

# OPTIMIZATION OF MEDICAL ACCELERATORS PROJECT

## TUMOR TRACKING IN PARTICLE THERAPY

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OMA TOPICAL WORKSHOP - PSI



Università degli Studi  
di Pavia



fondazione **CNAO**  
Centro Nazionale di Adroterapia Oncologica

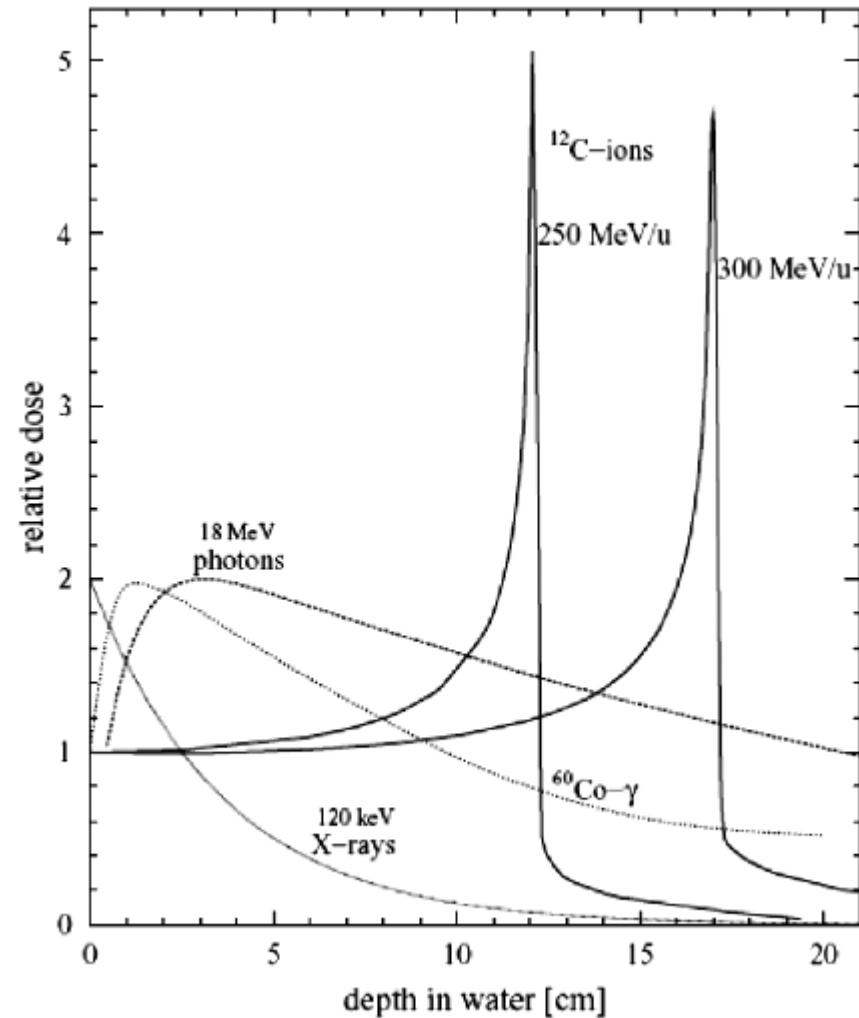
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## Moving tumors in particle therapy

The integration of the adaptive particle therapy in clinical practice consists of two major approaches:

