QUANTIFICATION OF BEAM LATENCY USING ALIGNRT

Rachel Barlow & Josh Naylor

OUR CENTRES


NHS
University Hospital Southampton
NHS Foundation Trust
NHS
University Hospitals Dorset
NHS Foundation Trust
Patchway
Bristol
Keynsham
Bath
Chippenham
Corsham
Marlborough
Devizes
Trowbridge
Newbury
Reading
Bracknell
Slough
Windsor
London
Hounslow
Kingston upon Thames
Croydon
Bromley
Orpington
Dartford
Camberley
Woking
Epsom
Farnborough
Basingstoke and North ...
Aldershot
Guildford
Frome
Wells
Warminster
Tidworth
Andover
Amesbury
Salisbury
Gillingham
Shaftesbury
Yeovil
Horley
Crawley
Horsham
Haywards Heath
Burgess Hill
Petersfield
Eastleigh
University Hospital So...
Southampton
Fordingbridge
Waterlooville
Blandford Forum
Ringwood
Fareham
Havant
Portsmouth
Chichester
Arundel
Worthing
Brighton
Lewes
Newhaven
Wimborne Minster
Brockenhurst
Bognor Regis
Lymington
Ryde
Selsey
Isle of Wight
Shanklin
Dorset County Hospital
Wareham
University Hospitals D...


X1
X6
X1
X3
Patchway
Yate
Bristol
Keynsham
Chippenham
Corsham
Bath
Trowbridge
Devizes
Marlborough
Reading
Slough
Windsor
London
Hounslow
Dartford
Bracknell
Kingston upon Thames
Bromley
Croydon
Orpington
Camberley
Woking
Epsom
Farnborough
Basingstoke and North ...
Aldershot
Guildford
Farnham
Tidworth
Andover
Frome
Warminster
Wells
Amesbury
Horley
Crawley
Horsham
Gillingham
Shaftesbury
Petersfield
Haywards Heath
Burgess Hill
Eastleigh
University Hospital So...
Southampton
Fordingbridge
Waterlooville
Blandford Forum
Ringwood
Fareham
Havant
Chichester
Arundel
Lewes
Portsmouth
Worthing
Brighton
Wimborne Minster
Brockenhurst
Bognor Regis
Newhaven
Lymington
Ryde
Selsey
Dorset County Hospital
Wareham
Isle of Wight
Shanklin
Weymouth

OUR CENTRES

Dictionary

Definitions from Oxford Languages · Learn more

latency

noun

noun: **latency**; plural noun: **latencies**

1. the state of existing but not yet being developed or manifest; concealment.
   "tension, and the latency of violence, make the greatest impressions"
   - the state of a disease not yet manifesting the usual symptoms.

2. **COMPUTING**
   the delay before a transfer of data begins following an instruction for its transfer.
   "poor performance due to network latency"

Use over time for: latency

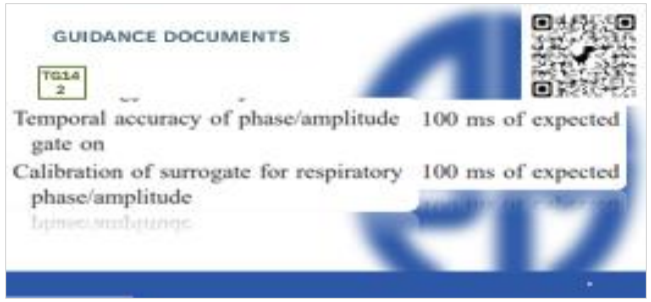

end-to-end
Elekta
BEAM:
HELD
RADIATION OFF

GUIDANCE DOCUMENTS

TG147

"III.B.4.b. Temporal accuracy (latency). System latency and time (frequency) of tracking should also be evaluated."

TG142



TG302

3.3.2 | Implications of temporal accuracy/latency for dynamic radiation delivery

GUIDANCE DOCUMENTS

TG142

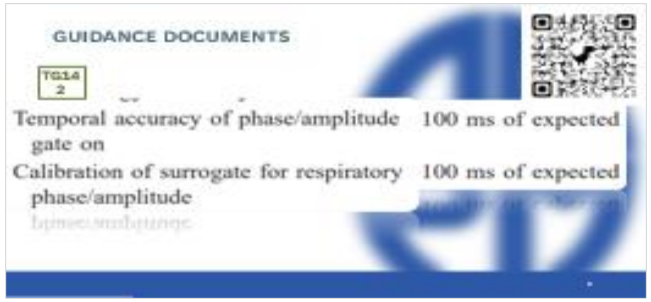
Temporal accuracy of phase/amplitude gate on	100 ms of expected
Calibration of surrogate for respiratory phase/amplitude	100 ms of expected

GUIDANCE DOCUMENTS

TG147

"III.B.4.b. Temporal accuracy (latency). System latency and time (frequency) of tracking should also be evaluated."

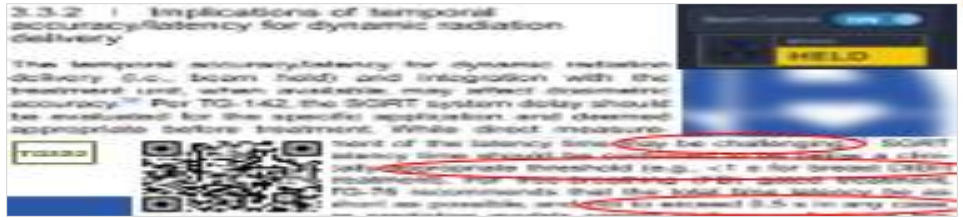
TG142


GUIDANCE DOCUMENTS

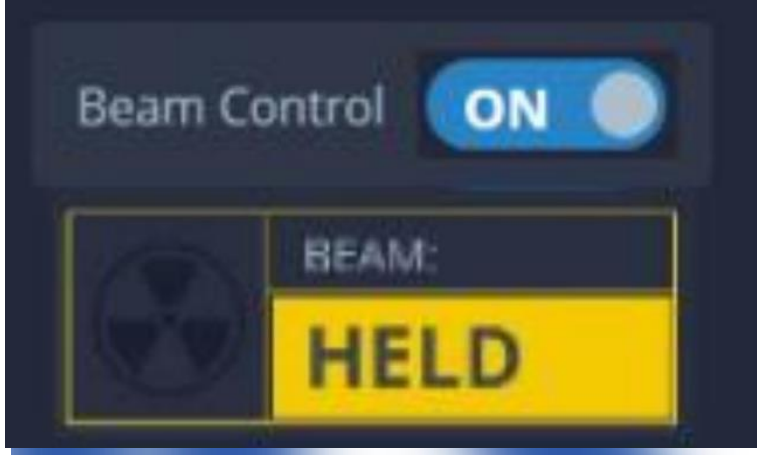
TG142

Temporal accuracy of phase/amplitude gate on	100 ms of expected
Calibration of surrogate for respiratory phase/amplitude	100 ms of expected

TG302


3.3.2 Implications of temporal accuracy/latency for dynamic radiation delivery

3.3.2 | Implications of temporal accuracy/latency for dynamic radiation delivery



The temporal accuracy/latency for dynamic radiation delivery (i.e., beam hold) and integration with the treatment unit, when available, may affect dosimetric accuracy.[36] Per TG-142, the SGRT system delay should be evaluated for the specific application and deemed appropriate before treatment. While direct measurement of the latency time may be challenging,[37] SGRT latency time should be confirmed to be below a clinically appropriate threshold (e.g., <1 s for breast DIBH treatment). For free-breathing (FB) gated treatment, TG-76 recommends that the total time latency be as short as possible, and not to exceed 0.5 s in any case, as prediction models cannot perform well above this

