QUANTIFICATION OF BEAM LATENCY USING ALIGNRT

Rachel Barlow & Philip Yeo

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

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

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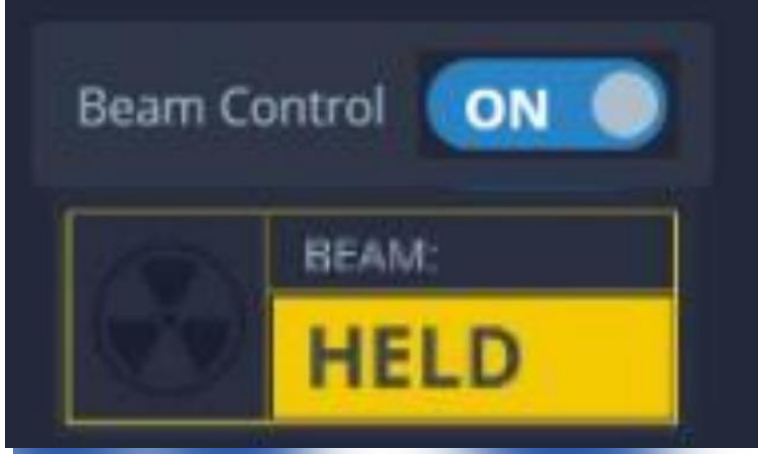
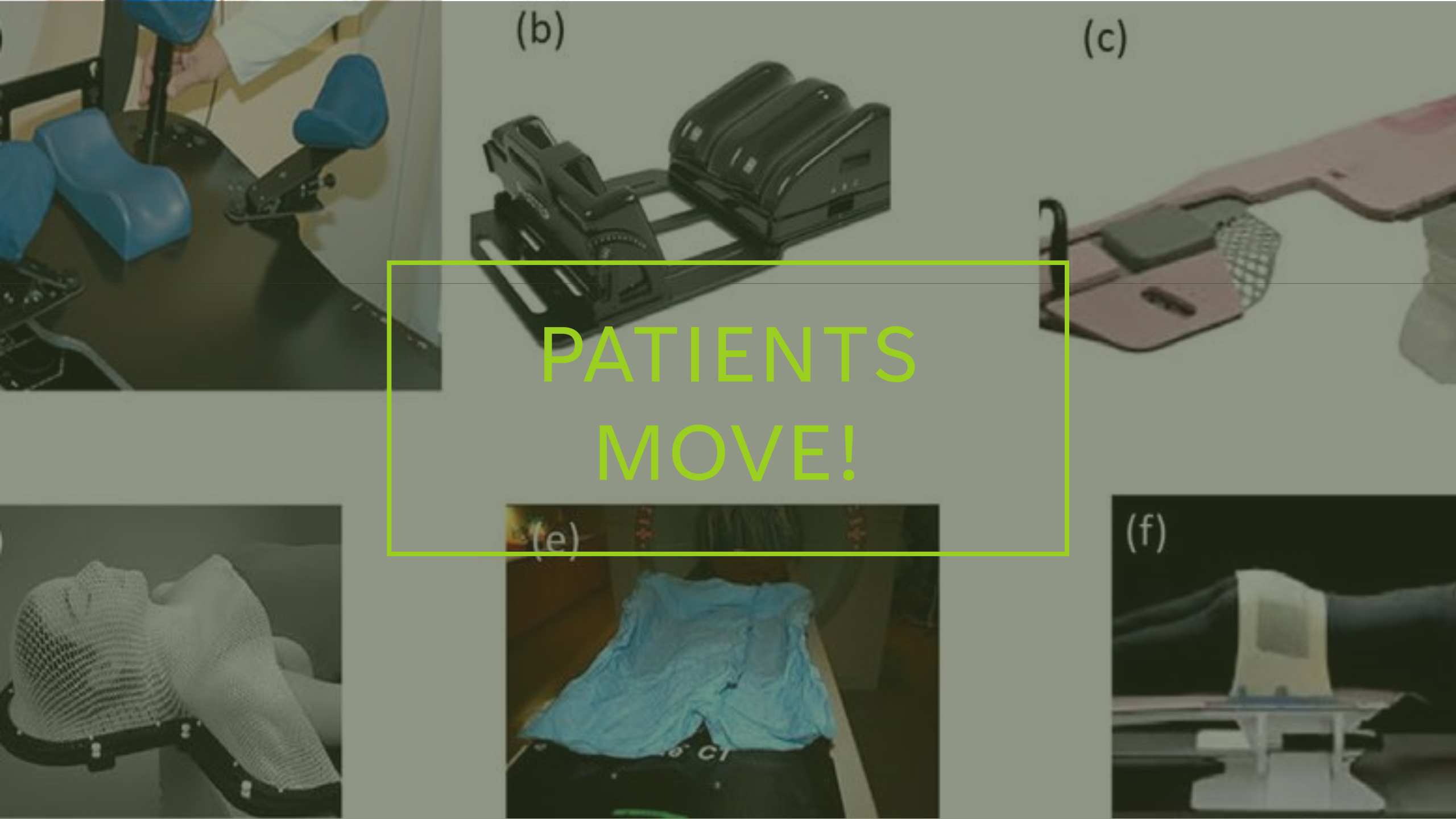
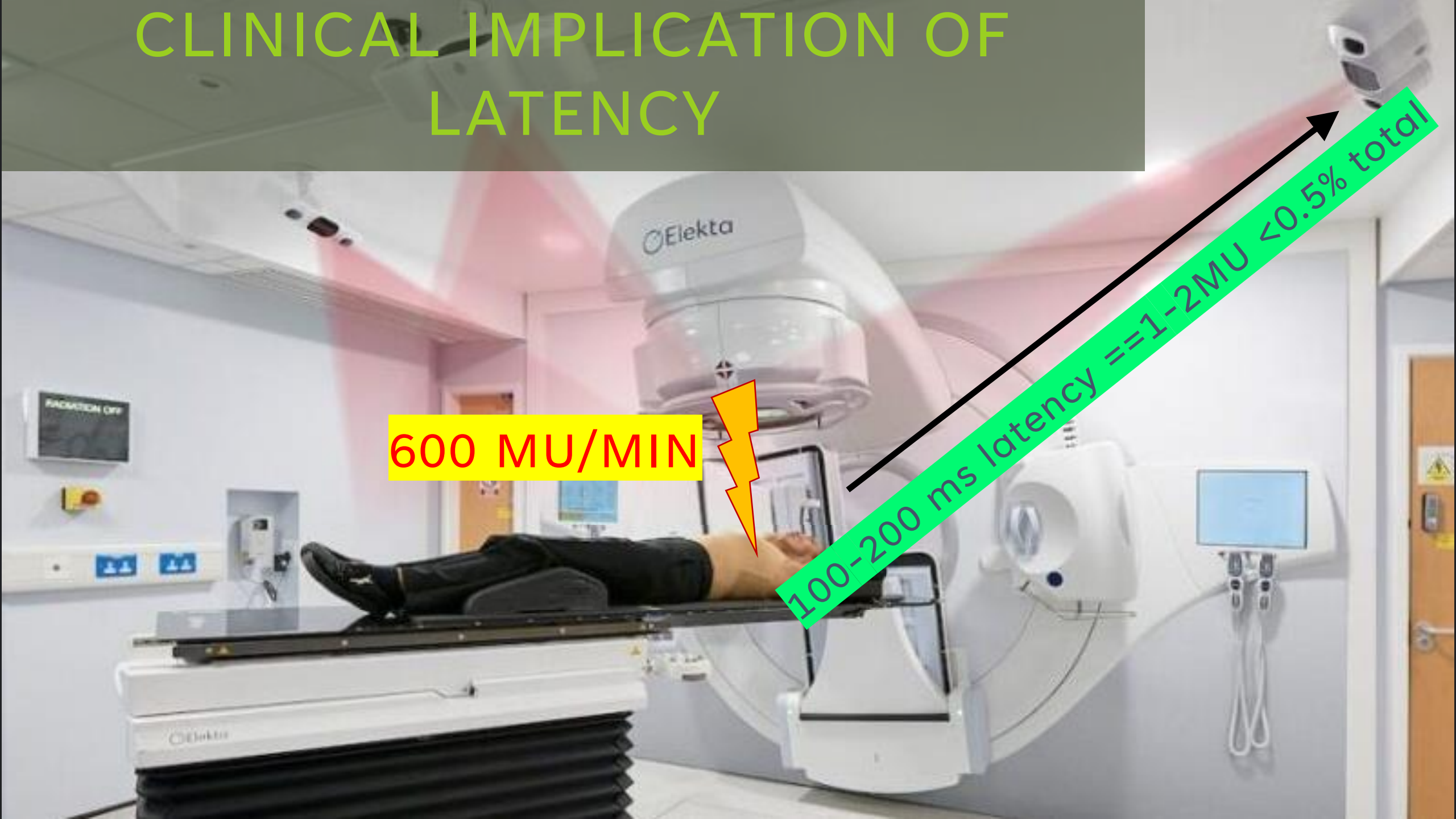


The temporal accuracy/latency for dynamic radiation delivery (i.e., beam hold) and integration with the treatment unit, when available, may affect dosimetric accuracy.[36] Per TG-142, the SGRT system delay should be evaluated for the specific application and deemed appropriate before treatment. While 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,

TG302


(b)
(c)
PATIENTS
MOVE!
(e)
(f)

