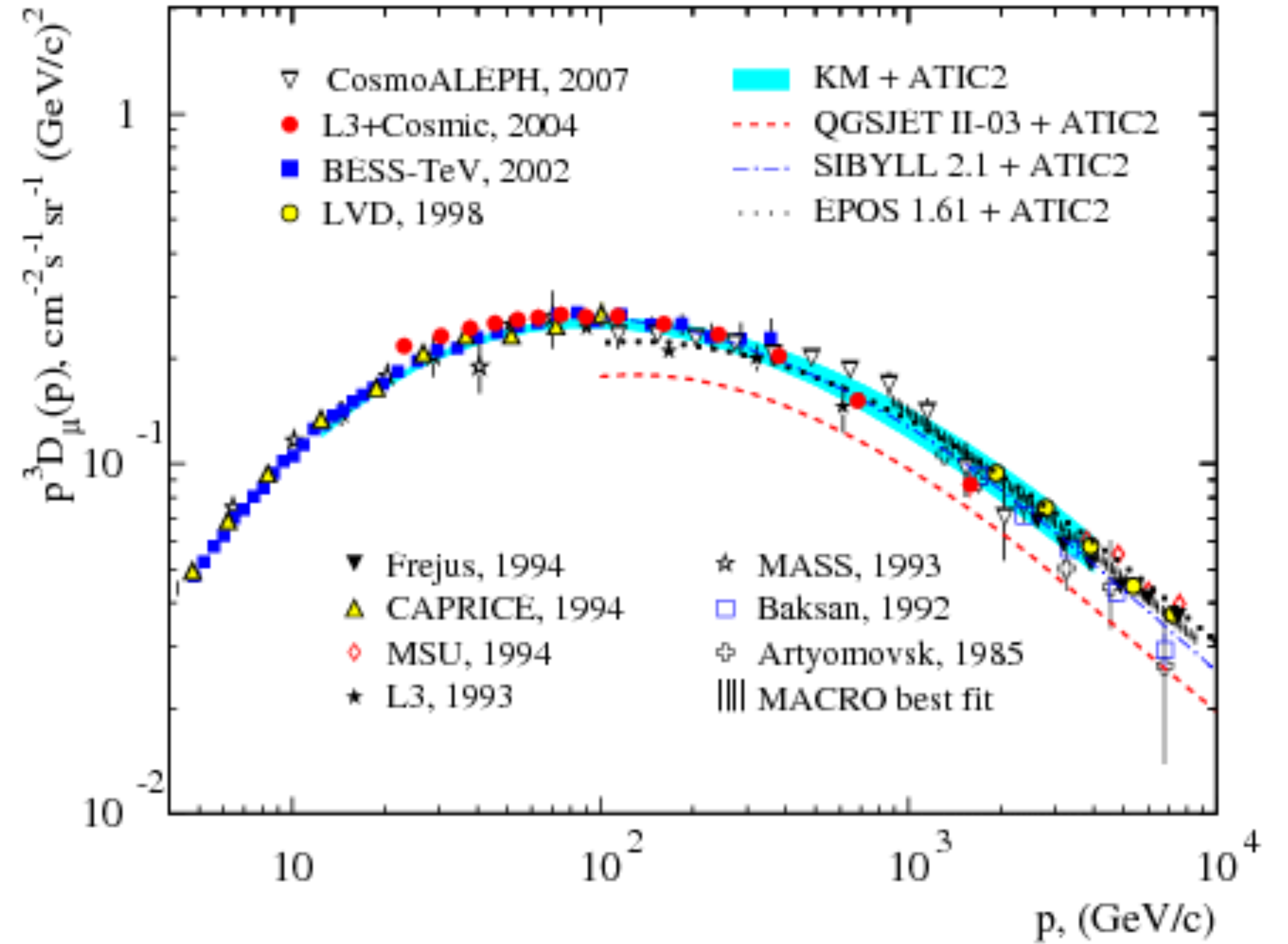
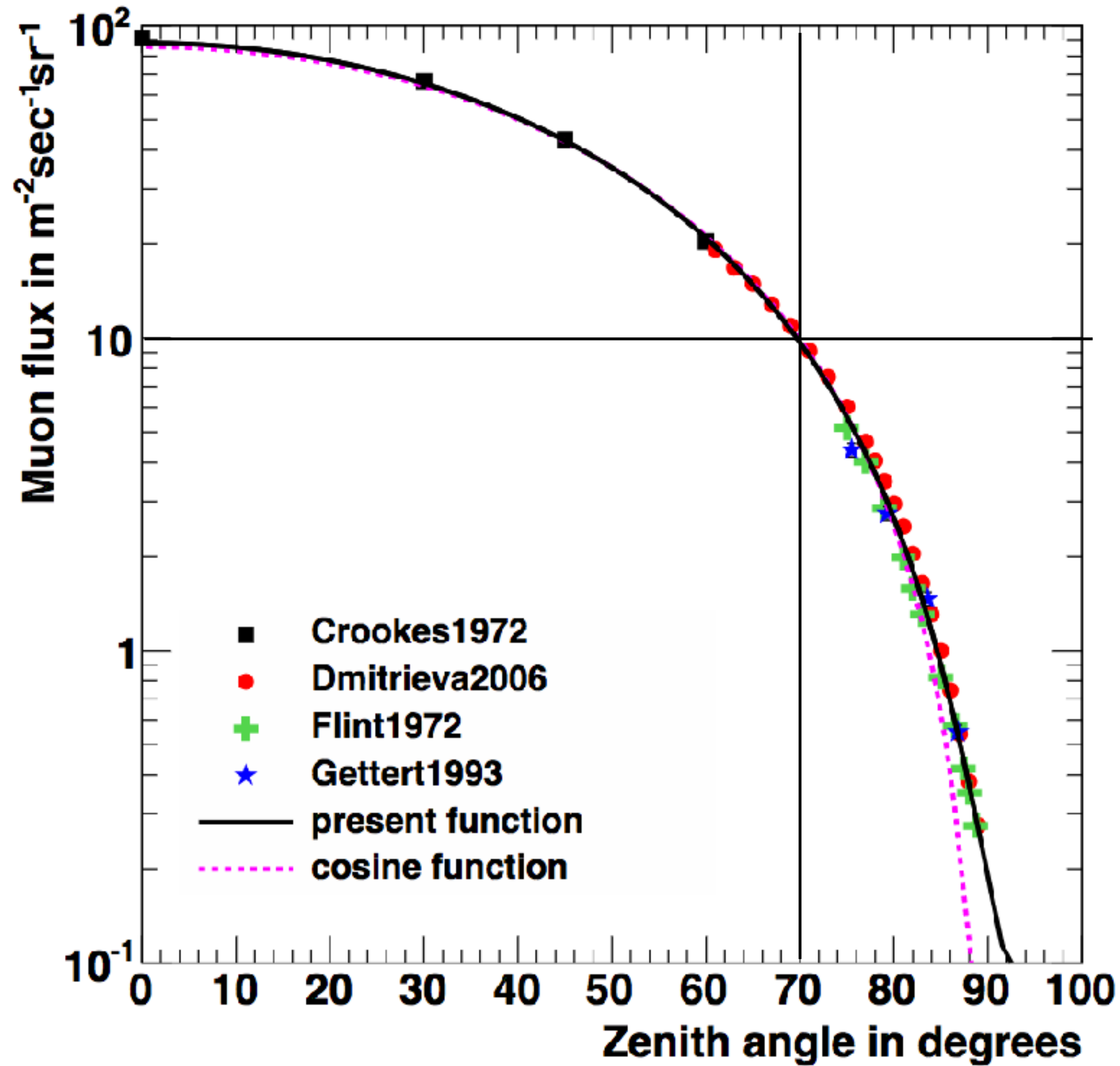


Cosmic-Ray Muography

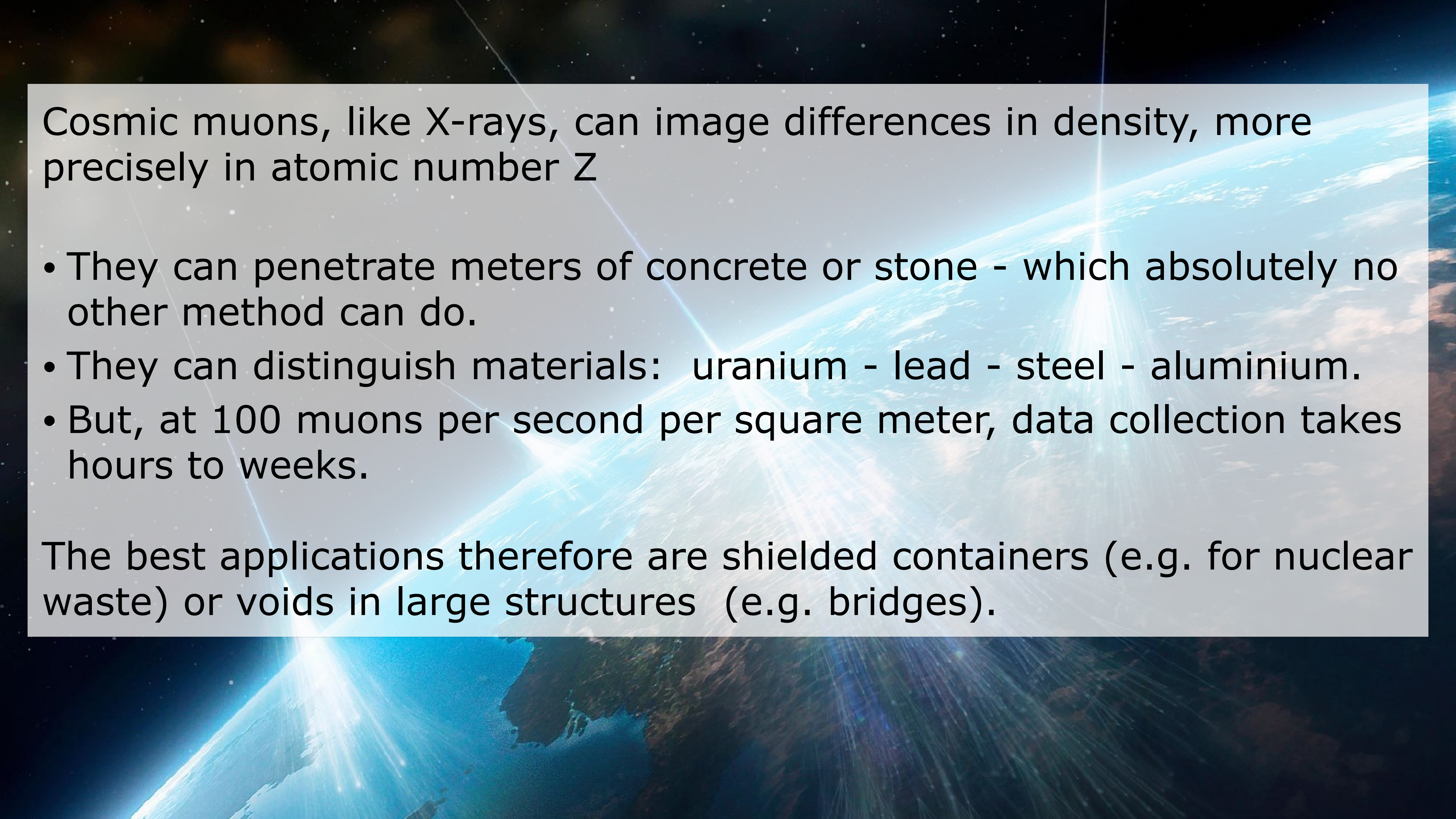
Prof Ralf Kaiser



Cosmic Muons - Angular and Energy Spectrum



<https://arxiv.org/pdf/1606.06907.pdf>



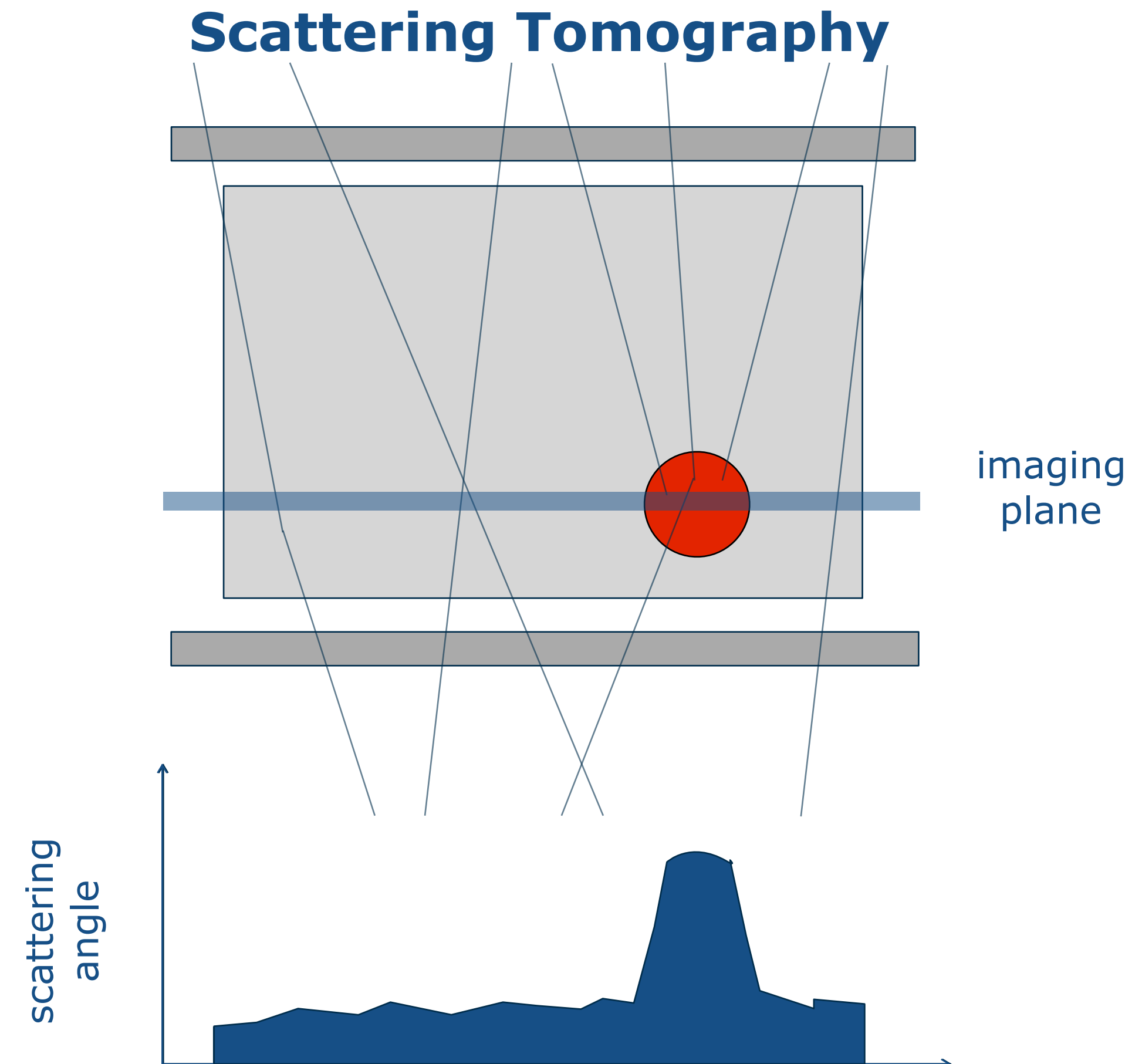
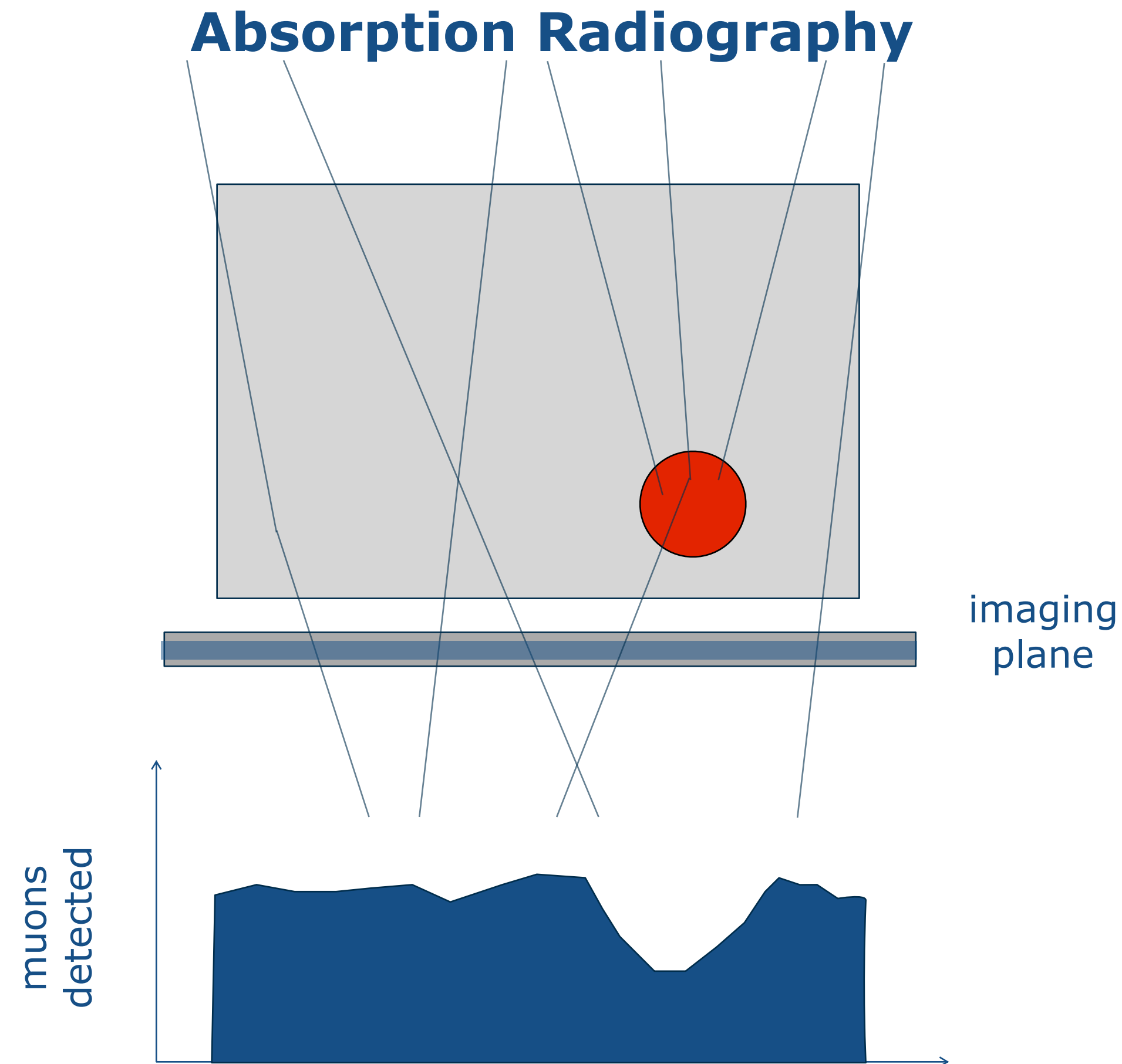
Cosmic muons, like X-rays, can image differences in density, more precisely in atomic number Z

- They can penetrate meters of concrete or stone - which absolutely no other method can do.
- They can distinguish materials: uranium - lead - steel - aluminium.
- But, at 100 muons per second per square meter, data collection takes hours to weeks.

The best applications therefore are shielded containers (e.g. for nuclear waste) or voids in large structures (e.g. bridges).



