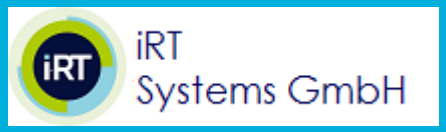
Real-time detection of deviations in radiotherapy beam delivery using a head-mounted detector

A beta test of the IQM system in cooperation with



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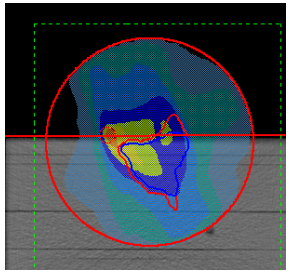
Radboudumc

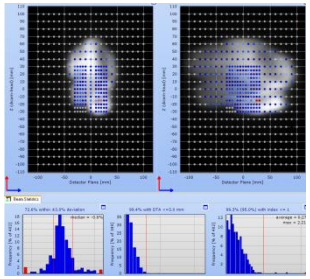
Outline

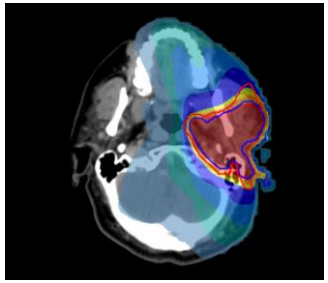
- Current practice of treatment monitoring
- The IQM system
- Testing the IQM system
- Discussion & Conclusions

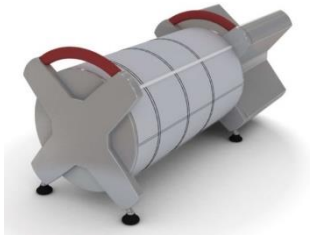
Current practice

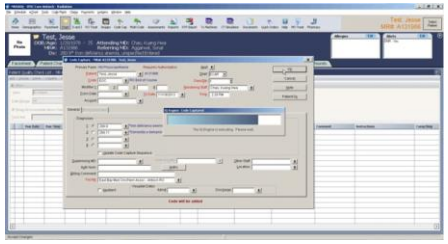
Prescription











Patient Dose

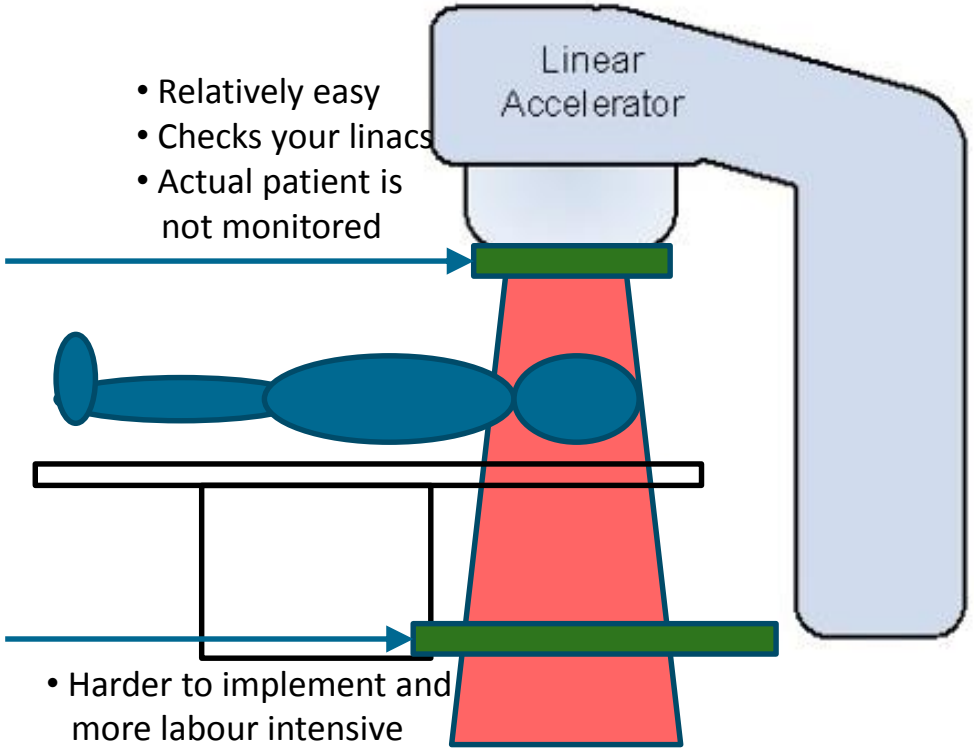
Current practice

Errors in	Delta 4 pre treatment QA
Prescription	✗
TPS	✓
R&V	✓
Linac	-- Not always treatment linac
Transfer	-- Not always treatment linac
Absolute dosimetry	-- Not always treatment linac
Delivered beam	✗
Dose in patient	✗

