

ANOMALY DETECTION IN OPERATIONAL MUON CARGO INSPECTION

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Thanks to collaborators!

**Silent
Border**



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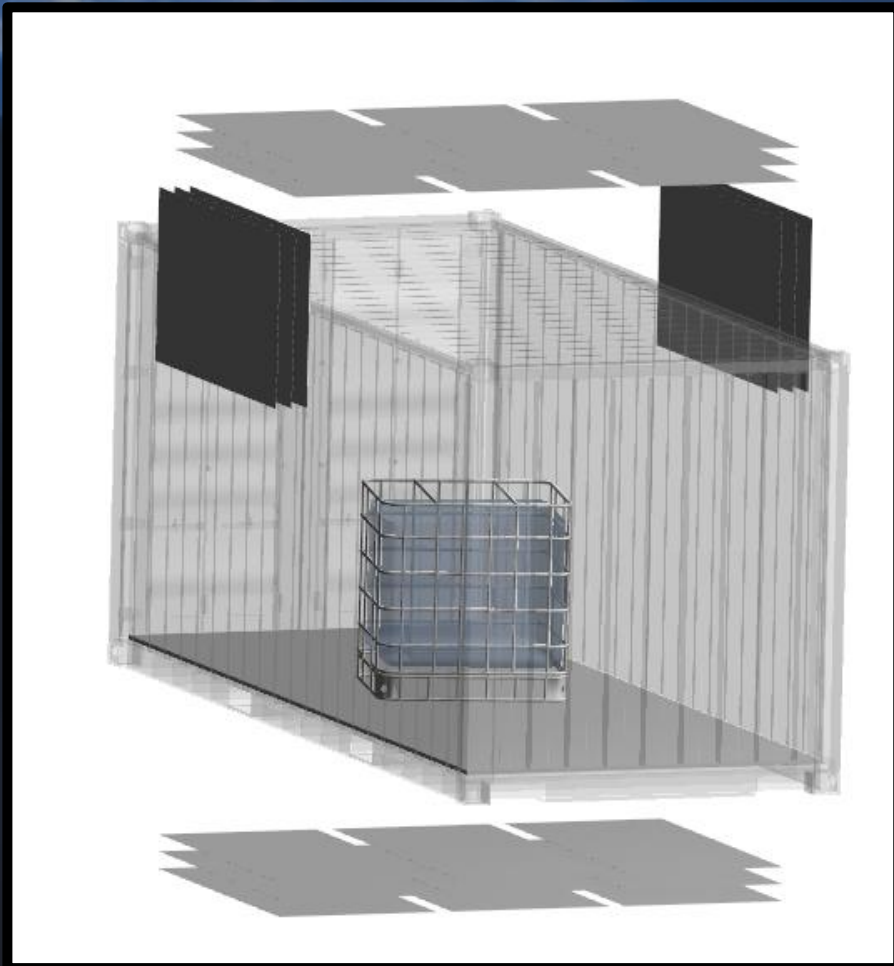
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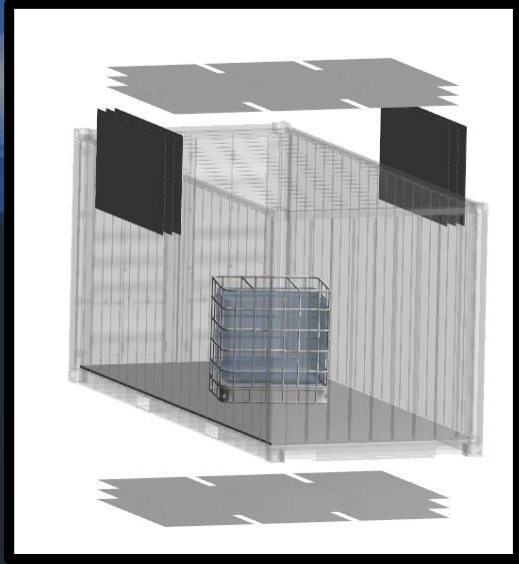
Simulation Data