TG302

PROBLEM

LACK OF EXPERTISE

COMMISSIONING

LINAC ACCESS

TIME

EQUIPMENT

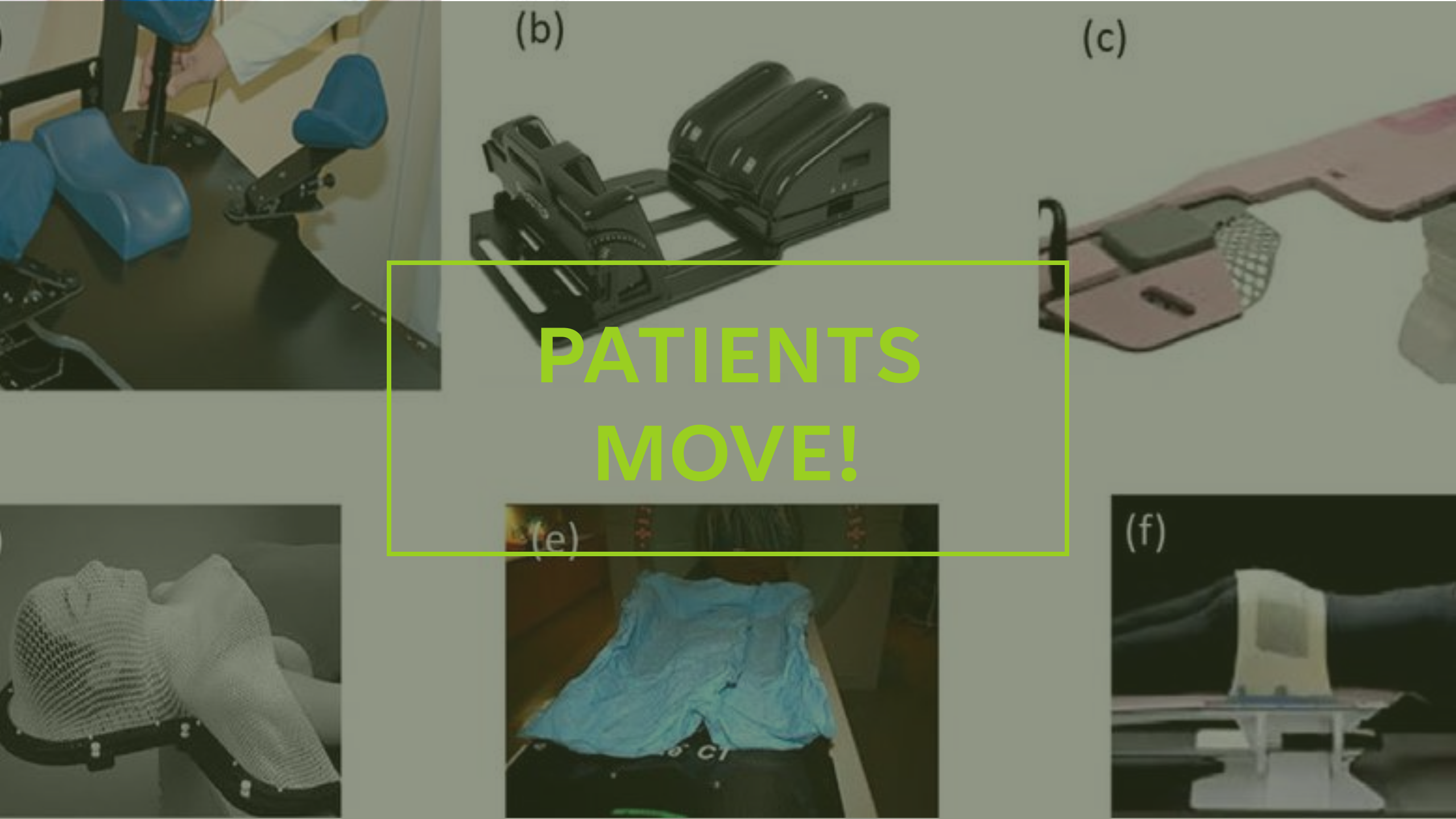
SOLUTION

COLLABORATE CROSS CENTRE

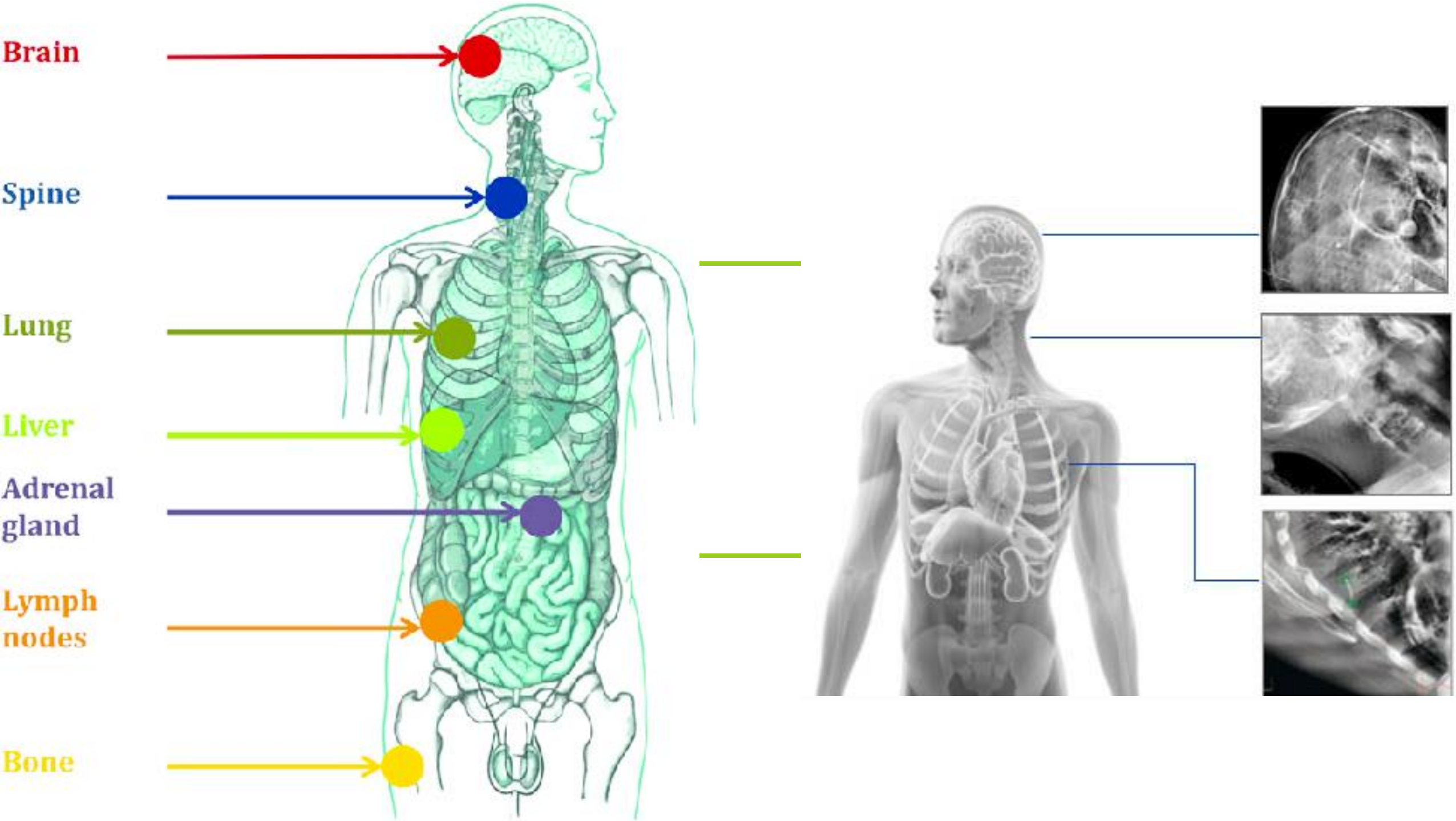
MIXED LINACS

MIXED CAMERA TECH

POOL STAFF / EQUIPMENT RESOURCE



PATIENTS MOVE!


Brain
Spine
Lung
Liver
Adrenal gland
Lymph nodes
Bone

Lung treatment breathing motion mgmt

[redacted] Preparation Treatment Logged in as a Service User NOT FOR CLINICAL USE Service

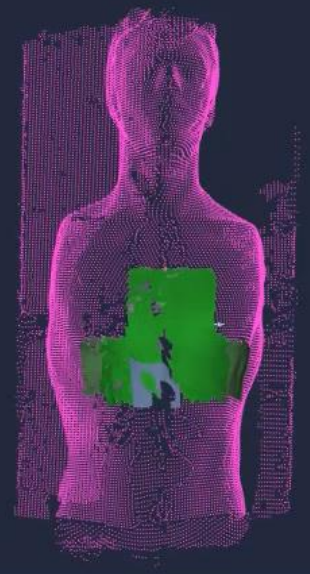
lung ISO 1 | SGRT External | ROI1

VRT cm	0.01
LNG cm	0.02
LAT cm	-0.02
MAG cm	0.04
YAW °	-0.1
ROLL °	0.2
PITCH °	0.2

Reference | Treatment | Couch 0.0° | Beam Control

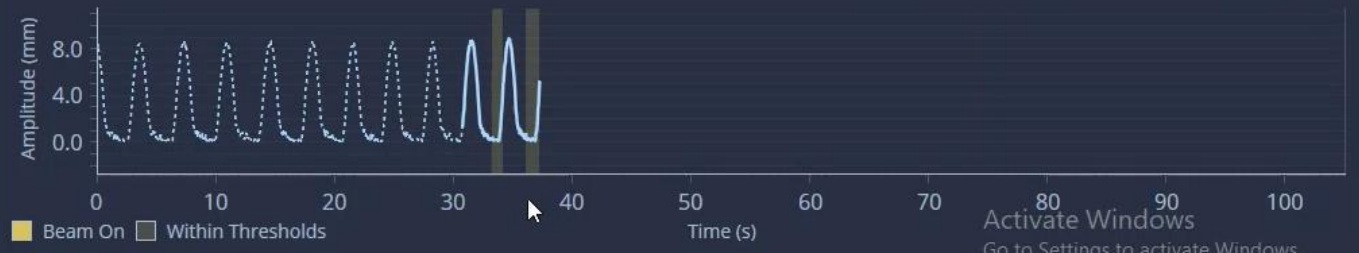
01/12/2022 11:05:00

Gated Capture



Respiratory Module® Patch Movement
Phase Based

120 BPM PHASE 75% Start 30% Stop 70%



Activate Windows
Go to Settings to activate Windows.

Surface | Deformation | Video | Patch

alignrt® | Patch 24.8 fps ROI 15.4 fps | TreatmentMonitoringState | 1650.60 MB | System Status | 01/12/2022 11:58

CLINICAL IMPLICATION OF LATENCY

IPEM 81

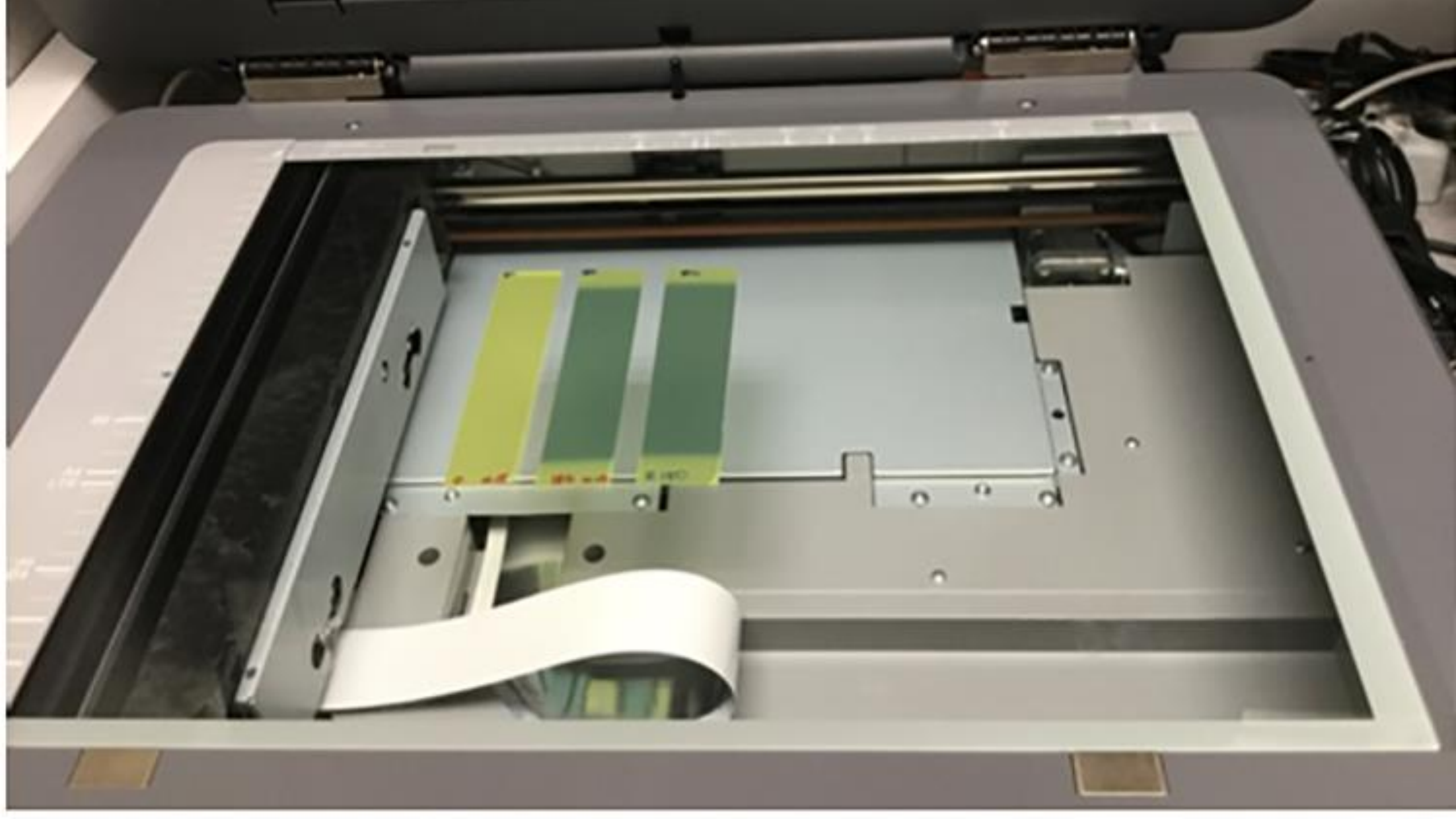
1.2.1.5 Summary of accuracy requirements

