Clinical Aspects of Medical Radiation Physics

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What is Medical Physics?

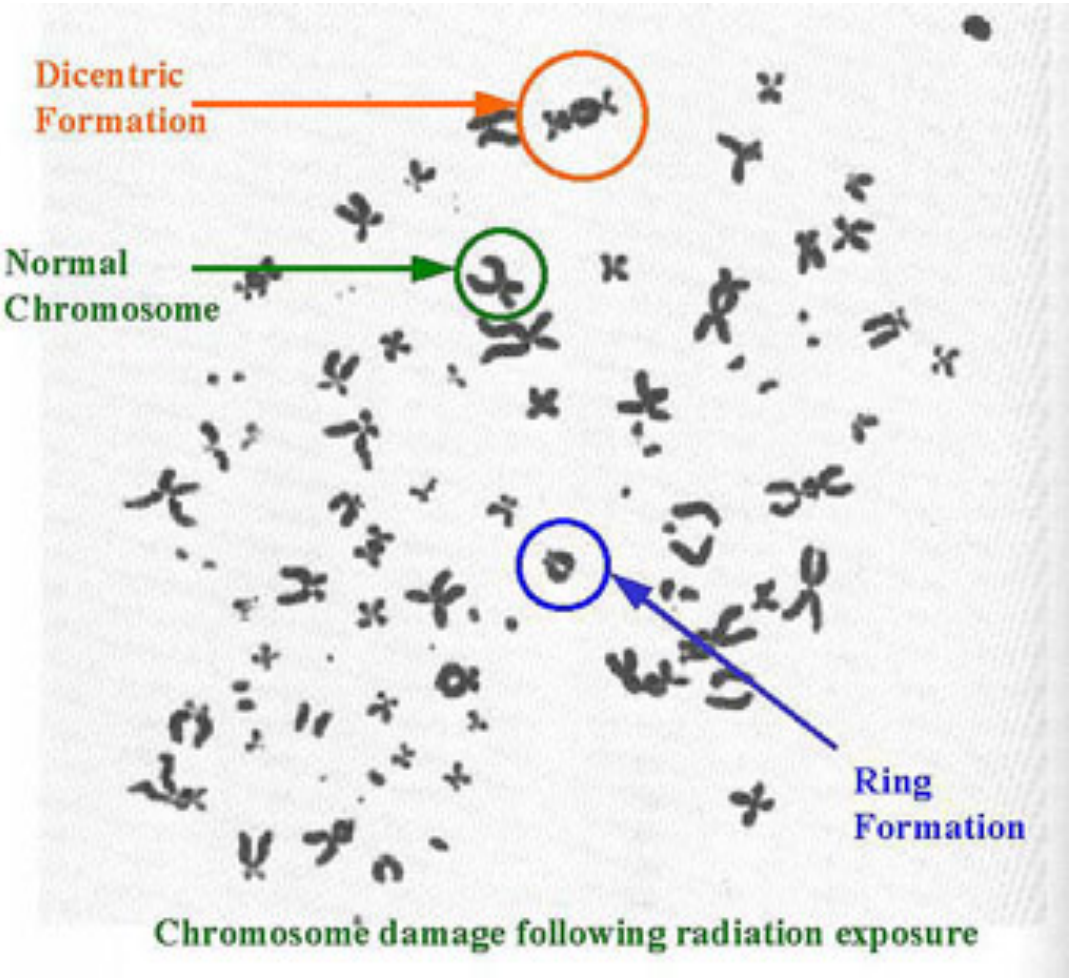
- A medical physicist is a professional who specializes in the application of the concepts and methods of physics to the diagnosis and treatment of human disease.

- Therapeutic Physics
- Diagnostic Physics
- Nuclear Physics
- Medical Health Physics

Therapeutic Radiological Physics

- The therapeutic applications of x-ray, gamma ray, neutron, electron, and charged particle beams, and radiation from sealed radionuclide sources.
- The equipment associated with their production, use, measurement and evaluation. The quality of images resulting from their production and use.
- Medical Health Physics

Cell Killing By Ionizing Radiation

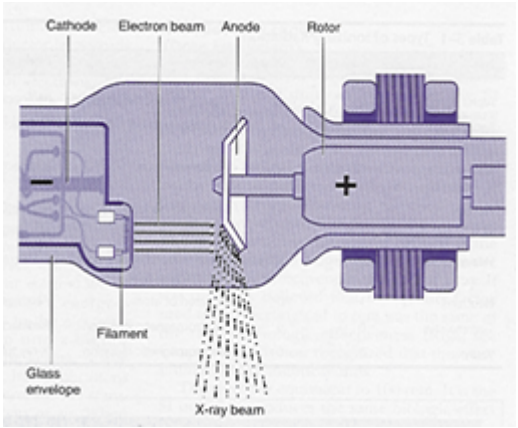


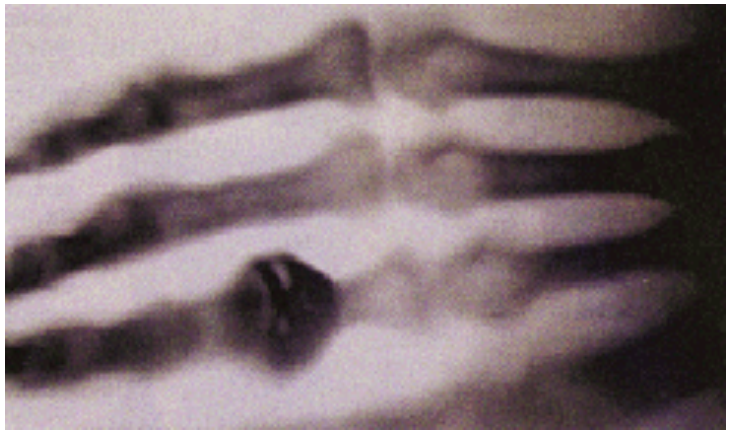
Diagnostic Radiological Physics

- The diagnostic applications of x-rays, gamma rays from sealed sources, ultrasonic radiation, and radio frequency radiation and magnetic fields.
- The equipment association with their production, use, measurement and evaluation.
- The quality of images resulting from their production and use.
- Medical Health Physics

Discovery of X-rays

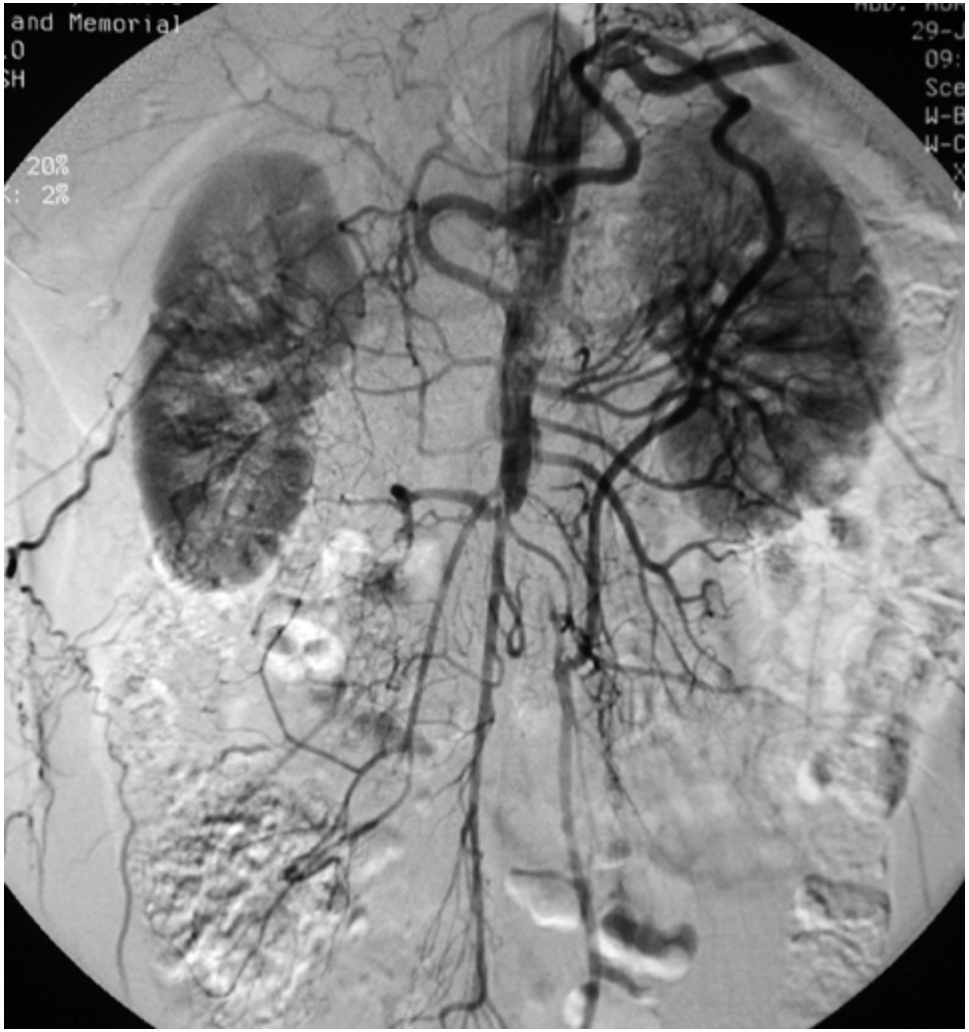
- On 8 Nov 1895, Wilhelm Conrad Röntgen (accidentally) discovered an image cast from his cathode ray genera





Diagnostics

- X-ray Machines
- Fluoroscopy
- Computerized Tomography-CT Scanner
- Magnetic Resonance Imager- MRI
- MR Spectroscopy
- Positron Emission-PET Scanner
- CT-PET Scanner

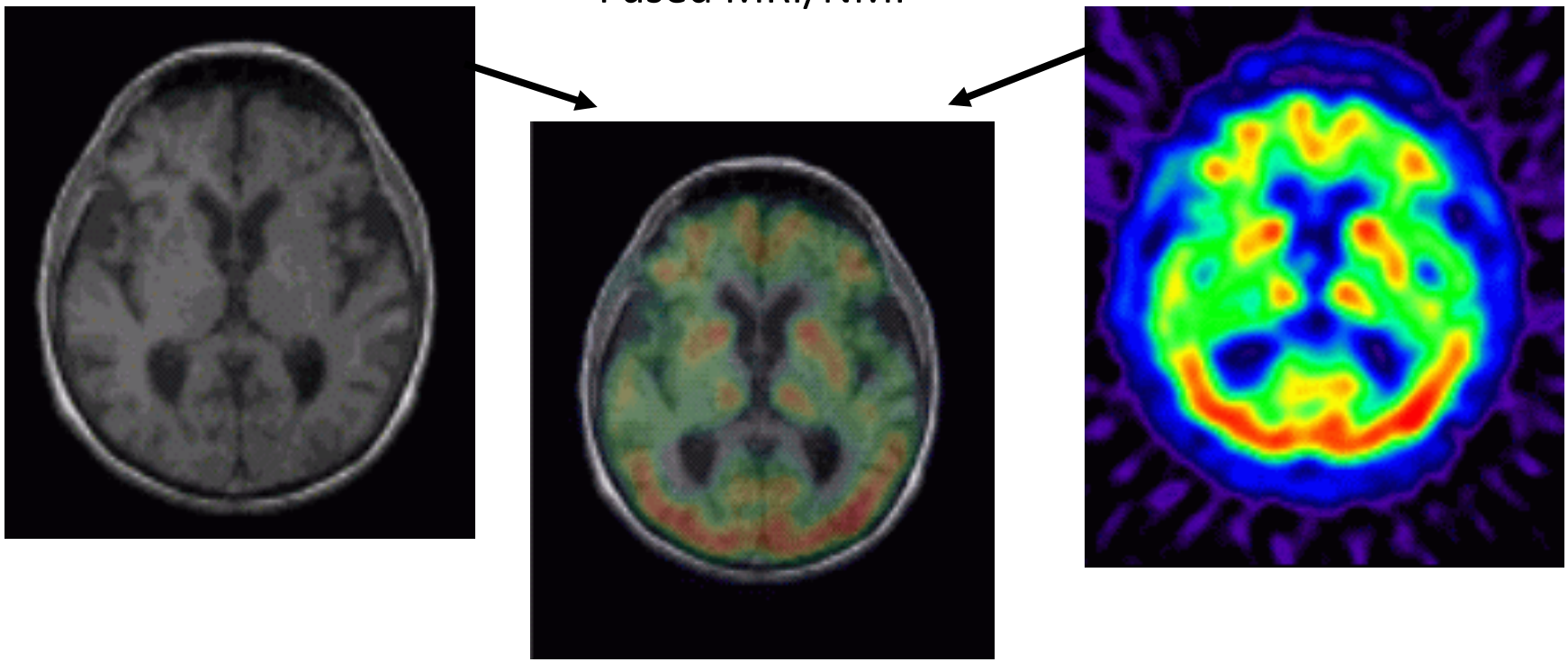


Medical Nuclear Physics

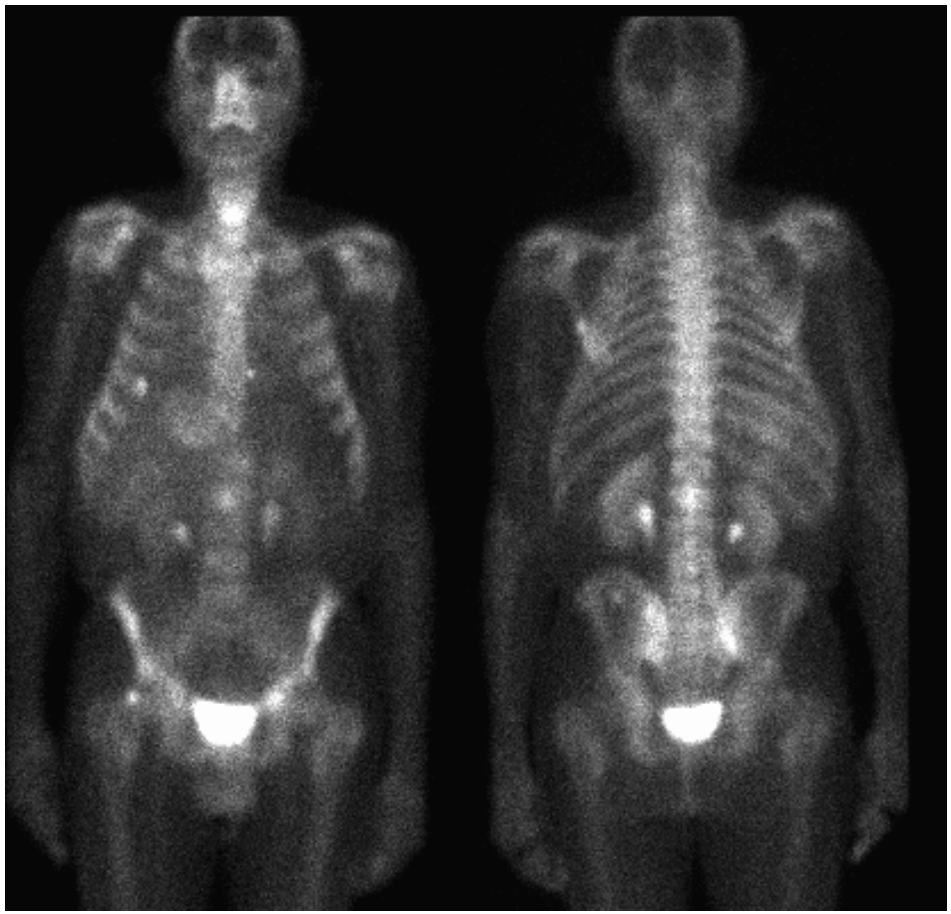
- The therapeutic and diagnostic applications of radionuclides in unsealed sources
- The equipment association with their production, use, measurement, and evaluation.
- The quality of images resulting from their production and use.
- Medical Health Physics

Nuclear Medicine

- Radioactive Materials injected or ingested
- Radioactivity yields images of function
  - Fused MRI/NMI



Gamma Camera Scan



Medical Health Physics

- The safe use of x-ray, gamma ray, neutron, electron and other charged particle beams or radionuclides in medicine (for diagnostic or therapeutic purposes).
- The instrumentation required to perform appropriate radiation surveys.
- Radiation Safety Officer

