# Optimisation of Elements beam model and Integral Quality Monitor dose calculation model for single isocentre multiple brainmets patient specific dosimetry


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# Background

Elements treatment planning system (*Brainlab Limited, Germany*) and Integral Quality Monitor (IQM, *iRT Systems GmbH, Germany*) were acquired in our department to enable single isocentre treatment for multiple brainmets (MBM) and patient specific dosimetry (PSD) for Elekta Agility Versa HD linac.

This study aimed to find the best fit Elements multi leaf collimator (MLC) parameters and improve the accuracy of the IQM dose calculation model for small field dosimetry.

# Method

The IQM system was originally commissioned for field sizes from 1x1 $cm^2$ and above as per default manufacturer requirement. This did not include very small fields of sub centimetre sizes that are relevant for stereotactic treatments. To improve IQM beam model accuracy, additional area output factors were measured for very small field sizes down to 0.3x0.5 $cm^2$ as highlighted in yellow in figure 1.

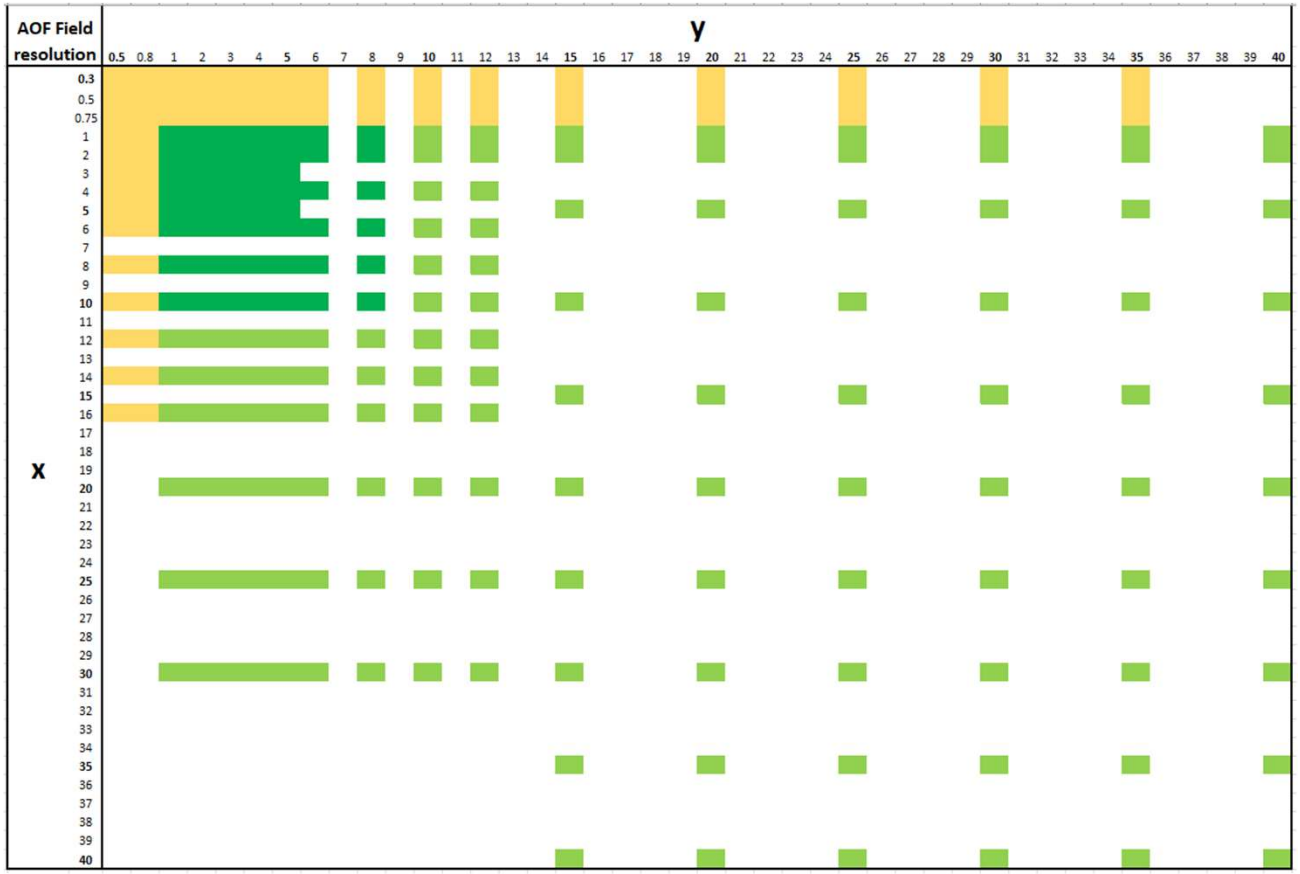


*Fig. 1: List of small field area output factors measured to improve small field IQM beam modelling*

