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PUSAN NATIONAL UNIVERSITY

RADIATION IMAGING LABORATORY

Monte Carlo estimation of the absorbed dose in computed tomography

@2016 KNS spring meeting

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Outline

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II. Methods
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   b. Simulation geometry
   c. Data categorizing algorithm

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   b. Relative dose

IV. Discussion

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Introduction

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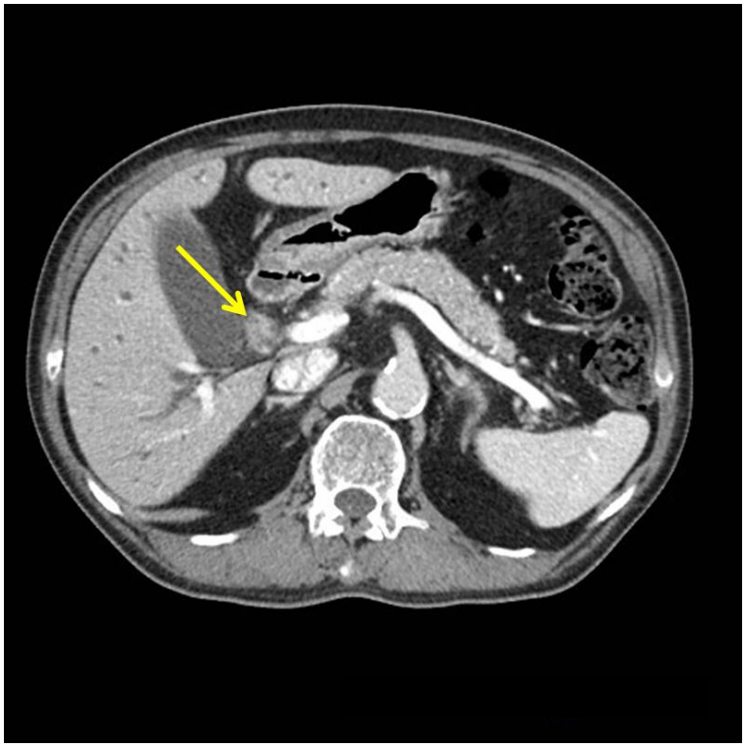
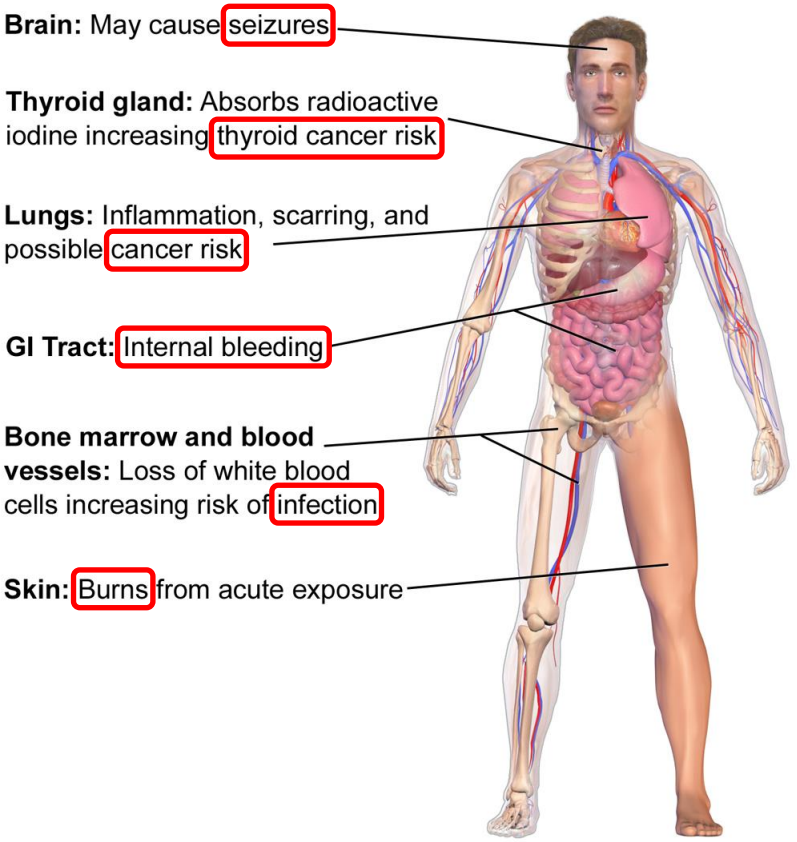
Introduction



Axial CT image of the abdomen



Selected Risks from Radiation Sickness

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Introduction

Conventional CT dose index (CTDI)

- ✓ CTDI limitations
  - Standardized dimension
    - Head phantom (Φ16 cm)
    - Body phantom (Φ32 cm)
  - Homogeneous composition
    - No distinction of organ
  - Measureable to only the average dose at particular location

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Introduction

Monte Carlo method

MCNP5™ Los Alamos NATIONAL LABORATORY

✓ CT dose estimation

- Patient specific dose estimation
  - Applicable to a variety of body shape
- Organ dose estimation
  - Dose imparted to each organ
- Relative dose estimation
  - Dose due to primary photons
  - Dose due to secondary photons

