iba Dosimetry

# COMPASS

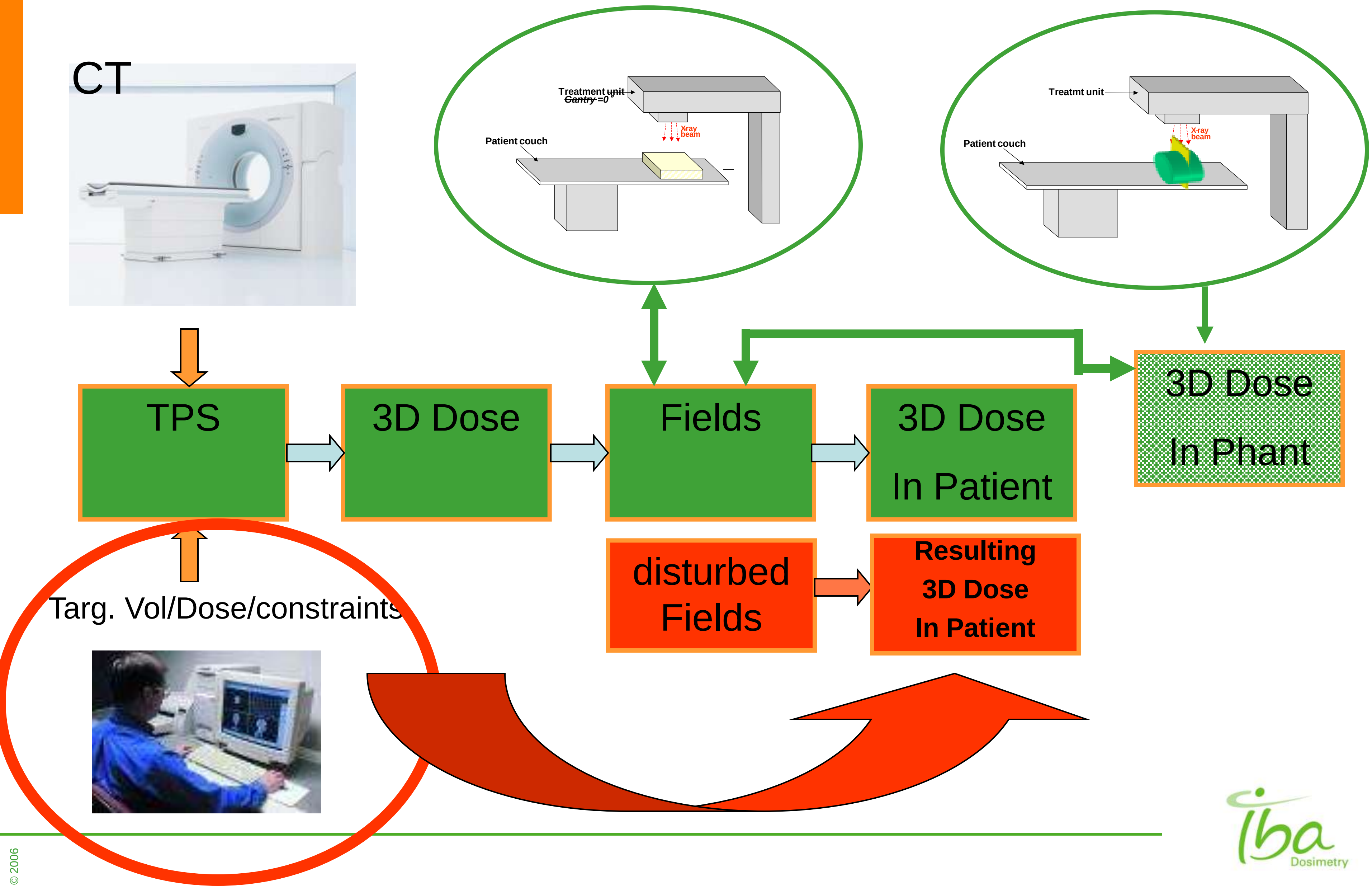
**3D IMRT Verification in Patient Anatomy**

**AK IMRT**
**Bamberg April 2010**

**Dr. Lutz Müller**

FASTest mostACCURATE mostRELIABLE

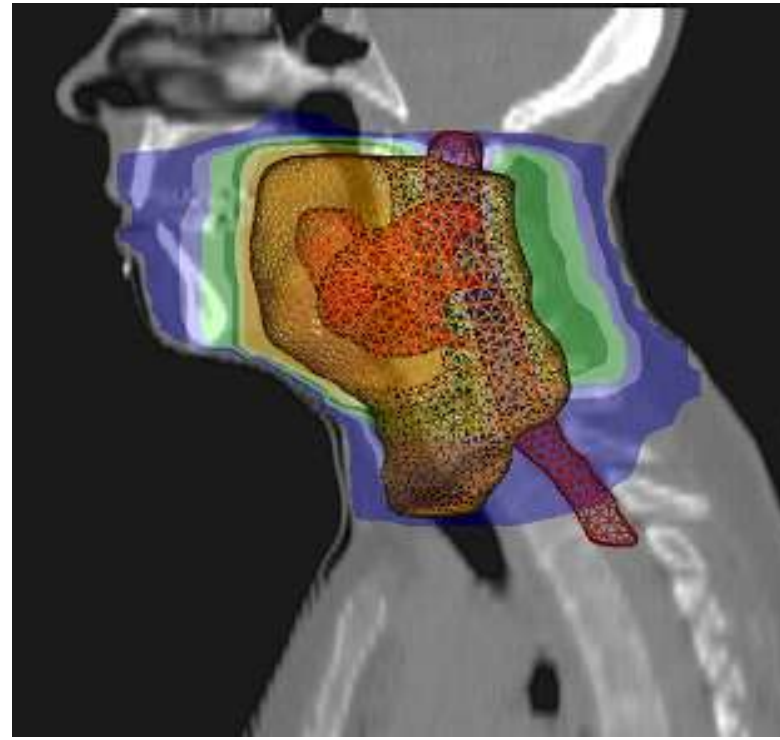
# Patient-specific Verification ?



# Generations of electronic IMRT Dosimetry

1st

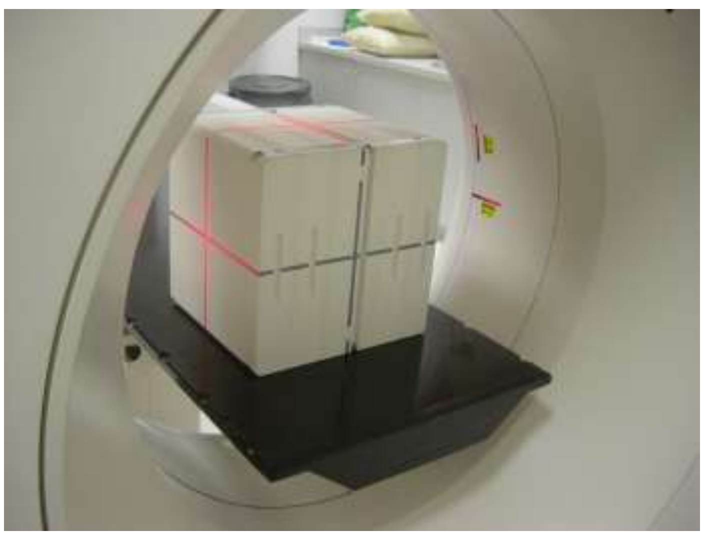
Single fields, perpendicular



2nd

Homo-geneous phantom,

composite



3rd

COMPASS

# 2nd Generation

# How to assess dose to the patient for IMRT?

- **Invasive Method: place a film in the patient**



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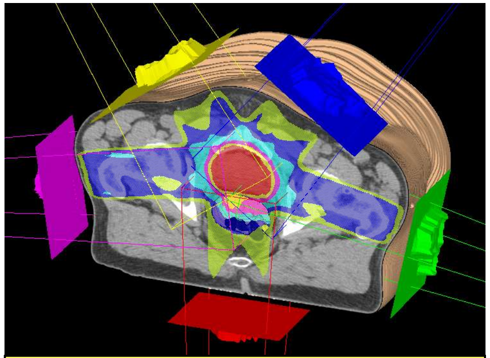
# What is COMPASS ?

**Detector**

+

**Beam model**

+



**Dose engine**

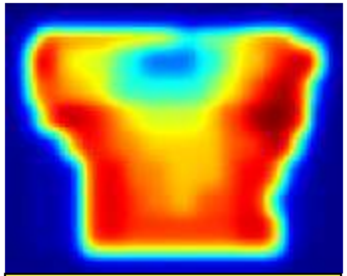
NOTE: all these elements are PART of COMPASS, not only the transmission detector

# Compass: from Entrance Fluence to 3D Patient Dose

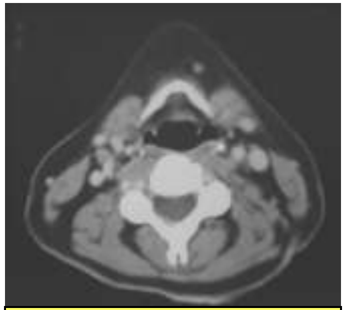
DICOM plan

Beam model

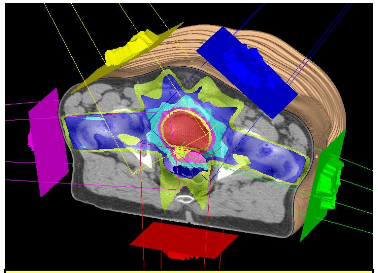
Transmission Detector



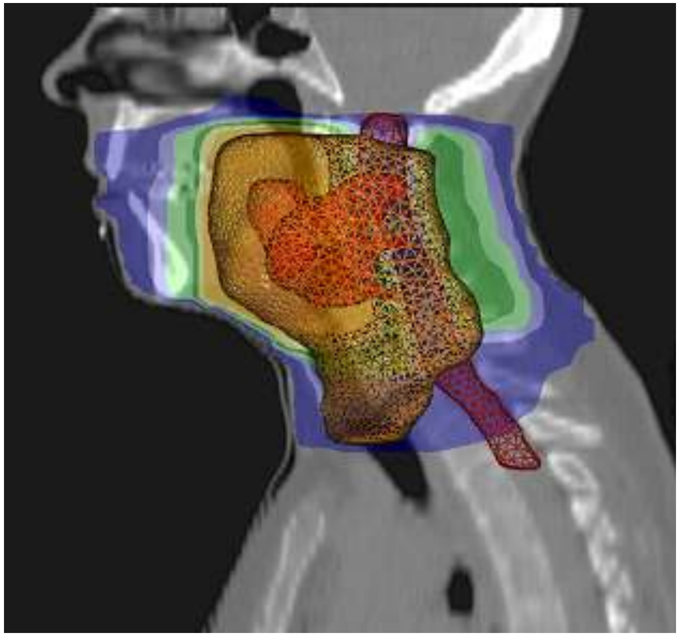
Real Fluence

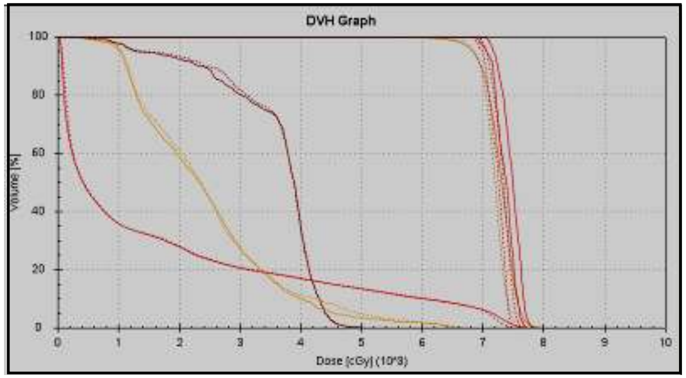


CT



Dose engine





# 2 Detectors for COMPASS

## MatriXX

- 1020 ion chambers
- Pre-treatment verification
- Verification of systematic errors
- Display of 3D dose distribution in patient anatomy

## Transmission Detector

- 1600 ion chambers
- Pre-treatment + online verification
- Dose distribution *measurement during patient treatment*
- Systematic and random errors
- Display of 3D dose distribution in patient anatomy



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# 2 detectors for COMPASS


MatriXX


Transmission

# New Transmission Detector

Available Fall 2010

Wireless data transmission

Battery operated

Minimal clearance reduction

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# The Beam Model (RaySearch)

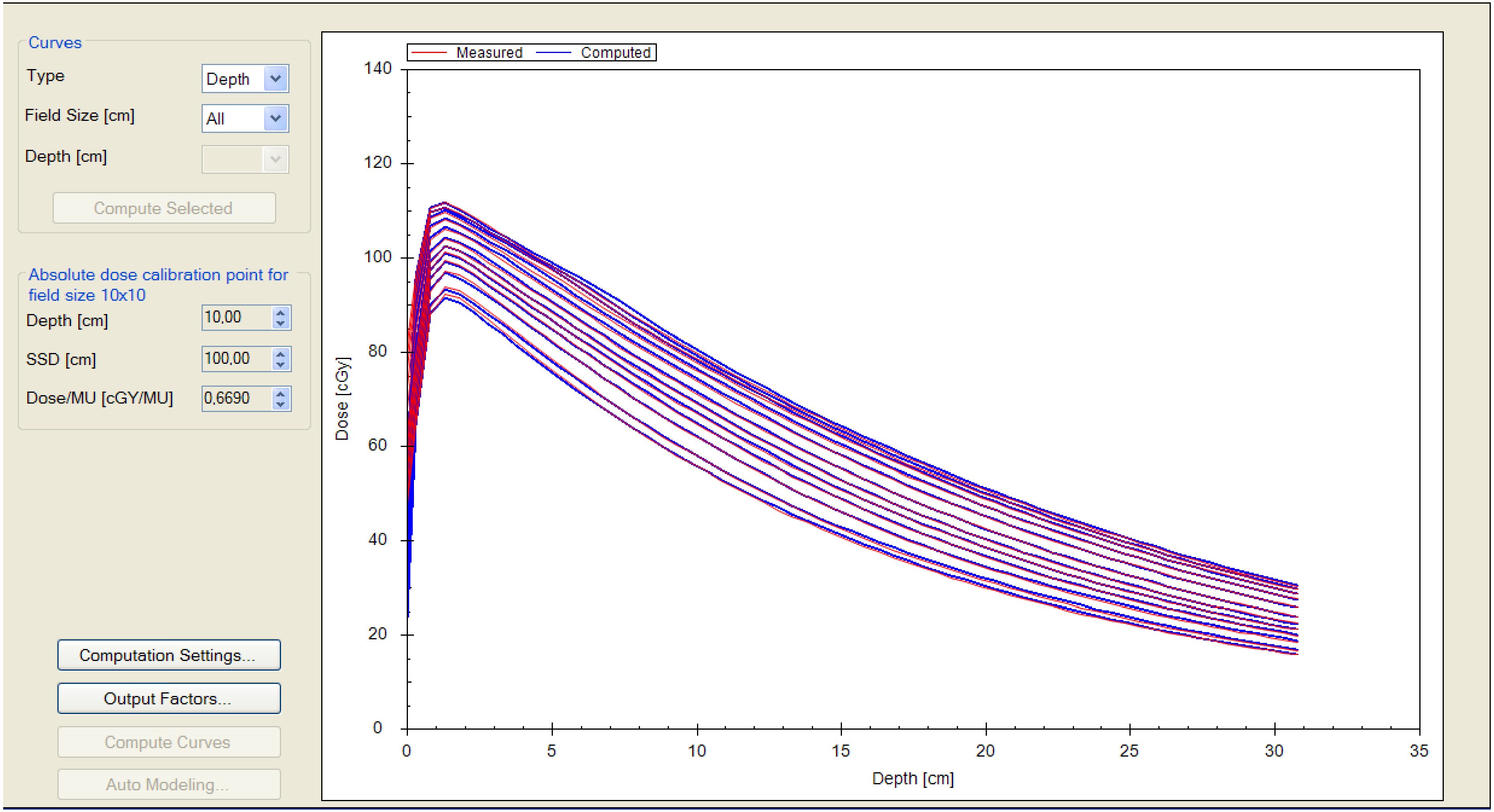
## A Beam Model...

Is a ‚virtual accelerator‘, which allows fluence and spectrum calculation from MU number and collimator settings

## In order to do so...

The model needs to be commissioned, i.e. has to ‚learn‘ features of specific accelerator and energy

# Commissioning of COMPASS

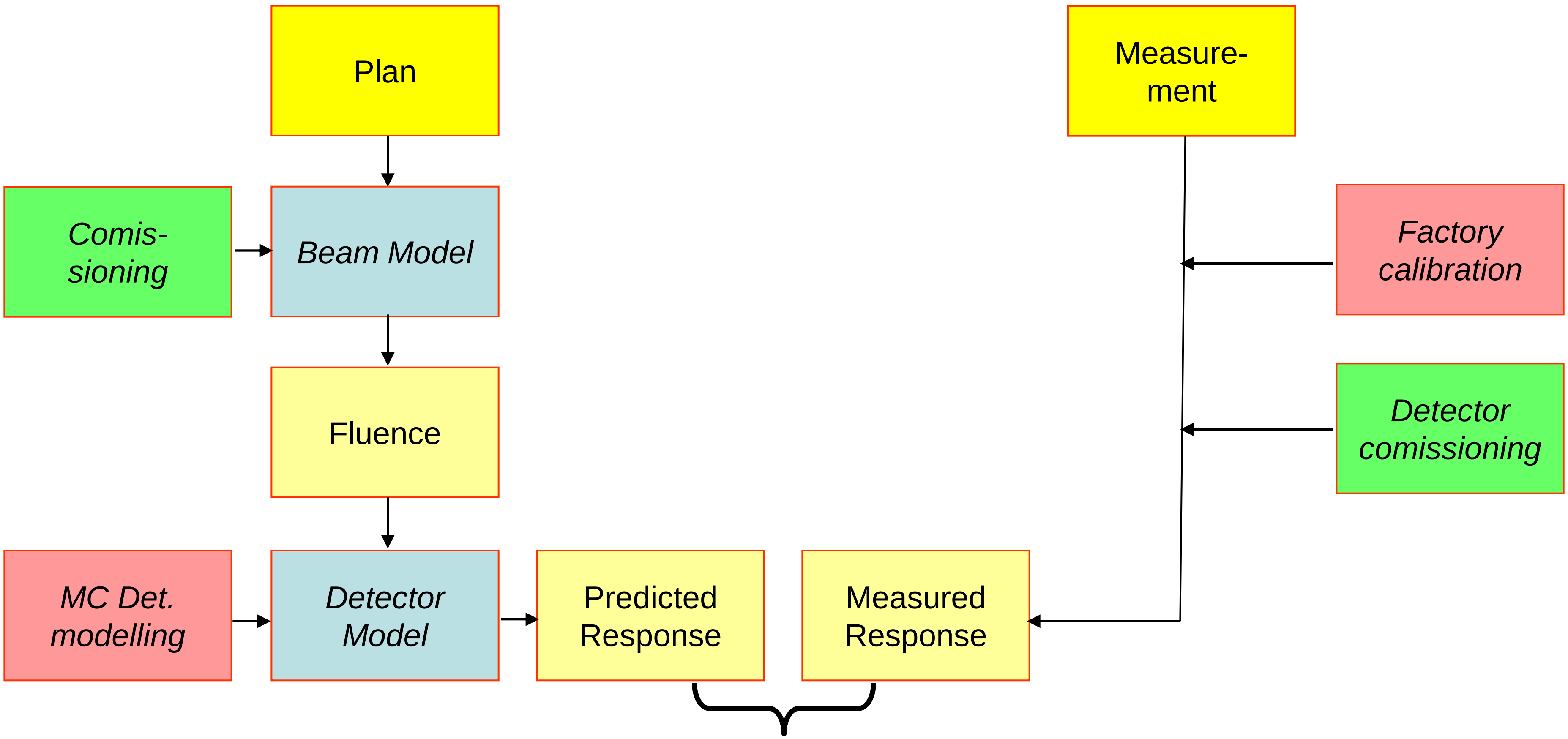


# Auto Modelling

| Auto modelling function | Affected parameters | Target function |
|---|---|---|
| Electron energy spectrum | Electron spectrum parameters E and c, secondary electron source weights, direct electron source width and weight. | Depth dose curves from zero depth |
| Energy spectrum and output factor corrections | Photon energy spectrum and output factor corrections | Depth dose curves deeper than 1 cm |
| Primary and flattening filter sources | Primary and flattening filter photon sources: weight, widths, positions. | 10 cm × 10 cm field profiles for different depths. |
| Beam profile corrections and off axis softening | Beam profile corrections and off-axis softening | Largest field x- and y-profiles for different depths. |
| Output factor corrections | Value of the output factor corrections | Depth dose curves at the calibration point depth |

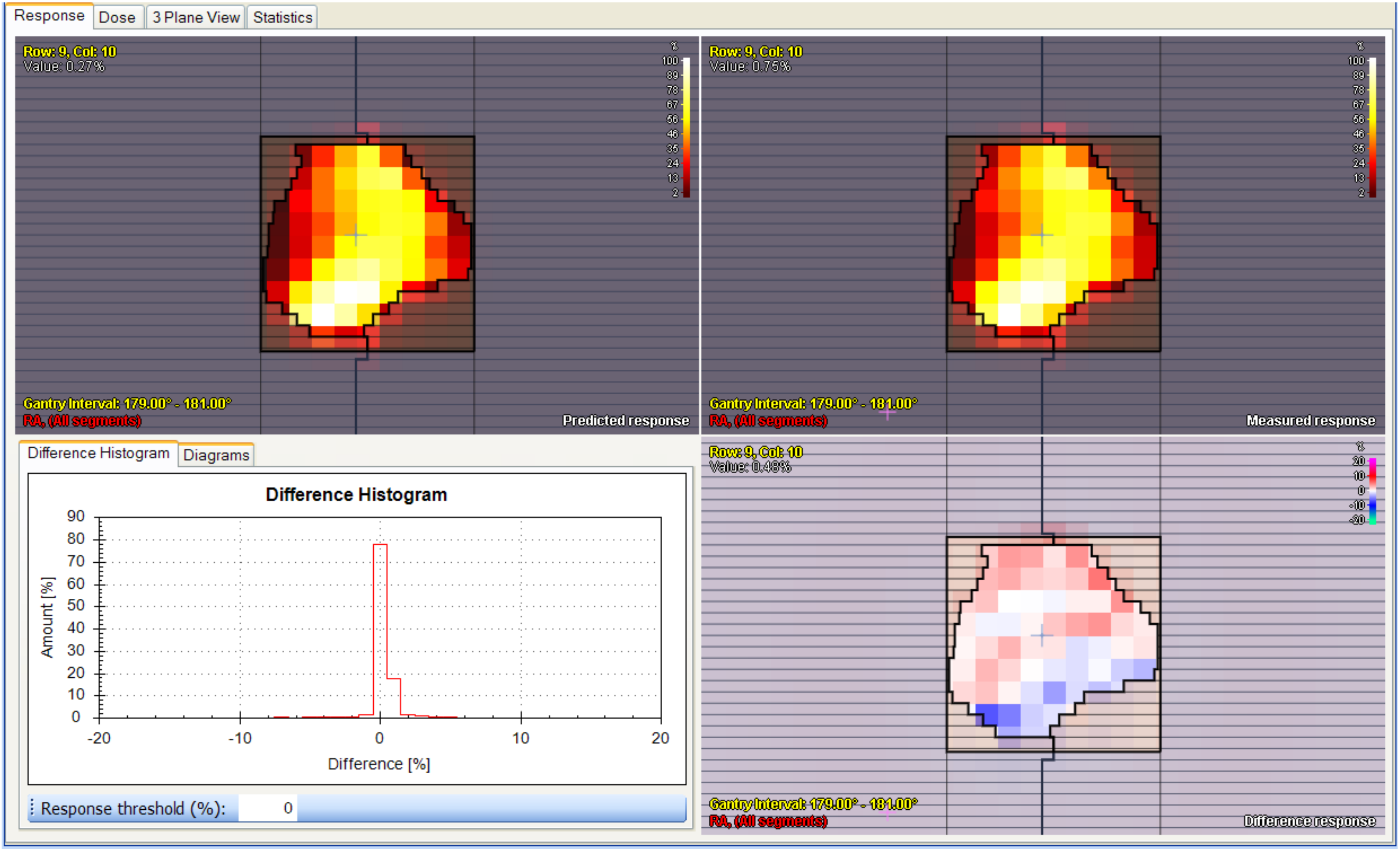
Note that for any given MLC position, it is assumed that the MLC-leaves and settings have the proper scale, so that their projected size onto the iso-center plane does not vary. If the projected size (or projected position) does not match the nominal values, this is regarded as a position calibration, and not as an off-set of the z-position.

