

# Feasible 4D Intervention Guidance: Initial Concept Evaluation

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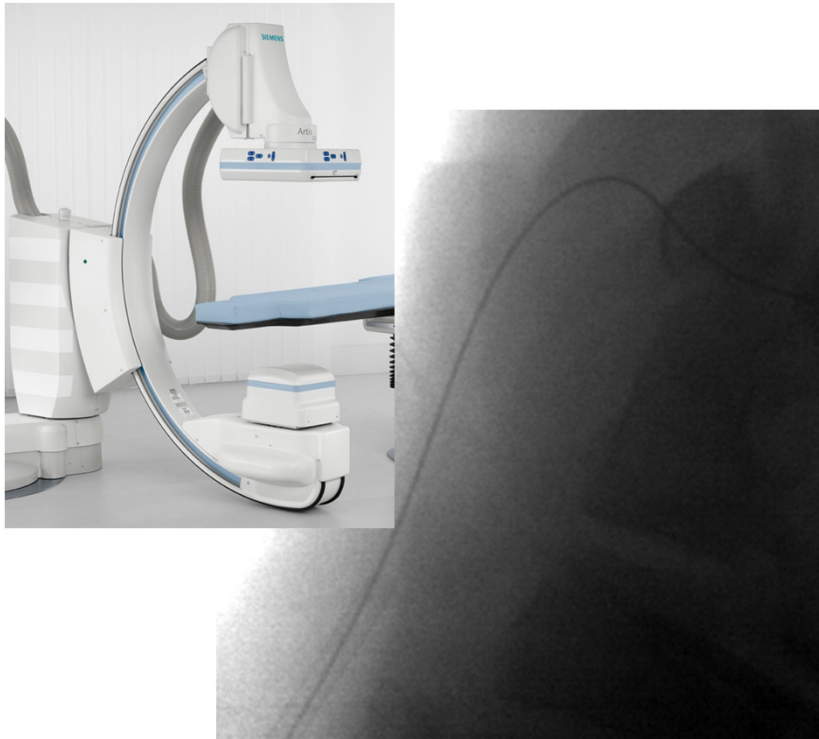
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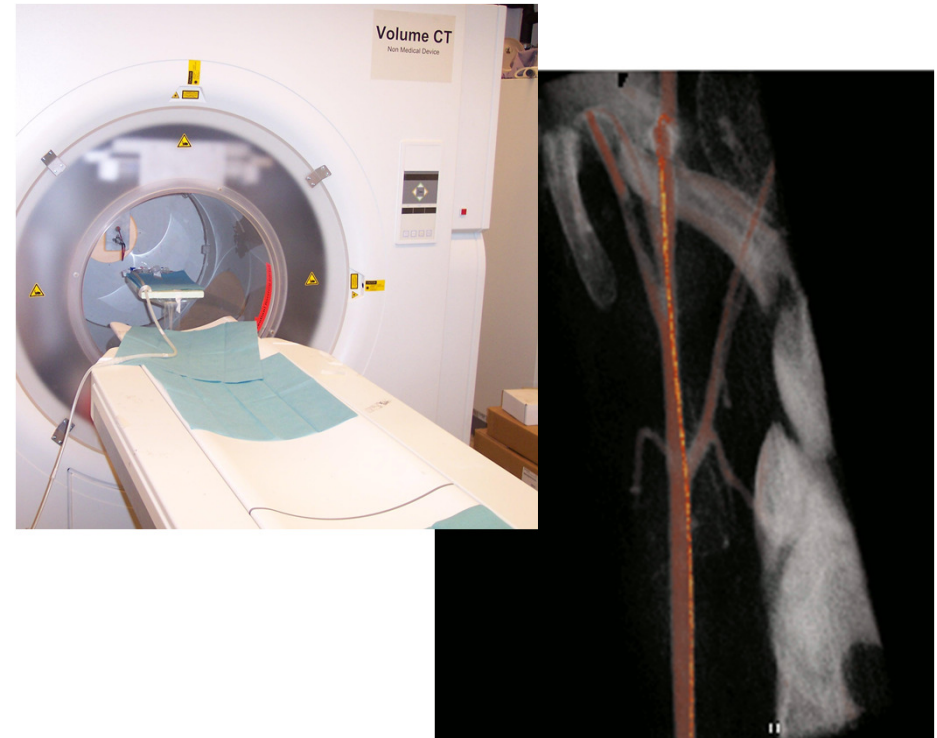
## 4D Intervention Guidance: Principles

