

“The more distant we look into the past,
the farther we can see into the future.”

Winston Churchill

Performance Study of An Automated Real-Time Beam Monitoring system For SBRT Treatments

Makan Farrokhkish

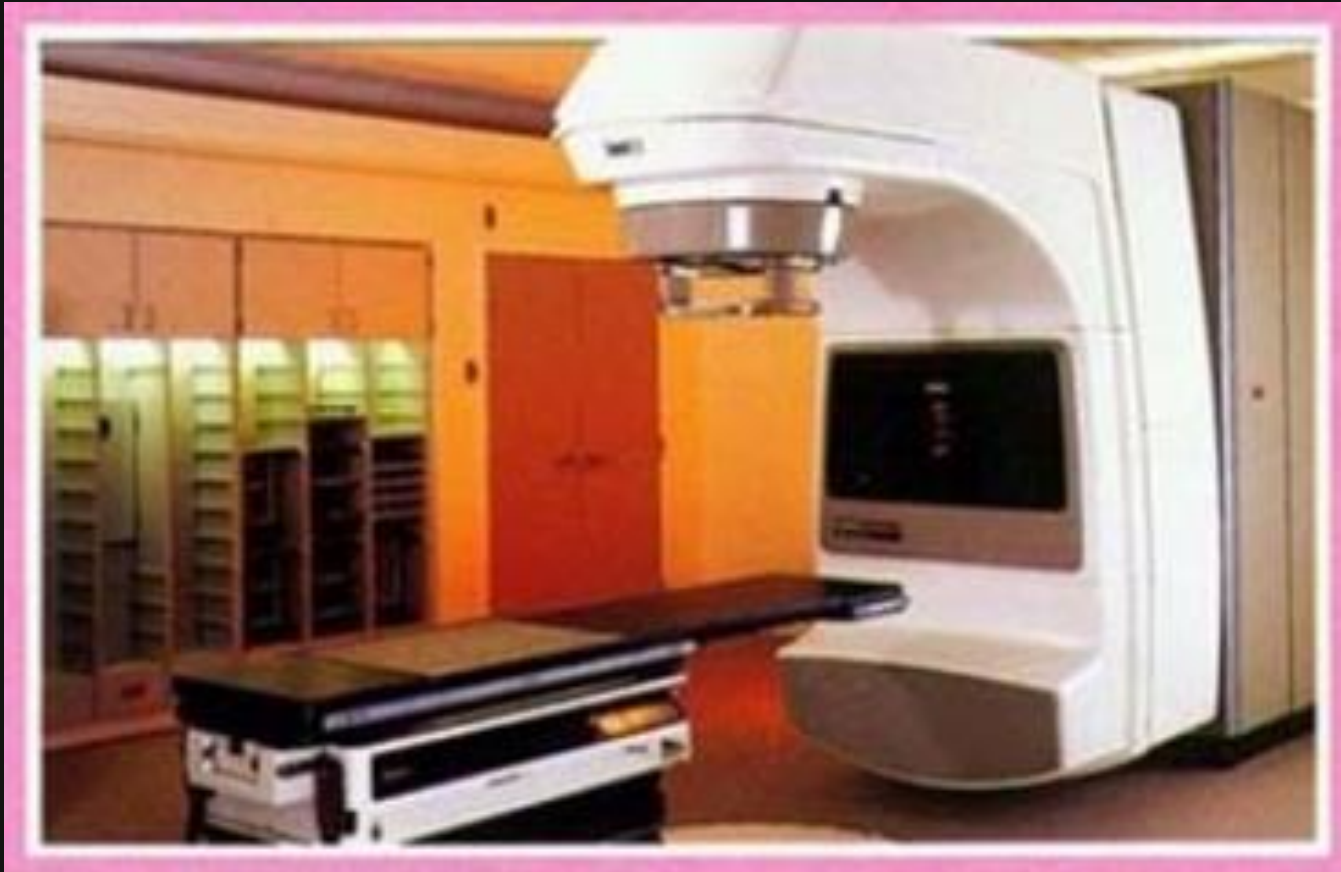
Department of Radiation Physics, Radiation Medicine Program

Princess Margaret Cancer Centre , Toronto

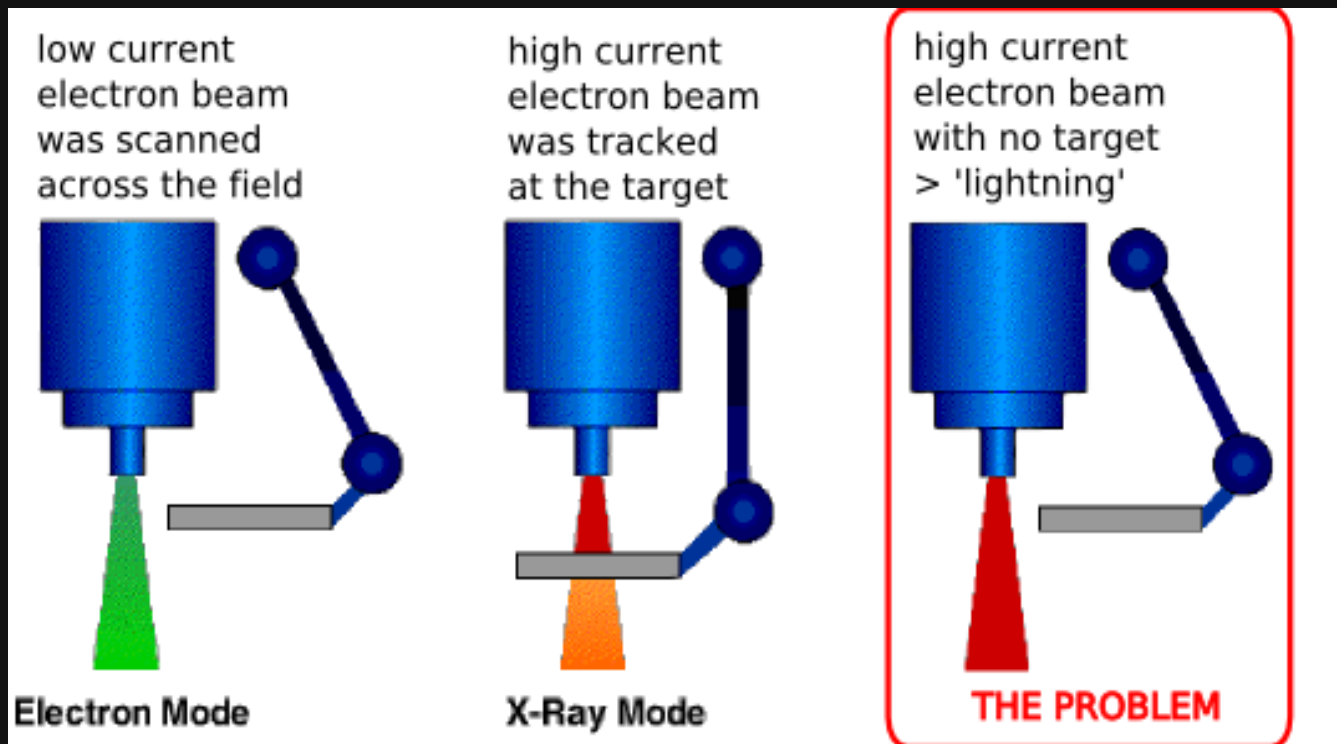


Princess Margaret
Cancer Centre  UHN

The Therac 25...



The Therac 25...



The Therac 25...

An Investigation of the Therac-25 Accidents

Nancy Leveson, University of Washington

Clark S. Turner, University of California, Irvine

Reprinted with permission, *IEEE Computer*, Vol. 26, No. 7, July 1993, pp. 18-41.

The Therac 25...



Therac 25

by Adam Pettle

★★★★☆ 3.57 ·  rating details · 7 ratings · 1 review

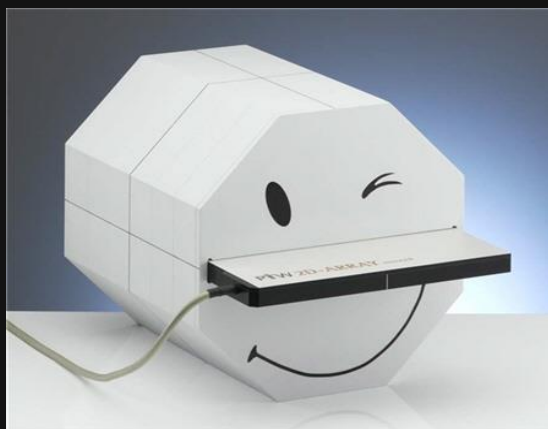
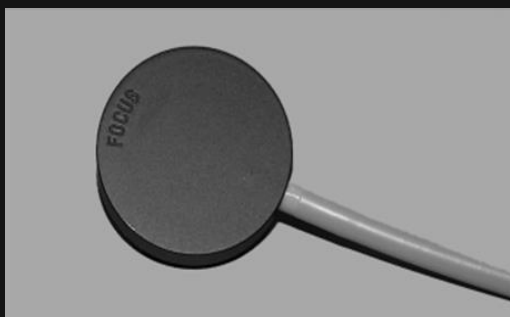
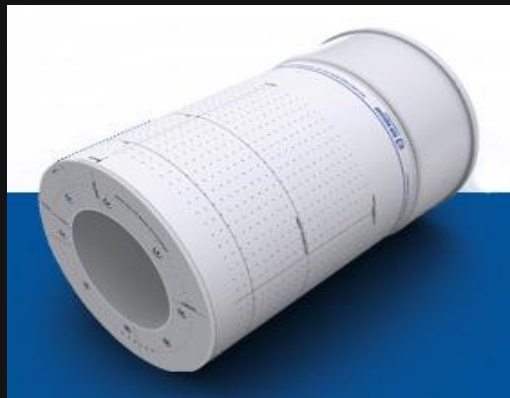
Alan and Moira are young, and they are falling in love...in the corridors of the Princess Margaret Hospital, where they are both undergoing cancer treatment. Humorous and moving, "Therac 25" is a love story unlike any other--a play you won't easily forget.

Paperback, 48 pages

Published September 16th 2000 by J. Gordon Shillingford Publishing

[more details...](#)

[edit details](#)





Online Quality Assurance Is a Missing piece to
Complete the QA process

And That's the essence behind....

Independent

Online

Segment by segment

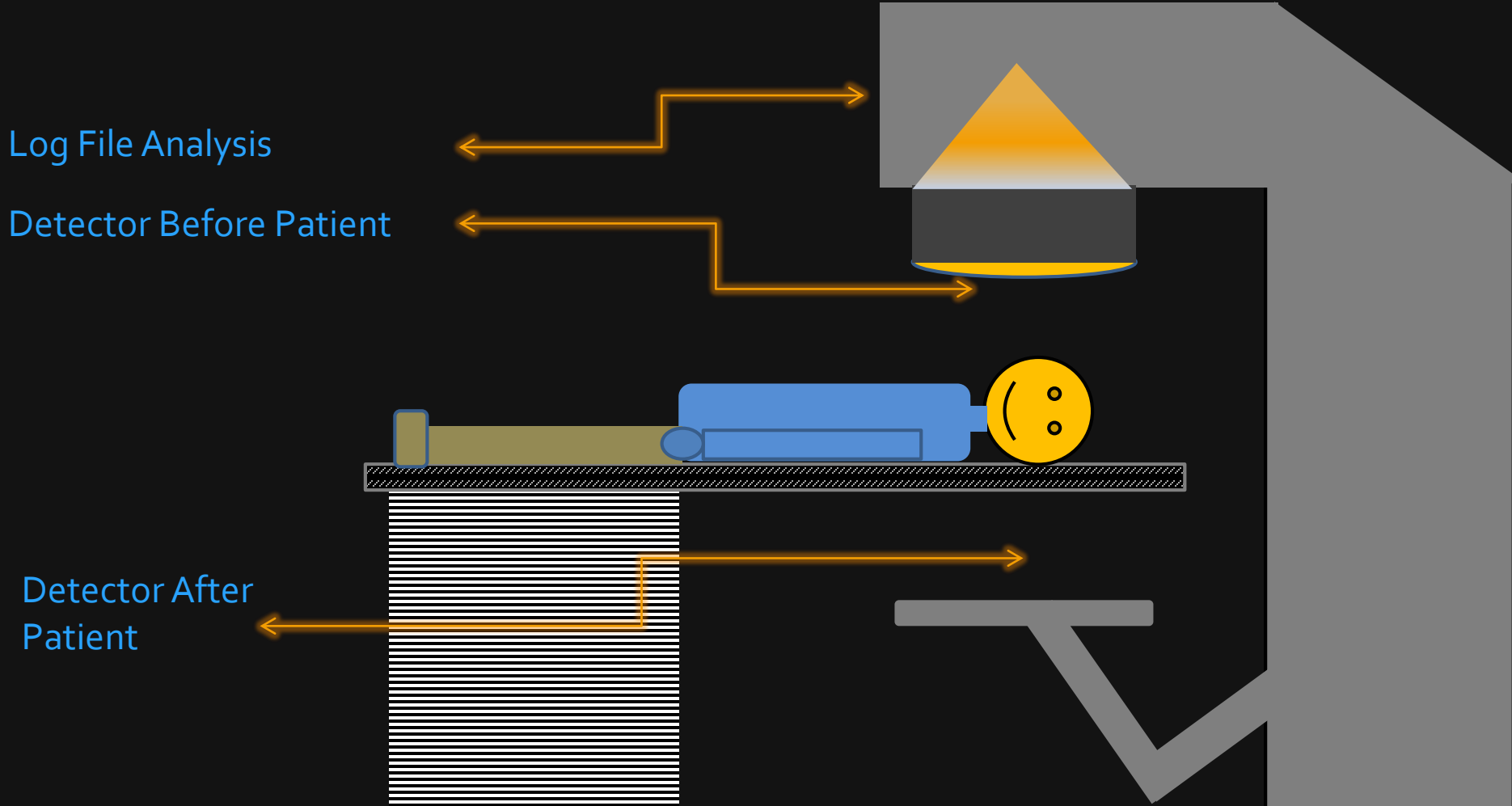
IQM
Integral Quality Monitor

Beam Monitoring System



Technology

Real Time Monitoring Methods



Offline QA → Online QA



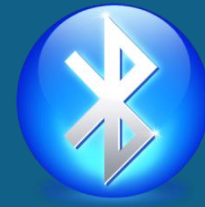
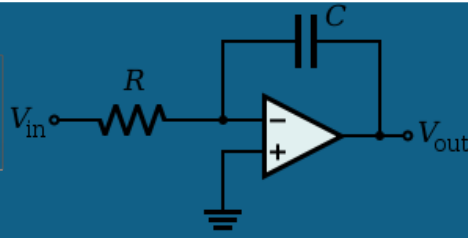
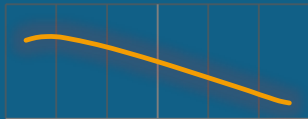
Good Old Yahoo Messenger !

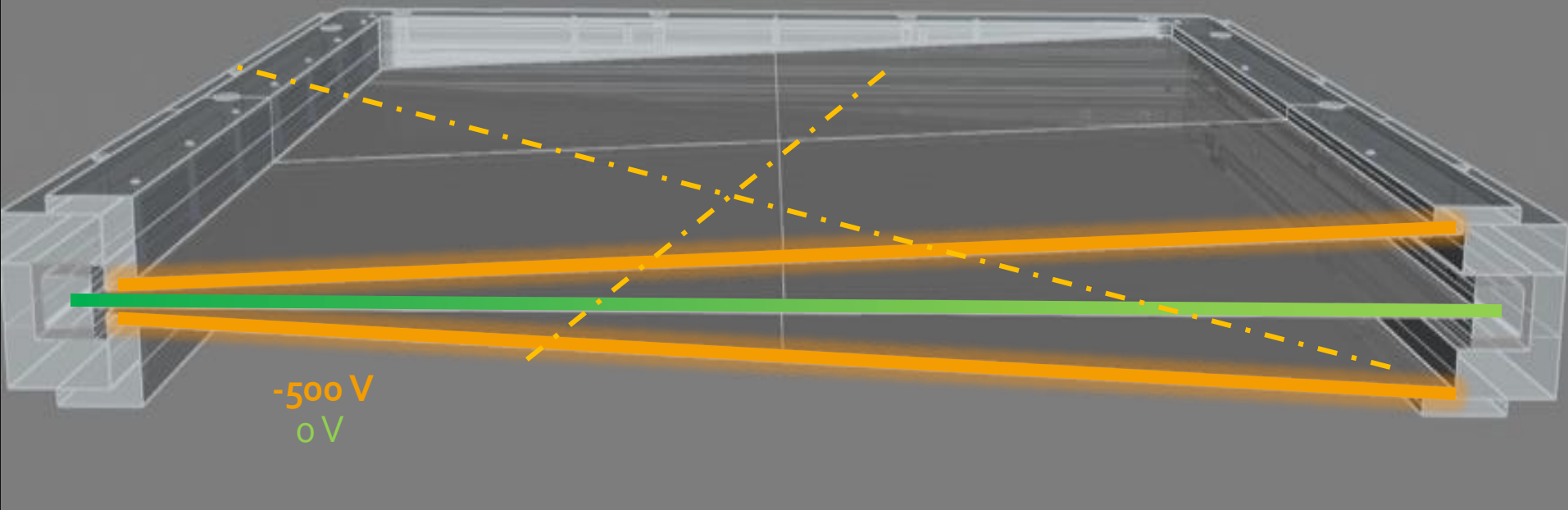
Design Consideration

To design a device that is as simple as possible without compromising its functionality and Performance

