IEO
Istituto Europeo di Oncologia

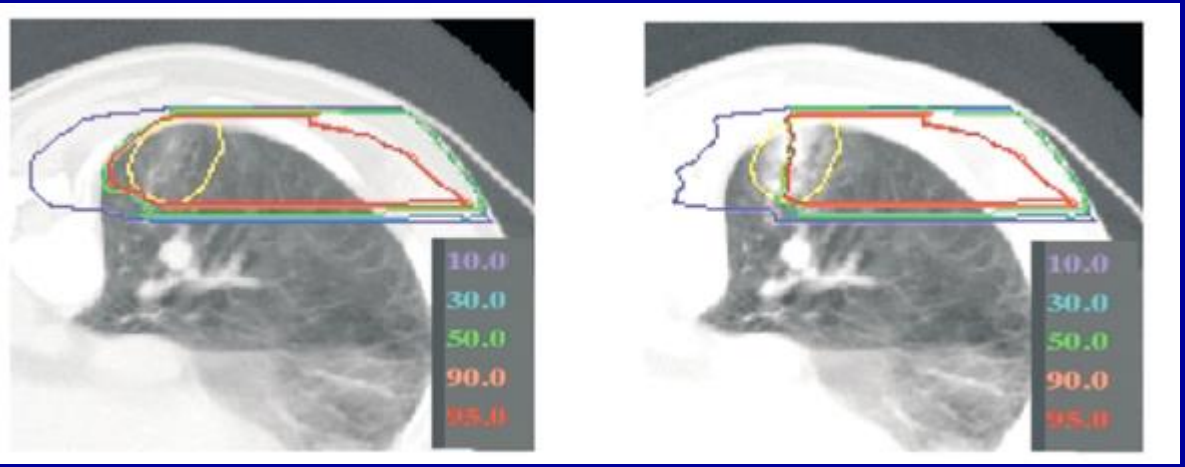
fondazioneCNAO

Treatment of moving targets with active scanning carbon ion beams

(P. Fossati)

Organ motion and particle therapy

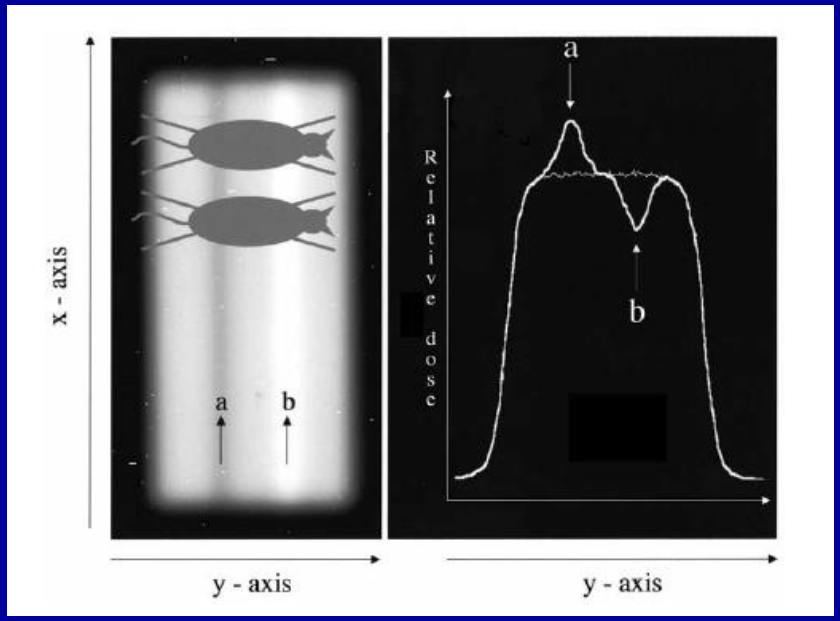
- 1 Steep gradients → (ITV , PTV)
- 2 Effect of range modification → (ITV is not enough)



