Development of a Practical Phantom for Quality Assurance in Lung Cancer Screening CT

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Aim

- **Low-dose CT lung cancer screening is being implemented worldwide.**

- **Standardized screening protocols require dedicated quality assurance.**

- **Existing commercial phantoms are costly.**

- **We aim to develop a modular, cost-efficient semi-anthropomorphic lung screening phantom based on widely available materials.**

- **The proposed concept is intended to enable affordable, reproducible, on-site manufacturing in resource-limited settings.**

Phantom Requirements

- **Requirements for such a screening phantom are manifold:**
  - **Thoracic shape and size** that roughly mimics an adult patient and provides accordant intersection lengths
  - Lungs filled with **a foam mimicking lung tissue**, i.e. about -800 HU
  - Interesting structures such as **ground glass or solid nodules**
  - Structures suitable for **image quality assurance.**
  - The phantom should be **easy to machine, assemble and should be cost-efficient.**

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Body, Lung, GGN and Nodule Materials

- A variety of candidate materials, including plastics, foams, and resins, can be considered for constructing the phantom, each offering distinct mechanical and radiological properties that influence performance and realism.

- All materials considered in the following are non-toxic, can be processed using standard workshop tools (e.g., drilling, cutting, milling), and do not produce hazardous byproducts during machining.
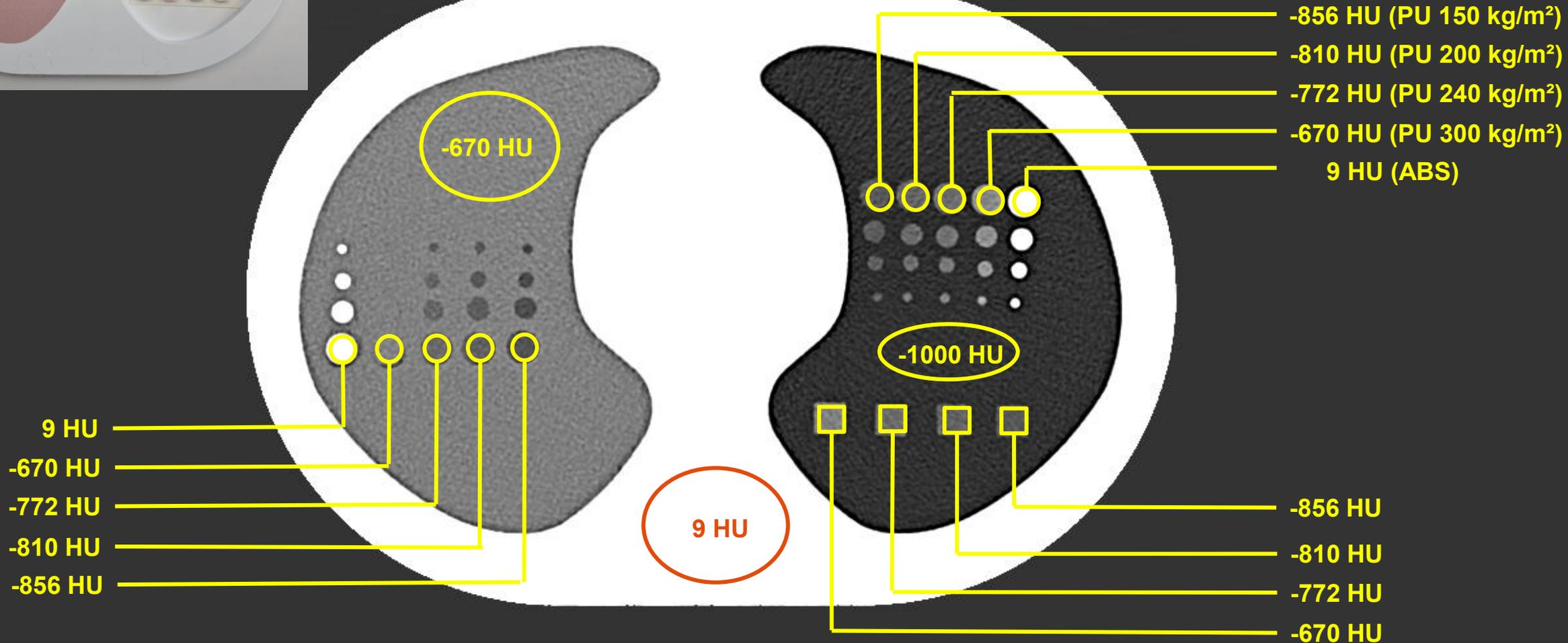
Materials and CT Values

