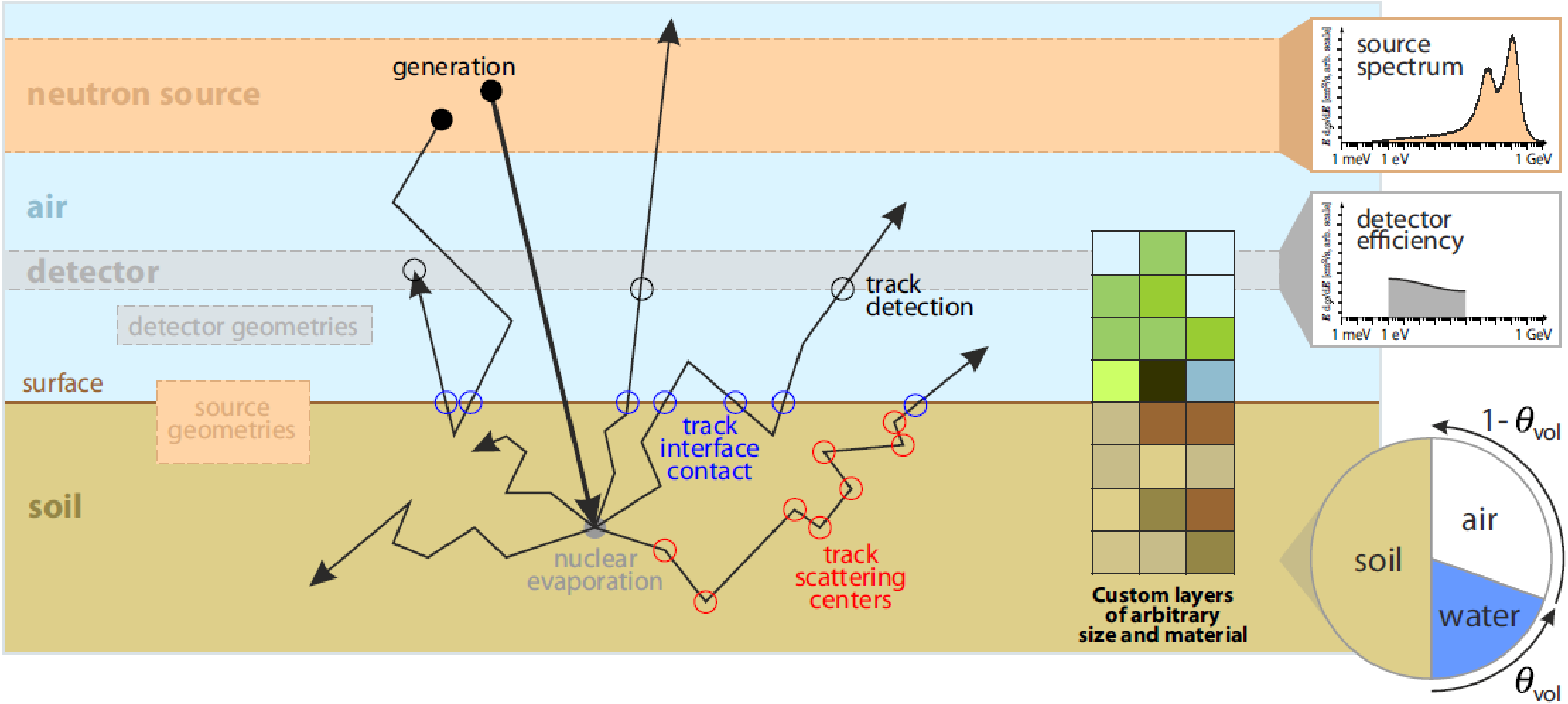
USER Interface



USER Interface

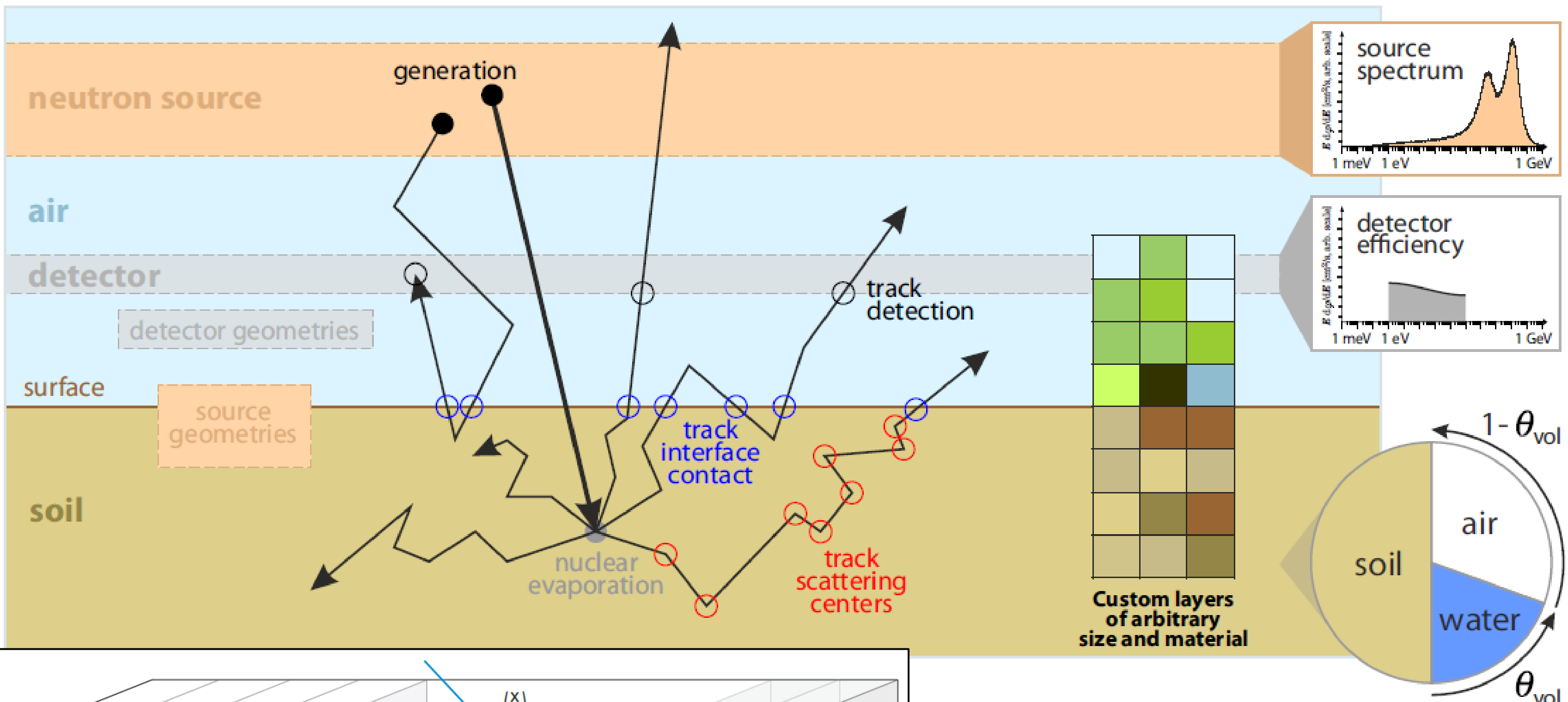


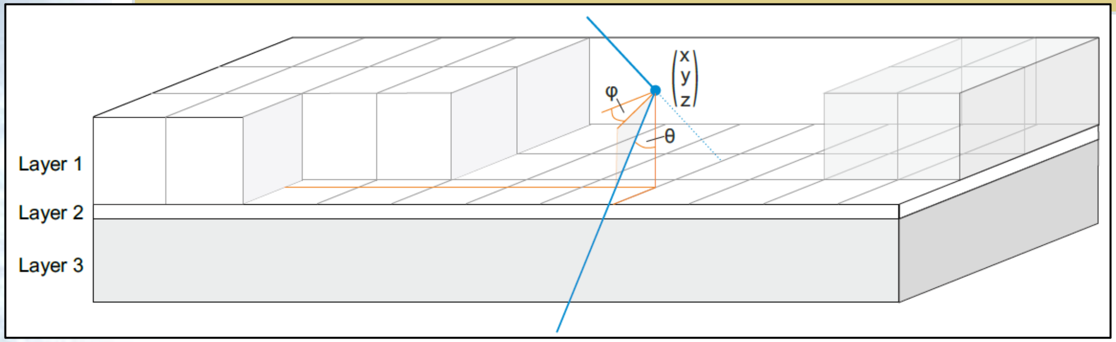
URANOS Buildup



* T. Sato
Features and applications of the analytical model for estimating terrestrial cosmic-ray fluxes: PARMA/EXPACS

URANOS Buildup





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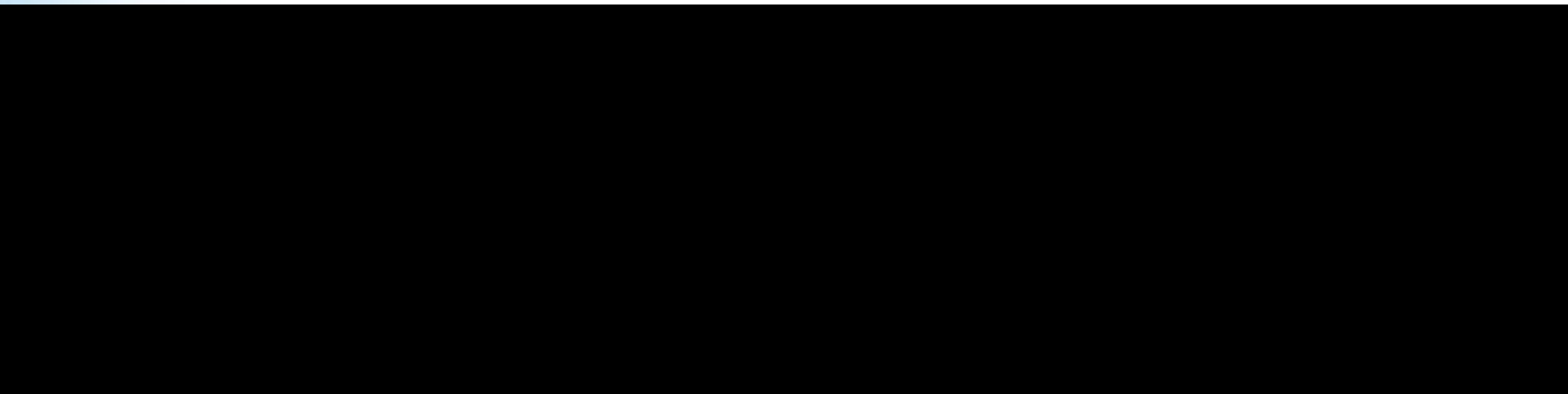
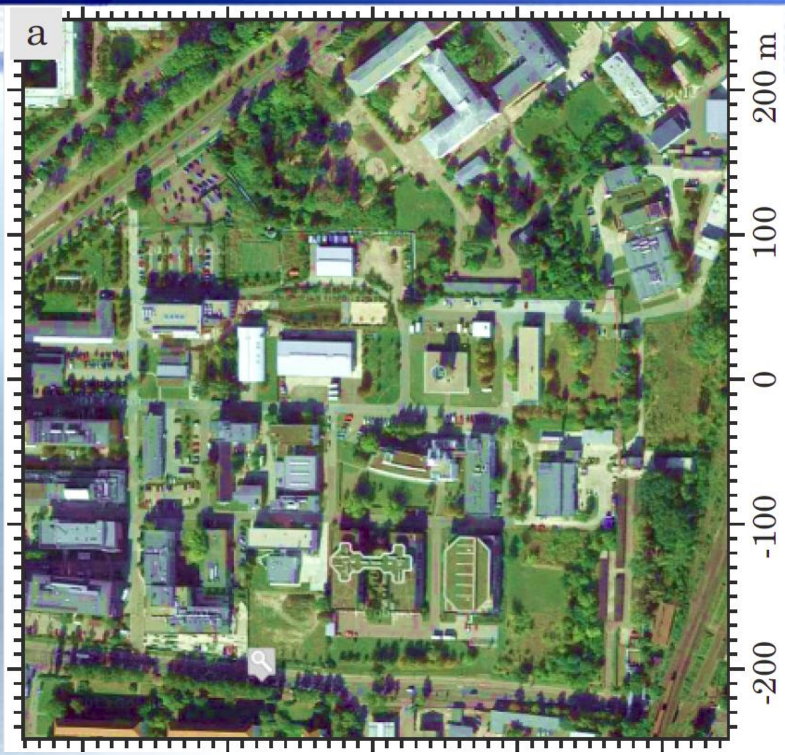
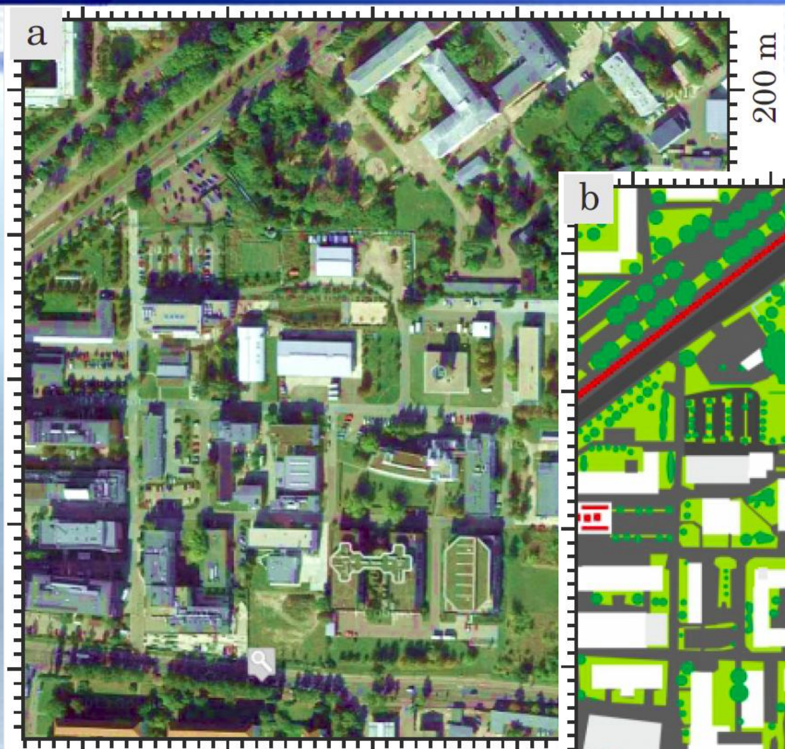