CLINICAL IMPLICATION OF LATENCY



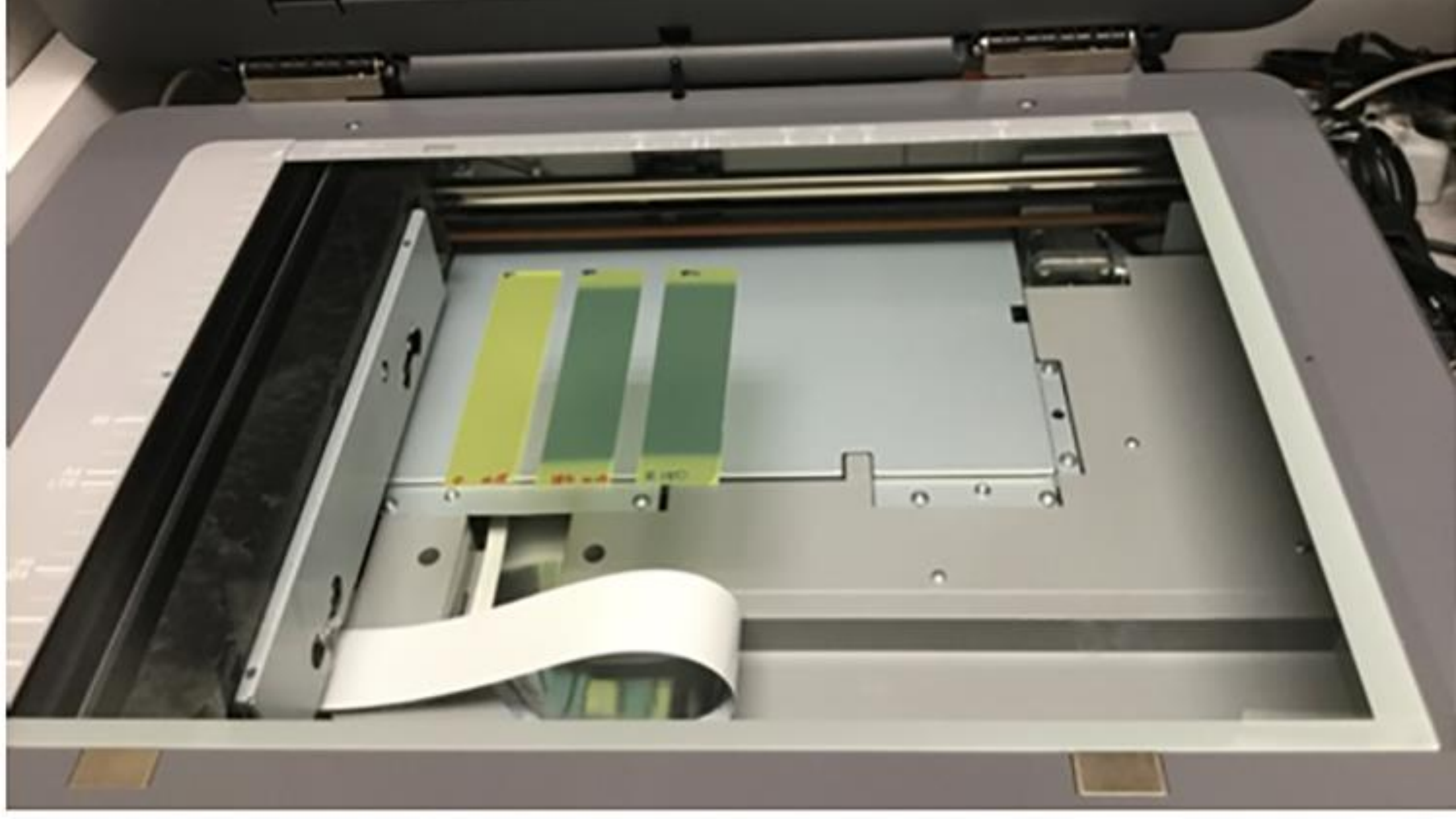
IPEM 81

1.2.1.5 Summary of accuracy requirements

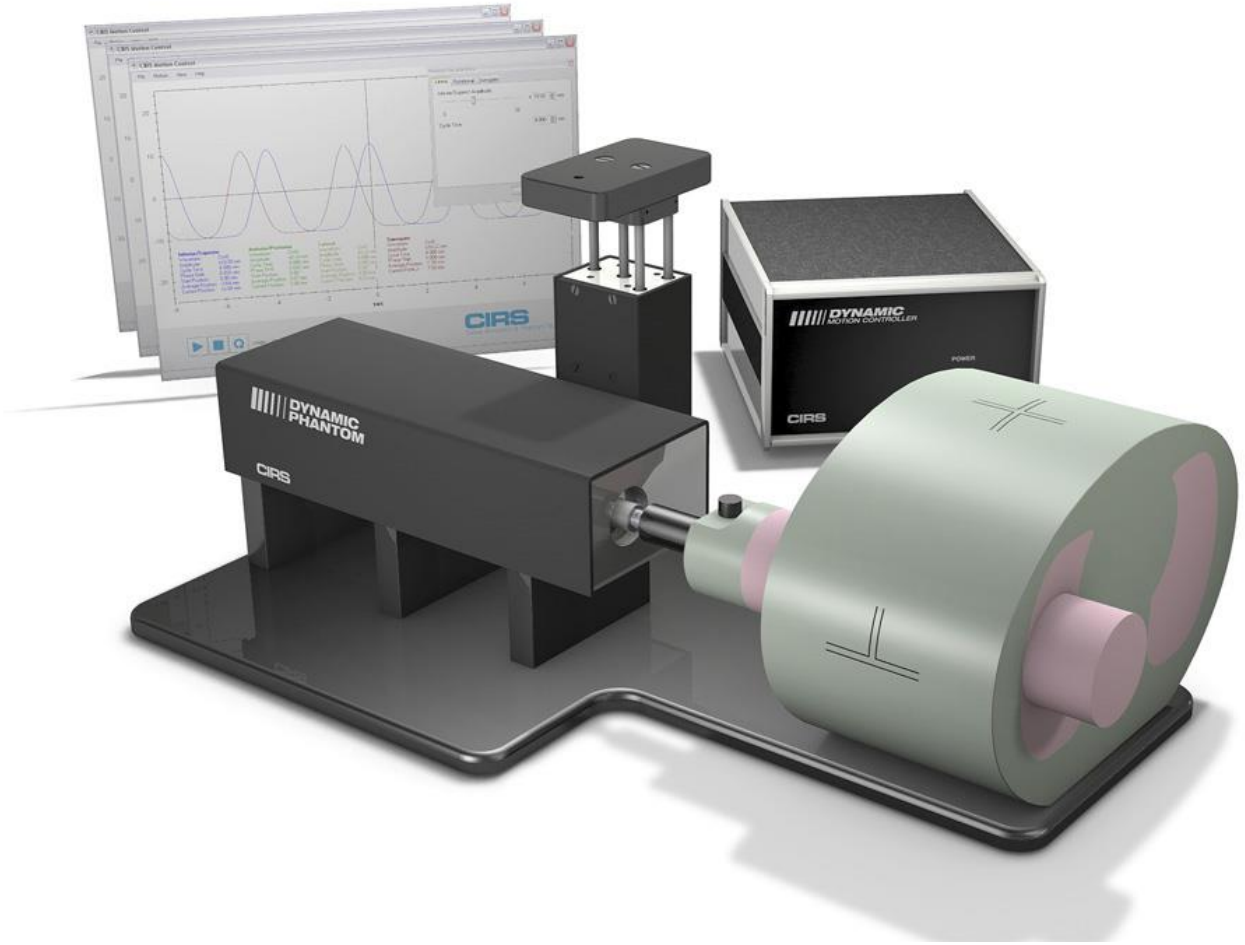
These recommendations concerning accuracy in radiotherapy can be summarised as:

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%

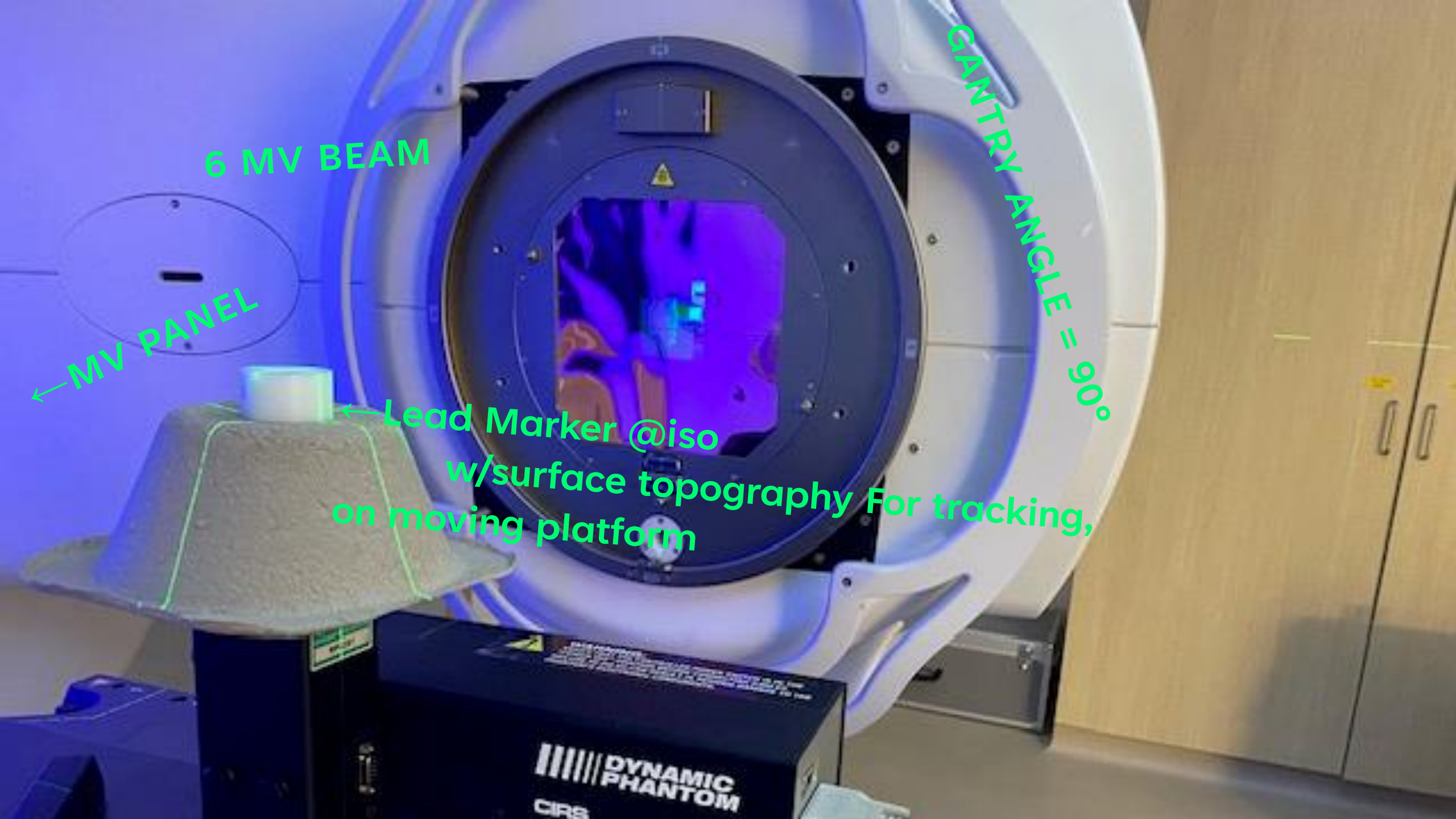


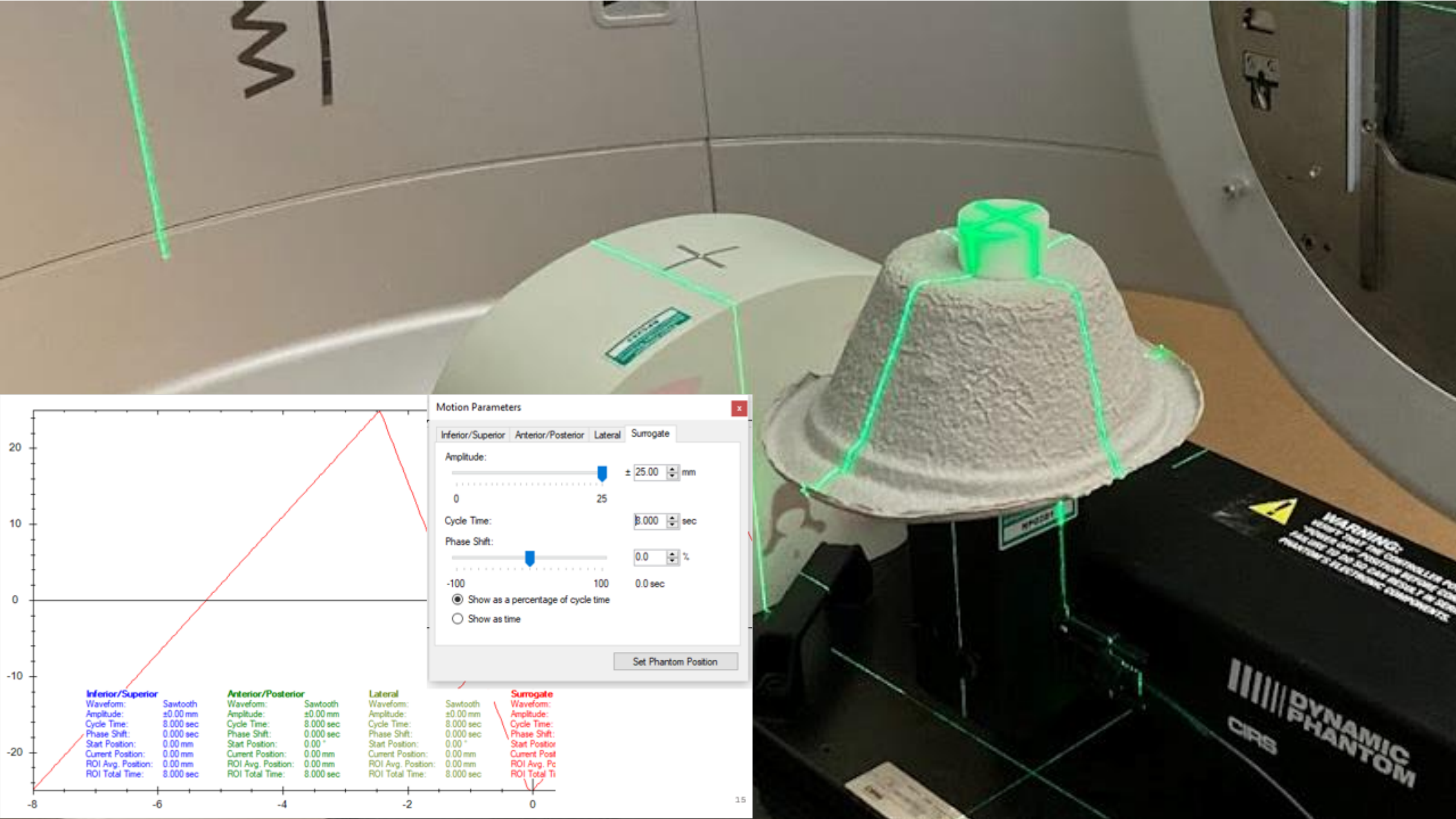
PHANTOM CHOICE

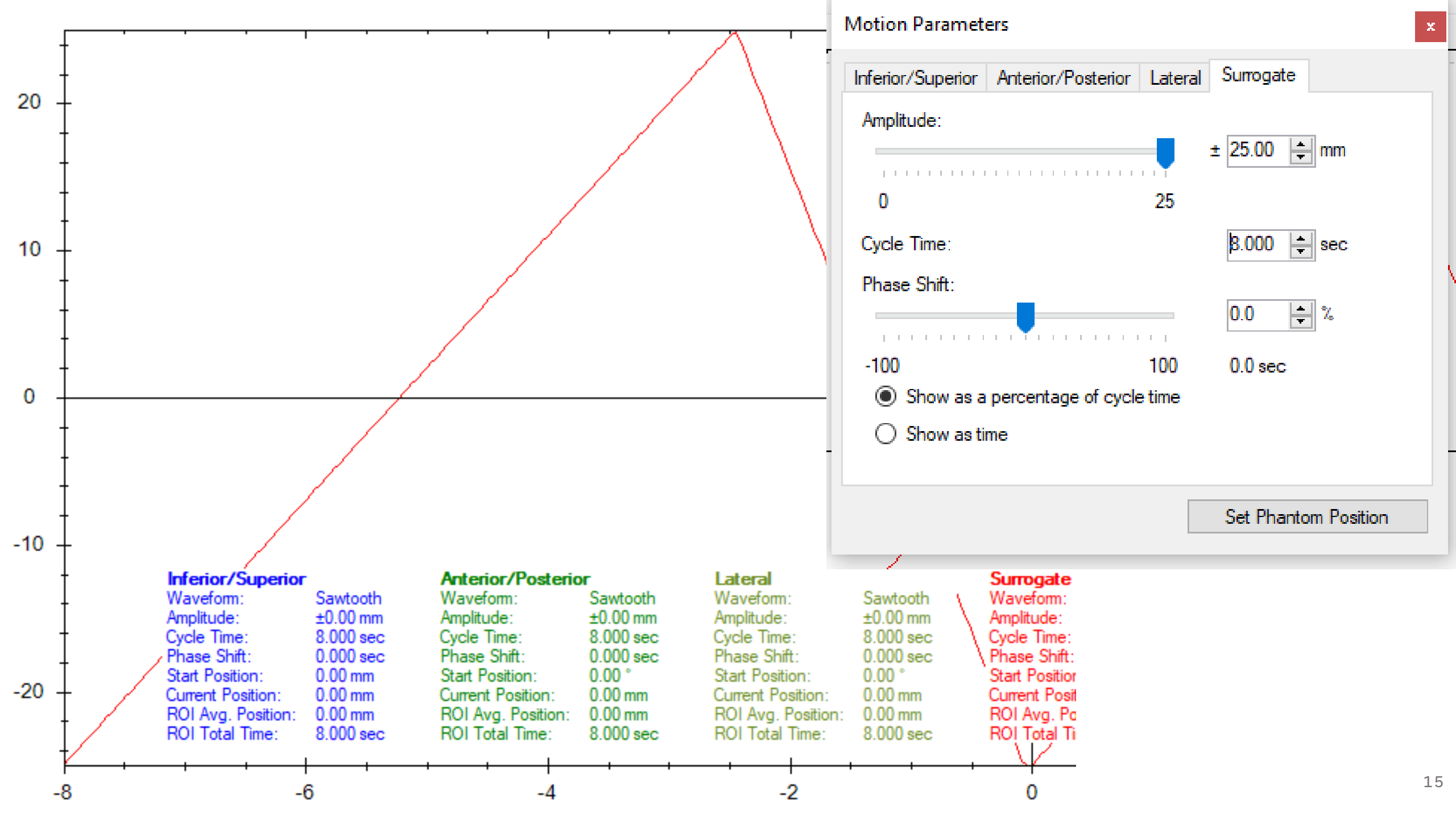


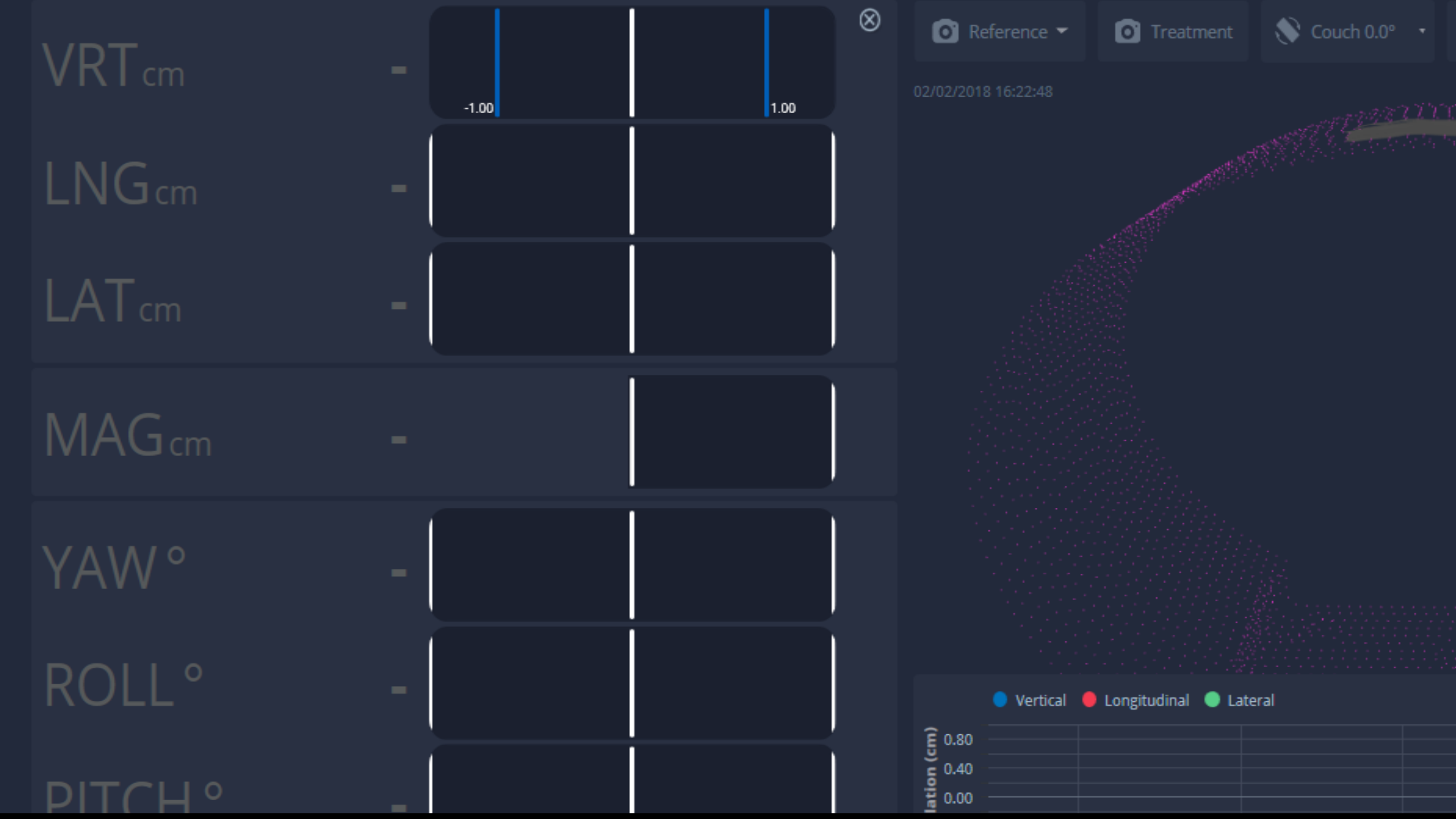
CIRS 4dCT

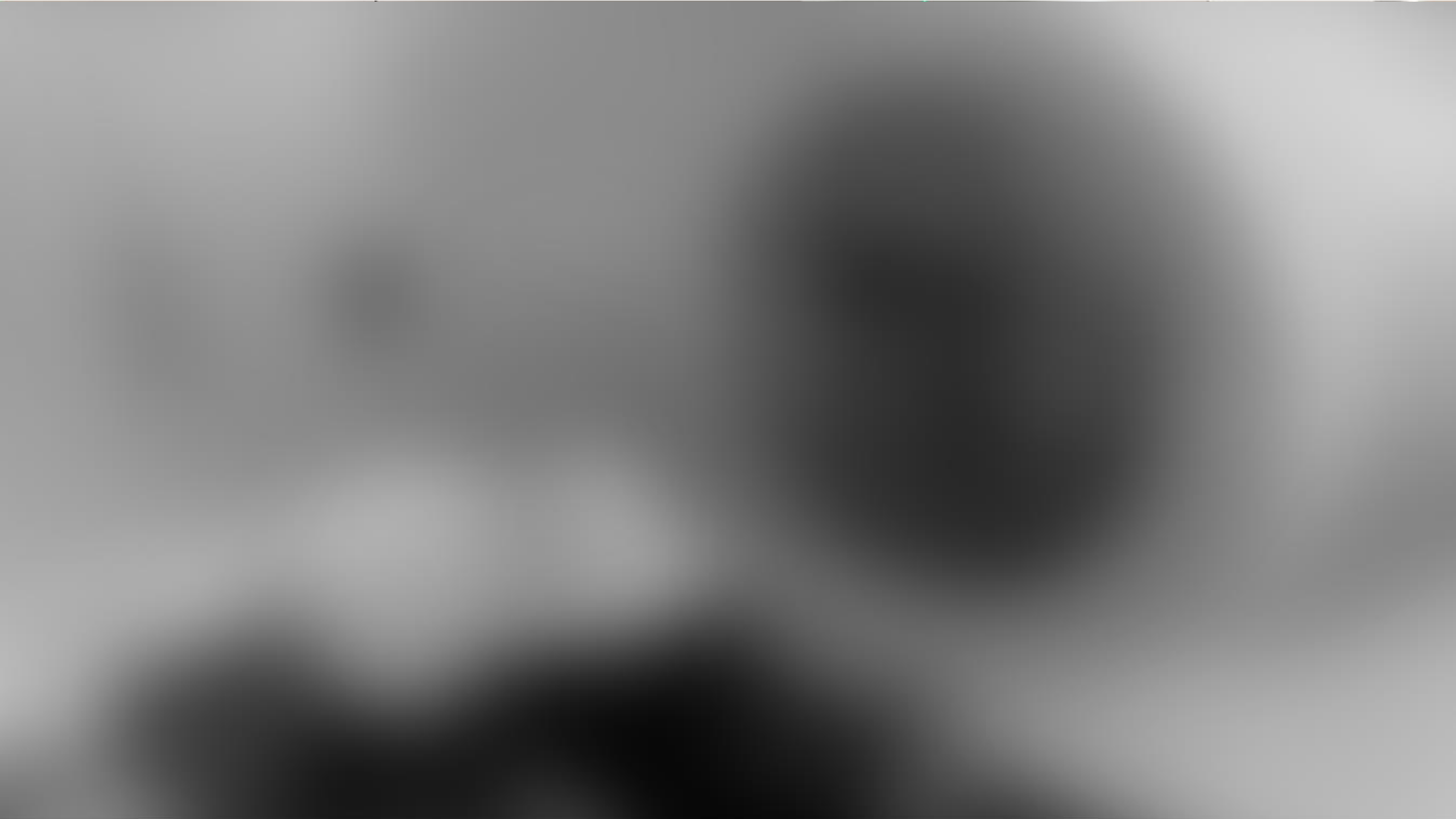

Elekta


6 MV BEAM
←MV PANEL
←Lead Marker @iso
w/surface topography For tracking,
on moving platform
GANTRY ANGLE = 90°
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 Positior
Current Posit
ROI Avg. Pc
ROI Total Ti
20
10
0
-10
-20
-8
-6
-4
-2
0
DYNAMIC PHANTOM
CIRS


20
10
0
-10
-20
-8
-6
-4
-2
0
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. Po
ROI Total Ti
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


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



Lead

- Static
- @0mm

Lead

- Start motion

Lead

- In motion
- @10mm

Lead

- Stopped
- Back @0mm

Linac

- Beam off
- "MV ready" (TB)

