Quality assurance with the IQM system

The Radboud UMC experience

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The Nijmegen RT department

- 7 Elekta linacs (6 Agility, 1 MLCi2)
- ~3000 patients/year
- 14 Radiation oncologists
- 7 Physicists

Outline

- Current practice of pre-treatment QA and treatment monitoring in Nijmegen
- The IQM system
- Our use of IQM
- Testing the IQM system
  - Stability
  - Influence on beam
  - Sensitivity in clinical beams
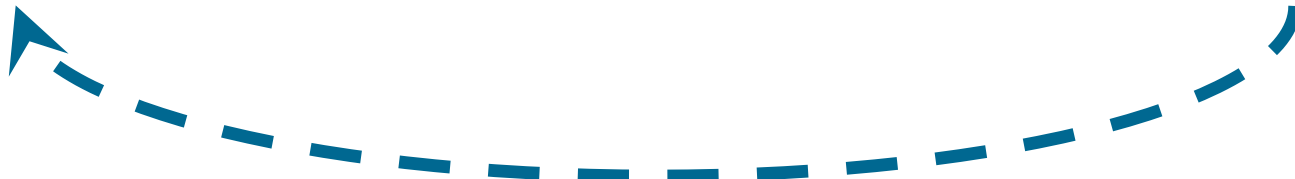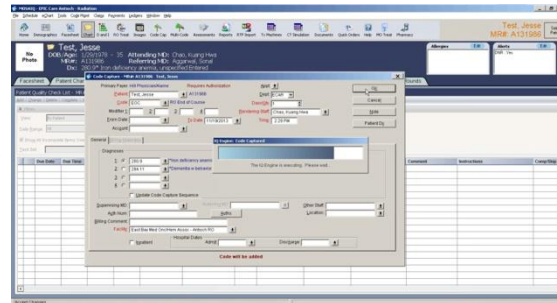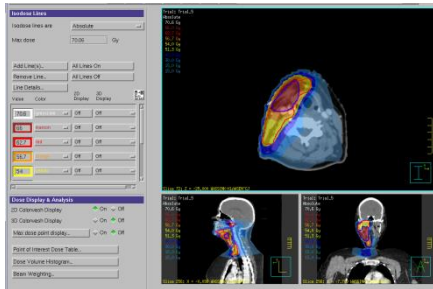- Discussion & Conclusions

Our current practices

- Pre-treatment QA for all stereotactic plans, most VMAT plans, and on random basis for IMRT plans
- Delta4: always, film & pinpoint: when new techique or when complicated
- Single patient >1hr

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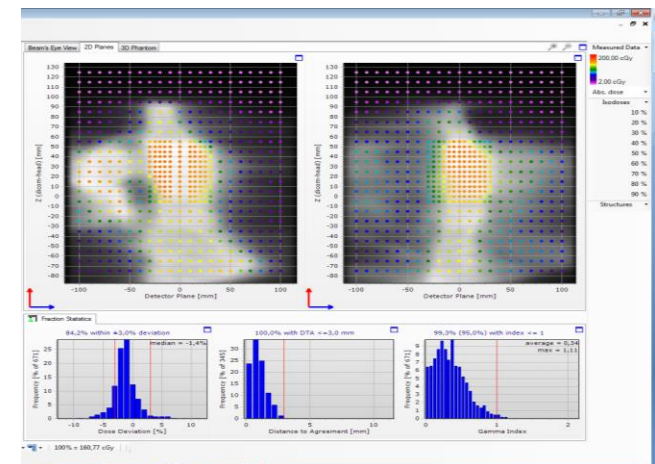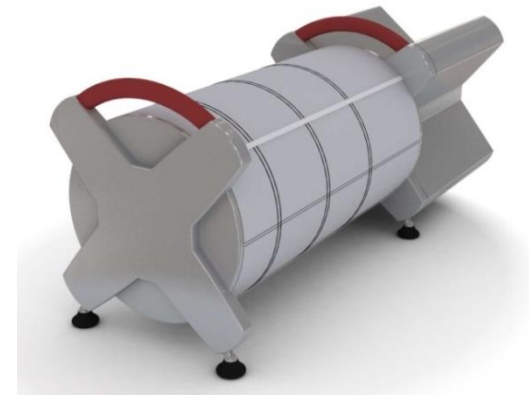
Our current practices

- No intra fractional / in vivo monitoring
- No closing of the TPS – R&V – Linac circle
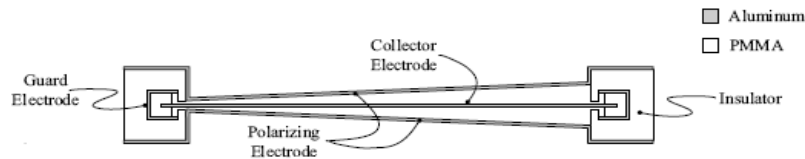
The IQM system

- Head mounted ionization chamber

The IQM system

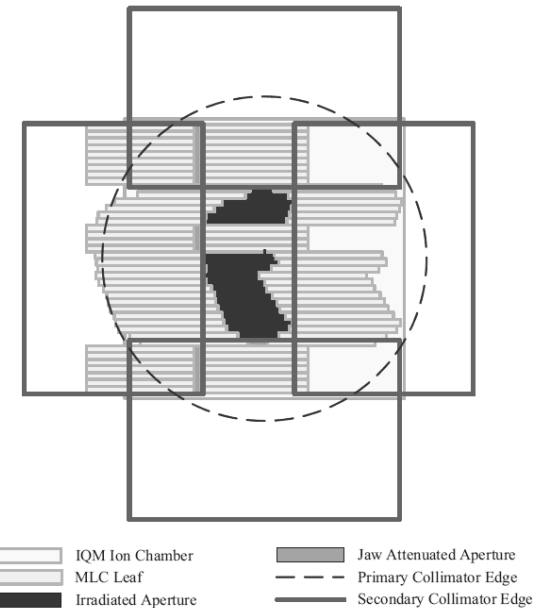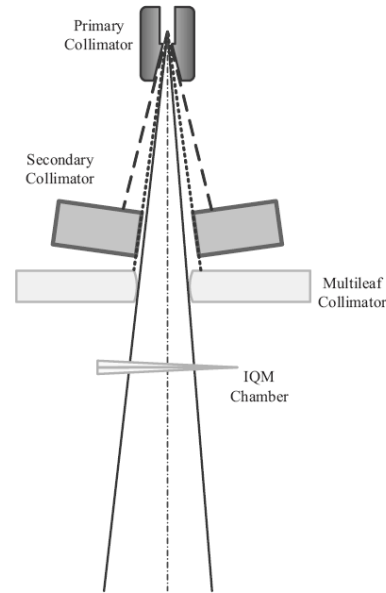## consists of:

➤ Large Area Ion Chamber

➤ Electrometer
➤ Inclinometer
      for VMAT/Rapid Arc Verification
➤ Barometer/Thermometer
      for Absolute Dose Correction
➤ Bluetooth
      for data transfer
➤ Batteries
      as power supply

Courtesy J. Oellig

The IQM system

Integrates

- Dose
  ### Monitor Units
- Jaw settings
  ### Field Size
- Leaf positions
  ### Beam Shape
- Spatial Chamber response
  ### Beam placement

into a **checksum**

Primary Collimator

Secondary Collimator

Multileaf Collimator

IQM Chamber

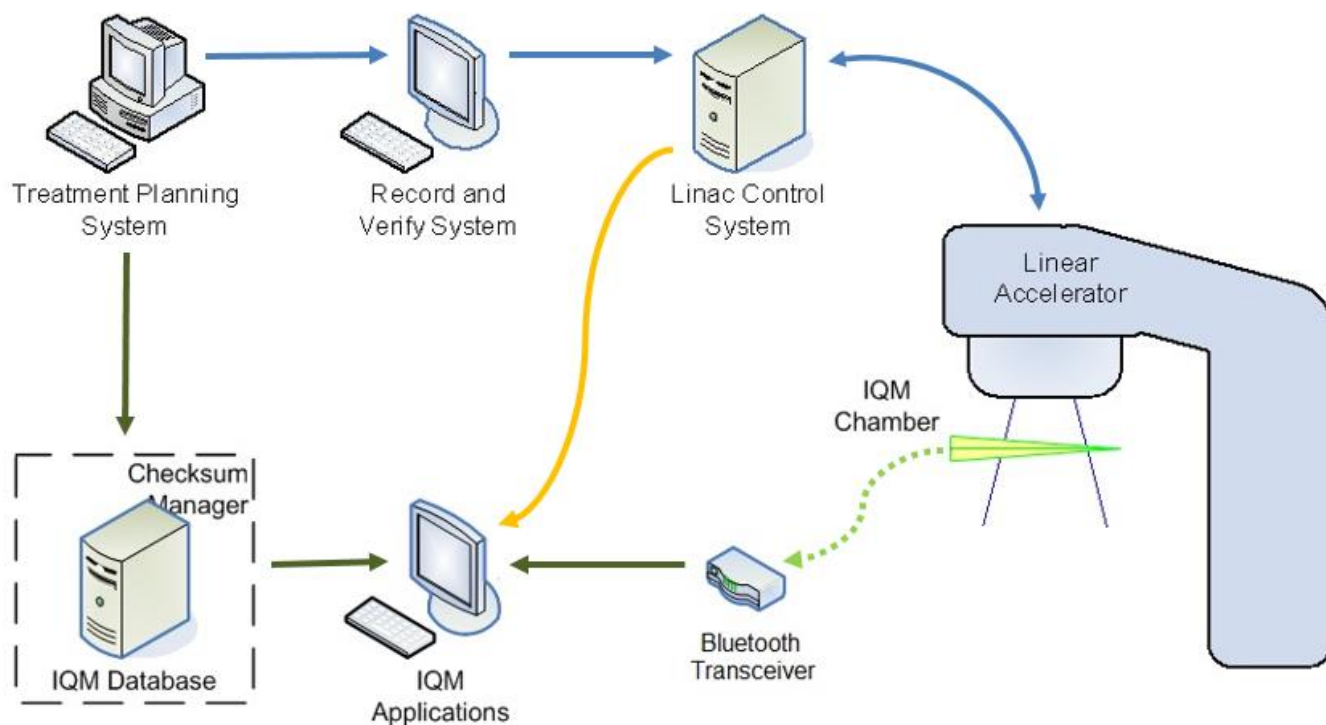|	
IQM Ion Chamber	Jaw Attenuated Aperture
MLC Leaf	Primary Collimator Edge
Irradiated Aperture	Secondary Collimator Edge

Gantry & Collimator angle are checked with the built-in inclinometer

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

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Courtesy J. Oellig

The IQM system

- Very limited interaction required
  - Send plan to IQM
  - One – click calculation
  - Ready for monitoring

Treatment Planning System

Record and Verify System

Linac Control System

Linear Accelerator

IQM Chamber

Checksum Manager

IQM Database

IQM Applications

Bluetooth Transceiver

Our use of the IQM system

- Real-time treatment monitoring
  - Increased patient safety
  - Per segment/control point insight in linac behaviour

