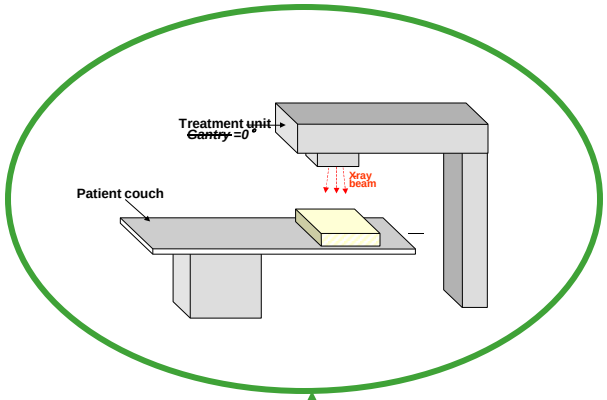
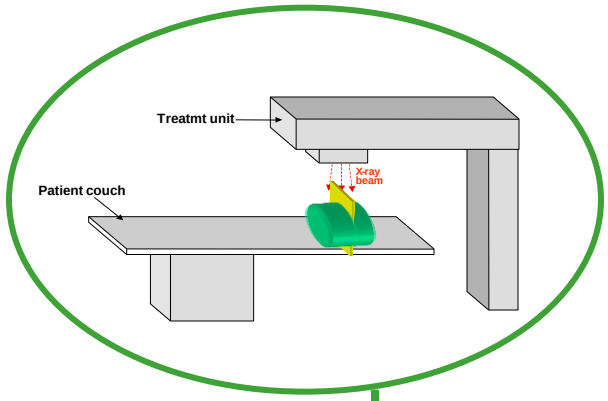
Verifikation der Intensitätsmodulierten Strahlentherapie

Dr. Lutz Müller, Director ICC
IBA Dosimetry, Schwarzenbruck

Patient-specific Verification ?

CT





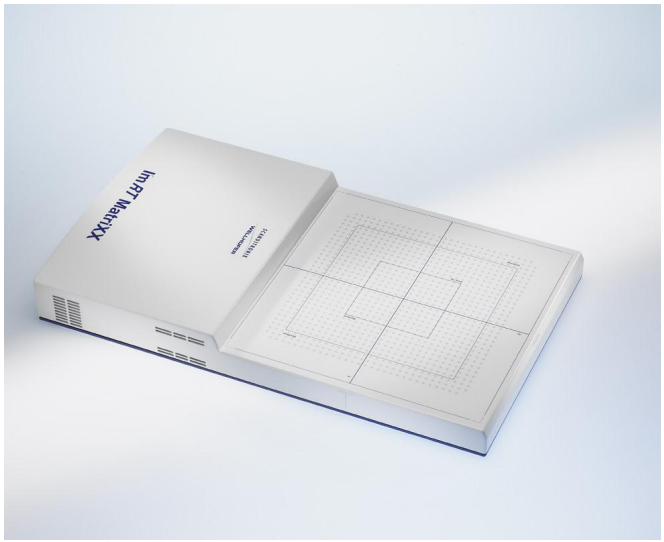
TPS → 3D Dose → Fields → 3D Dose In Patient → 3D Dose In Phant

disturbed Fields → **Resulting 3D Dose In Patient**

Targ. Vol/Dose/constraints

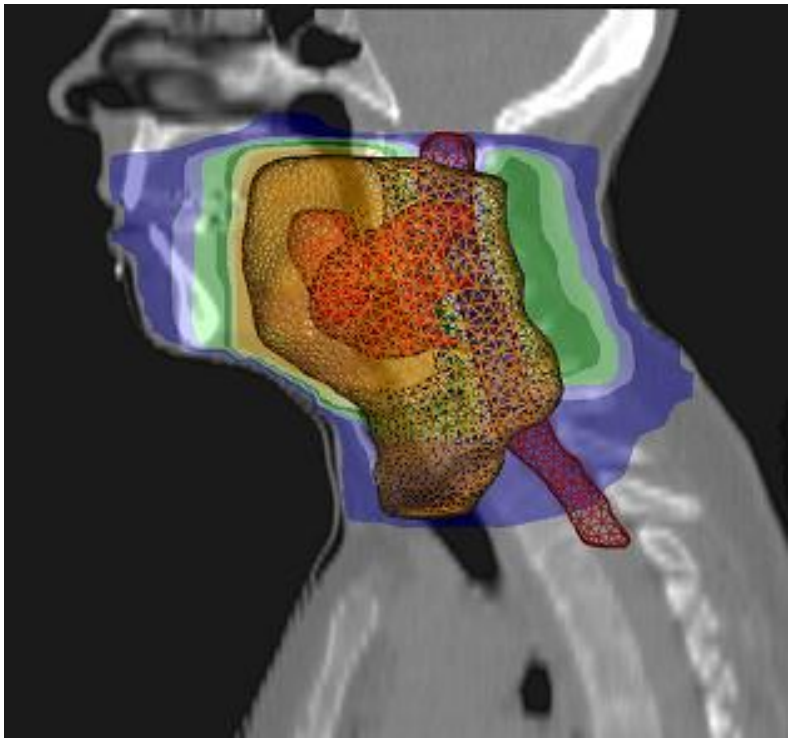
iba Dosimetry

Generations of electronic IMRT Dosimetry



1st

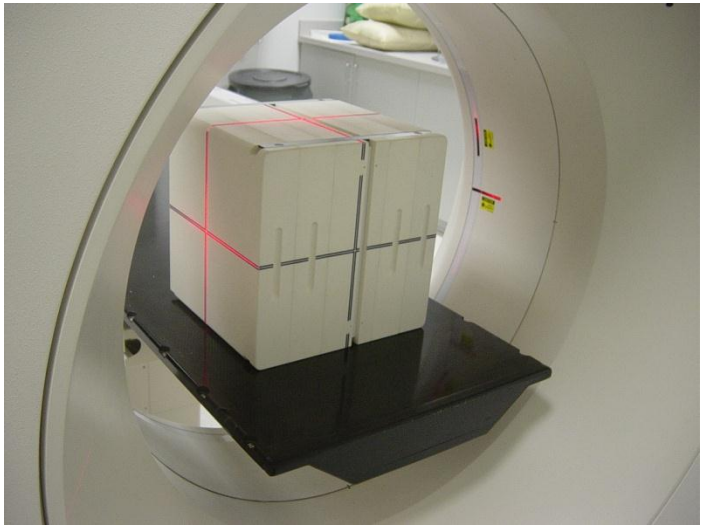
Single fields, perpendicular



2nd

Homo-geneous phantom,

composite



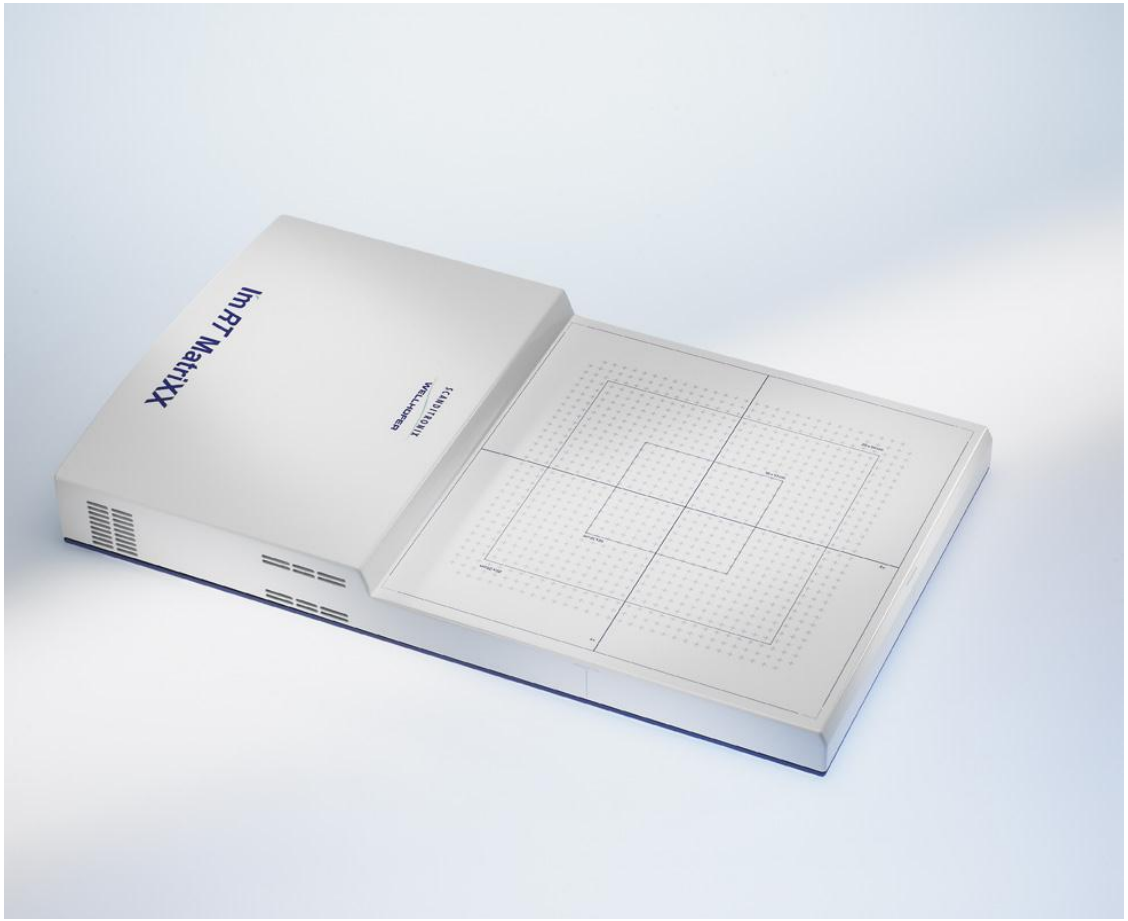
3rd

COMPASS

iba Dosimetry

The First Generation

I'm*RT* MatriXX key features



Pixel Ion chamber technology (air vented)

1020 (MXX) detectors in 24x24 cm matrix

Single detector Φ = 4.5 mm (height 5mm), 0.07 cc

Parallel reading w/o dead time

Real time measurements

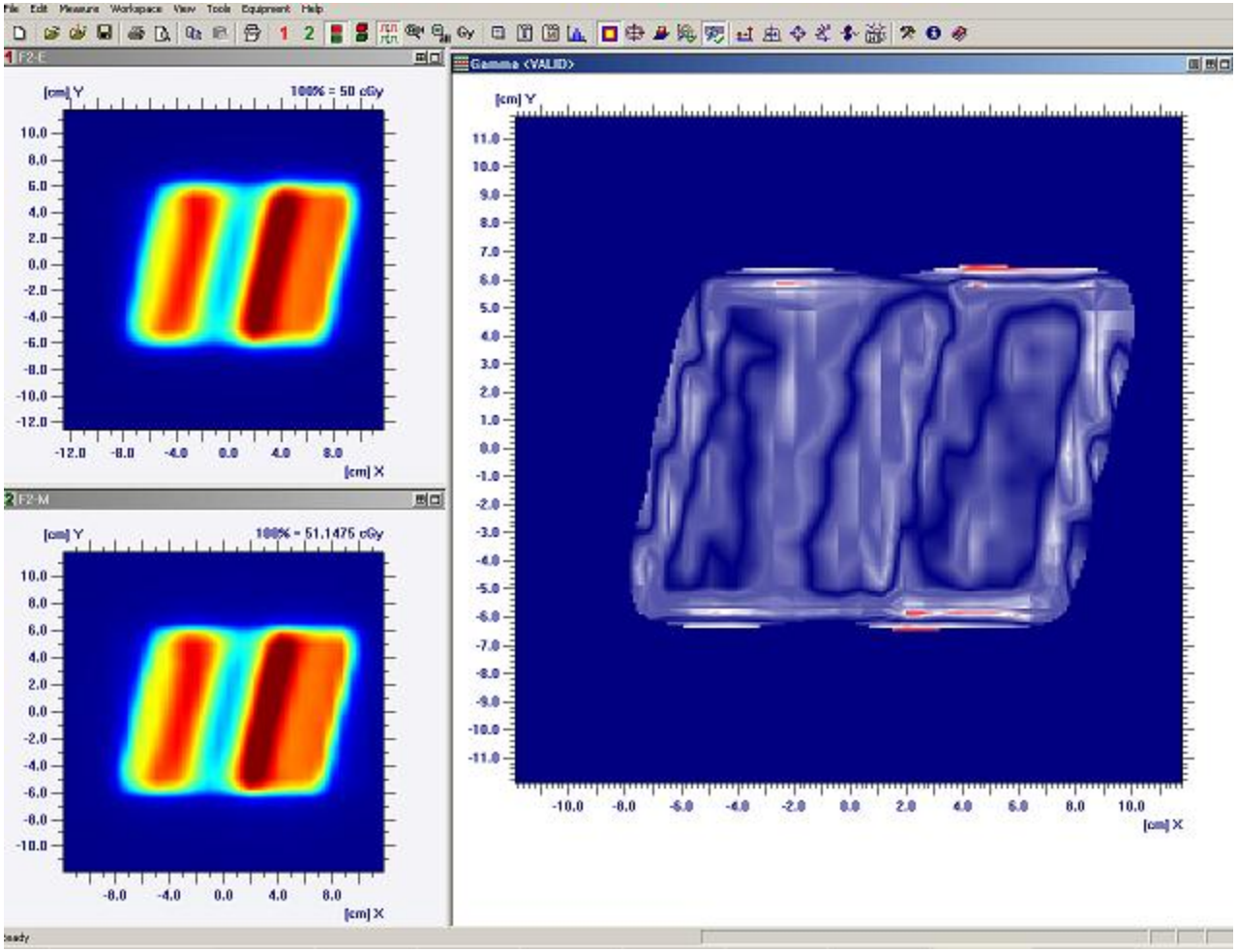
Software (OmniPro ImRT, Accept)

Dosimetry

Quasimodo Study – plan & MatriXX 1 x 1 mm

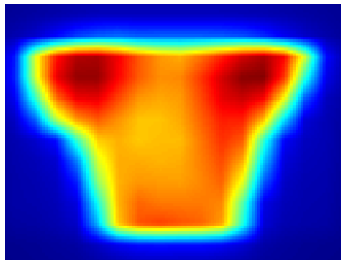
Plan

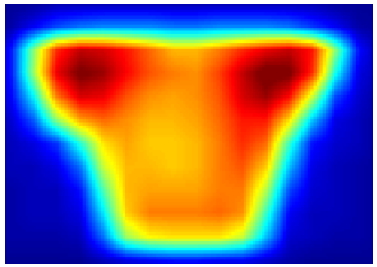
MatriXX

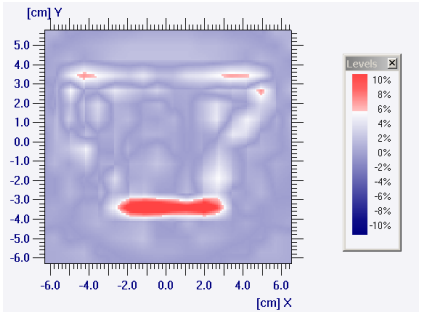


Gamma eval 3%/3mm

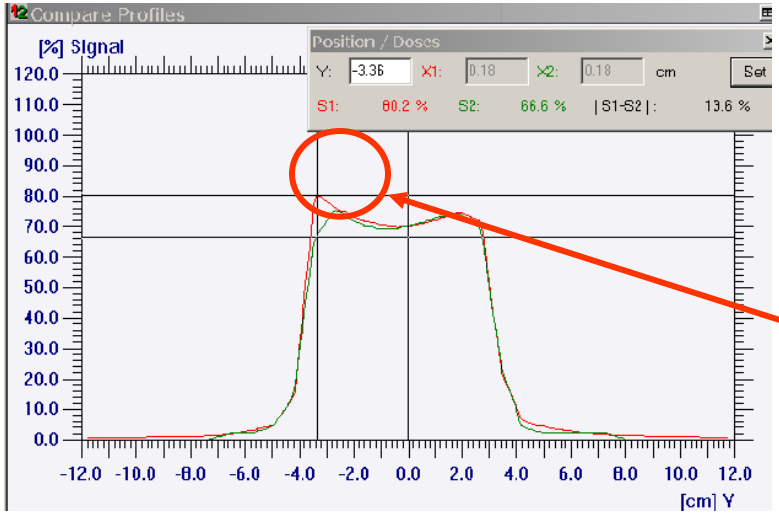
Example: error in jaw position

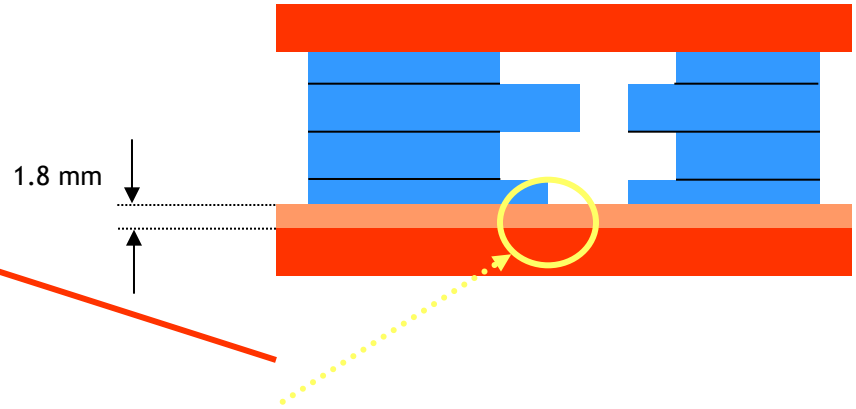






Plan measured difference





Profiles __plan __measured

Y1 jaw displaced by 1.8 mm

iba Dosimetry

OmniProIMRT+

Fast plan verification: menu-driven efficiency in 4 simple steps!