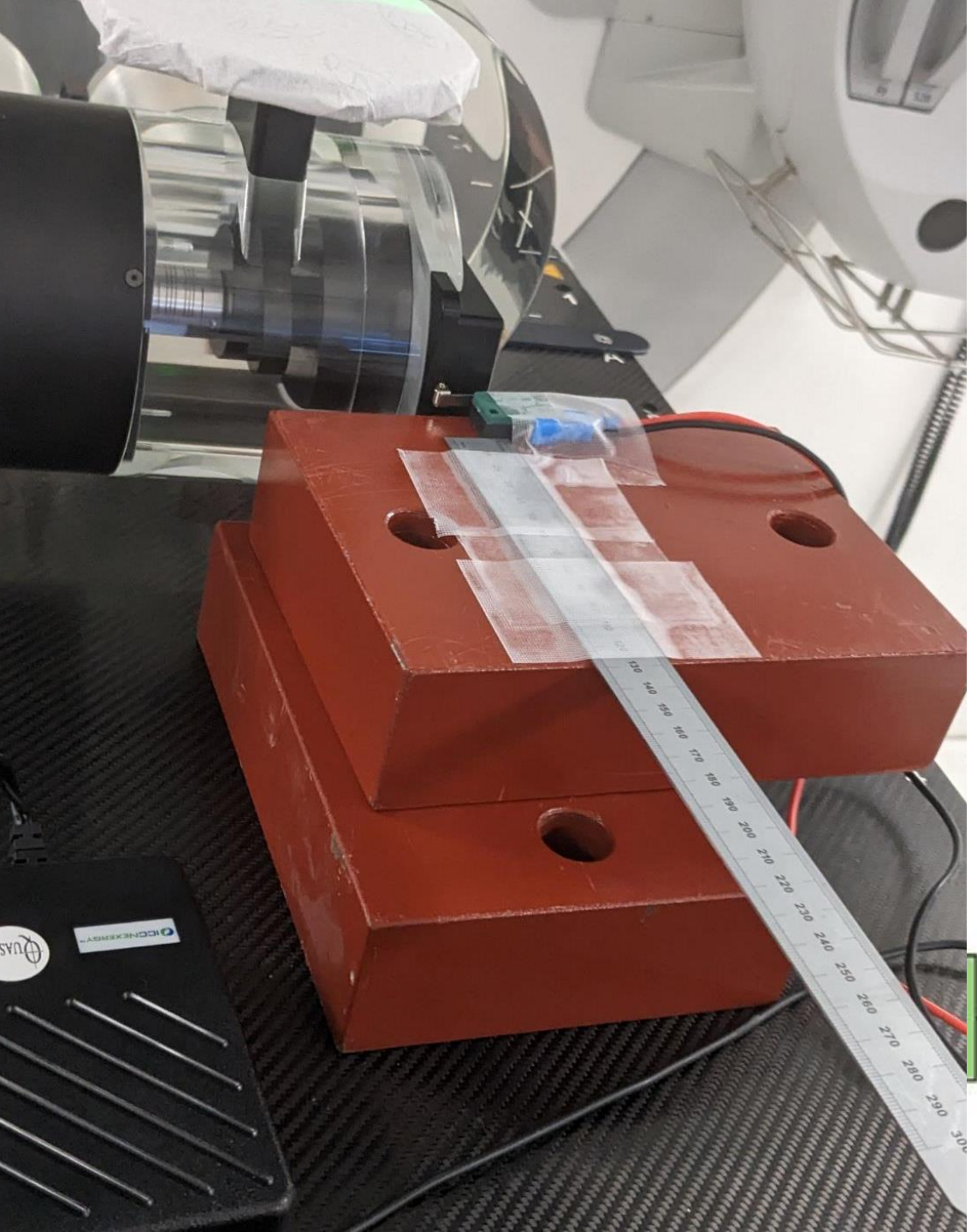
These recommendations concerning accuracy in radiotherapy can be summarised as:

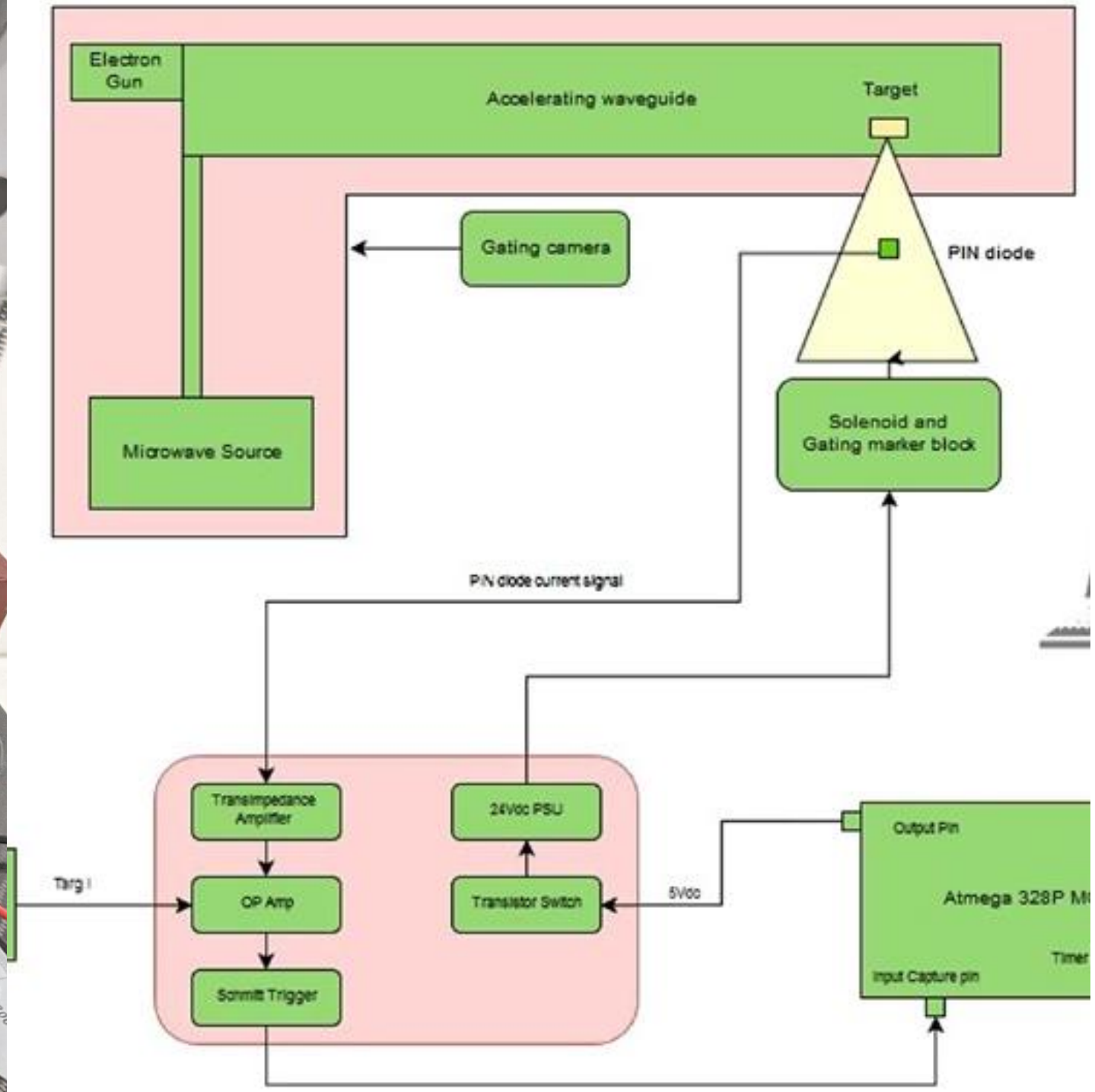
10 *Physics Aspects of Quality Control in Radiotherapy*

3 per cent on the absorbed dose delivered to the specification point;
5 per cent on the dose at all other points in the target volume;
4 mm on the position of field edges and shielding blocks in relation to the PTV.

Secondary a		
Emergency-		
Movement i		
Coded lead		
Backup tim		
Gantry and collimator rotation scales	5.2.4.6	±0.5°
Optical field size variation for different field sizes	5.2.6.2	2 mm (small sizes)
Isocentre quick check	5.2.4.3	2 mm diameter
Shadow tray alignment	5.2.7	1 mm from centre
Distance indication at different SSDs	5.2.4.4	2 mm
Couch movement calibration	5.2.8	2 mm relative
Couch vertical movement	5.2.8	2 mm
Gantry angle indication	5.2.4.6	1^0
Radiation field versus light field (one field size)	5.2.9.1	2 mm
Calibration in water	5.2.12.2	±2%
Energy check using dose ratio	5.2.13	Ratio ±2%
Arc therapy (if used)	5.2.14	Dose ±2%



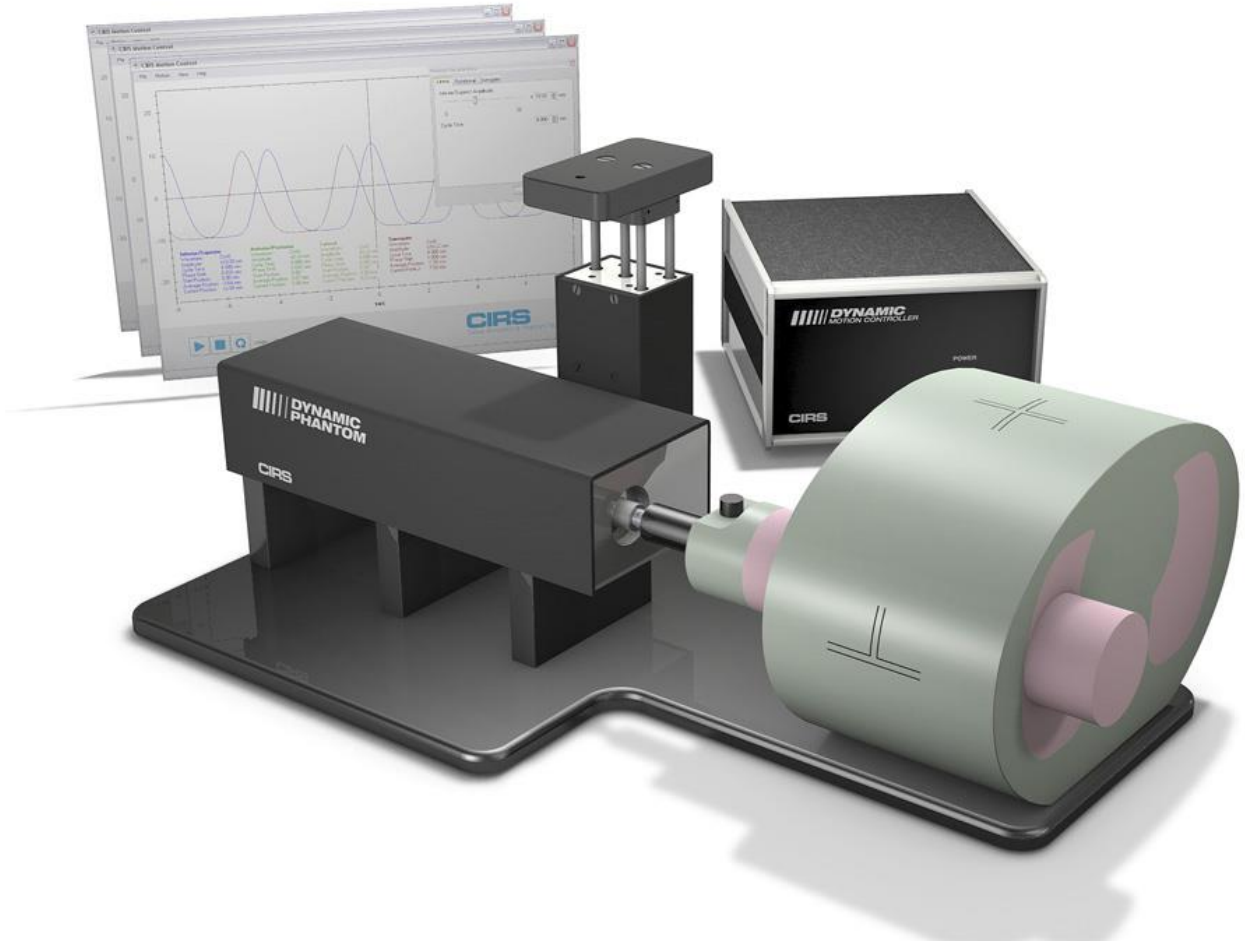



Electron Gun
Accelerating waveguide
Target
Gating camera
PIN diode
Microwave Source
Solenoid and Gating marker block
P/N diode current signal
Transimpedance Amplifier
24Vdc PSU
Output Pin
Targ I
OP Amp
Transistor Switch
5Vdc
Atmega 328P M
Timer
Schmitt Trigger
Input Capture pin


