
ALERT Workshop 2014

ADSA10 - Explosives Detection in Air Cargo

3D CT with few projections for freight container inspection

Stefan Moser

Victoria Heusinger, Siegfried Nau, Manfred Salk

Boston

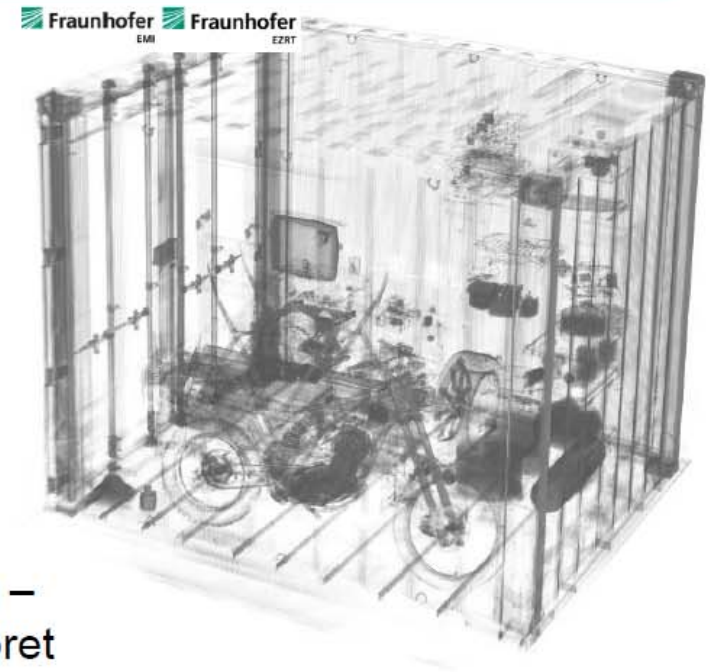
May 6th, 2014

3D CT with few projections for cargo security

The benefit of 3D reconstructions



→
3D scanning (CT)



2D X-Ray images are sometimes hard to interpret.

3D volume reconstructions – even with limited resolution – allow to find threats otherwise hidden; or to help to interpret the complex 2D images (overlaps, full absorption areas).

3D is not yet used in freight scanning, because of challenges in hardware and algorithms development.

In this talk, first results of large-scale 3D freight scanning are presented.

3D CT with few projections for sea freight container inspection

Talk Agenda

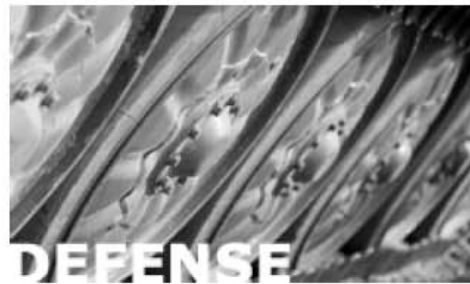
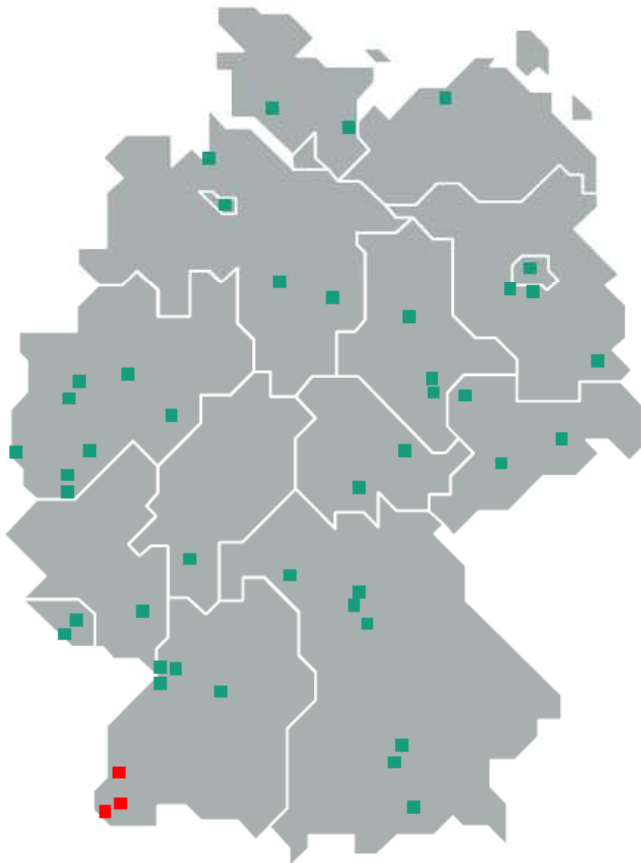
Content	Introduction	■ Our approach: High-Speed Computed Tomography (HSCT)
	Experiment	■ Experimental setup and border conditions
	Results	■ Comparison of reconstruction results for different projection numbers
	Summary & Outlook	■ Current research demand ■ Vision for further research topics

The Fraunhofer EMI

One of ~ 60 Fraunhofer institutes in Germany

Institute: 3 facilities:
Freiburg, Efringen-Kirchen, Kandern

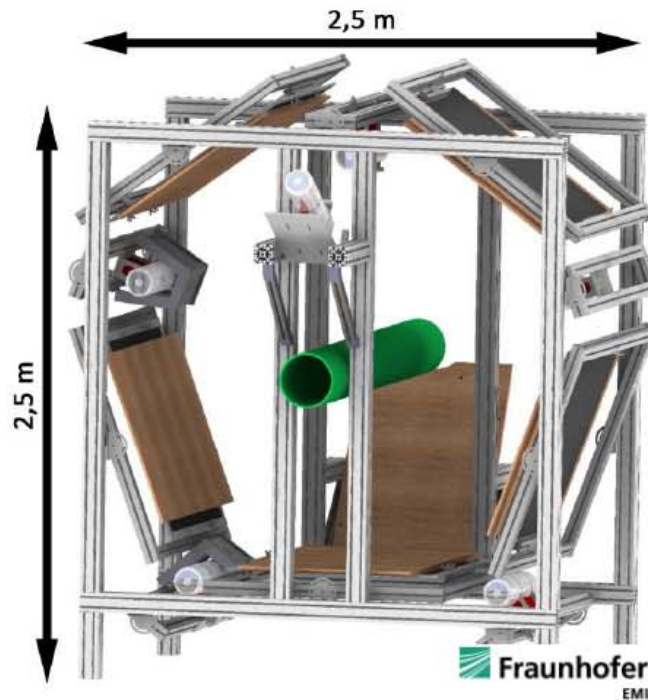
Institute: ~ 300 employees; annual budget ~ 22 Million €
4 business segments