Bert et al. PMB 2011

Organ motion and particle therapy

- 3 Interplay effect → unpredictable hot and cold spots



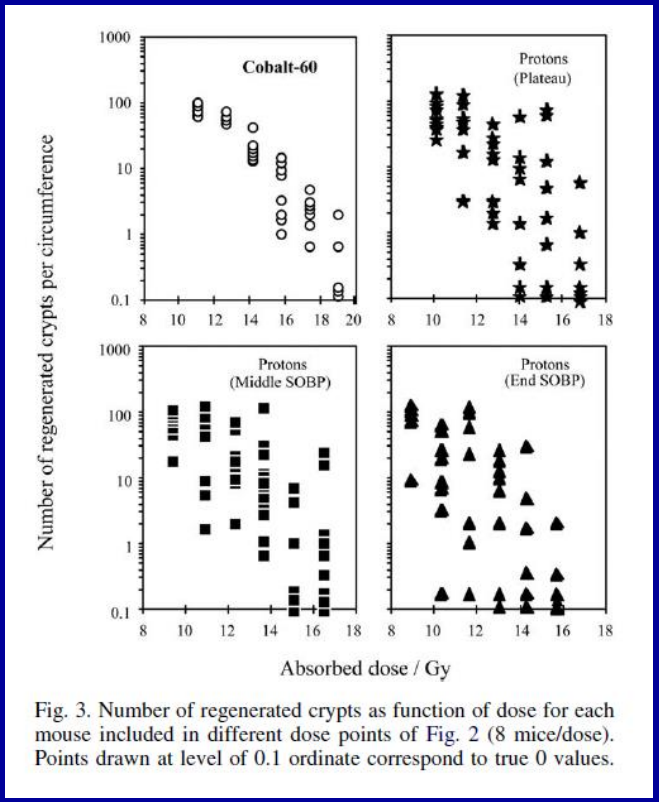


Fig. 3. Number of regenerated crypts as function of dose for each mouse included in different dose points of Fig. 2 (8 mice/dose). Points drawn at level of 0.1 ordinate correspond to true 0 values.

Guelette et al. IJROBP 2005

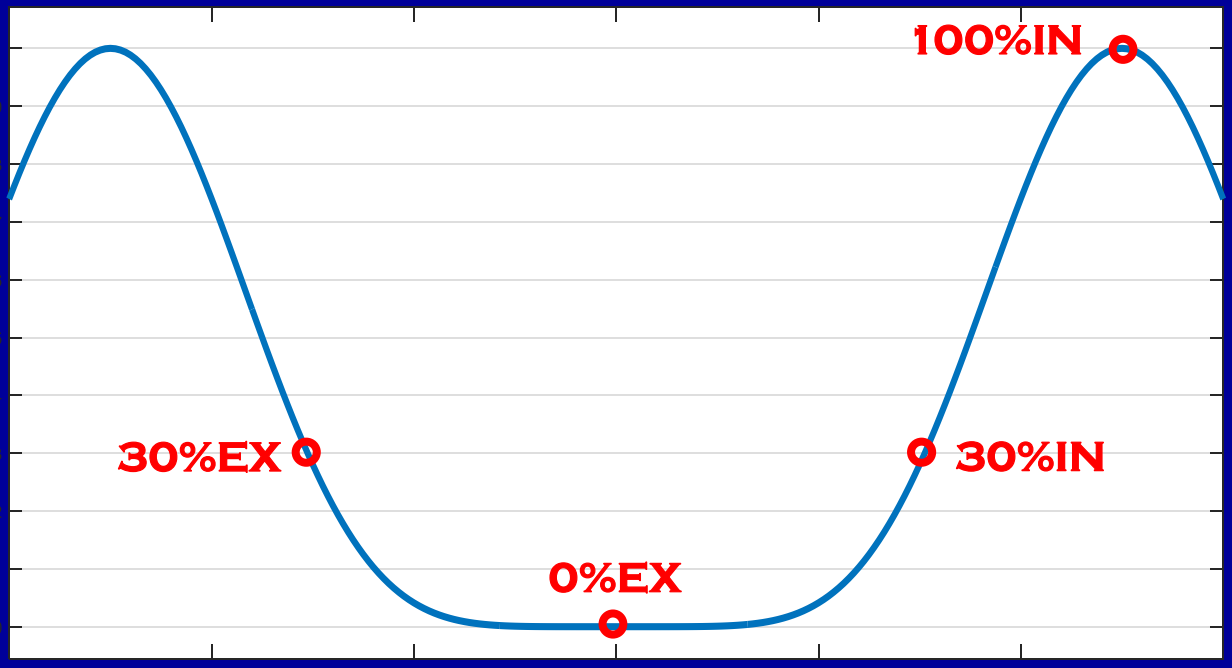
Active carbon ion irradiation of moving target at CNAO

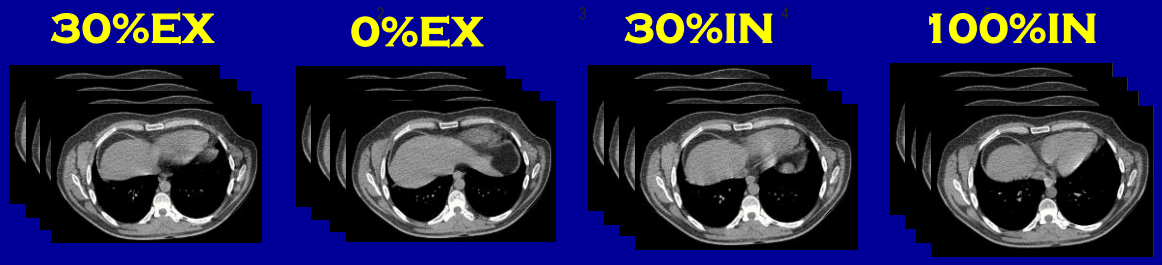
- Moderate abdominal compression
- 4D CT scan
- Plan on 0% exp phase
- Check robustness on adjacent phases and replan
- Gated beam delivery (Anzai AZ-733V) (check with optolectronic markers)
- 5 times rescanning