VARIAN
TrueBEAM


Elekta
Harmony
Chambers, Jane

PHANTOM CHOICE



CIRS 4dCT

DEVELOPMENT OF METHOD

INITIAL TRIAL

TrueBeam @UHDorset

Surrogate for surface / BB inside phantom at iso

METHOD CHANGE

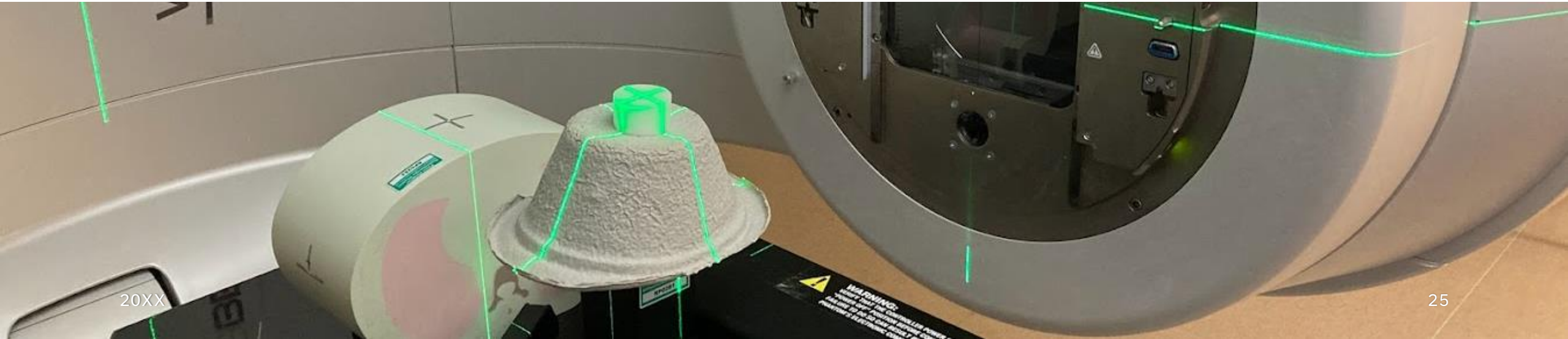
Versa HD @UHSouthampton

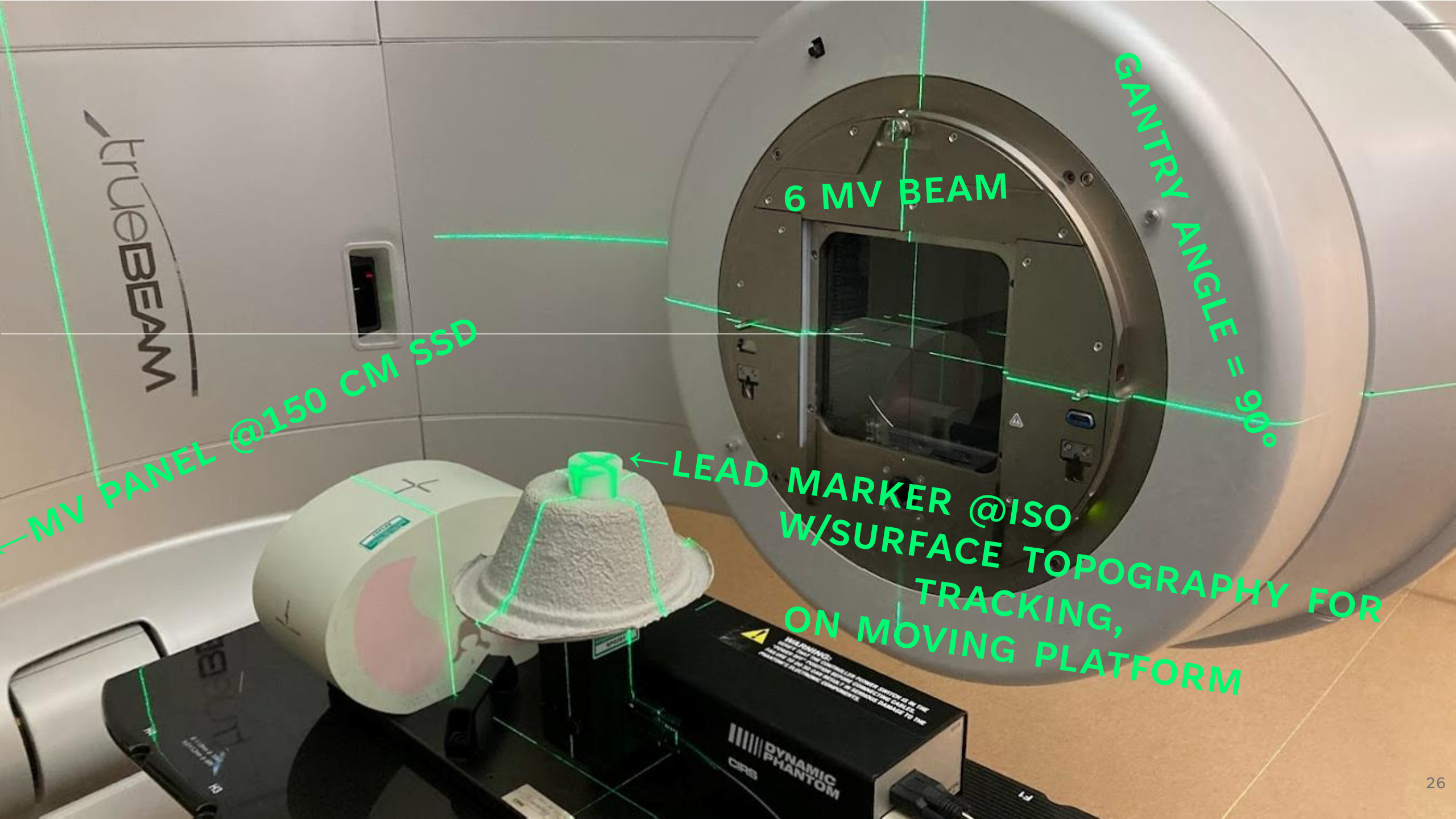
Testing on different linac, and optimizing method

