Monitoring proton therapy treatments with in-beam positron emission tomography or with a multislat prompt-gamma imaging camera: simulation results

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IGFAE workshop on technologies and applied research at the future Galician proton-therapy facility

Santiago de Compostela – May 9-10, 2023

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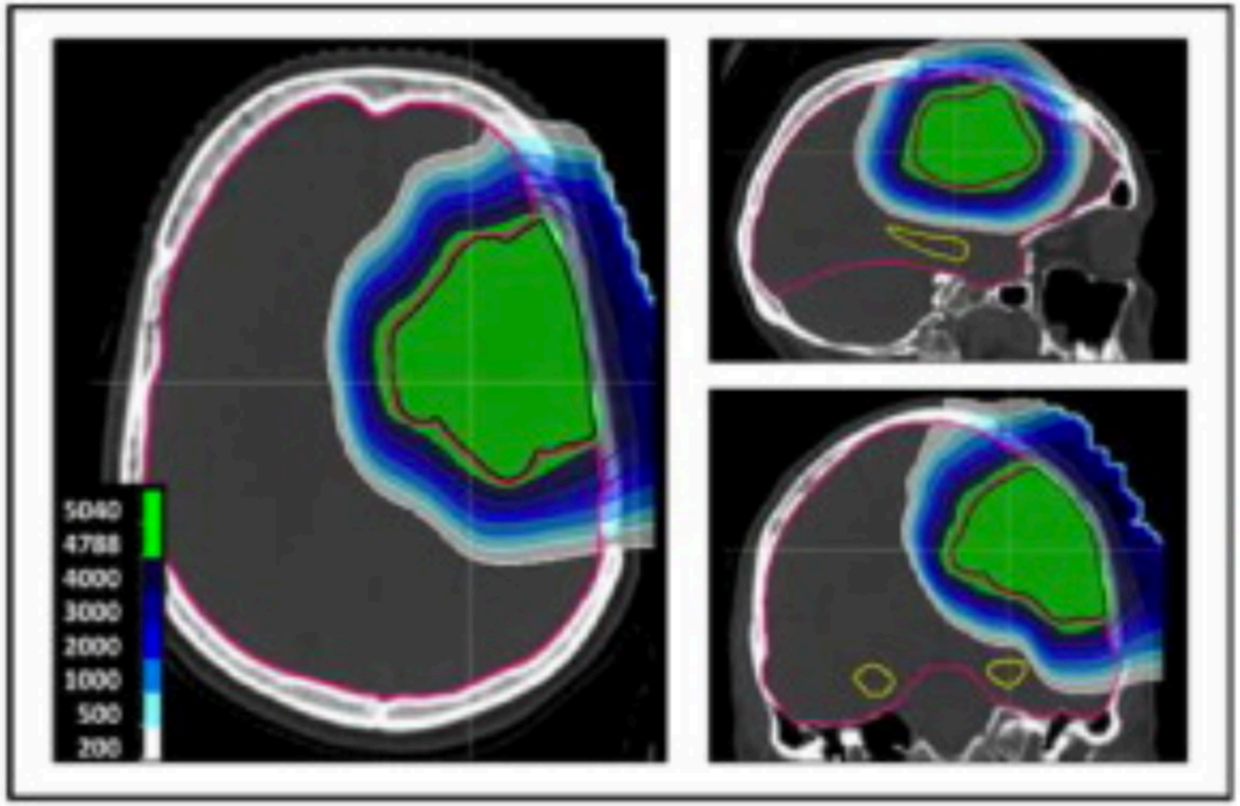
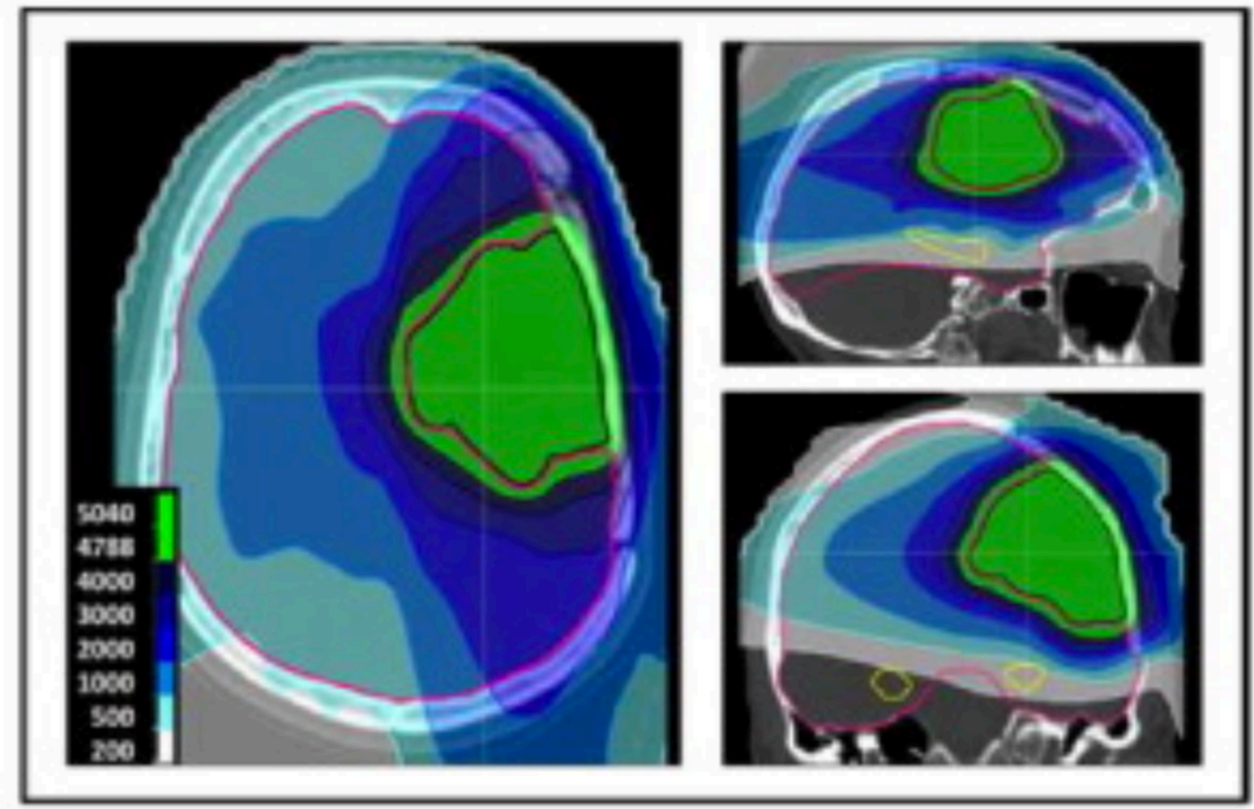
Some evidence of advantages of PT over state-of-the-art X-rays

Low-grade glioma, female, 38 y.o.: **dose reduction accepted as being clinically relevant**

