WP4: Ion therapy for intra-fractional moving targets

WP Coordinators:

Dietmar Georg, MUW and Christoph Bert, GSI

Sub-workpackages

- 4D imaging: acquisition, analysis, and modelling of image data
- Motion monitoring
- Organ motion compensator for the CNAO dose delivery
- Implementation of rescanning at UKL-HD
- Quality assurance aspects of 4D ion beam therapy

Non-science information

- We had a couple of telephone conferences, video conference planned after this meeting
- Face-to-face meeting at GSI on April 28th
  - 15 participants from 9 institutions
  - Next meeting planned at CNAO spring 2011

Sub-package 4.1:
4D imaging: acquisition, analysis, and modelling of image data

Who are we?

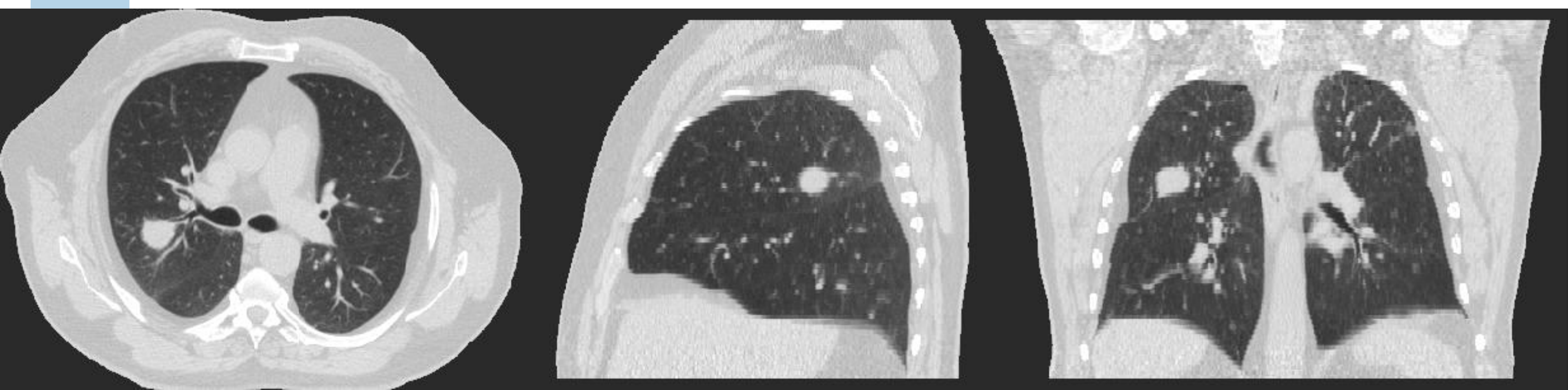
- Joël Schaerer (Lyon)
- Aurora Fassi (Milano)
- David Sarrut (Lyon)
- Guido Baroni (Milano)

→ Working at Léon Bérard Cancer Center, Lyon

Objective (JRA 4.2 & 4.5)

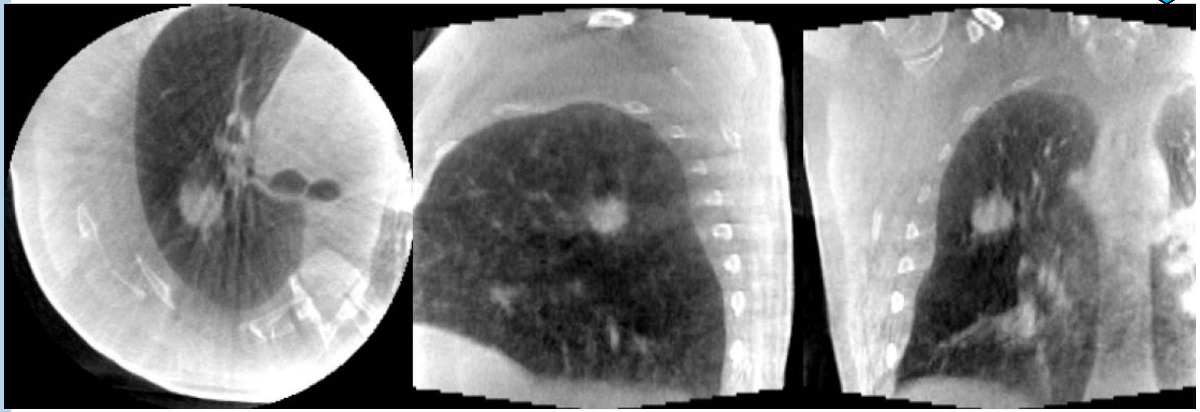
- Study and model external and internal **respiratory motion**. Propose a method for **internal tumor tracking** using the non invasive VisionRT optical system

1) Phillips 4D CT Scanner



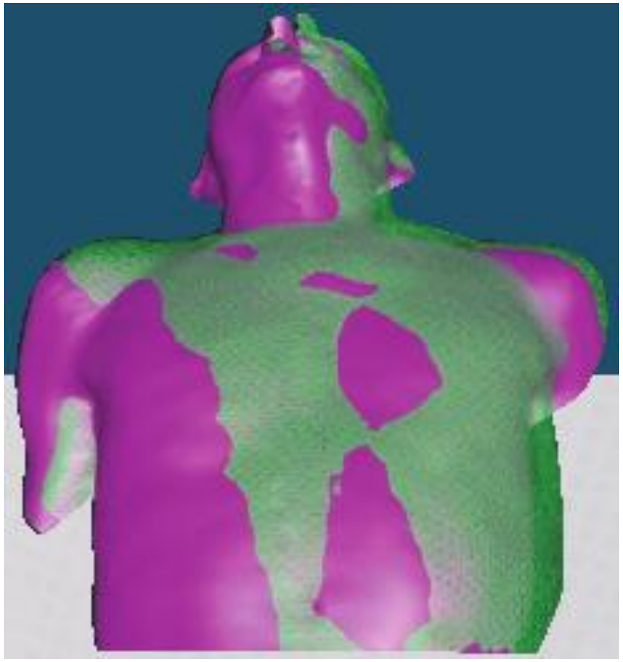
2) Elekta Cone-Beam

Reconstruction
(4D available [Rit '05])






3) VisionRT optical tracking system






Multimodality respiratory motion database for thoracic cancer

Objective

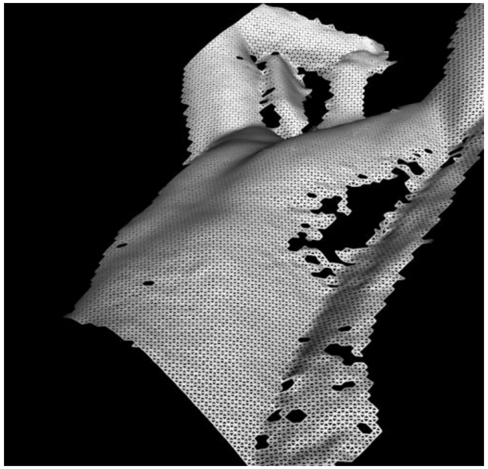
Acquisition of synchronized internal & external information to study the correlation and variability of respiratory motion

Included subjects

16 Non-Small Cell Lung Cancer (NSCLC) patients treated at Léon Bérard Cancer Center in Lyon, France

Content (per patient)

- 4DCT images (2-3 mm slice spacing) → 900 MB
- one/two CBCT acquisitions per treatment session (on average 10 CBCT per patient) → 3.5 GB
- synchronized VisionRT optical surface acquisitions during each CBCT → 2 GB
- continuous VisionRT acquisitions (>5 min) during treatment delivery → 3 GB



Database will be available via http to all ULICE project members

Link to WP11?