- Today's fluoroscopy is limited to 2D projection images
- Continuous CT acquisition would exceed acceptable dose levels

### Projective Fluoroscopy



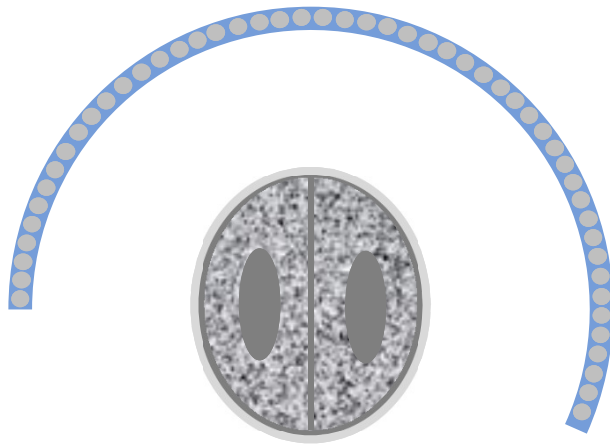
### 4D Intervention Guidance



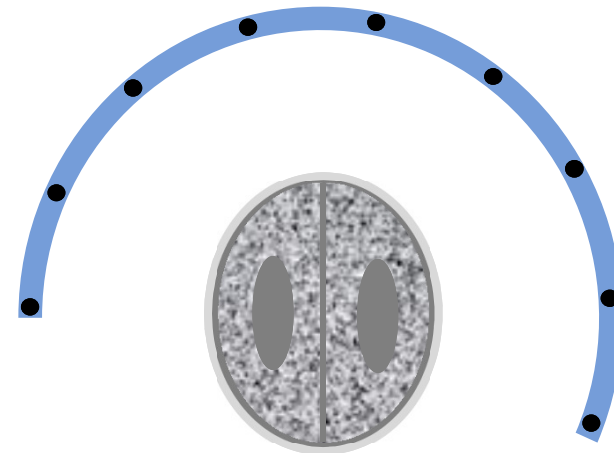
## 4D Intervention Guidance: Introduction

- Dose can be distributed to various number of projections

**Large number of  
low dose of projections**



**Small number of  
higher dose projections**



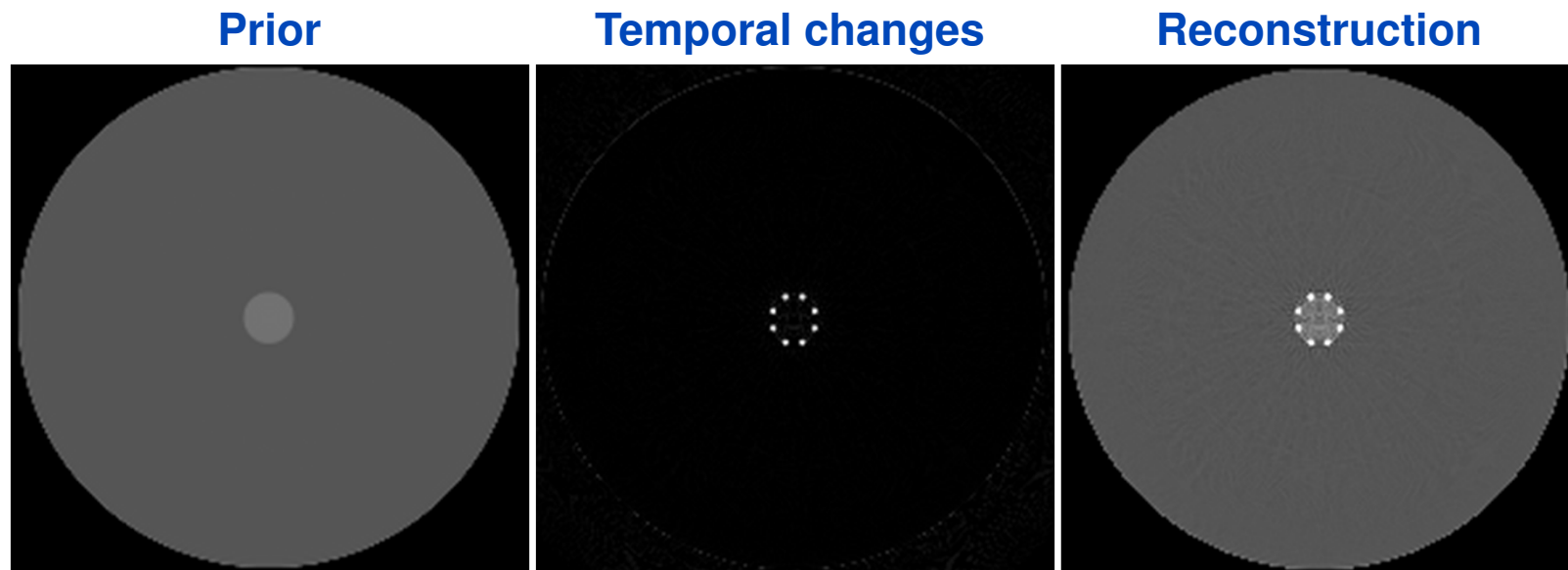
Using constant overall doses:

- Are there optimal scanning parameters?
- How many projections result in the maximum image quality?

## Material and Methods

Simulations and phantom measurements were performed using:

- various exposure levels (single, double, four-fold dose)
- various number of projections per reconstruction (9 - 81 projections)
- various iterative compressed sensing reconstructions (PICCS, ASD-POCS, PrIDICT)
- constant overall dose per reconstruction
- prior image without interventional material was incorporated in all reconstructions



## Material and Methods

Automated quality analyses and visual quality assessment was performed:

- Mean squared contingency

$$\frac{\chi^2}{N} = \frac{1}{N} \sum_i \sum_j \frac{\left(h_{ij} - \frac{h_i h_j}{n}\right)^2}{\frac{h_i h_j}{n}} \quad h_{i.} = \sum_j h_{ij} \quad h_{.j} = \sum_i h_{ij}$$

	Image f	high	low
Image g			
high		$h_{11}$	$h_{1j}$
low		$h_{i1}$	$h_{ij}$

- Pearson correlation

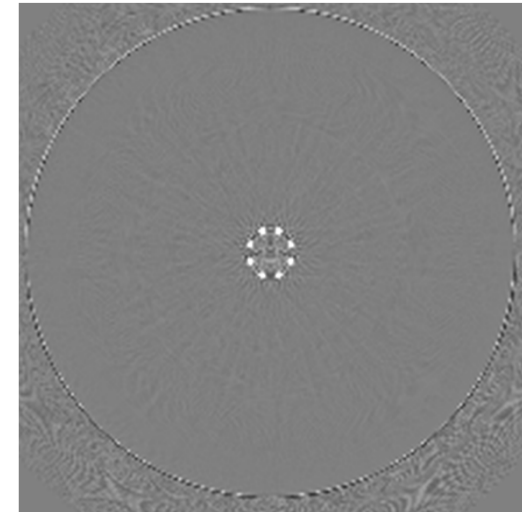
$$\rho = \frac{\text{Cov}(f,g)}{\sqrt{\text{Var}(f)}\sqrt{\text{Var}(g)}} = \frac{\sigma_{fg}}{\sigma_f \sigma_g}$$

$$\sigma_{fg} = \frac{1}{N-1} \sum_{i=1}^N (f_i - \bar{f})(g_i - \bar{g})$$

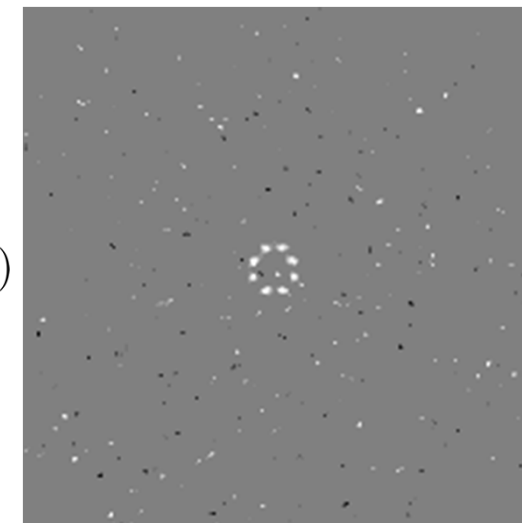
$$\sigma_f^2 = \frac{1}{N-1} \sum_{i=1}^N (f_i - \bar{f})^2$$

