Deutsche Gesellschaft für Medizinische Physik e.V.

DGMP

Gemeinsames Treffen **des Arbeitskreises IMRT** *und* **der Regionalsektion Nord**

27./28.03.2014

Braunschweig
Bildungszentrum, Naumburgstraße 2

High-Precision Kamera-Verfahren mit Triangulationsmethoden während der Strahlentherapie :

medizinische Anwendungsmöglichkeiten und Beiträge zur Patientensicherheit durch präzise Patientenlagerungsüberwachung.

Dr. Franco Canestri

C-RAD Positioning AB, Schweden
- und -
C-RAD GmbH, Berlin

C-RAD

Agenda

Background

Methods used in triangulation

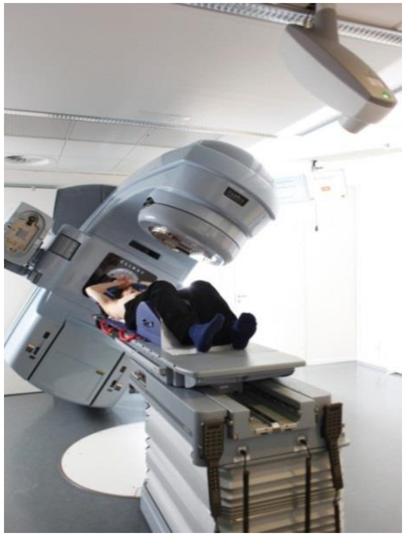
Flow CT-RT

→ New 3-Camera System for Stereotactic and PT Applications

→ New Portal Dosimetry via Ionization Chambers

Video Clips

Discussion



Background of the Presenter

- Ph.D in Medical Physics from University of Genoa and National Cancer Institute of Milan - Italy („Lasers in Surgery and Oncology“)

- Since 29 Years in Germany

- Professional Experiences with Hewlett-Packard Medical and Agilent Technologies Optical Division in Böblingen (Product Design). With C-RAD since beginning 2013.

- Scientific Publications : www.franco-canestri.de

Background of the Company :
C-RAD Positioning AB, Sweden

- Product ideas based on specific studies about patient positioning and monitoring during radiation therapy at the

Karolinska Institutet, Stockholm

- Research and first developments started back in 1997

- C-RAD company was founded in 2003

Core values

Improving safety and accuracy in Radiation Oncology

„Forecasting is very difficult, especially about the future“

(W. Churchill - 1945)

C-RAD

Today's Challenges in the Treatment Chain

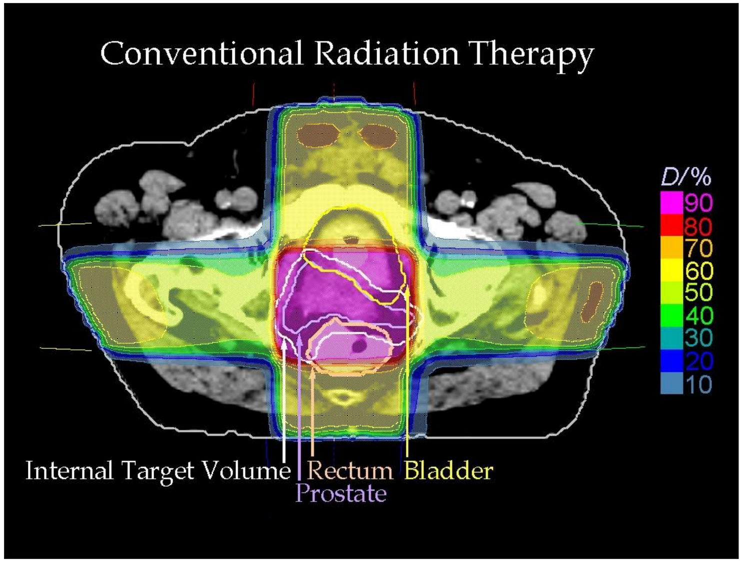
Correcting posture errors

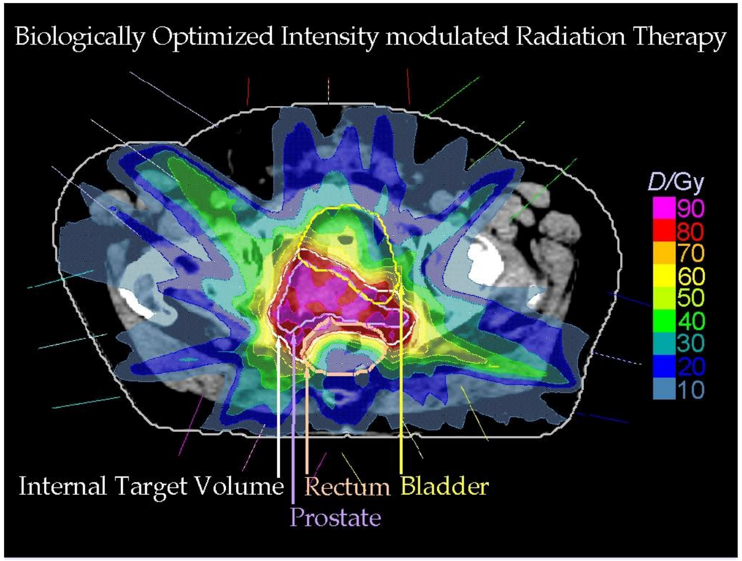
Improve positioning accuracy

Detect intrafraction movements

Respiratory Gating (DIBH)