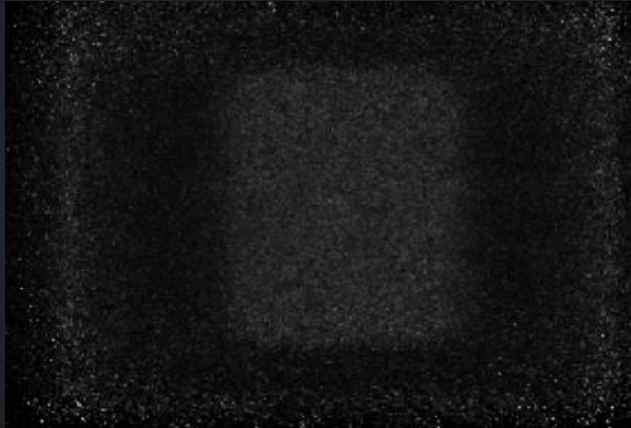
Real Measurements



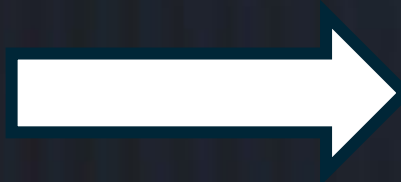
Simulation Data



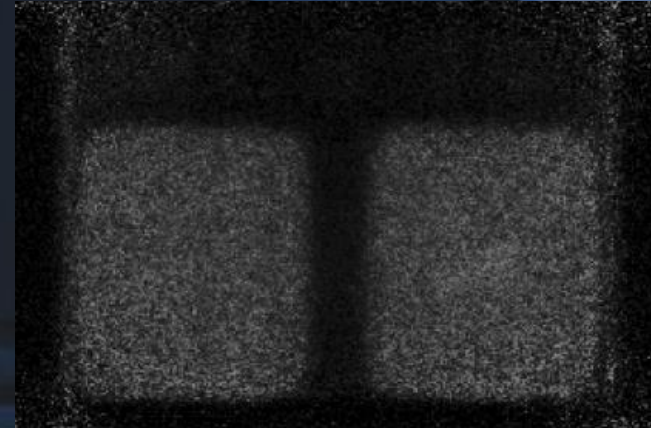
Real Measurements



Simulation Data 2D slice

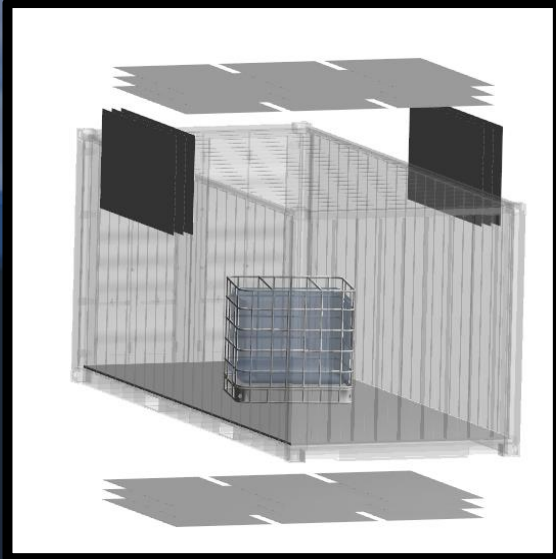


Domain gap

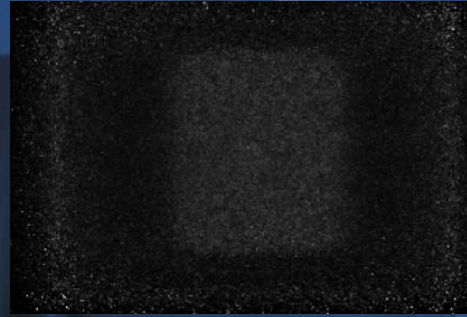


Real measurements Data 2D slice

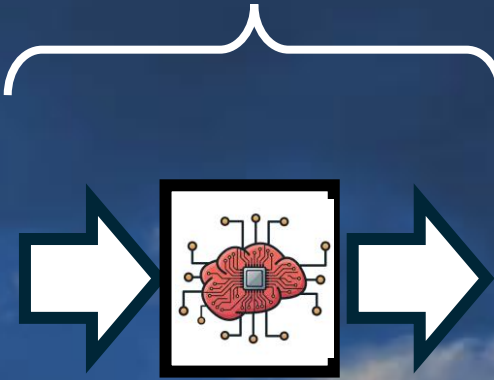
Simulation Data



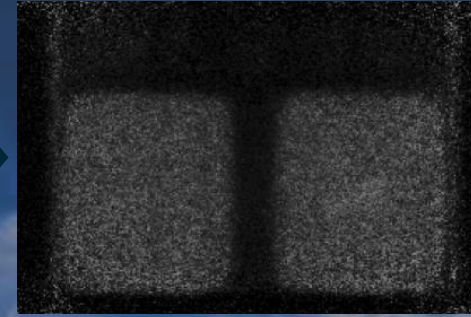
Domain gap



Simulation Data 2D slice



AI



Real measurements Data 2D slice

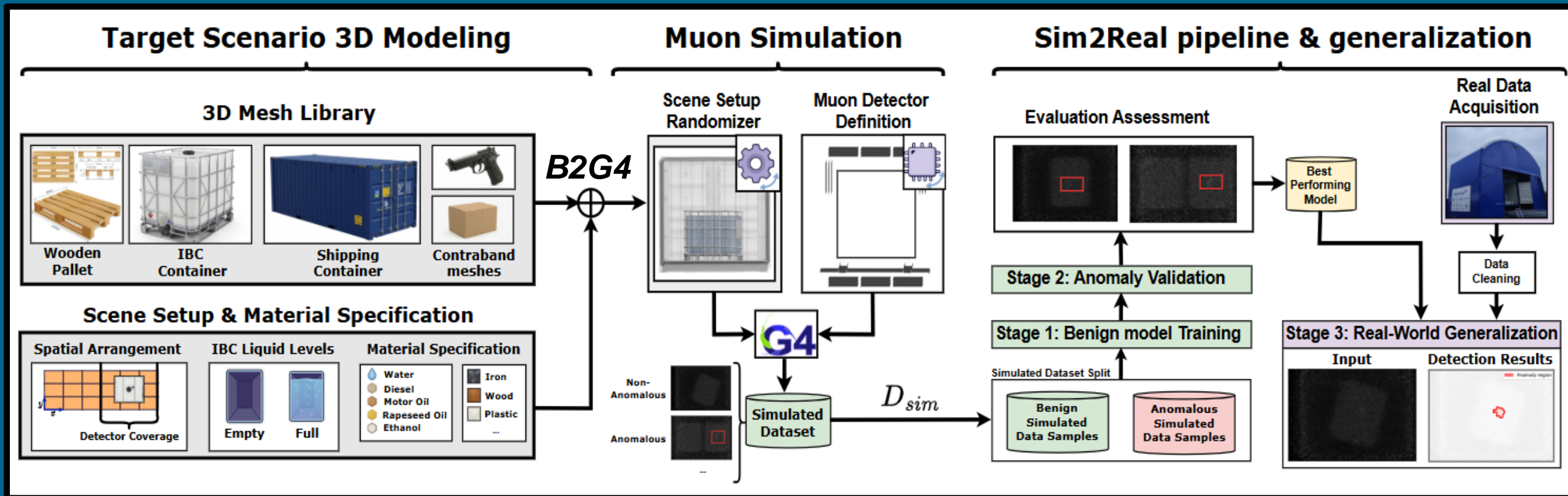
Real Measurements



Can we train an AI on synthetic data that successfully detects anomalies in real muon tomography measurements?

Anomaly detection for muon tomography

- We establish the *sim2real* pipeline, from early scenario definition to real measurement generalization