Solutions to monitor the delivered beam (and patient)

Monitor fluence from linac head

- Relatively easy
- Checks your linacs
- Actual patient is not monitored



Epid dosimetry

- Harder to implement and more labour intensive
- Actual delivered dose to the patient can be made visible

Error detection with in vivo monitoring

Errors in	Delta 4 pre treatment QA	Epid dosimetry	Linac head monitor
Prescription	✗	✗	✗
TPS	✓	✓	✓
R&V	✓	✓	✓
Linac	-- Not always treatment linac	✓	✓
Transfer	-- Not always treatment linac	✓	✓
Absolute dosimetry	-- Not always treatment linac	✓	✓
Delivered patient beam	✗	✓	✓
Dose in patient	✗	✓	✗

Error detection with in vivo monitoring

Errors in	Delta 4 pre treatment QA
Prescription	✘
TPS	✓
R&V	✓
Linac	-- Not always treatment linac
Transfer	-- Not always treatment linac
Absolute dosimetry	-- Not always treatment linac
Delivered beam	✘
Dose in patient	✘

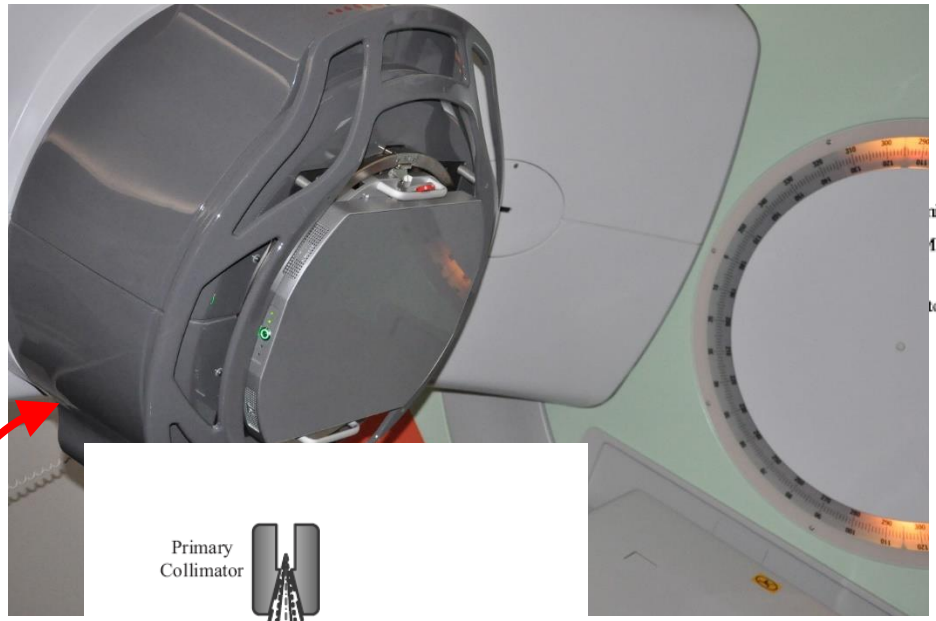
The IQM system

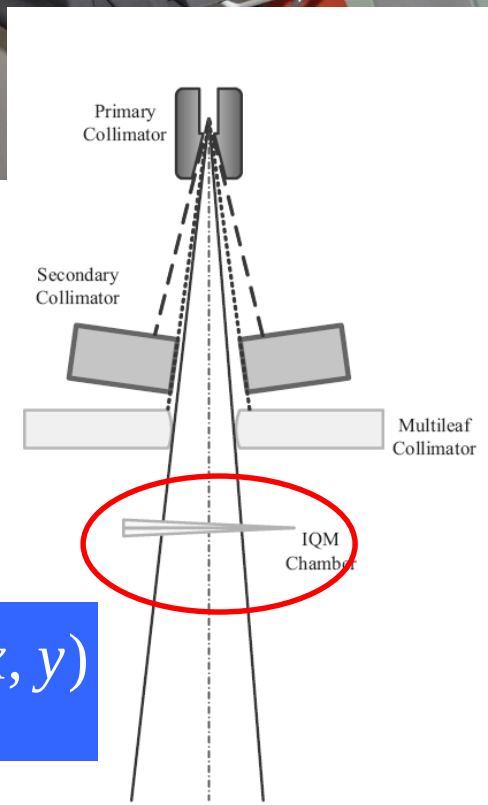
Integral Quality Monitor

Wedge shaped ionization chamber

Signal dependent on:

- Field/segment position
- Field size and shape
- Monitor units





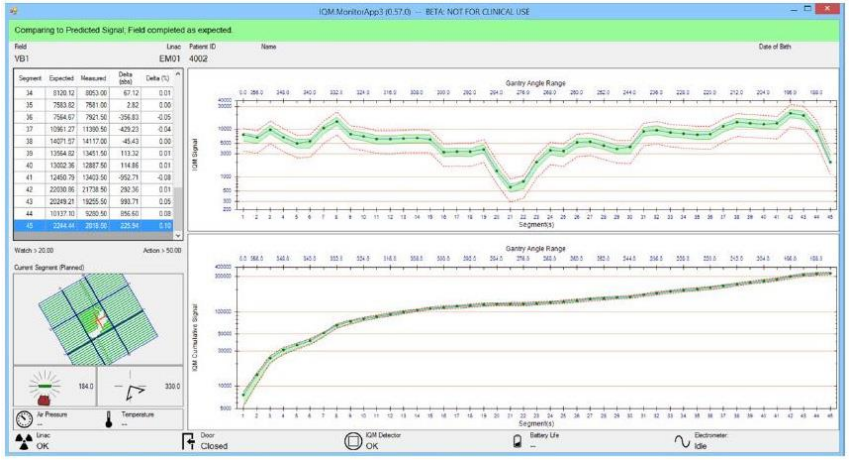
Checksum

one number, sensitive for many parameters

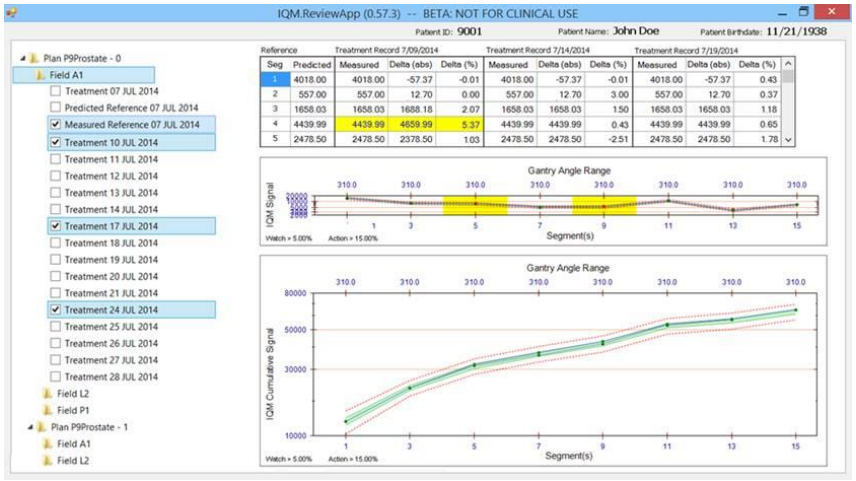
$$C_{IQM} = MU \cdot AOF(x,y) \cdot \oint_{Area} I_{field} \cdot S(x,y)$$

Intended use of the IQM system

- In vivo treatment monitoring
  - Realtime monitoring of beam delivery
  - Increased patient safety
  - Insight in the linac behaviour per segment/control point