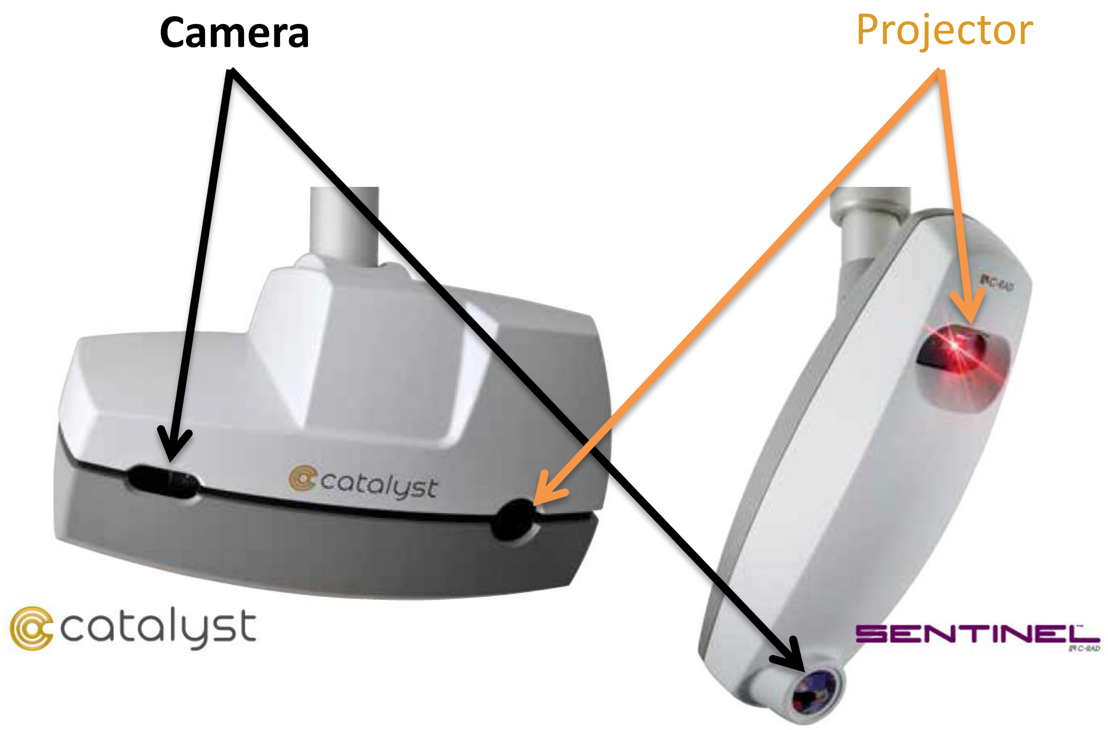
Core competence





Courtesy of RaySearch Laboratories AB

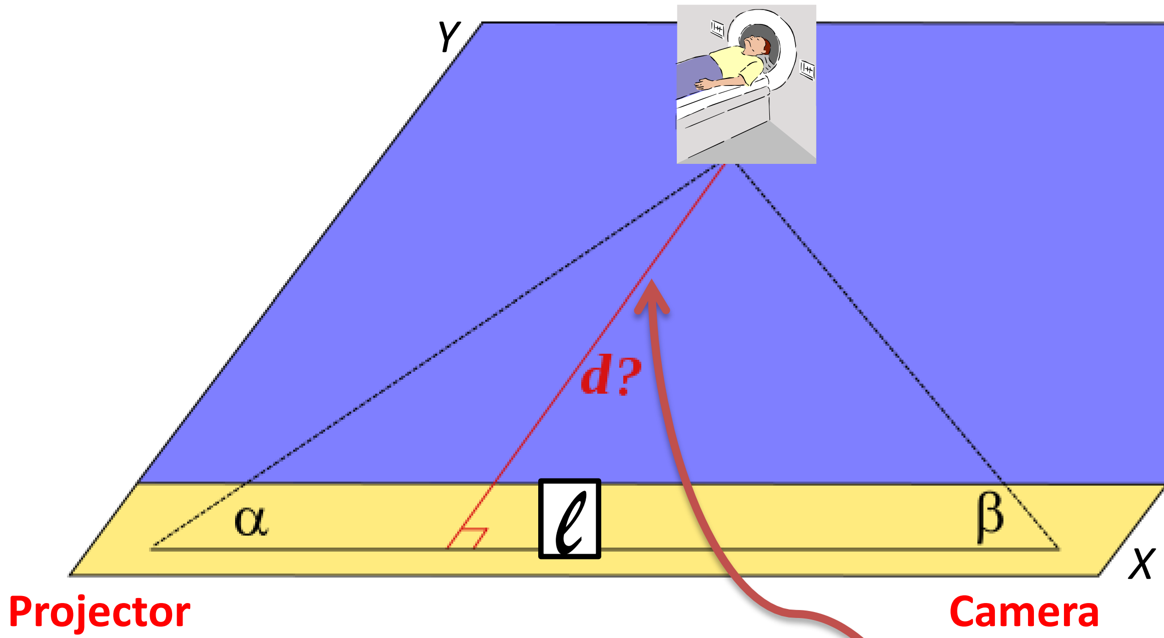
C-RAD Approach to precise patient positioning



For Linac Room

For CT Room

Triangulation



$$\ell = \frac{d}{\tan\alpha} + \frac{d}{\tan\beta}$$

therefore :

$$d = \ell \,/\, (\tfrac{1}{\tan\alpha} + \tfrac{1}{\tan\beta})$$

We know that :

tan α = sin α / cos α

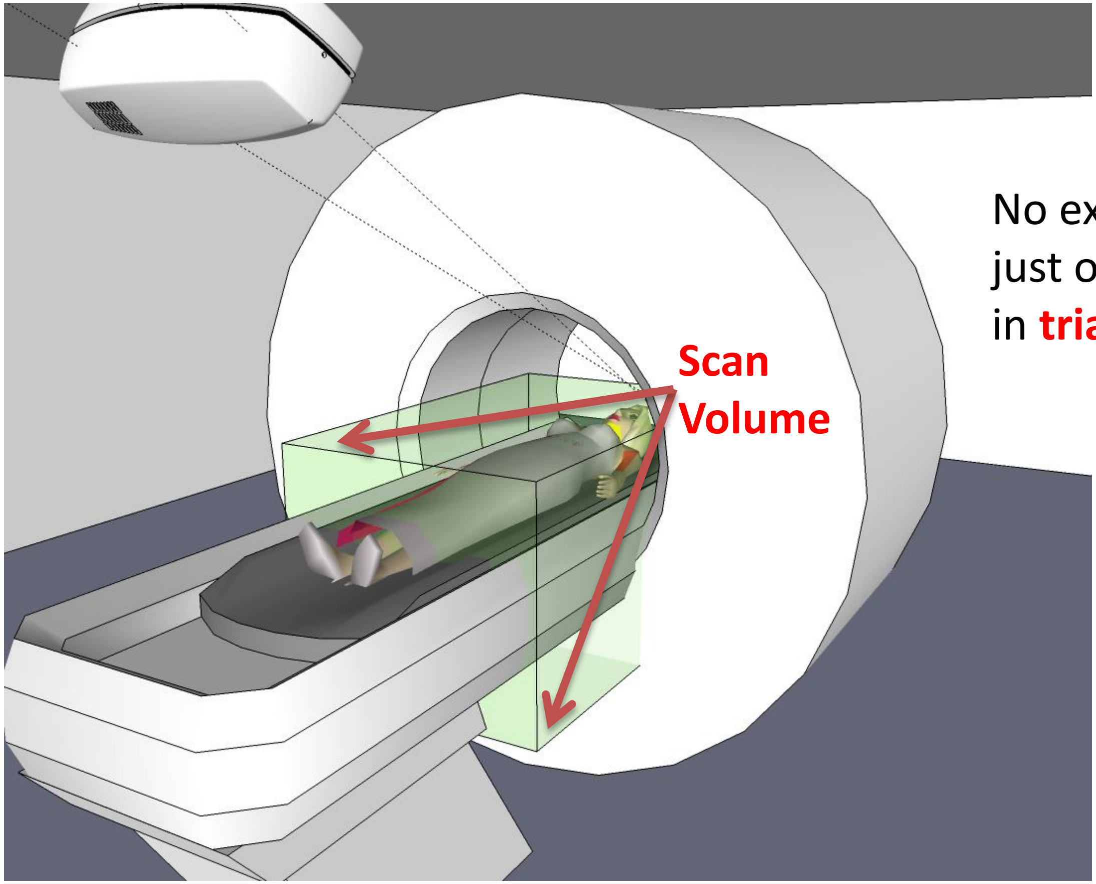
and that :

sin(α + β) =
sin α cos β + cos α sin β

$$d = \frac{\ell \sin\alpha \sin\beta}{\sin(\alpha+\beta)}$$

Measurement Principles

Projector   Camera



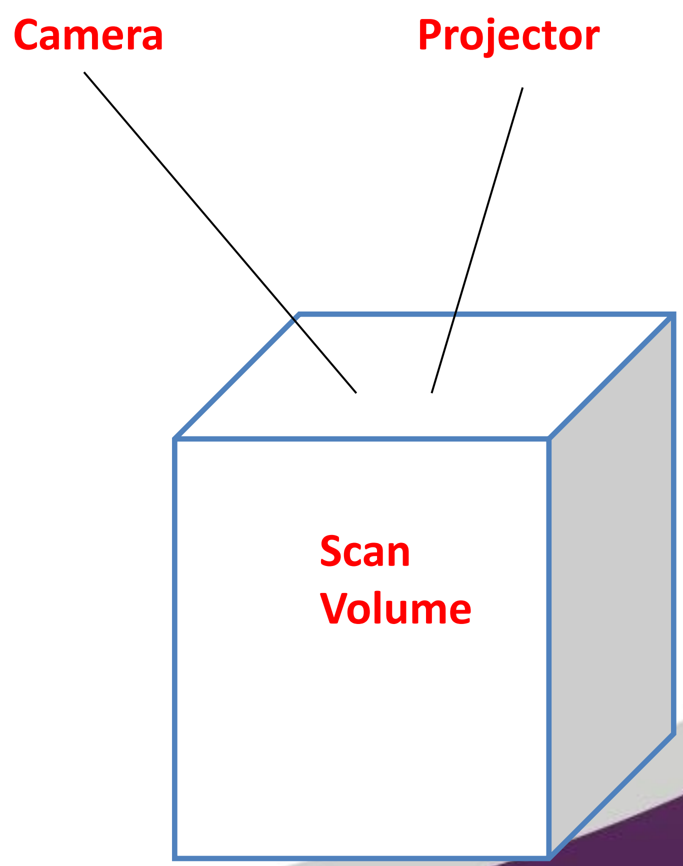
No extra ionizing radiation, just optical LED cameras in **triangulation**

