From Double Scattering to Pencil Beam Scanning, Clinical and Operational Summary

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Requirements for Ideal Proton Delivery Modality

- Cost:
- Initial purchase
- Operation (manpower)
- Maintenance

- Operation:
- Ease of planning, QA, delivery
- Efficiency

Requirements for Ideal Proton Delivery Modality

- Clinical:
- Good conformality for complex shaped targets
- Large fields
- Low dose to normal tissue proximal to the tumor
- IMPT
- Can be used for static and moving targets
- Small penumbra
- Low secondary neutrons

Clinical limitations of DS/US versus PBS Conformality

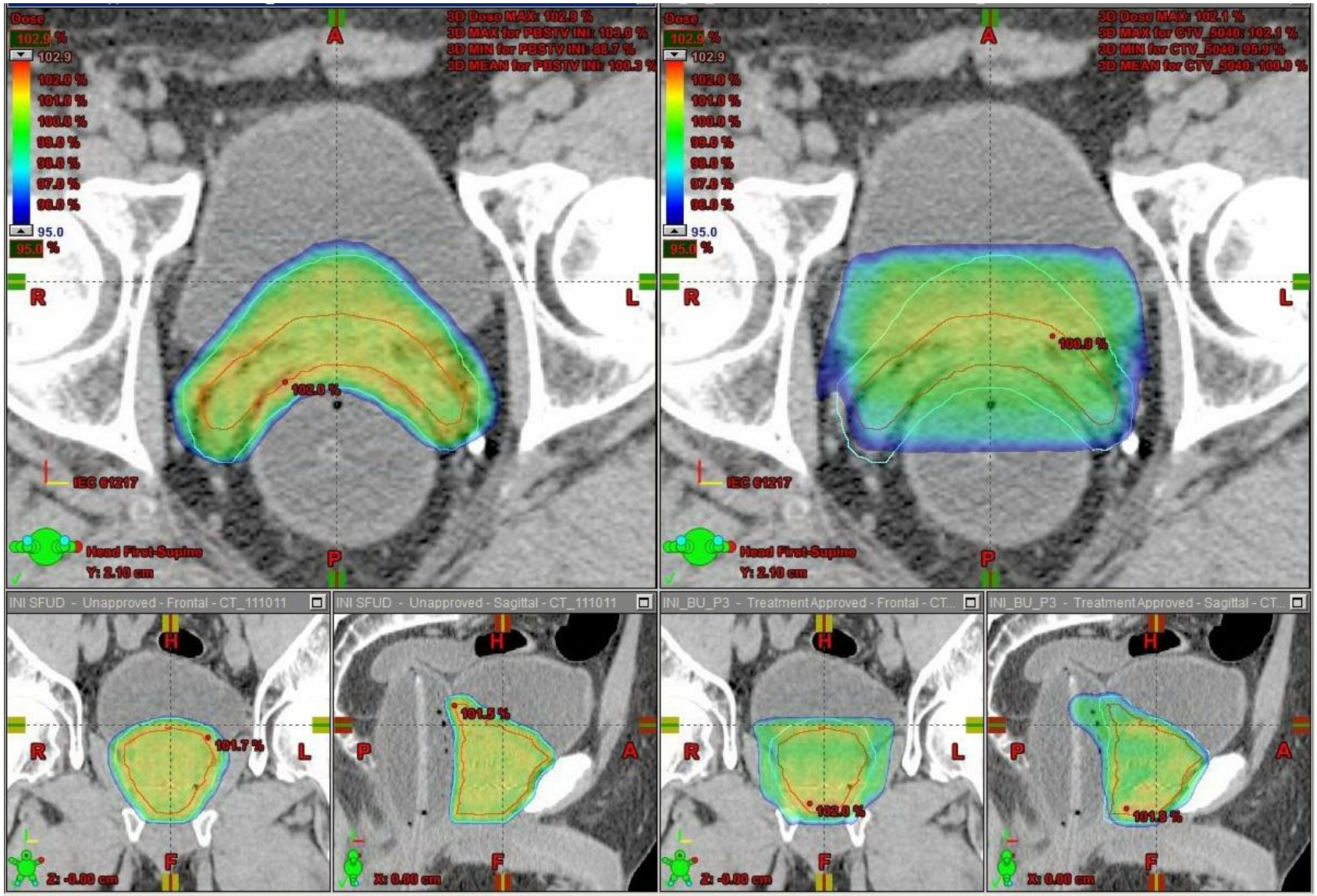
DS/ US

- Limited conformality- base of skull, spinal cord-need patching.
- Patching is problematic.

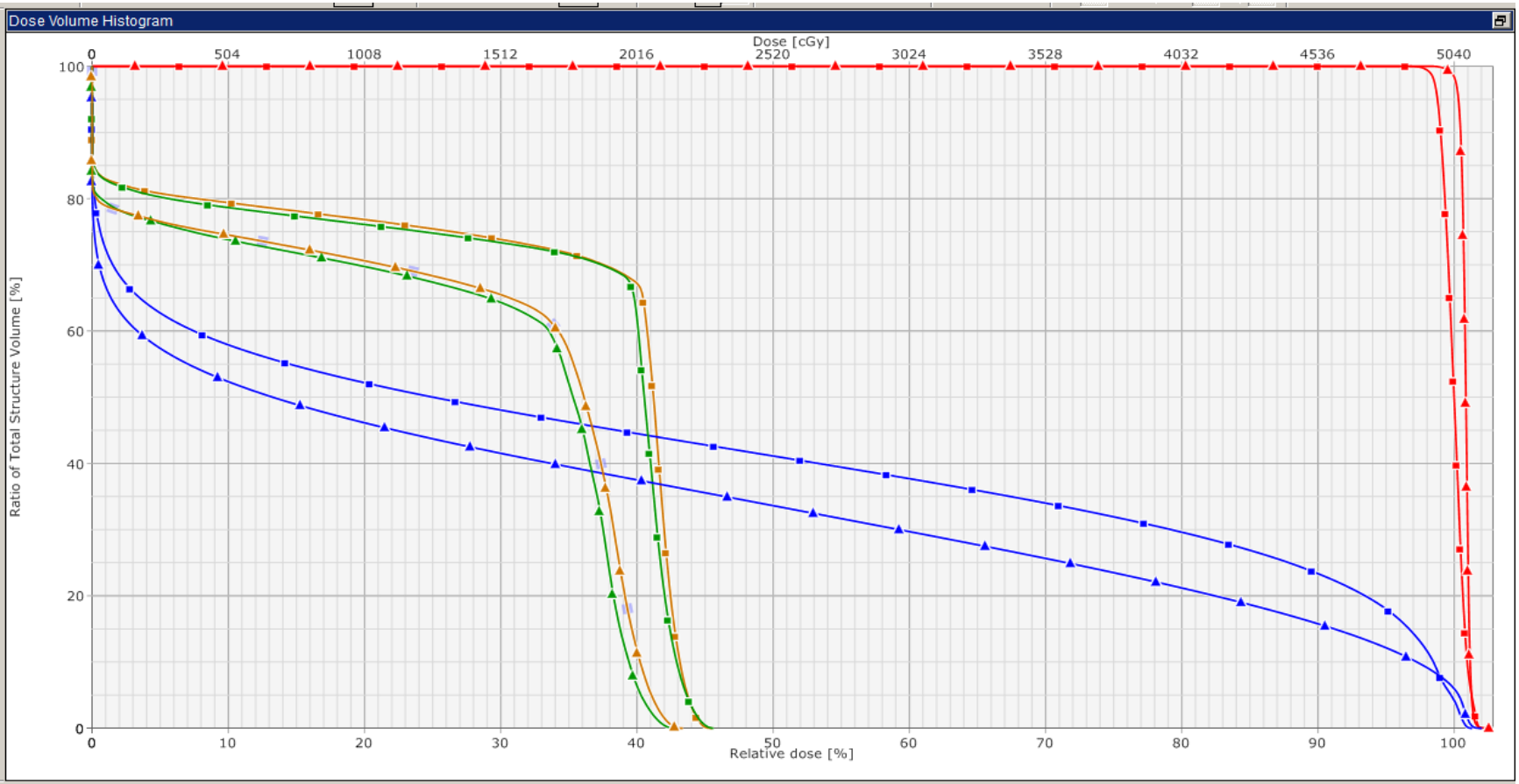
PBS

- Very good conformality
- No need for patching

PBS DS


Dose
102.9 %
102.9
102.0 %
101.0 %
100.0 %
99.0 %
98.0 %
97.0 %
96.0 %
95.0
95.0 %
3D Dose MAX: 102.0 %
3D MAX for PBSTV INI: 102.0 %
3D MIN for PBSTV INI: 88.7 %
3D MEAN for PBSTV INI: 100.2 %
3D Dose MAX: 102.1 %
3D MAX for CTV_5040: 102.1 %
3D MIN for CTV_5040: 95.9 %
3D MEAN for CTV_5040: 100.0 %
A
P
R
L
102.0 %
100.0 %
IEC 61217
Head First-Supine
Y: 2.10 cm
INI SFUD - Unapproved - Frontal - CT_111011
INI SFUD - Unapproved - Sagittal - CT_111011
INI_BU_P3 - Treatment Approved - Frontal - CT...
INI_BU_P3 - Treatment Approved - Sagittal - CT...
H
F
101.7 %
101.5 %
102.0 %
101.8 %
Z: -9.00 cm
X: 0.00 cm