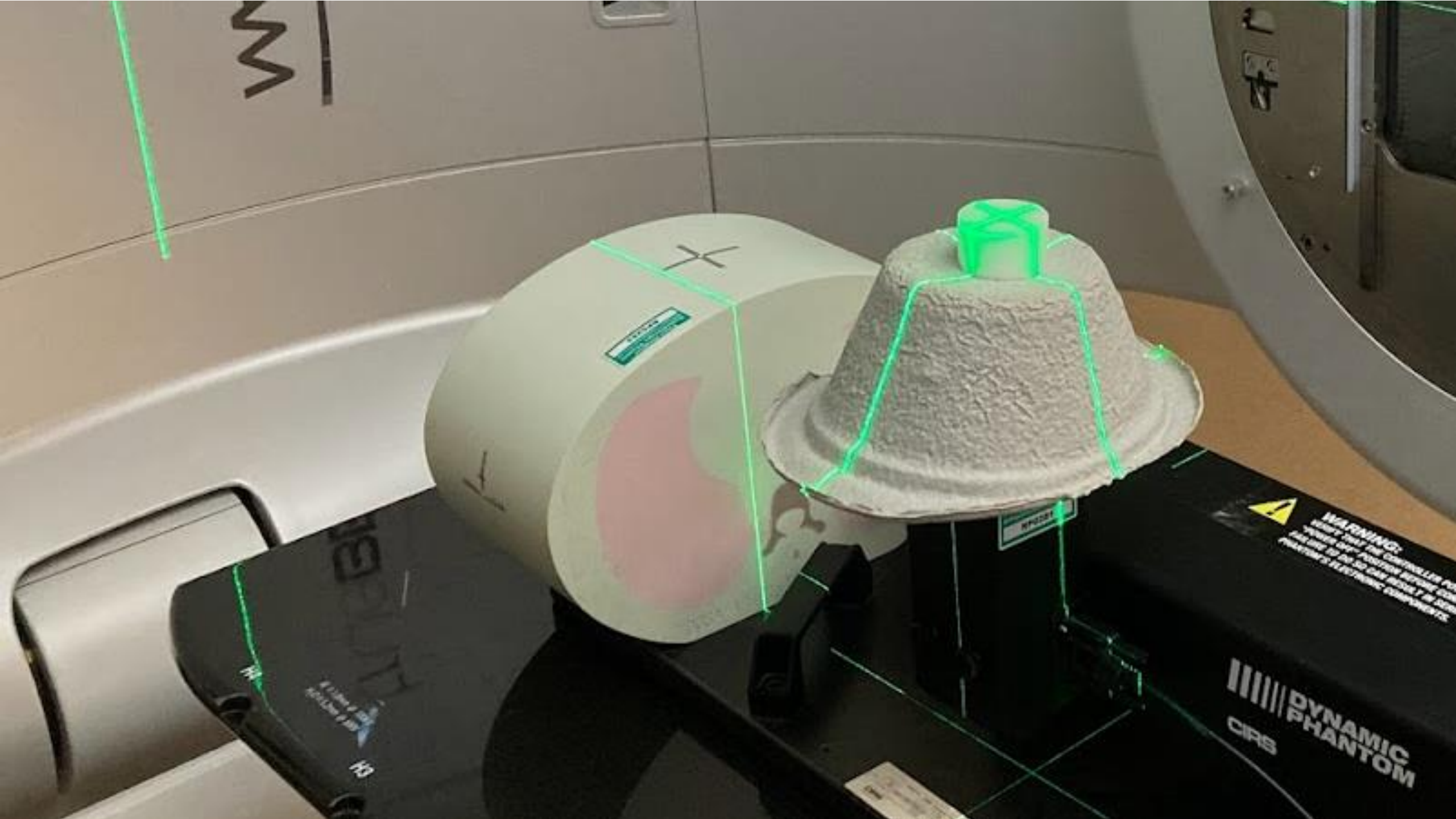
FINAL TECHNIQUE

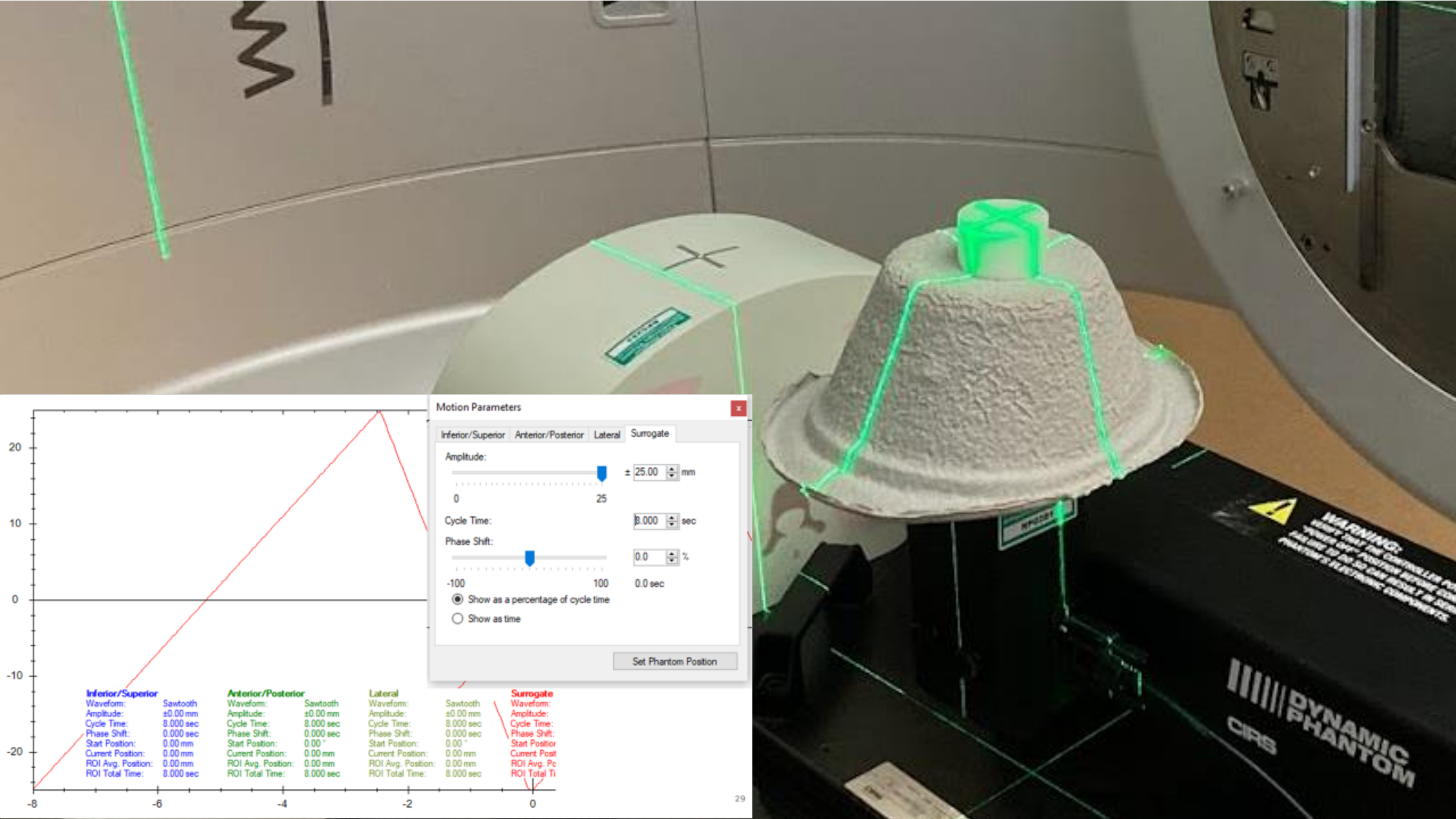
Both linacs

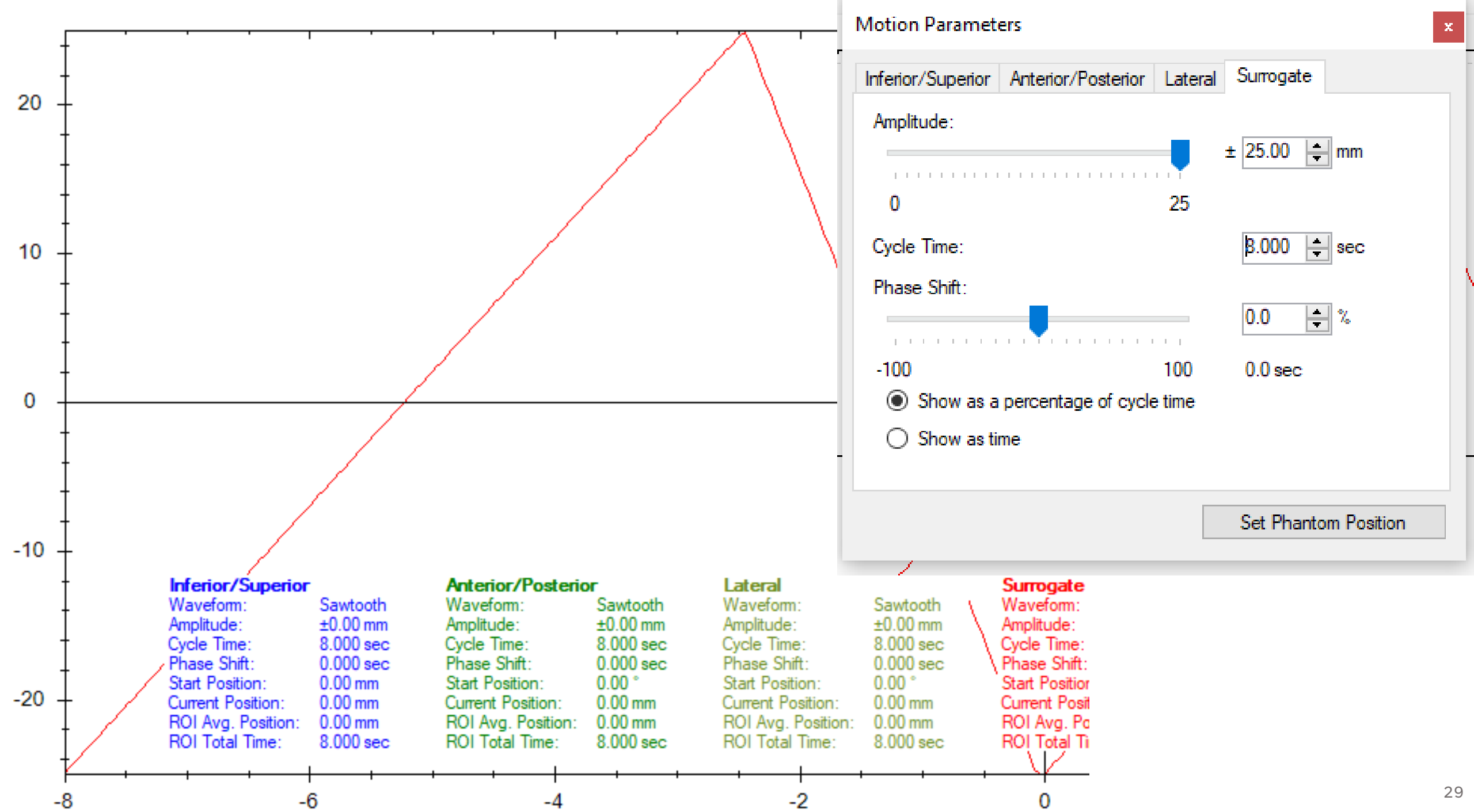
Surrogate platform for surface AND with lead marker at iso for image

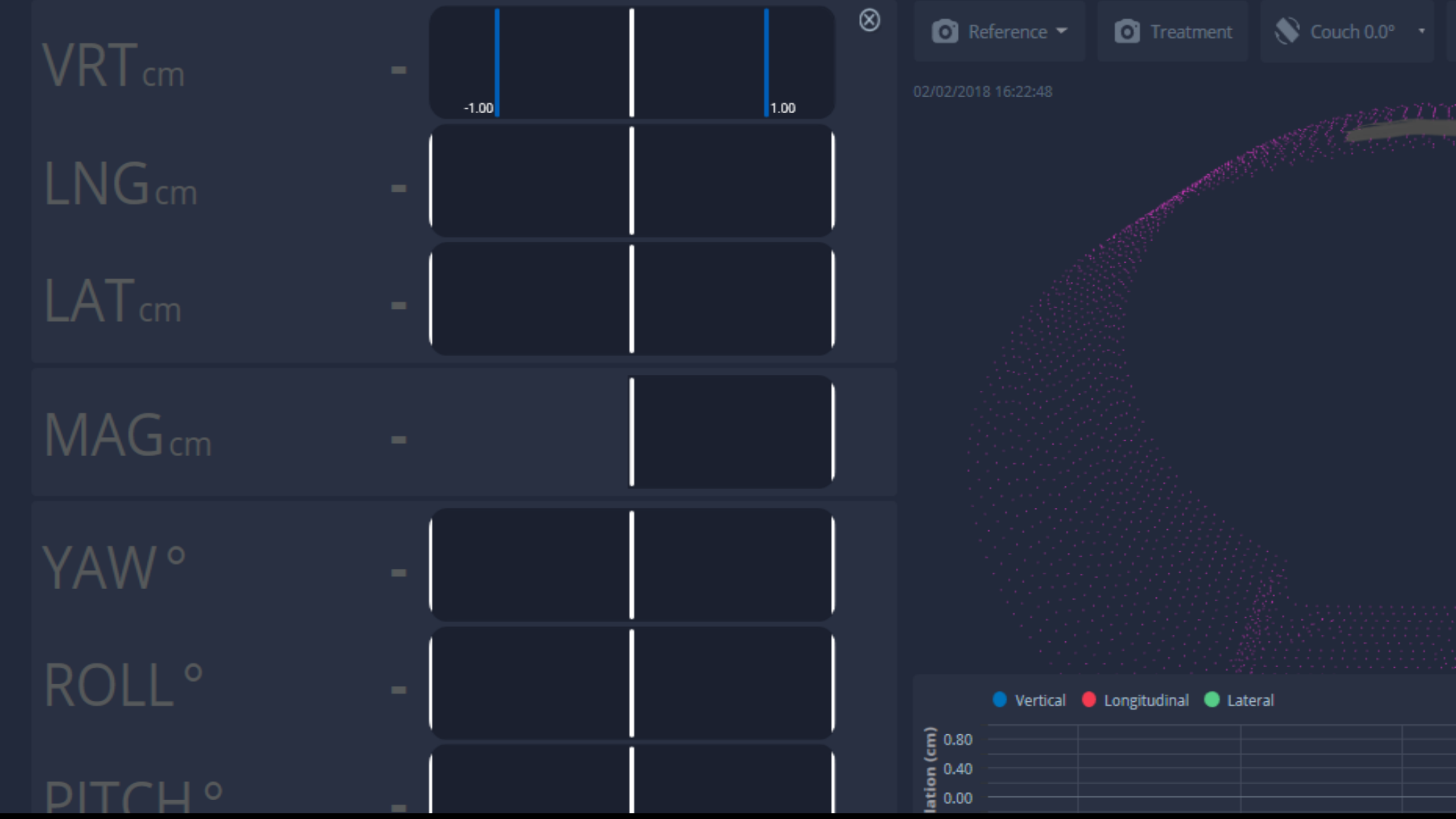


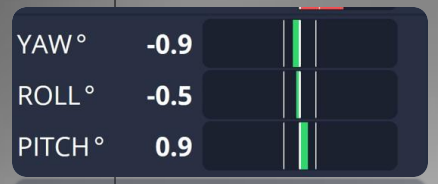

6 MV BEAM
GANTRY ANGLE = 90°
←MV PANEL @150 CM SSD
←LEAD MARKER @ISO
W/SURFACE TOPOGRAPHY FOR
TRACKING,
ON MOVING PLATFORM
trueBEAM
DYNAMIC PHANTOM
CIRS


DYNAMIC PHANTOM
CIRS


Motion Parameters
Inferior/Superior
Anterior/Posterior
Lateral
Surrogate
Amplitude:
± 25.00 mm
0
25
Cycle Time:
8.000 sec
Phase Shift:
0.0 %
-100
100
0.0 sec
Show as a percentage of cycle time
Show as time
Set Phantom Position
Inferior/Superior
Waveform: Sawtooth
Amplitude: ±0.00 mm
Cycle Time: 8.000 sec
Phase Shift: 0.000 sec
Start Position: 0.00 mm
Current Position: 0.00 mm
ROI Avg. Position: 0.00 mm
ROI Total Time: 8.000 sec
Anterior/Posterior
Waveform: Sawtooth
Amplitude: ±0.00 mm
Cycle Time: 8.000 sec
Phase Shift: 0.000 sec
Start Position: 0.00 "
Current Position: 0.00 mm
ROI Avg. Position: 0.00 mm
ROI Total Time: 8.000 sec
Lateral
Waveform: Sawtooth
Amplitude: ±0.00 mm
Cycle Time: 8.000 sec
Phase Shift: 0.000 sec
Start Position: 0.00 "
Current Position: 0.00 mm
ROI Avg. Position: 0.00 mm
ROI Total Time: 8.000 sec
Surrogate
Waveform:
Amplitude:
Cycle Time:
Phase Shift:
Start Position
Current Posit
ROI Avg. Pc
ROI Total Ti
20
10
0
-10
-20
-8
-6
-4
-2
0
29
WARNING:
DYNAMIC PHANTOM
CIRS


Motion Parameters
Inferior/Superior
Anterior/Posterior
Lateral
Surrogate
Amplitude:
± 25.00 mm
0
25
Cycle Time:
8.000 sec
Phase Shift:
0.0 %
-100
100
0.0 sec
Show as a percentage of cycle time
Show as time
Set Phantom Position
Inferior/Superior
Waveform: Sawtooth
Amplitude: ±0.00 mm
Cycle Time: 8.000 sec
Phase Shift: 0.000 sec
Start Position: 0.00 mm
Current Position: 0.00 mm
ROI Avg. Position: 0.00 mm
ROI Total Time: 8.000 sec
Anterior/Posterior
Waveform: Sawtooth
Amplitude: ±0.00 mm
Cycle Time: 8.000 sec
Phase Shift: 0.000 sec
Start Position: 0.00 °
Current Position: 0.00 mm
ROI Avg. Position: 0.00 mm
ROI Total Time: 8.000 sec
Lateral
Waveform: Sawtooth
Amplitude: ±0.00 mm
Cycle Time: 8.000 sec
Phase Shift: 0.000 sec
Start Position: 0.00 °
Current Position: 0.00 mm
ROI Avg. Position: 0.00 mm
ROI Total Time: 8.000 sec
Surrogate
Waveform:
Amplitude:
Cycle Time:
Phase Shift:
20
10
0
-10
-20
-8
-6
-4
-2
0

