

Tomotherapy Physics

Machine Twinning and Quality Assurance



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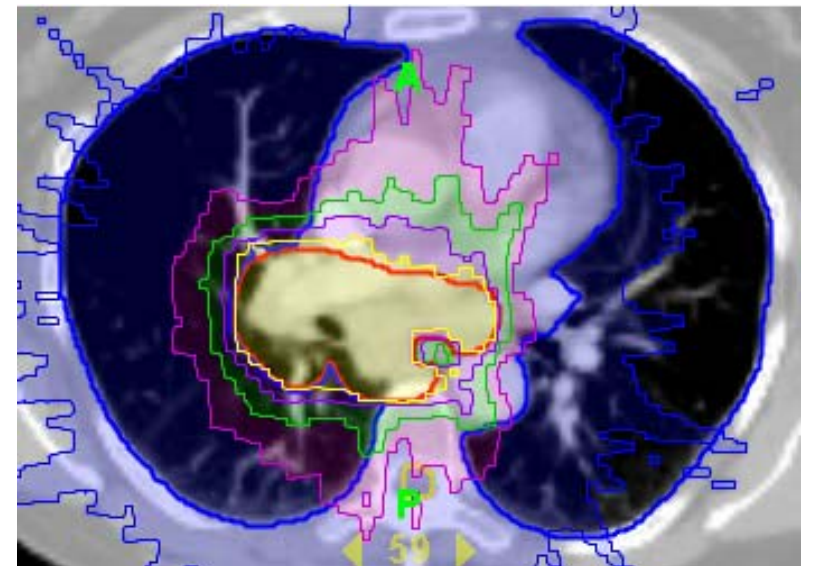
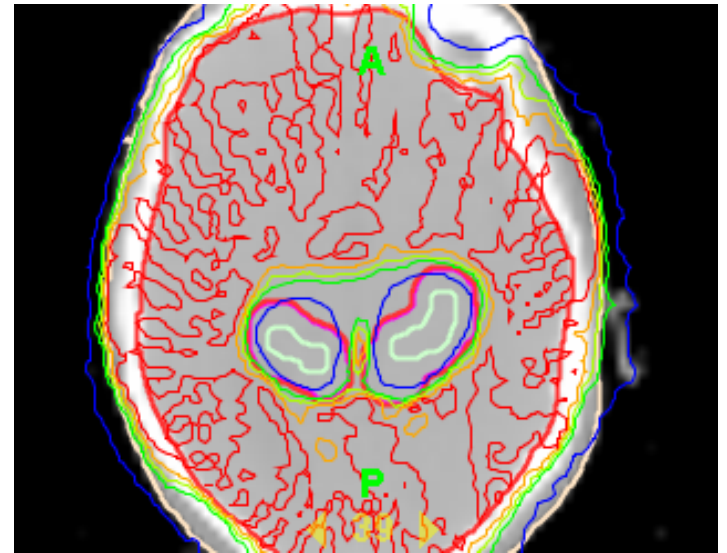
Emilie Soisson, MS



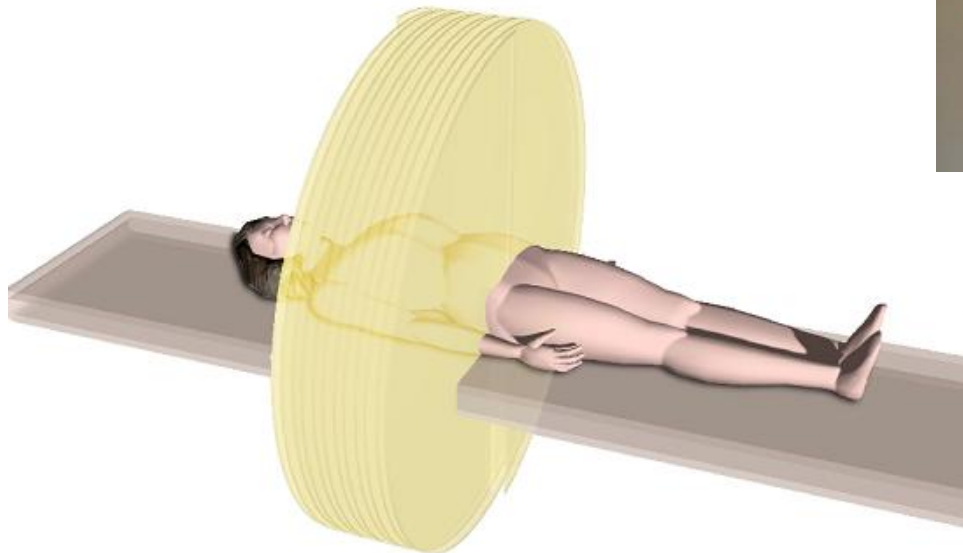
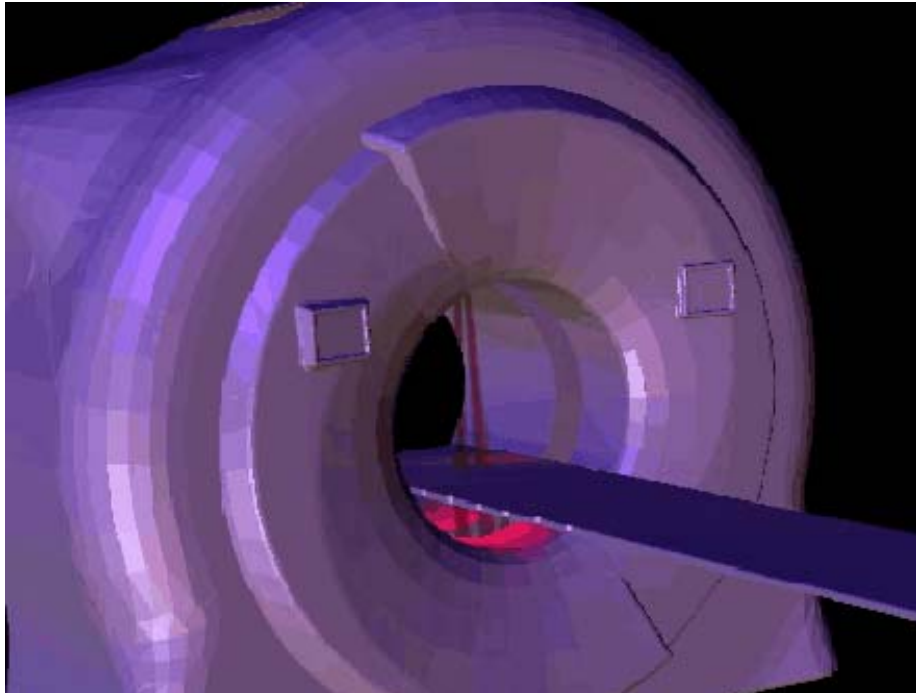
Tomotherapy at UW-Madison



- Treating for nearly 5 years
- Up to ~45 patients a day on 2 tomo units
 - Units twinned to facilitate transfers July 2007
- Program Highlights:
 - Prostate Hypofractionation
 - Lung dose escalation
 - SBRT Lung
 - Conformal Avoidance H&N
 - Hippocampus Avoidance WB



Machine Review - Helical Delivery



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Unique Tomo Features

- Fan beam on a ring gantry
- One energy – 6MV. No electrons.
- CT-like construction allows for creation of a pre-treatment megavoltage CT for image guidance.
- Specifically designed for IMRT
 - 51 projections per rotation vs. a few static beams
- Integrated system

