# COMPASS

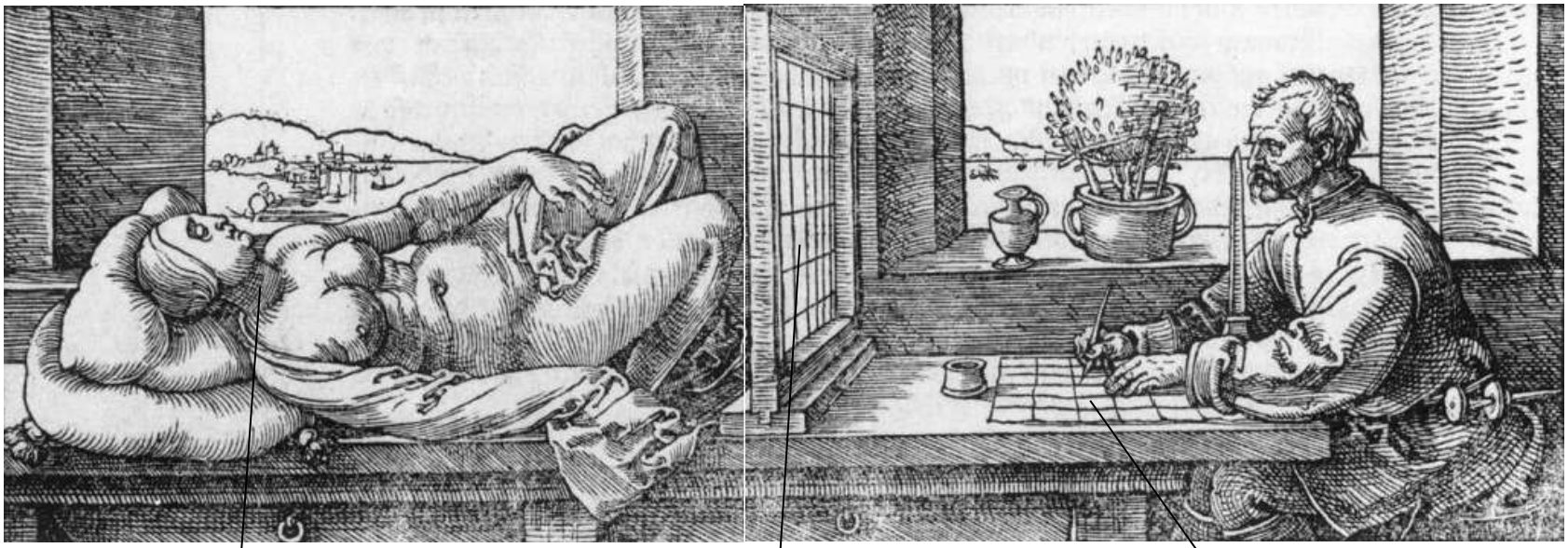
## *Ist die zweidimensionale Qualitätssichering der IMRT ausreichend ?*

***Hamburg, Feb 2011***

**Dr. Lutz Müller**

**COMPASS clinical collaborations & Application**

# Albrecht Dürer, wood engrave



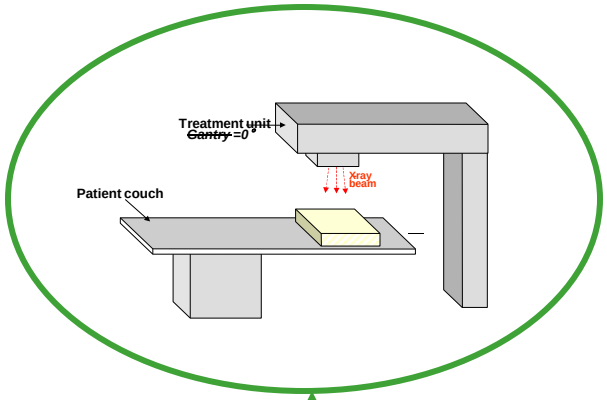
3D Anatomy

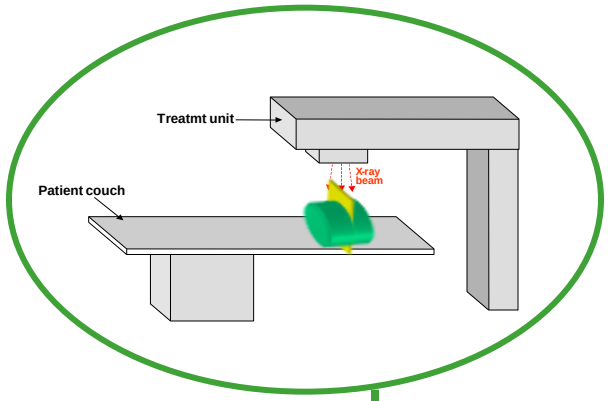
Beamlets

2D plot

# Patient-specific Verification ?

CT




TPS

3D Dose

Fields

3D Dose In Patient

3D Dose In Phant

disturbed Fields

**Resulting 3D Dose In Patient**

Targ. Vol/Dose/constraints

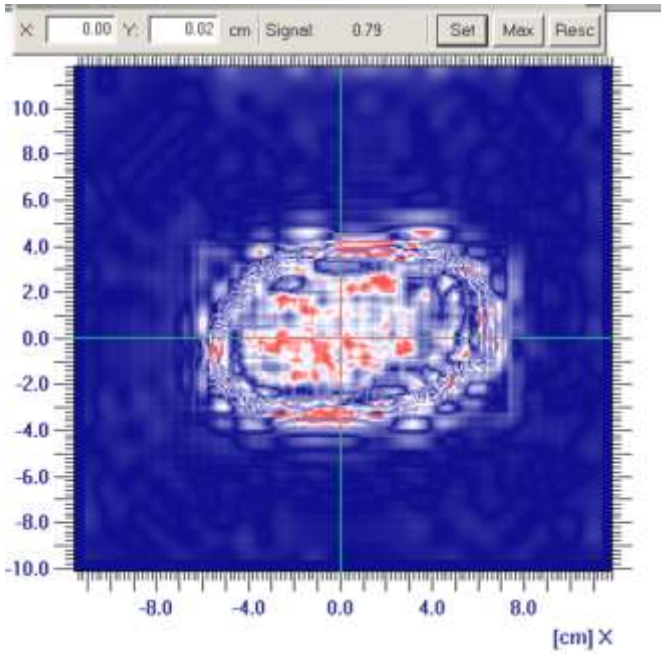
# Commissioning & Validating COMPASS in a Clinical Environment

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

# POLL QUESTION

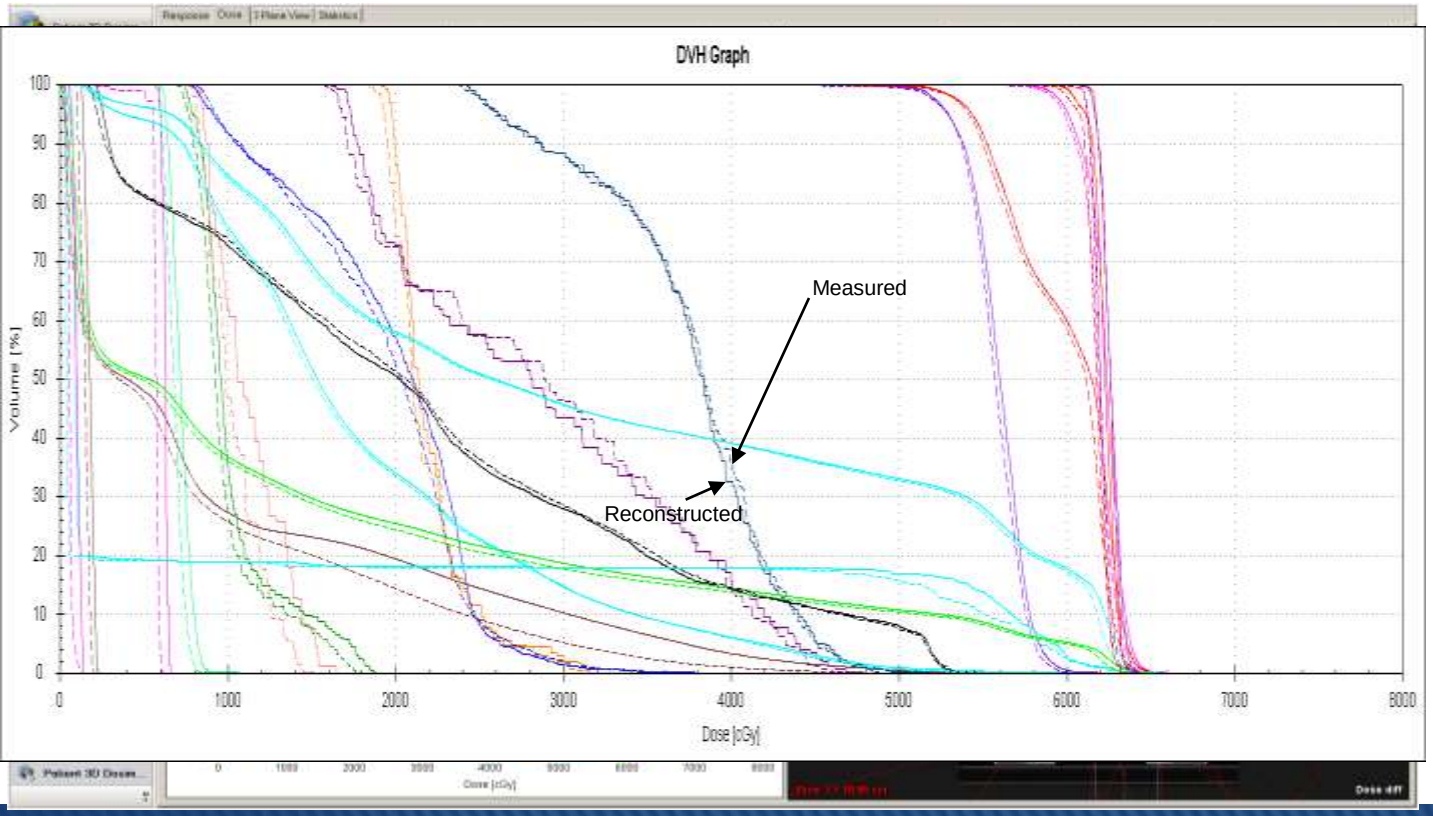
- Raise your hand if your physician would understand this?

95% of Pixels with
Gamma < 1.0



# POLL QUESTION

- What about this?  Or this?



# Is 2D QA really *clinically* relevant ?

**Per-beam, planar IMRT QA passing rates do not predict clinically relevant patient dose errors**[a)]


Benjamin E. Nelms[b)]
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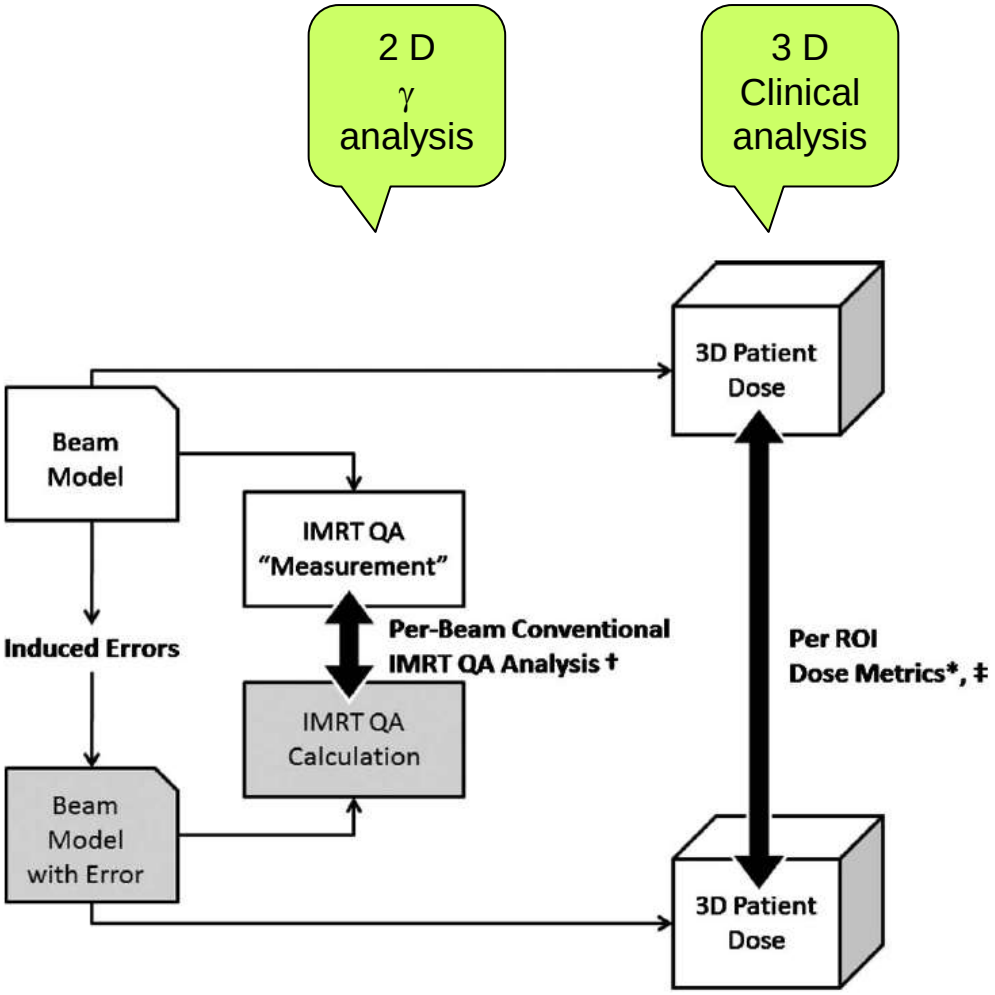
# Methodology




† Using full density (film equivalent) planes and high resolution (1 mm x 1 mm) pixels
* Max dose and D1cc (cord), mean dose (parotids, larynx), and D95 (CTV60)
‡ Comparison metrics were generated blind

Clinical Parameters:

Max dose
Dose to 1cc sp. Cord
Mean dose
Dose to 95%

# Requirement for QA Procedure

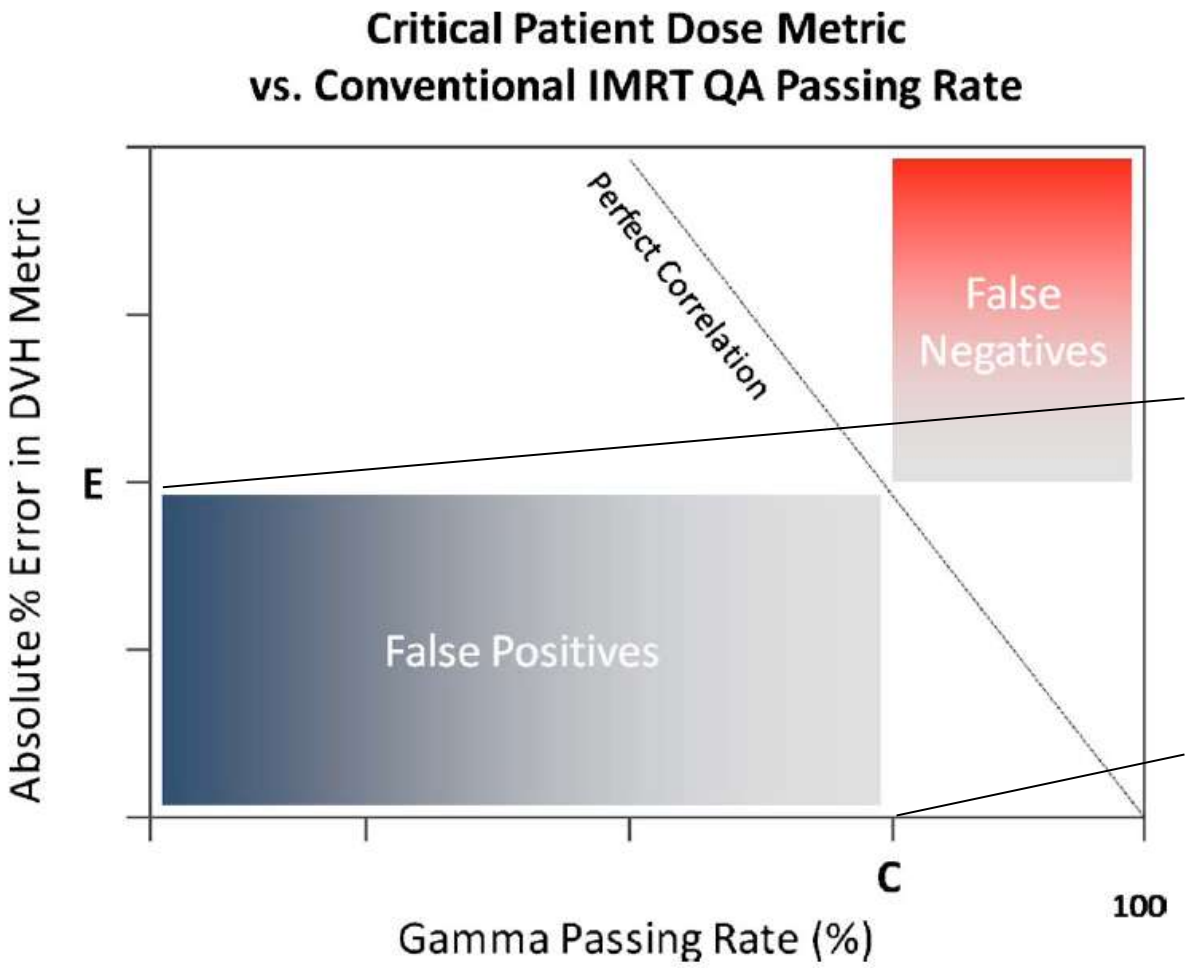
In presence of clinically relevant errors, the QA procedure should result in ‚fail‘