- Pre-treatment QA
  - Can be run in between regular treatments or whenever there is free time.
  - RTT's can run the tests
  - Substantial reduction of effort in pre-treatment QA
  - Possible to measure not so critical plans at 1st fraction
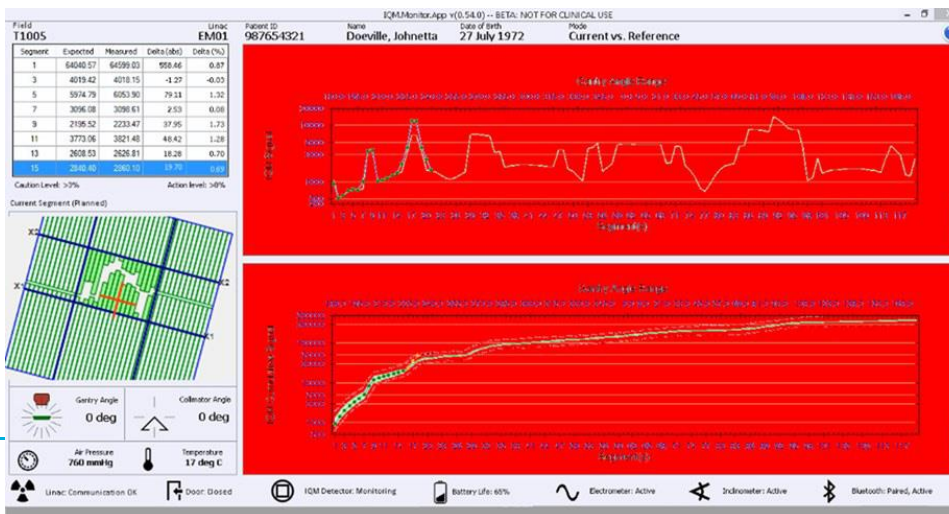
Our use of the IQM system

- Per segment monitoring and cumulative monitoring
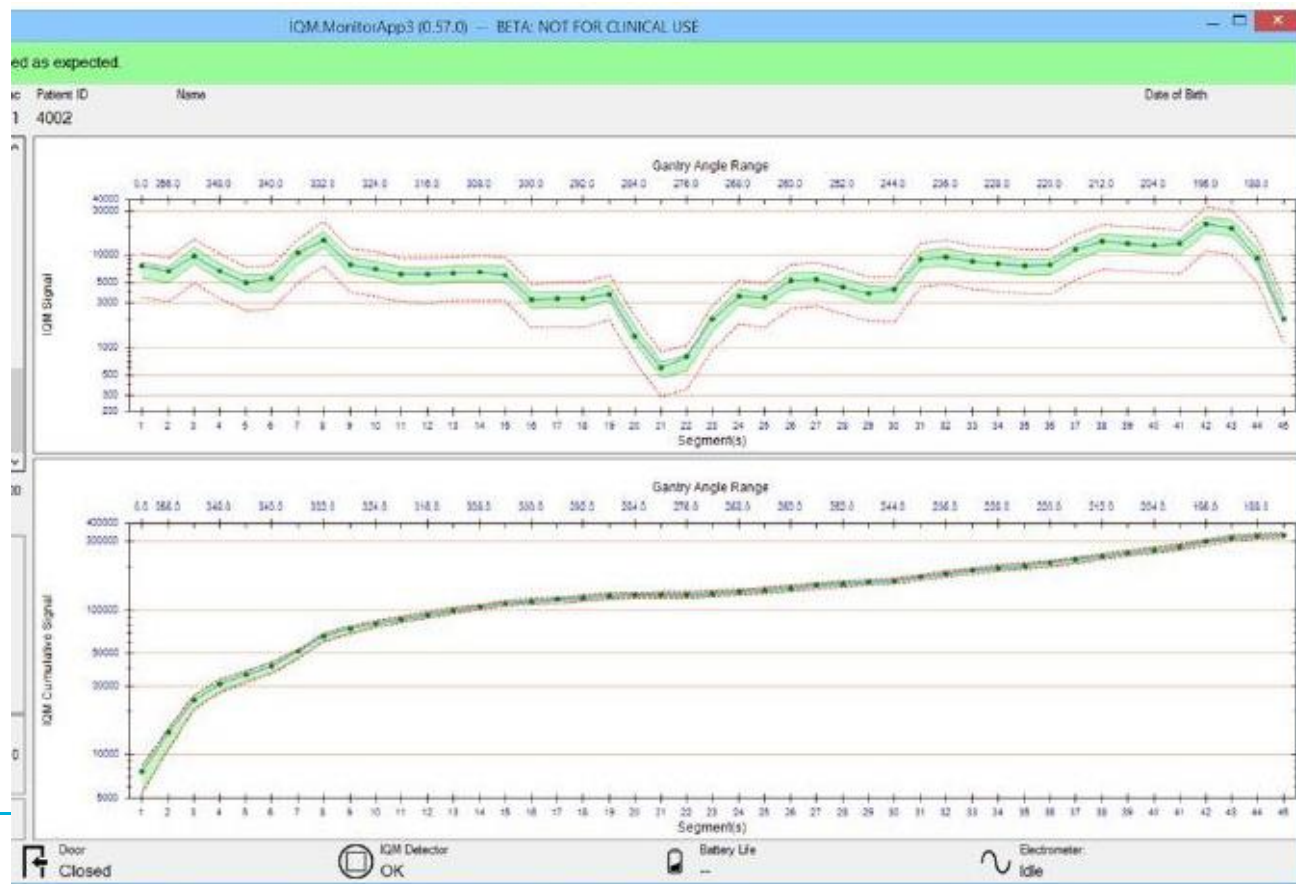
Testing the IQM system

- Is it stable?
- Can we use it on the linac head during treatment with a simple tray factor in the TPS?
- Can it detect errors in beam delivery, at least comparable to our current dosimetry systems?
- Can it be a replacement of our current pre-treatment QA?

