Acceptance Testing and Routine QA on an Elekta VersaHD

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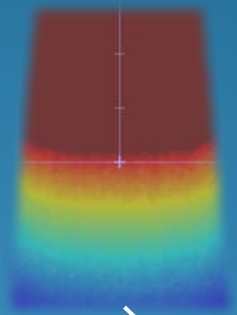
KETTERING HEALTH NETWORK℠

Acceptance Testing and Routine QA on an Elekta VersaHD

- No conflicts of interest to disclose

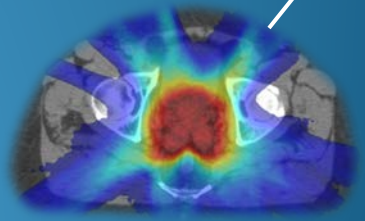
Installation/Acceptance Timeline

May, 2013
Installation begins



July, 2013
Beam modeling begins

June, 2013
Acceptance &
Commissioning begins



August, 2013
First patient treatment

Versa Overview

Versa Overview

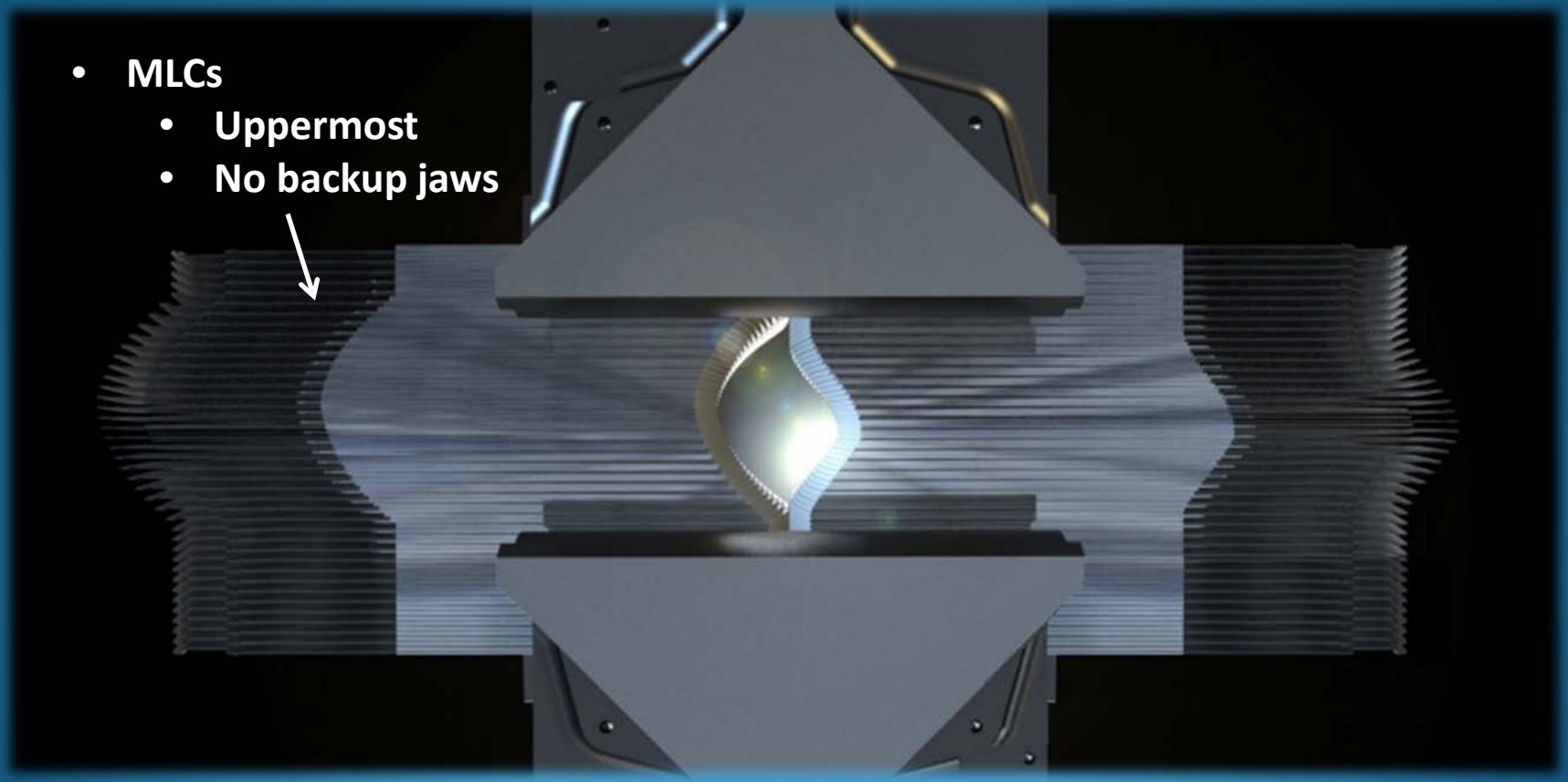
iViewGT™
MV imaging
(planar)

