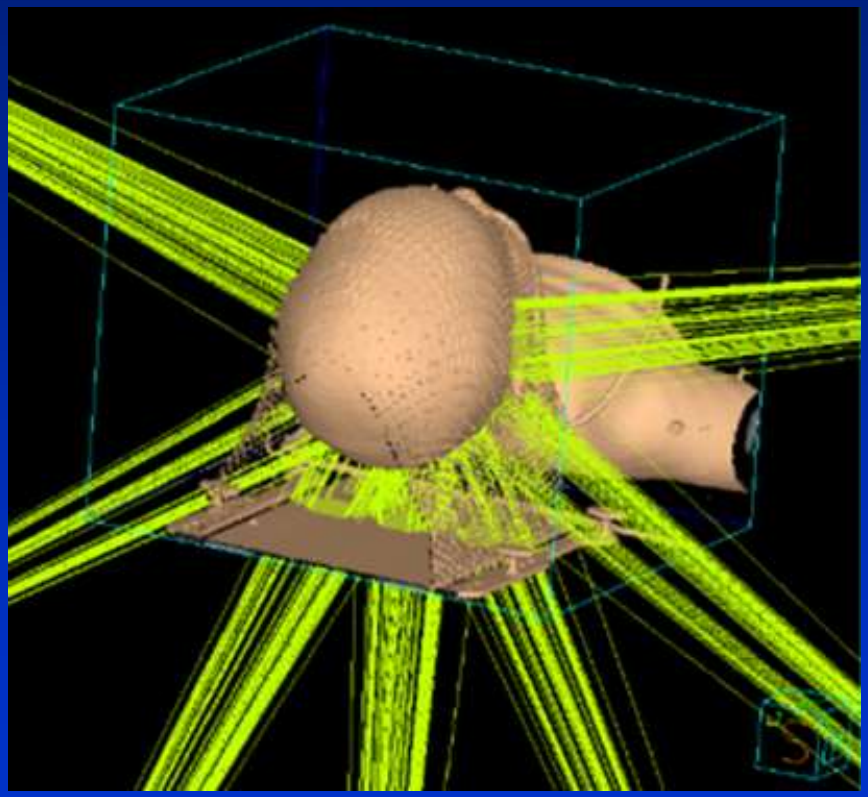
State of the Art: Radiation Treatment for Brain Tumours

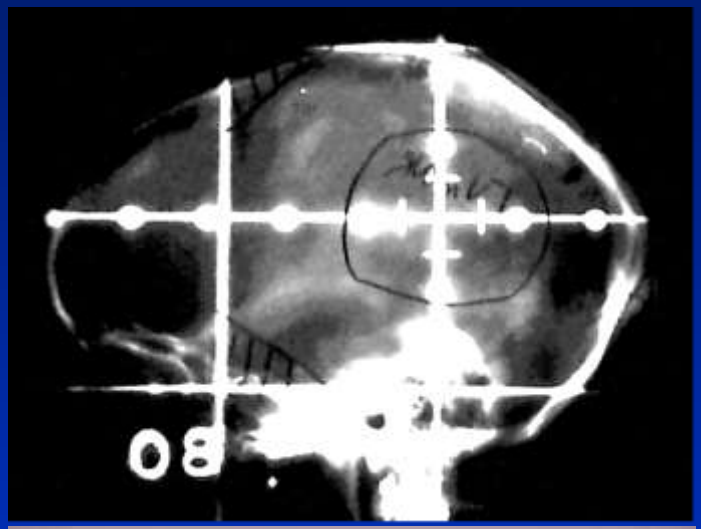


N. Laperriere, MD FRCPC
Department of Radiation Oncology
Princess Margaret Cancer Centre
Division of Hematology/Oncology
Hospital for Sick Children
University of Toronto
Toronto, Canada

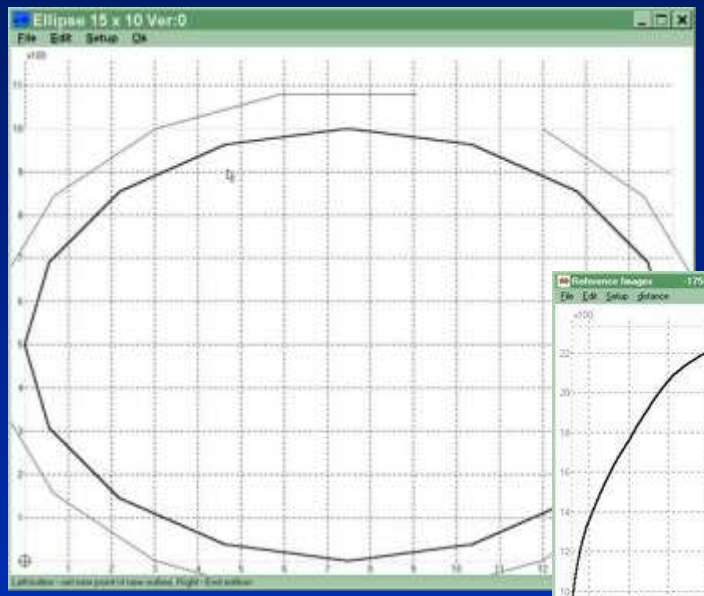
Radiation Planning Process
Basic Principles

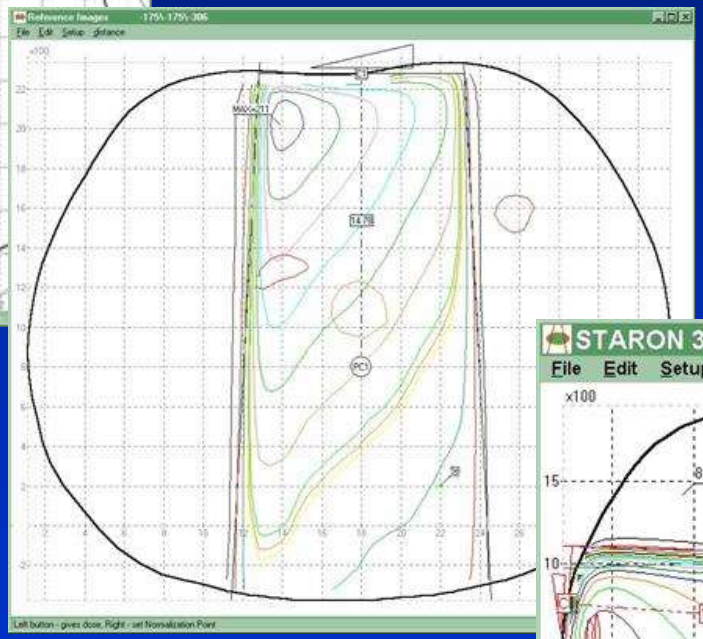
- Immobilization
- Imaging in treatment position
- Outlining tumour/normal structures
- Devising a radiation plan that is specific for the unique circumstances of each patient
- Transferring all data electronically to the linear accelerator that will be treating this specific patient

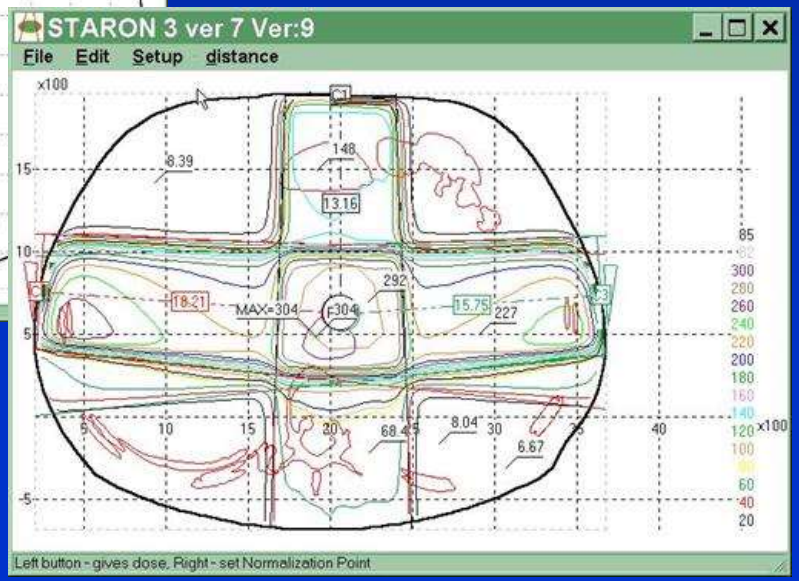
Radiation Planning Process
1960s-1990s



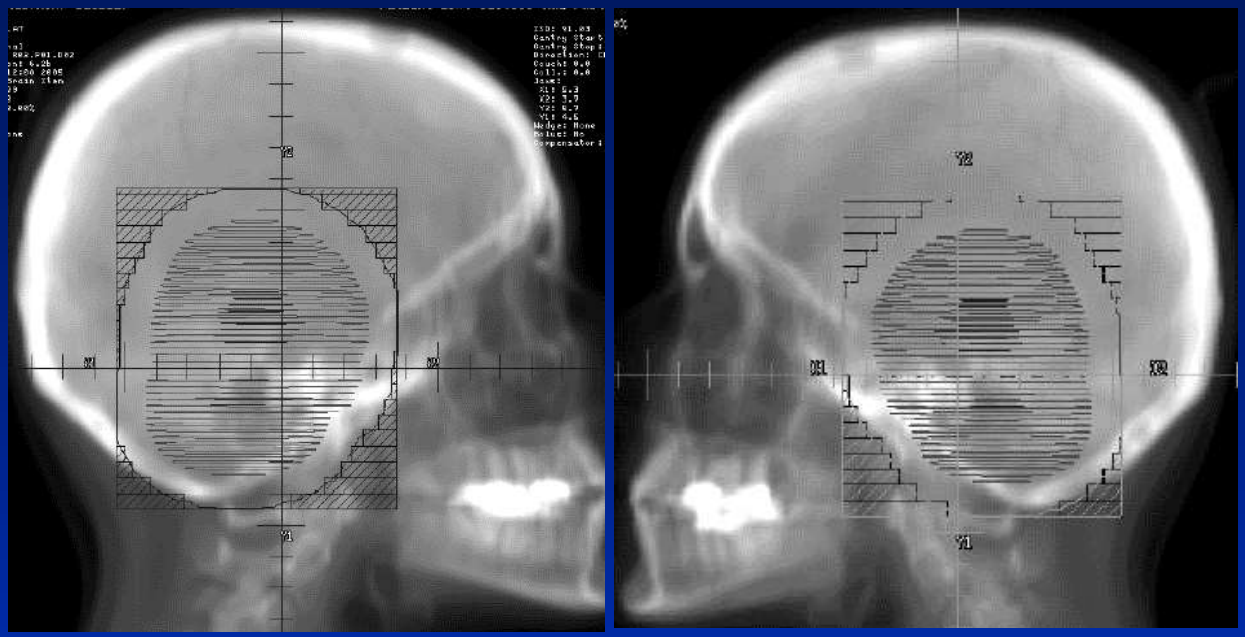
Radiation Planning Process
1960s-1990s

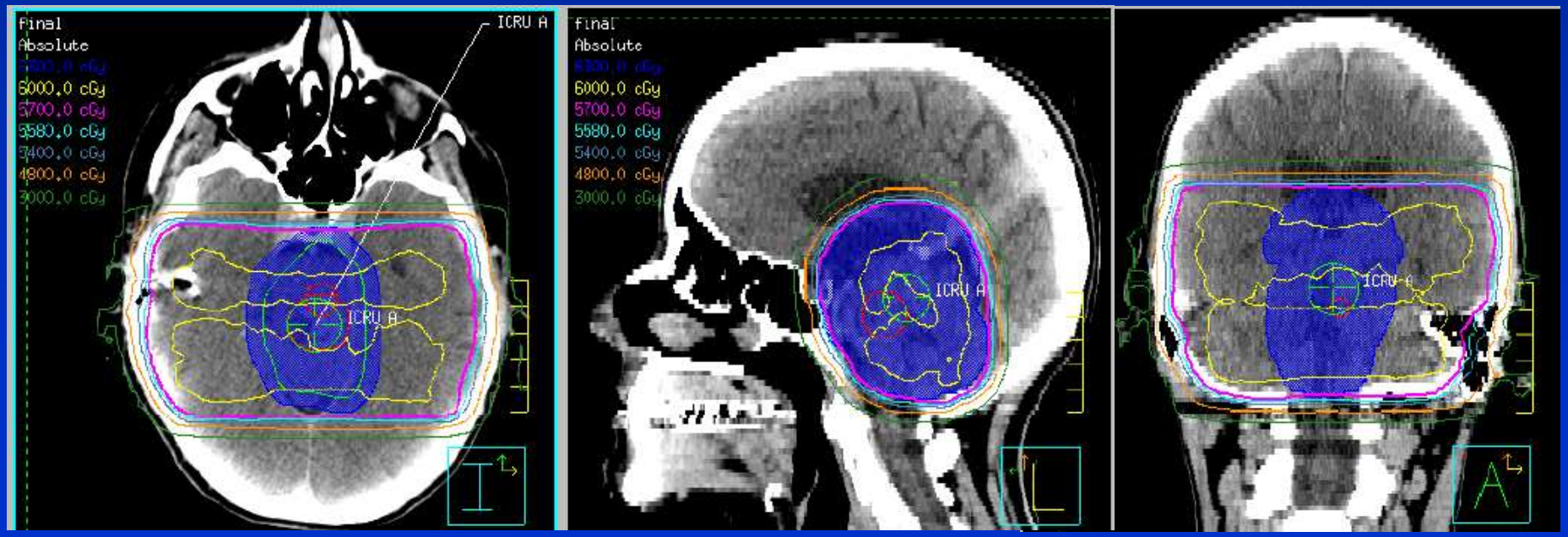






Lateral Opposed Fields





Consequences of Radiation Therapy 1960s-1990s

- Major uncertainties of tumour location
- Major uncertainties of day to day set up
- Limited # of large fields from few directions

- Large volumes of normal tissue taken to full dose
- The normal tissue tolerances limited RT doses
- Significant legacy of late effects

Major Reasons for Advances in RT Technology

- Advances in medical imaging
- Advances in computer software
- Advances in linear accelerator design and shielding accessories
- Integration of daily Image Guidance
- New RT units (radiosurgery, protons)

Major Improvements in Radiation Technology

Immobilization

CT/MRI Simulators

Intensity Modulated Radiation Therapy (IMRT)

Image Guided Radiation Therapy (IGRT)

Radiosurgery

Protons

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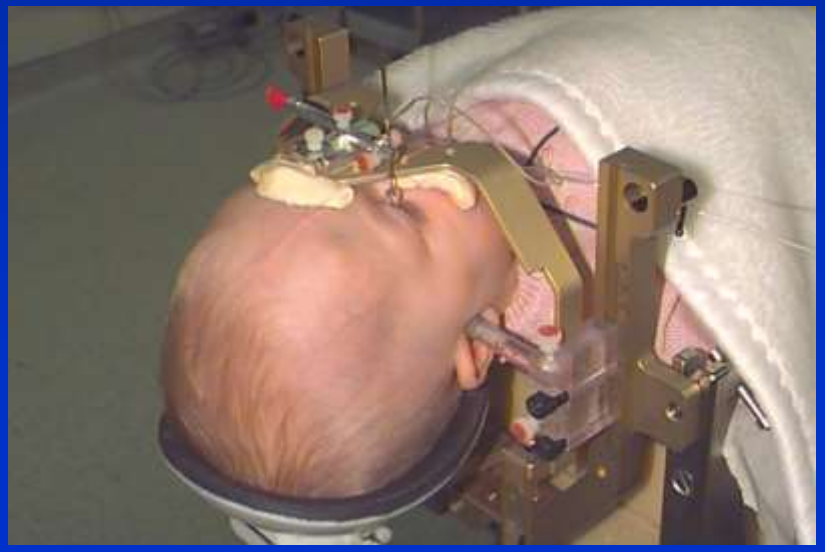
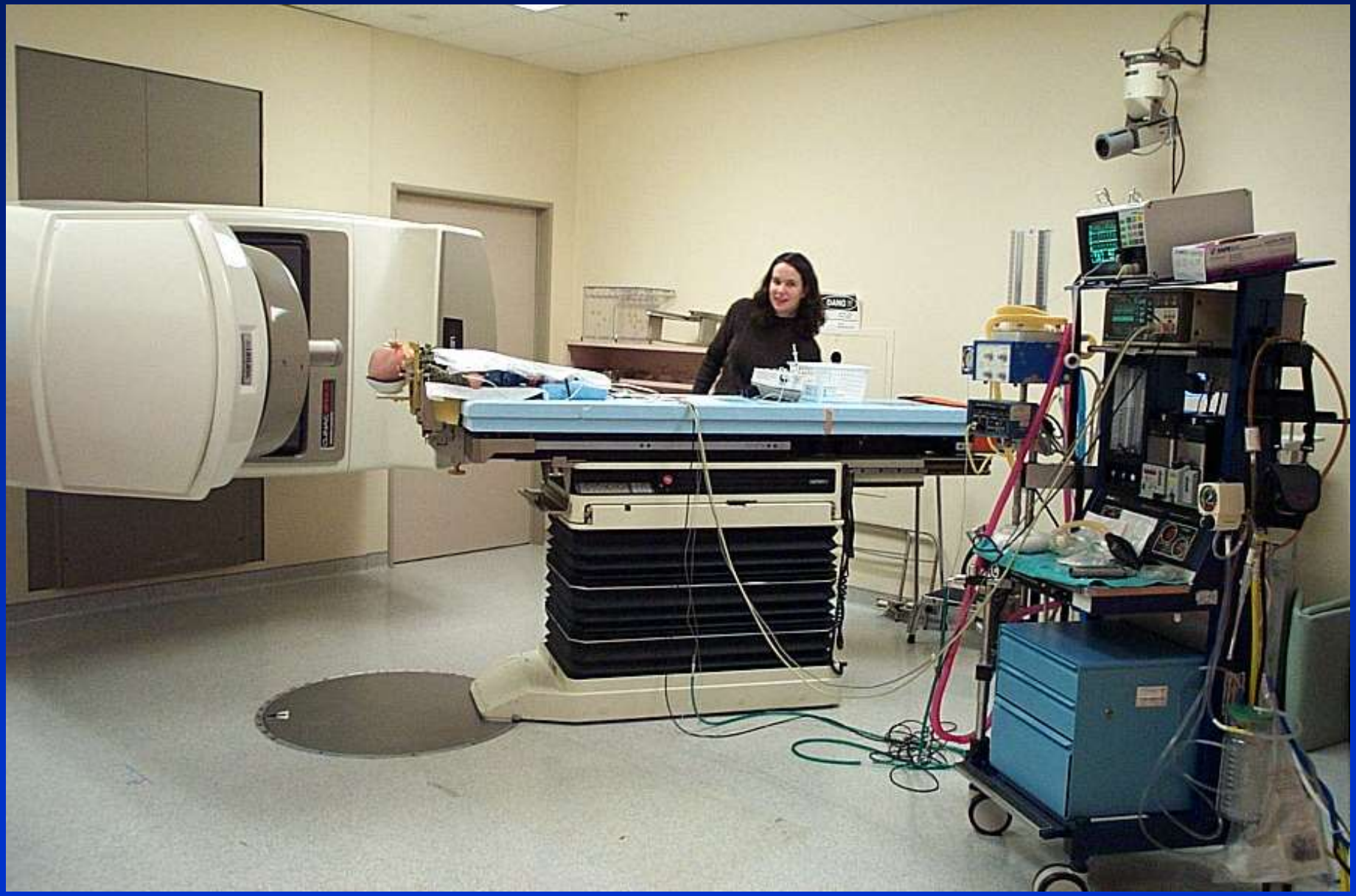
Immobilization