This means to avoid 2 Situations:

QA procedure results in ‚pass‘ but error is present (false negative)

QA procedure results in ‚fail‘ but error is not present (false positive)

# Correlation between 2D and clinical analysis




e.g. Max tollerable dose to 1cc of spinal cord

e.g. 95% min pass rate for 3%/3mm

# Types of errors

## Modified Beam Models (‚wrong comissioning‘)

Low MLC Transmission Beam Model LTBM 1.94% -> 0.97%

High MLC Transmission Beam Model HTBM 1.94% -> 3.88%

Shallow Penumbra MLC Transmission Beam Model SPBM

4.5mm (Dmax) ->7.2 mm

Very Shallow Penumbra MLC Transmission Beam Model VSPBM

4.5mm (Dmax) ->9.2 mm

# Effect of simulated errors (dashed curves)

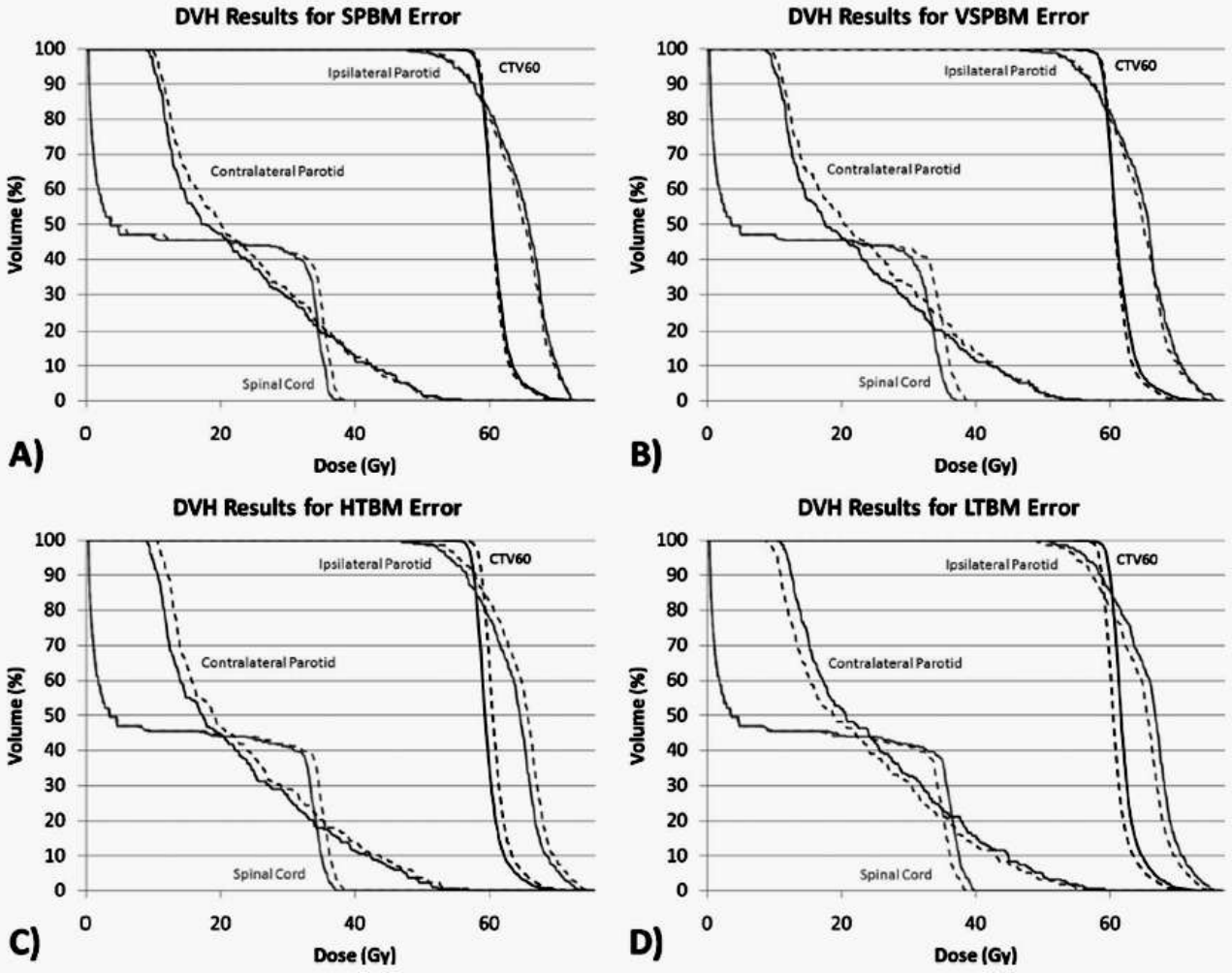



FIG. 2. Sample DVH differences between the induced-error beam models (dashed lines) and the virtual measurement beam models (solid lines). These are the results for patient plan no. 22 (of 24).

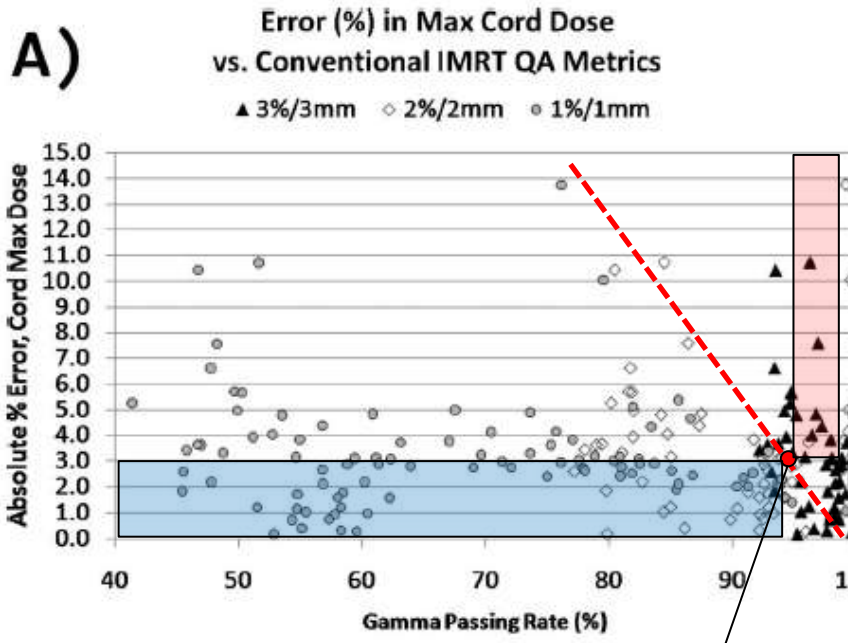
Broad penumbra:

*lower dose to Target, higher dose to OARs*

High MLC transmission:
*higher overall dose*

Low MLC transmission:
*Lower overall dose*

# Conventional vs. ROI oriented 3D QA



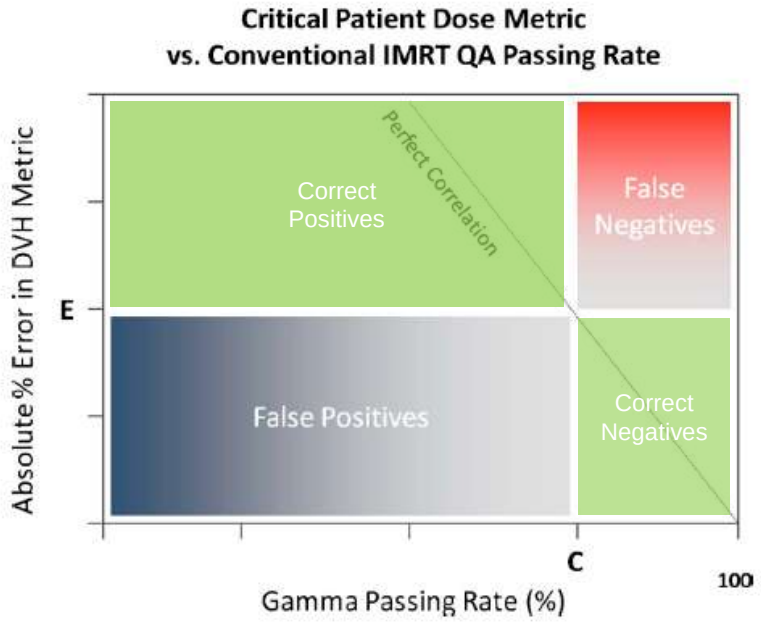



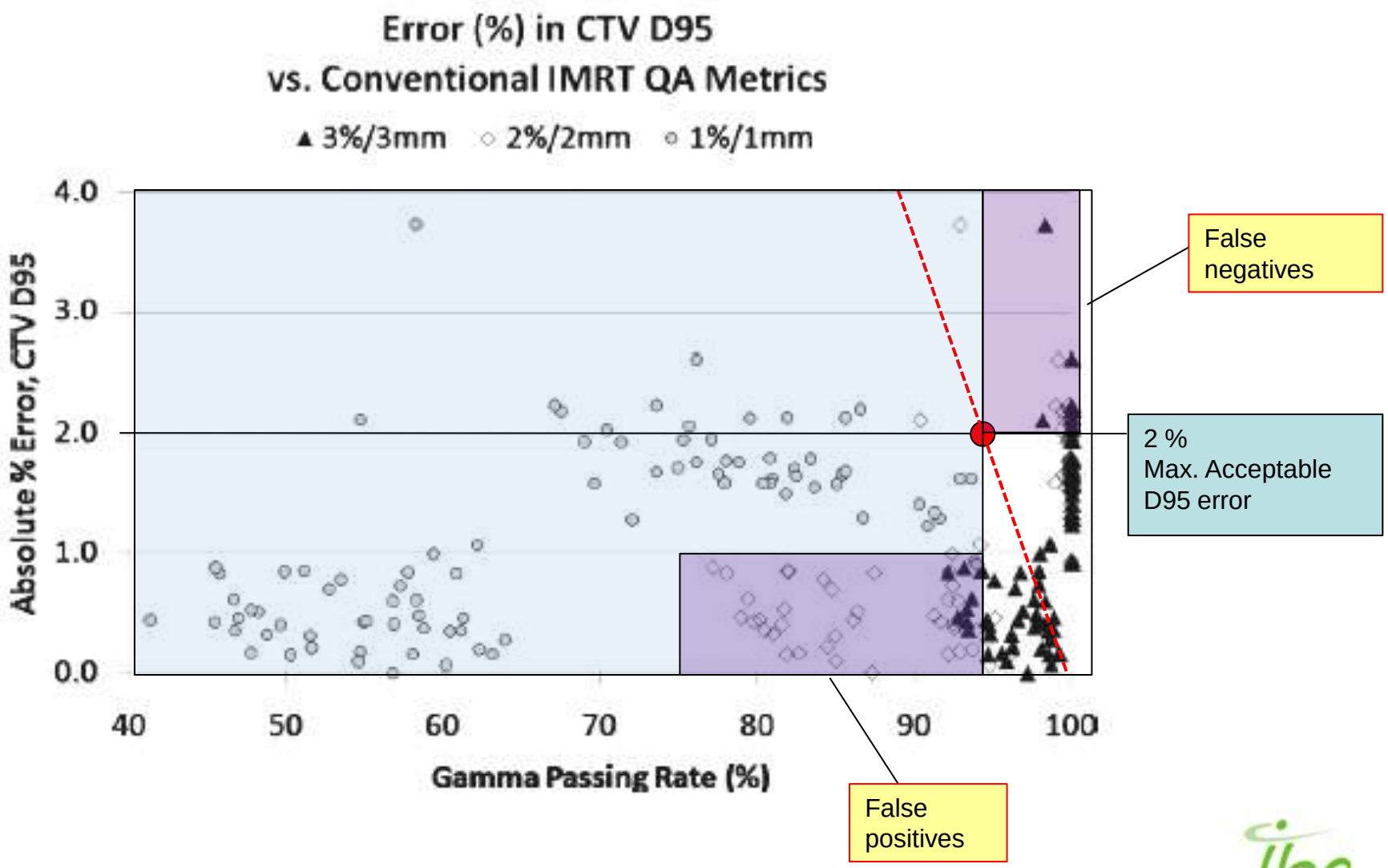

FIG. 8. Generalized illustration of regions of false negatives (high passing rates despite critical patient dose errors) and false positives (low QA passing rates but with noncritical patient dose errors) when correlating critical patient dose errors to conventional IMRT QA Gamma passing rates. In this schematic, the critical dose error threshold is "E" and the standard acceptance criteria for Gamma passing rates is "C."

