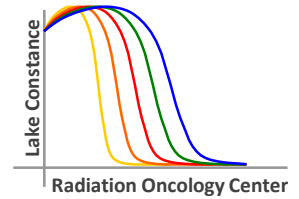


Pre-clinical tests of the Integral Quality Monitor (IQM) System

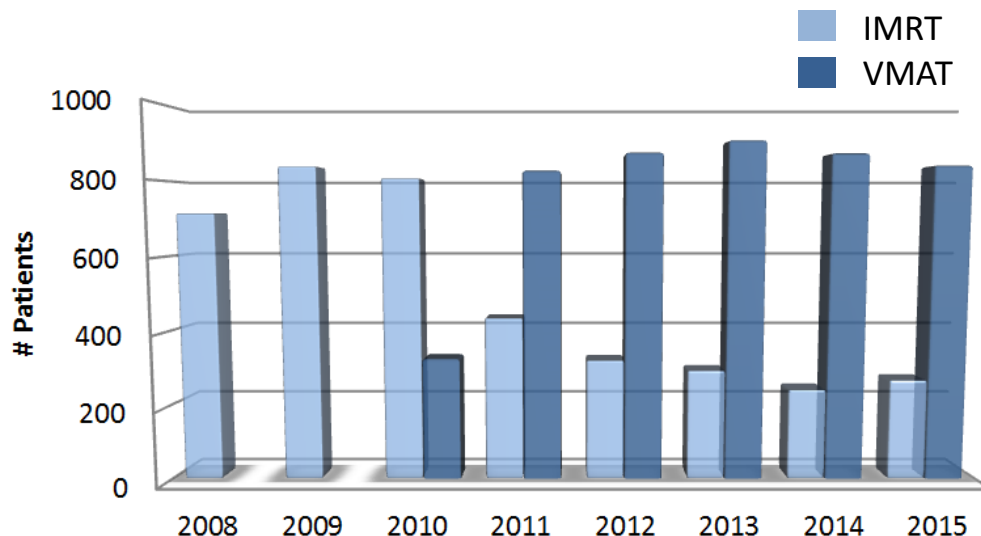
Marlies Pasler

Lake Constance Radiation Oncology Center Friedrichshafen

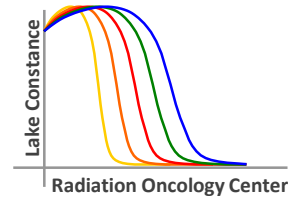
Lake Constance Radiation Oncology Center



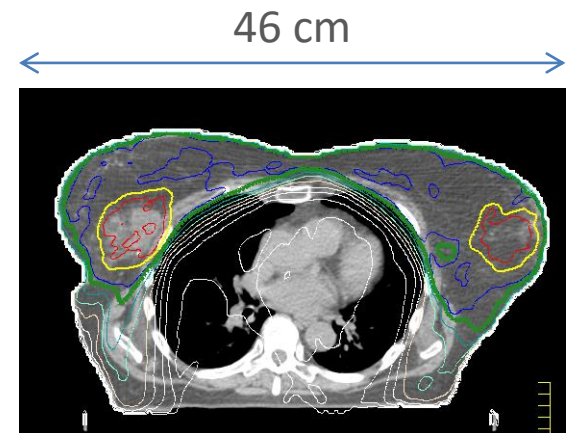
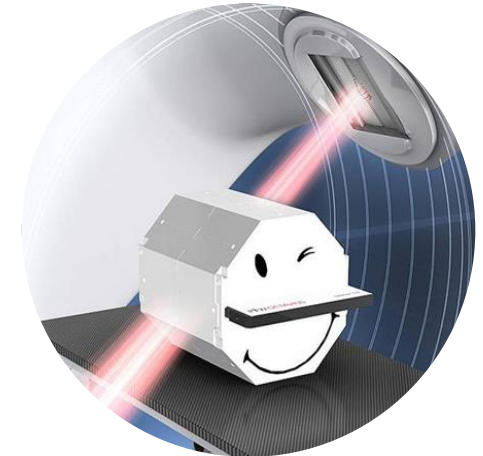
- 3 Elekta Synergy/ MLCi2
- Pinnacle³ TPS
- 5 Radiation oncologists & 4 medical physicists
- > 70% VMAT



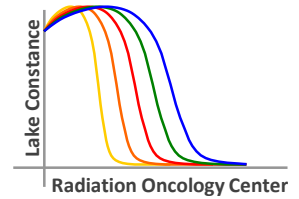
QA: status quo



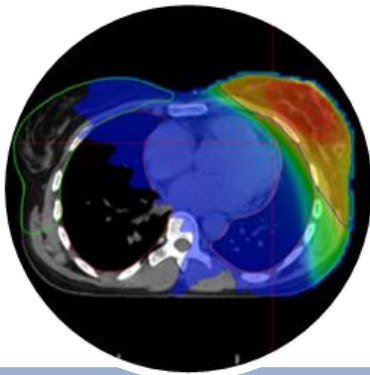
- Pre-treatment verification
 - PTW equipment
 - Octavius II/ 2D Array 729/Verisoft 6.2
- γ -passing rate (3mm/3%) > 95%
- Concerns
 - Not VMAT-specific
 - No full field coverage
 - Workload per day: ~2h



IQM: towards online QA



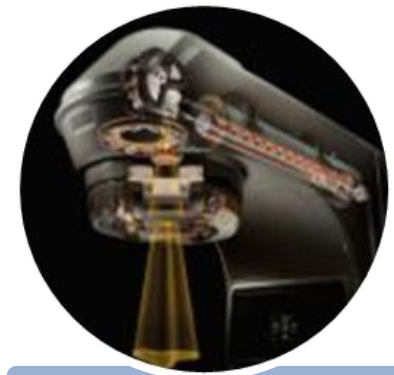
- Can IQM catch errors before they become clinically relevant?
- Can we improve on efficiency?
- Can we resign pre-treatment QA?



treatment planning

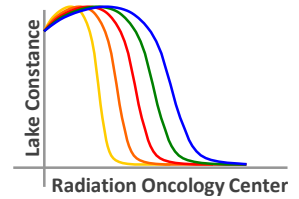


plan verification

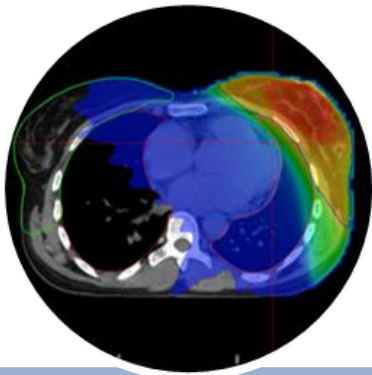


treatment delivery

IQM: towards online QA



- Can IQM catch errors before they become clinically relevant?
- Can we improve on efficiency?
- Can we resign pre-treatment QA?

