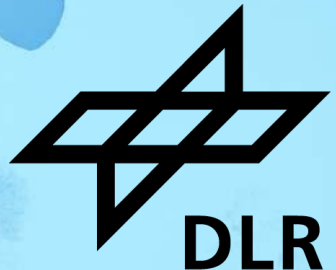


B2X SEAMLESS INTEGRATION OF COMPLEX 3D SCENES WITH MONTE CARLO FRAMEWORKS

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Angel Bueno Rodriguez, Maurice Stephan, Sarah Barnes

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Introduction

Large-scale cosmic ray tomography



Vision

Improve maritime **situational awareness** using **cosmic ray tomography**

Key factors

- Simulation of highly realistic scenarios mimicking real-world problems
- Provide automatic ground-truth with complex annotations (for machine-learning)
- For this we created B2G4¹ (Blender-to-Geant4) and used it in several projects
- Using our previous experience we decided to extend it significantly



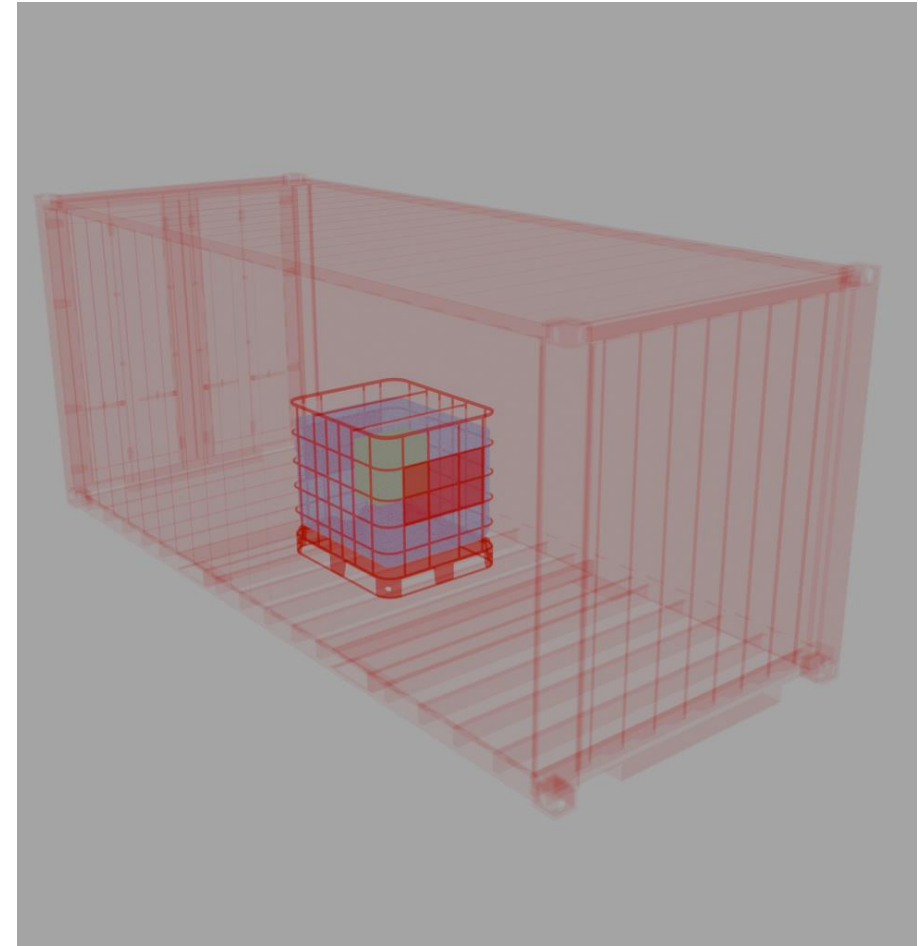
Develop a tool that allows easy scene editing, management and automatic annotation across several frameworks

1. Rodriguez, A. B., Sattler, F., Perez Prada, M., Stephan, M., Barnes, S. (2024). B2G4: A synthetic data pipeline for the integration of Blender models in Geant4 simulation toolkit. JAIS, 2024, 476. <https://doi.org/10.31526/jais.2024.476>