- Department:
»Experimental Ballistics«; Dr. M. Salk

Flash X-Ray High Speed Computed Tomography (HSCT)

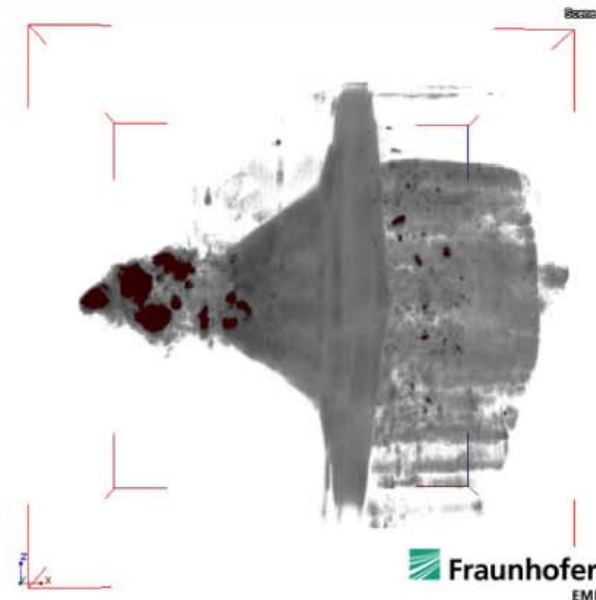
Where we come from



High-Speed CT¹⁾ was developed for dynamic applications on the scale of microseconds

- Few projections (3 to 6)
- 1 channel (source + detector) for each projection
- Simultaneous image acquisition

Experimental setup (top) and reconstruction result (right) of an ceramic armor penetration event with a fragmenting steel projectile (impact velocity ~ 1 km/s; post-impact fragment velocity ~ 300 m/s)





TomDamage 2012

**From post-mortem to dynamic in-situ computed
tomography (CT) analysis**

August 29 – 31, 2012
Freiburg, Germany

www.tomodamage2012.org

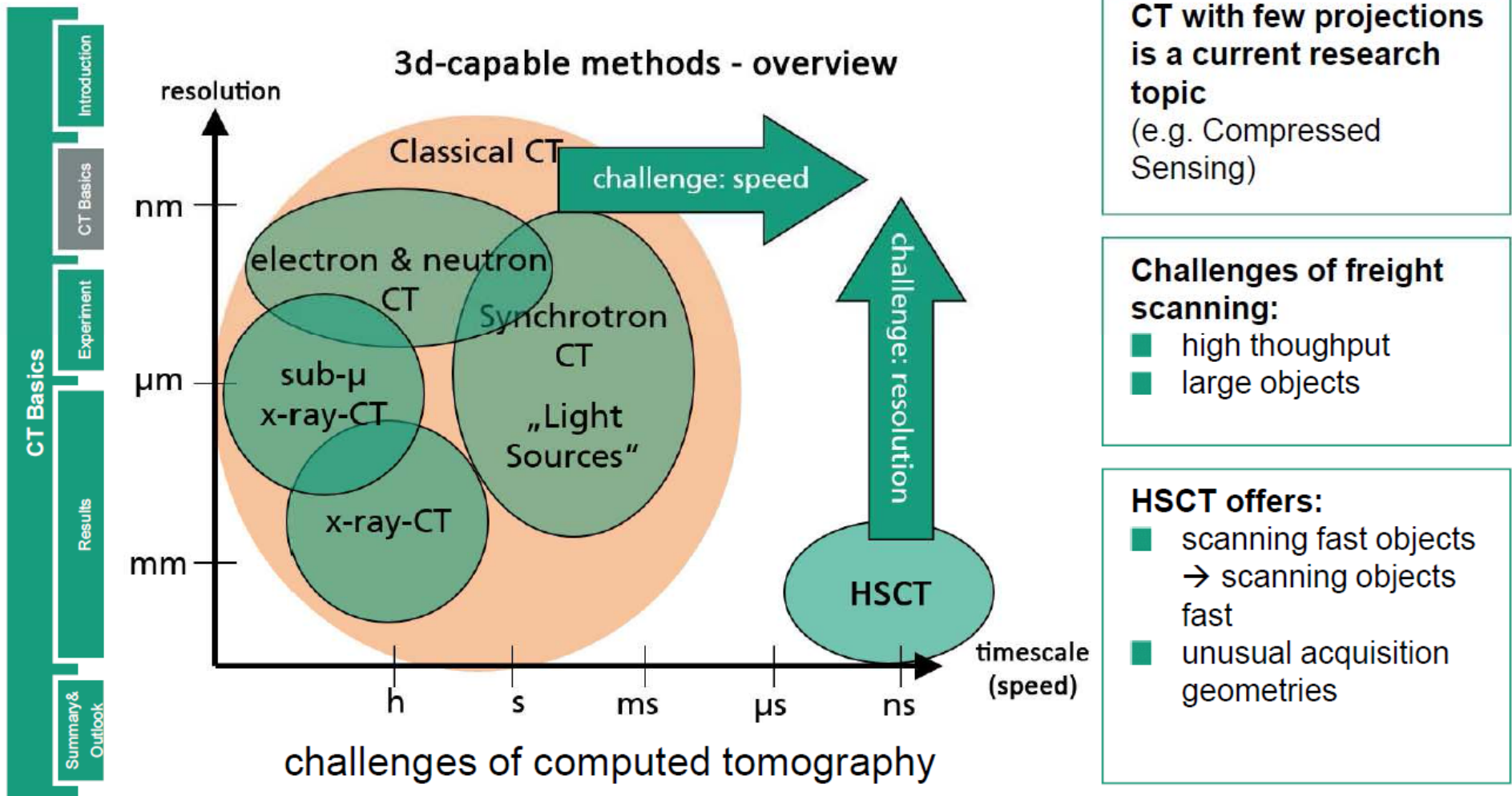
Organized by Fraunhofer Institute for High-Speed Dynamics, in cooperation with ONRG