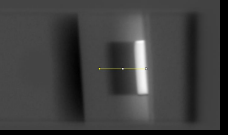

VRT cm
-
-1.00
1.00
LNG cm
-
LAT cm
-
MAG cm
-
YAW °
-
ROLL °
-
PITCH °
-
Reference
Treatment
Couch 0.0°
02/02/2018 16:22:48
Vertical
Longitudinal
Lateral
0.80
0.40
0.00


YAW °
-0.9
ROLL °
-0.5
PITCH °
0.9

ANALYSIS

ImageJ

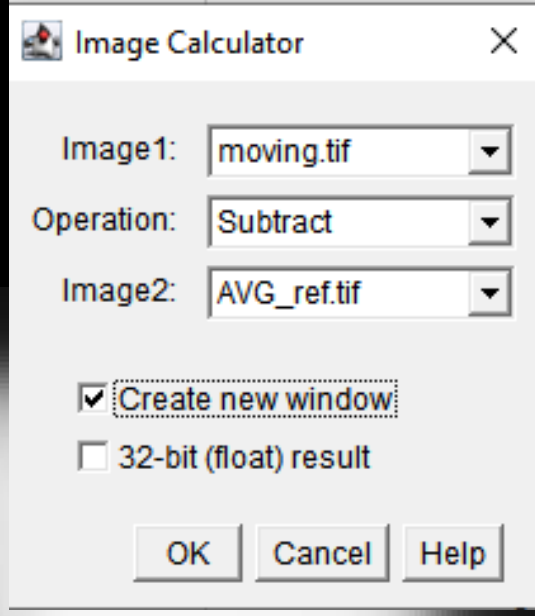
ANALYSIS



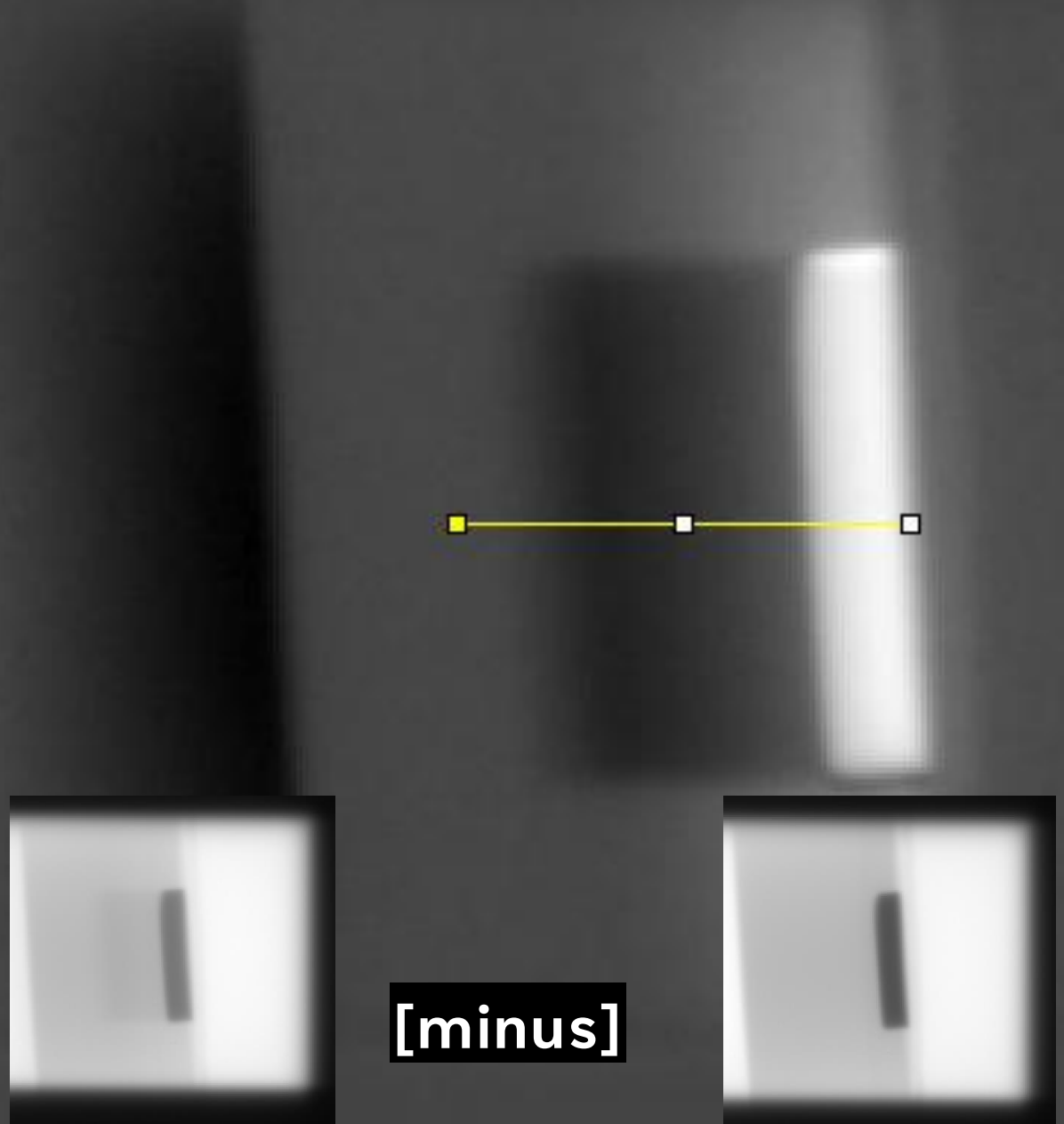
Moving lead image

[minus]

Static reference image

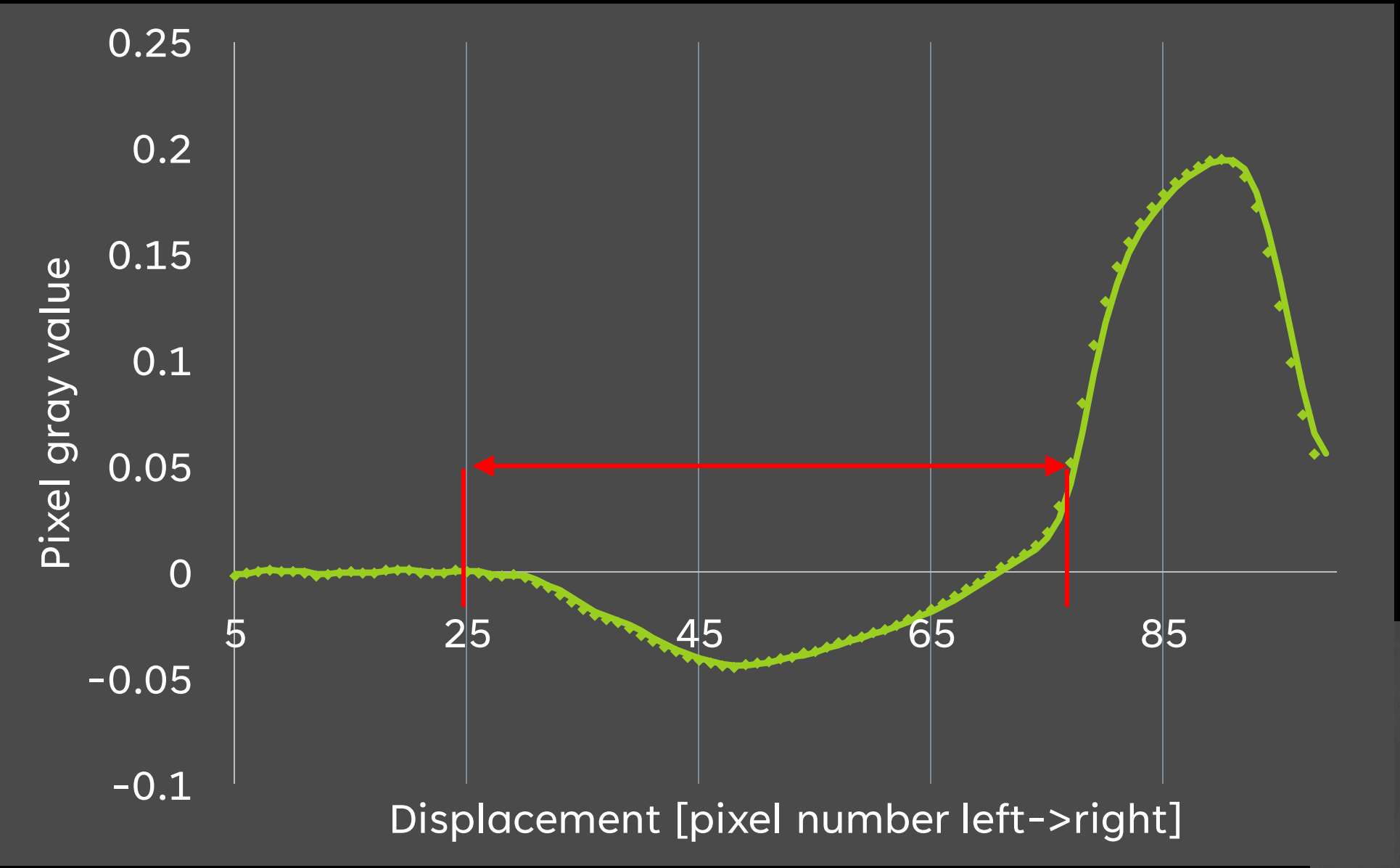


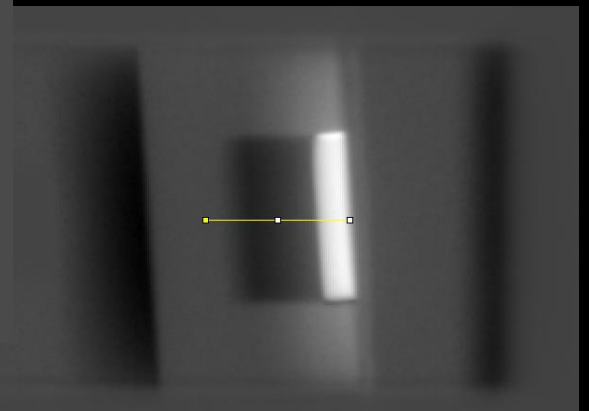
ANALYSIS



[minus]