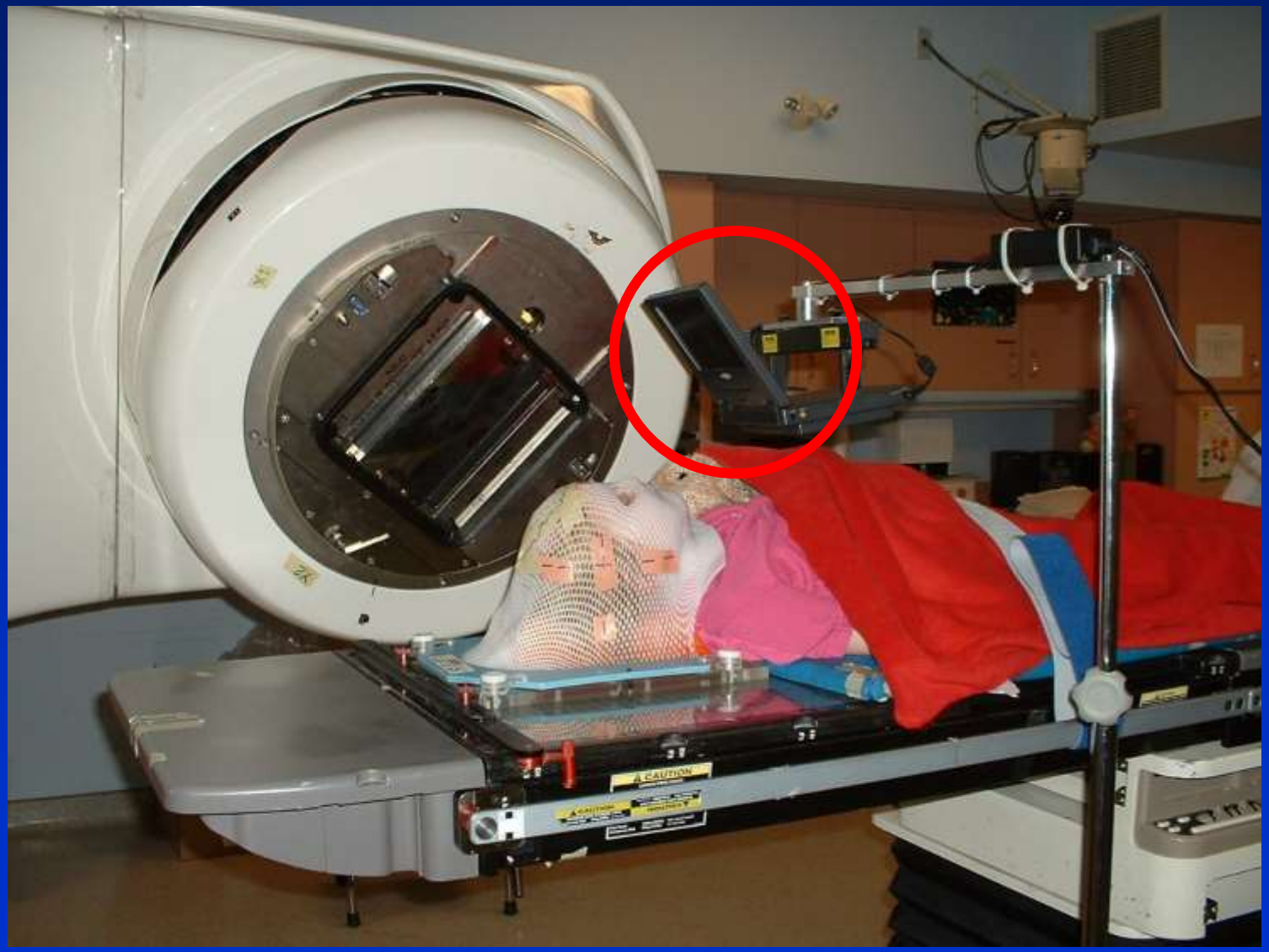


Pediatric Immobilization: Anesthesia



Most Effective Immobilization Device for Awake Children

Most Effective Immobilization Device for Awake Children



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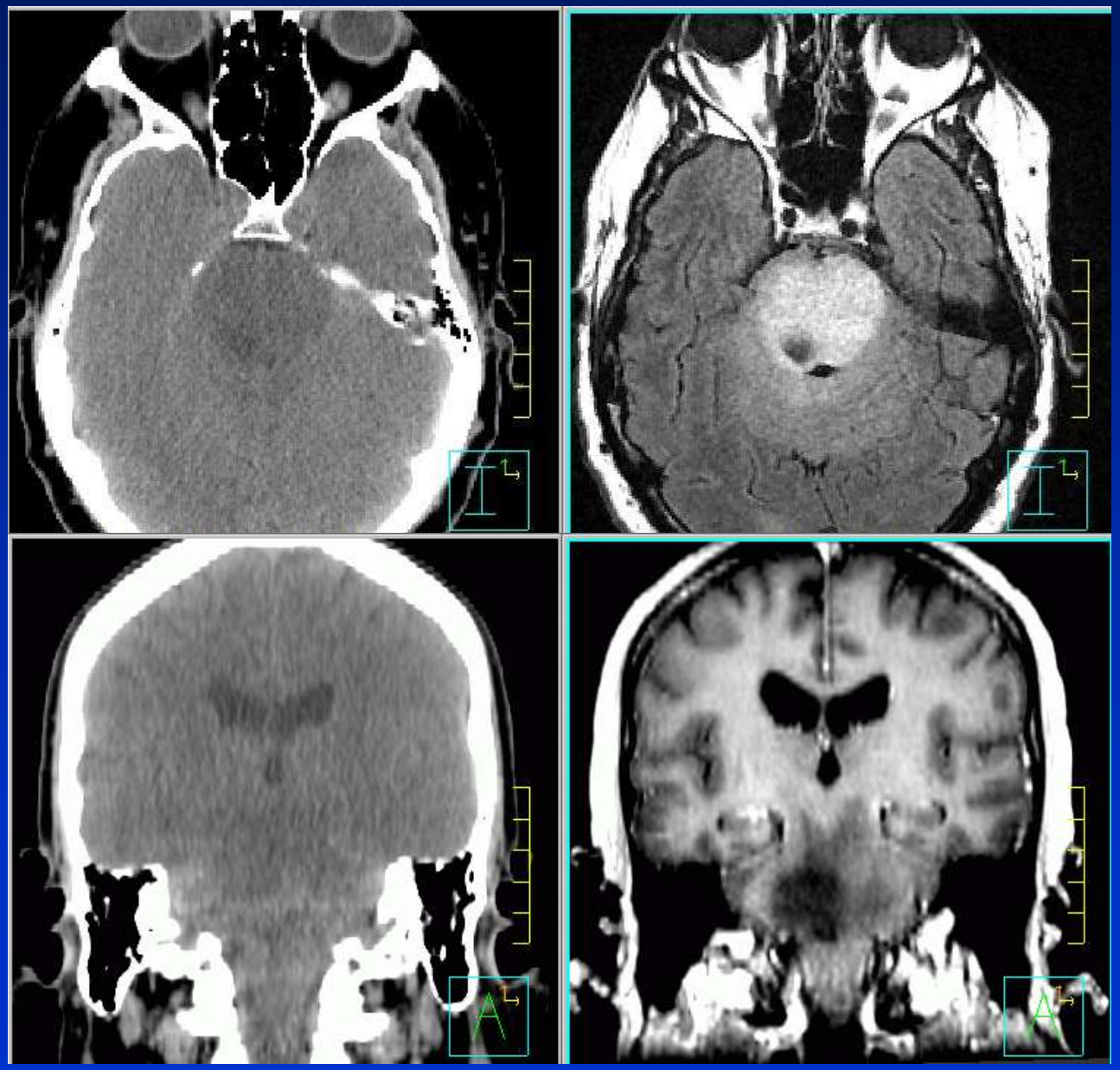
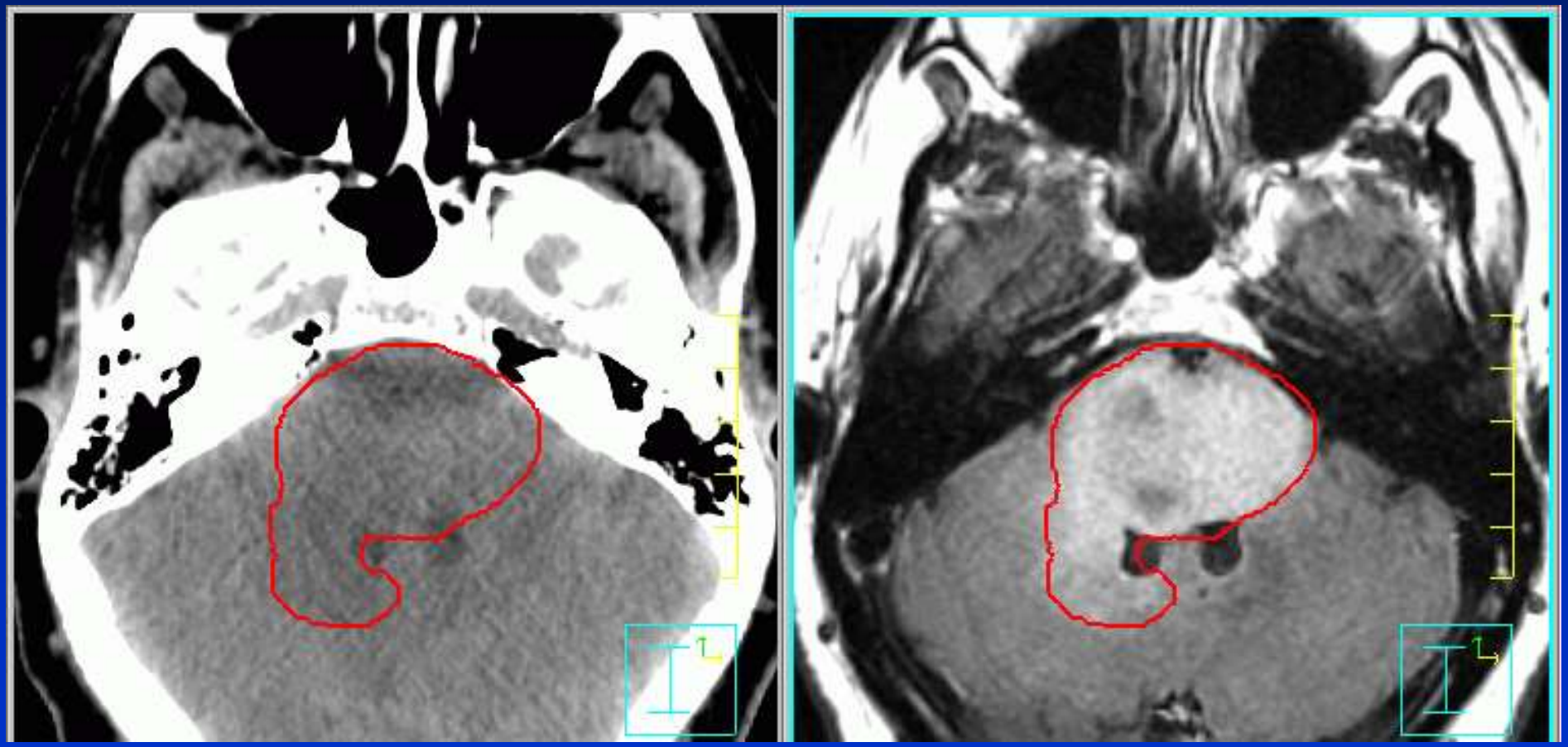
Protons

CT/MRI Simulation

CT-MRI Registration



Contouring



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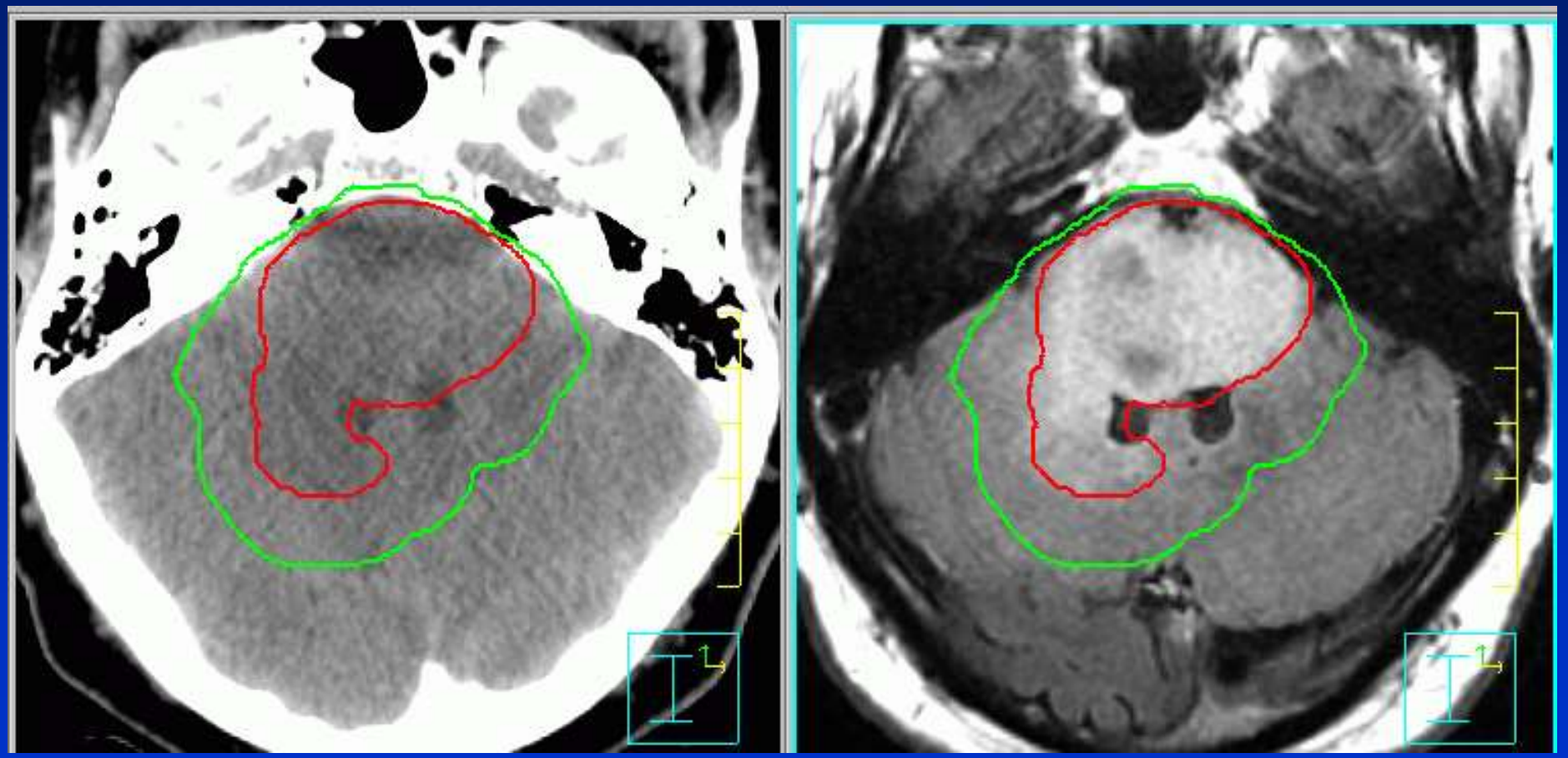

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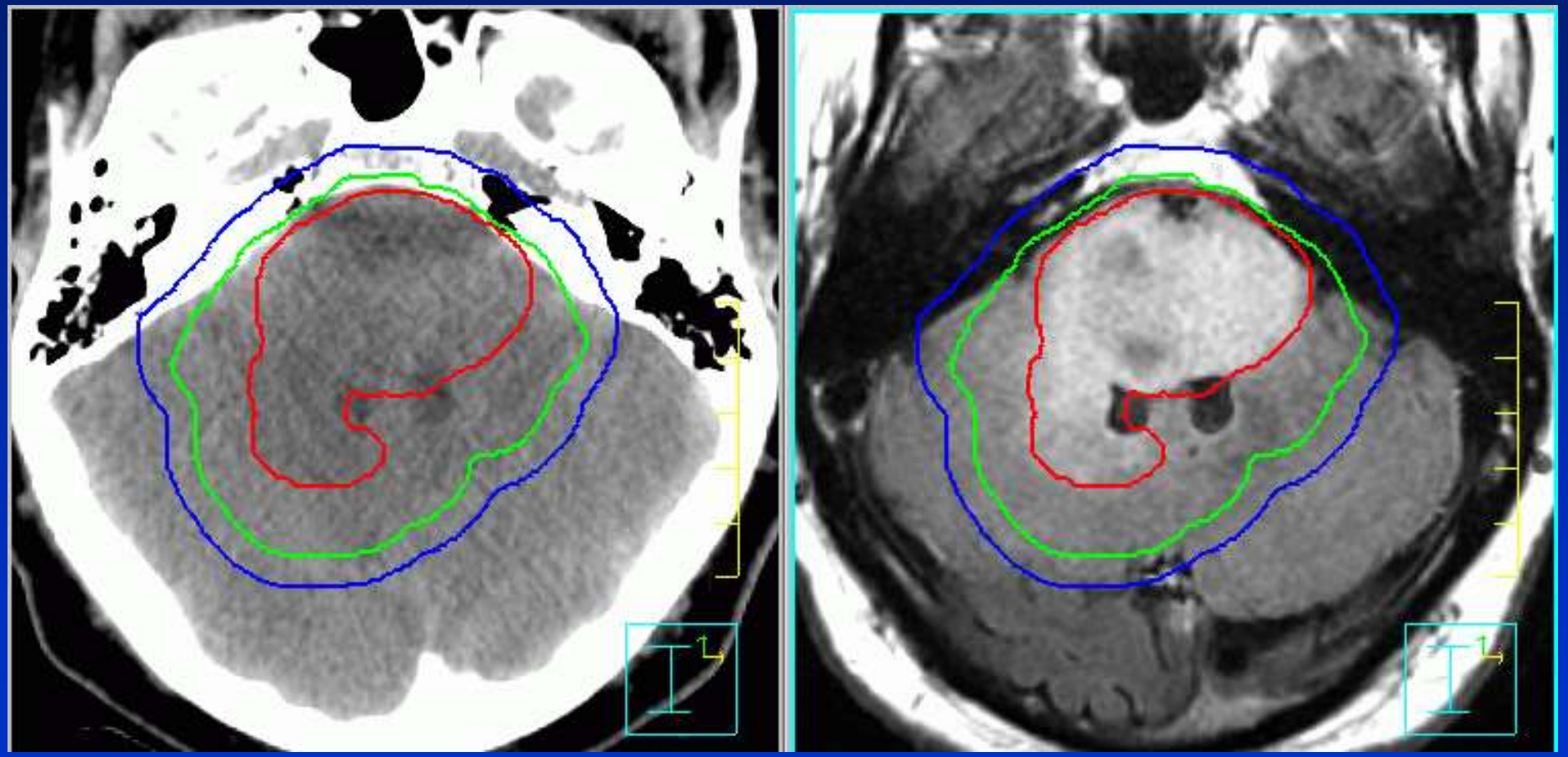

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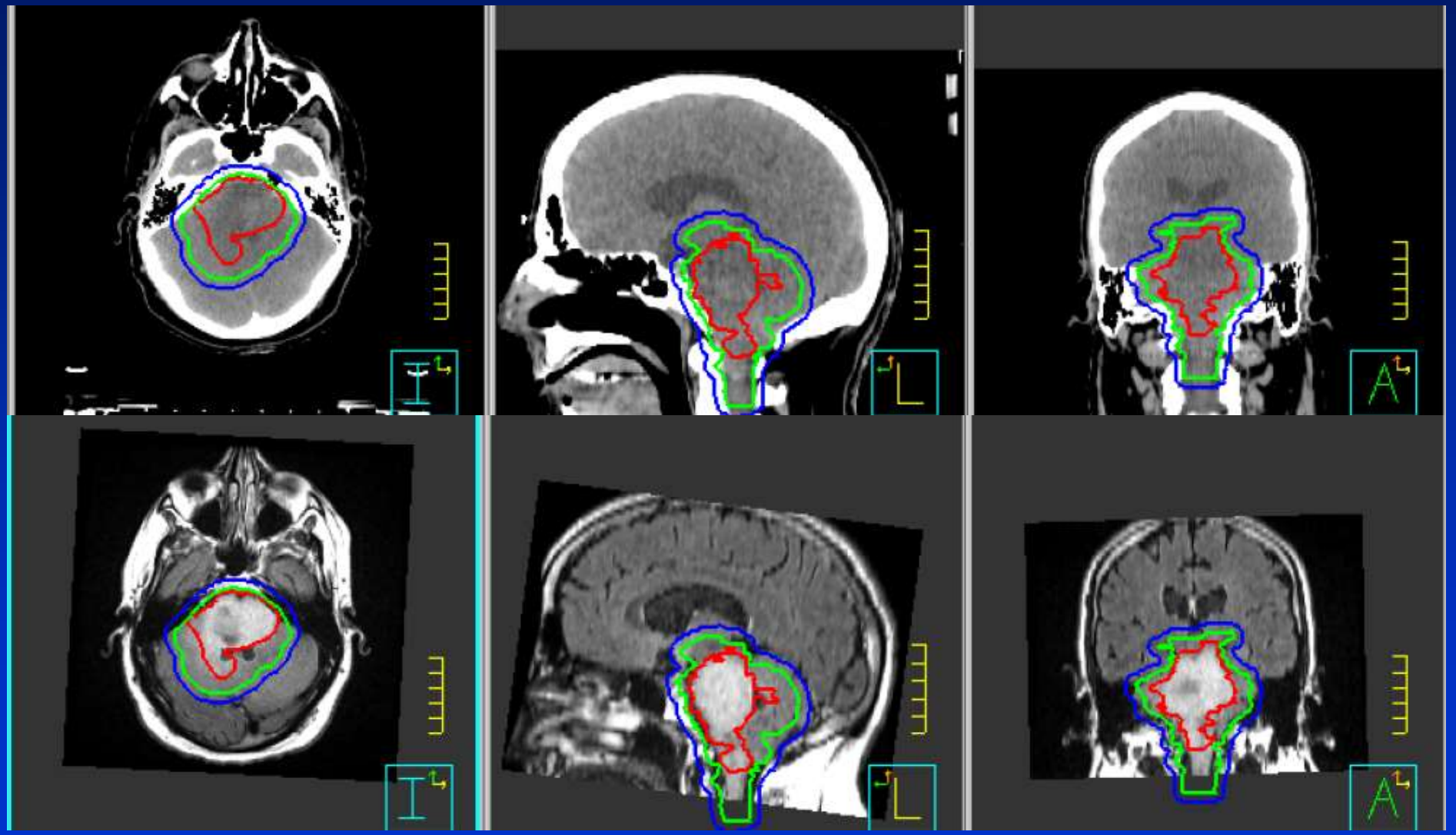