 **Fraunhofer**
EMI

One of the TomoDamage results: research missions

Different approaches to advancing Tomography



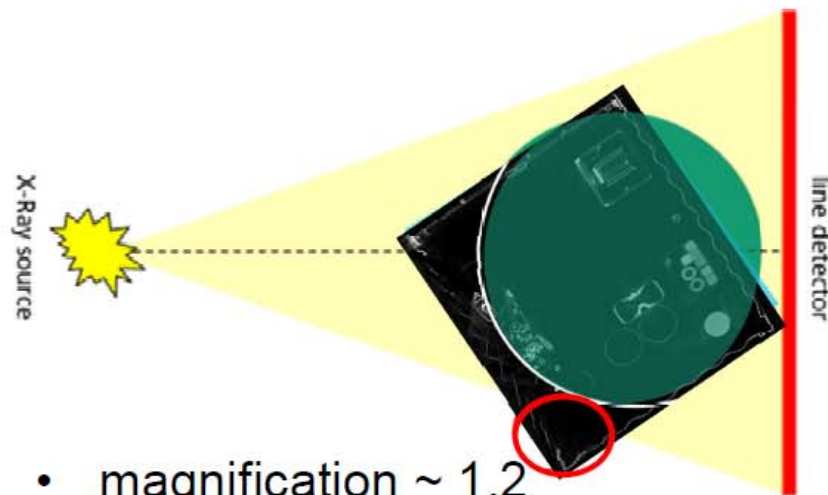
3D CT with few projections for sea freight container inspection

The experiment: setup and technical border conditions

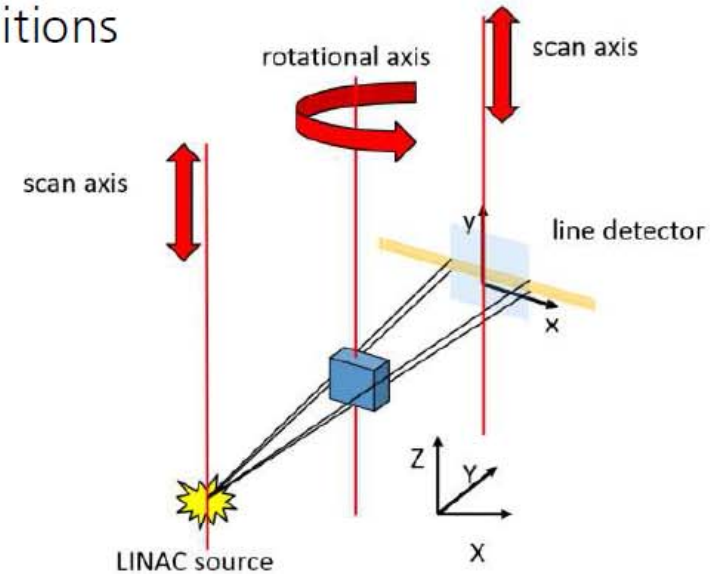
- Experimental setup
- Introduction
- CT Basics
- Experiment
- Results
- Summary & Outlook

XXL X-Ray CT NDT facility
Fraunhofer EZRT; Fürth (Germany)

- 3 m rotating table (up to 10 t specimen weight)
- 9 MeV Linear Accelerator
- line detector



- magnification ~ 1.2
- 180° limited angle
- truncated images



Project „ECSIT“; technology partners:
Fraunhofer **EMI** & **EZRT**; **Smiths Detection**



3D CT with few projections for sea freight container inspection

The experiment: Dummies representing different threat scenarios; other items



The „cargo“ of the container consists of

- dummies of „dangerous items“
- large variety of cargo to conceal said dummies (e.g. motorbike, steel pipes, electronic devices (e.g. washing mashine, TV, radios ...))

List of dummies hidden in the container:

high-Z scenarios:

- dirty Bomb mock-up
- high-Z Device mock-up
- high-Z material dummy

Explosives scenarios:

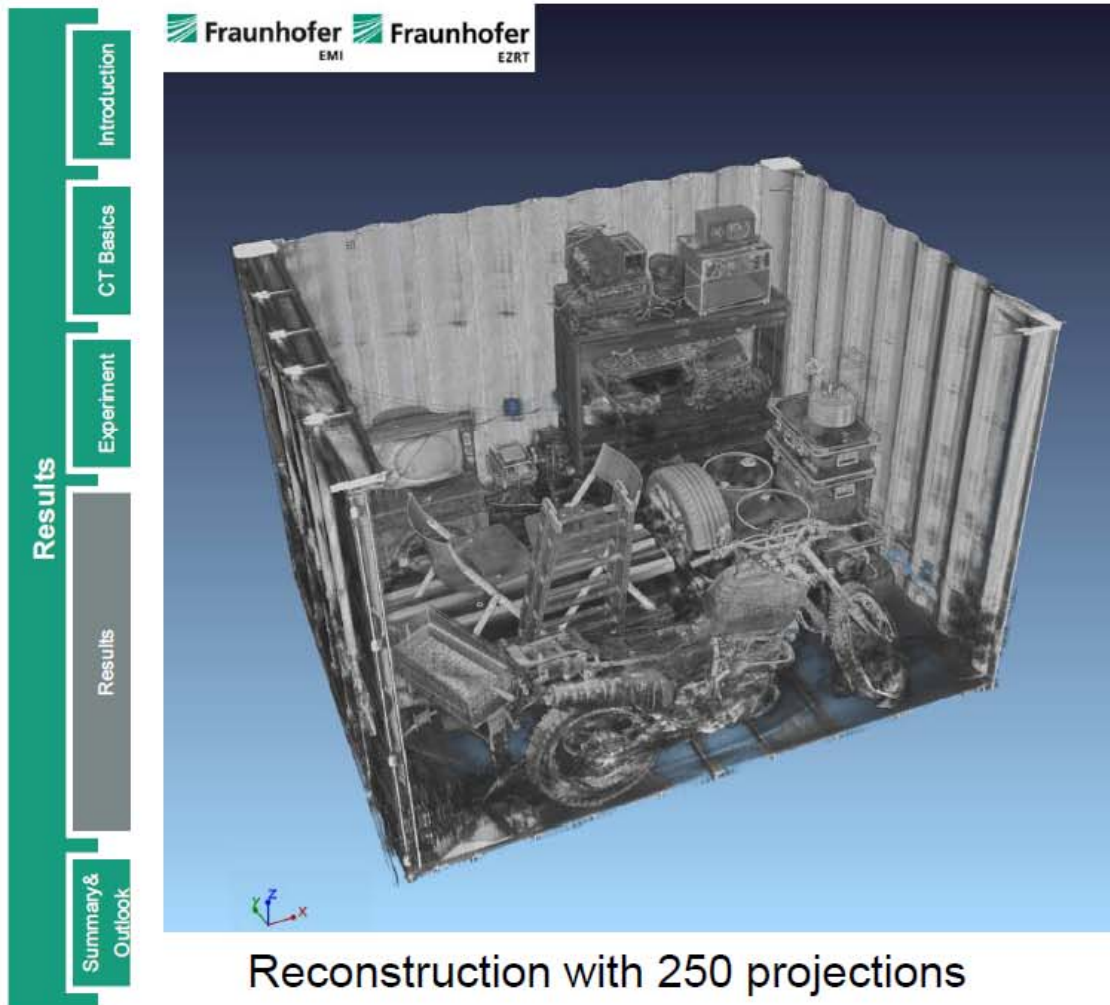
- pipe-bomb mock-up
- IED mock-up

Other scenarios:

- Fluids of different density
- Hidden small arms gun
- Small quantities of substances with different densities

3D CT with few projections for sea freight container inspection

Results: Overview



Reconstruction parameters

Input data:

- Datasets with 25, 50, 100 and 250 projections
- Image size 1331 x 841 pixels (3 mm pixel-pitch by binning of the high-resolution line detector)

Reconstruction:

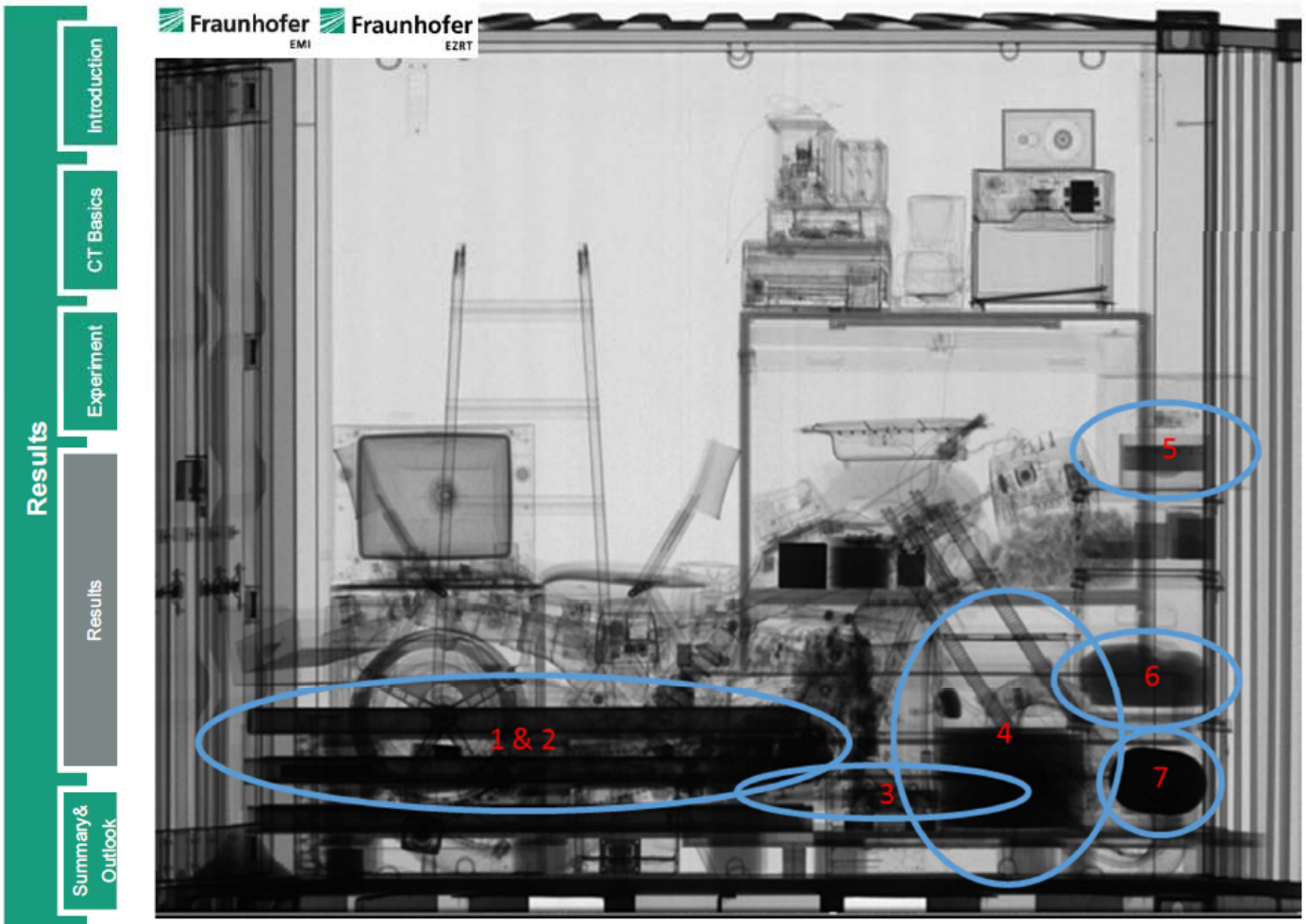
- ART with moderate regularization
- 250 iterations

Reconstruction volume:

- ~ 3 x 3 x 2.1 m
- Voxel-Size 2.5 mm (→ 1215x1215x841 voxels)

3D CT with few projections for sea freight container inspection

Results: where are the dummies located in the container?



Dummy locations

- 1: high-Z material dummy
- 2: pipe bomb mock-up
- 3: small arms gun
- 4: barrels with fluids
- 5: dirty bomb mock-up
- 6: IED mock-up
- 7: high-Z device mock-up

Difficult configuration:

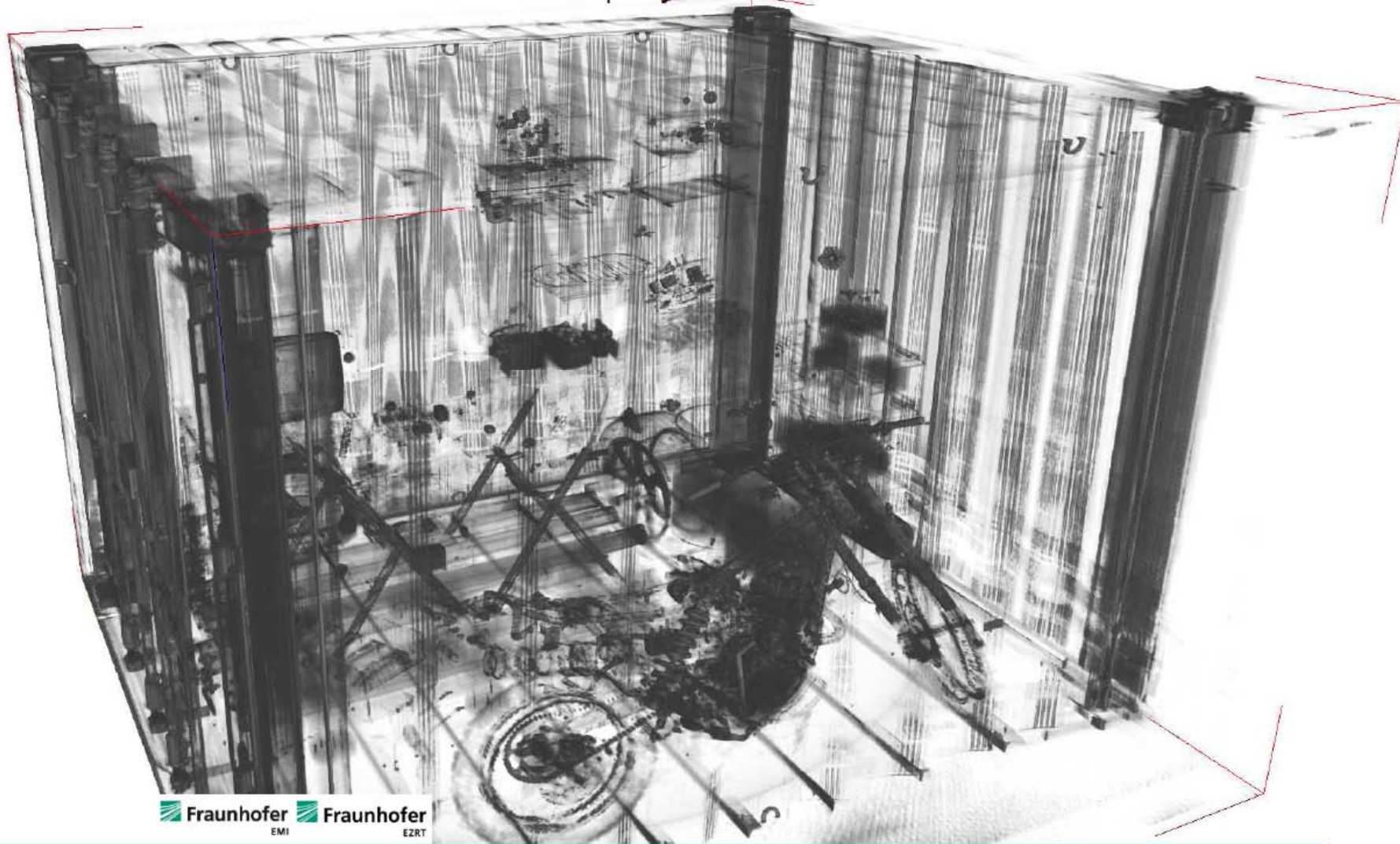
- many different objects all consisting of different materials
- many overlapping contours
- dense materials near full absorption

Results

- Introduction
- CT Basics
- Experiment
- Results
- Summary & Outlook

3D CT with few projections for sea freight container inspection

3D animation of reconstruction with 250 projections



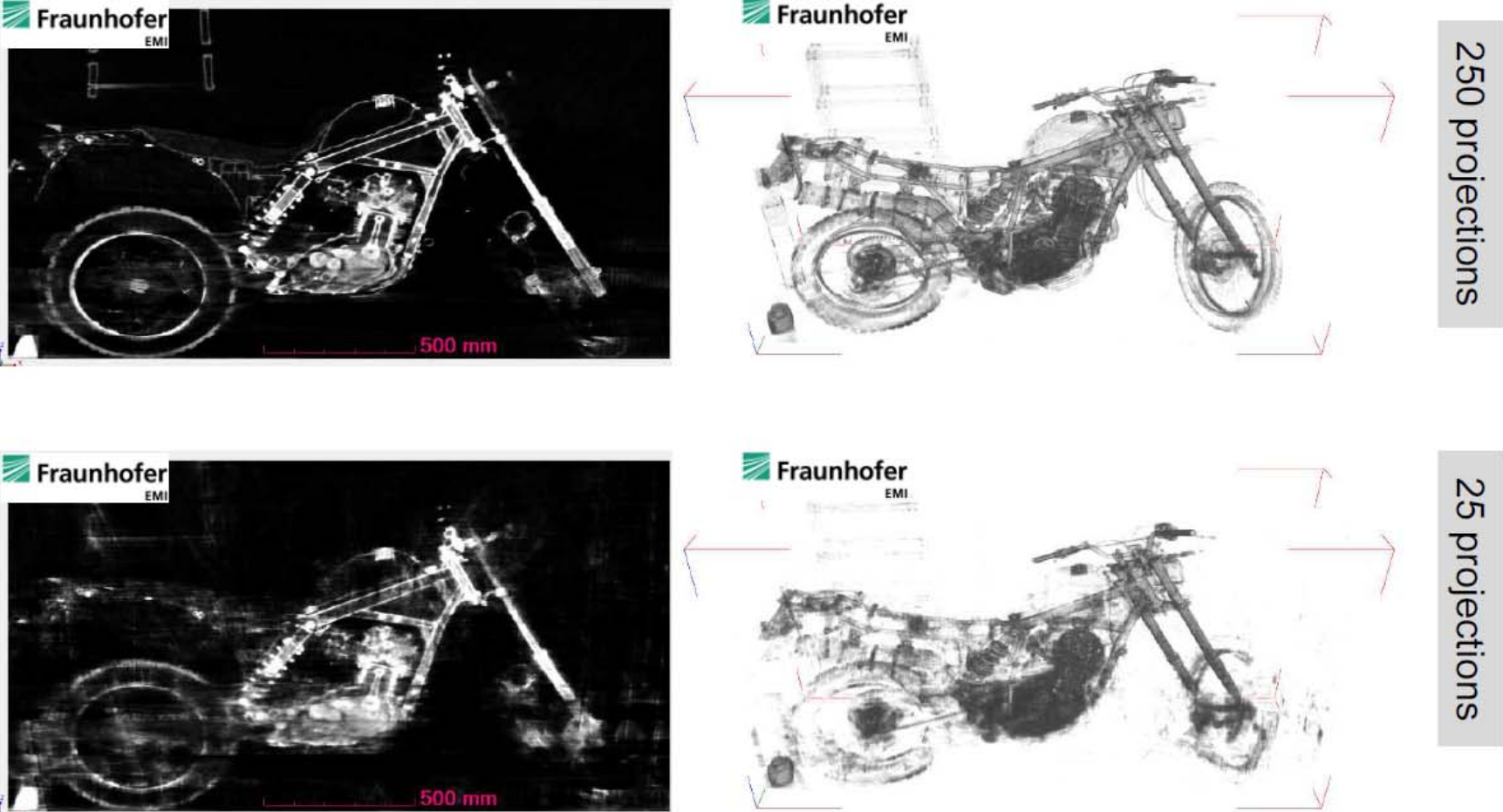
Fraunhofer EMI Fraunhofer EZRT

3D CT with few projections for sea freight container inspection

Results: motorcycle (partially truncated image data)

Results

- Introduction
- CT Basics
- Experiment
- Results
- Summary & Outlook



The figure displays four panels comparing the results of 3D CT scans of a motorcycle. The top row shows results from 250 projections, and the bottom row shows results from 25 projections. Each row contains a grayscale CT image on the left and a corresponding 3D reconstruction on the right. The 3D reconstructions are shown with red arrows indicating the viewing directions. A 500 mm scale bar is present in the bottom right of each grayscale image. The 250 projection results show a much clearer and more complete 3D model compared to the 25 projection results, which exhibit significant artifacts and missing data.

