

A Novel Index Method of Analyzing Imaging & Radiation Coordinate Agreement with the MultiMet Winston-Lutz Test

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MMWL Problems:

- Tolerance thresholds do not consider all error sources**
- It is difficult to interpret overall coordinate agreement**

Purpose

- Redefine tolerance thresholds considering all applicable error sources
- De-dimensionalize agreement from all imaging geometries into one index value

Methods

- Creating new thresholds: Added TG-142 thresholds for applicable error sources in quadrature for each geometry
 - Isocenter Concentricity = 1mm [all geometries]
 - Table walkout = 1mm [table rotations]
 - Table Angle = $\sin(1 \text{ degree}) * (\text{target distance from iso})$ [table rotations & off-iso targets]
 - Collimator Walkout = 1mm [collimator rotations]
 - Gantry Angle = $\sin(1 \text{ degree}) * (\text{lateral distance from iso})$ [gantry rotations and laterally off-iso targets]
- Calculated Summarizing Index
 - Clearance = $(\text{Measured Offset} - \text{Threshold}) / \text{Threshold}$
 - Index: Clearance values averaged over all targets & geometries
 - Value of 1 shows perfect MV & kV isocenter agreement
 - Value of 0 shows the worst possible pass
- Average threshold value: 1.52 (52% less strict)

Gantry	Couch	Collimator	Iso	1	2	3	4	5
0°	0°	0°	1.00	1.00	1.00	1.00	1.00	1.00
0°	0°	90°	1.41	1.41	1.41	1.41	1.41	1.41
0°	0°	270°	1.41	1.41	1.41	1.41	1.41	1.41
0°	45°	45°	1.73	1.81	1.83	1.81	2.01	2.12
0°	45°	225°	1.73	1.81	1.83	1.81	2.01	2.12
0°	90°	0°	1.41	1.51	1.53	1.51	1.74	1.87
0°	270°	0°	1.41	1.51	1.53	1.51	1.74	1.87
0°	315°	135°	1.73	1.81	1.83	1.81	2.01	2.12
0°	315°	315°	1.73	1.81	1.83	1.81	2.01	2.12
90°	0°	90°	1.41	1.41	1.51	1.41	1.51	1.41
90°	0°	270°	1.41	1.41	1.51	1.41	1.51	1.41
180°	0°	0°	1.00	1.00	1.00	1.00	1.00	1.00
180°	0°	90°	1.41	1.41	1.41	1.41	1.41	1.41
270°	0°	90°	1.41	1.41	1.51	1.41	1.51	1.41
270°	0°	270°	1.41	1.41	1.51	1.41	1.51	1.41

Figure 1: The tolerance values for each target and treatment position are displayed for the Varian Edge

Robustness Testing

- The test was completed end-to-end 5 times consecutively on a Varian TrueBeam and Edge
- This quantifies robustness of index to measurement error
- 95% Confidence Intervals: Edge- 0.11 TB- 0.03