$$\sigma_g^2 = \frac{1}{N-1} \sum_{i=1}^N (g_i - \bar{g})^2$$

Reference

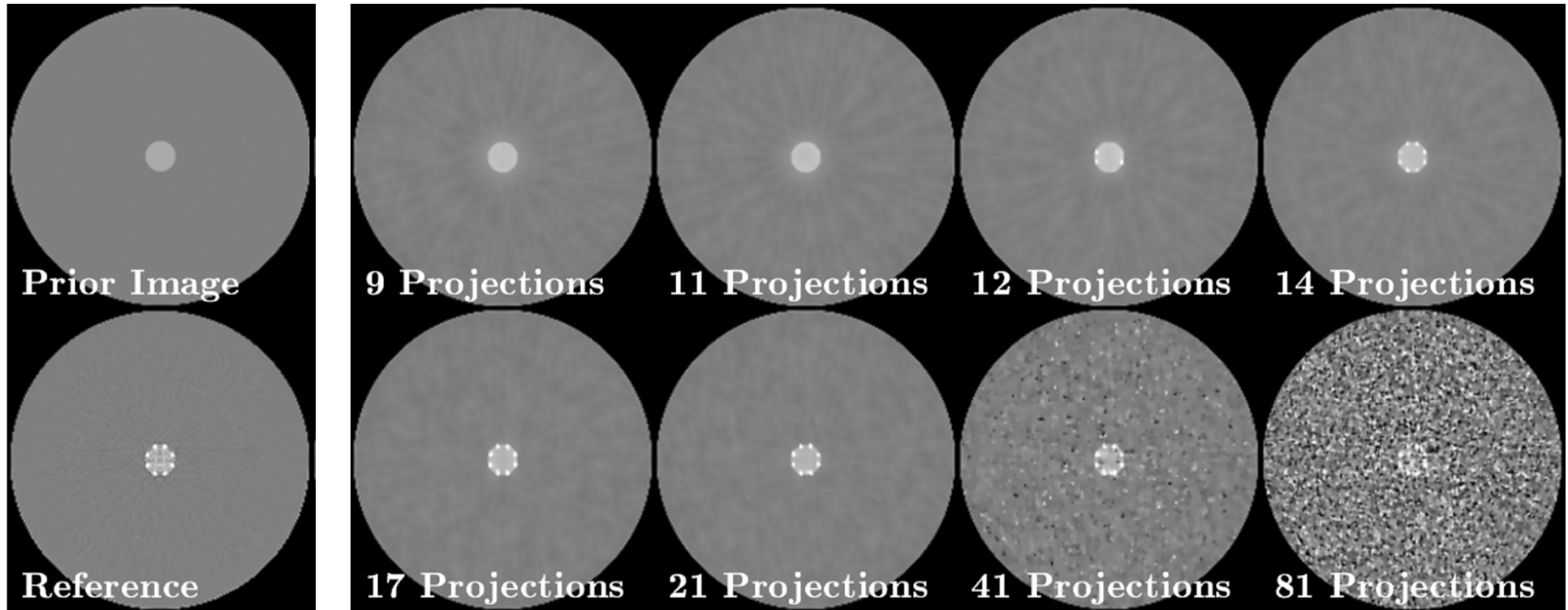


Reconstruction



## Results: Visual Assessment of the Image Quality

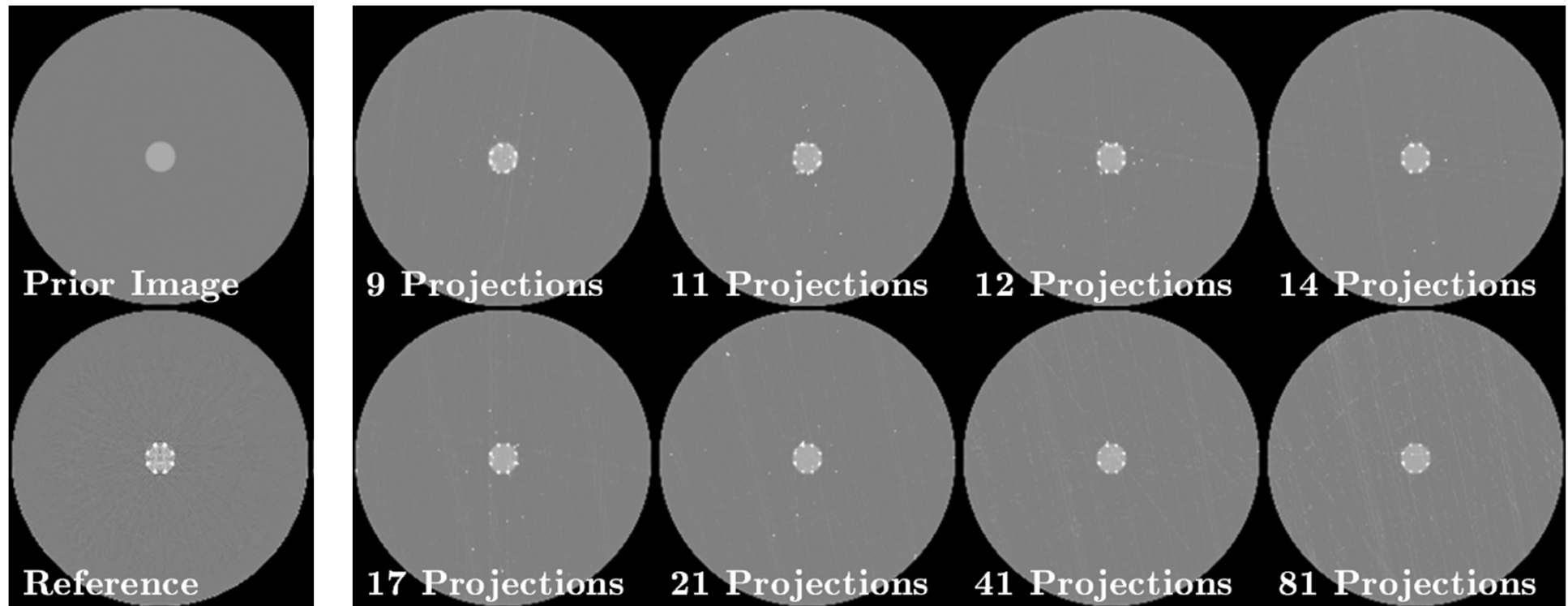
