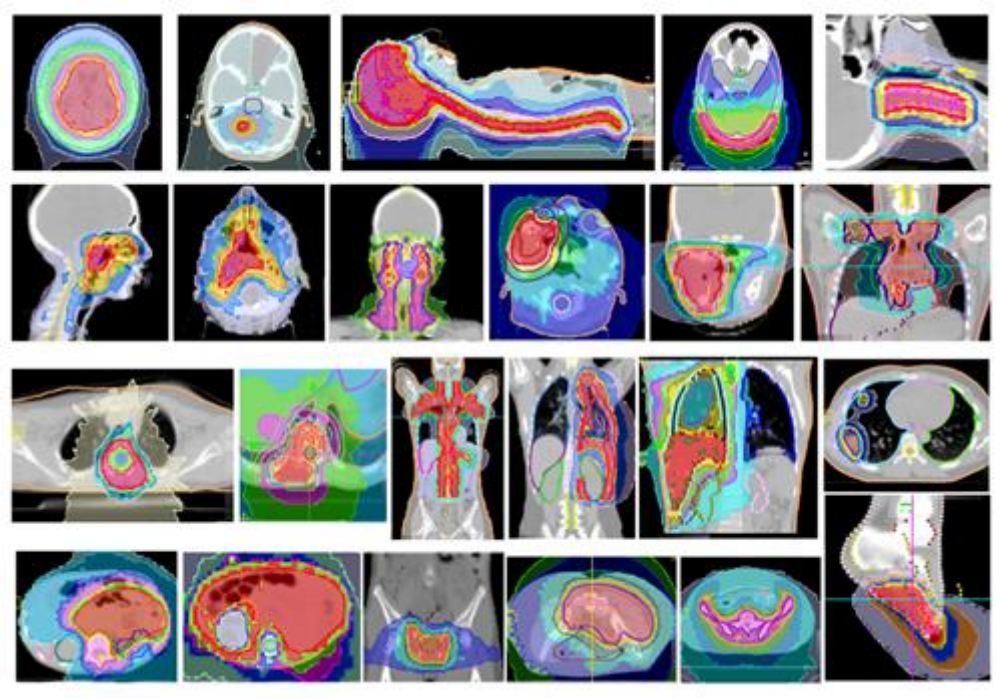
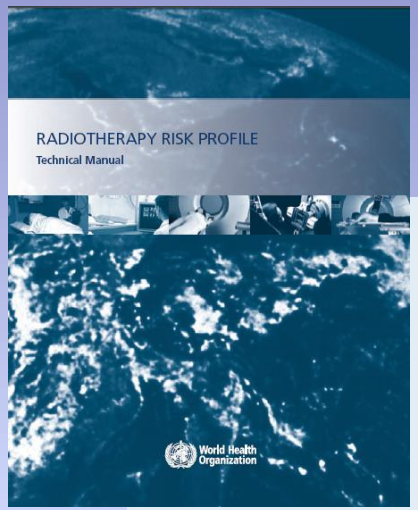
Conformal RT and 3D-CRT planning

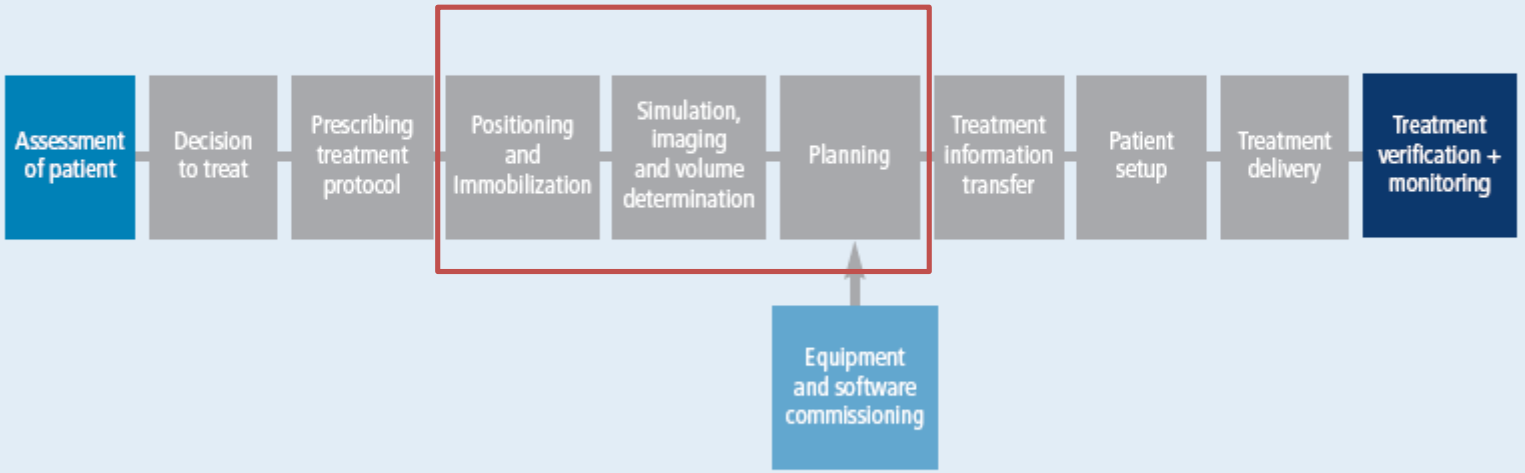


Dott. Paola Chiovati , Medical Physicist, CRO Aviano
E-mail : pchiovati@cro.it

Picture dr. Mascarin – Pediatrician and Radiation Oncologist

WORLD HEALTH ORGANIZATION





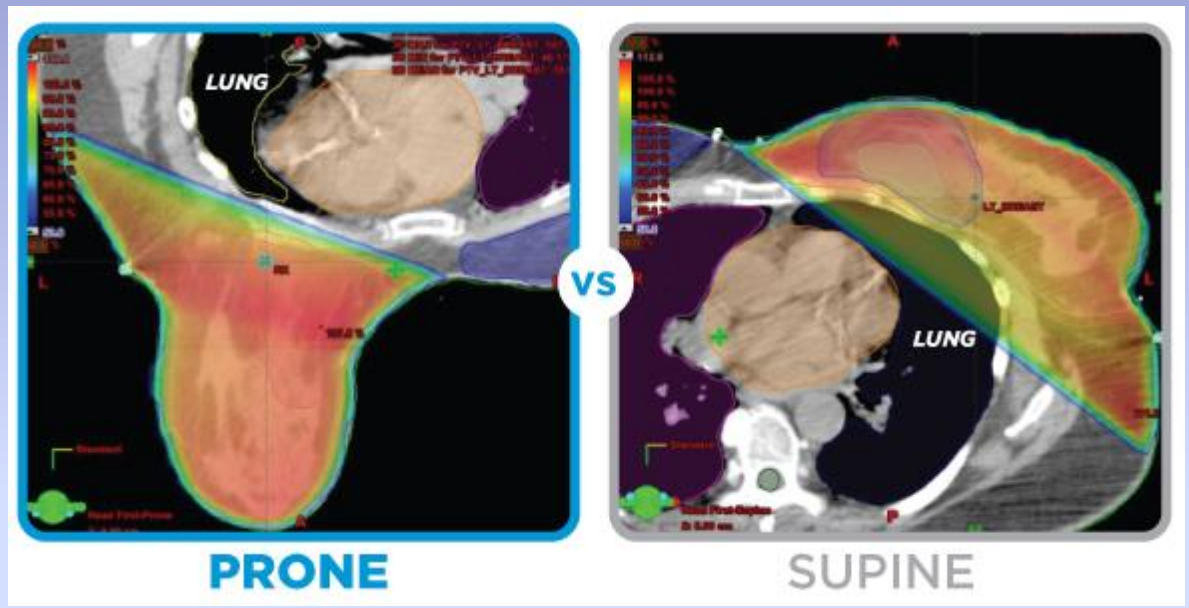
PATIENT SET UP CRT 3D-CRT

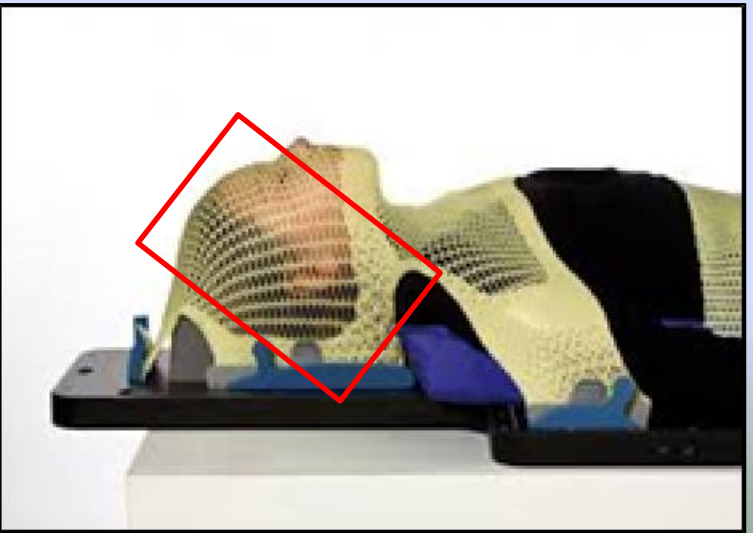
POSITIONING AND IMMOBILIZING

Positioning is not immobilization

<u>confortable</u>→ mantain the position for long time

Help the <u>OAR sparing</u>





PATIENT SET UP CRT 3D-CRT

POSITIONING AND IMMOBILIZING

Immobilization in CRT: Desirable

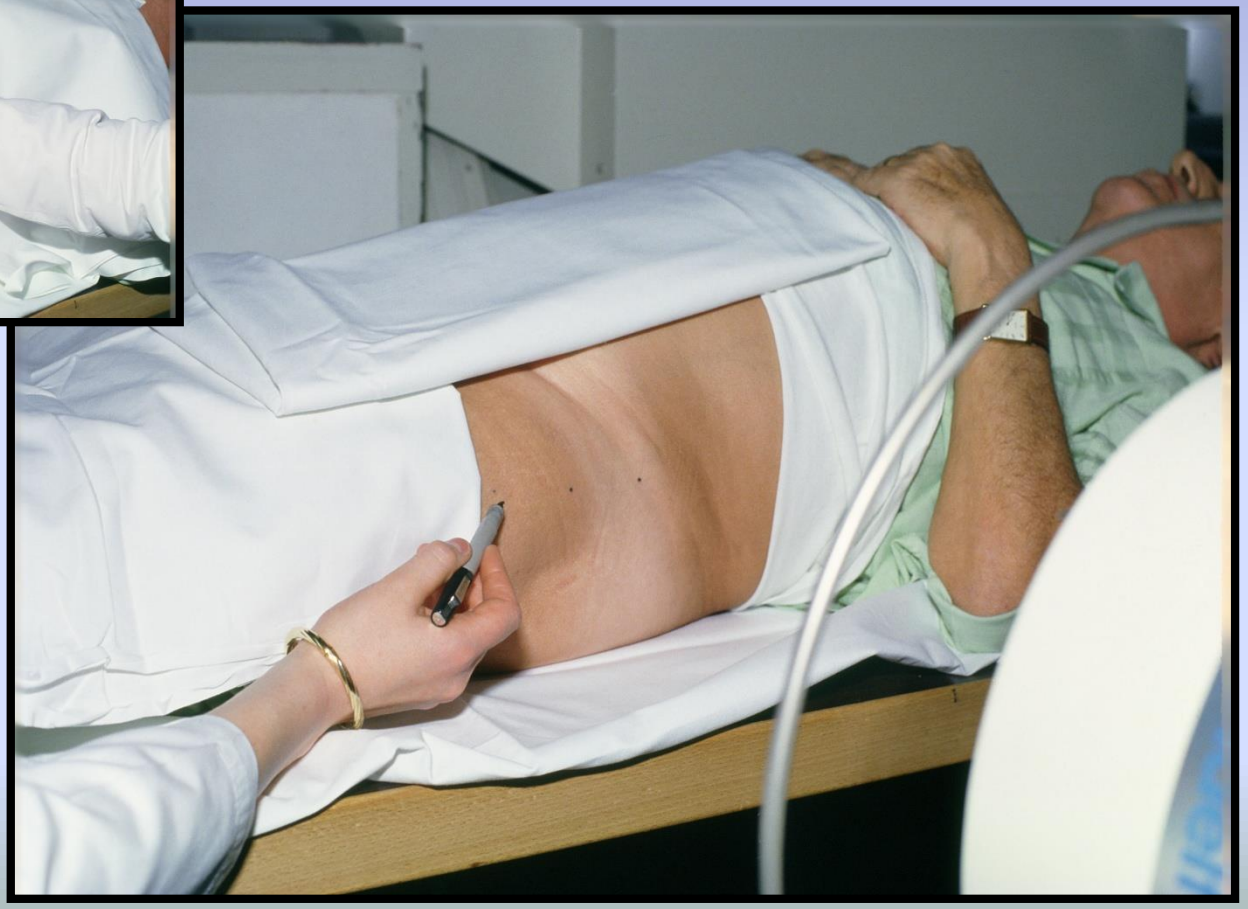
Immobilization In 3D-CRT: customized to the patient

PATIENT SET UP CRT 3D-CRT

Immobilization In 3D-CRT:
customized to the patient

Basic CRT

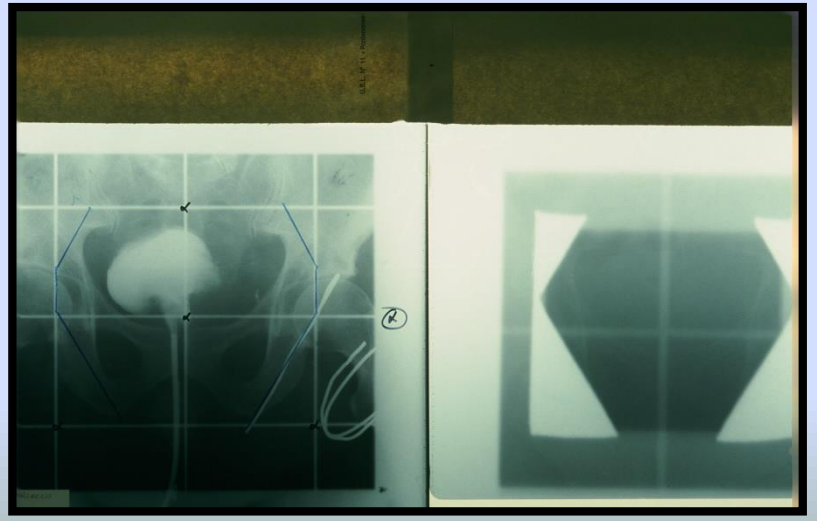
Immobilization: Desirable



Skin marker

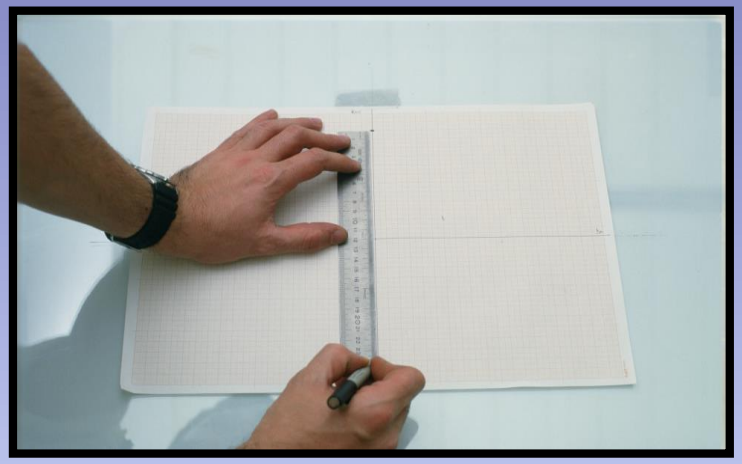
IAEA-TECDOC-1588

Basic CRT

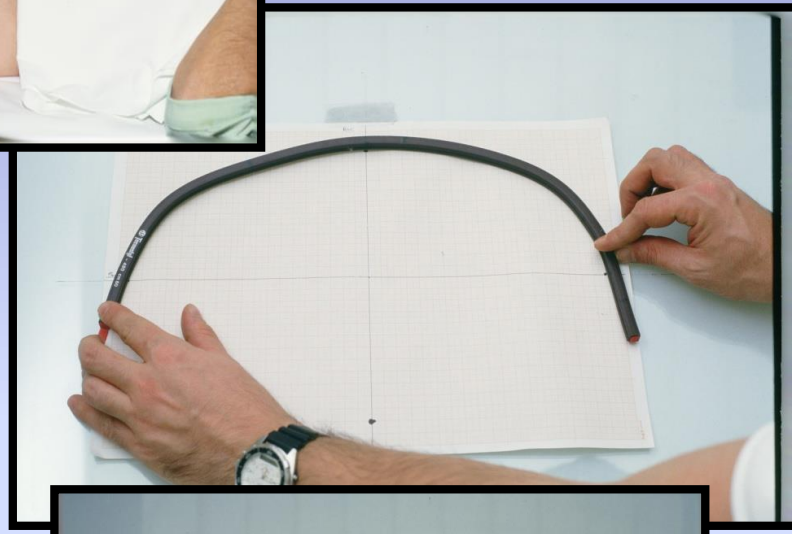


Field Shape and dimension drawn on simulation films

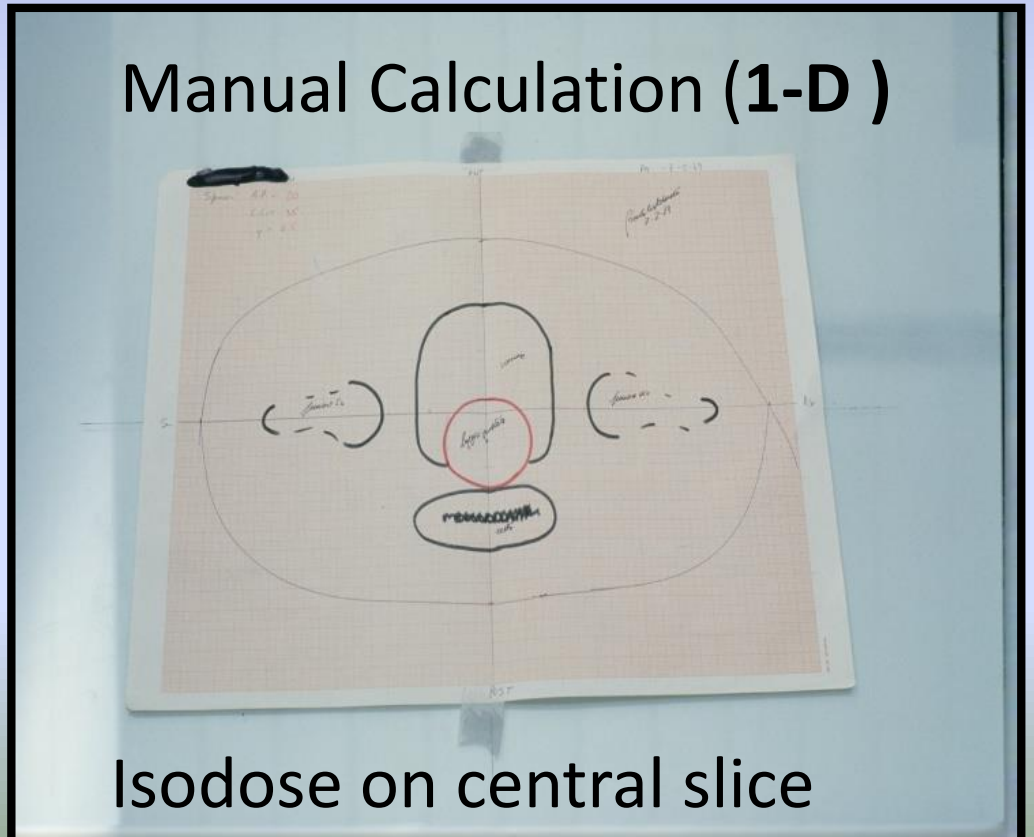
Basic CRT

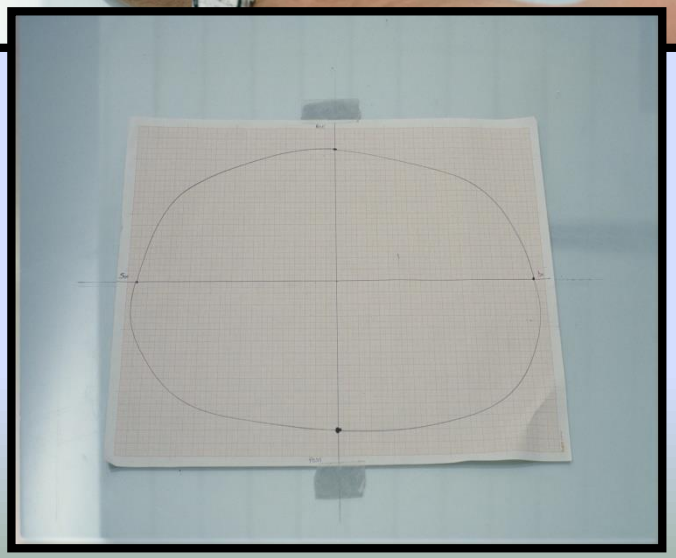


Contour individual slices

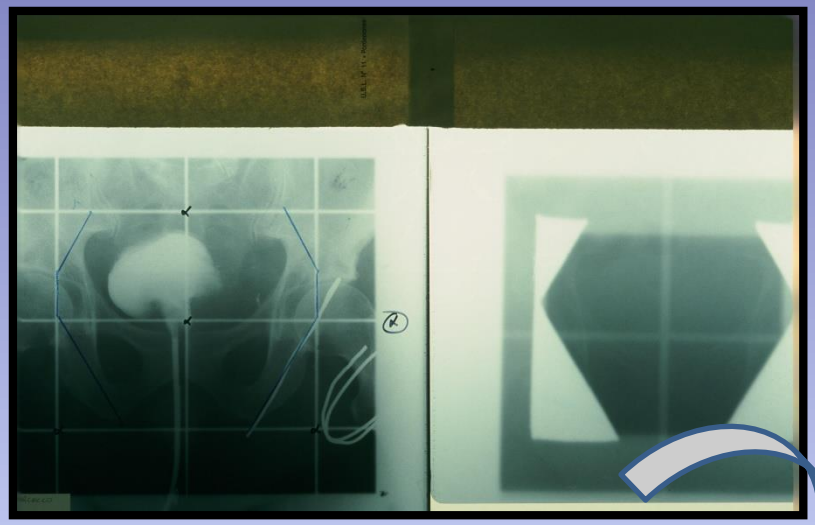


Manual Calculation (**1-D)**



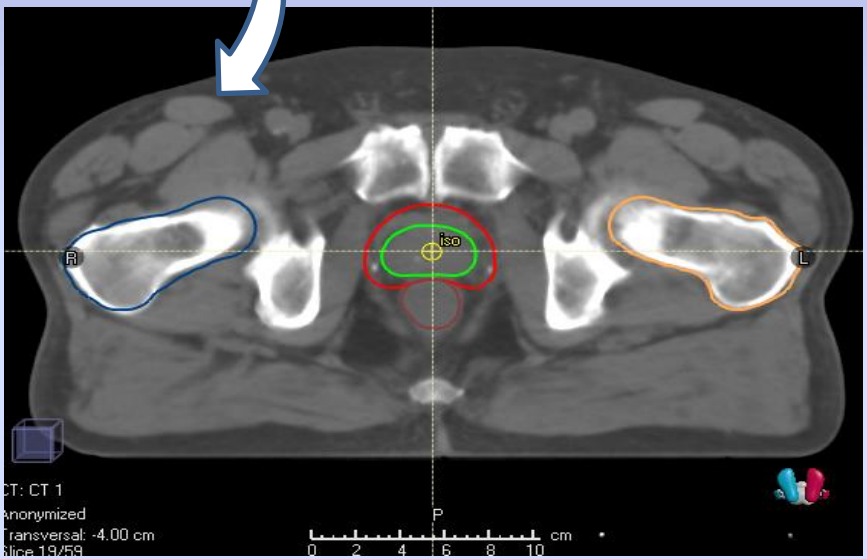


Isodose on central slice



Basic CRT optional

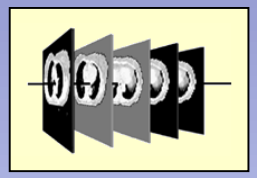
few CT slices optional

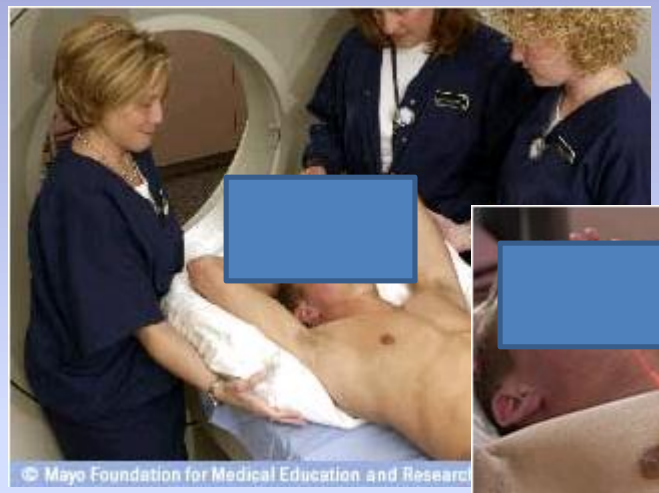


Dose calculation 2-D (slice) ± inhomogeneity

Image Acquisition 3D-CRT

adjacent thin slices **CT slices**





Skin Marker

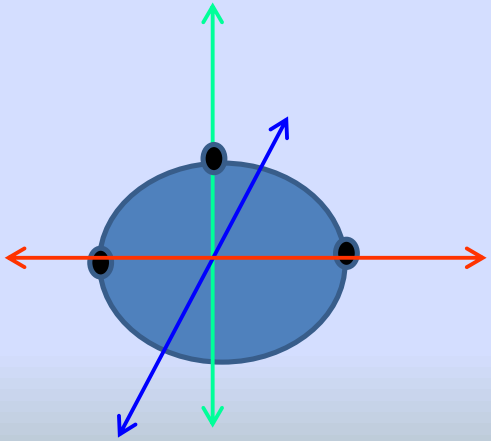
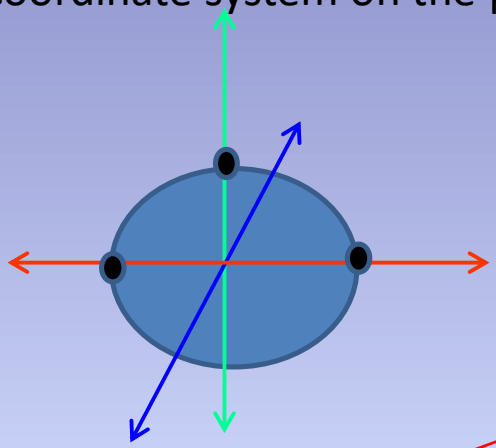
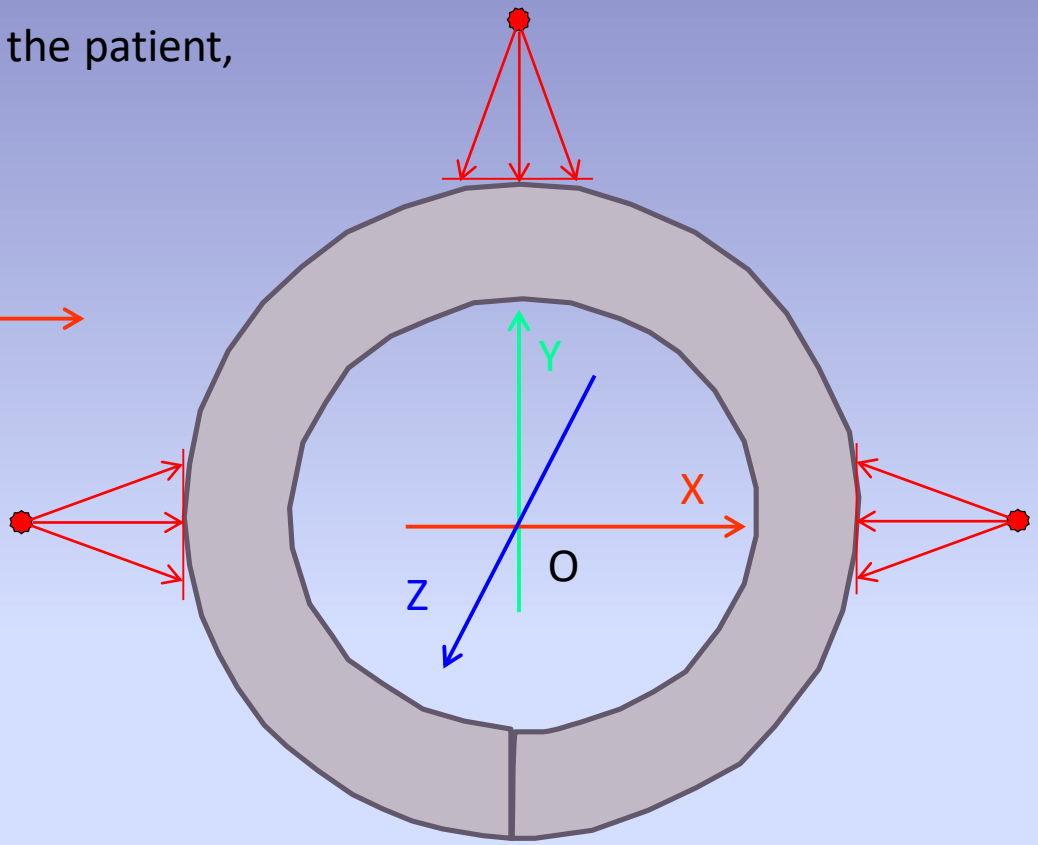