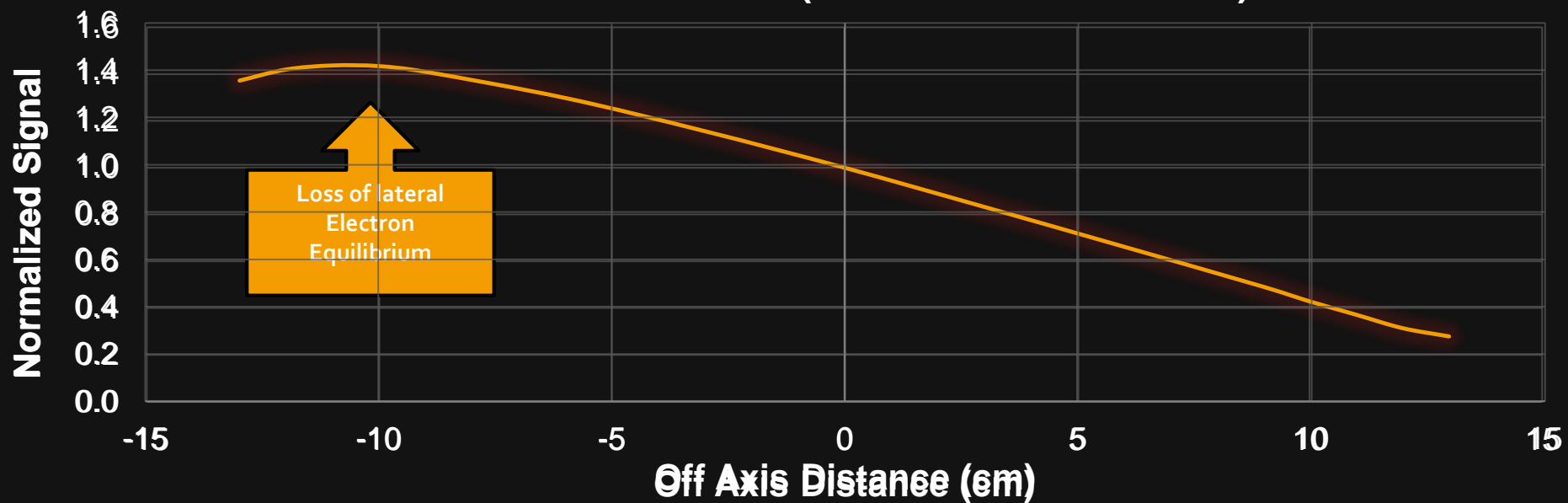
IQM Features

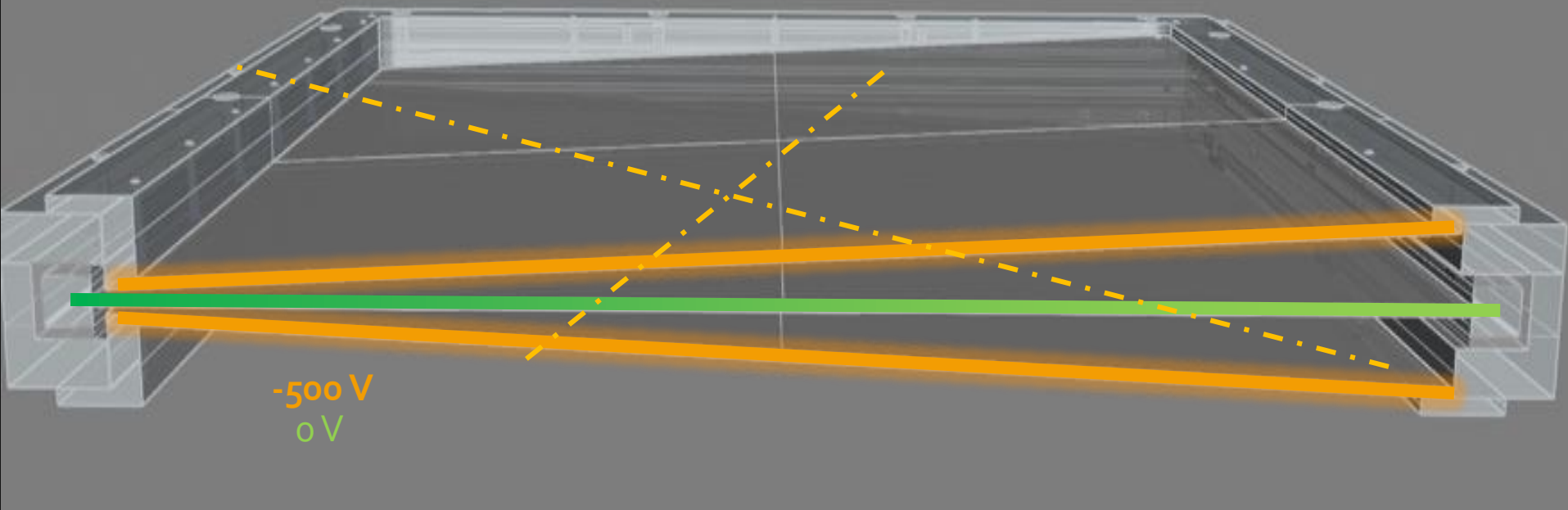
- Spans the entire beam projection area
- 5% / Cm intrinsic Gradient
- Built-in 2 channel Electrometer
- 3- Axis MEMS Accelerometer
- Temperature and pressure sensors
- Wireless Bluetooth Communication
- Battery Management system



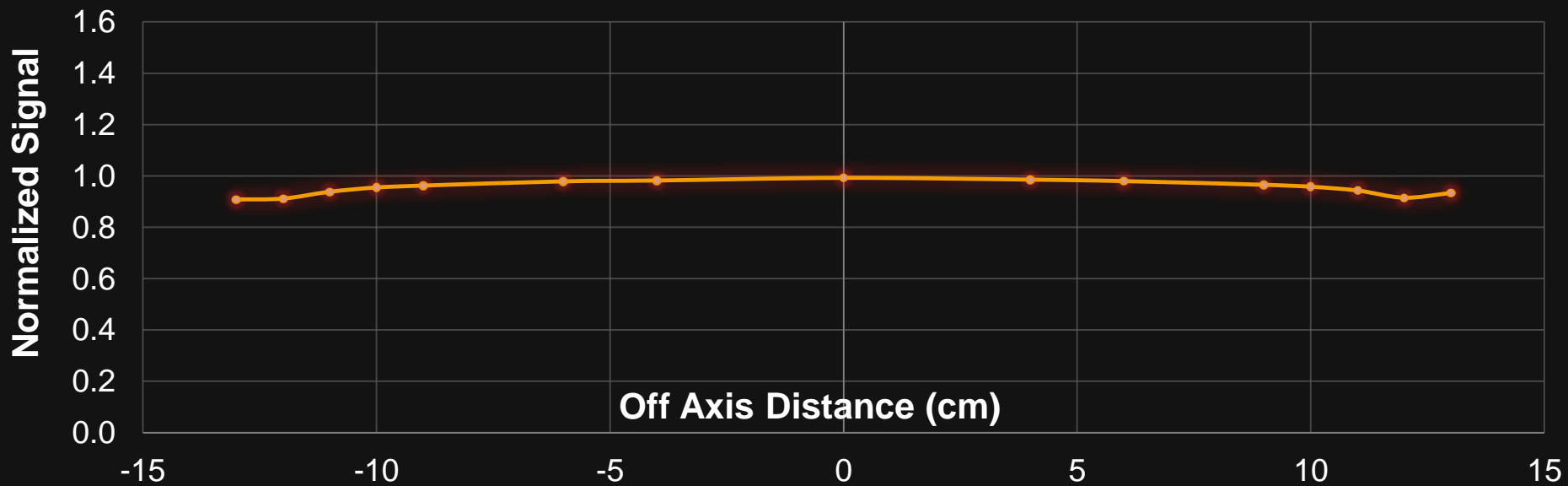


Central Gradient Profile (Normalized To Centre)

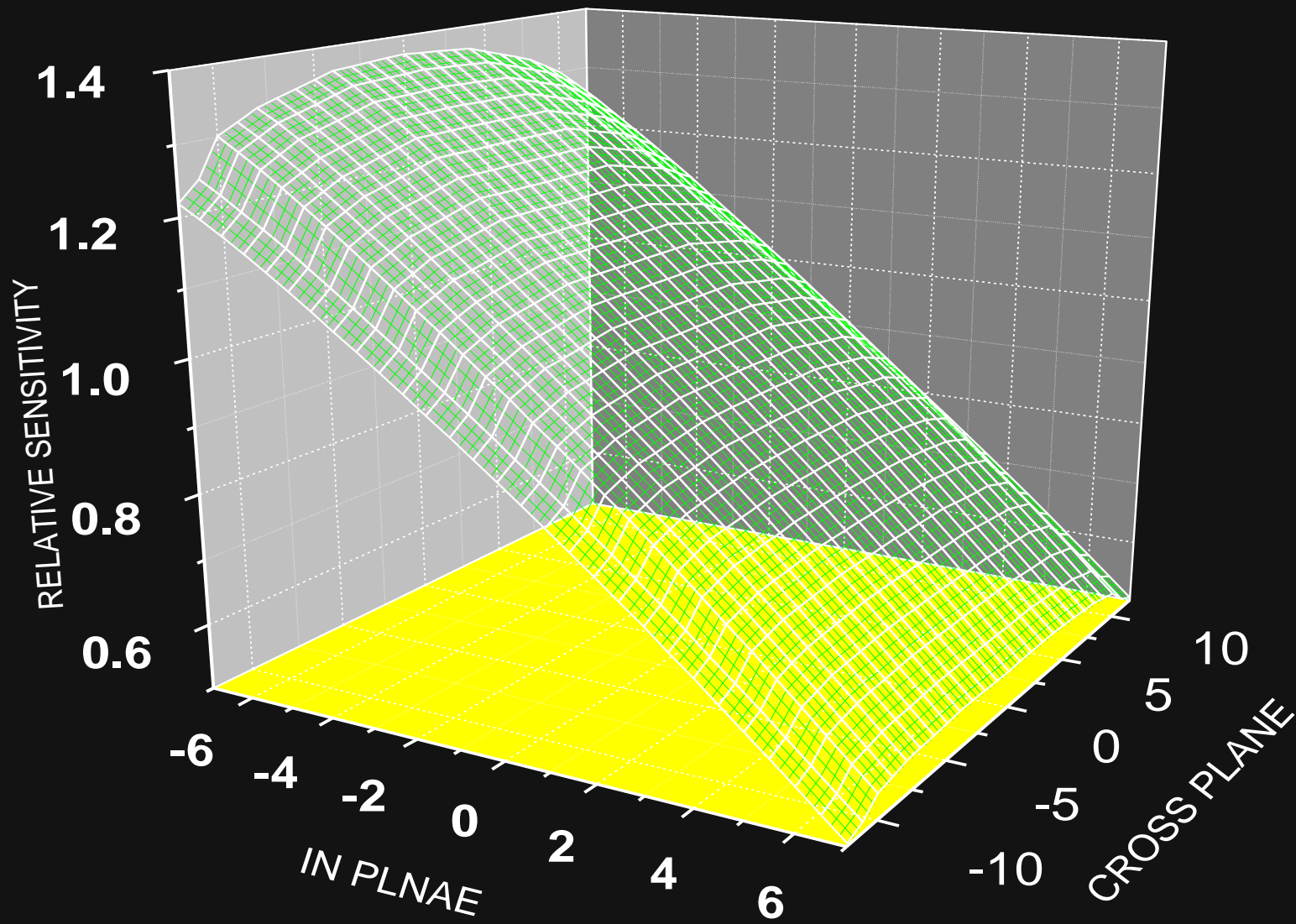




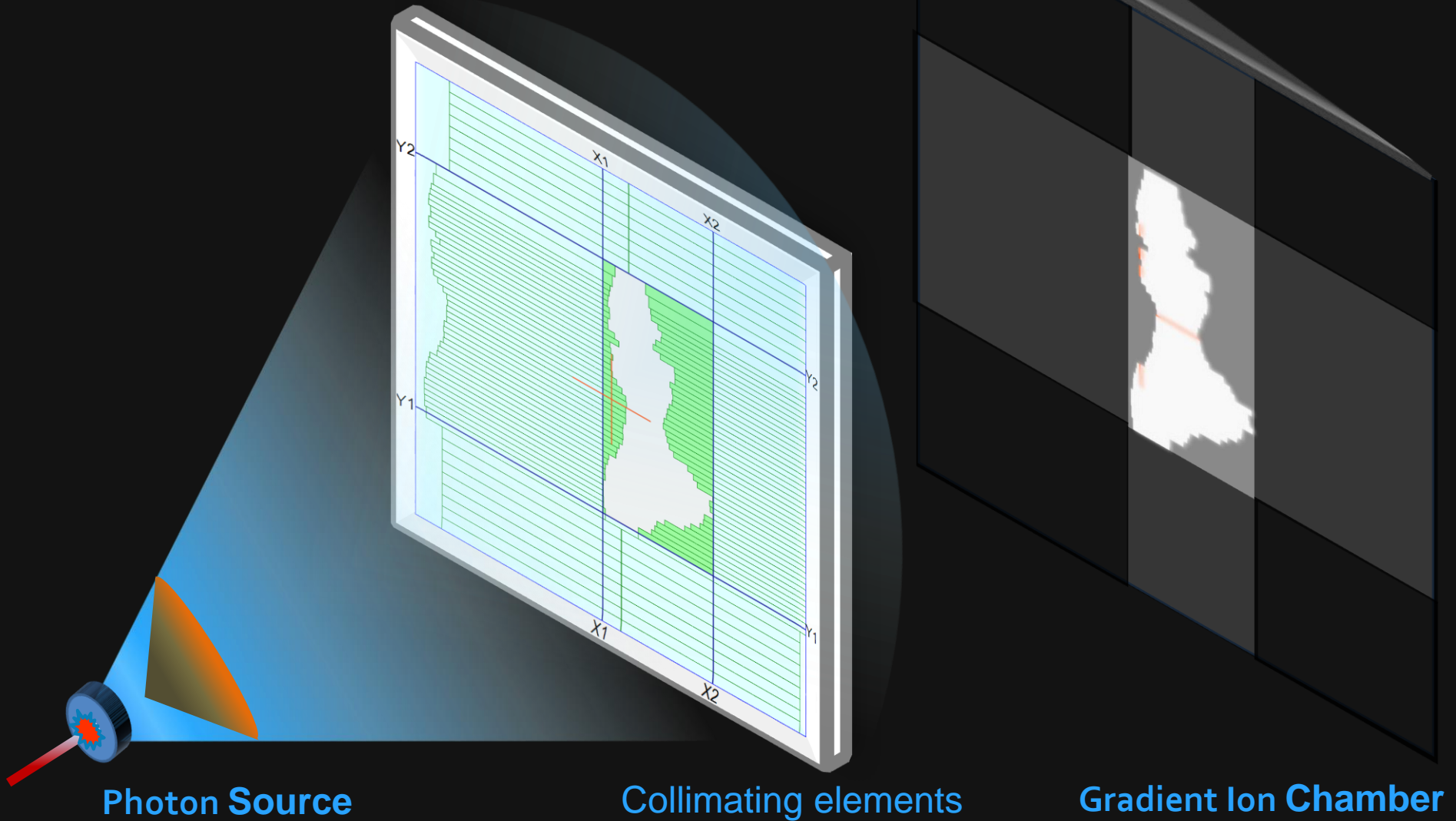
Canteral None-Gradient Profile (Normalized To Centre)