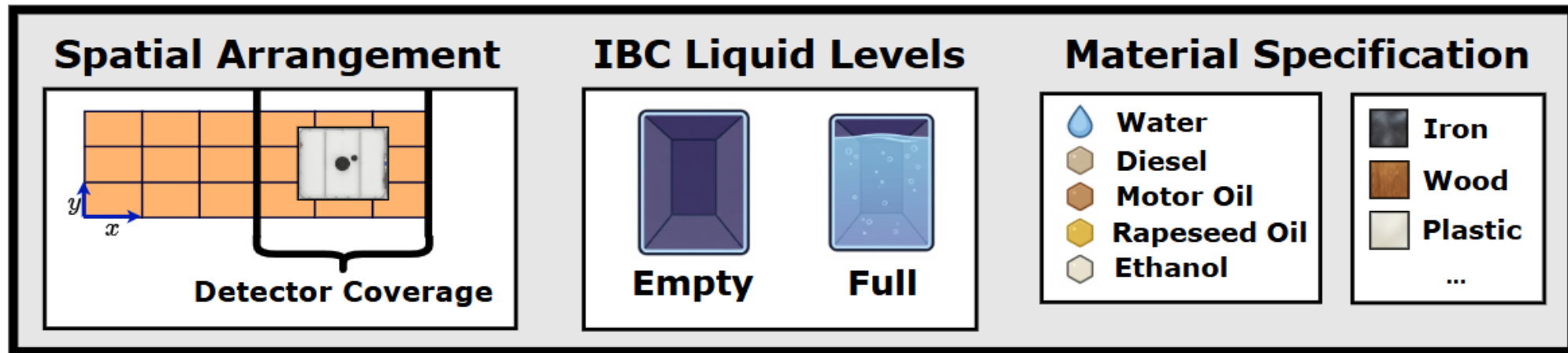
Target scenario 3D Modeling: B2G4



3D Mesh Library

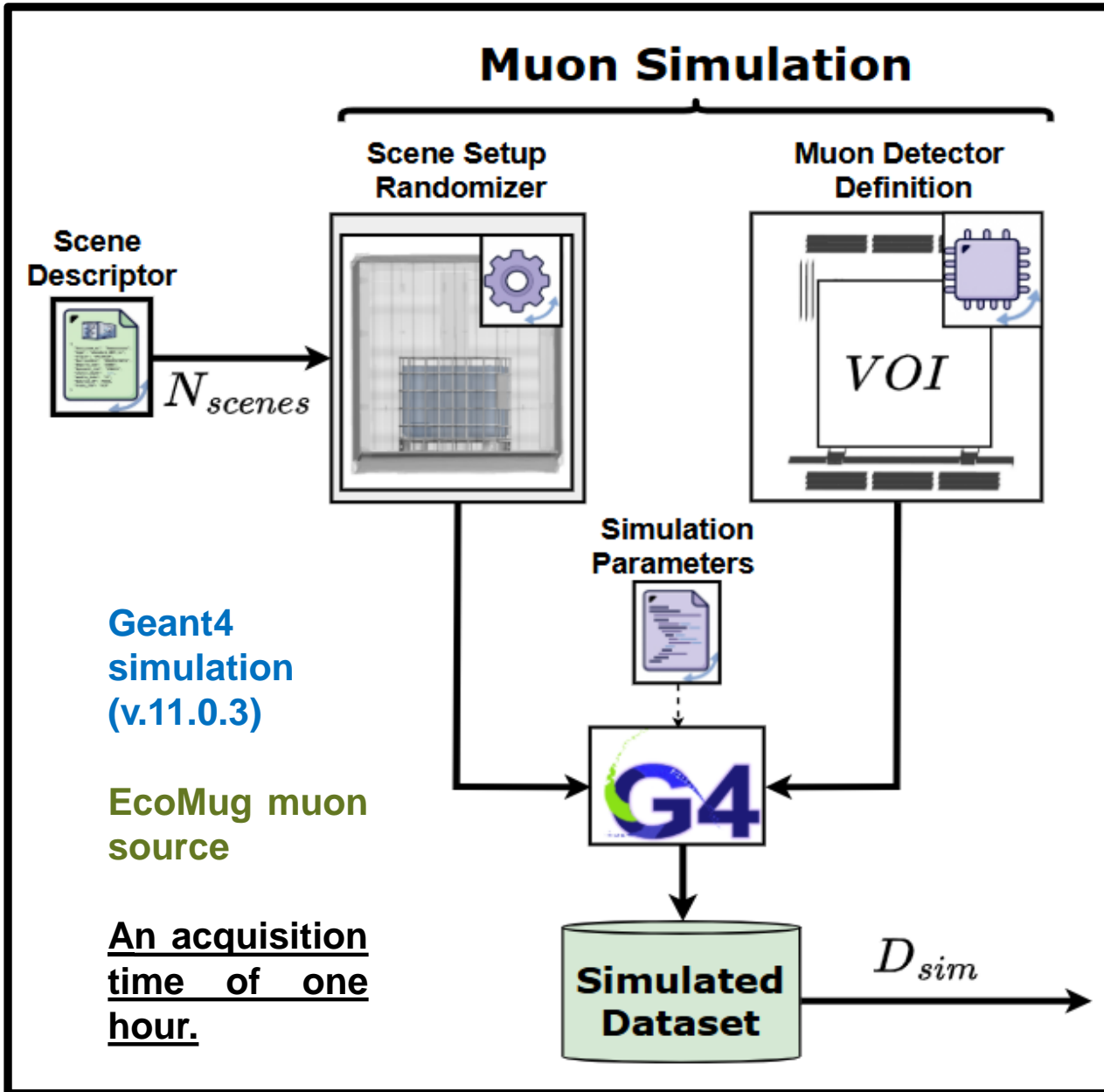