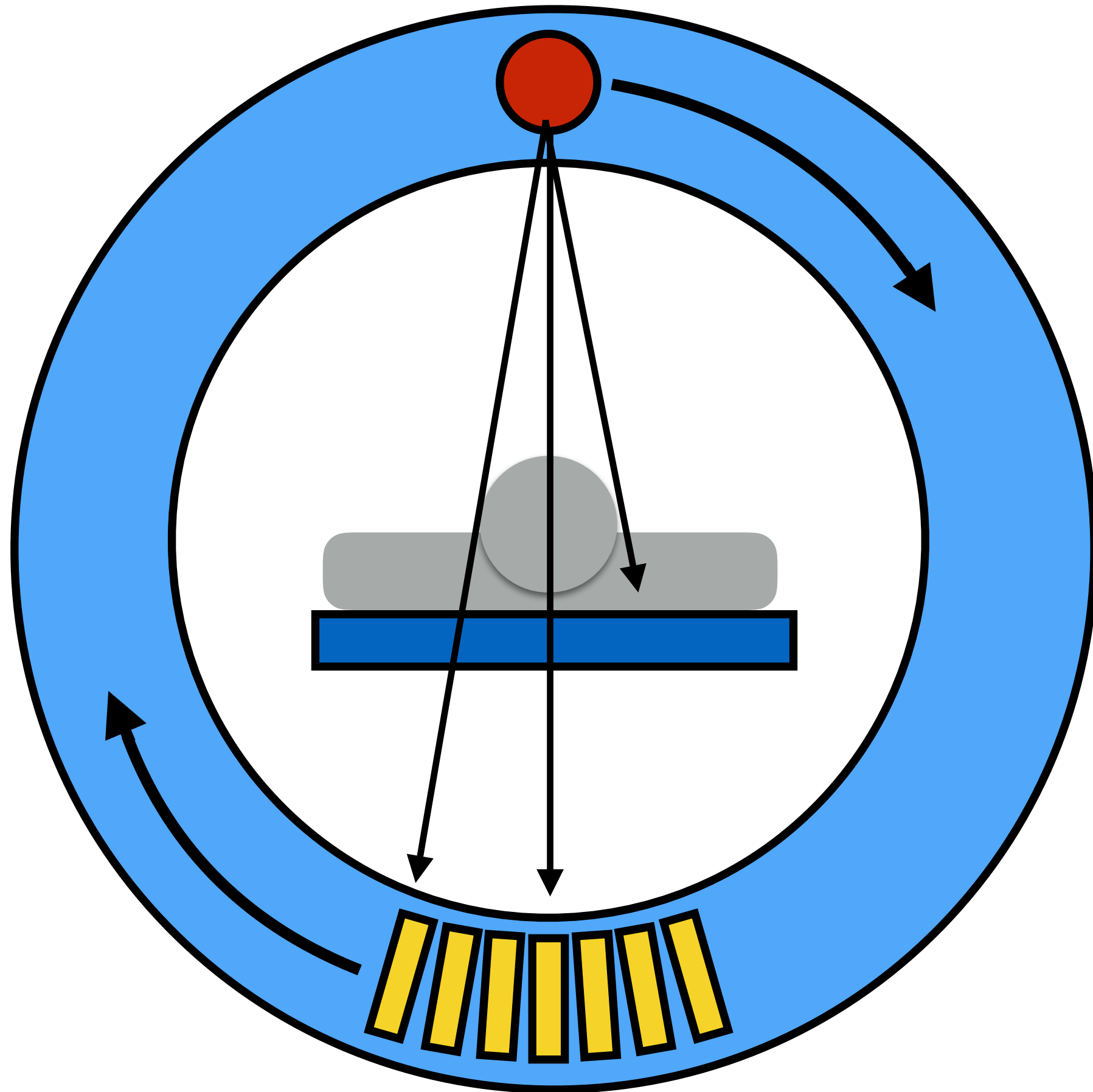
Muon Tomography



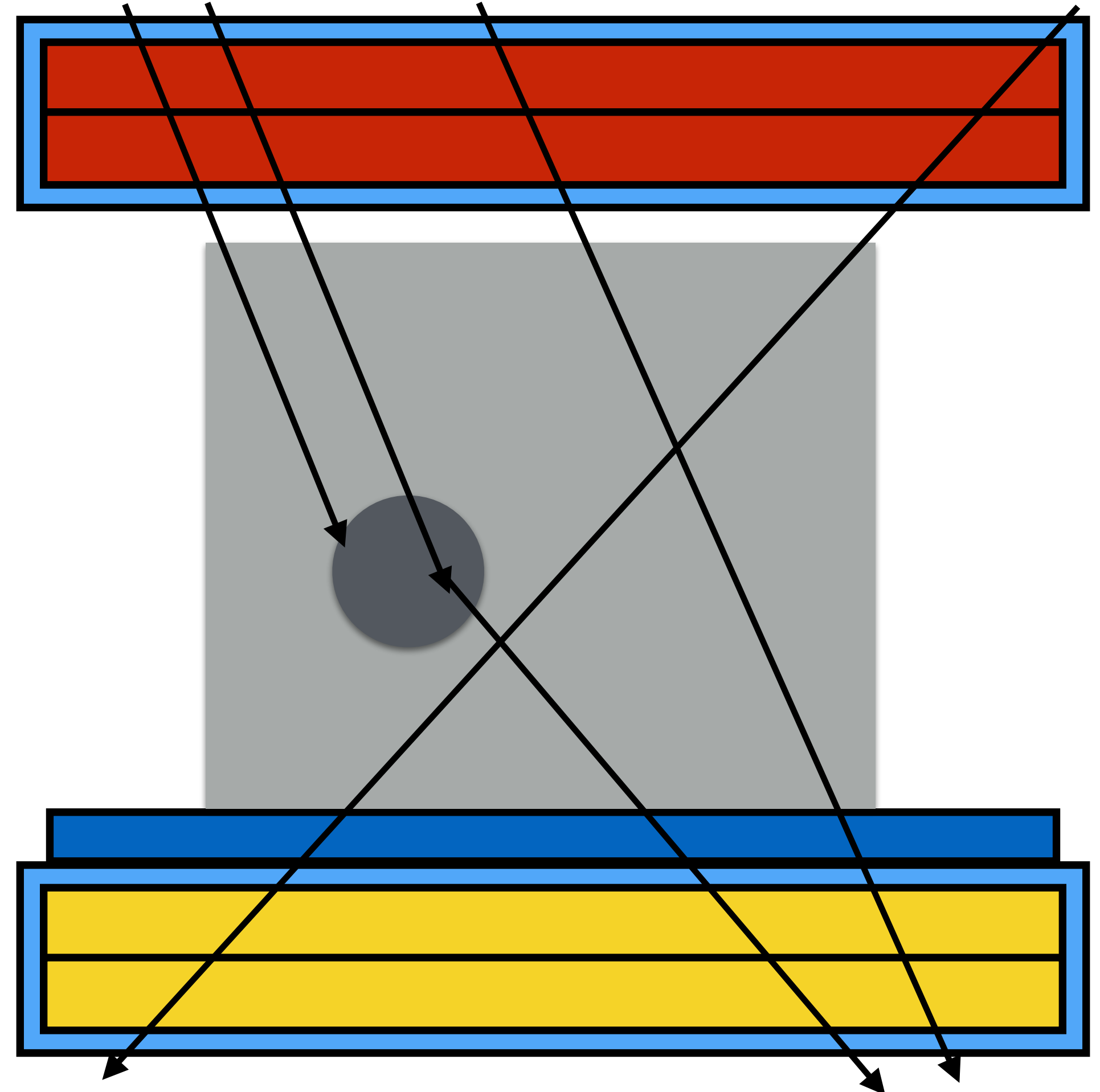
Higher density material absorbs muons and material with higher atomic number Z scatters muons through larger angles. Lynkeos Technology's imaging software combines all available information in one likelihood algorithm.



Muon Tomography

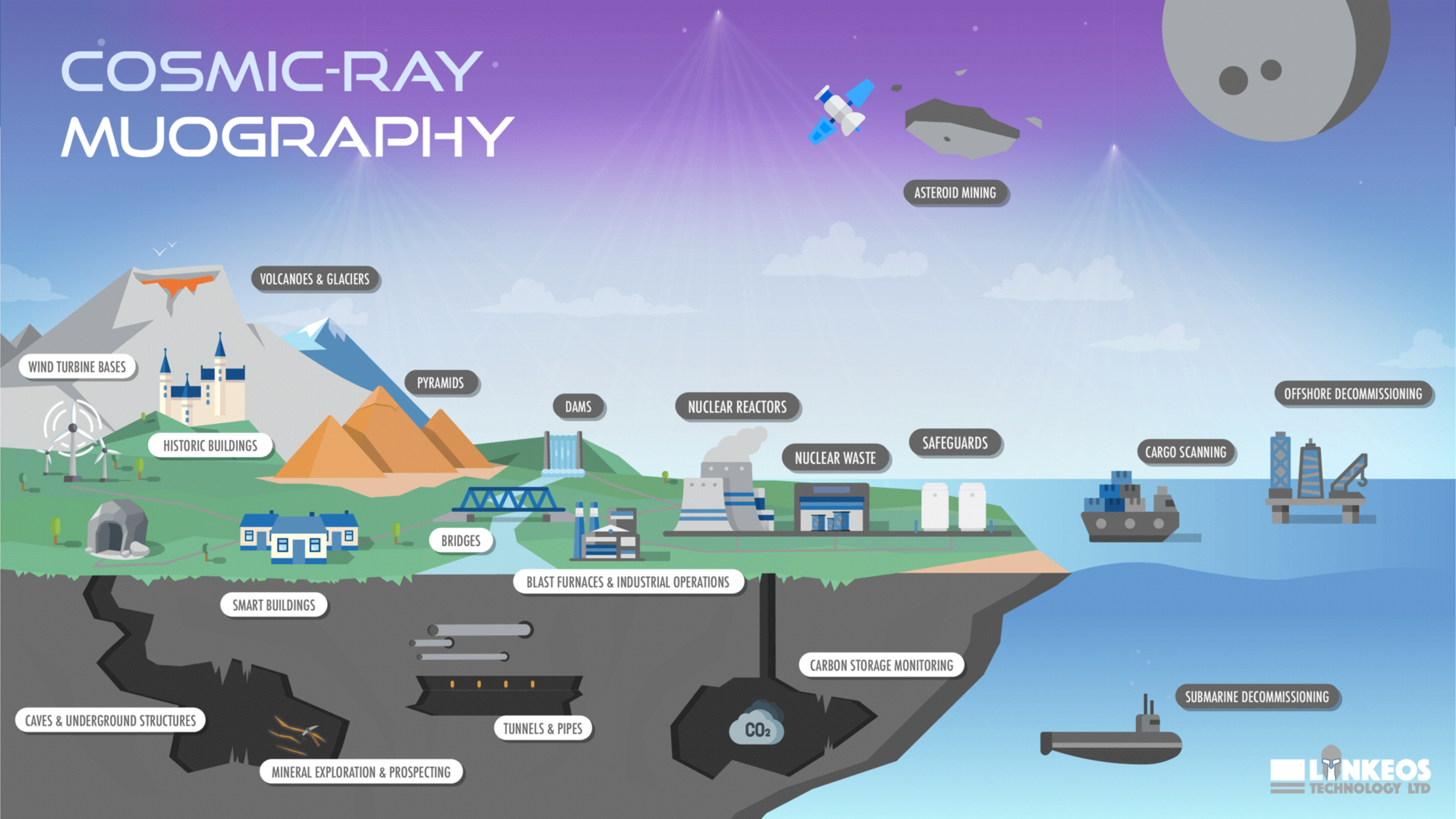


**+ - 180°
Absorption
Density**



**+ - 70° (or geometry)
Absorption & Scattering
Density & Atomic Number Z**

COSMIC-RAY MUOGRAPHY



ASTEROID MINING

VOLCANOES & GLACIERS

WIND TURBINE BASES

HISTORIC BUILDINGS

PYRAMIDS

DAMS

NUCLEAR REACTORS

NUCLEAR WASTE

SAFEGUARDS

CARGO SCANNING

OFFSHORE DECOMMISSIONING

BRIDGES

BLAST FURNACES & INDUSTRIAL OPERATIONS

CARBON STORAGE MONITORING

CAVES & UNDERGROUND STRUCTURES

TUNNELS & PIPES

MINERAL EXPLORATION & PROSPECTING

SUBMARINE DECOMMISSIONING

Great Pyramid of Khufu



The ScanPyramids project, led by K.Morishima has now found evidence for a large hidden chamber.

Nature,
2.11.2017.

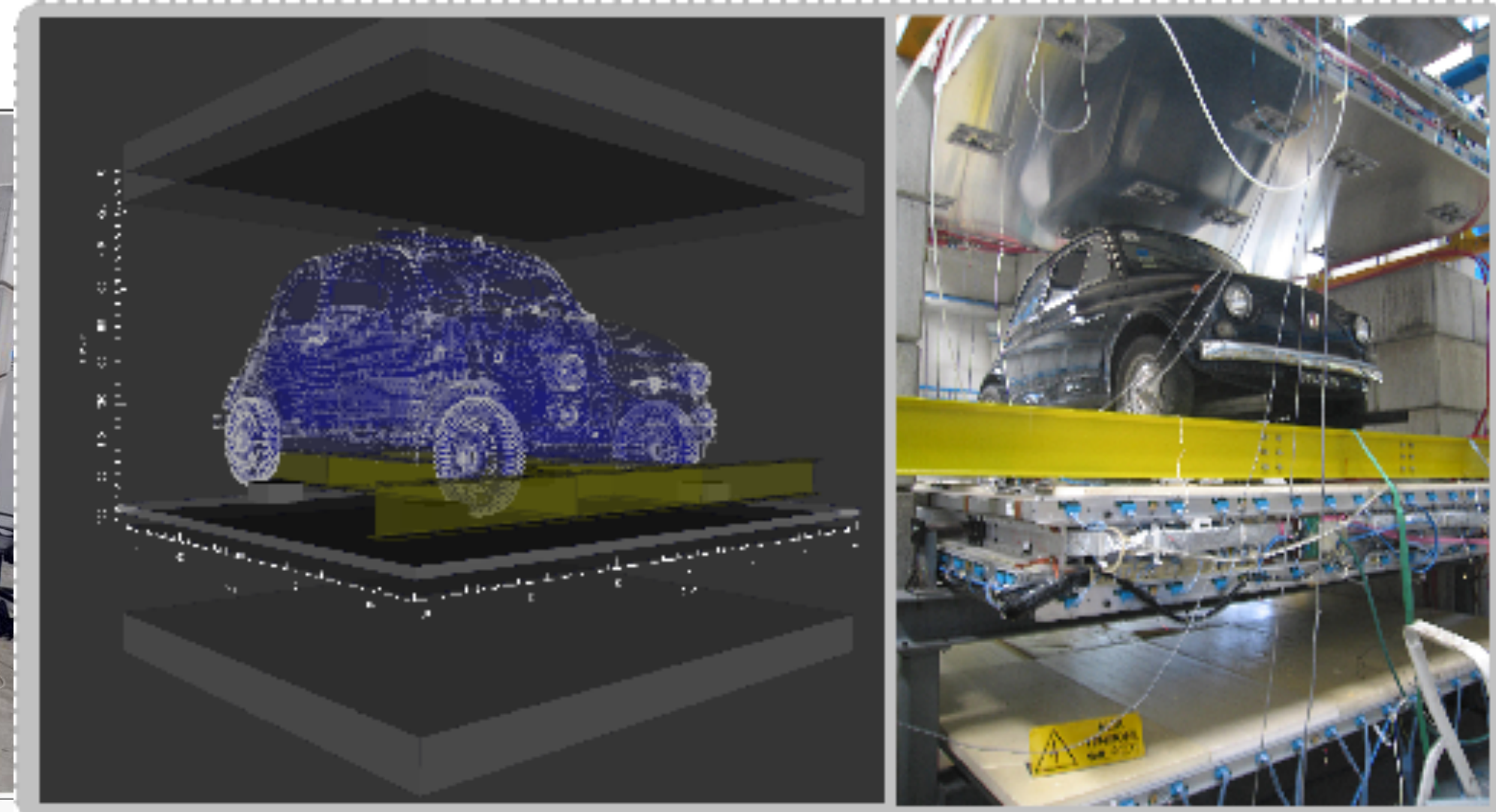
doi:10.1038/nature24647

[Procureur, RS
Workshop]



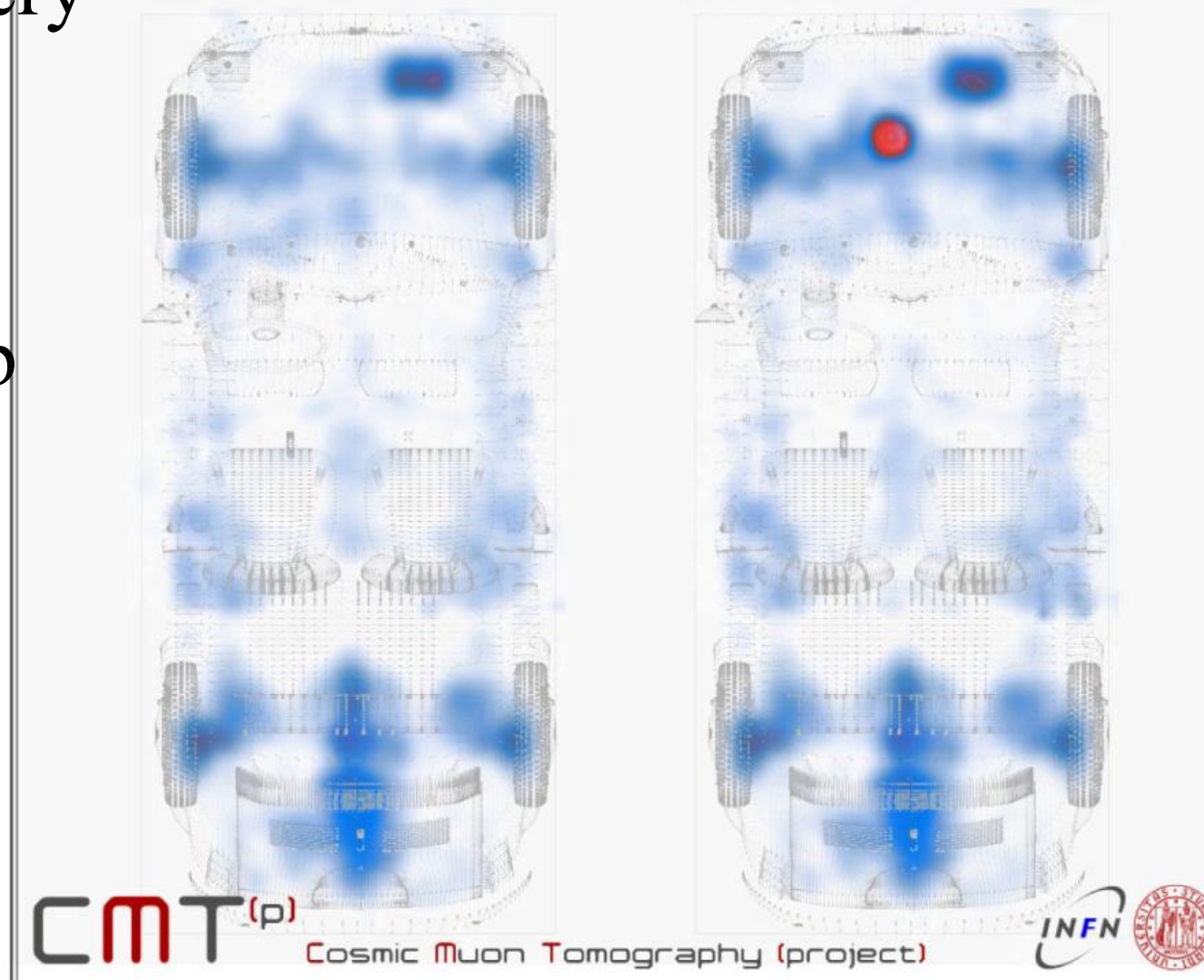
Applications - Transport Control

Other example: **FIAT 500L**
on demonstrator

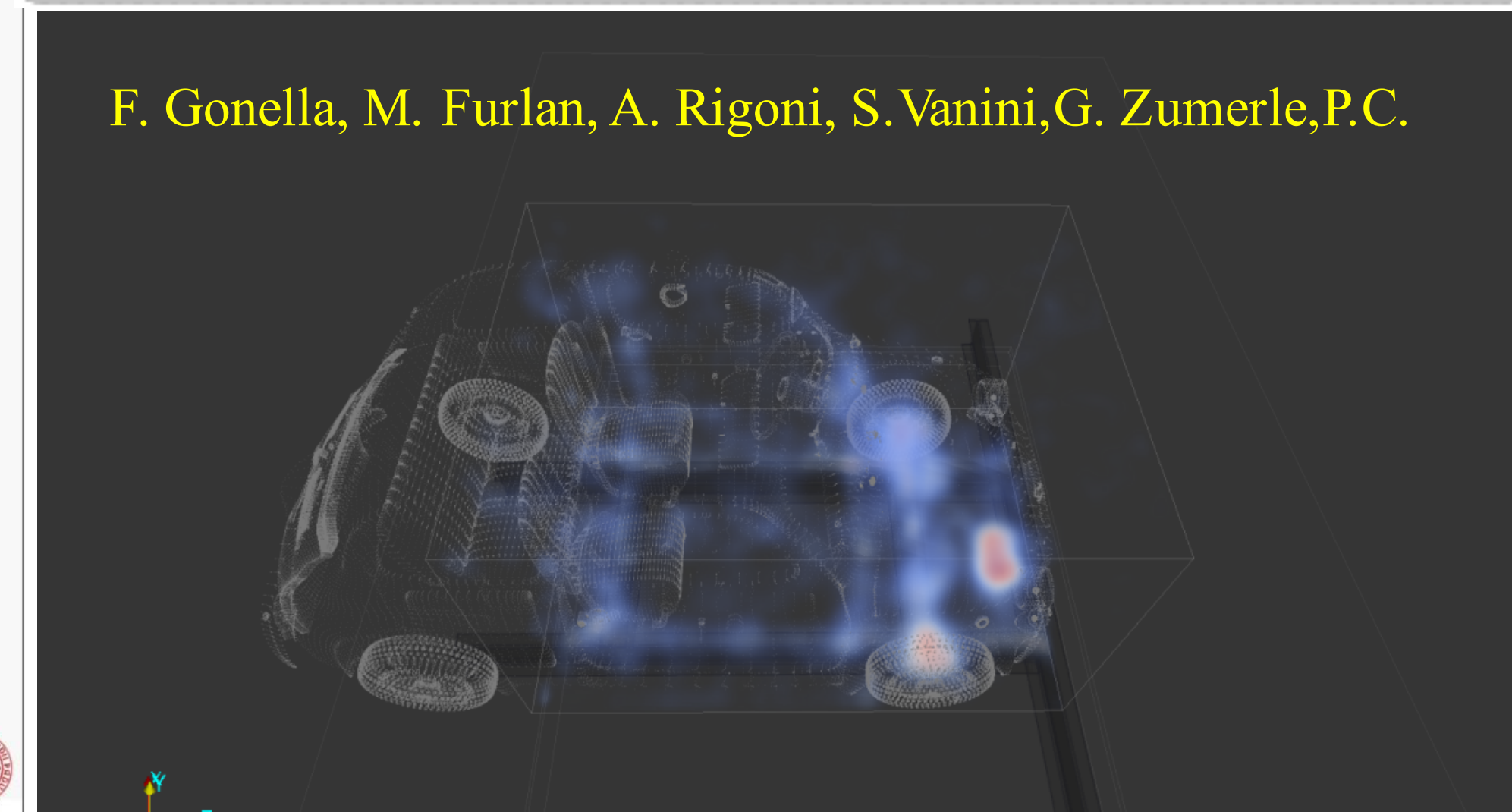


Battery

11 Pb



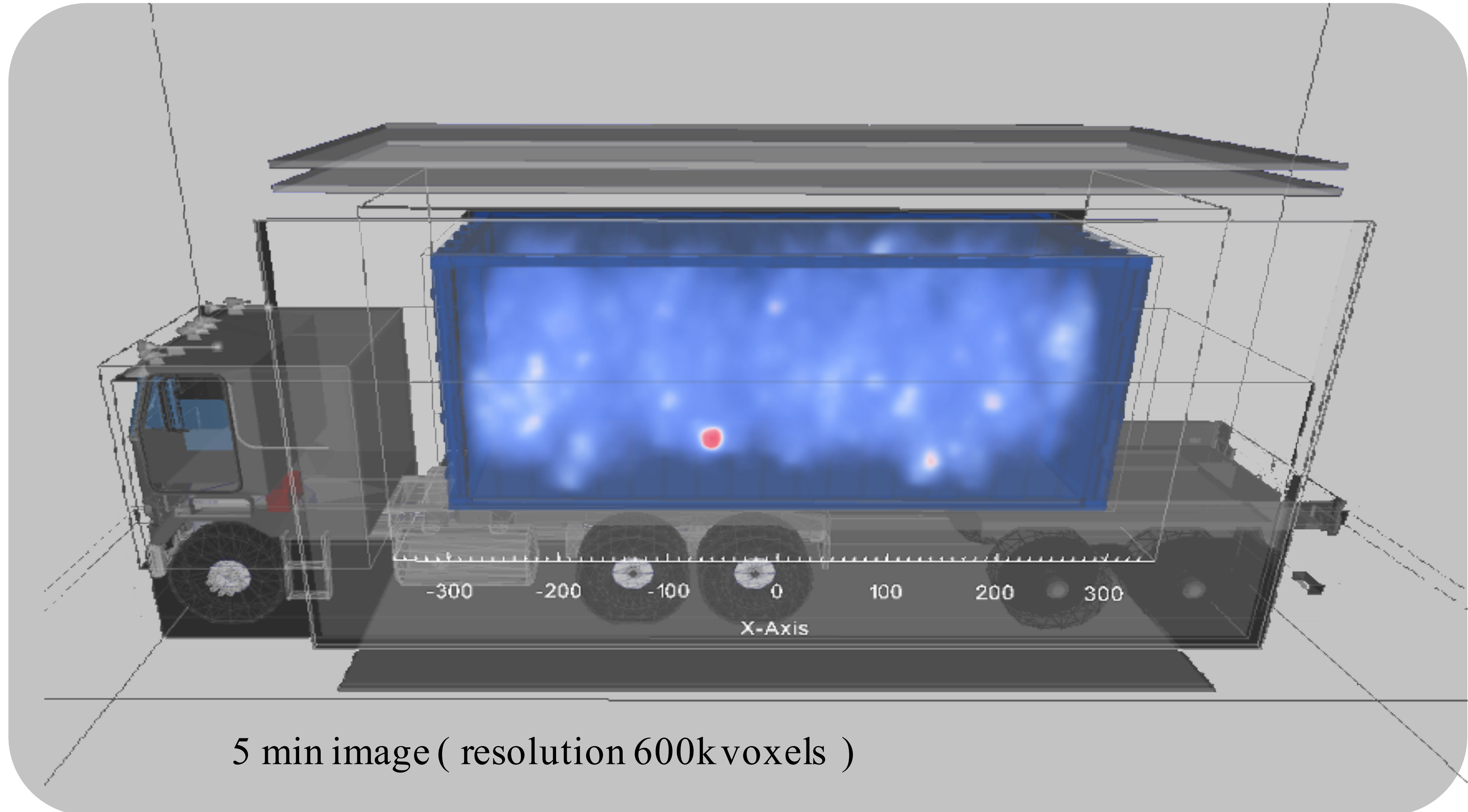
F. Gonella, M. Furlan, A. Rigoni, S. Vanini, G. Zumerle, P.C.