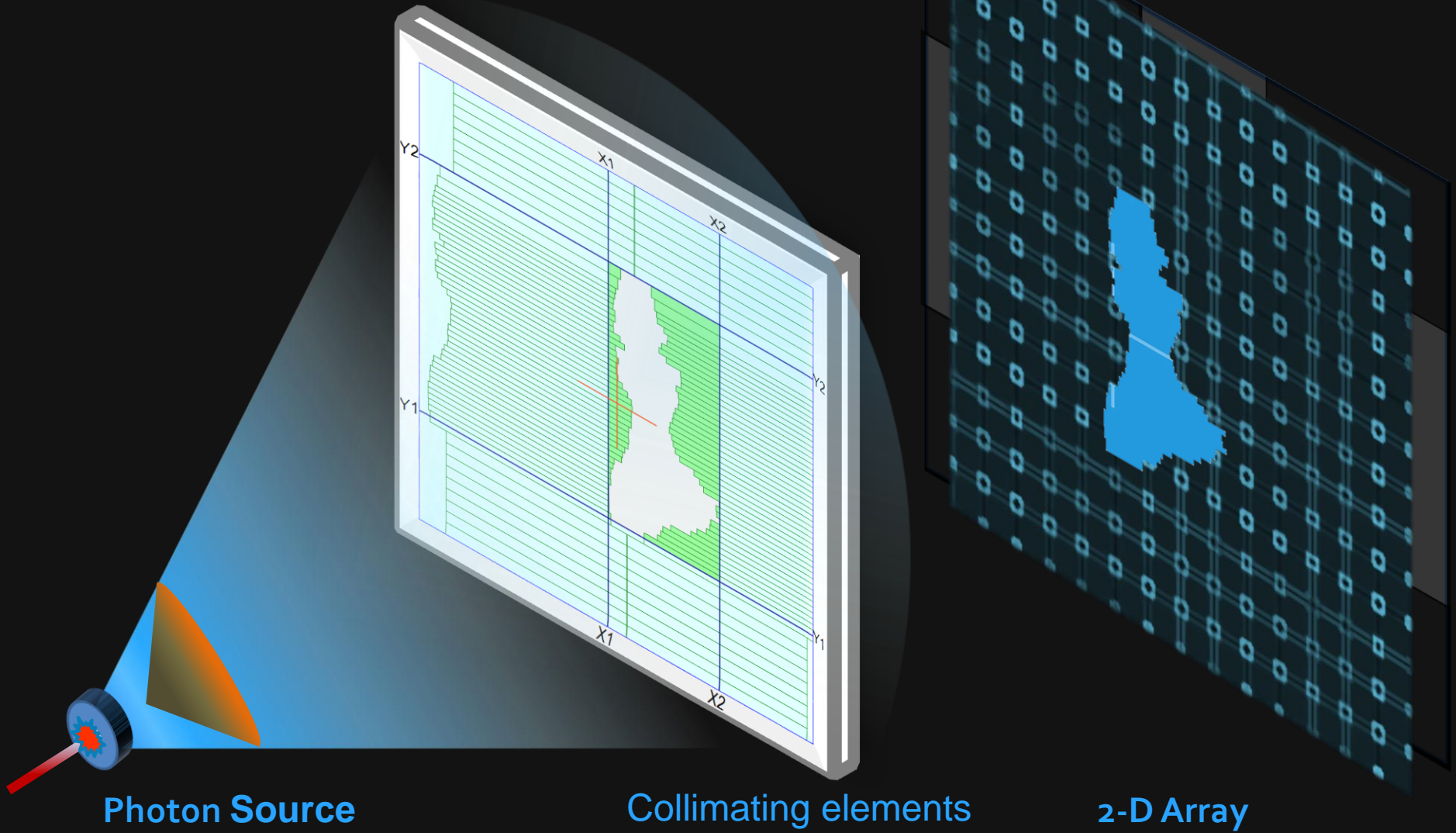
IQM Intrinsic Sensitivity Map



$$S_M \propto \text{Dose} \cdot \text{Area}$$



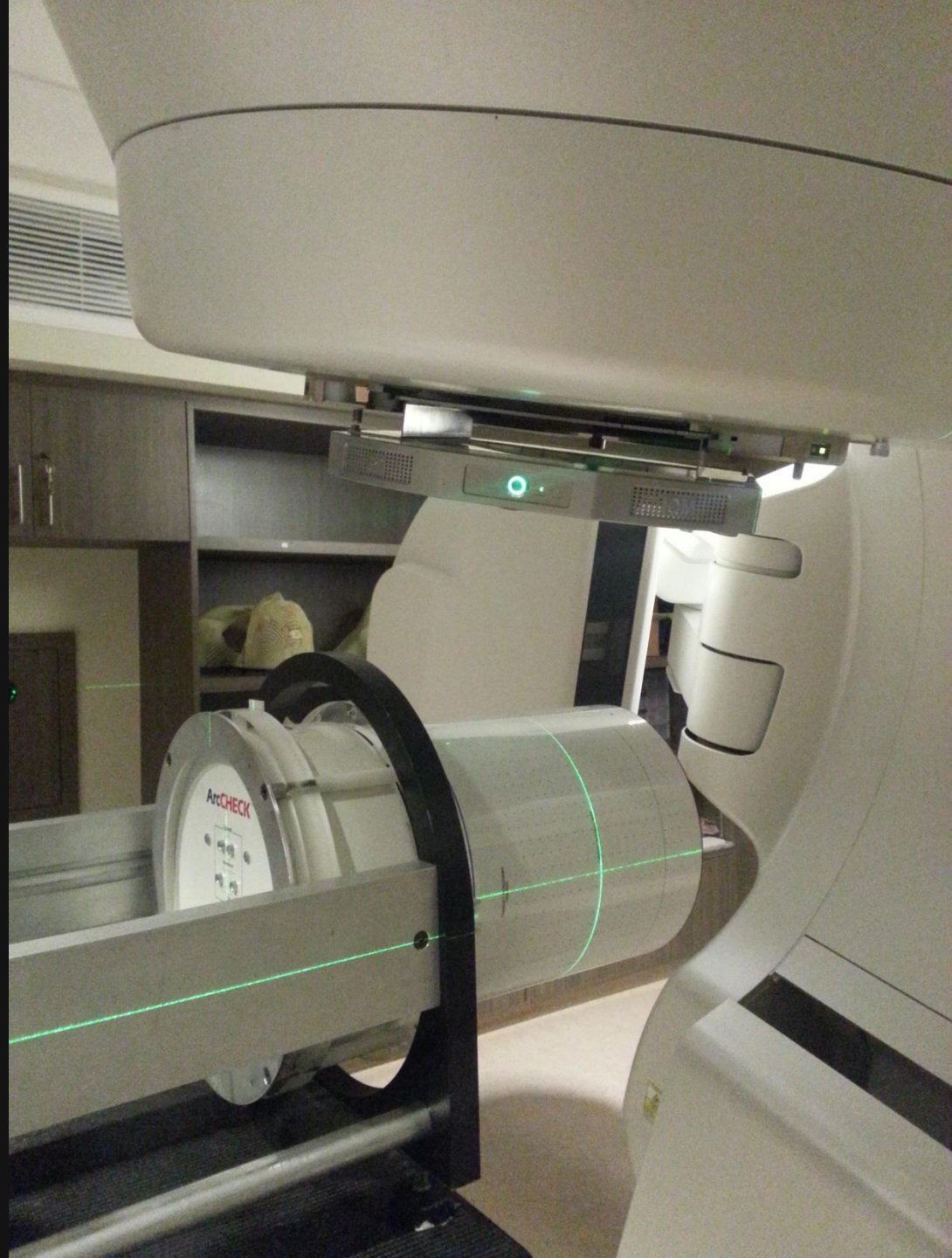
$$S_M \propto \text{Dose} \cdot \text{Area}$$



IQM Reference (1st Measured Fraction)



IQM Reference (Pre-TX QA)



Monitoring Mode:
Record (No Verification)

Monitoring Status:
Field recorded as a new reference

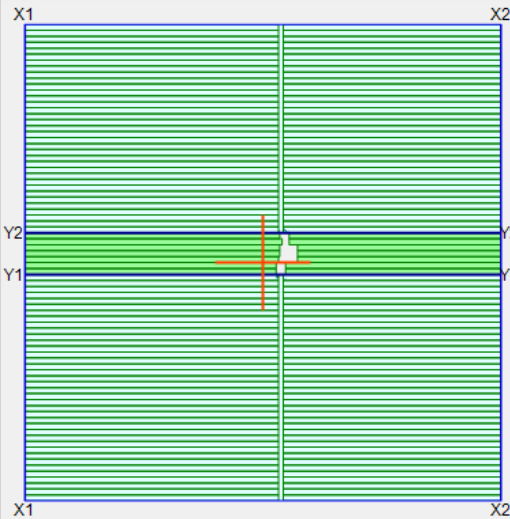


Field ID: I2 Linac: NA10 Patient ID: I2015 Name: John Smith Date of Birth: 1958-Jul-12

Segment	Expected	Measured	Delta (abs)	Delta (%)
1	n/a	18 605	n/a	n/a
3	n/a	13 536	n/a	n/a
5	n/a	5 838	n/a	n/a
7	n/a	8 033	n/a	n/a
9	n/a	10 668	n/a	n/a
11	n/a	14 771	n/a	n/a
13	n/a	13 951	n/a	n/a
15	n/a	12 635	n/a	n/a

Current Segment 15 (from treatment plan)

Field Shape:



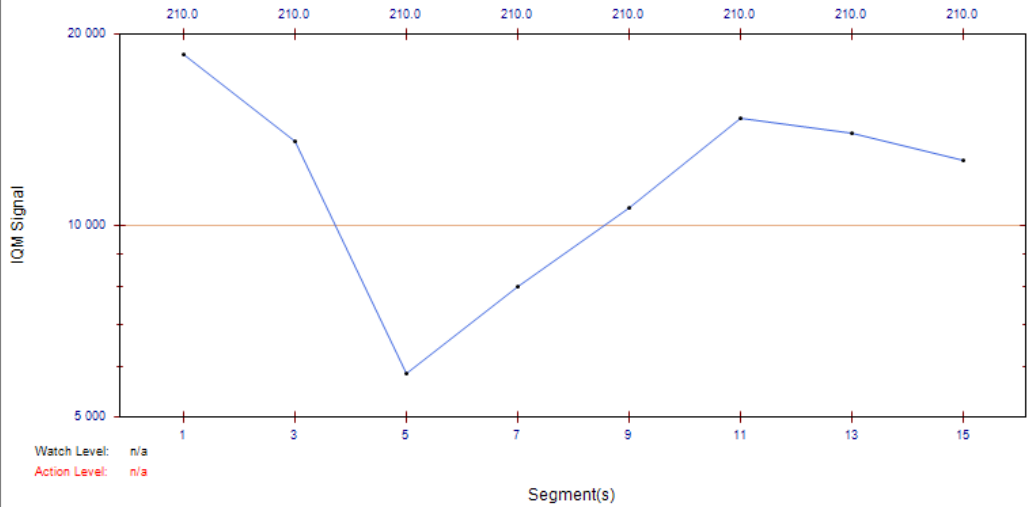
Gantry Angle:
210.0°



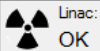
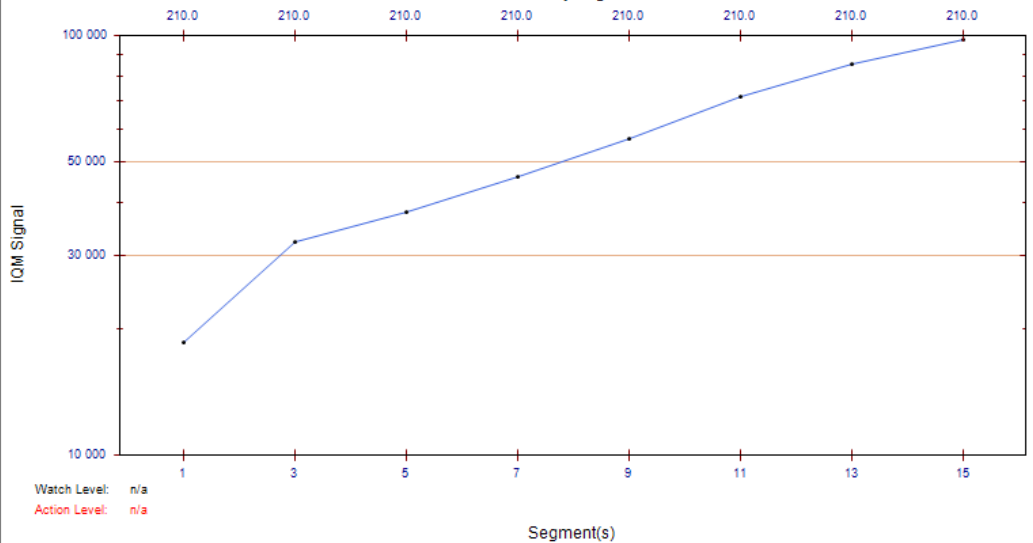
Collimator Angle:
0.0°

Air Pressure:
764.50 mmHg

Segment-by-Segment



Cumulative



Linac:
OK



Door:
Closed



IQM Detector:
Monitoring



Battery:
02:31 hours



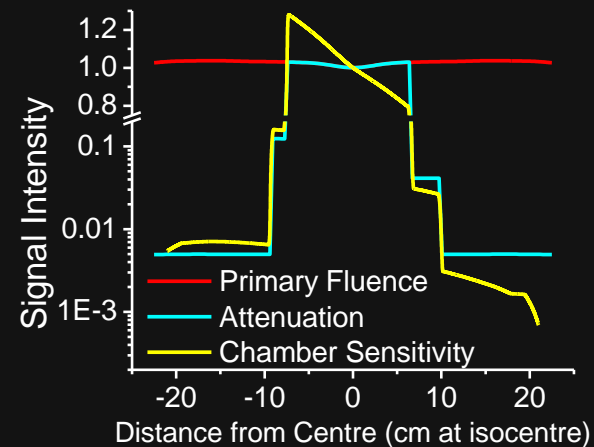
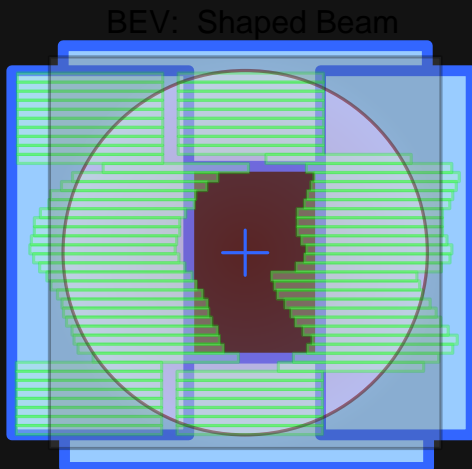
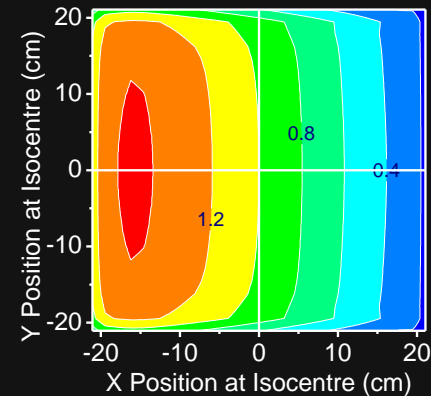
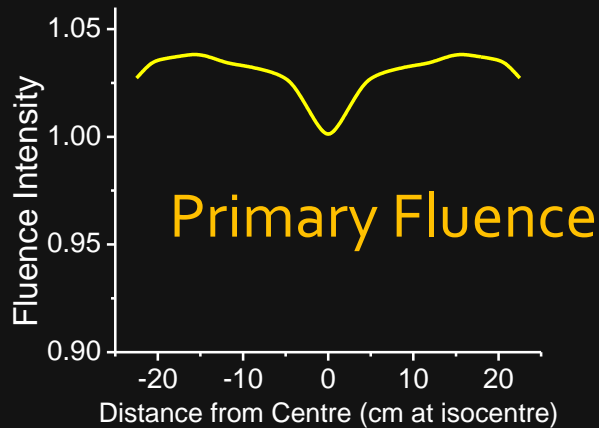
Electrometer:
OK



Inclinometer:
OK

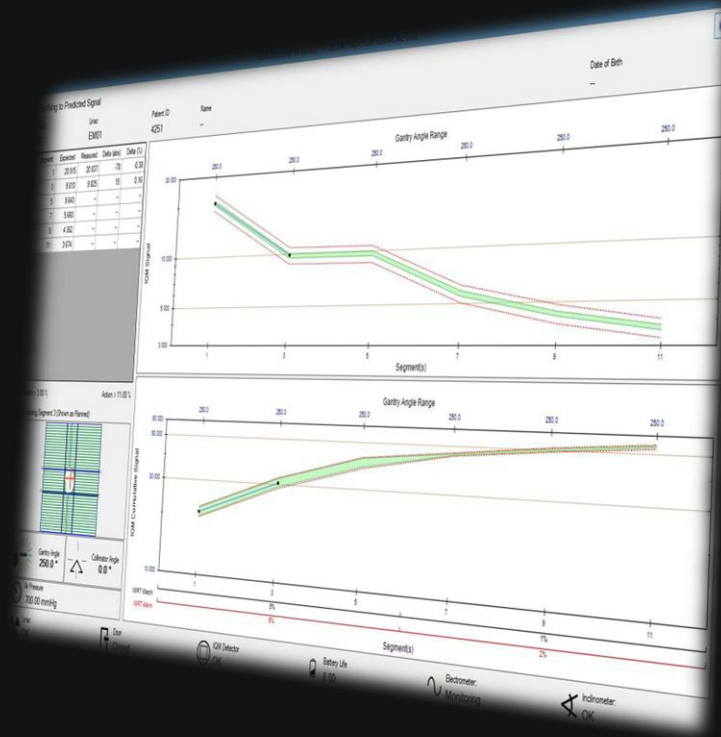
IQM Reference (Calculated)

$$C_{IQM} = MU \cdot AOF(x, y) \cdot \int_{Area} I_{field} \cdot S(x, y)$$



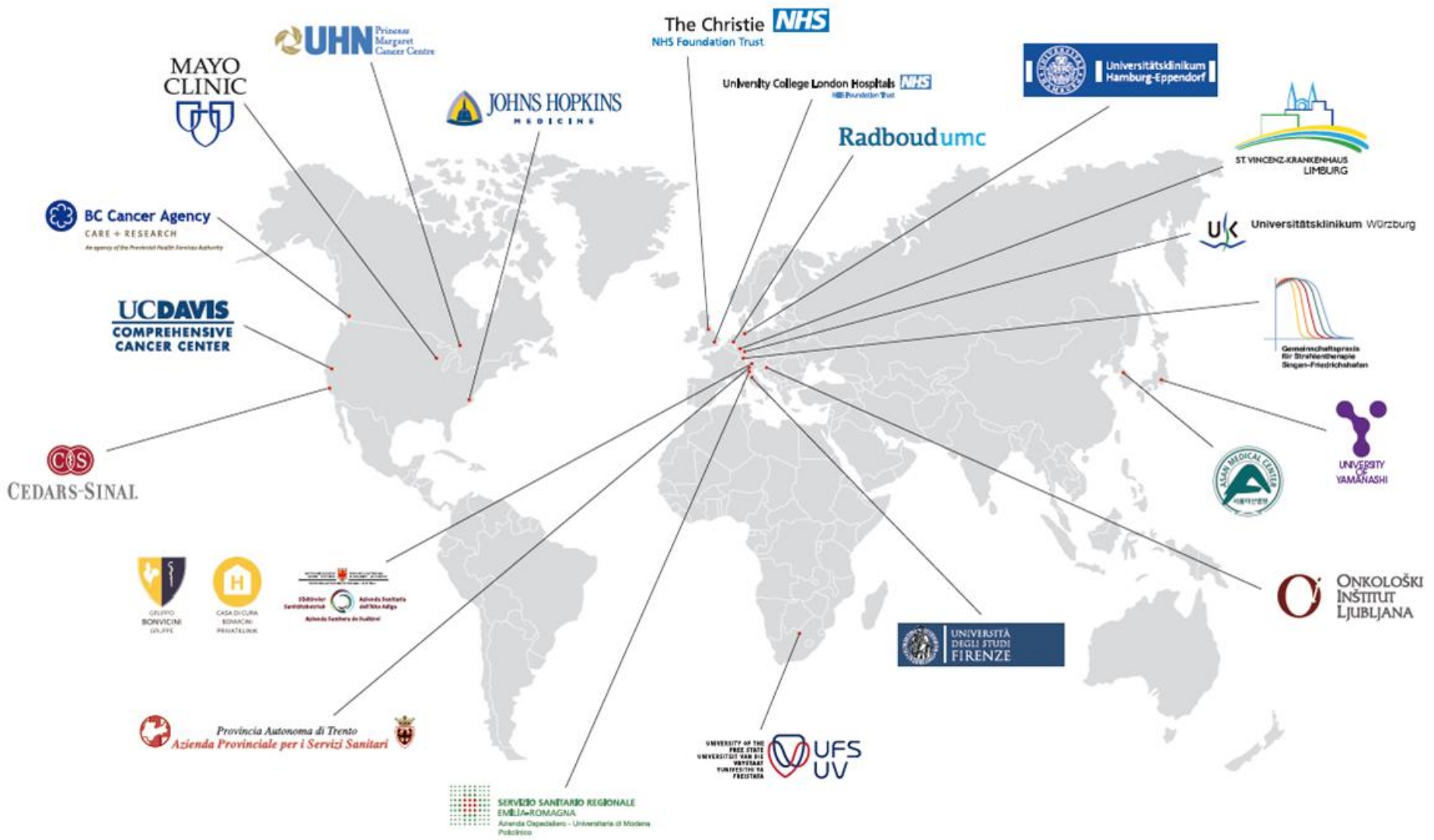
IQM Reference (Calculated – Measurement Hybrid)