Contouring

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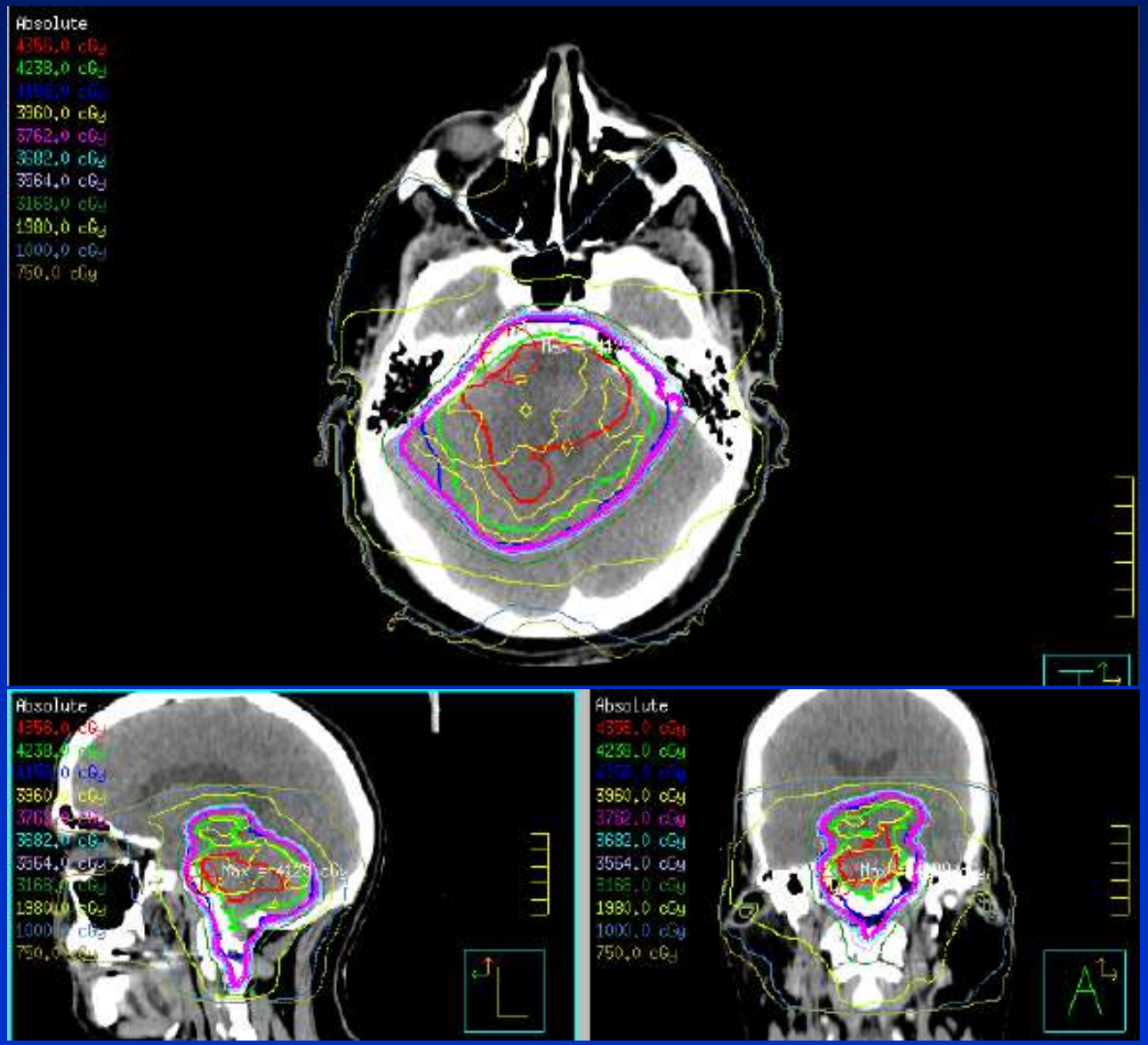
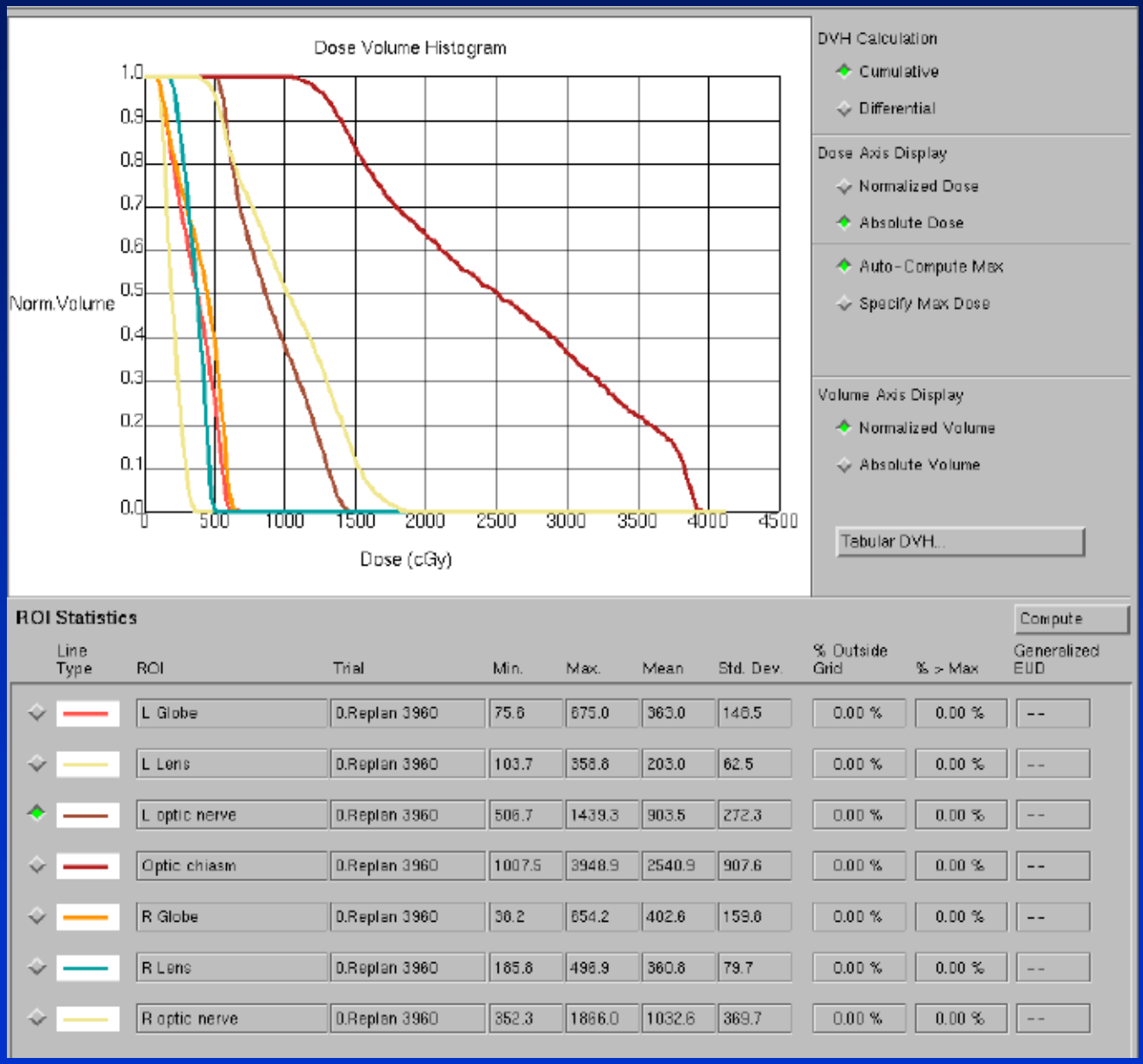
Protons

Radiation Distribution

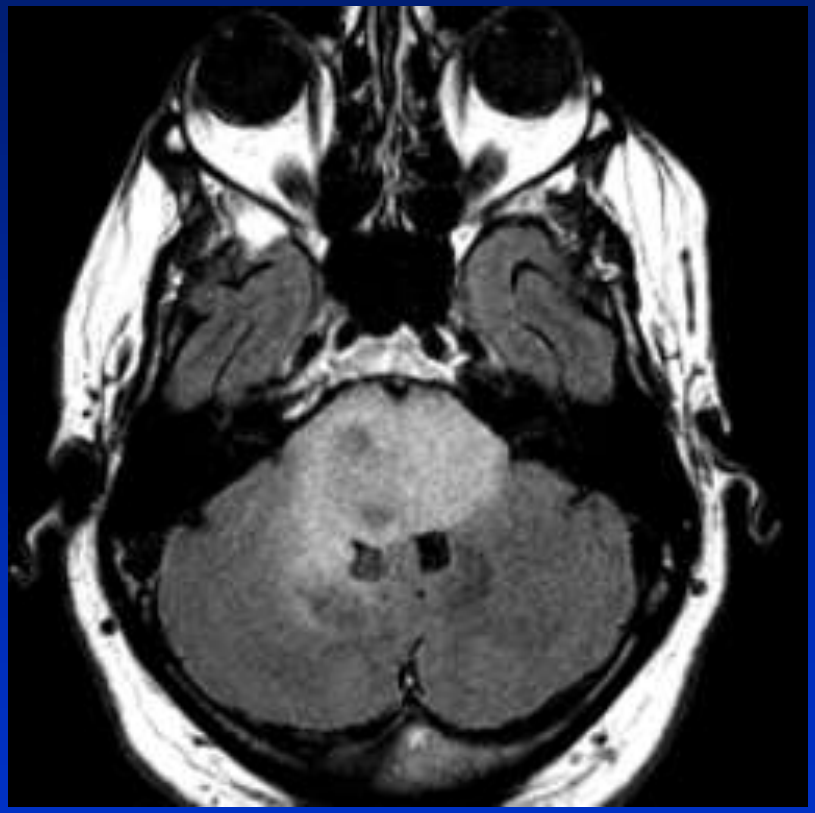


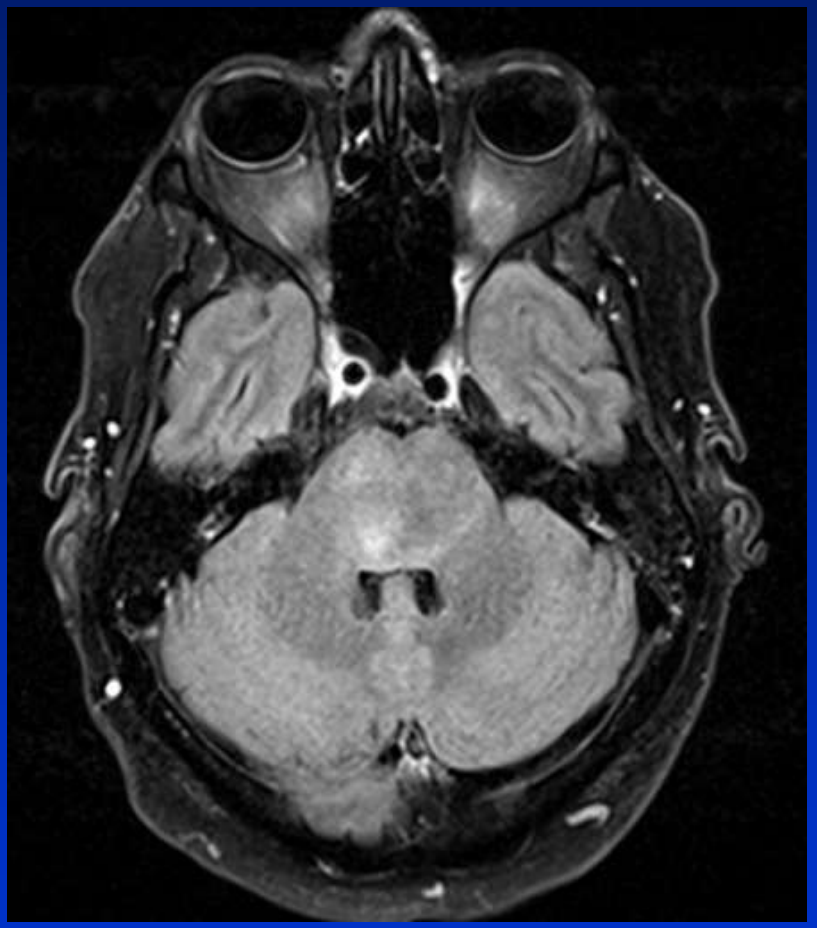
Dose Volume Histogram



Line Type	ROI	Trial	Min.	Max.	Mean	Std. Dev.	% Outside Grid	% > Max	Generalized EUD
	L Globe	0.Replan 3960	75.6	675.0	363.0	146.5	0.00 %	0.00 %	--
	L Lens	0.Replan 3960	103.7	358.6	203.0	62.5	0.00 %	0.00 %	--
	L optic nerve	0.Replan 3960	506.7	1439.3	903.5	272.3	0.00 %	0.00 %	--
	Optic chiasm	0.Replan 3960	1007.5	3948.9	2540.9	907.6	0.00 %	0.00 %	--
	R Globe	0.Replan 3960	36.2	654.2	402.6	159.8	0.00 %	0.00 %	--
	R Lens	0.Replan 3960	185.8	496.9	360.8	79.7	0.00 %	0.00 %	--
	R optic nerve	0.Replan 3960	352.3	1866.0	1032.6	369.7	0.00 %	0.00 %	--

Brain Stem Glioma: 46 yo male
RT 54 Gy/30 in 6 weeks



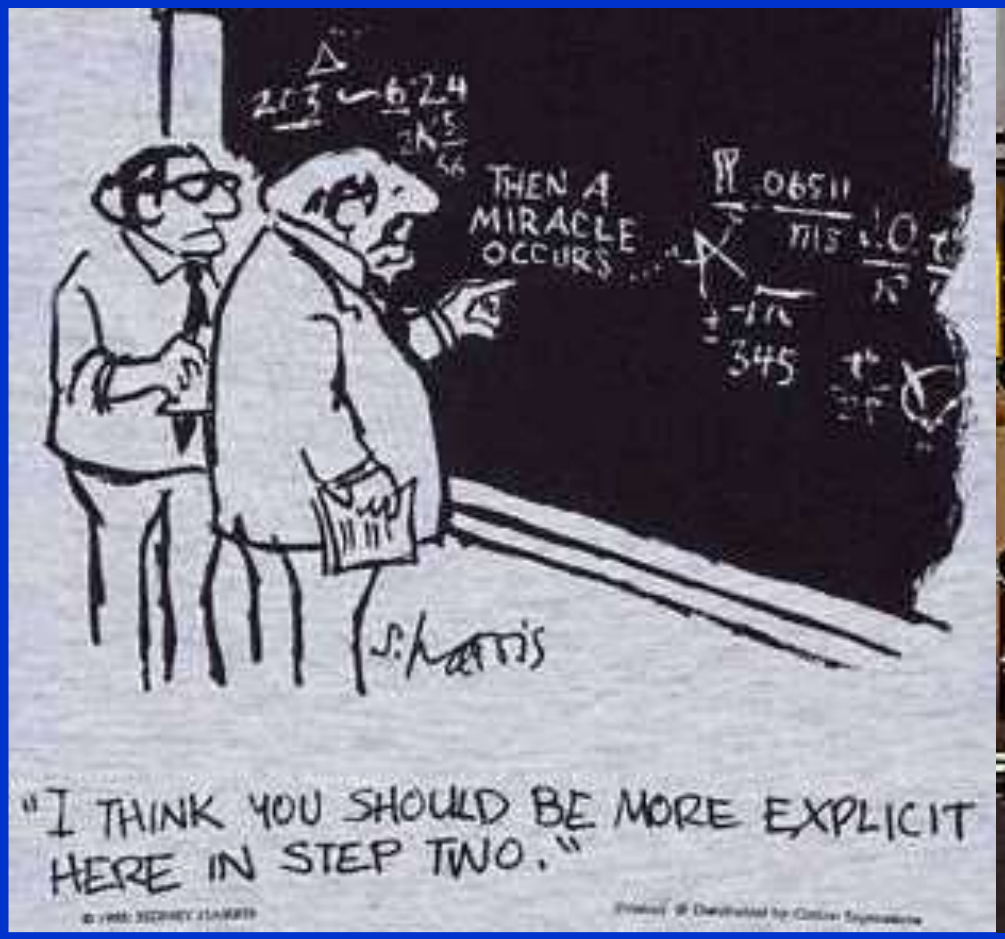


August 2013 October 2013

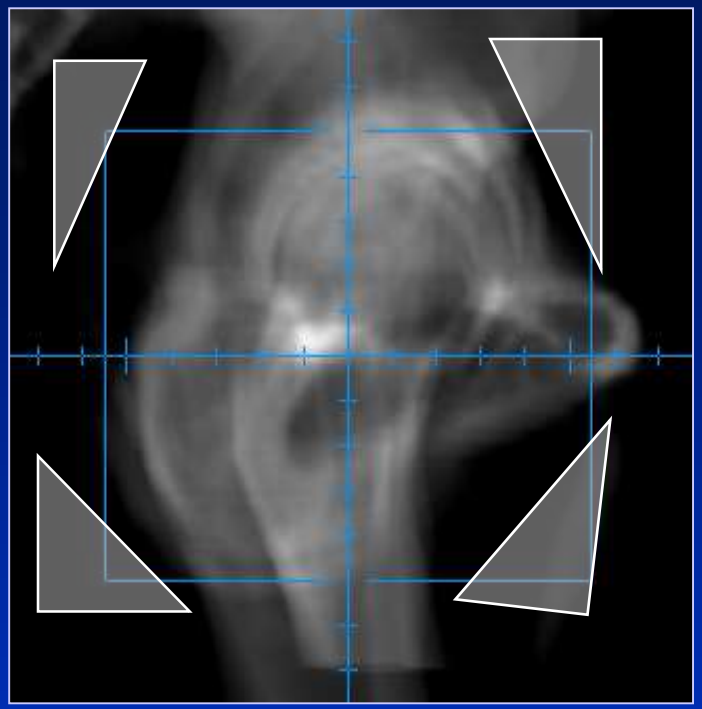
Complete resolution of double vision and ataxia

