

# Small Pixel Effect and Prefilter Effect in Energy-Integrating and in Photon-Counting CT

Jöken Wucherpennig<sup>1</sup>, Lukas Rotkopf<sup>1,2</sup>, Heinz-Peter Schlemmer<sup>1,2</sup>,  
Matthias Frölich<sup>3</sup>, Stefan Schönberg<sup>3</sup>, Stefan Sawall<sup>1,2</sup>,  
and Marc Kachelrieß<sup>1,2</sup>

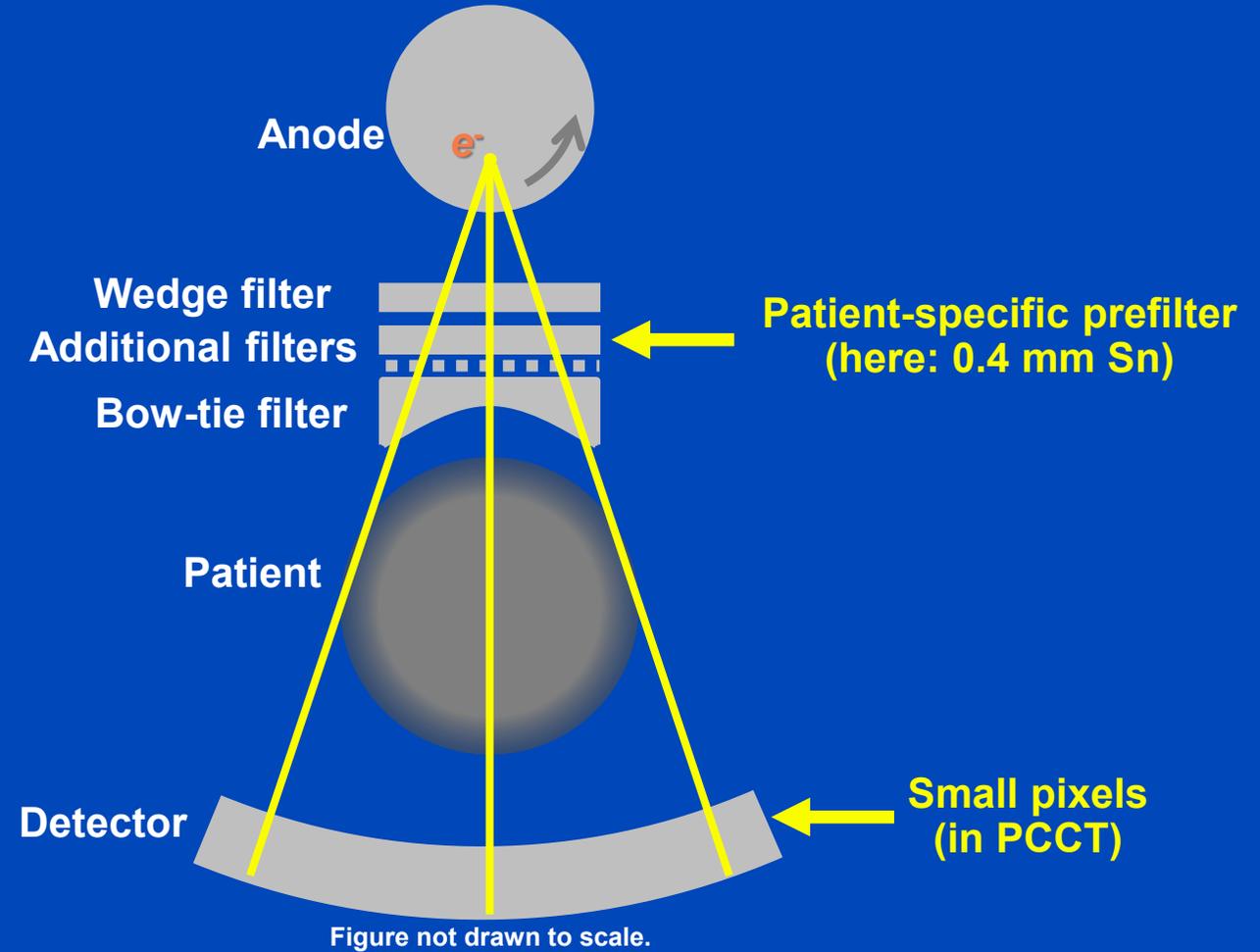
<sup>1</sup>German Cancer Research Center (DKFZ), Heidelberg, Germany