DVH of bladder and hip joint-DS vs PBS



Dose Prescription | Dose Statistics

ew	DVH Line	Structure	Approval Status	Plan	Course	Volume [cm³]	Dose Cover.[%]	Sampling Cover....	Min Dose [%]	Max Dose [%]	Mean Dose [%]
☑		FEMORAL HEAD...	Approved	INI_BU_P3	C1 Prostate	218.3	100.0	100.0	0.0	45.6	31.9
☑		FEMORAL HEAD...	Approved	INI SFUD	C1 Prostate	218.3	100.0	100.0	0.0	43.5	26.9
☑		FEMORAL HEAD...	Approved	INI_BU_P3	C1 Prostate	213.2	100.0	100.0	0.0	45.7	31.4
☑		FEMORAL HEAD...	Approved	INI SFUD	C1 Prostate	213.2	100.0	100.0	0.0	43.1	26.1
☑		CTV_5040	Approved	INI_BU_P3	C1 Prostate	103.3	100.0	100.0	95.9	102.1	100.0
☑		CTV_5040	Approved	INI SFUD	C1 Prostate	103.3	100.0	100.0	98.4	102.9	100.8
☑		BLADDER	Approved	INI_BU_P3	C1 Prostate	212.3	100.0	100.0	0.0	101.4	40.9
☑		BLADDER	Approved	INI SFUD	C1 Prostate	212.3	100.0	100.0	0.0	102.1	34.0

ontouring | External Beam Planning | Brachytherapy Planning | Plan Evaluation

Clinical comparison of DS/US versus PBS Field size

DS/ US

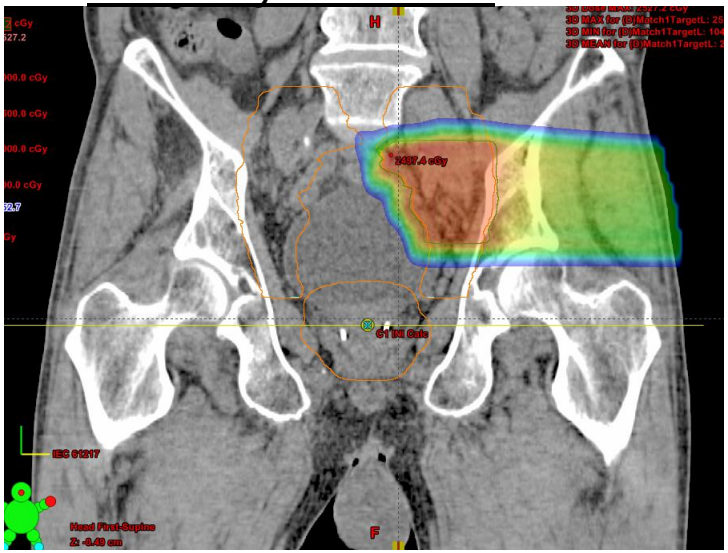
- Limited field size- Maximum of 25cm- can not treat large fields- Whole pelvis, chest wall and LN, lymphoma- mediastinum and neck, head and neck.

PBS

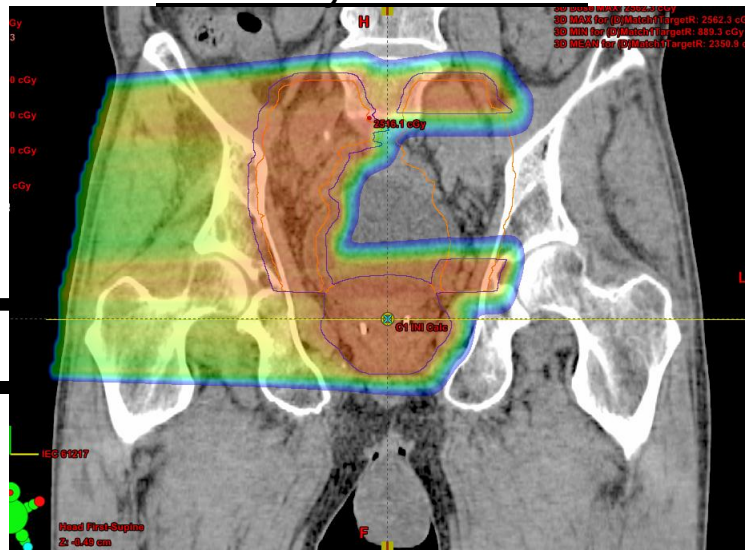
- Large field size~ 35cm (vendor dependent)- can treat all body sites.

Method 1: Whole pelvis using PBS matching laterals
4 plans, 2 plans per day, Single isocenter in the prostate