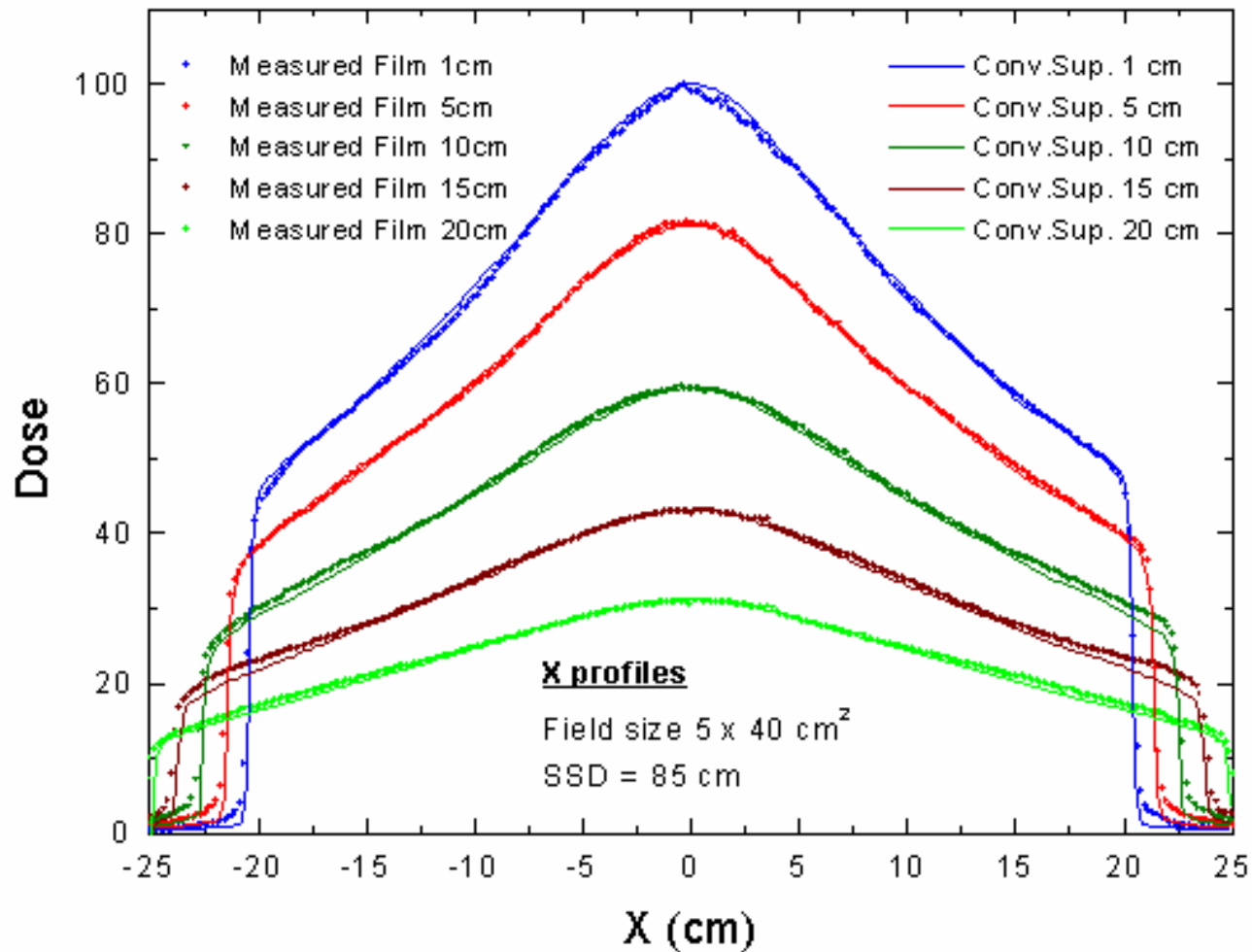


Binary Multileaf Collimator

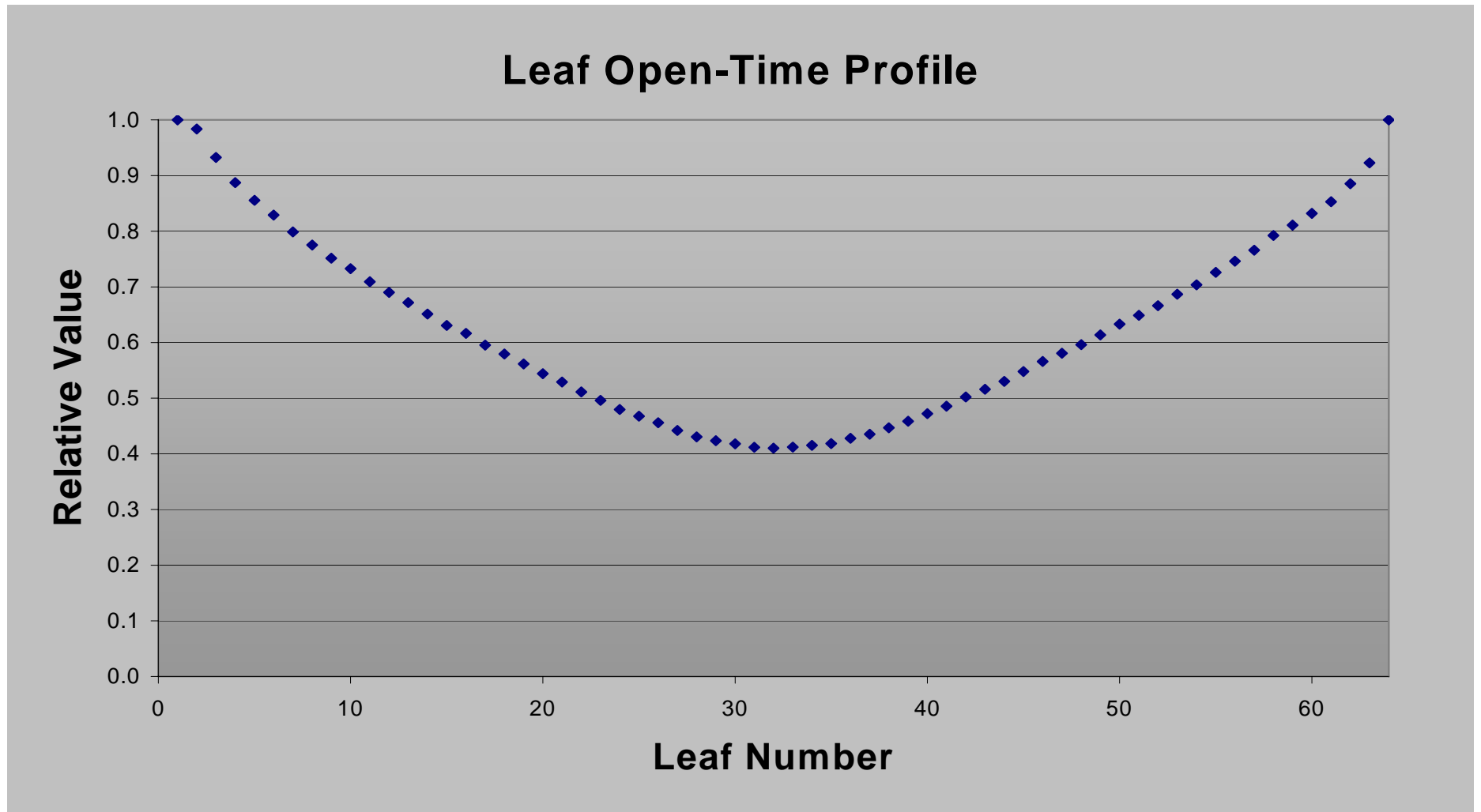
- 64 Binary Collimator Leaves
- 0.6 cm Width at Isocenter
- 10 cm Thick, 95% Tungsten
- 20 ms Leaf Transit Time

Lateral Profiles

Use a nearly unfiltered bremsstrahlung beam which is distinctly forward directed.
NO FLATTENING FILTER!!

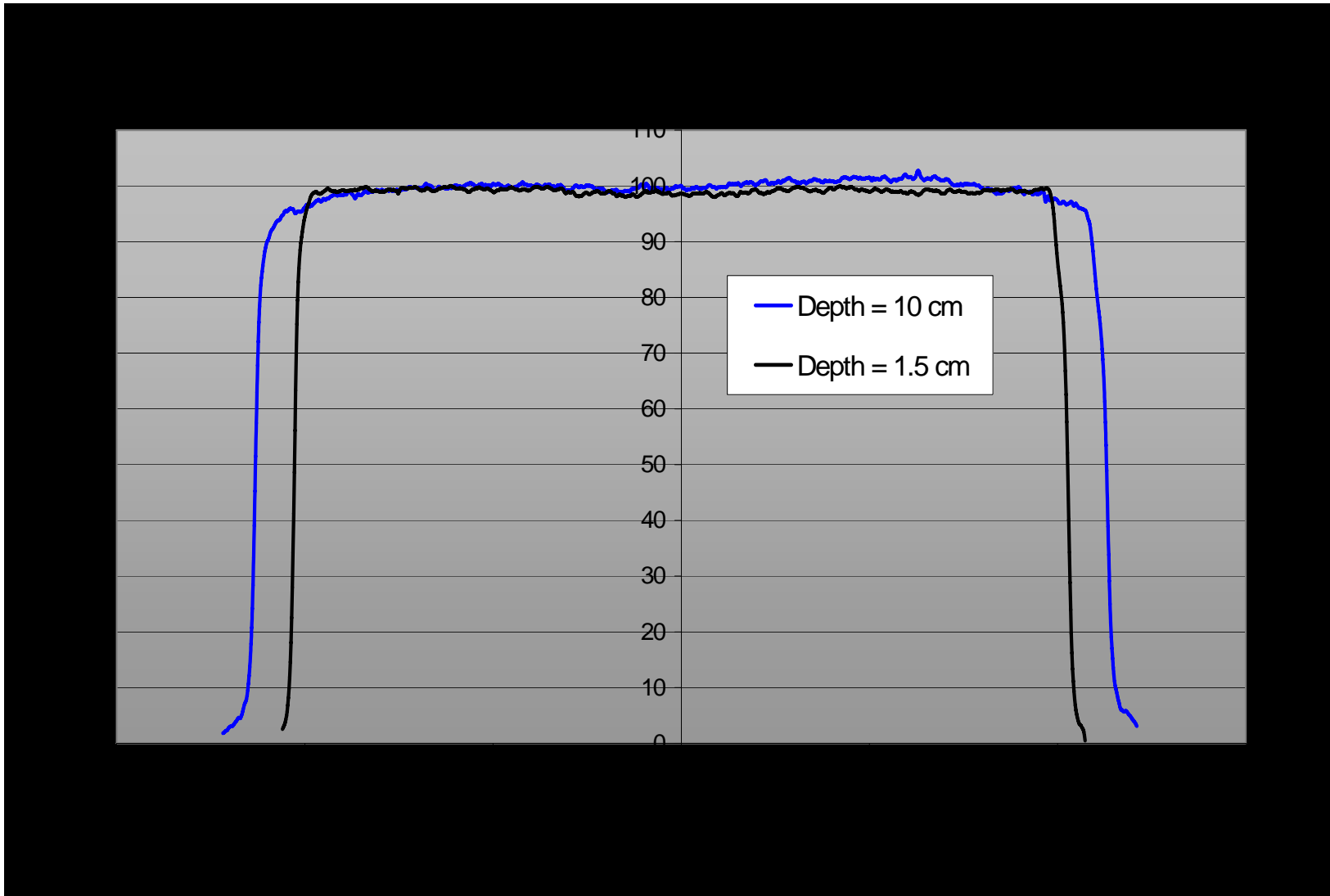


Intensity Profile to Make the Beam Uniform



You can vary the intensity across the field to obtain a flat profile.

