OR-Imaging

1. Ortho CT (Orthogonal Computed Tomography for X-Ray Therapy)
2. O-PGI (Orthogonal Prompt-Gamma Imaging for Proton Therapy)
3. TPPT (In-beam TOF-PET for Proton Therapy)

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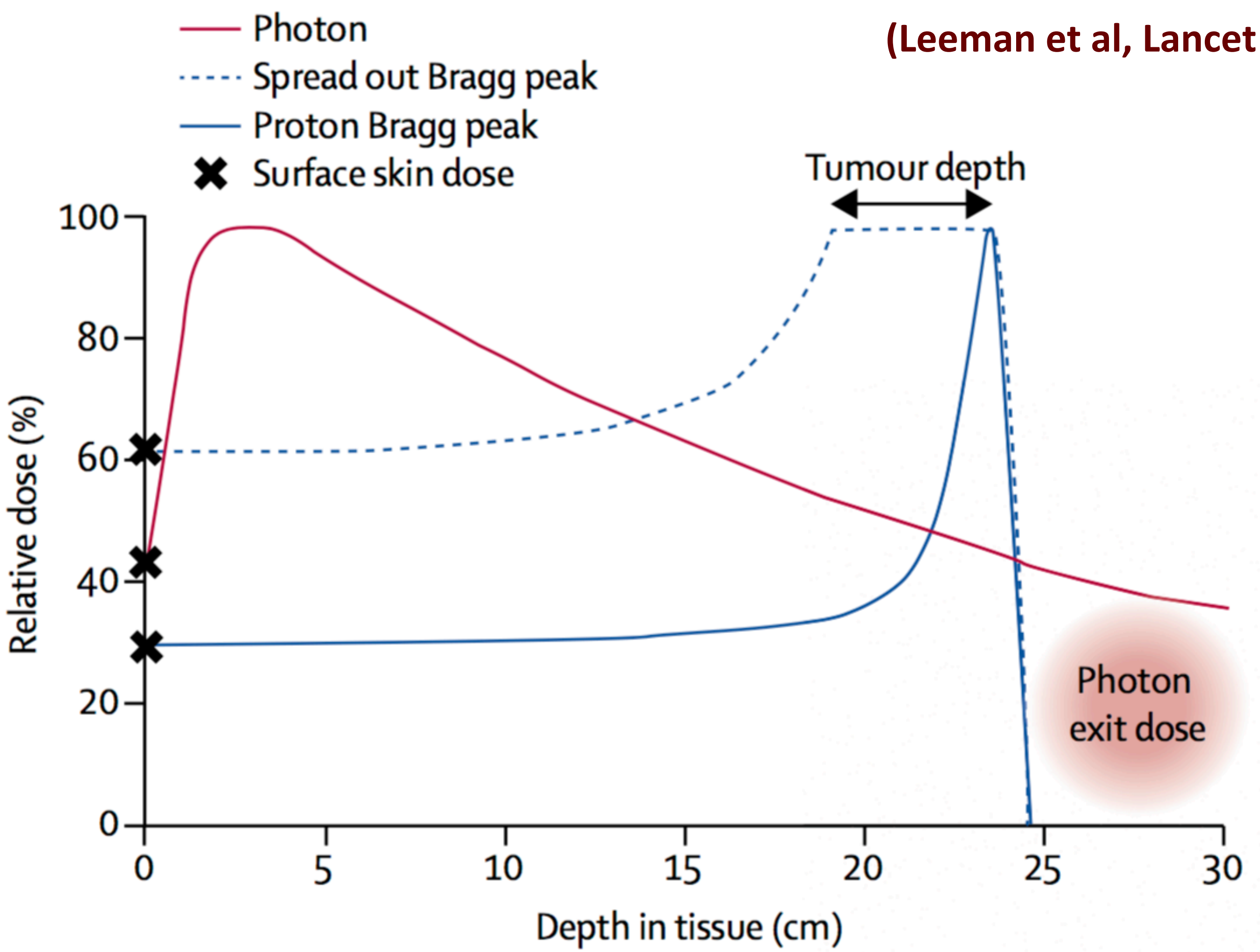
Outline

1. Motivation
2. Rationale for in-vivo imaging in proton radiotherapy (RT)
3. Orthogonal prompt-gamma imaging in proton RT
4. In-beam TOF-PET for proton RT

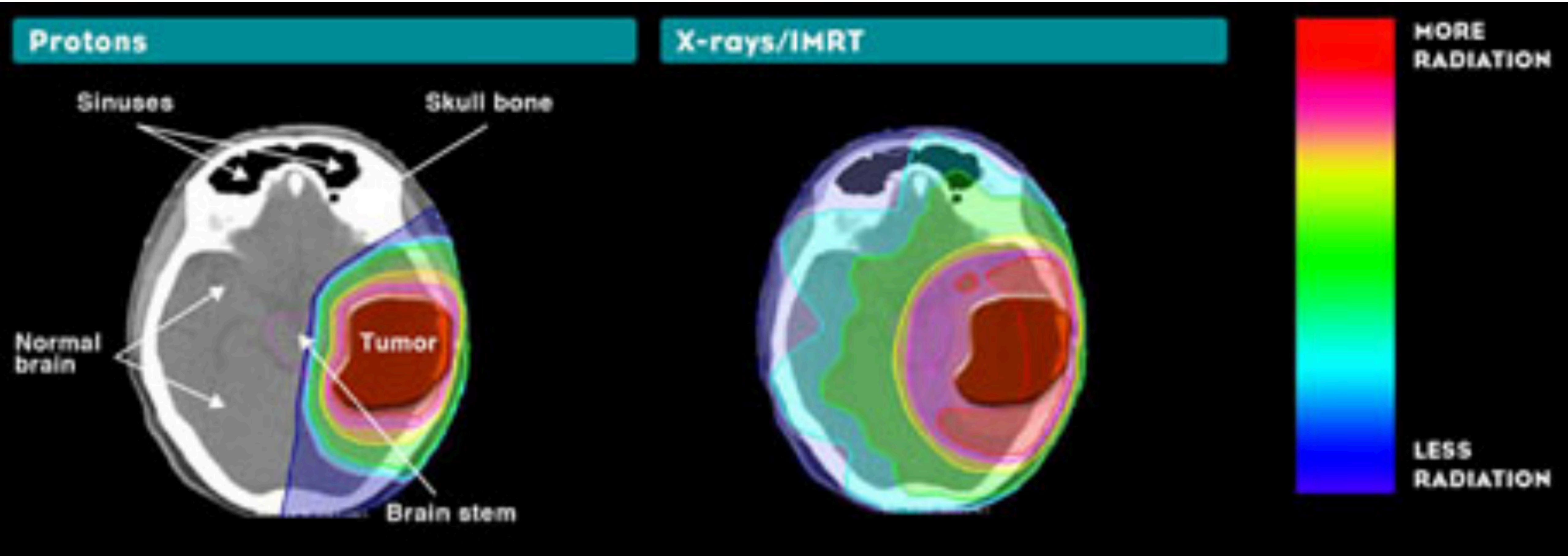
Acknowledgments

1. Motivation: Proton therapy physical advantage over photons

(Leeman et al, Lancet Oncol 2017)