Introduction

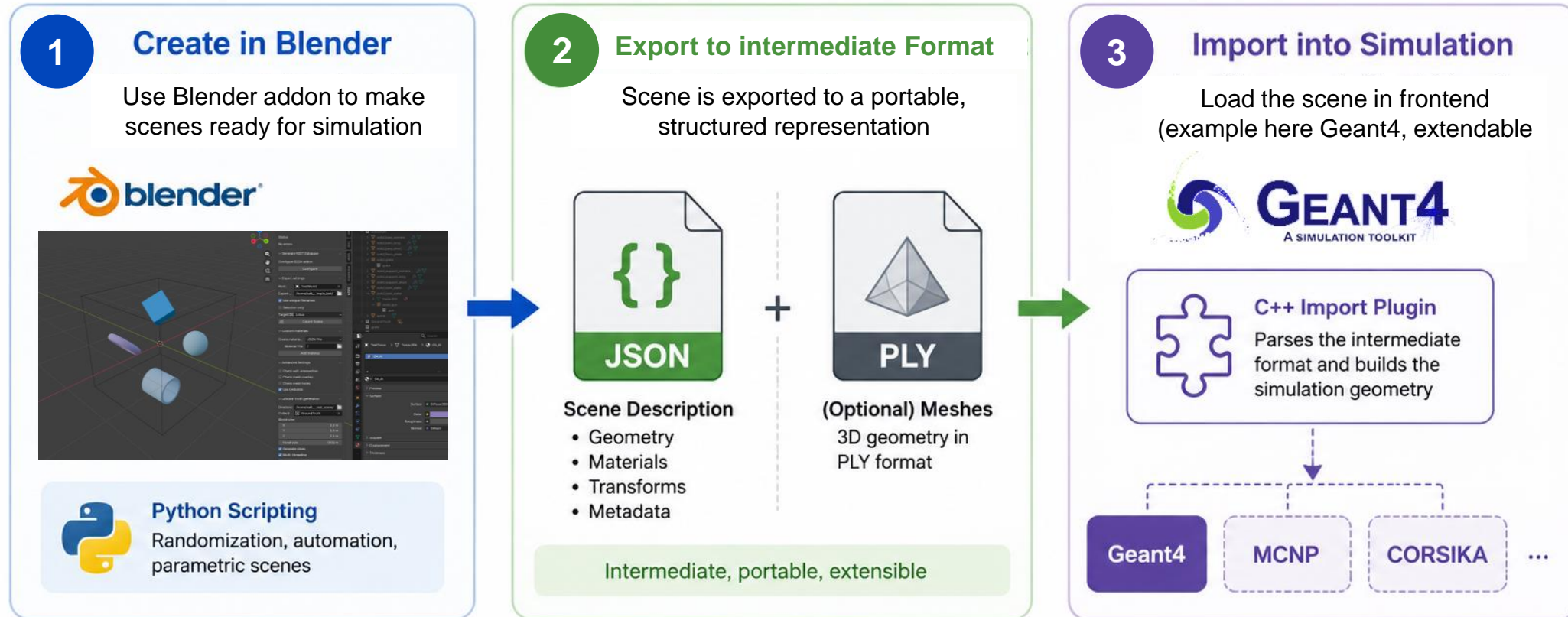
Cosmic ray tomography & machine learning

- Bridging the synthetic-to-real gap is a big challenge for machine learning approaches
 - Datasets must be as close as possible to reality
- For an efficient **integration of muon tomography** with **complex scenarios** we need:
 - Easy creation of highly-detailed scenes by including CAD files, photogrammetry and 3D scan data
 - Automatic randomization and scene generation for varied datasets
 - Sustainable scene management, important when working with different scenario variations
 - Coherent data across different simulation & verification frameworks