Resultant Flat Profiles

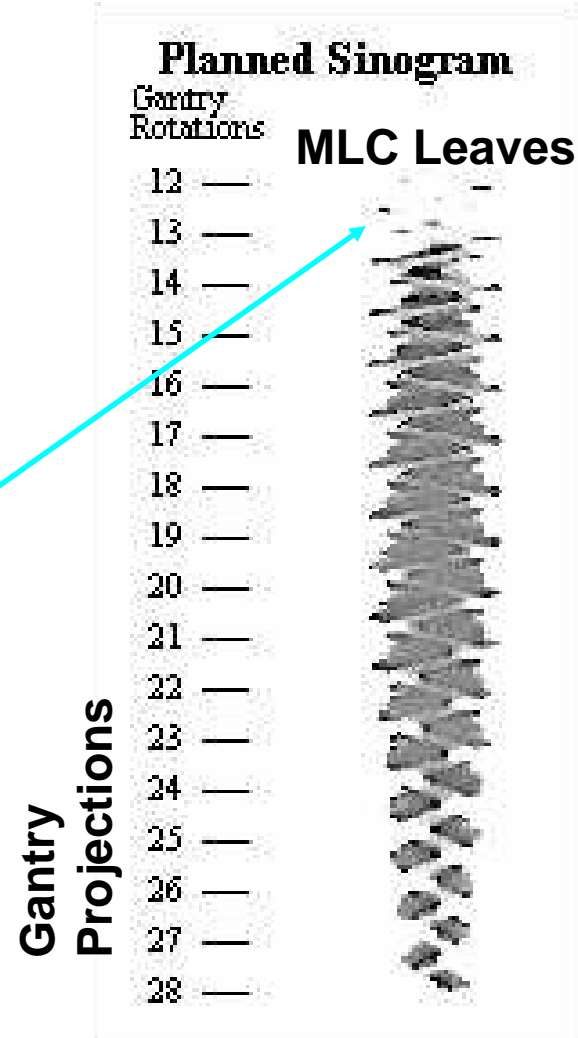


MLC Sinogram

Sinogram:

The pattern of MLC leaf opening times throughout successive rotations

Stack of beamlet intensities. Each element shows how long each leaf is open at a given gantry angle during a given rotation.



New Challenges and Simplifications in Quality Assurance

Challenges

- Dynamic Components
- Precise Synchrony Requirements
- No protocols
- Fewer tools
- New technology

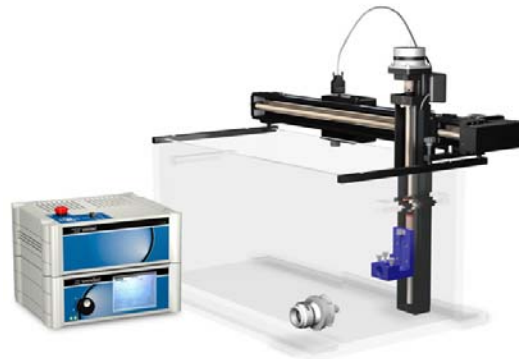
Simplifications

- Collimator does not rotate
- No accessories
- Only 3 FWs
- One energy
- No flattening filter



Machine Twinning

- Same beam model on both machines to allow for transfer of plans from one machine to the other
- Both machines are altered as necessary to match this model
- Only difference at the end of the process should be dose rate and MLC dependent, can be accounted for by the transfer software.
- The following should be within stated tolerance:
 - *Output: +/-2%*
 - *IEC-X Beam Profile: Within 2% and 2mm*
 - *IEC- Y FWHM: Within 1% of standard*
 - *IEC-Y profile Shape: Within 2% and distance that is 1% of FWHM*



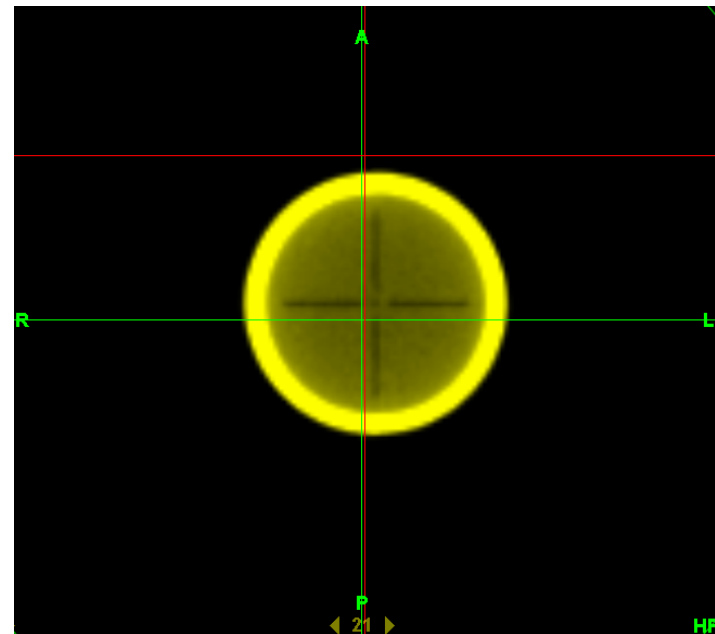
Step 1: Tomo “Gold” Beam Model Loaded on Both Machines

- Fluence Attenuation Tables (FAT)
- Convolution Kernels
- Beam model shape data



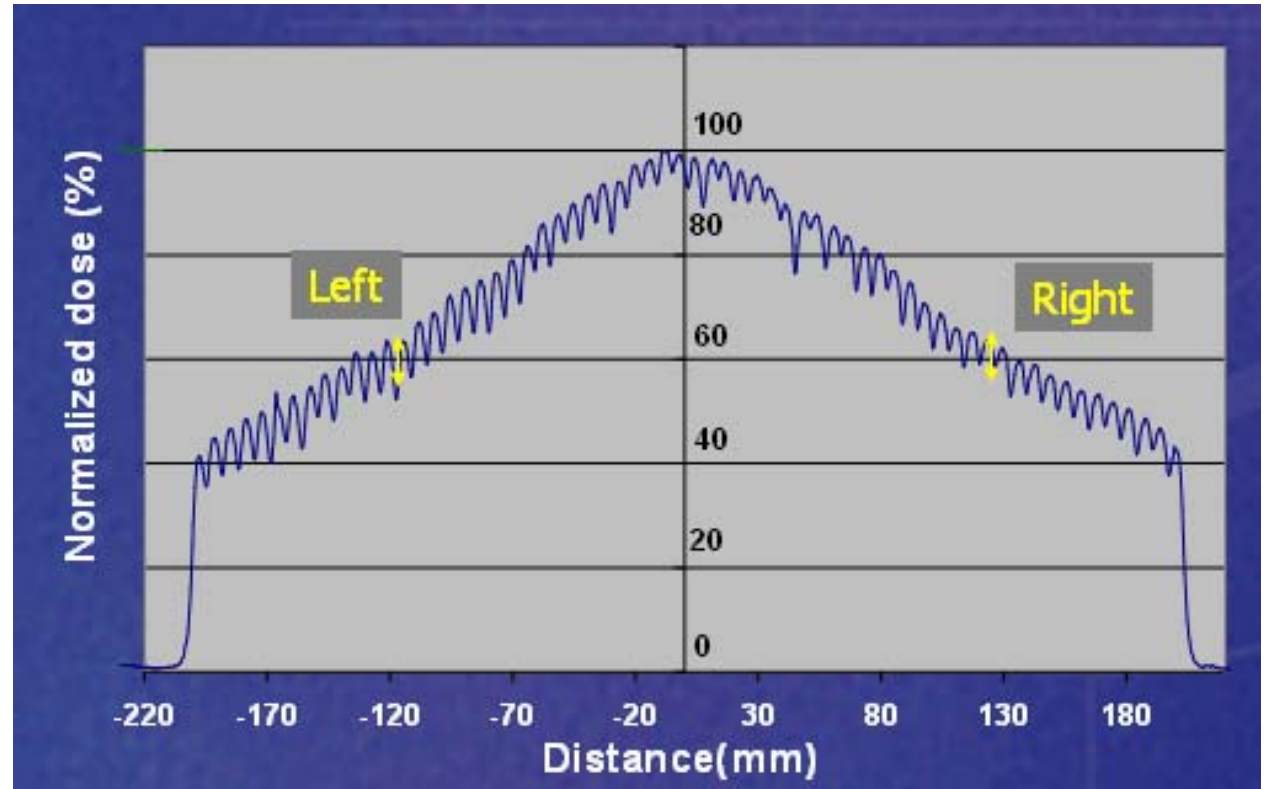
Step 2: Verify Machine Geometry

- Align all lasers
- Tongue and groove
- Jaw Shift
- Y-Axis misalignment
- MLC Alignment



