Efficient and Enhanced QA Testing of Linear Accelerators using a Real-time Beam Monitor

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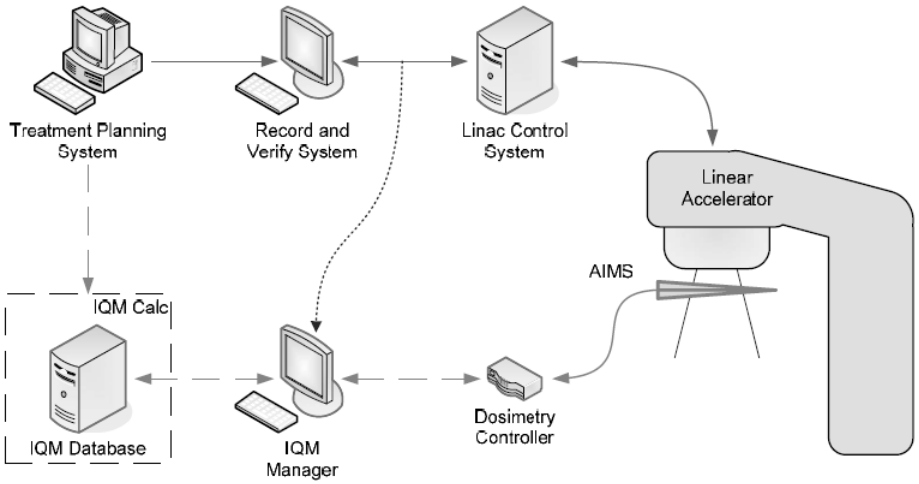
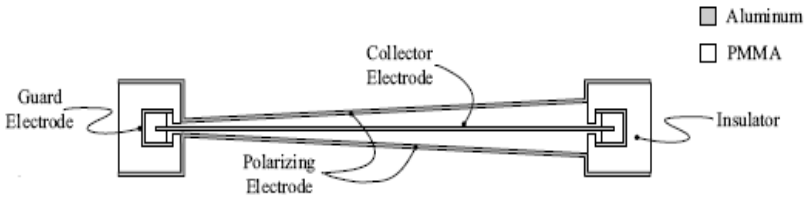
Integral Quality Monitor (IQM)



- Independent **beam monitoring** system

- **Segment-by-segment** monitoring by **comparison** with **calculation** or **reference measurement**

Integral Quality Monitor (IQM)



- Consists of large area **ion-chamber**
- **1D sensitivity gradient**

  → Check beam aperture is at **right location**

Integral Quality Monitor (IQM)

- Attached to Linac head to monitor beam delivery
- Potentially used for some of the required QA of the Linac

List of QAs Investigated

- Beam Output
- Beam Symmetry
- Relative Dose Factor (RDF)
- MLC Calibration
- Output as Function of Dose Rate
- Dose Linearity
- Output as Function of Gantry Angles