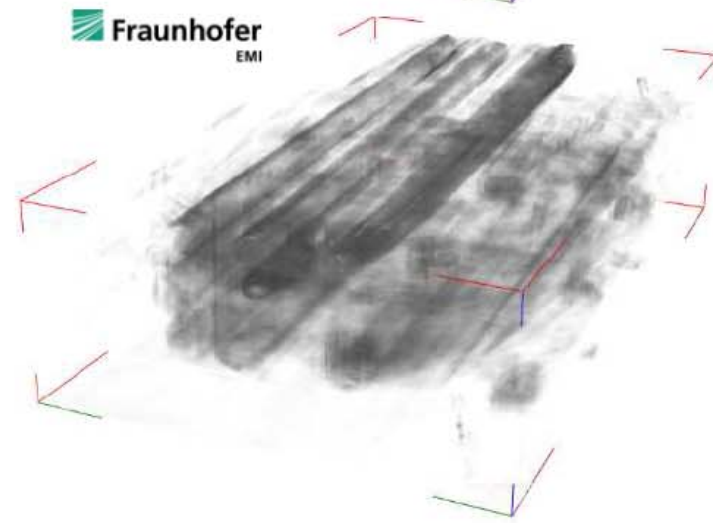
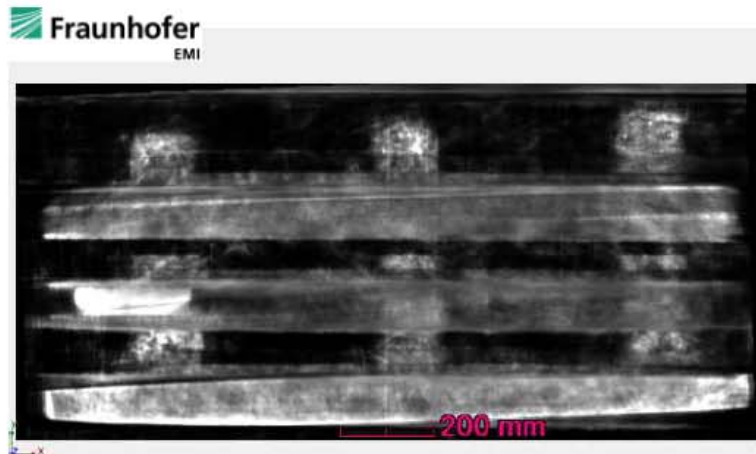
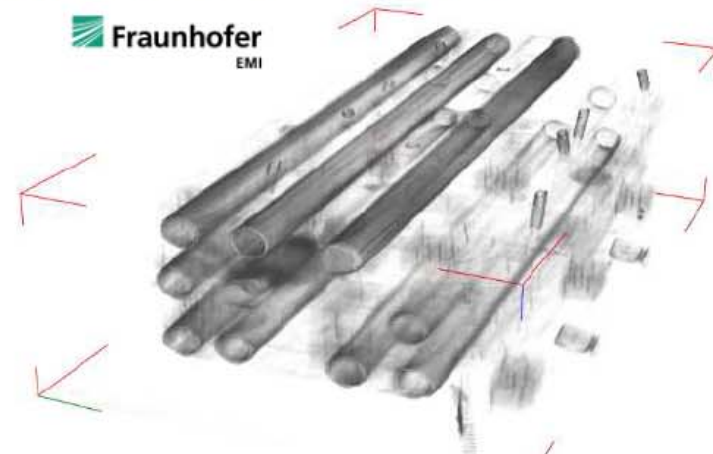
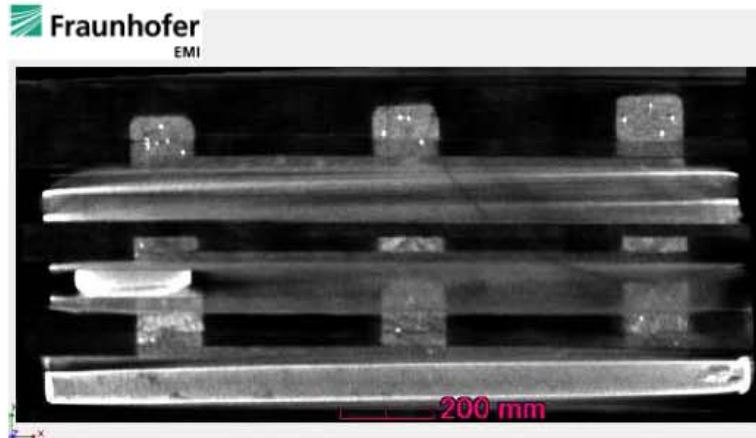
250 projections