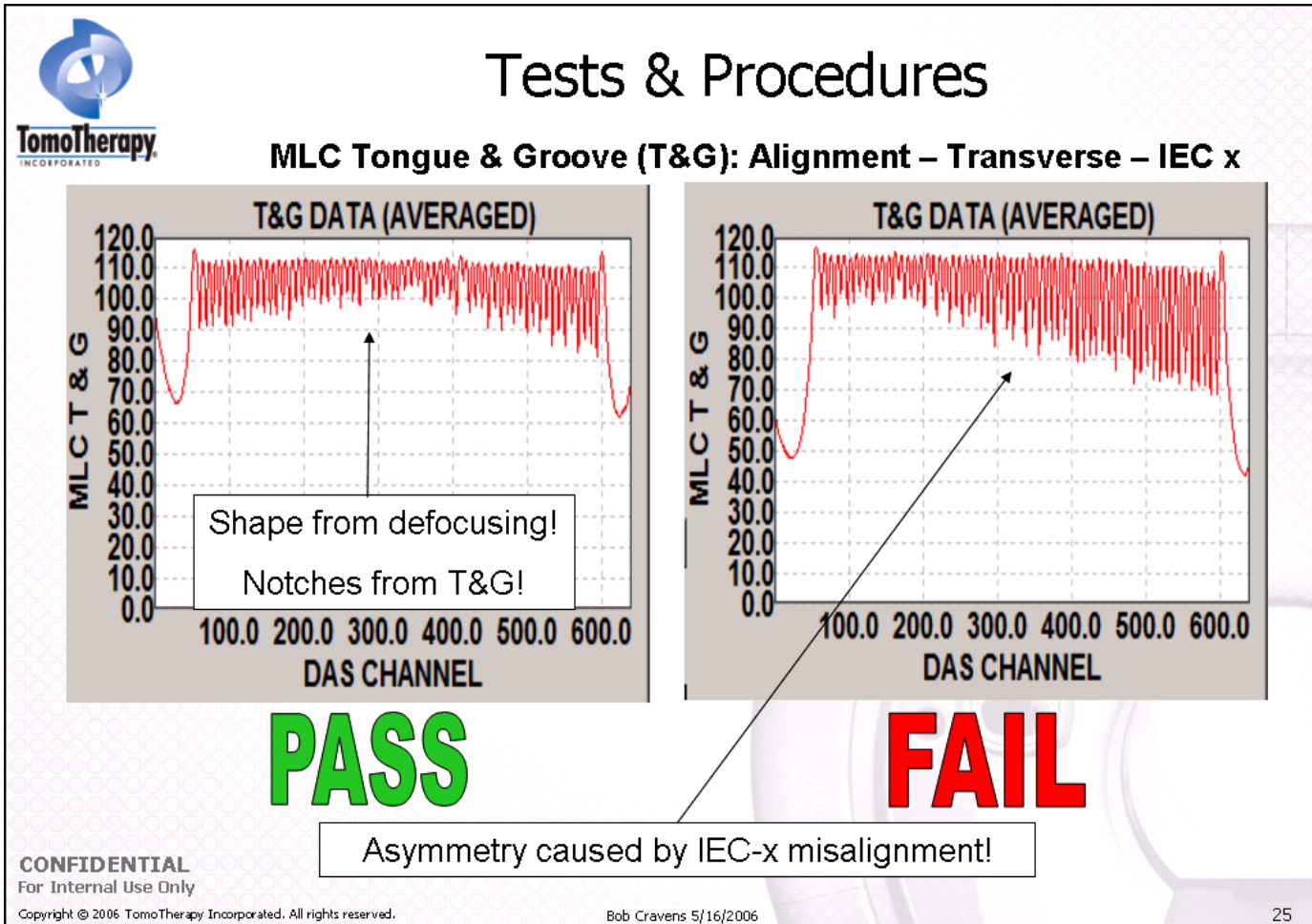
Tongue and Groove

- Tests IEC-X position of the linac
- Use MVCT detector
- Superposition of dose due to opening all of the even leaves followed by opening of all of the odd leaves.
- The ripples in the dose should have the same amplitude on the right and left.
- Spec: 2%



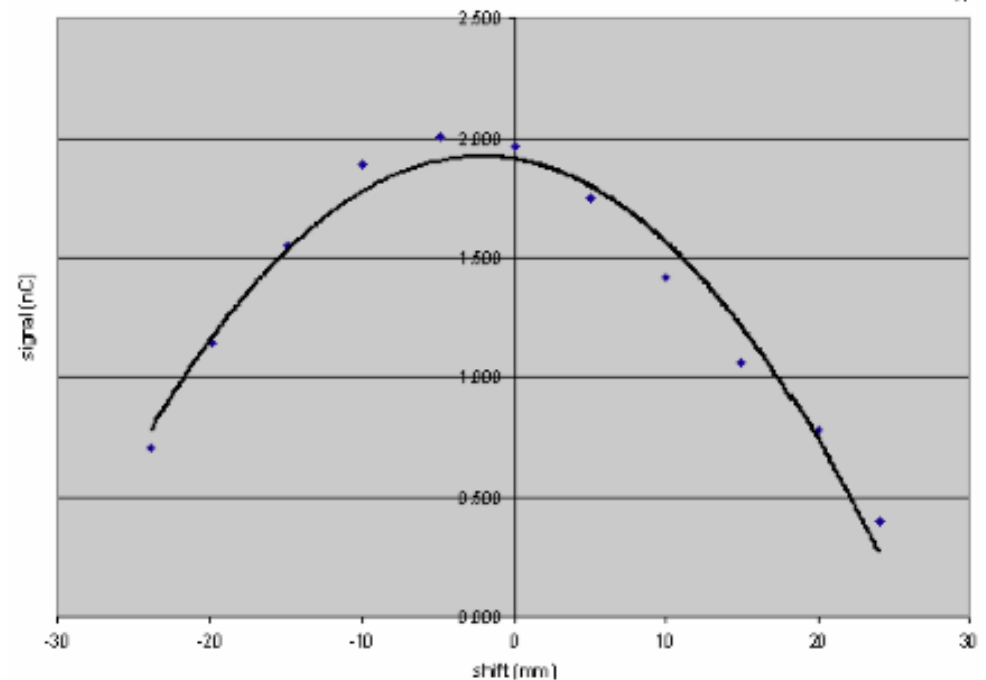
In this test, the amplitude on the left side is slightly greater than the right side indicating that there is not perfect alignment.

Normalized to all open exposure



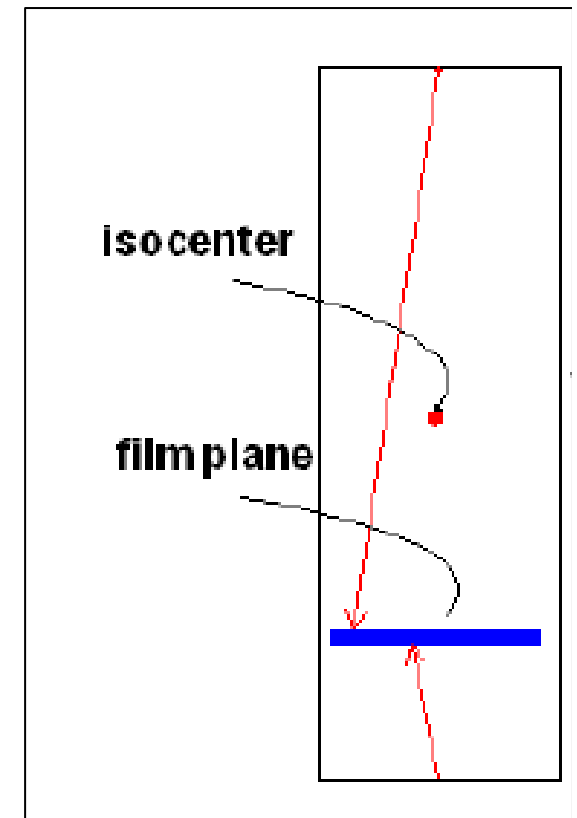
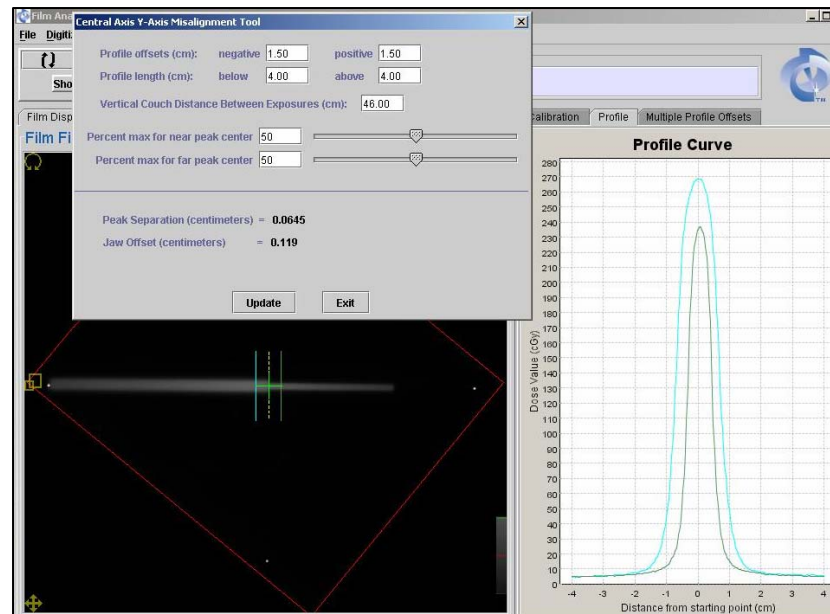
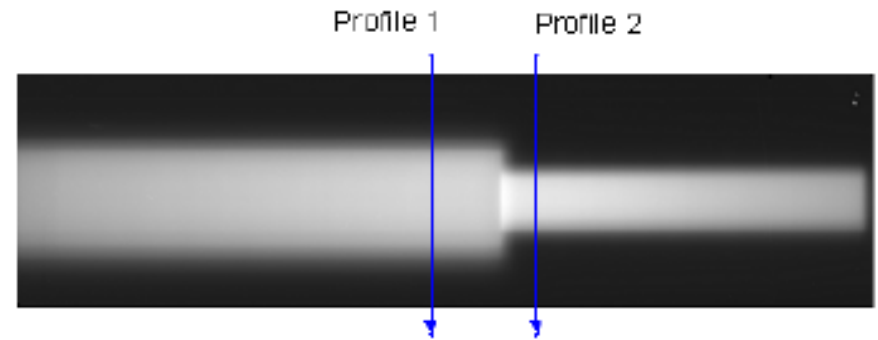
Jaw Shift Test