Department of Bioengineering

C.A.R.T Lab – T.B.M Lab

POLITECNICO DI MILANO





FP7 ULICE Project - JRA Pillar

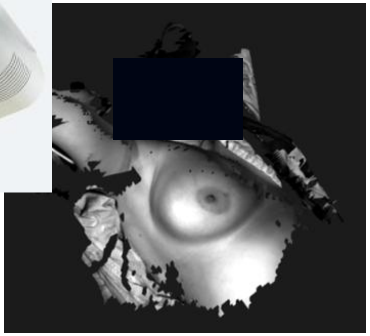
WP 4 – Ion therapy for intra-fractional moving targets

4.2 Motion Monitoring

Guido Baroni - Marco Riboldi

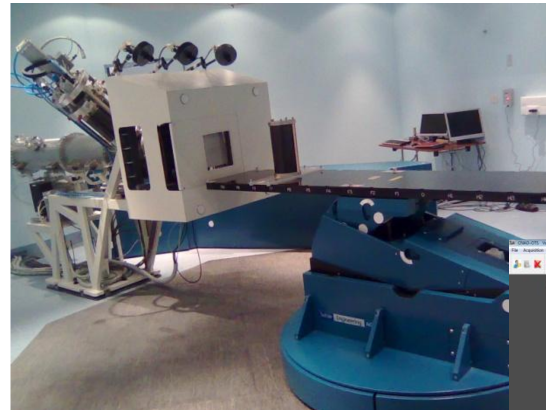
WP 4.2
Technology development

- Motion tracking technologies:
  - Passive marker based systems
    - based on NDI technology
    - Support commercial systems in conventional radiotherapy (BrainLab ExacTrac)
    - Inter-fractional set-up errors detection and compensation by means of corresponding points registration
    - Breathing phase detection capabilities (Varian RPM)
  - Surface detection technologies
    - Avoid patient manual marking
    - Inter-fractional set-up errors detection and compensation by means of not-corresponding points registration (ICP algorithm and variants)
    - VisionRT (UK) most succesful among commercial systems
    - C-Rad Sentinel (S) among competitors
    - Breathing detection capabilities via small ROI real-time tracking (not-corresponding)
  - Hybrid custom-made system (JRA 4.2)
    - enhance flexibility by featuring detection of passive markers and laser patterns
    - Inter-fractional set-up errors detection and compensation by means of constrained not-corresponding points registration
    - Breathing detection capabilities based on passive control points

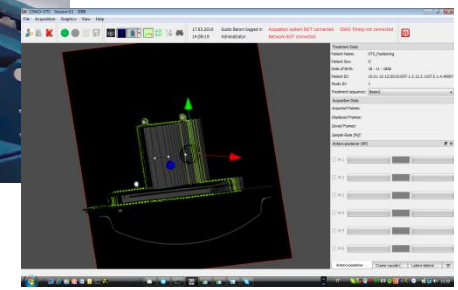


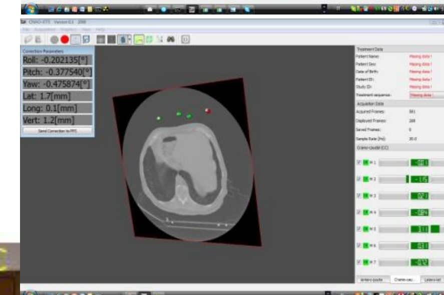
1. <u>Hybrid motion tracking</u>:

- based on commercial general purpose motion analysis technology (SMART-D system, BTS, Italy)
- based on off-the-shelf general purpose motion capture system (BTS, Spa)
- 3 IR digital TV cameras configuration
- 512x512 image resolution @70 Hz
- automatic recognition and 3-D reconstruction of :
  - co-operative passive markers (1 cm diameter)
  - laser spots projected on patient skin
  - programmable laser pattern projector synchronized with TVC acquisition (optimal sync for maximal spot number per frame is ongoing work)
- peak error in control points 3-D identification (1 m^3 working volume) lower than 0.5 mm
- automatic point-based, surface-based and constrained iterative registration featuring 6 dof with correction vector computation
- breathing detection capabilities based subset of markers (optimal selection, if any, is ongoing work)



Motion tracking TVC set-up @ CNAO (bunker 1)





Motion tracking application snapshot

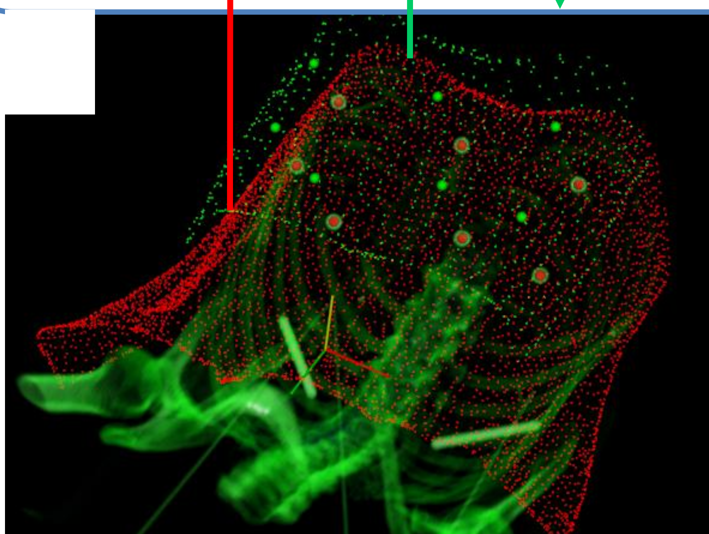
Laboratory set-up for hybrid surface surrogates acquisition and registration

WP 4.2
Methods development

Passive markers

CT localized markers

Current markers



CT body contour

In-room detected surface patch

Surfaces

- Constrained registration (ICP based) (C++, open sources libraries)
- Tests on phantom and patient data
- Algorithm evaluation by varying number of passive markers and tolerance relocalization value
- Comparison of implementation with respect to standard contrained minization algorithms (MatLab)
- Influence of model spatial resolution