### Simulation results in PICCS reconstructions



- Visually, 14 - 21 projections provide best image quality

## Results: Visual Assessment of the Image Quality

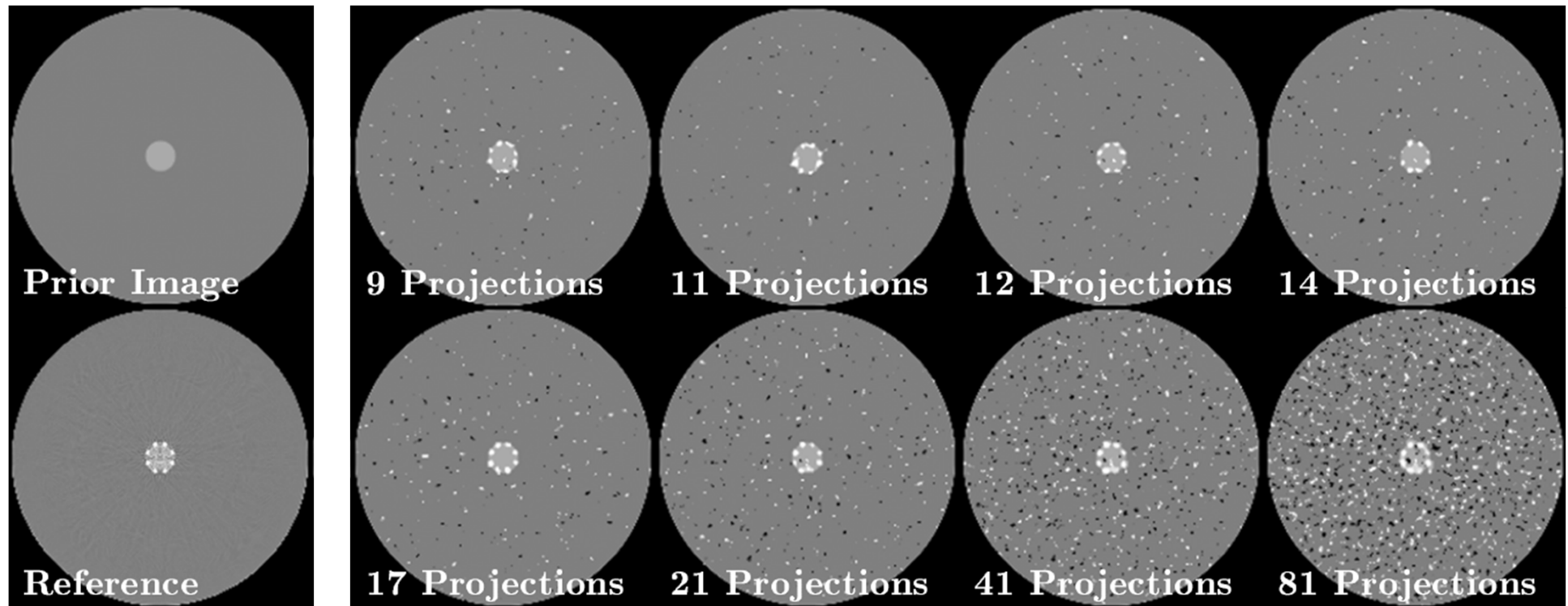
### Simulation results in ASD-POCS reconstructions