Linac

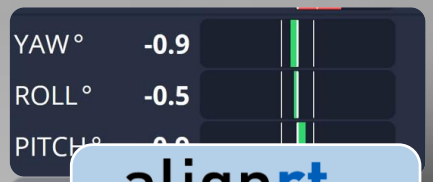
- Beam on
- *User*

trueBEAM

- *AlignRT*

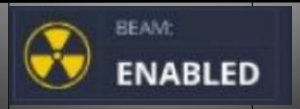
trueBEAM

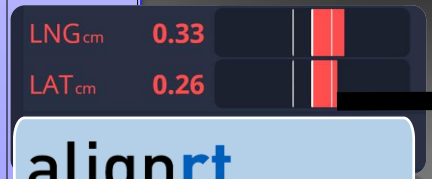
- Beam off
- *User*



alignrt

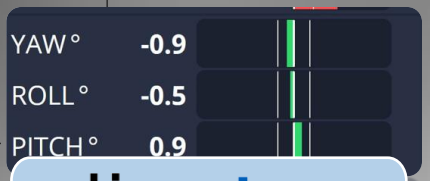
- **Monitoring**
- @0mm vert





alignrt

- Vert RTD = **RED**
- @10mm

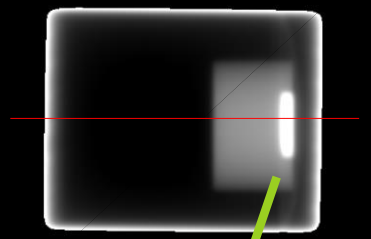


alignrt

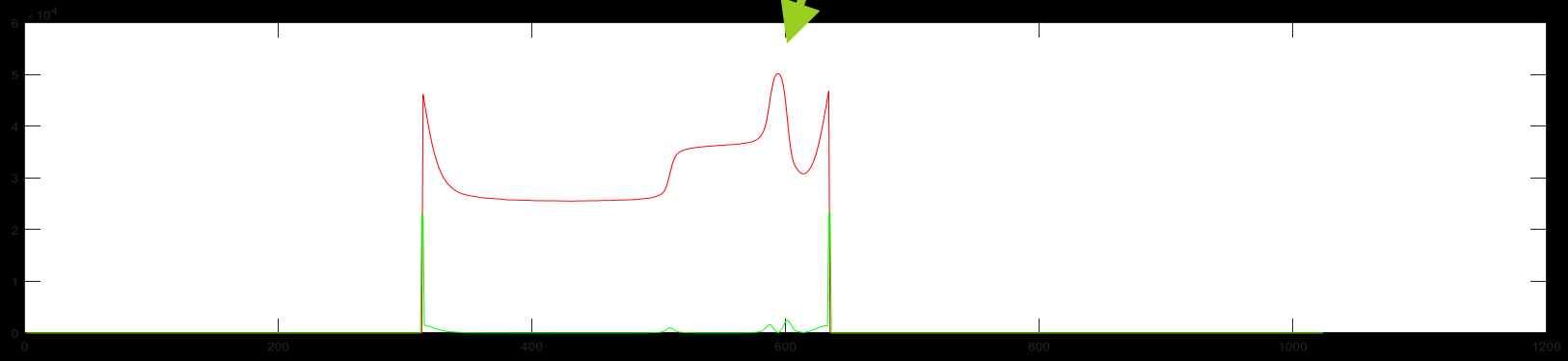
- Vert RTD = **GREEN**
- <10mm

ANALYSIS

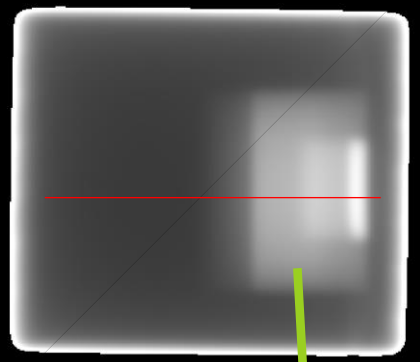
ANALYSIS

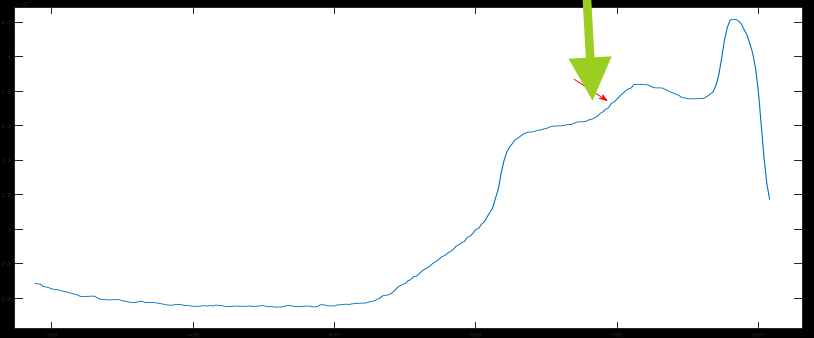


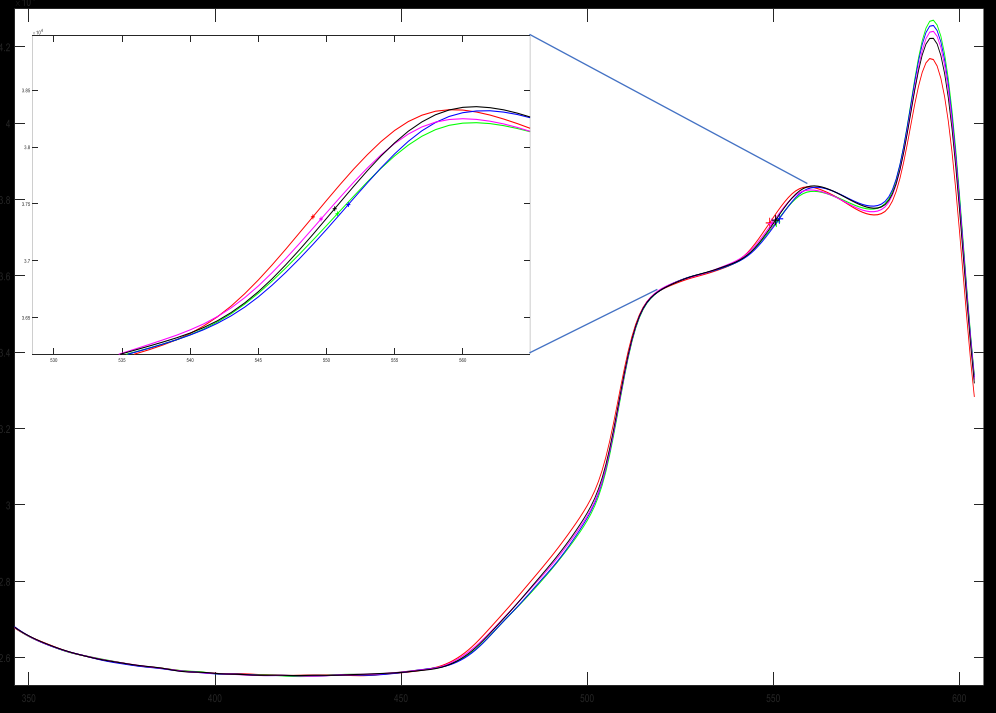
- Locate the pixel position of the lead marker on the EPID image of the static phantom