<sup>2</sup>Ruprecht-Karls-University, Heidelberg, Germany

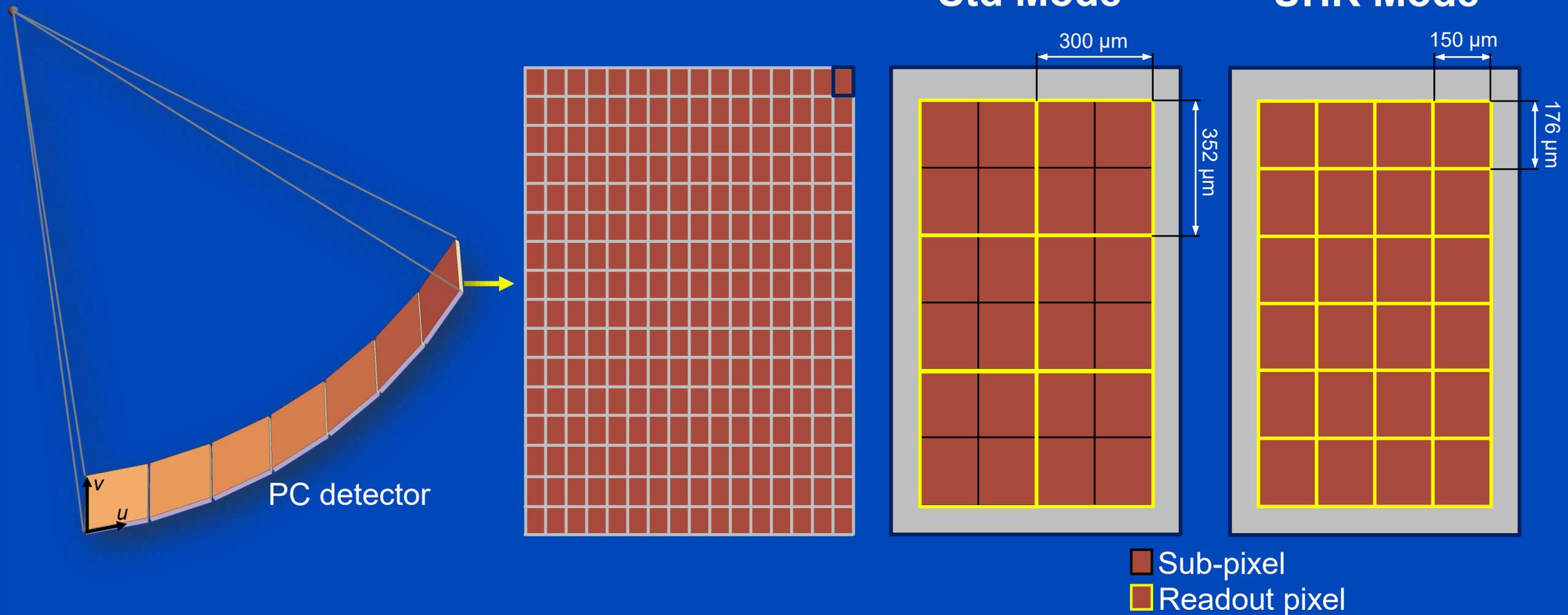
<sup>3</sup>University Medical Centre, Mannheim, Germany



