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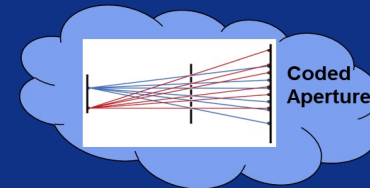
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Planar Coded Aperture Reconstruction for Gamma Imaging via Machine Learning and the TOPAS simulation toolkit
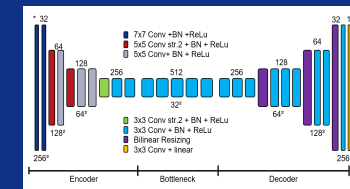
Can a *smaller but more realistic* training dataset improve reconstruction quality of a CNN?
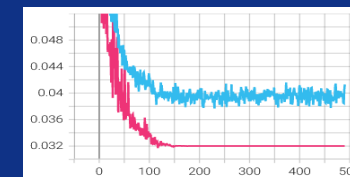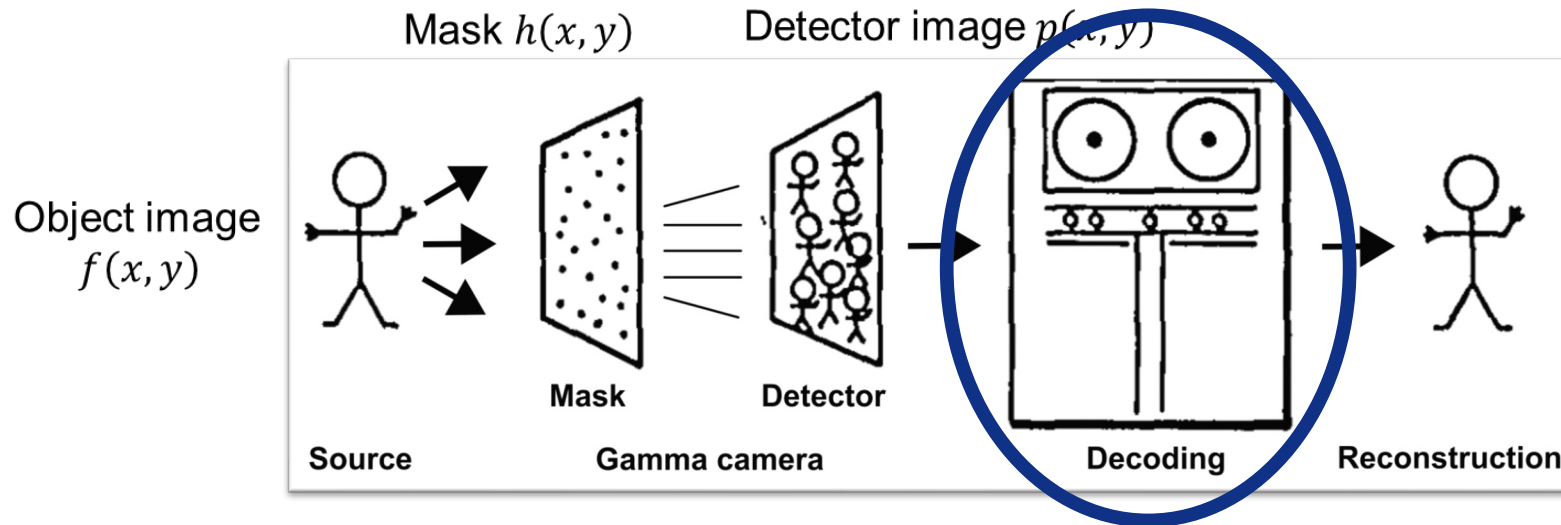
Agenda

Introduction

Material & Methods

Results & Discussion

Conclusion

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How does Coded Aperture Imaging work?