Assumption:
Acceptance > 95% $\gamma$ pass

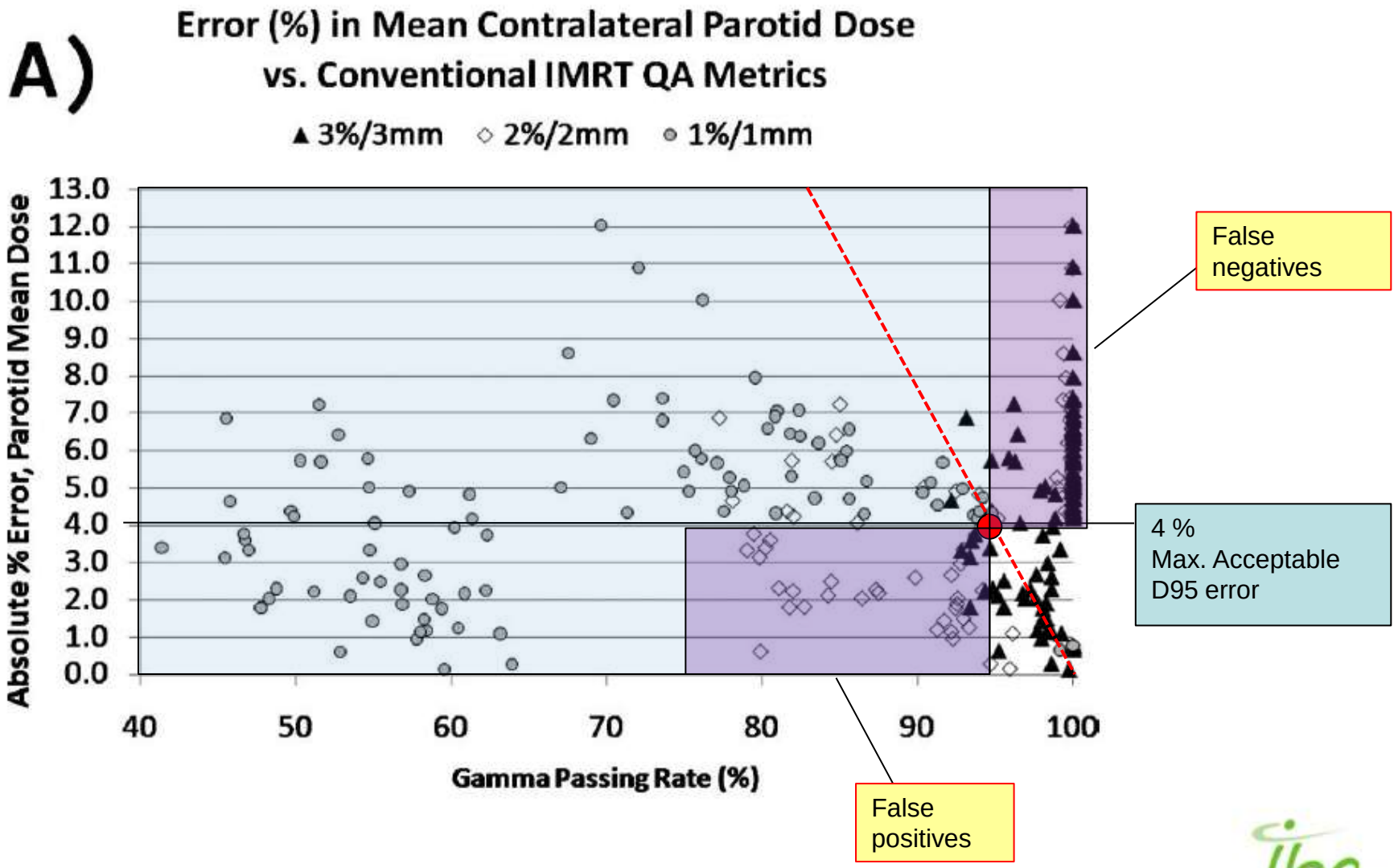
For 3%/3mm

Many **FALSE NEGATIVES**
Some **FALSE POSITIVES**

# 95% Volume Dose to Target



# Mean Contralateral parotid Dose



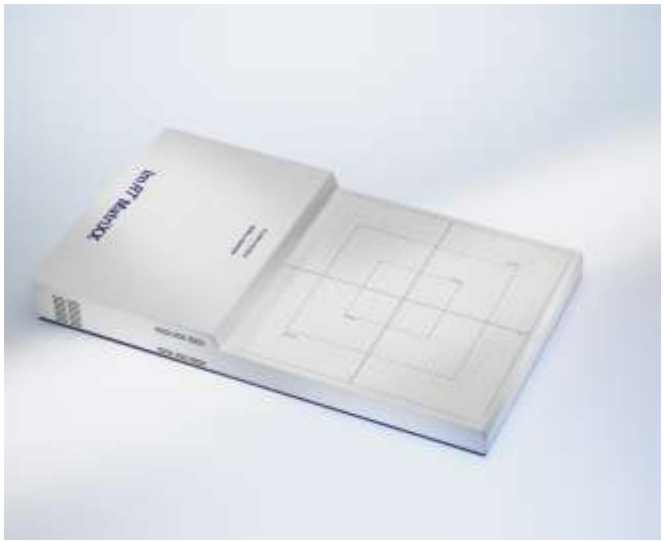
# Error Range and Conclusion

| Anatomy dose metric | | Observed errors[a] (%) in DVH dose metrics for plans exceeding ≥95% passing rate[b] (3/3 and 2/2 criteria) and exceeding ≥90% passing rate[b] (1/1 criteria) | | |
|---|---|---|---|---|
| | | 3%/3 mm ($N$=83) | 2%/2 mm ($N$=51) | 1%/1 mm ($N$=12) |
| Spinal cord | Range of % Errors | [−11.1, 15.7] | [−11.1, 15.7] | [−2.7, 3.3] |
| $D1cc$ | Mean absolute error[c] (%) | 3.222 | 3.367 | 2.309 |
| Contralateral | Range of % errors | [−10.9, 12.0] | [−10.9, 12.0] | [−5.1, 5.7] |
| Parotid mean | Mean absolute error[c] (%) | 4.50 | 5.52 | 4.04 |
| Ipsilateral | Range of % errors | [−3.7, 4.1] | [−3.7, 4.1] | [−1.4, 1.7] |
| Parotid mean | Mean absolute error[c] (%) | 1.49 | 2.06 | 1.45 |
| Larynx mean | Range of % errors | [−15.9, 9.2] | [−7.6, 9.2] | [−3.2, 3.7] |
| | Mean absolute error[c] (%) | 5.66 | 5.32 | 2.50 |
| CTV $D95$ | Range of % errors | [−3.7, 2.6] | [−2.2, 2.6] | [−1.6, 1.6] |
| | Mean absolute error[c] (%) | 1.26 | 1.66 | 1.30 |

## V. CONCLUSIONS

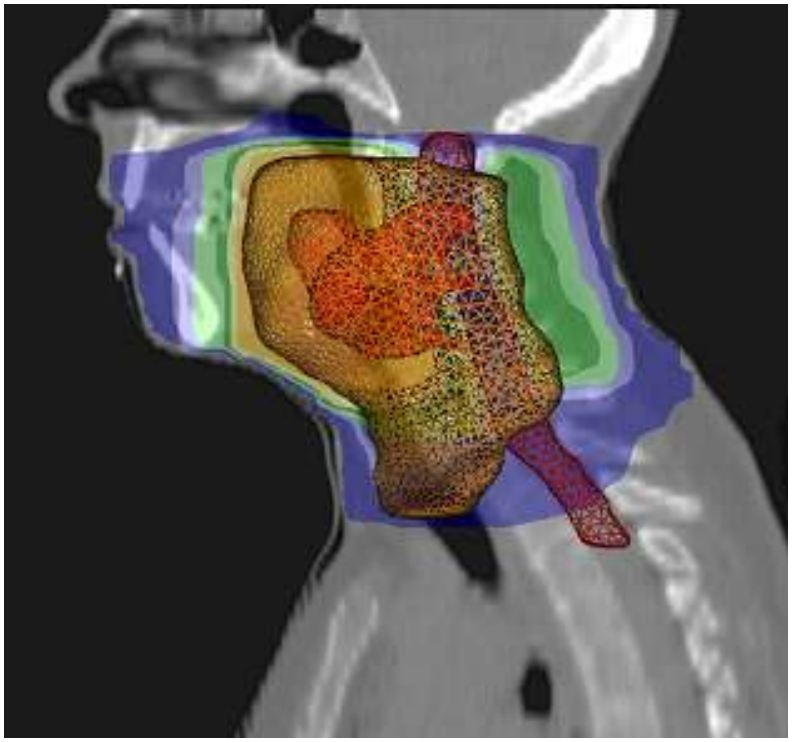
There is a lack of correlation between conventional IMRT QA performance metrics (Gamma passing rates) and dose differences in critical anatomic regions-of-interest. The most common acceptance criteria and published actions levels therefore have insufficient, or at least unproven, predictive power for per-patient IMRT QA. Moreover, the methodology of basing action levels on prior performance achievements using these conventional methods is unwarranted because meeting these criteria does not ensure that clinically acceptable dose errors.

# Generations of electronic IMRT Dosimetry



1st

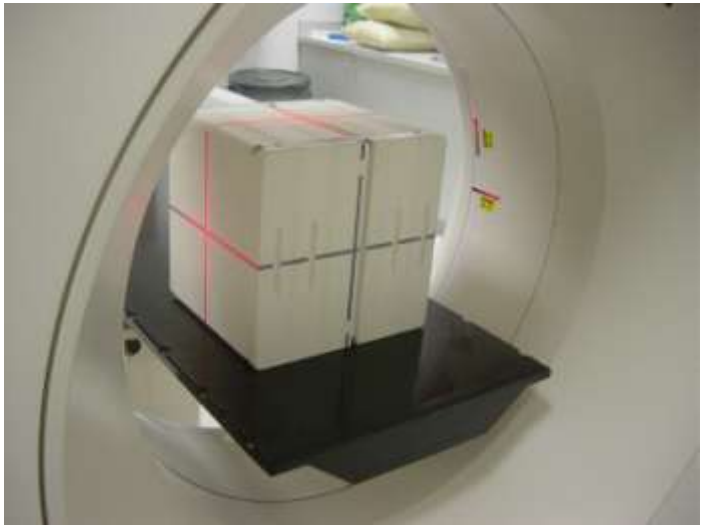
Single fields, perpendicular



2nd

Homo-geneous phantom,

composite



3rd

COMPASS

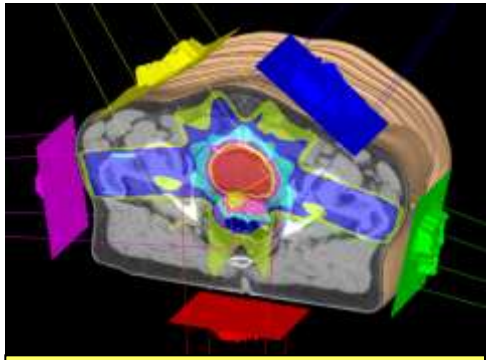
# What is COMPASS ?

**Detector**

+

**Beam model**

+



**Dose engine**

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



iba Dosimetry

# Detectors for COMPASS

Gravity-based Angle Sensor to be mounted on gantry

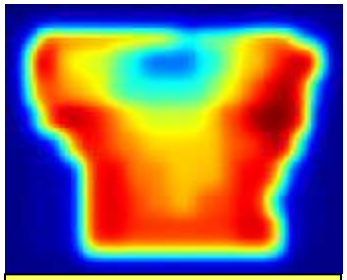
MatriXX Detector @ Gantry Mount (SSD 762 or 1000 mm)

# Compass: from Entrance Fluence to 3D Patient Dose

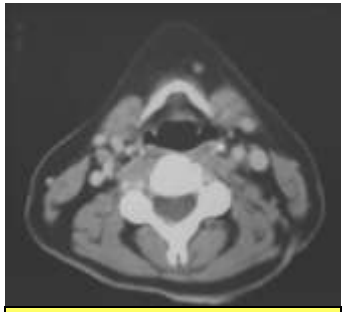
DICOM plan

Beam model

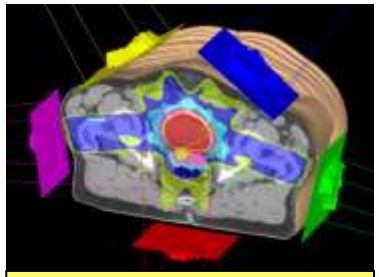
Transmission Detector



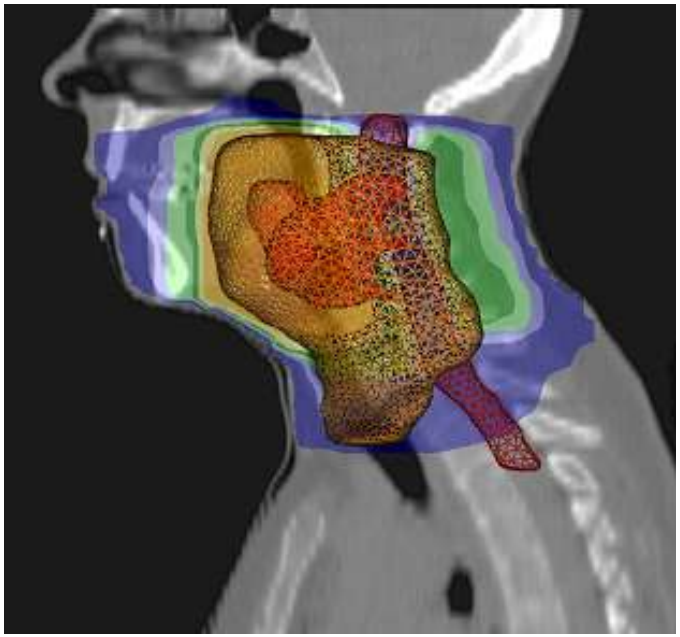
Real Fluence

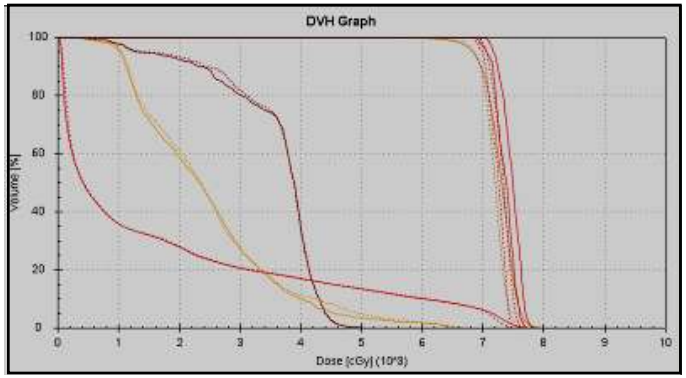


CT



Dose engine

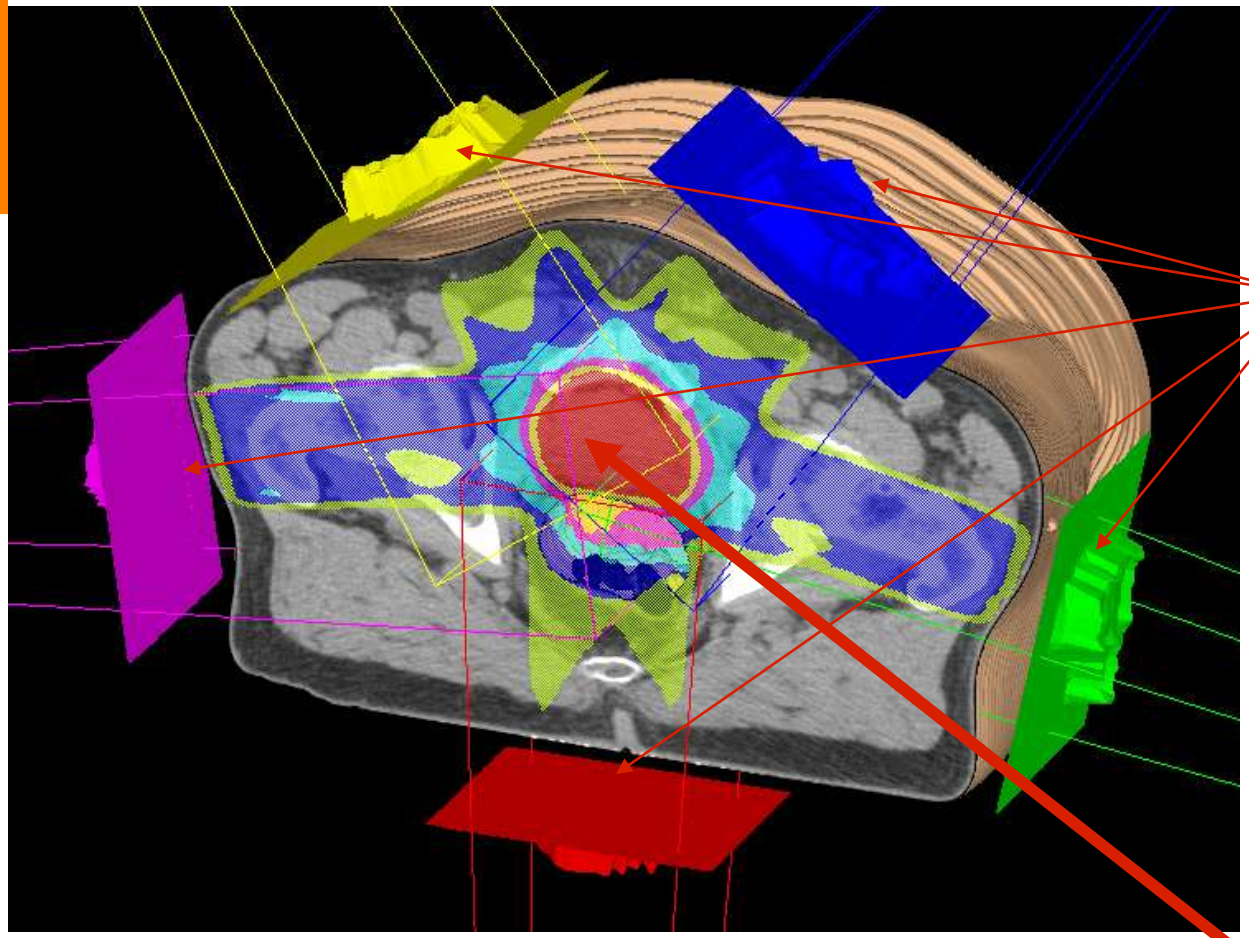







iba Dosimetry

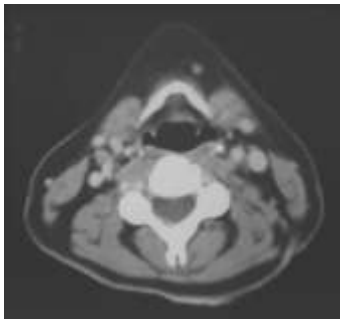
# Dose engine (Collapsed Cone Superposition)