1 TPS import

Swift and convenient import from TPS

2 Measurement

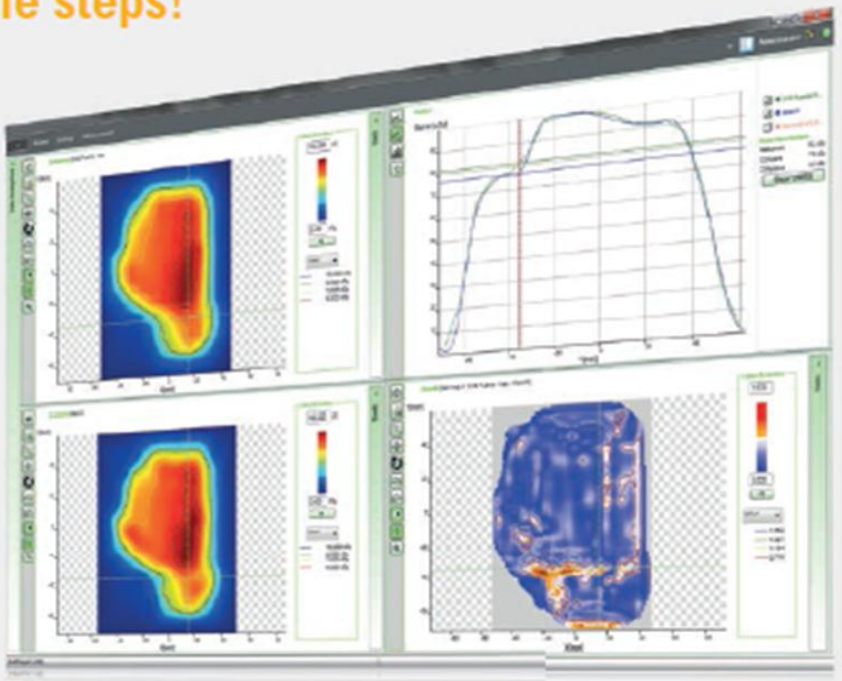
Fast measurement interface with MatriXX detector

3 Verification

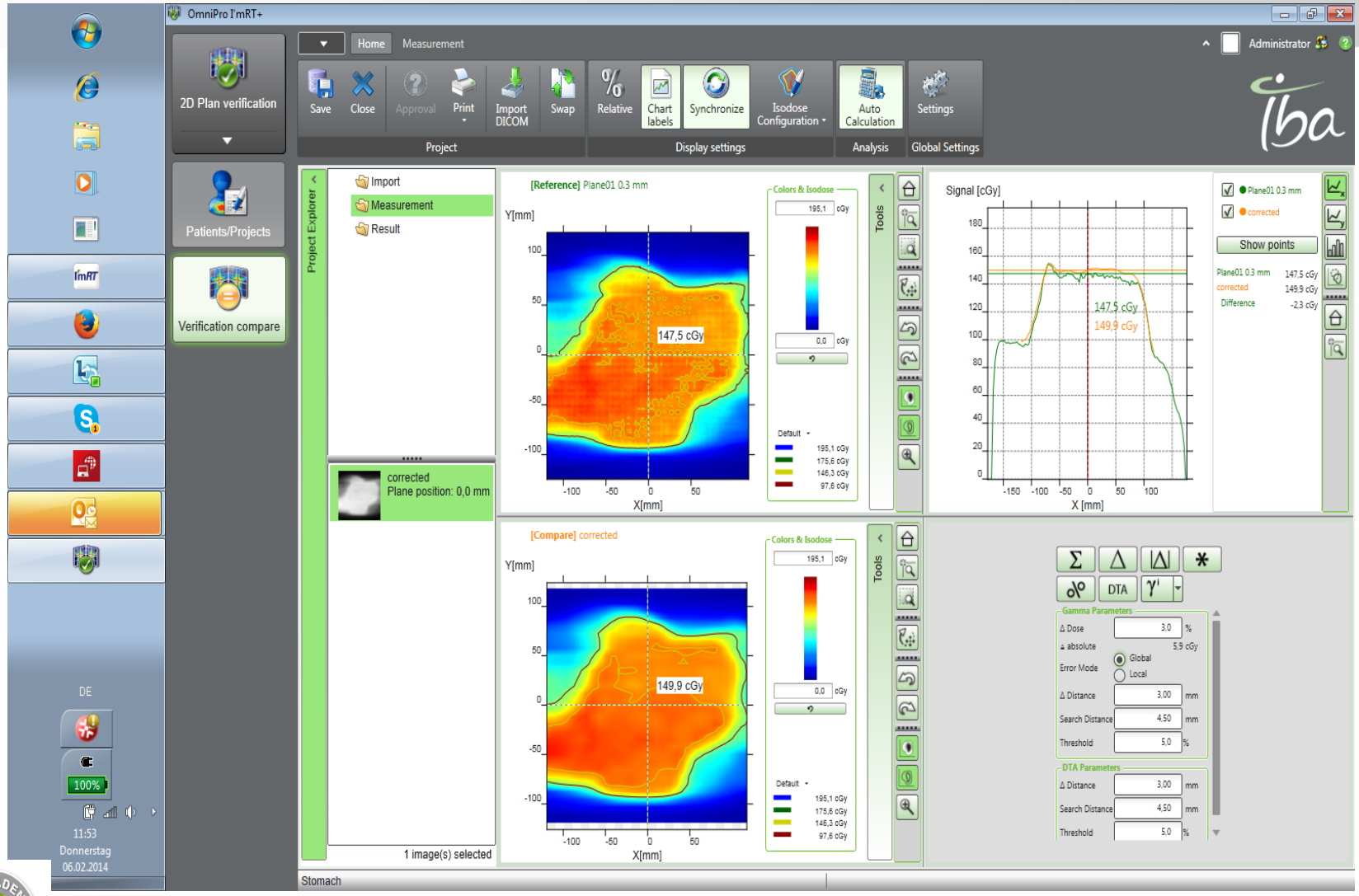
Rapid calculation of results for fast review

4 Reporting & export

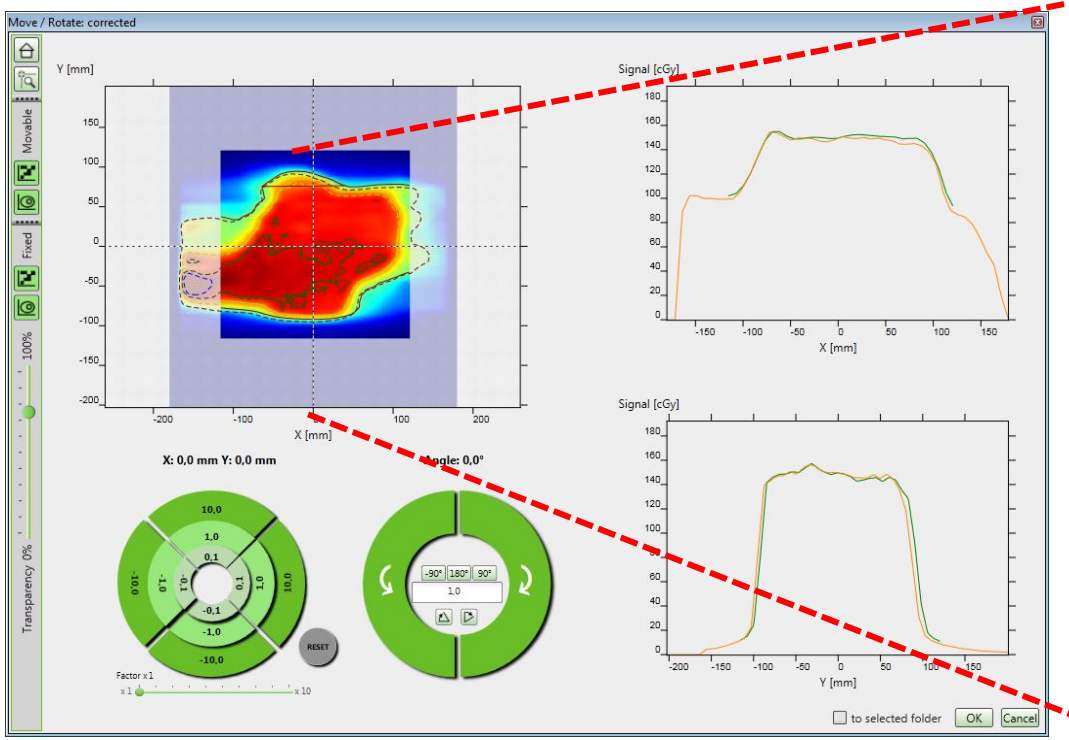
Template-based reporting; fast archiving & export

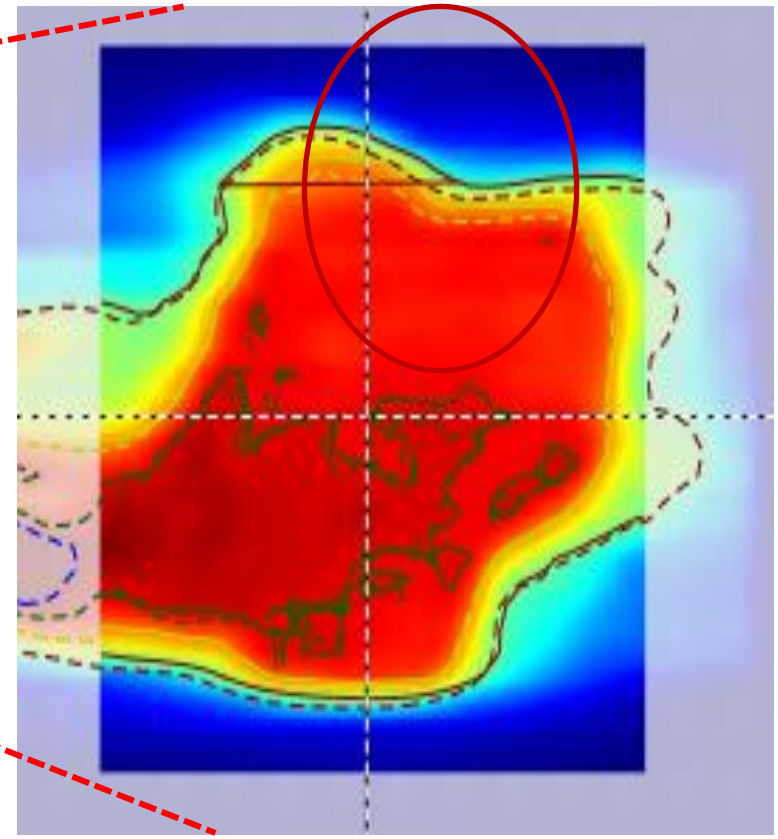


Compare plan and measurement



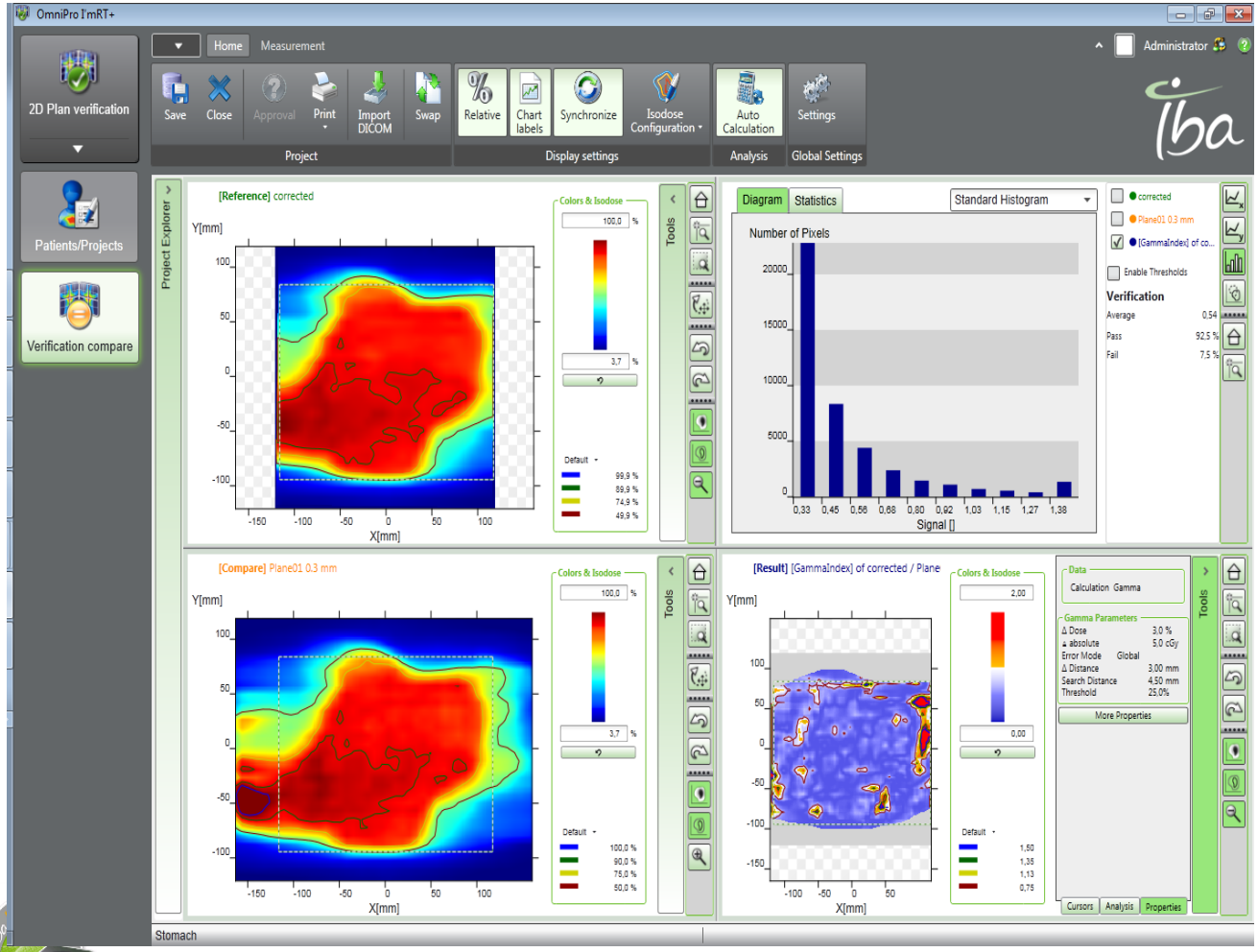
Measure Displacement and Rotation

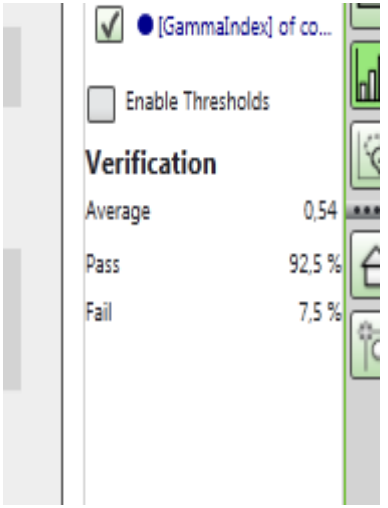




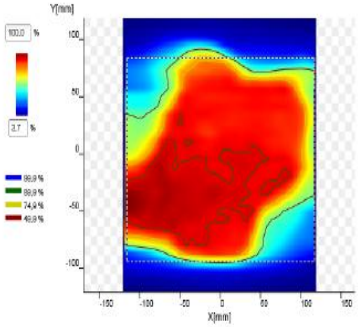
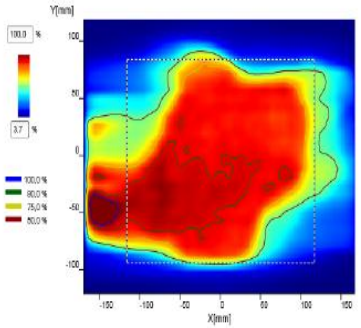
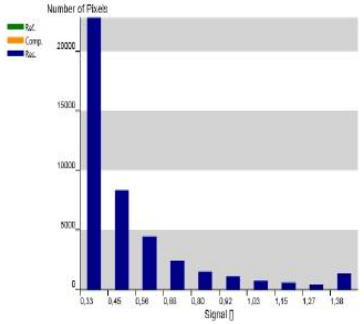
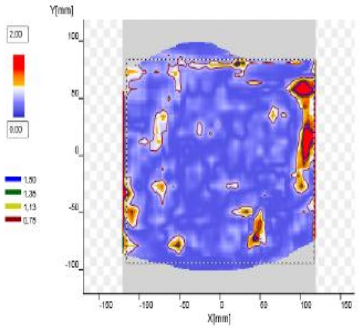
Gamma Evaluation

No grid adaptation needed





Verification Report

Patient N/A Project Stomach	**Plan Verification Report**	Clinic N/A Location N/A
Patient Info Patient ID N/A Patient Birthday N/A Patient Gender N/A **Reference** Treatment Device N/A Radiation Type N/A Energy Value N/A Gantry Angle N/A Plane Position 0,0 mm Dose Ratio (100%) 166,9 cGy **Compare** Treatment Device N/A Radiation Type N/A Energy Value N/A Gantry Angle N/A Plane Position 0,0 mm Dose Ratio (100%) 166,9 cGy **Result** Analysis Method GammaIndex Delta Dose Ratio 3,0 % Delta Dose Abs 5,0 cGy Dose Error Mode Global Delta Distance 3,0 mm Search Distance 4,5 mm Threshold 25,0 % **Histogram Info** Average Value 0,54 Passing Values 92,5 % Failing Values 7,5 % Threshold T1 0,33 Threshold T2 1,50 Values < T1 0,0 % T1 < Values < T2 97,4 % Values > T2 2,6 % **Points Of Interest** Name / Max Dose / Cursor Pos. Coordinates N/A (7,4 ; -52,1) Reference Value 166,7 cGy 149,6 cGy Compare Value 192,7 cGy 148,0 cGy Difference Value -26,0 cGy 1,6 cGy **Project Notes** Multicube	**Reference : corrected**  **Compare : Plane01 0.3 mm** 	**Histogram**  **Result : [GammaIndex] of corrected / Plane01 0.3 mm** 
Approved Status N/A Approval Date N/A Approver Name N/A	Approver Notes N/A	Approver Signature

The Second Generation

MatriXX Evolution: MULTICube phantom

- Multiple Configurations (6 cm increments)
- Multiple depth positionning on the MatriXX
- Optional film cassette