1. Motivation: Proton therapy physical advantage over IMRT



(Proton Therapy Today 2019)

1. Motivation: Proton therapy clinical benefits

Brain/Head & Neck

45% reduction in overall risk of needing a feeding tube for **nasopharyngeal cancer**

27% reduction in overall risk of needing a feeding tube for **oropharyngeal cancer**

44% increase of relative 5-year disease free survival rate for **nasal and paranasal sinus cavity cancers**

50% overall increase of disease control for **chordomas**

Less side effects during first 3 months after treatment, quicker return to normal function

50% less likely to have secondary tumor from treatment

Breast

Delivers 8-18 times less overall radiation to the heart than IMRT

50-83% less relative risk of heart attack or another major coronary event depending on age

50% reduction of clinically significant radiation doses to the heart

97% of partial breast irradiation patients experience **no breast tumor recurrence at 5 years**

90% of cases result in good to excellent cosmetic outcomes at 5 years

Liver
(Hepatocellular)

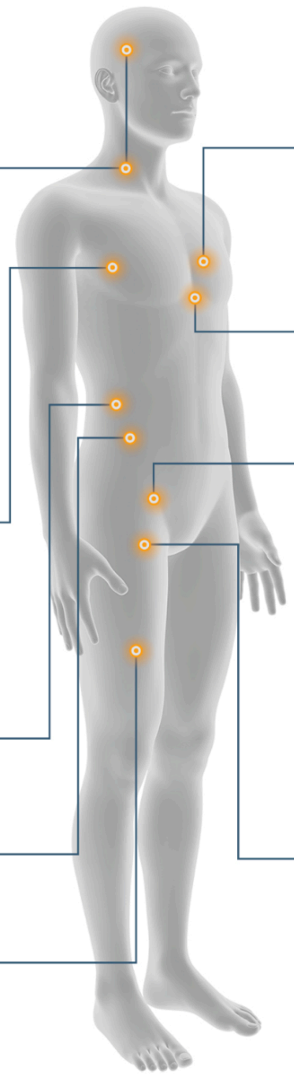
58% higher overall survival rate (2 years)

Bile Duct

54% higher overall survival (4 years)

Sarcoma

49-75% reduction in complications



Lung

56% relative reduction in incidences of grade 3 esophagitis

50% reduction in relative risk of recurrence

Higher radiation dose to the tumor while reducing risks of overall side effects

64% relative increase in 5-year overall survival

Esophageal

3 to 4-day reduction in average hospital stay

5.1-22.8% overall reduction in pulmonary complications

68% relative reduction in wound complications

Prostate

4.9% higher overall 5 year survival rate

35% less radiation to bladder and **59% less radiation** to the rectum

Proton patients are almost twice as likely to report **treatment had NO IMPACT on their quality of life** compared to surgery, conventional radiation, and brachytherapy

Half as many incidences of long term (2+ years) moderate or severe bowel problems

42% reduction in relative risk of developing a secondary malignancy

Significantly fewer reports of gastrointestinal, genitourinary, endocrine, or "other" complications

Rectal/Anal

More than 50% reduction in radiation dose to critical structures including bone marrow

Overall

31% relative reduction in occurrence of secondary cancers after treatment

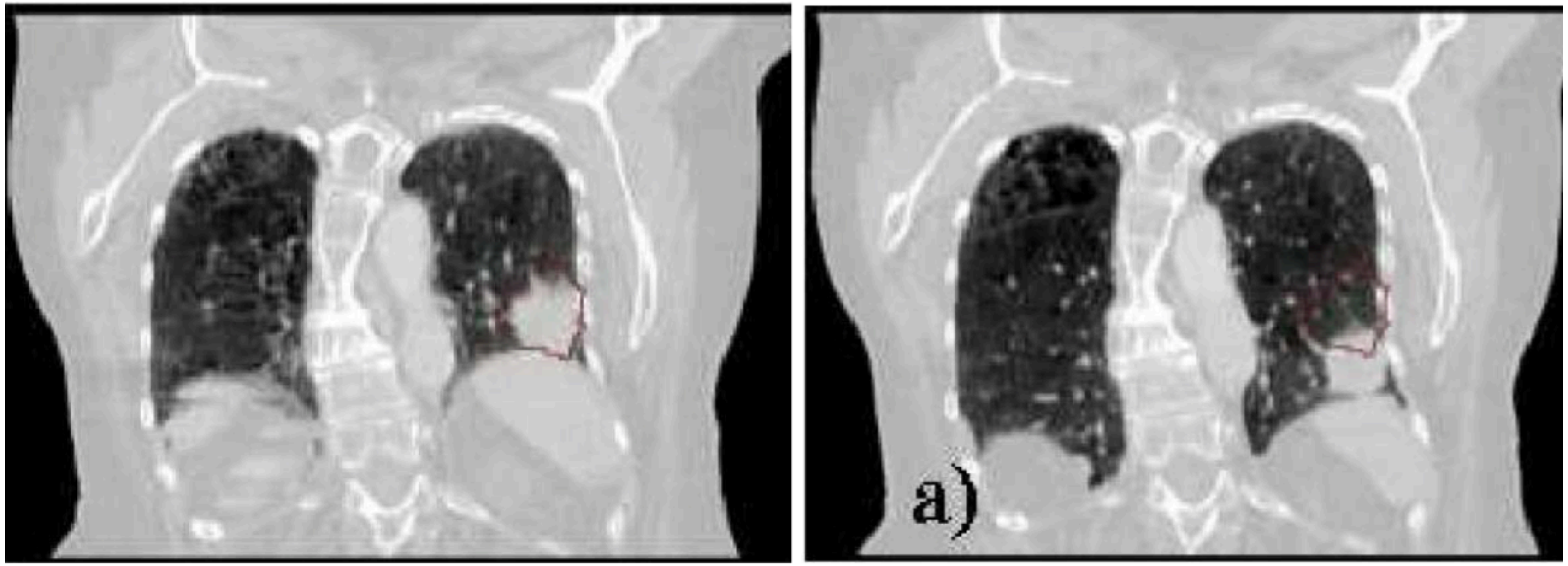
PROVISION CARES
PROTON THERAPY

**References available upon request. Results from separate studies compared in some instances. The benefits of proton therapy for each individual patient will vary based on their individual diagnosis. A personal consultation with a proton-trained physician is recommended in all cases.*

2. Rationale for in-vivo imaging in proton RT

Target volumes and organ motion: tumor displacement

- Breathing (intrafraction)