# Fluence Correction:  1. Residual Response

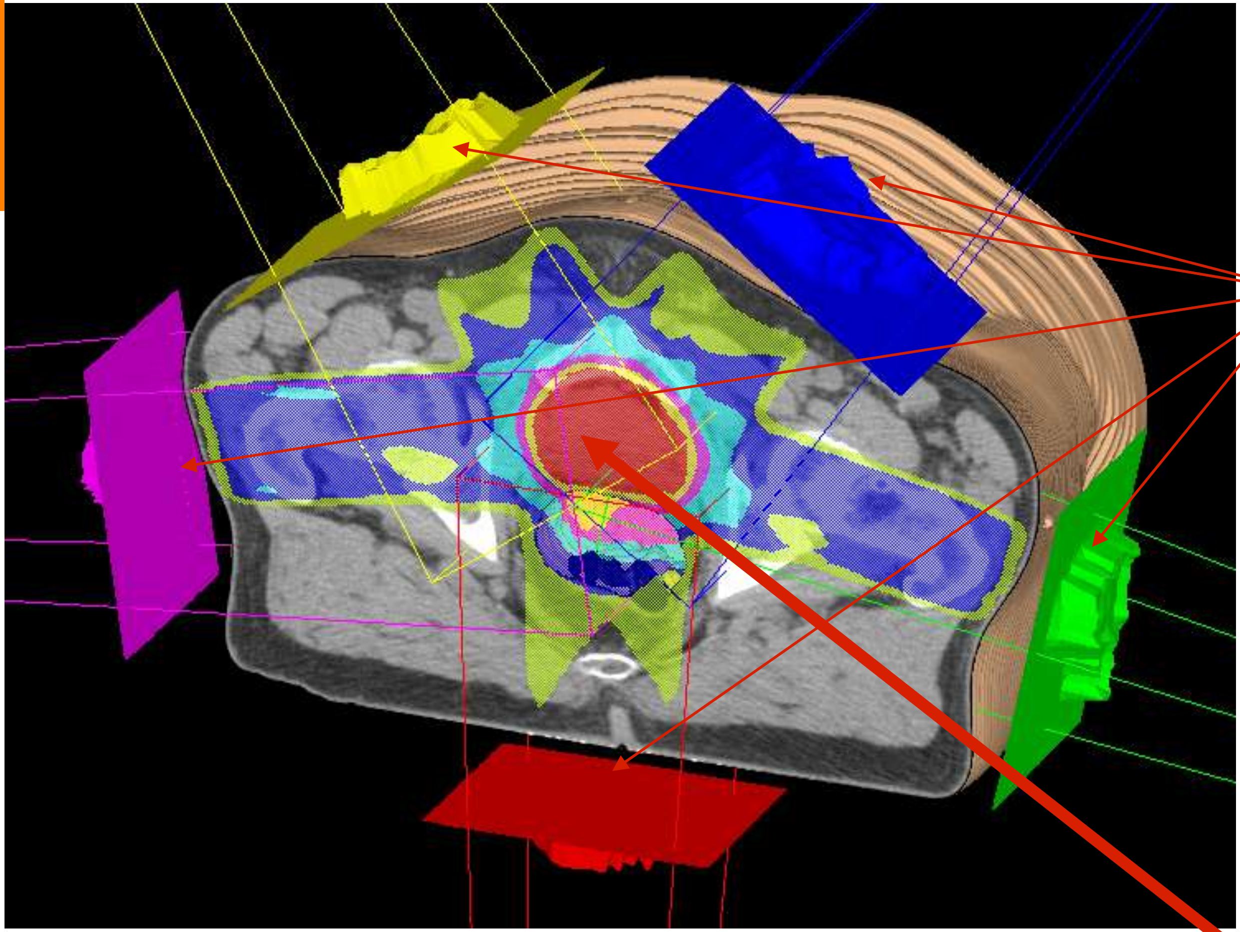



$$r_{residual} = r_{comp} - r_{meas}$$

# Response Prediction and Comparison



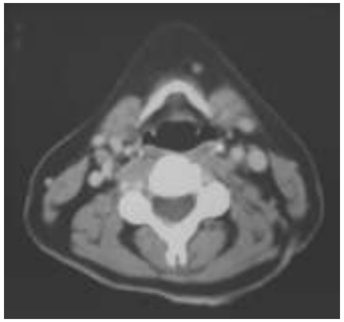
# Dose engine (Collapsed Cone Superposition)



## A Dose Engine...

Takes the incoming fluences

Takes the CT



**Calculates the resulting dose distribution in patient anatomy**

Copyright philips



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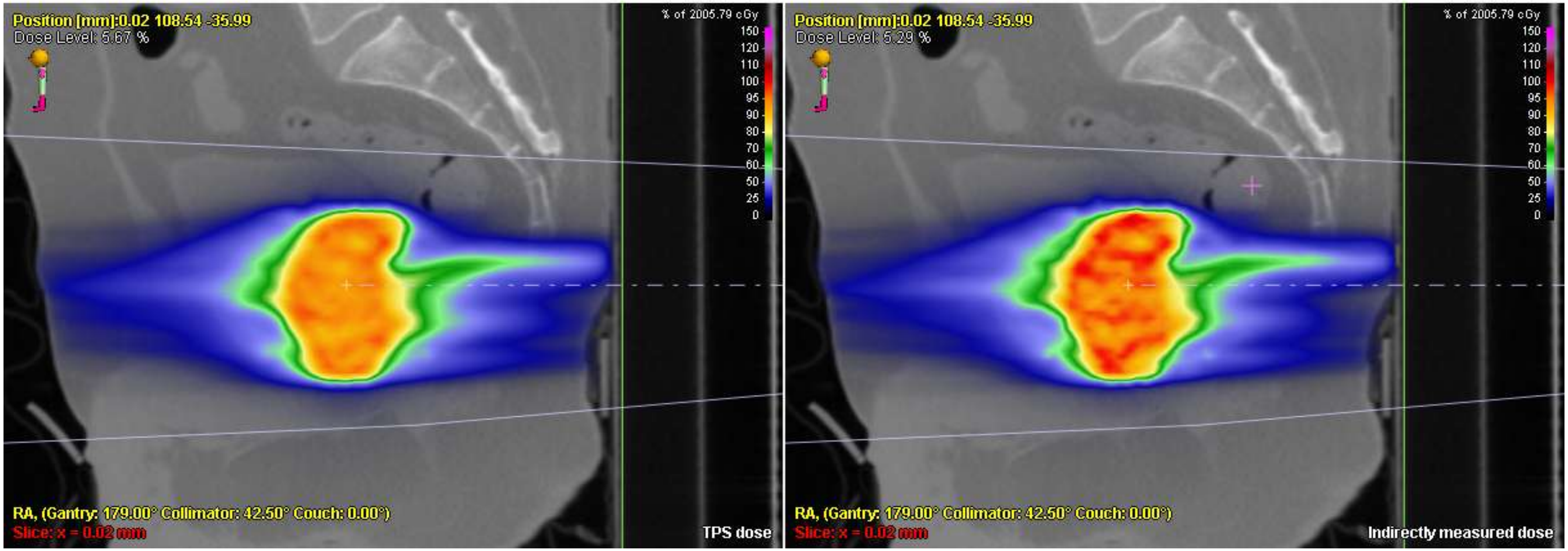
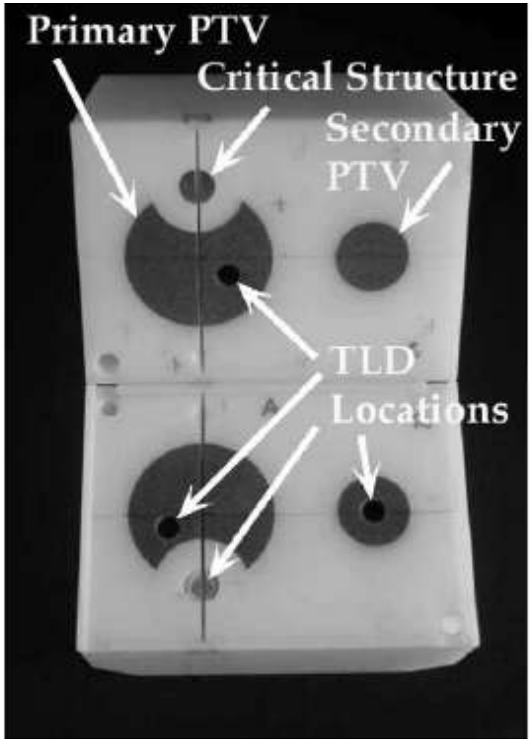
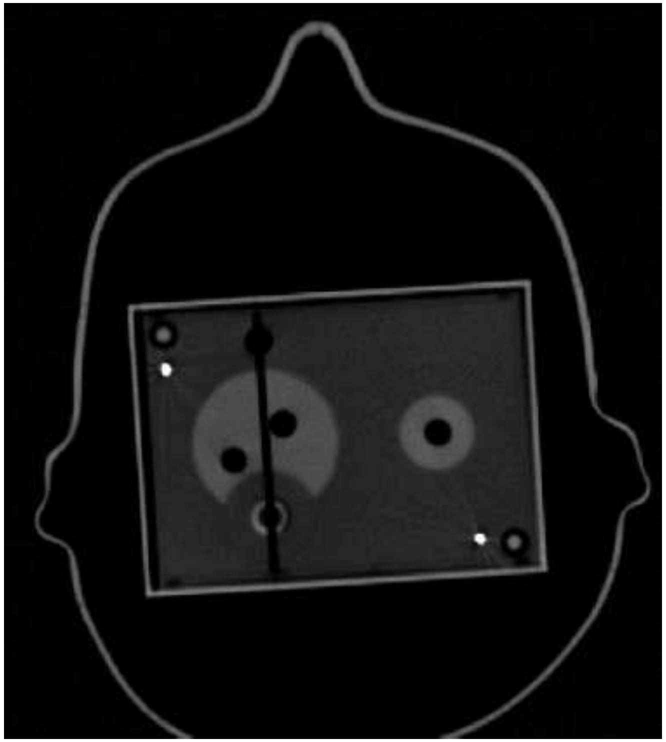
# Planned vs. Reconstructed Dose



# IMRT Quality Comparative Study



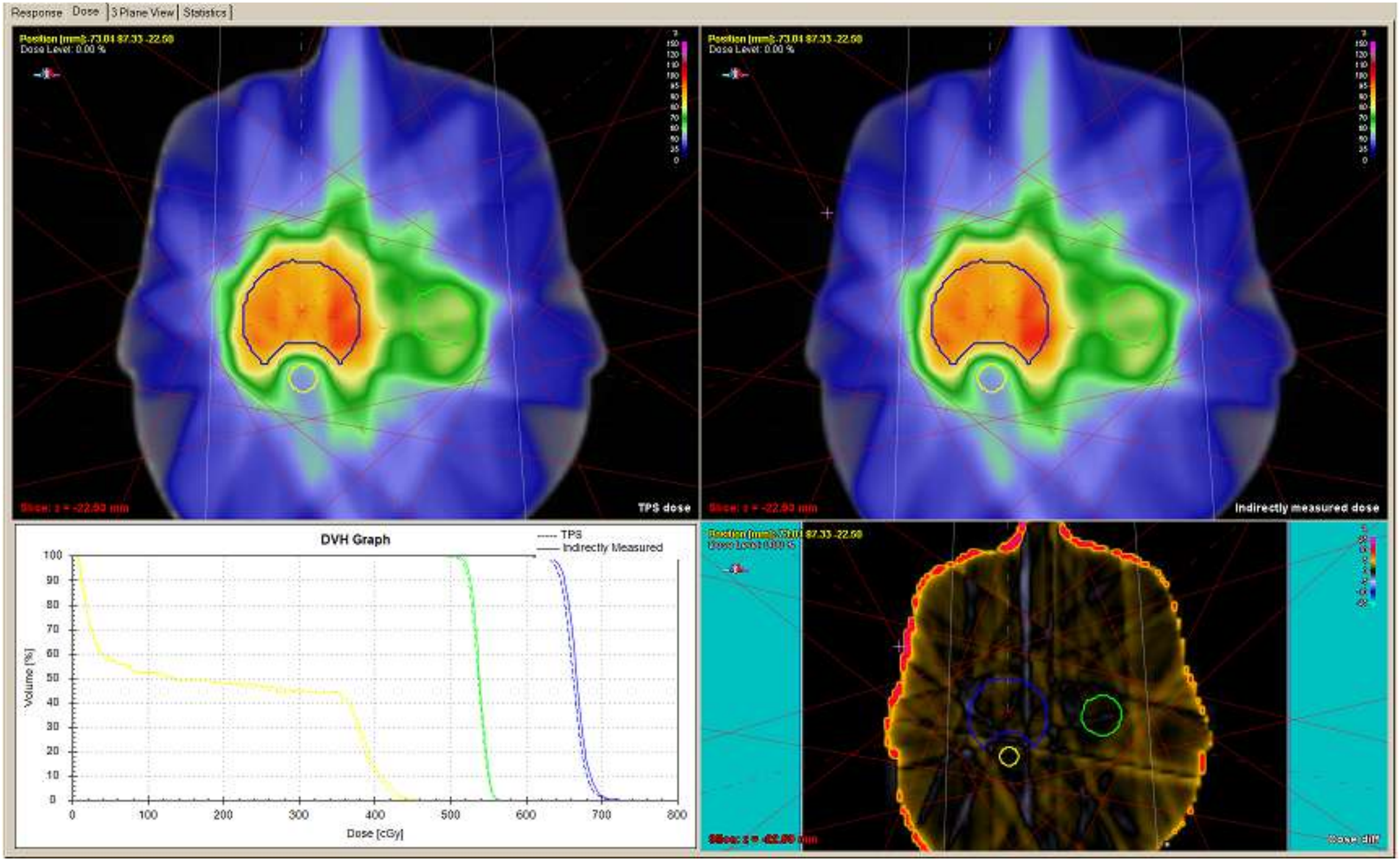
**DESIGN AND IMPLEMENTATION OF AN ANTHROPOMORPHIC QUALITY ASSURANCE PHANTOM FOR INTENSITY-MODULATED RADIATION THERAPY FOR THE RADIATION THERAPY ONCOLOGY GROUP**

ANDREA MOLINEU, M.S.,* DAVID S. FOLLOWILL, PH.D.,* PETER A. BALTER, PH.D.,*WILLIAM F. HANSON, PH.D.,* MICHAEL T. GILLIN, PH.D.,* M. SAIFUL HUQ, PH.D.,†AVRAHAM EISBRUCH, M.D.,‡ AND GEOFFREY S. IBBOTT, PH.D.*

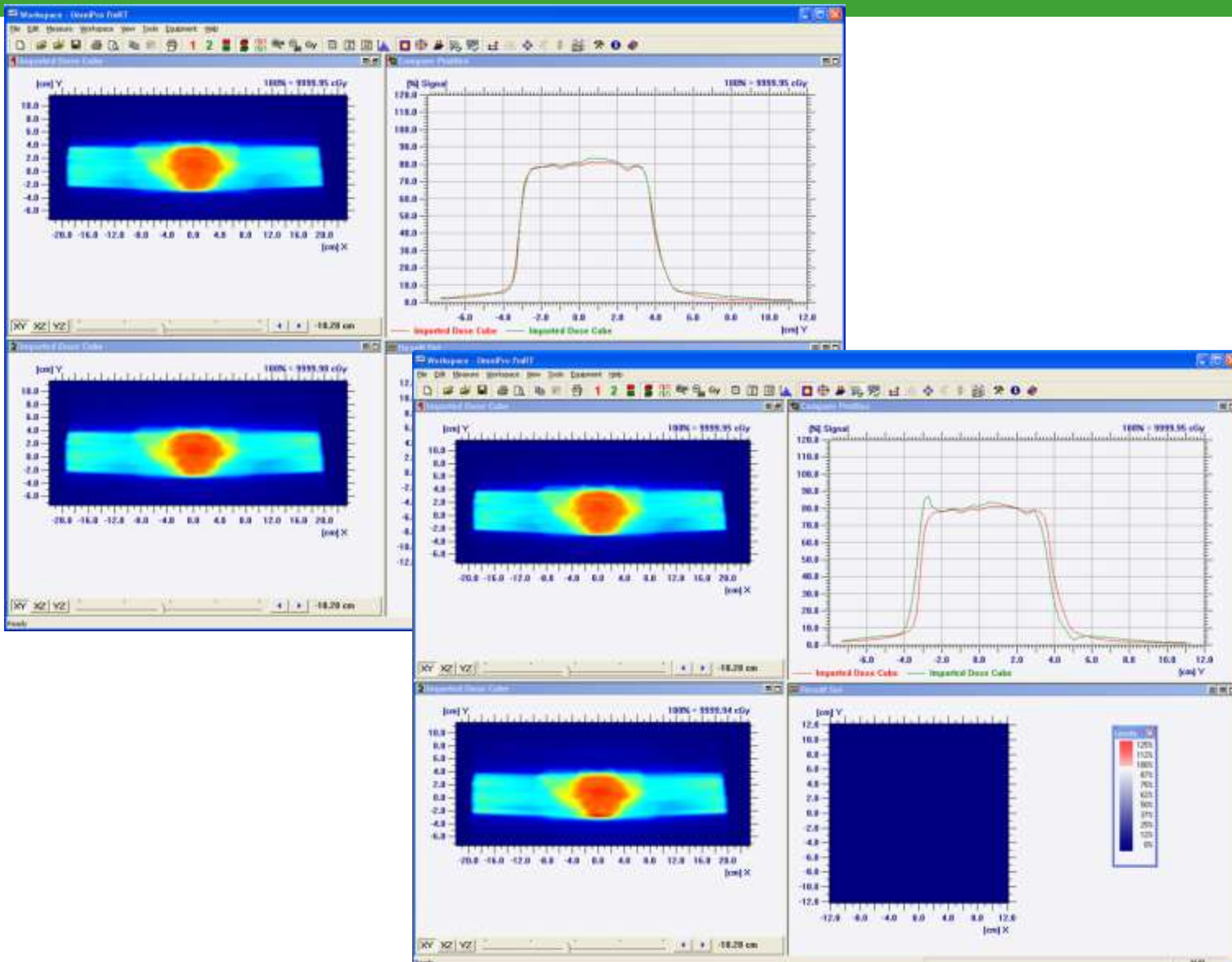
*Department of Radiation Physics, The University of Texas M. D. Anderson Cancer Center, Houston, TX; Department of Radiation Oncology, University of Pittsburgh Medical Center, Pittsburgh, PA; ‡Department of Radiation Oncology,University of Michigan Medical Center, Ann Arbor, MI

## 7%/4mm ca. 30 % fail !

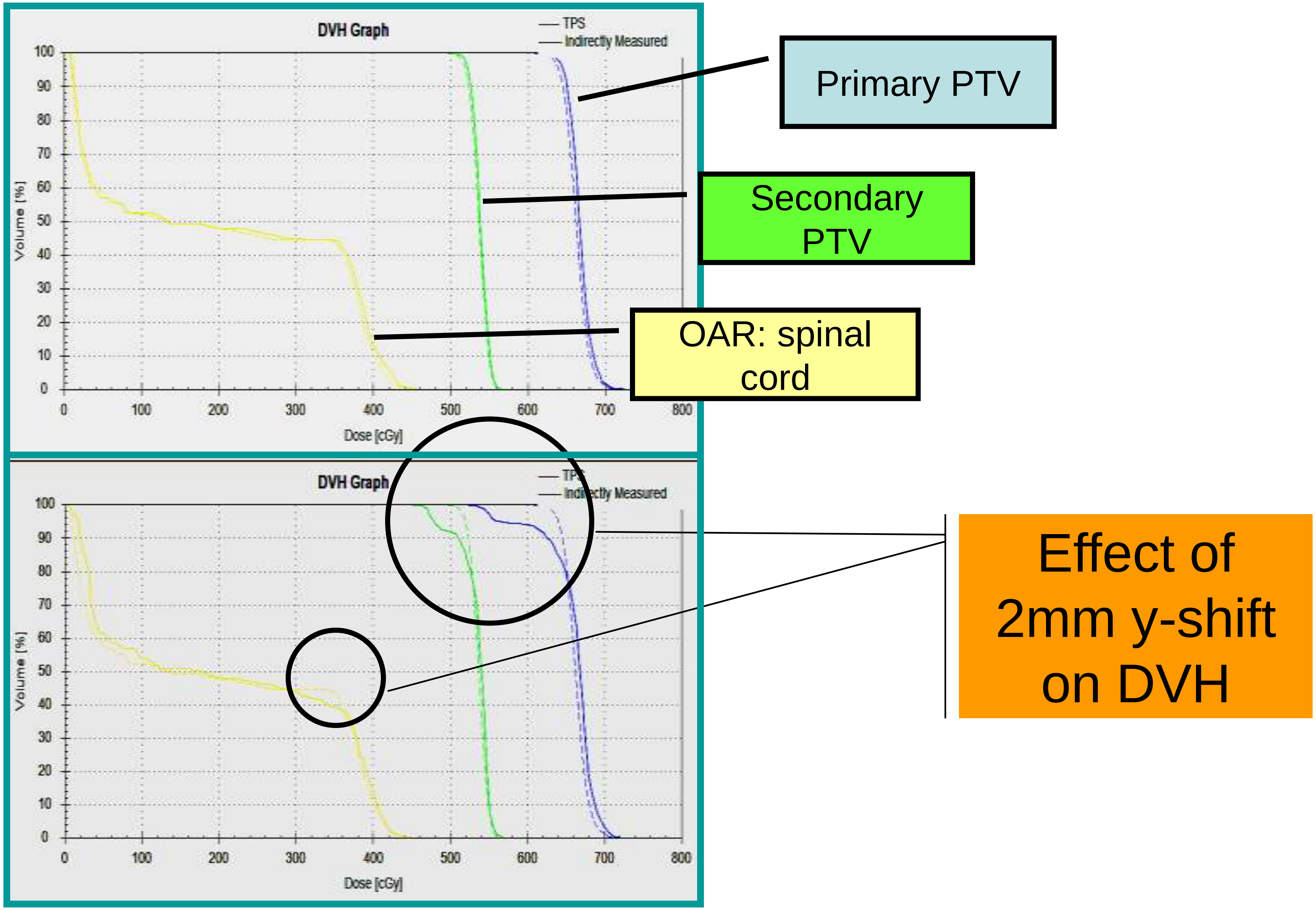
# 3rd Generation. Dose in the Patient Anatomy



# Delivery Error – 2mm Shift (Generation 2)



# Delivery error in RPC phantom case

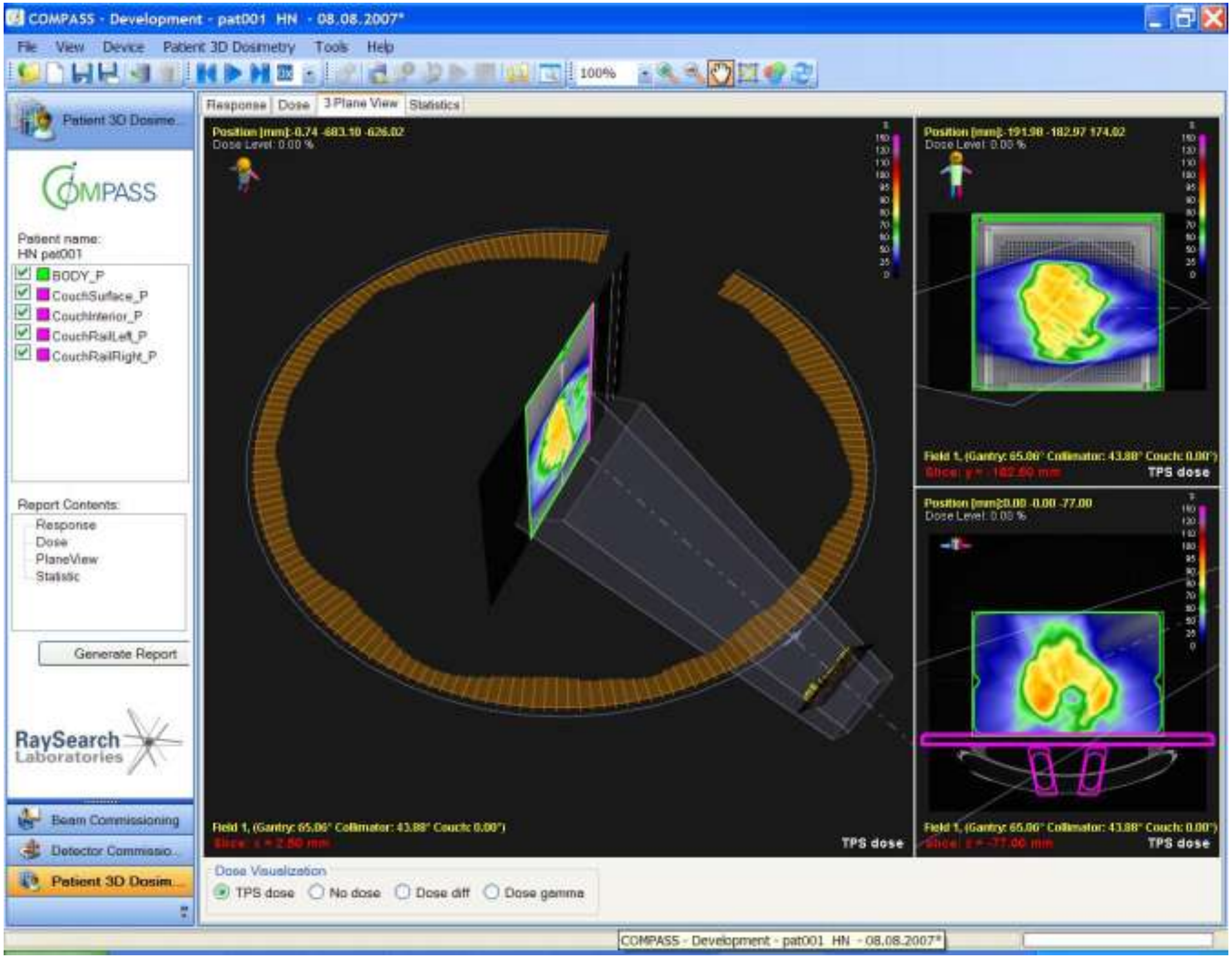


# Collecting the Gantry Angle Information

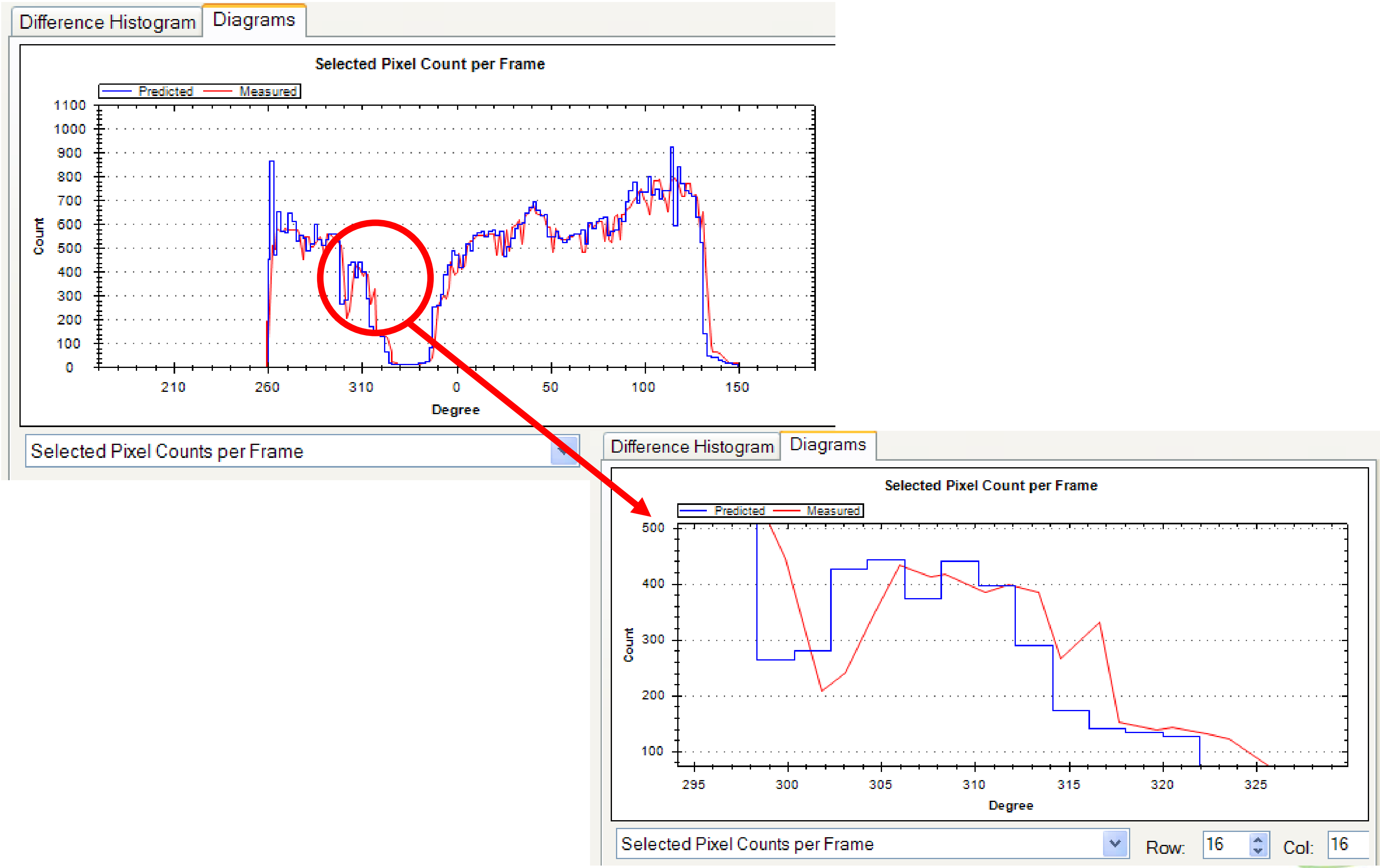
- **Starting with R2.0 Compass allows to track the gantry angle while measuring the treatment plan.**


Gravity-based Gantry Angle Sensor to be mounted on gantry.