# Method

5 different Elements beam models were generated for Elekta Agility 6MVFFF energy, Versa HD MLC with varying minimum MLC gaps ranging from 0 to 5 mm. In addition, the number of guard leaves were set to 0 and home position of closed leaves behind the Y diaphragm were set to be at the centre in order to correctly mimic their position for dynamic treatment delivery.

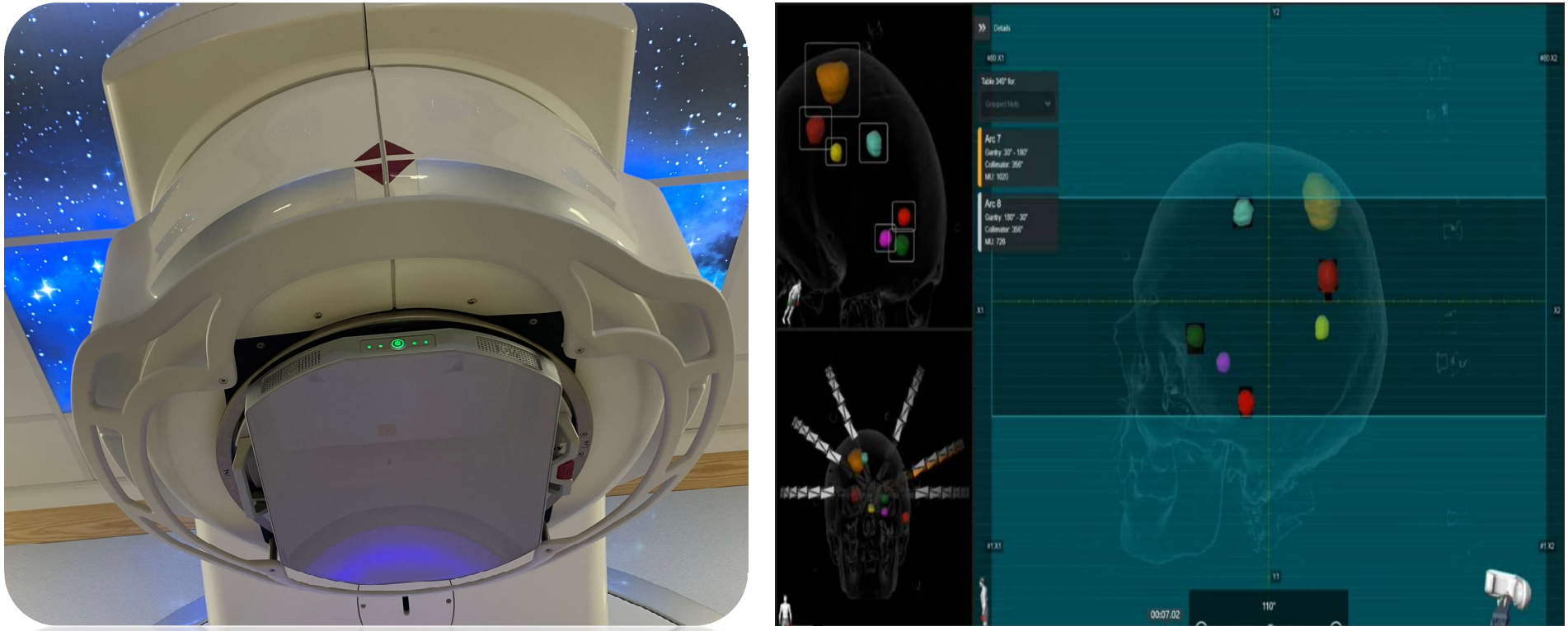


*Fig. 2: IQM attached to linac head for measurement (left) Elements single isocentre treatment plan for 7 MBM (right)*

# Method

- Treatment plans were generated for solitary brainmets and single isocentre treating 2-7 MBM using all 5 beam models.
- The treatment plan file was exported for IQM reference signal calculation after which the plans were measured with IQM.
- Additionally, 20 clinical test plans were done with the best fit beam model parameters and measured with IQM.

# Results

- Agreement of measurements against the calculated cumulative and segment-by-segment signal were assessed for plans done with all 5 beam models.