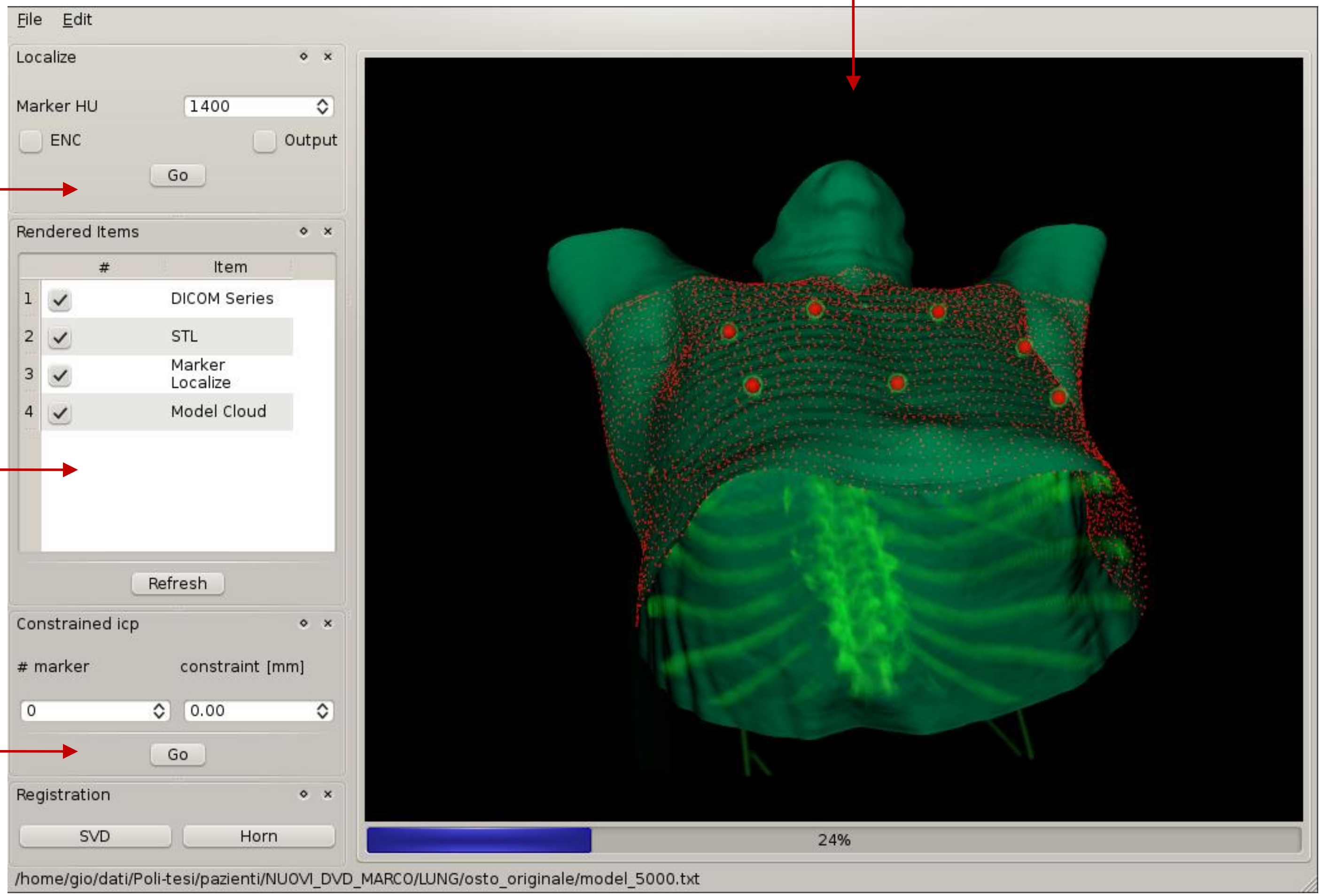
WP 4.2
SW integration

Render Window

Marker localization

Actors on screen

Constrained hybrid registration



WP 4.3: Organ motion compensator for CNAO Dose Delivery

F2F meeting ULICE WP4 – GSI (Darmstadt)

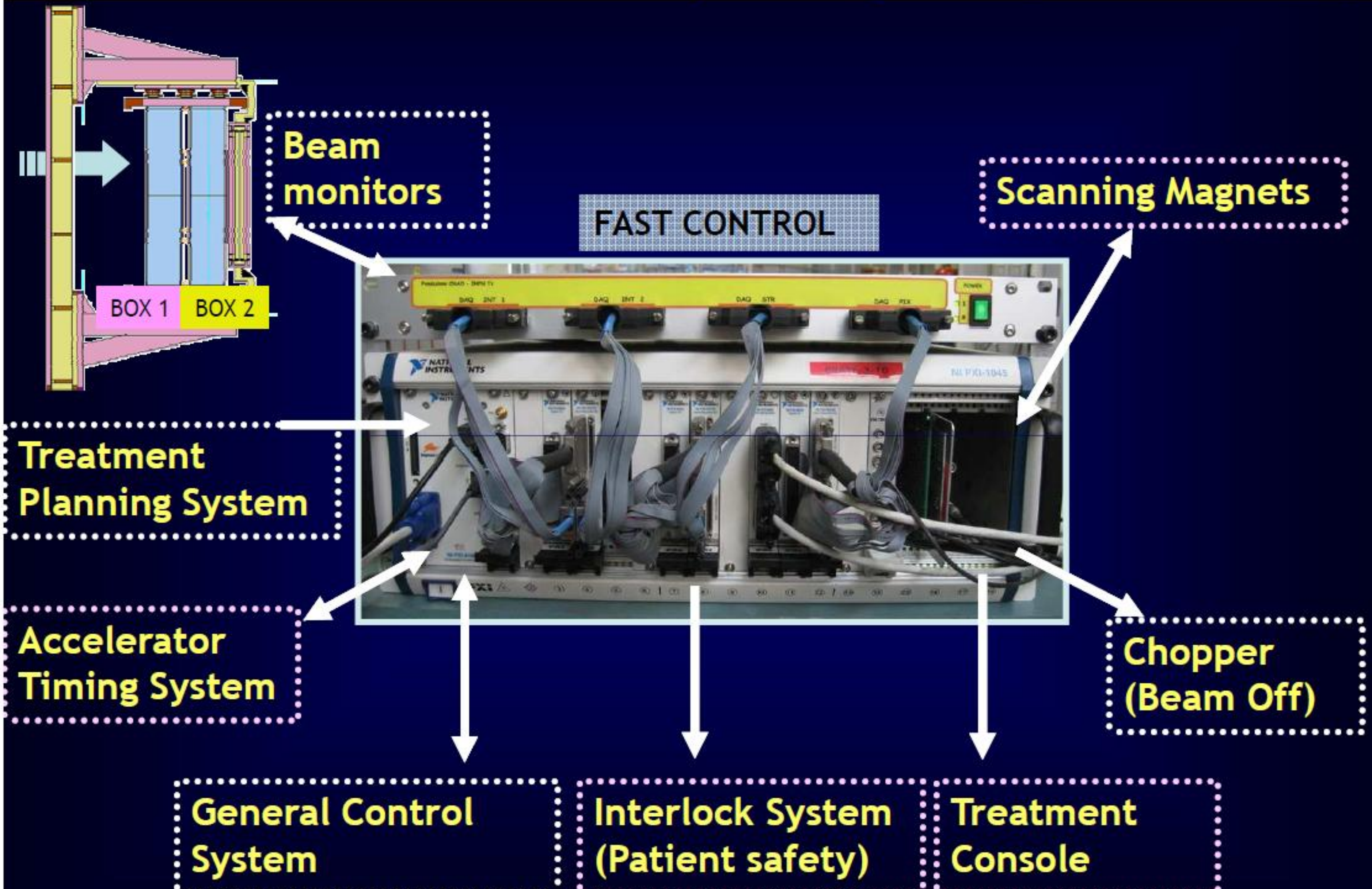
F. Marchetto (INFN-Torino)

