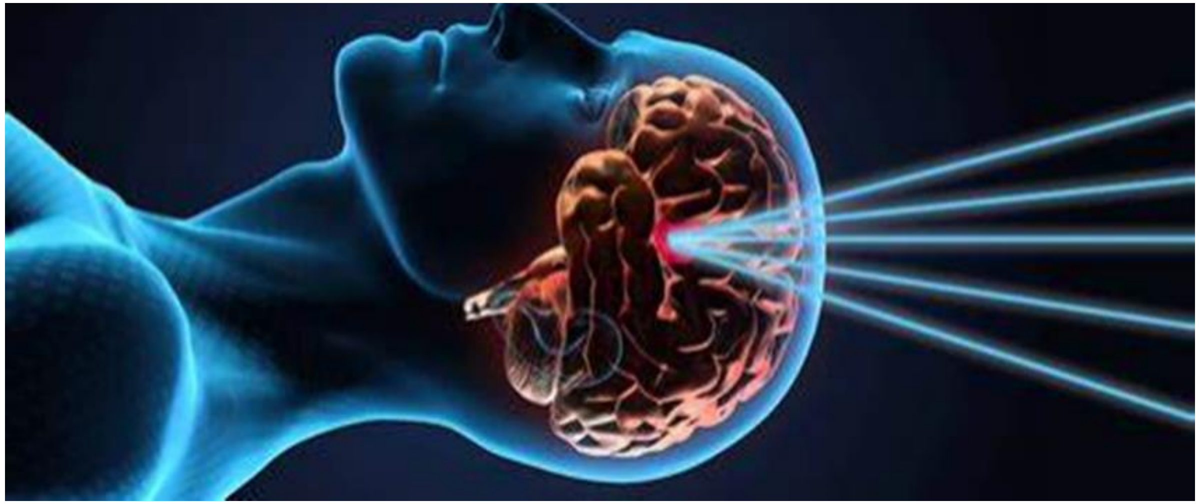
SRS Treatment Planning for Endocranial Tumor



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Head of Medical Physics Dept.,
Cancer Hospital of Thessaloniki
"Theagenio"

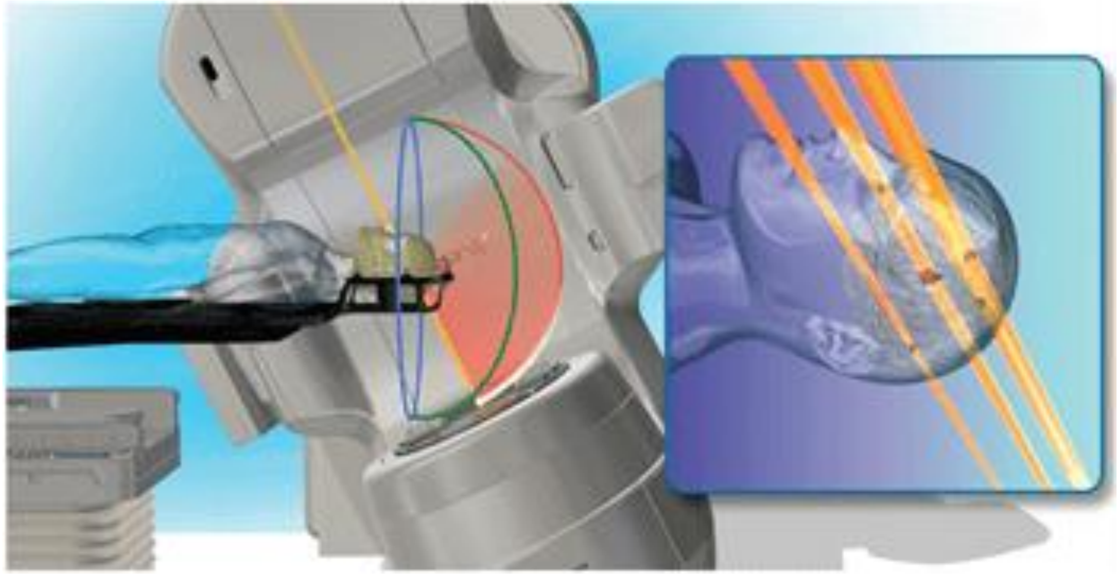
Introduction in SRS

Stereotactic radiosurgery (SRS) uses many precisely focused radiation beams or beam arcs to treat tumors and other problems in the brain, neck, lungs, liver, spine and other parts of the body.

It is not surgery in the traditional sense because there's no incision. Instead, stereotactic radiosurgery uses 3D imaging to target high doses of radiation to the affected area with minimal impact on the surrounding healthy tissue.

Like other forms of radiation, stereotactic radiosurgery works by damaging the DNA of the targeted cells. The affected cells then lose the ability to reproduce, which causes tumors to shrink.

Stereotactic radiosurgery of the brain and spine is typically completed in a single session. Body radiosurgery (SBRT) is used to treat lung, liver, adrenal and other soft tissue tumors, & treatment typically involves multiple (3-5) sessions.



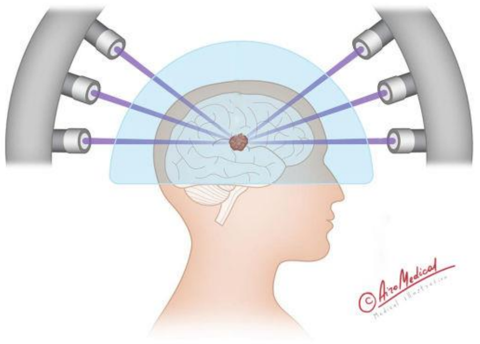
Equipment

•**Linear accelerator** (LINAC) machines use X-rays (photons) to treat cancerous and noncancerous abnormalities in the brain and other parts of the body.
LINACs are also known by the brand name of the manufacturer, such as **CyberKnife** TrueBeam and Versa HD. These machines can perform stereotactic radiosurgery (SRS) in a single session or 3-5 sessions for larger tumors, which is called fractionated stereotactic radiotherapy.

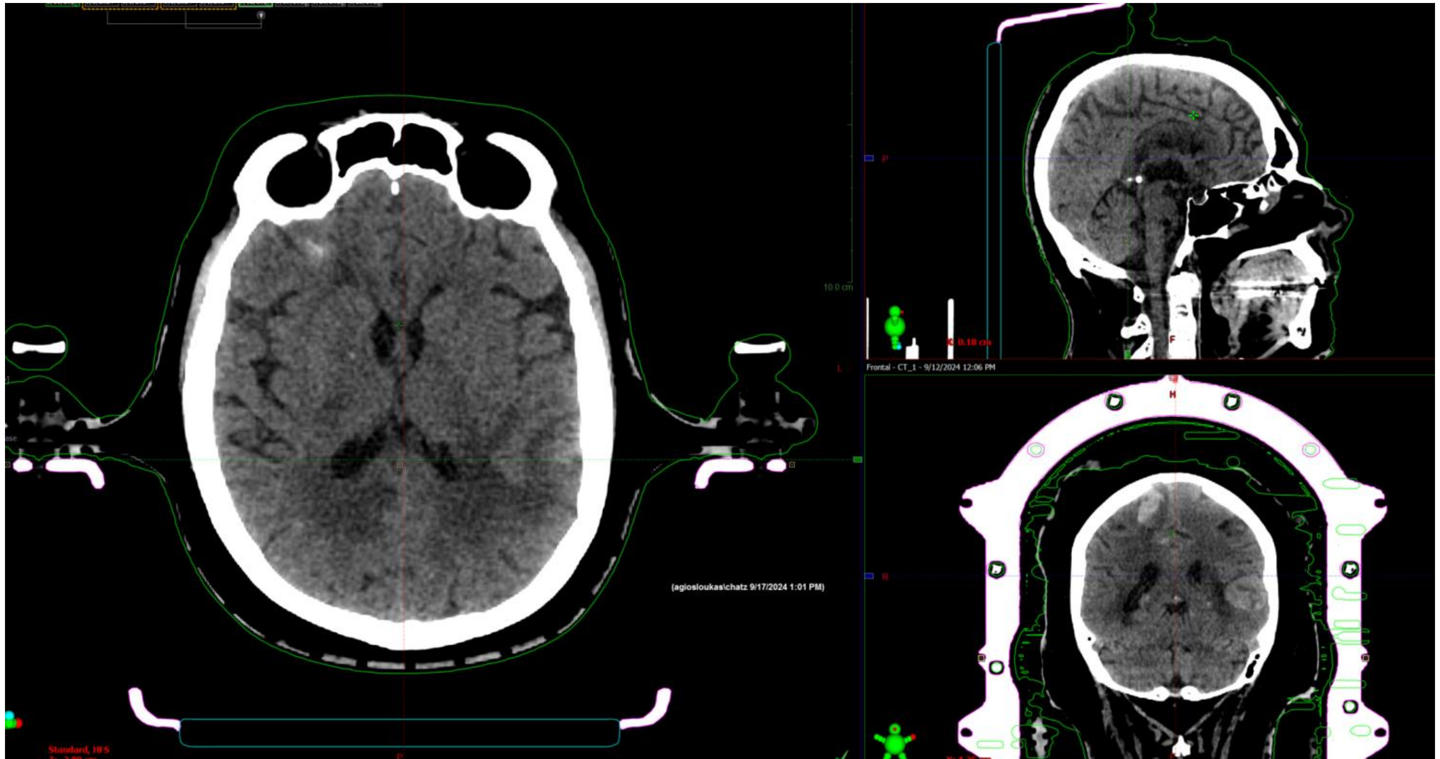
•**Gamma Knife** machines use 192 or 201 small beams of gamma rays to target and treat and are less common than LINACs . They are used primarily for small to medium tumors and lesions in the brain associated with a variety of conditions.

•**Proton beam therapy** is the newest type of stereotactic radiosurgery and is available in only a few centers, although the number of centers offering proton beam therapy has greatly increased in the last few years. Proton beam therapy can treat brain cancers in a single session using stereotactic radiosurgery, or it can use fractionated stereotactic body radiotherapy.