Modeling steps

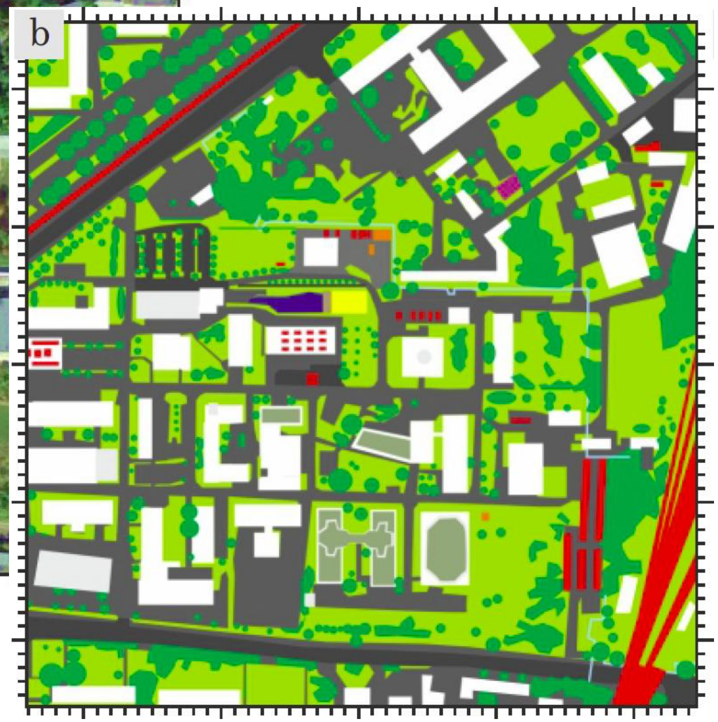


topography

Modeling steps

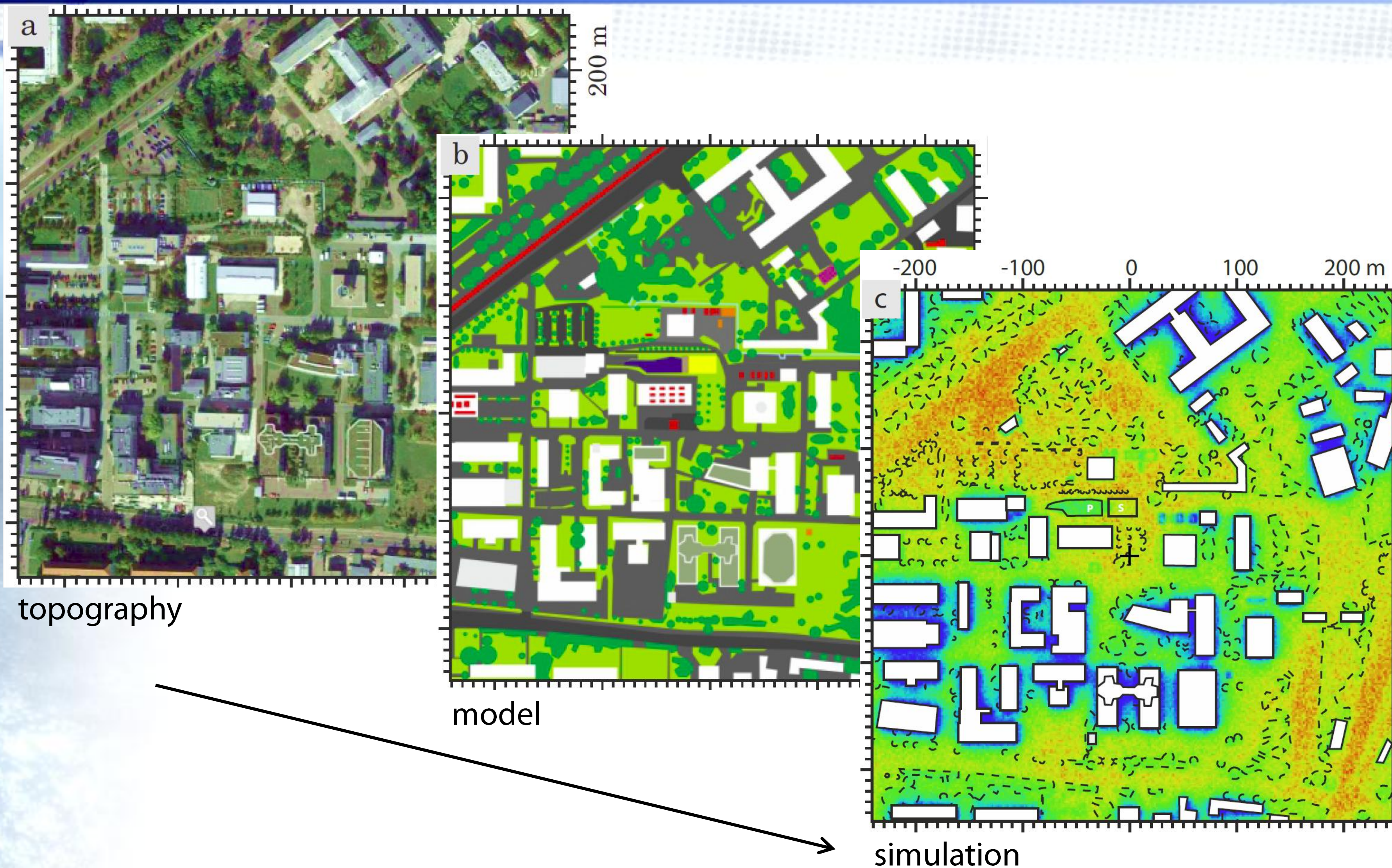


topography



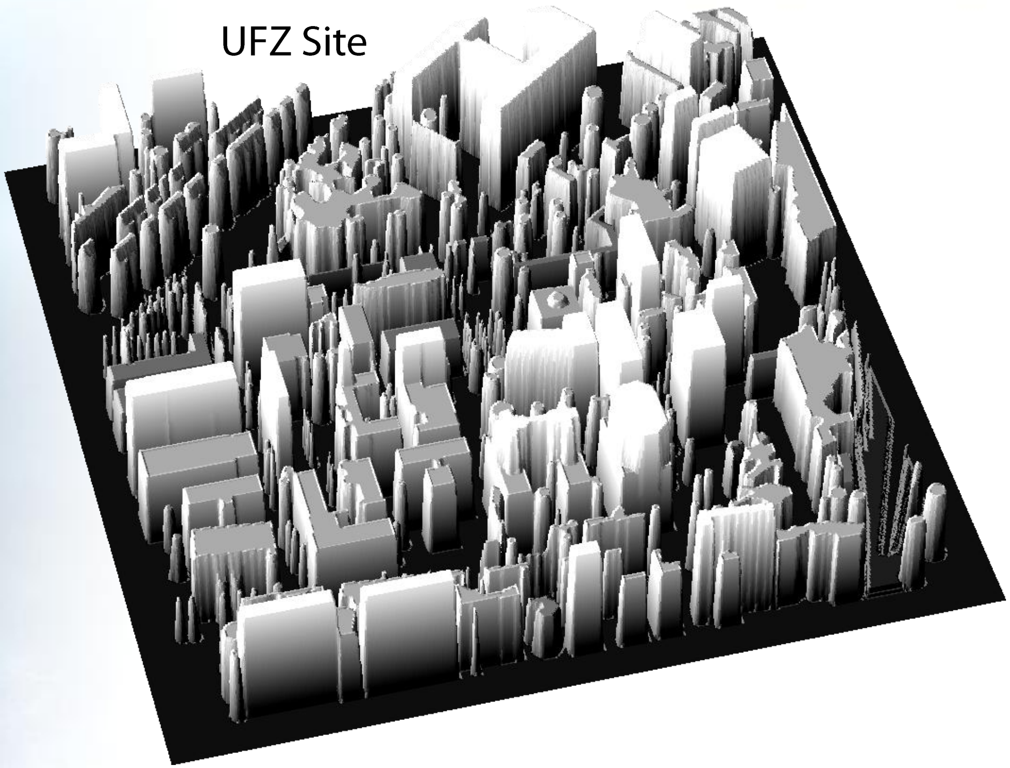
model

Modeling steps

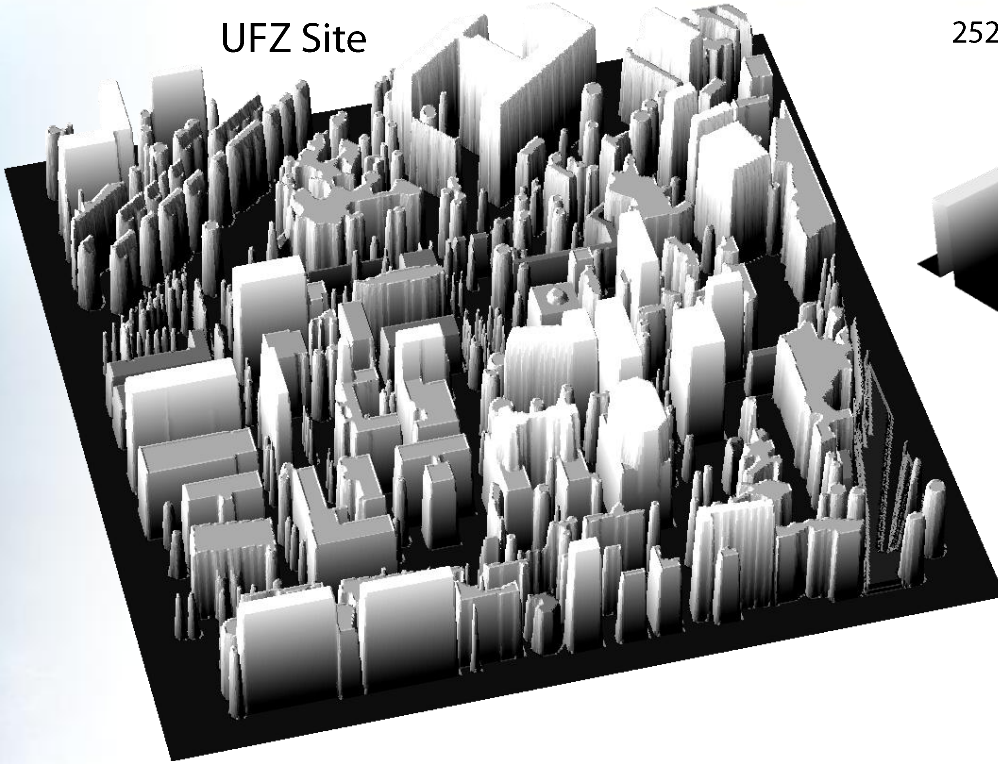


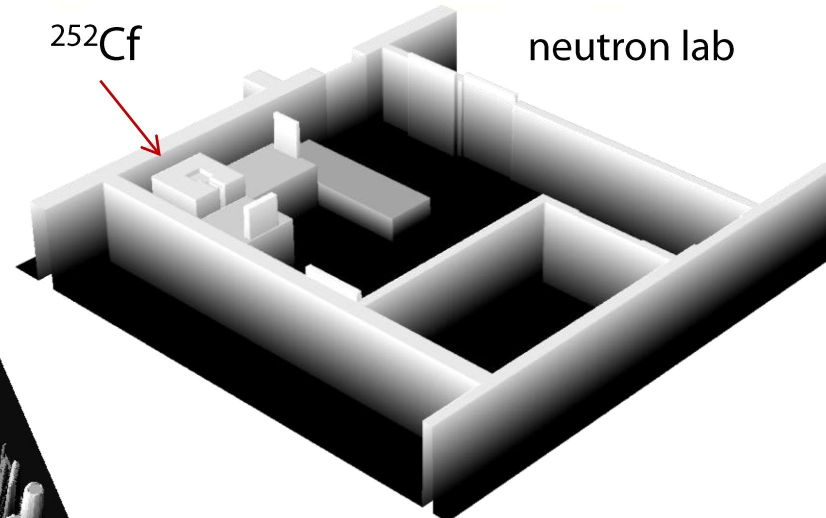
URANOS voxel engine

UFZ Site

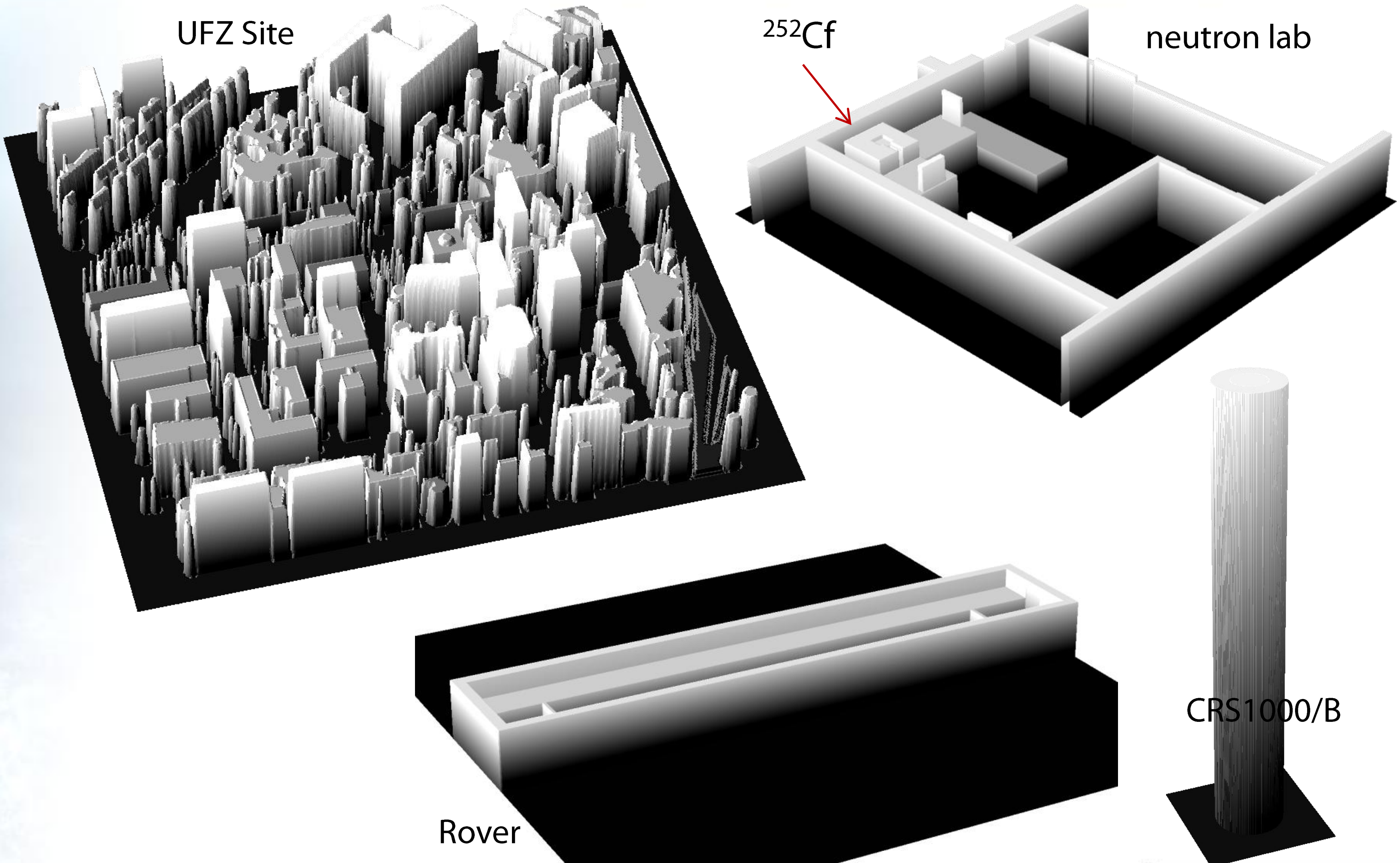


URANOS voxel engine



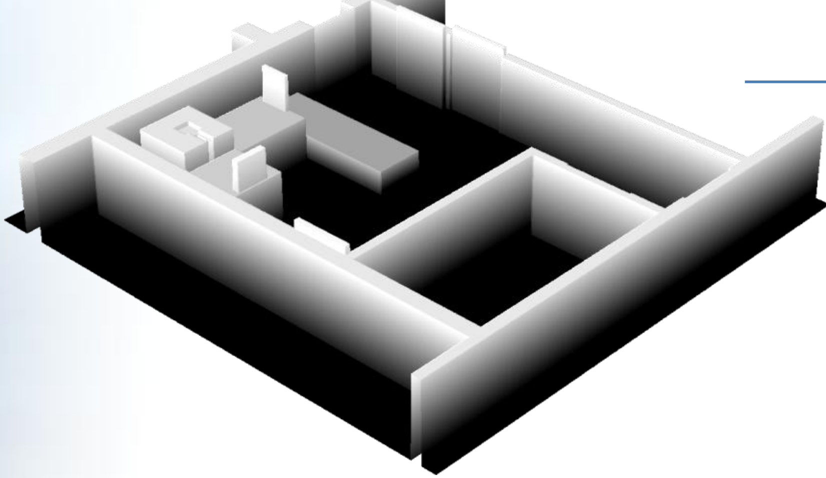


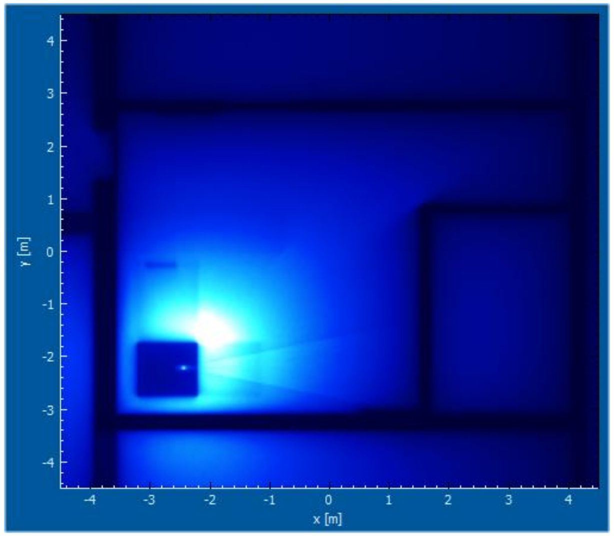
URANOS voxel engine



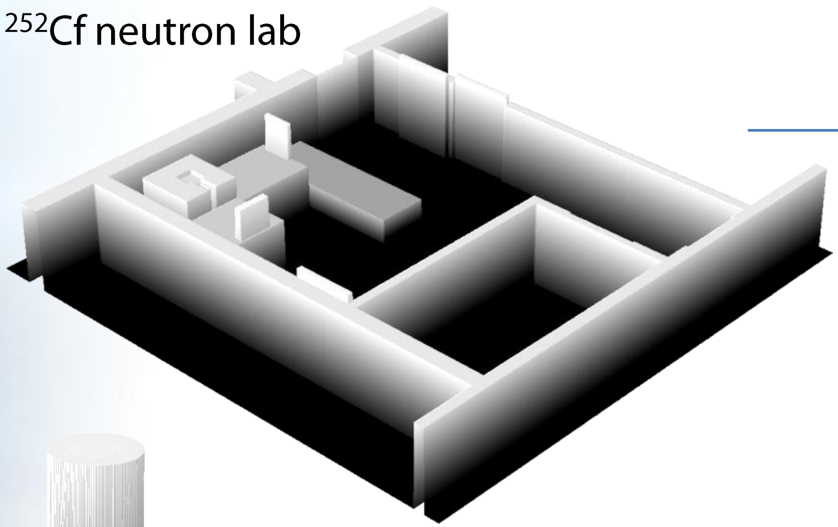
URANOS voxel engine

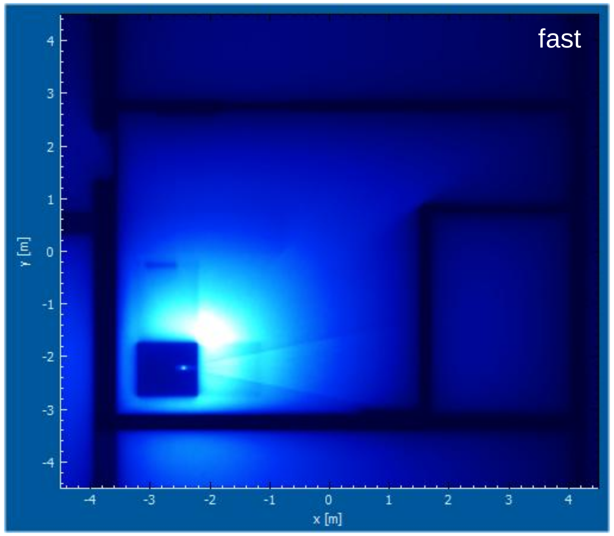