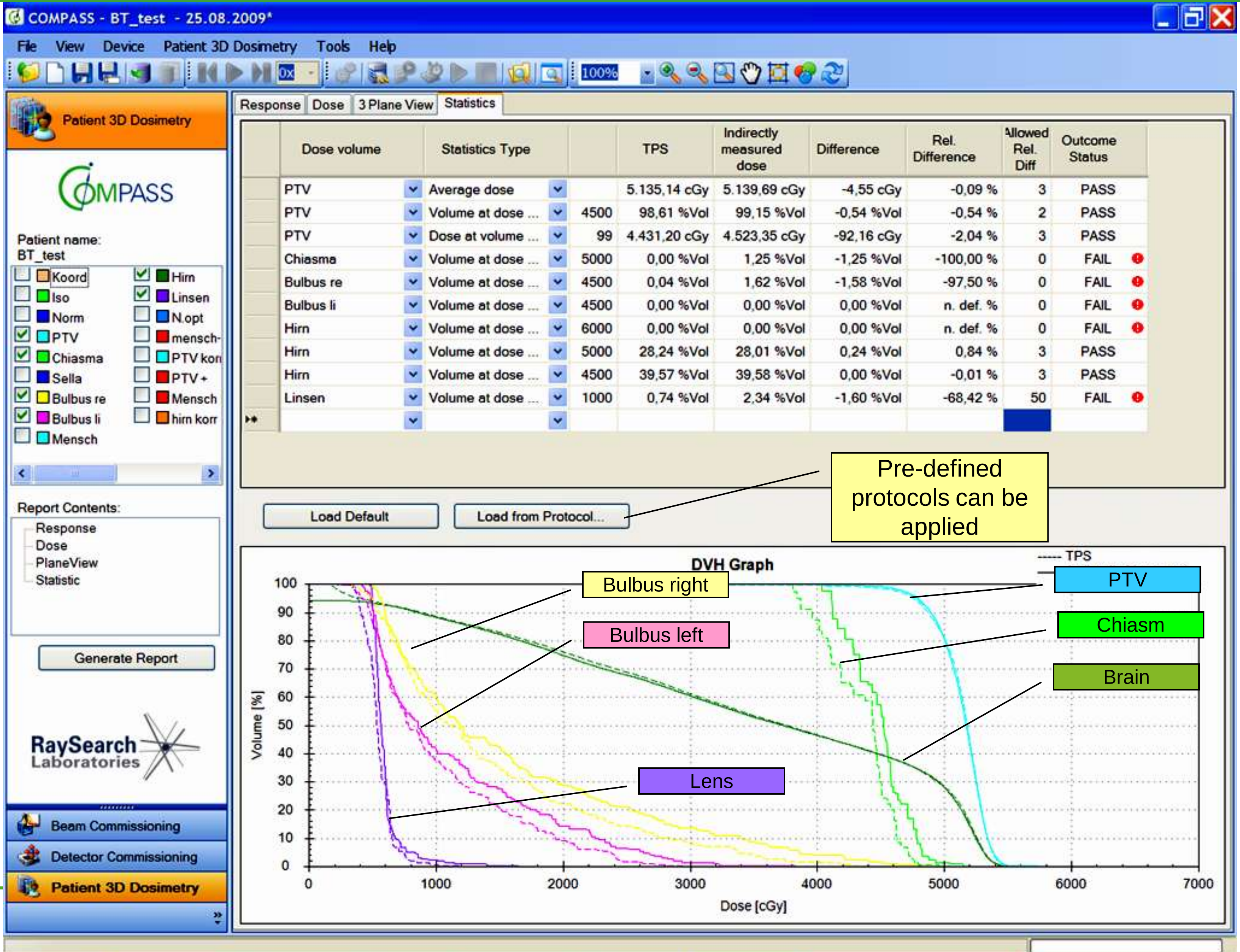
# Plane View


COMPASS - Development - pat001 HN - 08.08.2007*
File View Device Patient 3D Dosimetry Tools Help
Response Dose 3 Plane View Statistics
Patient name:
HN pat001
BODY_P
CouchSurface_P
CouchInterior_P
CouchRailLeft_P
CouchRailRight_P
Report Contents:
Response
Dose
PlaneView
Statistic
Generate Report
RaySearch Laboratories
Beam Commissioning
Patient 3D Dosim...
TPS dose
Dose Visualization
TPS dose
No dose
Dose diff
Dose gamma

# Response/control point (Plan vs. Measurement)



# Statistical evaluation



| Dose volume | Statistics Type | | TPS | Indirectly measured dose | Difference | Rel. Difference | Allowed Rel. Diff | Outcome Status |
|---|---|---|---|---|---|---|---|---|
| PTV | Average dose | | 5.135,14 cGy | 5.139,69 cGy | -4,55 cGy | -0,09 % | 3 | PASS |
| PTV | Volume at dose ... | 4500 | 98,61 %Vol | 99,15 %Vol | -0,54 %Vol | -0,54 % | 2 | PASS |
| PTV | Dose at volume ... | 99 | 4.431,20 cGy | 4.523,35 cGy | -92,16 cGy | -2,04 % | 3 | PASS |
| Chiasma | Volume at dose ... | 5000 | 0,00 %Vol | 1,25 %Vol | -1,25 %Vol | -100,00 % | 0 | FAIL |
| Bulbus re | Volume at dose ... | 4500 | 0,04 %Vol | 1,62 %Vol | -1,58 %Vol | -97,50 % | 0 | FAIL |
| Bulbus li | Volume at dose ... | 4500 | 0,00 %Vol | 0,00 %Vol | 0,00 %Vol | n. def. % | 0 | FAIL |
| Hirn | Volume at dose ... | 6000 | 0,00 %Vol | 0,00 %Vol | 0,00 %Vol | n. def. % | 0 | FAIL |
| Hirn | Volume at dose ... | 5000 | 28,24 %Vol | 28,01 %Vol | 0,24 %Vol | 0,84 % | 3 | PASS |
| Hirn | Volume at dose ... | 4500 | 39,57 %Vol | 39,58 %Vol | 0,00 %Vol | -0,01 % | 3 | PASS |
| Linsen | Volume at dose ... | 1000 | 0,74 %Vol | 2,34 %Vol | -1,60 %Vol | -68,42 % | 50 | FAIL |

# Report Export to e.g. EXCEL

AJ33 =IF(R33<AI33;"PASS";"FAIL")

Plan label: Teilhirn.0

| Dose Volume | Type | Value | TPS | Indirectly measured dose (%) | Difference | Rel. Difference | Allowed Rel. Diff [%] | Outcome | max dev dose (%) | |
|---|---|---|---|---|---|---|---|---|---|---|
| PTV | Average dose | | 5.135,14 | 5.139,69 cGy | -4,55 cGy | -0,09 % | 3 | PASS | | |
| PTV | Volume at gamma | 1 | | | 0,60 %Vol | 0,60 % | 2 | PASS | | |
| PTV | Average gamma | | | | 0,27 | 0,27 | 0,5 | PASS | | |
| Chiasma | Volume at dose [cGy] | 500 | 0,00 %Vol | 1,25 | -1,25 %Vol | -100,00 % | 0 | FAIL | | |
| Bulbus re | Volume at dose [cGy] | 450 | 0,04 %Vol | 1,62 | -1,58 %Vol | -97,50 % | 0 | FAIL | 2 | PASS |
| Bulbus li | Volume at dose [cGy] | 450 | 0,00 %Vol | 0 | 0,00 %Vol | n. def. % | 0 | FAIL | 2 | PASS |
| Hirn | Volume at dose [cGy] | 600 | 0,00 %Vol | 0 | 0,00 %Vol | n. def. % | 0 | FAIL | 1 | PASS |
| Hirn | Volume at dose [cGy] | 500 | 28,24 %Vol | 28,01 | 0,24 %Vol | 0,84 % | 3 | PASS | 33 | PASS |
| Hirn | Volume at dose [cGy] | 450 | 39,57 %Vol | 39,58 | 0,00 %Vol | -0,01 % | 3 | PASS | 66 | PASS |
| Linsen | Volume at dose [cGy] | 100 | 0,74 %Vol | 2,34 | -1,60 %Vol | -68,42 % | 50 | FAIL | 2 | FAIL |



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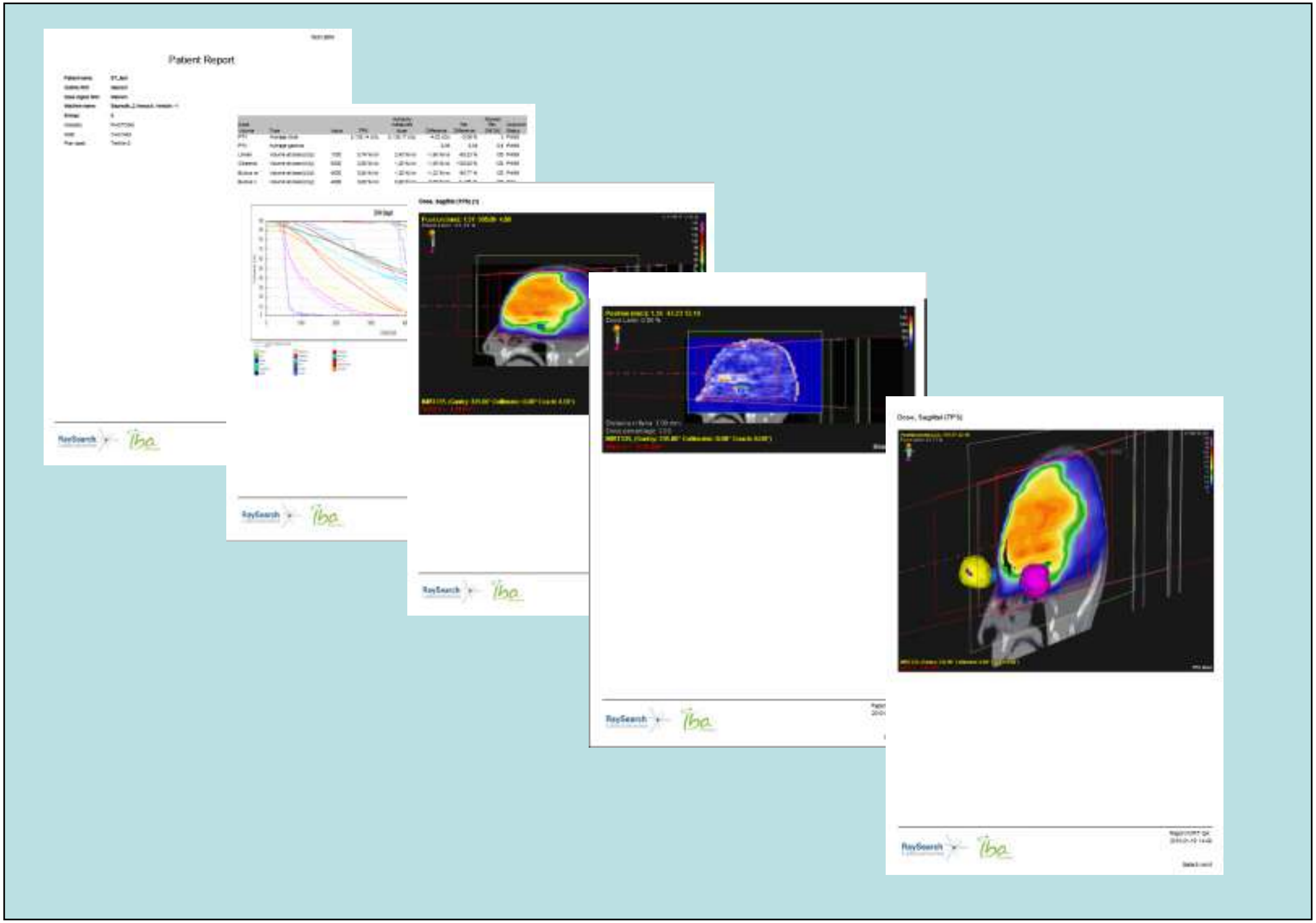
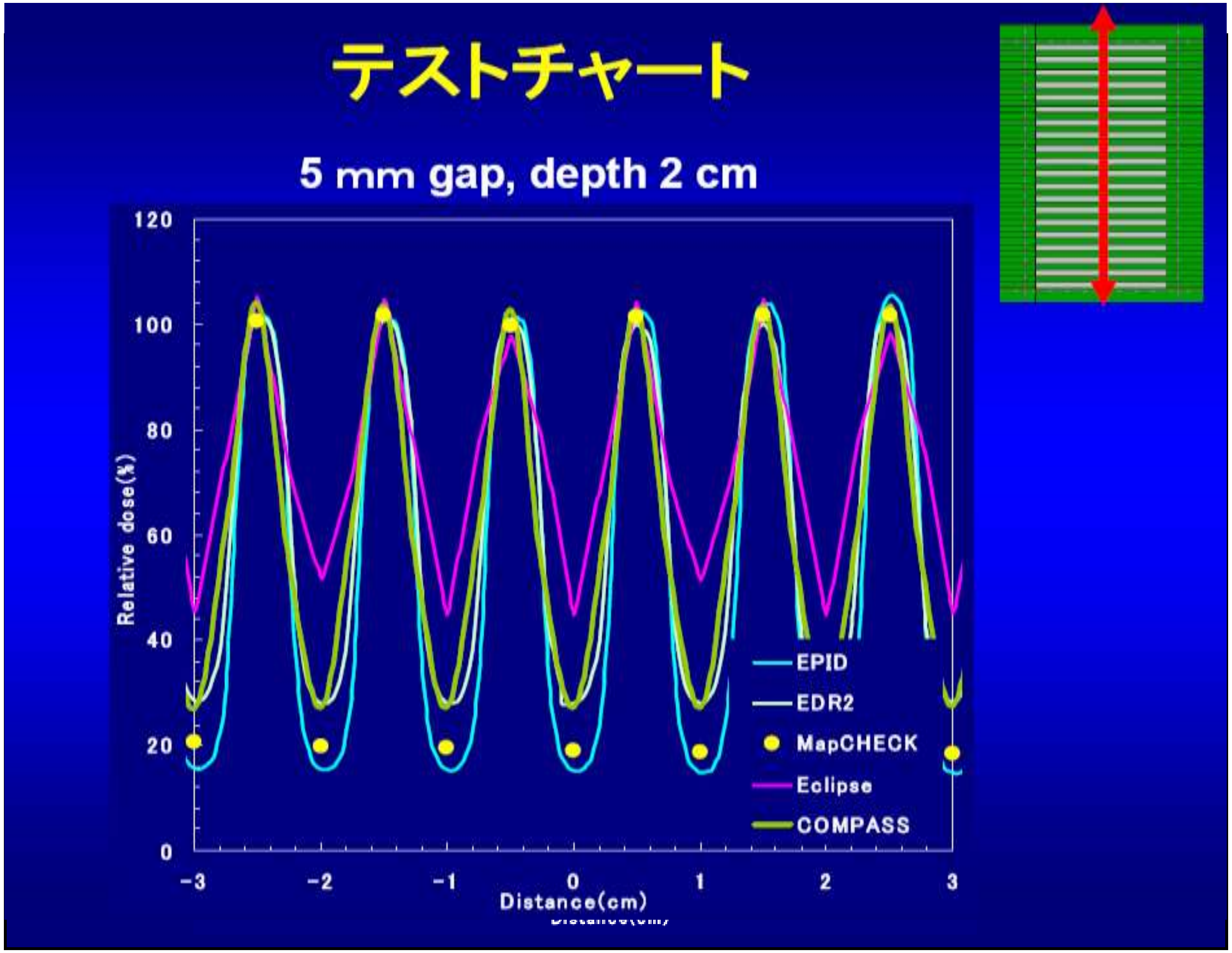
# Reporting and Archiving (India)

# COMPASS Report



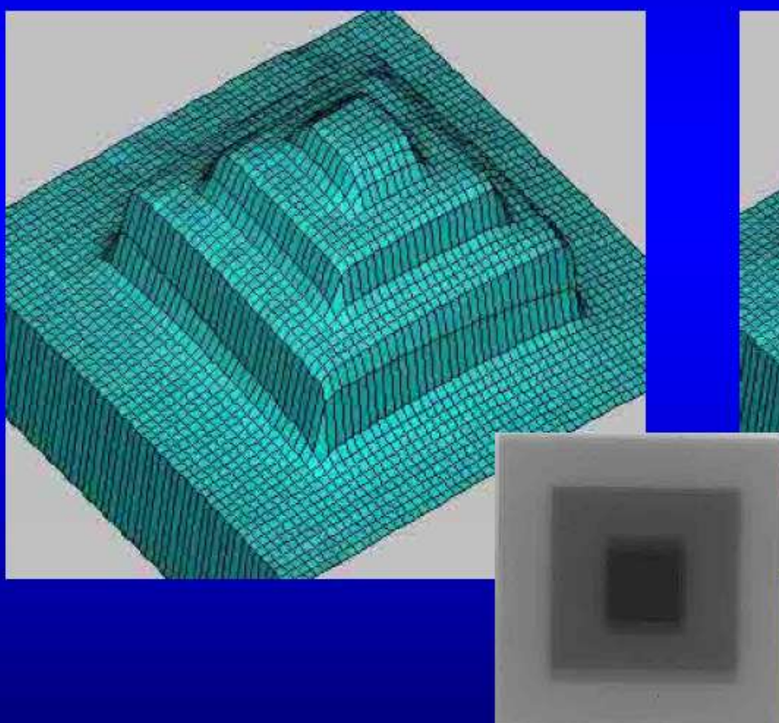
# Data from Fujio Araki, Kumamoto university