Technical performances

Scan volume: 80cm x 130cm x 70cm

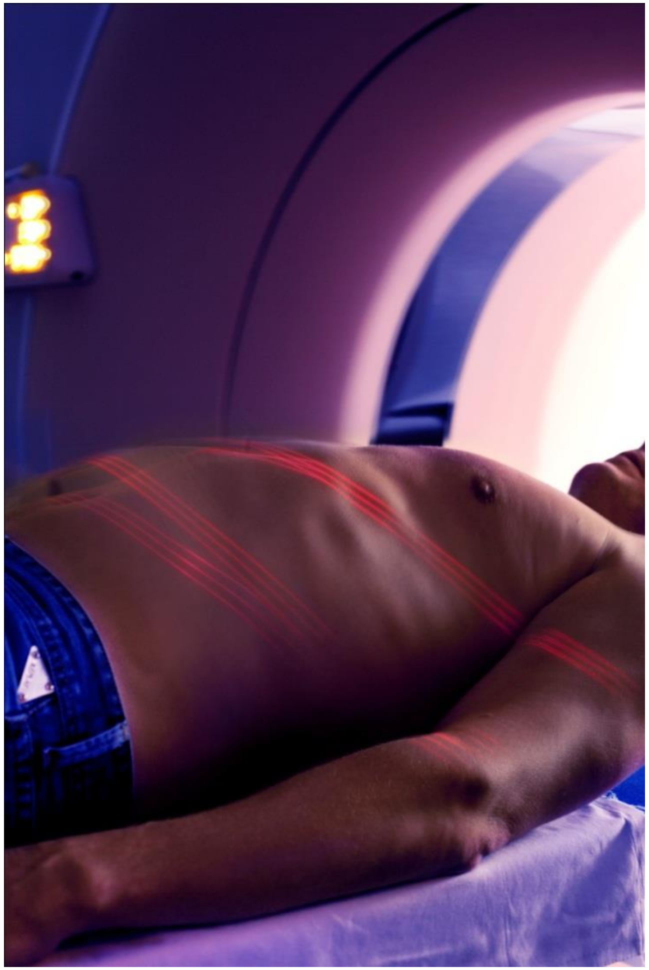
Position accuracy: <1mm

Motion detection accuracy: <1mm



Step 1 - CT

SENTINEL



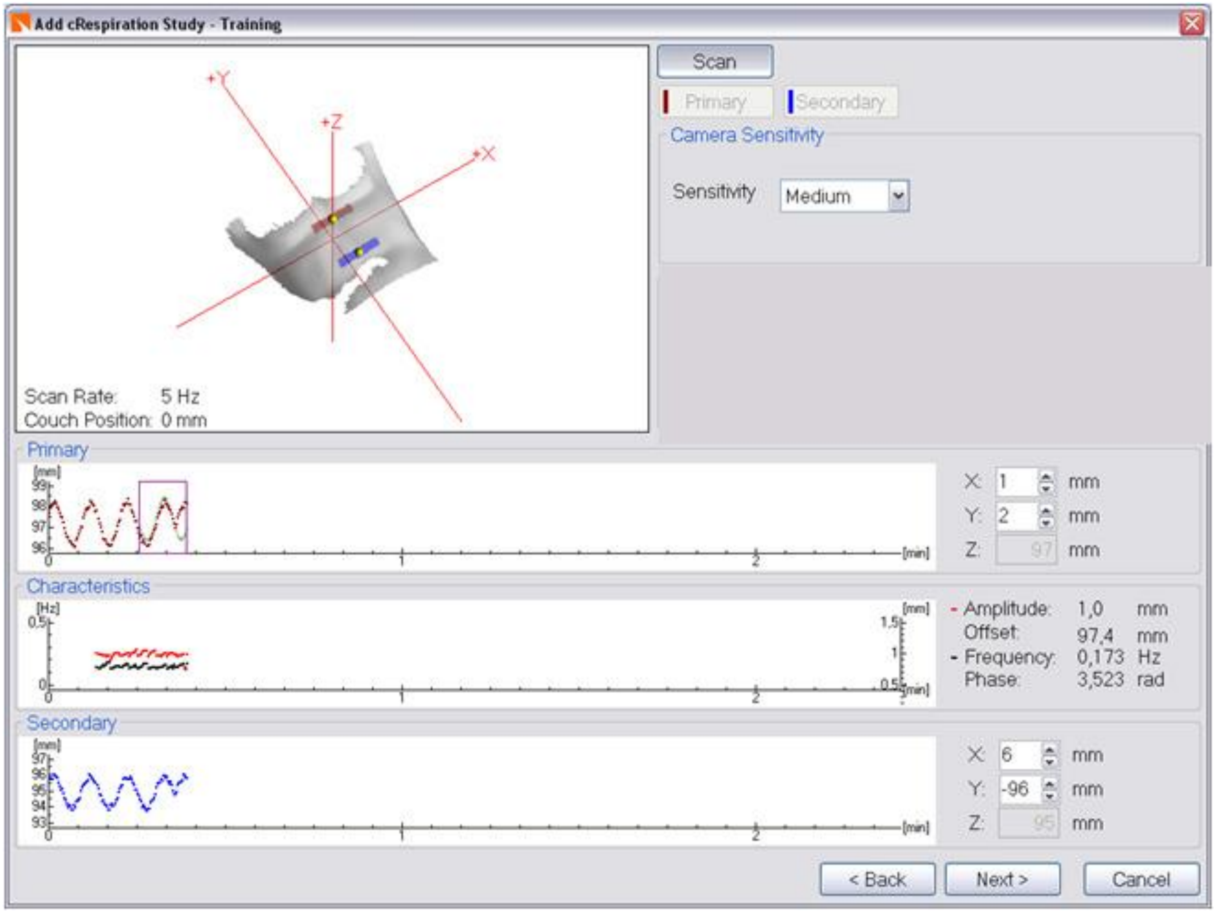
4DCT prospective and retrospective gating

- No markers on the patient
- Multiple tracking points
- Audio- and Visual feedback

C-RAD

Step 1 - CT

SENTINEL

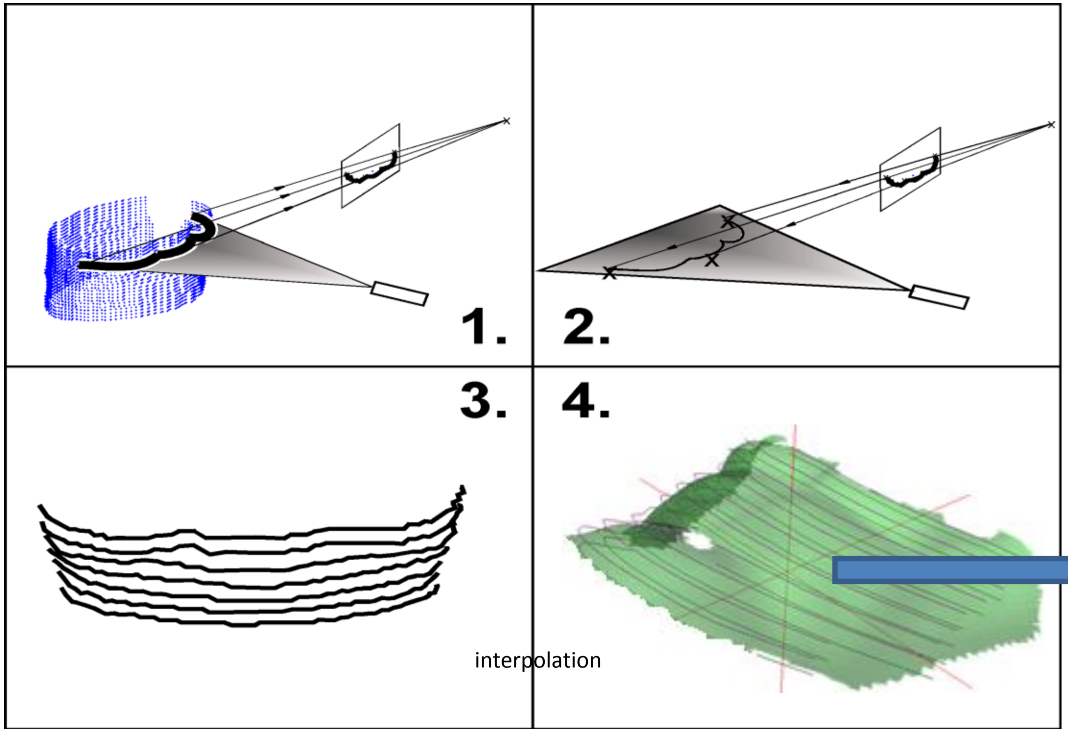


4DCT prospective and retrospective (CT) gating

C-RAD

Step 1 - CT

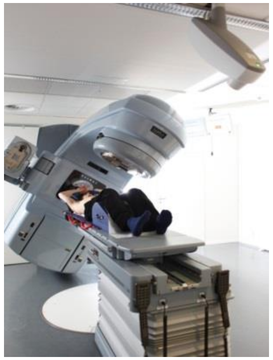
Optical triangulation in **CT Room**



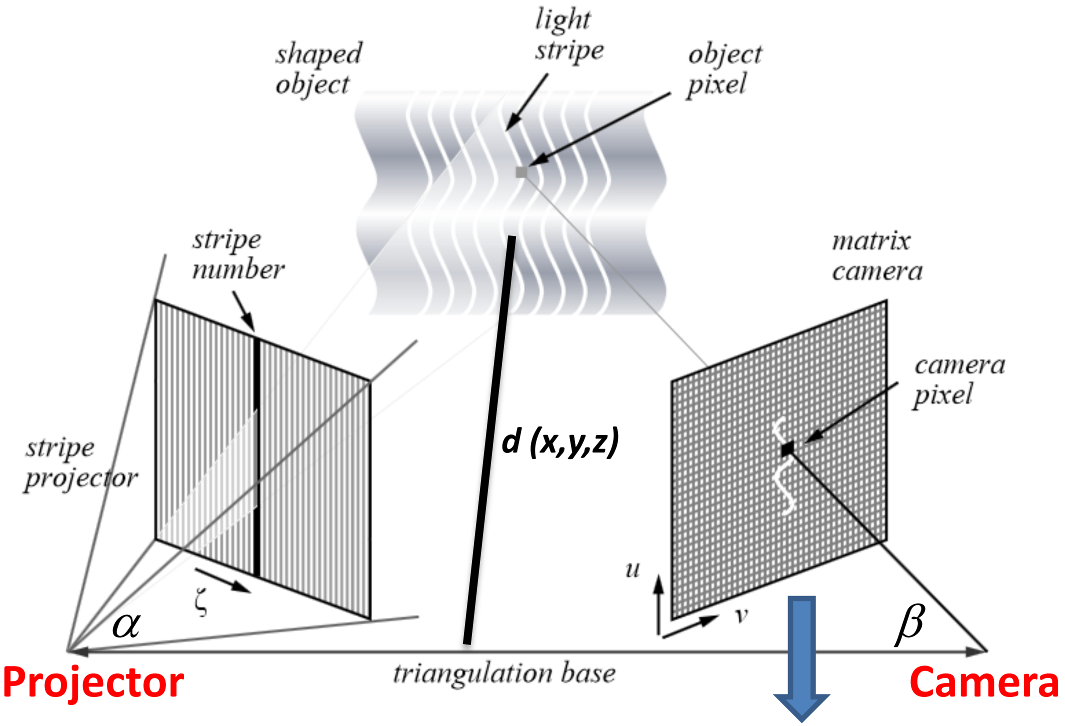
Multiple 3D point tracking with one unit, up to 60 times per second.