Two-field intensity modulated PT



Volumetric intensity modulated arc therapy

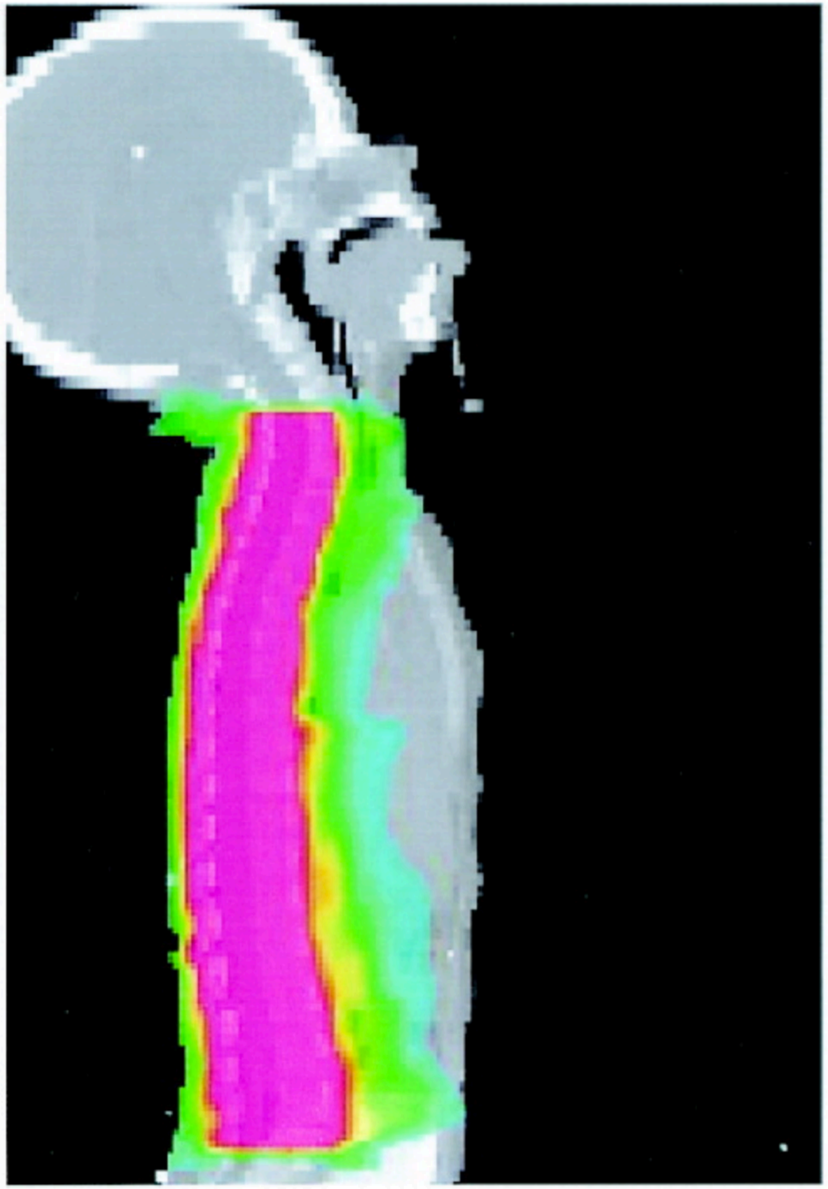


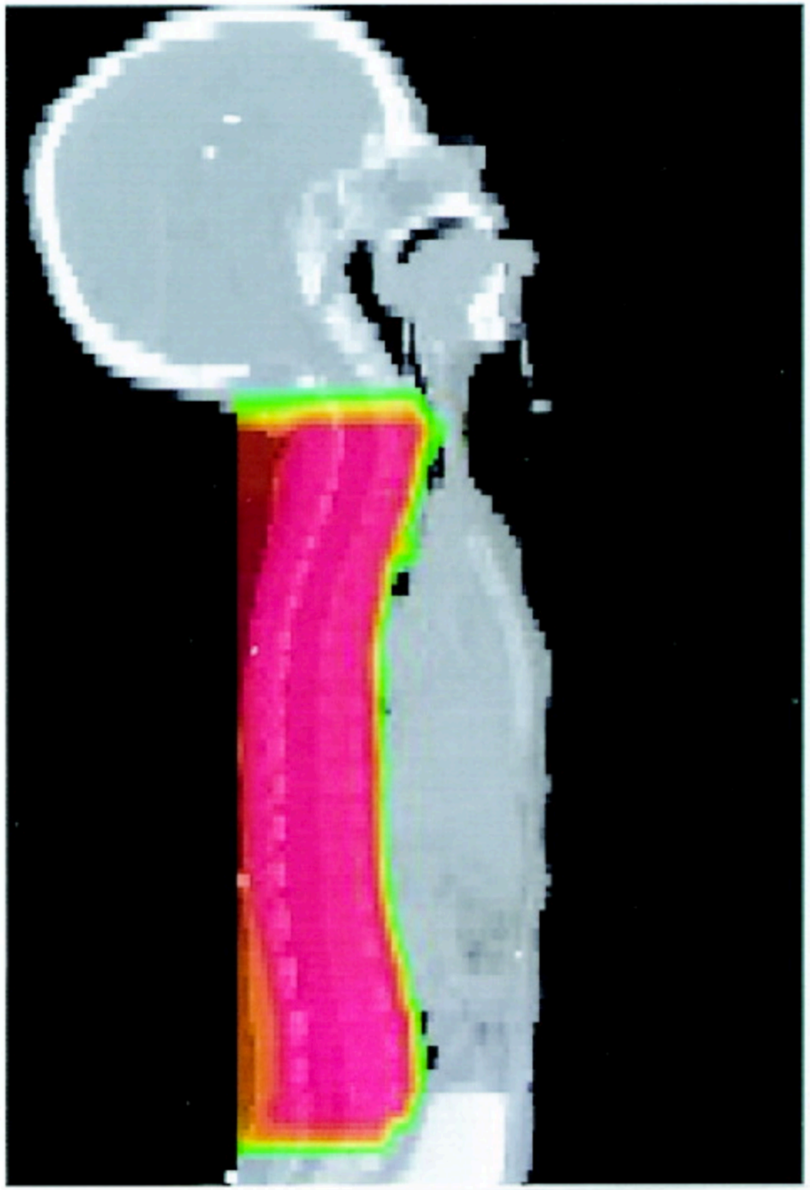
van der Weide et al., Radiother Oncol (2020)

Some evidence of advantages of PT over state-of-the-art X-ray therapy

Pediatric medulloblastoma: **Dose to 50% of the heart volume was reduced from 29.5% for IMRT to 0.5% for protons**

IMRT – intensity modulated radiation therapy





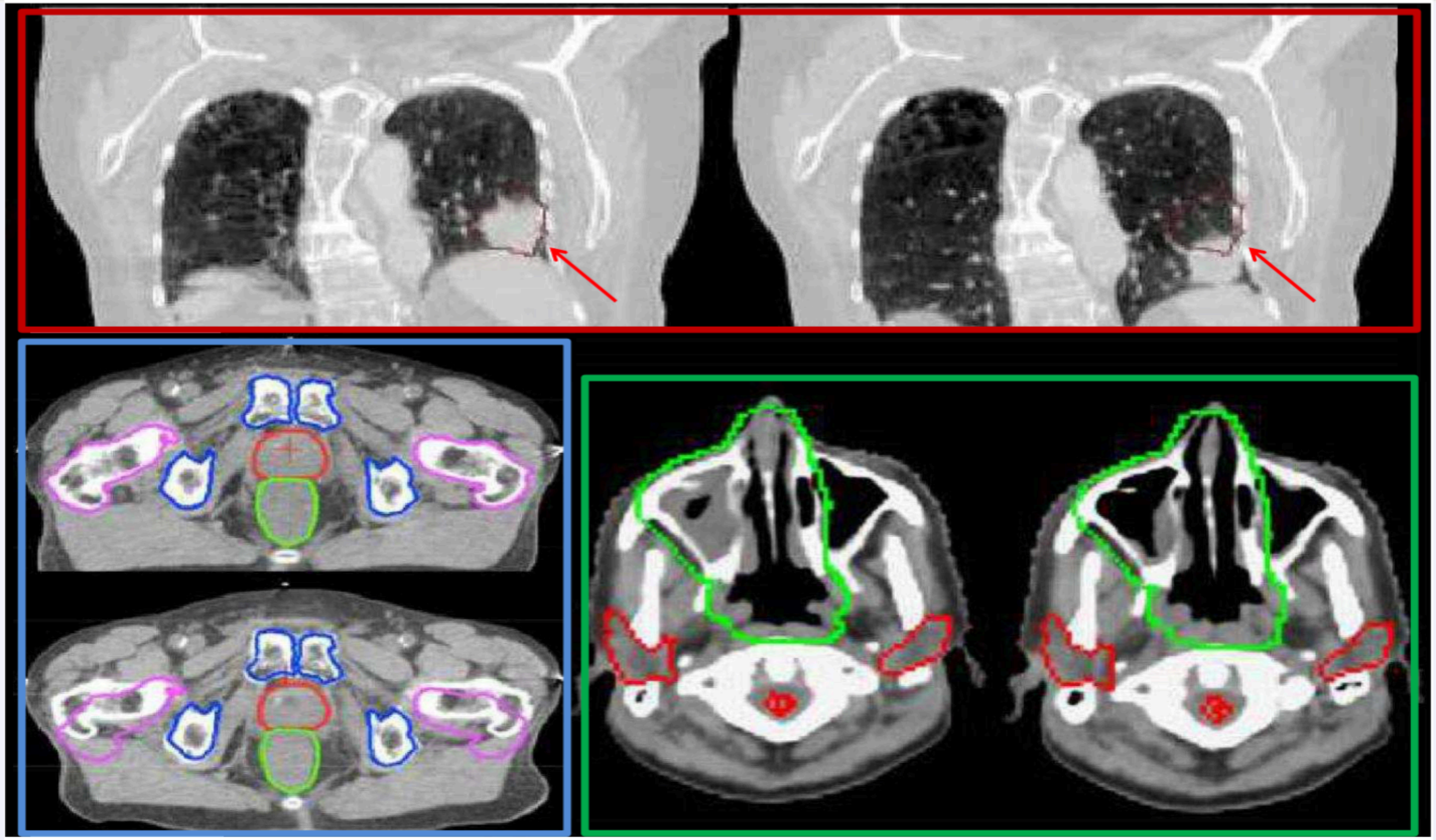
PT

Clair et al., IJROBP (2004)