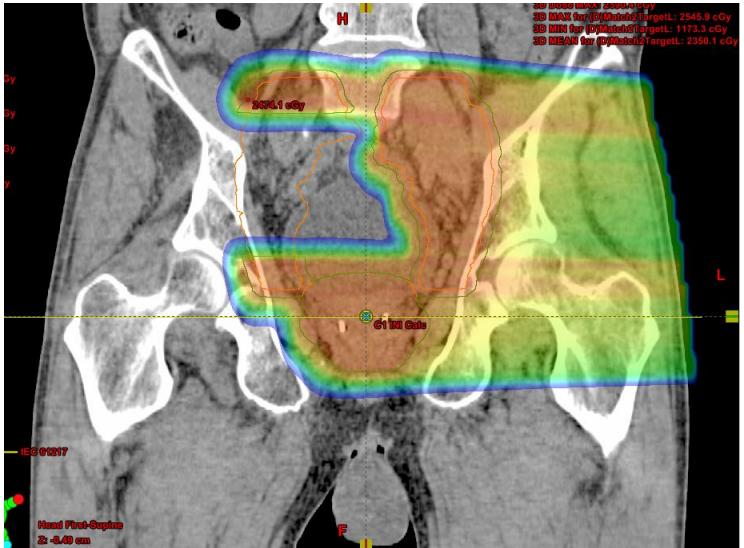
Day 1: LT LAT



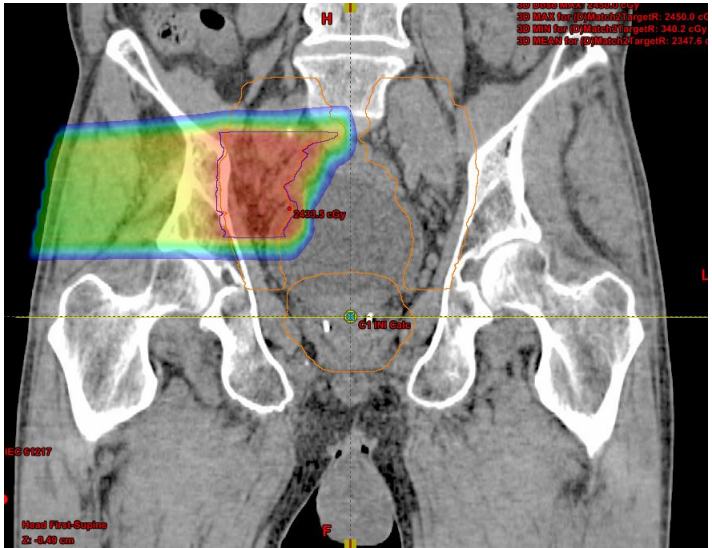
Day 1 : RT LAT



Day 2: LT LAT

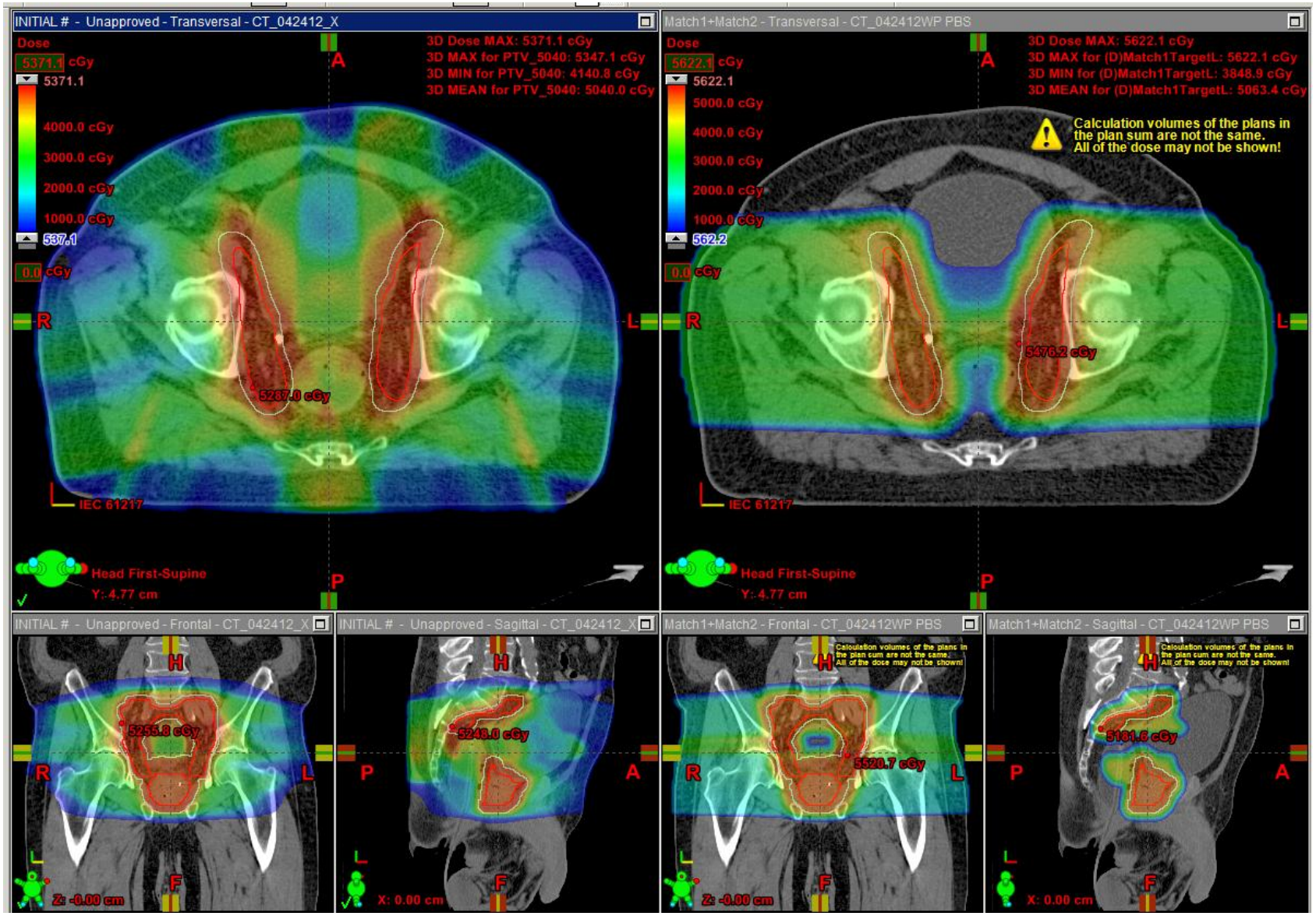


Day 2: RT LAT



IMRT

PBS


INITIAL # - Unapproved - Transversal - CT_042412_X
Dose
5371.1 cGy
5371.1
4000.0 cGy
3000.0 cGy
2000.0 cGy
1000.0 cGy
537.1
0.0 cGy
3D Dose MAX: 5371.1 cGy
3D MAX for PTV_5040: 5347.1 cGy
3D MIN for PTV_5040: 4140.8 cGy
3D MEAN for PTV_5040: 5040.0 cGy
5287.0 cGy
IEC 61217
Head First-Supine
Y: 4.77 cm
Match1+Match2 - Transversal - CT_042412WP PBS
Dose
5622.1 cGy
5622.1
5000.0 cGy
4000.0 cGy
3000.0 cGy
2000.0 cGy
1000.0 cGy
562.2
0.0 cGy
3D Dose MAX: 5622.1 cGy
3D MAX for (D)Match1TargetL: 5622.1 cGy
3D MIN for (D)Match1TargetL: 3848.9 cGy
3D MEAN for (D)Match1TargetL: 5063.4 cGy
Calculation volumes of the plans in the plan sum are not the same. All of the dose may not be shown!
5476.2 cGy
IEC 61217
Head First-Supine
Y: 4.77 cm
INITIAL # - Unapproved - Frontal - CT_042412_X
5255.8 cGy
Z: -0.00 cm
INITIAL # - Unapproved - Sagittal - CT_042412_X
5248.0 cGy
X: 0.00 cm
Match1+Match2 - Frontal - CT_042412WP PBS
5520.7 cGy
Z: -0.00 cm
Match1+Match2 - Sagittal - CT_042412WP PBS
5181.6 cGy
X: 0.00 cm

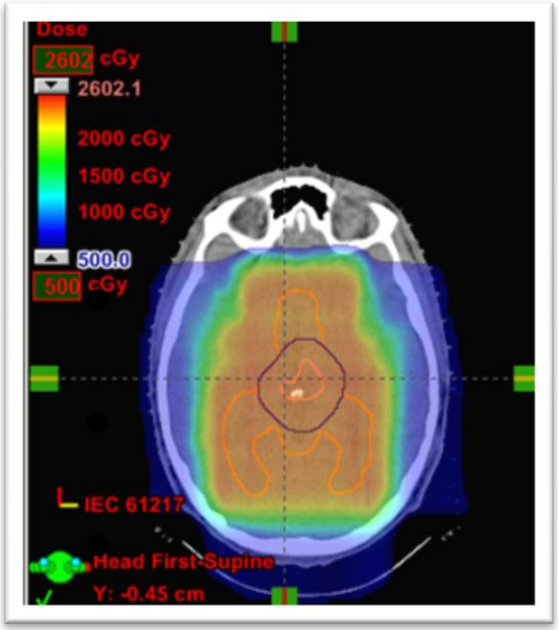
Clinical limitations of DS/US versus PBS

DS/ US	PBS
No IMPT option	IMPT enabled
High dose to normal tissue in proximal beam	• Lower dose to normal tissue in proximal beam