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Methods

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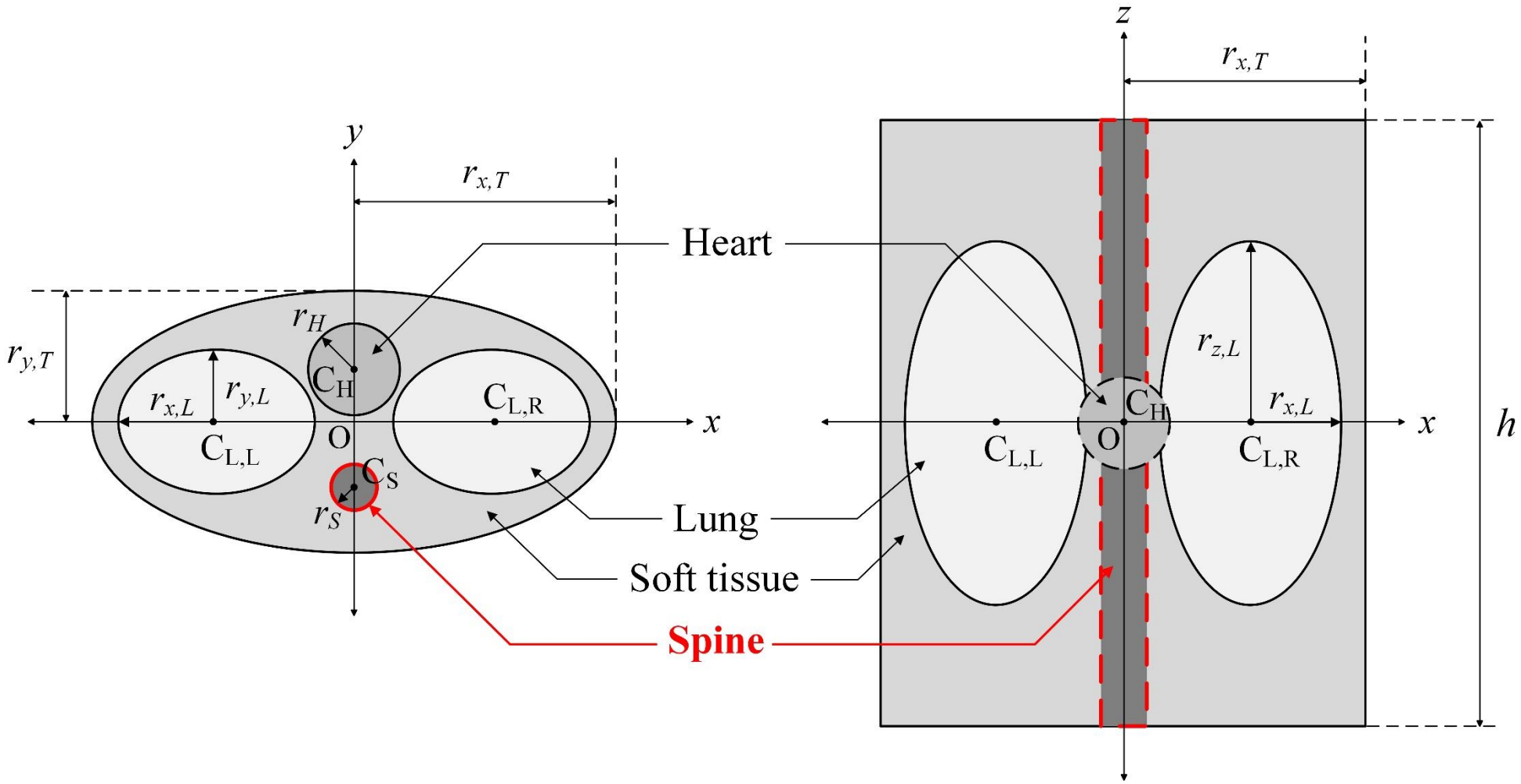
Numerical phantom



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Katia Sourbelle, Thorax phantom, Institute of Medical Physics (IMP)

Numerical phantom

Part	Shape	Center	Dimension (cm)	Material	Density (g/cm^3)
Thorax	Elliptical cylinder	$O = [0,0,0]$	$h = 50$ $r_{x,T} = 20$ $r_{y,T} = 10$	Soft tissue	1.00
Lung	Ellipsoid	$C_{L,L} = [-10.5,0,0]$ $C_{L,R} = [10.5,0,0]$	$r_{x,L} = 7.5$ $r_{y,L} = 5.5$ $r_{z,L} = 15$	Lung	0.26
Heart	Sphere	$C_H = [0,4,0]$	$r_H = 3.5$	(Striated) muscle	1.04
Spine	Cylinder	$C_S = [0,-5,0]$	$r_C = 1.75$	(Cortical) bone	1.92

Table: Definition of the different parts of the phantom

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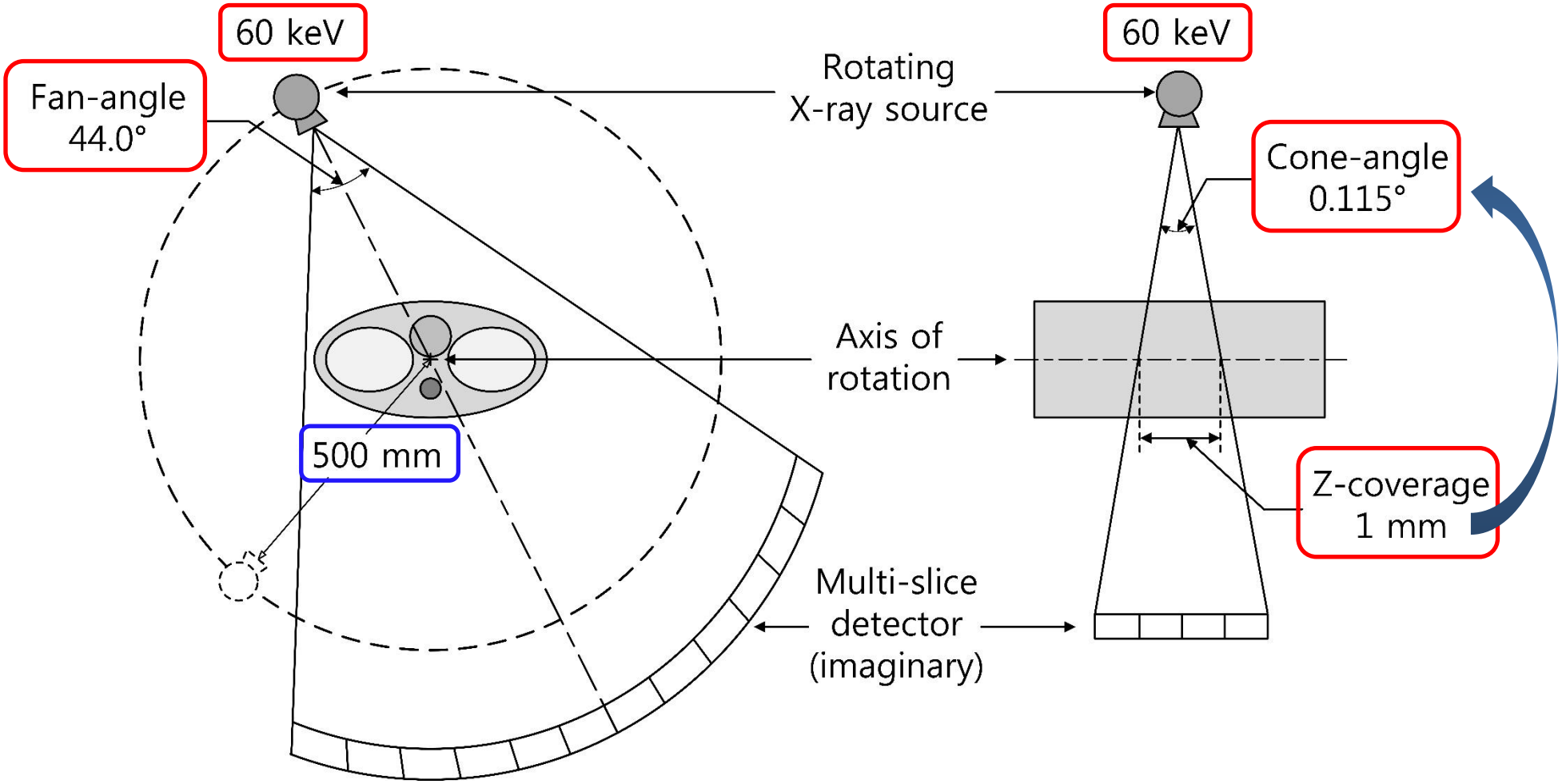
XCOM: Photon Cross Sections Database,
National Institute of Standards and Technology (NIST)

