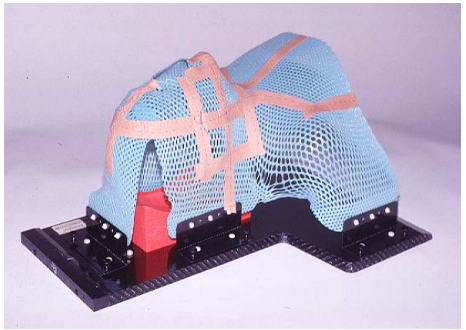
UNIVERSITE CATHOLIQUE DE LOUVAIN
Ecole Polytechnique de Louvain (EPL)
ICTEAM Institute
Communications and Remote Sensing Laboratory (TELE)

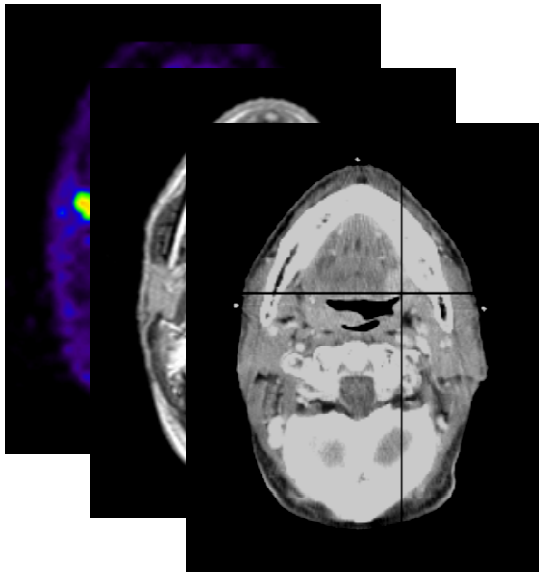
On the use of 4D imaging in cancer treatment

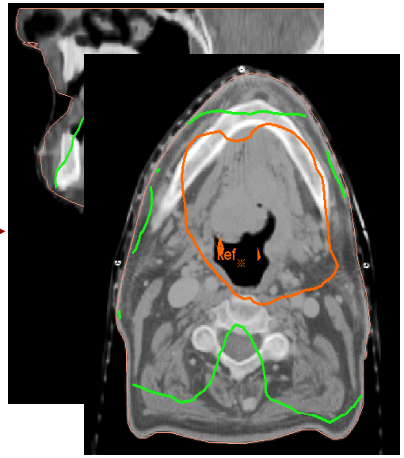
Guillaume Janssens

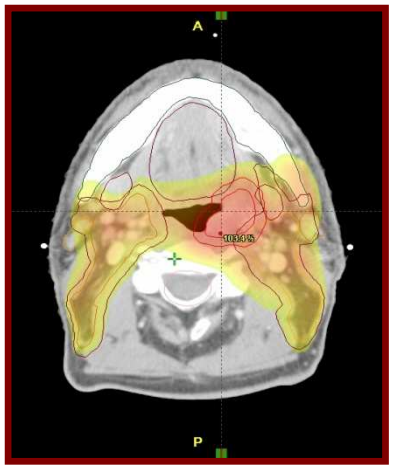
October 2011

Radiotherapy







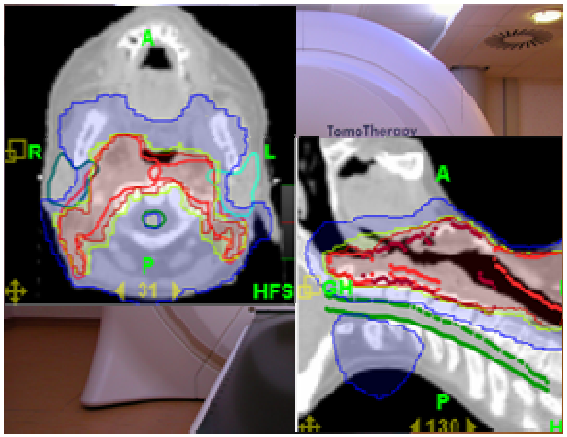


Radiotherapy planning is a balistic problem

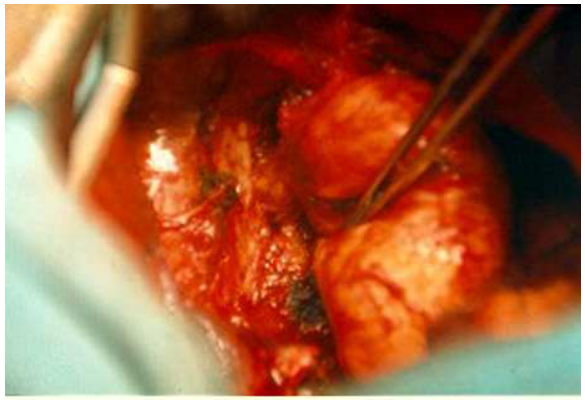
SURGERY

RADIOTHERAPY

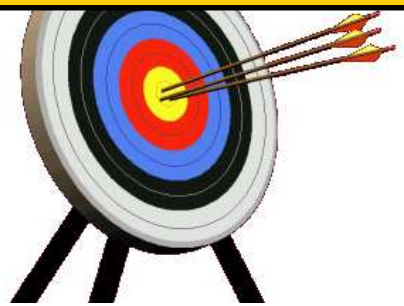
TOOLS



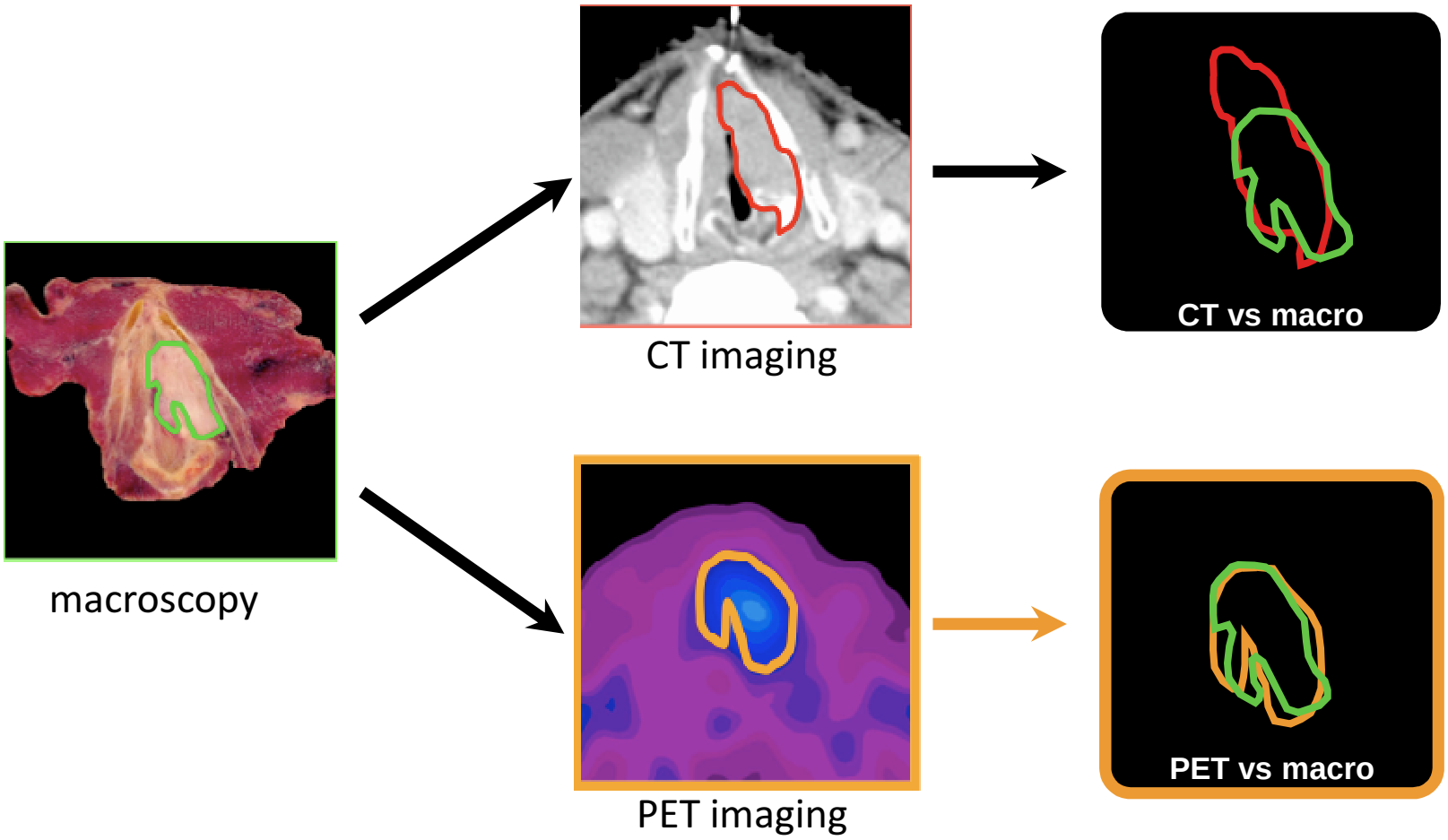
TARGET



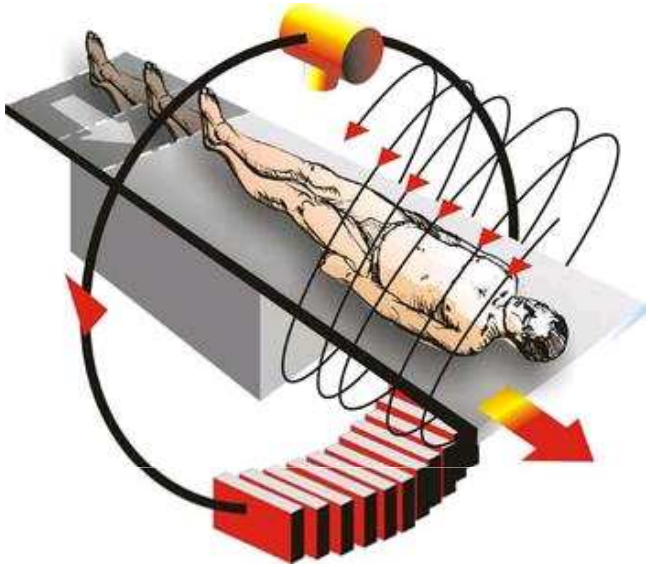
TARGET VOLUMES ???



Different image modalities emphasize different biological properties for defining target regions

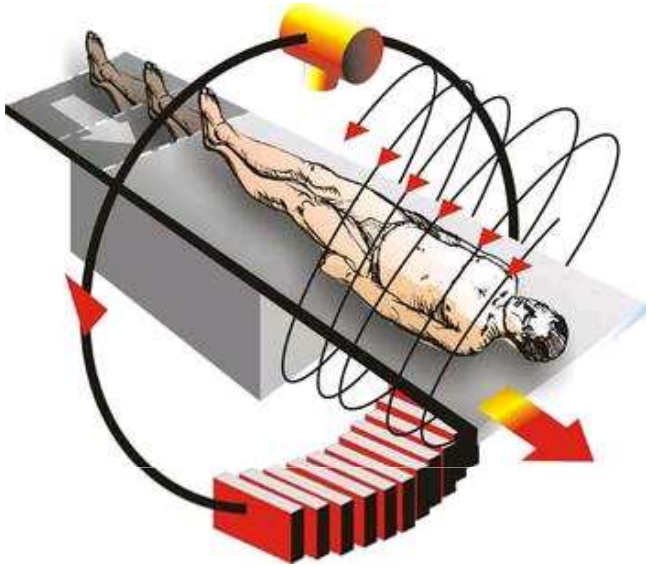


CT scan



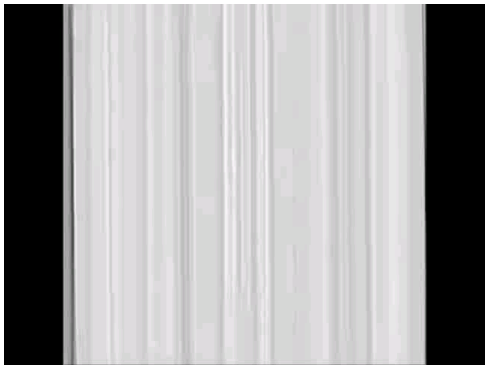
Set of 1D X-ray projections (sinogram)

CT scan

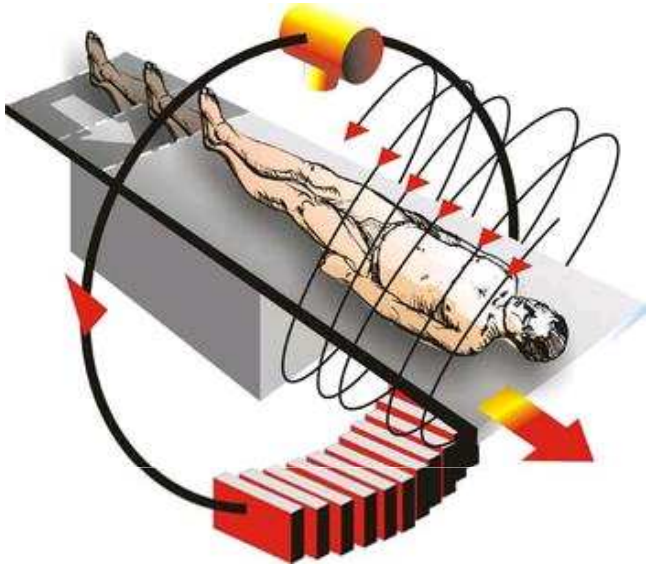


Set of 1D X-ray projections (sinogram)

