MAYO CLINIC

Do's and Don'ts of Gafchromic Film Dosimetry

Mike Grams, PhD
Medical Physicist
Mayo Clinic, Rochester, MN
grams.michael@mayo.edu

Disclosure

- Ashland provided me with travel support.
- Mayo Clinic does not endorse Ashland or its products.

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Learning objectives

- To discuss considerations for starting and maintaining a film dosimetry program
- To understand some common errors in film dosimetry and how to avoid them
- To see the benefits of using film through clinical applications of FilmQA Pro software

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My background in film dosimetry

- In 2012, someone said “It would probably be worth it if you could figure out how to use film.”
- I had no prior film experience whatsoever, but I did have time.
- I made a lot of mistakes early on, but learned a lot from them.
- ***My goal today is to help people avoid the same problems I encountered, and therefore quickly become proficient with film dosimetry***

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“Why would you want to use film?”

- It’s a very useful dosimeter because
  - It’s nearly water equivalent
  - It’s thin, flexible, and water resistant
  - Sub-millimeter spatial resolution
  - Largely energy independent from ~50 keV to >18 MV
  - No electronics to plug in or warm up or avoid hitting with radiation
  - No angular correction
  - No dose rate correction
  - No temperature correction
  - No polarity correction
  - One film for electrons, photons, HDR brachy sources…

Too good to be true?

- Not really, but you do have to follow some rules!
- Choose the film that's ideal for your application
- Define a procedure that works accurately and consistently and stick to it
  - Shortcuts or skipping details can lead to bad results
  - You want to be able to trust the film, all the time, every time

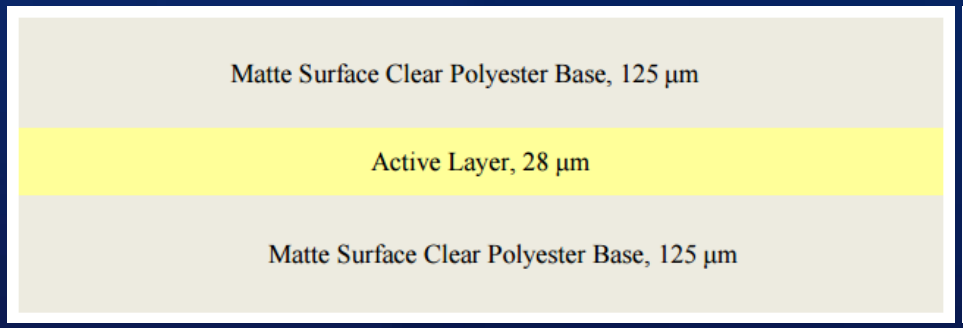
Film Dosimetry – What do you need?

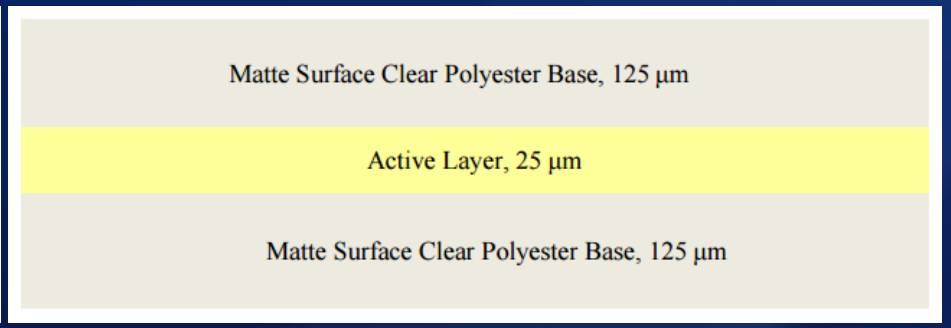
- Radiation source
- Film
- Suitable phantom material
- Computer with film analysis software
- Flatbed document scanner
- Guillotine Cutter
- **~3 mm thick glass sheet to push films flat on scanner**

The vast majority of my experience is with Epson 10000/11000 XL scanners and FilmQA Pro software.

The film

- In my clinic, we only use EBT3 and EBT-XD
  - EBT3 for applications <10 Gy
  - EBT-XD for high dose applications >10 Gy





EBT3 EBT-XD

Since the active layer is in the middle of the film, it <u>does not</u> matter which side is up for scanning (not true with previous versions of film, e.g., EBT2)

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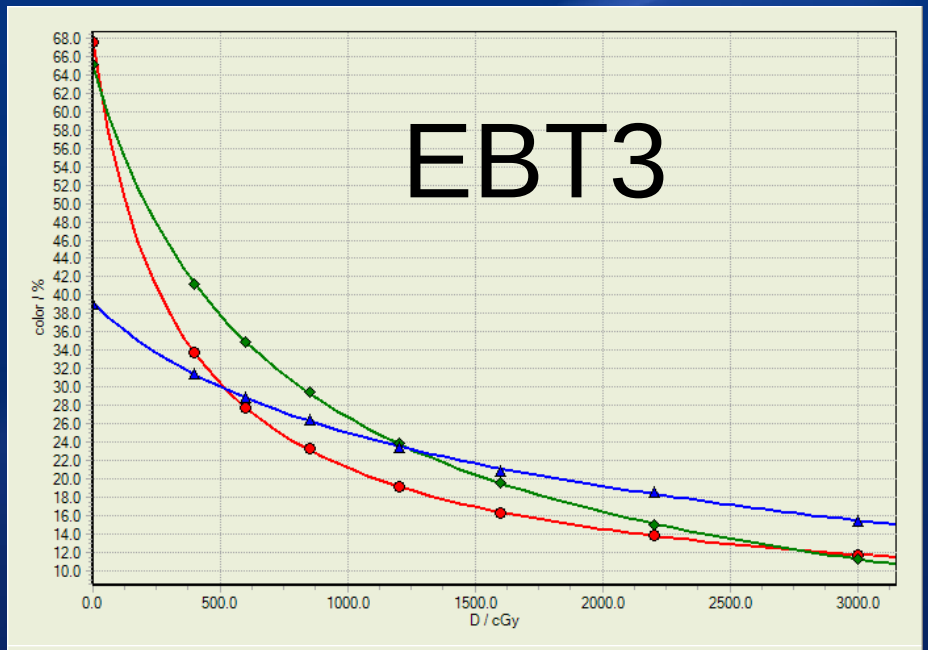

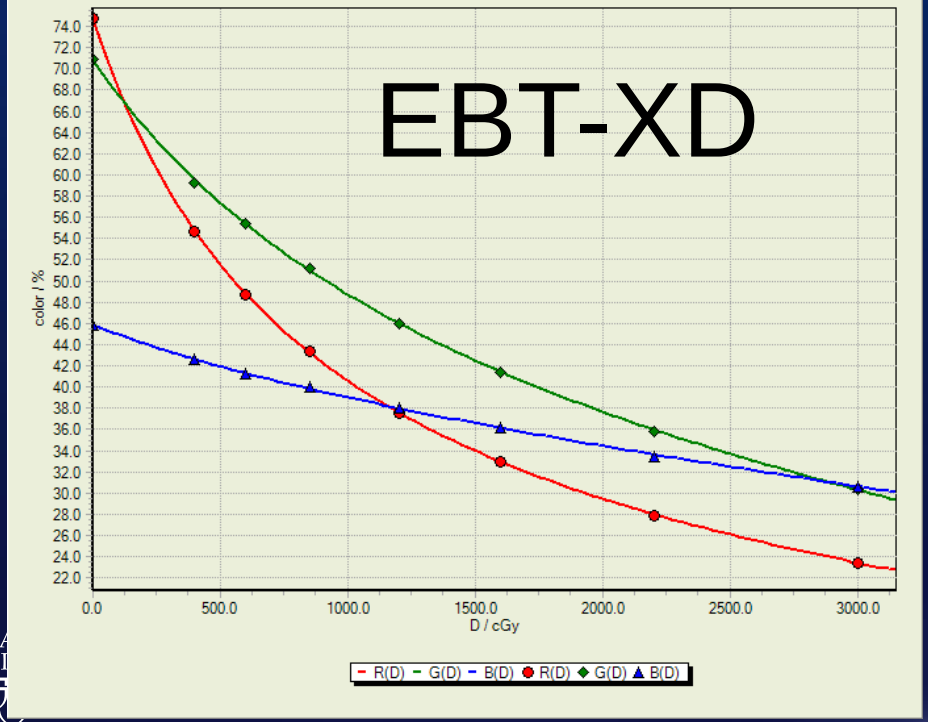

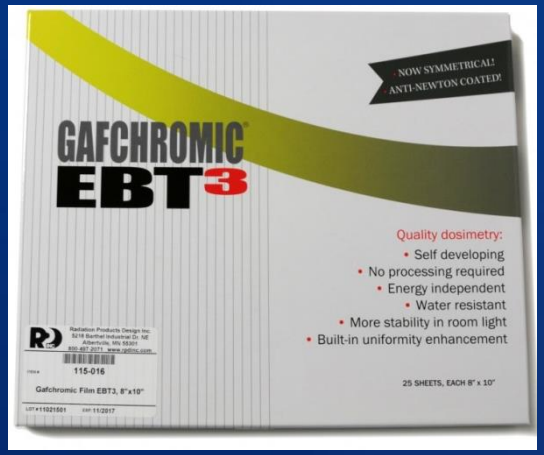

At higher doses, the signal from EBT3 films tends to saturate. XD is less sensitive, so at higher doses saturation is less of an issue.

The calibration

- Expose films to a uniform dose under conditions where you know what that dose is
  - In my clinic, I calibrate in solid water at d_{max} using a 10x10 cm^2 field and a 6 MV beam where 1 MU = 1 cGy
- I use 6 MV for all calibrations
- I create calibrations from 0 – 3 Gy, 0 – 6 Gy, and 0 – 10 Gy for EBT3 and from 0 – 40 Gy for EBT-XD
  - I use 4 – 7 doses, more dose points does not necessarily mean higher accuracy!

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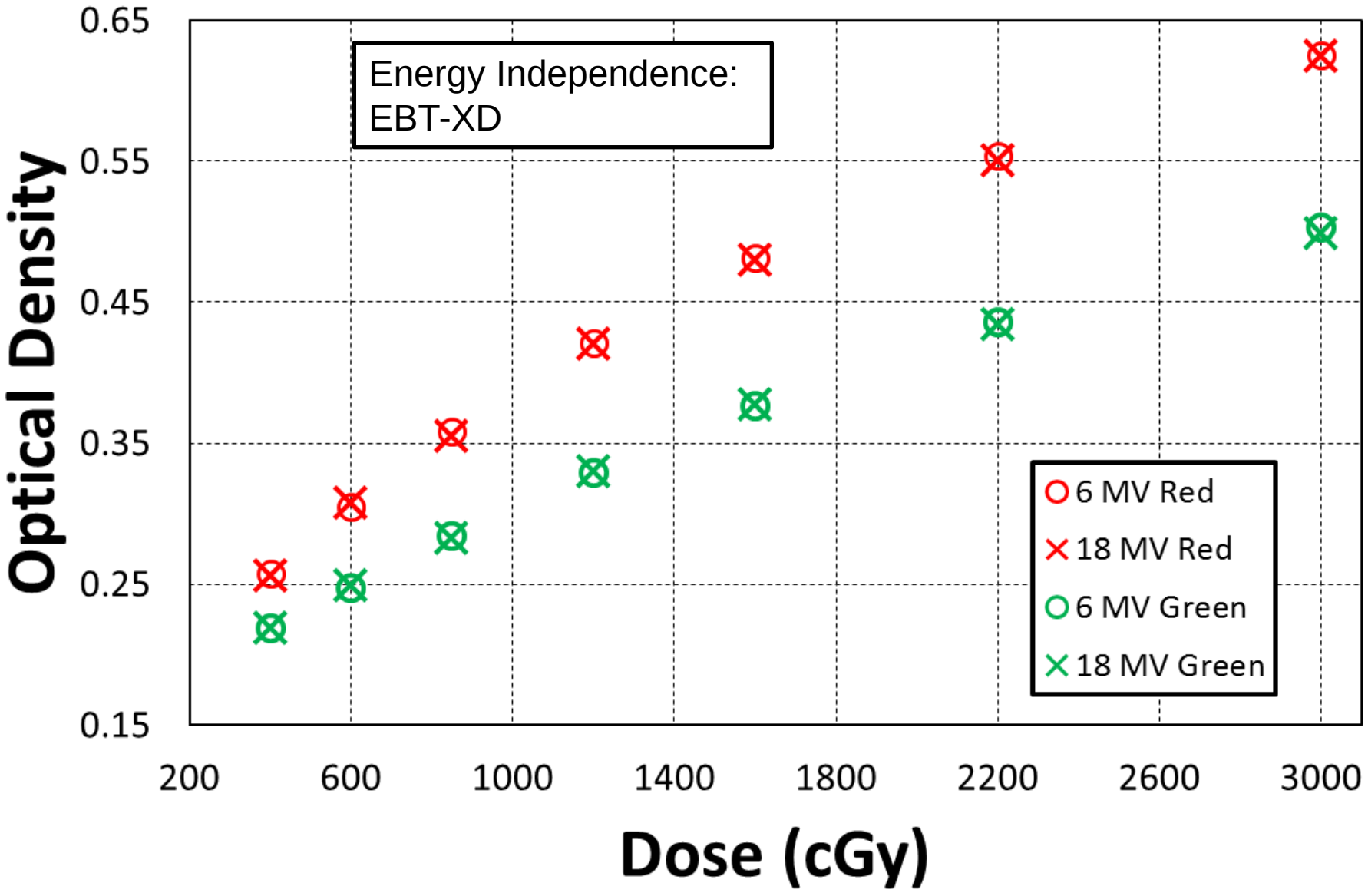
Energy Independence:
EBT-XD
Optical Density
0.65
0.55
0.45
0.35
0.25
0.15
200
600
1000
1400
1800
2200
2600
3000
Dose (cGy)
6 MV Red
18 MV Red
6 MV Green
18 MV Green

The calibration

- Use a glass plate to push the films flat and position them at the center of the scanner

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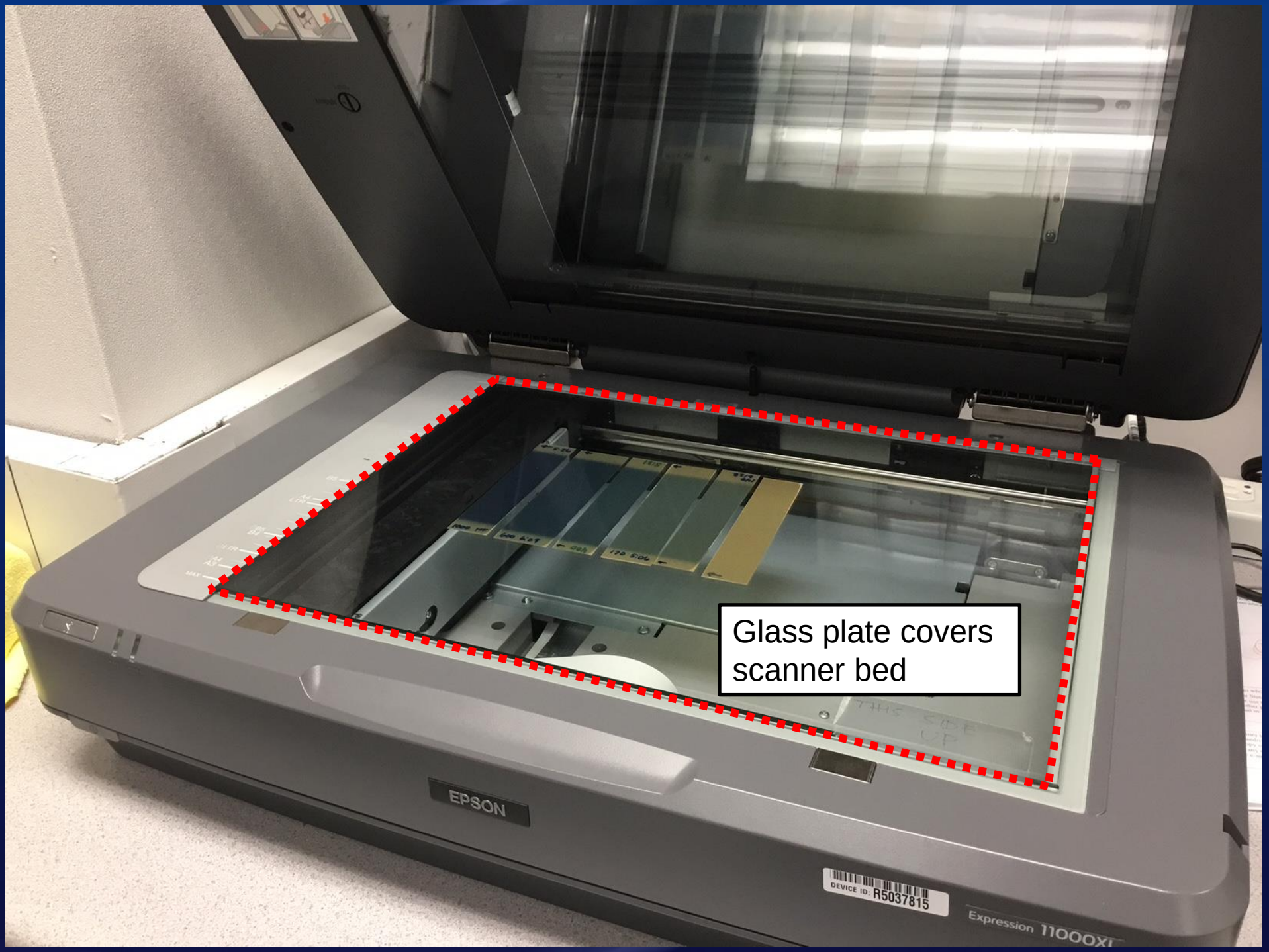
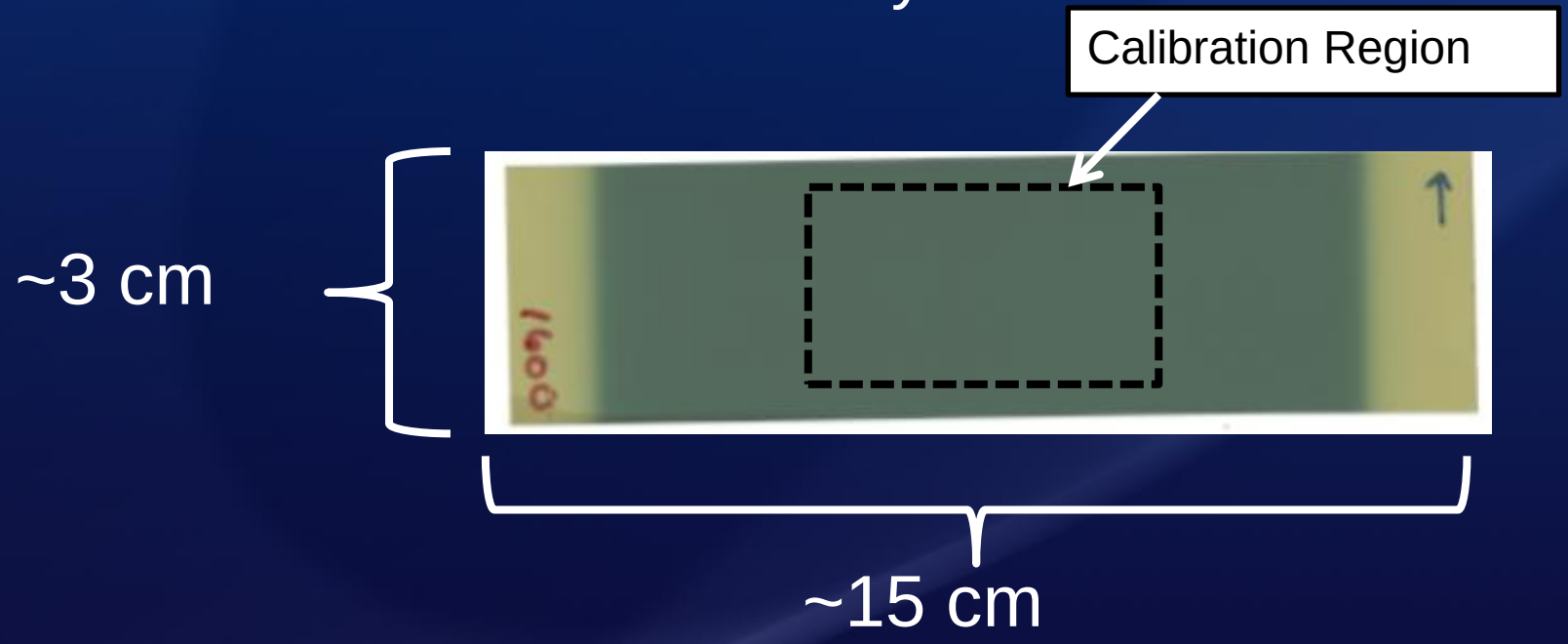

Glass plate covers scanner bed
EPSON
DEVICE ID: R5037815
Expression 11000XL

The calibration

- Use a glass plate to push the films flat and position them at the center of the scanner
- The calibration curve should represent the average behavior of the film as much as possible
- Try not to use really small calibration strips!
  - You could catch an anomaly



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Scan Parameters

- The scanner is the weakest link in the film dosimetry process, it will try to mess you up every chance it gets!
- Scanners are designed to make pretty pictures. They have lots of added features which can enhance, smooth, change the sharpness or contrast, etc.
- Don't use any of those features.
- Do turn off anything and everything that will alter the raw image data.

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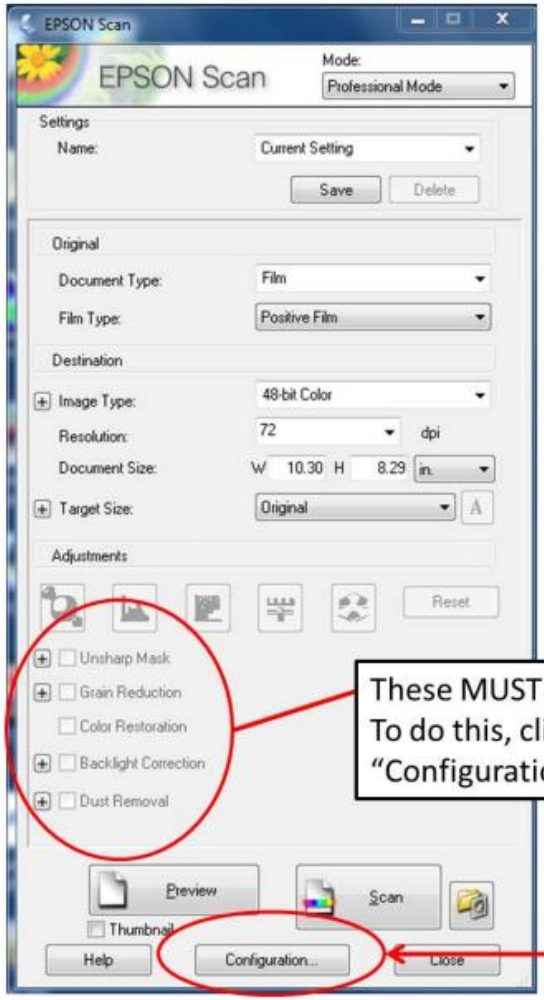

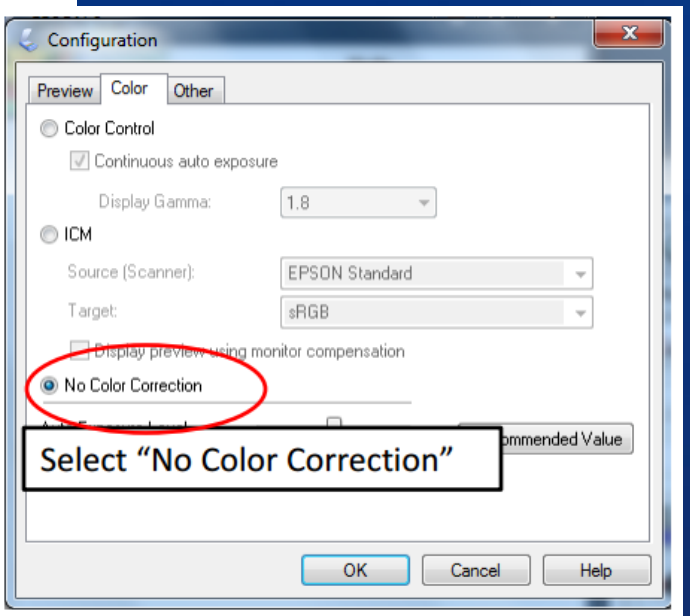

Select "No Color Correction"

These MUST all be unchecked! To do this, click on the "Configuration…" tab

You MUST turn off all color corrections and anything else that will alter the image. You want the raw data.

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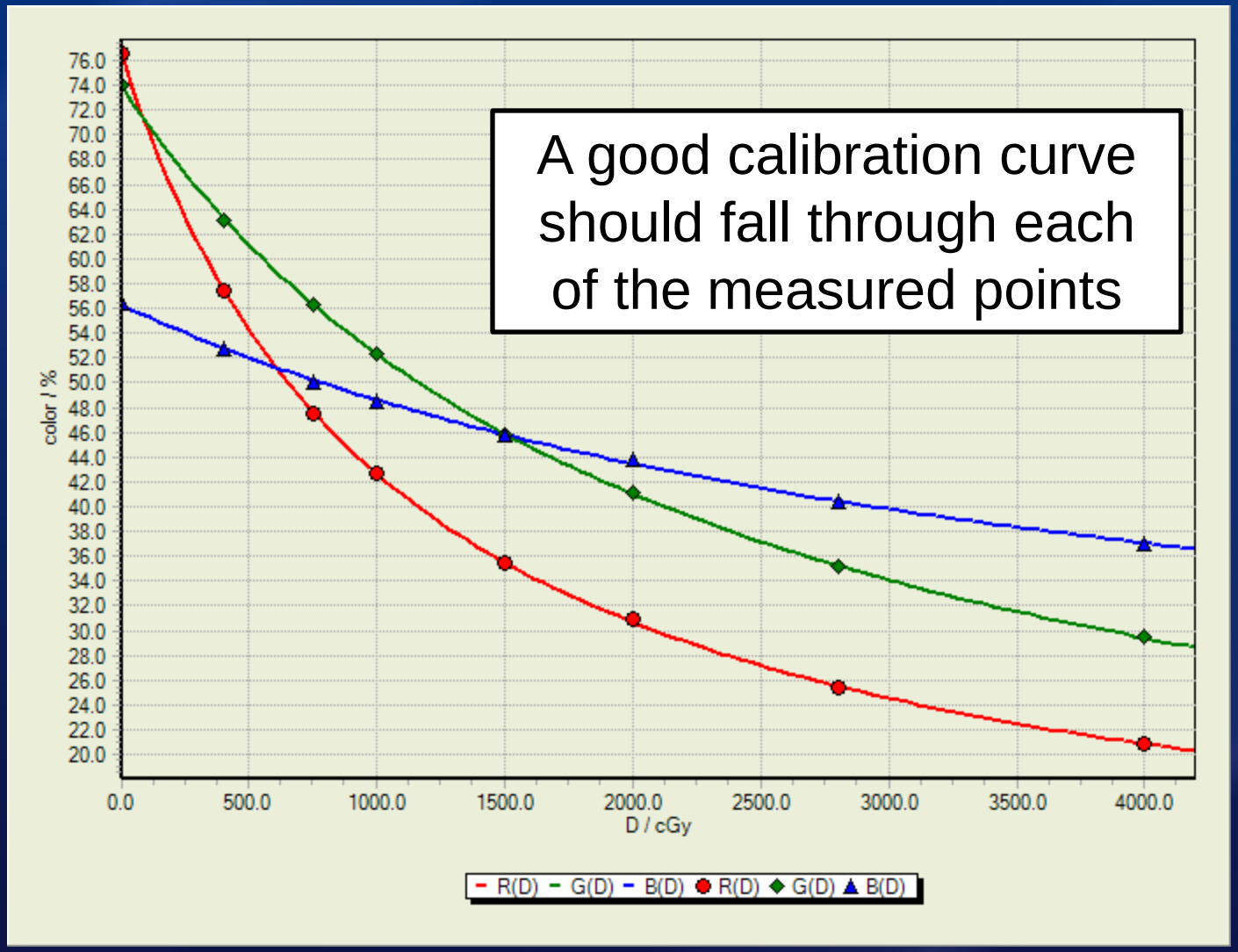
Checking the calibration

- Visually inspect your calibration curve
  - It should go right through your data points, if not something is wrong


A good calibration curve should fall through each of the measured points
color I %
76.0
74.0
72.0
70.0
68.0
66.0
64.0
62.0
60.0
58.0
56.0
54.0
52.0
50.0
48.0
46.0
44.0
42.0
40.0
38.0
36.0
34.0
32.0
30.0
28.0
26.0
24.0
22.0
20.0
0.0
500.0
1000.0
1500.0
2000.0
2500.0
3000.0
3500.0
4000.0
D / cGy
R(D) G(D) B(D) R(D) G(D) B(D)

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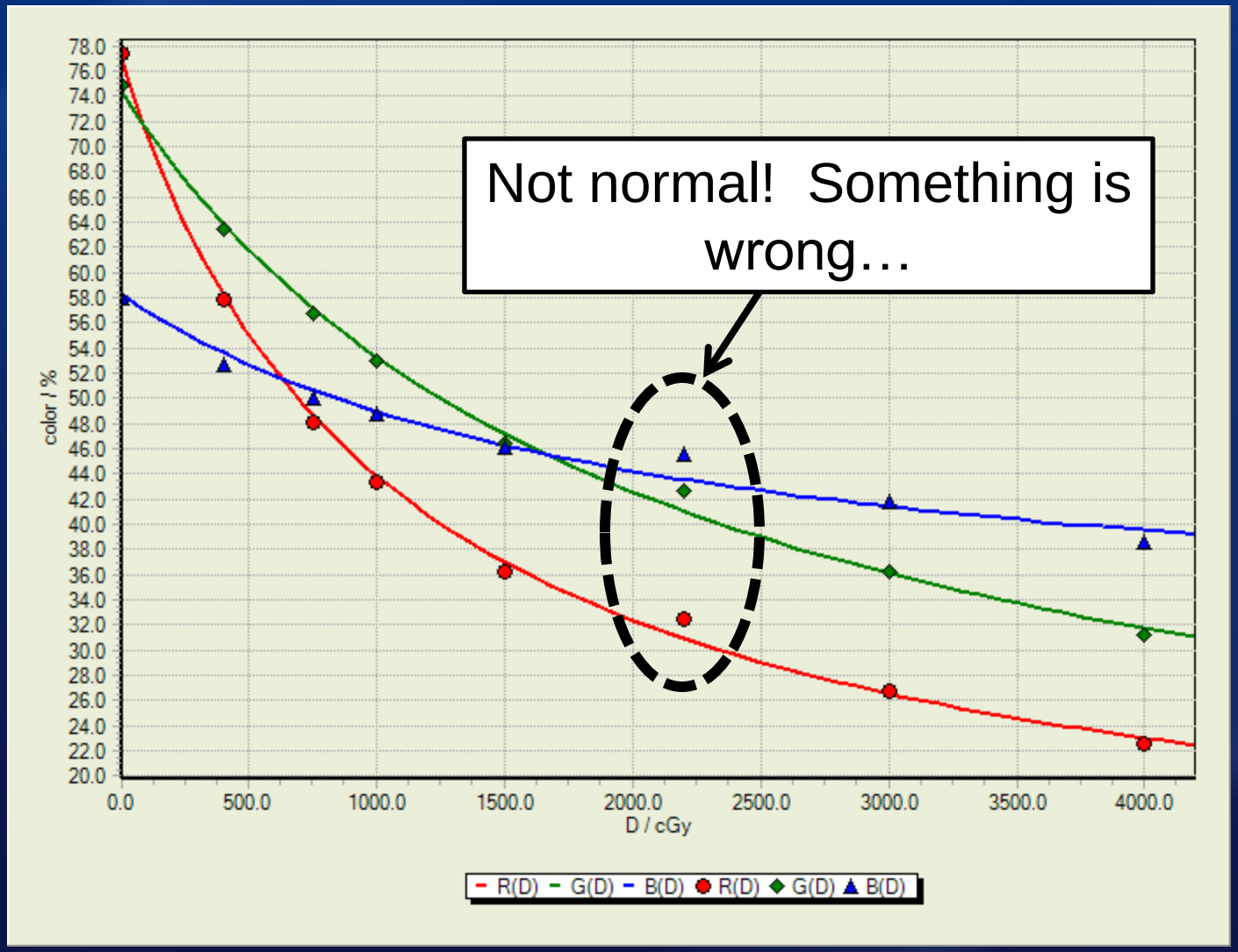

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Checking the calibration

- Visually inspect your calibration curve
  - It should go right through your data points, if not something is wrong
- If something is wrong, try to determine what happened and fix it
  - Delivered wrong dose?
  - Calibration conditions incorrect?
  - You can delete an offending dose point, but it’s better to understand what was wrong

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QA the calibration

- QA your calibration curve before you proceed!
- Don't assume that if the calibration curve looks ok, everything is fine, you really should test it
- Do expose a number of other films to known doses and make sure you get the right results
- Use simple, open fields to establish consistency and accuracy
- I commission each new batch of film this way before it's released for clinical use (~2-2.5 hours of work)

