Deutsche Gesellschaft für Medizinische Physik e.V.
DGMP

**Dr. Franco Canestri**
**C-RAD GmbH**

# Medizinische Anwendungsmöglichkeiten und Beiträge zur Patientensicherheit durch präzise C-RAD Patientenlagerungsüberwachung und Atem Gating während der Strahlentherapie.

Treffen des AK IMRT der DGMP
30. und 31.05.2016
Leipzig

C-RAD

# Agenda

Background

C-RAD methods used in optical triangulation

Workflow CT → RT

Clinical Benefits and Published Results

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 32 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

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

***Karolinska Institutet, Stockholm***


- *Research and first developments by Anders Brahme started back in 1997*

- *C-RAD company was founded in 2003, now with Main Subsidiaries in USA, Germany, France and China plus 20+ Distributors world-wide.*

***<u>→ C-RAD GmbH in Germany : 3 Offices in Berlin, Karlsruhe and Lüneburg.</u>***

# Ziel :


**Mehr Patienten pro Tag,**

**besser und**

**mit mehr Sicherheit behandeln.**

C-RAD

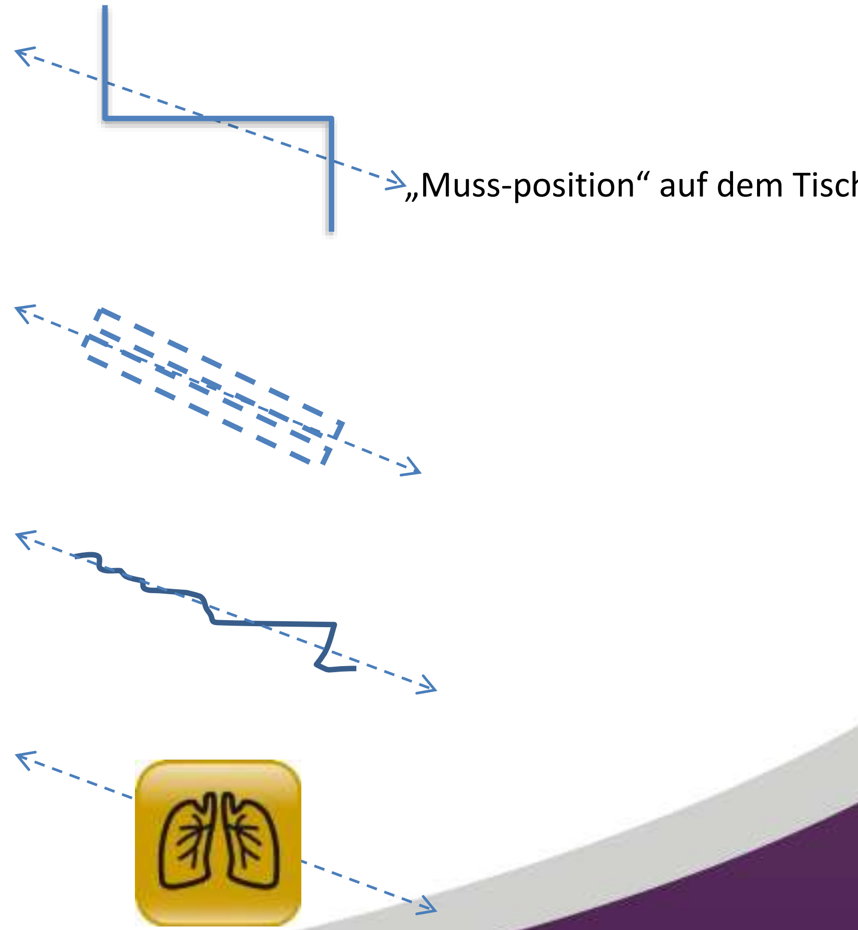
# Strahlentherapie : Herausforderungen

”Posture Errors” (Haltung)

Genauigkeit

Bewegungen

”Respiratory Gating (DIBH)” vs. ”Free Breathing”



# End-to-end treatment solution

Sentinel 4DCT
in CT room

**For all CT Manufacturers**

Catalyst/HD/PT in
RT room



Multi Vendor
Support

ELEKTA

TomoTherapy

iba

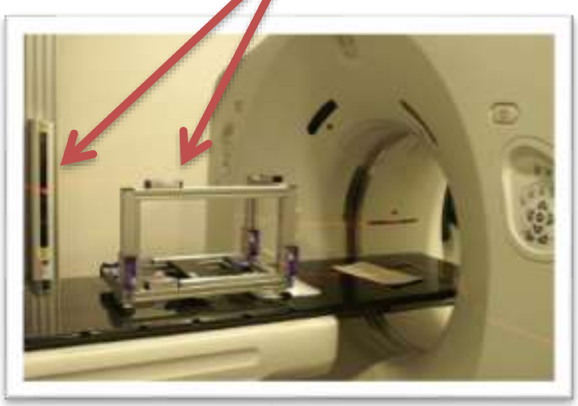
VARIAN medical systems

Siemens

C-RAD

# C-RAD Approach to precise and safer patient positioning

**C-RAD ultra-precise ( ~ 0.1 mm at isocenter) Room Lasers :**
**- ) with dual-diode (red + green)**
**- ) and automatic calibration (< 9 Min.).**



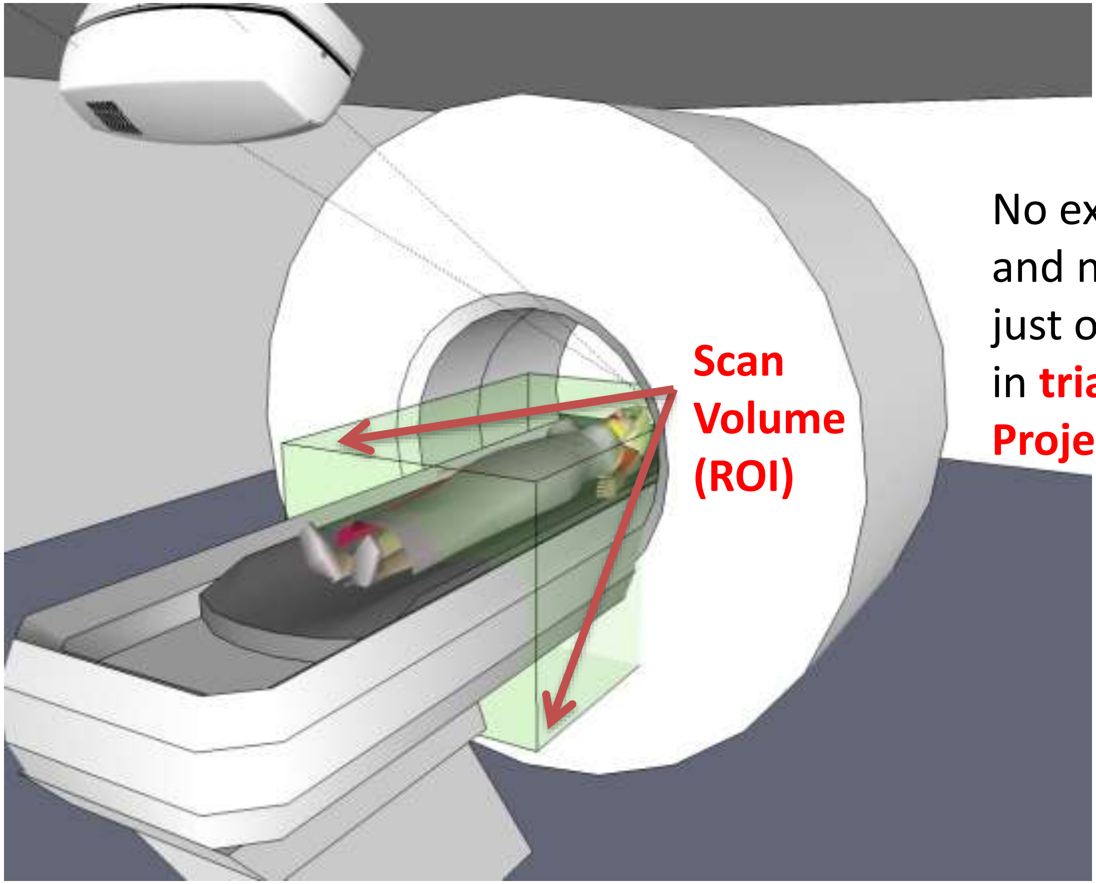
**For CT + RT Rooms**


**For RT Room**


**For CT Room**

# Measurement Principles and Patient ID

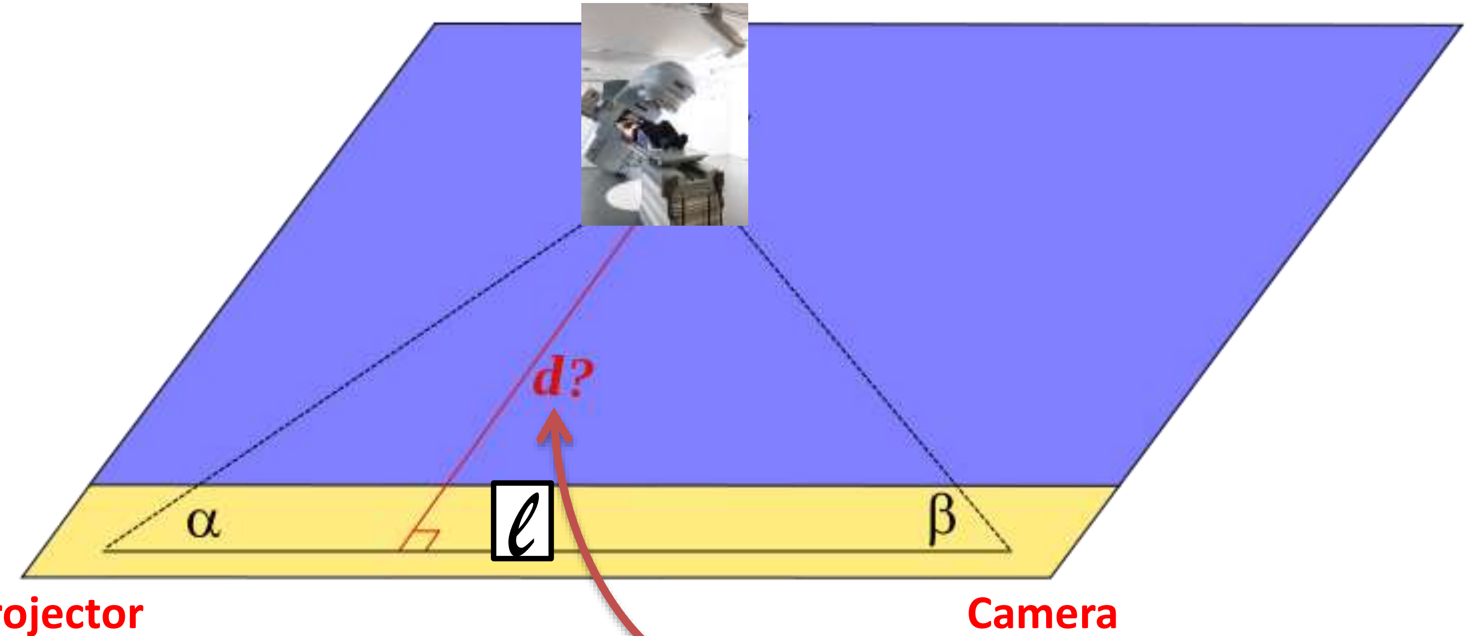
**Projector** **Camera**




No extra ionizing radiation
and no lasers,
just optical LED cameras
in **triangulation between**
**Projector – Kamera – ROI**

**Patient Vicinity and**
**Safety infos also ...**

# Triangulation Method




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

therefore :

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

We know that :