**Naeotom Alpha at University  
Hospital Mannheim**



# Naeotom Alpha Detector Readout Modes



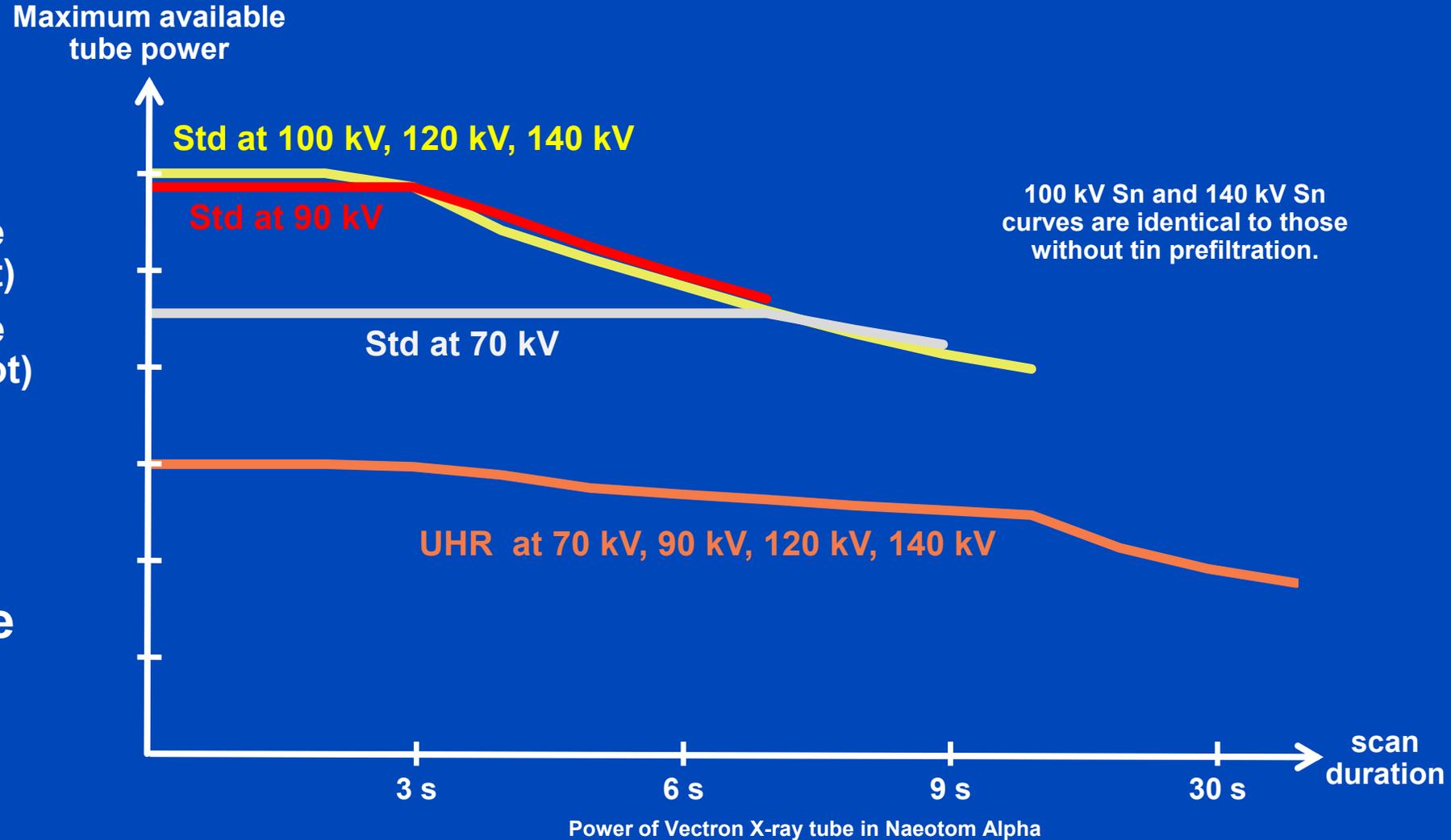
# Naeotom Alpha Focal Spot Sizes

- Standard mode: 0.8×1.1 mm
- UHR mode: 0.4×0.5 mm
- Small focal spot in UHR to correspond with small detector pixel size
- Onset of target melting (rule of thumb)<sup>1</sup>: 1 W/μm
- Tube power is limited by the onset of target melting
  - smaller focal spot = less tube power available
  - larger focal spot = more tube power available

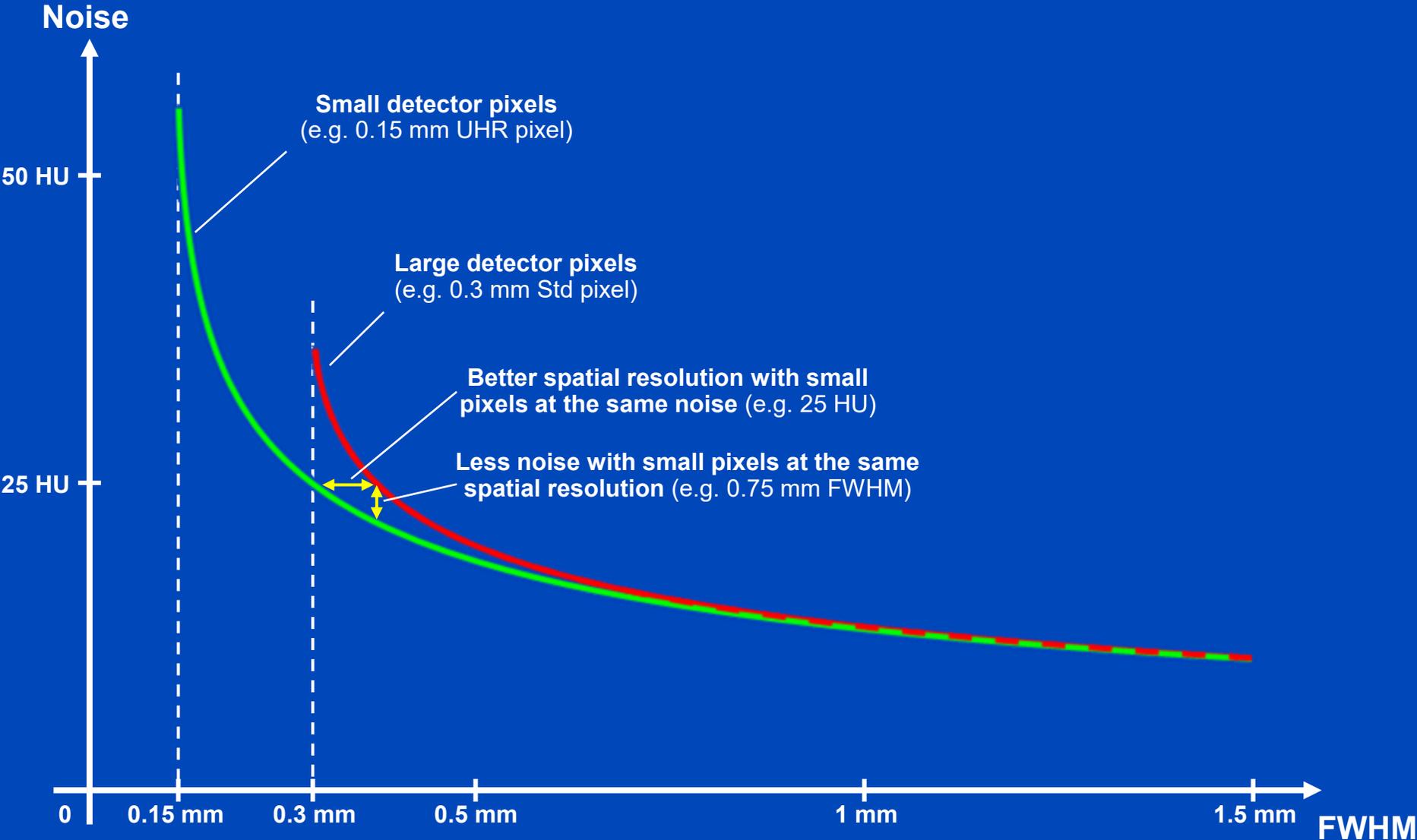
<sup>1</sup> D.E. Grider, A. Writh, and P.K. Ausburn. Electron Beam Melting in Microfocus X-Ray Tubes. J. Phys. D: Appl. Phys 19:2281-2292, 1986