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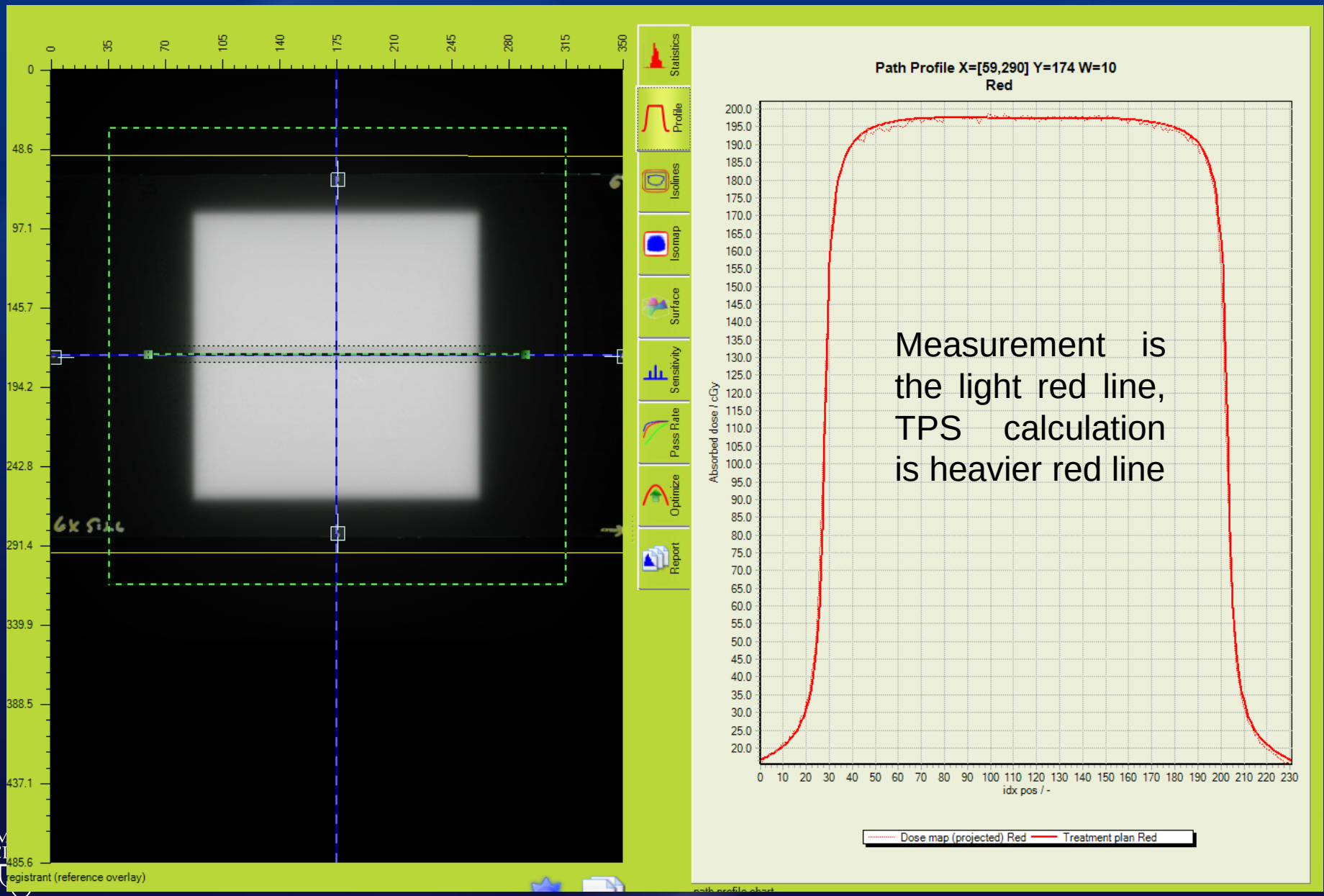
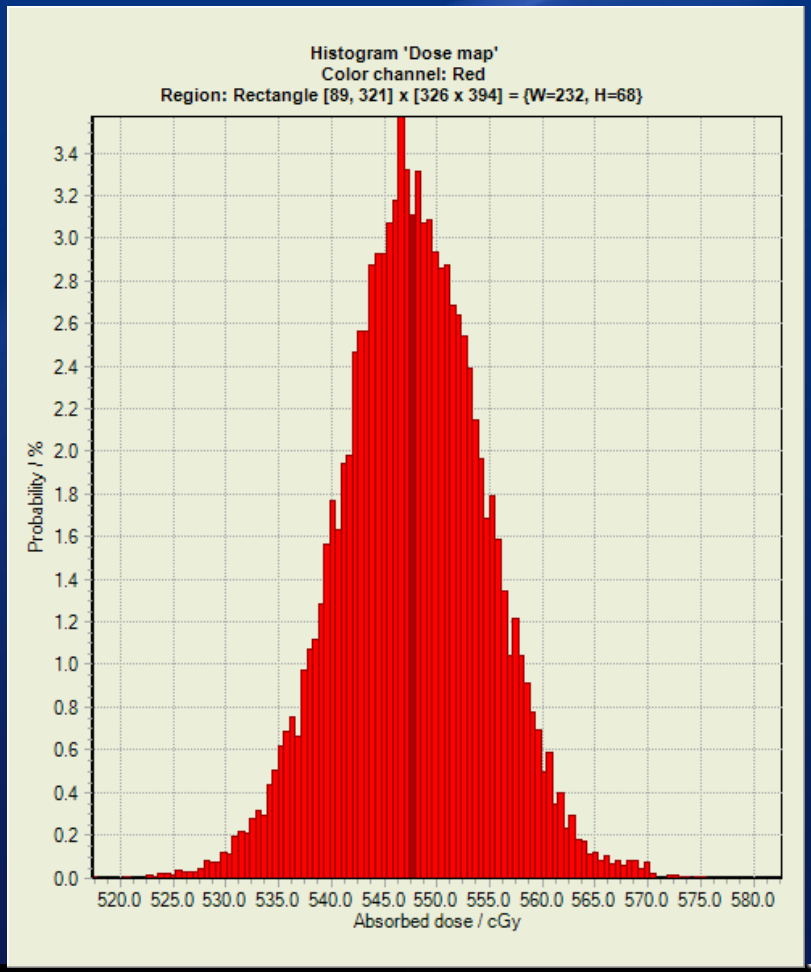
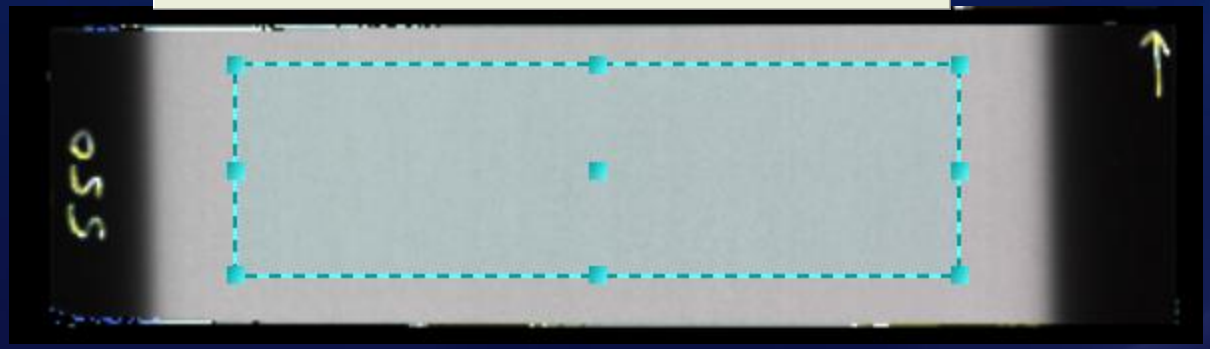
Start simple: Check basic open fields (dose and profiles)





Expected Dose = 550 cGy
Measured Mean = 547.8 cGy
Standard Dev. = 6.8 cGy

My criteria is the measured mean MUST be within 2% of the expected value (most of the time I'm around 1%)



Make sure your calibration is accurate over the entire range!

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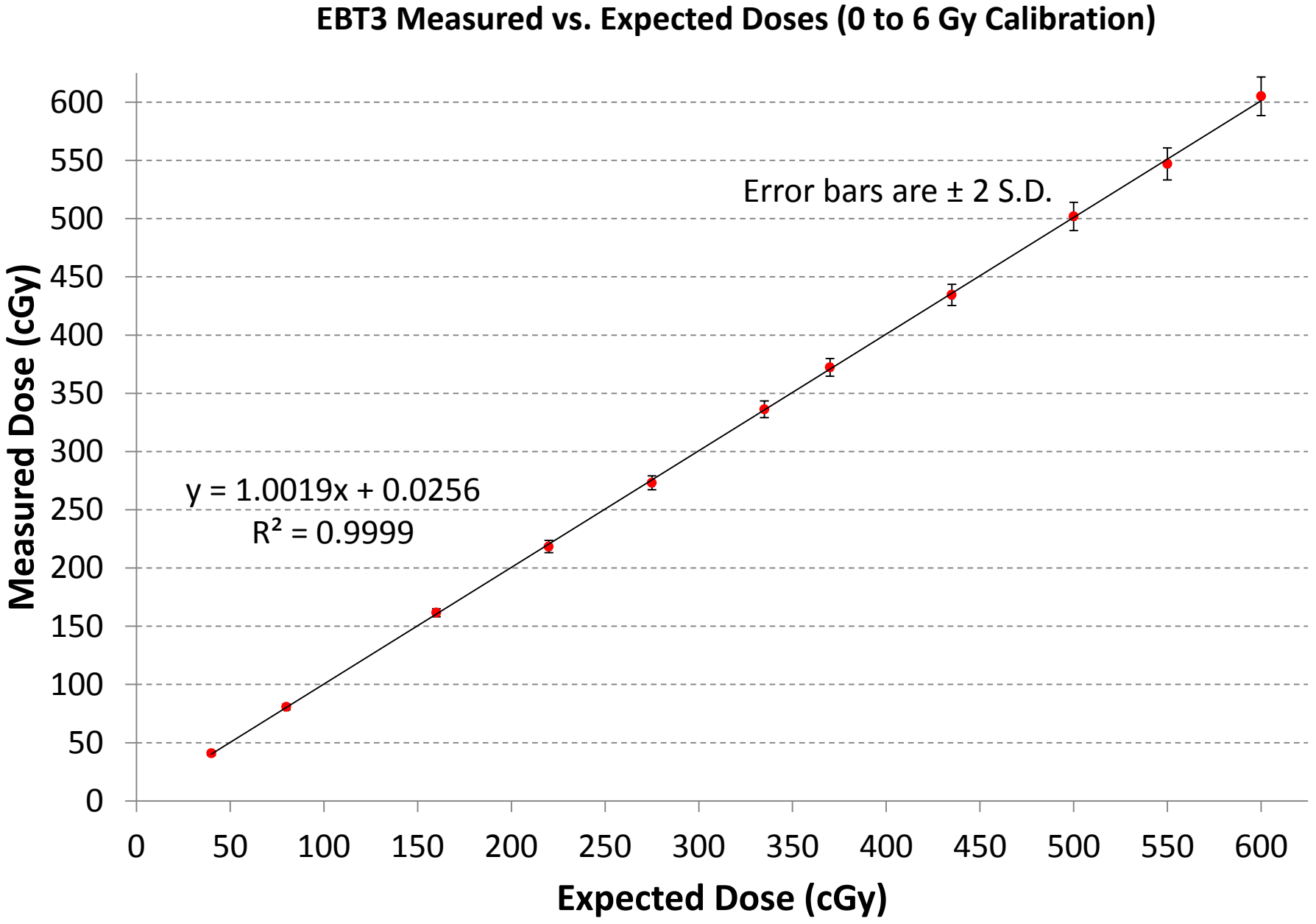
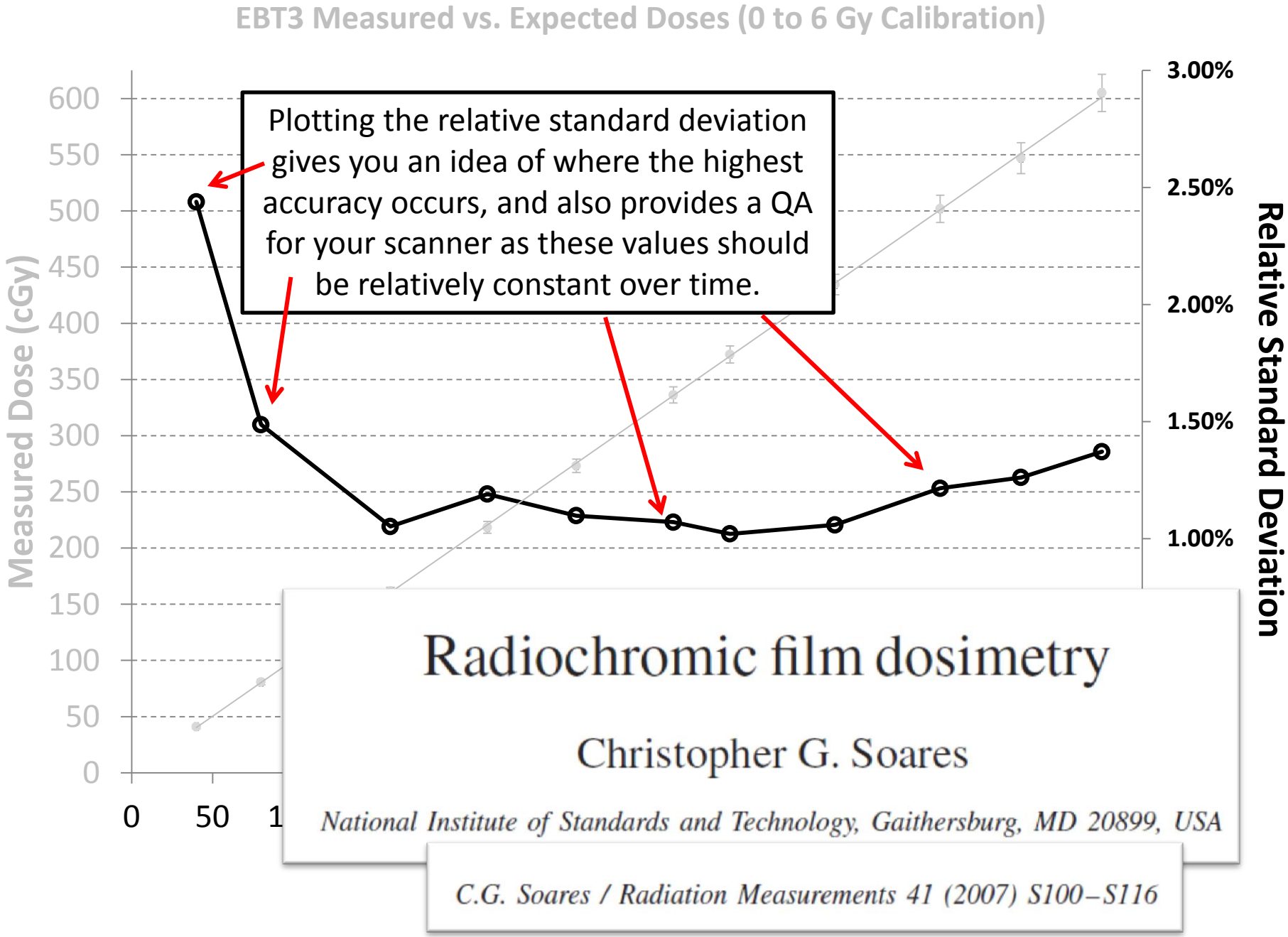

EBT3 Measured vs. Expected Doses (0 to 6 Gy Calibration)
Error bars are ± 2 S.D.
y = 1.0019x + 0.0256
R² = 0.9999
Measured Dose (cGy)
Expected Dose (cGy)
0
50
100
150
200
250
300
350
400
450
500
550
600


EBT3 Measured vs. Expected Doses (0 to 6 Gy Calibration)
Measured Dose (cGy)
600
550
500
450
400
350
300
250
200
150
100
50
0
0
50
3.00%
2.50%
2.00%
1.50%
1.00%
Relative Standard Deviation
Plotting the relative standard deviation gives you an idea of where the highest accuracy occurs, and also provides a QA for your scanner as these values should be relatively constant over time.
Radiochromic film dosimetry
Christopher G. Soares
National Institute of Standards and Technology, Gaithersburg, MD 20899, USA
C.G. Soares / Radiation Measurements 41 (2007) S100–S116

Other pitfalls

- Once you've established an accurate calibration, you're ready to move on
- But there's still several things that can mess you up!
- It is very helpful to understand some basic things about
  - The film
  - The scanner
  - How the two interact with each other

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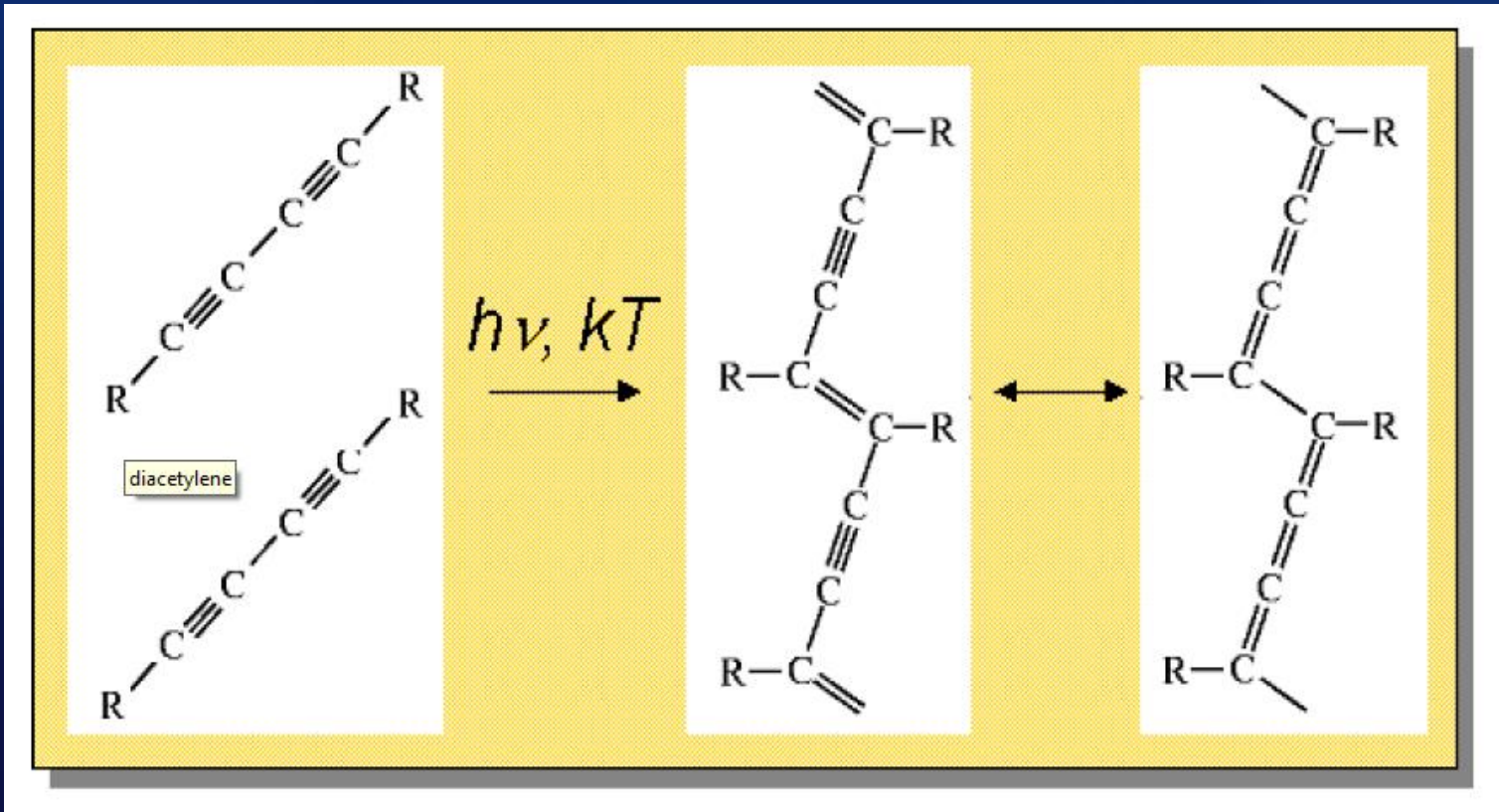
Gafchromic Film – How does it work?

- When irradiated, the long monomers of active ingredient polymerize into even longer chains



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Gafchromic Film – How does it work?

- The reaction continues on even after the radiation stops, and the film gets darker over time
- The reaction proceeds very quickly at first, and then slows down considerably after a few hours
- I usually wait 16-24 hours before I scan my calibration films
- You then need to wait the same amount of time before scanning other films UNLESS you use the one scan protocol

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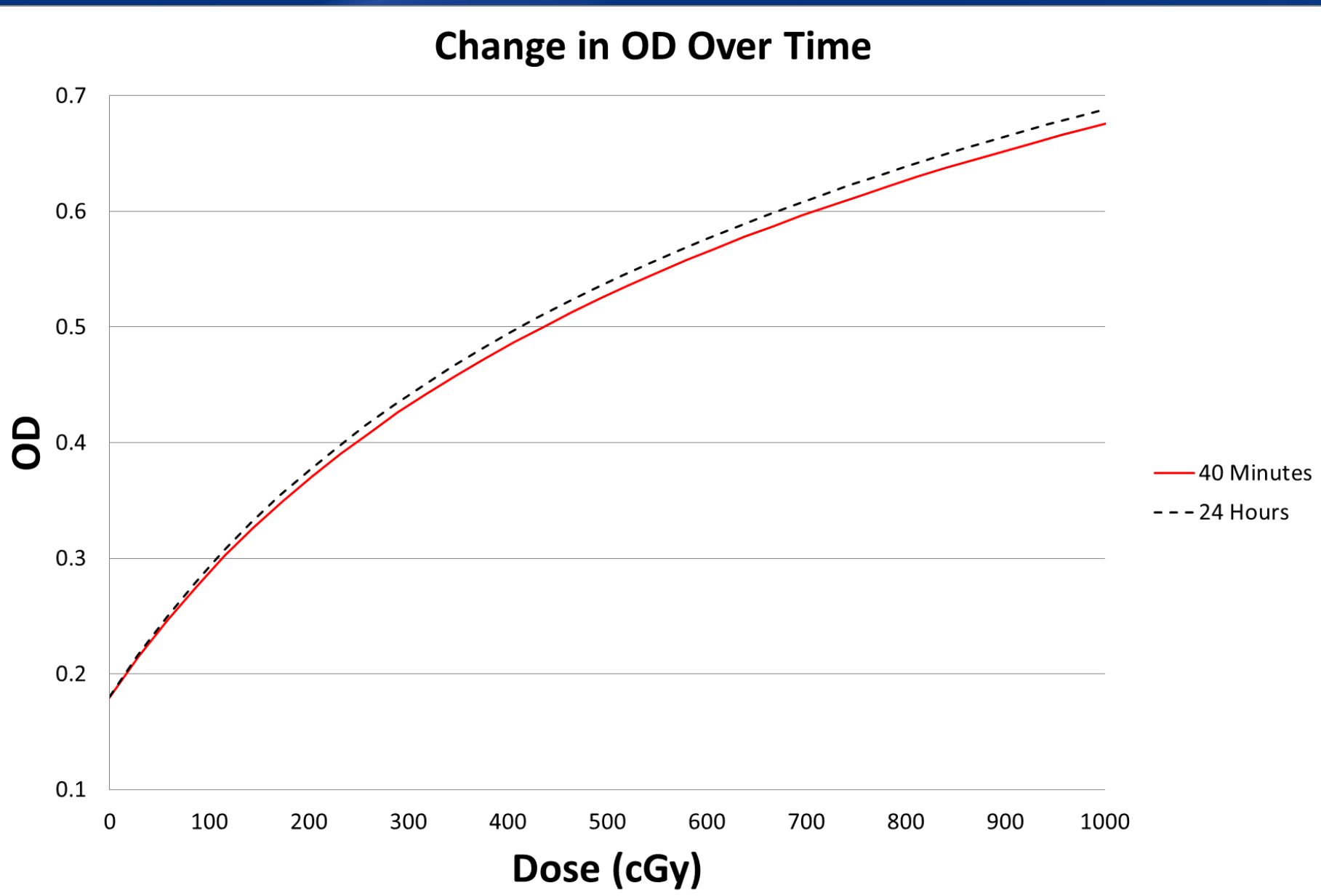
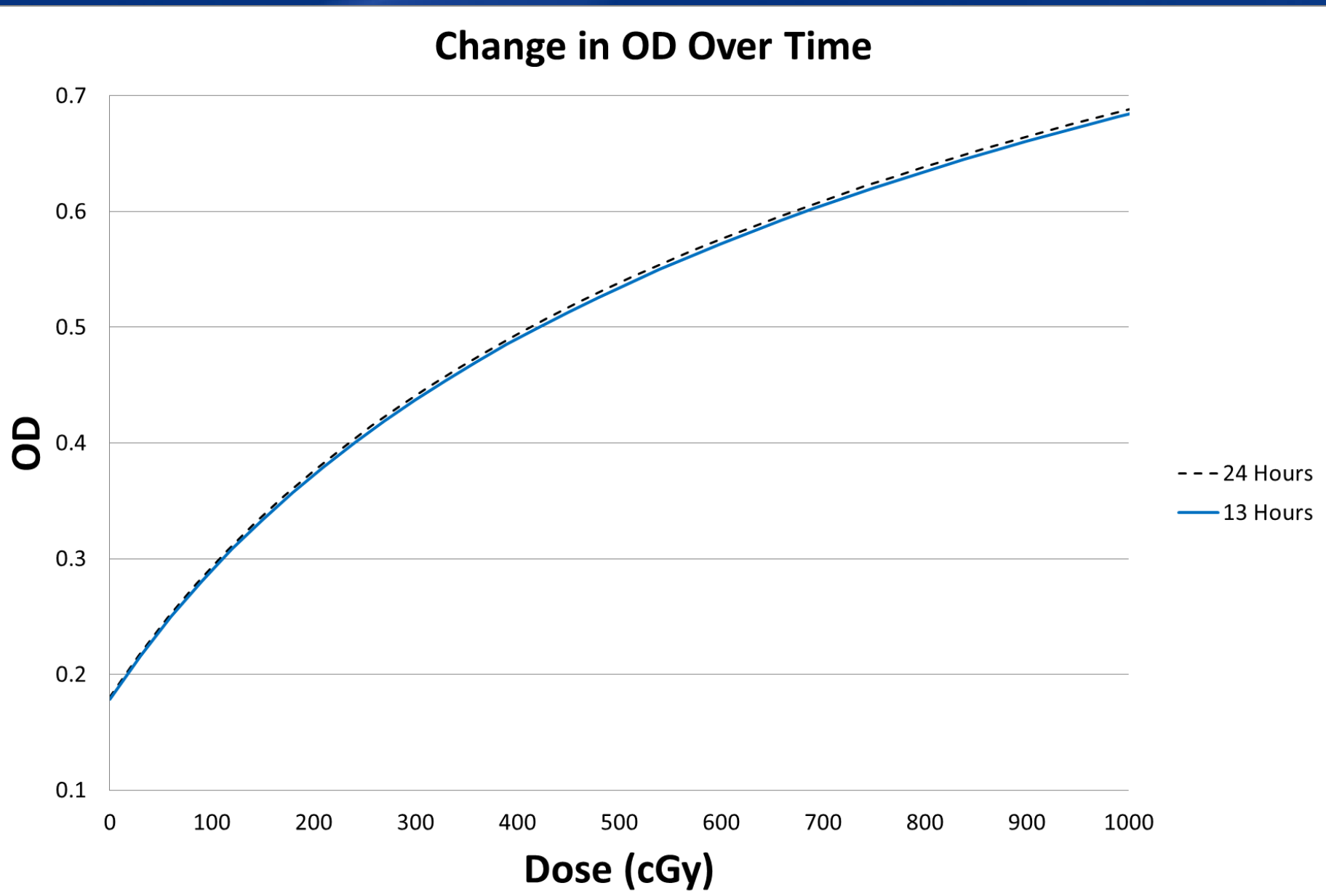
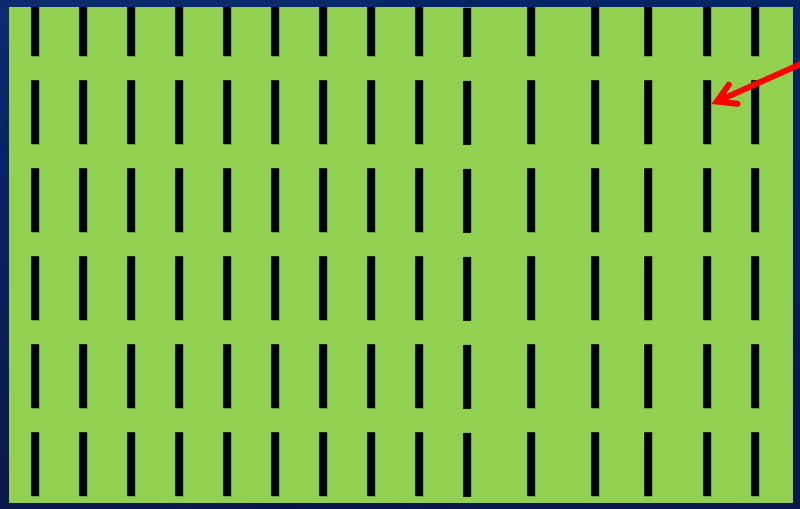

Change in OD Over Time
0.7
0.6
0.5
0.4
0.3
0.2
0.1
OD
0
100
200
300
400
500
600
700
800
900
1000
Dose (cGy)
40 Minutes
24 Hours

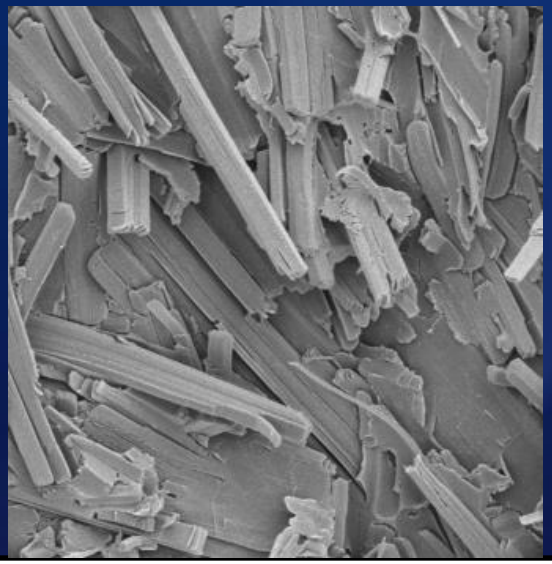

Change in OD Over Time
0.7
0.6
0.5
0.4
0.3
0.2
0.1
OD
0
100
200
300
400
500
600
700
800
900
1000
Dose (cGy)
24 Hours
13 Hours

Gafchromic Film - Structure

- The active ingredient has a preferentially oriented direction



"Hair like" active ingredient is preferentially oriented parallel to the short side of the film



Since the active component tends to lie in the same general direction, it <u>does</u> matter which way the film is placed on the scanner.

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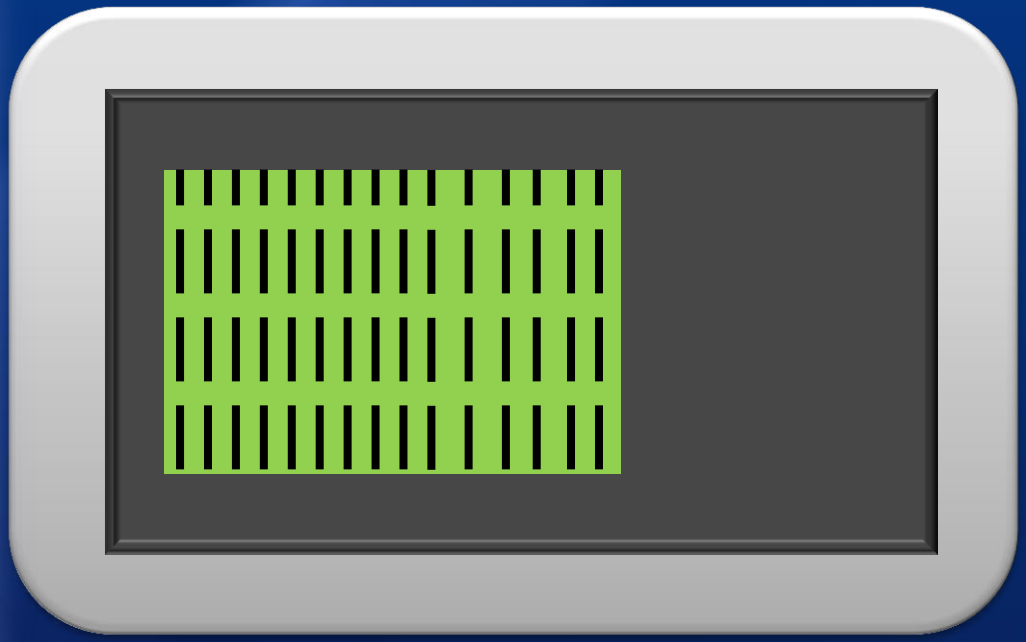
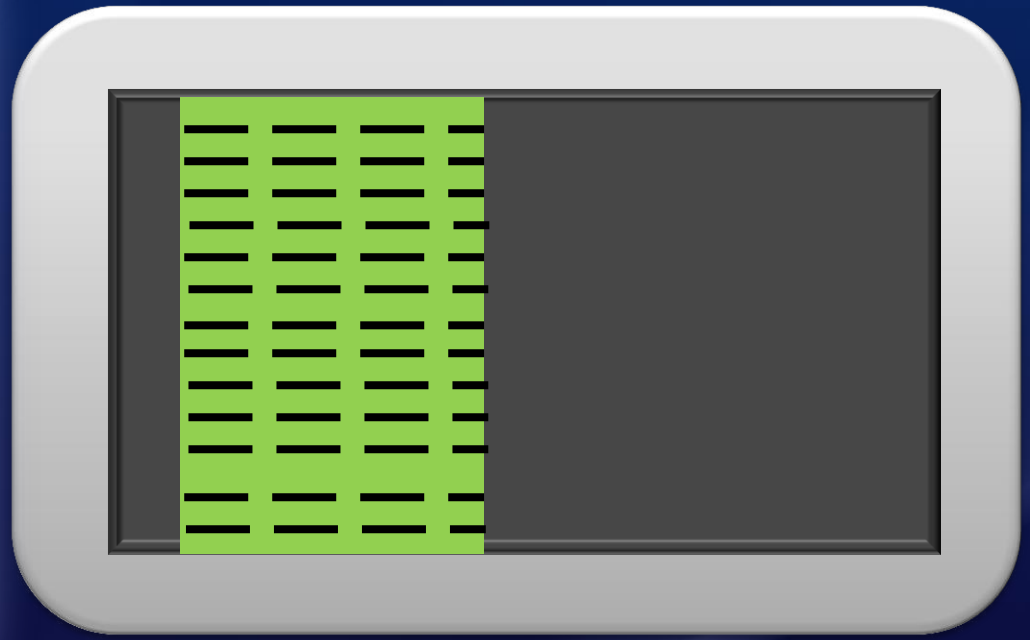


Different!



