Dosimetric Advantages of Proton Simultaneous In-field Boost (PSIB) Technique for Treating Lung Cancer

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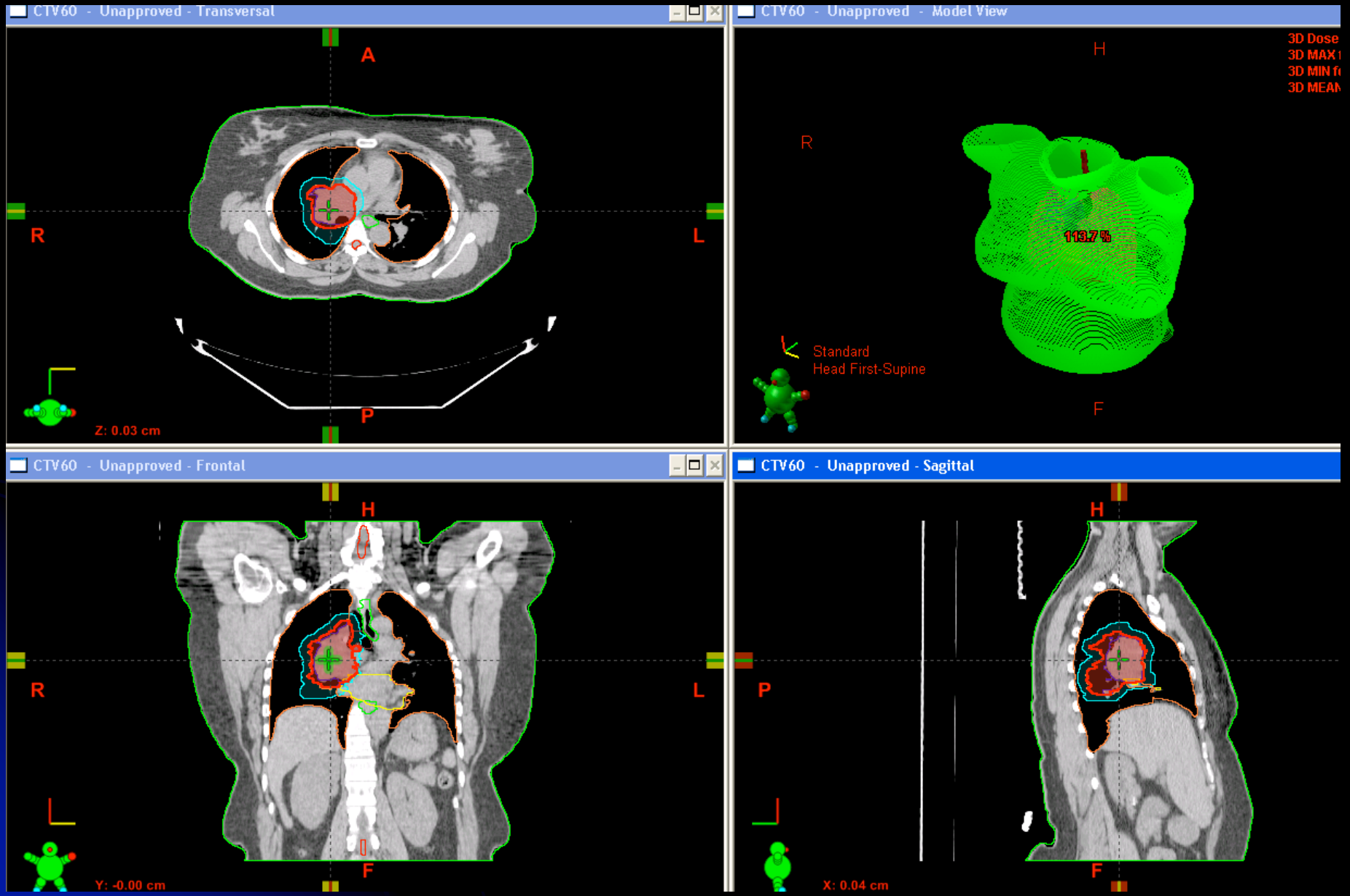
Objectives

- To evaluate a Simultaneous In-field Boost (SIB) technique for treating lung cancer
  - To treat the high tumor burden (GTV) at a higher dose level
  - To maintain the same minimum peripheral dose to CTV
- To evaluate dosimetric benefits
  - Normal tissue doses to lung, esophagus, heart, and spinal cord.

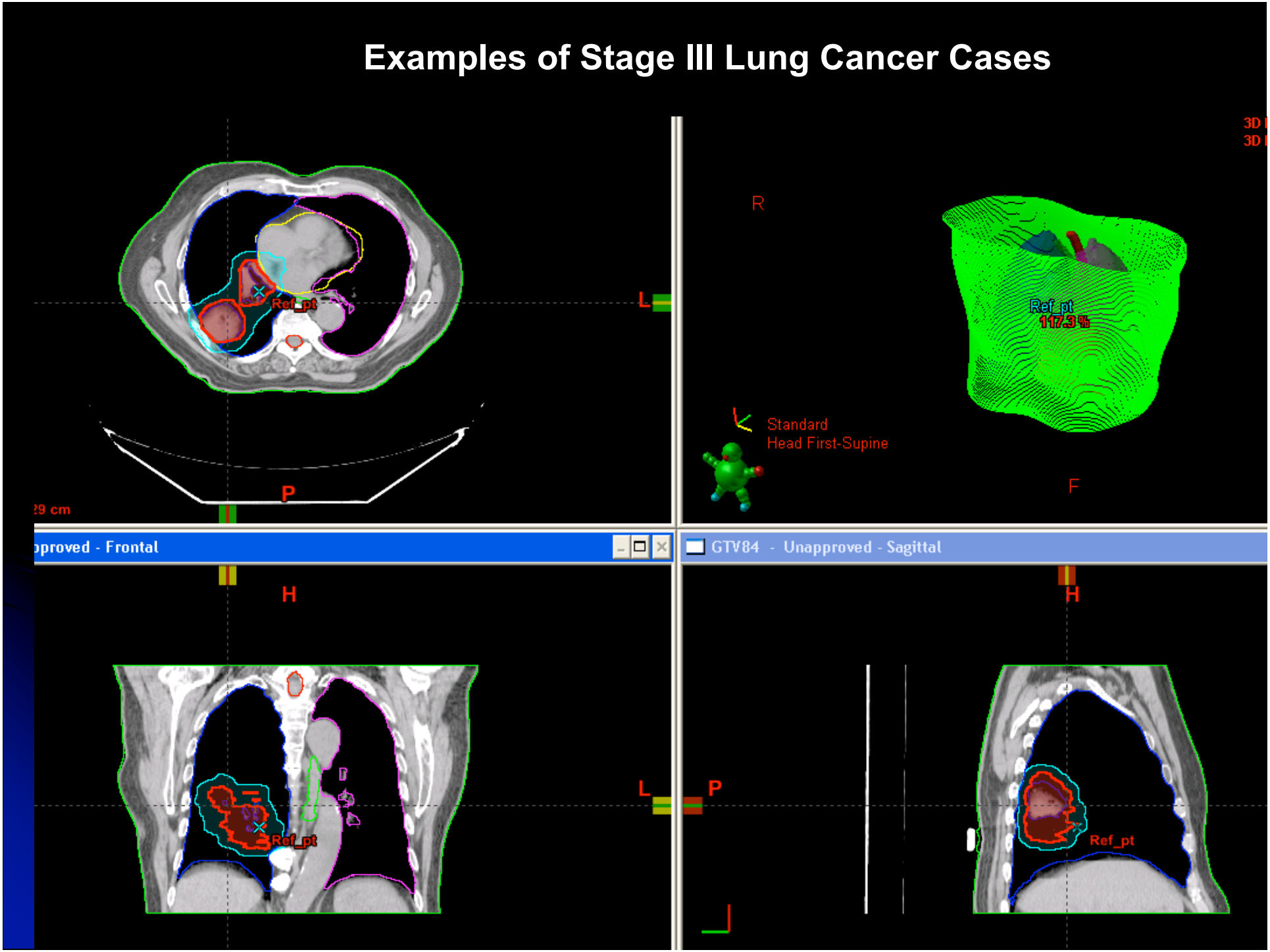
Background

- SIB is a typical treatment technique for IMRT planning
- Is it possible to design proton SIB plans with passively scattered protons?
- What are the dosimetric benefits?
- Which site is a good application?