# Limiting Factors

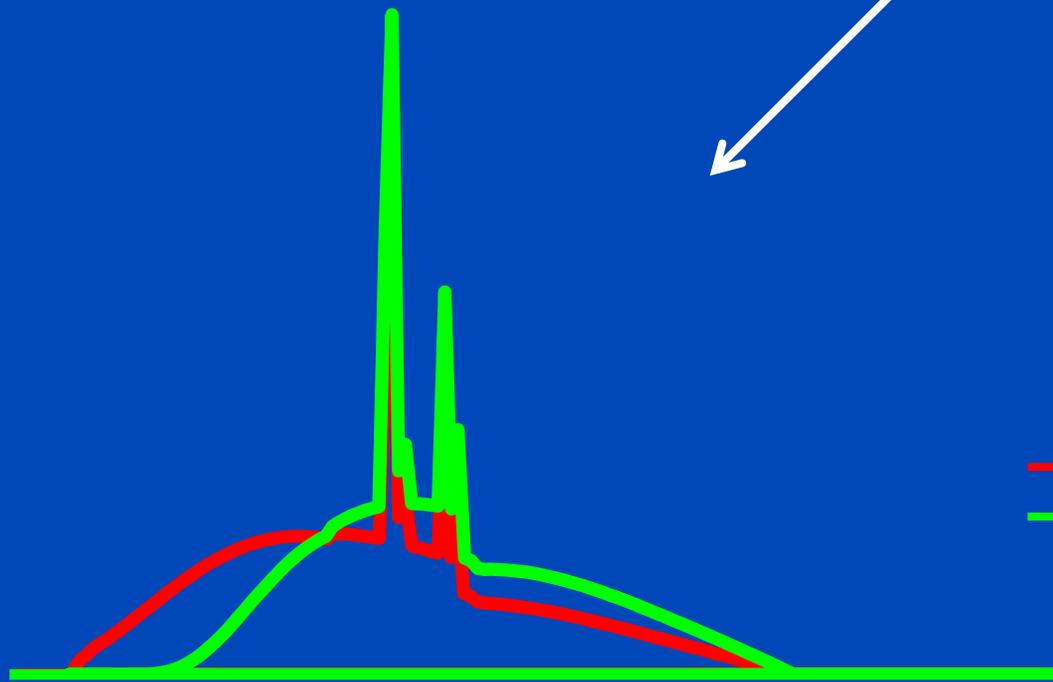
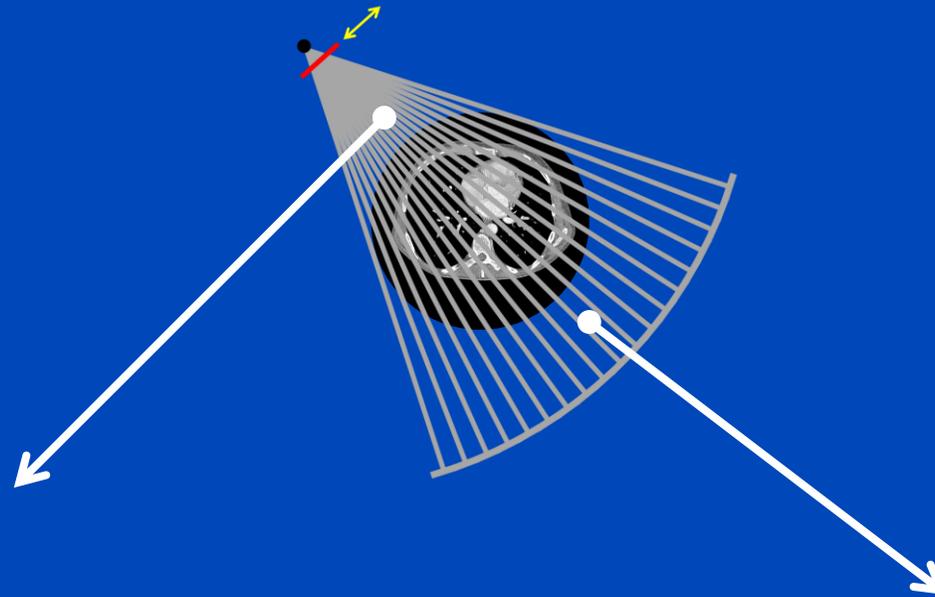
- **Maximum available tube power**
    - Std mode: 120 kW tube power (large focal spot)
    - UHR mode: 70 kW tube power (small focal spot)
  - **Higher tube power needed to apply the prefilter**
- Problem with obese patients