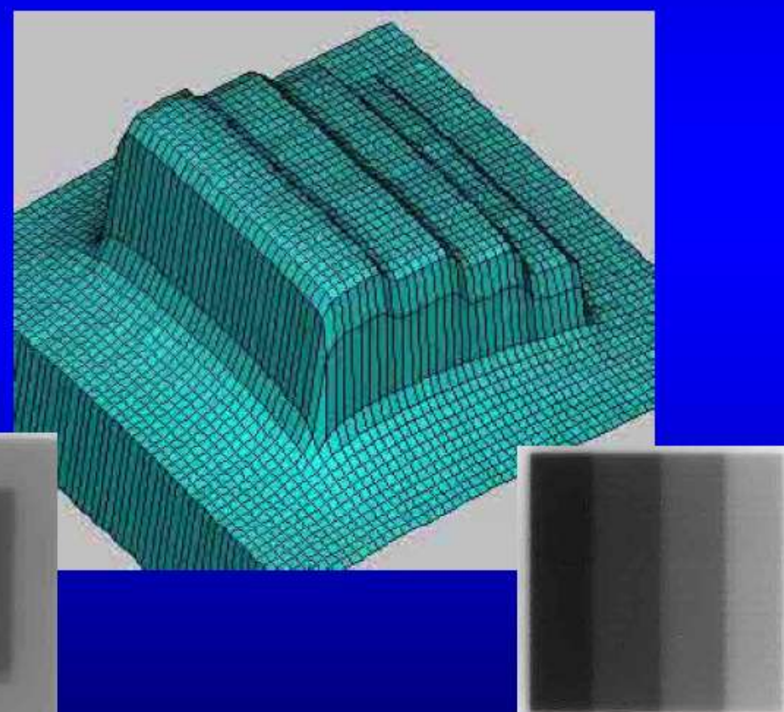
# テストチャート

## Leaf test pattern

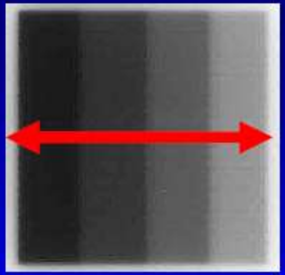
Pyramid



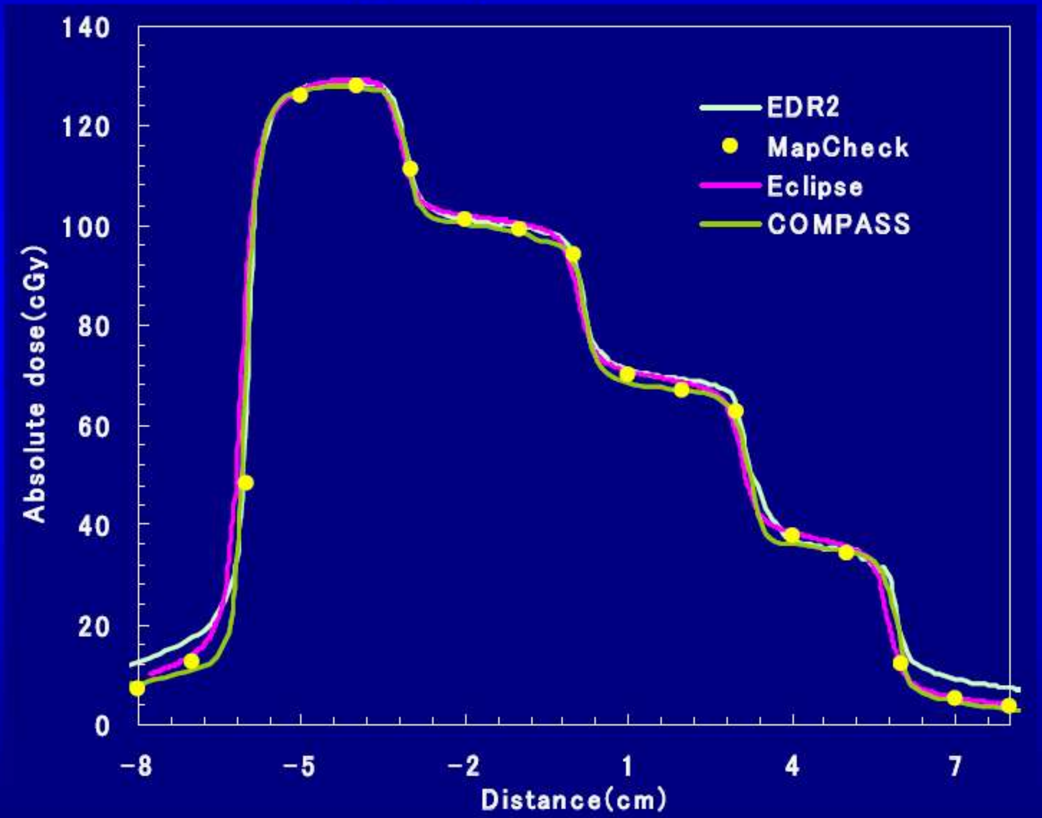
Step



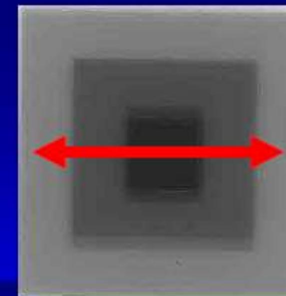
# テストチャート



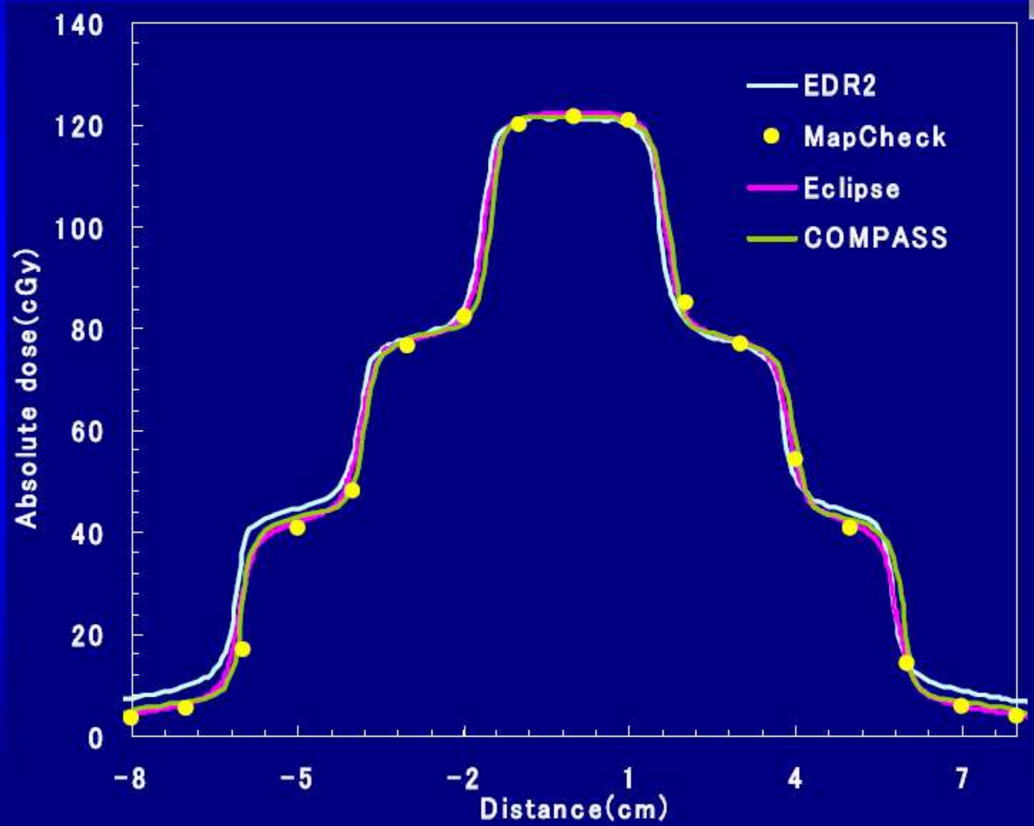
## Step, depth 10 cm



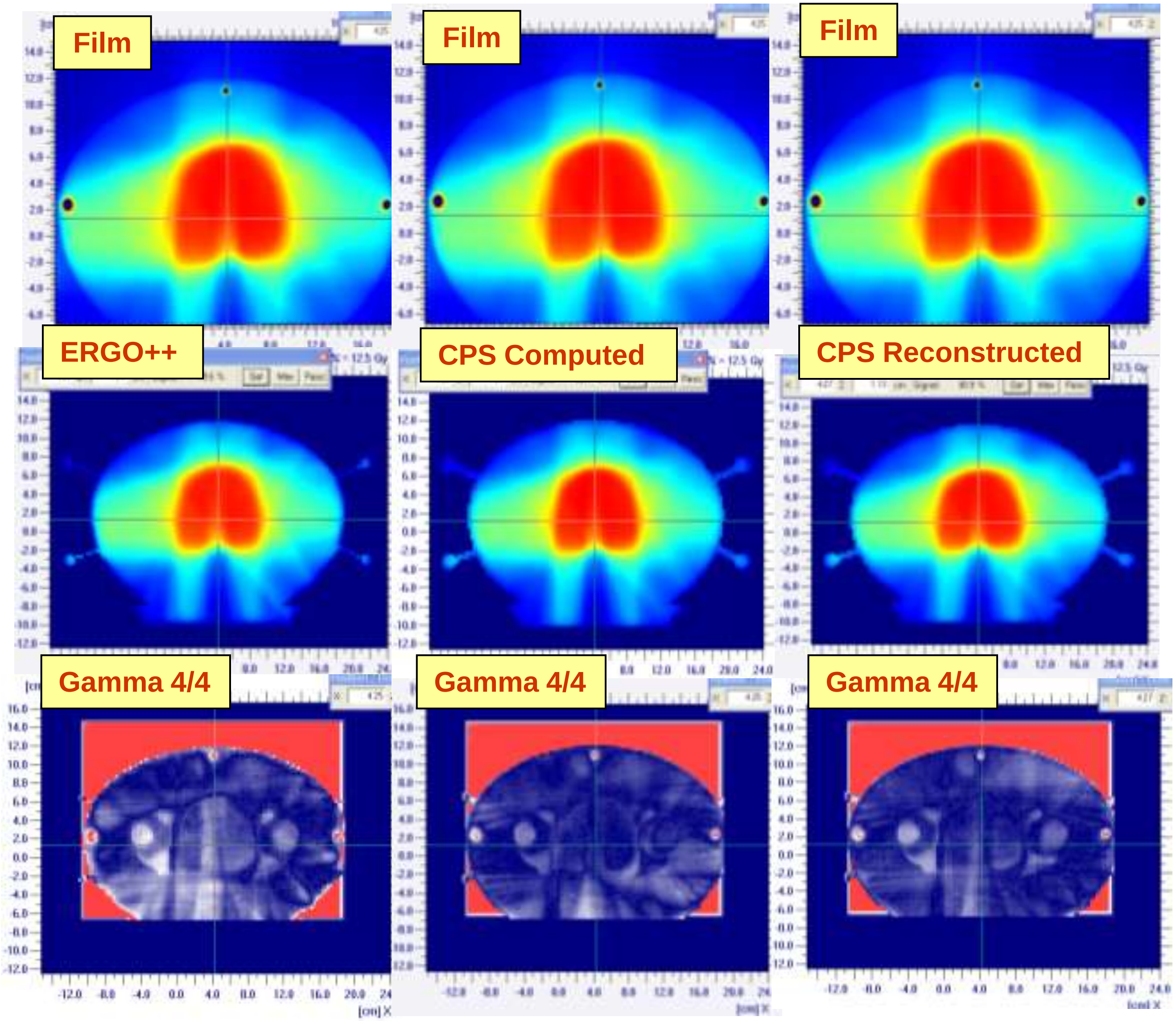
# テストチャート



## Pyramid, depth 10 cm

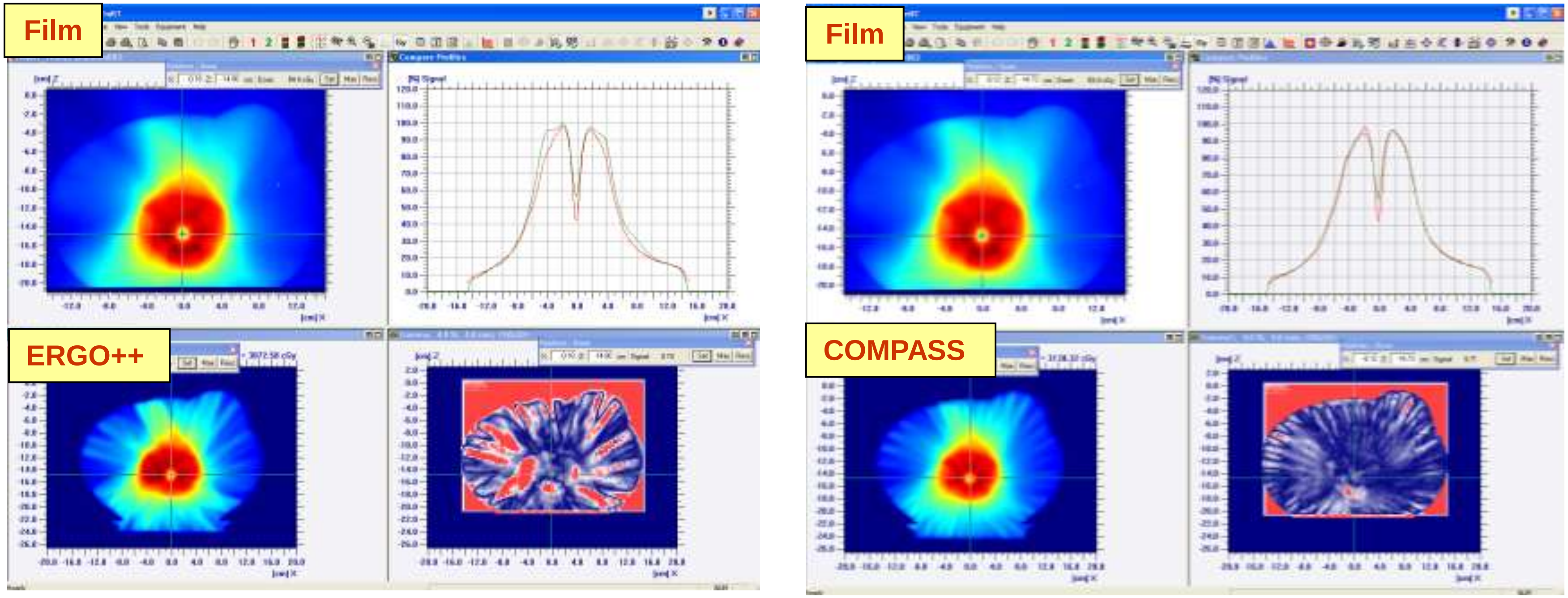


# Prostate Case 3




Data from Ramesh Boggula, Mannheim (submitted)

# Para spinal Case 3

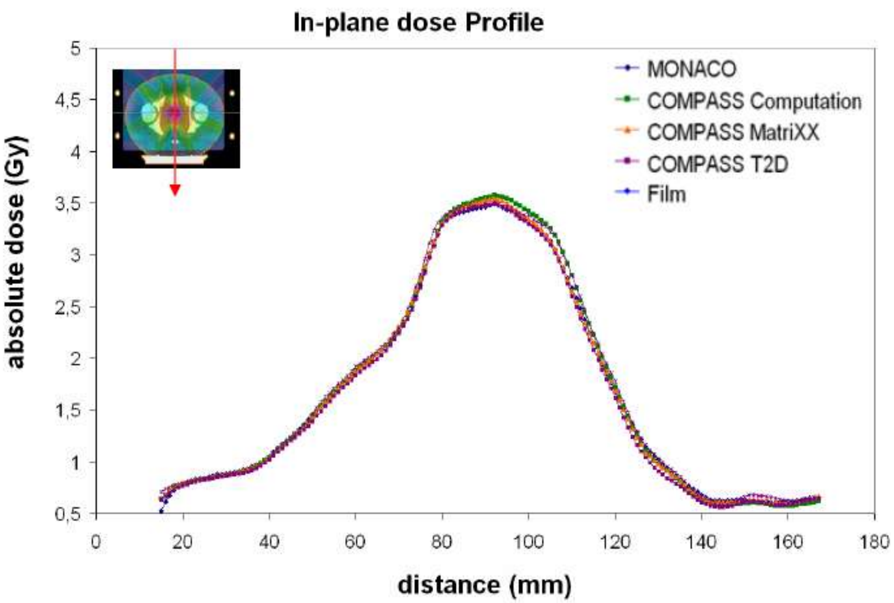


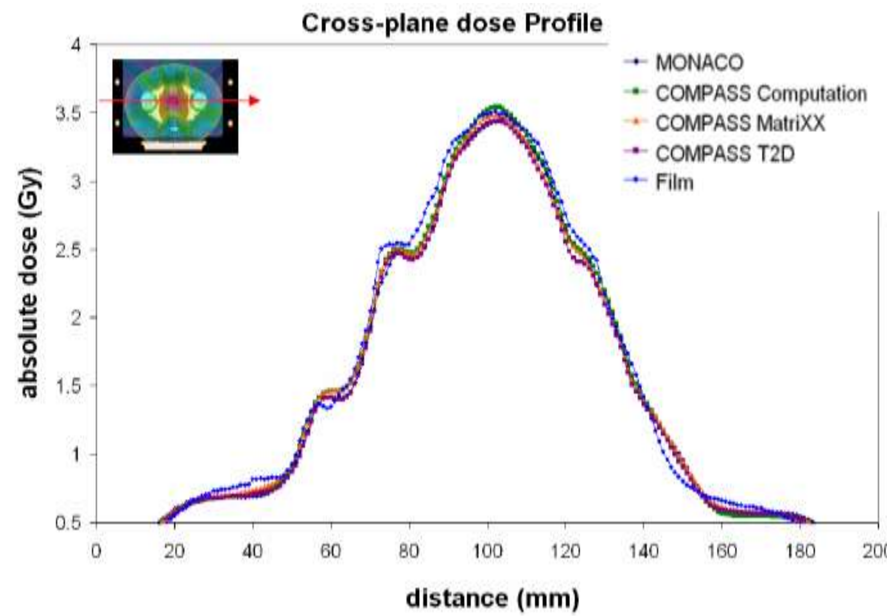

Plan was computed on a inhomogeneous thorax phantom



Data from Ramesh Boggula, Mannheim (submitted)

# COMPASS vs. MONACO MC IMRT

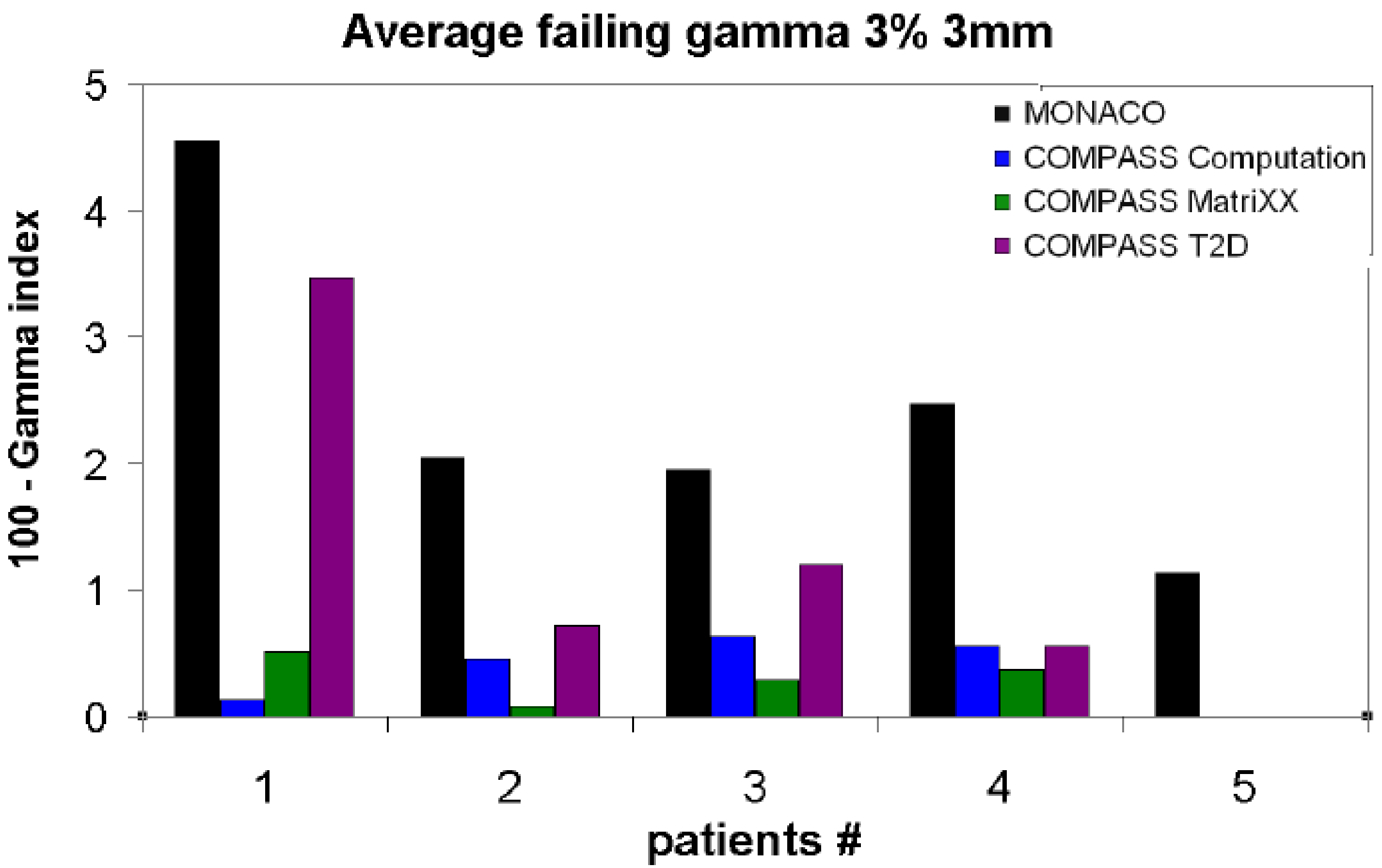


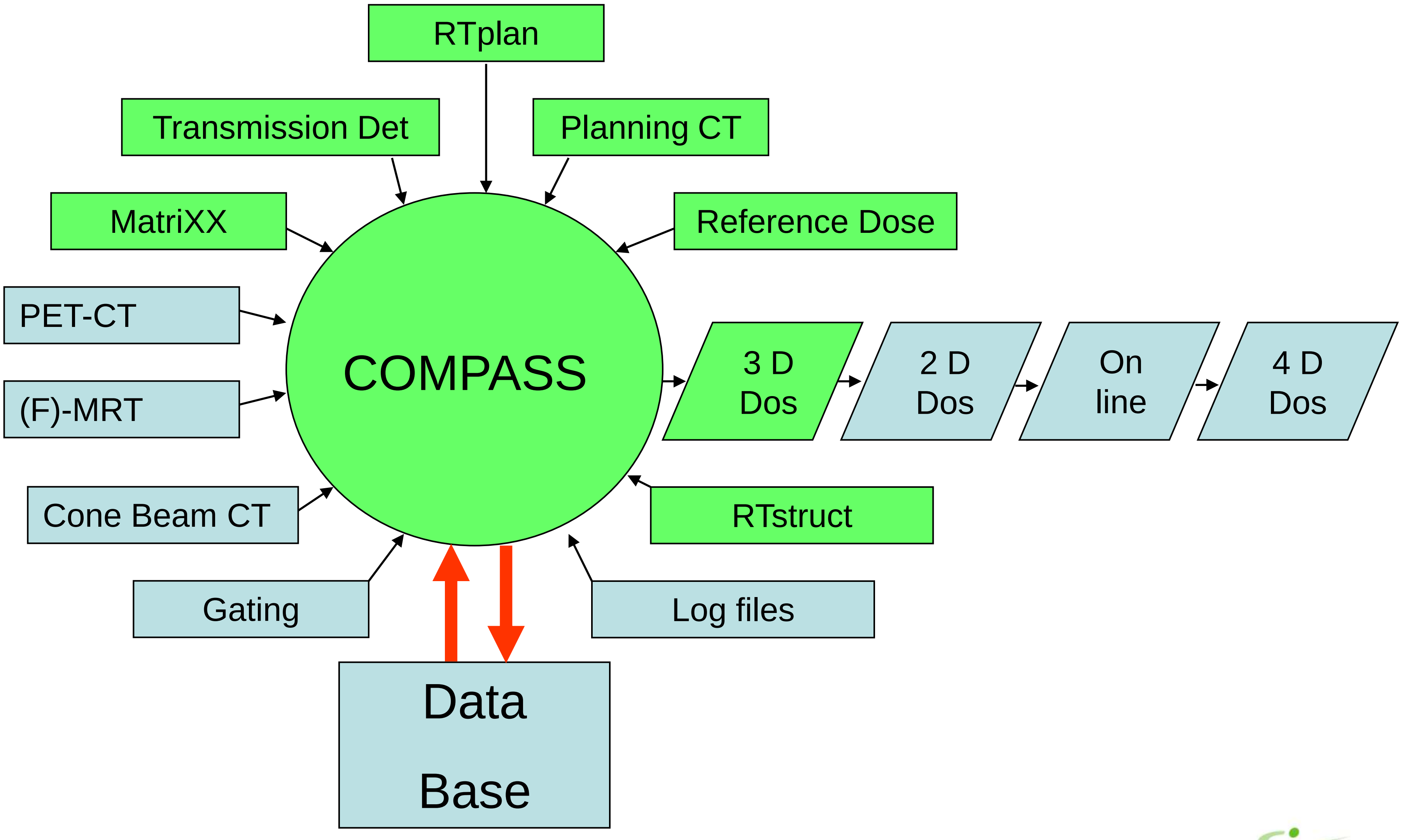

5 Prostate Plans on Inhomogeneous Pelvic Phantom

EDR 2 Film

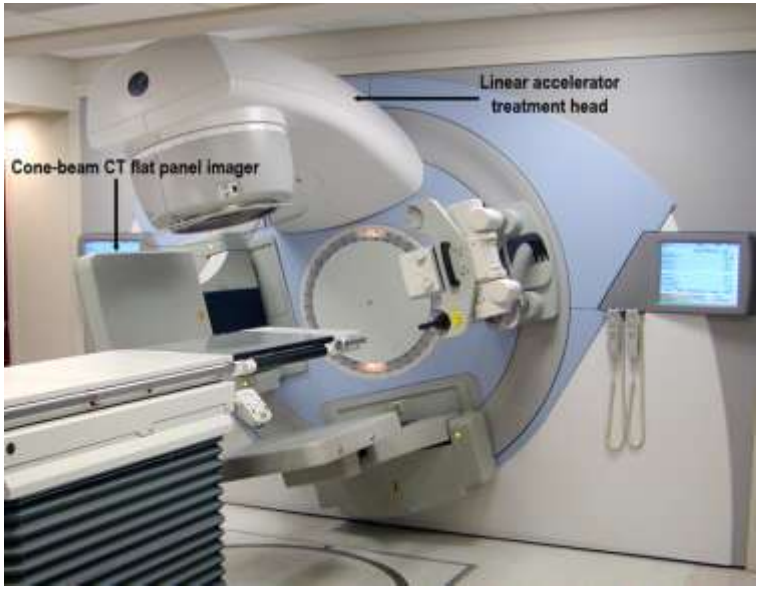
Data from Ramesh Boggula, Mannheim (to be published)

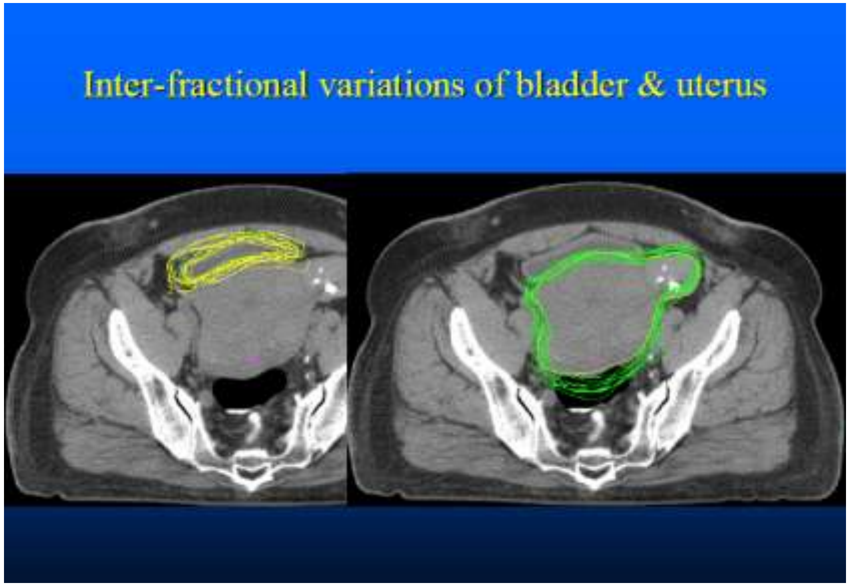

Average failing gamma 3% 3mm
100 - Gamma index
0
1
2
3
4
5
patients #
MONACO
COMPASS Computation
COMPASS MatriXX
COMPASS T2D