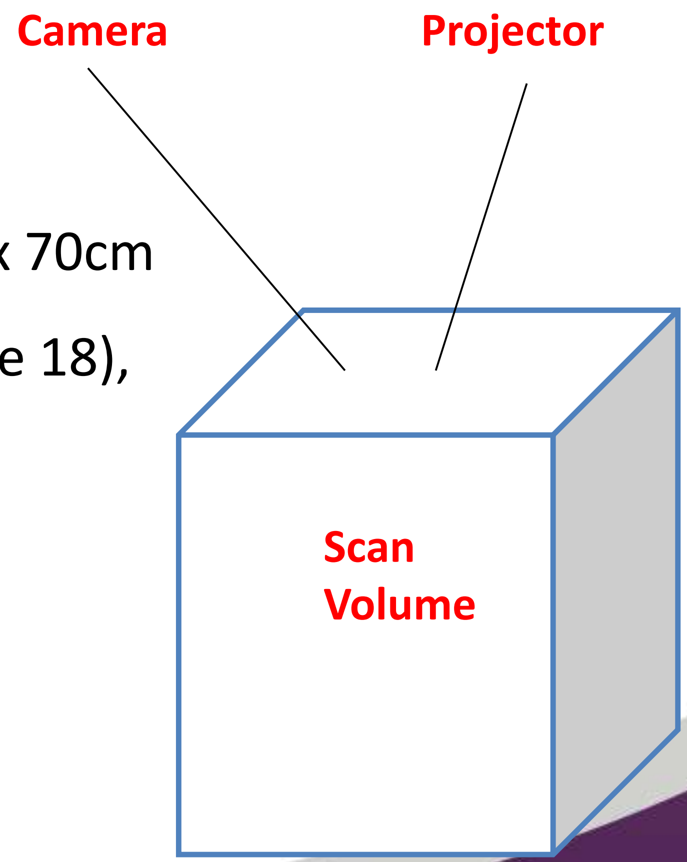
**tan α = sin α / cos α**

and that :

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

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

# Technical performances

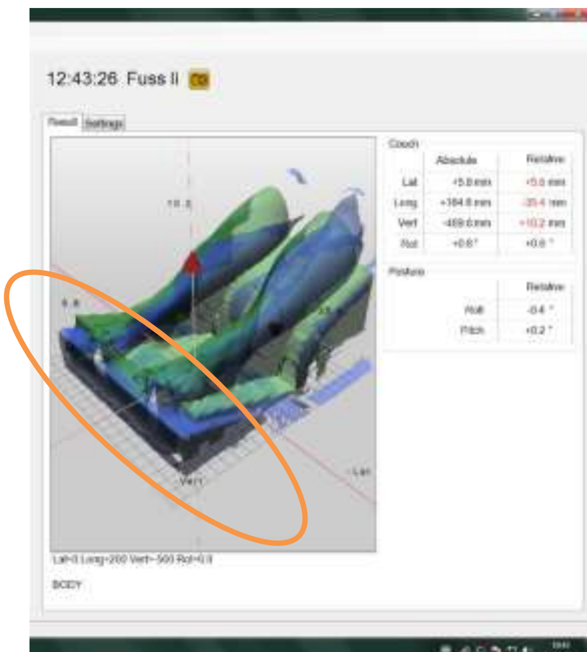



**<u>One</u> Scan Volume (ROI)**: up to 80cm x 130cm x 70cm with elastic, non-rigid patient registration (Slide 18), and “crop” functionality.

Position & Safety accuracy: <1mm

Motion detection & Safety accuracy: <1mm

# Patient Vicinity and Safety


C-RAD

# Workflow : Step 1 - CT

SENTINEL


*FOR YOUR CT-ROOM*

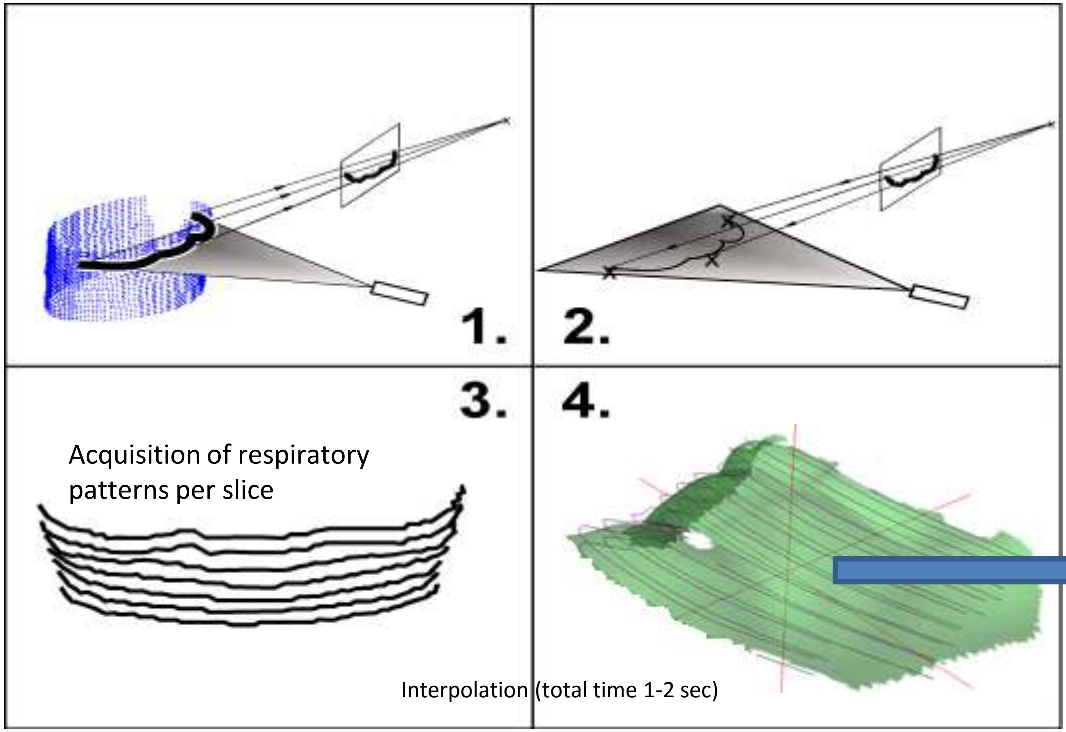
***Sentinel addresses two major 4DCT tasks ... :***

C-RAD

# Workflow : Start am CT

## 1 of 2 : Surface detection as first reference image.

Optical triangulation via Sentinel in **CT Room**

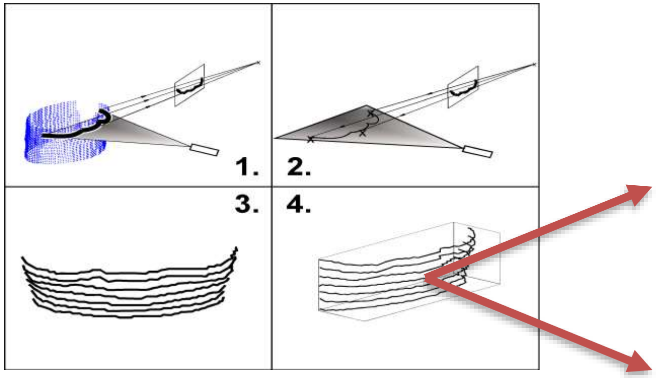



Multiple 3D point tracking with one unit, up to 50 times per second.

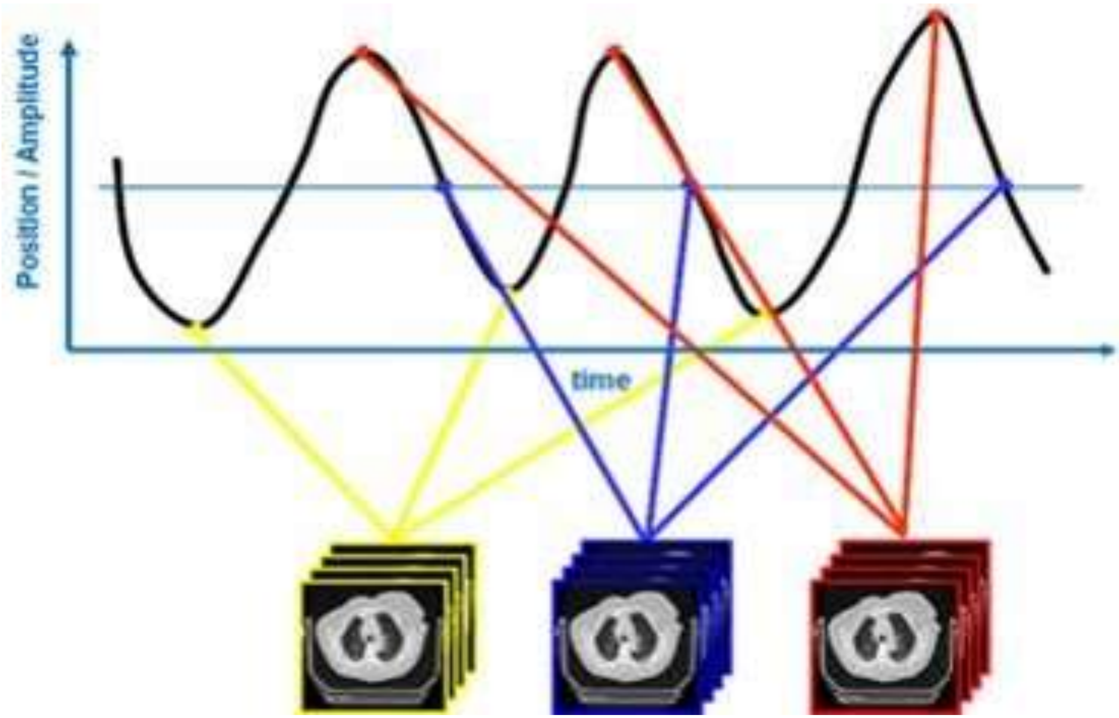
First CTs Patient Reference Image.

# 2 of 2 : Correlation CT <-> Breathing curves (Gating)

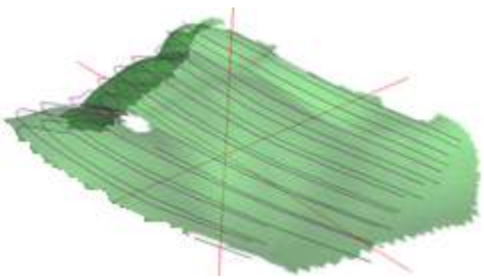
Sentinel



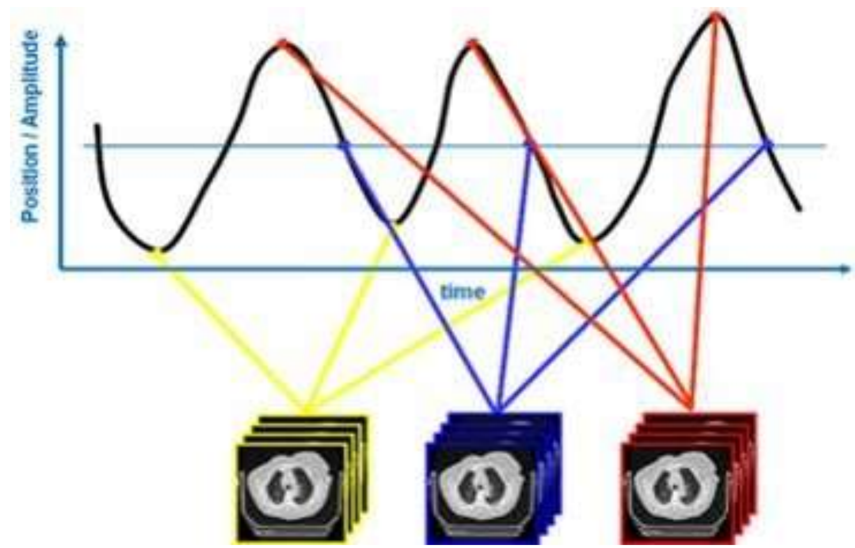

CT



# Two Sentinel‘s Contributions are now available :



+




**TPS informations !**

**DICOM**

**to the Catalyst at Linac.**

First CTs Patient‘s Surface

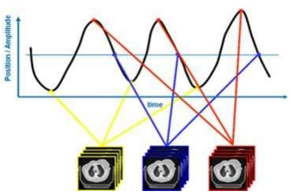
+

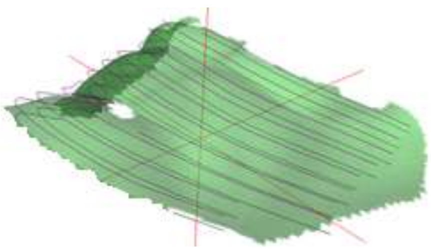
Gating correlation

# Workflow : Step 2 – RT (first Fraction)

**from** CT Room

SENTINEL





**in** RT Room

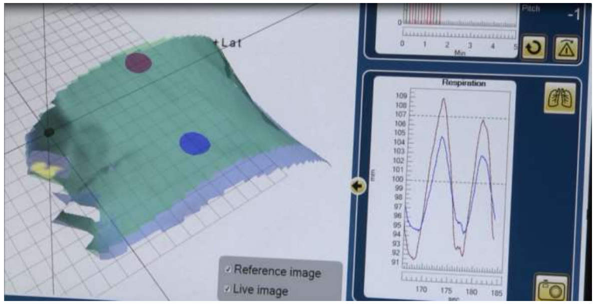
catalyst

- **Again : Patient's Surface (now, first fraktion at the Linac) + local Gating**