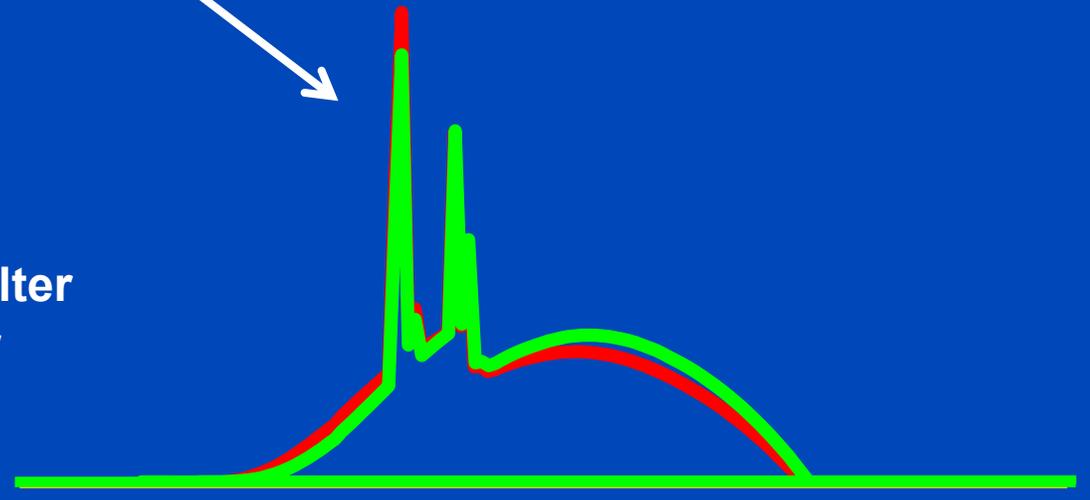
# The Small Pixel Effect



# The Prefilter Effect



Normalized spectrum of 120 kV + 0 mm water with and without prefilter



Normalized spectrum of 120 kV + 320 mm water with and without prefilter

— No prefilter  
— Prefilter

# Task- and Patient-Specific (i.e. Removable) Prefilters in Use Today

- 0.4 and 0.7 mm Sn for Siemens` Naeotom Alpha.Peak and Alpha.Pro
- 0.4 mm Sn for Siemens` Naeotom Alpha.Prime
- 0.6 mm Sn for Siemens` Somatom Force, Edge Plus, go.Top and Definition Edge
- 0.4 mm Sn for Siemens` Somatom Flash, Drive, go.Now, go.Up, go.all, and pro.Pulse
- 0.4 mm and 0.7 mm Sn for Siemens` Somatom X.cite
- $\approx 0.5$  mm Au for Canon`s Aquilion ONE Prism Edition
- $\approx 1$  mm Cu “for scout scans” in GE`s Revolution Apex systems

In the energy range of clinical CT and with objects similar to patients we find that **0.5 mm Ag  $\approx$  0.6 mm Sn  $\approx$  2.0 mm Cu.**

# Aim

To evaluate the separate and combined influence of the small pixel effect and the prefilter effect.