Simulation geometry



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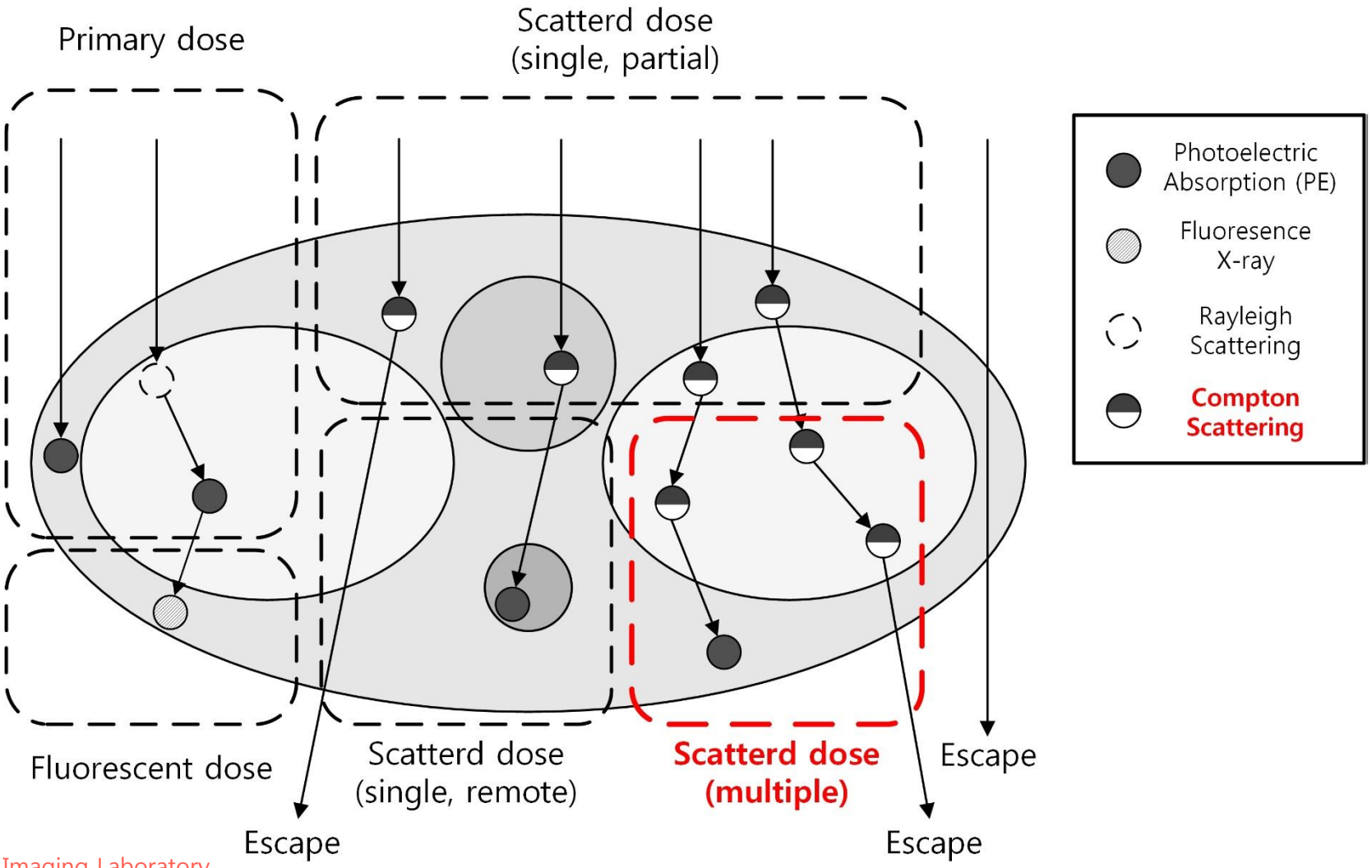
Data categorizing algorithm



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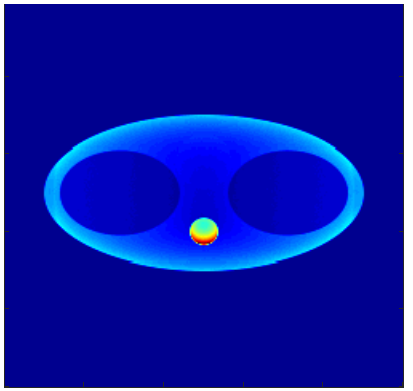
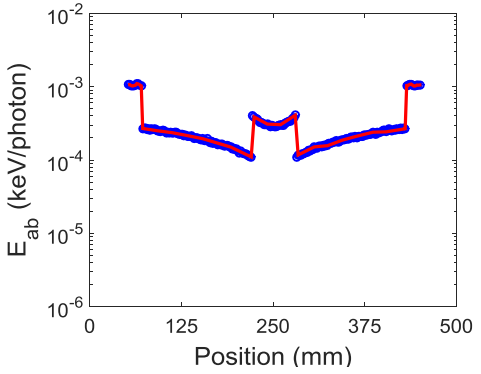
Workflow

MC output (raw data) → Categorize → **Categorized data set** → Post-process → **Energy / Dose estimation**

#	TYP	POS	ERG
1	SRC†	P_S	E_S
2	CS	P_1	E_1
3	CS	P_2	E_2
4	PE	P_3	E_3
5	TER‡	P_3	E_3
6	SRC	P_S	E_S
7	PE	P_4	E_4
8	FX	P_5	E_5
9	TER	P_5	E_5

#	TYP	POS	ERG	
2	CS	P_1	E_1	Single scatter
3	CS	P_2	E_2	Multiple scatter
4	PE	P_3	E_3	
7	PE	P_4	E_4	Primary
8	FX	P_5	E_5	Fluore-scence





