AI can help optimize CT scan radiation dose

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Challenges of Radiological Protection in Research and Society referring to Medical Field

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ALARA

[Council Directive 2013/59/EURATOM]

CHAPTER VII

MEDICAL EXPOSURES

Article 55

Justification

1. Medical exposure shall show a sufficient net benefit, weighing the total potential diagnostic or therapeutic benefits it produces, including the direct benefits to health of an individual and the benefits to society, against the individual detriment that the exposure might cause, taking into account the efficacy, benefits and risks of available alternative techniques having the same objective but involving no or less exposure to ionising radiation.

Article 56

Optimisation

1. Member States shall ensure that all doses due to medical exposure for radiodiagnostic, interventional radiology, planning, guiding and verification purposes are kept as low as reasonably achievable consistent with obtaining the required medical information, taking into account economic and societal factors.

[D.Lsg 101/2020]

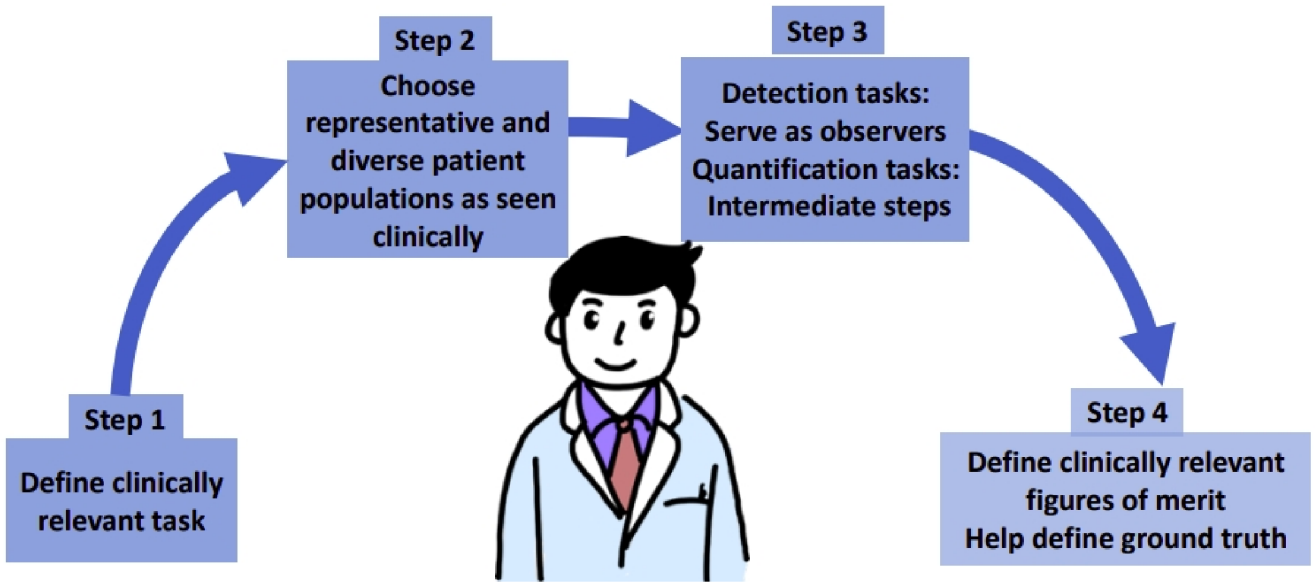
ART. 158

(Applicazione del principio di ottimizzazione alle esposizioni mediche(direttiva 59/2013/EURATOM, articolo 22, comma 4, lettera c) punto i), e articolo 56; decreto legislativo 26 maggio 2000, n. 187, articolo 4))