Beam Output– Conventional Method

- Conventionally done using Farmer-type ion-chamber or 2D detector system

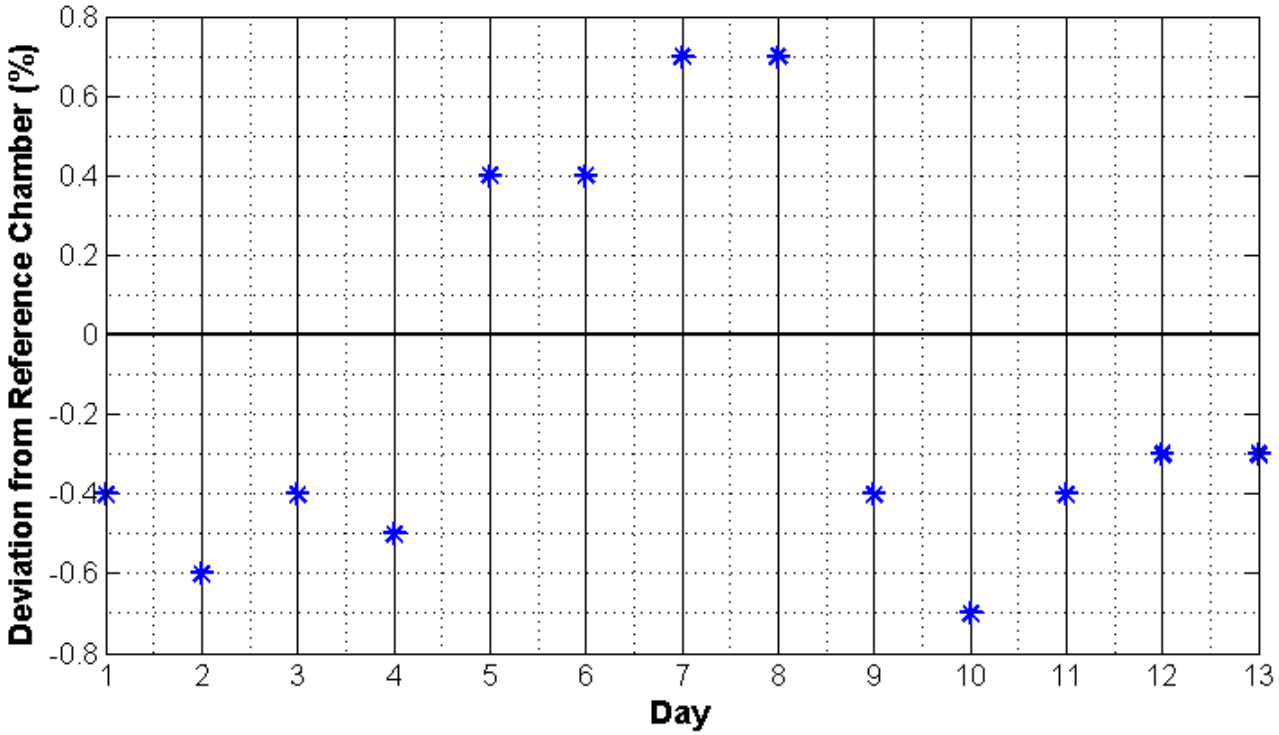
Beam Output – Using IQM

- Check the deviation from reference
  - Temperature and pressure corrected

- Concurrent reference Farmer-type chamber measurement

IQM Beam Output Results

- Deviation of IQM measurement from Farmer-type chamber



*for 13 different days over a period of 2 months

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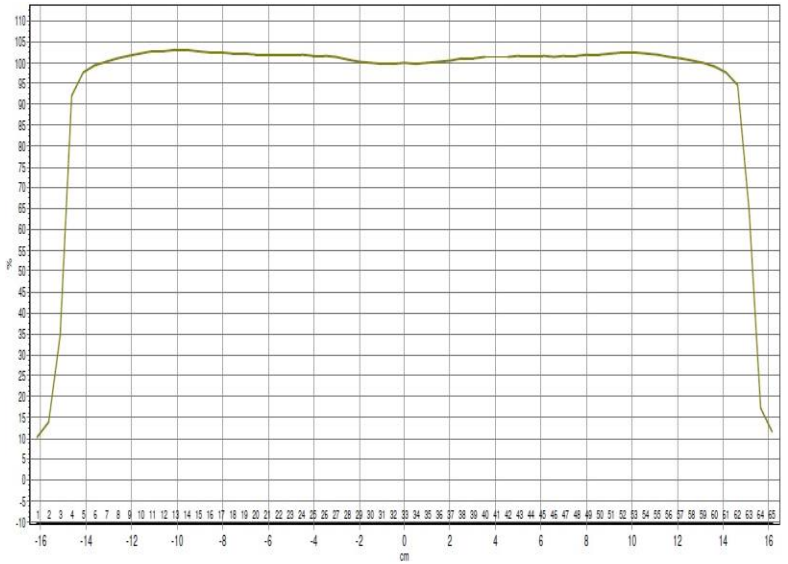
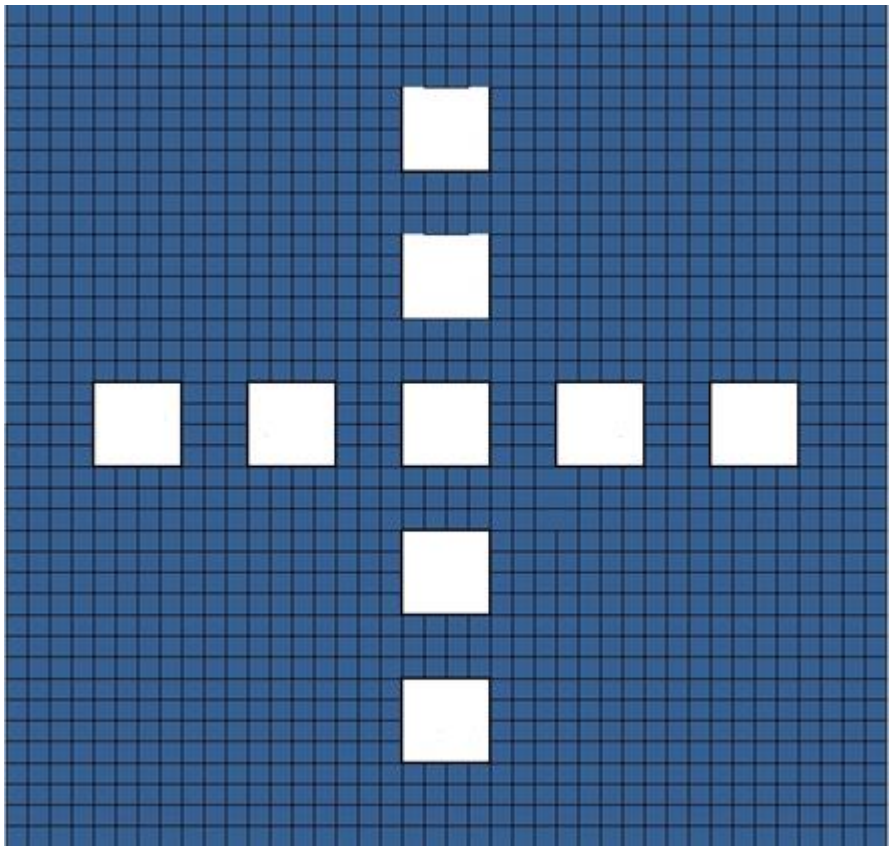
Beam Symmetry – Conventional Method

- 2D detector array system



Beam Symmetry – Using IQM

- Off-axis square field measurements



Beam Symmetry – Using IQM

- IQM Symmetry Parameter:

$$\frac{Measurement_{+d} - Measurement_{-d}}{Measurement_{central}} \times 100\%$$

- The parameter changes as beam symmetry changes

- Constancy parameter, not representing real symmetry value

Beam Symmetry – Using IQM

- Parameters for 3% beam symmetry compared to baseline (< 0.3% symmetry)

- Margin of error* of the parameters is 0.5%

  → Sensitive for difference greater than 1%

Off-axis distance (cm)	Gradient			Non-Gradient		
	3% (%)	Baseline (%)	Difference (%)	3% (%)	No tilt (%)	Baseline (%)
9	-46.4	-44.0	-2.4	2.0	0.3	1.7
12	-61.2	-59.0	-2.2	2.5	0.4	2.1
15	-70.4	-68.0	-2.4	2.4	0.7	1.7