Emergency Management of Radiation Casualties

CONTAMINATED AREA

Radiation Exposure/Contamination

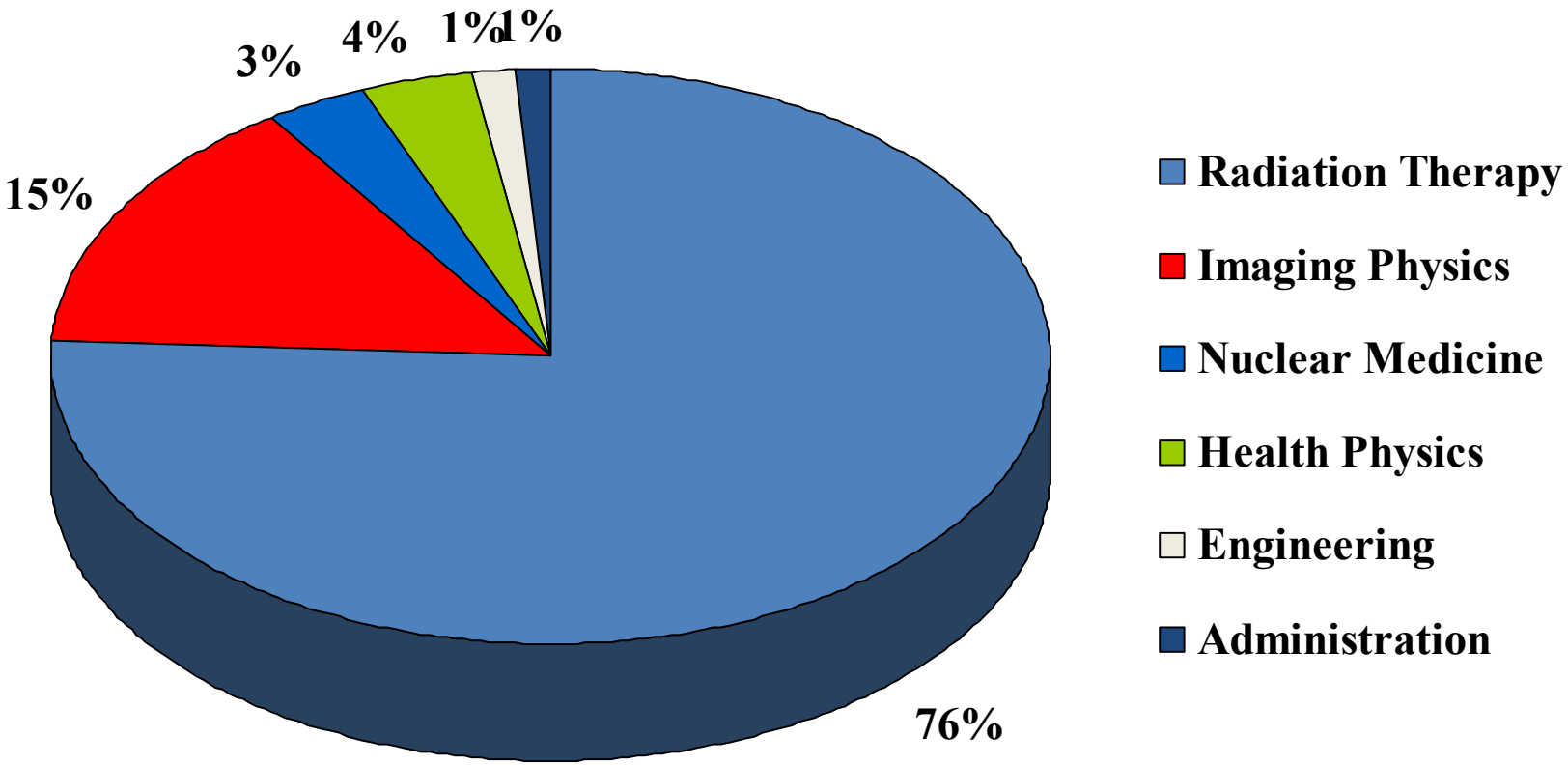
- Accidents
- Nuclear reactor
- Industrial irradiator
- Lost/stolen sources
- Transportation
- Medical radiation
- Terrorist Event

Radiation Doses and Dose Limits

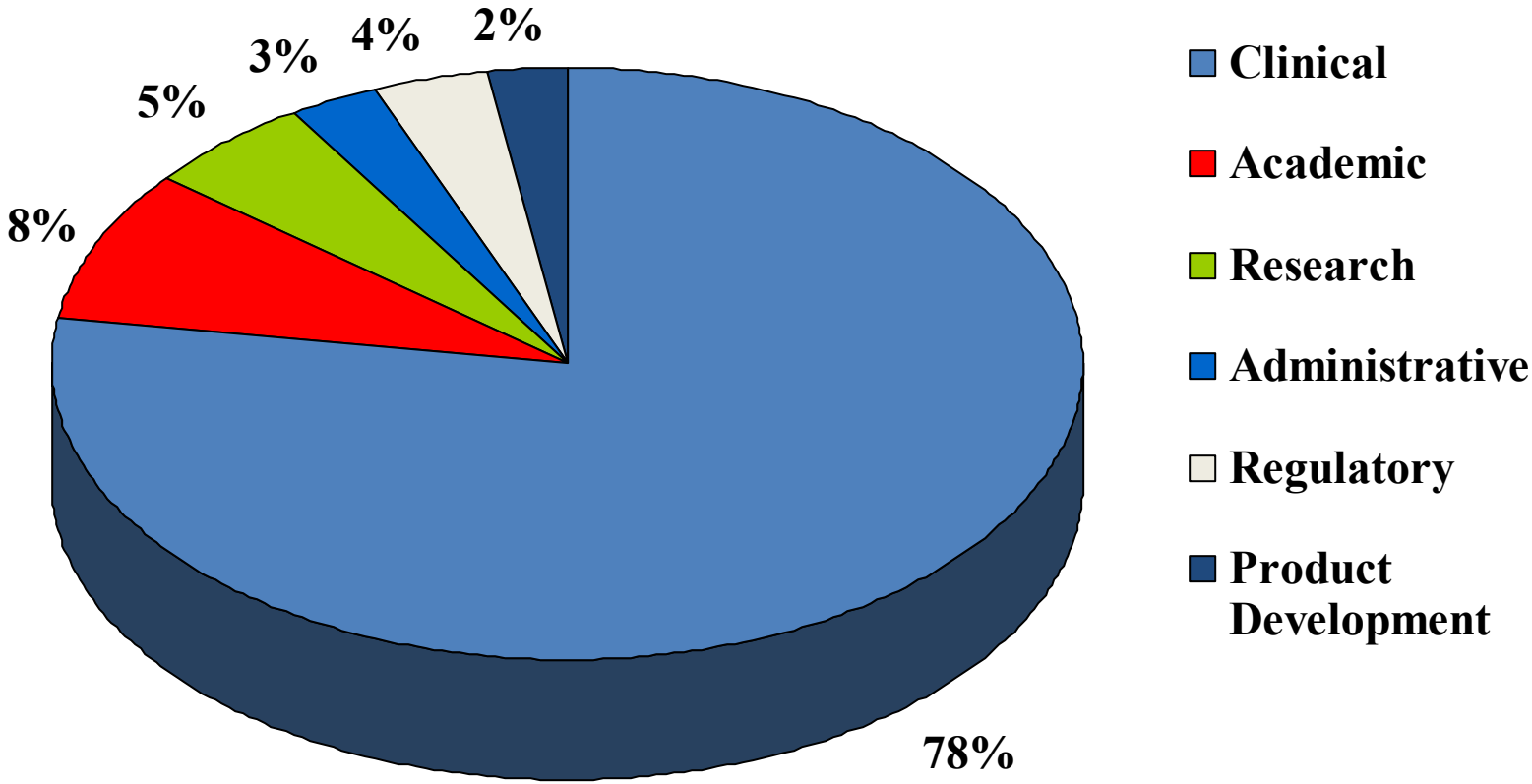
- Flights—LA to London 5 mrem
- Annual Public dose limit 100 mrem
- Natural Background annual 300 mrem

- Heart Catherization, Barium enema, Chest X-ray, fetal dose limit, radiation worker limit…
- Governs worker safety, patient safety, staff safety, general public safety

Primary Discipline



Primary Responsibility



Clinical Responsibilities

- Daily clinical support
- Equipment acquisitions
- Site planning
- Quality assurance-d-w-m-a
- Dose calculations
- Liaison between other medical professionals, manufacturers, regulatory agencies
- Development, investigate, scientific research

Professional Training

- MS or PhD in Medical Physics
- MS or PhD in physics or related discipline with post-graduate academic training in medical physics

CLINICAL TRAINING

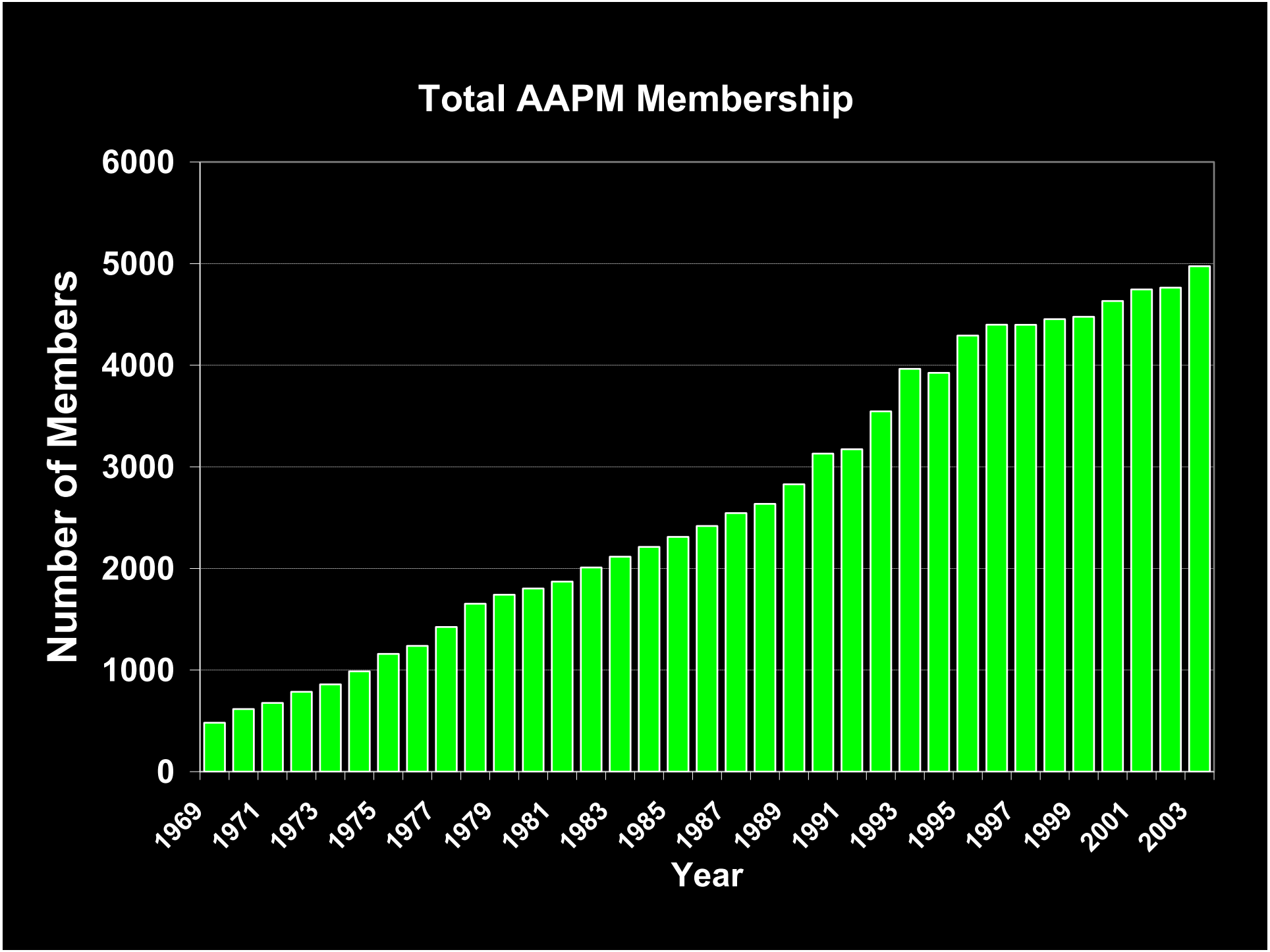
- Residency in clinical medical physics-CAMPEP

BOARD ELIGIBILITY 2014

- Must have CAMPEP approved residency

LSU Medical Physics Program

- Phys.lsu.edu
  - Medical Physics & Health Physics Program
  - Graduate Program
  - CAMPEP Accredited
  - Curriculum-Health Physics or Medical Physics
- Marybird.org- Medical Physics Program
  - Graduate Training Program
  - Residency Training Program