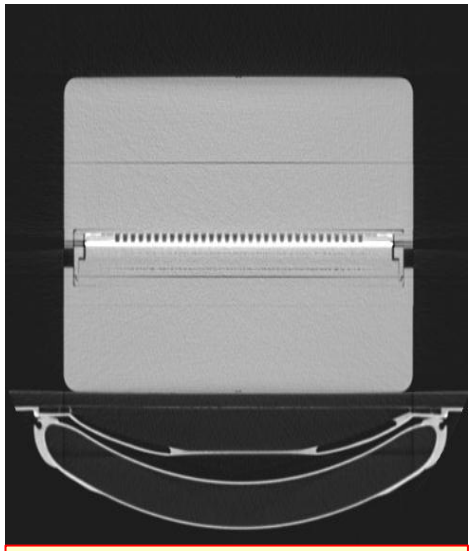




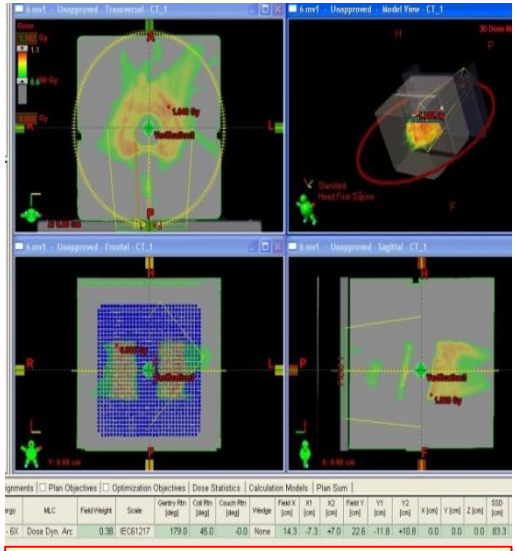

Dosimetry

Workflow of Multicube Verification

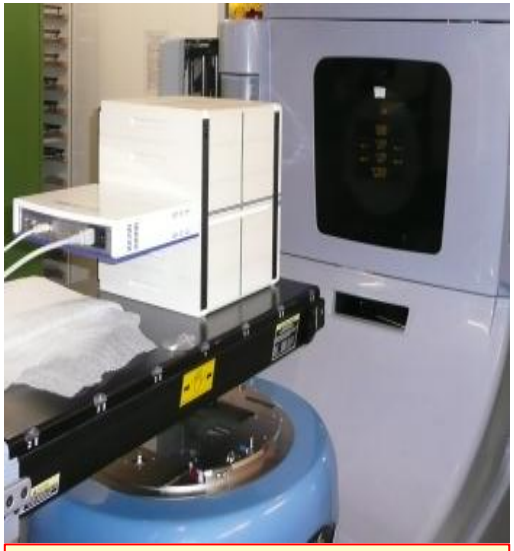
Phantom and Hybride Plan



Scan Phantom

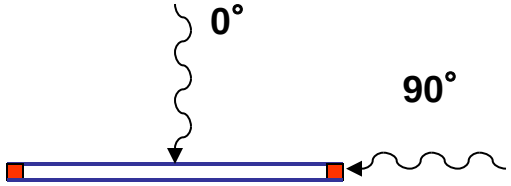


Plan to Phantom



Irradiate Phantom

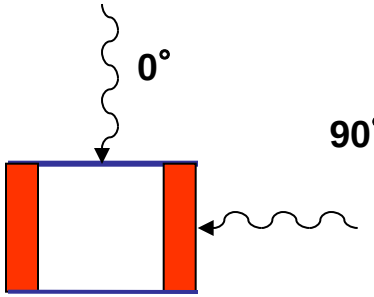
Pixel Chamber angular acceptance



Classical parallel plate chamber

extended electrodes, small gap

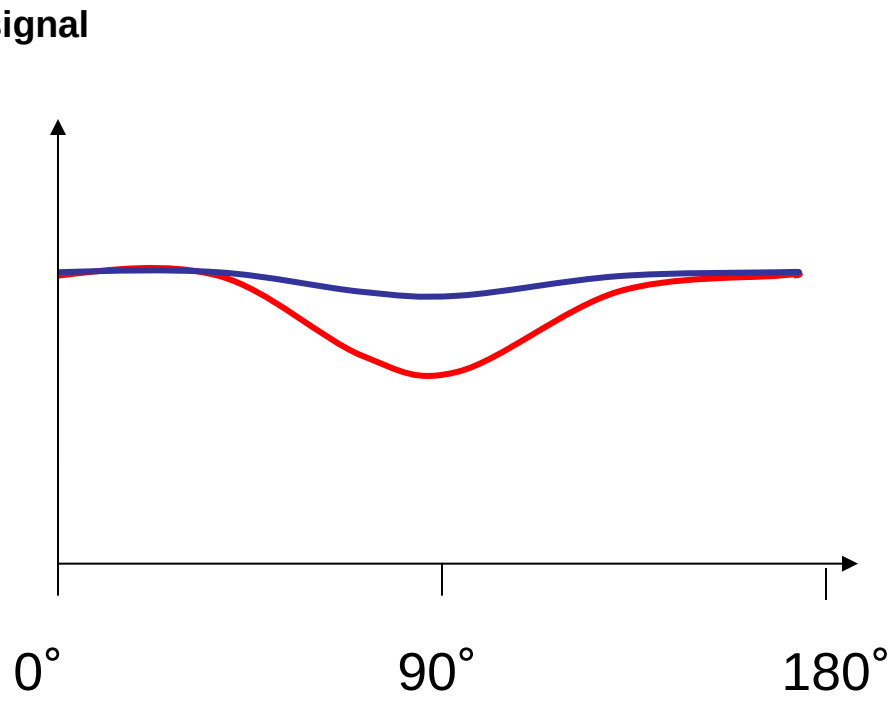
-> strongly anisotropic response



PIC ion chamber

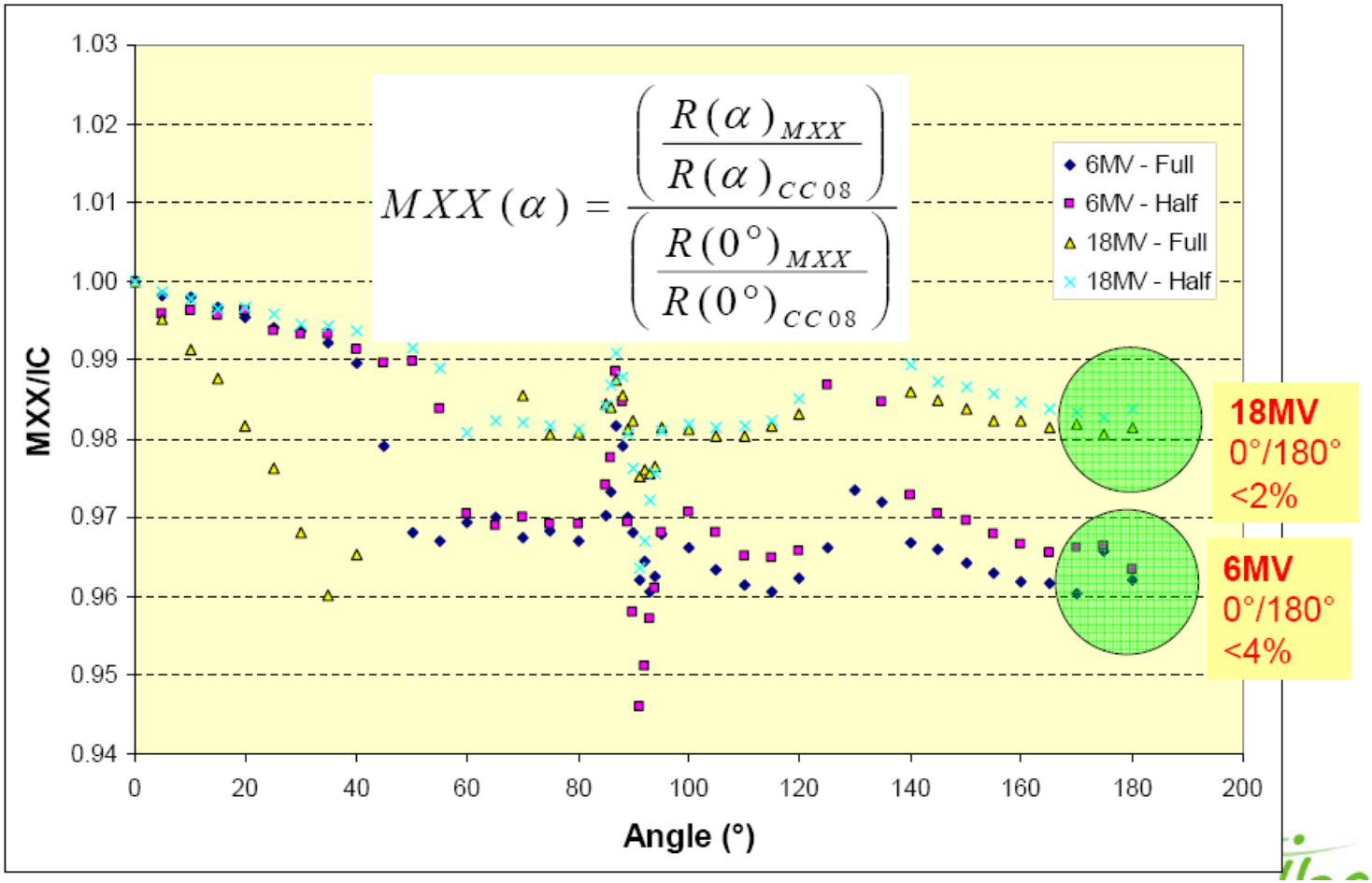
Diameter (4.5mm) and gap (5mm) almost equal

-> nearly isotropic response



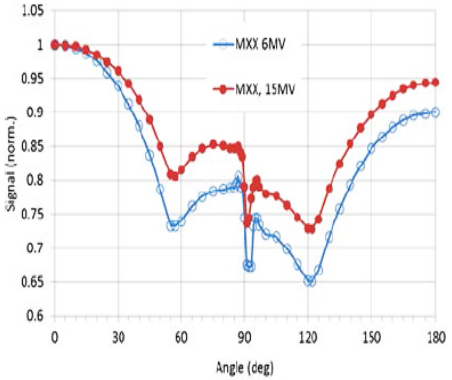
Irradiation of MatriXX from ALL angles (0° - 360°) ?

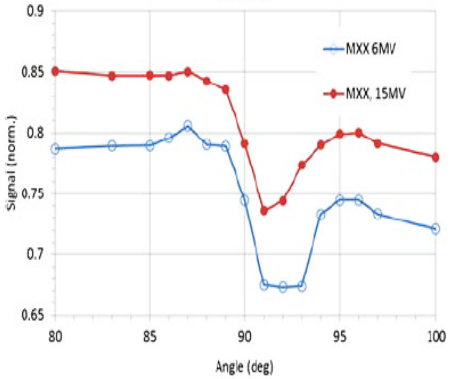
MatriXX - Residual angular dependence



Angular Response of MatriXX

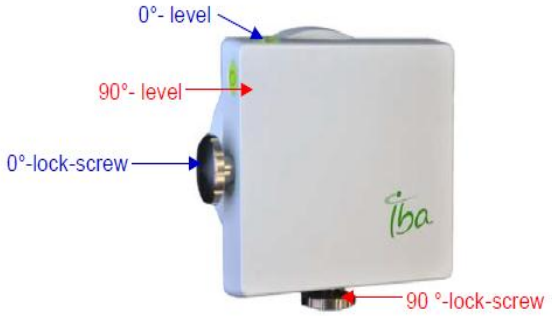
Response correction with lookup table



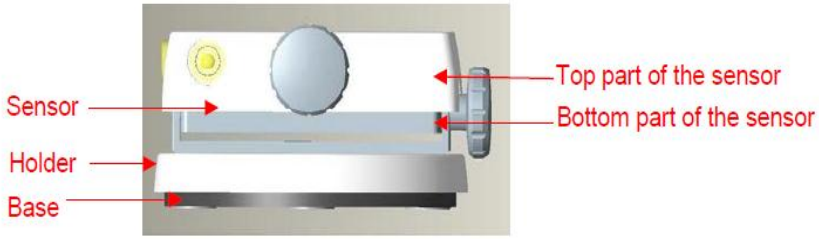


Top: Typical normalized signal measured by irradiating MatriXX^{FFF} inside MultiCube Lite with various angles of incidence in the range 0-180° (0° means normal incidence on MatriXX top surface). Two beam qualities have been used (6MV and 15MV) to deliver 200MU with 10 cm x 10cm field size from an Elekta Agility LINAC.

Bottom: zoom between 80° -100°.



Gantry angle sensor (not showing the cable)

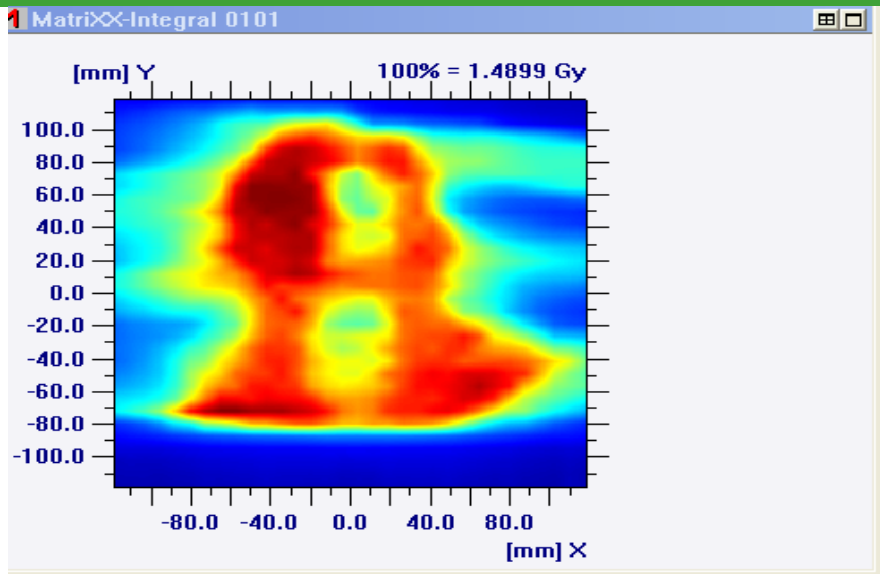


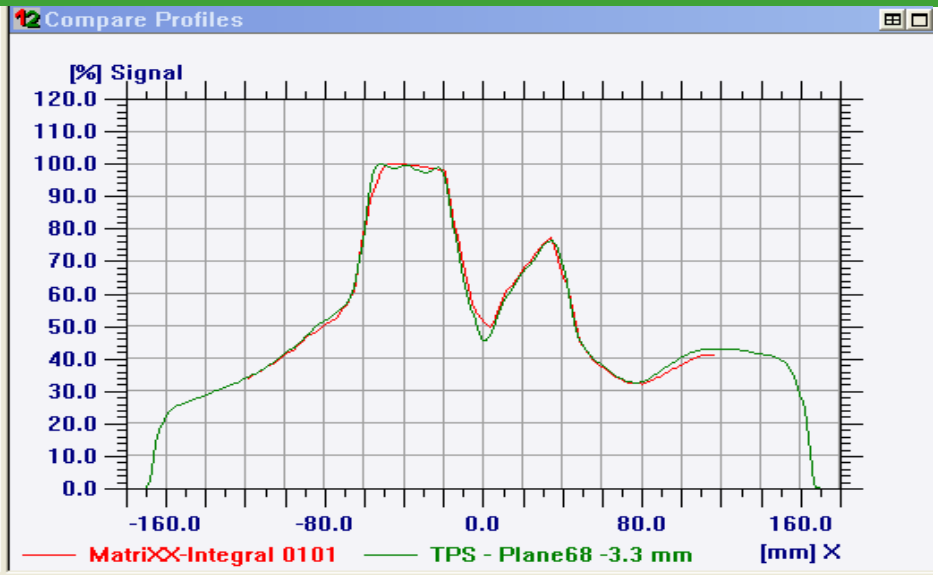
Plan Verification in Multicube phantom

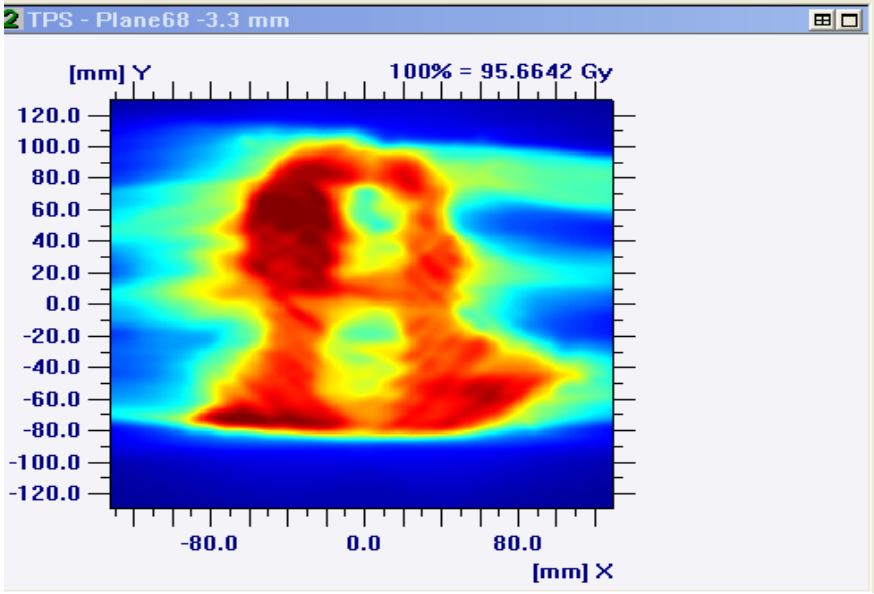
ICC

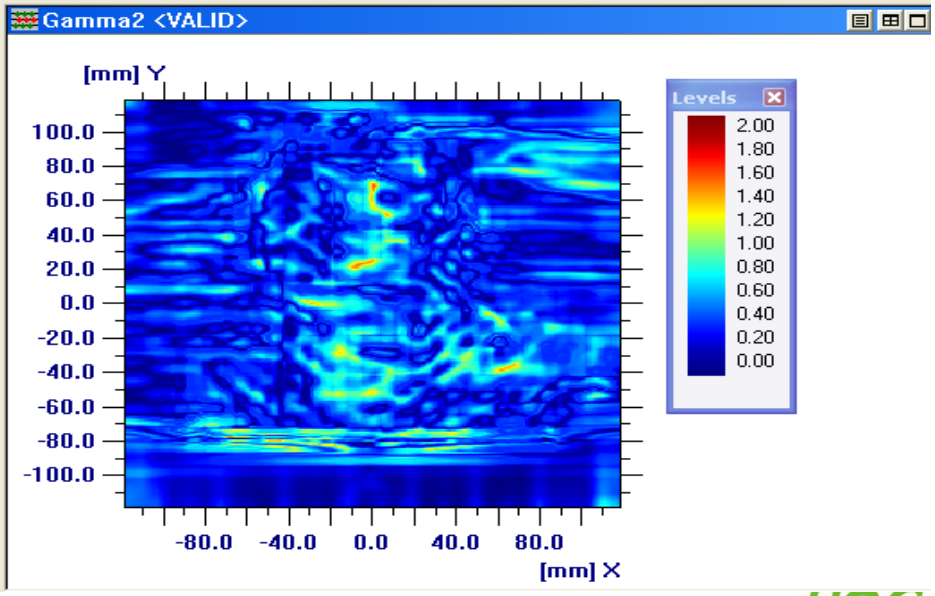
iba Dosimetry

Varian RapidArc™ – RIGS, Copenhagen University, Denmark









IBA Dosimetry

Welcome to Nuremberg

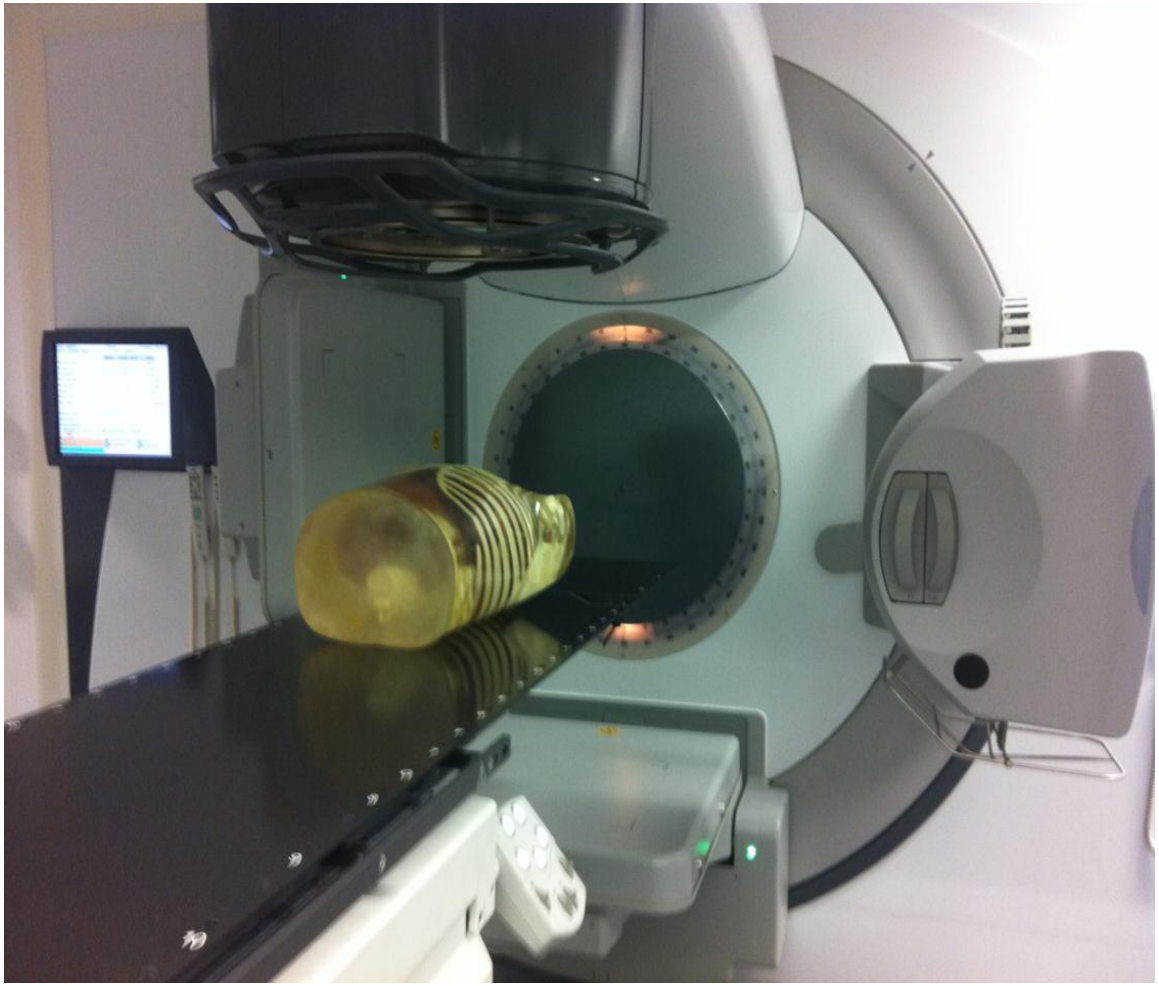
iba Dosimetry

Training in Hospitals

Patients waiting, Emergency cases, Equipment in treatment room...