**Delta < 0**

**Delta = 0**

**Delta > 0**



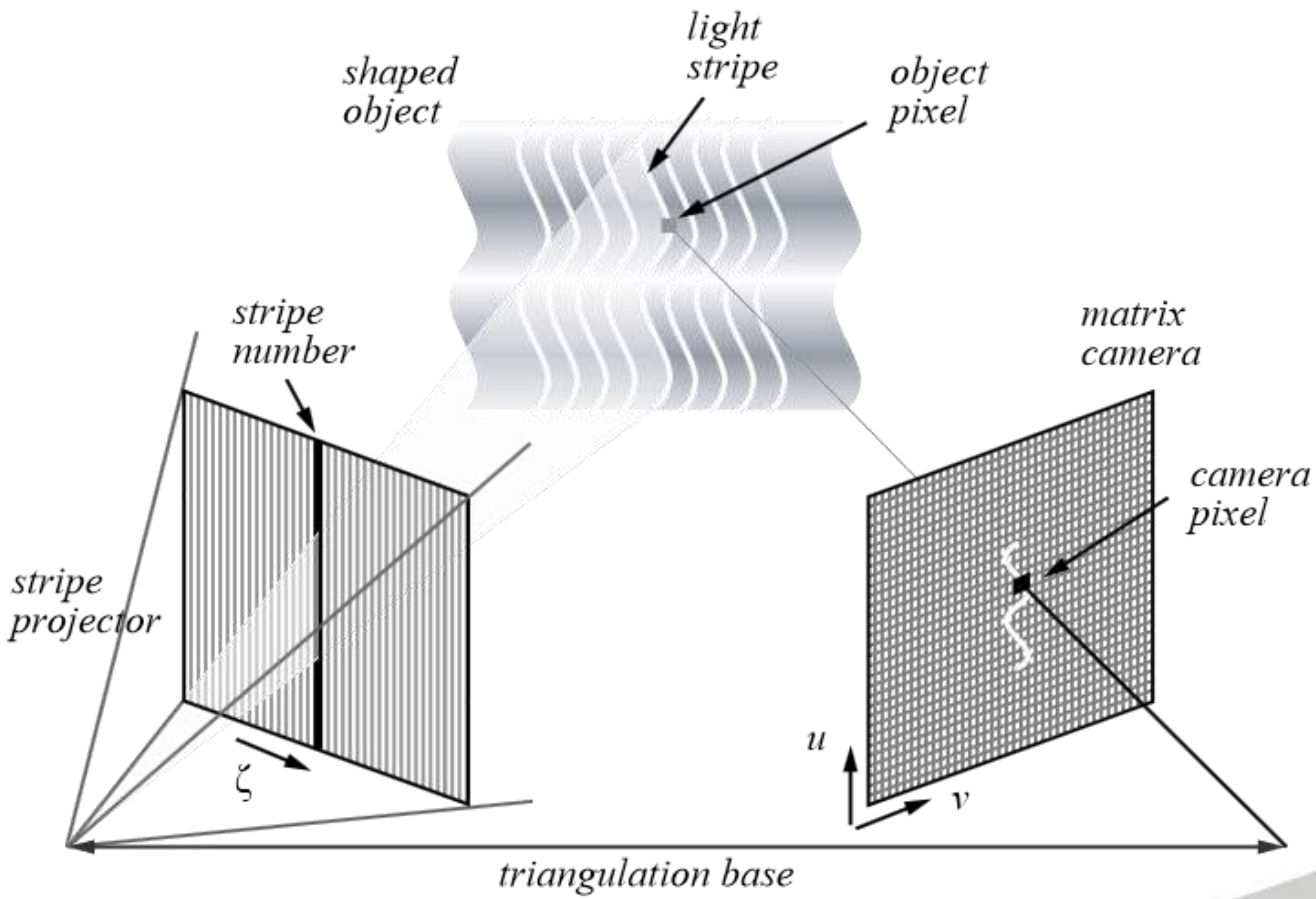

Gating at Linac

Back-projection,
Patient Vicinity & Safety

Isocenter

C-RAD

# Catalyst Algorithm



# Rückprojektion : Beispiel Torso Rotation

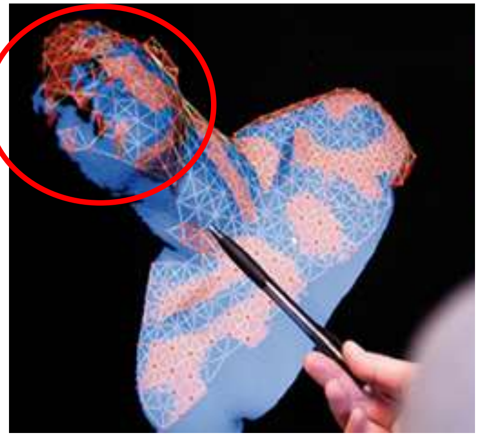
Muss nach **unten** (weil Rot ist)


Muss nach **oben** (weil Gelb ist)

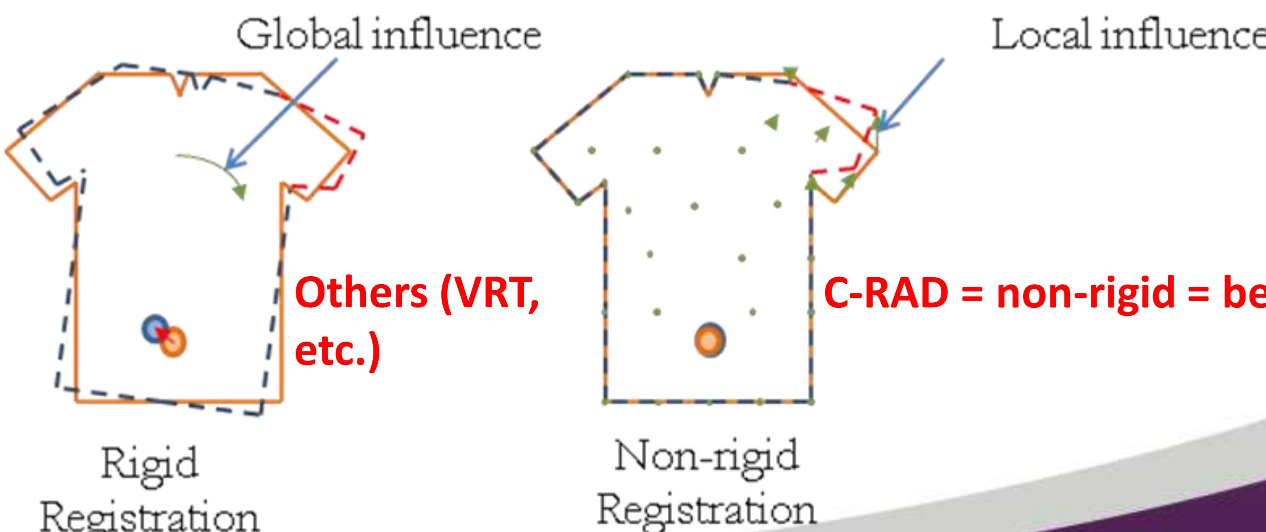
C-RAD

# Sub-matrixes and non-rigid elastic registration

**Patient recognition**



Linked, independent and elastic sub-matrixes on the patient‘s surface




**Others (VRT, etc.)**

**C-RAD = non-rigid = best Gating !**

# Depth Sensor-Based Realtime Tumor Tracking for Accurate Radiation Therapy

Björn Nutti[1,2] Åsa Kronander[1] Mattias Nilsing[1] Kristofer Maad[1] Cristina Svensson[1] Hao Li[3]

[1]C-RAD Positioning AB [2]AlgoritmFabriken AB [3]University of Southern California

**Abstract**

*We present an image guided radiation therapy (IGRT) system for tracking tumors in realtime based on continuous structured light imaging. While an accurate positioning of the radiation isocenter to pre-imaged cancer cells is critical to minimize the risk of damaging healthy tissues, patients undergo involuntary motions such as breathing or unpredictable gestures during treatment. Moreover, multiple sessions are typically necessary and repositioning the patient accurately can be difficult. Our approach consists of determining the tumor position by densely tracking the deformation of a stream of 3D scans using a realtime variant of a state-of-the-art non-rigid registration algorithm and an FEM simulation on the interior body. We use interactive reprojection for visual guidance to adjust the posture of the patient and couch position, depending on the tumor location. Compared to existing techniques, our method uniquely estimates tumor deviations under body deformations. Our pipeline has been successfully commercialized as part of the C-RAD AB Catalyst™ product line and is already deployed in a number of hospitals.*

C-RAD

# Guaranteed Accuracy Performances :

| | |
|---|---|
| Long term stability: | Within 0.3 mm |
| Measurement reproducibility: | 0.2 mm |
| Frame Rate: | 200 frames/s |
| Positioning accuracy Catalyst | Within 1 mm for rigid body |
| Positioning accuracy CatalystHD | Within 0.5 mm for rigid body |
| Motion detection accuracy Catalyst | Within 1 mm for rigid body when couch is in fixed position during treatment<br>Within 3 mm for rigid body when couch is moving during treatment (e.g. Tomotherapy) |
| Motion detection accuracy CatalystHD | Within 0.5 mm for rigid body when couch is in fixed position during treatment |
| cRespiration detection accuracy | Within 1 mm for rigid body |

C-RAD

catalyst

## Modules (min. 1 must be configured) :

... always present and monitoring the ROI <u>in real-time</u> ...

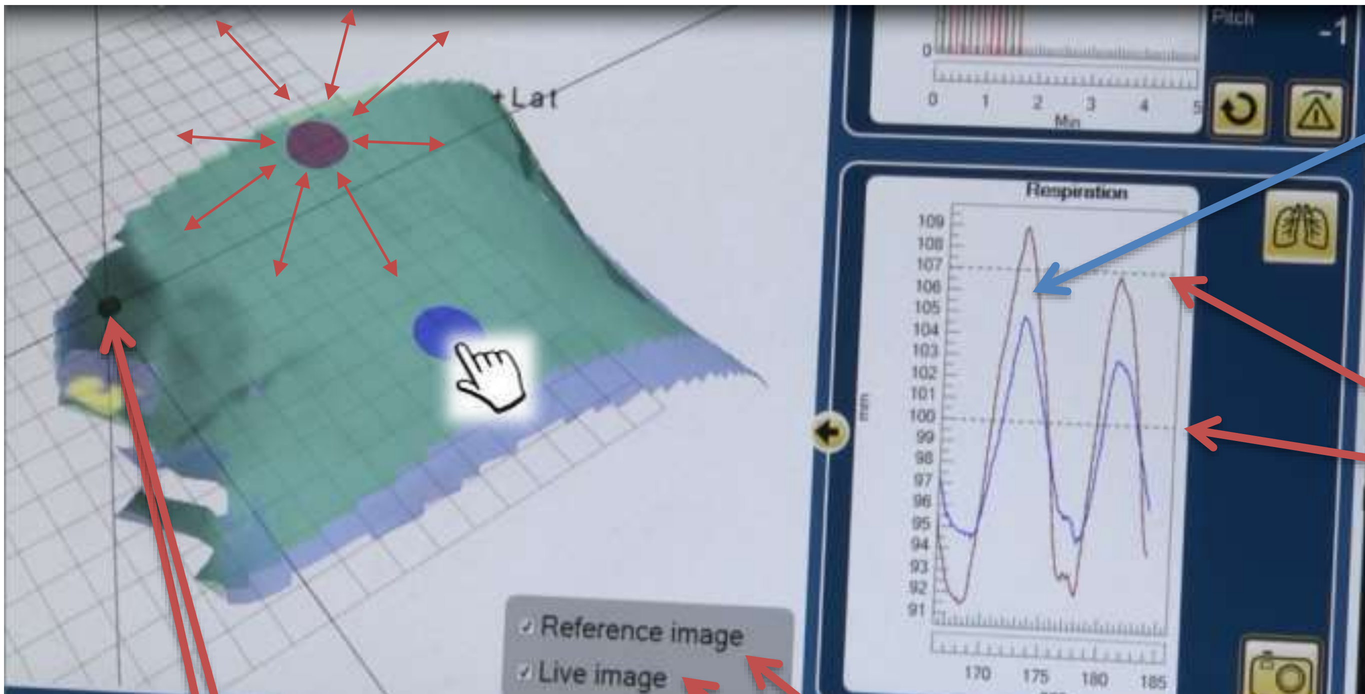
Patient setup, Positioning and Vicinity Recognition (Module)