^{252}Cf neutron lab

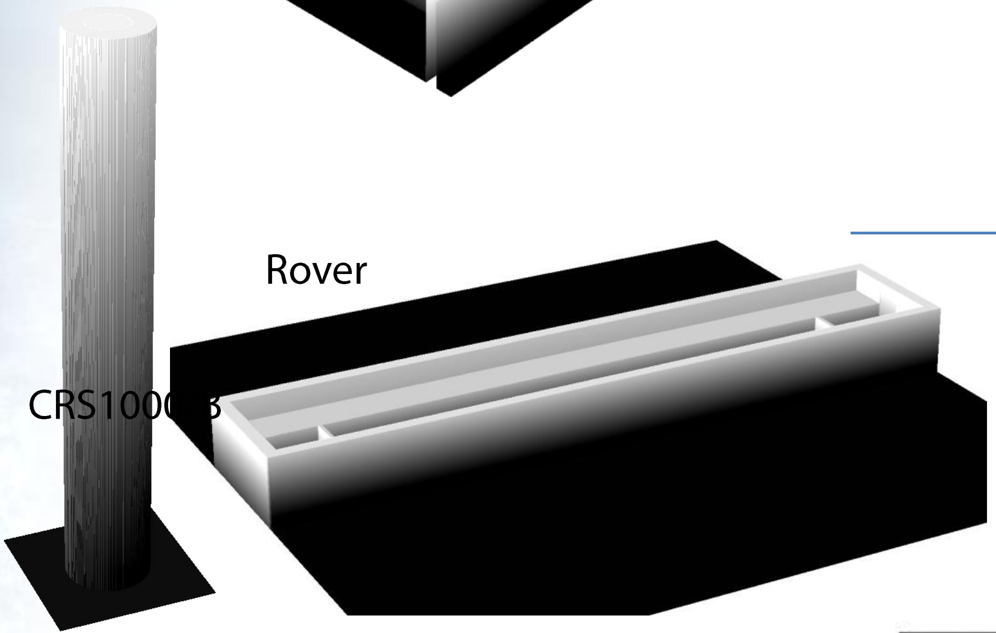


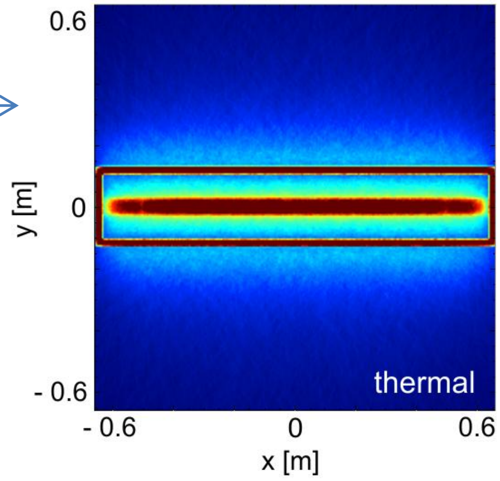


URANOS voxel engine

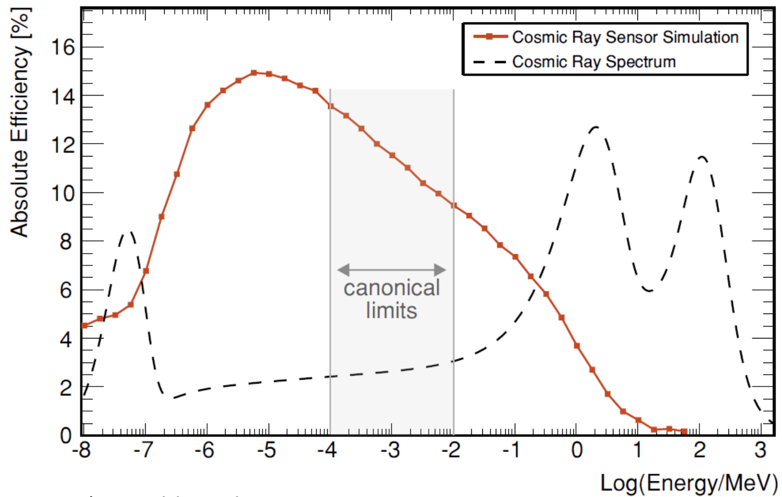




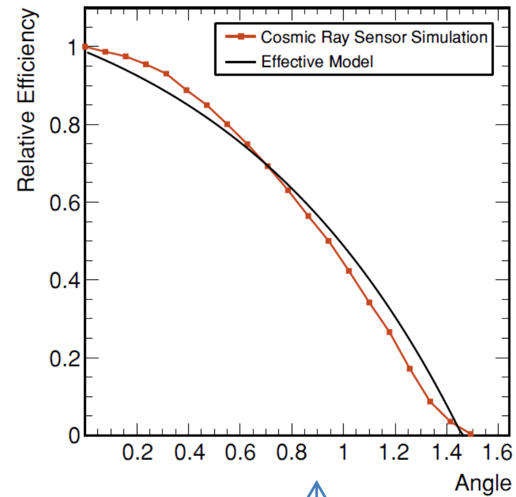


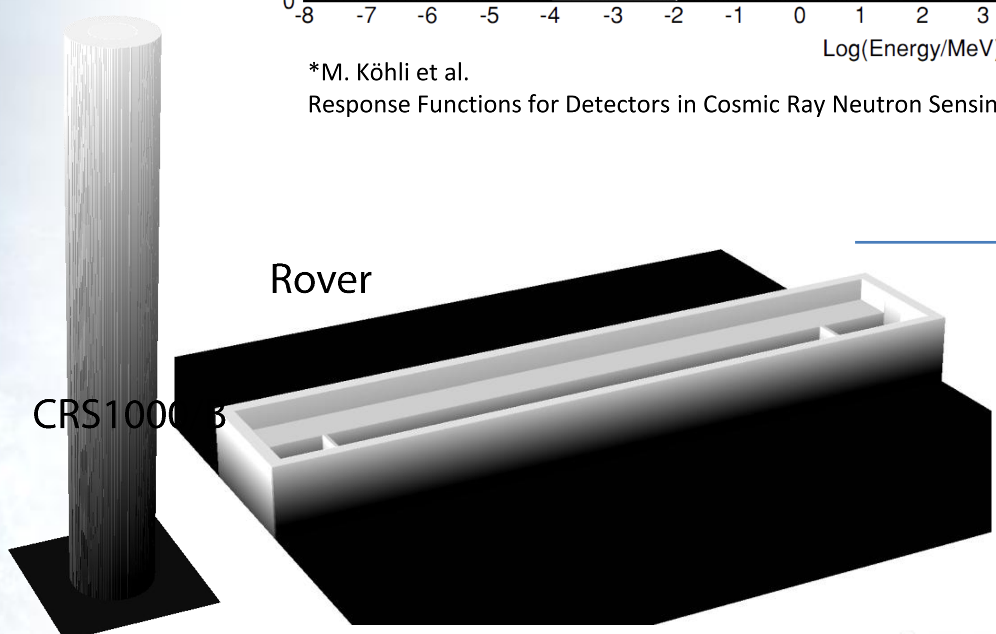


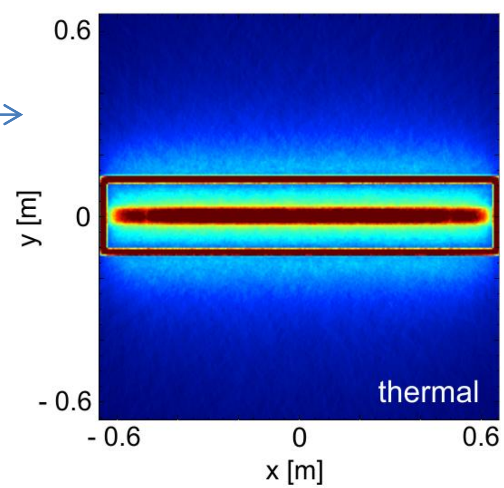
URANOS voxel engine



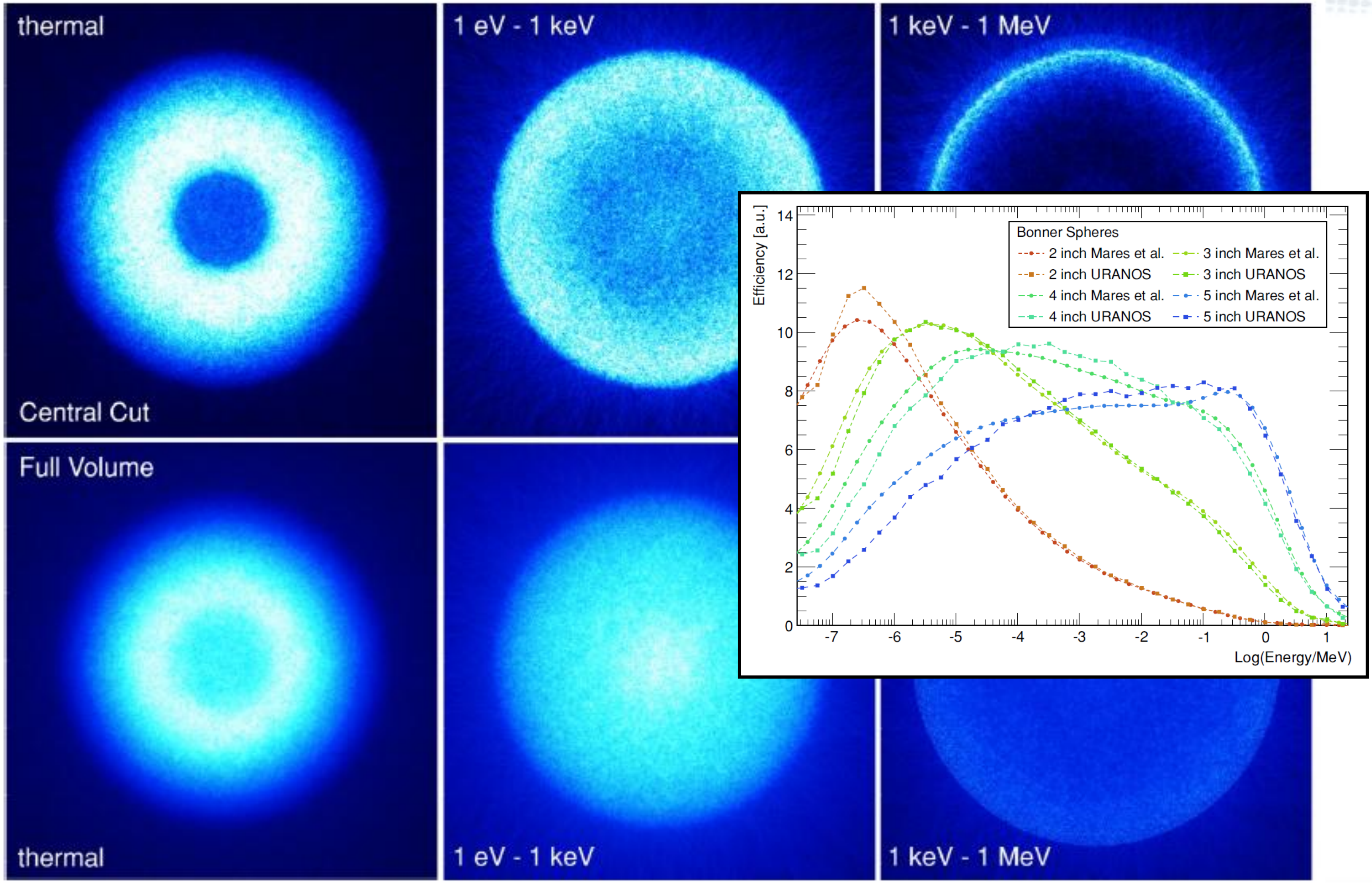
*M. Köhli et al.
Response Functions for Detectors in Cosmic Ray Neutron Sensing



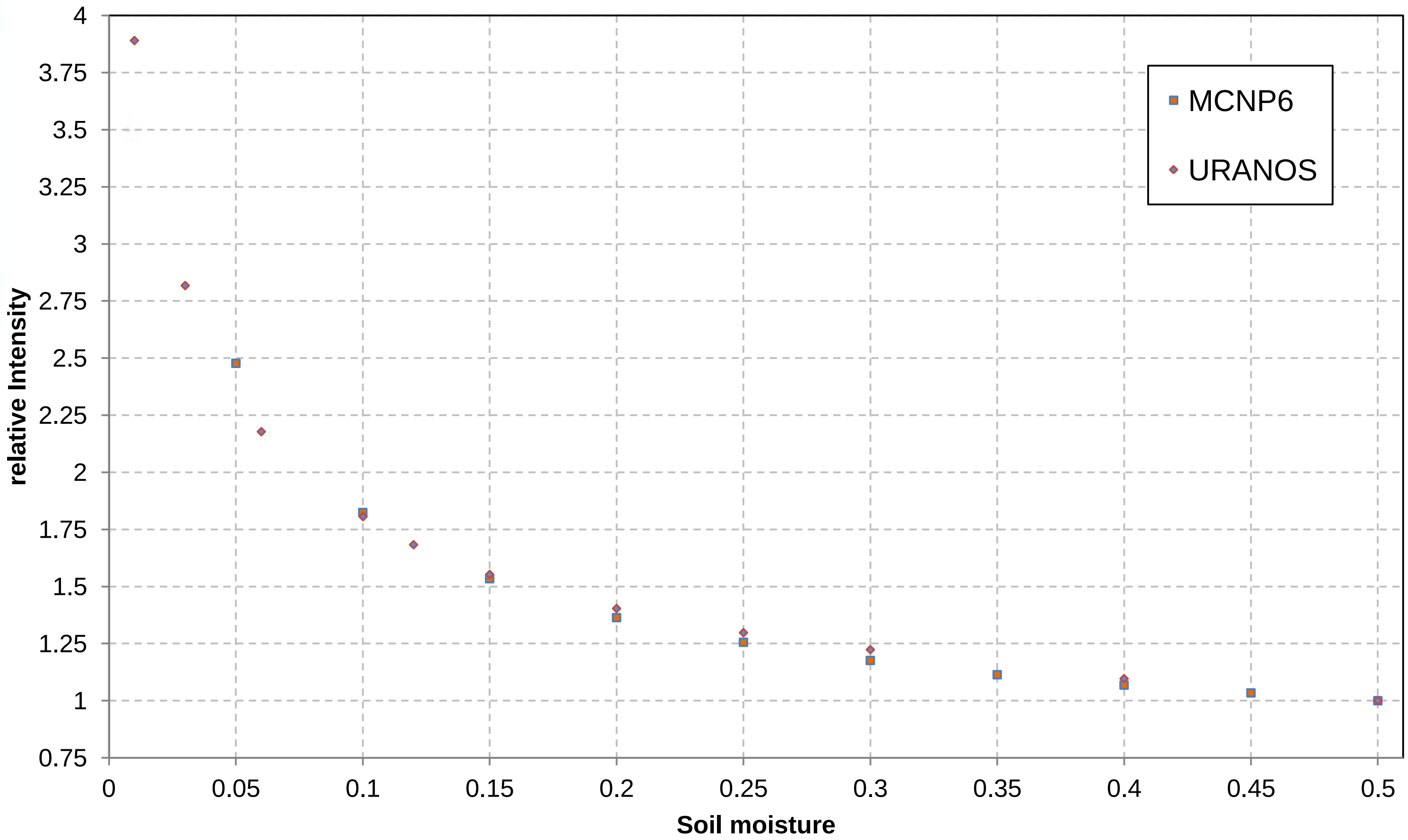




Bonner Spheres



Intensity Benchmark



WRR Paper 2015

AGU PUBLICATIONS

Water Resources Research

RESEARCH ARTICLE