	70 kV	90 kV	120 kV	140 kV	Sn100 kV	Sn140 kV	Mean ± SD
PU-Foams							
26 kg/m³	-966 HU	-970 HU	-979 HU	-980 HU	-973 HU	-975 HU	= -974 HU ± 5 HU
35 kg/m³	-961 HU	-965 HU	-970 HU	-970 HU	-966 HU	-966 HU	= -966 HU ± 3 HU
60 kg/m³	-928 HU	-932 HU	-942 HU	-941 HU	-938 HU	-939 HU	= -937 HU ± 5 HU
150 kg/m³	-855 HU	-859 HU	-870 HU	-867 HU	-859 HU	-861 HU	= -862 HU ± 5 HU
200 kg/m³	-809 HU	-811 HU	-814 HU	-813 HU	-812 HU	-819 HU	= -813 HU ± 3 HU
240 kg/m³	-780 HU	-782 HU	-787 HU	-786 HU	-784 HU	-784 HU	= -784 HU ± 2 HU
300 kg/m³	-677 HU	-678 HU	-683 HU	-683 HU	-679 HU	-683 HU	= -681 HU ± 2 HU
Plastics							
ABS	0 HU	10 HU	7 HU	-1 HU	12 HU	-6 HU	= 4 HU ± 6 HU
PMMA	54 HU	80 HU	82 HU	49 HU	91 HU	69 HU	= 71 HU ± 14 HU
PC	39 HU	91 HU	91 HU	52 HU	106 HU	85 HU	= 77 HU ± 22 HU
PEHD	-135 HU	-82 HU	-76 HU	-82 HU	-62 HU	-74 HU	= -85 HU ± 22 HU

All data were acquired using a Naeotom Alpha.Peak system.

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CT Values

-856 HU (PU 150 kg/m²)
-810 HU (PU 200 kg/m²)
-772 HU (PU 240 kg/m²)
-670 HU (PU 300 kg/m²)
9 HU (ABS)

-670 HU

-1000 HU

9 HU

9 HU
-670 HU
-772 HU
-810 HU
-856 HU

-856 HU
-810 HU
-772 HU
-670 HU
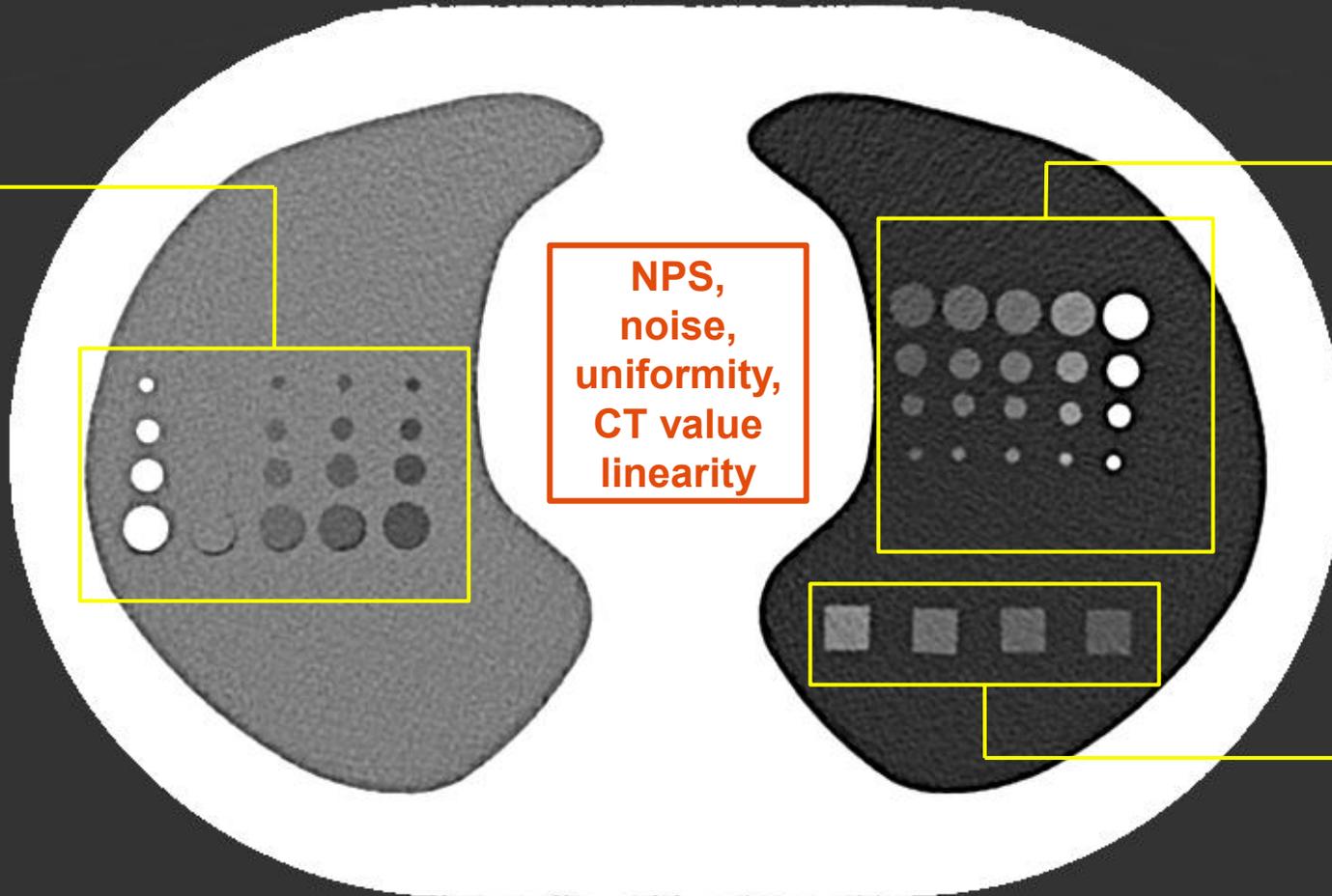
All data were acquired using a Naeotom Alpha.Peak system at 120 kV, *C*= -600 HU, *W*= 1500 HU.