Brain tumors- PBS vs. DS/US

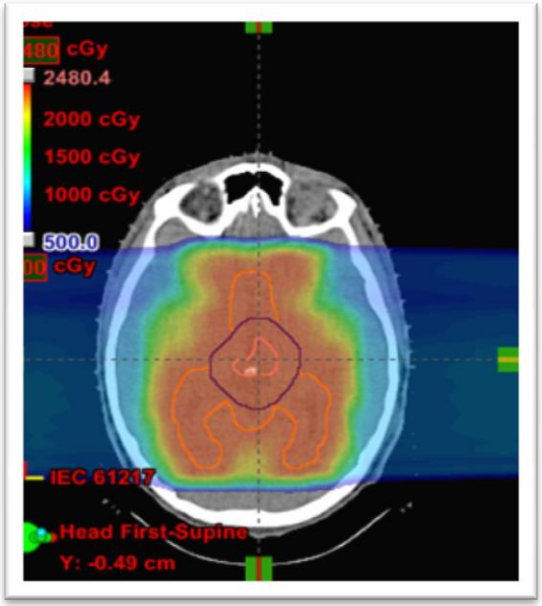
Major improvement for deep targets

Pineal Germinoma

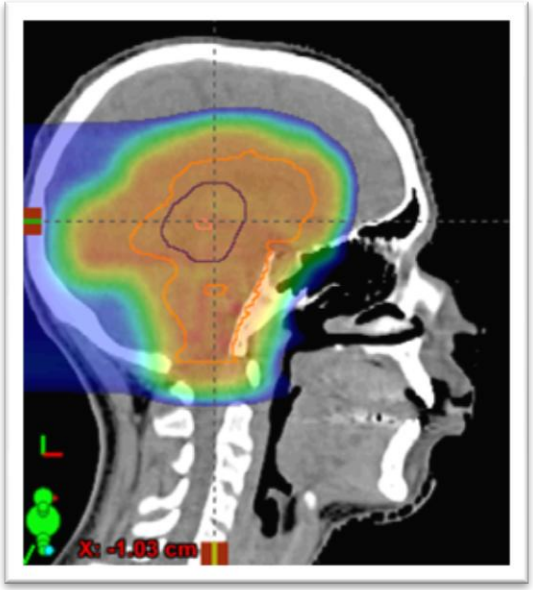


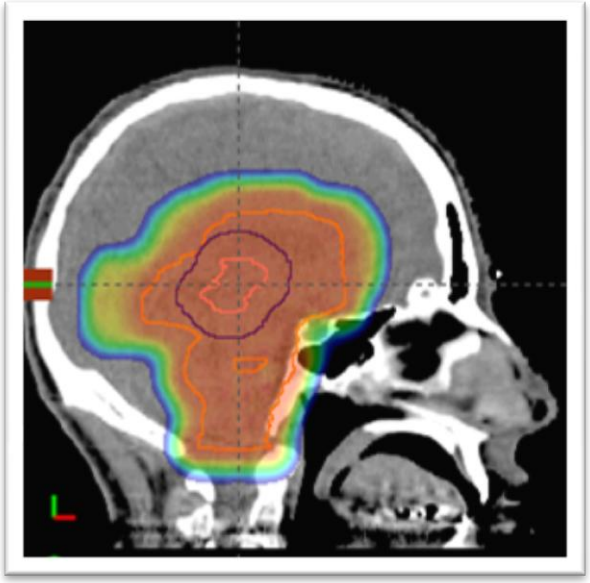
DS 3 Field

Dose to temporal lobes reduced by 20-25%

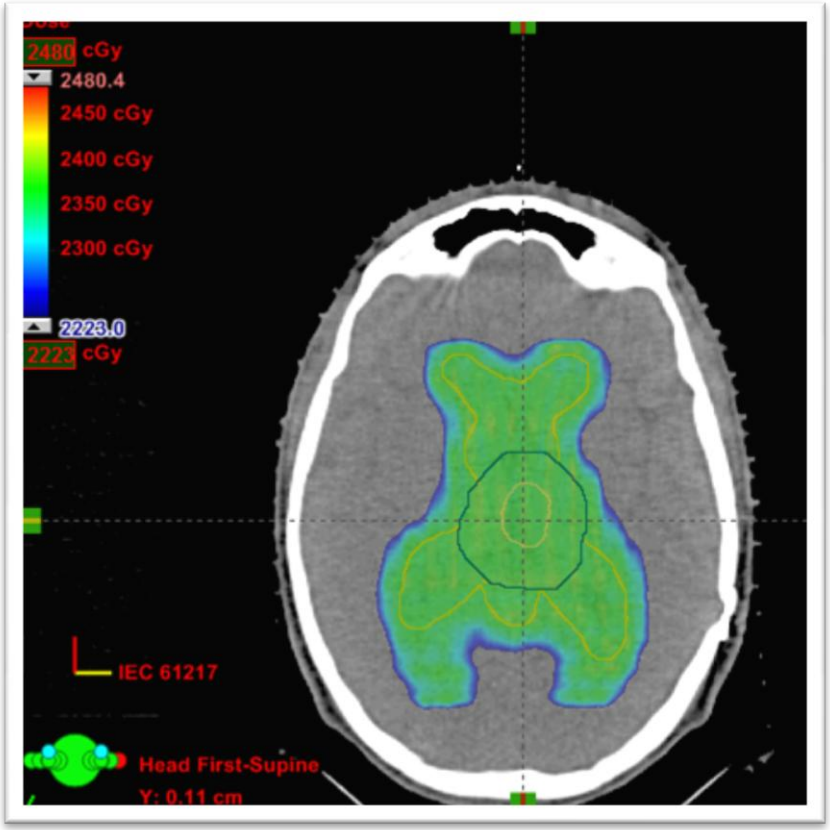


PBS 2 lat Field

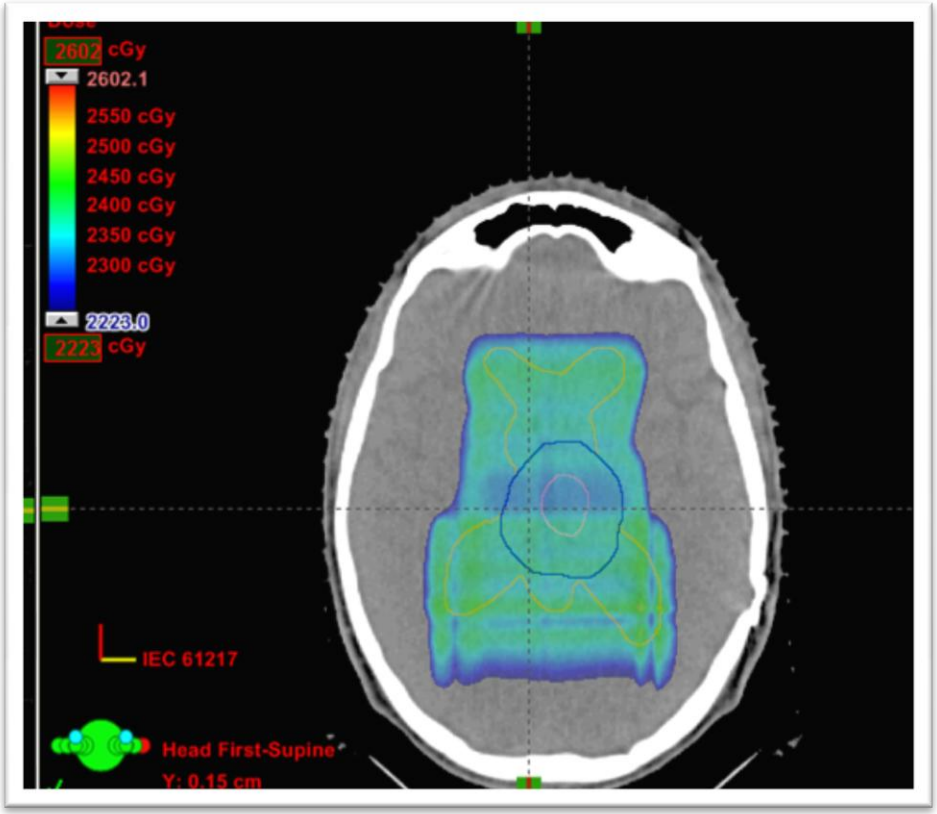




D95%, better conformality with PBS. Coverage more homogeneous



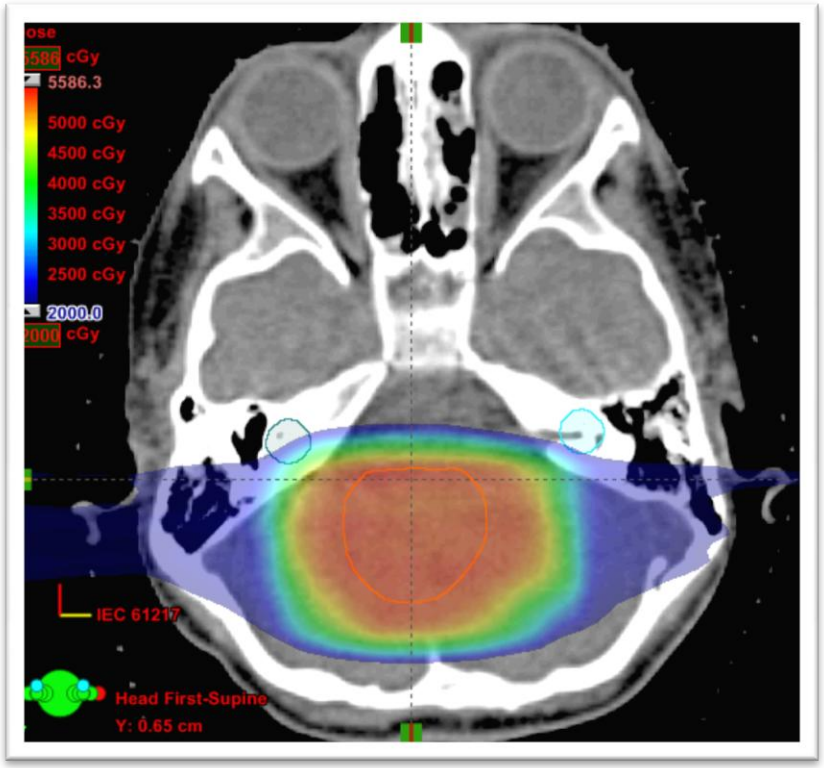
PBS



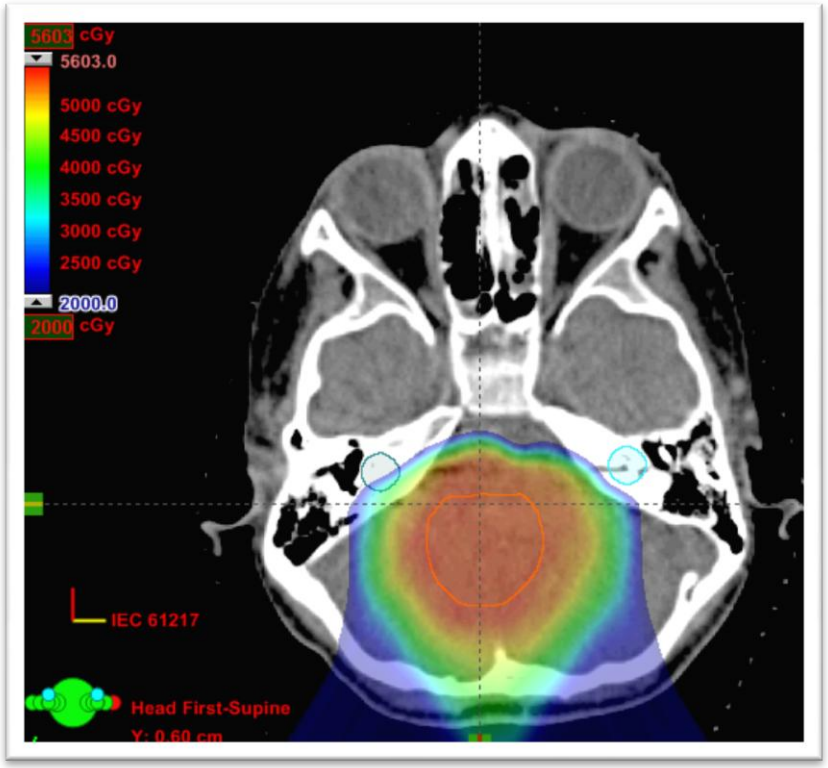
DS

Posterior fossa- not always PBS is better then DS

PBS fixed beam



DS gantry



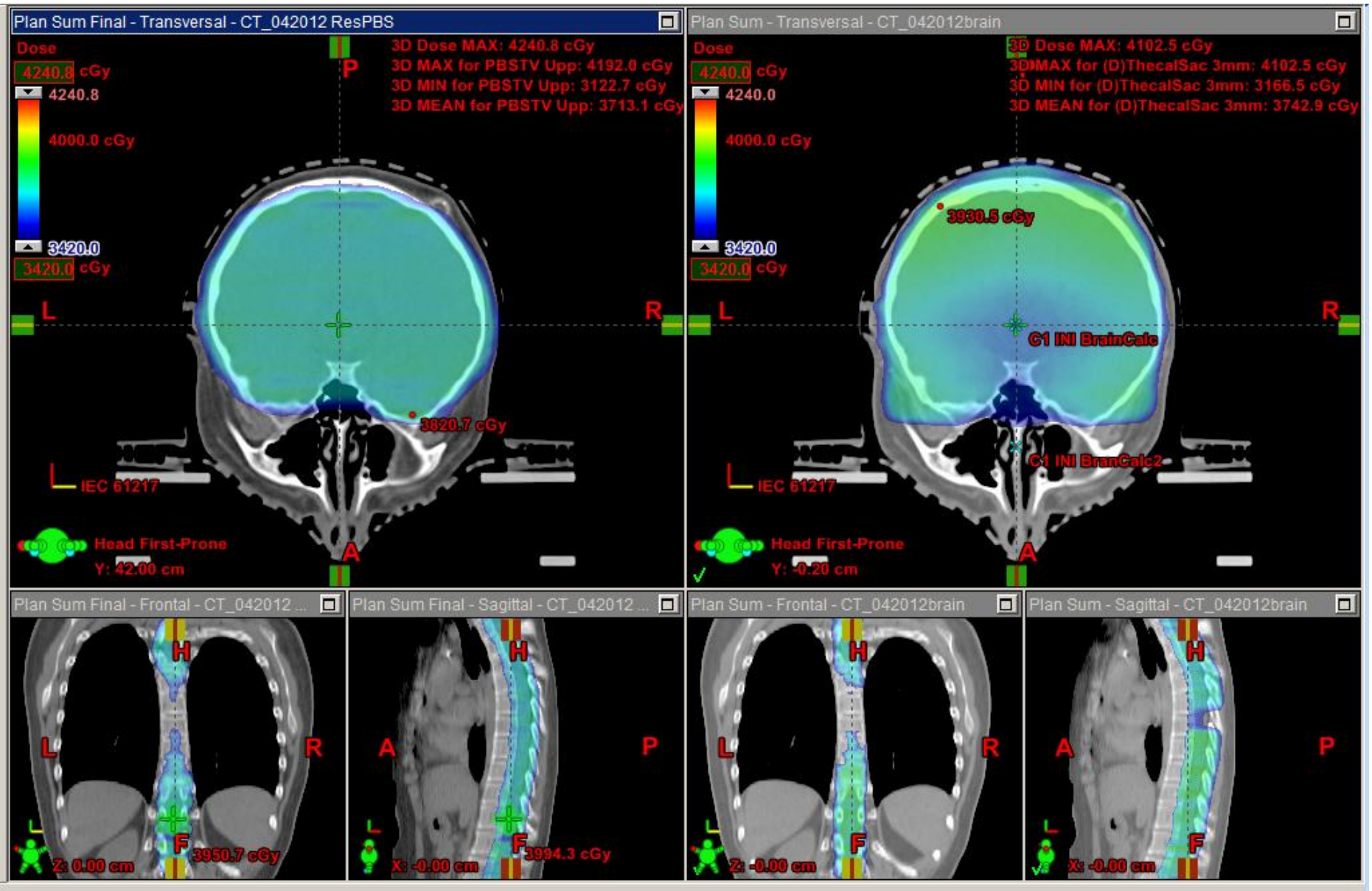
astrocytoma pilocytic juvenile Grade I recurrent