ICC Linac

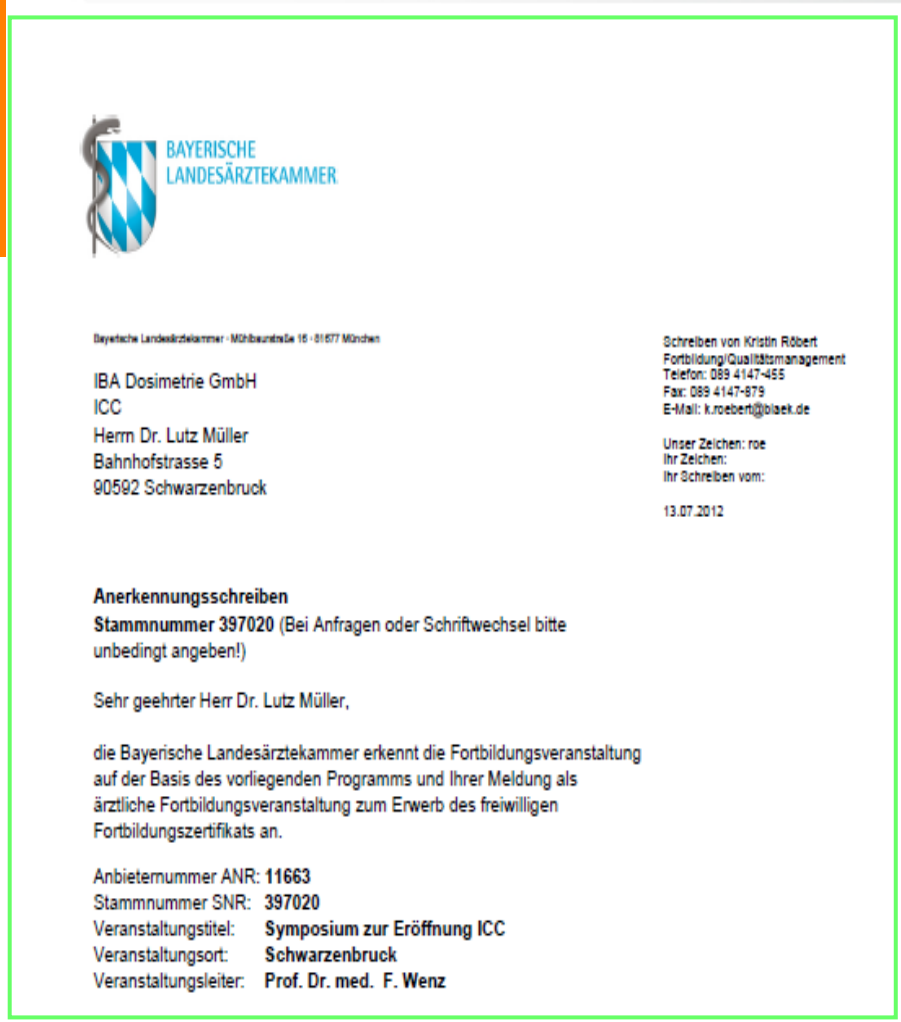
State-of-the-Art Equipment



- FFfree
- Vmat
- Cone-Beam CT
- 160 Leaf collimator
- EPID
- Monte-Carlo TPS

CME Credit Recognition

Oncology & Medical Physics



BAYERISCHE LANDESÄRZTEKAMMER

Bayerische Landesärztekammer · Mühlbaurstraße 16 · 81677 München

IBA Dosimetrie GmbH
ICC
Herrn Dr. Lutz Müller
Bahnhofstrasse 5
90592 Schwarzenbruck

Schreiben von Kristin Röbert
Fortbildung/Qualitätsmanagement
Telefon: 089 4147-455
Fax: 089 4147-879
E-Mail: k.roebert@blaek.de

Unser Zeichen: roe
Ihr Zeichen:
Ihr Schreiben vom:

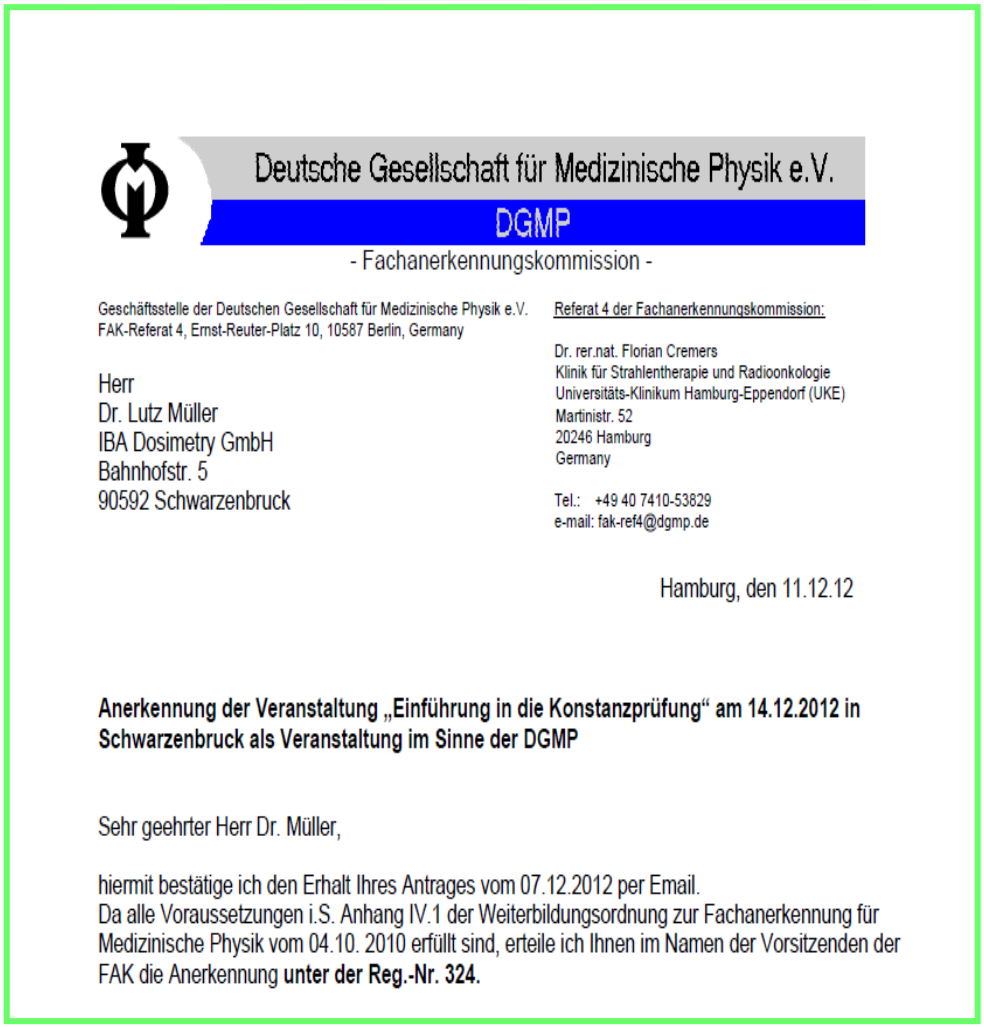
13.07.2012

Anerkennungsschreiben
Stammnummer 397020 (Bei Anfragen oder Schriftwechsel bitte unbedingt angeben!)

Sehr geehrter Herr Dr. Lutz Müller,

die Bayerische Landesärztekammer erkennt die Fortbildungsveranstaltung auf der Basis des vorliegenden Programms und Ihrer Meldung als ärztliche Fortbildungsveranstaltung zum Erwerb des freiwilligen Fortbildungszertifikats an.

Anbieternummer ANR: **11663**
Stammnummer SNR: **397020**
Veranstaltungstitel: **Symposium zur Eröffnung ICC**
Veranstaltungsort: **Schwarzenbruck**
Veranstaltungsleiter: **Prof. Dr. med. F. Wenz**



Deutsche Gesellschaft für Medizinische Physik e.V.

DGMP

- Fachanerkennungskommission -

Geschäftsstelle der Deutschen Gesellschaft für Medizinische Physik e.V.
FAK-Referat 4, Ernst-Reuter-Platz 10, 10587 Berlin, Germany

Herr
Dr. Lutz Müller
IBA Dosimetry GmbH
Bahnhofstr. 5
90592 Schwarzenbruck

Referat 4 der Fachanerkennungskommission:

Dr. rer.nat. Florian Cremers
Klinik für Strahlentherapie und Radioonkologie
Universitäts-Klinikum Hamburg-Eppendorf (UKE)
Martinistr. 52
20246 Hamburg
Germany

Tel.: +49 40 7410-53829
e-mail: fak-ref4@dgmp.de

Hamburg, den 11.12.12

Anerkennung der Veranstaltung „Einführung in die Konstanzprüfung“ am 14.12.2012 in Schwarzenbruck als Veranstaltung im Sinne der DGMP

Sehr geehrter Herr Dr. Müller,

hiermit bestätige ich den Erhalt Ihres Antrages vom 07.12.2012 per Email.
Da alle Voraussetzungen i.S. Anhang IV.1 der Weiterbildungsordnung zur Fachanerkennung für Medizinische Physik vom 04.10. 2010 erfüllt sind, erteile ich Ihnen im Namen der Vorsitzenden der FAK die Anerkennung **unter der Reg.-Nr. 324.**

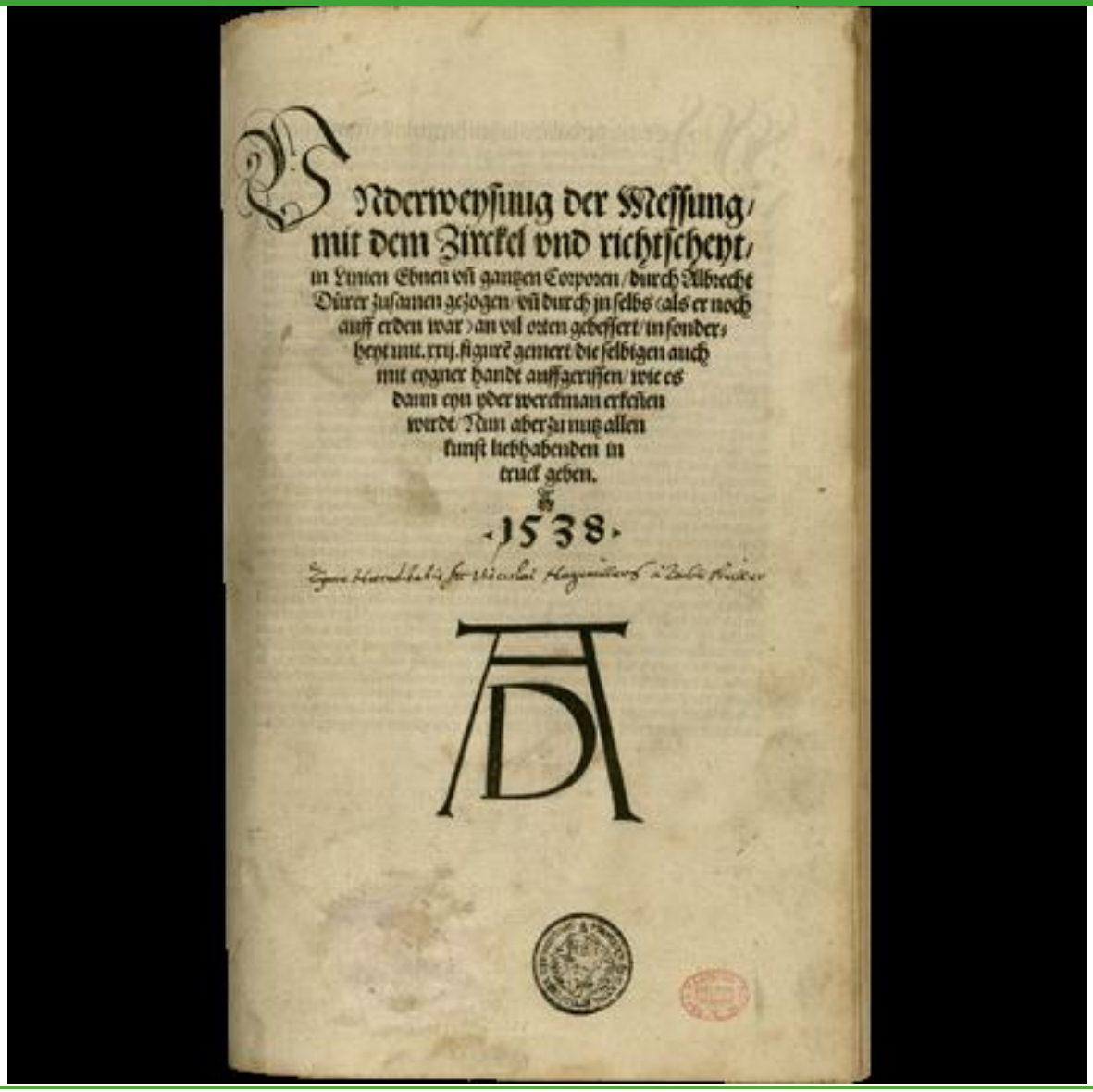
iba Dosimetry

Relative Dosimetry Course

W/ Mark DeWeese, Mid-South Radiation Physics

Dosimetry

Albrecht Dürer 1525

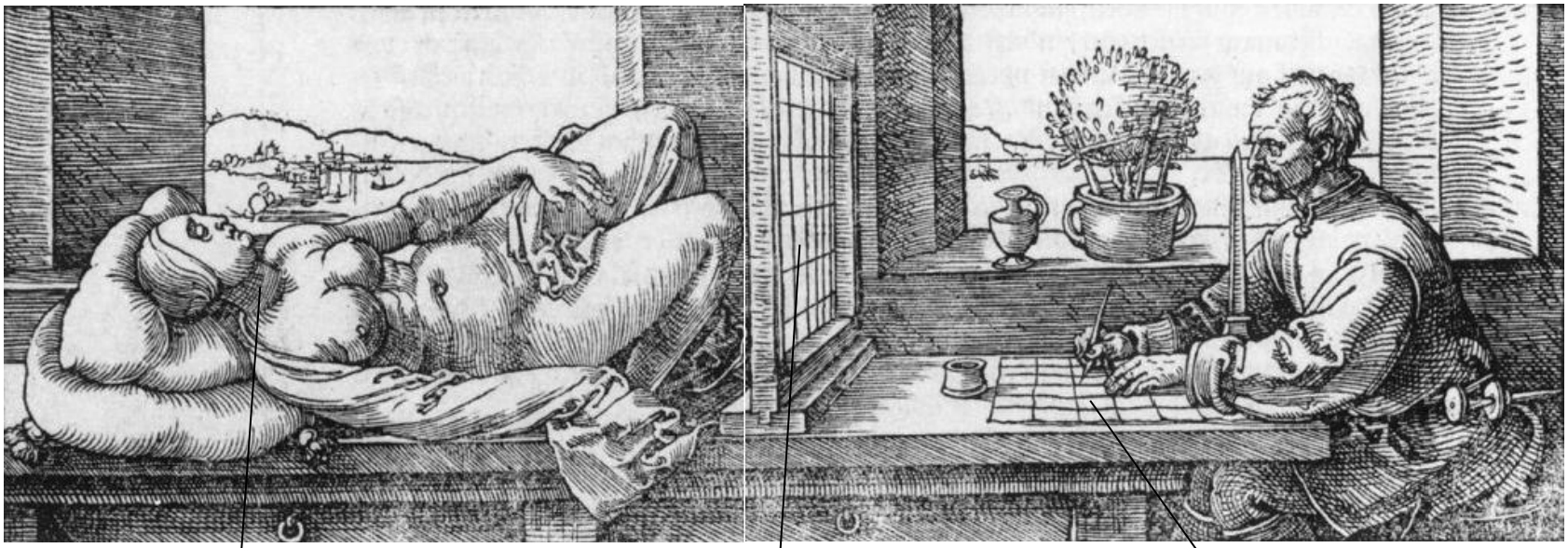

Vnderweysung der Messung/
mit dem Zirckel vnd richtscheyt/
in Linien Ebnen vñ gantzen Corporen/durch Albrecht
Dürer zusamen gezogen/ vñ durch jn selbs (als er noch
auff erden war) an vil orten gebessert/ in sonder-
heyt mit. rrij. figurē gemert die selbigen auch
mit eygner handt auffgerissen/ wie es
dann eyn yder werckman erfaren
wirdt/ Nun aber zu nutz allen
kunst liebhabenden in
truck geben.
M
D
XXXVIII

Underweysung der Messung, mit dem Zirckel und Richtscheyt, in Linien, Ebenen unnd gantzen corporen

durch Albrecht Dürer zů sammen getzogen / vnd zů nutz allen kunstlieb habenden mit zů gehörigen figuren / in truck gebracht / im jar. M. D. X X v.

iba Dosimetry

Albrecht Dürer, wood engrave



3D Anatomy

Beamlets

2D plot

iba Dosimetry

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)]
Canis Lupus LLC and Department of Human Oncology, University of Wisconsin, Merrimac, Wisconsin 53561

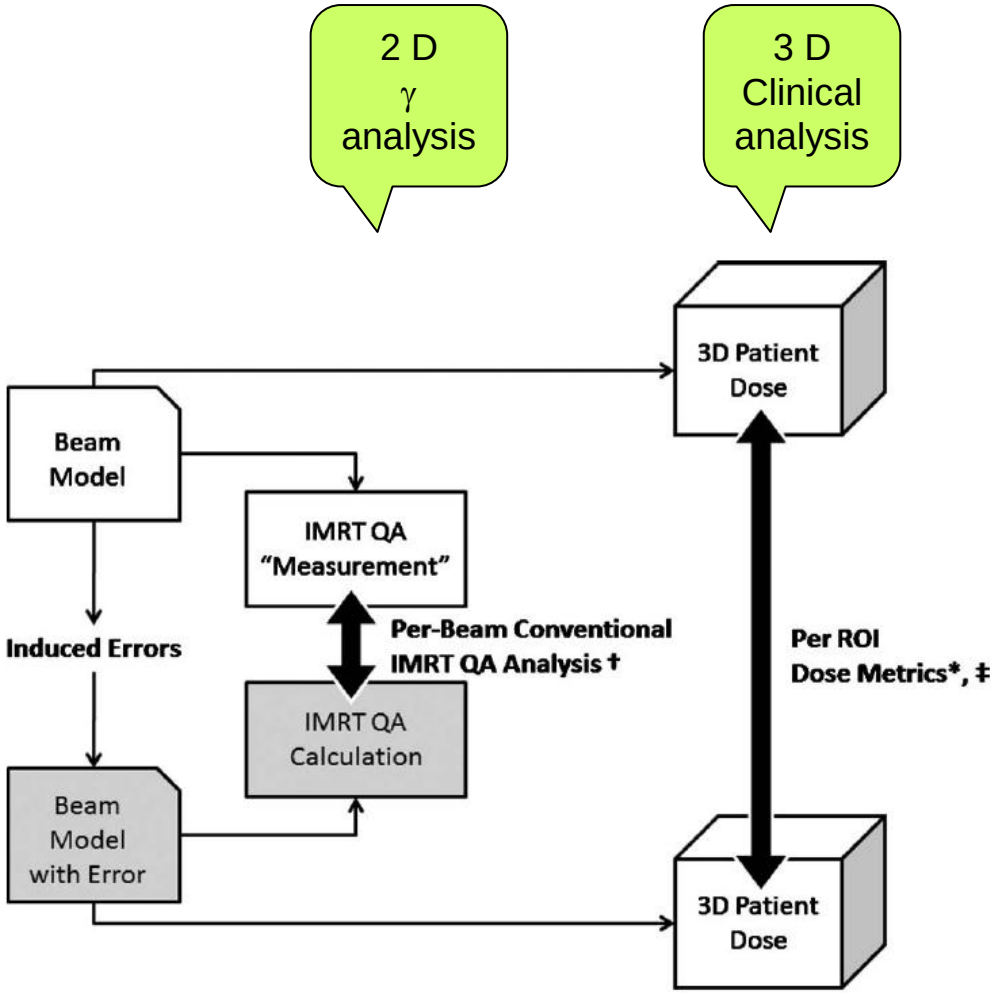
Heming Zhen
Department of Medical Physics, University of Wisconsin, Madison, Wisconsin 53705

Wolfgang A. Tomé
Departments of Human Oncology, Medical Physics, and Biomedical Engineering, University of Wisconsin, Madison, Wisconsin 53792

Medical Physics, Vol. 38, No. 2, February 2011

iba Dosimetry

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%

iba Dosimetry

Requirement for QA Procedure

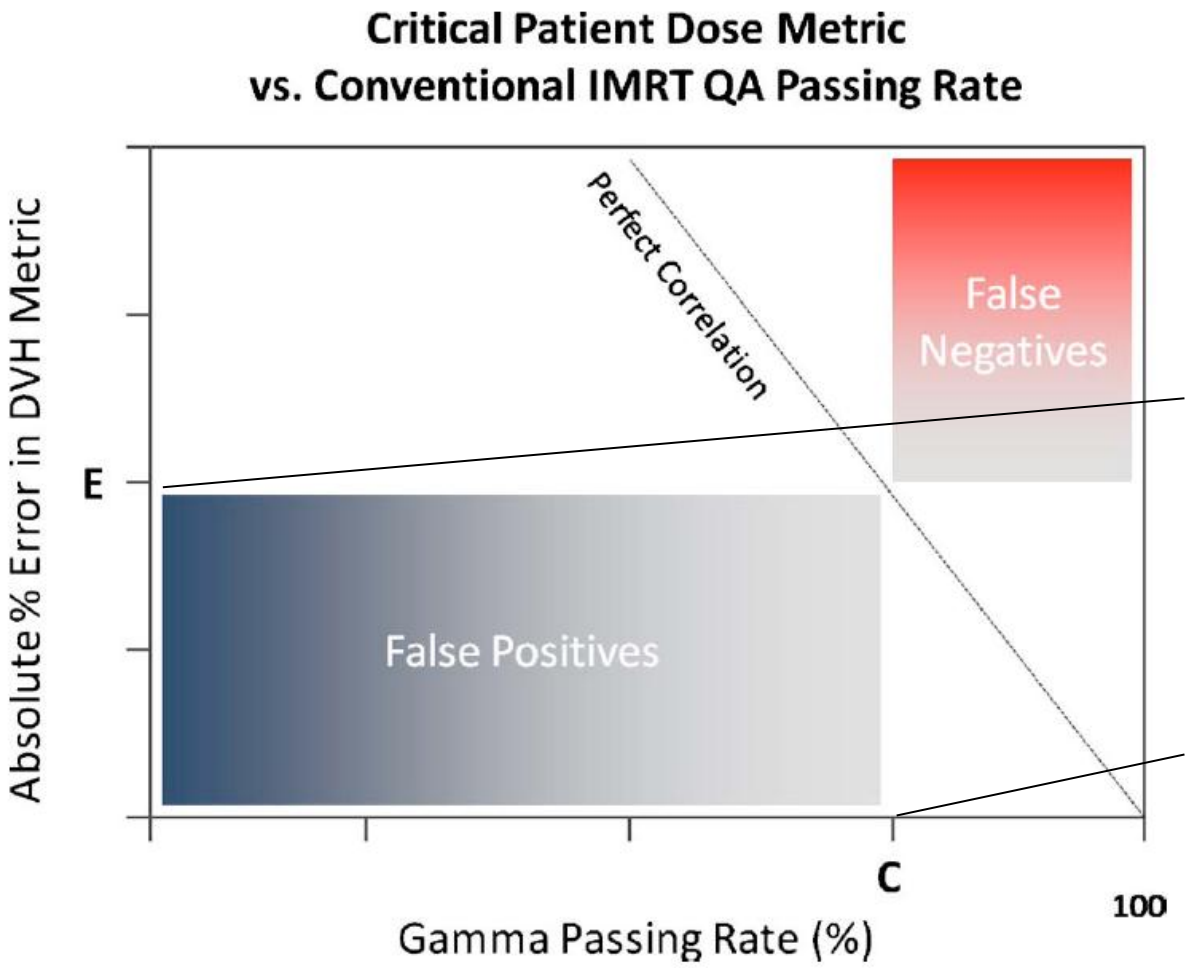
In presence of clinically relevant errors, the QA procedure should result in ‚fail‘