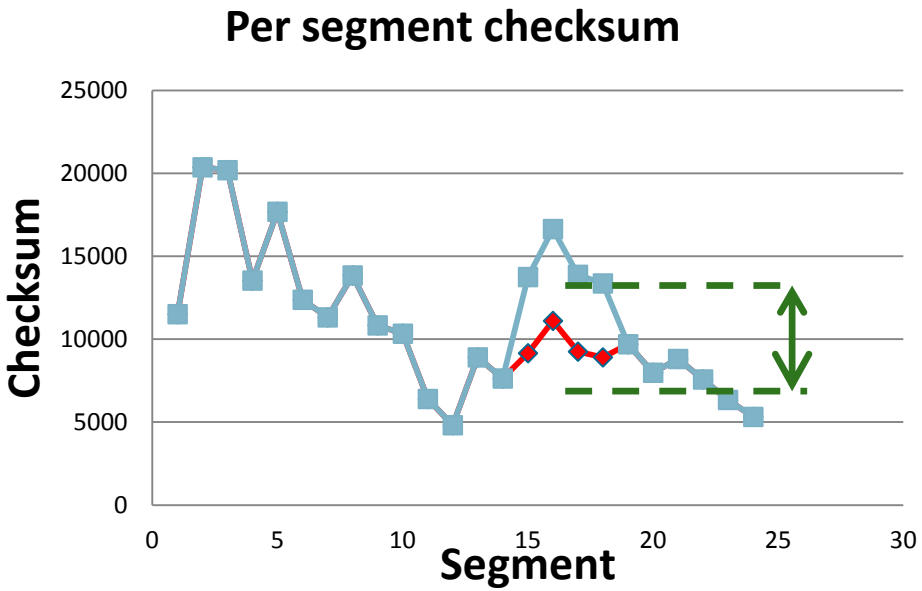
- Pre-treatment QA
  - Can be run in between regular treatments or whenever there is free time.
  - RTT's can run the tests
  - Reduces a substantial effort in pre-treatment QA
  - Possible to measure plans during 1st fraction if not critical.

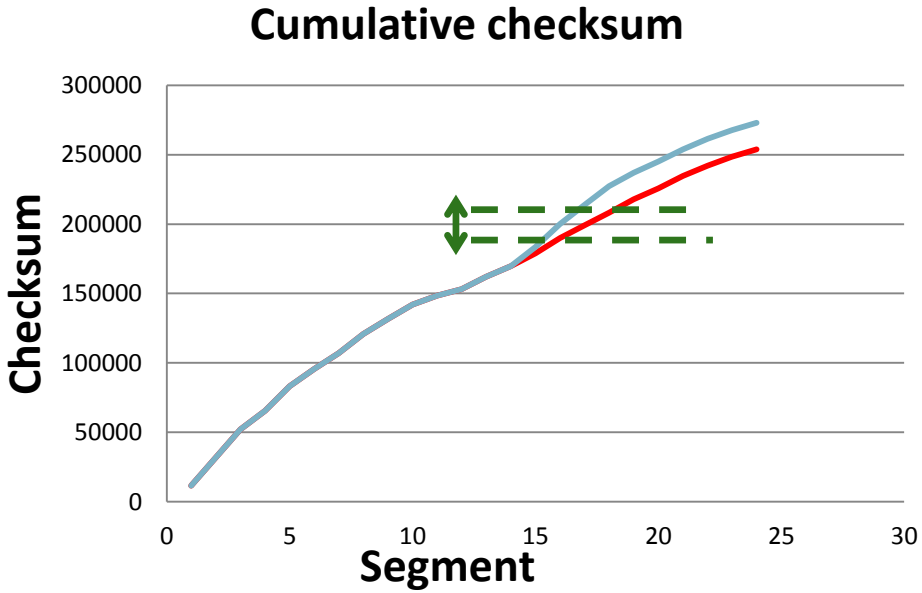


Tests:error detection sensitivity

How well does IQM perform in intra-fractional detection?