## A Dose Engine...

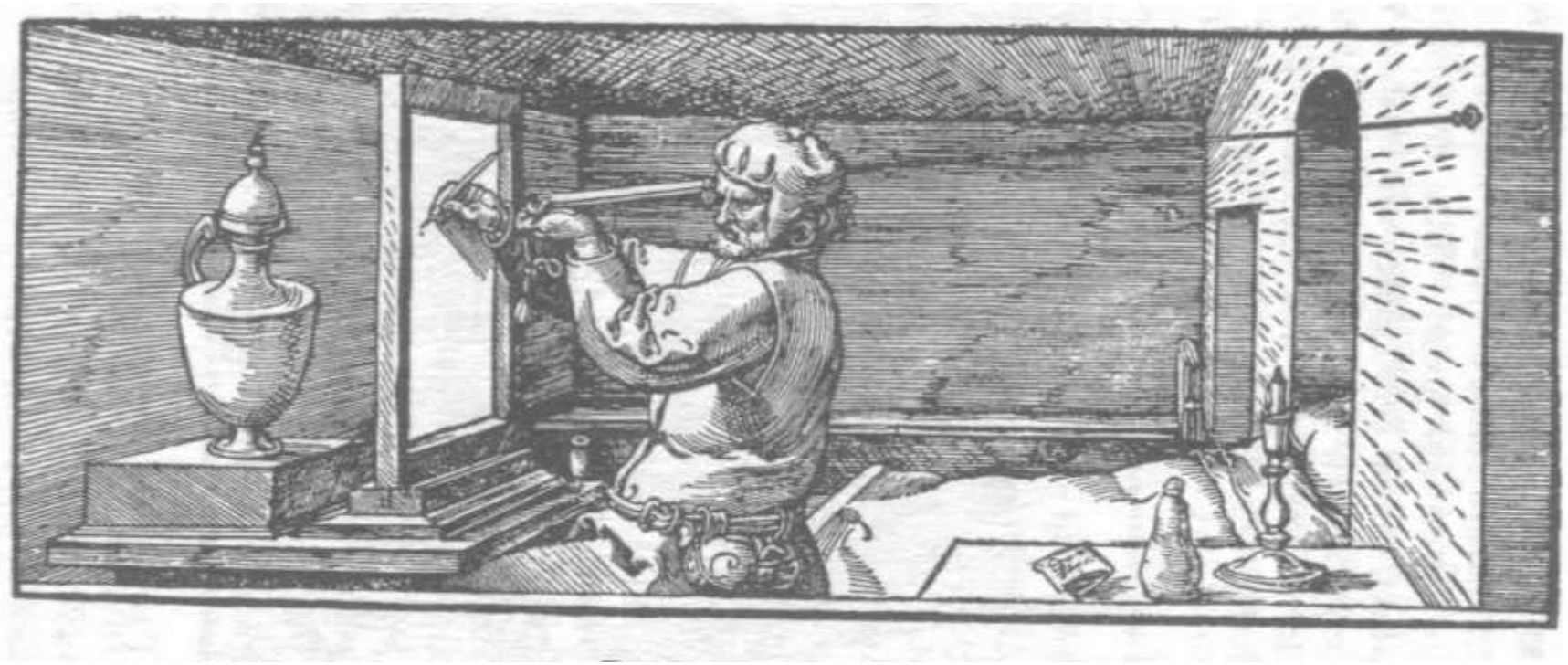
**Takes the incoming fluences**

**Takes the CT**



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

# Dürer again.Ray Tracing...



...Is not used on COMPASS, but full dose computation using approved Collapsed Cone algorithm

# DIN 6875 /3 (Germany)

- **In case no dosimetric verification of the treatment plan is performed, at least an independent MU-calculation has to be performed for each field.**

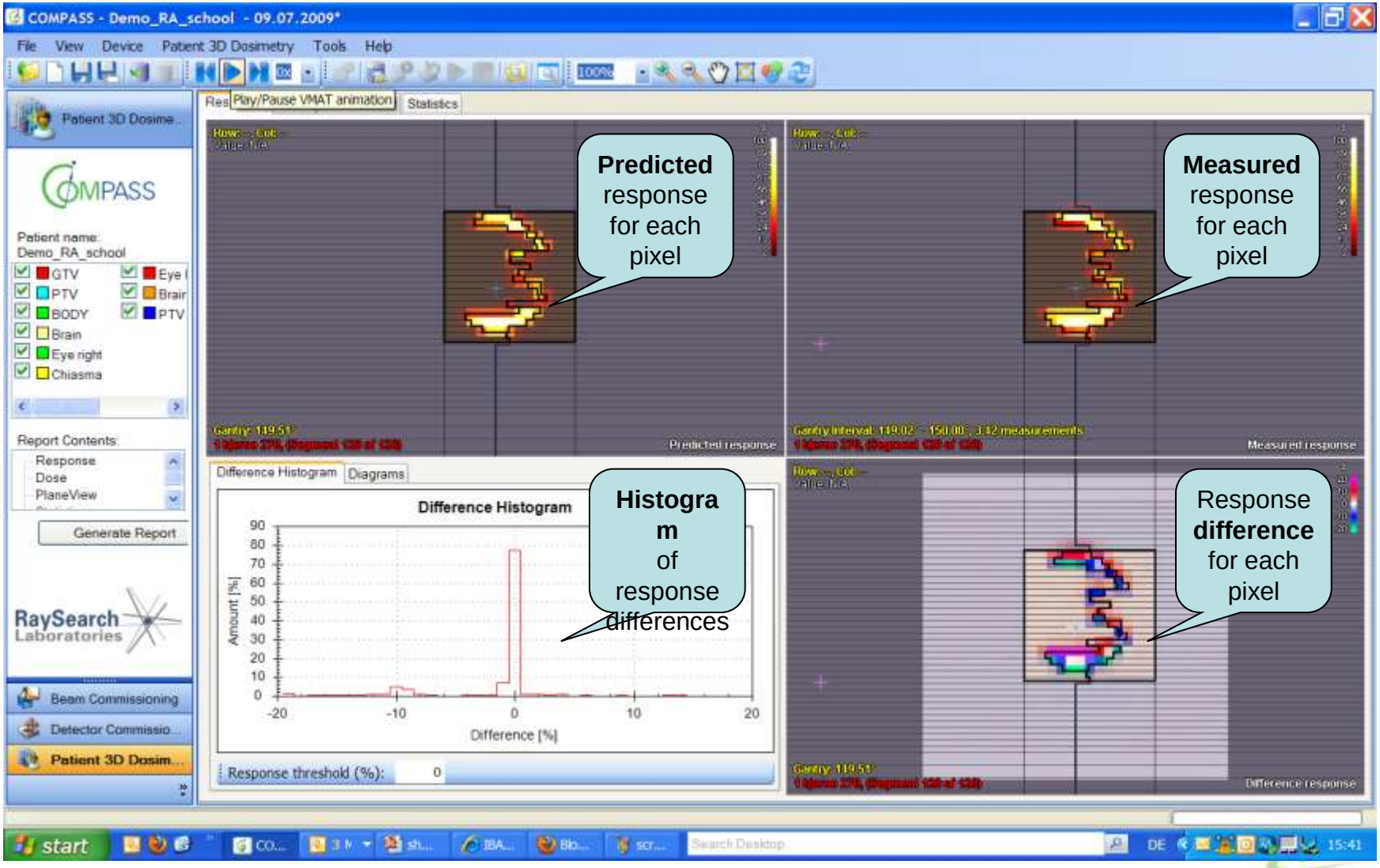
- **This can be done also using an independent, validated, sufficiently accurate 3D dose alorithm, which is independent from the original treatment planning system.**

# Auto Modelling

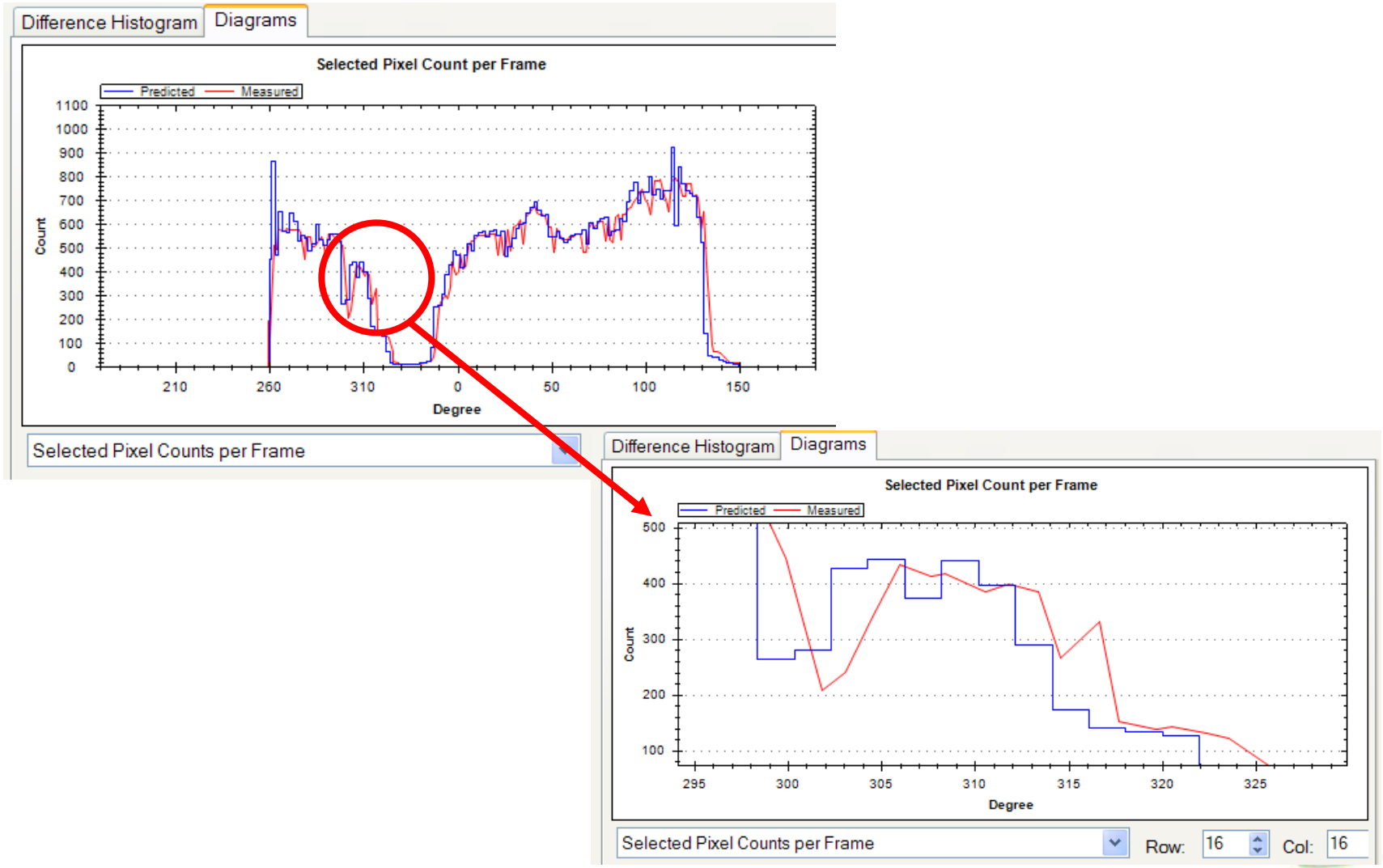
| Auto modelling function | Affected parameters | Target function |
|---|---|---|
| Electron energy spectrum | Electron spectrum parameters E and c, secondary electron source weights, direct electron source width and weight. | Depth dose curves from zero depth |
| Energy spectrum and output factor corrections | 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.