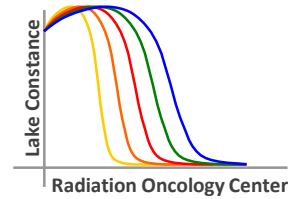


treatment planning

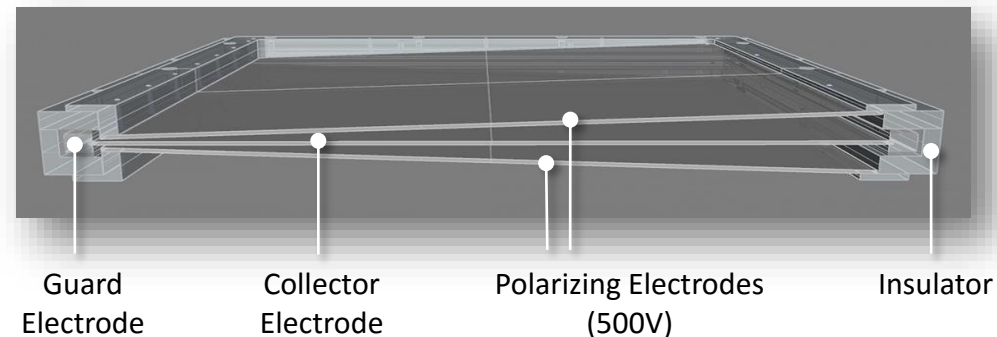


online & real time verification

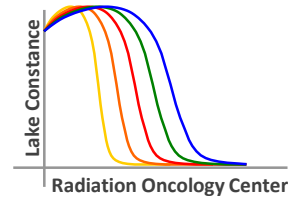
Online patient QA: IQM



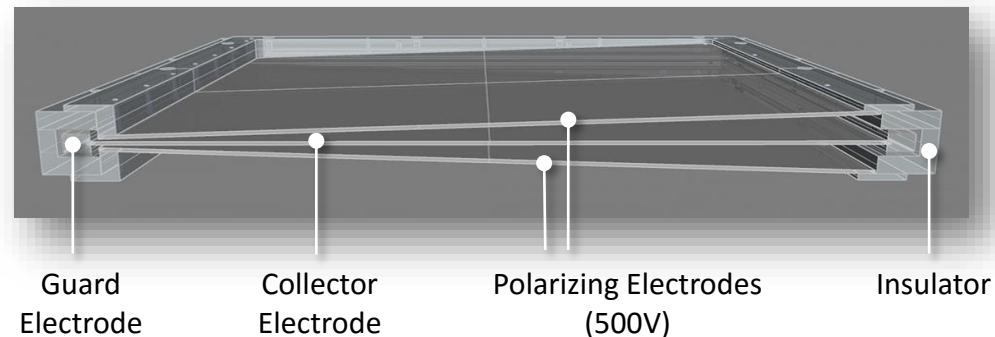
- Single large area ion chamber
 - Gantry mounted detector
 - Fully automated
 - Full field coverage
 - Real time online tracking
 - Intra-fraction linac monitoring
- Signal readout
 - Segment-by-Segment
 - Cumulative
- Reference for evaluation
 - Calculated signal
 - Measured signal



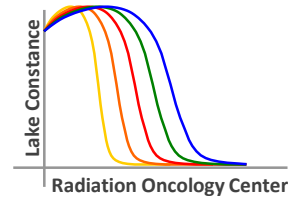
Pre-Clinical tests of the IQM system



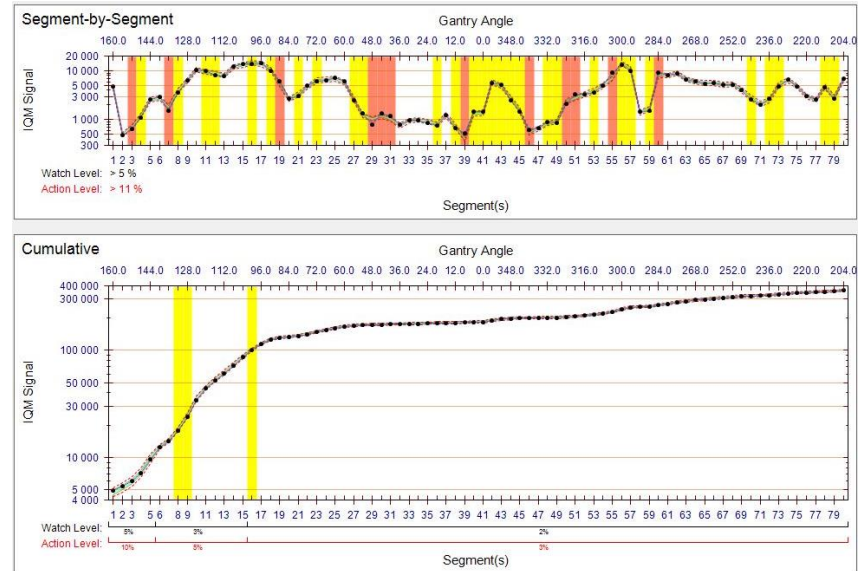
- Clinical VMAT plans:
 - Prostate/ Breast/ H&N
- IQM signal stability
 - inter fraction repeatability
- Detection of geometric errors
- Detection of dosimetric errors



IQM signal stability



- VMAT plans
 - Prostate
 - Breast with SIB
 - H&N
- Signal reproducibility
 - 10 measurements



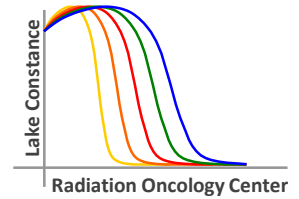
Segment-by-segment

Cumulative

	Prostate	Breast with SIB	H&N
measurement uncertainty	1.75%	1.57%	2.01%
calculated vs. measured signal	-2.36%	4.74%	4.19%

	Prostate	Breast with SIB	H&N
measurement uncertainty	0.32%	0.23%	0.43%
calculated vs. measured signal	-6.03%	-1.44%	-1.47%

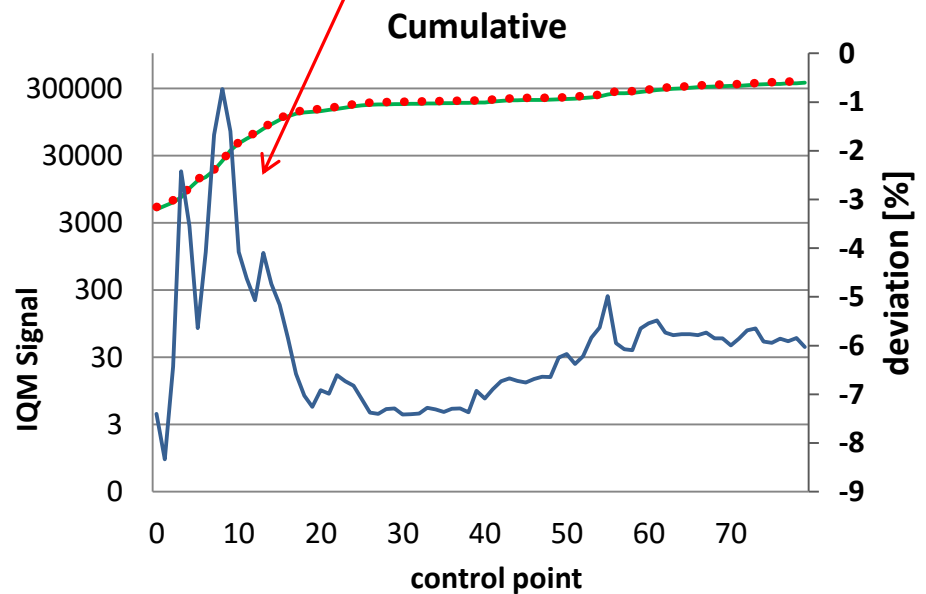
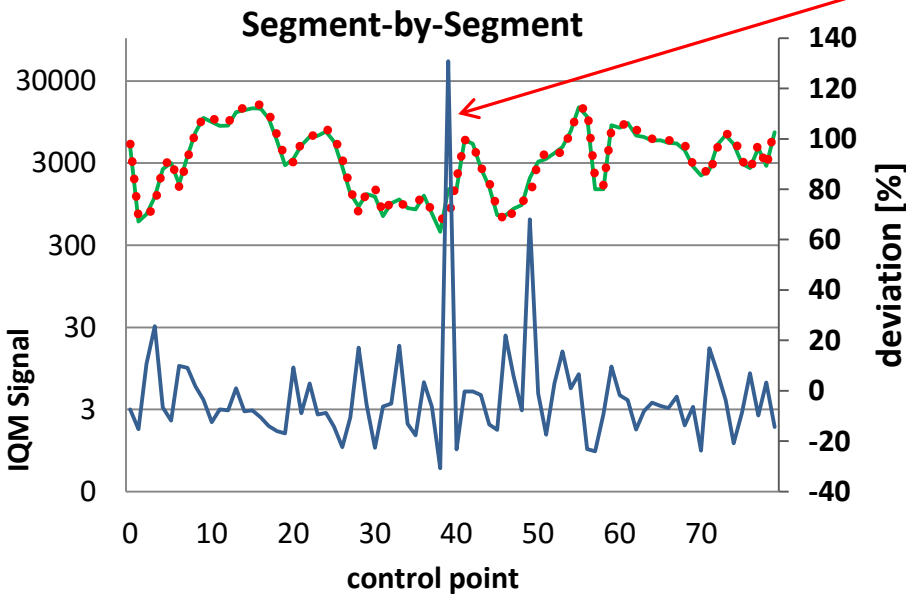
IQM signal calculation