Versa Overview

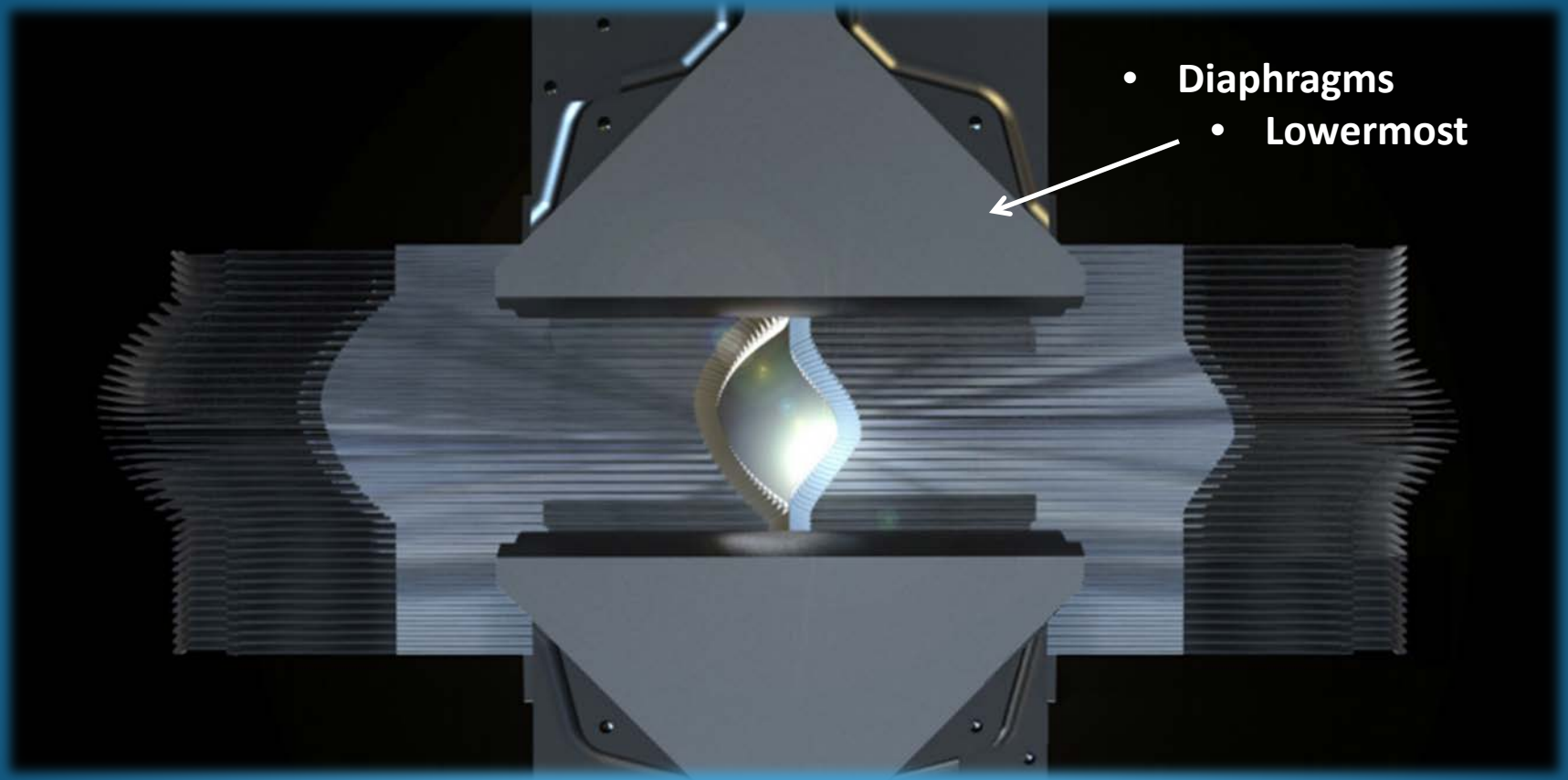
- **Treatment Modalities**
  - **6 MV**
  - **10 MV**
  - **15 MV**
  - **6 MV FFF**
  - **10 MV FFF**
  - **6 – 15 MeV**