† Source, ‡ Termination

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Results

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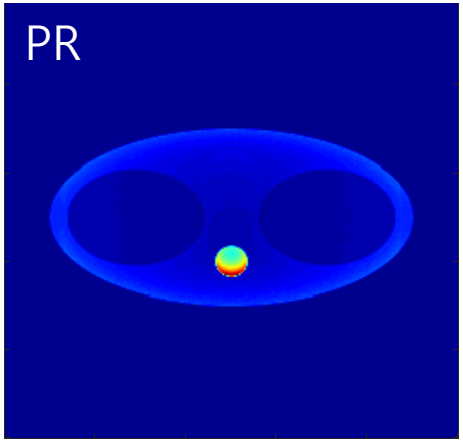
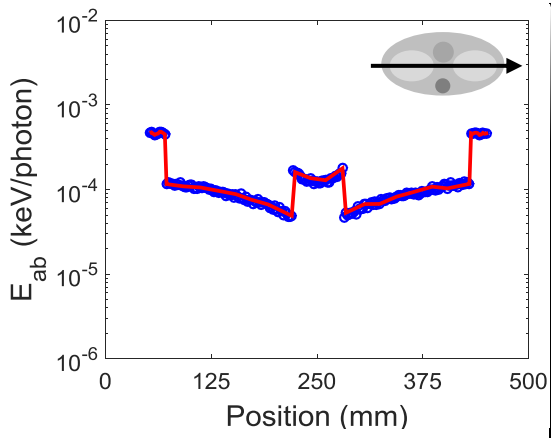
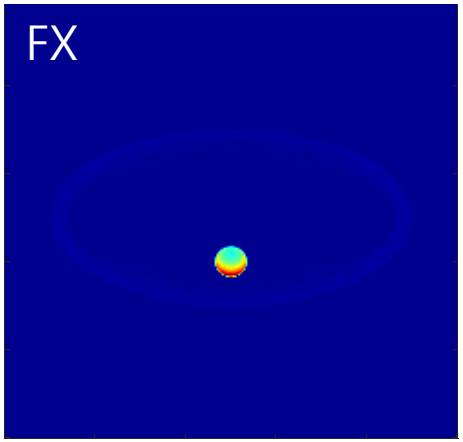
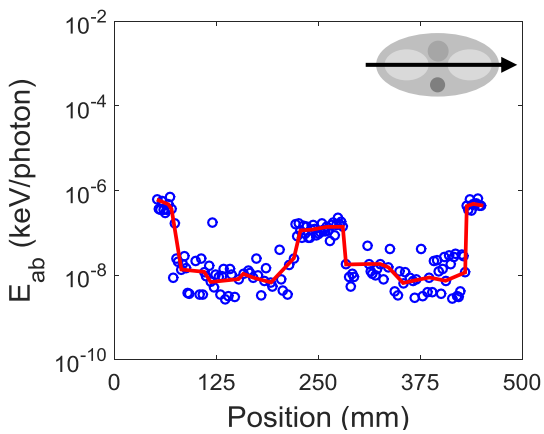
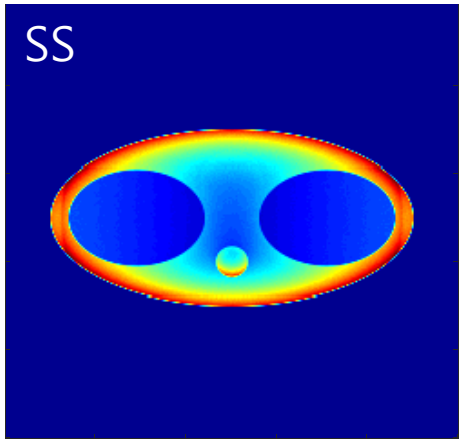
Absorbed energy distribution

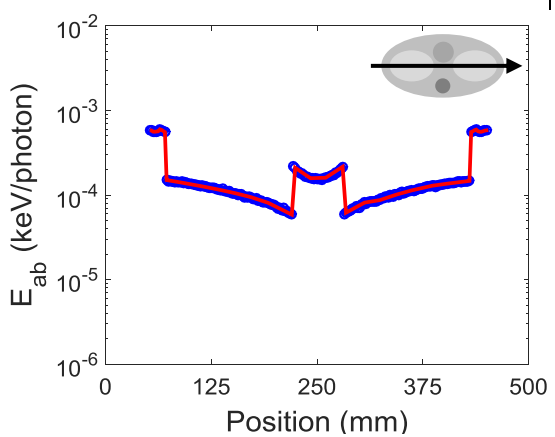


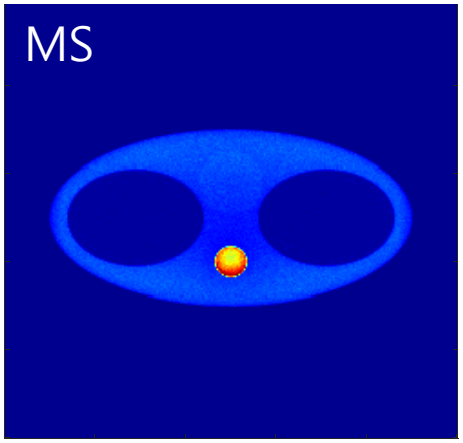


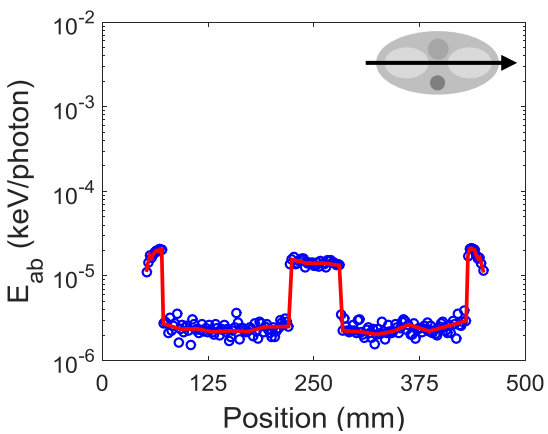












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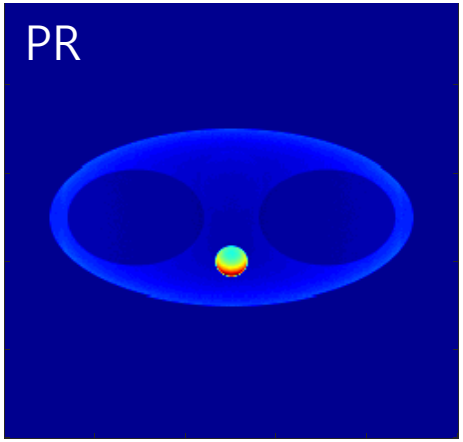
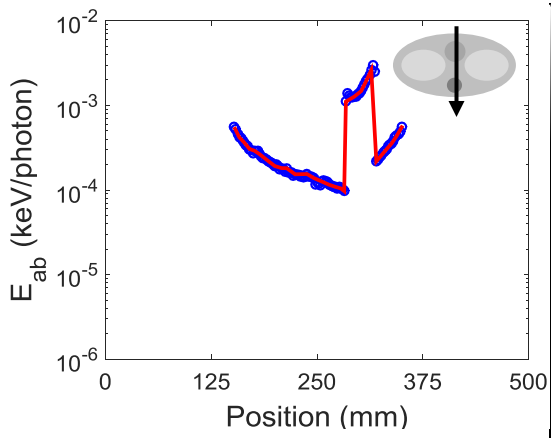
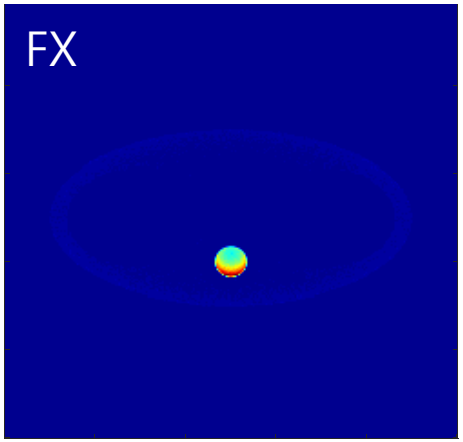
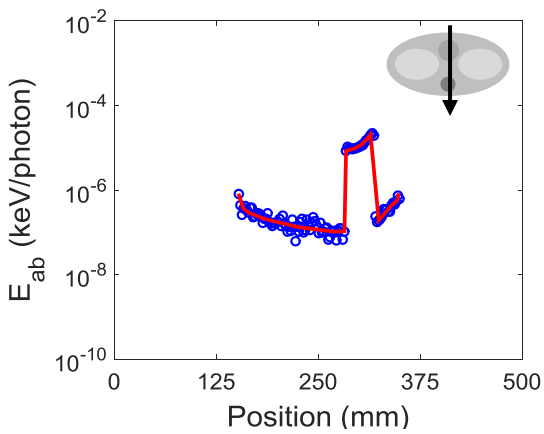
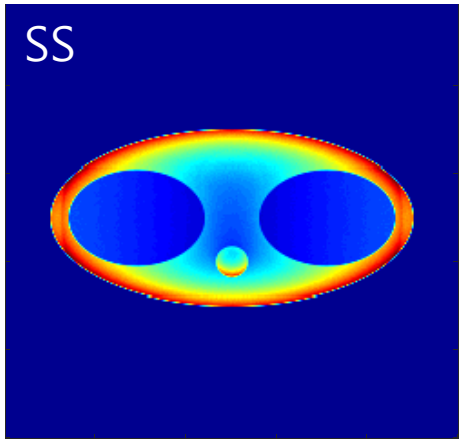
Absorbed energy distribution