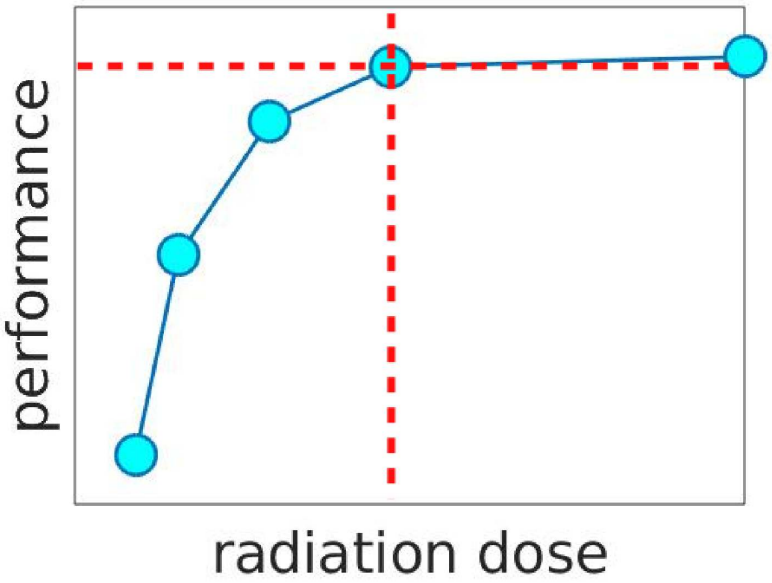
1. Tutte le dosi dovute alle esposizioni di cui all'articolo 156, comma 2, a eccezione delle procedure radioterapeutiche, devono essere mantenute al livello piu' basso ragionevolmente ottenibile e compatibile con il raggiungimento dell'informazione diagnostica richiesta, tenendo conto di fattori economici e sociali.

Medical Image quality evaluation

- The only accepted approach to estimate the minimum dose is the interpretation of CT images by medical staff
- More in general **the radiologist is the bench mark for image quality evaluation**
- Physicist tend to use quantitative metrics to assess IQ
- Quality indicator must be the diagnostic accuracy