Nominal energy	6MV	10MV
Maximum nominal dose rate (FFF)	1400	2200

Agility™ Head



Agility™ Head



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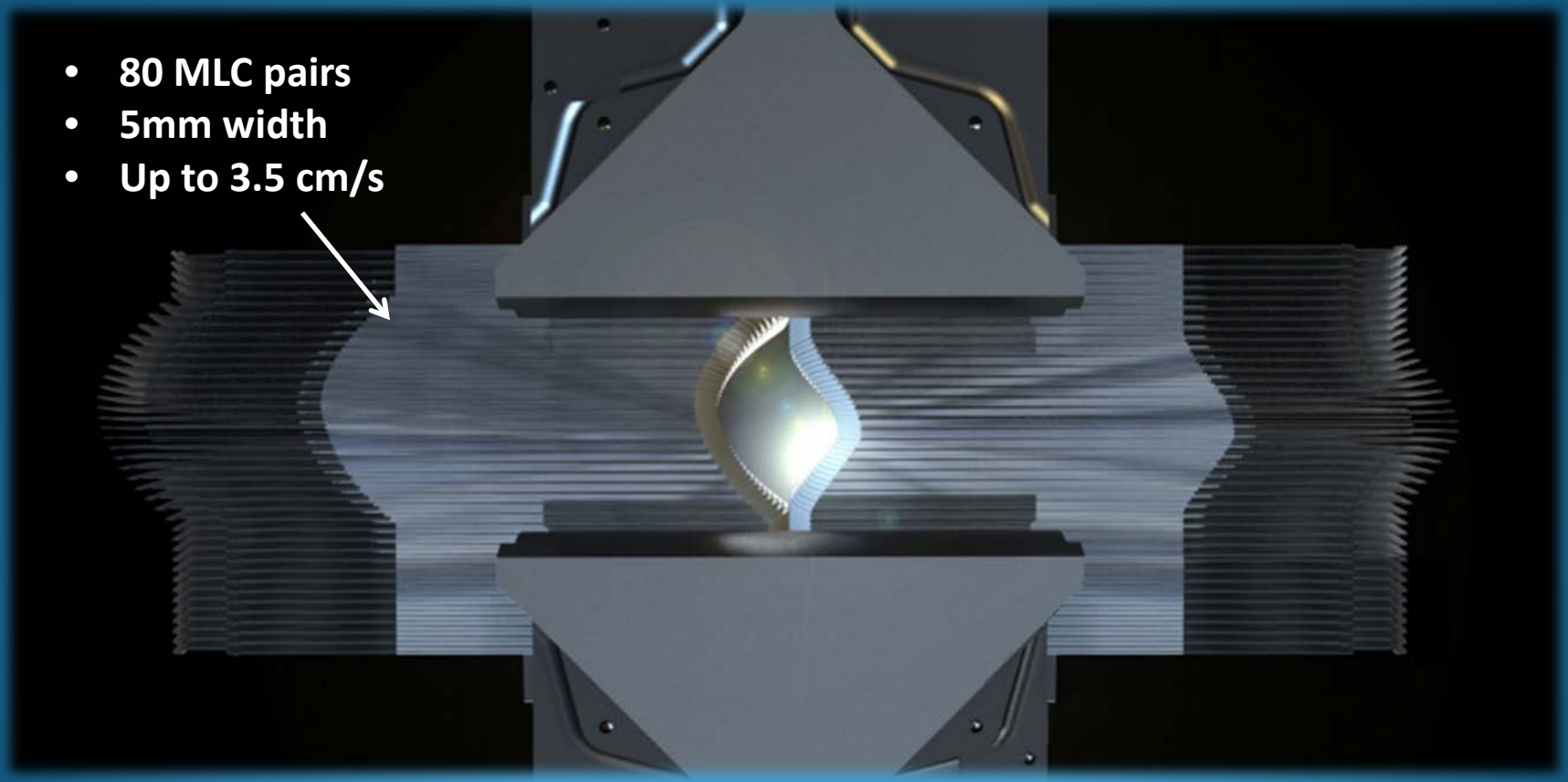
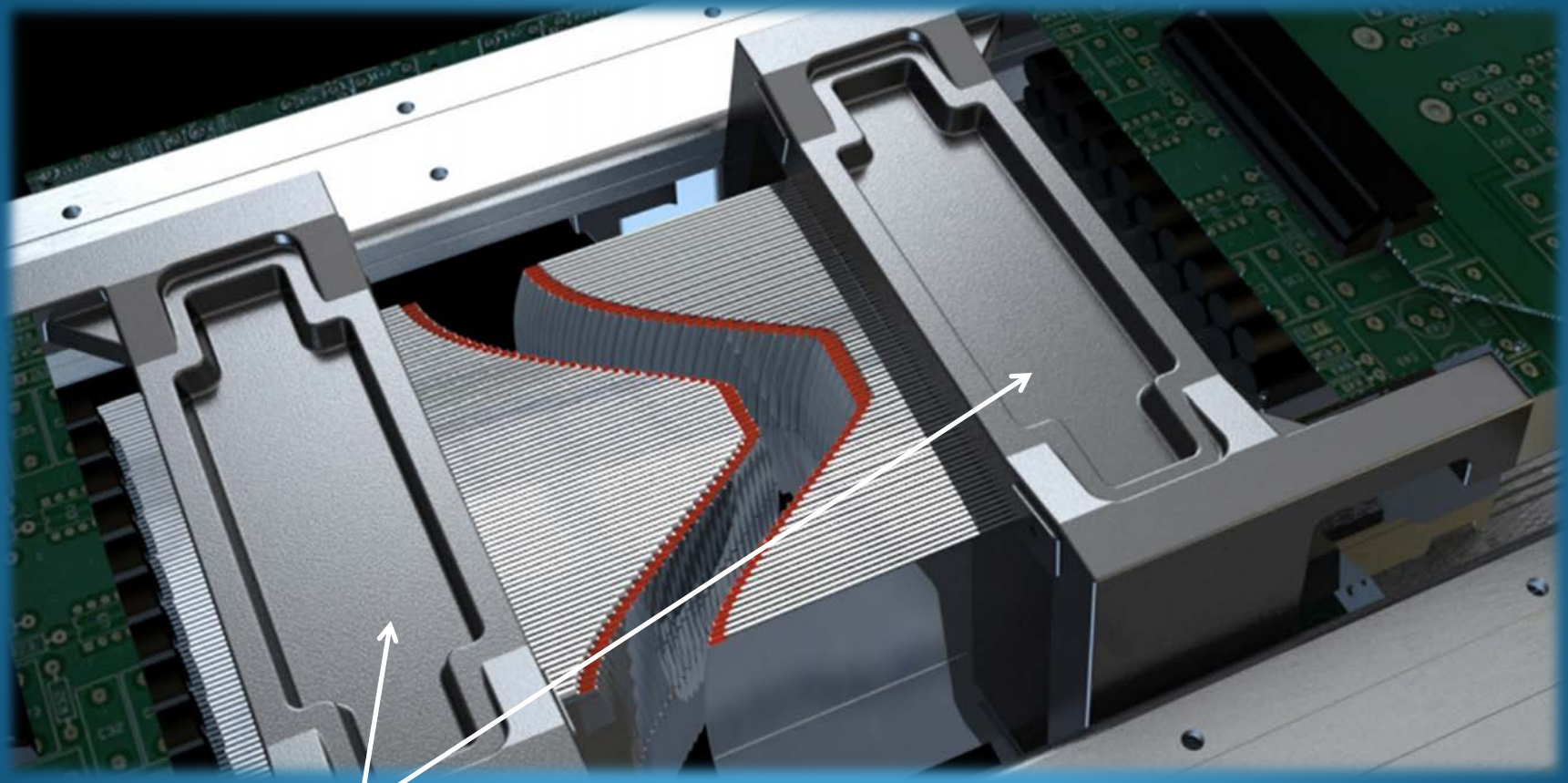


Agility™ Head



With Dynamic Leaf Guide and MLC, effective leaf speed is 6.5 cm/s

Acceptance Procedure

- The scope of acceptance, commissioning, and routine tests of a machine is vast
- Only a portion of tests will be covered in this presentation as commonplace tests will be excluded.