2D slices reconstruction

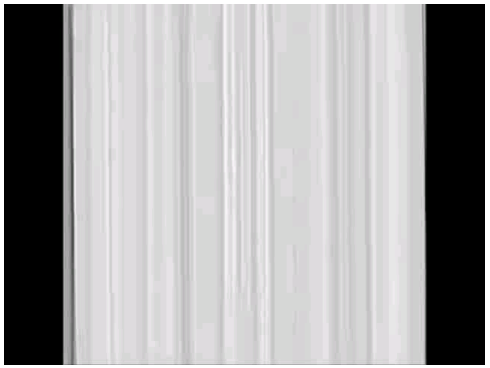


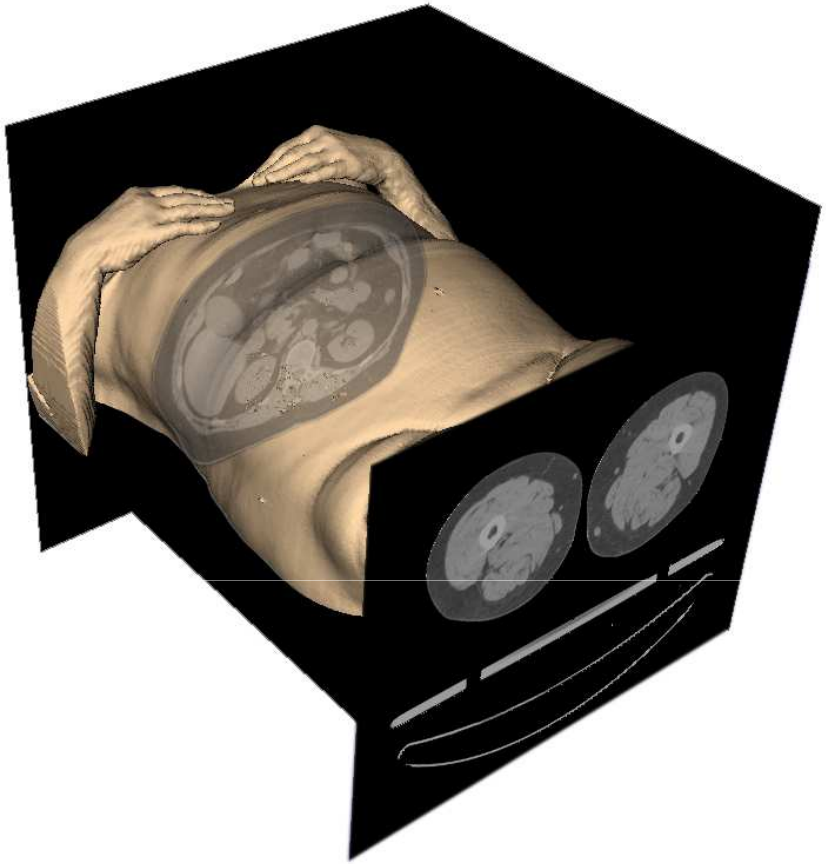
CT scan



Set of 1D X-ray projections (sinogram)

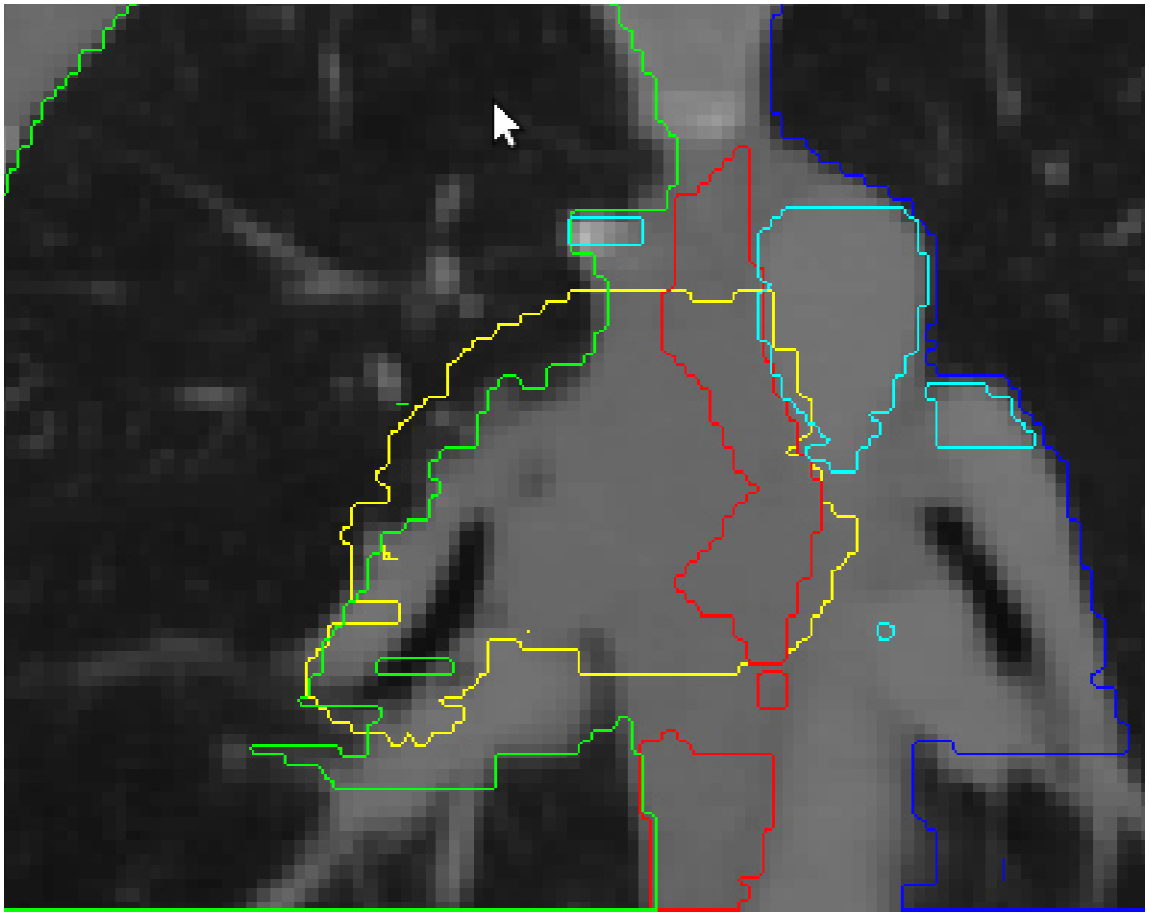
2D slices reconstruction



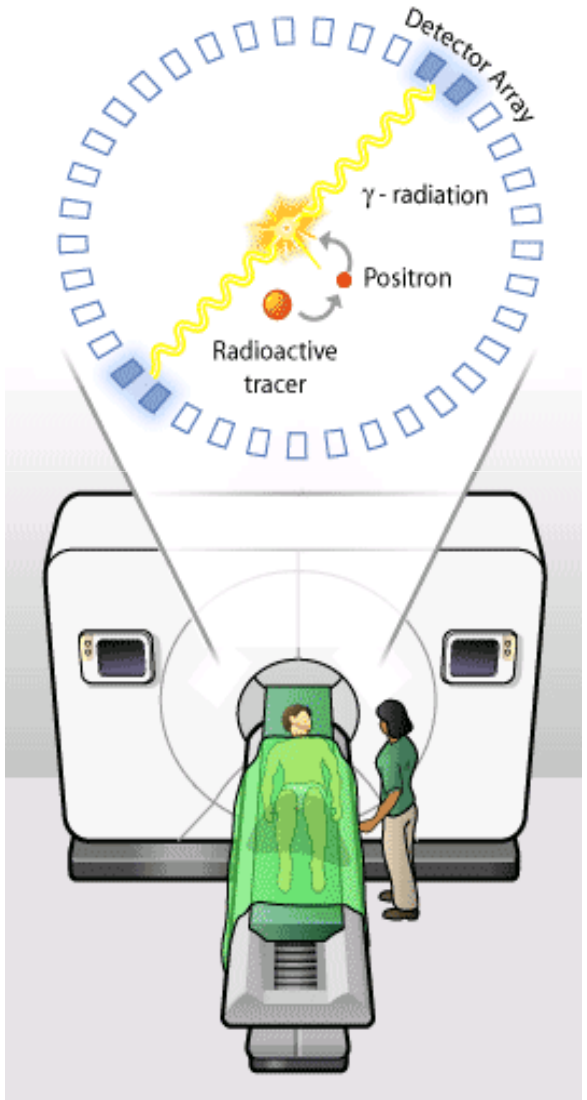


3D image
(set of 2D slices)

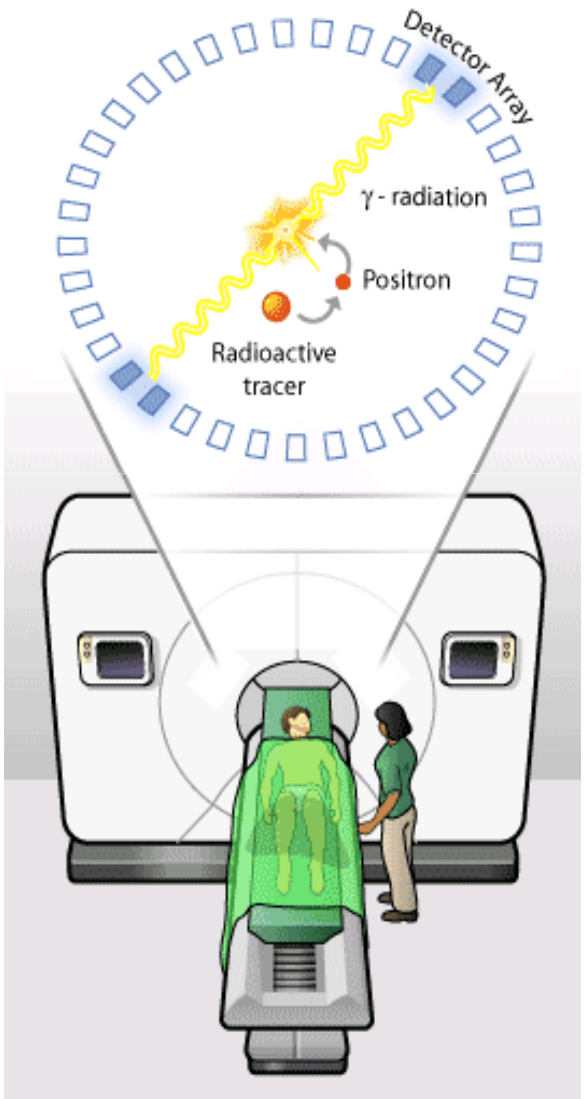
Anatomy is easily identifyable on CT



PET scan



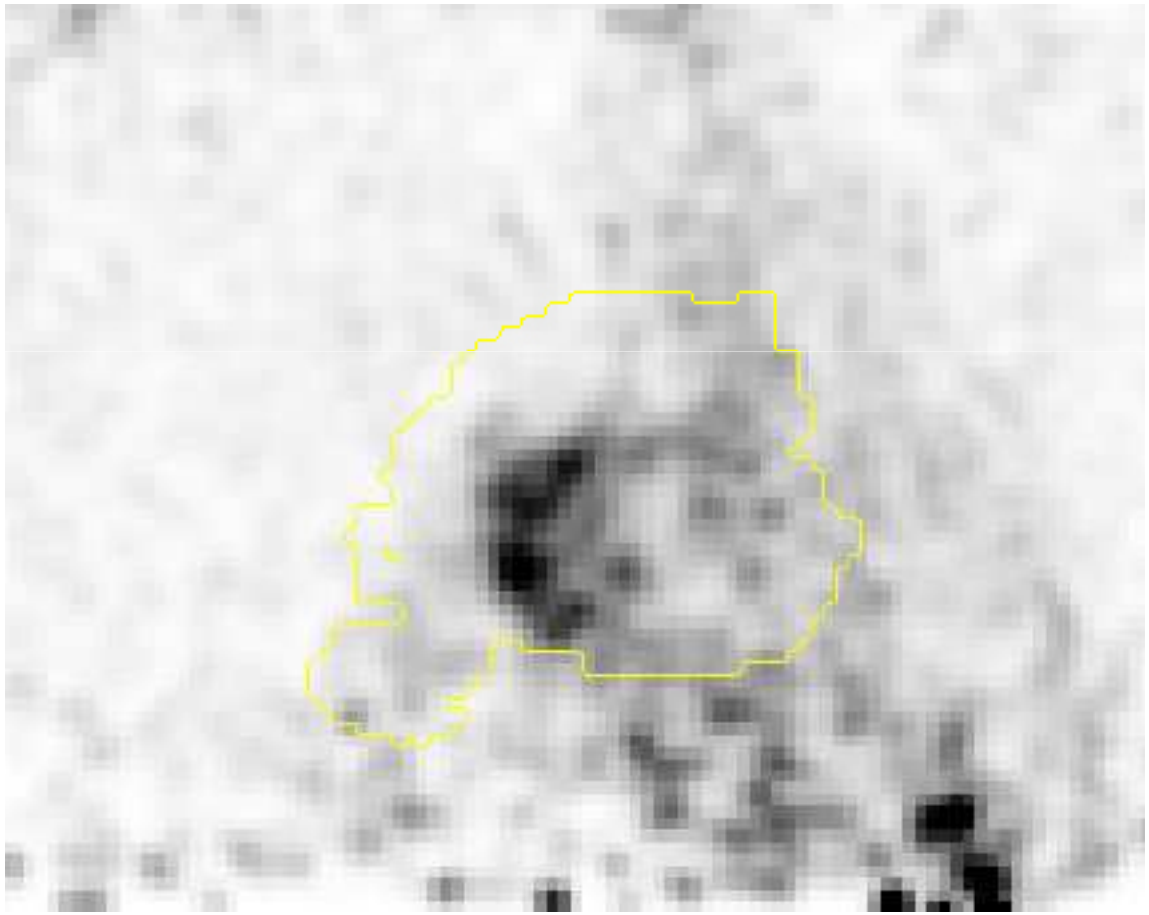
PET scan



- Different tracers for different biological properties (metabolism, hypoxia, …)
- Reconstruction based on statistics (coincident events)
- Poor SNR (trade-off between resolution and noise)
- SNR increases with acquisition duration
- Point spread function (blurring by convolution)