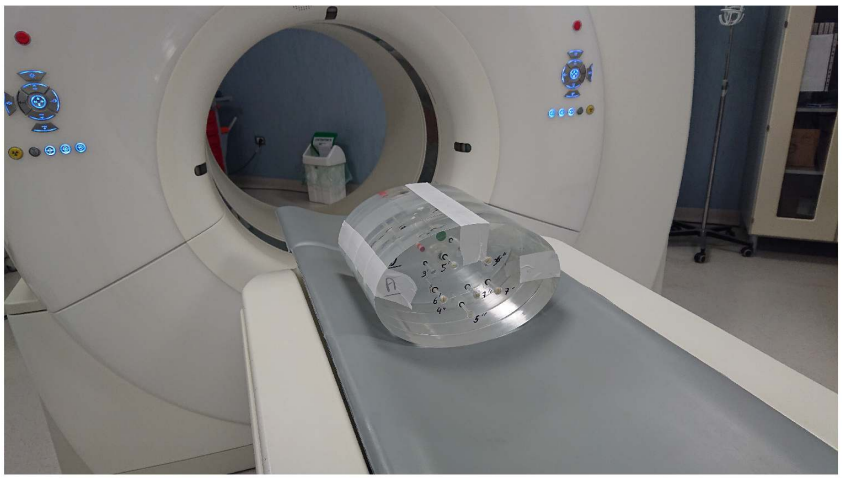
CT protocol optimization



- **optimum dose** = minimum dose compatible with medical diagnosis

CT Phantom

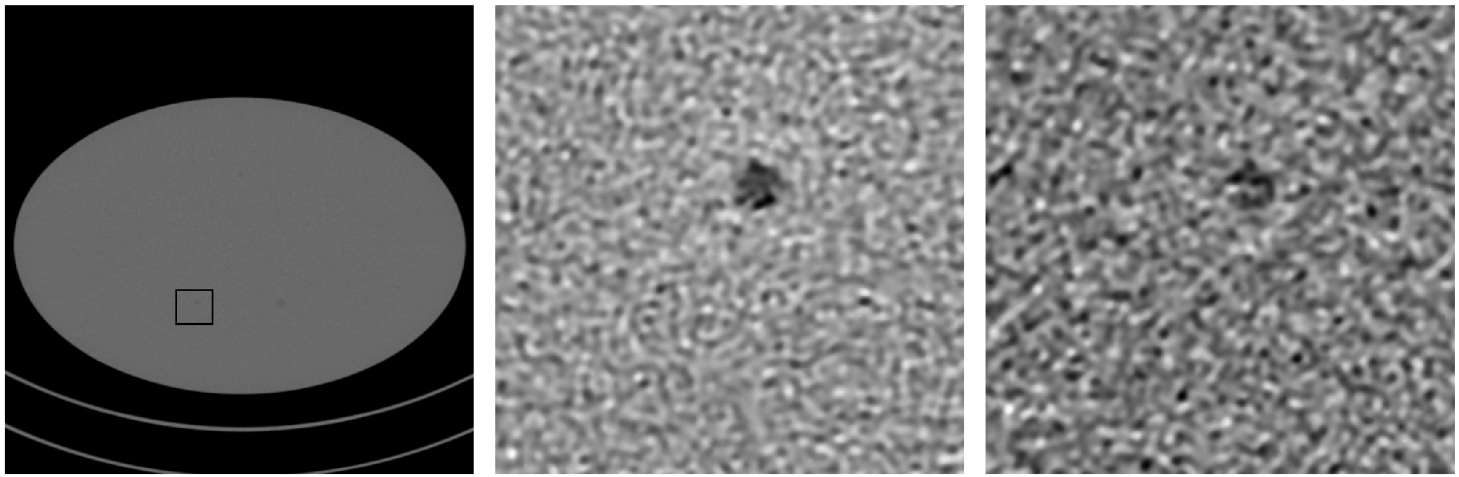
- Impractical method because there is no availability of CT scans at different dose levels
- Phantom realized @ mechanical workshop @ UNIFI
- Inserts of different sizes filled with iodinated contrast media at different concentration
- CT acquisitions at 8 different dose levels and two different reconstruction techniques



[S. Doria et al., Phys. Med., **83** *(2021)*

CT image dataset

- Dataset: 30 000 images (different reconstruction techniques sizes, contrasts, dose)