Acceptance Procedure

- Relative Dosimetry Checks
  - PDDs
  - Profiles (crossline, inline).

Acceptance Procedure

- Relative Dosimetry Checks
  - Measurement equipment

Sun Nuclear 3DS

Sun Nuclear
Edge Detector

PTW 0.125 cm^3
Semiflex Chambers

Acceptance Procedure

- Relative Dosimetry Checks
  - Measurement equipment

PTW 0.125 cm^3 Semiflex Chambers

- Ion chambers are dose rate dependent (as dose rate increases, ion collection efficiency decreases)
  - Dose per time
  - Dose per pulse
- PTW 0.125 cm^3 Semiflex has 99% collection efficiency if…
  - Dose per time ≤ 12 Gy/s
  - Dose per pulse ≤ 1 mGy
- Versa maximum FFF dose rate is…
  - 0.4 Gy/s
  - 1 mGy /pulse

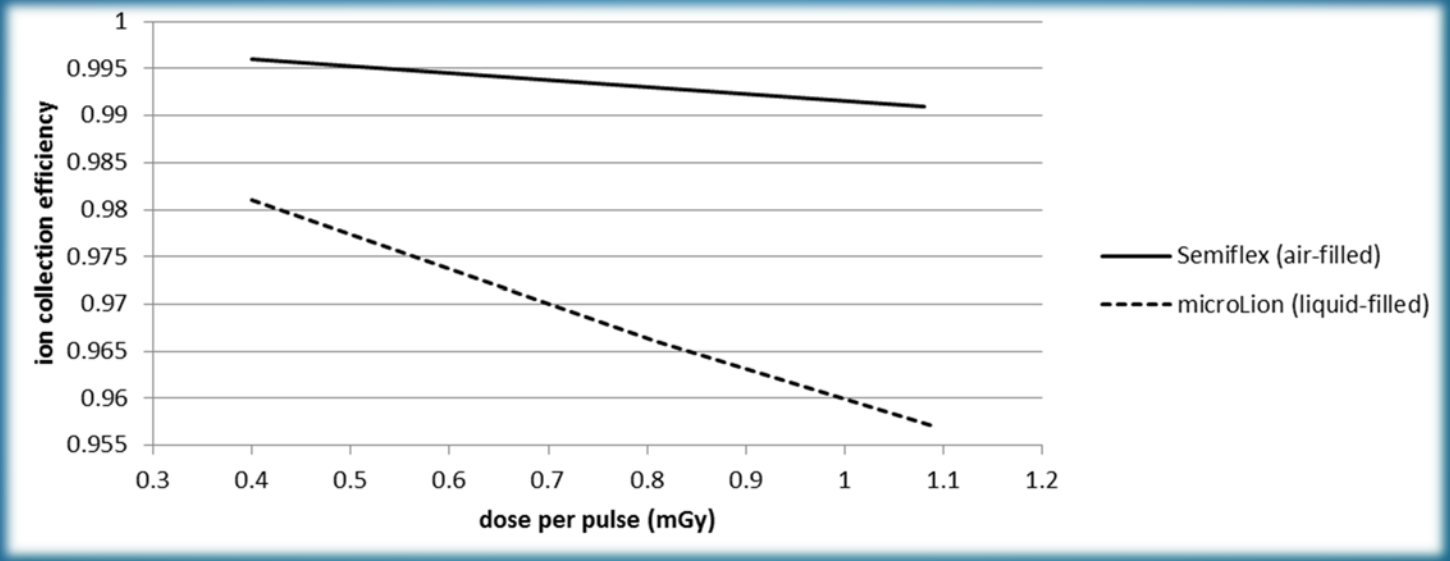
At reference conditions

Acceptance Procedure

- Relative Dosimetry Checks
  - Lang et al.[1] studied collection efficiency vs. dose per pulse in FFF beams
    - PTW Semiflex (air-filled)
    - PTW microLion (liquid-filled).