- Introduction to the CNAO Dose Delivery
- Organ motion compensator for the CNAO Dose Delivery: a first lookout

fondazione CNAO

INFN

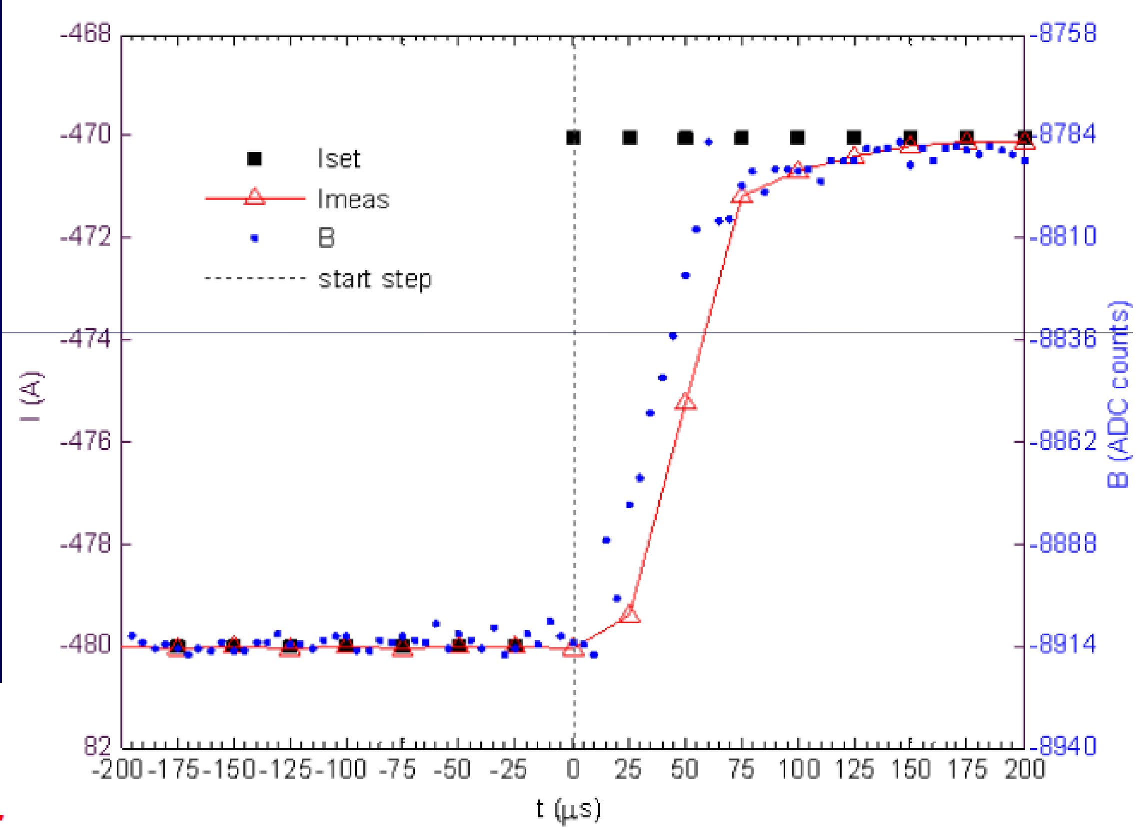
Dose Delivery Interfaces (Fast Control)



Magnet speed and time behaviour

Several measurements have been focused to characterize the time performance of the scanning system as a function of the magnet current and the step amplitude.

Example: measurement of the current and magnetic field as a function of time during a 10 A step from -480 A to -470 A



■ Iset (A) → Current set by the Dose Delivery (40 kHz).

Δ Imeas → Current read by the Power Supply control loop (40 kHz).

● B (a.u.) → Hall probe measurement in arbitrary unit (200 kHz).

10 A step → ~ 3.3 mm for C^{6+} at 270 MeV/u

• Looking for a post-doc (electronic engineering background)

• Necessary to define a transmission protocol (WP4.2 is involved) to exchange the movement phase or directly the organ movement in both directions during the treatment

• Position approved by INFN administration
• Appointment will start asap

For the movement in the transverse plane (X,Y):

• Add a FPGA card upstream the FPGA4 (magnet control) to:

a) Store the movement amplitude as a function of the phase

b) Compute the shift in the transverse plane as a function of the phase

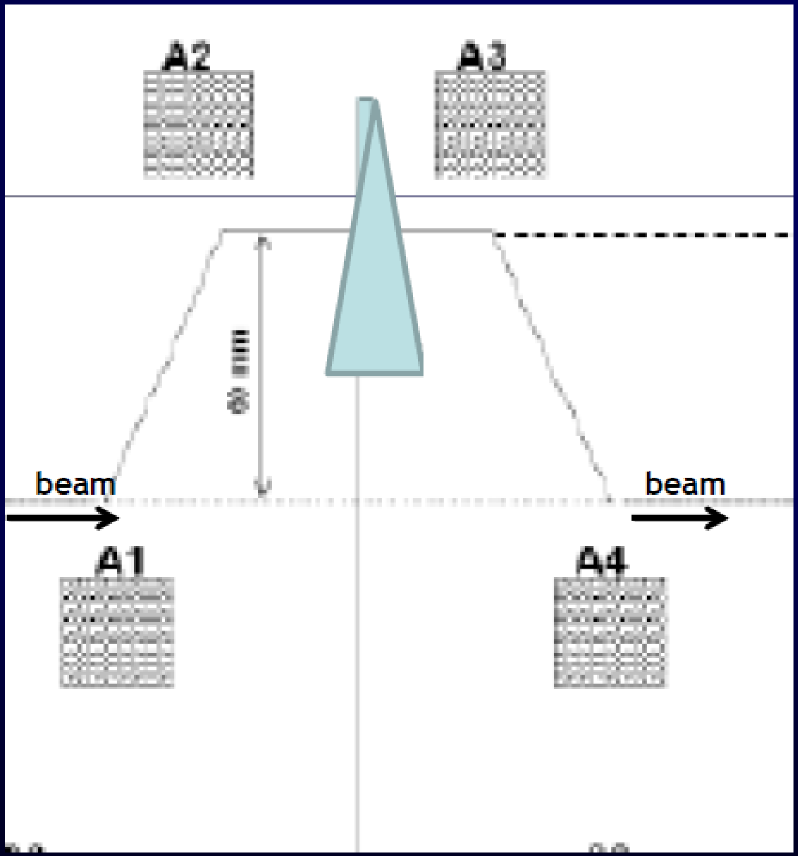
c) Apply the computed shift to the actual deviation of the beam to obtain the corrected beam steering