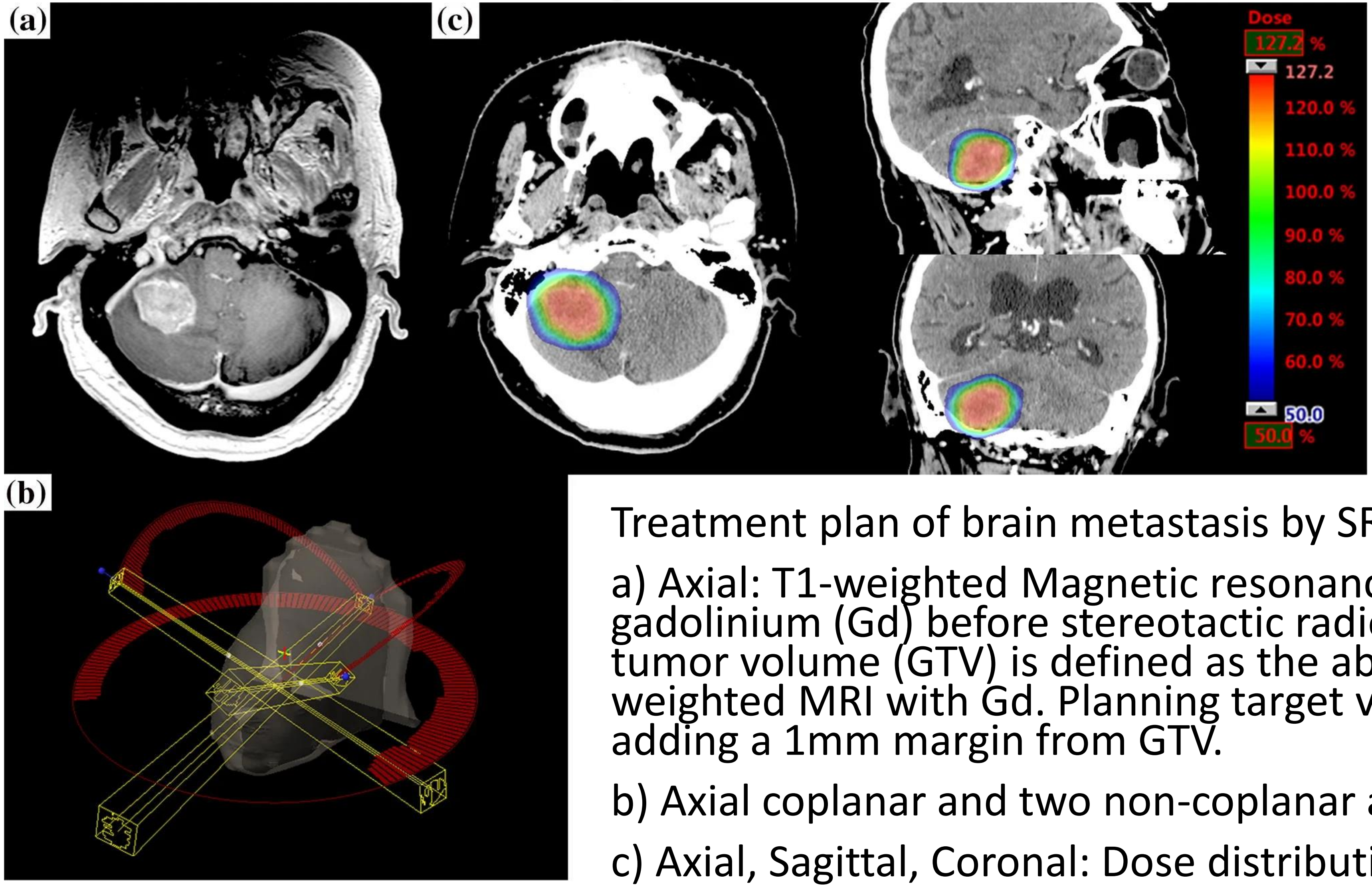
Equipment



Immobilization System



MRI series for Target Delineation



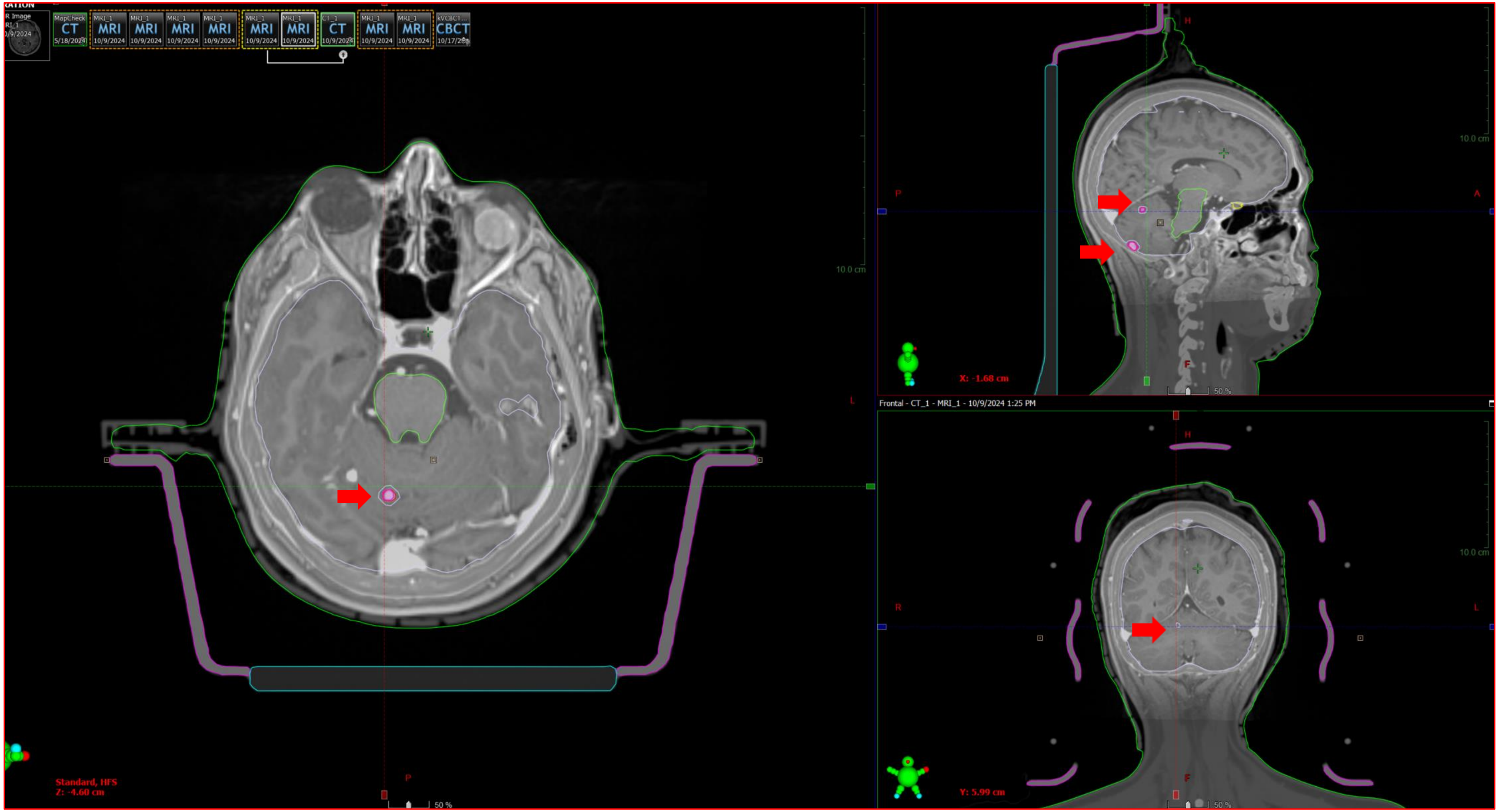
Treatment plan of brain metastasis by SRS

a) Axial: T1-weighted Magnetic resonance imaging (MRI) with gadolinium (Gd) before stereotactic radiotherapy (SRT). Gross tumor volume (GTV) is defined as the abnormality on the T1-weighted MRI with Gd. Planning target volume is generated by adding a 1mm margin from GTV.