Scene Setup & Material Specification

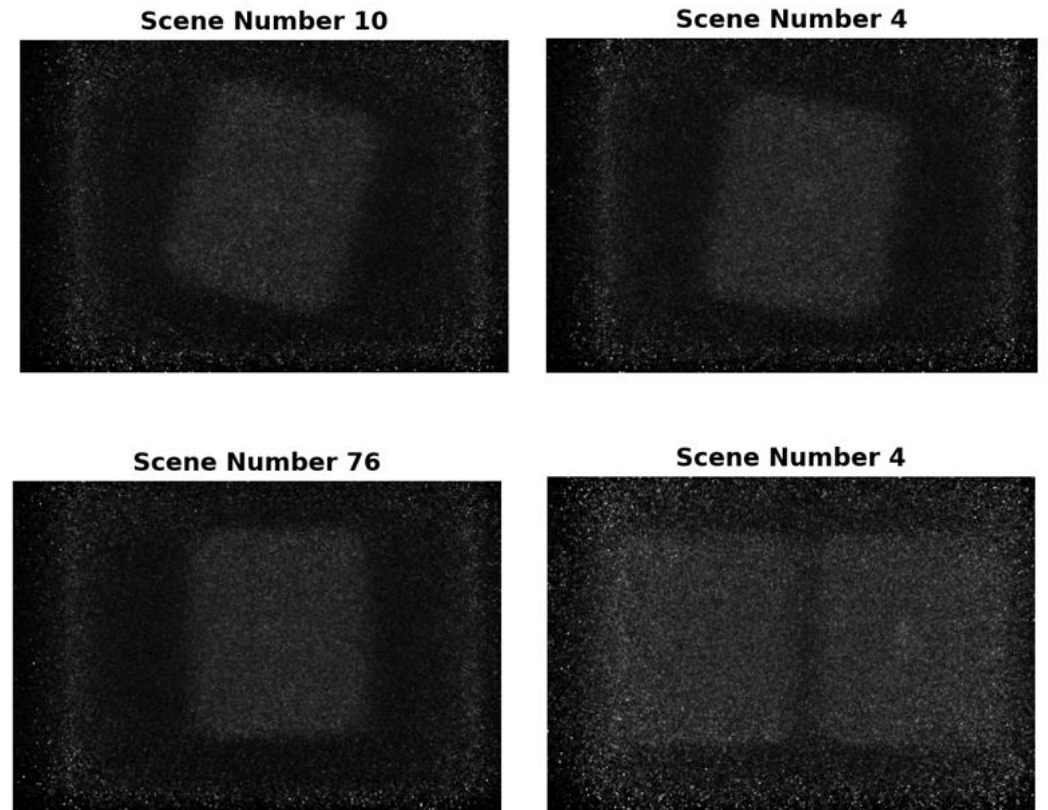


Realistic Simulation Logic: different IBC container setups, liquids and fill levels