Craniospinal PBS

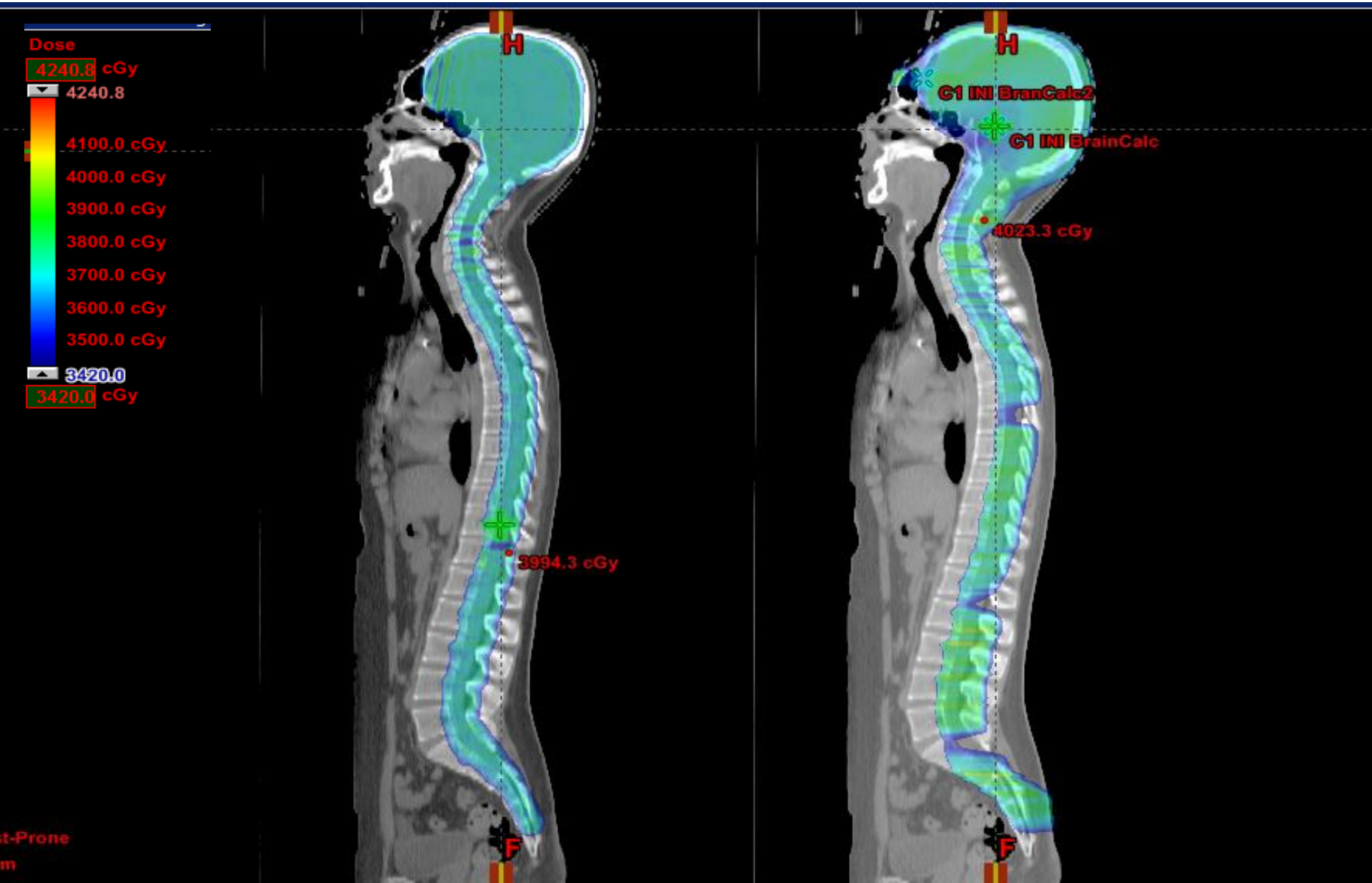
DS- Patient prone , difficult set us, long table time.

PBS- Can treat supine, easier set up , faster treatment

Adult case: prescription 180cGyx20=3600cGy

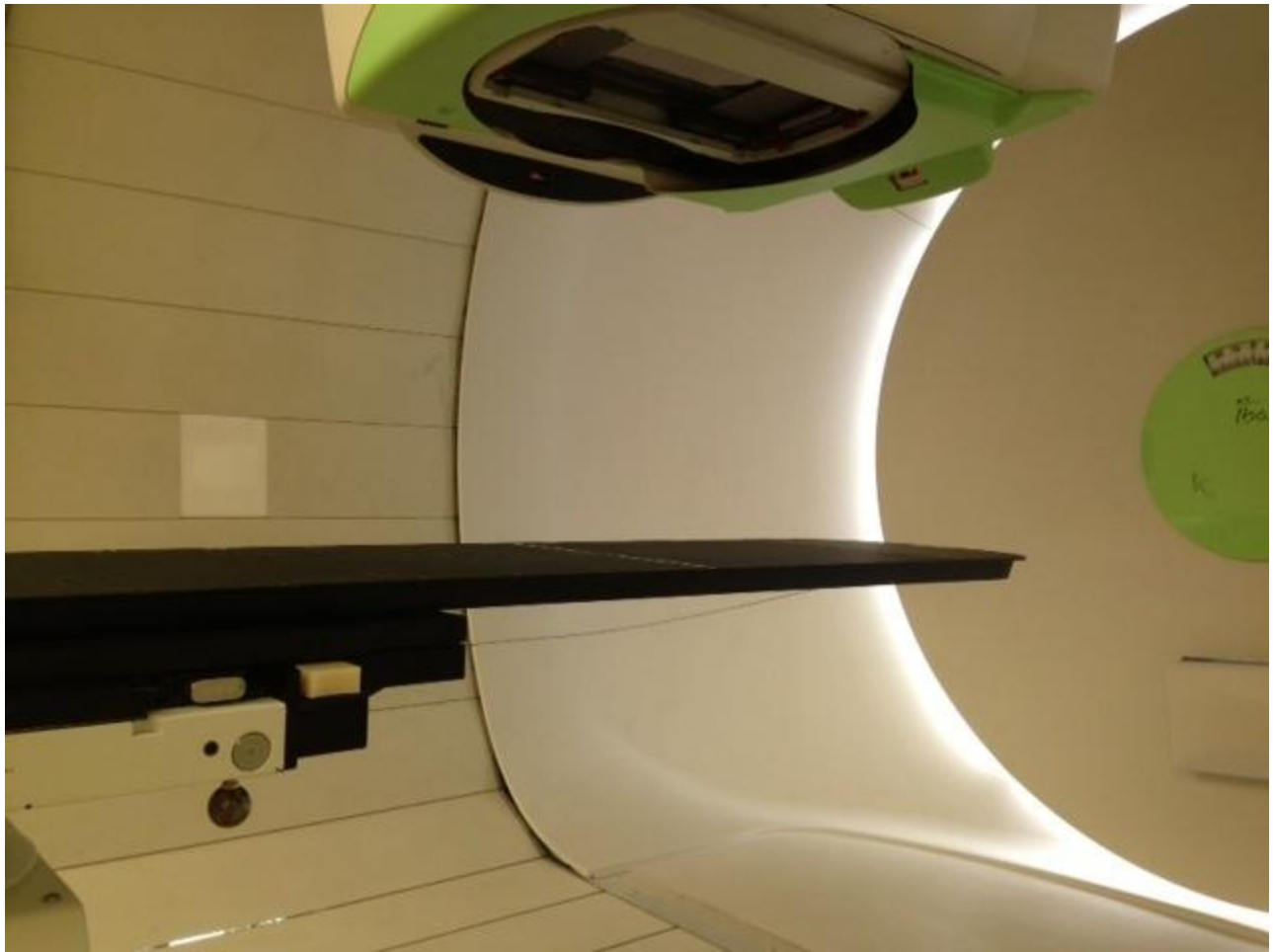


Adult case: prescription 180cGyx20=3600cGy



Bolus -7.5cm to enable PBS treatments from the skin for brain and head and neck tumors