Image Acquisition3D-CRT

coordinate system on the patient,

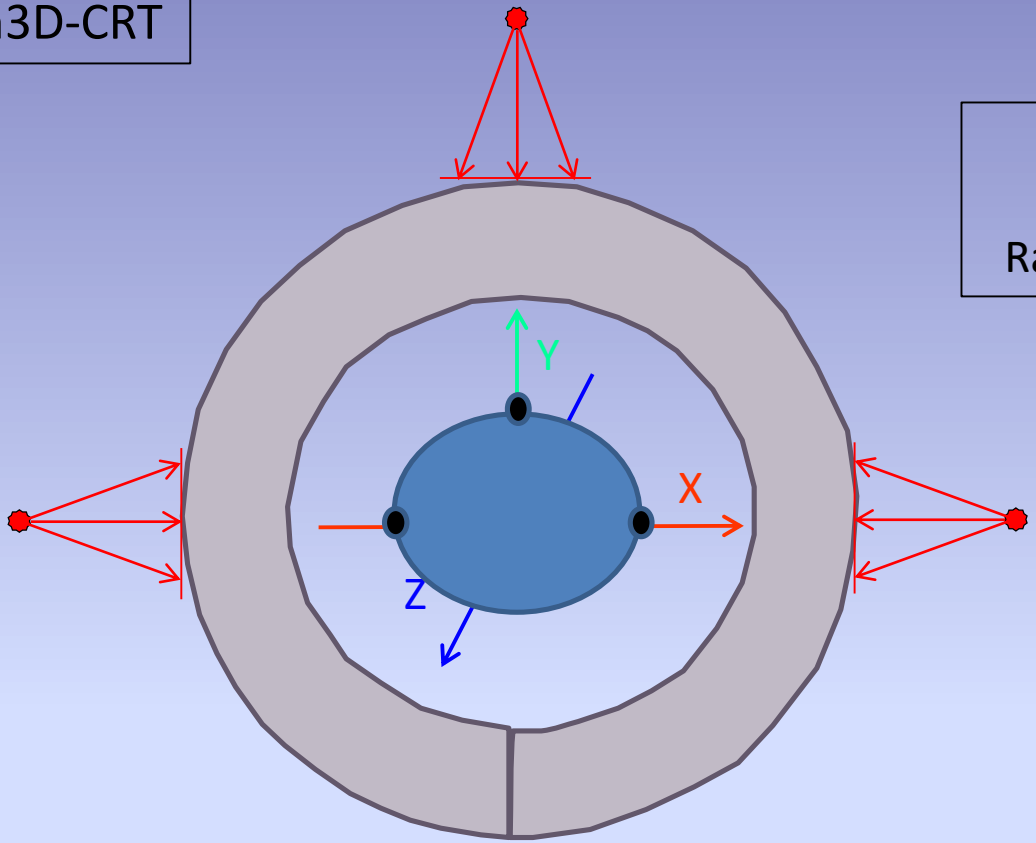




THE CT coordinate system and origin IS EXPRESSED BY LASERS

Image Acquisition3D-CRT

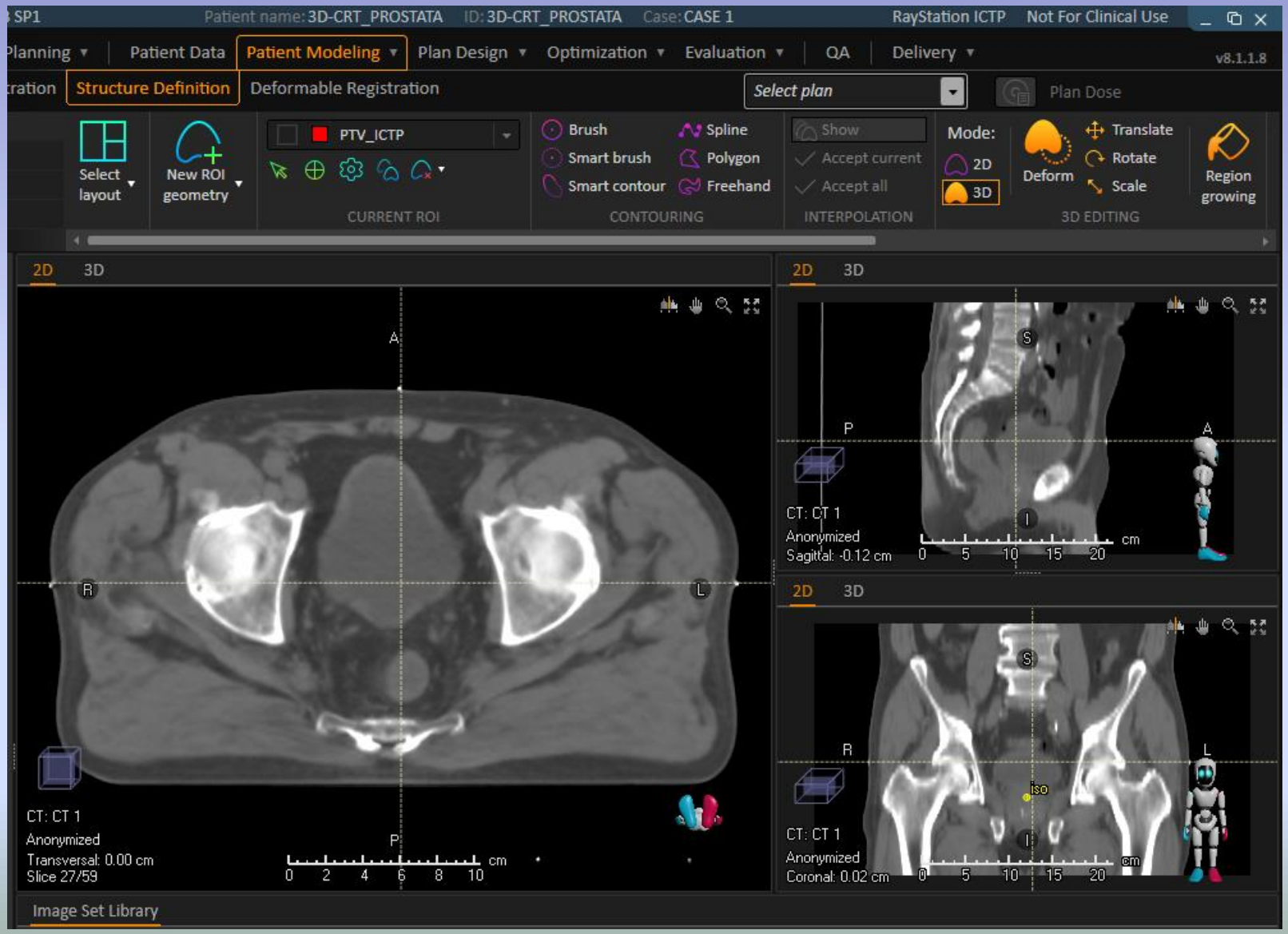
Skin Marker
+
Radiopaque Marker



The coordinate system of the equipment must match with the coordinate system on the patient, and the two origin must match.

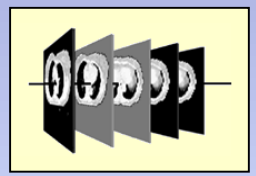
Radiopaque Marker over the skin marker in order to see them in CT aquisition

Image Acquisition3D-CRT

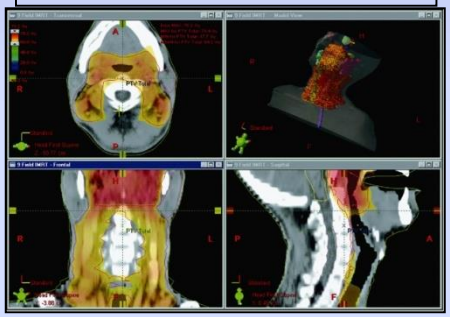


Contouring in 3D-CRT

IMAGING



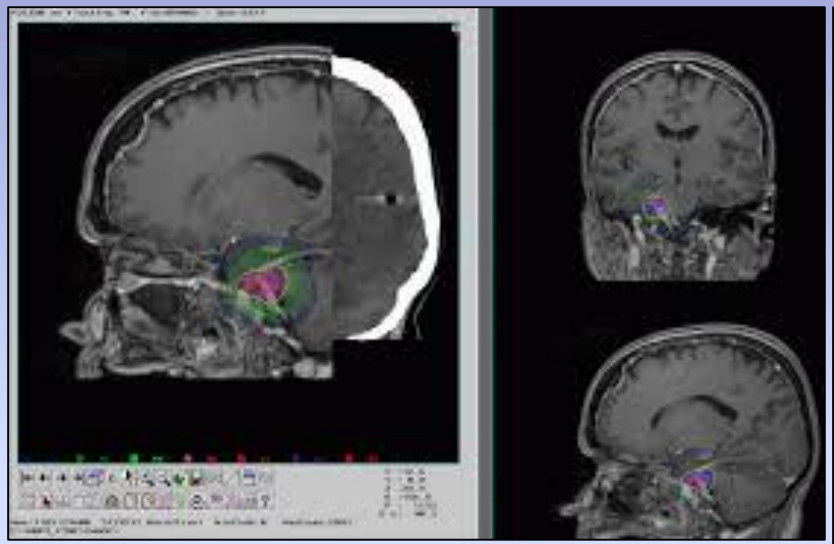
TPS or contouring Station

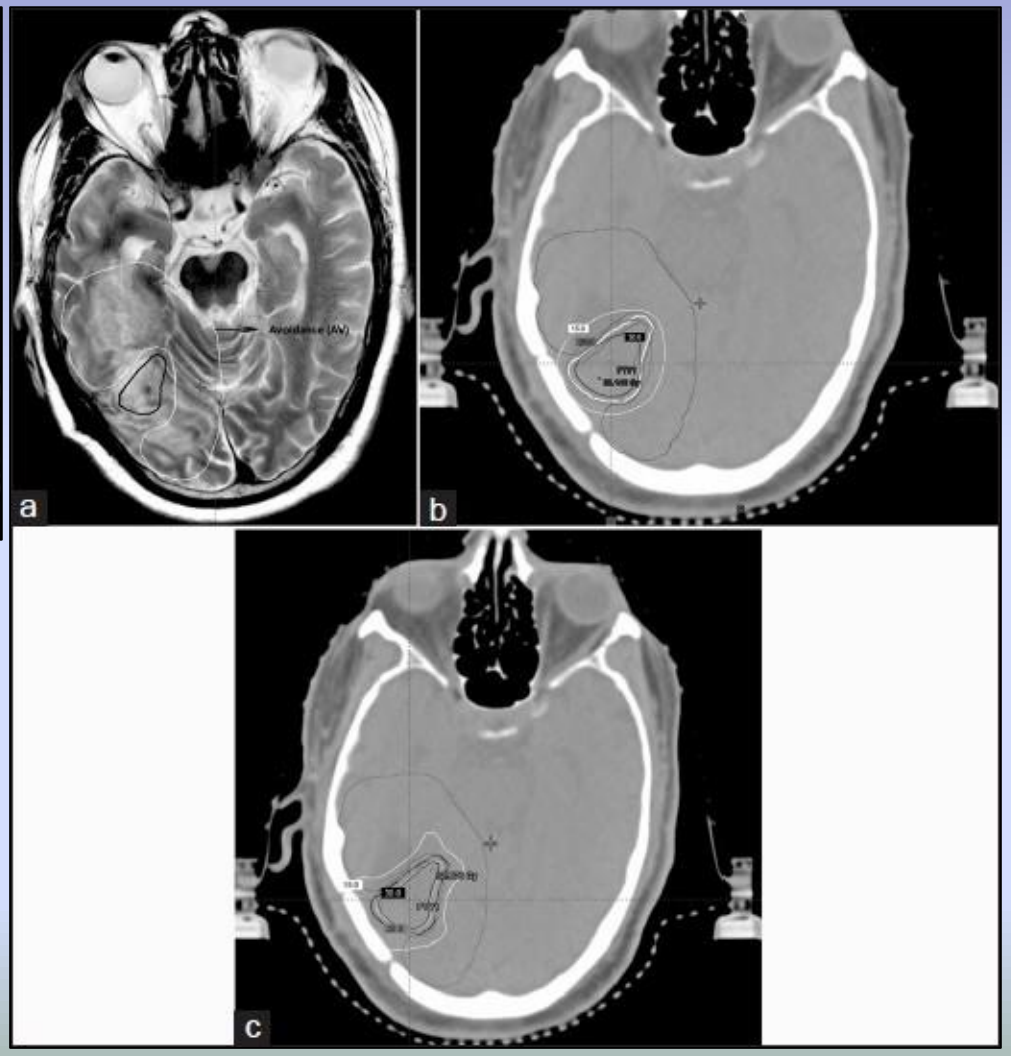


In TC SLICES AND A 3D VOLUME RECONSTRUCTED FROM SLICES, **Radiation Oncologist or Radiation Therapy Technologist countour:**

- GROSS TUMOR VOLUME (GTV)
- CLINICAL TARGET VOLUME (CTV)
- ORGANS AT RISK

Image registration with other Modality for Contouring in 3D-CRT





Optional in 3D-CRT
Mandatory in Advanced 3D-CRT

3D-CRT PTV

ICRU 51-62

PTV : PLANNING TARGET VOLUME

PTV is a geometric concept designed to ensure that the radiotherapy prescription dose is the dose delivered to the CTV.

PTV= CTV+IM+SM:

the internal margin (IM), that takes in account the variation of CTV that may result from:

- ❖respiration
- ❖different filling of bladder and rectum
- ❖heath beat
- ❖intestine movements
- ❖...

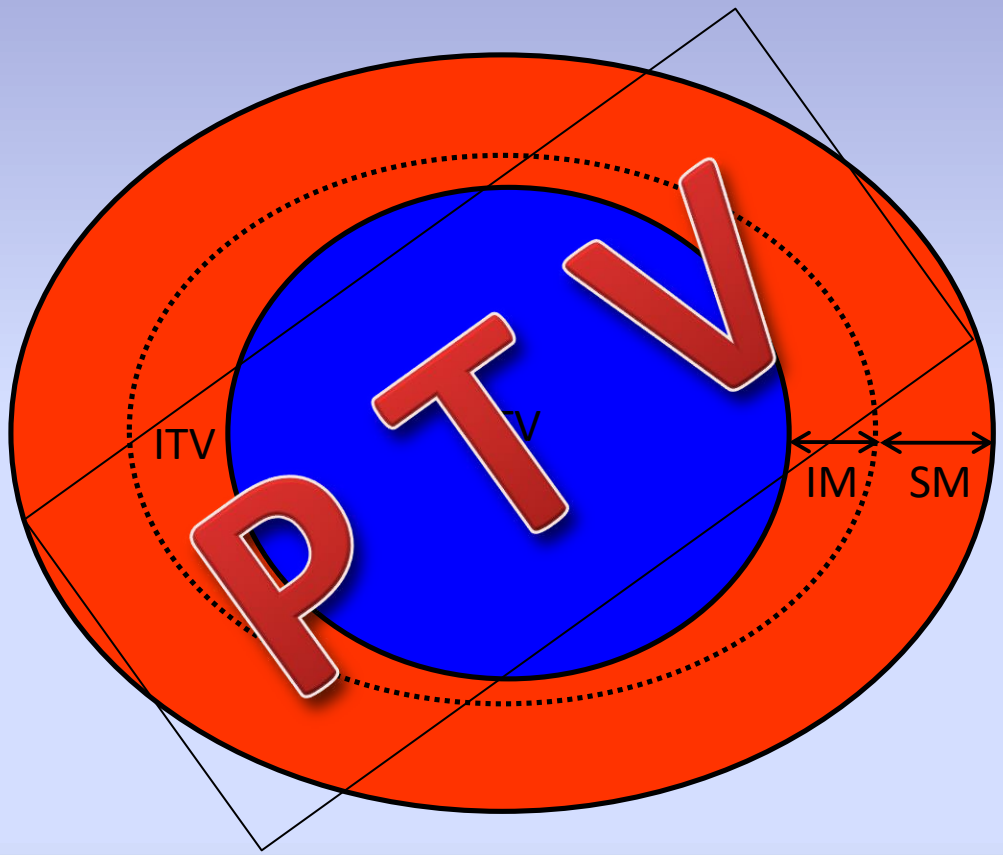
they are physiological variations which are difficult or impossible to control.

the set up margin (SM), that takes in account the overall inaccuracy and lack of reproducibility in patient positioning, in beam alignment and field dimensions during a session and through all treatment session. they depends on:

- ❖ variation in patient positioning
- ❖mechanical uncertainties of the equipment
- ❖dosimetric uncertainties
- ❖transfer set up errors from CT or simulator to the treatment unit
- ❖human factors

3D-CRT PTV

Medical Physicist:
Audit of set up error

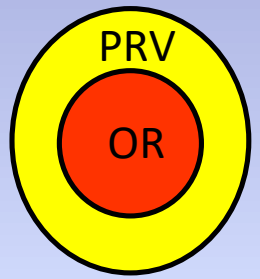


ICRU 50 o M. VAN HERK and other formula…

3D-CRT PRV

PRV: PLANNING ORGAN AT RISK VOLUME

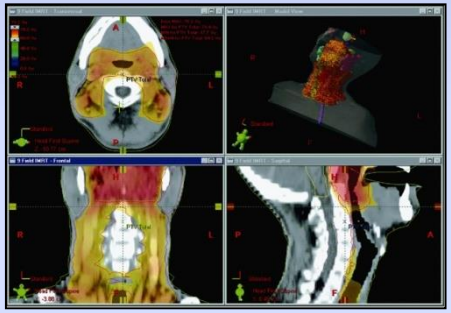
in some specific circumstances, it is necessary to add a margin analogous to the PTV margin around an or to ensure that the organ cannot receive a higher than safe dose; this gives a planning organ at risk volume. This applies to an organ such as the spinal cord, where damage to a small amount of normal tissue would produce a severe clinical manifestation.



3D-CRT TPS

Commissioning

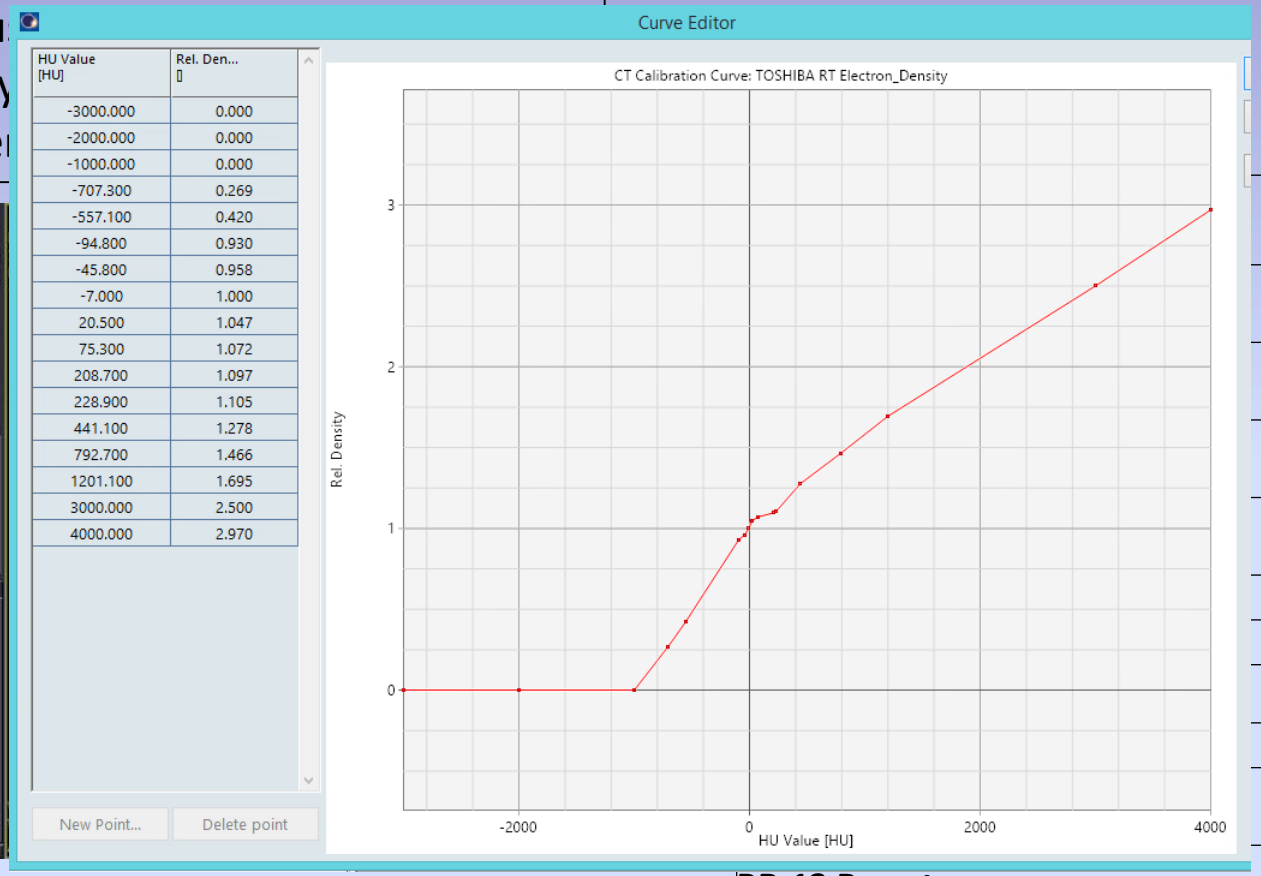
TPS



CT Calibration

IMAGING WITH X-RAY COMPUTED TOMOGRAPHY

in order to calculate the doses, the TPS u
density
differe



	Electron density	(HU) 120kV
	1.695	1229.5
	1.466	827.6
	1.278	460
	1.105	240.1
	1.097	223.3
	1.072	92.2
	1.047	30.4
	1.000	2.7
	0.988	7.325
BR-12 Breast	0.958	-39.4
AP6 Adipose	0.930	-88.2
LN - 450 Lung	0.420	-554.2
LN - 300 Lung	0.269	-706.2

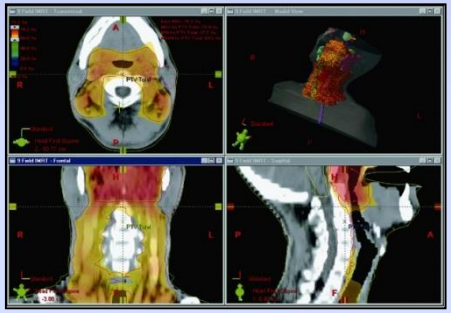
CALIBRATION CT N° VS RELATIVE ELECTRONIC or MASS DENSITY

3D-CRT TPS

Commissioning

CALIBRATION CT NUMBER VS RELATIVE ELECTRONIC or MASS DENSITY

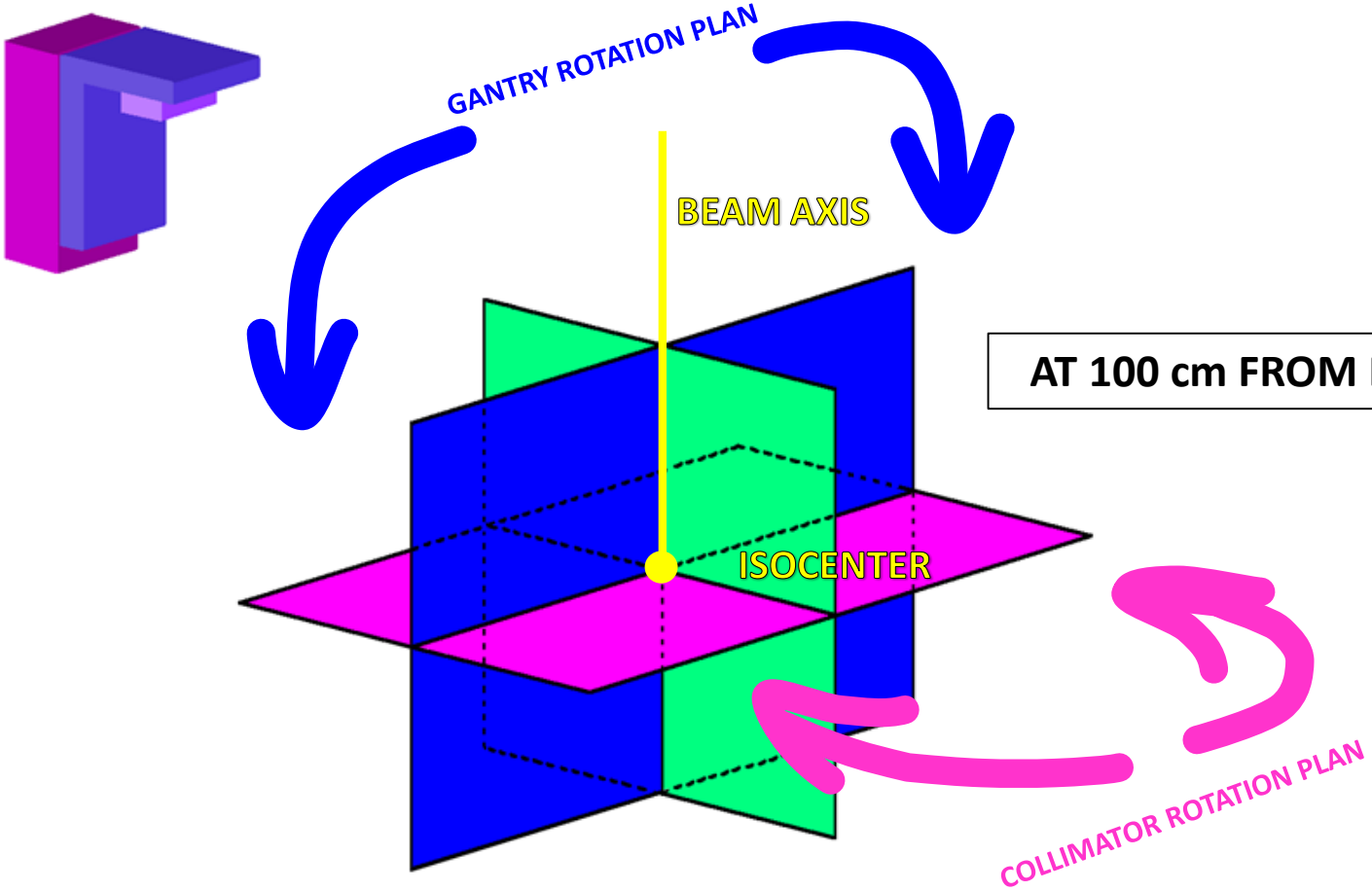
TPS



3D volume and slices with contours of OAR and Target

3D-CRT Planning

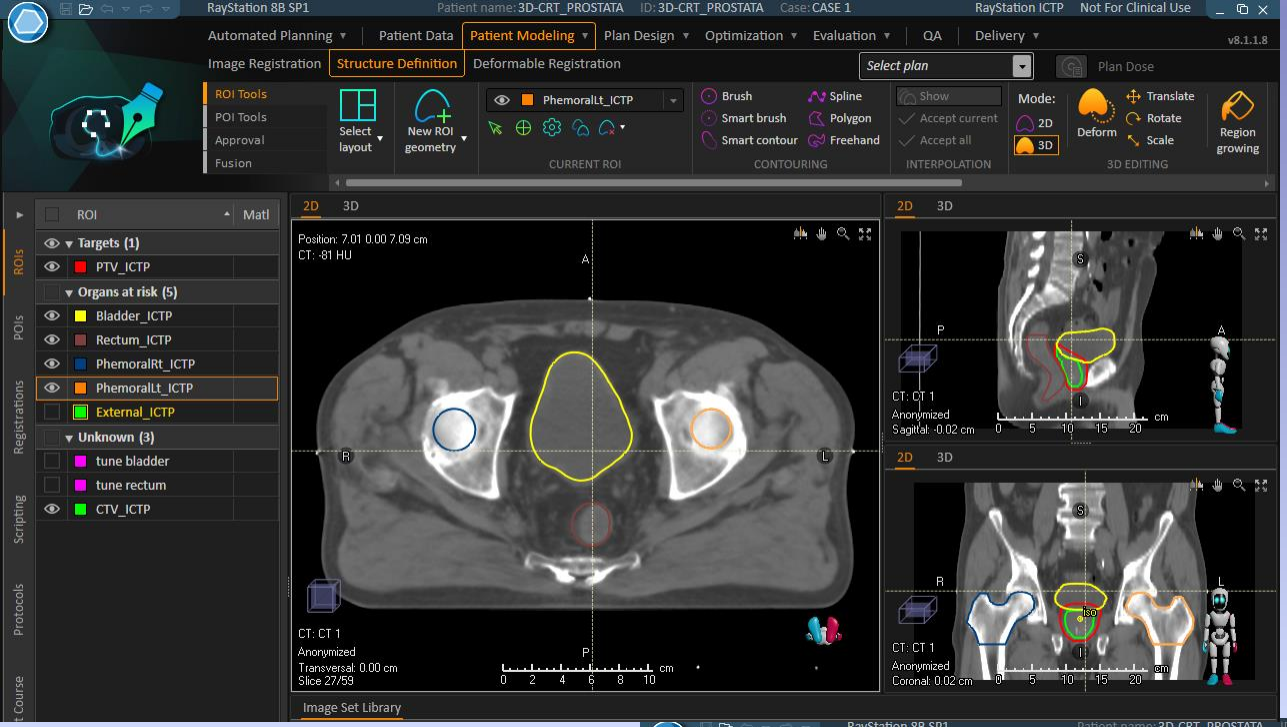
ISOCENTER



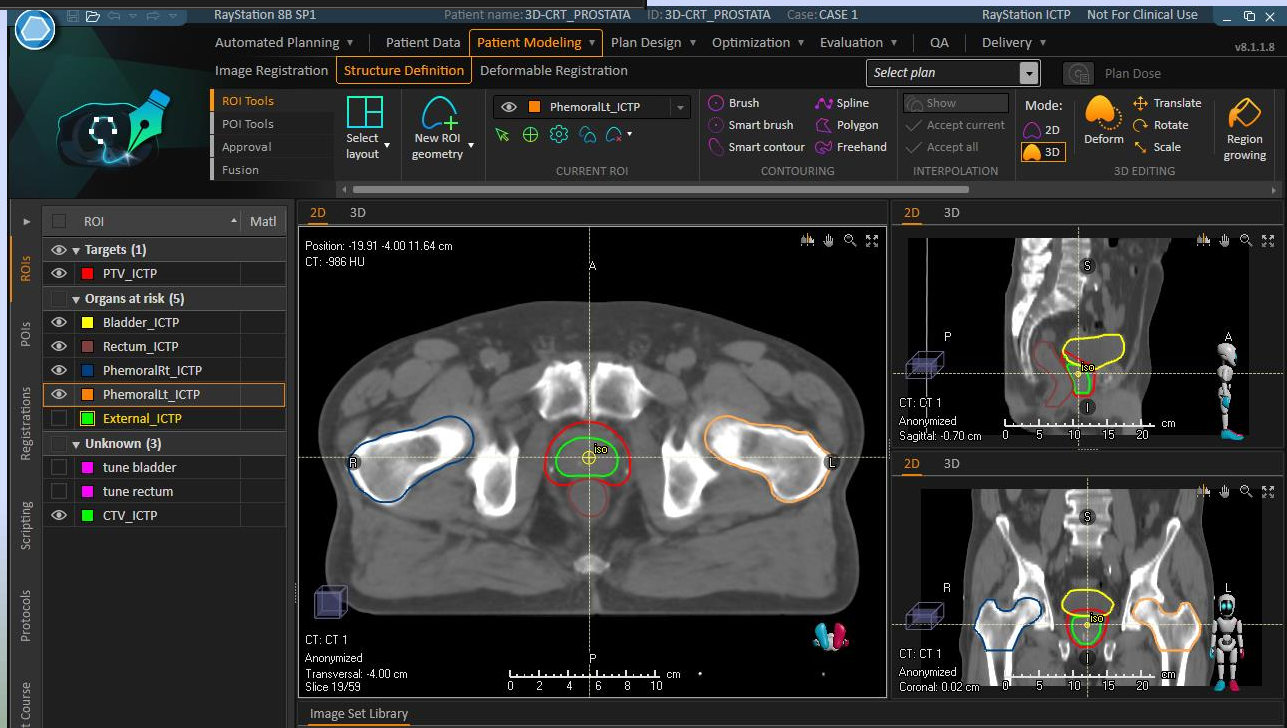
AT 100 cm FROM BEAM FOCUS

IN THE 3DCRT TREATMENT THE ISOCENTER IS LOCATED GENERALLY AT THE CENTER, OR IN THE CENTRAL PART, OF THE PTV (SAD TECNIQUE)