This image to RT Room
+ isocenter info
+ prospecting gating
+ planung CT files

Step 2 - RT



Optical triangulation in **RT Room**



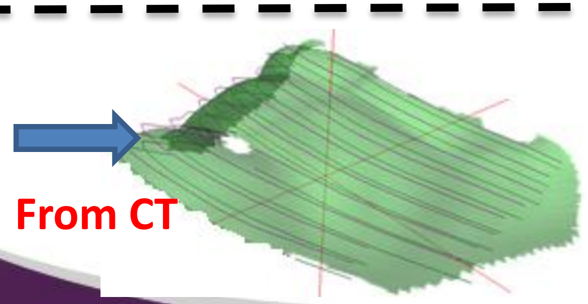
3D surface capturing with <u>one</u> unit, up to 60 times per second

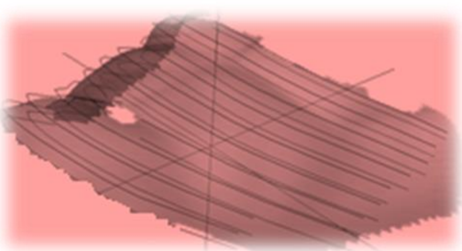
$$d = \frac{\ell \sin\alpha \sin\beta}{\sin(\alpha+\beta)}$$

with

$\alpha = \alpha(\xi)$

$\beta = \beta(u,v)$





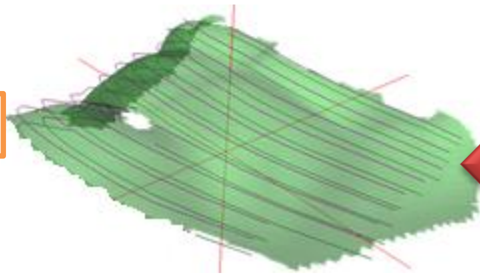
$S_i(d_{rt}) = S_i(d(\xi,u,v))$

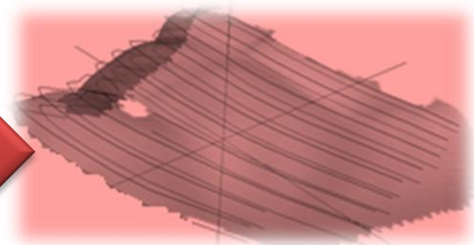
Back-projection on patient in RT : Step 3 - RT

from CT Room

in RT Room

$S_{i\text{-}ct}$





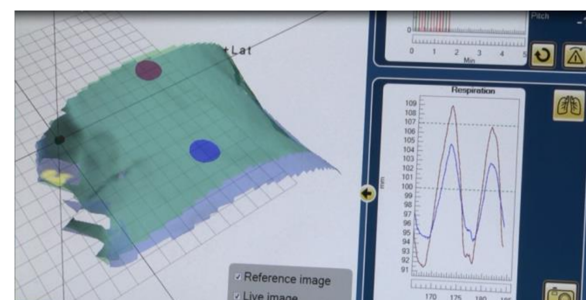
$S_i(d_{rt}) = S_i(d\,(\xi,u,v))$

Matching „*S*" areas with
colors assignment where required

→ **No extra markers**

Isocenter and red areas

Yellow areas



Gating

Geometrical corrections via couch and Intefaces to Linacs

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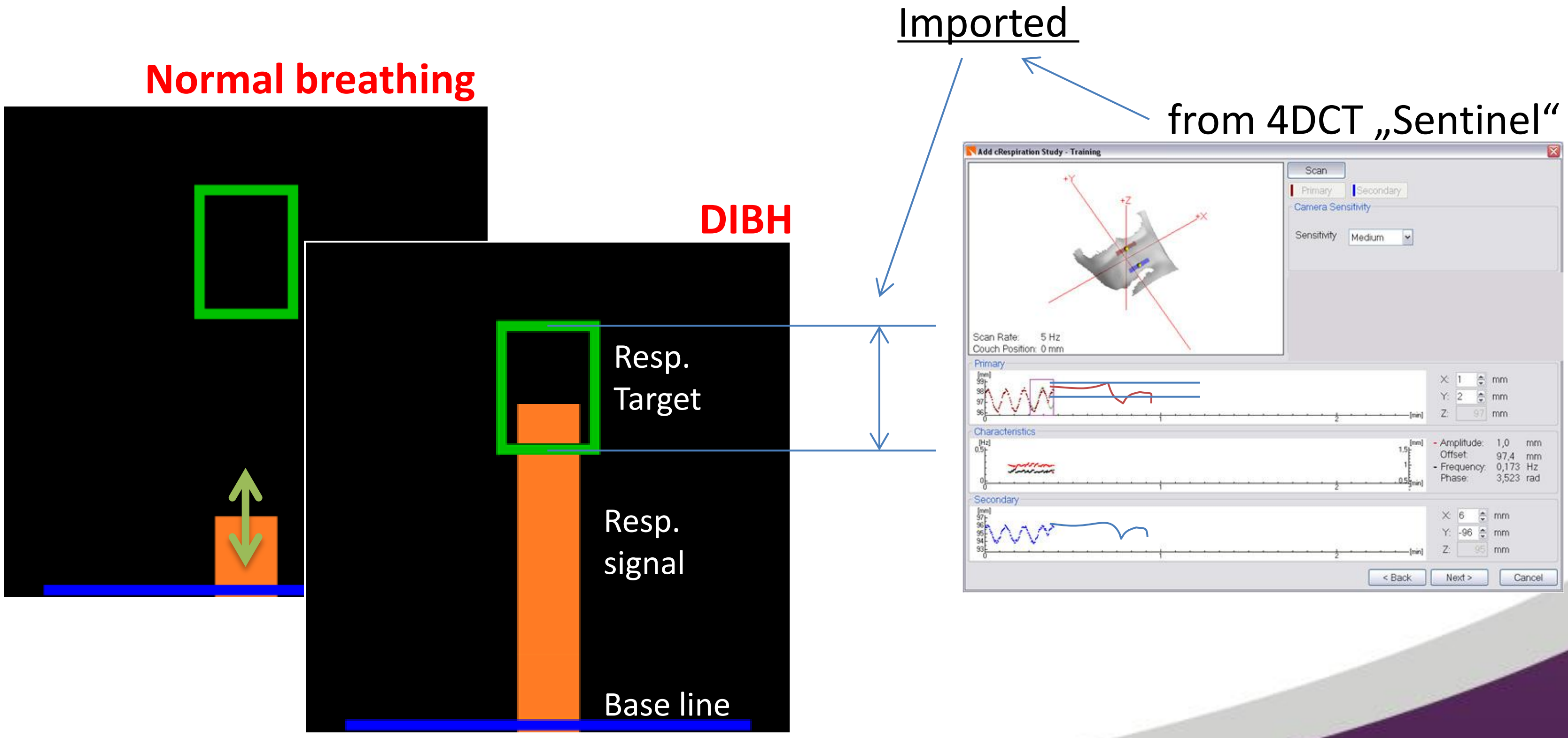
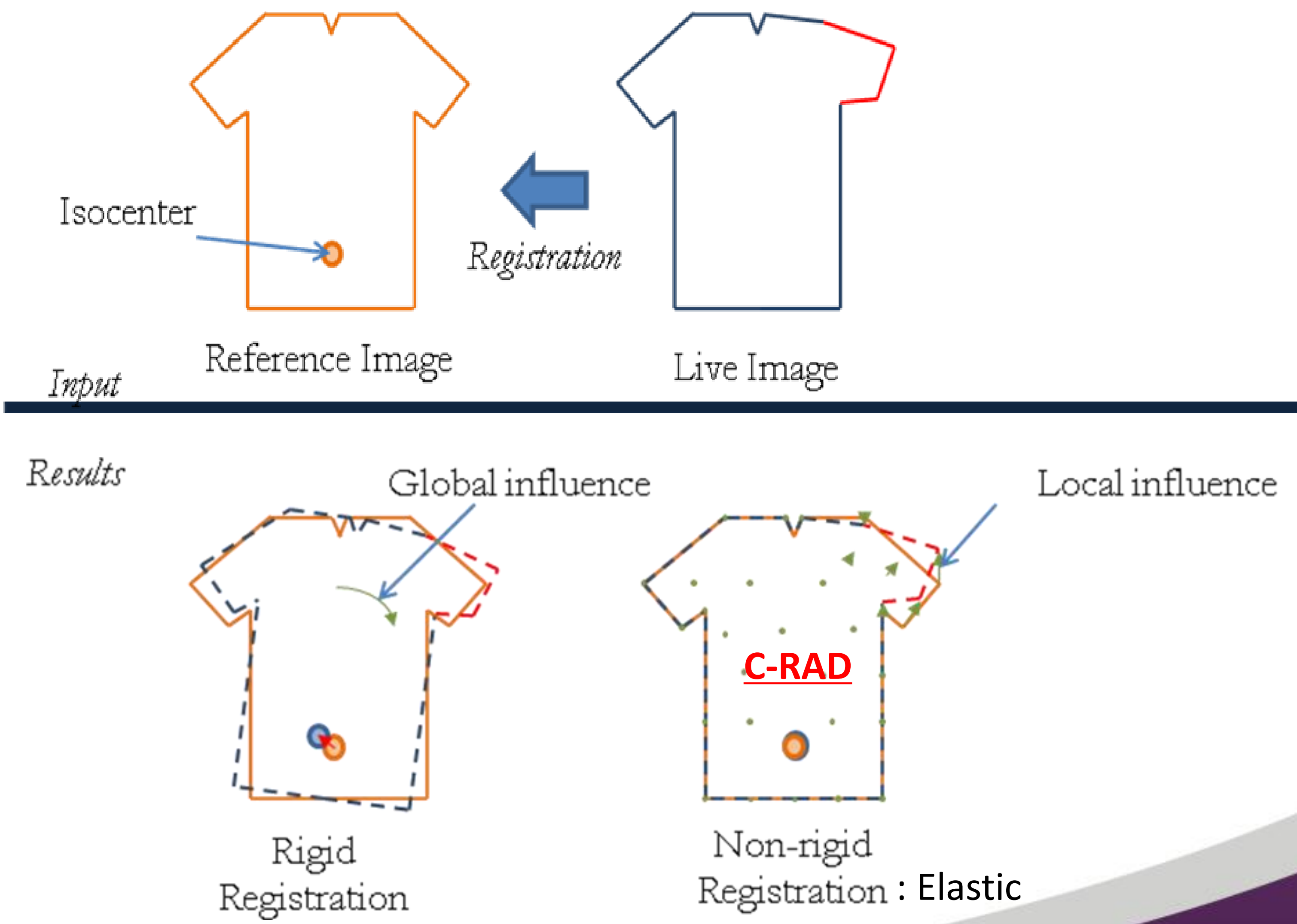
Respiratory gating / coaching (DIBH)