Object image $f(x,y)$ — Mask $h(x,y)$ — Detector image $p(x,y)$

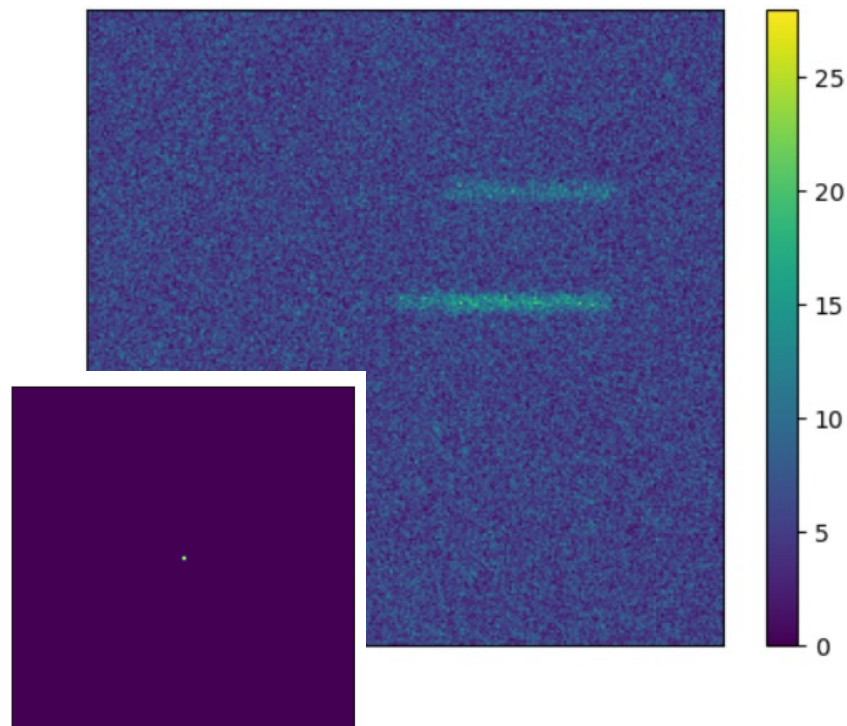Source — Mask — Detector — Gamma camera — Decoding — Reconstruction
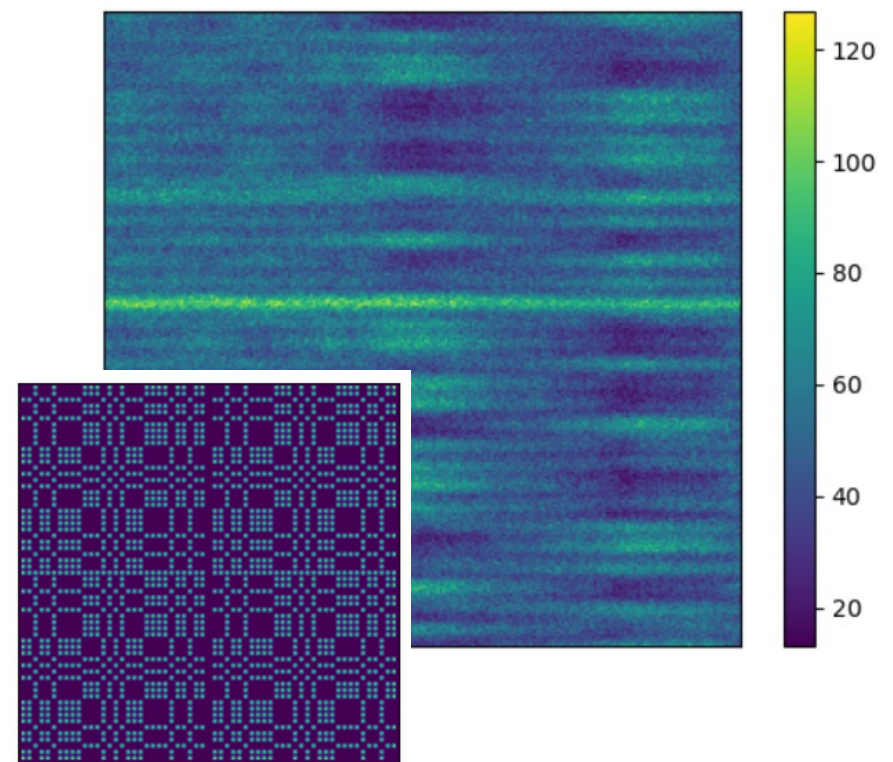
$$p(x,y) = f(x,y) * h(x,y)$$

- Coded aperture offers better compromise between resolution and photon efficiency
- **Planar CAI** can be described by the **convolution operation** bound to **Poisson noise**
- Overlapping projections ➡ **uninterpretable** detector image ➡ Reconstruction necessary