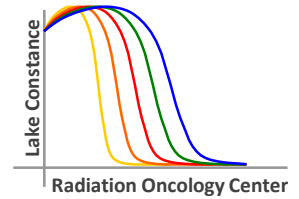
- VMAT prostate plan
 - calculated vs. average measured signal

— mean measured value
••• expected calculated value
— relative disagreement [%]

Inclinometer readout & gantry movement



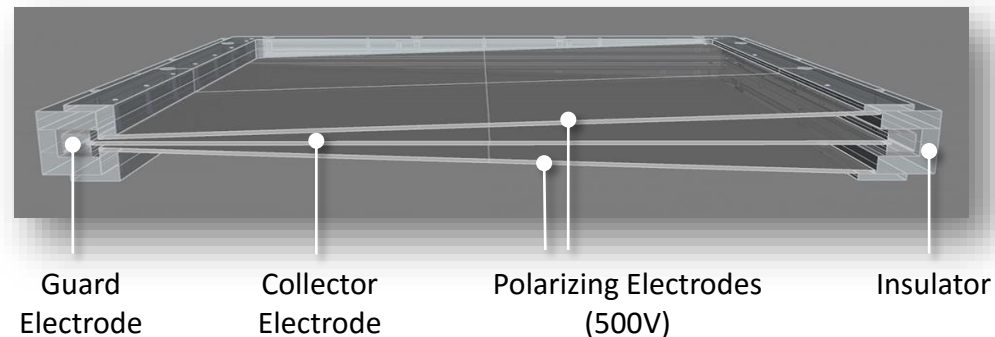
Pre-Clinical tests of the IQM system



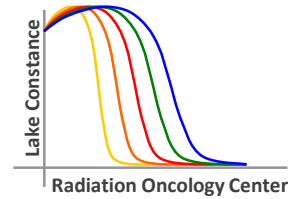
- Clinical VMAT plans:

Prostate/ Breast/ H&N

- IQM signal stability
- Detection of geometric errors
 - Implementation of systematic & random errors
- Detection of dosimetric errors



Geometric errors

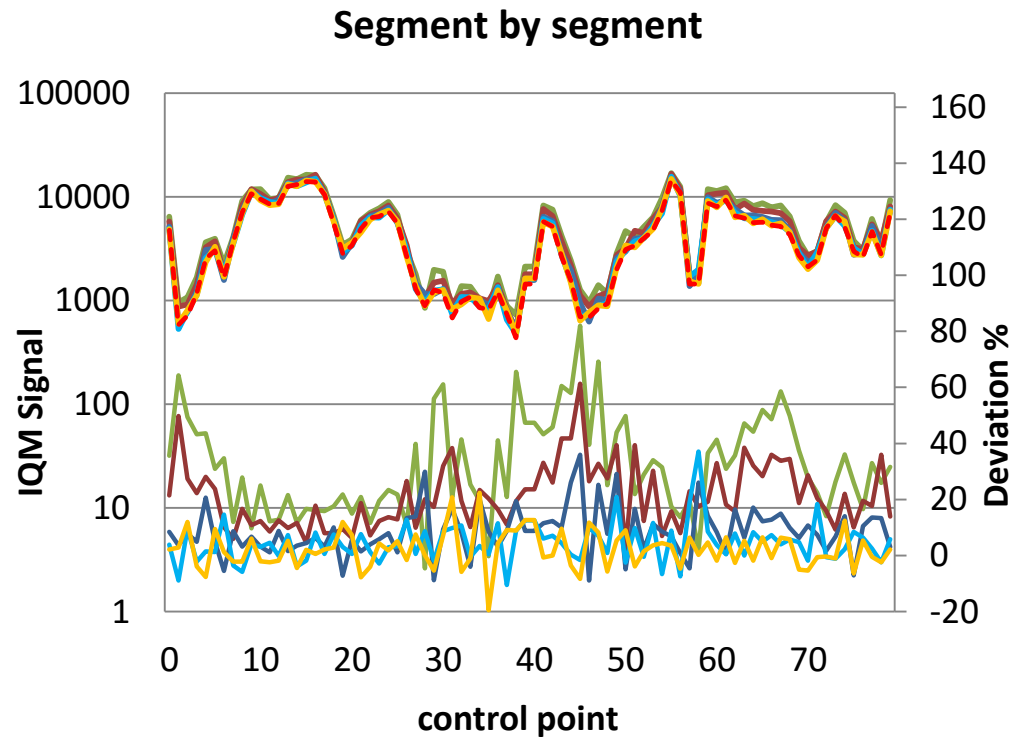


- **systematic** MLC leafbank shift (0.5-8mm)

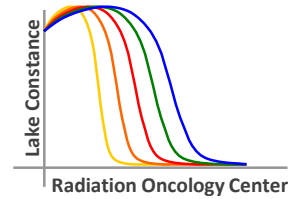
- VMAT prostate plan
- reference: average of 10 measurements

- 0.5mm — 2mm
- 1mm — 5mm
- 8mm

Error	rel. disagreement	
	Segm	Cum
Y2+0.5mm	2.2%	1.2%
Y2+1mm	4.5%	2.6%
Y2+2mm	8.6%	6.0%
Y2+5mm	21.1%	15.5%
Y2+8mm	31.9%	24.2%



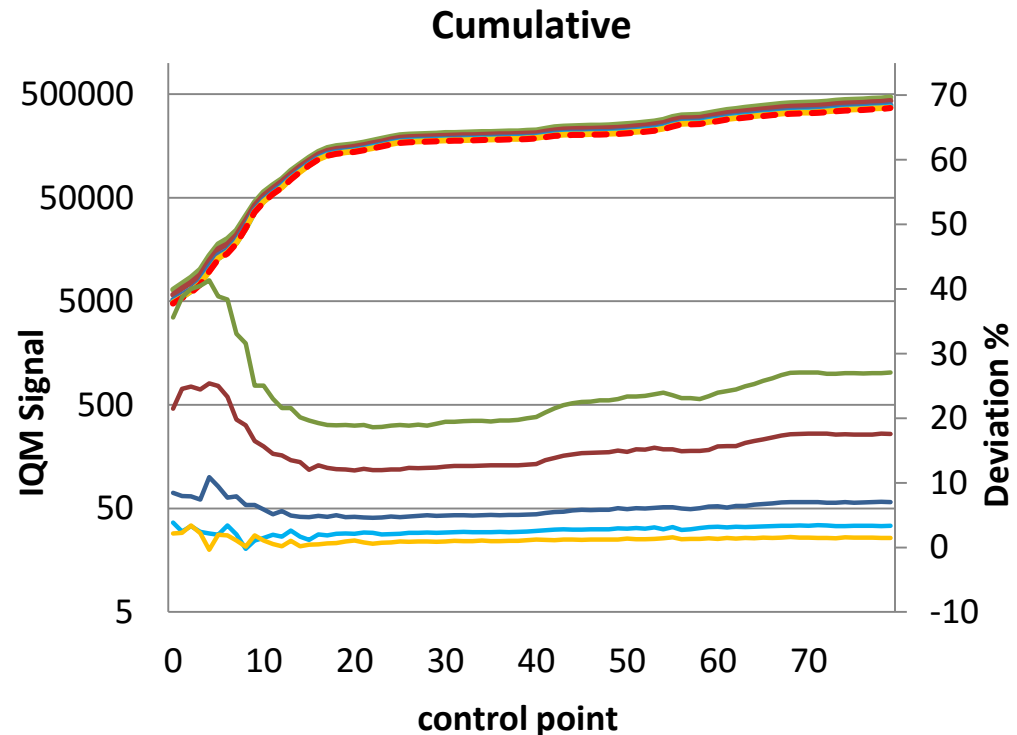
Geometric errors



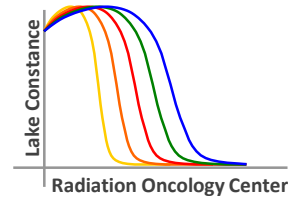
- **systematic** MLC leafbank shift (0.5-8mm)
 - VMAT prostate plan
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Y2+0.5mm	2.2%	1.2%
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Y2+5mm	21.1%	15.5%
Y2+8mm	31.9%	24.2%