Motion detection (Module)

Respiratory gating (Module)

C-RAD

# Respiratory Gating with the Catalyst in Linac Room (with Touch Screen Option) with non-rigid registr.




Real-time Measurements (free breathing) in Linac Room

From CT for free-breathing and DIBH

From Sentinel - CT

From Catalyst - Linac

1) Tumor‘s Isocenter

2) Linac = Catalyst Isocenter

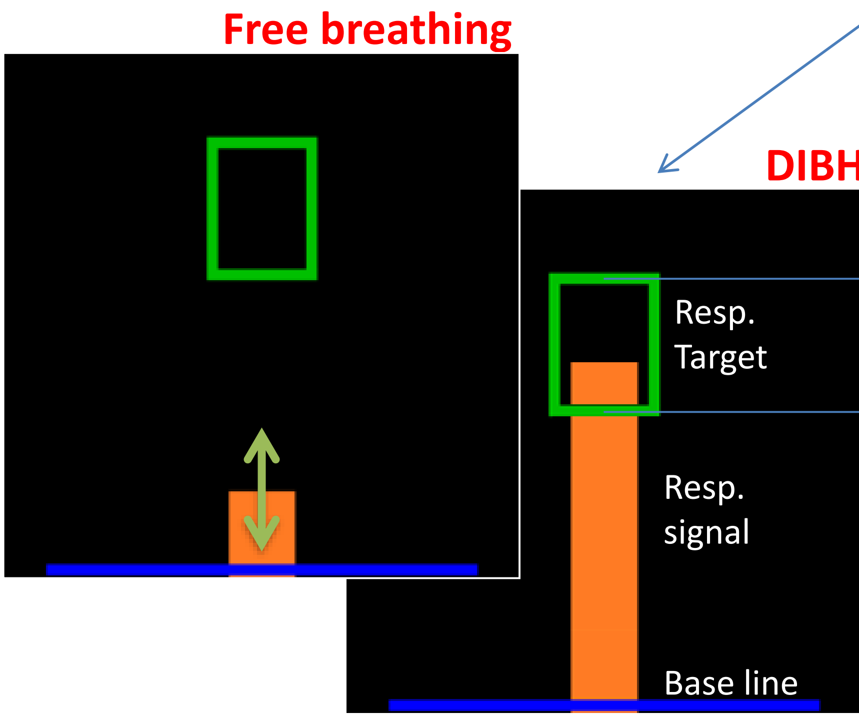
# Respiratory gating / coaching for ”Deep Inspiration Breath Hold” (DIBH)

„Catalyst“ „Sentinel“

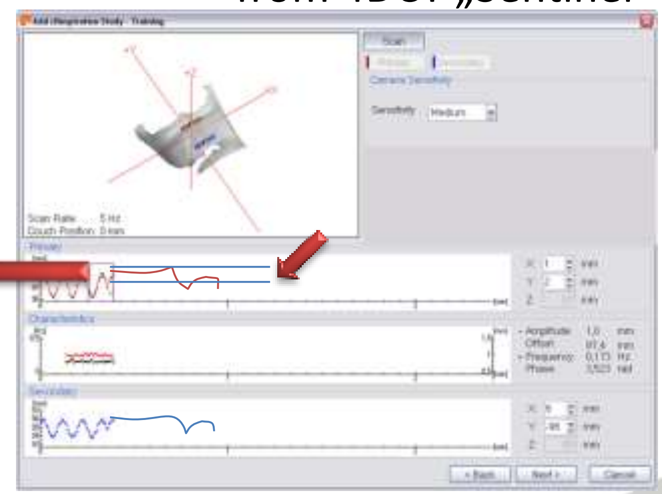
**RT ← CT**

## Patient’s Visual feedback

Exported via DICOM

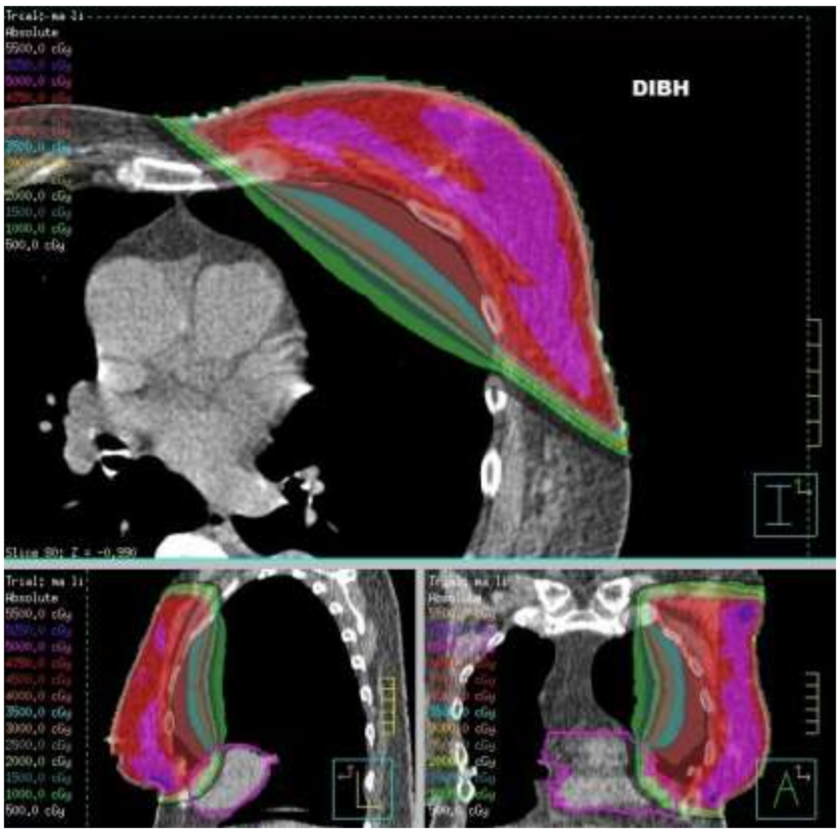


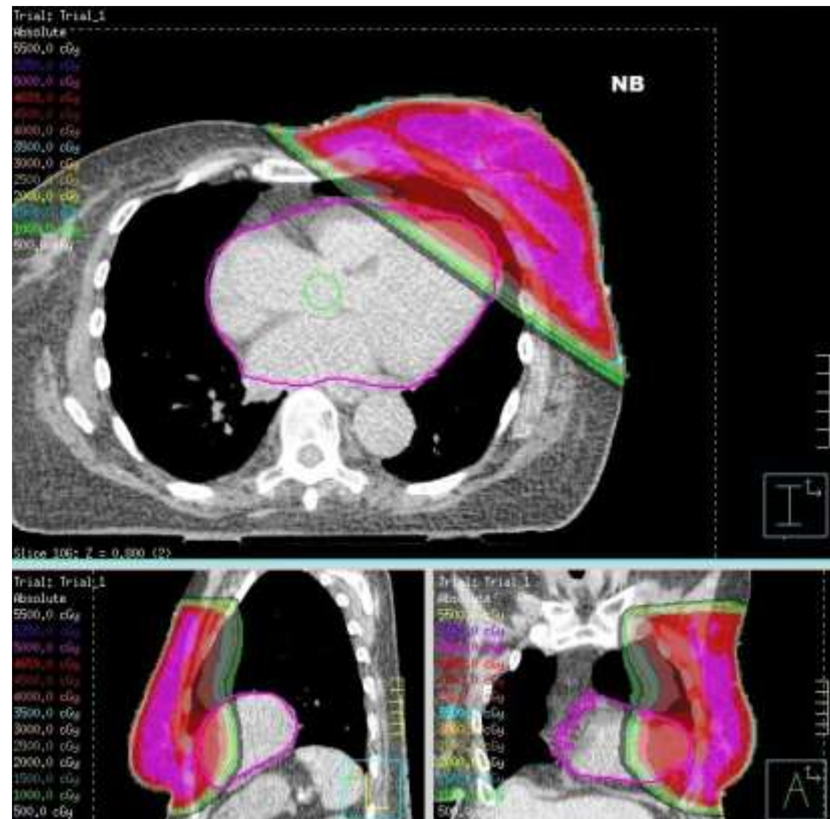

from 4DCT „Sentinel“



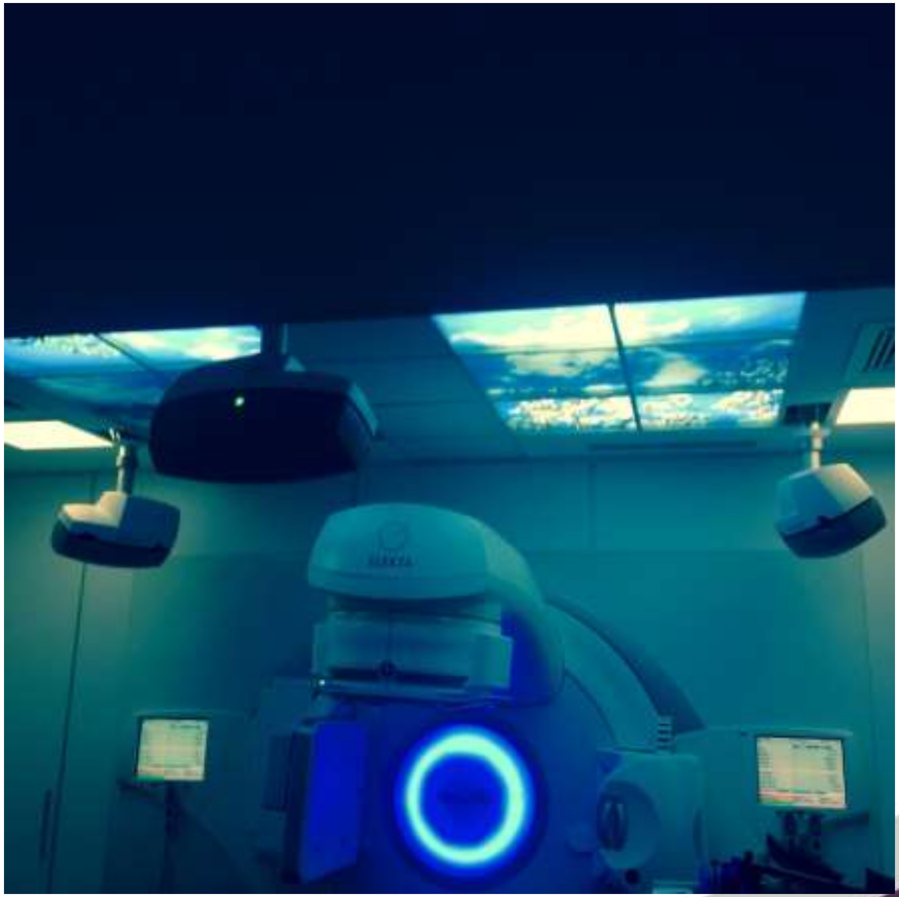
C-RAD

# Dosimetrical comparison between Plans in DIBH and free breathing via C-RAD Goggles.



# 1-camera vs. 3-camera
# Upgrade and final Installation

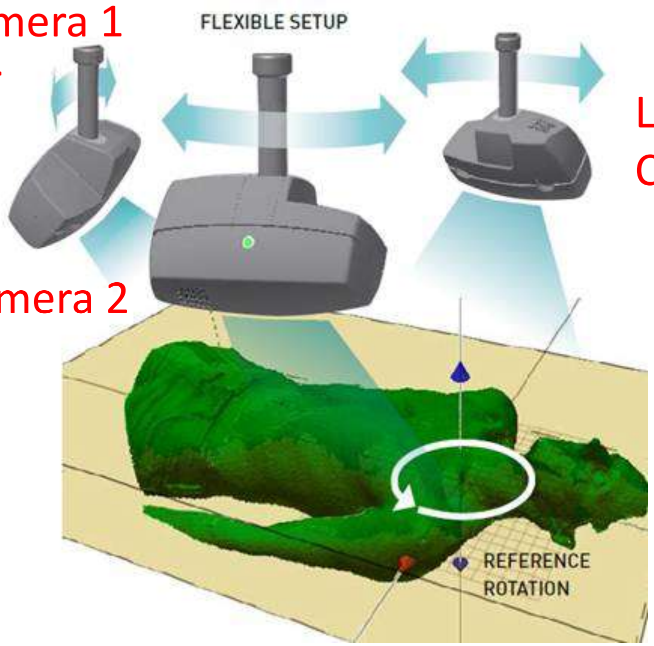
# 3-Camera Catalyst PT with IBA Interface