Abdominal compression with mask

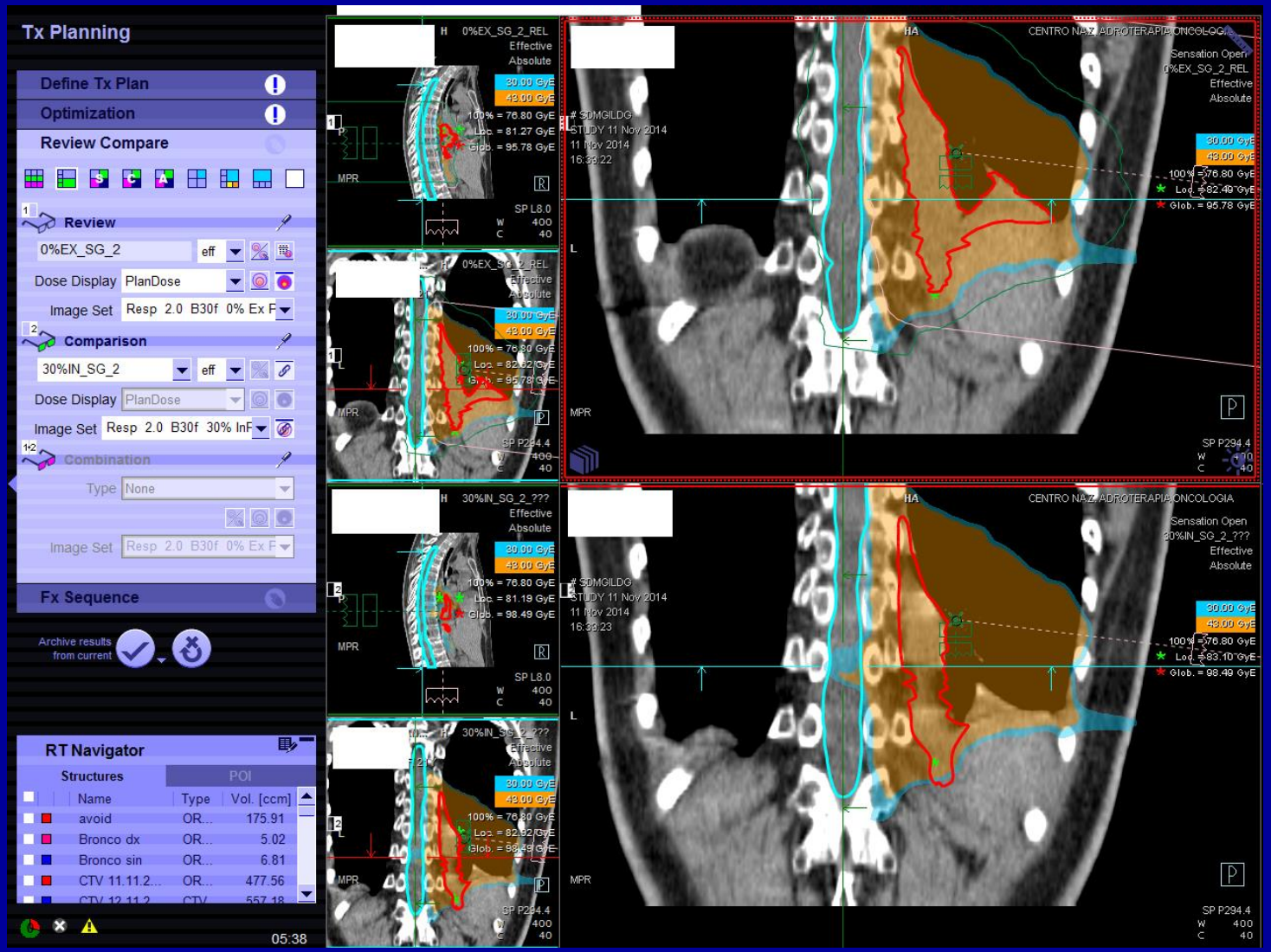
	Average diaphragm displacement mean (max)
30% inspiration	3,3 mm (8,7 mm)
30% expiration	4,6 mm (9,3 mm)
100% inspiration	5,4 mm (14 mm)