Patient's Visual feedback



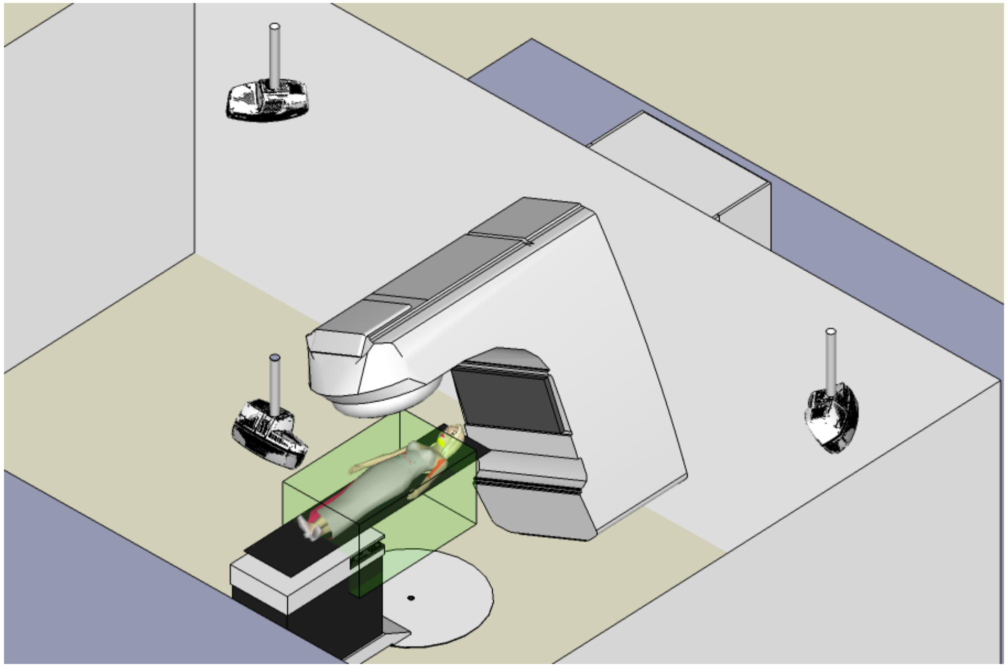
Non-rigid algorithm for isocenter calculation :



3-Camera Solution

- Reference Installation in Wien -

KFJ Spital



- Application for Stereotactic and PT Treatments
- Full Patient Surface coverage
- Monitoring independent from couch kicks