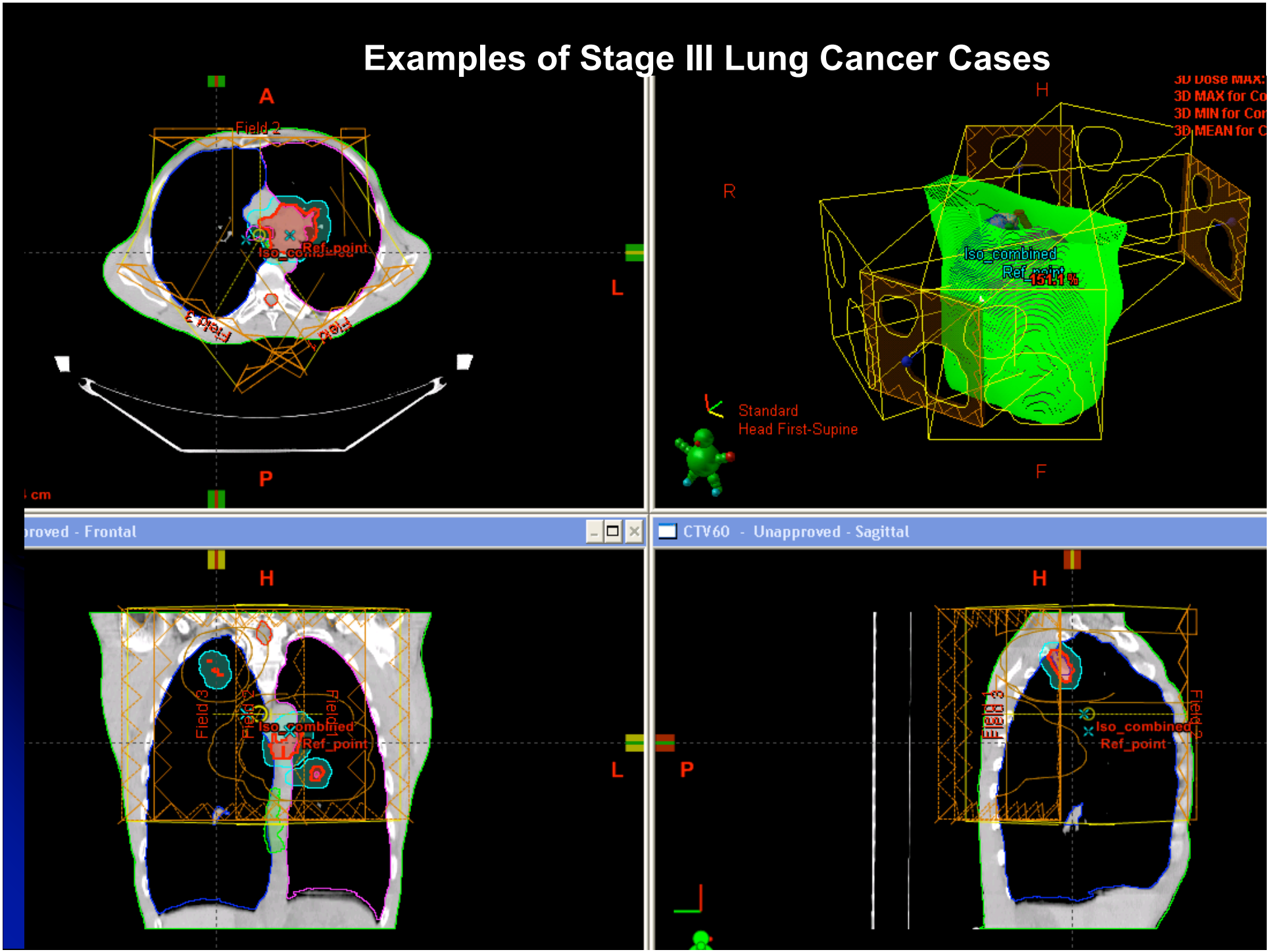
Examples of Stage III Lung Cancer Cases



Examples of Stage III Lung Cancer Cases



Examples of Stage III Lung Cancer Cases



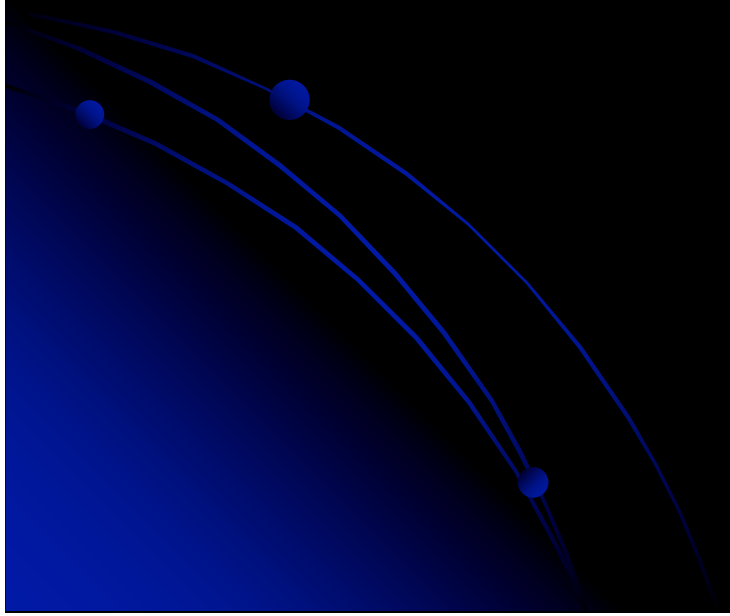
Proton SIB (Simultaneous In-field Boost) Protocol

- CTV 60 Gy/30fx (2Gy/fx)

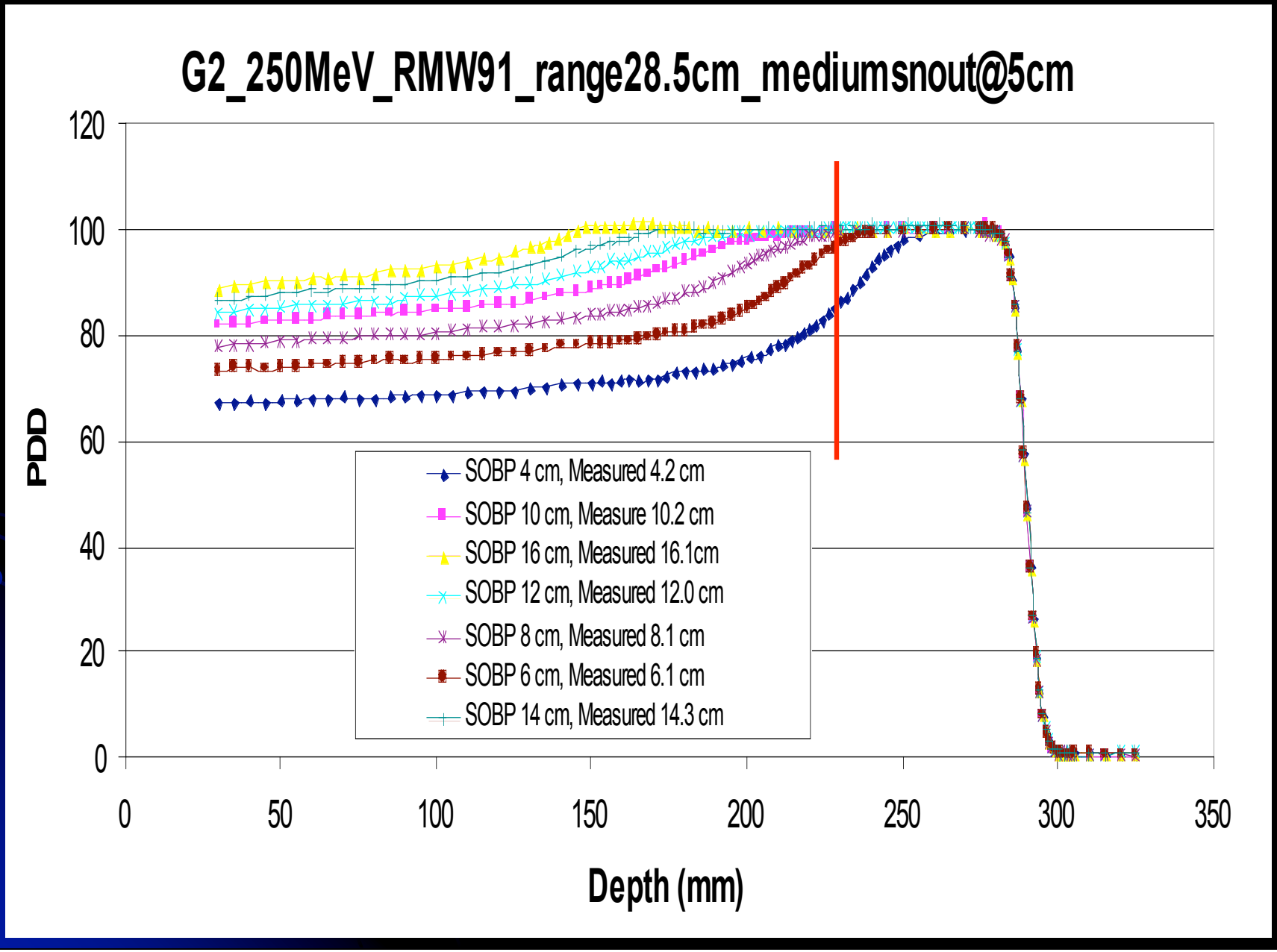
Table 1. Dose escalation schedule for phase I part of the trial.

Total dose (CGE)	No. fractions	Faction dose (CGE)	BED (Acute)		BED (Late)	
nd	n	d	$1+{}^{d}/_{\alpha/\beta}$	BED	$1+{}^{d}/_{\alpha/\beta}$	BED
			$\alpha/\beta=10$		$\alpha/\beta=3$	
CTV dose						
60 CGE	30	2.0	1.2	72	1.67	100.2
SIBV dose						
66 CGE	30	2.2	1.22	80.52	1.73	114.18
72 CGE	30	2.4	1.24	89.28	1.8	129.6
78 CGE	30	2.6	1.26	98.28	1.87	145.86
84 CGE	30	2.8	1.28	107.52	1.93	162.12