If from WP4.2 we obtain directly the organ movement then the problem is much simpler and only c) is necessary

• Organ movement along Z

This is much more complex and we have not a strategy yet

In general if there is a reasonable space along the extracted beamline we would like to insert an achromat (a set of 4 dipoles) to displace the beam and set it back

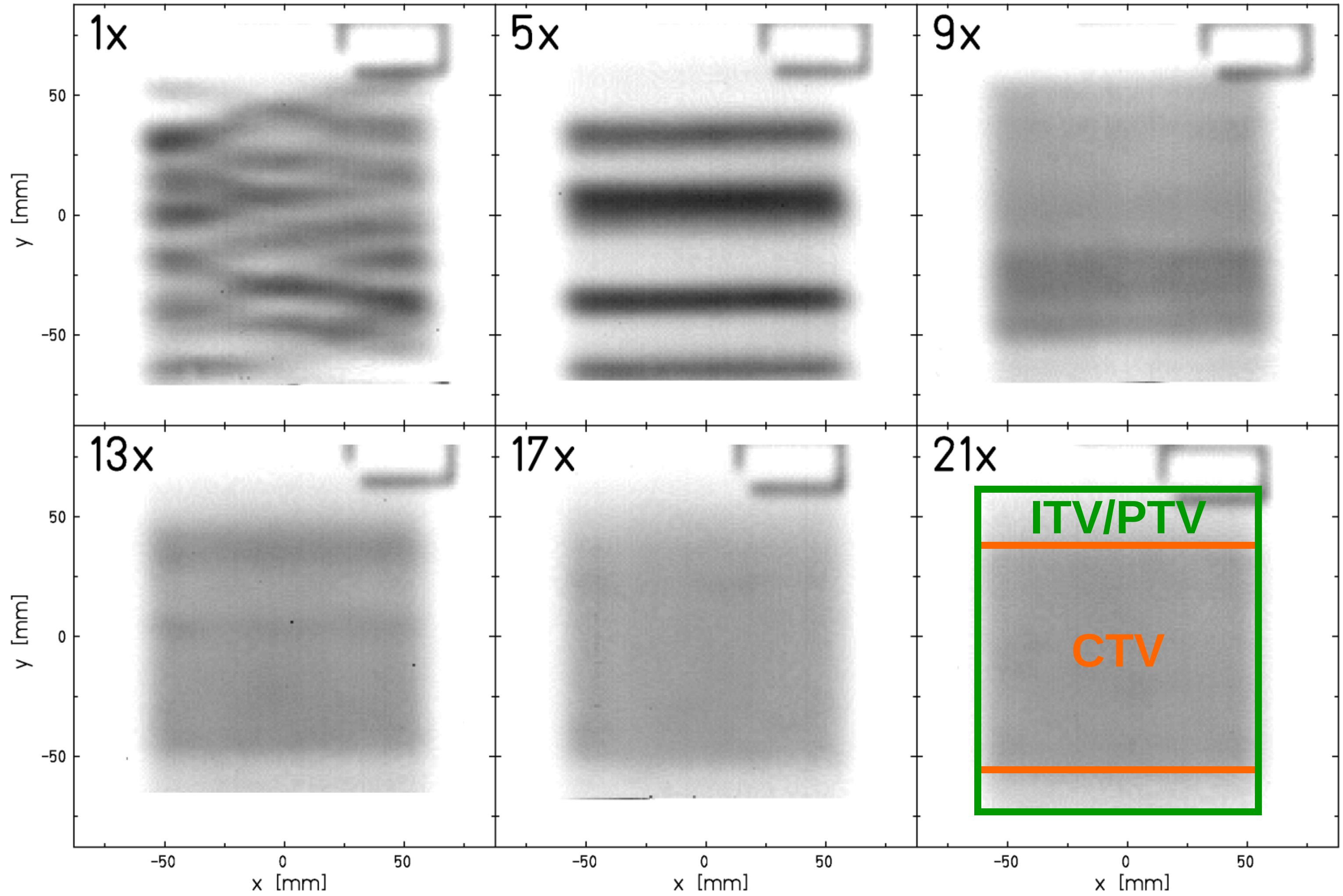