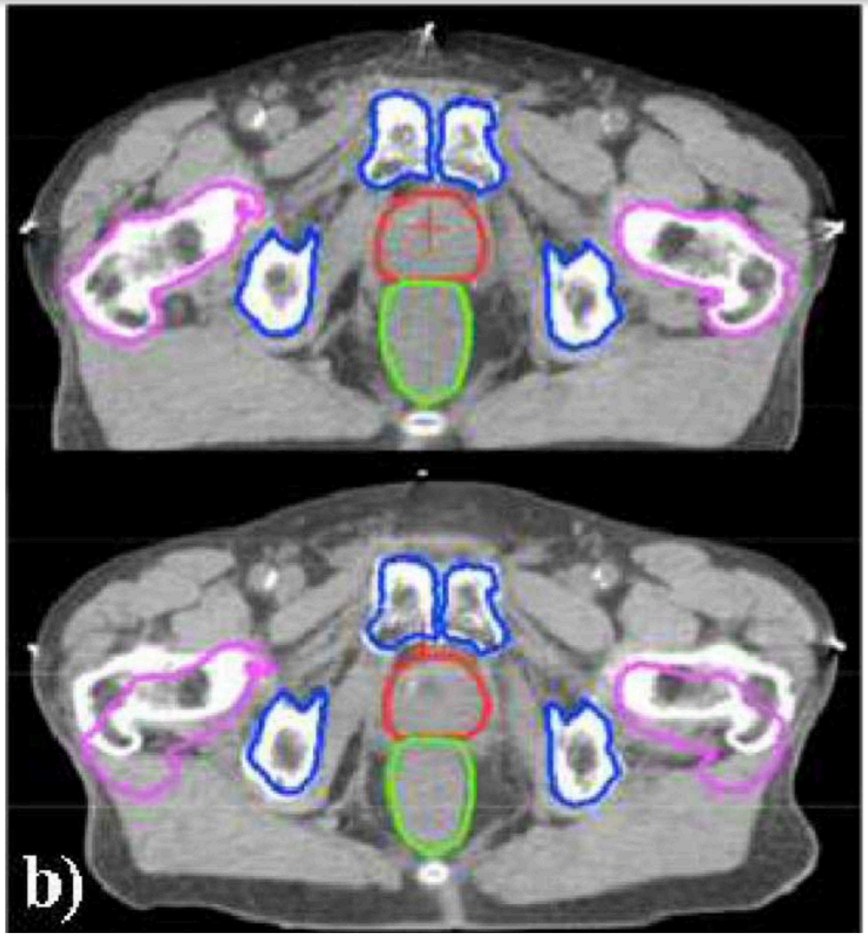


Engelsman and Bert 2011
Lüchtenborg PhD 2012

2. Rationale for in-vivo imaging in proton RT

Target volumes and organ motion: patient displacement/deformation

- Mispositioning (interfraction)

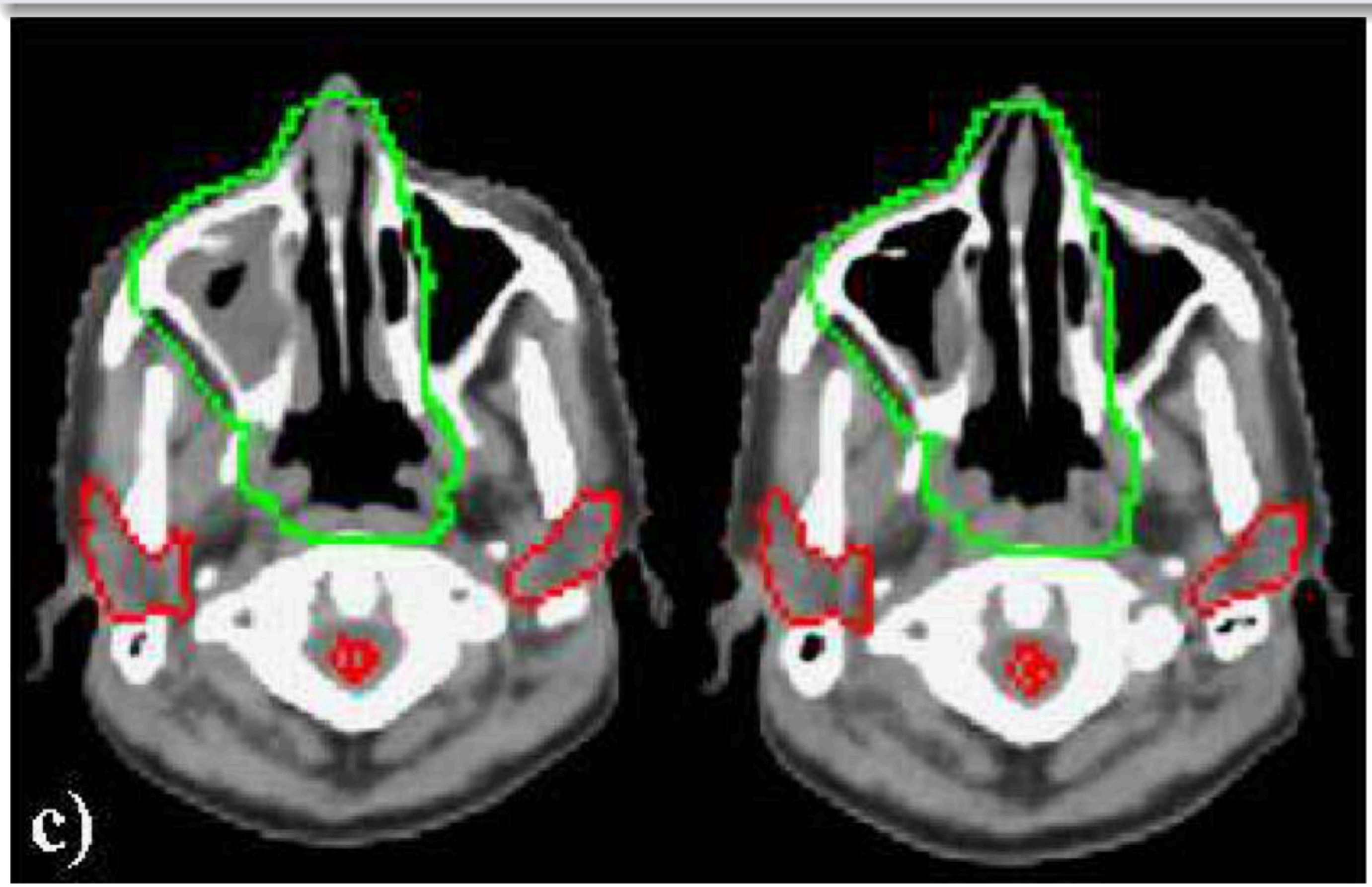


Engelsman and Bert 2011
Lüchtenborg PhD 2012

2. Rationale for in-vivo imaging in proton RT

Target volumes and organ motion: cavity filling/wall thickening

- Tissue-density modification (interfraction)