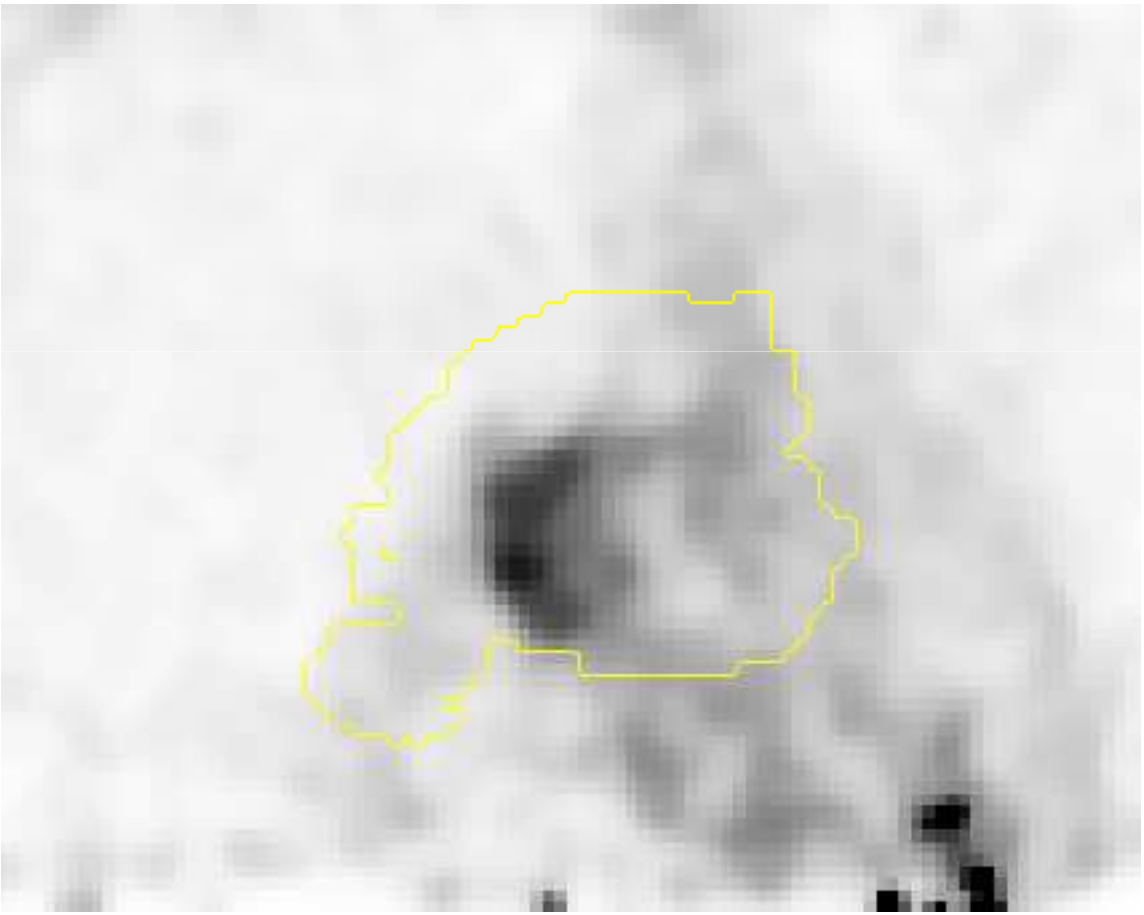
Once anatomical target has been delineated, highly-resistant regions can be segmented using PET

Automatic segmentation of radio-resistant regions in PET images



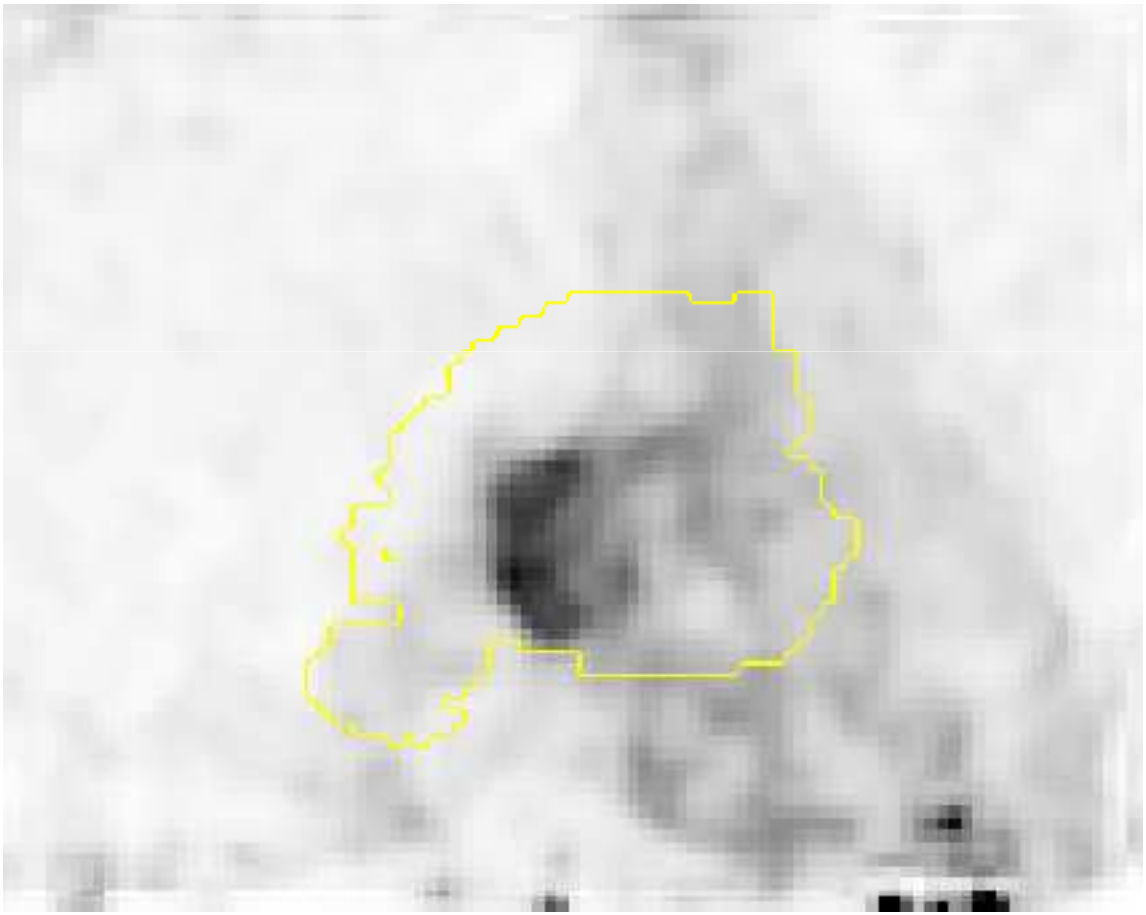
Metabolical image (FDG - PET)

1. Noise reduction using bilateral filtering (edge-preserving smoothing)



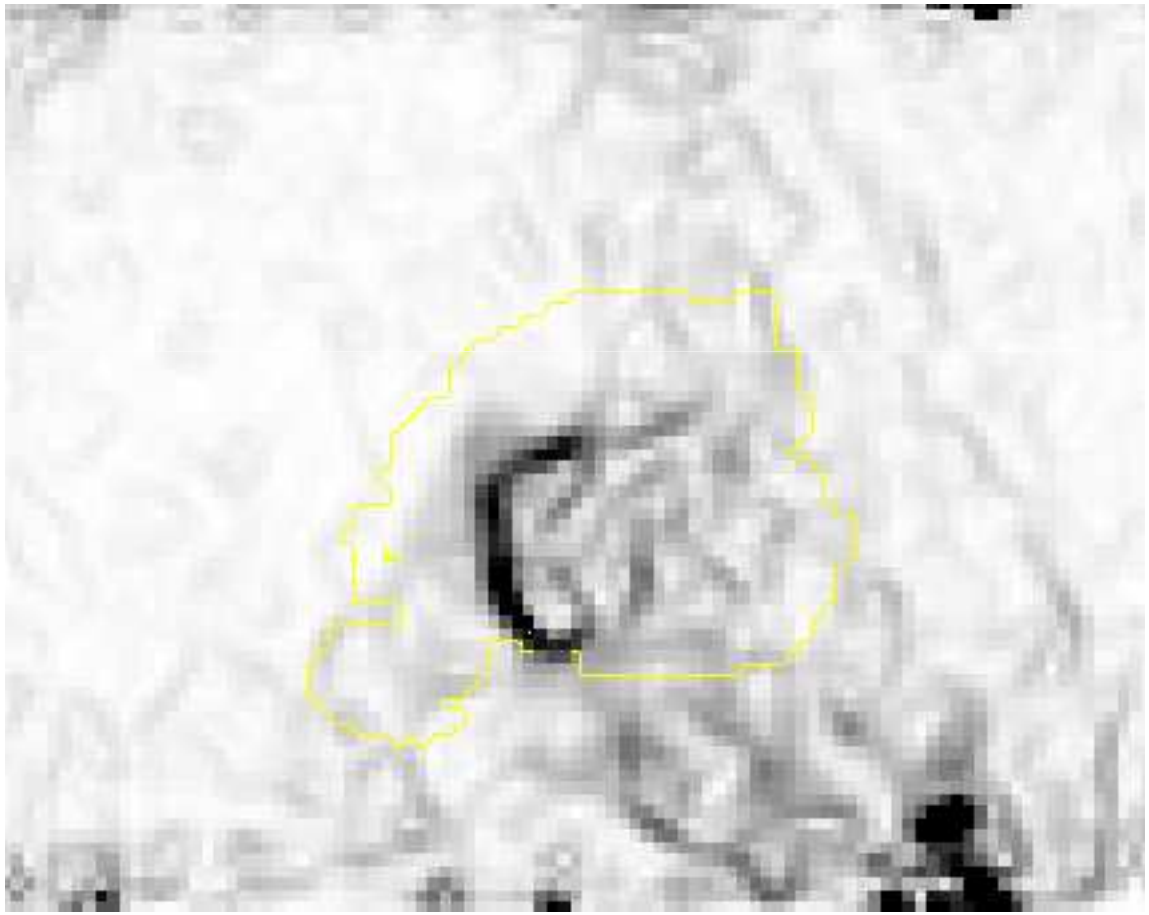
Denoising *(bilateral filtering)*

2. Inversion of PSF using iterative constrained deconvolution



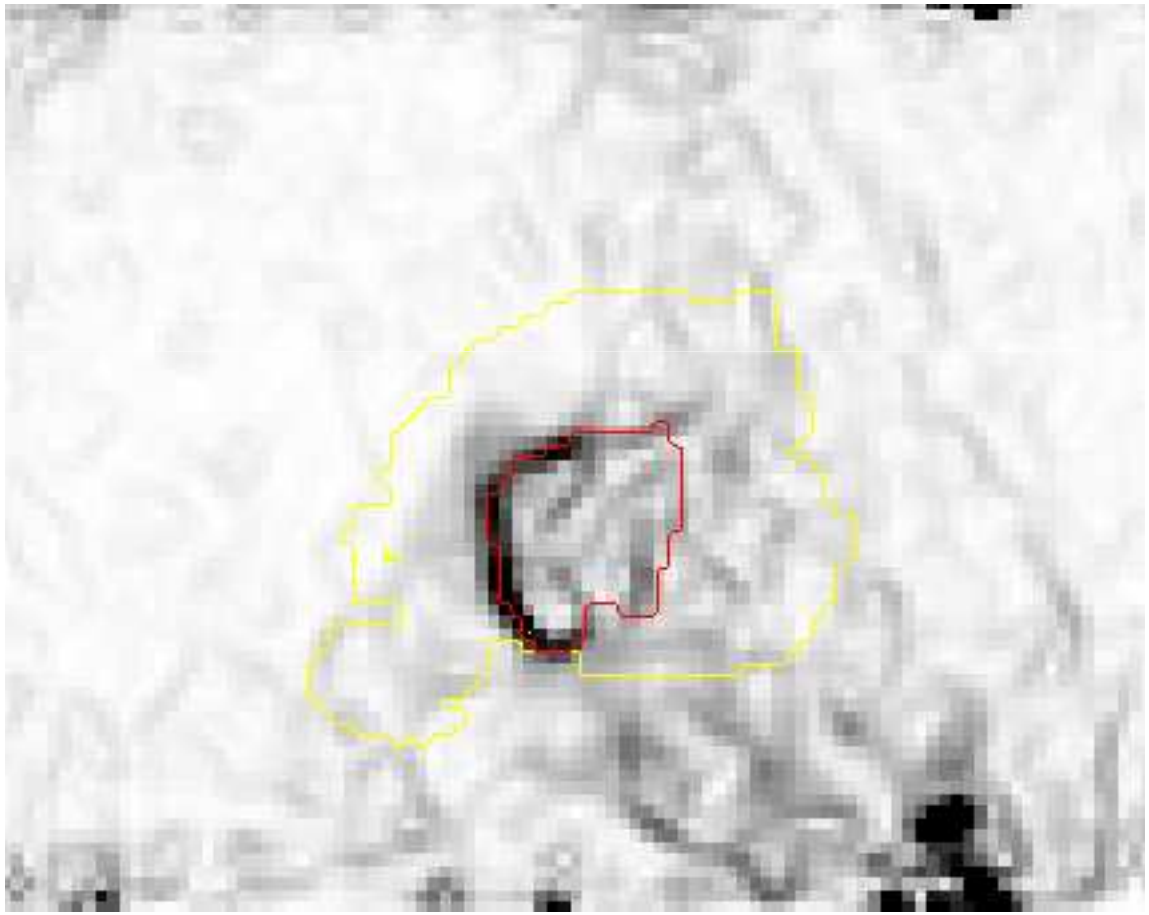
« Sharpness » enhancement *(deconvolution)*