WP 4.4: Implementation of rescanning at UKL-HD

Dirk Müssig, Christoph Bert

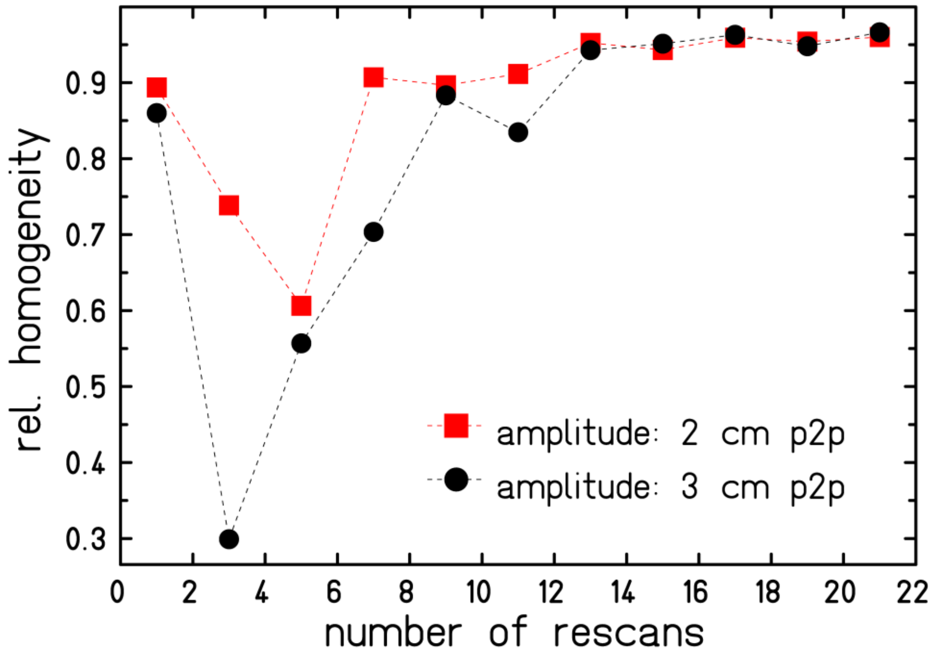
GSI Darmstadt, Germany

Rescanning – experimental data

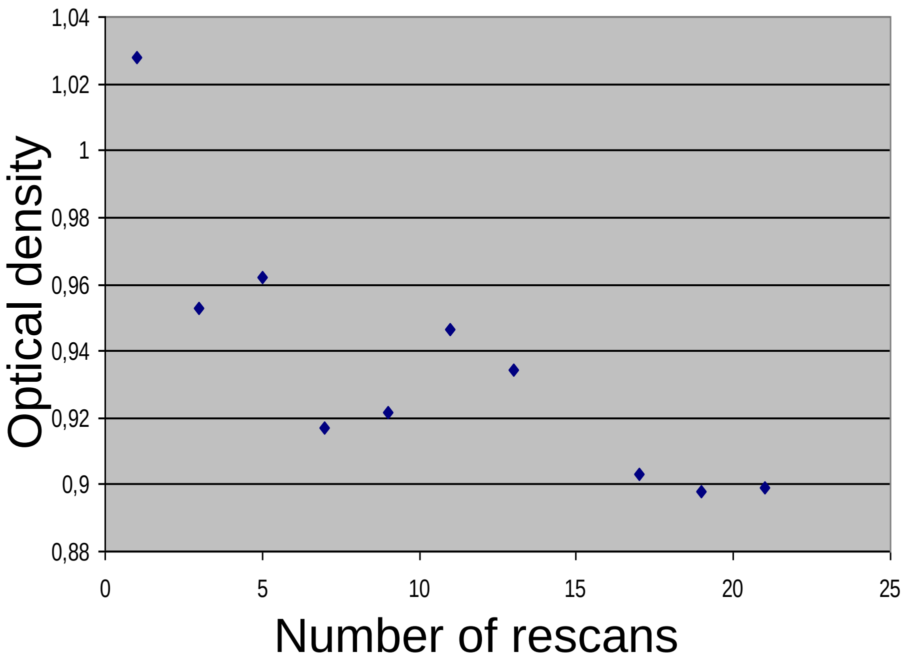


Rescanning – Experimental Data

Homogeneity

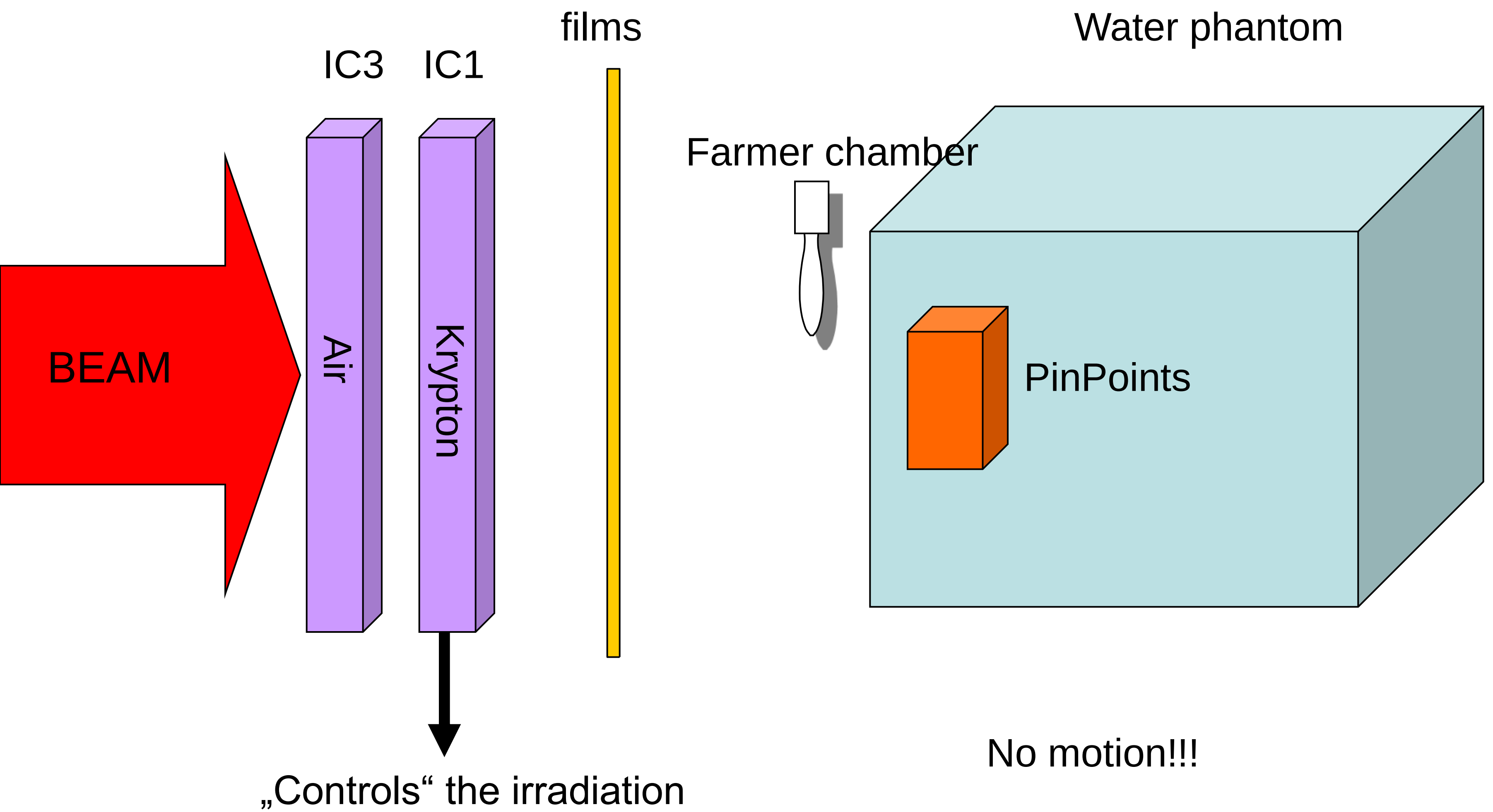


Optical density



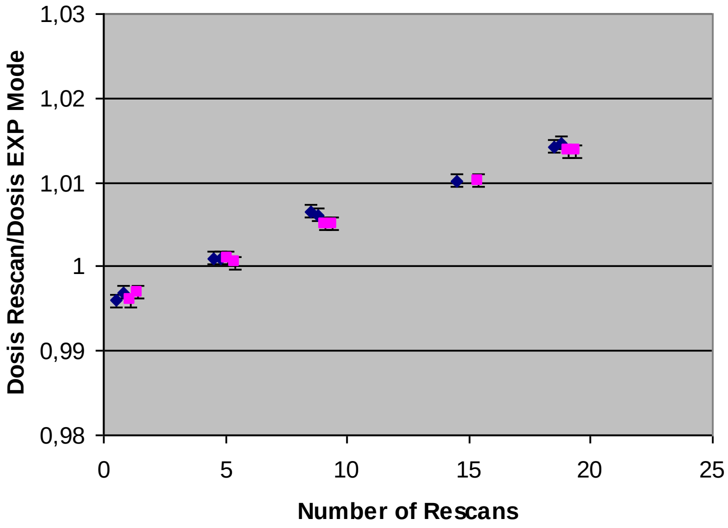
Decreasing optical density due to Rescanning?

