



Memorial Sloan Kettering
Cancer Center

Automation in Patient-Specific and Machine QA

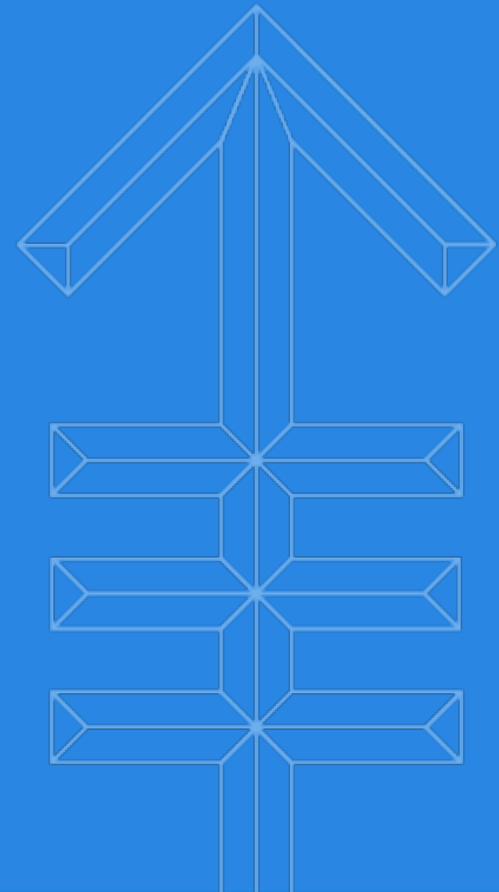
Are We Ready to Go?

Chengyu Shi, Ph.D.

Memorial Sloan Kettering Cancer Center

60th Annual Meeting of AAPM

Nashville, TN



Disclosure

I owe to my colleagues for their excellent works on this talk...

Binbin Wu

Sean Berry

Ping Wang

Albert Wang

Maria Chan

MP Computer Services

Treatment Planning

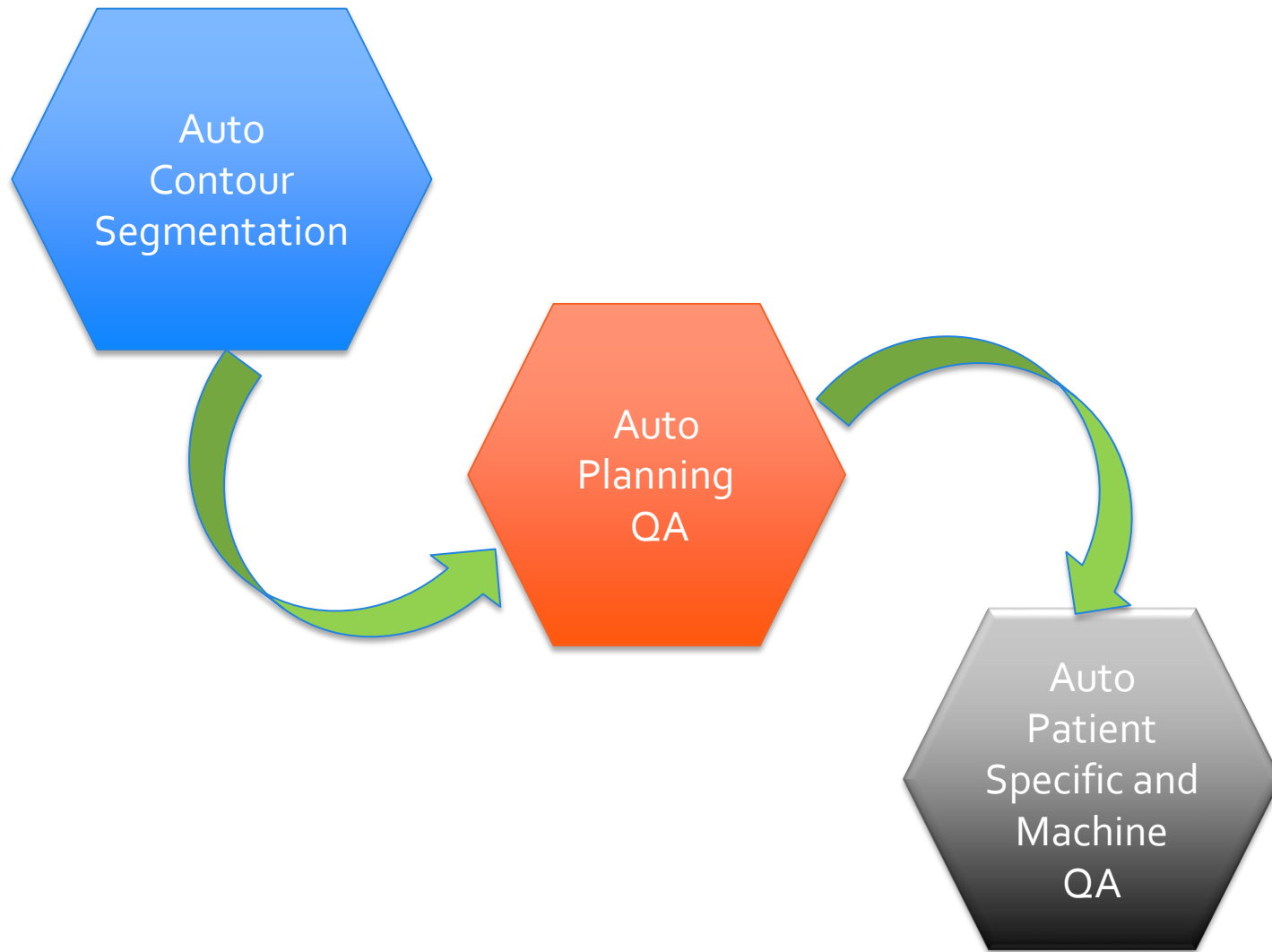
Dosimetry Groups

Margie Hunt

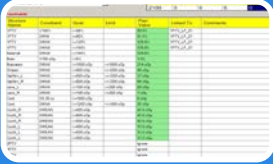
Joe Deasy



Automation in Radiotherapy



Agenda



Auto Plan Checking



Daily Email on QA Results



Machine Performance Check (MPC)