Potential Image Quality Metrics

All data were acquired using a Naeotom Alpha.Peak system at 120 kV, C = -600 HU, W = 1500 HU.

Lung Cancer Screening in Germany

Parameter	Requirement	Comment
Dose conversion	k = 0.019 mSv/mGy/cm	$D_{eff} = k \cdot DLP$
Topogram CTDI	$\leq$ 20% of screening CTDI	Use additional prefilter
Scan length	Adapt to lung	Not longer than lung
Scan time	$\leq$ 15 s	Breath-hold required
Rotation time	$\leq$ 1 s	
Screening CTDI	must not exceed 1.3 mGy	
TCM, auto kV-selection	Yes	TCM in α and z
Dynamic collimation	Yes, if at least 64 detector rows	To avoid overbeaming
Reconstruction	Iterative or deep learning	
Spatial resolution (FWHM)	between 0.8 and 1.0 mm	For low contrasts (150 HU)
Slice thickness	up to 0.7 mm	
Viewing thickness	up to 3.0 mm	

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Point Spread Function as Function of Contrast

FWHM @ 140 HU = 0.71 mm
FWHM @ 190 HU = 0.63 mm
FWHM @ 215 HU = 0.56 mm
FWHM @ 320 HU = 0.47 mm

— 140 HU ·····190 HU – –215 HU – · 320 HU

All data were acquired using a Naeotom Alpha.Peak system at 120 kV using 1.3 mGy and a Bl60 kernel (QIR3).