# COMPASS Present and Future



# Integrated Imaging Systems



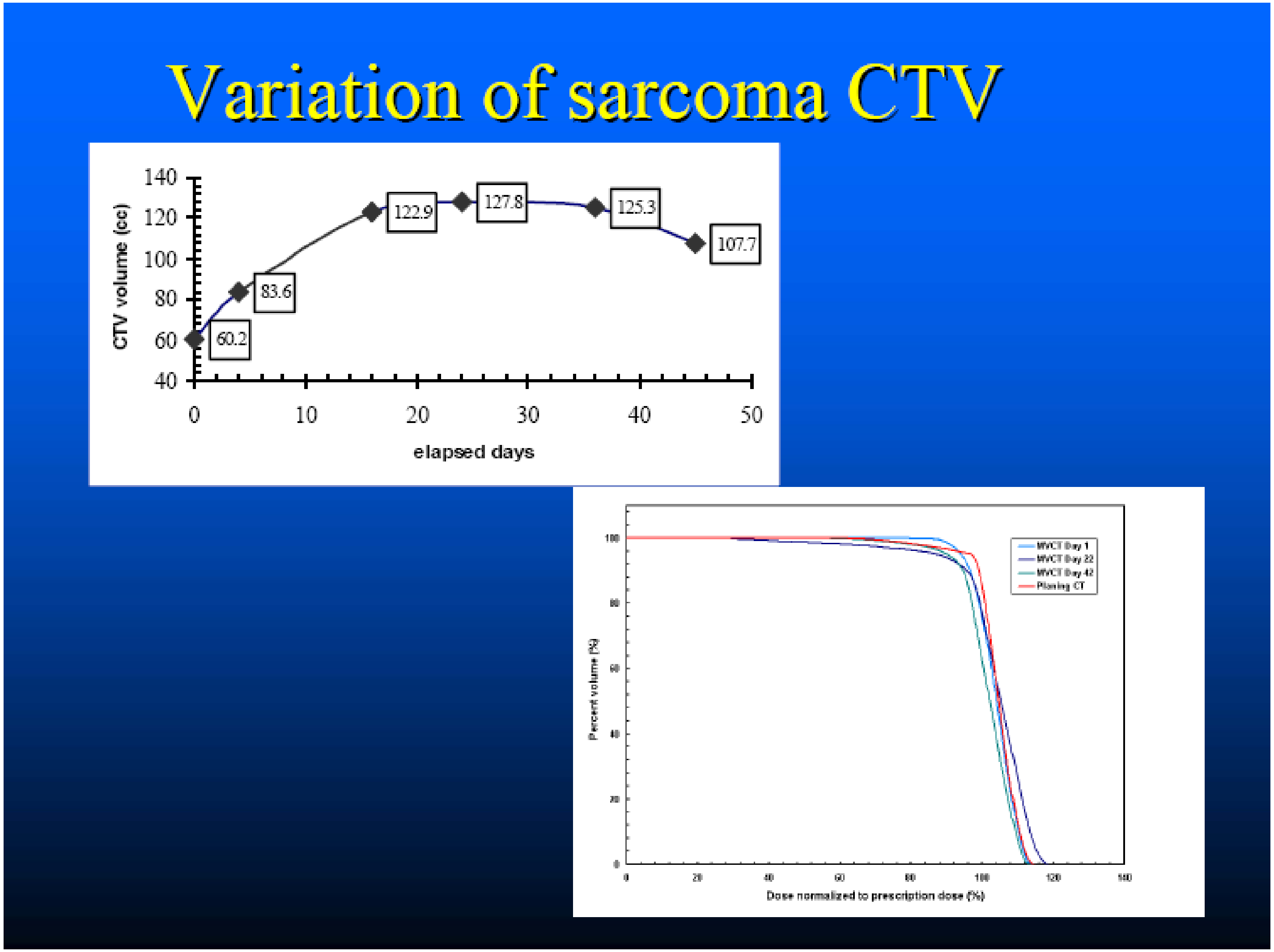




Integrated Imaging System

fraction-to fraction monitoring of organ position AND shape

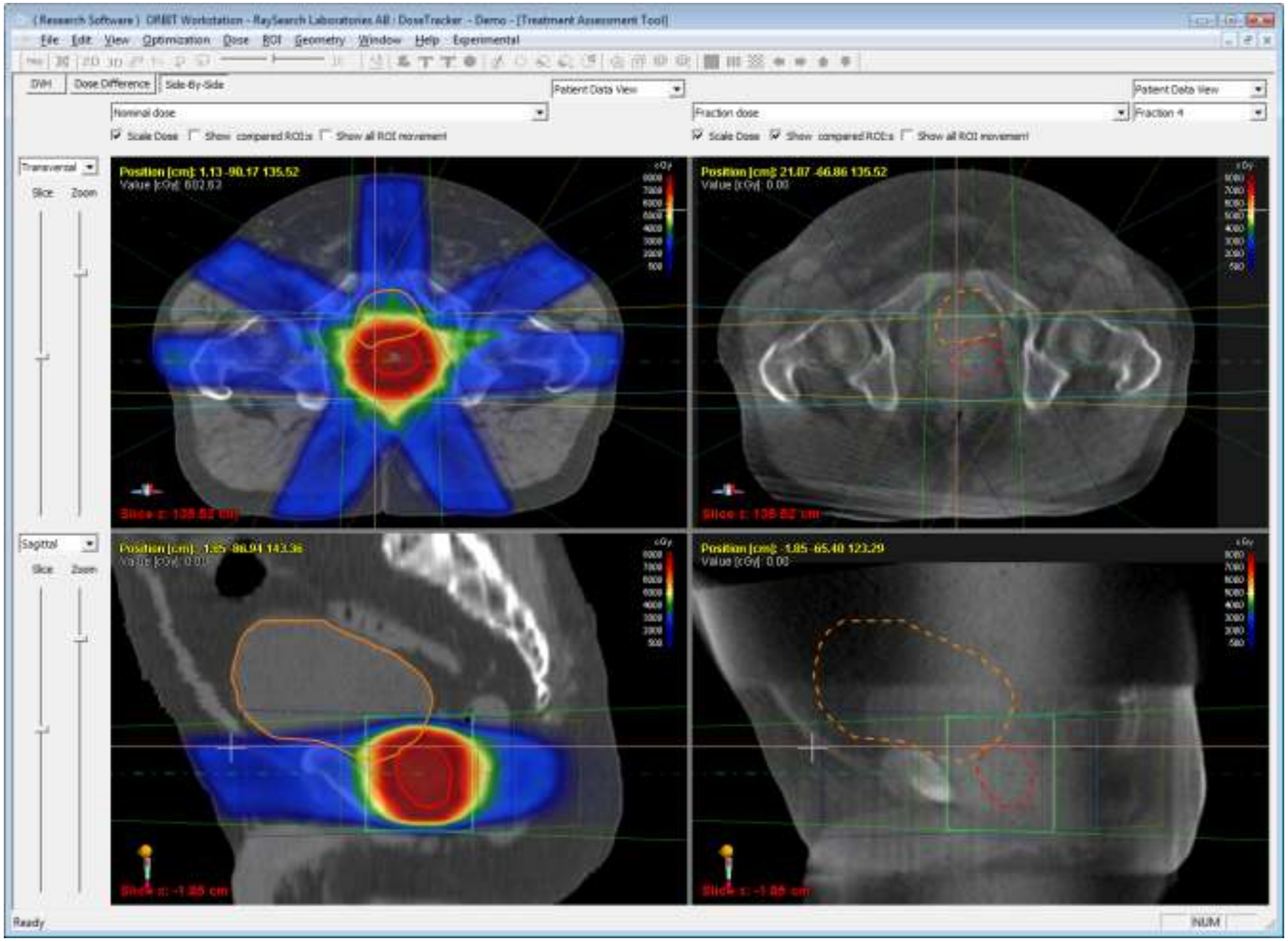
Data from X.A.Li et al., Medical Collegue of Wisconsin

# CTV Volume and Shape change



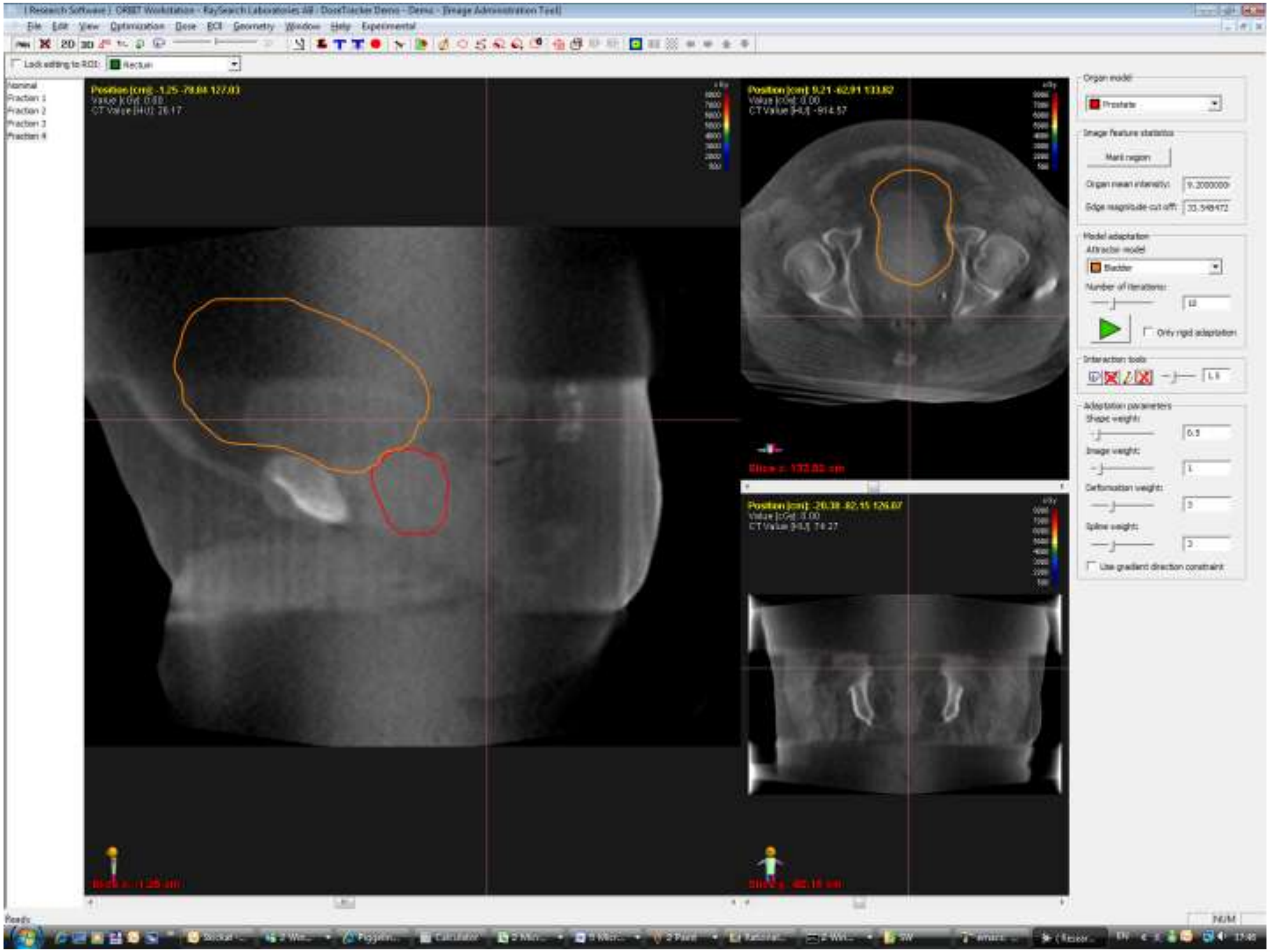

Data from X.A.Li et al., Medical Collegue of Wisconsin

# Cone beam CT import




CT CBCT

# Variation due to bladder filling (fraction 4)





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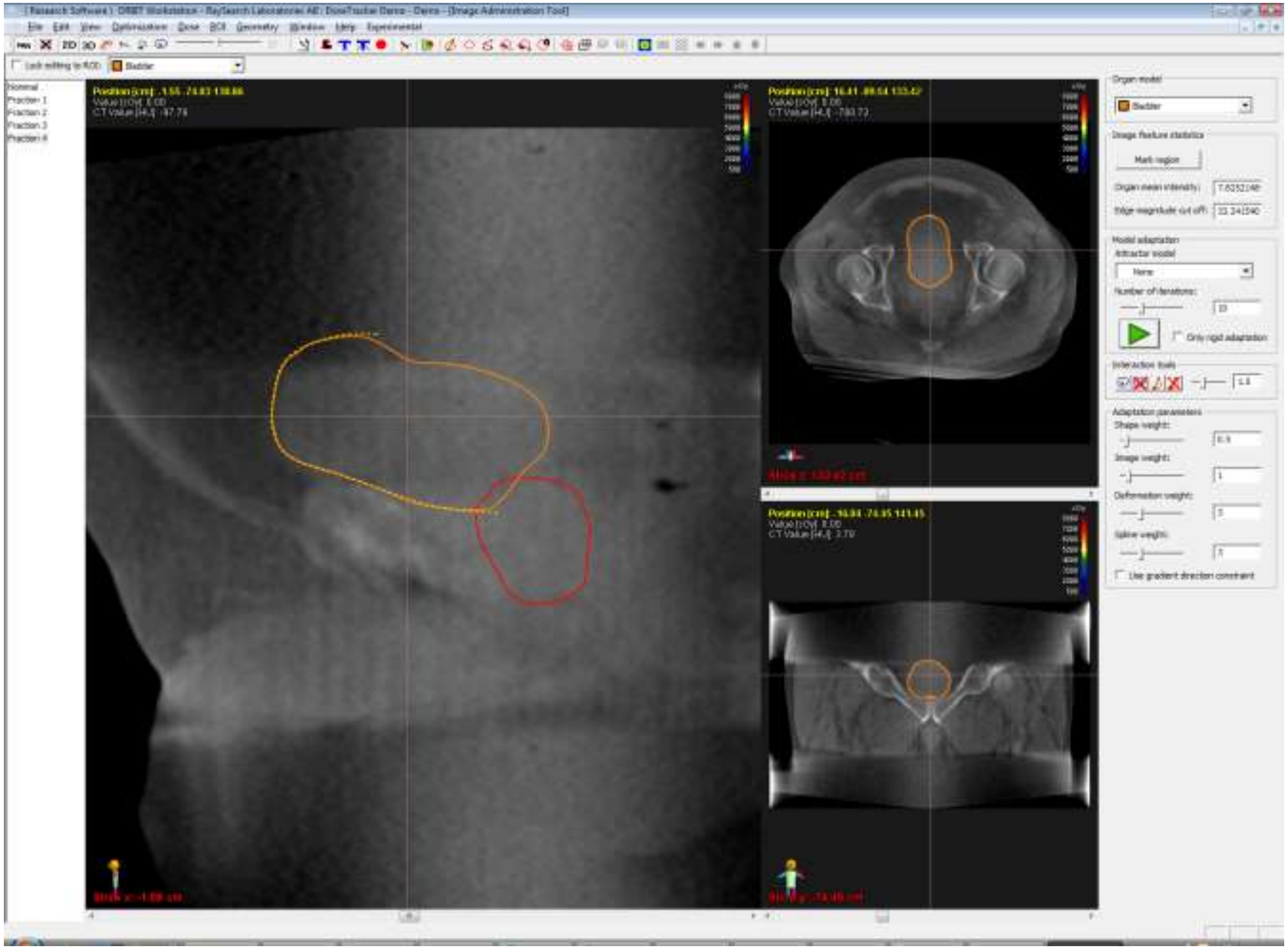
# Initial manual countouring

Draw a spline to help the algorithm finding the border of the bladder, especially where it is going outside of the higher quality image area.

# Automatic adaptation



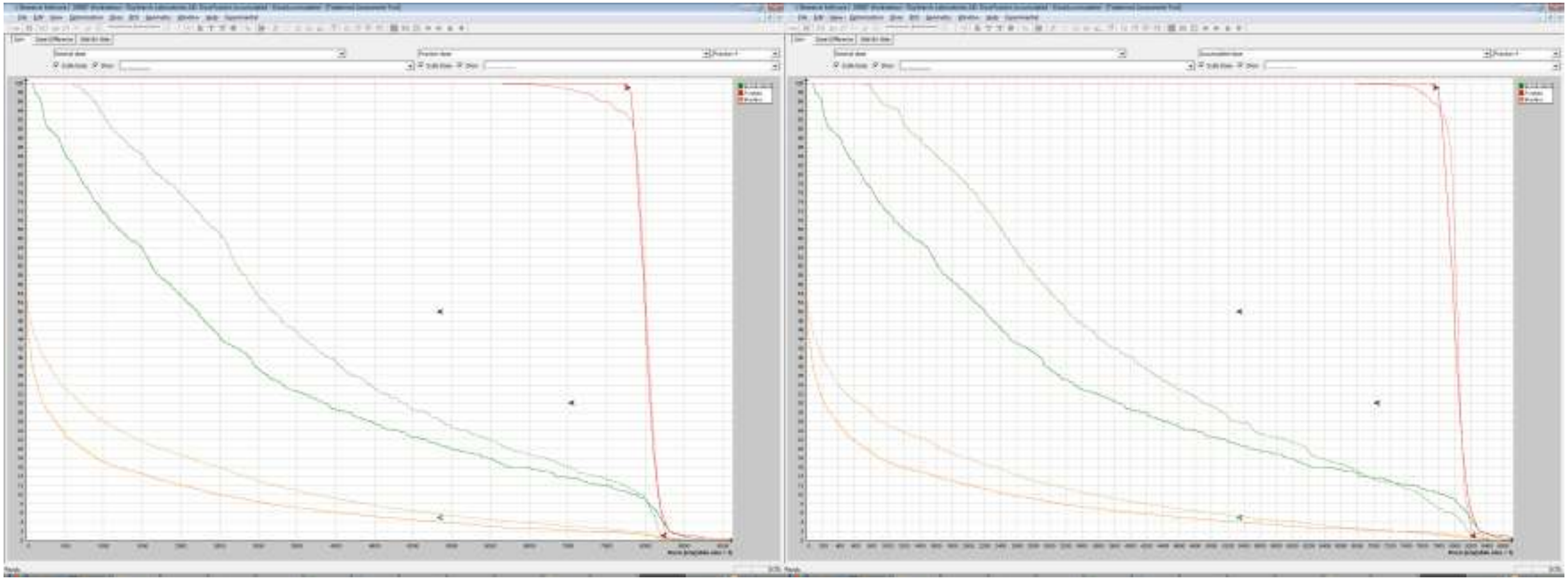
# Rigid registration (Prostate)

Adaptation of prostate is done in the same manner. Only rigid movements however since really hard to identify by grayscale. Need personal clinical knowledge to deform by your own.

# 3D ROI Adaptation

**All adaptation work on the full 3d volume description of the ROI's**

# Cumulative DVH



Fraction 4 | After all fractions

Planned

COMPASS

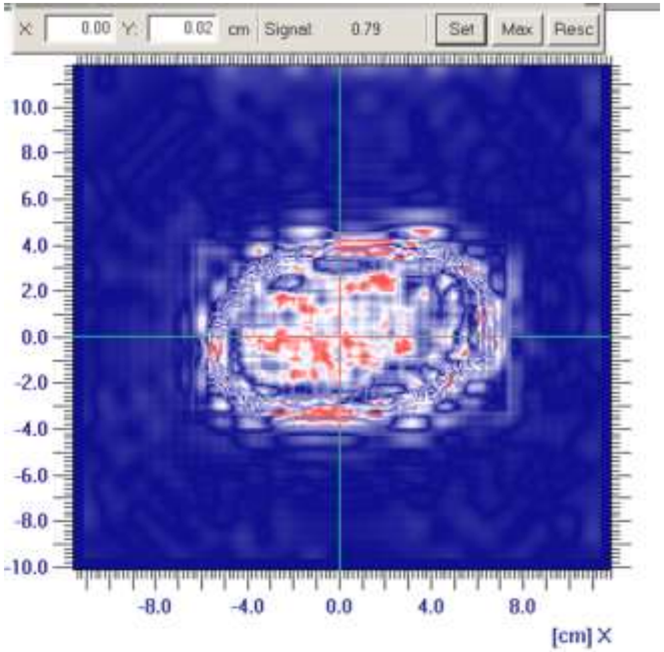
# Commissioning & Validating COMPASS in a Clinical Environment

Vanderbilt-Ingram Cancer Center
Radiation Oncology Department
Jostin Crass, M.S.

# POLL QUESTION

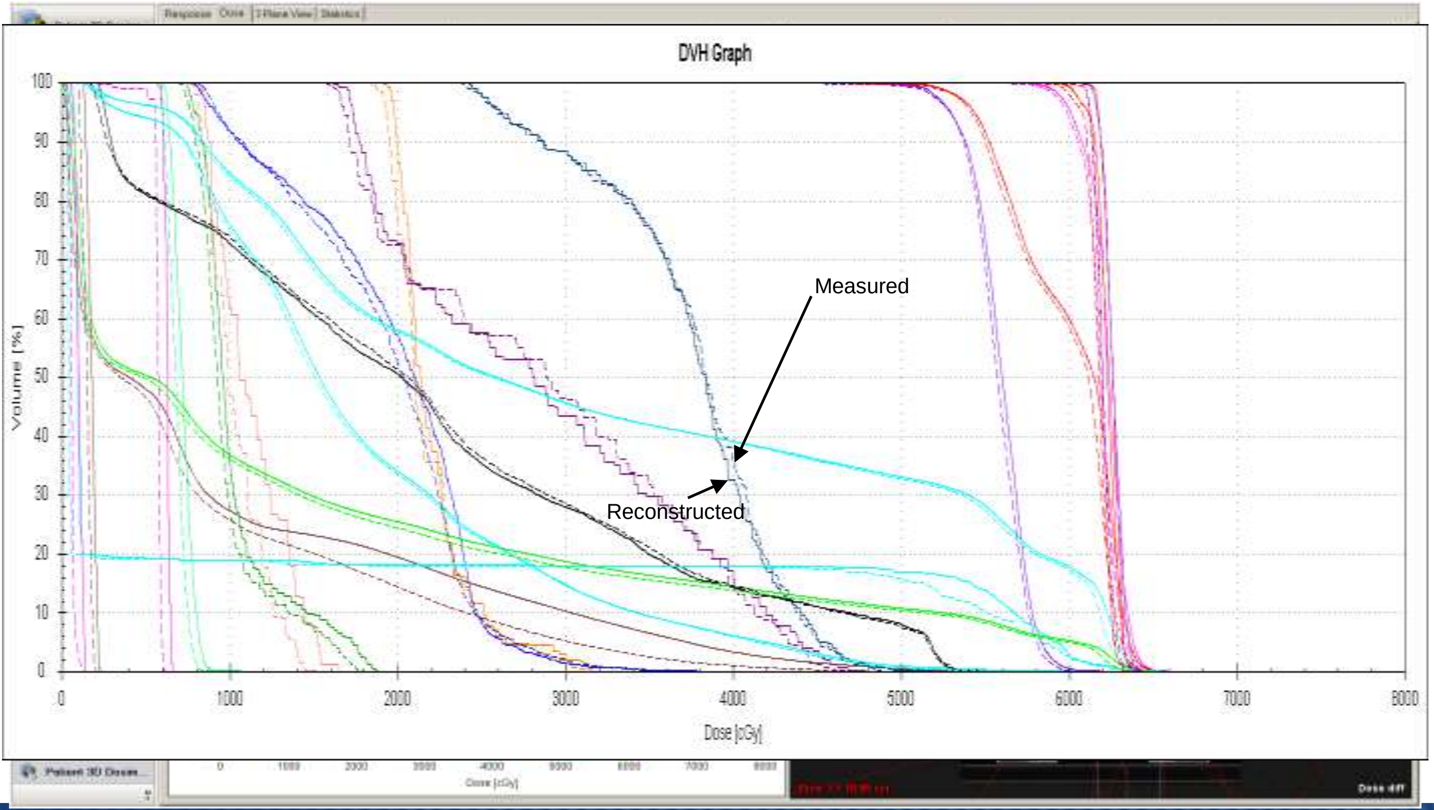
- Raise your hand if your physician would understand this?

95% of Pixels with
Gamma < 1.0



# POLL QUESTION

- What about this? Or this?