4D-CT scan

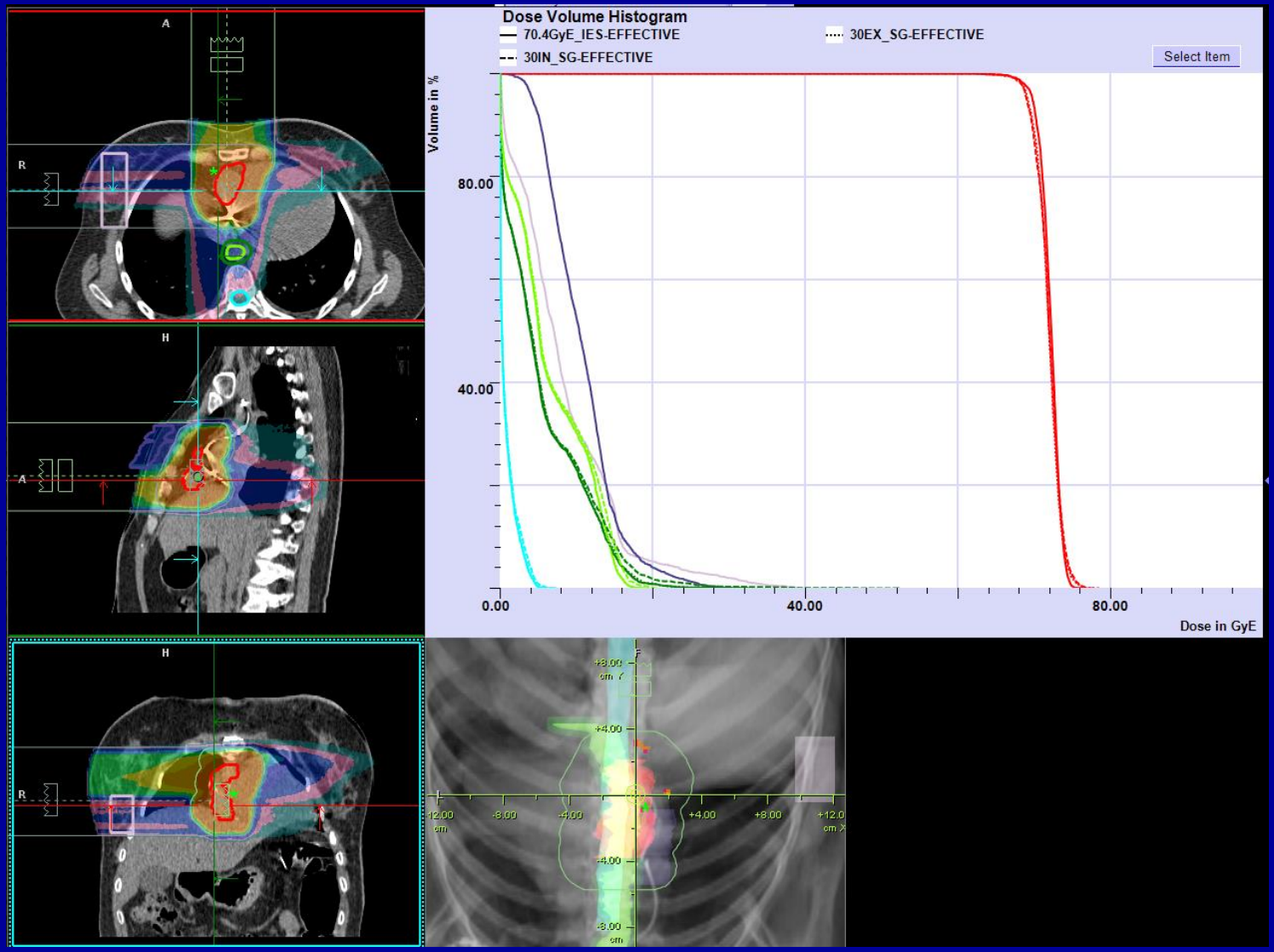