Total AAPM Membership
Number of Members
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5000
4000
3000
2000
1000
0
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
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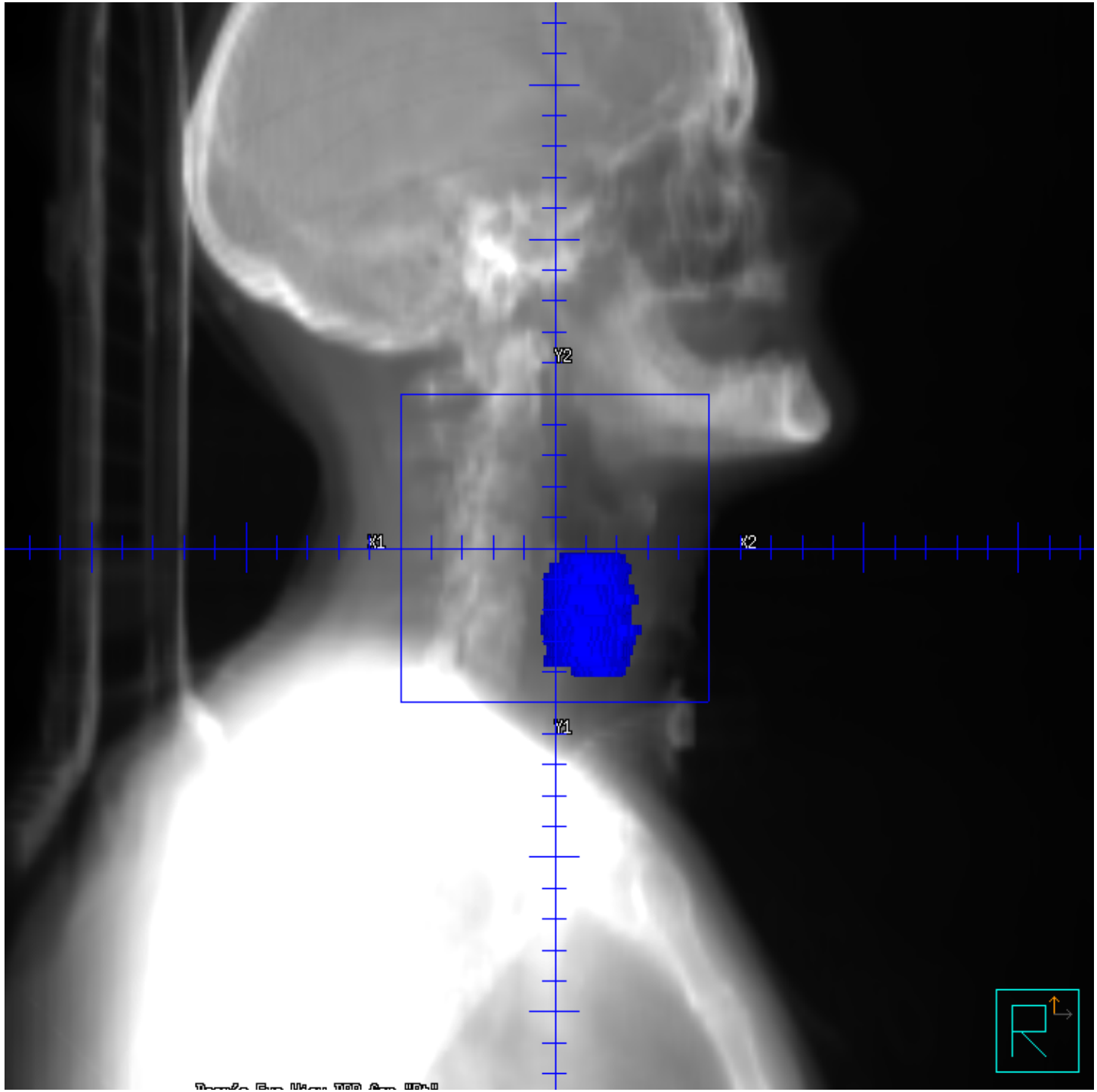
Year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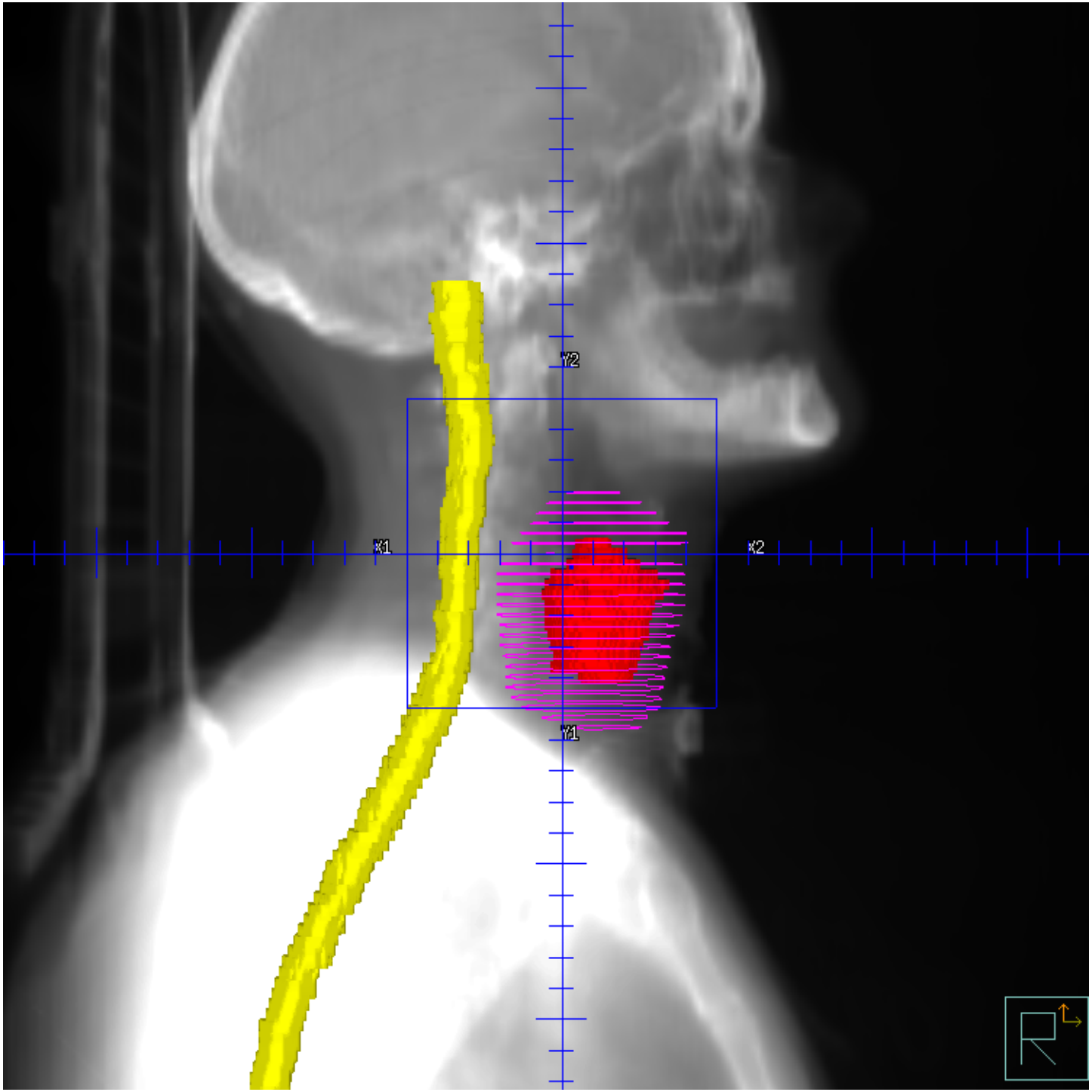
X1
X2
Y1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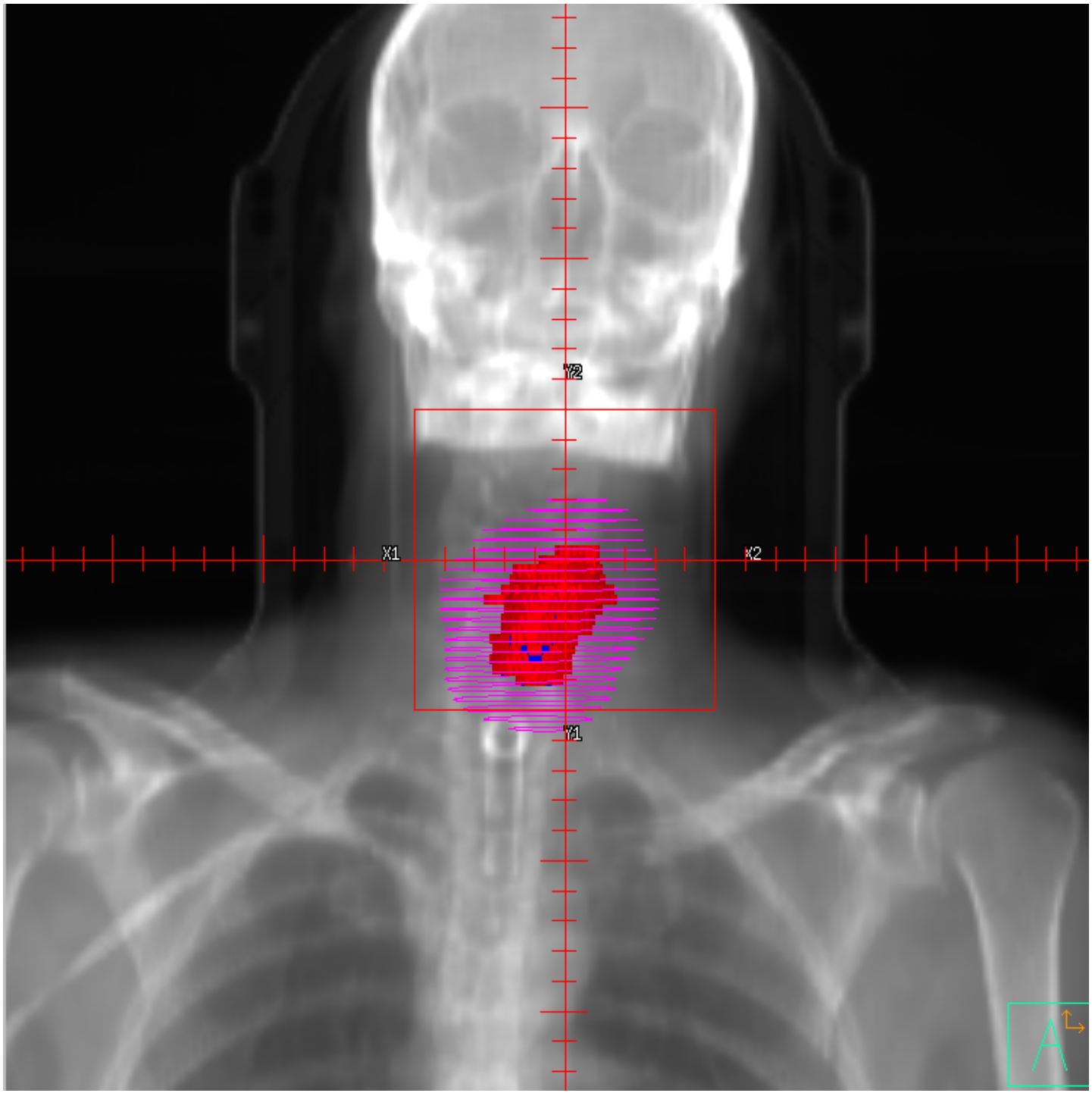
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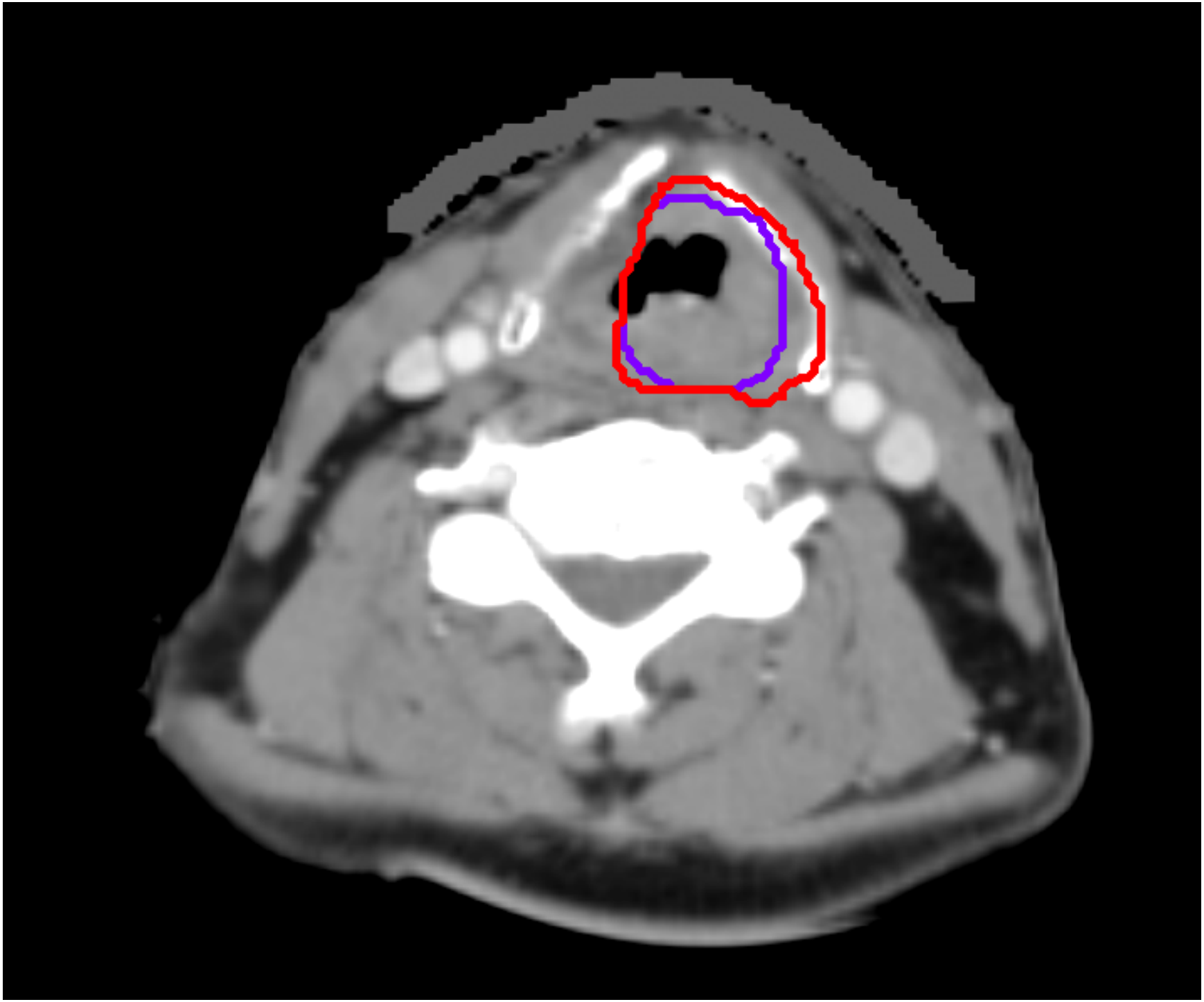