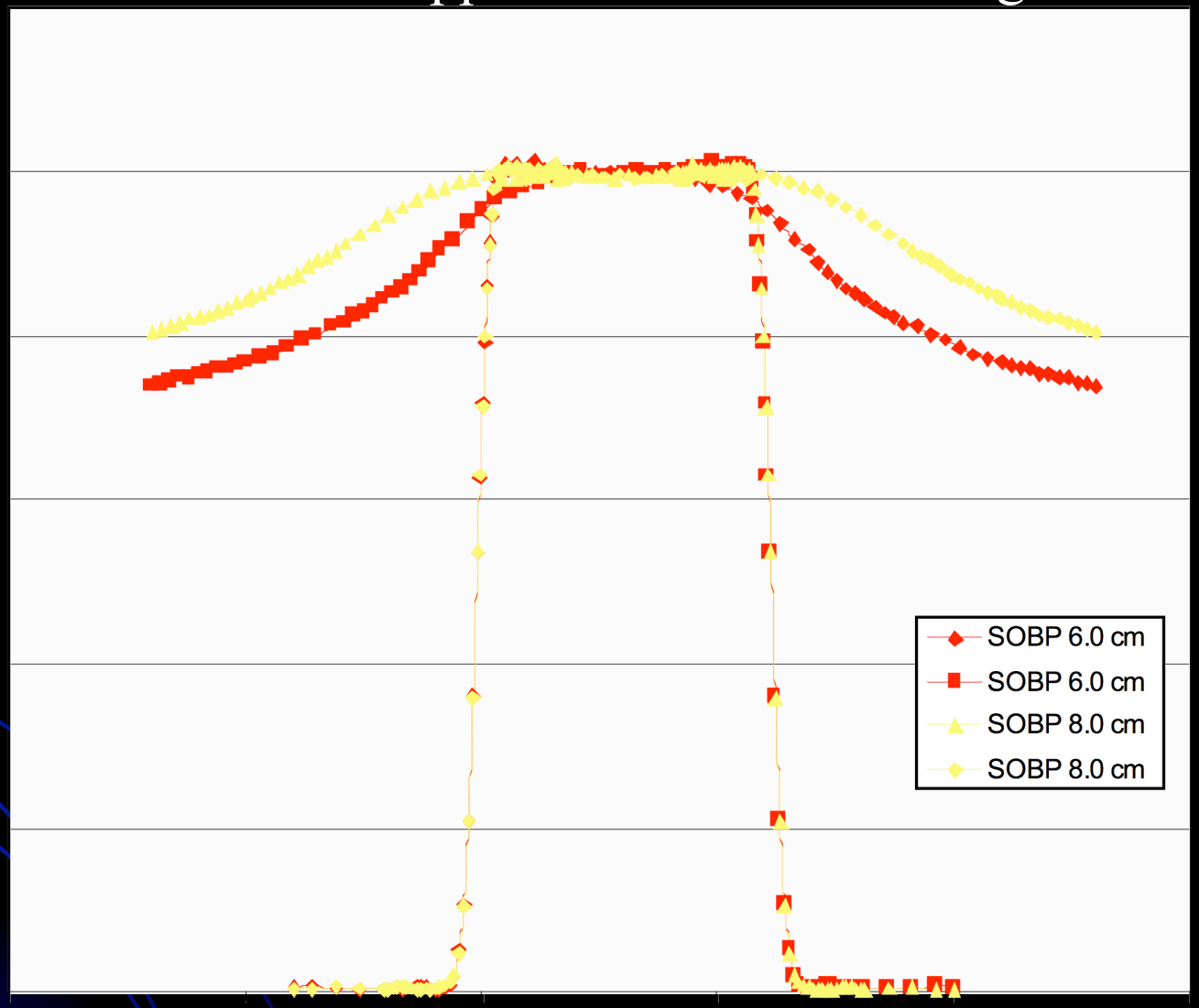
Rationale



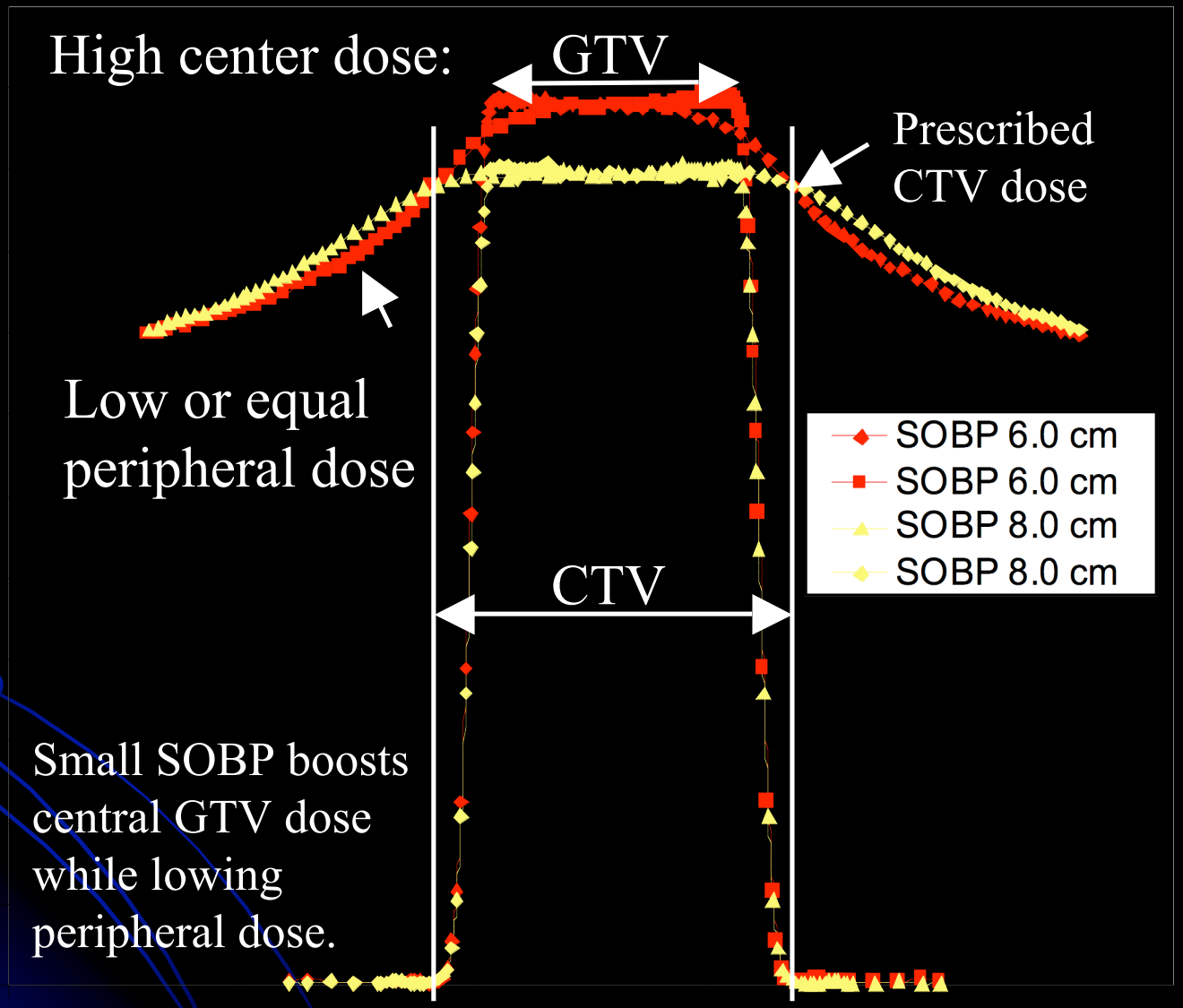
Entrance Dose for Different SOBP Widths



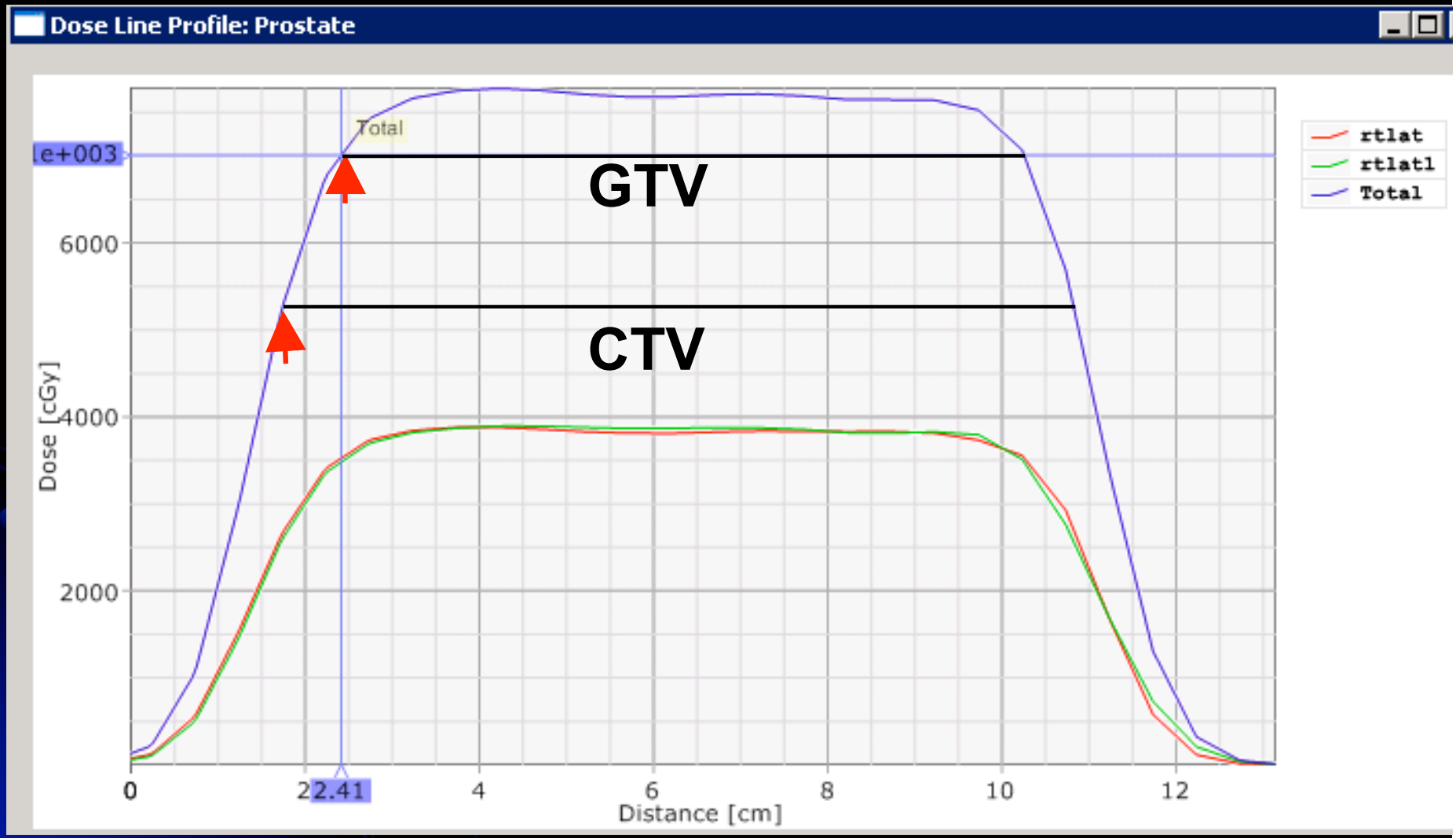
Parallel-opposed Two-field Arrangement



Depth Profile



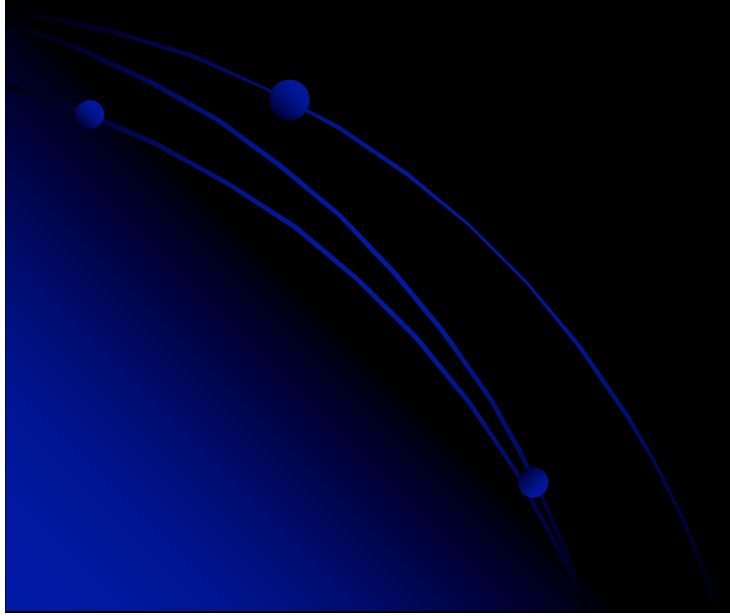
Additional Benefit of Normalizing to a Lower Dose Level → Pushing Penumbra into the field

