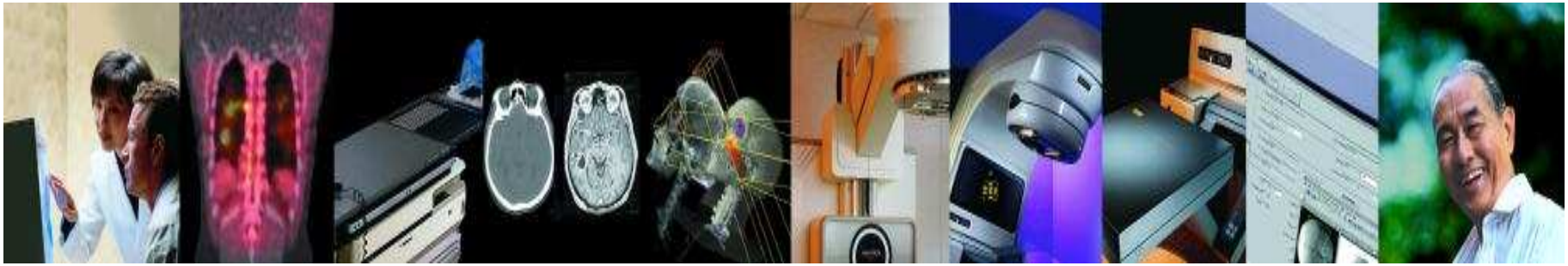
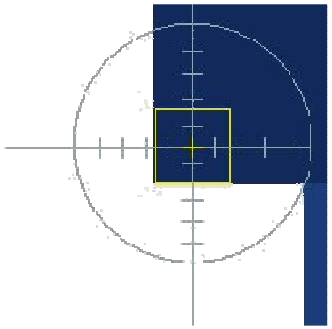
Rapid Arc in der Praxis: ein Jahr Erfahrung



S. Puccini
Strahlentherapie Bonn-Rhein-Sieg

Rapid Arc?



Patientenbestrahlung in 3 Minuten

- 2 Minute Lagerungskontrolle (CBCT)
- 1 Minute Bestrahlung

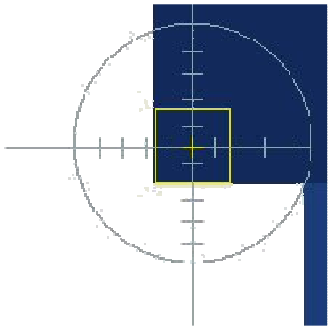
Rapid Arc vs. IMRT

- Kurze Bestrahlungszeiten
- Weniger MUs

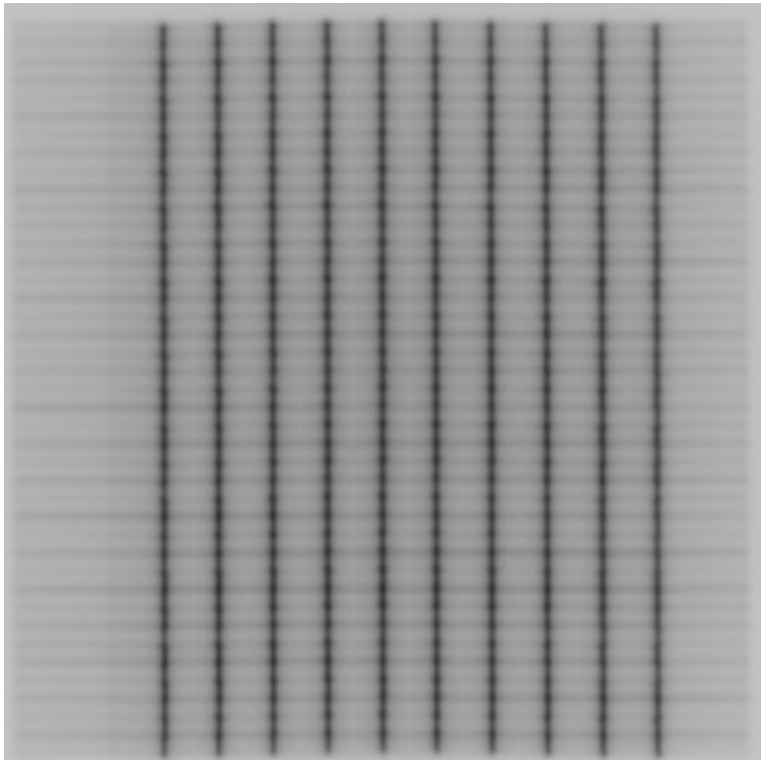
Fluenzmodulation: Anpassung der

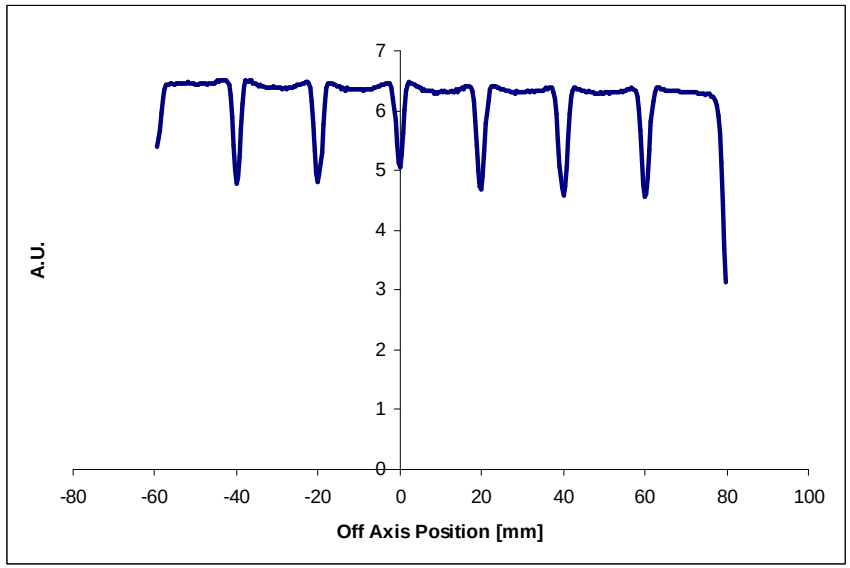
- Gantrygeschwindigkeit:
  0.5 – 4.8 Grad/Sek
- Dosisrate: 0-600 MU/min
- Dosis pro Grad: 0-20 MU/Grad
- MLC-Geschwindigkeit:
  0-2.25 cm/Sek

RA Einführung - 1



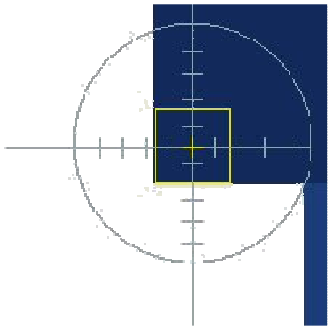
- Stabilität der Outputfaktoren bei Arc-Segmenten
- MLC-Bewegungen bei statischer vs. rotierender Gantry (Gartenzaun-Test)





Clifton Ling et al., Int. J. Rad. Onc. Biol. Phys. 72 (2), 575-581 (2008)

RA Einführung - 1



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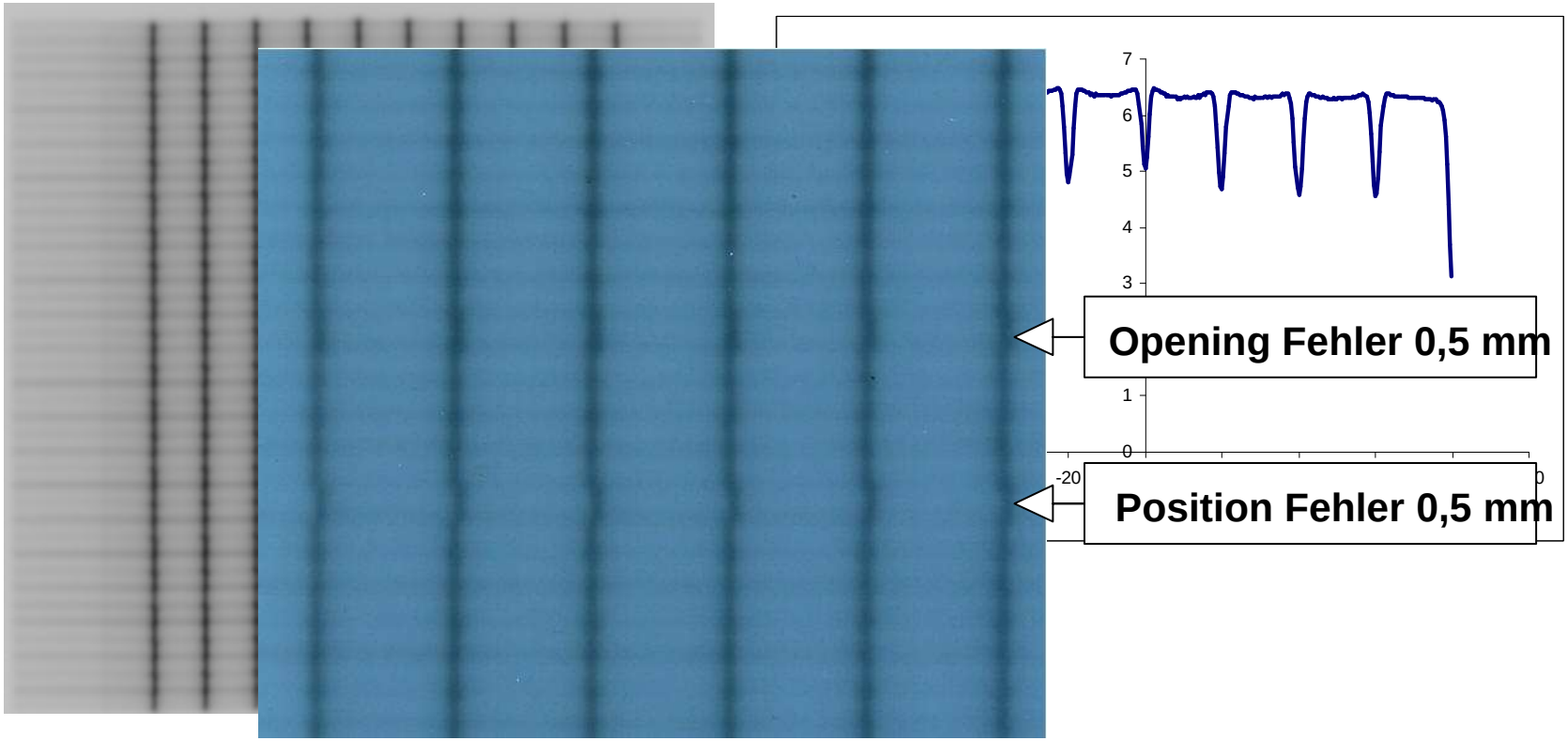
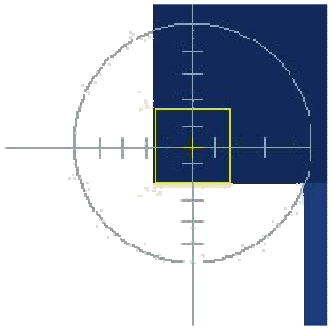


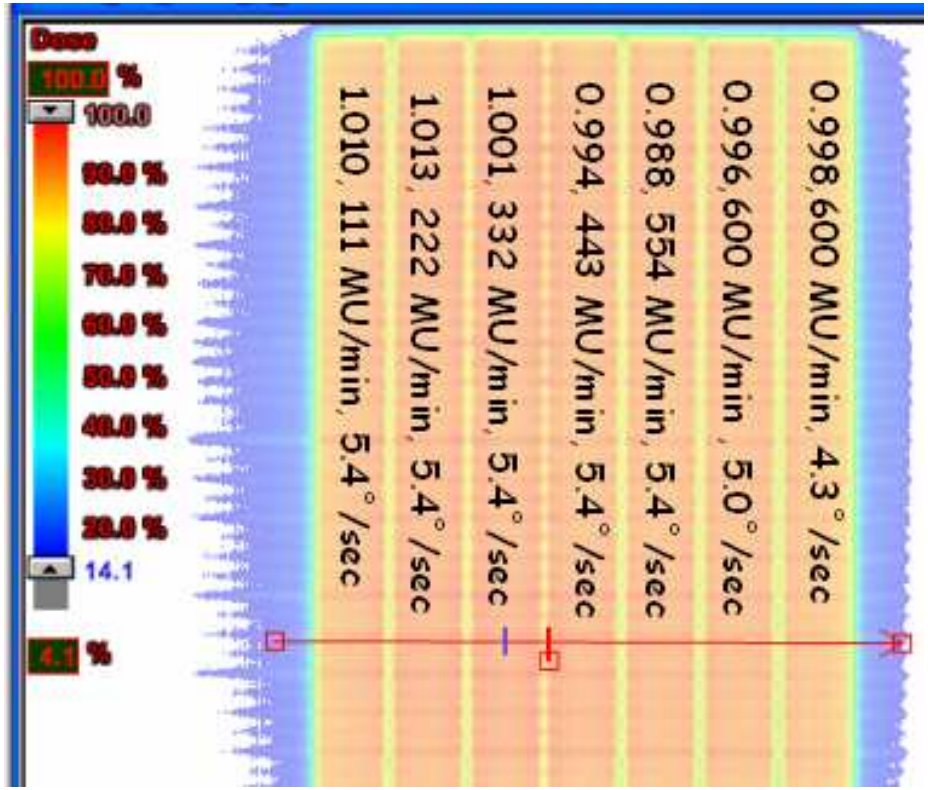
Clifton Ling et al., Int. J. Rad. Onc. Biol. Phys. 72 (2), 575-581 (2008)

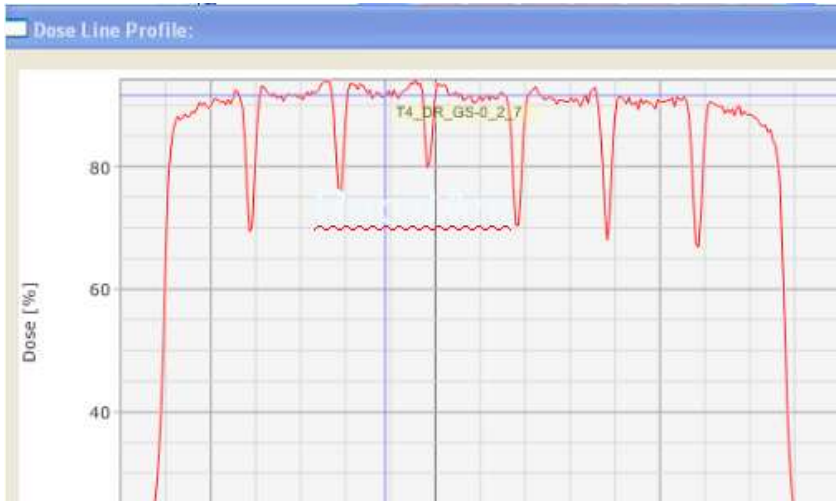
RA Einführung - 2



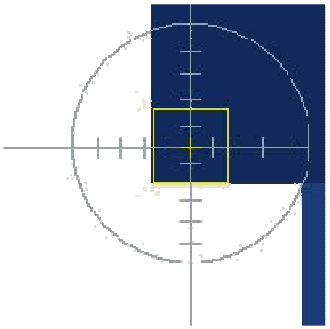
Stabilität der Dosisoutput bei Modulation der:

1. Gantrygeschwindigkeit + Dosisrate





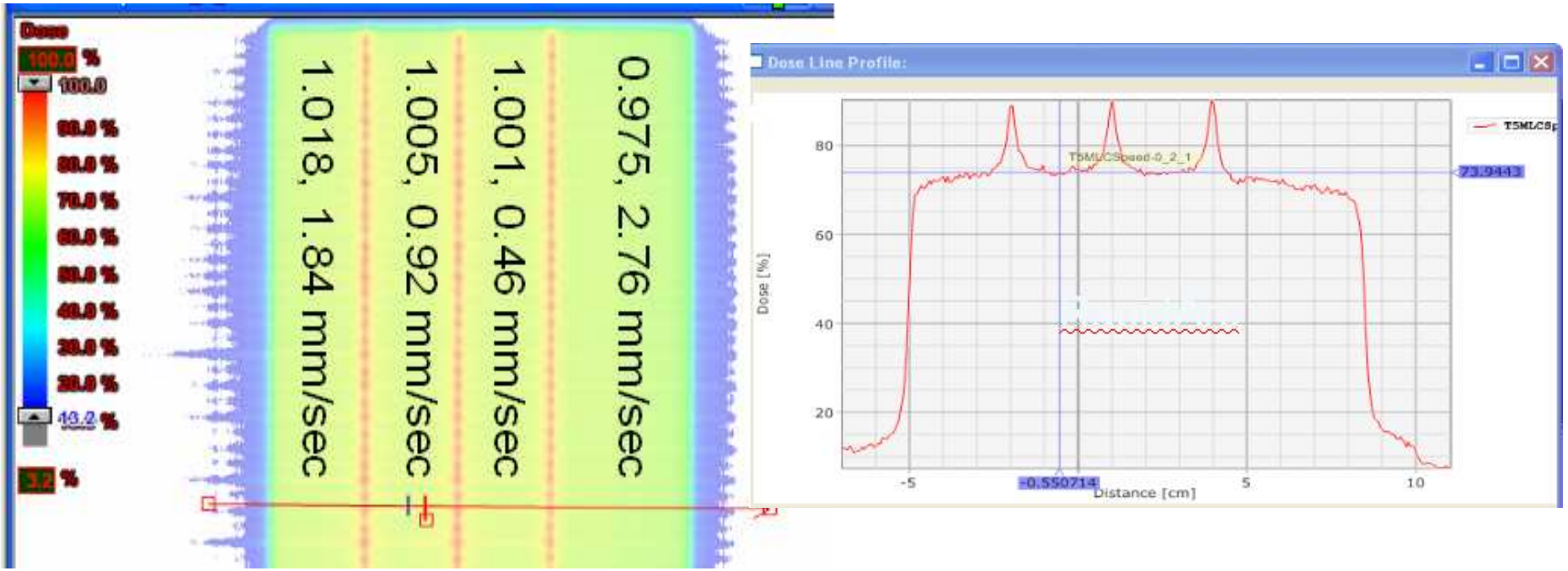
RA Einführung - 2



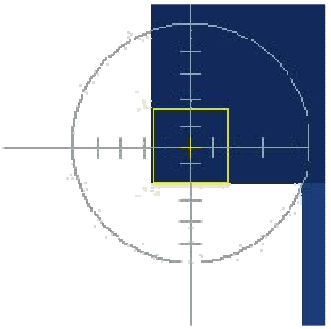
Stabilität der Dosisoutput bei Modulation der:

1. Gantrygeschwindigkeit + Dosisrate

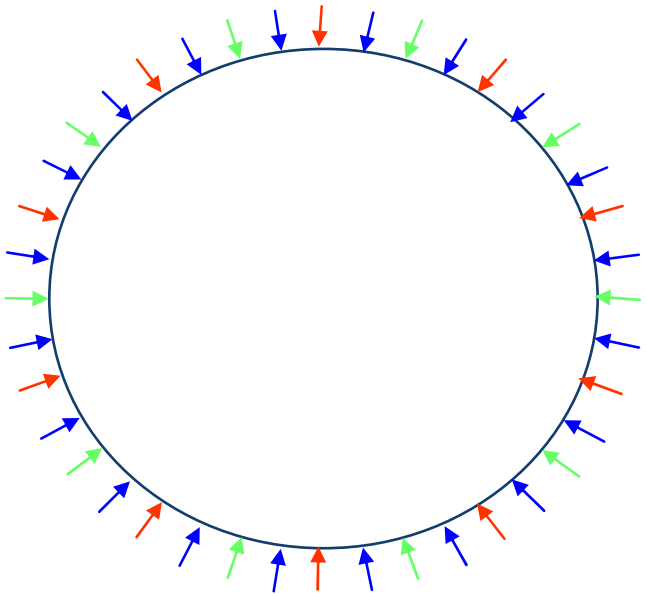
2. MLC-Geschwindigkeit + Dosisrate



RapidArc Bestrahlungsplanung: PRO



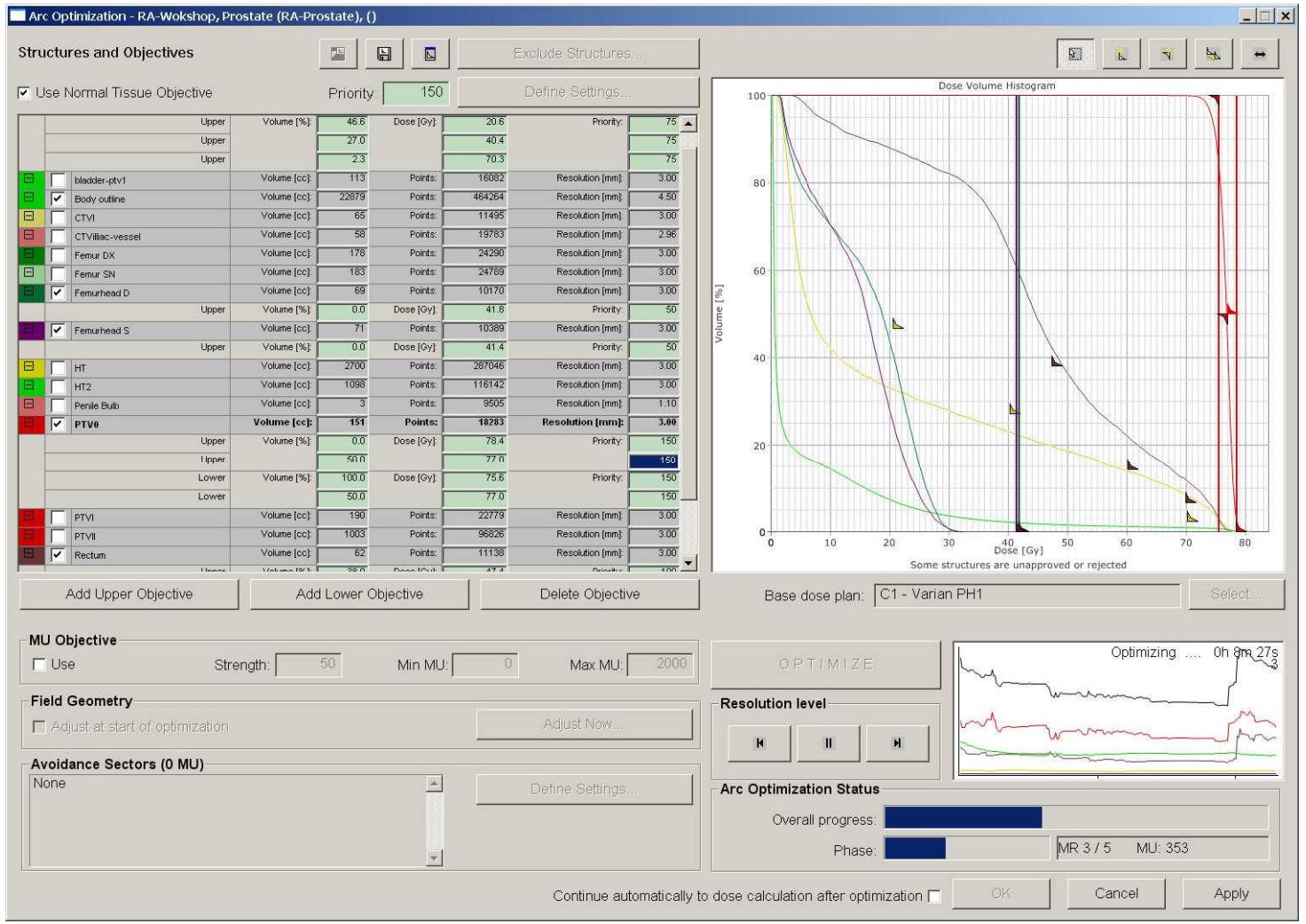
- **Planungssystem (Varian Eclipse 8.5)**
  - PRO (Progressive Resolution Optimizer)
- » MLC Dosimetric Leaf Gap, MLC DoseRate dynamic
- » Basisdatensätze PCB
- » AAA für die Berechnung



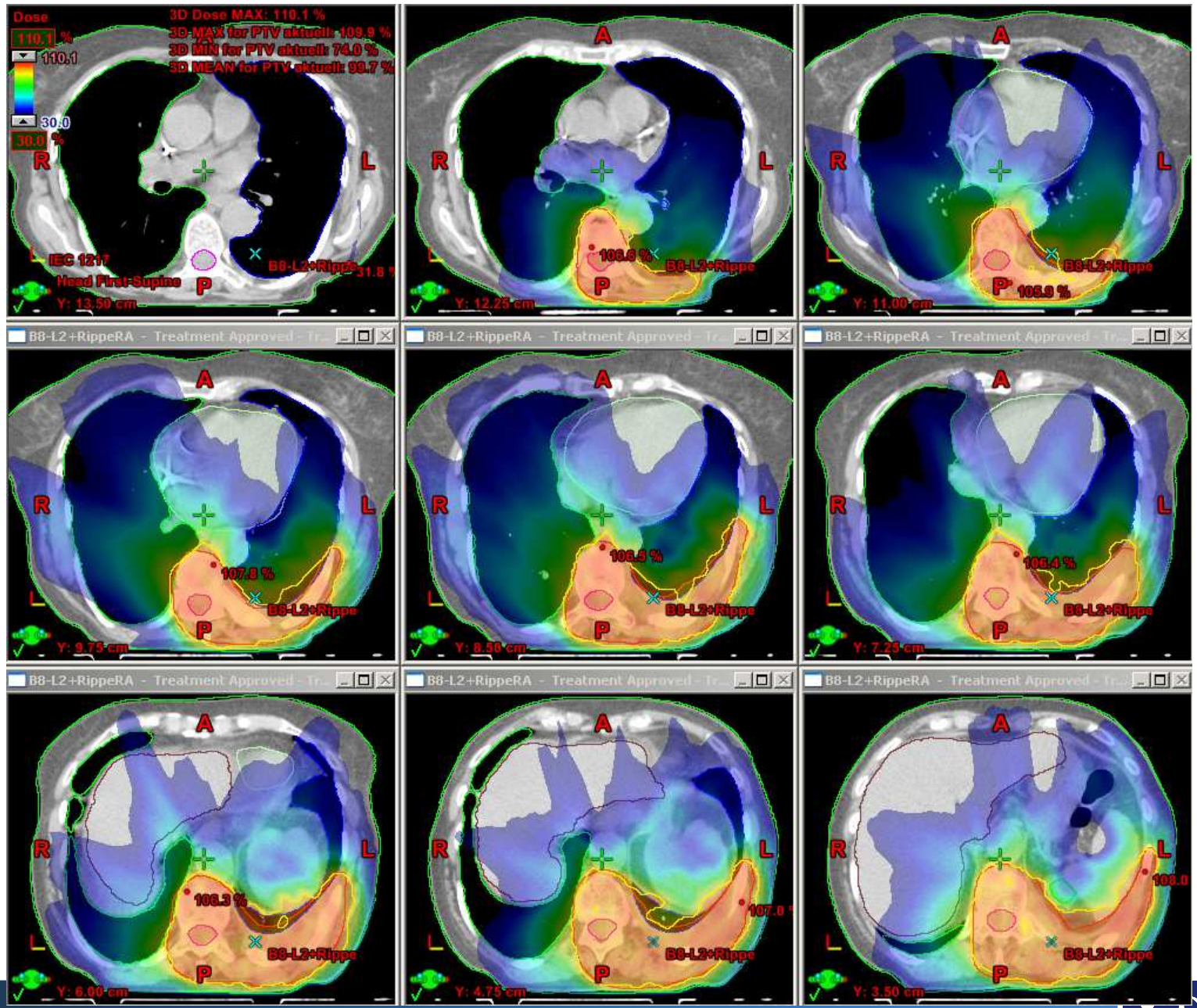
- Fängt mit wenigen Richtungen an
- Optimierung von Dose Rate, MLC, und Gantry-geschwindigkeit für jeden Kontrollpunkt
- Unter Berücksichtigung der technischen Einschränkungen des Clinacs

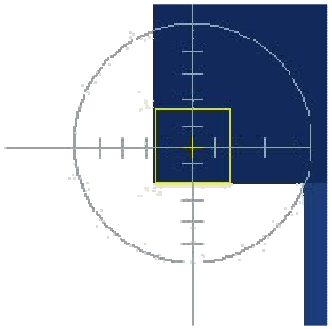
Planung: „Dose Constraints“

- Cave: max. Punktanzahl für die Optimierung: 1.000.000!