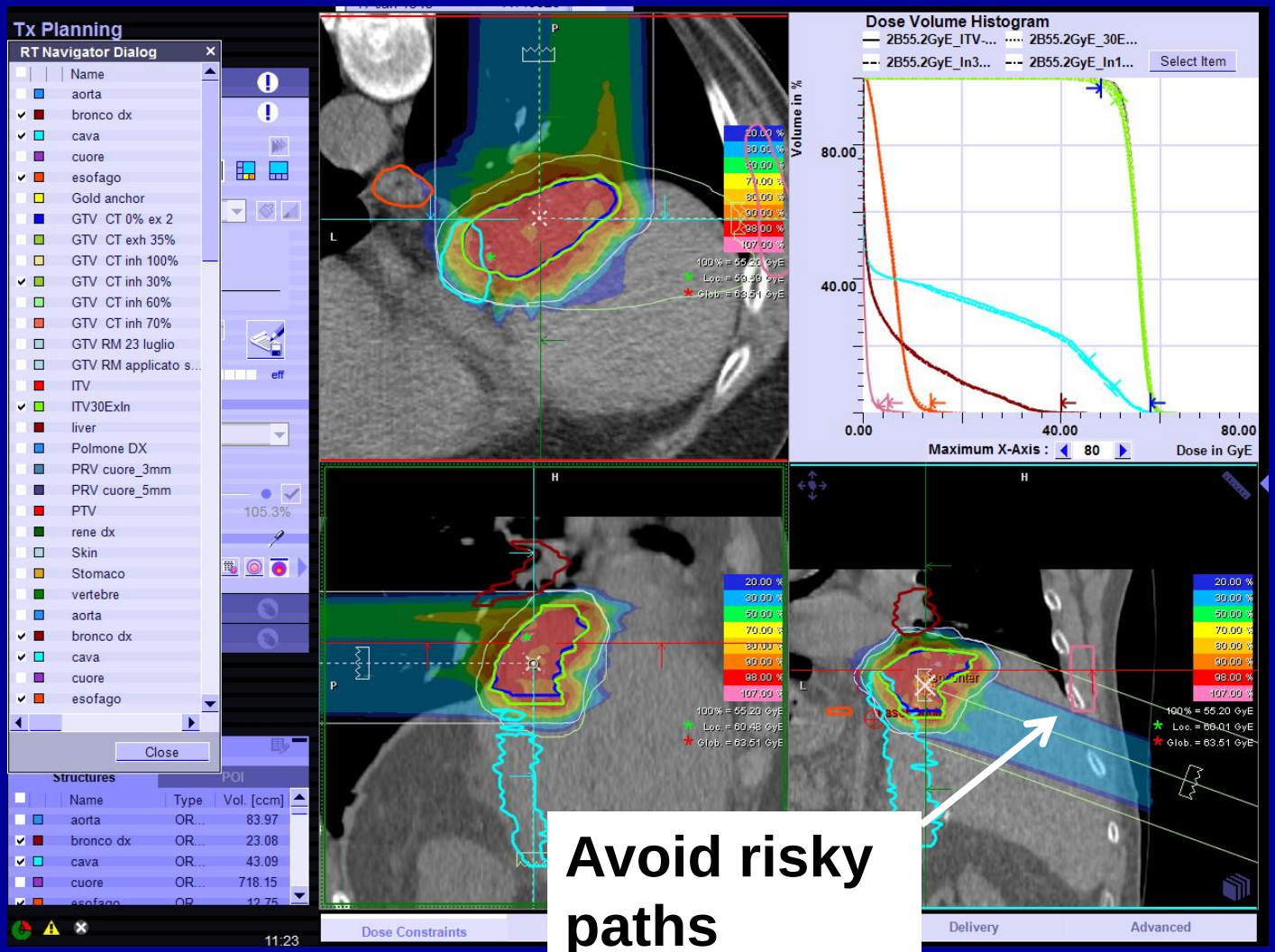
Plan on 0% EX , recalculate on adjacent phases