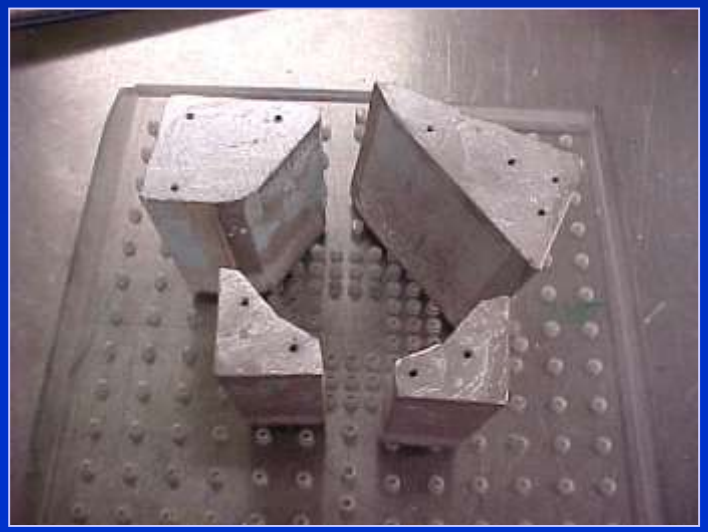
IMRT

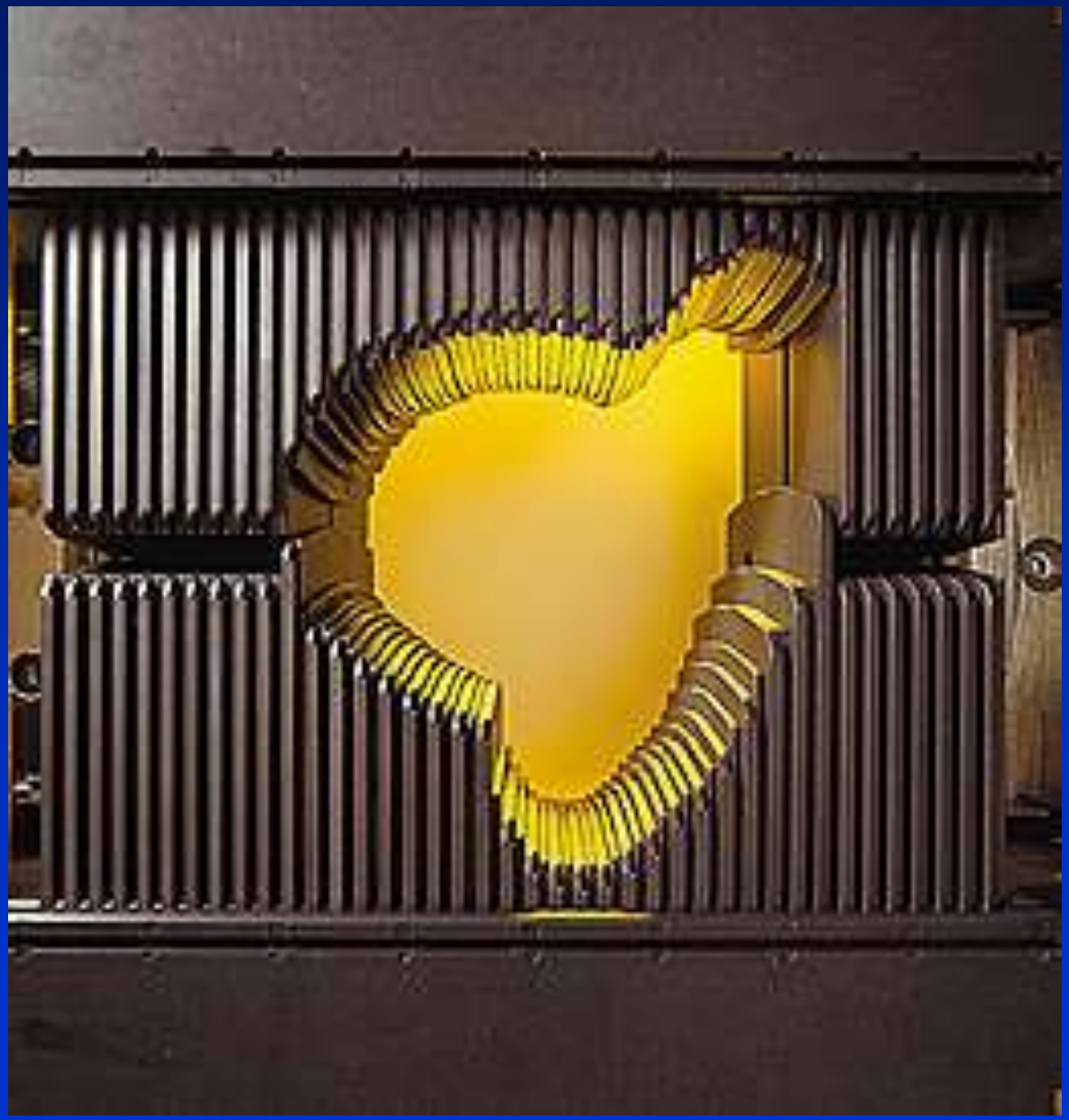
Vary the intensity of the radiation at any point in a x-ray beam using multileaf collimators

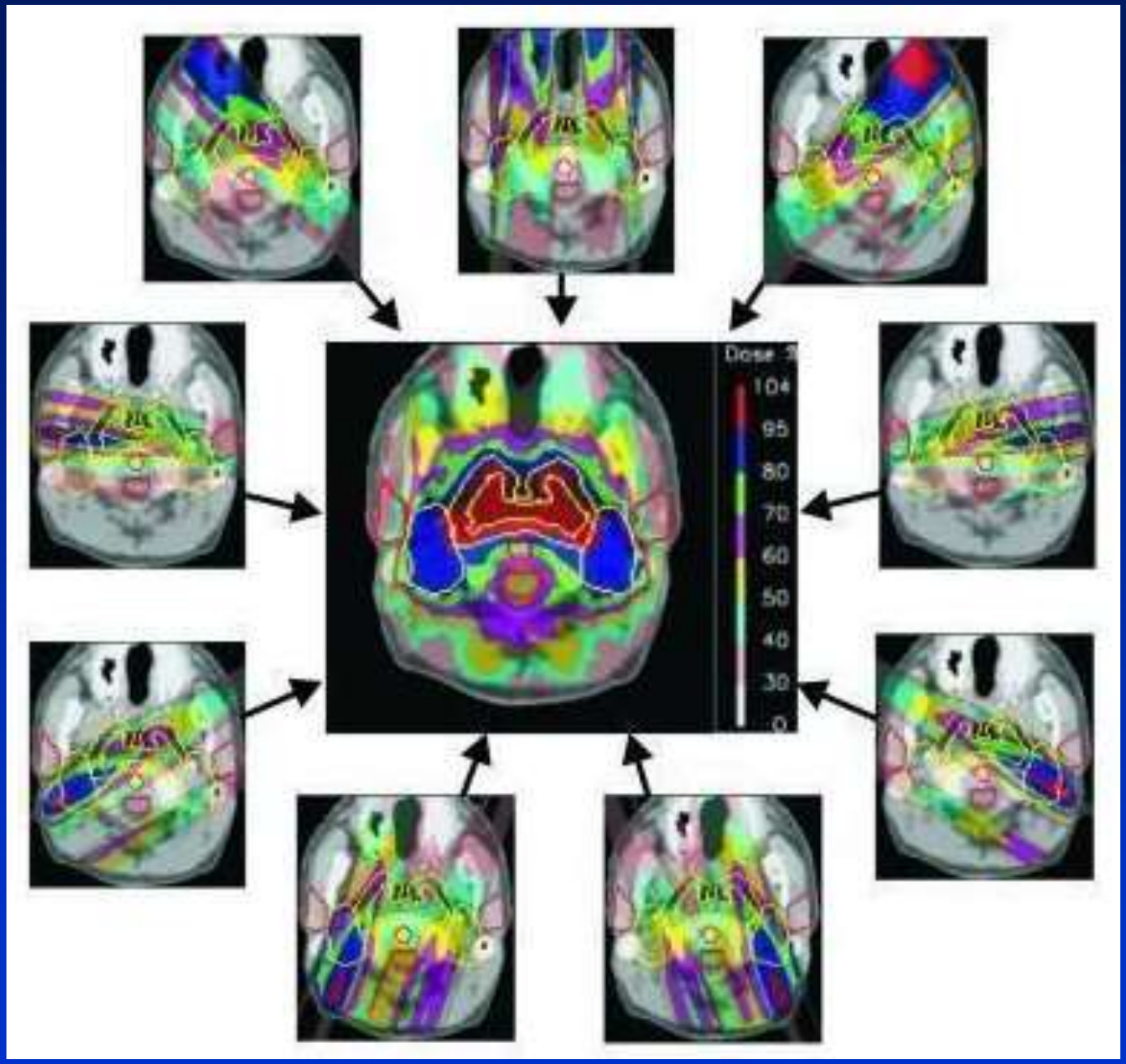


Multileaf Collimators

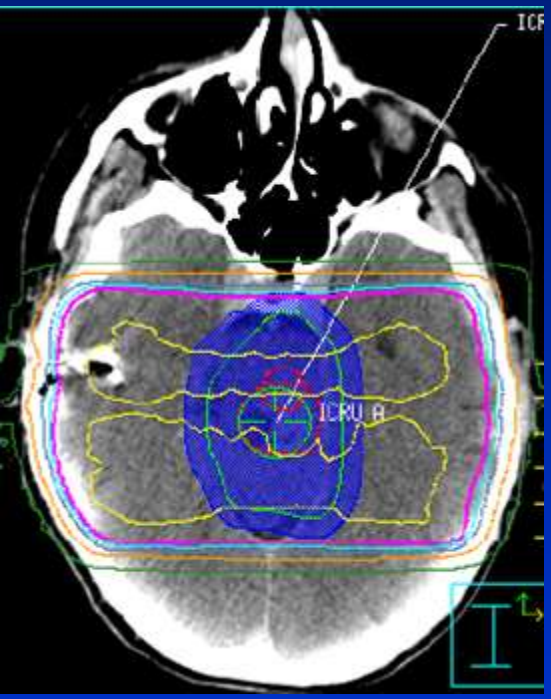




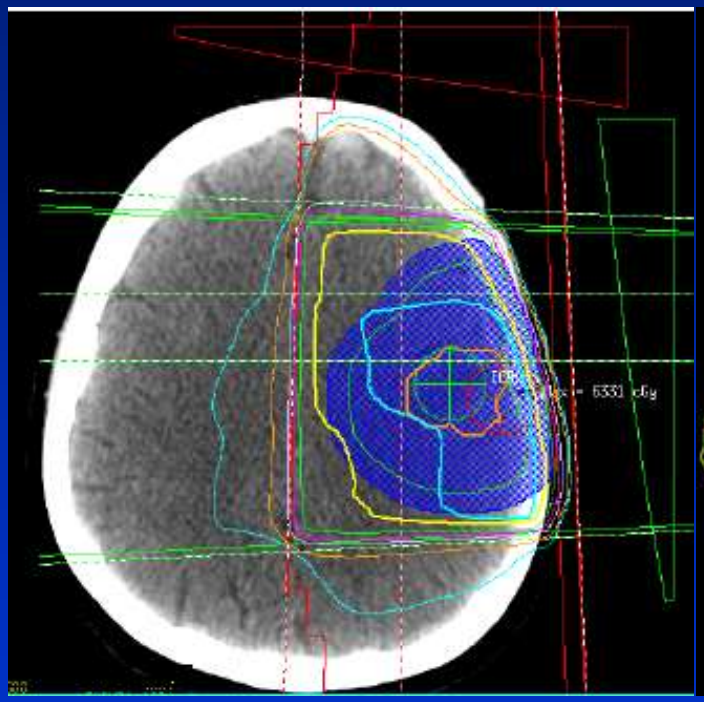



Dose
104
95
80
70
60
50
40
30
0

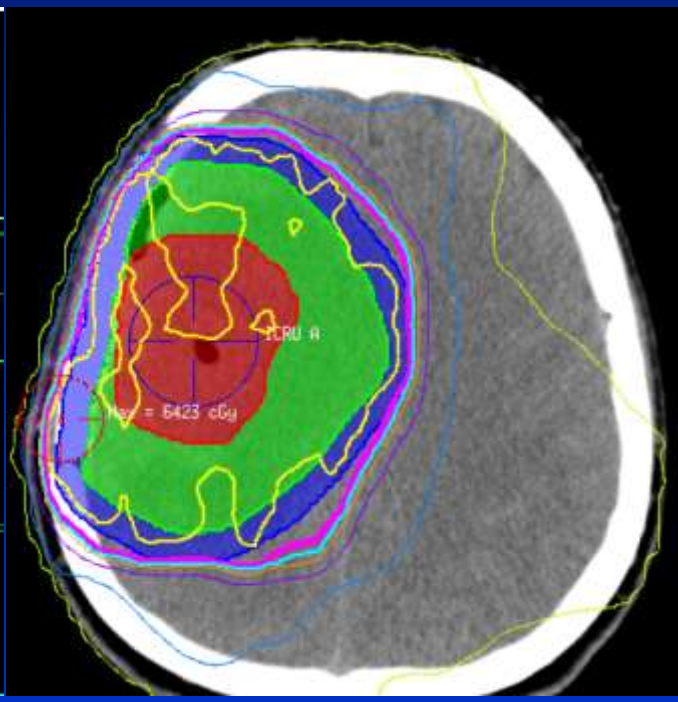
Benefits of IMRT



Opposed lat beams



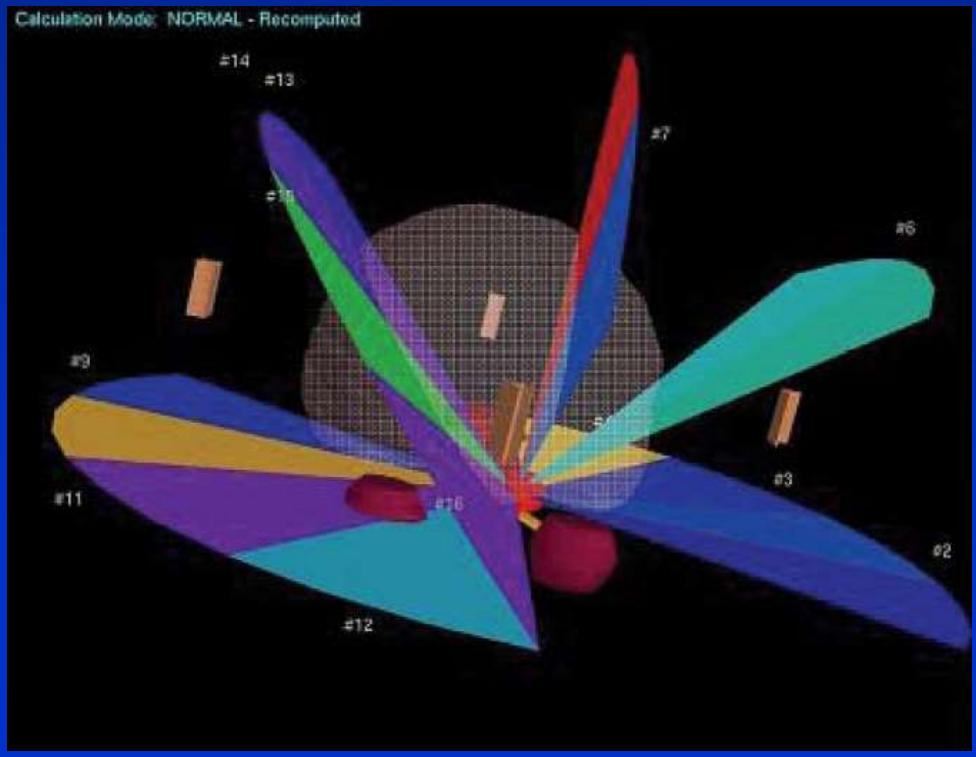
3D Conformal

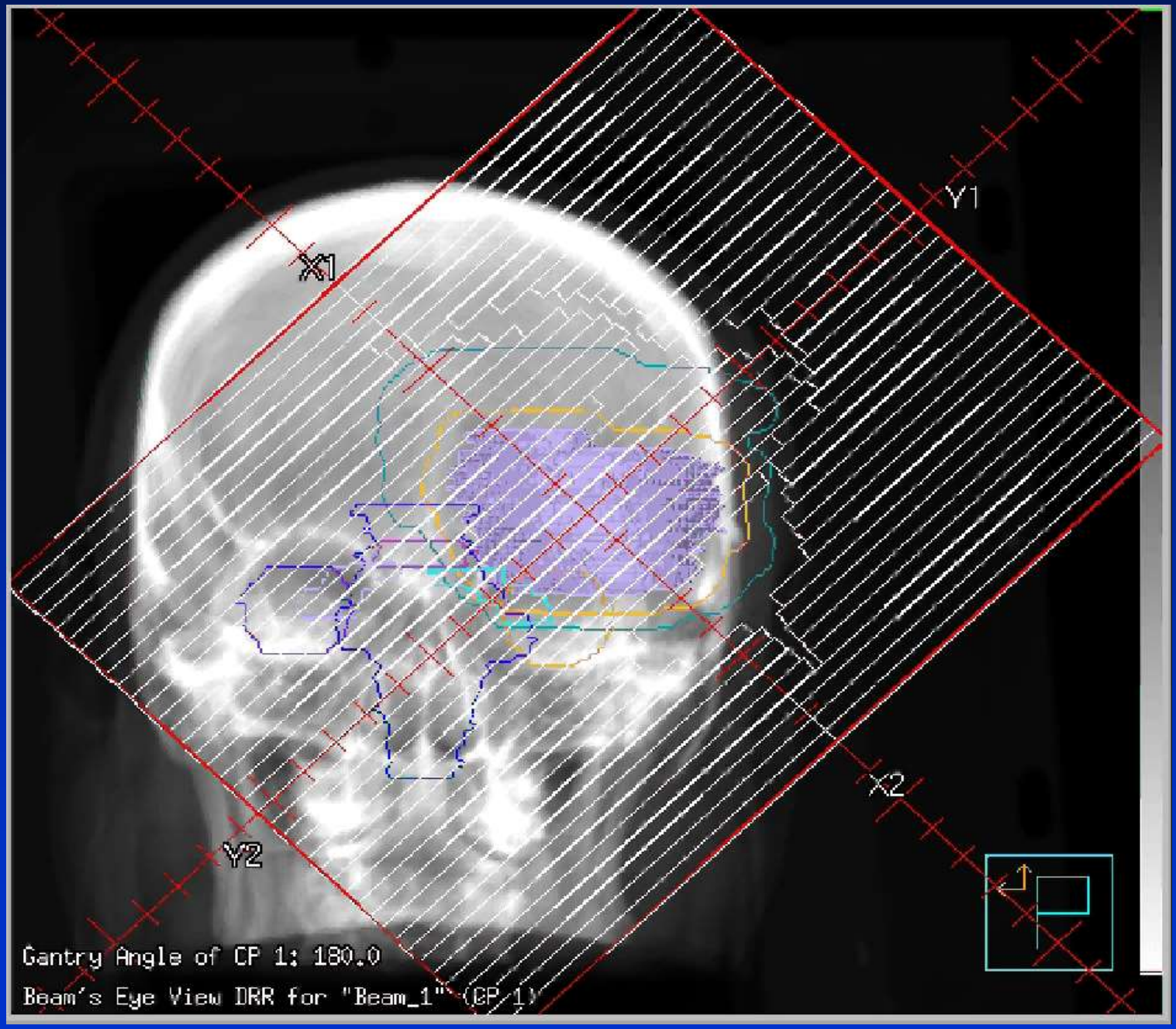


IMRT

VMAT – Volumetric Modulated Arc Therapy

- Delivers beam while gantry is rotating
- New degrees of freedom
  - Gantry speed
  - Gantry rotation
  - MLC leaf positions
  - Dose rate
- Faster Delivery





Courtesy Doug Moseley, Clinical Physics, PMH/UHN

Major Improvements in Radiation Technology

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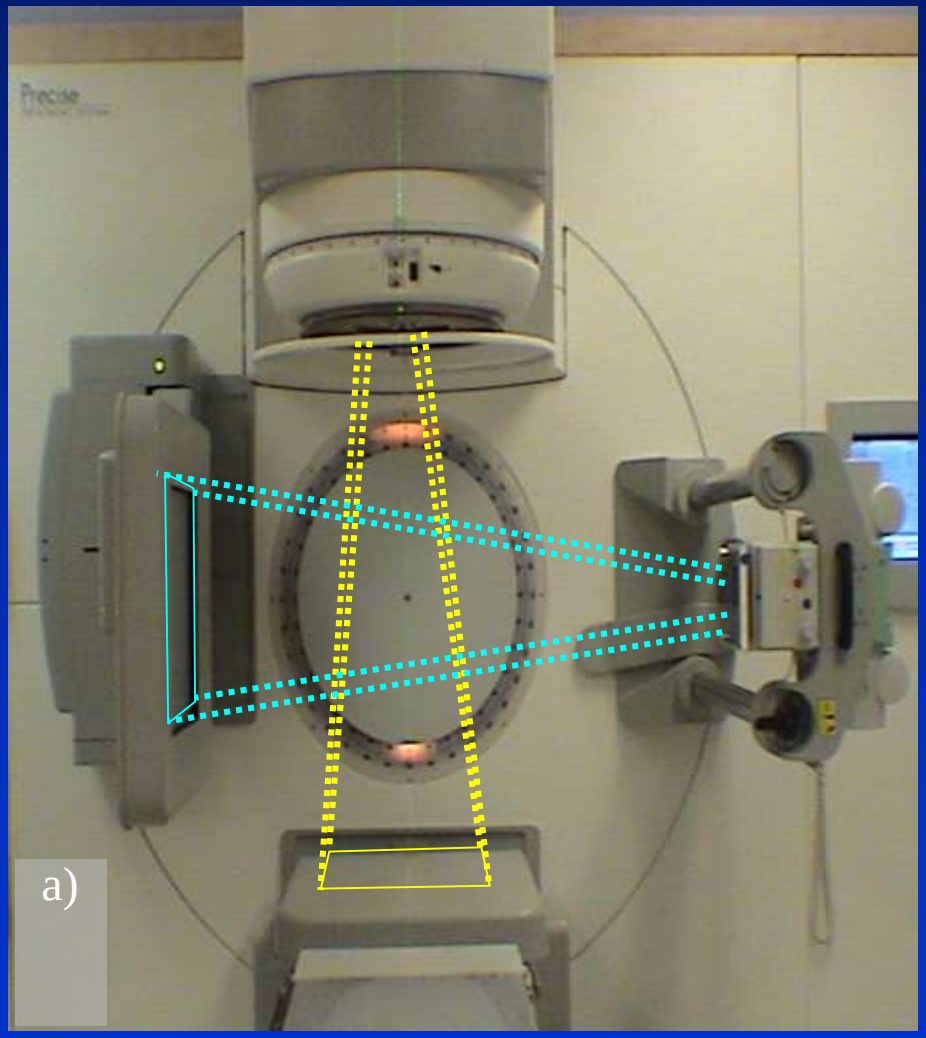
Image Guided Radiation Therapy (IGRT)