- A total of 128 arcs and 1903 segments were evaluated.

- A minimum leaf gap of 0 mm gave the best agreement with IQM measurements as it accurately modelled the varying effective rounded end leaf gap of unused MLCs between lesions.

- Distribution of data points and segment-by-segment deviation measured against the field size.

# Results

| Distribution of Datapoints | | | AOF-Y [cm] | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 0.5 | 0.8 | 1 | 2 | 3 | 4 | 5 | 6 | 8 | 10 | 12 | 15 | 20 | 25 | 30 | 35 | 40 |
| | | | 0.0 | 0.6 | 0.9 | 1.5 | 2.5 | 3.5 | 4.5 | 5.5 | 7.0 | 9.0 | 11.0 | 13.5 | 17.5 | 22.5 | 27.5 | 32.5 | 37.5 |
| | | | 0.6 | 0.9 | 1.5 | 2.5 | 3.5 | 4.5 | 5.5 | 7.0 | 9.0 | 11.0 | 13.5 | 17.5 | 22.5 | 27.5 | 32.5 | 37.5 | 40.0 |
| AOF-X [cm] | 0.36 | 0.0 | 0.4 | | | | | | 8 | | 39 | 50 | | | | | | | |
| | 0.5 | 0.4 | 0.6 | | | | | 15 | 72 | 26 | 43 | 71 | 39 | | | | | | |
| | 0.75 | 0.6 | 0.9 | | 34 | 55 | 11 | 20 | 17 | 14 | 69 | 38 | 15 | | | | | | |
| | 1 | 0.9 | 1.5 | | 65 | 303 | 30 | 55 | 73 | 2 | 7 | 40 | 15 | | | | | | |
| | 2 | 1.5 | 2.5 | | | 231 | 263 | 2 | | | | | | | | | | | |
| | 3 | 2.5 | 3.5 | | | | 19 | | | | | | | | | | | | |
| | 4 | 3.5 | 4.5 | | | | | | | | | | | | | | | | |
| | 5 | 4.5 | 5.5 | | | | | | | | | | | | | | | | |
| | 6 | 5.5 | 7.0 | | | | | | | | | | | | | | | | |
| | 8 | 7.0 | 9.0 | | | | | | | | | | | | | | | | |
| | 10 | 9.0 | 11.0 | | | | | | | | | | | | | | | | |
| | 12 | 11.0 | 13.0 | | | | | | | | | | | | | | | | |
| | 14 | 13.0 | 15.0 | | | | | | | | | | | | | | | | |
| | 16 | 15.0 | 18.0 | | | | | | | | | | | | | | | | |
| | 20 | 18.0 | 22.5 | | | | | | | | | | | | | | | | |
| | 25 | 22.5 | 27.5 | | | | | | | | | | | | | | | | |
| | 30 | 27.5 | 32.5 | | | | | | | | | | | | | | | | |
| | 35 | 32.5 | 37.5 | | | | | | | | | | | | | | | | |
| | 40 | 37.5 | 40.0 | | | | | | | | | | | | | | | | |