… other Vendors Interfaces coming soon …

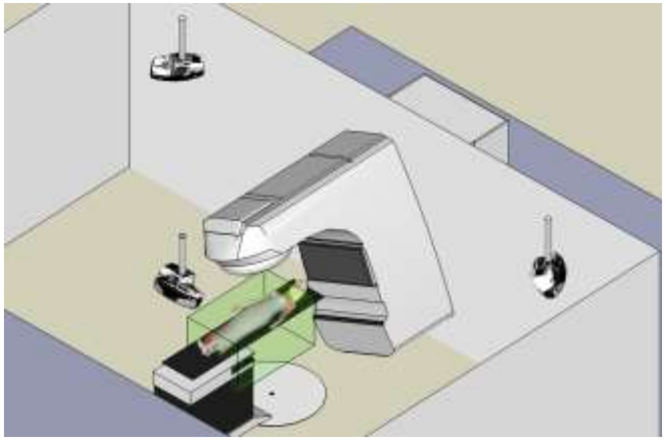
# 3-Camera Solution

Central Camera 1
+ Projector

Right Camera 2




Left
Camera 3



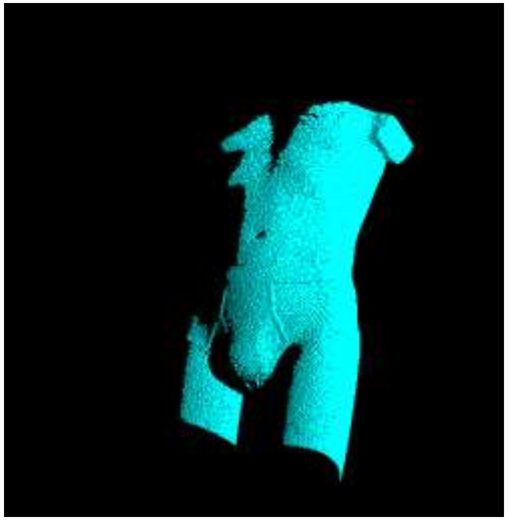
# 3-Camera Solution
# KFJ Spital – Wien –

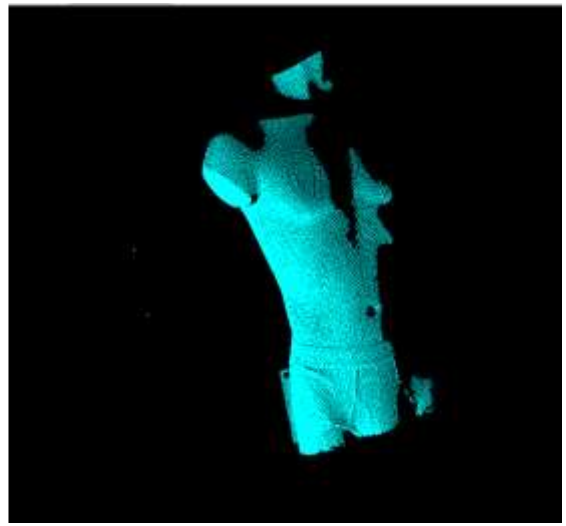
- Also for Stereotactic and PT Treatments
- Full Patient Surface coverage
- Monitoring independent from couch kicks

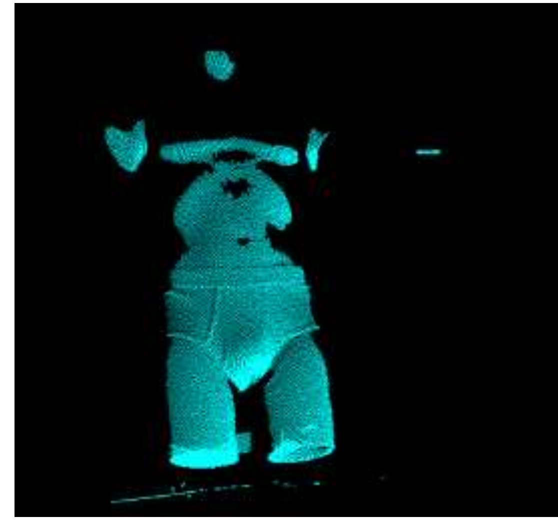
C-RAD

Right Camera 2 | Left Camera 3 | Central Camera 1

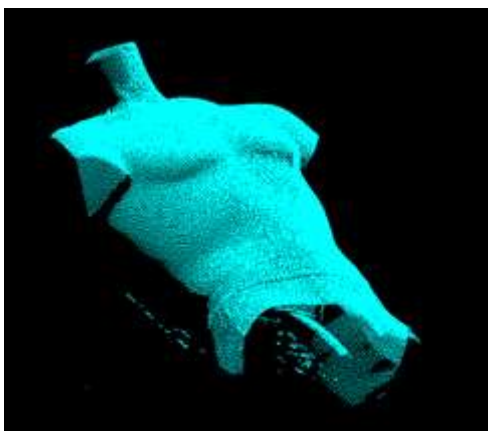
**Camera Shots**



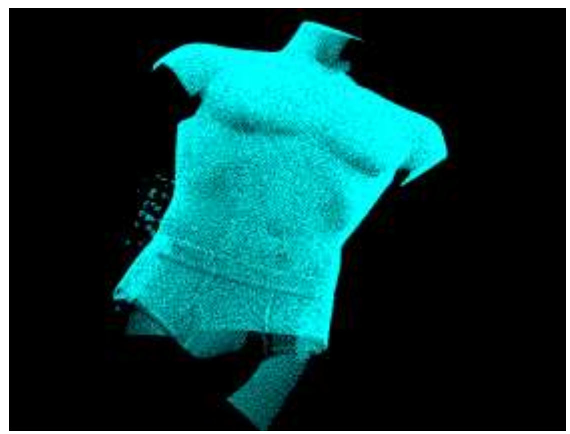




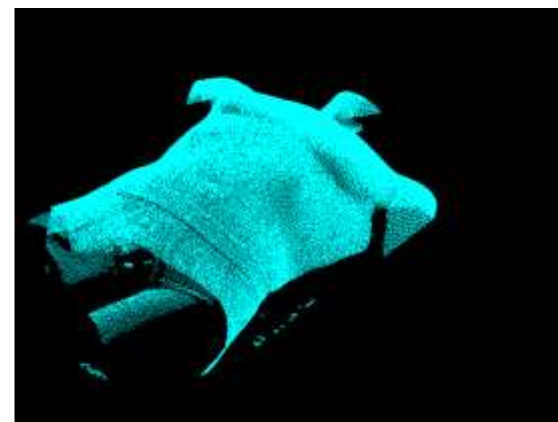
**Composite Global Views (R2+L3+C1 Camera Shots Super-impositions)**



Right View

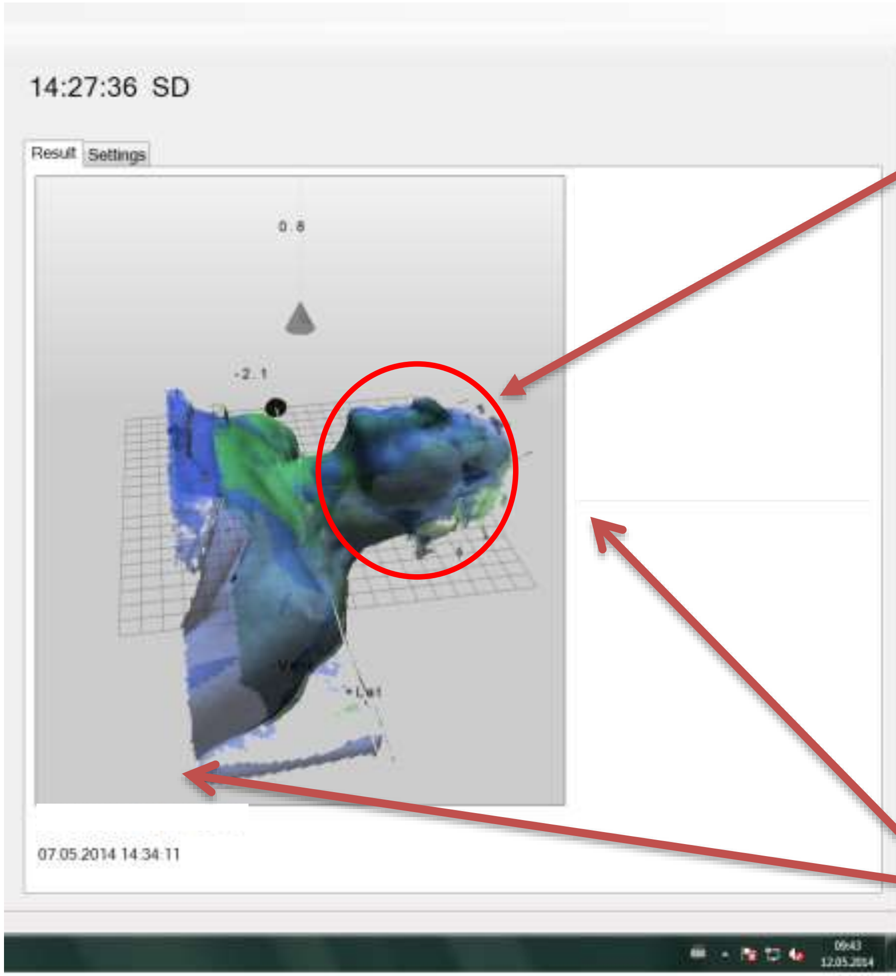


Central View



Left View

# 3-Camera Catalyst Stereotactic Report with Screen View




**Patient Vicinity Recognition**

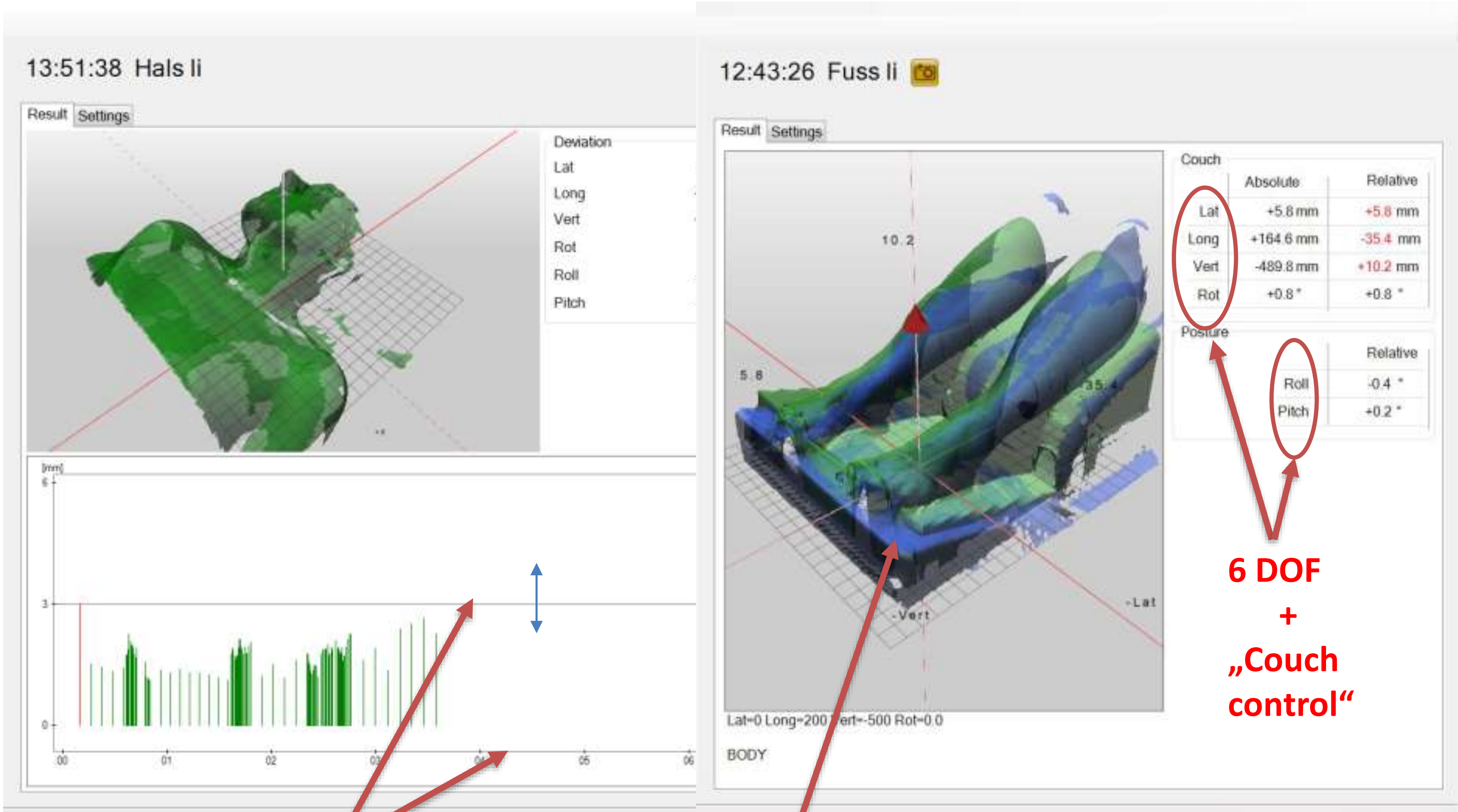
Benefits for Stereotactic Applications :