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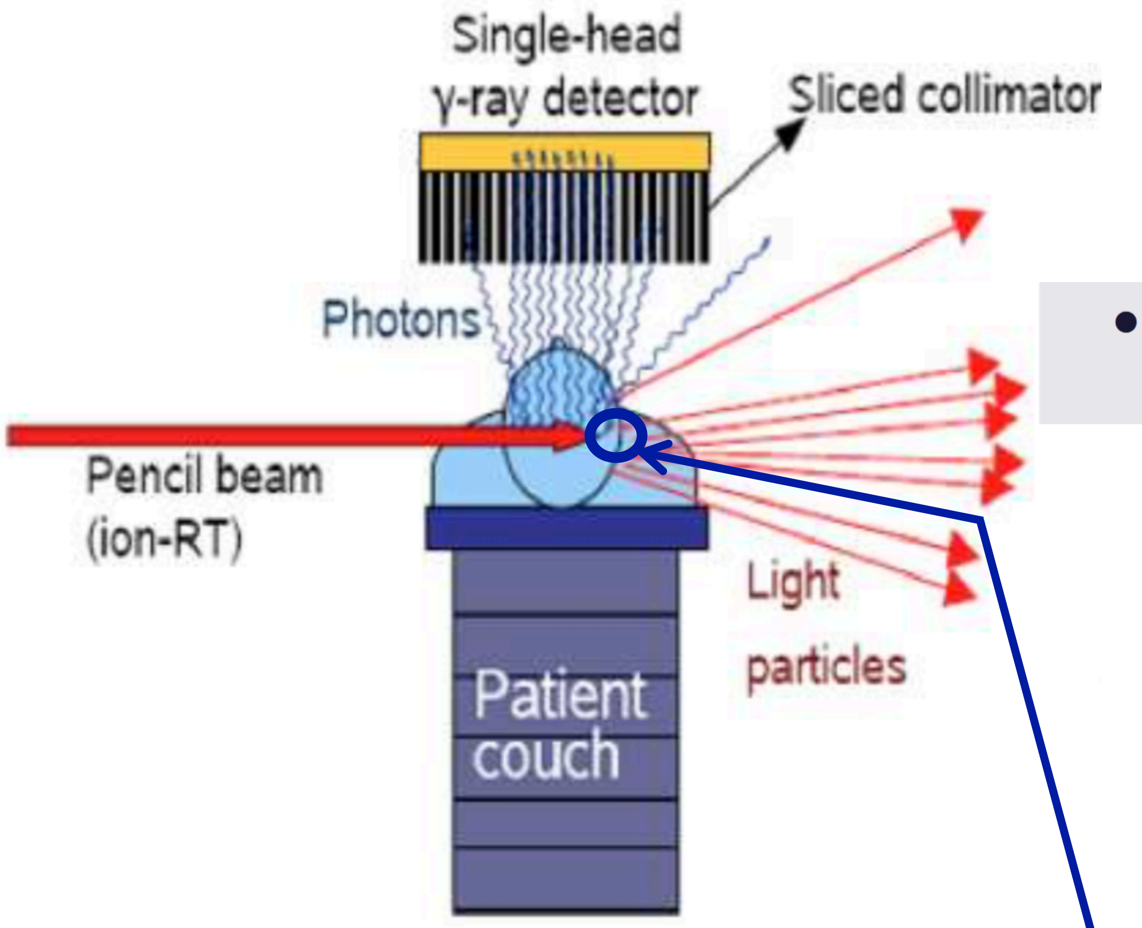
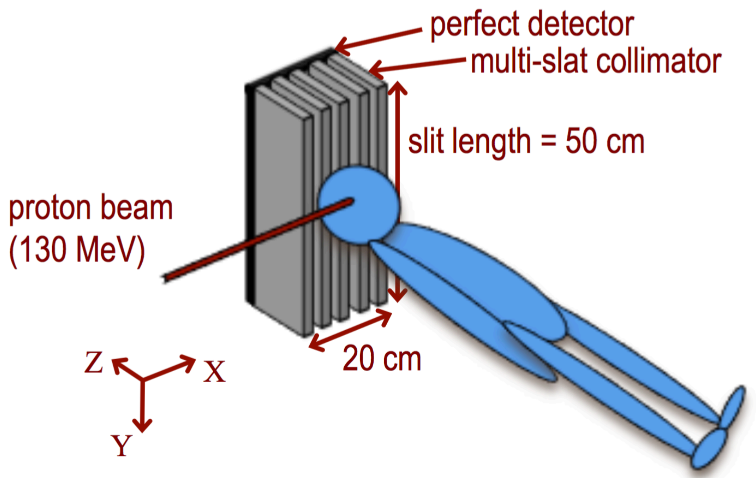
3. Orthogonal prompt-gamma imaging in proton RT



- Head irradiation: nasal cavities (cavity filling) and pituitary (change in brain density)



(Cambraia Lopes PhD 2017)

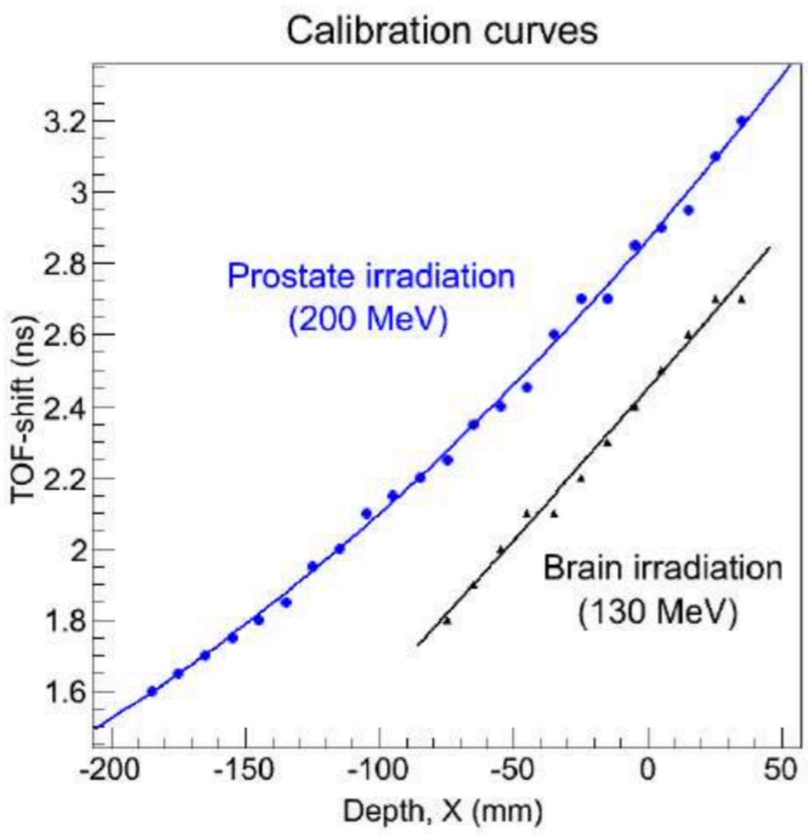
Provides real-time images of selected region without rotation of beam source.