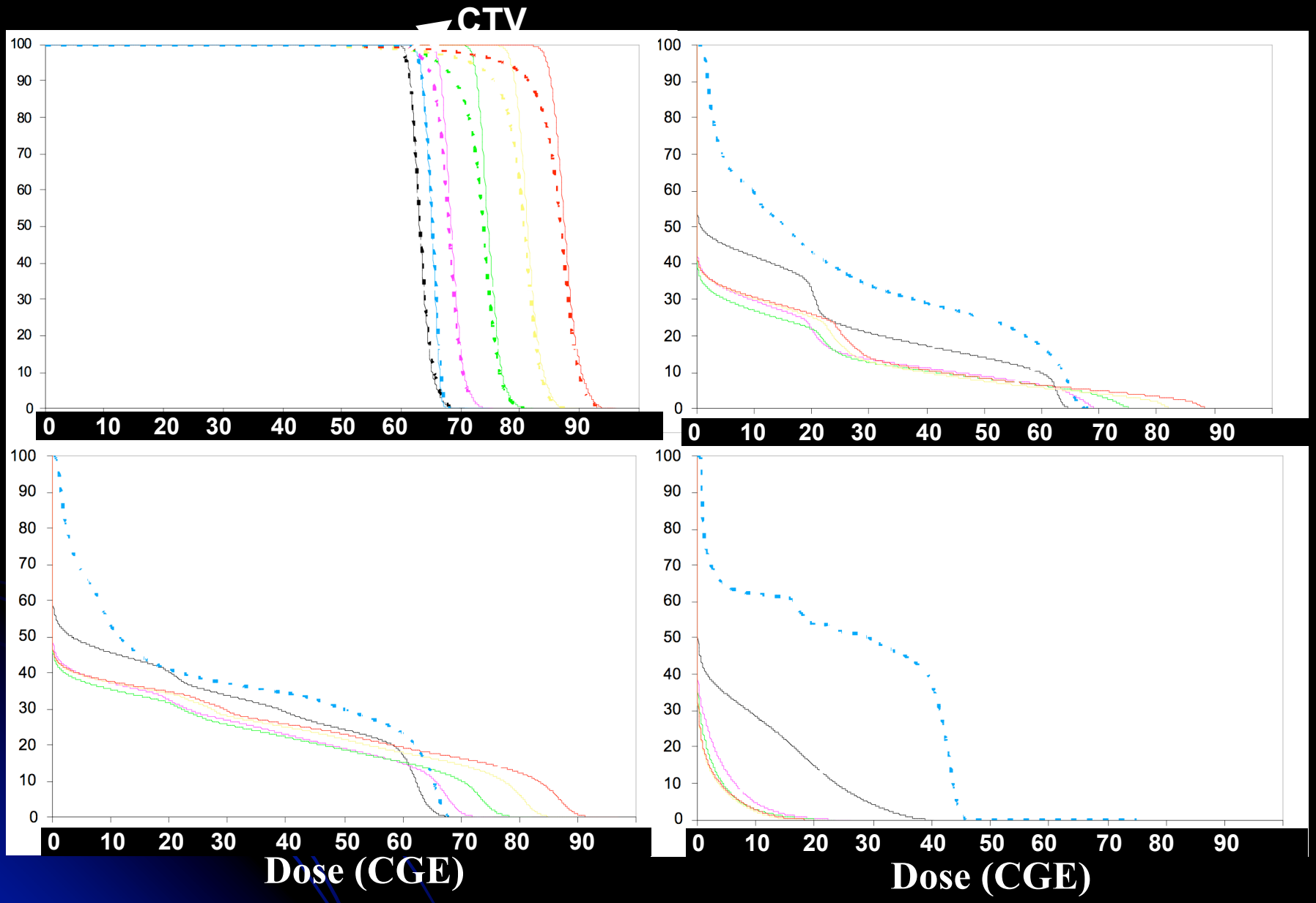


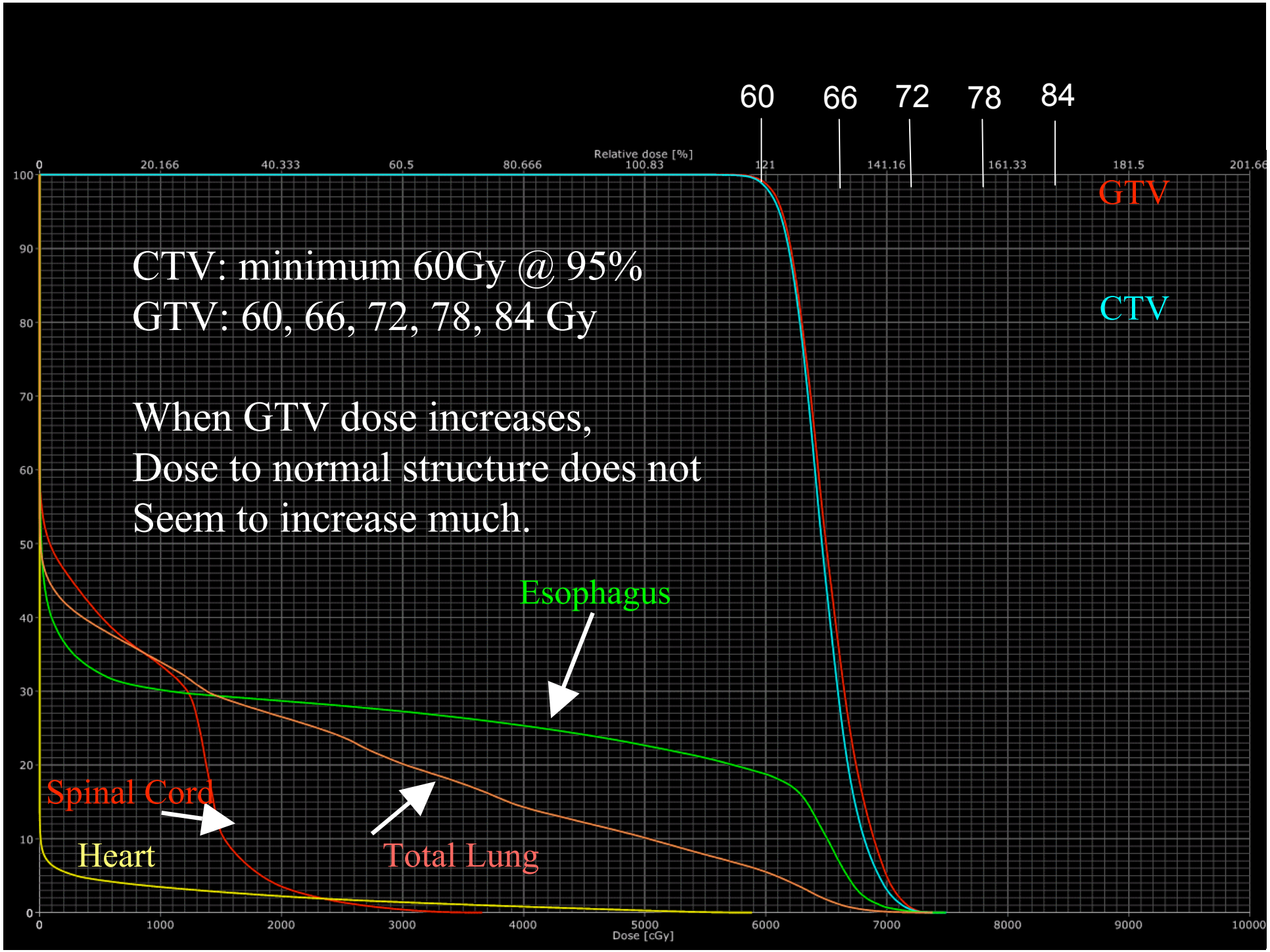
Lateral Profile

14 Stage-III NSCLC cases

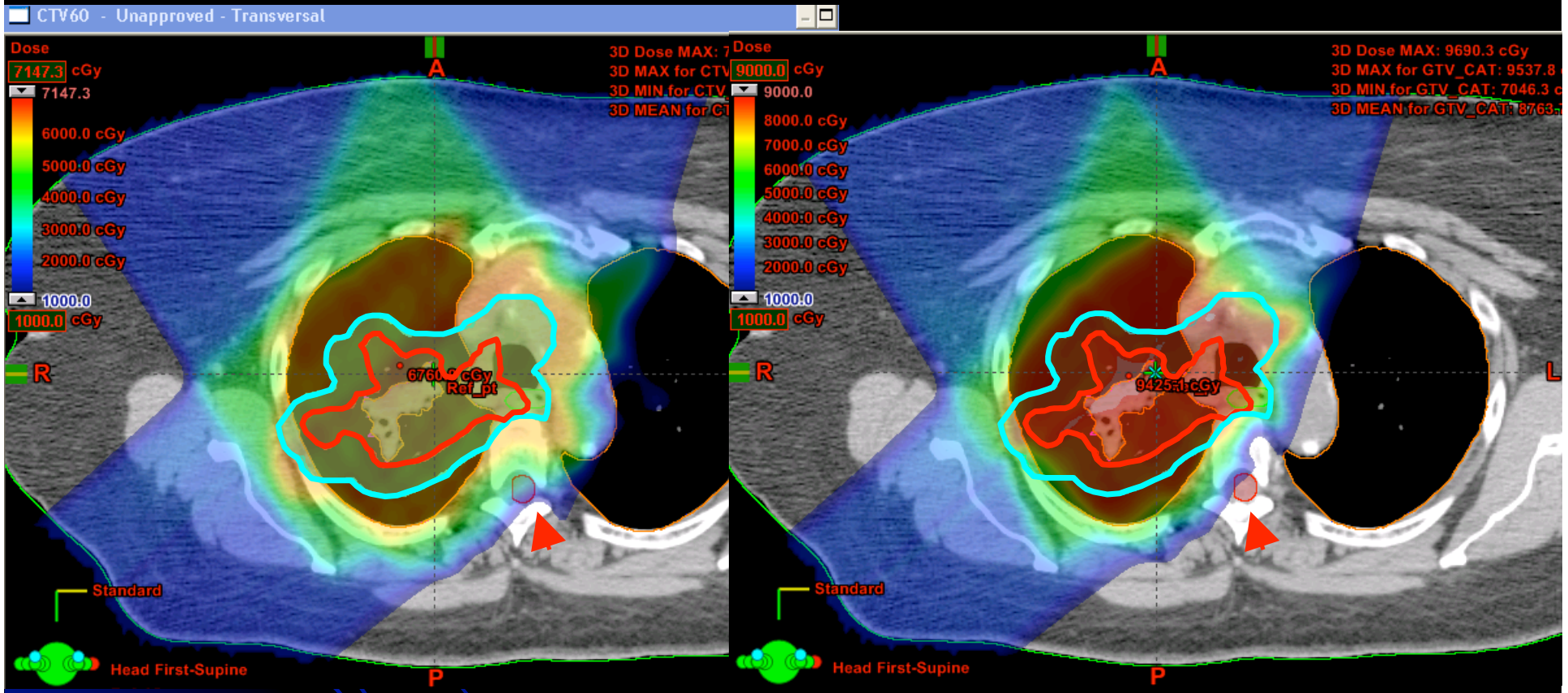
Results




CTV
100
90
80
70
60
50
40
30
20
10
0
0 10 20 30 40 50 60 70 80 90
Dose (CGE)
Dose (CGE)