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

**Critical Angles / Views**

**→ Instant verification of postural errors (shoulder and head rotation)**

# „Patient Vicinity“ und Sicherheit :

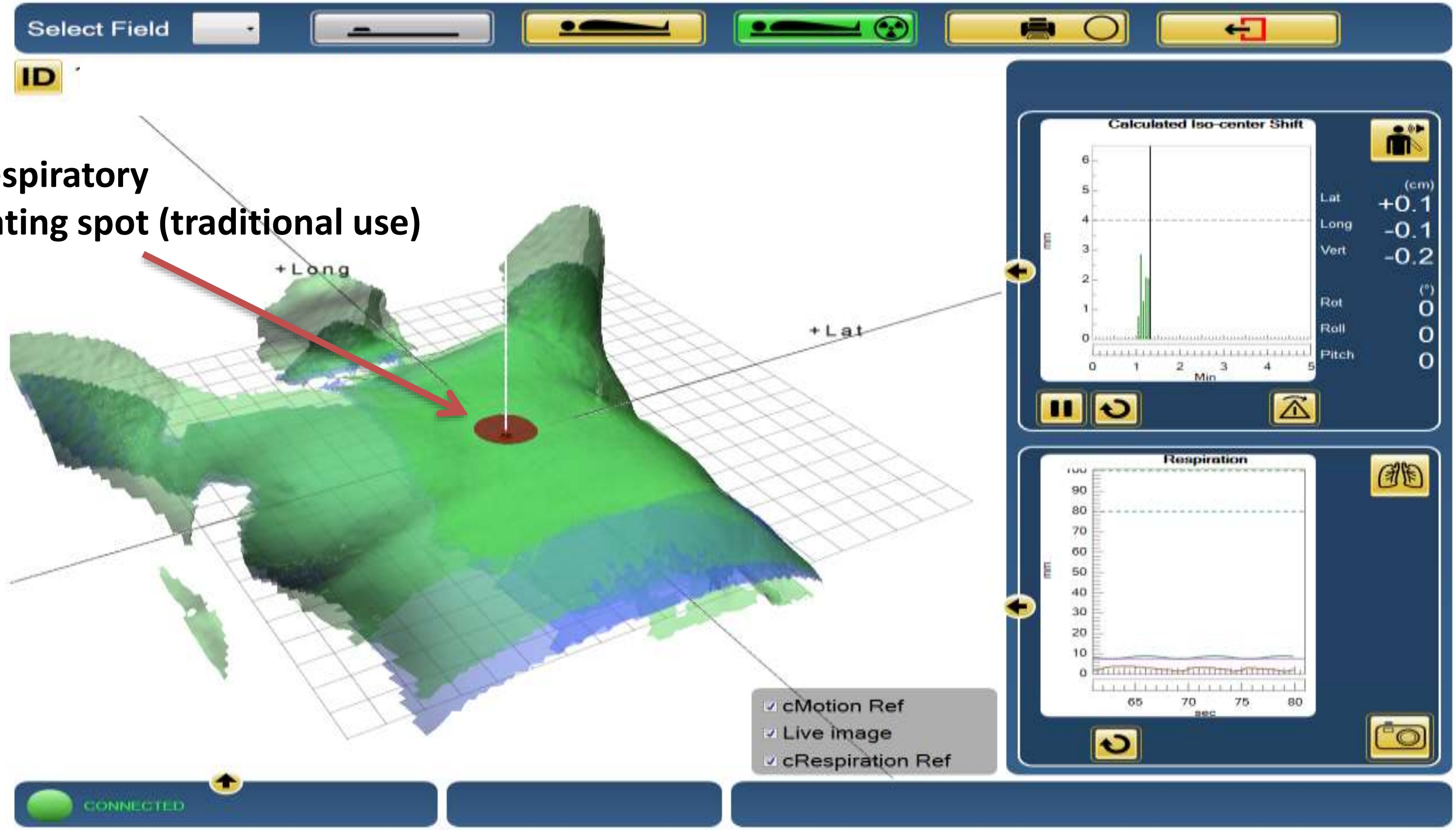



**Sicherheitsfenster (konfigurierbar)**

**Lagerungshilfe Infomationen …**

C-RAD

# Flexibilität des Systems … mit / ohne Brille



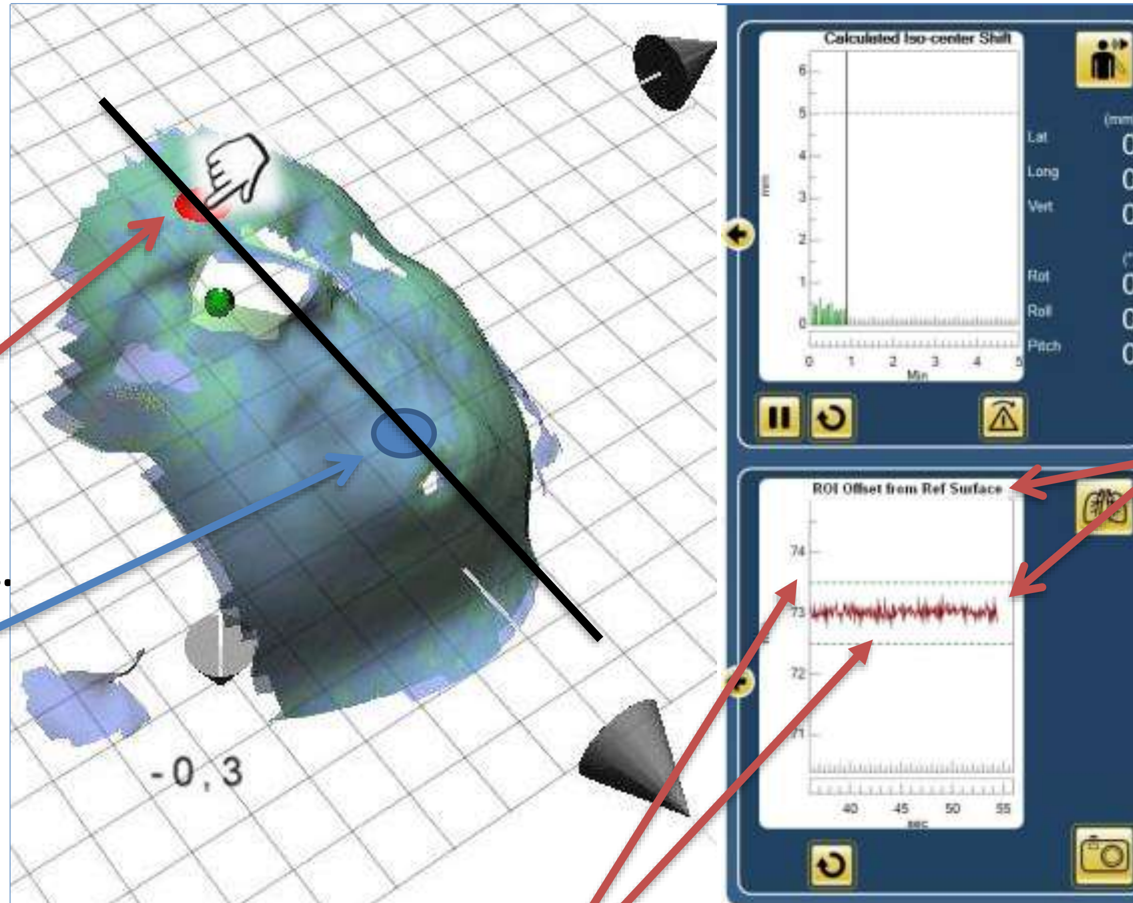

C-RAD

# Head & Neck … ohne Masken … (Sweden)

“Reduced fixation with optical monitoring for palliative whole brain radiotherapy treatment”.