PSQA with Machine Learning



Auto Plan Checking [1]



EclipsePlanCheck

Version 13.3.4.0

Patient Id: [REDACTED]

Name: [REDACTED]

Course: [REDACTED]

Plan: [REDACTED]

User: [REDACTED]

About

Select Body Site

- Default
- Breast
- Tangents
- Prostate
- ECHO
- Paraspinal
- Ablative GI
- Calc
- Cranial Single or Hypo
- iPlan SRS

Stage 1 : Reported Items for Manual Review

Item	St.	Results	Notes
<input checked="" type="checkbox"/> Report Patient Orientation		Patient Orientation is "HeadFirstSupine"	
<input checked="" type="checkbox"/> Report DICOM offset		Image CT_HN_121817: DICOM Offset (cm) = (-3.22, 1.83, 38.64)	
<input checked="" type="checkbox"/> Report Study ID		Study ID: [REDACTED]	
<input checked="" type="checkbox"/> Report Plan UID		Plan UID: 1.2.246.352.71.5.181627416654.2956007. [REDACTED]	
<input checked="" type="checkbox"/> Report gating status		Gating is set to "OFF" for clinical plan "RT SCLAV"	

Stage 2 : Contours

Item	St.	Results	Notes
<input checked="" type="checkbox"/> Ensure adjacent structures overlap.		Automatic Checks passed	
<input checked="" type="checkbox"/> Check for empty structures and missing slices.		Automatic Checks passed	
<input checked="" type="checkbox"/> Check for overlap between body and couch		Automatic Checks passed	

Stage 3 : Naming Conventions and Demographics

Item	St.	Results	Notes
<input checked="" type="checkbox"/> Naming Convention: 3D Image, RTSS		Automatic Checks passed	
<input checked="" type="checkbox"/> Naming Convention: Clinical Course		Automatic Checks passed	
<input checked="" type="checkbox"/> Verify non-clinical courses are completed		Automatic Checks passed	
<input checked="" type="checkbox"/> Check for invalid characters		Automatic Checks passed	

Stage 4 : Beams, optimization, and calculation

Item	St.	Results	Notes
<input checked="" type="checkbox"/> Report CT Overrides			
<input checked="" type="checkbox"/> Ensure Bolus HU=0		Automatic Checks passed	
<input checked="" type="checkbox"/> Appropriately used support structure		Automatic Checks passed	
<input checked="" type="checkbox"/> Report Isocenter (x,y,z)		Isocenter 1 (0.000, 0.000, 0.000) Automatic Checks passed	
<input checked="" type="checkbox"/> Report isocenter shift from user origin		No moves from user origin. SSD at gantry zero: 94.914	
<input checked="" type="checkbox"/> 180E Used When Appropriate		Automatic Checks passed	
<input checked="" type="checkbox"/> Couch collisions in small room		Automatic Checks passed	
<input checked="" type="checkbox"/> FFF beams used when appropriate.		Automatic Checks passed	
<input checked="" type="checkbox"/> Plan naming and normalization		Automatic Checks passed	
<input checked="" type="checkbox"/> Reasonable Fluence Checker		Automatic Checks passed	

Run Checks

Save Notes

Preview Report

Upload to Aria

Auto Plan Checking [2]

Template Names

Brain SRS 1Fx

Target Prescription [cGy]

1PTV	2PTV	3PTV	4PTV	5PTV
2100	0	0	0	0

Constraints

Structure Name	Constraint	Goal	Limit	Plan Value	Linked To	Comments
1PTV	V100%	>=98%		99.0%	1PTV_LP_21	
1PTV	DMIN	>=90%		91.5%	1PTV_LP_21	
1PTV	DMAX	>=125%		129.8%	1PTV_LP_21	
1PTV	DMAX	<=140%		129.8%	1PTV_LP_21	
External	DMAX	<=140%		129.8%		
Brain	V700 cGy	<=5%		1.0%		
Brainstem	DMAX	<=1500 cGy	<=1800 cGy	214 cGy		
Chiasm	DMAX	<=800 cGy	<=1200 cGy	98 cGy		
OptNrv_L	DMAX	<=800 cGy	<=1200 cGy	37 cGy		
OptNrv_R	DMAX	<=800 cGy	<=1200 cGy	69 cGy		
Lens_L	DMAX	<=100 cGy	<=200 cGy	29 cGy		
Lens_R	DMAX	<=100 cGy	<=200 cGy	7 cGy		
Cord	D0.35 cc	<=1000 cGy		6 cGy		
Cord	DMAX	<=1200 cGy	<=1400 cGy	25 cGy		
Cochl_R	DMEAN	<=400 cGy		42.6 cGy		
Cochl_R	DMEAN	<=600 cGy		42.6 cGy		
Cochl_R	DMEAN	<=800 cGy		42.6 cGy		
Cochl_L	DMEAN	<=400 cGy		13.0 cGy		
Cochl_L	DMEAN	<=600 cGy		13.0 cGy		
Cochl_L	DMEAN	<=800 cGy		13.0 cGy		
2PTV				Ignore		
3PTV				Ignore		
4PTV				Ignore		
5PTV				Ignore		

Auto Plan Checking [3]

Plan:

Exported Time:

Plan time:

Patient plan:

User input for report only

Treatment Course:

Rx (cGy): Prescribed to level:

Dose calculation model in phantom:

Beam Name	MU	Check Point	Eclipse Dose (cGy)	Check Dose (cGy)	Dose Difference (%)	Dose Gradient (cGy/mm)	Gamma Pass Rate (%)	Mean field dose (cGy)	MLC penumbra	Machine/ Energy
01	725	Verification	416.8	412.5	1.0	1.3	100.0	238.38	HET_6x-10-2...	MON_TB2 - 6X
03	851	Verification	448.9	445.6	0.7	2.2	100.0	246.72	HET_6x-10-2...	MON_TB2 - 6X
04	728	Verification	446.8	441.0	1.3	1.6	97.7	255.27	HET_6x-10-2...	MON_TB2 - 6X
02	804	Verification	568.0	559.5	1.5	3.1	97.2	322.44	HET_6x-10-2...	MON_TB2 - 6X
05	760	Verification	415.4	412.3	0.7	2.0	100.0	232.21	HET_6x-10-2...	MON_TB2 - 6X

GI Calculation for Cranial SRS/SBRT V3.0

PTV	Vol. cc	pGI	GI	CI
1PTV_LP_21:	1.63	4.5	3.1	1.21

OK

Average gamma pass rate (%)

Gamma analysis parameters

Distance to agreement (mm):

Search radius (mm):

Dose difference(3% of field average): Set dose difference floor (cGy)

Gamma cutoff for passing test:

Couch Model:

Notes

*Dose difference is shown in red if it is outside the tolerance of 3%.

**All independent dose is calculated with 1mm transmission resolution

Auto Plan Checking [4]

Plan Integrity Check V11.1

Patient Filters:

Campus Machine MRN

MRN	Name	Course: Plan	Machine	Appt Time

Eclipse

ID	Name	Status
08		PASS
09		PASS
10		PASS
11		PASS
APK...	APKV_BONE	Setup
RLK...	RLKV_BONE	Setup
CBCT	CBCT	Setup
LLK...	LLKV_BONE	Setup
PAK...	PAKV_BONE	Setup

RTPlan

ID	InEclipse
08	Y
09	Y
10	Y
11	Y

IMU Status: PASS

NumberOfControlPointsCheck:
PASS: All fields have >2 CPs.

Patient plan found in ARIA.
PatientPlanName: RT SCLAV

Sum-of-field-MUs check:
Not applicable: all fields have > 2CPs.

RTPlan is loaded successfully.

Plan Check Status: PASS

08: PASS
09: PASS
10: PASS
11: PASS

Plan is ready to go?

Check Plan

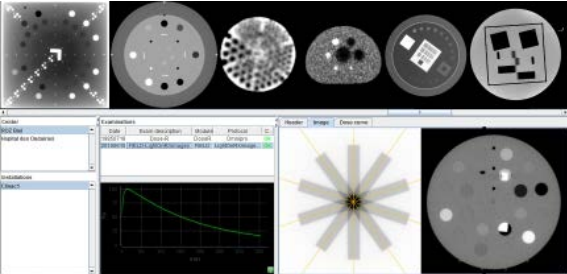
Save Log

Traditional and Forthcoming IMRT/VMAT QA

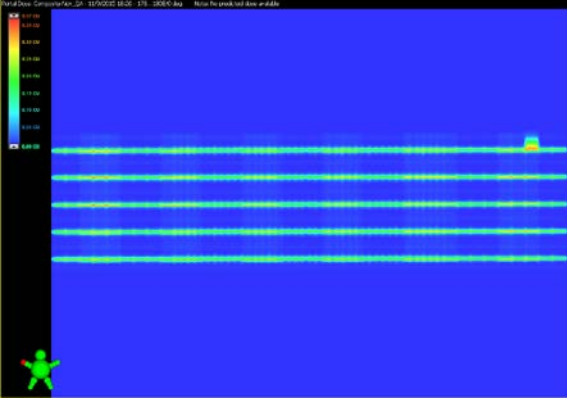
- Point measurement, MU check, Fluence measurement
- Clinical-relevant IMRT QA
 - ✓ *3DVHTM/CompassTM*
- Phantom-less IMRT QA
 - ✓ *DynaLog files/R&V output*
- Software-based IMRT QA
 - ✓ *Separate QA_Sys & QC_Pt*
- In-vivo Portal Dosimetry
 - ✓ *PerFRACTIONTM/AdaptivoTM*
- Virtual IMRT QA
 - ✓ *Machine-learning*



MSK comprehensive QA program encompasses the extensive system QA, complete patient QC (pre/post-tx), and intra-tx IGRT