- IC with long collecting volume and flat response set up with the long axis parallel to the couch
- Slit field created by setting jaws asymmetrically is swept across the IEC-Y axis
- Measure response at each position.
- Symmetry is affected by source position. Asymmetry shows that source is not aligned in the IEC-Y direction.
- Center should be within 0.3mm of $Y=0$



Y-Axis Misalignment

- Superposition on radiographic film of exposures taken with the linac directed downward (gantry angle 0 deg.) and the linac directed upwards (gantry angle 180 deg) with leaves 1-32 open.
- The film is offset below the isocenter.
- The purpose of this test is to verify that the beam is parallel to and directed in the plane of gantry rotation. An offset between the two shown profiles would indicate a divergence.



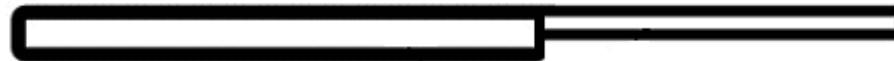
Poor Alignment and Jaw Twist Examples



Example of Y-divergence Film Image with No Beam Twist or Divergence with respect to the gantry rotation plane



Example of Y-divergence Film Image with Beam Twist with respect to the gantry rotation plane

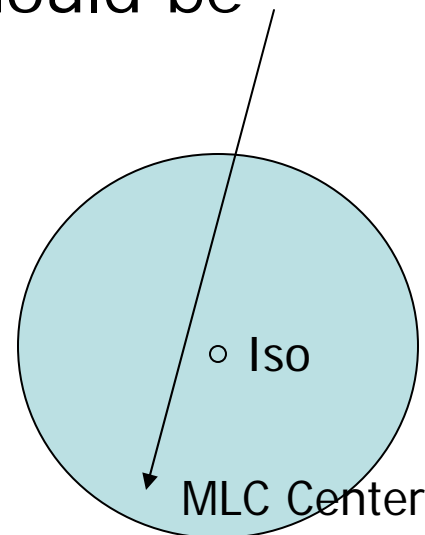
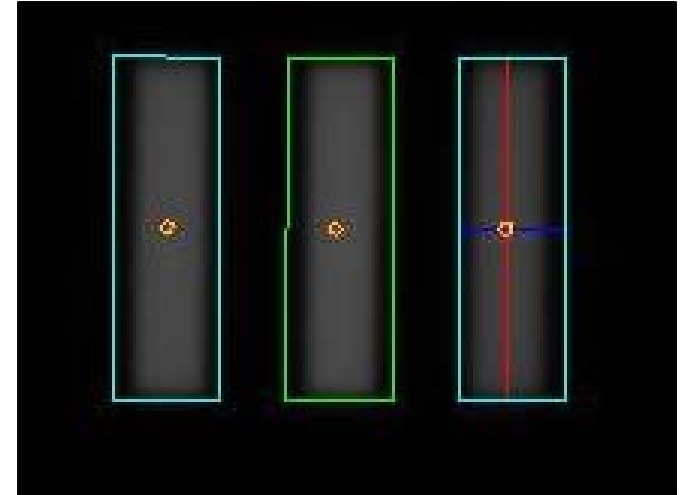


Example of Y-divergence Film Image with Beam Divergence with respect to the gantry rotation plane