Testing the IQM system - Stability

- One month monitoring of a series of plans
- Standard deviation 0.6% for open beams
- ~1% SD for IMRT/VMAT test

Max = 1.81 Gy

Y = 0.500 plan

Signal per segment

Relative difference per segment [%]

dumc
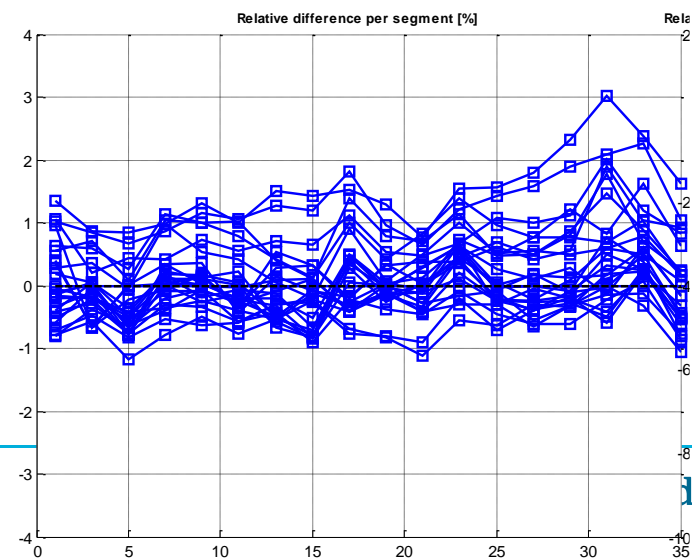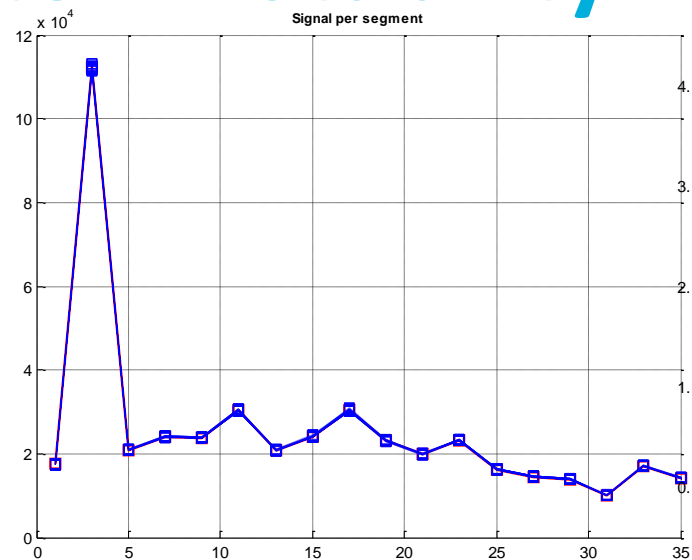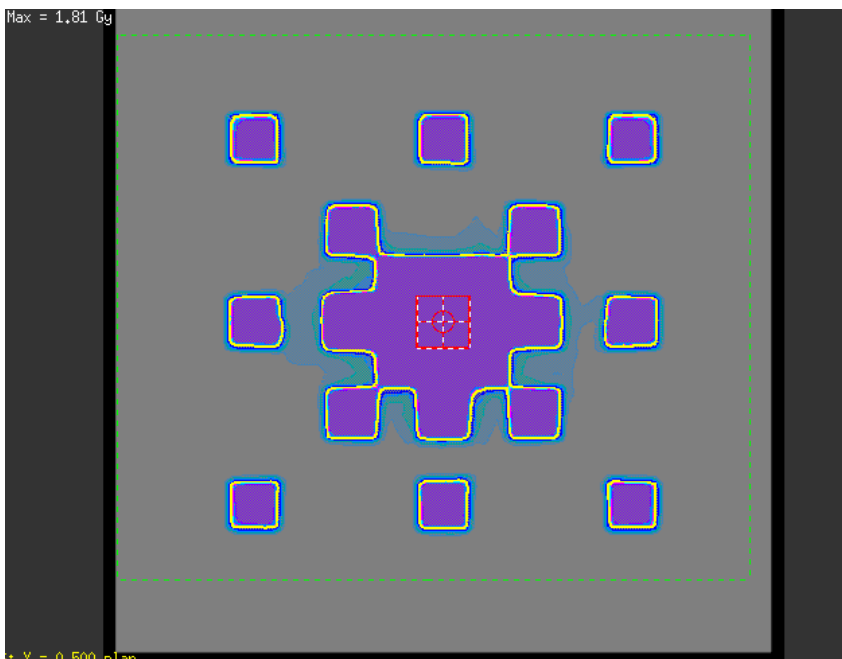
Testing the IQM system – beam changes