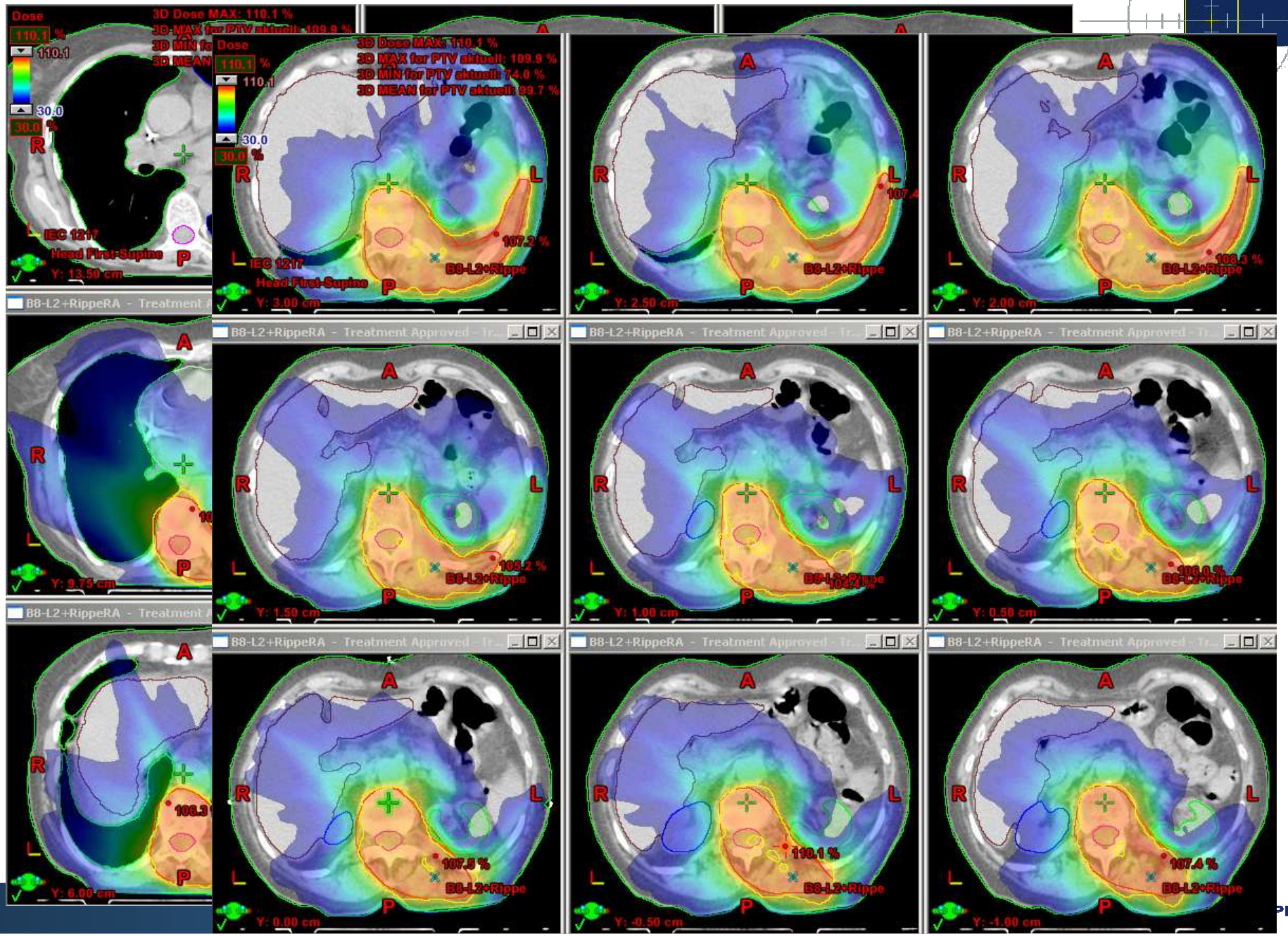
Patient Nr. 1: NHL, Knochenbefall





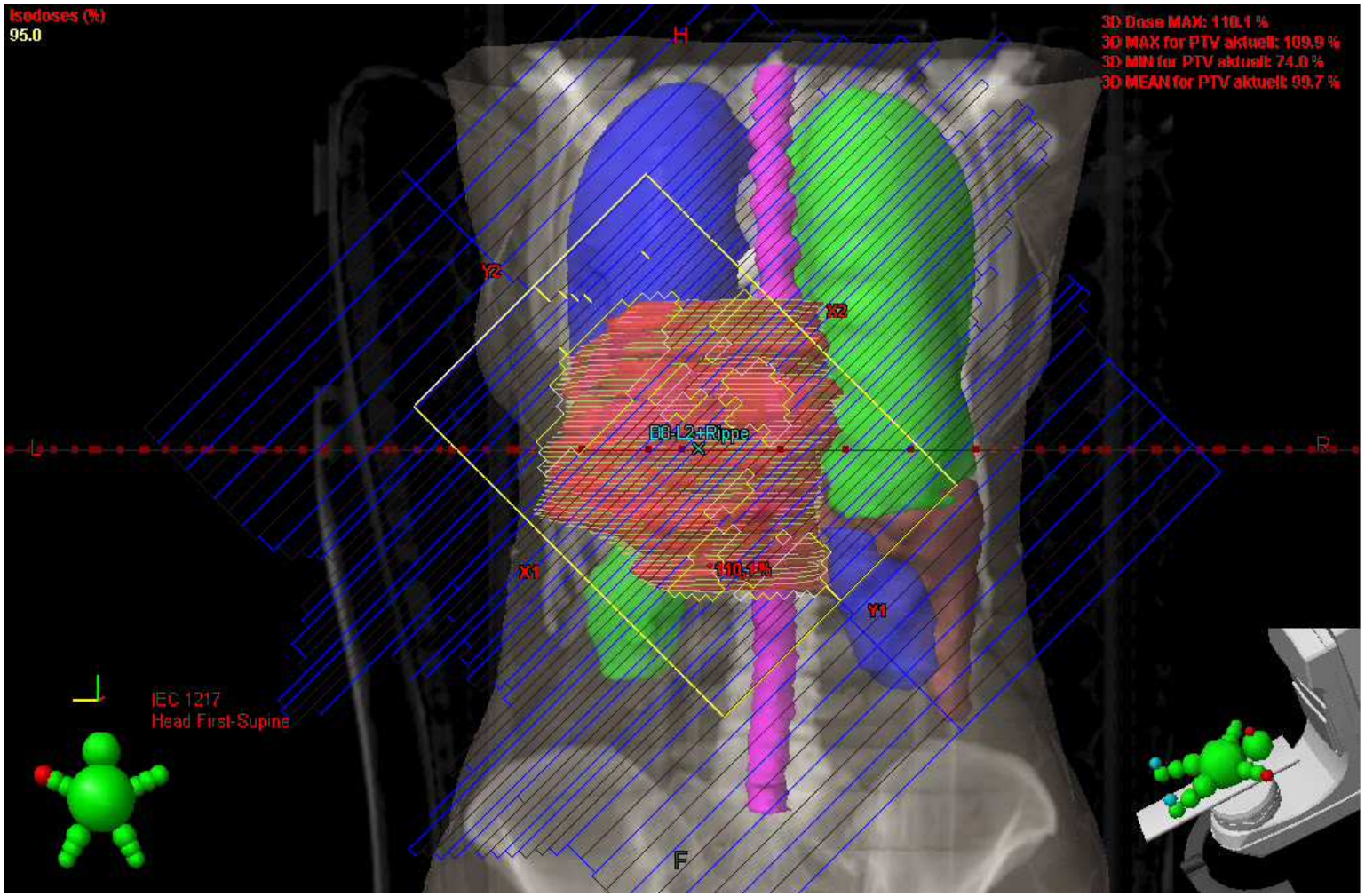
STRAHLENTHERAPIE
BONN-RHEIN-SIEG

Patient Nr. 1: NHL, Knochenbefall

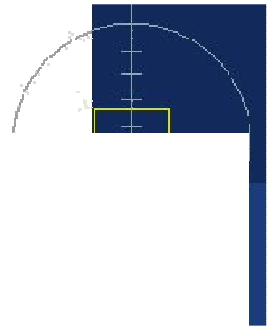


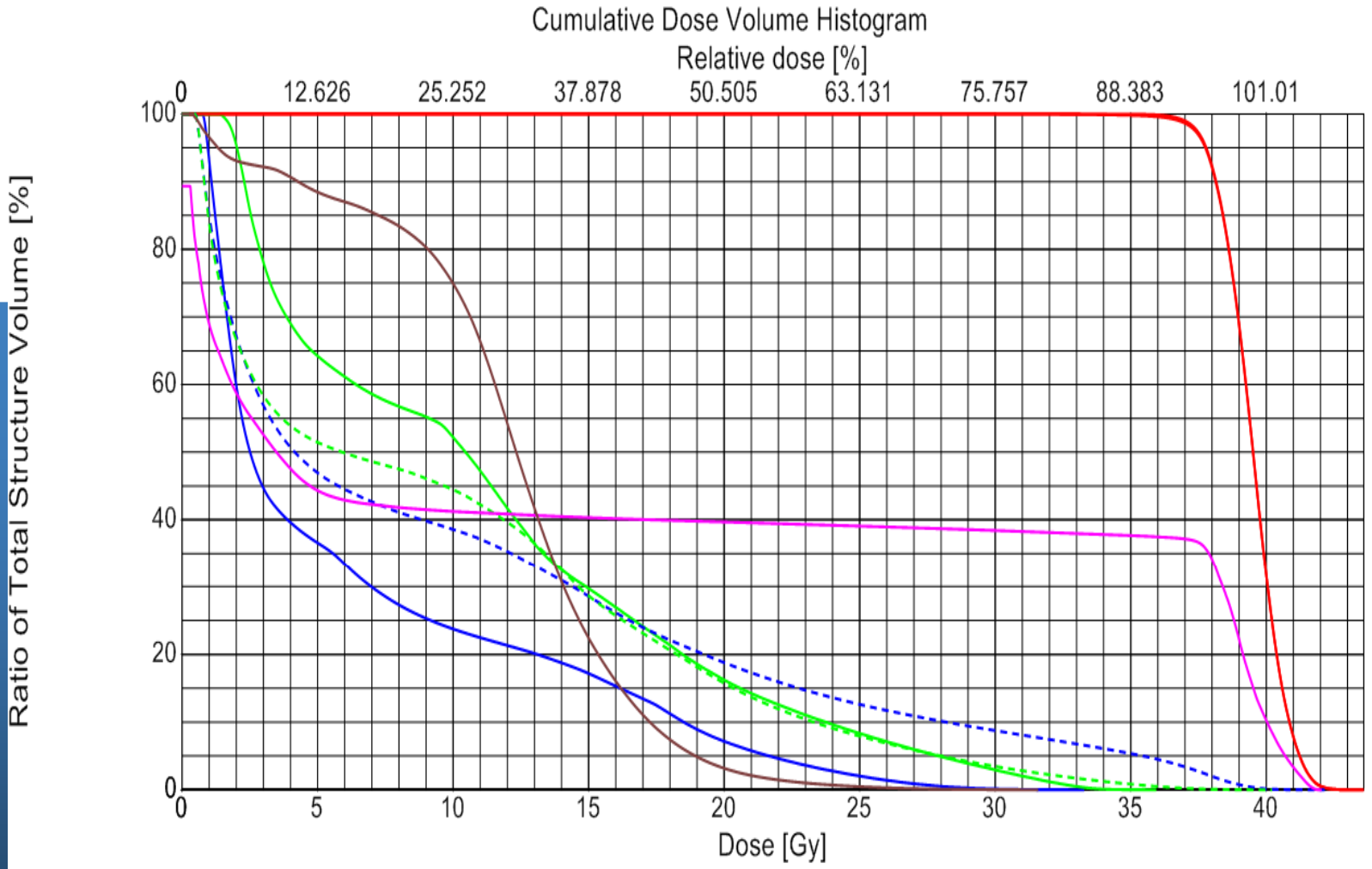
Patient Nr. 1: NHL, Knochenbefall

1 ARC, 530 MU



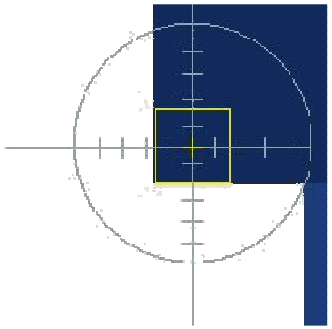
Patient Nr. 1: NHL, Knochenbefall



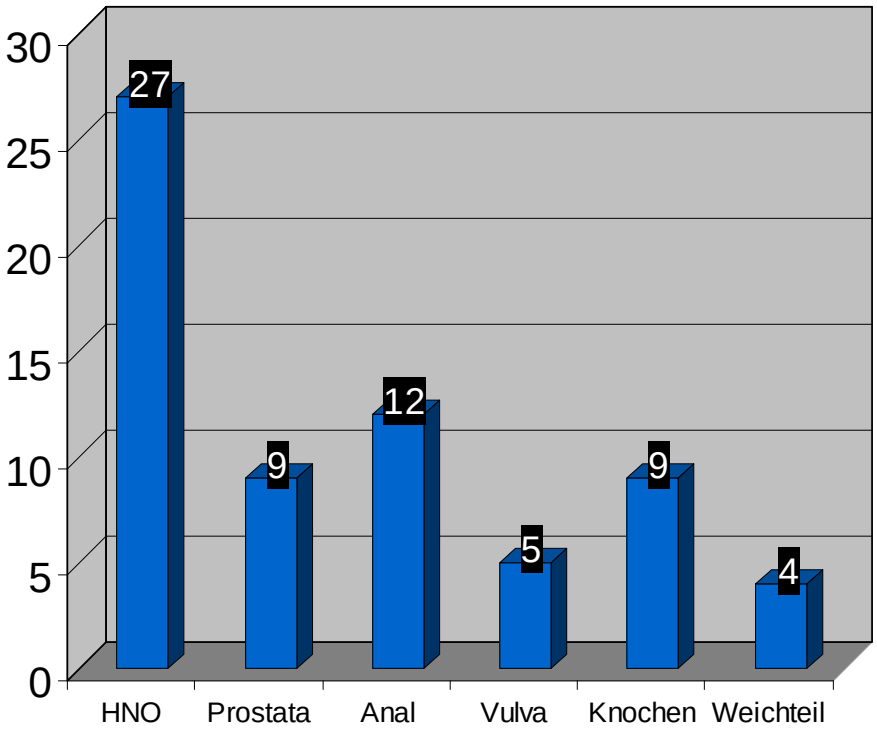


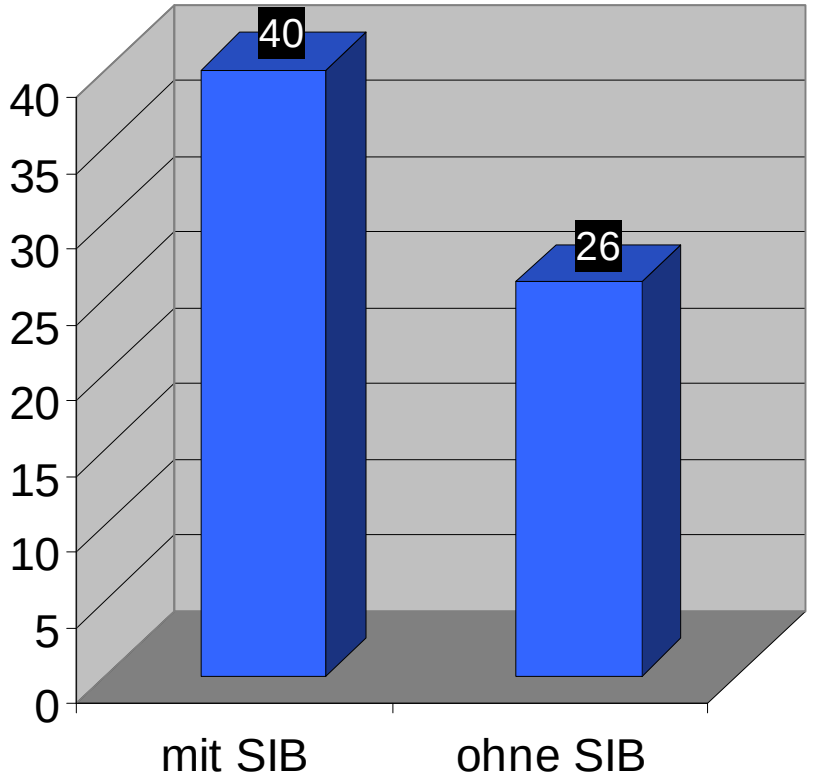
Structure	Plan	Plan Status	Course	Coverage [%/%]	Volume	Min Dose	Max Dose	Mean Dose	Modal Dose	Median Dose	Std Dev
li.Niere	B8-L2+RippeRA ()	Treatment Approved	Metas Apr09	100.0 / 100.0	92.7 [cm³]	1.3 Gy	35.9 Gy	11.2 Gy	2.4 Gy	10.5 Gy	8.3 Gy
Myelon	B8-L2+RippeRA ()	Treatment Approved	Metas Apr09	89.3 / 99.7	93.5 [cm³]	0.3 Gy	42.1 Gy	18.5 Gy	0.3 Gy	4.9 Gy	18.3 Gy
re.Niere	B8-L2+RippeRA ()	Treatment Approved	Metas Apr09	100.0 / 100.0	112.8 [cm³]	0.7 Gy	33.3 Gy	6.4 Gy	1.0 Gy	2.5 Gy	7.1 Gy
PTV Test RA	B8-L2+RippeRA ()	Treatment Approved	Metas Apr09	100.0 / 100.0	869.2 [cm³]	31.4 Gy	43.6 Gy	39.5 Gy	39.6 Gy	39.5 Gy	1.0 Gy
PTV aktuell	B8-L2+RippeRA ()	Treatment Approved	Metas Apr09	100.0 / 100.0	872.5 [cm³]	29.4 Gy	43.6 Gy	39.5 Gy	39.6 Gy	39.5 Gy	1.1 Gy
Leber	B8-L2+RippeRA ()	Treatment Approved	Metas Apr09	100.0 / 100.0	905.2 [cm³]	0.4 Gy	31.6 Gy	11.9 Gy	11.9 Gy	12.3 Gy	4.8 Gy
li.Lunge	B8-L2+RippeRA ()	Treatment Approved	Metas Apr09	100.0 / 100.0	1301.3 [cm³]	0.5 Gy	42.2 Gy	10.1 Gy	0.8 Gy	4.2 Gy	11.0 Gy

Patientenkollektiv

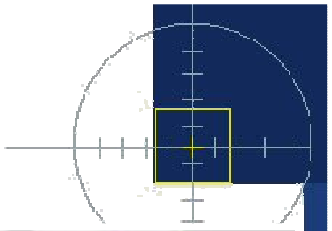


- 66 Patienten (ca. 1,2 neuer Pat. Pro Woche)
- z.T. mit Simultan Intgriertem Boost (SIB)



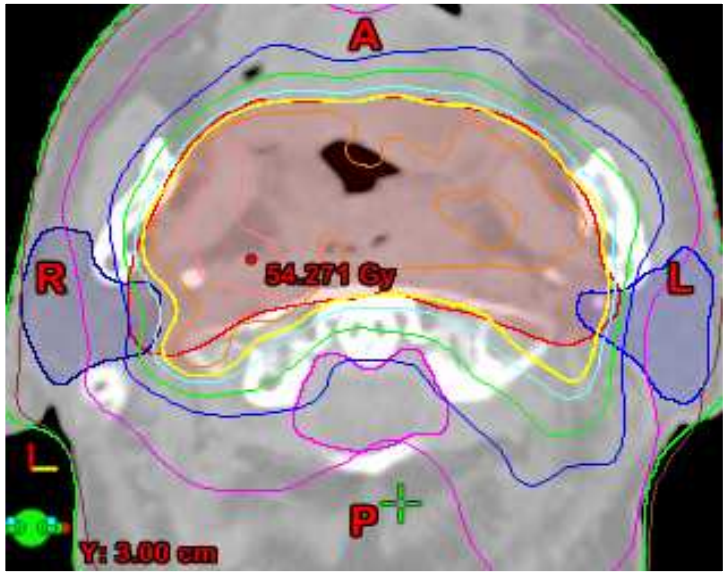


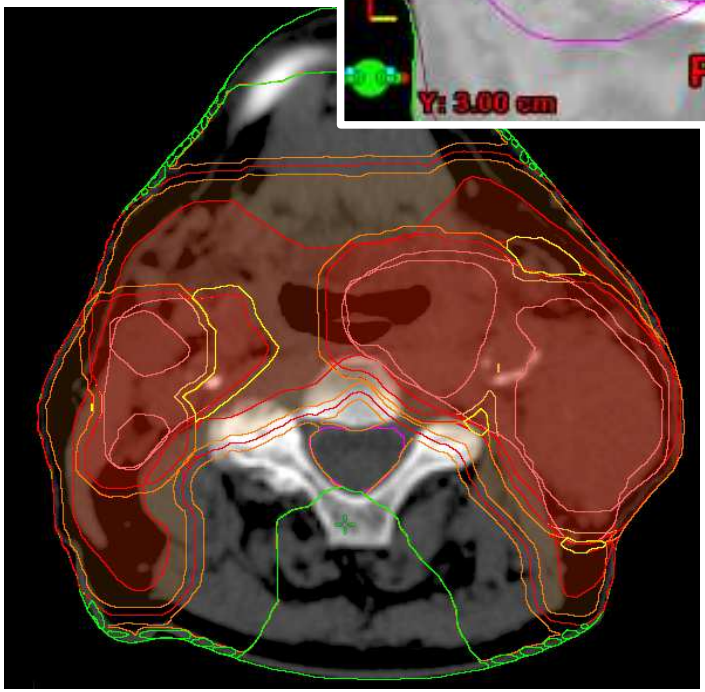
Workflow Rapid Arc



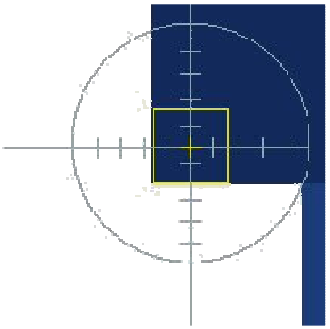
1 Std.

- **Konturierung** trotz automatischer Segmentation
- Optimierung
- Berechnung
- Planverifikation
- Lagerung + Kontrolle
- Bestrahlung





Workflow Rapid Arc

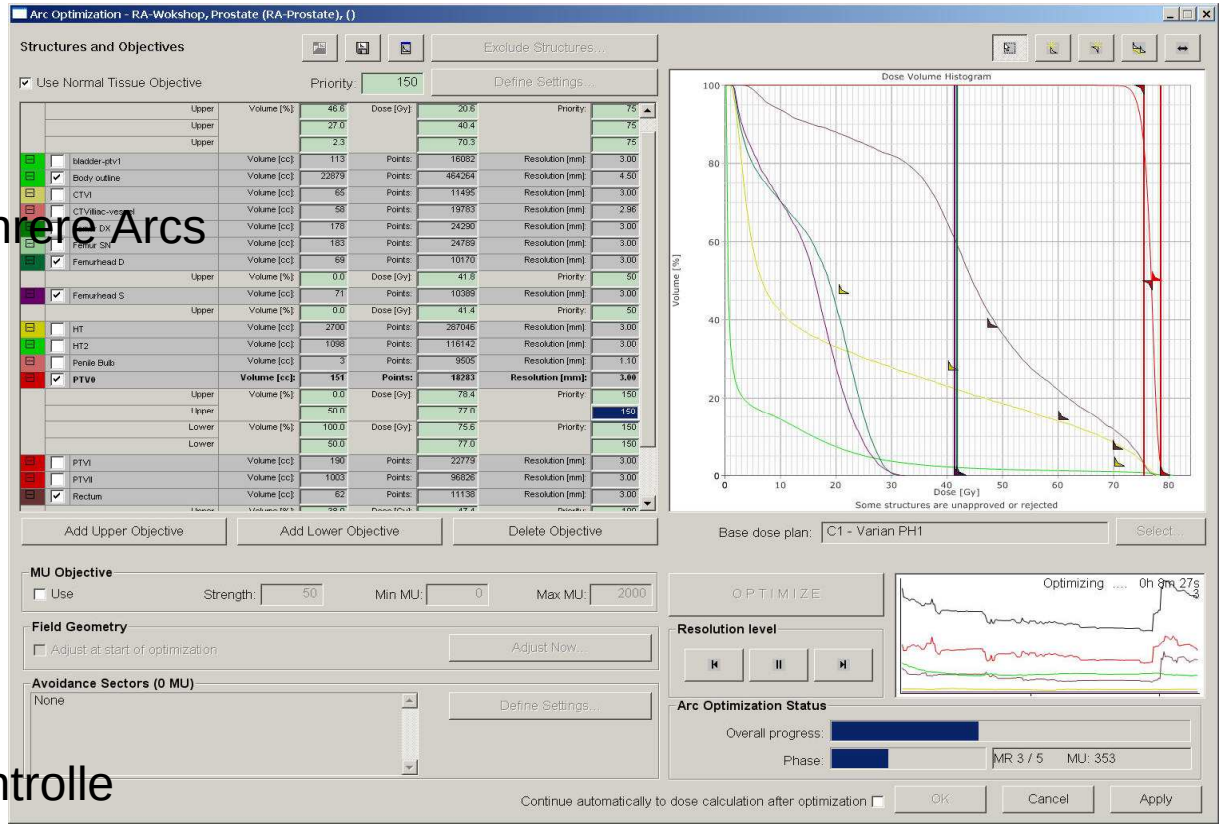


1 Std.

- Konturierung

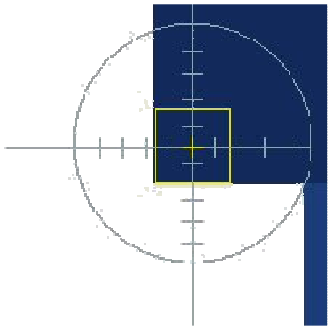
1 Std.

- **Optimierung**
  Templates, mehrere Arcs



- Berechnung
- Planverifikation
- Lagerung + Kontrolle
- Bestrahlung

Workflow Rapid Arc



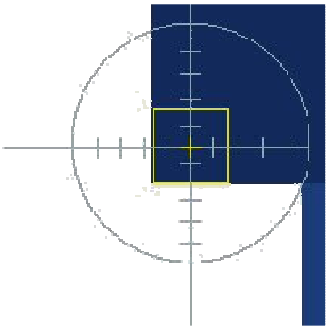
1 Std.
- Konturierung

1 Std.
- Optimierung

1,5 Std.
- **Berechnung** meistens 2 Arcs,
  3 Kontrollpunkten gleichzeitig (8-cores)

3-4 Std.
- Plan fertig für die Planbesprechung
- Planverifikation
- Lagerung + Kontrolle
- Bestrahlung

Workflow Rapid Arc



1 Std.
- Konturierung

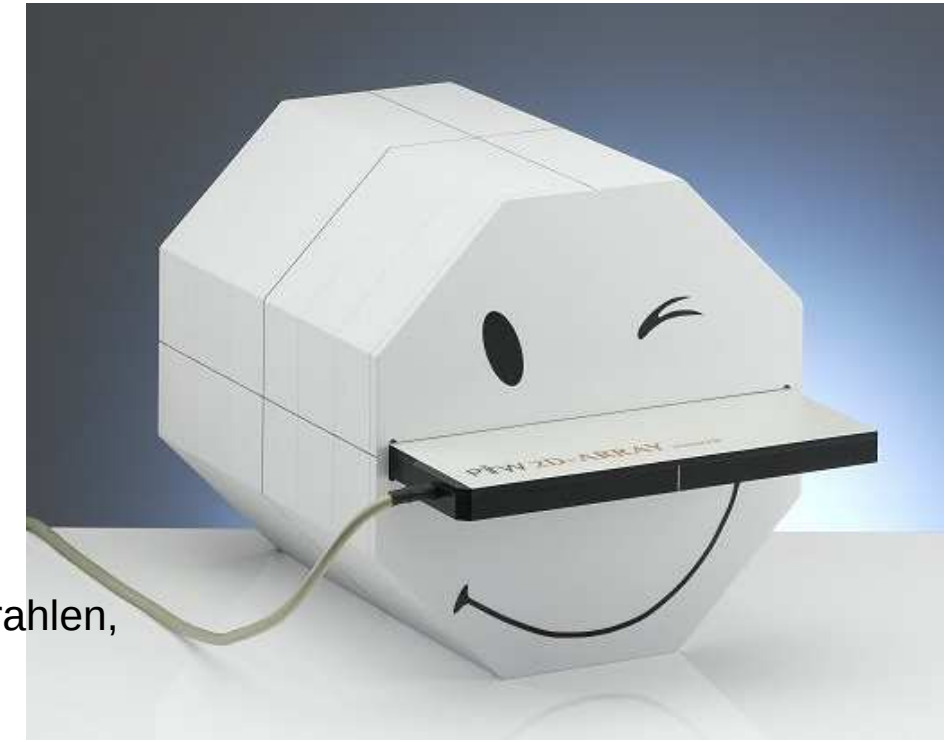
1 Std.
- Optimierung

1,5 Std.
- Berechnung

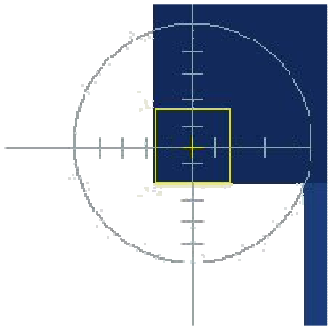
3-4 Std.
- Planverifikation

  Plan erstellen + vorbereiten
  Phantom justieren, Plan bestrahlen,
  Auswerten

5-6 Std.
- Lagerung + Kontrolle
- Bestrahlung



Workflow Rapid Arc



1 Std.
- Konturierung

1 Std.
- Optimierung

1,5 Std.
- Berechnung

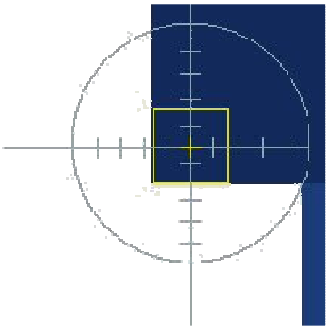
- Planverifikation
  Plan erstellen + vorbereiten
  Phantom justieren, Plan bestrahlen,
  Auswerten