Extensive Linac QA

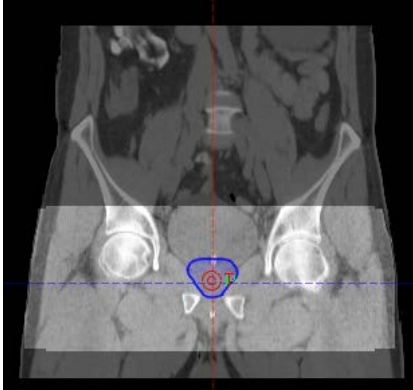


PD of Picket-Fence

QA System

Beam id	01	02	03	04	05	06
Jaw	X1(cm)	4.5	7.8	4.5	7.8	8.3
	X2(cm)	7.8	4.5	7.3	4.5	4.3
	Y1(cm)	8.5	4.8	5.5	8.0	8.8
	Y2(cm)	3.5	6.8	6.3	4.5	3.8
Isocenter(cm)	0.00 10.0	0.00 10.0	0.30 10.0	0.00 10.0	0.00 10.0	0.00 10.0
MU	113	158	145	175	109	115
Penumbra	Minimum_x	Minimum_x	Minimum_x	Minimum_x	Minimum_x	Minimum_x
Check point	Patient name	Diagnose_ID	Diagnose_ID	Diagnose_ID	Diagnose_ID	Diagnose_ID
	Diagnose coordinates (cm)	2.0, 0.1, -2.0	0.1, 0.0, 1.0	0.0, 0.1, -1.0	-1.0, 0.1, -1.0	0.0, 0.1, -1.0
	BEV x, y (cm)	2.0, -2.0	-2.0, 0.0	0.0, 1.0	0.0, -1.0	-1.0, -1.0
	Eclipse dose (cGy)	35.7	31.8	40.3	41.3	32.9
	Check dose (cGy)	35.6	31.6	40.1	41.0	32.8
	Check dose difference (%)	0.2	0.5	0.4	0.5	0.3
	Closest match (%)	0.00	0.42	0.28	0.54	0.32
	Check lip	1.006	1.005	1.005	1.007	1.007
	Check Sc	1.011	1.011	1.010	1.012	1.012
Plane dose	Gamma calculation depth (cm)	5.0	5.0	5.0	5.0	5.0
	Plane calculation resolution (cm)	0.13	0.13	0.13	0.13	0.13
	Average dose inside CIAO (cGy)	29.04	34.14	38.73	38.52	28.66
	Gamma pass rate(%)	99.97	99.83	99.64	100.00	99.72
MLC leaf stats	Mean gap all pairs (mm)	22.7	20.7	22.6	19.8	23.3
	Leaf pair number for smallest mean	14	27	42	15	14
	Smallest mean gap (mm)	5.6	9.0	0.5	7.7	8.5
Machine/Energy	60V-210kV-65	60V-210kV-65	60V-210kV-65	60V-210kV-65	60V-210kV-65	60V-210kV-65
gantry angle	0	0	0	0	0	0
Collimator angle	0	0	0	0	0	0

The average gamma pass rate is 99.82



Leaf B45, suggest to watch.

=====
 Campus: Regionals
 Room Name: BSK2100IX2
 Patient Name: [REDACTED]
 MRN: [REDACTED]
 Plan Name: HN_7F
 Plan UID: 1.2.246.352.71.5.181627416654.1110940.20140926101624
 BeamNumber in log file: 5
 BeamName in ARIA: RAO, BeamName in Log: 5
 BeamDescription: RAO
 Dynalog A carriage file Date/Time: 11/7/2014 1:24:14 PM
 Dynalog B carriage file Date/Time: 11/7/2014 1:24:14 PM
 CRC check is OK
 Carriage/Leaf #: B/45 -> Percent difference for this leaf(%): 26.7
 Carriage/Leaf #: B/45 -> Avg Diff for this leaf(mm): .99

Campus: Regionals
 Room Name: BSK2100IX2
 Patient Name: [REDACTED]
 MRN: [REDACTED]
 Plan Name: HN_7F
 Plan UID: 1.2.246.352.71.5.181627416654.1110940.20140926101624
 BeamNumber in log file: 6
 BeamName in ARIA: RPO2, BeamName in Log: 6
 BeamDescription: RPO2
 Dynalog A carriage file Date/Time: 11/7/2014 1:24:57 PM
 Dynalog B carriage file Date/Time: 11/7/2014 1:24:57 PM
 CRC check is OK
 Carriage/Leaf #: B/45 -> Percent difference for this leaf(%): 21.2
 Carriage/Leaf #: B/45 -> Avg Diff for this leaf(mm): .88

Pre/post/intra tx QC

QC Patient



Memorial Sloan Kettering
Cancer Center

Daily Treatment Delivery Automation



Thu 1/4/2018 1:07 AM

wanga

No problem: Regionals, TrajectoryLog, version:11.4.0.0

To  zzPDL_MPH_MPCSRadQaReg;

No DMLC fields or jaw positions or planned MU or delivered MU are out of tolerance.
No daily dose delivered are out of tolerance.



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Daily Log (Dynalog/Trajectory) Automation Analysis

Leaf motion
0.5mm (TB)
and 2mm (C-
series)