[Checchia,
RS workshop]



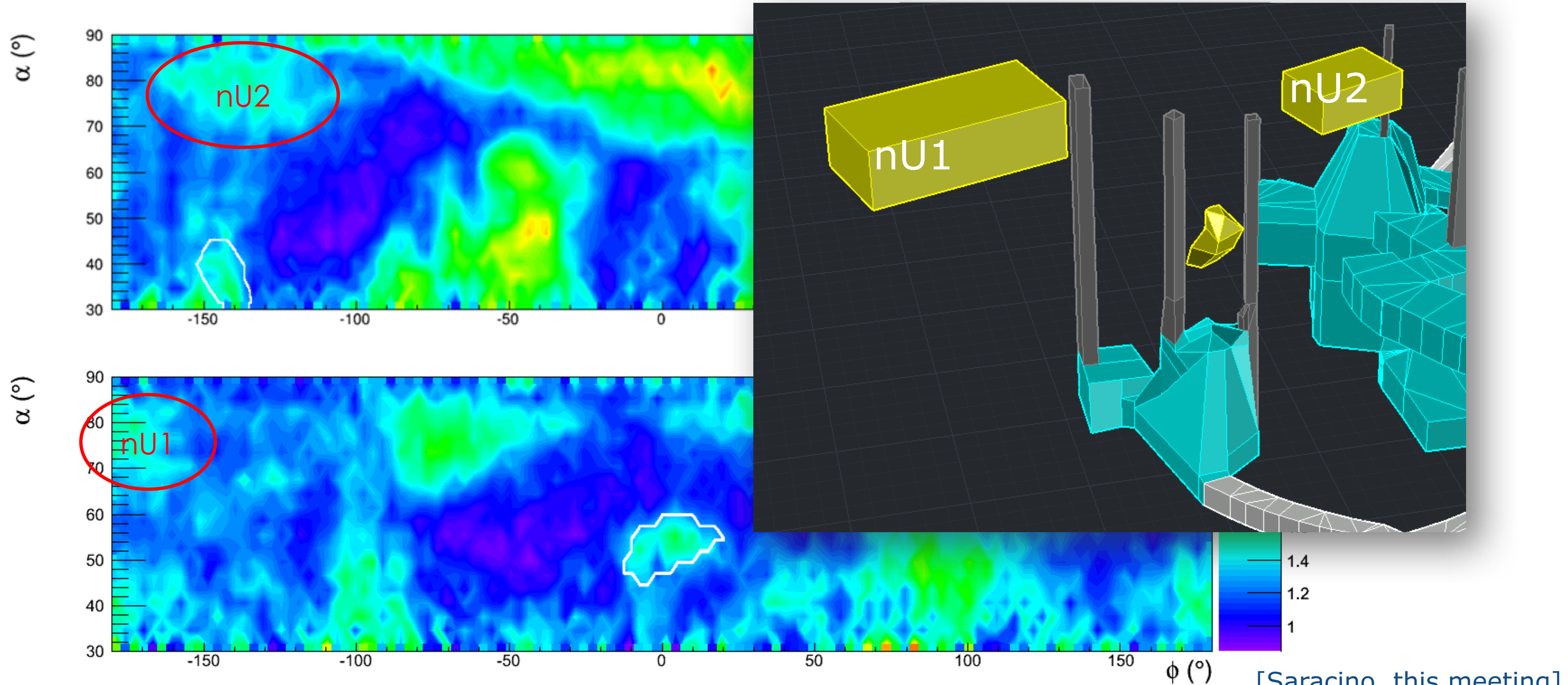
Applications - Cargo Inspection



5 min image (resolution 600k voxels)

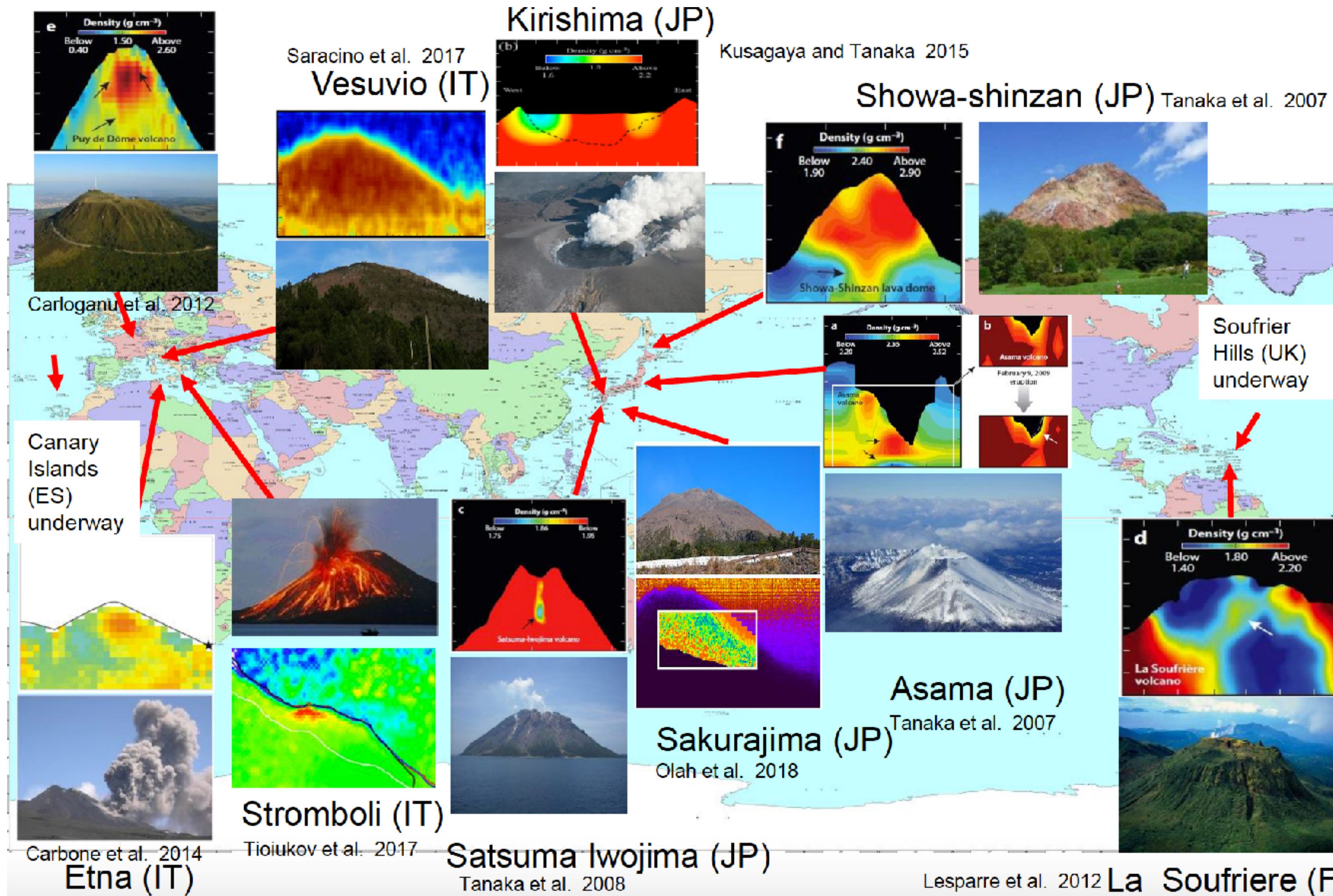


Applications - Underground Structures



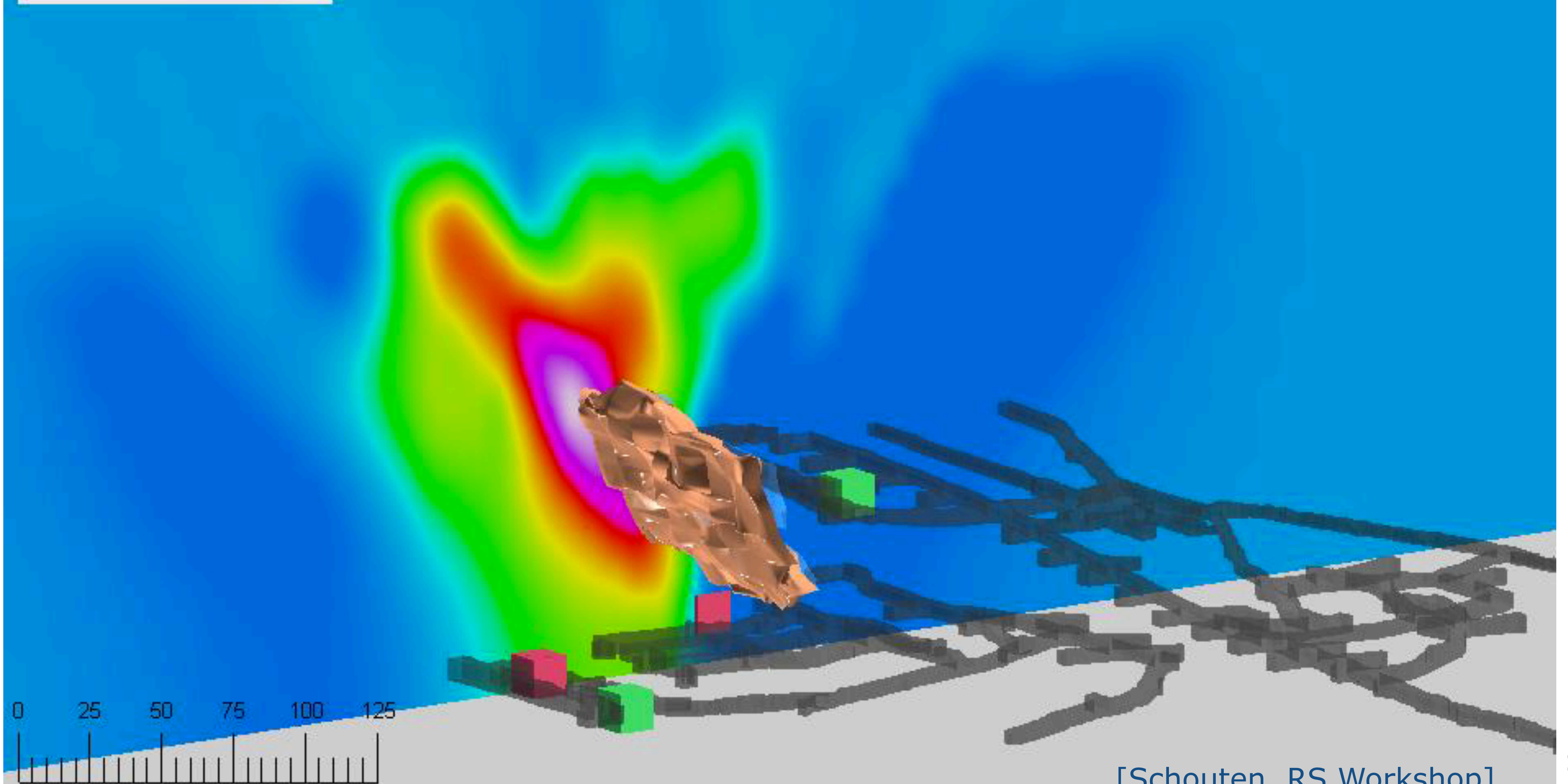
[Saracino, this meeting]