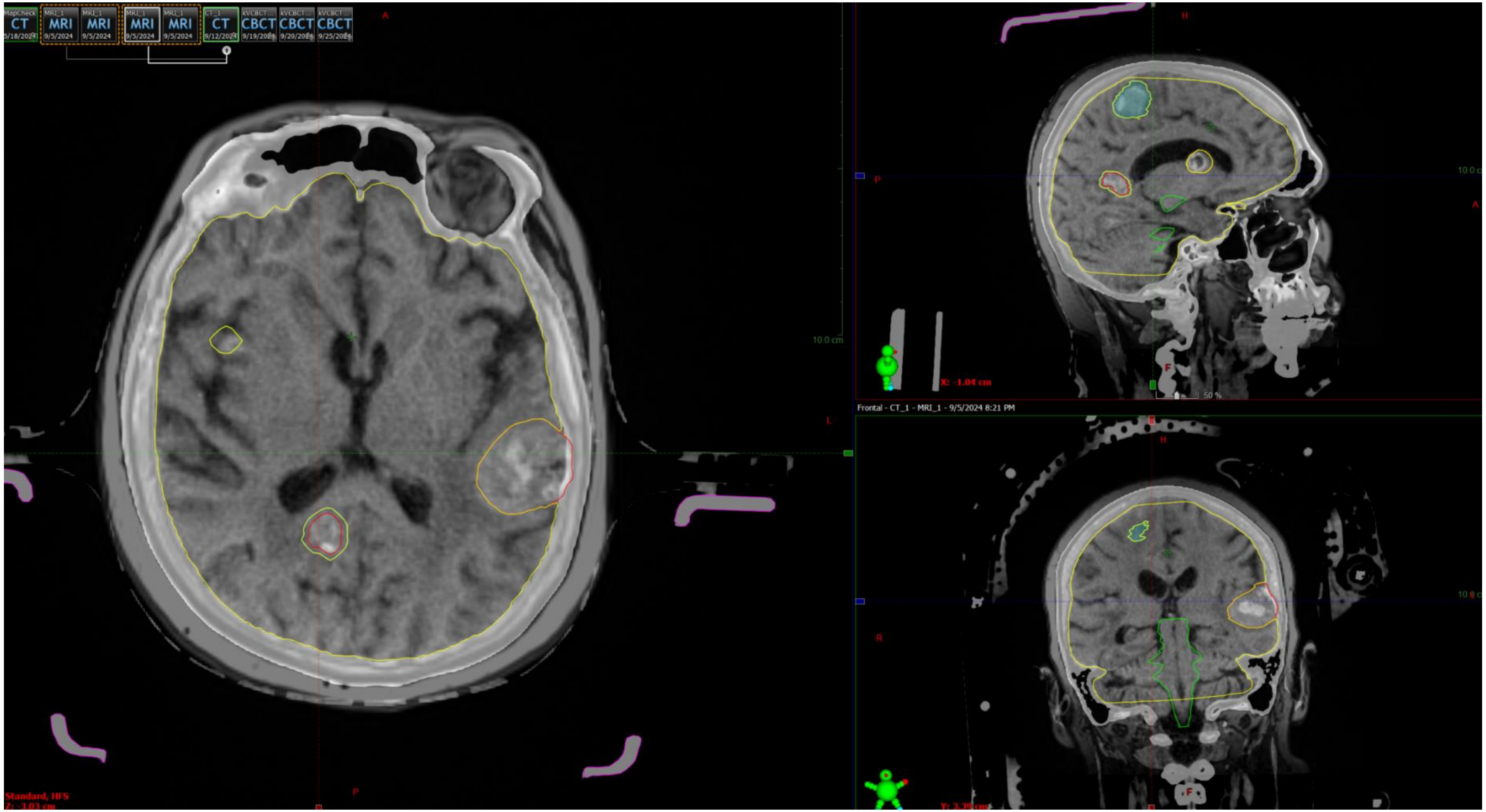
b) Axial coplanar and two non-coplanar arcs of VMAT.