Acceptance Procedure

- Relative Dosimetry Checks
  - Lang et al.[1] studied collection efficiency vs. dose per pulse in FFF beams



Acceptance Procedure

- Relative Dosimetry Checks
  - Lang et al.[1] conclusions
    - Don't use liquid-filled ion chambers for FFF relative dosimetry
    - Air-filled ion chambers are suitable for FFF relative dosimetry
    - Be aware of your detector's collection efficiency as a function of dose per time and dose per pulse.

Acceptance Procedure

- Relative Dosimetry Checks
  - Electrometer limitations
    - Electrometers can become overloaded
    - Be aware of the amp limit specification
    - Diodes have a higher sensitivity than ion chambers, resulting in a higher current through the electrometer.

Acceptance Procedure

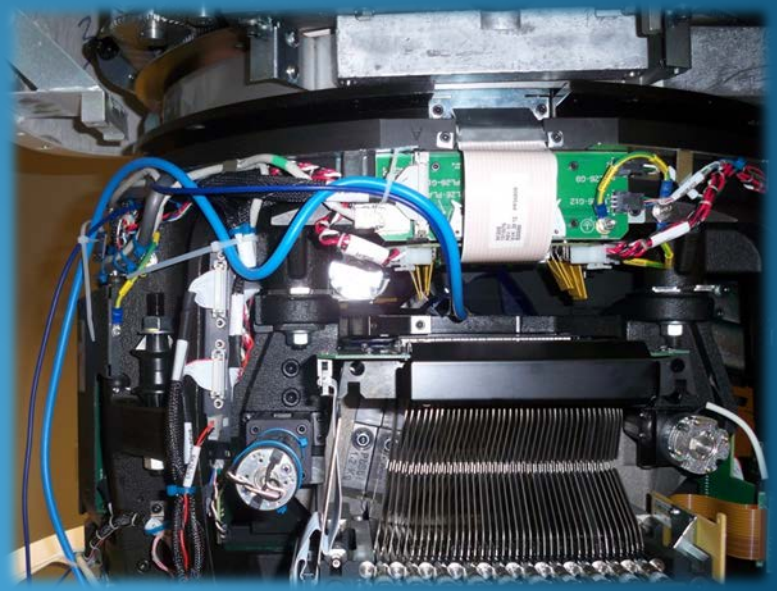
- Relative Dosimetry Checks
  - Measurement Equipment

Sun Nuclear
Edge Detector

- Used for small fields (≤ 5 x 5 cm^2)
- The same n-type diode die in the Edge Detector has been shown to have small instantaneous dose rate dependence[2]
- Energy dependence is insignificant for small field PDDs[3]
  - ± 1% agreement with RK chamber for 10 x 10 cm^2 PDD.