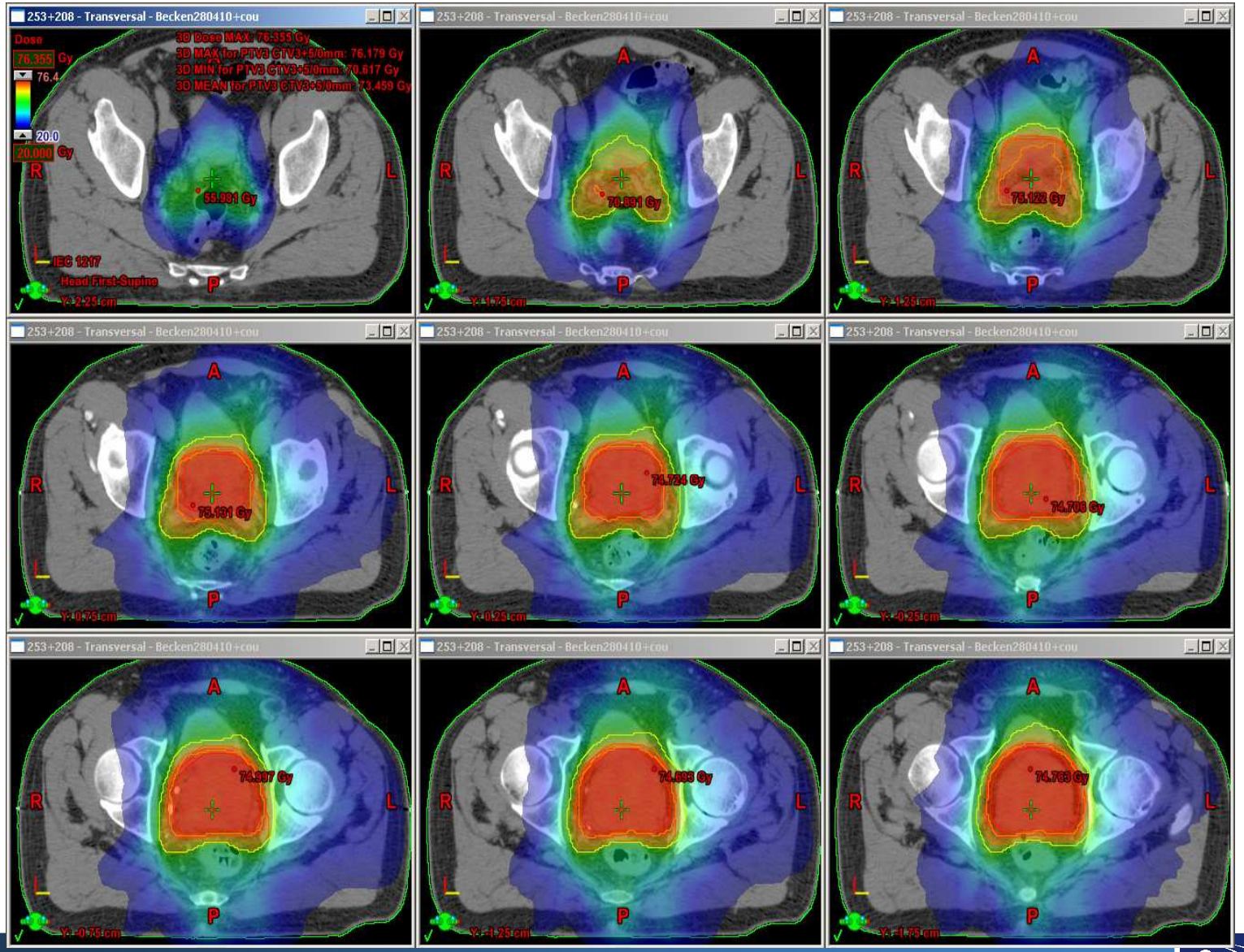
5-6 Std.

- **Lagerung + Kontrolle**
- **Bestrahlung**

20 Minuten Slot

Beispiel Prostata, 2 Arcs, 253+208 MU





CHIPP Studie

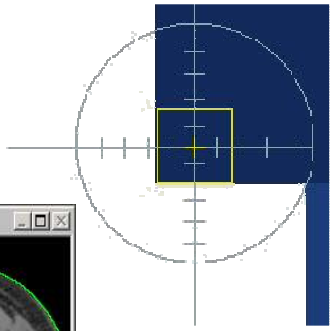
PTV1 59,2 Gy
(Prost+SB)

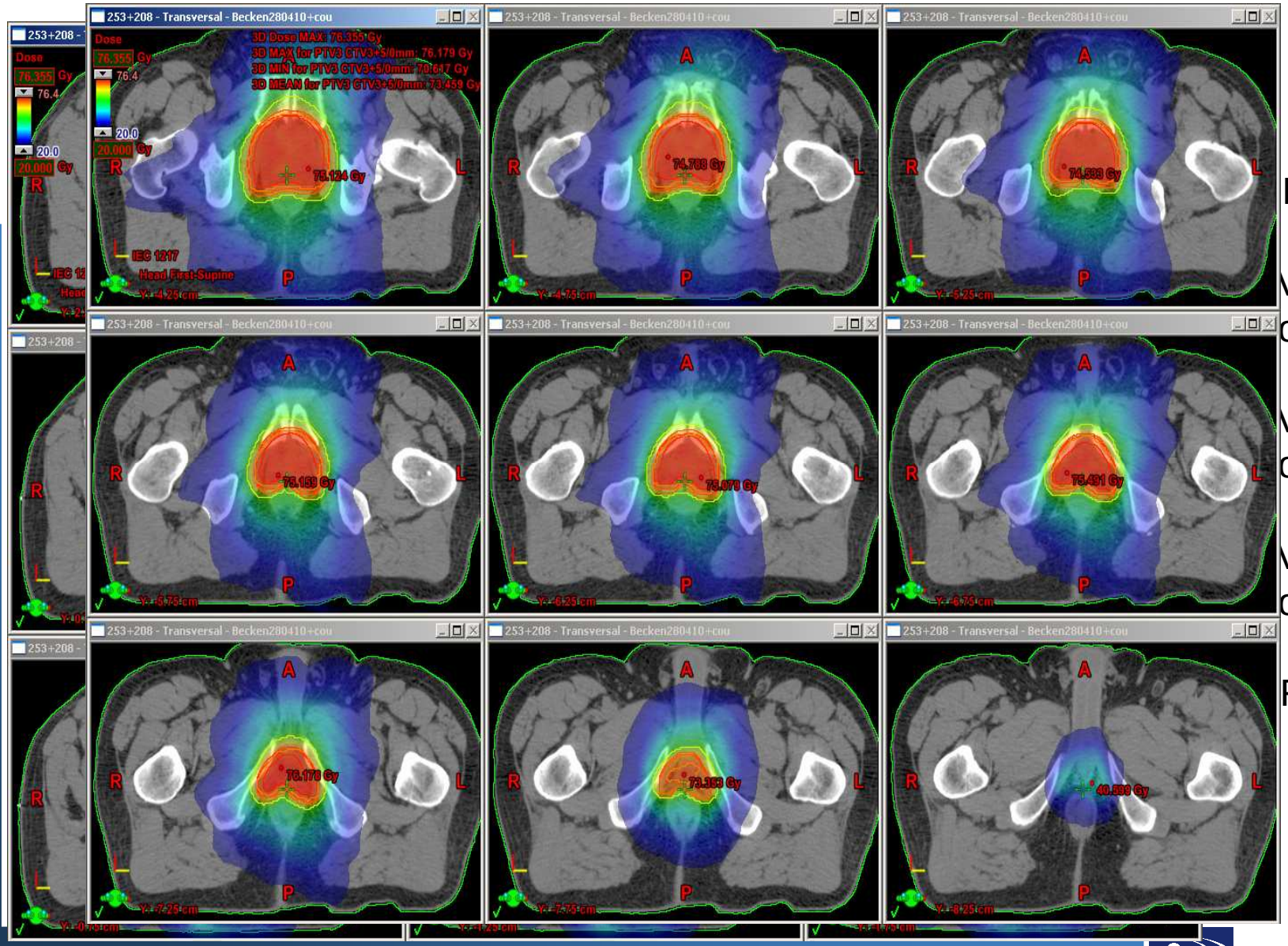
PTV2 71,0 Gy
(Pros+10mm)

PTV3 74,0 Gy
(Pros+5mm)

37 Fraktionen

Beispiel Prostata, 2 Arcs, 253+208 MU





IPP Studie

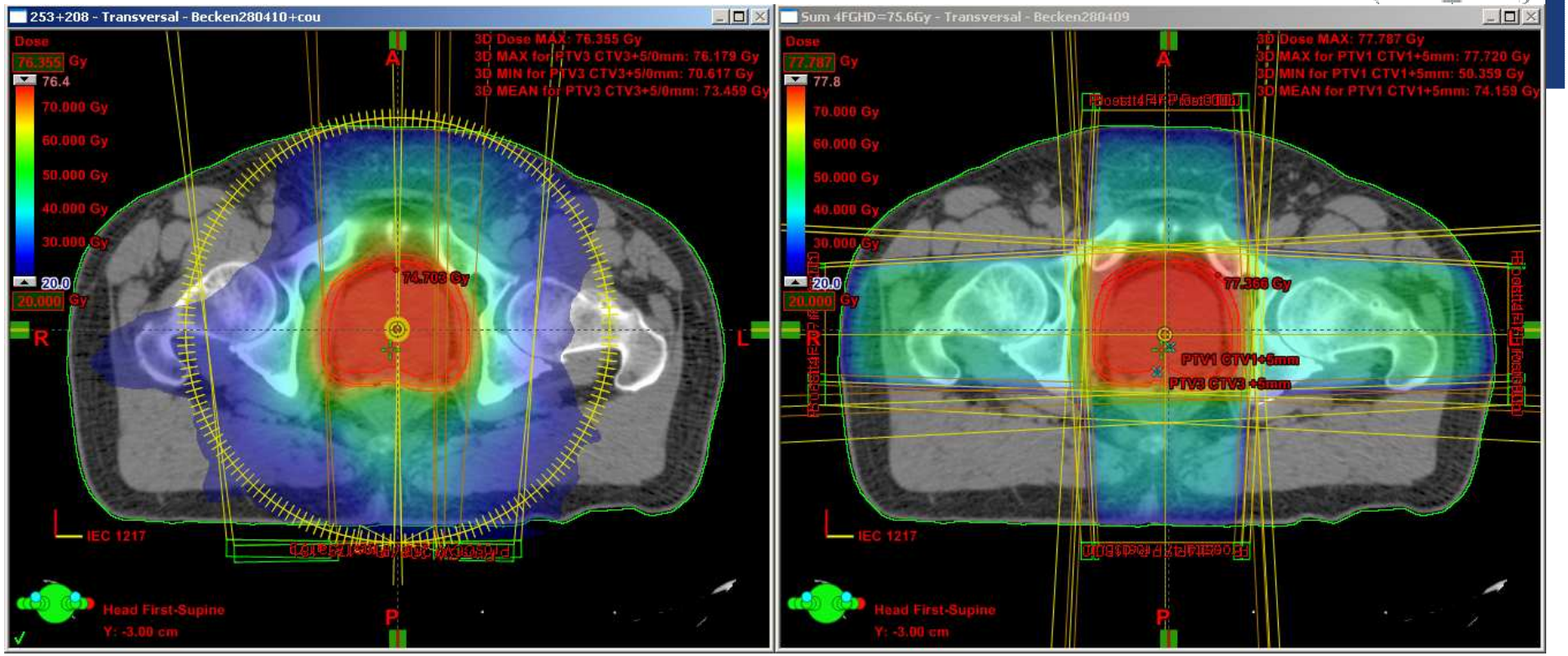
V1 59,2 Gy
ost+SB)

V2 71,0 Gy
os+10mm)

V3 74,0 Gy
os+5mm)

Fraktionen

Beispiel Prostata



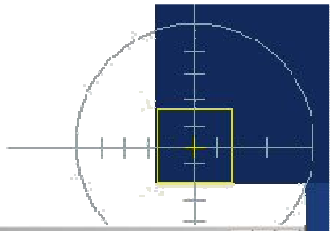
Rapid Arc

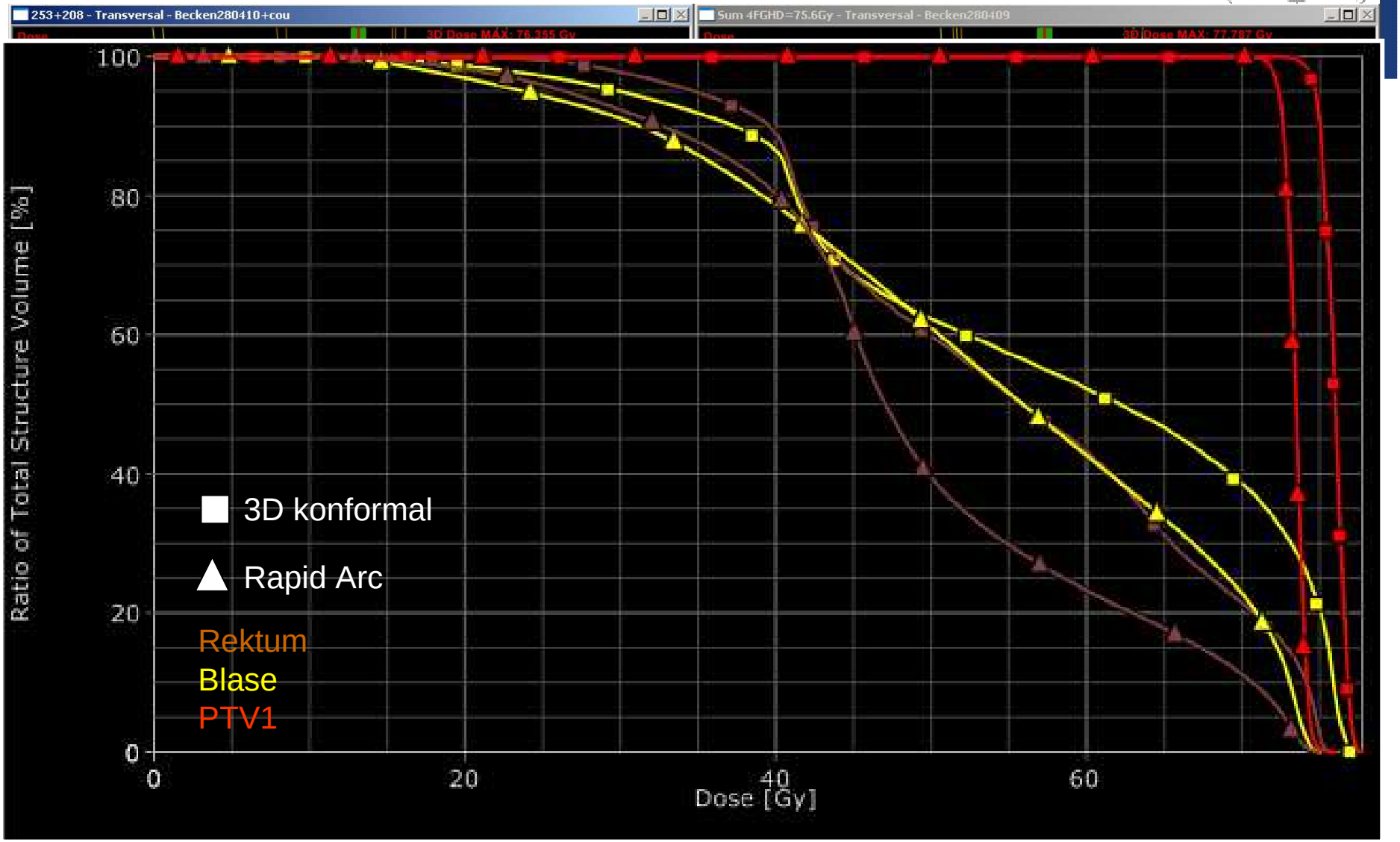
PTV 1 59,2 Gy
PTV 2 71,0 Gy
PTV 3 74,0 Gy
37 Fraktionen
ED 2,0 Gy (PTV 1)

3D Konformal

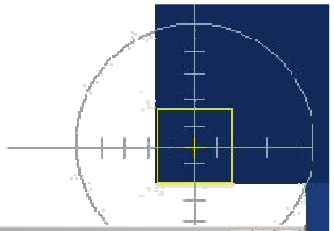
PTV 1 50,4 Gy
PTV 2 66,6 Gy
PTV 3 75,6 Gy
42 Fraktionen
ED 1,8 Gy (PTV 1)