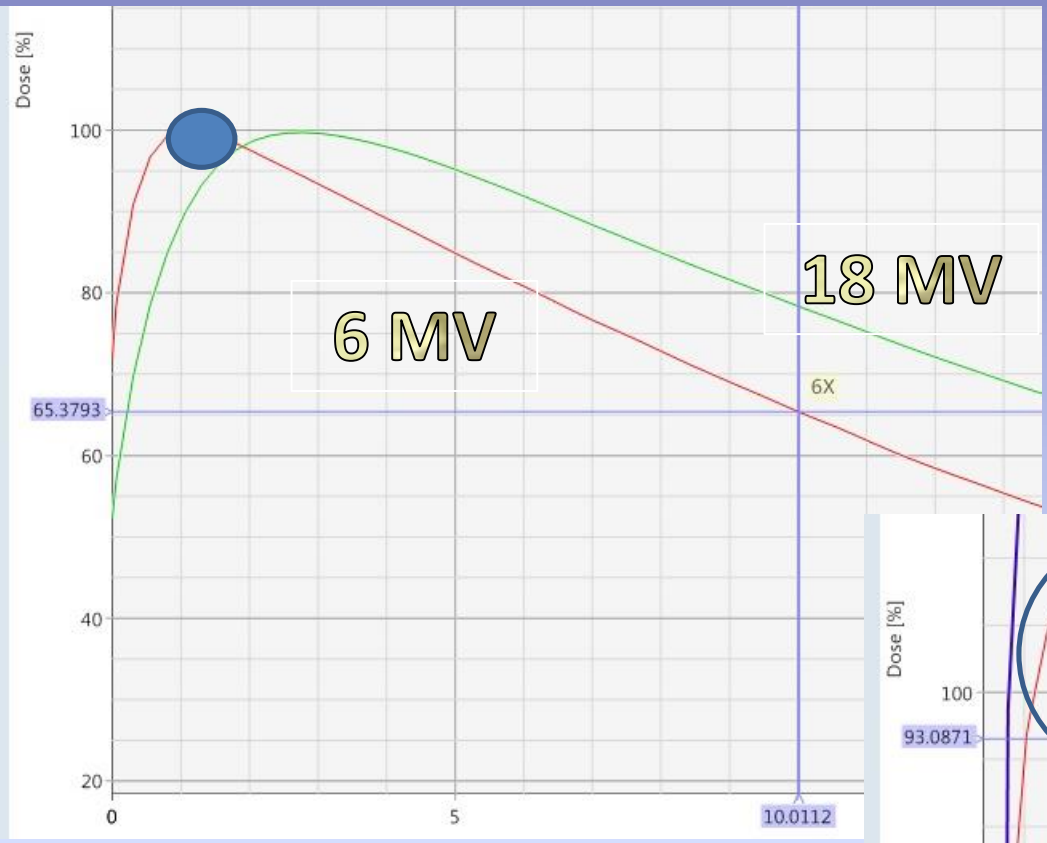
ISOCENTER

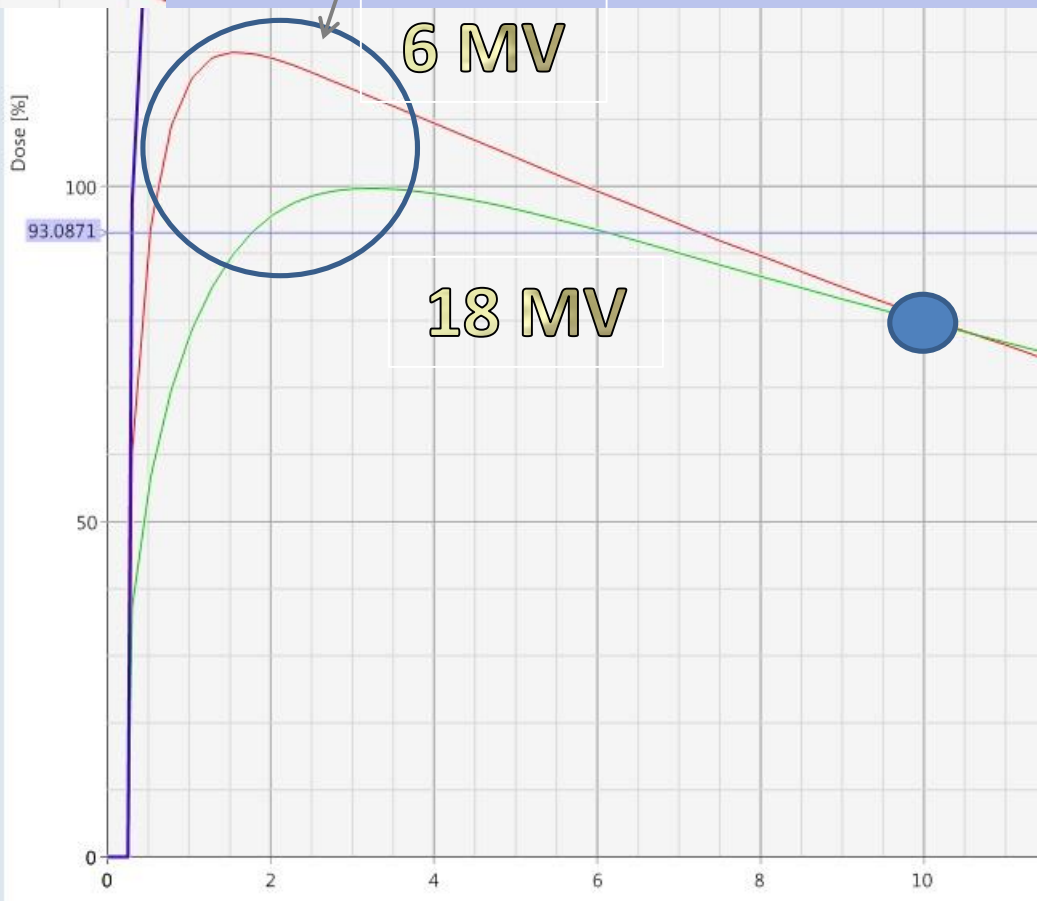


…origin could be different from isocenter



BEAM ENERGY


Dose [%]
100
80
65.3793
60
40
20
0
5
10.0112
6X
6 MV
18 MV

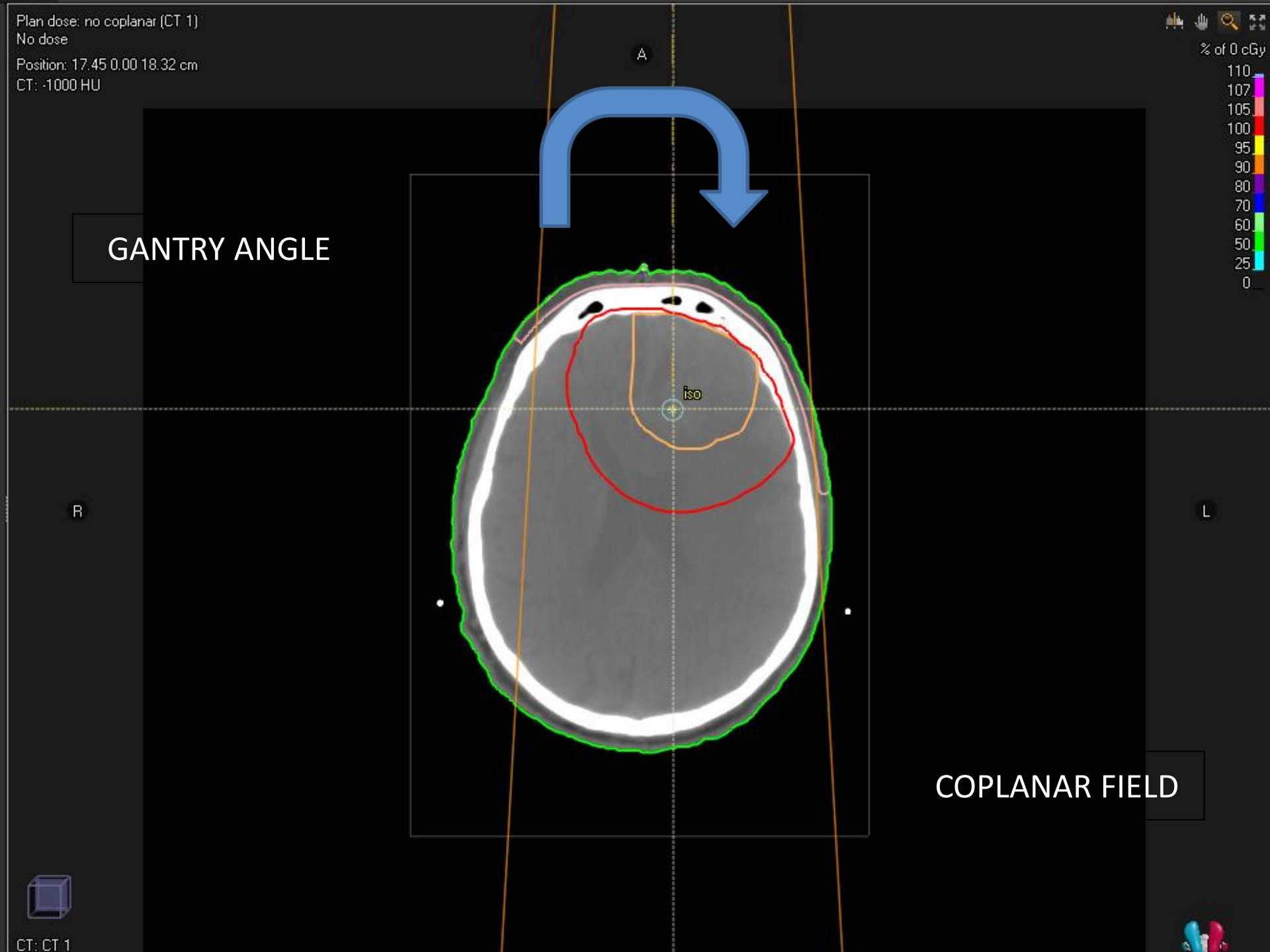

Δ120%
6 MV
18 MV
Dose [%]
100
93.0871
50
0
0
2
4
6
8
10

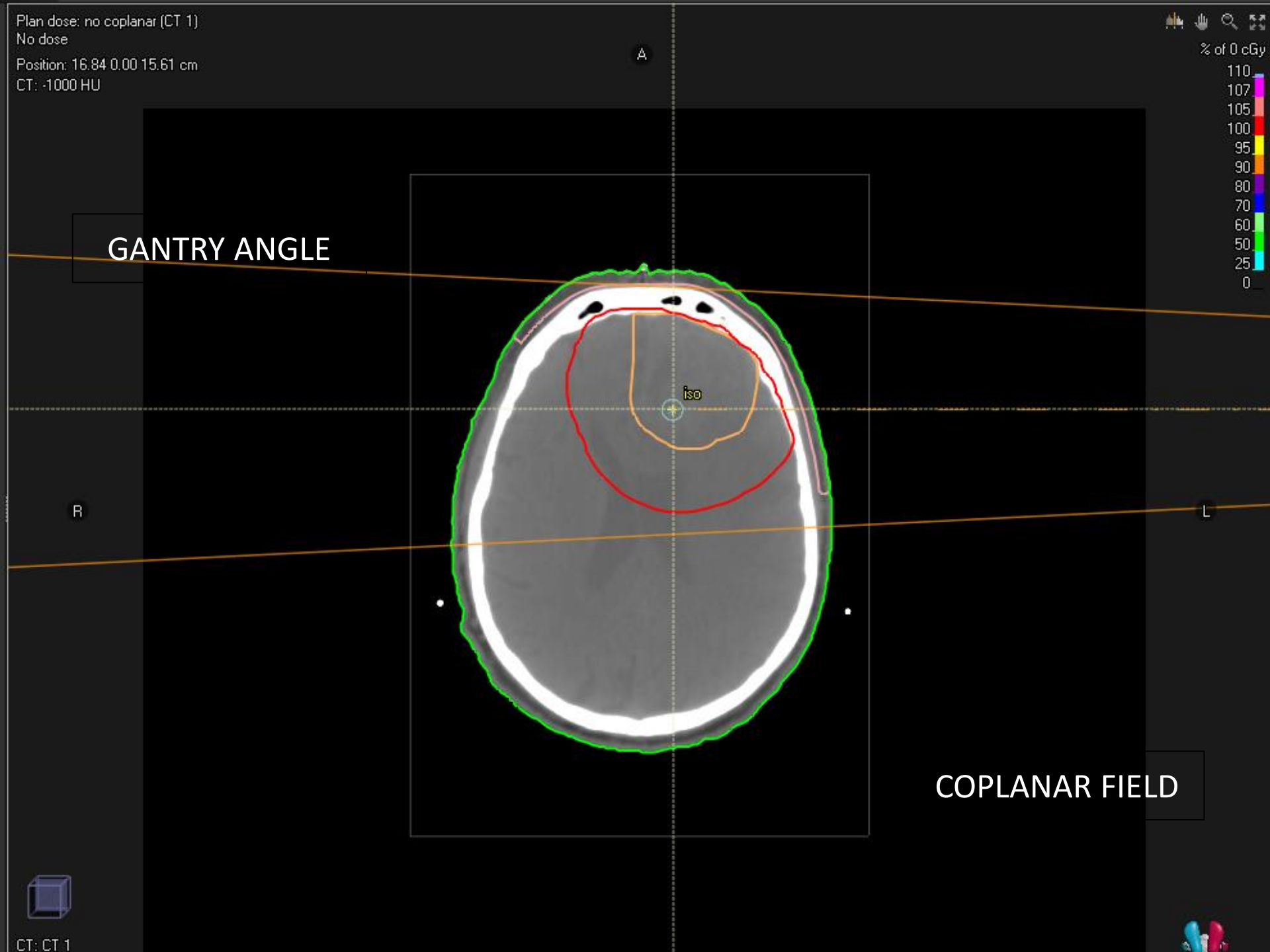
BEAM ENERGY

preferably, small depth target, low energy, big depth target, high energy (except low electron density tissues – for example lung)

because... “the algorithms have different accuracy particularly in low hounsfield units (low density) regions” ....6 MV photons may be the prudent choice.

avoide energy ≥ 8 MV in the presence of CIED or Pacemaker because the production of neutron could damage electrical devices

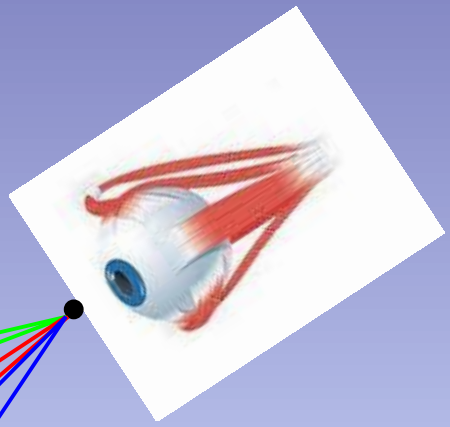

Plan dose: no coplanar (CT 1)
No dose
Position: 17.45 0.00 18.32 cm
CT: -1000 HU
A
% of 0 cGy
110
107
105
100
95
90
80
70
60
50
25
0
GANTRY ANGLE
iso
R
L
COPLANAR FIELD
CT: CT 1

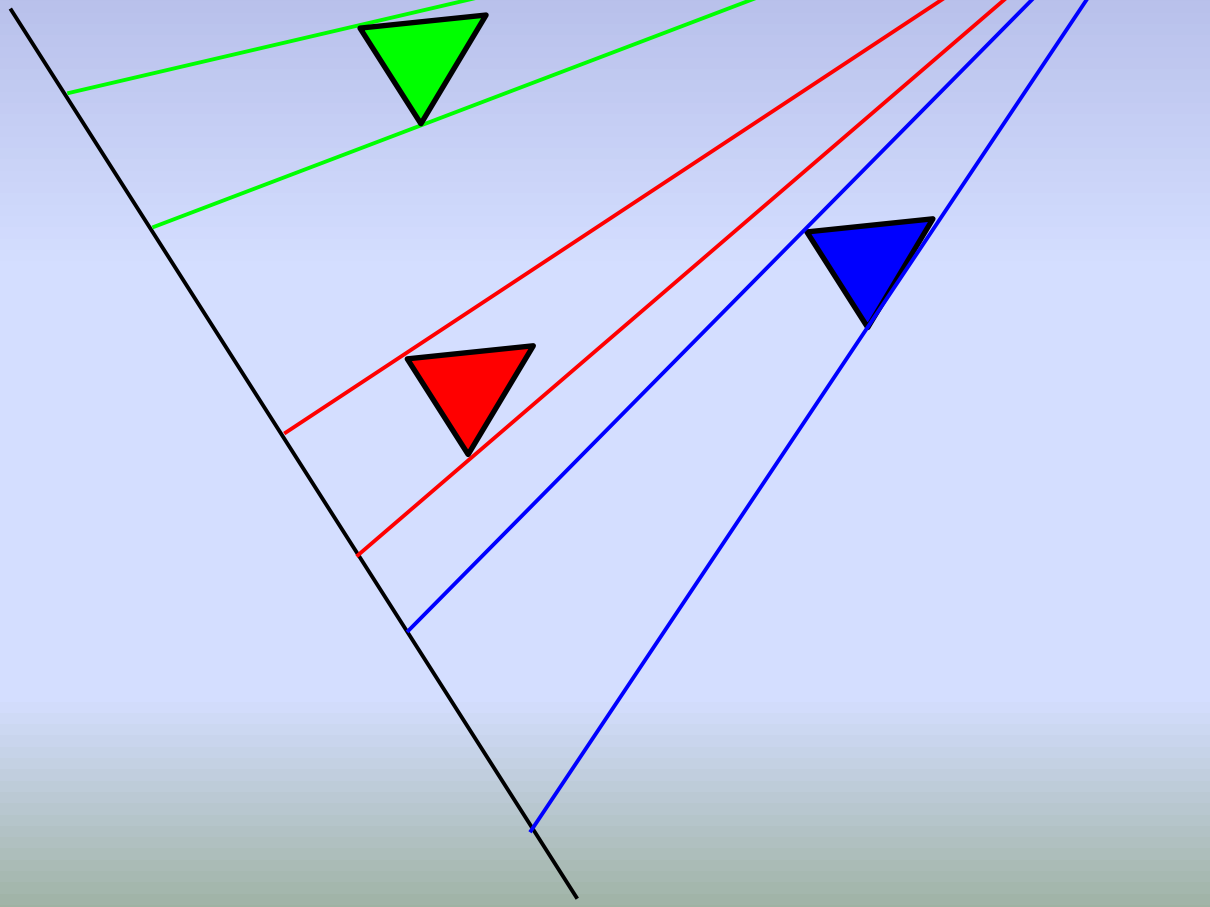

Plan dose: no coplanar (CT 1)
No dose
Position: 16.84 0.00 15.61 cm
CT: -1000 HU
A
% of 0 cGy
110
107
105
100
95
90
80
70
60
50
25
0
GANTRY ANGLE
iso
R
L
COPLANAR FIELD
CT: CT 1