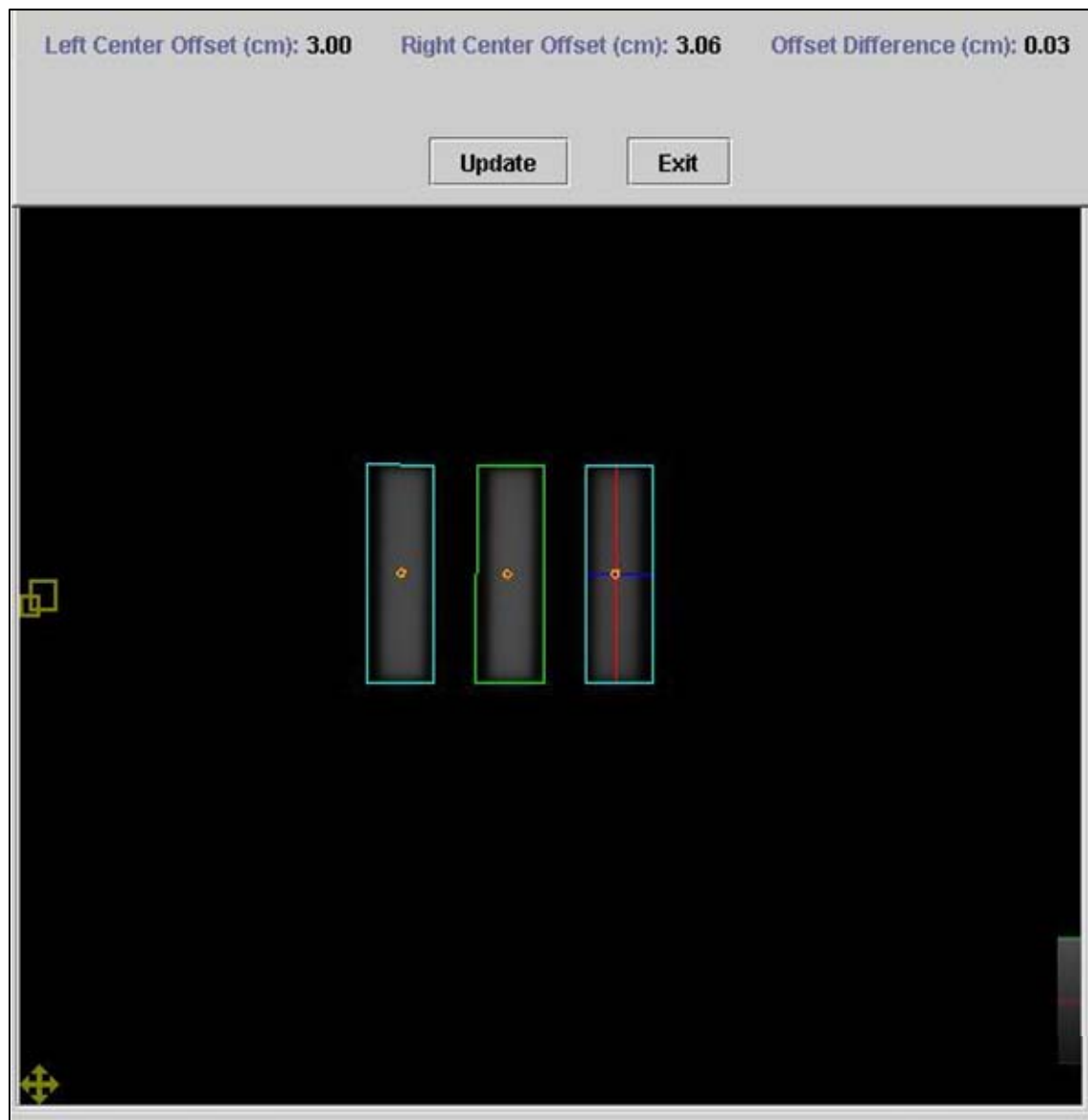


MLC vs Gantry Center

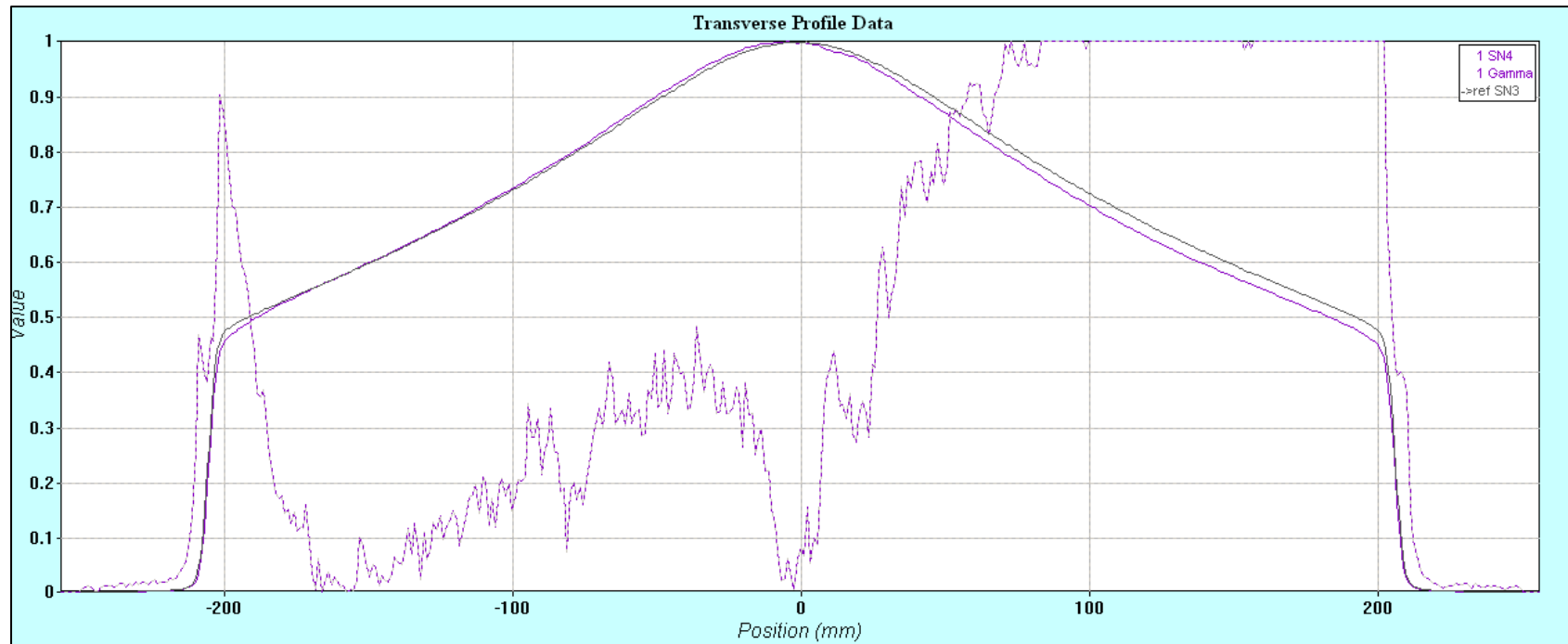
- Center of MLC must match isocenter
- Double exposure
 - Center of MLC is between leaves 32 and 33
 - 28,29 and 32,33 open at 0°
 - 28,29 only at 180°
- Distance between center of 32,33 and fields to either side should be equal



MLC vs Gantry Center

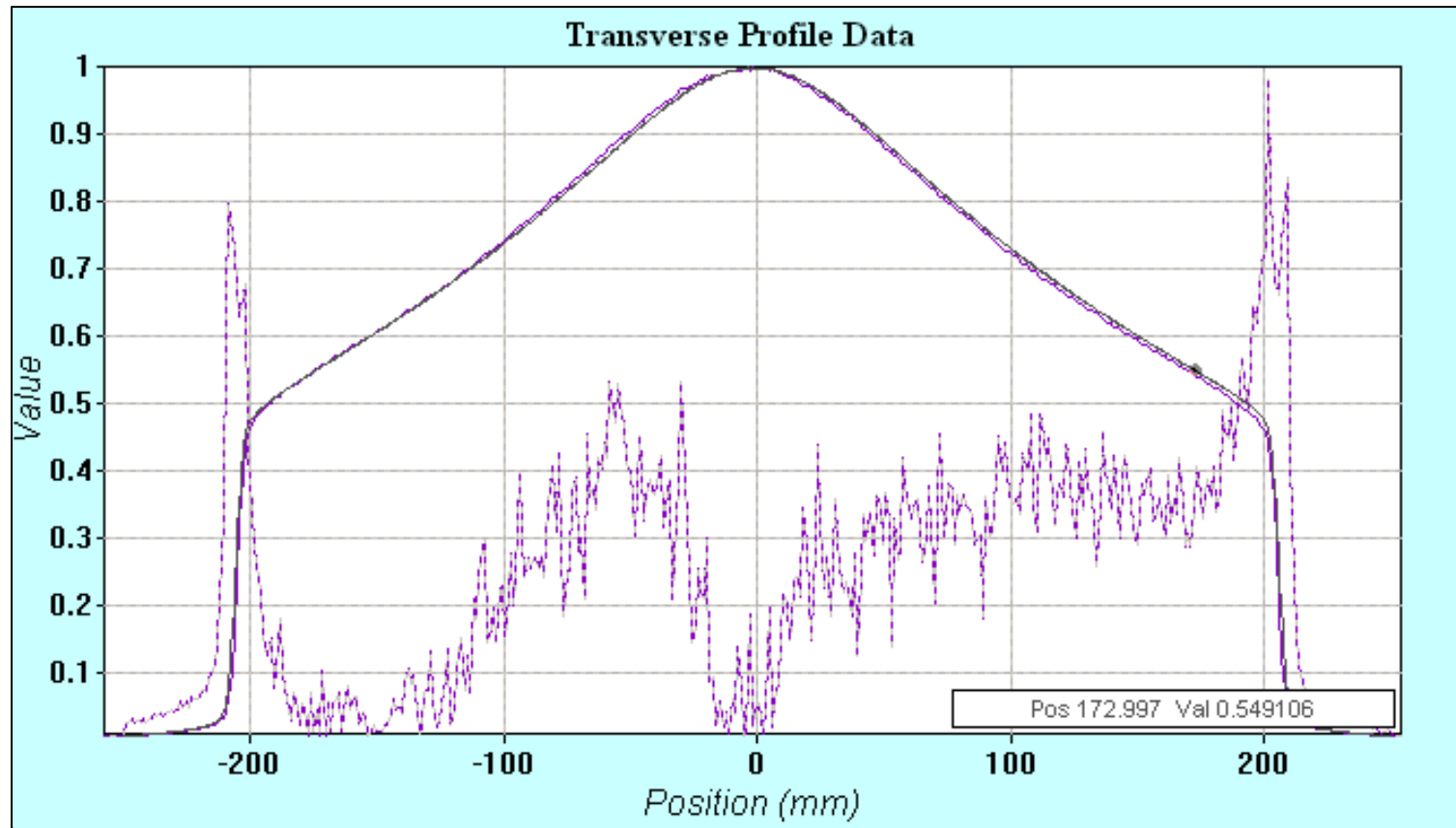


Step 3: Verify all profiles within tolerance



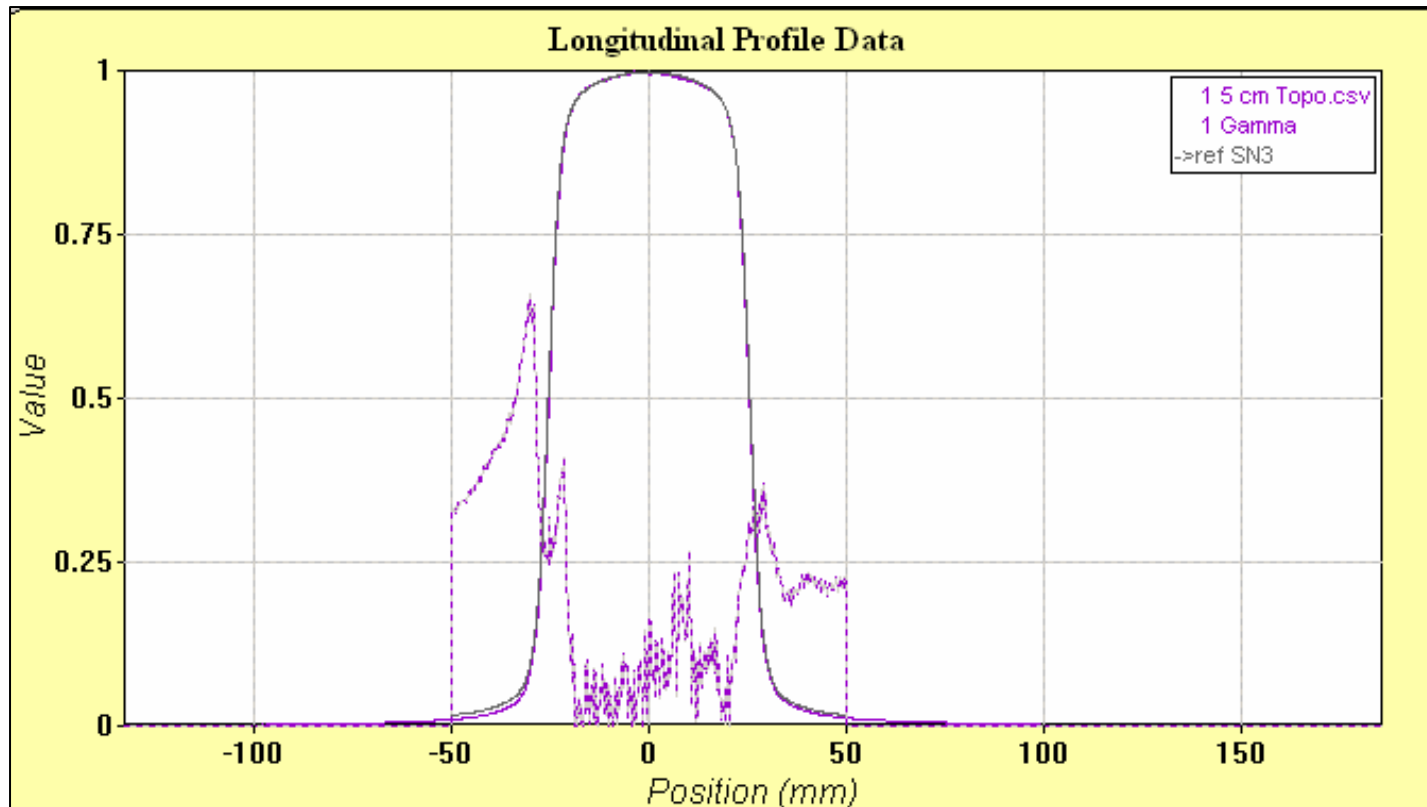
- Profiles do not match
- Gamma value in purple - 2% and 2mm