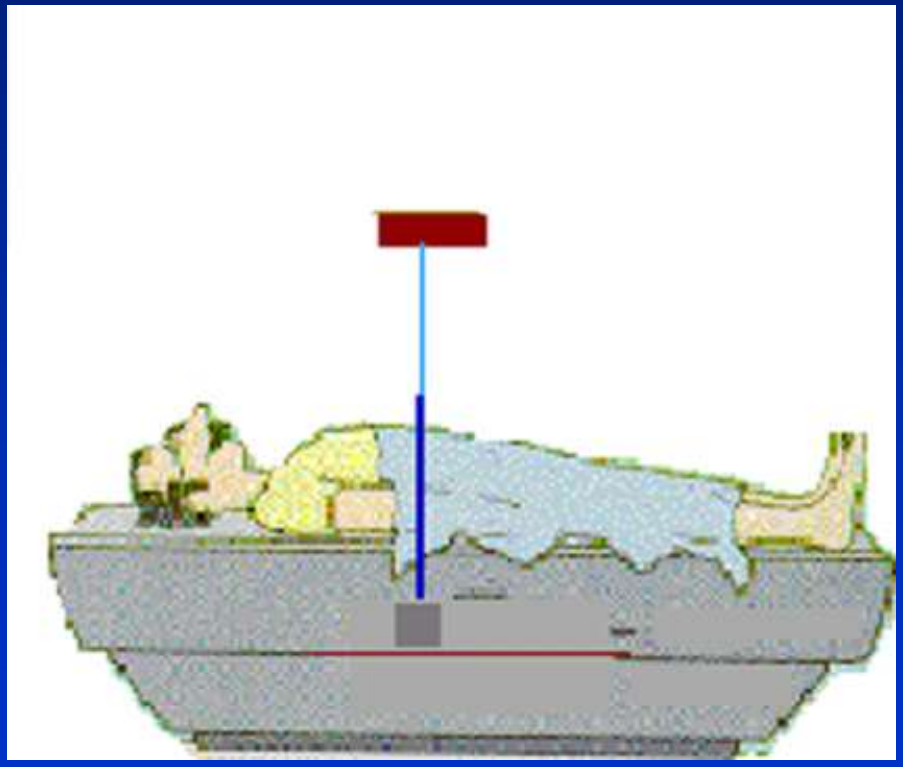
Radiosurgery

Protons

Image-Guided RT Platform
Cone Beam CT



Cone Beam CT



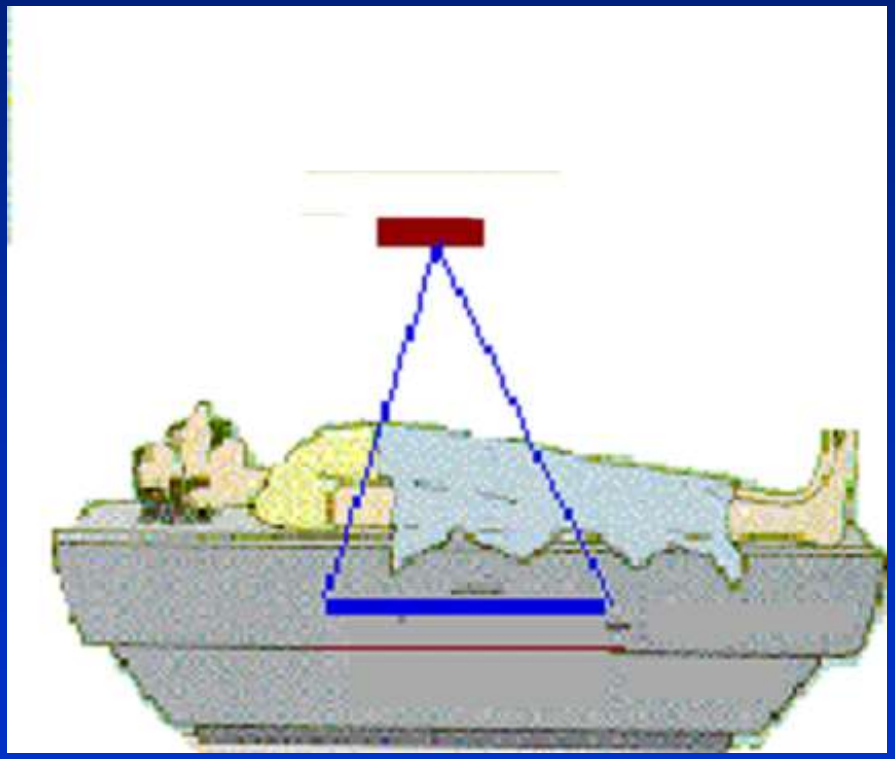
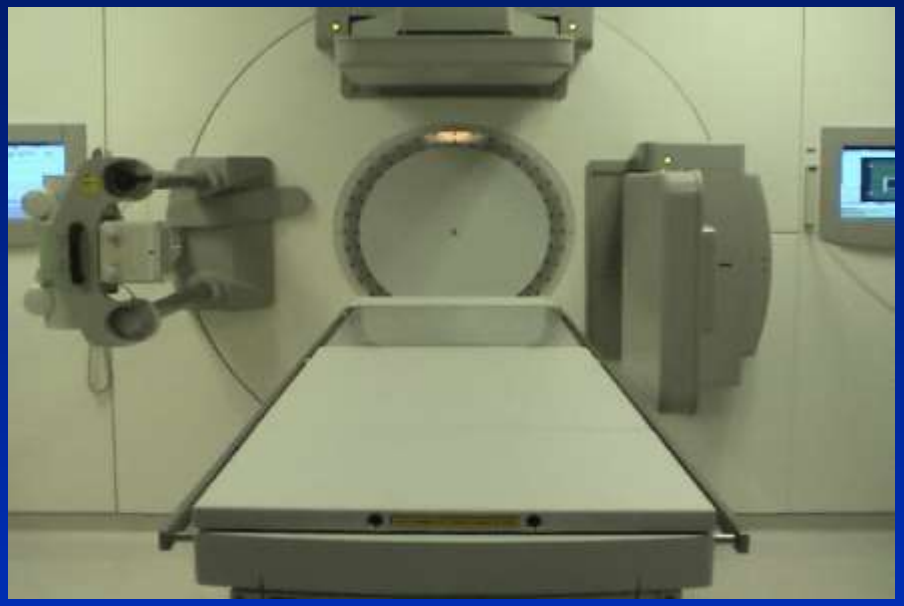
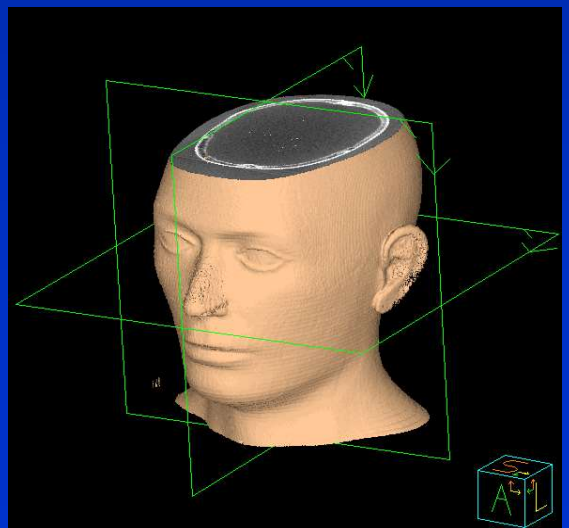
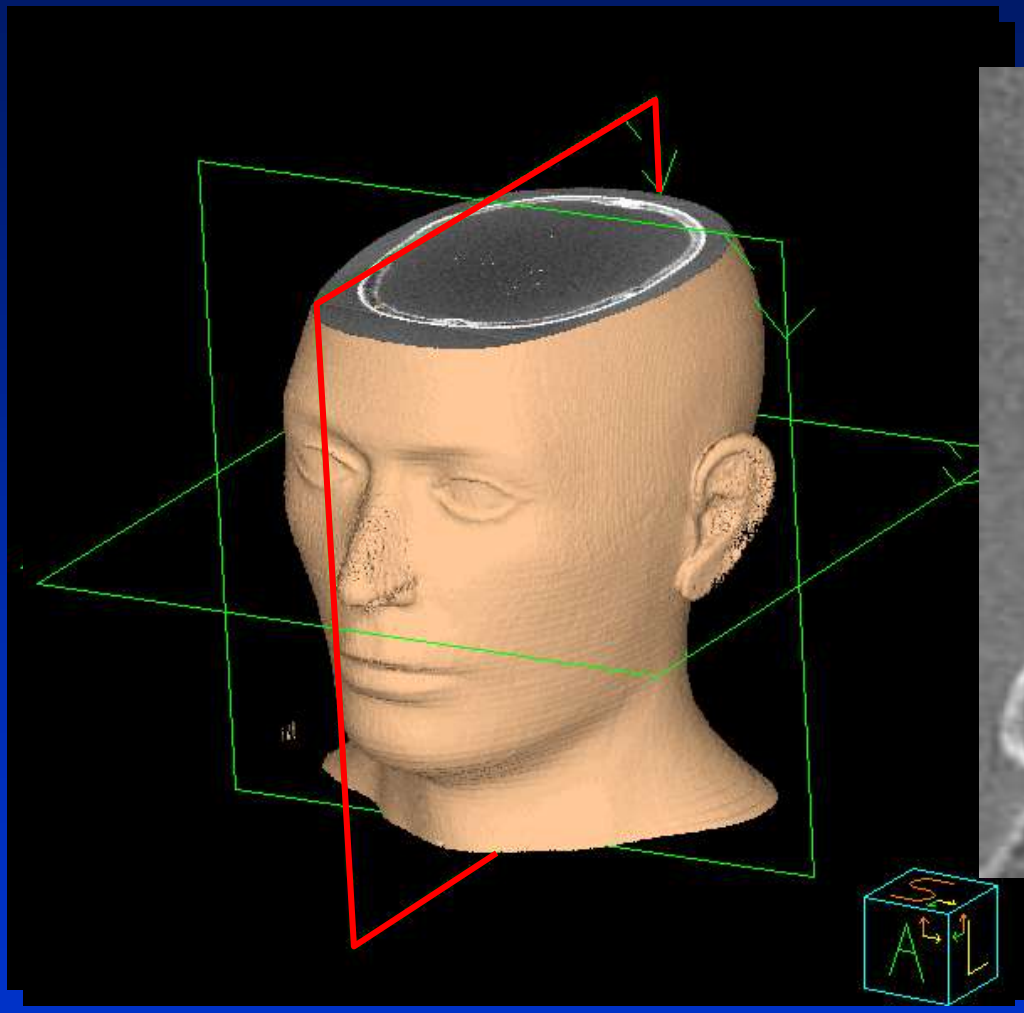


Image-Guided RT: Platform Cone Beam CT





Example Image: Skull Phantom



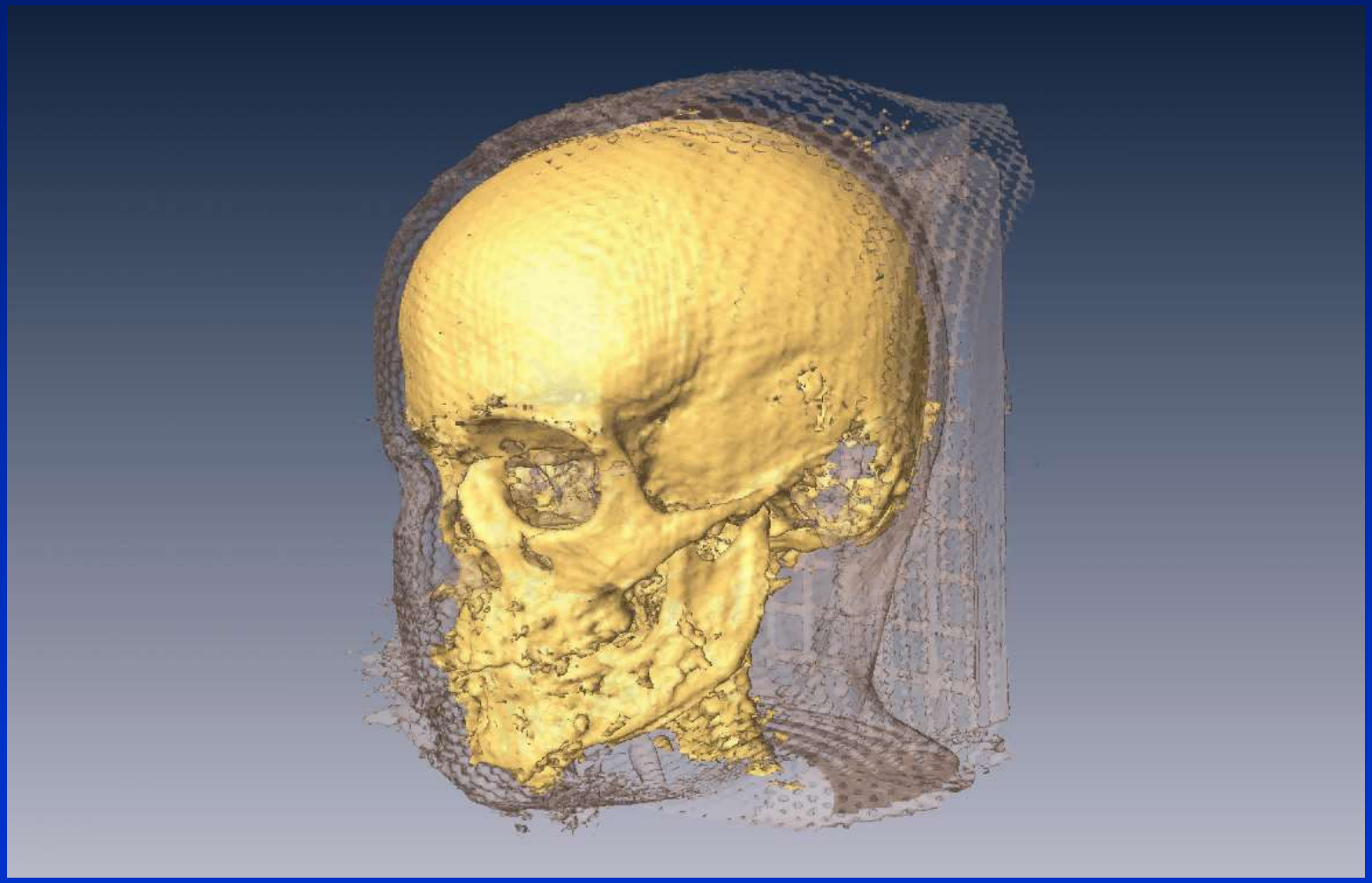
Sagittal

320 Projections; 120 kVp, 200 mAs; 180 s.

(0.25 x 0.25 x 0.25) mm^3 voxels

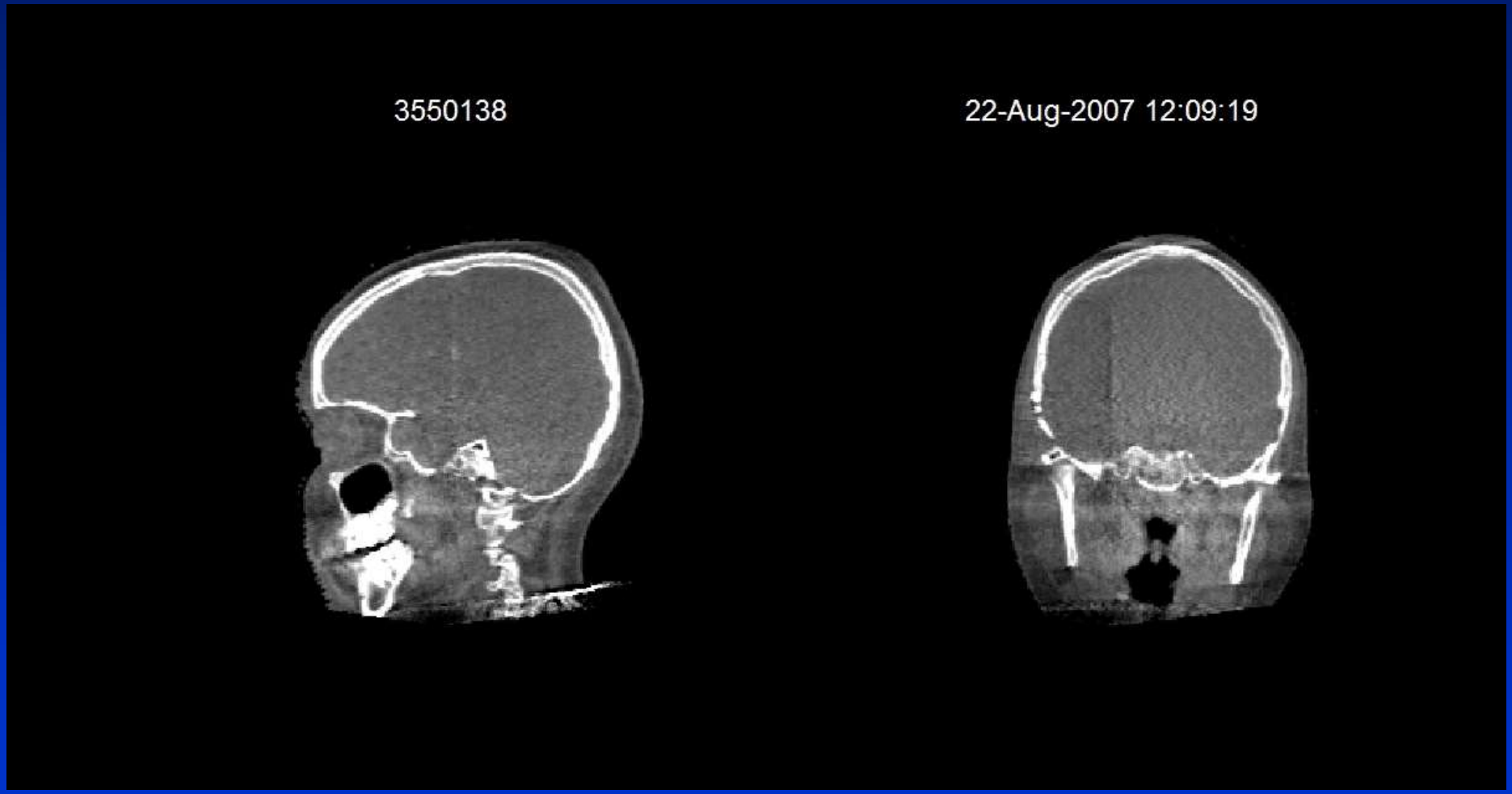
Cone Beam CT

7 yo male, Recurrent Anaplastic Ependymoma



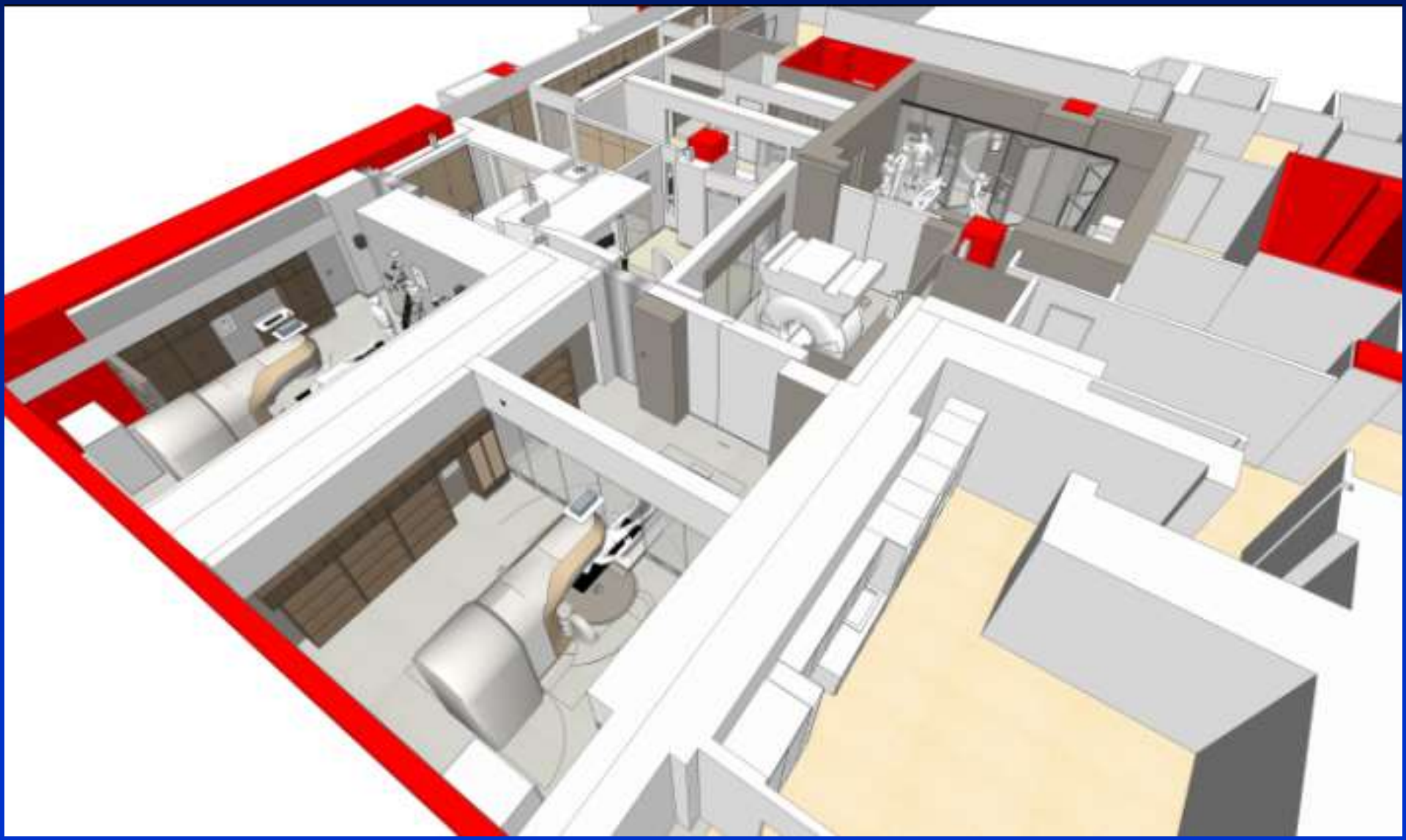
Courtesy Doug Moseley, Clinical Physics, PMH/UHN