- PDD: D...
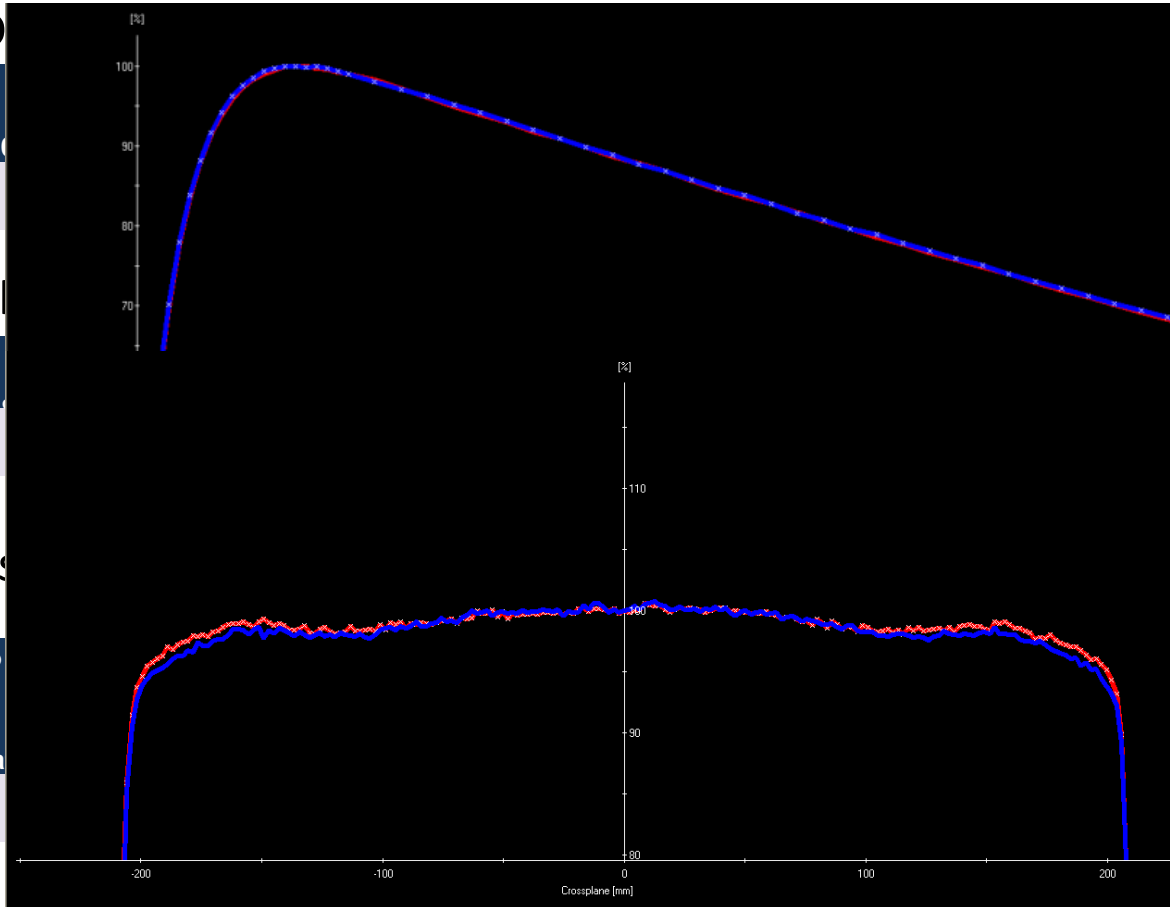
PDD	D10
X6	
X10	

- PDD: QI

PDD	QI
X6	
X10	

- Flatness

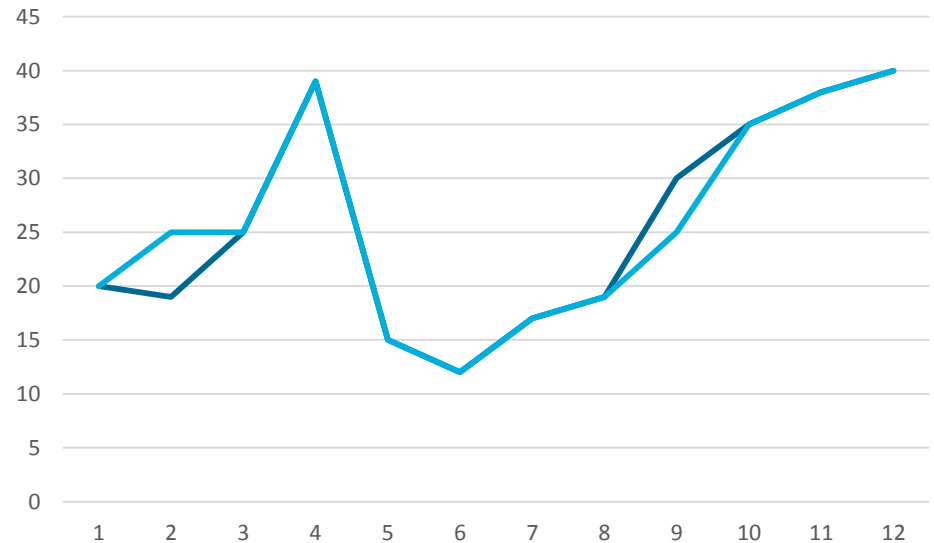|	No
Flatness/symmetry	Fla
X6	
X10	

Testing the IQM system – detecting errors

- H&N IMRT and VMAT
- Larynx VMAT
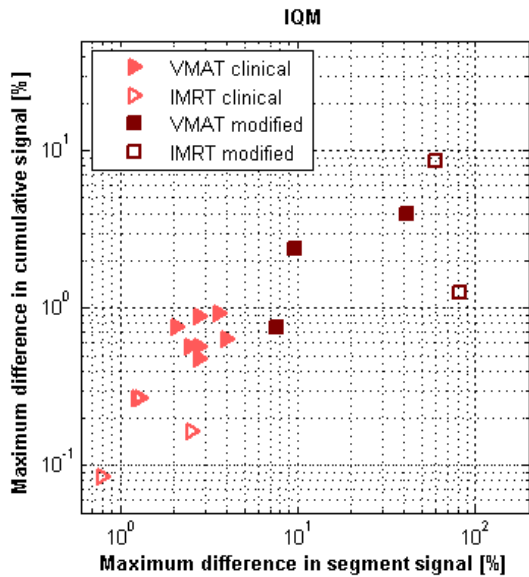- Lung VMAT
- Lung stereotactic

- Clinical beam as a reference
- Repetitions of clinical beam to assess uncertainty in IQM measurements
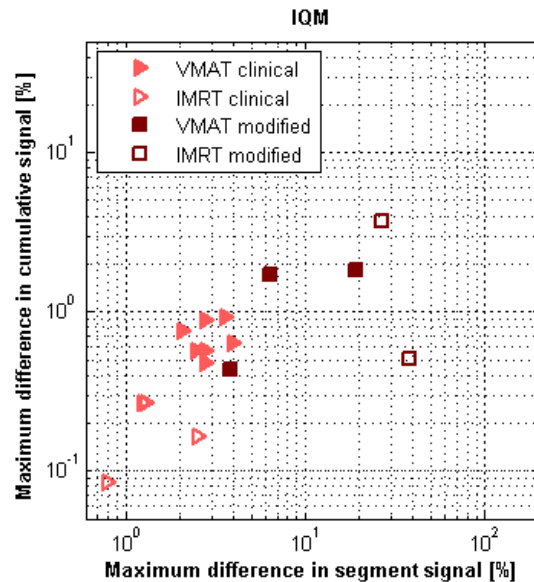
- Single segment change in MU