Method

Framework structure

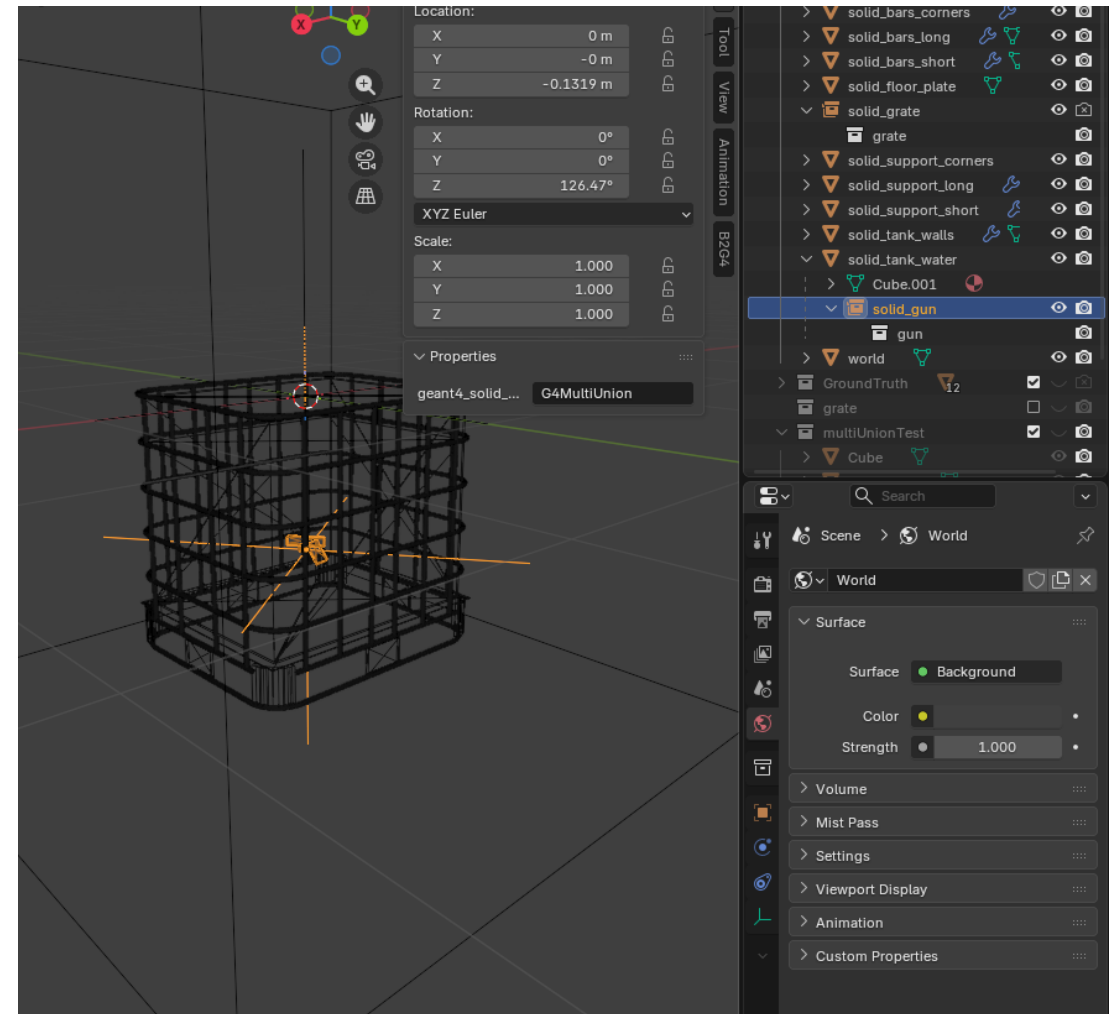


- Three different stages: Scene generation, intermediate representation, parsing
- Every frontend (user software) implements a parser that reads intermediate format
- Modular design: New frontends possible by implementing intermediate format

Method

Scene generation

- For simulation in G4 / MCNP / etc. people need scenes with
 - clear hierarchies,
 - defined geometry,
 - no overlaps or holes
 - Physical materials
- Using B2X users can create these scenes in Blender from scratch, CAD files or 3D scans
- B2X can be used to create simulation-ready scene with automatic **ground-truth generation**



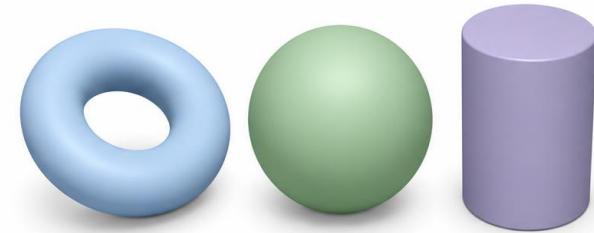
Method

Intermediate format & scene parsing

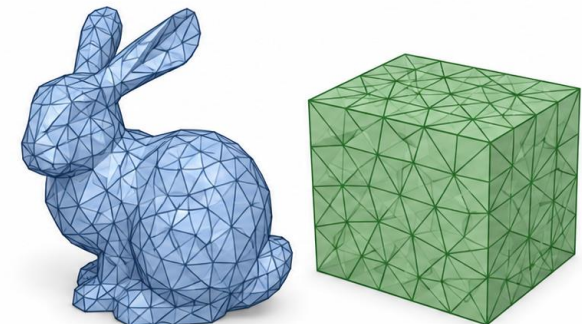


- Intermediate format contains: scene hierarchy, material definitions, geometry (implicit or explicit), optional metadata
- We provide implementations for:
 - **Geant4**: reference implementation, distributed alongside B2X
 - **CORSIKA 8**: WIP implemented by @UCLouvain, aimed to become part of the official CORSIKA 8 repo
 - **MCNP6**: WIP converter from intermediate format to MCNP input files
- We also provide reference implementations for Geant4 and MCNP to use tetrahedral (unstructured) meshes