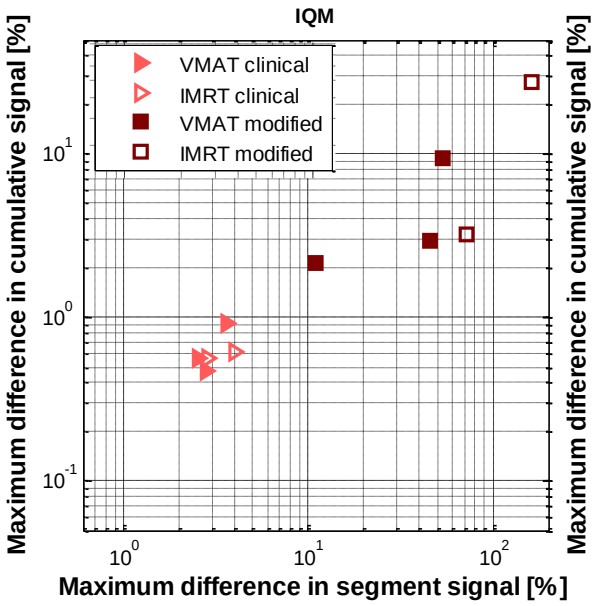
- Various IMRT and VMAT clinical beams,
- Same beams with induced errors
  - One segment/control point retraction of leaves by 10, 5 and 2 mm
  - One segment increase of 10, 5 or 2 MU
- Comparison to Delta4