25 projections

3D CT with few projections for sea freight container inspection

Results: pipe bomb mock-up and dense material block in steel pipes

- Introduction
- CT Basics
- Experiment
- Results**
- Summary & Outlook



3D CT with few projections for sea freight container inspection

Results: IED mock-up

Results

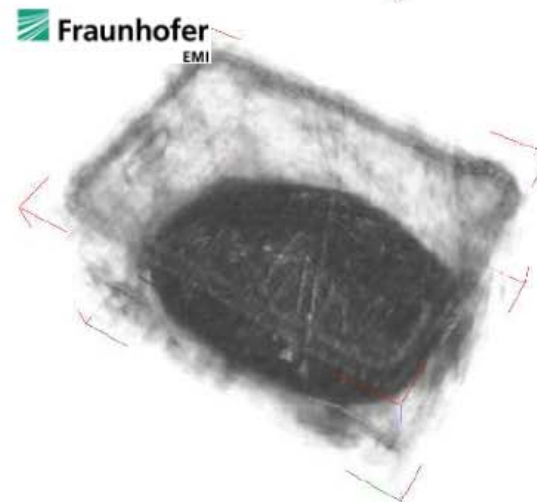
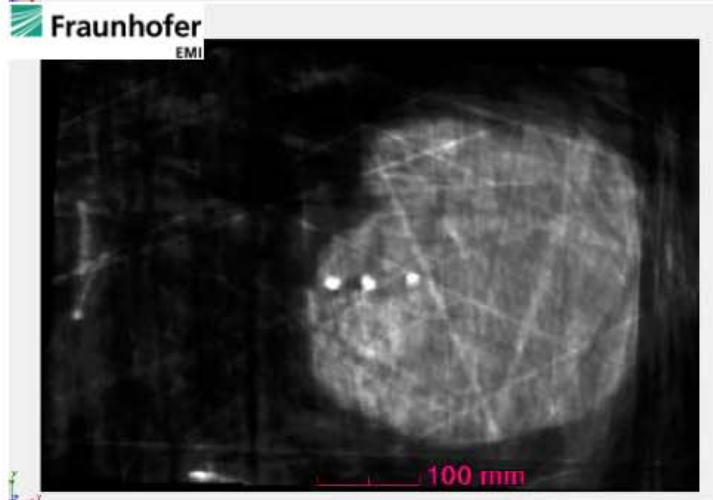
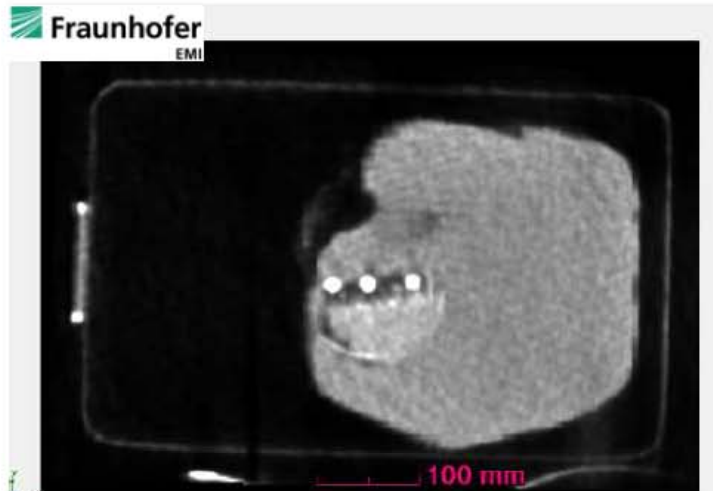
Introduction

CT Basics

Experiment

Results

Summary & Outlook



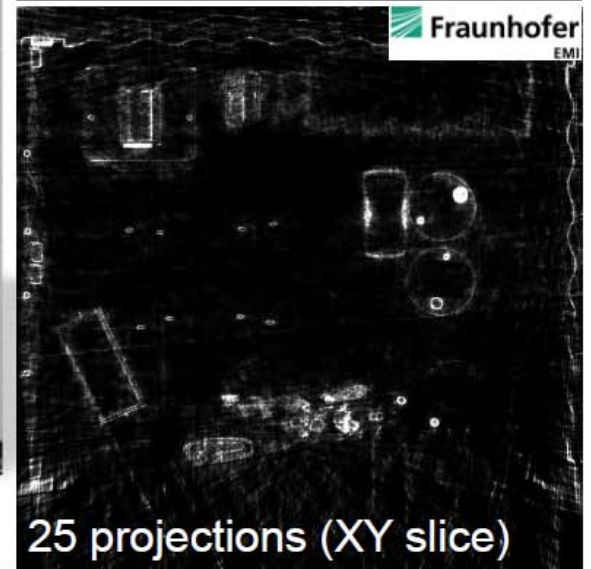
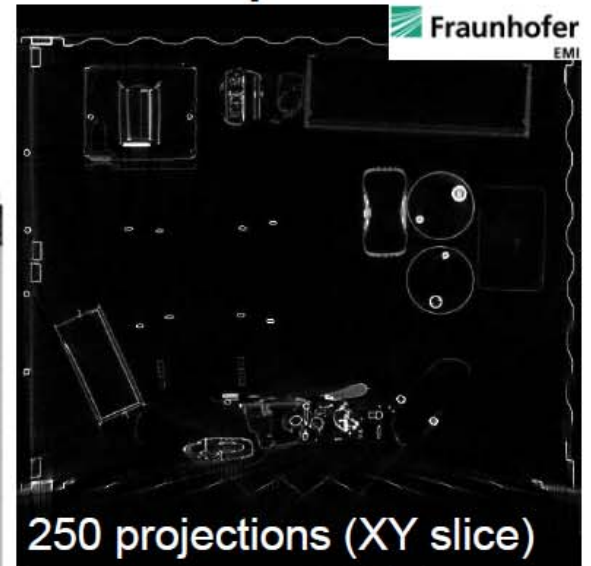
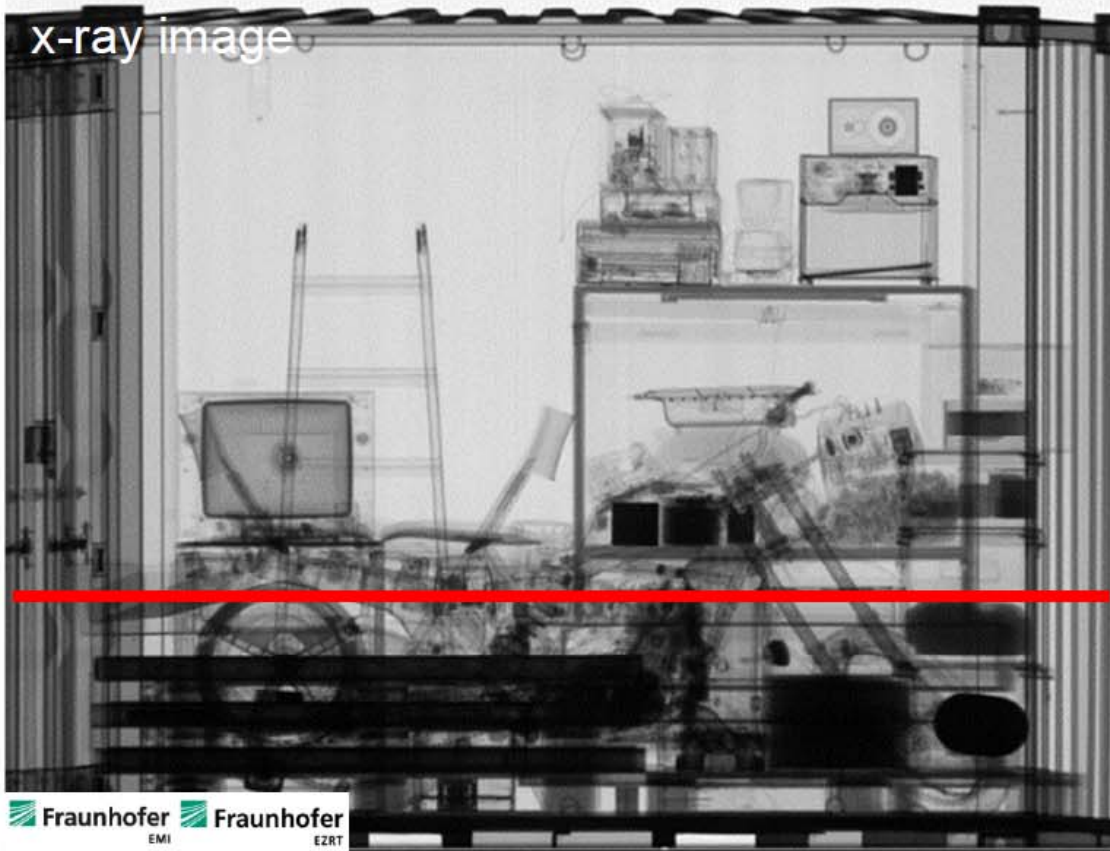
250 projections