10.1002/2015WR017169

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

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

M. Köhli[1], M. Schrön[2], M. Zreda[3], U. Schmidt[1], P. Dietrich[2], and S. Zacharias[2]

ploration Technologies,
and Water Resources,

Key Points:

- Neutron transpo

HELMHOLTZ CENTRE FOR ENVIRONMENTAL RESEARCH – UFZ

TERENO

HEIDELBERG UNIVERSITY

HESS Paper 2017

Improving calibration and validation of cosmic-ray neutron sensors in the light of spatial sensitivity

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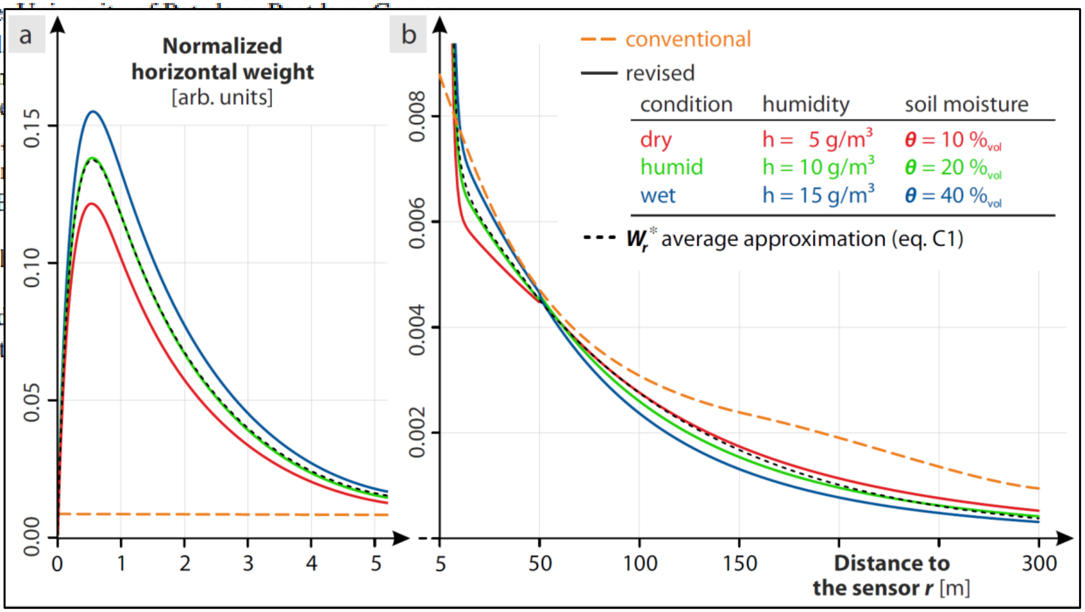