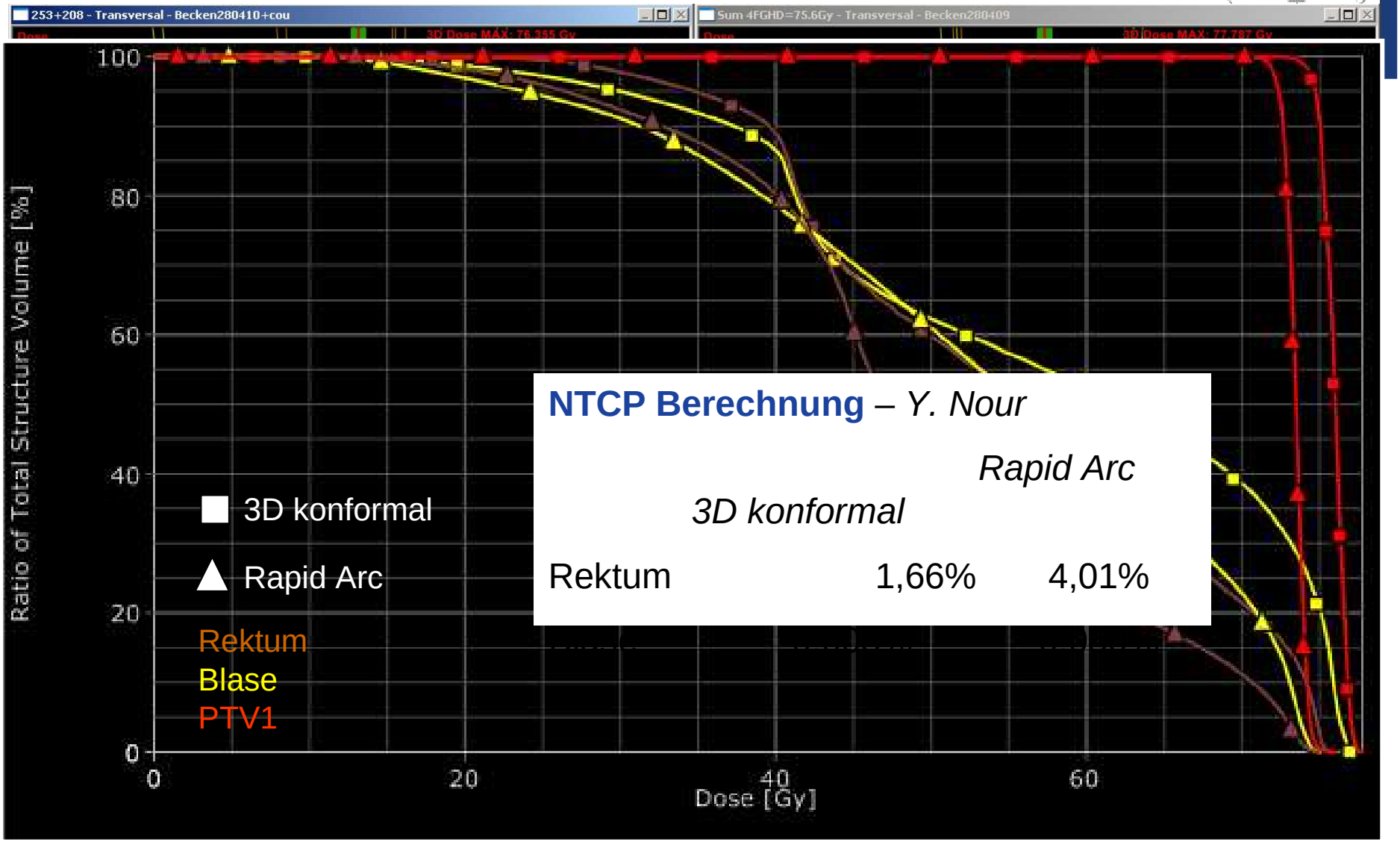
Beispiel Prostata





Beispiel Prostata

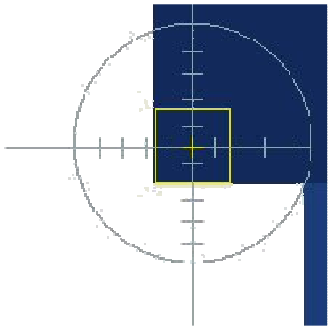




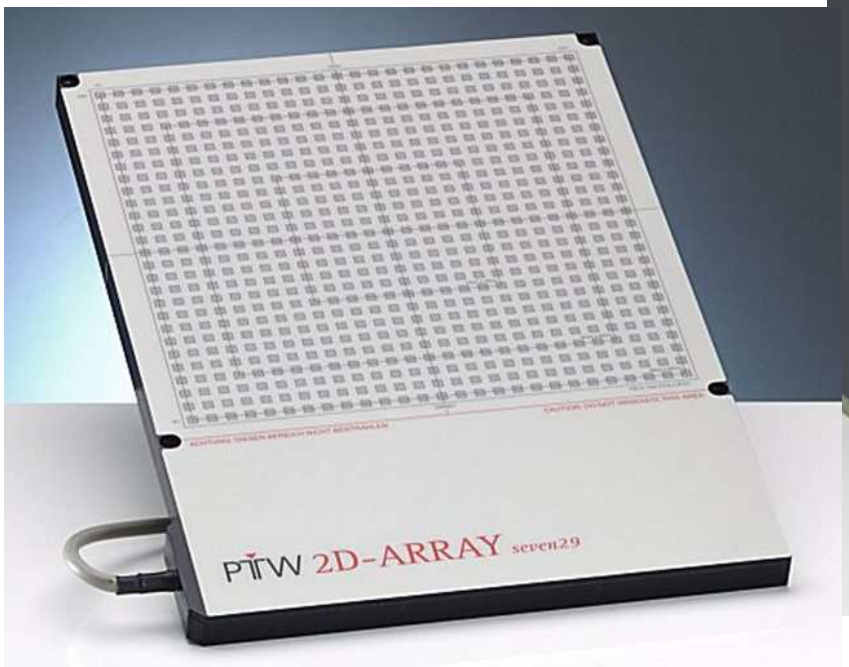
NTCP Berechnung – *Y. Nour*

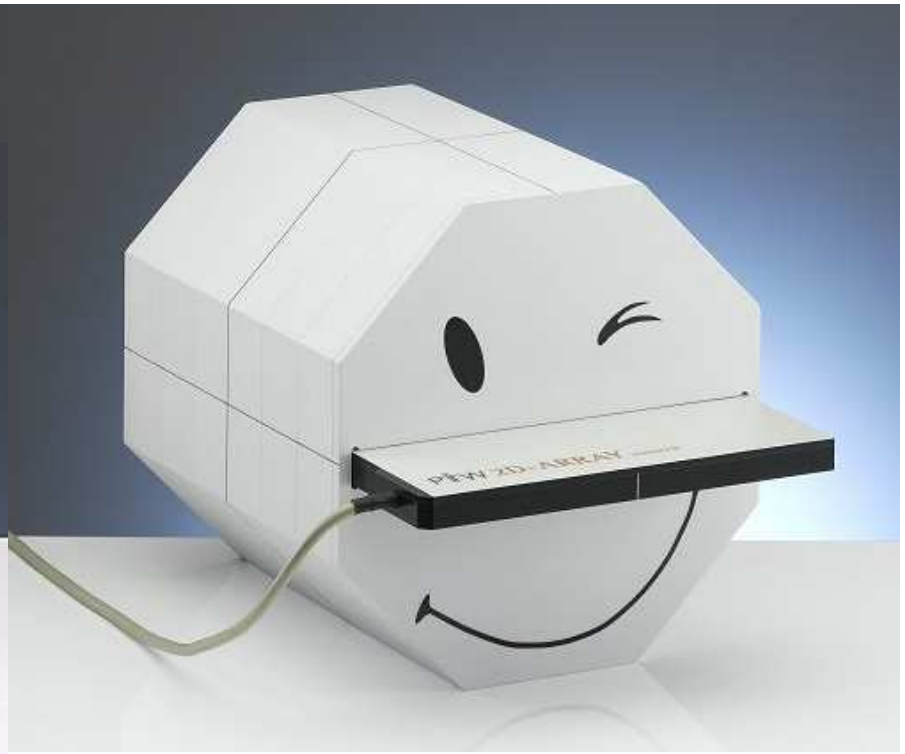
	3D konformal	*Rapid Arc*
Rektum	1,66%	4,01%

Planverifikation

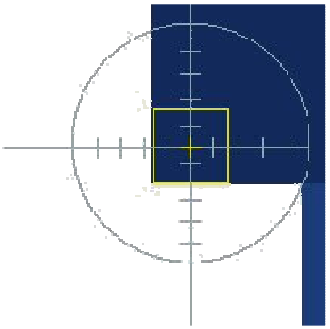


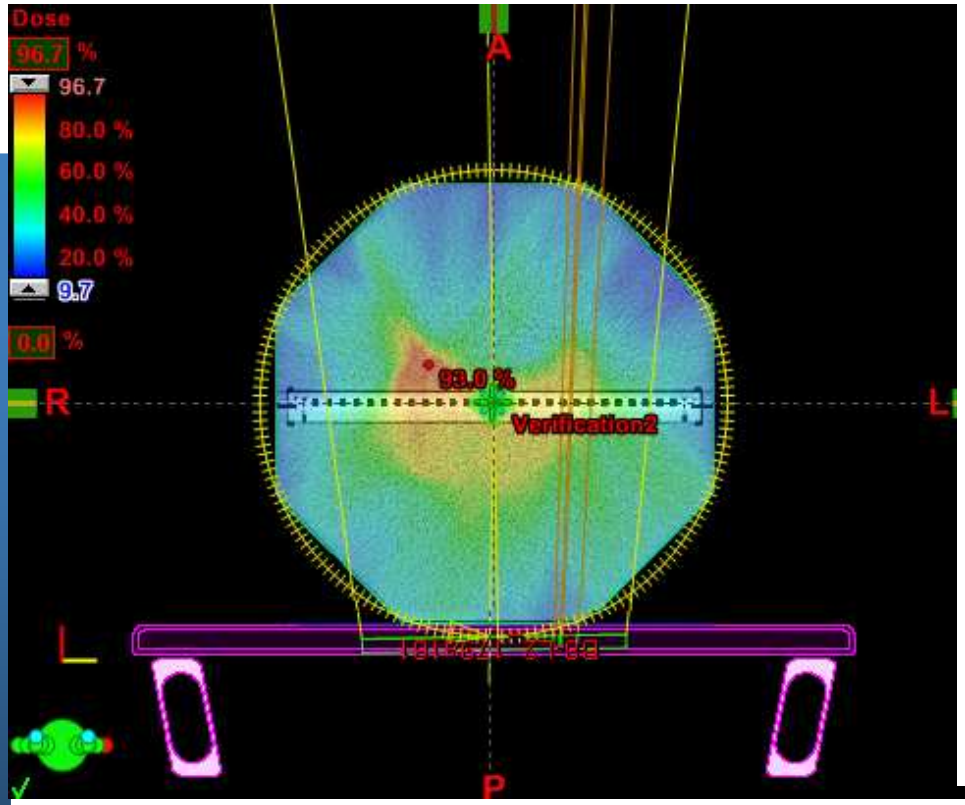
- Keine EPID-Messung möglich **?**
- Gleiche Bestrahlungsgeometrie

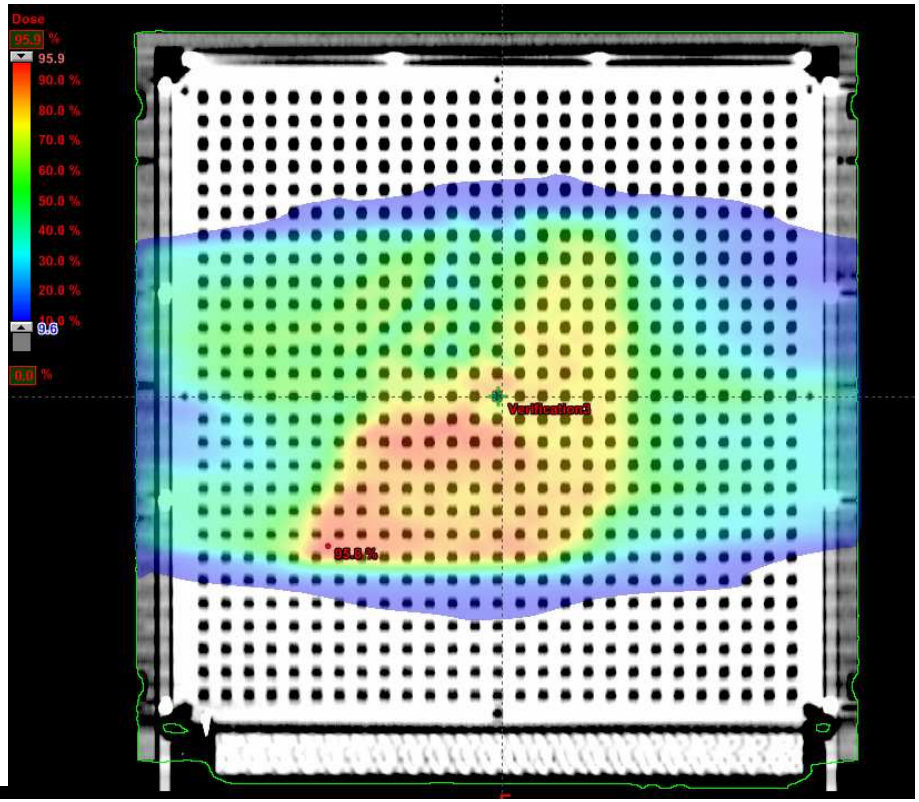




Planverifikation



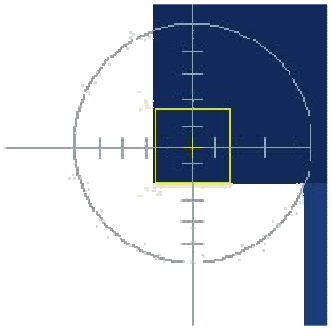


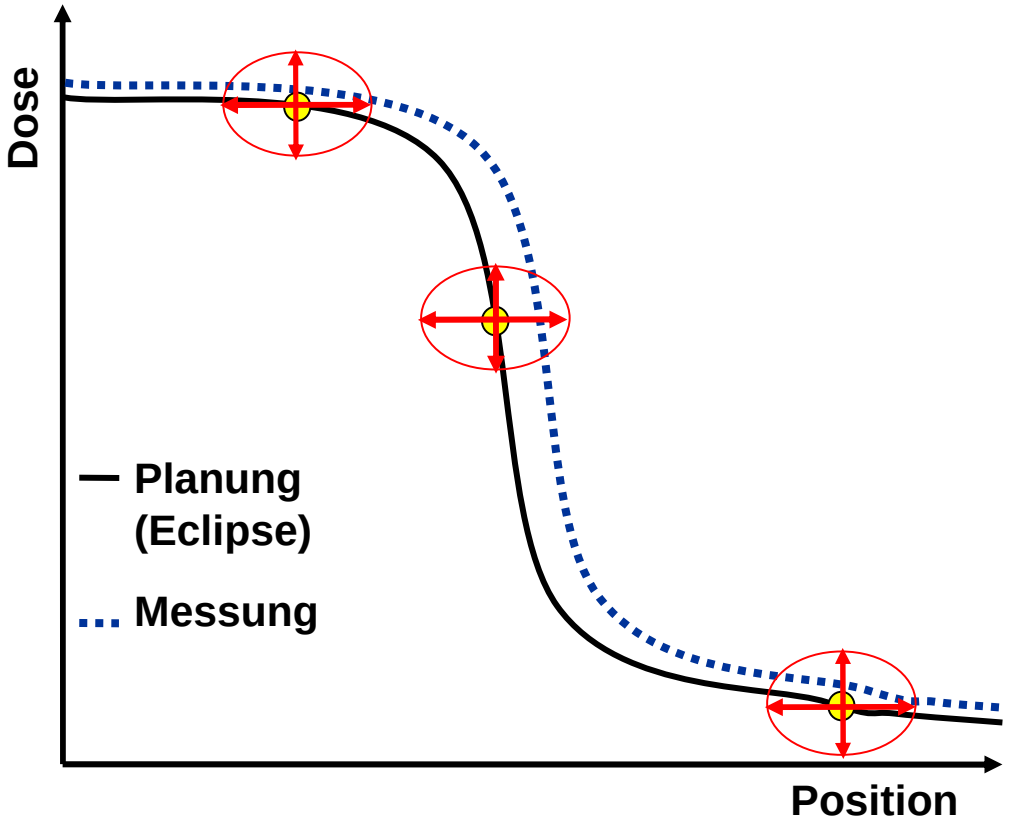


Planar Dose Details

	size		points	resolution	
Matrix X	27	cm	109	0.250	cm
Matrix Y	27	cm	109	0.250	cm

Gamma Kriterium

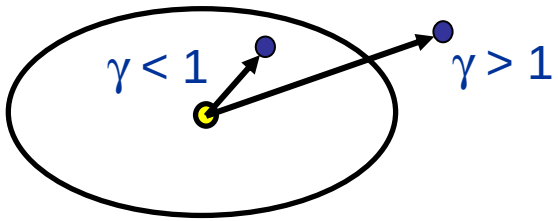




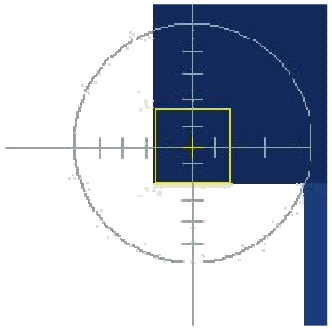
ΔD_{max} = max. Dosisabweichung

DTA = Distance To Agreement

$$\gamma = \sqrt{\frac{\Delta D^2}{\Delta D_{max}{}^2} + \frac{\Delta d^2}{DTA^2}}$$



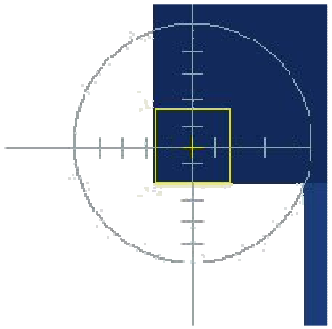
Passkriterien



Gamma Evaluation

- Punkten mit Dosis < 10% werden nicht ausgewertet
- ΔD des globalen Maximums
- Ergebnis: mehr als 95%
  zwischen 90 und 95%
  weniger als 90%
- DTA **2 mm**
- ΔD **2%**

Passkriterien



Gamma Evaluation

- Punkten mit Dosis < 10% werden nicht ausgewertet
- ΔD des globalen Maximums
- Ergebnis:
  - 🟢 mehr als 95%
  - 🟡 zwischen 90 und 95%
  - 🔴 weniger als 90%
- DTA **2 mm**
- ΔD **2%**

Für alle Körperregionen?