Rationale for imaging in hadrontherapy

Morphologic changes / patient positioning:

Engelsman and Bert 2011
Lüchtenborg PhD 2012

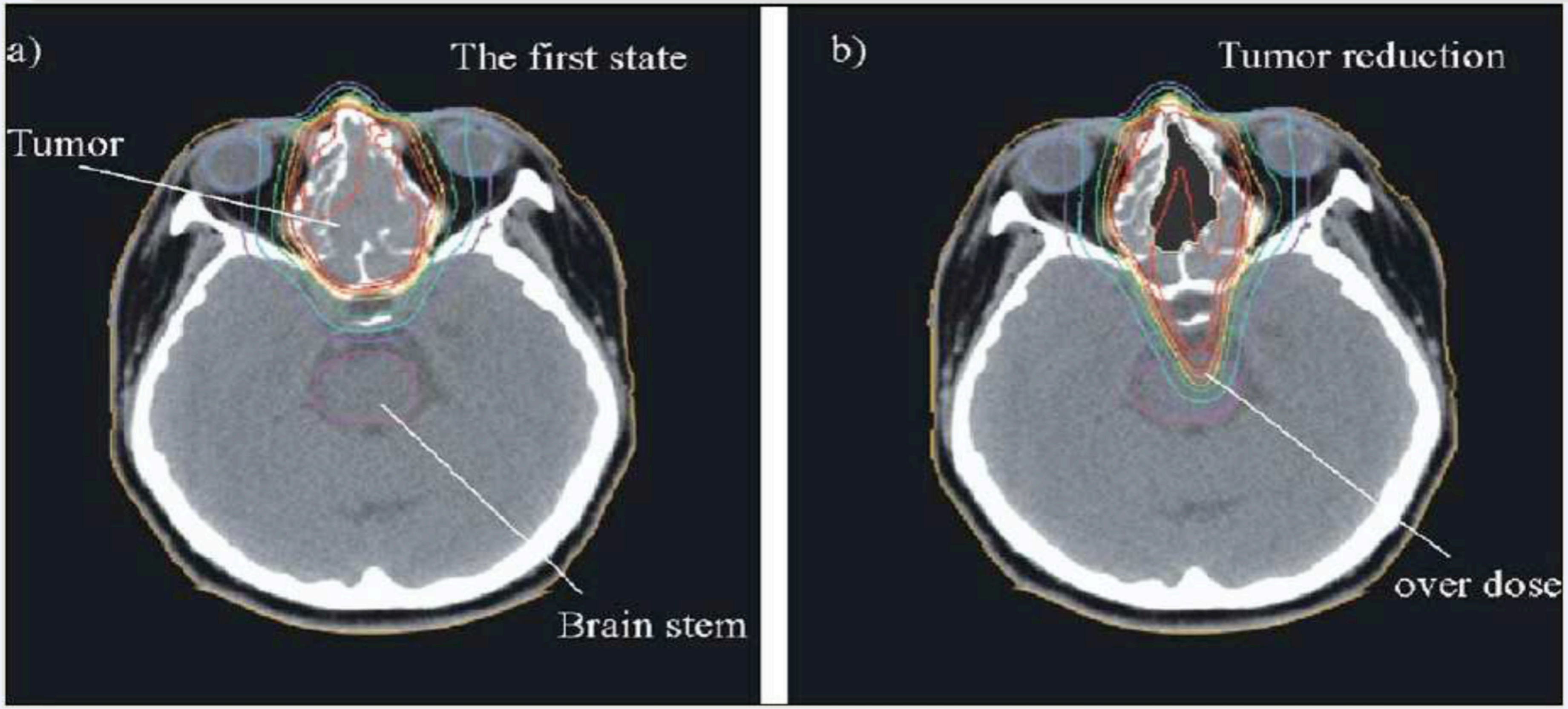


Very high conformality provides high-precision and highly accurate RT, but need for RT imaging also increases (e.g. next slide).

Rationale for imaging in hadrontherapy

Morphologic changes / patient positioning:

- Modification of target density (inter-fractional tumor regression)