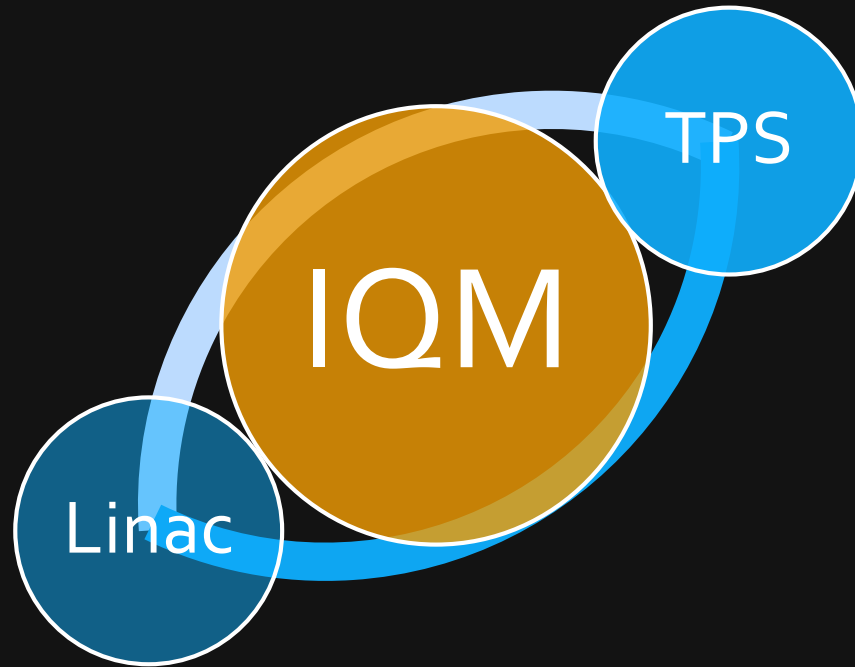
$$C_{IQM} = MU \cdot AOF(x, y) \cdot \int_{Area} I_{field} \cdot S(x, y)$$



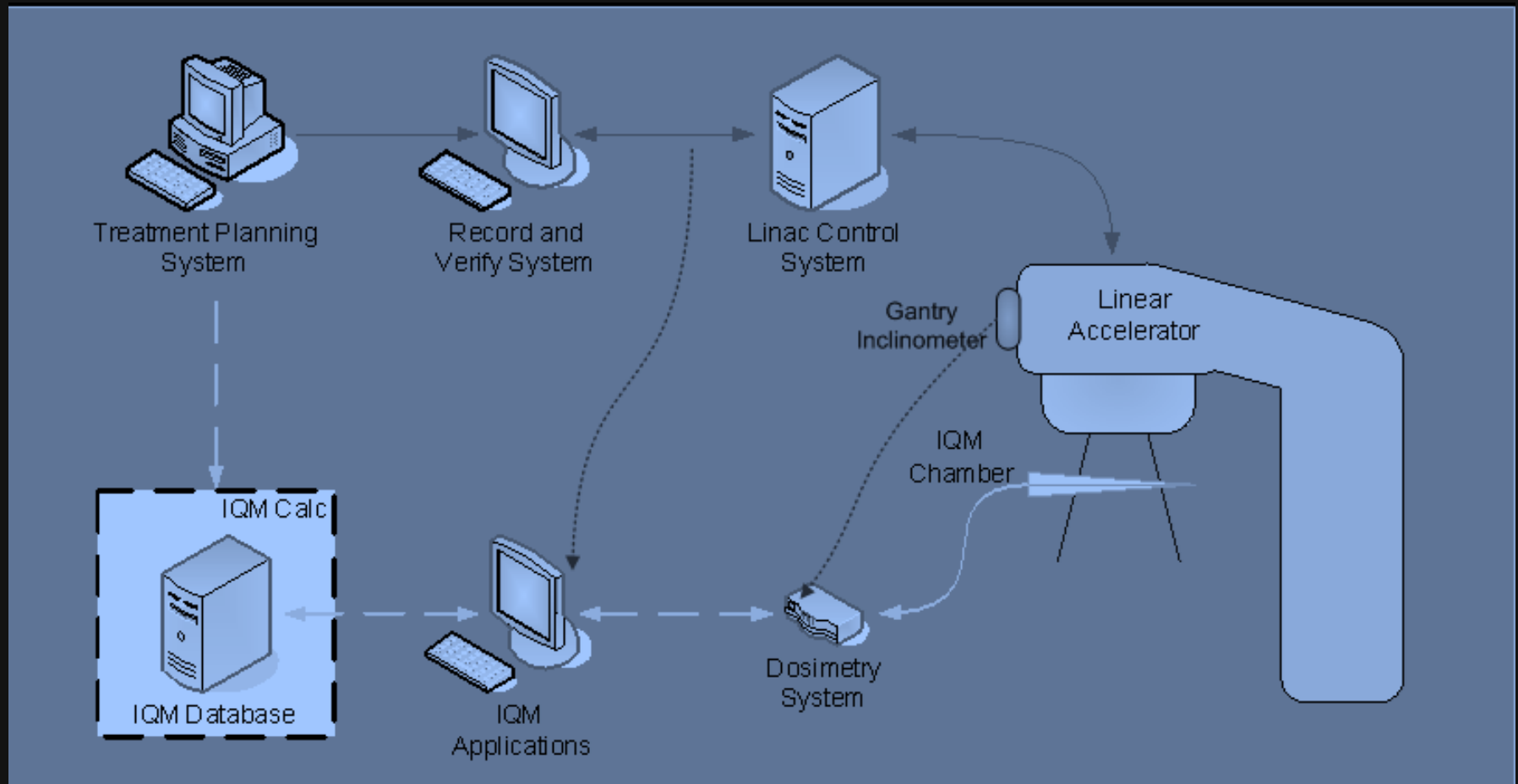
Integrating IQM



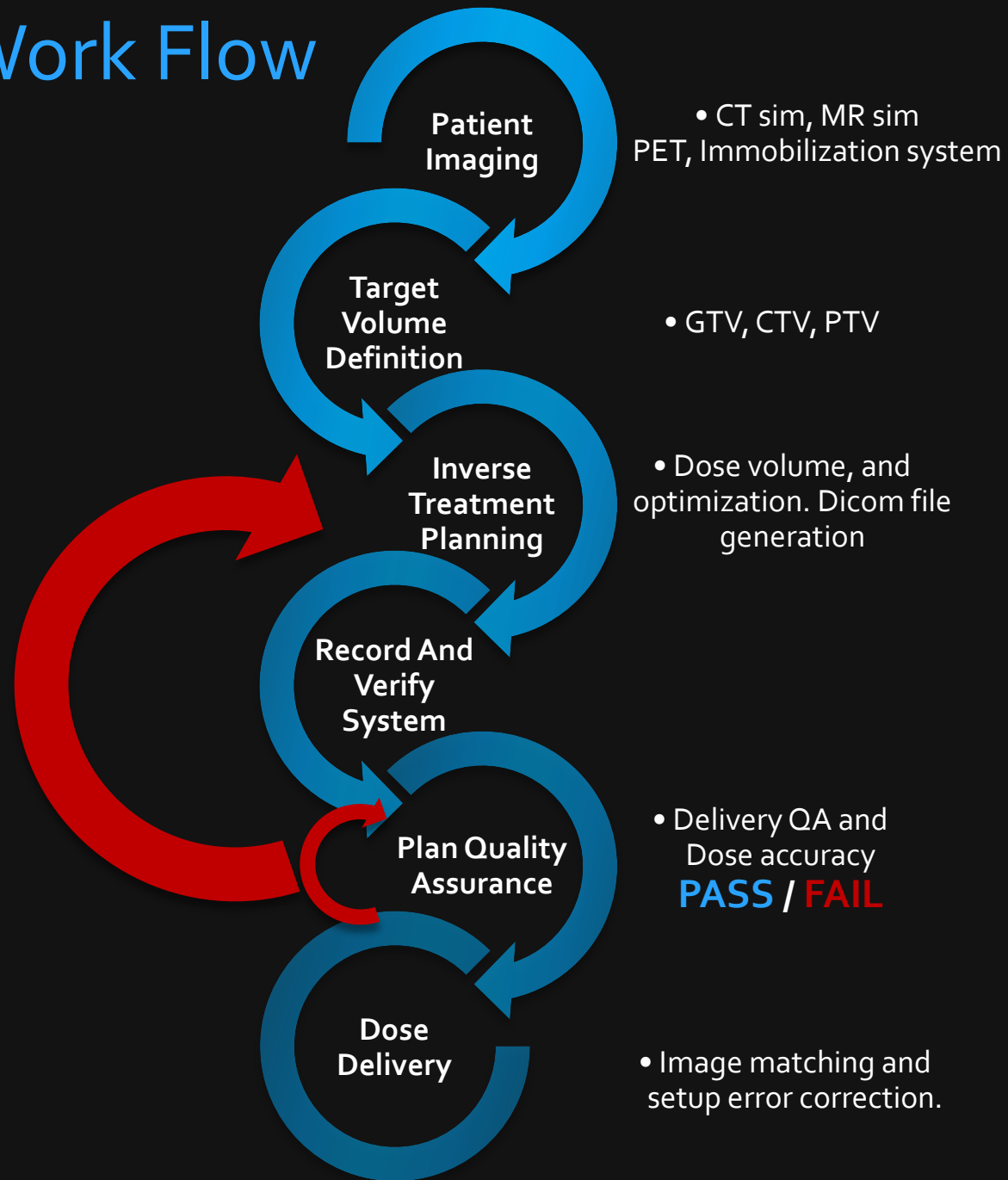




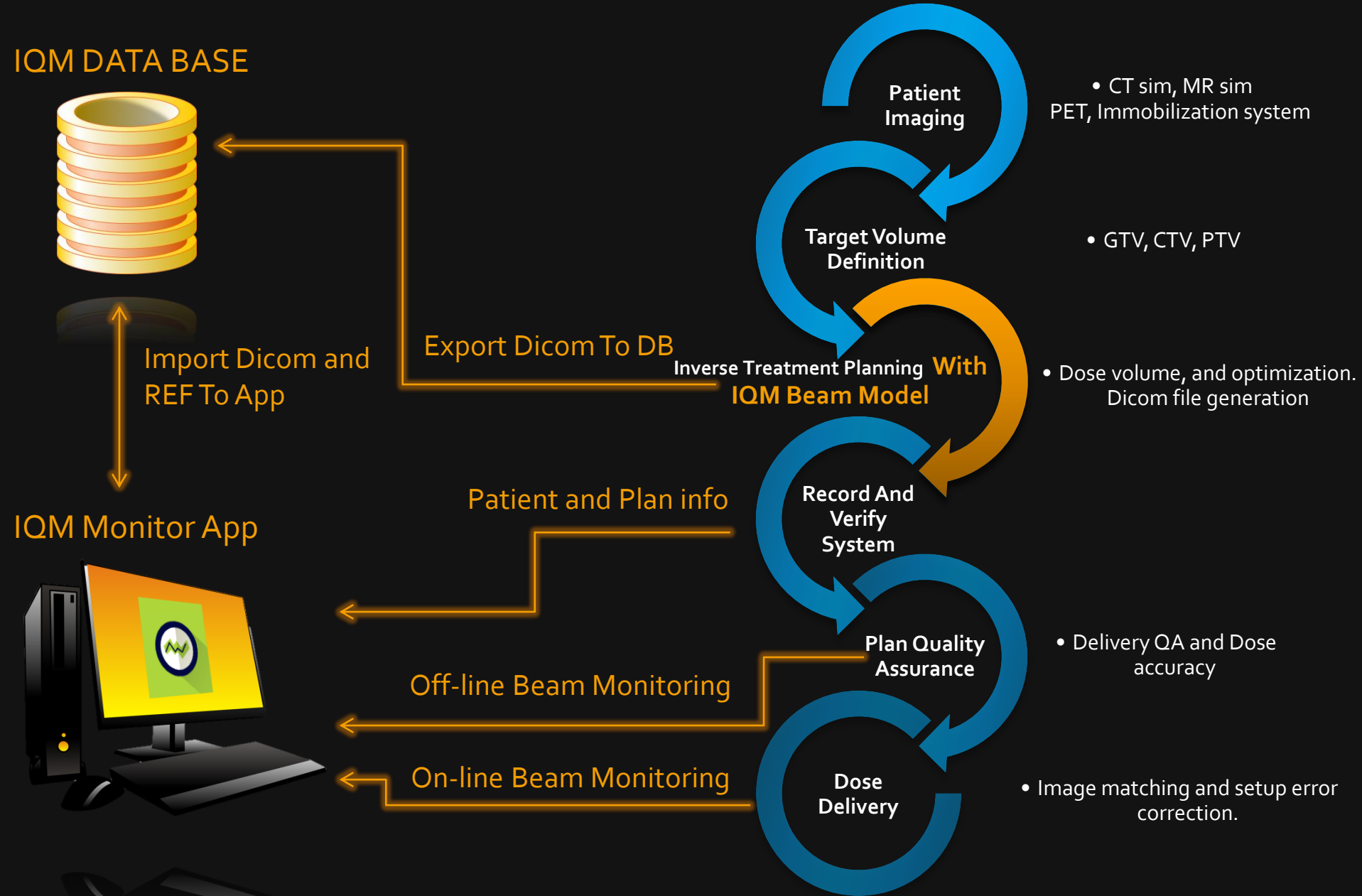
IQM Integrated Linac



Current Clinical Work Flow

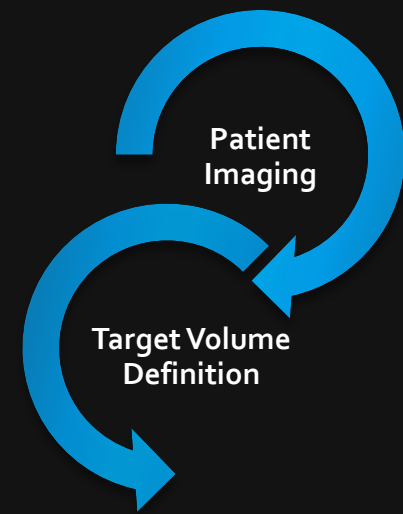


IQM Integrated Clinical Work Flow

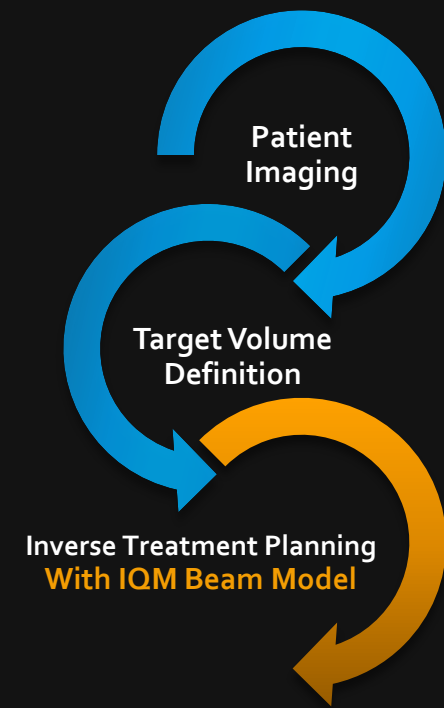


Patient Imaging

No IQM involved



IQM Beam Model

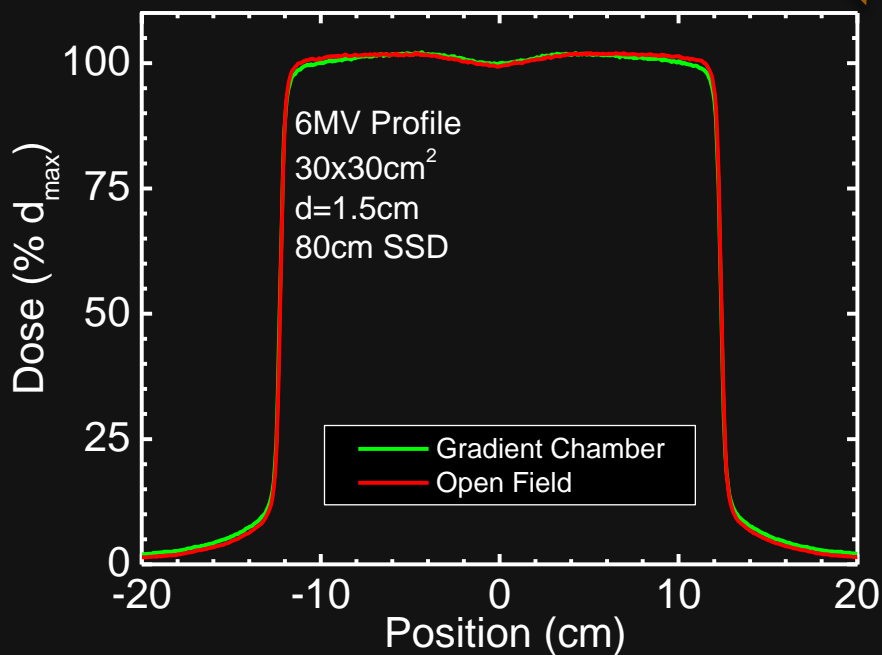
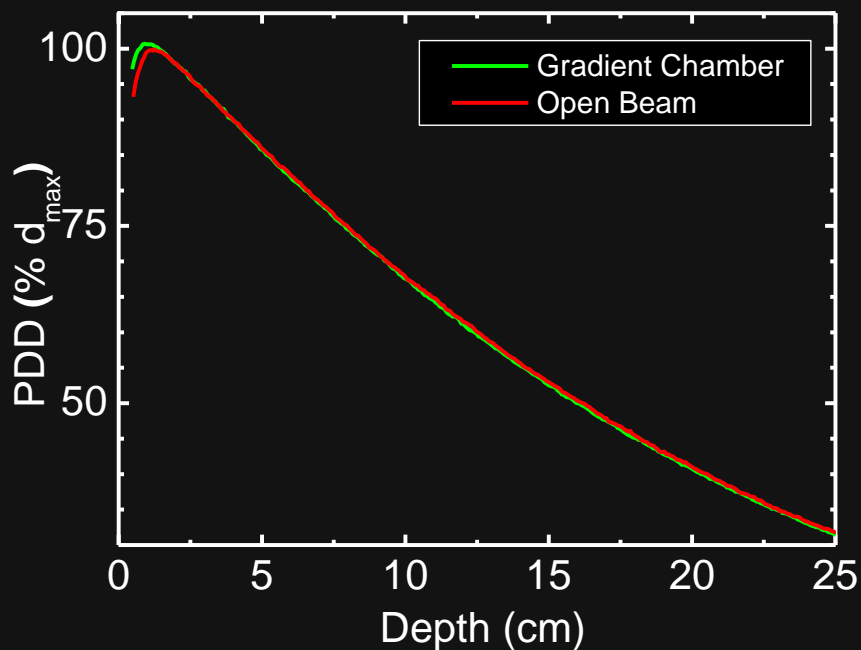
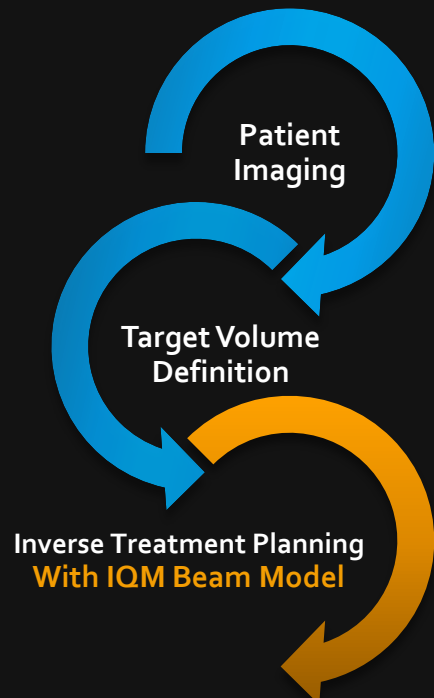