3. Gradient extraction



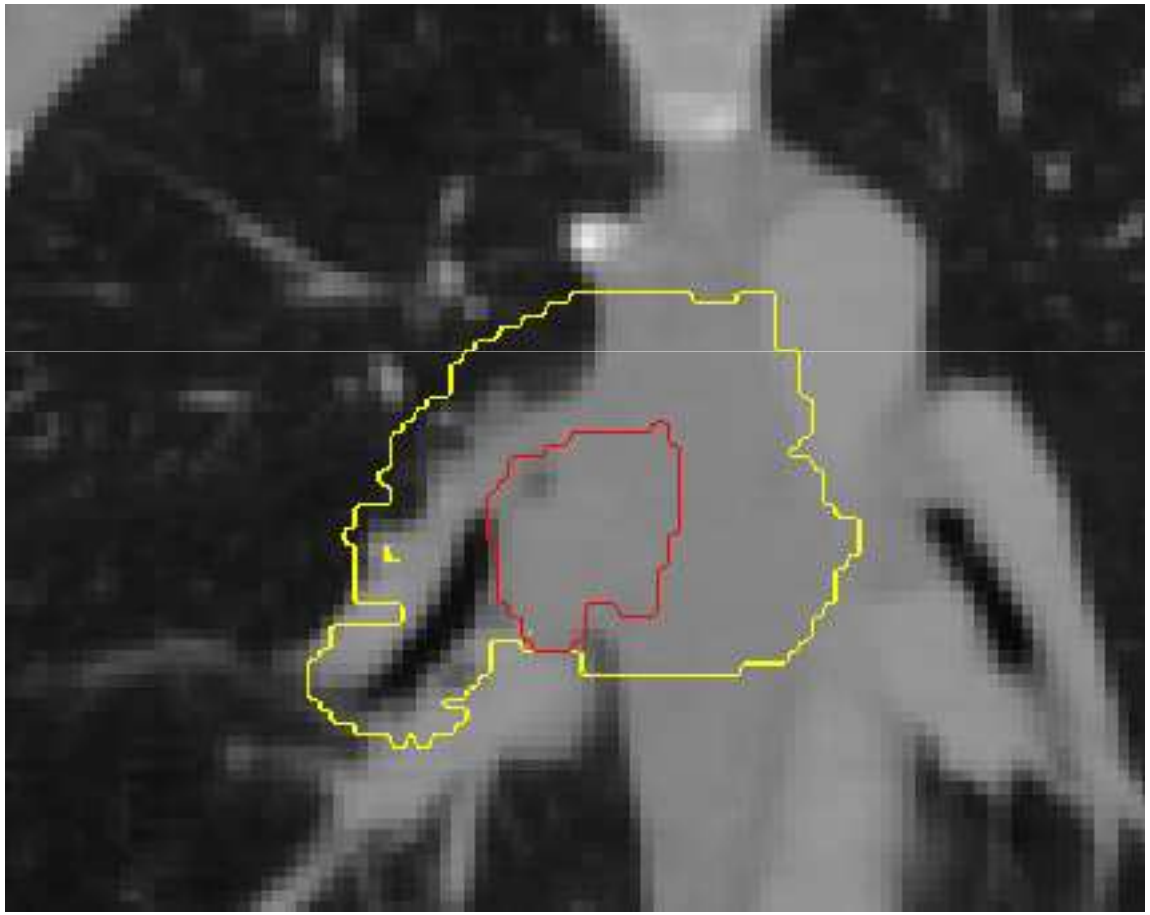
Gradient image

4. Watersheds and clustering



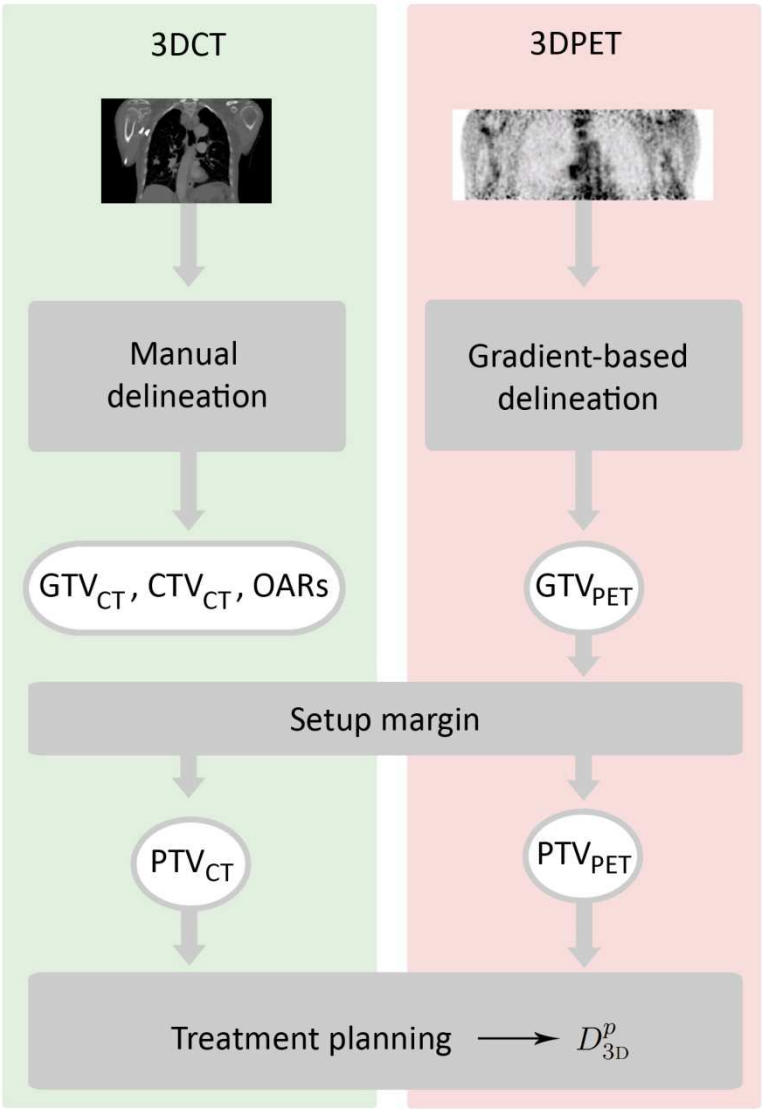
Segmentation *(watersheds + clustering)*