- Visually, image quality is nearly constant between 12 and 41 projections
- In general image quality is slightly poorer than in PICCS reconstructions

## Results: Visual Assessment of the Image Quality

### Simulation results in PrIDICT reconstructions



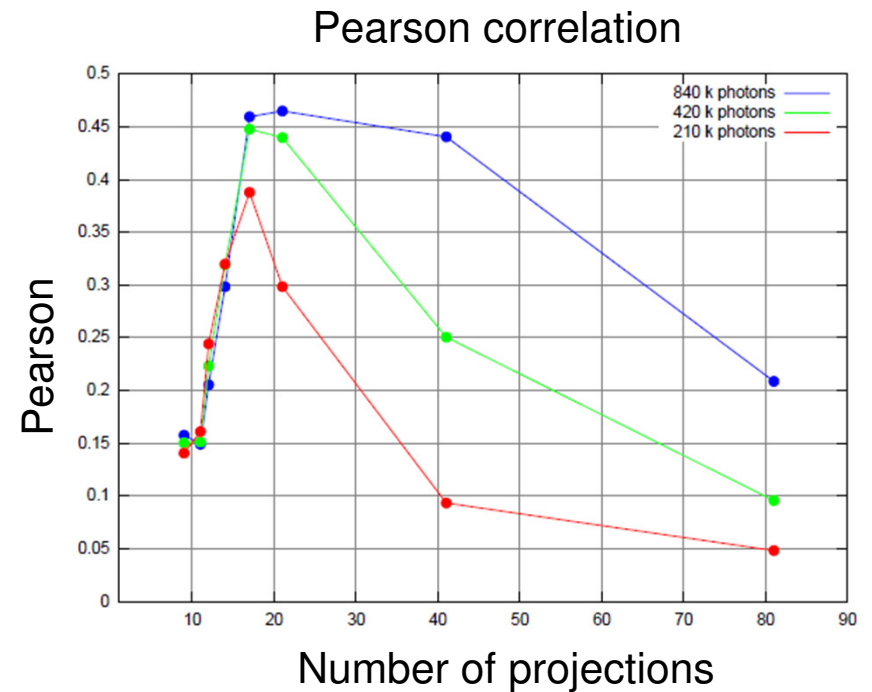
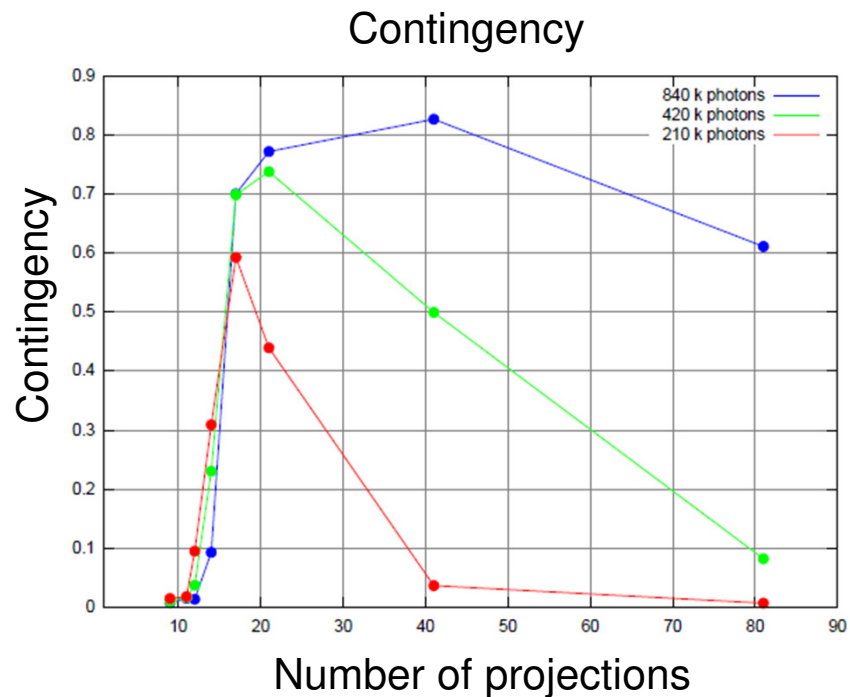
- Best image quality using 12 – 21 projections
- Increasing artifacts using higher projection numbers