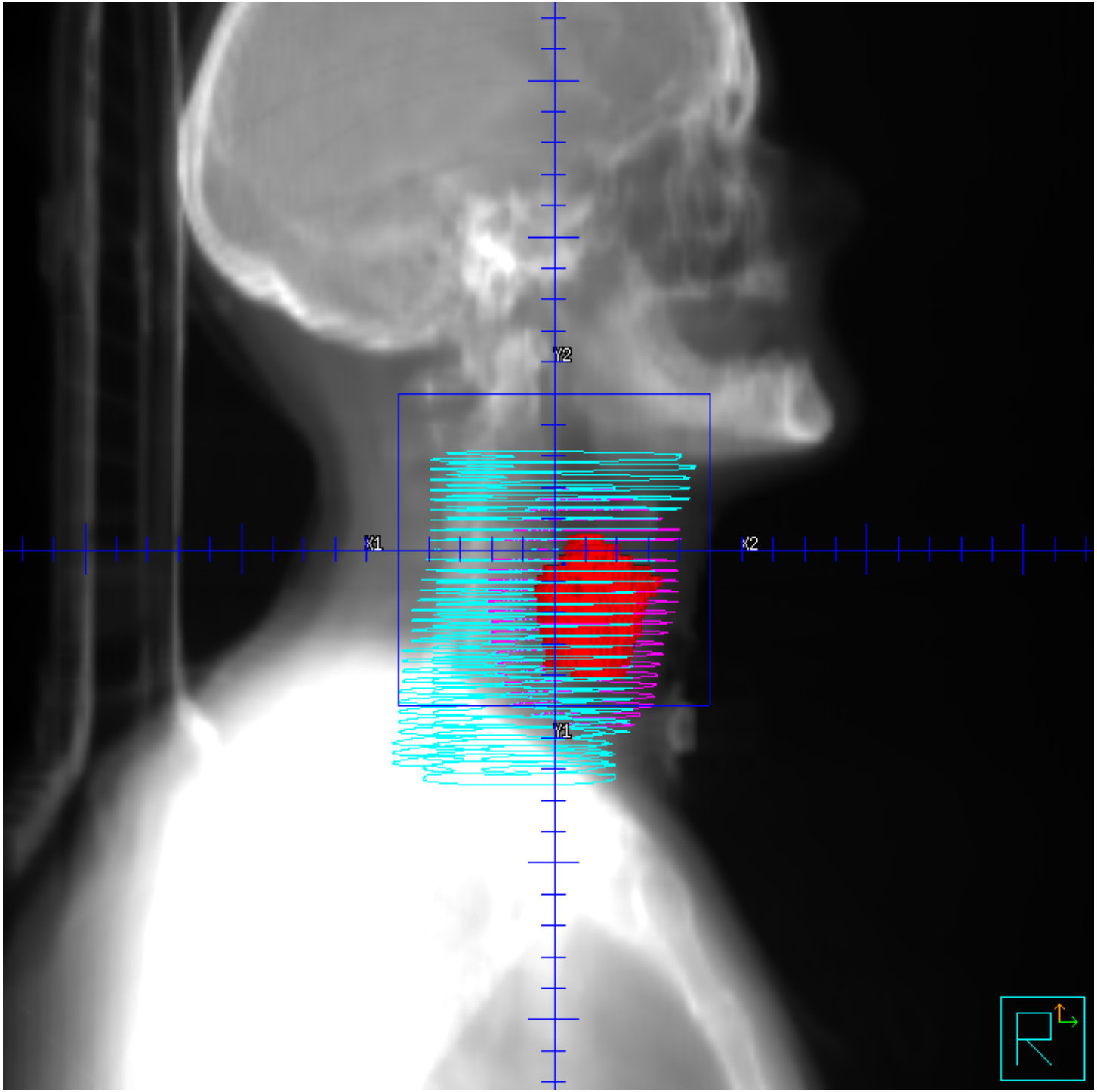
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X2
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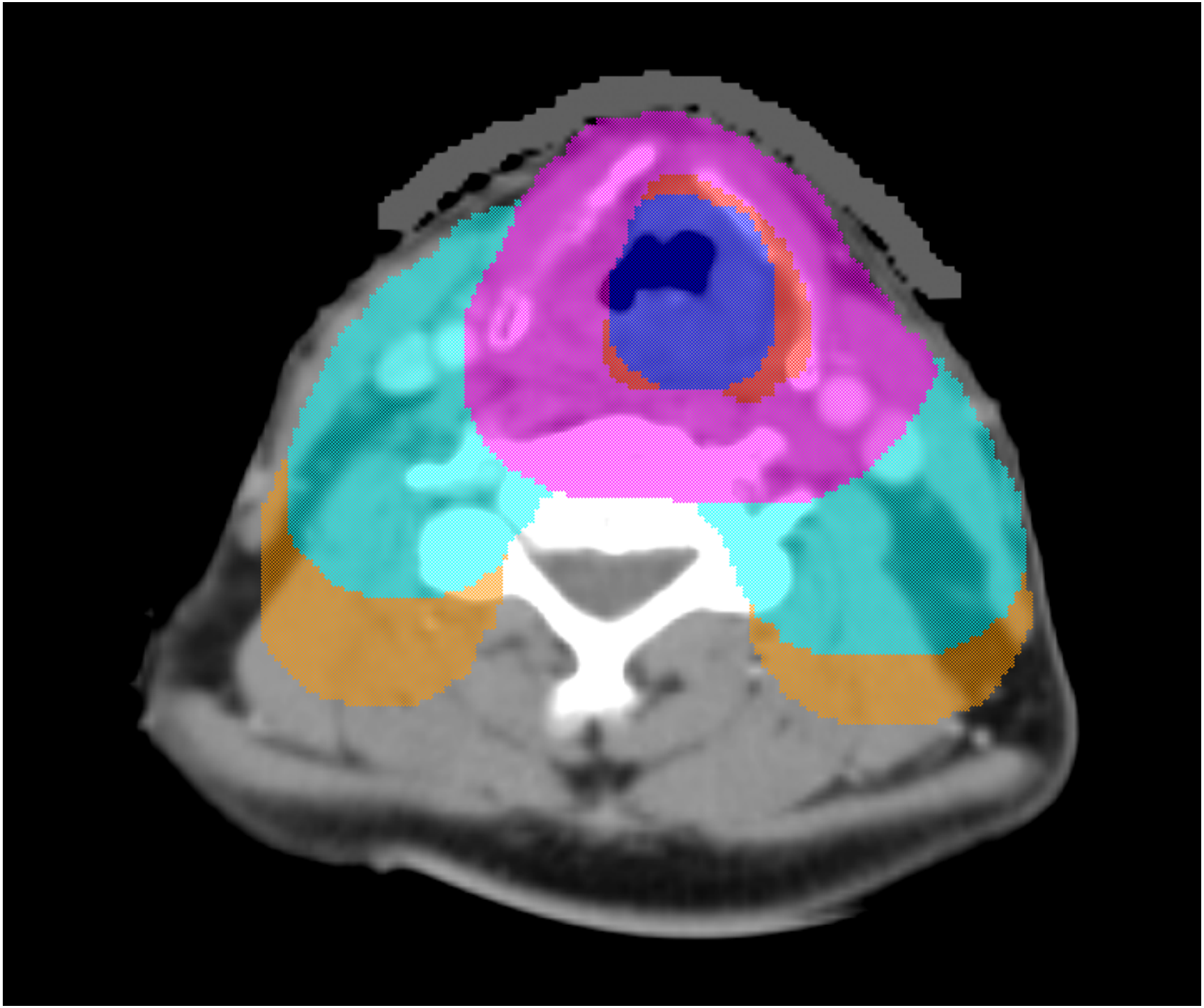
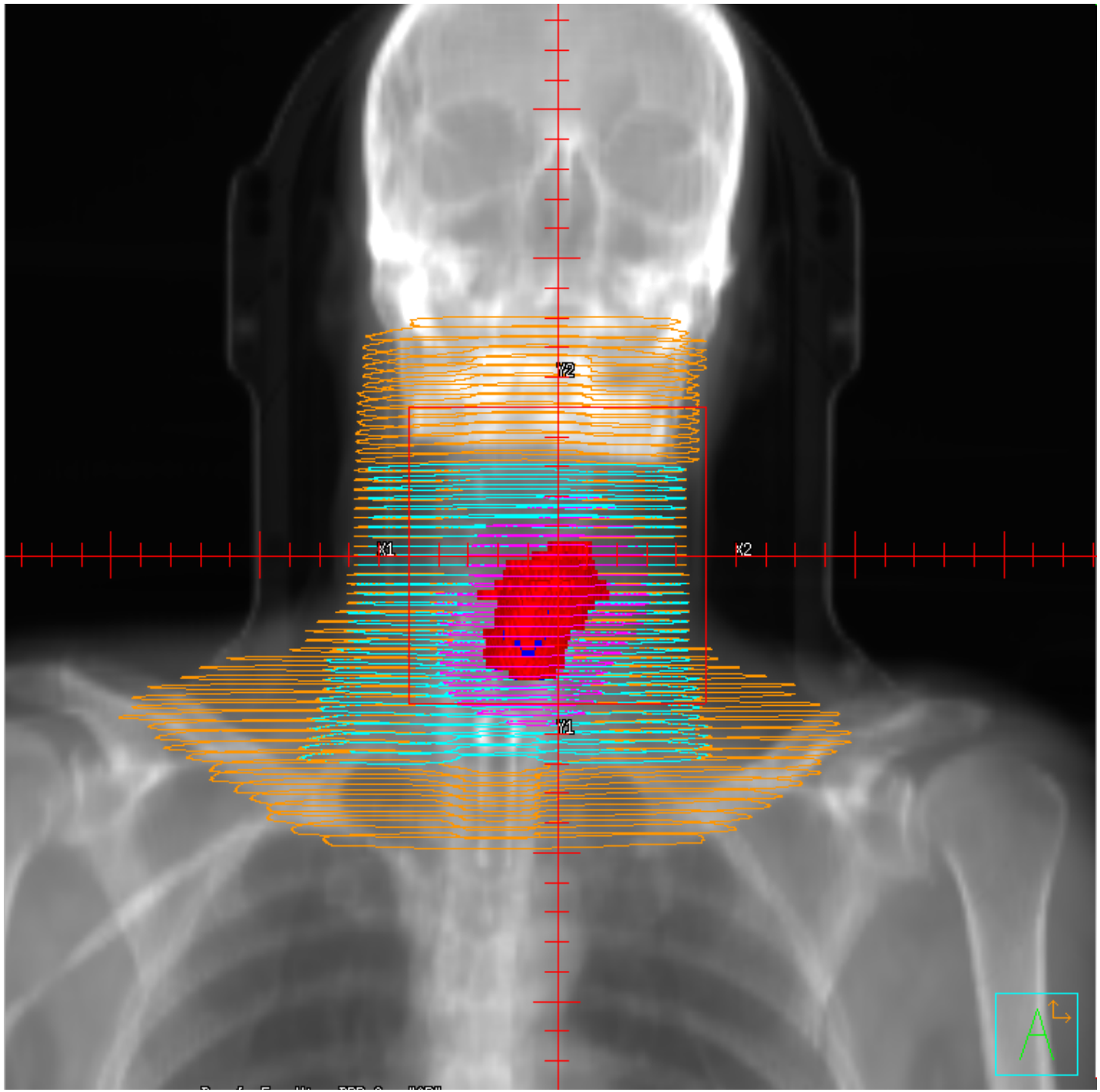
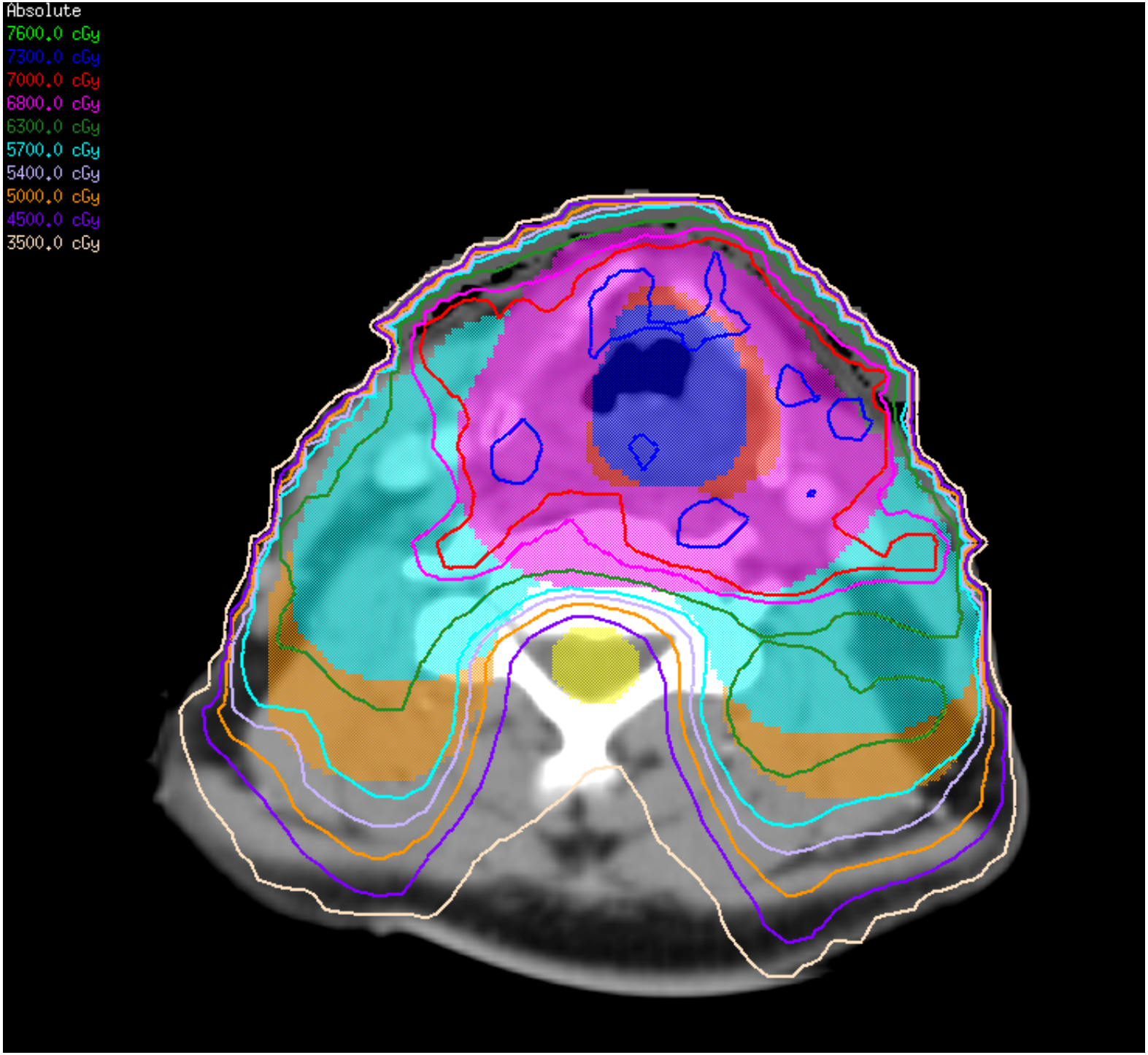
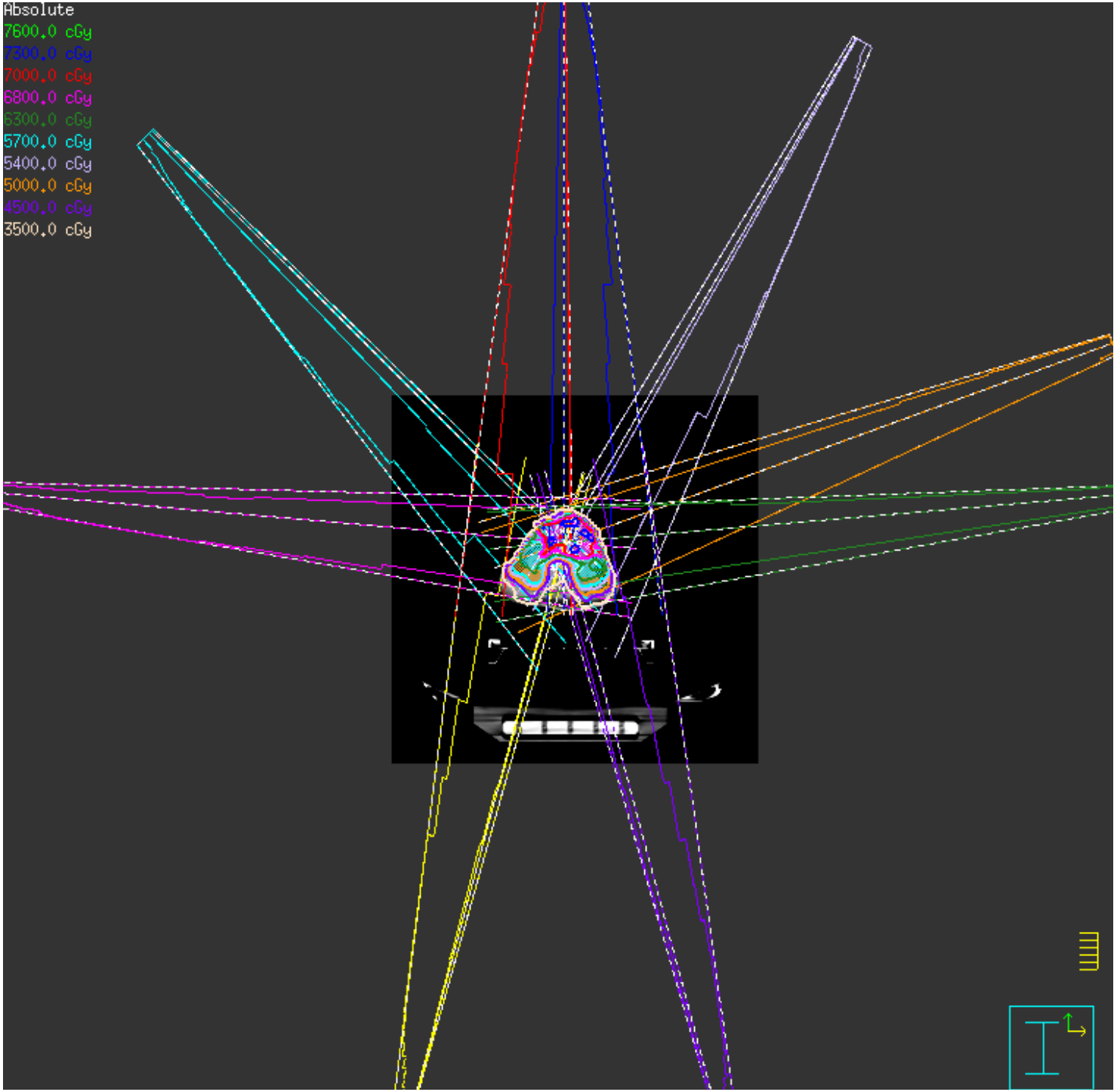



Y2
X1
X2
Y1


Absolute
7600.0 cGy
7300.0 cGy
7000.0 cGy
6800.0 cGy
6300.0 cGy
5700.0 cGy
5400.0 cGy
5000.0 cGy
4500.0 cGy
3500.0 cGy


Absolute
7600.0 cGy
7300.0 cGy
7000.0 cGy
6800.0 cGy
6300.0 cGy
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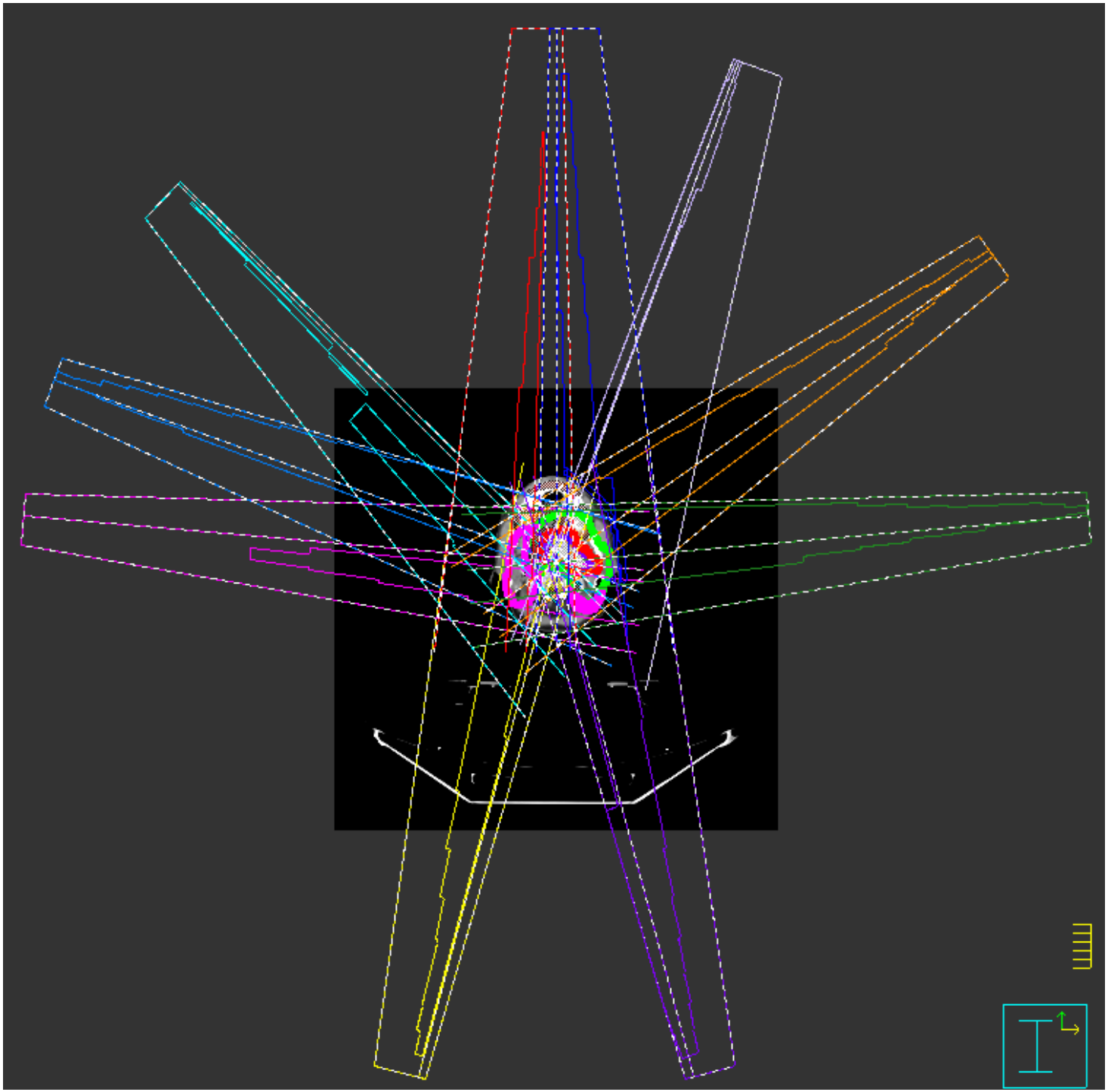
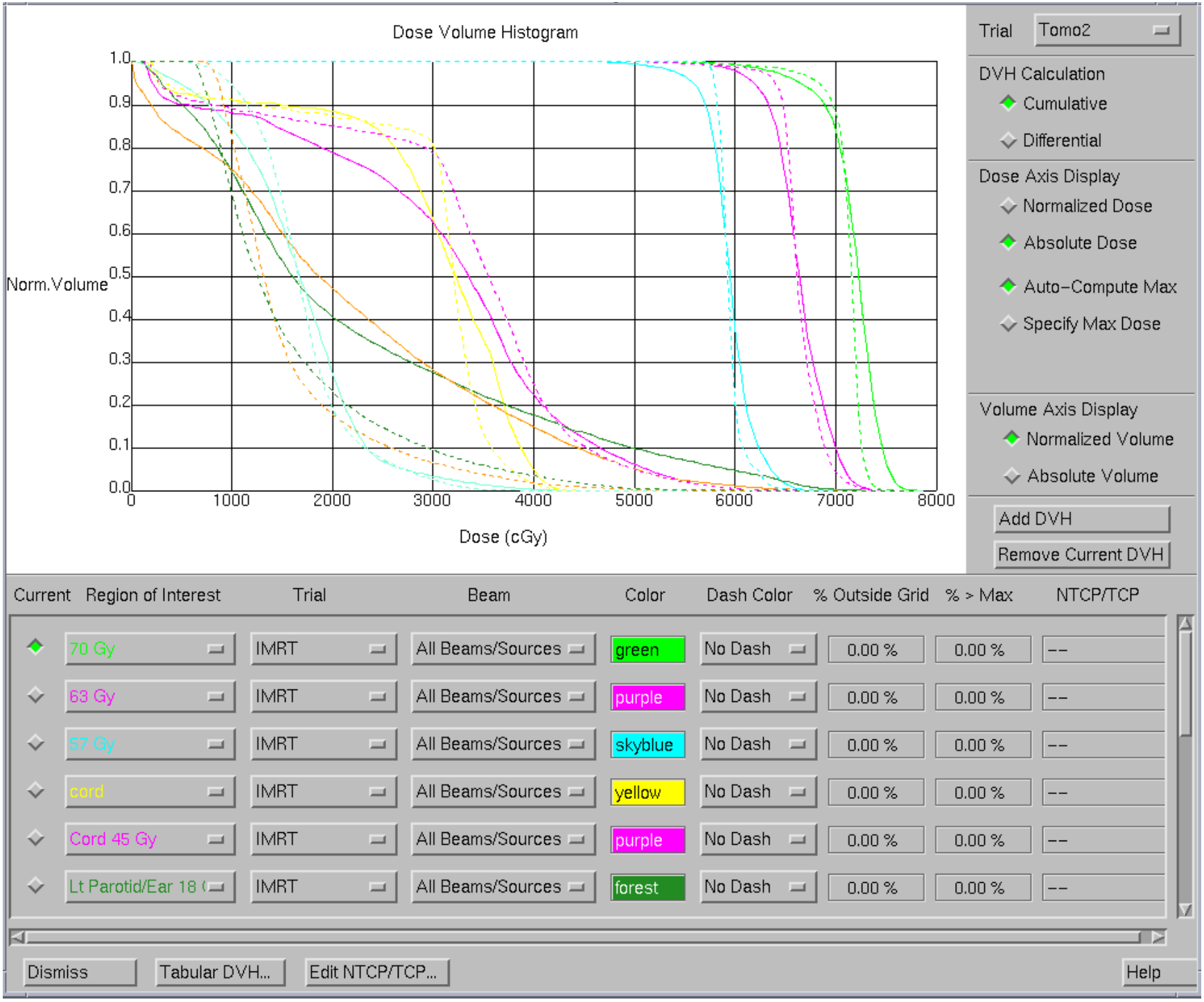
5400.0 cGy
5000.0 cGy
4500.0 cGy
3500.0 cGy