IQM Beam Model (Simplified)

Beam Attenuation: 5.5% (6 MV), 4.5% (18 MV)

Δ Surface Dose: Modest increase (negligible)

Effect on Beam Quality: Negligible





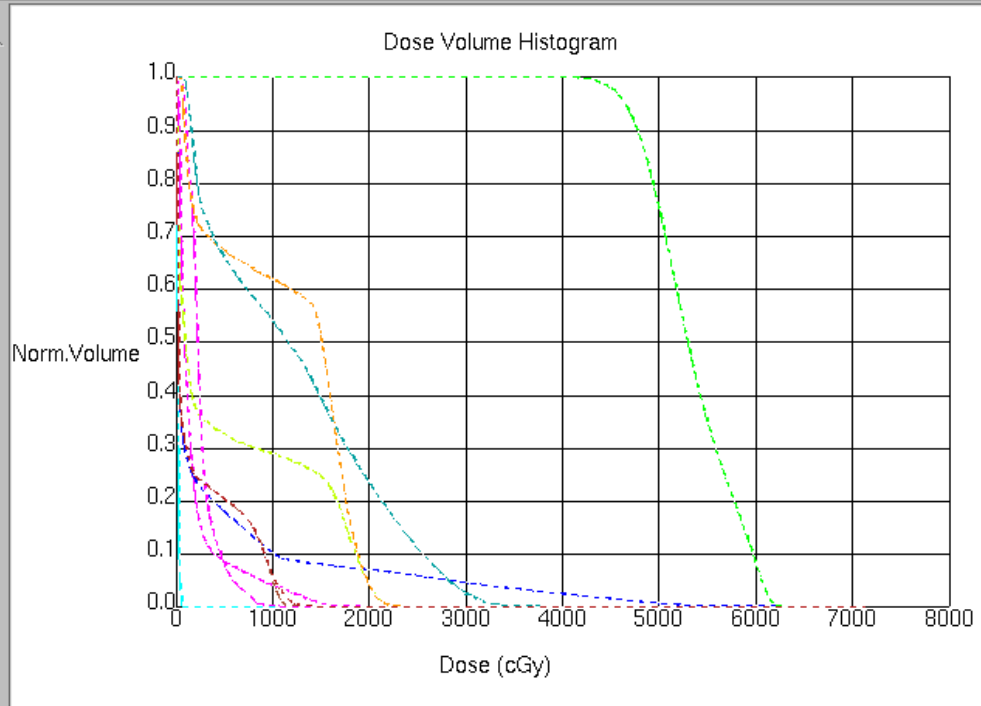
ROI ROI Group

Trials

Display	Name	Line Type
<input type="checkbox"/>	0.True Beam	Thick Solid
<input type="checkbox"/>	1.Trial_IQM	Thick Dashed
<input checked="" type="checkbox"/>	2.True Beam C	Thin Solid
<input checked="" type="checkbox"/>	3.IQM_Copy	Thin Dashed

ROIs

Display	Name	a
<input type="checkbox"/>	GTV-T_ex-5400	1
<input type="checkbox"/>	GTV-T_in-5400	1
<input type="checkbox"/>	ITV-T-5400	1
<input checked="" type="checkbox"/>	PTV-T-5400	1
<input checked="" type="checkbox"/>	HEART	1
<input checked="" type="checkbox"/>	BRONCH	1
<input checked="" type="checkbox"/>	RPLEXUS	1
<input checked="" type="checkbox"/>	TRACHEA	1
<input checked="" type="checkbox"/>	ESOPHAGUS	1
<input checked="" type="checkbox"/>	CANAL	1
<input checked="" type="checkbox"/>	prvCANAL-3mm	1
<input type="checkbox"/>	prvCANAL-5mm	1



DVH Calculation

- Cumulative
- Differential

Dose Axis Display

- Normalized Dose
- Absolute Dose
- Auto-Compute Max
- Specify Max Dose

Volume Axis Display

- Normalized Volume
- Absolute Volume

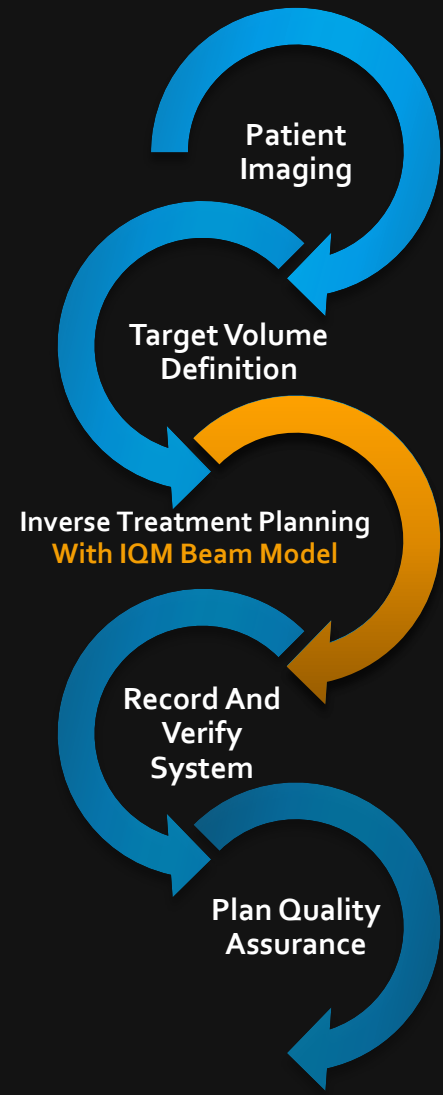
Tabular DVH...

DVH Tools Reset

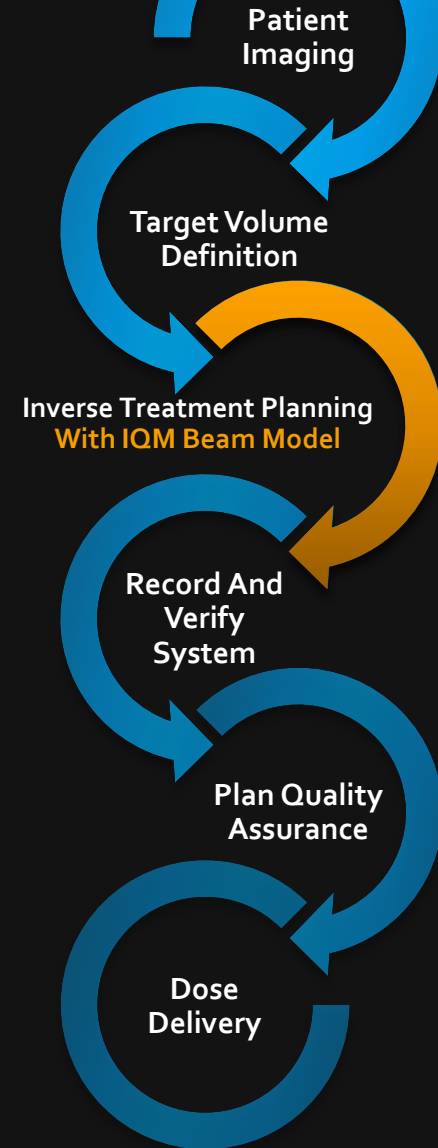
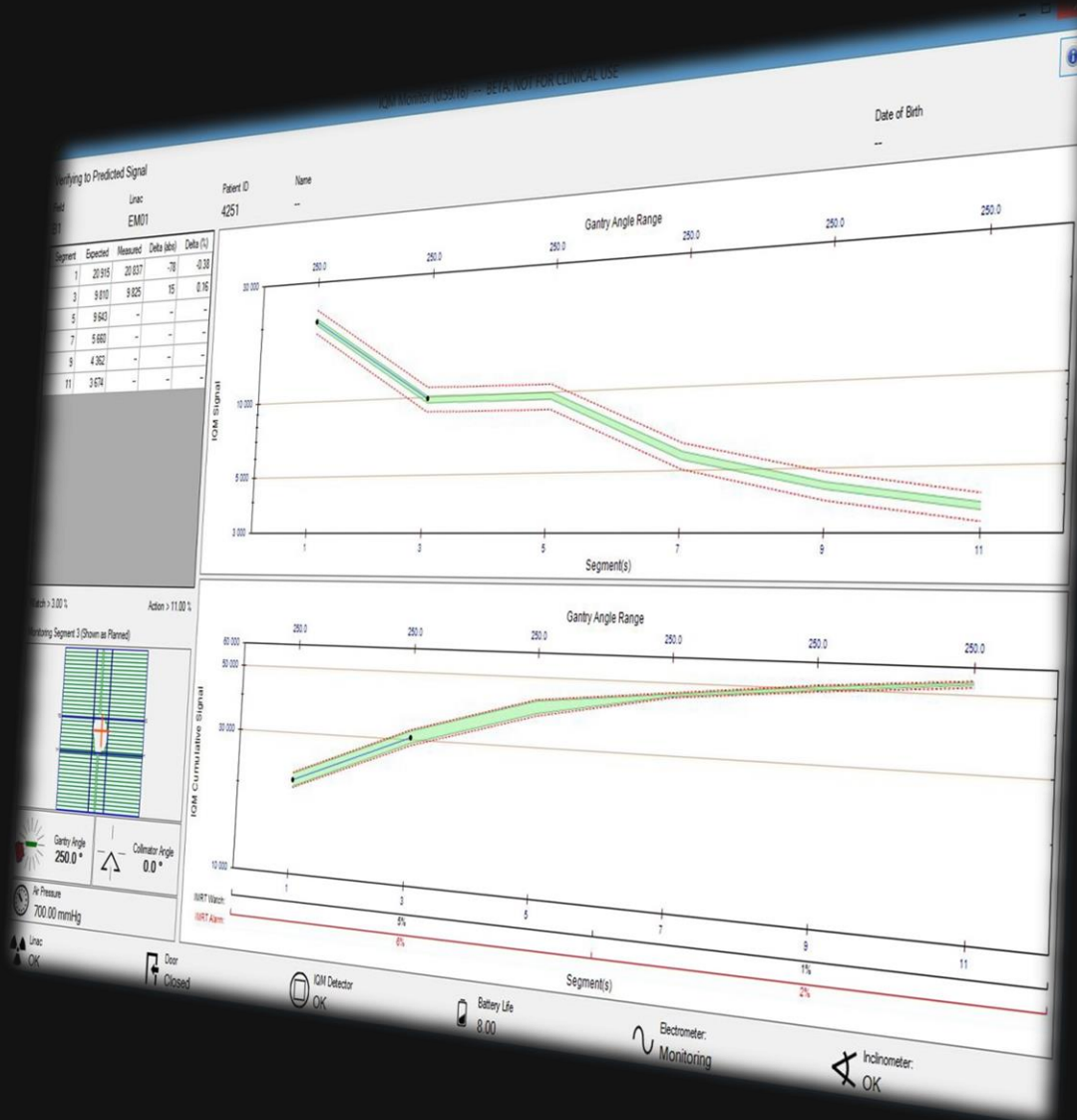
ROI Statistics

Line Type	ROI	Trial or Record	Min.	Max.	Mean	Std. Dev.	% Outside Grid	% > Max	Generalized EUD
<input type="checkbox"/>	NONGTVLUNG	2.True Beam Copy	2.0	6242.7	390.6	944.3	0.00 %	0.00 %	--
<input type="checkbox"/>	NONGTVLUNG	3.IQM_Copy	2.0	6233.9	391.1	945.4	0.00 %	0.00 %	--
<input type="checkbox"/>	PTV-T-5400	2.True Beam Copy	3726.3	6257.7	5329.2	440.7	0.00 %	0.00 %	--
<input type="checkbox"/>	PTV-T-5400	3.IQM_Copy	3737.3	6255.1	5333.0	441.2	0.00 %	0.00 %	--
<input type="checkbox"/>	RPLEXUS	2.True Beam Copy	80.8	1058.6	263.8	150.3	0.00 %	0.00 %	--
<input type="checkbox"/>	RPLEXUS	3.IQM_Copy	80.5	1053.8	264.5	151.3	0.00 %	0.00 %	--
<input type="checkbox"/>	TRACHEA	2.True Beam Copy	62.6	2306.6	1123.2	731.6	0.00 %	0.00 %	--
<input type="checkbox"/>	TRACHEA	3.IQM_Copy	62.5	2302.2	1122.5	731.0	0.00 %	0.00 %	--

Compute

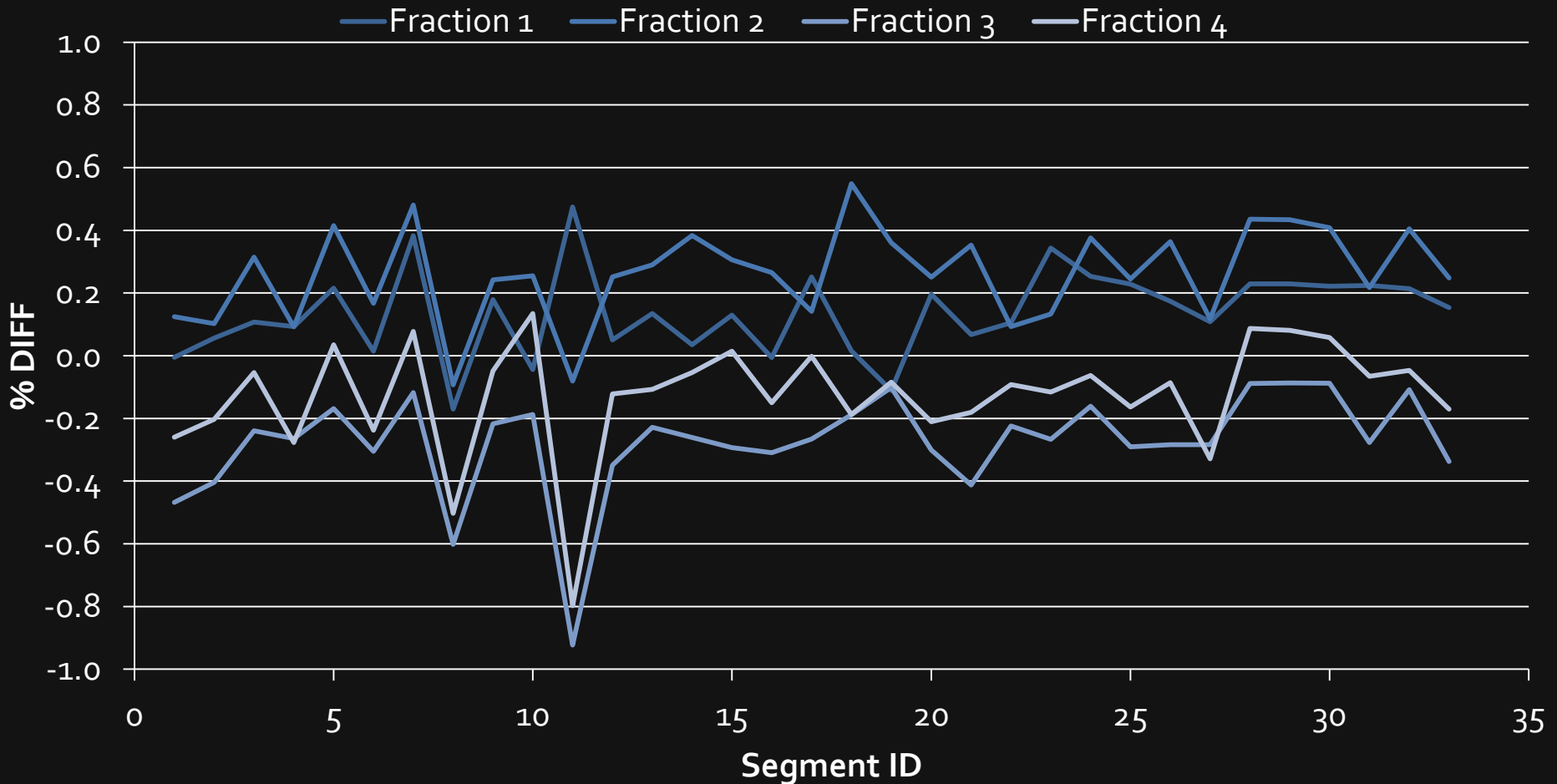


IMRT SBRT beam monitoring



IMRT SBRT beam monitoring

IMRT SBRT % Difference WRT Measured REF
(33 Segment)



IMRT SBRT beam monitoring

Total number of segments delivered : 132

Total number of segment out of 0.5 % tolerance: 5

IQM Signals were within the tolerance 96.2 % of the times

VMAT SBRT beam monitoring



VMAT SBRT beam monitoring

Monitoring Mode: n/a Monitoring Status: System Ready

Field ID: n/a Linac: SV03 Patient ID: n/a Name: n/a Date of Birth: n/a

Segment	Expected	Measured	Delta (abs)	Delta (%)
---------	----------	----------	-------------	-----------