*Fig. 3a: Distribution of data points measured against the field size*

# Results

| ◉ Deviations ○ AOF | | | AOF-Y [cm] | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 0.5 | 0.75 | 1 | 2 | 3 | 4 | 5 | 6 | 8 | 10 | 12 | 15 | 20 | 25 | 30 | 35 | 40 |
| Shading Limits | > ± 3.0% | | 0.0 | 0.6 | 0.9 | 1.5 | 2.5 | 3.5 | 4.5 | 5.5 | 7.0 | 9.0 | 11.0 | 13.5 | 17.5 | 22.5 | 27.5 | 32.5 | 37.5 |
| | > ± 4.0% | | 0.6 | 0.9 | 1.5 | 2.5 | 3.5 | 4.5 | 5.5 | 7.0 | 9.0 | 11.0 | 13.5 | 17.5 | 22.5 | 27.5 | 32.5 | 37.5 | 40.0 |
| AOF-X [cm] | 0.36 | 0.0 – 0.4 | | | | | | | -1.7 | | 0.4 | 0.5 | | | | | | | |
| | 0.5 | 0.4 – 0.6 | | | | | | 1.4 | 0.0 | 1.4 | 1.0 | -0.3 | -0.9 | | | | | | |
| | 0.75 | 0.6 – 0.9 | | | -1.4 | 0.2 | -0.3 | 2.5 | 1.2 | 1.6 | 0.3 | -0.6 | -0.1 | | | | | | |
| | 1 | 0.9 – 1.5 | | | -2.2 | -0.9 | 1.5 | 0.2 | 2.3 | -0.9 | -1.0 | -1.0 | -1.3 | | | | | | |
| | 2 | 1.5 – 2.5 | | | | 0.4 | 0.6 | 2.6 | | | | | | | | | | | |
| | 3 | 2.5 – 3.5 | | | | | -1.3 | | | | | | | | | | | | |
| | 4 | 3.5 – 4.5 | | | | | | | | | | | | | | | | | |
| | 5 | 4.5 – 5.5 | | | | | | | | | | | | | | | | | |
| | 6 | 5.5 – 7.0 | | | | | | | | | | | | | | | | | |
| | 8 | 7.0 – 9.0 | | | | | | | | | | | | | | | | | |
| | 10 | 9.0 – 11.0 | | | | | | | | | | | | | | | | | |
| | 12 | 11.0 – 13.0 | | | | | | | | | | | | | | | | | |
| | 14 | 13.0 – 15.0 | | | | | | | | | | | | | | | | | |
| | 16 | 15.0 – 18.0 | | | | | | | | | | | | | | | | | |
| | 20 | 18.0 – 22.5 | | | | | | | | | | | | | | | | | |
| | 25 | 22.5 – 27.5 | | | | | | | | | | | | | | | | | |
| | 30 | 27.5 – 32.5 | | | | | | | | | | | | | | | | | |
| | 35 | 32.5 – 37.5 | | | | | | | | | | | | | | | | | |
| | 40 | 37.5 – 40.0 | | | | | | | | | | | | | | | | | |

*Fig. 3b: Distribution of average segment-by-segment deviation measured against the field size*

# Results

- The average segment-by-segment deviation between calculated and measured IQM signals for small fields were found to be within 3%.
- All clinical test plans matched the final cumulative signal deviation criteria.
- All measured clinical test plans passed the watch and action level set on the cumulative signal.
- However, only 15/20 clinical plans passed the segment-by-segment pass rate which was attributed to high signal fluctuations between the measured control points.
- But these clinical plans were found to be within the watch level.

# Results

| Output | | | |
|---|---|---|---|
| Amount of evaluated Fields | | 128 | |
| Amount of evaluated Segments | | 1903 | |
| **Tolerance Parameters** | | | |
| Watch Level | Constant Watch | 3.00 | |
| | Slope (+ / -) | -0.6361 | -0.6361 |
| | ΔSbS (+ / -) | 13.92 | 13.92 |
| Action Level | Constant Action | 6.3 | 6.3 |
| | Slope (+ / -) | -0.6361 | -0.6361 |
| | ΔSbS (+ / -) | 27.85 | 27.85 |
| Regression Range | Regression Until CP# (+ / -) | 11 | 11 |
| | Regression starting at CP# | 1 | |
| **Data Evaluation** | | | |
| % of Signals within reg. Watch Level | | 99.00% | |
| % of Signals within const. Watch Level | | 98.99% | |
| % of Signals within full Watch Level | | 99.00% | |
| Average Deviation (at constant Tolerance) | | 0.00 ± 1.25% | |
| Average Final Deviation | | 0.08 ± 1.21% | |
| **Code Strings for IQM.Config.ini-File** | | | |
| Watch Level | 13.9,1, 9,2, 6.9,3, 5.8,4, 5,5, 4.5,6, 4,7, 3.7,8, 3.4,9 | | |
| Action Level | 27.8,1, 17.9,2, 13.8,3, 11.5,4, 10,5, 8.9,6, 8.1,7, 7.4 | | |