## Results: Quantitative Analyses of Image Quality

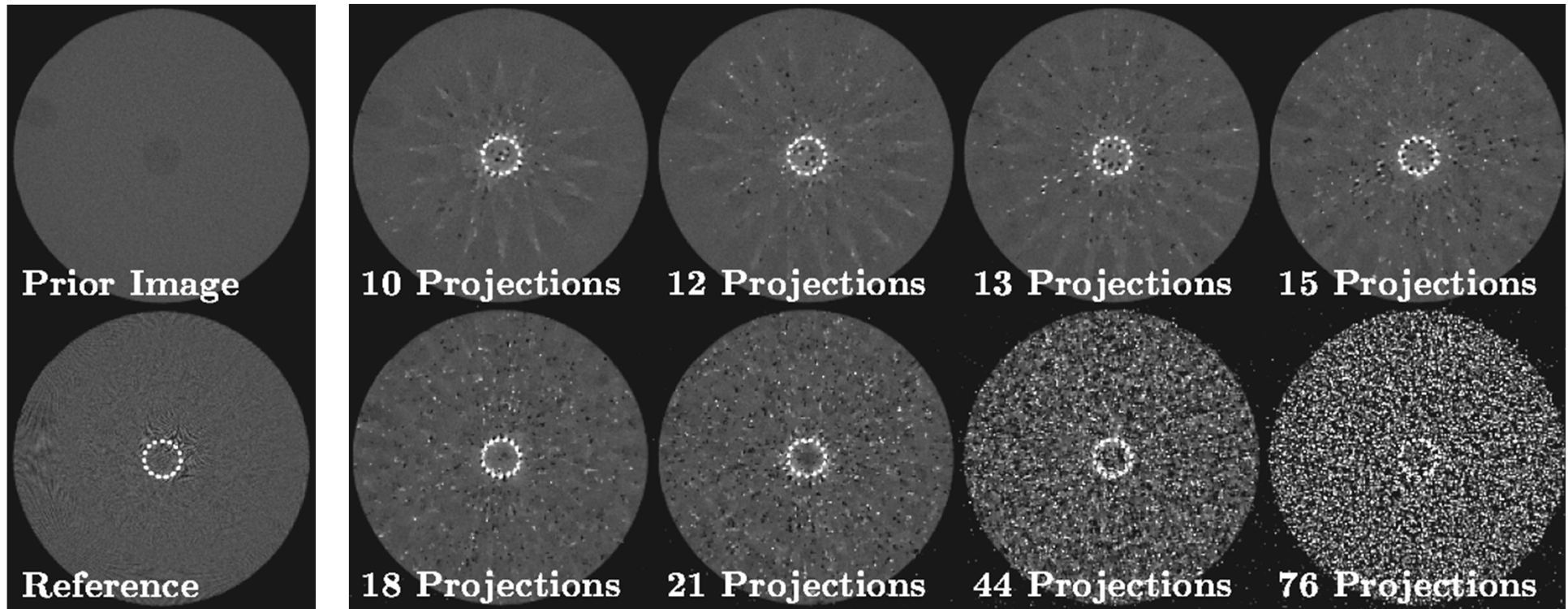
- Automated analyses confirm good image quality using 14 - 21 projections
- Optimal image quality depends on applied dose