Segment-by-Segment Gantry Angle

Watch Level: n/a
Action Level: n/a

Current Segment

Field Shape: n/a

Gantry Angle: n/a Collimator Angle: n/a

Air Pressure: 751.21 mmHg

VSDC Free Screen Recorder

Linac: OK Door: Closed Monitoring 7.07 volts Inclinometer: OK

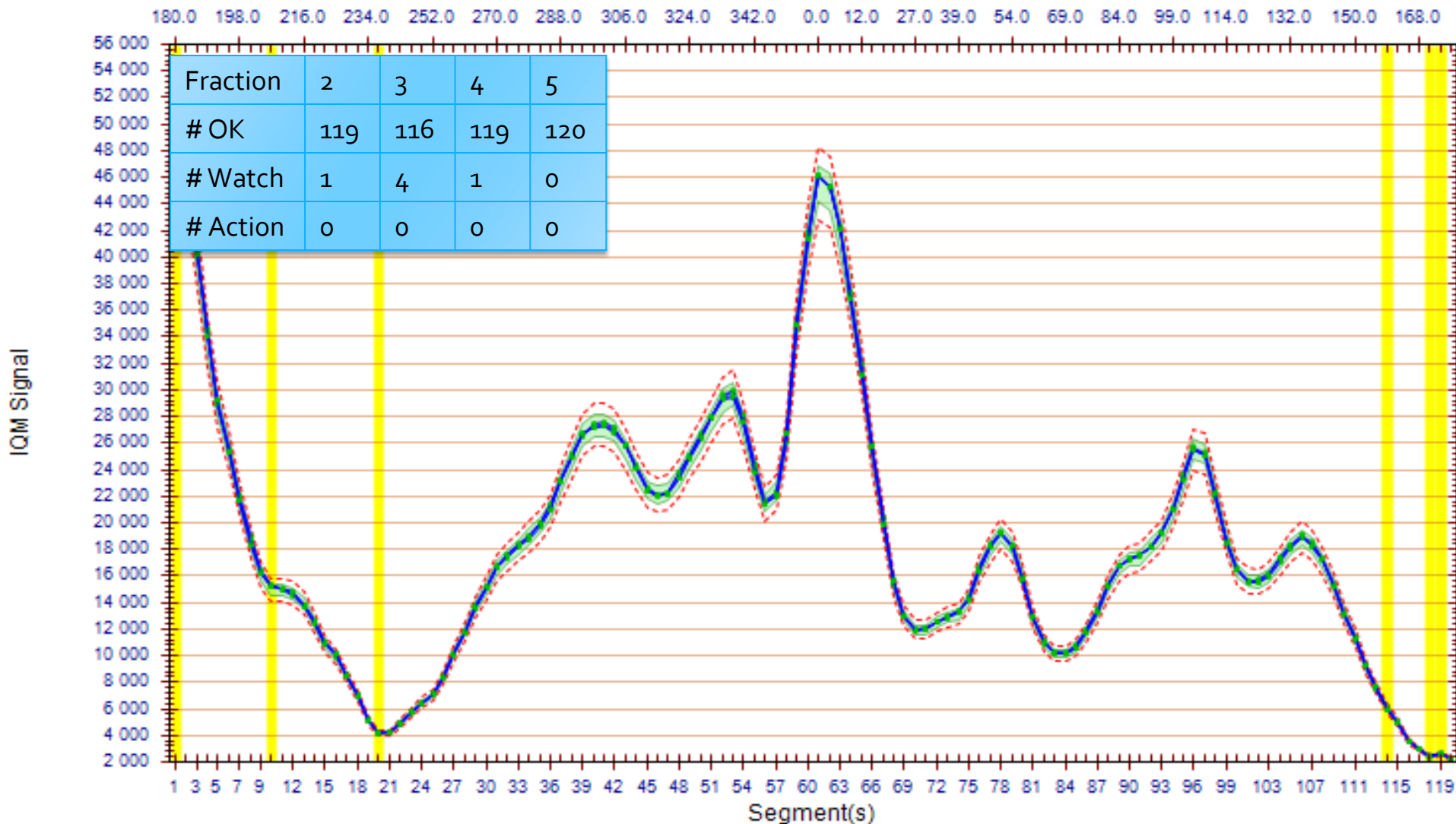
Detailed description: The image shows a software interface for VMAT SBRT beam monitoring. At the top, a green status bar indicates 'Monitoring Mode: n/a' and 'Monitoring Status: System Ready'. Below this, patient and linac information is displayed: 'Field ID: n/a', 'Linac: SV03', 'Patient ID: n/a', 'Name: n/a', and 'Date of Birth: n/a'. A table with columns for 'Segment', 'Expected', 'Measured', 'Delta (abs)', and 'Delta (%)' is present but empty. The main area contains two graphs: 'Segment-by-Segment' and 'Cumulative', both plotting 'IOM Signal' (log scale from 10 to 1000) against 'Gantry Angle'. The 'Current Segment' section shows 'Field Shape: n/a'. Below that, 'Gantry Angle: n/a' and 'Collimator Angle: n/a' are shown with a beam diagram. An 'Air Pressure: 751.21 mmHg' gauge is also visible. A 'VSDC Free Screen Recorder' window is overlaid on the bottom right. The bottom status bar shows 'Linac: OK', 'Door: Closed', 'Monitoring', '7.07 volts', and 'Inclinometer: OK'.

VMAT SBRT beam monitoring

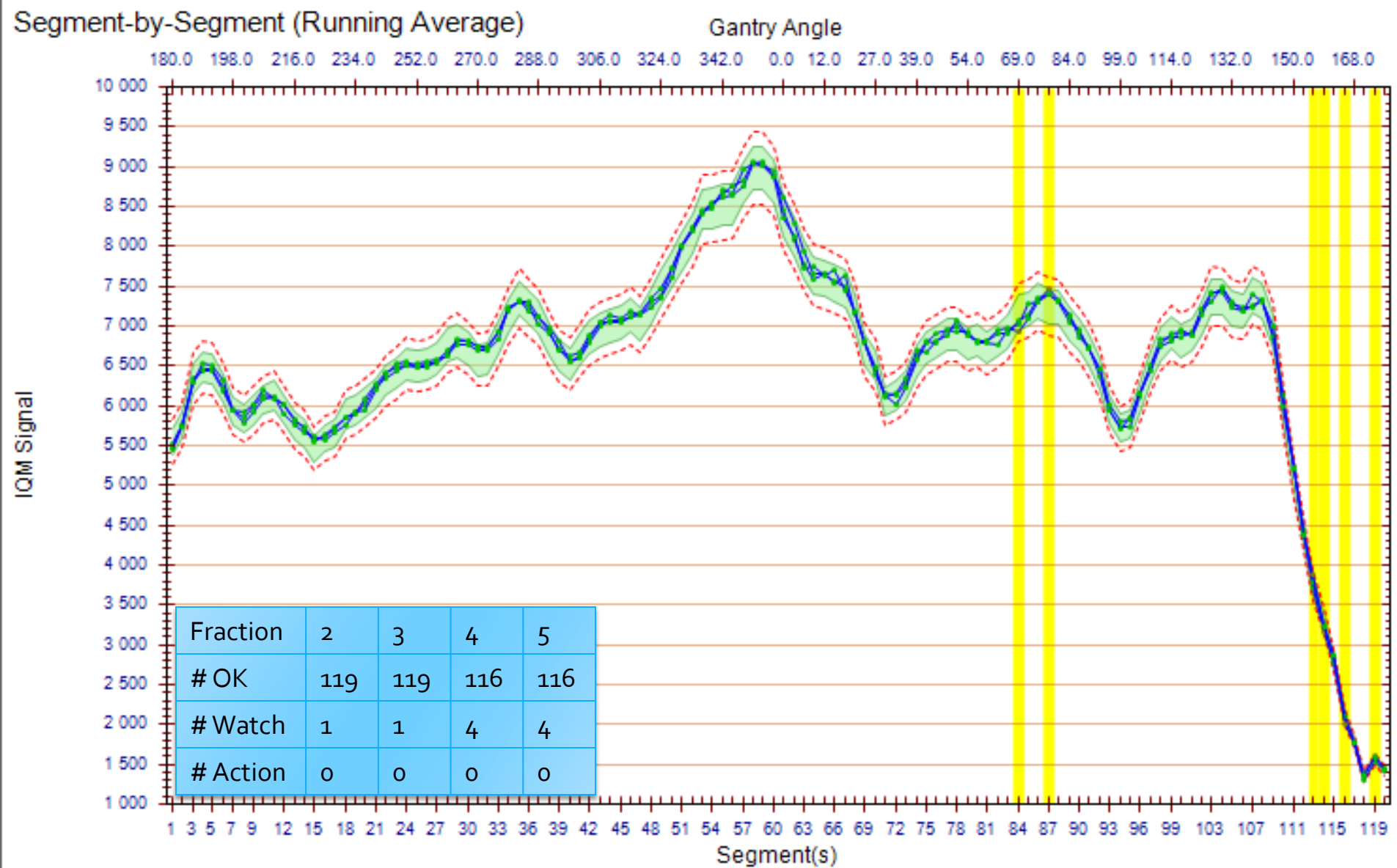
3% - 3 point Running Average

Segment-by-Segment (Running Average)

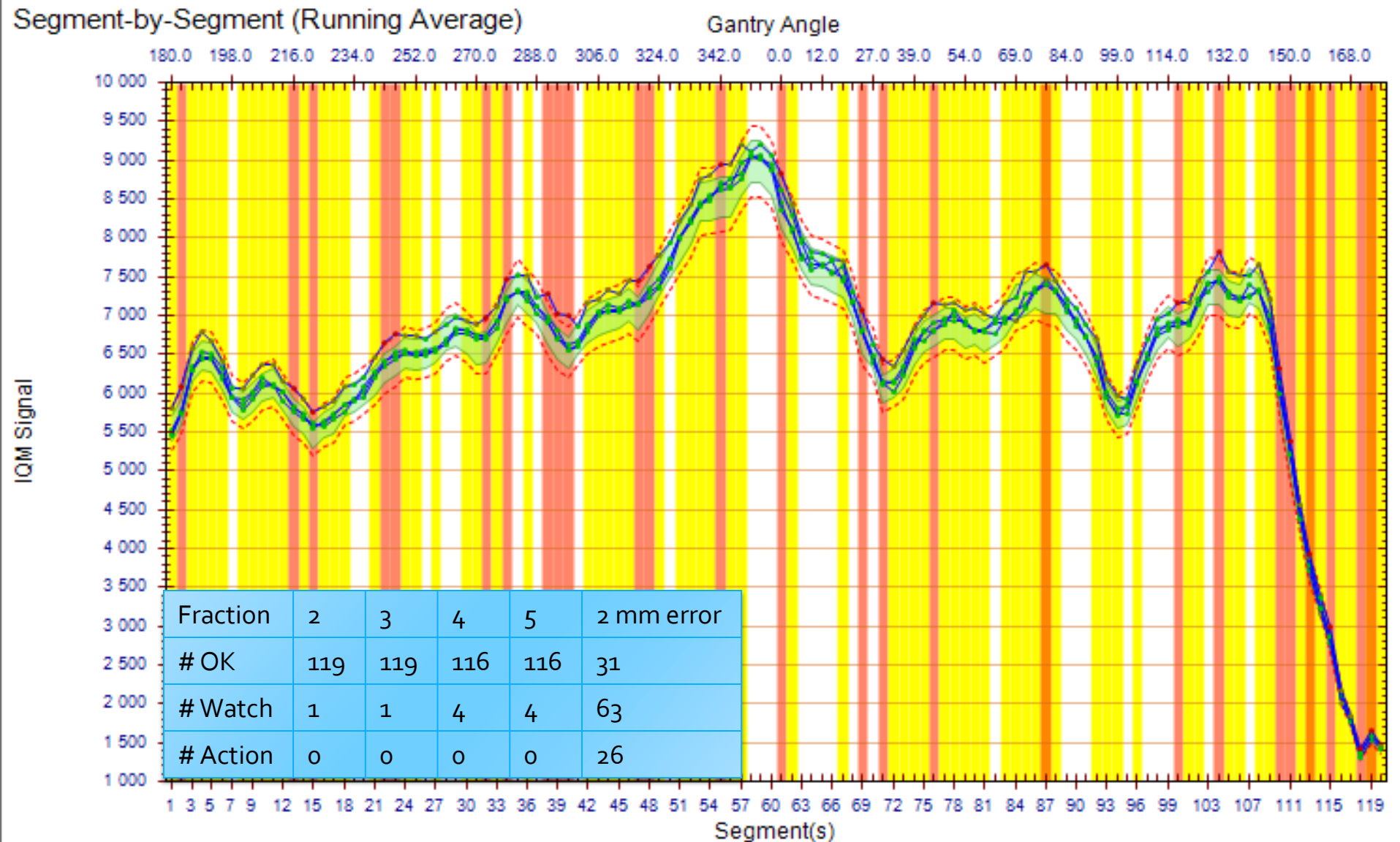
Gantry Angle



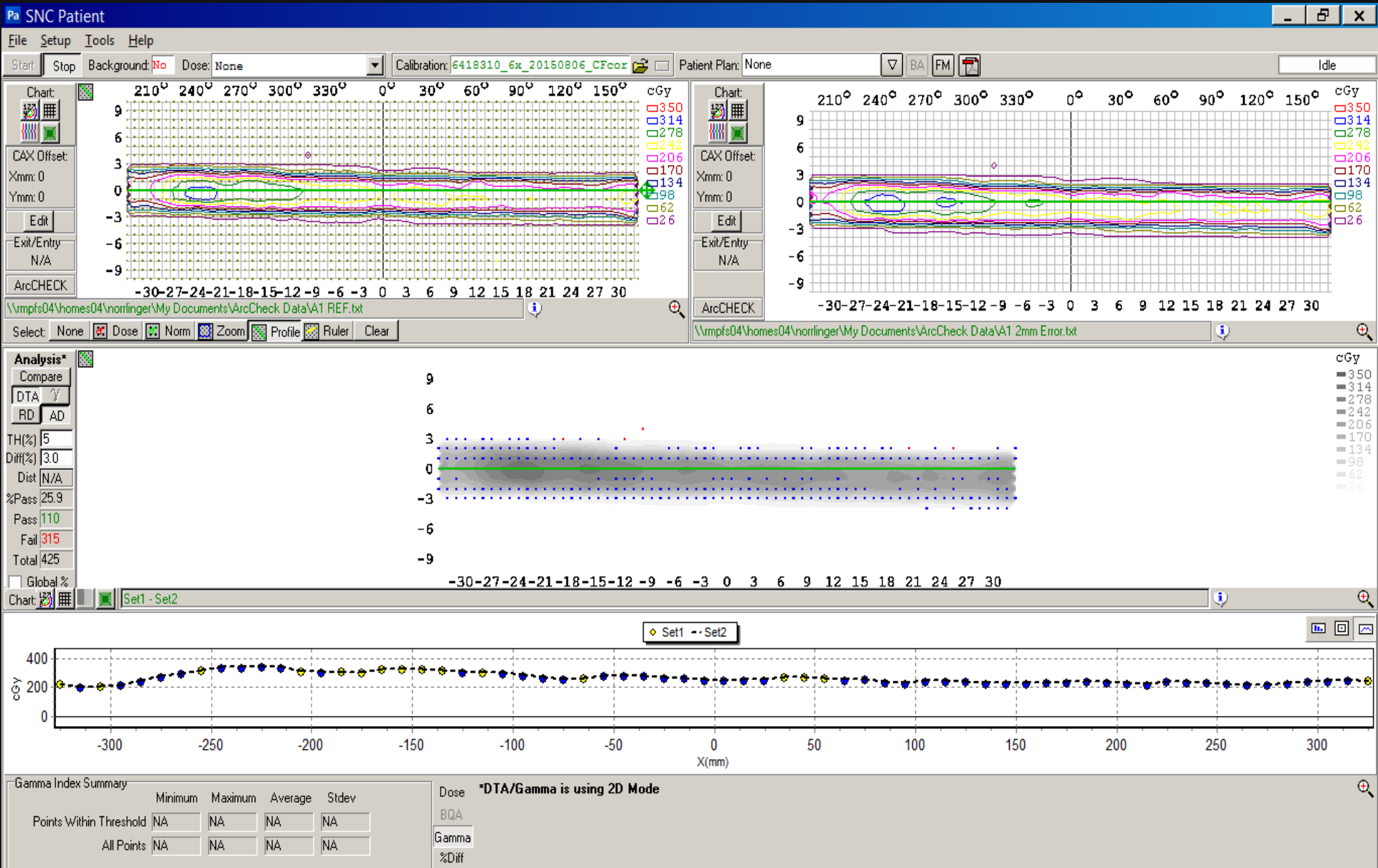
VMAT SBRT beam monitoring (p2 No Error)



VMAT SBRT beam monitoring (p2 2mm Error)



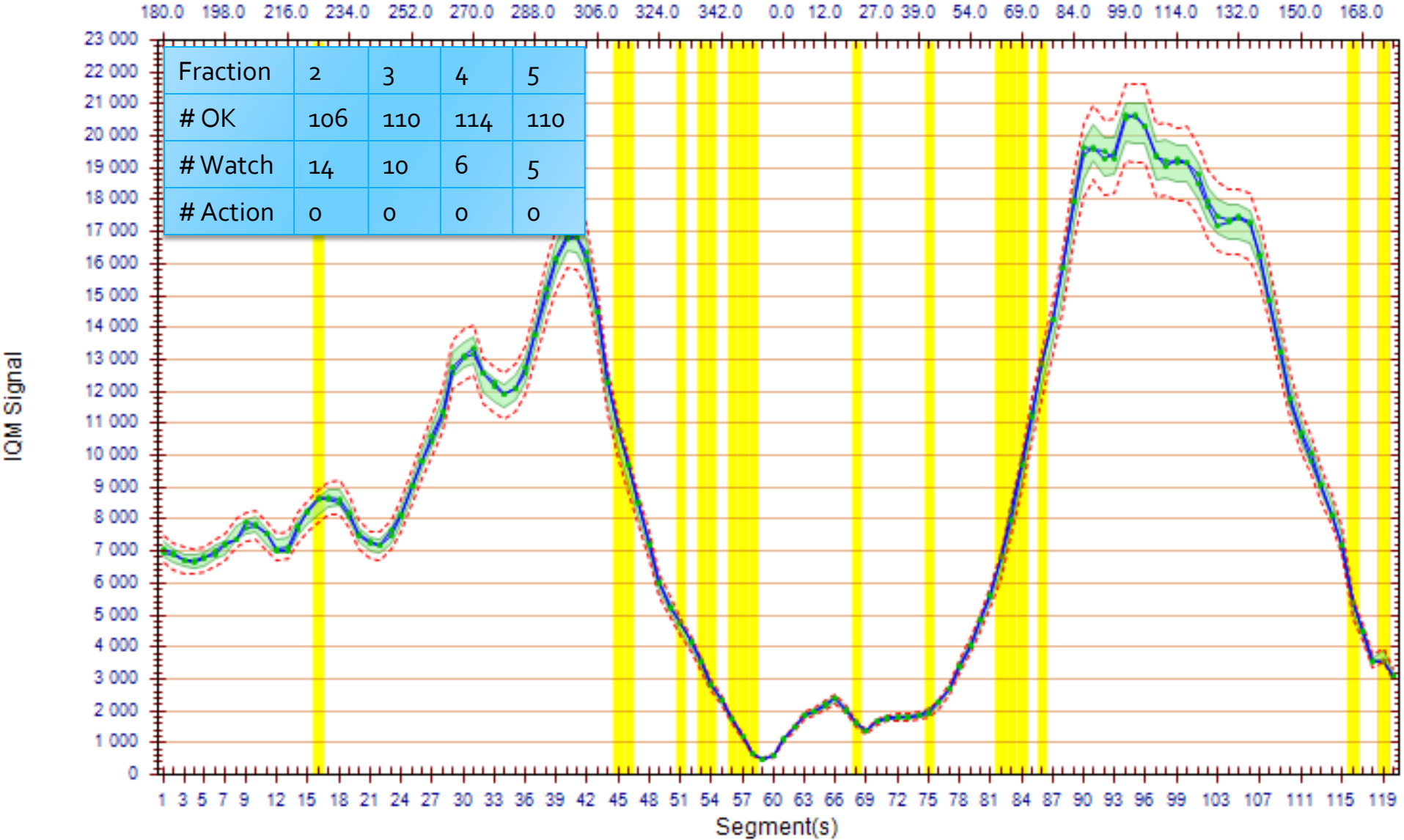
VMAT SBRT ArcCheck(p2 2mm Error)