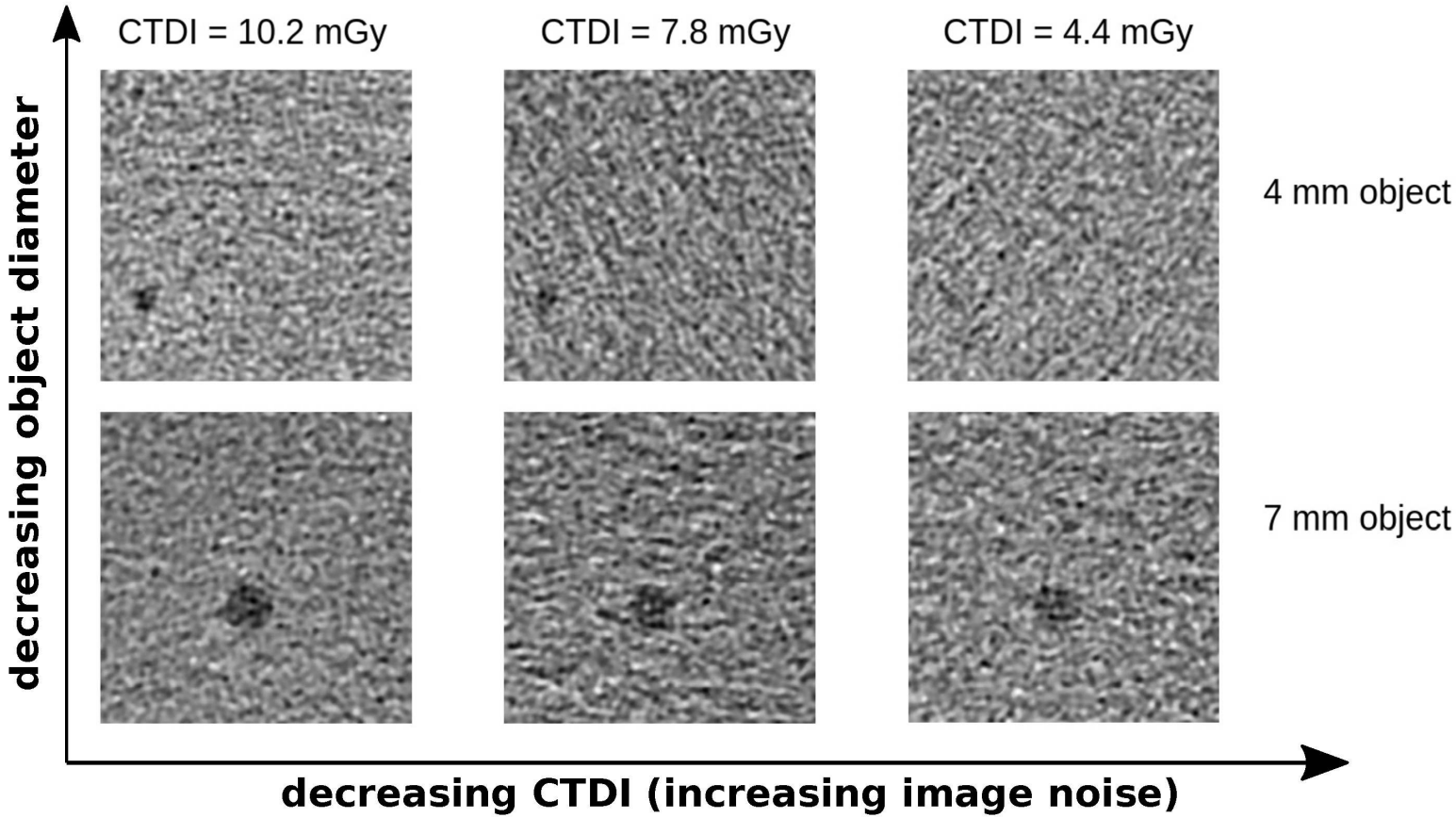


[S. Doria et al., Phys. Med., **83** *(2021)*

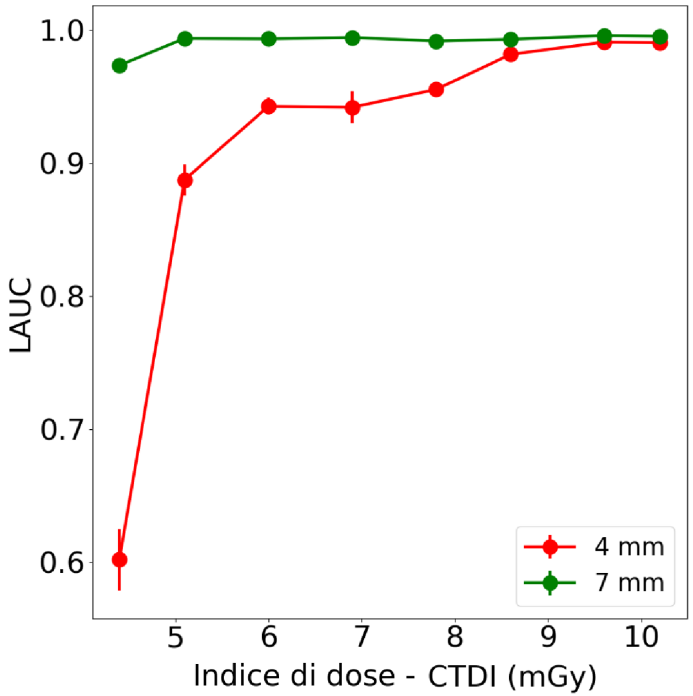
- Radiologists visual examination of the entire dataset
- Collected data: localization and confidence level on object presence

Radiologists visual examination

- The performance of a human observer to detect the low-contrast objects in the images depends on different variables: dose, contrast, size...