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Gafchromic Film - Structure

- Is the preferential orientation of the active ingredient a problem?
- No, as long as you scan the films in the same orientation as the calibration films.
- Don't lose track of the film orientation (especially if cutting smaller squares)
- Do pick an orientation, mark it, and always stay consistent

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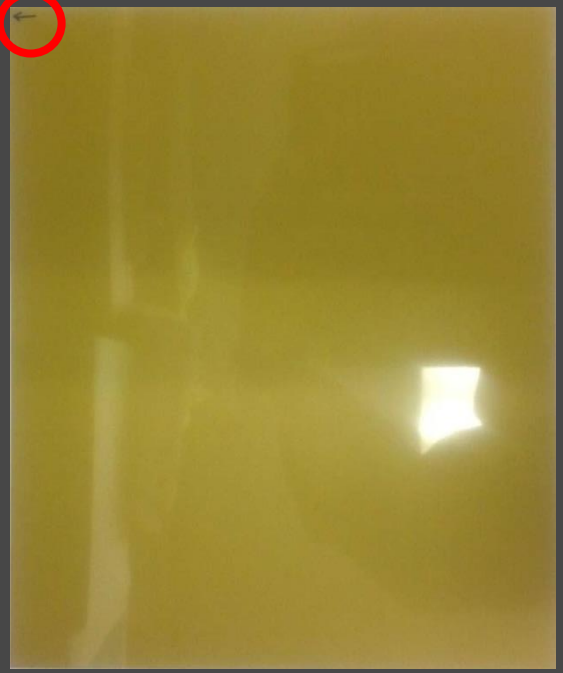

It doesn’t matter which orientation you pick, you just have to stick with it

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It doesn’t matter which orientation you pick, you just have to stick with it

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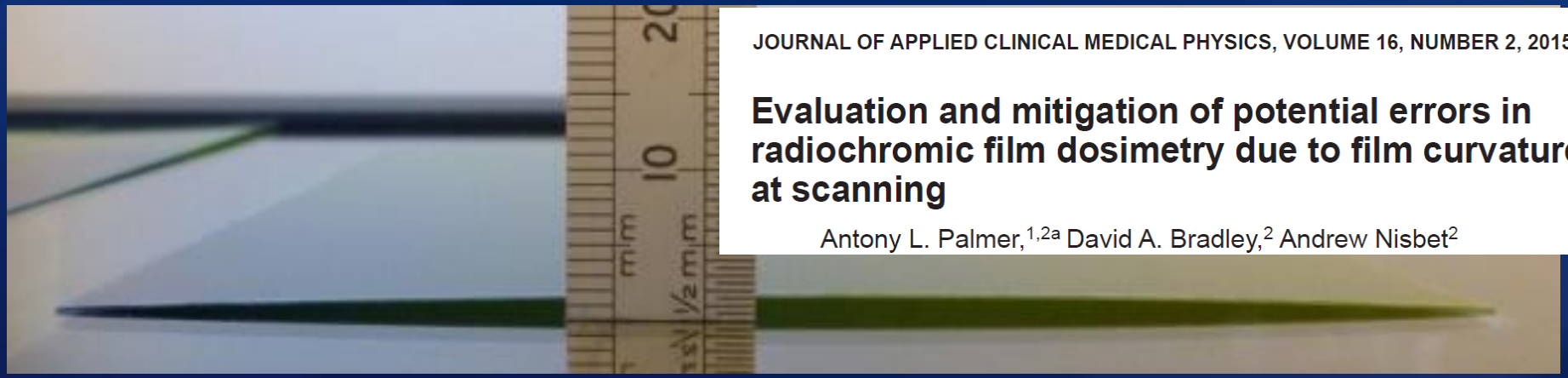
The scanner – film interaction

- Don't let the film curl on the scanner!!!

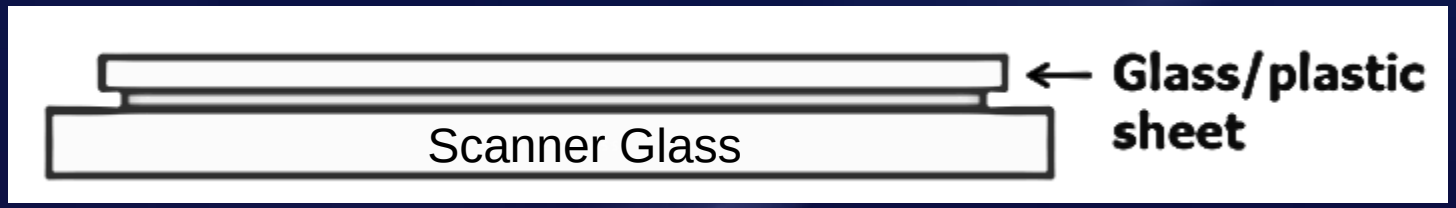


JOURNAL OF APPLIED CLINICAL MEDICAL PHYSICS, VOLUME 16, NUMBER 2, 2015

Evaluation and mitigation of potential errors in radiochromic film dosimetry due to film curvature at scanning

Antony L. Palmer,[1,2a] David A. Bradley,[2] Andrew Nisbet[2]

- Do press it flat with a glass plate. You might get lucky when some films lay flatter than others, but in the long run your results will be inconsistent



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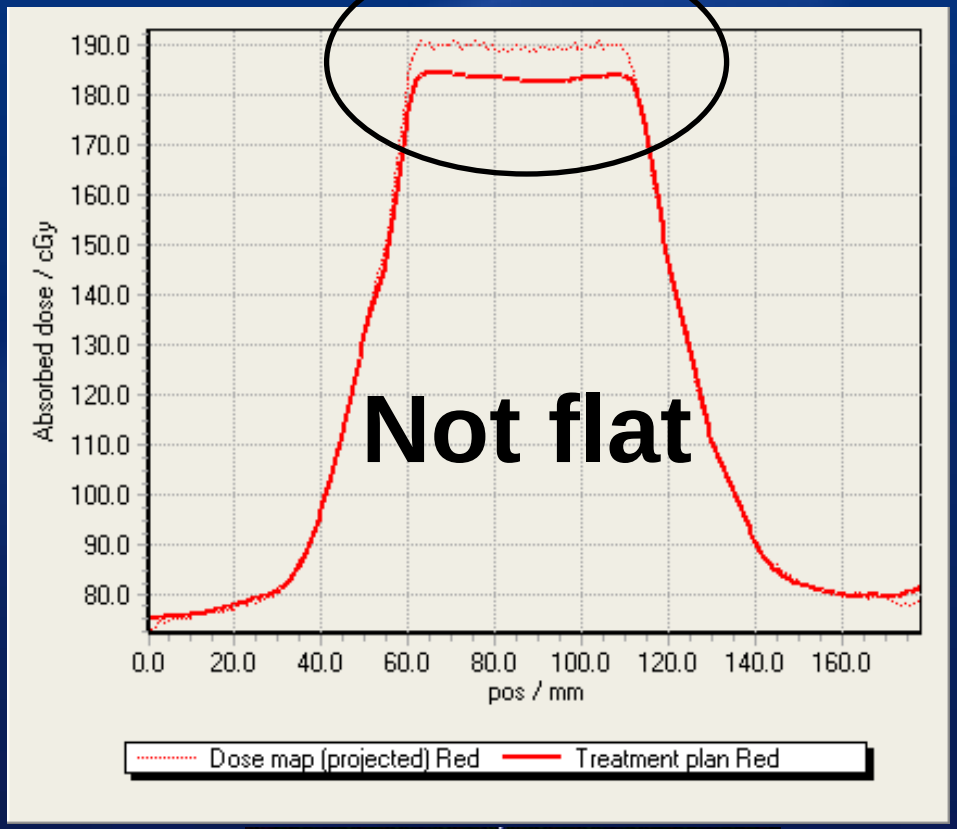
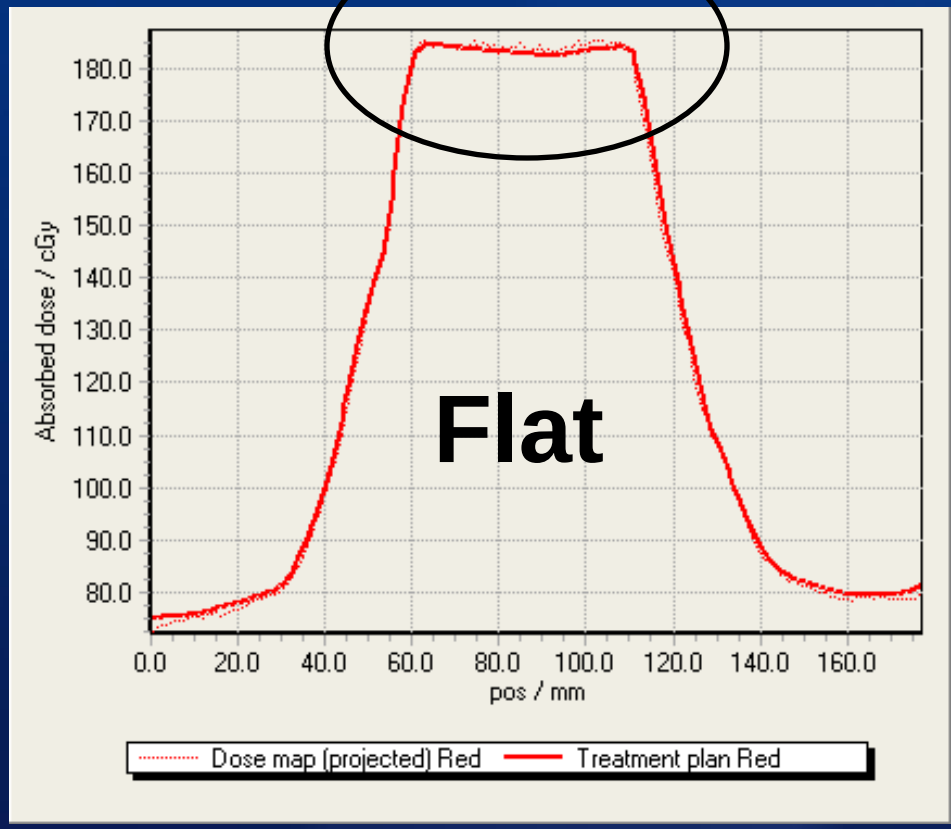
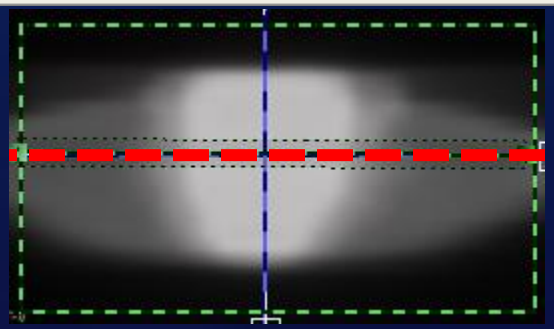
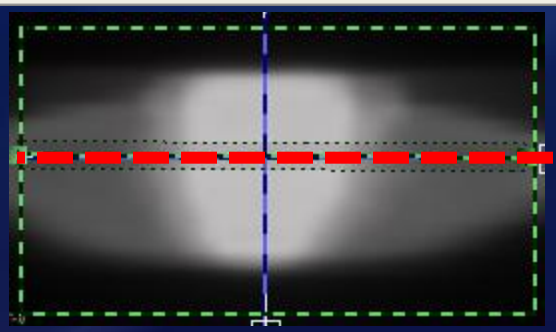

Not flat
Absorbed dose / cGy
190.0
180.0
170.0
160.0
150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0
pos / mm
Dose map (projected) Red
Treatment plan Red


Flat
Absorbed dose / cGy
180.0
170.0
160.0
150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0
pos / mm
Dose map (projected) Red
Treatment plan Red





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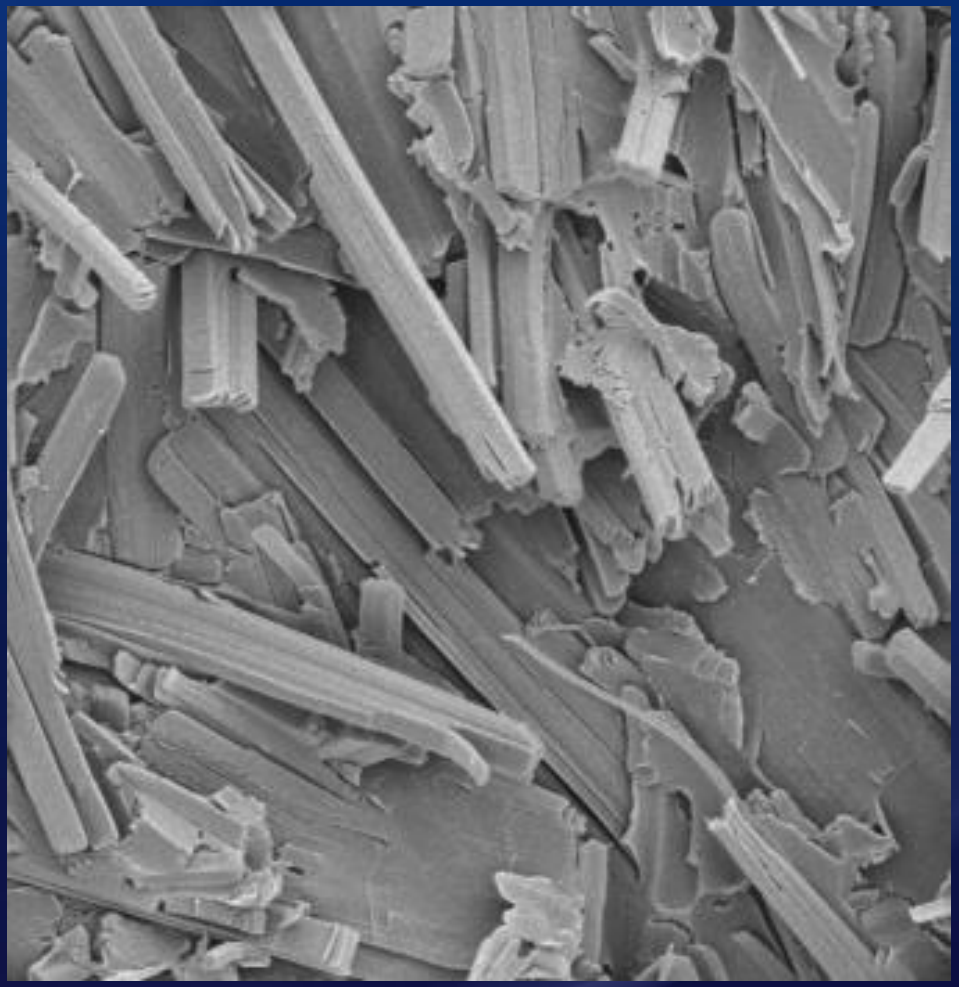
The scanner – film interaction

- Remember those long polymer chains?



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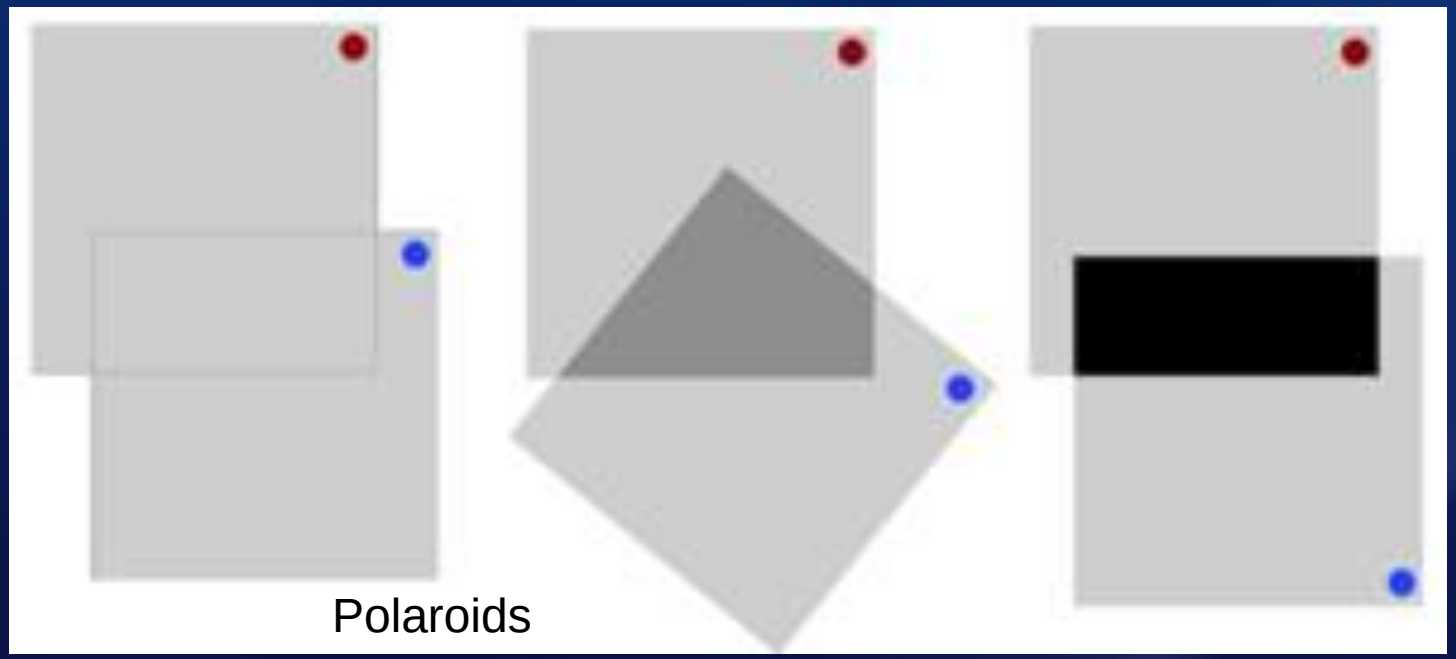
Gafchromic Film

- These long chains act to polarize the light passing through the film



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Gafchromic Film

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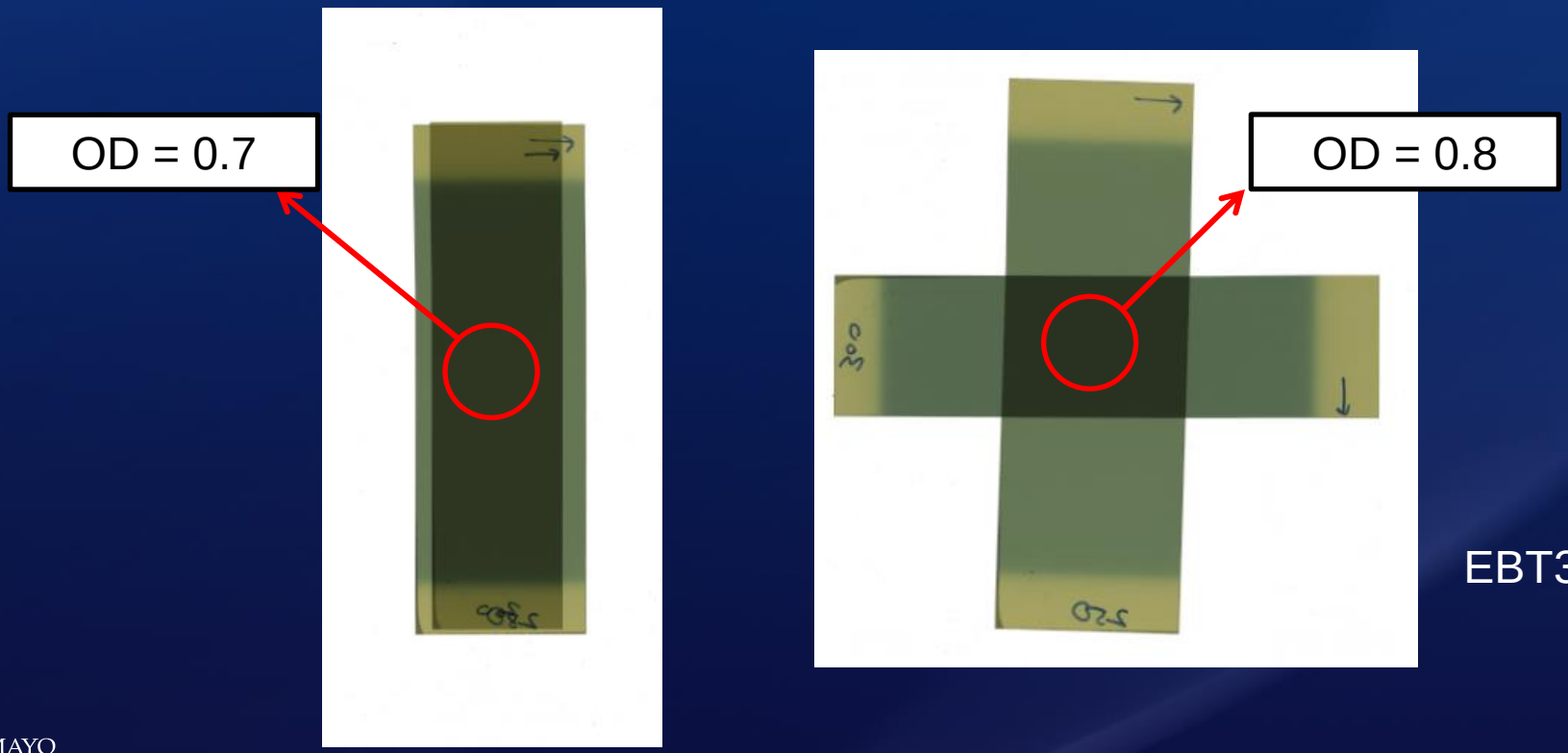

EBT3 Film

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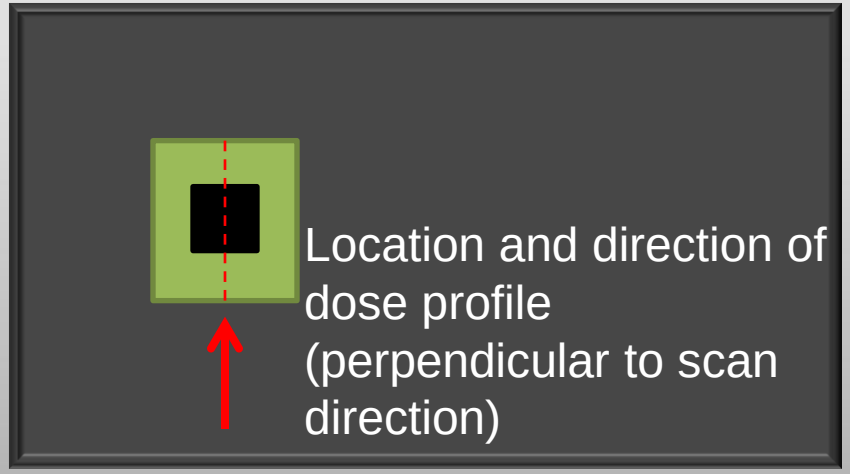
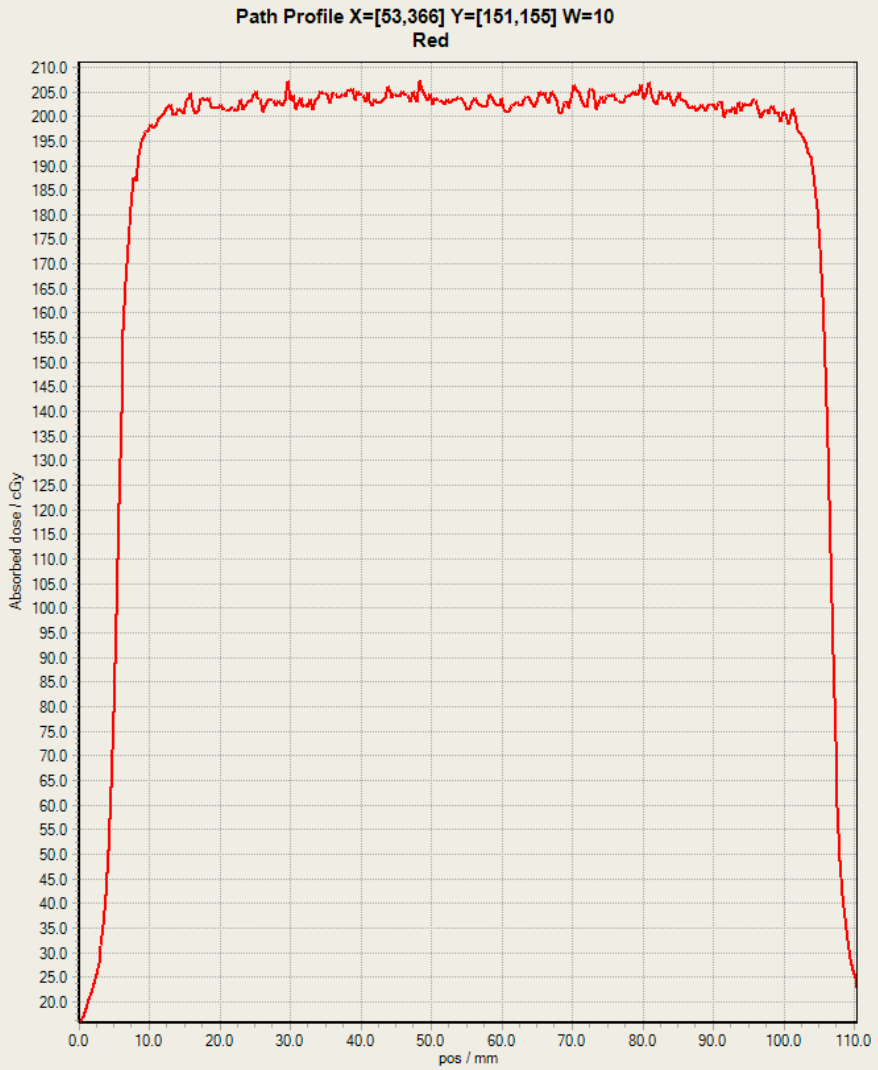


Scan Direction

Piece of EBT3 exposed to 10x10 cm^2 field and centered on scanner bed



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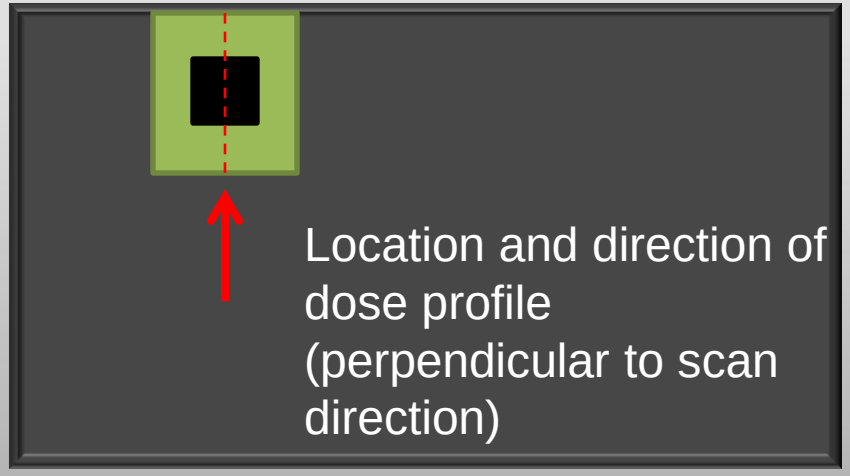
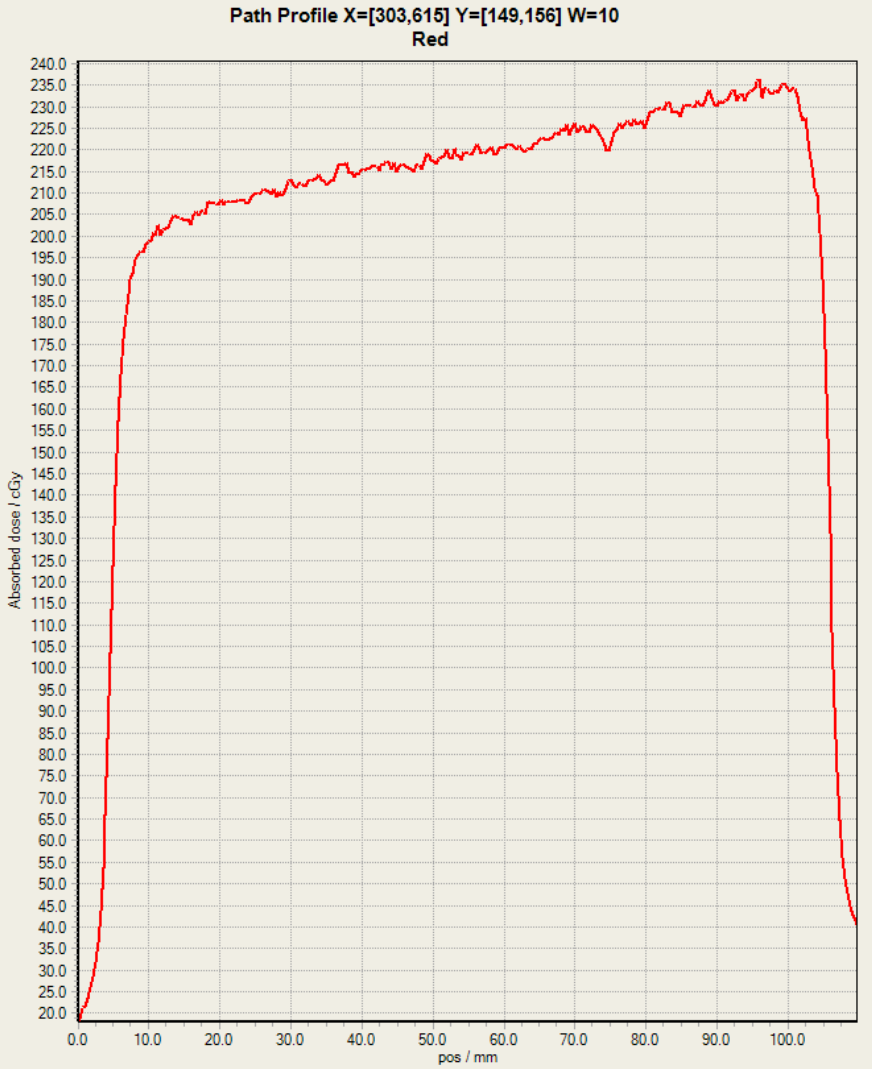
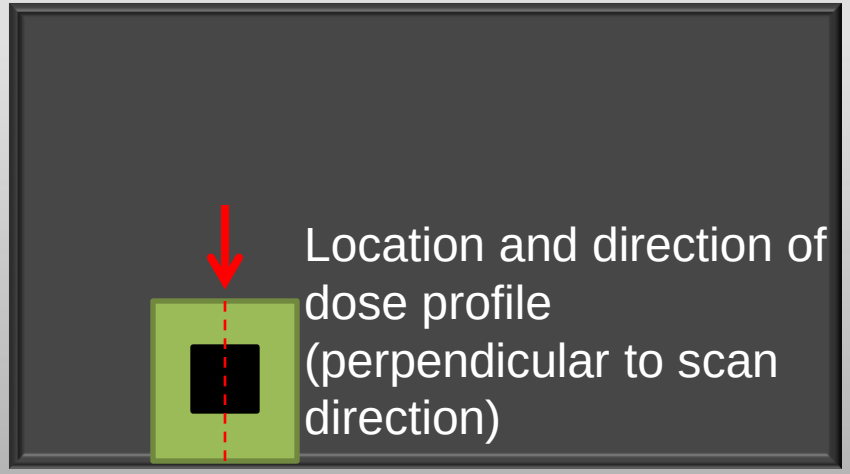