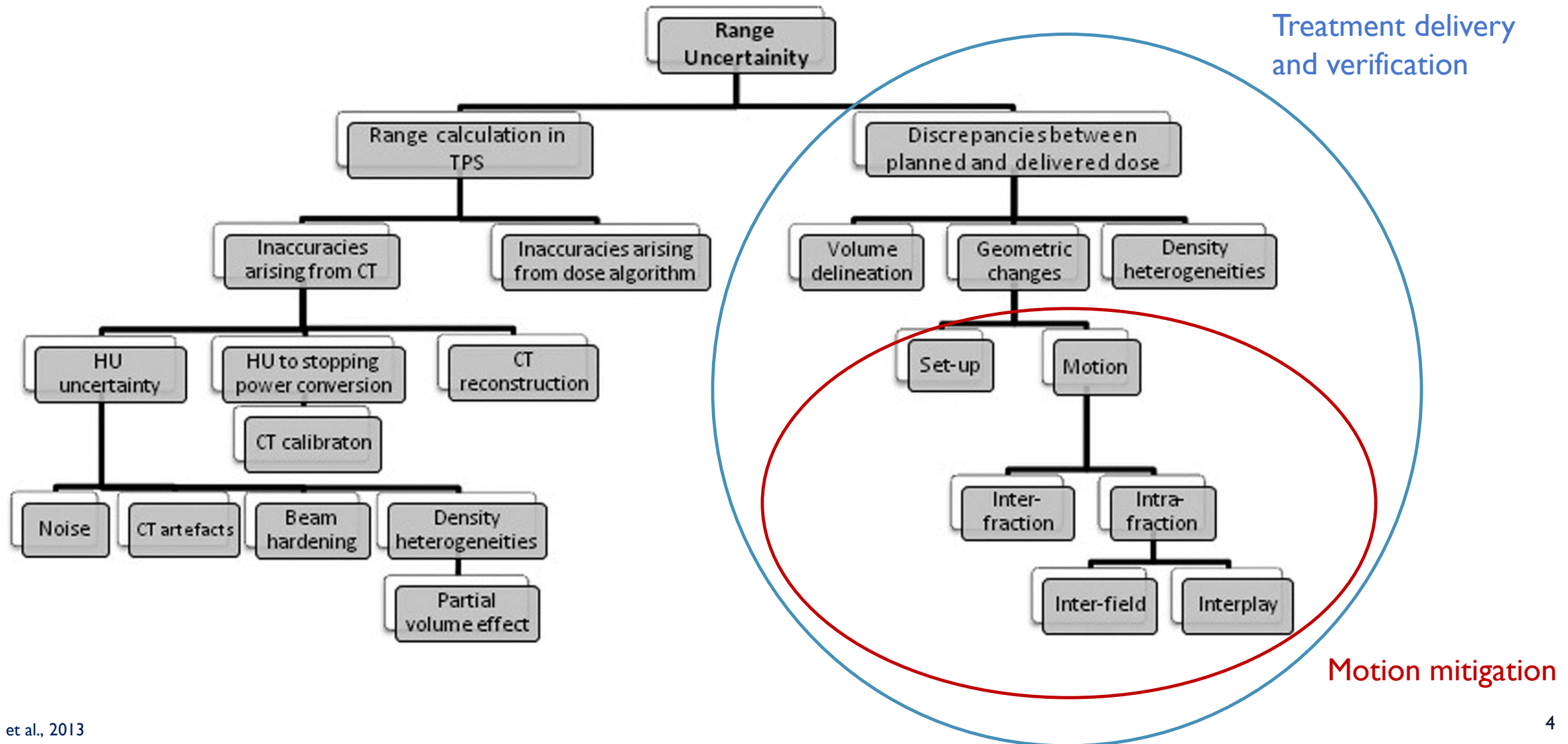
- (1) Treatment preparation** by measuring the target displacement which includes acquisition of breathing motion, target delineation and treatment simulations
- (2) Treatment delivery** where irradiation is delivered to the patient under free breathing conditions using real-time respiratory motion tracking system

# Moving tumors in particle therapy



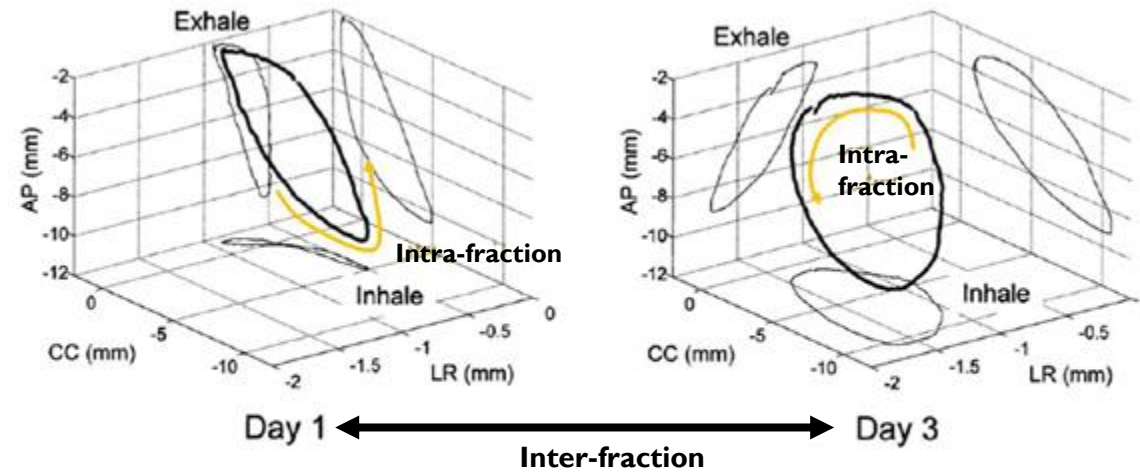
Dose profile in water of carbon ion and X and gamma-rays at different energies