Dose Volume Histogram
Norm.Volume
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
1000
2000
3000
4000
5000
6000
7000
8000
Dose (cGy)
Trial
Tomo2
DVH Calculation
Cumulative
Differential
Dose Axis Display
Normalized Dose
Absolute Dose
Auto-Compute Max
Specify Max Dose
Volume Axis Display
Normalized Volume
Absolute Volume
Add DVH
Remove Current DVH
Current
Region of Interest
Trial
Beam
Color
Dash Color
% Outside Grid
% > Max
NTCP/TCP
70 Gy
IMRT
All Beams/Sources
green
No Dash
0.00 %
0.00 %
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63 Gy
IMRT
All Beams/Sources
purple
No Dash
0.00 %
0.00 %
--
57 Gy
IMRT
All Beams/Sources
skyblue
No Dash
0.00 %
0.00 %
--
cord
IMRT
All Beams/Sources
yellow
No Dash
0.00 %
0.00 %
--
Cord 45 Gy
IMRT
All Beams/Sources
purple
No Dash
0.00 %
0.00 %
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Lt Parotid/Ear 18 (
IMRT
All Beams/Sources
forest
No Dash
0.00 %
0.00 %
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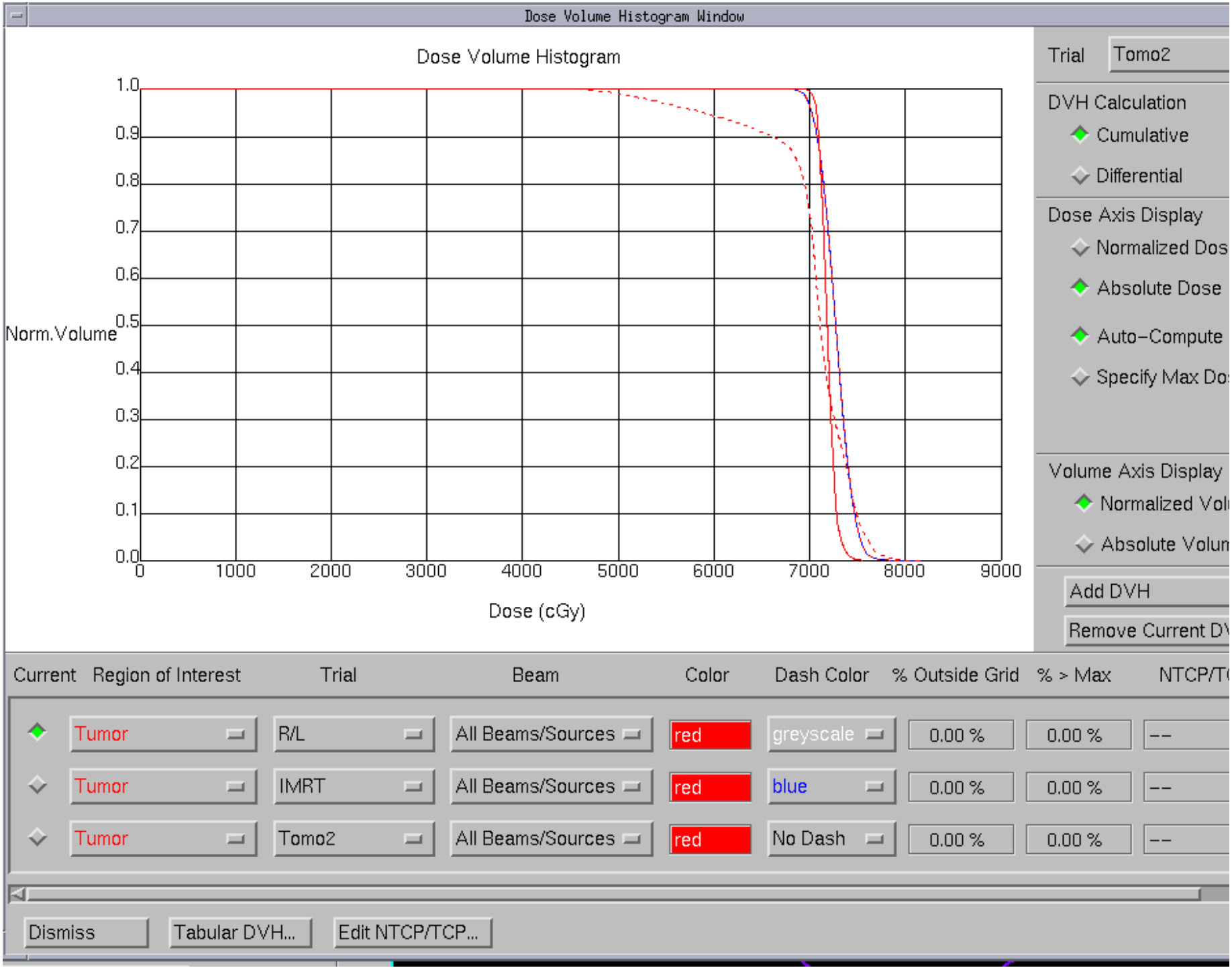
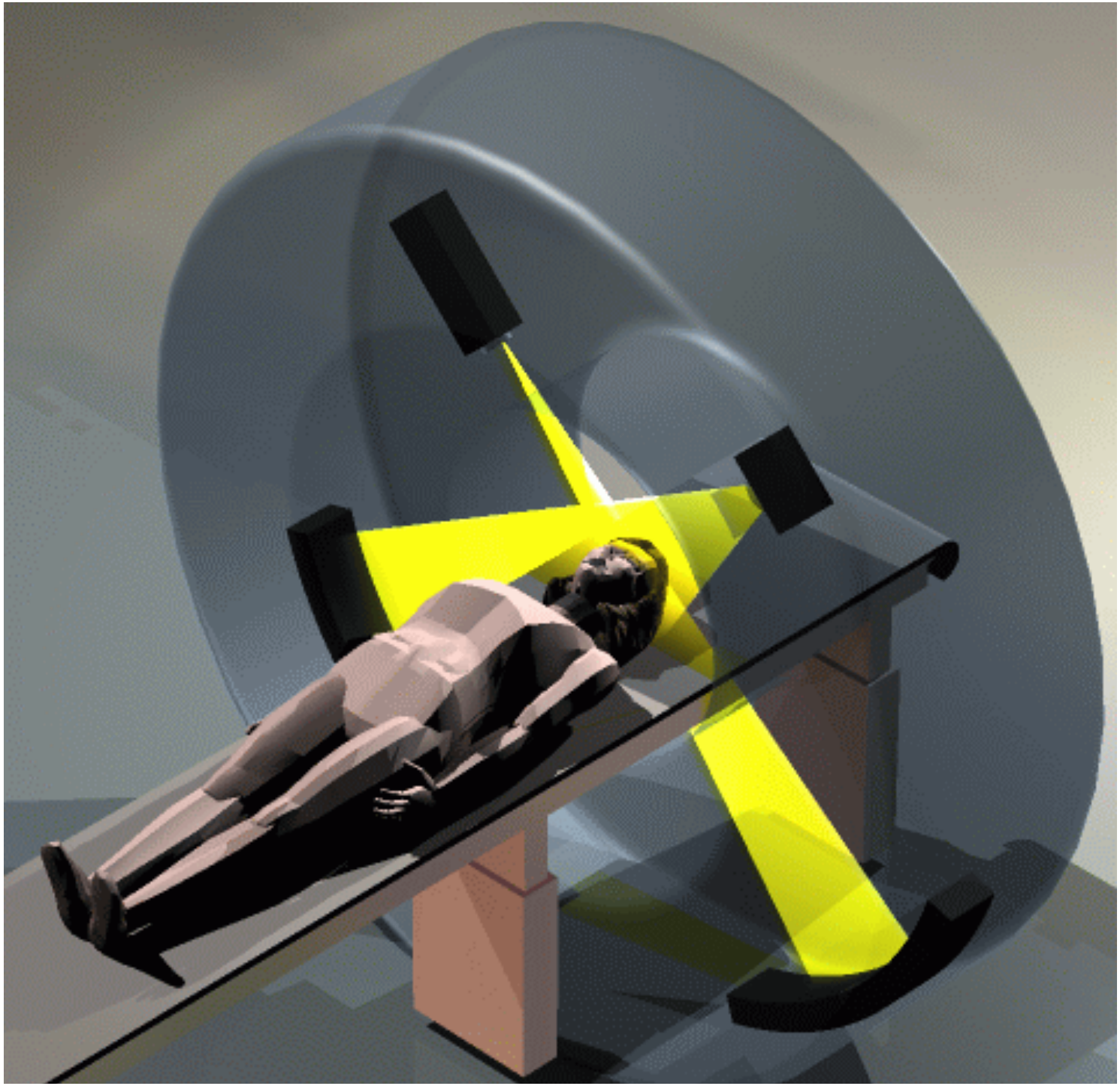
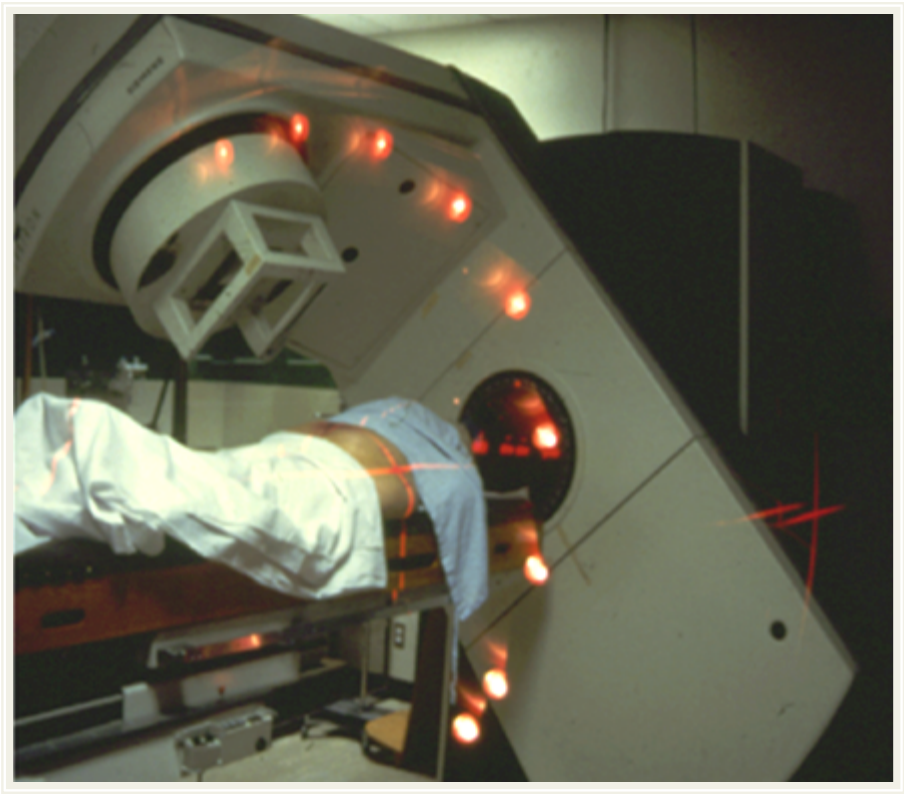
Dismiss
Tabular DVH...
Edit NTCP/TCP...
Help

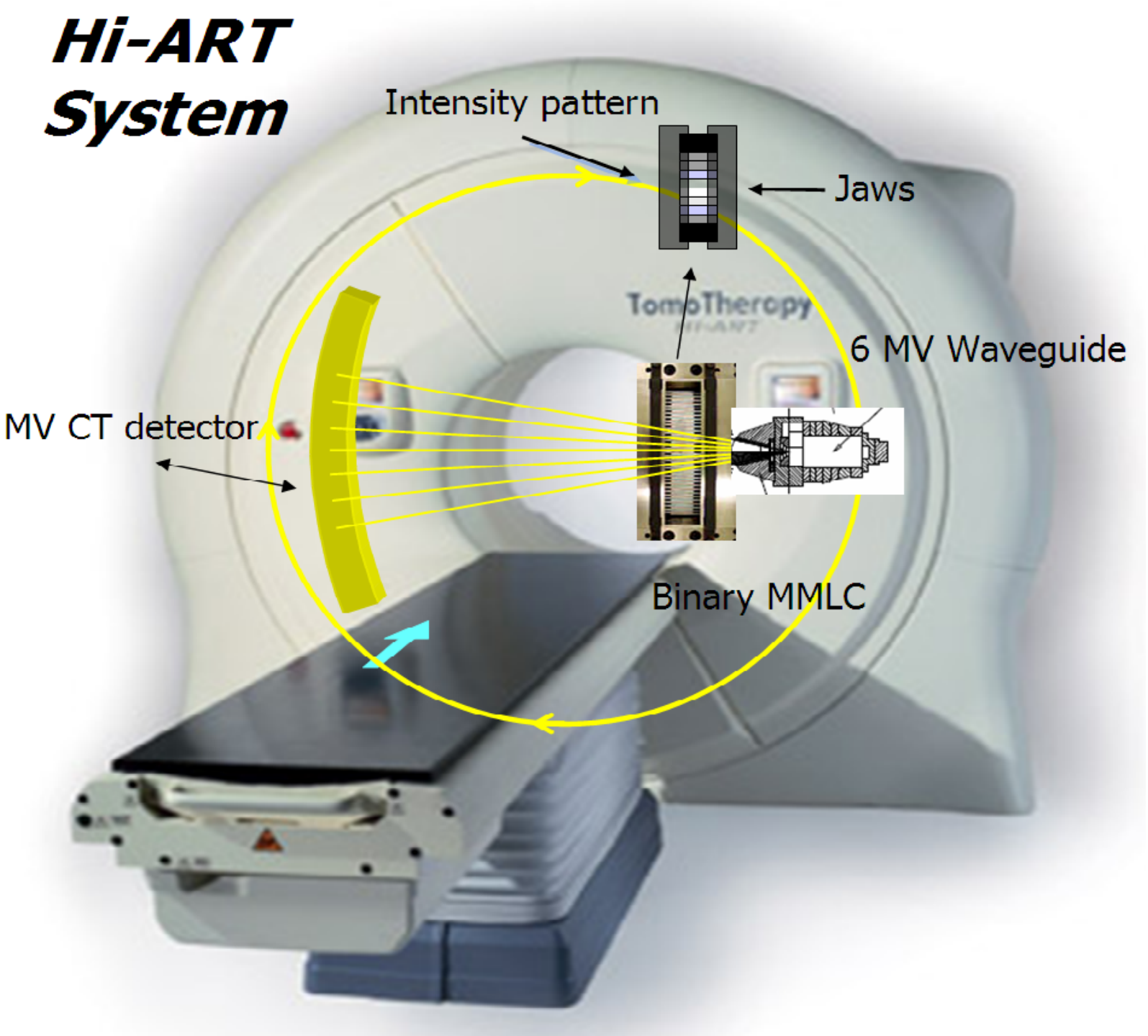

Dose Volume Histogram Window
Dose Volume Histogram
Norm.Volume
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
Dose (cGy)
Trial
Tomo2
DVH Calculation
Cumulative
Differential
Dose Axis Display
Normalized Dos
Absolute Dose
Auto-Compute
Specify Max Do
Volume Axis Display
Normalized Vol
Absolute Volum
Add DVH
Remove Current D
Current
Region of Interest
Trial
Beam
Color
Dash Color
% Outside Grid
% > Max
NTCP/T
Tumor
R/L
All Beams/Sources
red
greyscale
0.00 %
0.00 %
--
Tumor
IMRT
All Beams/Sources
red
blue
0.00 %
0.00 %
--
Tumor
Tomo2
All Beams/Sources
red
No Dash
0.00 %
0.00 %
--
Dismiss
Tabular DVH...
Edit NTCP/TCP...