Image Guide RT: Cone Beam CT

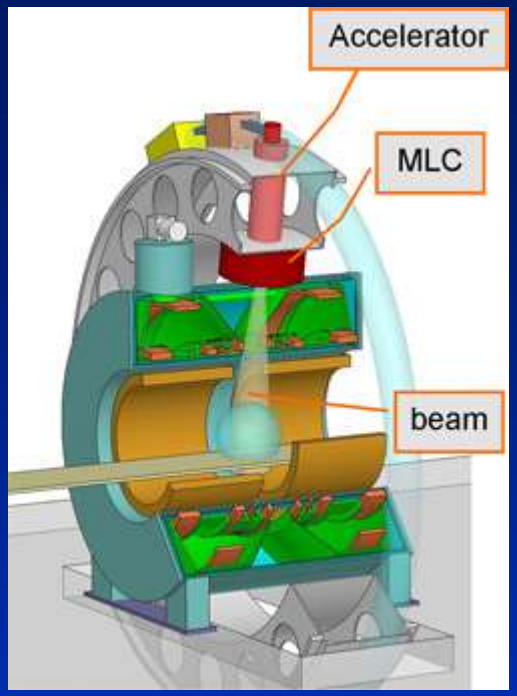


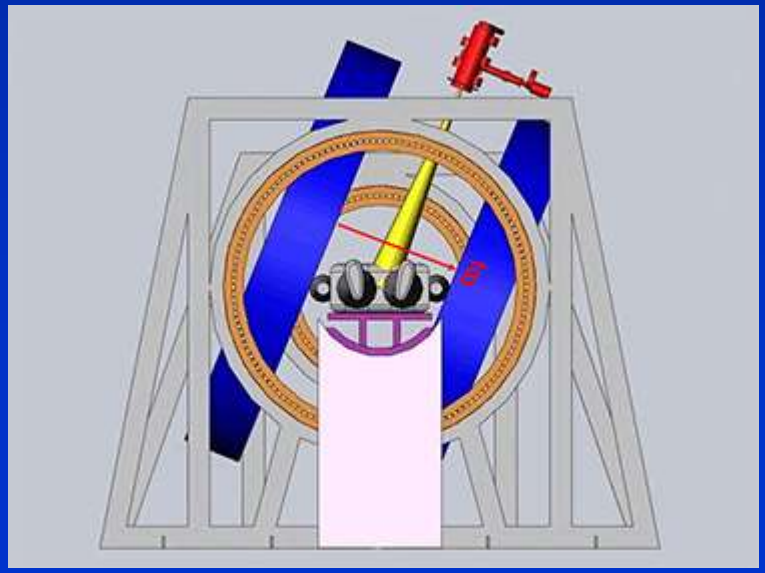
Courtesy Doug Moseley, Clinical Physics, PMH/UHN