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

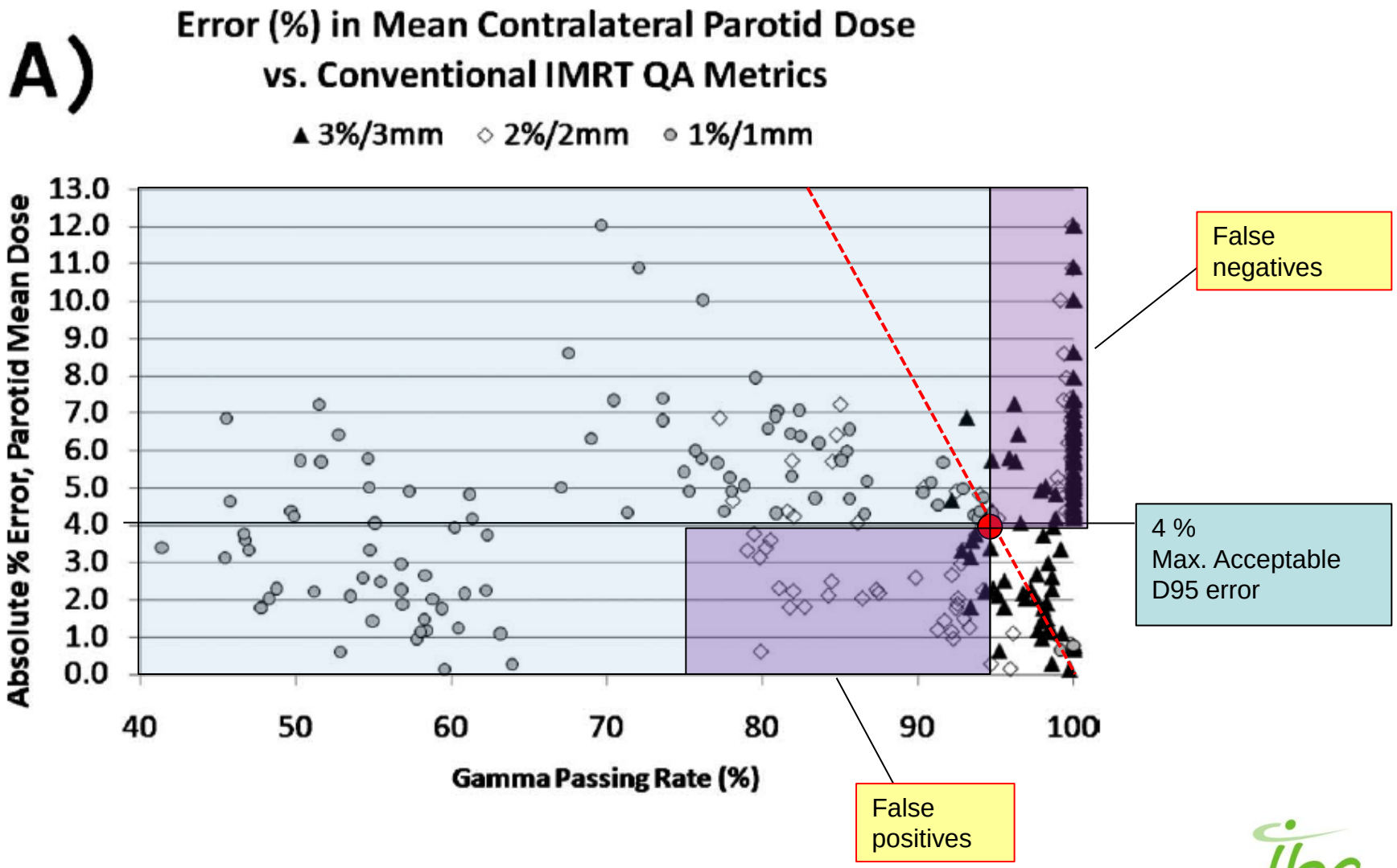


e.g. Max tollerable dose to 1cc of spinal cord

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

Dosimetry

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

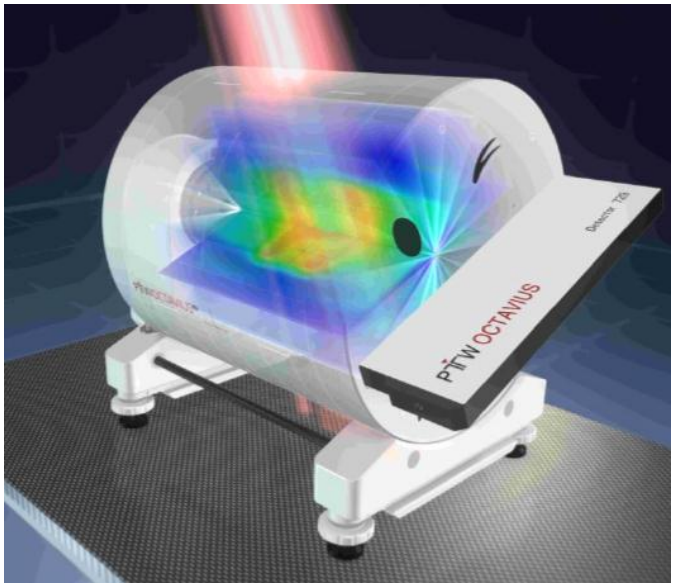
There is a lack of correlation between conventional IMRT QA performance metrics (Gamma passing rates) and dose differences in critical anatomic regions-of-interest. The most common acceptance criteria and published actions levels therefore have insufficient, or at least unproven, predictive power for 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.

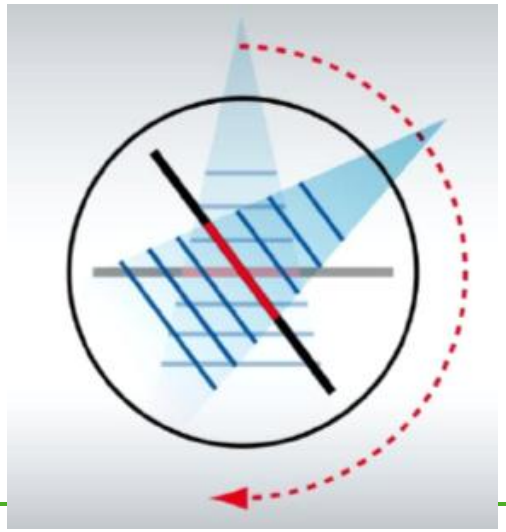
Dose Reconstruction in Patient Anatomy

Salvador *Dalí*
Venus de Milo with Drawers

Original plaster of 1936 with metal knobs on the drawers and white fur tuft covers

The PTW approach





OCTAVIUS 4D

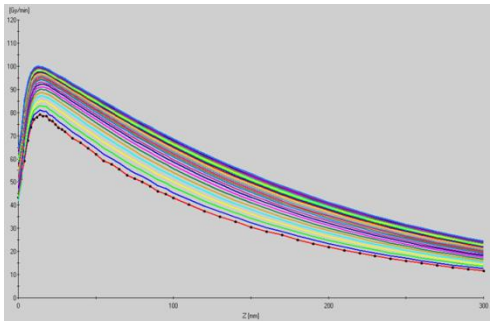
- 2D IC Array
- 729 ionization chambers
- chamber volume: 0.125cm³
- chamber distance : 10 mm
- active area: 27x27 cm²
- Sampling time: 200 ms

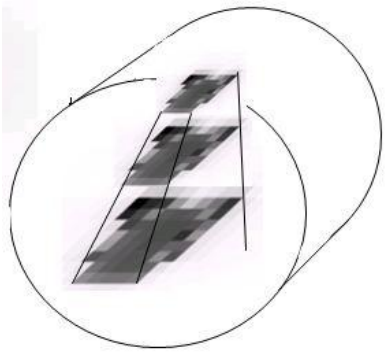
- Phantom rotates motor driven simultaneous with the gantry
- Inclinometer
- no correction for gantry angle dependent response needed

Courtesy of B.Rhein, DKFZ

The PTW approach

3D dose projection inside the phantom





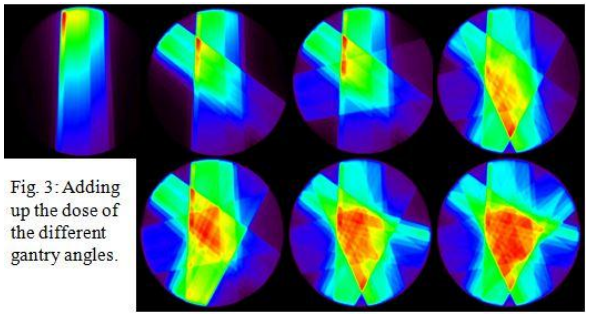
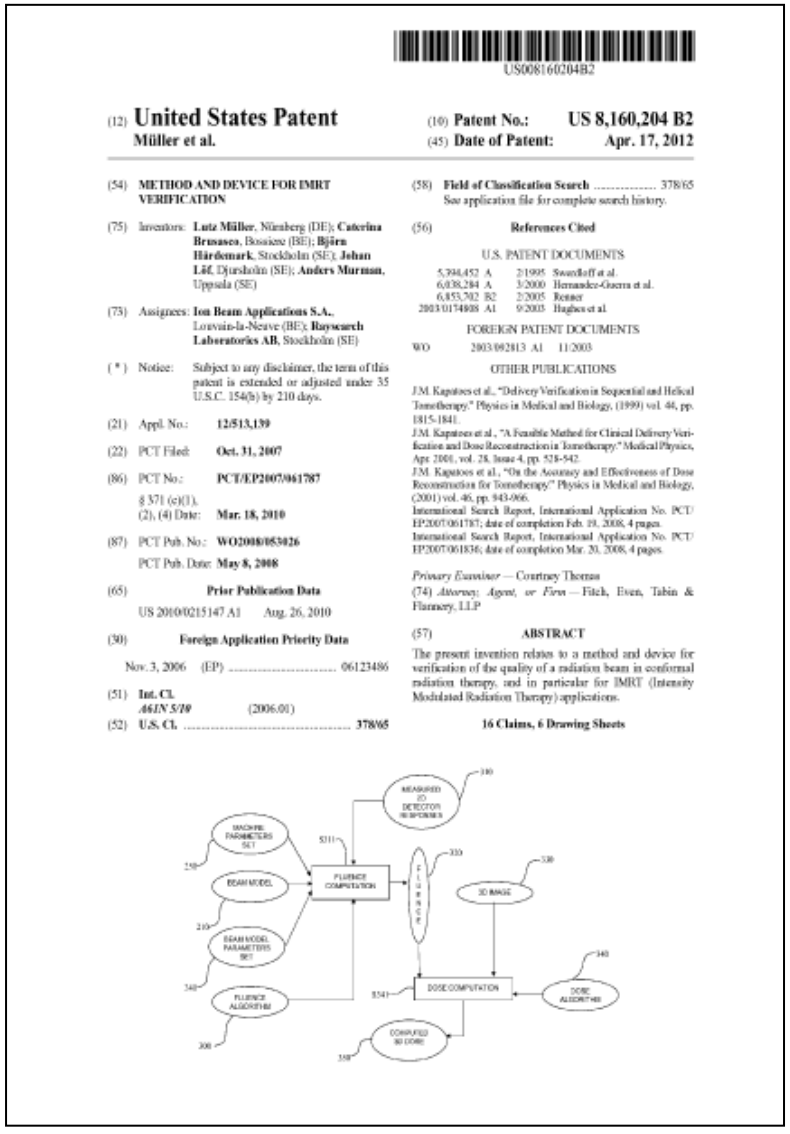


Fig. 3: Adding up the dose of the different gantry angles.

- Measured depth dose curves
- The equivalent field size for each segment or control point is calculated from detector signal
- The depth dose for the equivalent field size is normalized to the detector dose for each segment (or control point)
- All projected 3D doses per segment or control points are summed up

COMPASS patents



US008160204B2

(12) **United States Patent**
Müller et al.

(10) **Patent No.: US 8,160,204 B2**
(45) **Date of Patent: Apr. 17, 2012**

(54) **METHOD AND DEVICE FOR IMRT VERIFICATION**

(75) Inventors: **Lutz Müller**, Nürnberg (DE); **Caterina Brusasco**, Bossière (BE); **Björn Härdemark**, Stockholm (SE); **Johan Löf**, Djursholm (SE); **Anders Murman**, Uppsala (SE)

(73) Assignees: **Ion Beam Applications S.A.**, Louvain-la-Neuve (BE); **Raysearch Laboratories AB**, Stockholm (SE)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 210 days.

(21) Appl. No.: **12/513,139**

(22) PCT Filed: **Oct. 31, 2007**

(86) PCT No.: **PCT/EP2007/061787**
§ 371 (c)(1),
(2), (4) Date: **Mar. 18, 2010**

(87) PCT Pub. No.: **WO2008/053026**
PCT Pub. Date: **May 8, 2008**

(65) **Prior Publication Data**
US 2010/0215147 A1 Aug. 26, 2010

(30) **Foreign Application Priority Data**
Nov. 3, 2006 (EP) 06123486

(51) **Int. Cl.**
A61N 5/10 (2006.01)

(52) **U.S. Cl.** **378/65**

(58) **Field of Classification Search** 378/65
See application file for complete search history.

(56) **References Cited**

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FOREIGN PATENT DOCUMENTS

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J.M. Kapatoes et al., "A Feasible Method for Clinical Delivery Verification and Dose Reconstruction in Tomotherapy." Medical Physics, Apr. 2001, vol. 28, Issue 4, pp. 528-542.
J.M. Kapatoes et al., "On the Accuracy and Effectiveness of Dose Reconstruction for Tomotherapy." Physics in Medical and Biology, (2001) vol. 46, pp. 943-966.
International Search Report, International Application No. PCT/EP2007/061787; date of completion Feb. 19, 2008, 4 pages.
International Search Report, International Application No. PCT/EP2007/061836; date of completion Mar. 20, 2008, 4 pages.

Primary Examiner — Courtney Thomas
(74) *Attorney, Agent, or Firm* — Fitch, Even, Tabin & Flannery, LLP

(57) **ABSTRACT**

The present invention relates to a method and device for verification of the quality of a radiation beam in conformal radiation therapy, and in particular for IMRT (Intensity Modulated Radiation Therapy) applications.

16 Claims, 6 Drawing Sheets

特　許　証
(CERTIFICATE OF PATENT)

特許第５０８５６６０号
(PATENT NUMBER)

発明の名称
(TITLE OF THE INVENTION)
オンラインＩＭＲＴ検証の方法および装置

特許権者
(PATENTEE)
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ヴ・シュマン・デュ・サイクロトロン・３
国籍　ベルギー王国
イオン・ビーム・アプリケーションズ・
エス・アー

その他別紙記載

発明者
(INVENTOR)
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カテリーナ・ブルサスコ
ビュルン・ホルデマルク

その他別紙記載

出願番号
(APPLICATION NUMBER)
特願２００９－５３５０８６

出願日
(FILING DATE)
平成１９年１１月　２日(November 2, 2007)

登録日
(REGISTRATION DATE)
平成２４年　９月１４日(September 14, 2012)

この発明は、特許するものと確定し、特許原簿に登録されたことを証する。
(THIS IS TO CERTIFY THAT THE PATENT IS REGISTERED ON THE REGISTER OF THE JAPAN PATENT OFFICE.)

平成２４年　９月１４日(September 14, 2012)

特許庁長官
(COMMISSIONER, JAPAN PATENT OFFICE)
岩井良行

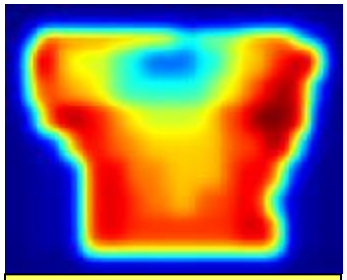
iba Dosimetry

Compass: from Entrance Fluence to 3D Patient Dose

DICOM plan

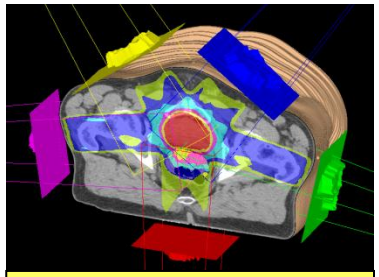
Beam model

MatriXX Detector

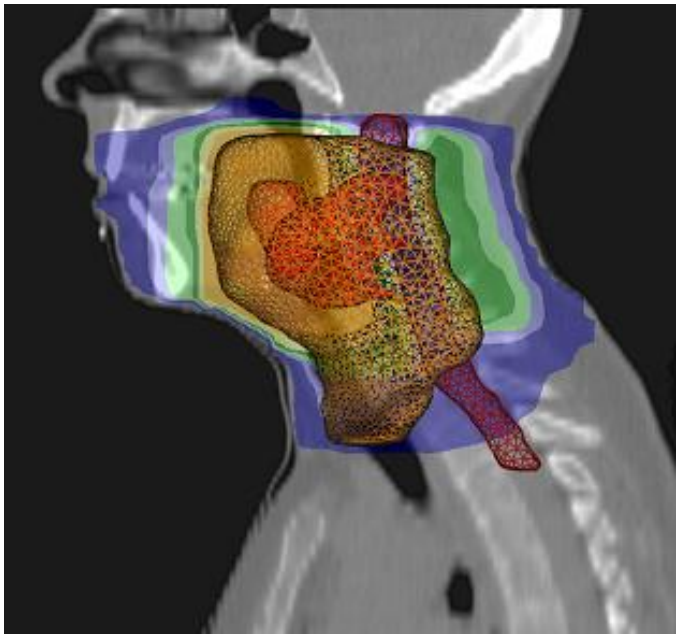


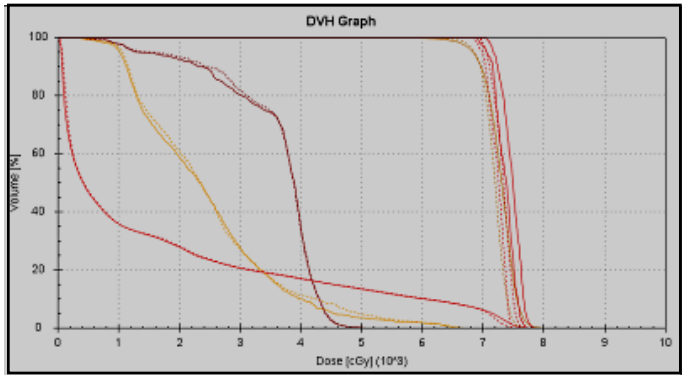
Real Fluence

CT



Dose engine





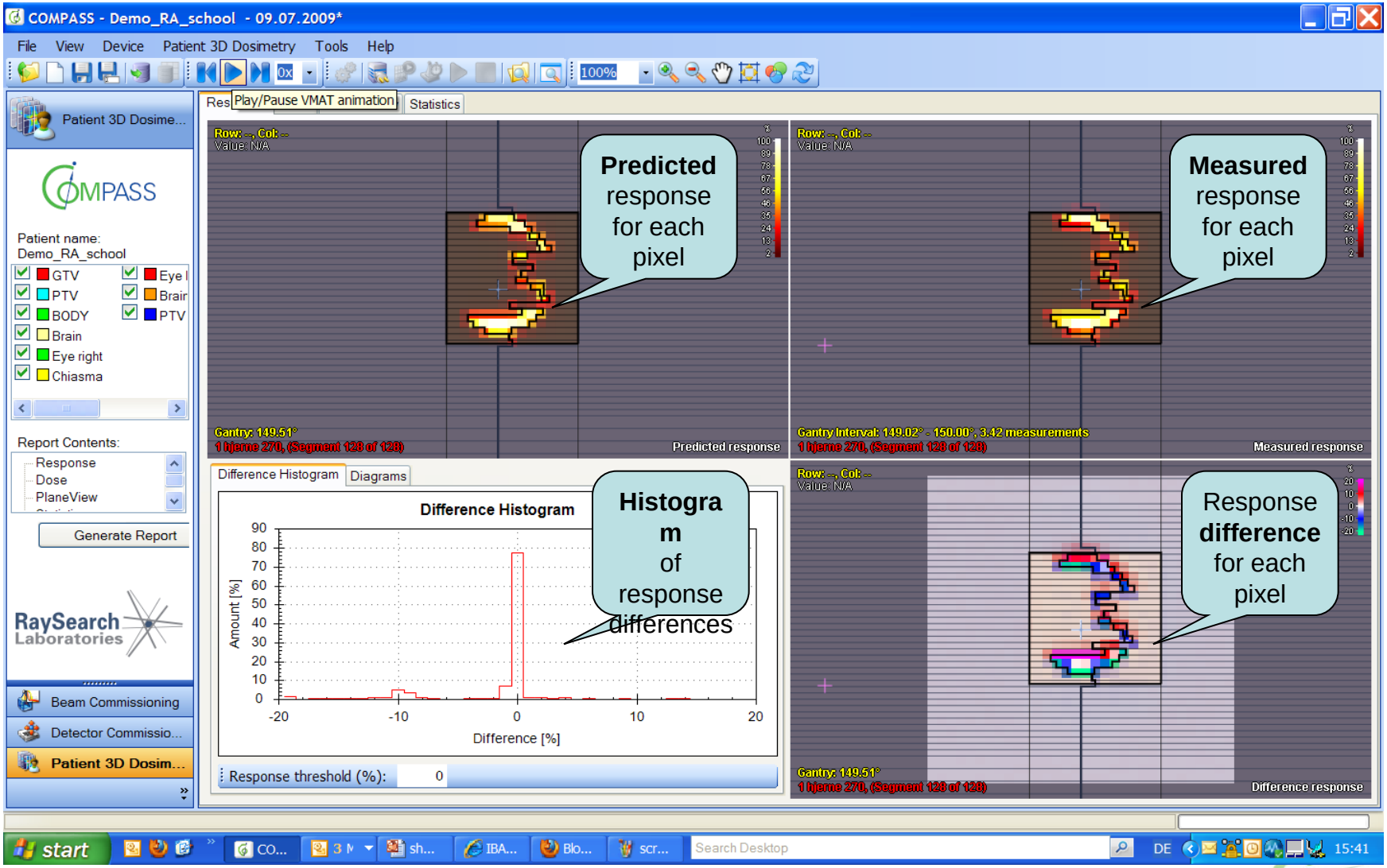
iba Dosimetry

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.