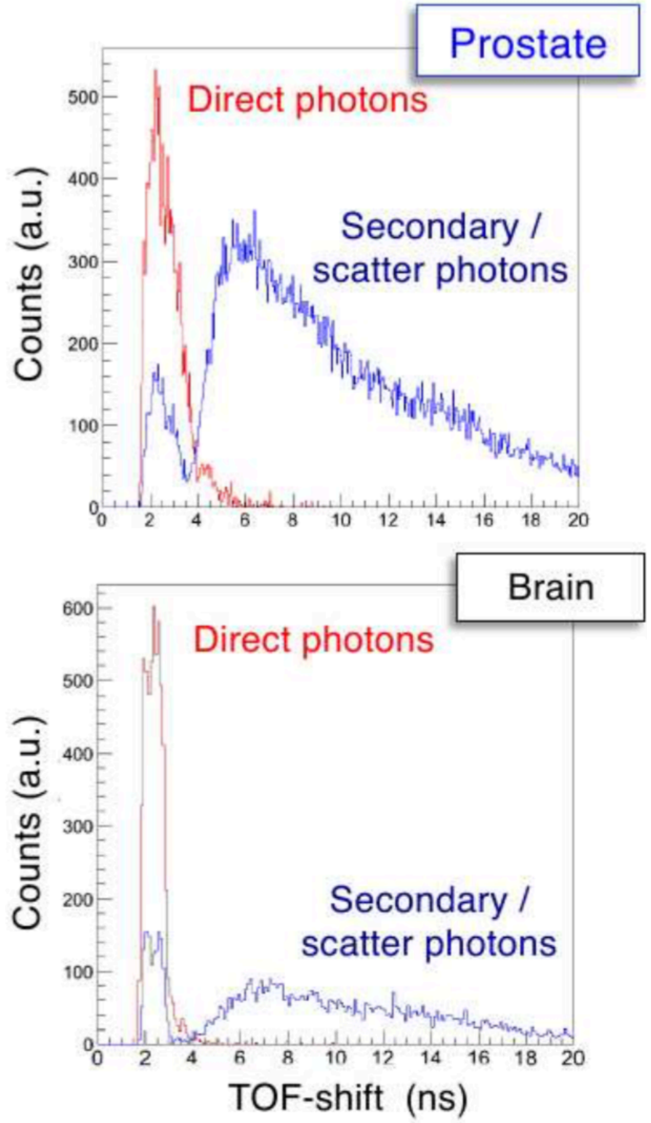
Image with prompt gammas “stops” at beam range

3. Orthogonal prompt-gamma imaging in proton RT

Data analysis

Shifting Time-of-Flight (TOF) selection





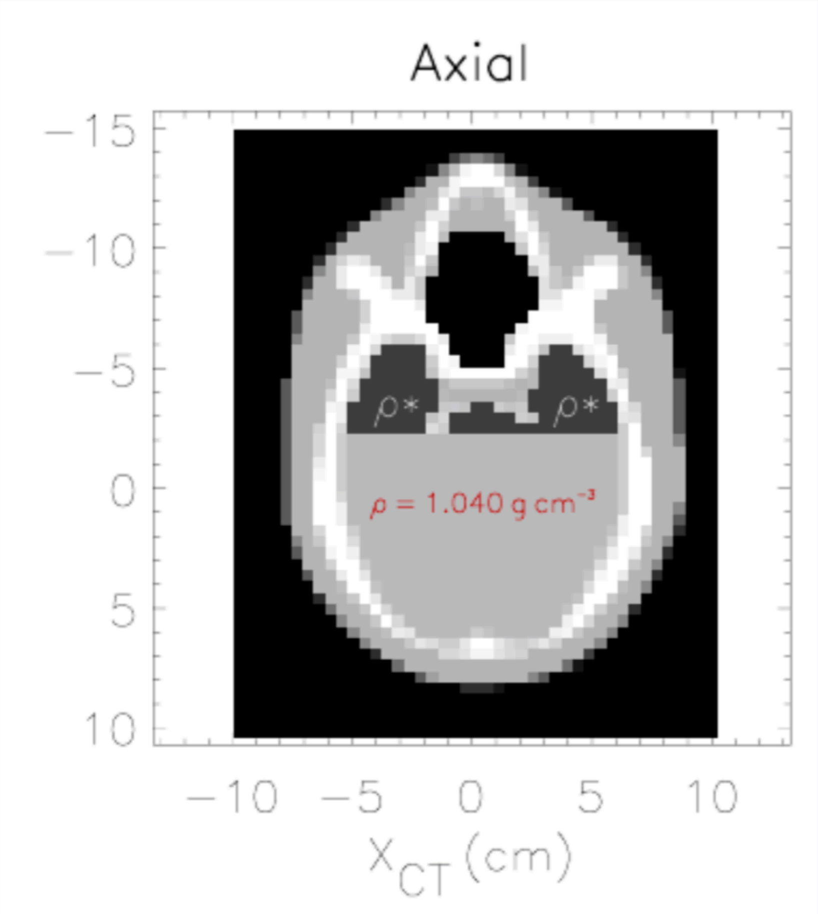
→ *Method according to Biegun et al. PMB 2012*

(Cambraia Lopes PhD 2017)

3. Orthogonal prompt-gamma imaging in proton RT

3.1 Change of brain density due to fractionated RT

- Conjecture: brain tissue hypo/hyperdense due to fractionated RT Denham et al Radiother Oncol 2002



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3. Orthogonal prompt-gamma imaging in proton RT