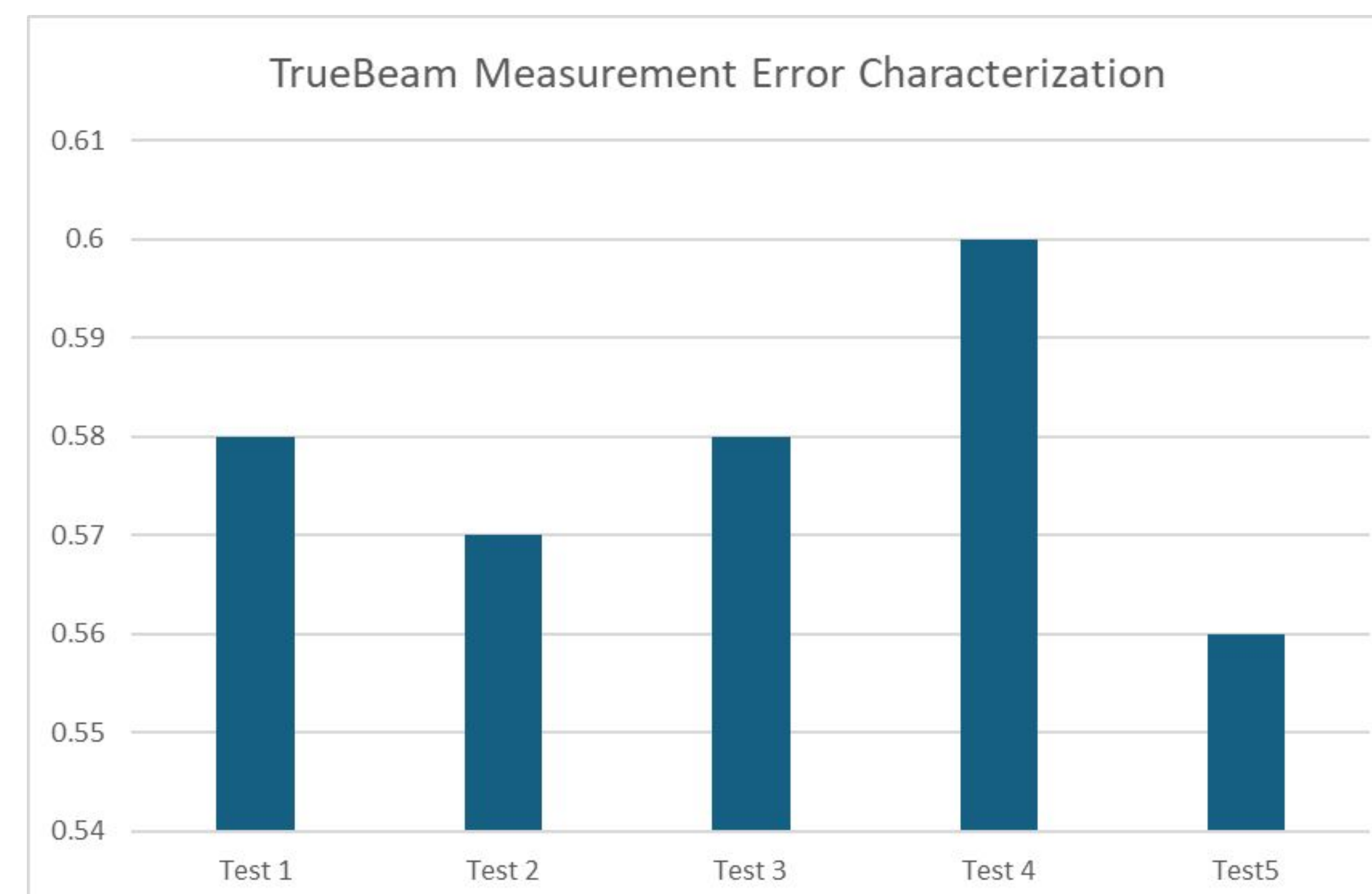