Implicit surfaces



Explicit surfaces



Method

Verification

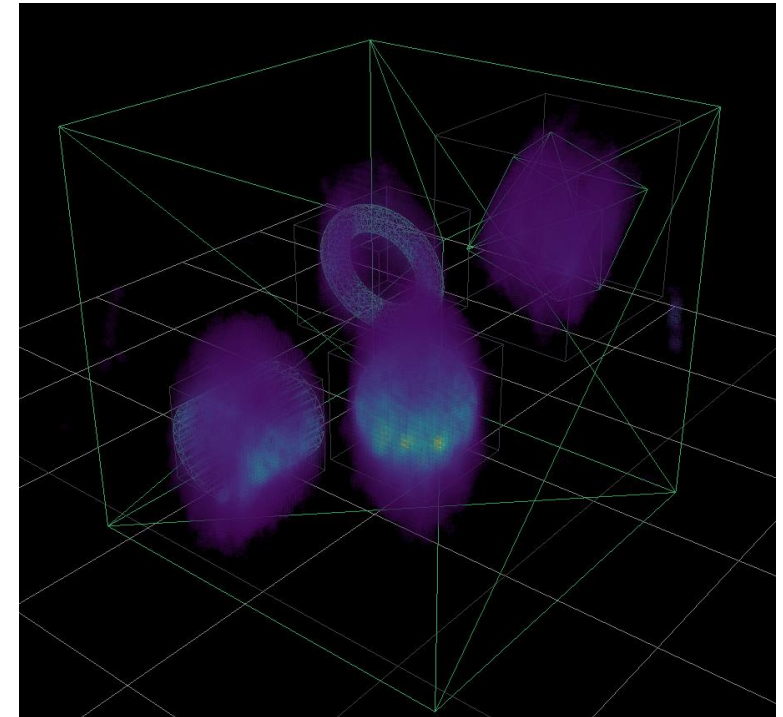
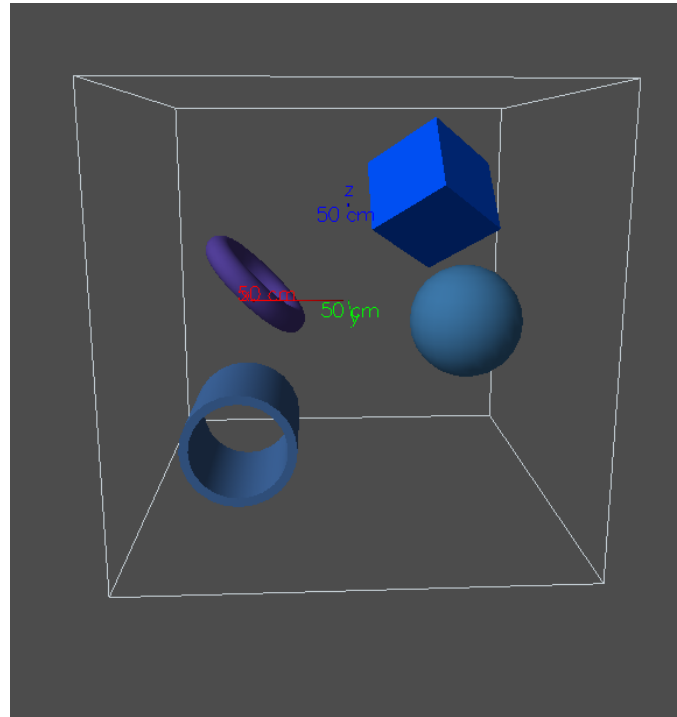
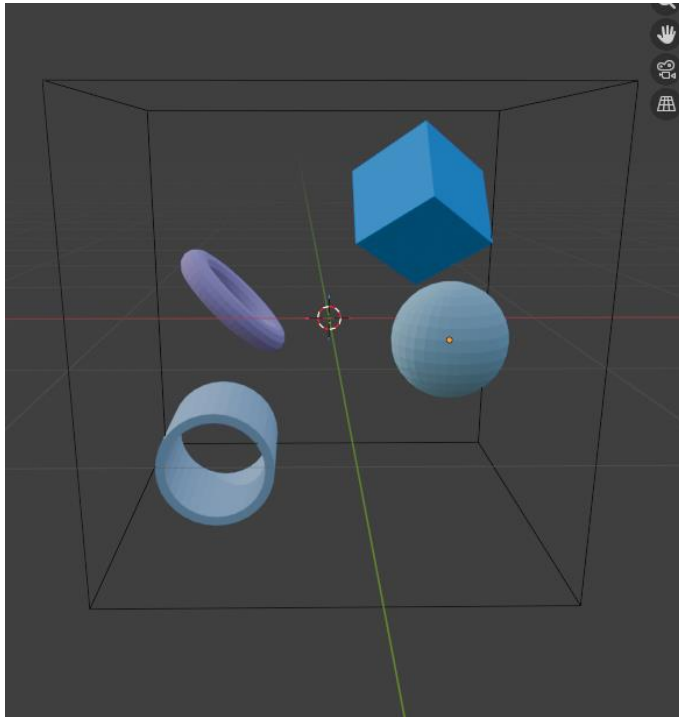