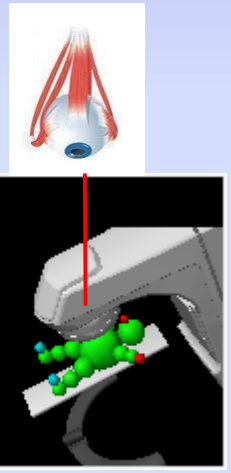
GANTRY ANGLE

BEV

BEAM EYE VIEW



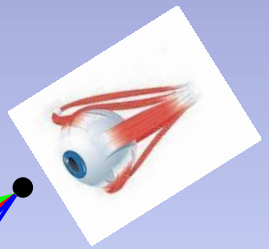


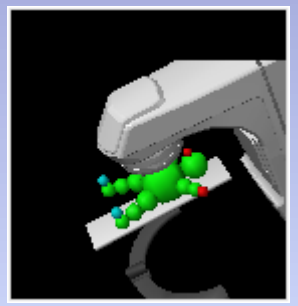


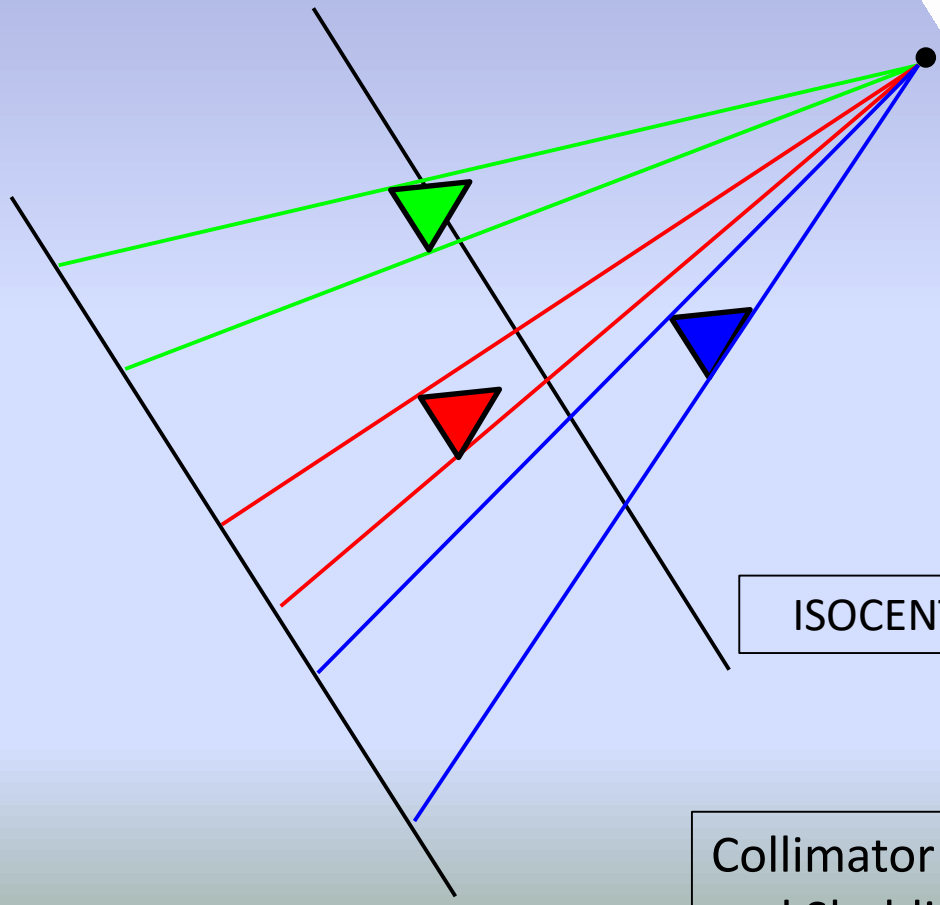
GANTRY ANGLE

BEV

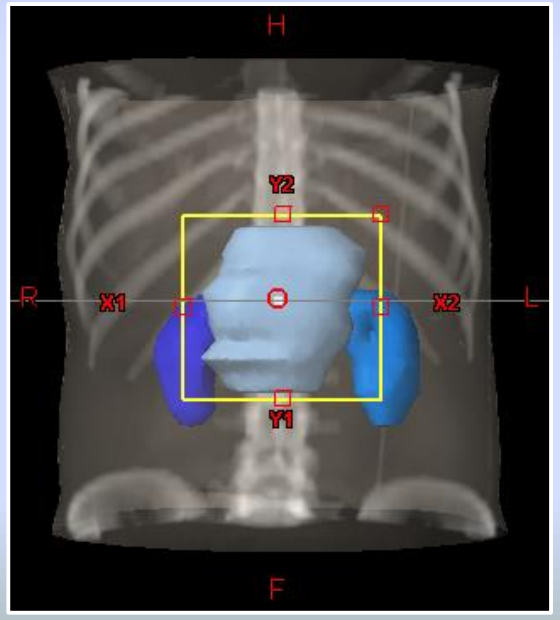
BEAM EYE VIEW





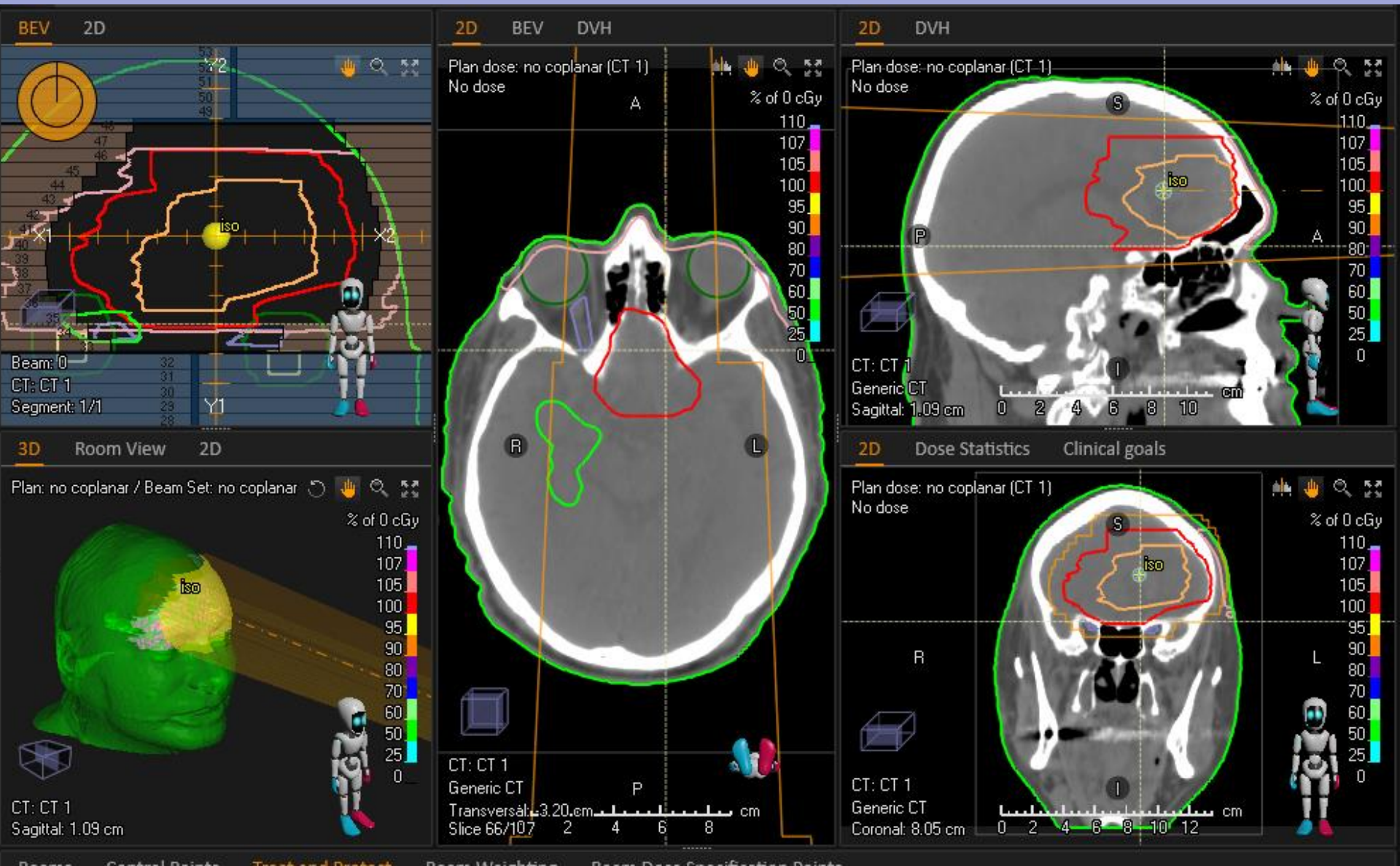


ISOCENTER PLANE

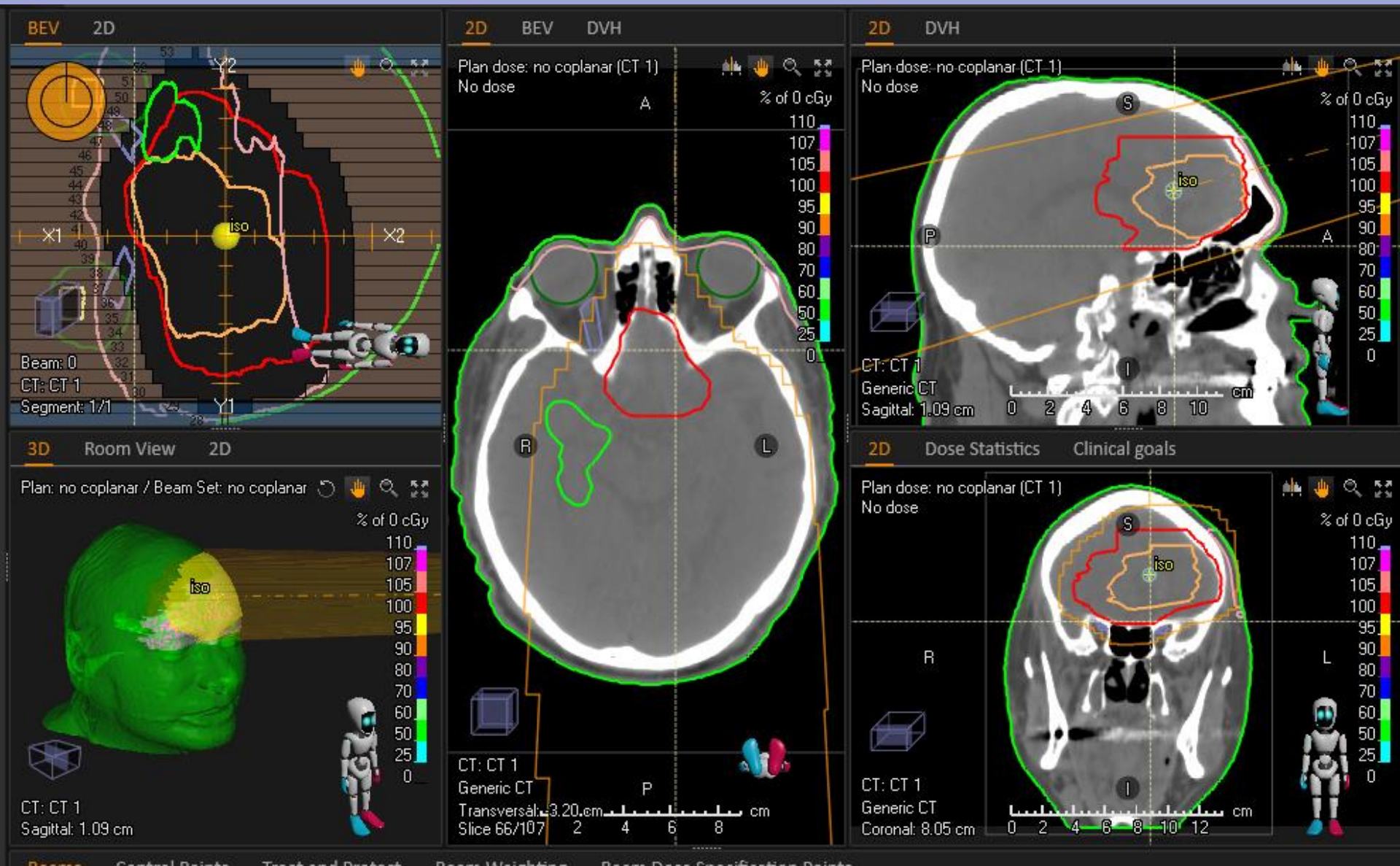


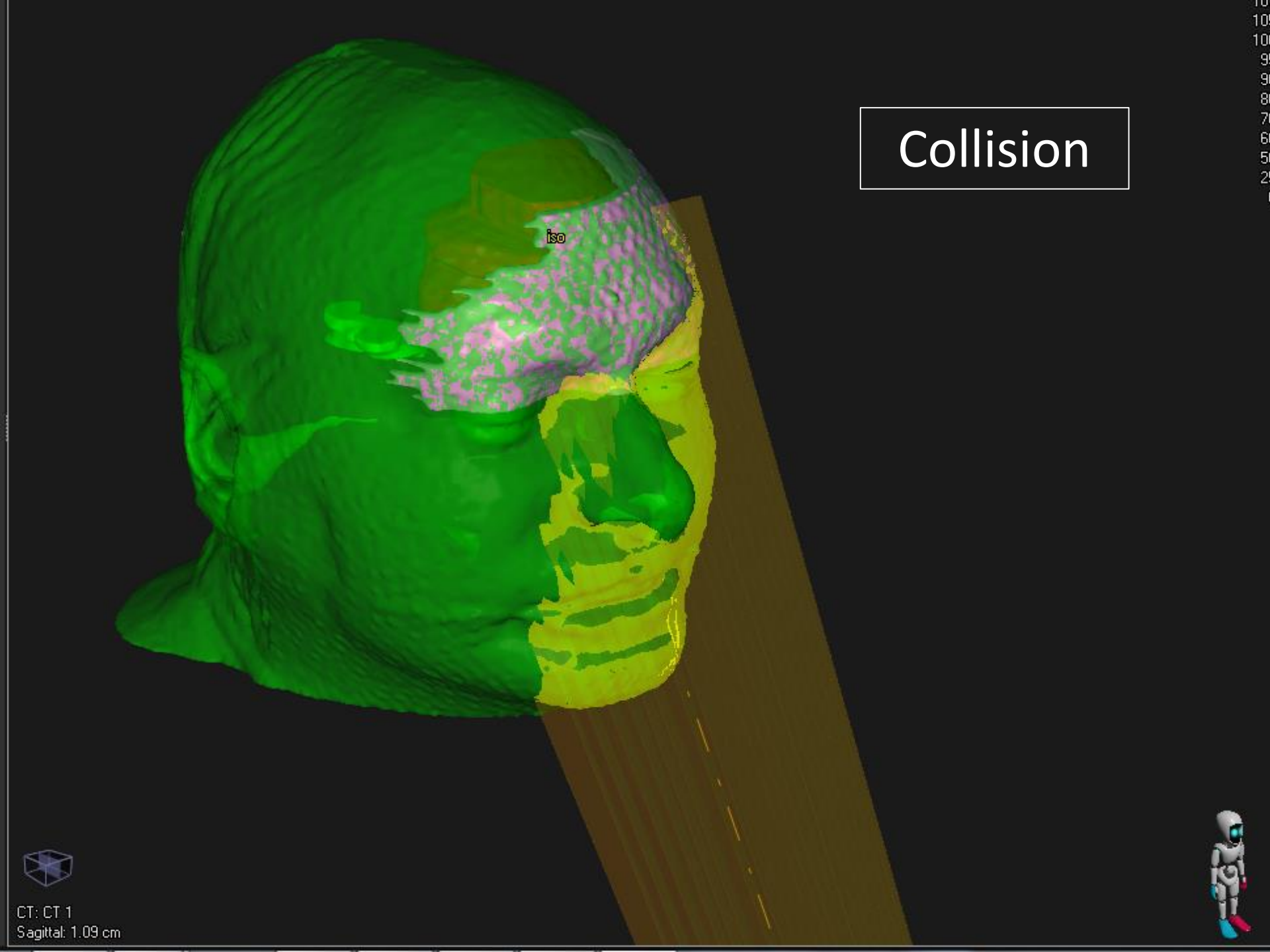
Collimator Angle and Shelding

GANTRY ANGLE

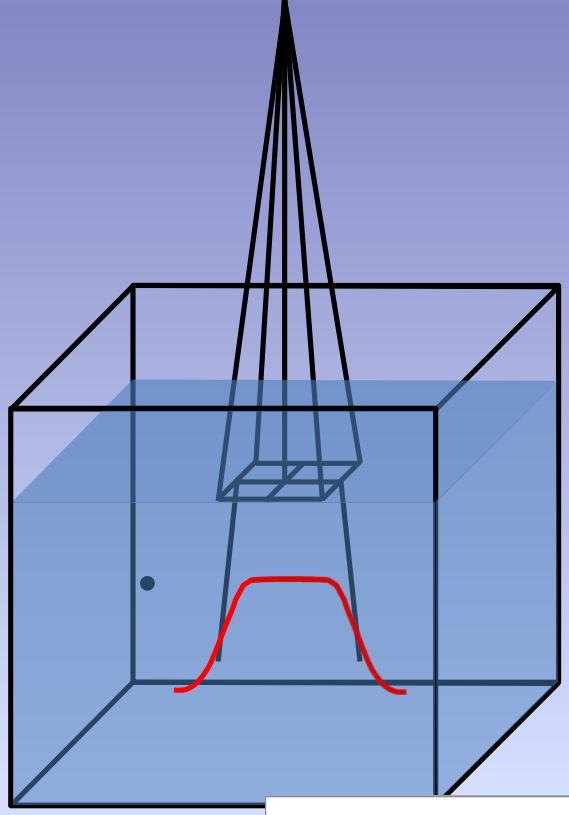


GANTRY ANGLE → COUCH ROTATION → NO COPLANAR FIELD

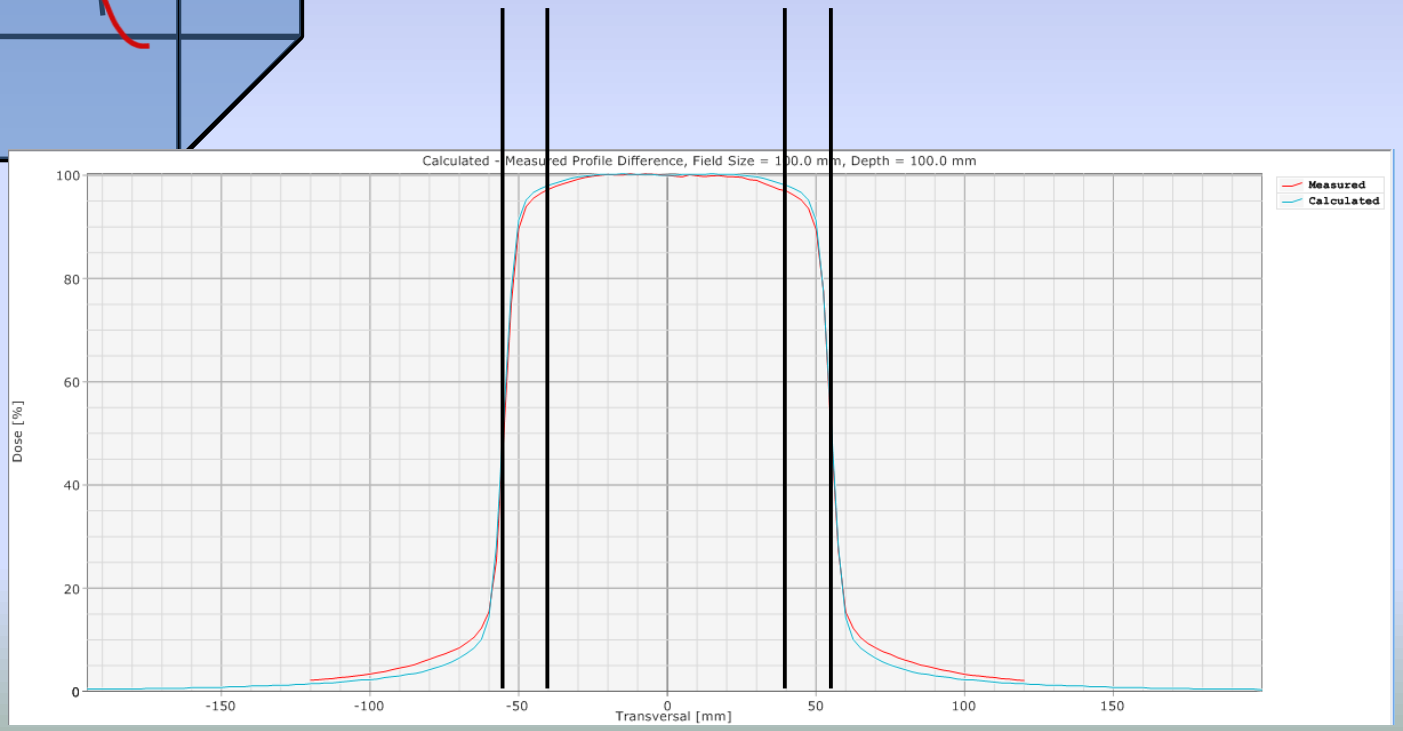



Collision
iso
CT: CT 1
Sagittal: 1.09 cm

FIELD DIMENSION

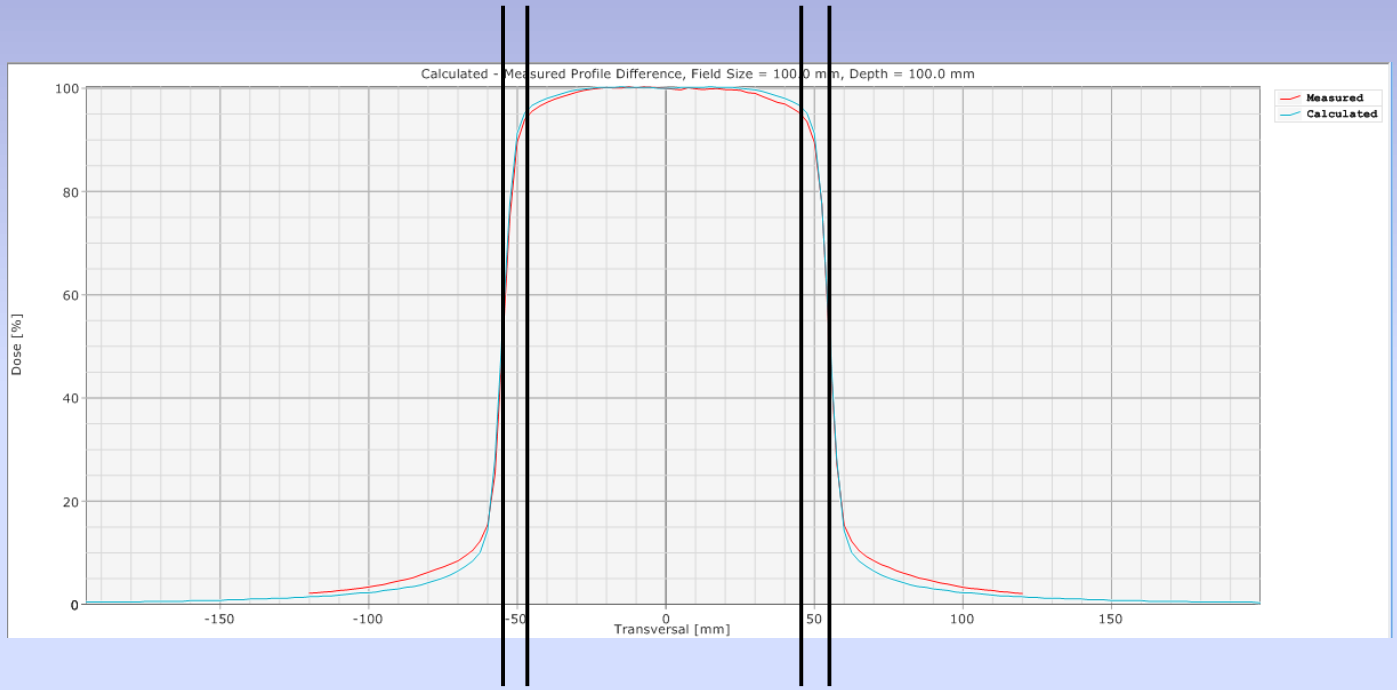


at any depth (…) the field dimensions correspond to the 50% of the dose on the beam axis …



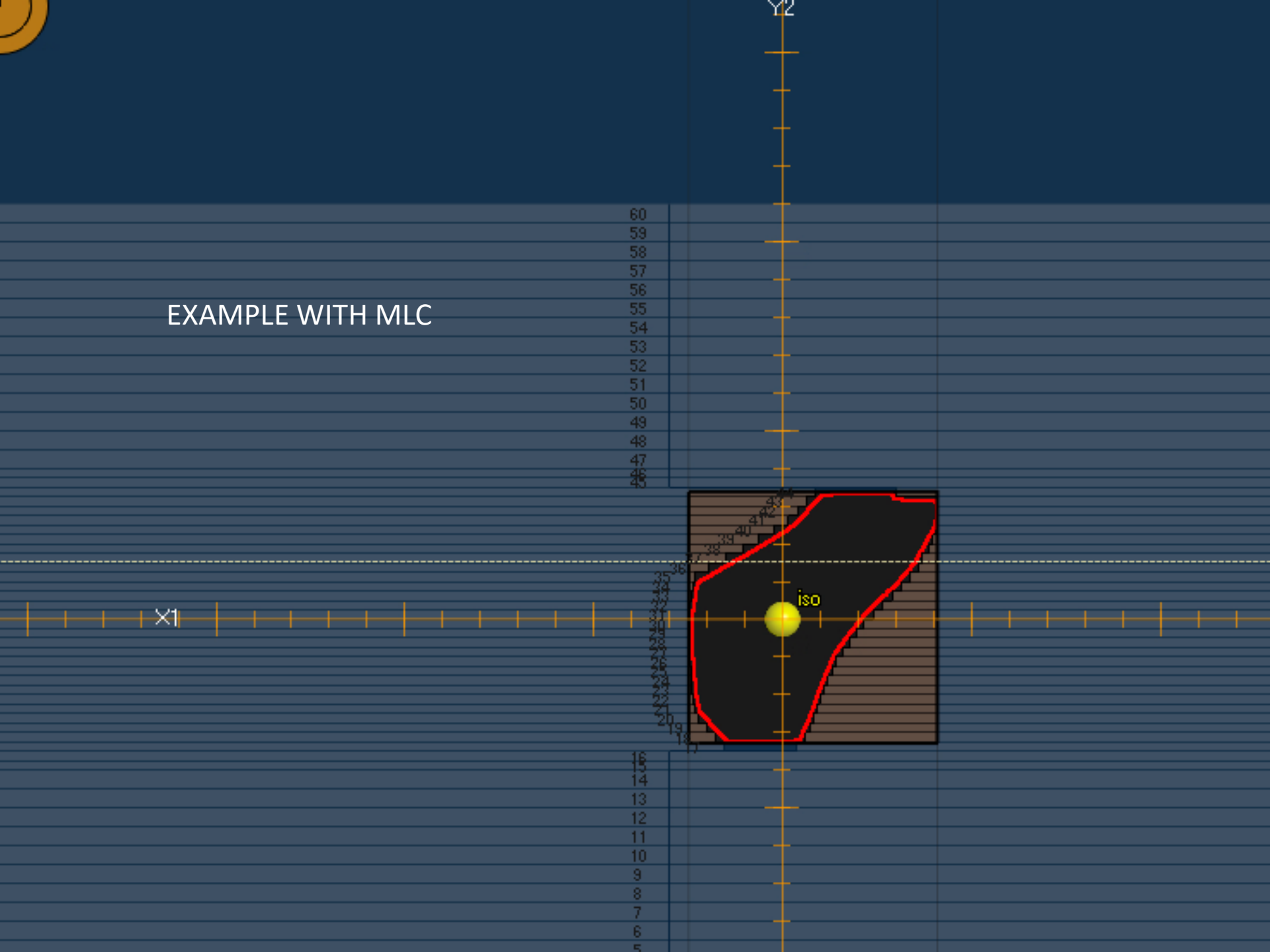
FIELD DIMENSION

ICRU 50: ... “a certain degree of heterogeneity, today in the best technical and clinical conditions, should be +7% and -5% of $D_{PRESCR.}$”

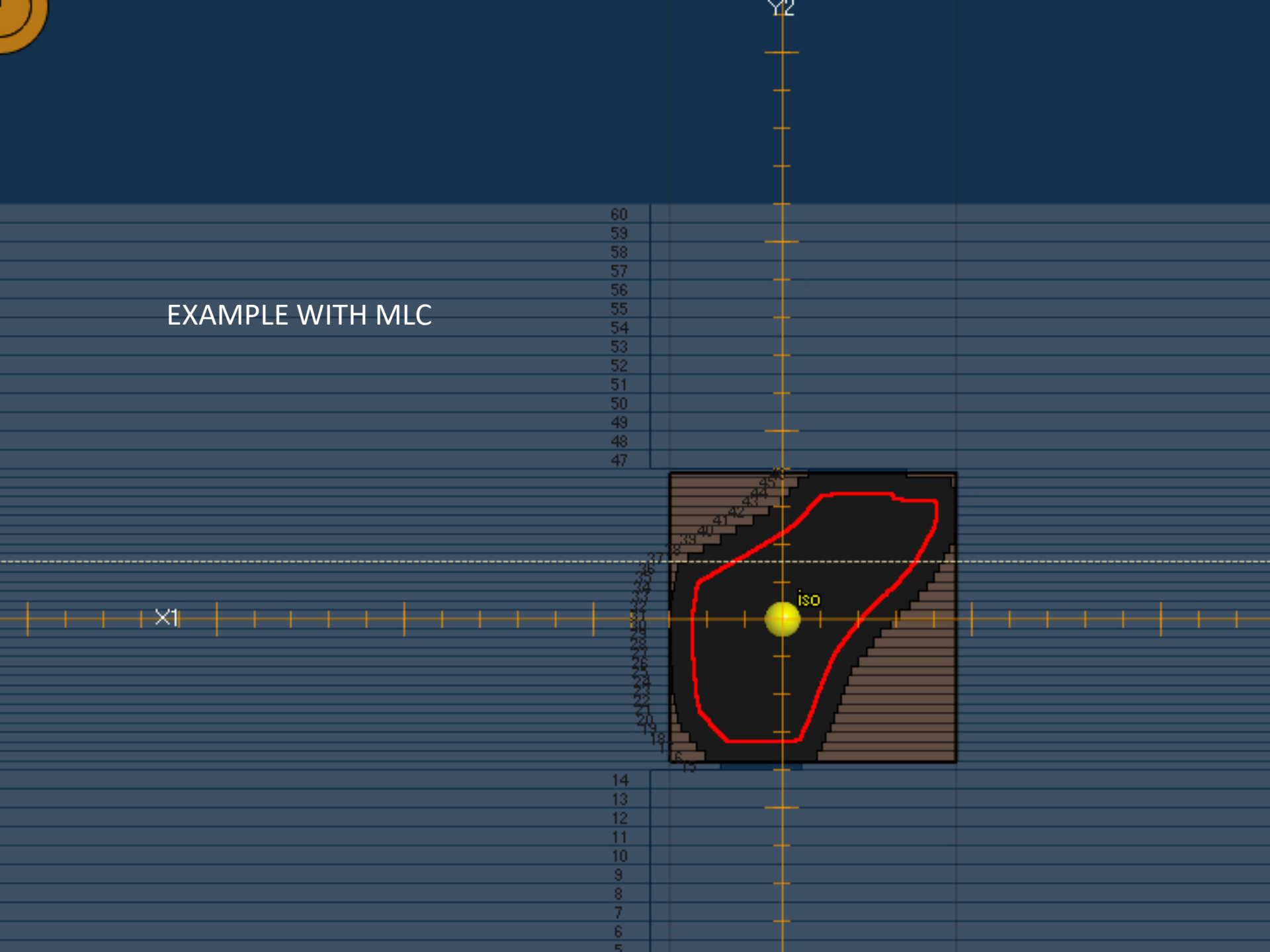


in both directions (x and y) the field edge must be bigger than the PTV dimension of 5÷10 mm

EXAMPLE WITH MLC

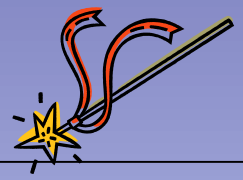


EXAMPLE WITH MLC



DOSE PRESCRIPTION

FROM ICRU 50



THE ICRU REFERENCE POINT

3.3 general recommendations for reporting doses:
the doses **at or near the center** of the planning target volume as well as the maximum and the minimum dose to the PTV shall be reported …

3.3.1 the ICRU reference point
the ICRU reference point shall be selected according to the following general criteria:

- the dose at the point should be clinically relevant and representative of the dose throughout the planning target volume
- the point should be easy to define in a clear and unambiguous way
- the point should be selected where the dose can be accurately determined (physical accuracy)
- the point should be selected in a region where there is no steep dose gradient

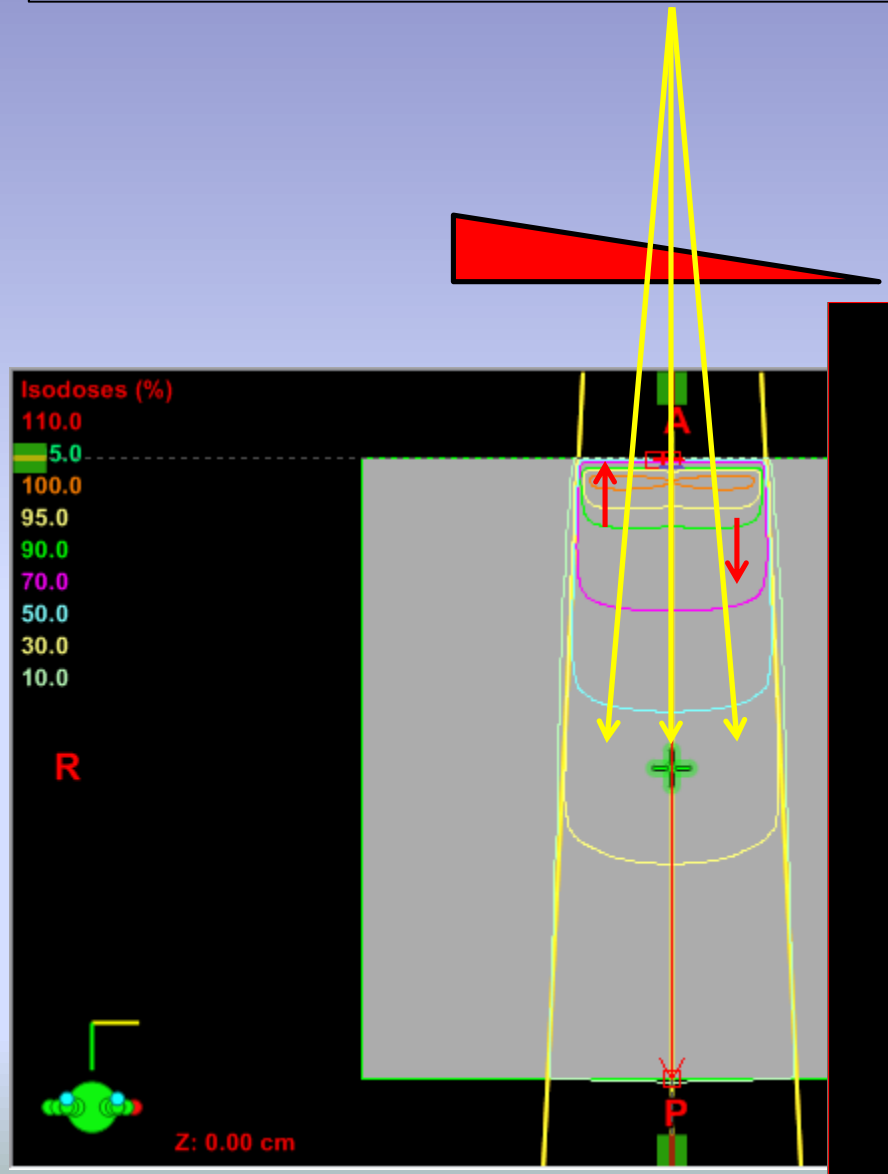
a treatment planned in SAD condition, is usually normalized and prescribed at isocenter that became the ICRU reference point

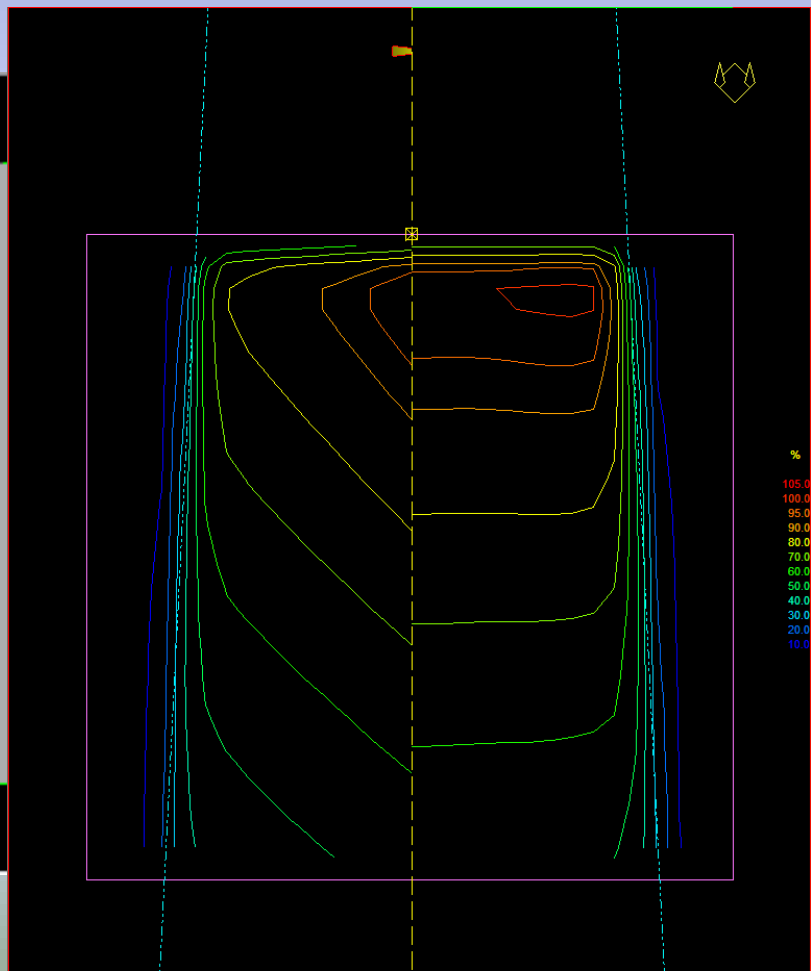
….but the isocenter and the prescription point could be different.