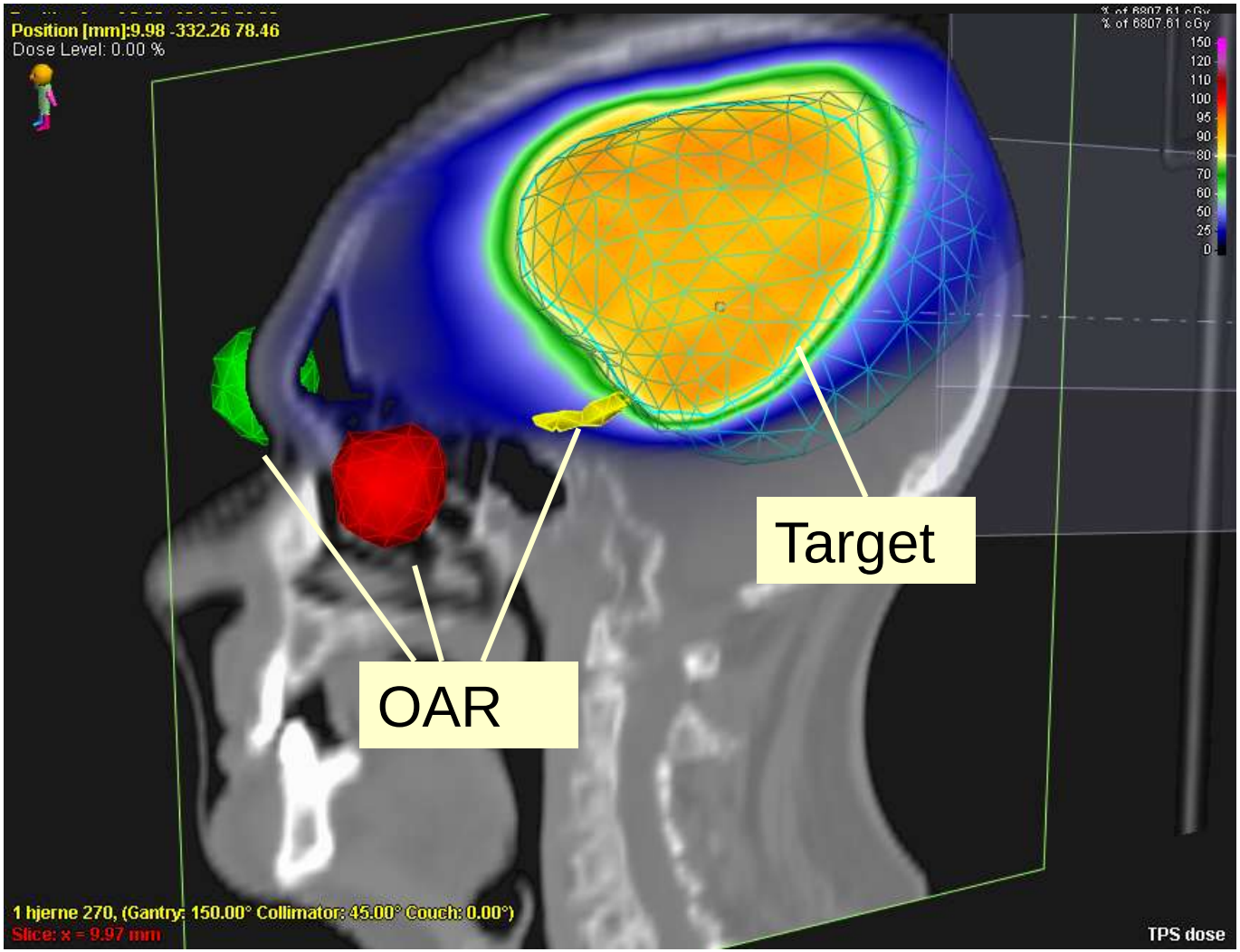
# Response –Prediction vs. Measurement



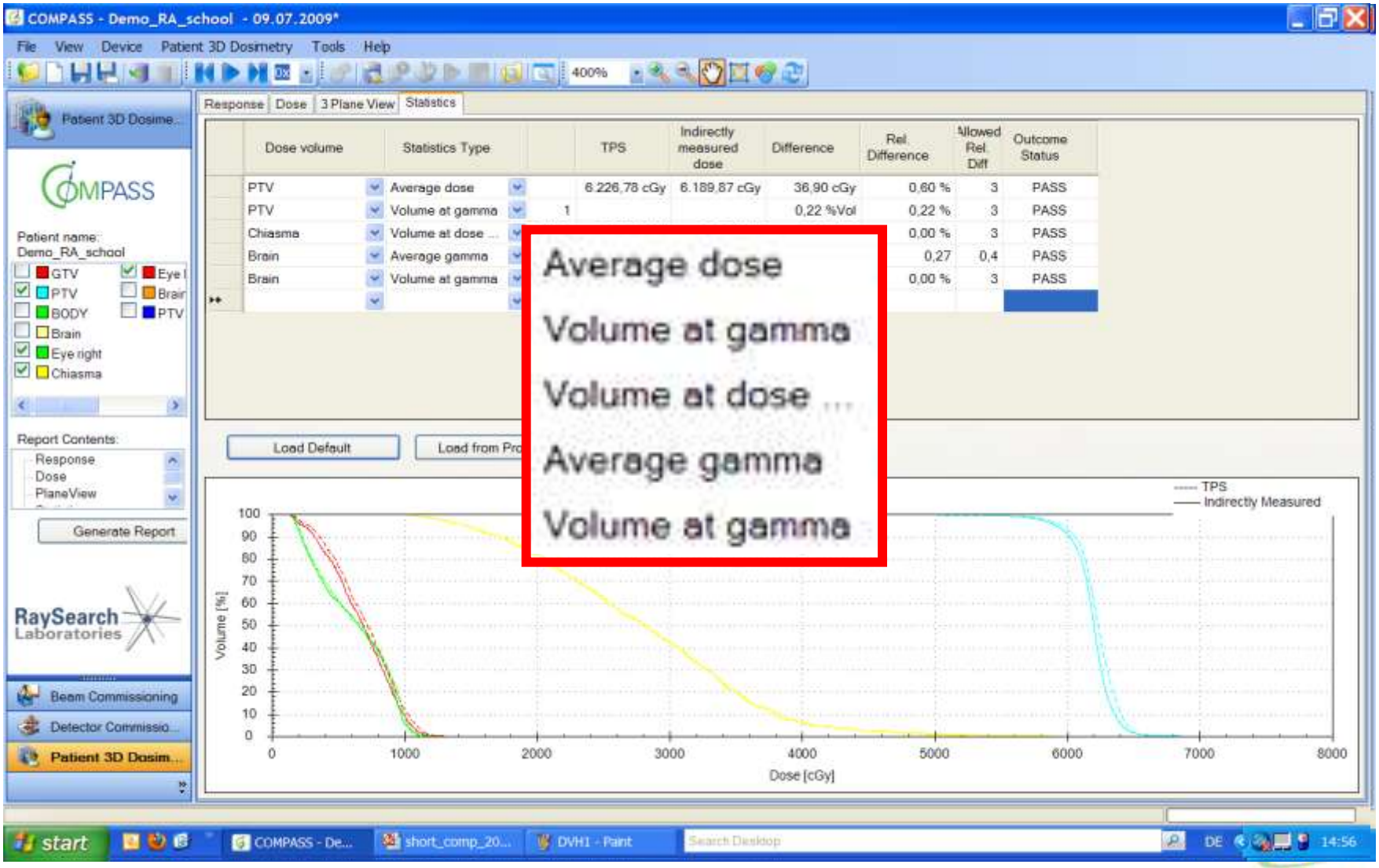
# Response/control point (Plan vs. Measurement)



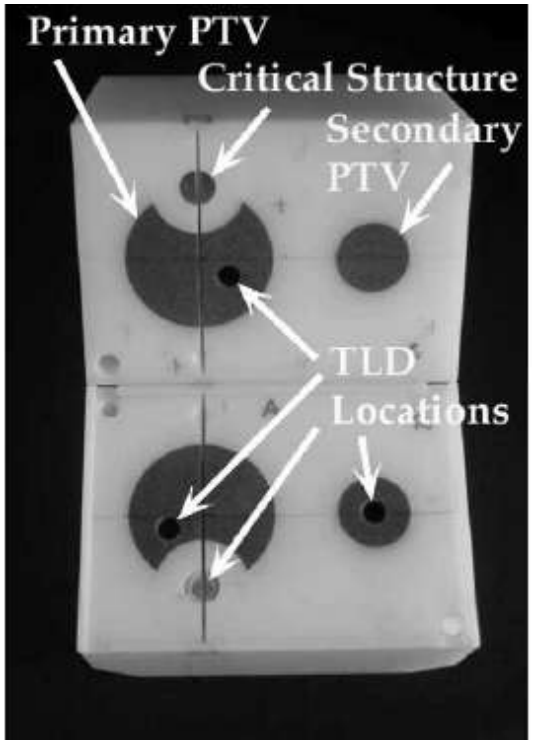
# Dose measured

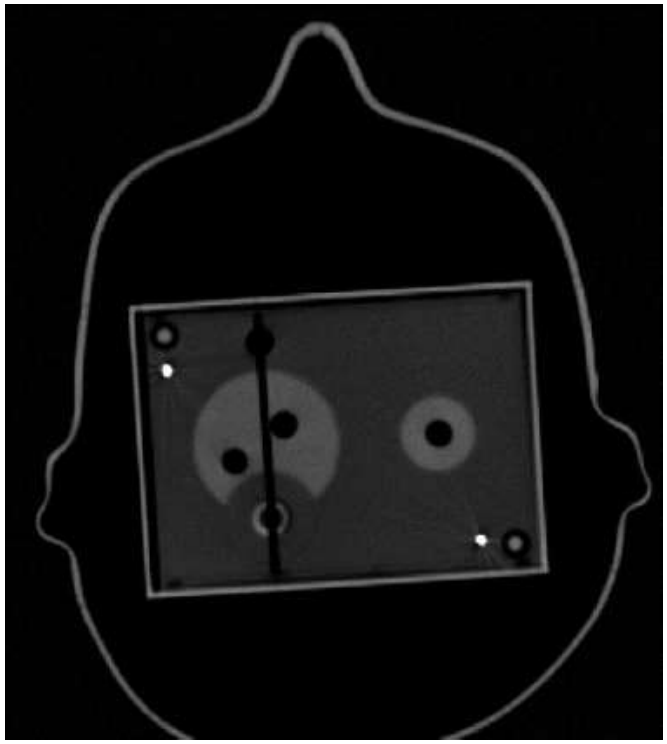


# DVH and beyond



# IMRT Quality Comparative Study



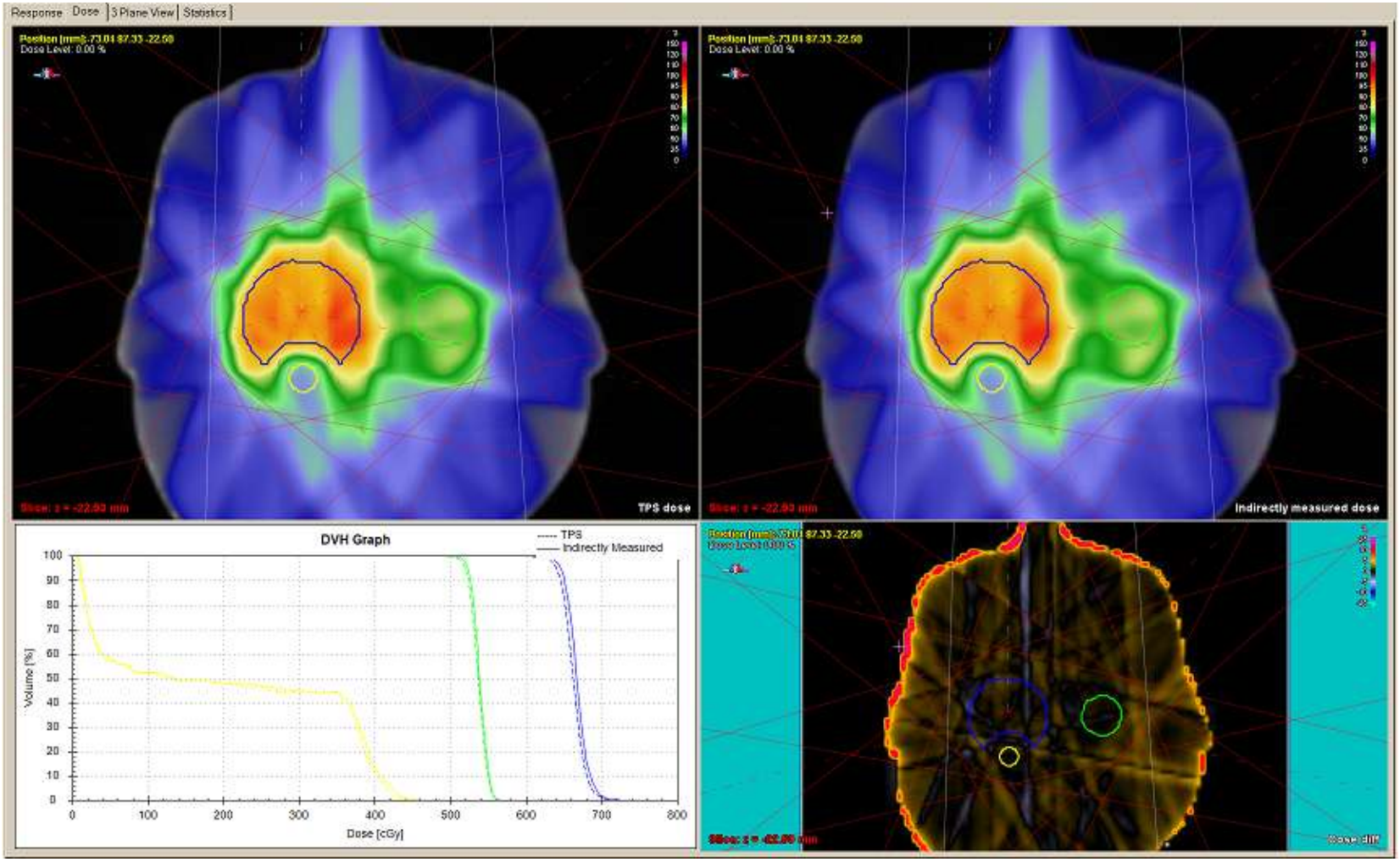
**DESIGN AND IMPLEMENTATION OF AN ANTHROPOMORPHIC QUALITY ASSURANCE PHANTOM FOR INTENSITY-MODULATED RADIATION THERAPY FOR THE RADIATION THERAPY ONCOLOGY GROUP**

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 !**

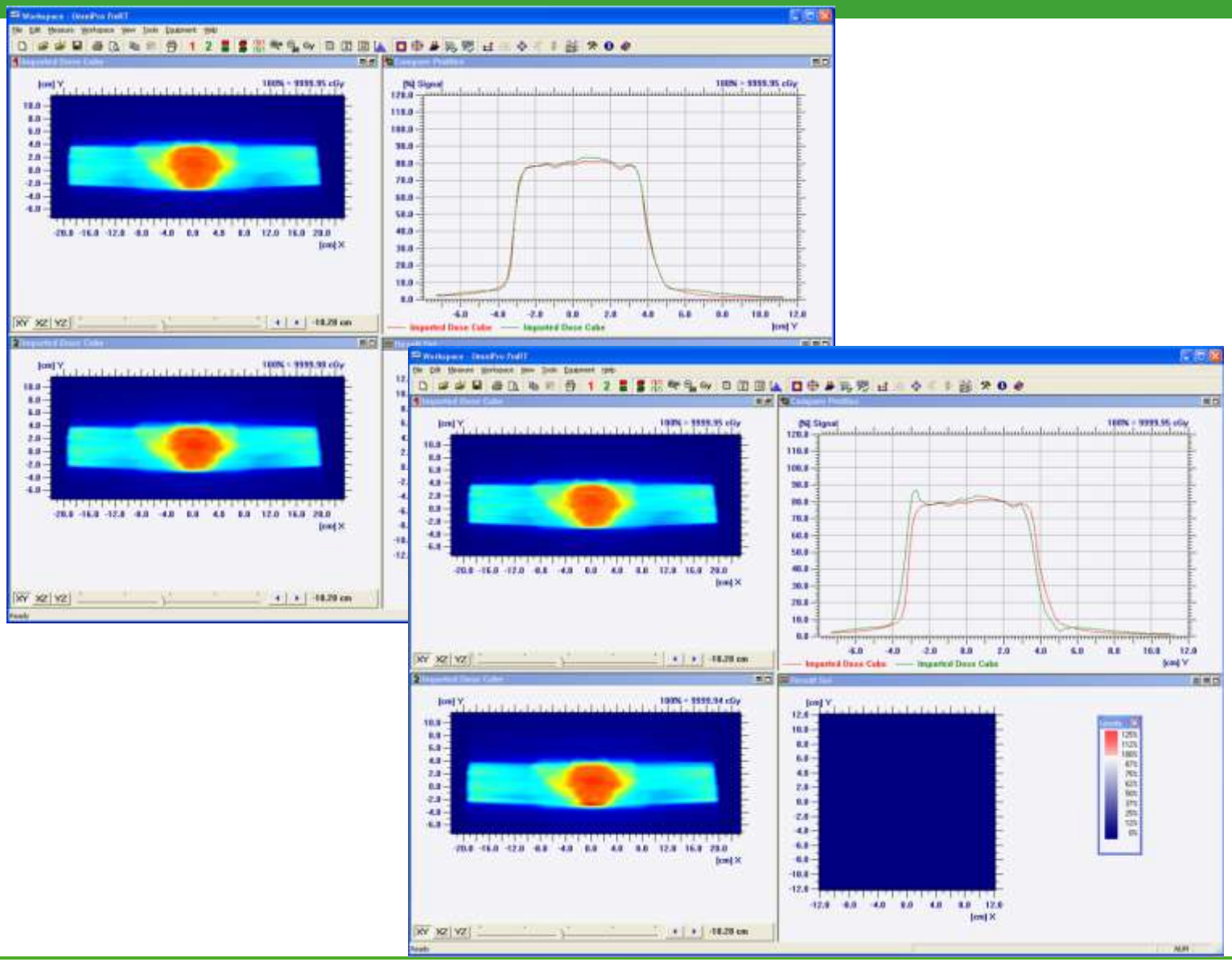
# 3rd Generation. Dose in the Patient Anatomy