### Quality analyses of PICCS reconstructions



## Results : Measurements

### Measured phantom data reconstructed with the PICCS algorithm



- The phantom measurements confirm our simulation results

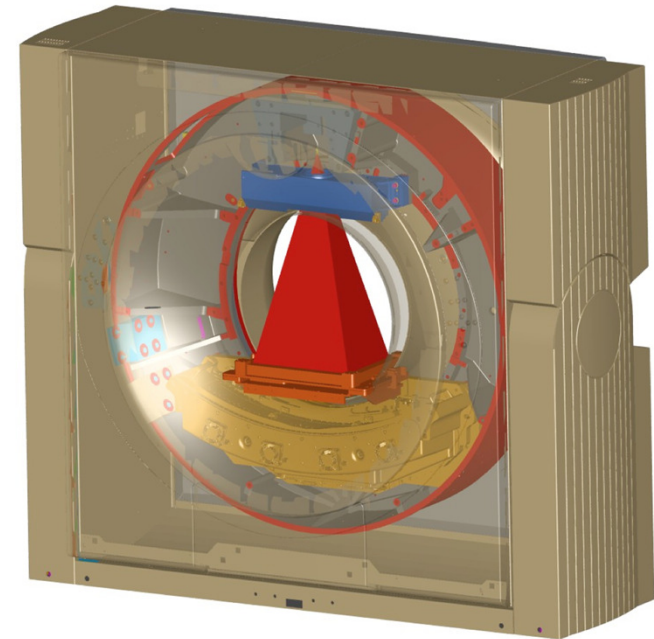
## Conclusion

- Using constant overall dose, a maximum image quality can be reached in the range of 14 to 21 projections
- Including electronic noise would further decrease image quality using larger projection numbers

Specifications for 4D intervention guidance:

- Continuous rotations
- Rotation speed  $> 720^\circ/\text{s}$
- Short pulse X-ray tube
- Flat-panel detectors
- Readout rates of 30 fps - 60 fps
- Exact angular positioning

### Continuous 4D acquisition

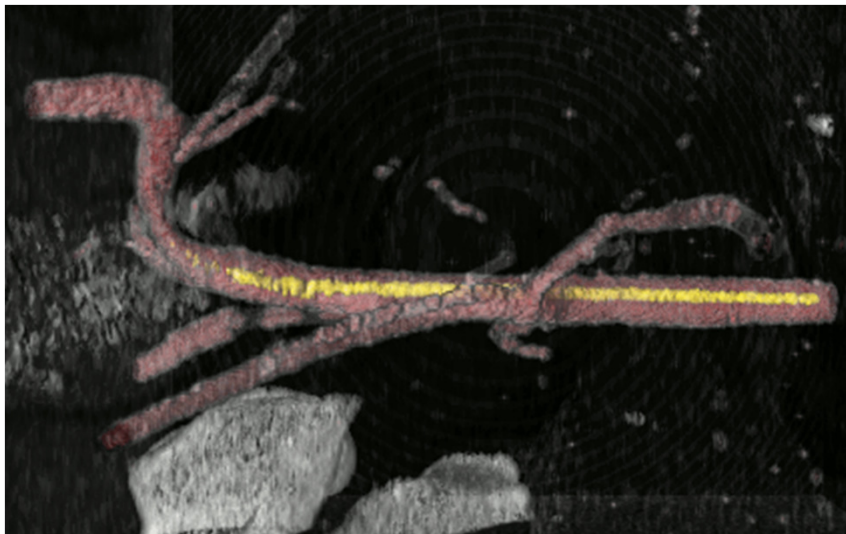


## Conclusion

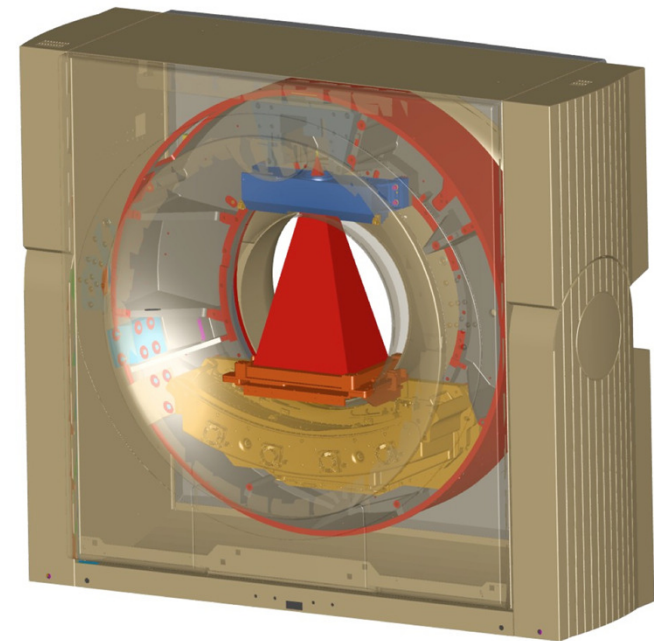
- This study shows specific requirements for interventional radiology

4D intervention guidance might be possible using

- Today's flat panel detector devices and
- Current CT gantry systems



## Continuous 4D acquisition



## Acknowledgement

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