MLC
Tolerances



Planned vs.
Delivered
<5%

MU
Tolerances



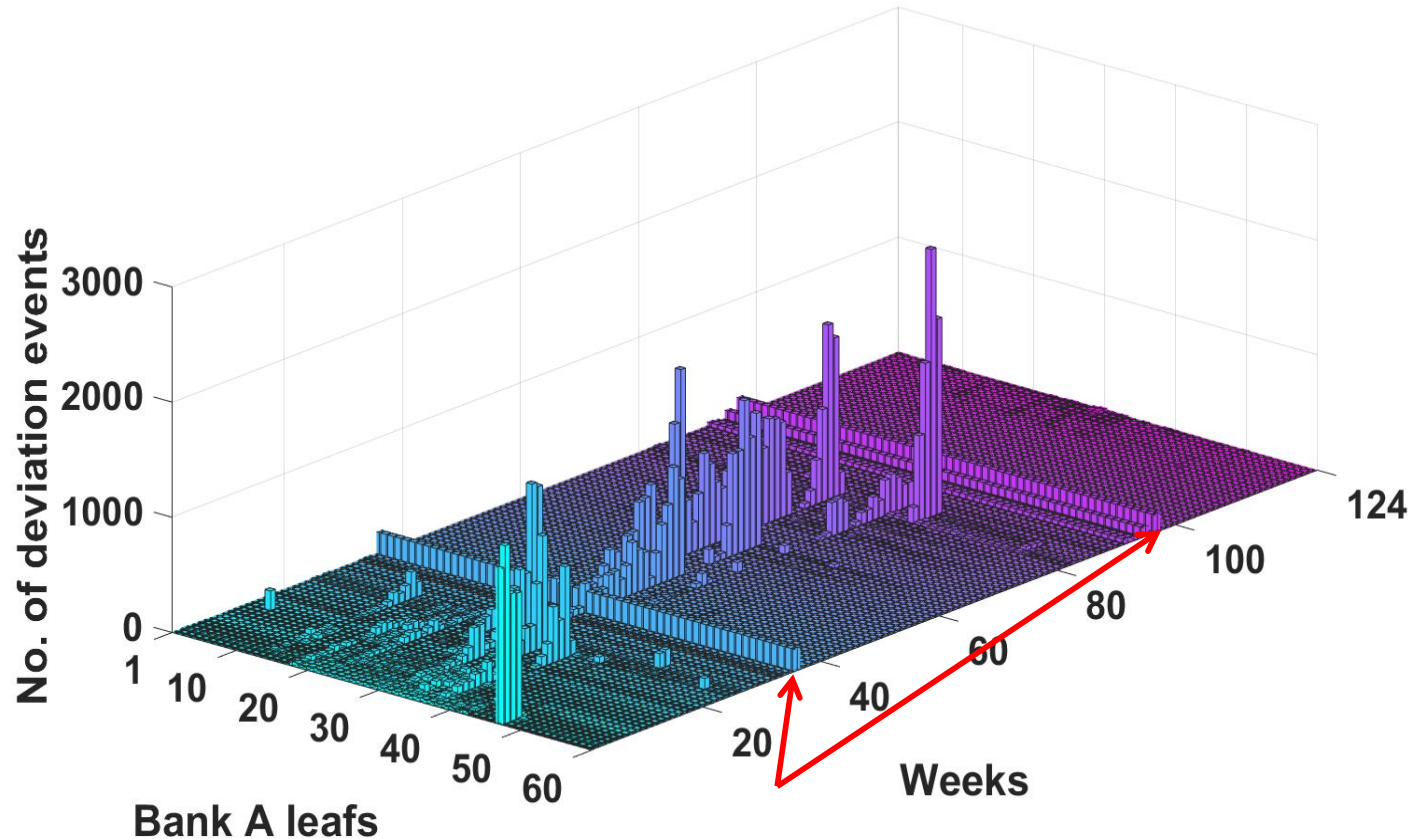
1 degree

Gantry/Coll
Tolerances



Bank A: Deviation Event (>0.1 mm) Map

01/02/2015 to 05/02/2017:124 weeks with 28313 trajectory logs.



Systematic deviations for all Bank A leaves.

After 09/09/2015, the systematic deviations were gone.

No events in service report correspond to 9/9/2015 issue.

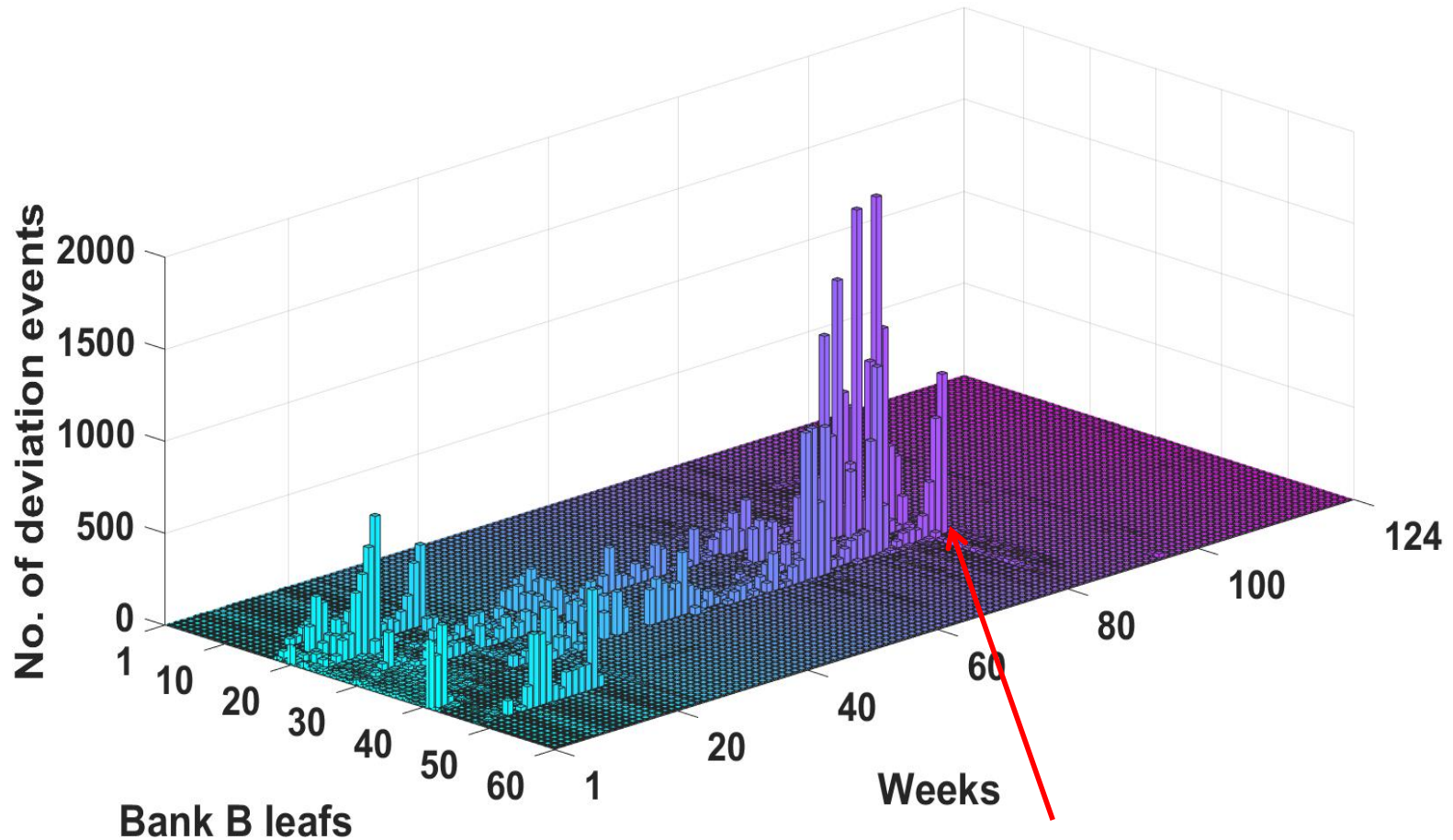
After 11/12/2016, the systematic deviations were gone.