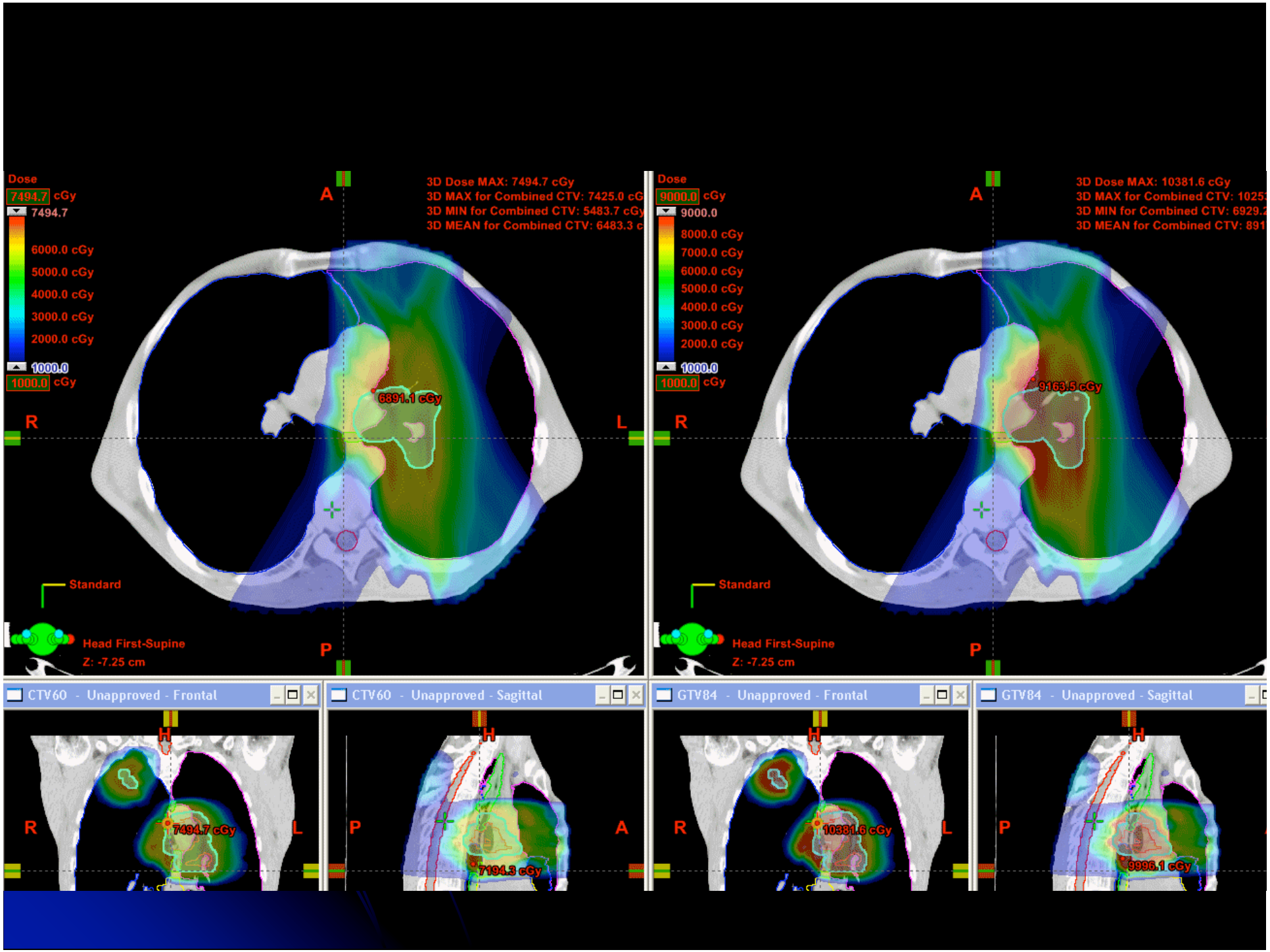

60
66
72
78
84
Relative dose [%]
0
20.166
40.333
60.5
80.666
100.83
121
141.16
161.33
181.5
201.66
GTV
CTV
CTV: minimum 60Gy @ 95%
GTV: 60, 66, 72, 78, 84 Gy
When GTV dose increases,
Dose to normal structure does not
Seem to increase much.
Esophagus
Spinal Cord
Heart
Total Lung
100
90
80
70
60
50
40
30
20
10
0
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
Dose [cGy]