TomoTherapy

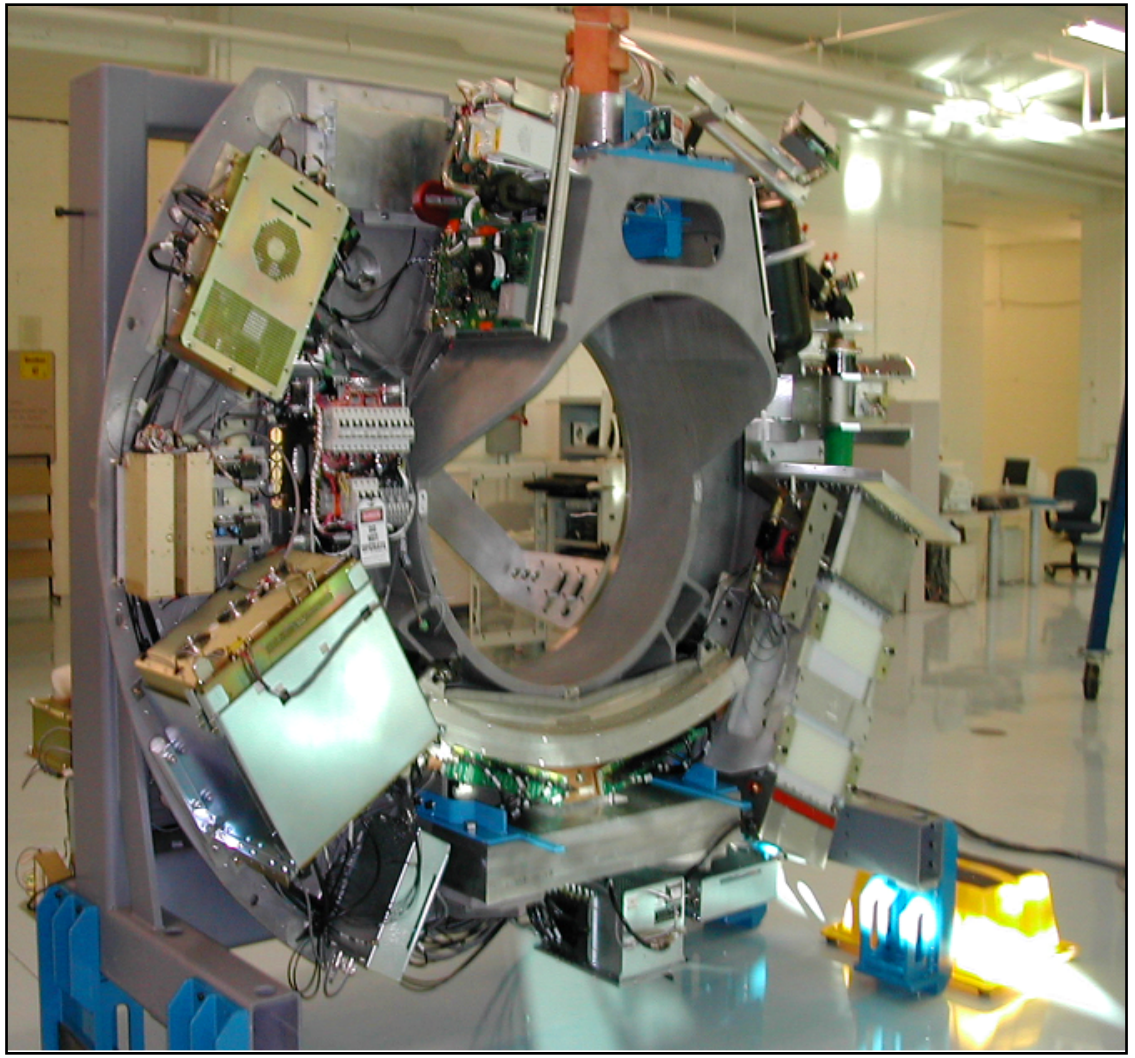


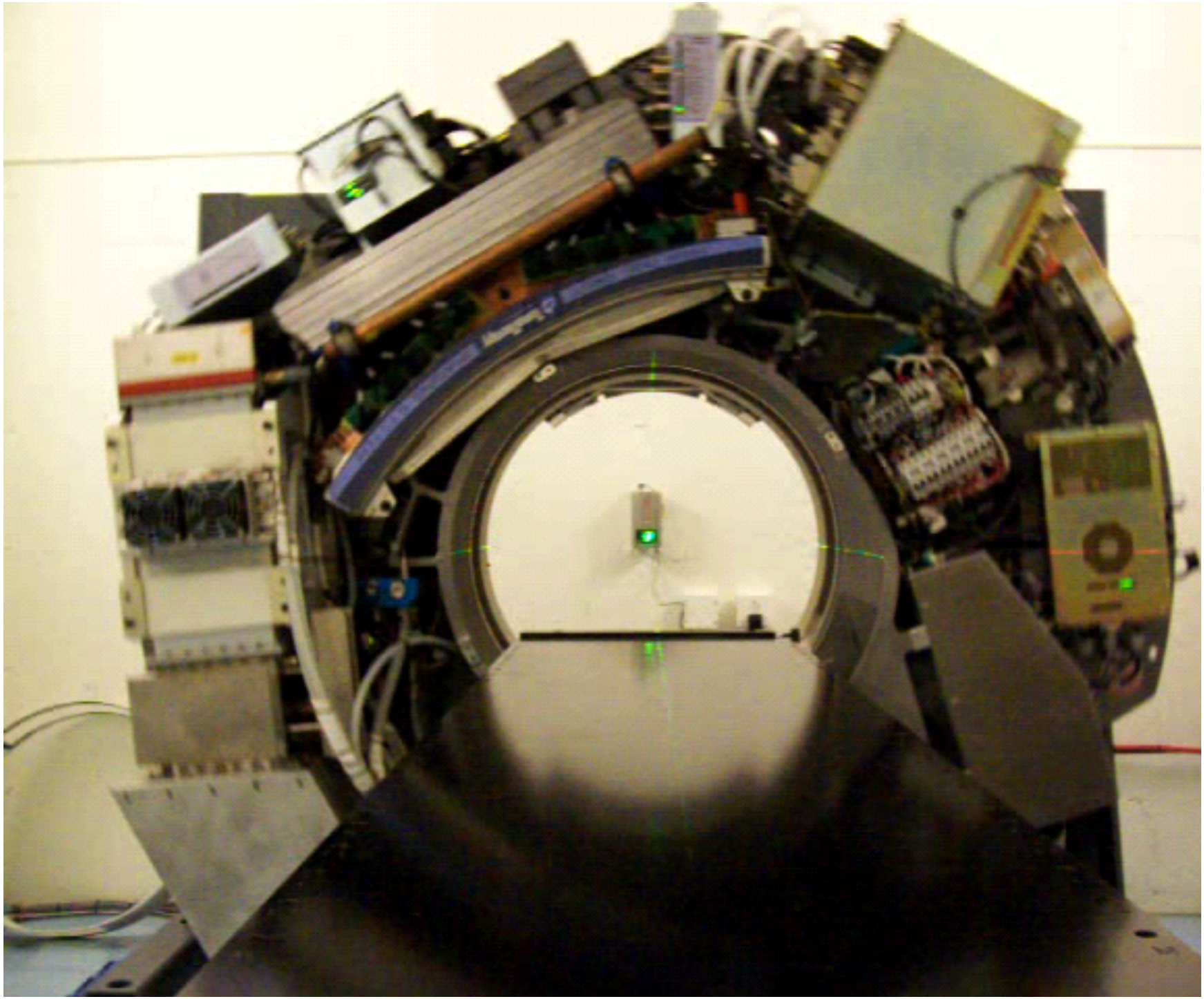


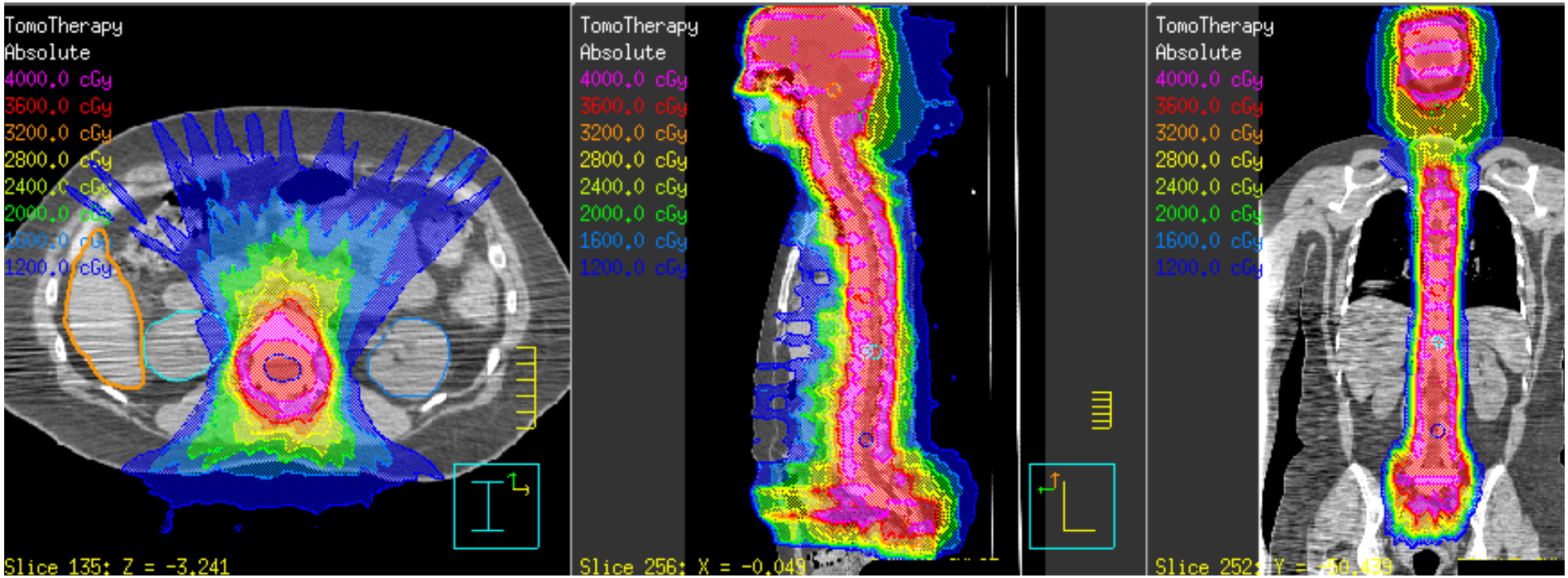
Hi-ART System




TomoTherapy






TomoTherapy
Absolute
4000.0 cGy
3600.0 cGy
3200.0 cGy
2800.0 cGy
2400.0 cGy
2000.0 cGy
1600.0 cGy
1200.0 cGy
Slice 135: Z = -3.241
TomoTherapy
Absolute
4000.0 cGy
3600.0 cGy
3200.0 cGy
2800.0 cGy
2400.0 cGy
2000.0 cGy
1600.0 cGy
1200.0 cGy
Slice 256: X = -0.049
TomoTherapy
Absolute
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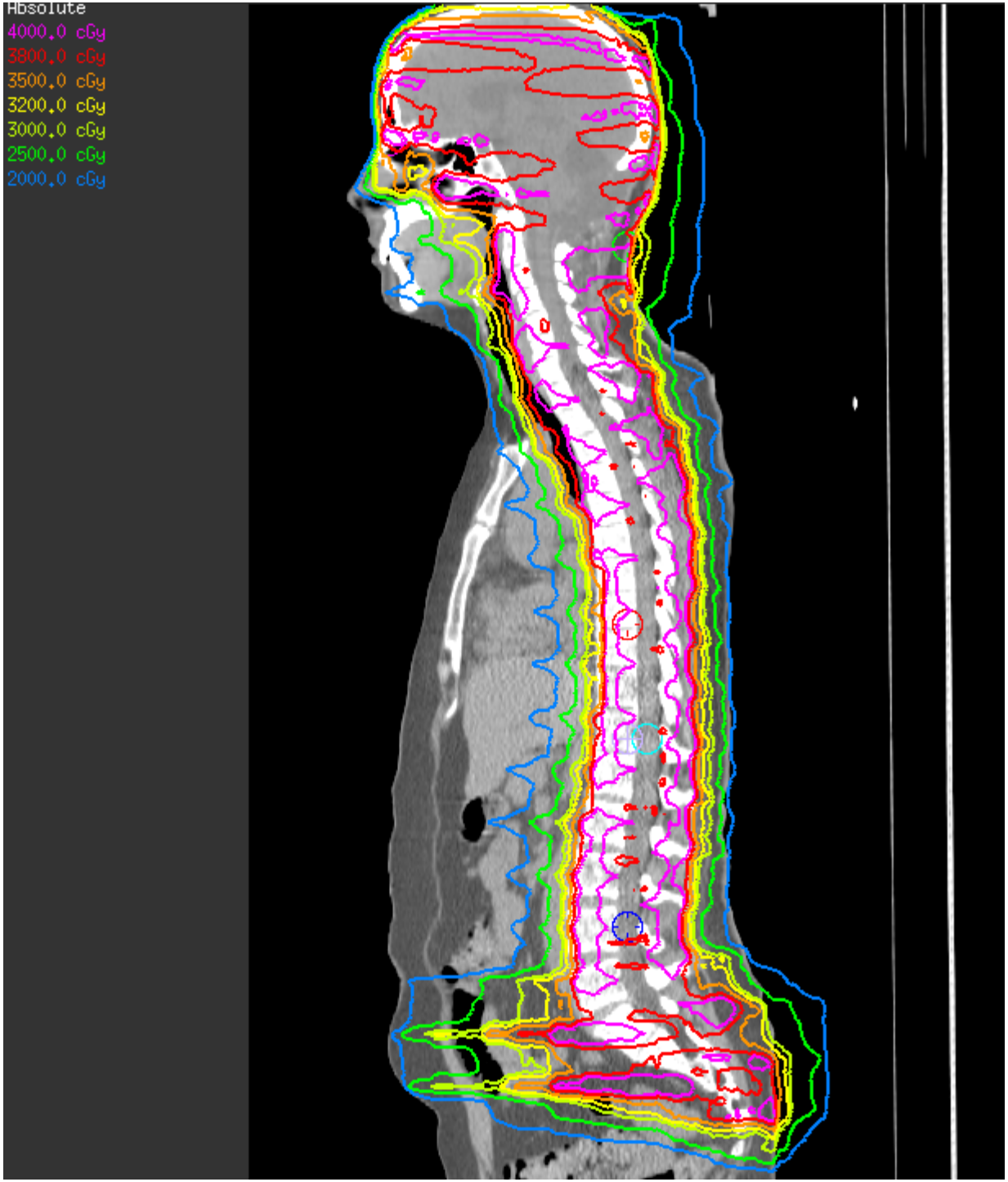
3200.0 cGy
2800.0 cGy
2400.0 cGy
2000.0 cGy
1600.0 cGy
1200.0 cGy