ANALYSIS

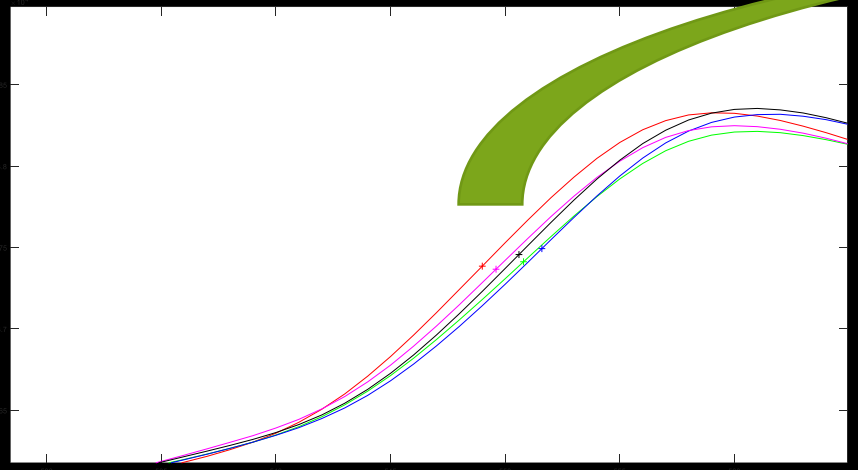


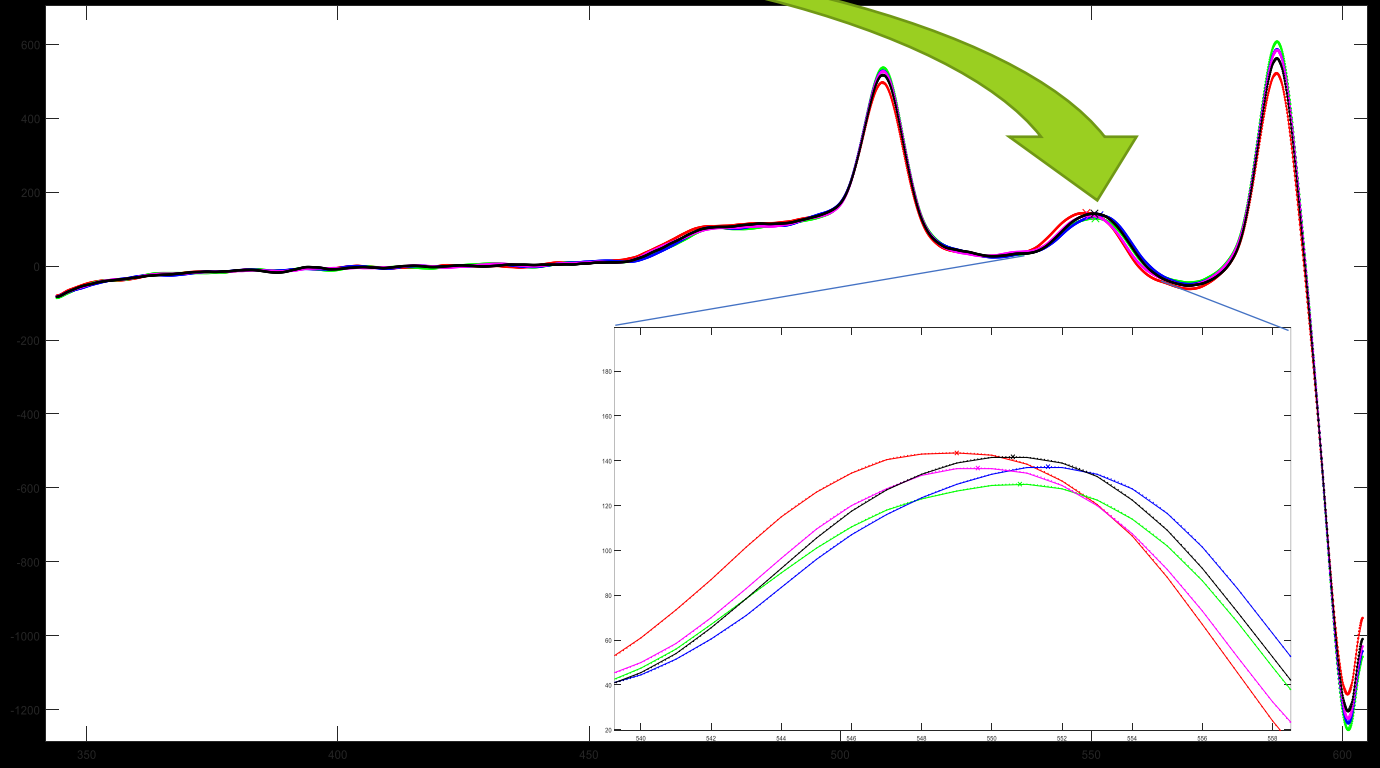




ANALYSIS

Take First Derivative

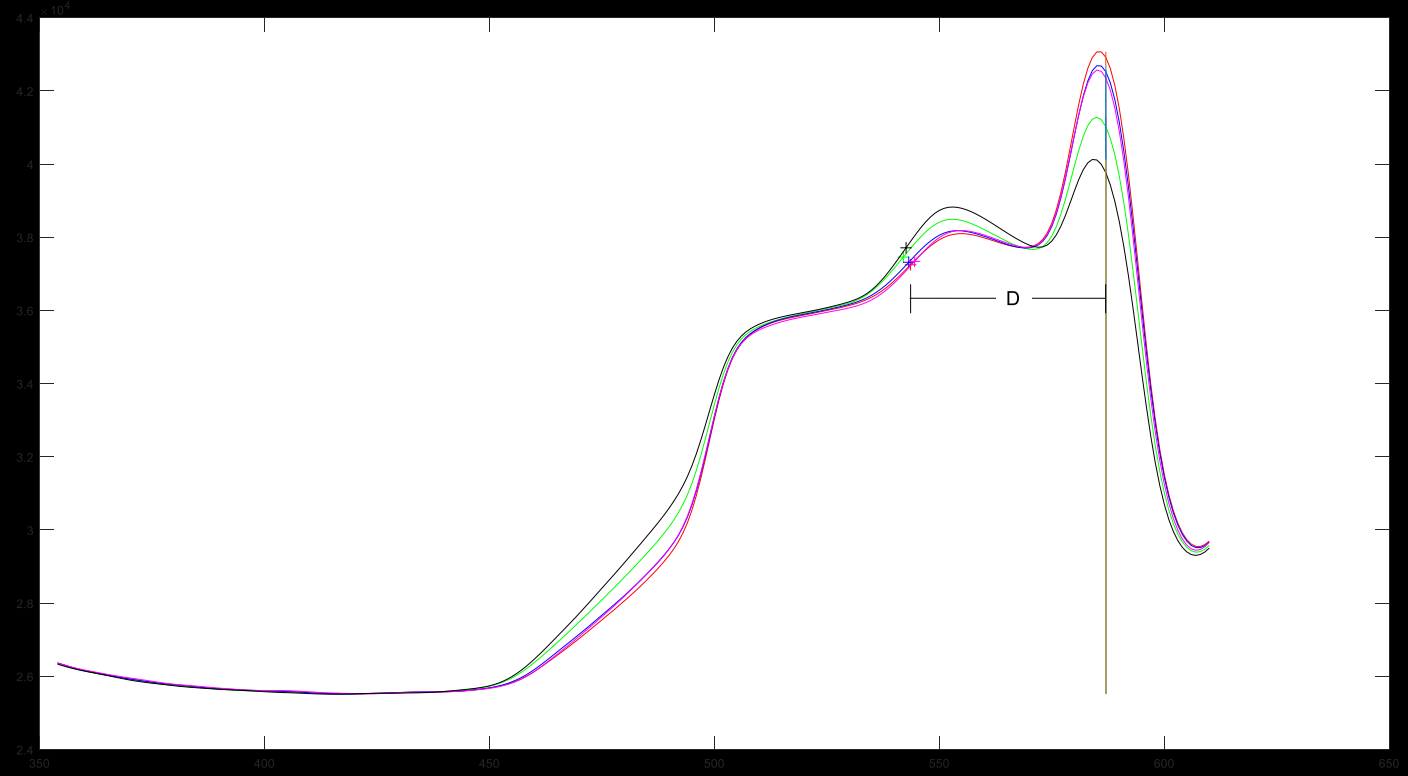




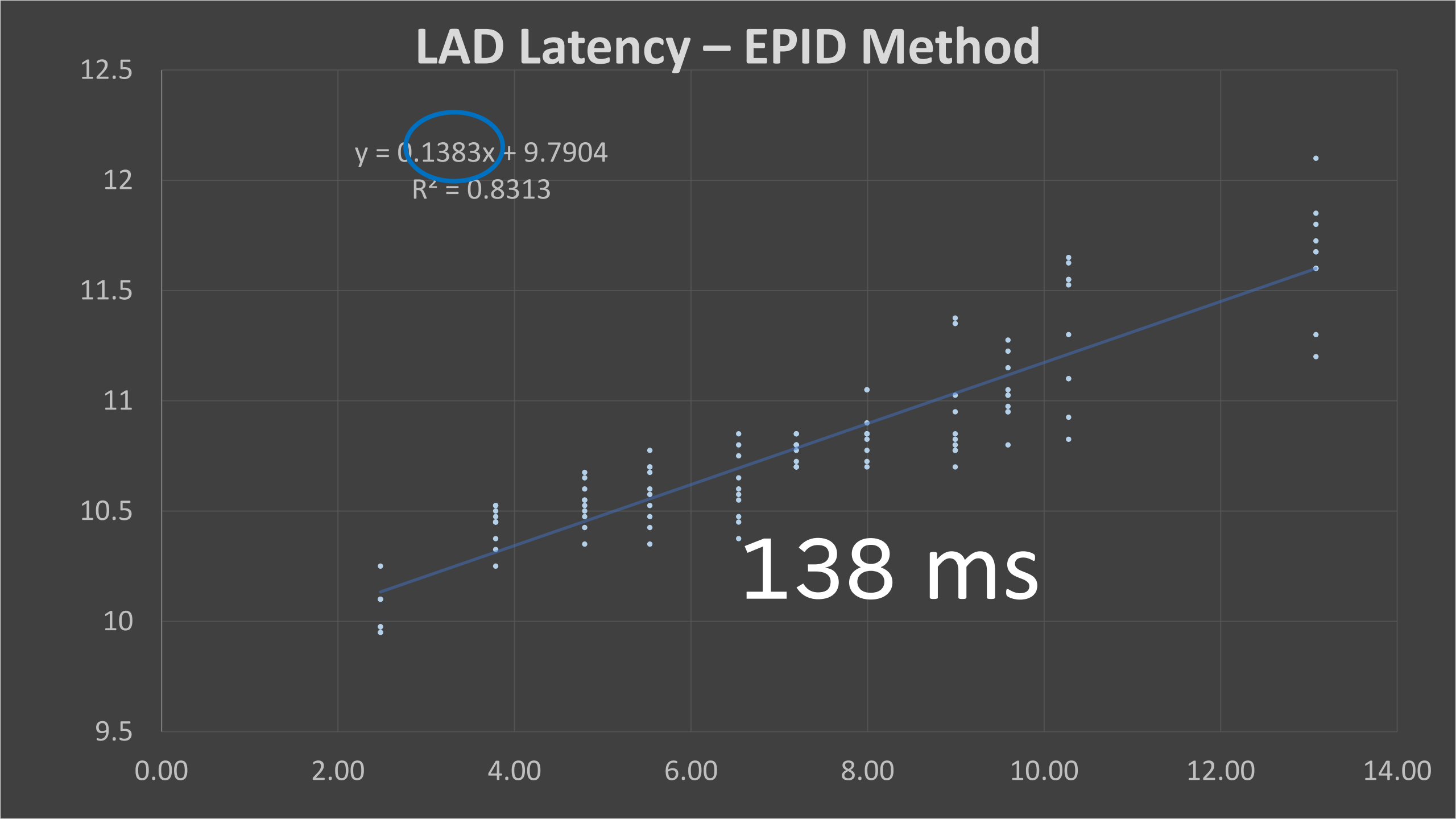
ANALYSIS

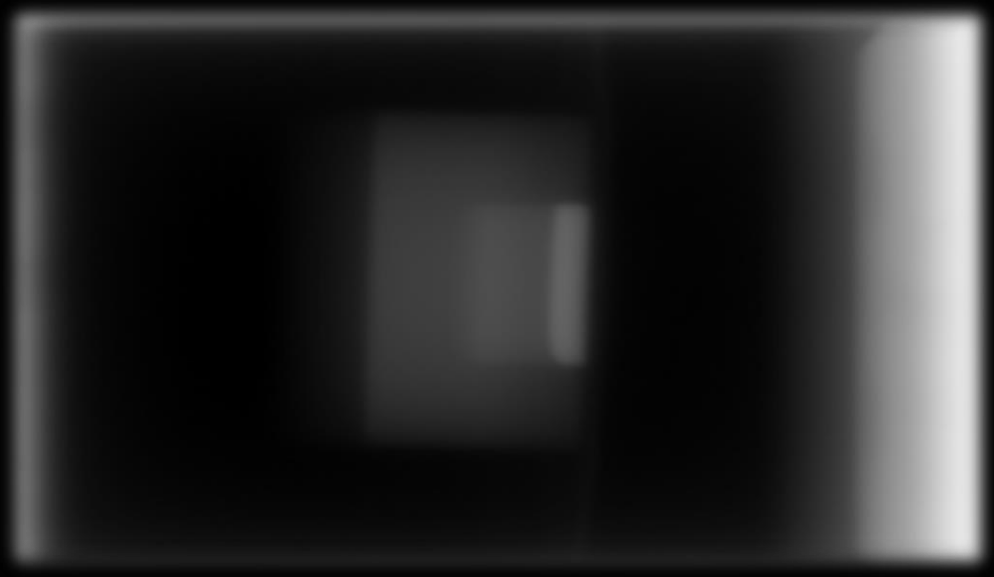
Distance travelled by the Lead Marker in pixels:

$$D = |\text{LeadPosn}_{\text{static}} - \text{LeadPosn}_{\text{moving}}|$$

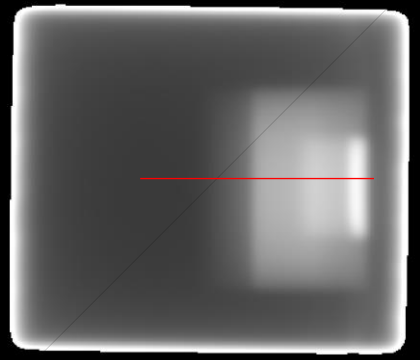


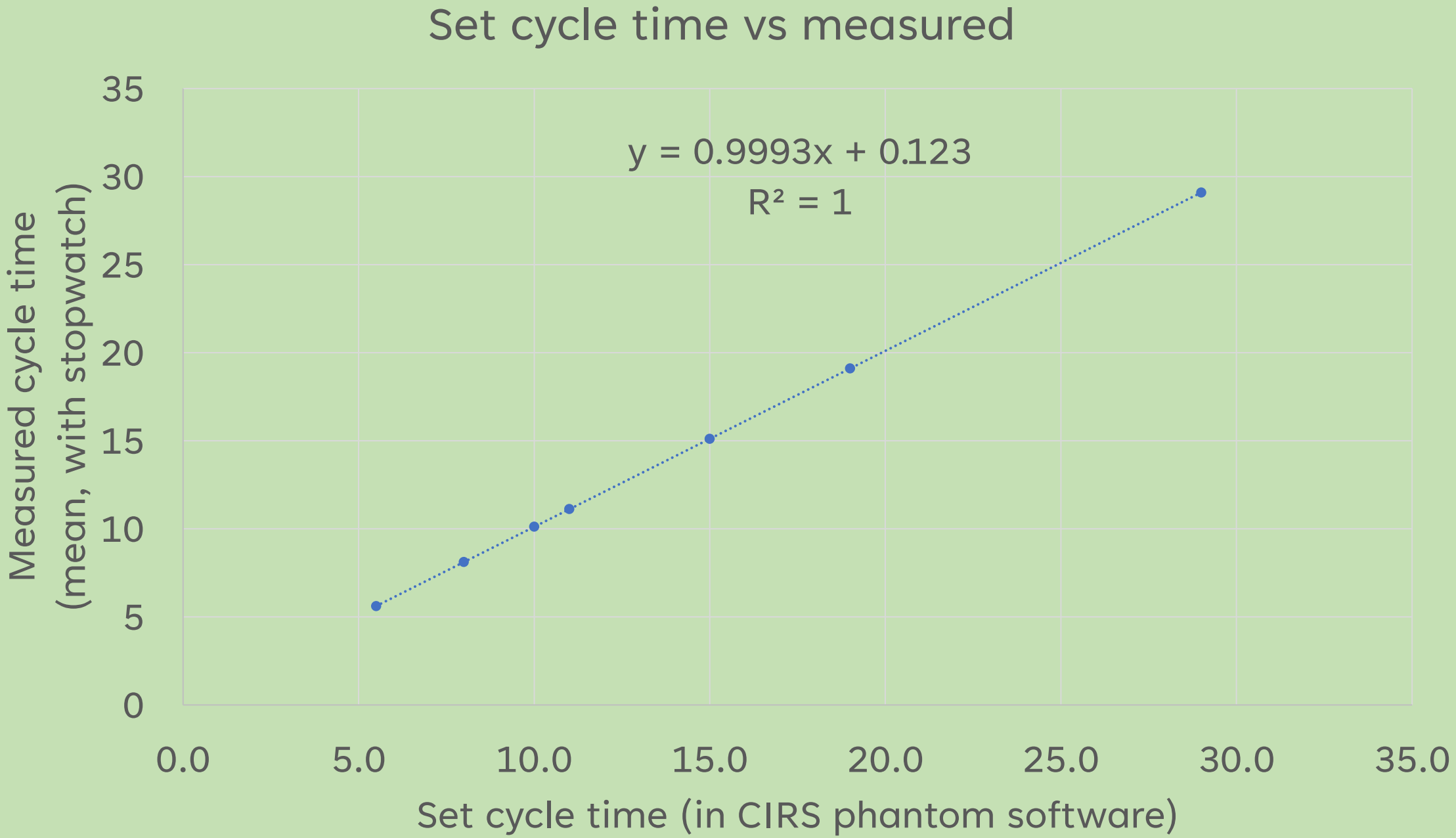

PROJECT
AHEAD


LAD Latency – EPID Method
y = 0.1383x + 9.7904
R² = 0.8313
138 ms
12.5
12
11.5
11
10.5
10
9.5
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00



UNCERTAINTIES




Set cycle time vs measured
y = 0.9993x + 0.123
R² = 1
Measured cycle time
(mean, with stopwatch)
0
5
10
15
20
25
30
35
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	

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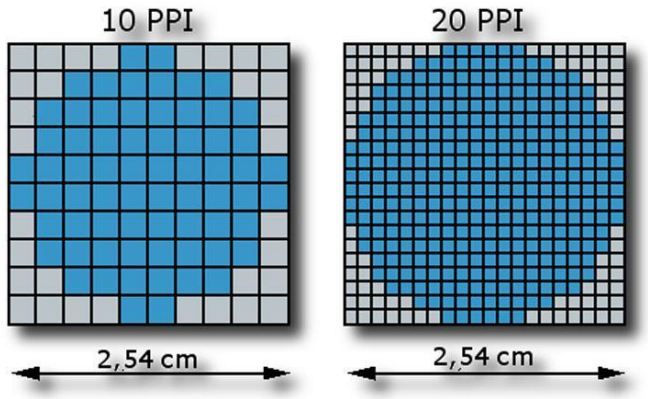
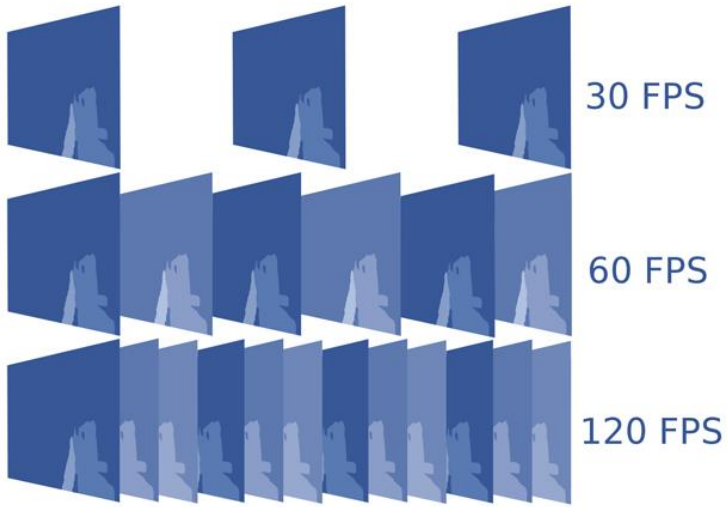
	RTC Display Latency (between AlignRT display refresh and RTC display refresh)	≤300ms	

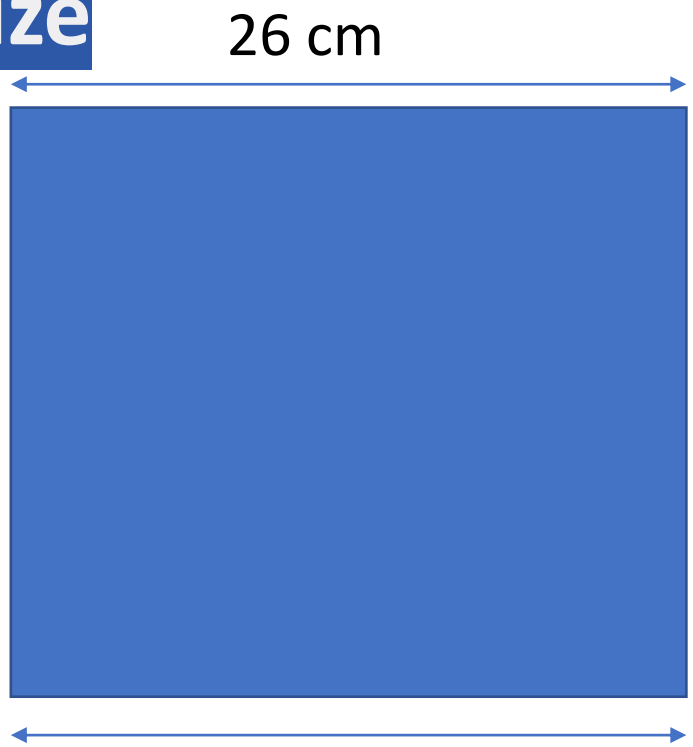
[8]Data is available on request.
[9]Measured on rigid object under controlled conditions.
[10]Figures quoted for standard installation configurations.
[11]On systems calibrated with stereotactic cube calibration.
[12]Motion monitoring accuracy relative to SGRT reference surface.
[13]Requires periodic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