c) Axial, Sagittal, Coronal: Dose distribution of SRT using VMAT

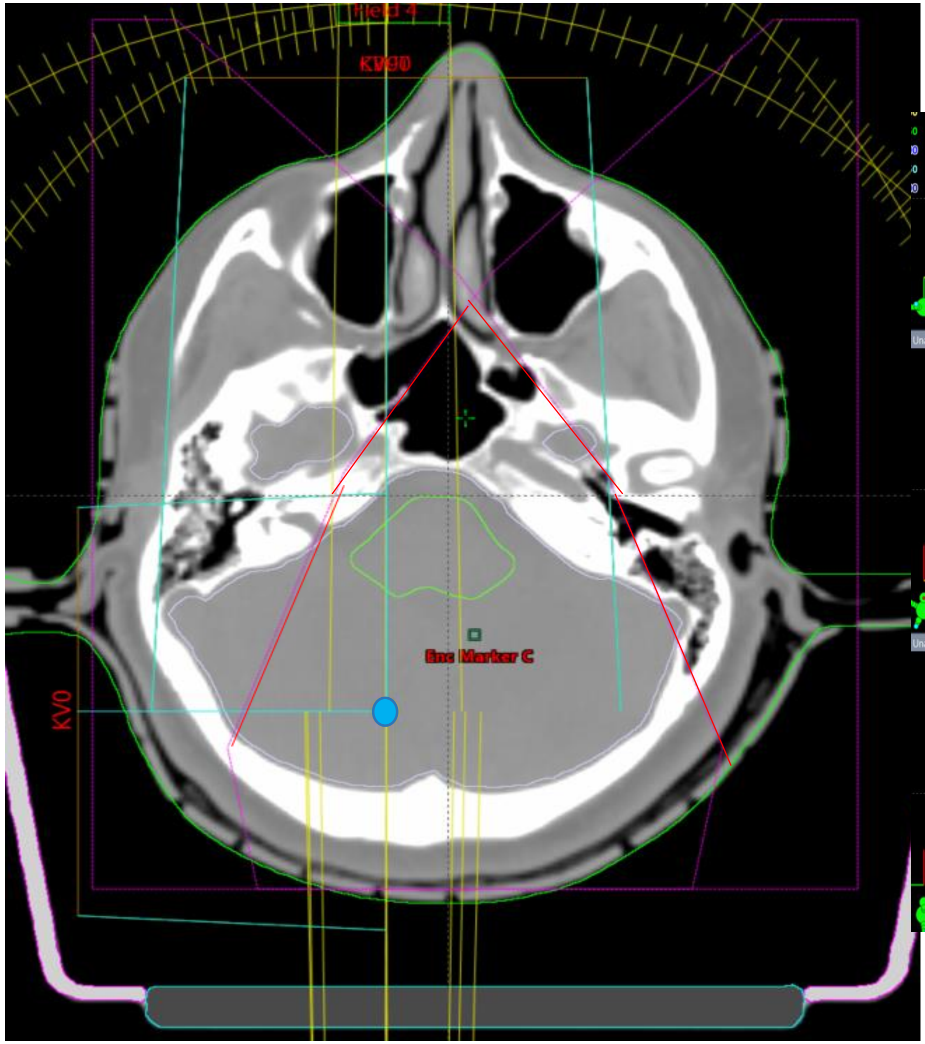
MRI series for Target Delineation

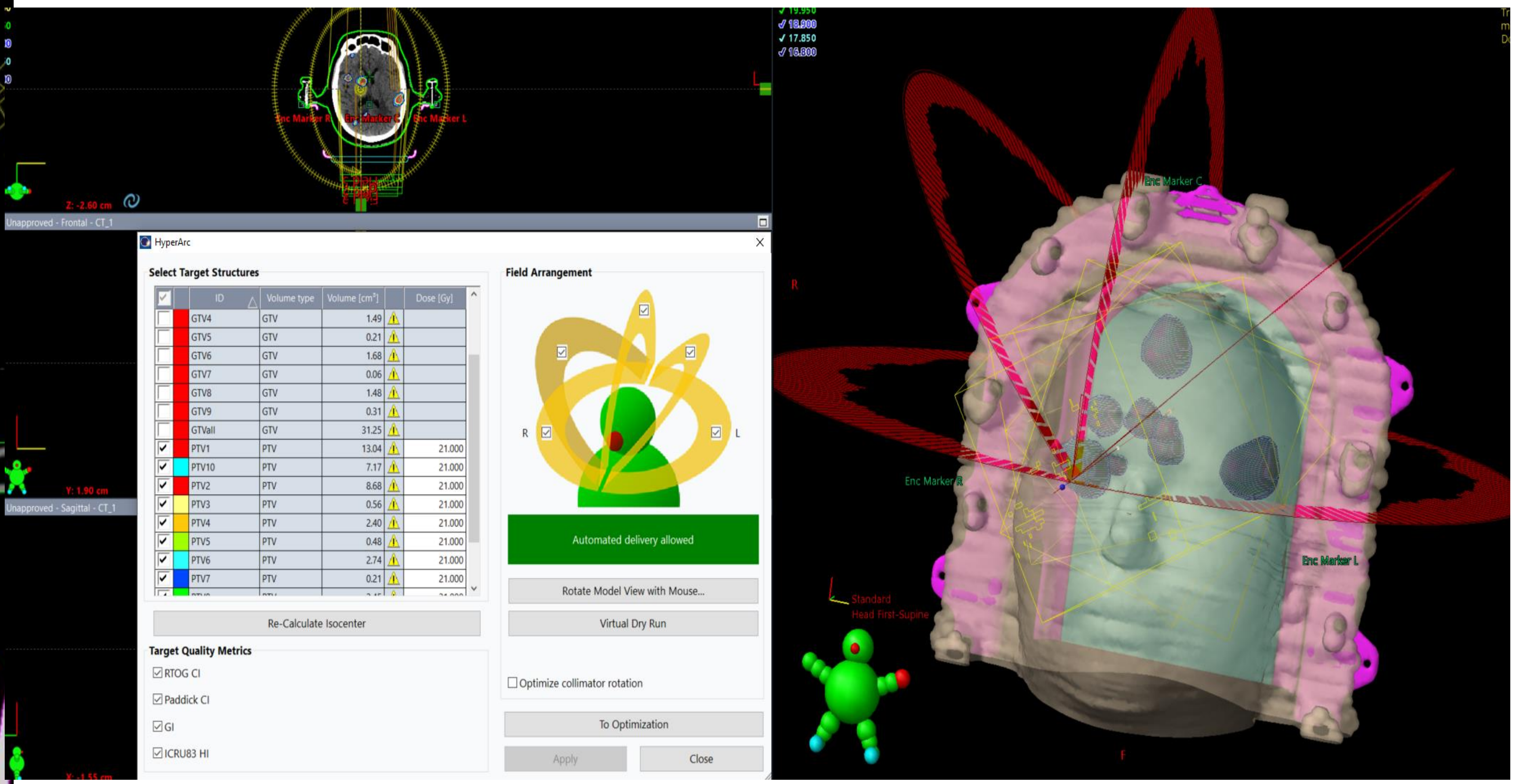


MRI registration with CT Simulation

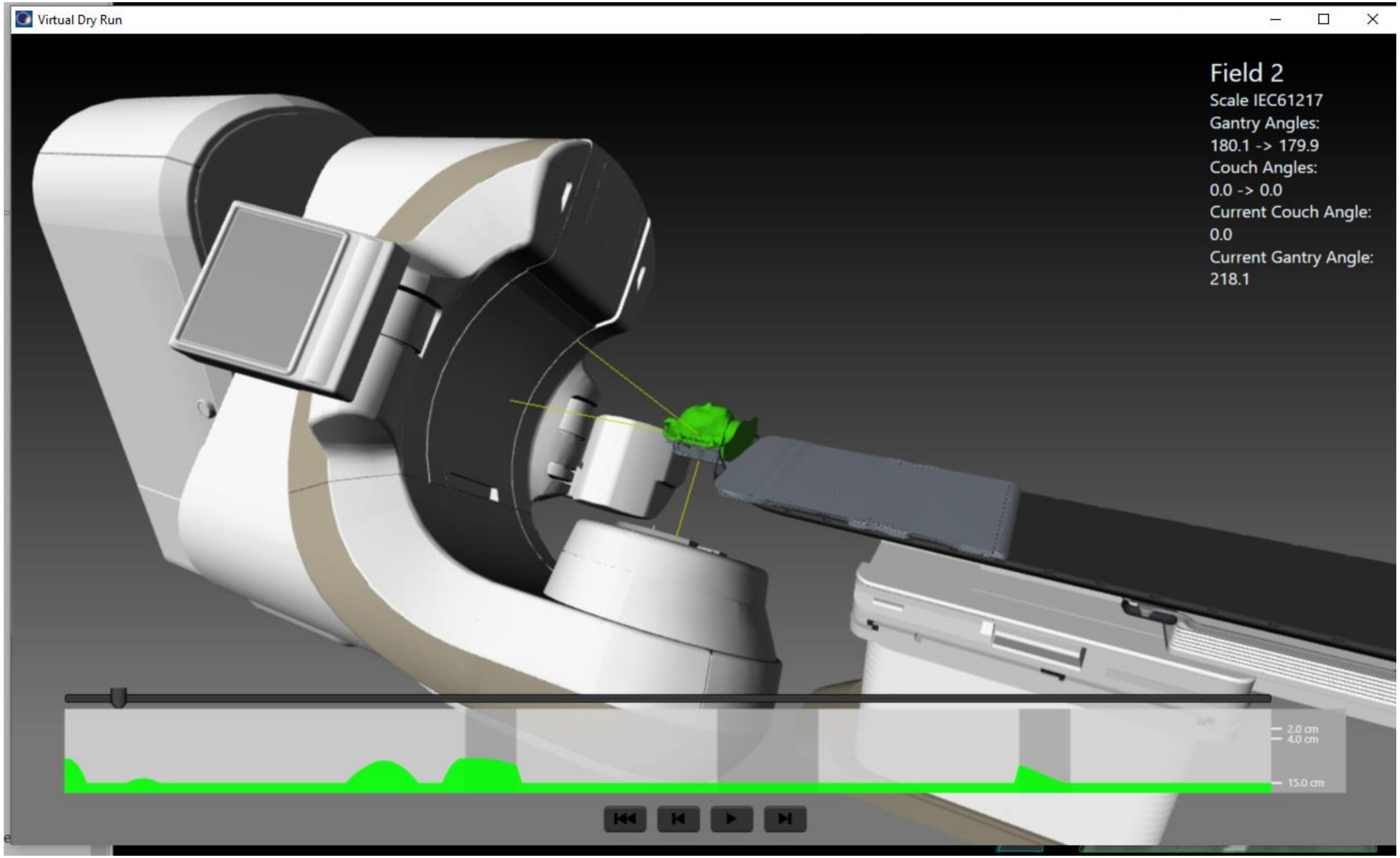


Isocenter and Field Selection

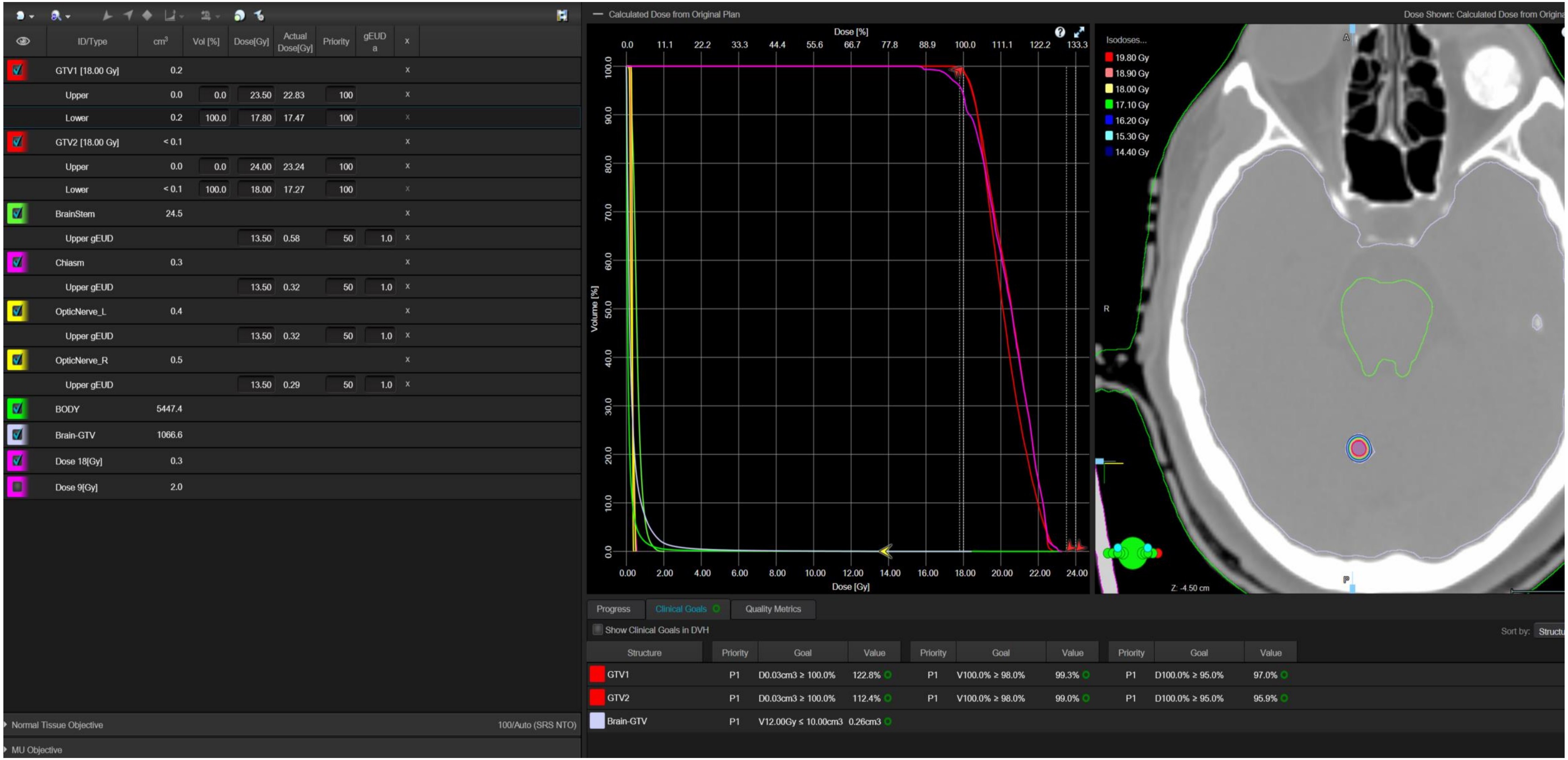




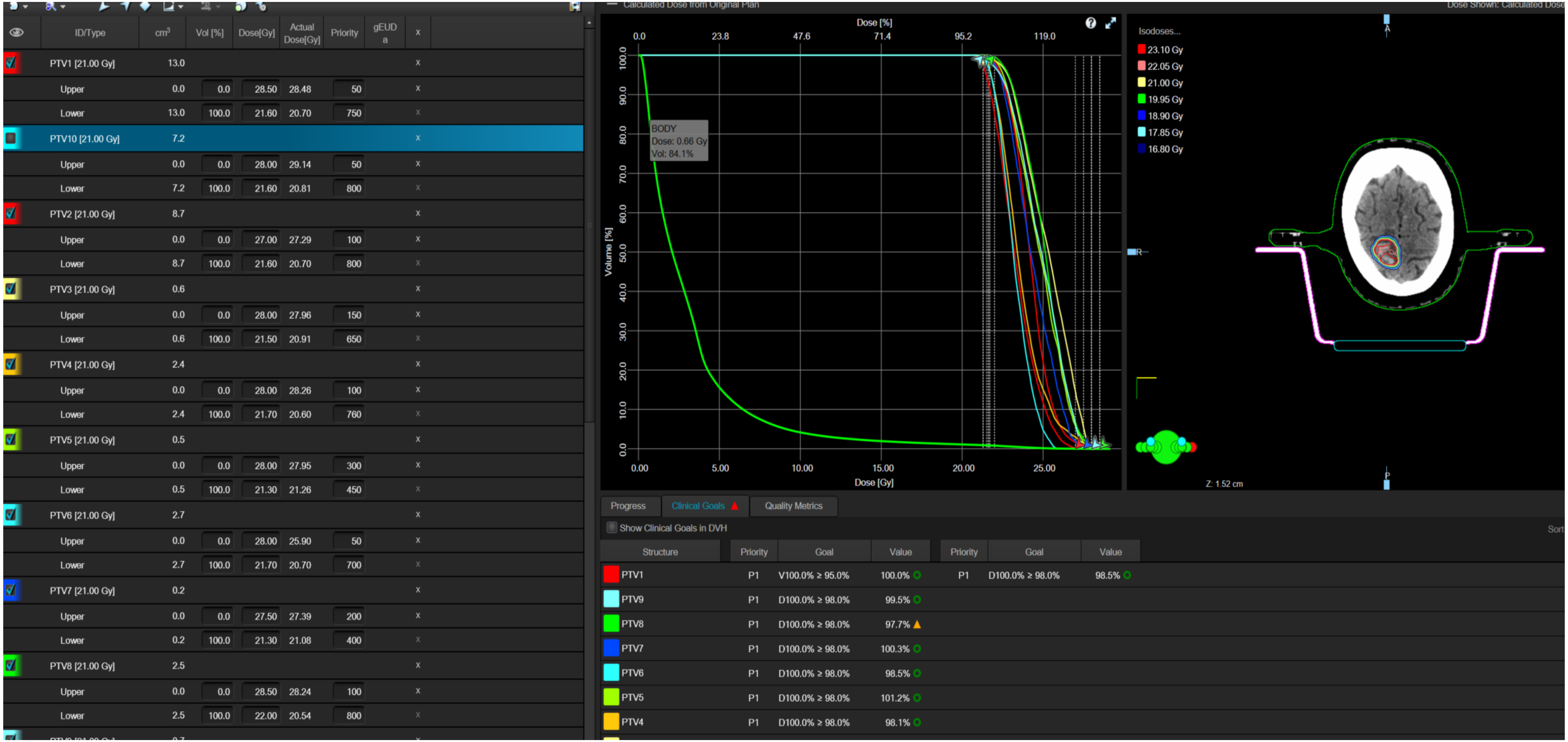
Virtual Dry Run



Optimization Objectives



Optimization Objectives



ID/Type	cm³	Vol [%]	Dose[Gy]	Actual Dose[Gy]	Priority	gEUD a	x
PTV1 [21.00 Gy]	13.0						x
Upper	0.0	0.0	28.50	28.48	50		x
Lower	13.0	100.0	21.60	20.70	750		x
PTV10 [21.00 Gy]	7.2						x
Upper	0.0	0.0	28.00	29.14	50		x
Lower	7.2	100.0	21.60	20.81	800		x
PTV2 [21.00 Gy]	8.7						x
Upper	0.0	0.0	27.00	27.29	100		x
Lower	8.7	100.0	21.60	20.70	800		x
PTV3 [21.00 Gy]	0.6						x
Upper	0.0	0.0	28.00	27.96	150		x
Lower	0.6	100.0	21.50	20.91	650		x
PTV4 [21.00 Gy]	2.4						x
Upper	0.0	0.0	28.00	28.26	100		x
Lower	2.4	100.0	21.70	20.60	760		x
PTV5 [21.00 Gy]	0.5						x