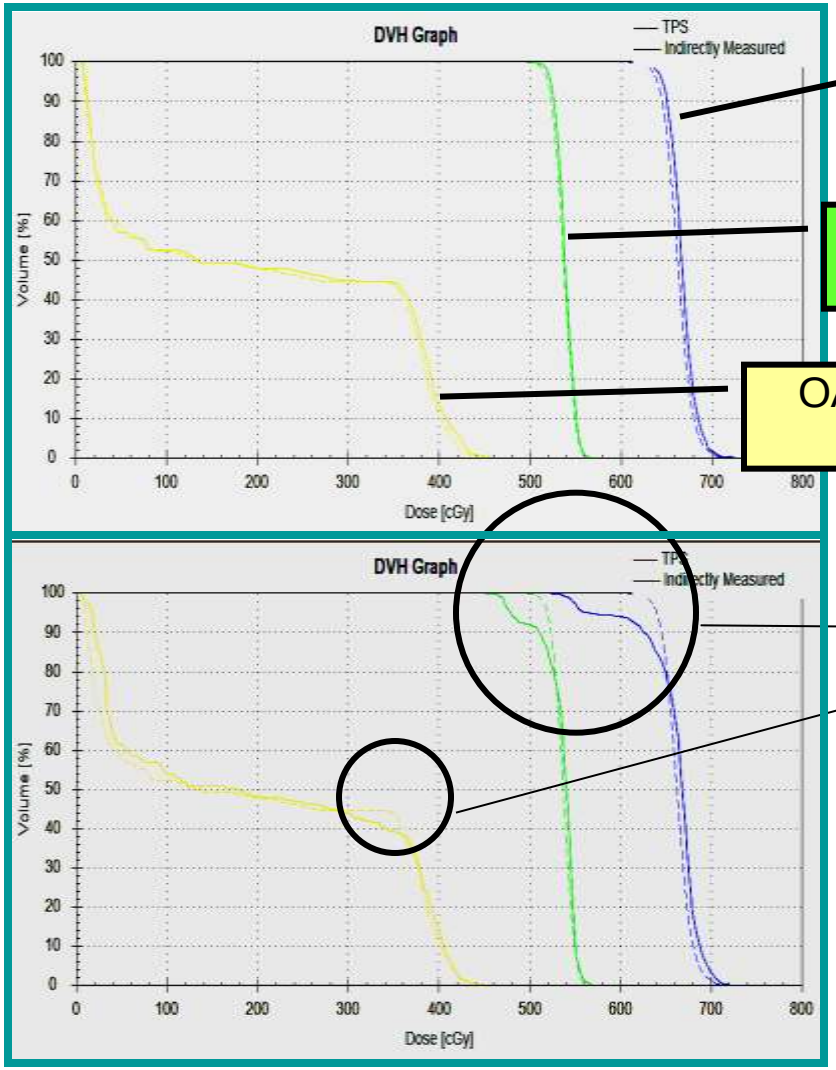



iba Dosimetry

# Delivery Error – 2mm Shift (Generation 2)



# Delivery error in RPC phantom case



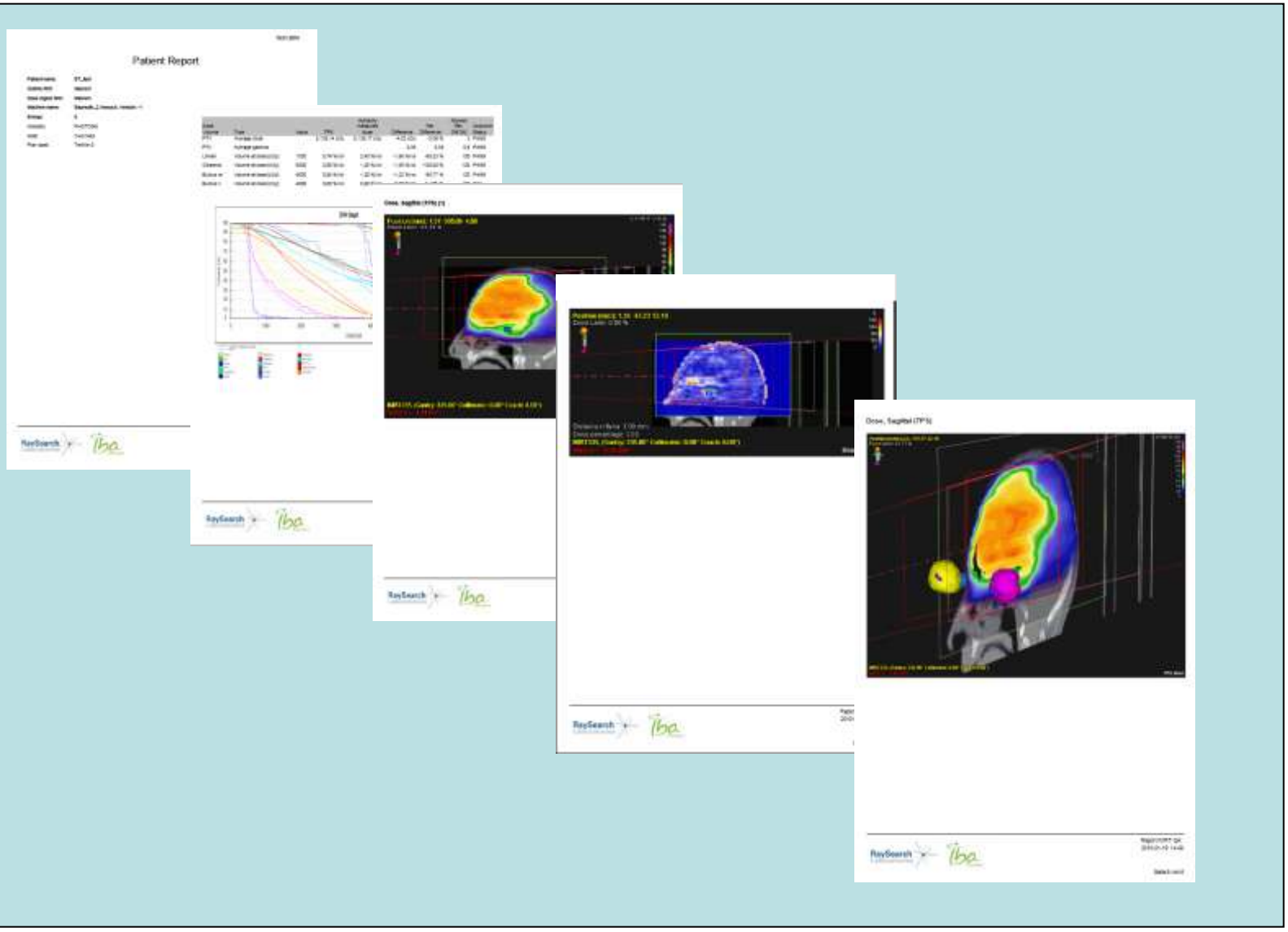

Primary PTV

Secondary PTV

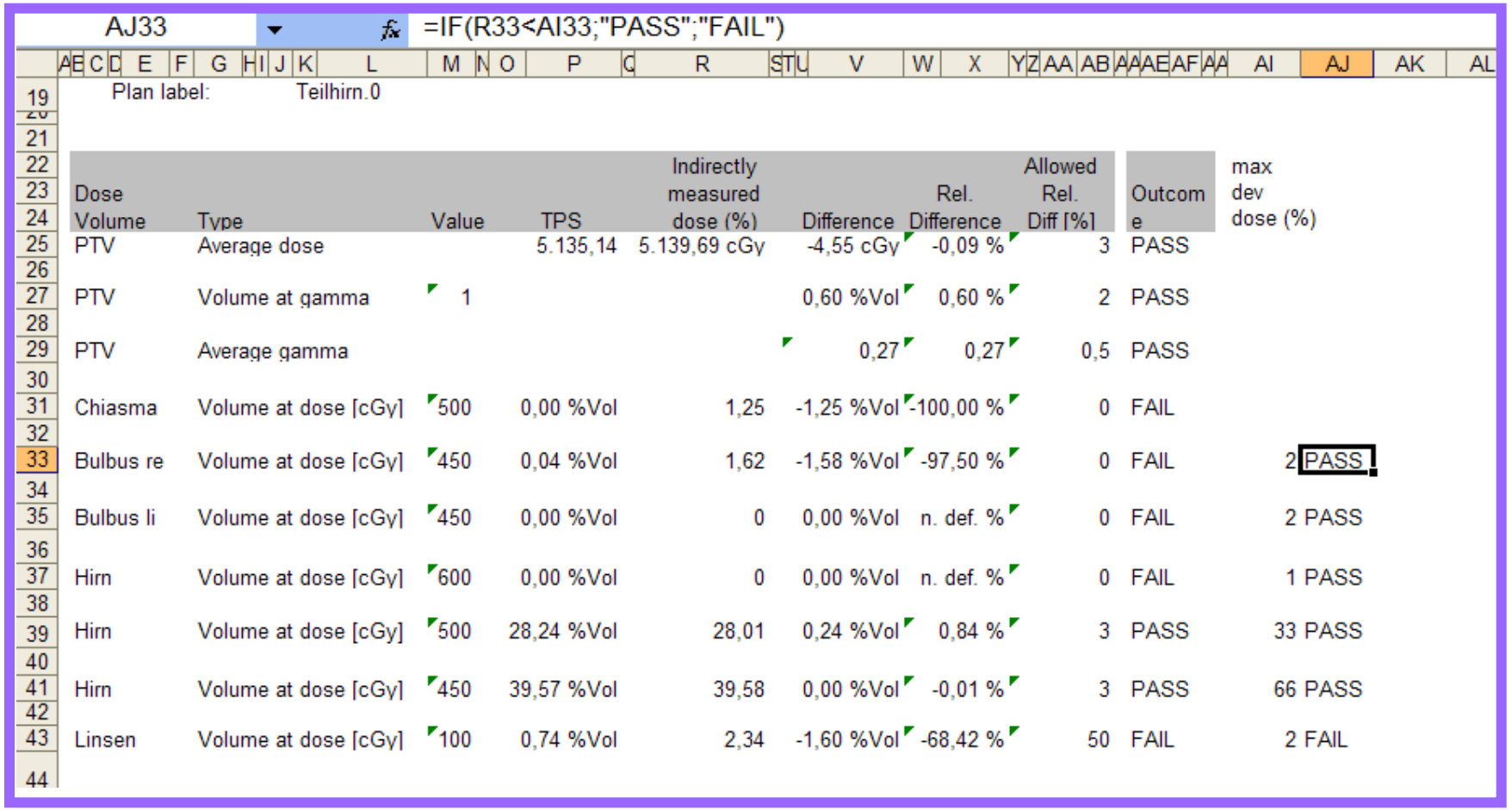
OAR: spinal cord

Effect of 2mm y-shift on DVH

# COMPASS Report



# Report Export to e.g. EXCEL

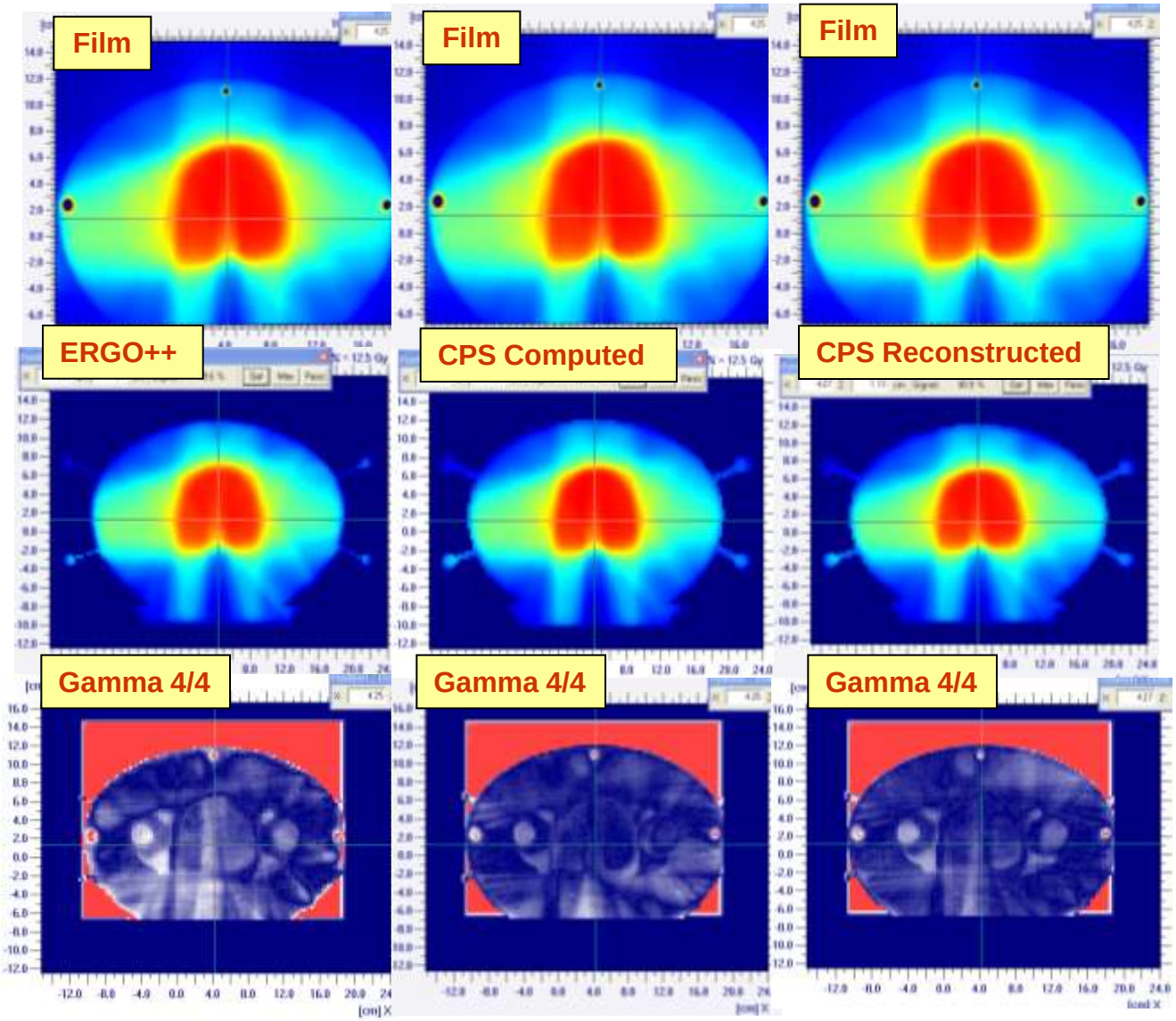


AJ33 =IF(R33<AI33;"PASS";"FAIL")

Plan label: Teilhirn.0

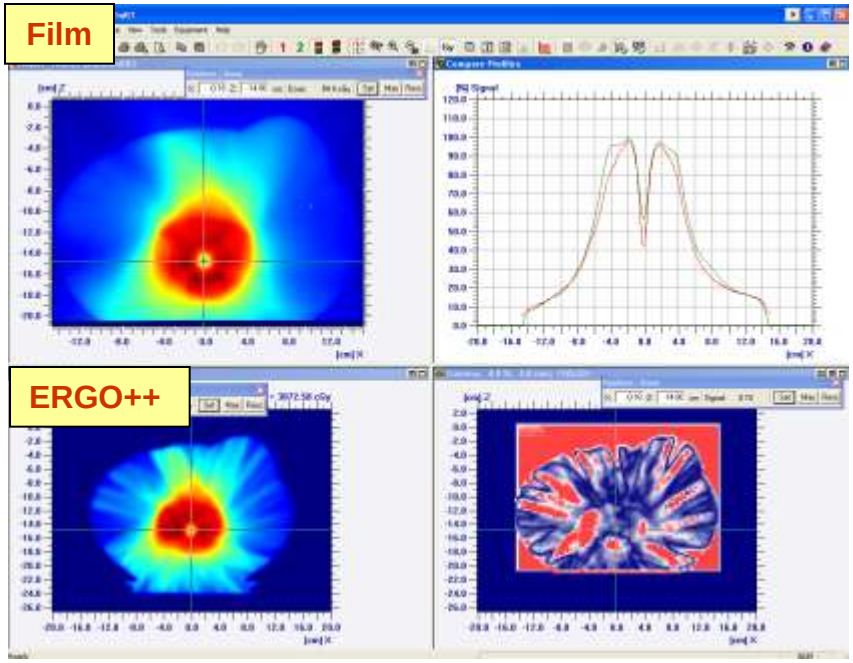
| Dose Volume | Type | Value | TPS | Indirectly measured dose (%) | Difference | Rel. Difference | Allowed Rel. Diff [%] | Outcome | max dev dose (%) | |
|---|---|---|---|---|---|---|---|---|---|---|
| PTV | Average dose | | 5.135,14 | 5.139,69 cGy | -4,55 cGy | -0,09 % | 3 | PASS | | |
| PTV | Volume 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 |

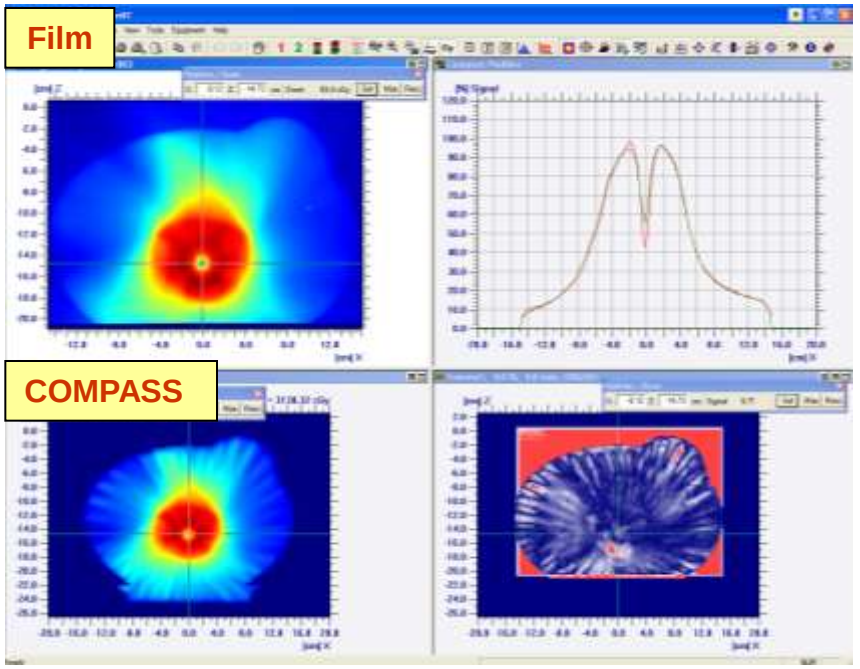
# Prostate Case 3




Data from Ramesh Boggula, Mannheim (submitted)