VMAT SBRT beam monitoring (P₃ No error)

Segment-by-Segment (Running Average)

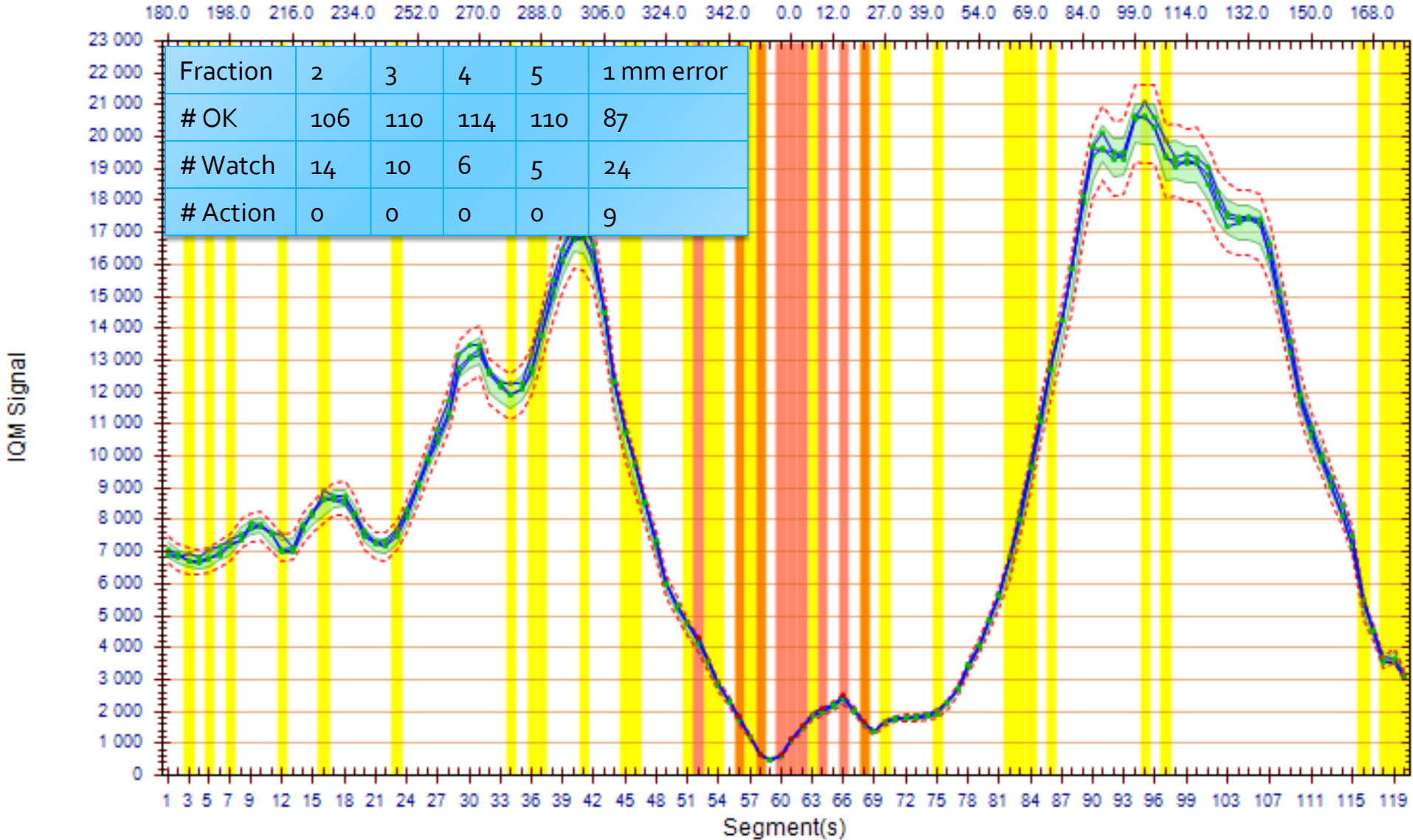
Gantry Angle



VMAT SBRT beam monitoring (P₃ 1mm Error)

Segment-by-Segment (Running Average)

Gantry Angle



VMAT SBRT ArcCheck (P3 1mm Error)

Pa SNC Patient

File Setup Tools Help

Start Stop Background: No Dose: None Calibration: 6418310_6x_20150806_CFloor Patient Plan: None BA FM

Chart: 210° 240° 270° 300° 330° 0° 30° 60° 90° 120° 150° cGy

720
648
576
504
432
360
288
216
144
72

CAX Offset: Xmm: 0 Ymm: 0

Chart: 210° 240° 270° 300° 330° 0° 30° 60° 90° 120° 150° cGy

720
648
576
504
432
360
288
216
144
72

CAX Offset: Xmm: 0 Ymm: 0

Analysis* Compare DTA RD AD TH(%) 5 Diff(%) 3.0 Dist N/A %Pass 46.3 Pass 234 Fail 271 Total 505 Global %

Chart: Set1 - Set2

9 6 3 0 -3 -6 -9

-30 -27 -24 -21 -18 -15 -12 -9 -6 -3 0 3 6 9 12 15 18 21 24 27 30

9 6 3 0 -3 -6 -9

-30 -27 -24 -21 -18 -15 -12 -9 -6 -3 0 3 6 9 12 15 18 21 24 27 30

Set1 - Set2

cGy

500

0

-300 -250 -200 -150 -100 -50 0 50 100 150 200 250 300

X(mm)

Gamma Index Summary

	Minimum	Maximum	Average	Stdev
Points Within Threshold	NA	NA	NA	NA

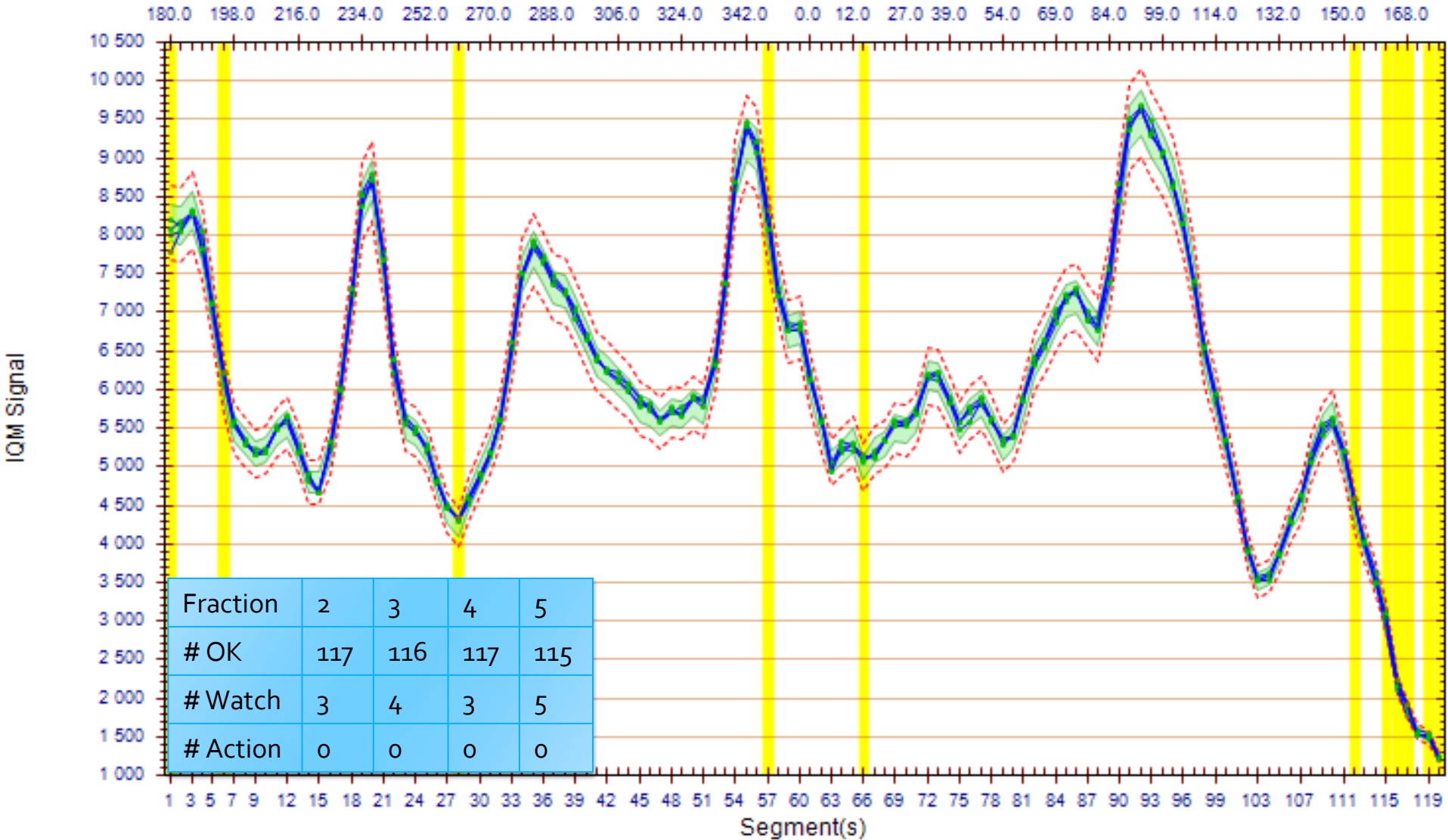
Dose *DTA/Gamma is using 2D Mode BQA

9:21 PM 2015-10-19

VMAT SBRT beam monitoring (P₄ No Error)

Segment-by-Segment (Running Average)

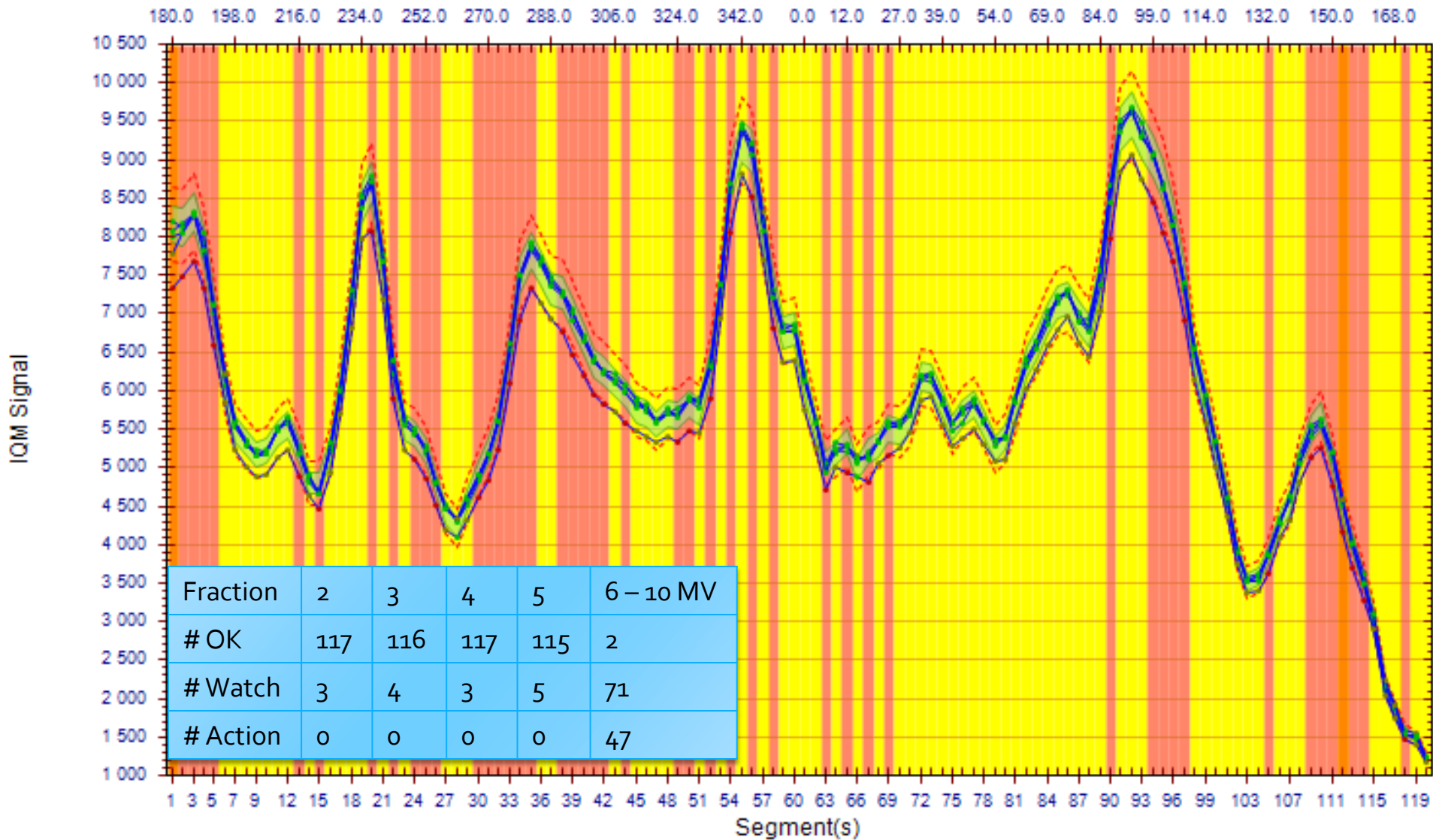
Gantry Angle



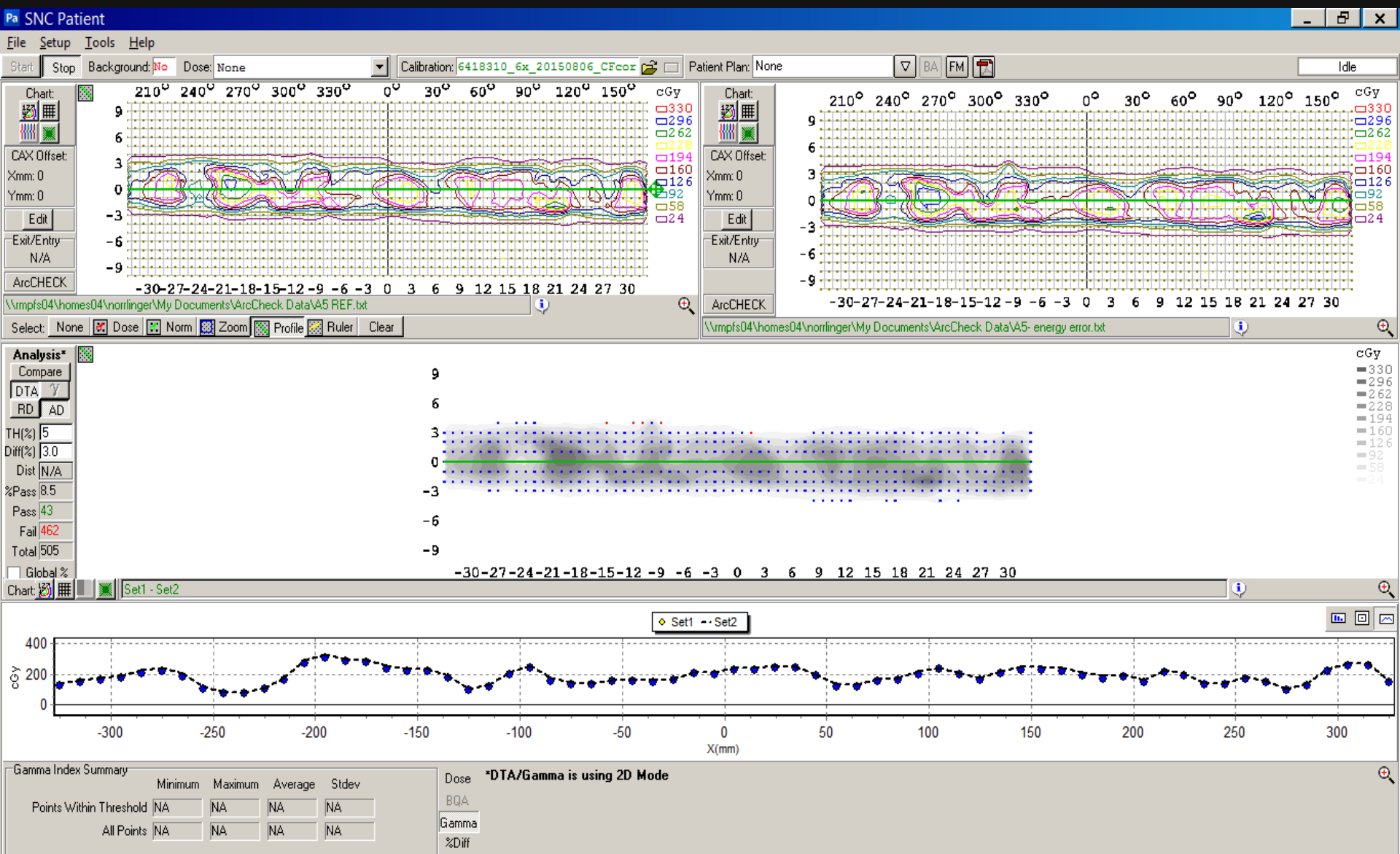
VMAT SBRT beam monitoring (P₄ Energy Error)

Segment-by-Segment (Running Average)