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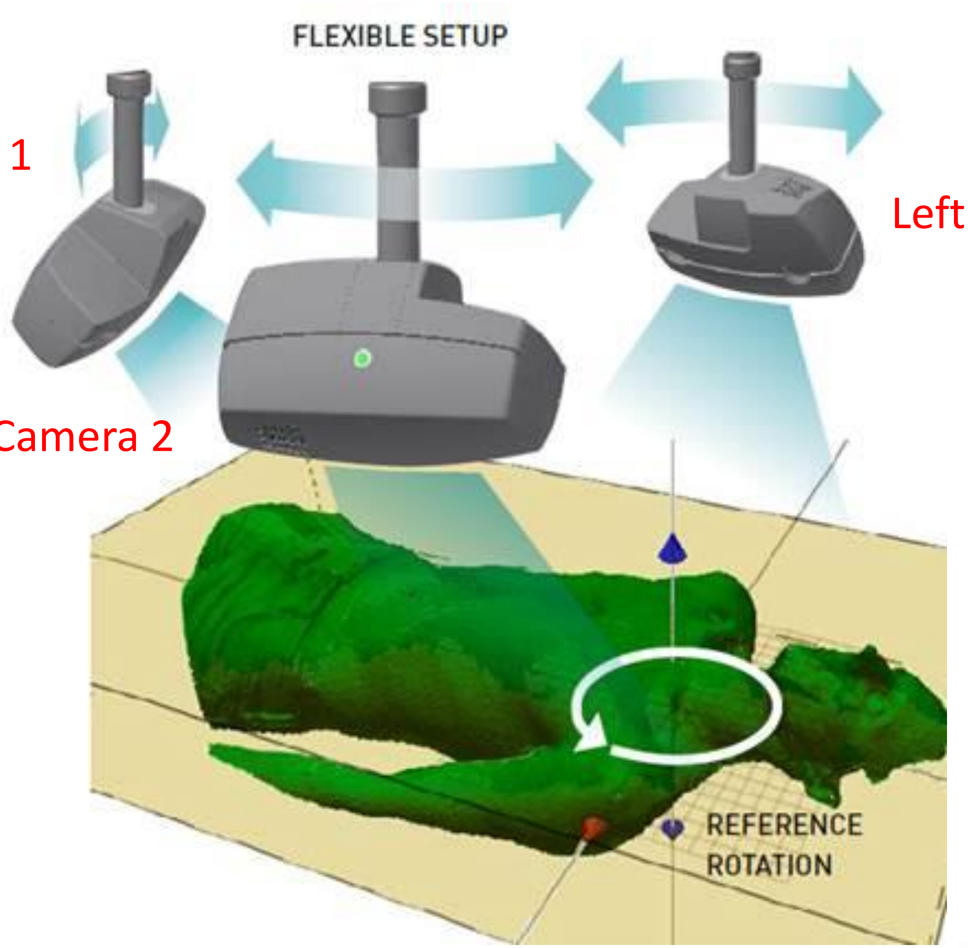
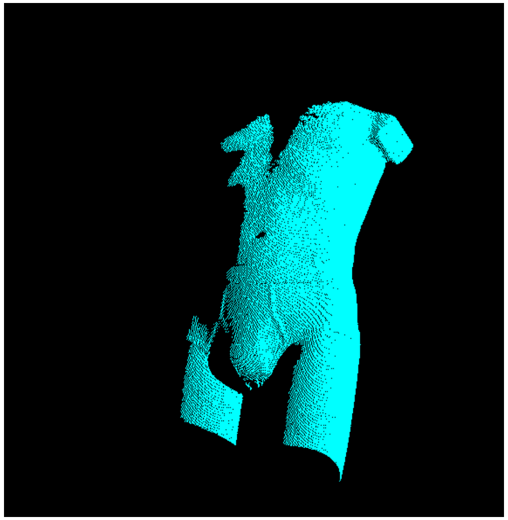
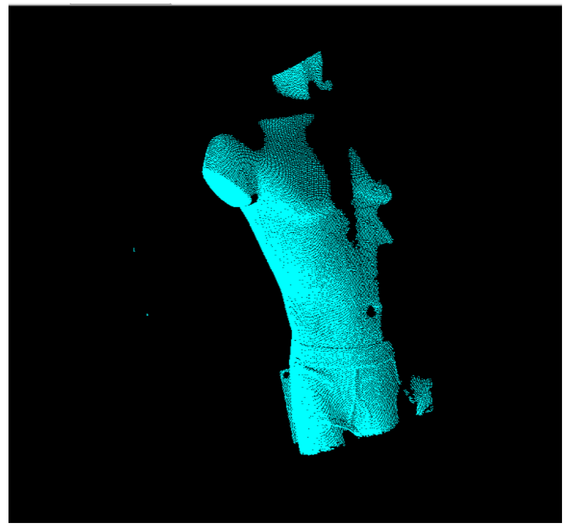
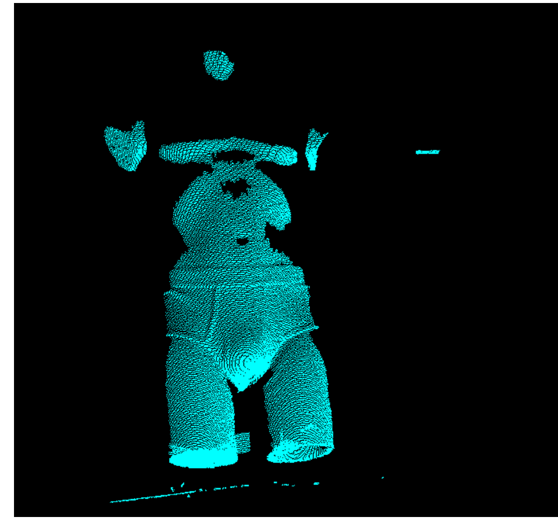
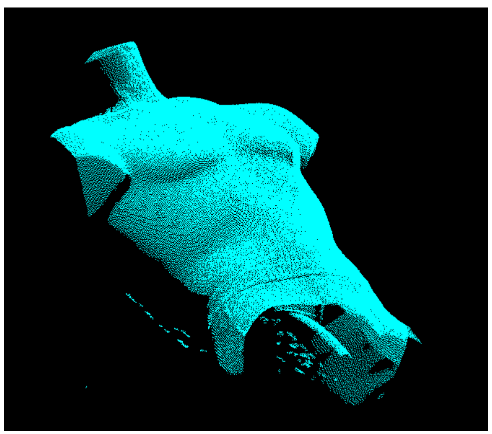
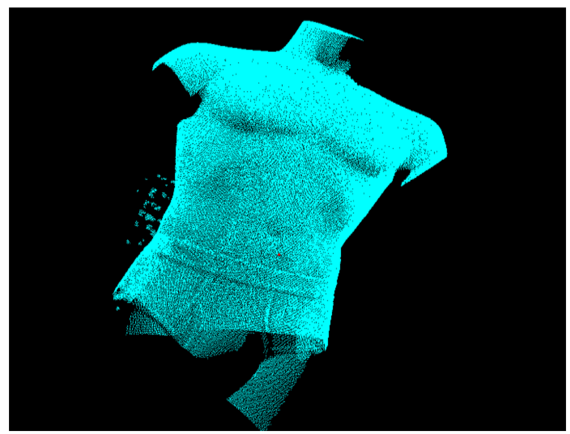
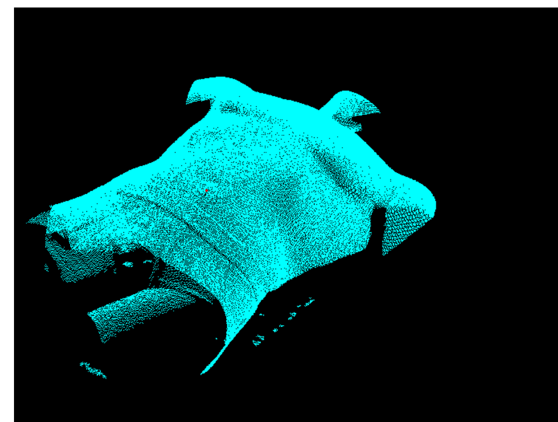
3-Camera Solution for Stereotactic and PT Therapies

Central Camera 1
+ Projector



Left Camera 3

Right Camera 2

	Right Camera 2	Left Camera 3	Central Camera 1
Camera Shots			
Composite Global Views (R2+L3+C1 Camera Shots Super-impositions)			
	Right View	**Central** View	**Left** View

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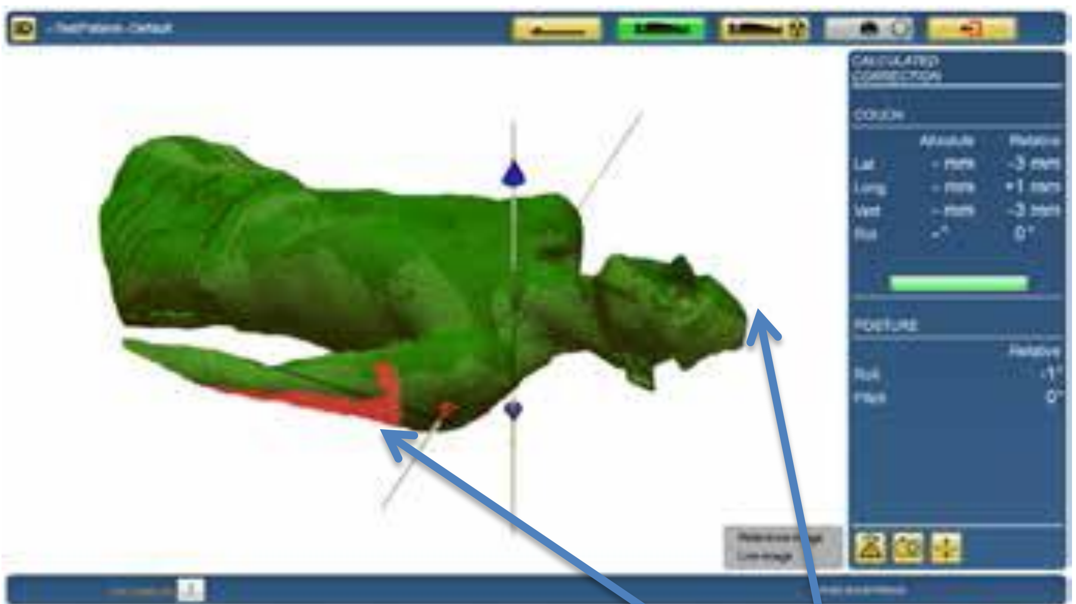
Catalyst Stereotactic Screen View (MTRA / Control Room)



Critical Angles / Views

Benefits for Stereotactic Applications :

1) Full patient coverage indep. from couch kicks
2) Positioning
3) Motion
4) Gating
5) Audio/Vidual (Googles)
6) Non-rigid Algorithm

C-RAD

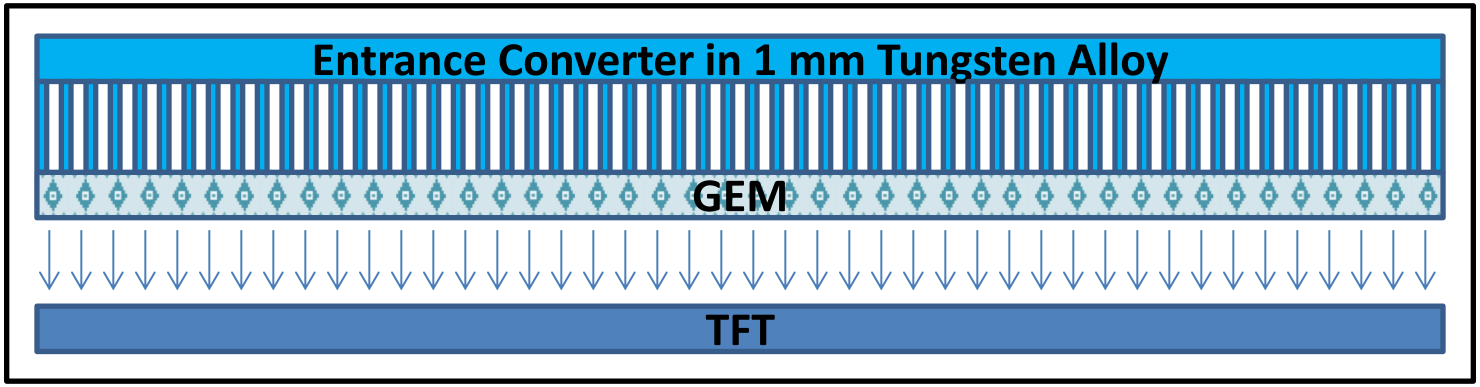
Principal overview of the C-RAD gas-mix Design of the new Portal Dosimetry Solution