Plan on 0% EX , riecalculate on adjacent phases



Optimize plan and strive for robustness

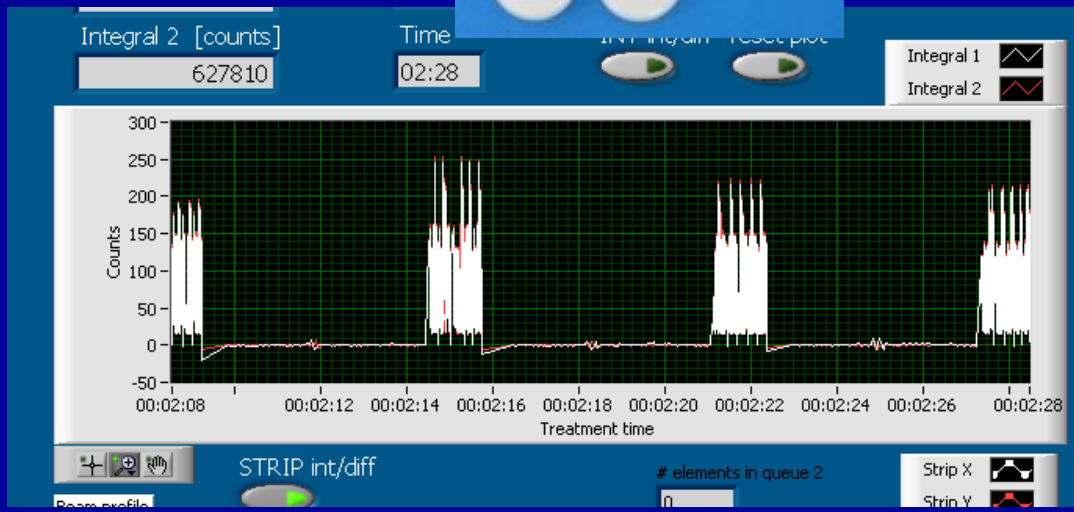


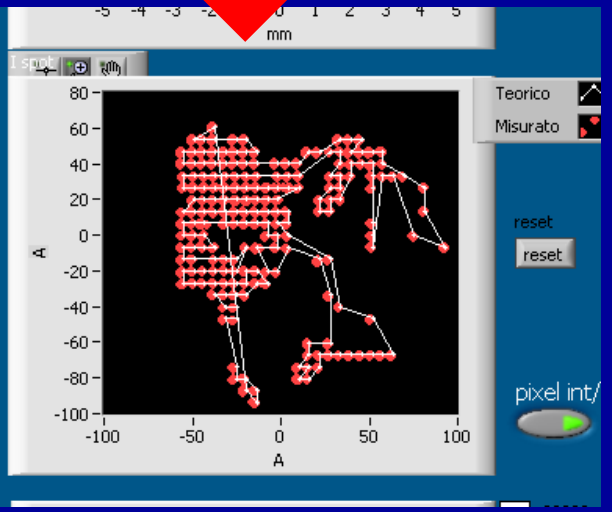
EXAMPLE OF ROBUSTNESS EVALUATION

Pancreas cancer					
ROI	Dose 0% Ex (Gy RBE)	Dose 30% Ex (Gy RBE)	Dose 30% In (Gy RBE)	Diff % 30 Ex	Diff % 30 In
D95% GTV	**33,3**	**33,5**	**33,9**	**0,6%**	**1,8%**
D1% spinal cord	**29,3**	**28,9**	**28,9**	**-1,4%**	**-1,4%**
D1% Duodenum	**32**	**32**	**31,5**	**0,0%**	**-1,6%**
D1% Stomach	**30**	**29,9**	**32,7**	**-0,3%**	**9,0%**

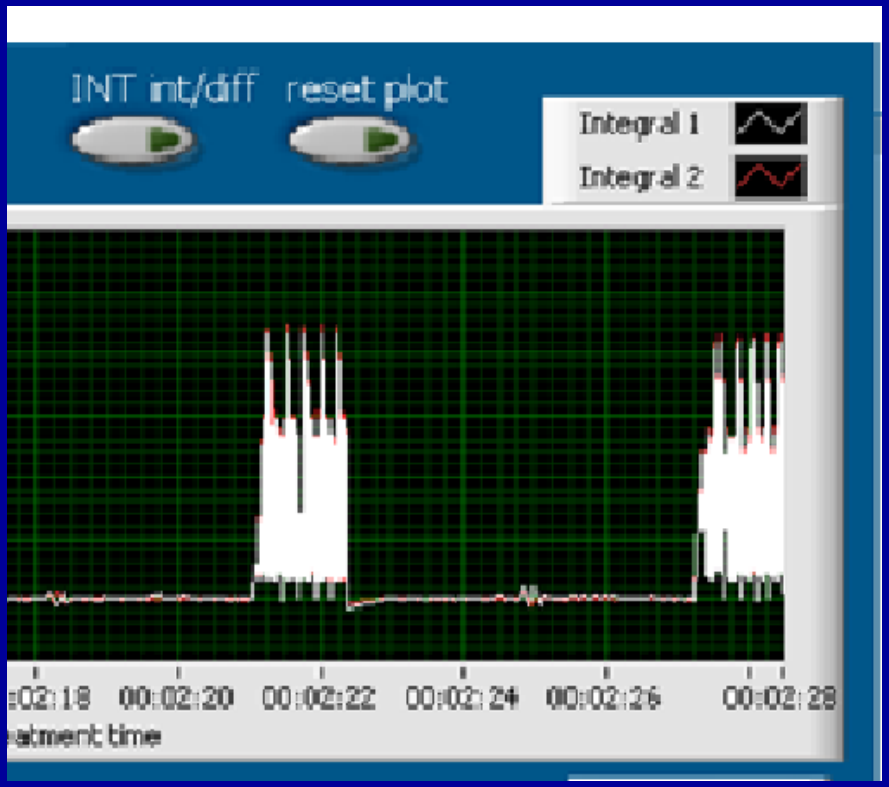
Gated beam delivery

- Gated orthogonal X rays and non-gated cone beam CT for patient set up
- Beam extraction synchronized with patient breathing