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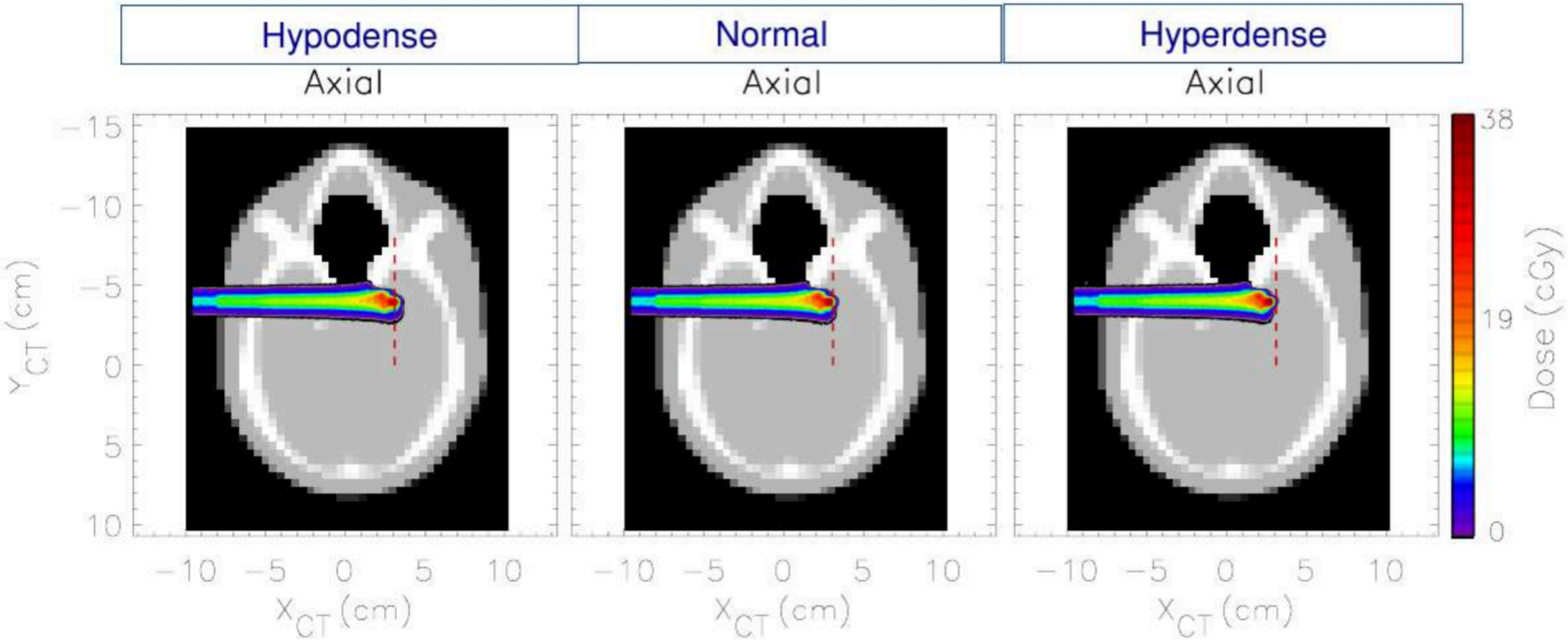
- Conjecture: brain tissue hypo/hyperdense
- Corresponding dose distributions (protons):



(Cambraia Lopes PhD 2017)

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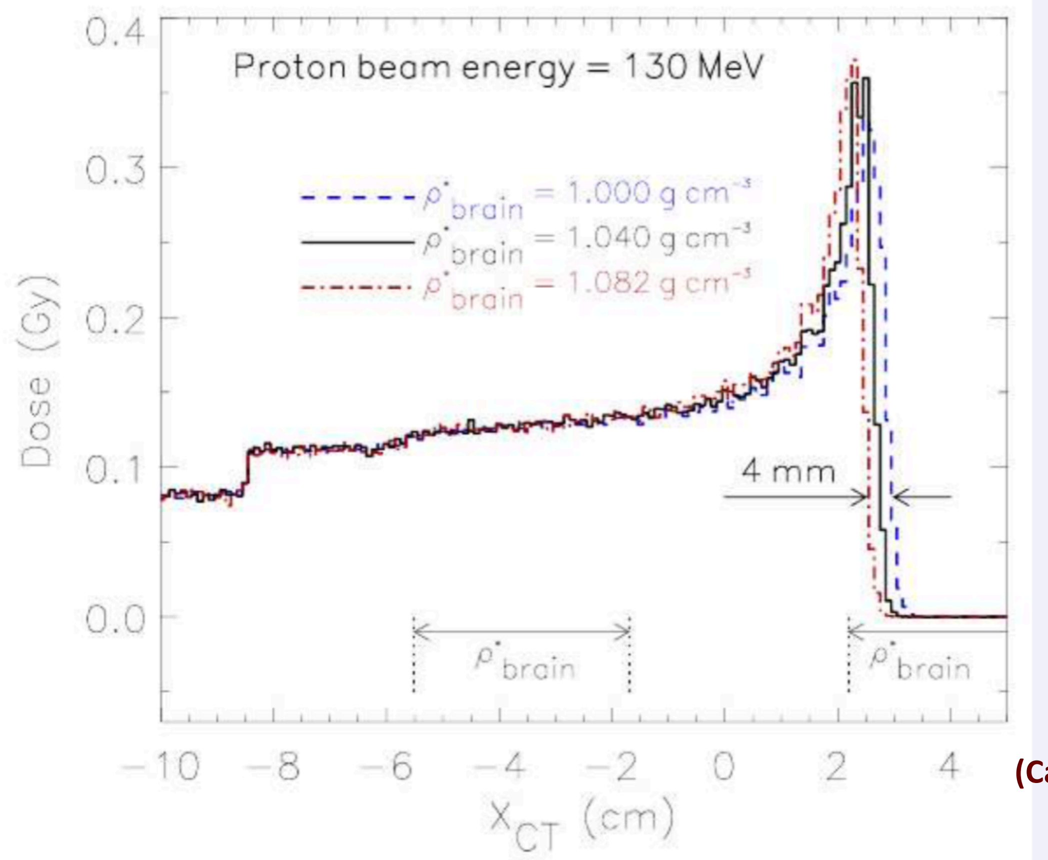
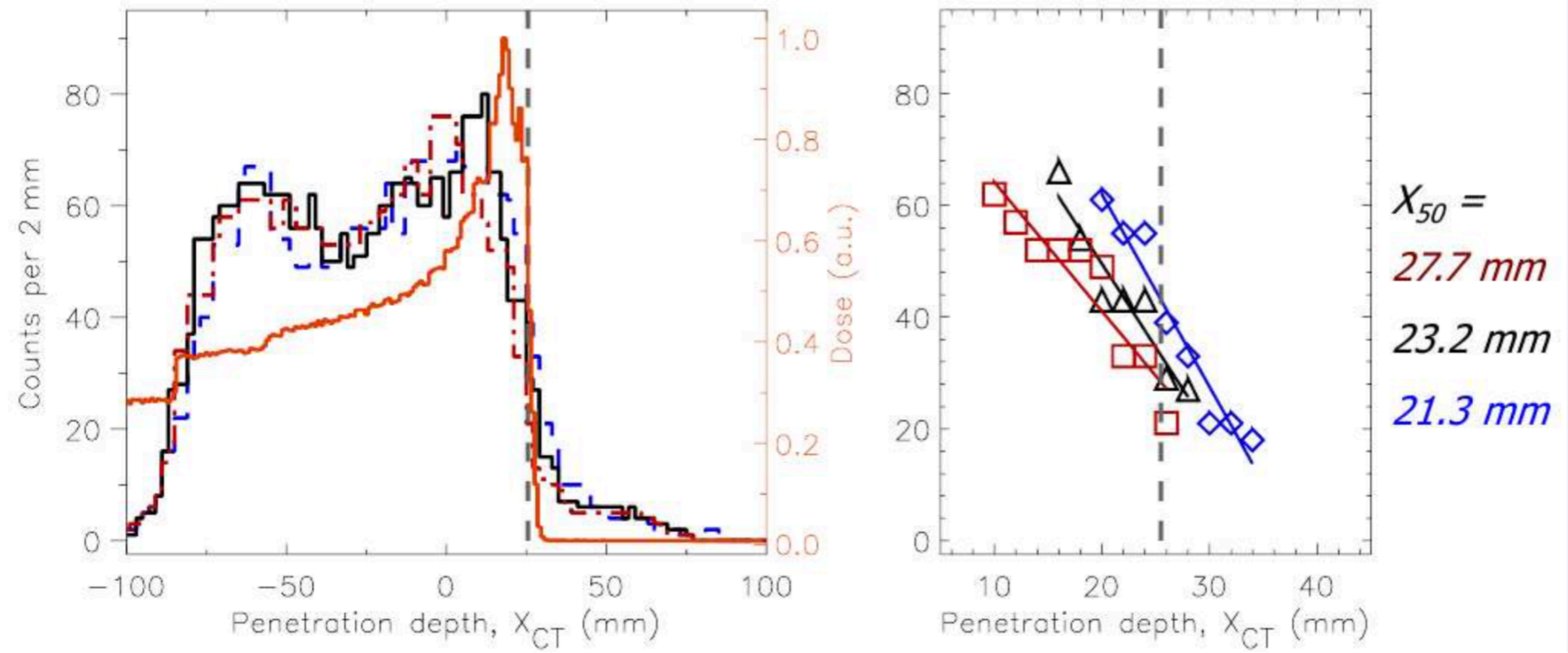