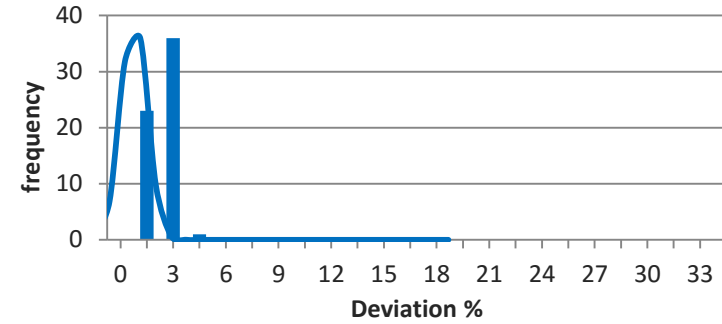
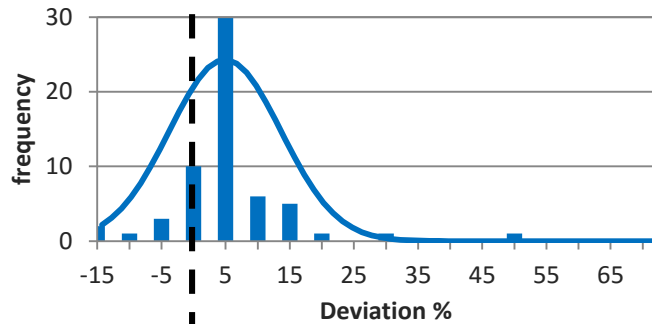
Geometric errors: Histograms



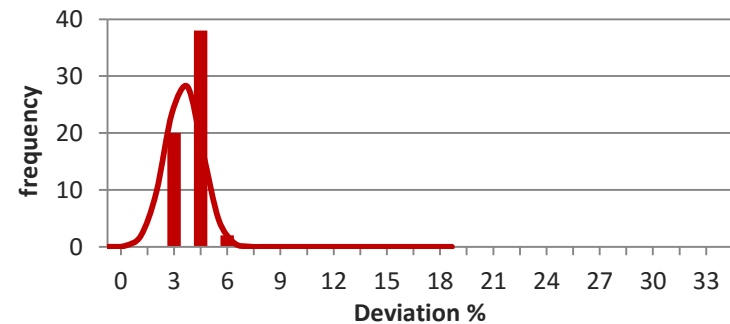
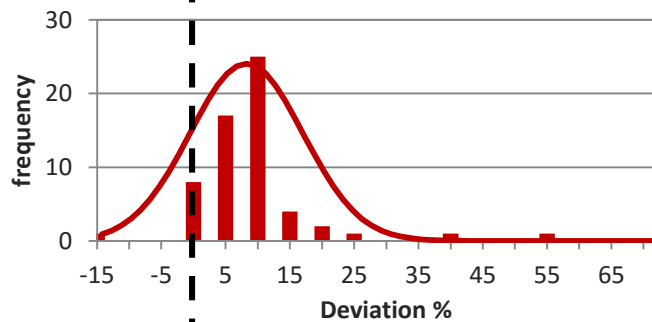
Segment by segment

Cumulative

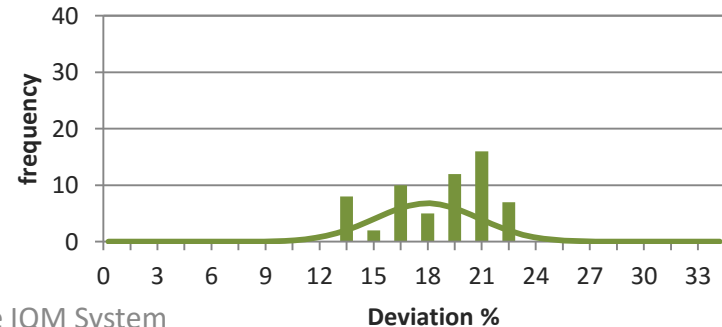
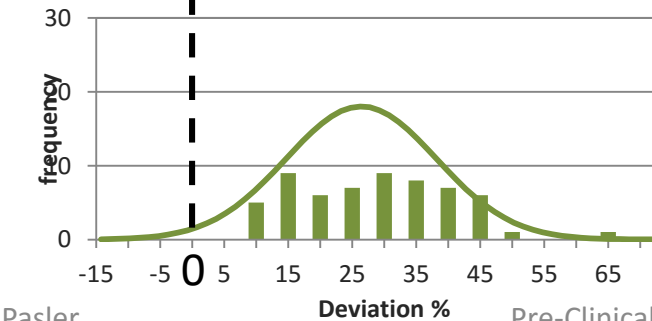
Y2+2mm



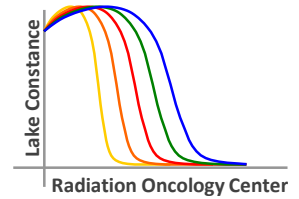
Y2+5mm



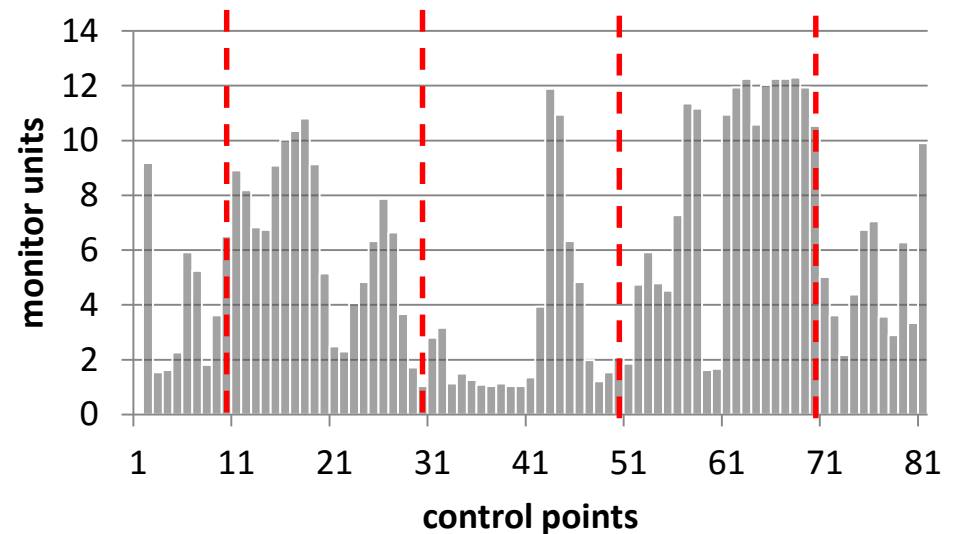
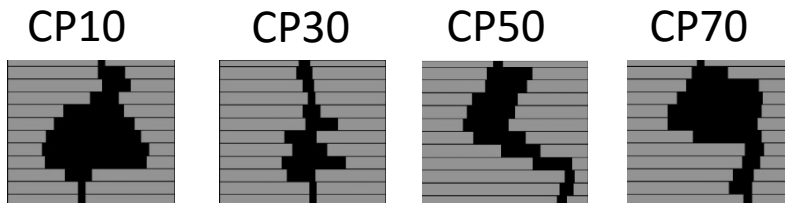
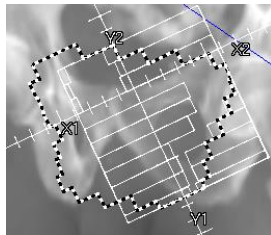
Y2+8mm