*2 standard deviation

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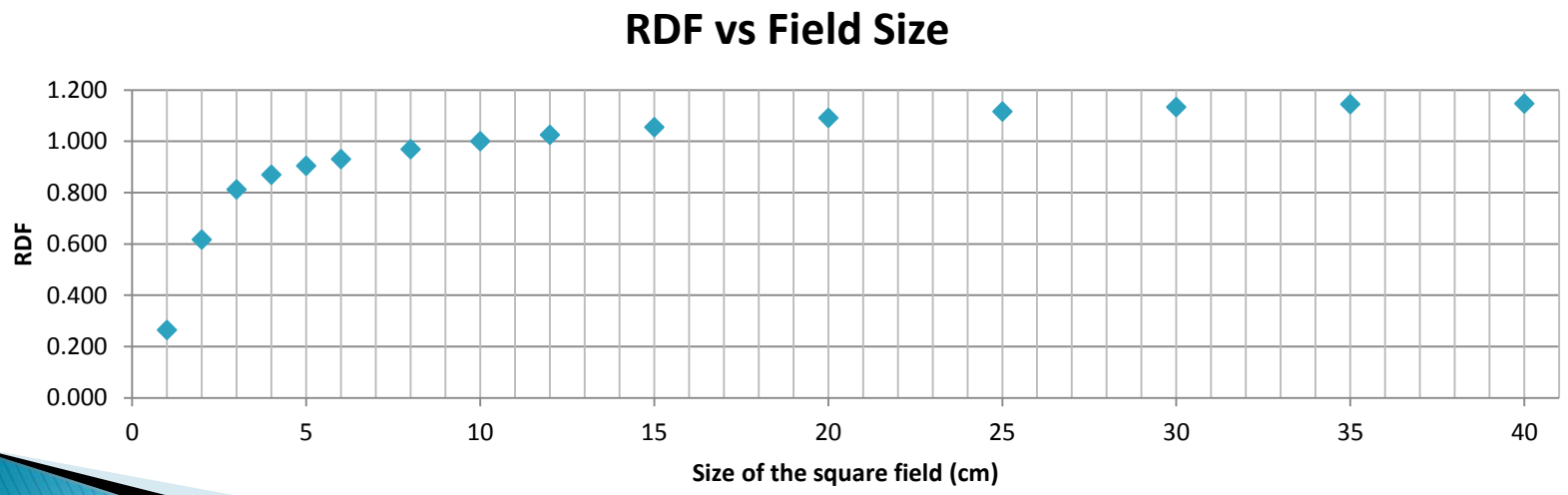
Relative Dose Factor (RDF) – Conventional Method

- Farmer type ion-chamber inserted inside solid water block

- Constancy check of square fields measurement from 1 x 1cm^2 to 40 x 40cm^2

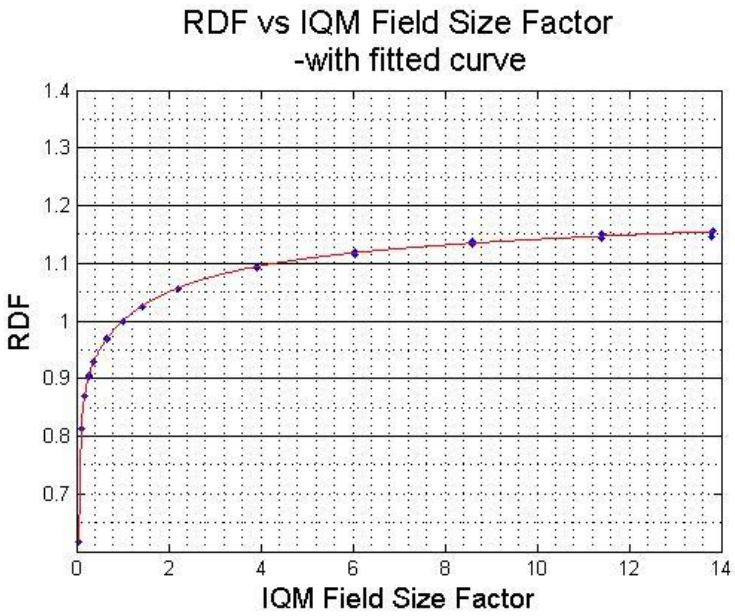


Relative Dose Factor – Using IQM

- Measure square fields from 1 x 1cm^2 to 40 x 40cm^2 using IQM
- Normalize with respect to 10 x 10cm^2 measurement
  → IQM Field Size Factor
- Measure RDF and IQM Field Size Factor concurrently

Relative Dose Factor – Using IQM

- RDF vs IQM Field Size Factor fitted with rational function



- RDF obtained from converting *IQM Field Size Factor*

IQM RDF QA

- Compare calculated RDF to measured RDF on different set of measurements

- Percentage Difference < 0.5% (ignoring 2x2)

Size of the field	Calculated RDF	Measured RDF	Percentage difference (%)
2 x 2	0.6176	0.6124	0.84
3 x 3	0.8123	0.8109	0.16
4 x 4	0.8721	0.8704	0.19
5 x 5	0.9052	0.9054	-0.02
6 x 6	0.9294	0.9303	-0.09
8 x 8	0.9677	0.9691	-0.15
10 x 10	0.9989	1.0000	-0.11
12 x 12	1.0255	1.0257	-0.01
15 x 15	1.0572	1.0559	0.12
20 x 20	1.0941	1.0933	0.08
25 x 25	1.1181	1.1199	-0.16
30 x 30	1.1348	1.1389	-0.36
35 x 35	1.1469	1.1526	-0.50
40 x 40	1.1547	1.1571	-0.21