# Moving tumors in particle therapy

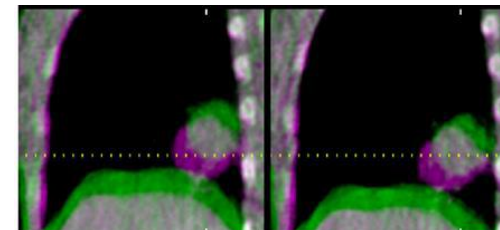
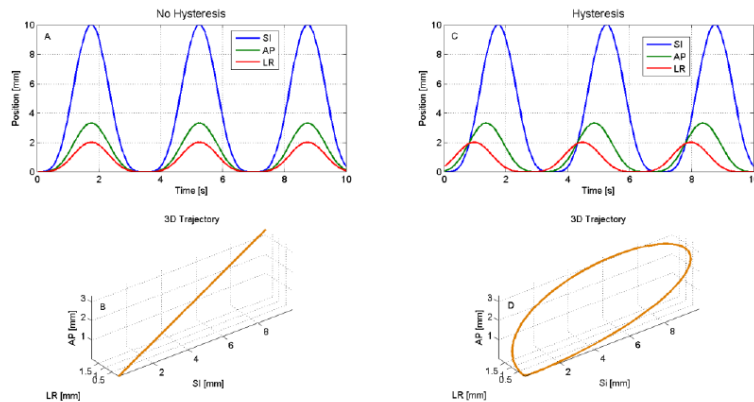