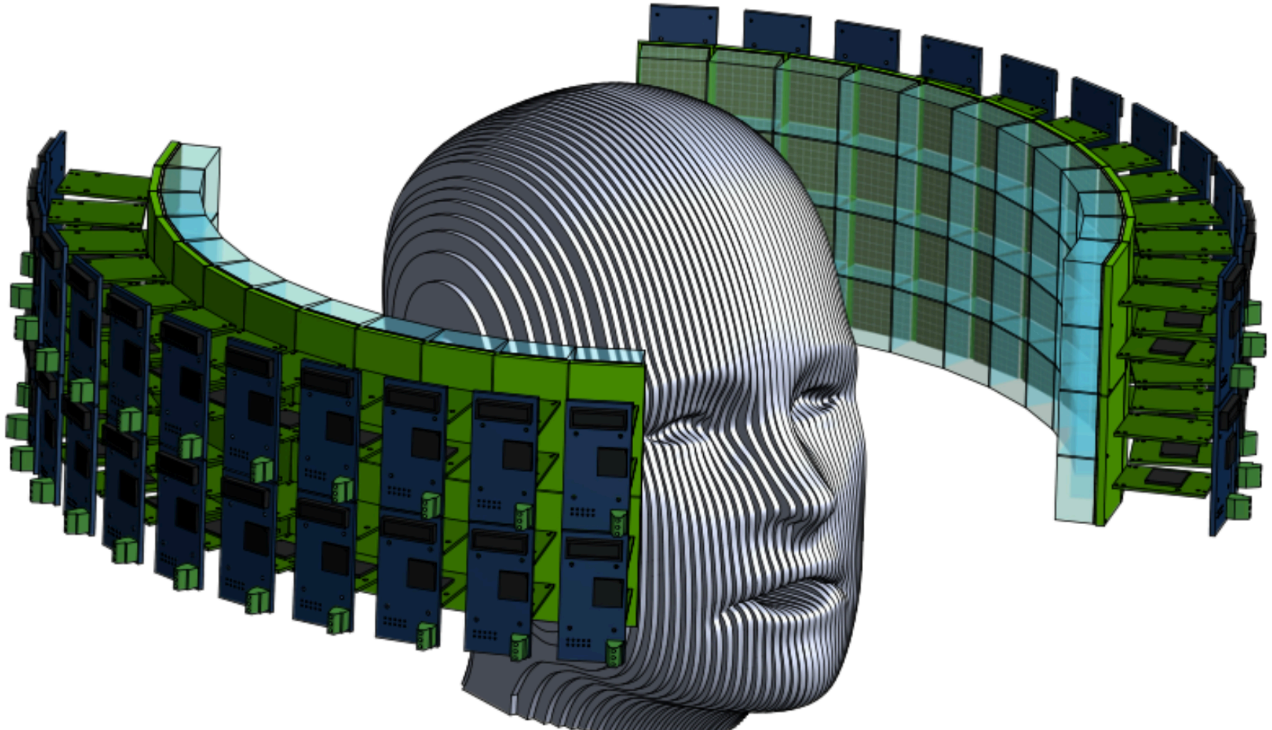
Nishio et al Med Phys 2006

In-beam TOF-PET: monitoring proton therapy

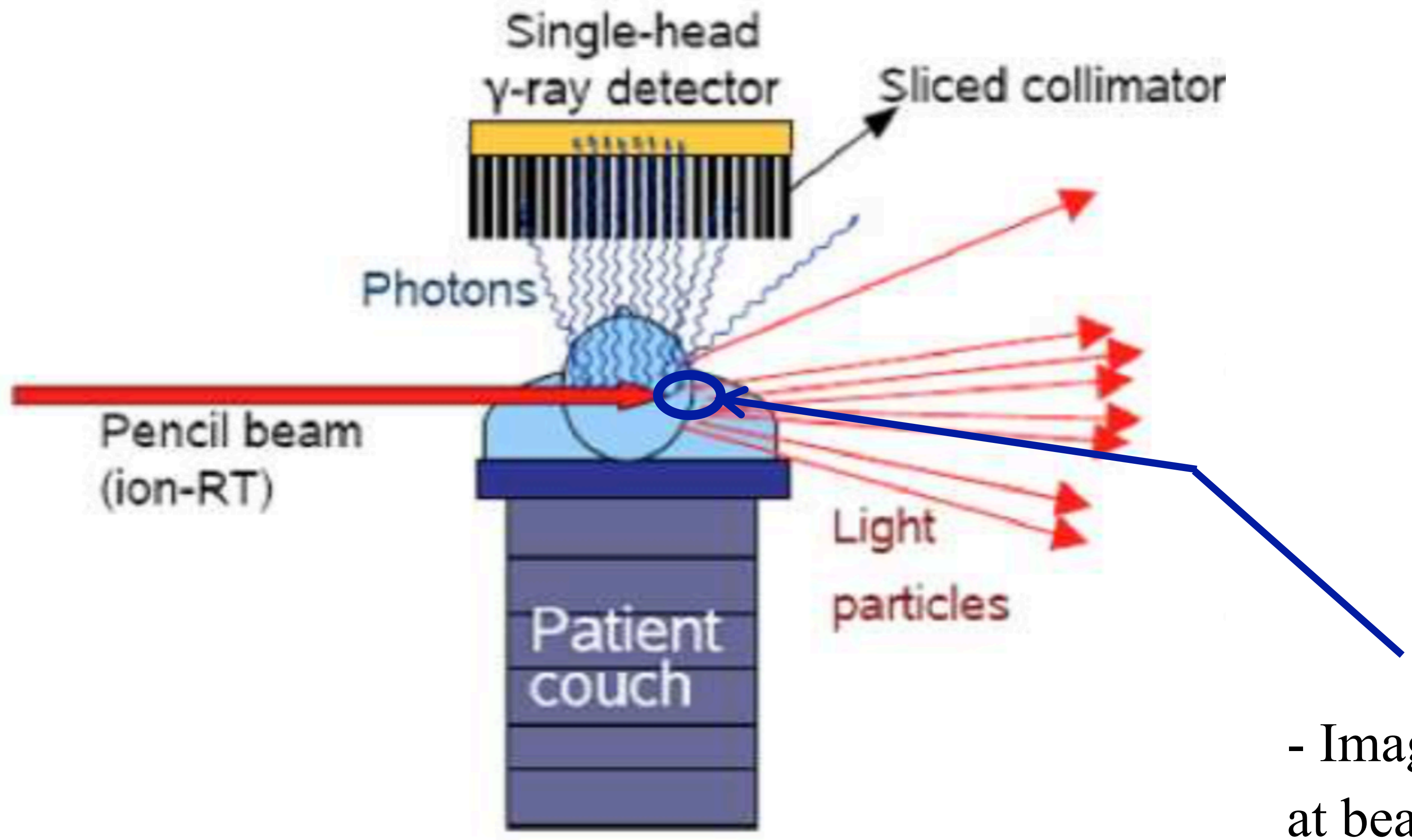
- Consortium between PETsys Electronics (Lisbon), LIP (Lisbon & Coimbra), ICNAS-UC, IST, Un. Texas at Austin, USA, MDACC (Houston), USA

TOF-PET for Proton Therapy (TPPT) – In-beam Time-of-Flight (TOF) Positron Emission Tomography (PET) for proton radiation therapy

Coincidence time resolution of 200 ps FWHM (corresponds to Gaussian with 3 cm FWHM)



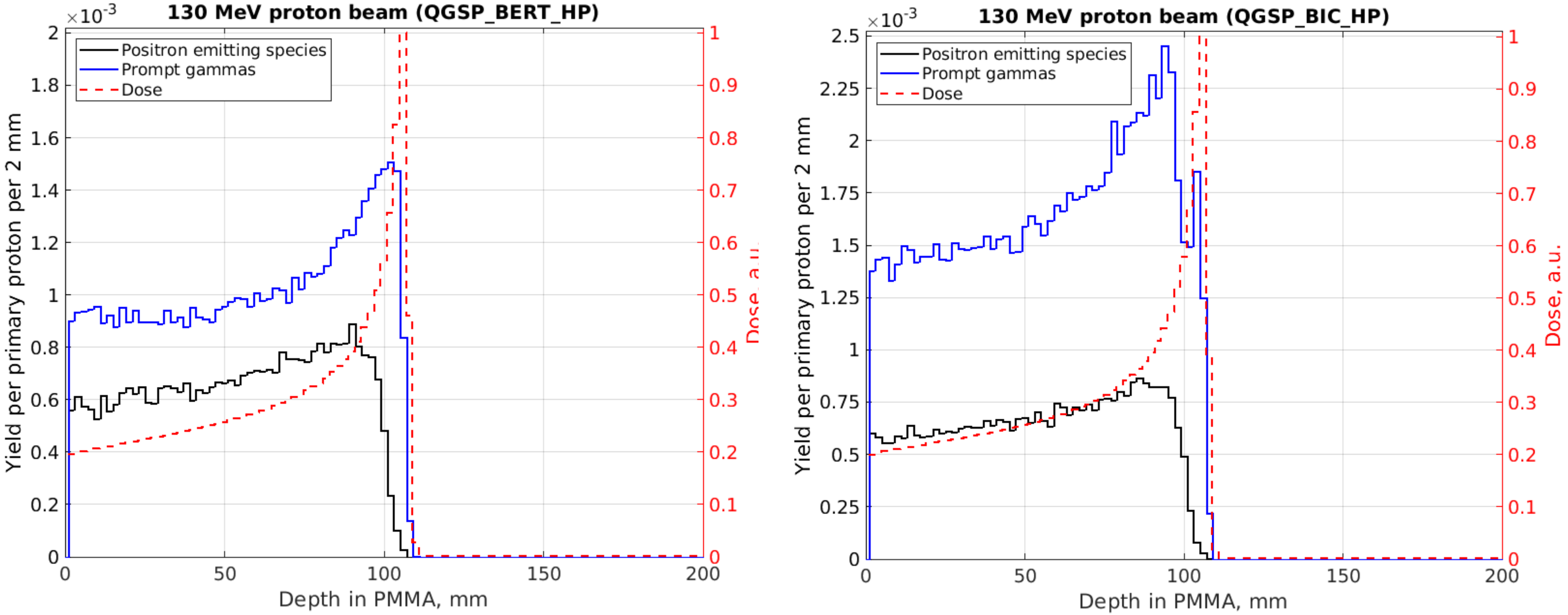
Prompt-gamma imaging: the concept of the multislat O-PGI



- Image with prompt gammas “stops” at beam range
- Neutron-induced gamma rays contaminate prompt-gamma image. Solution: TOF-discrimination