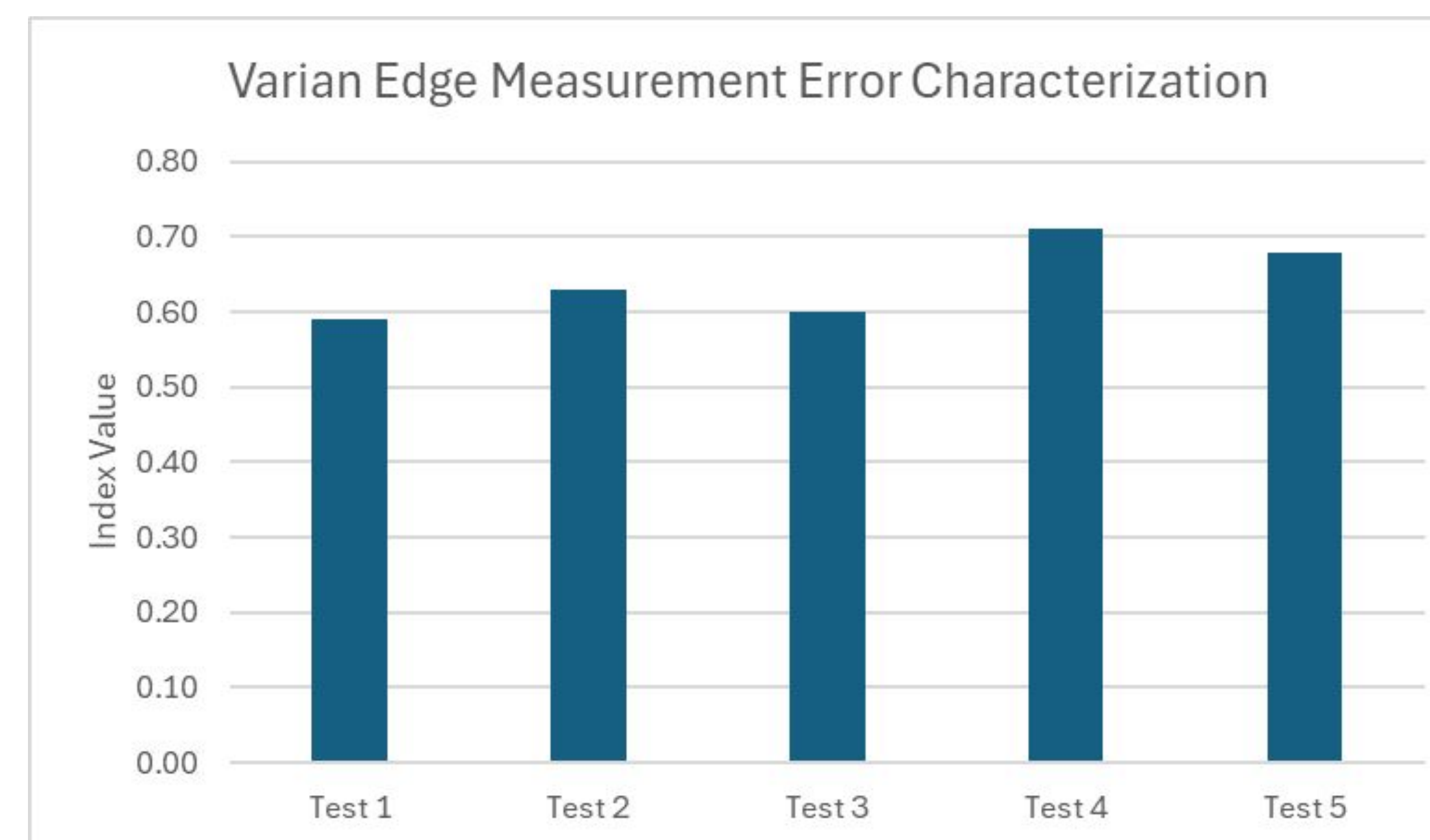