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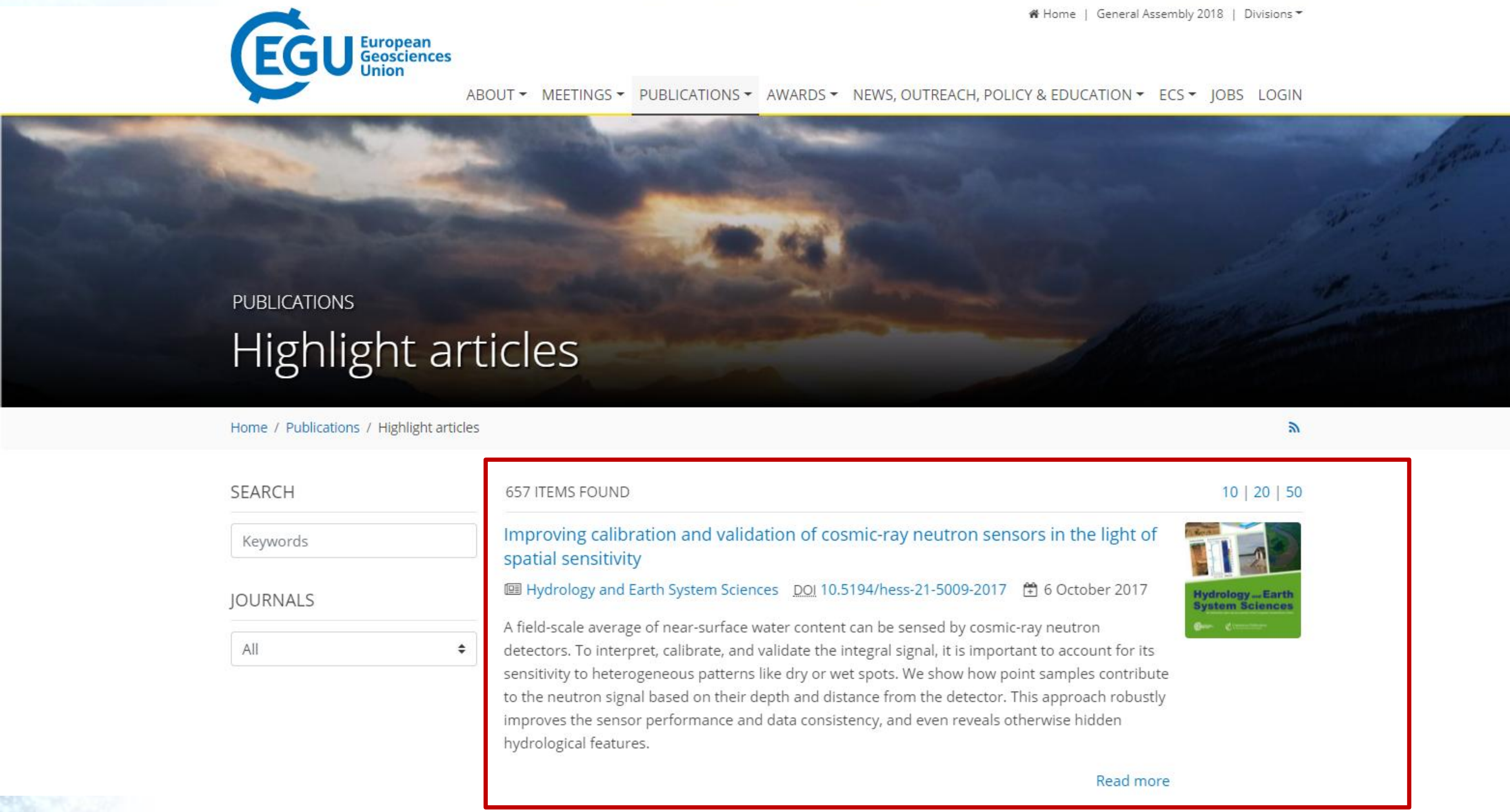
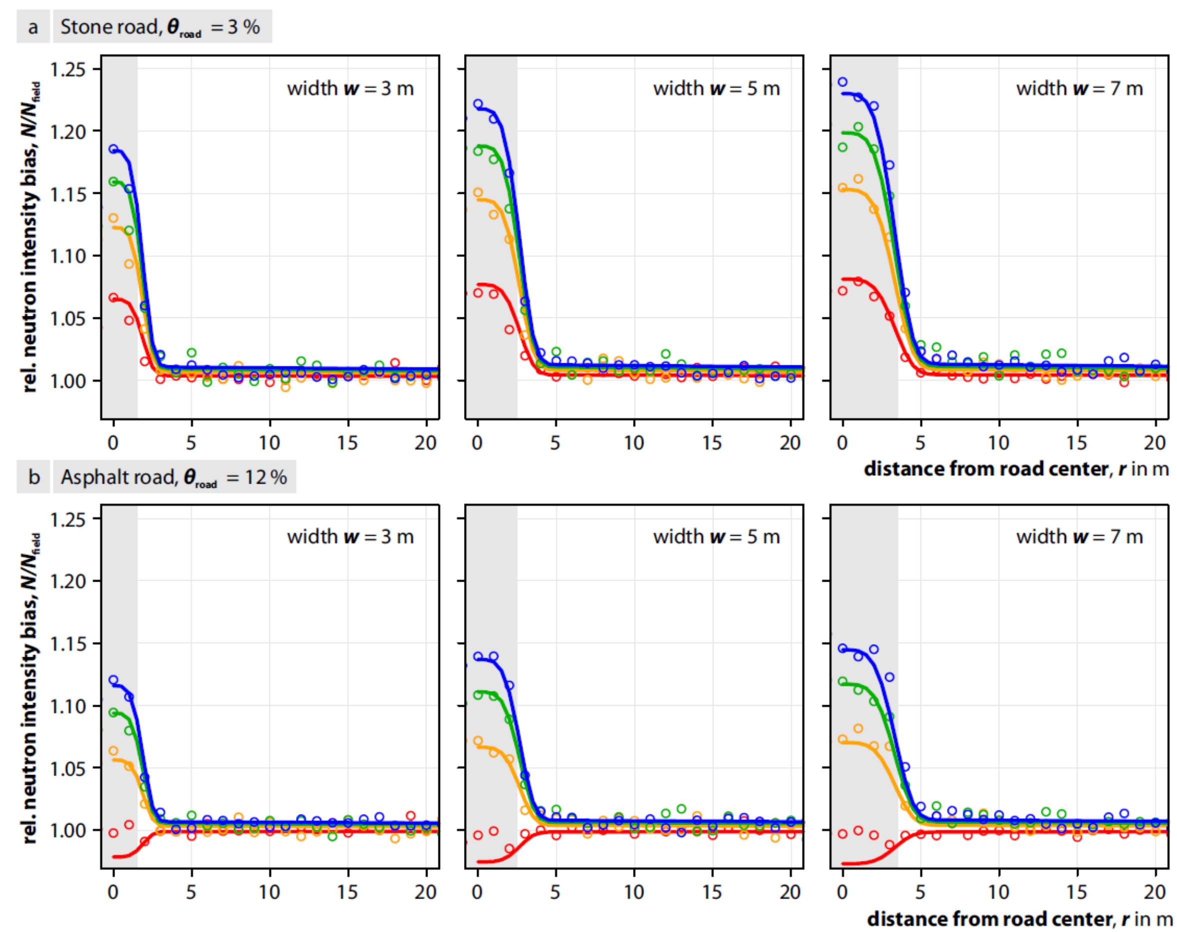
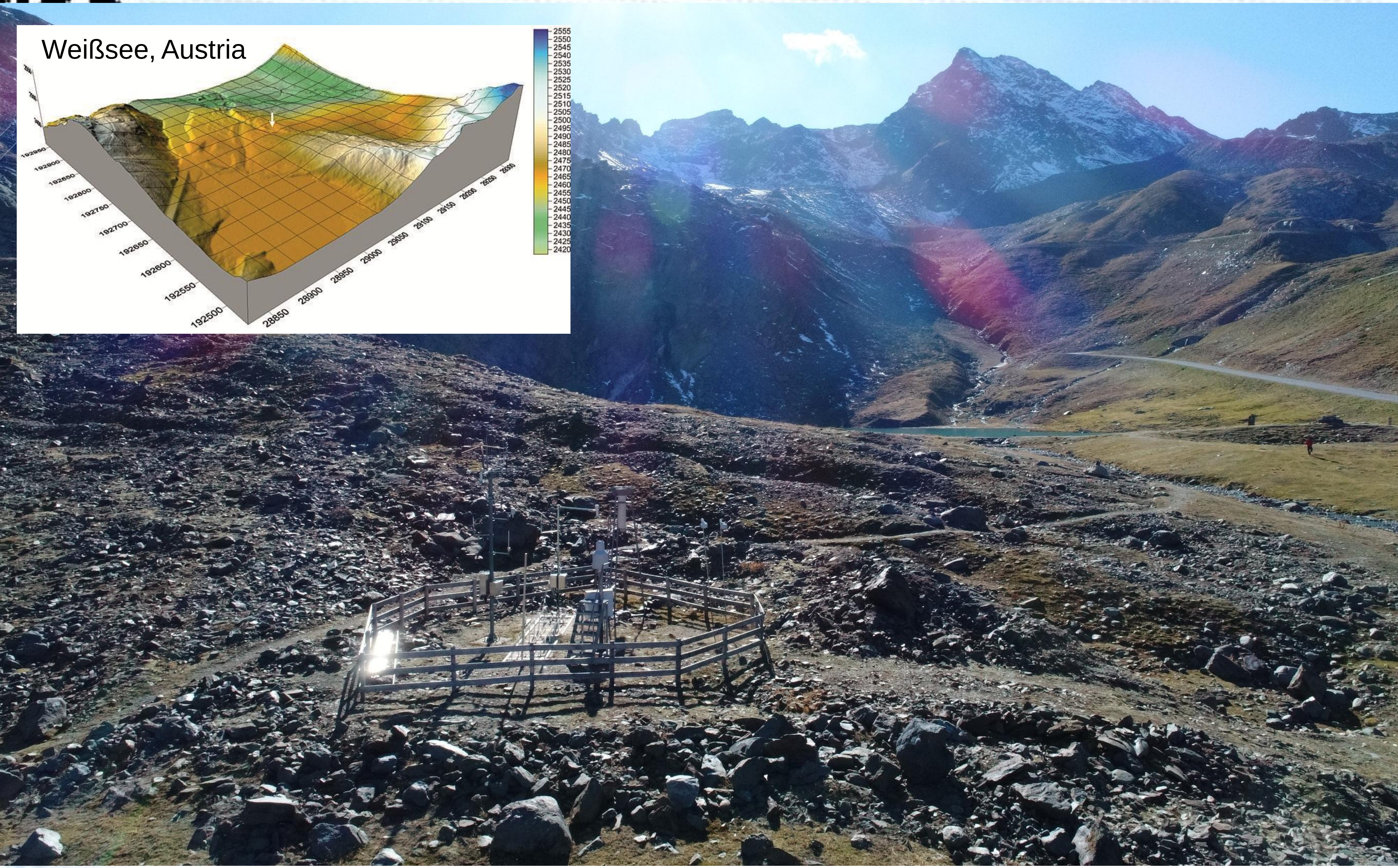


The Road Effect

In collaboration with
Martin Schrön
UFZ Leipzig



Snow Water Equivalent

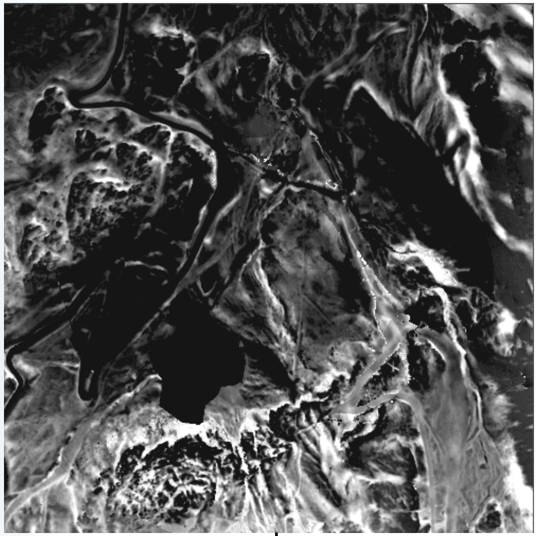


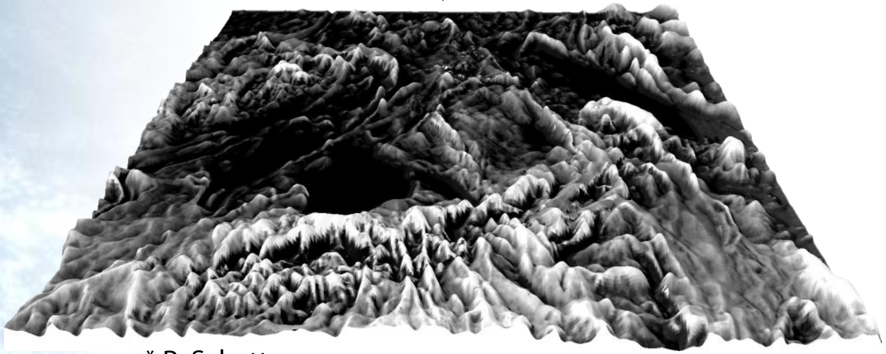
P. Schattan et al., to be published

URANOS voxel engine

3D Laser Scanner

P. Schattan – Kaunertal Glacier at N46° 52.2 E10 °42.6





* P. Schattan
Cosmic-ray neutron sensing of snow water equivalent in heterogeneous alpine terrain

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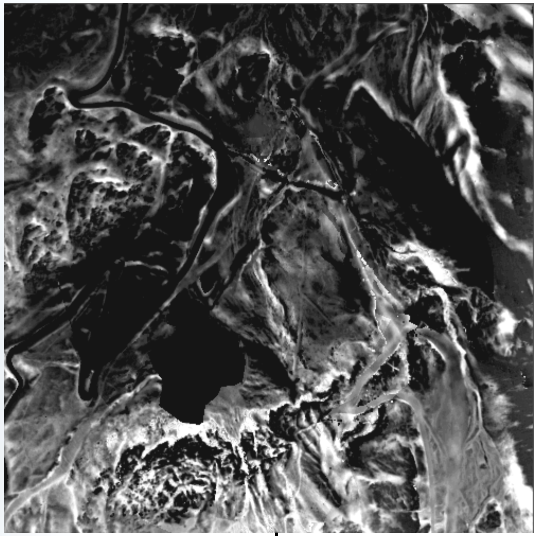

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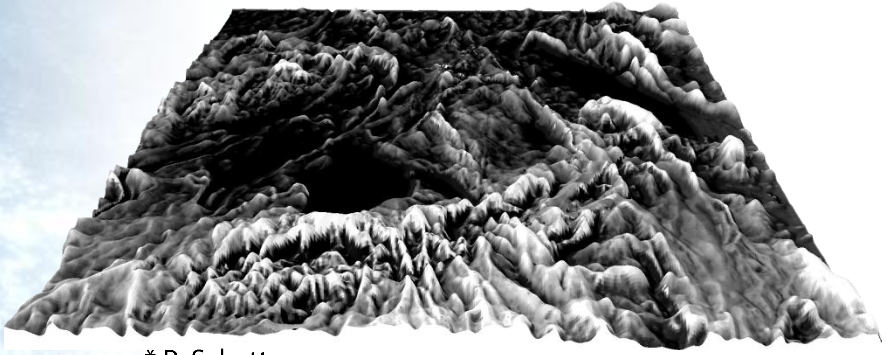