(Cambraia Lopes PhD 2017)

3. Orthogonal prompt-gamma imaging in proton RT

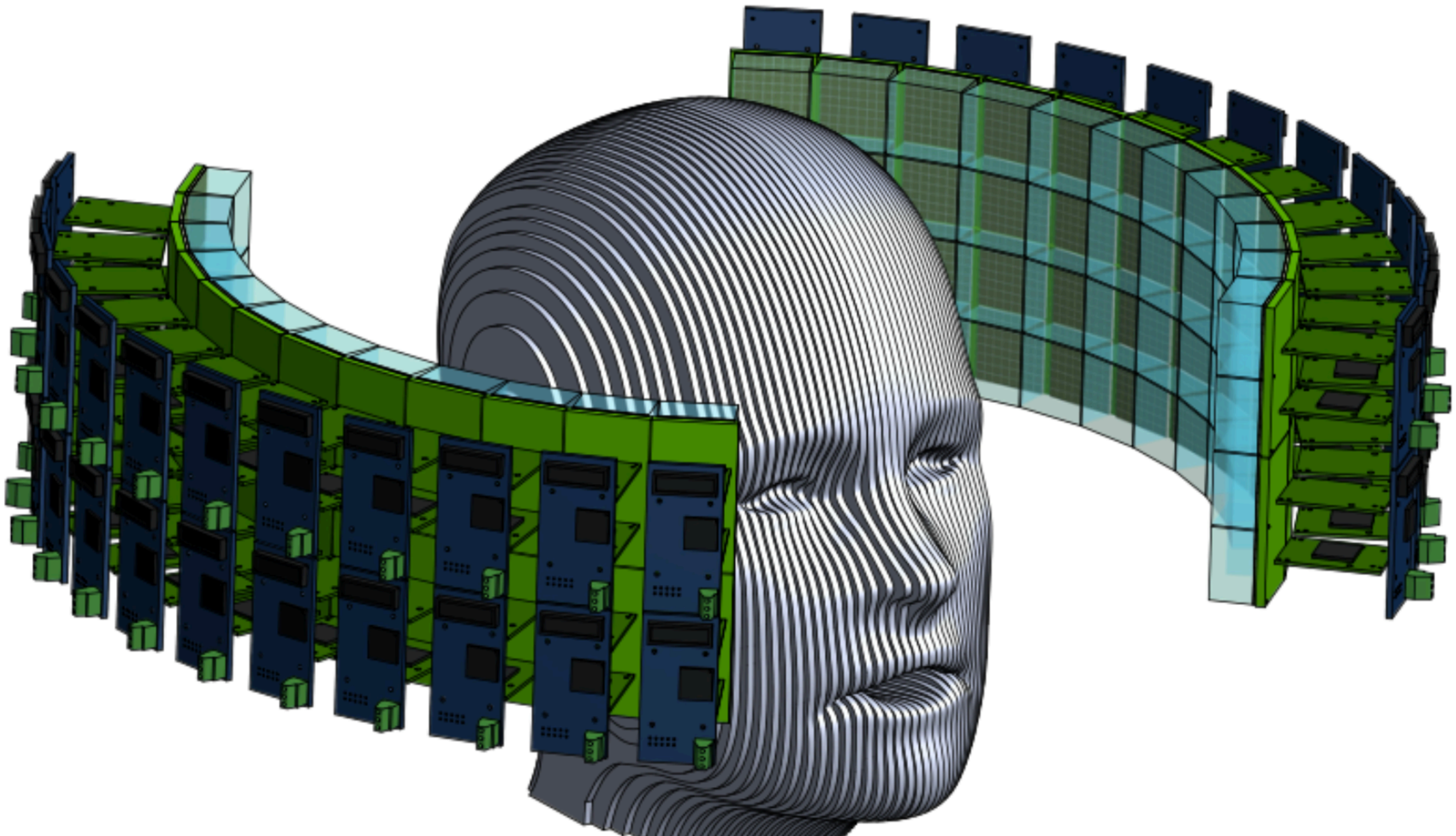
3.1 Change of brain density due to fractionated RT

- Conjecture: brain tissue hypo/hyperdense
- Monte Carlo results with proposed detector (Geant4):