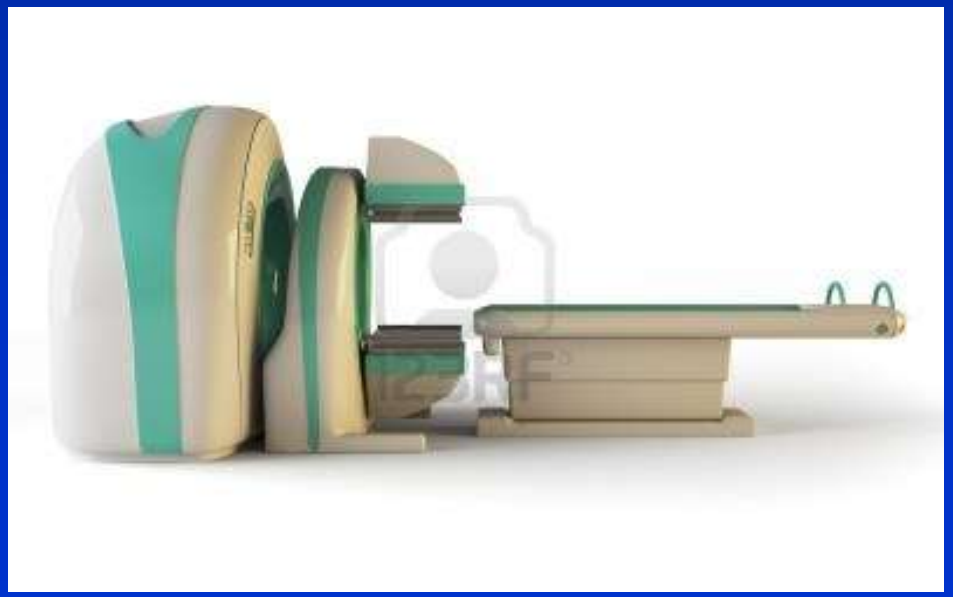
MRI IGRT Princess Margaret



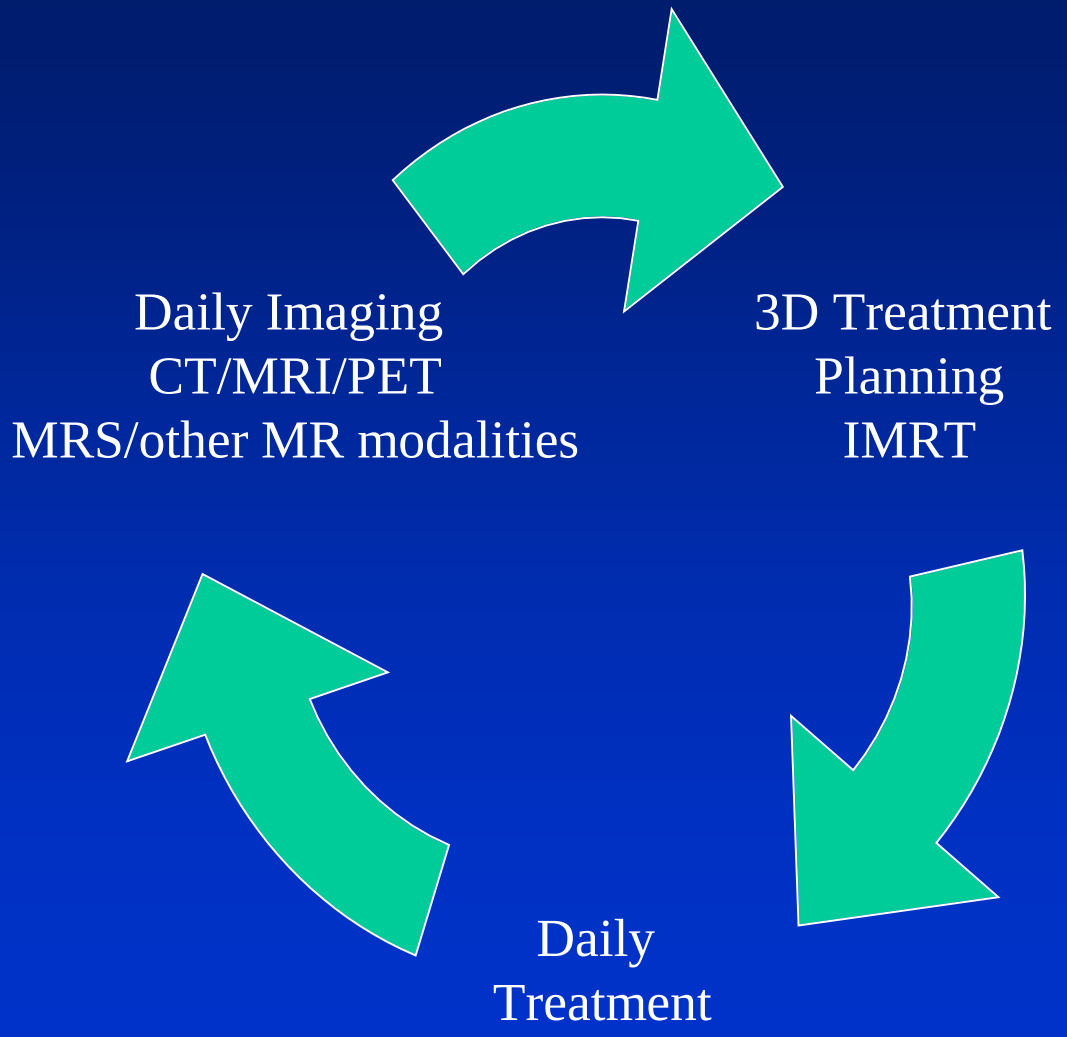
Combined MRI/RT Units



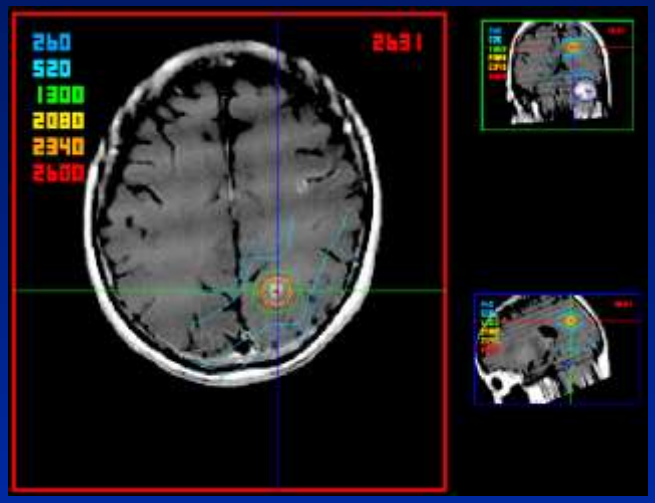


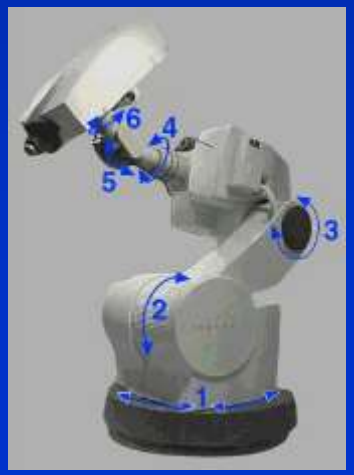


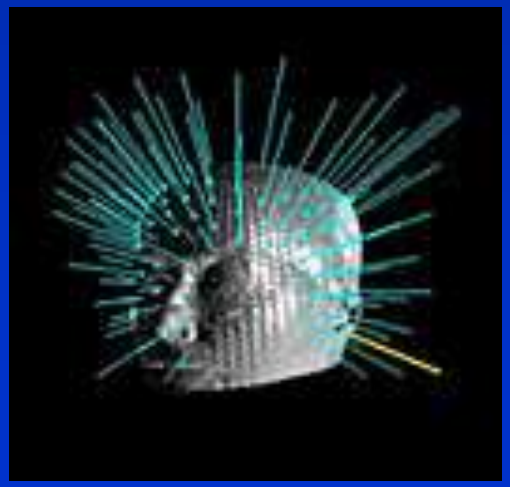
Adaptive Radiotherapy



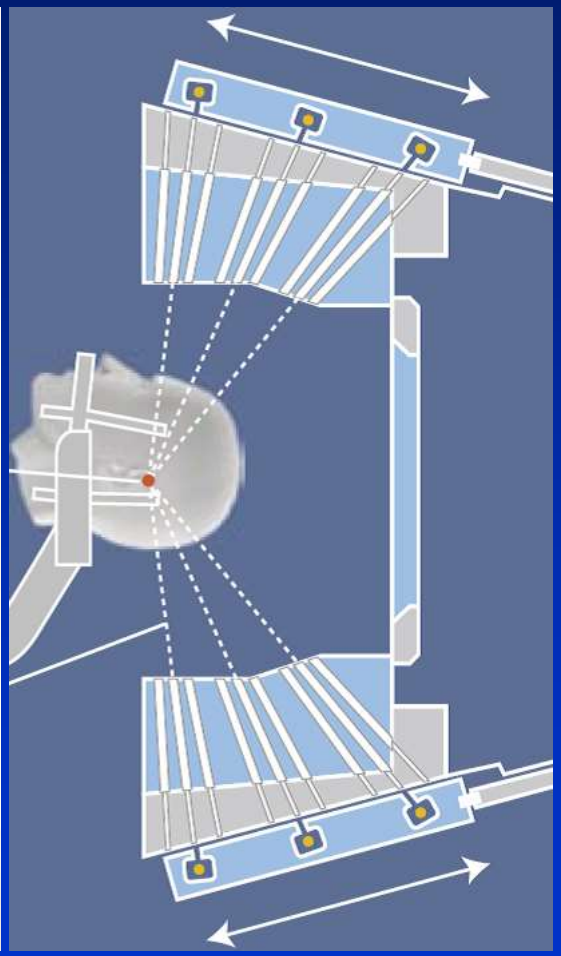
Radiosurgery



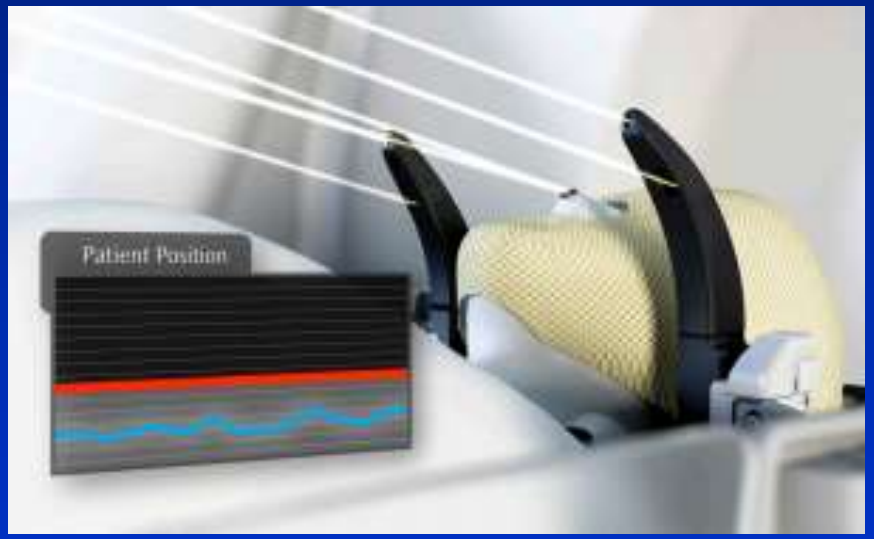




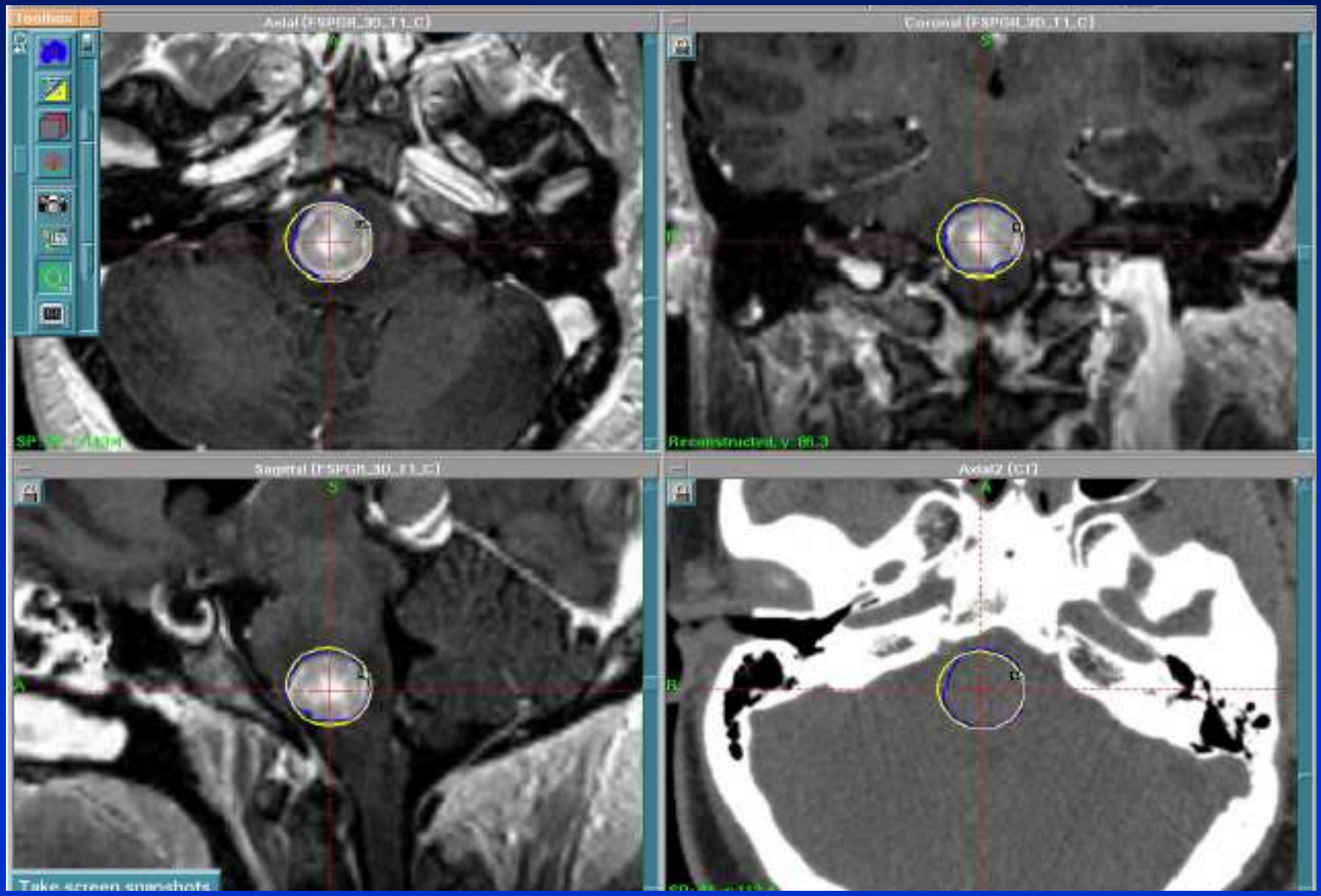
Gamma Knife Unit



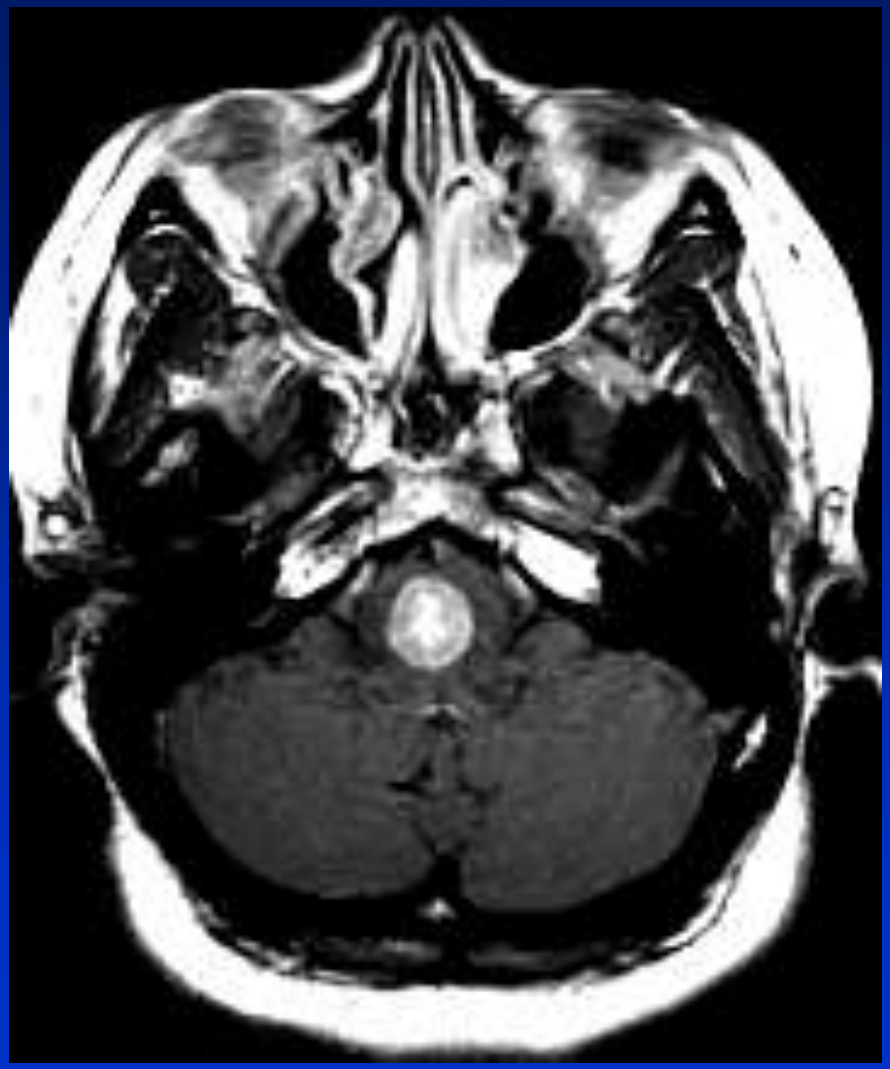
Gamma Knife Icon



Brain Metastases



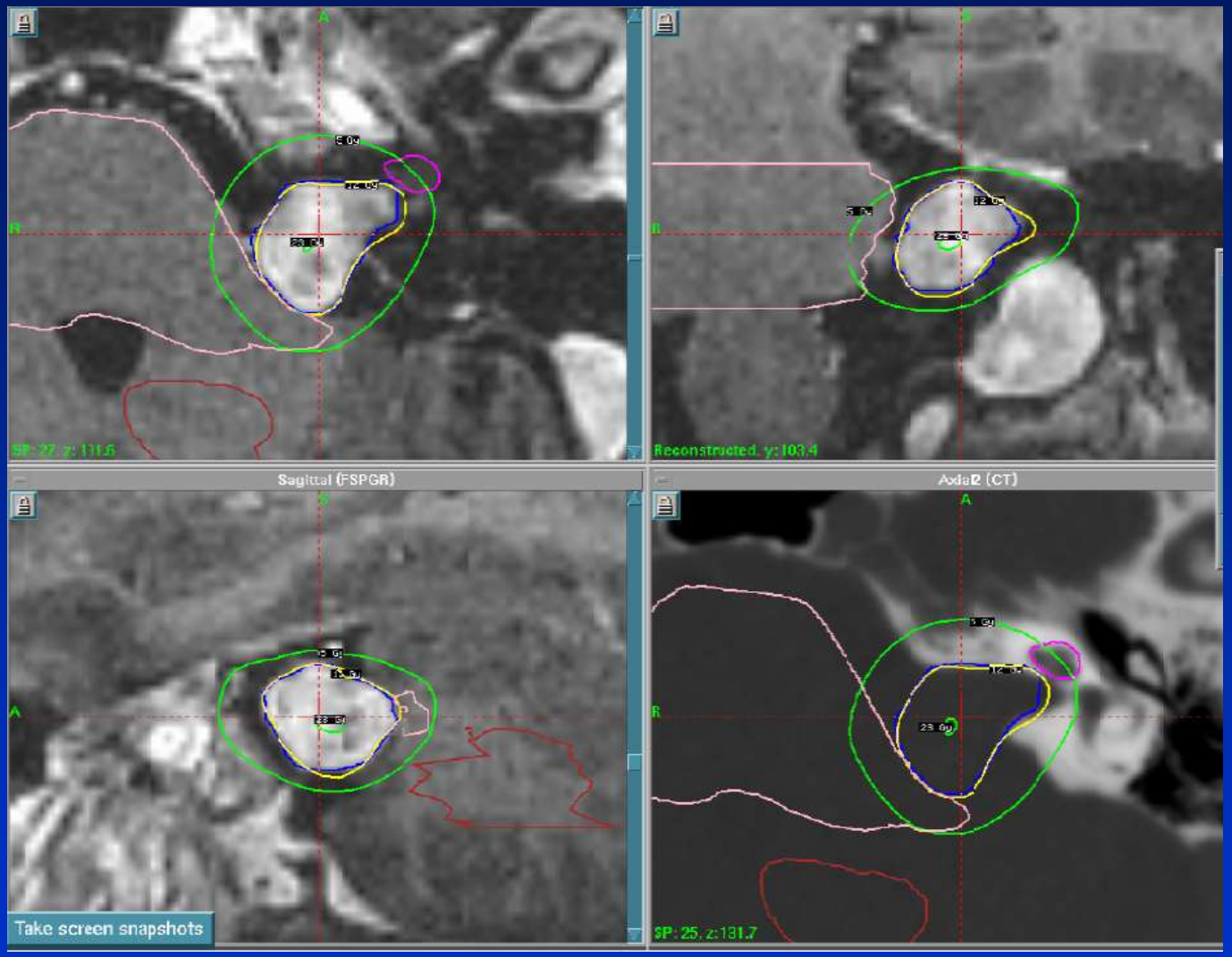
SRS 15 Gy to 50%



April 2006

June 2006

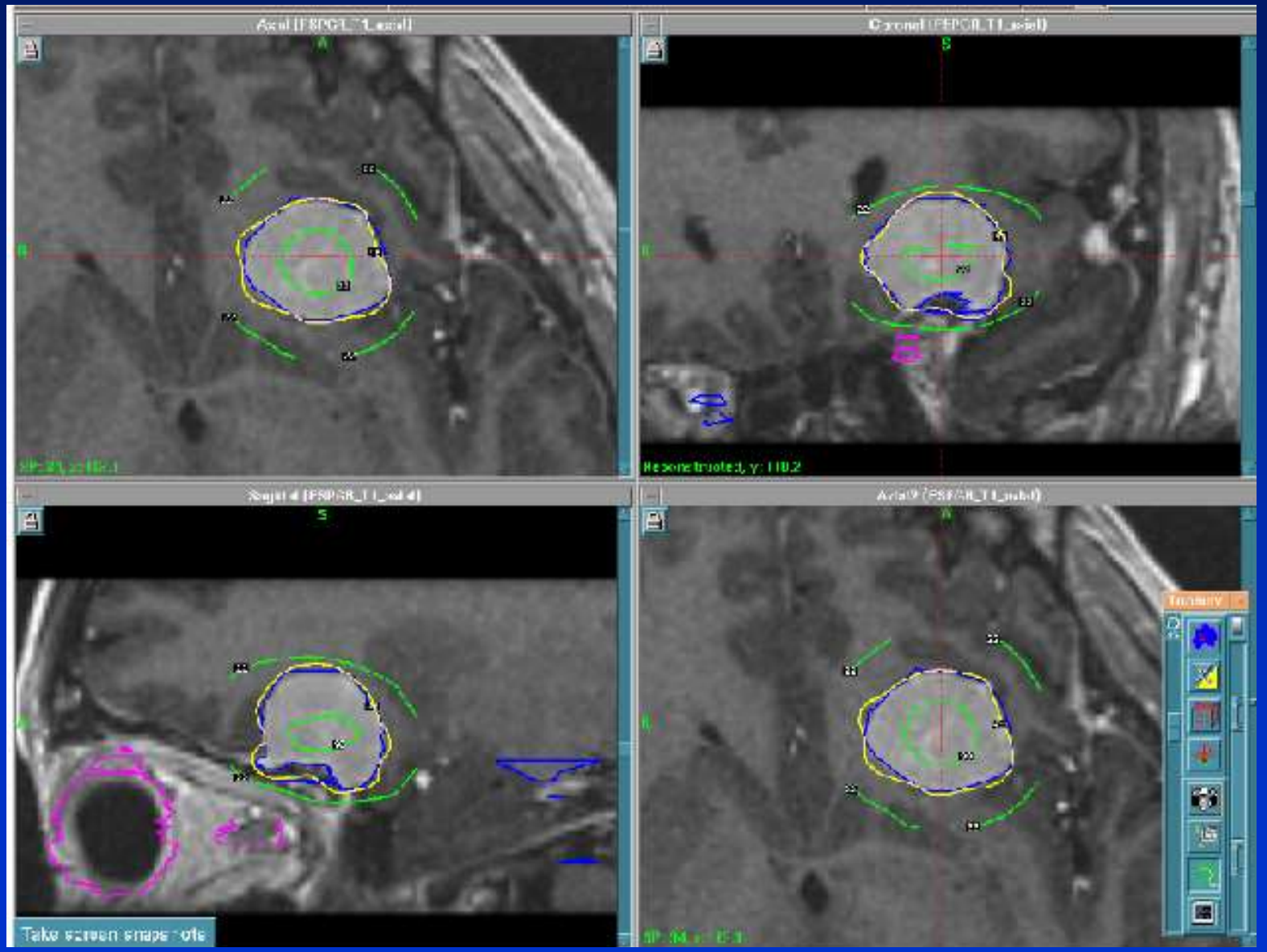
Acoustic Neuroma



Growing tumours, significant clinical symptoms

12 Gy to 50% isodose

Meningiomas



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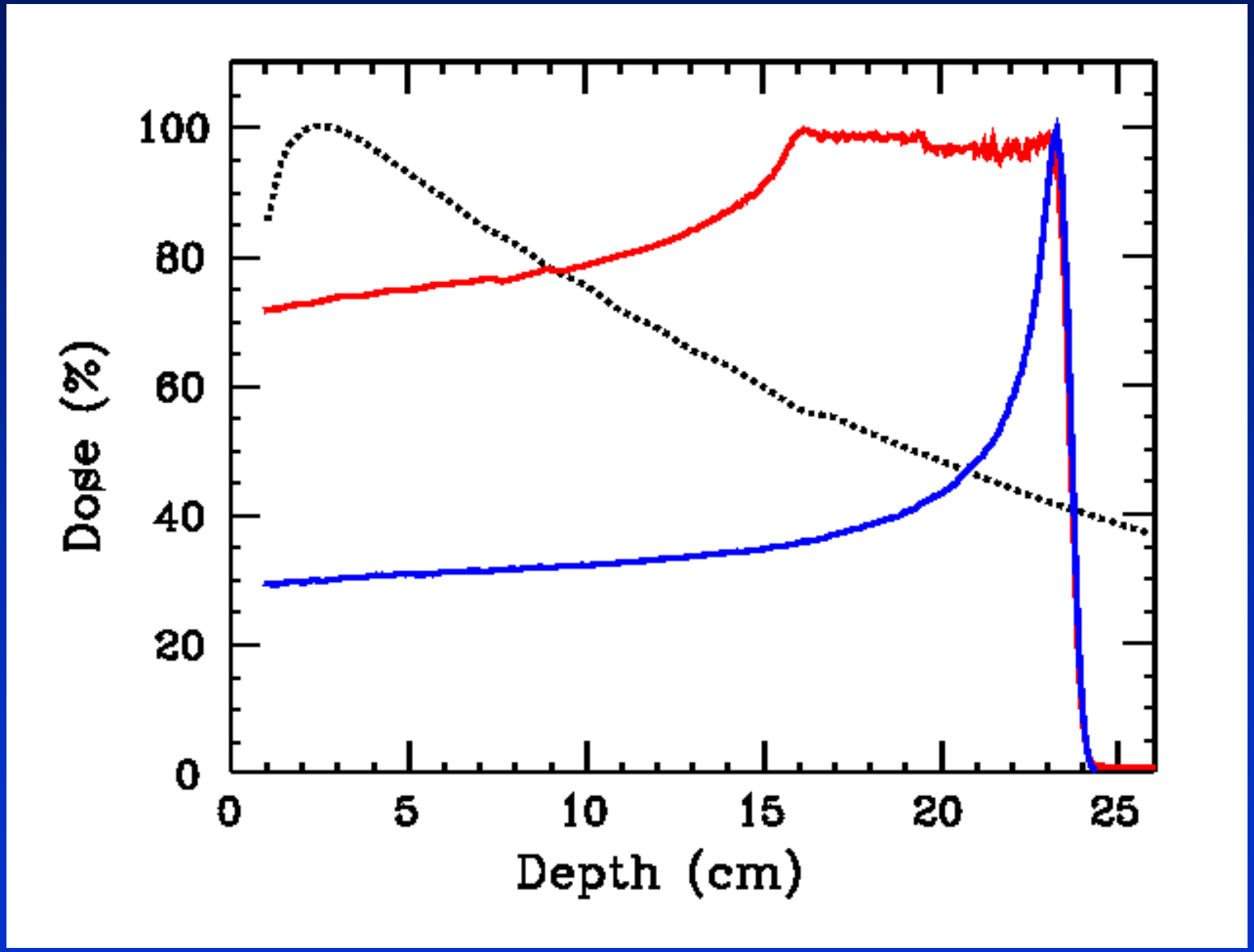
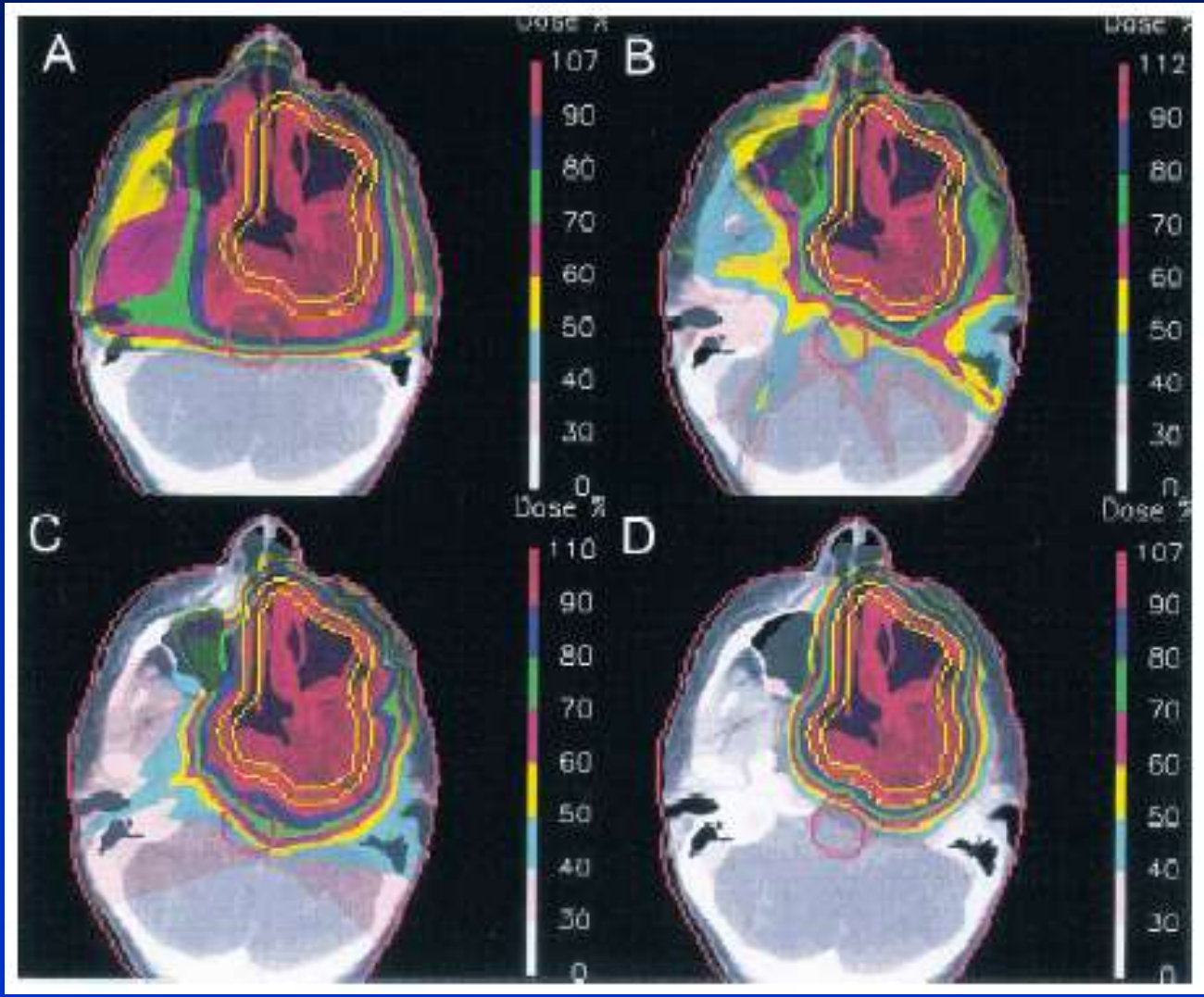