# Moving tumors in particle therapy

## Intra- and inter-fractional motion



## Baseline shift

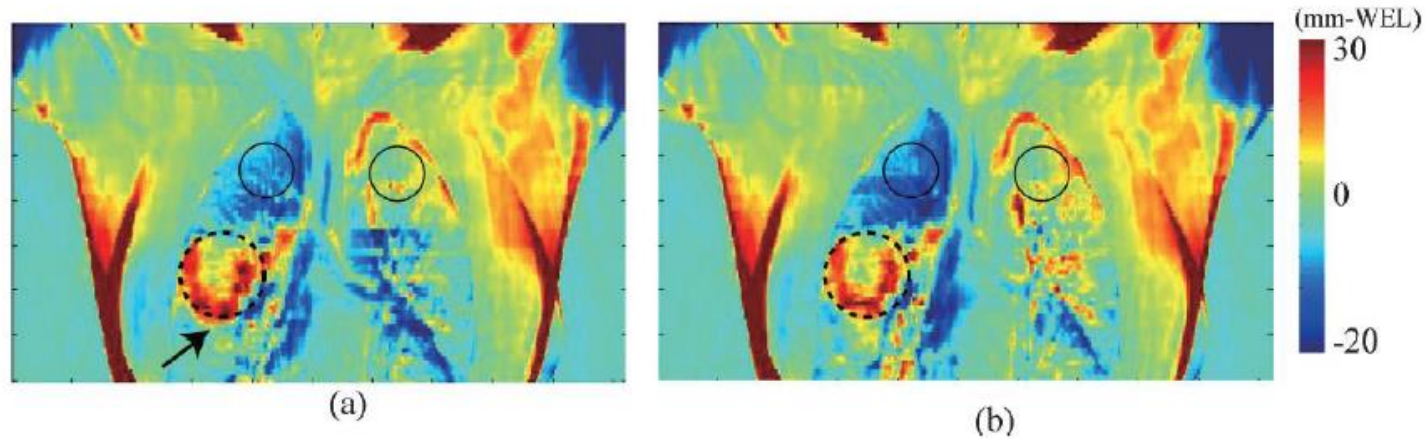


Baseline shift observed on two overlaid CBCT scans



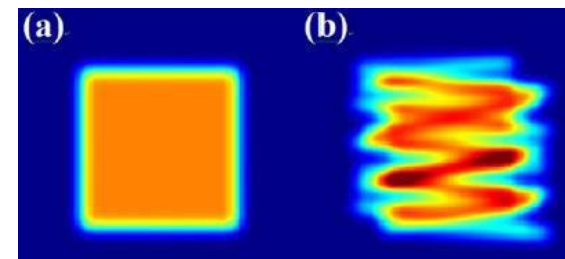
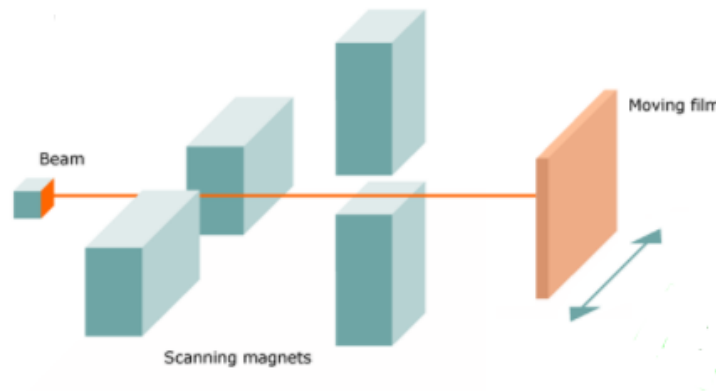
# Moving tumors in particle therapy

## Water equivalent path length variation



Coronal  $\Delta$ WEL maps at end-inhale (a) and end-exhale (b) phase. Tumor region is identified by a dotted circle, while ROI in the lungs are identified by solid circles.