5 times rescanning

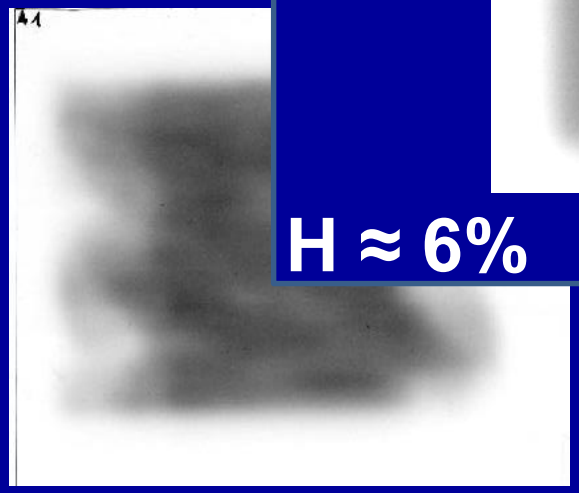


1. Static

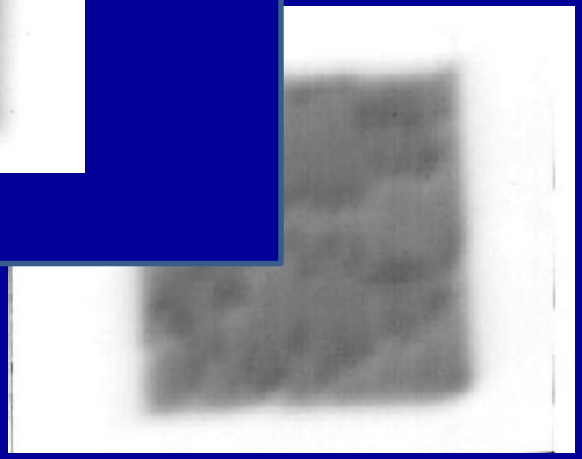
H ≈ 4%

2. Dynamic V-H

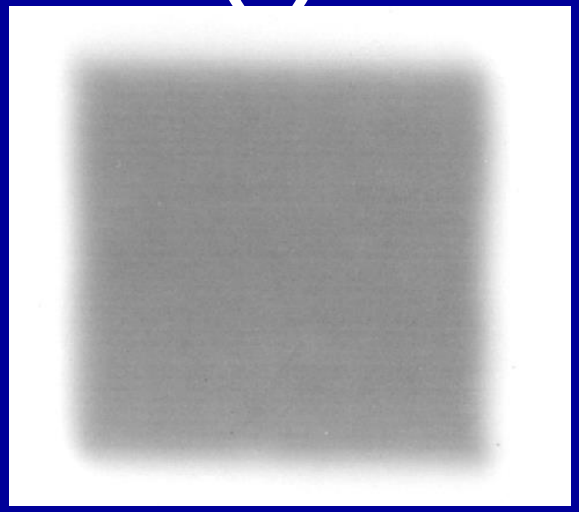
3. Repai



ating



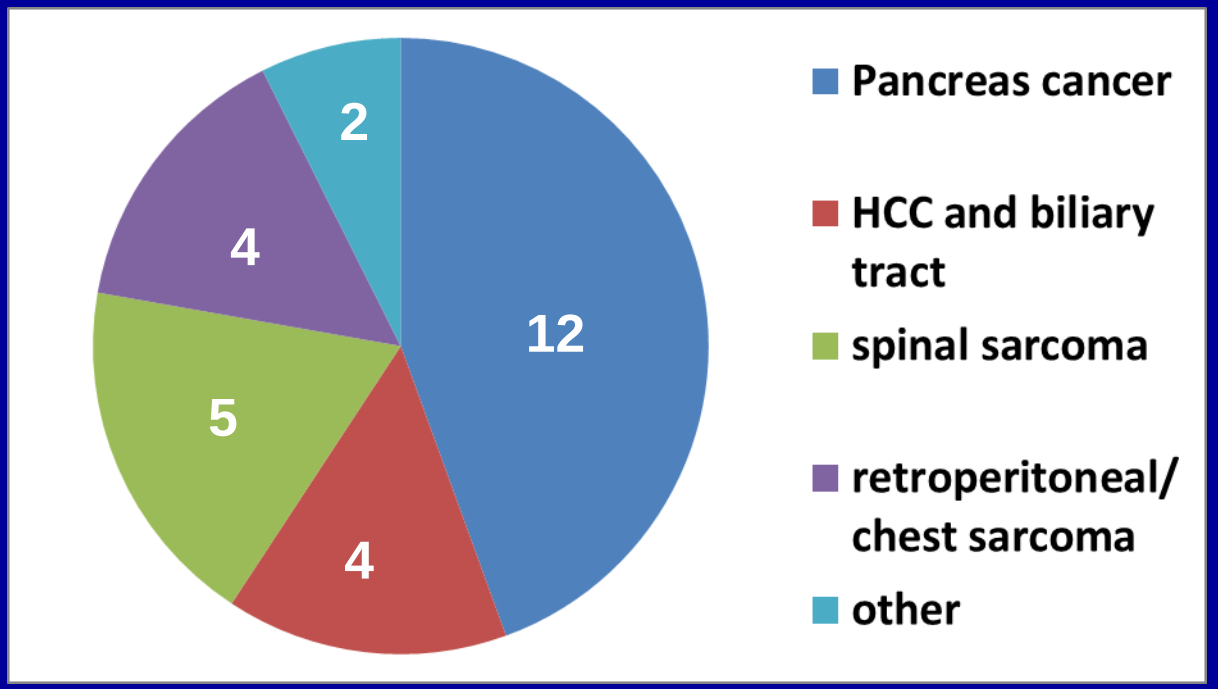
6. Gating & Repainting (5)



H ≈ 6%

TREATED PATIENTS

- 27 patients
- No lung cancer
- Short FU (median 5 months)