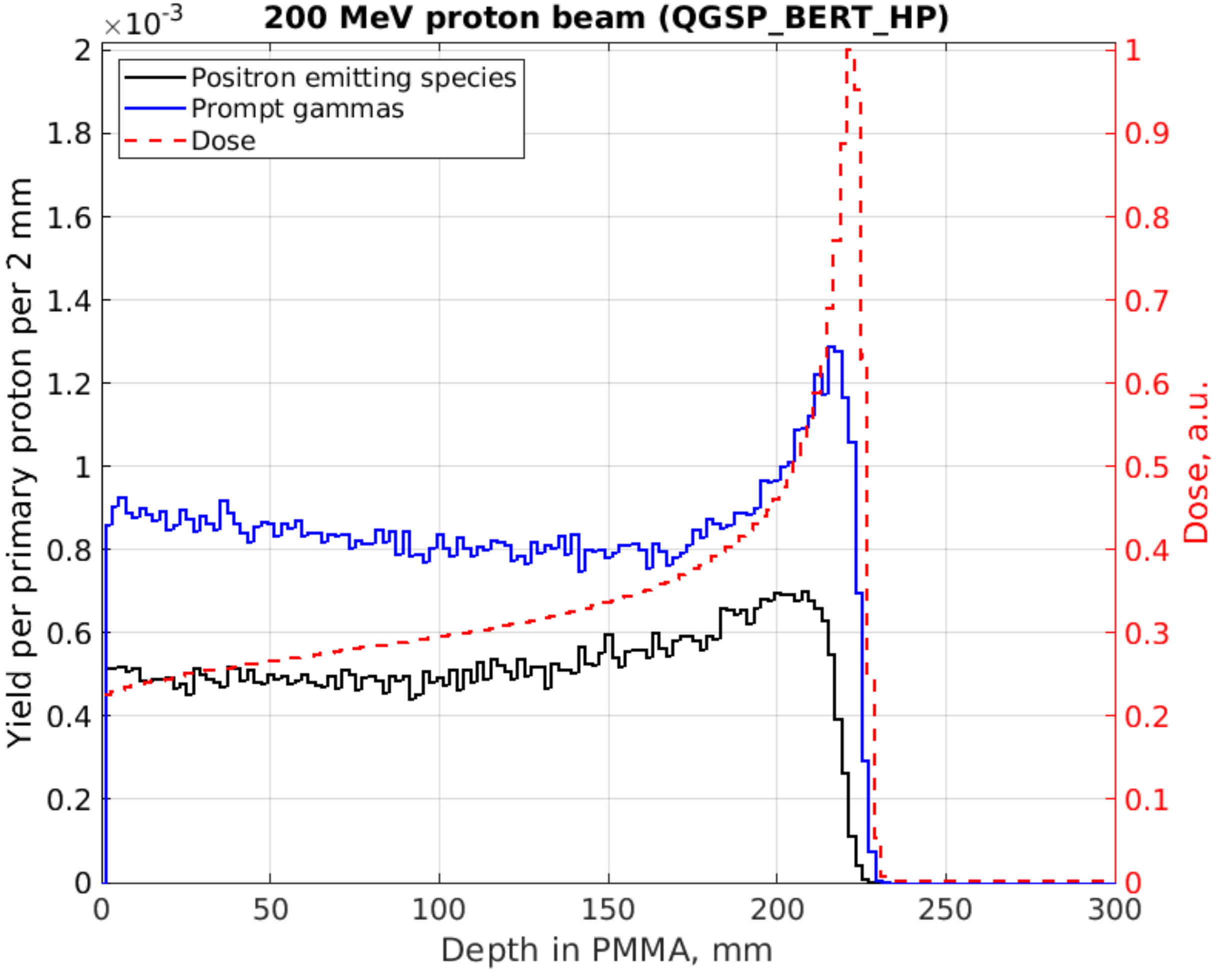
Provides real-time images of selected region without rotation of beam source.

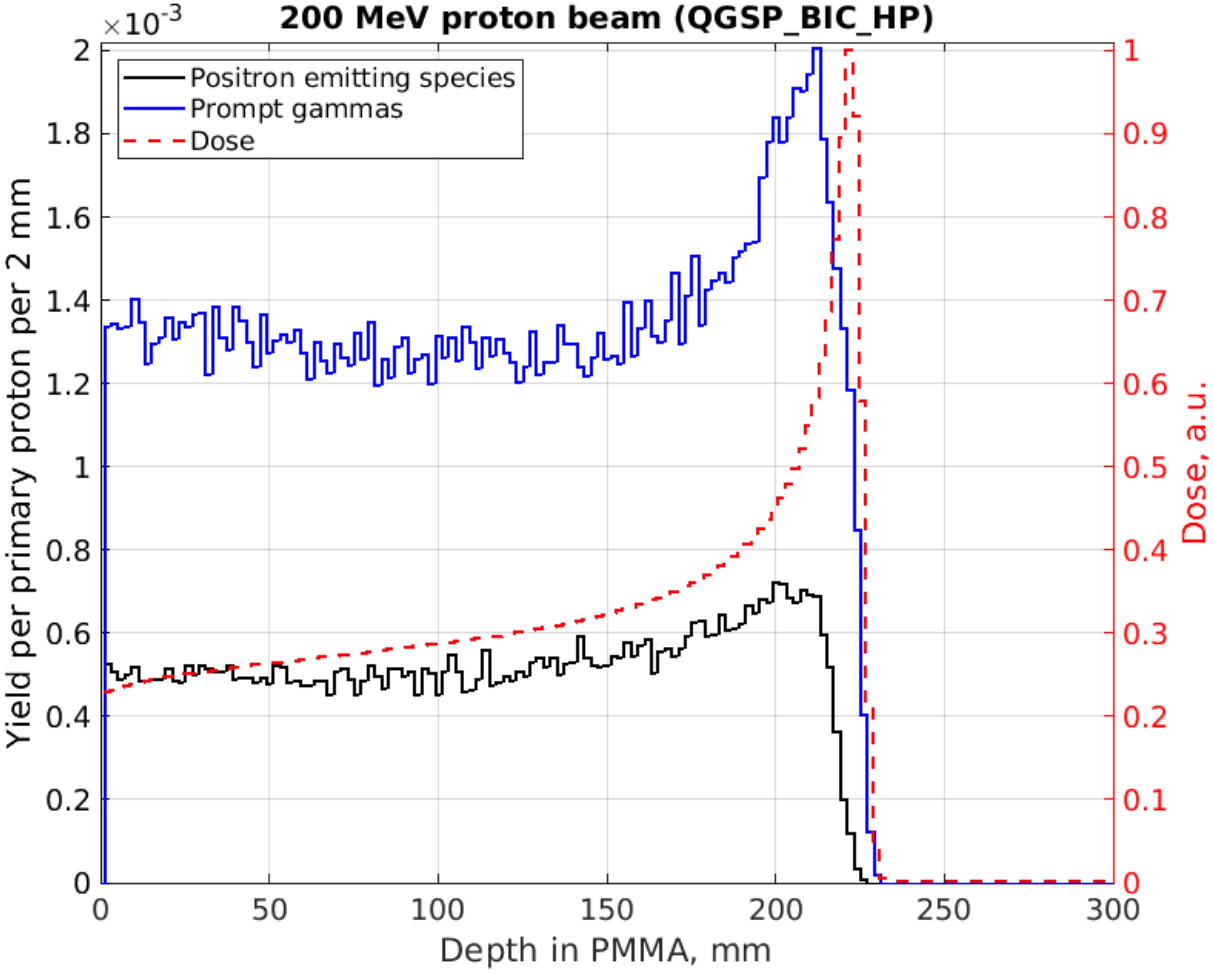
Simulated positron emitting species (β^+) vs prompt-gamma emission