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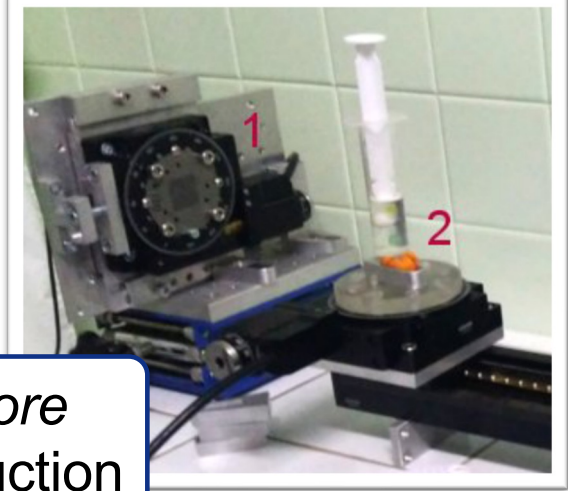Universitätsklinikum Mannheim
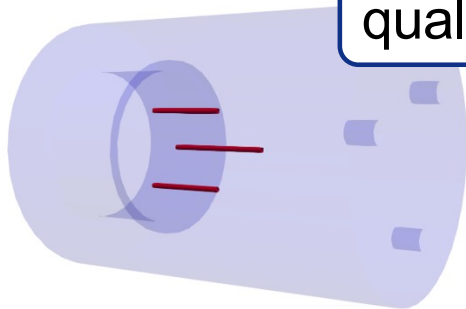
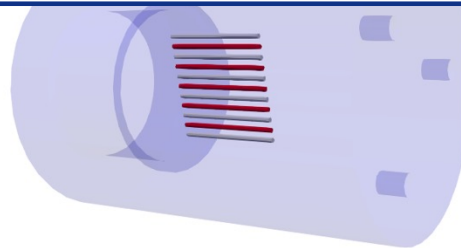# How does Coded Aperture Imaging work?

Validation Data

- Provided by Rozhkov et al. from Dubna acquired with an experimental γ-camera:
  - Three hot-rod phantoms à 120 images: SRP, LRP and CP

- Ground truth data were derived from the geometric computer models

> **Research question**: Can a *smaller but more realistic* training dataset improve reconstruction quality of a CNN?

SRP   LRP   CP

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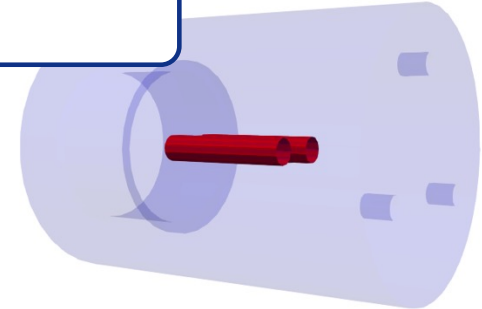
Comparing TOPAS to the convolutional simulation:

TOPAS

30min

Convolutional Simulation

$$p(x, y) = P\{f(x, y) * h(x, y)\}$$

*

250ms / 25ms

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Training procedure
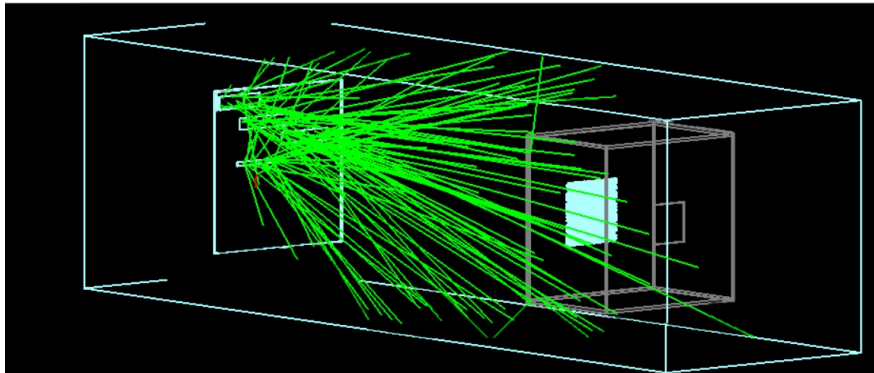
Pre-training

CED-IN

trained on ImageNet:
35k + 10k

CED-Lin

trained on Lines:
35k + 10k

Fine-tuning

CED-Topas

trained on TOPAS Lines:
2k + 0.8k

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Results & Discussion

Different methods on single acquisition data. 8 points outside the range [0, 12]

model	SRP med	SRP IQR	LRP med	LRP IQR	CP med	CP IQR
MURA Decoding	1.919403	0.743022	0.554774	0.621717	0.619765	0.325278
CED-IN	2.646774	1.050028	0.921391	1.455012	1.226864	0.658762
CED-Lin	5.223905	2.820664	0.518019	2.451659	1.422173	1.525226
CED-Topas	4.687822	1.252599	0.903519	2.952684	1.530729	1.069747

Different results for different phantoms:
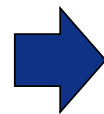
- SRP ΔCNR: -0.53 → Convolutional simulation performs far better
- LRP ΔCNR: 0.39 → TOPAS performs better
- CP ΔCNR: 0.11 → TOPAS performs a little better