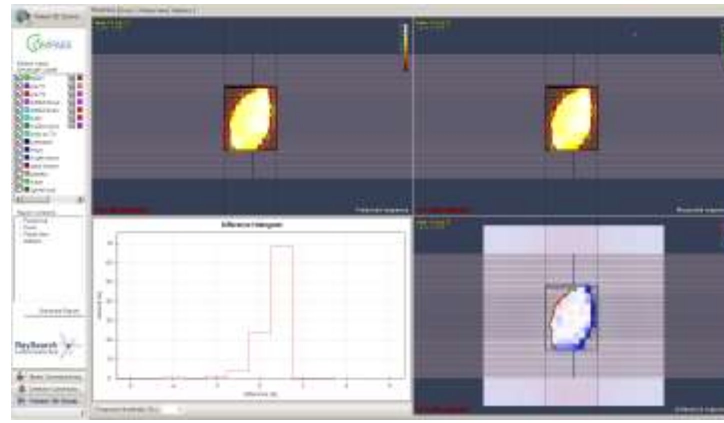


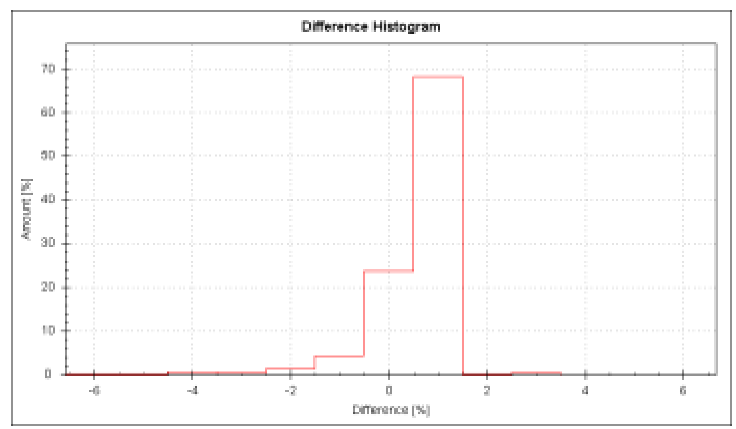
# Validating COMPASS

- Validate our TPS
- Validate COMPASS computation algorithm
- Validate COMPASS prediction algorithm
- Validate COMPASS reconstruction algorithm

# Validating COMPASS

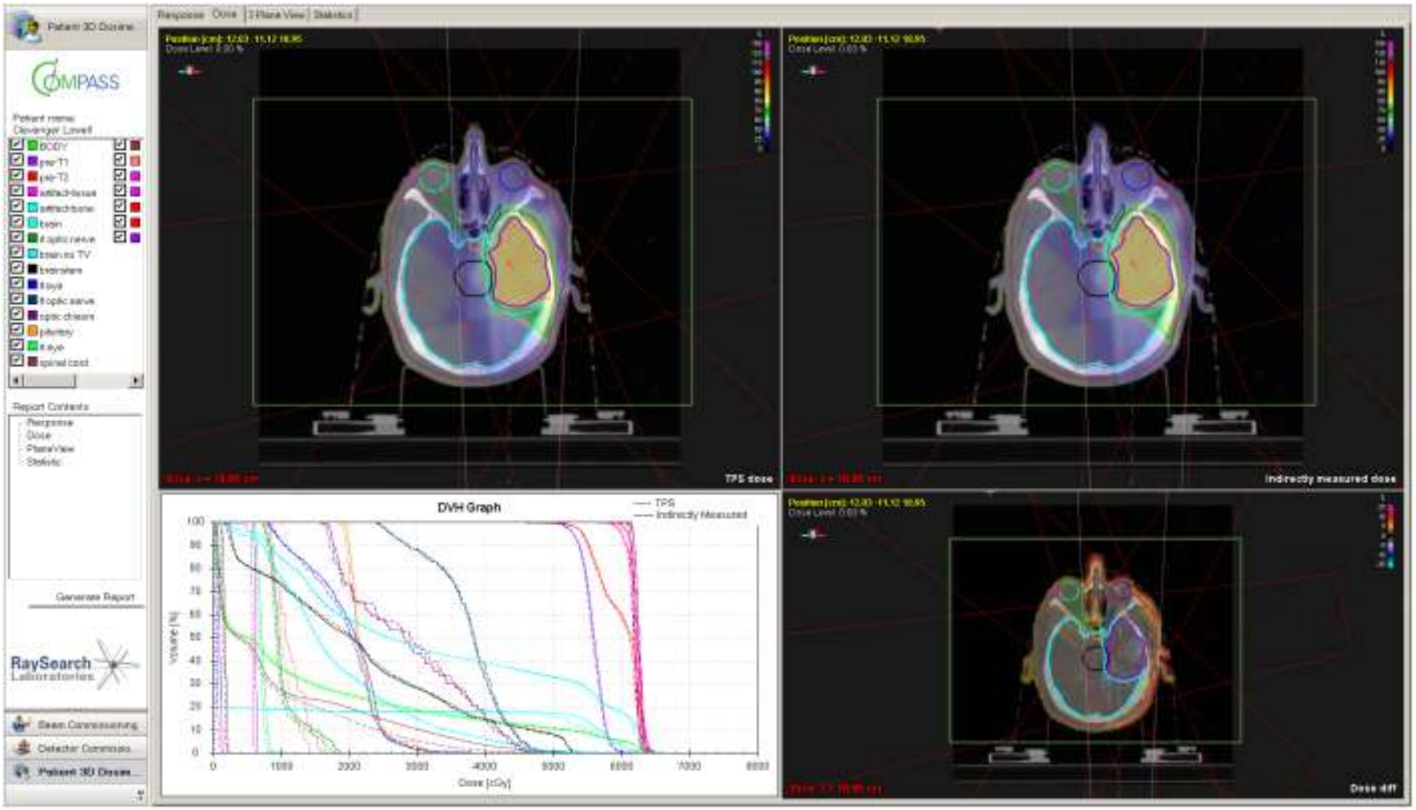
- Validate COMPASS prediction algorithm
  - Compare COMPASS predicted response to response measured on MatriXX
  - Difference Histogram
    - ~96% of the pixels are within ±1.5% Difference
    - Compared Field by Field for complete validation





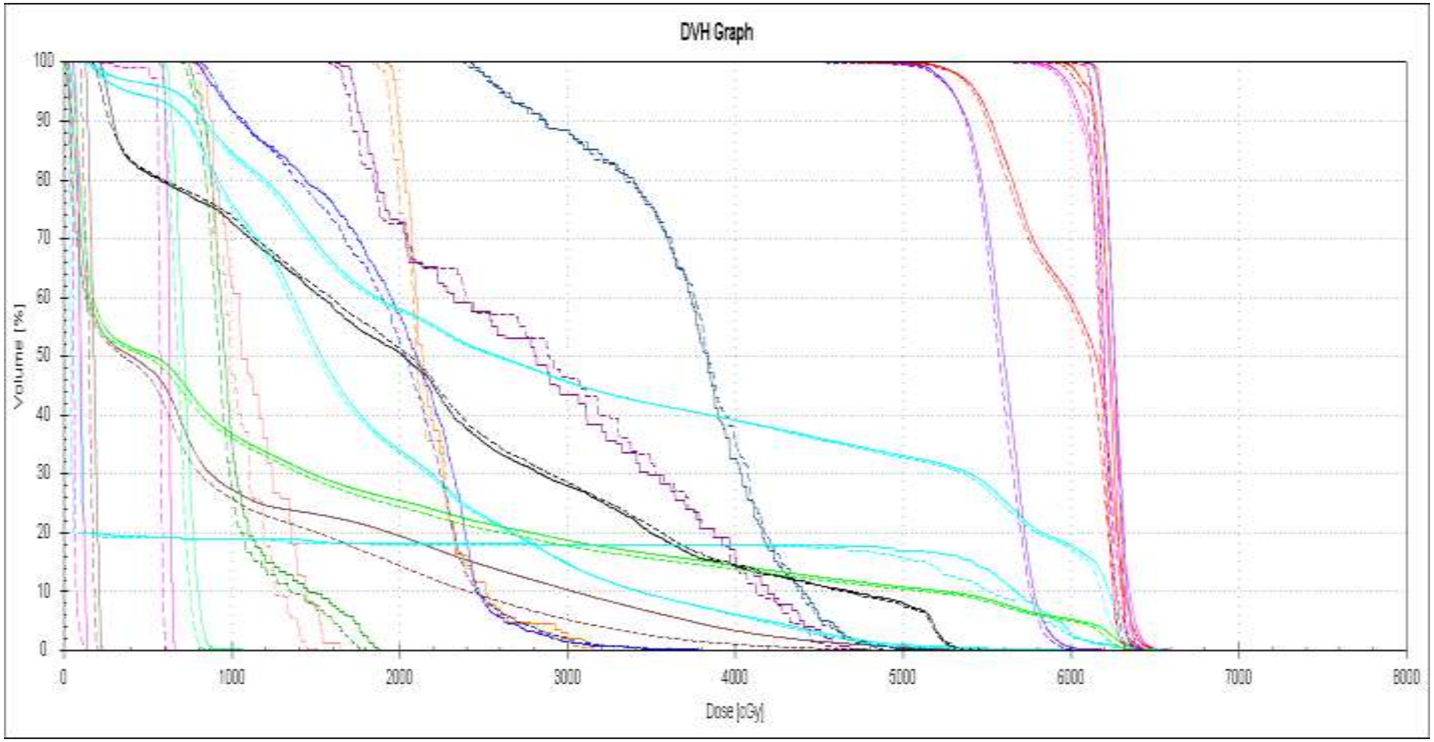
# Validating COMPASS

- Validate COMPASS reconstruction algorithm



# Validating COMPASS

- Validate COMPASS reconstruction algorithm



# COMPASS Pros & Cons

- Cons
  - Beam Modeling
    - should be more automated and intuitive
    - Improve documentation
  - Need to integrate OmniPro IMRT functionality
  - CT numbers add to another uncertainty category

# COMPASS Pros & Cons

- Pros
  - Intuitive GUI
  - Simple Measurement Setup
  - TRIGGER MODE is AWESOME
  - Customizable Reports
  - Dose Visualization
  - Physician Friendly Analysis

# A Novel 3D Approach to Rotational Verification

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Eric Elder, Ph.D.

Department of
Radiation Oncology

EMORY
UNIVERSITY

# Method of Evaluating COMPASS

## Comparison Studies Between TPS, Film, MatriXX and COMPASS

Film

MatriXX

COMPASS

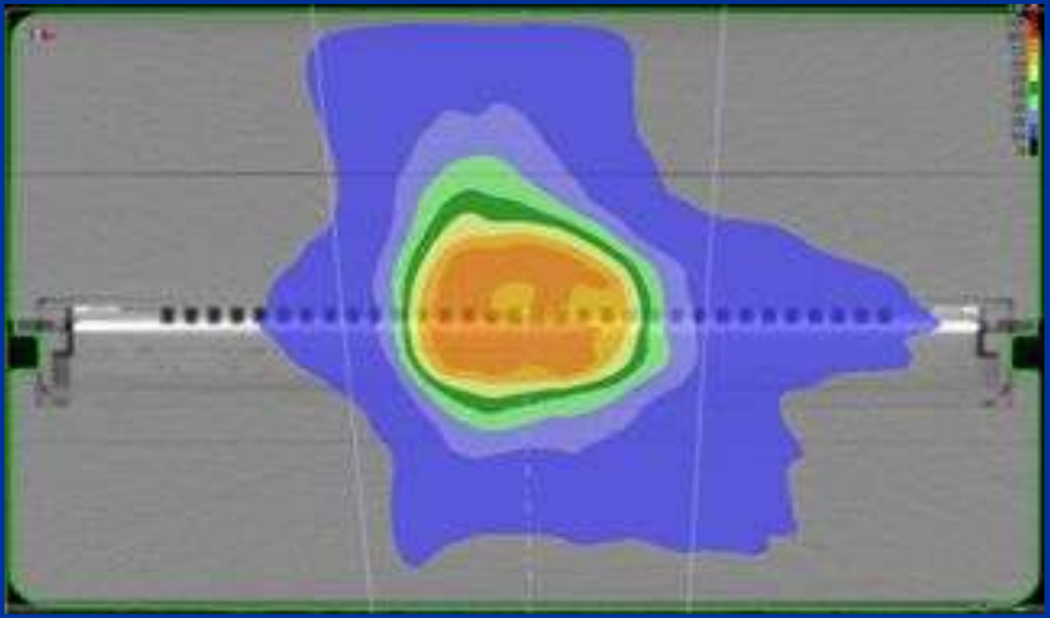
# Method of Evaluating COMPASS

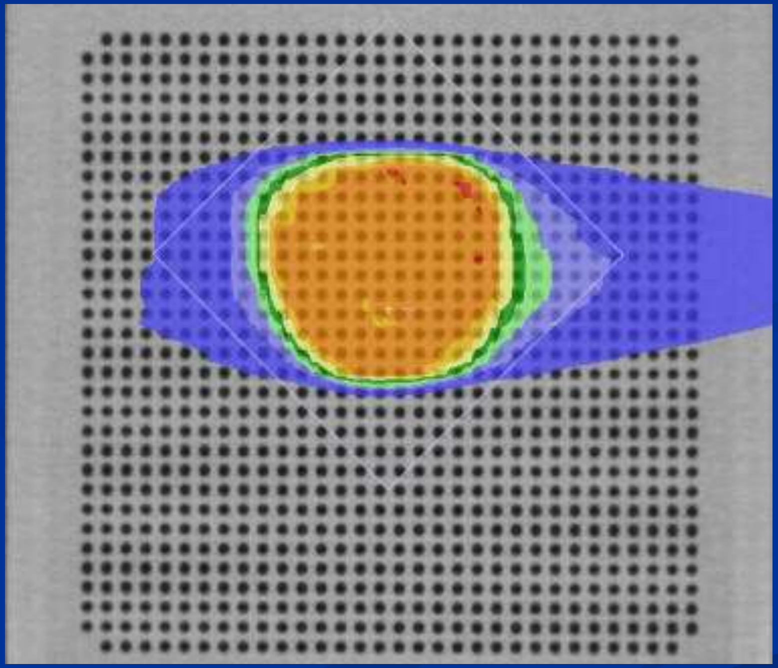
1. Gafchromic Film Dosimetry
2. Conventional Chamber array (MatriXX)
3. TPS

compared to

Planar dose extracted from COMPASS indirectly measured dose

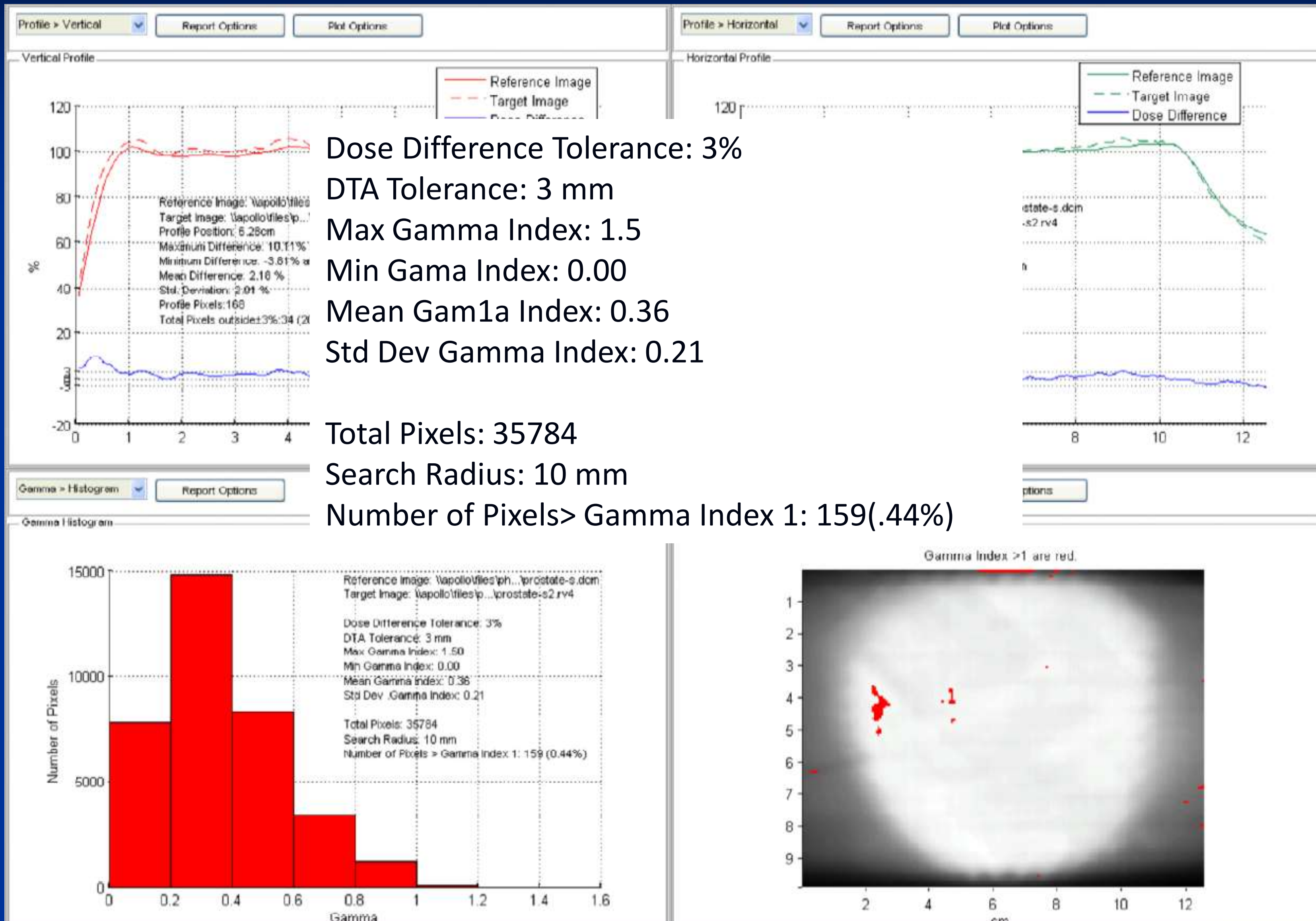
# Planar Dose





Plan on a phantom

# Film vs. TPS




Dose Difference Tolerance: 3%

DTA Tolerance: 3 mm

Max Gamma Index: 1.5

Min Gama Index: 0.00

Mean Gam1a Index: 0.36

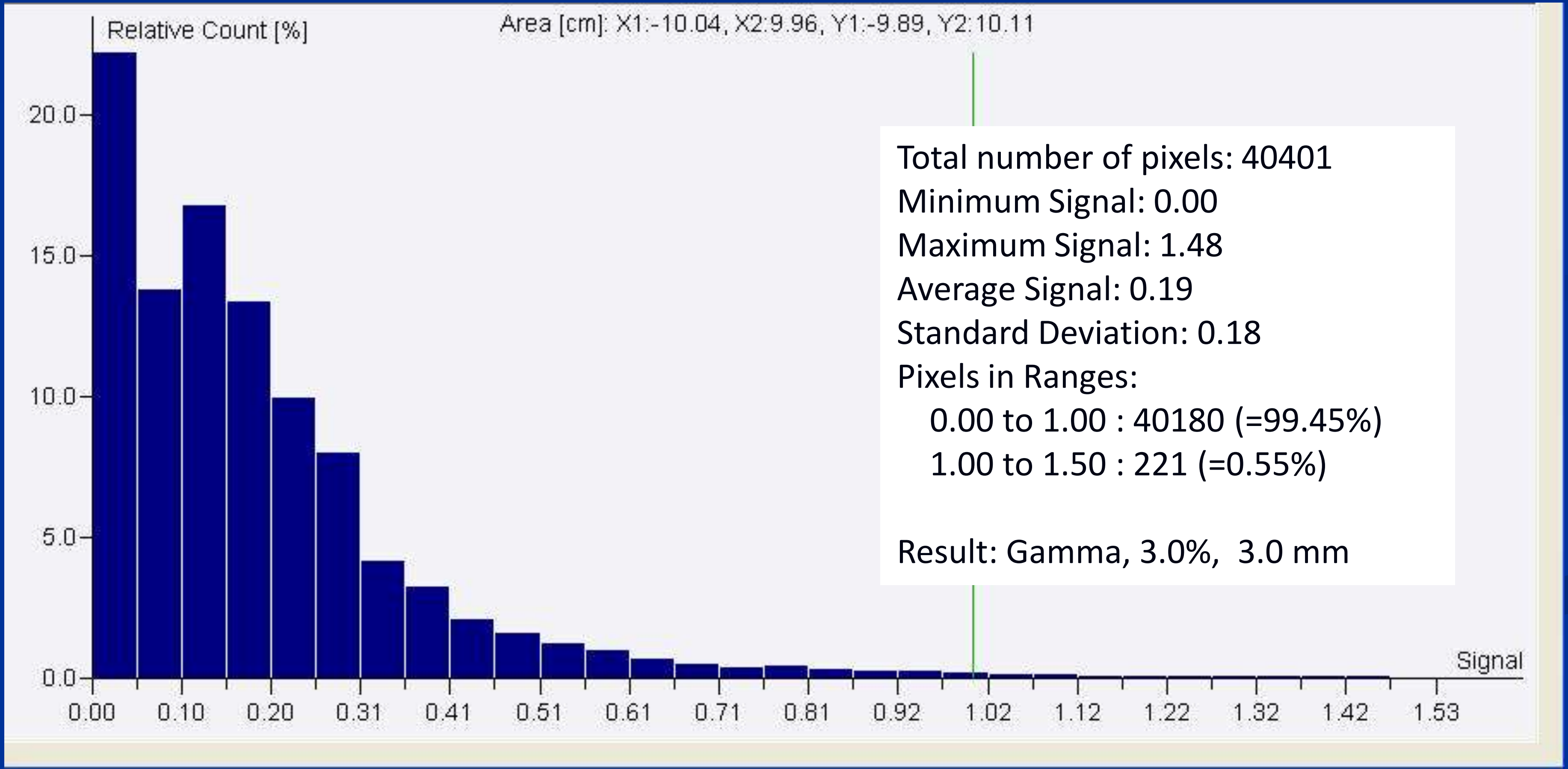
Std Dev Gamma Index: 0.21

Total Pixels: 35784

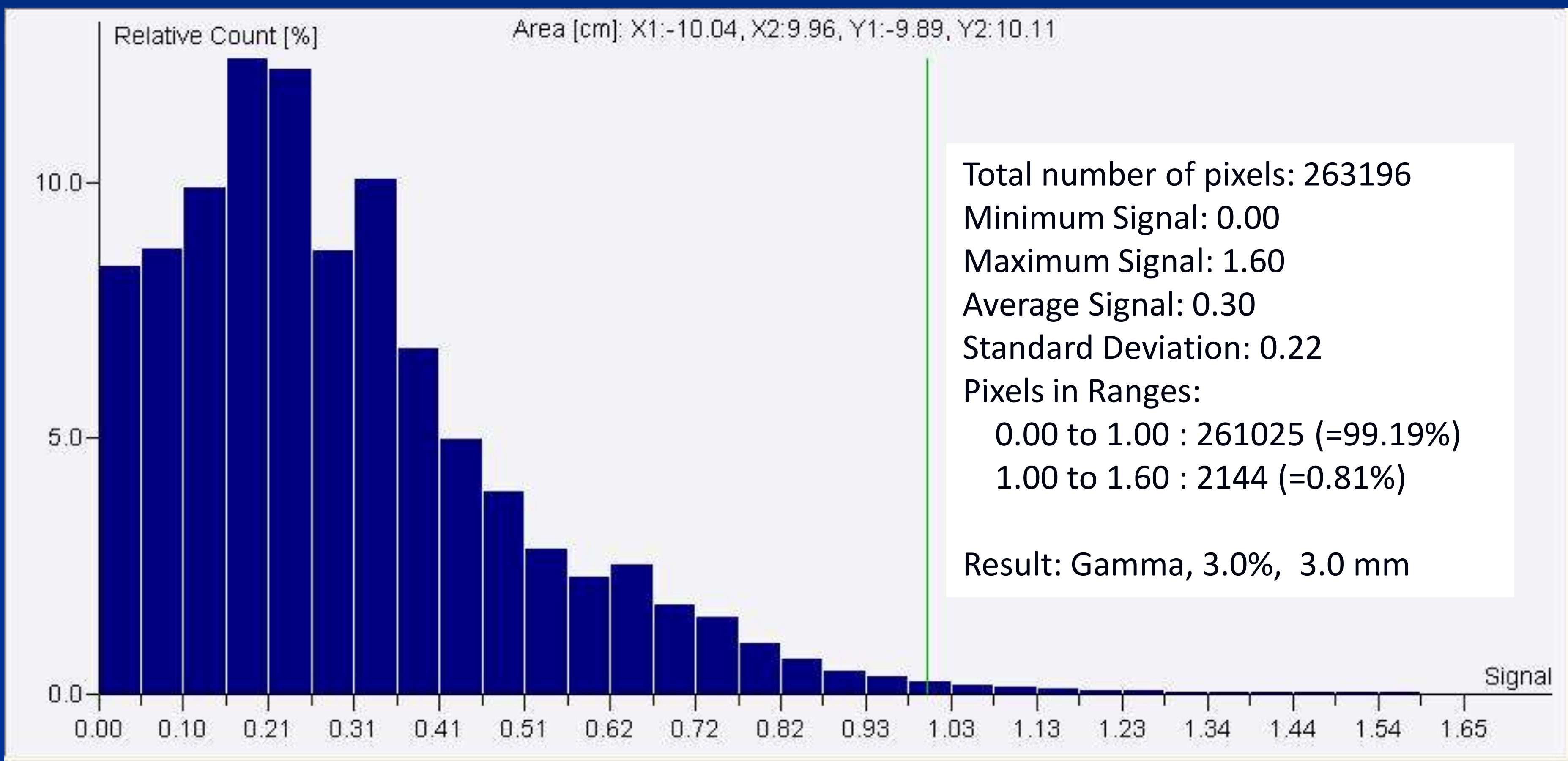
Search Radius: 10 mm

Number of Pixels> Gamma Index 1: 159(.44%)