Muography of Volcanoes



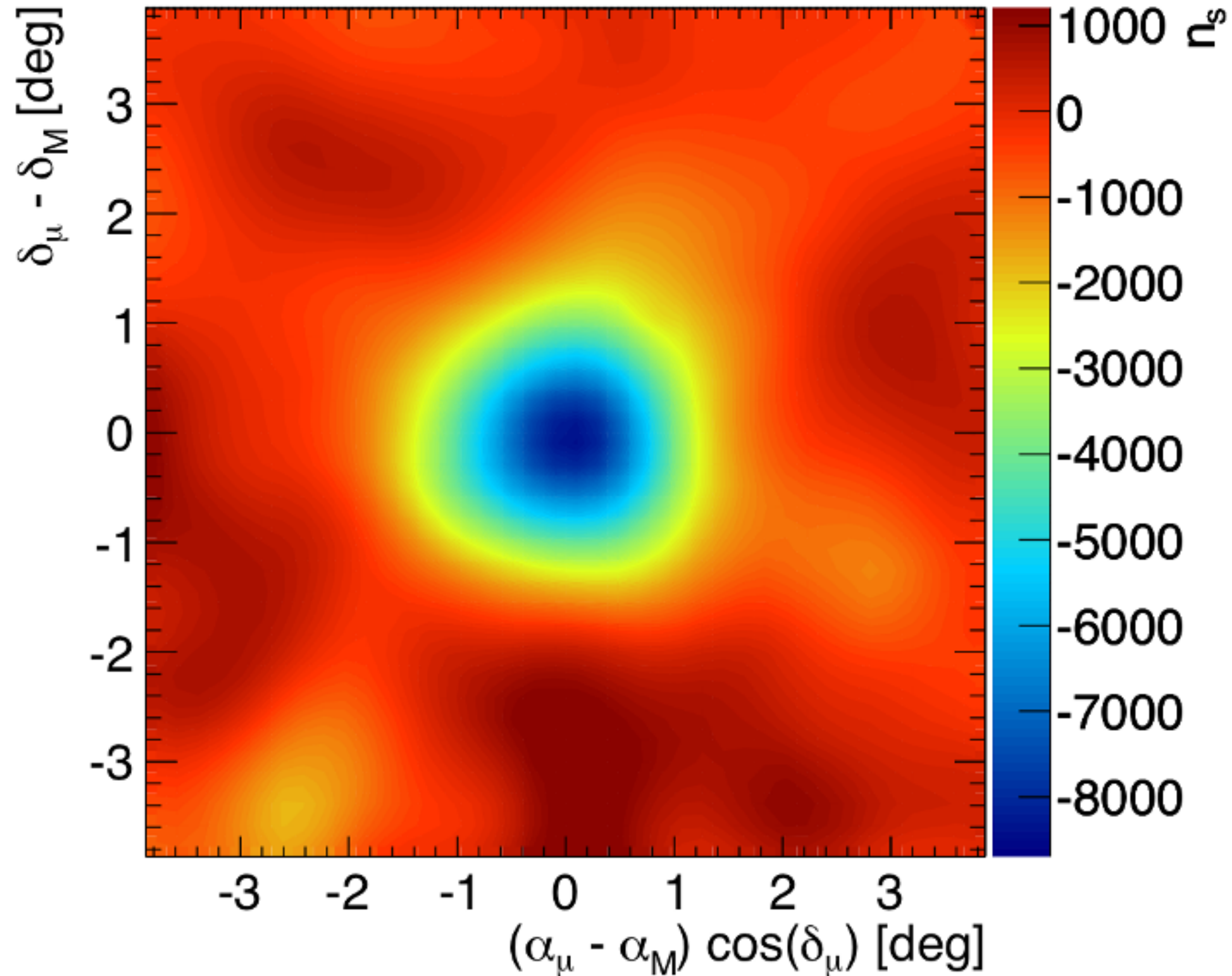


Field Data





Underground Detector Calibration



Muon shadow
of the Moon
as seen by
Icecube



Static Systems



MIS, Lynkeos Technology, UK



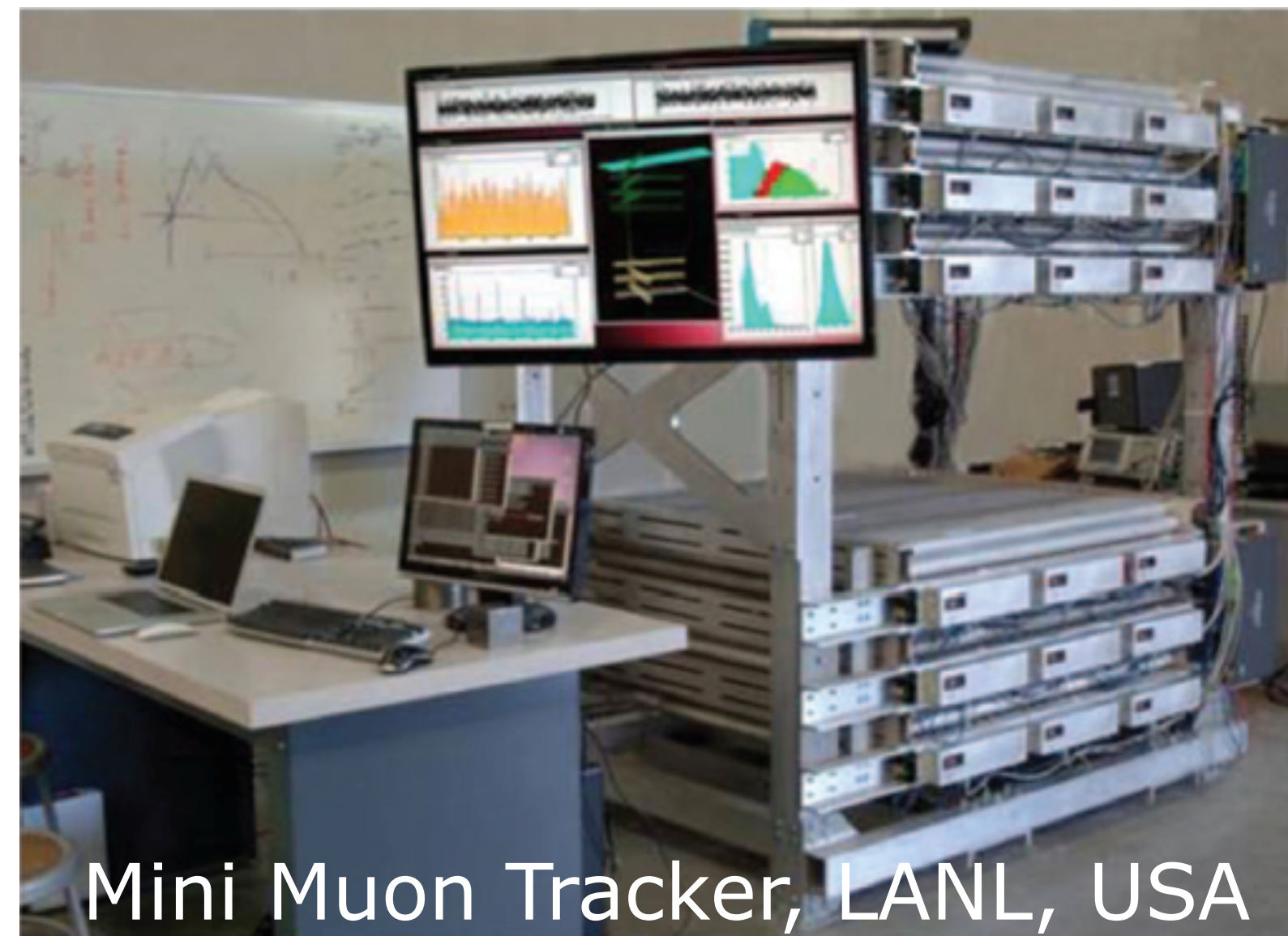
INFN Padova, Italy



Muon Systems, Spain



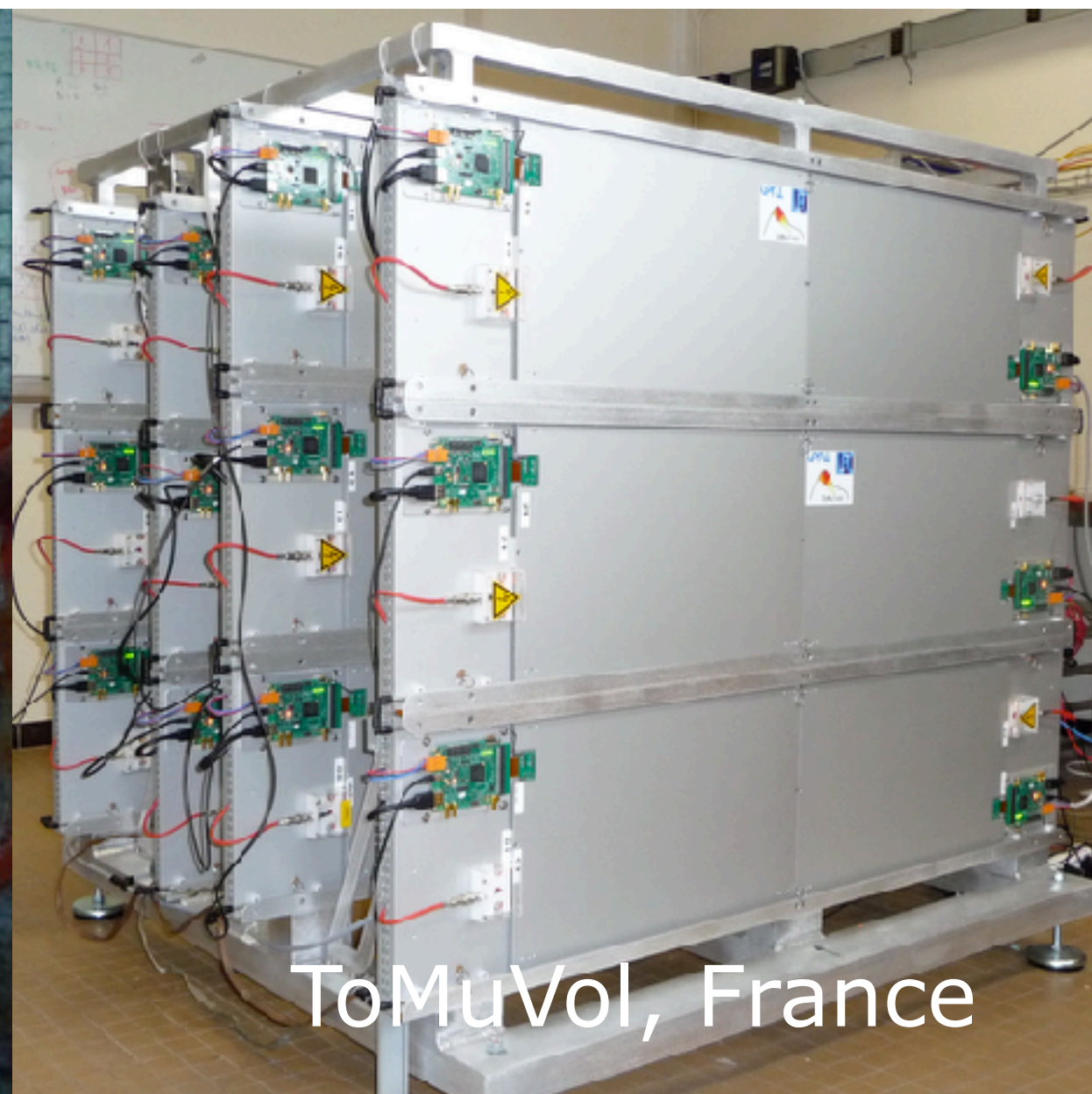
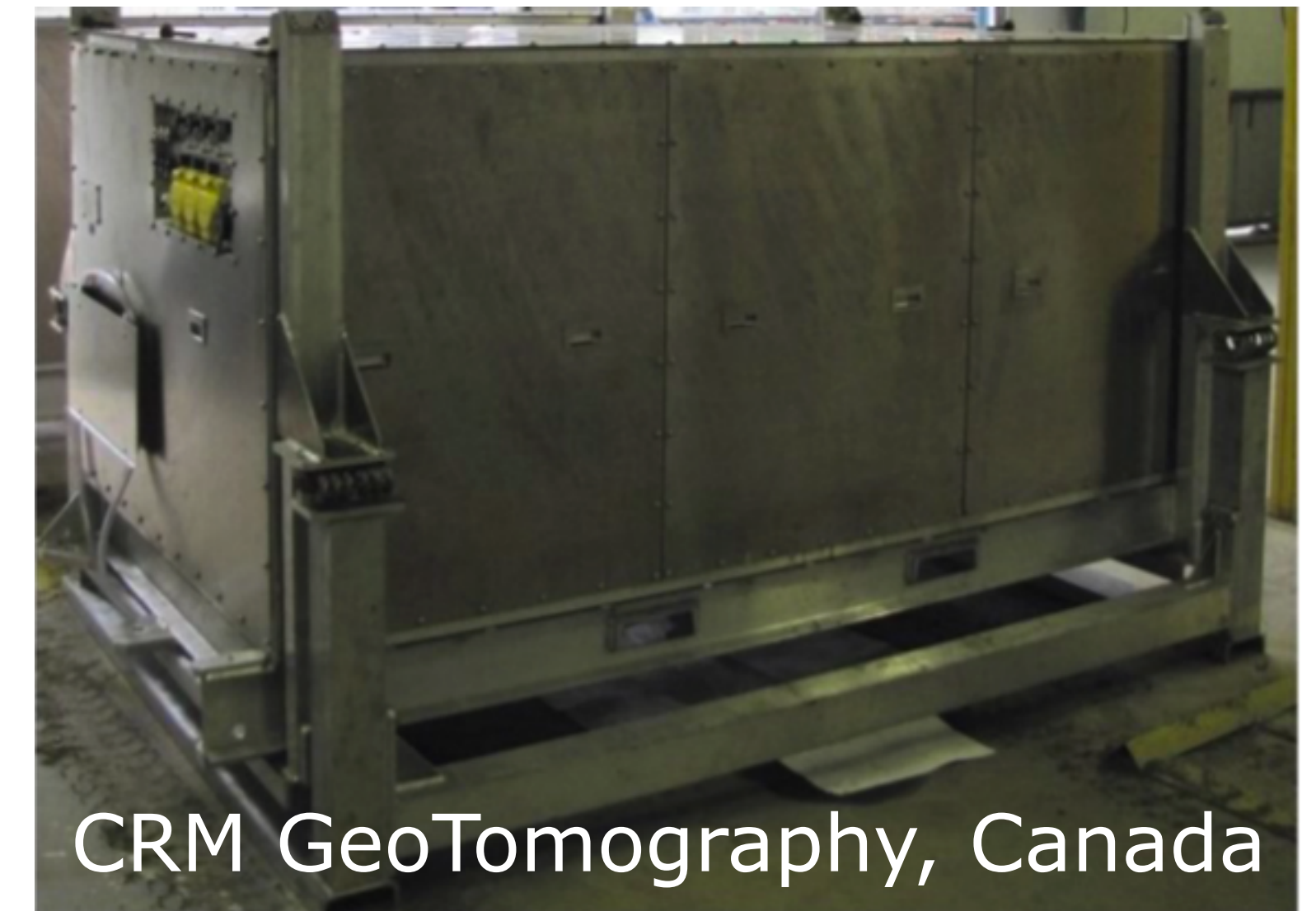
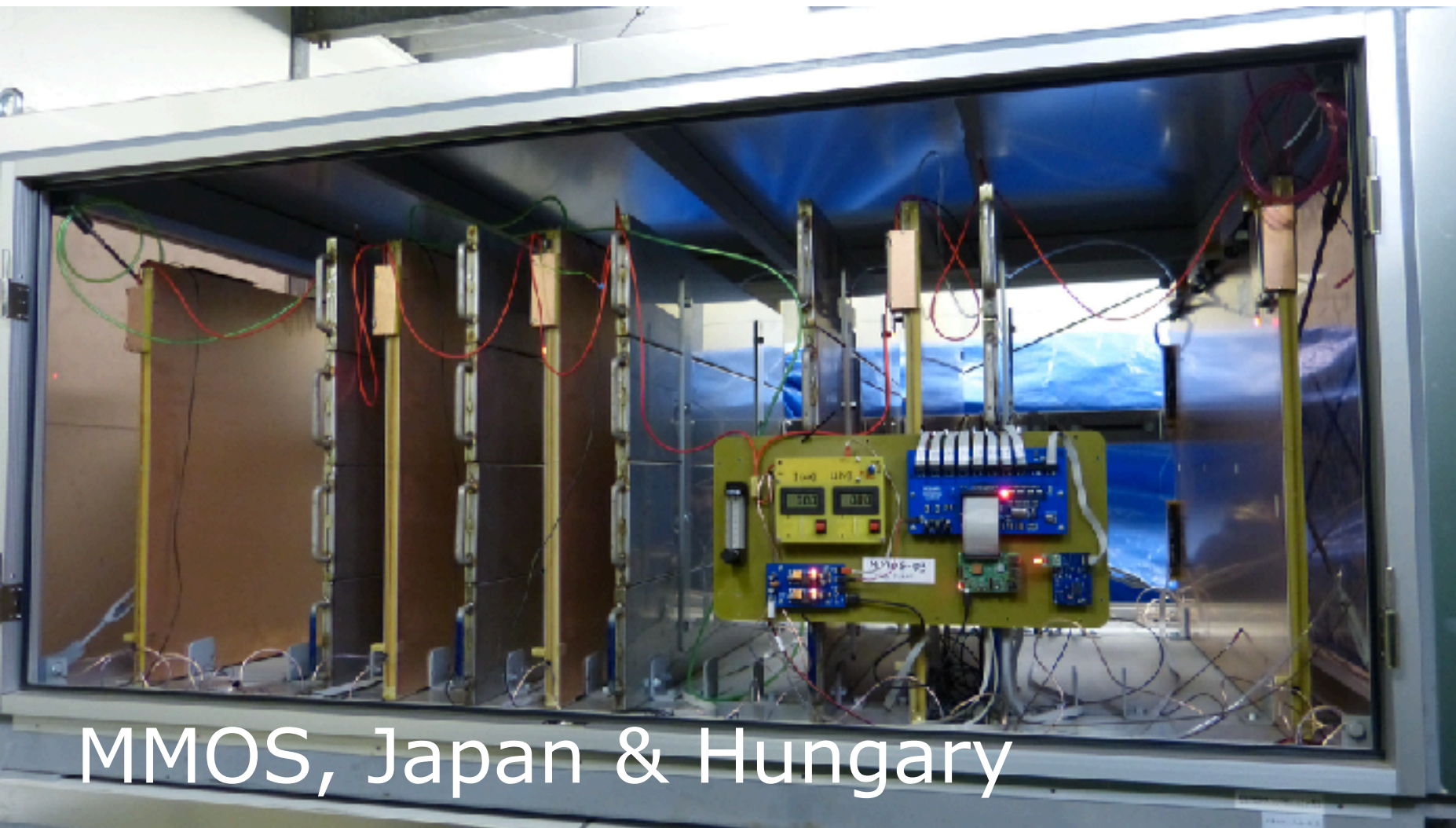
Decision Sciences, USA



Mini Muon Tracker, LANL, USA



Mobile Systems





Lynkeos Technology Ltd.



Lynkeos was one of the Argonauts who accompanied Jason on his quest aboard the Argo to retrieve the golden fleece.

He was said to have excellent sight, even being able to see through trees, walls and underground to warn of any hidden dangers.

Lynkeos Technology Ltd. has developed an innovative 3D imaging system that harnesses the power of the Universe to do very much the same thing...



Lynkeos Timeline

2009

'Muon Project' initiated by



University of Glasgow



with funding from the UK NDA and Sellafield Ltd.

- Simulation feasibility study (2009)
- Small-scale prototype R&D (2009-2011)
- First results (2012)
- Successful blind test (2012)

2013

Full-scale Demonstrator R&D started

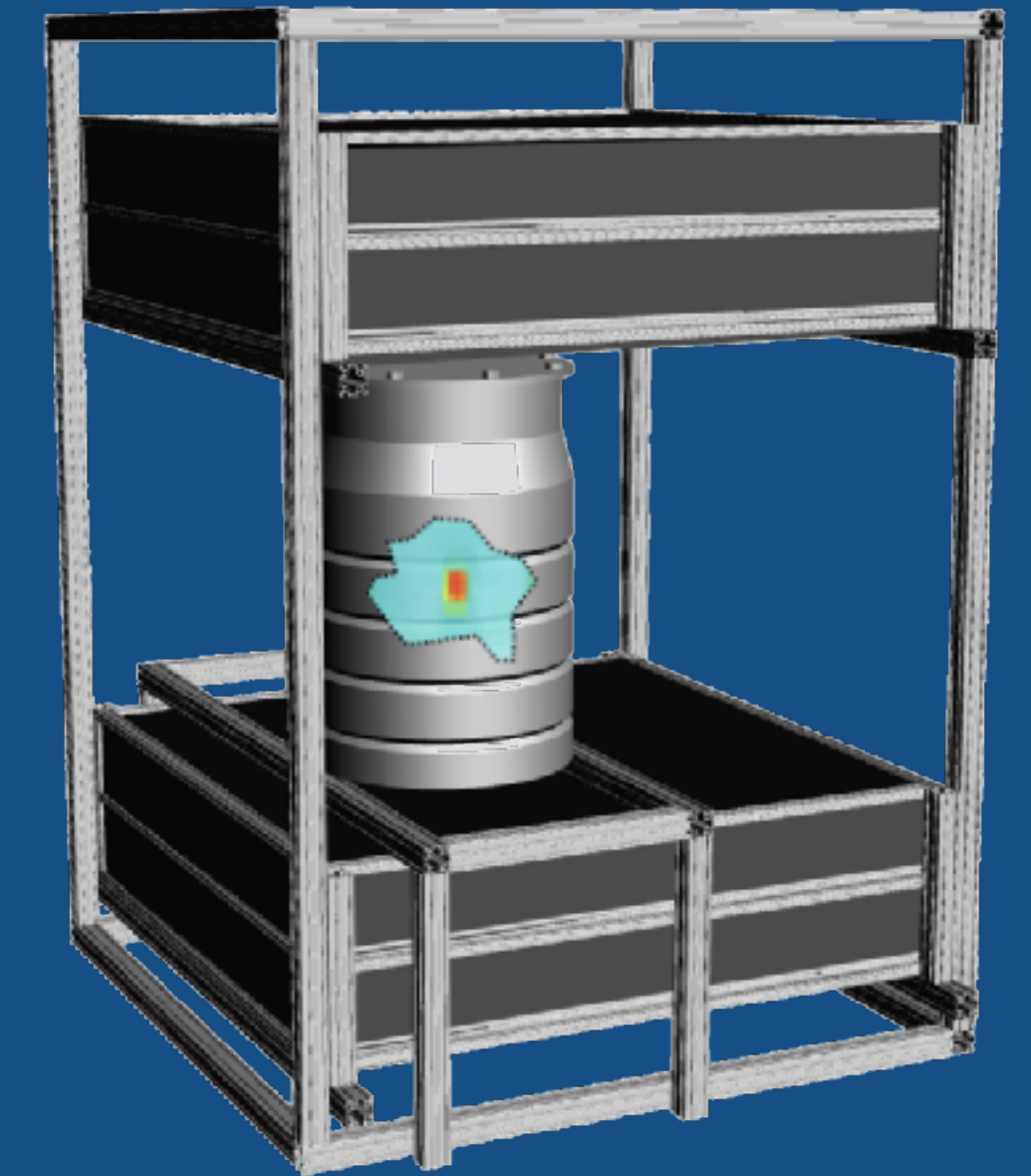
- R&D Programme (2013-2015)
- Collaboration with INFN Napoli & Firenze on nuclear silos (2014)
- First Demonstrator results (2016)
- Successful blind test with industry standard (2016)

2016

Lynkeos Technology formed

- Innovate UK First Of A Kind Deployment of Innovation contract (2017)
- CE Certification achieved for Muon Imaging System (2018)
- First commercial imaging contract (GeoMelt®, 2018)
- Global, first deployment at Sellafield (2018)
- Highly Commended technology by UK NDA (2018)
- Institute of Physics Business Start-up Award (2018)
- Rushlight Nuclear Energy Award (2018/19)
- H2020 ATTRACT '3DSCINT' project started with Swansea University (2019)

Present



 **Rushlight Awards**
Winner 2018/19

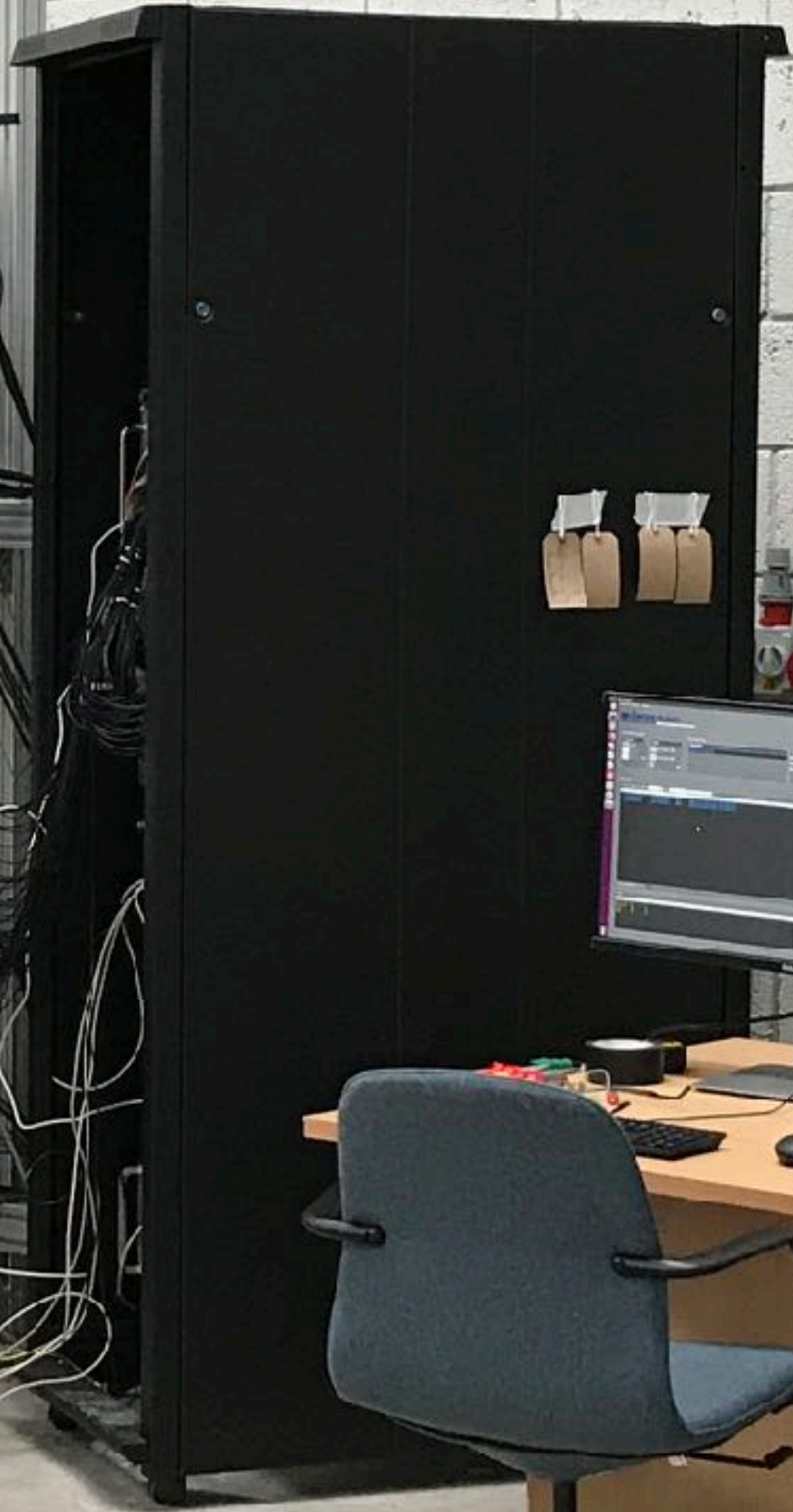
 **Business Start-up Award 2018**
IOP Institute of Physics

 **NDA Group Supply Chain Awards 2018**
HIGHLY COMMENDED



LYNKEOS
TECHNOLOGY LTD
lynkeos.co.uk

MUON
IMAGING
SYSTEM





Lynkeos Muon Imaging System at NNL Central Lab

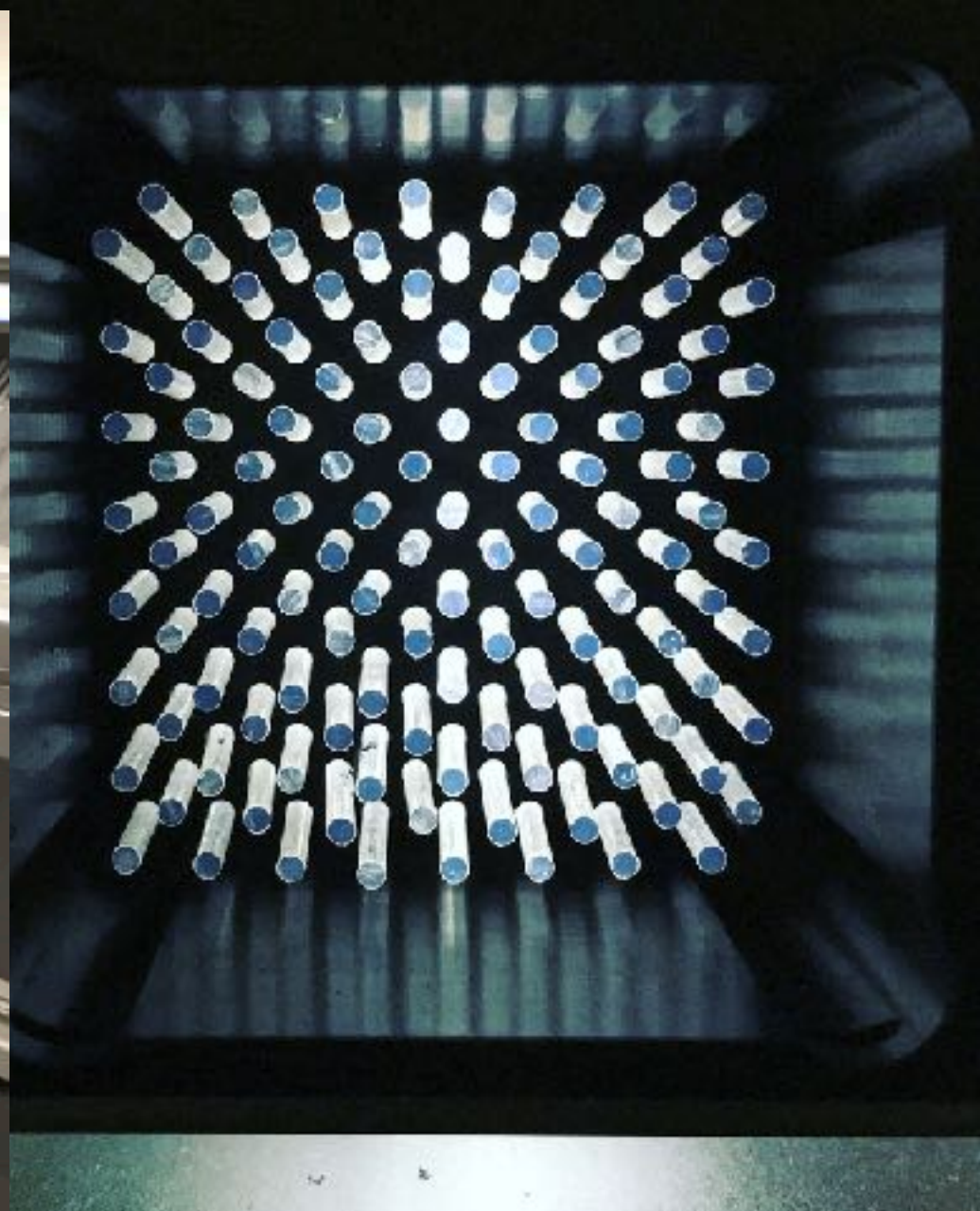
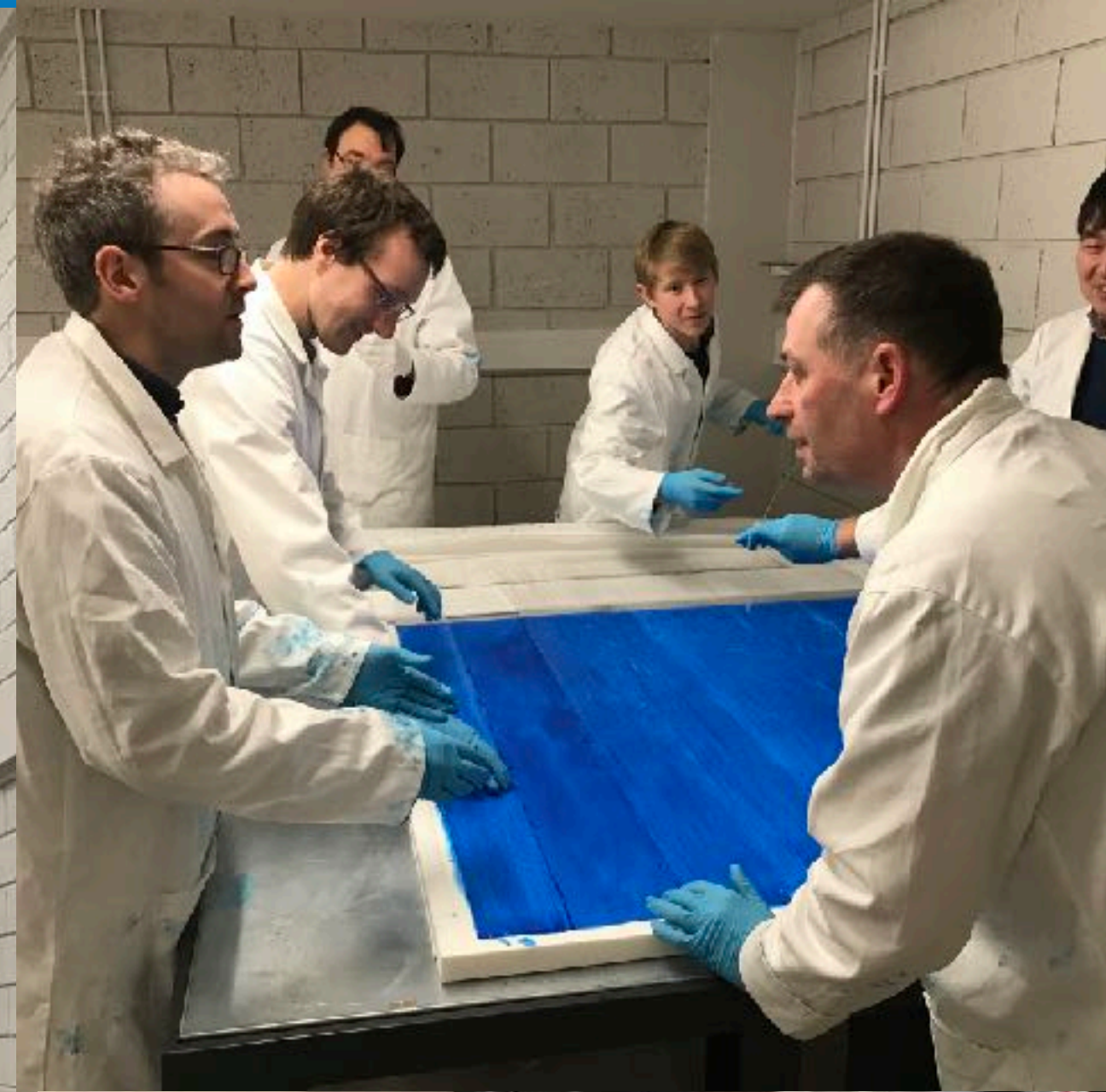