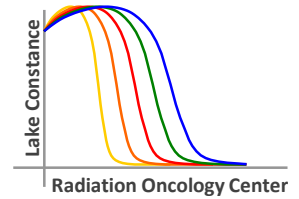
Geometric errors



- **Random** leafbank errors
 - MLC bank shift: 2/5/8 mm @ 4 control points
 - VMAT prostate plan



Geometric errors

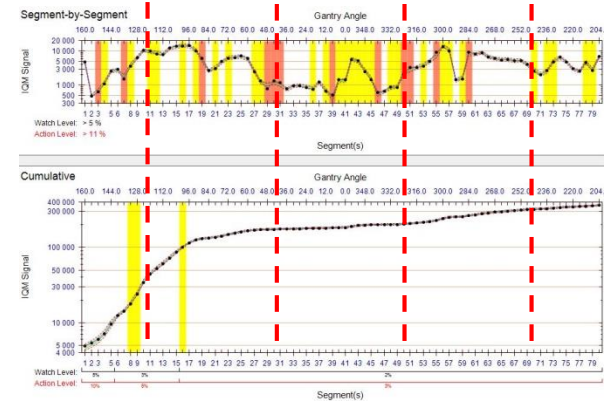


- Random leafbank errors**

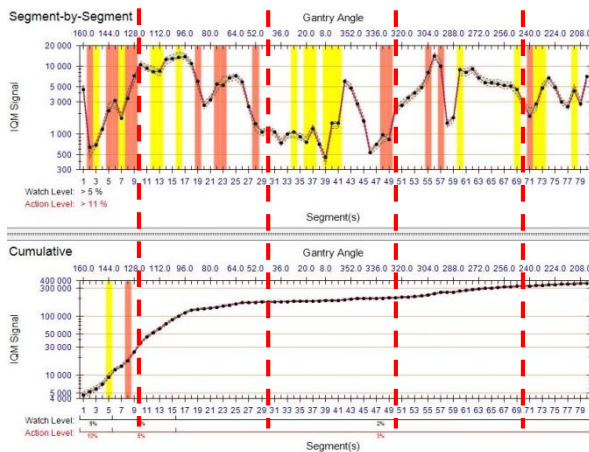
Tolerance levels

Segment by segment: **5%** **11%**
 Cumulative: **1,5%** **3%**

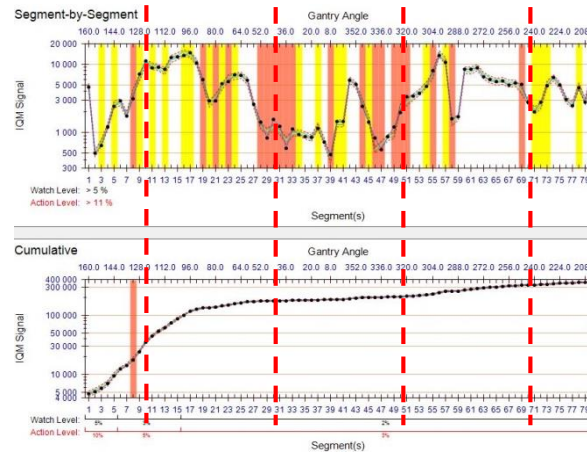
No errors



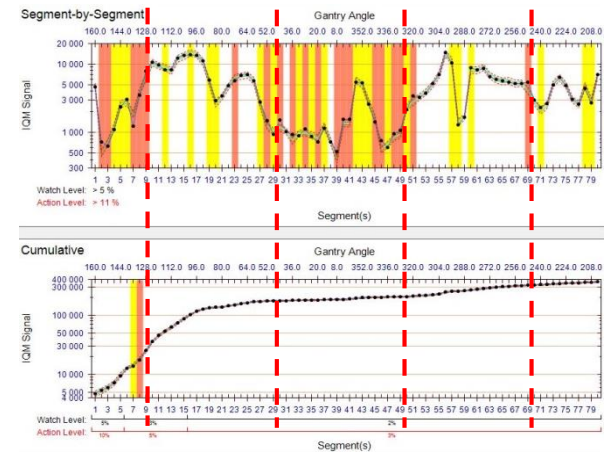
2mm



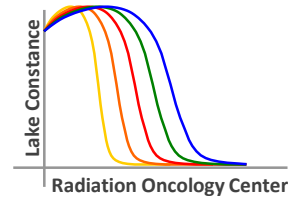
5mm



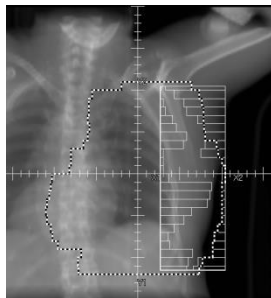
8mm



Geometric errors



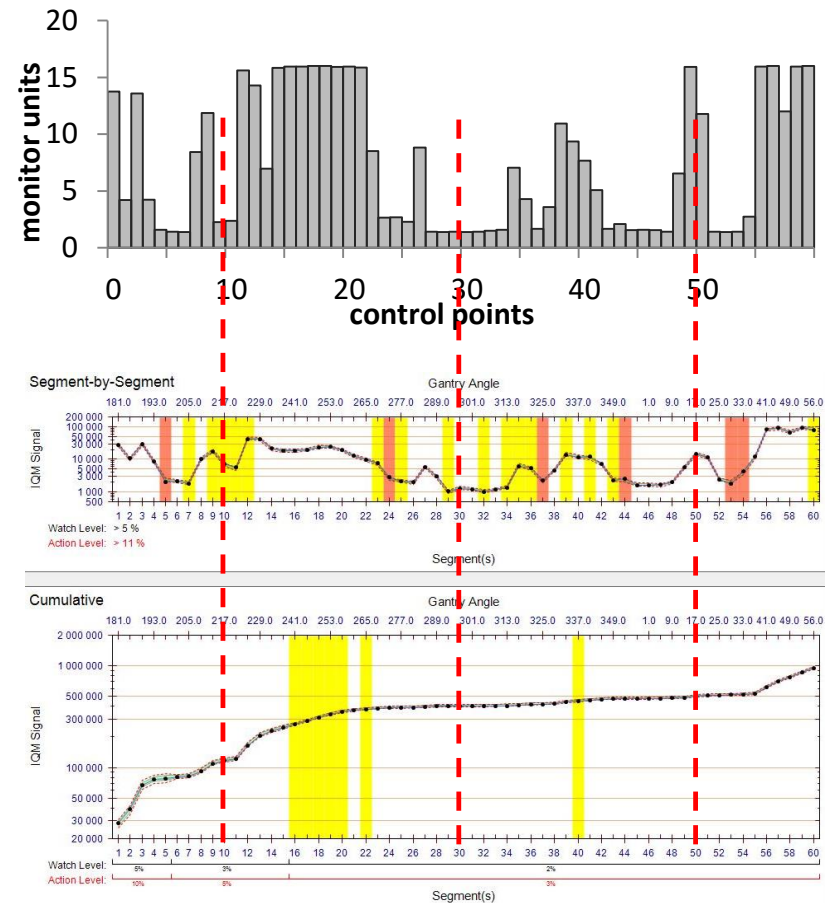
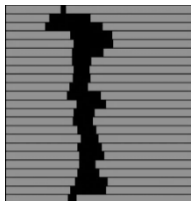
- Random leafbank errors
 - 8mm @ 3 control points
 - VMAT for breast with SIB