## Interplay effect

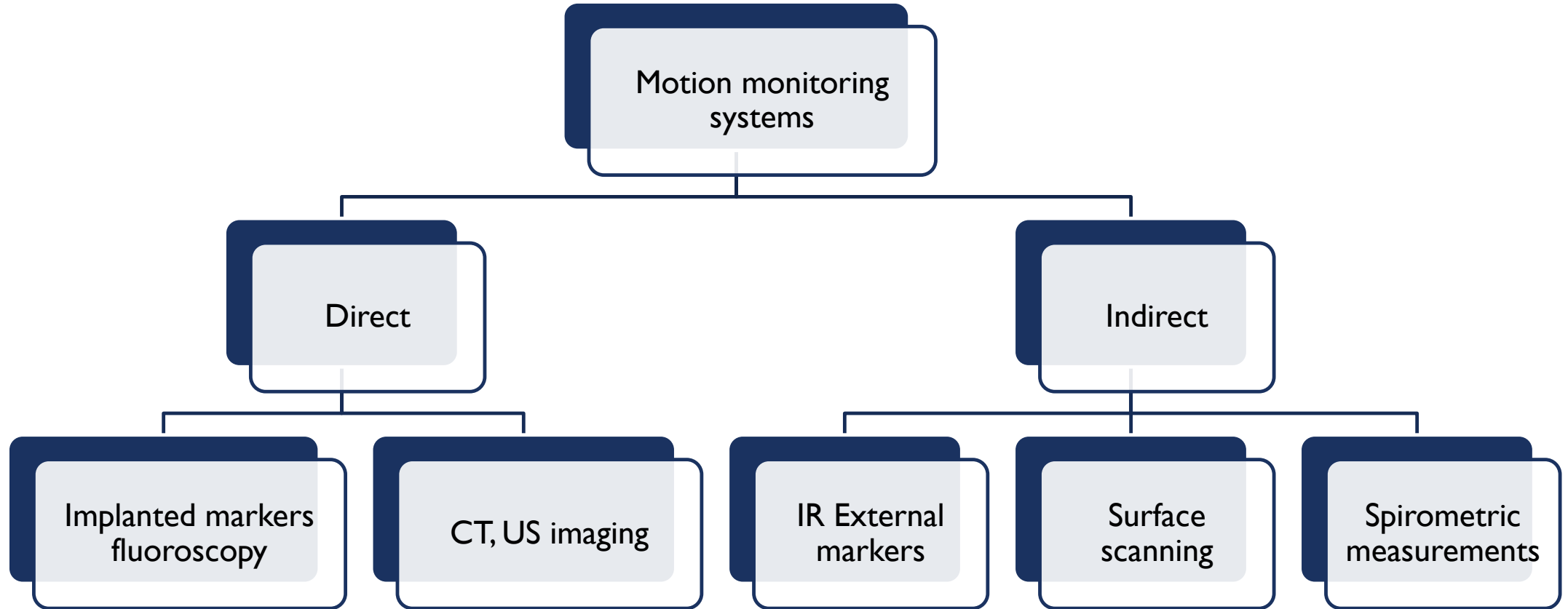


(a) Dose distribution delivered with a scanned beam to a static target. (b) Dose distribution delivered to a moving target: the interplay effect is clearly visible.

## Tracking as a motion mitigation technique

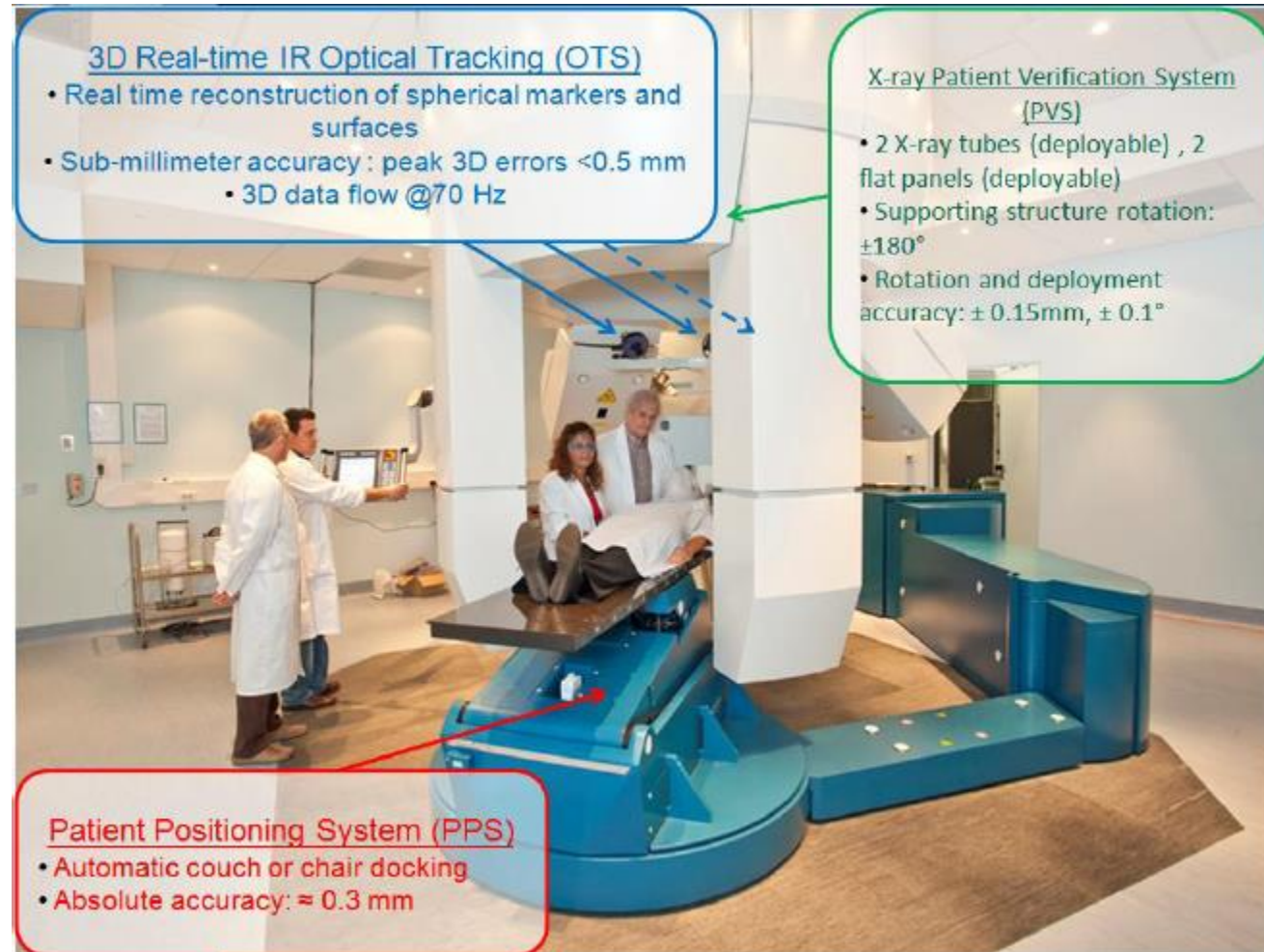
“...**Tracking** attempt to make the particle beam follow the target motion, which entails the real-time modulation of the beam direction and energy, to accurately conform the delivered dose to the target motion without increasing the treatment time...”