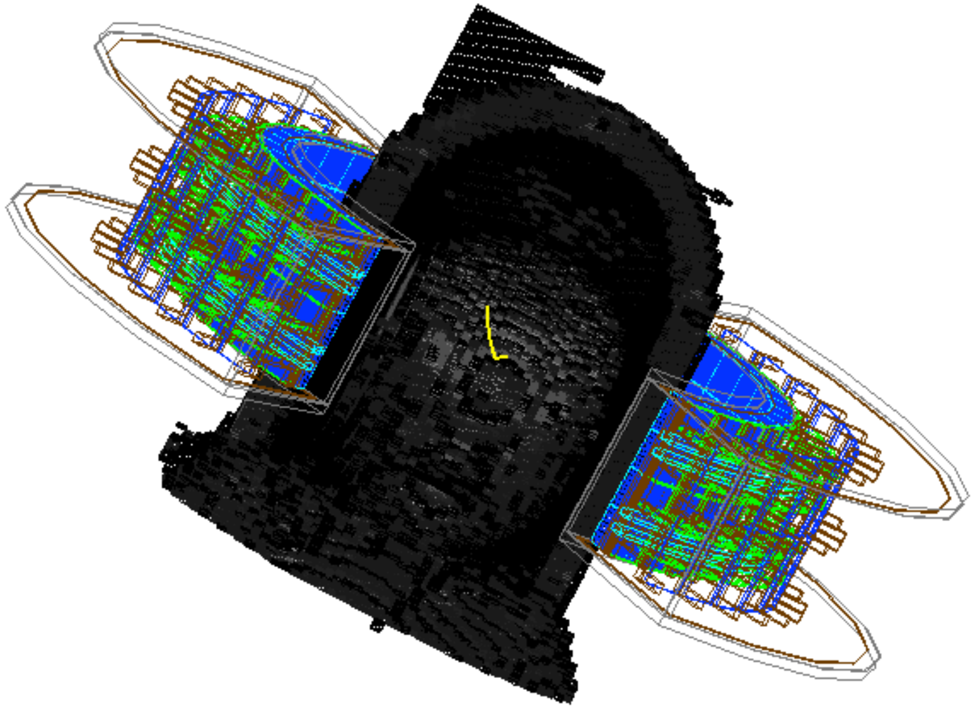
(Cambraia Lopes PhD 2017)

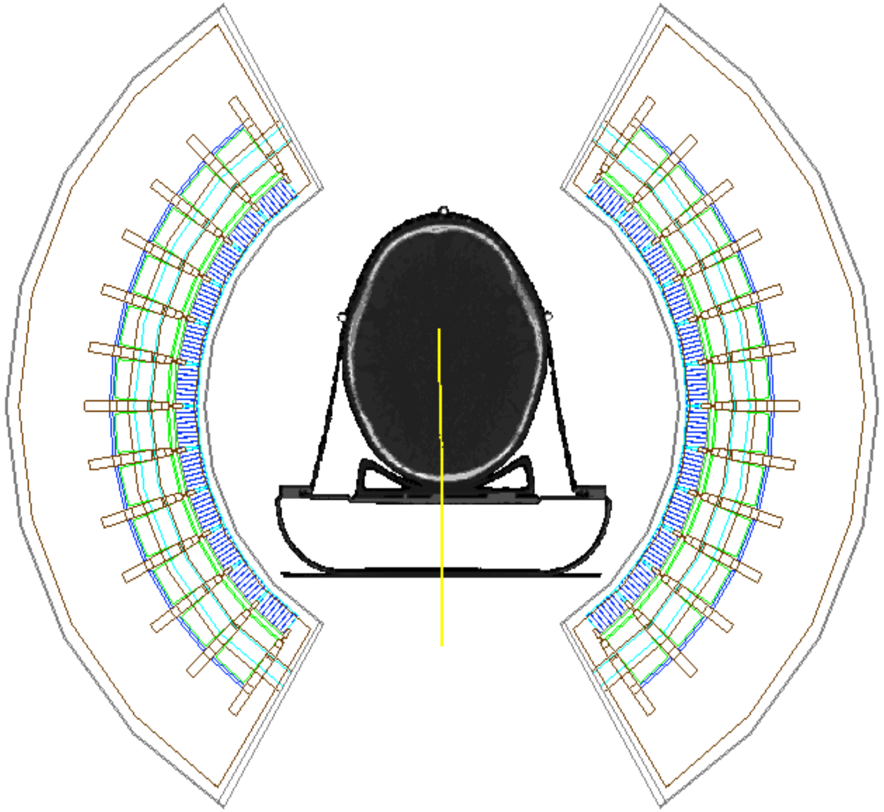
4. In-beam TOF-PET for proton RT



4. In-beam TOF-PET for proton RT

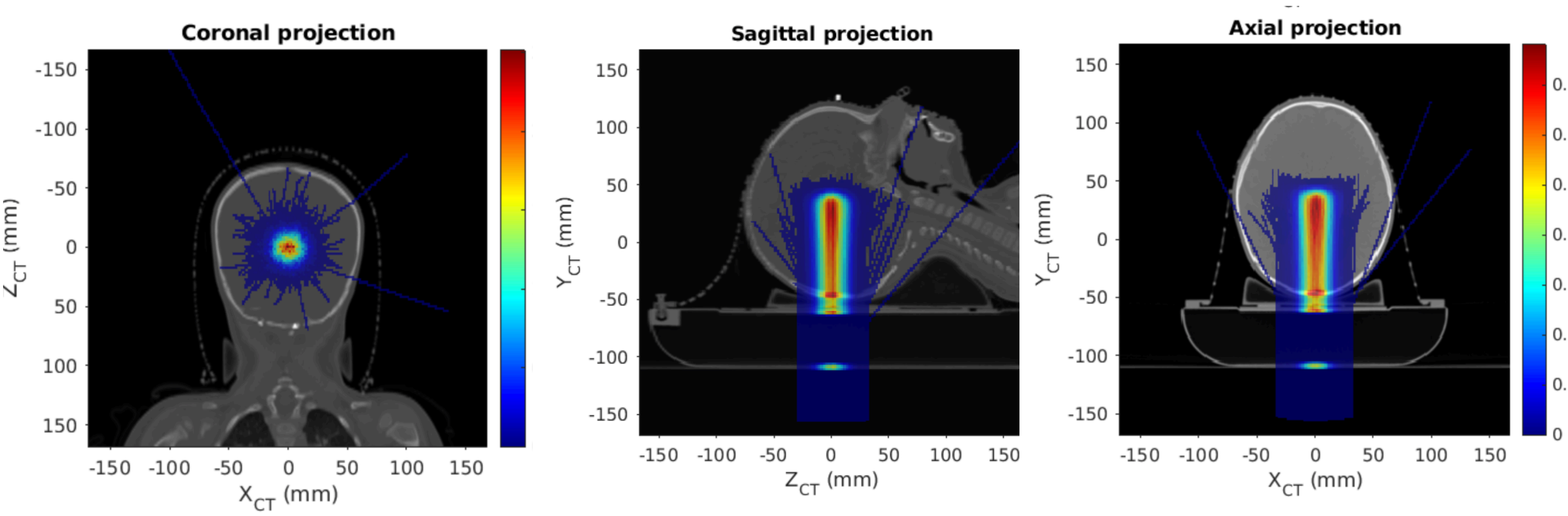
A full simulation with an arbitrary single beamlet





Starting position: (0, -155, 0)
Direction: Y (gantry angle of 180 degrees)
Energy: 131 MeV
Beamlet spread size: 8.42 mm sigma
Beamlet duration: 4 ms

4. In-beam TOF-PET for proton RT



Thank you for your attention

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