Area under ROC = AUC (LAUC)



L-AUC: area under ROC curve

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a measure of **diagnostic accuracy**

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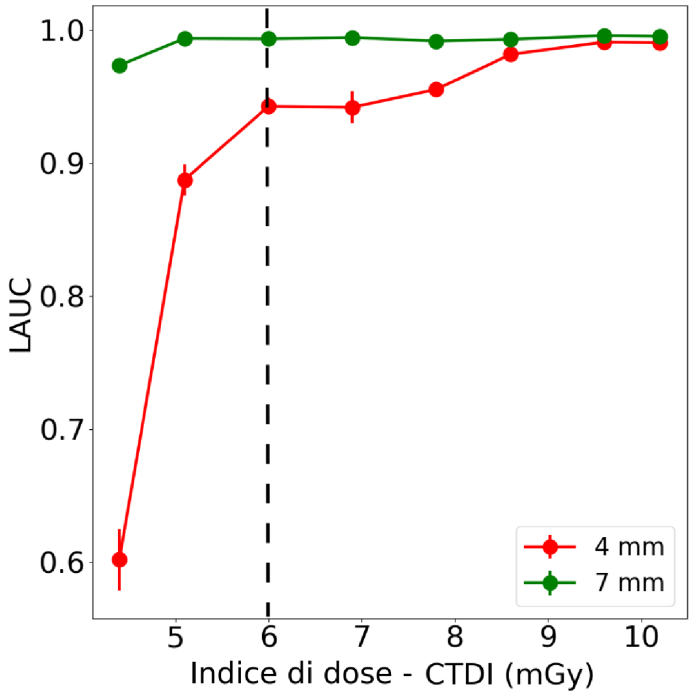
- CT dose protocol optimization : optimum dose=minimum dose compatible with medical diagnosis

Area under ROC = AUC (LAUC)



L-AUC: area under ROC curve

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a measure of **diagnostic accuracy**

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- CT dose protocol optimization: optimum dose=minimum dose compatible with medical diagnosis

AI-based Model Observer

- **Reader studies** are time-consuming → development of Model Observers: algorithms able to reproduce trained human observers