Sliding table- 6.8 cm for PBS treatments



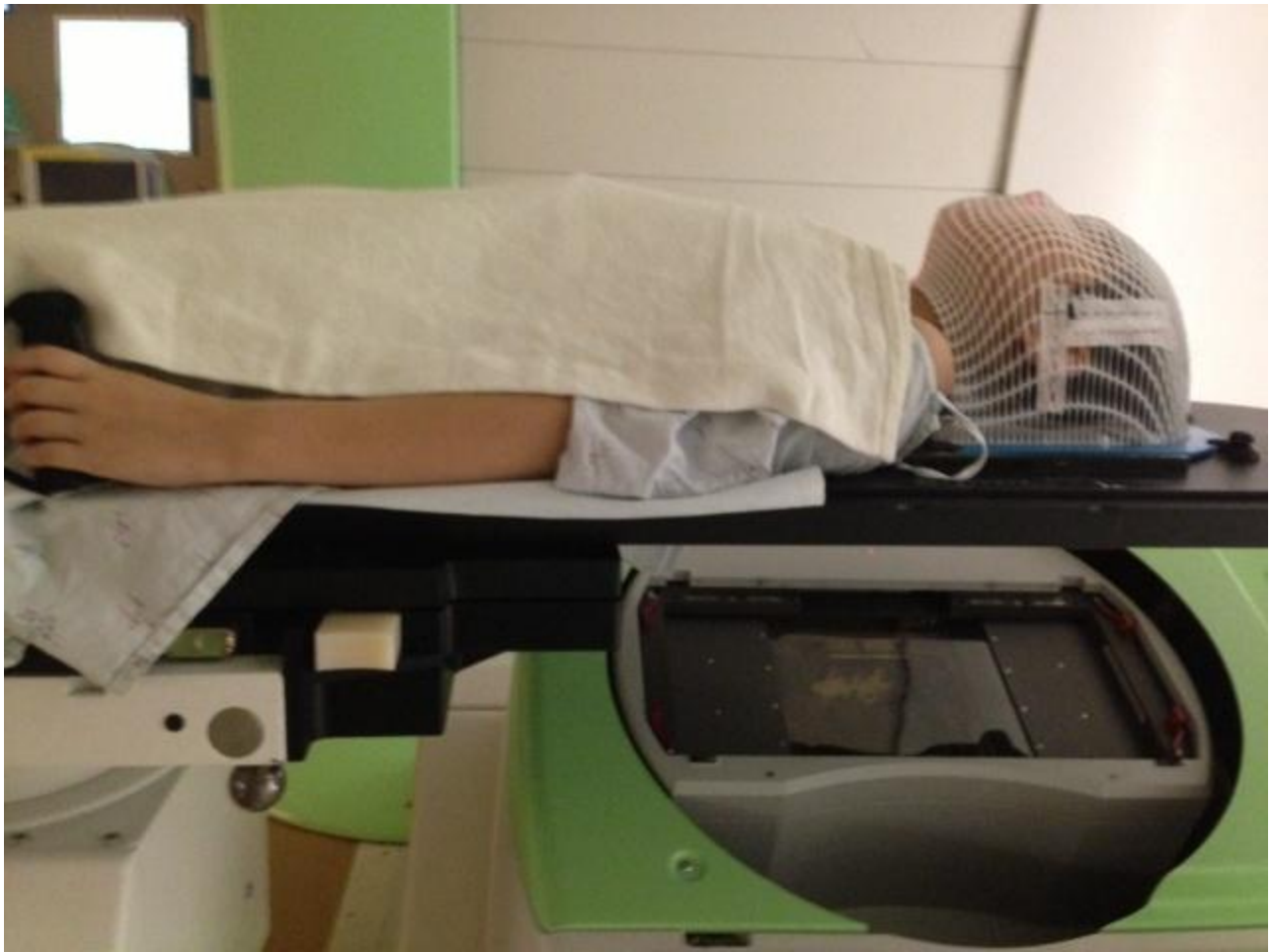
Head and Neck Tumors

- With DS/US- treatment of salivary glands, paranasal sinuses, orbits, sarcomas of head and neck
- With PBS- treatment of primary- oropharynex or nasoparynex plus bilateral neck nodes-
- Two fields- SFUD plus IMPT