On Saturday 11/12/2016, Varian rebuild Bank A MLC.



Bank B: Deviation Event (>0.1 mm) Map

01/02/2015 to 05/02/2017: 124 weeks with 28313 trajectory logs.



Few deviation errors happened after Monday, 8/29/2016.

Varian did MLC PMI on Saturday, 8/27/2016

Varian rebuild Bank B MLC on 9/17/2016 and 9/26/2016.



Daily Treatment Delivery Automation QA



Thu 1/4/2018 4:23 AM

wangp

Nightly Check of Eclipse: NO PROBLEM

To

*****BRIEF*****

Production: NO PROBLEM

Development: NO PROBLEM

Training: NO PROBLEM

Test: NO PROBLEM

IndependentMU: NO PROBLEM

[Click For Full Report](#)



Memorial Sloan Kettering
Cancer Center

Daily Treatment Delivery Automation QA

Subject: Nightly Check of Eclipse: WARNING

Importance: High

*****BRIEF*****

Production: NO PROBLEM

Development: NO PROBLEM

Training: NO PROBLEM

Test: NO PROBLEM

IndependentMU: WARNING

=[IndependentMU]=[IndependentMU]=[IndependentMU]=ENDRY=[IndependentMU]=[IndependentMU]=[IndependentMU]=

=====LOG ENTRY: [INDEPENDENTMU],[IndependentMU]=====

LOG ENTRY: [IndependentMU], [BeamData], [1/11/2018 3:02:44 AM]

347 Files are tracked totally

1 Files status are modified

.....	Status	Modified Time	<u>File Path</u>	Modified By
.....	Modified	12/13/2017 2:31:07 PM	<u>\\pensmph6\treatplanapp\NewRTP\BeamDataTables\CTtoElectronDensity.xml</u>	MSKCC\Yang

LOG END: [IndependentMU], [BeamData], [1/11/2018 3:03:44 AM]

LOG ENTRY: [IndependentMU], [CTCalibrationCurves], [1/11/2018 3:06:15 AM]

5 Files are tracked totally

0 Files status are modified

LOG END: [IndependentMU], [CTCalibrationCurves], [1/11/2018 3:06:16 AM]

LOG ENTRY: [IndependentMU], [PrintAndDRRTemplates], [1/11/2018 3:09:46 AM]

5 Files are tracked totally

0 Files status are modified

LOG END: [IndependentMU], [PrintAndDRRTemplates], [1/11/2018 3:09:46 AM]

ARIA/Eclipse Database Analysis

Back up
calibration
files, bin files,
and important
database files
daily 24 hours

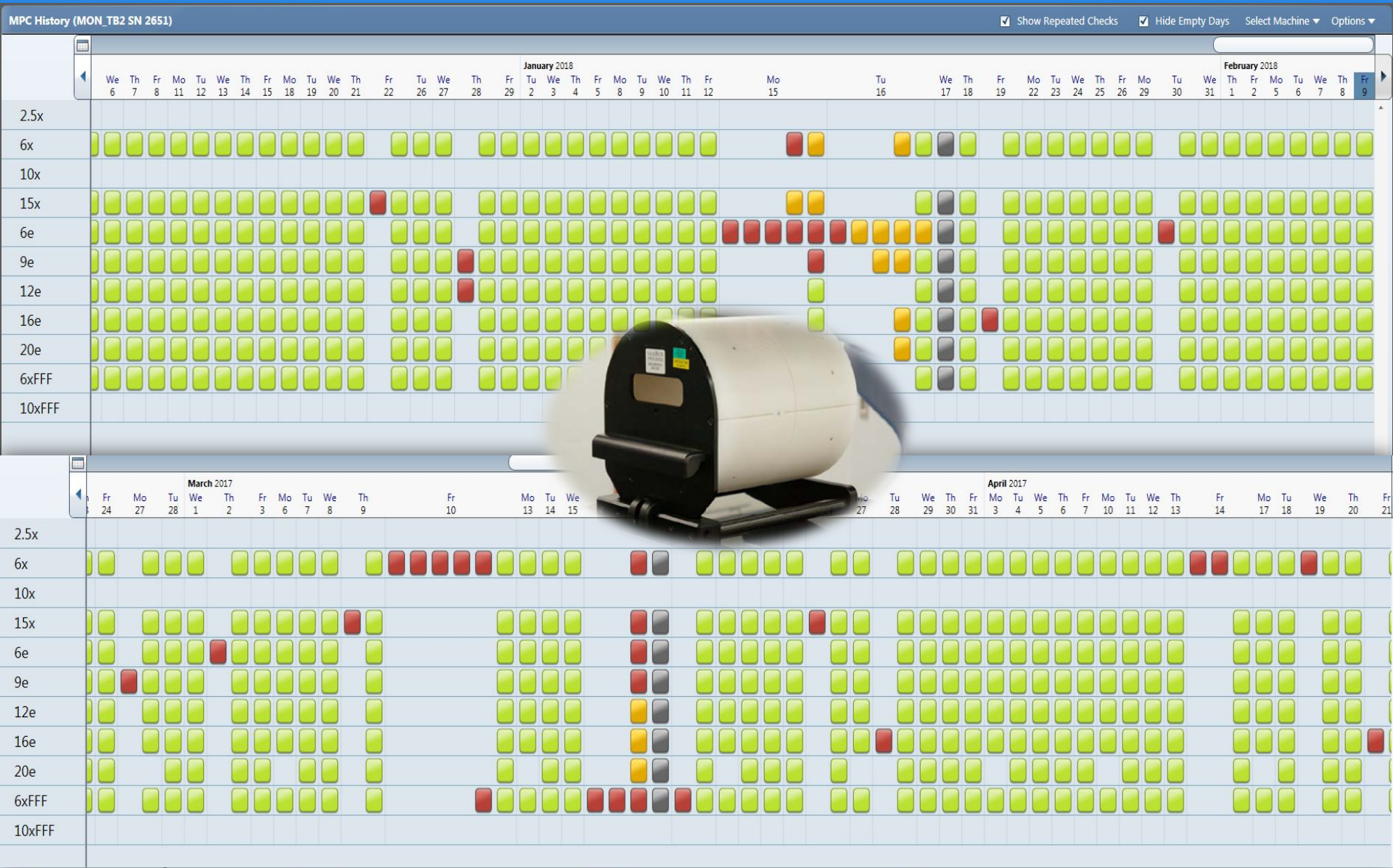
Compare the
previous data
backup vs.
current data
file using CRC
checking