Muon Simulation

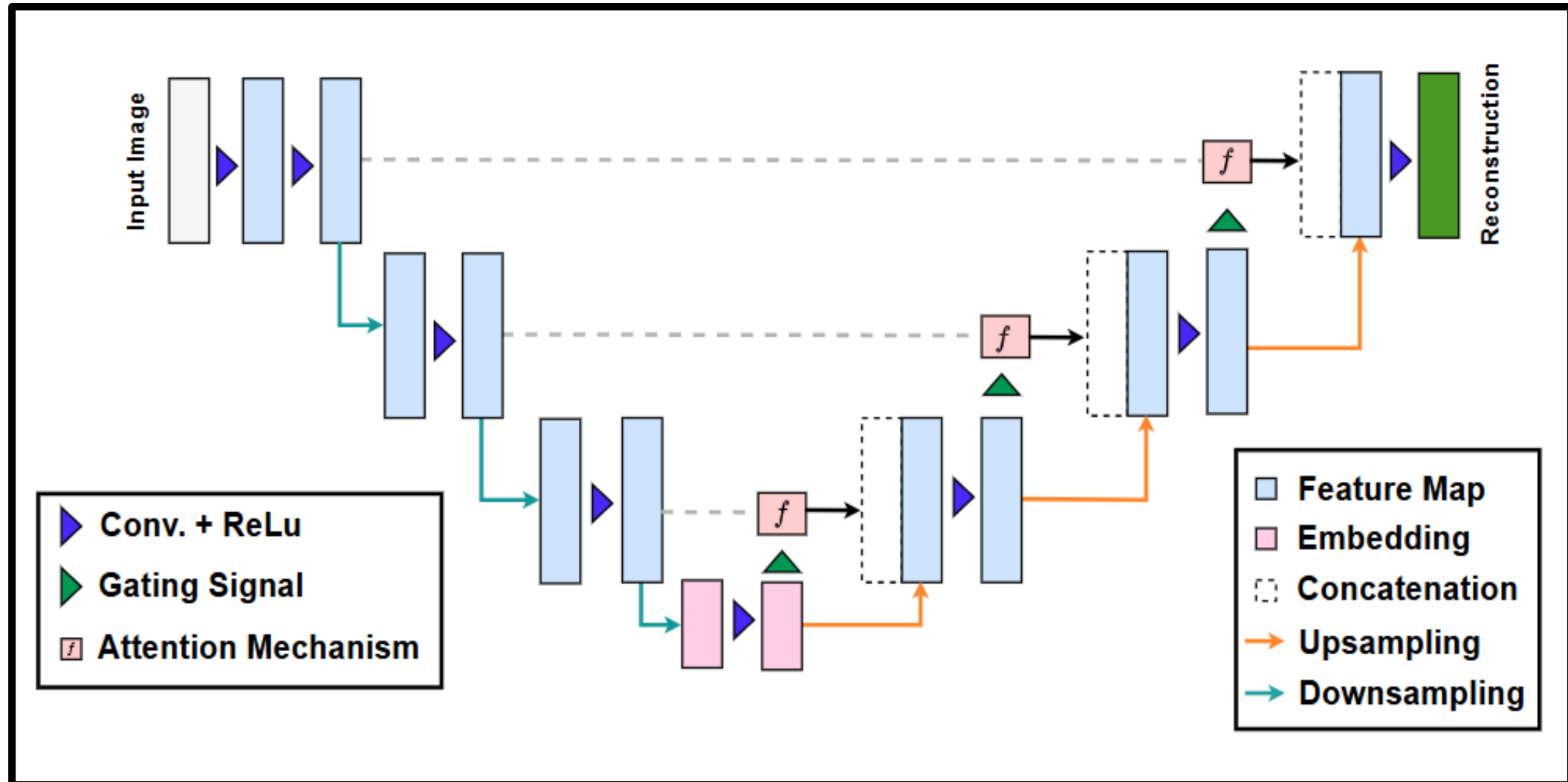


Examples of simulated scenes:

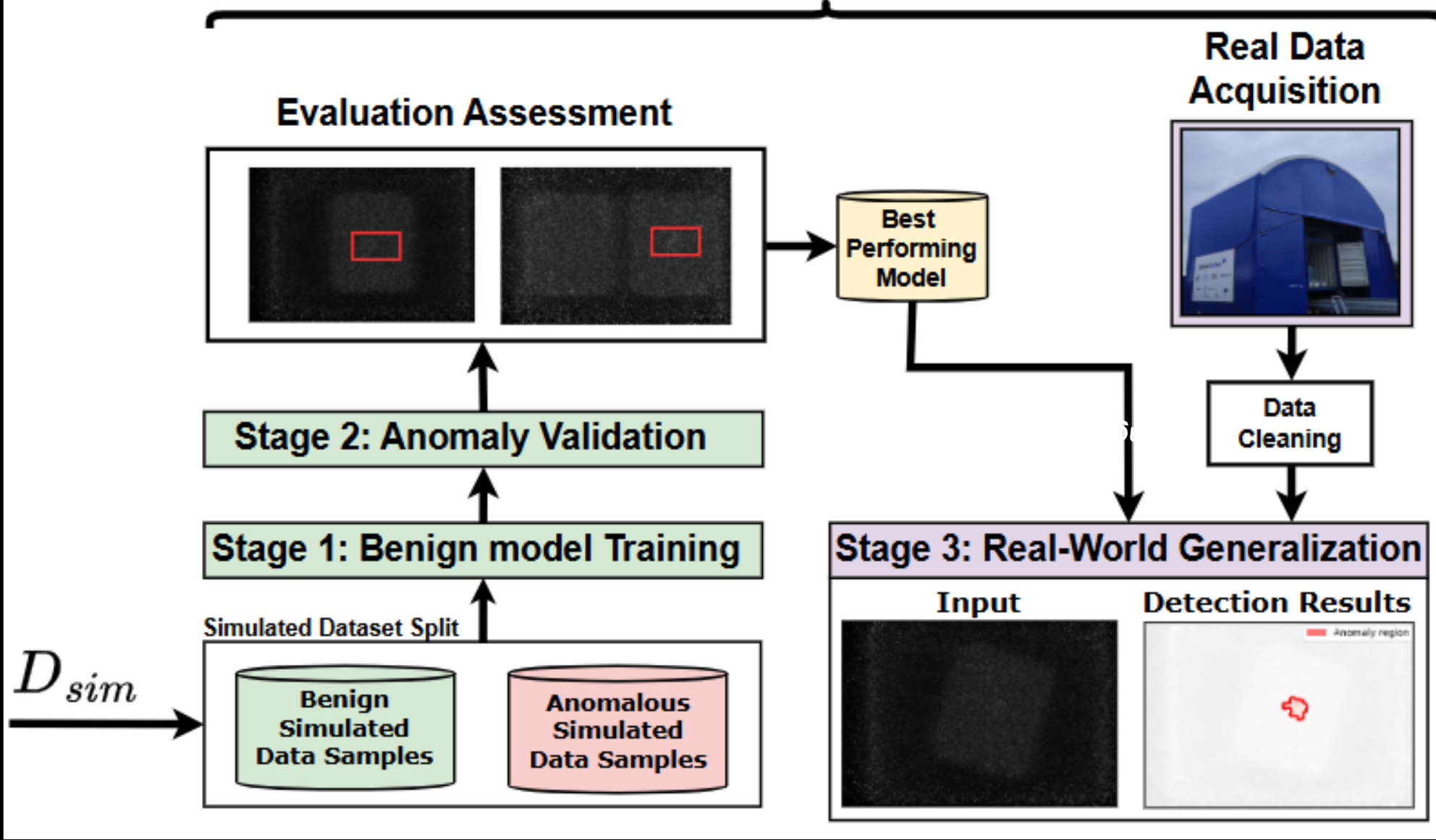


Anomaly detection in SilentBorder: NN

Suspicious and contraband materials can take on many different forms and configurations, making them very challenging to identify. Thus, we do not assume exact ground truth labels.