EPID uncertainties

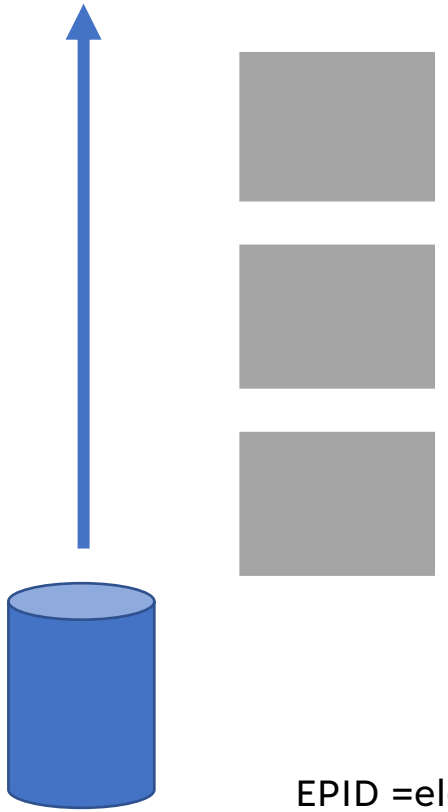




- **Pixel size**



- **Frame Rate**



EPID =electronic portal imaging device aka MV panel

Project aims and methods

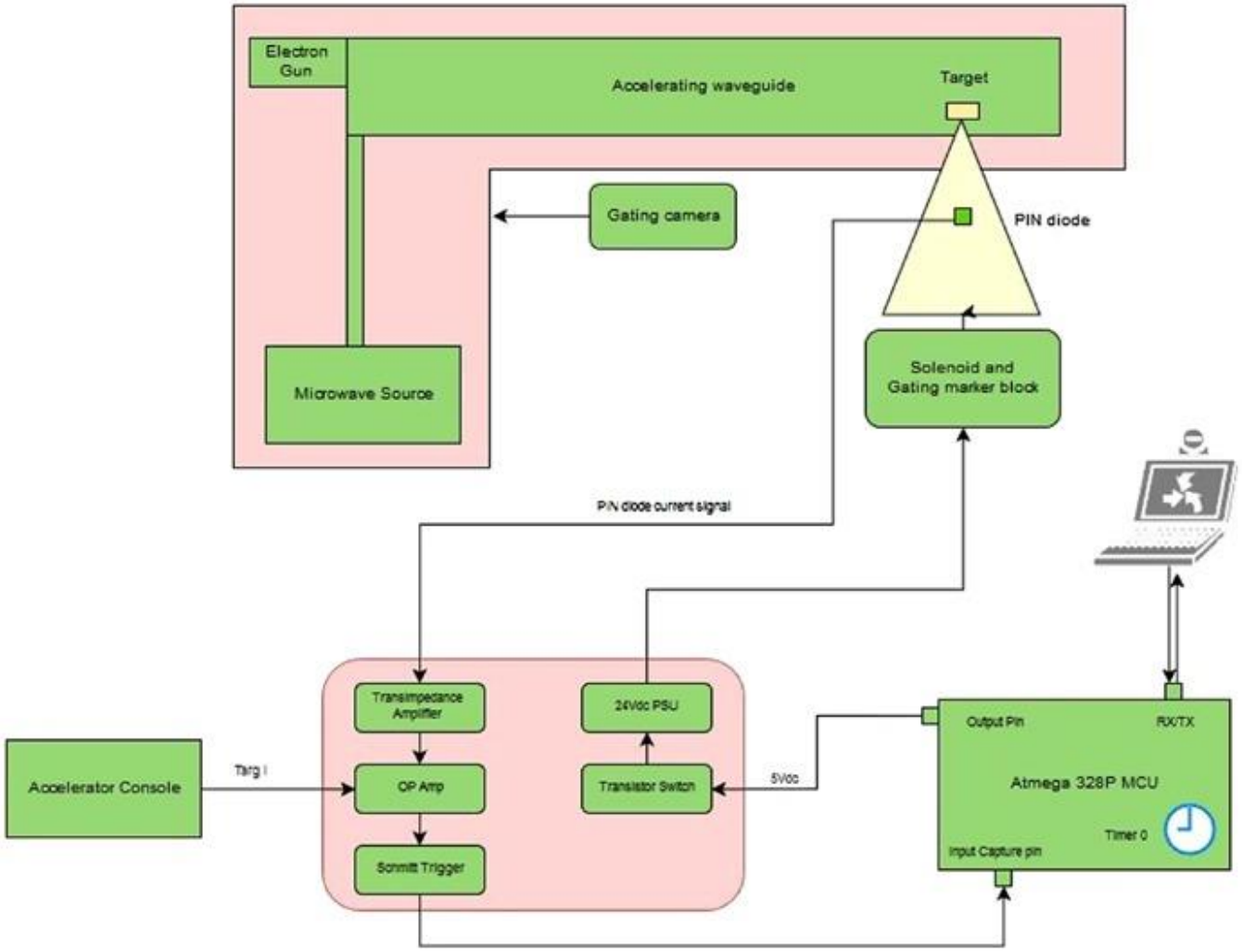
Create an electronics-based method to characterise gating latency in AlignRT.

Easily repeatable for routine QA.

UHS and BNHH: Elekta Linacs.

Compare results against portal imaging method and literature.

Literature inspiration



(Lempart, et al., 2016)