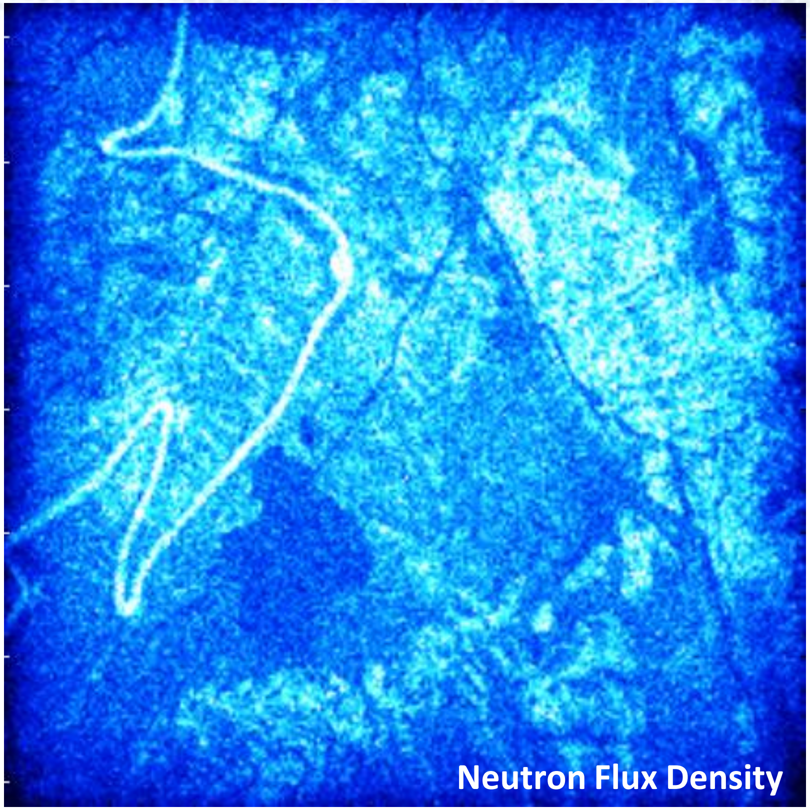

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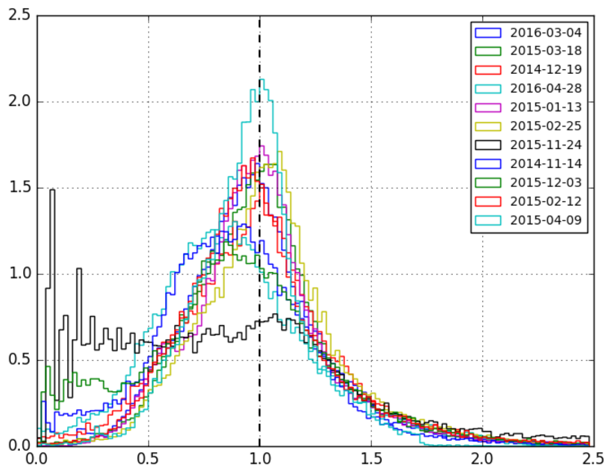
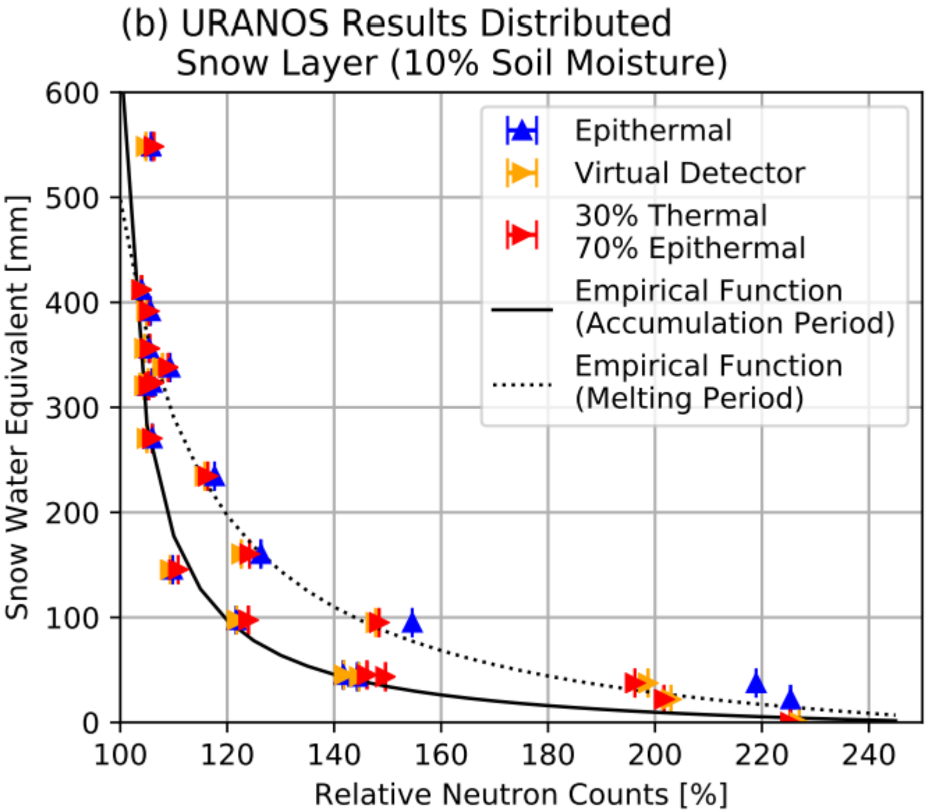
Snow Water Equivalent

In collaboration with
Paul Schattan
Uni Insbruck

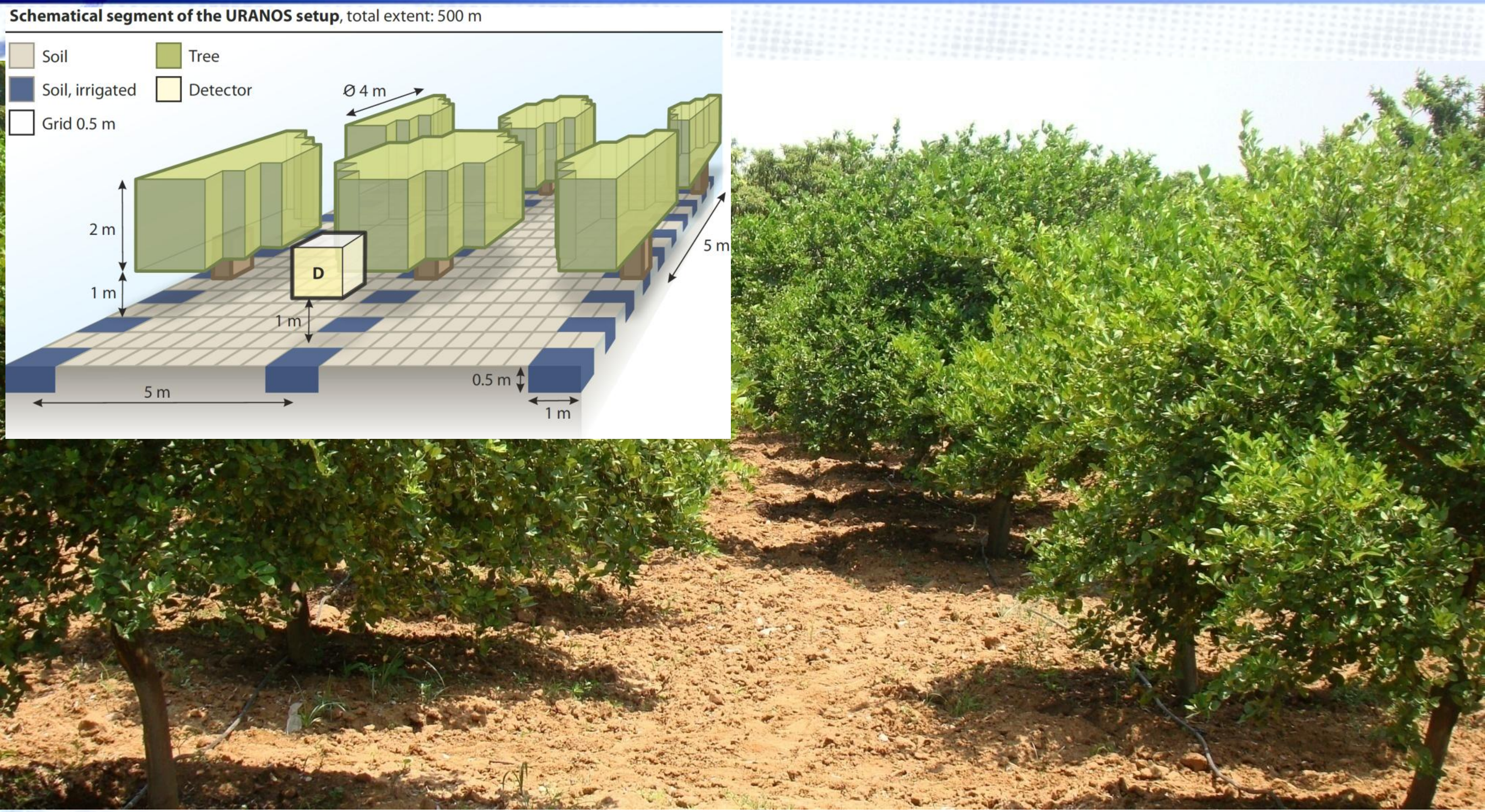
3D Laser scanner
snow distribution measurements





P. Schattan et al., to be published

Lemon trees in Valenica



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Can Drip Irrigation be Scheduled with Cosmic-Ray Neutrons

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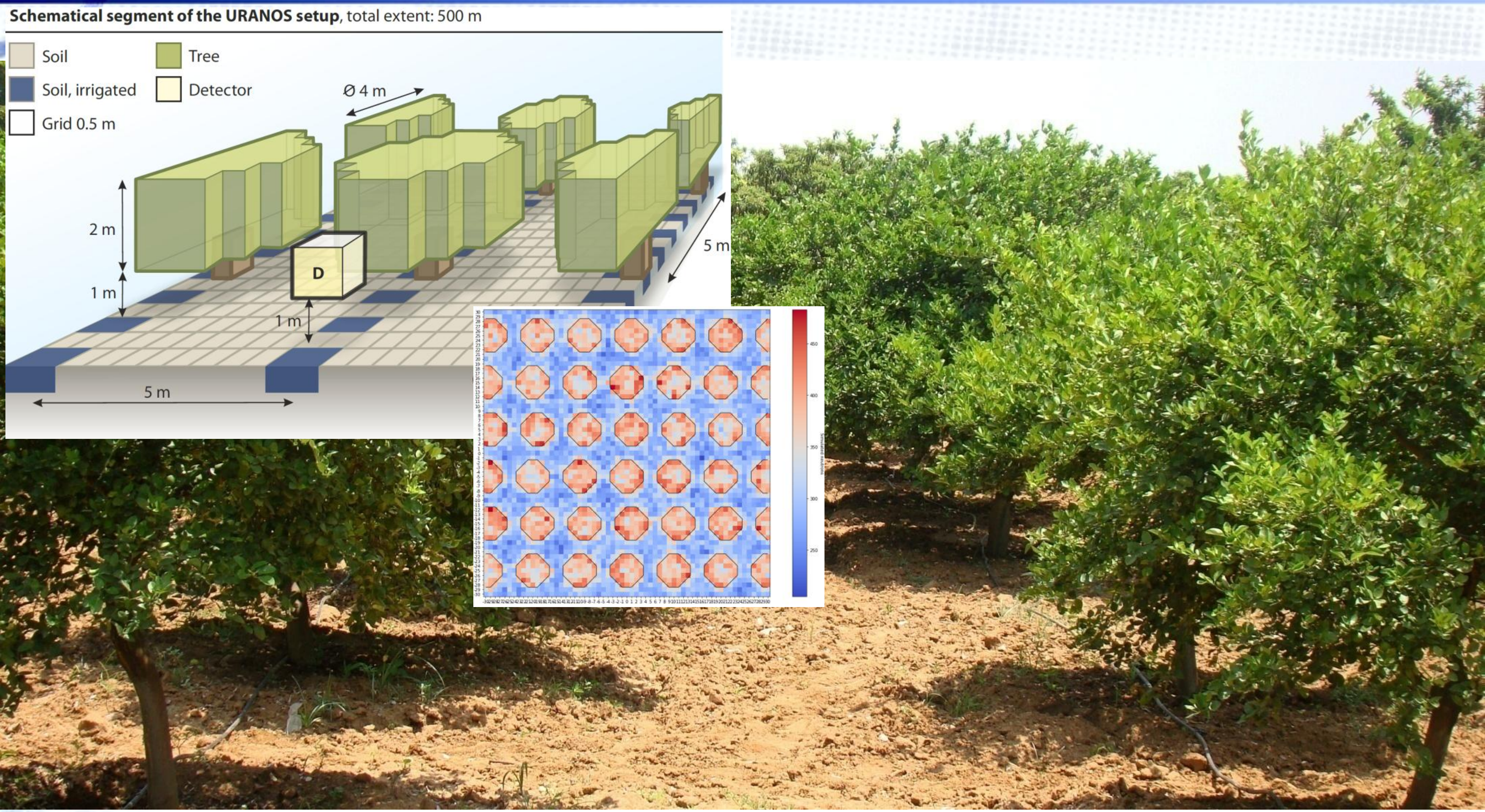

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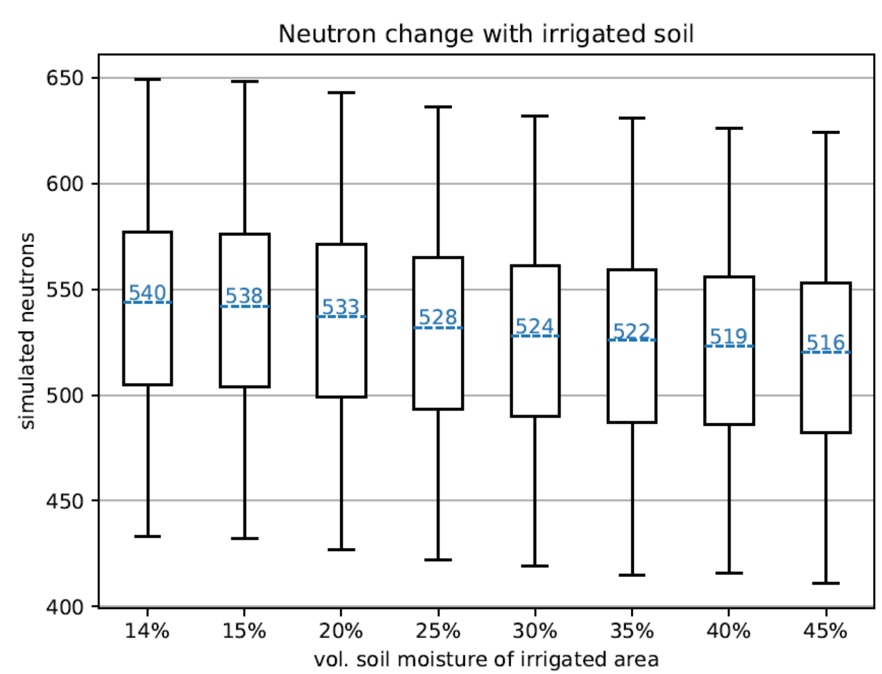
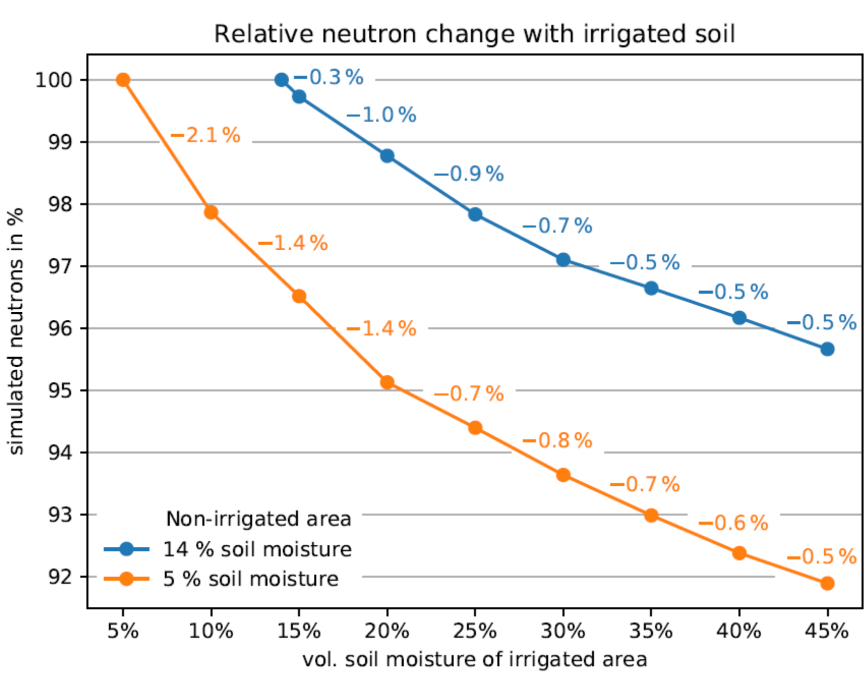
Can Drip Irrigation be Scheduled with Cosmic-Ray Neutrons