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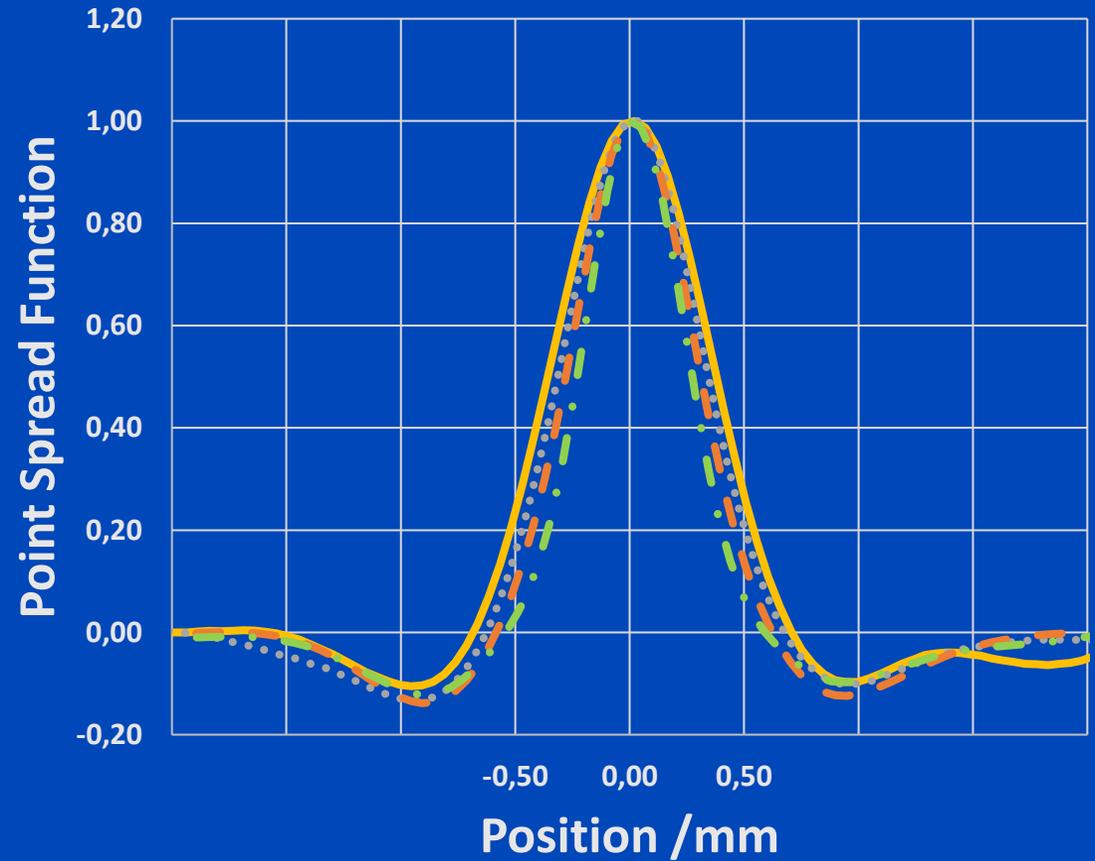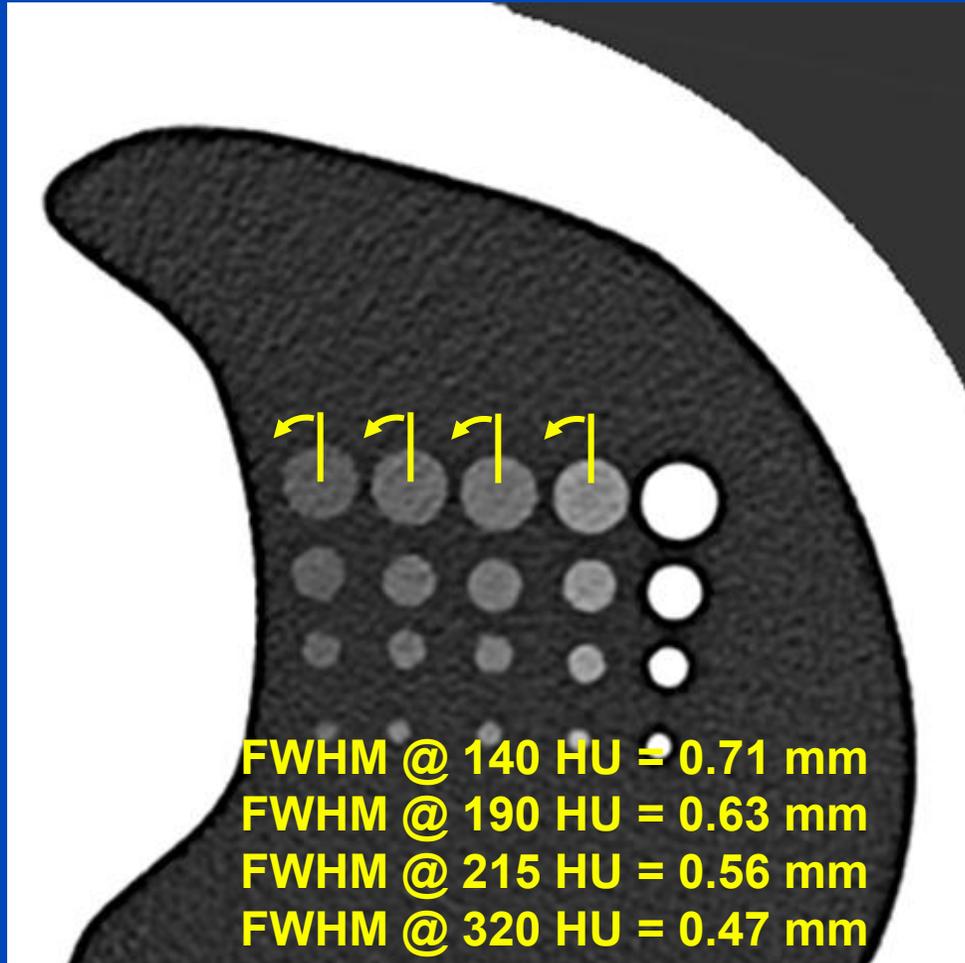
Summary & Conclusions

- The proposed phantom provides a modular system that can be extended by manufacturing custom lung lobes.

- The embedded structures enable the evaluation of key image quality metrics.

- The phantom is highly cost-efficient, with material costs of only about 50 €.

- The materials used are non-toxic, widely available in hardware stores, and easy to machine.

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Thank You!

This presentation will soon be available at www.dkfz.de/ct.