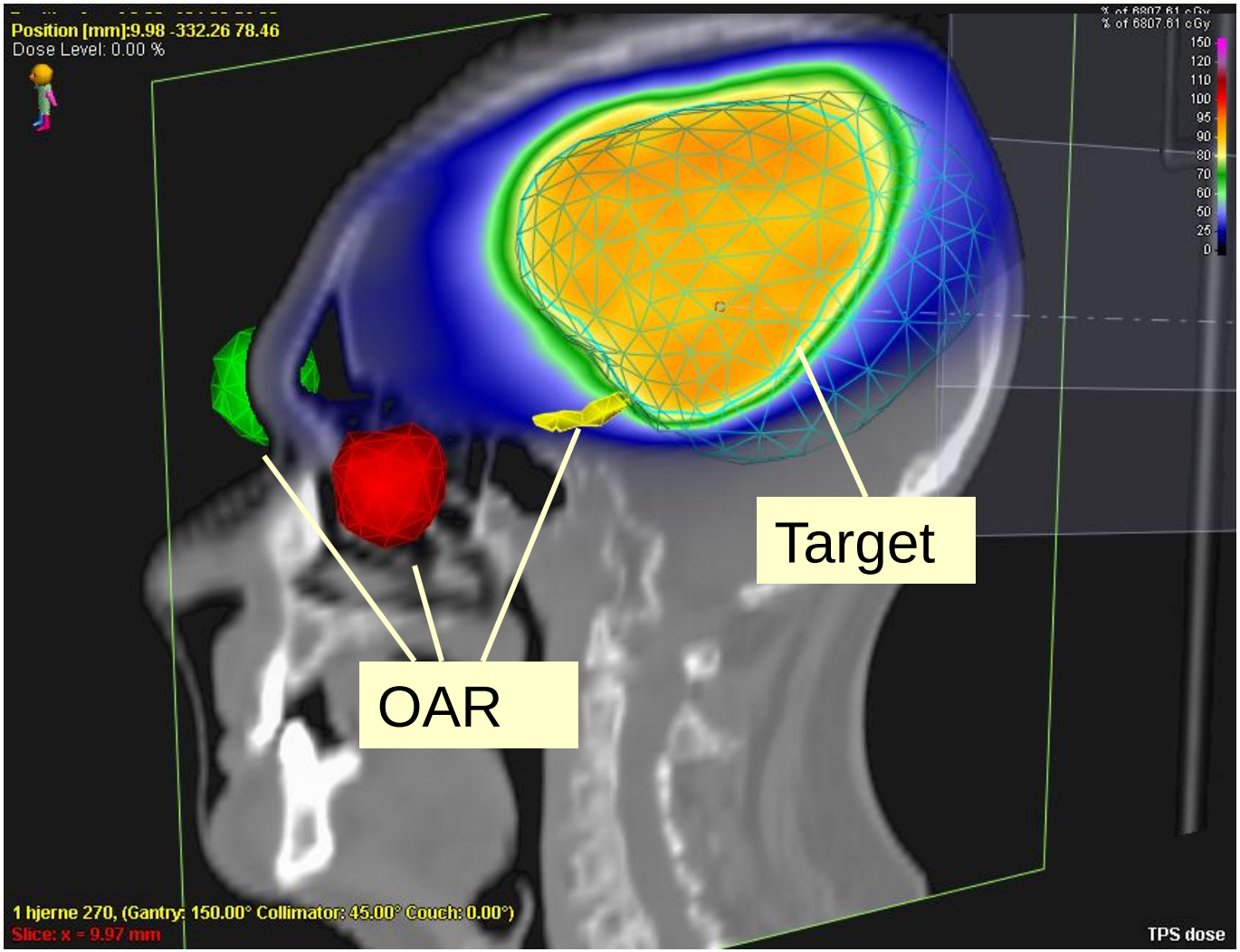
- This can be done also using an independent, validated, sufficiently accurate 3D dose alorithm, which is independent from the original treatment planning system.
- New in COMPASS 3.0 -> direct comparison measured- computed SHOWS INFLUENCE OF DELIVERY DIRECTLY

Response –Prediction vs. Measurement



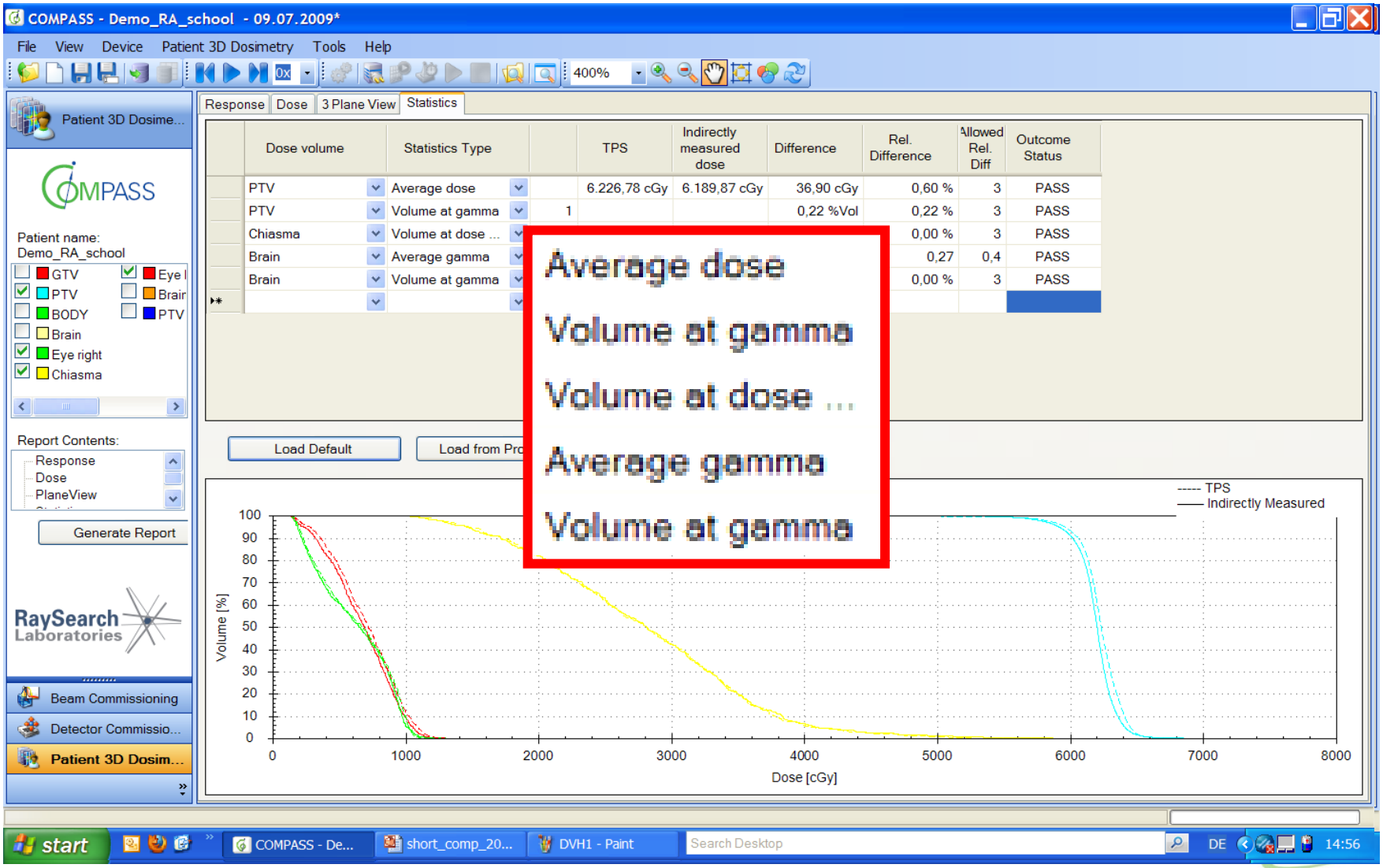
Iba Dosimetry

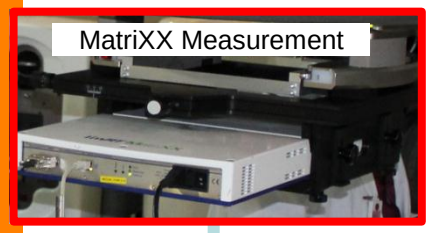
Dose measured

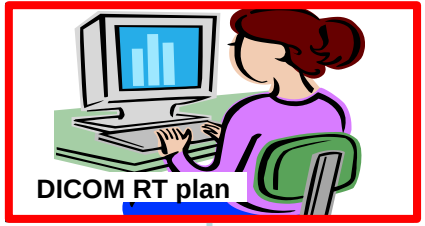


Dosimetry

DVH and beyond







Segment

Beam Model

Segment Fluence

apply

Weighted Fluence

Detector Model

Delivered Fluence

Measured Response

Predicted Response

A_{corr}

compare

Rescale

Residual Fluence

Residual Response

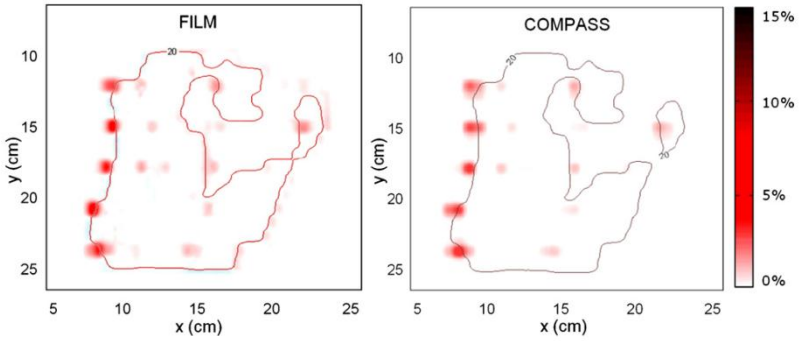
Deconvolution

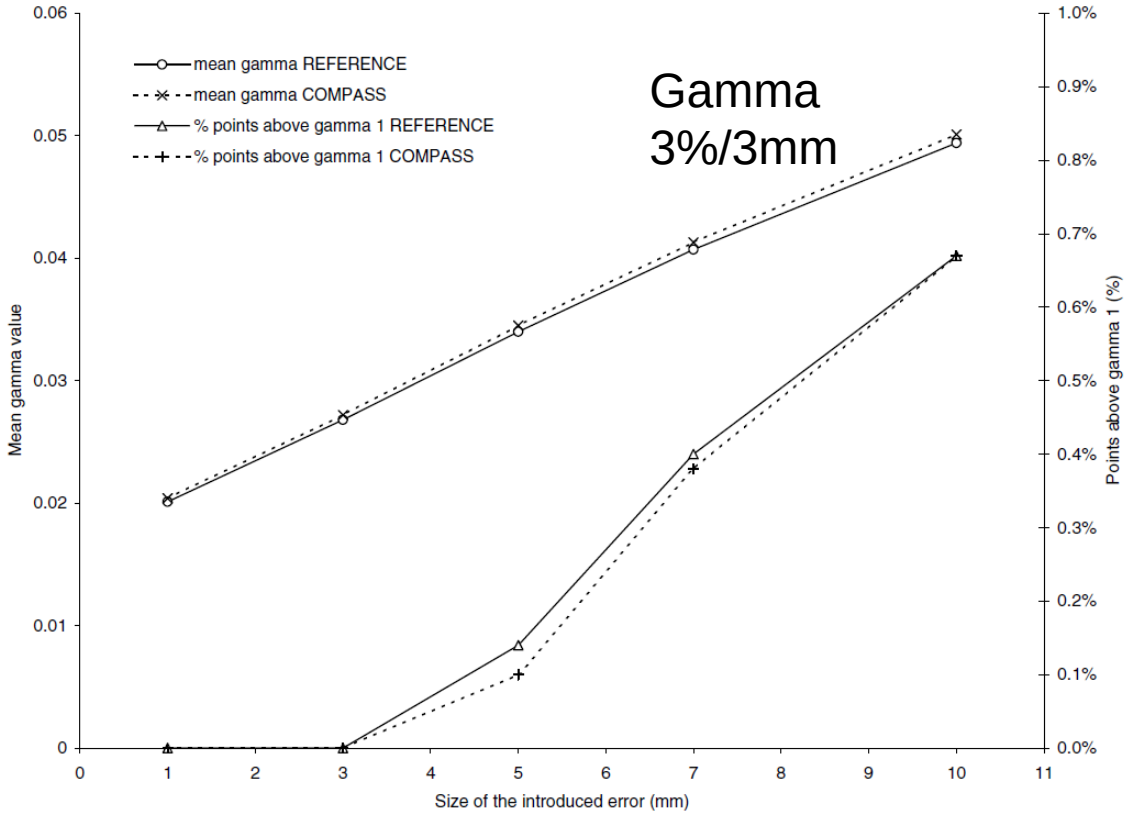
Dosimetry

New in Compass 3.0

- Patient Data Base
- Simplified Detector Commissioning (1 field only)
- 2D Functionality (~OmniProIMRT/gantry holder)
- Better Commissioning
- Reconstructed/Calculated direct Comparison
- Multiple Measurements w/o Plan Reload
- Faster Algorithm (3-5 times)
- Upcoming COMPASS 3.1: Quick Check

COMPASS vs. Film





IOP PUBLISHING PHYSICS IN MEDICINE AND BIOLOGY
Phys. Med. Biol. **56** (2011) 5029–5043 doi:10.1088/0031-9155/56/15/023

Reconstruction of high-resolution 3D dose from matrix measurements: error detection capability of the COMPASS correction kernel method

J Godart[1], E W Korevaar[1], R Visser[1,2], D J L Wauben[1] and A A van't Veld[1]

iba Dosimetry

Correlation 2D/D

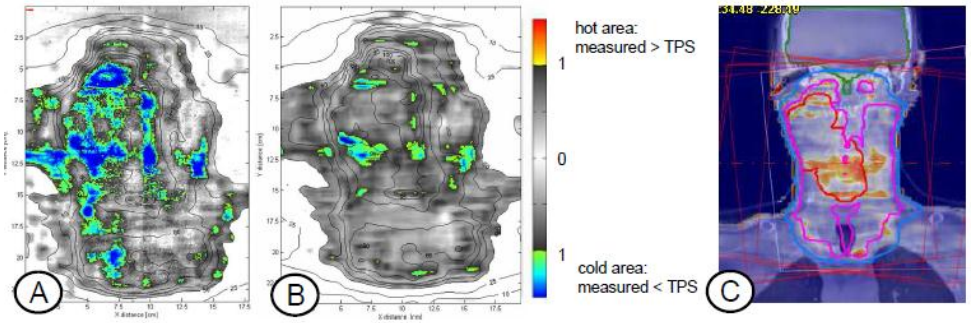


Figure 4: Mean gamma evaluations of (A) TPS vs film (B) TPS vs COMPASS plane QA (C) TPS vs COMPASS CT QA

Film Compass2D Compass3D

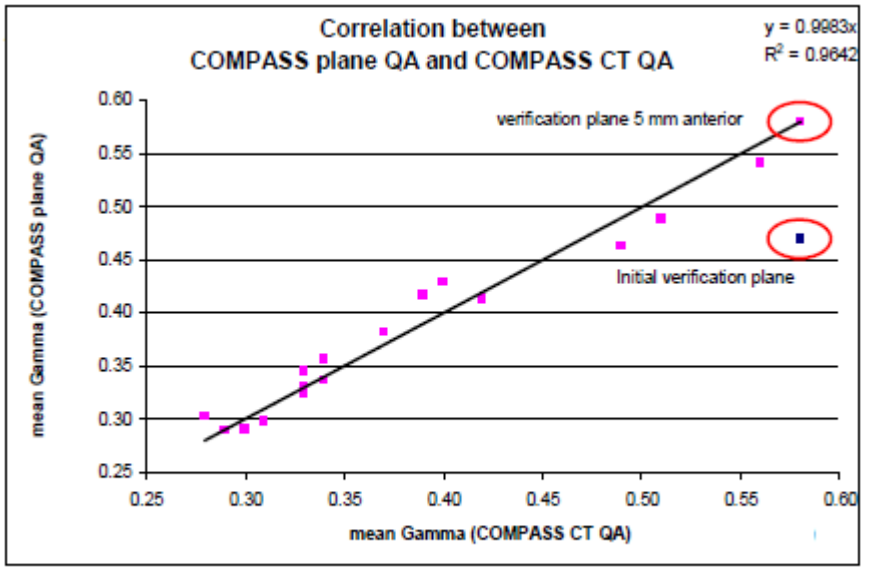


Figure 5: Correlation between COMPASS plane QA and COMPASS CT QA

It showed

CONCLUSION

The transition from pre-treatment QA using film in a phantom, to QA verification in patient CT by using the COMPASS system with the MatriXX detector was done without any difficulties.

Discrepancies can be quantified in clinical relevant structures using the patient CT and clinical PTVs and OARs. Physicians are now more aware whether discrepancies detected are of clinical importance. The method has been clinically introduced in December 2009.

D.J.L Wauben et al.
ESTRO 2010

iba Dosimetry

A Customer Testimonial: Compass: The Hull Experience

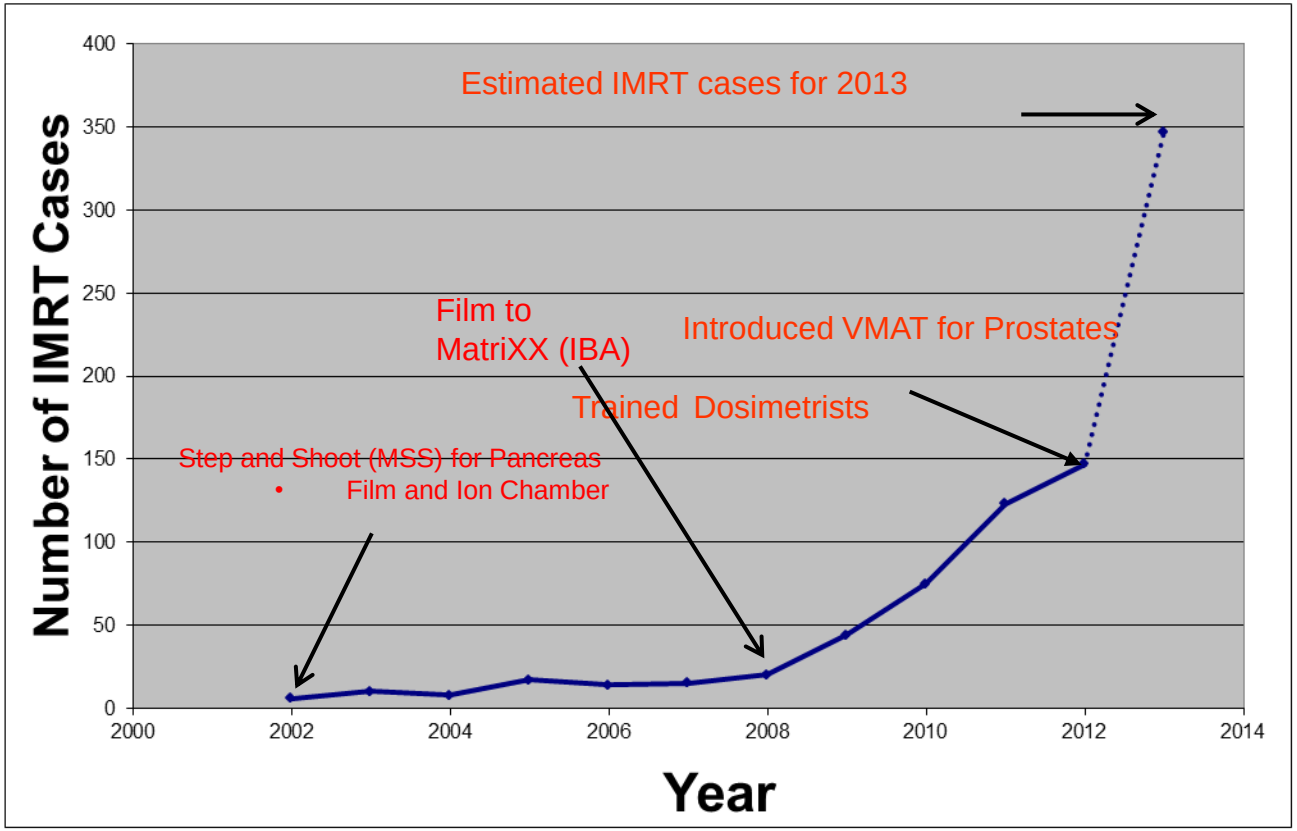
Kevin Brownsword

Castle Hill Hospital, Hull, UK

ESTRO 2013
Geneva, Switzerland

Dosimetry

Background to IMRT in Hull



Why Compass?