Beispiel HNO

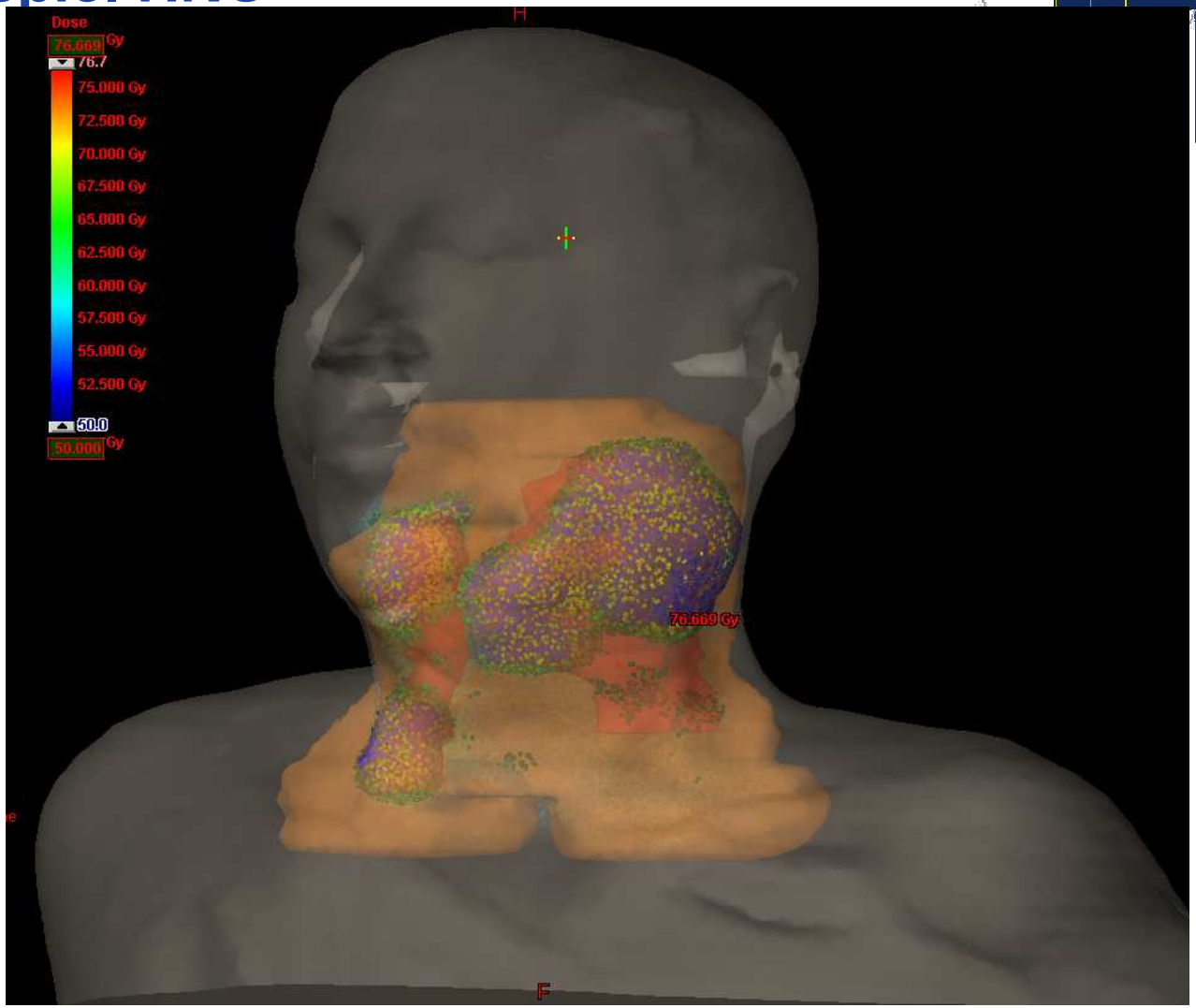
Hyphopharynx

GTV 70,0 Gy

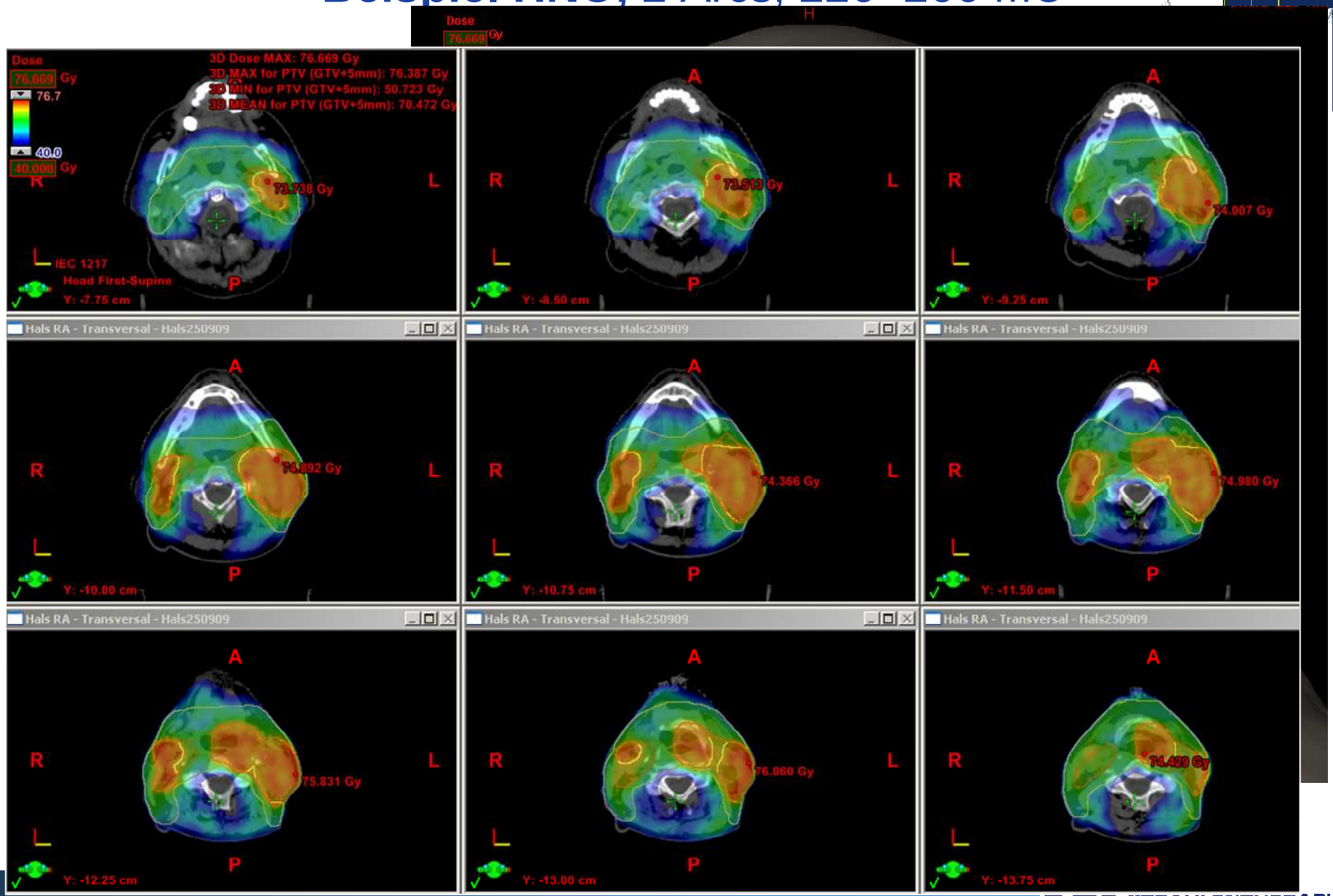
PTV high risk 59,4 Gy

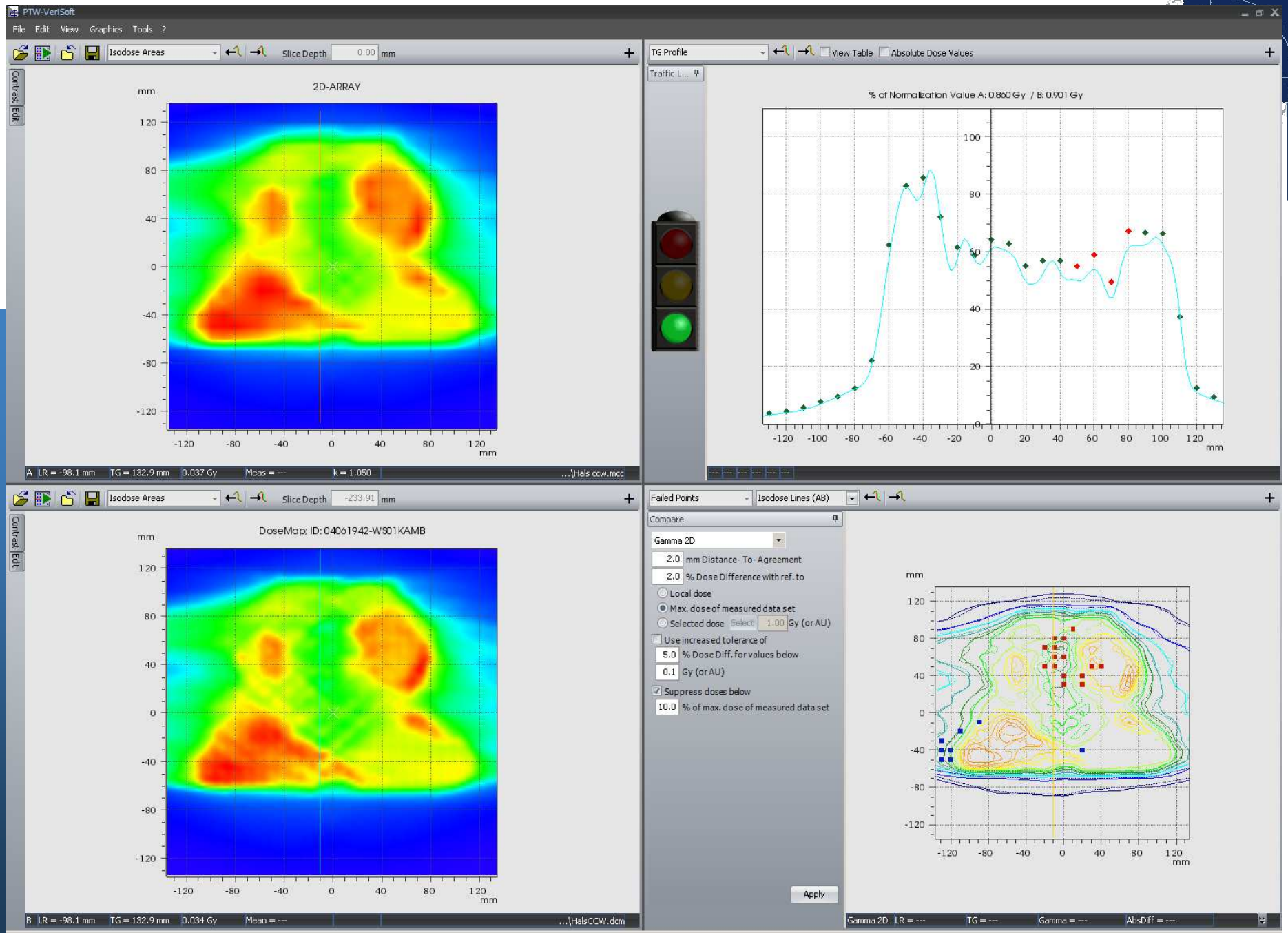
PTV low risk 54,0 Gy
(nicht befallene LK Level II-V)

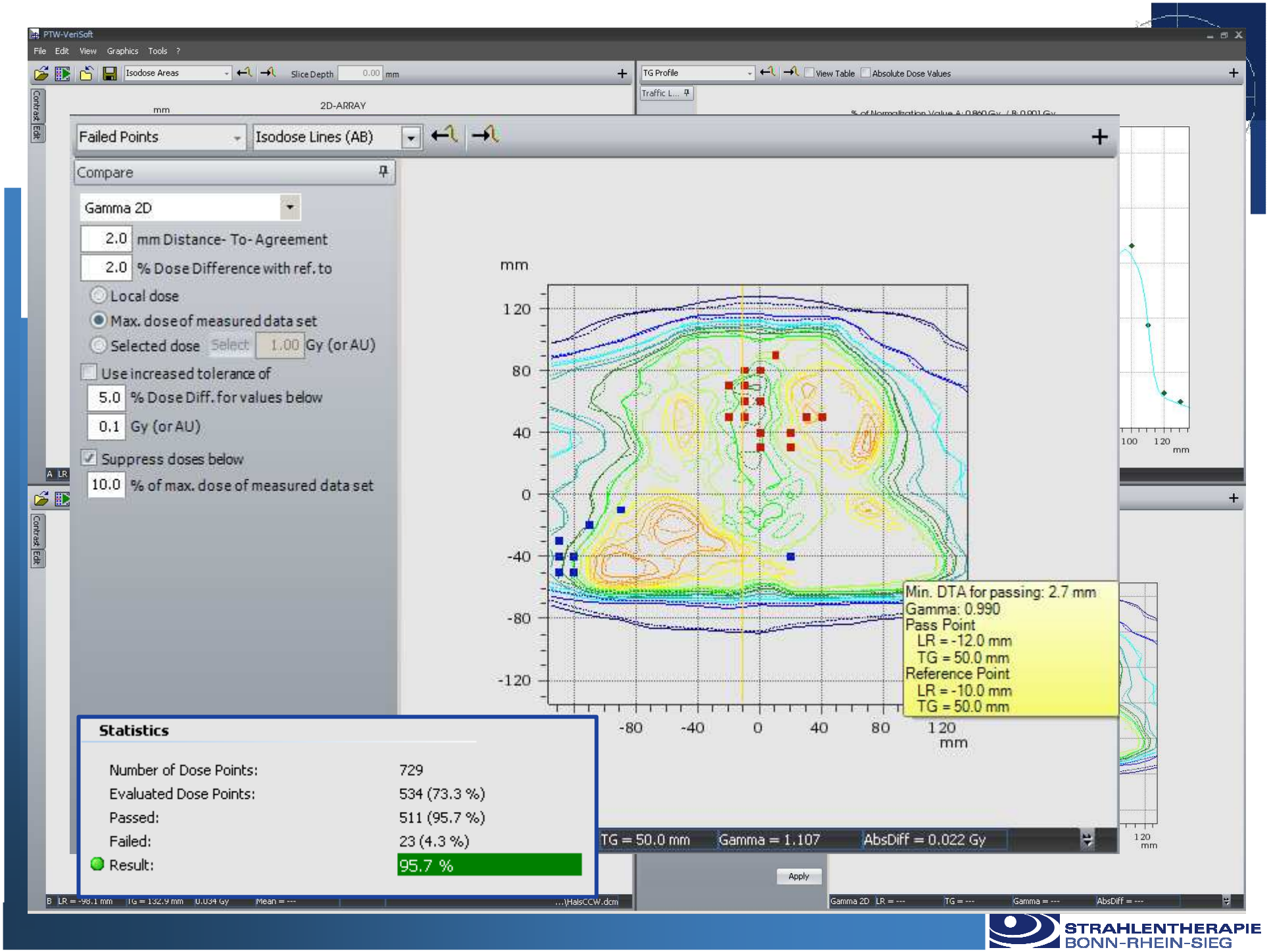
33 Fraktionen
(ED 2,12 1,8 1,64)