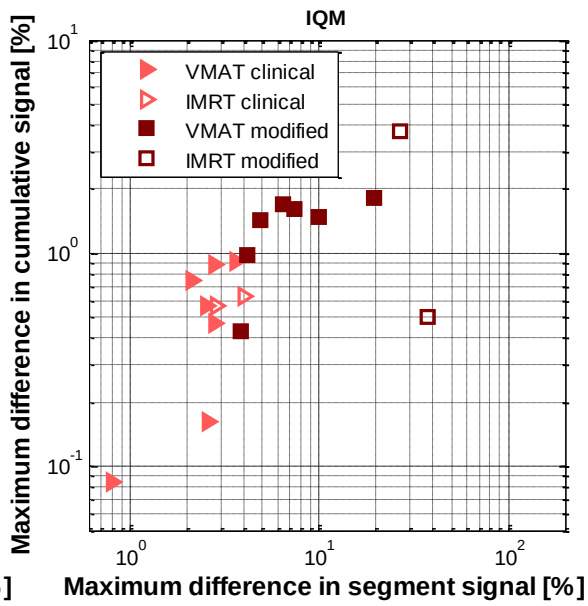


Testing the IQM system – detecting errors: one segment different MU

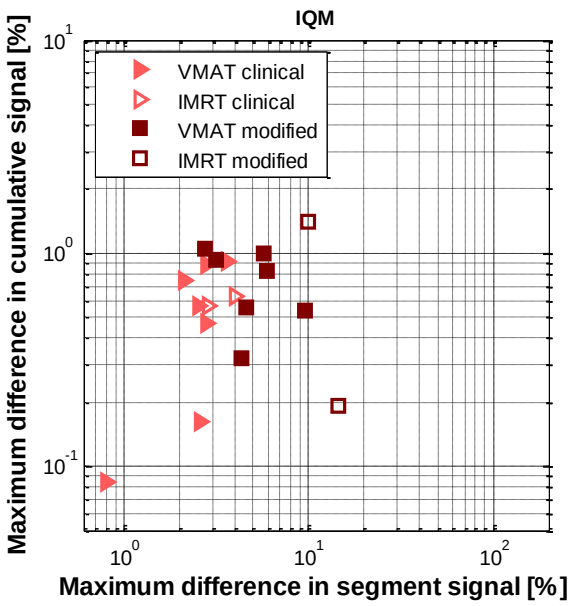
- 10MU



- 5MU

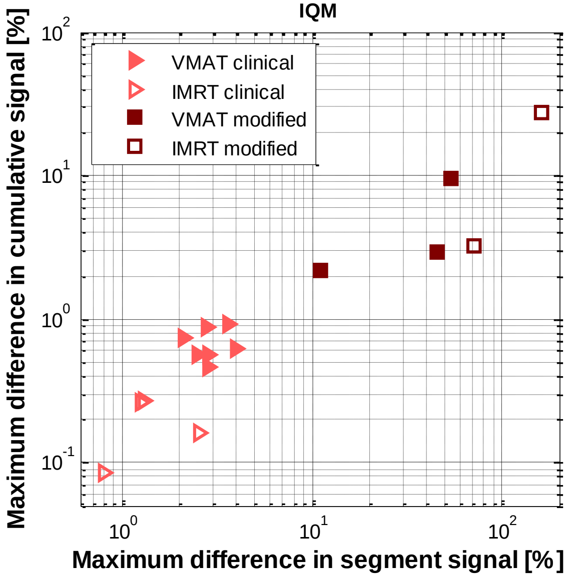


- 2MU

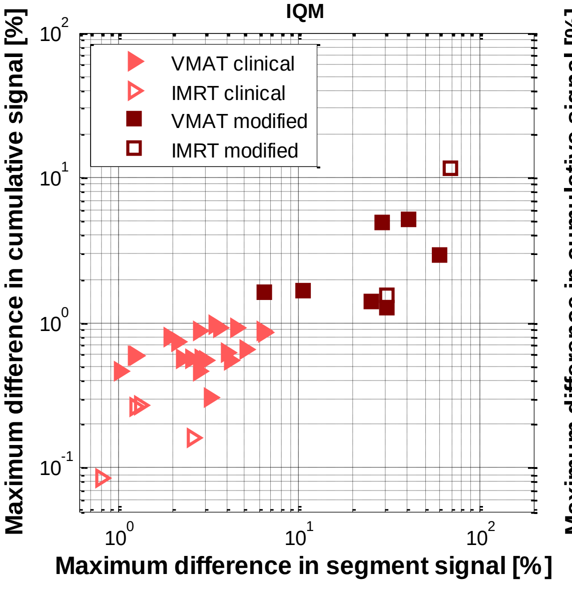


Testing the IQM system – detecting errors: one segment leaf retraction

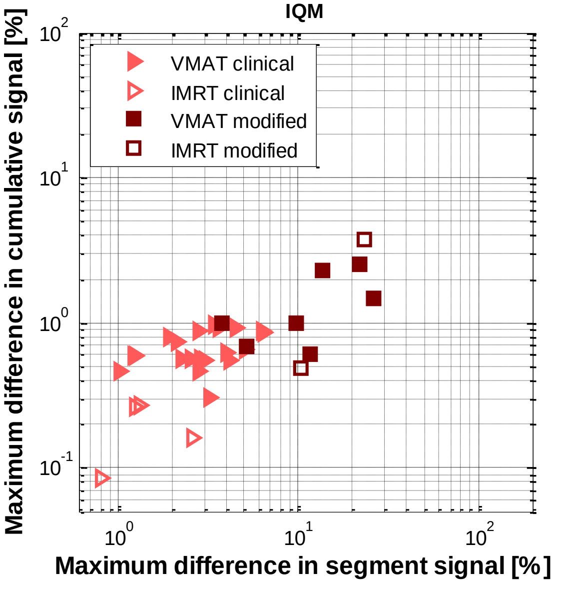
- 10mm



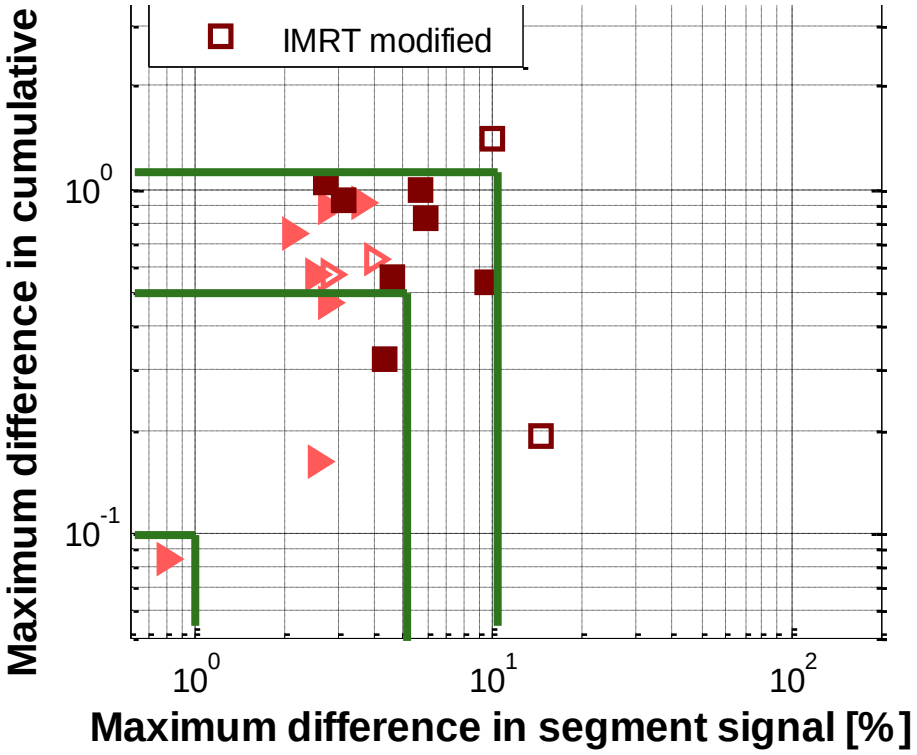
- 5mm