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- Beam Output
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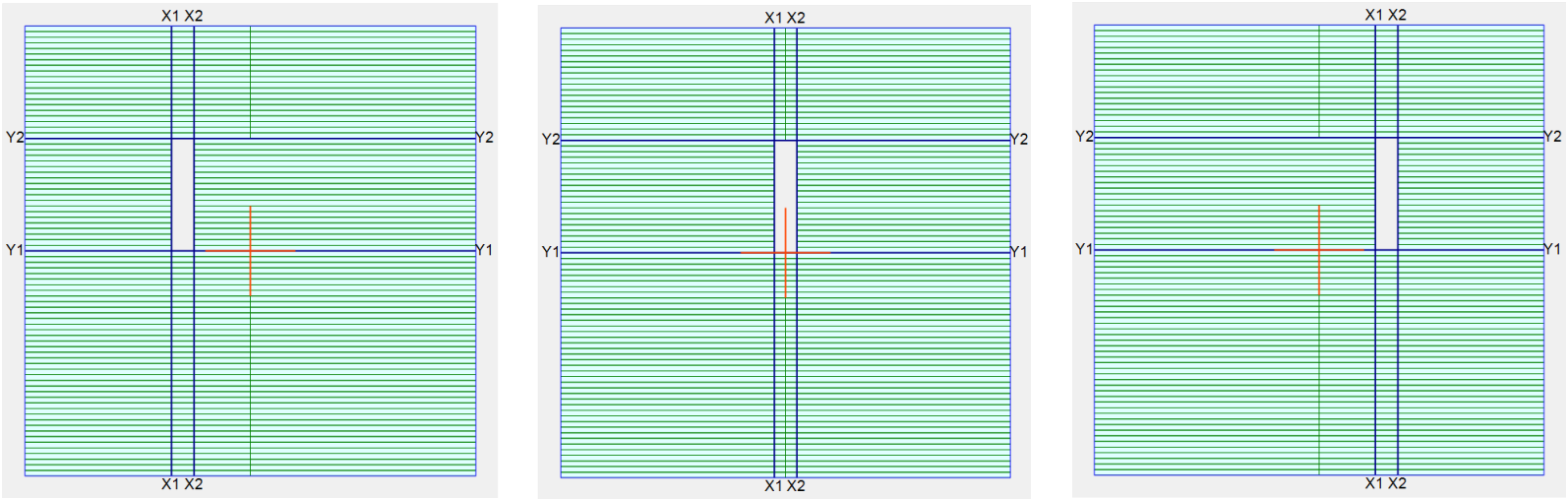
- **MLC Calibration**
- Output as Function of Dose Rate
- Dose Linearity
- Output as Function of Gantry Angles

MLC Calibration Constancy Check

- Picket-Fence type test
- 2 x 10cm^2 fields at off-axis positions along the gradient