Figure 2: Repeated measurements showed acceptable (SD = 0.05) agreement for Edge and greater (SD = 0.02) agreement for TrueBeam

Intentional Error Analysis

- Analysis was also performed with intentional 2mm lateral shift from isocenter (clinically unacceptable difference)
- Index value decreased from 0.56 to 0.14
 - Significant, but within worst possible pass threshold
- Overall Index underrepresents unacceptable change
 - Error only reflected at certain gantry & table angles
 - Individual thresholds still identified failures

Historical Analysis

- Index Values were calculated retrospectively for the 2 LINACS
 - 9 months for TrueBeam 18 Months for Edge
- Identified 7 months of reduced concentricity (Edge: 3 & TB: 4)
 - Only 1 failed TG-142 (Edge: Aug. 2025)
 - 2 failing TG-142 were not significant (Edge: June & Oct. 2024)

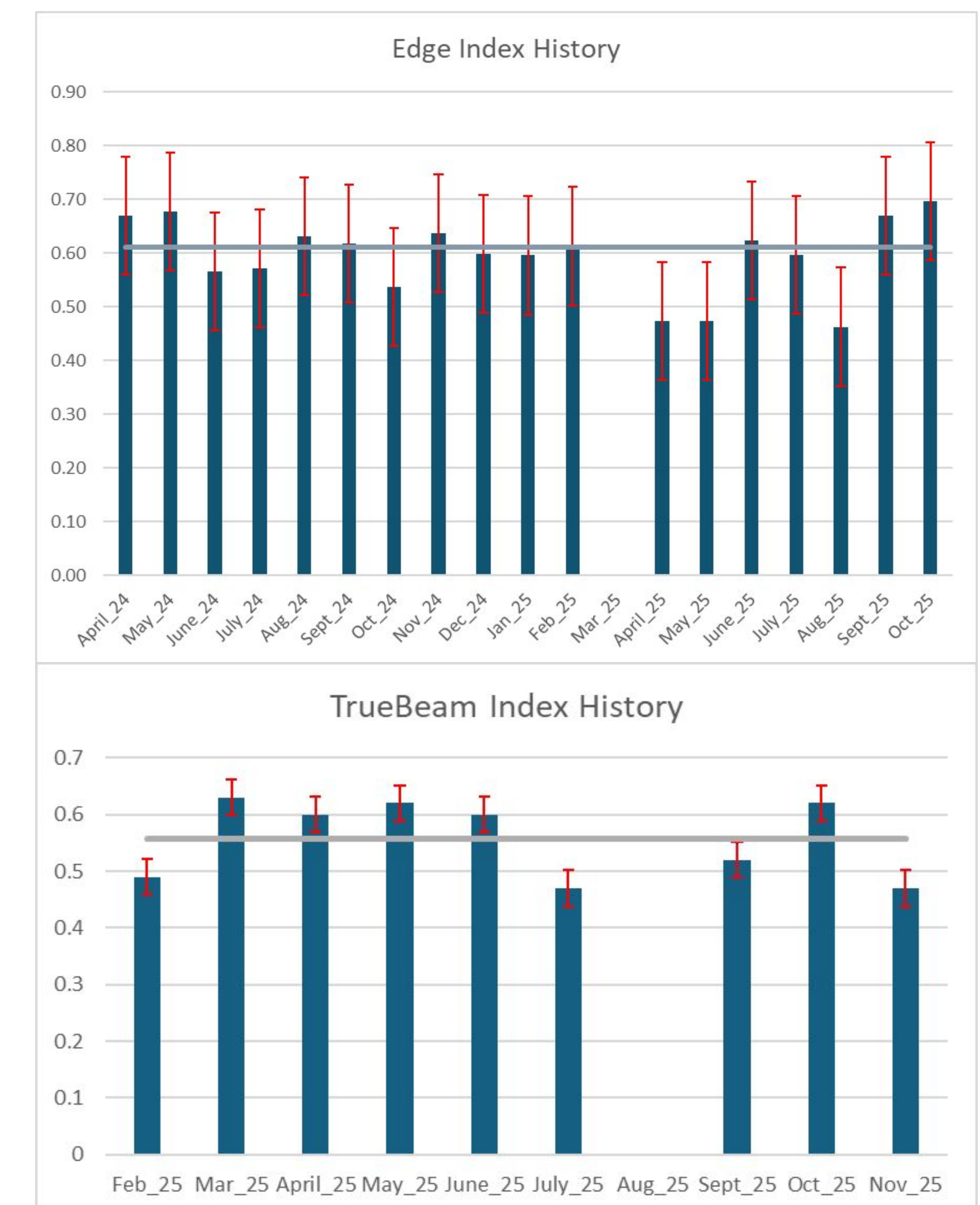


Fig 3: Index values were fluctuating but consistent for both machines. The mean index value for each machine is displayed by the horizontal line (Edge: 0.6 & TB: 0.56).

Conclusions

- Index solves both motivating problems**
- Errors noticeably reflected in result w/ small uncertainty**
- Is robust and sensitive enough to analyze month to month performance differences**
 - Identified 7 Instances of performance reduction**
 - 8 disagreements with TG-142 criteria**
 - Measurement uncertainty depends on machine**