Passing Lateral (IEC-X) Profile



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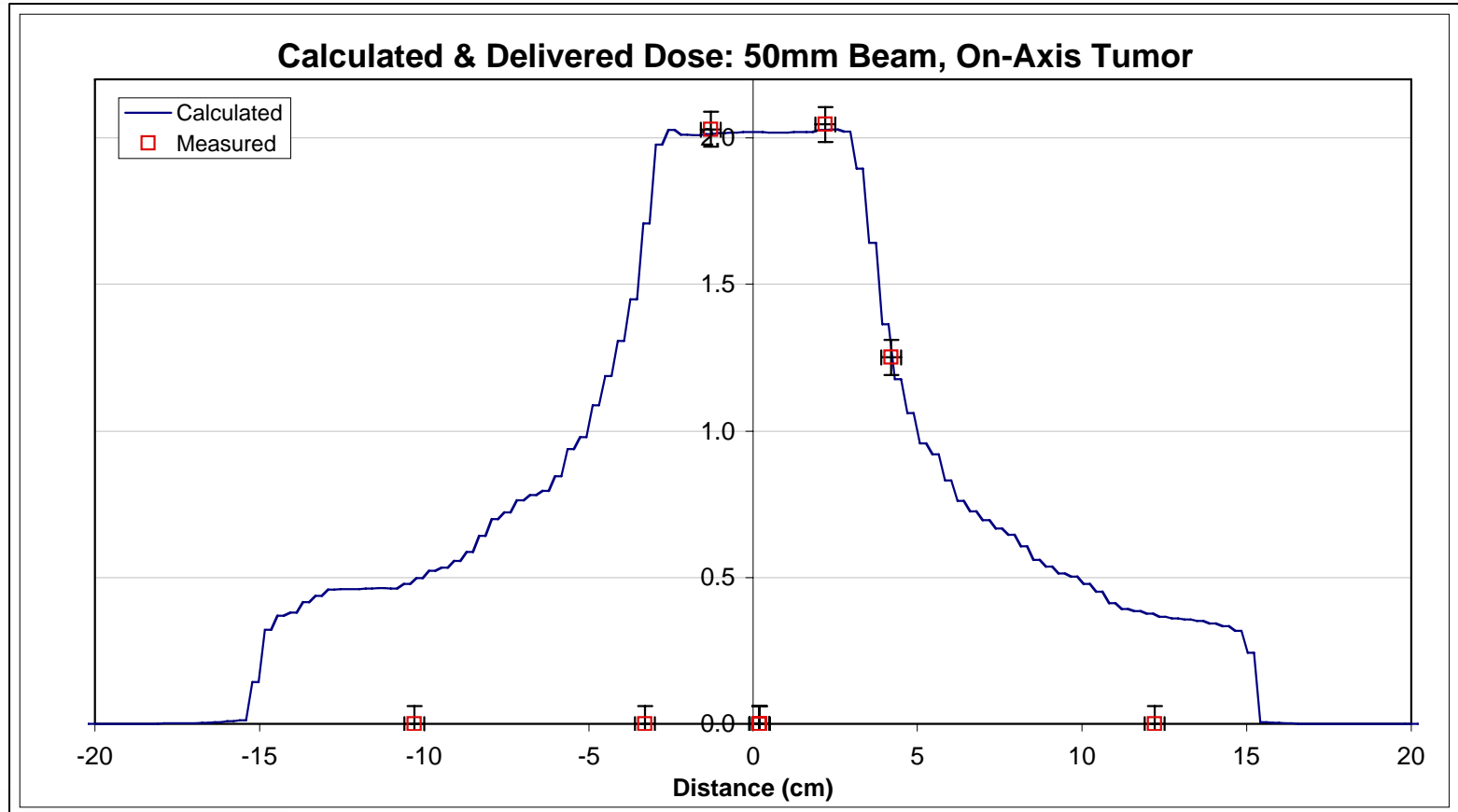
Longitudinal Profile



FWHM must be within 1% to avoid dosimetric inaccuracies due to helical delivery and overlap.



IMRT Verification

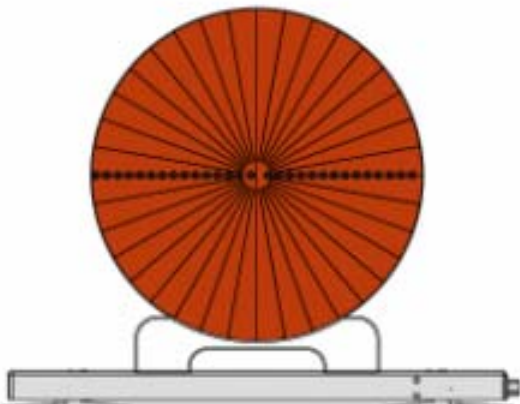


Point Measurements compared
to calculated profile



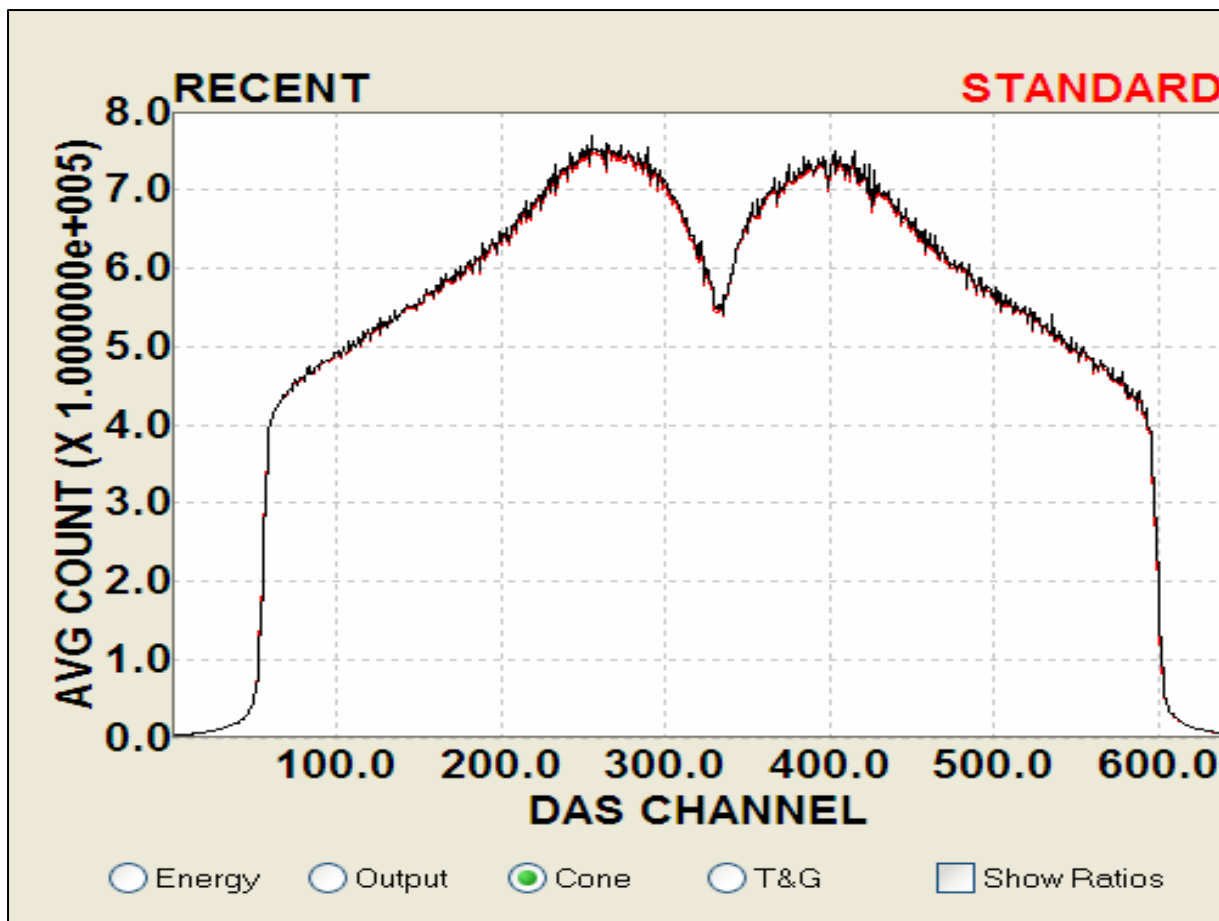
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Cheese Phantom Orientation