NATIONAL NUCLEAR LABORATORY






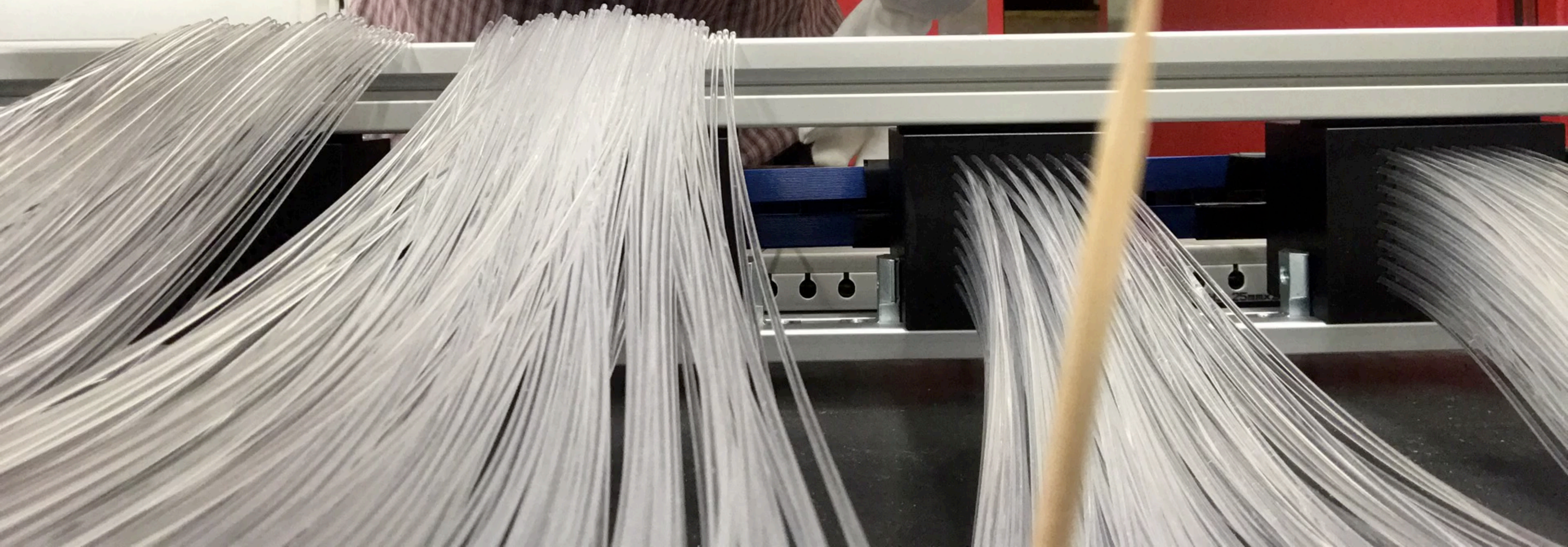
Muon Imaging System Construction



TOP

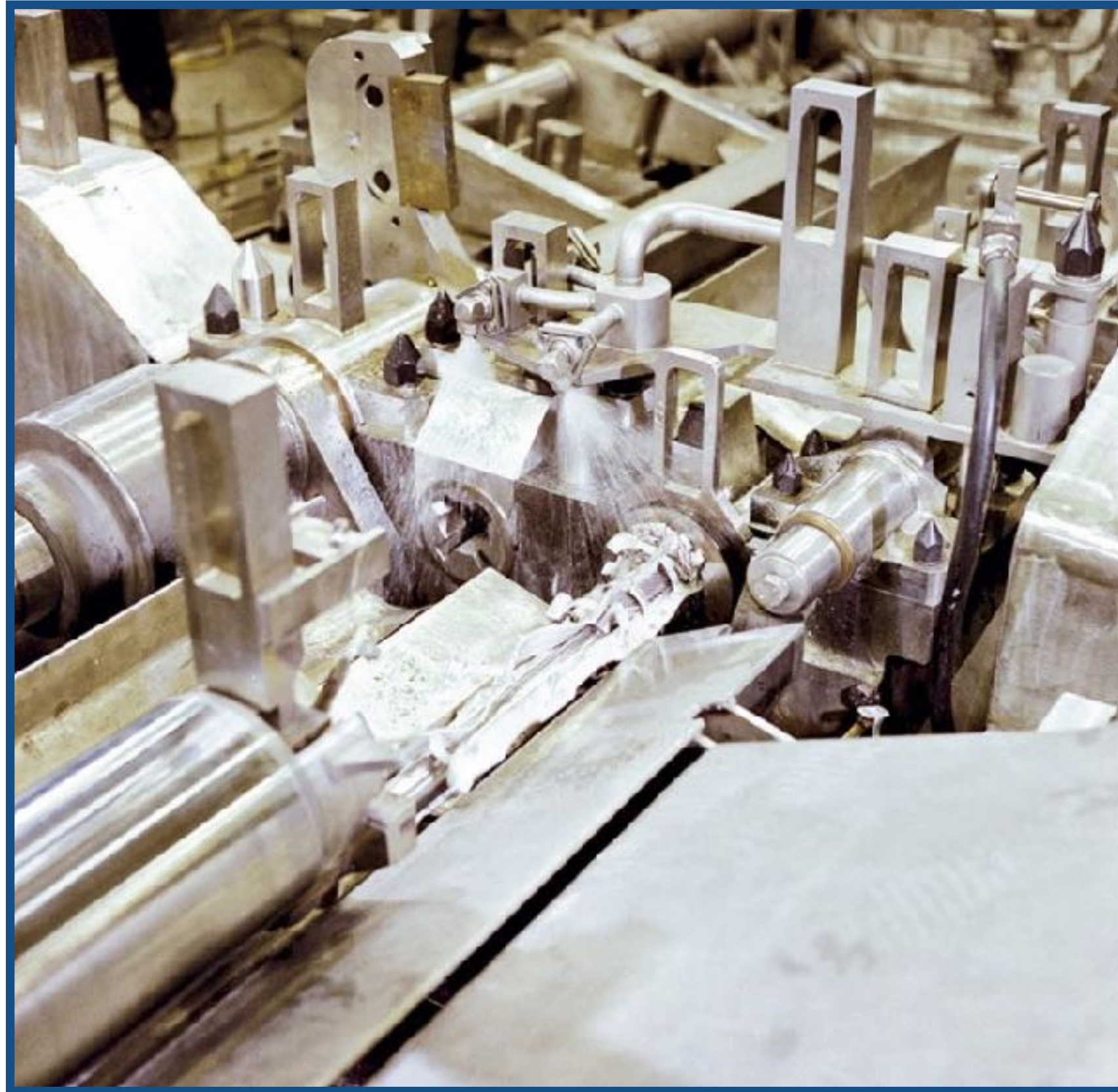


Hi TC,
I pinched the maps
to re-simulate the
change we discussed.
Maps are in my office.
DAVID
xy





Nuclear Waste Characterisation



Fuel Rod Cladding Removal



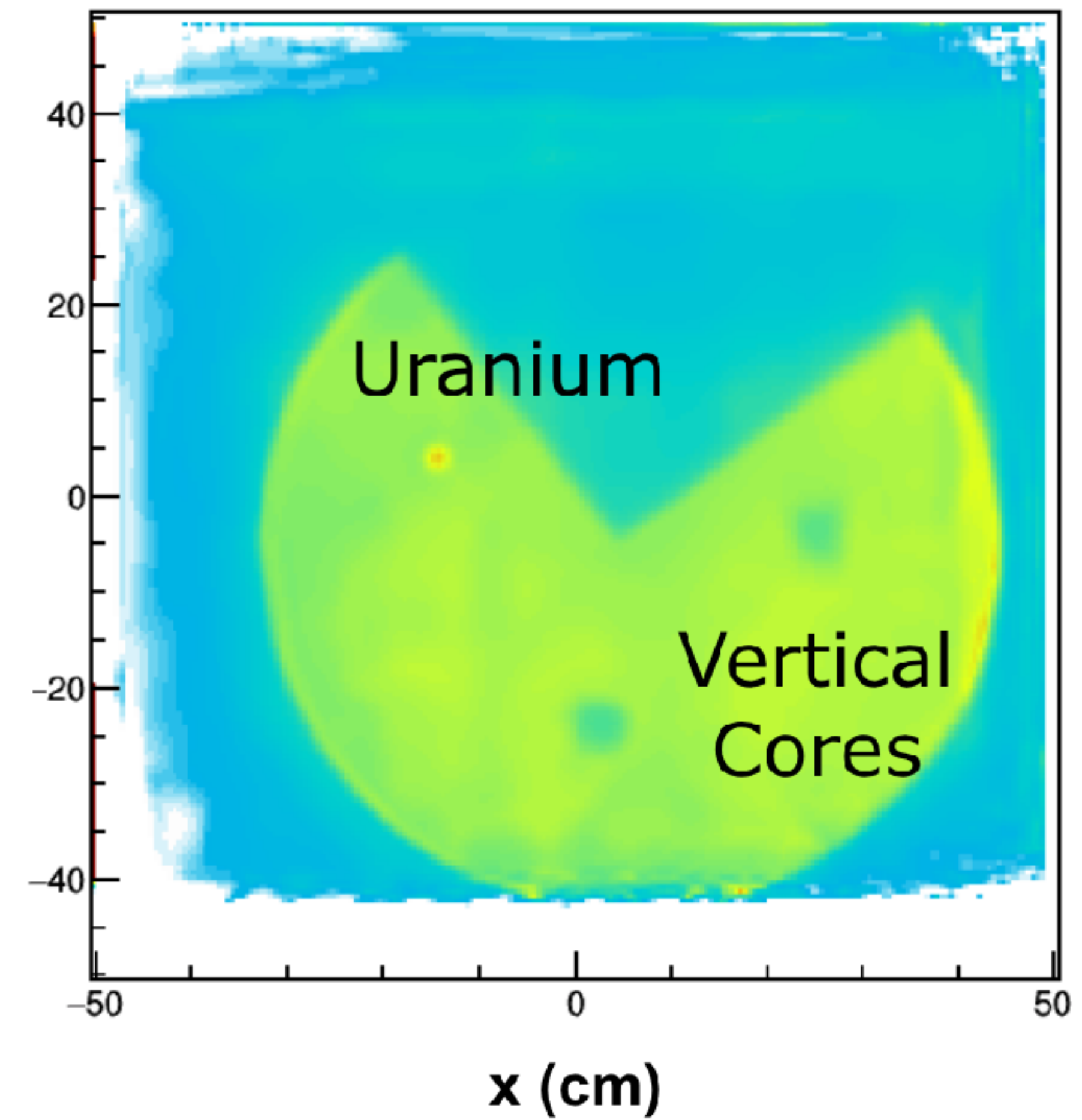
ILW Cross Section, Cladding & Grout



ILW Drum (3D Scan)

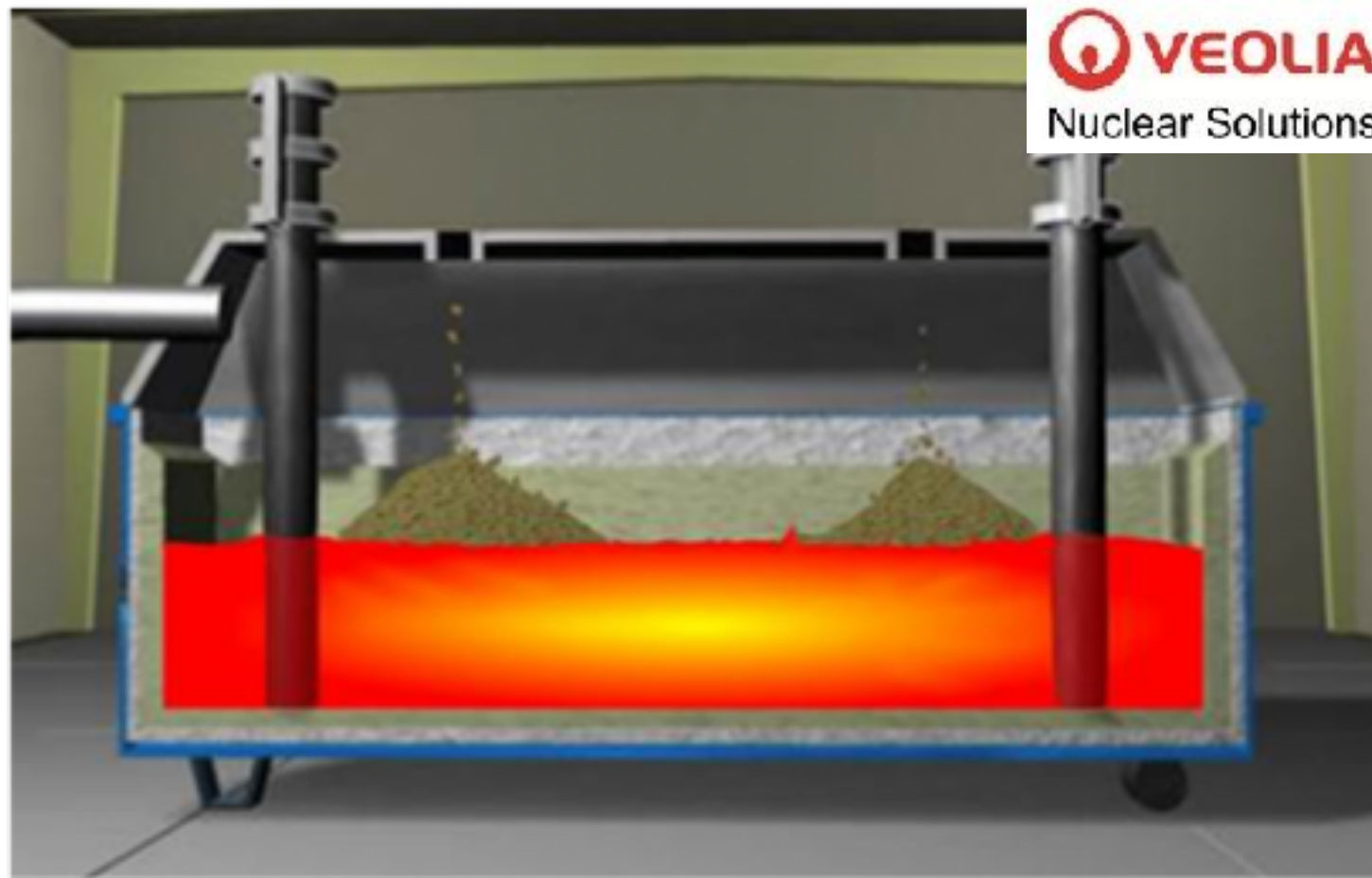
While stripping the cladding from nuclear fuel rods, pieces of uranium may end up in the waste drums. Over time this uranium corrodes and can ultimately lead to a breach of the containment. Were a barrel to suffer a containment breach, it would become necessary to build a new store and to repackage.

ILW Drum

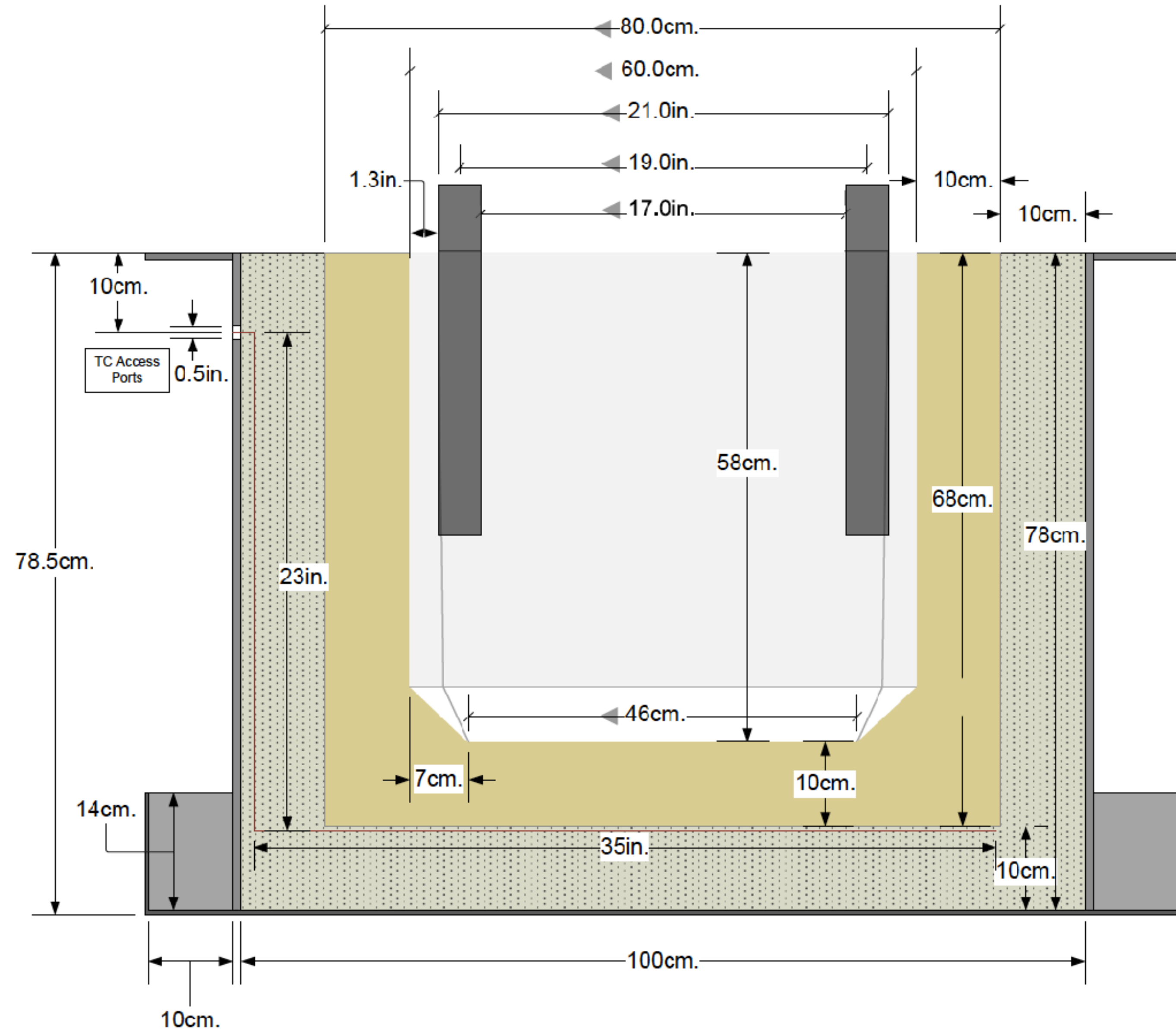
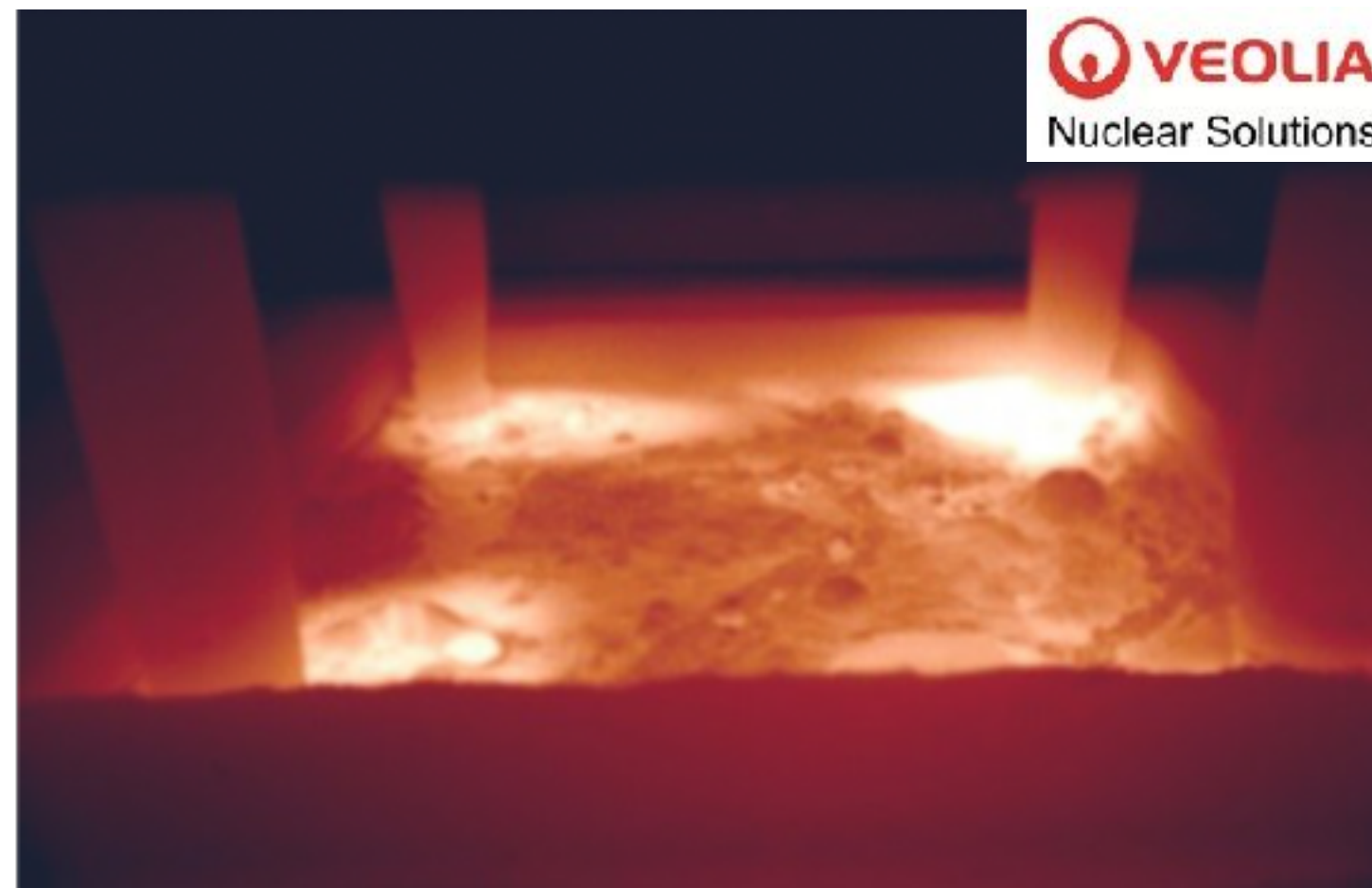