Protons

Conventional Photons

Spot Scanned Protons

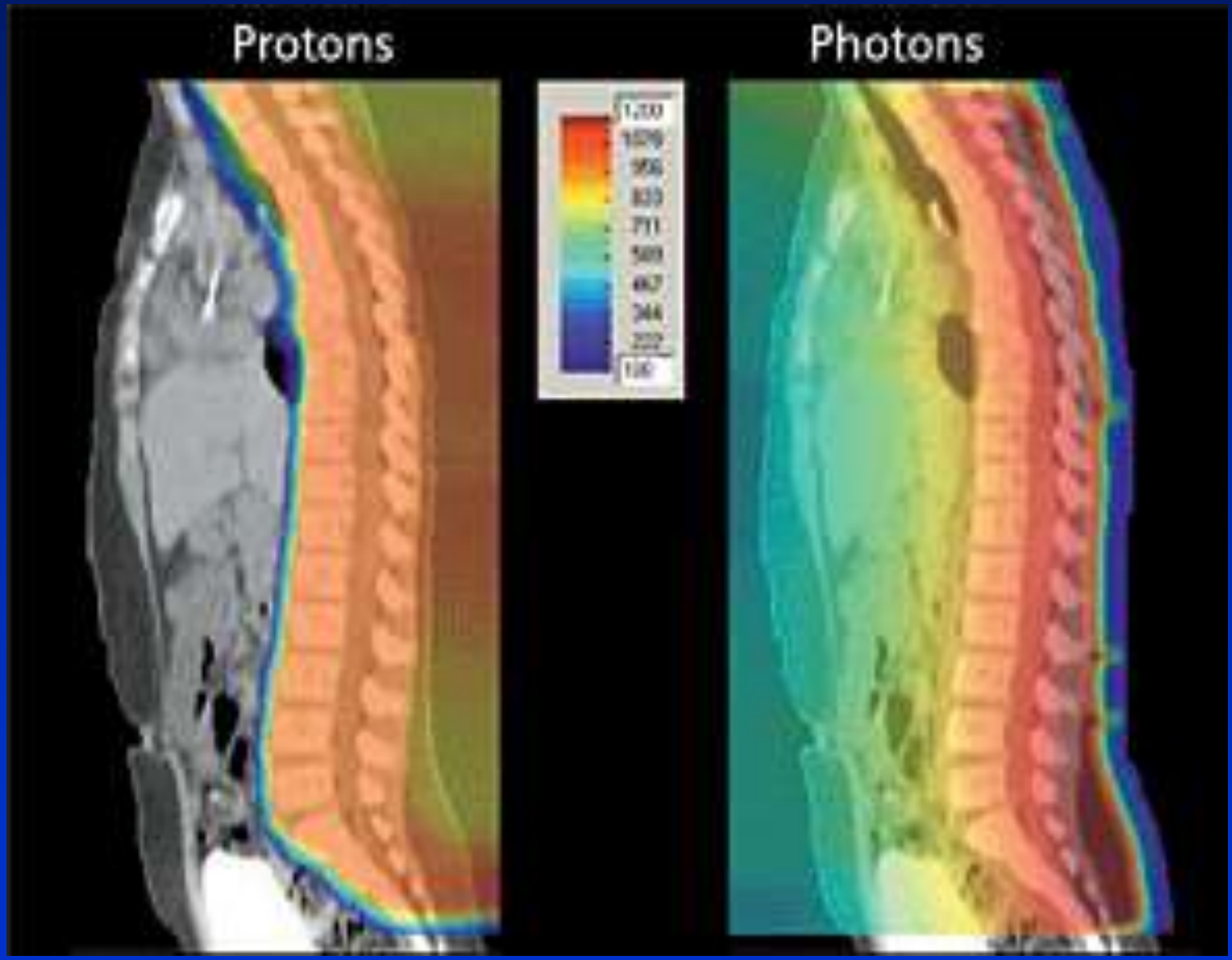


IM Photons

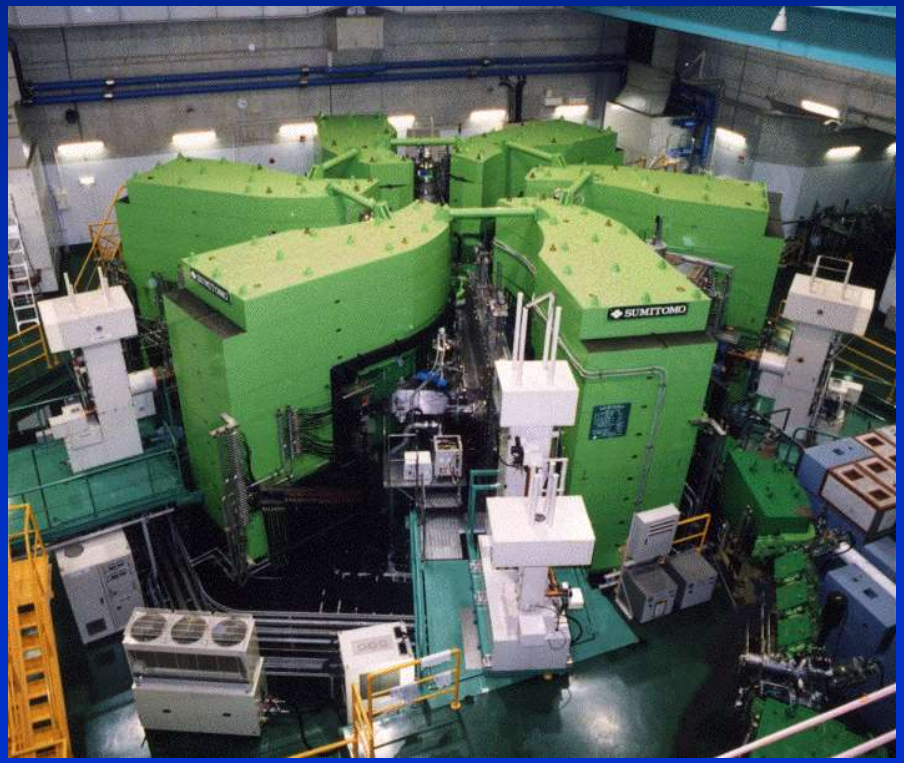
IM Protons

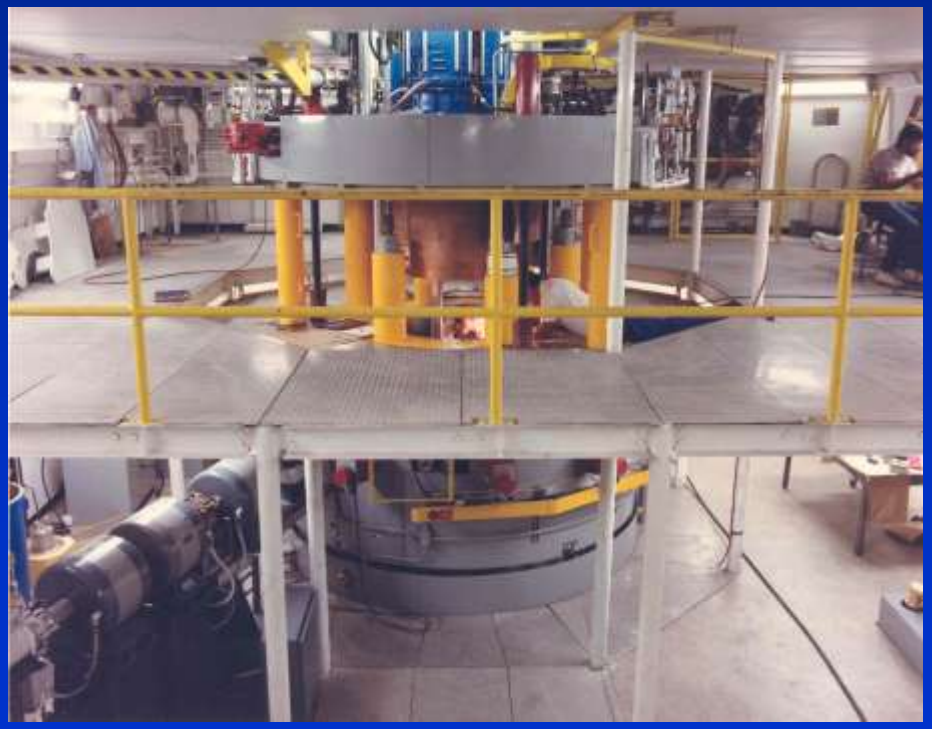
Mirabell R, et al: Int J Rad Onc Biol Phys 54:824-829, 2002.

Protons: Spine RT

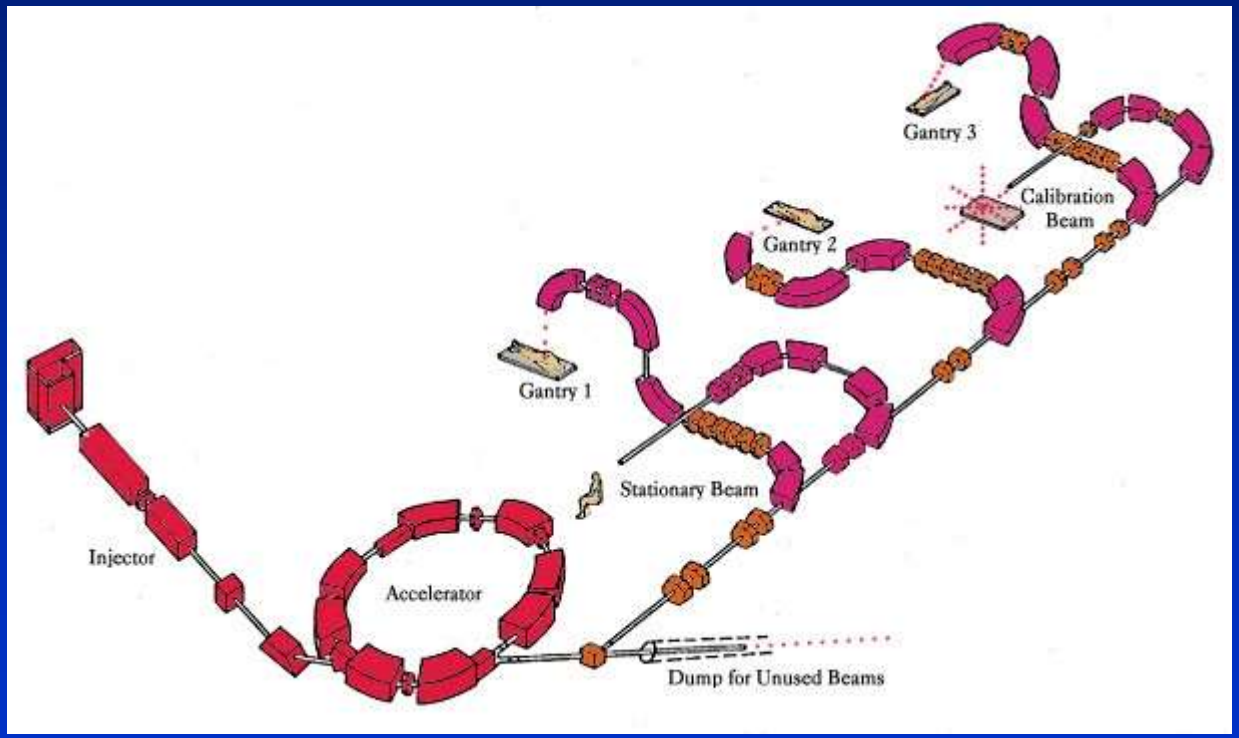


Protons
Cyclotrons





Hospital Based Protons



Conclusions

Recent advances in radiation technology has resulted in increased precision and reliability,

and this has allowed us to:

- Safely increase dose to tumour
- Marked decreased dose to normal tissues

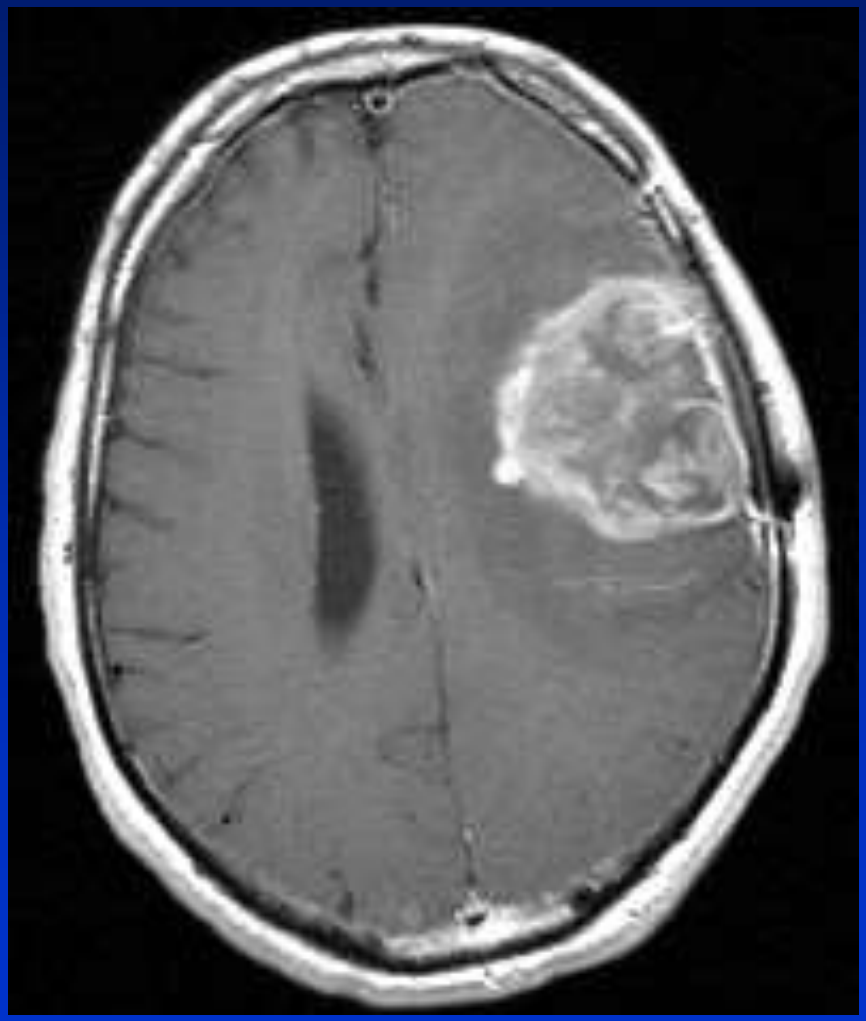
Both of which allow improved tumour control rates with a marked reduction in acute & long term morbidity.

Future Advancements

Molecular Imaging

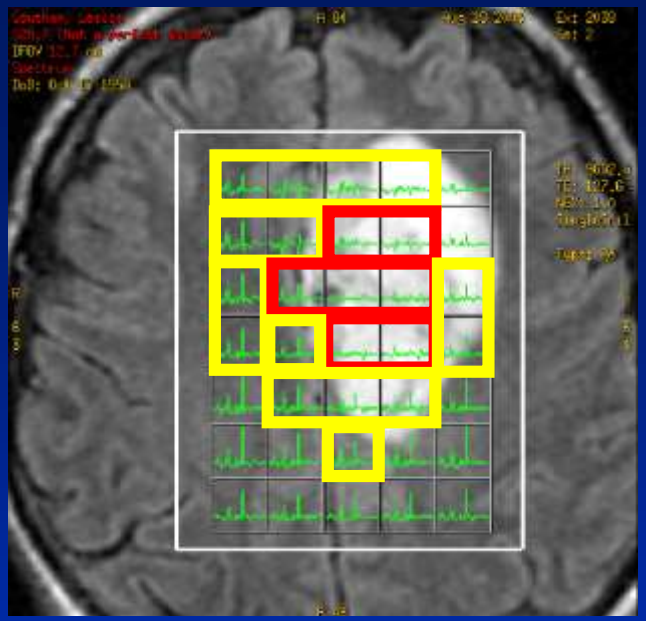
Adaptive Radiation Therapy

Molecular Imaging



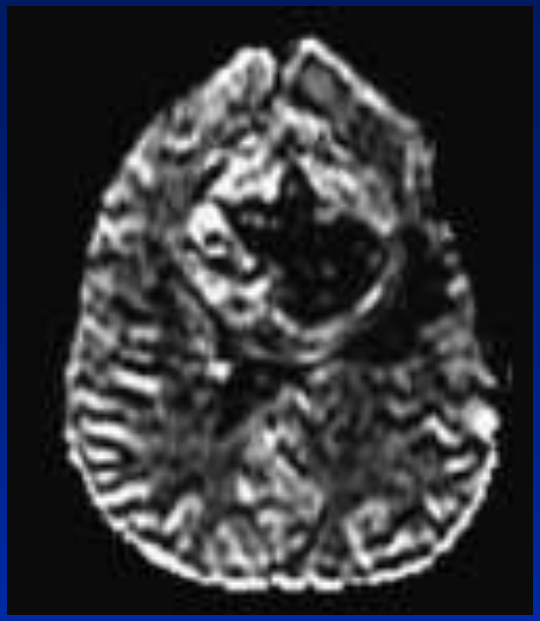
- Anatomic imaging
- Limitations in delineating microscopic extent tumour
- Changes in anatomic imaging lag weeks/months behind molecular events

MR Sequences, PET/SPECT

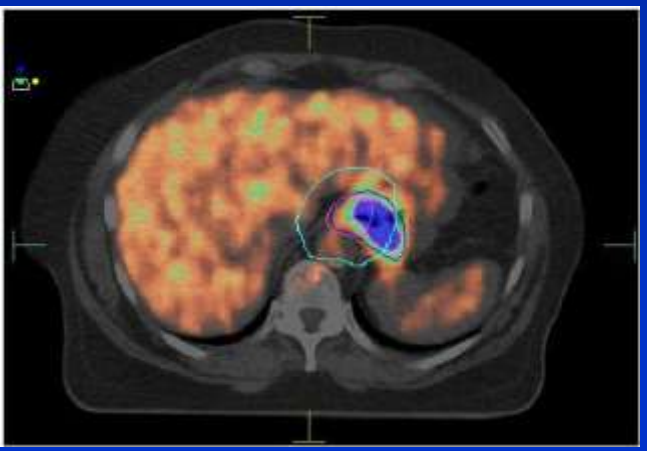


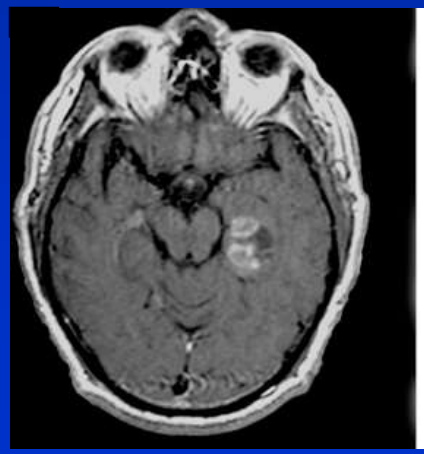
MR Spectroscopy

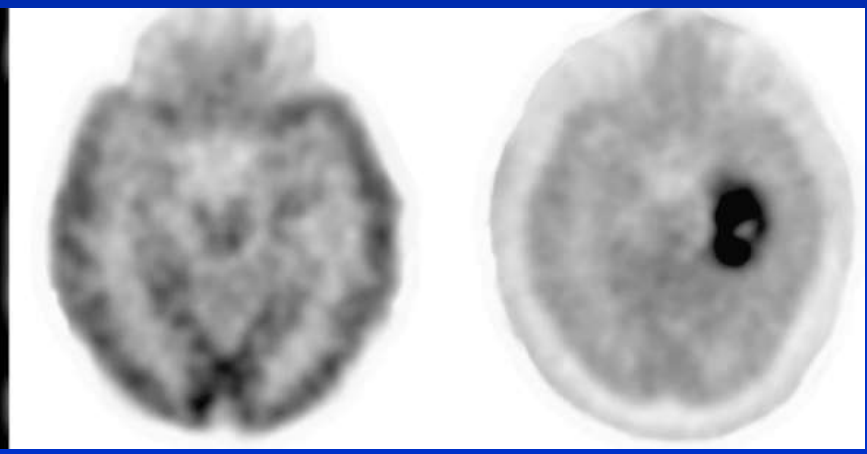
Diffusion Weighted MRI



Dynamic Perfusion







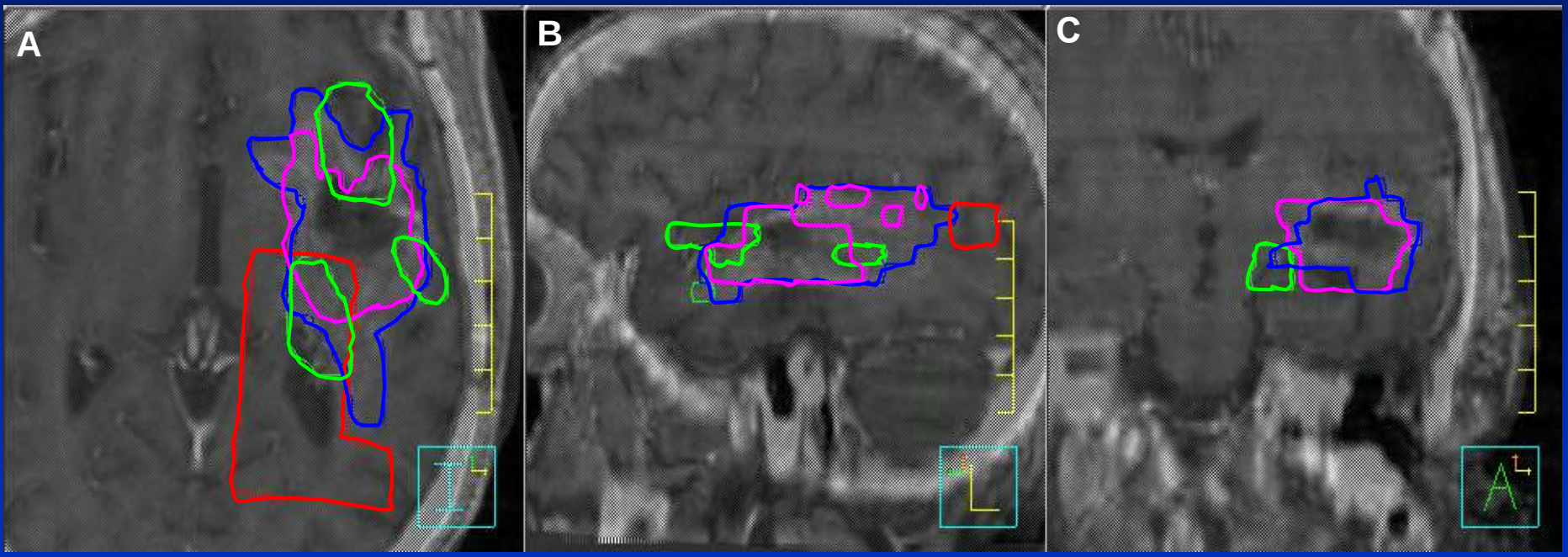
Chen W, J Nucl Med, 2007

Correlation of MRS with recurrence pattern

Figure 7. Prediction of the location of tumor recurrence based on CNI contours. The image on the left is the post-operative Gd-enhanced T1-weighted image, the image in the middle is the same image with the CNI contours superimposed, and on the right is an aligned image obtained 4.5 months later. The new regions of Gd enhancement correspond closely to the previous CNI = 3 contours.

Nelson et al, J MRI 16:464-476, 2002

Smart Targeting: Physiological MRI maps



GTV=blue $CTV_{perfusion}$= green $CTV_{hypoxia}$= pink CTV_{MRSI} = red

Mehta, 2003

Adaptive Radiotherapy

- Altering a treatment plan frequently (eventually daily) based on repeated imaging of patient (preferably on treatment unit) during course of treatment over several weeks
- Related to fact that normal tissues and tumours change over the several week course of radiation

Adaptive Radiotherapy

- Imaging could be as simple as CT/MRI to account for changes in anatomy, but eventually will be molecular (PET/various MR modalities) to change plan accordingly to changes in hypoxia/oxygenation, perfusion, diffusion, etc…..