- We created two test scenes:
 - A simple scene containing three implicit surfaces and a CSG structure (cylinder)
 - A real-world security scene (taken from Horizon2020 project SilentBorder) with an IBC water container holding a concealed gun
- For Geant4, we ran a simulation and reconstructed with ASR¹
- For MCNP we used the simple scene and only verified the geometry
- For CORSIKA 8 we used an open-source dummy PLY mesh to test basic polygonal mesh + native solid handling

1. Stapleton, M., Burns, J., Quillin, S., Steer, C. (2014). Angle Statistics Reconstruction: A robust reconstruction algorithm for Muon Scattering Tomography. Journal of Instrumentation, 9, P11019. <https://doi.org/10.1088/1748-0221/9/11/P11019>

Results

Geant4 – Manual vs. B2X Scene Comparison



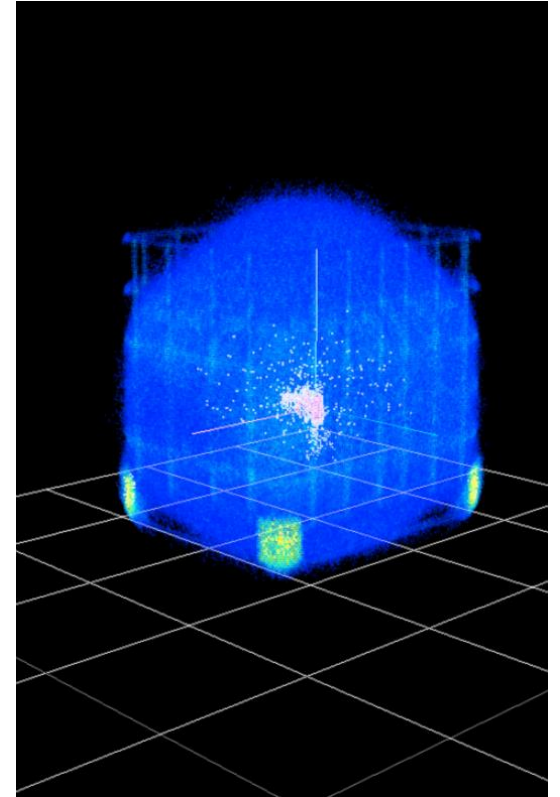
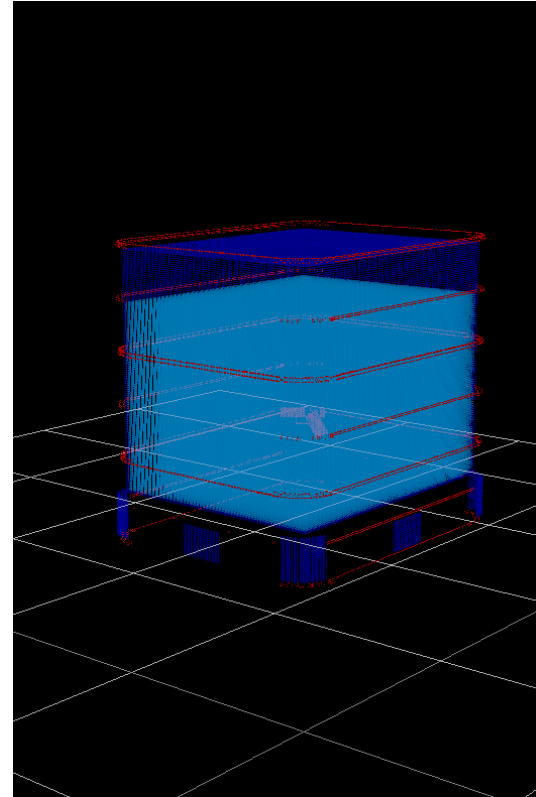
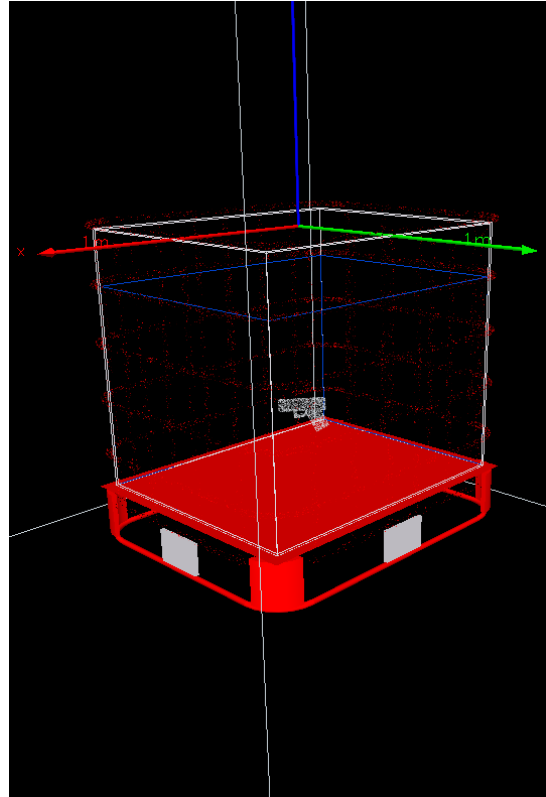
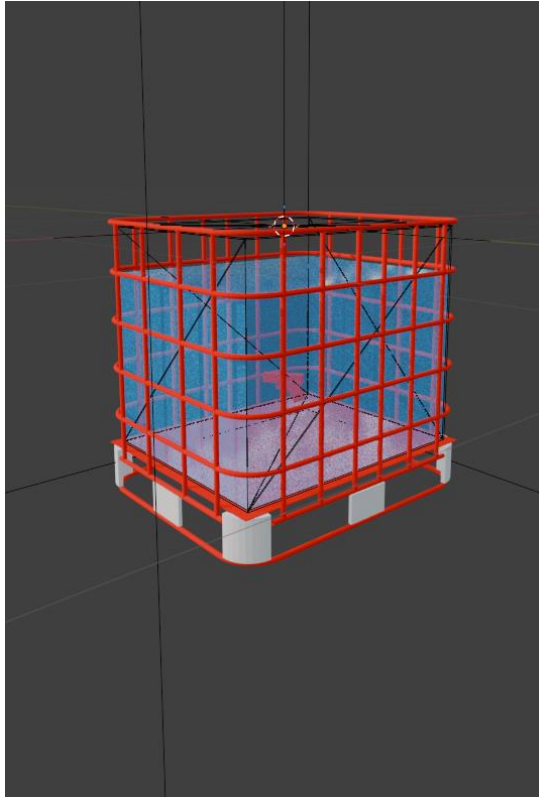
Left: Scene in Blender