# Para spinal Case 3

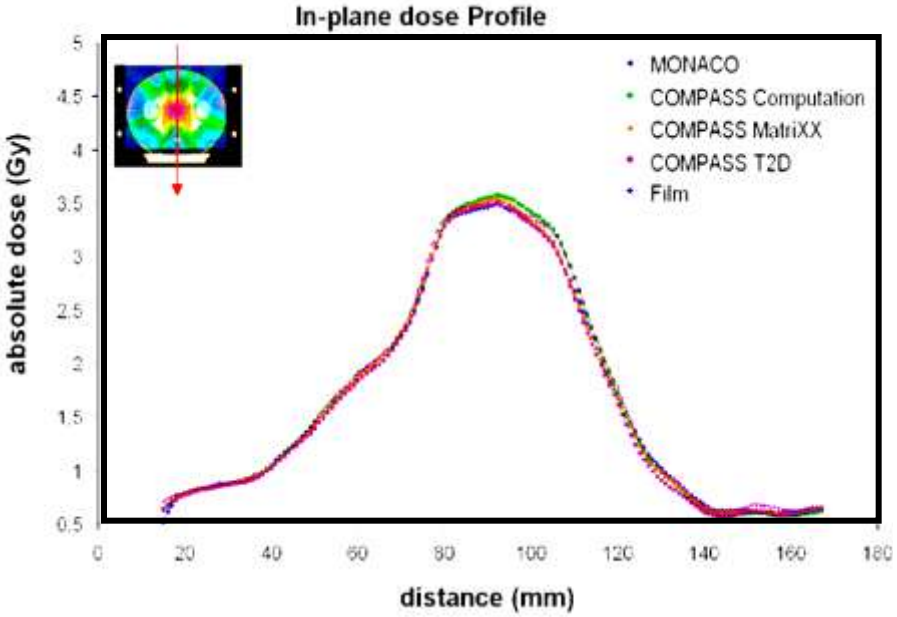


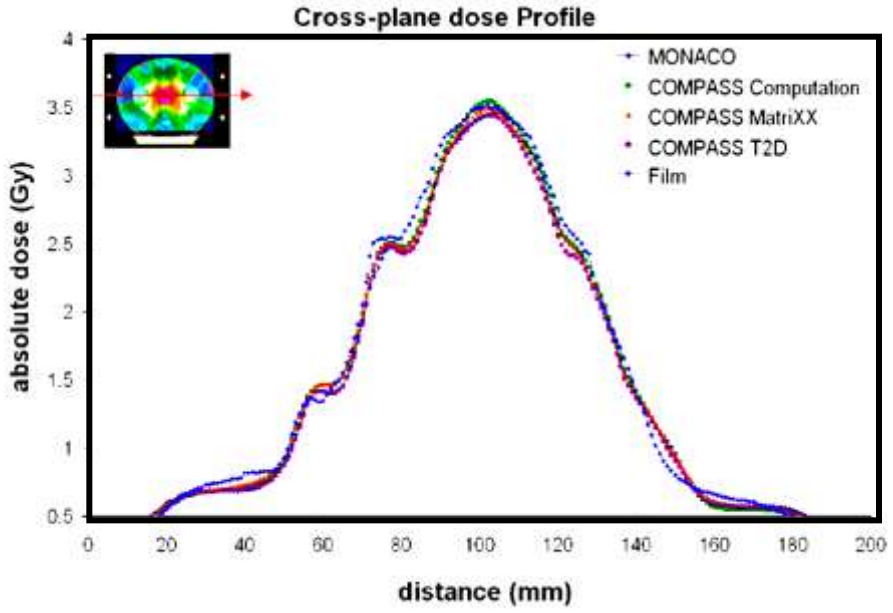




Plan was computed on a inhomogeneous thorax phantom

Data from Ramesh Boggula, Mannheim (submitted)

# COMPASS vs. MONACO MC IMRT



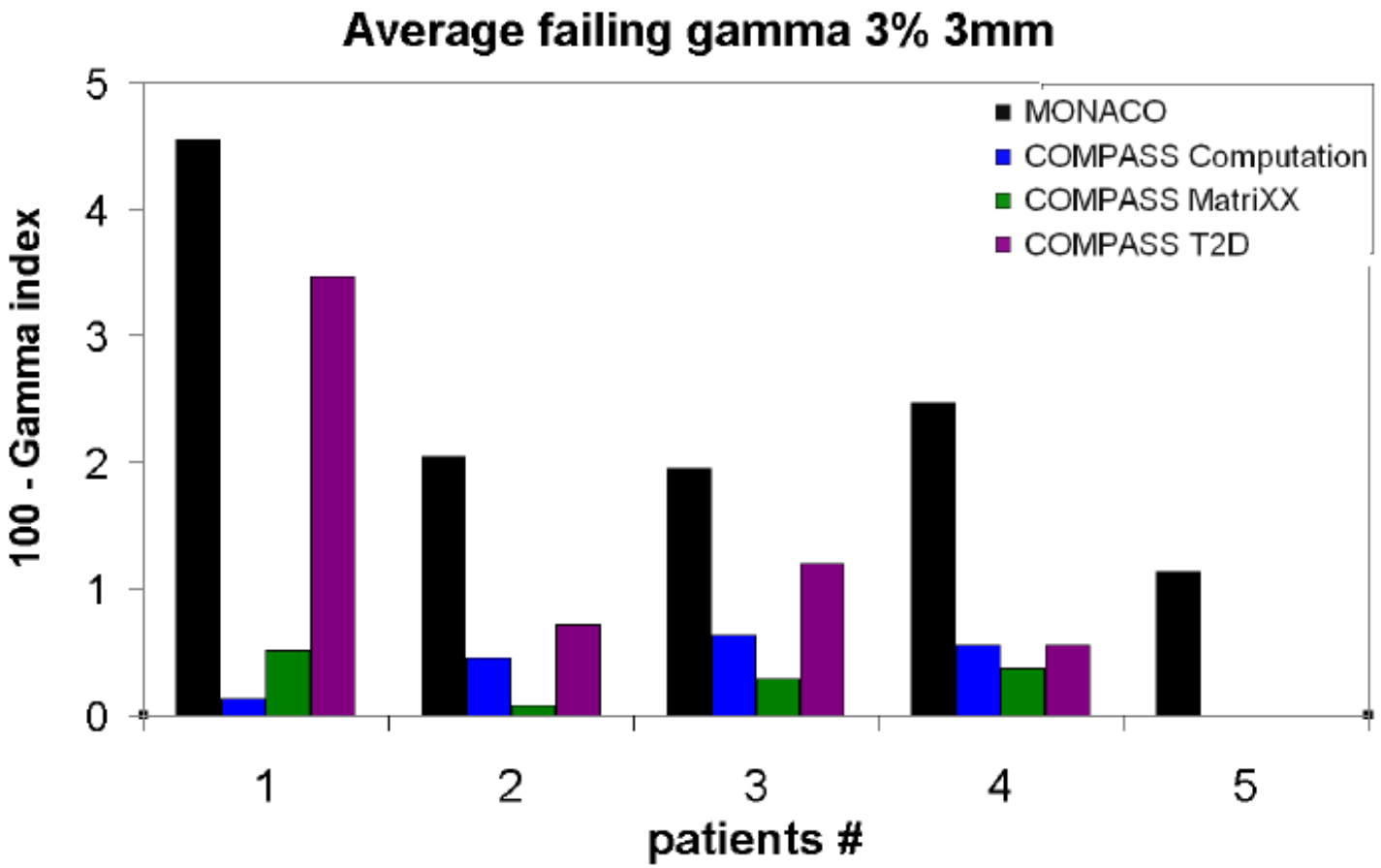




5 Prostate Plans on Inhomogeneous Pelvic Phantom

EDR 2 Film

Data from Ramesh Boggula, Mannheim (to be published)

# COMPASS vs. MONACO MC IMRT



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

**COMPASS (IBA Dosimetry)*

*Continuous Online Monitoring PAtient Safety System*

Erik Korevaar
Dept of Radiation Oncology
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?

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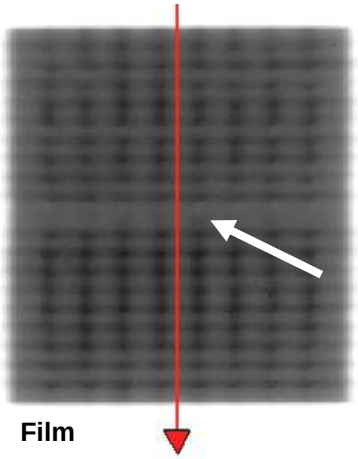
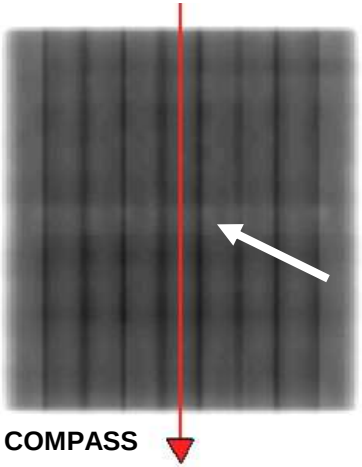
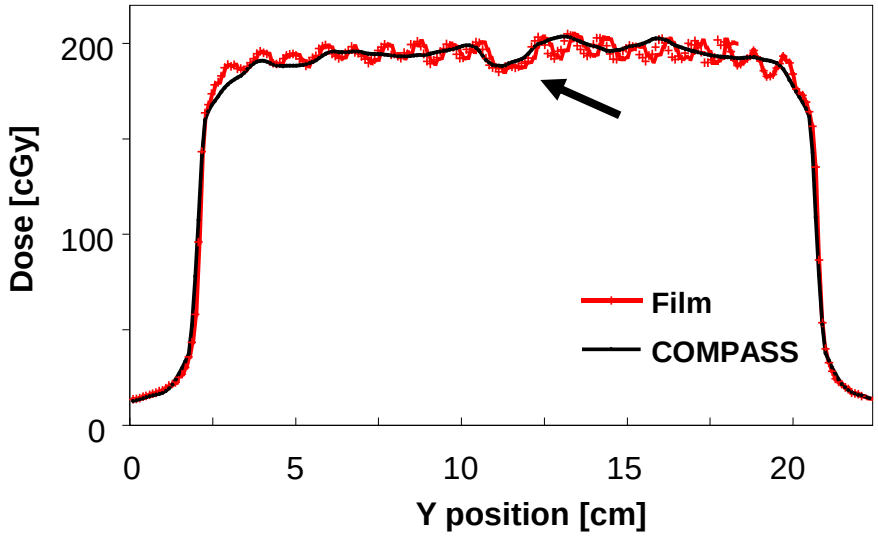
# MLC geometry: Strip test

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

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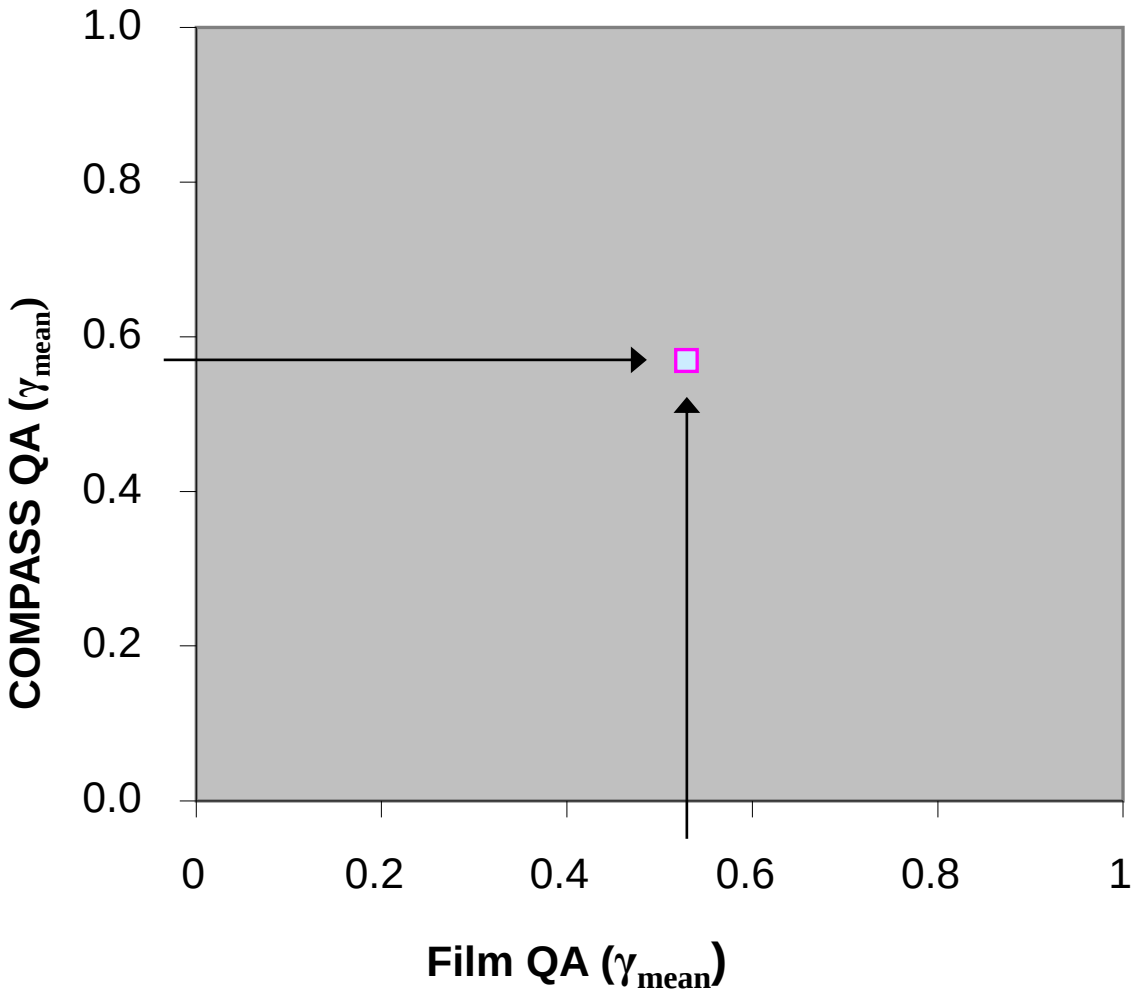
# COMPASS QA vs Film QA

## Gamma index correlation

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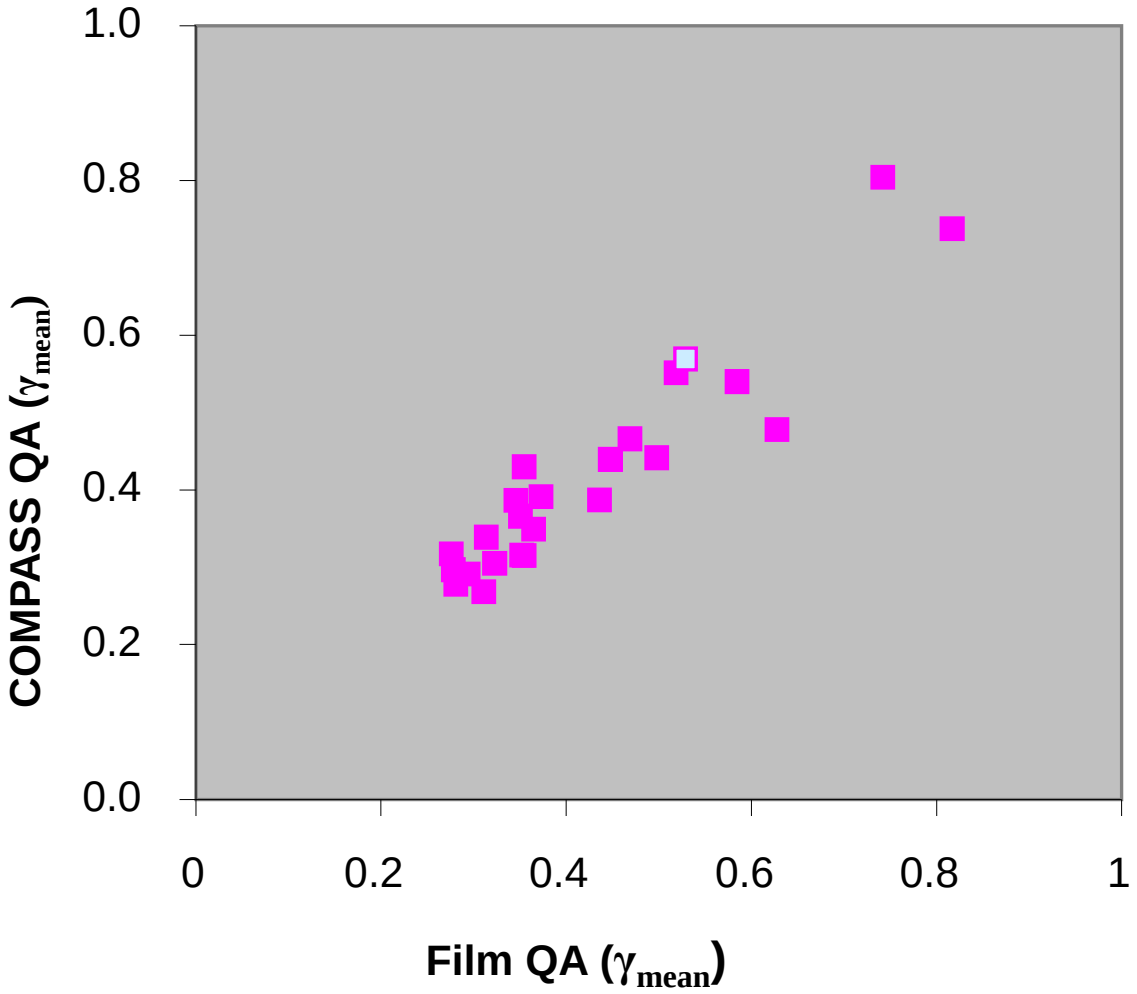
# COMPASS QA vs Film QA