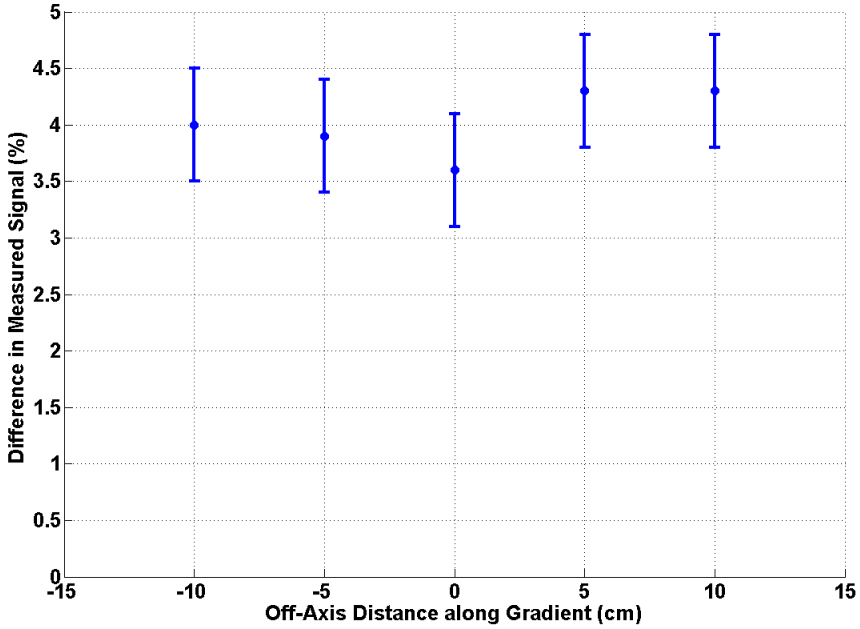


- Normalized measurements checked for constancy

MLC Calibration Constancy Check

- Introduced 1mm shift of one MLC bank
- Margin of error 0.5% (2 standard deviation)

  → sensitive to change bigger than this



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Output as a function of Dose Rate

- IQM measurement compared with reference ion-chamber measurement
- Normalized to measurement at 600MU/min
- Agree within around 0.5%

D/R	IQM Meas. (%)	Ion-chamber Meas. (%)	% Diff to 600MU/min	
600	100.00	100.00	0.00	0.00
500	100.03	100.45	0.03	0.45
400	100.01	100.45	0.01	0.44
300	100.03	100.29	0.03	0.29
100	100.03	100.29	0.03	0.29
60	99.98	100.59	-0.02	0.59
40	99.97	100.51	-0.03	0.51
20	99.89	100.56	-0.11	0.56

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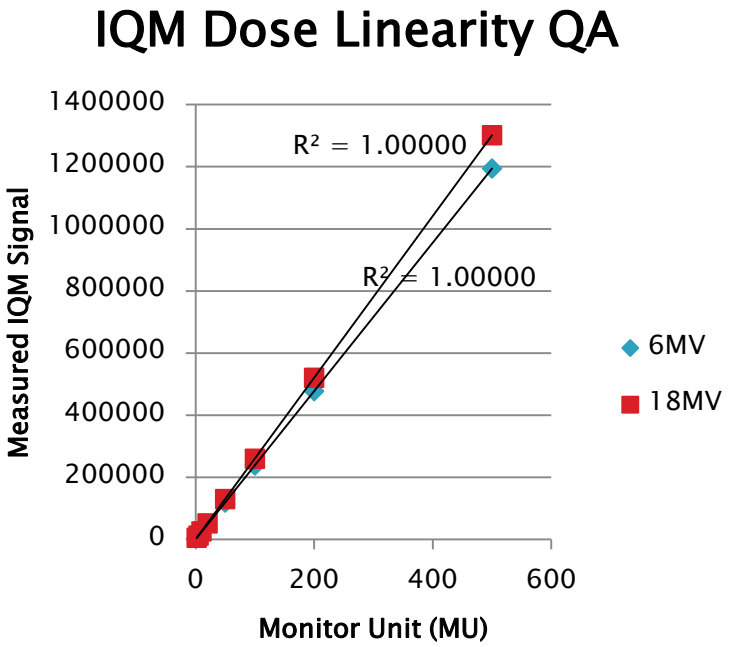
- Output as Function of Dose Rate
- **Dose Linearity**
- **Output as Function of Gantry Angles**

Dose Linearity & Output as Function of Different Angles

- Showed < 0.5% agreement to the reference ion-chamber measurement



Angle (degrees)	Difference from 180 degree (%)
180	0
90	-0.1
0	-0.1
270	-0.2
180	0.1

Summary

- IQM showed potential to be used for Linac QA
- Further work required to polish up procedures and tolerance levels

Summary – Potential Benefits

- Some QA can be done at different angles
- Ex)
  - Daily beam output at different gantry angles
  - Beam symmetry at different gantry angles

Summary – Potential Benefits

- Save time
  - Easily accessible
  - Single equipment
- Minimum user-interaction
  - **multiple IQM QA tests done by an IMRT field**
  - **report results automatically to QA management system**
- Easy to use

QA can be done more frequently and cost efficiently

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