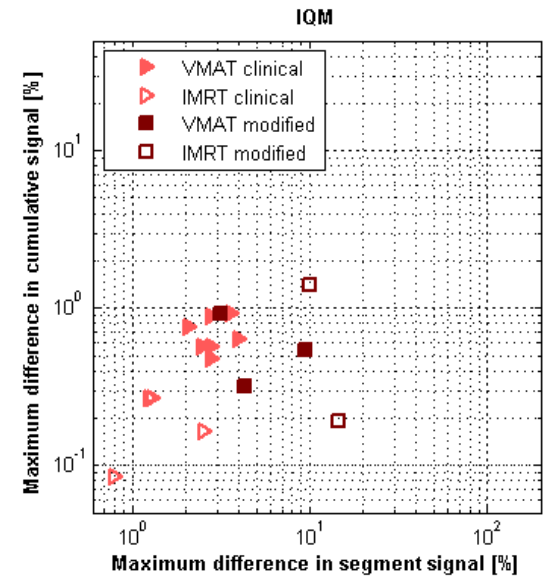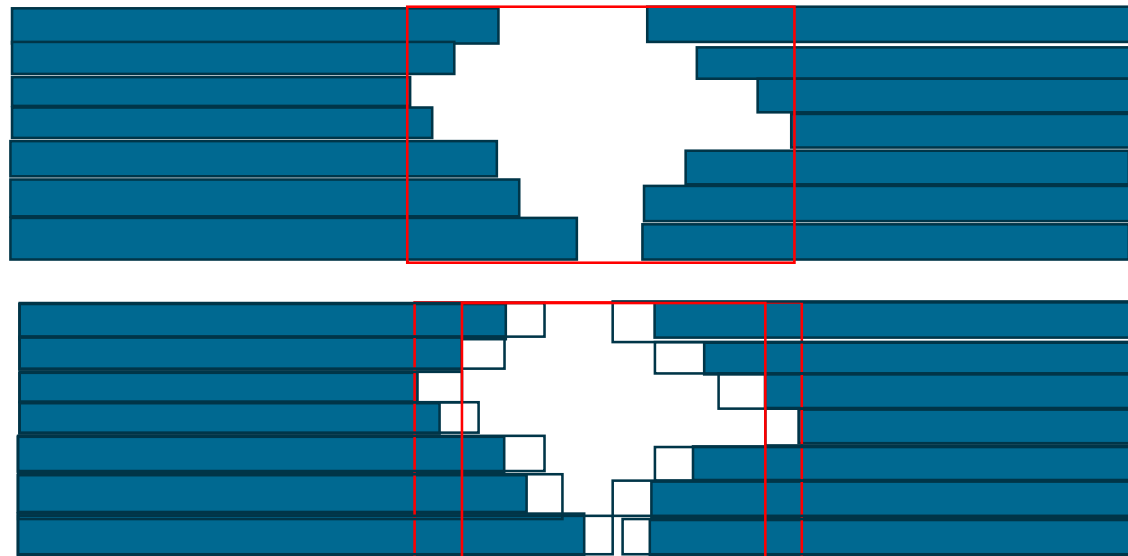# Testing the IQM system – detecting errors

- 10MU
- 5MU
- 2MU

Testing the IQM system – detecting errors
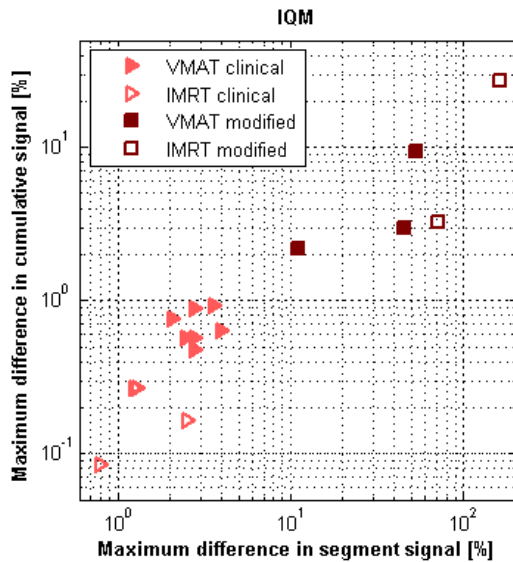
- H&N IMRT and VMAT
- Larynx VMAT
- Lung VMAT
- Lung stereotactic

- At different time during beam (especially relevant for cumulative)
- Single segment retraction of leaves

Testing the IQM system – detecting errors
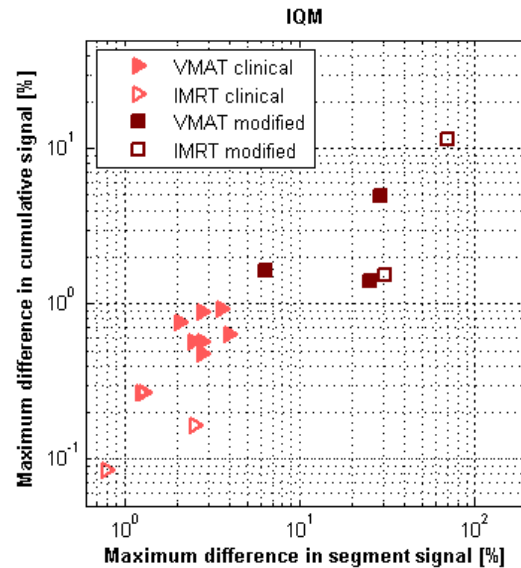
- 10mm
- 5mm
- 2mm
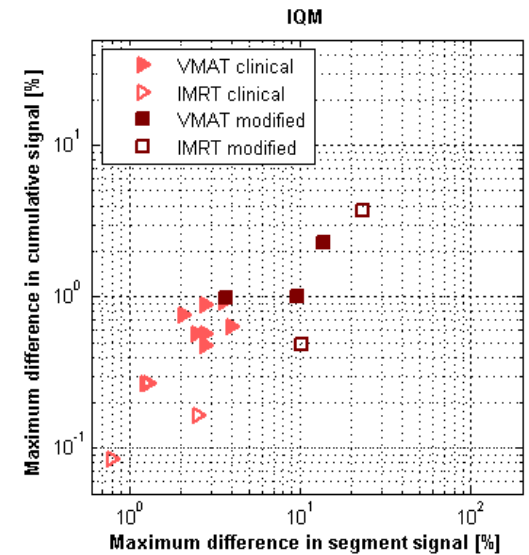
Testing the IQM system – detecting errors