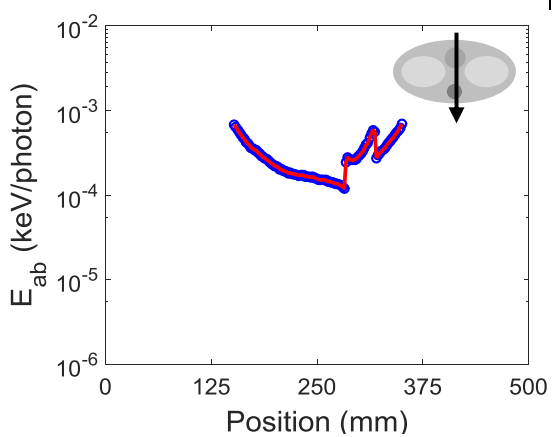


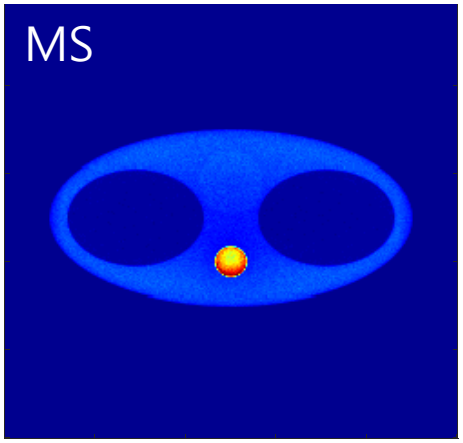


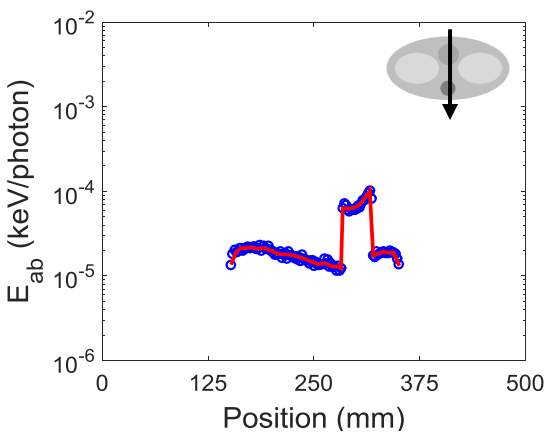












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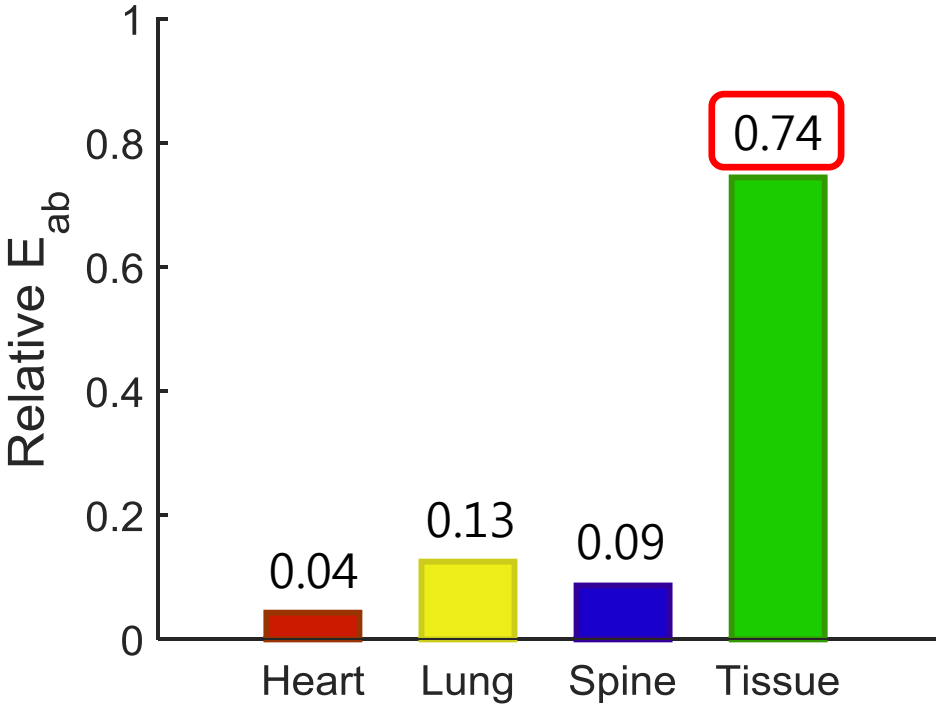
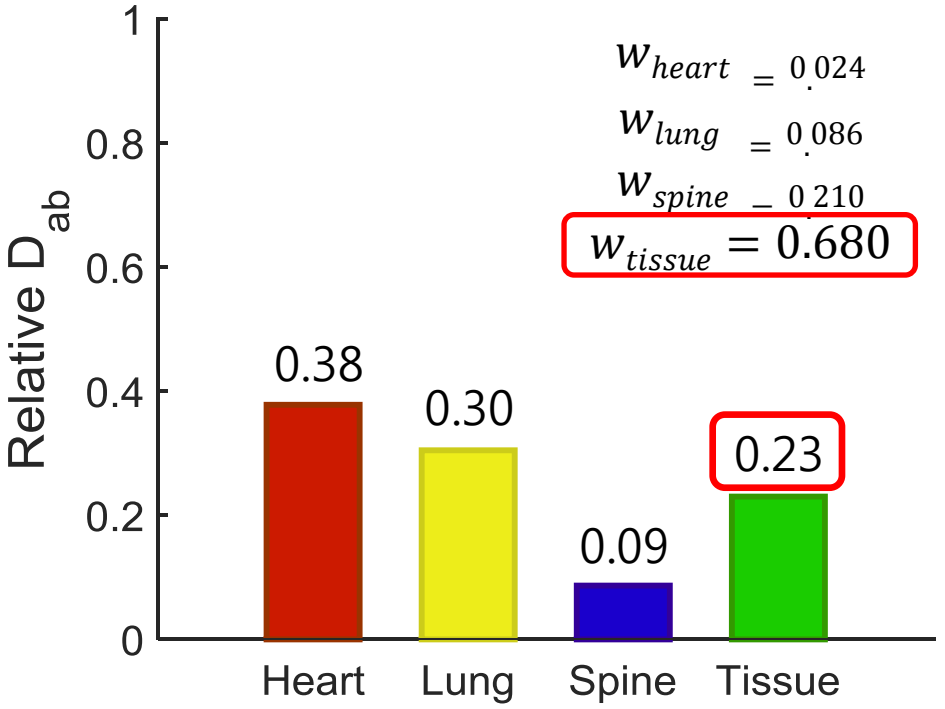
Organ dose