25 projections

3D CT with few projections for sea freight container inspection

Whole container investigation – only 25 projections

- Introduction
- CT Basics
- Experiment
- Results
- Summary & Outlook

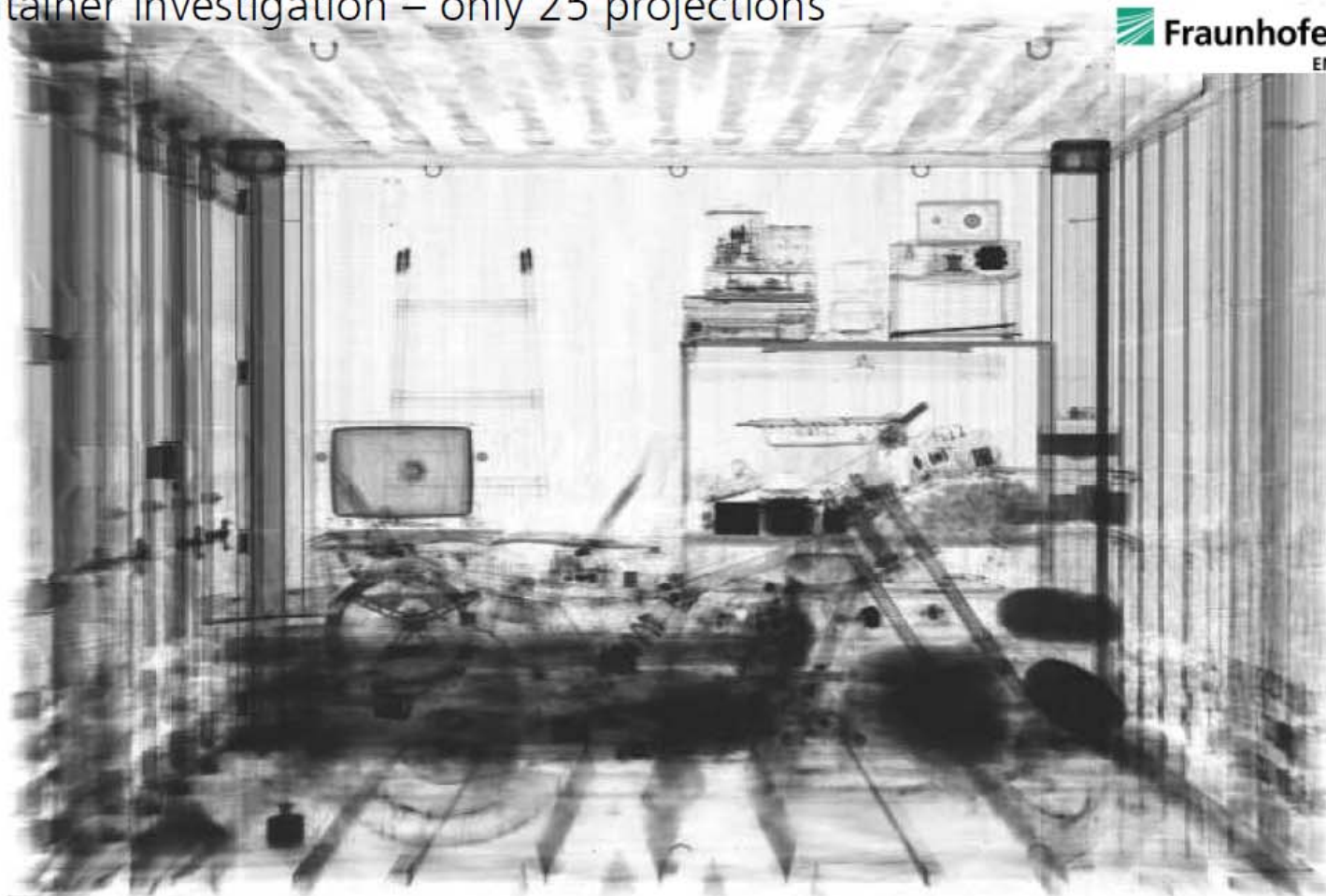


3D CT with few projections for sea freight container inspection

Scene

Whole container investigation – only 25 projections

Fraunhofer
EMI



Results

Introduction

CT Basics

Experiment

Results

Summary &
Outlook



3D animation – 25 projections

3D CT with few projections for sea freight container inspection

Summary & Outlook

■ **application:** 3D data supports the operator in

- determining the location of objects in complex / diverse cargo items with lots of overlapping objects
- identifying said objects → threat or no threat?
- scalability of the method via projection numbers

■ **Current research:** 3D scanning of freight can be done with currently available hard- & software, but needs to be further adapted to cope with throughput demands:

- image acquisition: geometry, sources, detectors
- reconstruction algorithms: regularization, compressed sensing
- using synergy effects with other methods (e.g. materials identification methods)

■ **Next necessary steps:** advancement of data analysis:

- help operators interpret 3D data: post-processing, artefact reduction, segmentation
 - comparison to freight documents
 - threat-oriented machine vision
- **vision:** advancement of data analysis:
 - Automated 3D data analysis

**Thank you for your
attention!**



Stefan Moser

Fraunhofer EMI
Am Klingelberg 1
79588 Efringen-Kirchen
Tel.: +49 76 28 / 90 50 – 635
email: moser@emi.fhg.de

Further Information:

Dr. Siegfried Nau

Fraunhofer EMI
Am Klingelberg 1
79588 Efringen-Kirchen
Tel.: +49 76 28 / 90 50 – 635
email: nau@emi.fhg.de