Target volumes for planning

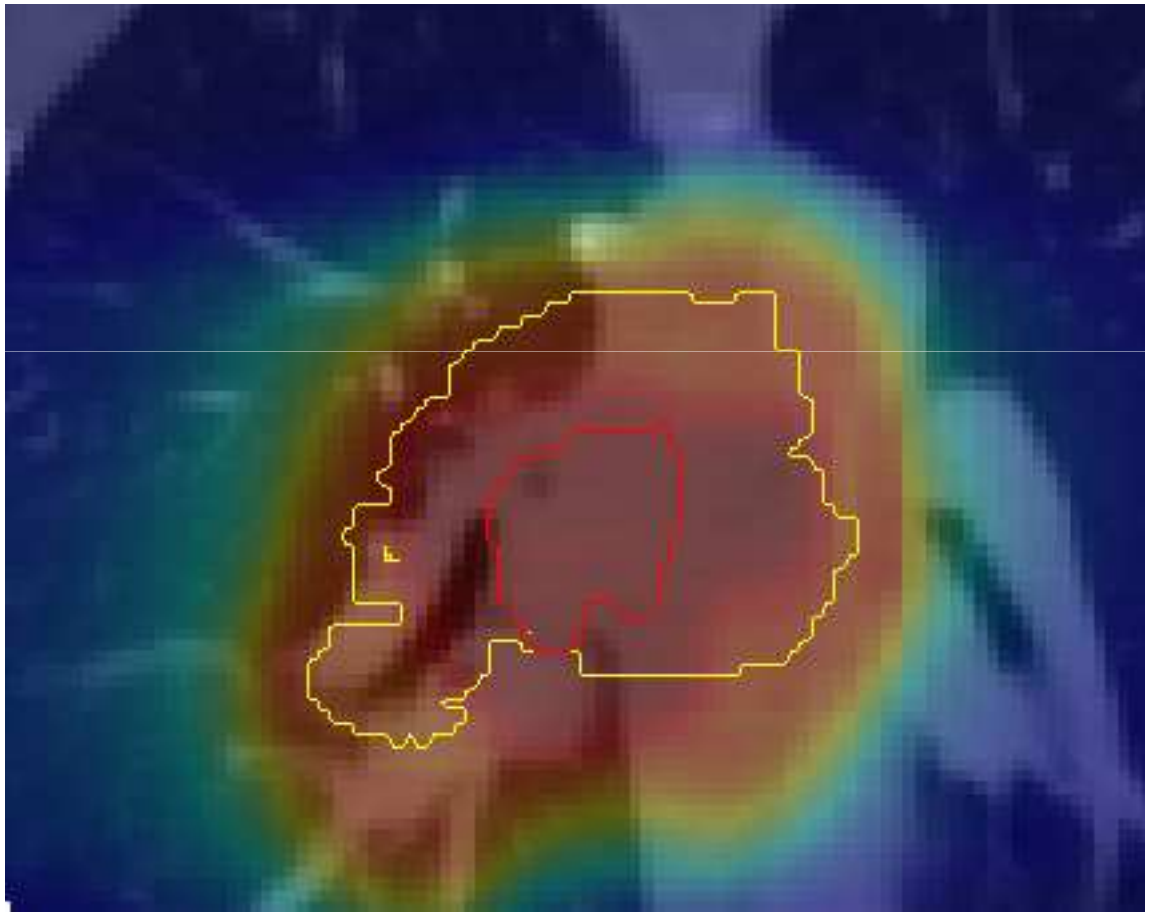


Target tumor volume and radio-resistant « boost » region

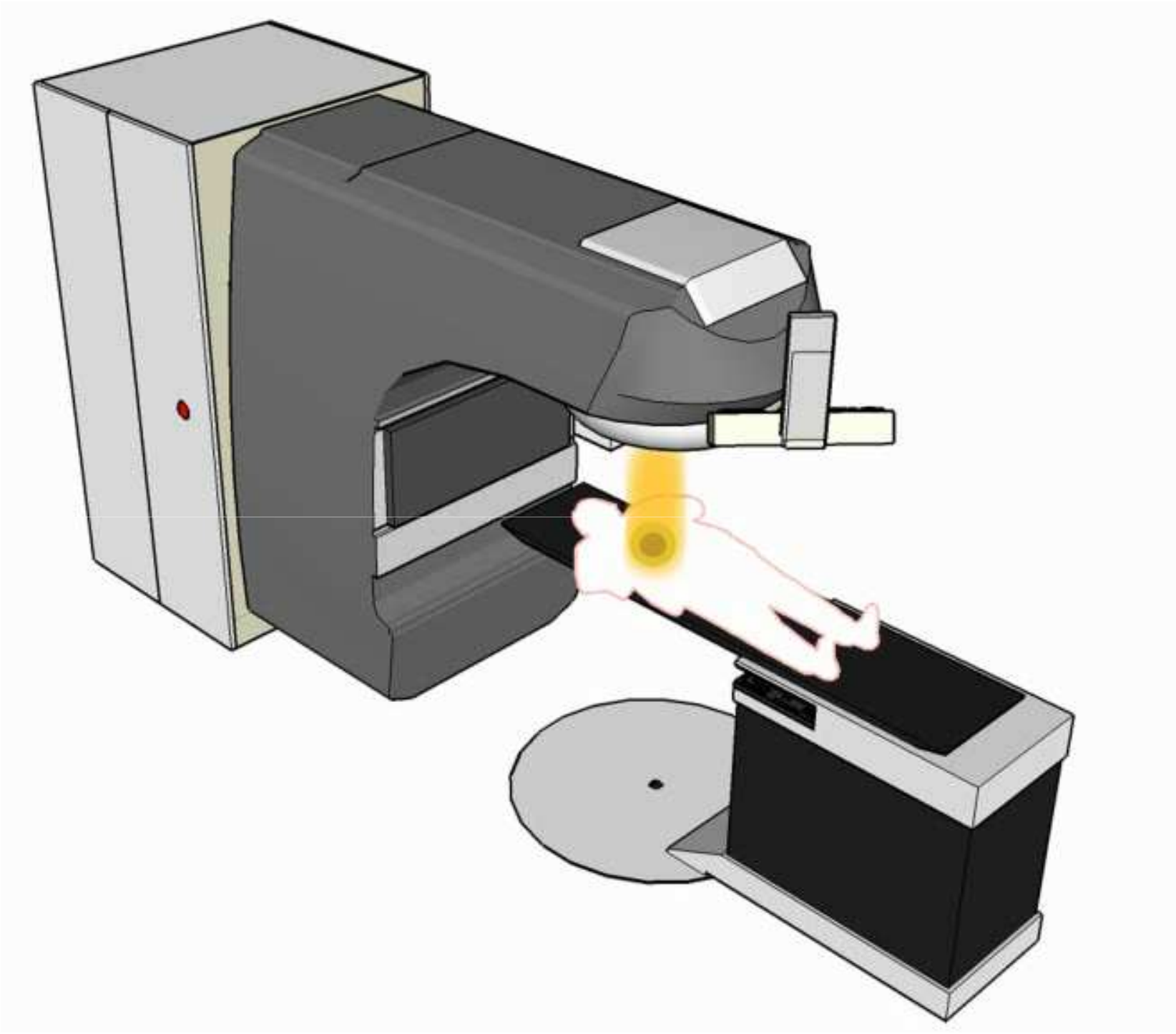
3D target volume delineation workflow



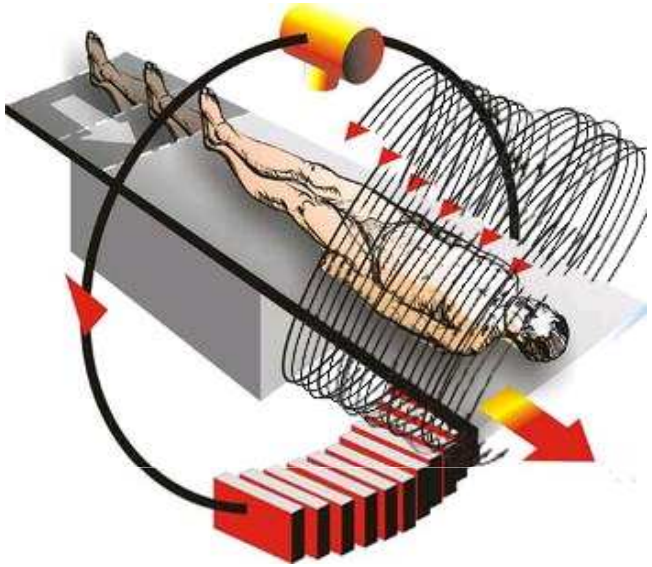
Dose planning

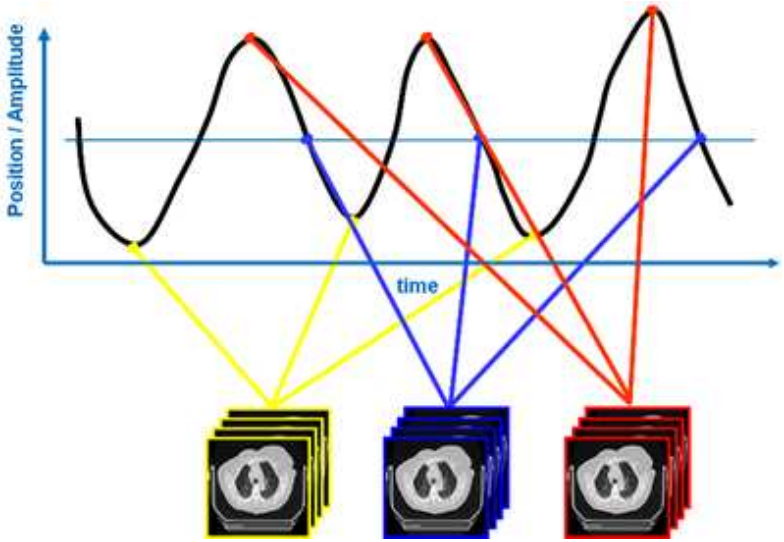


X-Ray dose that is planned to be delivered (tumor + boost region)



Slow CT scans can be divided into 3D phases





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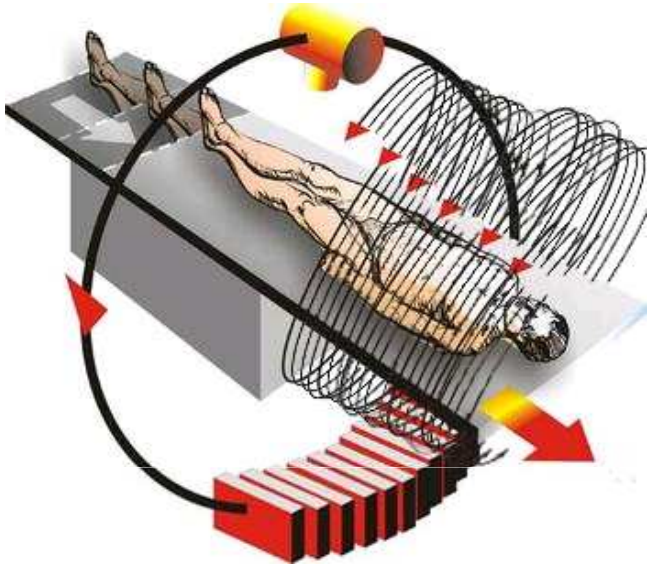
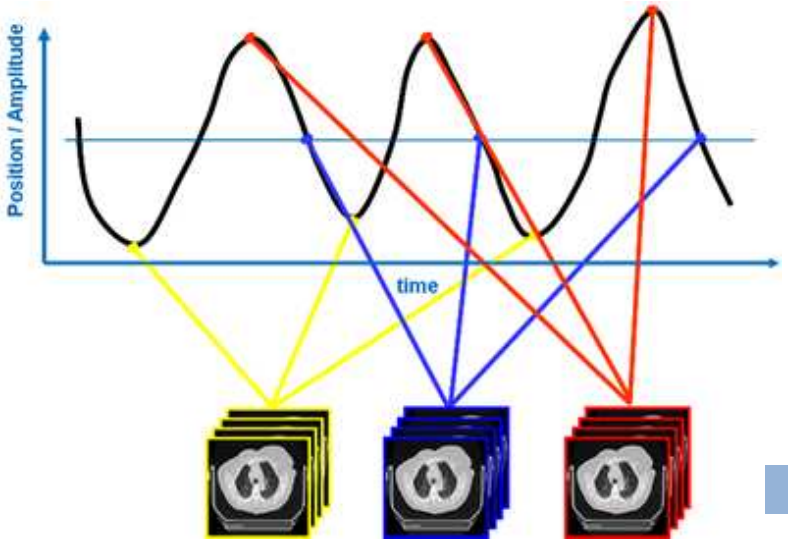
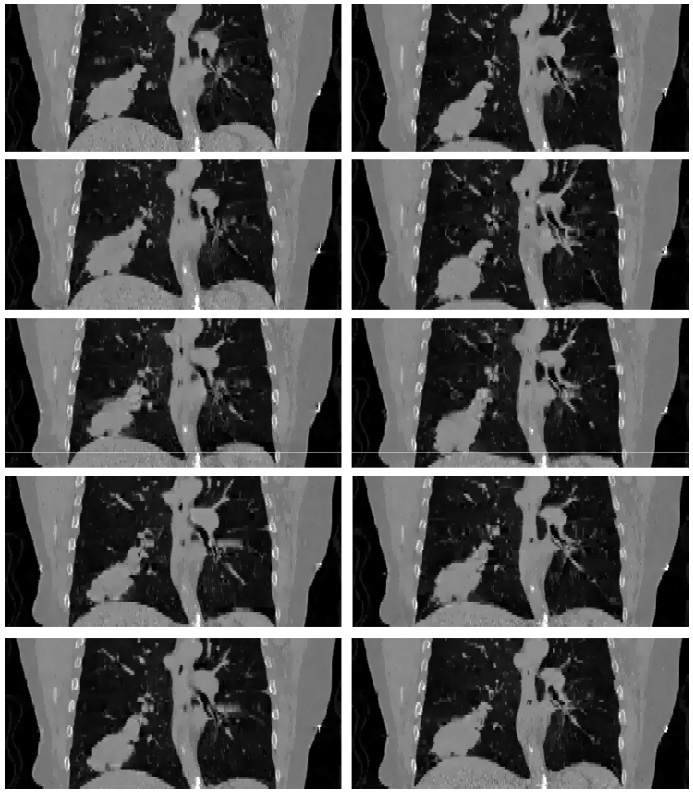
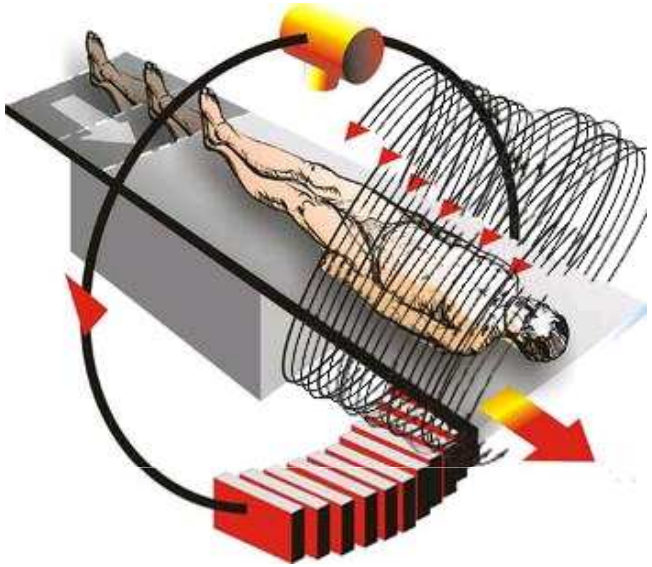


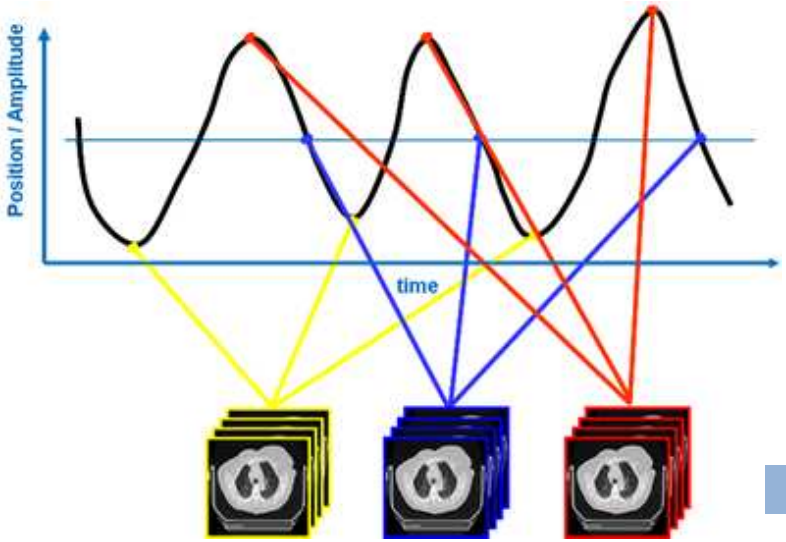


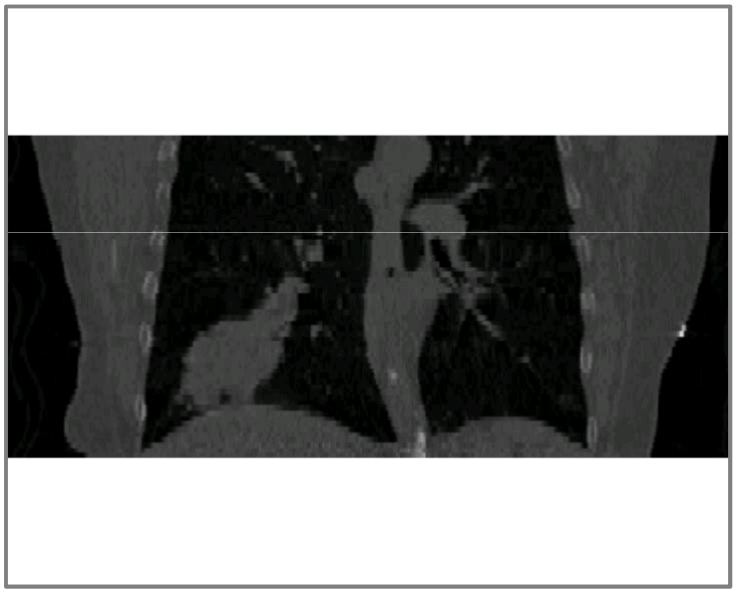


RCCT
(set of ten 3D images)