- is this case normaliation must match with the prescription point that became the ICRU reference point

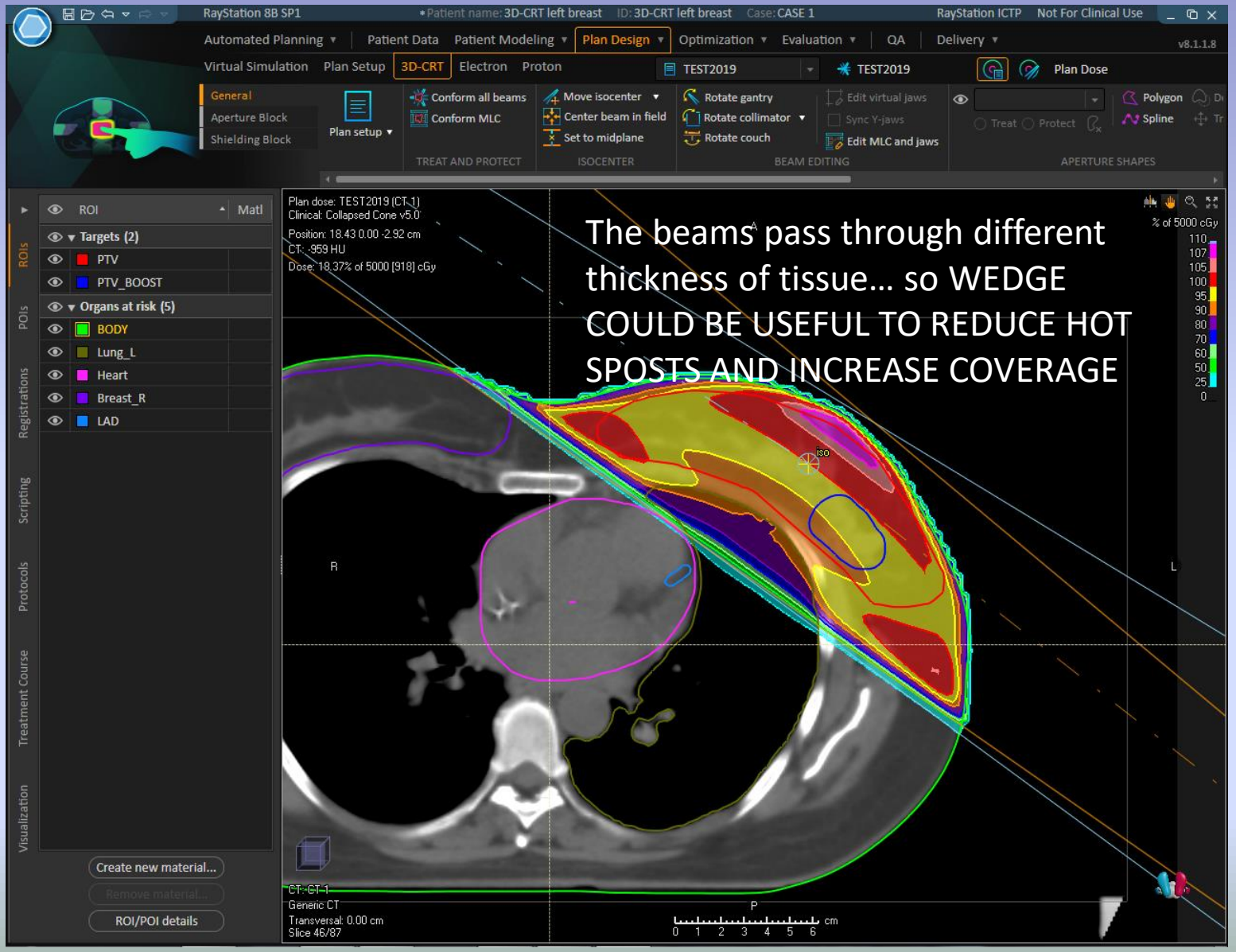
WEDGE

in some situations, there is the necessity to introduce a beam modificator to correct the isodoses curves, to maintain a correct dose distribution on PTV

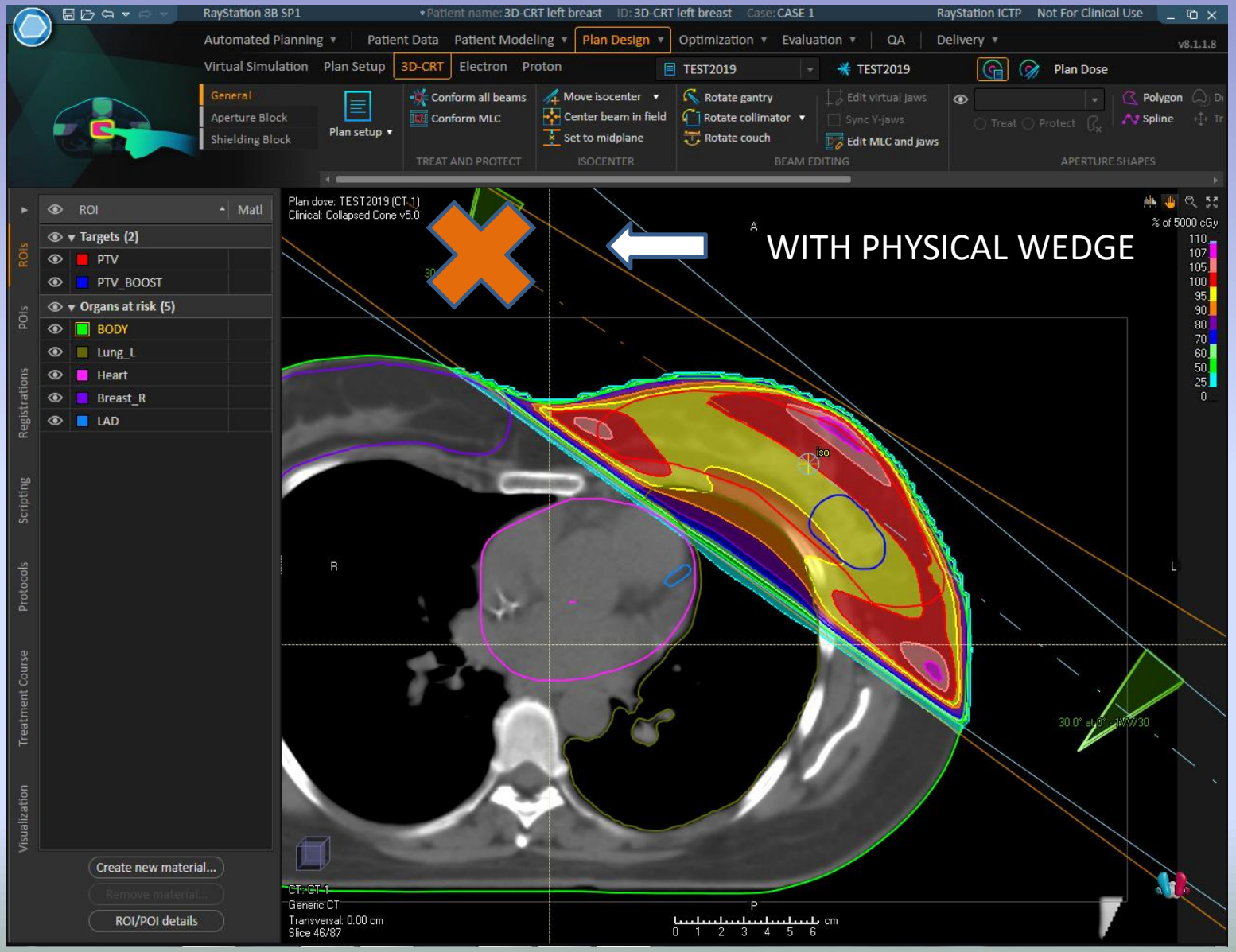




WEDGE


RayStation 8B SP1
Patient name: 3D-CRT left breast ID: 3D-CRT left breast Case: CASE 1
RayStation ICTP Not For Clinical Use
Automated Planning
Patient Data
Patient Modeling
Plan Design
Optimization
Evaluation
QA
Delivery
v8.1.1.8
Virtual Simulation
Plan Setup
3D-CRT
Electron
Proton
TEST2019
TEST2019
Plan Dose
General
Aperture Block
Shielding Block
Plan setup
Conform all beams
Conform MLC
TREAT AND PROTECT
Move isocenter
Center beam in field
Set to midplane
ISOCENTER
Rotate gantry
Rotate collimator
Rotate couch
Edit virtual jaws
Sync Y-jaws
Edit MLC and jaws
BEAM EDITING
Polygon
Spline
Treat
Protect
APERTURE SHAPES
ROI
Matl
Targets (2)
PTV
PTV_BOOST
Organs at risk (5)
BODY
Lung_L
Heart
Breast_R
LAD
Create new material...
Remove material...
ROI/POI details
ROIs
POIs
Registrations
Scripting
Protocols
Treatment Course
Visualization
Plan dose: TEST2019 (CT 1)
Clinical: Collapsed Cone v5.0
Position: 18.43 0.00 -2.92 cm
CT: -959 HU
Dose: 18.37% of 5000 [918] cGy
% of 5000 cGy
110
107
105
100
95
90
80
70
60
50
25
0
The beams pass through different thickness of tissue… so WEDGE COULD BE USEFUL TO REDUCE HOT SPOSTS AND INCREASE COVERAGE
iso
R
L
CT: CT 1
Generic CT
Transversal: 0.00 cm
Slice 46/87
cm
0 1 2 3 4 5 6

WEDGE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BODY
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Heart
Breast_R
LAD
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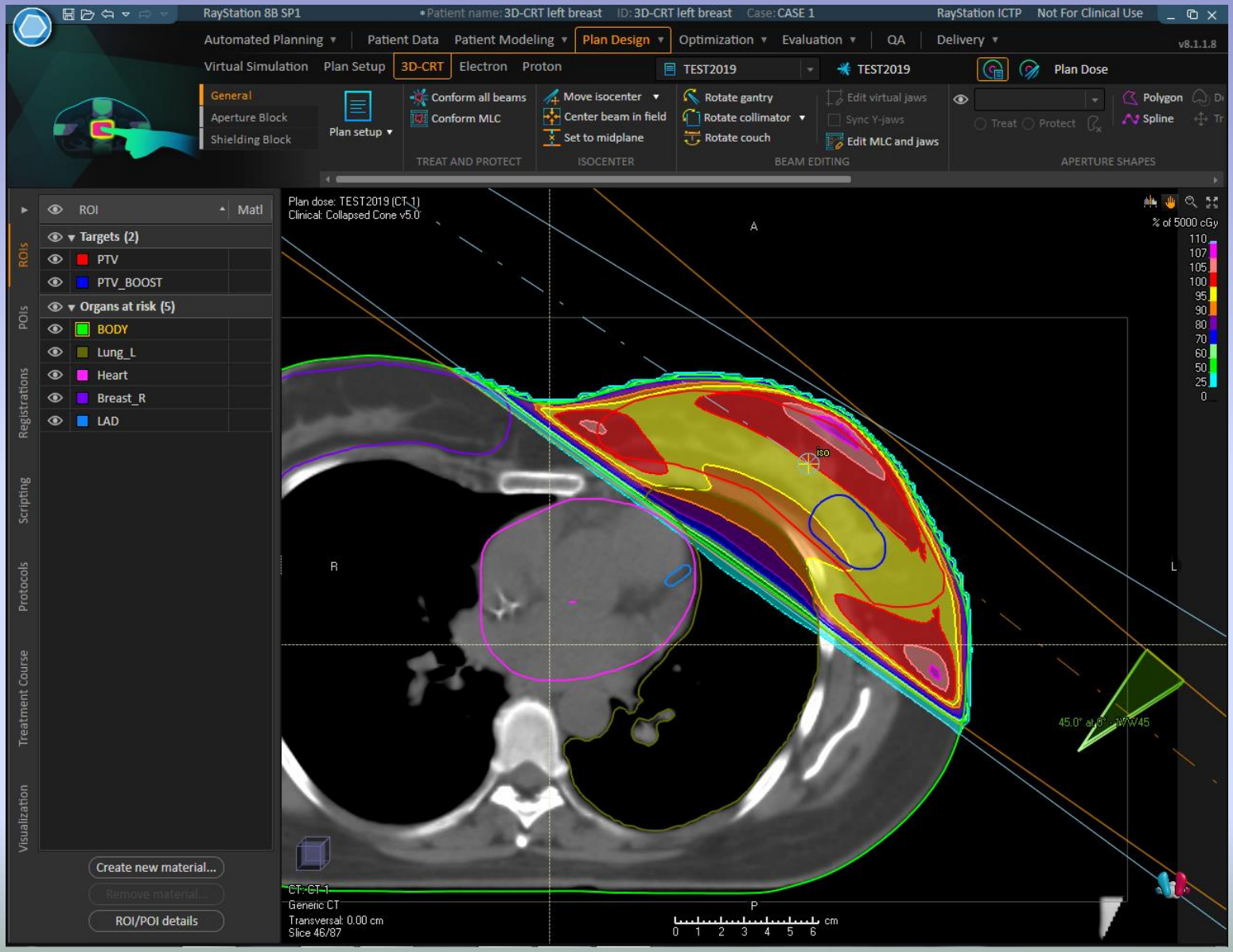
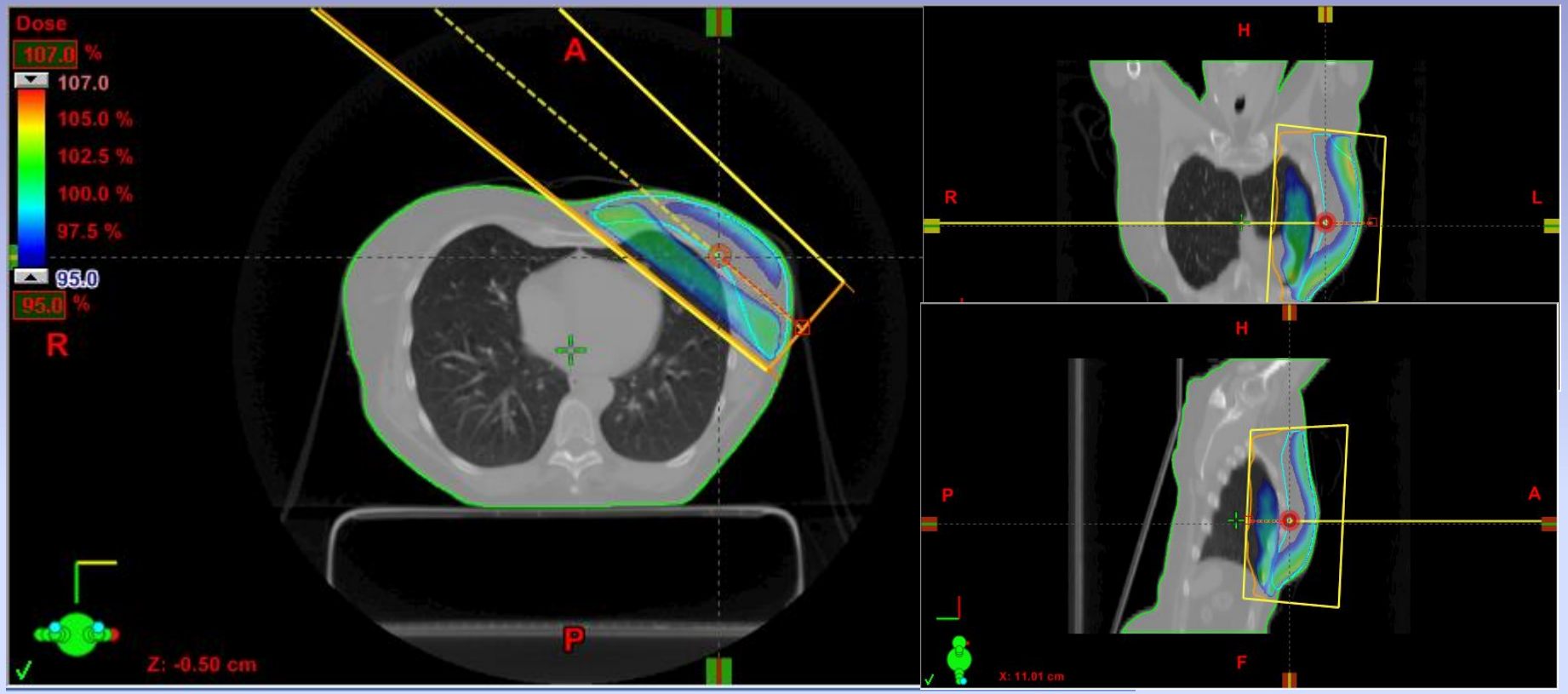
POIs
Registrations
Scripting
Protocols
Treatment Course
Visualization
Create new material...
Remove material...
ROI/POI details
Plan dose: TEST2019 (CT 1)
Clinical: Collapsed Cone v5.0
WITH PHYSICAL WEDGE
% of 5000 cGy
110
107
105
100
95
90
80
70
60
50
25
0
A
R
L
P
iso
30.0° at 0° HW30
CT: CT 1
Generic CT
Transversal: 0.00 cm
Slice 46/87
0 1 2 3 4 5 6 cm

PHYSICAL WEDGE

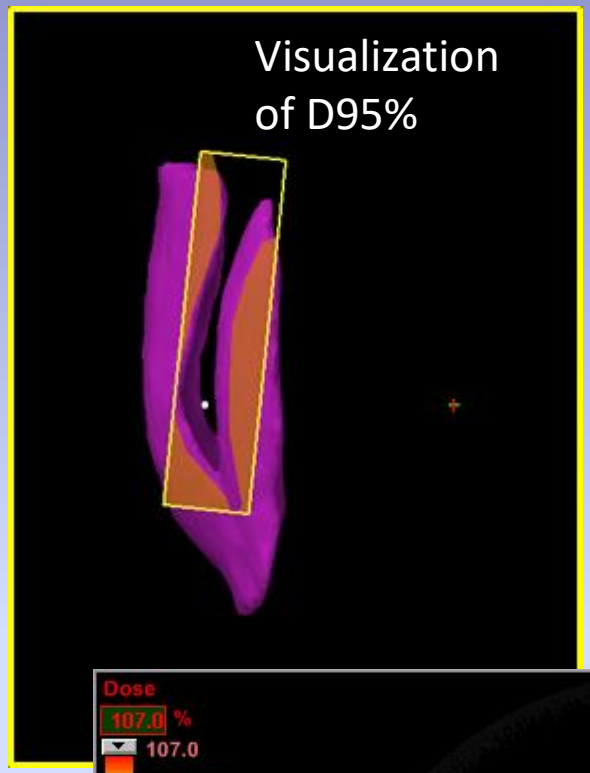


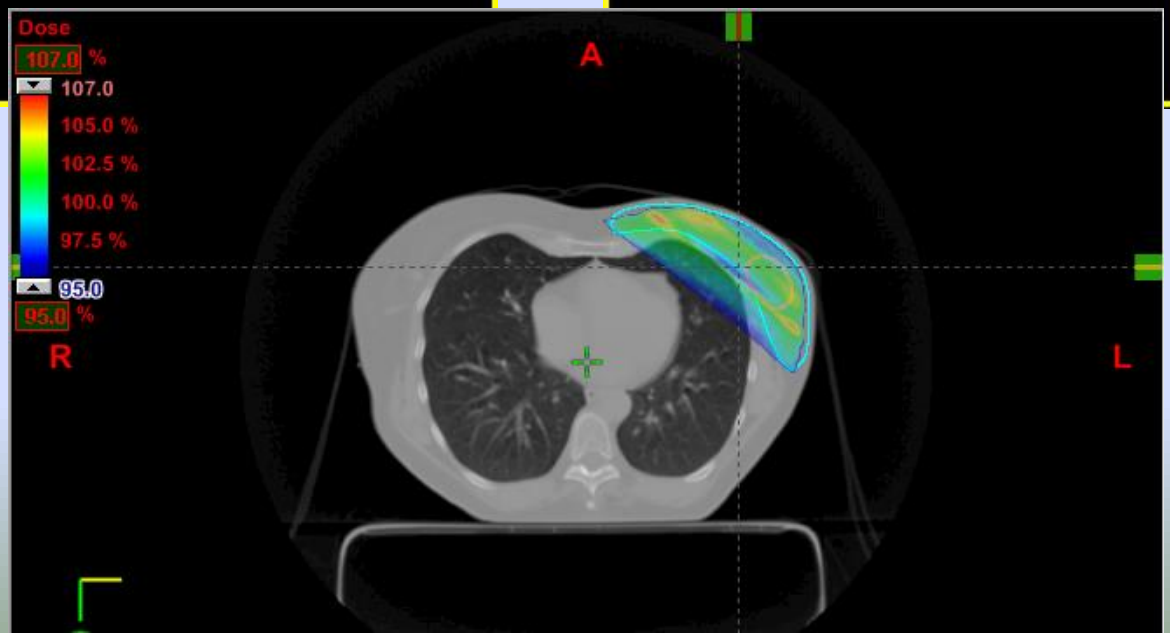
FiF TECNIQUE



Group	Field ID	Technique	Machine/Energy	MLC	Field Weight	Scale	Gantry Rtn [deg]	Coll Rtn [deg]
☑	307	STATIC-I	600 C - 6X		0.930	Varian IEC	307.0	359.0
☑	131	STATIC-I	600 C - 6X		0.930	Varian IEC	131.0	2.0

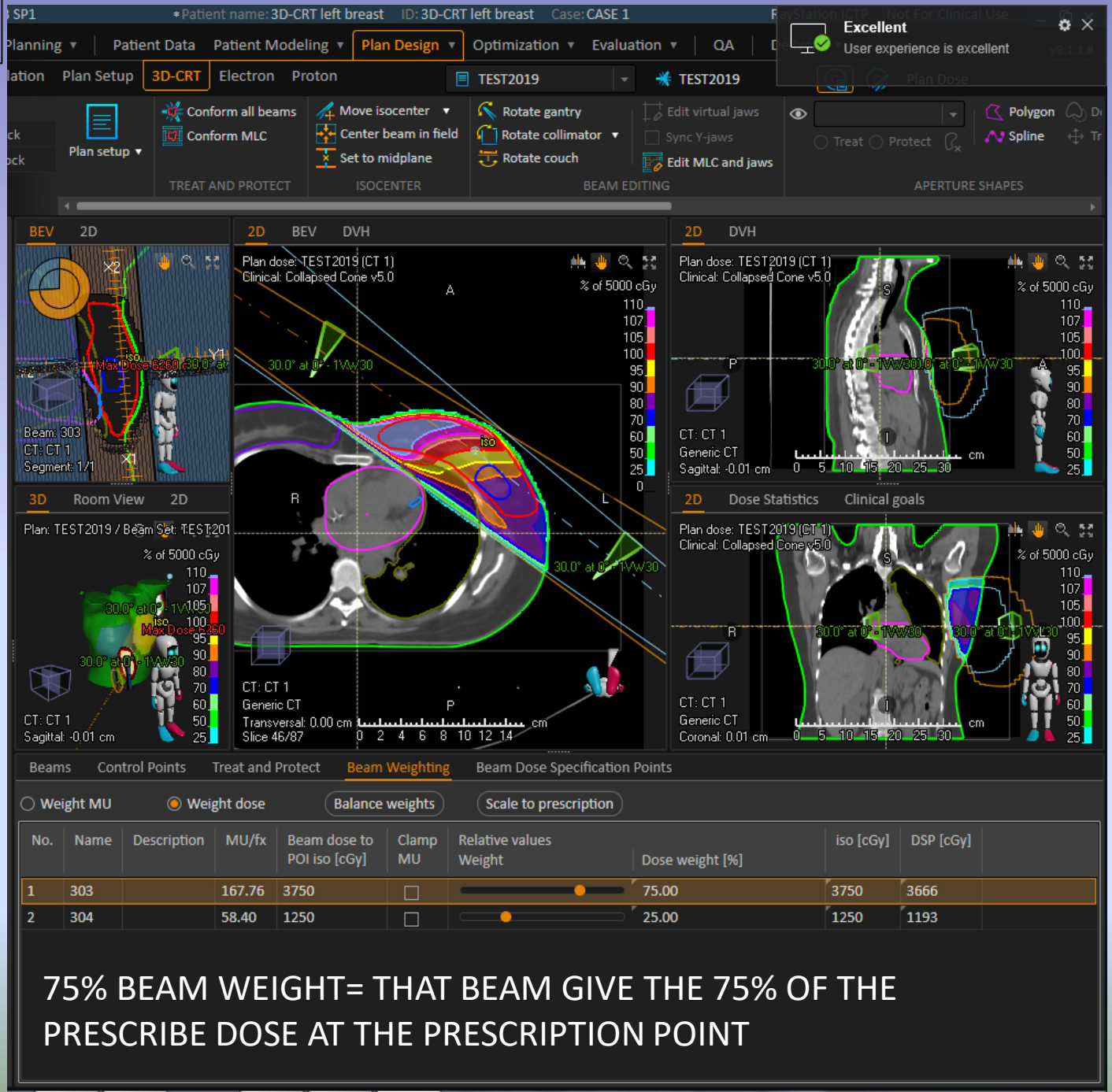
FiF TECNIQUE





FIELD	WEIGHT
307_1	45.60%
131_1	45.60%
307_2	5%
131_1	5%

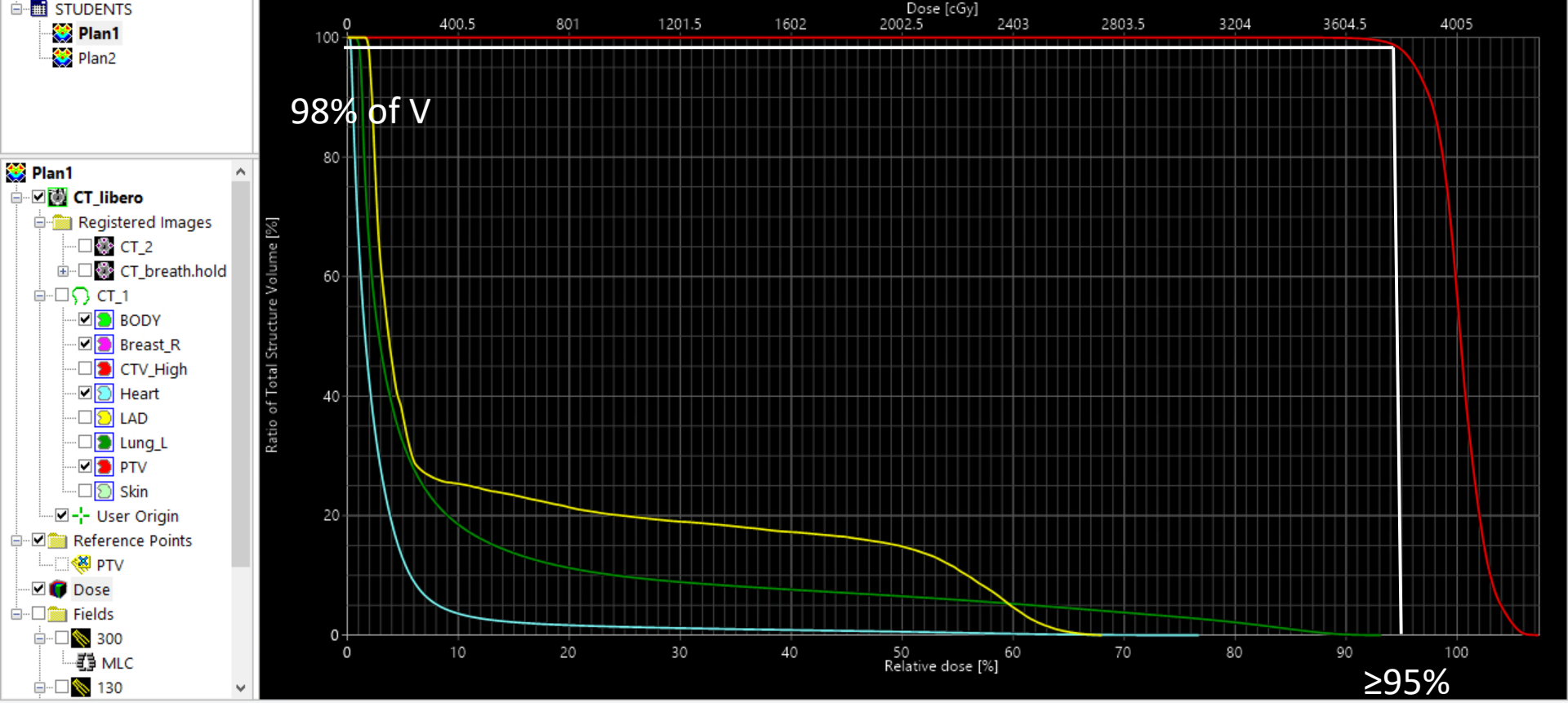
BEAM WEIGHT



75% BEAM WEIGHT= THAT BEAM GIVE THE 75% OF THE PRESCRIBE DOSE AT THE PRESCRIPTION POINT

BEAM WEIGHT

No.	Name	Description	MU/fx	Beam dose to POI iso [cGy]	Clamp MU	Relative values Weight	Dose weight [%]	iso [cGy]	DSP [cGy]
1	303		111.84	2500	☐		50.00	2500	2444
2	304		116.80	2500	☐		50.00	2500	2385



Fields | Dose Prescription | Field Alignments | Plan Objectives | Optimization Objectives | Dose Statistics | Calculation Models | Plan Sum

Show DVH	Structure	Approval Status	Plan	Course	Volume [cm³]	Dose Cover.[%]	Sampling Cover.[%]	Min Dose [%]	Max Dose [%]	Mean Dose [%]
☑	Lung_L	Approved	Plan1	STUDENTS	1206.3	100.0	100.0	0.5	93.3	9.7
☑	Heart	Approved	Plan1	STUDENTS	613.1	100.0	100.0	0.2	76.7	3.1
☑	PTV	Approved	Plan1	STUDENTS	567.8	100.0	100.0	54.6	107.4	100.3
☑	LAD	Approved	Plan1	STUDENTS	1.3	100.0	100.6	1.6	68.1	14.1
☐	CTV_High	Approved	Plan1	STUDENTS						

DVHs are usually displayed in the form of volume ("per cent of total volume" or in in cc) that received the dose ≥ the value in abscissa (% or Gy).

The main drawback of the DVHs is the loss of spatial information that results from the condensation of data when DVHs are calculated.

OTHER QUANTITATIVE EVALUATION : EXAMPLES

Homogeneity Index ("PTV DVH steepness")

$$HI = \frac{D1\% - D99\%}{Dprescription}$$

DX% = Dose at X% of PTV Volume

Conformity number ("how reference dose fit the PTV")

$$CN = \frac{TV_{RI}}{TV} \times \frac{TV_{RI}}{V_{RI}}$$

RI = reference isodose
V_{RI} = reference isodose volume
TV = target volume
TV_{RI} = target volume covered by reference isodose
= intersection of TV and VRI

Healty Tissue Conformity Index

$$HTCI = \frac{TV_{RI}}{V_{RI}}$$

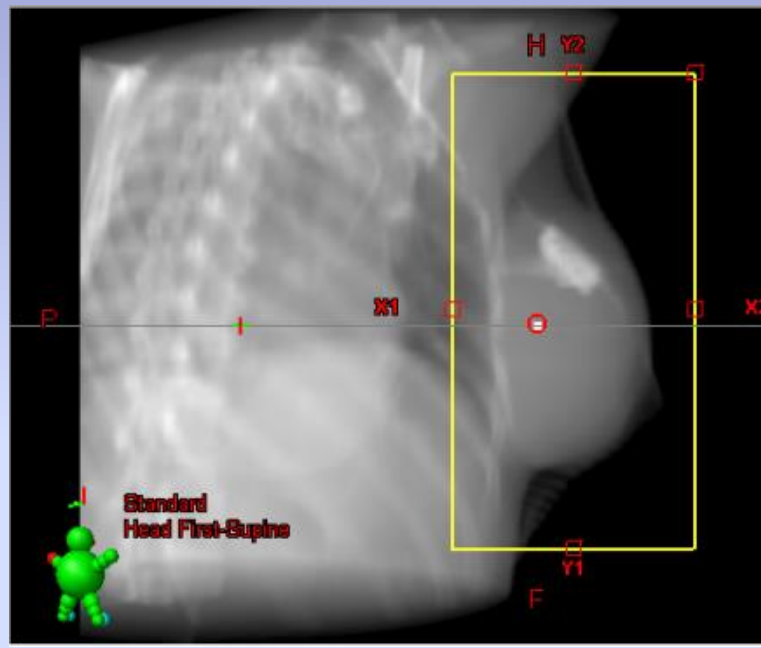
RI = reference isodose
V_{RI} = reference isodose volume
TV = target volume
TV_{RI} = target volume covered by reference isodose
= intersection of TV and VRI

Conformity index L. Feuvret et al. I.J. Radiation Oncology Biology Physics 2006 → CN Formula Van't Riet

DRR

Digitally Reconstructed Radiographs

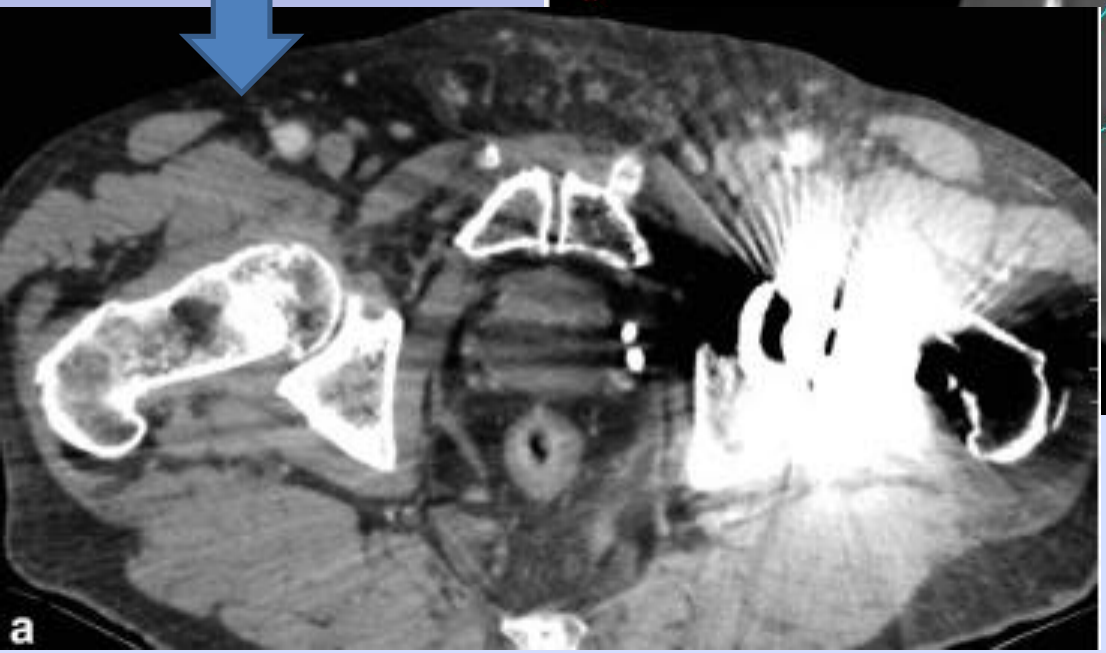
A digitally reconstructed radiograph (DRR) is the artificial version of an X-ray image. It can be computed from CT data and is a two-dimensional (2D) image simulating a normal X ray image or fluoroscopic image.