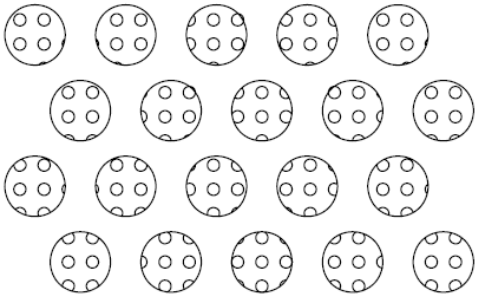
- versus -

conventional a-Si. EPID Panels

New at :
ESTRO 2014 in Wien
→ Product available
in Fall 2014 (t.b.conf.)

Panel 40 x 40 cm^2





900,000 discrete ionization chambers over an area of 400 mm x 400 mm (.45 mm pitch)

U.S. patent pending

C-RAD

Principal overview of the C-RAD gas-mix Design of the new Portal Dosimetry Solution

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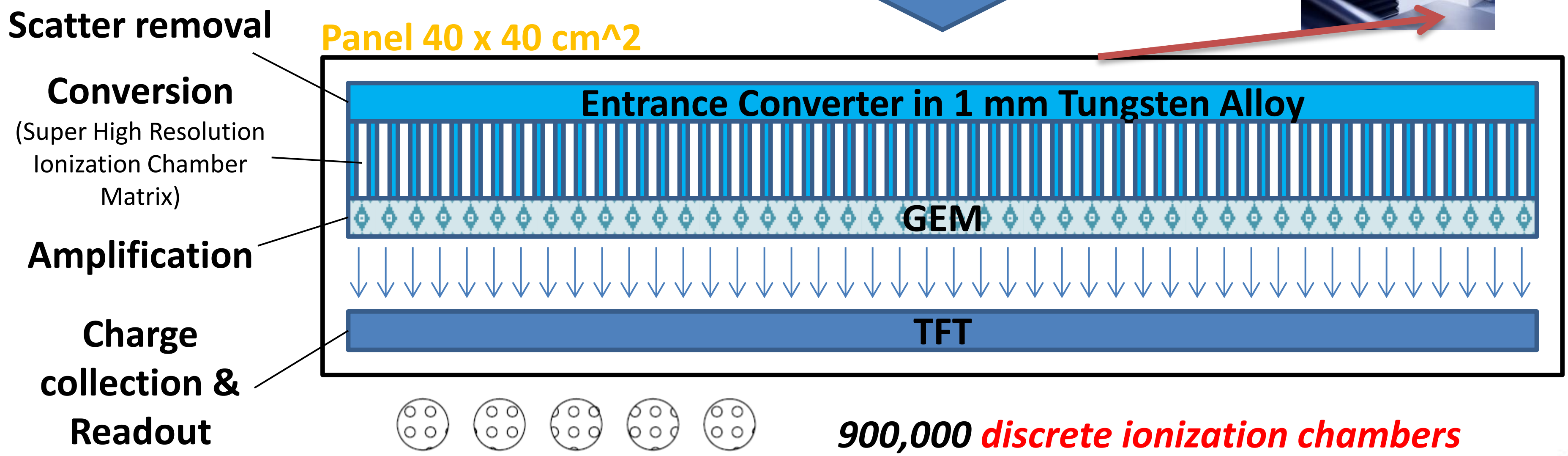
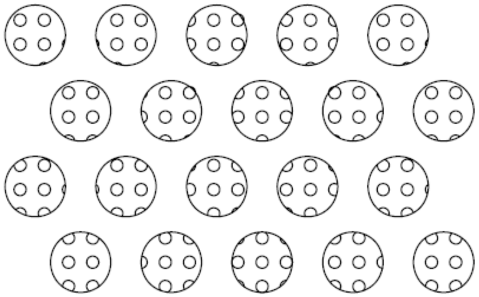




900,000 discrete ionization chambers over an area of 400 mm x 400 mm (.45 mm pitch)

U.S. patent pending

C-RAD Zusammenfassung : Klinische Vorteile – 1 von 2

- **Patienten Lagerung sowie Patienten Auto-Setup →**
  mit Tischinterface sowie Schnittstelle zum Bestrahlungssystem, interessant ist die Möglichkeit der **Rückprojektion**, d.h. Lagerungsfehler werden während des Setups direkt auf den Patienten projiziert (plus Screen im Kontrol Raum) : **Vorteil für die MTRA's.**

- **Patientenüberwachung nach der Positionierung und während der gesamten Bestrahlung →**
  dies ist insbesondere dann interessant, wenn entweder lange Bestrahlungszeiten vorliegen oder mit einer **hohen Dosisrate** bestrahlt wird.

- **Respiratory Gating →**
  Durch die Erfassung der Oberfläche und der Tatsache, dass **keine Marker** angebracht werden müssen, sehen wir große Vorteile für die Bestrahlung von linken Mammen.

C-RAD Zusammenfassung : Klinische Vorteile – 2 von 2

- Die Bestrahlung von Mamma Patientinnen zum einen für die reproduzierbare Lagerung der Brust, ohne die Anwendung von ionisierender Strahlung. Über eine Gating-schnittstelle kann der **Linearbeschleuniger direkt ge-triggert** werden. Großer Vorteil ist hier, dass Sie **keinerlei Marker** auf den Patienten aufbringen müssen.

- Die Bewegungsüberwachung **während der Bestrahlung**. Insbesondere bei langen Bestrahlungszeiten oder wenn mit einer **hohen Dosisleistung** bestrahlt wird. Über eine Schnittstelle gibt es ein Signal im Kontrollraum oder es lässt sich der Linac via Elekta und / oder Varian Interfaces sogar **abschalten** (programmierbar, wenn gewünscht).

- Die Patienten Lagerung und Positionierung. Da das System sowohl misst als auch direkt auf den Patienten die Lagerungsinformationen projiziert kann somit ein quantifizierter Setup durchgeführt werden **(Tisch).**

- **3-Kamera Lösung (Stereotaxie)** und **Portal Dosimetry (Ionisation Chambers Methode)**

Results

catalyst

AT SKÅNE UNIVERSITY HOSPITAL, SWEDEN

Skåne University Hospital has a deep experience in respiratory gating. The clinical implementation of respiratory gated treatments was in 2006 based on the Varian RPM System.

Since 2011 the Skåne University Hospital has been involved in the evaluation and implementation of clinical workflows for the new functionalities based on the unique features of the Catalyst system. The installations are on Varian 2100 Clinacs and on Siemens Somatom Definition CT scanner.

Markerless and accurate solution

The respiratory gating solution is based on deep inspiration breath hold used on left sided breast patients with prospective CT image acquisition on the Siemens scanner. The aim of this technique is to save organs at risk (heart, coronary artery) for the breast patients and therefore minimize the side effects of the treatment. A gated CT scan is performed and gated treatment is delivered only when the separation between the target and organs at risk is as planned.

It is important that the breathing is reproducible from day to day, therefore it is valuable that the respiratory signal is expressed in absolute coordinate system indicating if there is a base shift in the signal. The patient is guided with audio and visual coaching in order to ensure that the breathing has the same pattern as during the CT acquisition.

"One of the many strengths with the C-RAD's gating solution is that we are able to gather one or two respiratory signals directly on the skin, with no need for markers and without constraints on the location for signal acquisition."

Charlotte Thornberg, PhD.

In parallel with the gated treatment delivery the patient is monitored in real time and the beam will be turned off via the MMI interface if the movements are outside allowed intervals.

Interactive adjustment for posture errors

Especially for breast patients it is important that the arms are placed in the same position in every fraction since their position may affect the target placement. If an arm is not in the correct position the system is projecting a clear indication of the magnitude and direction of the adjustment that need to be done. This indication is updated in real time with the remaining adjustment. When the posture errors have been corrected the couch is moved to the correct position with automatic couch adjustment.

Overall the system is very intuitive and easy to use.