No detection system considered

Simulated positron emitting species (β⁺) vs prompt-gamma emission

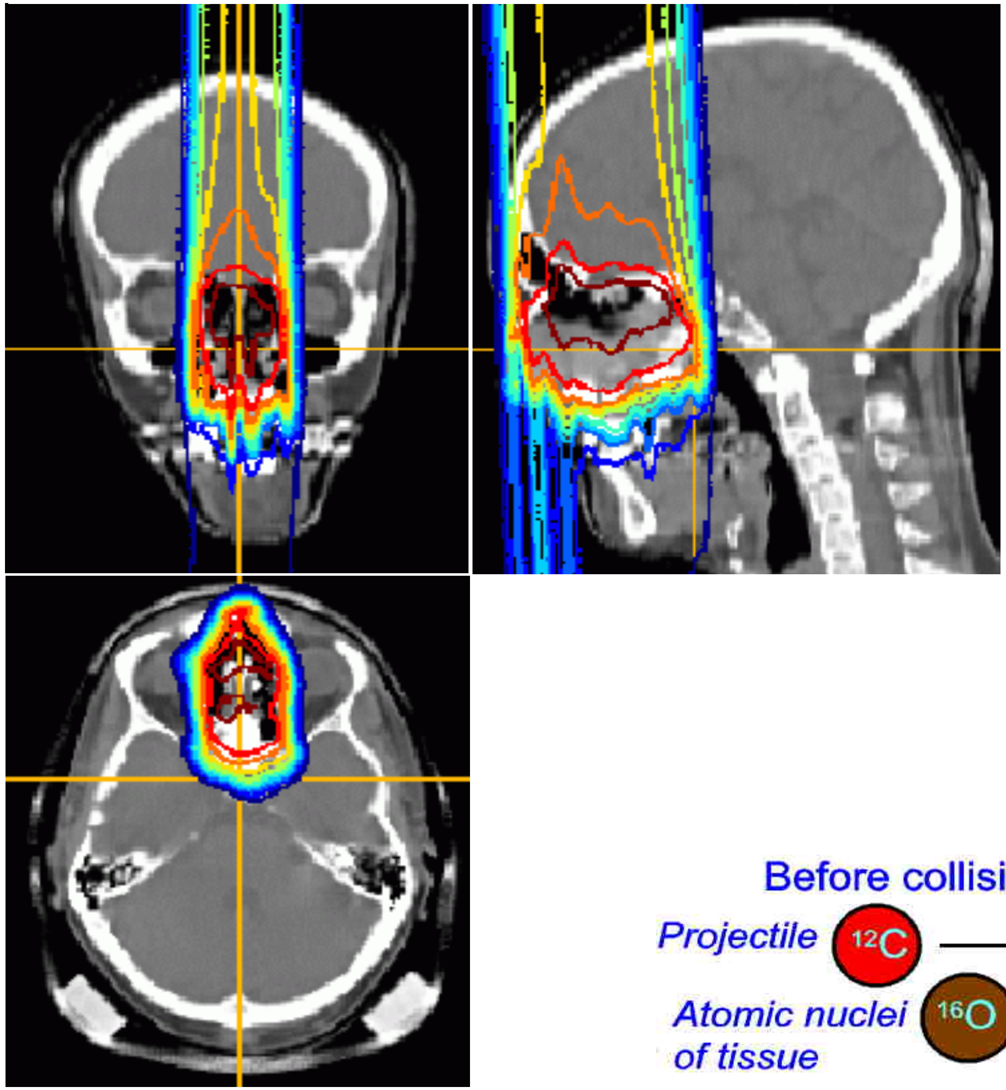


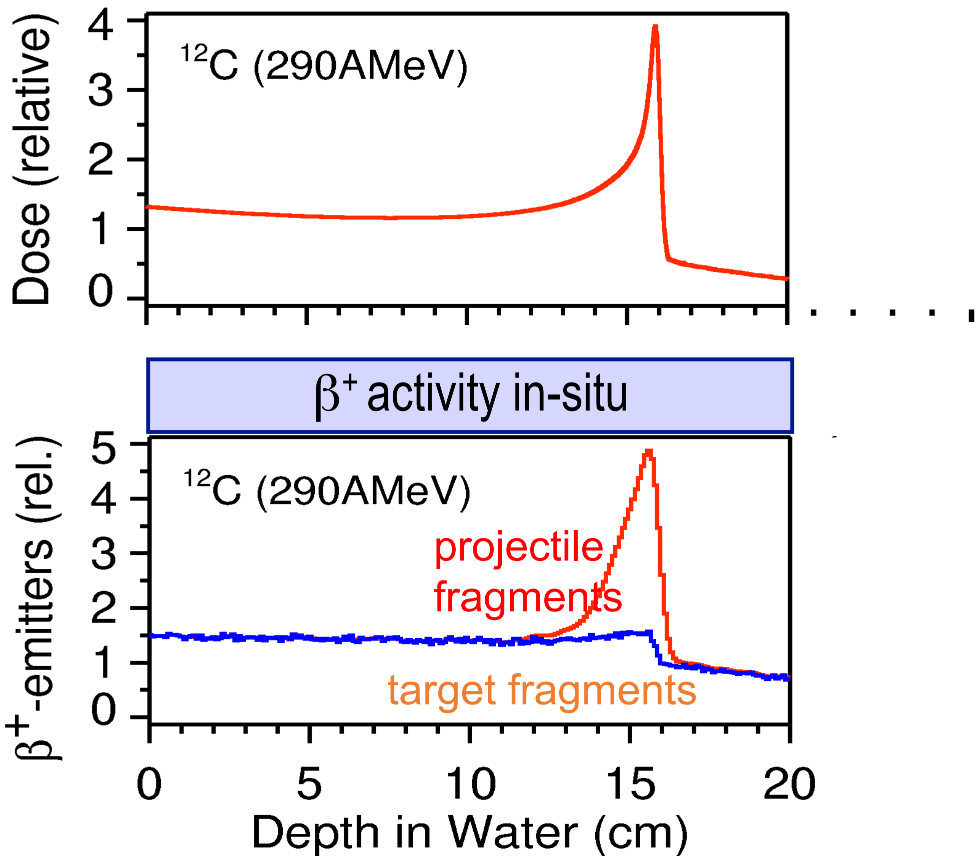


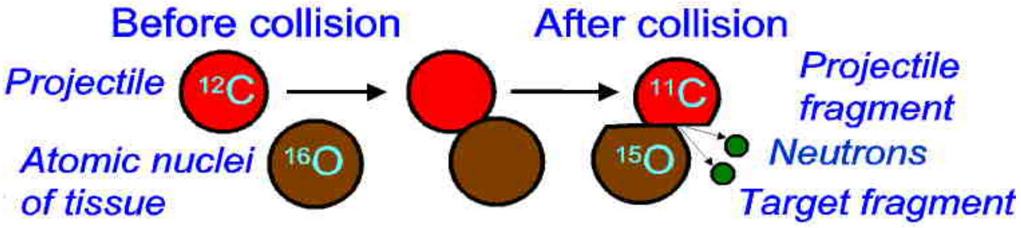
No detection system considered

In-Beam Positron Emission Tomography

Very high tumor conformity

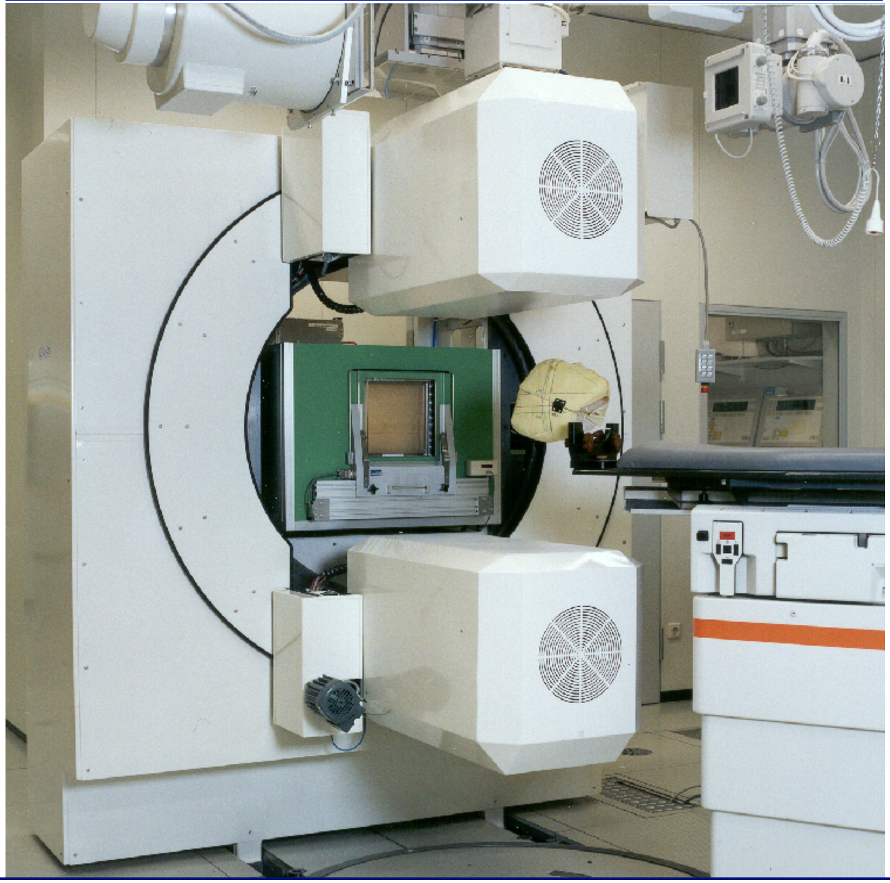






3. In-Beam Positron Emission Tomography

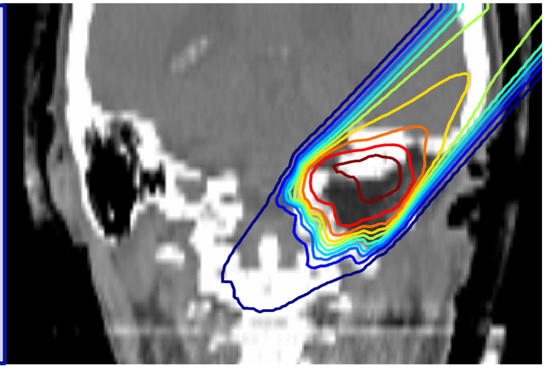
Former treatment site at GSI



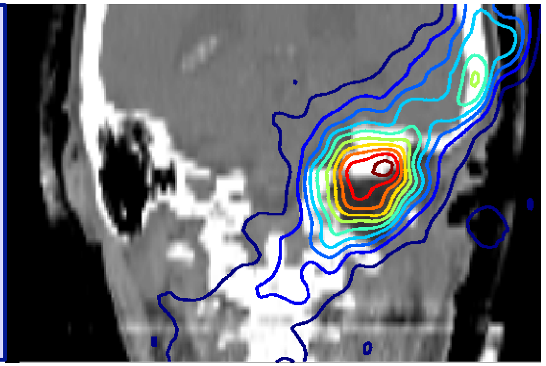
► Monitor irradiation:

- Particle range
- Portal position
- Dose deviations

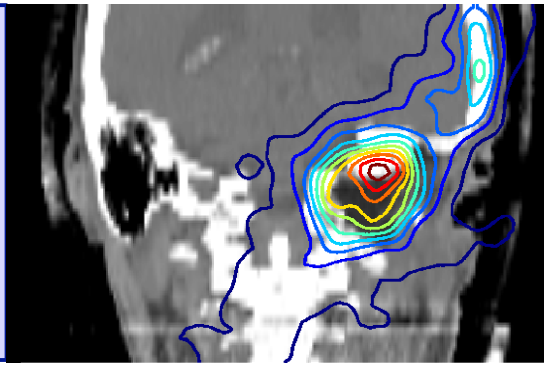
Dose



Expected β^+ activity



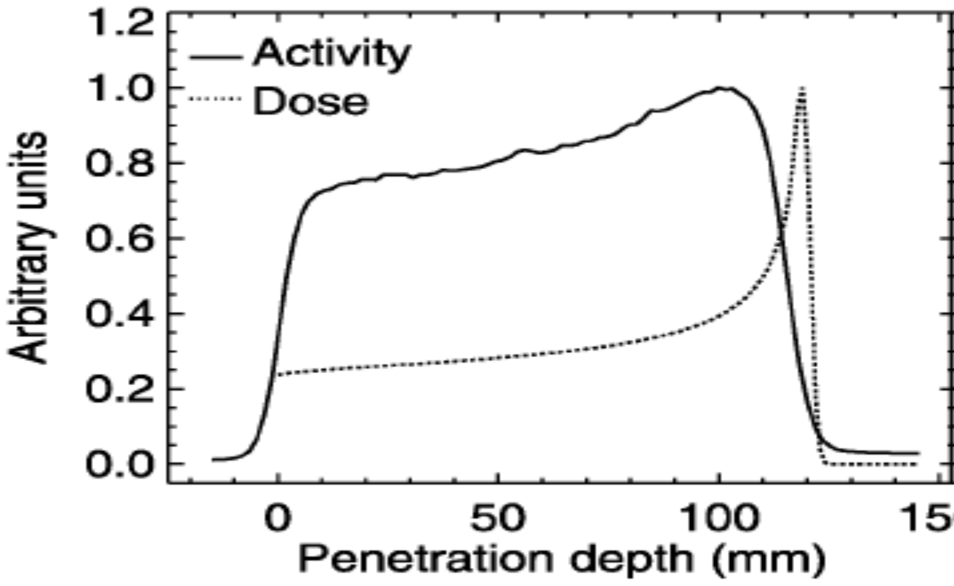
Measured β^+ activity



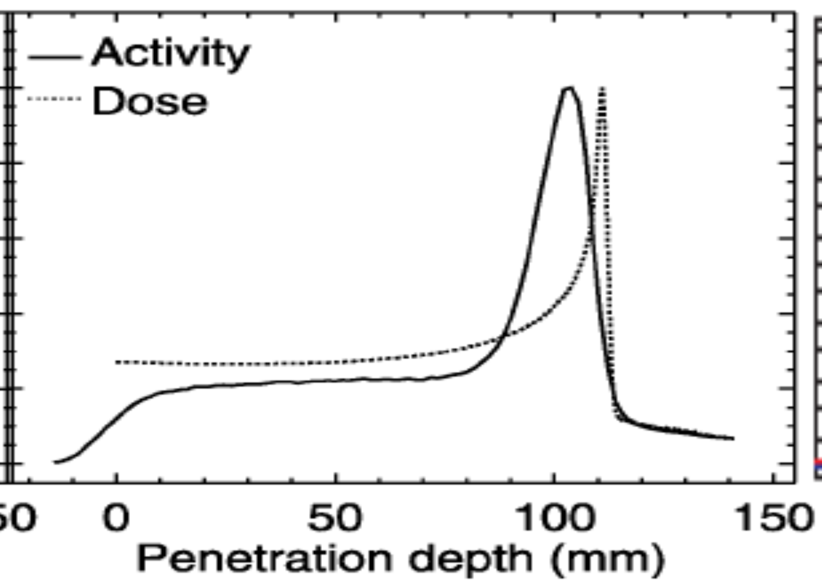
In-beam PET: valuable tool for the quality assurance of ion radiation therapy

In-beam PET: Monitoring other species

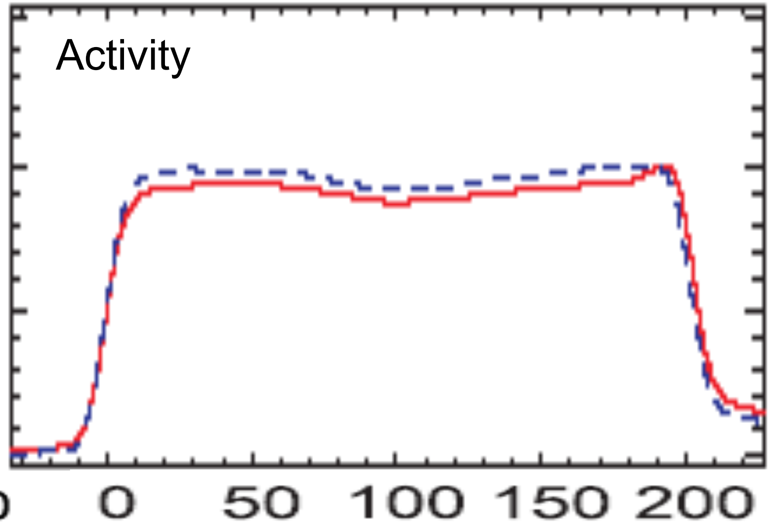
- Protons (p^+):



- Carbons (C^{6+}):



- Helium-3 (He^{2+}):



- Proton and helium: only target activation

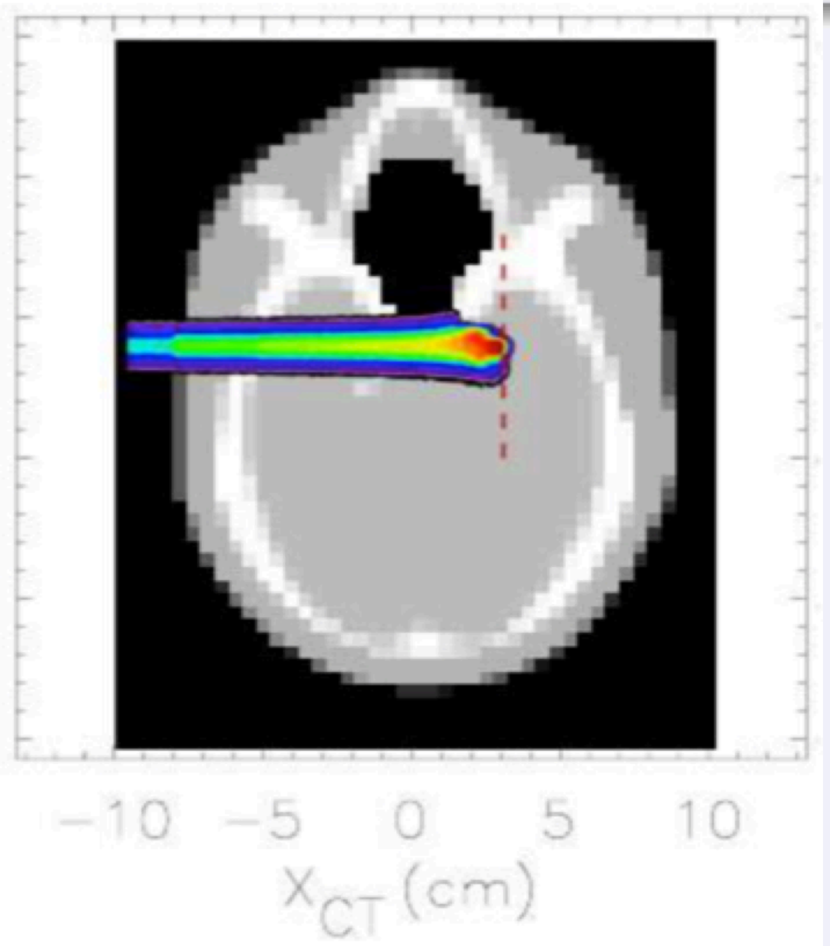
Protons: Parodi et al., IEEE Trans Nucl Sci 52 (2005)