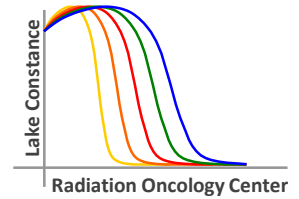
cp10

cp30

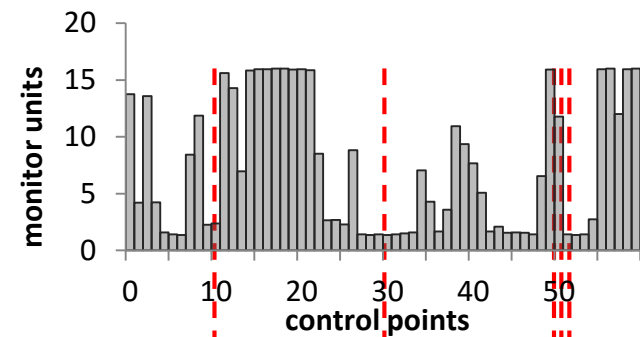
cp50



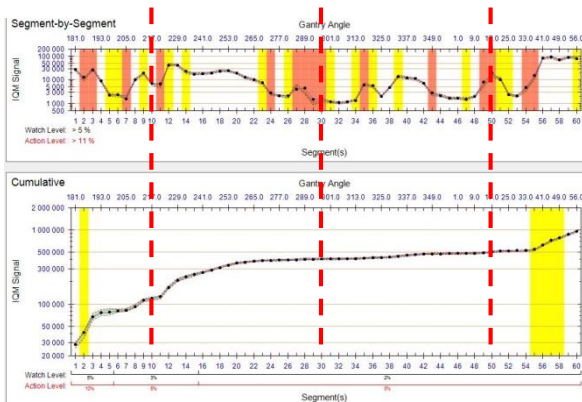
Geometric errors



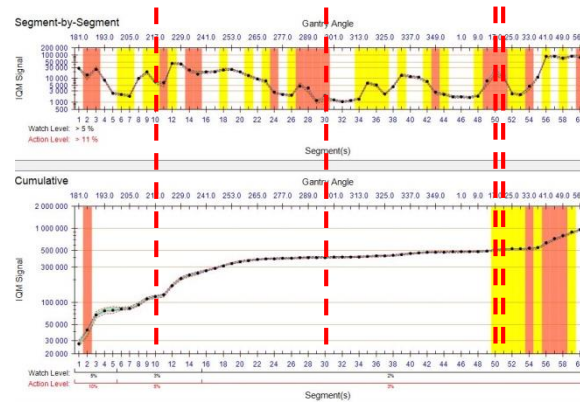
- Random leafbank errors
8mm @ 3 control points
+ consecutive cps



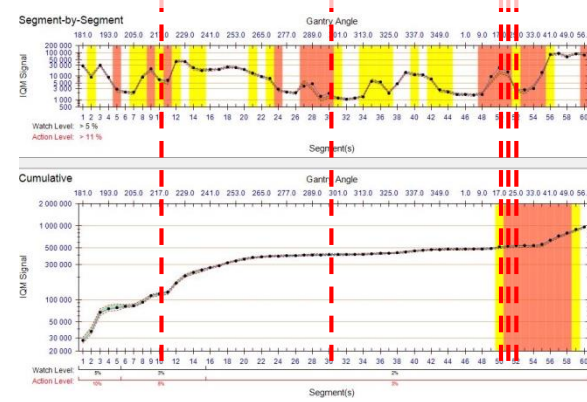
8mm @ cp10, cp30, cp50



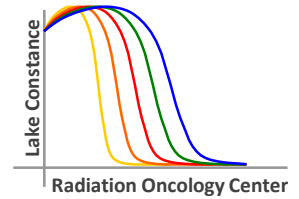
8mm @ cp10, cp30, cp50 + 51



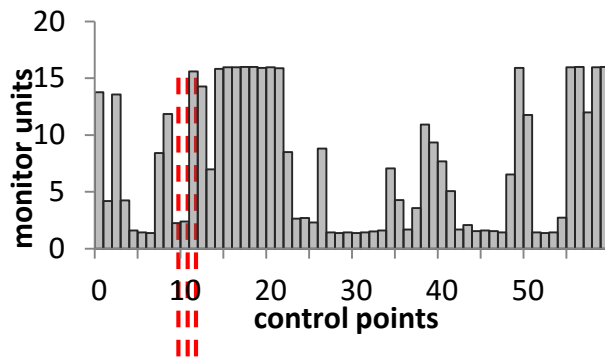
8mm @ cp10, cp30, cp50+51+52



Geometric errors



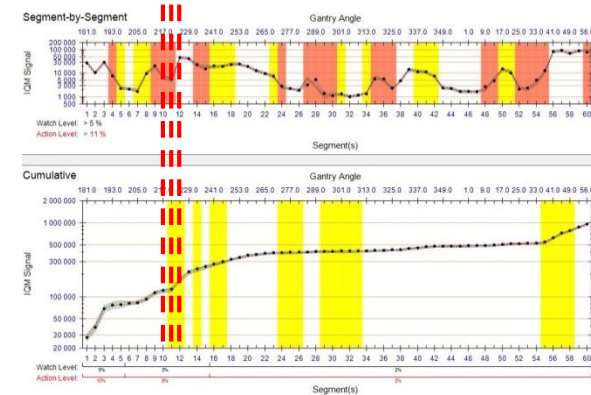
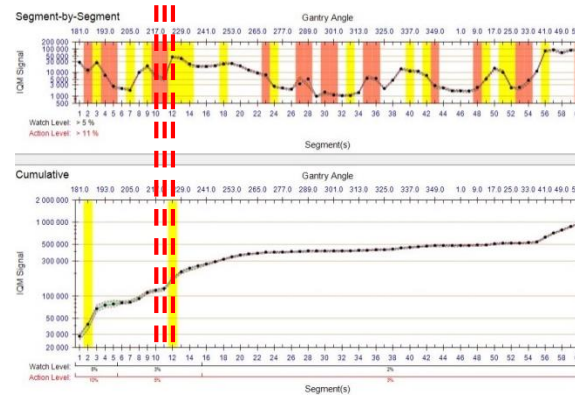
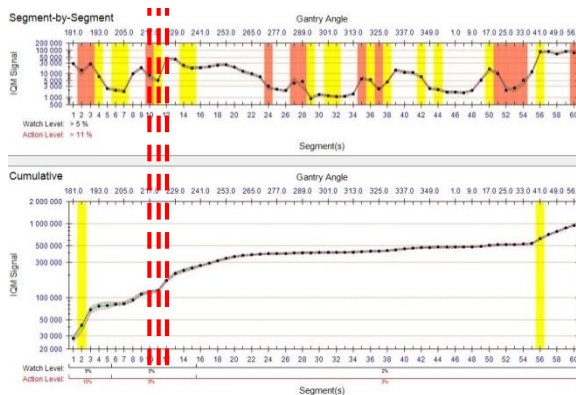
- Random leafbank shift @ 3 consecutive control points
 - Control points with **low relative weight** (2-10MU/cp)