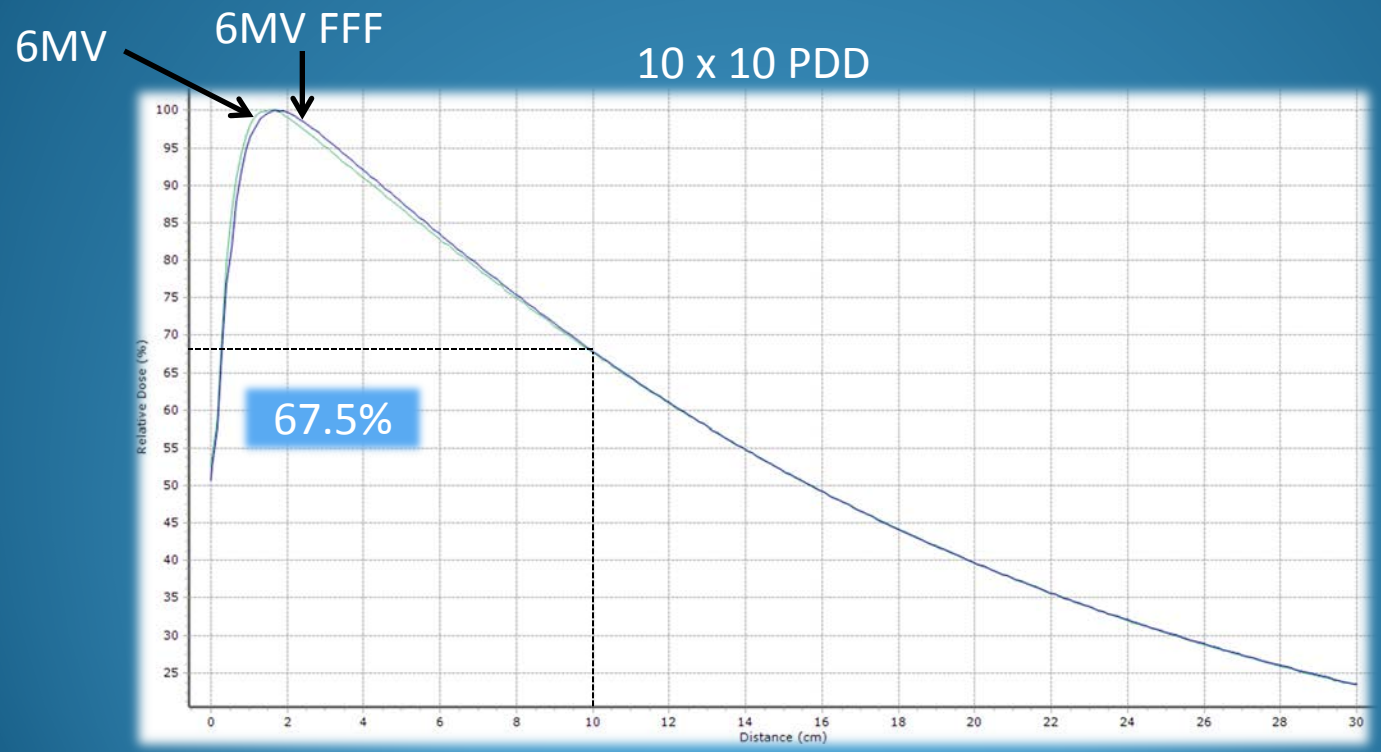
Acceptance Procedure

- Relative Dosimetry Checks
  - The reference detector can be placed inside of the head
  - Convenient because you never have to move the reference detector
  - Avoid perturbation in small fields
  - Remove head covers and 1 piece of lead.



Acceptance Procedure

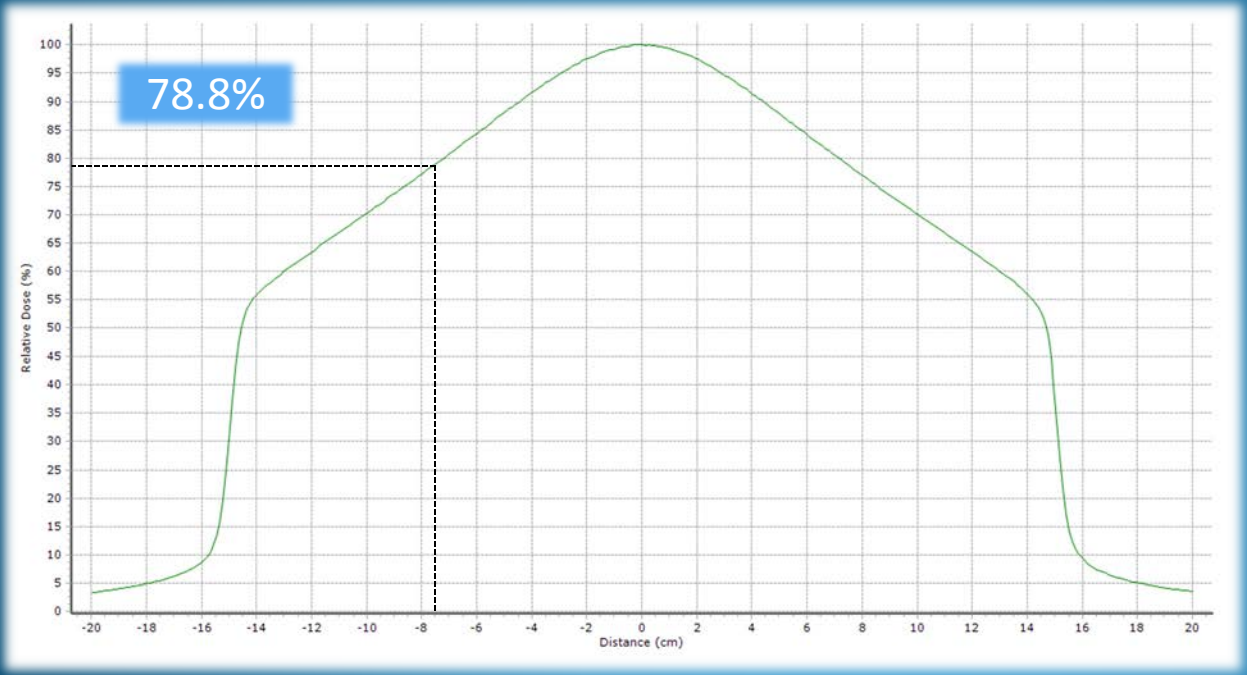
- Relative Dosimetry Checks
  - Specification for penetrative quality (PDD)