Relative absorbed energy of each organ



Relative absorbed dose of each organ

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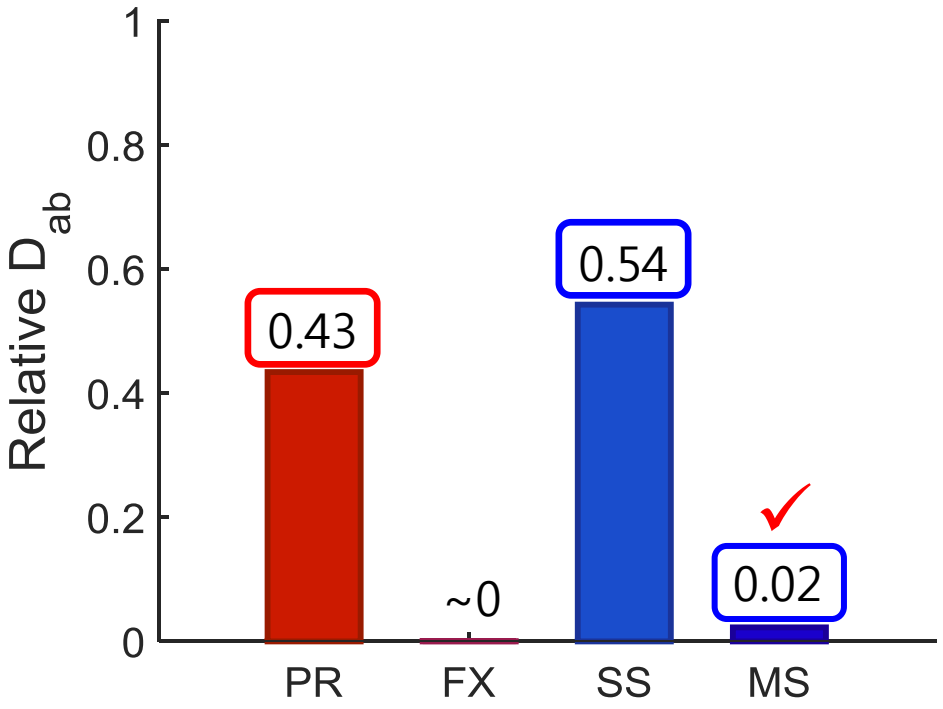
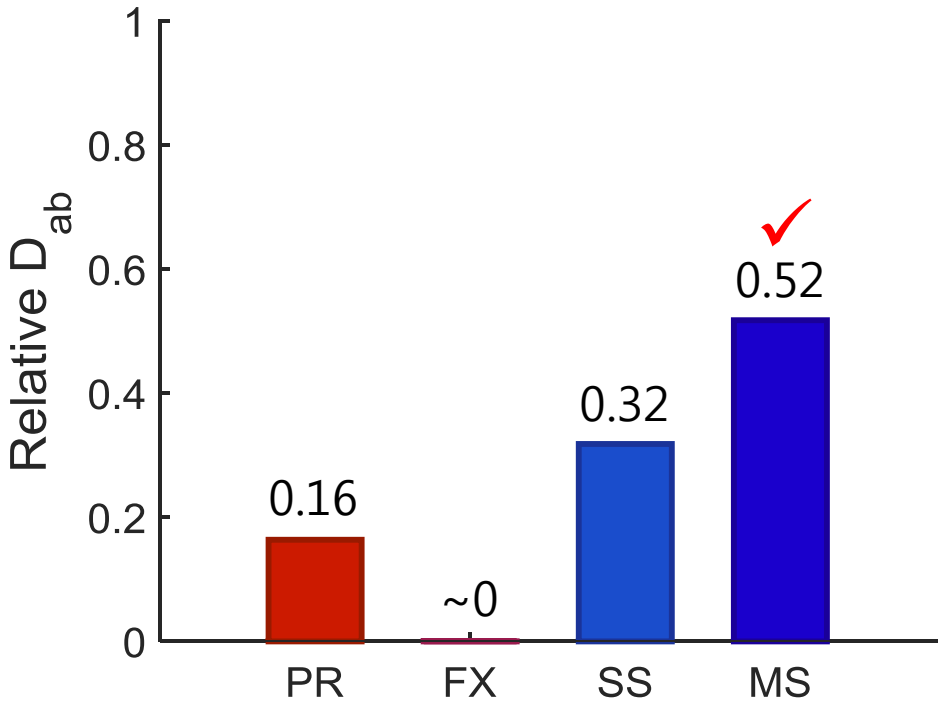
Reaction type – Tissue