Step 4: Data collected for Tomotherapy service baselines

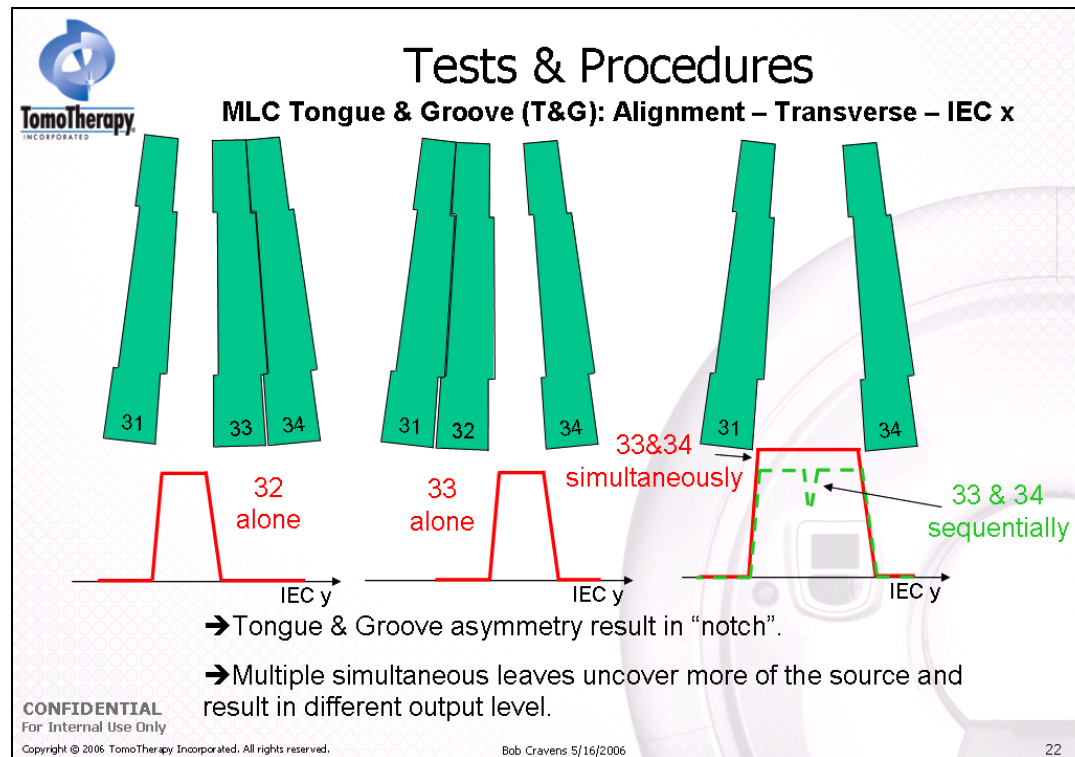
- Rotational Variation - As measured with CT detector
- Topographic profiles- FW measured with charge profile as couch moves into bore



Step 5: MLC properties updates in PTS - LFOF

Leaf fluence output factors collected for Patient Transfer Station

LFOF: difference in output with various leaf combinations open due to finite spot size on target

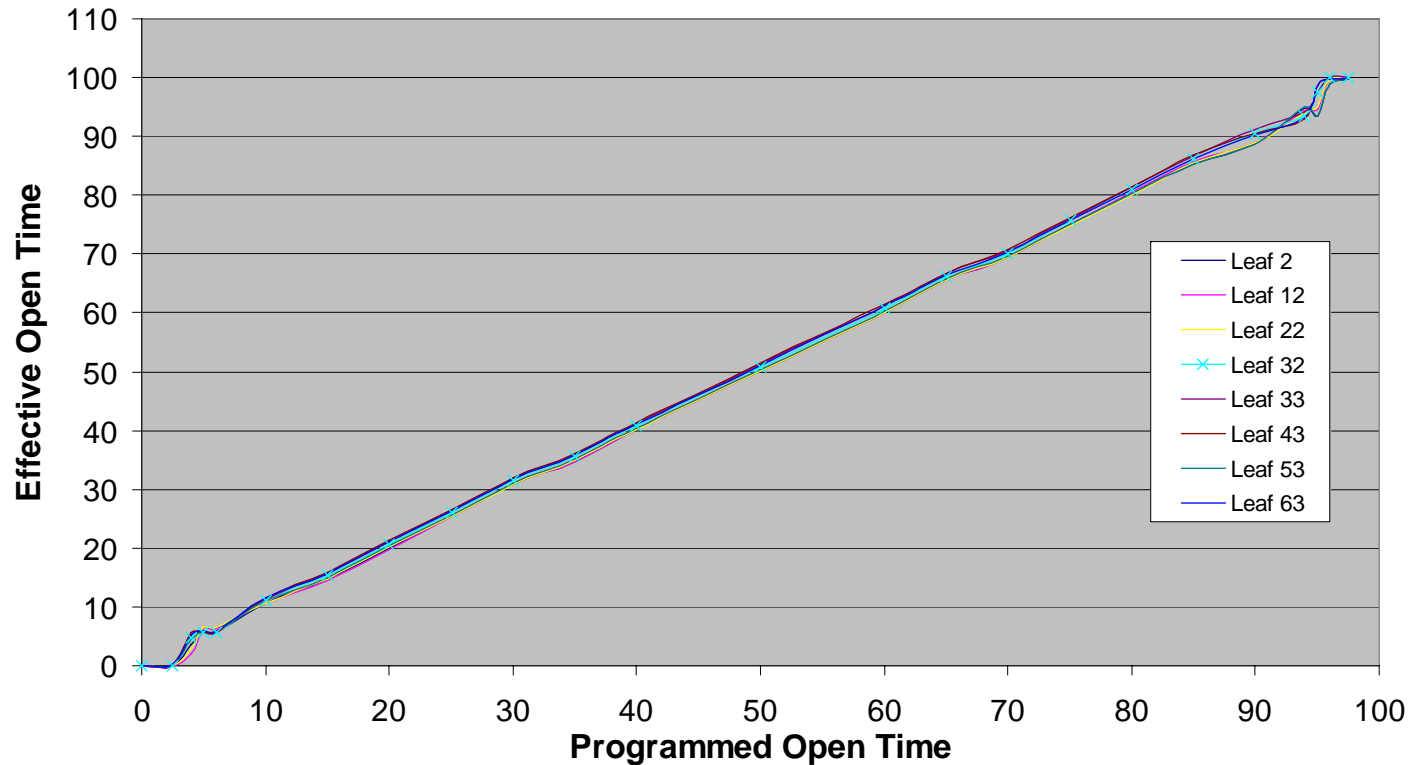


$$\text{LFOF}_{AB} = \text{Fluence}_{AB} / (\text{Fluence}_A + \text{Fluence}_B)$$



Update Leaf Latency Data

Effective Open vs. Programmed Open Time (500 ms)



- Leaf latency test for a variety of leaves for a 500 ms projection time. Effective open time, expressed as a percent of the projection time, is compared to a programmed open time.
- ~ 20 ms each to open and close the leaves, small difference between actual and requested leaf open times. Small differences can be measured.



Patient Transfer Stations

- Separate Workstation next to planning station
- QA check to verify proper functioning
- When machine is down, archive, calculate end of planning on new machine
- New isodose lines and DVH can be compared to original.
- When machines goes back up, archive on other machine, keeps fraction count, send to original machine.



Patient Review on Transfer Station

Select an Archive to Review

Print

Original Dose
 Transfer Dose
 Dose Difference

Transverse

Coronal

Sagittal

Isodose Levels

25

45

50

54

56

Isodose

DVH Chart

Cumulative DVH Relative

ROI Tables

Structure Set Name: _____

Display: **Tumors**

Name	Display	Color	Type	Overlap Priority
ptv	<input checked="" type="checkbox"/>		Tumor	1

Regions at Risk

Name	Display	Color	Type	Overlap Priority
R_lung	<input type="checkbox"/>		RAR	7
res lt lung	<input checked="" type="checkbox"/>		RAR	1
esophagus	<input checked="" type="checkbox"/>		RAR	2
Heart	<input checked="" type="checkbox"/>		RAR	3

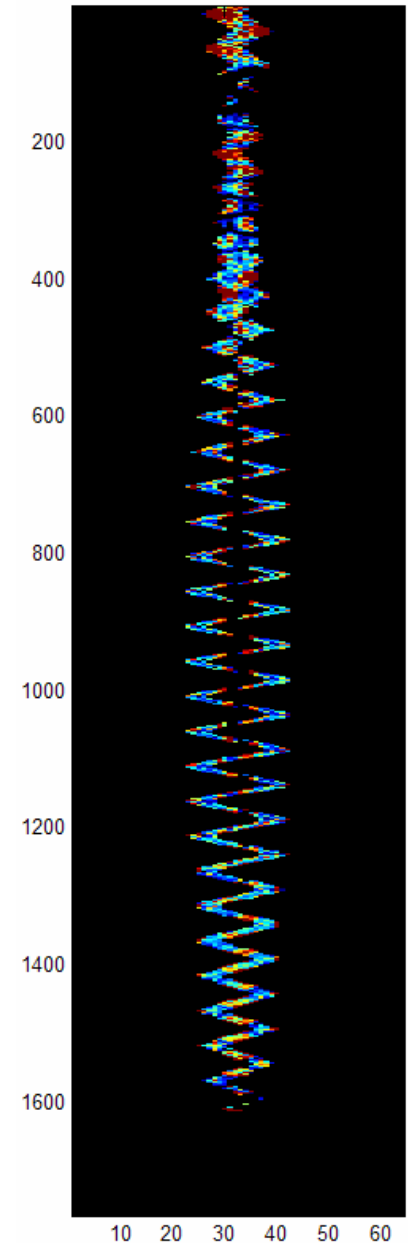
Transfer Specifics

Accounted For in Transferred Sinogram

- Small Differences in FW (changes pitch)
- Output Difference
- LFOF
- Latency

Not accounted for in transferred Sinogram

- Change in beam profile shapes
- Energy



Conclusions

- We were able to take our first generation tomo unit and our newer unit and twin them to within stated specifications
- Twinning the machines has improved efficiency and record keeping in the event that our machines are down
- It is important to have a comprehensive quality management program to ensure that the machines remain within these tight specifications.



Thank You!