Solenoid Phantom

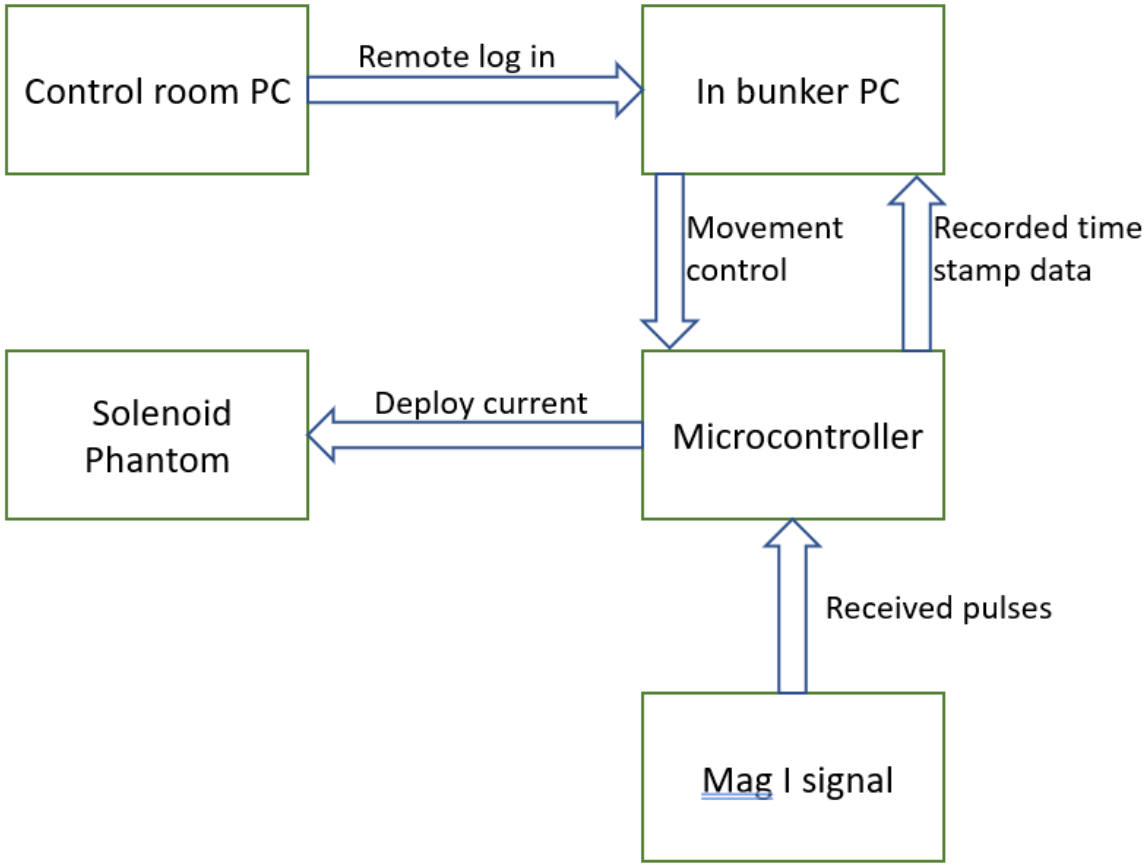
Targ I

PIN diode circuit

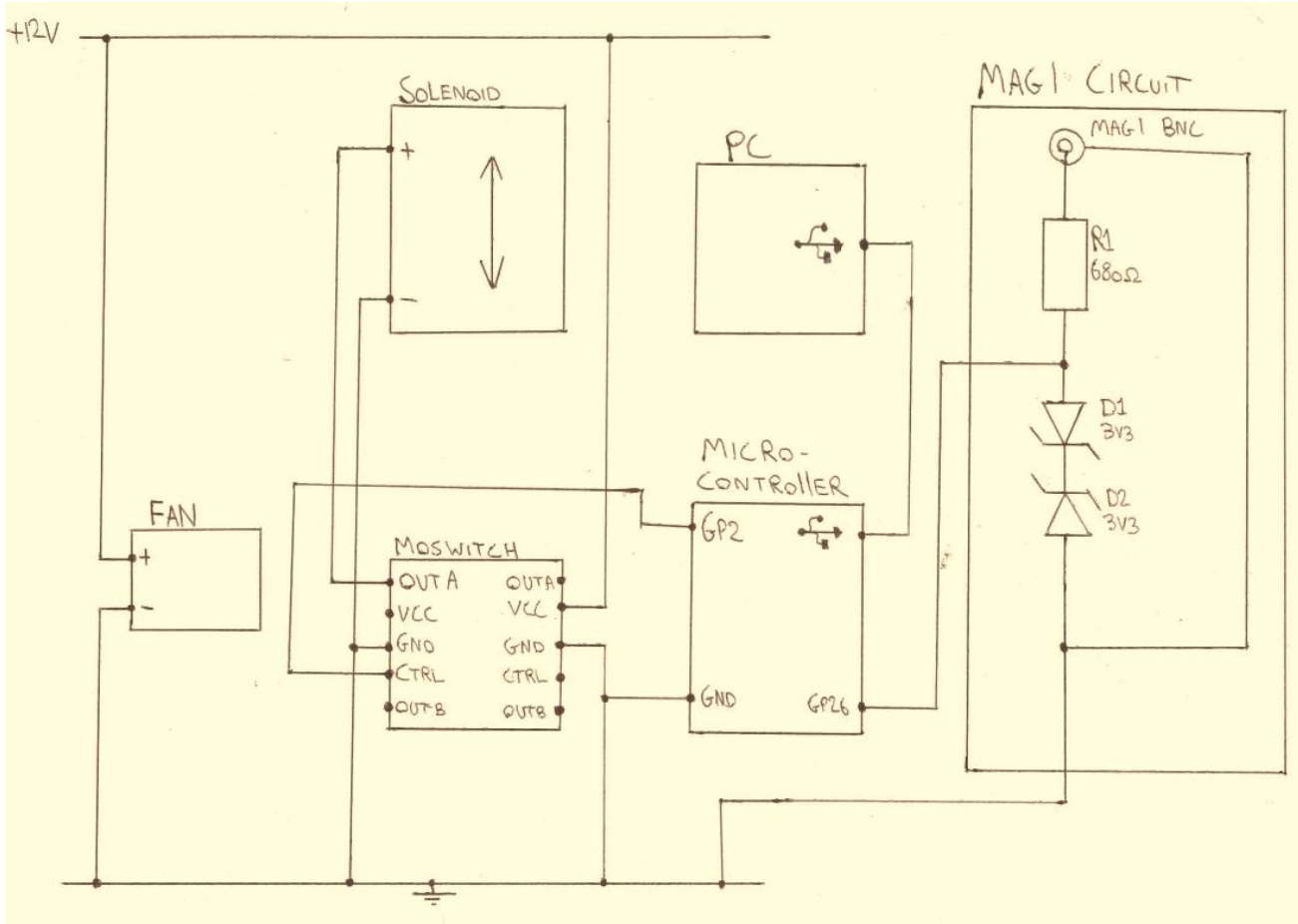
Device development and data collection

Magnetron Current circuit and Solenoid phantom

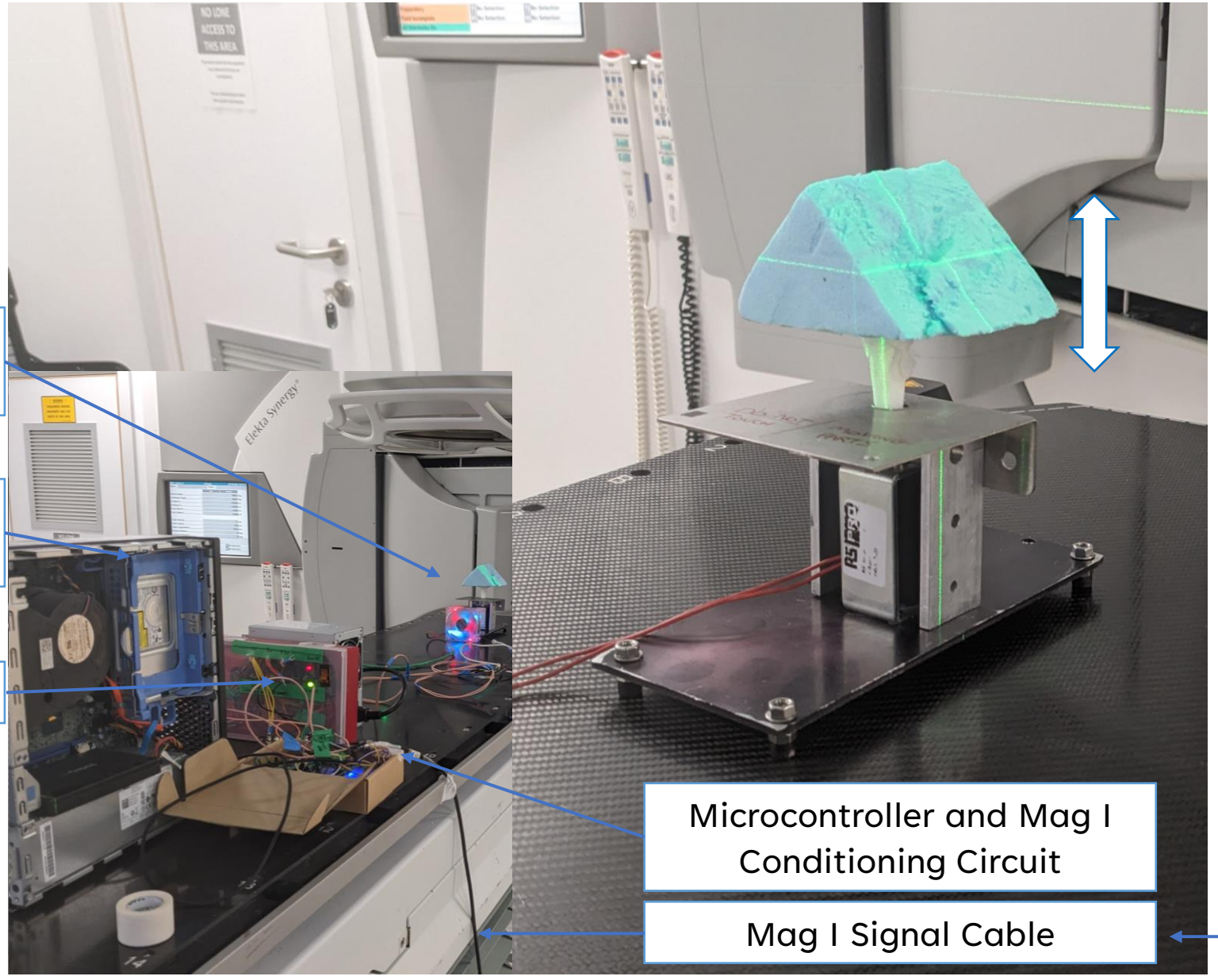
System Diagram



System Circuit Diagram



Device development and data collection

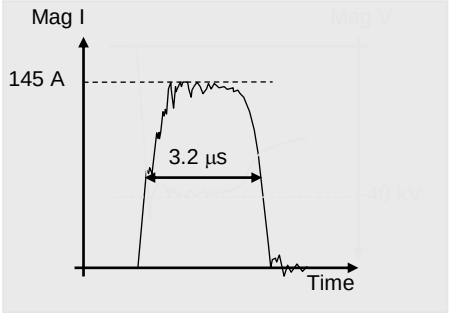


Time stamps generated when:

- Phantom moves in and out of gating tolerance.

- Every Mag I pulse.

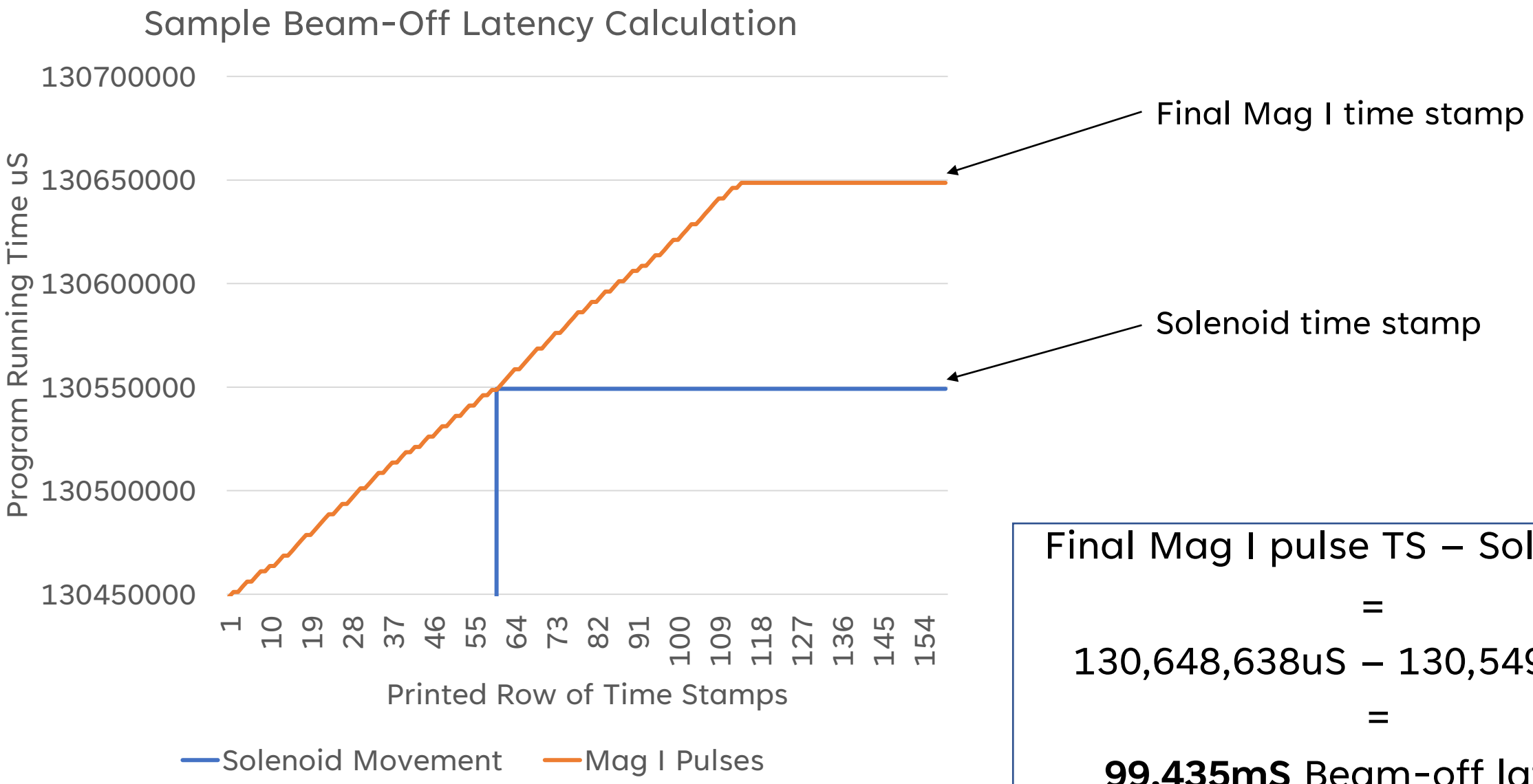
- Data sampled at 800Hz (every 1.25mS).



Device development and data collection

Phantom in and out of vertical tolerance

Data analysis method (beam-off latency)



Final Mag I pulse TS – Solenoid TS

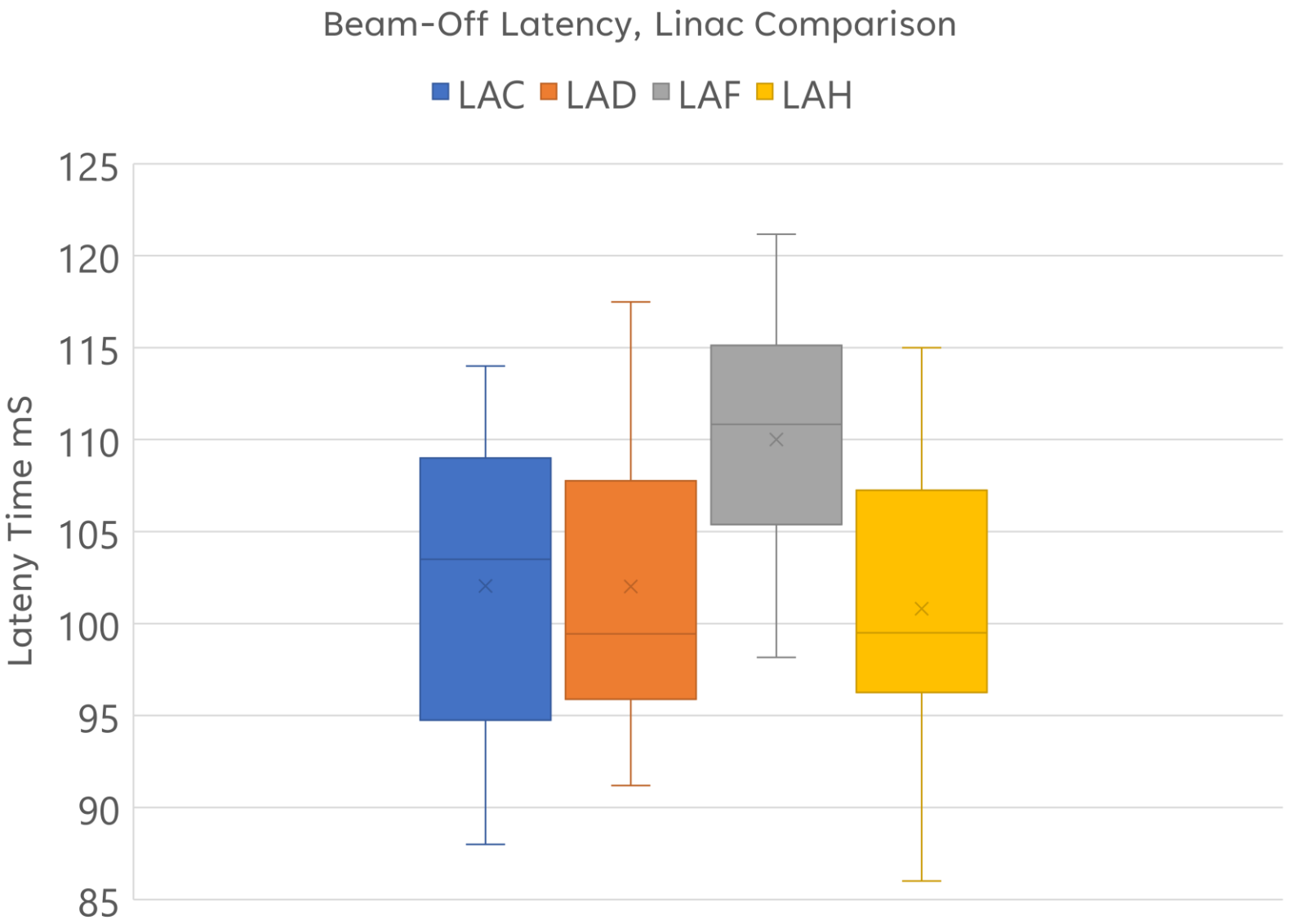
=

130,648,638uS – 130,549,203uS

=

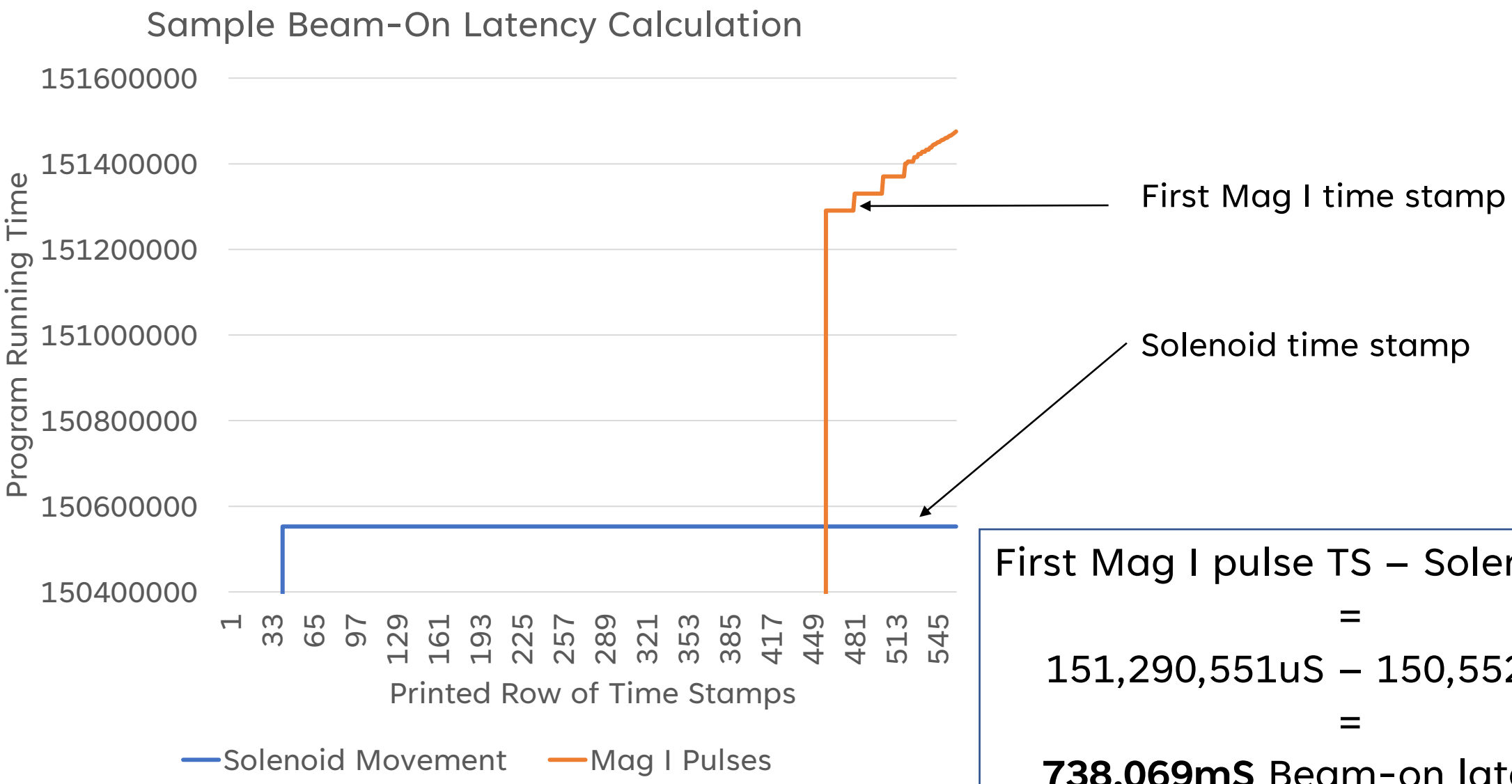
99.435mS Beam-off latency

Results and discussion (beam-off)