Send out
warning
messages if
there are
differences

Check all
databases
every 30 hours



Machine Performance Check (MPC)

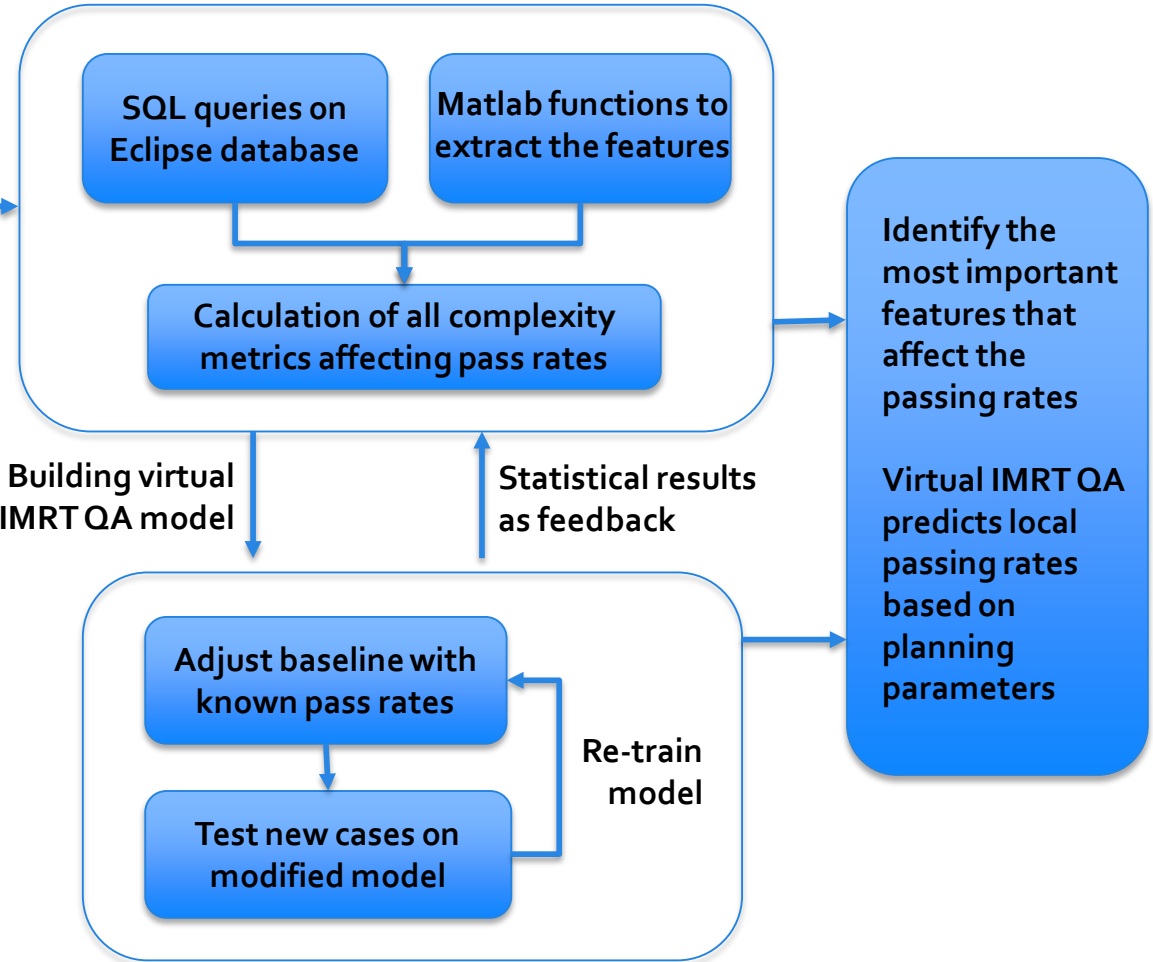


Legend:

- Within Thresholds
- Close within Thresholds
- Outside of Thresholds
- Baseline
- Notes attached

IMRT QA using Machine Learning [1]

Collected IMRT QA data:
MapCHECK2 (n=498)
Portal dosimetry (n=203)