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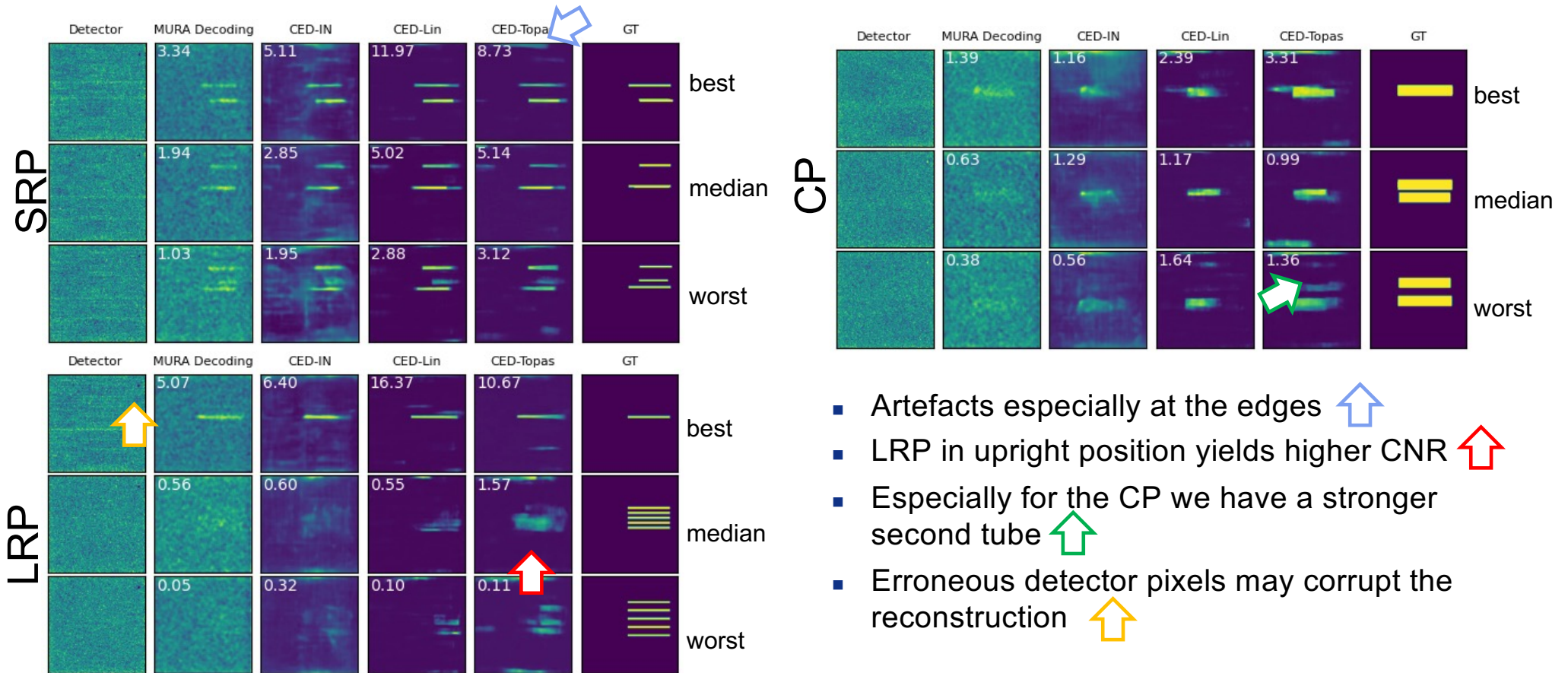
- Artefacts especially at the edges
- LRP in upright position yields higher CNR
- Especially for the CP we have a stronger second tube
- Erroneous detector pixels may corrupt the reconstruction

Conclusion & Outlook

Research question: Can a *smaller but more realistic* training dataset improve reconstruction quality of a CNN?
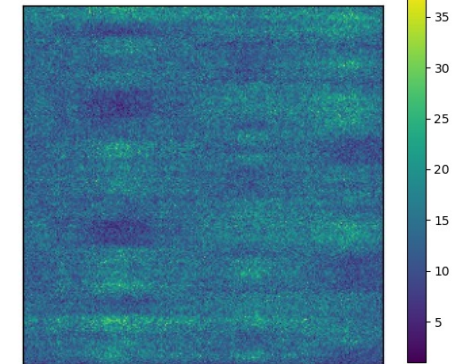
➡ High-fidelity simulation TOPAS *partially* improves reconstruction quality

➡ Amount of training data can be more important than the simulation quality

Outlook:

- How to deal with non-ideal detectors, *e.g.* erroneous pixels, non-homogeneous intensity, …?
- What is the influence of sources outside the focus plane (non-planarity)?
- How to increase robustness and reliability of the CED?

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Thanks for your attention

I am happy to answer your questions and will be open for feedback for the rest of the week (:

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Appendix

Sources

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