Scan Direction

Same piece of EBT3 scanned off-center

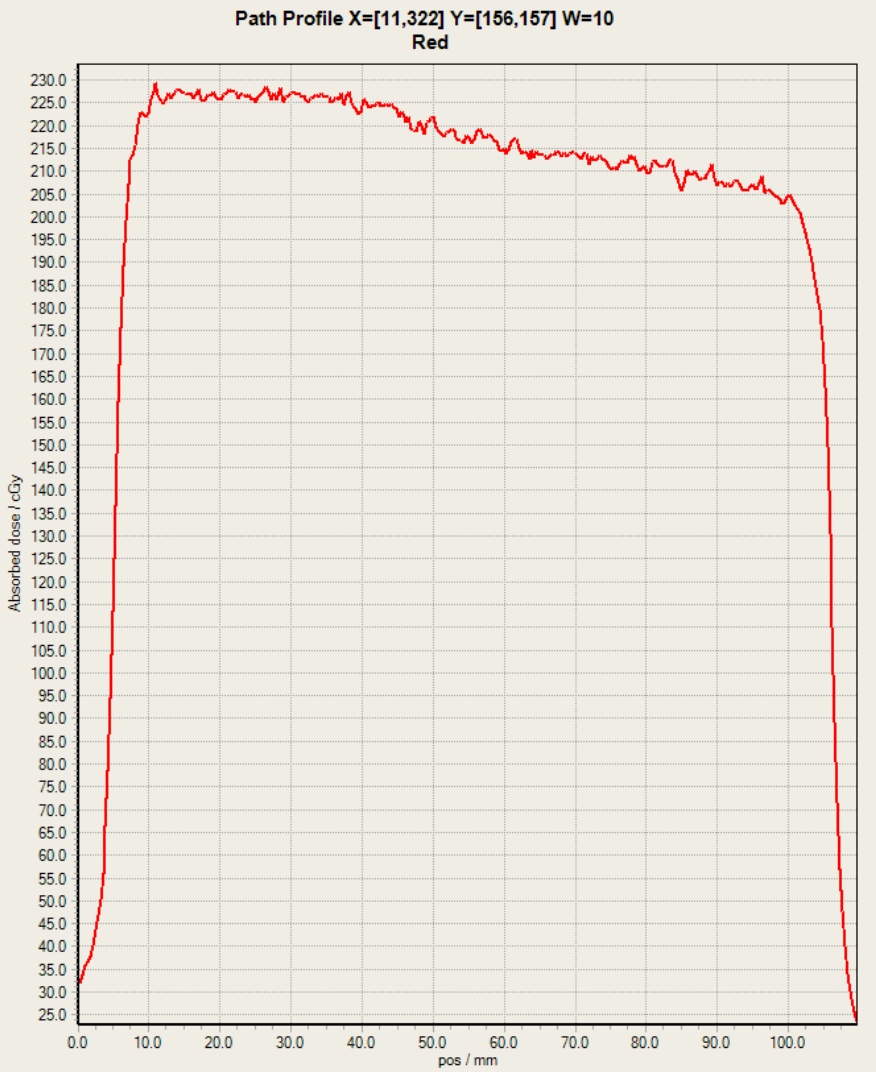


MAYO CLINIC



Scan Direction

Same piece of EBT3 scanned off-center



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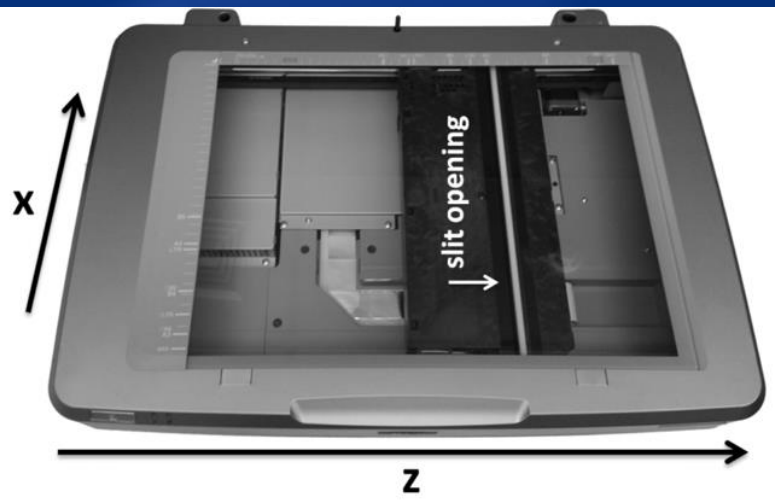
The Lateral Response Artifact (LRA)



The artefacts of radiochromic film dosimetry with flatbed scanners and their causation by light scattering from radiation-induced polymers

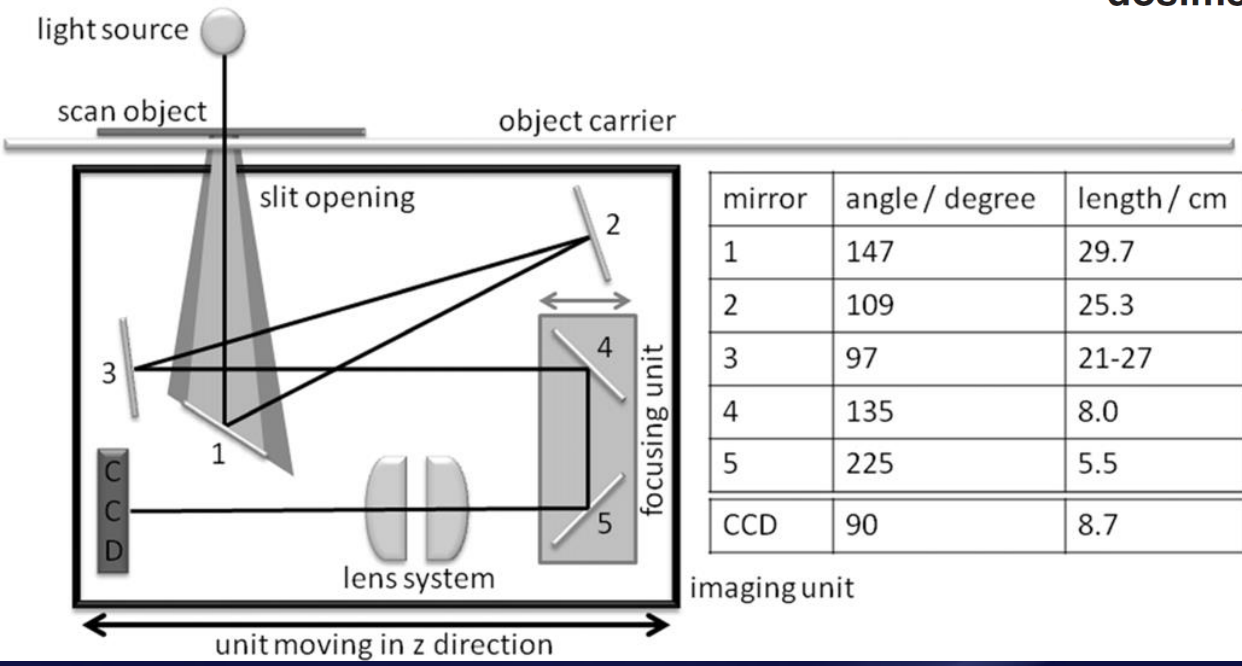
Andreas A Schoenfeld[1,2], Daniela Poppinga[1,2], Dietrich Harder[3], Karl-Joachim Doerner[4] and Bjoern Poppe[1,2]

Phys. Med. Biol. **59** (2014) 3575–3597

How flatbed scanners upset accurate film dosimetry

L J van Battum[1], H Huizenga[2], R M Verdaasdonk[1] and S Heukelom[1]

Phys. Med. Biol. **61** (2016) 625–649



mirror	angle / degree	length / cm
1	147	29.7
2	109	25.3
3	97	21-27
4	135	8.0
5	225	5.5
CCD	90	8.7

The Lateral Response Artifact (LRA)

- The reflection of polarized light by a mirror is dependent on the angle of incidence.
- The angle of incidence on the scanner's mirrors changes with distance from the scanner center
- The signal received at the center of the CCD array can be different than the signal at the edges
- It scales with dose, the effect is worse at higher doses

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The Lateral Response Artifact (LRA)

- Don't put your films anywhere but the center of the scanner!
  - Line them up in a single column

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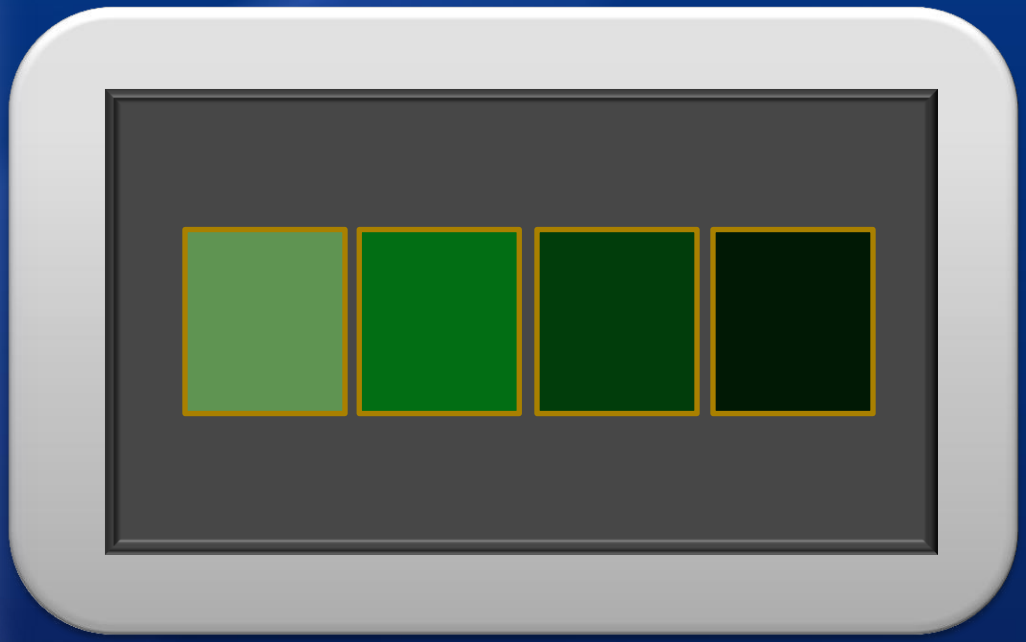

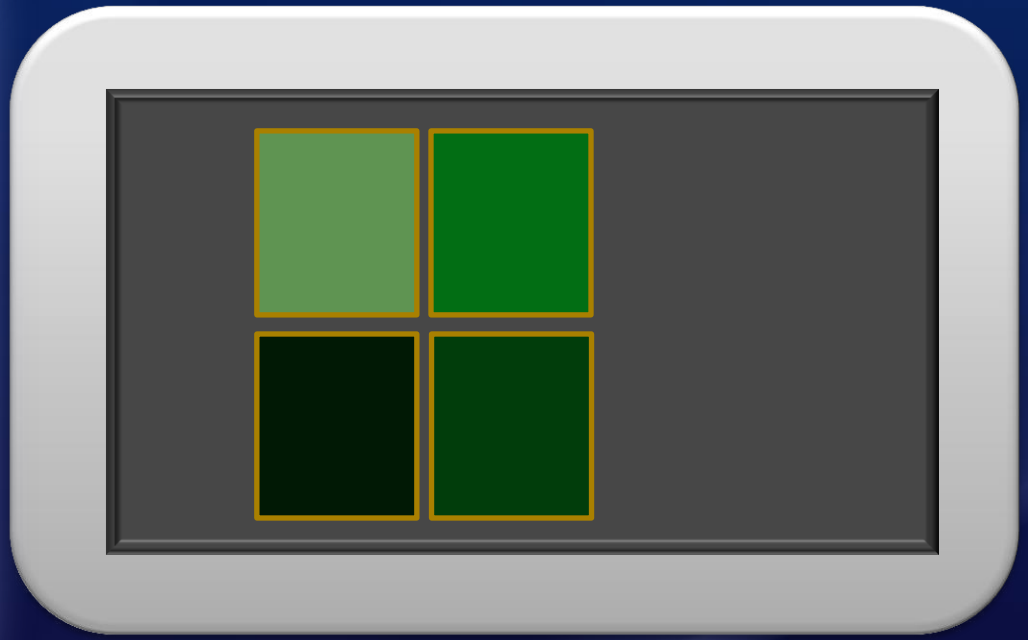

MAYO CLINIC

The Lateral Response Artifact (LRA)

- Don't put your films anywhere but the center of the scanner!
  - Line them up in a single column
- Do assess the magnitude of the LRA for your applications and determine if you need to correct for it
  - Scan different doses at lateral positions and measure the effect

LRA Summary

- The magnitude depends on the type of film, the dose, the scanner used, single vs. triple channel dosimetry, how far from the scanner center you are…
  - 5 Gy, 10 cm from center, ~10% error with EBT3 single channel dosimetry

Technical Note: Initial characterization of the new EBT-XD Gafchromic film

Michael P. Grams, Jon M. Gustafson, Kenneth M. Long, and Luis E. Fong de los Santos

Medical Physics **42**, 5782 (2015)

Conclusions: The LRA of EBT-XD is greatly reduced when compared to EBT3.

Technical Note: On GAFChromic EBT-XD film and the lateral response artifact

David F. Lewis and Maria F. Chan

Medical Physics **43**, 643 (2016)

We also conclude that for EBT-XD and EBT3 with equal exposure, the effect of LRA is markedly less for the former, making it preferred to EBT3 for doses >10 Gy.

Evaluation of Gafchromic EBT-XD film, with comparison to EBT3 film, and application in high dose radiotherapy verification

Phys. Med. Biol. **60** (2015) 8741–8752

Antony L Palmer[1,2], Alexis Dimitriadis[1,3,4], Andrew Nisbet[1,3] and Catharine H Clark[1,3,4]

In comparison to EBT3, EBT-XD gave improved evaluation results for the SRS-plan, had improved calibration curve gradients at high doses, and had reduced lateral scanner effect.

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LRA Summary

- Determine if it's a problem for your application
  - Small field SBRT/SRS likely won't be a problem (but XD film is still preferred!)
  - Larger field head and neck cases could be

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LRA Summary

- There are lots of publications out there which have devised methods to correct for the LRA

Correcting lateral response artifacts from flatbed scanners for radiochromic film dosimetry

David Lewis and Maria F. Chan

Medical Physics **42**, 416 (2015)

- Most of my measurements involve relatively small fields, and the larger ones are low dose (~2-3 Gy) so we don't correct for it (but you MUST be aware of it!)
- A simple solution is to just scan the film twice and shift each side of the film to the center

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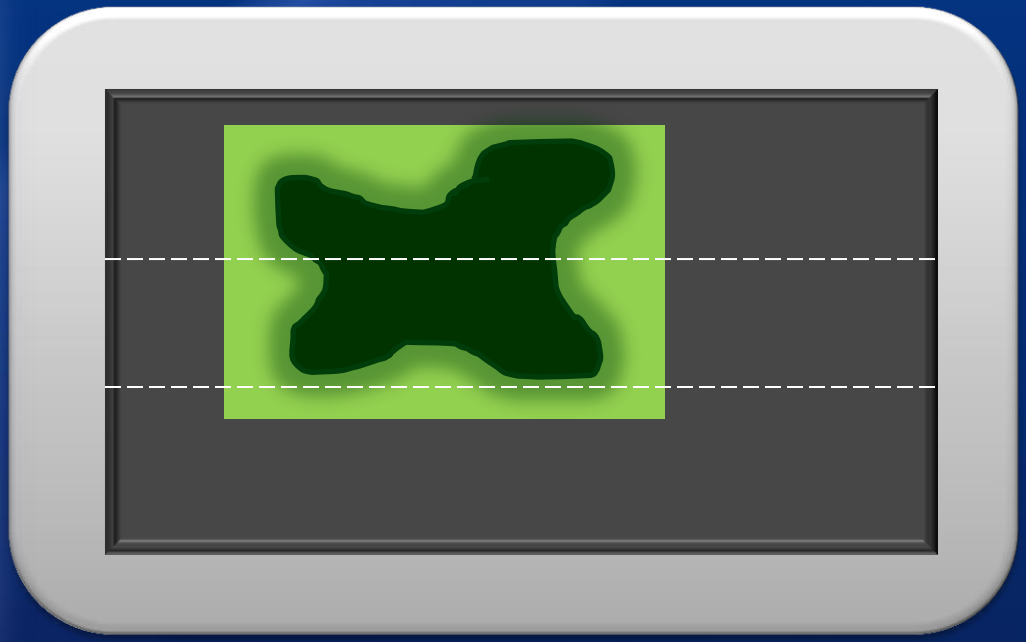
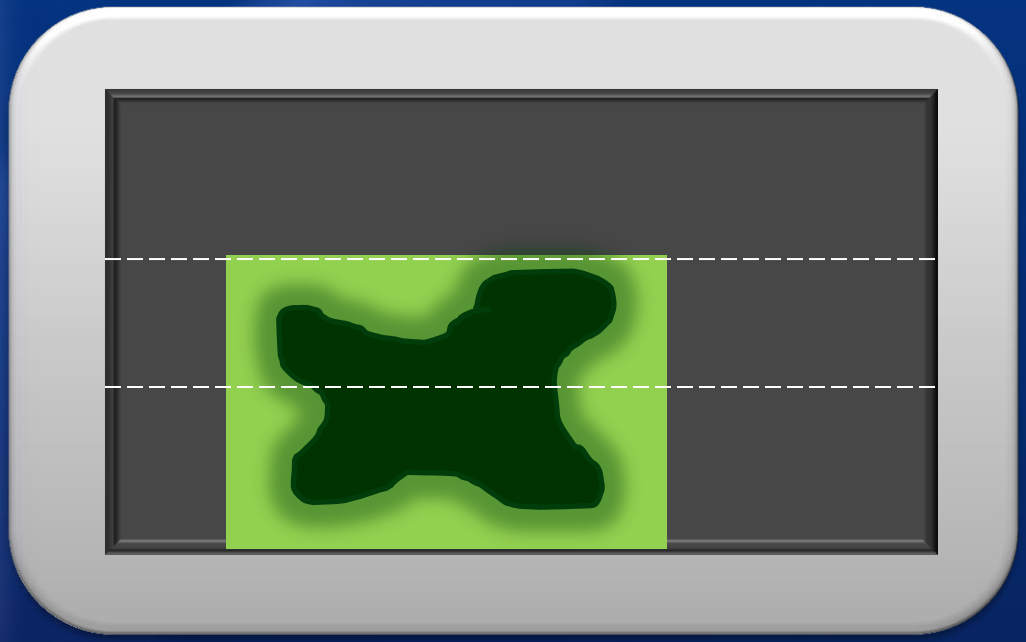


If you feel the LRA might be a problem, you can always scan the film twice: Once each with each half of the dose distribution centered within the scanner’s “sweet spot”

MAYO CLINIC



If you feel the LRA might be a problem, you can always scan the film twice: Once each with each half of the dose distribution centered within the scanner’s “sweet spot”

MAYO CLINIC

IMRT QA

- Our primary reason for wanting film in our clinic was for IMRT QA
- We were frustrated by some of the drawbacks of the MatriXX ion chamber array
  - Needs an angular correction
  - Have to warm up electronics
  - Can’t hit the electronics with radiation
  - ***Poor spatial resolution***

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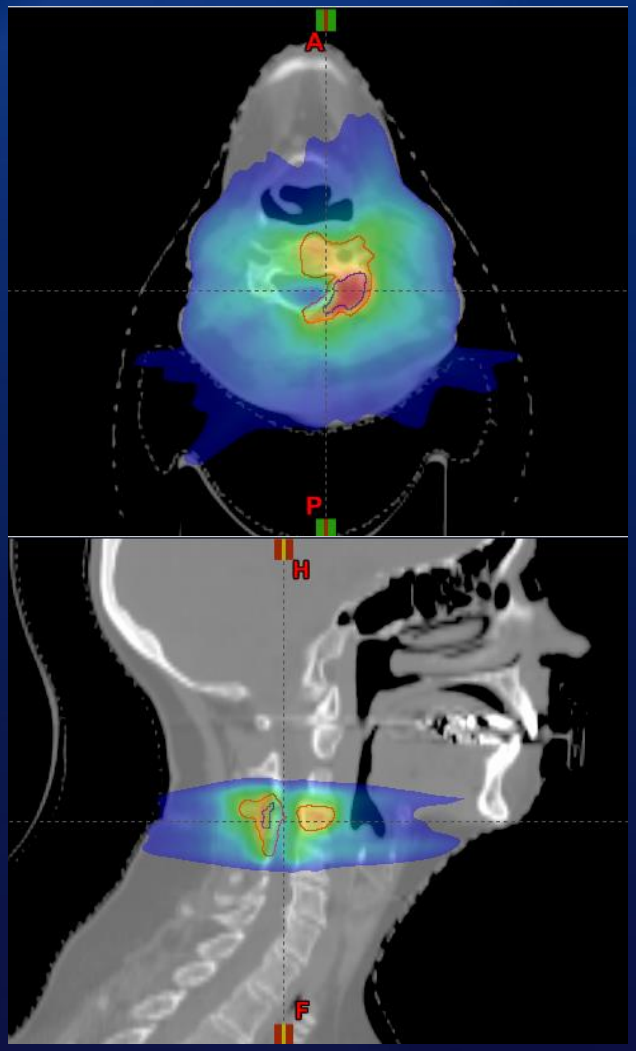
Clinical Example – Spine SBRT



C-Spine SBRT
24 Gy in 1 fx

PTV measures
2 cm x 1 cm x 1 cm

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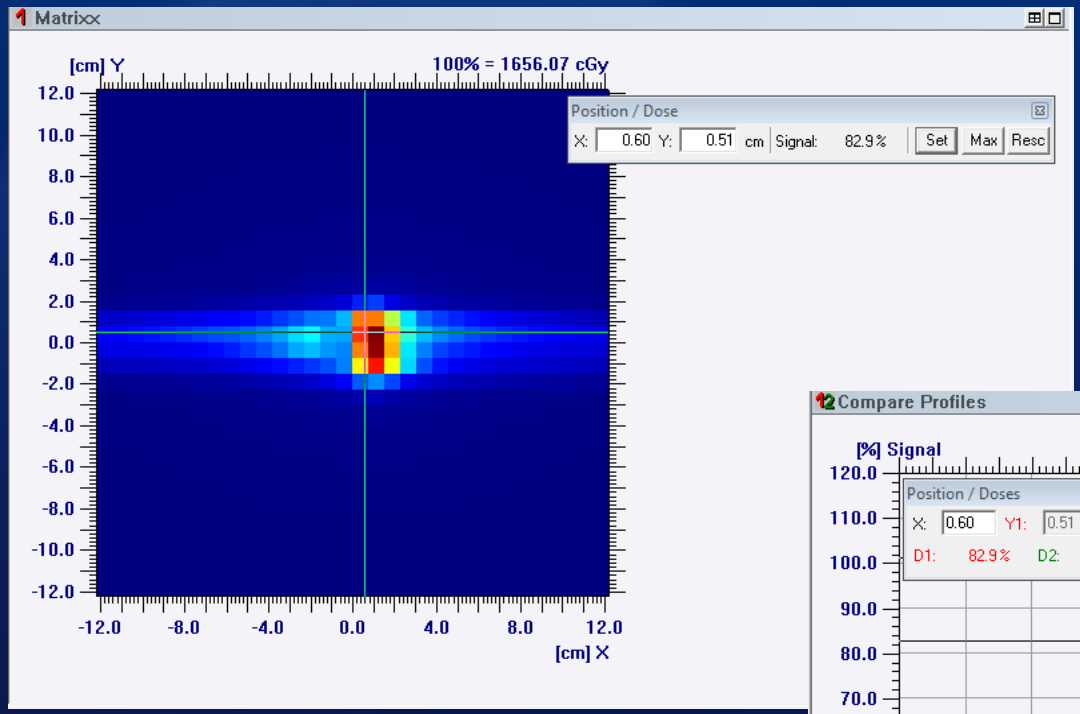
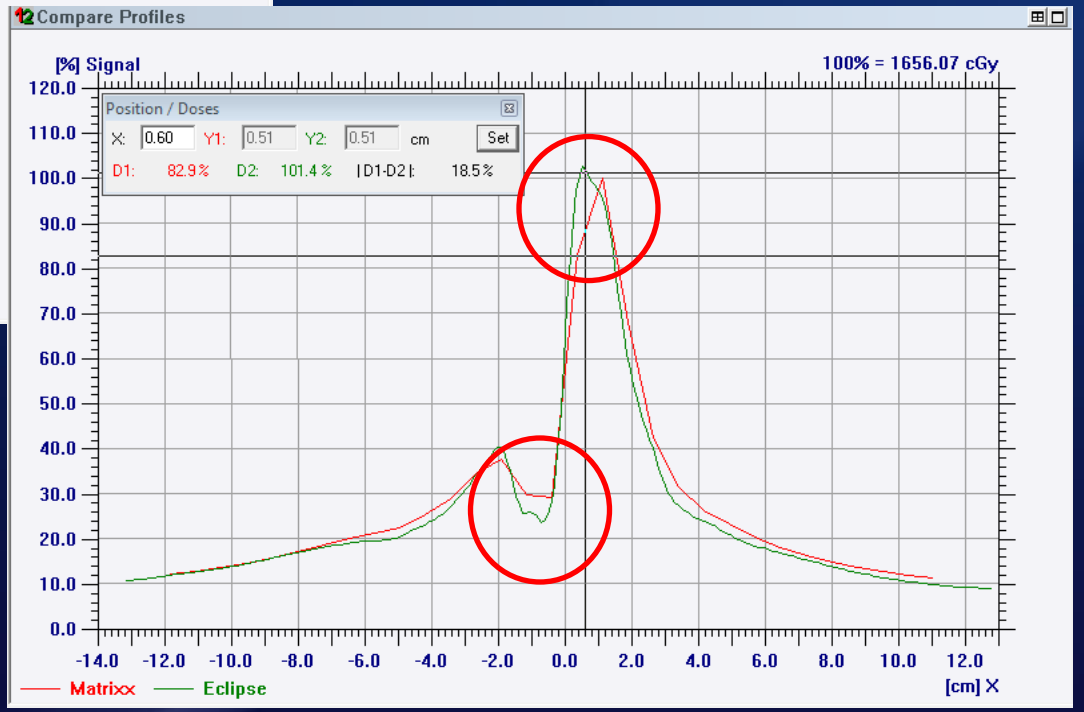
Clinical Example – Spine SBRT





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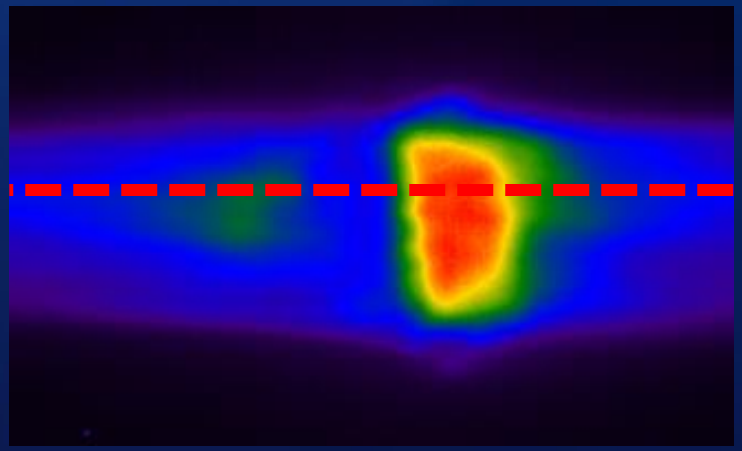
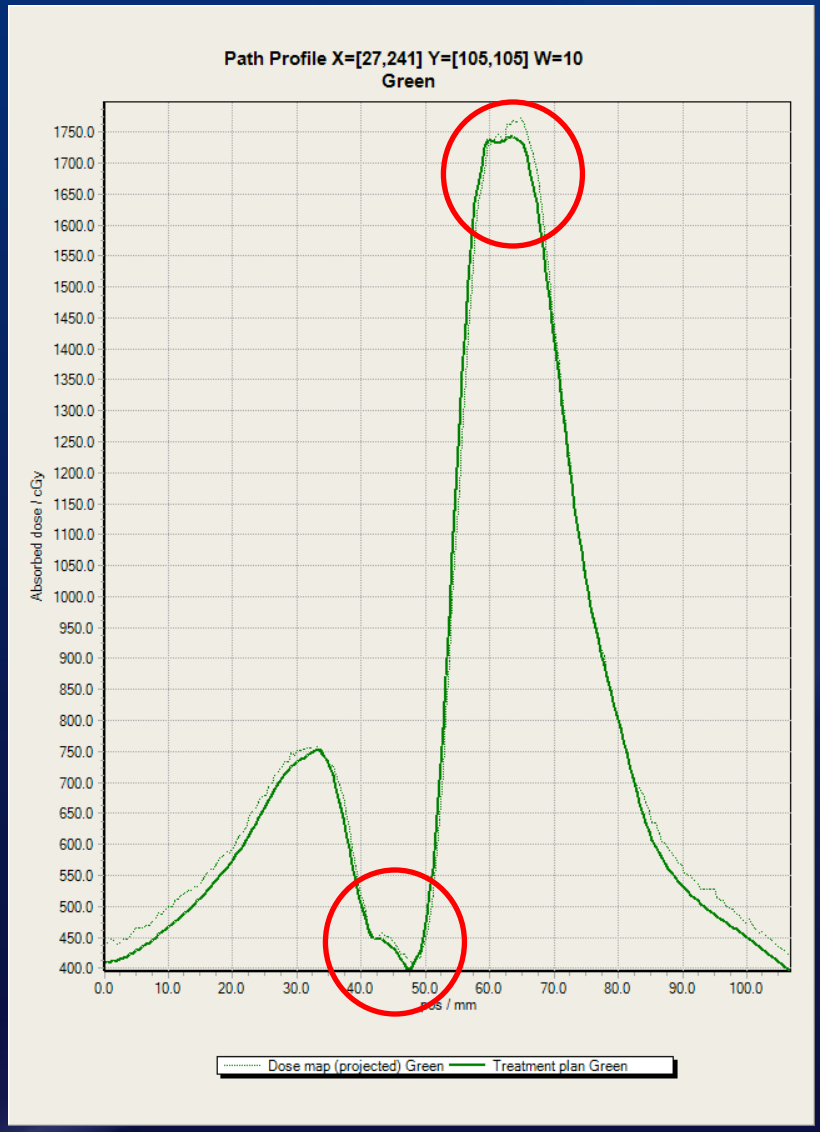
Clinical Example – Spine SBRT





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IMRT QA

- In our clinic we use film for IMRT QA measurements of
  - Any plan where the target is <2 cm in any direction
  - All spine SBRT plans
  - All SRS/SRT plans
  - Plans with couch kicks
  - Any plan where the physicist wants to use film, or wants a 2nd measurement to complement the MatriXX