Rescanning – Dosimetry Setup



Preliminary results

- No rescan effect for beam monitor ionization chambers and Farmer chamber (in plateau of Bragg Peak)
- Effect for parallel plate IC filled with air (but absolute values small)
- Large effect for radiographic films – analysis ongoing



Division of Medical Radiation Physics

Department of Radiotherapy

Medical University of Vienna / AKH Vienna

Sub-workpackage 4.5:

Quality assurance aspects of 4D ion beam therapy

IMAGING DOSE TO VARIOUS ORGANS AT RISK DURING IMAGE-GUIDED RADIOTHERAPY IN THE THORAX REGION

Åsa Palm, Markus Stock, Dietmar Georg

Department of Radiotherapy, Medical University of Vienna, Austria

IGRT modalities used

- ***kV Imaging Devices***
  - ➔ *CBCT at the Elekta Linac*
  - ➔ *CBCT at the Simulator*
  - ➔ *Siemens MultiSlice-CT*
  - ➔ *ExacTrac x-ray*
  - ➔ *Planar Imaging on Linac*
- ***MV Imaging Devices***
  - ➔ *Portal Imaging*
- ***Next steps - evaluate:***
  - ➔ *(PET)-CT (4D-CT) @ MUW*
  - ➔ *IBA imaging solutions*
  - ➔ *Imaging options @ CNAO*
  - ➔ *Imaging options @ HIT*

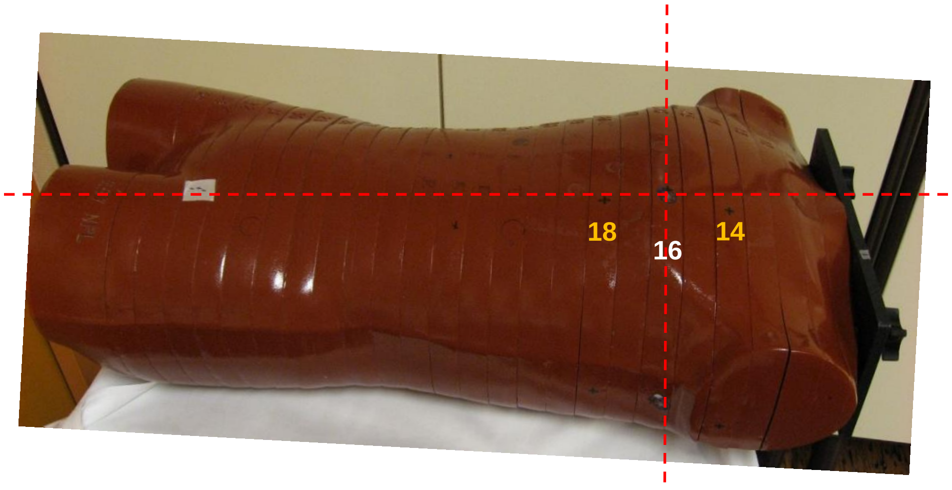
3D (CBCT at the Elekta Linac, CBCT at the Simulator, Siemens MultiSlice-CT)

2D (ExacTrac x-ray, Planar Imaging on Linac, Portal Imaging)

Measurement positions

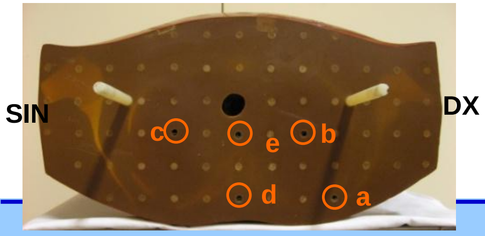
TLD placement :

Slab	Organ	„Measurement position“
13	Chestwall	a
	Lung contralat	b
	Lung ipsilat	c
	Spine	d
	Esophagus	e
14	Bronchus	f
	Skin (ap, pa, rl, ll)	
15	Heart	g
	Vertebrae	h
16	Chestwall	i
	Lung contralat	j
	Lung ipsilat	k (iso)
	Spine	l
	Esophagus	m
	Skin (ap, pa, rl, ll)	
18	Skin (ap, pa, rl, ll)	