60 Gy vs. 84 Gy

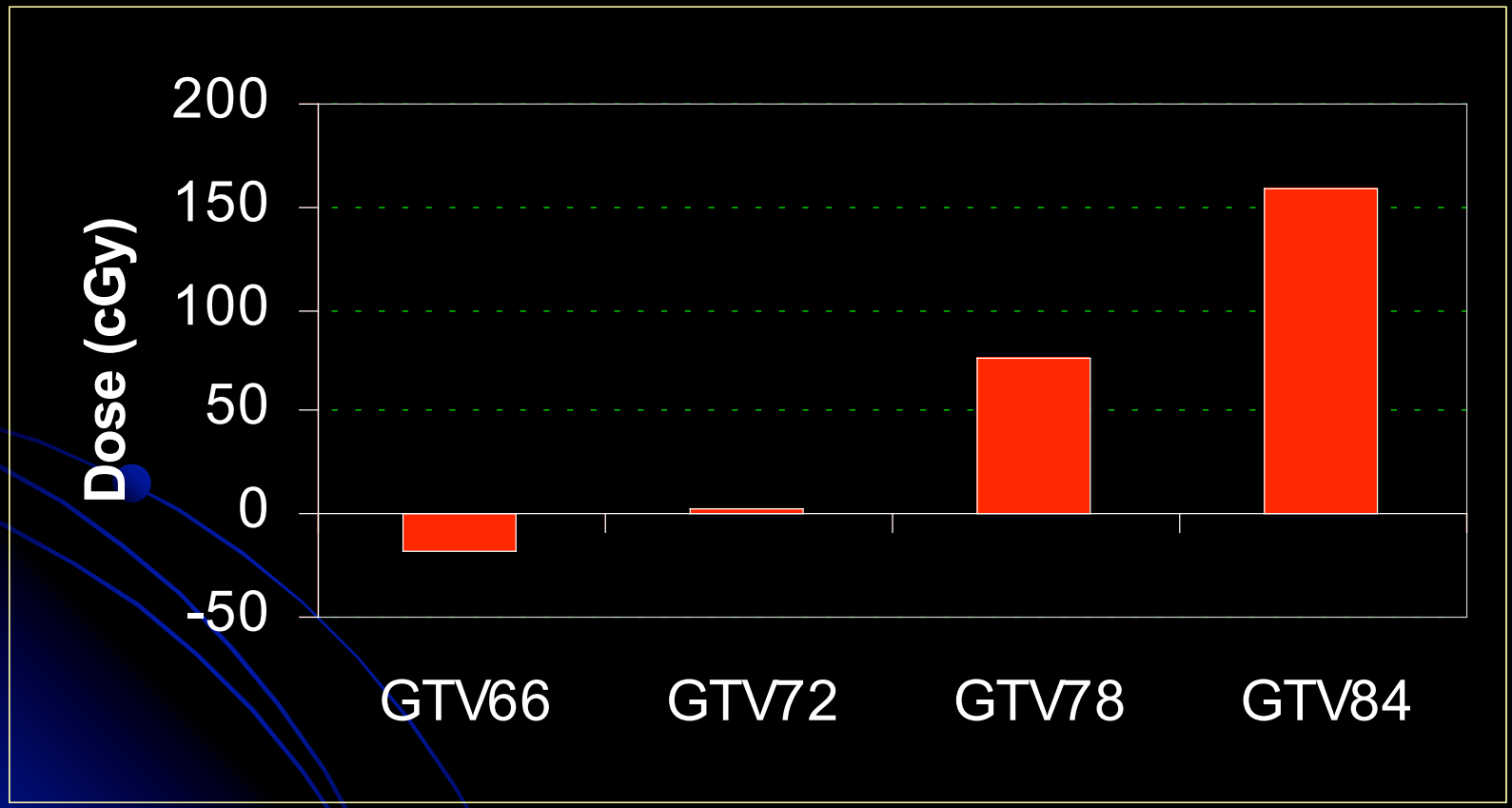


CTV and GTV at 60 Gy

CTV at 60 Gy and GTV at 84 Gy

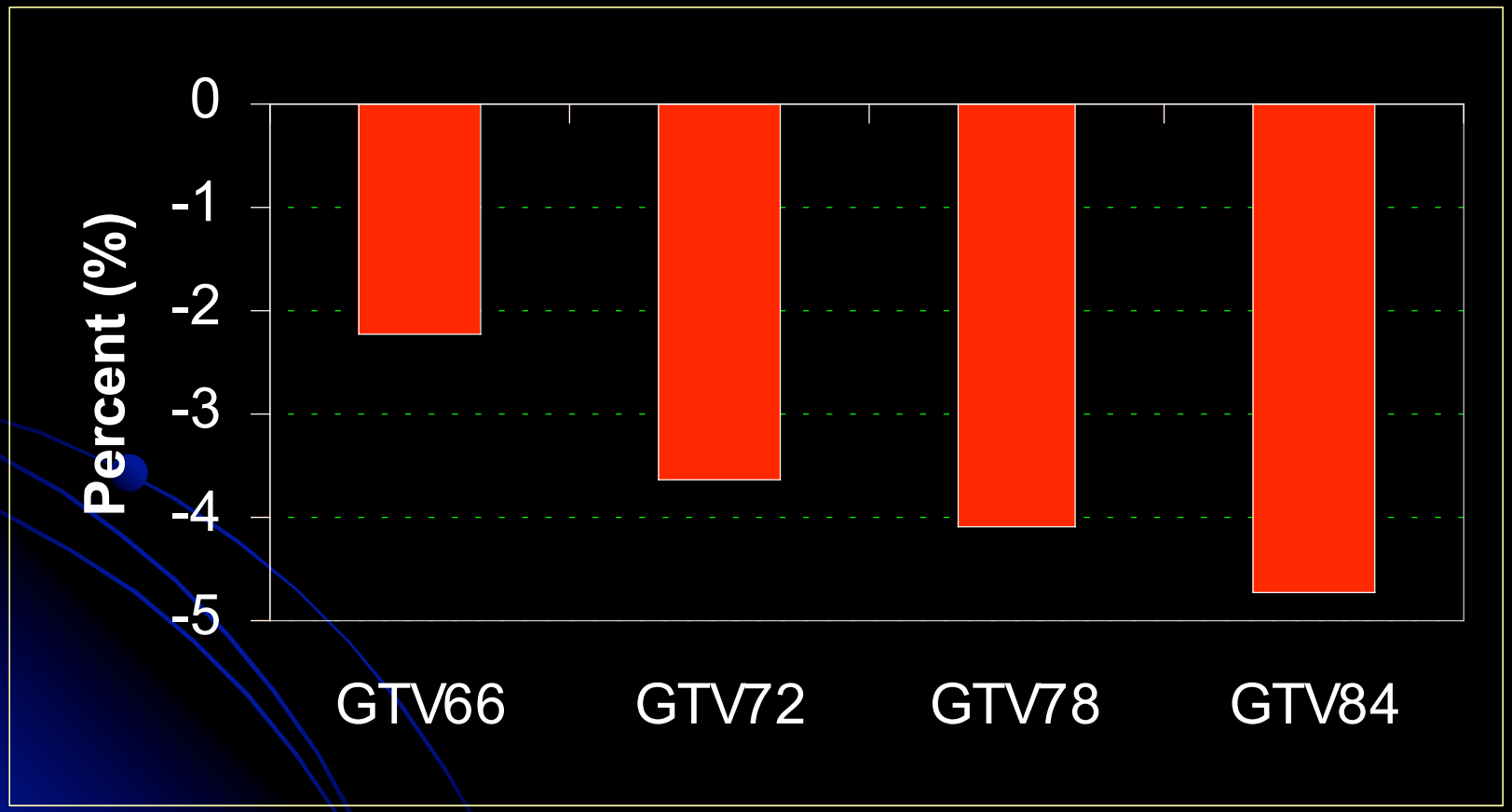

Dose
7494.7 cGy
7494.7
6000.0 cGy
5000.0 cGy
4000.0 cGy
3000.0 cGy
2000.0 cGy
1000.0
1000.0 cGy
3D Dose MAX: 7494.7 cGy
3D MAX for Combined CTV: 7425.0 cG
3D MIN for Combined CTV: 5483.7 cGy
3D MEAN for Combined CTV: 6483.3 c
A
R
L
P
6891.1 cGy
Standard
Head First-Supine
Z: -7.25 cm
Dose
9000.0 cGy
9000.0
8000.0 cGy
7000.0 cGy
6000.0 cGy
5000.0 cGy
4000.0 cGy
3000.0 cGy
2000.0 cGy
1000.0
1000.0 cGy
3D Dose MAX: 10381.6 cGy
3D MAX for Combined CTV: 1025
3D MIN for Combined CTV: 6929.2
3D MEAN for Combined CTV: 891
A
R
P
9163.5 cGy
Standard
Head First-Supine
Z: -7.25 cm
CTV60 - Unapproved - Frontal
H
R
L
7494.7 cGy
CTV60 - Unapproved - Sagittal
H
P
A
7194.3 cGy
GTV84 - Unapproved - Frontal
H
R
L
10381.6 cGy
GTV84 - Unapproved - Sagittal
H
P
9996.1 cGy

Mean Lung Dose Difference (Relative To the CTV60 Plan)

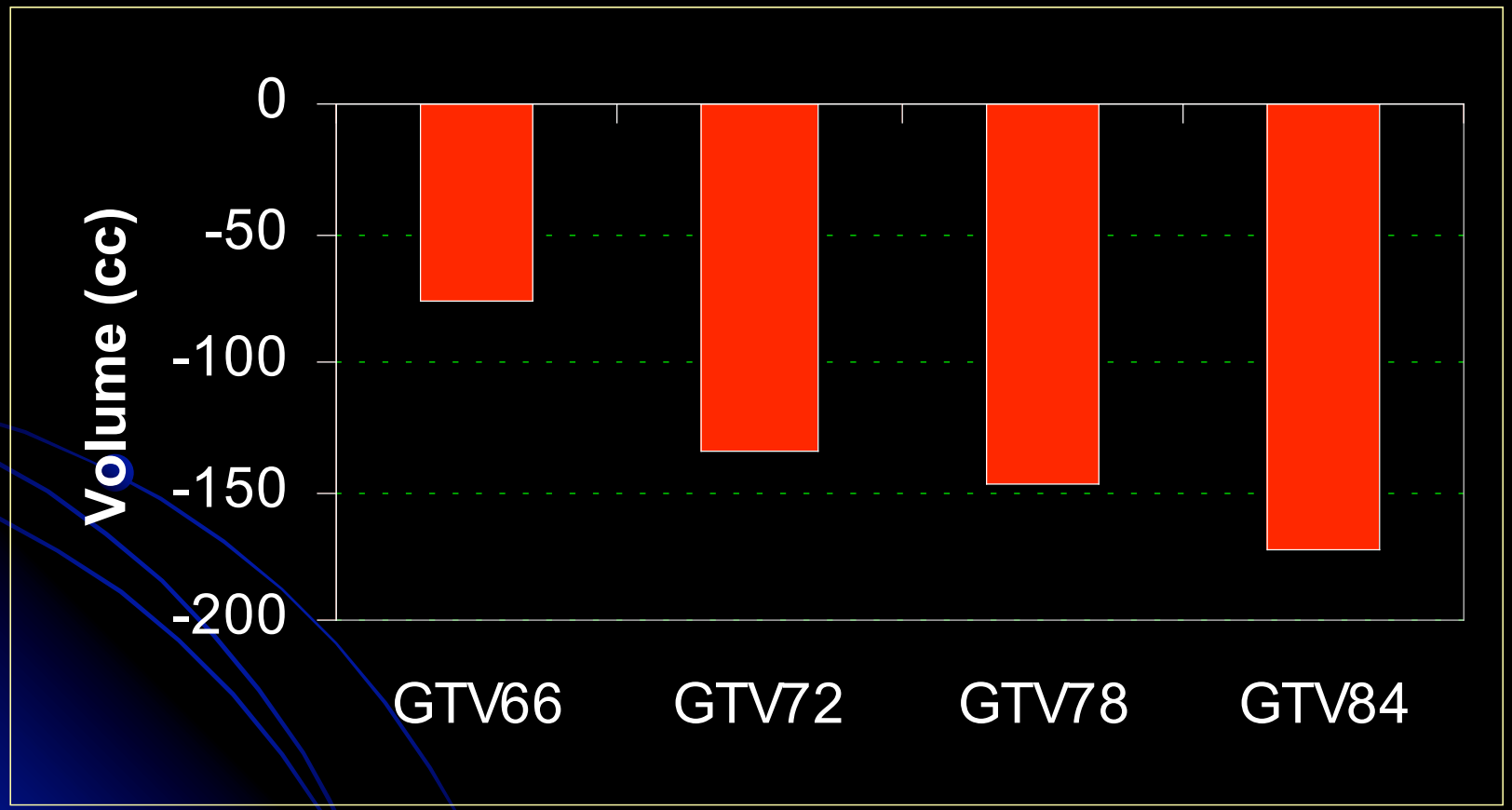


Average Over 14 cases

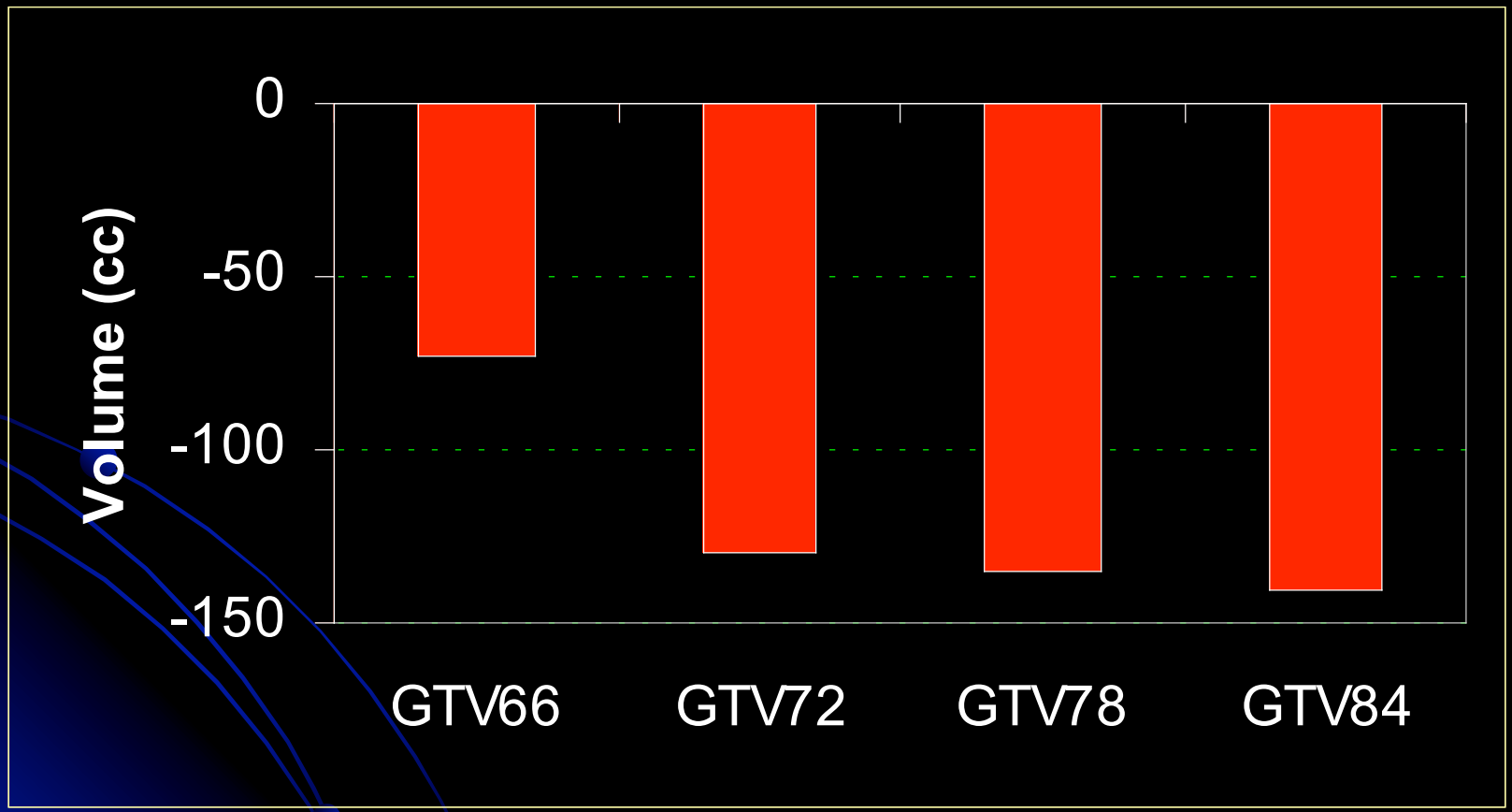
%Total Lung Volume at 5 Gy Relative To CTV60 Plan