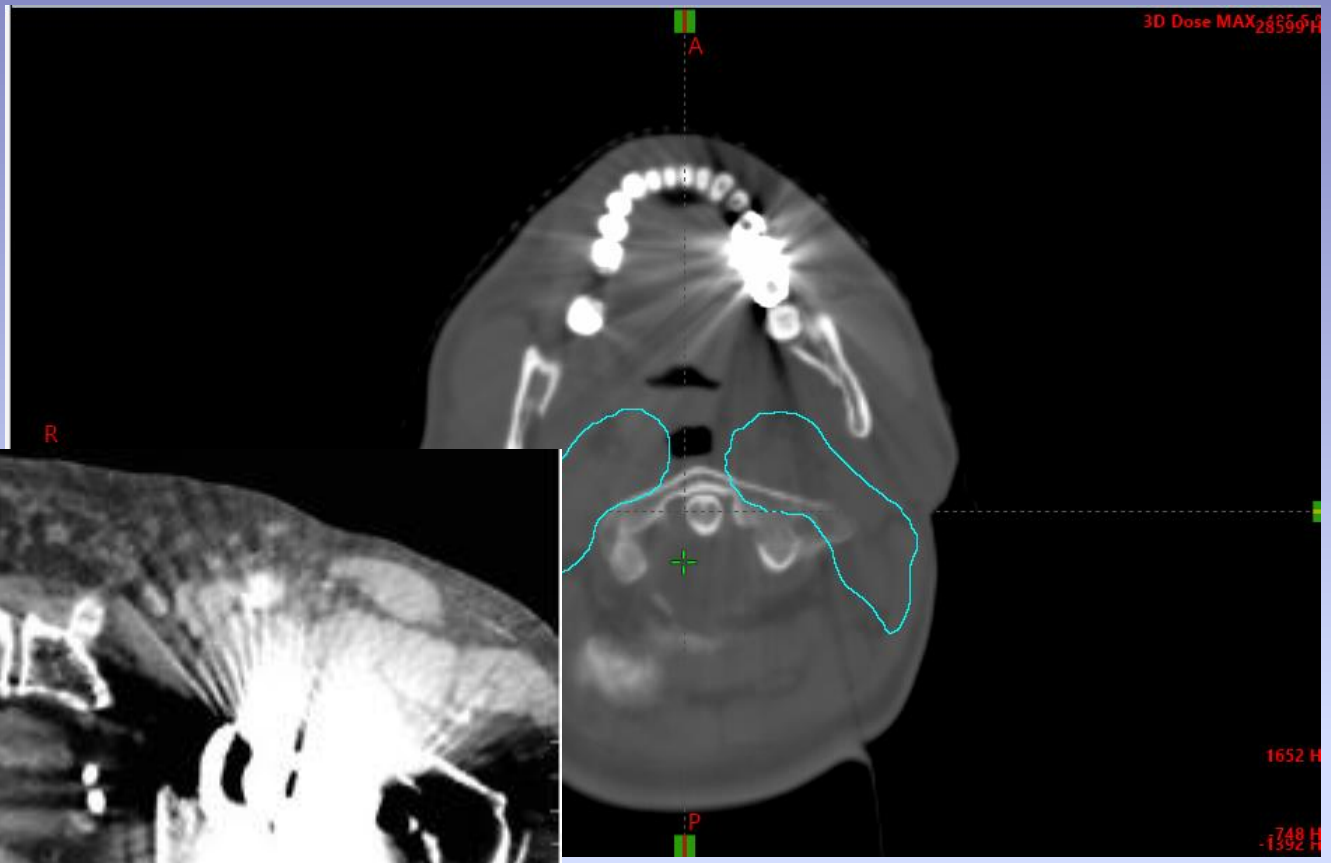


A digitally reconstructed radiograph (DRR) BECOME THE REFERENCE IMAGES FOR THE SET UP OF THE PATIENT BEFORE THE TREATMENT

METAL ARTIFACTS

Metal Prostheses must be avoid





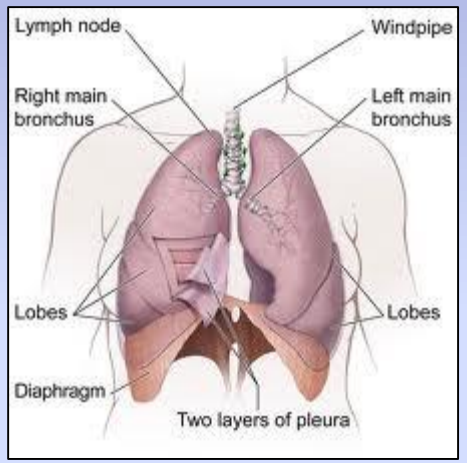
Contour artifact and assigne a new density value, generally water

the impact of dental metal artifacts on head and neck imrt dose distributions (Radiotherapy and Oncology 79 (2006) 198–202)

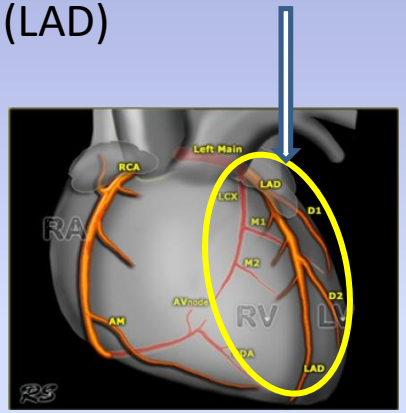
REPORT 63 AAPM (2003): Dosimetric considerations for patients with HIP prostheses undergoing pelvic irradiation

3D-CRT PLANNING: BREAST CASE

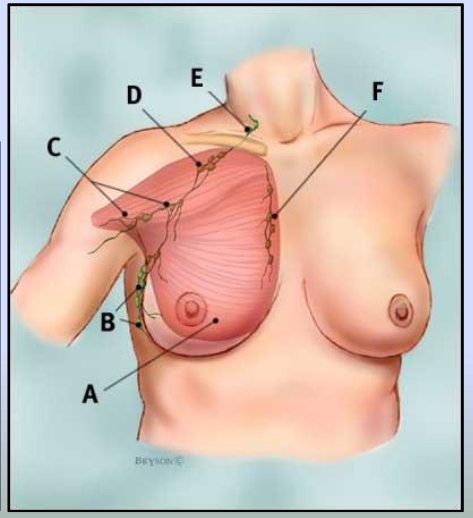
BREAST

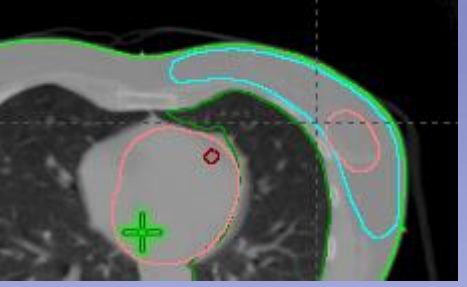


Left Anterior Descending artery (LAD)

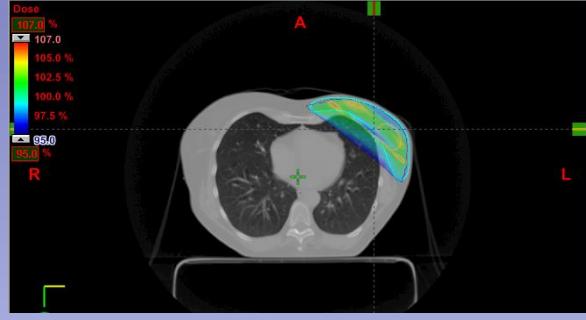


Patients with breast cancer can be (very) long term survival patients, and this is a good endpoint in breast cancer treatment. However, just because long-term survival patients, the radiation treatment can stimulate the development of radiation-induced cancers, which includes second primaries in the contralateral breast.





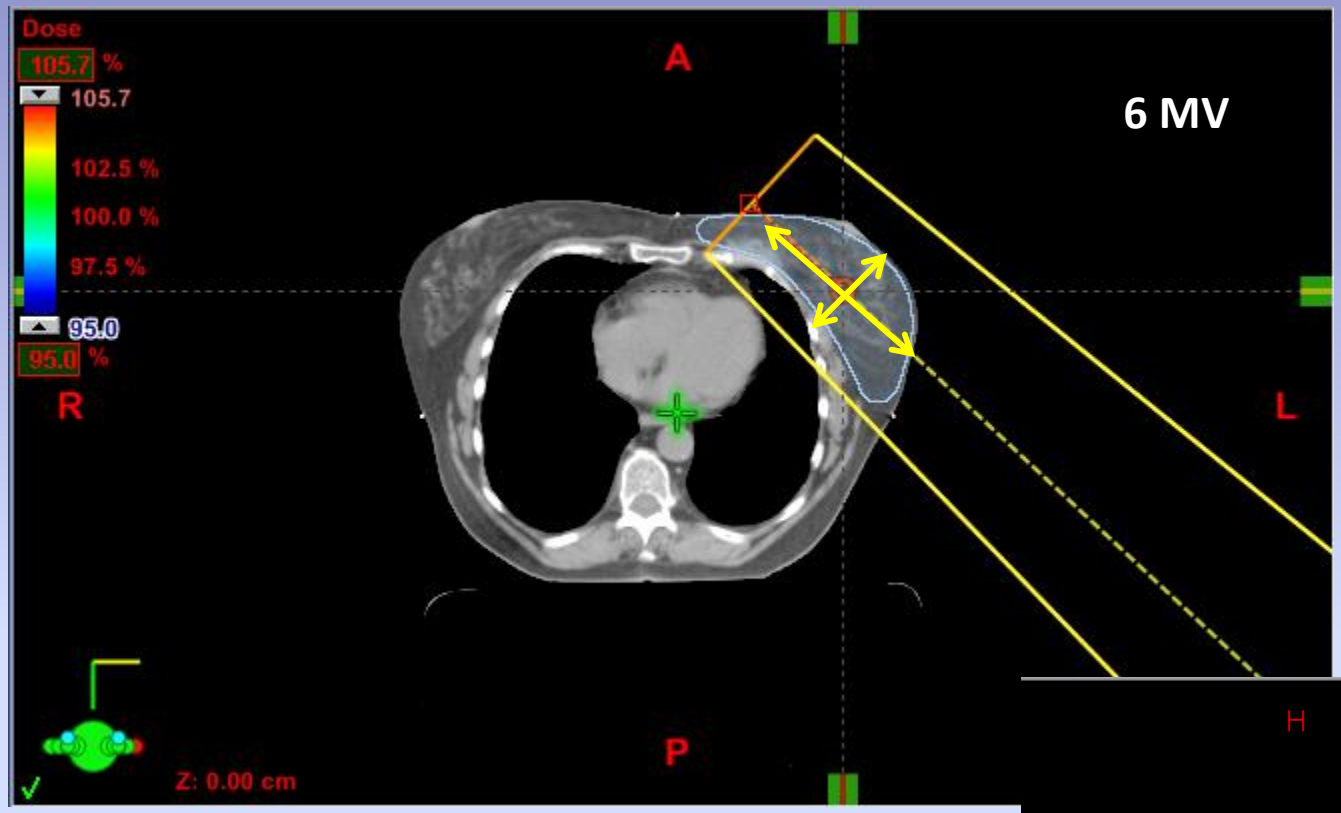
3D-CRT PLANNING: BREAST CASE

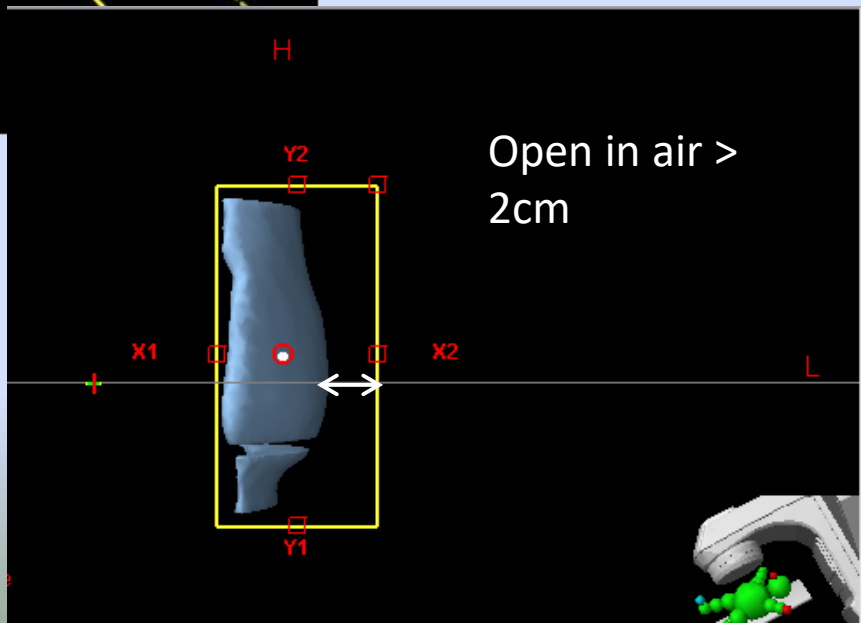


PTV	Prescription	N° fraction	Dose for Fraction
PTV	50 Gy	25	2 Gy

OAR	Dmax Gy	Dmean Gy	Contraints	Other, if it is possible
LAD	20			
Heart	20	5	$V_{5\%} < 25\%$	Dmean<3Gy
Lung			$V_{15Gy} < 15\%$ $V_{5Gy} < 42\%$	Isodose 50% 2cm from thorax wall
Controlateral Breast	3%			

Standard treatment tecnique: 2 tangential fields with wedge or FeF tecnique

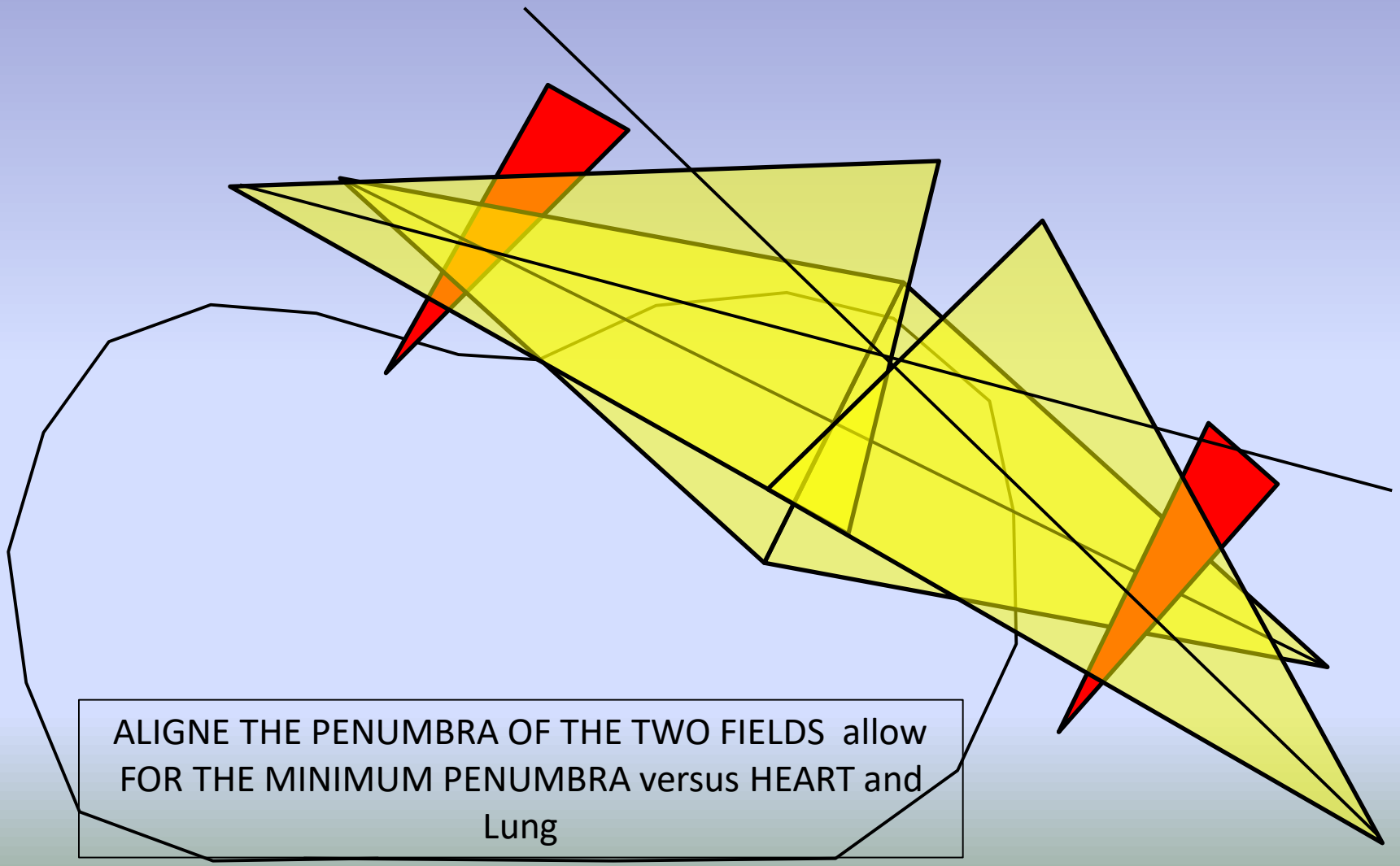




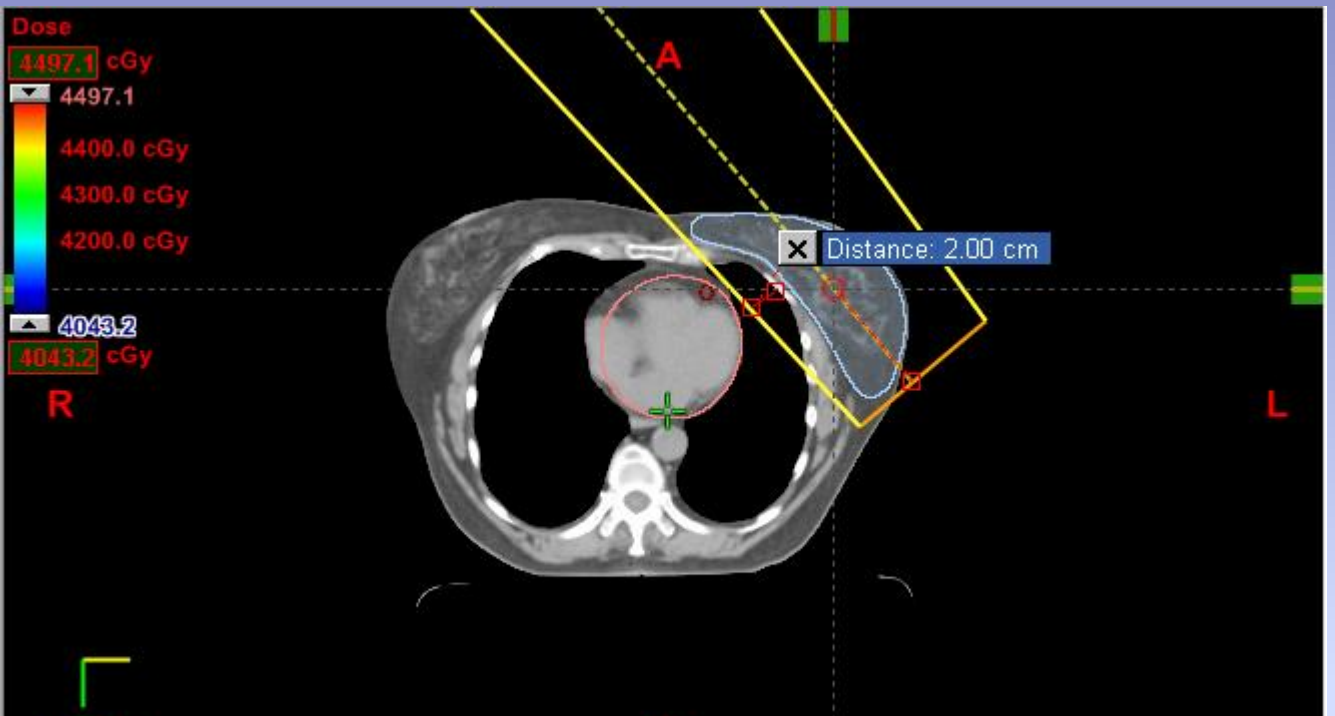
3D-CRT PLANNING: BREAST CASE

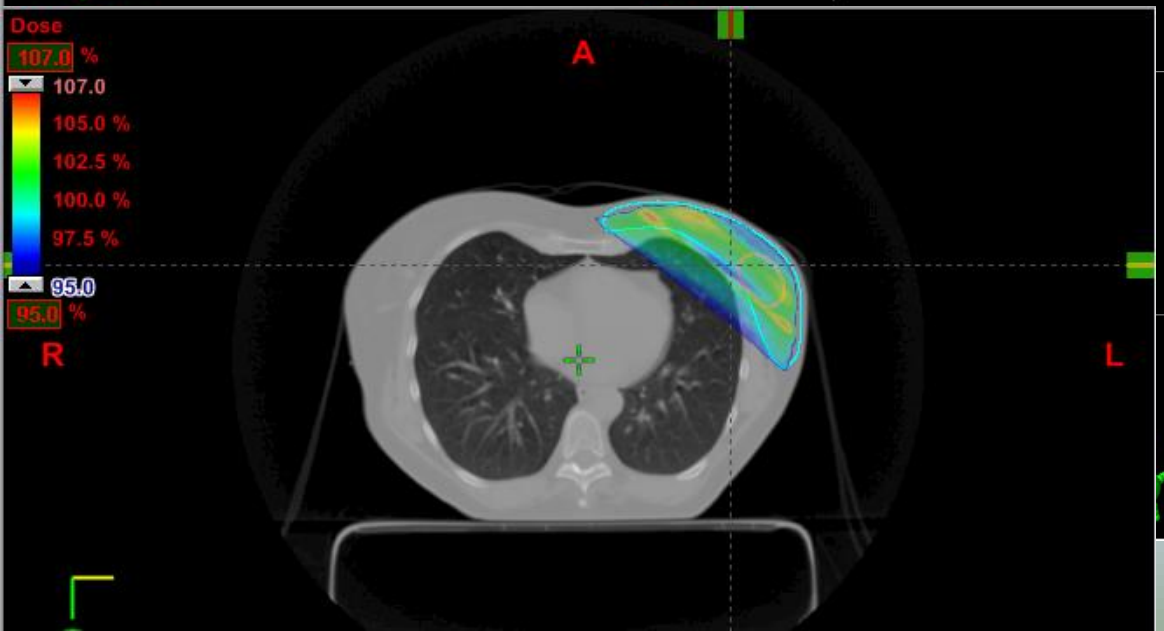
3D-CRT PLANNING: BREAST CASE

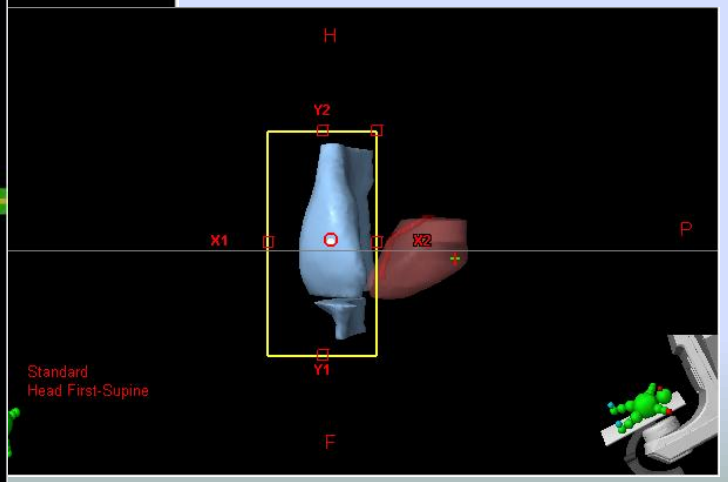
….pair of tangential radiation beams with wedges….



ALIGNE THE PENUMBRA OF THE TWO FIELDS allow FOR THE MINIMUM PENUMBRA versus HEART and Lung