Slow CT scans can be divided into 3D phases

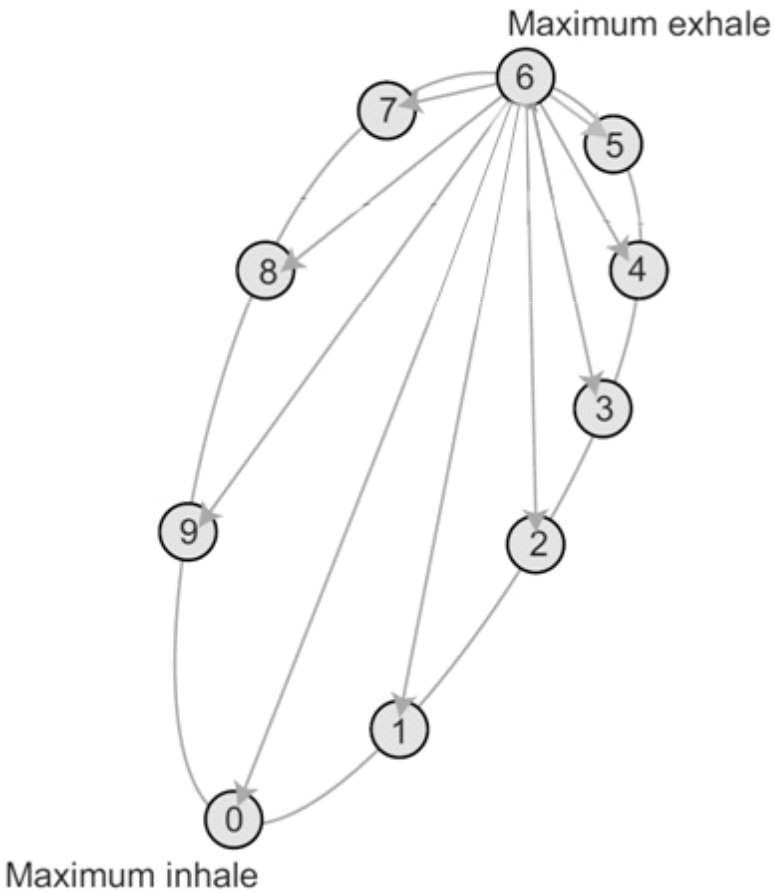


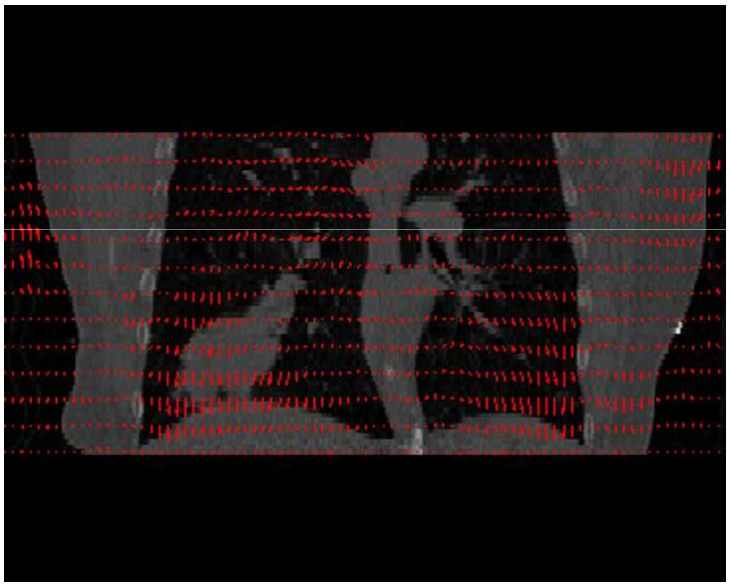




RCCT

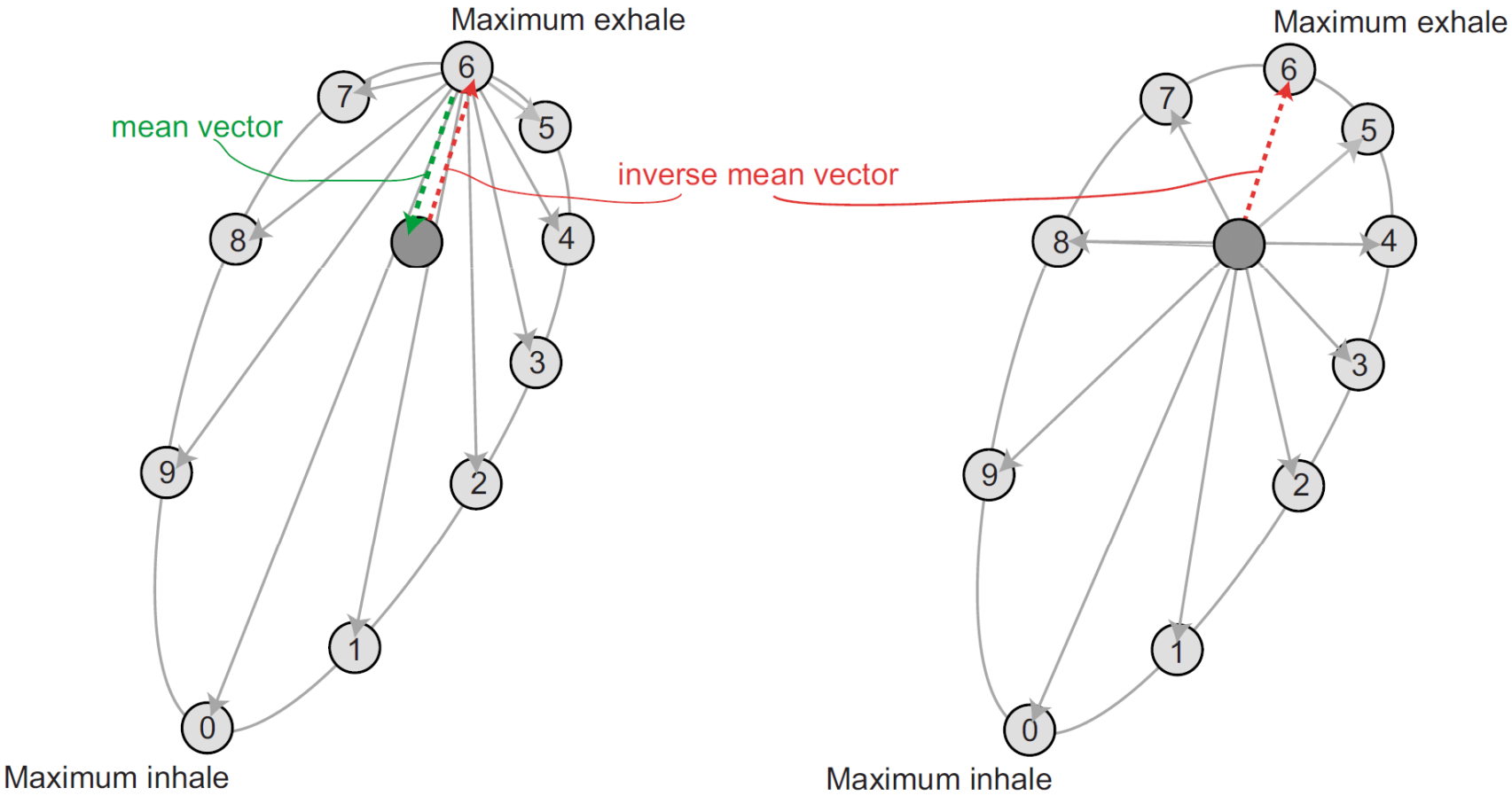
Breathing motion can be estimated using image registration



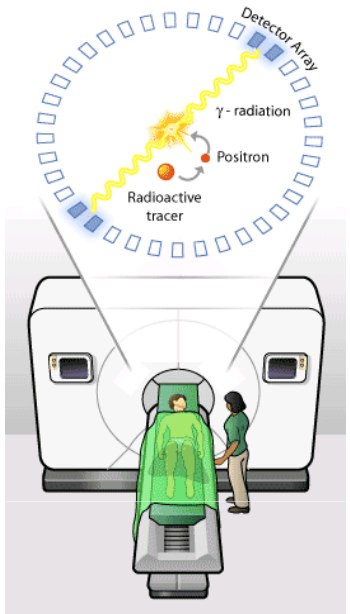


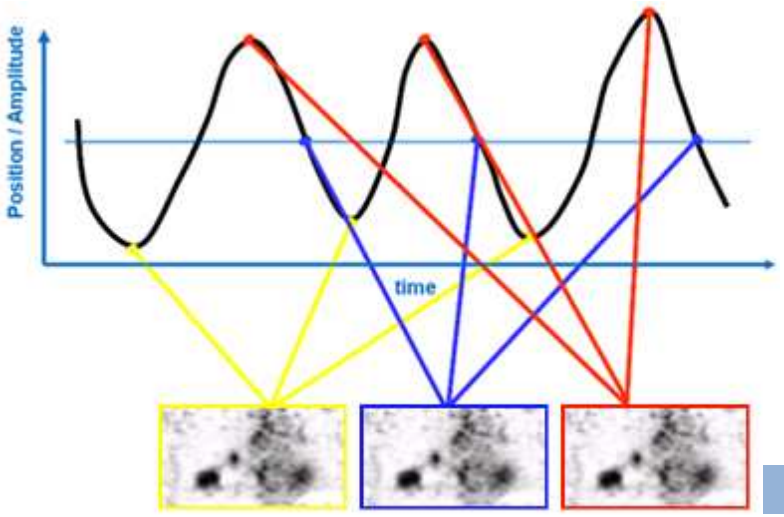
RCCT

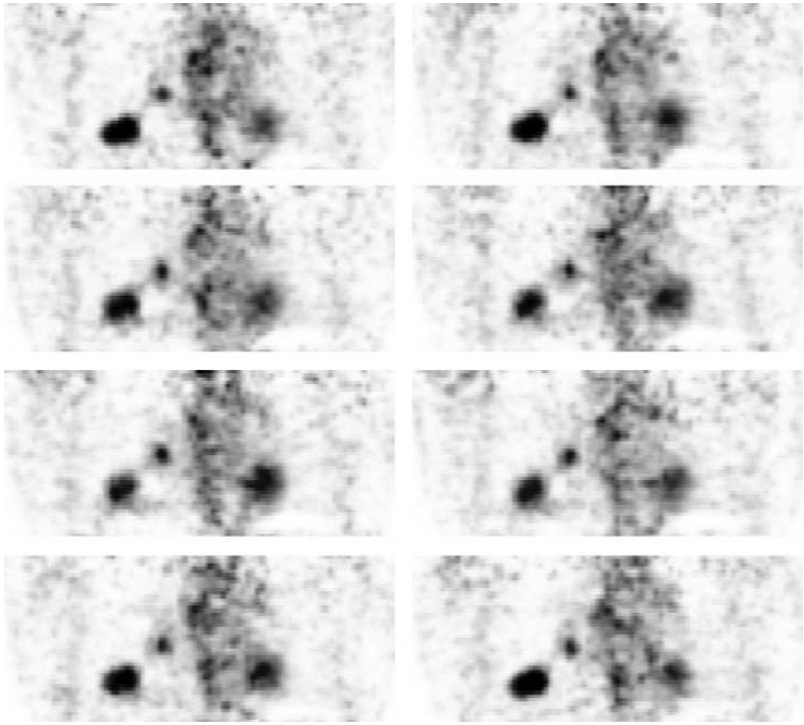
A mid-position CT can also be reconstructed