Head and Neck

2 posterior oblique fields . Treatment via the table

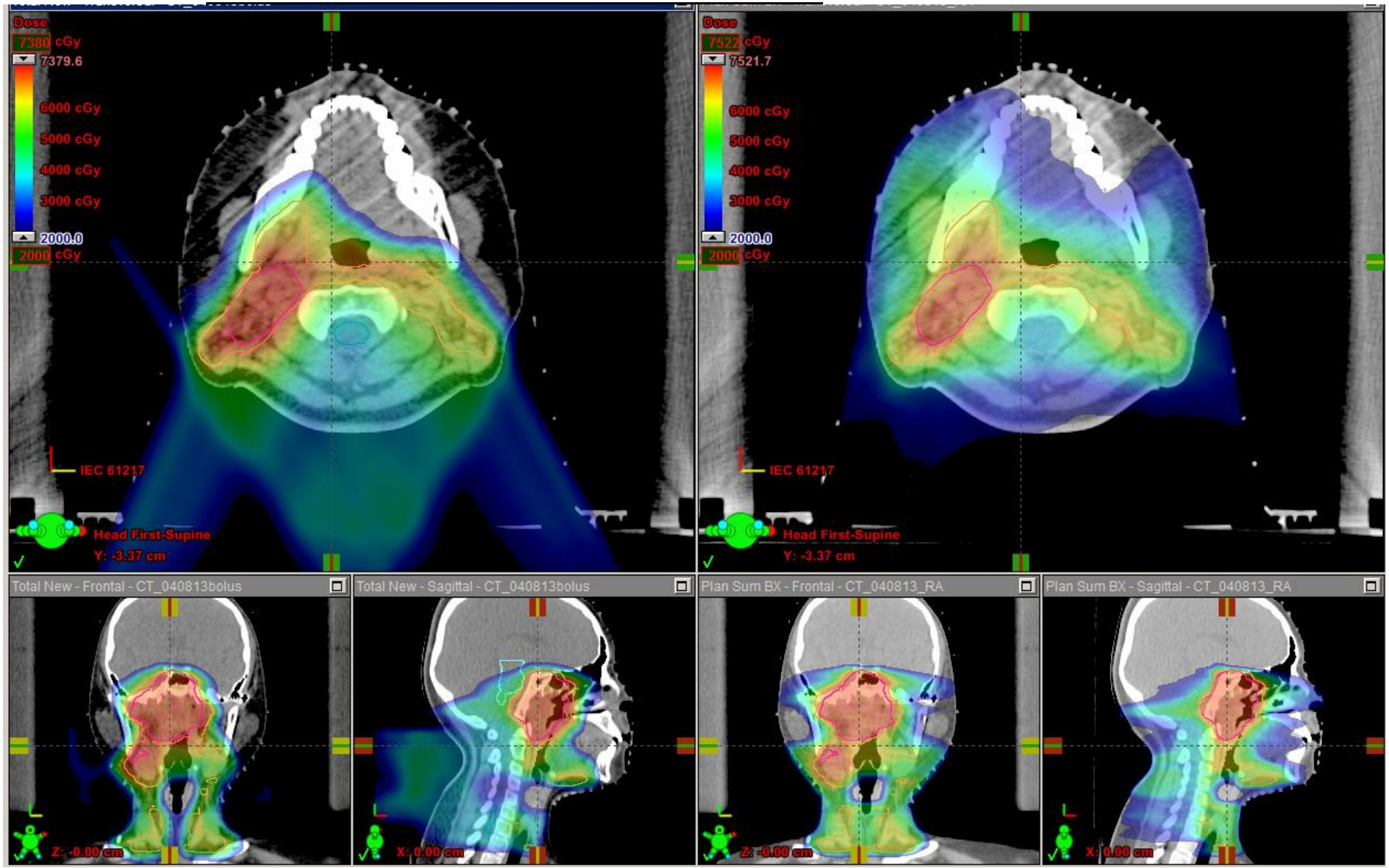
PBS- SFUD and IMPT



Sinus H&N case

PBS

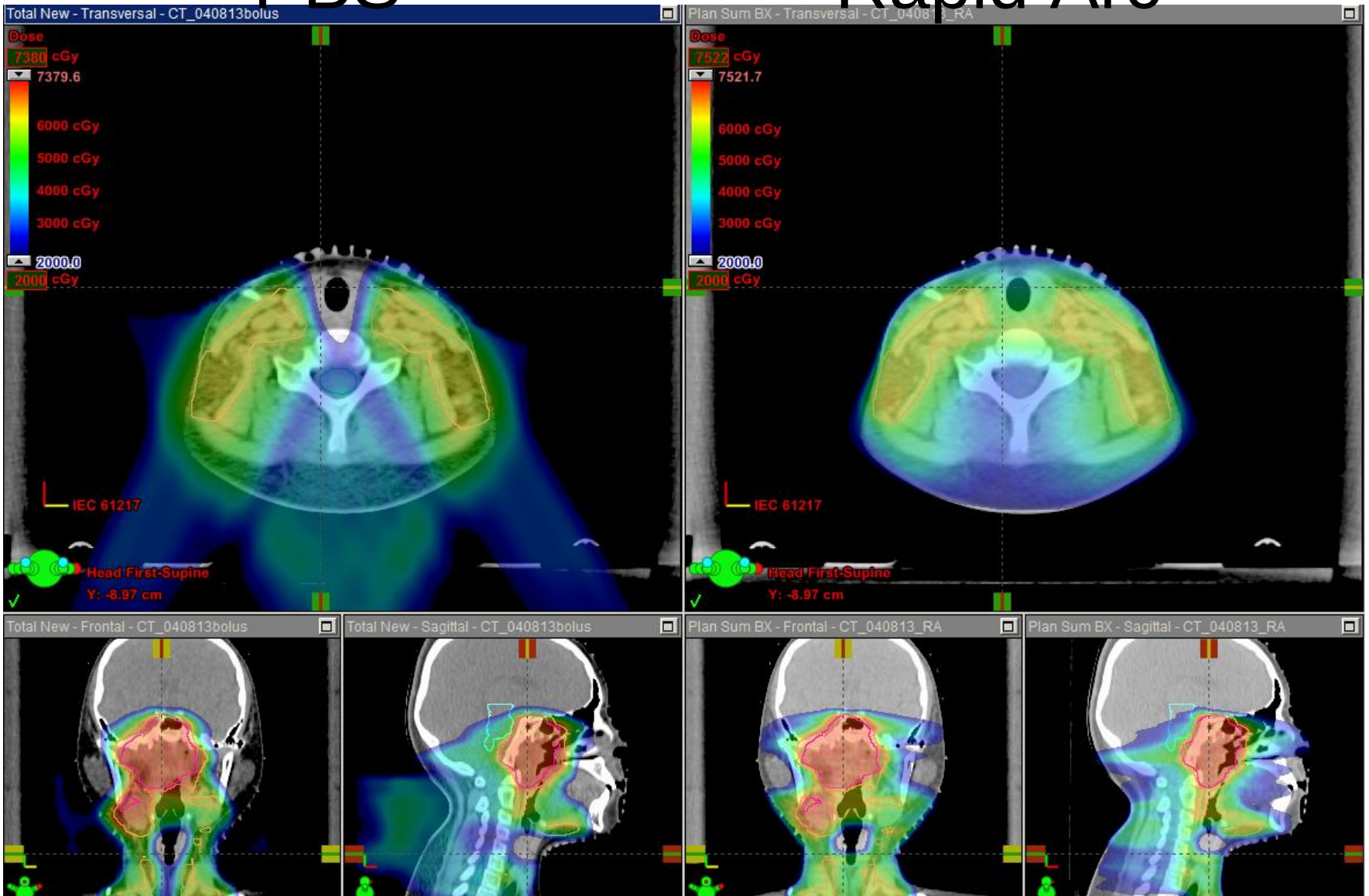
RA



Nasopharynx

PBS

Rapid Arc



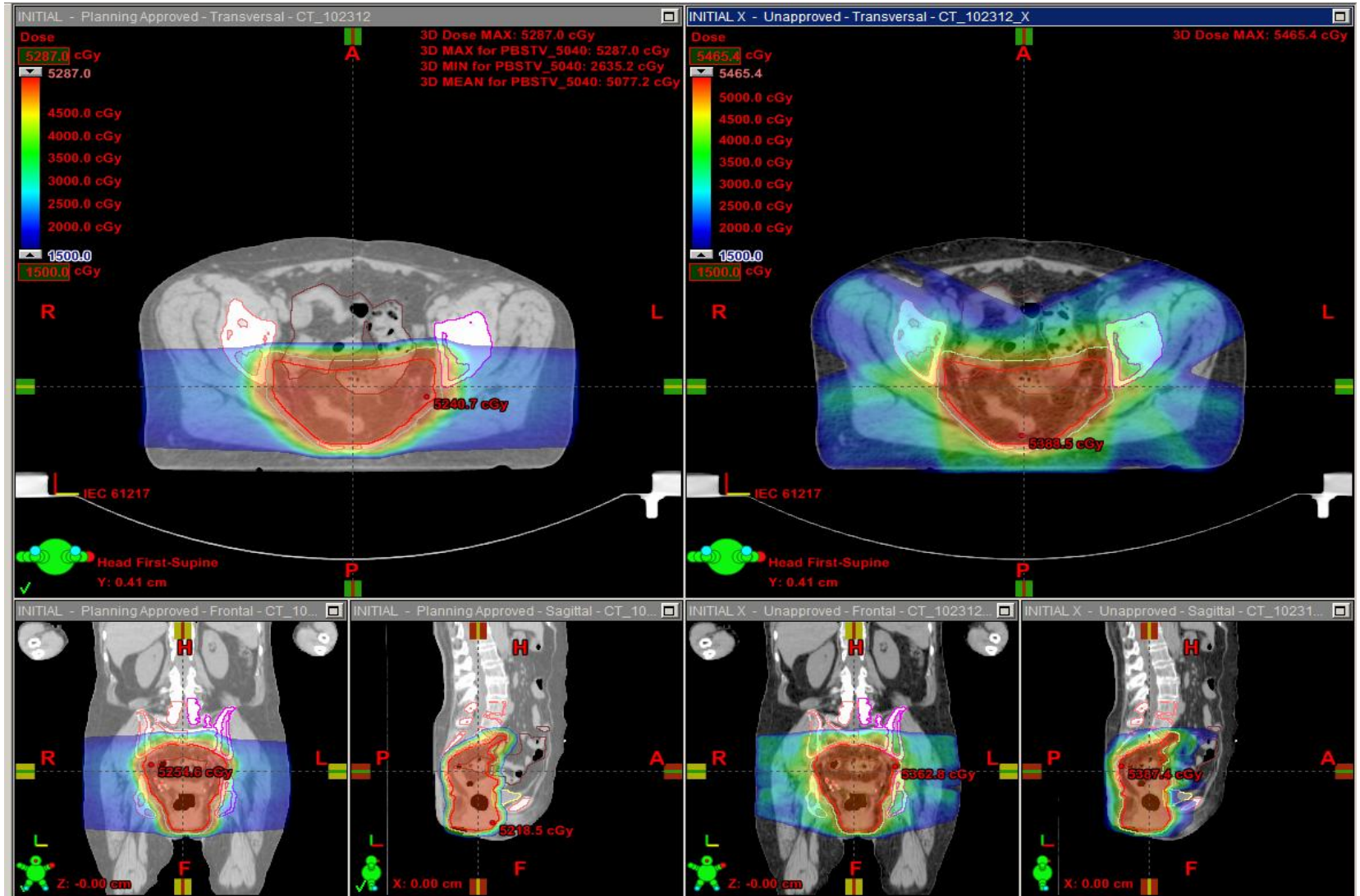
Gastro Intestinal Cancers

Using DS/US: Esophagus, Pancreas, Hepatobiliary

Using PBS: Rectal Cancer, Anal Cancer

Rectal Cancer

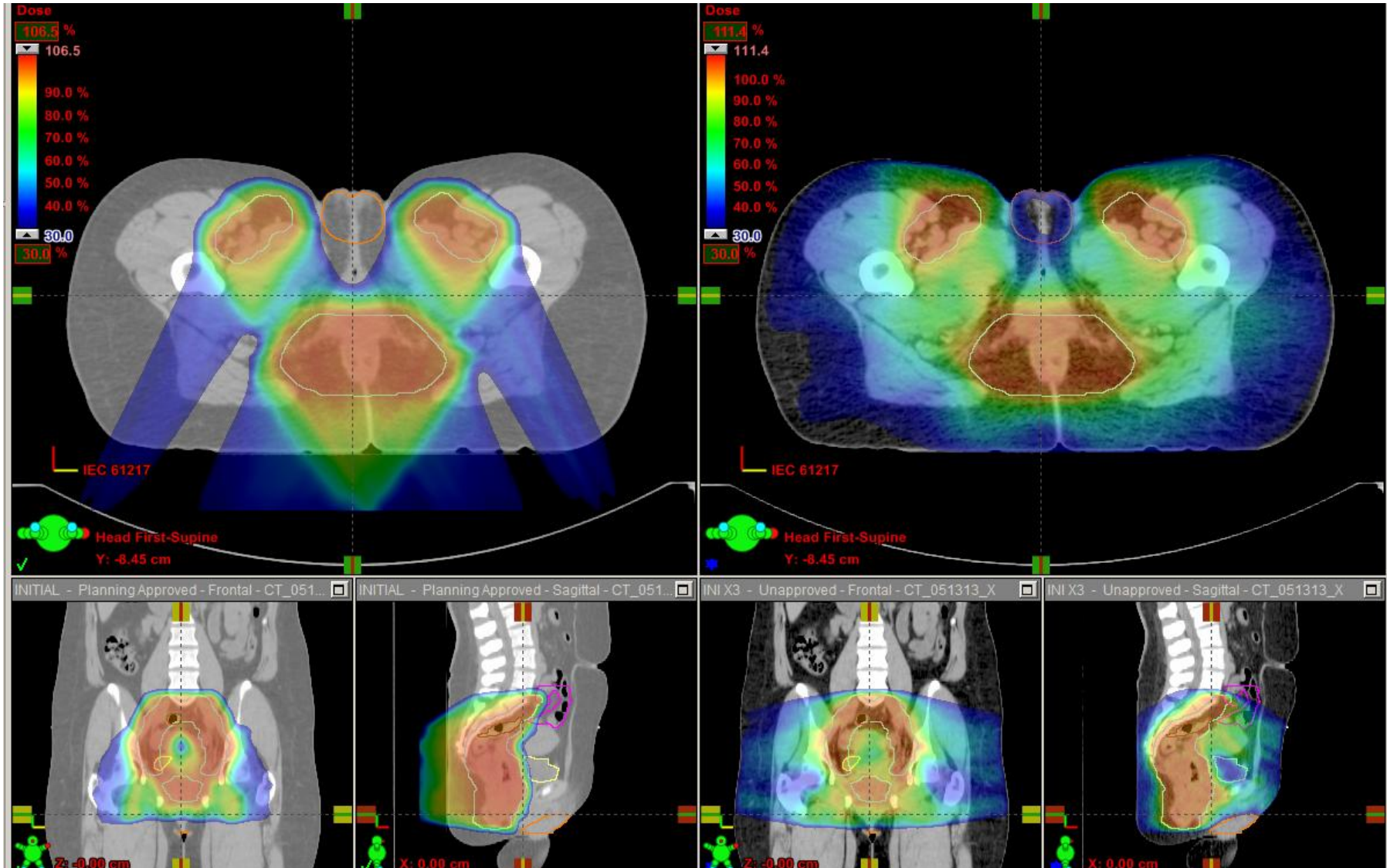
PBS IMRT



Anal Cancer

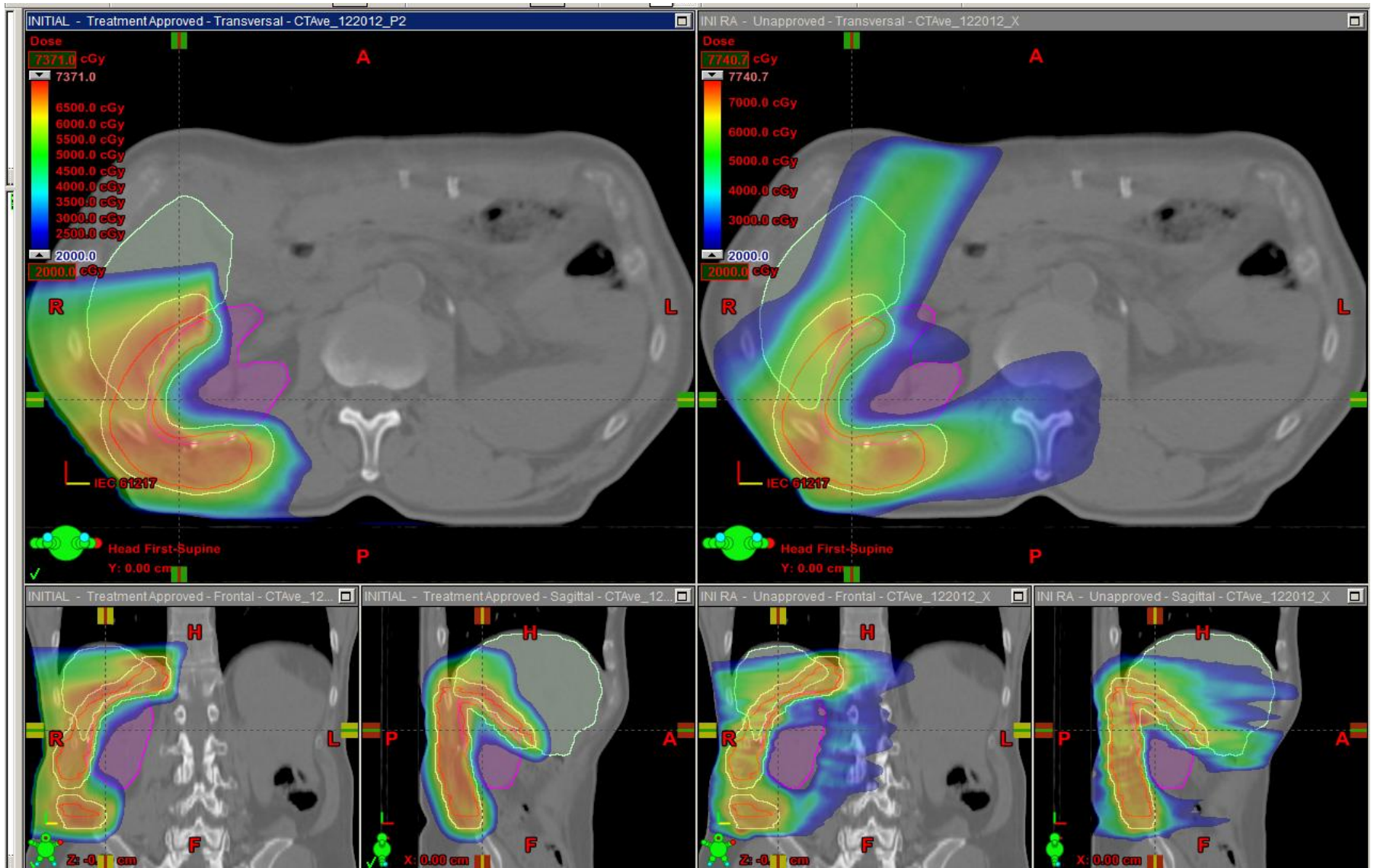
PBS

Rapid Arc

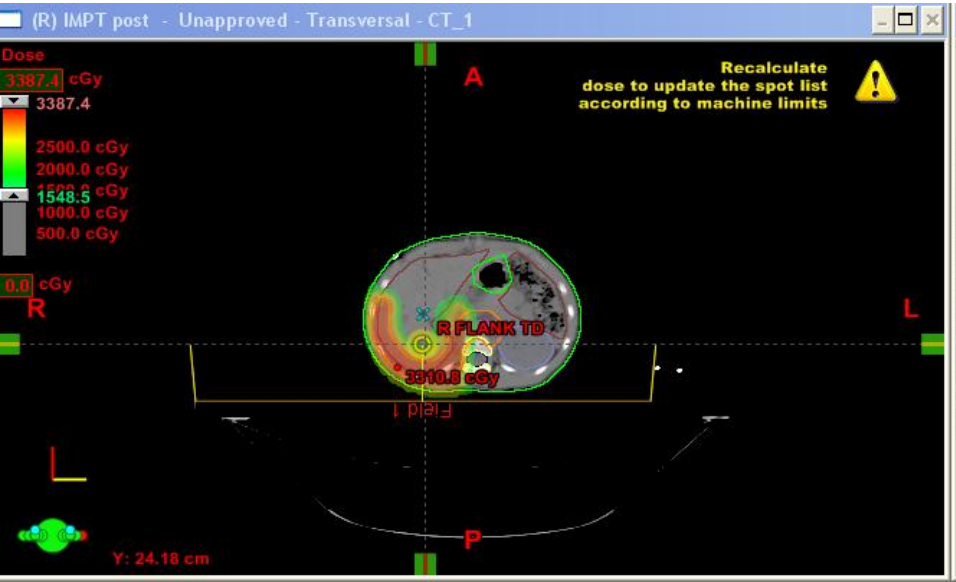


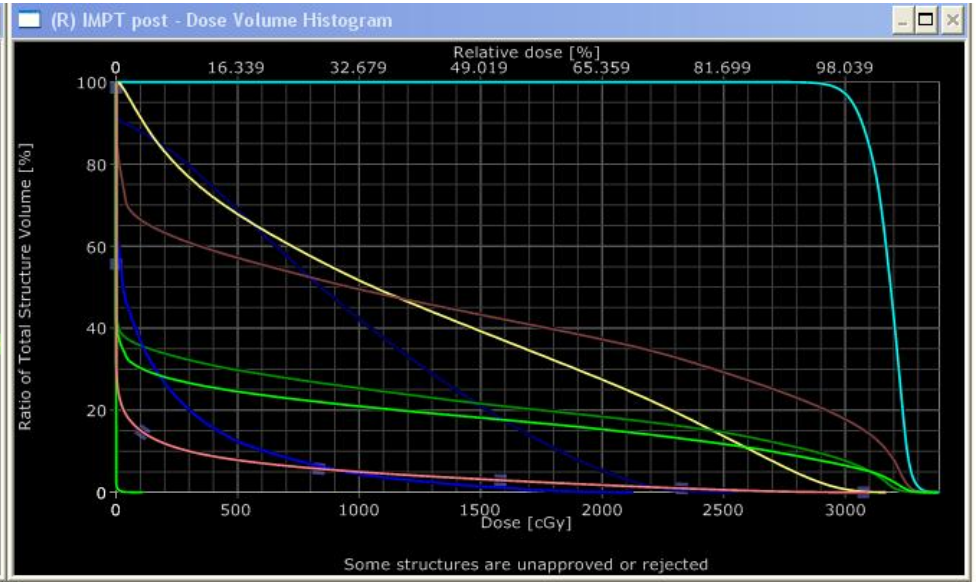
Retroperitoneal sarcoma

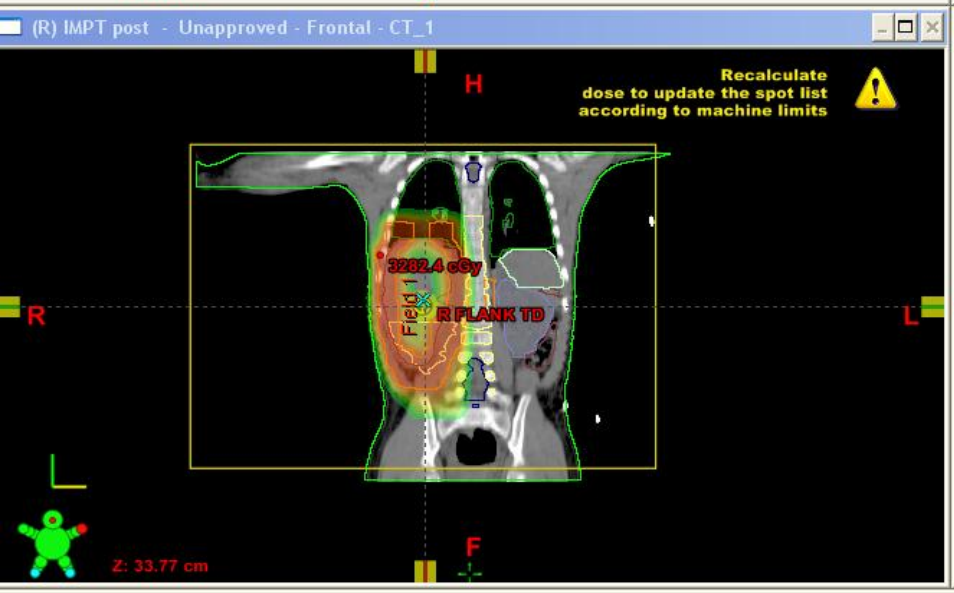
PBS IMRT



Wilms Proton







TREATMENT OF MOVING TARGETS- DS

- With DS routine treatments of mediastinum, lungs, hepatobiliary and upper abdomen.

- Can treat up to 1cm motion
- 4DCT simulation
- Gating/ Deep Inspiration Breath Hold- in some institution

TREATMENT OF MOVING TARGETS- PBS

Currently only targets with no or limited motion- up to 4-5mm can be treated.

Need faster PBS- rescanning

Gating/ Deep Inspiration Breath Hold

Need Cone Beam CT

Capability of PBS to treat moving targets is expected in 2-3 years

For Proton to replace x-rays as the main radiotherapy modality

Every site of the body need be treated efficiently with proton

With early version of the first generation of PBS we are already treating, or will be treating soon every site of the body except motion. Next generation of PBS- faster scanning with some motion control will allow treatment of lungs and upper GI

For Proton to replace x-rays as the main radiotherapy modality

1. Every site of the body should be treated efficiently with proton
2. The cost of purchasing proton system and operating should be reduced significantly

PBS-no need for compensator and aperture-saving of manpower and time for planning and treatment. Fewer beams per plan-higher thru put. Similar personnel to run a proton PBS room to Linac.

Proton will replace x-rays as the main radiotherapy modality

1. Every site of the body will be treated efficiently with proton

2. The cost of purchasing proton system and operating it will be reduced significantly

PBS is the only modality which will allow to achieve the two objectives

Proton development team

- All faculty and staff of PENN Rad Onc.
- Primarily:
- Stefan Both PhD
- James McDonough PhD
- Maura Kirk Ms.
- Huifang Zhai Ms.
- Sabina Vennarini MD