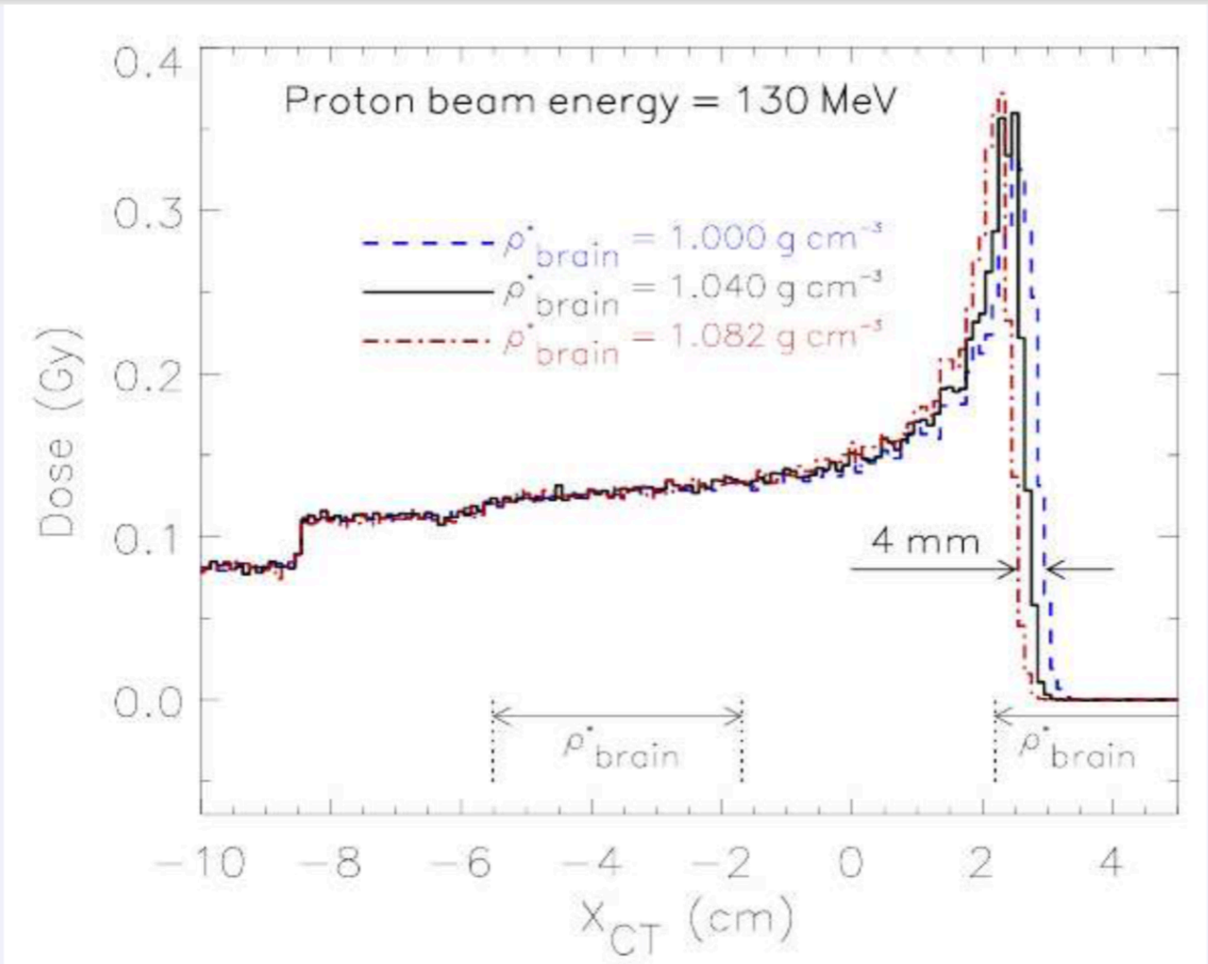
Helium: Fiedler et al., IEEE Trans Nucl Sci 53 (2006)

Prompt-gamma imaging via multislat O-PGI: feasibility study

Change of brain density due to fractionated RT

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



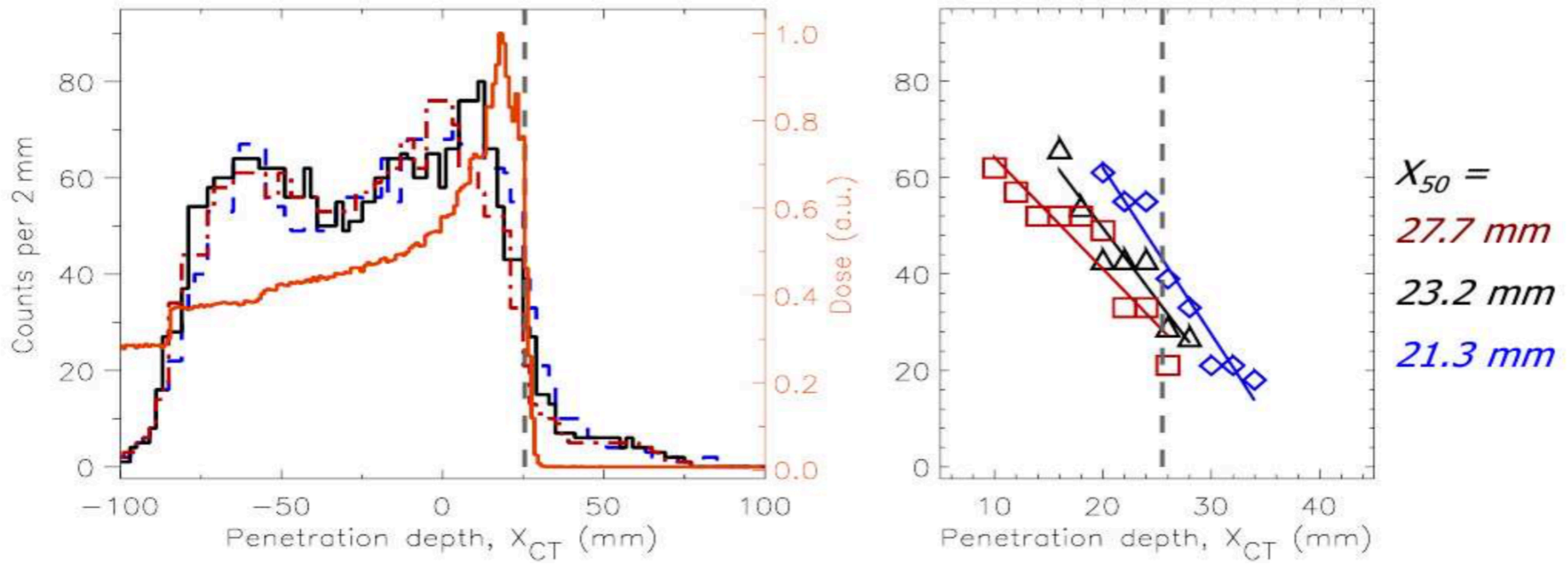


(Cambraia Lopes et al Physica Medica 2018)

Prompt-gamma imaging via multislat O-PGI: feasibility study

Change of brain density due to fractionated RT

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



(Cambraia Lopes et al Physica Medica 2018)

Thank you for your attention

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