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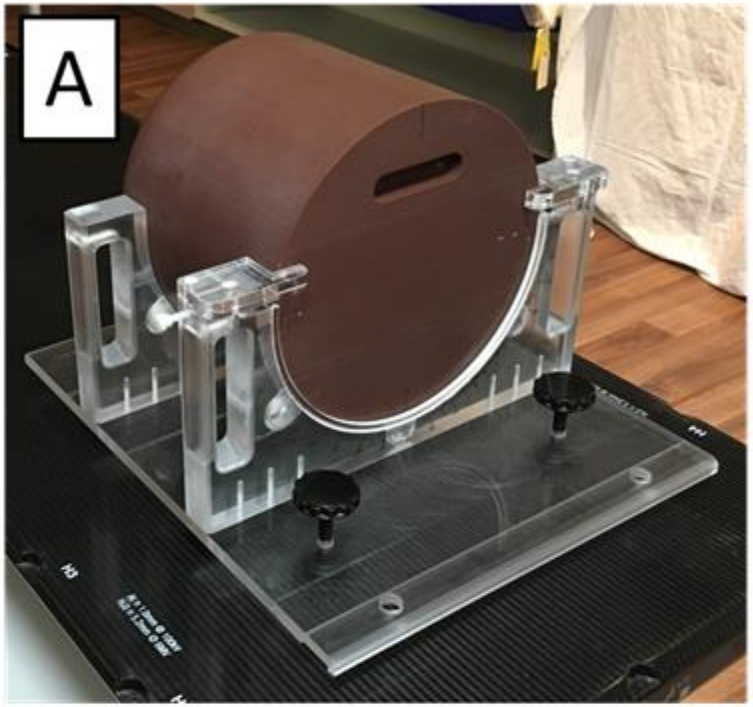
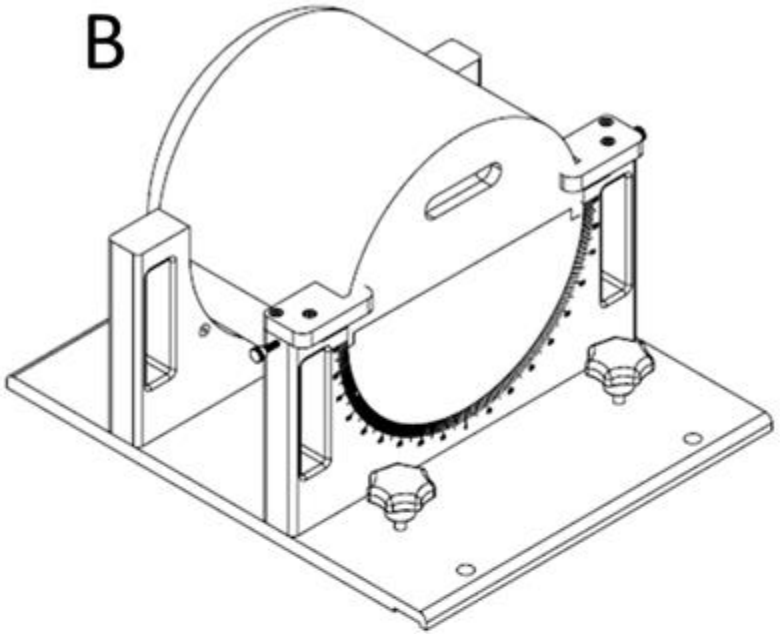
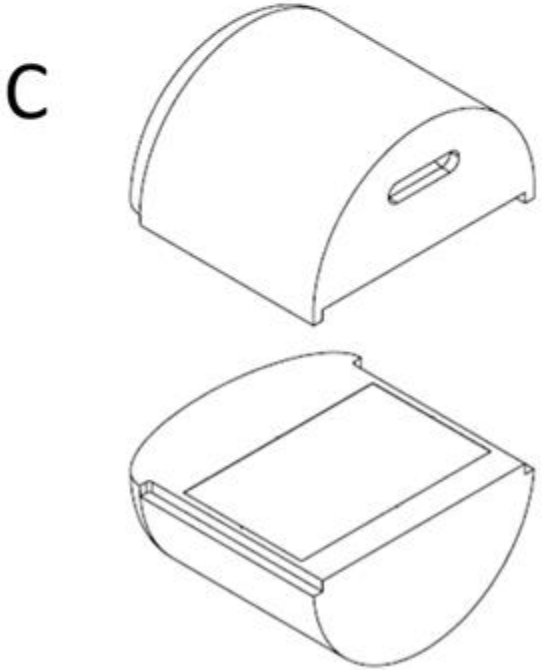
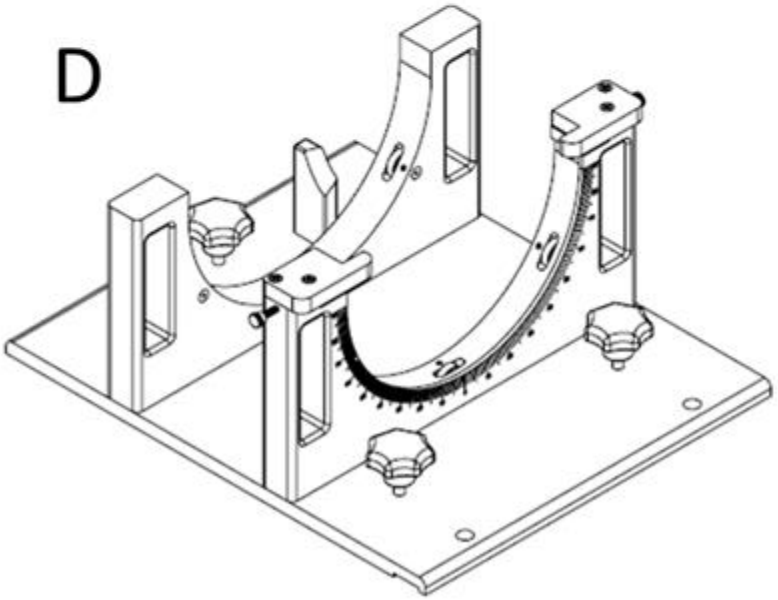
IMRT QA – Our Process

- We have developed an in-house phantom called the “Fong Phantom” for most of our film measurements
  - Cylindrical
  - Rotates 360°
  - Accomodates a half sheet of film

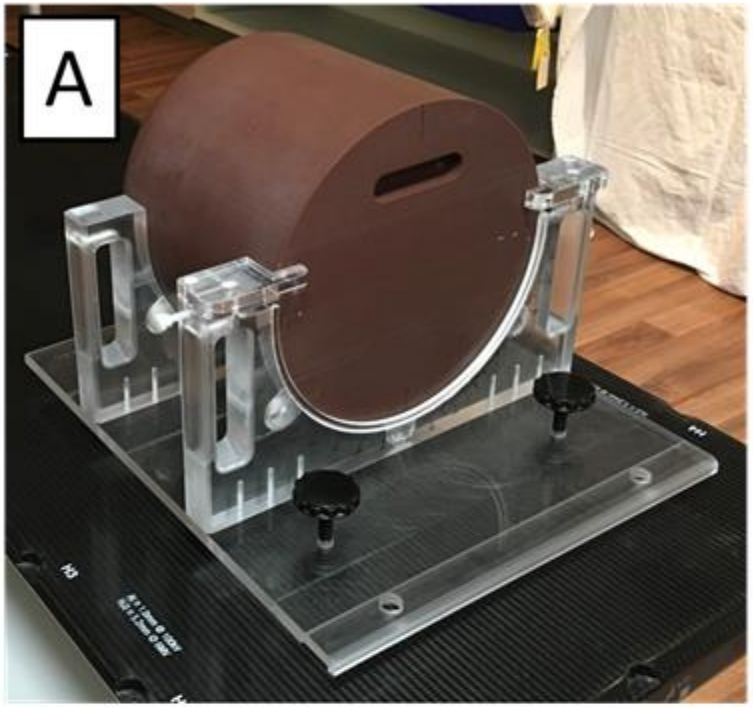


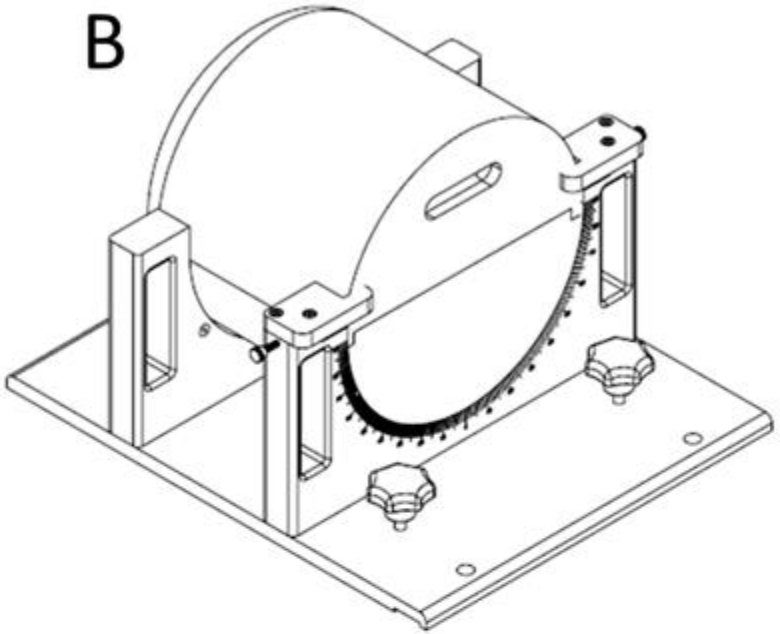


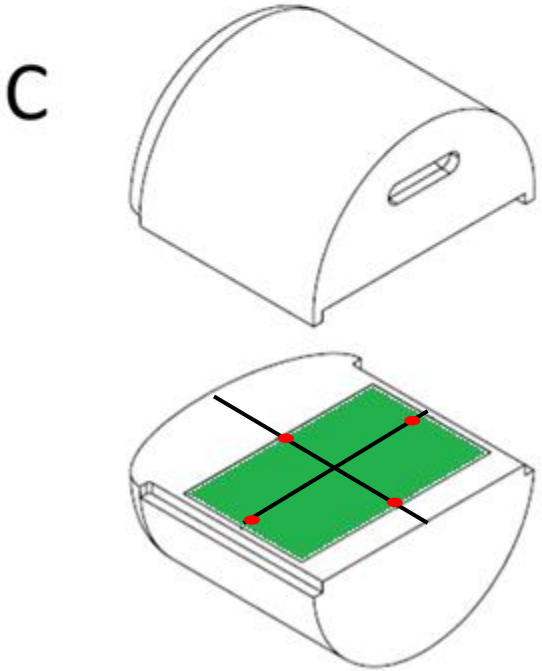


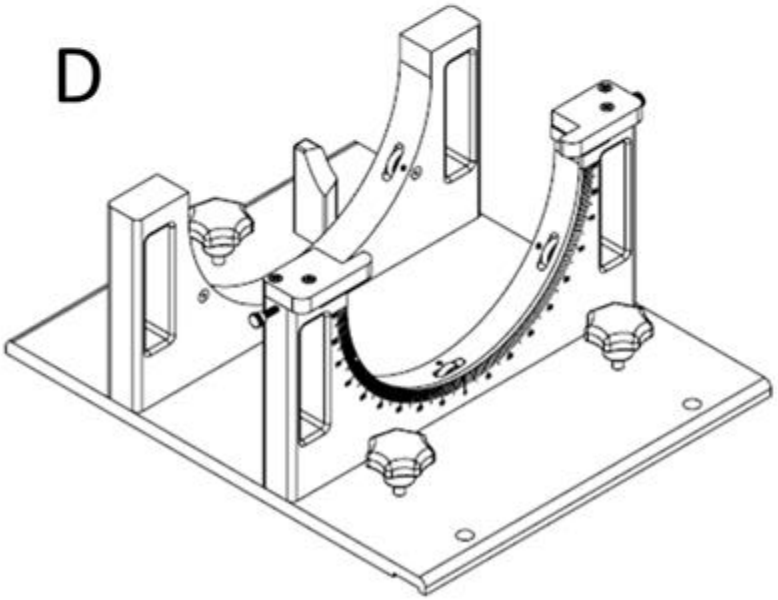


MAYO CLINIC









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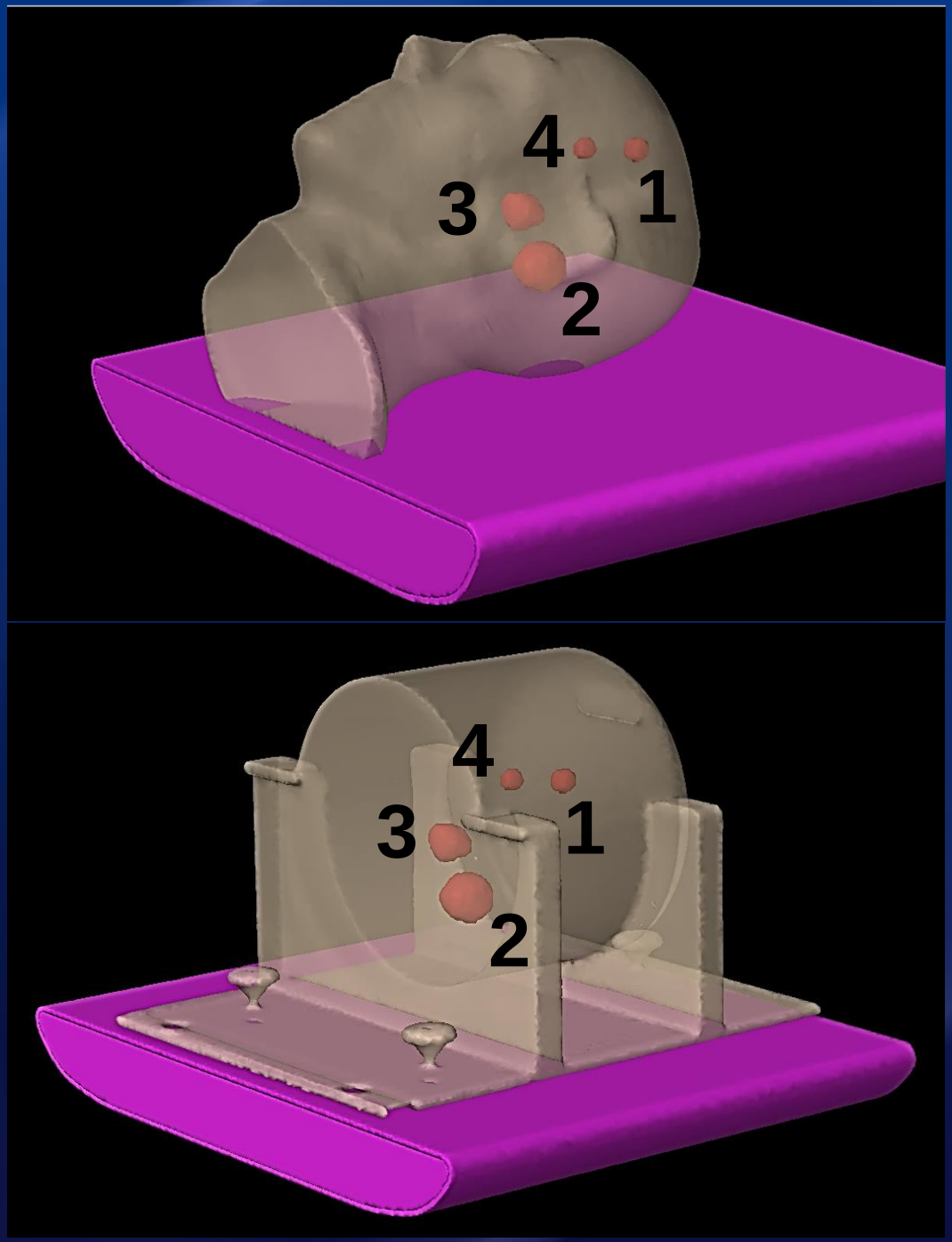
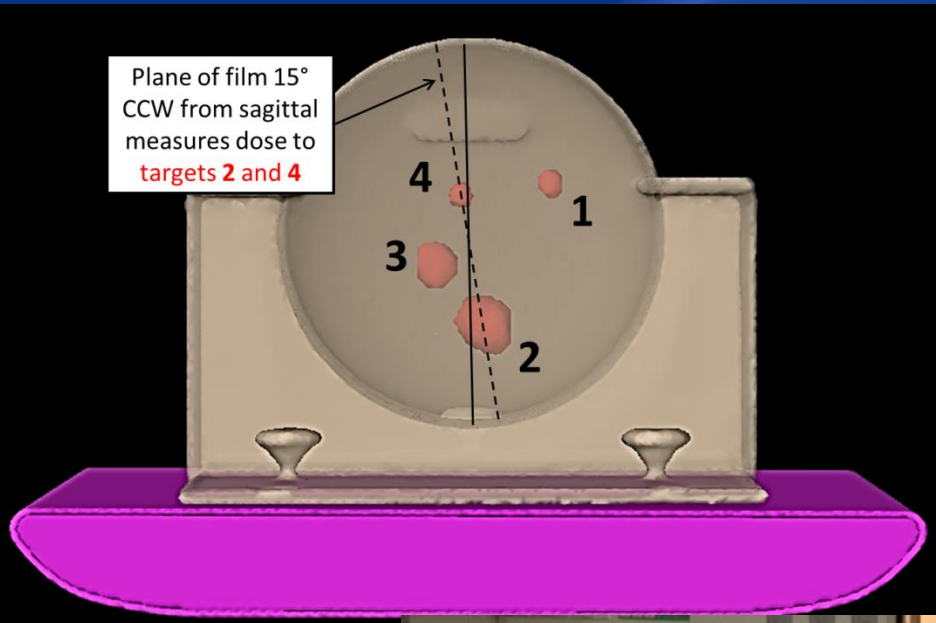
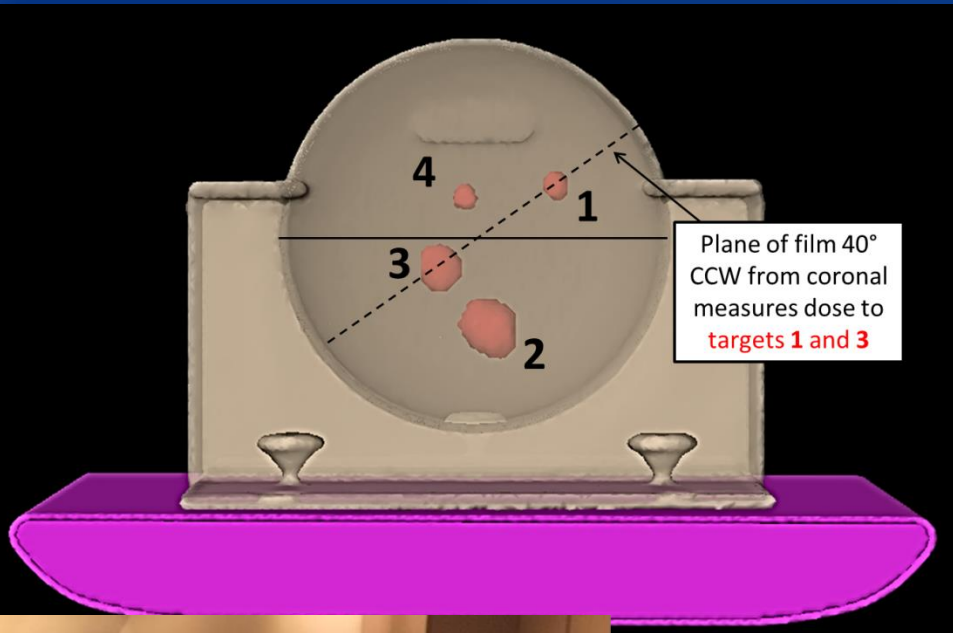
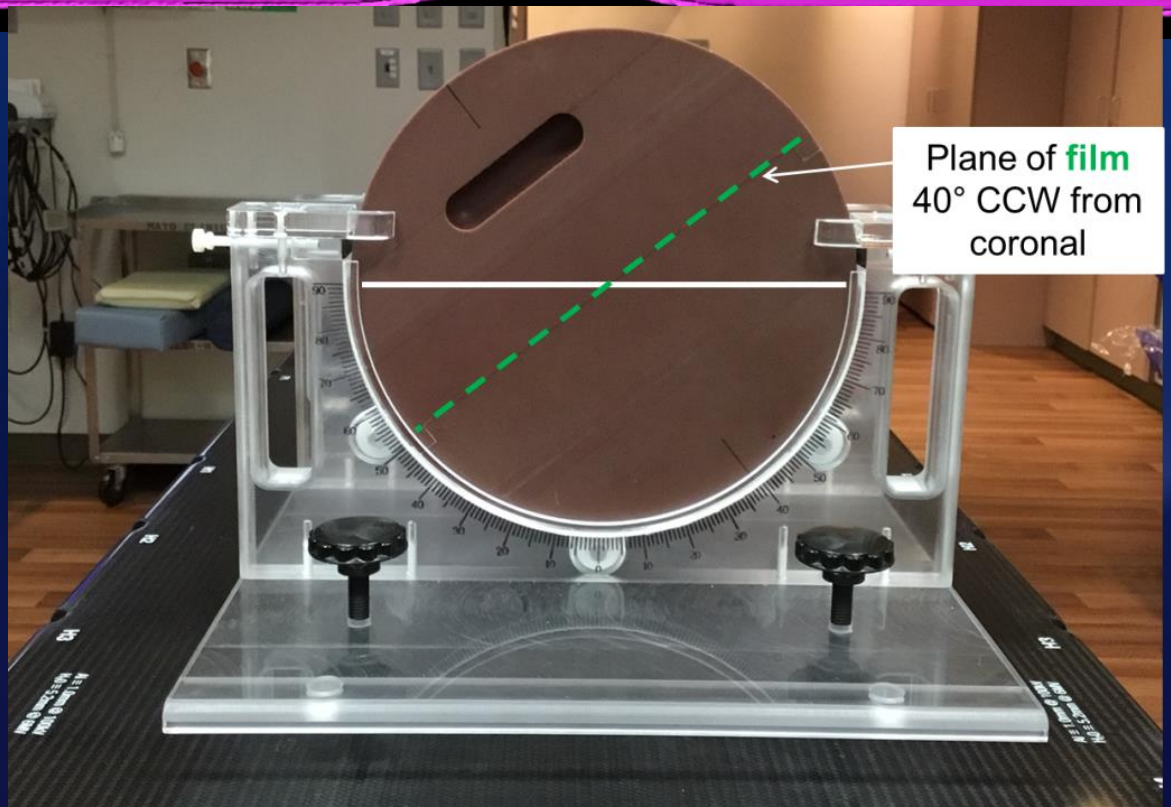


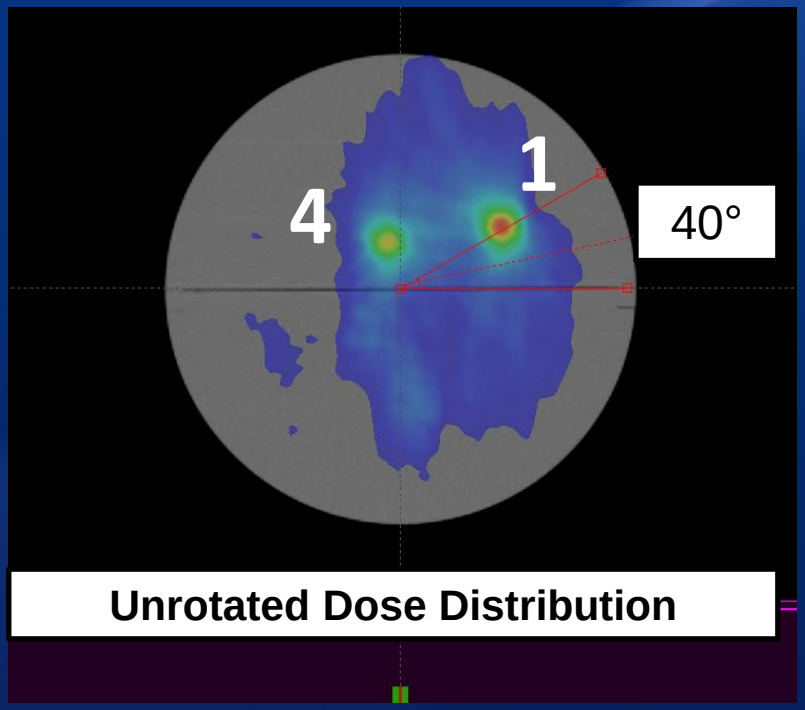
MAYO CLINIC


Plane of film 15° CCW from sagittal measures dose to targets 2 and 4
4
1
3
2

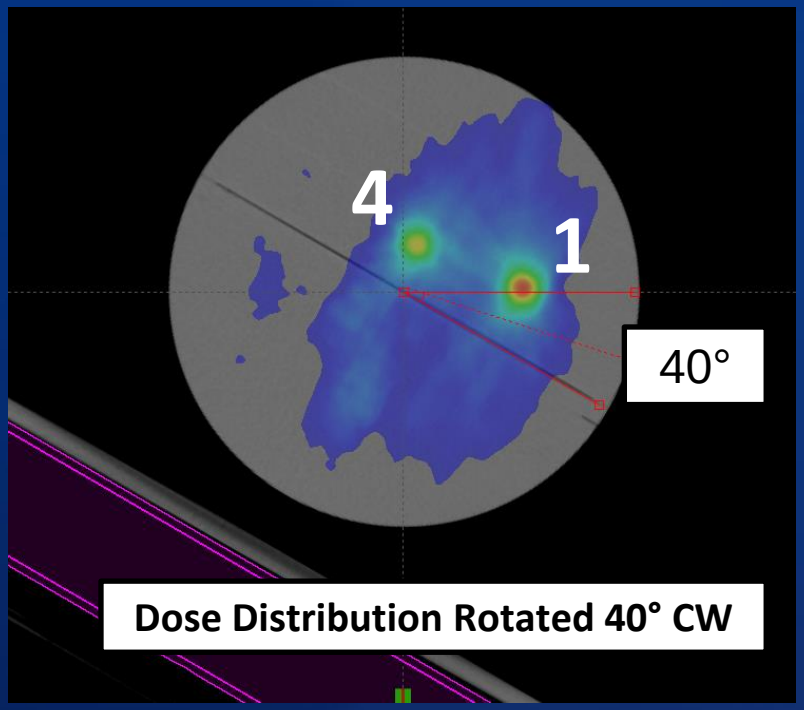

4
1
3
2
Plane of film 40° CCW from coronal measures dose to targets 1 and 3


Plane of film 40° CCW from coronal

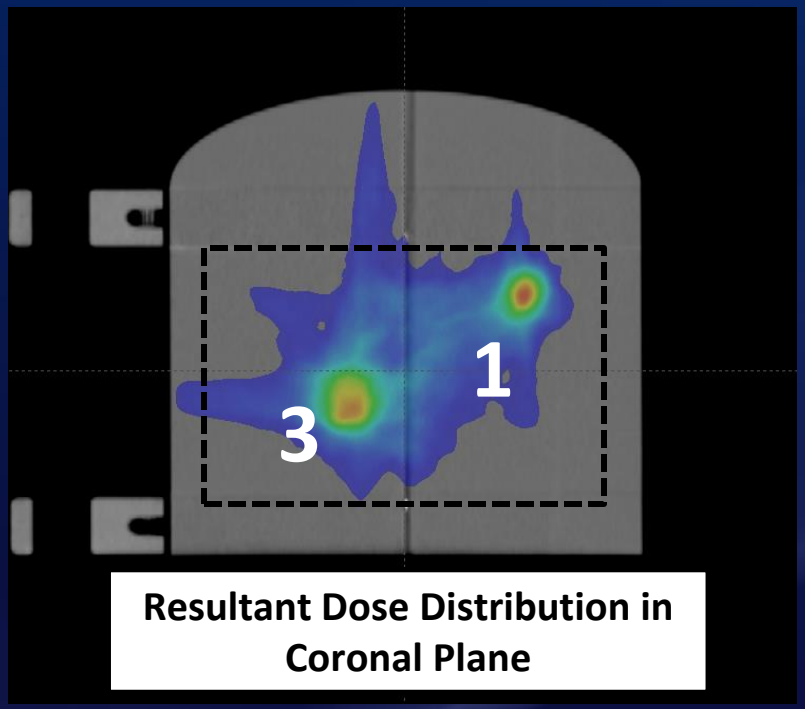
MAYO CLINIC



Unrotated Dose Distribution



Dose Distribution Rotated 40° CW



Resultant Dose Distribution in Coronal Plane

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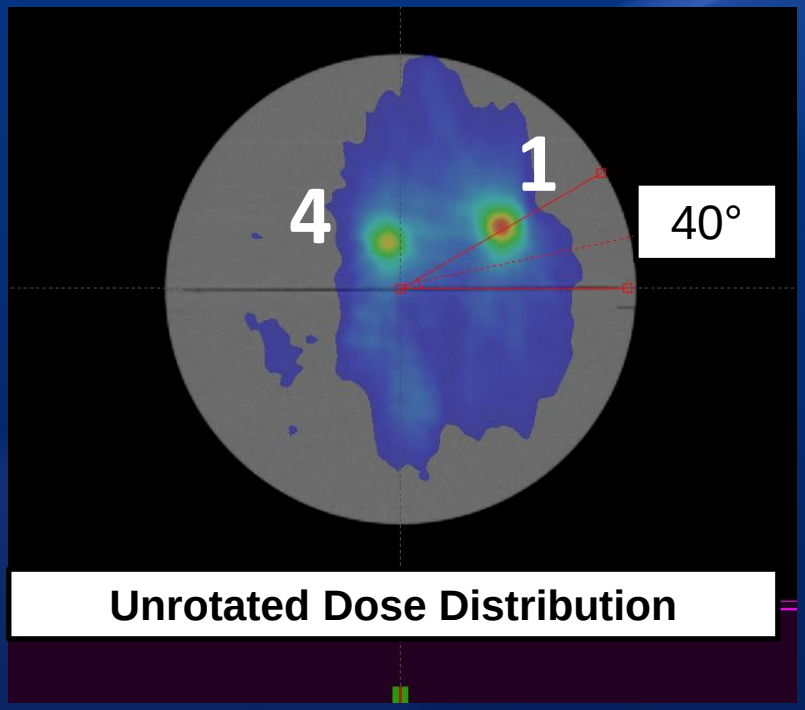
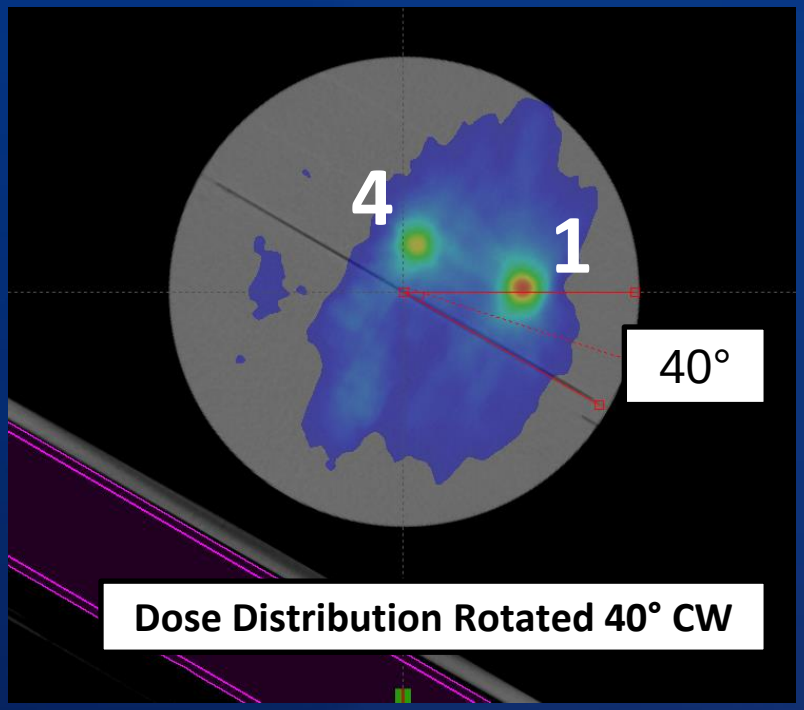
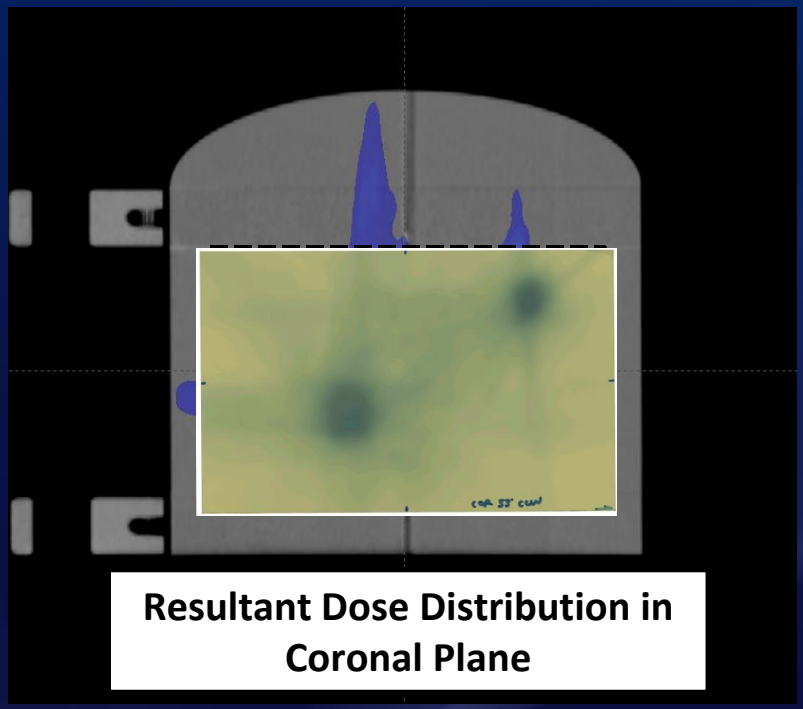