Relative dose of thorax at center slice



Average relative dose of thorax

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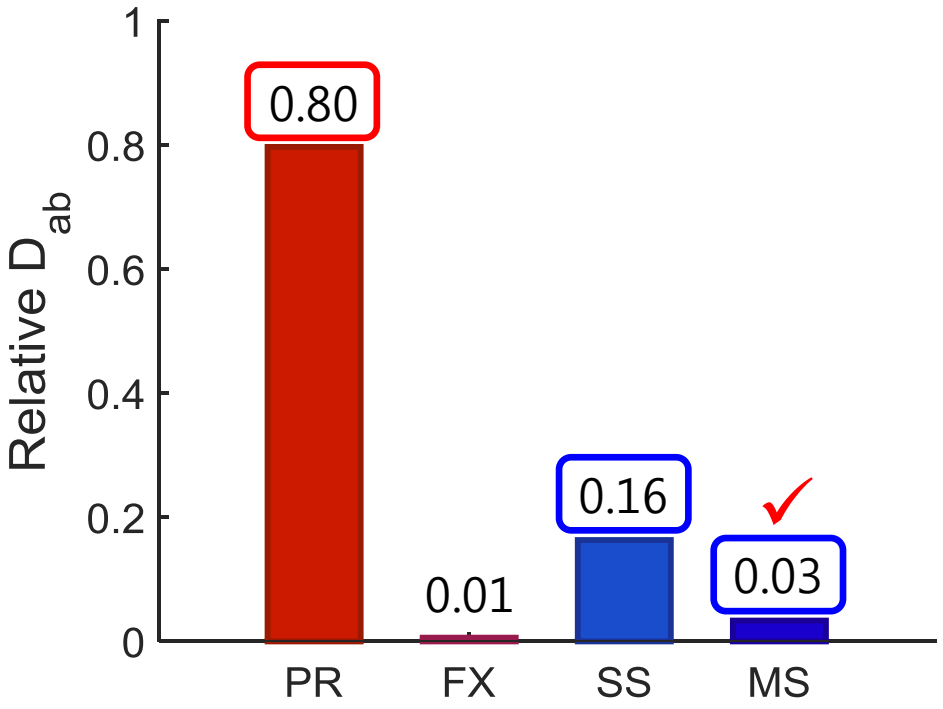
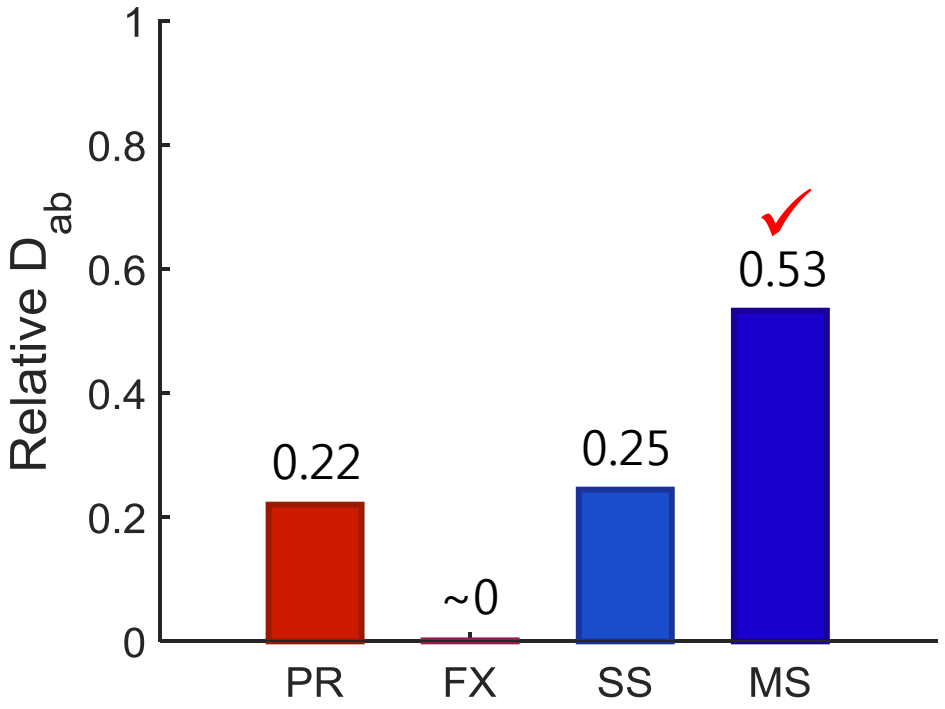
Reaction type – Spine



Relative dose of spine at center slice



Average relative dose of spine

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Discussion

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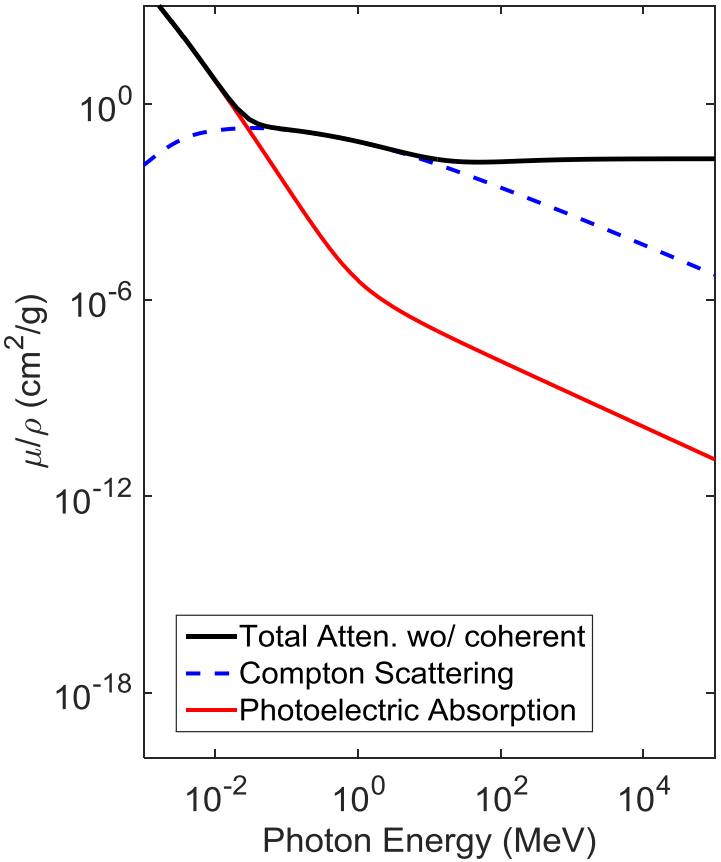
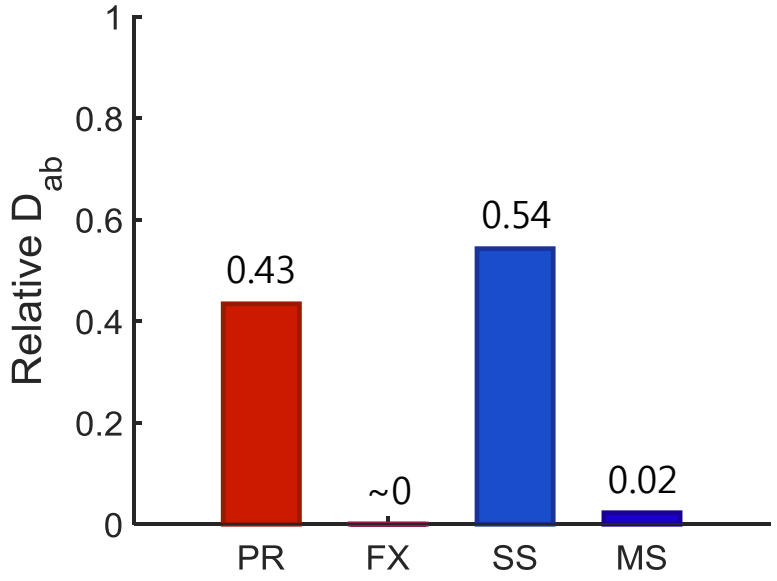