# Abdominal Phantoms



S: 20 × 30 cm



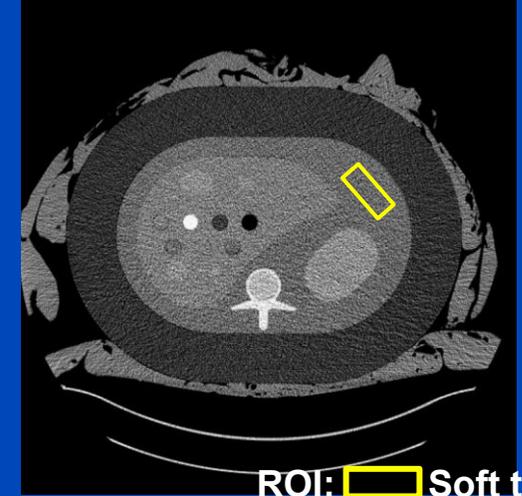
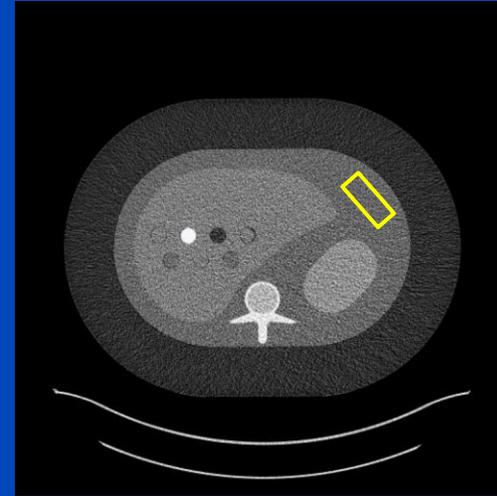
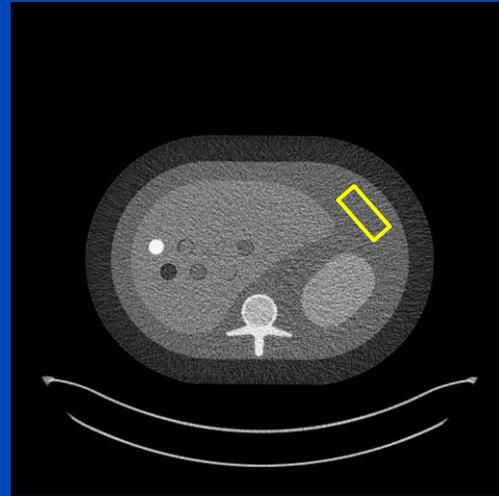
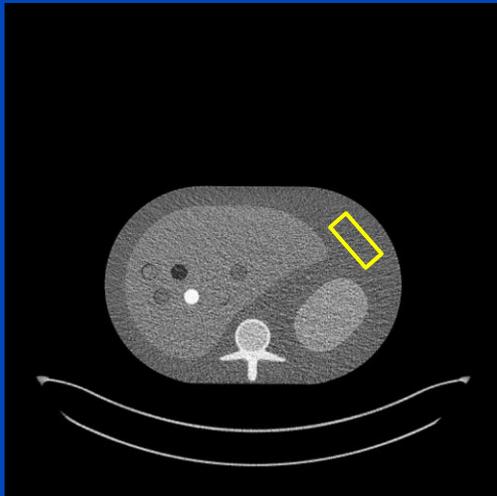
M: 25 × 35 cm



L: 30 × 40 cm



XL: 35 × 45 cm



ROI:  Soft tissue

# Image Quality Assessment

- Signal and noise are determined from the mean and standard deviation within the respective ROI.
- Measurement of ROI in all slices: mean value calculated across all slices
- Signal-to-noise ratio at unit dose:

$$\text{SNRD} = \frac{\mu_{\text{soft tissue}}}{\sigma_{\text{soft tissue}} \cdot \sqrt{D}}$$

- Dose reduction:

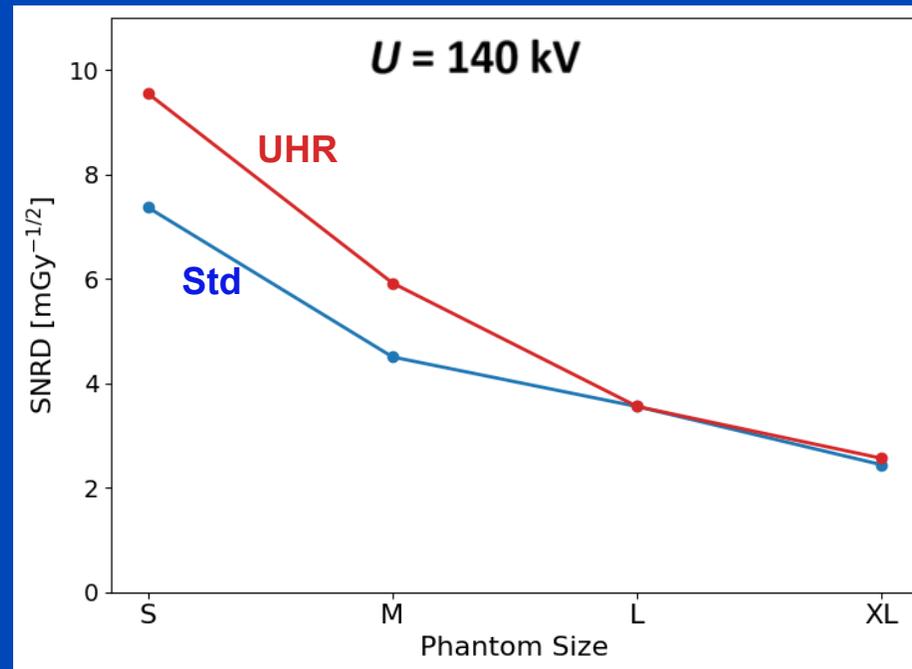
$$\text{DoseReduction} = 1 - \frac{\text{SNRD}_{\text{reference}}^2}{\text{SNRD}_x^2}$$

	<b>EICT Somatom Definition Flash</b>	<b>PCCT in Std mode Naeotom Alpha</b>	<b>PCCT in UHR mode Naeotom Alpha</b>
<b>Emitted spectrum</b>	140 kV, 140 kV Sn	140 kV, 140 kV Sn	140 kV, 140 kV Sn
<b>Exposure</b> (small pixel effect scans)	-	2.1 mGy, 18 mAs (S) 5.1 mGy, 44 mAs (M) 7.9 mGy, 68 mAs (L) 13.1 mGy, 114 mAs (XL)	1.2 mGy, 10 mAs (S) 2.7 mGy, 23 mAs (M) 8.3 mGy, 72 mAs (L) 12.0 mGy, 103 mAs (XL)
<b>Exposure</b> (prefilter effect scans)	5.1 mGy, 52 mAs 5.1 mGy, 141 mAs (Sn)	2.1 mGy, 18 mAs 2.1 mGy, 58 mAs (Sn)	2.1 mGy, 18 mAs 2.1 mGy, 58 mAs (Sn)
<b>Collimation</b>	128 × 0.6 mm	144 × 0.4 mm	120 × 0.2 mm
<b>Pitch</b>	0.55	1.2	1.2
<b>Rotation time</b>	0.33 s	0.5 s	0.5 s
<b>Reconstruction kernel</b>	D40f	Br56	Br56
<b>Reconstruction mode</b>	FBP	FBP	FBP
<b>Slice thickness</b>	1.0 mm	1.0 mm	1.0 mm
<b>Slice increment</b>	1.0 mm	1.0 mm	1.0 mm
<b>FOM</b>	A: 500 mm, B: 330 mm	500 mm	500 mm
<b>FOV</b>	400 mm	500 mm	500 mm
<b>Image matrix</b>	512 × 512	1024 × 1024	1024 × 1024

Tin filter thickness 0.4 mm. Dose values are CTDI<sub>vol 32 cm</sub>. Exposure for SPE scans set to have nearly same image noise.

# Small Pixel Effect

## PCCT Naeotom Alpha



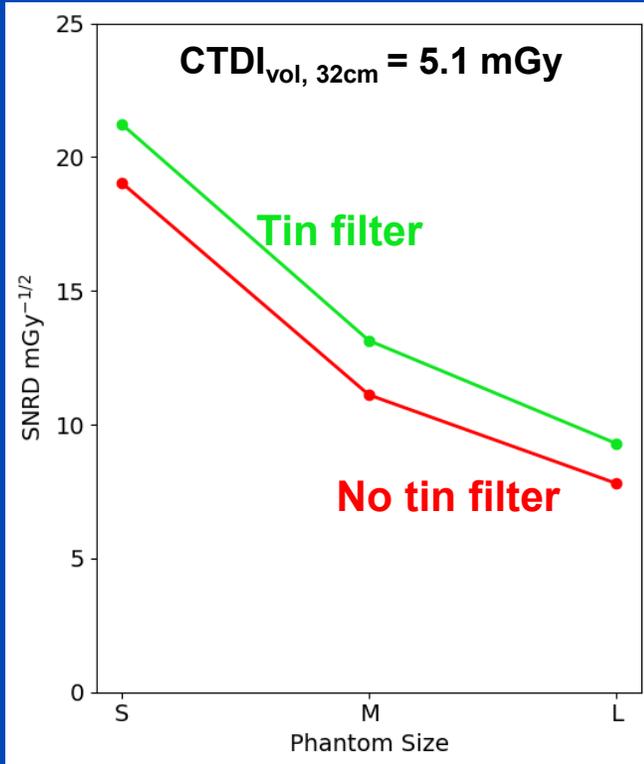
Dose reduction:

S	M	L	XL
40 %	42 %	0%	9 %

# Prefilter Effect

## EICT

Definition Flash

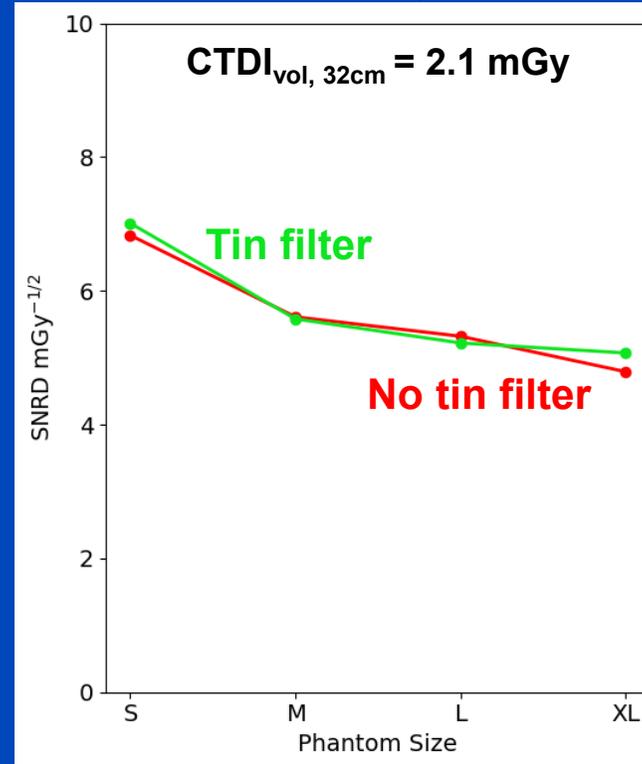


Dose reduction:

S	M	L	XL
20 %	29 %	30 %	-

## PCCT in Std mode

Naeotom Alpha

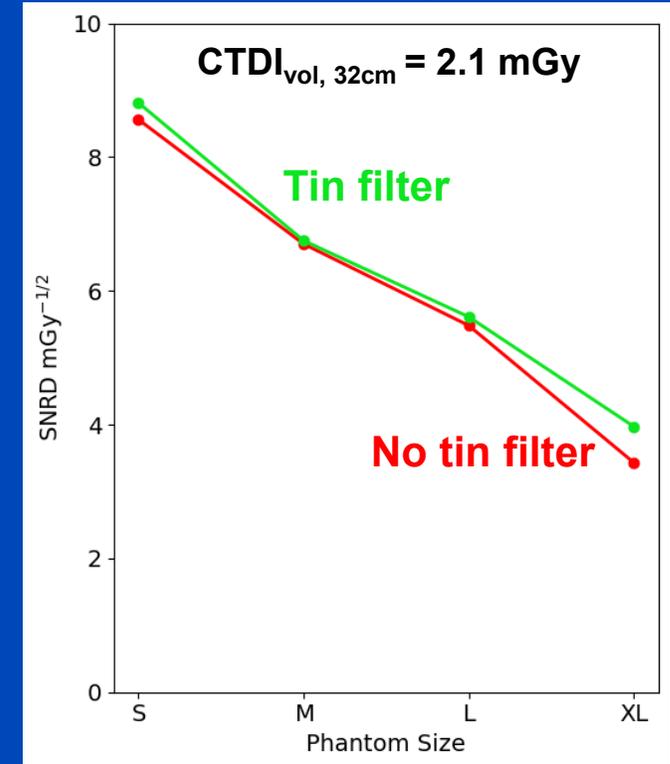


Dose reduction:

S	M	L	XL
5 %	0 %	0 %	11 %

## PCCT in UHR mode

Naeotom Alpha



Dose reduction:

S	M	L	XL
6 %	2 %	4 %	25 %

# Conclusions

- **Small pixel effect:**
  - Up to 37% dose reduction if UHR mode is used instead of Std mode.
- **Prefilter effect:**
  - As expected and well known with up to 30% dose reduction in the EICT system.
  - Not available/demonstratable at the Alpha PCCT scanner, although Sn filter is used. ☹
  - Suspected reason: proprietary signal-dependent filter. Vendor should take action!
- **Combined effect:**
  - Not available because prefilter effect is not available at Alpha PCCT. ☹

## Thank you!

- This presentation will soon be available at [www.dkfz.de/ct](http://www.dkfz.de/ct).
- Job opportunities through DKFZ's international PhD or Postdoctoral Fellowship programs ([marc.kachelriess@dkfz.de](mailto:marc.kachelriess@dkfz.de)).
- Parts of the reconstruction software were provided by RayConStruct® GmbH, Nürnberg, Germany.