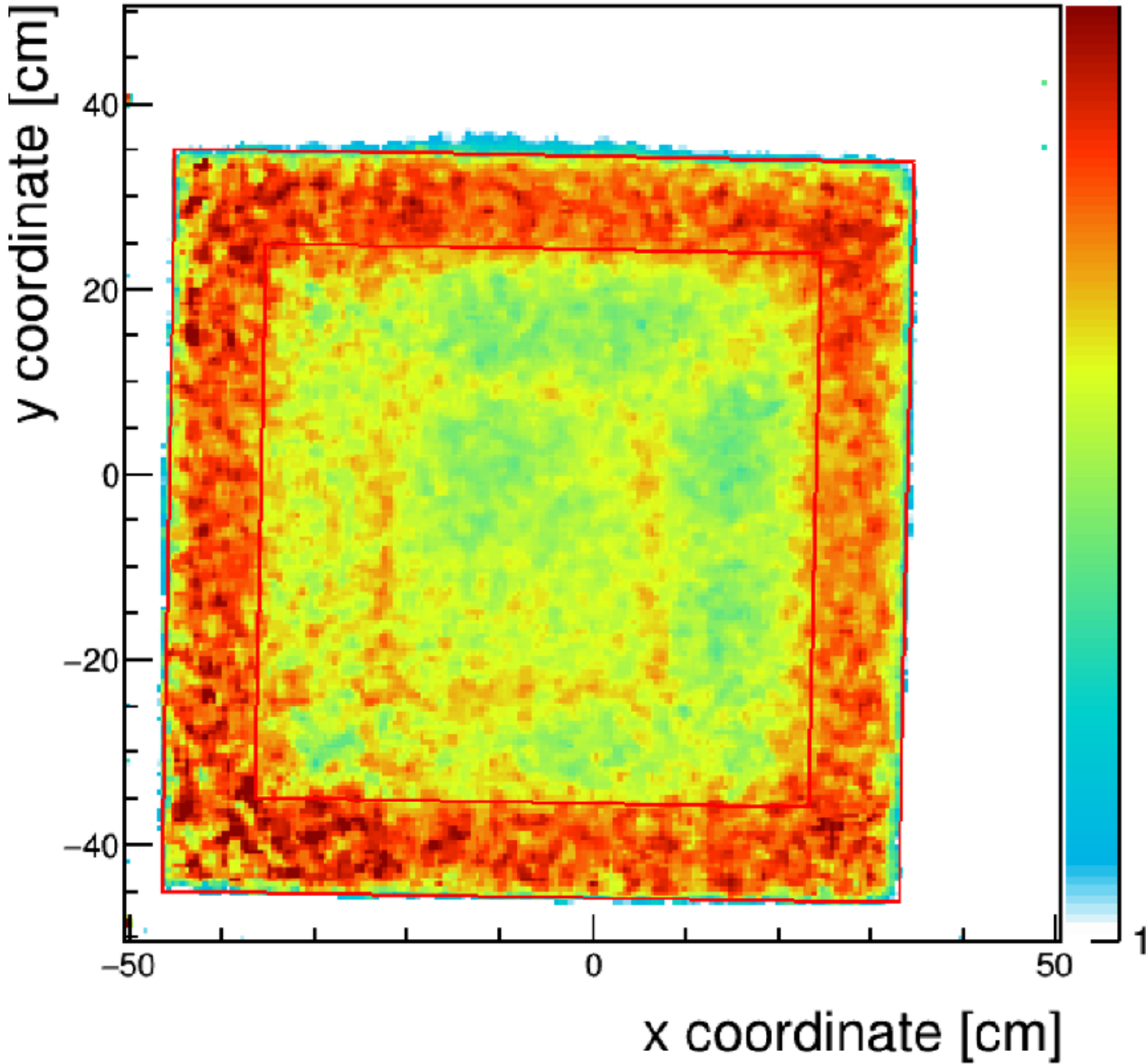
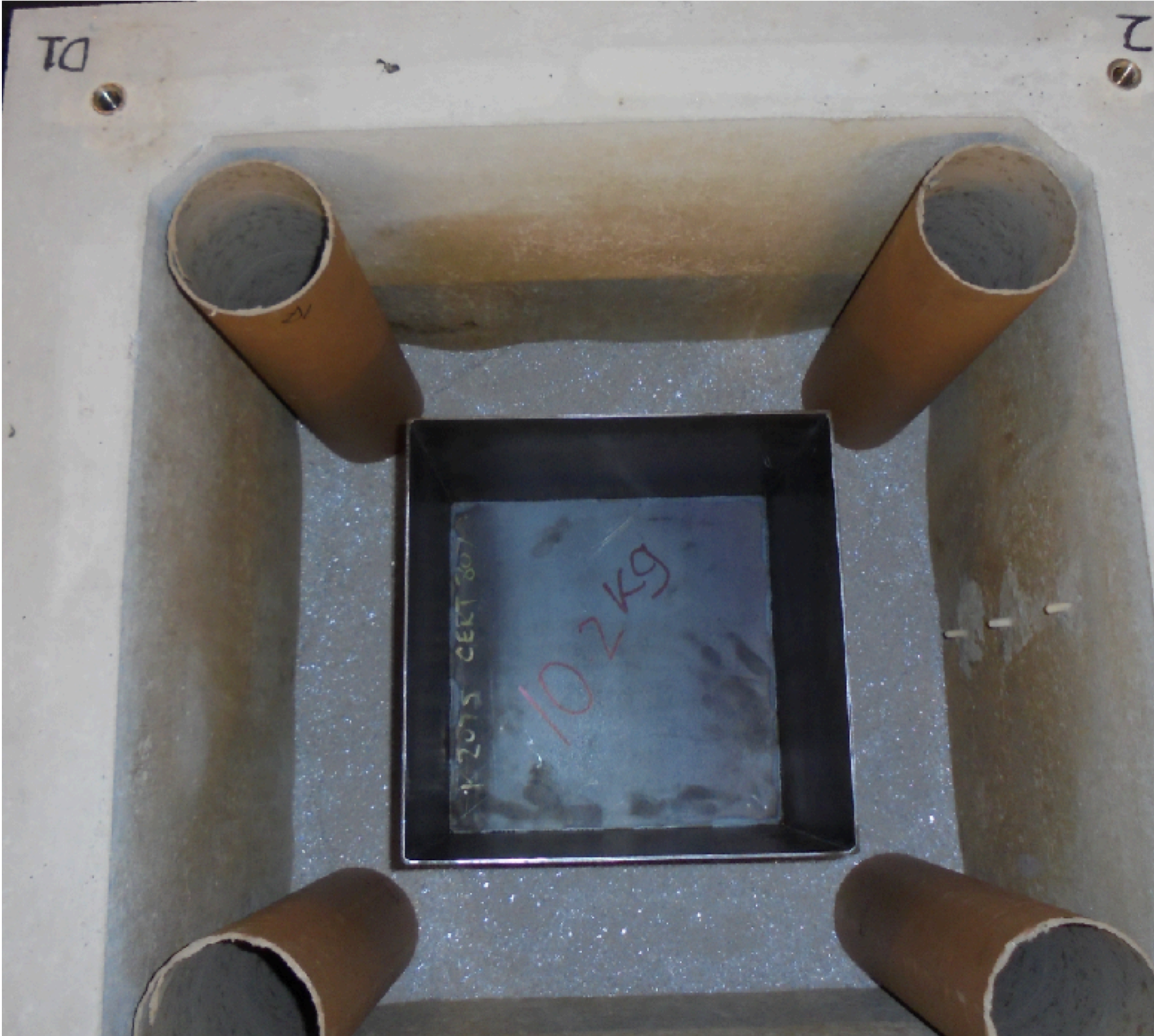
GeoMelt In-Container Vitrification



GeoMelt® In-Container Vitrification (ICV)™

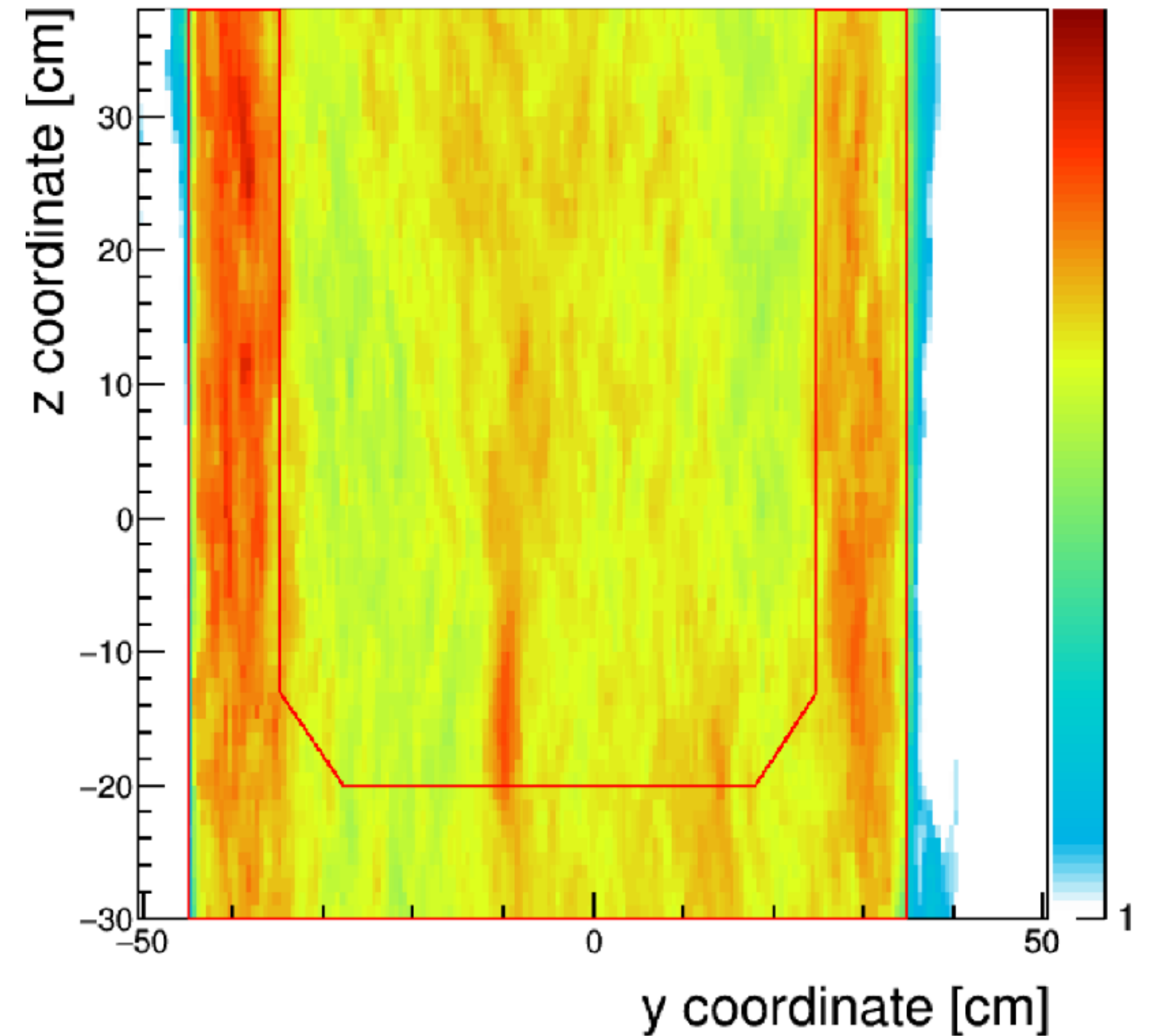
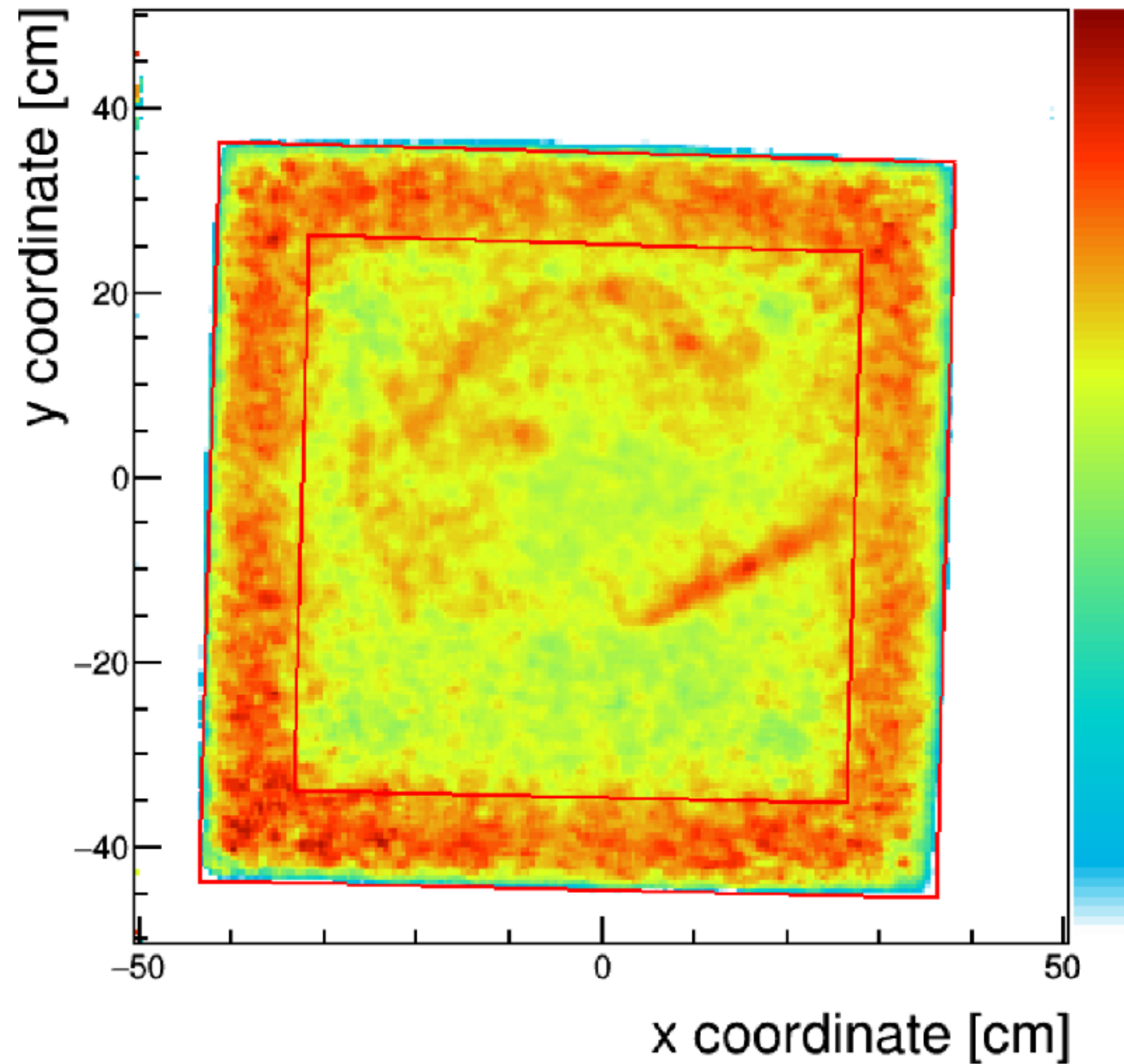