Mass attenuation coefficient of soft tissue

Photon Energy	Compton scattering	Photoelec. Absorption	Total wo/ coherent
5.00E-02	1.788E-01	2.878E-02	2.076E-01
6.00E-02	1.755E-01	1.583E-02	1.913E-01
8.00E-02	1.682E-01	6.160E-03	1.744E-01

Mass attenuation coefficient of soft tissue



Relative absorbed dose of soft tissue region

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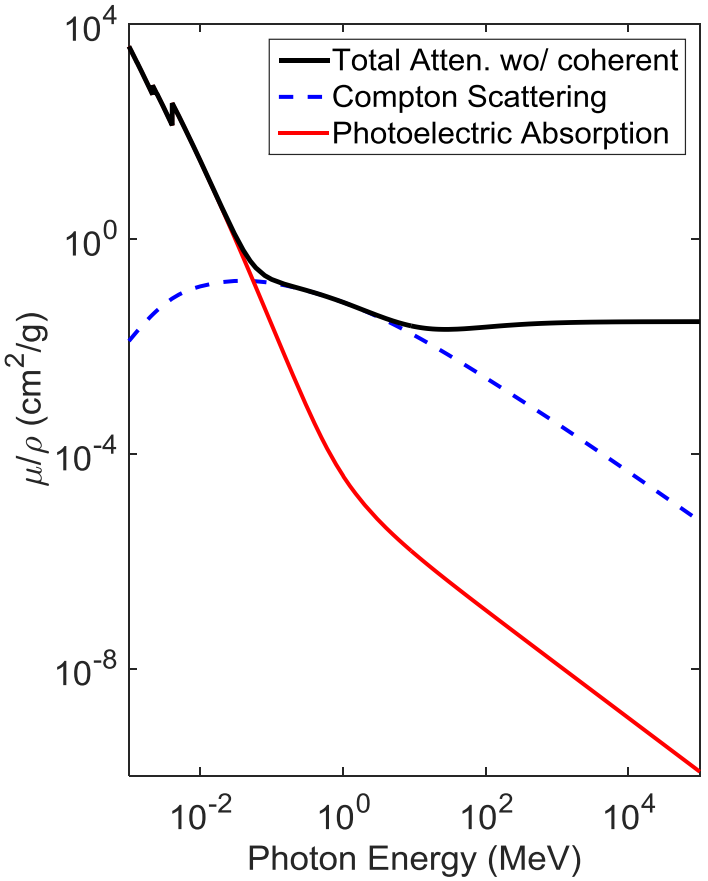
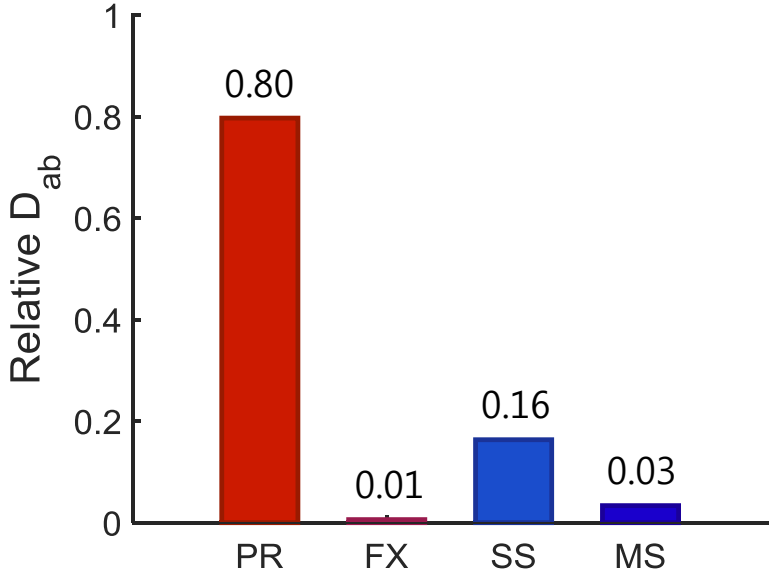
Discussion



Mass attenuation coefficient of spine

Photon Energy	Compton scattering	Photoelec. Absorption	Total wo/ coherent
5.00E-02	1.632E-01	2.221E-01	3.853E-01
6.00E-02	1.609E-01	1.225E-01	2.864E-01
8.00E-02	1.552E-01	5.072E-02	2.060E-01

Mass attenuation coefficient of spine



Relative absorbed dose of spine region

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Conclusions

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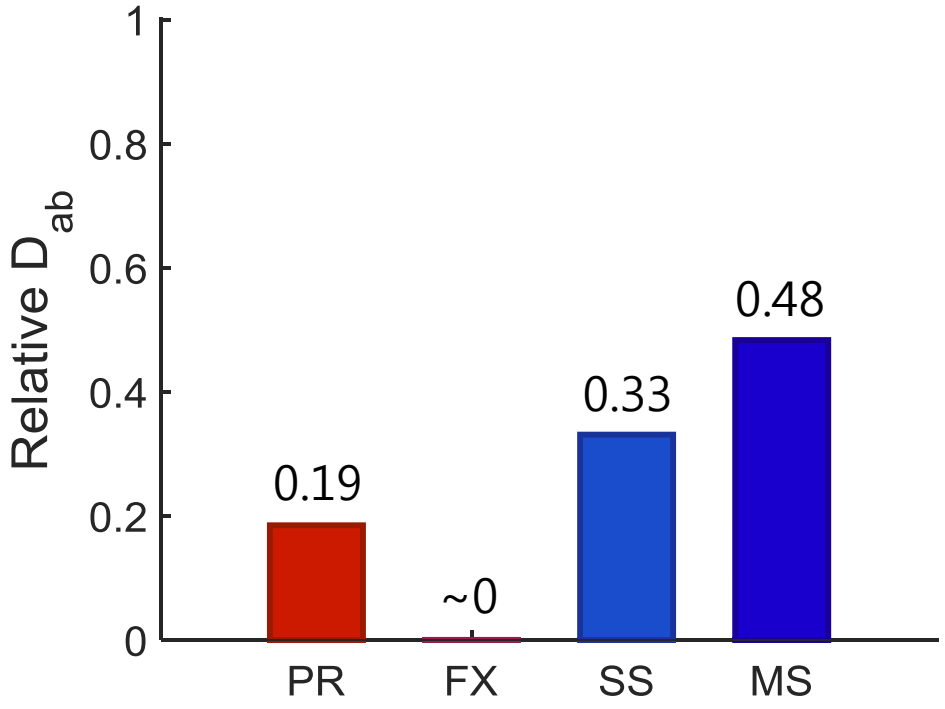
Conclusions



Relative dose of the whole phantom

- Secondary dose is more important than primary dose when radiation is used for low-Z material such as the human body.
- Thus, to estimate a radiation dose for the human body, we should not ignore the multiple-scattering.
- Further studies will be the validation of the algorithm with analytic calculation model and the study of dose distribution for the different CT scan conditions.

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Thanks for attention.

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