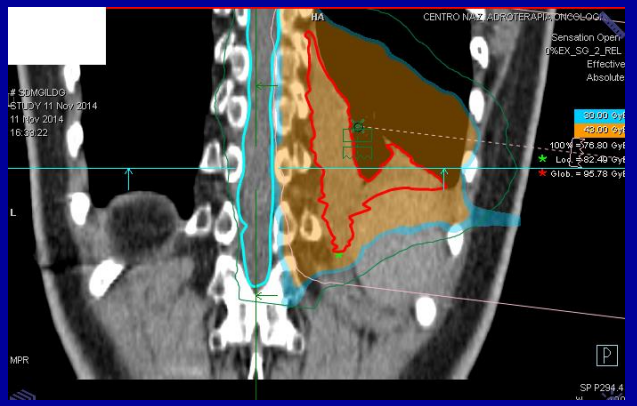


Critical OAR

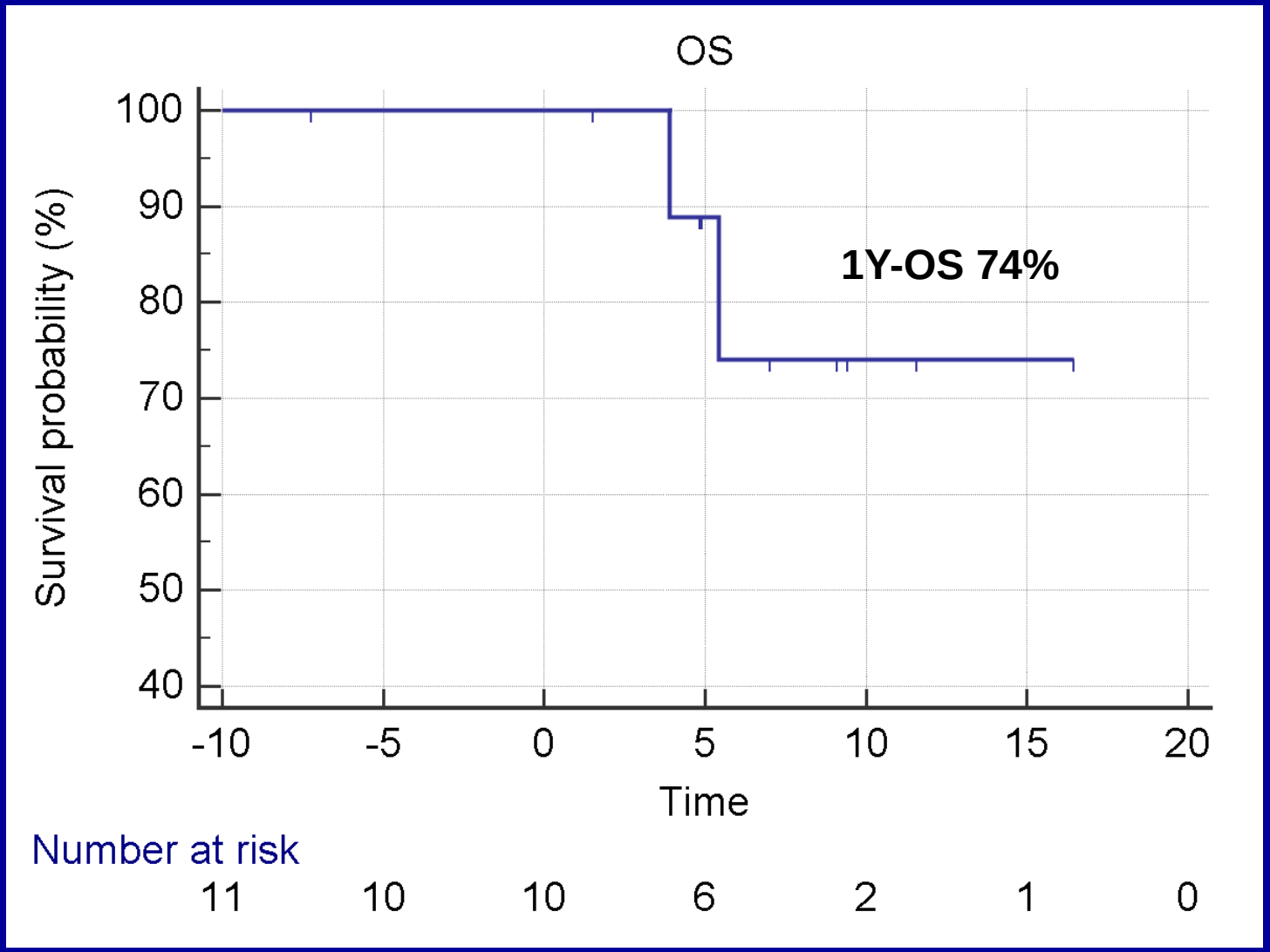
- Lung ⟶ G3 Toxicity
- Duodenum
- Small bowel
- Esophagus
- Stomac

No G3 Toxicity

- Spinal cord ⟶ Too early



Pancreas cancer OS



ADAPTIVE ?

We replan 0-3 times during therapy according to clinical judgement

What we are not doing:

- Fluoroscopy
- Phase controlled rescanning
- Dynamic dose accumulation evaluation
- Robust optimization
- 4D MR

Conclusion

- Our strategy to cope with organ motion and deliver active scanned carbon ion RT is
- **SAFE** and (probably)
- **EFFECTIVE**