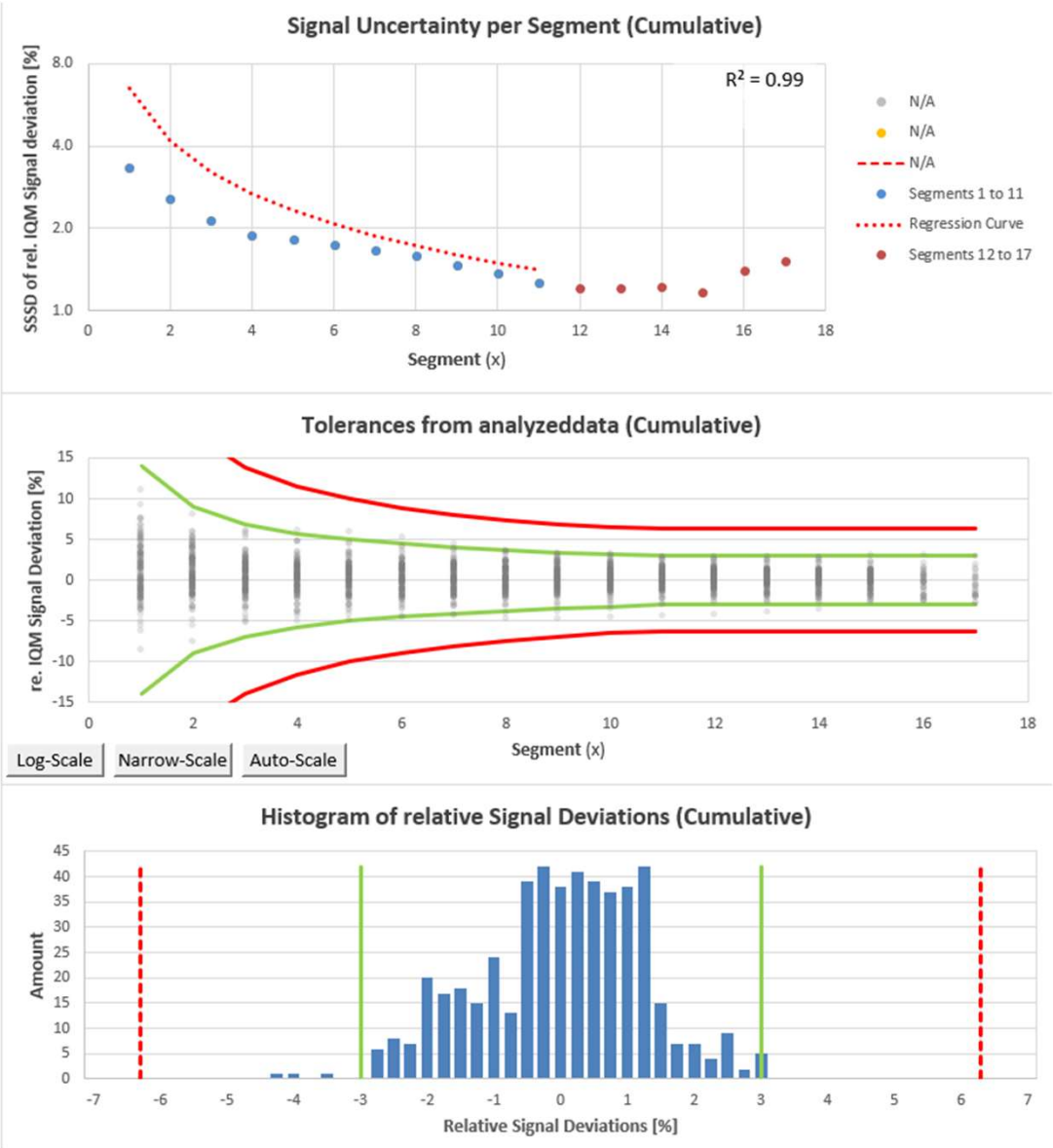


*Fig. 4a: Measured cumulative deviation against the watch and action level tolerance corridors*

# Results

| Output | | | |
|---|---|---|---|
| Amount of evaluated Fields | | 128 | |
| Amount of evaluated Segments | | 1903 | |
| Tolerance Parameters | | | |
| Watch Level | Constant Watch | 6.00 | |
| | Slope (+ / -) | 1.0000 | 1.0000 |
| | ΔSbS (+ / -) | 8.00 | 8.00 |
| Action Level | Constant Action | 12.0 | 12.0 |
| | Slope (+ / -) | 1.0000 | 1.0000 |
| | ΔSbS (+ / -) | 16.00 | 16.00 |
| Regression Range | Regression Until CP# (+ / -) | 1 | 1 |
| | Regression starting at CP# | 1 | |
| Data Evaluation | | | |
| % of Signals within reg. Watch Level | | 97.66% | |
| % of Signals within const. Watch Level | | 97.63% | |
| % of Signals within full Watch Level | | 97.64% | |
| Average Deviation (at constant Tolerance) | | -0.03 ± 2.51% | |
| Average Final Deviation | | -0.54 ± 3.18% | |
| Code Strings for IQM.Config.ini-File | | | |
| Watch Level | 8,1, 6 | | |
| Action Level | 16,1, 12 | | |