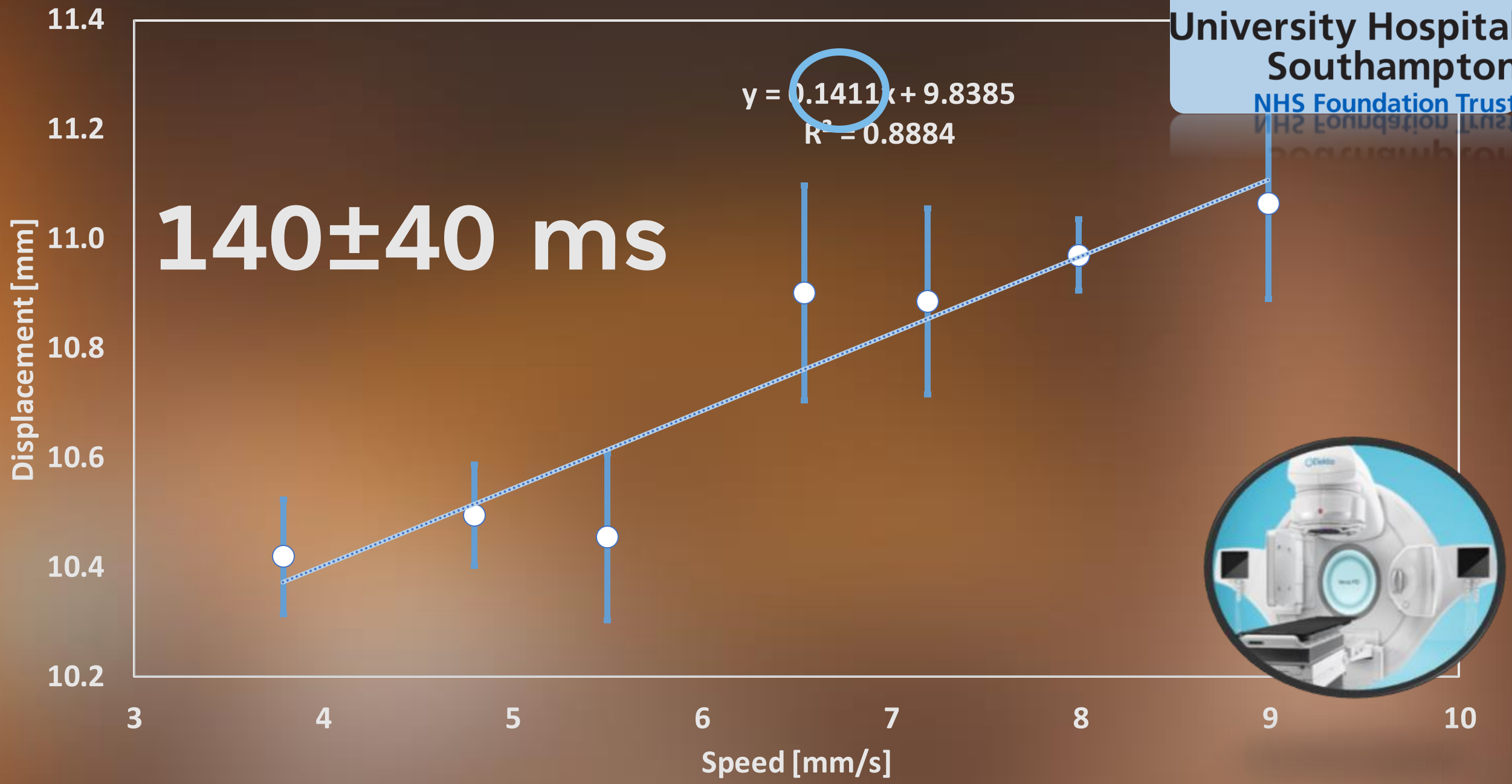
ANALYSIS


0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.1
Pixel gray value
5
25
45
65
85
Displacement [pixel number left->right]



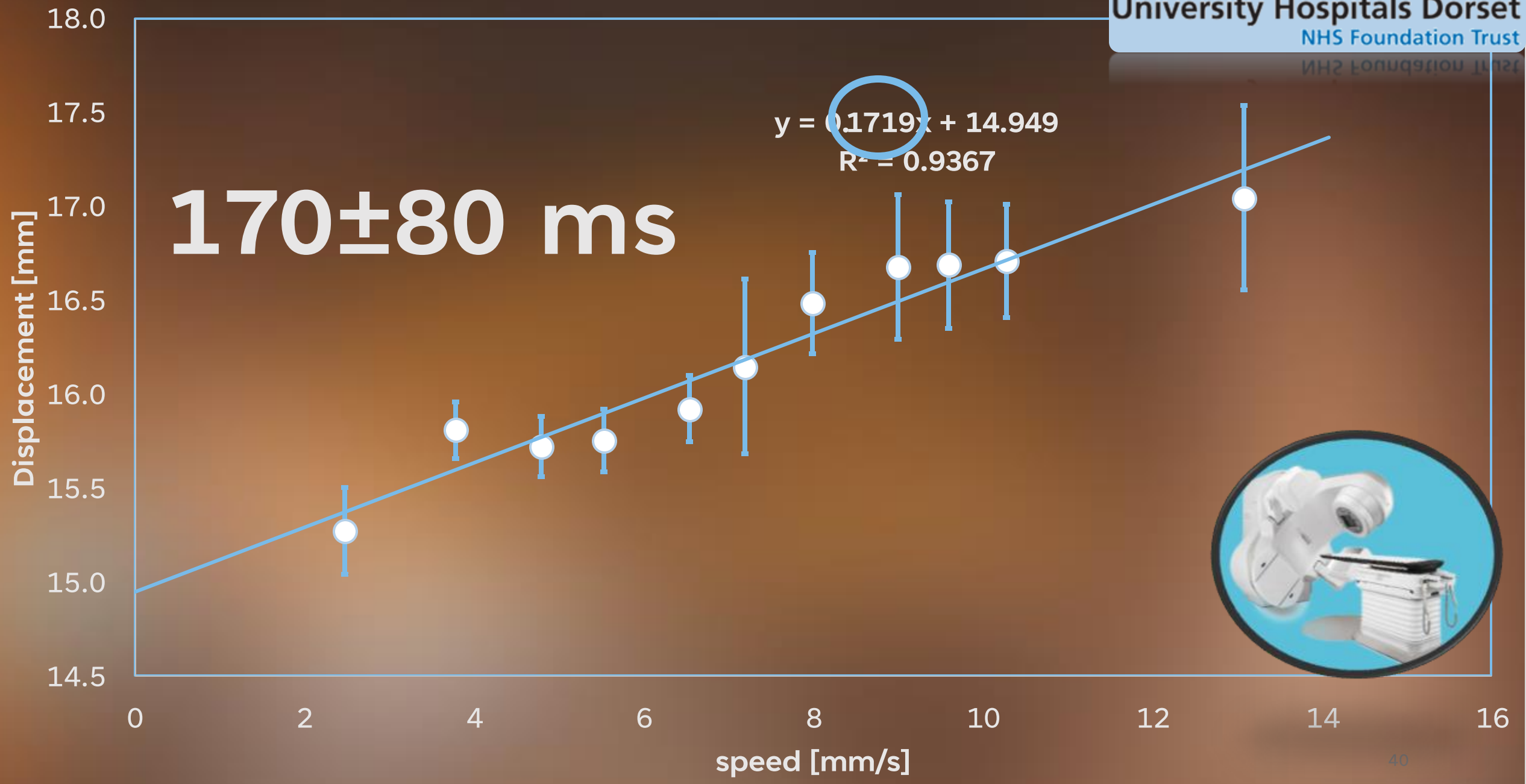

EXPECT
DELAYS

UH Southampton (Elekta Versa HD) Latency

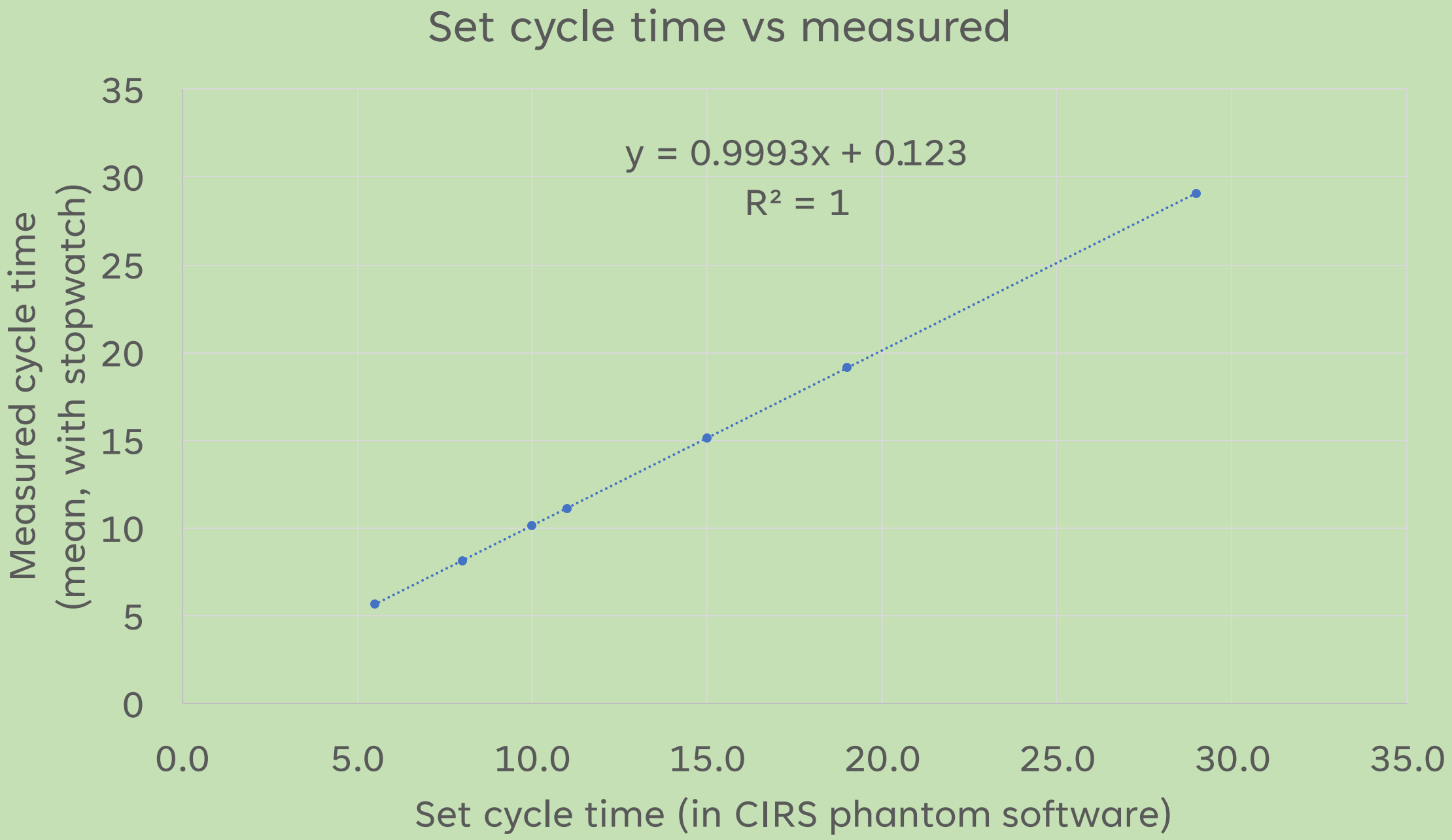


NHS
University Hospital Southampton
NHS Foundation Trust

UH Dorset (TrueBeam) Latency



UNCERTAINTIES


Set cycle time vs measured
y = 0.9993x + 0.123
R² = 1
Measured cycle time
(mean, with stopwatch)
35
30
25
20
15
10
5
0
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
Set cycle time (in CIRS phantom software)

30 APPENDIX M PERFORMANCE AND ACCURACY CLAIMS

The performance and accuracy claims for AlignRT are listed below[8 9 10].

Note: All performance claims relate to the Product configuration(s) (including hardware) in manufacture at the point of release of this documentation. Older versions of Product that are upgraded to later or current software may not achieve the same levels of performance.

Feature	Claim		
Accuracy	**Absolute Positioning Accuracy** relative to MV or kV isocentre position[11]	≤0.5mm translations ≤0.5° rotations	
	Motion Monitoring Accuracy[12] (0° couch rotation with no camera occlusions at mid-isocentre point)	Advanced Camera Optimization (ACO)[13] ≤0.2mm translations ≤0.1° rotations	Raised Plate Calibration ≤0.5mm translations ≤0.3° rotations
	Motion Monitoring Accuracy[14] (at any couch rotation, with some camera pod occlusions due to gantry angle and at deep isocentres ≤18cm)	Advanced Camera Optimization (ACO)[15] ≤0.5mm translations ≤0.2° rotations	Raised Plate Calibration ≤1.0mm translations ≤0.5° rotations
	SSD Measurement Accuracy	Root Mean Square error ≤2.0mm	
Stability	**Variation for every 1° Celsius change in room temperature**[16]	≤0.1mm translations ≤0.01° rotations	
	Stability and Accuracy During 8 Hours of Continuous Monitoring	≤0.2mm translations ≤0.2° rotations	
Speed and Latency	**Surface Monitoring Frame Rate**	Non-SRS 18-25 fps	SRS 7-10 fps
	Time from Detected Out-of-Tolerance Motion to Issuing Beam Hold	Typically: 50-100ms	
	RTC Display Latency (between AlignRT display refresh and RTC display refresh)	≤300ms	

[8]Data is available on request.