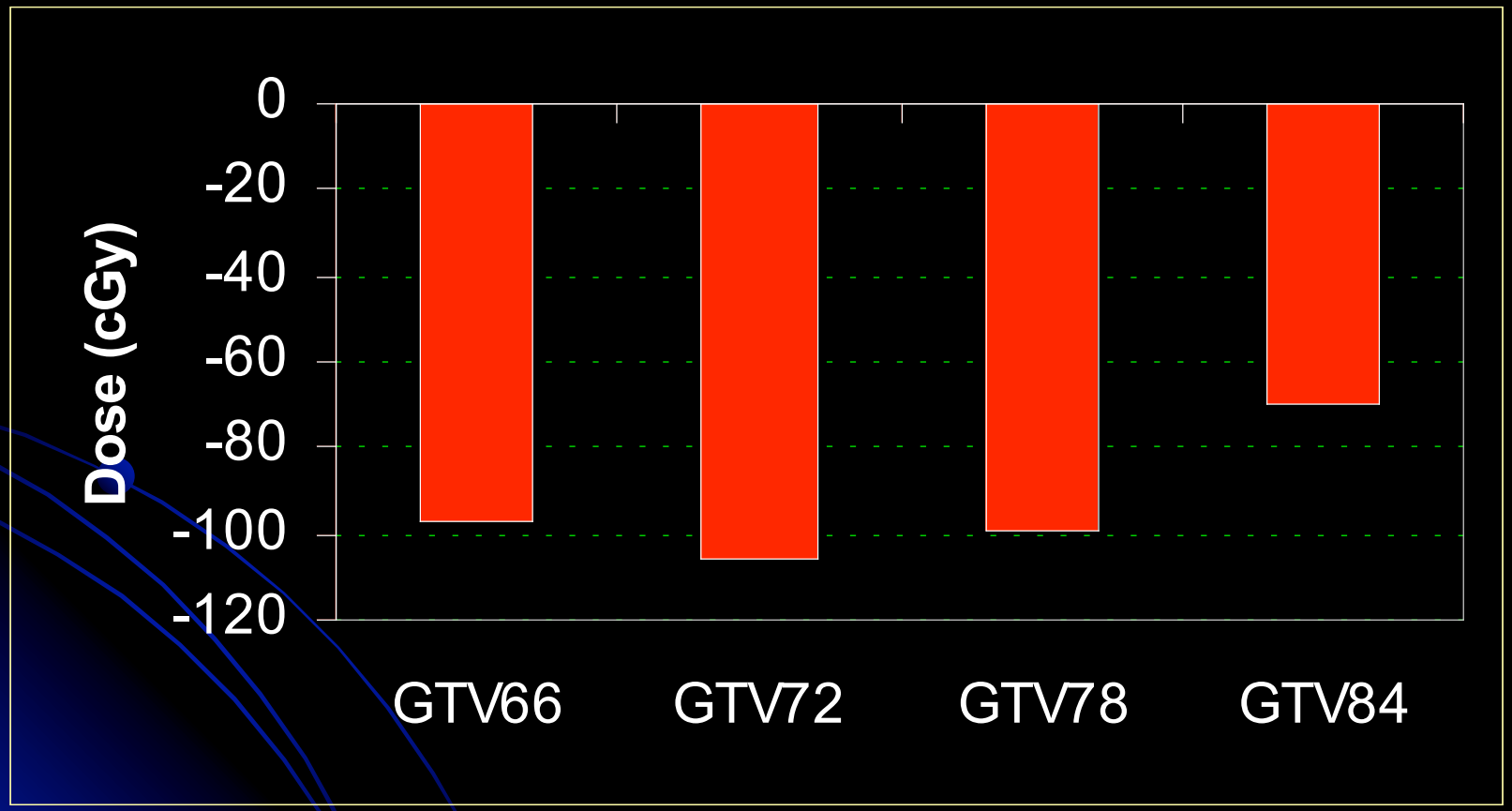
Absolute Lung Volume Difference at 5 Gy



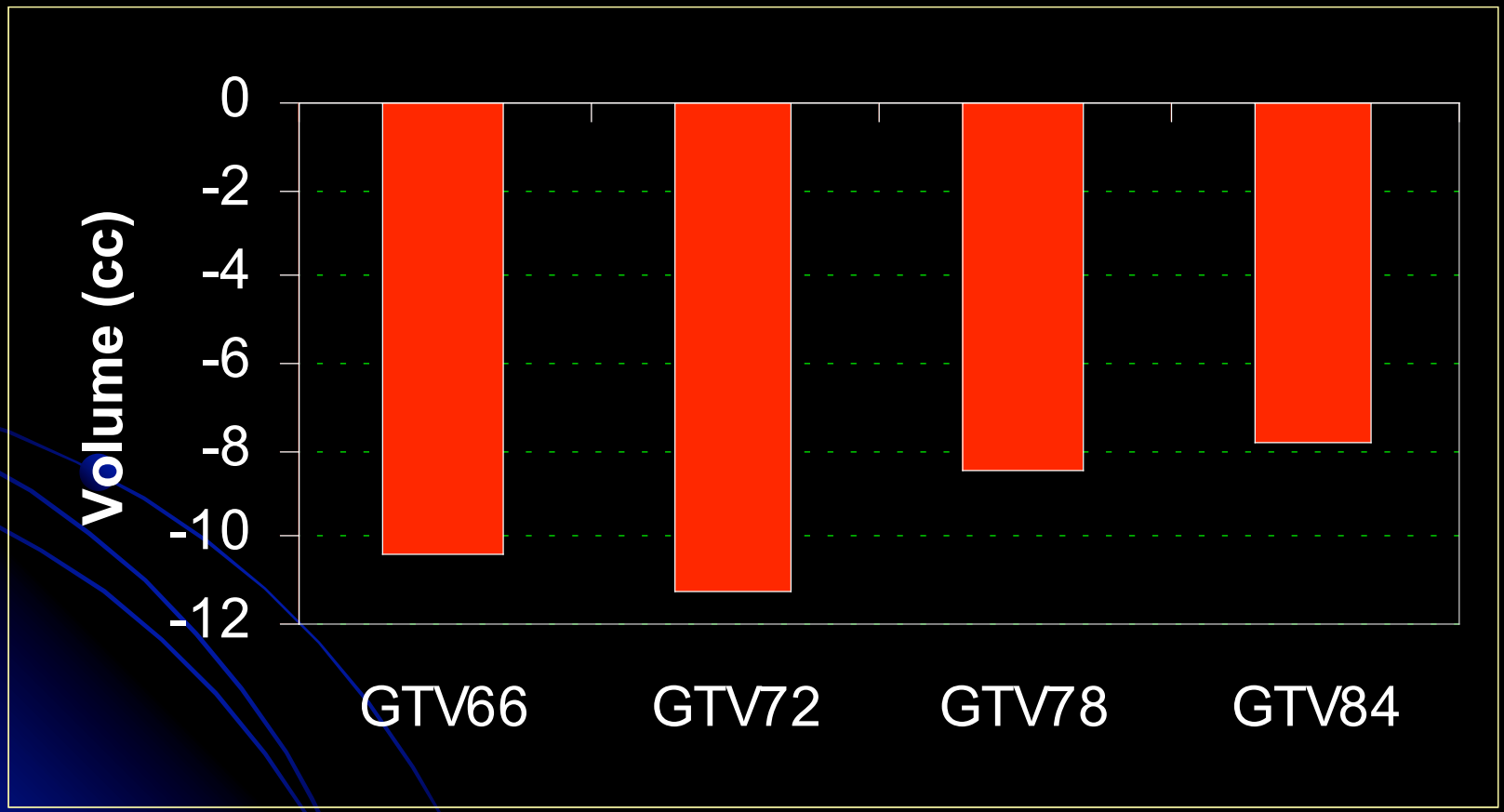
Absolute Lung Volume Difference at 10 Gy