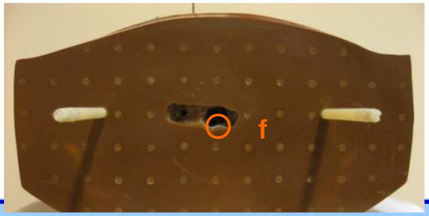


Iso

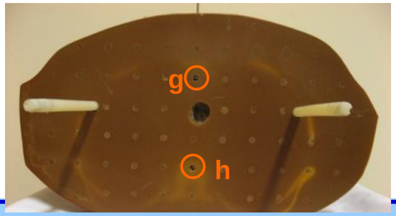
Slab 13



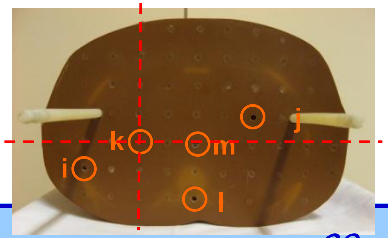
Slab 14



Slab 15

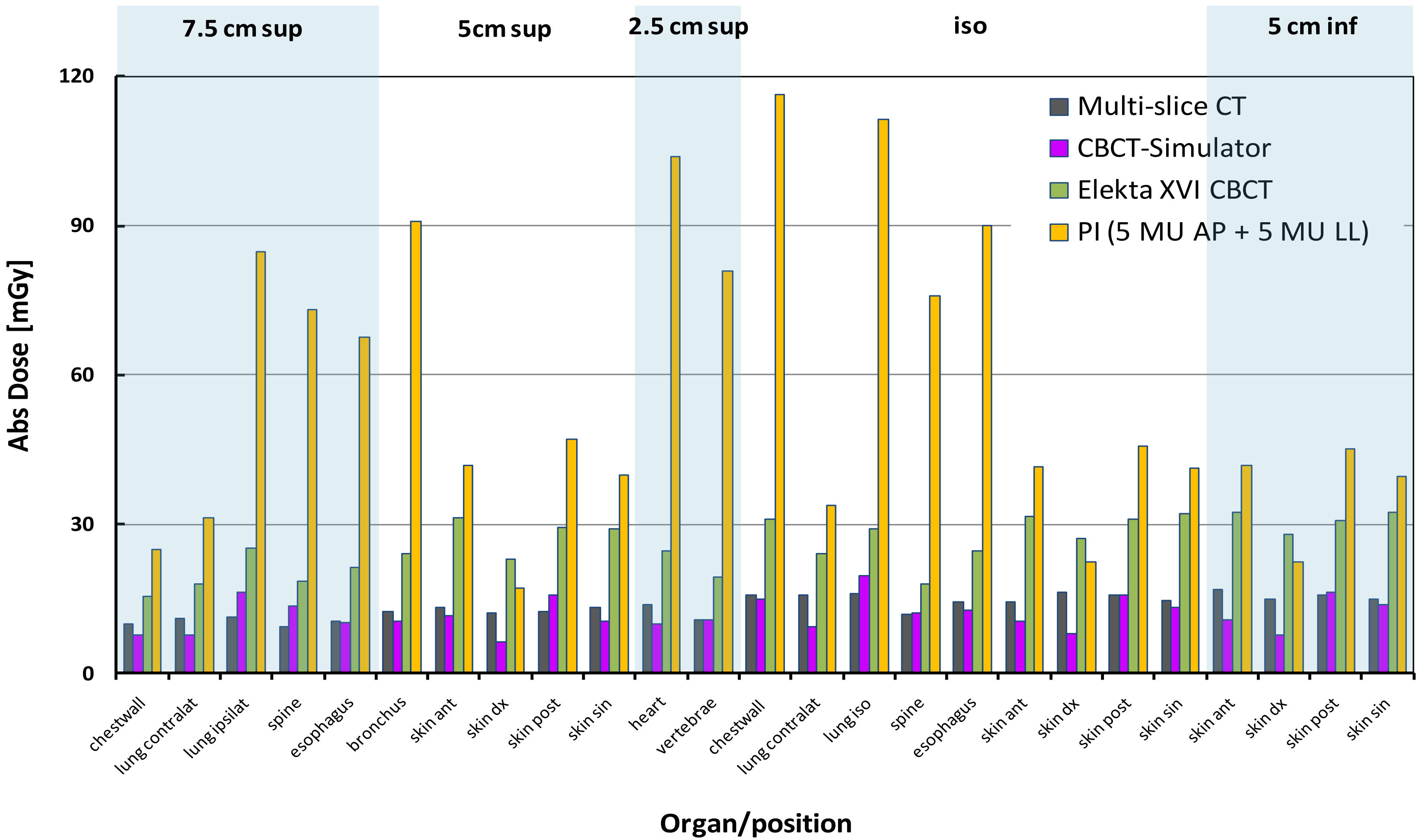


Slab 16



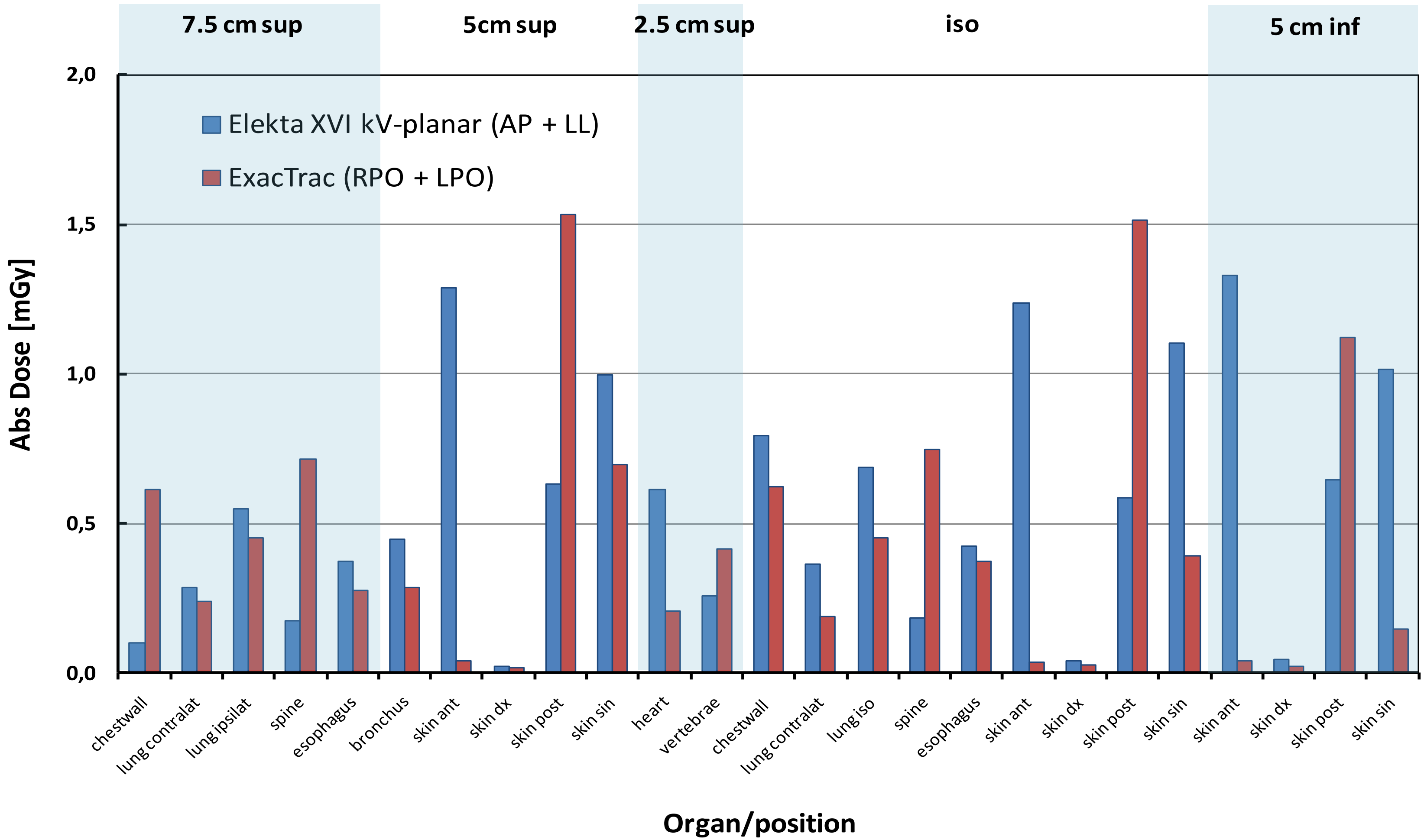
Results

- ***Absorbed dose per imaging procedure: 3D modalities, and PI***



Results

- ***Absorbed dose per imaging procedure: 2D kV modalities***



Summary/Conclusions

- Sub-WP starting working
- Data base offered by WP 4.1 (Lyon)
  - Could be hosted by Heidelberg's infrastructure (WP11)
- Exchange between institutions already ongoing (Milano/Lyon)
- Regular contact via telcon/videocon and face-to-face meetings