Upper	0.0	0.0	28.00	27.95	300		x
Lower	0.5	100.0	21.30	21.26	450		x
PTV6 [21.00 Gy]	2.7						x
Upper	0.0	0.0	28.00	25.90	50		x
Lower	2.7	100.0	21.70	20.70	700		x
PTV7 [21.00 Gy]	0.2						x
Upper	0.0	0.0	27.50	27.39	200		x
Lower	0.2	100.0	21.30	21.08	400		x
PTV8 [21.00 Gy]	2.5						x
Upper	0.0	0.0	28.50	28.24	100		x
Lower	2.5	100.0	22.00	20.54	800		x

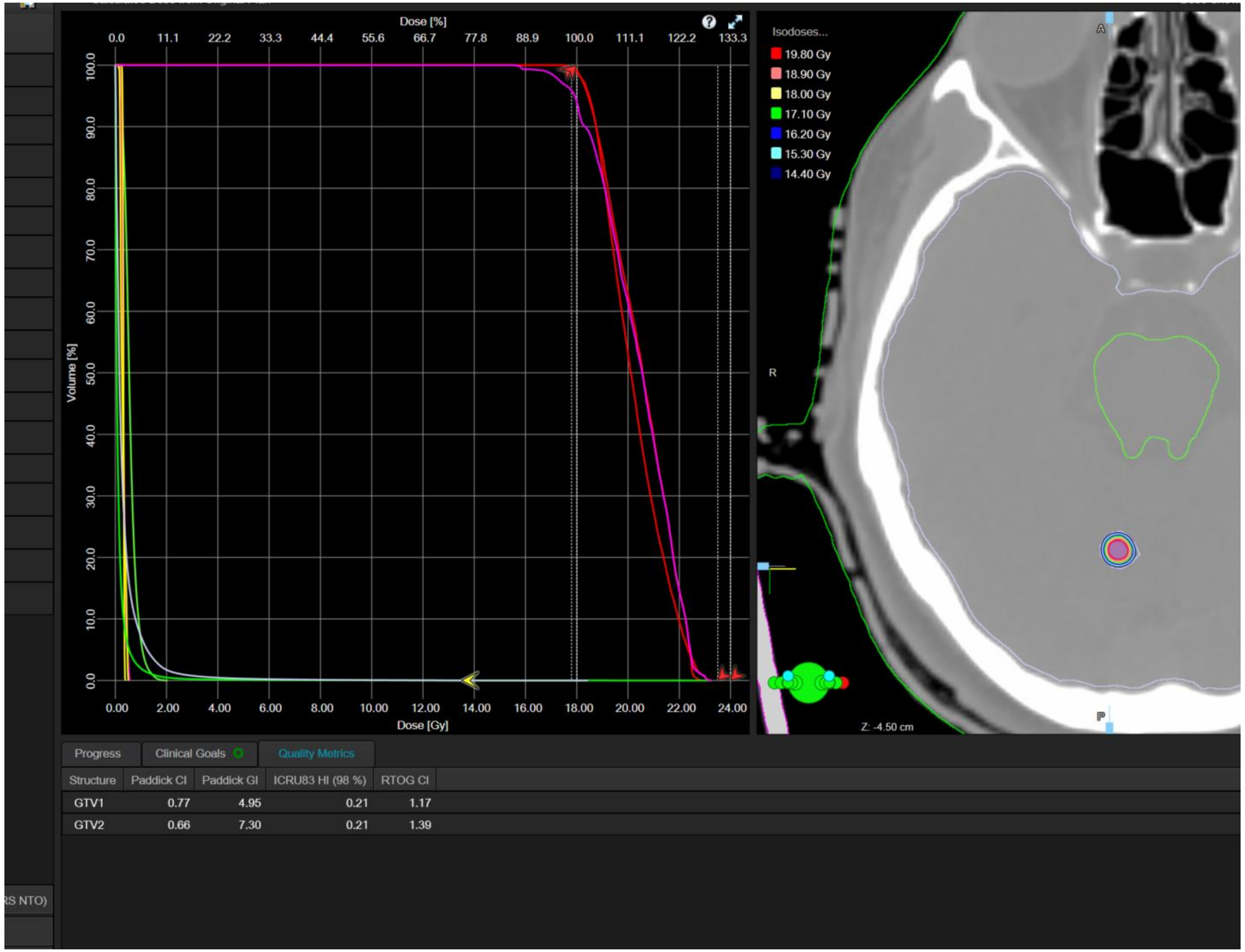
Structure	Priority	Goal	Value	Priority	Goal	Value
PTV1	P1	V100.0% ≥ 95.0%	100.0%	P1	D100.0% ≥ 98.0%	98.5%
PTV9	P1	D100.0% ≥ 98.0%	99.5%			
PTV8	P1	D100.0% ≥ 98.0%	97.7%			
PTV7	P1	D100.0% ≥ 98.0%	100.3%			
PTV6	P1	D100.0% ≥ 98.0%	98.5%			
PTV5	P1	D100.0% ≥ 98.0%	101.2%			
PTV4	P1	D100.0% ≥ 98.0%	98.1%			

Quality Metrics

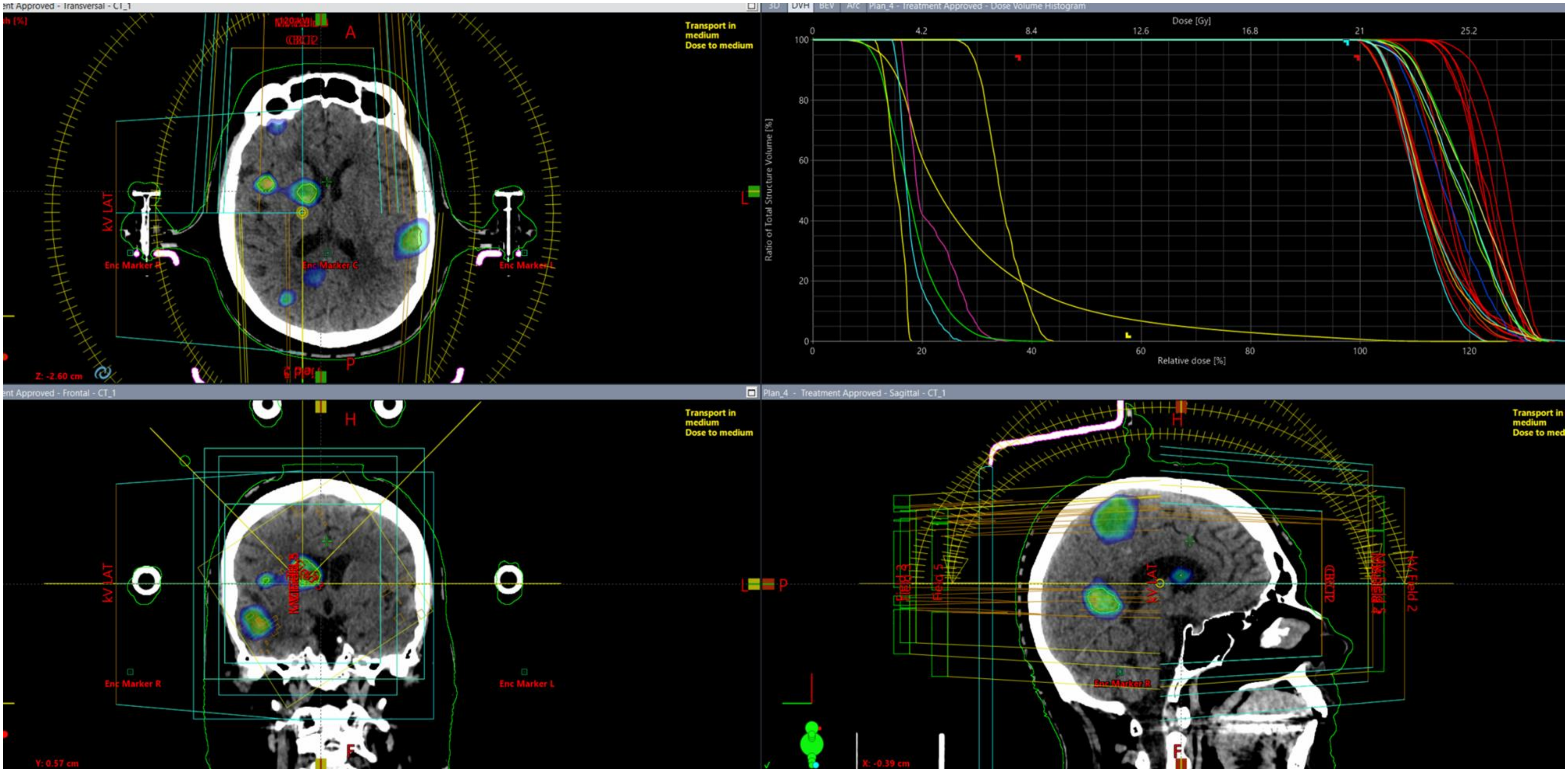
Conformity Index is an important metric for determining how tightly the prescription dose is conforming to the target. Defined as **CI = TV/ PTV** where ***TV*** is the treated volume enclosed by a given isodose surface (e.g. 100%, 80%) and ***PTV*** is the planning target volume.