Long PET scans can also be divided into phases

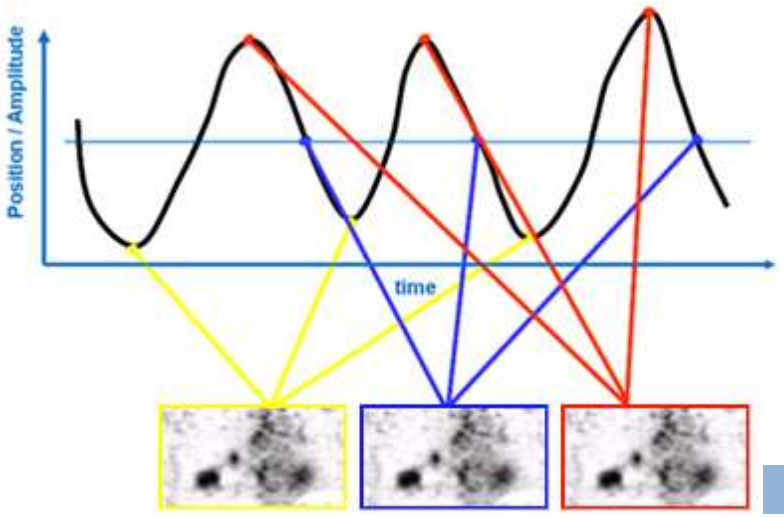


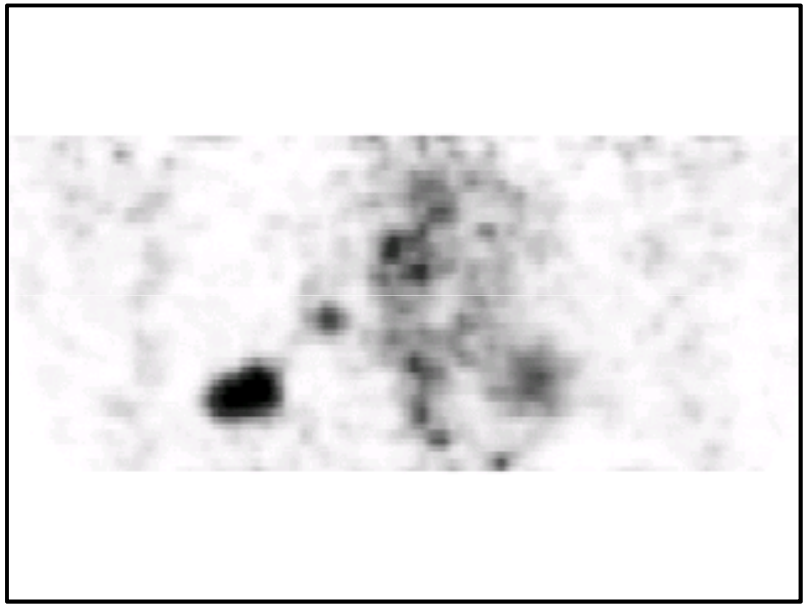




RCPET

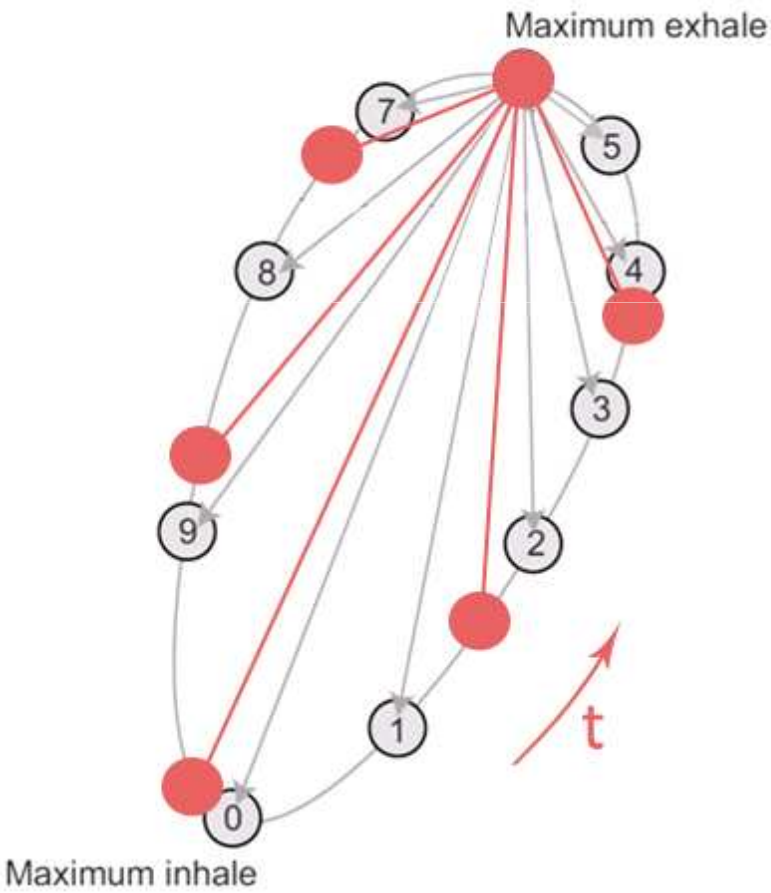
PET scan

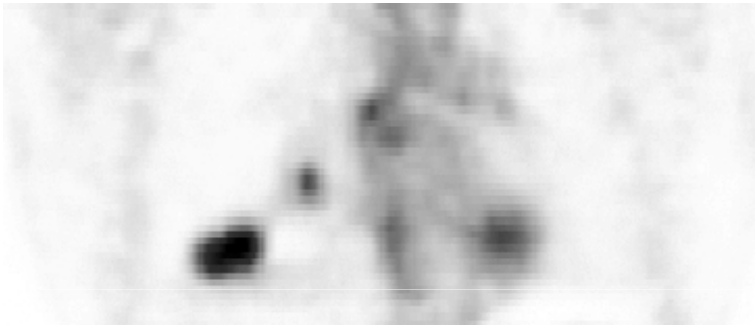




RCPET

Breathing motion estimation from CT can be used for correcting PET images

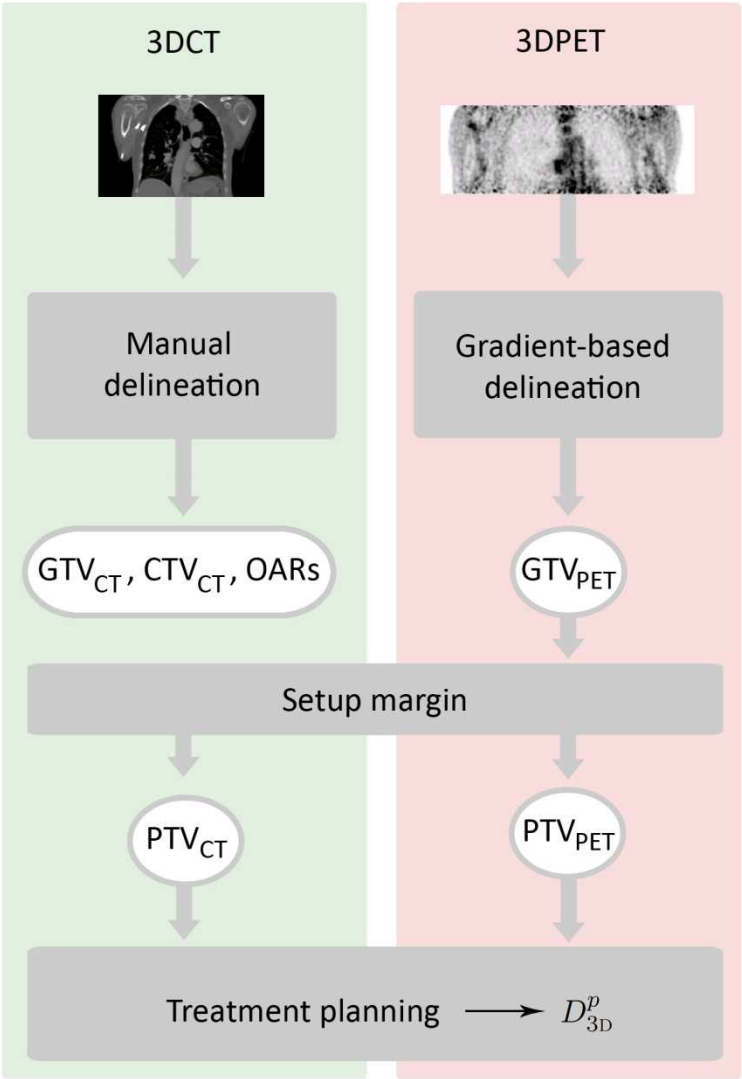




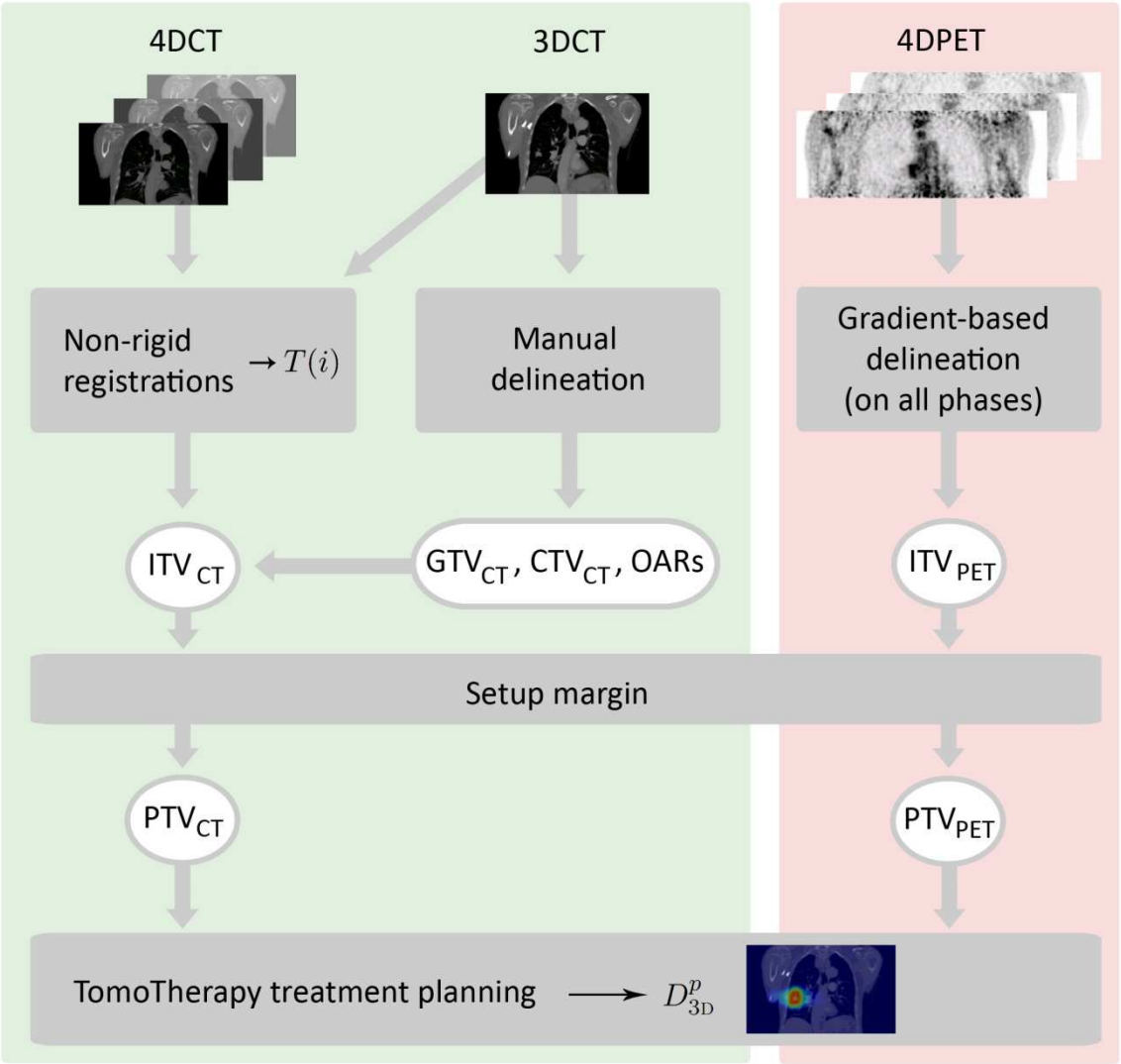
Corrected PET image

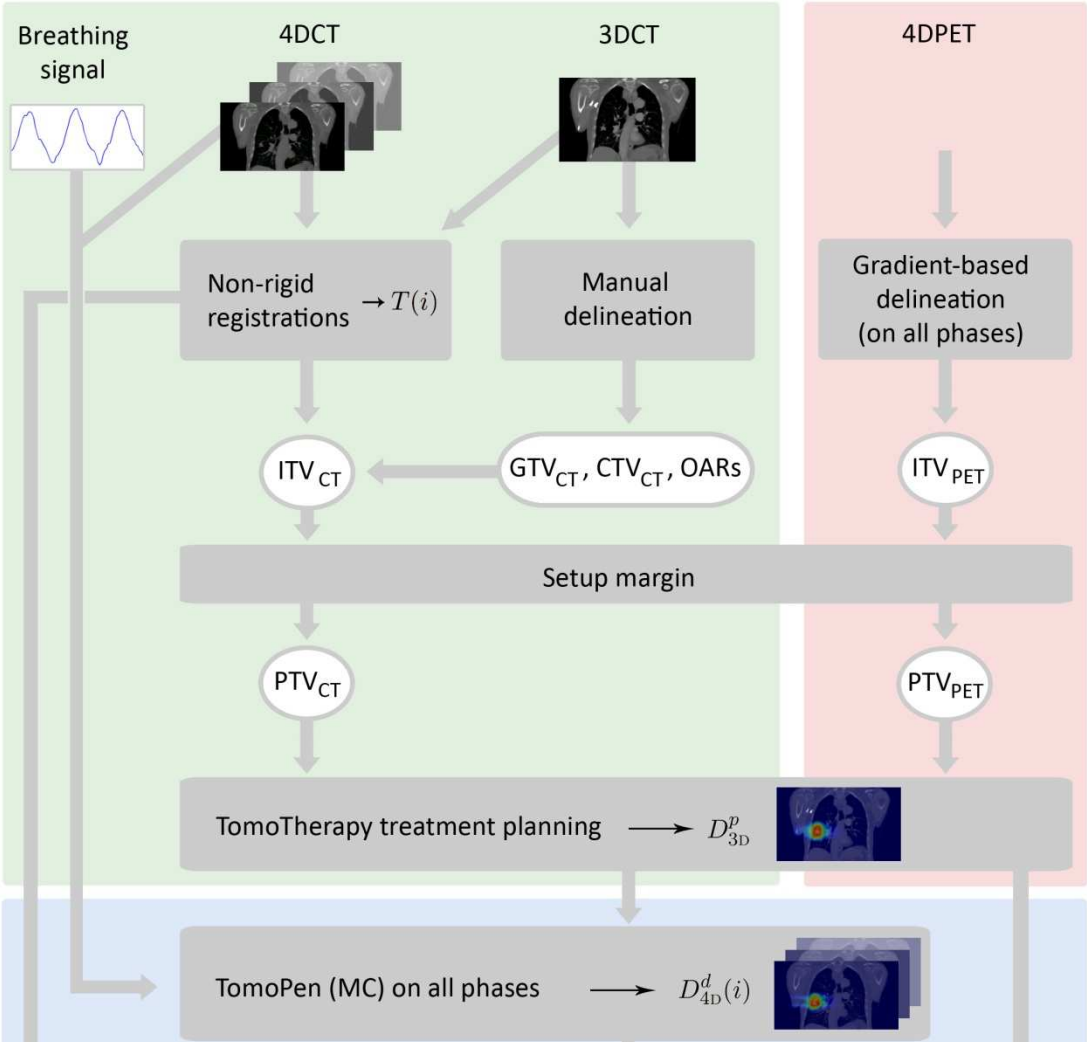
PET-CT fusion

3D target volume delineation workflow

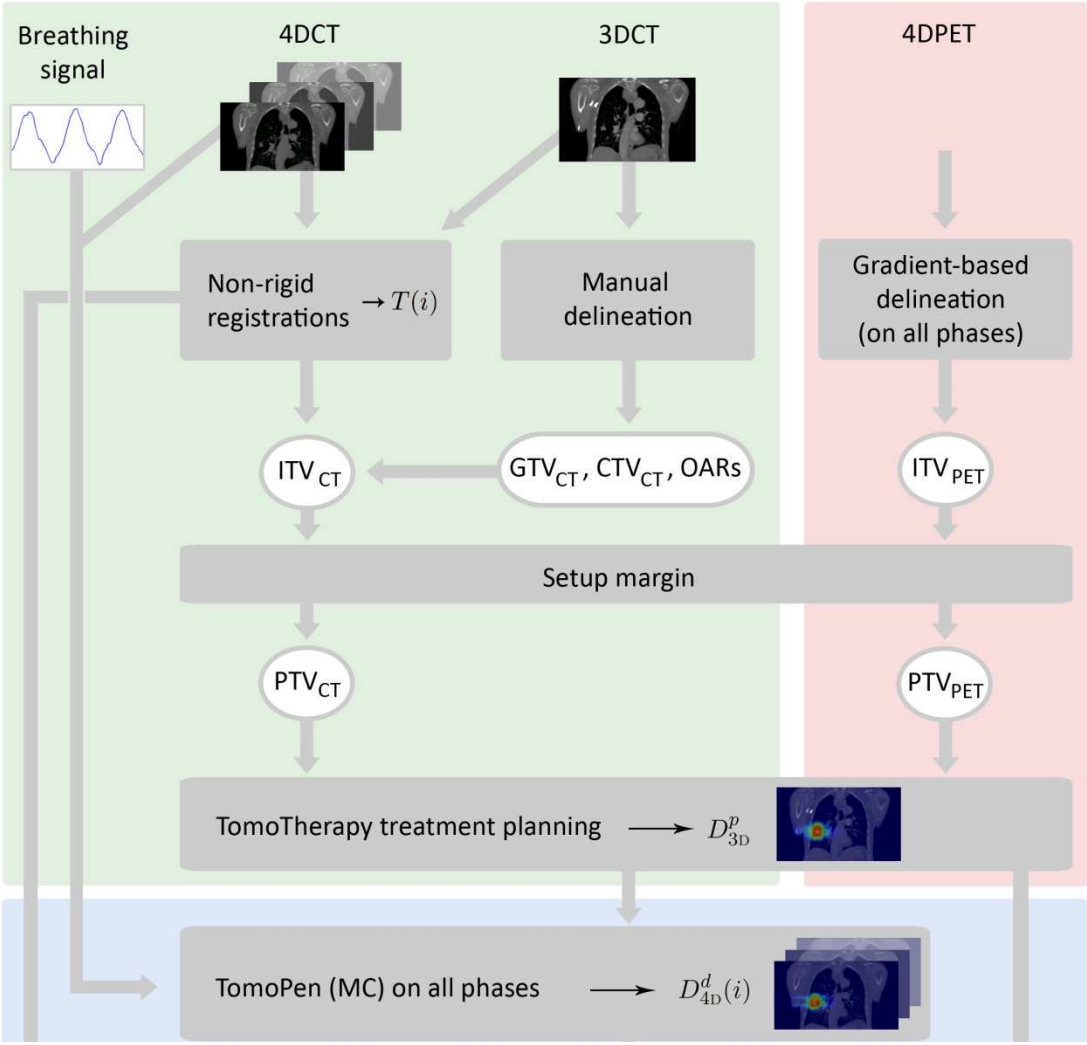


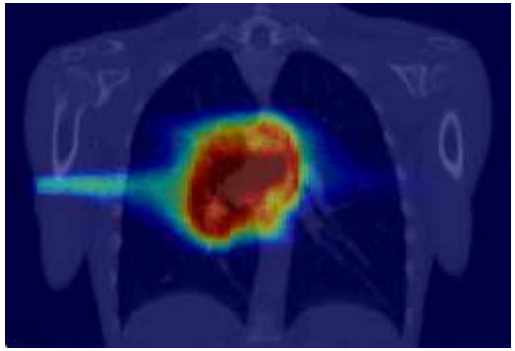
4D target volume delineation workflow



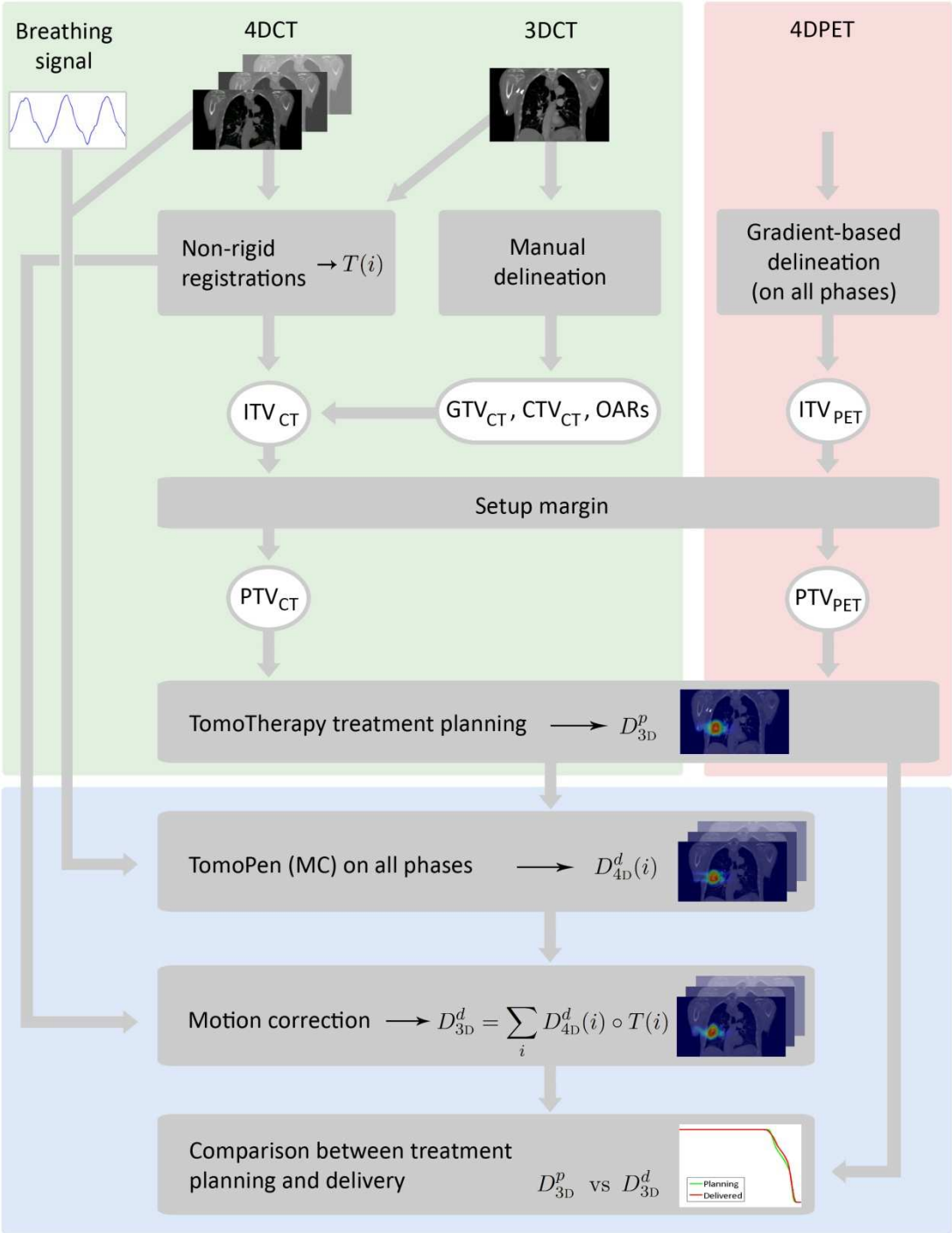