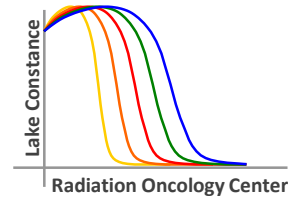
5mm @ cp10-12

8mm @ cp10-12

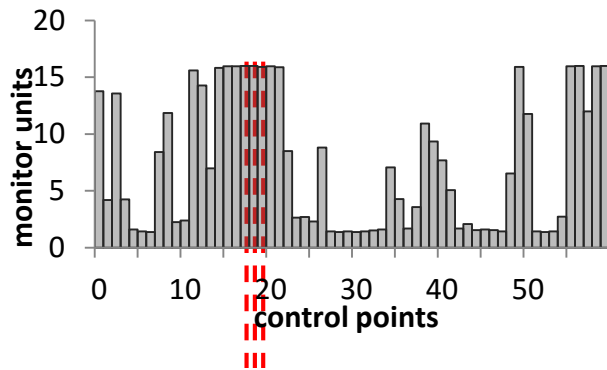
10mm @ cp10-12



Geometric errors



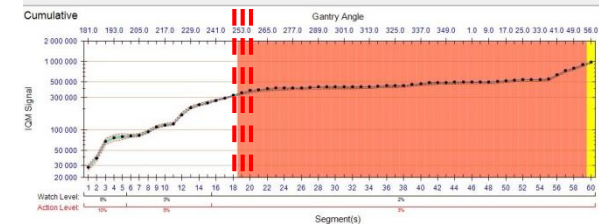
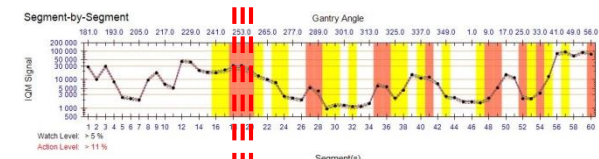
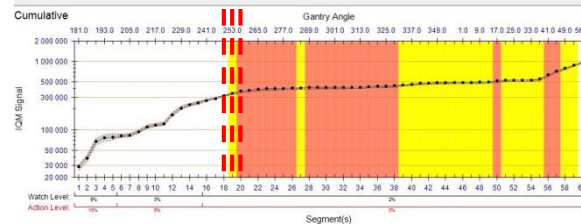
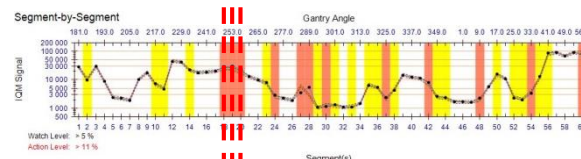
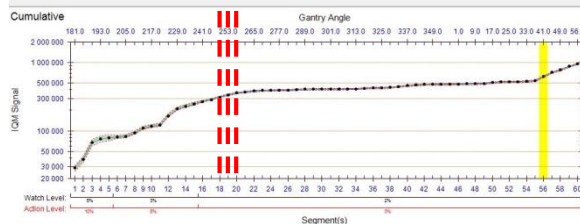
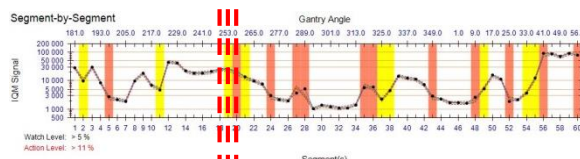
- Random leafbank shift @ 3 consecutive control points
 - Control points with **high relative weight** (16MU/cp)



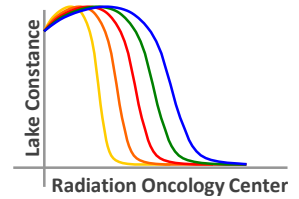
2mm @ cp18-20

5mm @ cp18-20

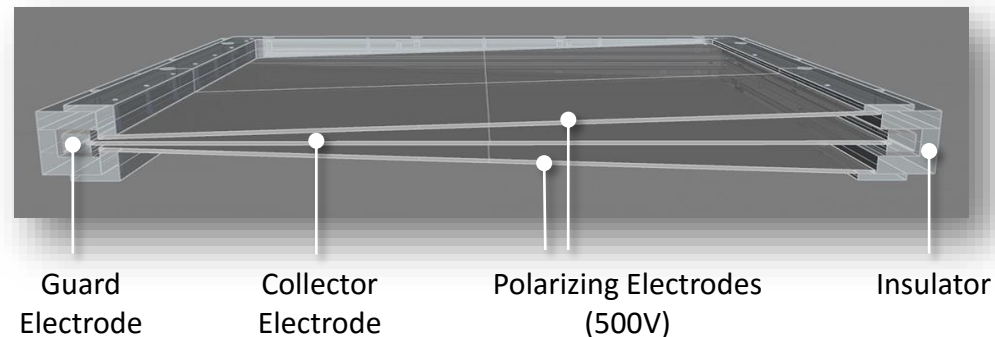
8mm @ cp18-20



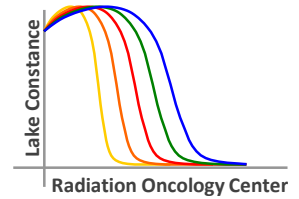
Pre-Clinical tests of the IQM system



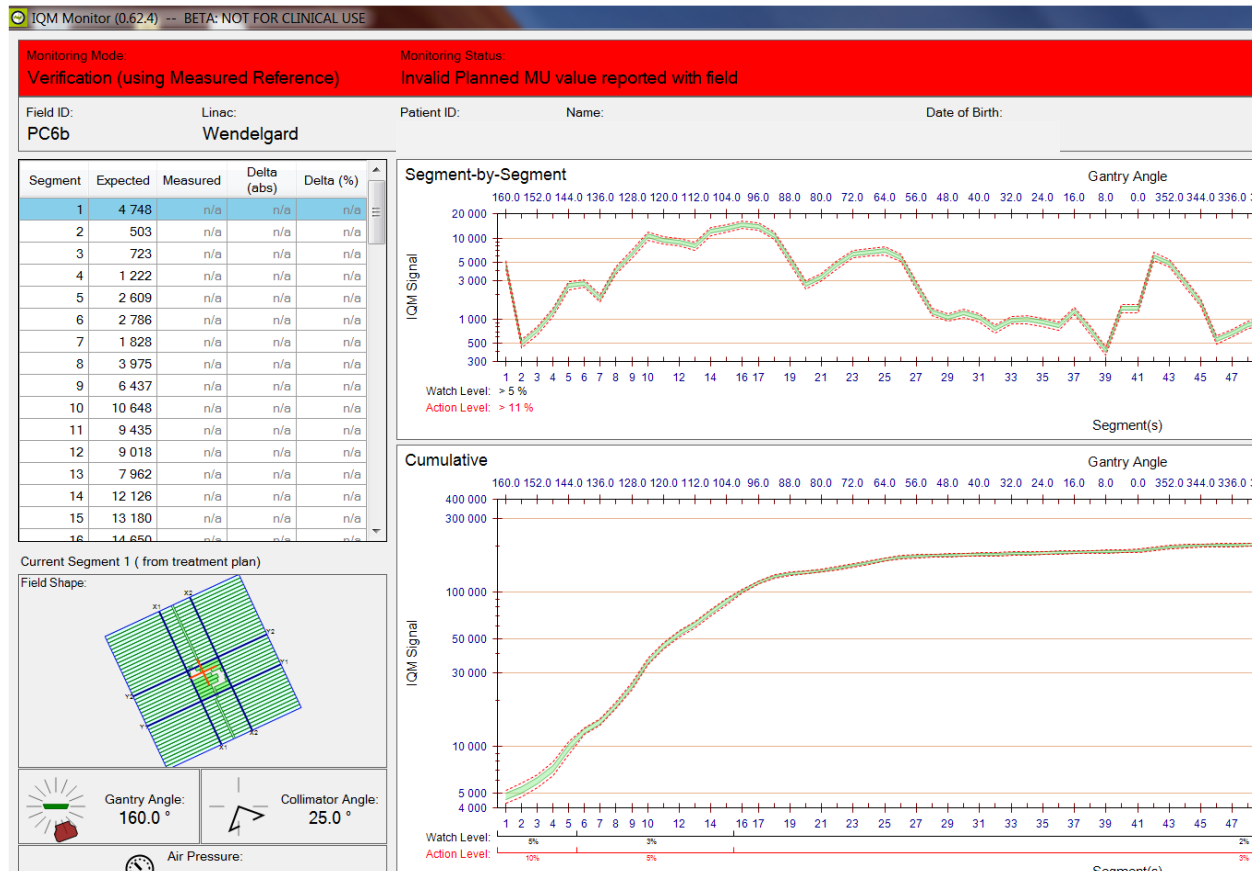
- Clinical VMAT plans:
Prostate/ Breast/ H&N
- IQM signal stability
- Detection of geometric errors
- Detection of dosimetric errors