Paddick Conformity Index:
$PCI = (TV_{PIV})^2/TV*PIV$ where TV_{PIV} is the target volume covered by the prescription isodose volume, ***TV*** is the Target Volume, and ***PIV*** is the prescription isodose volume.

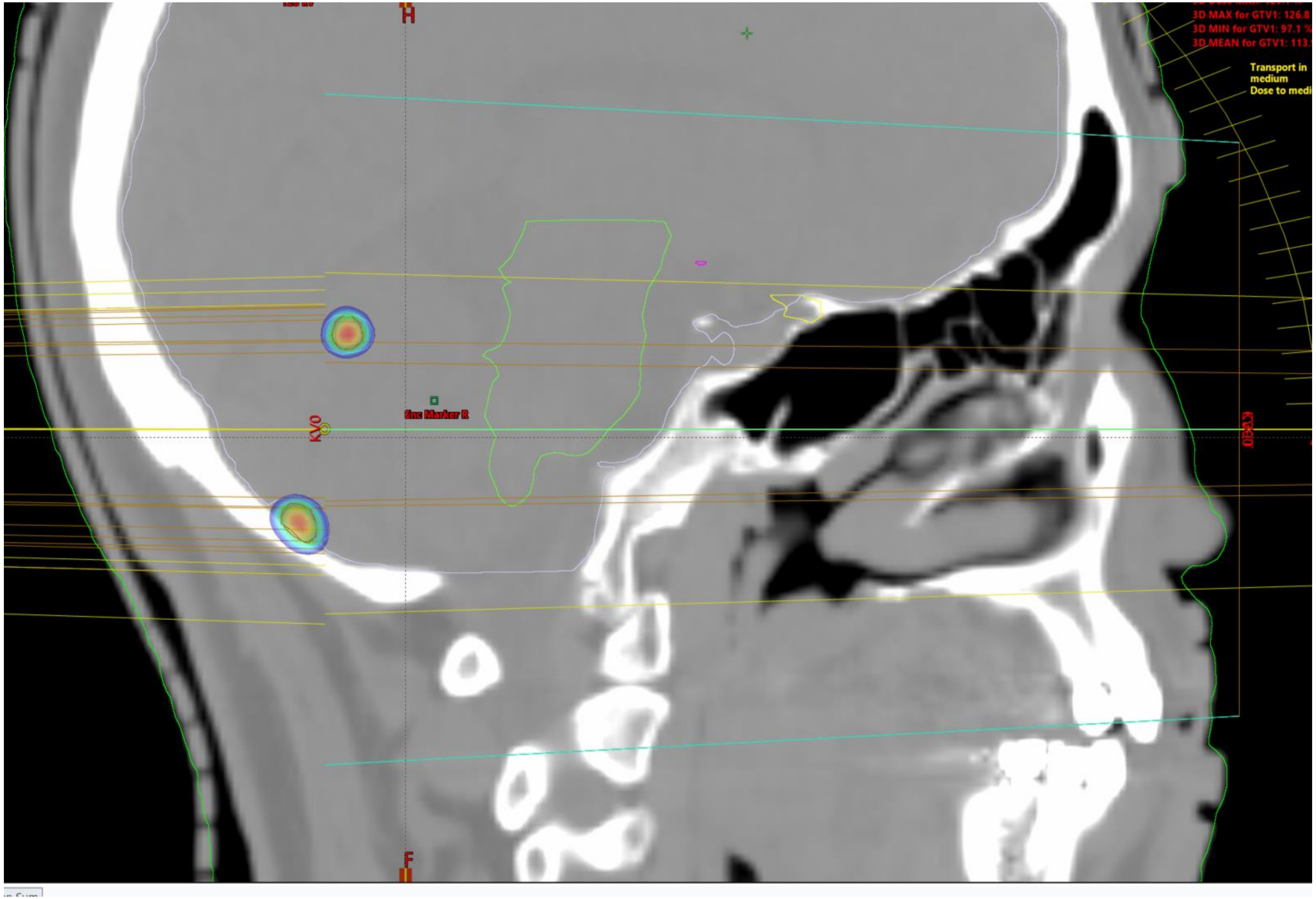
Gradient Index: $GI = PIV_{half} / PIV$
where PIV_{half} is the prescription isodose volume, at half the prescription isodose and ***PIV*** is the prescription isodose volume.