**Silke Engelholm at al.**

*Radiation Physics, Skåne University Hospital, Lund, Sweden*




„Gating“ primary spot …

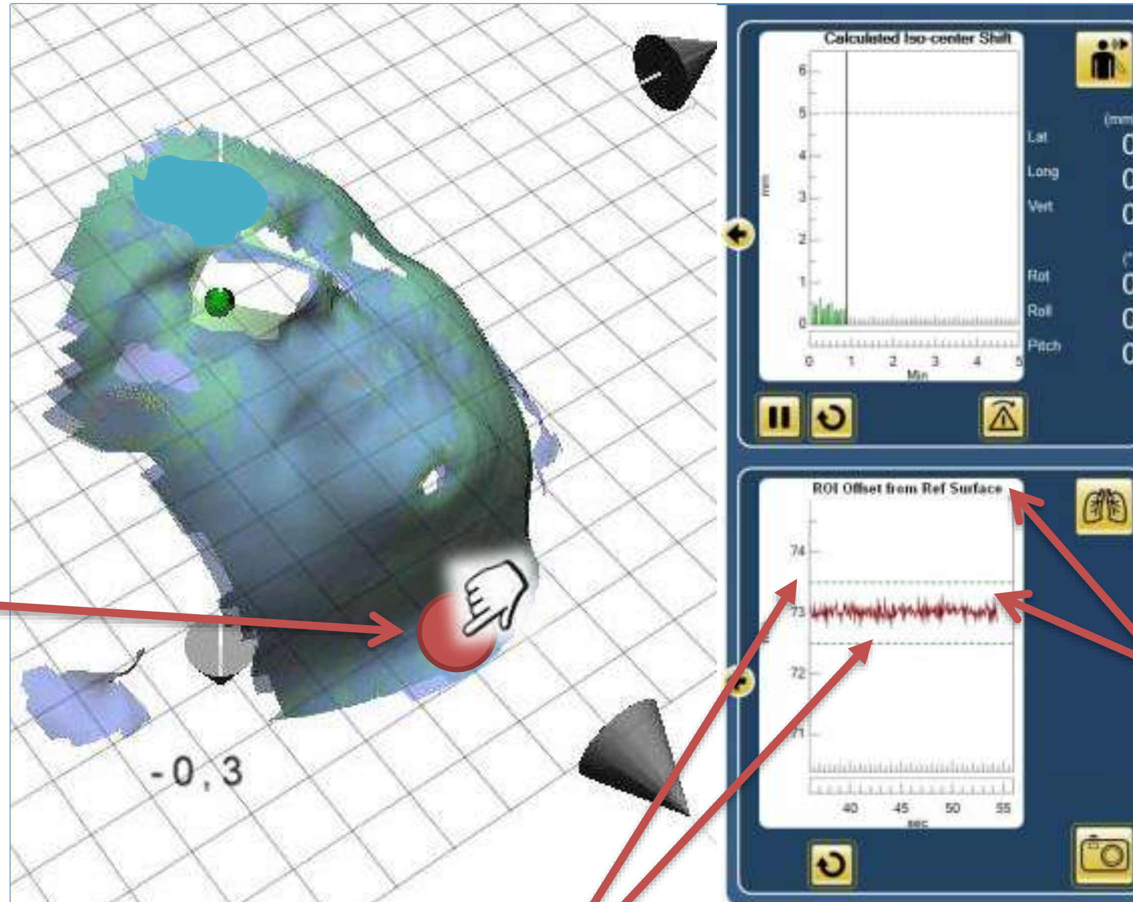
Secondary spot

Sicherheitsfenster

# Head & Neck … ohne Masken … (USA)

**“Application of Surface Mapping in detecting Swallowing for Head & Neck Cancer”**

David Shepard et al. - Swedish Hospital Seattle, USA

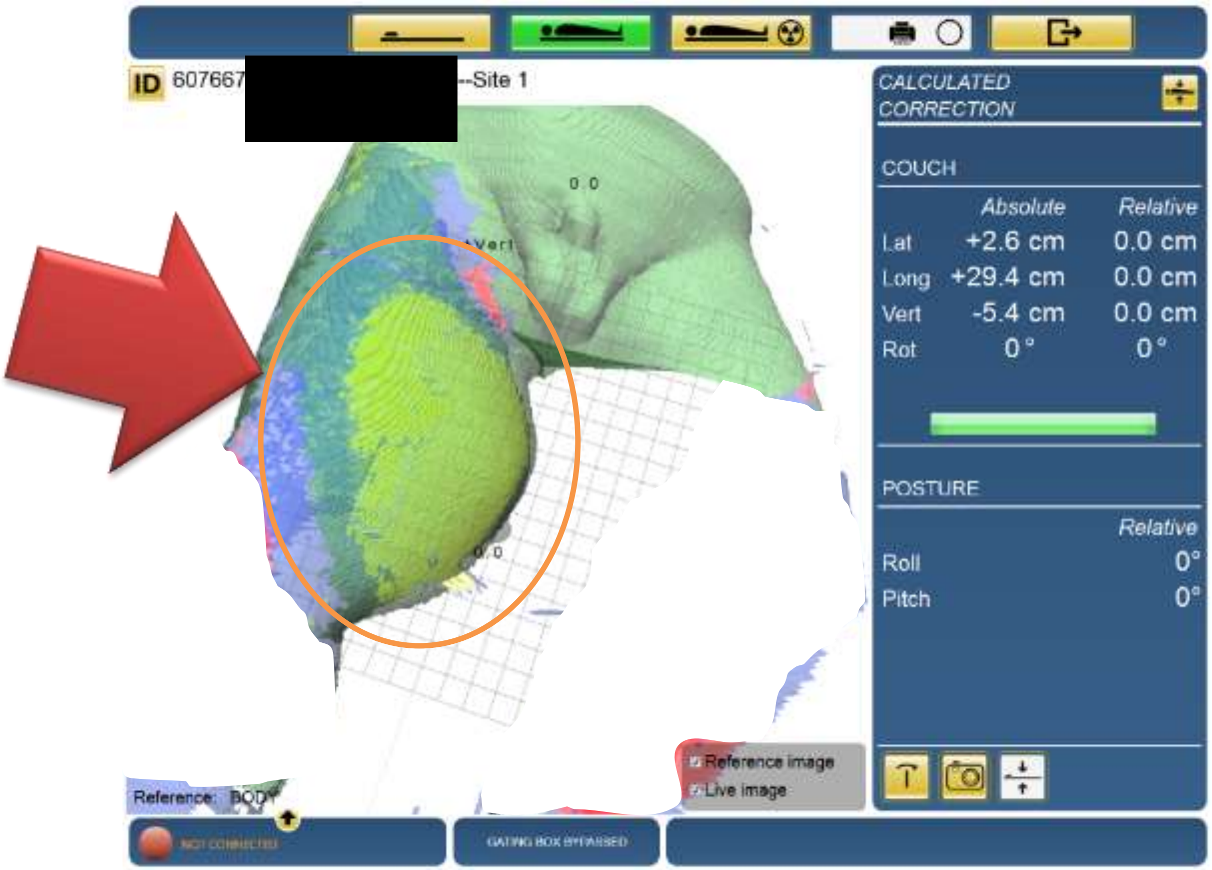



**„Gating“ spot …**

**Sicherheitsfenster**

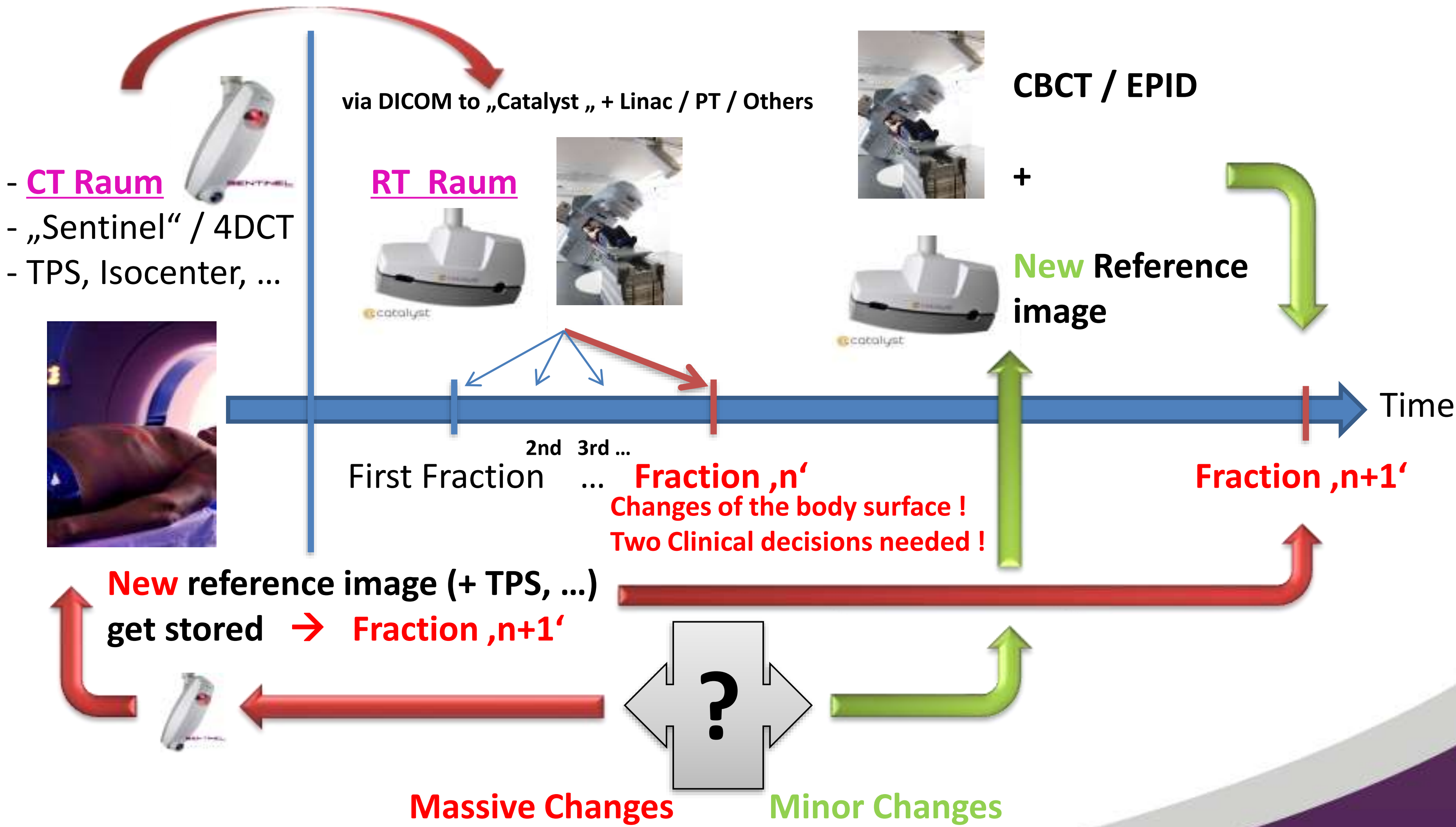
C-RAD

# Sarcoma Positioning after / during Pharmaceutical Treatment (with “crop” function)




**C-RAD Catalyst‘s „cPositioning“ shows fraction-by-fraction surface changes …**

## Has the patient‘s surface changed after the first fractions ?
## Always a safe dynamic Workflow :




C-RAD

# Clinical Training Process

Technical Training as part of the Installation

Target group: Physicist and Lead Therapist

Performed by: C-RAD Installation Engineer

4 hours

On-Site Clinical Application Training

Target Group: Physicians, Physicists and all therapists

Performed by: C-RAD Clinical Application Specialist

3 days

Optional: C-RAD Training center

Target group: “Super user”

2 days

Follow up On-Site Clinical Application Training

Target Group: Physicians, Physicists and all therapists

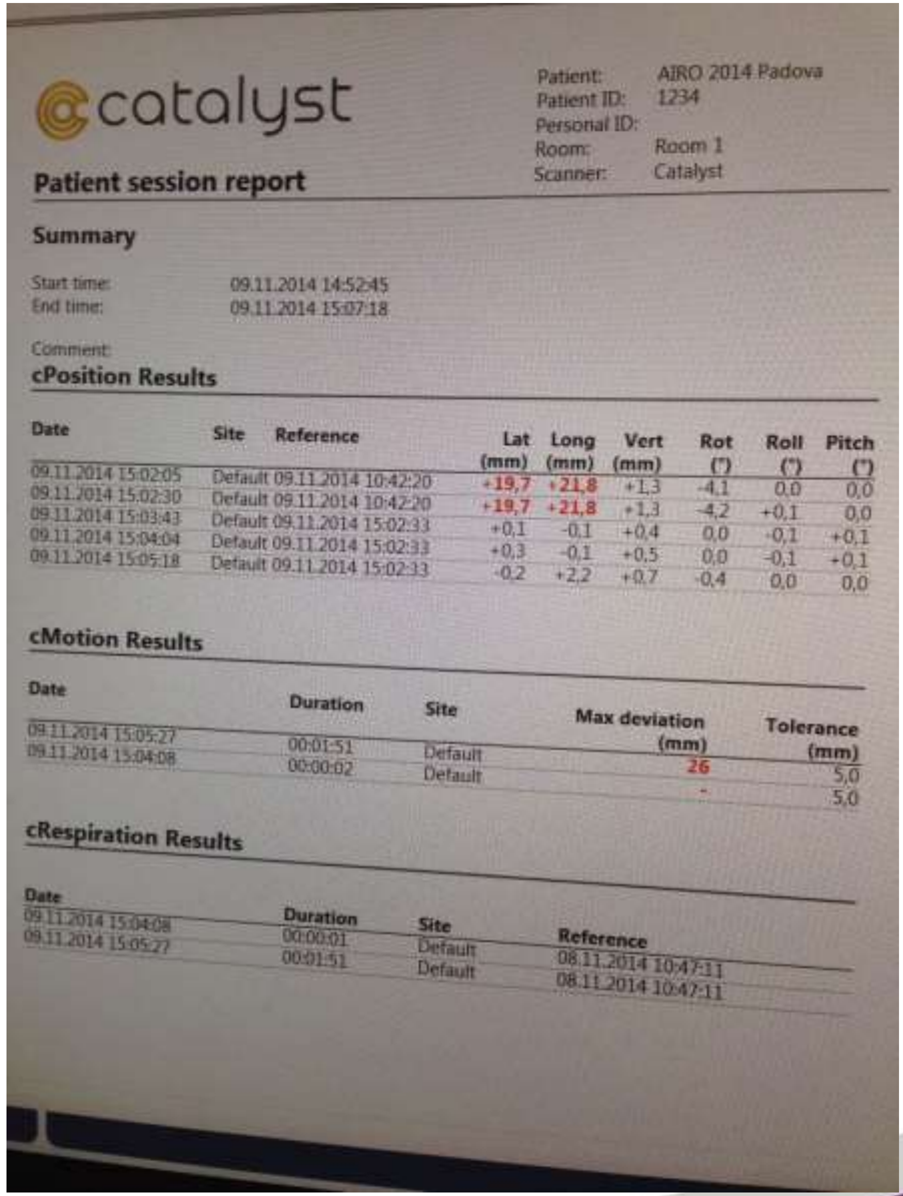
Performed by: C-RAD Clinical Application Specialist

2-3 days

Training and support on demand

C-RAD

# Reporting
(on screen and in .pdf)



catalyst

| | |
|---|---|
| Patient: | AIRO 2014 Padova |
| Patient ID: | 1234 |
| Personal ID: | |
| Room: | Room 1 |
| Scanner: | Catalyst |

## Patient session report

### Summary

Start time: 09.11.2014 14:52:45
End time: 09.11.2014 15:07:18

Comment:

### cPosition Results

| Date | Site | Reference | Lat (mm) | Long (mm) | Vert (mm) | Rot (°) | Roll (°) | Pitch (°) |
|---|---|---|---|---|---|---|---|---|
| 09.11.2014 15:02:05 | Default | 09.11.2014 10:42:20 | +19,7 | +21,8 | +1,3 | -4,1 | 0,0 | 0,0 |
| 09.11.2014 15:02:30 | Default | 09.11.2014 10:42:20 | +19,7 | +21,8 | +1,3 | -4,2 | +0,1 | 0,0 |
| 09.11.2014 15:03:43 | Default | 09.11.2014 15:02:33 | +0,1 | -0,1 | +0,4 | 0,0 | -0,1 | +0,1 |
| 09.11.2014 15:04:04 | Default | 09.11.2014 15:02:33 | +0,3 | -0,1 | +0,5 | 0,0 | -0,1 | +0,1 |
| 09.11.2014 15:05:18 | Default | 09.11.2014 15:02:33 | -0,2 | +2,2 | +0,7 | -0,4 | 0,0 | 0,0 |