## Gamma index correlation

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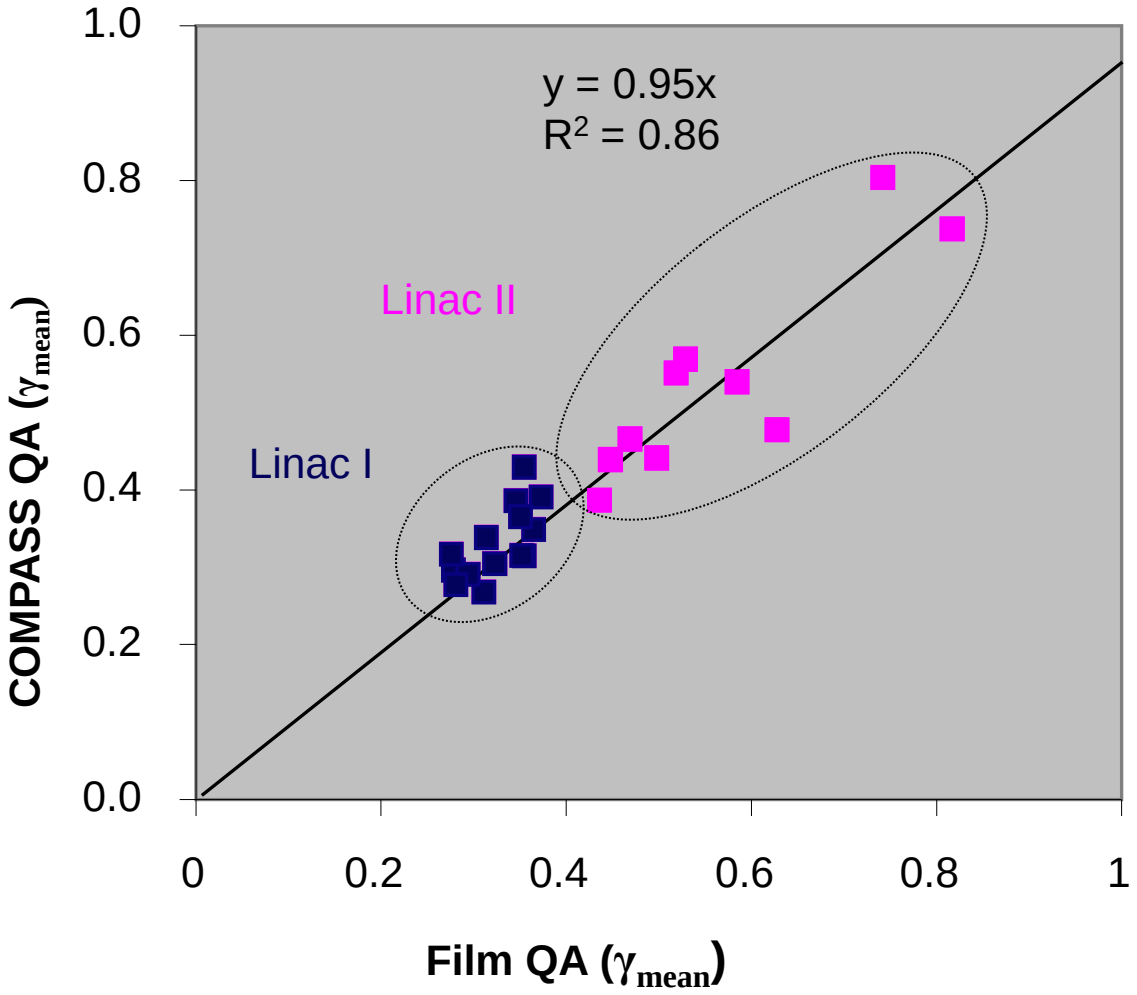
# COMPASS QA vs Film QA

## Gamma index correlation

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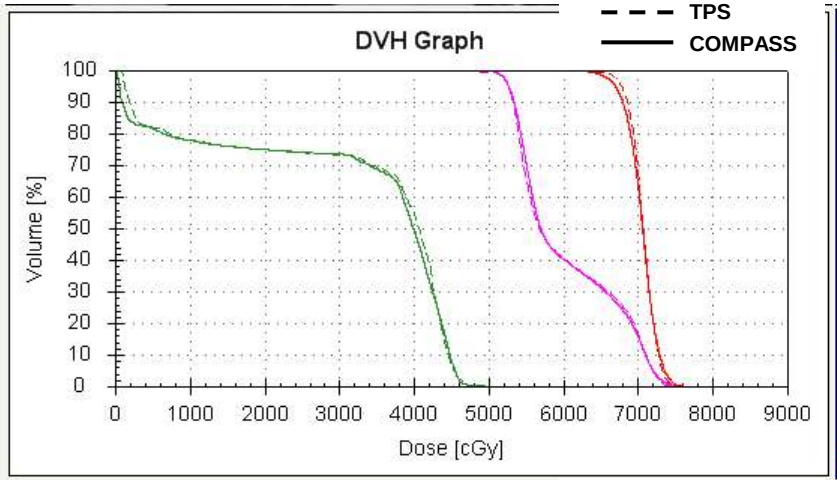
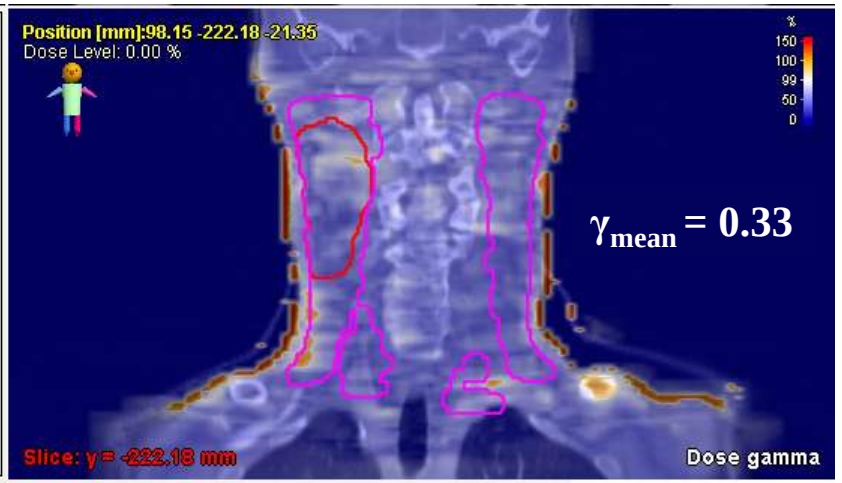
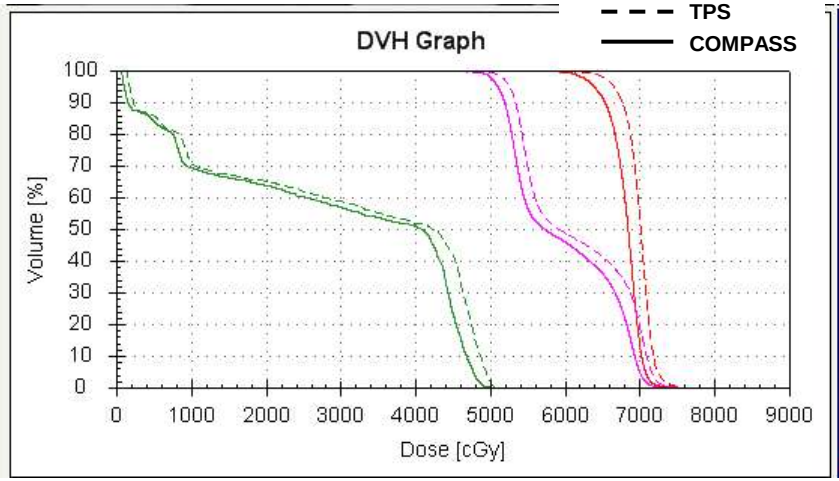
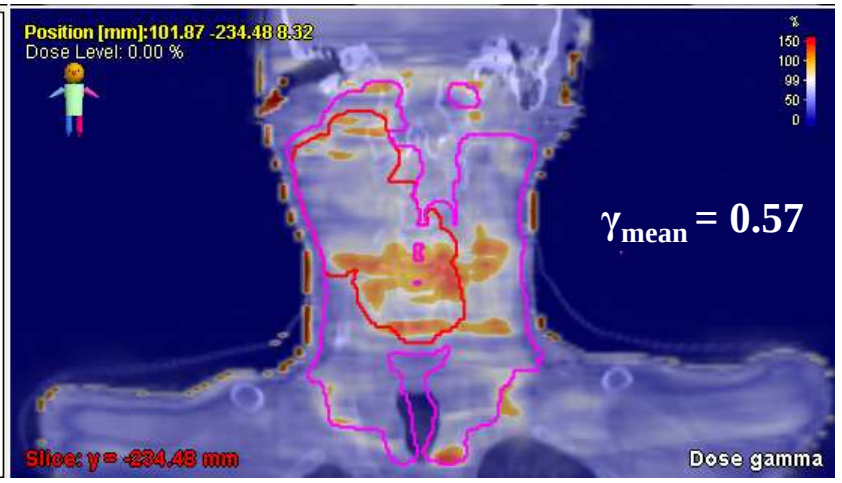
# COMPASS QA in patient CT




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

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

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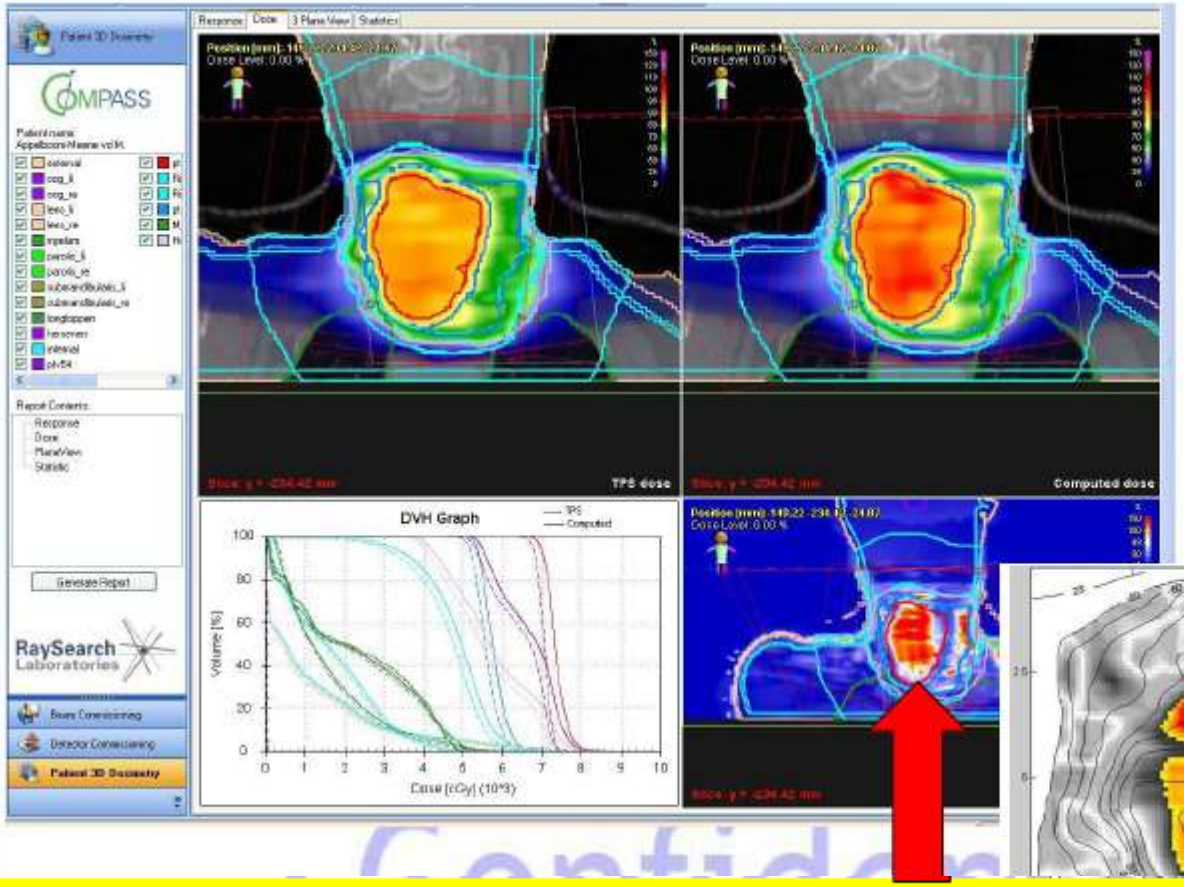
# Why do we do this? Patient 301..

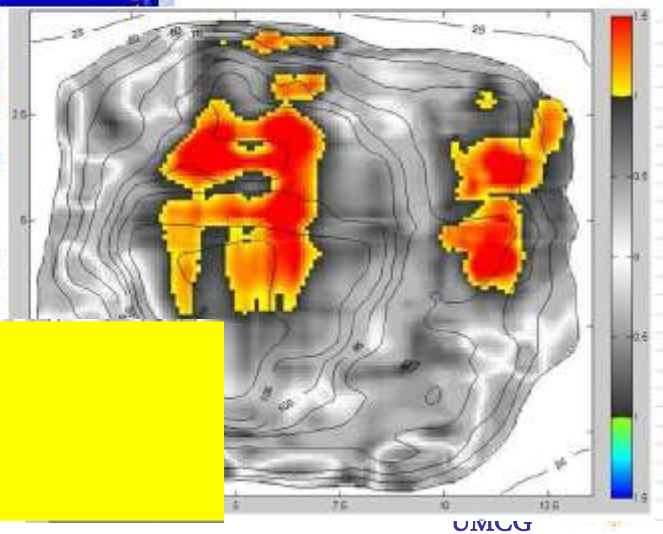
spinal cord (green), planning target volumes (purple, red)




**COMPASS**

**Calculation**

**(2nd check)**



**Cause: all IMRT fields were off-axis**

***Solution: reposition the isocenter***

# 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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# July 1st , 2010 (Dr. Erik Korevaar)

- We have verified about 140 patients more, so the total now is roughly **220** patients.
- From january 2010, we started to use COMPASS as an **independend dose calculation tool**
- in a selection of treatments a measurement with the MatriXX detector + COMPASS is done
- In the rest of the treatment plans dose is computed with COMPASS without a measurement. This made the QA process more flexible and it is not a limiting factor in the number of new patients starting IMRT treatment every week.
- The number of patients treated with 'full blown IMRT' has **roughly doubled**.

# PMB 55 (2010) 5619-5633

IOP Publishing | Physics in Medicine and Biology

Phys. Med. Biol. 55 (2010) 5619–5633 | doi:10.1088/0031-9155/55/19/001

# Experimental validation of a commercial 3D dose verification system for intensity-modulated arc therapies

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