Drip Irrigation

In collaboration with
Dazhi Li
FZ Jülich

Lemon trees: 3 kg/m^3 biomass
8 % of soil irrigated

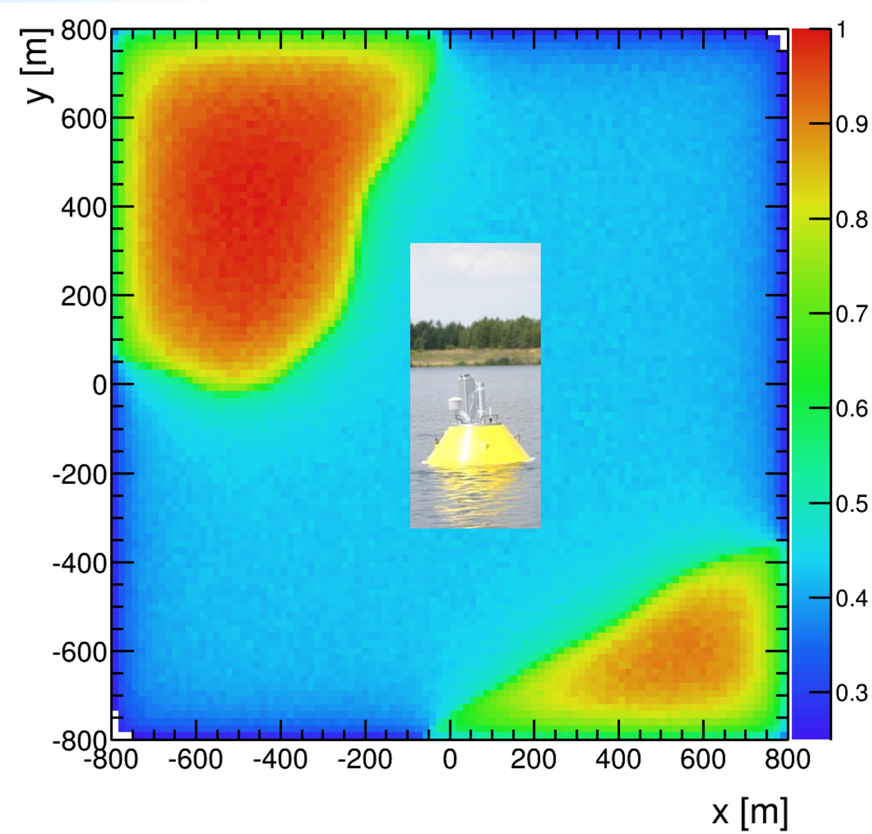




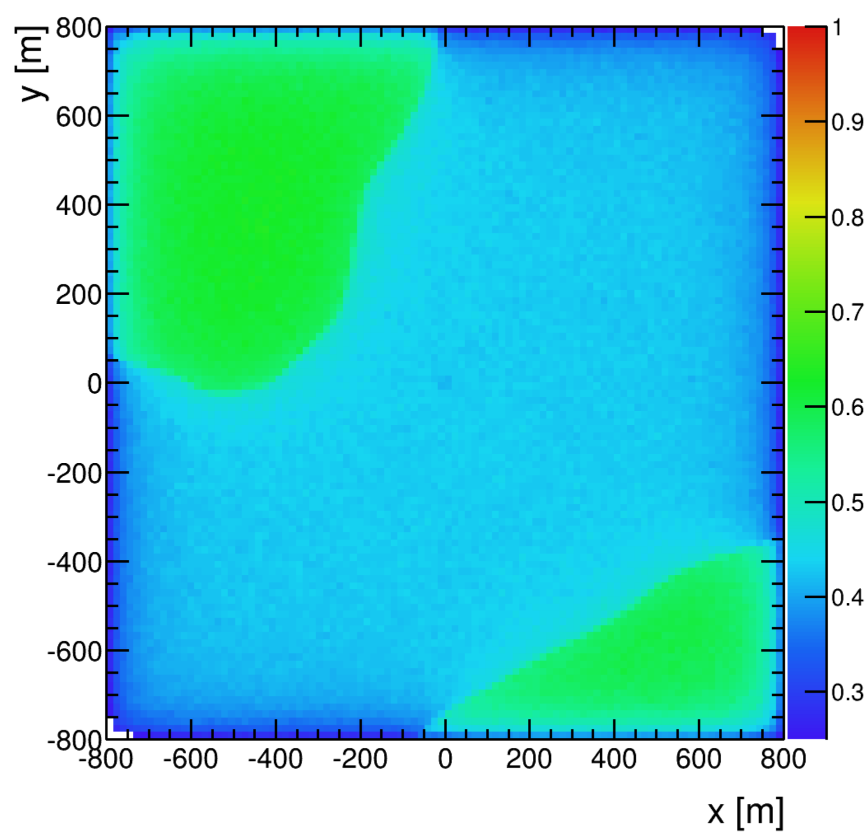
Only a few percent change -> needs large sensor

D. Li et al., to be published

Buoy on a lake



dry coast



wet coast

*M. Schrön
Correction of near-surface neutron measurements using incoming cosmic-ray fluxes from neutron monitors

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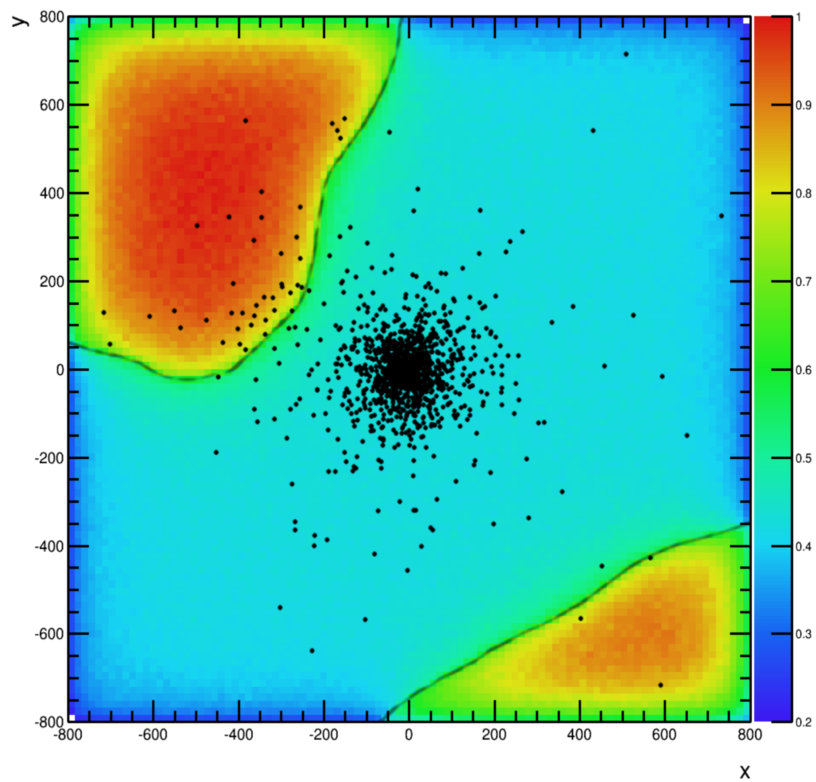

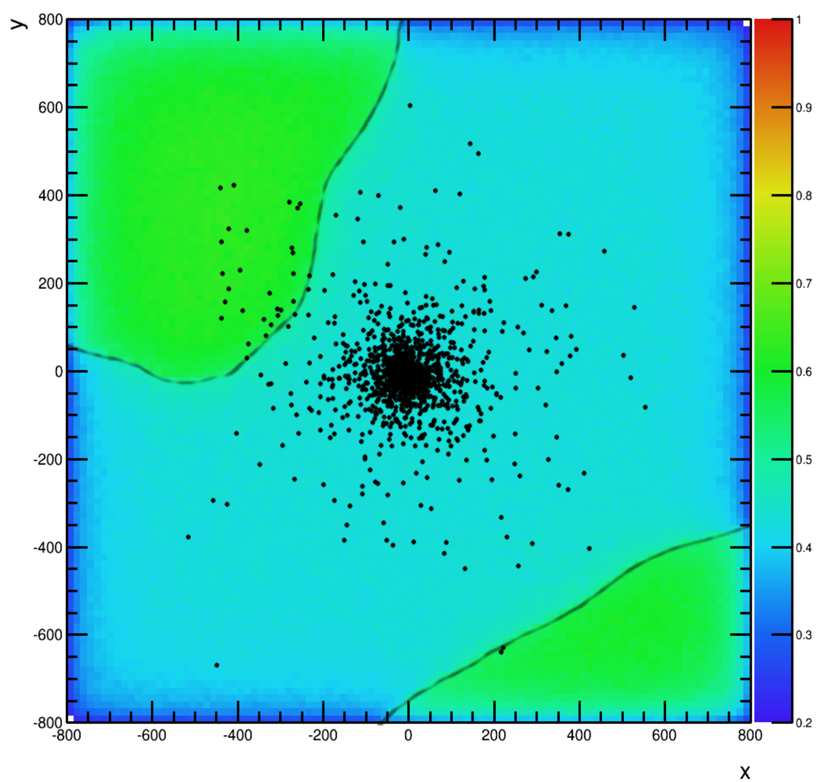

dry coast

wet coast

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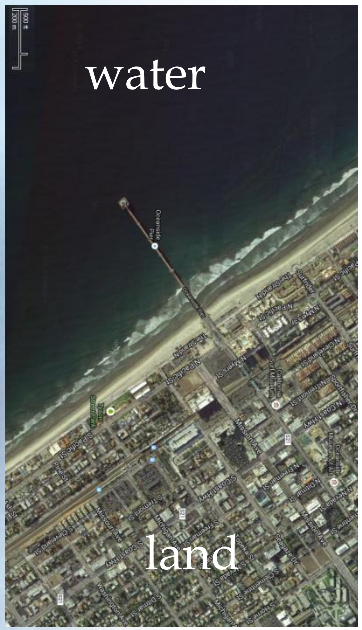
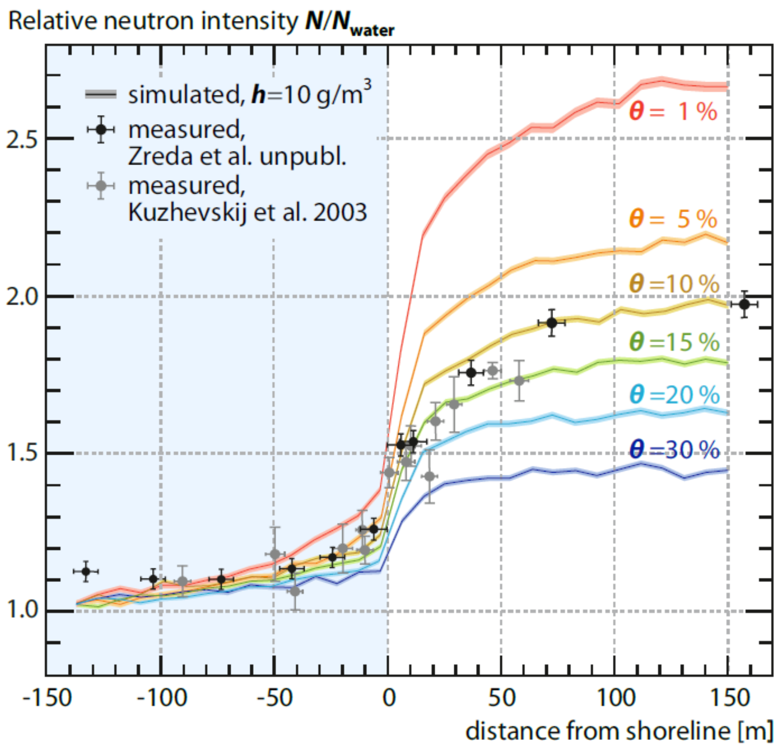
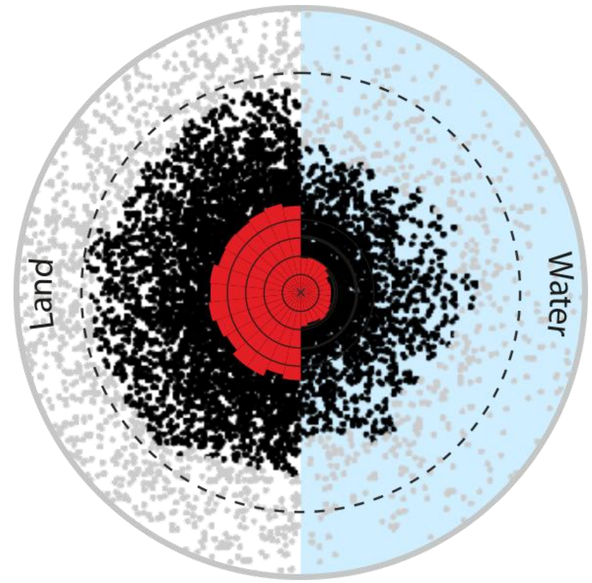
Correction of near-surface neutron measurements using incoming cosmic-ray fluxes from neutron monitors