GeoMelt® Measurements

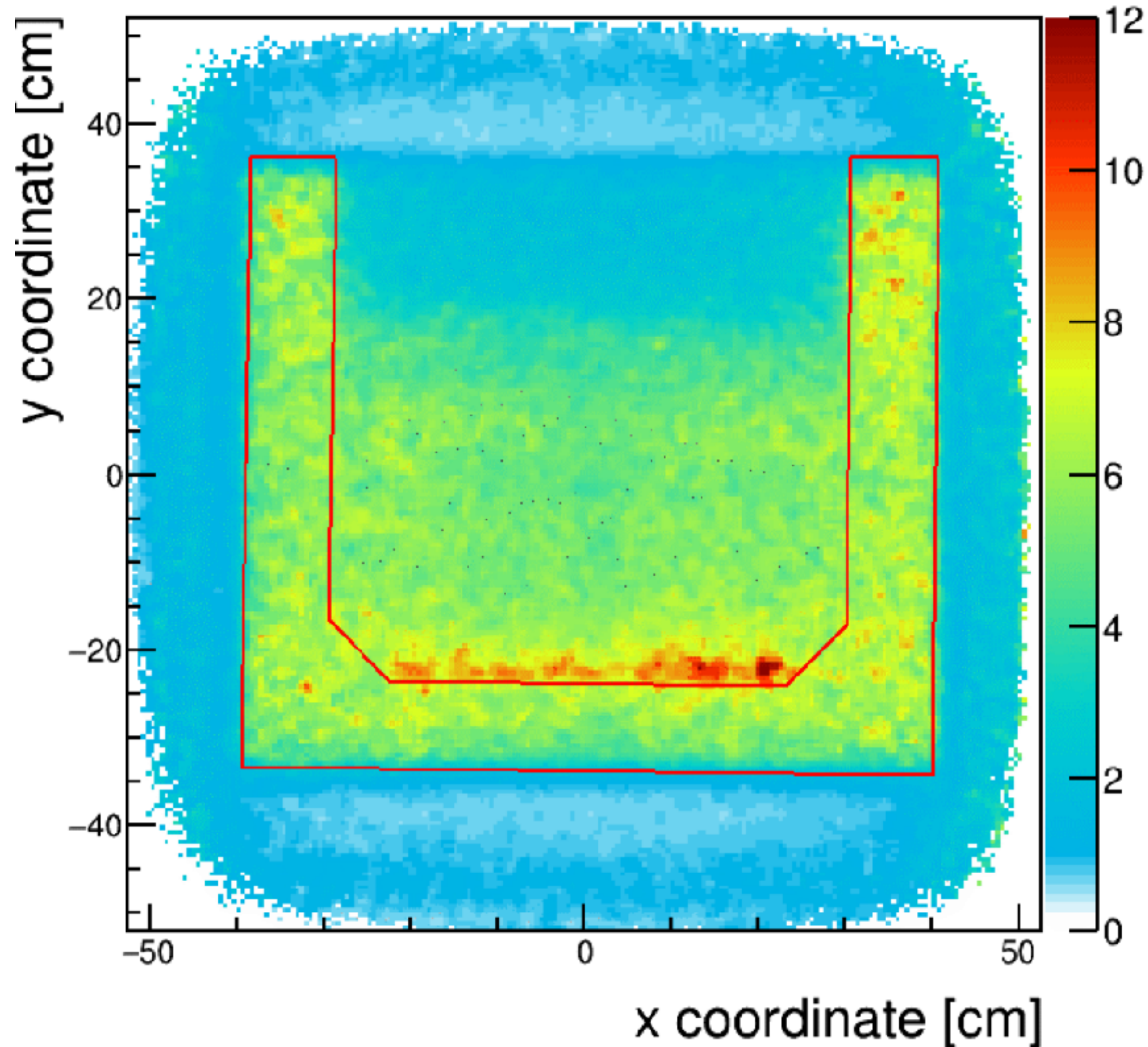


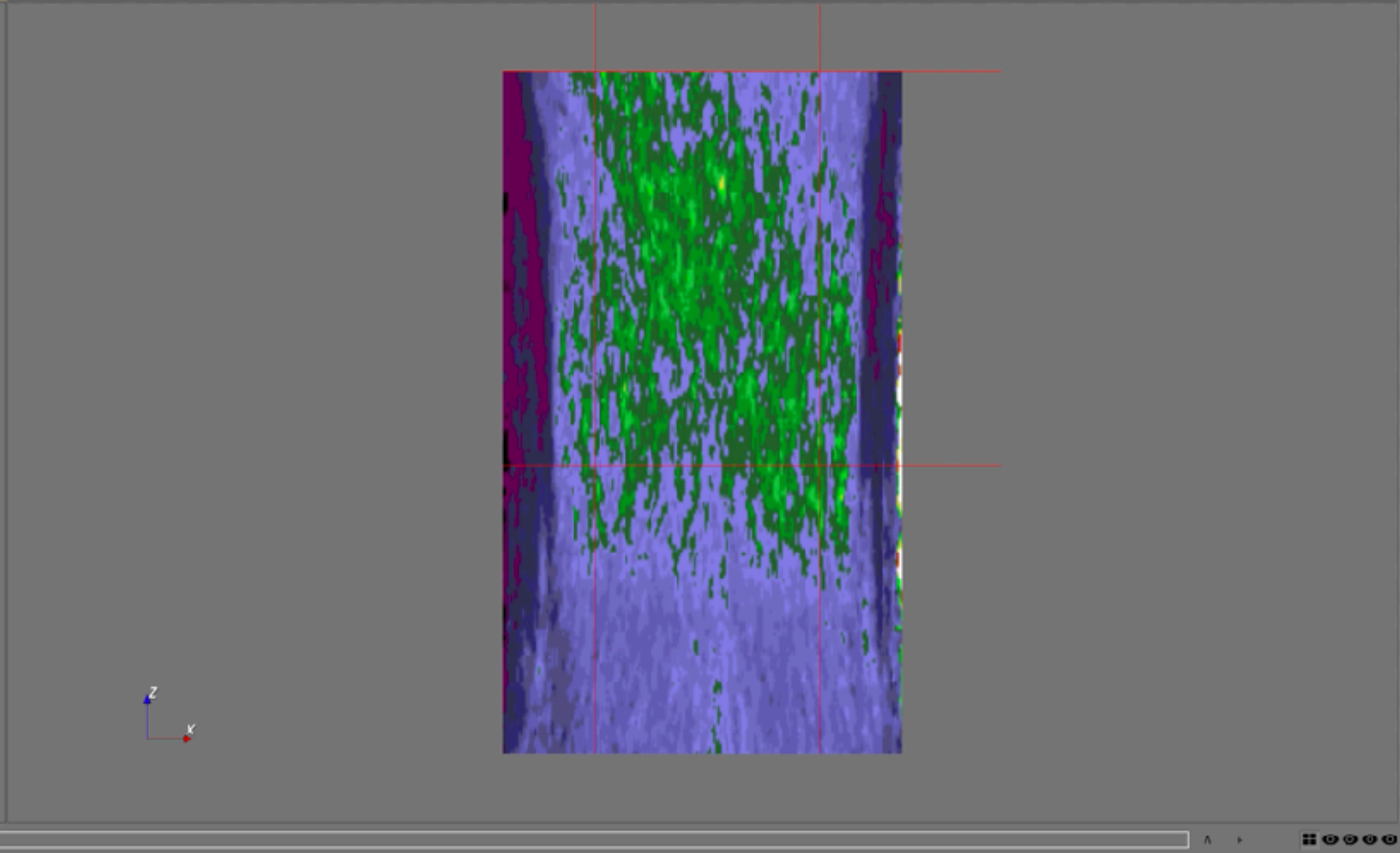
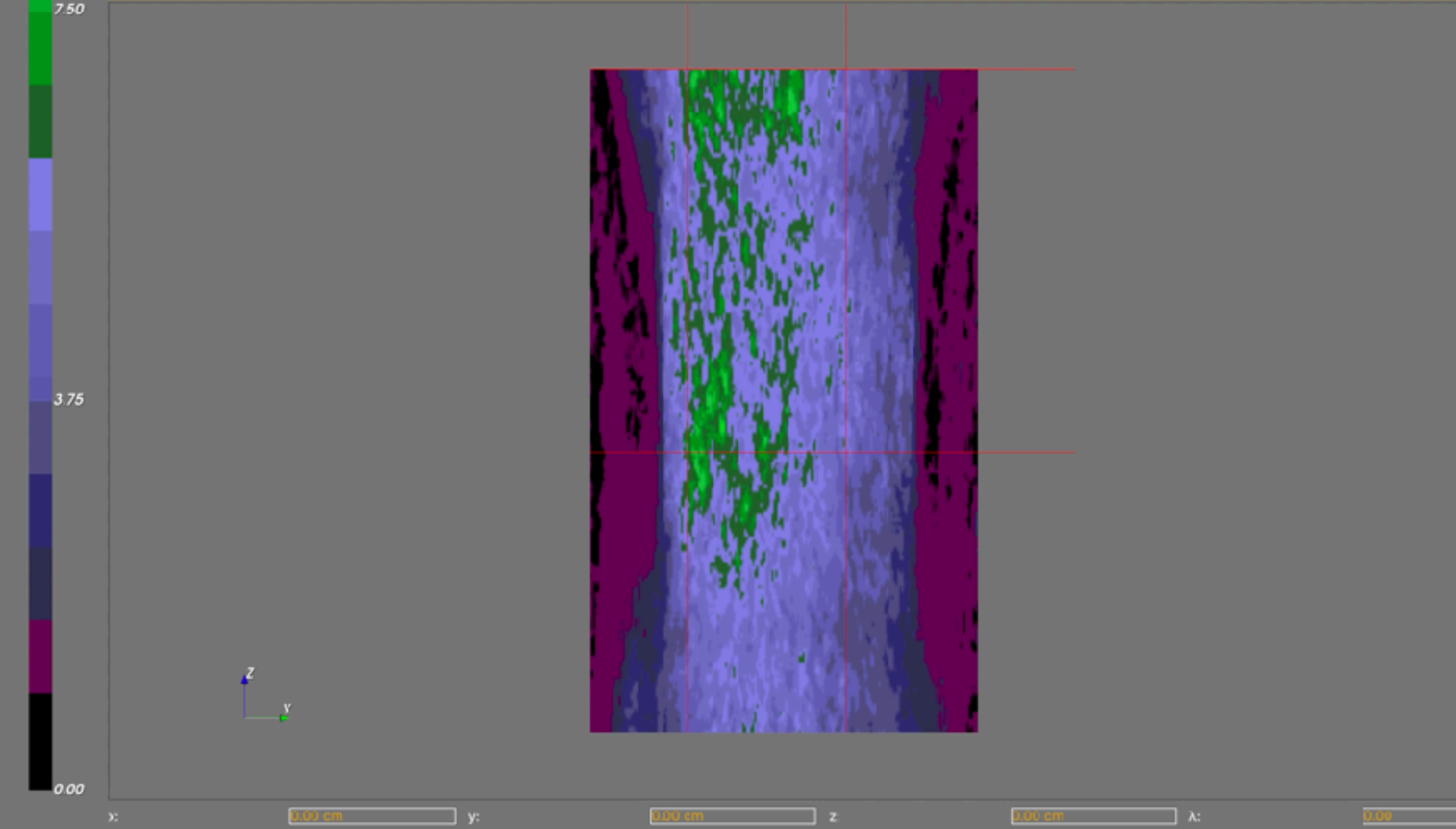
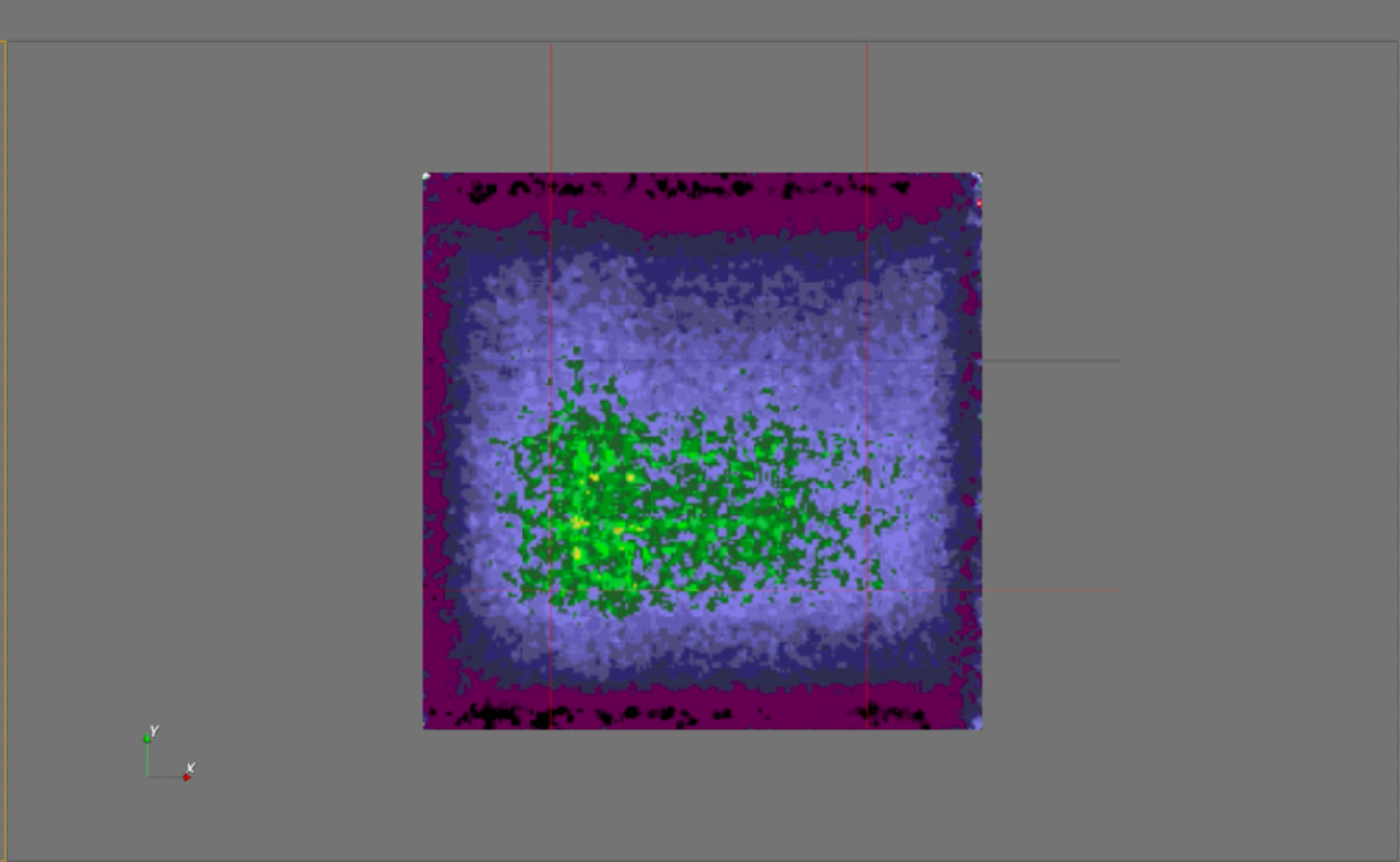
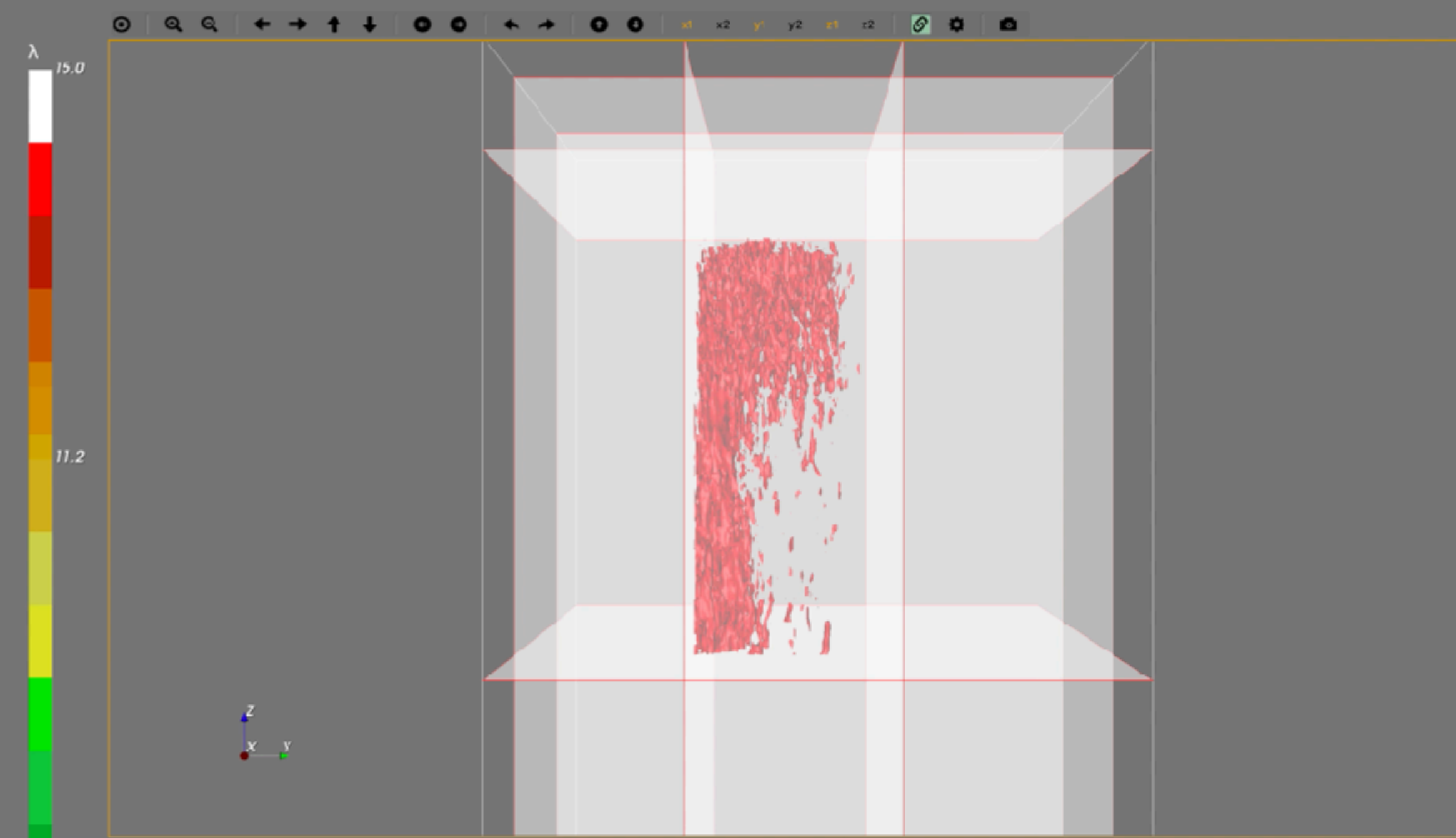


GeoMelt Sample



GeoMelt® Measurements





Render Objects

Type	Visible
1 Tonography D...	<input type="checkbox"/>
2 VO	<input type="checkbox"/>
3 Iso-Surface	<input checked="" type="checkbox"/>

Opacity 100%

Min 0.00 Max 15.00

Colour Map PET 20 Step

Plane Slice

x1 73.80 cm

x2 82.27 cm

y1 25.87 cm

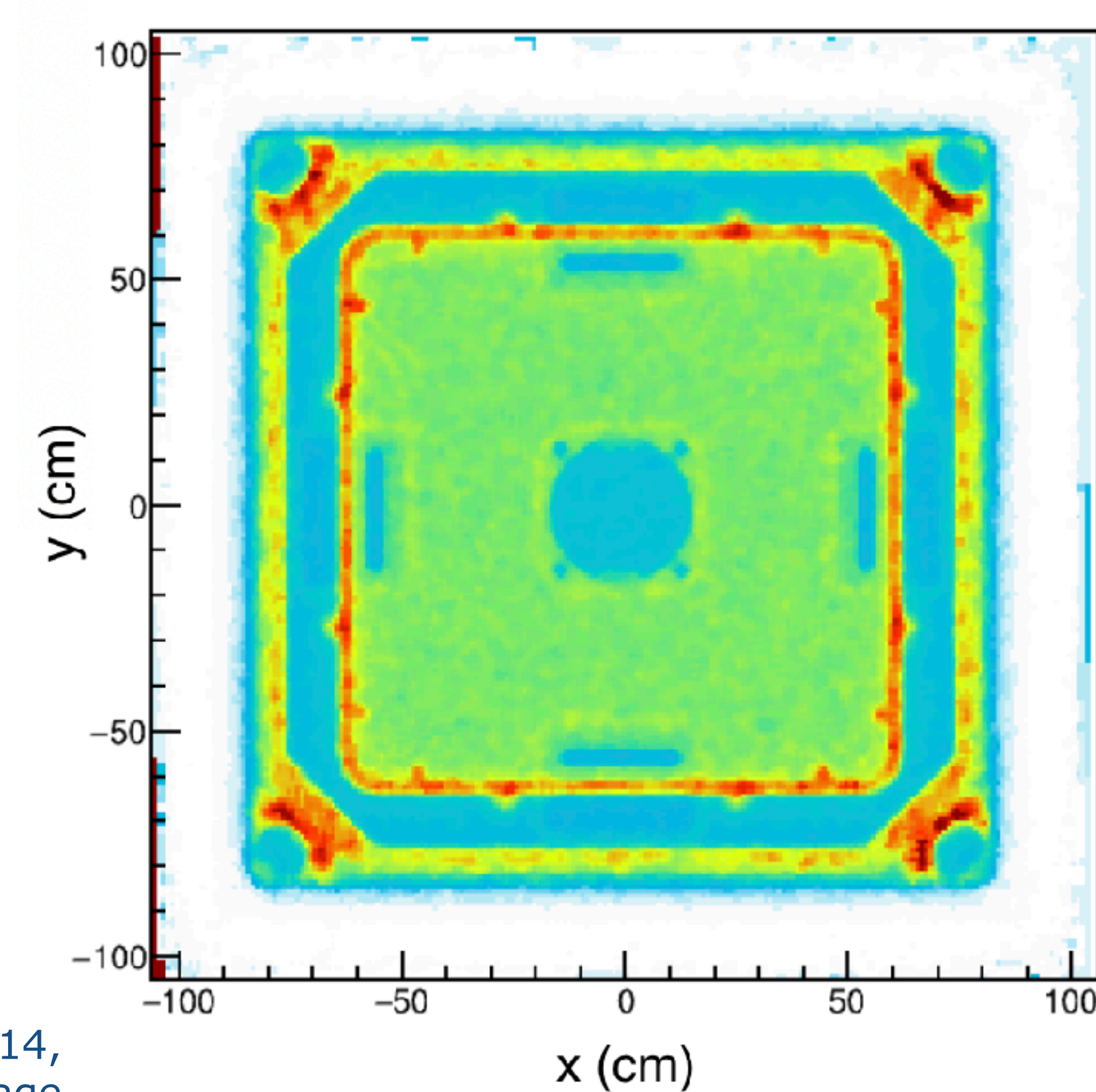
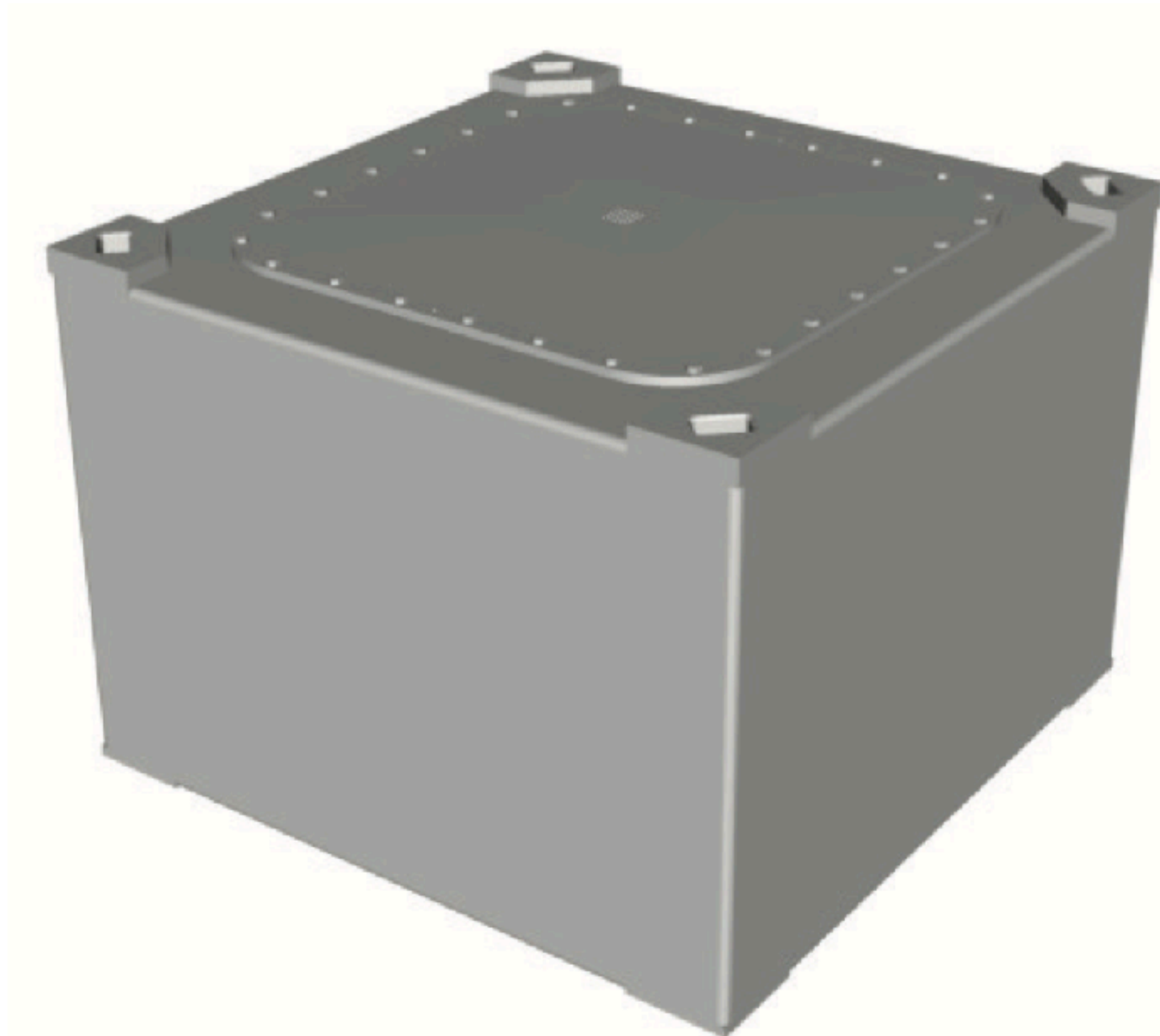
y2 68.30 cm

z1 177.01 cm

z2 74.58 cm



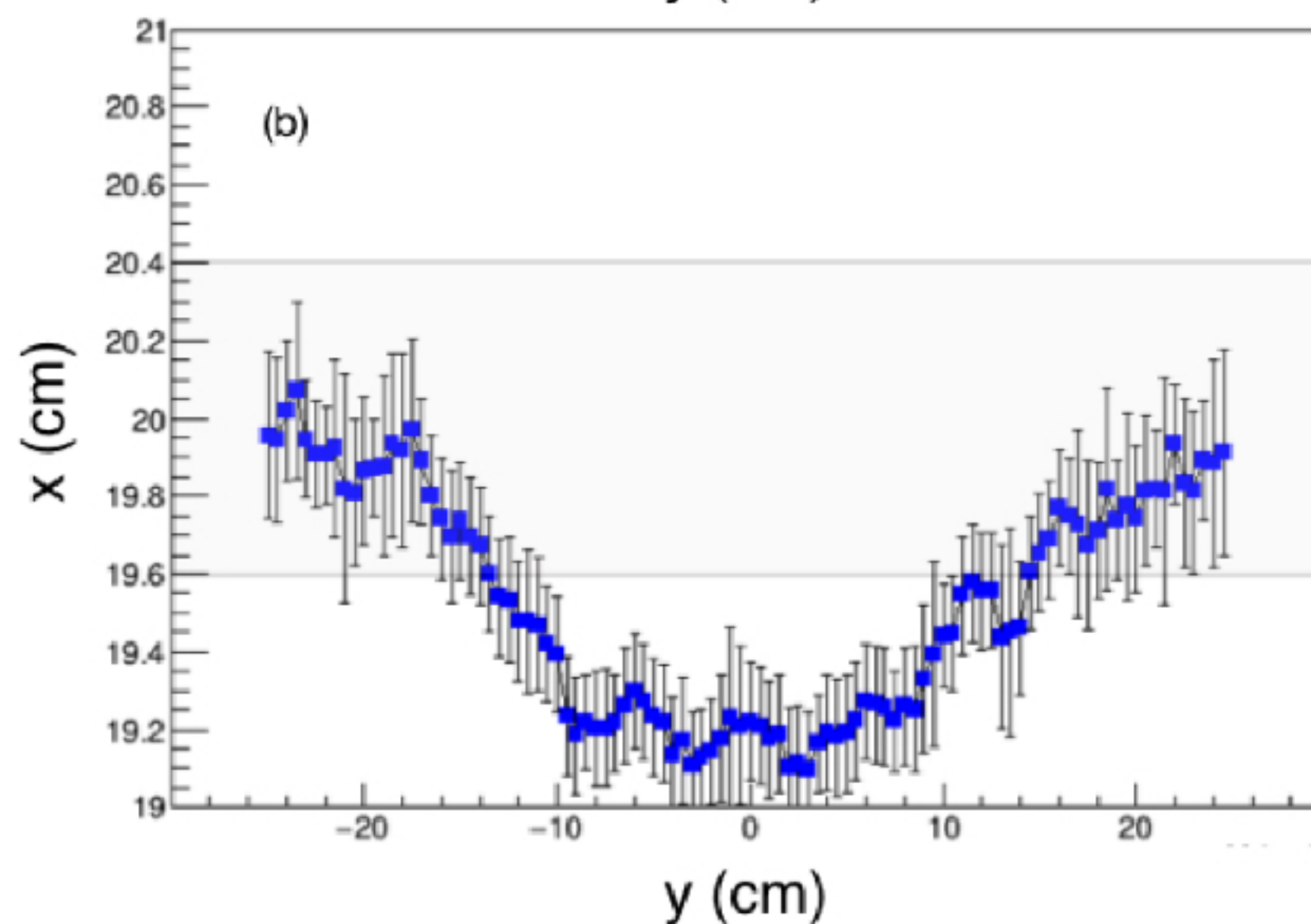
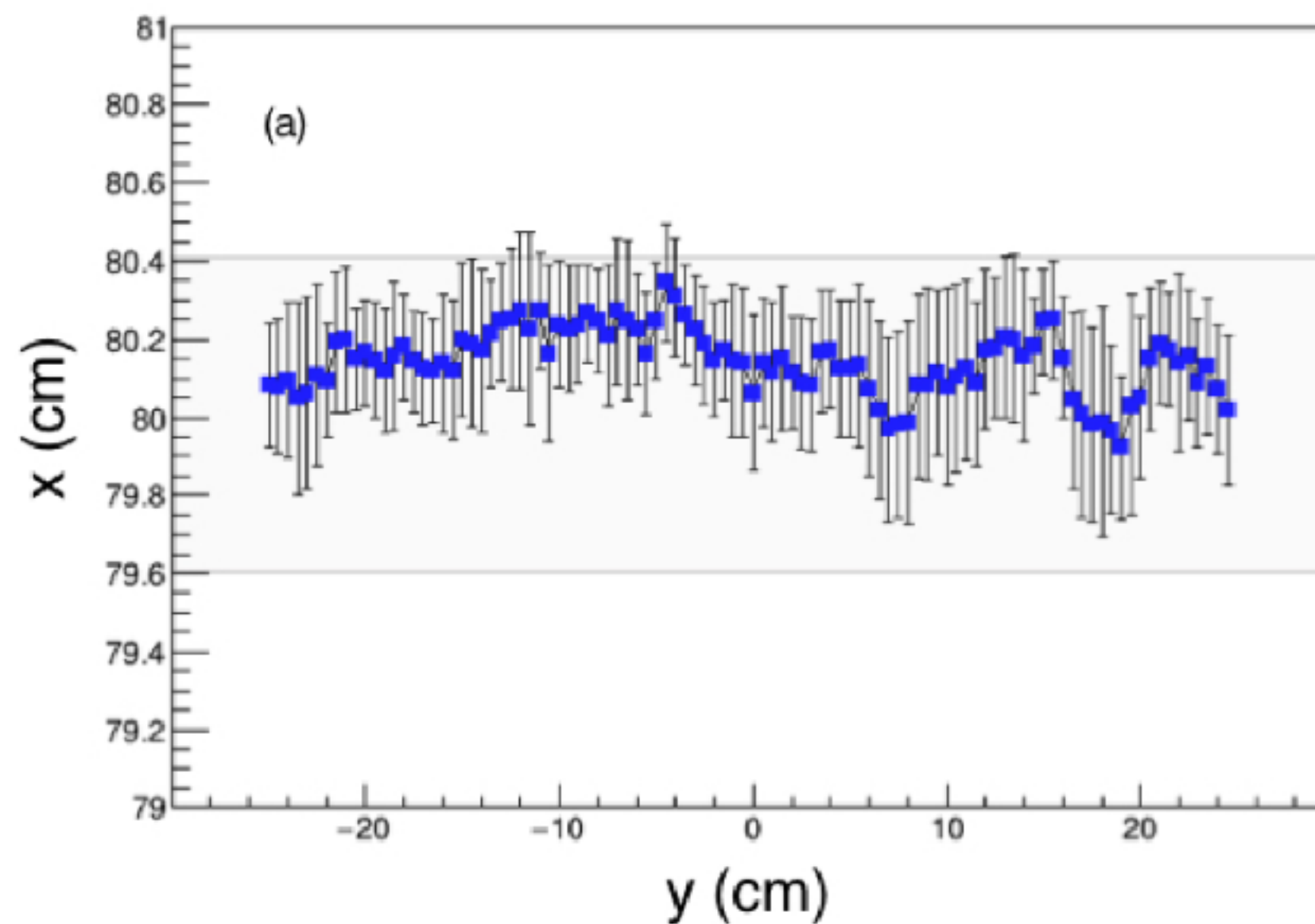
Larger Waste Packages: Simulation of 3m³ Intermediate Level Waste box