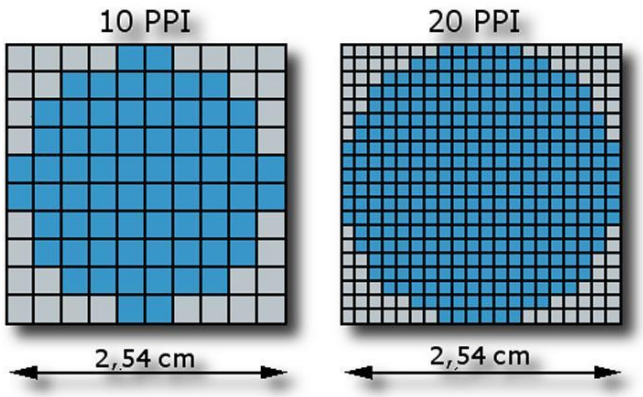
current software may not achieve the same levels of performance.

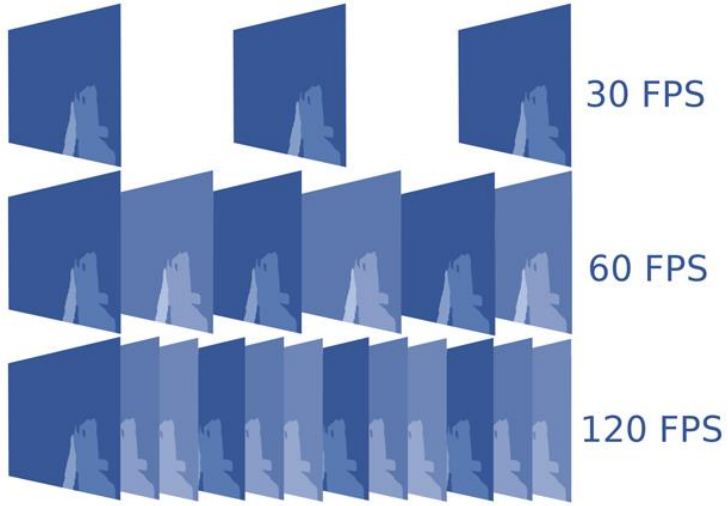
Feature	Claim		
Accuracy	**Absolute Positioning Accuracy** relative to MV or kV isocentre position[11]	≤0.5mm translations ≤0.5° rotations	
	Motion Monitoring Accuracy[12] (0° couch rotation with no camera occlusions at mid-isocentre point)	Advanced Camera Optimization (ACO)[13] ≤0.2mm translations ≤0.1° rotations	Raised Plate Calibration ≤0.5mm translations ≤0.3° rotations
	Motion Monitoring Accuracy[14] (at any couch rotation, with some camera pod occlusions due to gantry angle and at deep isocentres ≤18cm)	Advanced Camera Optimization (ACO)[15] ≤0.5mm translations ≤0.2° rotations	Raised Plate Calibration ≤1.0mm translations ≤0.5° rotations
	SSD Measurement Accuracy	Root Mean Square error ≤2.0mm	

Stability	**Stability and Accuracy During 8 Hours of Continuous Monitoring**	≤0.2mm translations ≤0.2° rotations	
Speed and Latency	**Surface Monitoring Frame Rate**	Non-SRS 18-25 fps	SRS 7-10 fps
	Time from Detected Out-of-Tolerance Motion to Issuing Beam Hold	Typically: 50-100ms	
	RTC Display Latency (between AlignRT display refresh and RTC display refresh)	≤300ms	

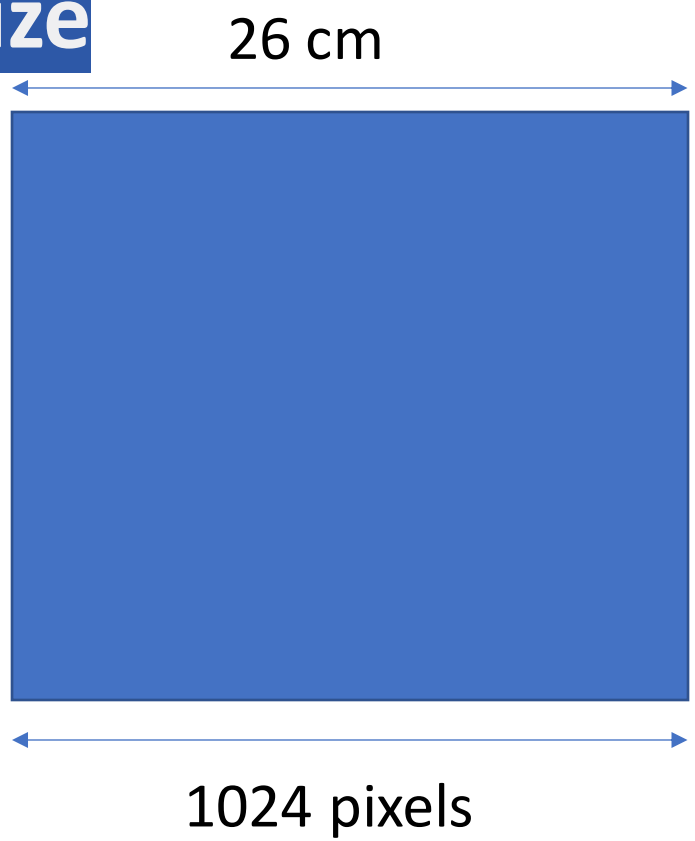
[8]Data is available on request.
[9]Measured on rigid object under controlled conditions.
[10]Figures quoted for standard installation configurations.
[11]On systems calibrated with stereotactic cube calibration.
[12]Motion monitoring accuracy relative to SGRT reference surface.
[13]Requires periodic maintenance visit.
[14]Motion monitoring accuracy relative to SGRT reference surface.
[15]Requires periodic maintenance visit.
[16]Within recommended operating temperature range.

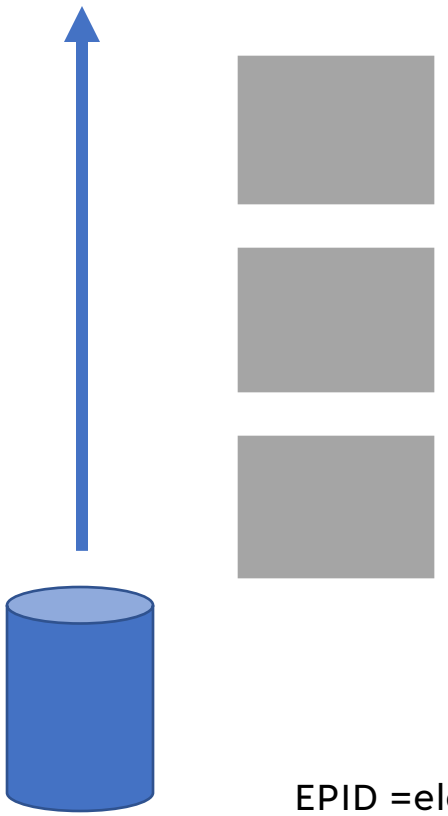
EPID uncertainties





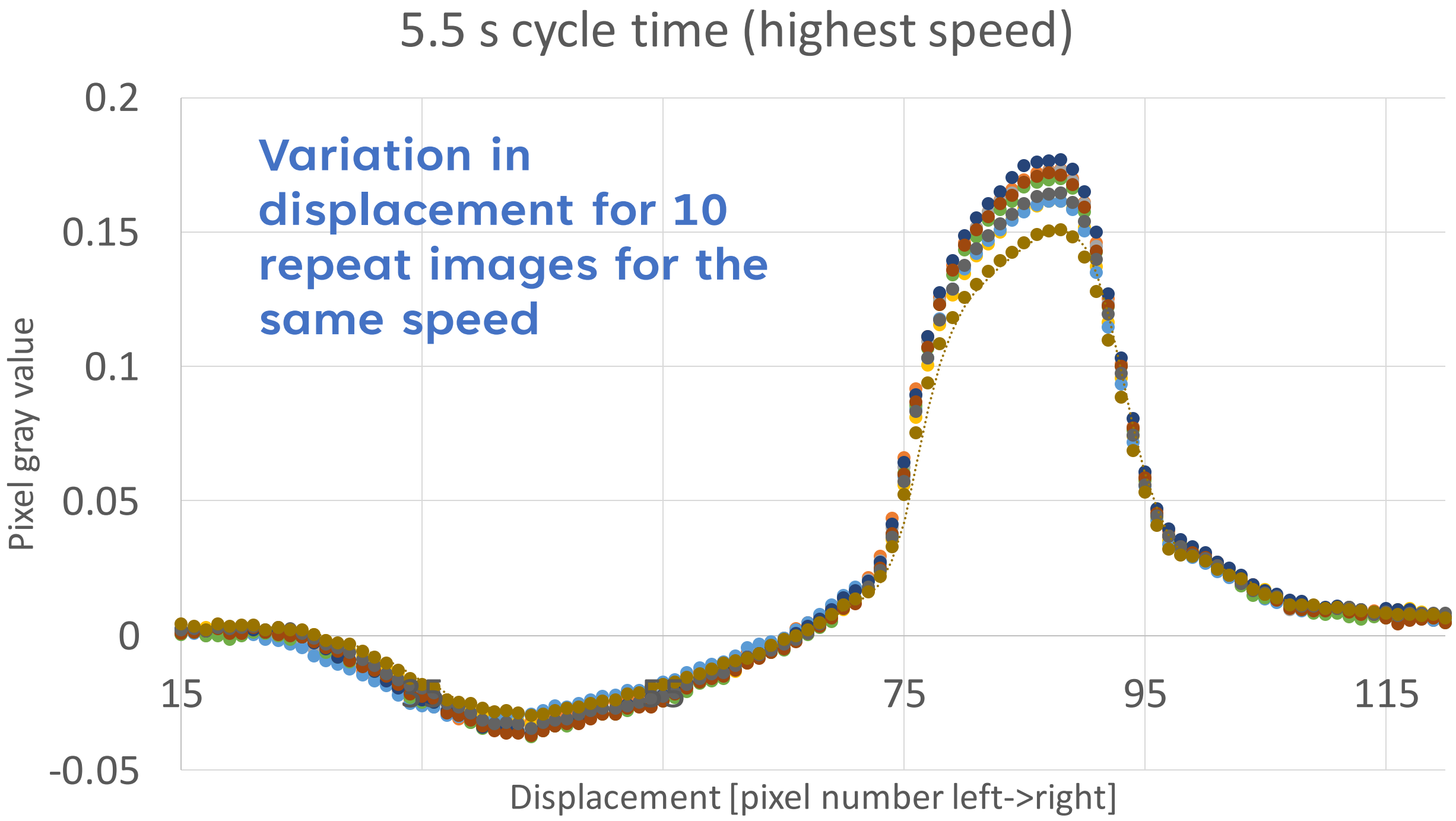
- **Pixel size**





- **Frame Rate**

EPID =electronic portal imaging device aka MV panel


5.5 s cycle time (highest speed)
Variation in displacement for 10 repeat images for the same speed
0.2
0.15
0.1
0.05
0
-0.05
Pixel gray value
15
75
95
115
Displacement [pixel number left->right]

CONCLUSION

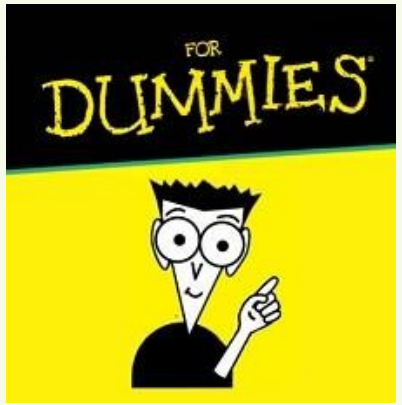
FUTURE PLANS

DIODE BSc PROJECT

METHOD AND LINAC COMPARISON

BEAM ON

DUMMIES GUIDE!



THANK YOU / QUESTIONS?

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