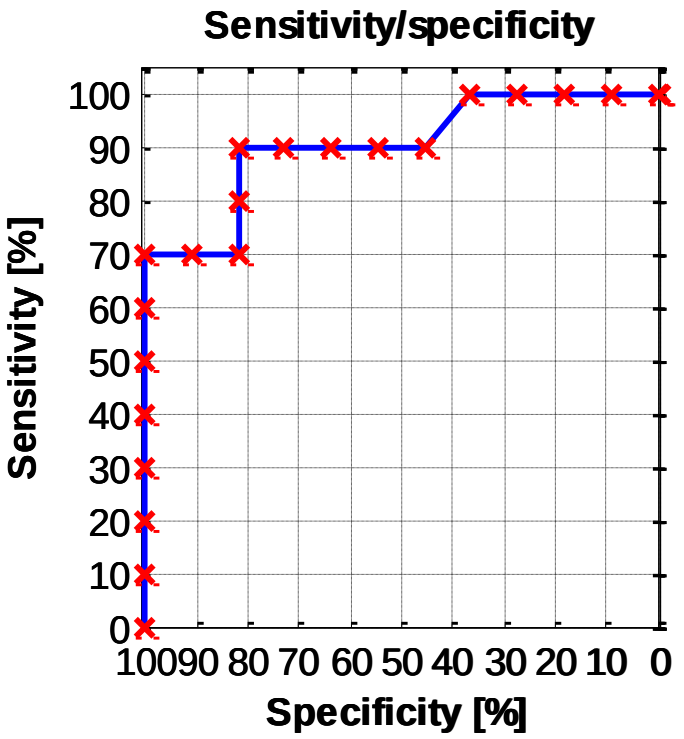


- 2mm



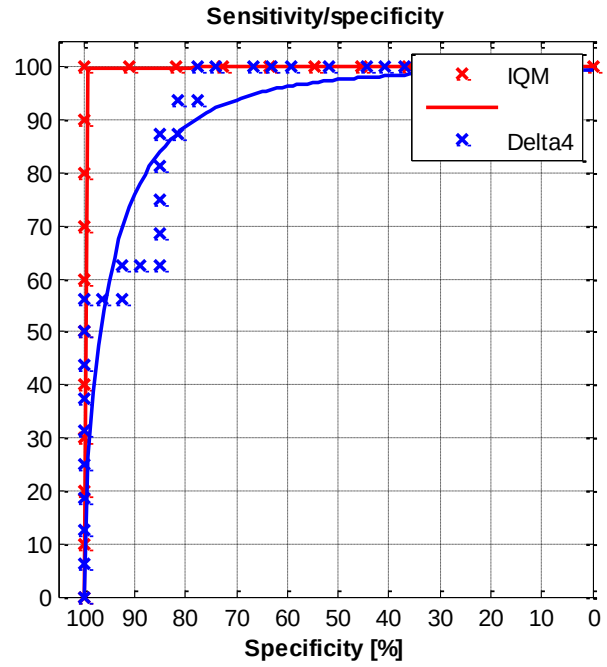
The ROC-curve

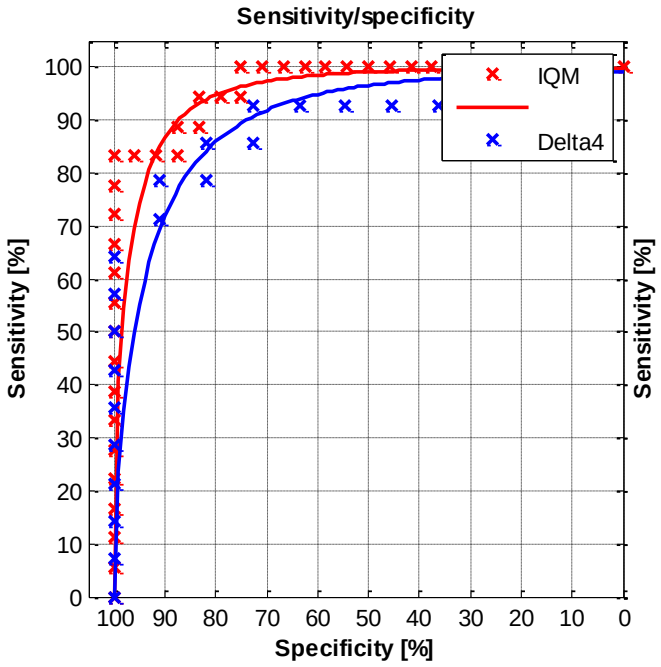


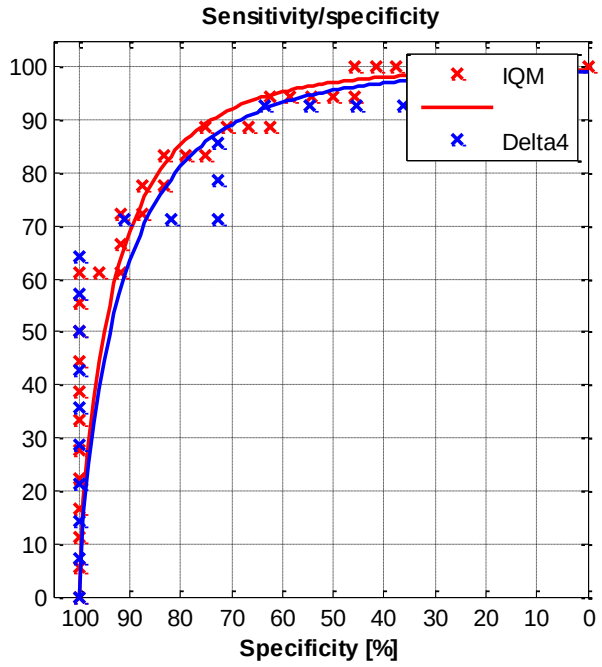


Testing the IQM system – detecting errors

- 10mm leaf retraction, 10MU
- 5mm, 5MU
- 2 mm, 2 MU







Discussion & Conclusions

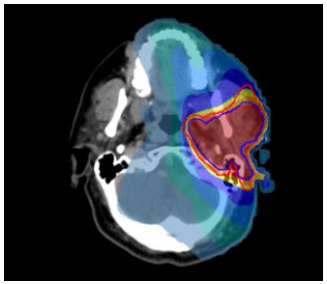
- IQM enables realtime, intrafraction monitoring of beam delivery
- Sensitivity and specificity can be expected to be sufficient for clinical practice, and at least equal to our current equipment
- Pre-treatment QA with IQM has the potential to save a lot of time, but has yet to be tested

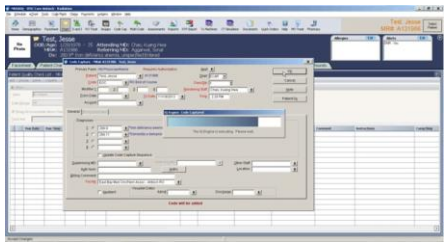
Conclusions

Prescription

Calculate plan Checksum

Compare with measured checksum





Realtime monitoring with almost no user interaction

Error detection well below clinically relevant limits

Patient Dose