Unrotated Dose Distribution



Dose Distribution Rotated 40° CW



Resultant Dose Distribution in Coronal Plane

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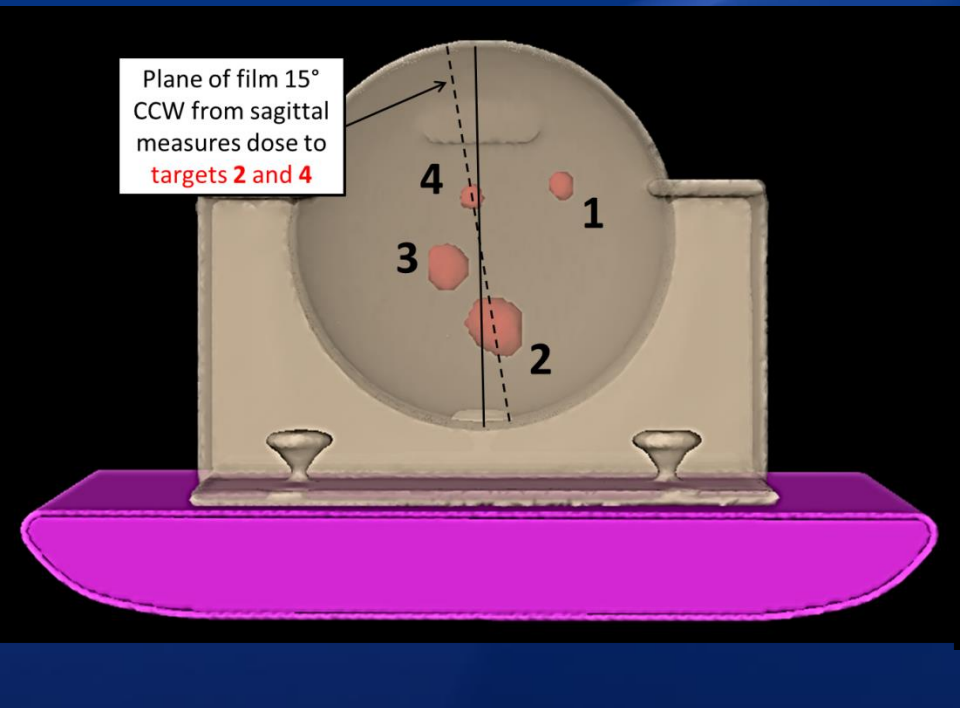
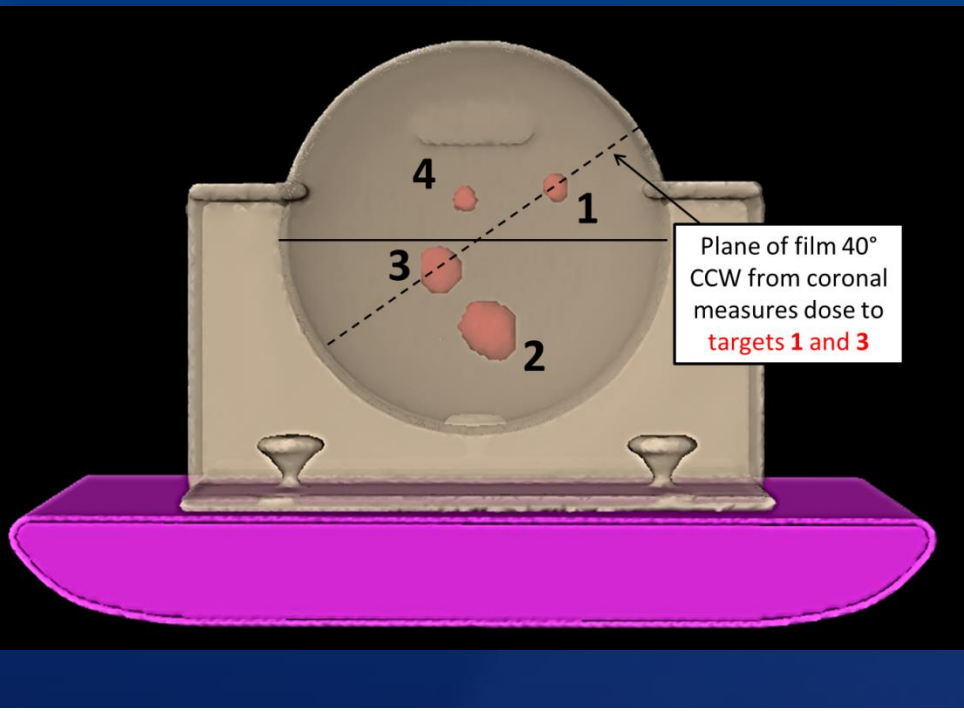
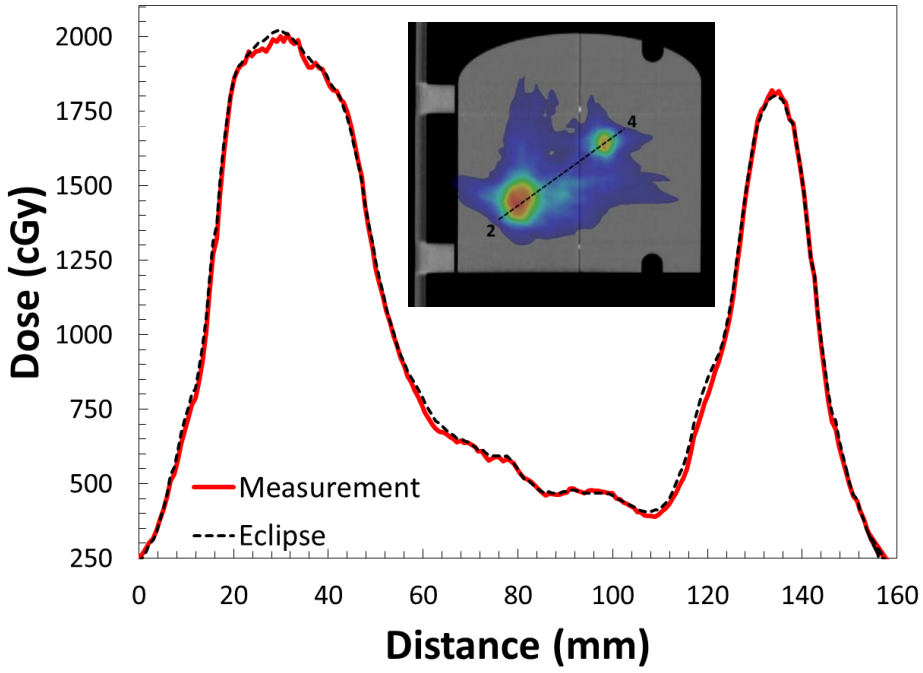
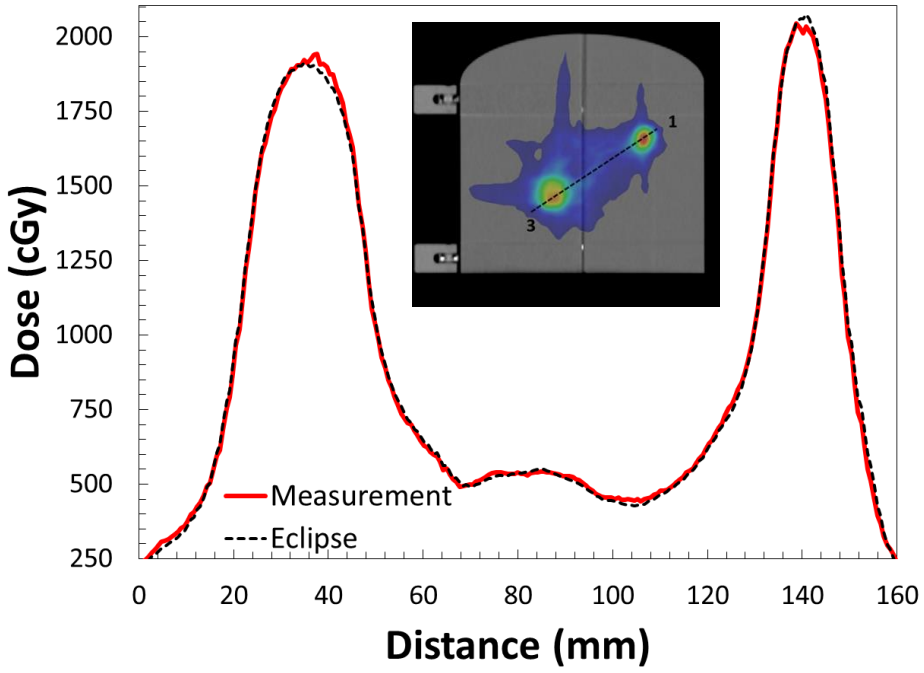
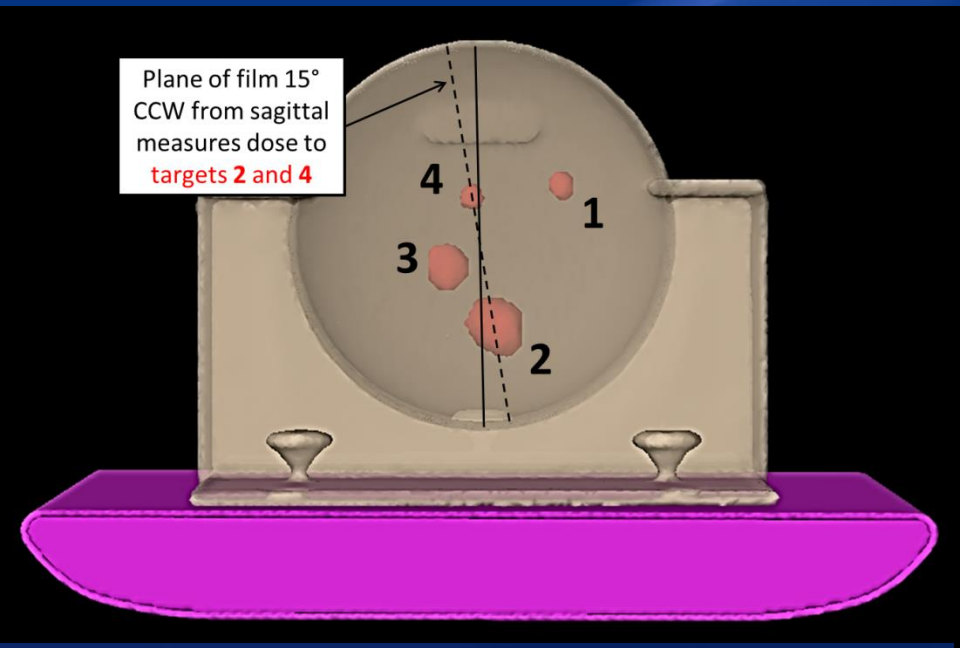
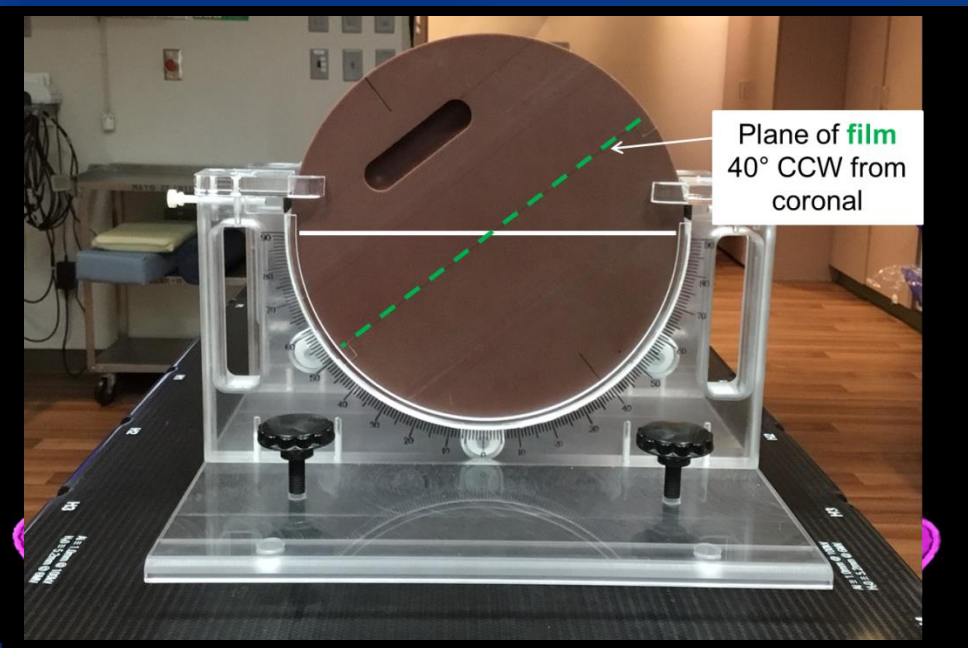

Plane of film 15° CCW from sagittal measures dose to targets 2 and 4
4
1
3
2

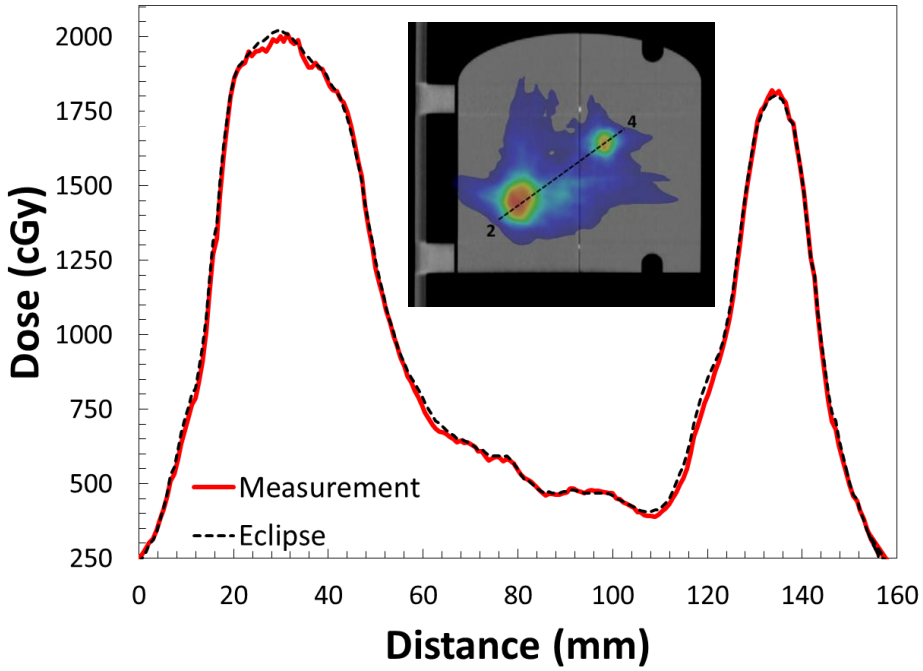

4
1
3
2
Plane of film 40° CCW from coronal measures dose to targets 1 and 3

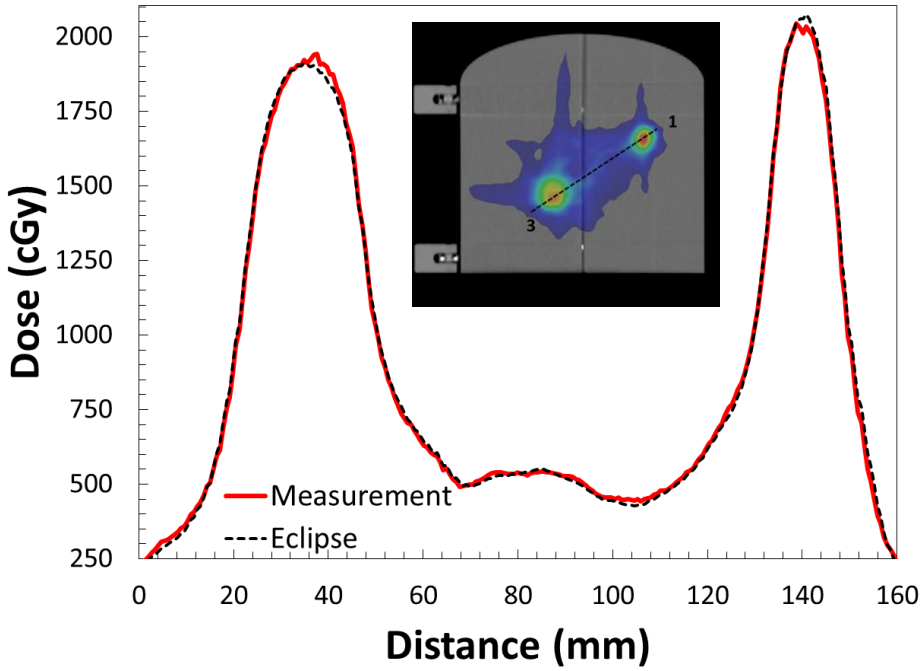

Dose (cGy)
2000
1750
1500
1250
1000
750
500
250
0
20
40
60
80
100
120
140
160
Distance (mm)
Measurement
Eclipse
4
2


Dose (cGy)
2000
1750
1500
1250
1000
750
500
250
0
20
40
60
80
100
120
140
160
Distance (mm)
Measurement
Eclipse
1
3


Plane of film 15° CCW from sagittal measures dose to targets 2 and 4
4
1
3
2

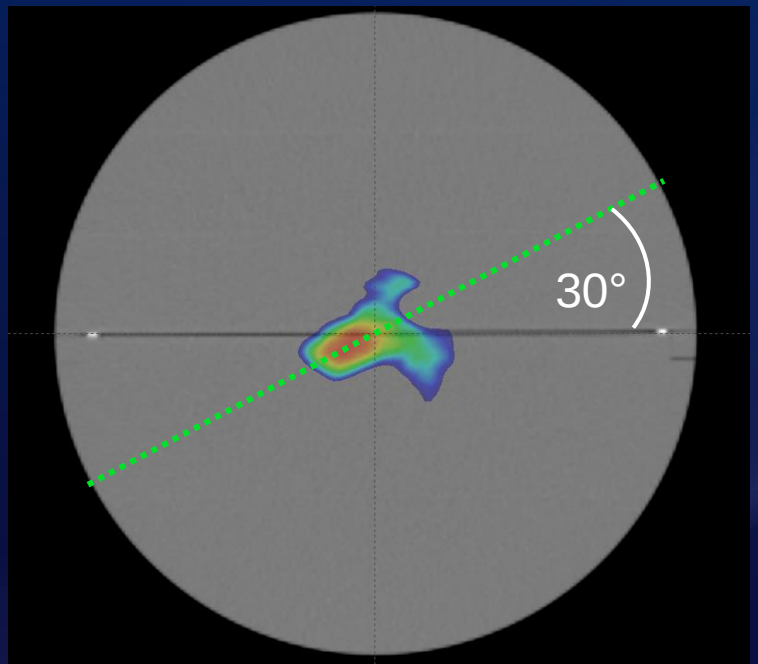

Plane of film 40° CCW from coronal


Dose (cGy)
2000
1750
1500
1250
1000
750
500
250
0
20
40
60
80
100
120
140
160
Distance (mm)
Measurement
Eclipse
4
2


Dose (cGy)
2000
1750
1500
1250
1000
750
500
250
0
20
40
60
80
100
120
140
160
Distance (mm)
Measurement
Eclipse
1
3

Spine SBRT – high dose with very steep gradients

Film is ideal because of its high spatial resolution



Want to measure in this rotated plane in order to catch the high dose PTV, low dose PTV, and the cord all in one measurement

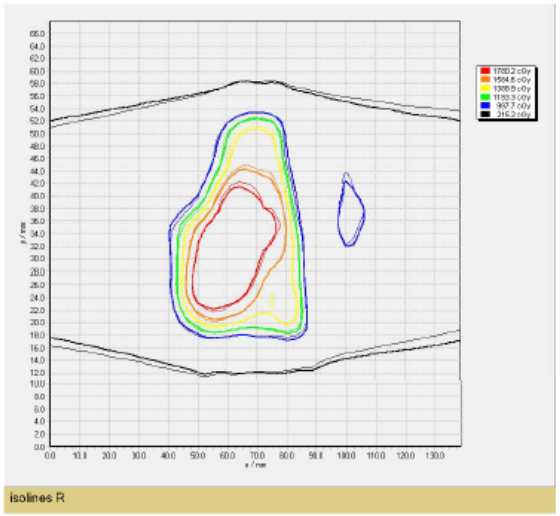
MAYO CLINIC

IMRT QA Report

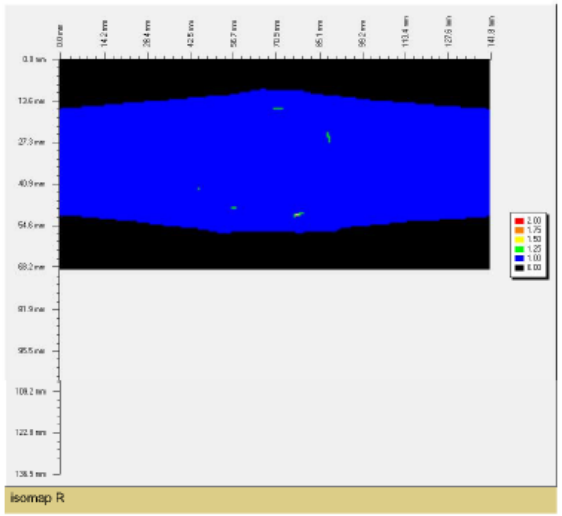
MAYO CLINIC

Patient	[redacted]
Id	[redacted]
Site	none
Facility	N/A
Plan	T7
Physicist	Grams, Michael Ph.D.

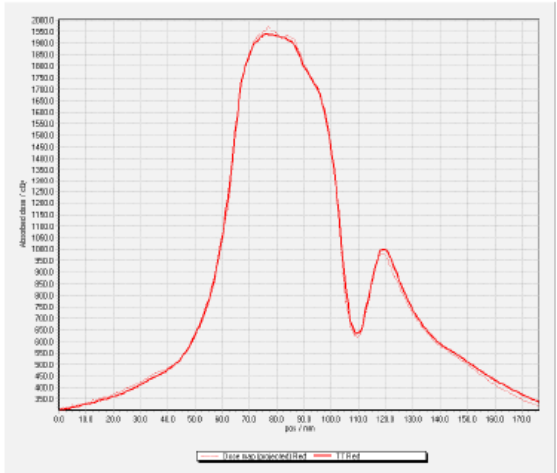
Charts 'Gamma' map



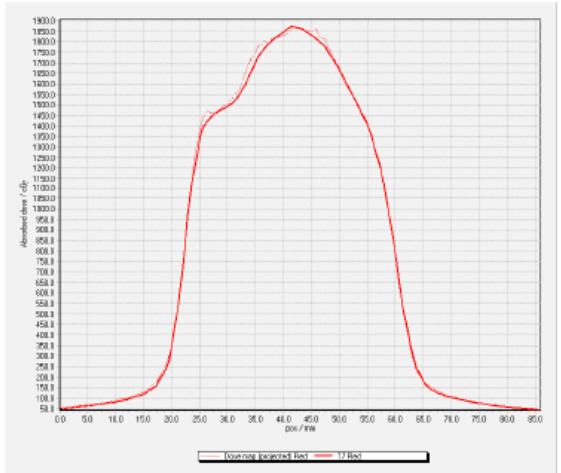
isolines R



isomap R

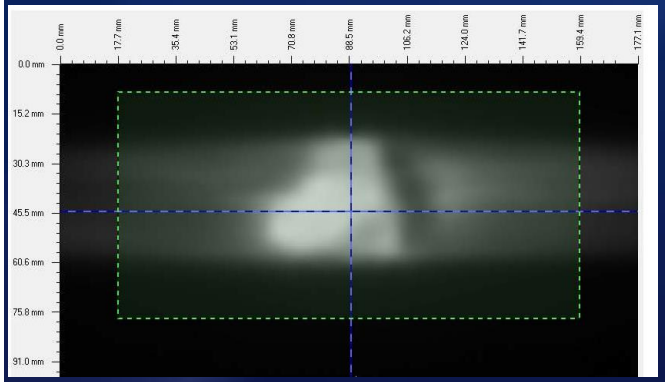


horizontal profile R



vertical profile R

	Gamma	Differential Delta	Distance to agreement
Criterion	2.0 %, 2.0 mm	|2.0 %|	2.0 %, 2.0 mm
Passing rate R	99.9 %	81.9 %	100.0 %
Failing rates R	-0.1,+0.1 %	-10.2,+7.9 %	-0.0,+0.0 %
Mean R	34.9 %	1.1 %	0.2 %
Std dev R	18.4 %	1.1 %	0.9 %



The One Scan Protocol

- FilmQA Pro has a really nice feature called the “one scan protocol” which speeds up the film process and also makes it more accurate
- We would never have been able to adopt film in our clinic without it
- You scan a reference strip, an unexposed piece of film, and the measurement film all at the same time
- Scanning all at the same time removes scan to scan variability

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The One Scan Protocol

- At some point either before or after your measurement, a 2nd film must be exposed to a known dose ~80-90% of the maximum dose you expect to measure
- If a time Δt elapses between exposure of the measurement film and the reference strip, you need to wait 4Δt before scanning and analyzing.

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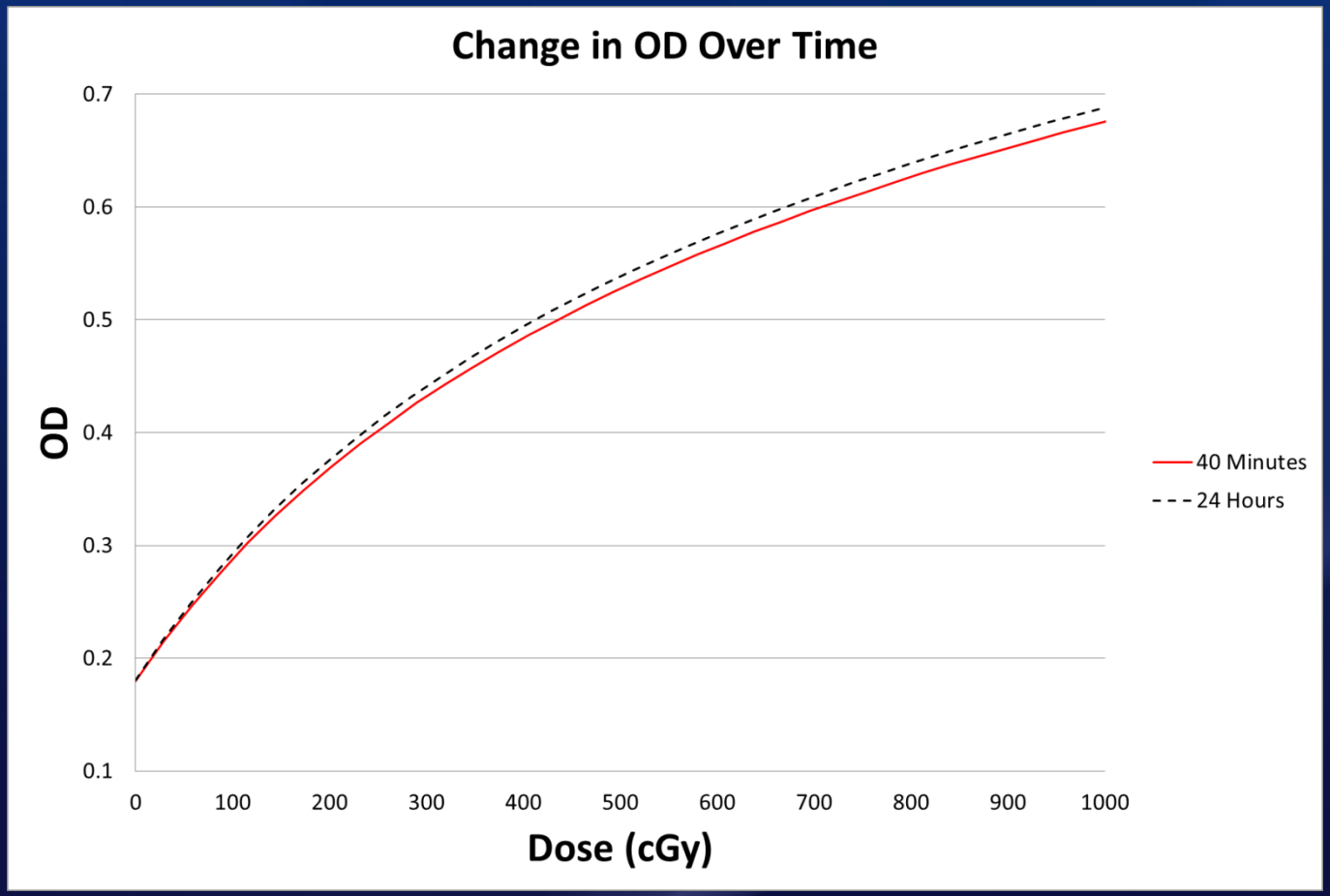
Why do you need the reference strip?

- The purpose of the reference strip is to “re-scale” the calibration curve and speed up the analysis process



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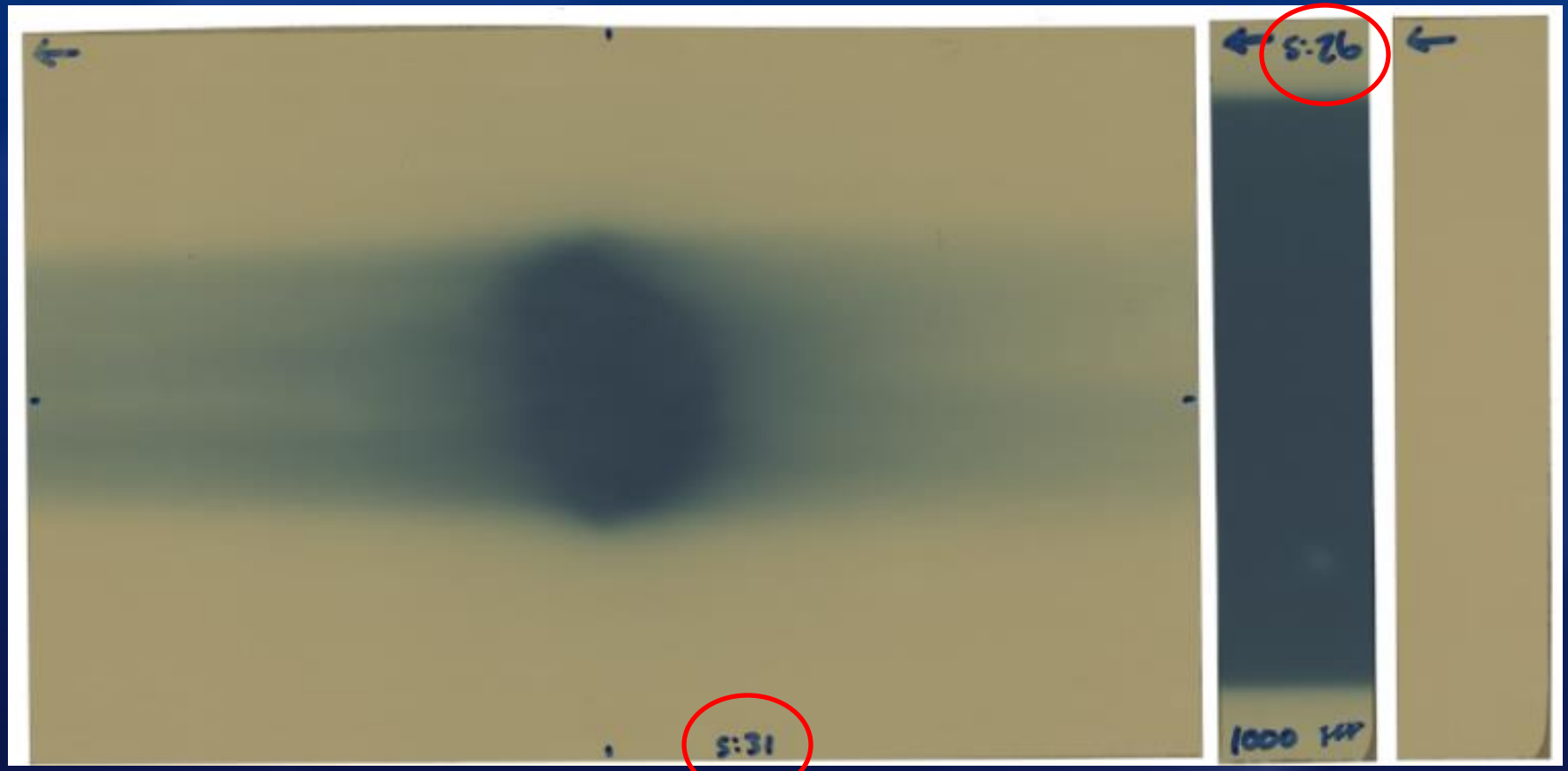
1000 cGy Reference exposed at 5:26 pm



Patient specific QA film exposed at 5:31 pm

Unexposed Film

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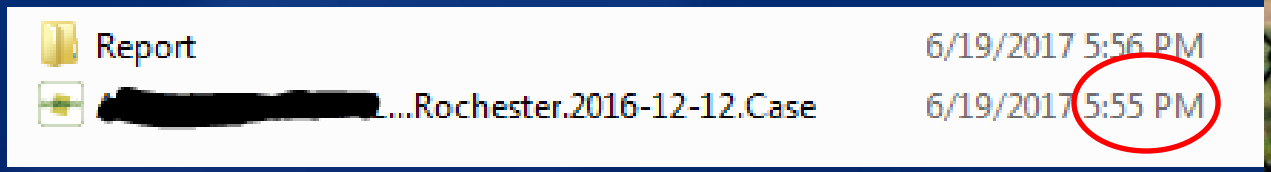
4Δt = 20 minutes, should wait until at least 5:51 pm to scan…



An efficient protocol for radiochromic film dosimetry combining calibration and measurement in a single scan

David Lewis, Andre Micke, and Xiang Yu
Advanced Materials Group, Ashland Inc., 1361 Alps Road, Wayne, New Jersey 07470

Maria F. Chan[a)]
Department of Medical Physics, Memorial Sloan-Kettering Cancer Center, 136 Mountain View Boulevard, Basking Ridge, New Jersey 07920

6339 Med. Phys. 39 (10), October 2012

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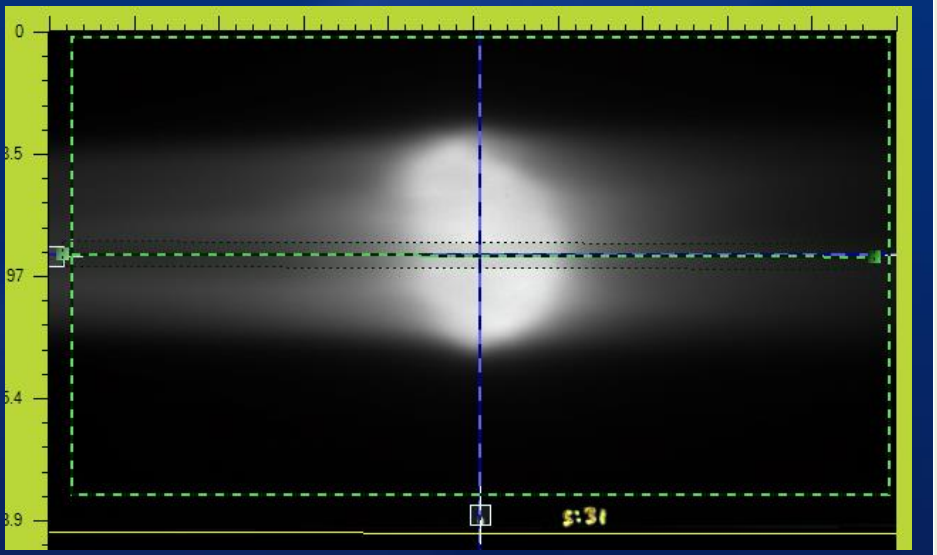
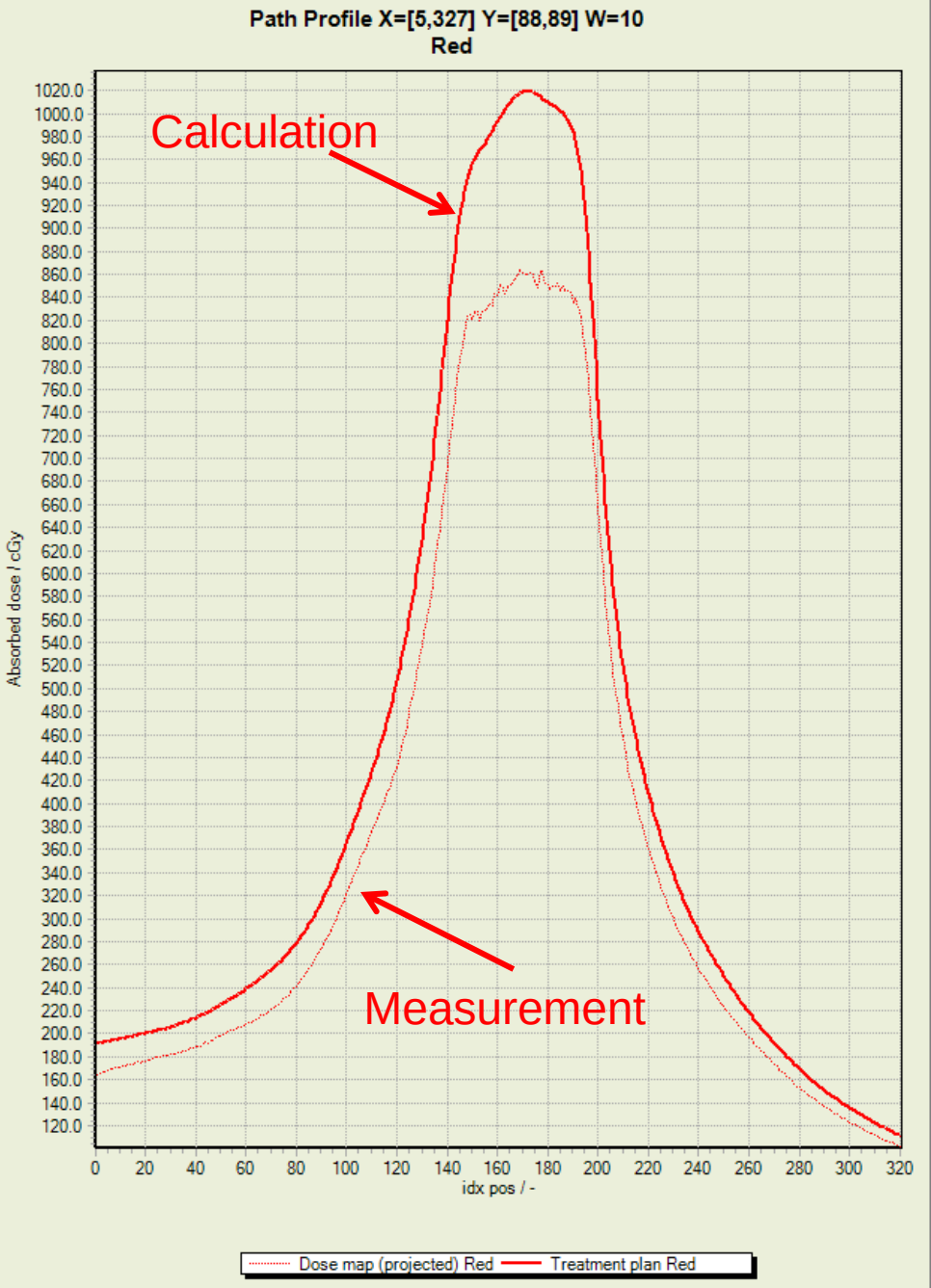
But does it work?