- Familiar equipment
- Accurate 3D dose algorithm for independent recalculations
- 2D measure of output
- Indicate impact of 2D changes in 3D on patient CT
- Possible add-ons in future

iba Dosimetry

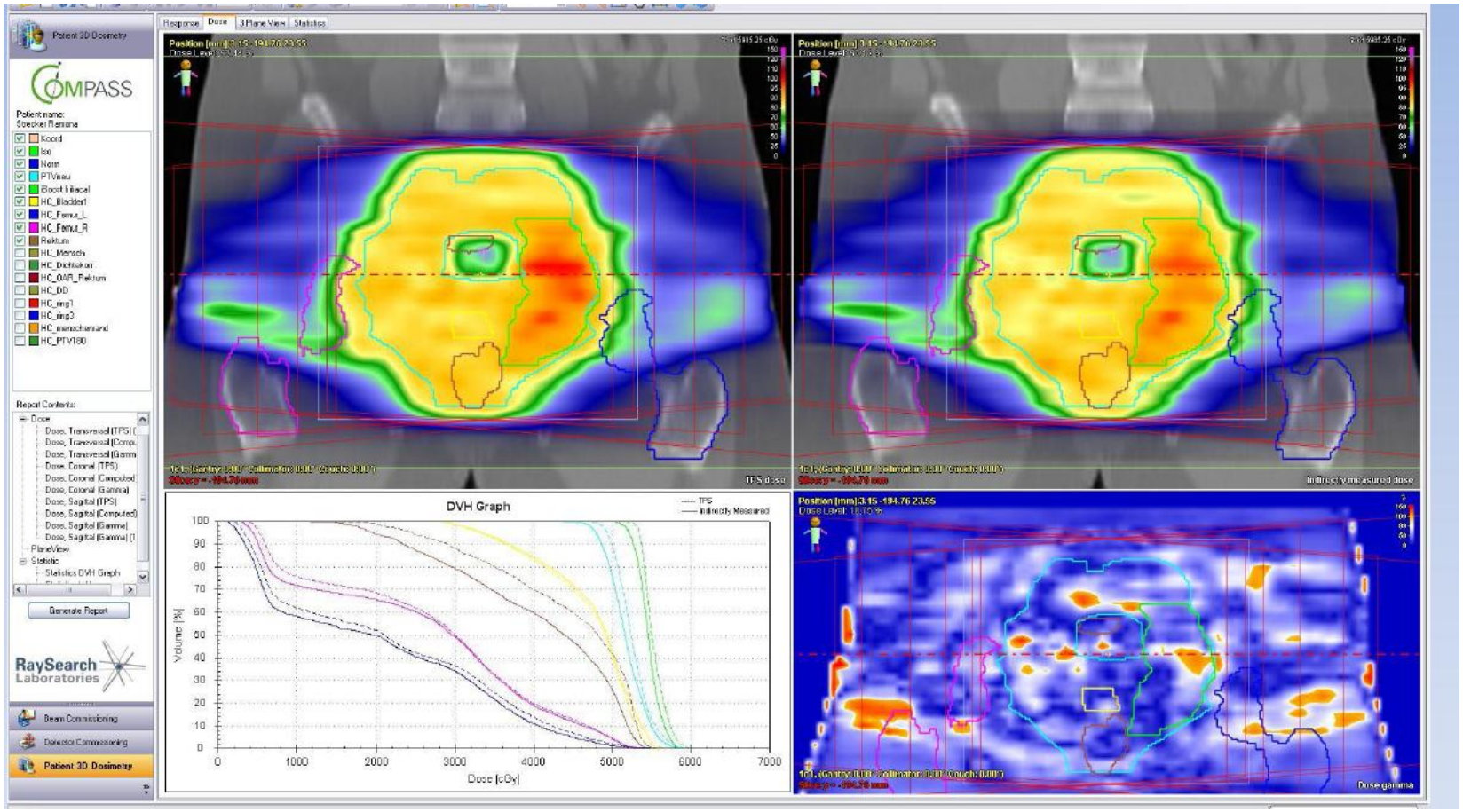
Clinical Plans

- **17 Clinical plans**
- **Assessment protocol as with pre-clinical plans**
- **2D Responses**
  - Most within ±2%
  - Worst around ±5%
- **Compass to CC13 comparison**

Linac	TPS (AAA)	Compass (Meas.)
CL1	-1.2%	-0.1%
CL2	-1.5%	1.0%
TB6	-0.8%	0.2%
Total	-1.6%	-0.2%

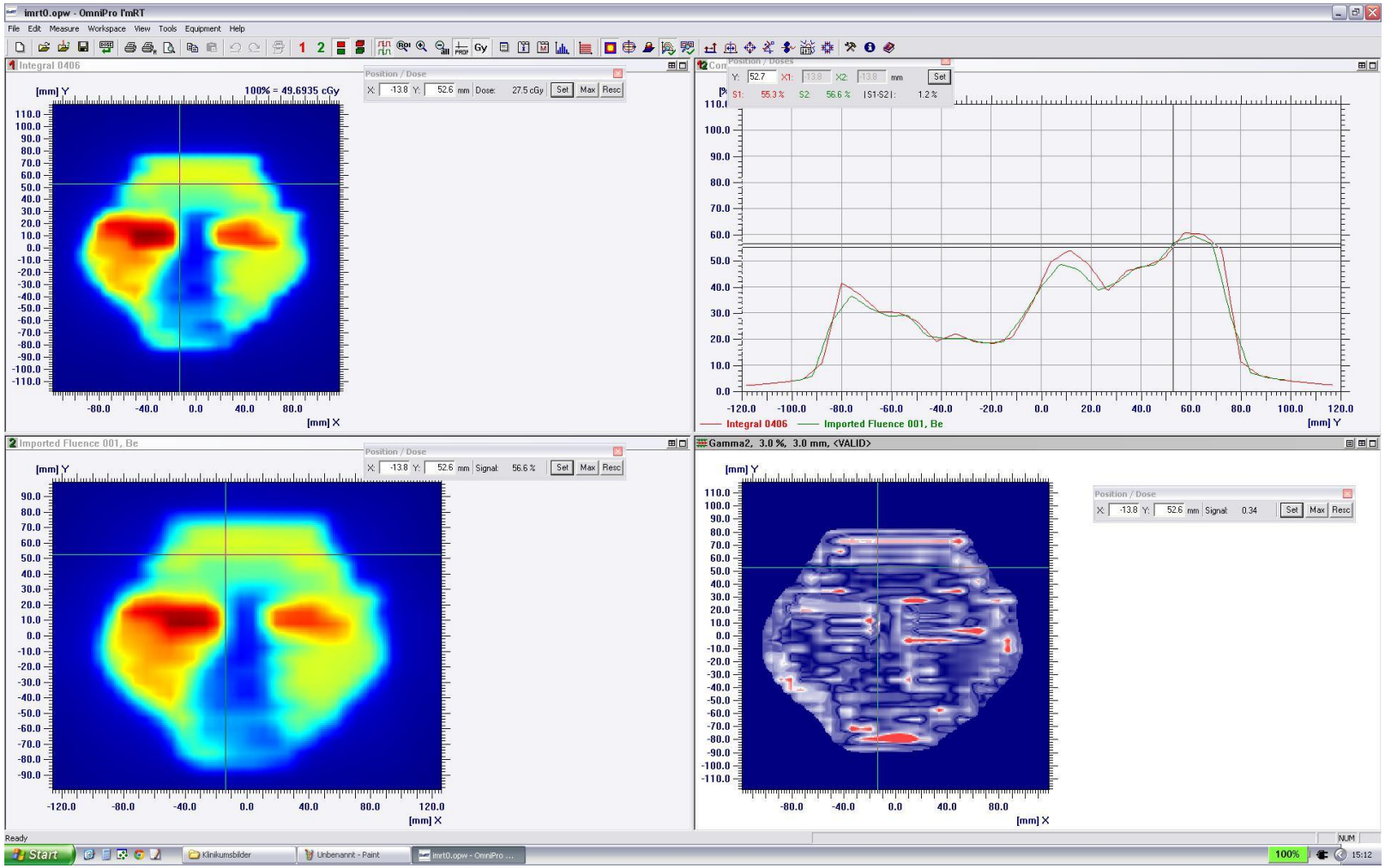
Mean deviation from point dose measurement

Deviations in a Pelvic Delivery



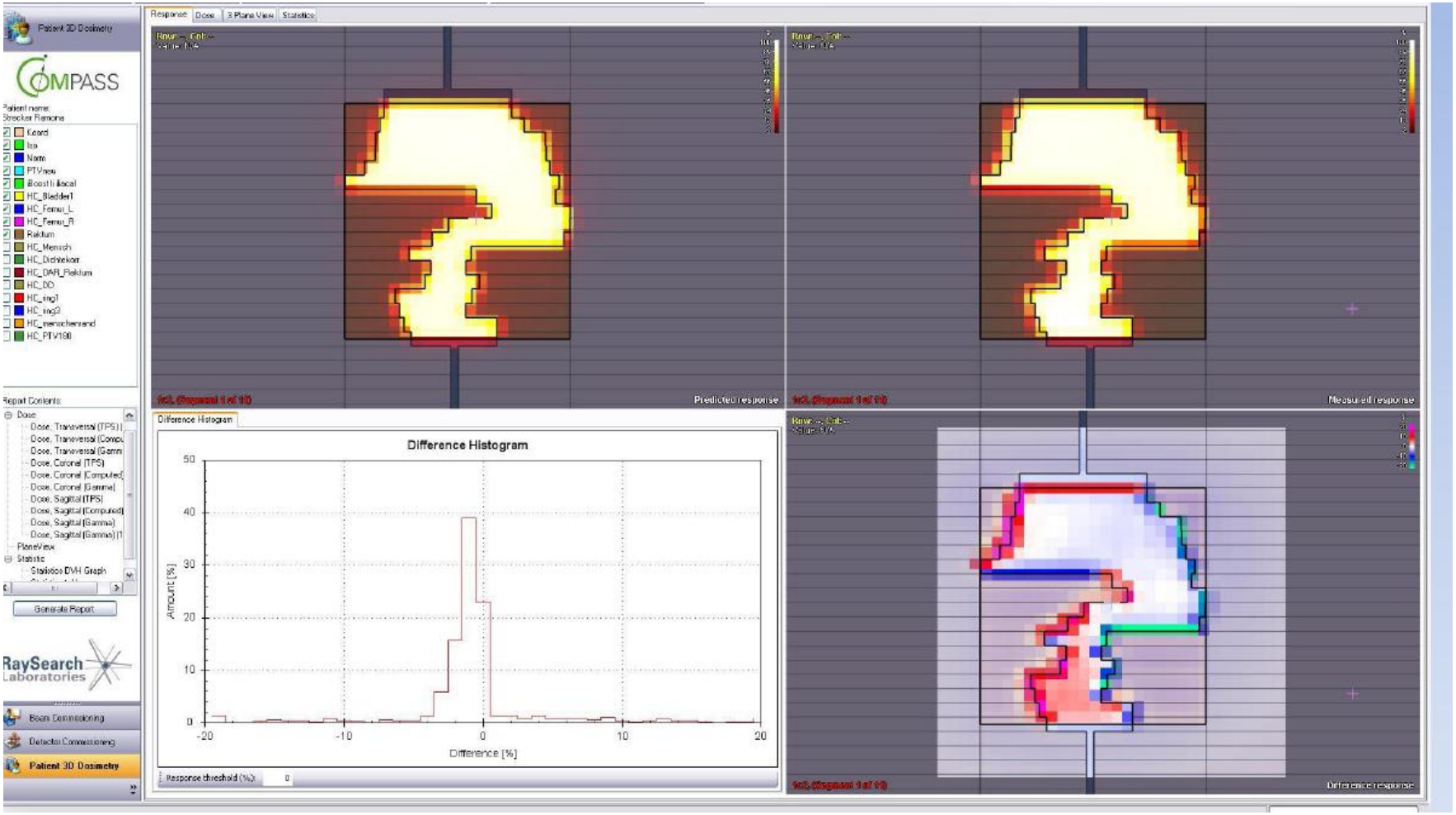
iba Dosimetry

2D QA Results



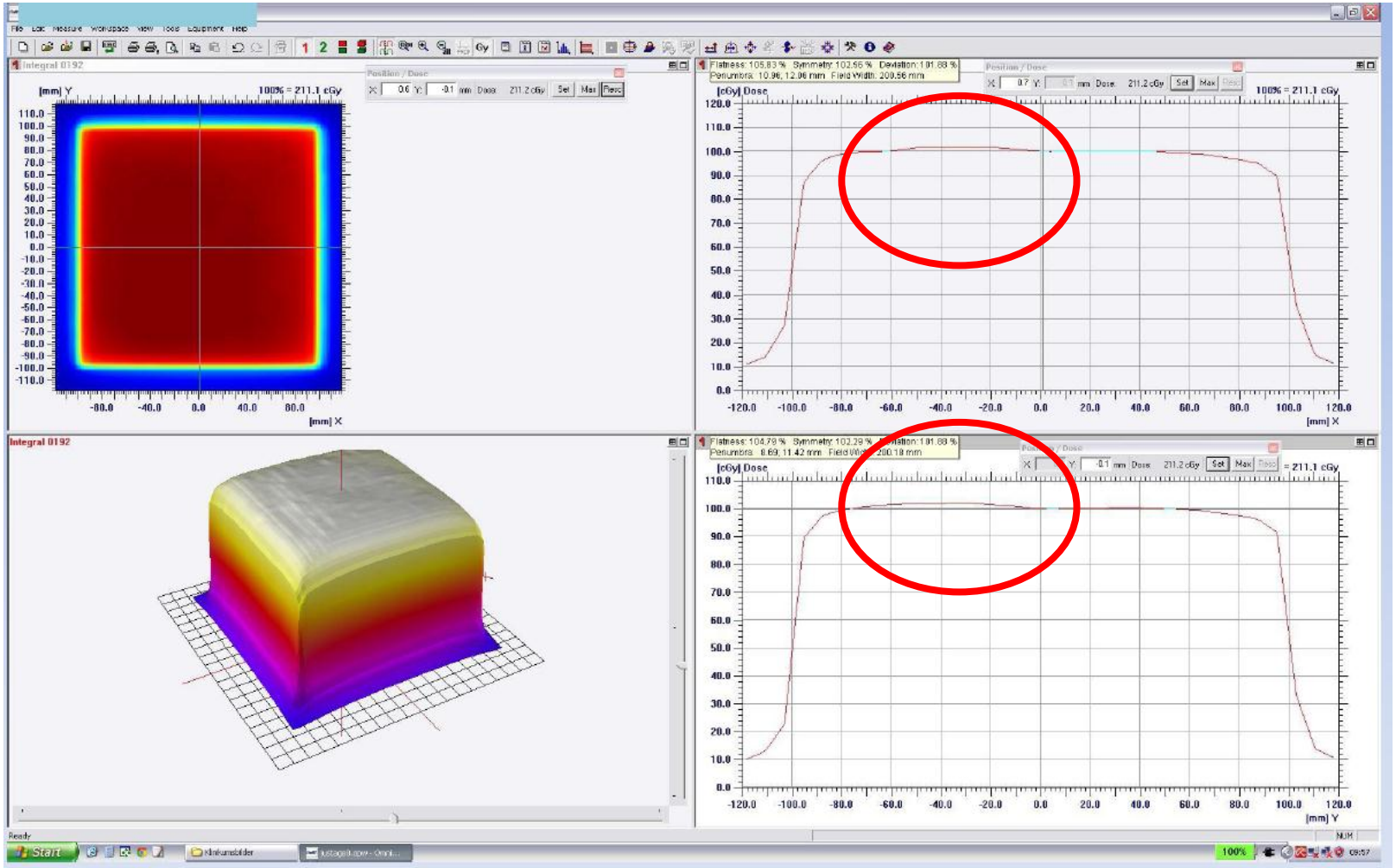
iba Dosimetry

Single Segment

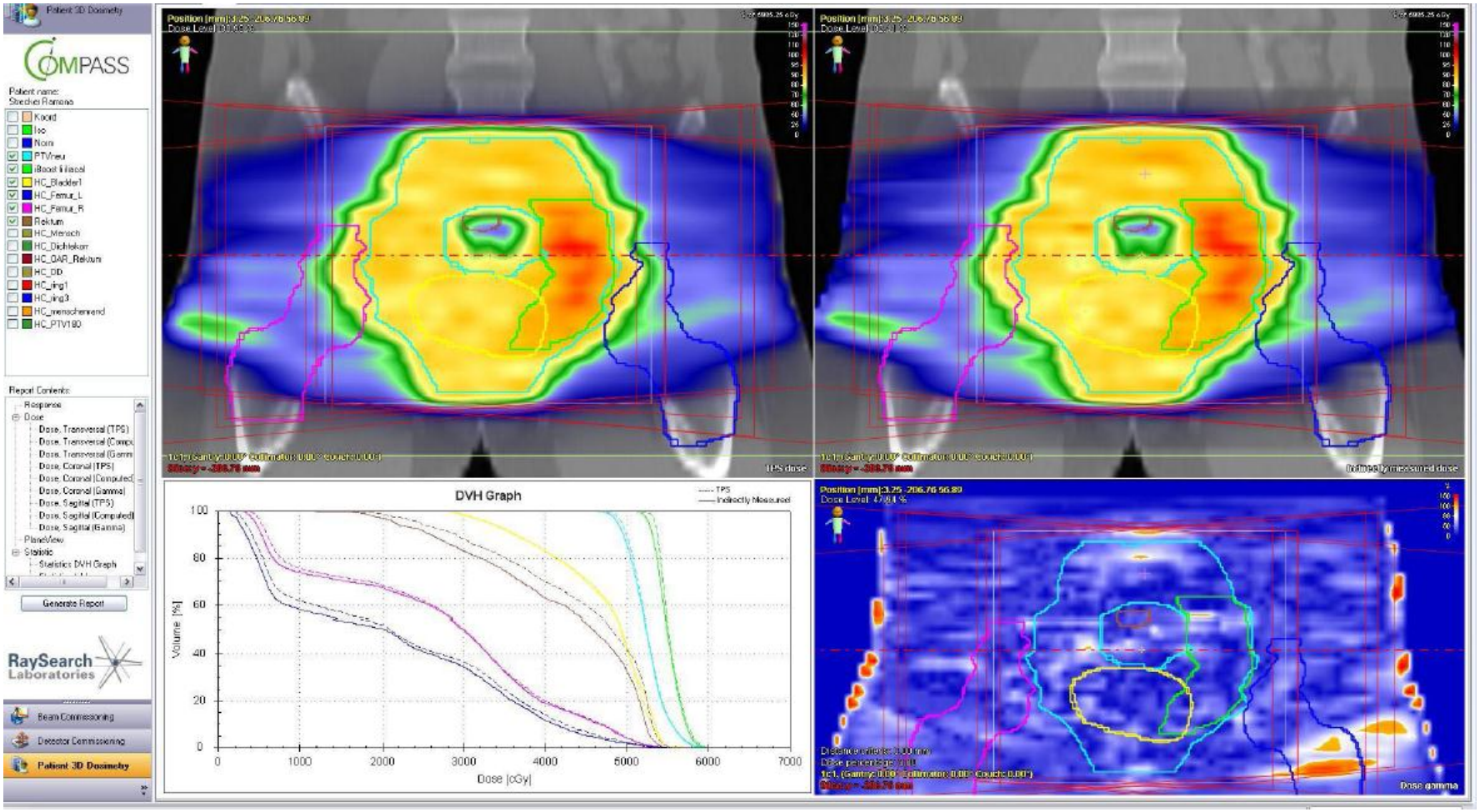


iba Dosimetry

Symmetry....