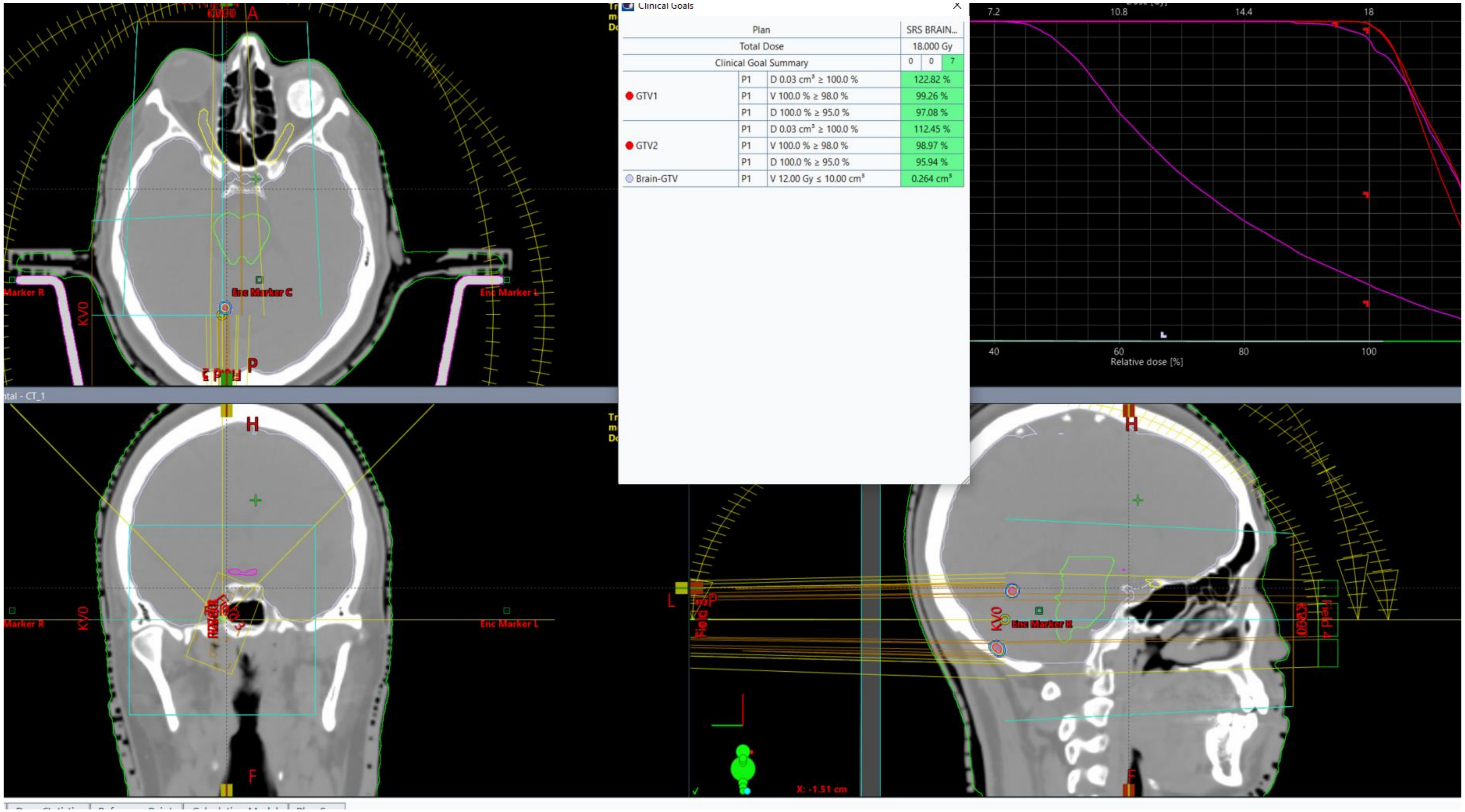
Dose Calculation



Dose Calculation



Normalization and Evaluation



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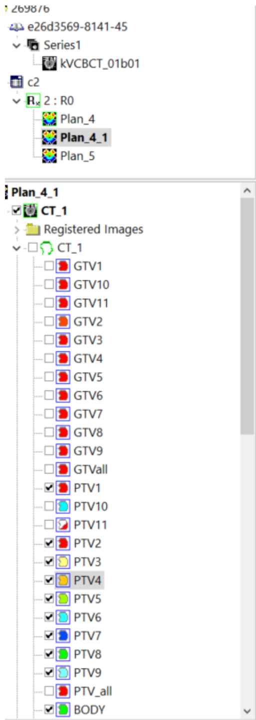
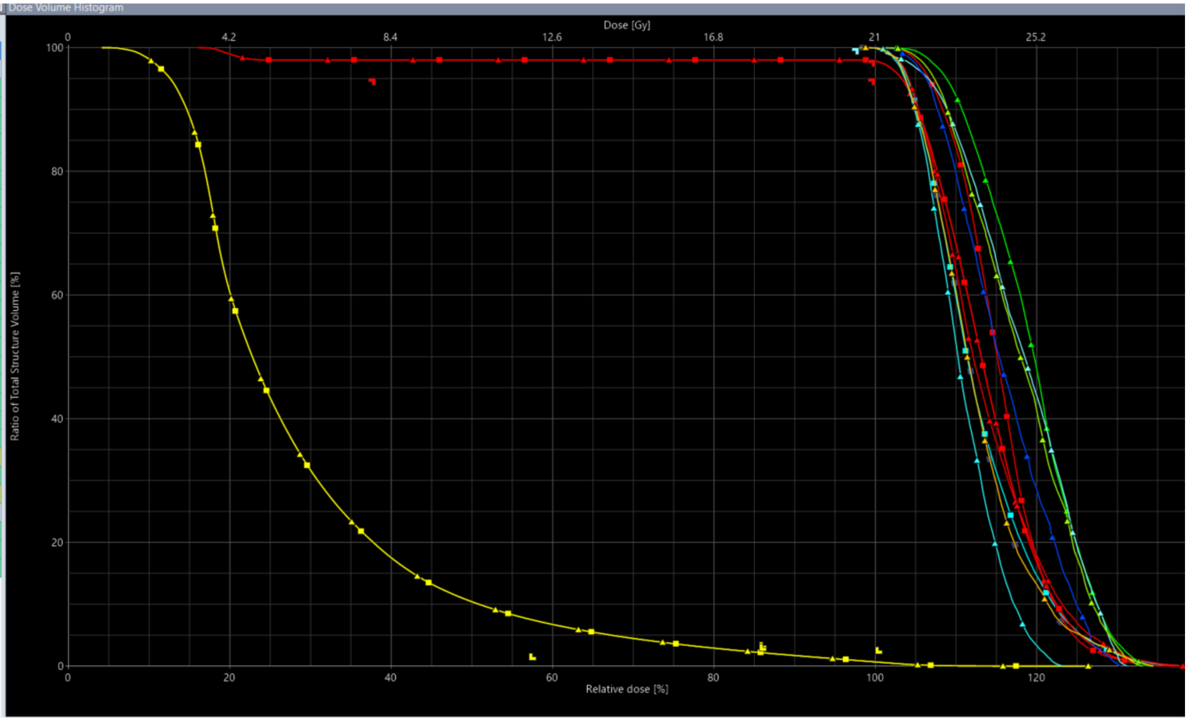


Overview

Clinical goals: All Plans ☐ Evaluate Goals for All Plans

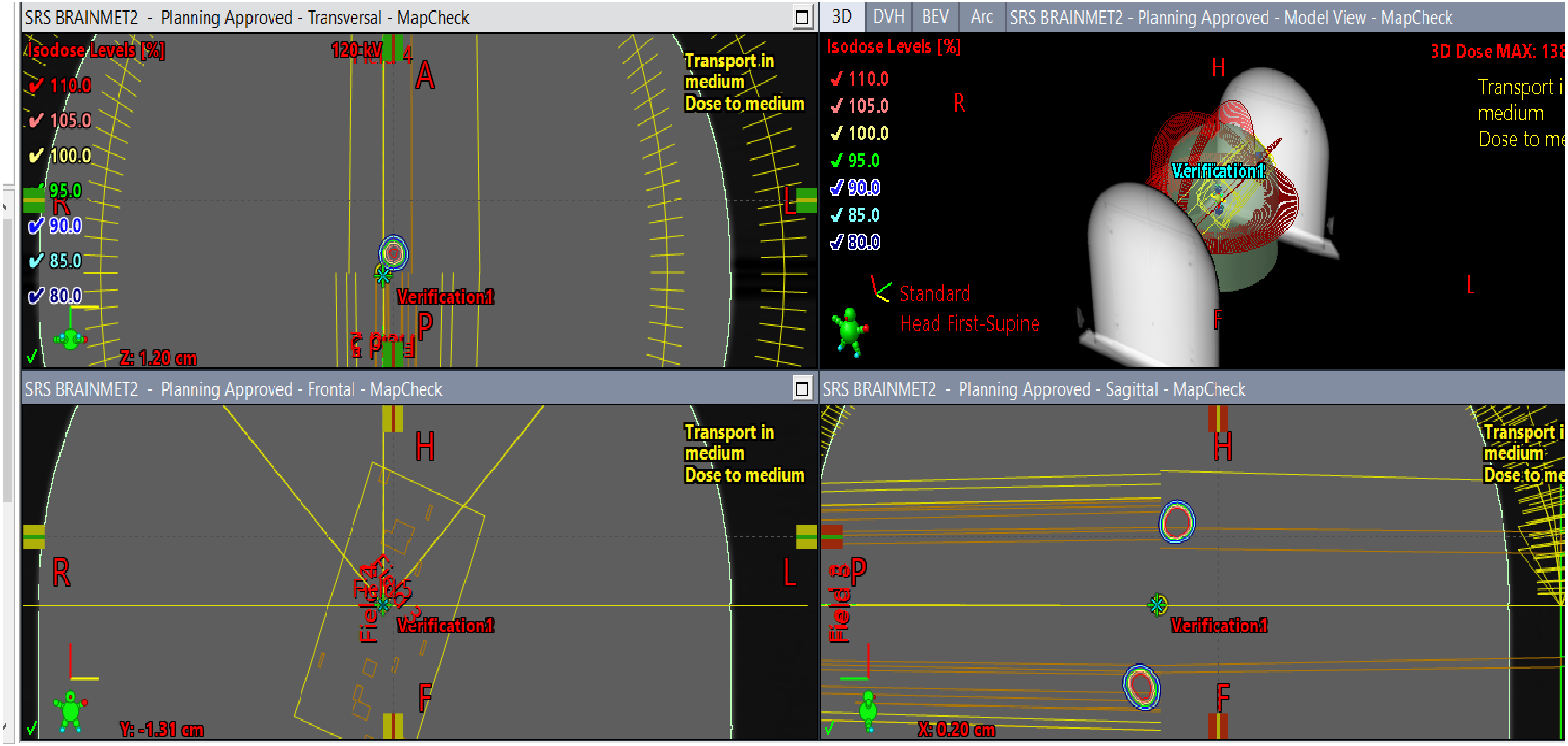
Plan			■ Plan_4	▲ Plan_4_1
Total Dose			21.000 Gy	21.000 Gy
Clinical Goal Summary			1 / 1 / 20	0 / 2 / 23
GTV1	P1	V 8.00 Gy ≥ 95.0 %	100.00 %	100.00 %
GTV10	**P1**	**V 8.00 Gy ≥ 95.0 %**	100.00 %	100.00 %
GTV2	P1	V 8.00 Gy ≥ 95.0 %	100.00 %	100.00 %
GTV3	P1	V 8.00 Gy ≥ 95.0 %	100.00 %	100.00 %
GTV4	P1	V 8.00 Gy ≥ 95.0 %	100.00 %	100.00 %
GTV5	P1	V 8.00 Gy ≥ 95.0 %	100.00 %	100.00 %
GTV6	P1	V 8.00 Gy ≥ 95.0 %	100.00 %	100.00 %
GTV7	P1	V 8.00 Gy ≥ 95.0 %	100.00 %	100.00 %
GTV8	P1	V 8.00 Gy ≥ 95.0 %	100.00 %	100.00 %
GTV9	P1	V 8.00 Gy ≥ 95.0 %	100.00 %	100.00 %
PTV1	P1	V 100.0 % ≥ 95.0 %	99.97 %	99.97 %
	P1	D 100.0 % ≥ 98.0 %	98.59 %	98.59 %
PTV10	P1	D 100.0 % ≥ 98.0 %	99.09 %	99.09 %
PTV2	P1	D 100.0 % ≥ 98.0 %	98.58 %	98.58 %
PTV3	P1	D 100.0 % ≥ 98.0 %	99.58 %	99.58 %
PTV4	P1	D 100.0 % ≥ 98.0 %	98.10 %	98.10 %
PTV5	P1	D 100.0 % ≥ 98.0 %	101.25 %	101.25 %
PTV6	P1	D 100.0 % ≥ 98.0 %	98.58 %	98.58 %
PTV7	P1	D 100.0 % ≥ 98.0 %	100.37 %	100.37 %
PTV8	P1	D 100.0 % ≥ 98.0 %	97.80 %	97.80 %
PTV9	P1	D 100.0 % ≥ 98.0 %	99.54 %	99.54 %
PTV_all	P1	V 100.0 % ≥ 98.0 %		97.86 %
Brain-PTVall	P1	V 12.00 Gy ≤ 10.00 cm³	83.694 cm³	
	P1	D 30.00 cm³ ≤ 18.00 Gy		17.10 Gy
	P1	V 21.00 Gy < 21.00 cm³		7.501 cm³
	P1	V 18.00 Gy ≤ 26.00 cm³		24.252 cm³