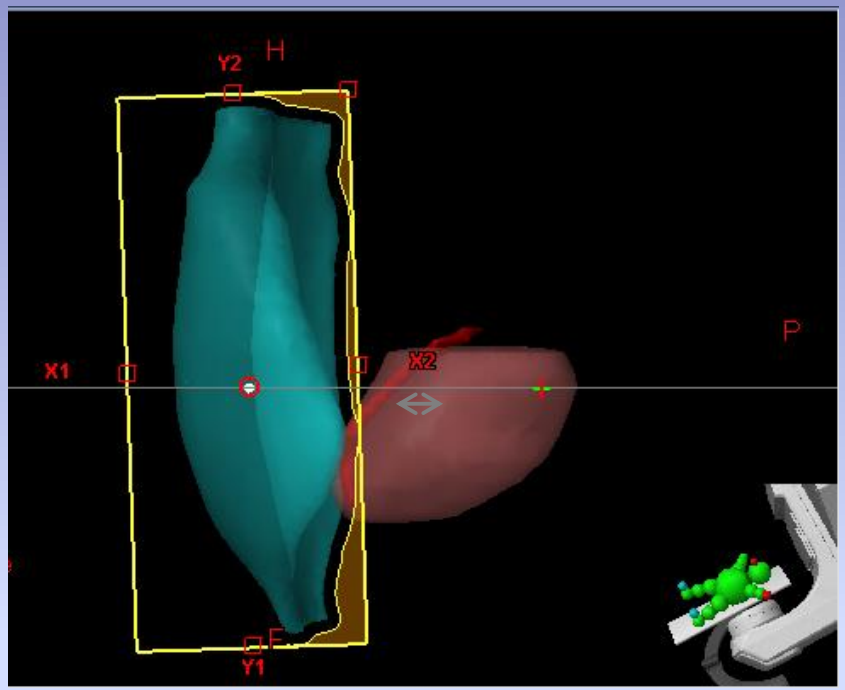




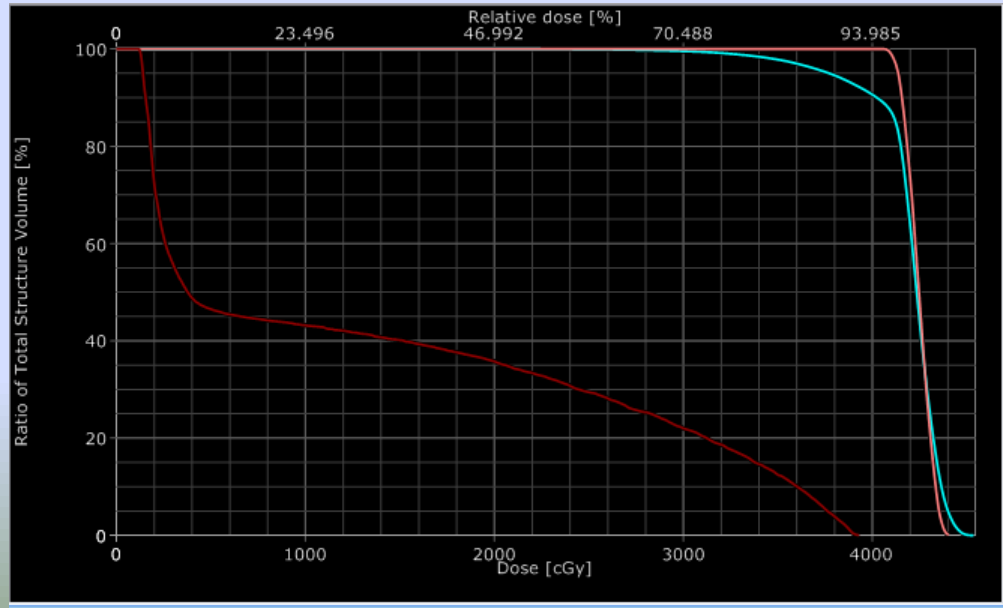


3D-CRT PLANNING:
BREAST CASE

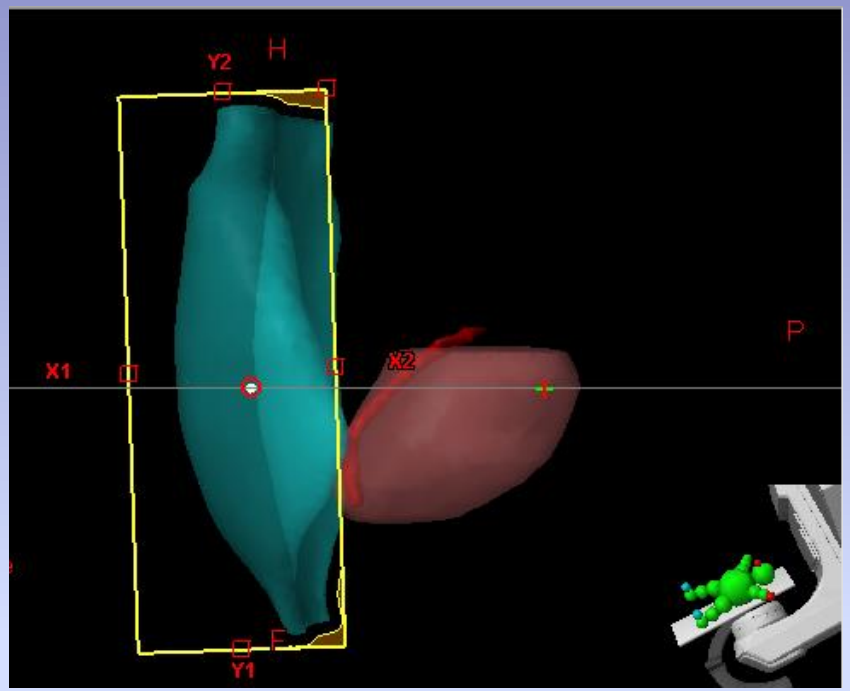
3D-CRT PLANNING: BREAST CASE



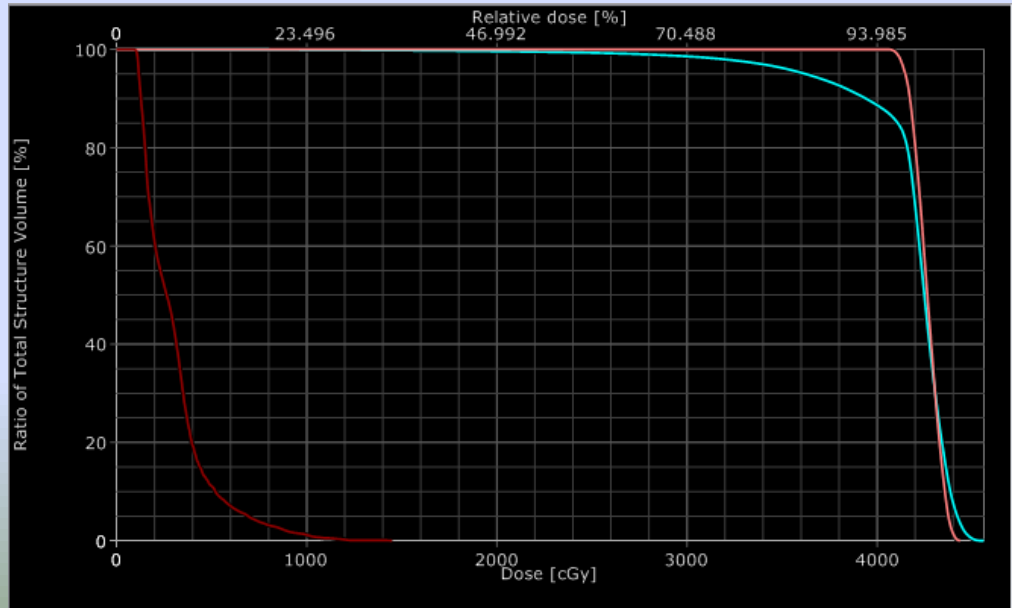
LAD	D_{MAX}	20 Gy



3D-CRT PLANNING: BREAST CASE

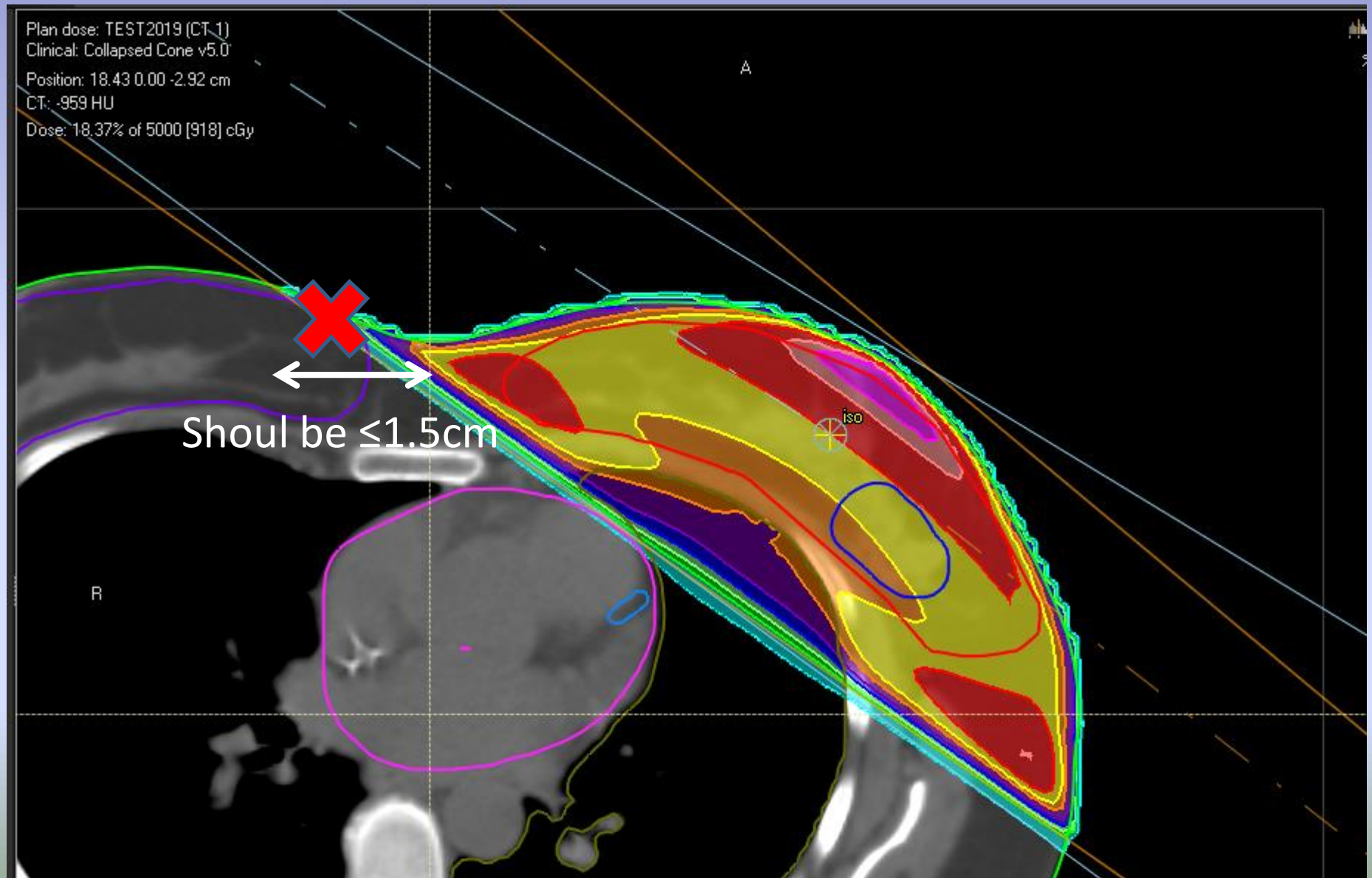


LAD	D_{MAX}	20 Gy



3D-CRT PLANNING: BREAST CASE

Controlateral Breast is OAR

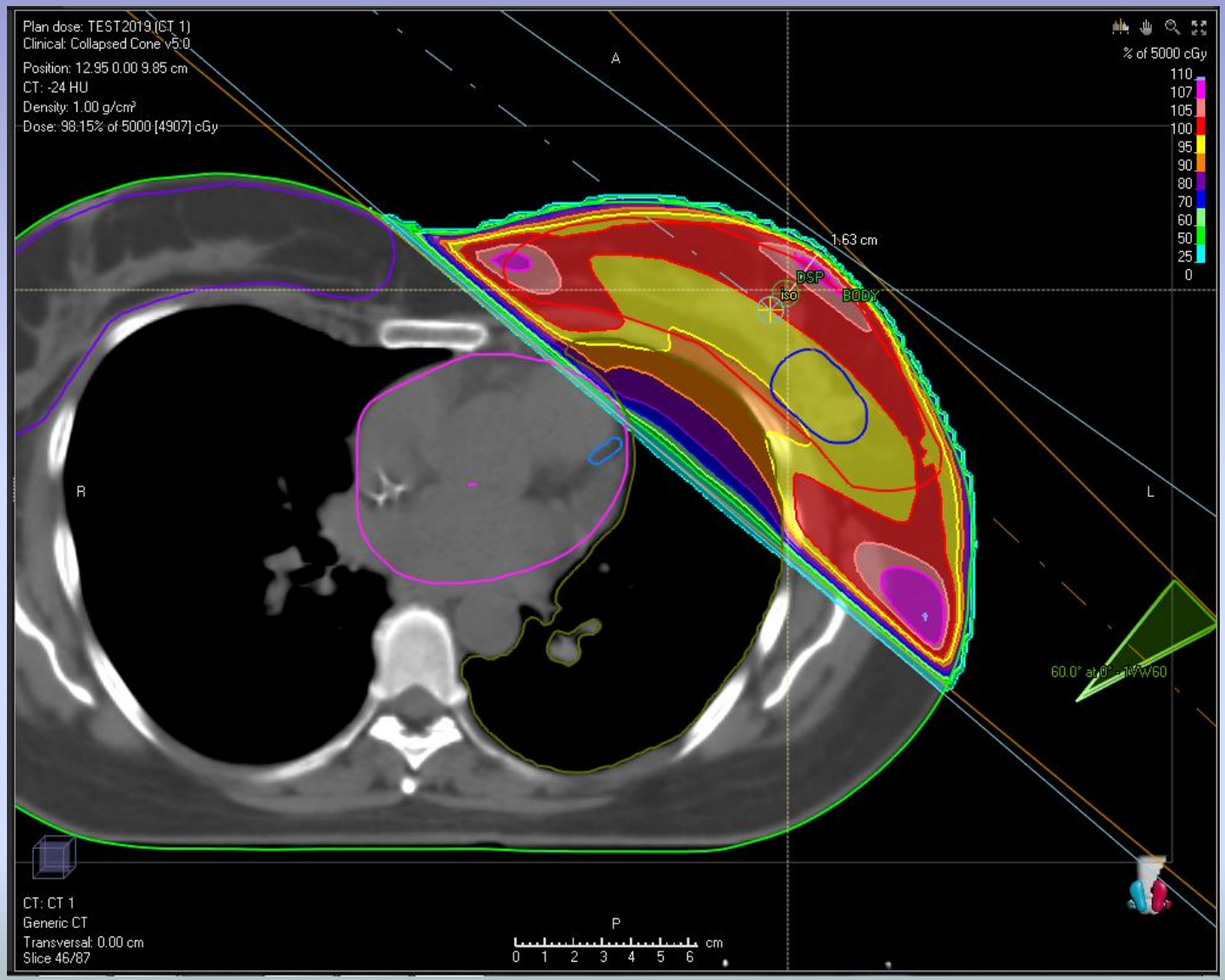


3D-CRT PLANNING: BREAST CASE

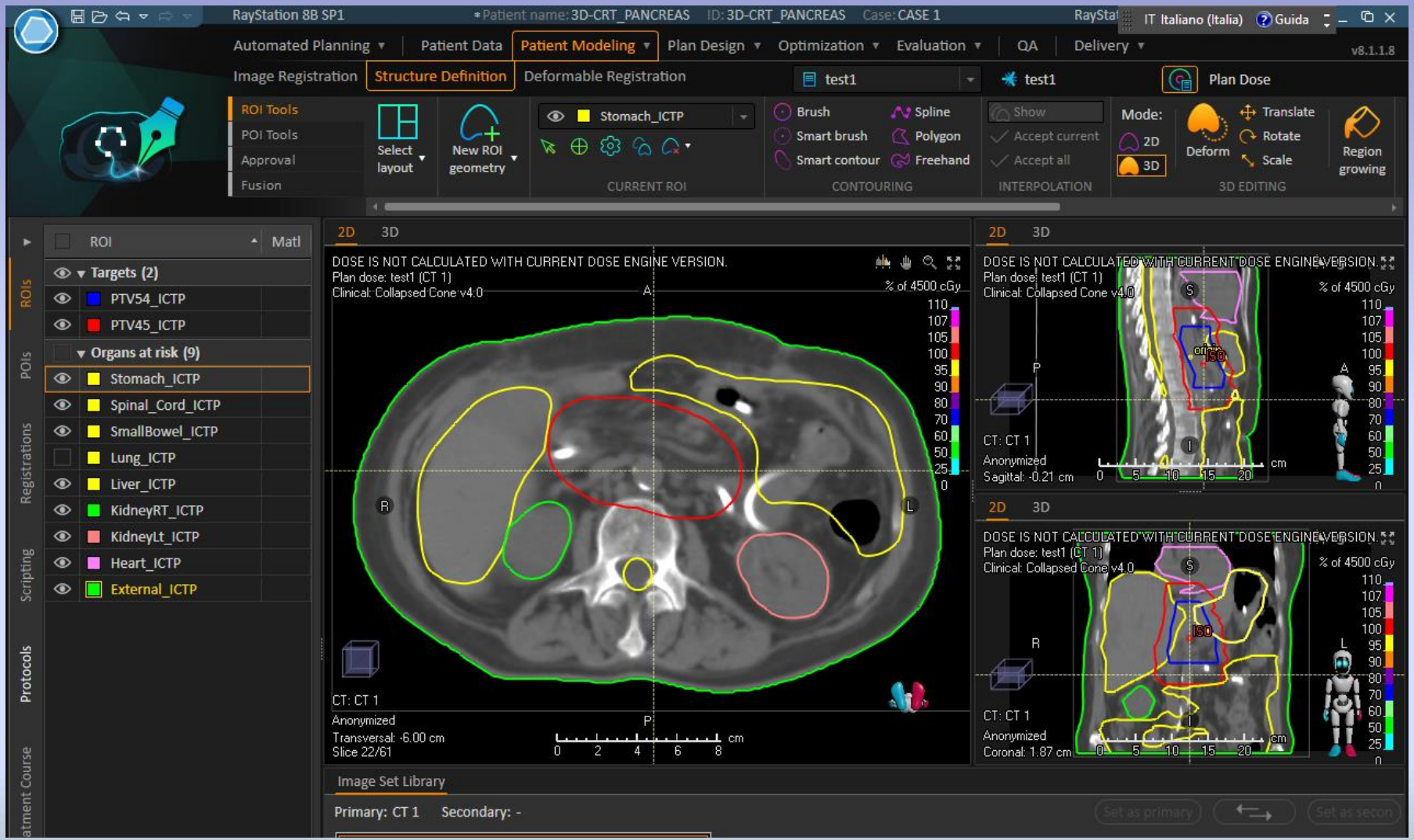
PRESCRIPTION POINT = ISOCENTER

3D-CRT PLANNING: BREAST CASE

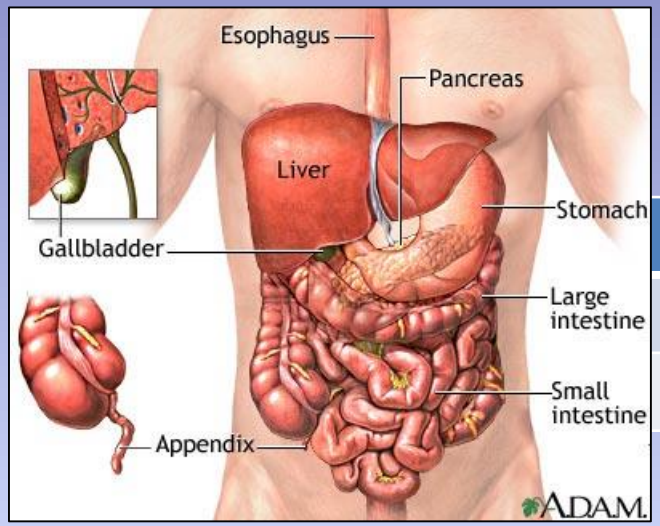
PRESCRIPTION POINT ≠ ISOCENTER

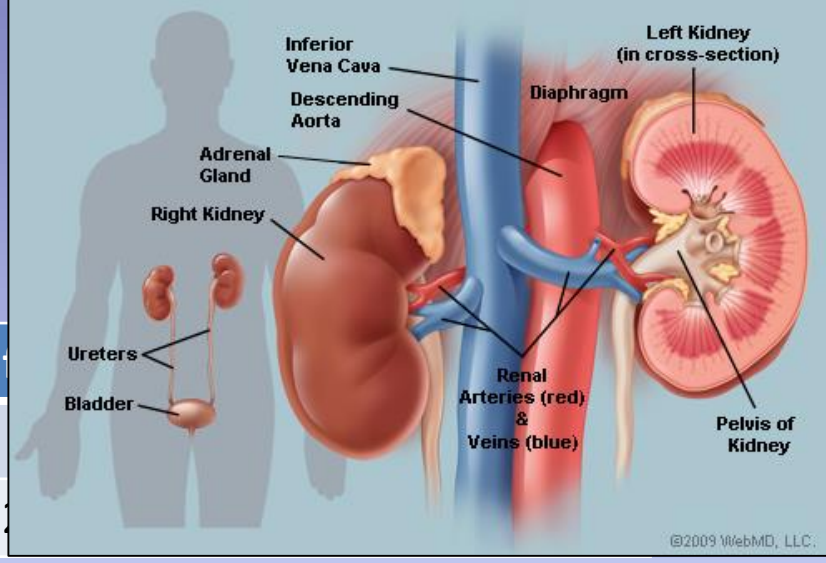


3D-CRT PLANNING: PANCREAS CASE



3D-CRT PLANNING: PANCREAS CASE



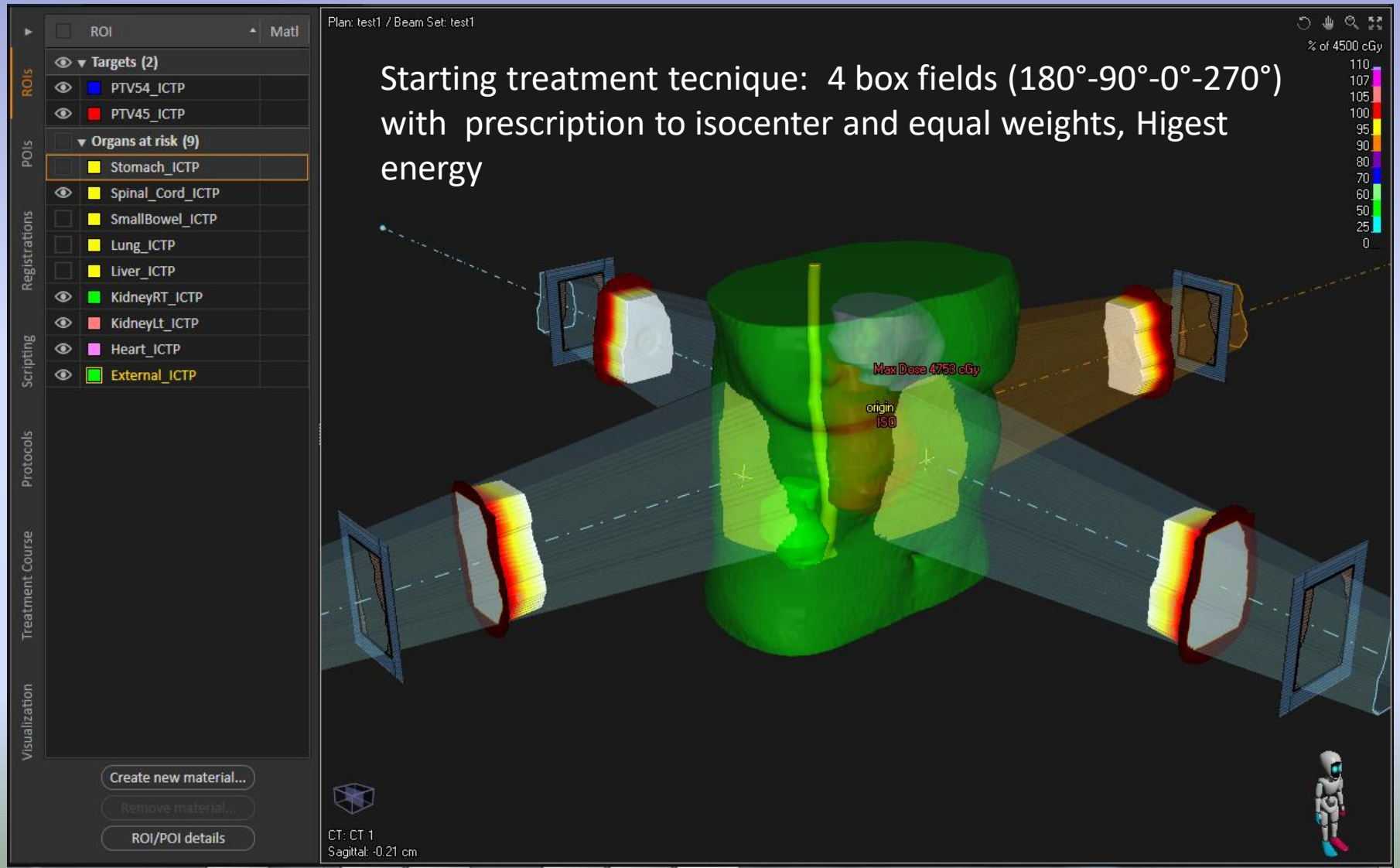


Prescription	N°
45 Gy	
54 Gy	

1 PLAN 25 FR ON PTV 45+ 2 PLAN 5 FR ON PTV 54

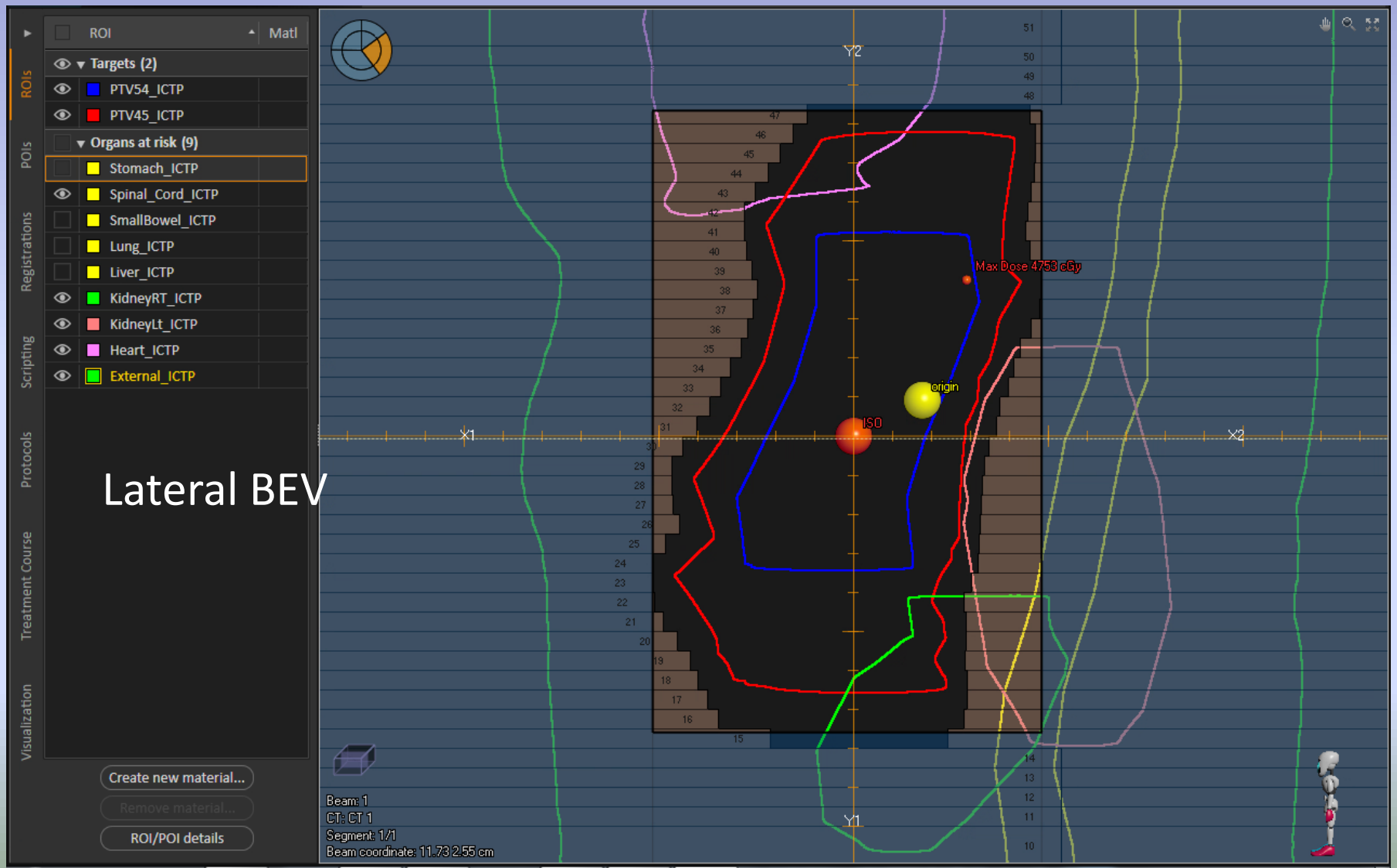
OAR	Dmax Gy	Dmean Gy	Contraints	Other, if it is possible
Spinal coord	50			D_{max}<45Gy
Kidney		18	V_{12Gy} < 55% V_{20Gy}< 30% V_{28Gy}< 20%	
Liver		30		
Intestine/Stomach (peritoneal cavity)	50		V45Gy <195CC	
Heart			V25Gy <10%	