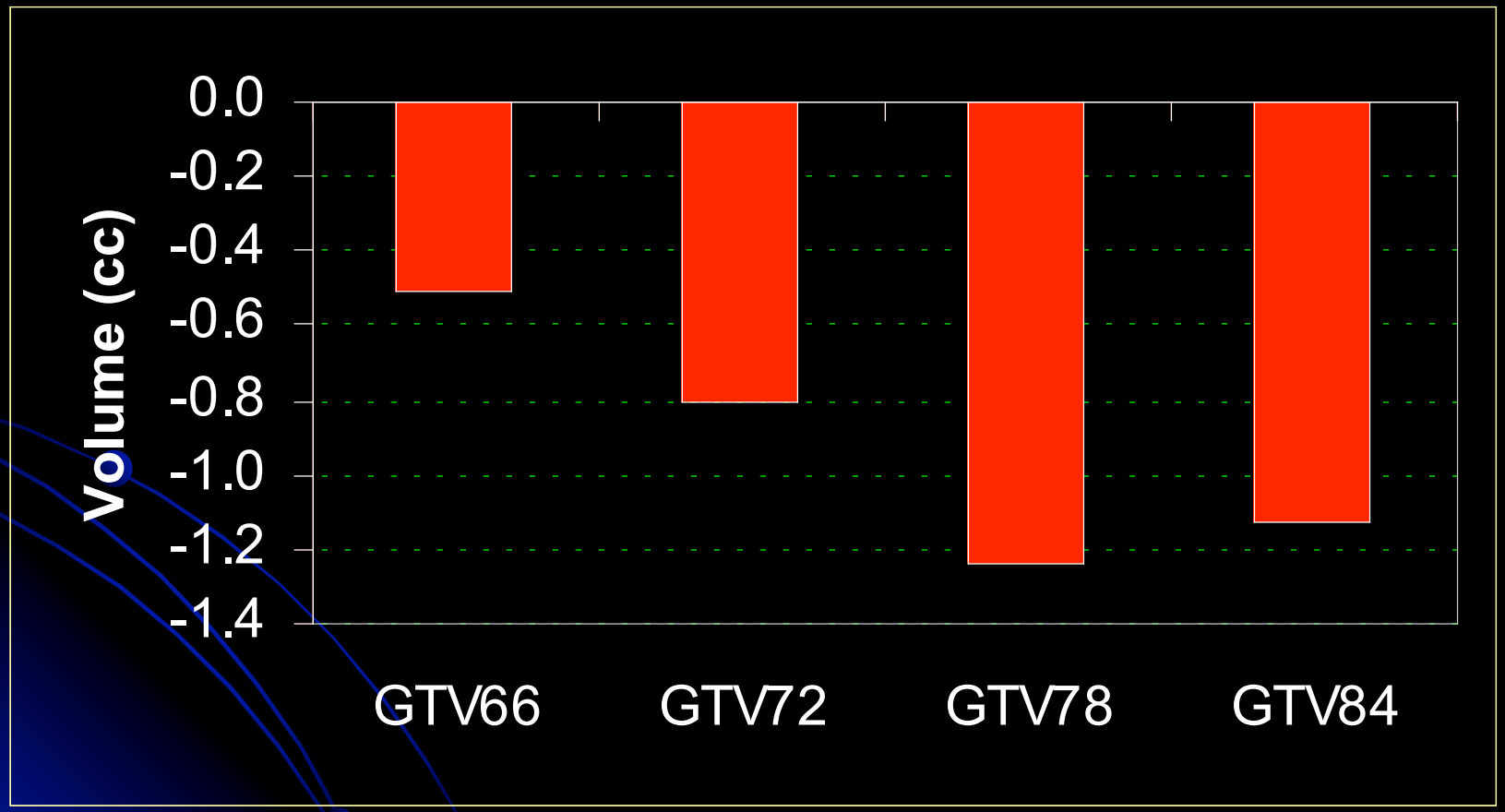
Mean Heart Dose Difference



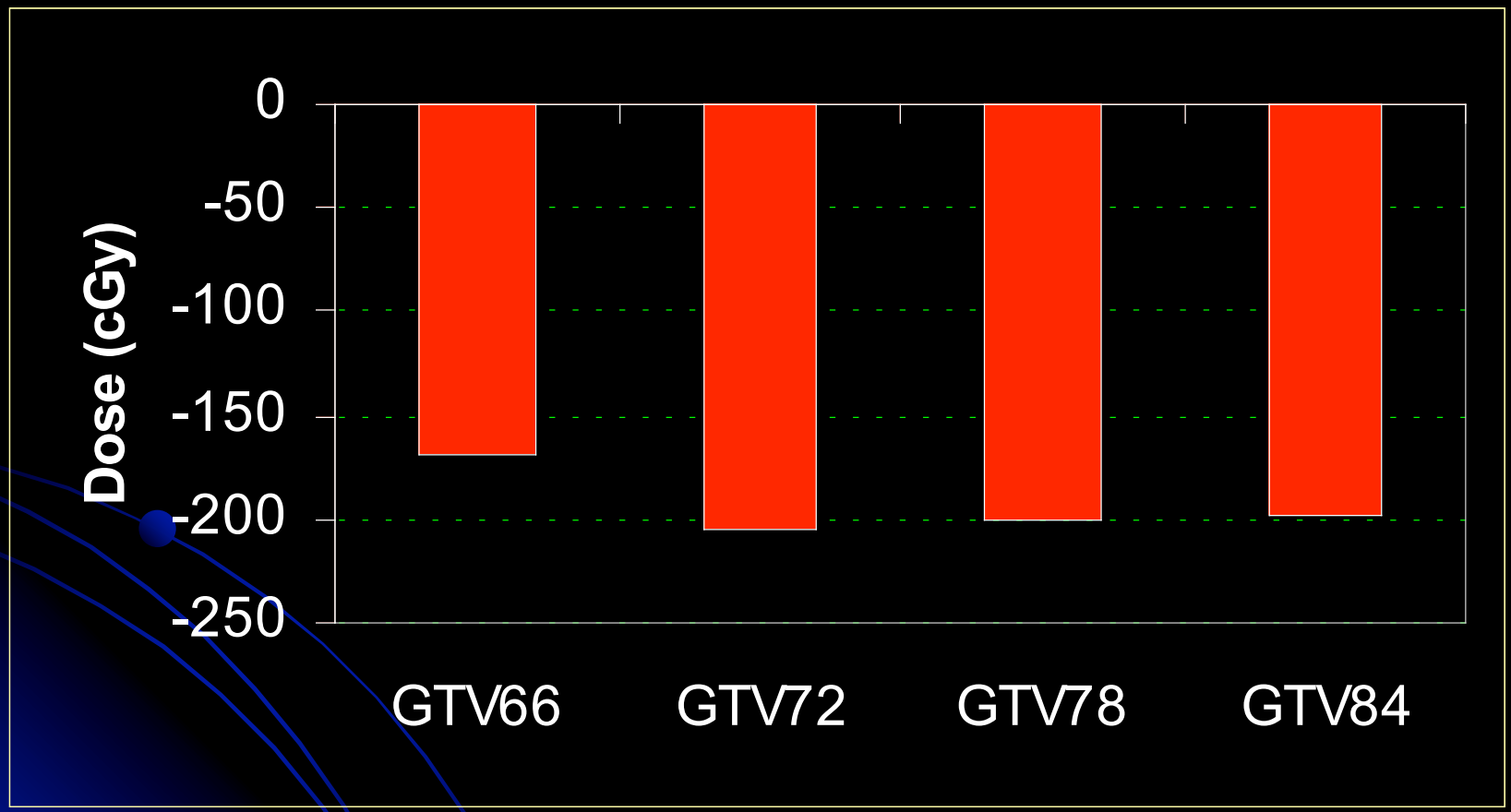
Volume of Heart > 40 Gy



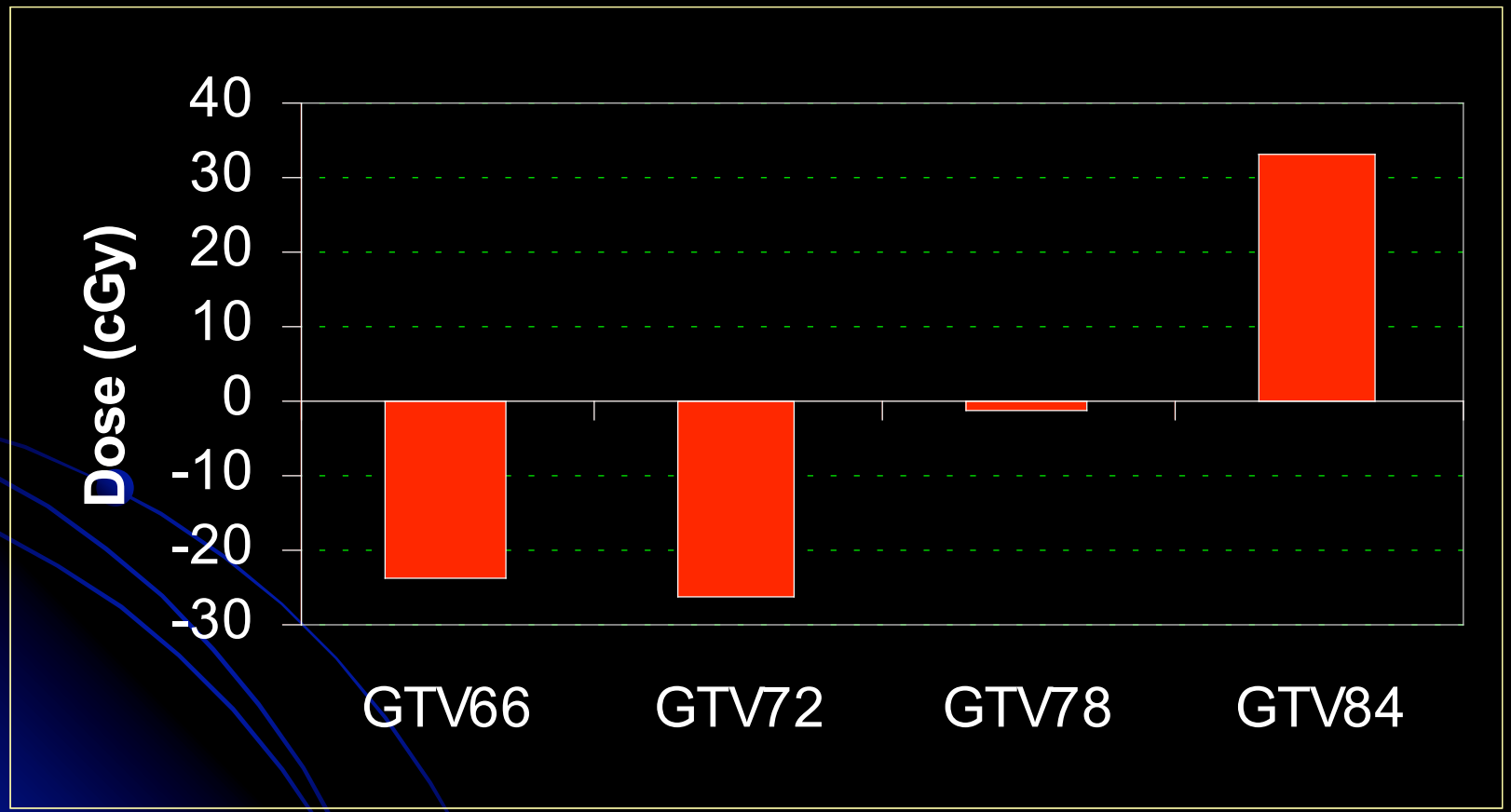
Absolute Esophagus Volume > 50 Gy



Maximum Cord Dose



Mean Body Dose



Conclusion

- Simultaneous In-field Boost (PSIB) technique is feasible with passively scattered protons.
  - Maybe a good application for lung cancer treatment.
- The method takes the advantage of a slowly-falling proximal SOBP dose distribution and large lateral penumbra to create a non-uniform dose gradient between the GTV and the CTV.
- Normal tissue toxicities are essentially unchanged from a GTV boost from 60 CGE to 84 CGE.

Thank you!