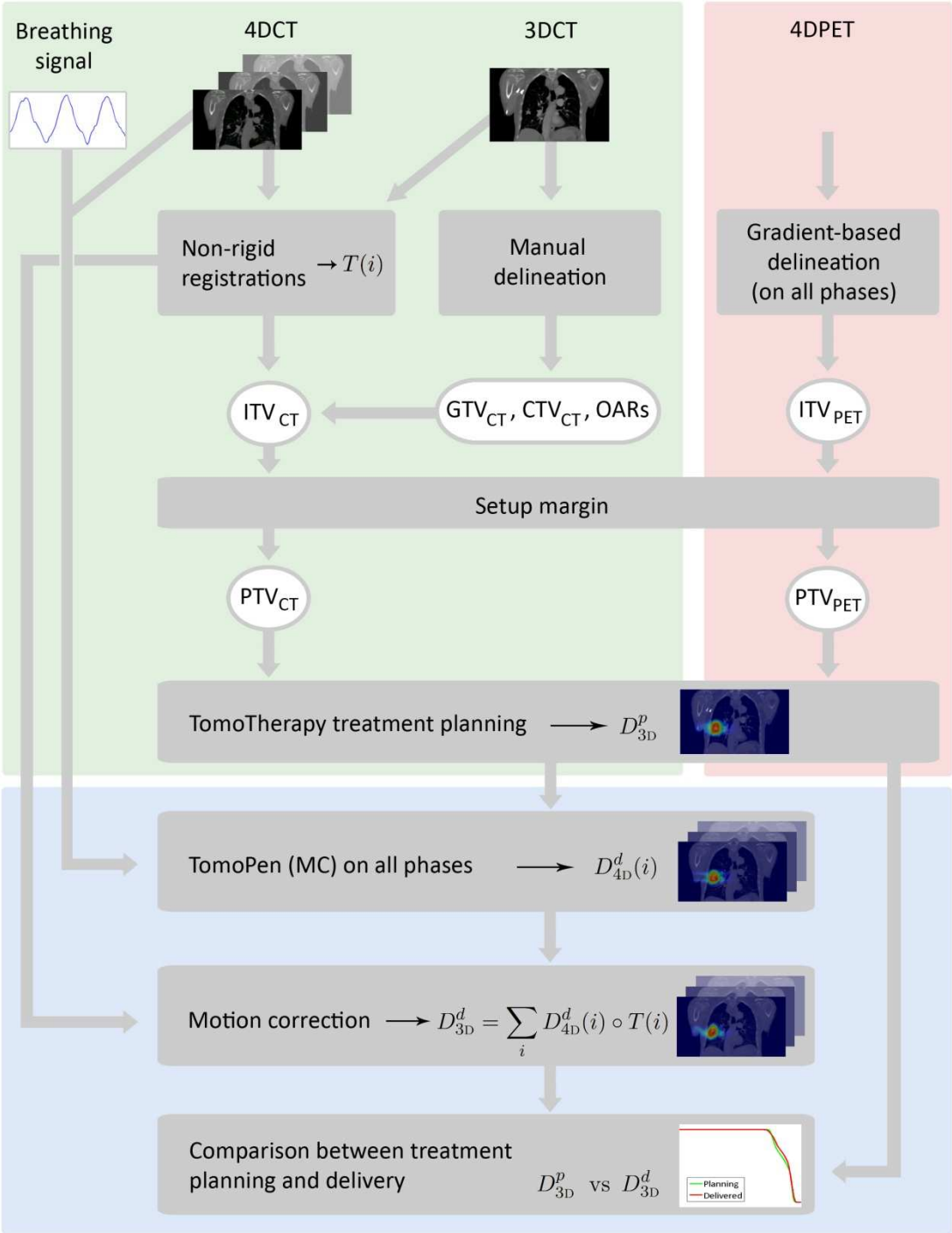
Validation of 4D treatment delivery

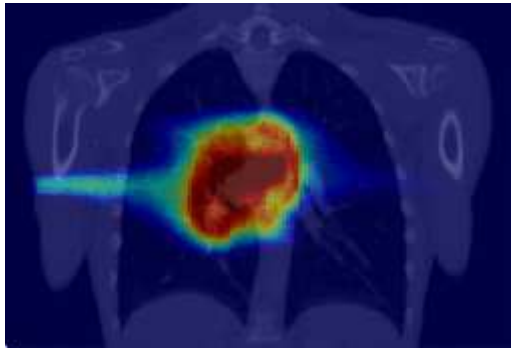




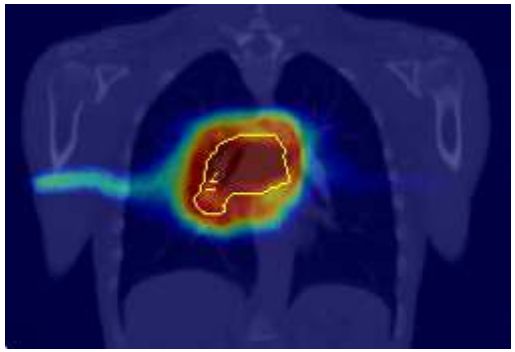
Planned dose on each phase


Breathing signal
4DCT
3DCT
4DPET
Non-rigid registrations → $T(i)$
Manual delineation
Gradient-based delineation (on all phases)
ITV CT
GTV$_{CT}$, CTV$_{CT}$, OARs
ITV PET
Setup margin
PTV$_{CT}$
PTV$_{PET}$
TomoTherapy treatment planning → D^p_{3D}
TomoPen (MC) on all phases → $D^d_{4D}(i)$
Motion correction → $D^d_{3D} = \sum_i D^d_{4D}(i) \circ T(i)$
Comparison between treatment planning and delivery
D^p_{3D} vs D^d_{3D}
Planning
Delivered





Planned dose on each phase



Delivered dose reference phase

Delivered vs Planned dose