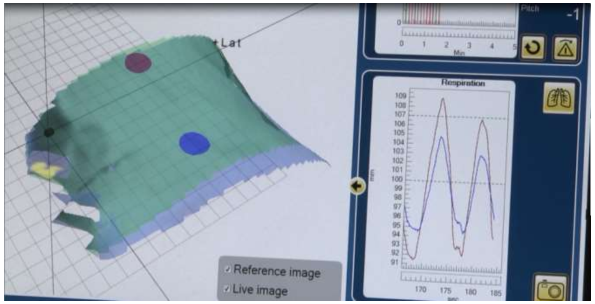
### cMotion Results

| Date | Duration | Site | Max deviation (mm) | Tolerance (mm) |
|---|---|---|---|---|
| 09.11.2014 15:05:27 | 00:01:51 | Default | 26 | 5,0 |
| 09.11.2014 15:04:08 | 00:00:02 | Default | - | 5,0 |

### cRespiration Results

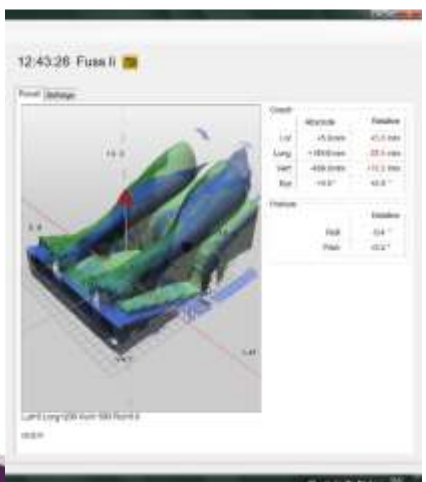
| Date | Duration | Site | Reference |
|---|---|---|---|
| 09.11.2014 15:04:08 | 00:00:01 | Default | 08.11.2014 10:47:11 |
| 09.11.2014 15:05:27 | 00:01:51 | Default | 08.11.2014 10:47:11 |

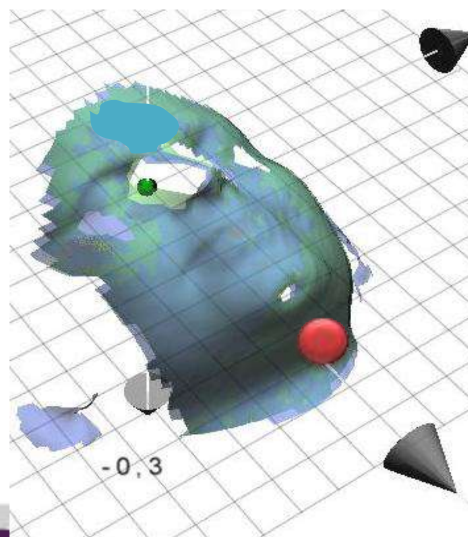
C-RAD

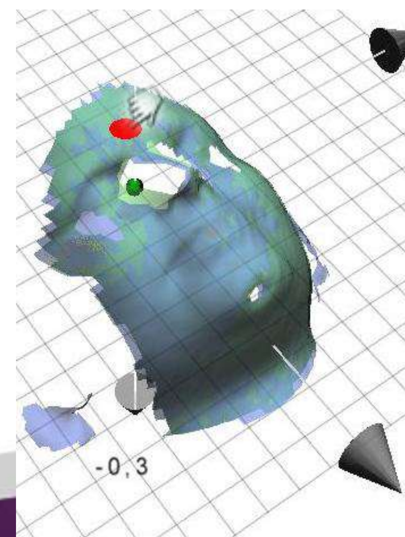




1) 1- bis 3-Kamera im Linac Raum
2) Immer in Real-time und kontinuierlich
3) Patient vicinity & recognition
4) Ohne Markers, Blocks, Belts, etc.
5) Flexibilität
6) Rückprojektion für Lagerung
7) Gating free breathing und DIBH
8) Bewegungsmonitoring
9) Nicht-rigide Registrierung
10) Alle CTs, Linacs, Tomo und PT ABI.





C-RAD

# „Installed base“ C-RAD Systeme in DACH :

„Sentinel“ (CT Raum) : 15

„Catalysts“ (Behandl. Raum) : 27

( „Catalysts HD“ (Behandl. Raum) : **10** **(*)** )

C-RAD „HIT“ Raum Lasers : 7

**Gesamt** : **47** **C-RAD Systeme - Deutschsprachige Länder (Status ende März 2016)**

**Publikationen** : **aus LMU, UMM, Uni Mainz, Gelsenkirchen, etc.**

**Uni Kliniken mit C-RAD** : **Aachen, Mainz, LMU x 2, UMM, Bonn, Köln, Essen.**

**(*)** : 3-Kamera Version

# Publications :

Hepp R, Ammerpohl M, Morgenstern C, Nielinger L, Erichsen P, Abdallah A,Galalae R. Deep inspiration breath-hold (DIBH) radiotherapy in left-sided breast cancer : Dosimetrical comparison and clinical feasibility in 20 patients. Strahlenther Onkol. 2015 Apr 18. [Epub ahead of print]

**Deep inspiration breath-hold (DIBH) Radiotherapy in left-sided breast cancer: Dosimetrical comparison and clinical feasibility in 20 patients**

**Bestrahlung der linken Brust in tiefer Inspiration und Atemanhaltetechnik (DIBH) bei linksseitigem Brustkrebs:**
**Dosimetrischer Vergleich und Prüfung der klinischen Durchführbarkeit in 20 Patientinnen.**

Rodrigo Hepp M.D.[1]; Nielinger[1, 2] B.Eng., P
M.D.

[1]Klinik für Strahlenthe
Evangelische Kliniken

[2]Hochschule Hamm-L

[3]Klinik für Senologie
Evangelische Kliniken

[4] Medizinische Fakult

Corresponding Author

Dr. med. Rodrigo Hep
Klinik für Strahlenthe
Evangelische Kliniken

Munckelstraße 27
45879 Gelsenkirchen

Tel: +49 209 160 300
Fax: +49 209 160 304
e-mail: heppdelosrios

**Sentinel/Catalyst surface tracking system for respiratory gating. Tests performed at Skåne University Hospital, SUS, Malmö.**

Charlotte Thornberg, Mattias Jönsson, Sofie Ceberg, Malin Kugele, Fredrik Nordström

## Introduction

In radiation treatment, gating can be used in different ways to minimize the absorbed dose to risk organs. A positive correlation has been observed between cardiac dose-volume and the level of excess risk of cardiac mortality from ischemic heart disease (1) as well as between the irradiated lung volume and radiation pneumonitis (2). Respiratory gating for breast cancer patients is a simple and straightforward way to reduce the absorbed dose to the heart and lungs [3]. In Malmö, gating of left sided breast cancer patients has been in use clinically since 2007 [Varian Real-time Position Management (RPM) system]. A Sentinel system was installed in2009 for evaluation and development of gating functionalities. In 2011, the Sentinel system in the treatment room was moved to the CT room and replaced by a Catalyst system.

This report describes some of the initial tests performed in the implementation of the gating functionality, as well as comparisons with the RPM system.

## Material and methods

### Catalyst

The Catalyst system is installed in connection with two treatment machines (Varian Xi 2100 Clinacs), and there is also a system in a training room for gating evaluation. Measurement in the Catalyst system is based on the principle of optical triangulation. A rapid and near-invisible sequence of patterns is projected onto the surface of the object to be measured. At the same time, images are captured by a camera, which is mounted at an angle from the projector. By analyzing the recorded image sequence, a high resolution 3D surface model can immediately be reconstructed. A complete surface can be captured in fractions of a second, with an accuracy of a few tenths of a millimeter – measured at a distance of several meters away.

Fig.1. The Catalyst system

SWEDISH

**Application of Surface Mapping in Detecting Swallowing for Head-&-Neck Cancer**

Daliang Cao, Xin Xie, Vivek Mehta, David M. Shepard
Swedish Cancer Institute, Seattle, WA

Introduction | Methods & Materials | Results | Results

Original article

F. Stieler · F. Wenz · M. Shi · F. Lohr

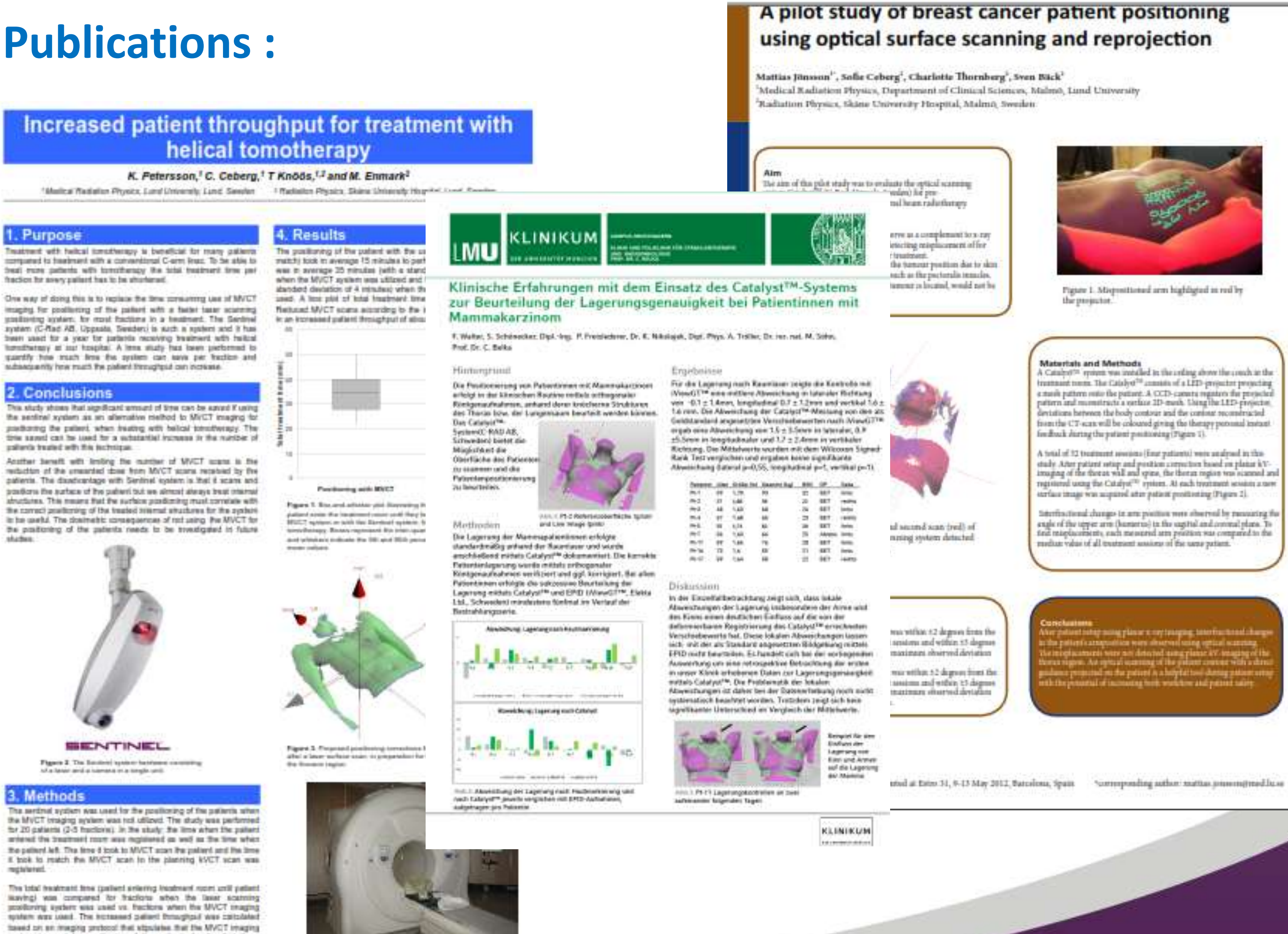
## A novel surface imaging system for patient positioning and surveillance during radiotherapy

### A phantom study and clinical evaluation

Materials and methods

C-RAD

# Publications :




C-RAD

# Ziel erreicht :


**Mehr Patienten pro Tag,**

**besser und**

**mit mehr Sicherheit behandeln.**

**Thank you for your attention !**

→ **Videos**

**www.c-rad.se**

franco.canestri@c-rad.com
Mobile : 0176.10023655

C-RAD