# MatriXX vs. TPS



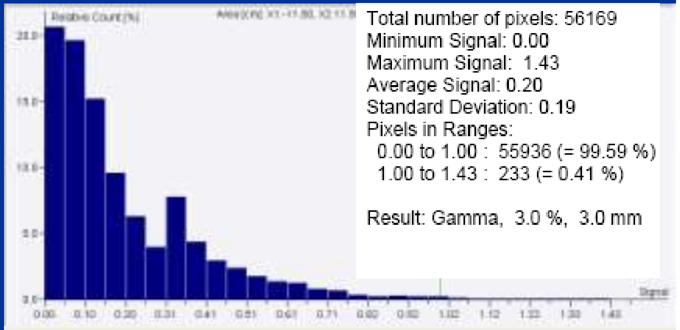
# COMPASS vs. TPS

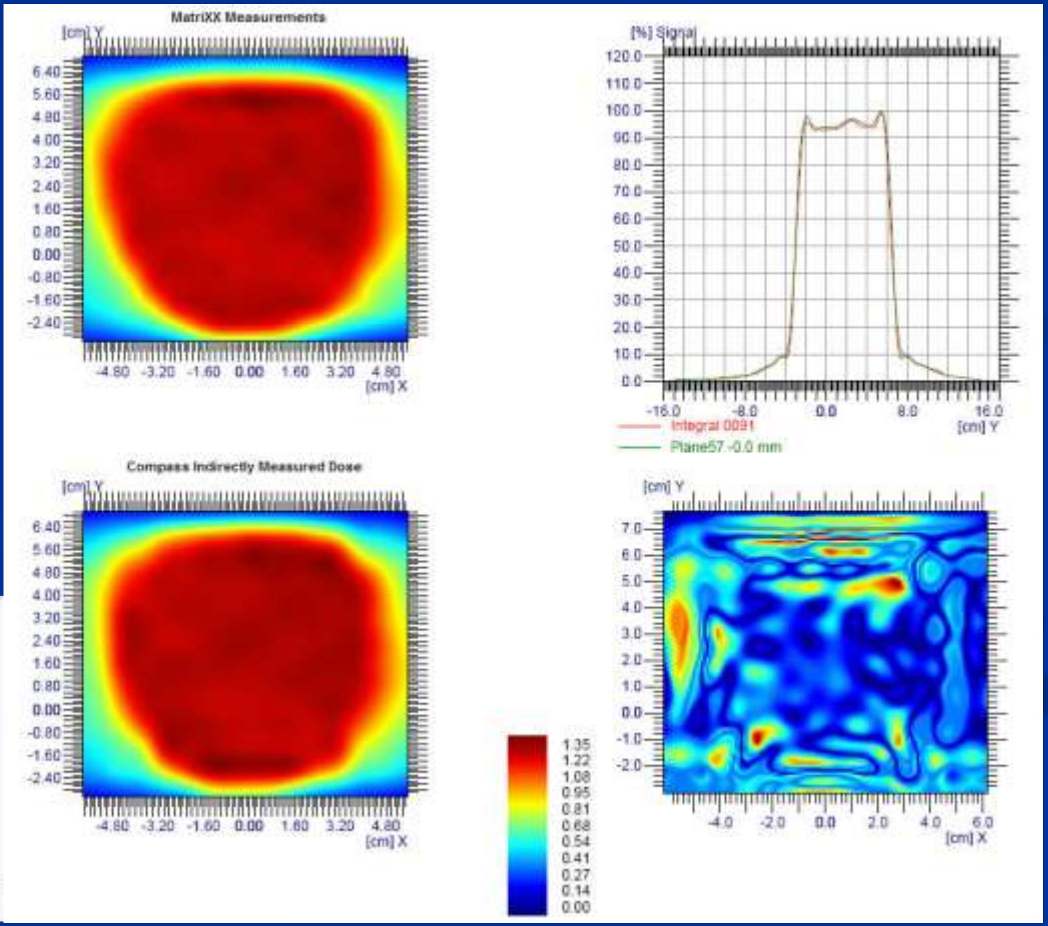


# MatriXX vs. COMPASS

- Results

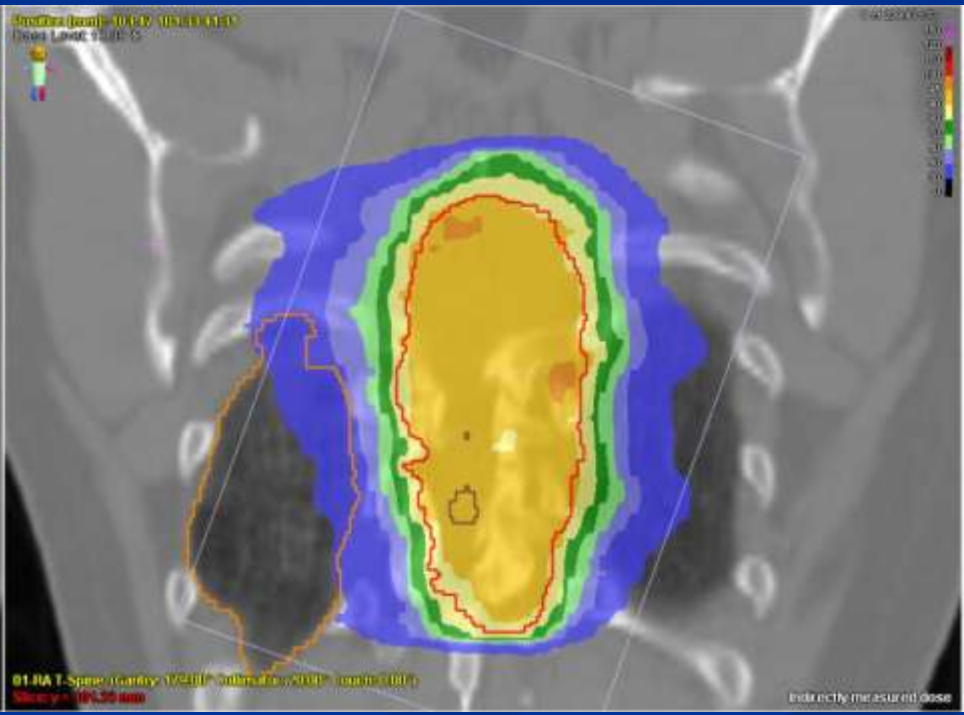
99% of pixels have
gamma index <1.0
Gamma 3%, 3 mm



# Clinical Example

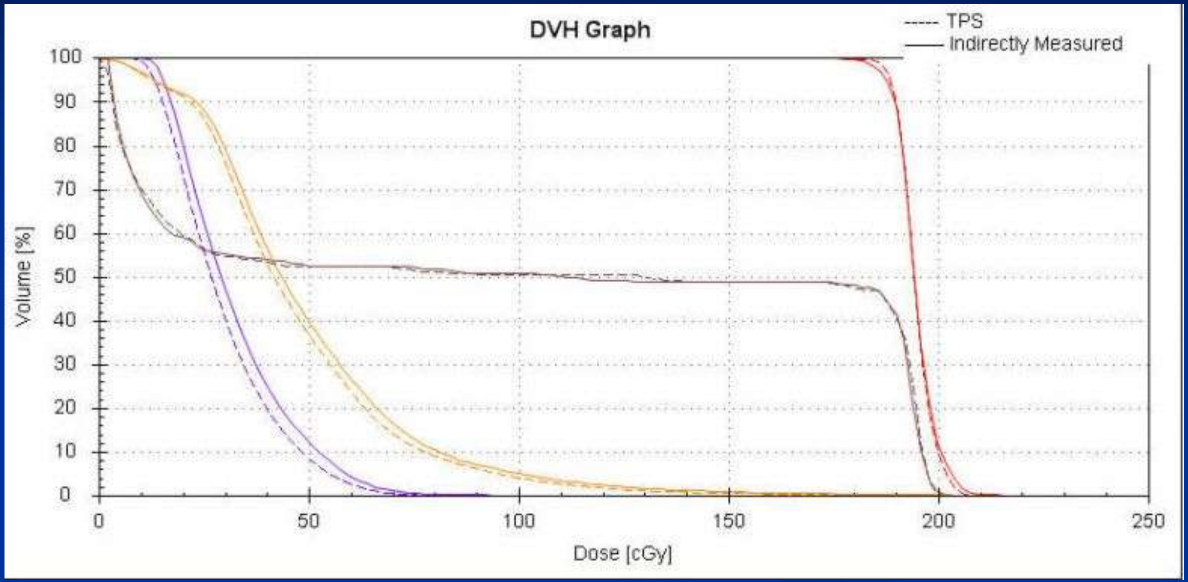
# Clinical Example - Coronal

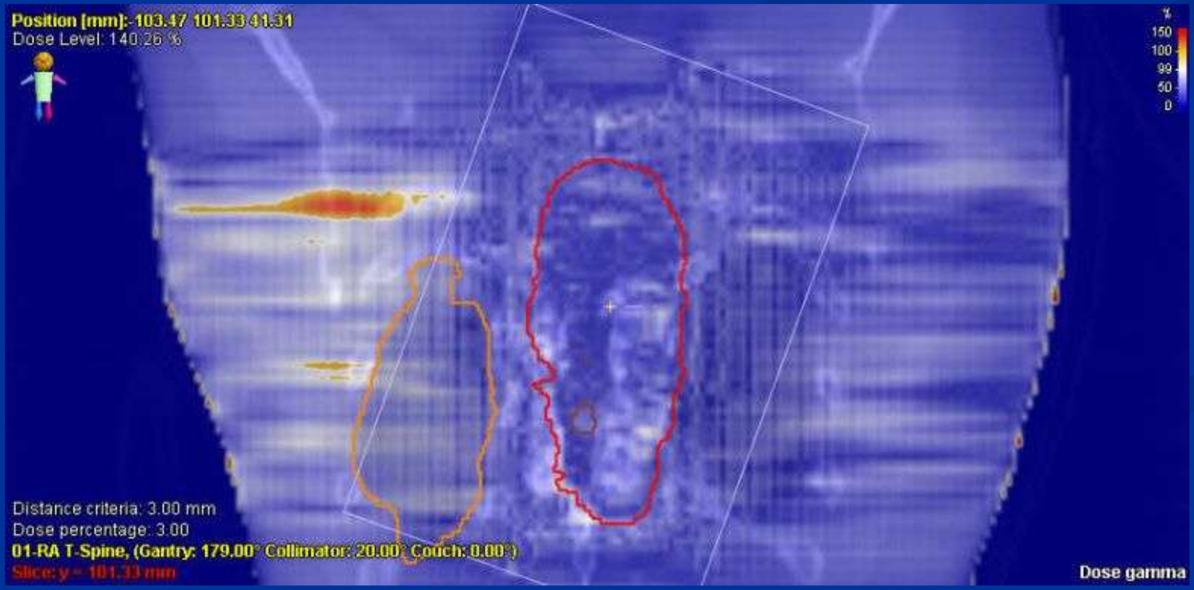




TPS

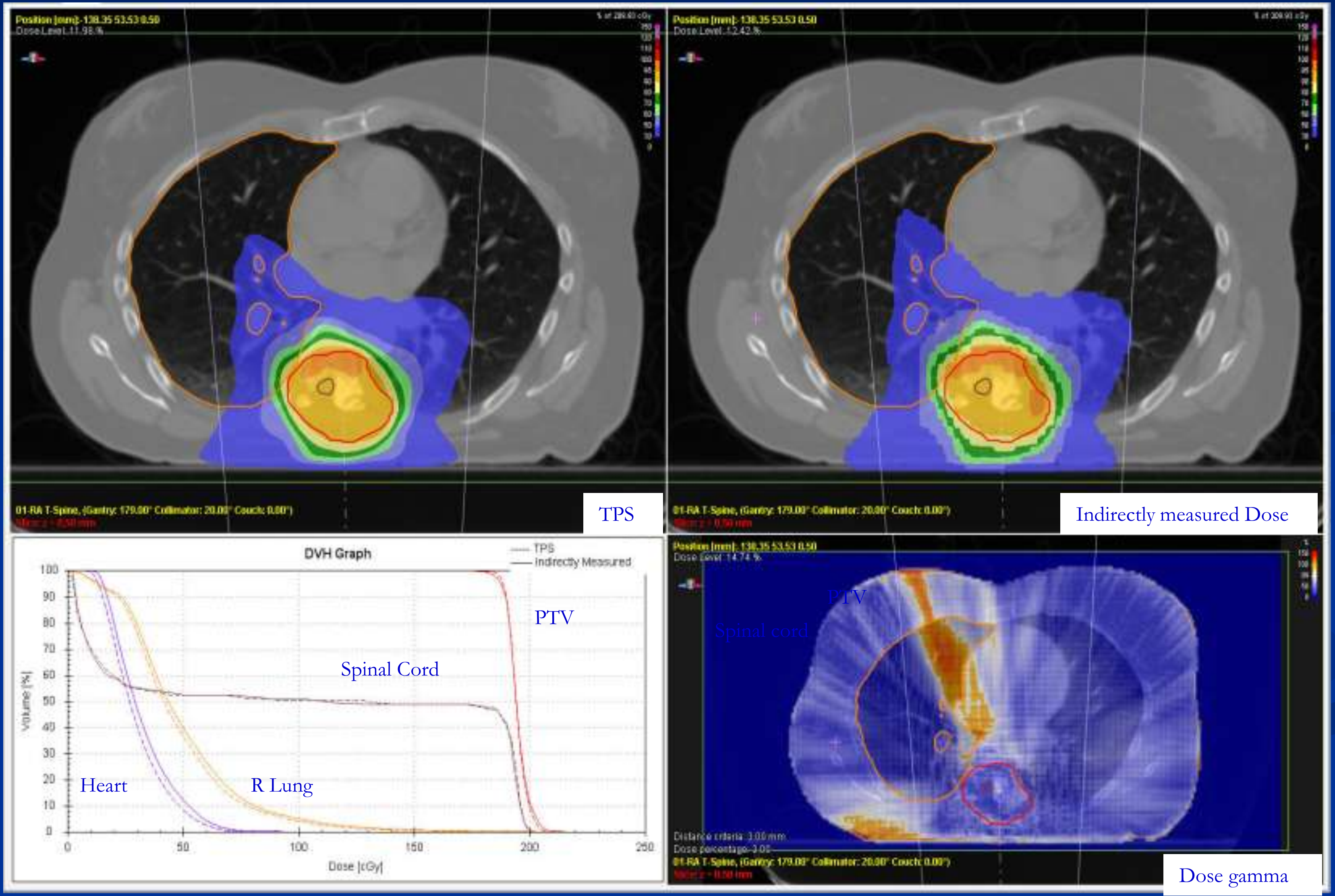
Compass-indirectly measured dose

# Clinical Example - Coronal

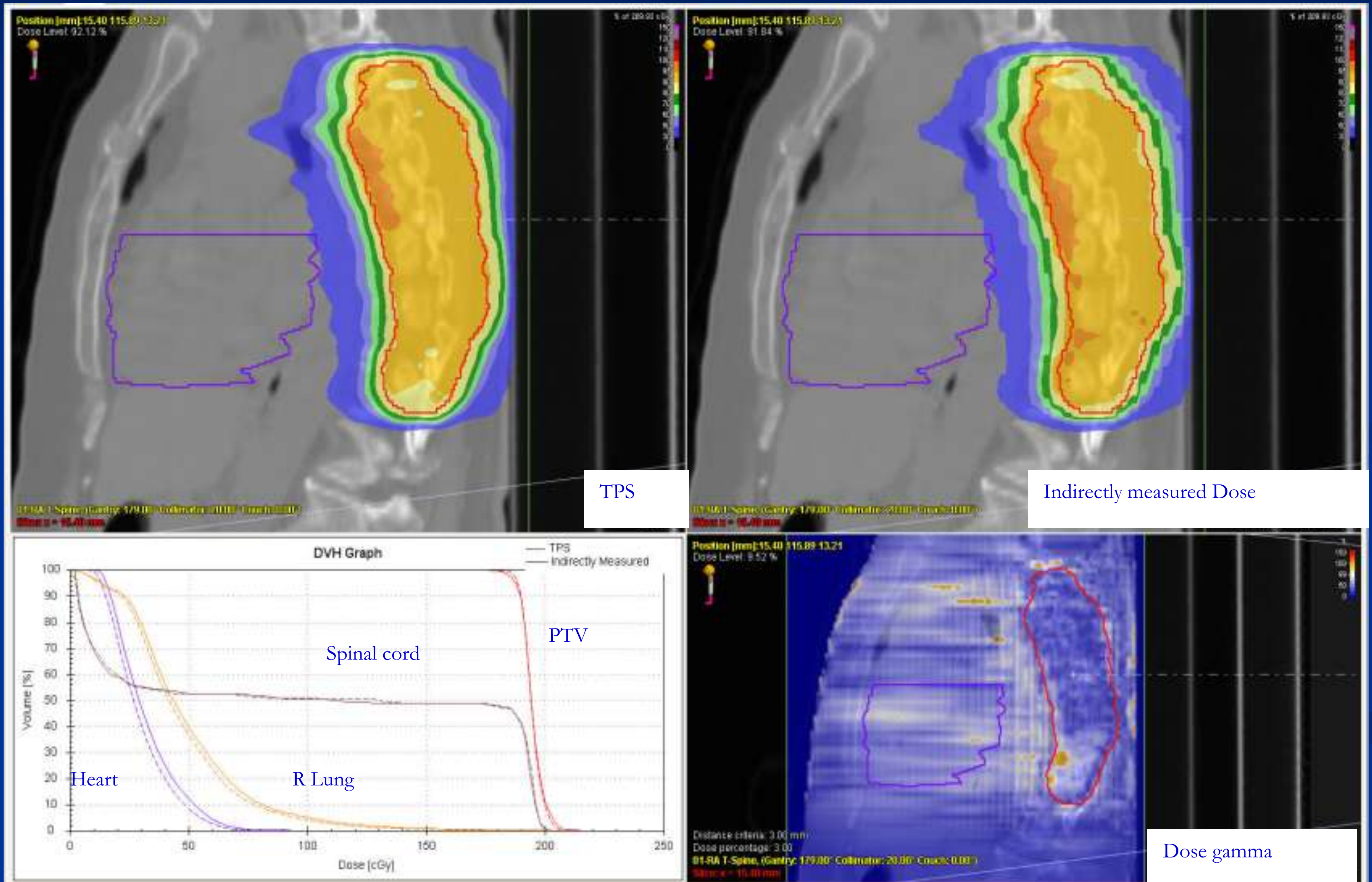


# Clinical Example - Axial



# Clinical Example - Sagittal



# Conclusion

- Provides 3D dose distribution within patient anatomy allowing detailed evaluation of plan.
- Directly identifies discrepancies between plan and delivery.
- Independent verification of treatment planning system.

# Verification and clinical introduction of a QA system* in head and neck IMRT

**COMPASS (IBA Dosimetry)*

*Continuous Online Monitoring PAtient Safety System*

Erik Korevaar
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University Medical Centre Groningen
The Netherlands

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# Purpose

1. Clinical introduction of COMPASS
2. COMPASS QA results identify ‘bad’ treatments as in standard (film based) QA?
3. Machine QA test correlates with patient IMRT QA?

# Methods

1. MLC test geometries
2. Head and neck IMRT test cases
   - 22 treatments on two 'twin' accelerators
   - Gamma index evaluation*: planned vs. delivered dose

| $\gamma_{mean}$ | < 0.5 | 0.5-0.6 | > 0.6 |
|---|---|---|---|
| | OK | | rejected |

*Low et al. Med. Phys. 25 (1998)

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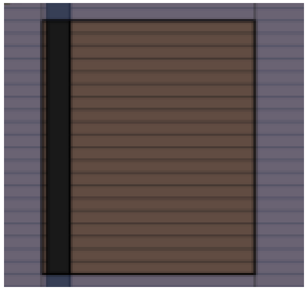
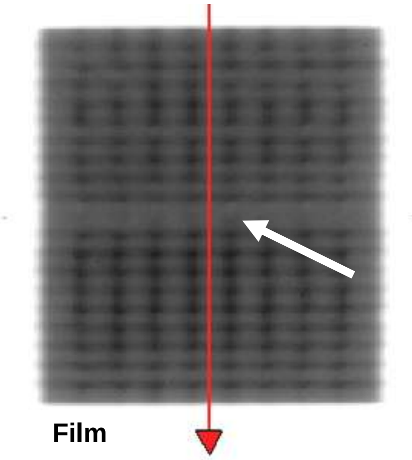
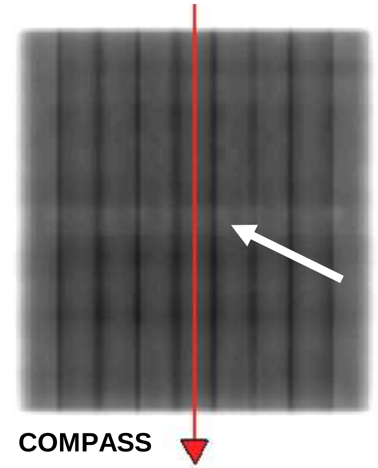
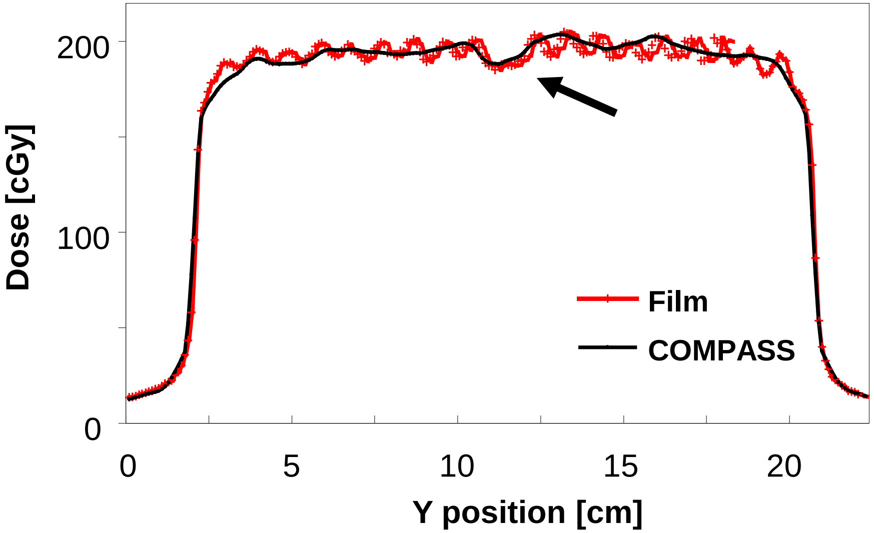
# MLC geometry: Strip test

## 9 adjacent 1.8x20cm$^2$ MLC segments



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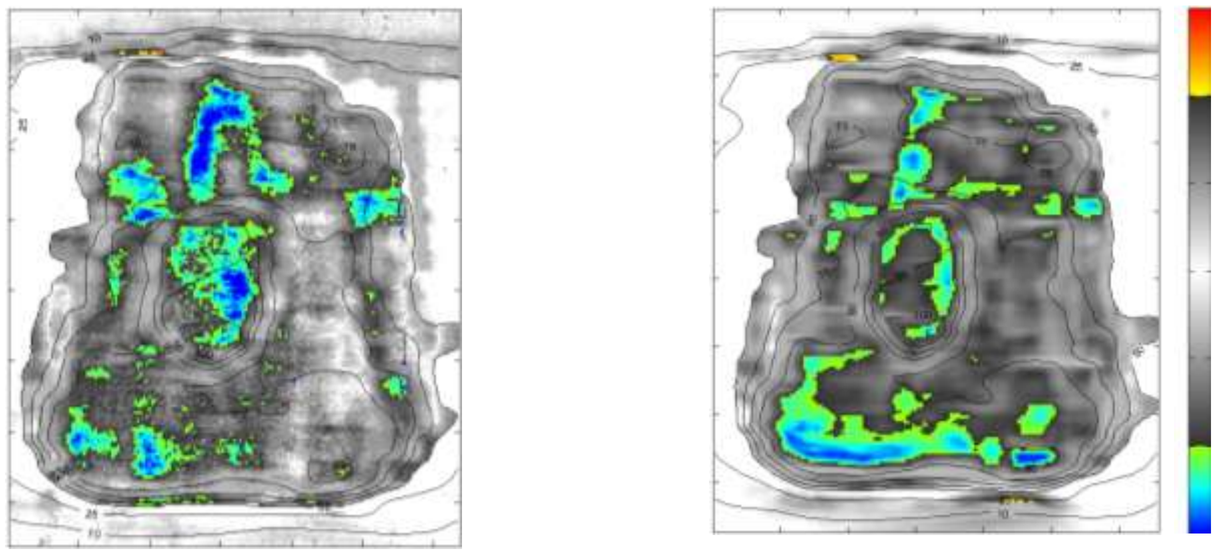
# Head and neck IMRT case #1

## Gamma index (3%/3mm)

$\gamma_{mean} = 0.53$ $\gamma_{mean} = 0.57$

$\gamma$




hot area: measured > TPS

cold area: measured < TPS

Film QA

COMPASS

QA

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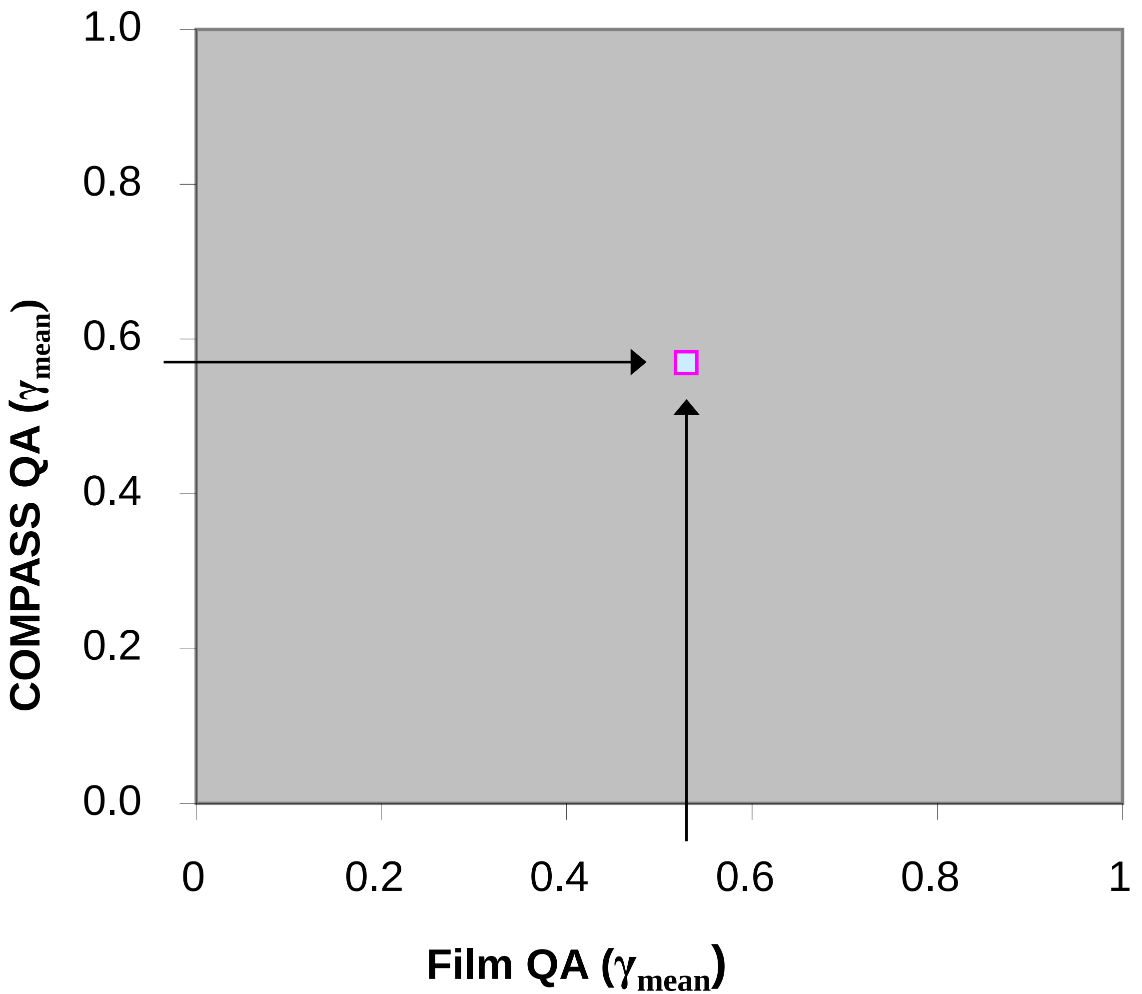
# COMPASS QA vs Film QA