Gantry Angle



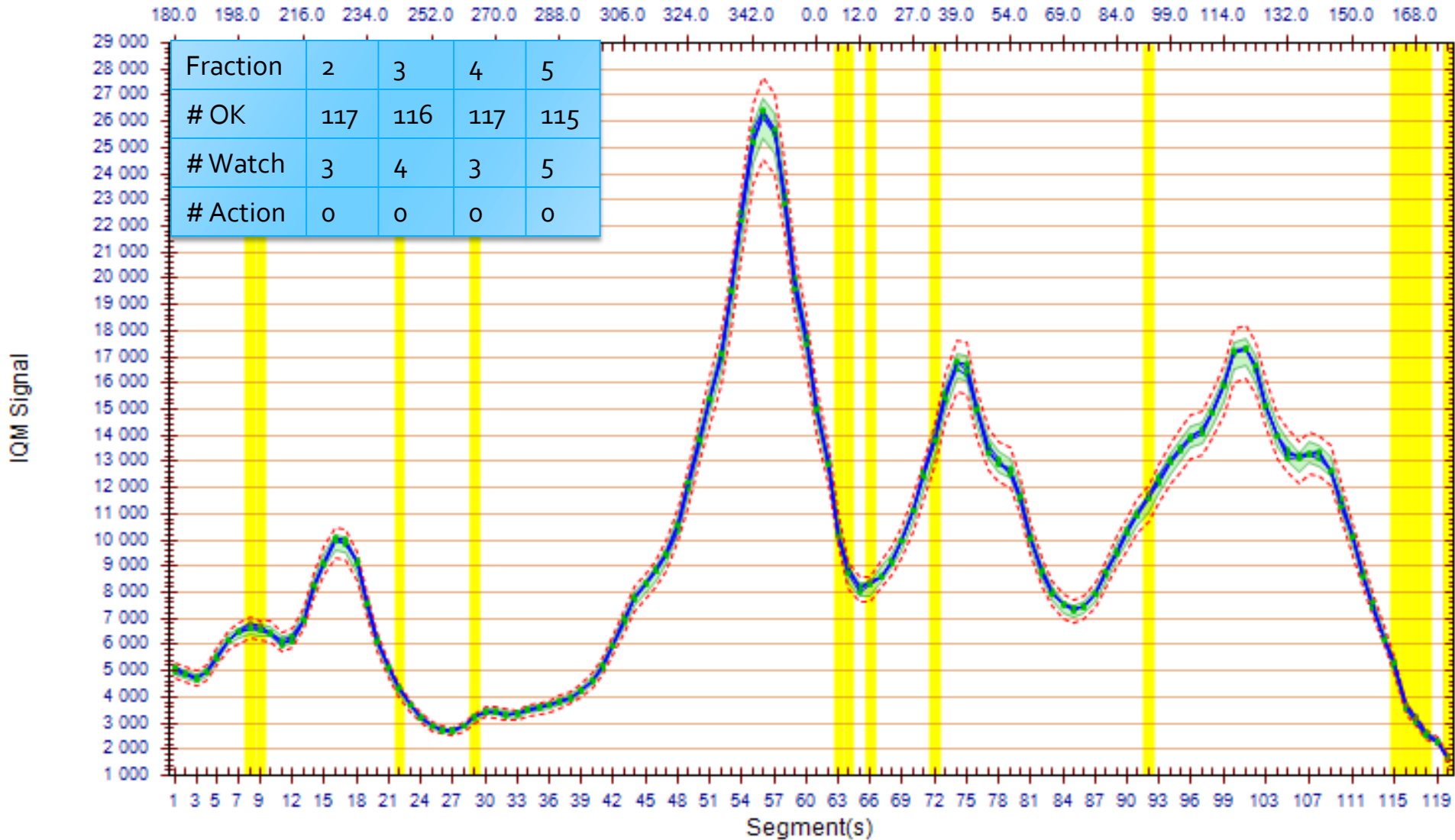
VMAT SBRT ArcCheck (P4 Energy Error)



VMAT SBRT beam monitoring (P5 No Error)

Segment-by-Segment (Running Average)

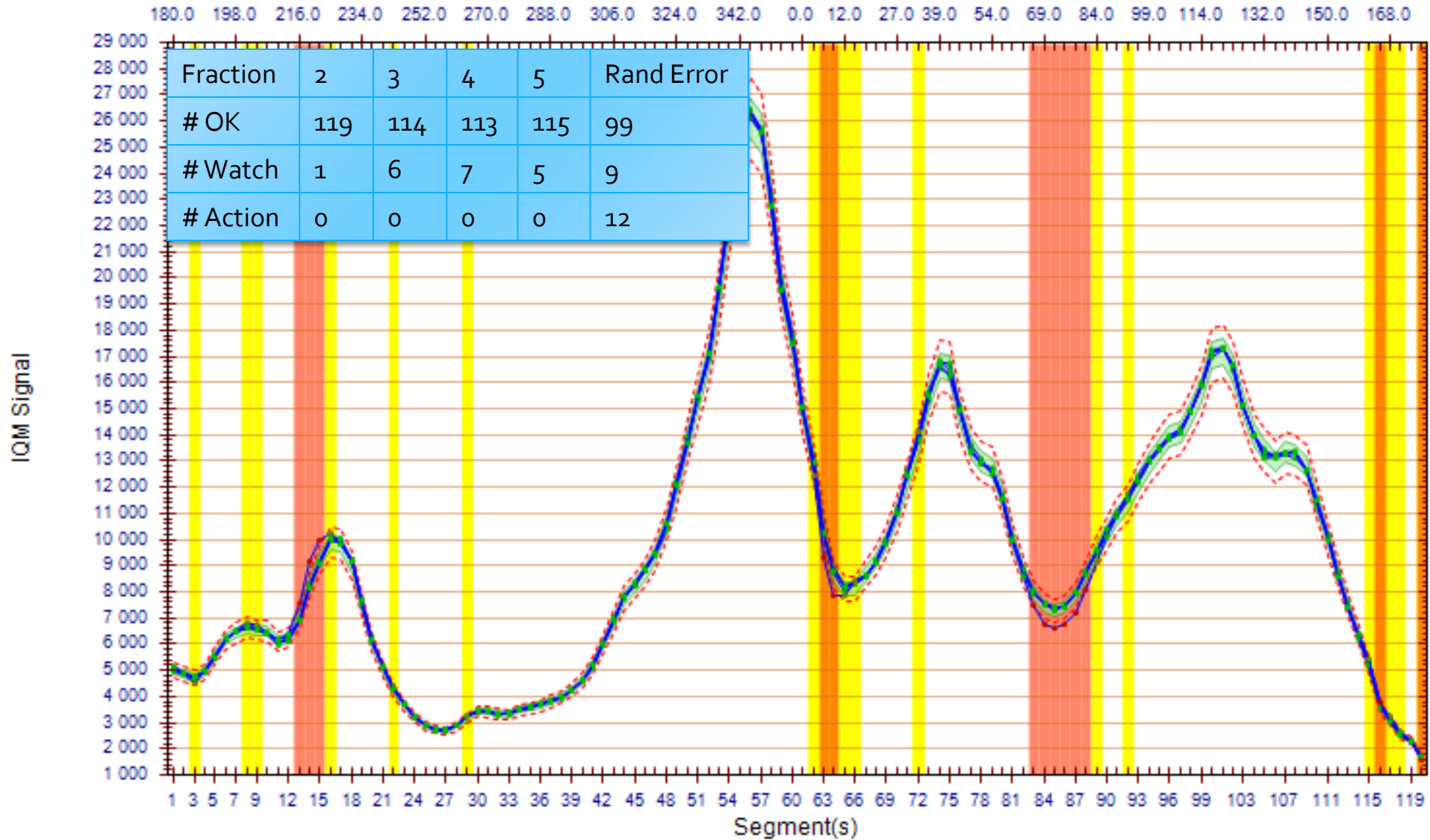
Gantry Angle



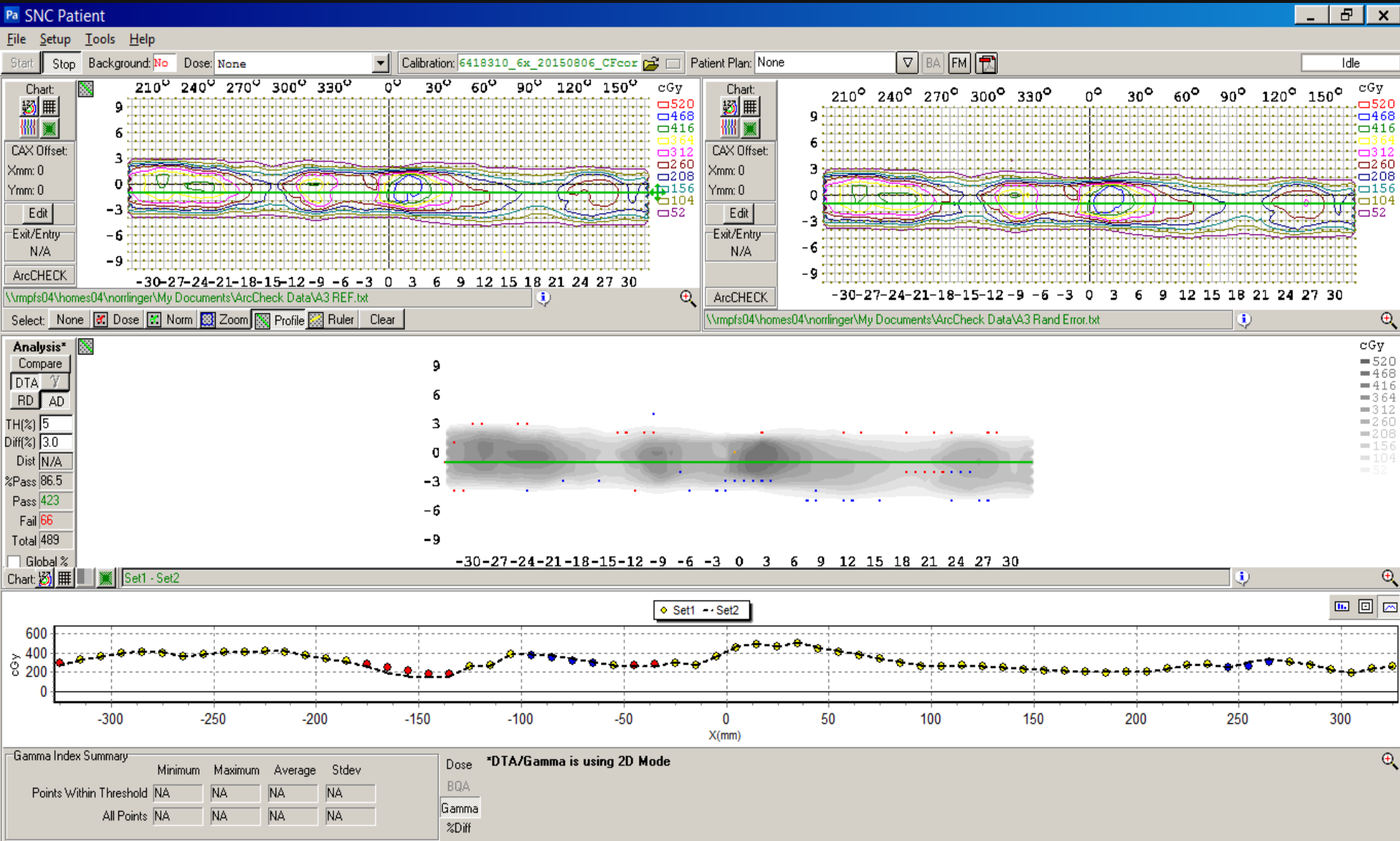
VMAT SBRT beam monitoring (P₅ Rand Error)

Segment-by-Segment (Running Average)

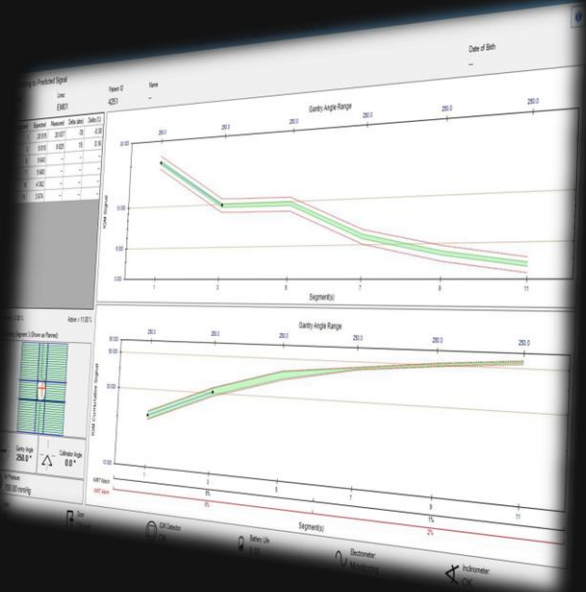
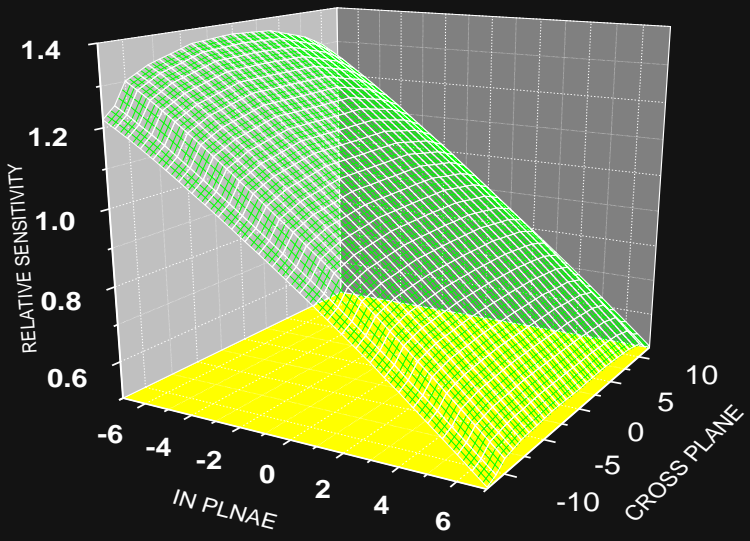
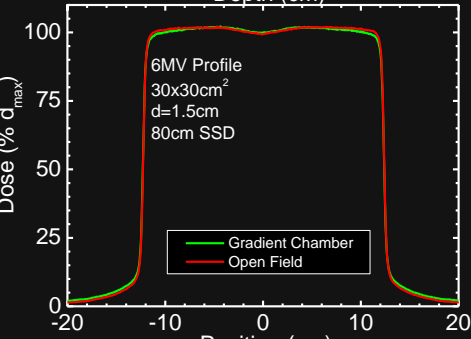
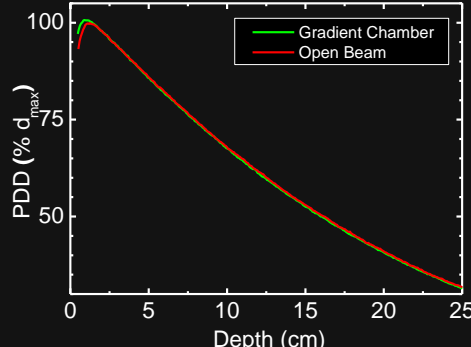
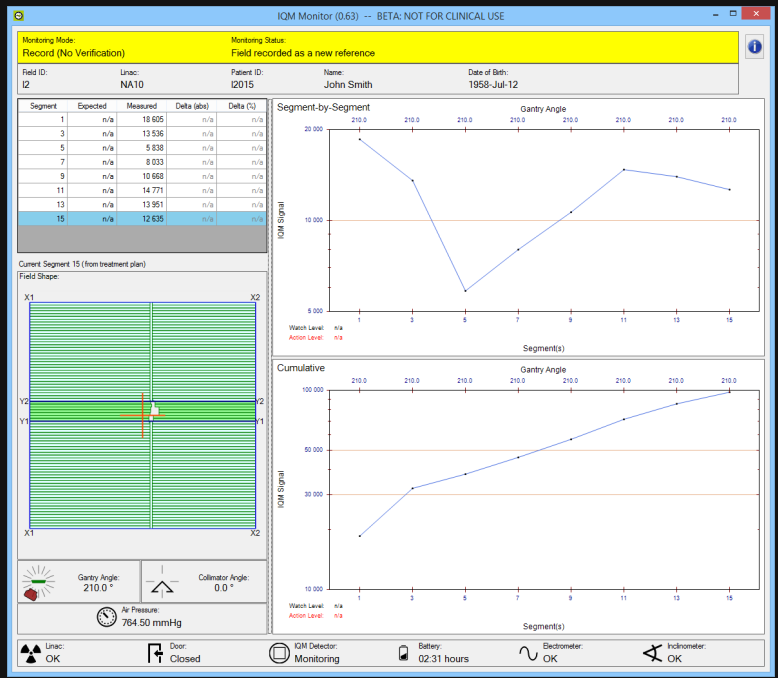
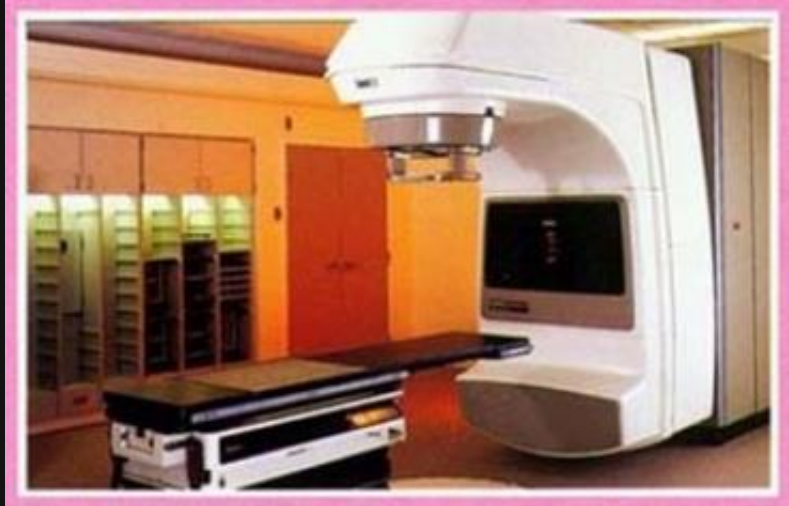
Gantry Angle



VMAT SBRT ArcCheck (P5 Rand Error)



Conclusions



“The more distant we look into the past,
the farther we can see into the future.”

Winston Churchill

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