- Segment at begin of beam

- Segment in middle of beam

- Segment at end of bea[m]

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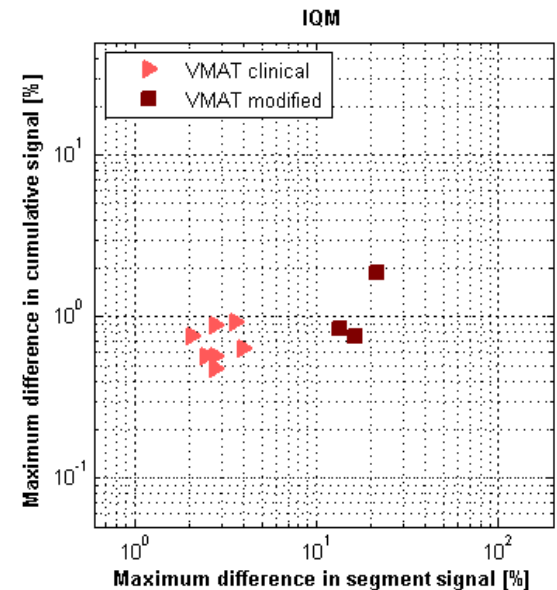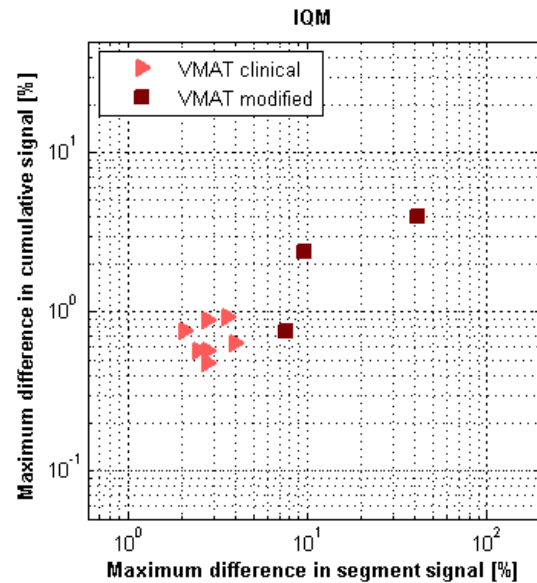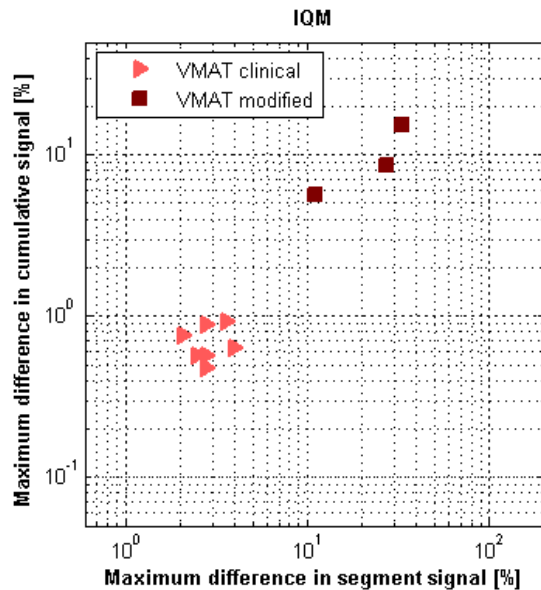
Testing the IQM system – detecting errors

- The same tests were performed with the Delta4 system
- Also here, a clincal beam was used as a reference
- Dose difference was used as a metric to assess the measurements

Testing the IQM system – detecting errors

- Large Errors,
  10mm leave retraction, 10MU
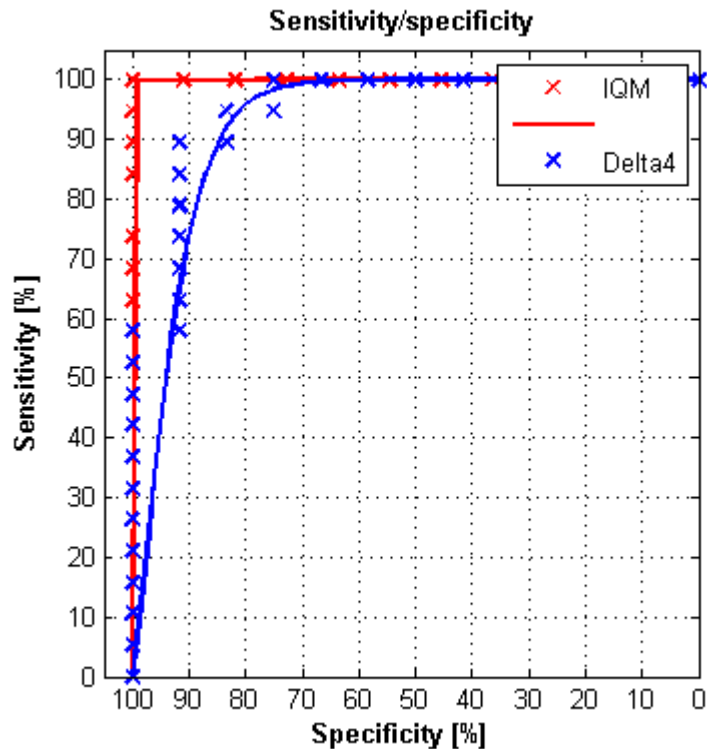
- Small Errors,
  2/5 mm leave retraction, 2/5 MU