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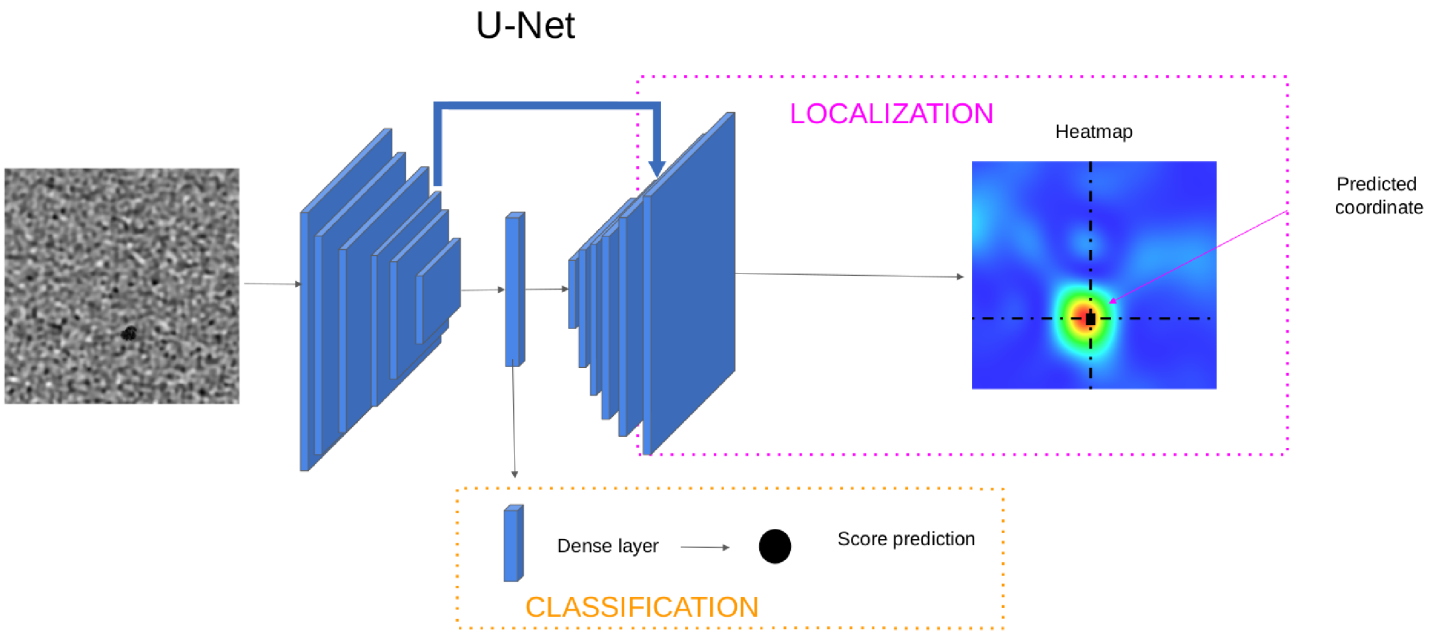
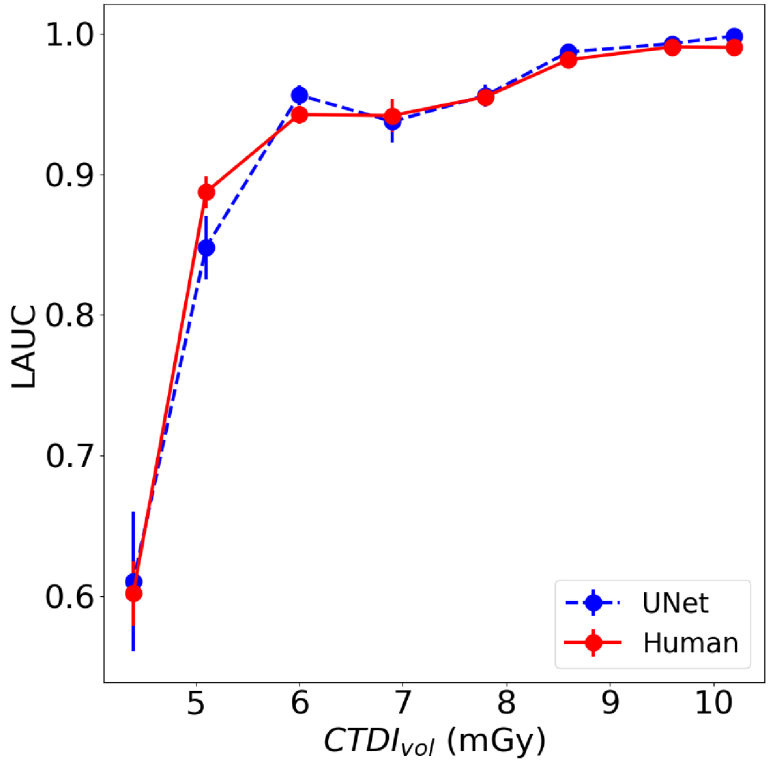
the performance must be comparable!



- 20 000 images previously labelled were used for training (double task of localization and classification)

L-AUC: Results

- 10 000 images used in the test phase
- Good qualitative agreement
- Quantitative agreement measured through different statistical indices/accuracy ($> 80\%$)