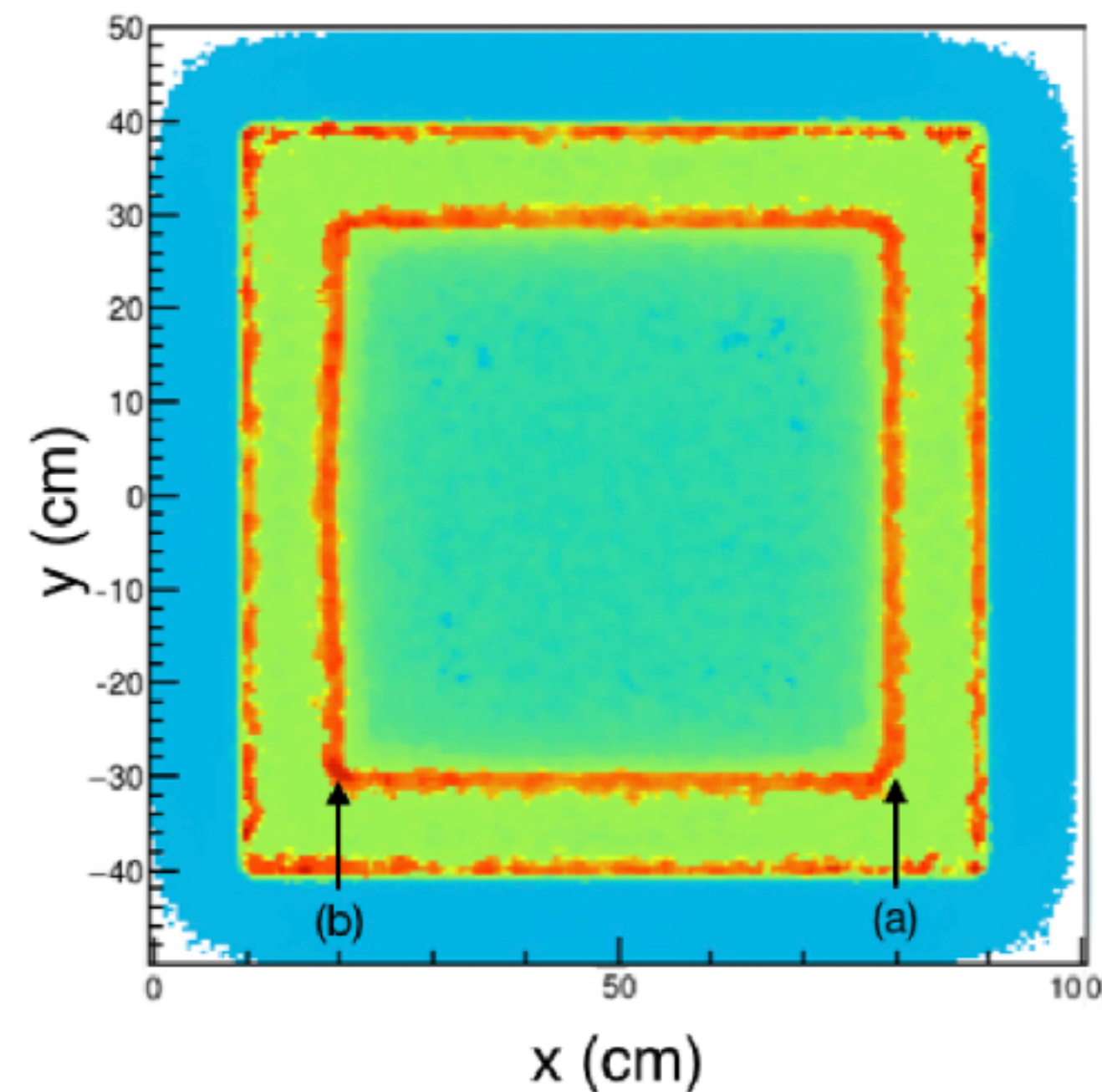
UK Nuclear Decommissioning Authority Report, July 2014, WPS/315/05 – “Geological Disposal: Waste Package Specification for corner-lifting variants of the 3 cubic metre box waste package”. Image shown is a 10mm horizontal slice through the internal skip lid



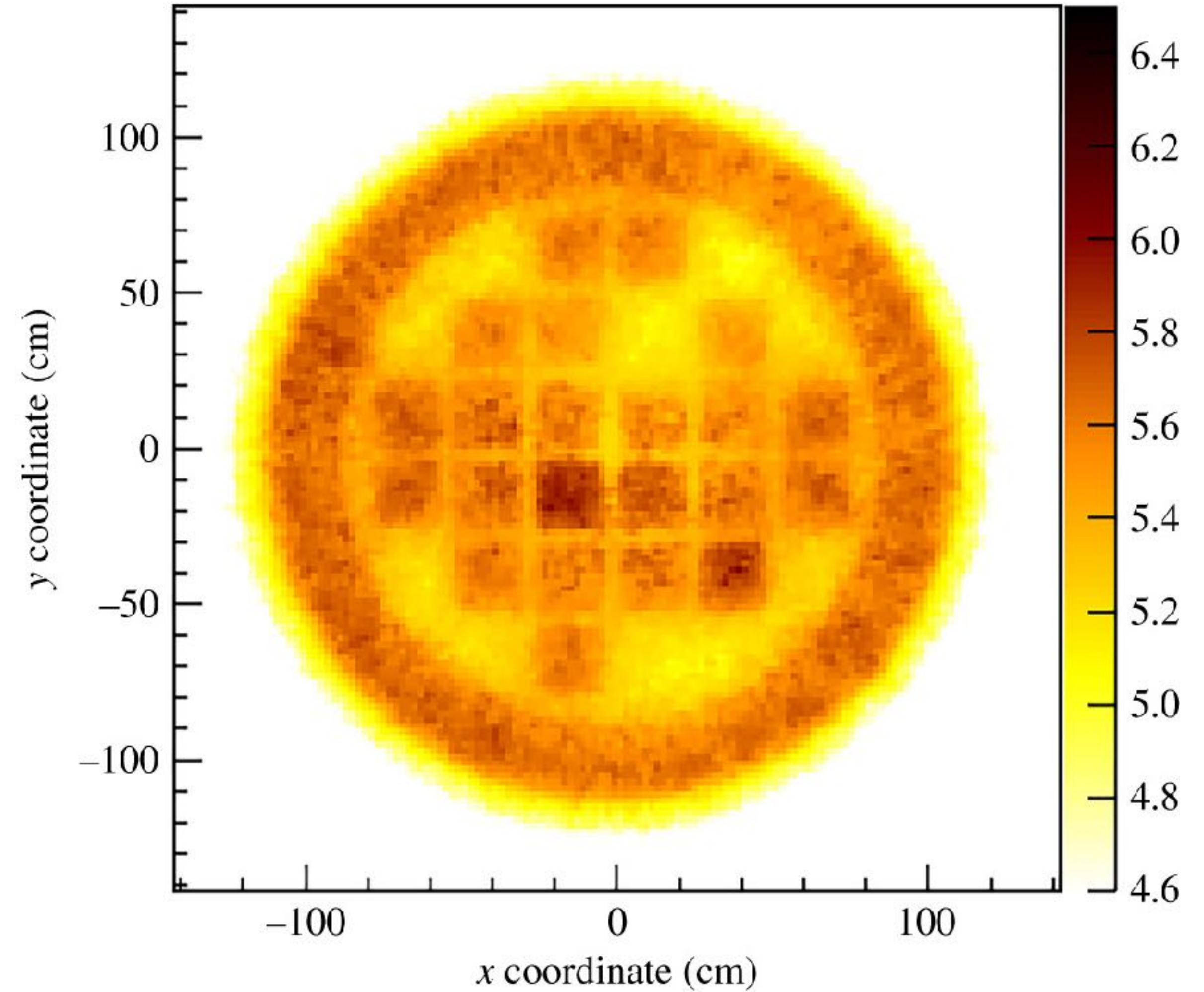
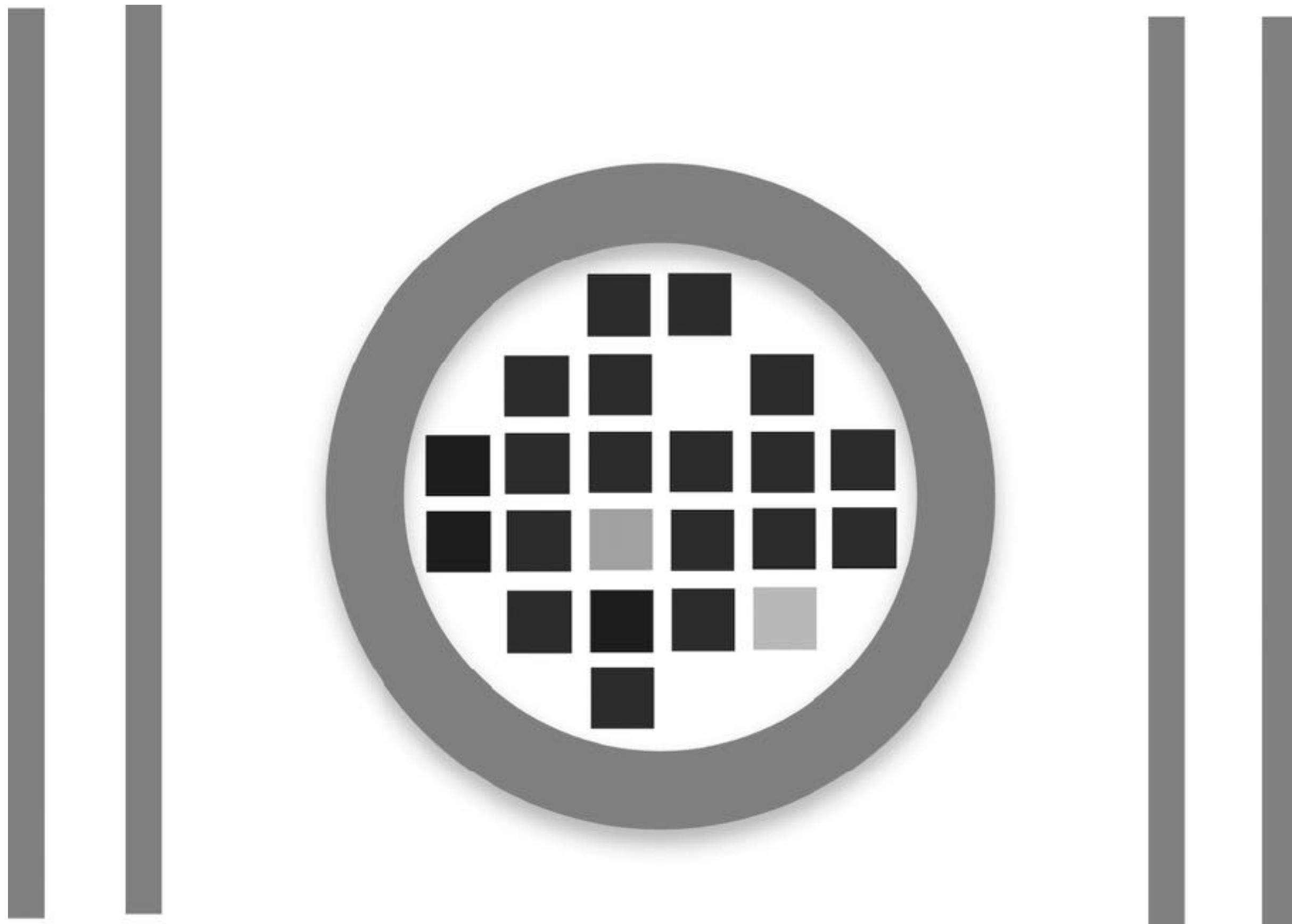
3m3 Box - Monte Carlo Simulation



Bulge Detection

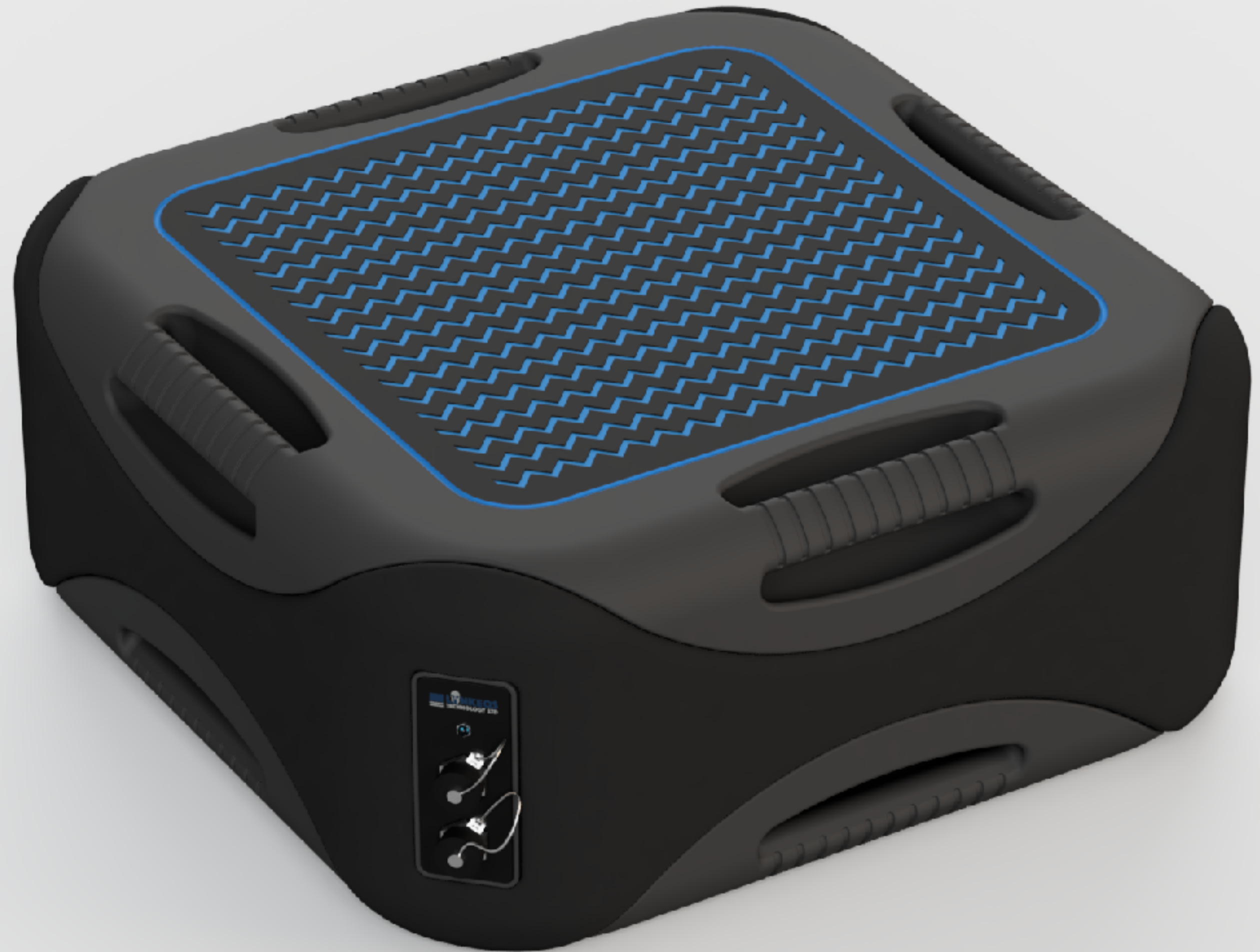


MC 10 Dry Storage Cask Simulation



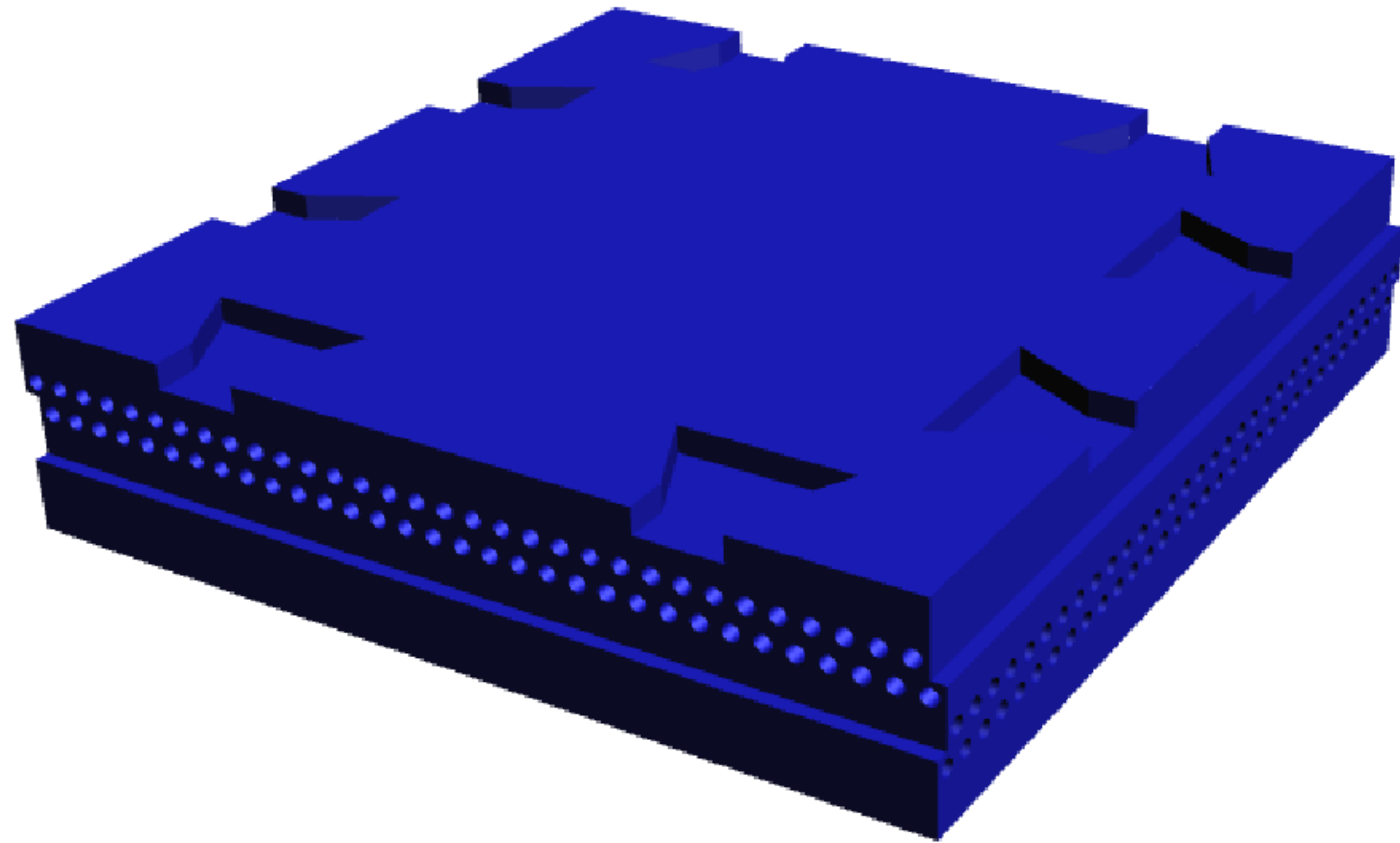


Mobile Muon Imaging System (M2IS)





Mobile Muon Imaging System (M2IS)



3D-printed matrix for scintillating fibre detector

- combines mechanical support and light-tight cover
- compact and lighter design
- modular design possible
- avoids glue and glueing procedure
- expensive fibres can be reused and replaced
- in combination with SiPM readout low voltage
- patent pending
- funding via H2020 ATTRACT Project

'Any sufficiently advanced technology is indistinguishable from magic.'

Arthur C. Clarke





LynkeosTech



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Lynkeos Technology Ltd
<https://www.linkedin.com/company/17999967/>



lynkeos

CONTACT DETAILS