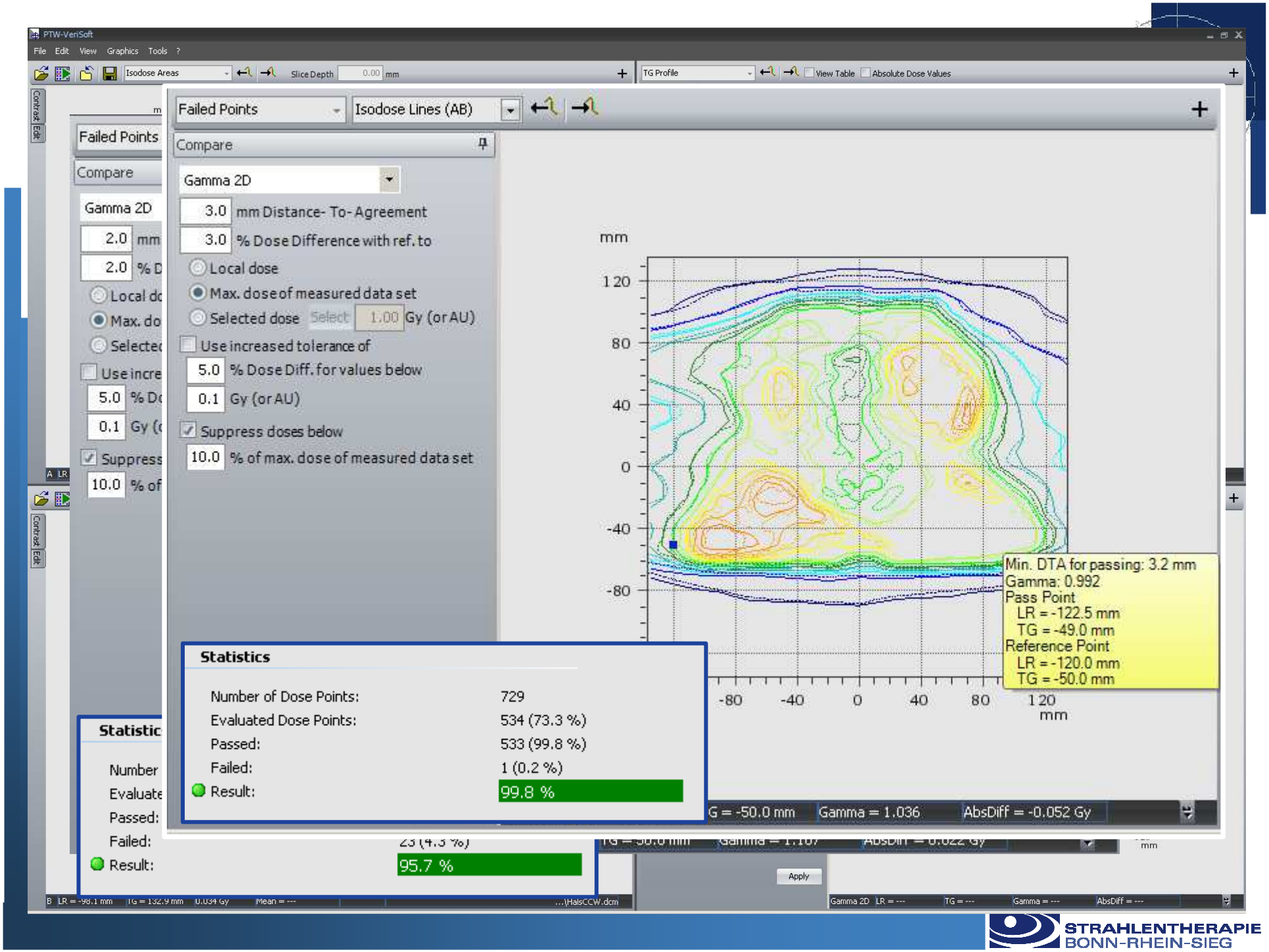


Beispiel HNO, 2 Arcs, 226+266 MU

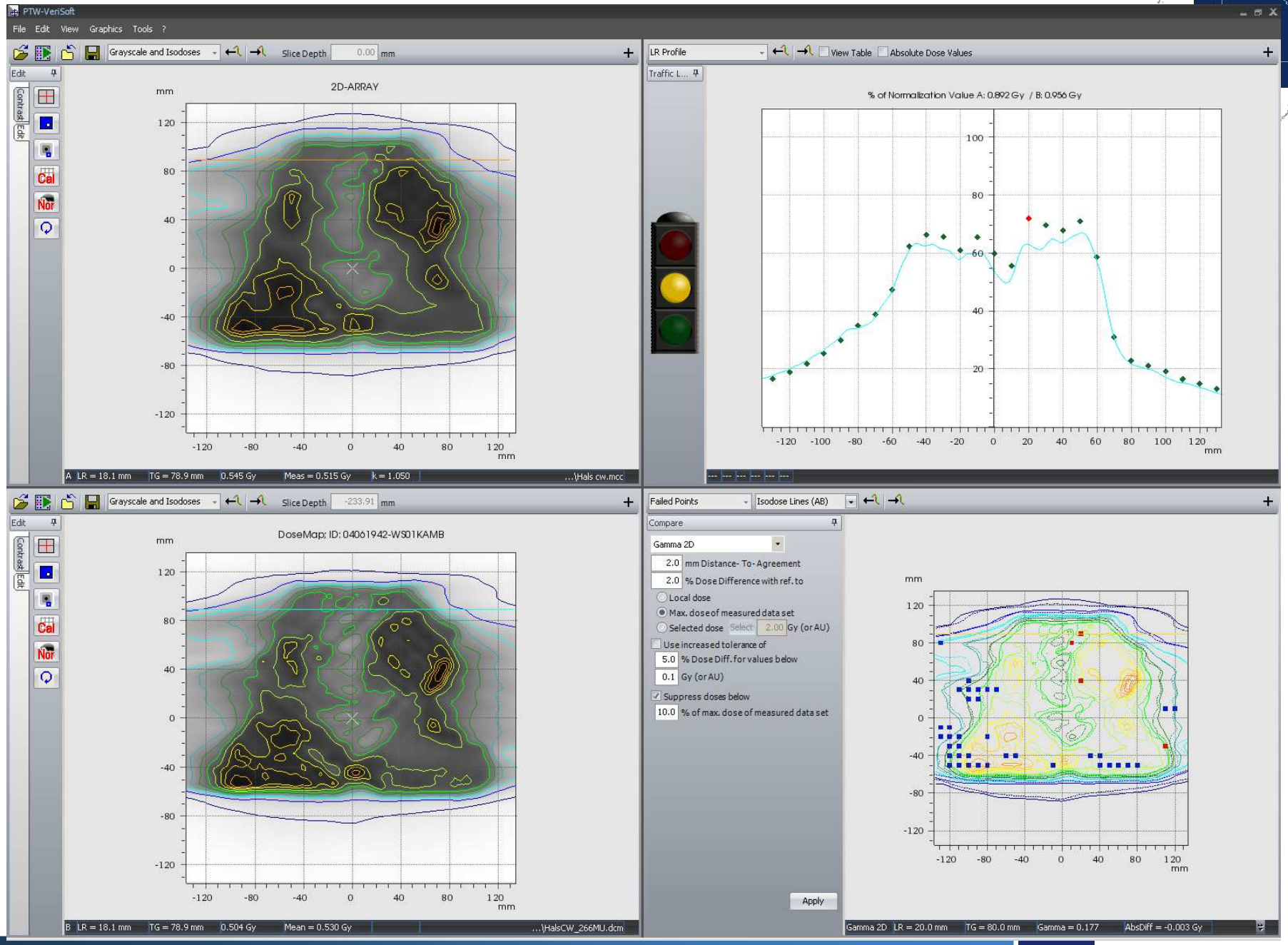


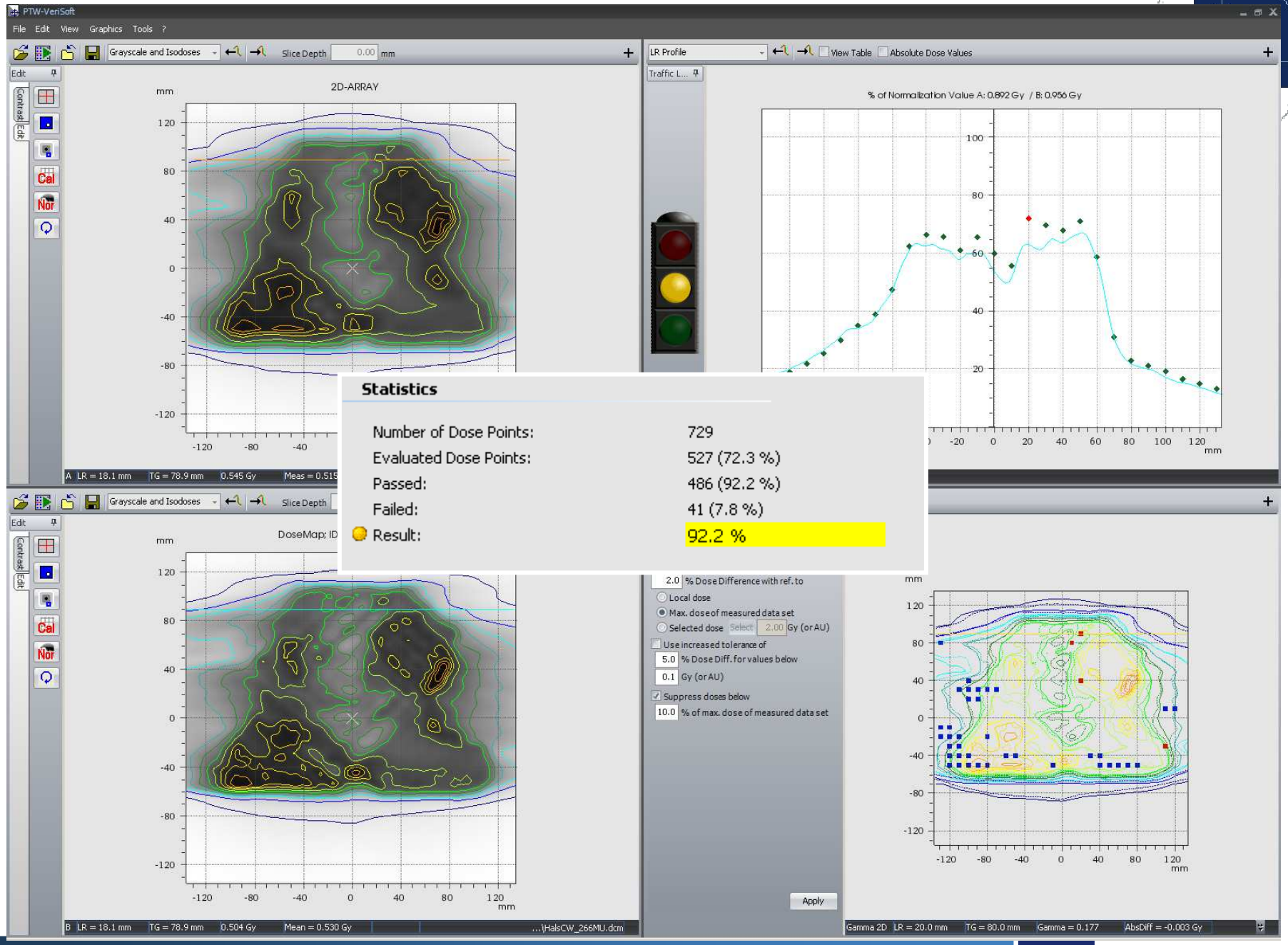

PTW-VeriSoft
File Edit View Graphics Tools ?
Isodose Areas
Slice Depth 0.00 mm
2D-ARRAY
mm
A LR = -98.1 mm TG = 132.9 mm 0.037 Gy Meas = --- k = 1.050 ...\Hals ccw.mcc
TG Profile
View Table
Absolute Dose Values
% of Normalization Value A: 0.860 Gy / B: 0.901 Gy
Isodose Areas
Slice Depth -233.91 mm
DoseMap; ID: 04061942-WS01KAMB
B LR = -98.1 mm TG = 132.9 mm 0.034 Gy Mean = --- ...\HalsCCW.dcm
Failed Points
Isodose Lines (AB)
Compare
Gamma 2D
2.0 mm Distance- To- Agreement
2.0 % Dose Difference with ref. to
Local dose
Max. dose of measured data set
Selected dose Select 1.00 Gy (or AU)
Use increased tolerance of
5.0 % Dose Diff. for values below
0.1 Gy (or AU)
Suppress doses below
10.0 % of max. dose of measured data set
Apply
Gamma 2D LR = --- TG = --- Gamma = --- AbsDiff = ---


PTW-VeriSoft
File Edit View Graphics Tools ?
Isodose Areas
Slice Depth 0.00 mm
2D-ARRAY
TG Profile
View Table
Absolute Dose Values
Failed Points
Isodose Lines (AB)
Compare
Gamma 2D
2.0 mm Distance- To- Agreement
2.0 % Dose Difference with ref. to
Local dose
Max. dose of measured data set
Selected dose Select 1.00 Gy (or AU)
Use increased tolerance of
5.0 % Dose Diff. for values below
0.1 Gy (or AU)
Suppress doses below
10.0 % of max. dose of measured data set
mm
120
80
40
0
-40
-80
-120
-80 -40 0 40 80 120
mm
Min. DTA for passing: 2.7 mm
Gamma: 0.990
Pass Point
LR = -12.0 mm
TG = 50.0 mm
Reference Point
LR = -10.0 mm
TG = 50.0 mm
Statistics
Number of Dose Points: 729
Evaluated Dose Points: 534 (73.3 %)
Passed: 511 (95.7 %)
Failed: 23 (4.3 %)
Result: 95.7 %
TG = 50.0 mm
Gamma = 1.107
AbsDiff = 0.022 Gy
Apply
100 120
mm

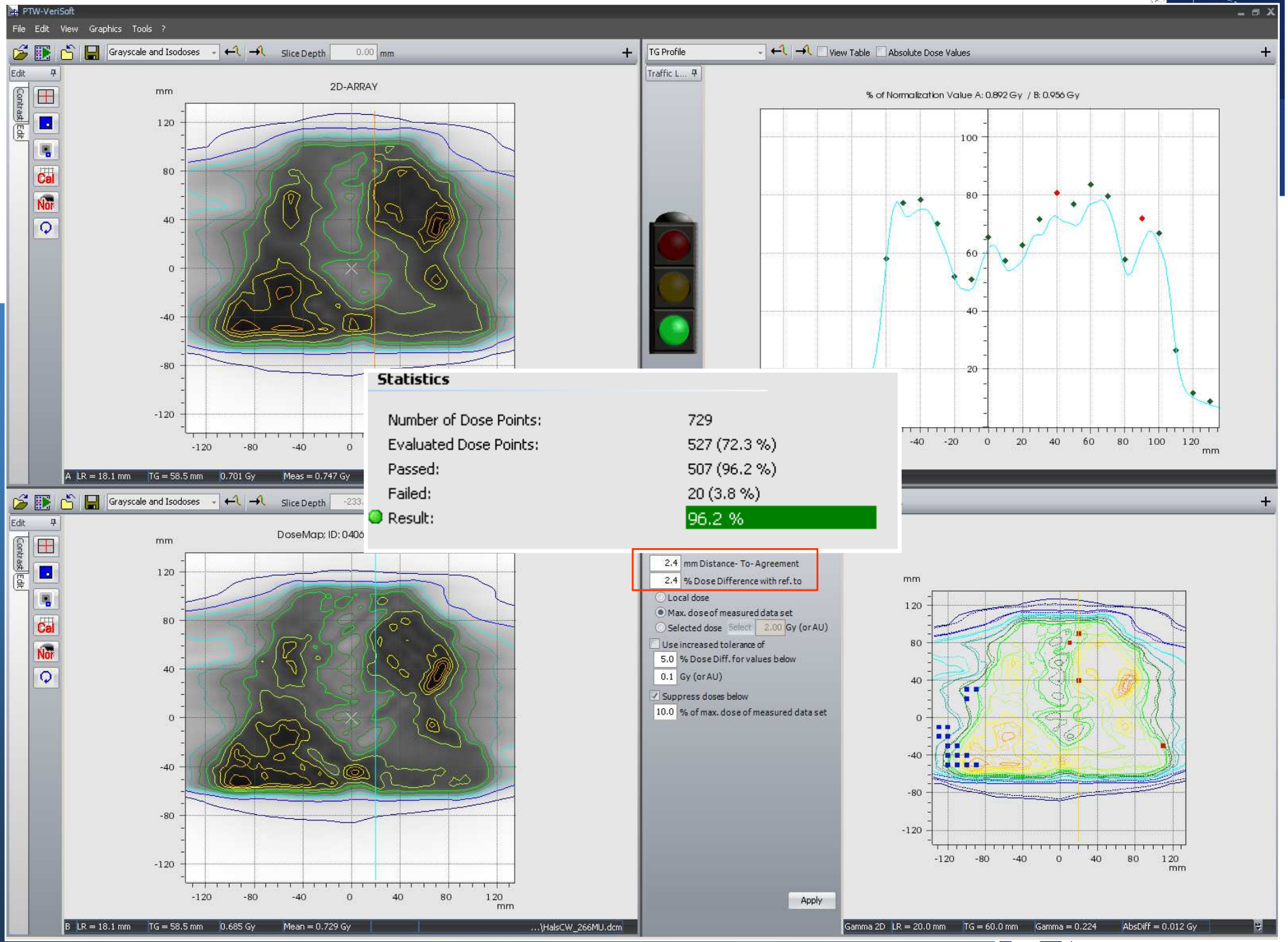


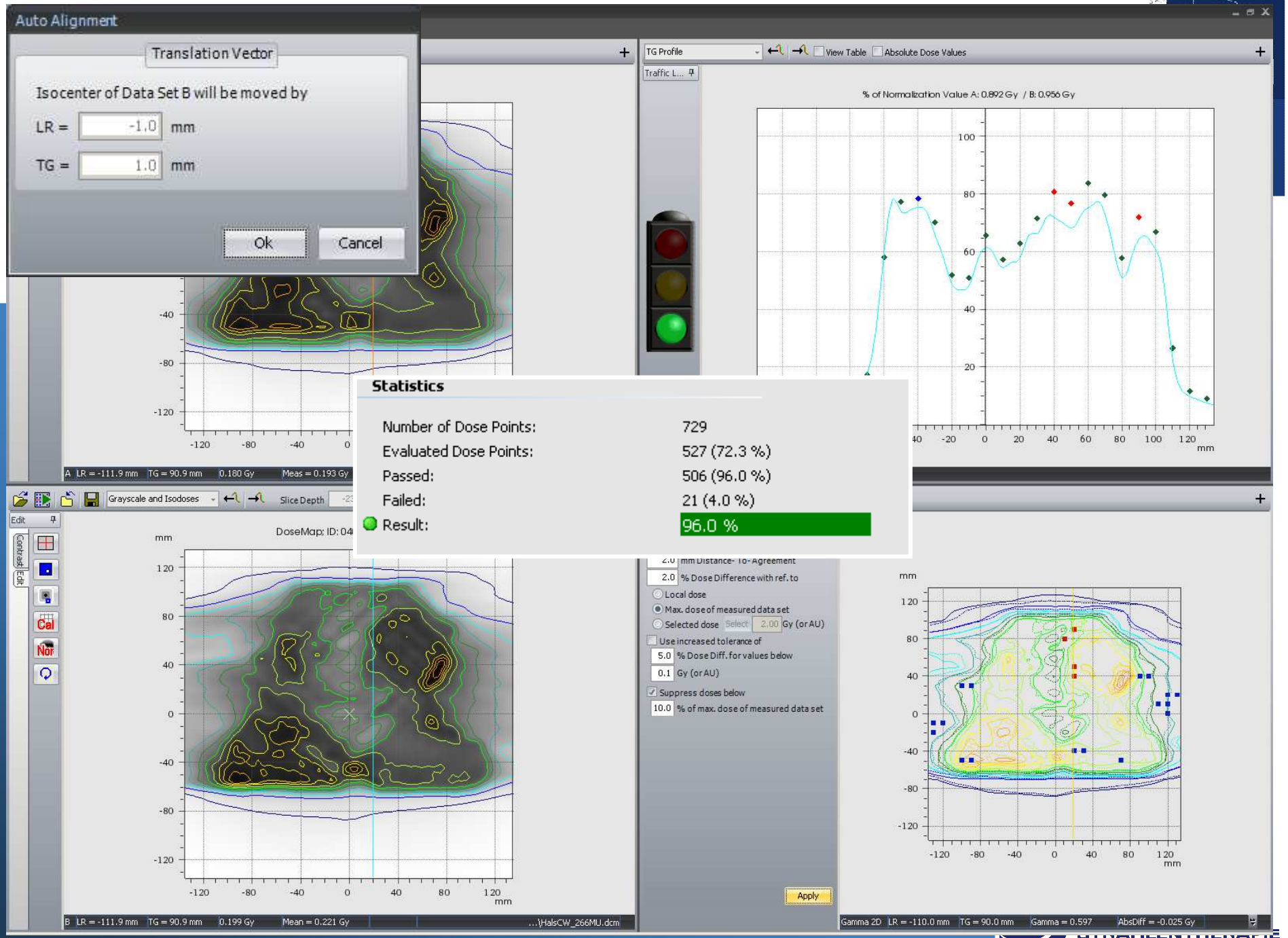
STRAHLENTHERAPIE BONN-RHEIN-SIEG


PTW-VeriSoft
File Edit View Graphics Tools ?
Grayscale and Isodoses
Slice Depth 0.00 mm
2D-ARRAY
mm
A LR = 18.1 mm TG = 78.9 mm 0.545 Gy Meas = 0.515 Gy k = 1.050 ...\Hals cw.mcc
LR Profile
View Table
Absolute Dose Values
% of Normalization Value A: 0.892 Gy / B: 0.956 Gy
mm
Grayscale and Isodoses
Slice Depth -233.91 mm
DoseMap; ID: 04061942-WS01KAMB
mm
B LR = 18.1 mm TG = 78.9 mm 0.504 Gy Mean = 0.530 Gy ...\HalsCW_266MU.dcm
Failed Points
Isodose Lines (AB)
Compare
Gamma 2D
2.0 mm Distance- To- Agreement
2.0 % Dose Difference with ref. to
Local dose
Max. dose of measured data set
Selected dose Select 2.00 Gy (or AU)
Use increased tolerance of
5.0 % Dose Diff. for values below
0.1 Gy (or AU)
Suppress doses below
10.0 % of max. dose of measured data set
Apply
mm
Gamma 2D LR = 20.0 mm TG = 80.0 mm Gamma = 0.177 AbsDiff = -0.003 Gy

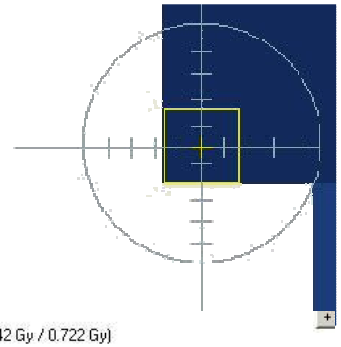


STRAHLENTHERAPIE BONN-RHEIN-SIEG


PTW-VeriSoft
File Edit View Graphics Tools ?
Grayscale and Isodoses
Slice Depth 0.00 mm
2D-ARRAY
TG Profile
View Table
Absolute Dose Values
% of Normalization Value A: 0.892 Gy / B: 0.956 Gy
Statistics
Number of Dose Points: 729
Evaluated Dose Points: 527 (72.3 %)
Passed: 507 (96.2 %)
Failed: 20 (3.8 %)
Result: 96.2 %
DoseMap; ID: 0406
2.4 mm Distance- To- Agreement
2.4 % Dose Difference with ref. to
Local dose
Max. dose of measured data set
Selected dose Select 2.00 Gy (or AU)
Use increased tolerance of
5.0 % Dose Diff. for values below
0.1 Gy (or AU)
Suppress doses below
10.0 % of max. dose of measured data set
Apply
A LR = 18.1 mm TG = 58.5 mm 0.701 Gy Meas = 0.747 Gy
B LR = 18.1 mm TG = 58.5 mm 0.685 Gy Mean = 0.729 Gy
Gamma 2D LR = 20.0 mm TG = 60.0 mm Gamma = 0.224 AbsDiff = 0.012 Gy

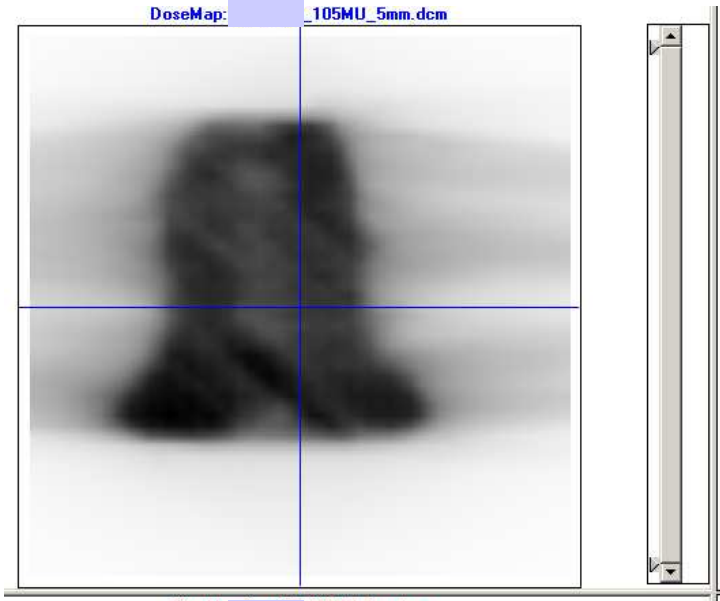

Auto Alignment
Translation Vector
Isocenter of Data Set B will be moved by
LR = -1.0 mm
TG = 1.0 mm
Ok
Cancel
TG Profile
View Table
Absolute Dose Values
% of Normalization Value A: 0.892 Gy / B: 0.956 Gy
Statistics
Number of Dose Points: 729
Evaluated Dose Points: 527 (72.3 %)
Passed: 506 (96.0 %)
Failed: 21 (4.0 %)
Result: 96.0 %
Grayscale and Isodoses
Slice Depth
DoseMap: ID: 04
2.0 % Dose Difference with ref. to
Local dose
Max. dose of measured data set
Selected dose
Use increased tolerance of
5.0 % Dose Diff. for values below
0.1 Gy (or AU)
Suppress doses below
10.0 % of max. dose of measured data set
Apply
A LR = -111.9 mm TG = 90.9 mm 0.180 Gy Meas = 0.193 Gy
B LR = -111.9 mm TG = 90.9 mm 0.199 Gy Mean = 0.221 Gy
Gamma 2D LR = -110.0 mm TG = 90.0 mm Gamma = 0.597 AbsDiff = -0.025 Gy

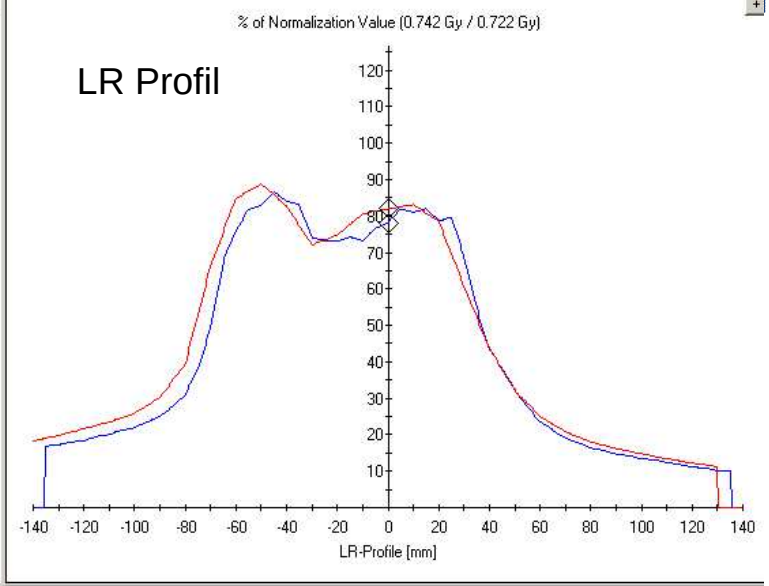
Ursachensuche: Ortsauflösung?