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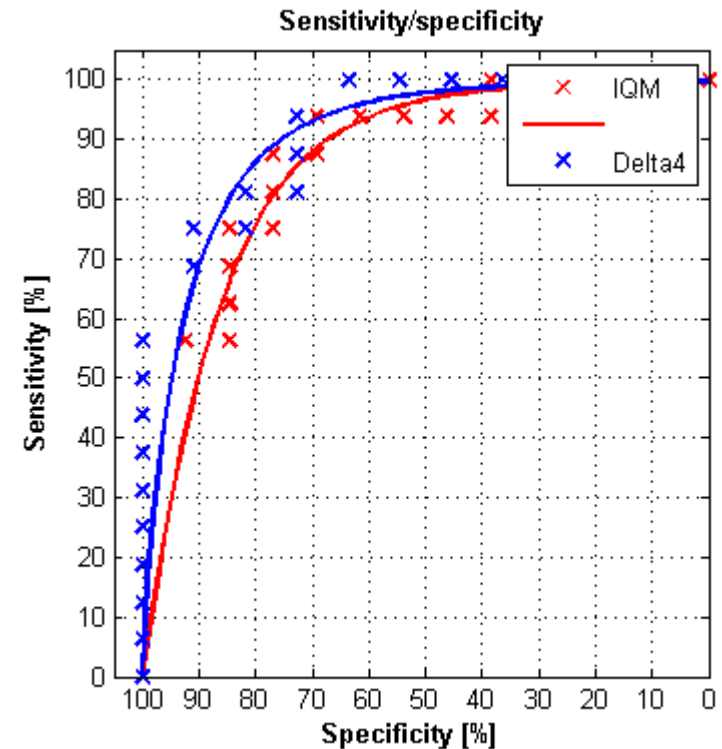
Discussion & Conclusions

What IQM does
Detect small errors in beam delivery with respect to precalculated beam
Detect small errors during treatment course with respect to reference beam
Operate with almost no user interaction necessary
Closes the TPS – R&V – Linac circle

Discussion & Conclusions

What IQM does NOT
Check your TPS
Check your machine model
Check patient dose

Discussion & Conclusions

- IQM does an excellent job in realtime monitoring of beam delivery

- Sensitivity and specificity can be expected to be sufficient for clinical practice

- Pre-treatment QA with IQM has the potential to save a lot of time

Real-time detection of deviations in radiotherapy beam delivery using a head-mounted detector

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Introduction

The Integral Quality Monitor (IQM) is a wedge shaped ionization chamber mounted on the linac head capable of:
- Measuring a checksum per segment dependent on fieldshape, field position, and number of MU
- Per segment in vivo verification of delivered beams
- Real-time comparison with calculated plan or reference treatment

Objective
In this study we assessed the sensitivity of the IQM for small beam errors and compared this to our current patient QA tool, the Delta4 on both Elekta MLCi2 and Agility linacs.

Materials and methods

The IQM system

The IQM system is a head mount wedge shaped ionization chamber (Figure 1). From the treatment plan, an expected checksum signal per segment is calculated, and compared with the actually measured signal (Figure 2).
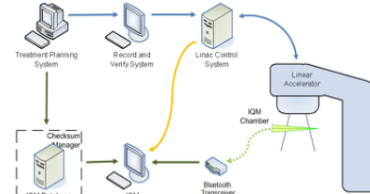
Figure 1: IQM system mount on linac head

Figure 2: IQM system monitoring the delivery of planned beam

Measurements
- Various IMRT, VMAT and stereotactic plans
- Repetitions of clinical beams used as references
- MLCi2: One segment changed 10 MU in different positions within the beam, size increased 10 mm, or re-optimization
- Agility: One segment changed 2 to 5 MU, or size increased 2 to 5 mm
- Same procedure for Delta4 measurements as our current standard of QA measurements

For IQM, the maximum segment difference and the maximum difference in cumulative signal are evaluated, with respect to the reference.
For Delta4, the median (DD50) and 95% dose differences (DD95) are evaluated, with respect to the reference.

Results

Figure 3 and 4 show the aforementioned differences for each measured repetition of the reference beams (triangles), and for the modified beams (squares) for MLCi2 and Agility.
Figure 5 shows the ROC-curve for combined values of the segment/cumulative or DD50/DD95 for both MLCi and Agility measurements.
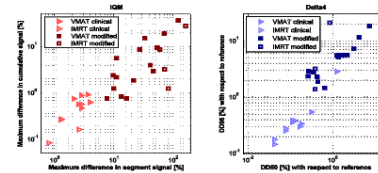
Figure 3: Modified and reference beams for MLCi2 linac, IQM(left) and Delta4(right)
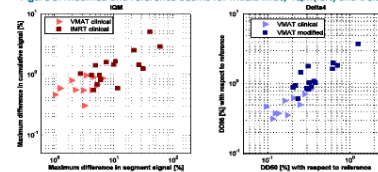
Figure 4: Modified and reference beams for Agility linac, IQM(left) and Delta4(right)
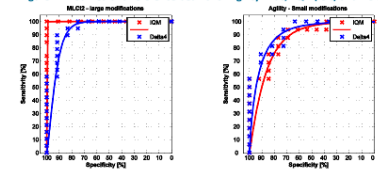
Figure 5: Resulting ROC curves for measured differences for MLCi2 (left) and Agility (right)

Beams including errors can be clearly distinguished, even small errors down to 2 MU. Sensitivity and specificity of the IQM is 100% for large segment errors (MLCi2) and ~80% for small segment errors (Agility). This is comparable to results obtained with the Delta4 system.

Discussion and Conclusion
- Good sensitivity and specificity for beam errors using a checksum measurement per segment
- Single segment deviations down to 2 MU or 2 mm can be detected, which is sufficient for clinical practice.
- Potential for real-time quality monitoring during patient treatment
- Possibilities for pre-treatment QA have to be investigated

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