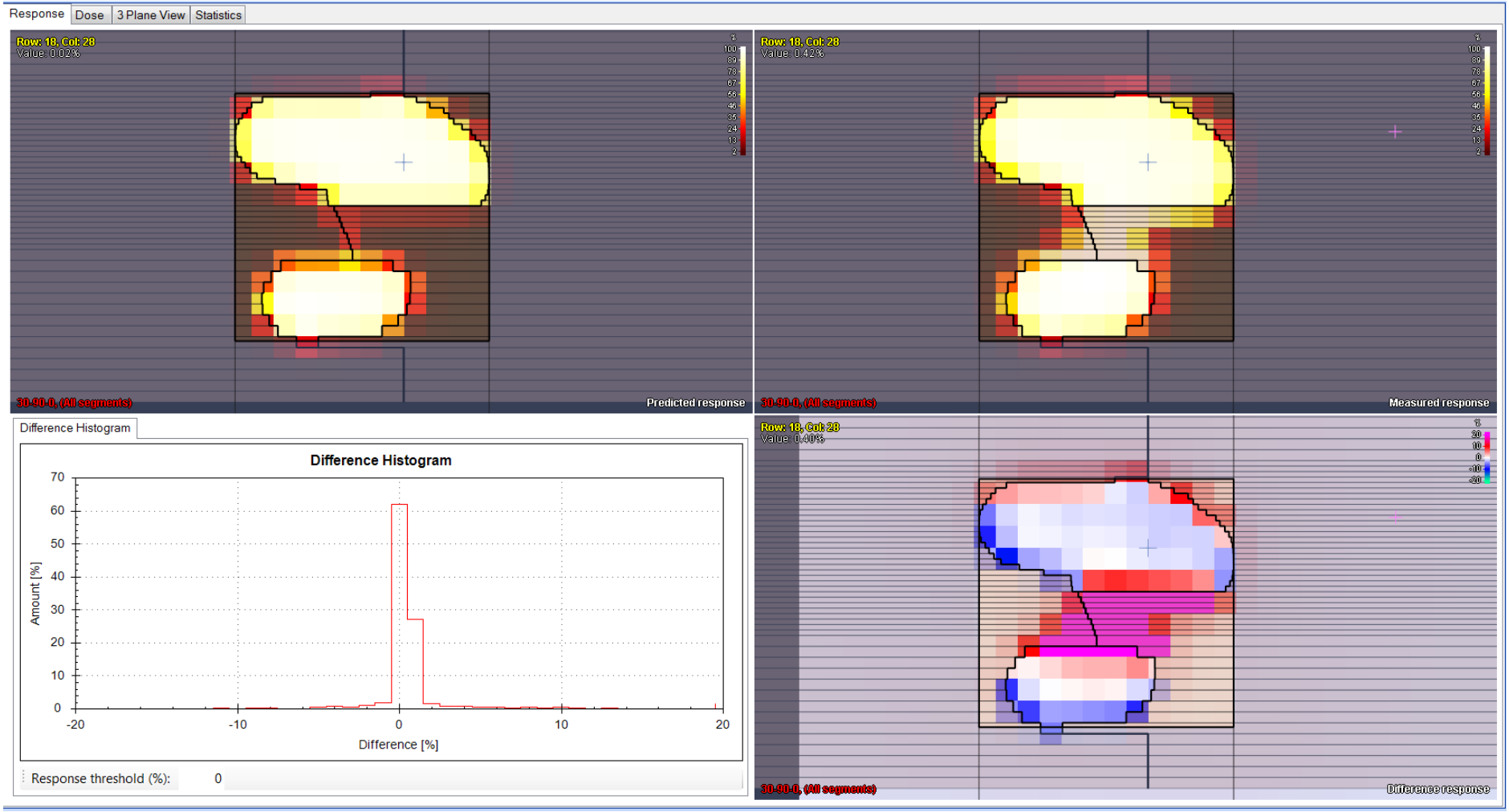

Integral 0192
[mm] Y
100% = 211.1 cGy
[mm] X
[cGy] Dose
[mm] X
Integral 0192
[cGy] Dose
[mm] Y

And after LINAC Repair

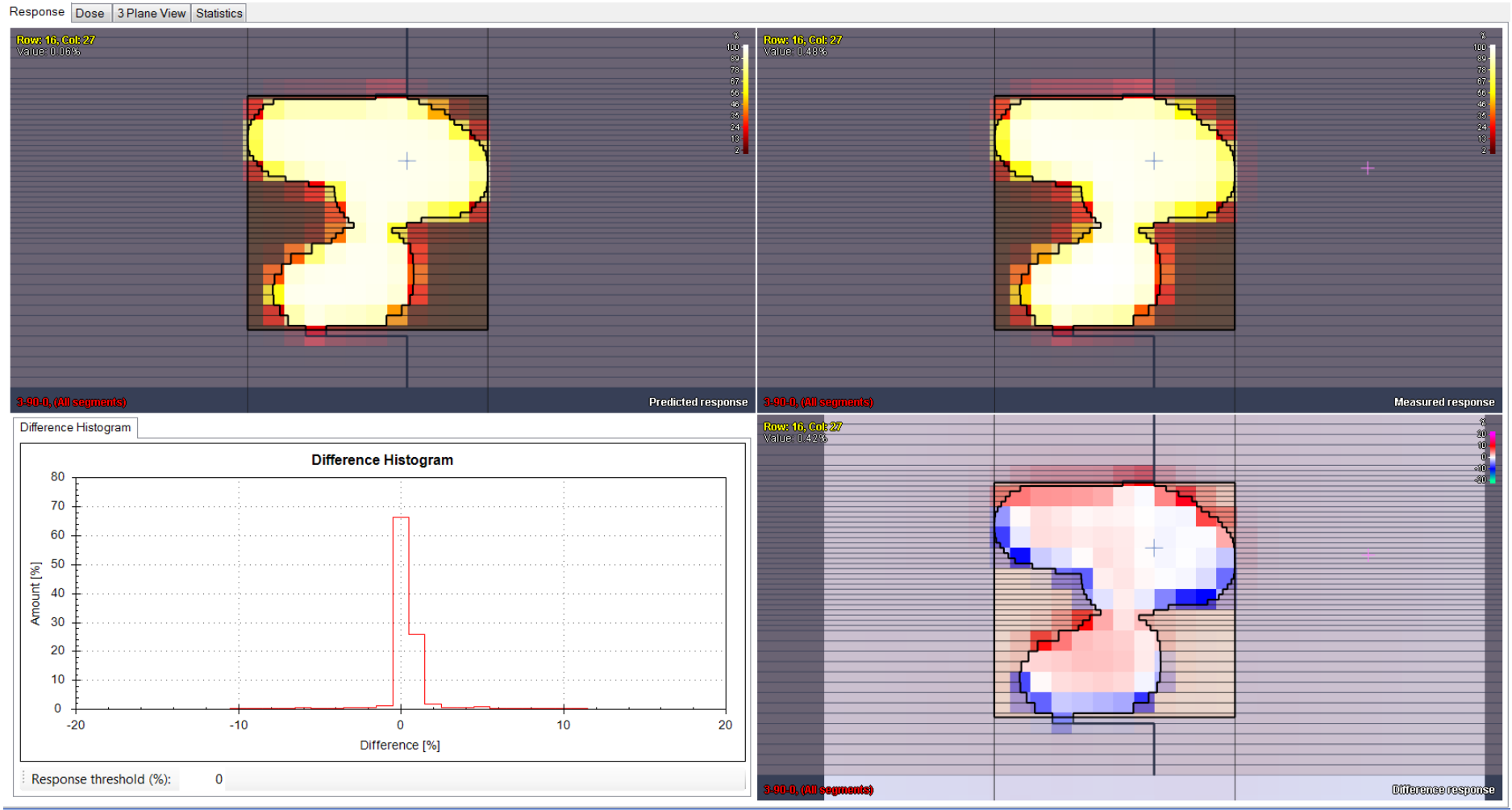


Dosimetry

Plan Iplan

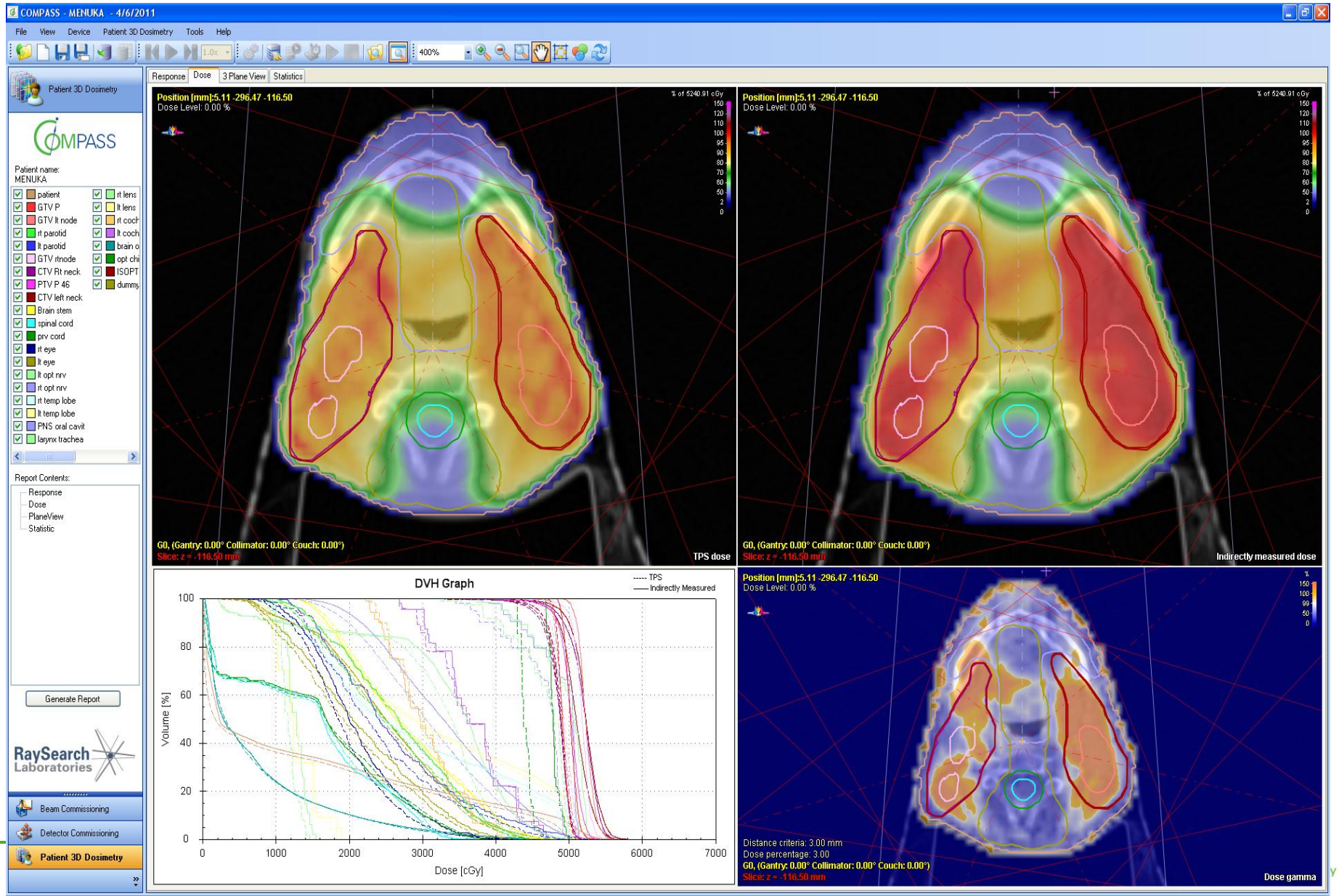


Plan Eclipse

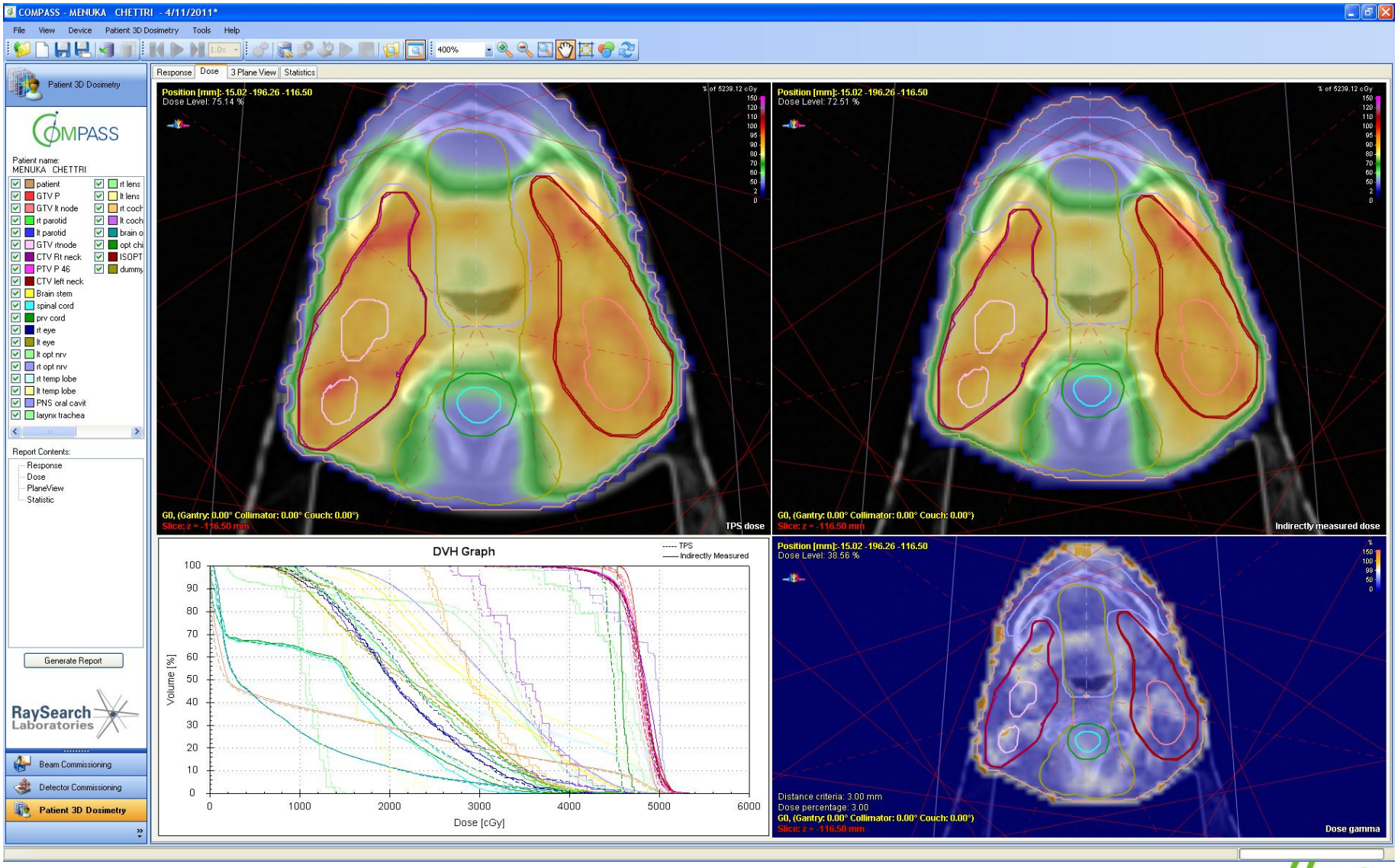


iba Dosimetry

PBC Recon Dose (6% higher than TPS)



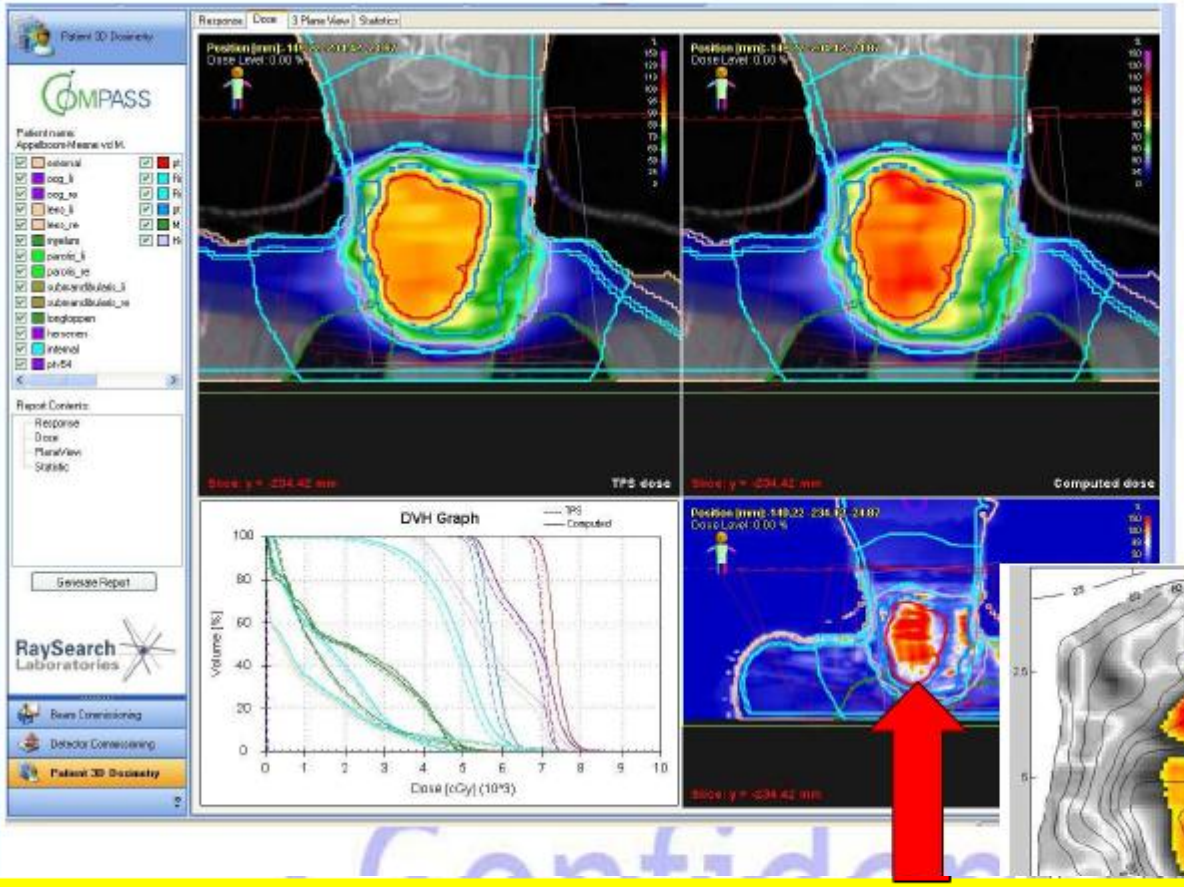
Monte Carlo Patient Plan



iba Dosimetry

Why do we do this? Patient 301..

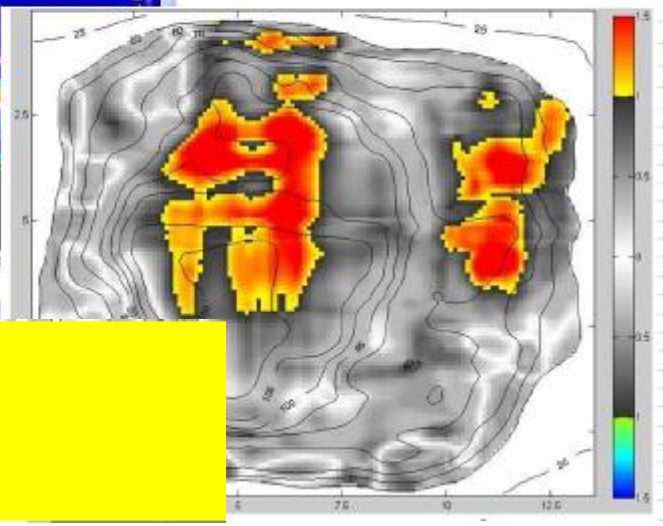
spinal cord (green), planning target volumes (purple, red)



COMPASS

Calculation

(2nd check)



Cause: all IMRT fields were off-axis

Solution: reposition the isocenter

Vielen Dank !

...und nicht vergessen

WWW.ICC-IBADOSIMETRY.COM

Dr. Lutz Müller, IBA Dosimetry, Germany