Scan 24 minutes after exposure
WITHOUT dose-rescaling

2%/2mm gamma = 57.06%



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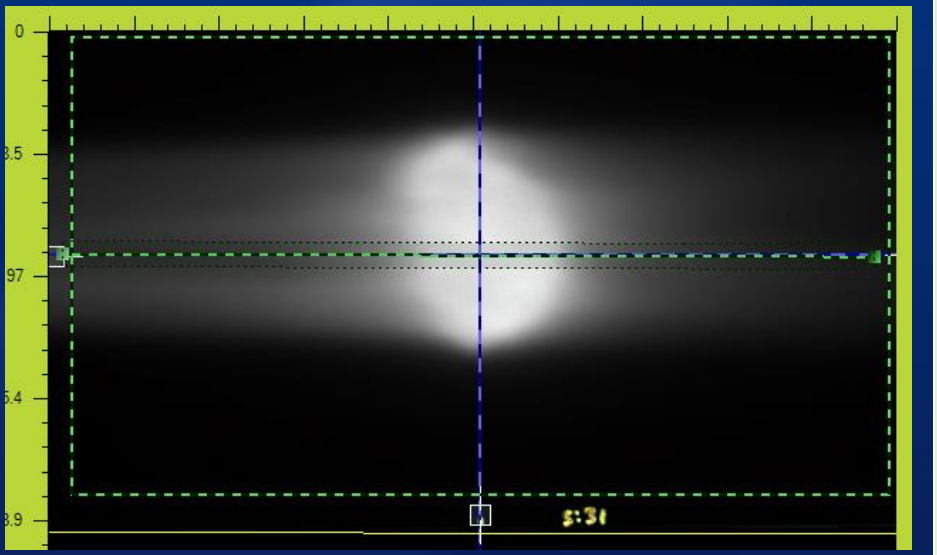
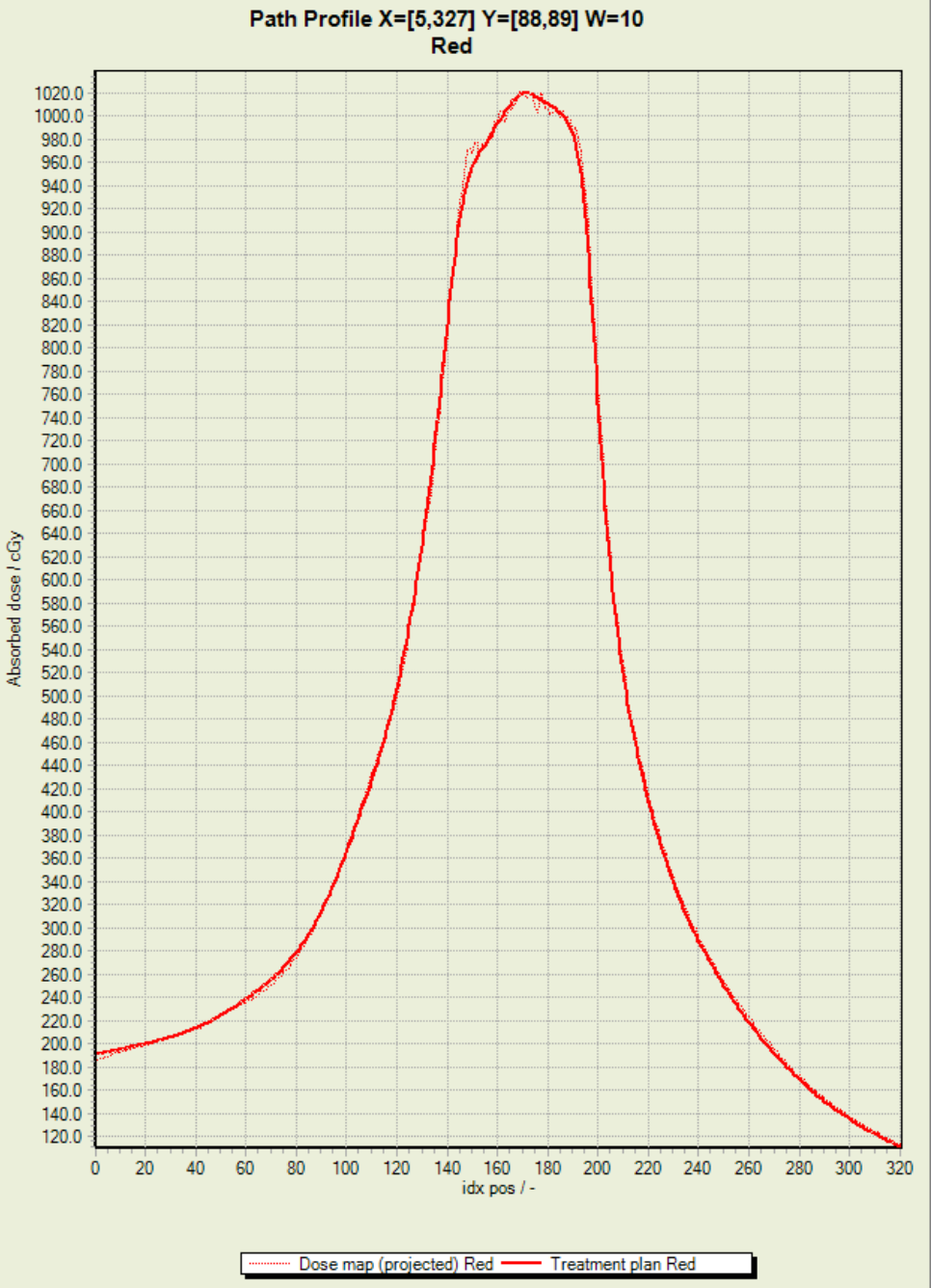
But does it work?



Scan 24 minutes after exposure
WITH dose-rescaling

2%/2mm gamma = 99.95%



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How well does the entire process work?

- In 2016, we made 276 IMRT QA measurements using the Fong phantom and FilmQA Pro software
- EBT3 used for doses <10 Gy, EBT-XD otherwise
- We use a 2% (global)/2 mm gamma criteria
  - Avg gamma = 99.3%
  - 72 of 276 measurements were rotated
    - Avg gamma = 99.4%

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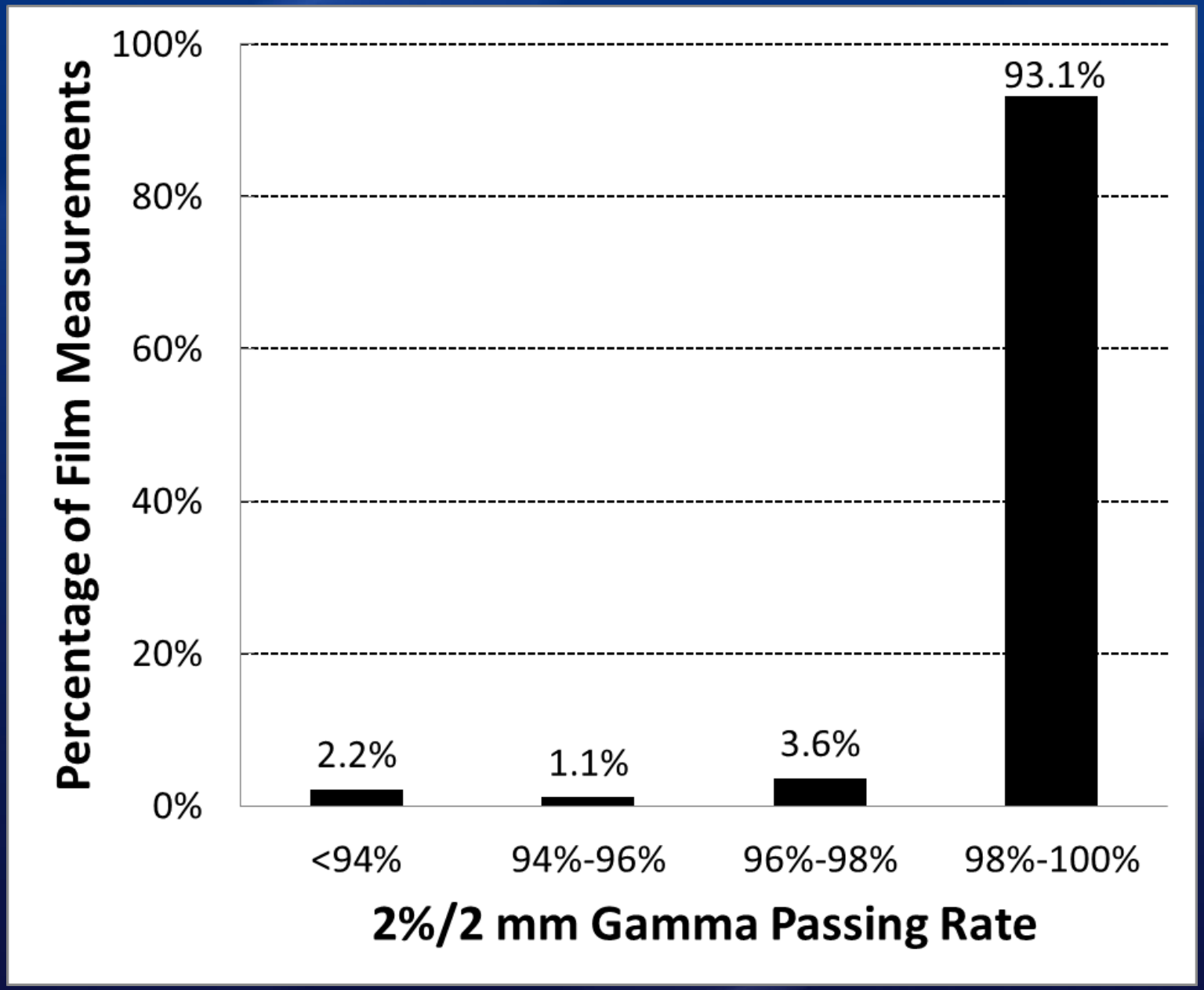
Percentage of Film Measurements
100%
80%
60%
40%
20%
0%
93.1%
2.2%
1.1%
3.6%
<94%
94%-96%
96%-98%
98%-100%
2%/2 mm Gamma Passing Rate

Summary

- Get a good calibration and ensure its accuracy over your intended dose range
  - Use simple fields to deliver known doses and check
  - If you don’t get good accuracy for the simplest cases, stop and figure out why
- Always keep the films flat on the scanner
  - Use a glass sheet to push them flat
- Always keep the films centered on the scanner
- Establish your working procedure and stick to it
  - No shortcuts or deviations!

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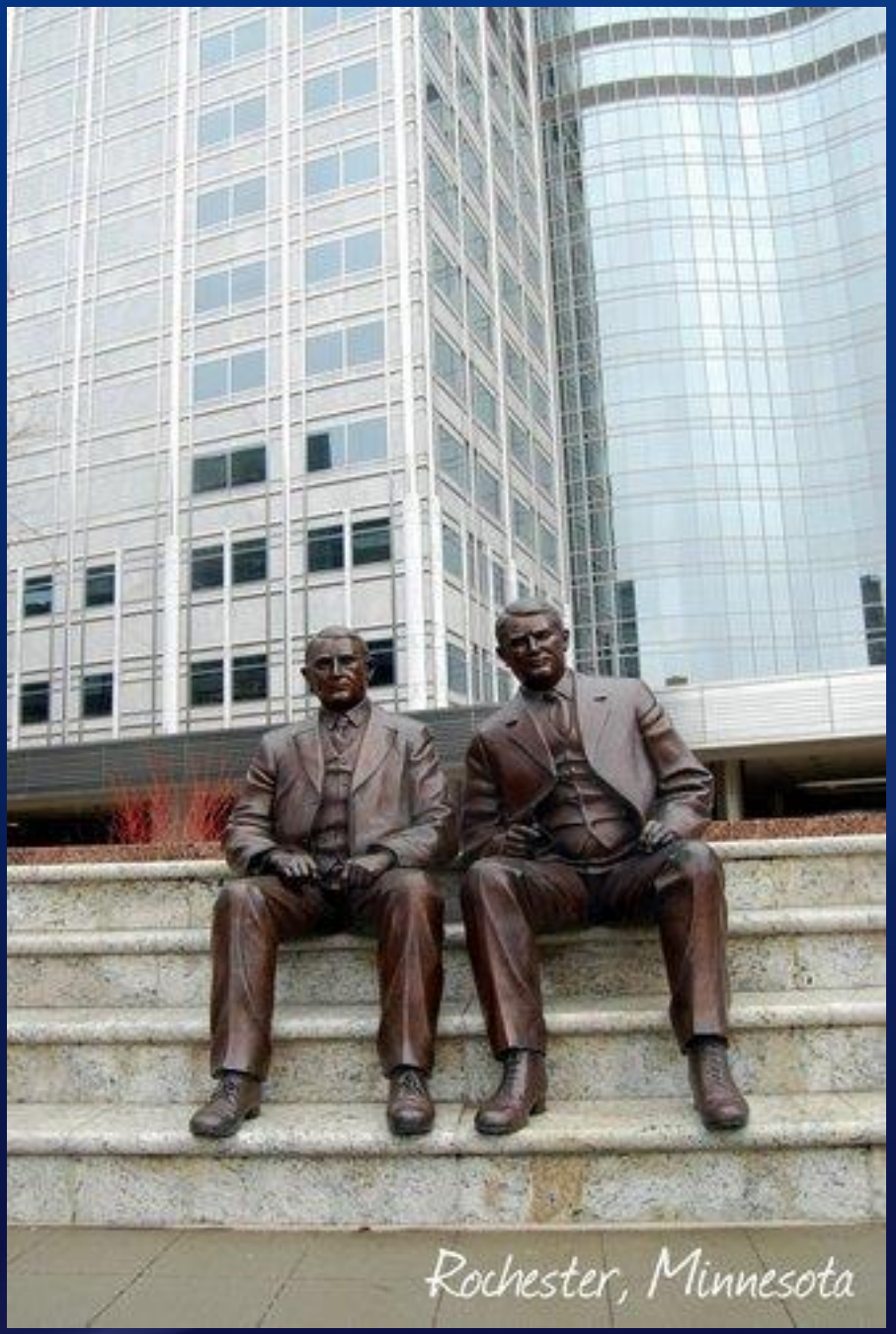
Thank you!

Questions?



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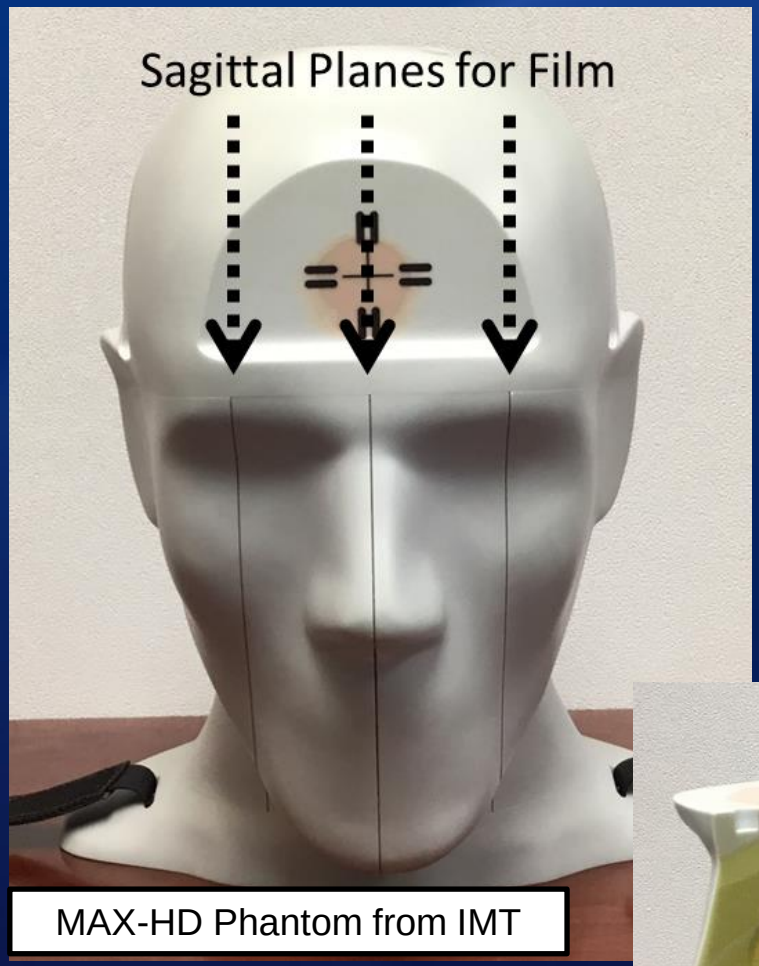
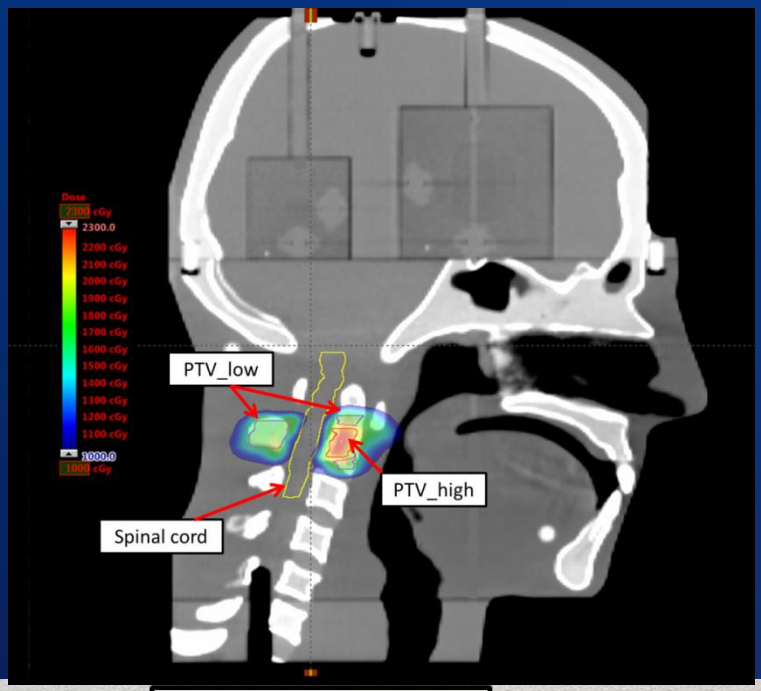
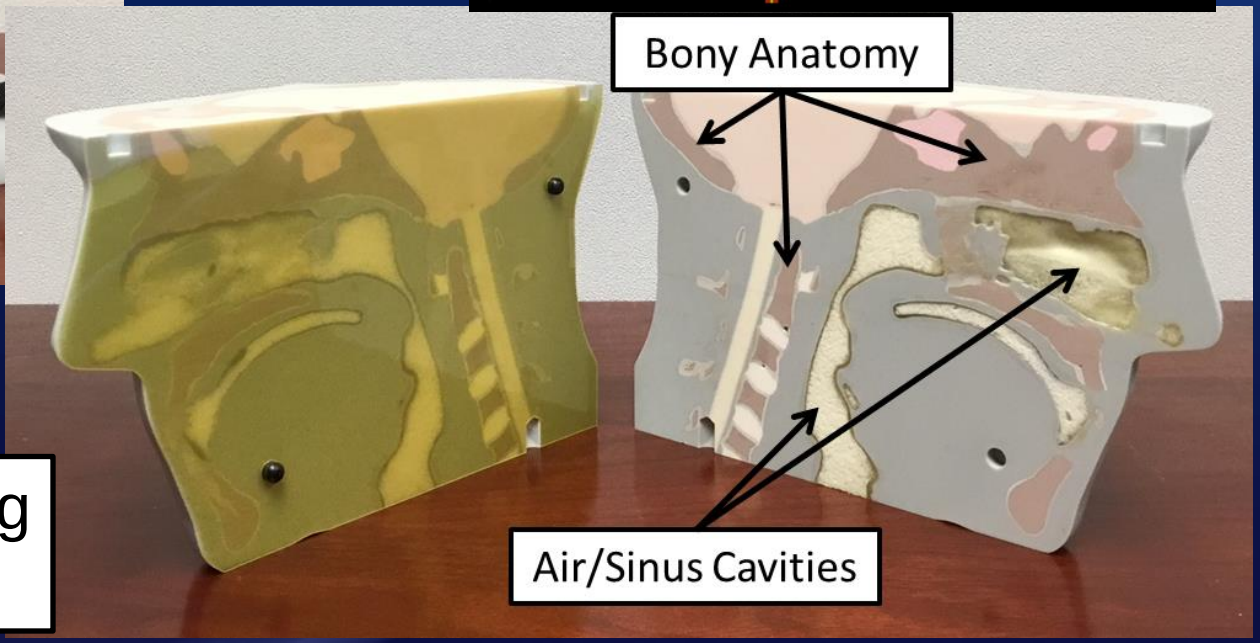
What have we used film for?

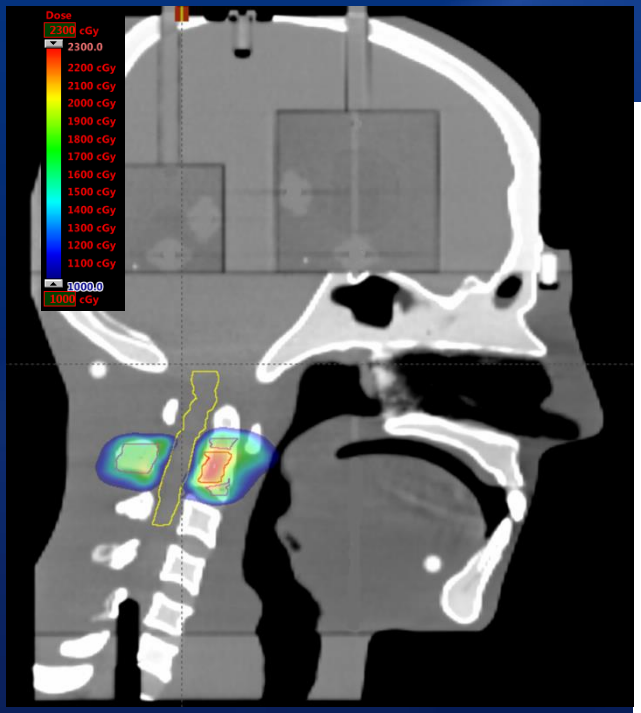


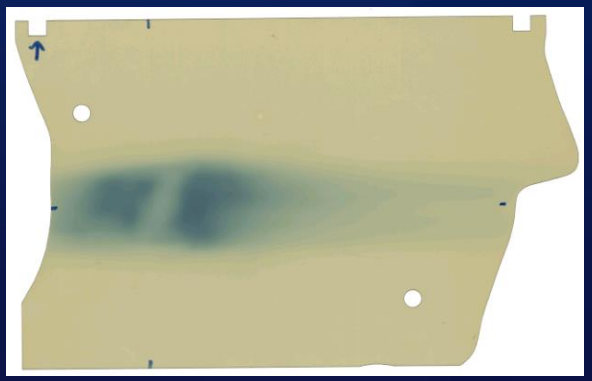
MAX-HD Phantom from IMT

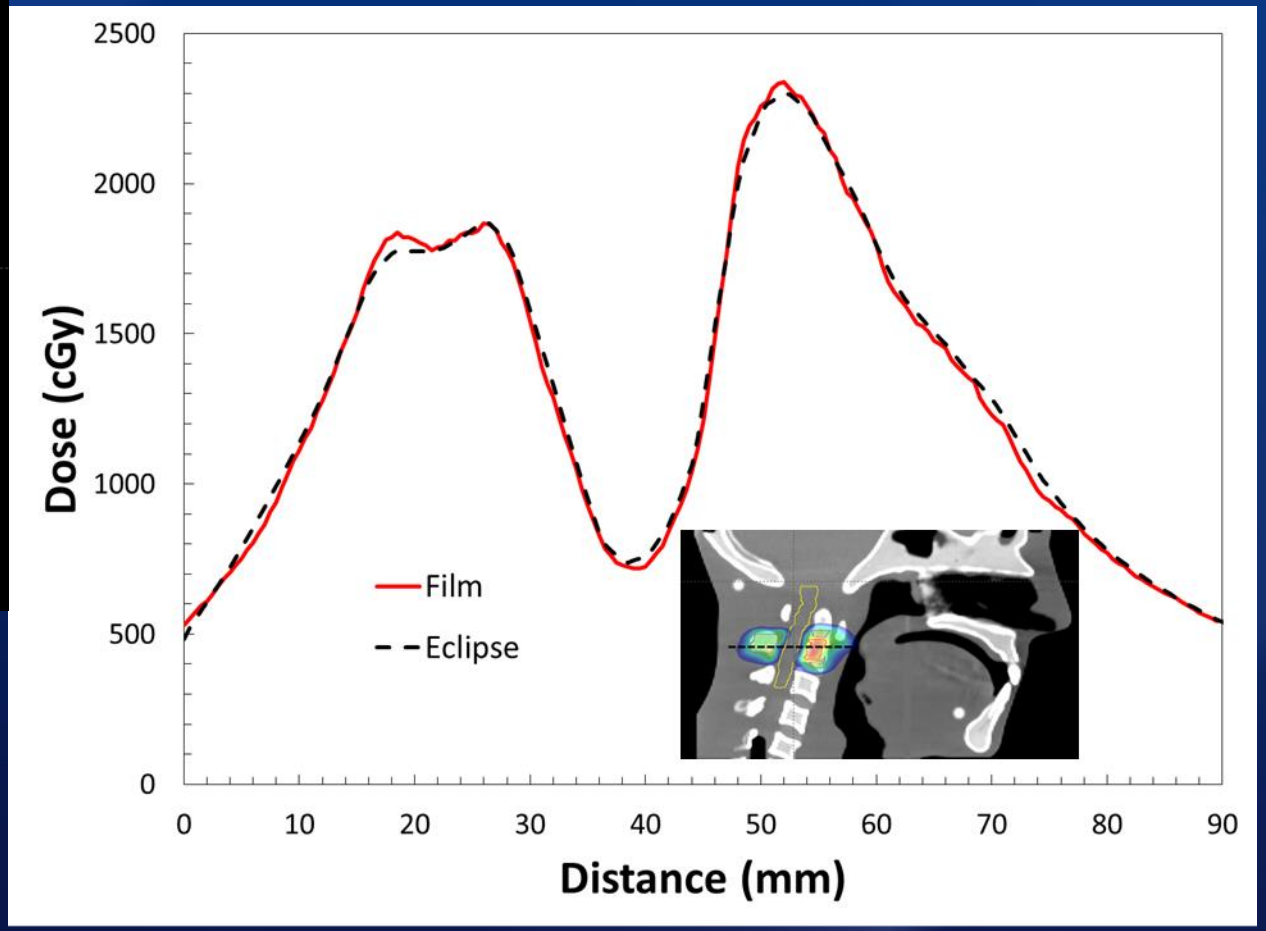




10FFF Commissioning
(E2E testing)


Dose
2300 cGy
2300.0
2200 cGy
2100 cGy
2000 cGy
1900 cGy
1800 cGy
1700 cGy
1600 cGy
1500 cGy
1400 cGy
1300 cGy
1200 cGy
1100 cGy
1000.0
1000 cGy




Dose (cGy)
2500
2000
1500
1000
500
0
0
10
20
30
40
50
60
70
80
90
Distance (mm)
Film
Eclipse

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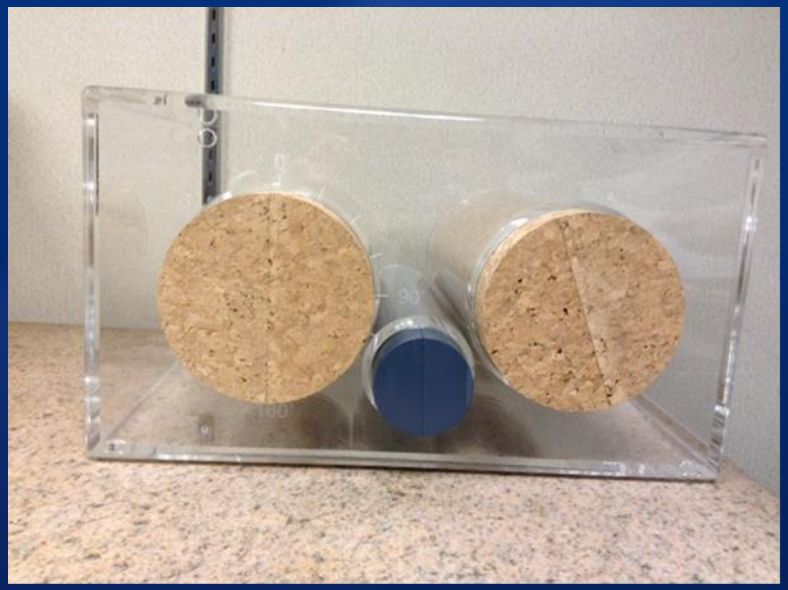