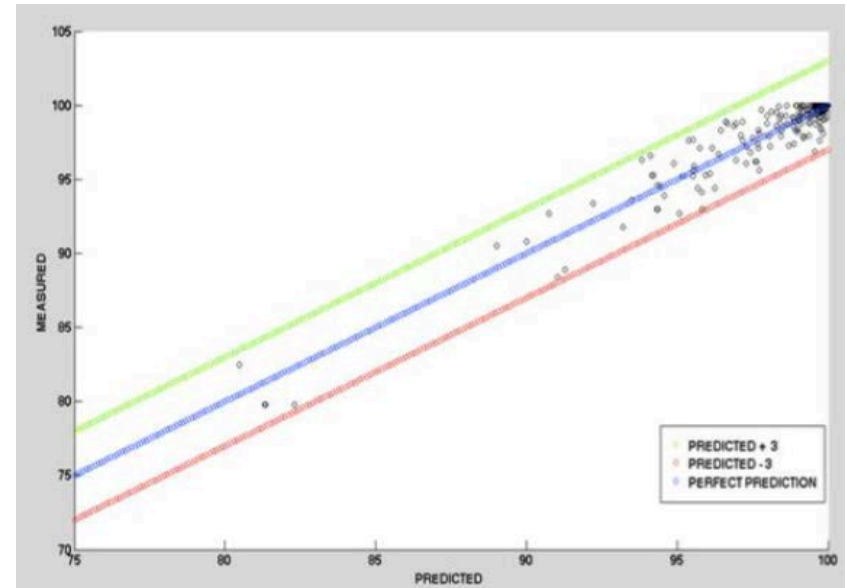
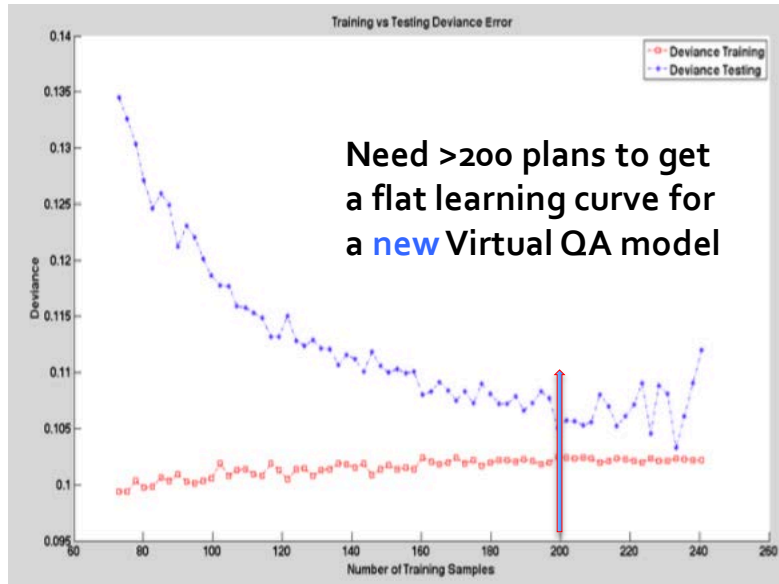
Failing Rate = 100 - passing rate = $e^{x\beta^T}$

-x is dimensional vector

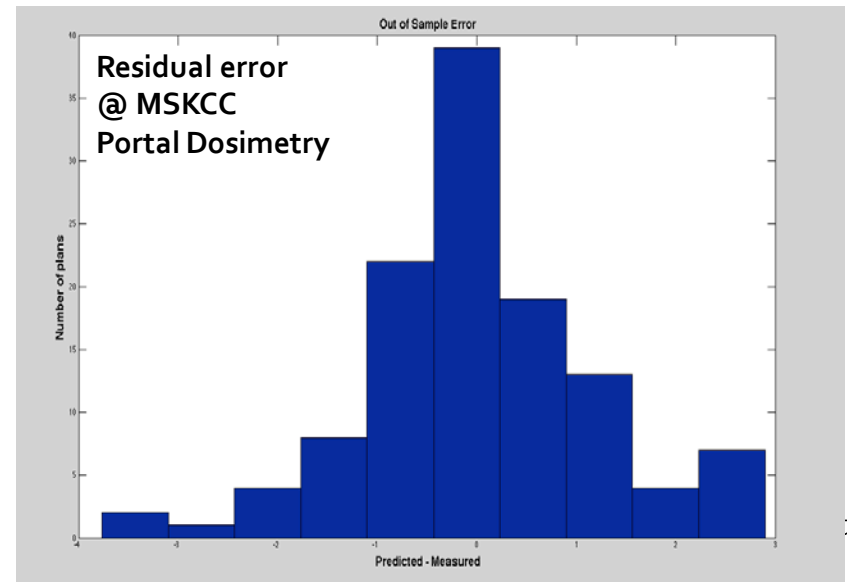
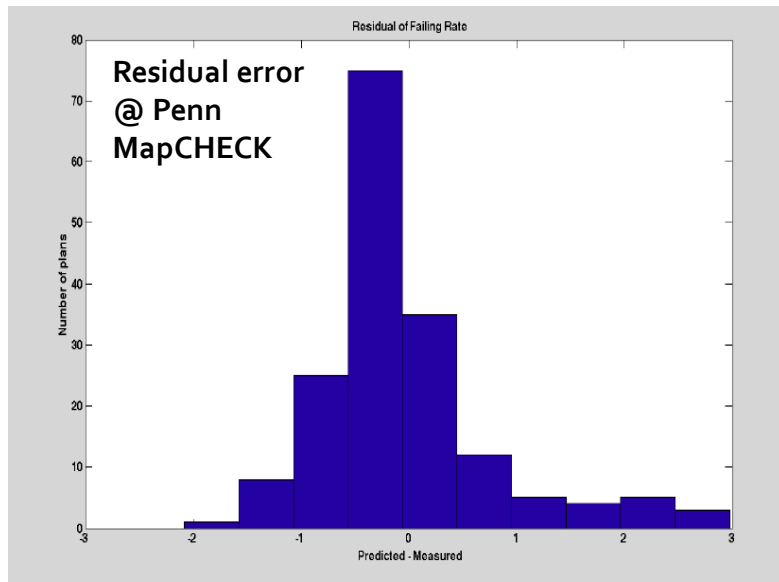
- β^T is the transpose of a constant vector with the same dimensions as x

- β is estimated as the constant vector maximizing the conditional probability of obtaining β giving our dataset of failing rates and complexity metrics

IMRT QA using Machine Learning [2]



Valdes G *et al.* Med Phys, 2016



Valdes G, Chan MF *et al.* JACMP, 2017

Summary