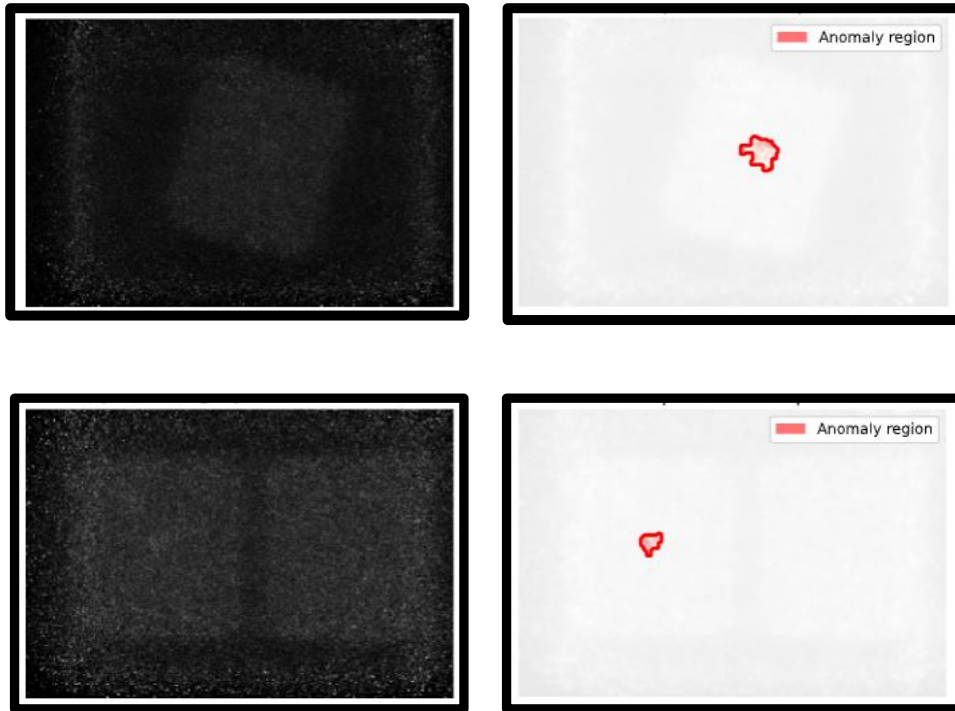
Sim2Real pipeline & generalization



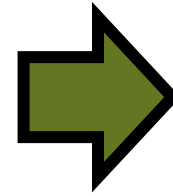
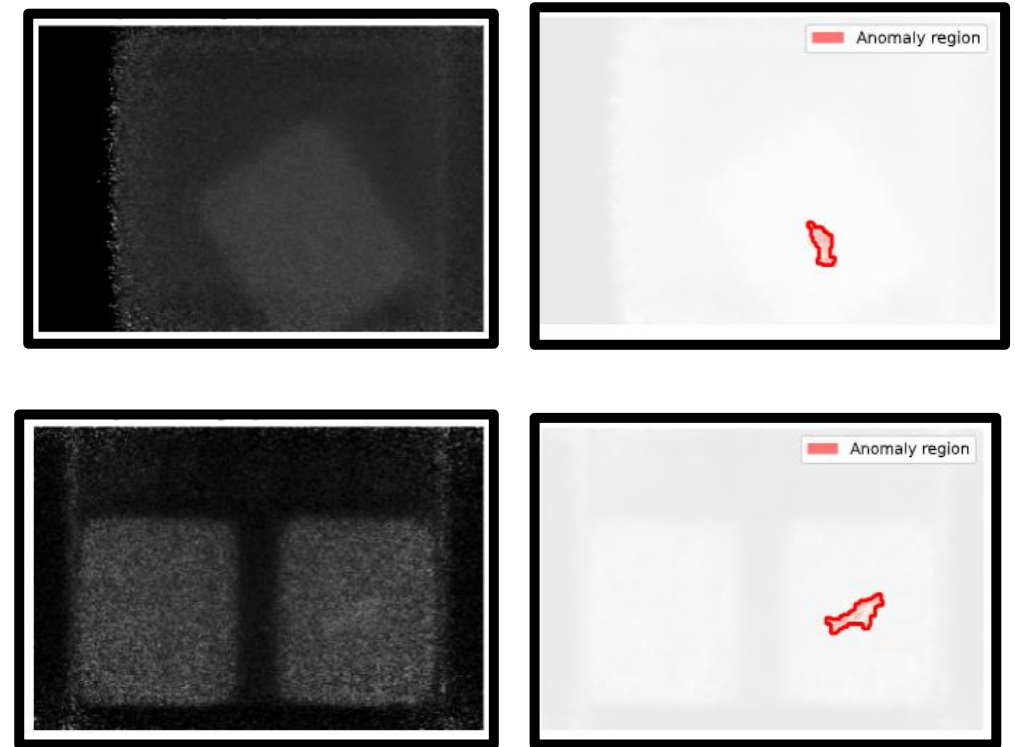
Real-World Generalization

- **Best performing model** jointly trained with synthetic IBC1+IBC2 with **AUROC (>0.75)** and **AUPRC (>0.84)**