Middle: Scene loaded and parsed in Geant4

Right: Simulation results, 15 minutes exposure, ASR, 5cm voxel resolution, 3x3x3m² world

Results

Geant4 – Complex Scenes



Left: Scene in Blender

Middle left: Scene loaded and parsed in Geant4

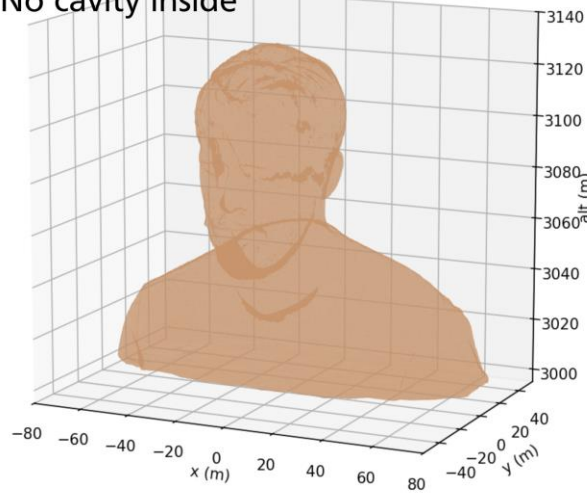
Middle right: Ground-Truth generated from Blender scene (2cm resolution)

Right: Simulation results, 4h exposure, ASR, 1cm voxel resolution, 1.5x1.5x1.5m² world