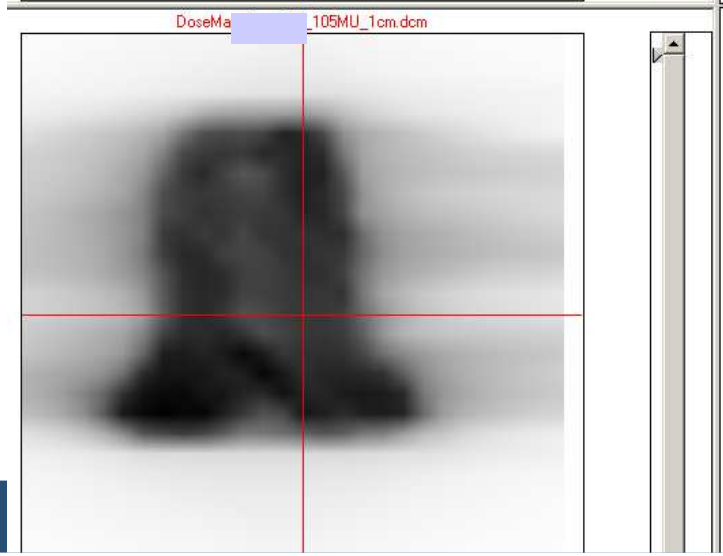
Gleiche geplante Dosisverteilung, exportiert aus dem Planungssystem

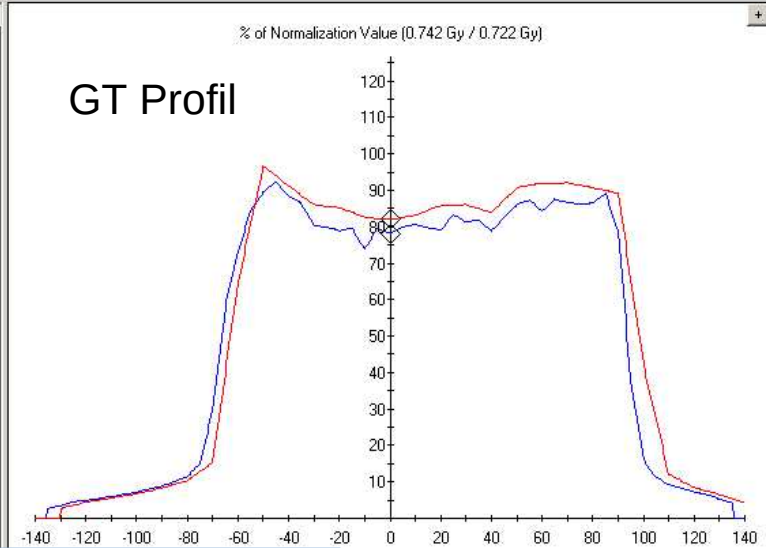
5mm Auflösung



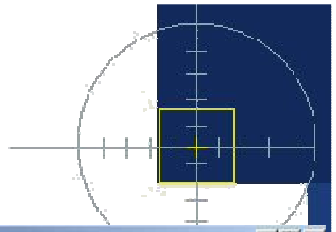


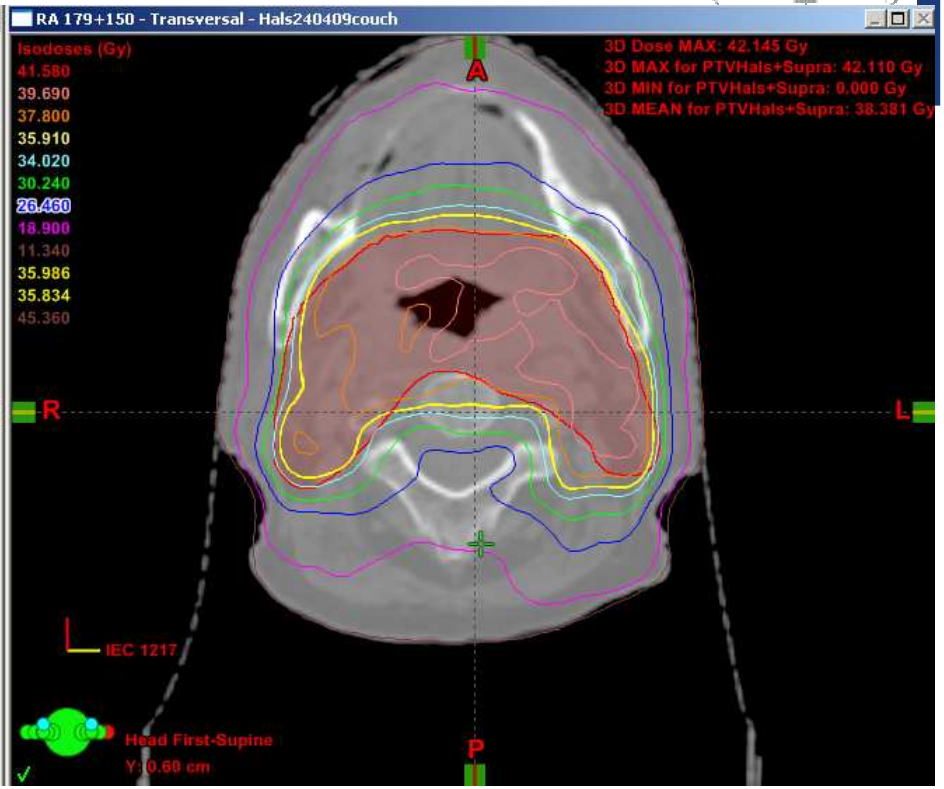
1cm Auflösung





HNO: RA vs 3D

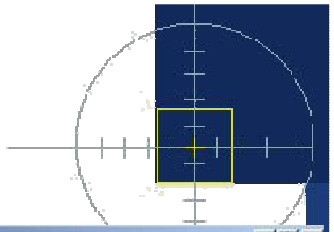


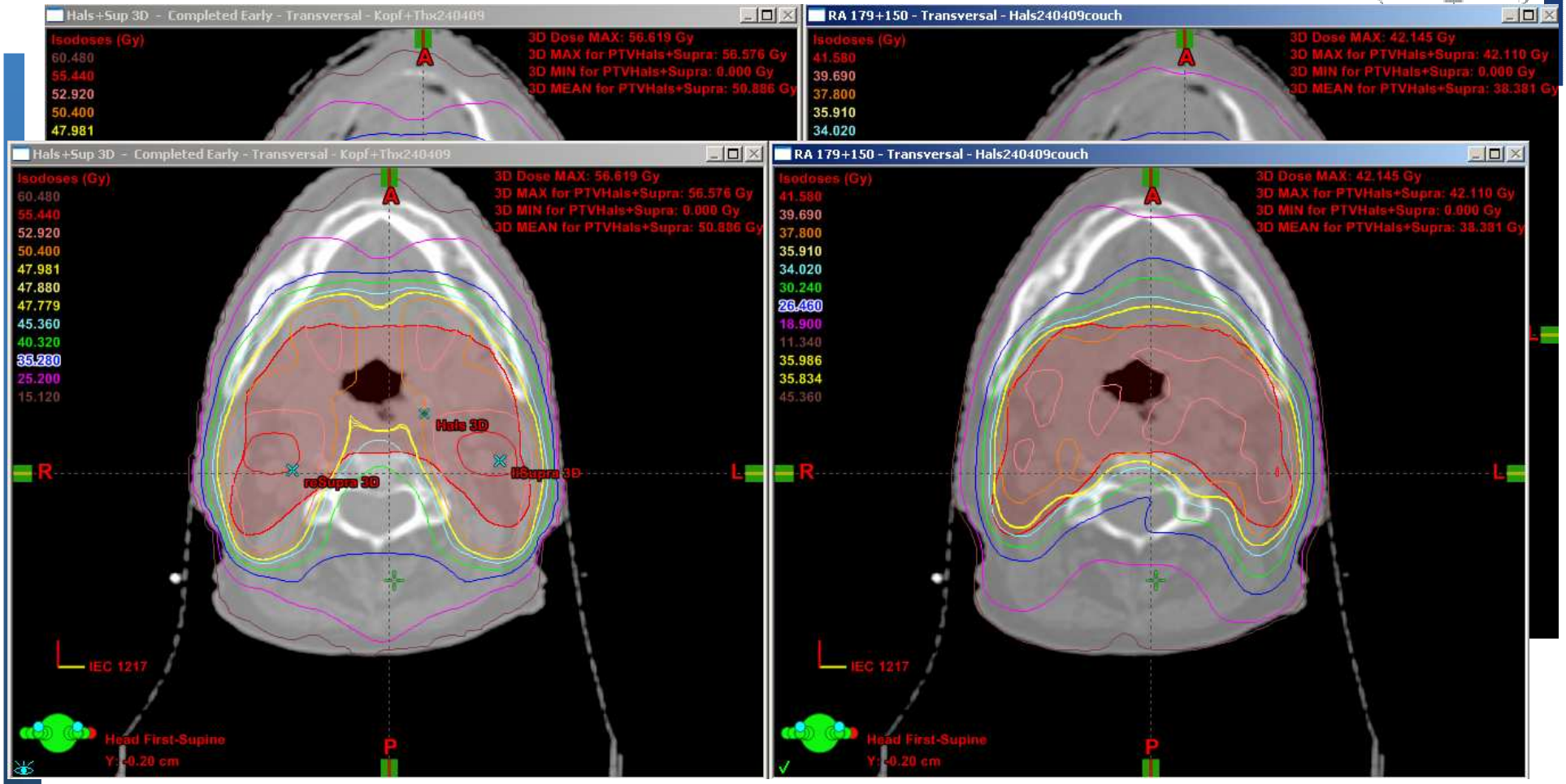


Anfang: 3D konformal

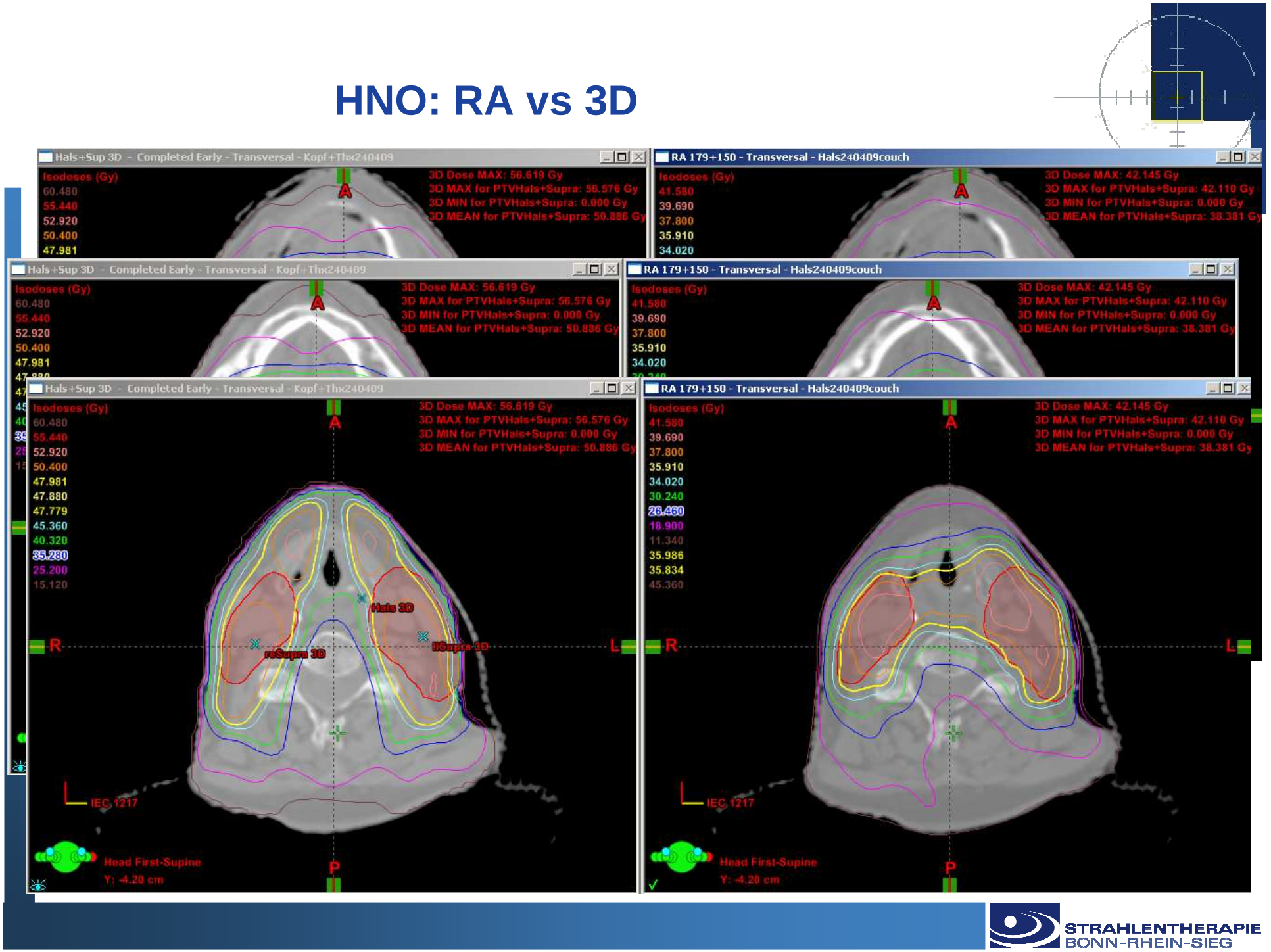
RA Umplanung nach 7 Fraktionen

HNO: RA vs 3D

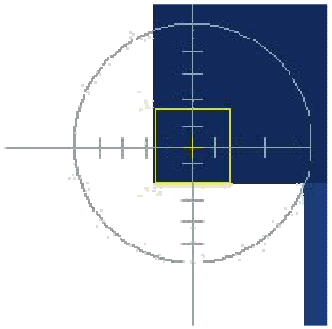



Hals+Sup 3D - Completed Early - Transversal - Kopf+Thx240409
Isodoses (Gy)
60.480
55.440
52.920
50.400
47.981
47.880
47.779
45.360
40.320
35.280
25.200
15.120
3D Dose MAX: 56.619 Gy
3D MAX for PTVHals+Supra: 56.576 Gy
3D MIN for PTVHals+Supra: 0.000 Gy
3D MEAN for PTVHals+Supra: 50.886 Gy
A
R
L
P
Hals 3D
reSupra 3D
liSupra 3D
IEC 1217
Head First-Supine
Y: -0.20 cm
RA 179+150 - Transversal - Hals240409couch
Isodoses (Gy)
41.580
39.690
37.800
35.910
34.020
30.240
26.460
18.900
11.340
35.986
35.834
45.360
3D Dose MAX: 42.145 Gy
3D MAX for PTVHals+Supra: 42.110 Gy
3D MIN for PTVHals+Supra: 0.000 Gy
3D MEAN for PTVHals+Supra: 38.381 Gy

HNO: RA vs 3D


Hals+Sup 3D - Completed Early - Transversal - Kopf+Thx240409
Isodoses (Gy)
60.480
55.440
52.920
50.400
47.981
3D Dose MAX: 56.619 Gy
3D MAX for PTVHals+Supra: 56.576 Gy
3D MIN for PTVHals+Supra: 0.000 Gy
3D MEAN for PTVHals+Supra: 50.886 Gy
RA 179+150 - Transversal - Hals240409couch
Isodoses (Gy)
41.580
39.690
37.800
35.910
34.020
3D Dose MAX: 42.145 Gy
3D MAX for PTVHals+Supra: 42.110 Gy
3D MIN for PTVHals+Supra: 0.000 Gy
3D MEAN for PTVHals+Supra: 38.381 Gy
Hals+Sup 3D - Completed Early - Transversal - Kopf+Thx240409
RA 179+150 - Transversal - Hals240409couch
Hals+Sup 3D - Completed Early - Transversal - Kopf+Thx240409
Isodoses (Gy)
60.480
55.440
52.920
50.400
47.981
47.880
47.779
45.360
40.320
35.280
25.200
15.120
3D Dose MAX: 56.619 Gy
3D MAX for PTVHals+Supra: 56.576 Gy
3D MIN for PTVHals+Supra: 0.000 Gy
3D MEAN for PTVHals+Supra: 50.886 Gy
Hals 3D
rSupra 3D
lSupra 3D
A
P
R
L
IEC 1217
Head First-Supine
Y: -4.20 cm
RA 179+150 - Transversal - Hals240409couch
Isodoses (Gy)
41.580
39.690
37.800
35.910
34.020
30.240
26.460
18.900
11.340
35.986
35.834
45.360
3D Dose MAX: 42.145 Gy
3D MAX for PTVHals+Supra: 42.110 Gy
3D MIN for PTVHals+Supra: 0.000 Gy
3D MEAN for PTVHals+Supra: 38.381 Gy
A
P
R
L
IEC 1217
Head First-Supine
Y: -4.20 cm

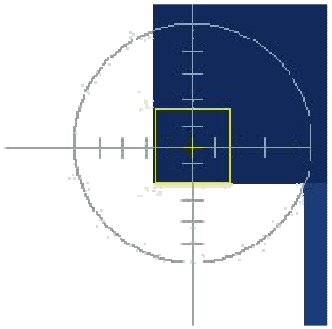
Zusammenfassung



- Rapid Arc machbar – auch in der Praxis
  - von Patienten gut toleriert
  - Dosisverteilung: sehr effektive Schonung der Risikoorgane

- QA ?
  - Ortsauflösung: EPID?
  - Jeder Plan?

Zusammenfassung



- Rapid Arc machbar – auch in der Praxis
  - von Patienten gut toleriert
  - Dosisverteilung: sehr effektive Schonung der Risikoorgane

- QA ?
  - Ortsauflösung: EPID?
  - Jeder Plan?

Vielen Dank für Ihre Aufmerksamkeit !