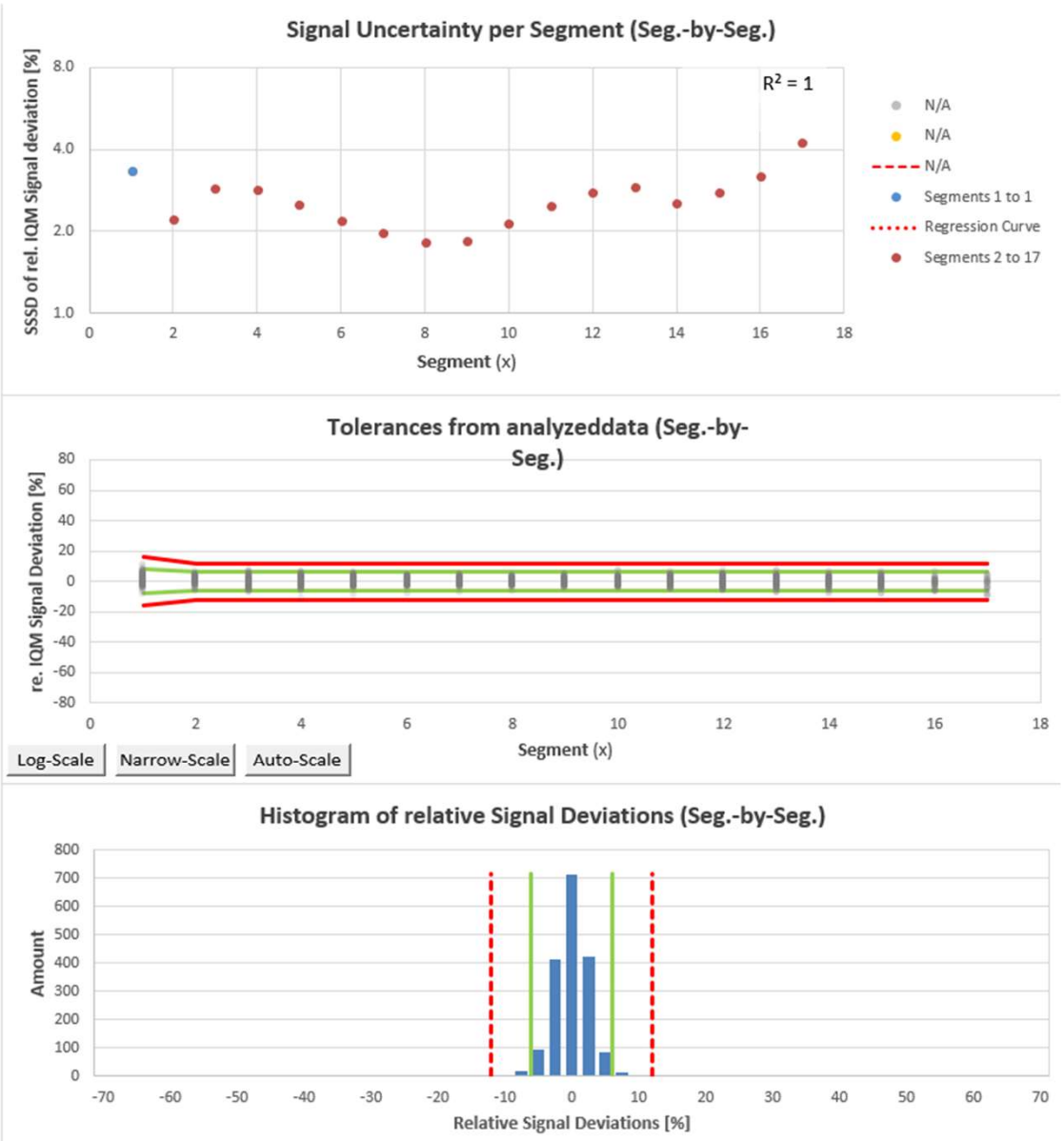


*Fig. 4b: Measured segment-by-segment deviation against the watch and action level tolerance corridors*

# Results

Based on the evaluation, a watch level of ± 3% and action level of -6.3% and +4% were set as the tolerance for all routine stereotactic patient specific dosimetry.

# Conclusion

Best fit MLC parameters for the Elements beam model were determined and IQM small field dose calculation model was improved enabling clinical implementation of IQM for PSD of single isocentre treatment for MBM.

# Thank you!!


## Acknowledgements

*Brainlab Limited, Germany* for Elements beam modeling

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