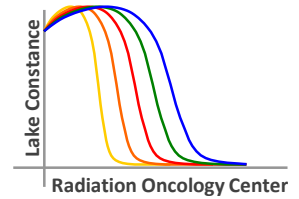
Dosimetric errors



- Total #MU changed
 - IQM monitor gives immediate alert

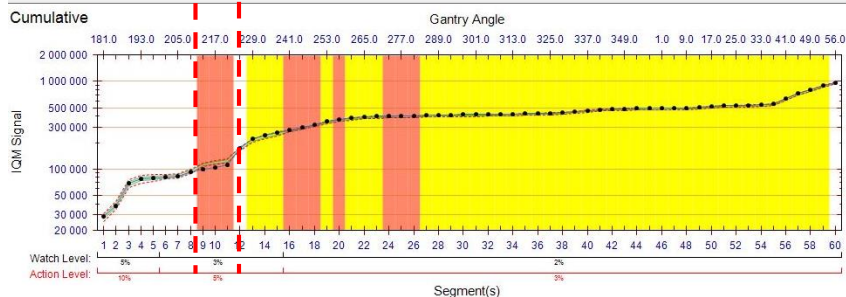
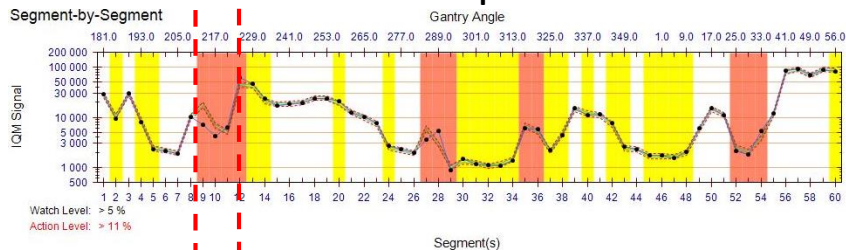
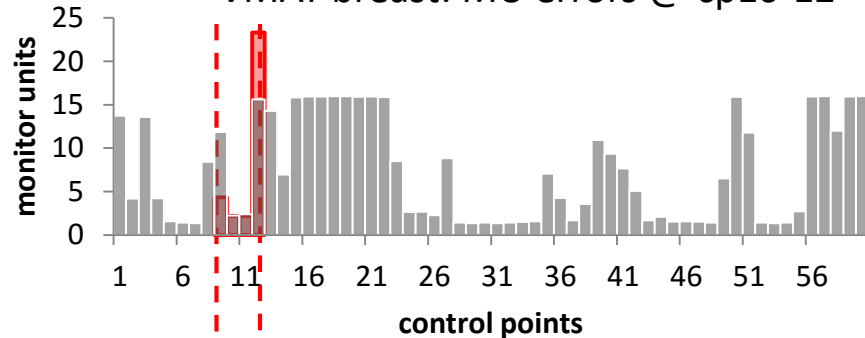


Dosimetric errors

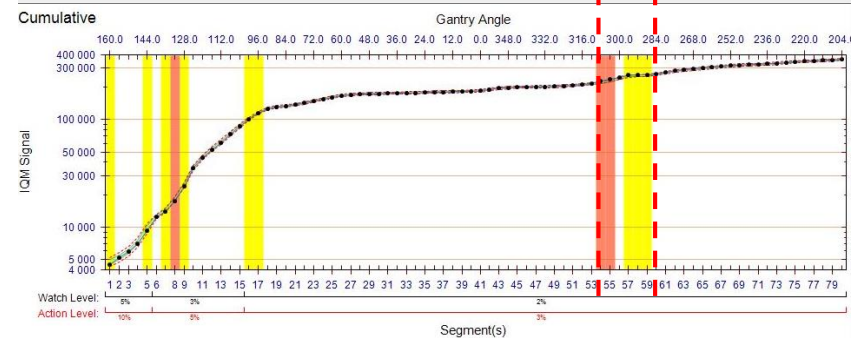
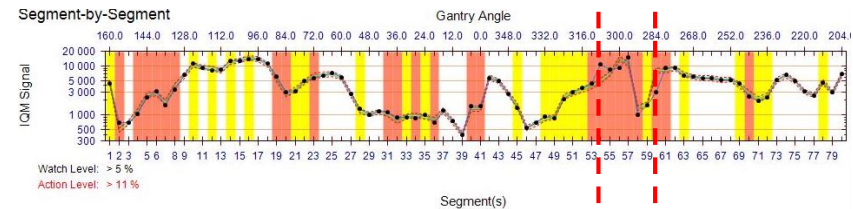
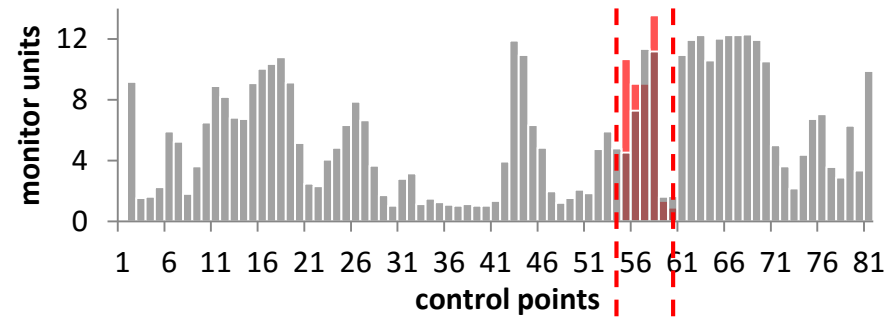


- Random errors @ single control points

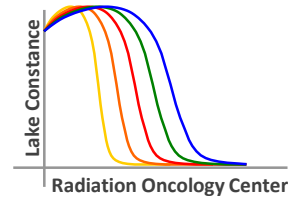
VMAT breast: MU errors @ cp10-12



VMAT prostate: MU errors @ cp55-60

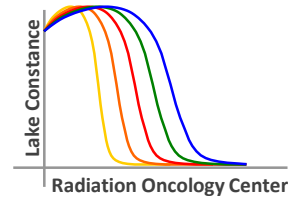


Summary



- General
 - Easy & robust workflow, no software crashes
 - User friendly interface
 - Consideration: no lightfield
 - Integration into clinical routine to be discussed
- Segment by segment analysis:
 - Calculated signal not yet clinically applicable
 - Inclinator refinement necessary (WIP)
 - Averaged signal (eg. 10 measurements) more robust
- Cumulative analysis:
 - High sensitivity: leaf bank shift > 1mm detectable
systematic & random dosimetric errors detectable

Conclusion



- Can we improve on efficiency?
 - **yes**
- Can IQM catch errors before they become clinically relevant?
 - Systematic errors: **yes**
 - Random errors: clinically relevant?
- Can we resign pre-treatment QA?
 - **not yet**

Thank you!

Acknowledgements

Kilian Michel

Johanna Christ

Michael Obenland

Holger Wirtz

& STTHZ Team

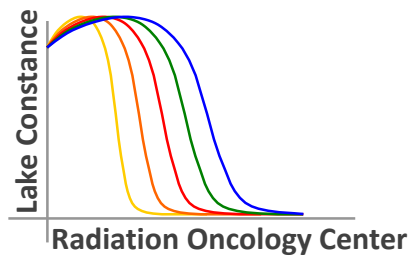
Juliane Botter

Andreas Wischek

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