## Gamma index correlation

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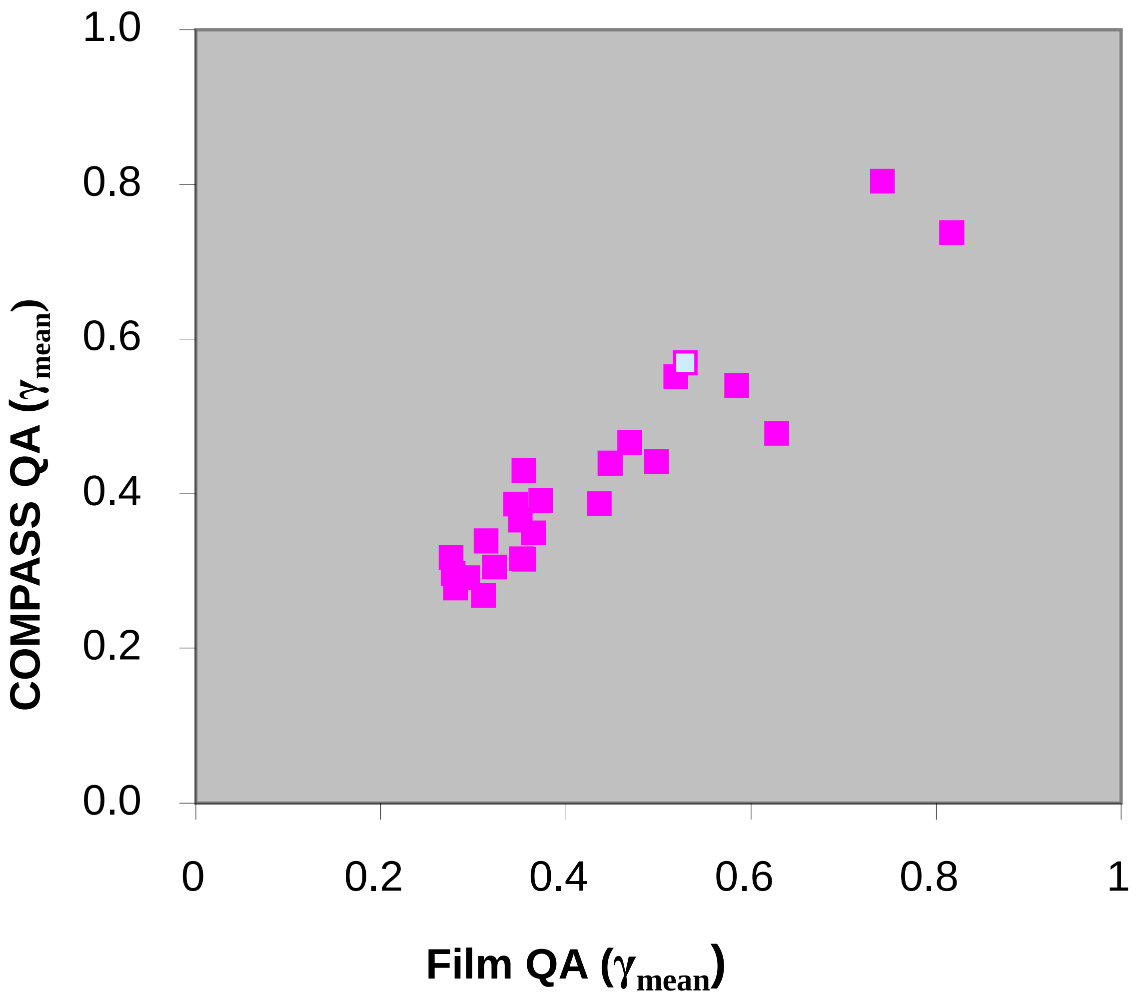
# COMPASS QA vs Film QA

## Gamma index correlation

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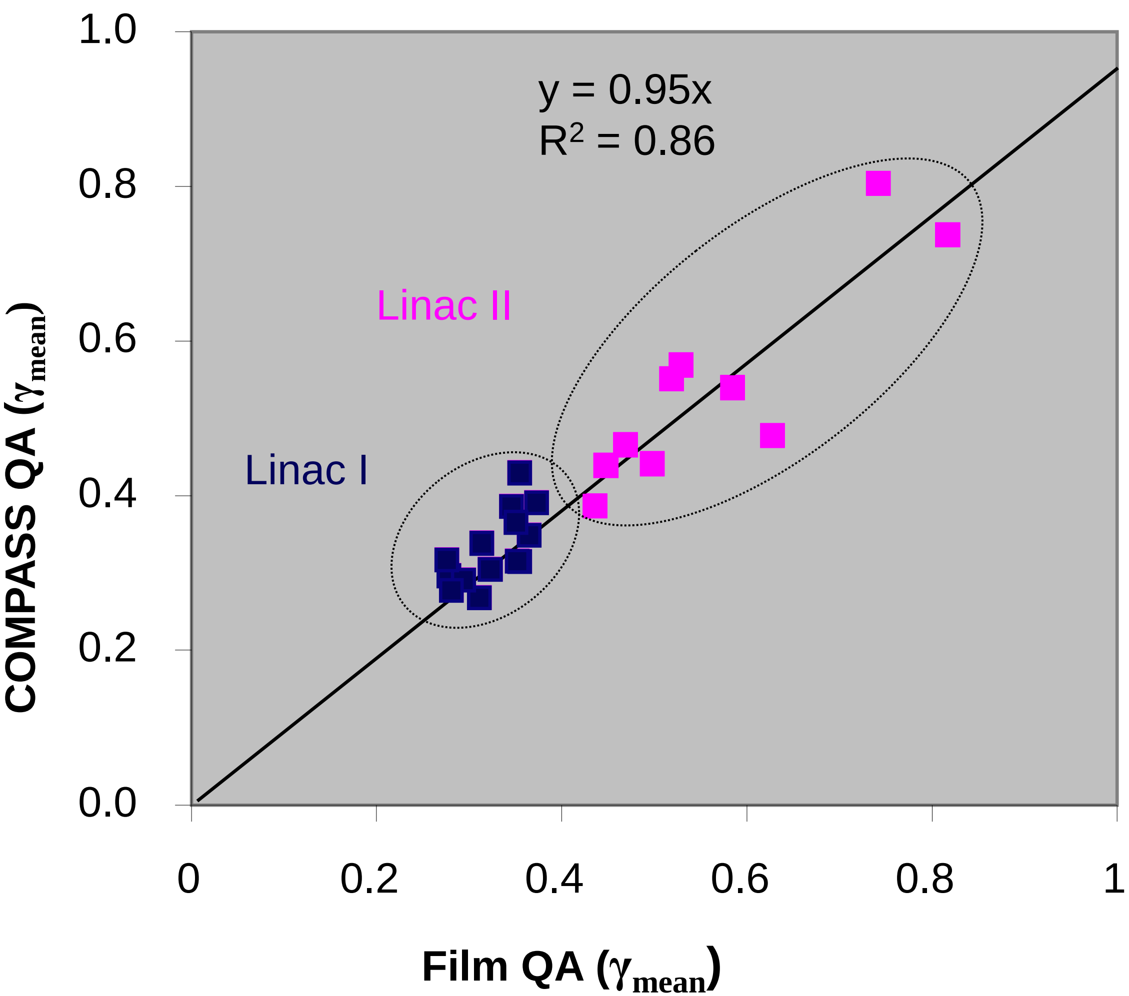
# COMPASS QA vs Film QA

## Gamma index correlation

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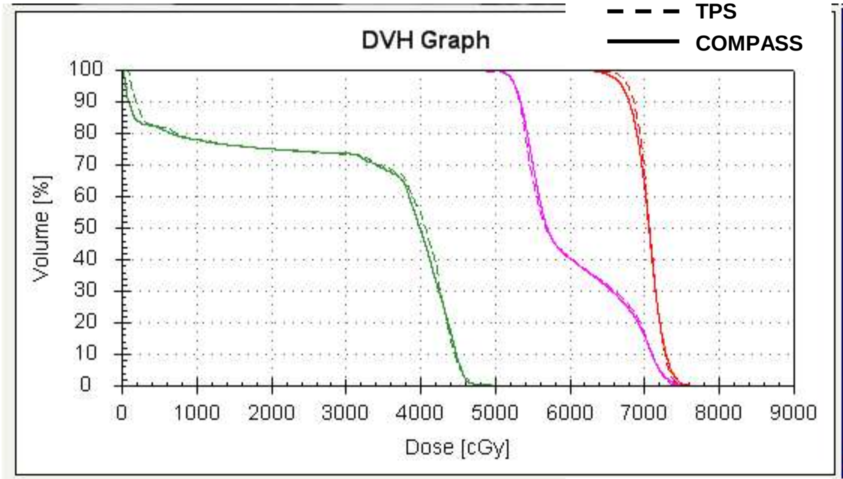
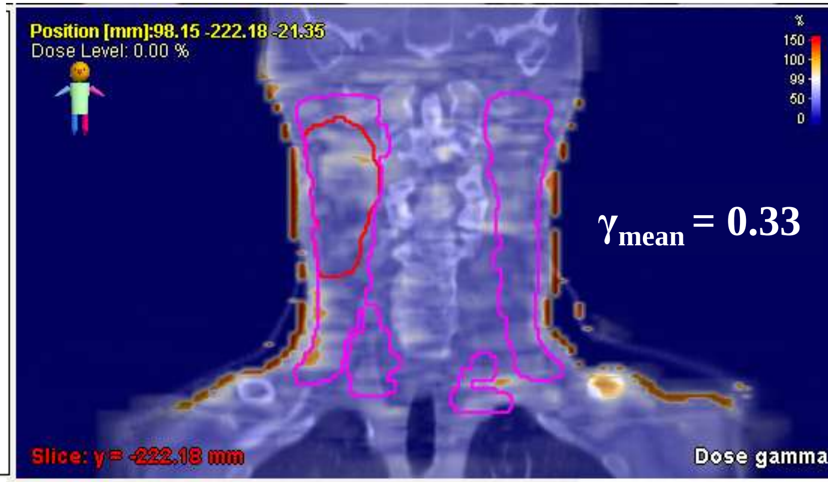
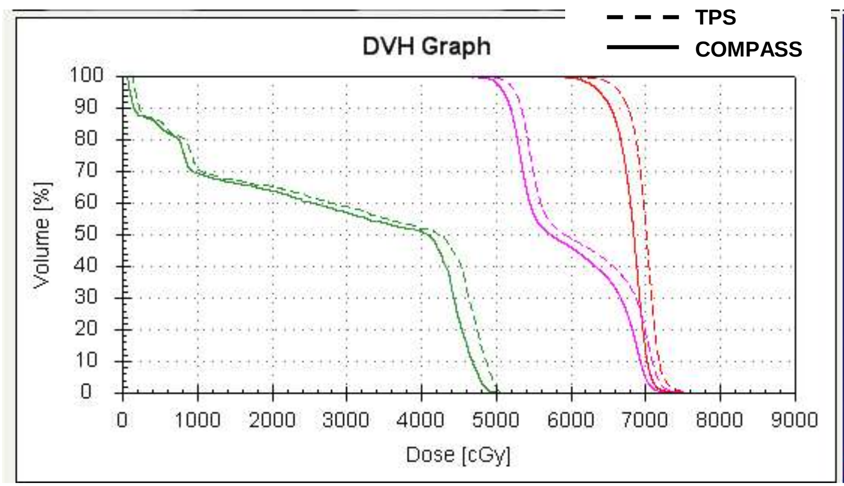
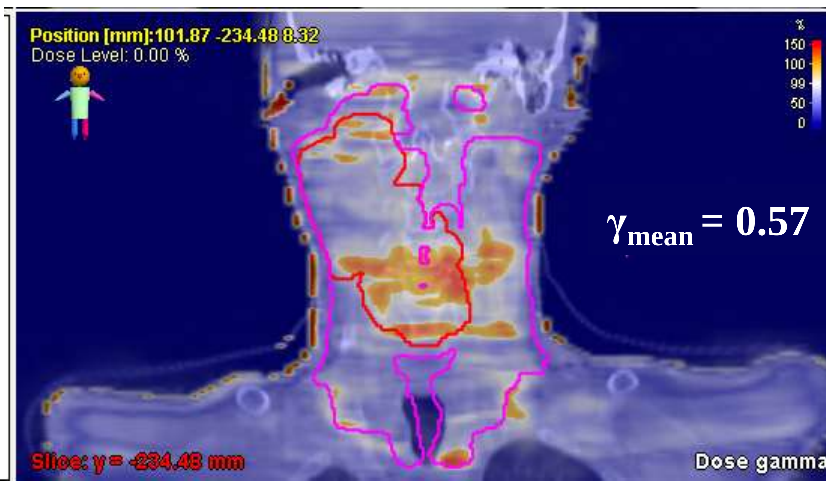
# COMPASS QA in patient CT




DVH: spinal cord (green), planning target volumes (purple, red)

Gamma index (orange: $\gamma$ >1 )

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# Conclusions

- COMPASS based QA agrees with film based QA
- Machine QA test correlates with patient QA

➔ In clinical use since February 2009

➔ IMRT QA time reduced by half

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# Acknowledgements


- University Medical Center Groningen
  University of Groningen, Department of Radiation Oncology
  Groningen, The Netherlands
- D. Wauben, P.C. van der Hulst, J.A. Langendijk, A.A. van ‘t Veld
- IBA Dosimetry GmbH
  Schwarzenbruck, Germany
- RaySearch Laboratories
  Stockholm, Sweden


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# Clinical Validation of COMPASS-System for Verification of Intensity Modulated Fields

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[1]Radiologie & Radioonkologie im Struenseehaus, Hamburg-Altona

[2]IBA-Dosimetry, Schwarzenbruck

# Materials and Methods

- Comissioning of COMPASS

Determination of dosimetric base data for 6MV photon beam with a water phantom. The LINAC used was ONCOR Impression (Siemens).

- Validation of COMPASS

Comparison of output factors, depth dose curves and lateral profiles vs. Base data for simple quadratic fields

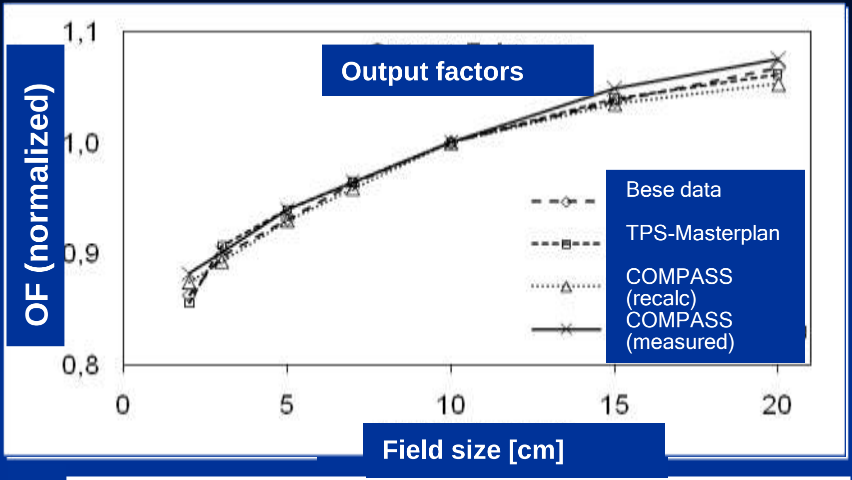
Similation of delivery errors by modification of planning data (photon energy variation, MLC and collimator positions).

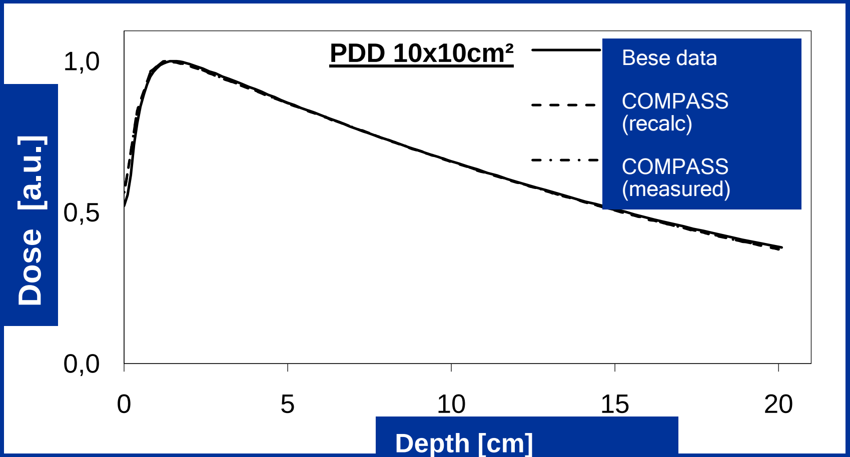
Clinical routine usage of COMPASS for 4 head-and-neck plans. The plans have been evaluated with COMPASS and compared to dose distributions from the planning system KonRad (Siemens)

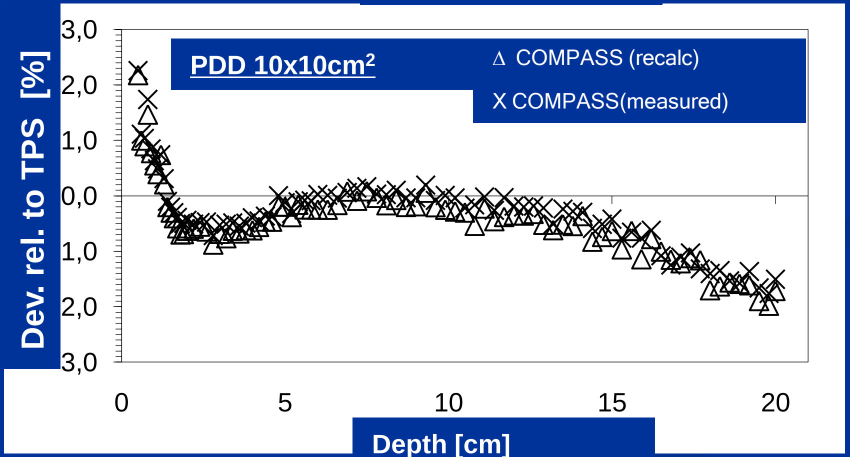
All measurements have been carried out using the ion chamber array MatriXX (IBA-Dosimetry) , using a gantry holder.

# Results

It could be shown that results both for COMPASS recalculated plans as well for COMPASS measurement based recon-struction yielded good agreement with base data for output factors, lateral profiles and depth dose curves.

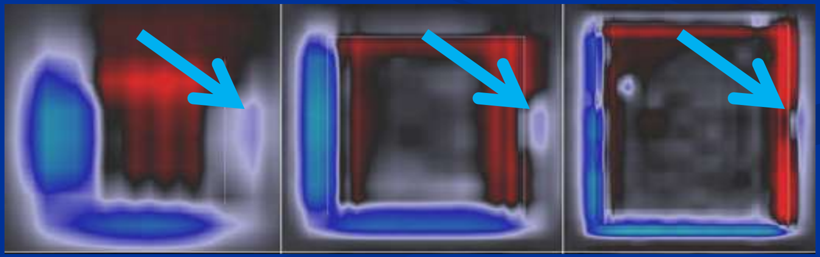



Intentionally applied modifications to the plans have shown that leaf displacements down to ±1mm could be identified unambigously.

A change in photon energy and collimator position could be detected for field sizes > 10x10cm² .

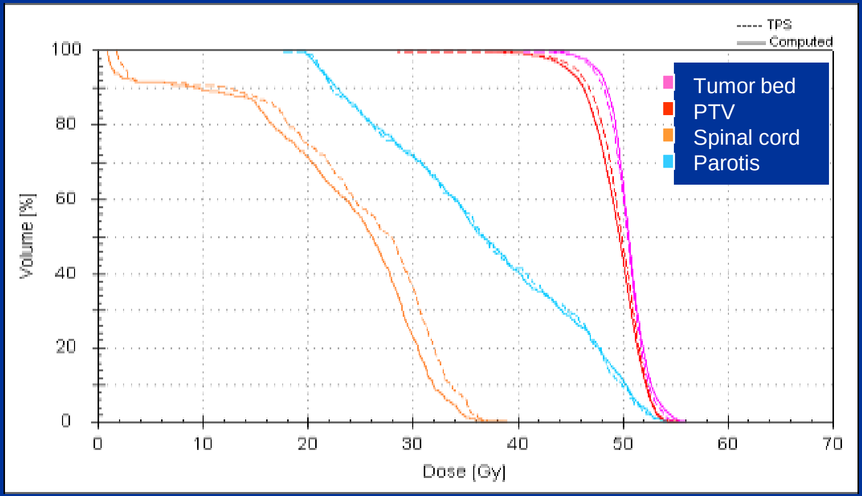


Leaf displacements for2x2cm², 5x5cm² und 10x10cm² fields. The arrows indicate the first appearance of the manipulated leaf

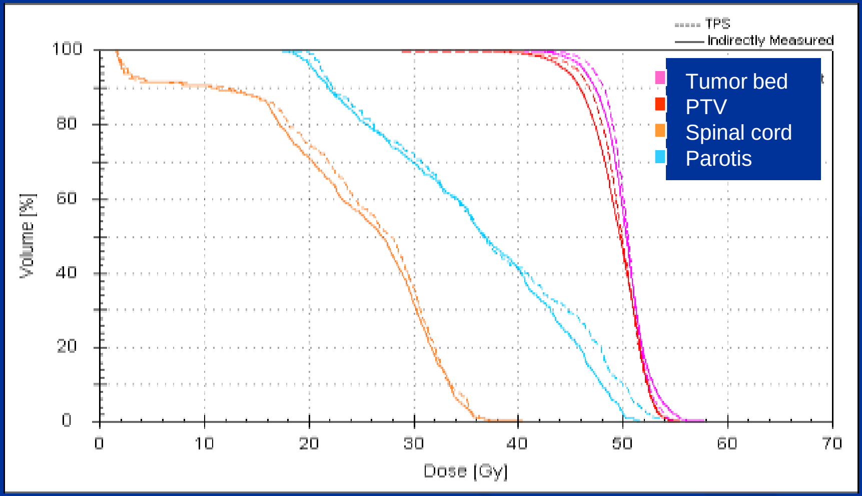
# Results

The comparison between COMPASS recalculated and measured dose distributions for target and OAR volumes for 6 MV head-and-neck plans shows good agreement with the TPS distributions, both for average doses and DVH slopes. Discrepancies were noticeable at transition areas to air cavities and are caused by different dose computation algorithms (KonRad=Pencil-Beam, COMPASS=Convolution-Superposition)

**COMPASS-recalculation vs. KonRad**




**COMPASS-measurement vs. KonRad**




Average dose [Gy]

| ROI | KonRad | COMPASS recalculated | Rel. Diff [%] | Abs. Diff [Gy] |
|---|---|---|---|---|
| Tumor bed | 50.35 | 50.60 | -0.50 | -0.25 |
| PTV | 49.62 | 49.36 | 0.54 | 0.27 |
| Parotis | 44.85 | 44.80 | 0.10 | 0.05 |
| Spinal cord | 24.71 | 23.25 | 6.31 | 1.47 |

Average dose [Gy]

| ROI | KonRad | COMPASS measurement | Rel. Diff [%] | Abs. Diff [Gy] |
|---|---|---|---|---|
| Tumor bed | 50.35 | 50.24 | 0.21 | 0.11 |
| PTV | 49.62 | 49.18 | 0.65 | 0.32 |
| Parotis | 44.85 | 45.54 | -1.52 | -0.69 |
| Spinal cord | 24.71 | 24.09 | 2.61 | 0.63 |

# Summary

The dosimetric validation of COMPASS shows good agreement to the base data

Leaf displacements in the dose difference plot can be identified unambiguously from ±1mm on

Comparison with IMRT-plans shows good agreement for both average target doses and DVH slopes

Time spent for plan QA (hybrid plan generation with KonRad, recalculation, measurement, evaluation) can be reduced from 3:30 h to about 1 h using COMPASS