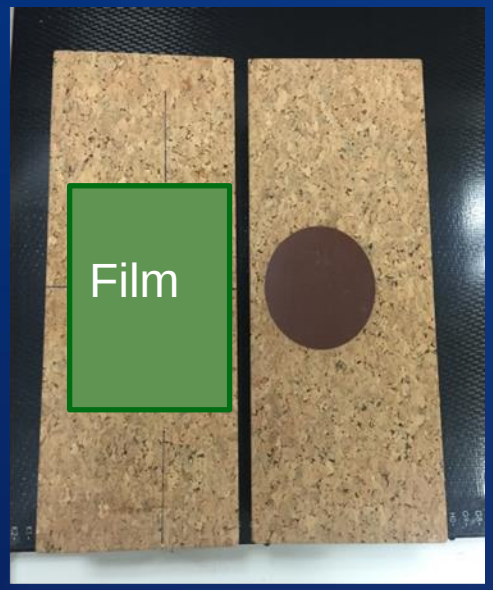

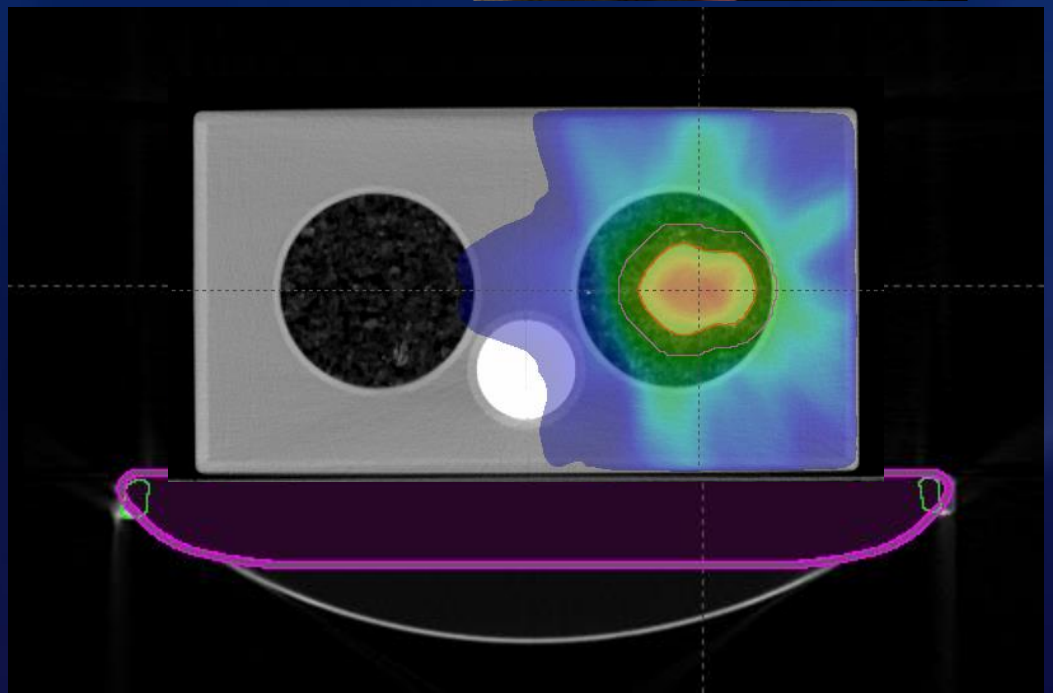

10FFF Commissioning

Comparisons of AAA and Acuros in “lung”

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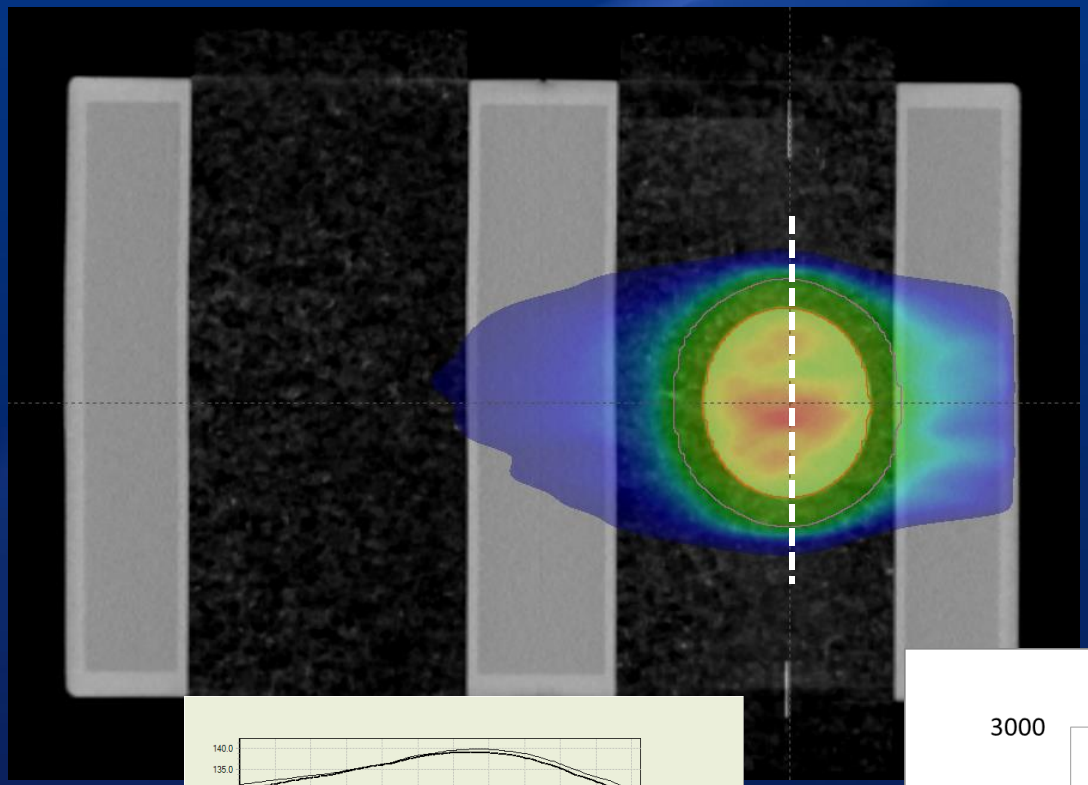
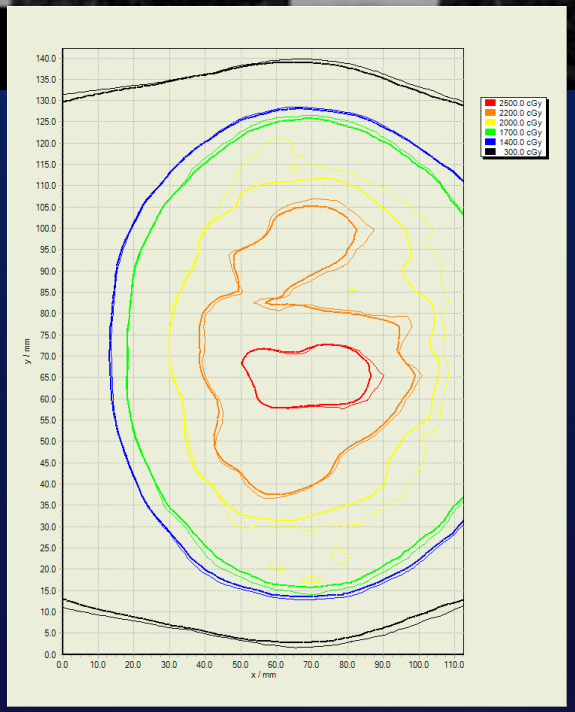
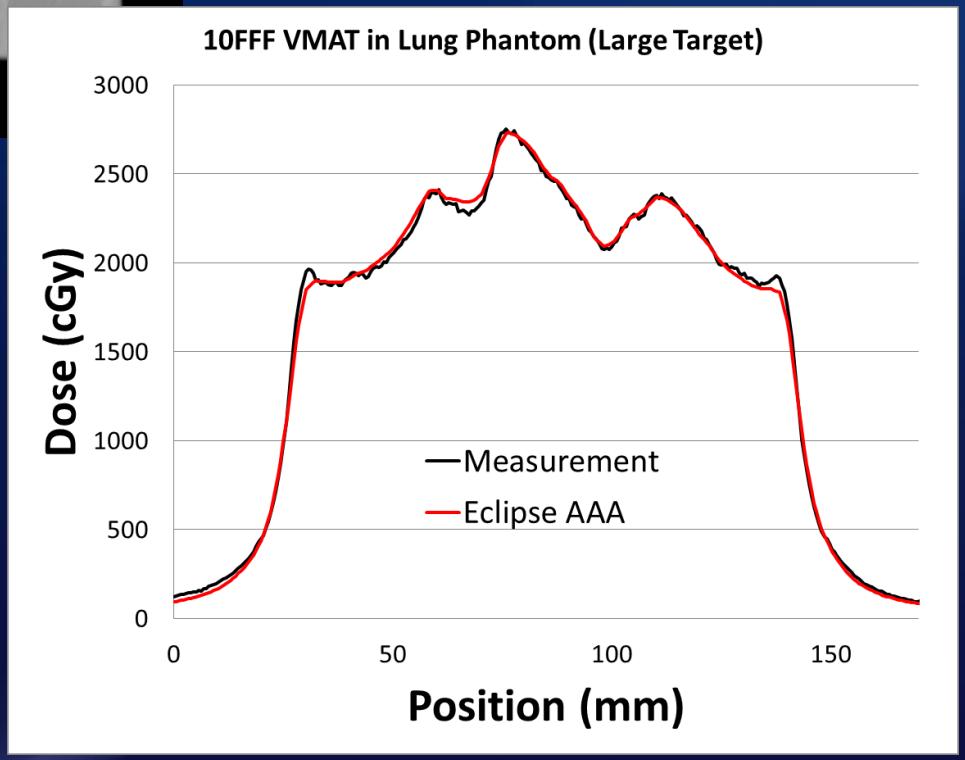


99% gamma passing rate at 2%/2mm





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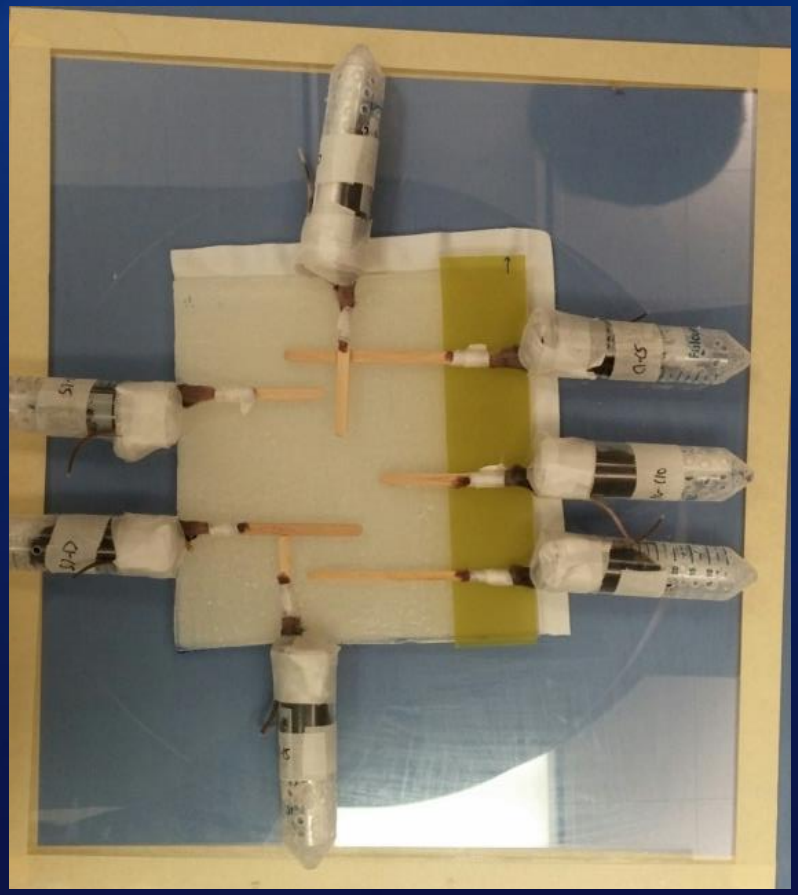
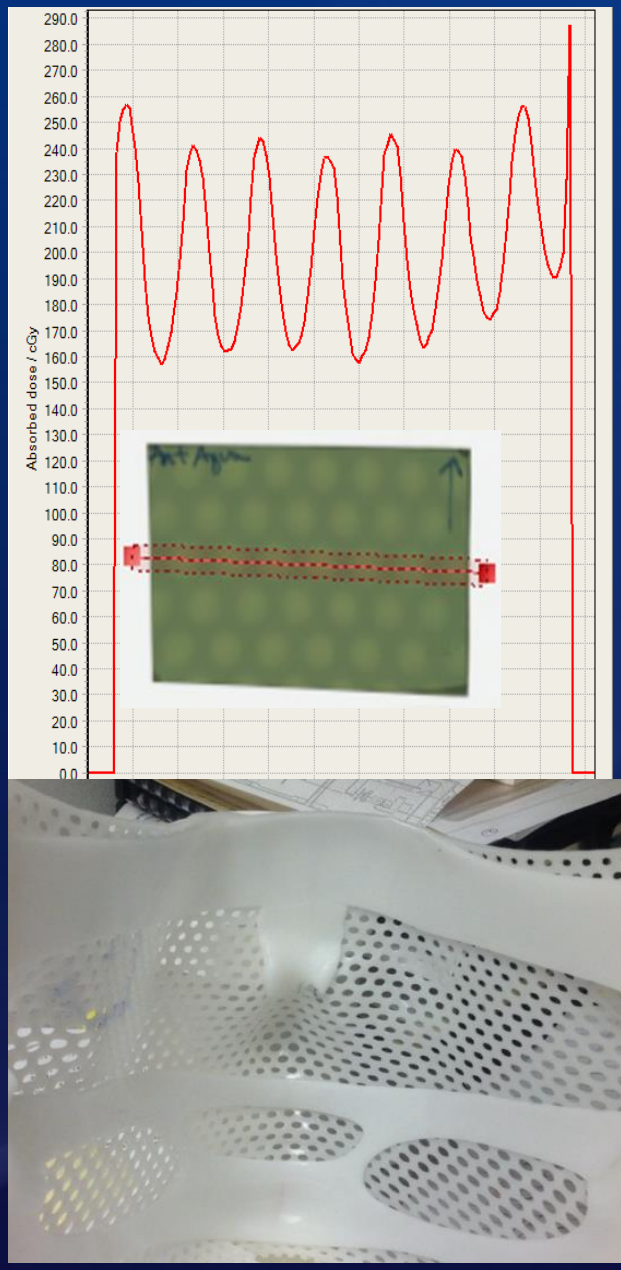
Small animal irradiation



Surface dose measurements under masks



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The scanner

- The scanner is the weakest link in the film dosimetry process, it will try to mess you up every chance it gets!
- Don’t let the scanner software alter the scanned images
- Do turn all color corrections, sharpening, etc. off
- Don’t turn the scanner off.
- Do always leave the scanner on and warm up the lamp with several preview scans

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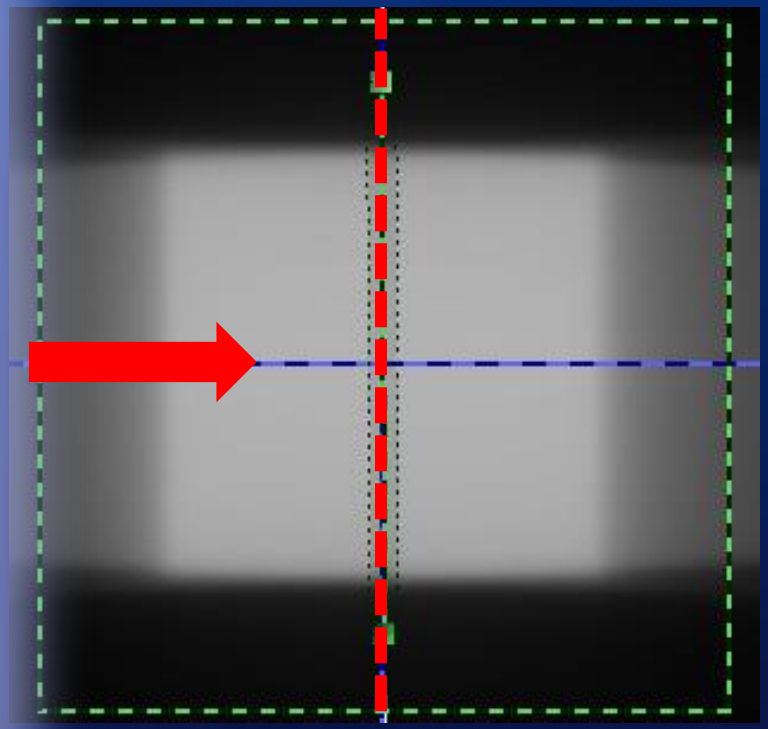
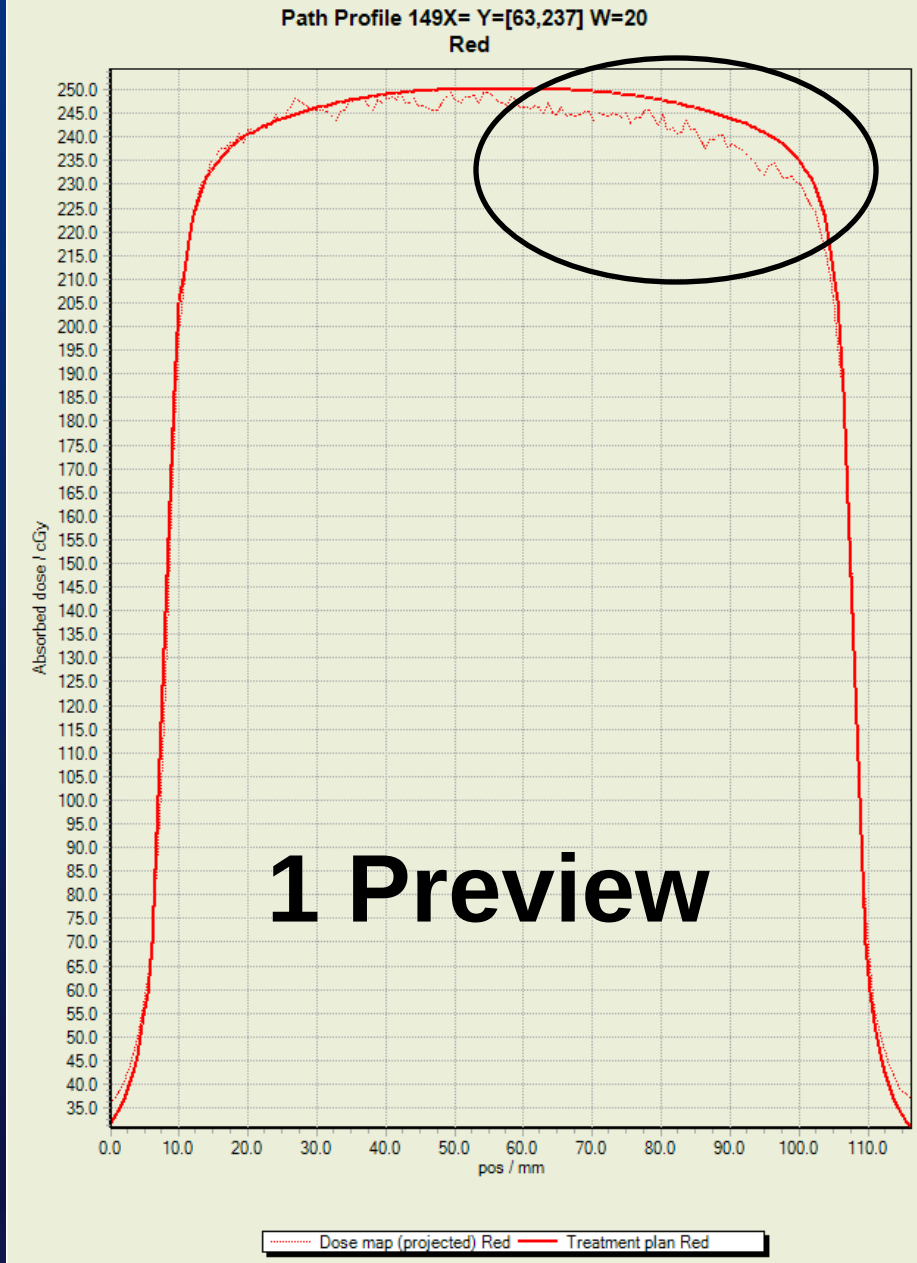
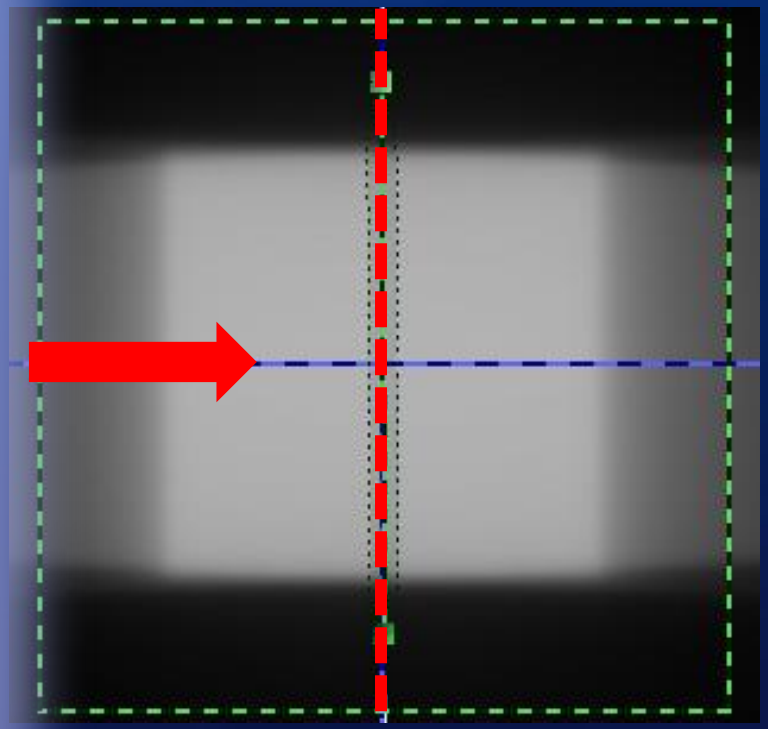
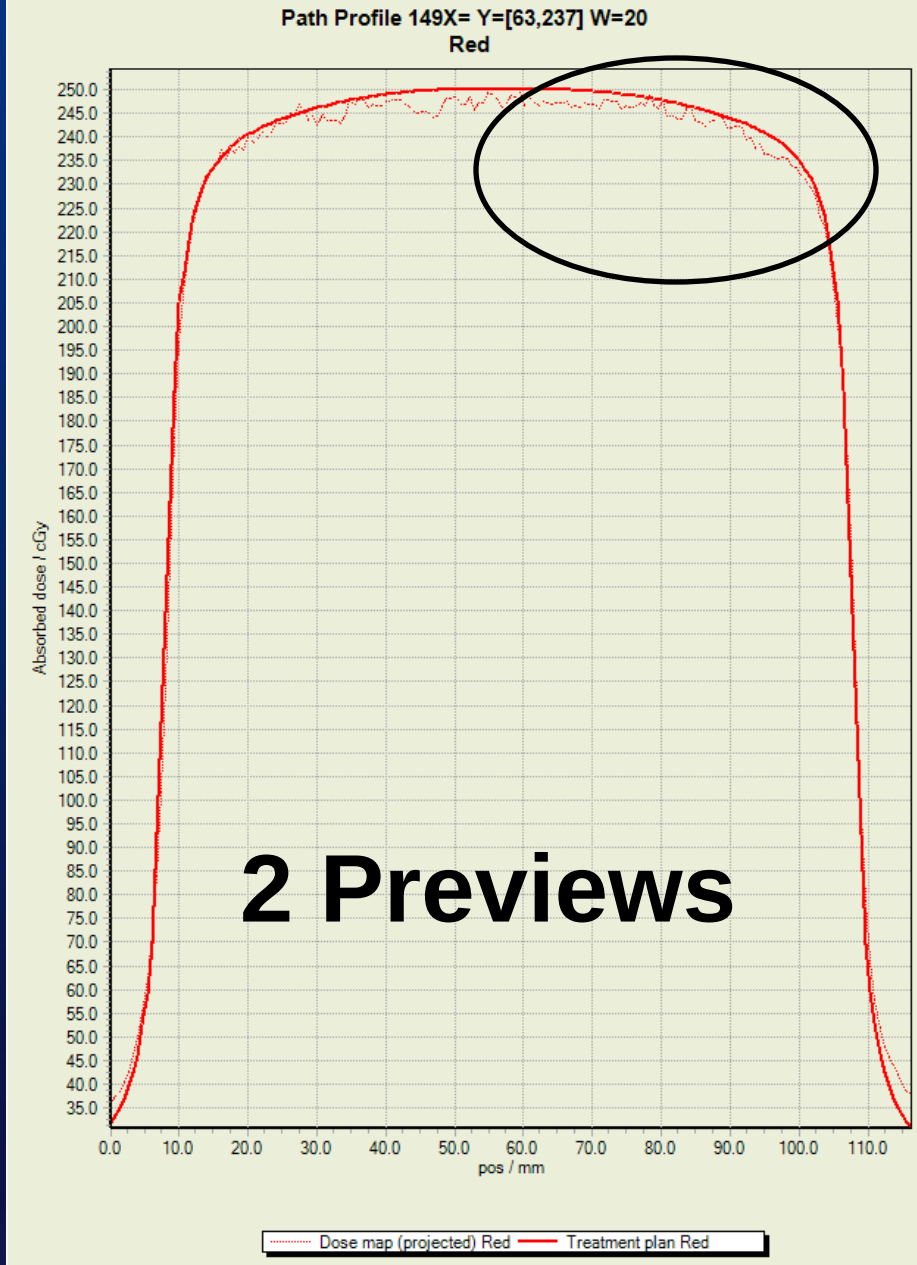


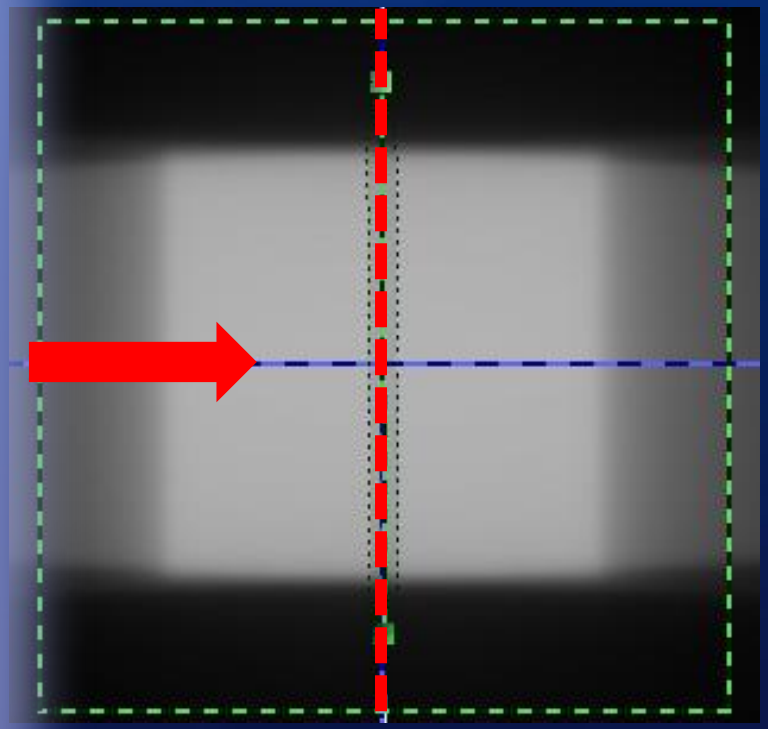

Path Profile 149X= Y=[63,237] W=20
Red
Absorbed dose / cGy
250.0
245.0
240.0
235.0
230.0
225.0
220.0
215.0
210.0
205.0
200.0
195.0
190.0
185.0
180.0
175.0
170.0
165.0
160.0
155.0
150.0
145.0
140.0
135.0
130.0
125.0
120.0
115.0
110.0
105.0
100.0
95.0
90.0
85.0
80.0
75.0
70.0
65.0
60.0
55.0
50.0
45.0
40.0
35.0
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
110.0
pos / mm
Dose map (projected) Red
Treatment plan Red
1 Preview

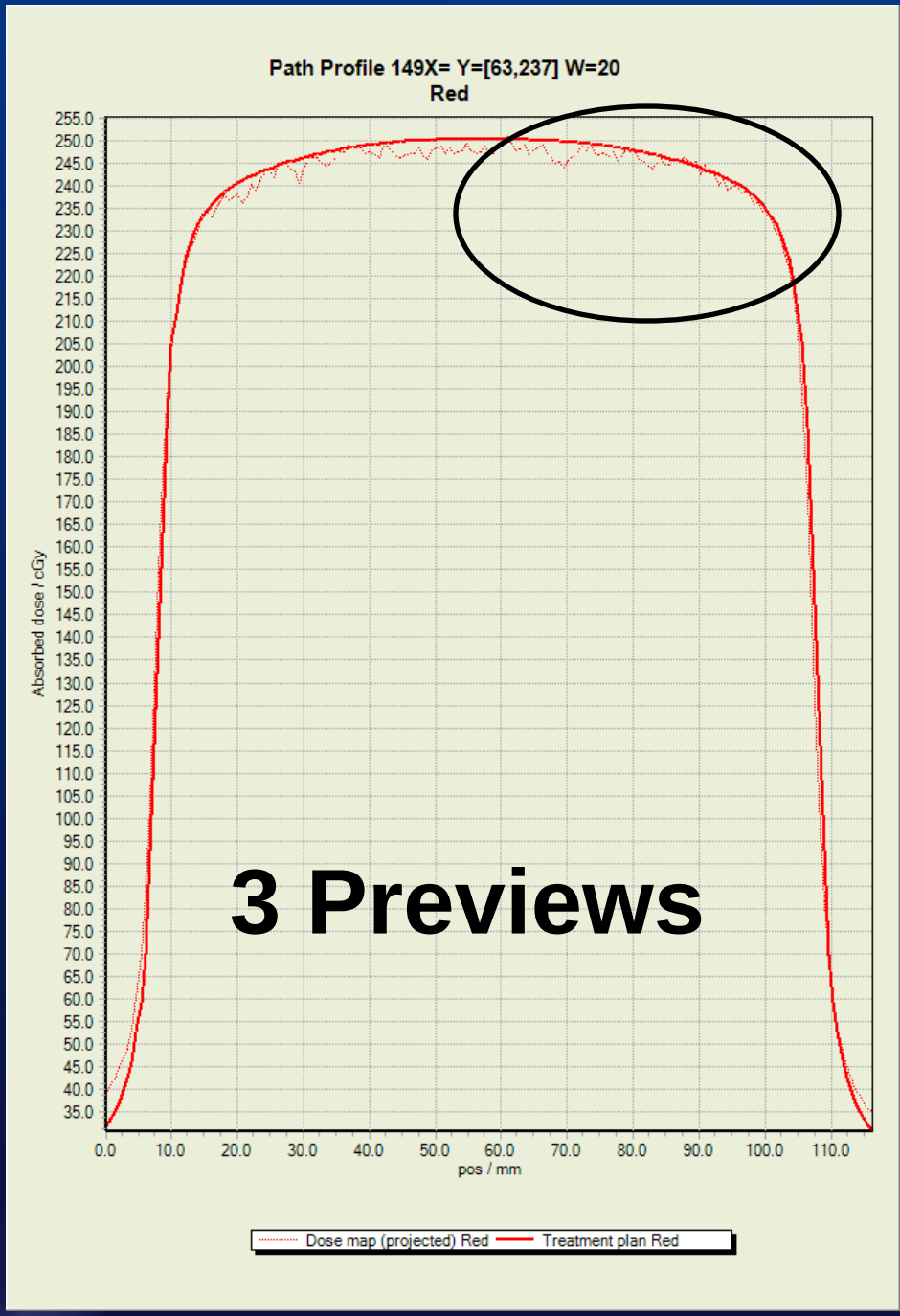
MAYO CLINIC




Path Profile 149X= Y=[63,237] W=20
Red
Absorbed dose / cGy
250.0
245.0
240.0
235.0
230.0
225.0
220.0
215.0
210.0
205.0
200.0
195.0
190.0
185.0
180.0
175.0
170.0
165.0
160.0
155.0
150.0
145.0
140.0
135.0
130.0
125.0
120.0
115.0
110.0
105.0
100.0
95.0
90.0
85.0
80.0
75.0
70.0
65.0
60.0
55.0
50.0
45.0
40.0
35.0
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
110.0
pos / mm
2 Previews
Dose map (projected) Red
Treatment plan Red

MAYO CLINIC




Path Profile 149X= Y=[63,237] W=20
Red
Absorbed dose / cGy
255.0
250.0
245.0
240.0
235.0
230.0
225.0
220.0
215.0
210.0
205.0
200.0
195.0
190.0
185.0
180.0
175.0
170.0
165.0
160.0
155.0
150.0
145.0
140.0
135.0
130.0
125.0
120.0
115.0
110.0
105.0
100.0
95.0
90.0
85.0
80.0
75.0
70.0
65.0
60.0
55.0
50.0
45.0
40.0
35.0
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
110.0
pos / mm
3 Previews
Dose map (projected) Red
Treatment plan Red

MAYO CLINIC