Absolute
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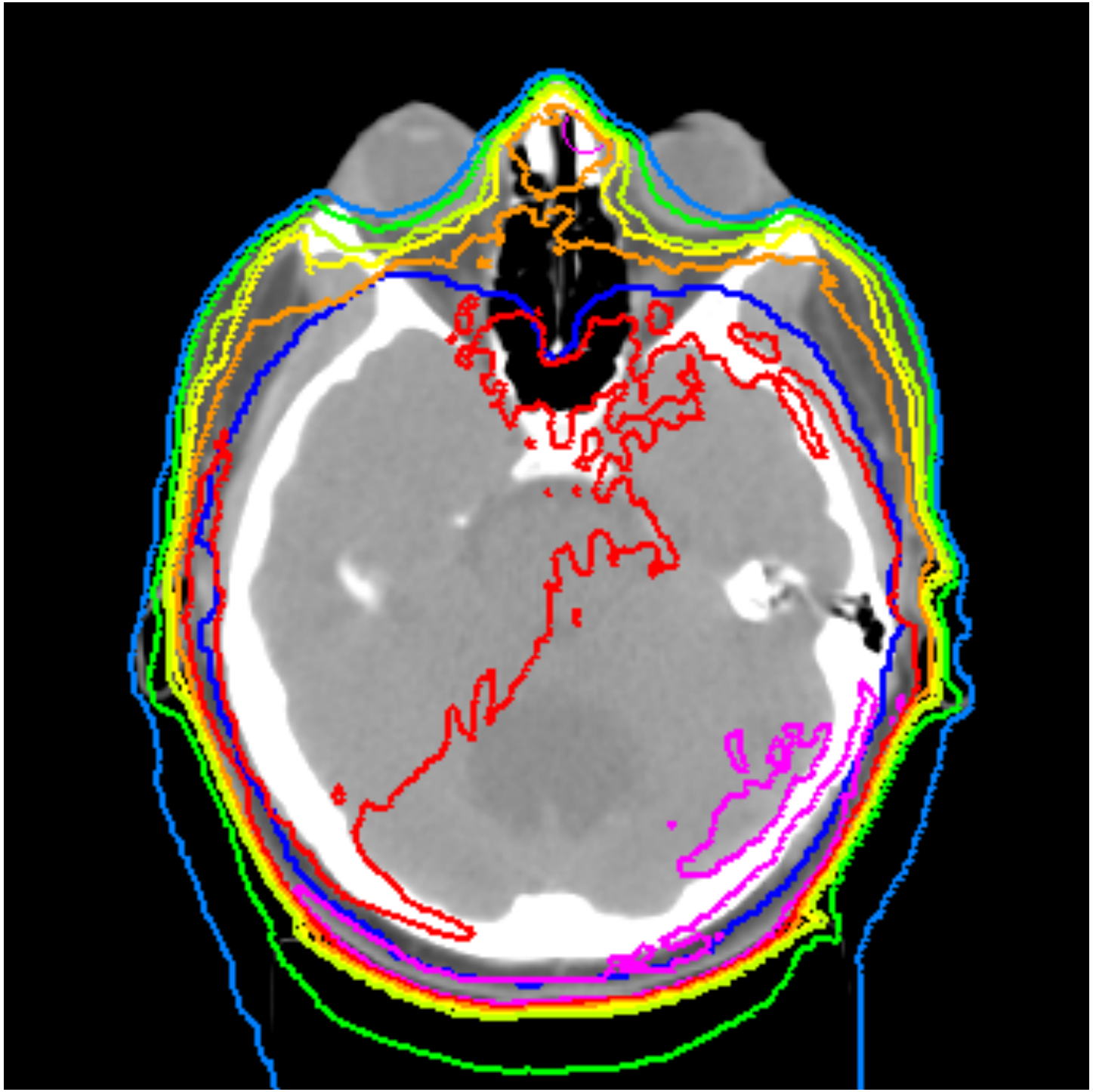
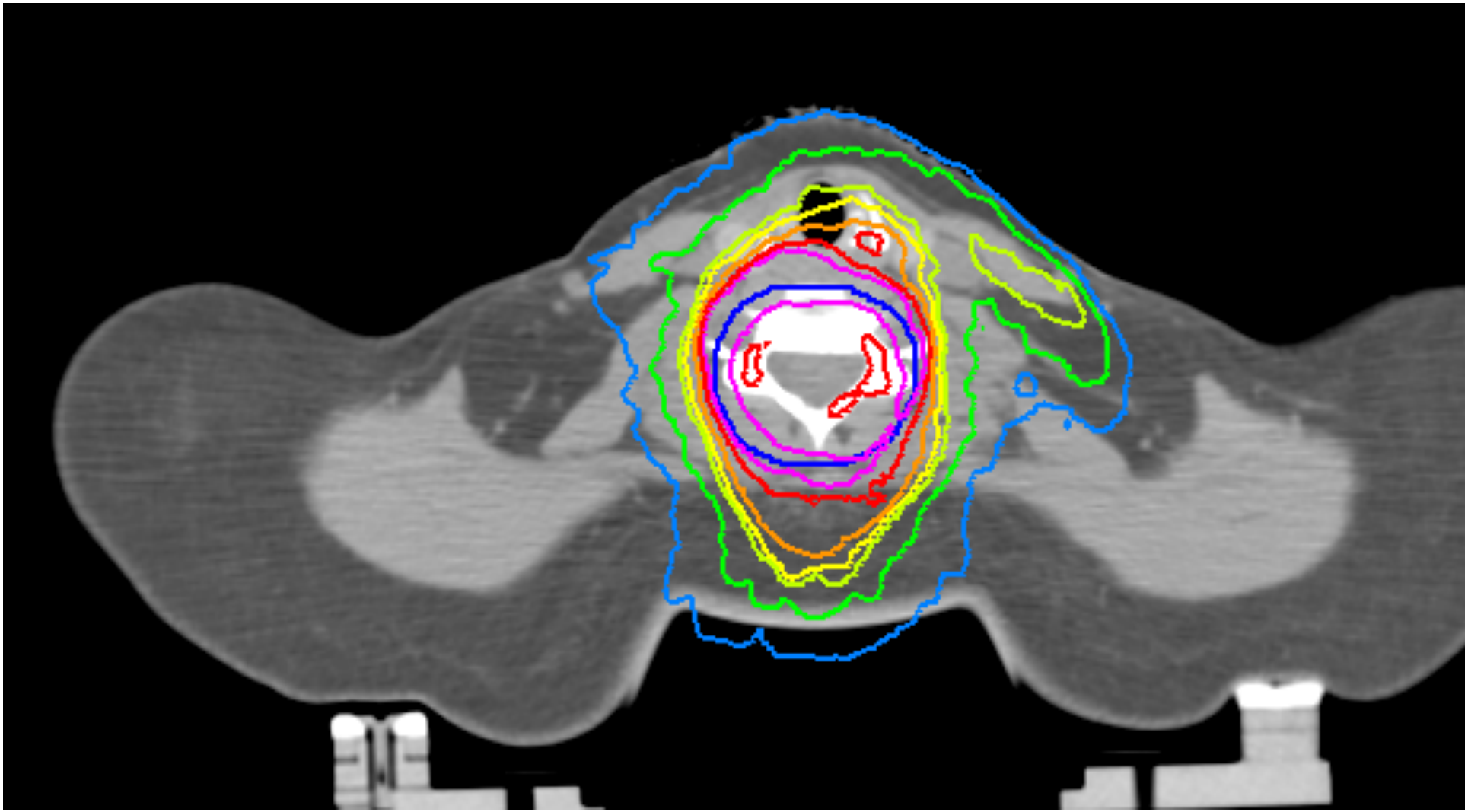
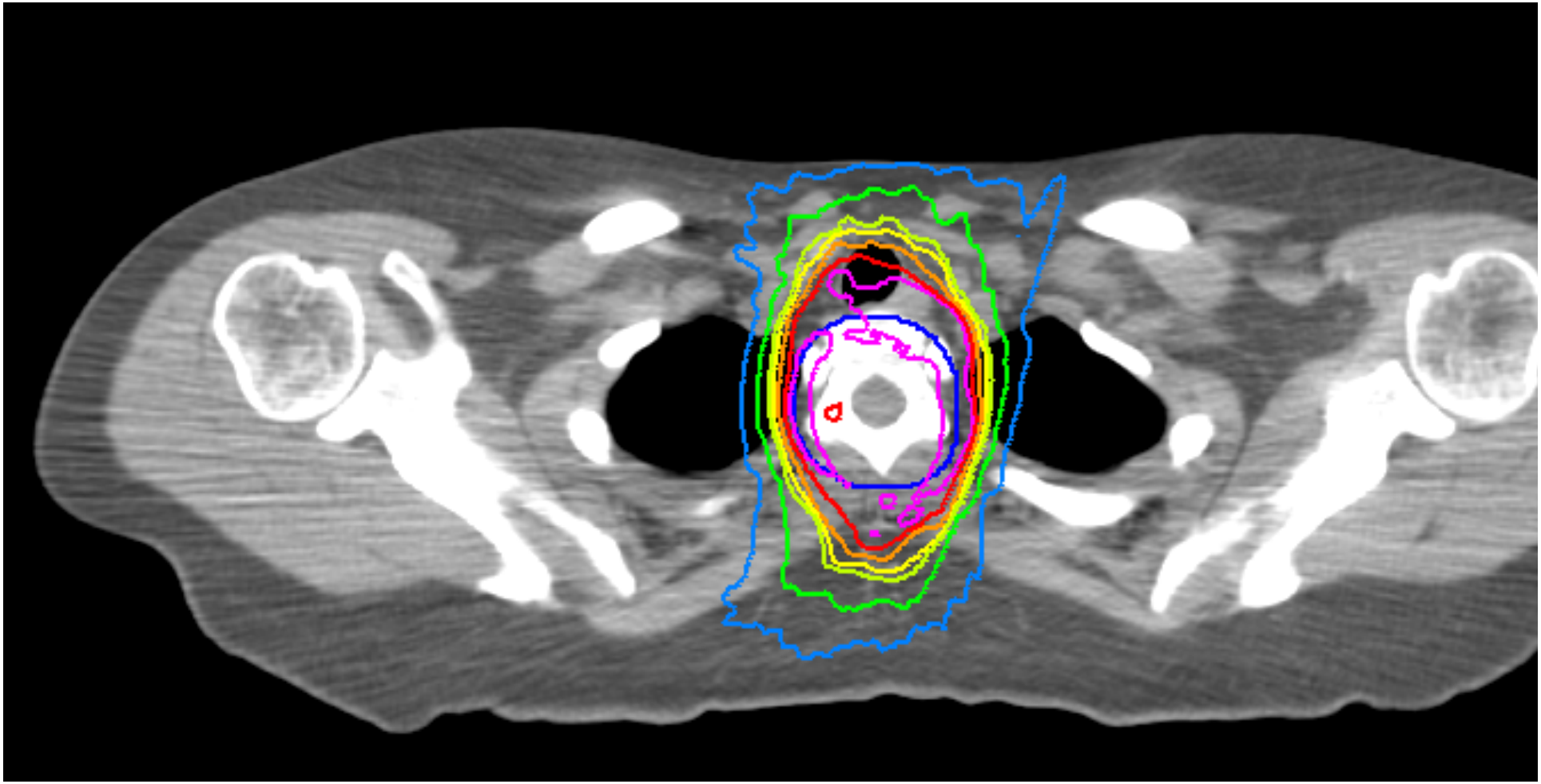
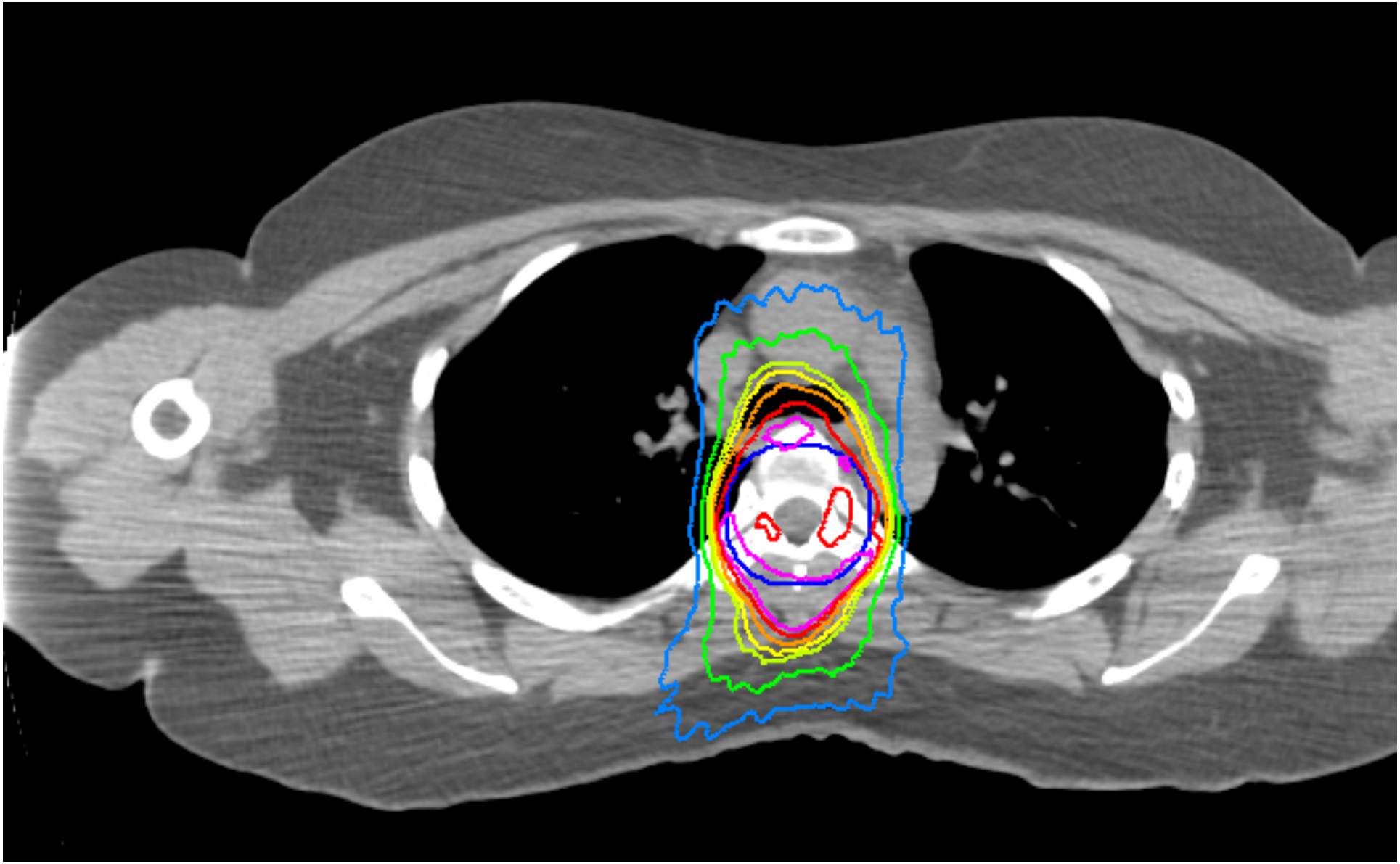
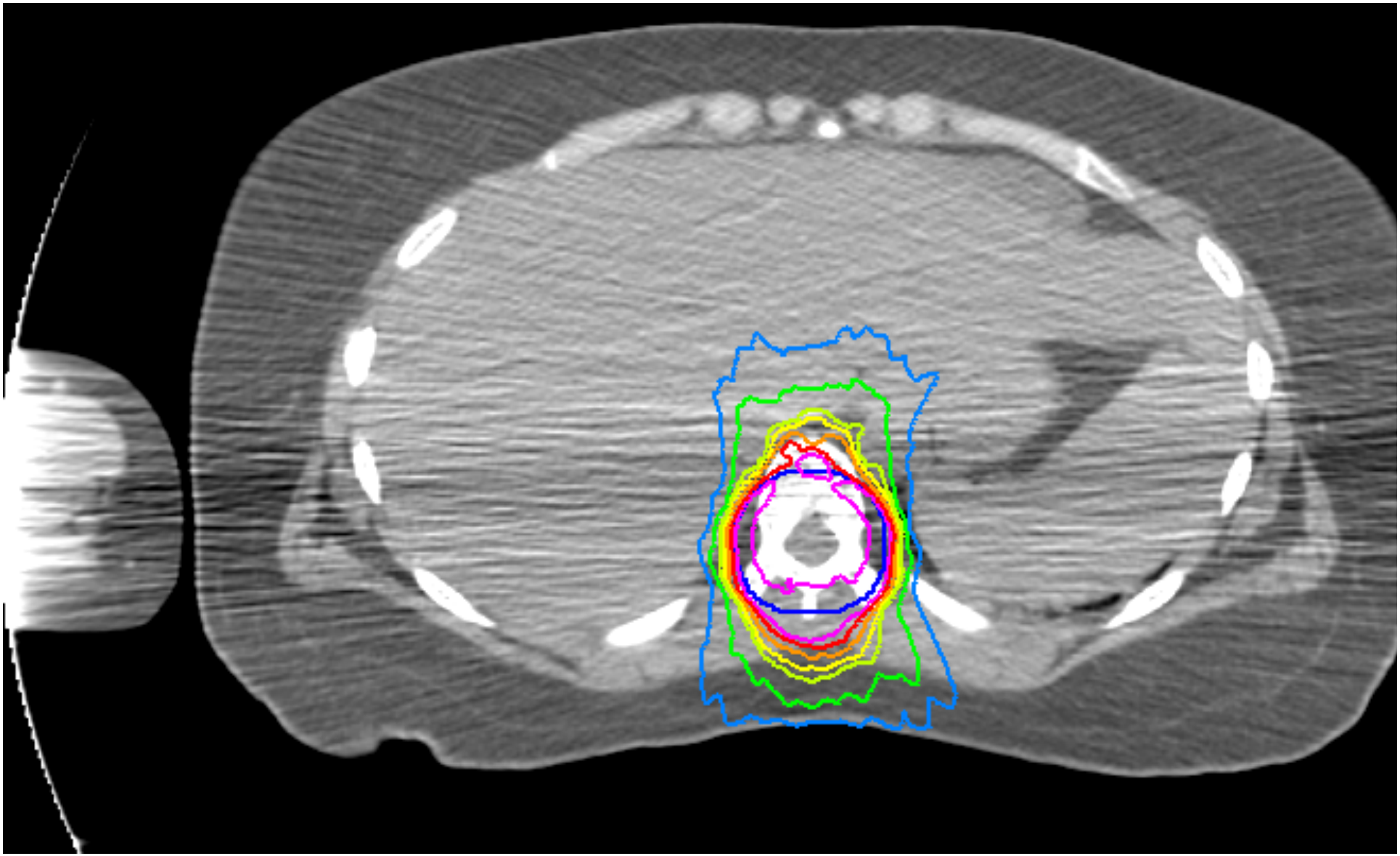
3800.0 cGy
3500.0 cGy
3200.0 cGy
3000.0 cGy
2500.0 cGy
2000.0 cGy