Beam-Off Latency (mS)		
LINAC	Mean Latency	Standard Deviation
LAC	98.55	19.28
LAD	102.01	7.65
LAF	110	6.74
LAH	100.8	8.35

Data analysis method (beam-on latency)



First Mag I pulse TS – Solenoid TS

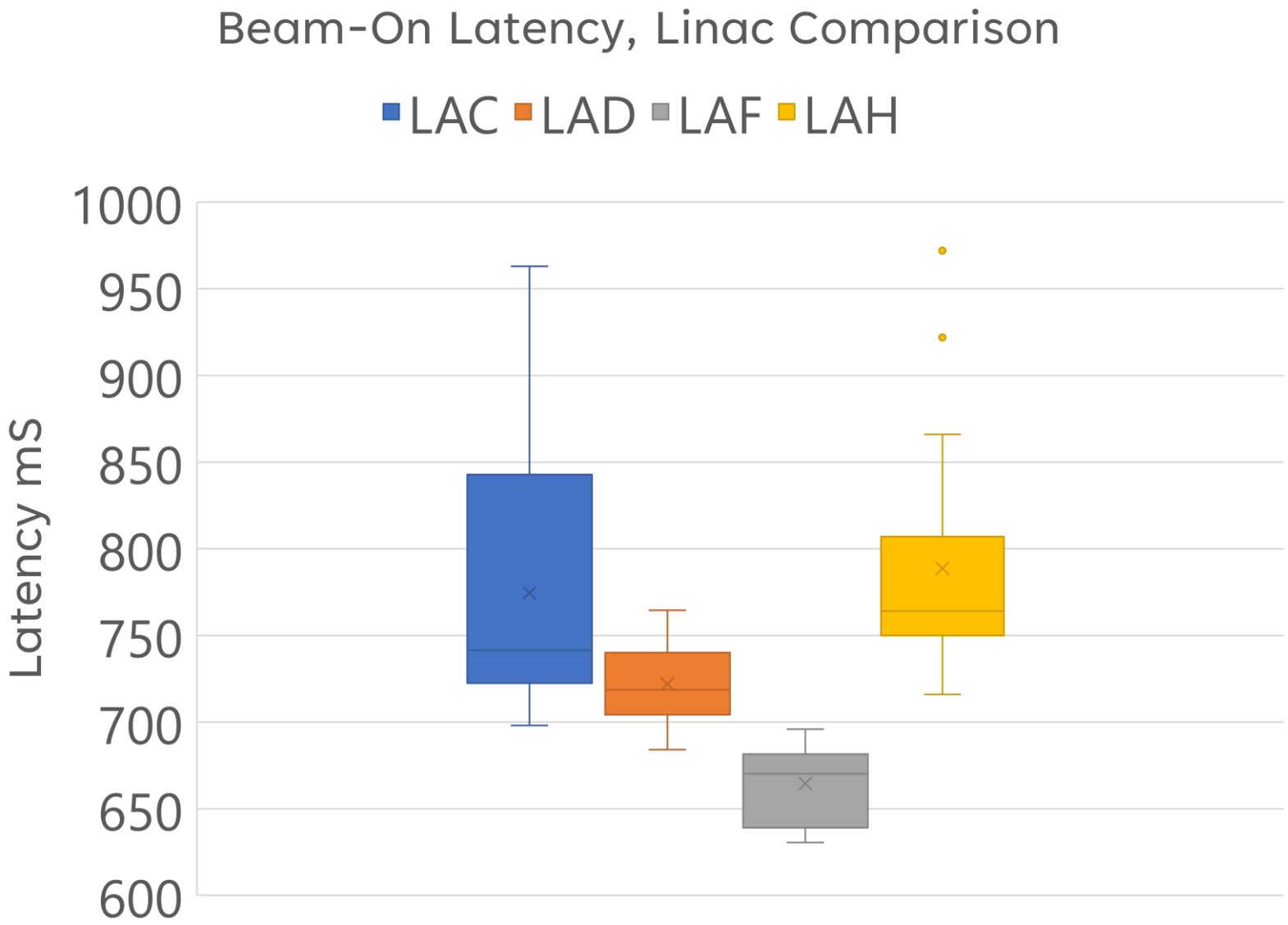
=

151,290,551uS – 150,552,482uS

=

738.069mS Beam-on latency

Results and discussion (beam-on)



Beam-On Latency (mS)		
LINAC	Mean Latency	Standard Deviation
LAC	774.5	77.13
LAD	722	22.79
LAF	664.58	21.85
LAH	788.68	67.07

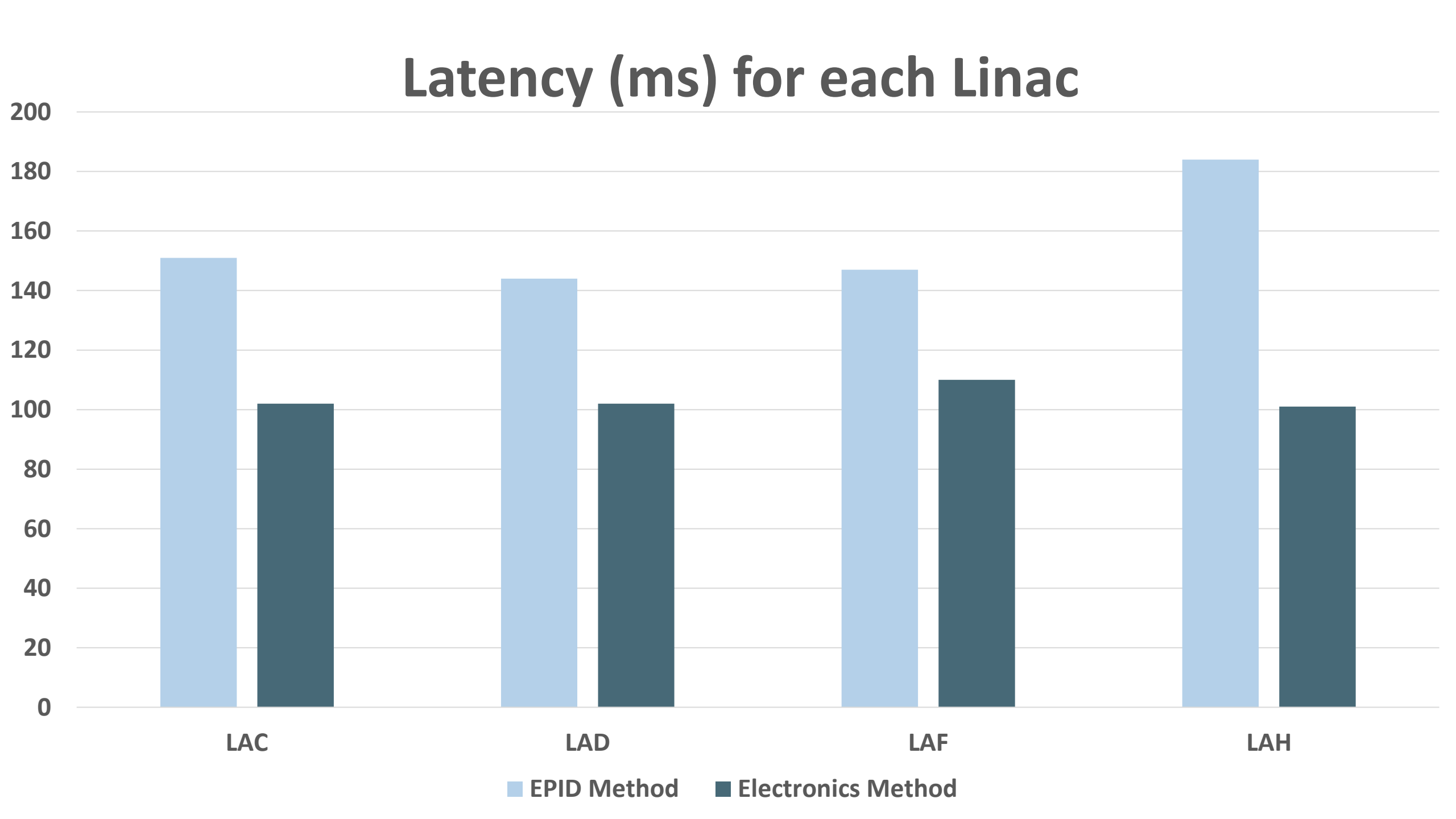
Electronics Method Future Prospects

- Refine hardware, and software: ease of set up, more professional.

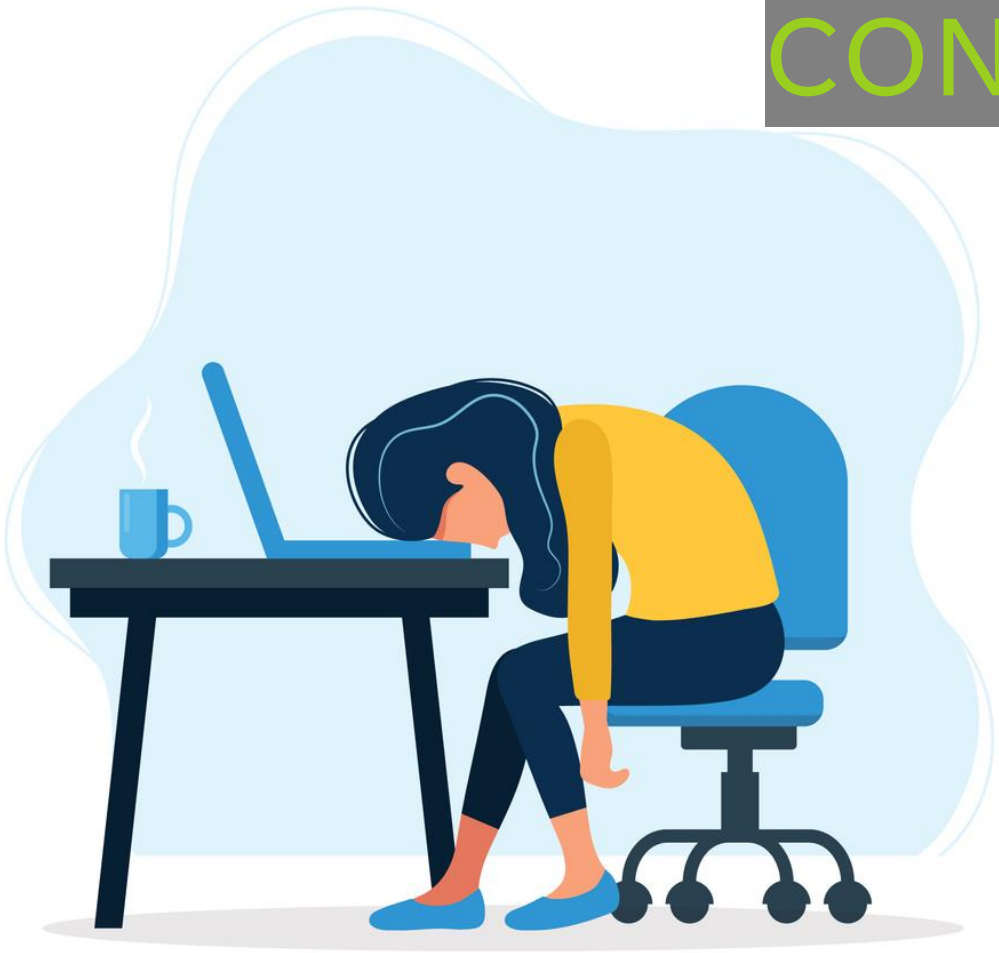
- Change phantom size (larger ROI), more clinically relevant frame rate.

- Use with different linacs.

- Use with other SGRT systems (Exactrac Dynamic).


Latency (ms) for each Linac
200
180
160
140
120
100
80
60
40
20
0
LAC
LAD
LAF
LAH
EPID Method
Electronics Method

CONCLUSION

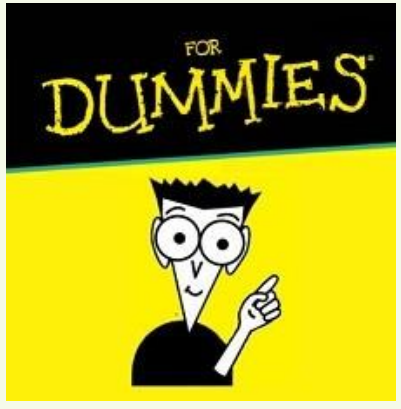


FUTURE PLANS

METHOD AND LINAC COMPARISON

BEAM ON

DUMMIES GUIDE!



THANK YOU / QUESTIONS?

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