3D-CRT PLANNING: PANCREAS CASE



3D-CRT PLANNING: PANCREAS CASE

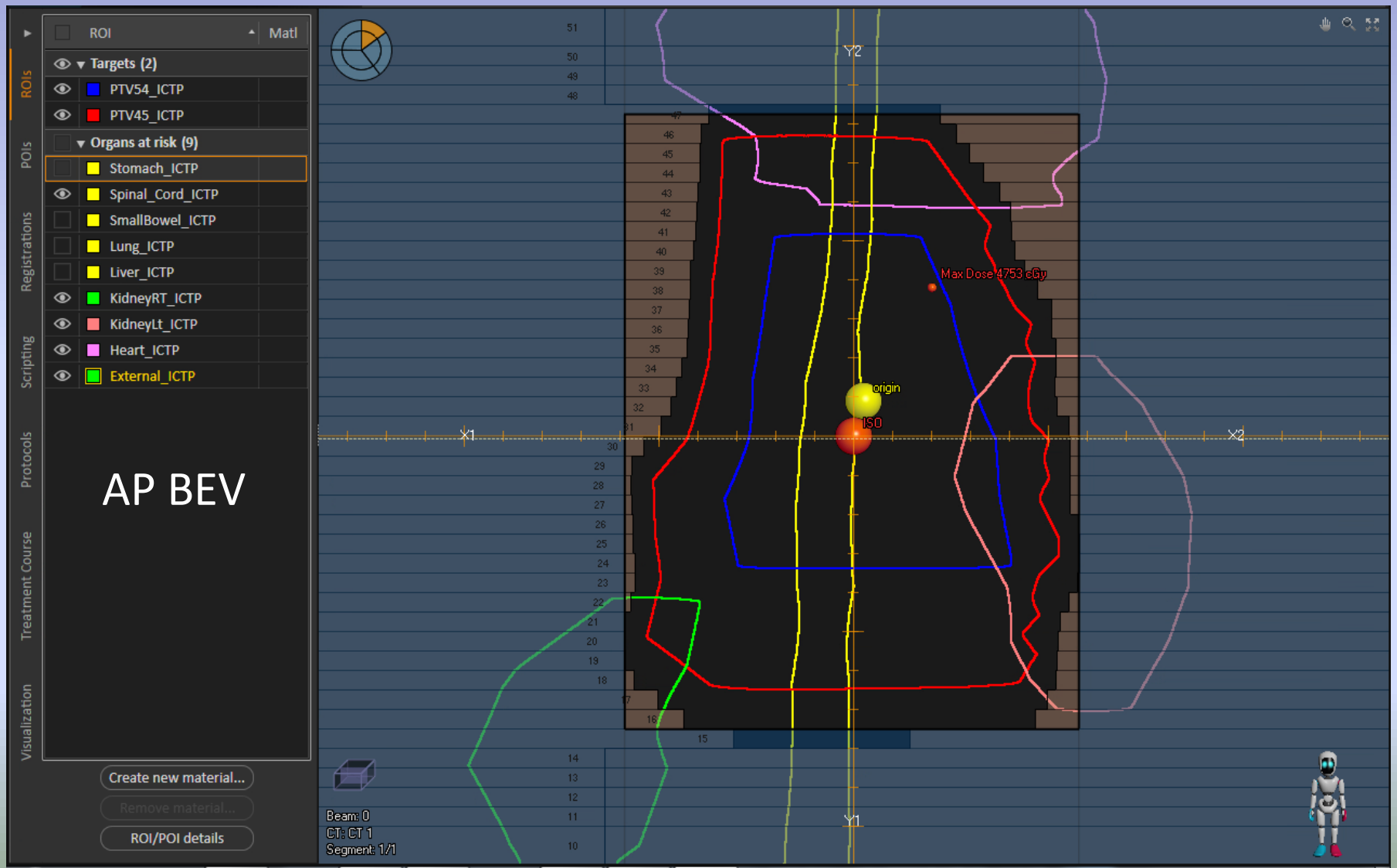
I° Plan:PTV45



Lateral BEV

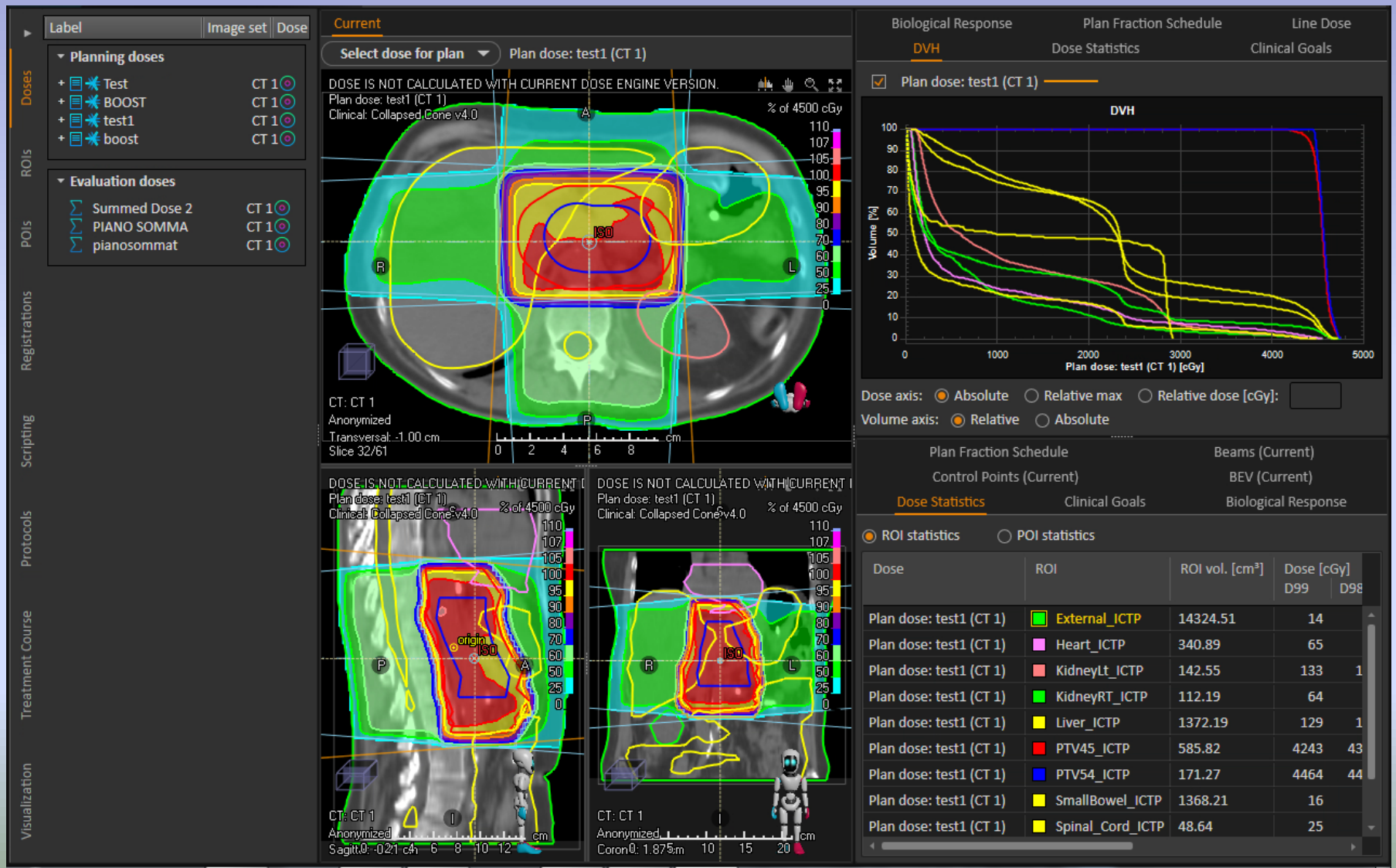
3D-CRT PLANNING: PANCREAS CASE

I° Plan:PTV45



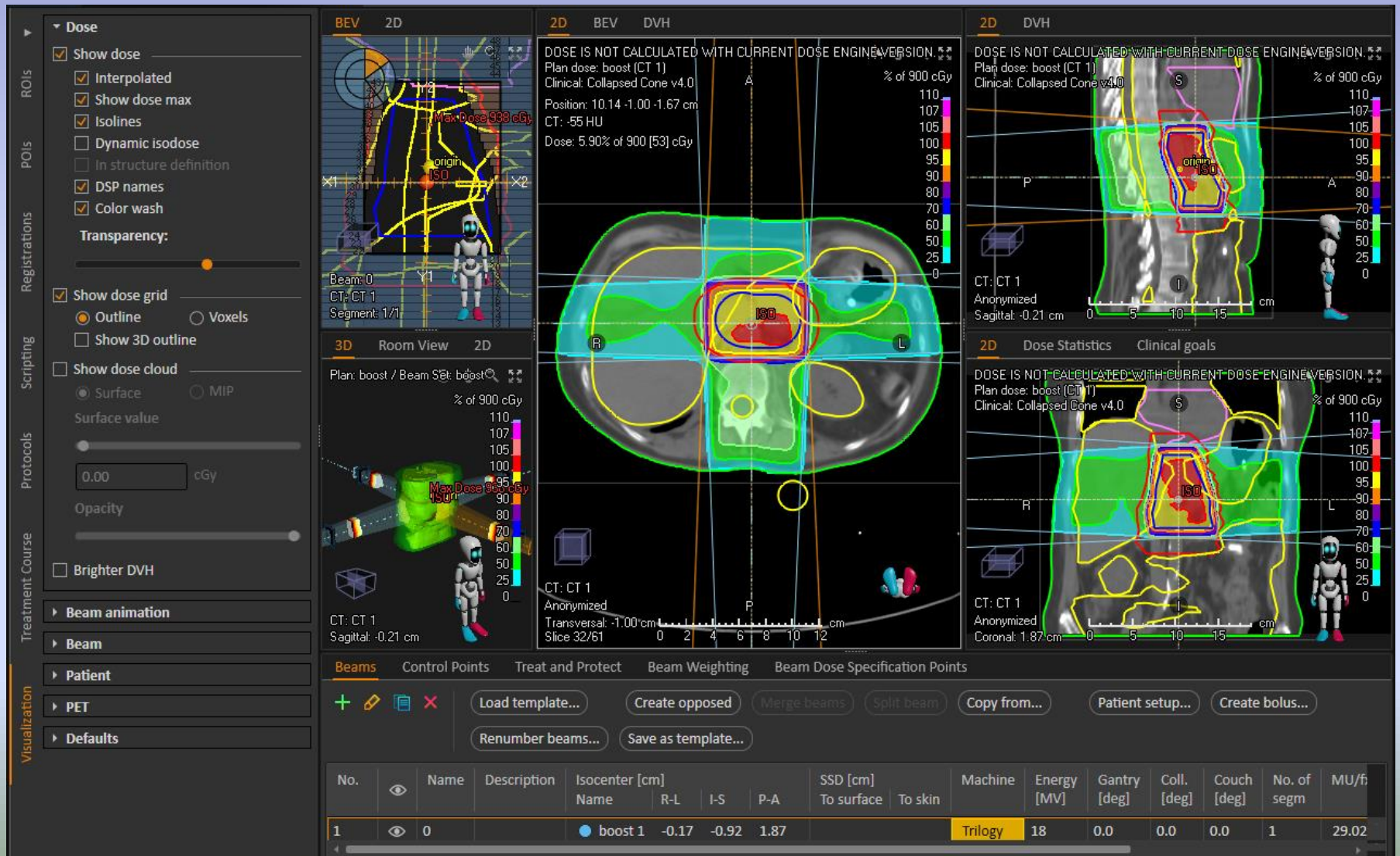
3D-CRT PLANNING: PANCREAS CASE

I° Plan:PTV45



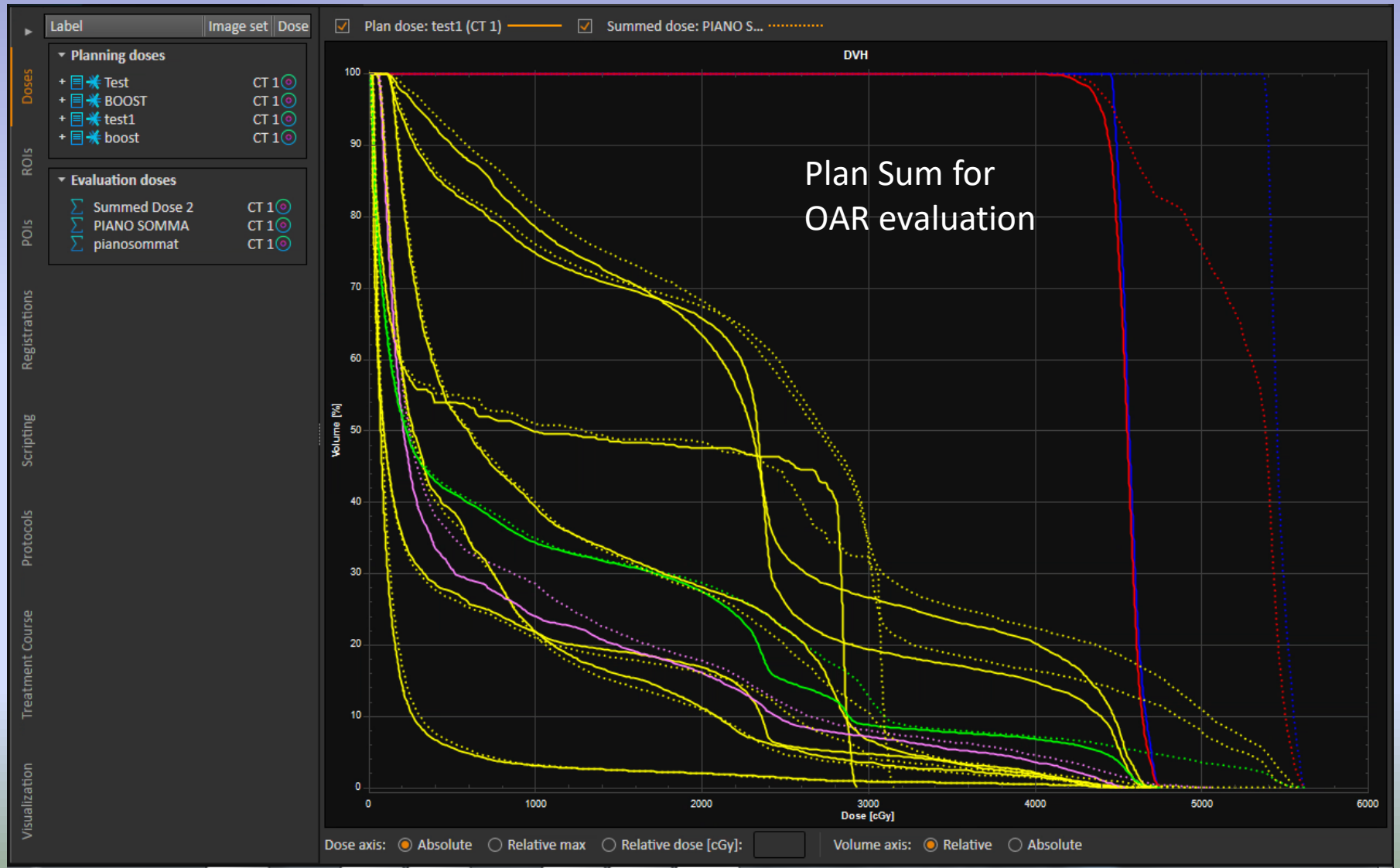
3D-CRT PLANNING: PANCREAS CASE

II° Plan:PTV54



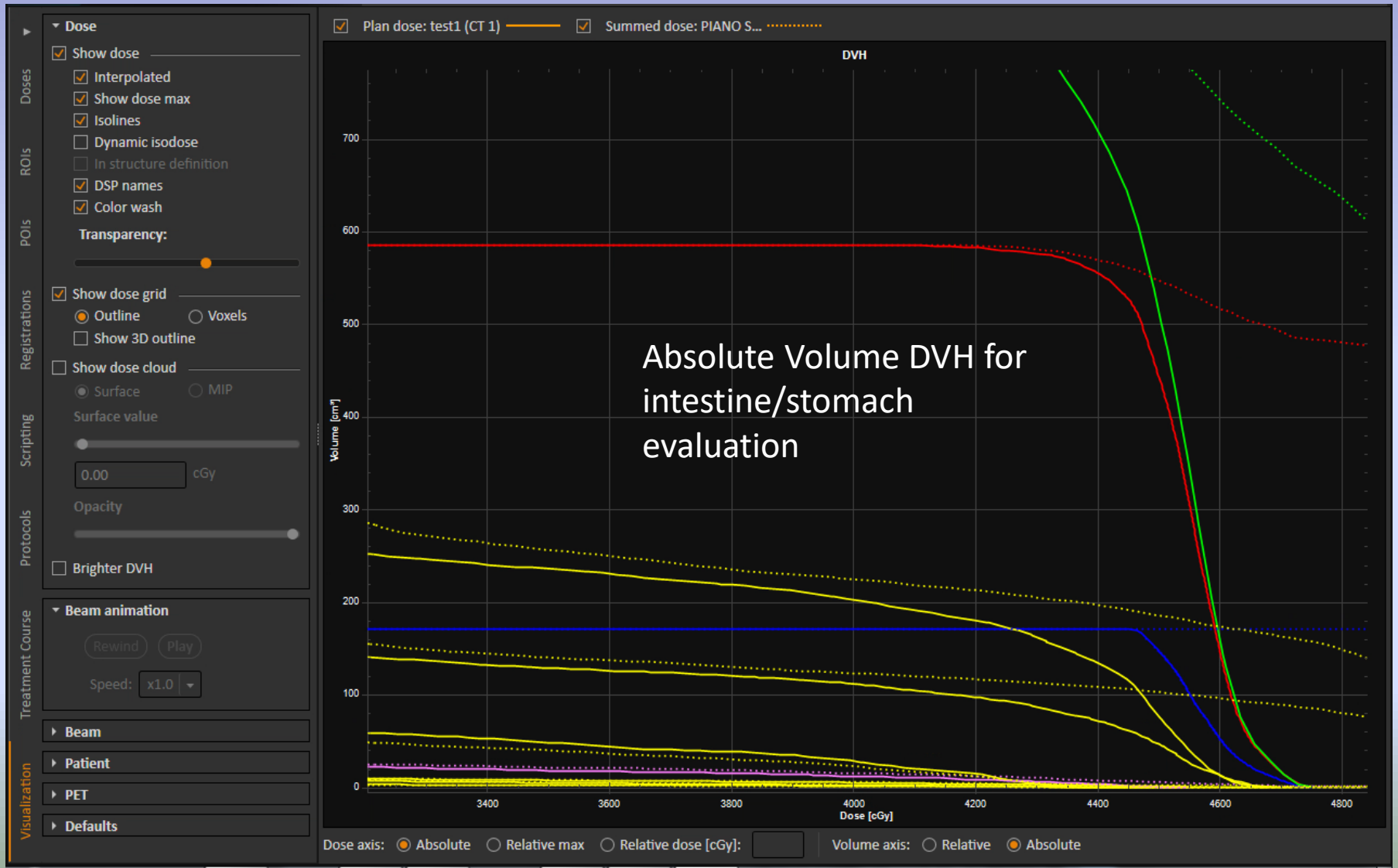
3D-CRT PLANNING: PANCREAS CASE

Plan Sum

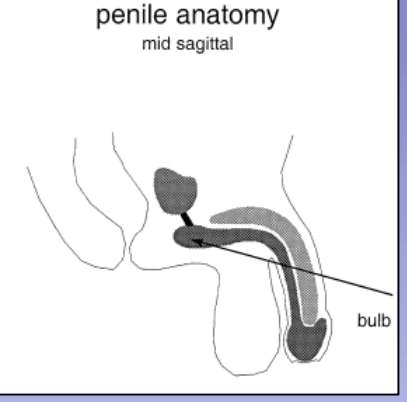


3D-CRT PLANNING: PANCREAS CASE

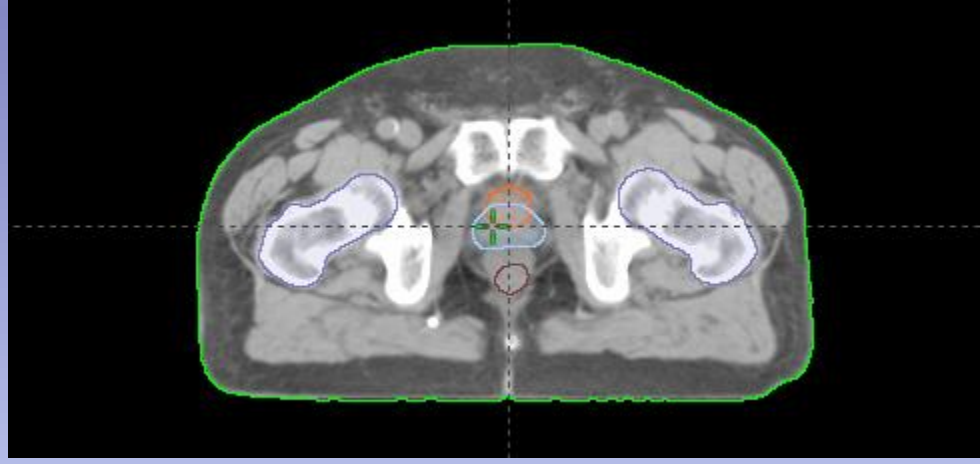
Plan Sum



THANKS FOR THE ATTENTION



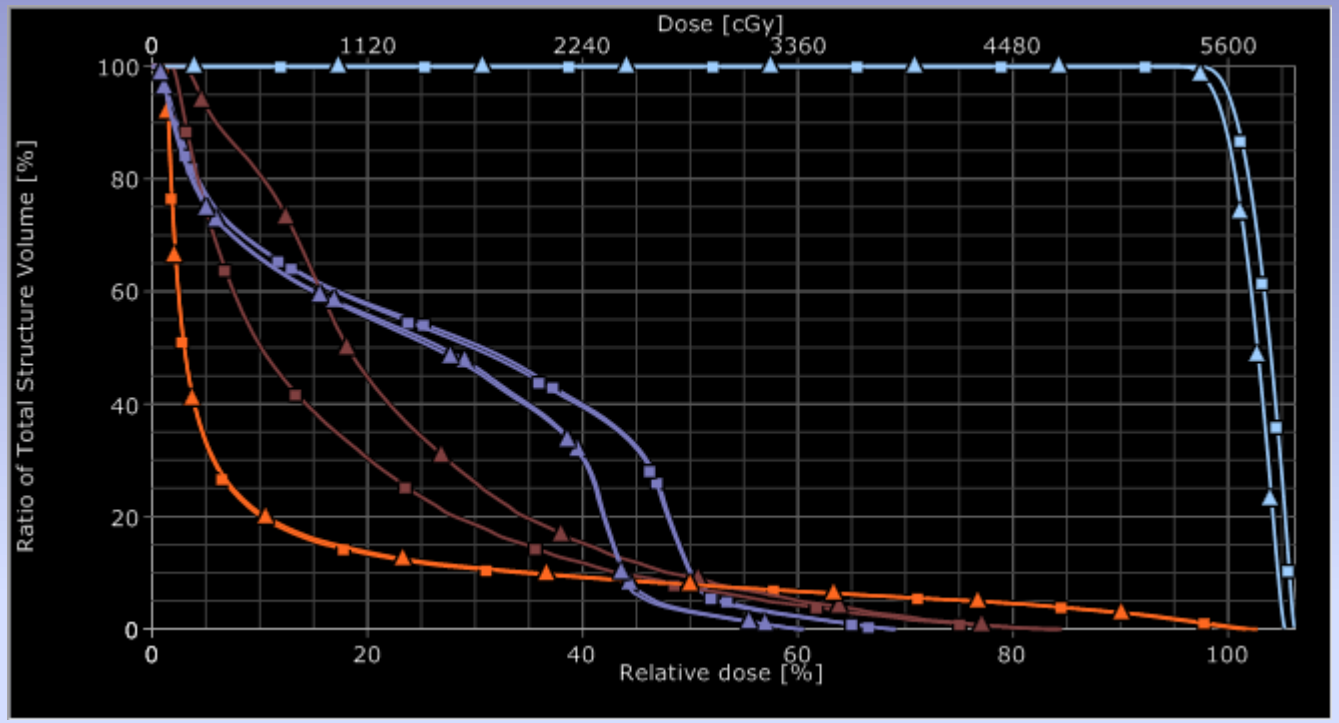
PROSTATE



PTV	Prescription	N° fraction	Dose for Fraction
PTV	70 Gy	35	1.8 Gy

OAR	Dmax Gy	Dmean Gy	Contraints	Other, if it is possible
Rectum			V_{65Gy}<25% V_{60Gy}<35% V_{50Gy}<50%	
Bladder			V_{65Gy}<50%	
Femoral Head			V_{50Gy}<5%	
Penile bulb		50		

THE DOSIMETRIC PLANNING



	Vescica	Approved	PROSTATA 2
	Vescica	Approved	PROSTATA 1
	Testa Fem Sn	Approved	PROSTATA 2
	Testa Fem Sn	Approved	PROSTATA 1
	Testa Fem Dx	Approved	PROSTATA 2
	Testa Fem Dx	Approved	PROSTATA 1
	Retto	Approved	PROSTATA 2
	Retto	Approved	PROSTATA 1
	PTV	Approved	PROSTATA 2
	PTV	Approved	PROSTATA 1

7 FIELDS – PROSTATA 1

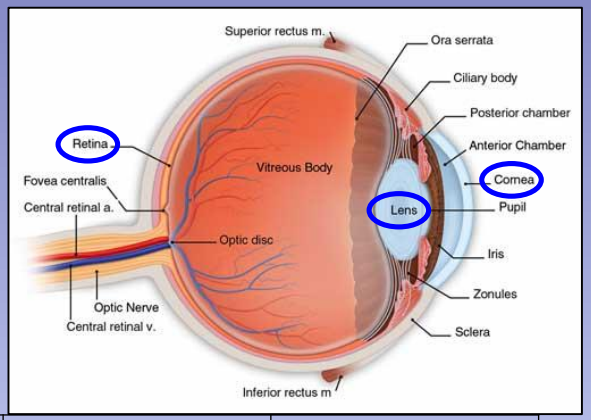
6 FIELDS – PROSTATA 2

PATIENT SET UP

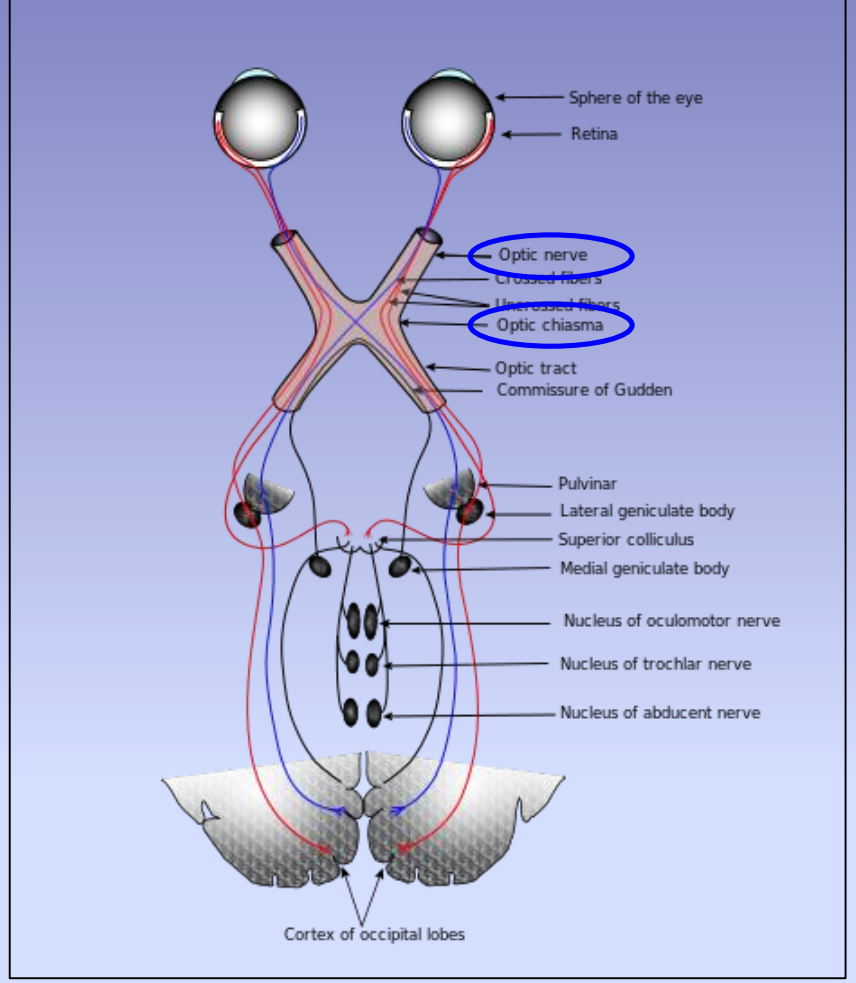
HEAD

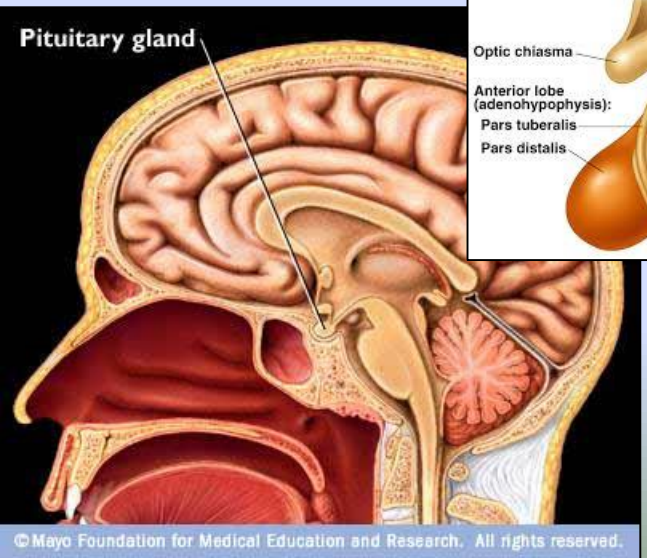
ORGAN AT RISK

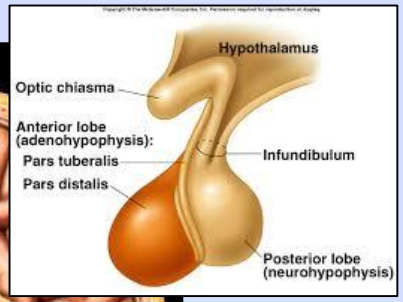
EYES



Site	Damage	Dose
lens	cataract	6-12 Gy
cornea	keratitis	50 Gy
retina	vision loss	45-50 Gy
optic chiasm	vision loss	50 cGy
http://www.aboutcancer.com/radiation_to_the_eye.htm		







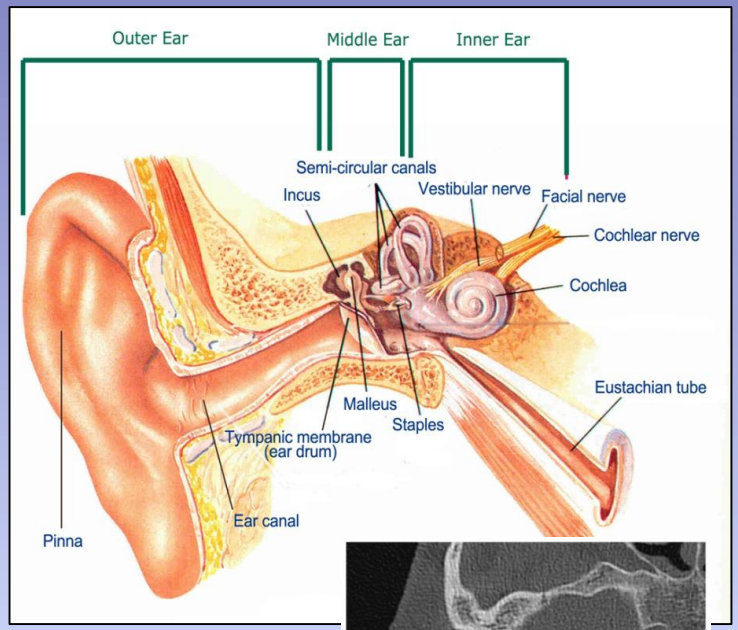
Site	Dose
PITUITARY GLAND	50 Gy

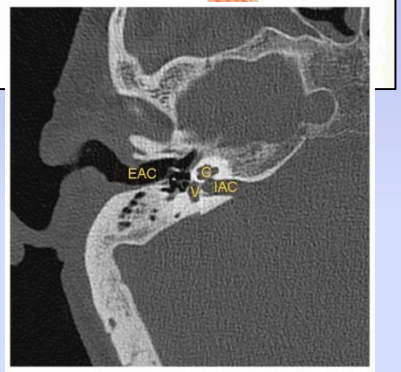
ORGAN AT RISK

EARS

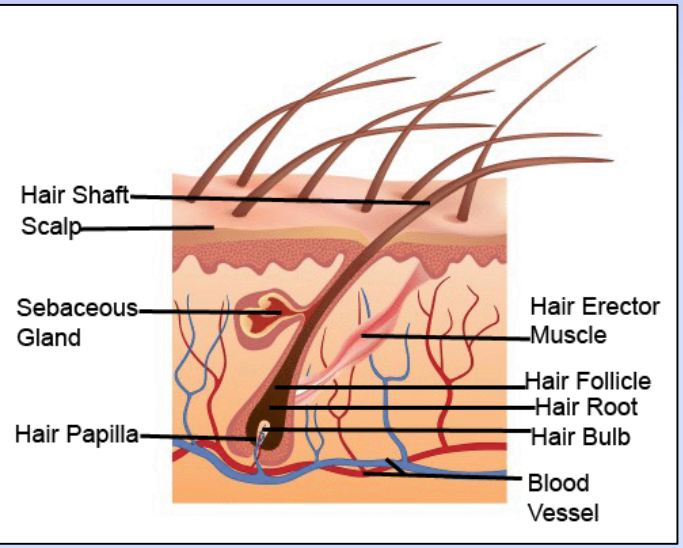
Site	Dose
COCLEA	Dmean<45Gy better 35Gy

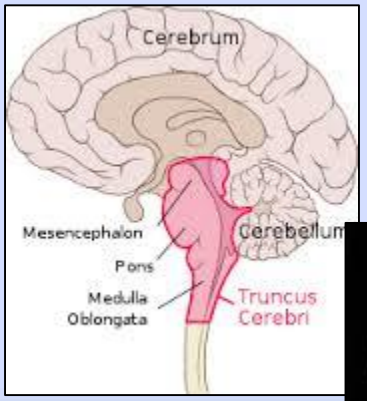
These doses may not apply in patients who have received radiotherapy combined with concurrent/adjuvant chemotherapy.

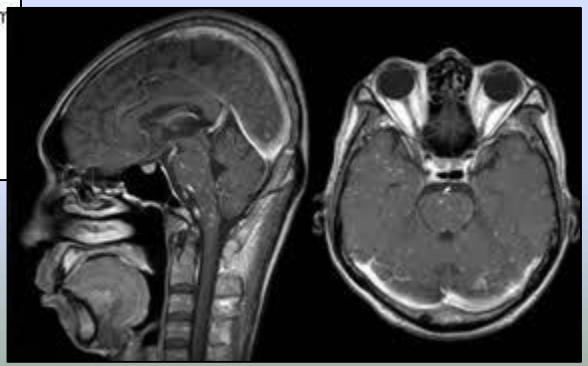




Dpermanent alopecia>43 Gy







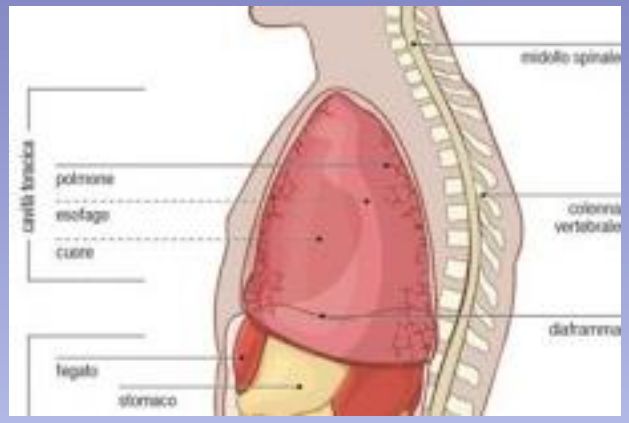
Site	Dose
BRAINSTEM	D1-100CC<59Gy D100%<54Gy

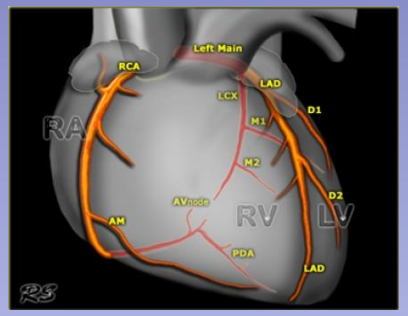
BRAIN

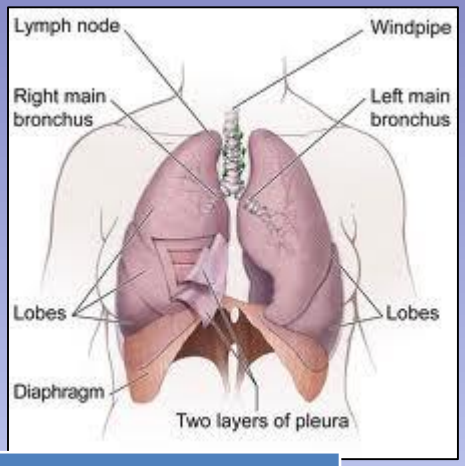
PTV	Prescription	N° fraction	Dose for Fraction
PTV	60 Gy	30	2Gy

OAR	Dmax Gy	Dmean Gy	Contraints	Other, if it is possible
Lens	6			
Eyes (retina)	50			
Brainstem	54			Dmax<50Gy
Optical Chiasm	55	50		Dmax<45Gy
pituitary gland	55			Dmax<45Gy
Optical nerve	55	50		Dmax<45Gy

- Treatment tecnique: coplanar and no-coplanar fields







PTV	Prescription	N° fraction	Dose for Fraction
PTV	60 Gy	30	2 Gy

OAR	Dmax Gy	Dmean Gy	Contraints	Other, if it is possible
Heart			V_{30Gy} < 46%	V_{25Gy} < 10%
Lung omolateral			V_{20Gy} < 30-40%	V_{20Gy} < 20%
Lung controlateral			V_{20Gy} < 20% V_{5Gy} < 42%	
Spinal coord	50			D_{max}<45Gy
Esophagus	74		V_{50Gy} < 40% V_{35Gy} < 50%	