# Motion monitoring systems

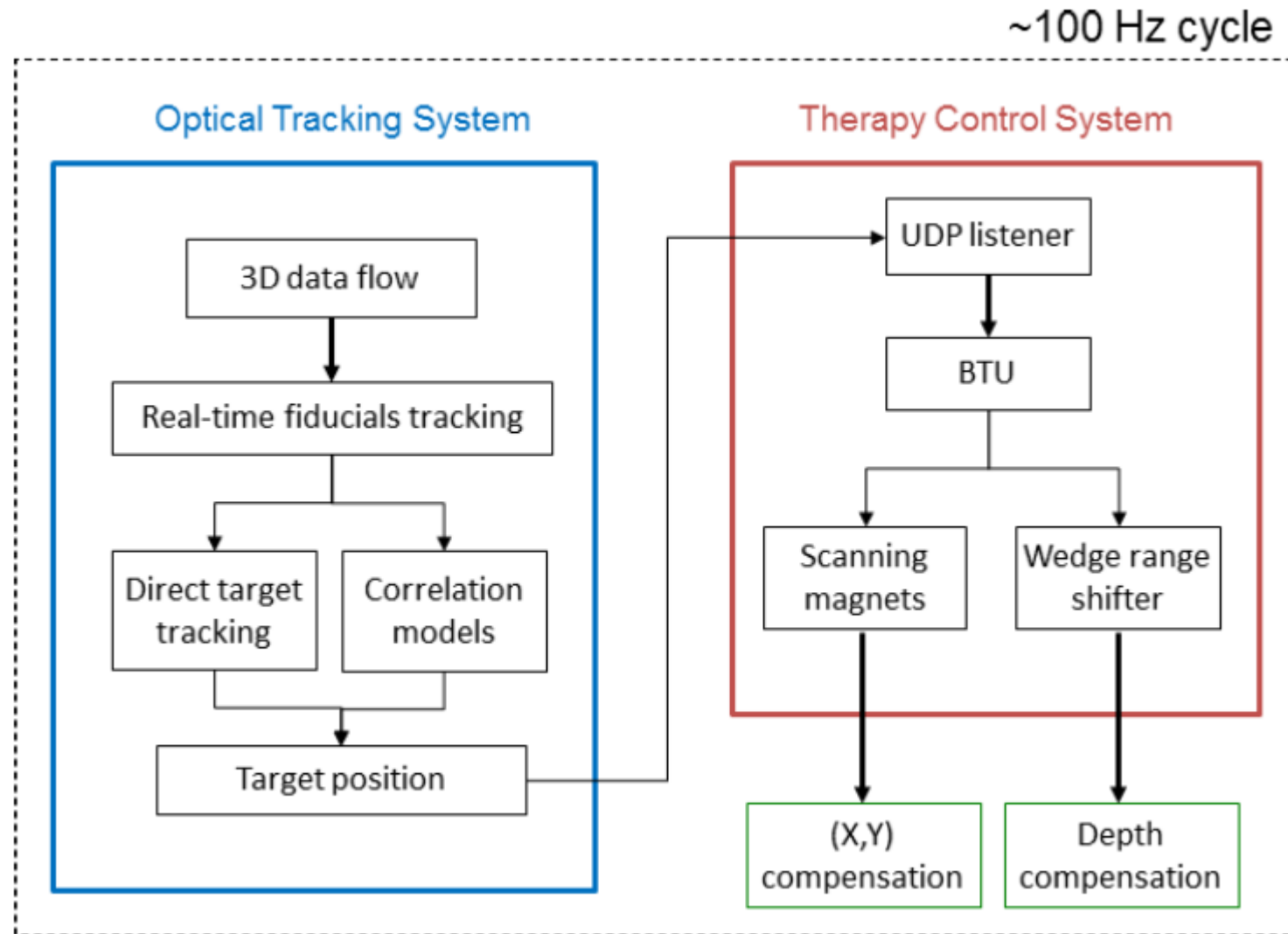




# Optical tracking @CNAO

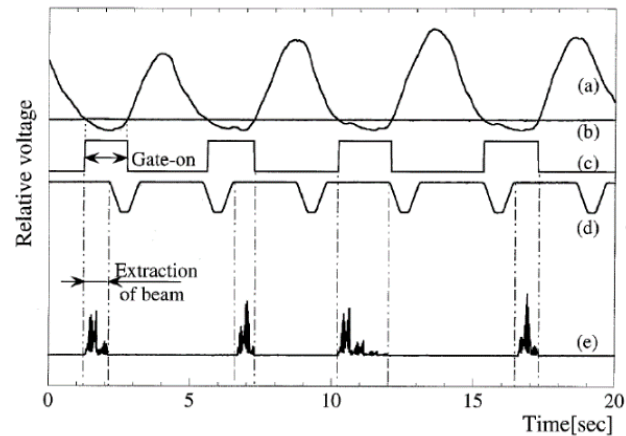


# Optical tracking framework

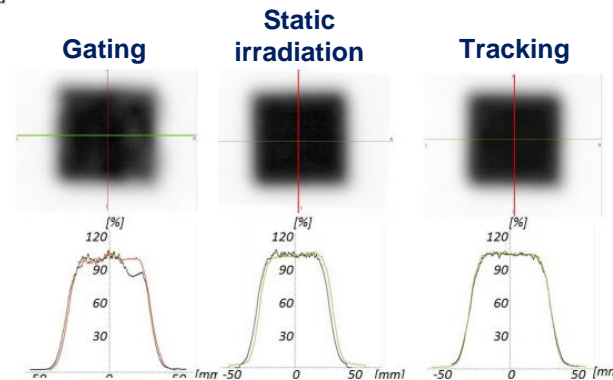
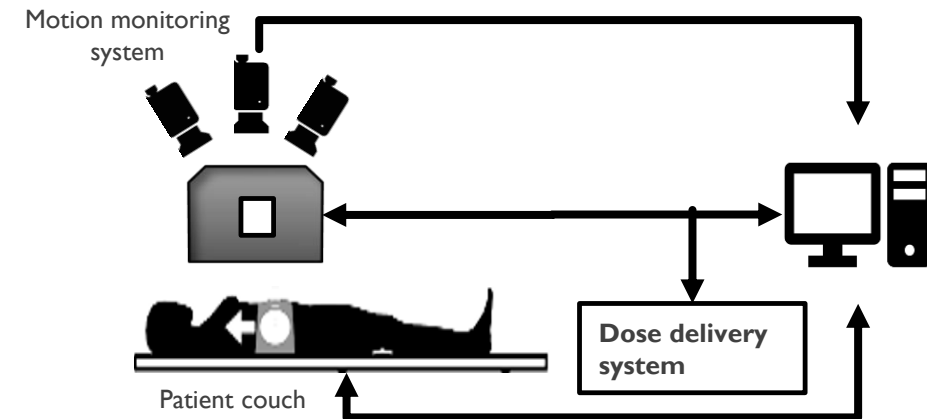


# Experimental results

## Gating & rescanning



## Tracking



- Compensates well for motion-induced interplay effect within the target volume
- Long treatment time due to breathing irregularities

- Better compensation for motion-induced interplay effect within the target volume and its borders
- Significant treatment time reduction expected
- Making better use of the extracted particle beam

# Conclusion

- The choice of a specific motion monitoring solution for PBS proton therapy is strongly influenced by the working environment and treatment unit design.
- Remaining challenge of ensuring that delivered plans are robust to range uncertainties in proton therapy.
  - Global motion models for adaptive strategies
  - Need for beam energy modulation strategy for longitudinal motion compensation
  - Real-time feedback on delivered dose variation as well as anatomical changes for respiratory correlated treatment
  - Need to perform clinical studies to investigate which approach is the best in a given clinical situation.



**Thank you !**

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# Conclusion