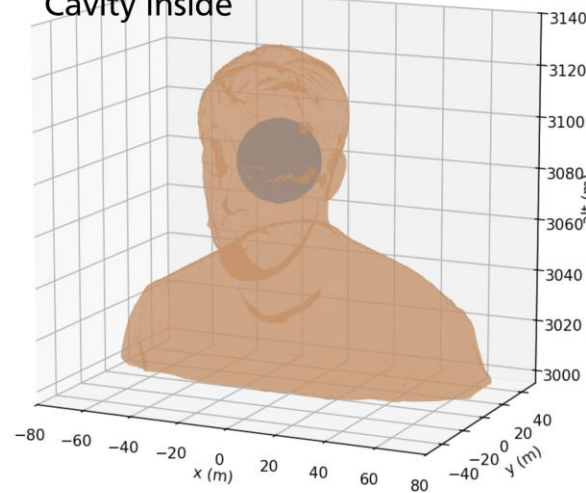
Results

CORSIKA 8 – Test scene

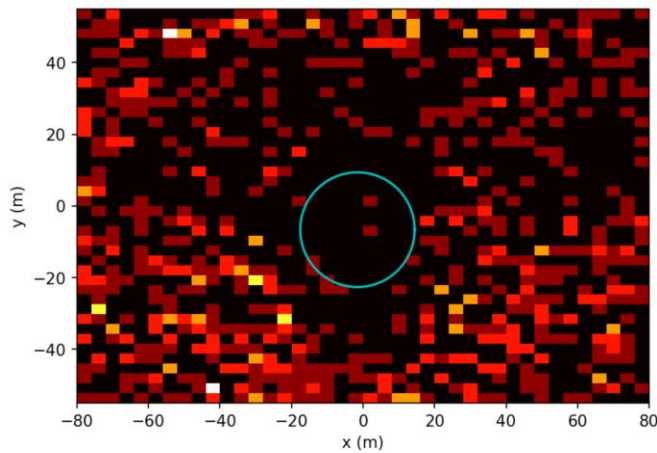
No cavity inside



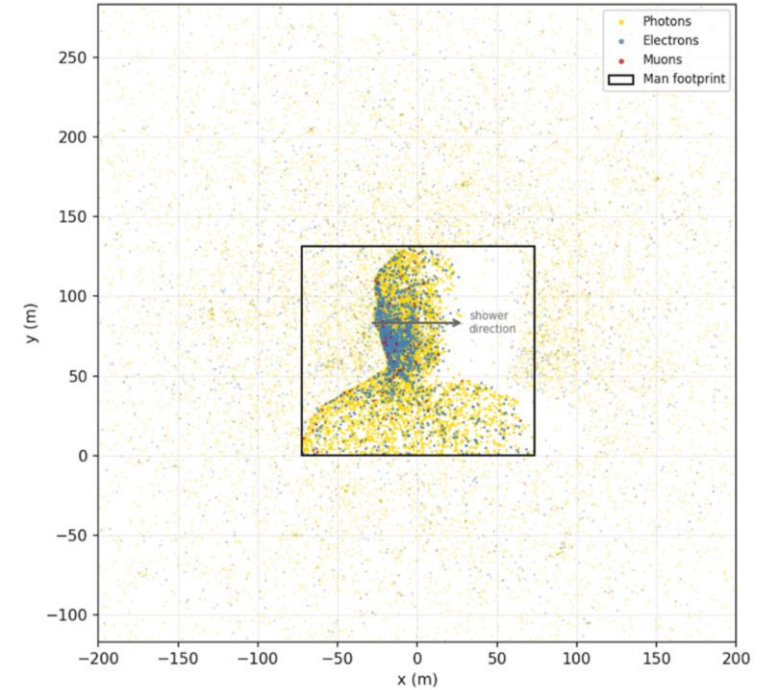
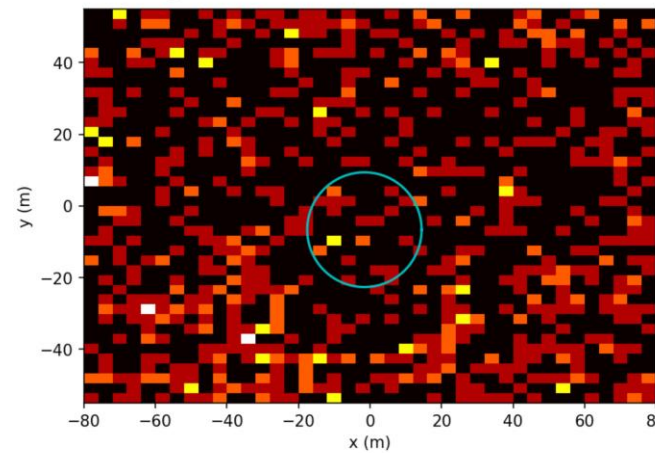
Cavity inside