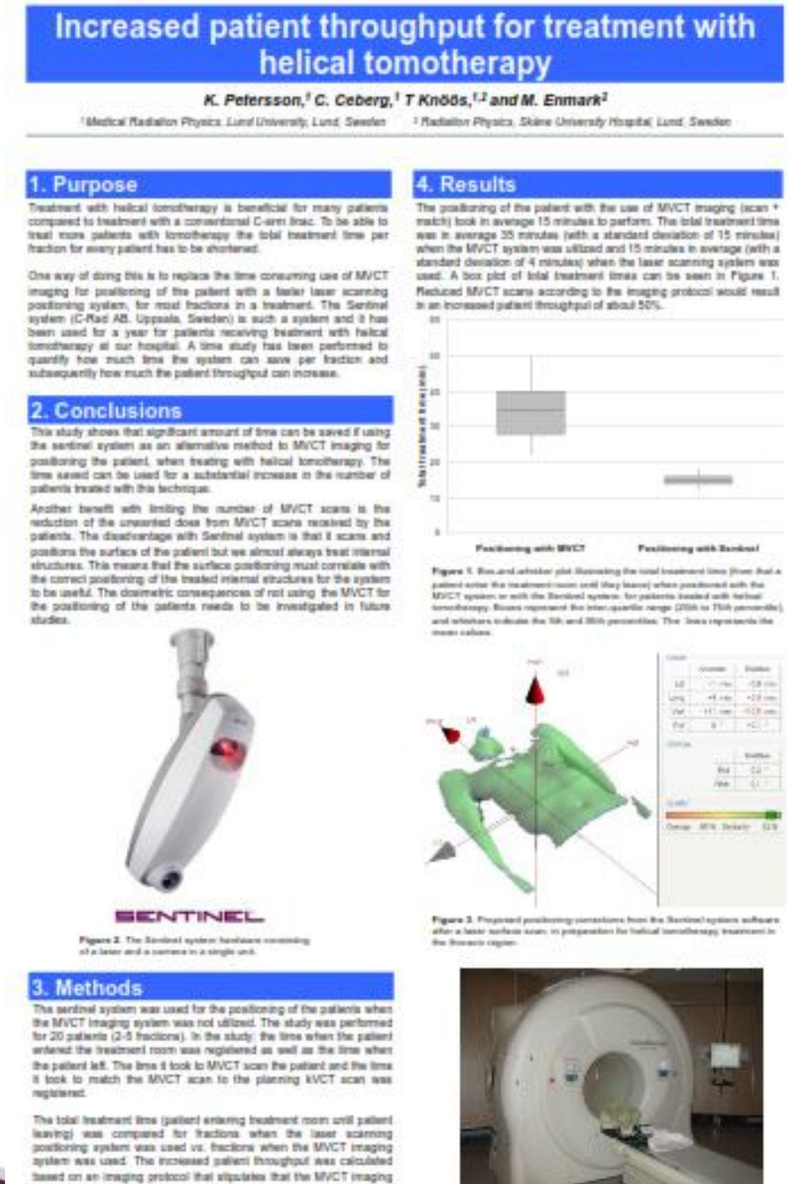
Ensure that treatment is not delivered when patient is moving

"The patient monitoring application shows clearly if the patients are moving during treatment delivery. This is something that was not easy to see before because the supervision was done visually by the treatment personnel. Using the beam hold function on the Linac we can make sure that treatment is not delivered when the patient movements exceed the thresholds.

We have also used the recorded results to show to anxious patients that the treatment went well and that they did not move, with the positive outcome that they felt more relaxed the following fractions."

(Charlotte Thornberg, PhD.)

Results



Increased patient throughput for treatment with helical tomotherapy

K. Petersson,[1] C. Ceberg,[1] T Knöös,[1,2] and M. Enmark[2]

[1] Medical Radiation Physics, Lund University, Lund, Sweden [2] Radiation Physics, Skåne University Hospital, Lund, Sweden

1. Purpose

Treatment with helical tomotherapy is beneficial for many patients compared to treatment with a conventional C-arm linac. To be able to treat more patients with tomotherapy the total treatment time per fraction for every patient has to be shortened.

One way of doing this is to replace the time consuming use of MVCT imaging for positioning of the patient with a faster laser scanning positioning system, for most fractions in a treatment. The Sentinel system (C-Rad AB, Uppsala, Sweden) is such a system and it has been used for a year for patients receiving treatment with helical tomotherapy at our hospital. A time study has been performed to quantify how much time the system can save per fraction and subsequently how much the patient throughput can increase.

2. Conclusions

This study shows that significant amount of time can be saved if using the sentinel system as an alternative method to MVCT imaging for positioning the patient, when treating with helical tomotherapy. The time saved can be used for a substantial increase in the number of patients treated with this technique.

Another benefit with limiting the number of MVCT scans is the reduction of the unwanted dose from MVCT scans received by the patients. The disadvantage with Sentinel system is that it scans and positions the surface of the patient but we almost always treat internal structures. This means that the surface positioning must correlate with the correct positioning of the treated internal structures for the system to be useful. The dosimetric consequences of not using the MVCT for the positioning of the patients needs to be investigated in future studies.

SENTINEL

3. Methods

The sentinel system was used for the positioning of the patients when the MVCT imaging system was not utilized. The study was performed for 20 patients (2-5 fractions). In the study, the time when the patient entered the treatment room was registered as well as the time when the patient left. The time it took to MVCT scan the patient and the time it took to match the MVCT scan to the planning kVCT scan was registered.

The total treatment time (patient entering treatment room until patient leaving) was compared for fractions when the laser scanning positioning system was used vs. fractions when the MVCT imaging system was used. The increased patient throughput was calculated based on an imaging protocol that stipulates that the MVCT imaging system is used for positioning of the patients for the first three

4. Results

The positioning of the patient with the use of MVCT imaging (scan + match) took in average 15 minutes to perform. The total treatment time was in average 35 minutes (with a standard deviation of 15 minutes) when the MVCT system was utilized and 15 minutes in average (with a standard deviation of 4 minutes) when the laser scanning system was used. A box plot of total treatment times can be seen in Figure 1. Reduced MVCT scans according to the imaging protocol would result in an increased patient throughput of about 50%.

Positioning with MVCT | Positioning with Sentinel

A pilot study of breast cancer patient positioning using optical surface scanning and reprojection

Mattias Jönsson[1*], Sofie Ceberg[1], Charlotte Thornberg[2], Sven Bäck[2]

[1]Medical Radiation Physics, Department of Clinical Sciences, Malmö, Lund University

[2]Radiation Physics, Skåne University Hospital, Malmö, Sweden

Aim

The aim of this pilot study was to evaluate the optical scanning system Catalyst™ (C-Rad, Uppsala, Sweden) for pre-treatment patient positioning for external beam radiotherapy.

Background

The Catalyst™ system is intended to serve as a complement to x-ray imaging with the potential benefit of detecting misplacement of for example the arms during breast cancer treatment.

Incorrect arm positions might affect the tumour position due to skin stretching and contraction of muscles such as the pectoralis muscles. Changes in the soft tissues, where the tumour is located, would not be detected using x-ray imaging.

Figure 1. Mispositioned arm highligted in red by the projector.

Figure 2. Reference (blue) and second scan (red) of a patient overlapping. The scanning system detected a difference in arm position.

Materials and Methods

A Catalyst™ system was installed in the ceiling above the couch in the treatment room. The Catalyst™ consists of a LED-projector projecting a mesh pattern onto the patient. A CCD-camera registers the projected pattern and reconstructs a surface 2D-mesh. Using the LED-projector, deviations between the body contour and the contour reconstructed from the CT-scan will be coloured giving the therapy personal instant feedback during the patient positioning (Figure 1).

A total of 52 treatment sessions (four patients) were analysed in this study. After patient setup and position correction based on planar kV-imaging of the thorax wall and spine, the thorax region was scanned and registered using the Catalyst™ system. At each treatment session a new surface image was acquired after patient positioning (Figure 2).

Interfractional changes in arm position were observed by measuring the angle of the upper arm (humerus) in the sagittal and coronal plane. To find misplacements, each measured arm position was compared to the median value of all treatment sessions of the same patient.

Results

In the sagittal plane, the arm position was within ±2 degrees from the median value in 62 % of the treatment sessions and within ±3 degrees in 72 % of the treatment sessions. The maximum observed deviation was 6 degrees from the median value.

In the coronal plane, the arm position was within ±2 degrees from the median value in 81 % of the treatment sessions and within ±3 degrees in 98 % of the treatment sessions. The maximum observed deviation was 6 degrees from the median value.

Conclusions

After patient setup using planar x-ray imaging, interfractional changes in the patient's armposition were observed using optical scanning. The misplacements were not detected using planar kV-imaging of the thorax region. An optical scanning of the patient contour with a direct guidance projected on the patient is a helpful tool during patient setup with the potential of increasing both workflow and patient safety.

LUND UNIVERSITY
Faculty of Medicine

Presented at Estro 31, 9-13 May 2012, Barcelona, Spain

*corresponding author: mattias.jonsson@med.lu.se

Thank you for your attention !

ESTRO 2014 in
Wien !

www.c-rad.se

→ Video Clips