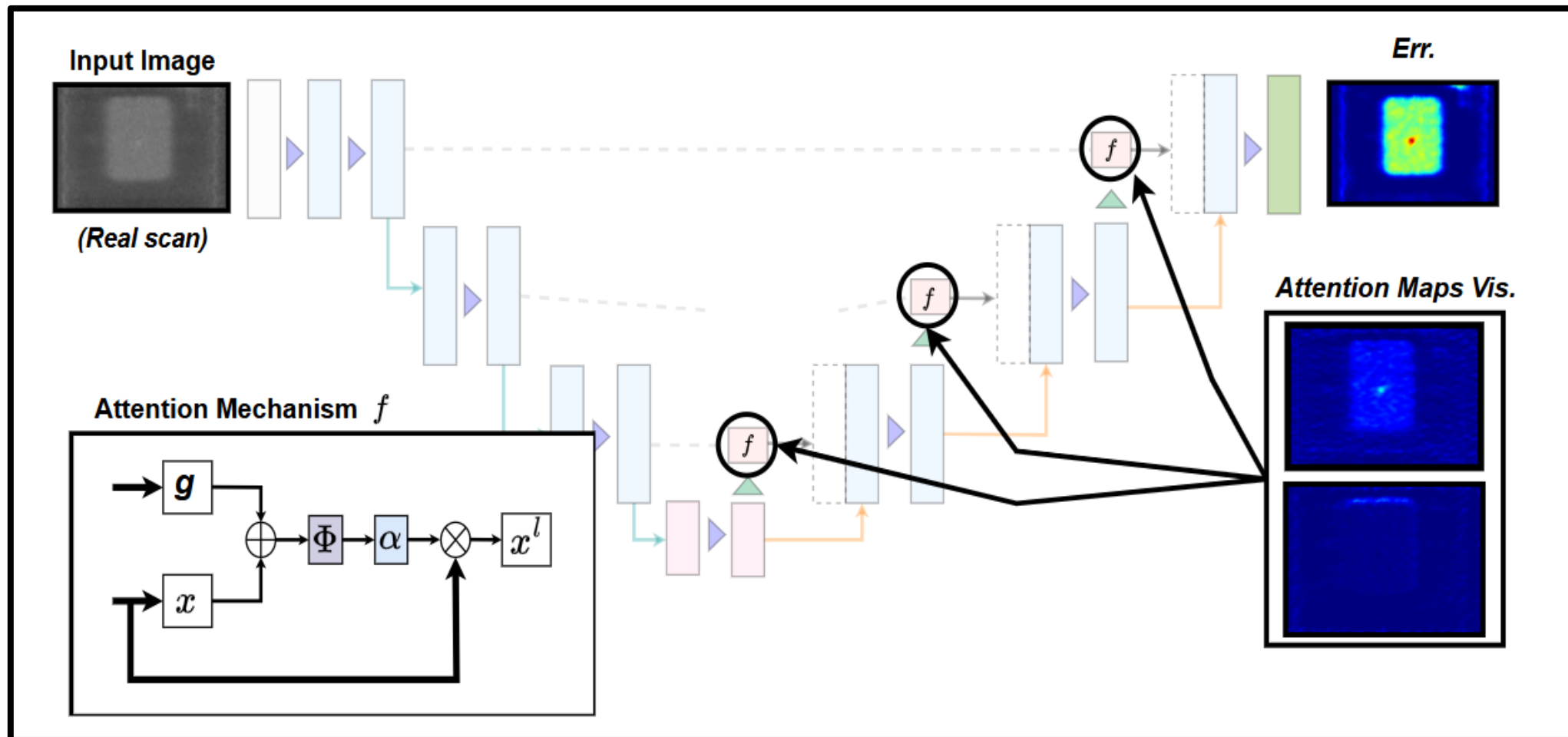
Synthetic predictions



Real Data



Anomaly detection in SilentBorder: NN Attn.



Real data with small anomaly: The attention maps within the network can already highlight the main components of the scanned scene ... and something within the IBC.

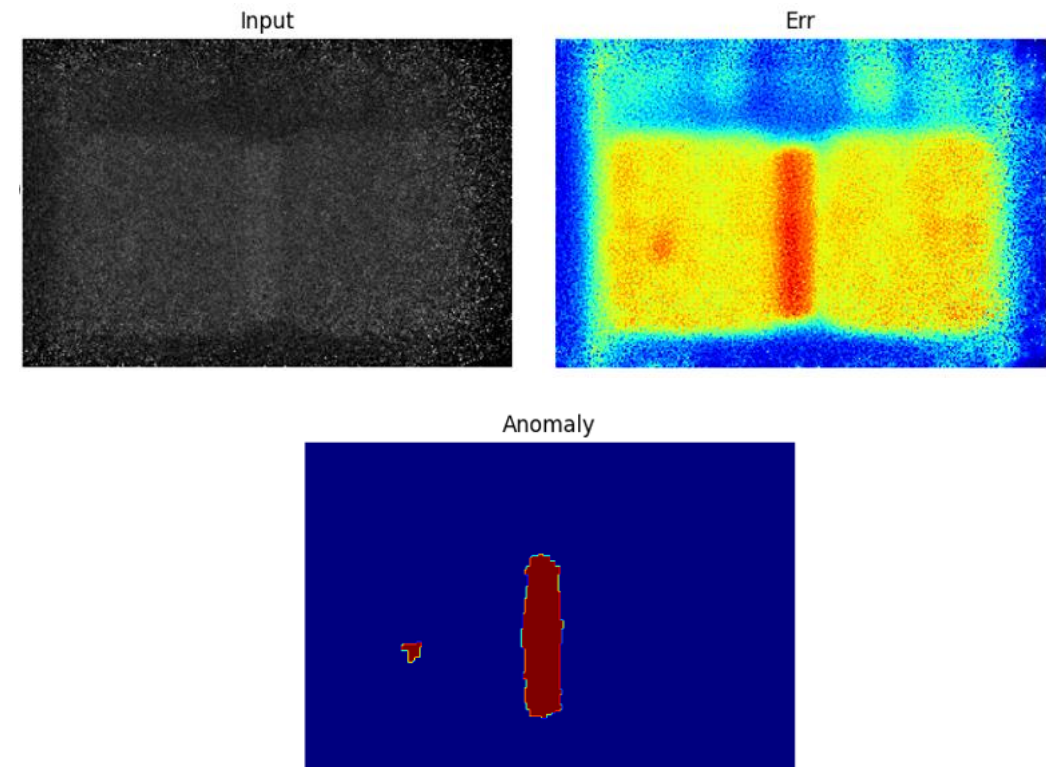
Anomaly detection: Conclusions



We bridge the simulation-to-real gap: trained on synthetic data, the pipeline detects anomalies on real scans.

Attention mechanisms can direct the focus of the network to specific anomalies. The introduced attention specializes in localizing anomalous homogeneous regions at the slice level, without assuming prior knowledge of the contraband.

Next, *in SilentBorder2.0 (See Sarah's Talk)*, we will introduce larger datasets, more cases, and more realistic samples to enhance the anomaly introduced here



Anomaly detection on an post-demo example with shielding



Thanks !

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Programming for Experiment design

1–7 Sept 2026
OAC conference center, Kolymbari,
Crete, Greece

Muography session