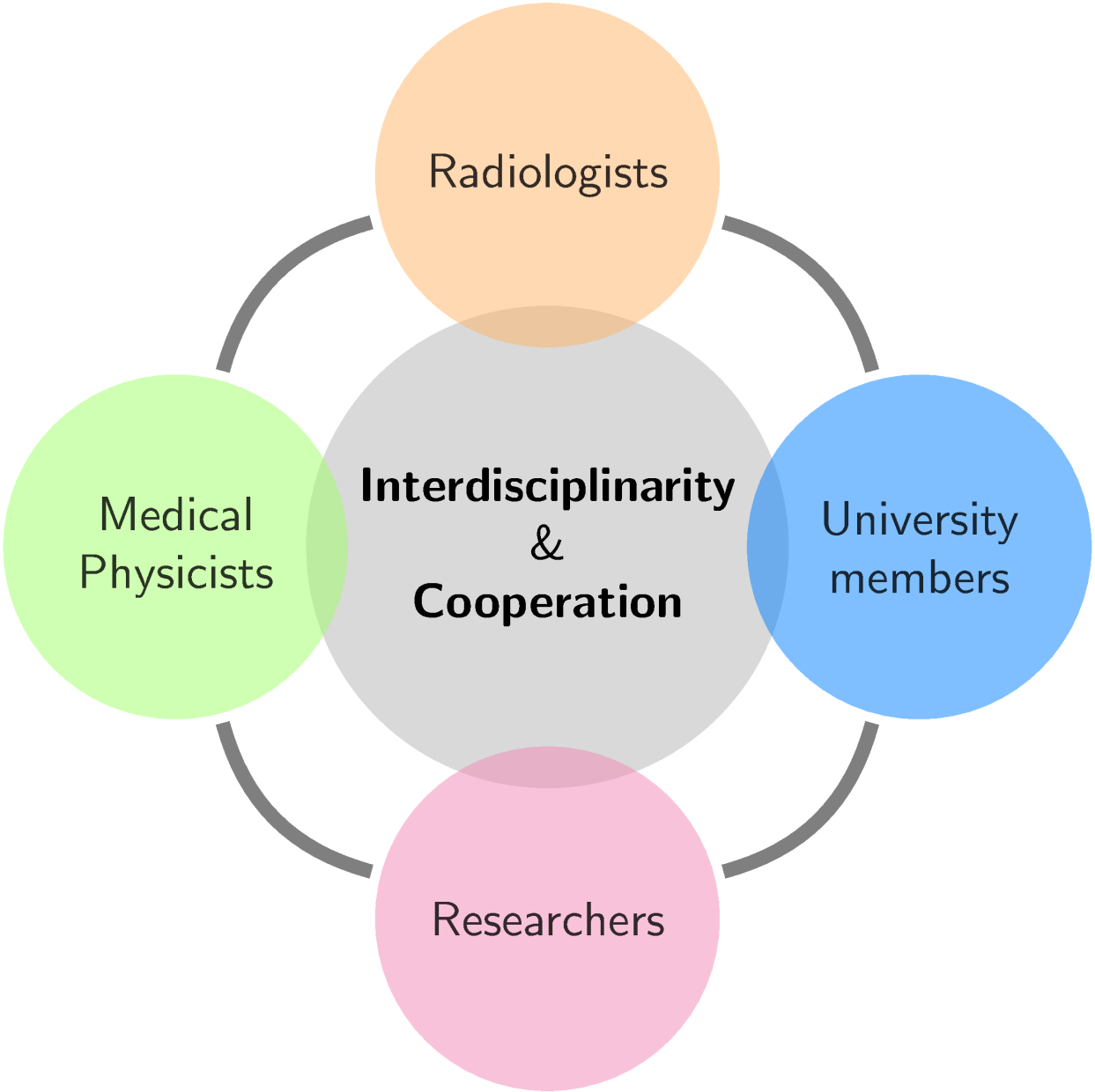


*[F. Valeri et al., J. Medical Imaging (SPIE), **10**, S1, S11904 (2023)]*

Future work and Conclusions

1. Generalization test of Model Observer: different CT scanners and protocols
2. Clinical Trials to evaluate dose reduction potential: new phantom

- Research project includes several national institutes
- Started in 2019 and renewed in 2022


Radiologists
Medical Physicists
Interdisciplinarity & Cooperation
University members
Researchers