Transects and detector options



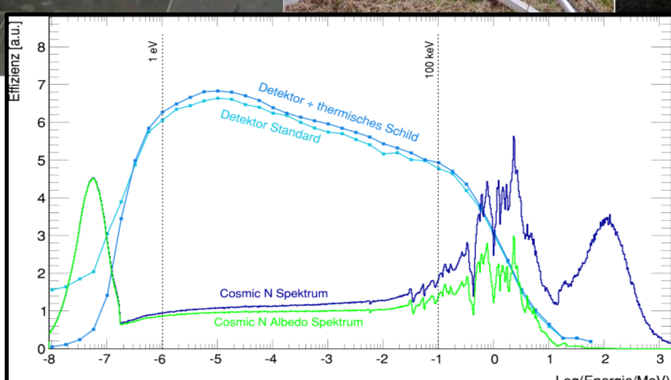


water land

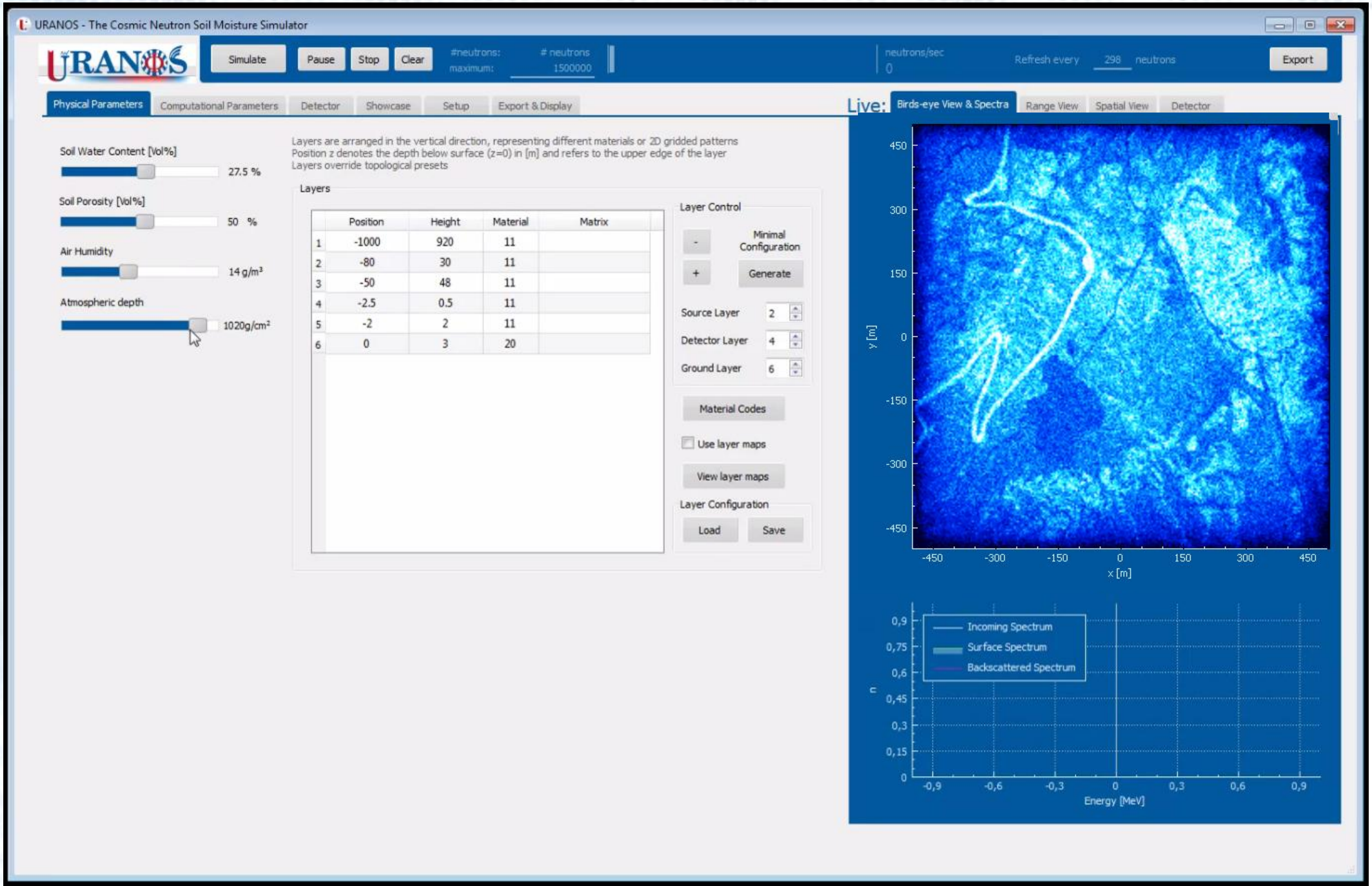


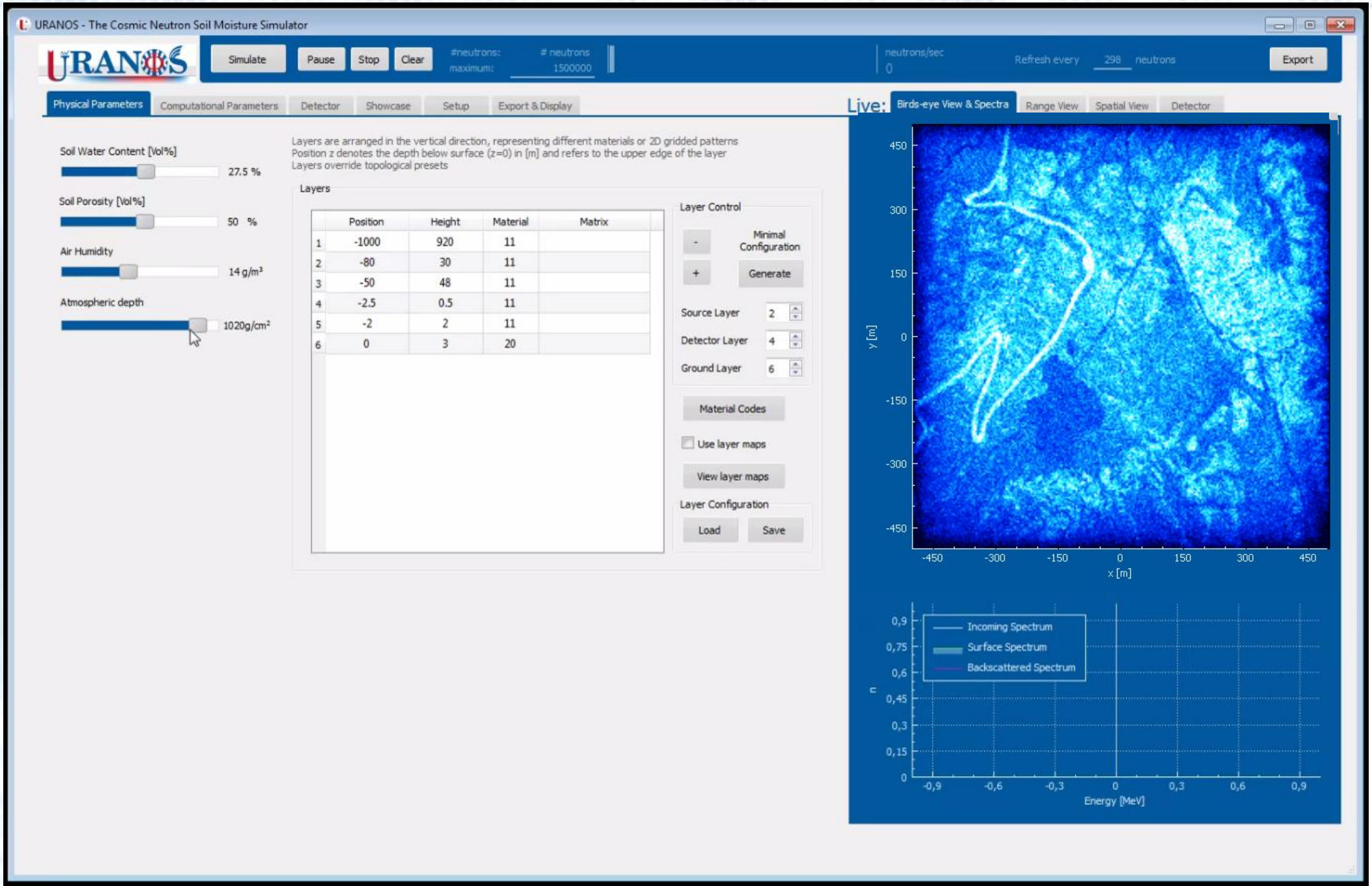
- Detected neutron origins (first contact to soil)
- Closest 86% of neutron origins for each 12° sector
- Neutron intensity for each 12° sector [arb. units]
- Footprint R_{86}(5g/m^3, 5 %)=210m for homogeneous soil

Detector flux calculations



URANOS Demonstration


URANOS - The Cosmic Neutron Soil Moisture Simulator
URANOS
Simulate
Pause
Stop
Clear
#neutrons:
maximum:
neutrons
1500000
neutrons/sec
0
Refresh every
298
neutrons
Export
Physical Parameters
Computational Parameters
Detector
Showcase
Setup
Export & Display
Live:
Birds-eye View & Spectra
Range View
Spatial View
Detector
Soil Water Content [Vol%]
27.5 %
Soil Porosity [Vol%]
50 %
Air Humidity
14 g/m³
Atmospheric depth
1020g/cm²
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] and refers to the upper edge of the layer
Layers override topological presets
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
Layer Control
Minimal Configuration
Generate
Source Layer 2
Detector Layer 4
Ground Layer 6
Material Codes
Use layer maps
View layer maps
Layer Configuration
Load
Save
y [m]
x [m]
Incoming Spectrum
Surface Spectrum
Backscattered Spectrum
n
Energy [MeV]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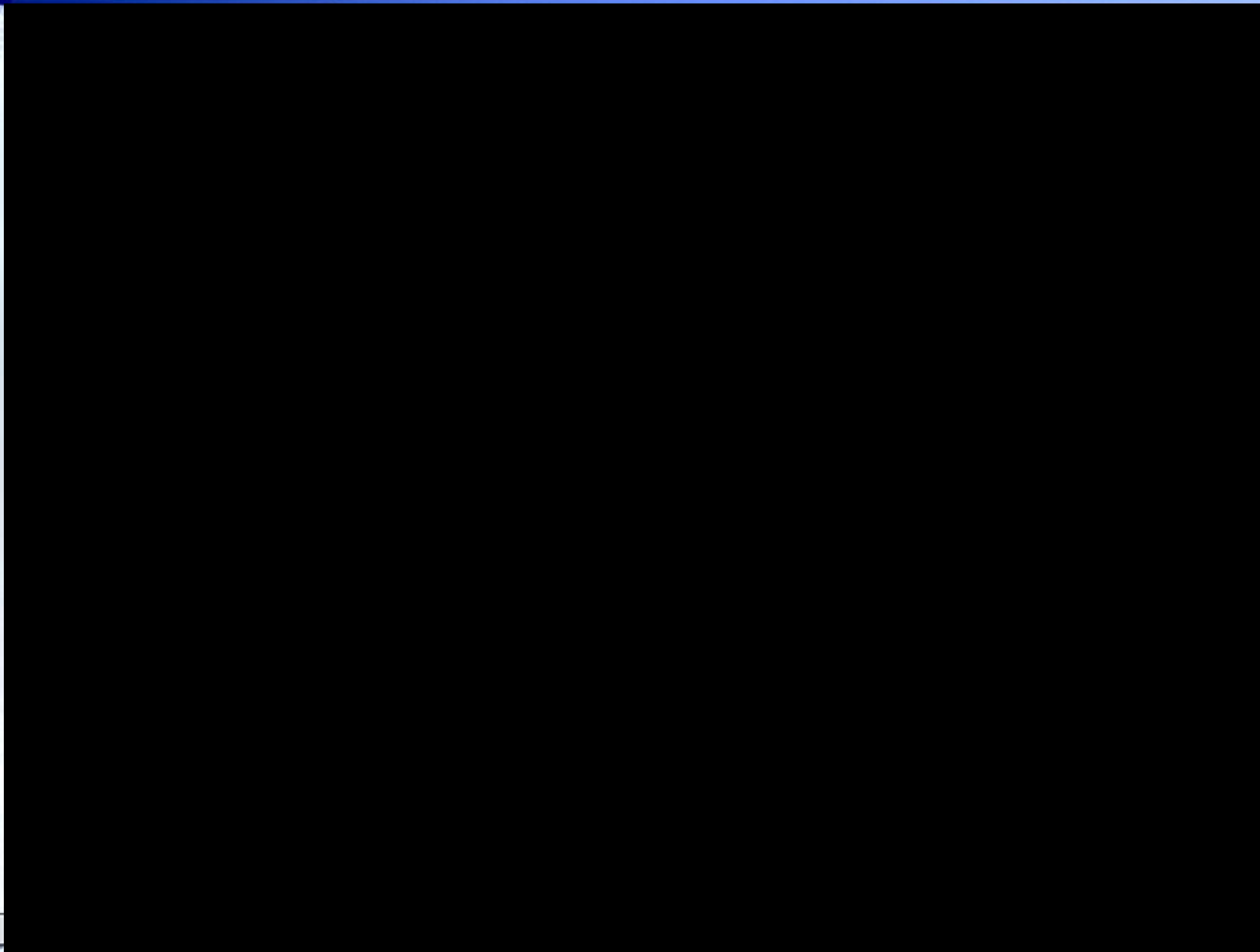
300
150
0
-150
-300
-450
Incoming Spectrum
Surface Spectrum
Backscattered Spectrum
n
0,9
0,75
0,6
0,45
0,3
0,15
0
-0,9
-0,6
-0,3
0
0,3
0,6
0,9
Energy [MeV]



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- Novel neutron Monte Carlo tool for Environmental Physics

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- Ready-to-use User Interface

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- Fast calculation using an analytical spectrum above the ground

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

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