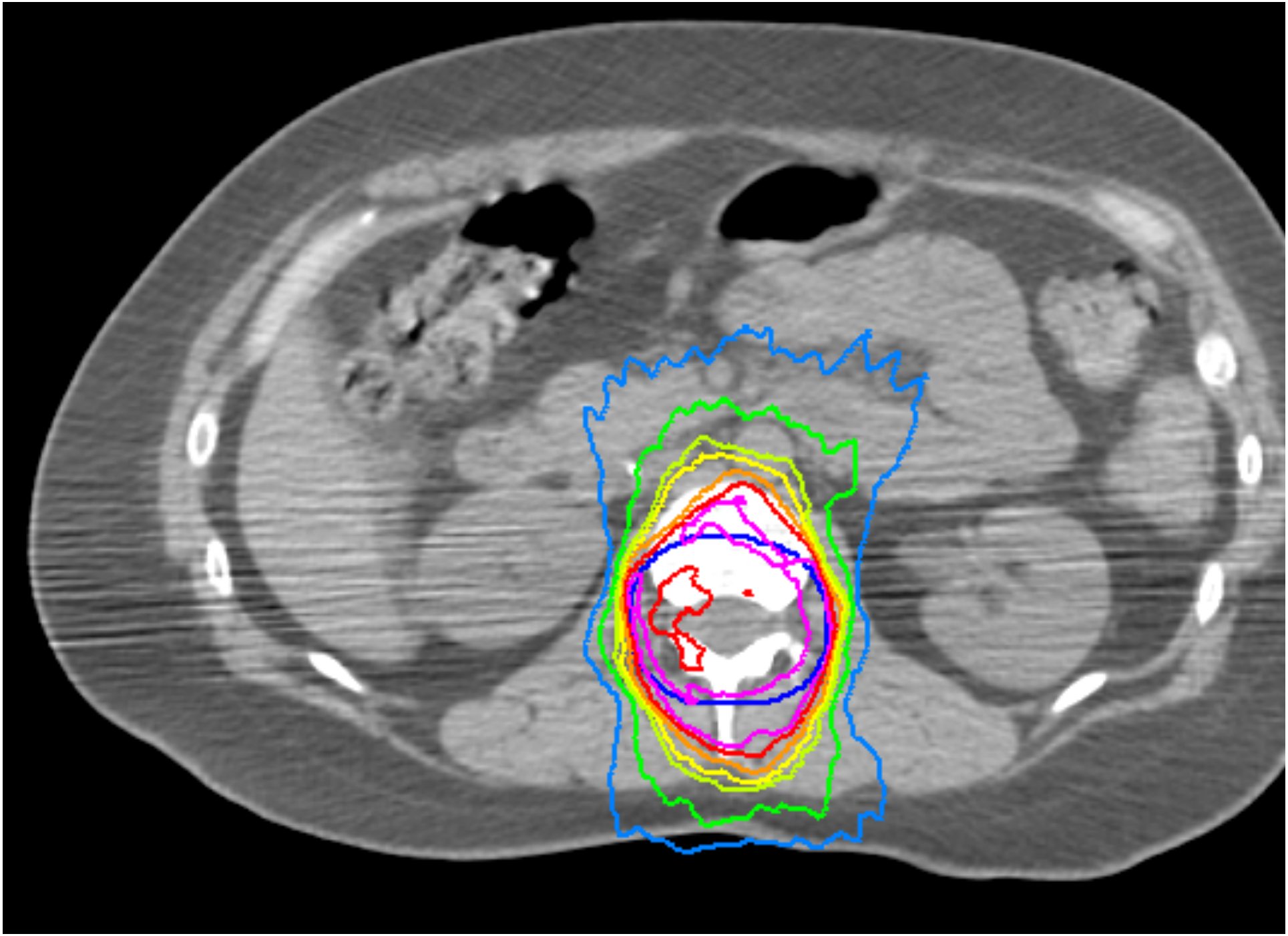


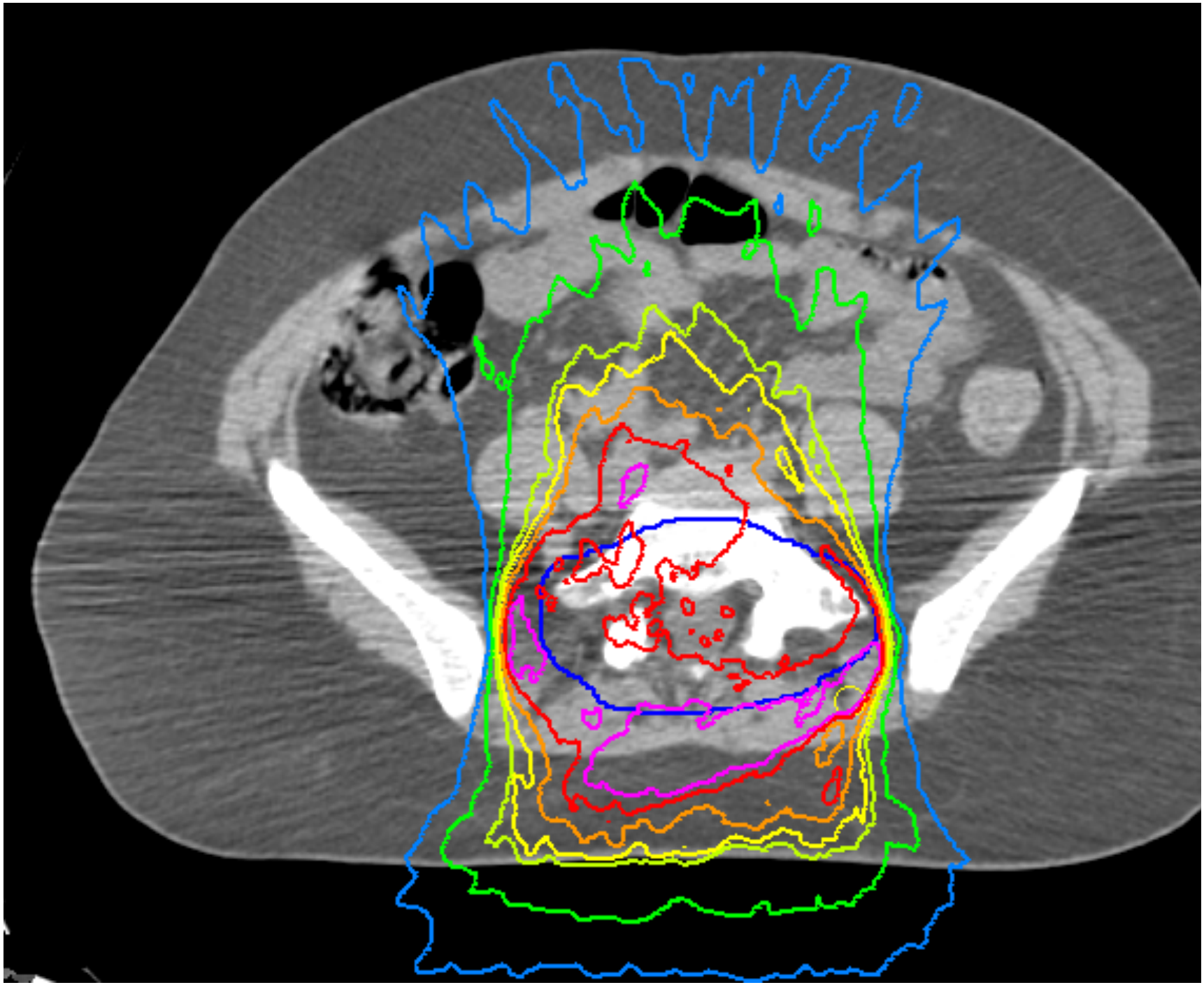


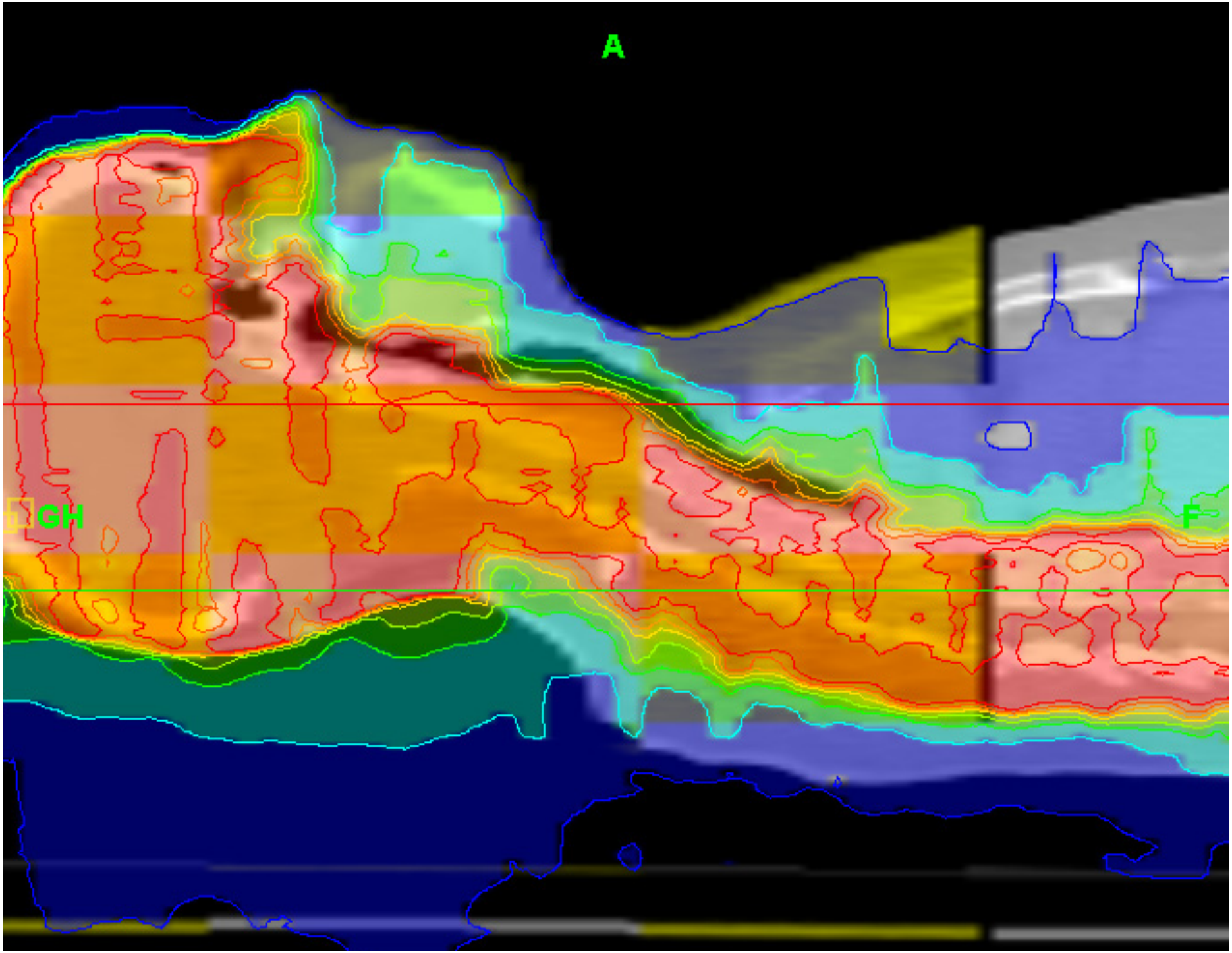











A
GH
F

$$ICF_{bone} = ICF_{meas,\,bone} \frac{\left(\frac{L}{\rho}\right)_{gas}^{bone}}{\left(\frac{L}{\rho}\right)_{gas}^{water}} \frac{P_{reple,bone} P_{wall,bone}}{P_{repl,water} P_{wall,water}}$$

$$ICF_{lung} = ICF_{meas,lung} \frac{\left(\frac{L}{\rho}\right)_{gas}^{lung}}{\left(\frac{L}{\rho}\right)_{gas}^{water}} \frac{P_{repl,lung} P_{wall,lung}}{P_{repl,water} P_{wall,water}}$$

$$D_w^Q = M P_{\mathrm{gr}}^Q \, k'_{R_{50}} \, k_{\mathrm{ecal}} \, N_{D,w}^{^{60}\mathrm{Co}} \quad (\mathrm{Gy})$$

$$\dot{D}(r,\theta) = \Lambda S_K \frac{G(r,\theta)}{G(1,\pi/2)} F(r,\theta) g(r)$$

$N_{D,w}^{^{60}\mathrm{Co}} \xrightarrow{k_Q} N_{D,w}^Q$ (photons or electrons)

$N_{D,w}^{^{60}\mathrm{Co}} \xrightarrow{k_{R_{50}}} N_{D,w}^Q$ (electrons[a])

$N_{D,w}^{^{60}\mathrm{Co}} \xrightarrow{k_{\mathrm{ecal}}} N_{D,w}^{Q_{\mathrm{ecal}}} \xrightarrow{k'_{R_{50}}} N_{D,w}^Q$ (electrons[a,b])

[a] also need P_{gr}^Q for cylindrical chambers.
[b] also need $P_{\mathrm{gr}}^{Q_{\mathrm{ecal}}}$ for cylindrical chambers.

Note that for electron beams $k_Q = P_{\mathrm{gr}}^Q \, k_{R_{50}}$ and $k_{R_{50}} = k'_{R_{50}} \, k_{\mathrm{ecal}}$.

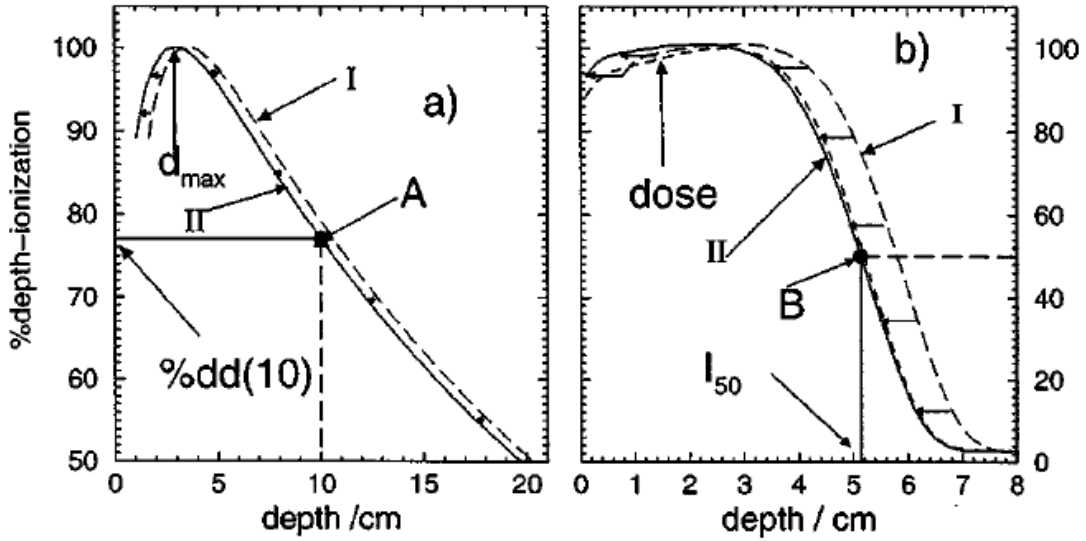
$$K_{\text{ref}} = \sum_{i=1}^{N} S_{K,i} \cdot t_i$$

$$P_{\text{pol}} = \left| \frac{(M_{\text{raw}}^{+} - M_{\text{raw}}^{-})}{2M_{\text{raw}}} \right|$$

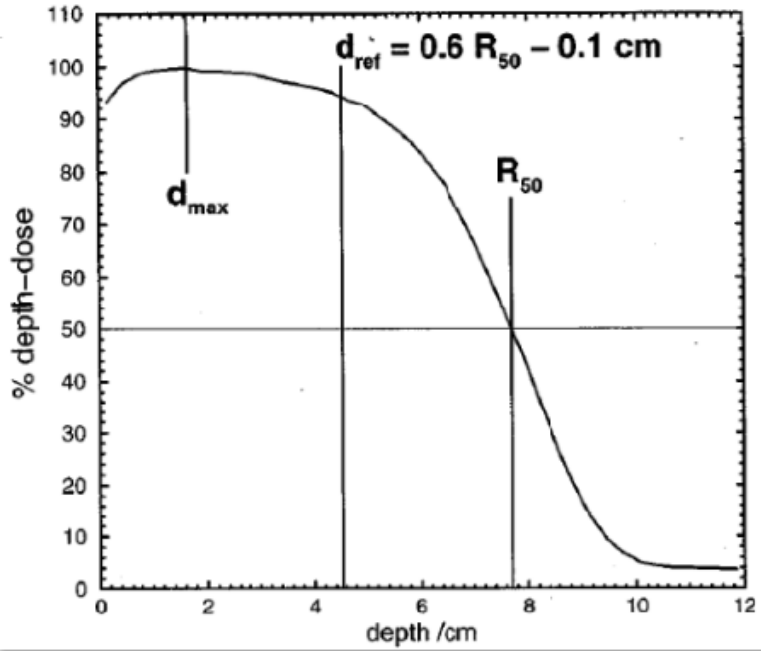
$$P_{\text{ion}}(V_H) = \frac{1. - V_H/V_L}{M_{\text{raw}}^{H}/M_{\text{raw}}^{L} - V_H/V_L}.$$

$$D_w^Q = MN_{D,w}^Q \quad \text{(Gy)}$$

$$k_Q = P_{\text{gr}}^Q \, k_{R_{50}}$$



$$M = P_{\text{ion}} P_{\text{TP}} P_{\text{elec}} P_{\text{pol}} M_{\text{raw}} \quad \text{(C or rdg)}$$



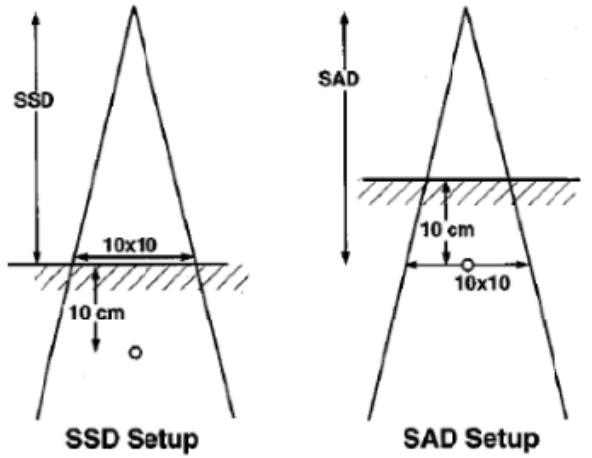


FIG. 3. Schematic of the SSD or SAD setups which may be used for photon beam reference dosimetry. In both cases the ion chamber is at a water equivalent depth of 10 cm in the water phantom. The actual value of SSD or SAD is that most useful in the clinic (expected to be about 100 cm).