No cavity inside



Cavity inside



Top: Example mesh made of iron without (left) and with (right) air cavity

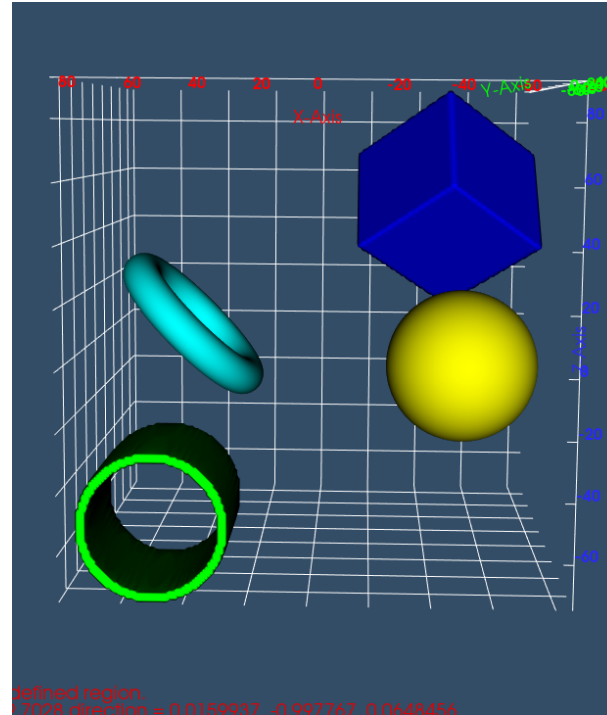
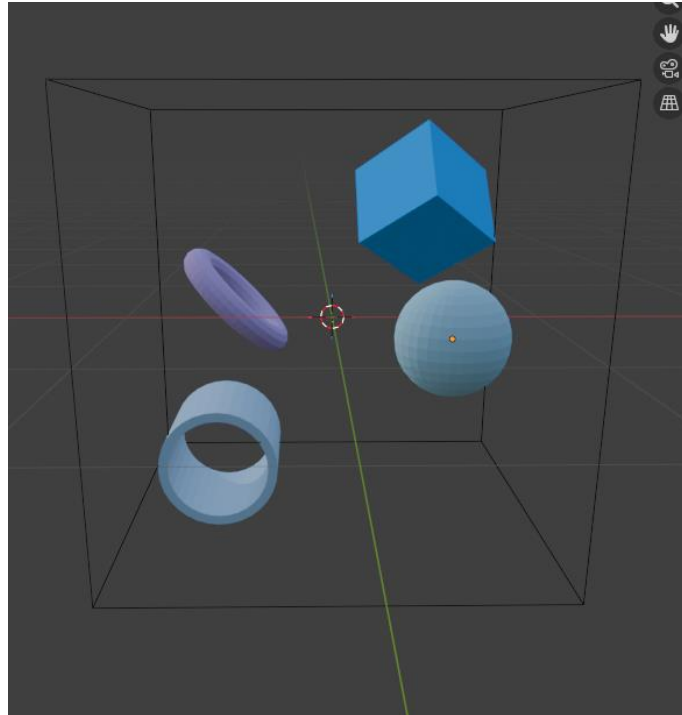
Bottom: Muon counts for respective setup

Right: Particle interactions with mesh

Contributed by
Jeffrey Lazar, UC Louvain

Results

MCNP6 – WIP First results



```

B2X Test Scene
c ***** BLOCK 1 -- Cells
c 1 0 -40 41 42 IMP:P=1 $ TestWorld, Air
c 2 11 -1.0 -41 IMP:P=1 $ TestCube, Water
c 3 12 -8.96 -42 IMP:P=1 $ TestSphere, Cu
c 4 13 -7.87 -44 43 45 -46 IMP:P=1 $ TestCylinder, Fe
c 5 14 -2.7 -47 IMP:P=1 $ TestTorus, Al
c 6 0 41 42 -43 44 -45 46 47 IMP:P=0 $ Void

c ***** BLOCK 2 -- Surfaces
c 40 BOX -100 -100 -100 200 0 0 0 200 0 0 0 200 $ TestWorld
c 41 1 BOX -25 -25 -25 50 0 0 0 50 0 0 0 50 $ TestCube
c 42 2 SPH 0 0 0 25 $ TestSphere
c 43 3 CZ 21 $ TestCylinder_inner
c 44 3 CZ 25 $ TestCylinder_outer
c 45 3 PZ -25 $ TestCylinder_cut_lower
c 46 3 PZ 25 $ TestCylinder_cut_upper
c 47 4 TZ 0 0 0 28.9 7.2 7.2 $ TestTorus

c ***** BLOCK 3 -- Materials and Data
c -----
c AIR
M10 7000 -0.755 8000 -0.232 18000 -0.013
c -----
c WATER
M11 1000 2 8000 1
c -----
c CU
M12 29000 1
c -----
c FE
M13 26000 1
c -----
c AL
M14 13000 1
c -----
c Transforms
c -----
TR1 -50 -50 50 0.000 -0.707 0.707 0.707 0.500 0.500 -0.707 0.500 0.500 1
TR2 -50 50 0 1.000 0.000 0.000 0.000 1.000 0.000 0.000 0.000 1.000 1
TR3 50 50 -50 1.000 0.000 0.000 0.000 0.000 1.000 0.000 -1.000 0.000 1
TR4 50 -50 0 -0.707 0.000 -0.707 0.000 -1.000 0.000 -0.707 0.000 0.707 1
c -----
c Dummy instruction
c -----
NPS 1
    
```

Left: Scene in Blender

Middle: Plotted scene from generated MCNP code

Right: Generated MCNP code from B2X

Thanks to Volodymyr Gulik from University of Tartu for his help!

Outlook

- Let B2X become part of Geant4's / MCNP / CORSIKA 8's standard suite of tools
- Flesh out MCNP support for complex scenes
- Add support for more parametric surfaces
- Evaluate automatic scene simplification & optimization
- Enhance ground-truth generation
 - Use more optimal spatial structures
 - Rely on standard volumetric libraries



**Feel free to check out
our work so far!**

<https://codeberg.org/DLR-MI/B2X>

Impressum



Thema: B2X - Seamless integration of complex 3D scenes with Monte Carlo frameworks

Datum: 2026-06-02

Autor: Felix Sattler *et al.*

Institut: DLR-MI SIT

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