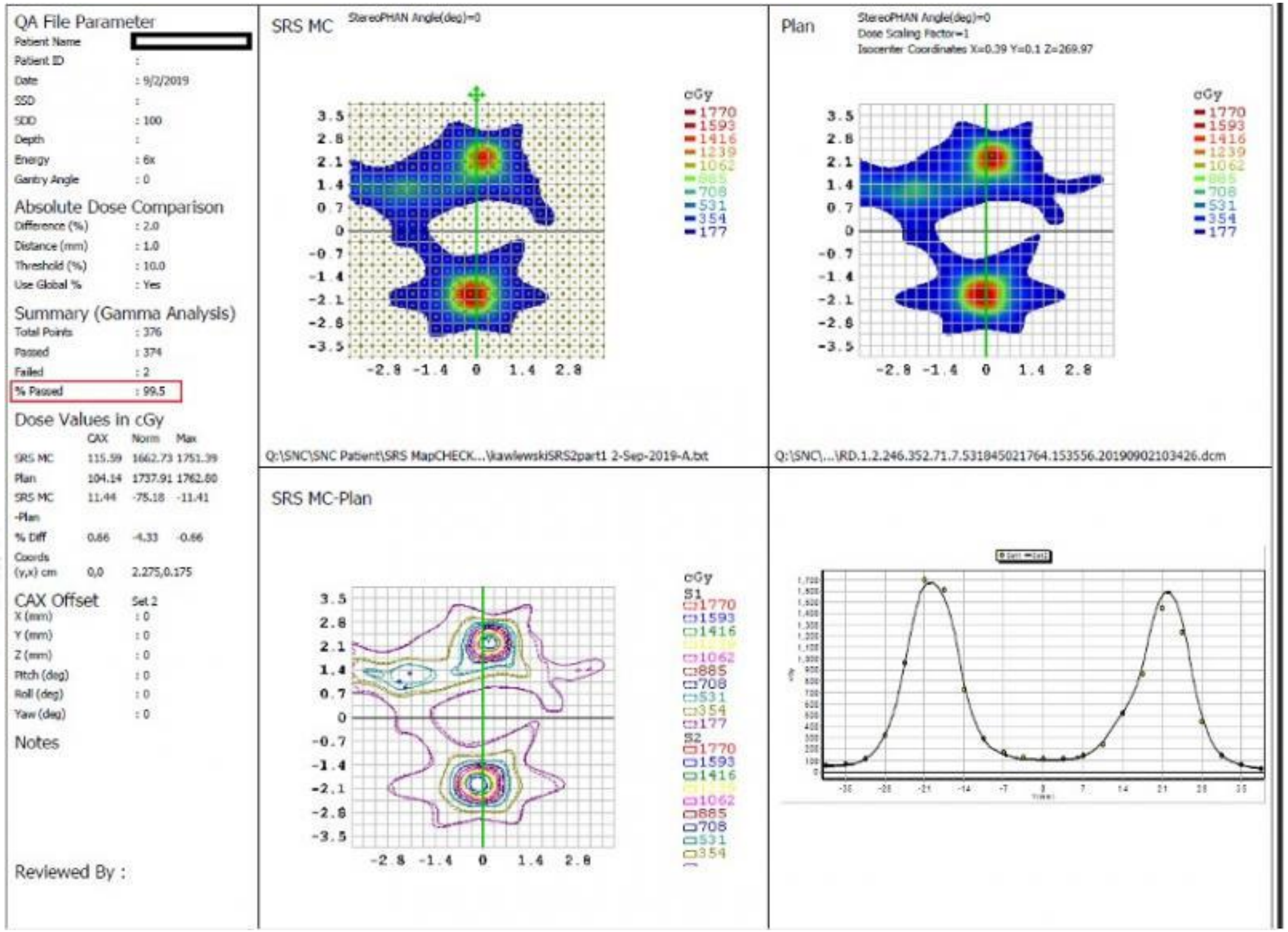
Fields | Dose | Reference Points | **Dose Statistics**

Structure	Approval Status	Plan	Course	Volume [cm³]	Dose Cover.[%]	Sampling Cover.[%]	Min Dose [%]	Max Dose [%]	Mean Dose [%]	Dose Level [Gy]	RTOG CI	Paddick CI	GI	ICRU83 HI
GTV9	Approved	Plan_4_1	c2	0.3	100.0	95.9	111.0	131.3	124.0	N/A	N/A	N/A	N/A	N/A
GTVall	Approved	Plan_4_1	c2											
PTV1	Approved	Plan_4_1	c2	13.0	100.0	100.1	98.6	135.6	115.3	21.000	1.24	0.80	3.21	0.20
PTV10	Approved	Plan_4_1	c2	7.2	100.0	100.1	99.1	138.8	112.7	21.000	1.34	0.74	3.80	0.24
PTV2	Approved	Plan_4_1	c2	8.7	100.0	100.2	98.6	130.0	111.2	21.000	1.25	0.78	6.86	0.21
PTV3	Approved	Plan_4_1	c2	0.6	100.0	100.3	99.6	133.2	120.2	21.000	1.53	0.62	4.96	0.21
PTV4	Approved	Plan_4_1	c2	2.4	100.0	100.3	98.1	134.6	112.5	21.000	1.37	0.72	23.10	0.24
PTV5	Approved	Plan_4_1	c2	0.5	100.0	99.9	101.3	133.1	118.0	21.000	1.49	0.62	110.98	0.21
PTV6	Approved	Plan_4_1	c2	2.7	100.0	100.3	98.6	123.4	110.7	21.000	1.40	0.70	5.86	0.17
PTV7	Approved	Plan_4_1	c2	0.2	100.0	98.7	100.4	130.4	115.9	21.000	1.66	0.54	67.28	0.20
PTV8	Approved	Plan_4_1	c2	2.5	100.0	100.2	97.8	134.5	119.3	21.000	1.47	0.67	21.17	0.20
PTV9	Approved	Plan_4_1	c2	0.7	100.0	100.6	99.5	131.3	118.2	21.000	1.59	0.60	4.96	0.22
PTV_all	Approved	Plan_4_1	c2	39.2	100.0	100.1	16.2	138.8	111.9	N/A	N/A	N/A	N/A	N/A
BODY	Approved	Plan_4_1	c2	4923.5	100.0	100.2	0.0	138.8	14.7	N/A	N/A	N/A	N/A	N/A
Brain	Approved	Plan_4_1	c2											
Brain-PTVall	Approved	Plan_4_1	c2	1102.6	100.0	100.0	4.1	126.9	28.8	N/A	N/A	N/A	N/A	N/A
BrainStem	Approved	Plan_4_1	c2											
Chiasm	Approved	Plan_4_1	c2											

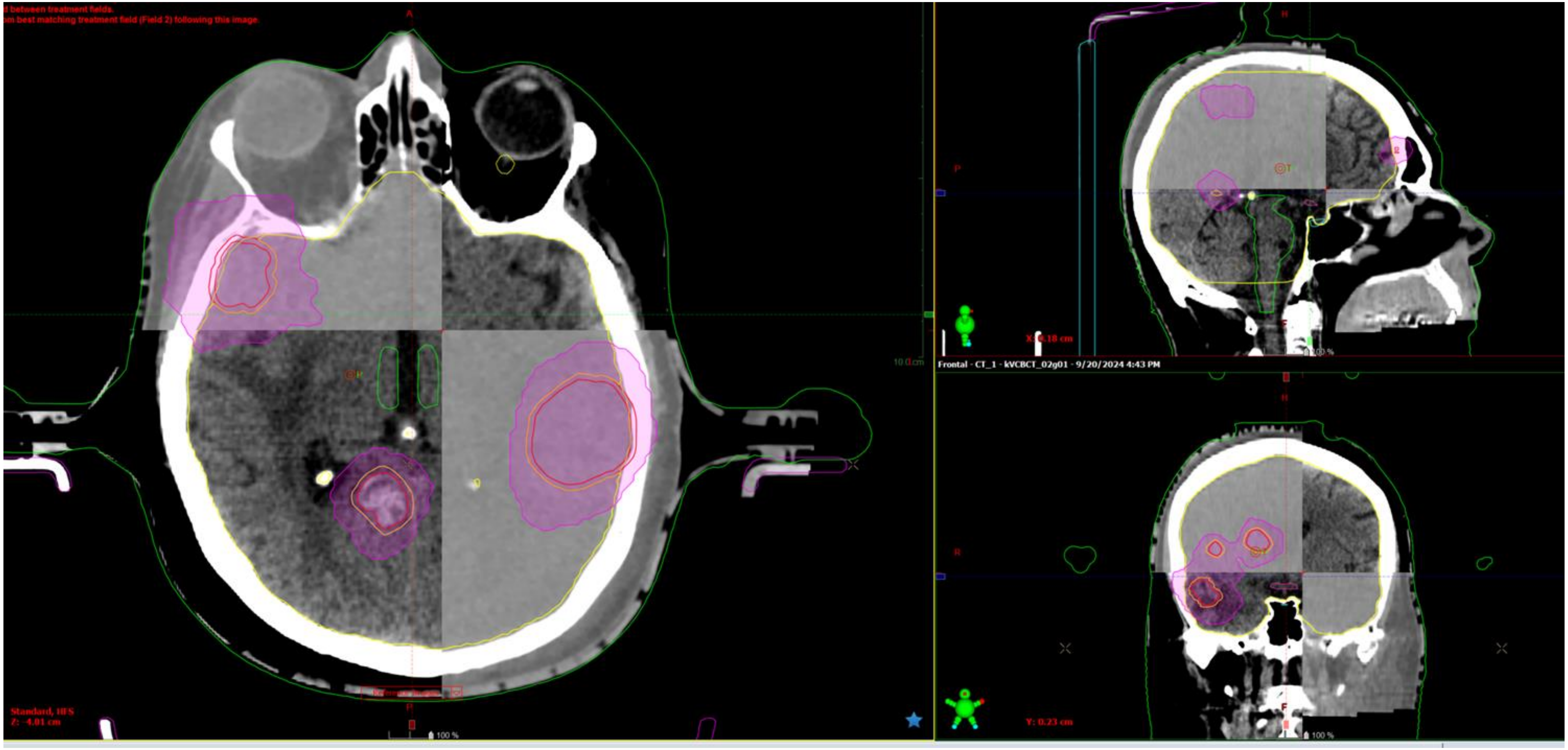
Patient Specific Quality Assurance



Patient Specific Quality Assurance



Treatment Delivery and Imaging



Treatment Delivery and Imaging

Machine Performance Checks

Use of IsoCal phantom

Built-in self-check tool

Among other things, they are checked:

- Coincidence of isocenter-Beam stability
- Coincidence of treatment & imaging isocenter
- Gantry rotation angle accuracy

Conclusion

Over the past 50y since Lars Leksell first utilized radiation to address deep and difficult to treat lesions of the central nervous system, intracranial SRS has become an increasingly valued tool for neurosurgeons and radiation oncologists.

Following developments in medical imaging, radiation technology and treatment planning, SRS has evolved from its first application in movement disorders to widespread use for a variety of malignant and benign conditions. SRS is a powerful, minimally invasive instrument that offers additional options for intervention to a diverse patient population.

The common indications for SRS, except brain metastases, are malignant gliomas, meningiomas, arteriovenous malformations vestibular schwannomas, pituitary adenomas, and functional disorders, as well as consider the future possibilities of combining radiosurgery with immunotherapy.

thank you