Acceptance Procedure

- Relative Dosimetry Checks
  - FFF Beam Specification Profile

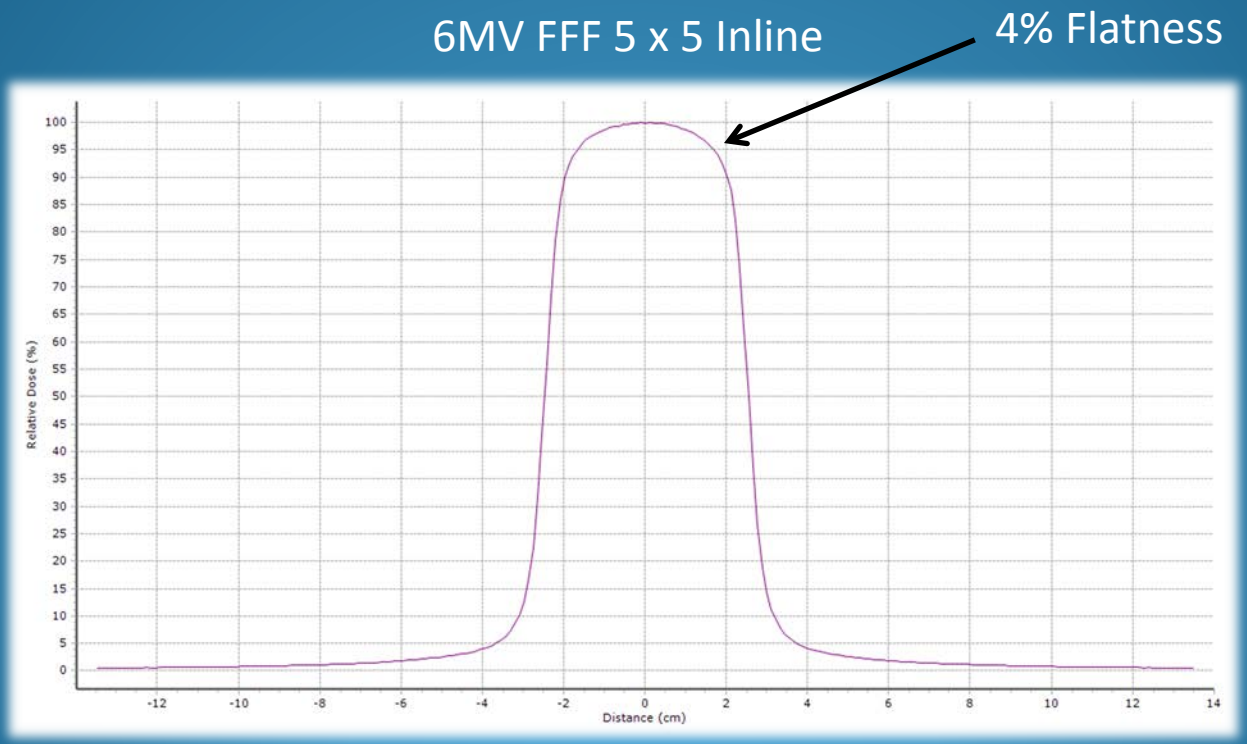
6MV FFF 30 x 30 Inline



SPECIFICATION	
Measurement point distance from CAX as a % of the half field width	Nominal relative dose
20%	94.6%
50%	78.2%
80%	62.6%

Acceptance Procedure

- Relative Dosimetry Checks
  - Small Field FFF Beam Profile

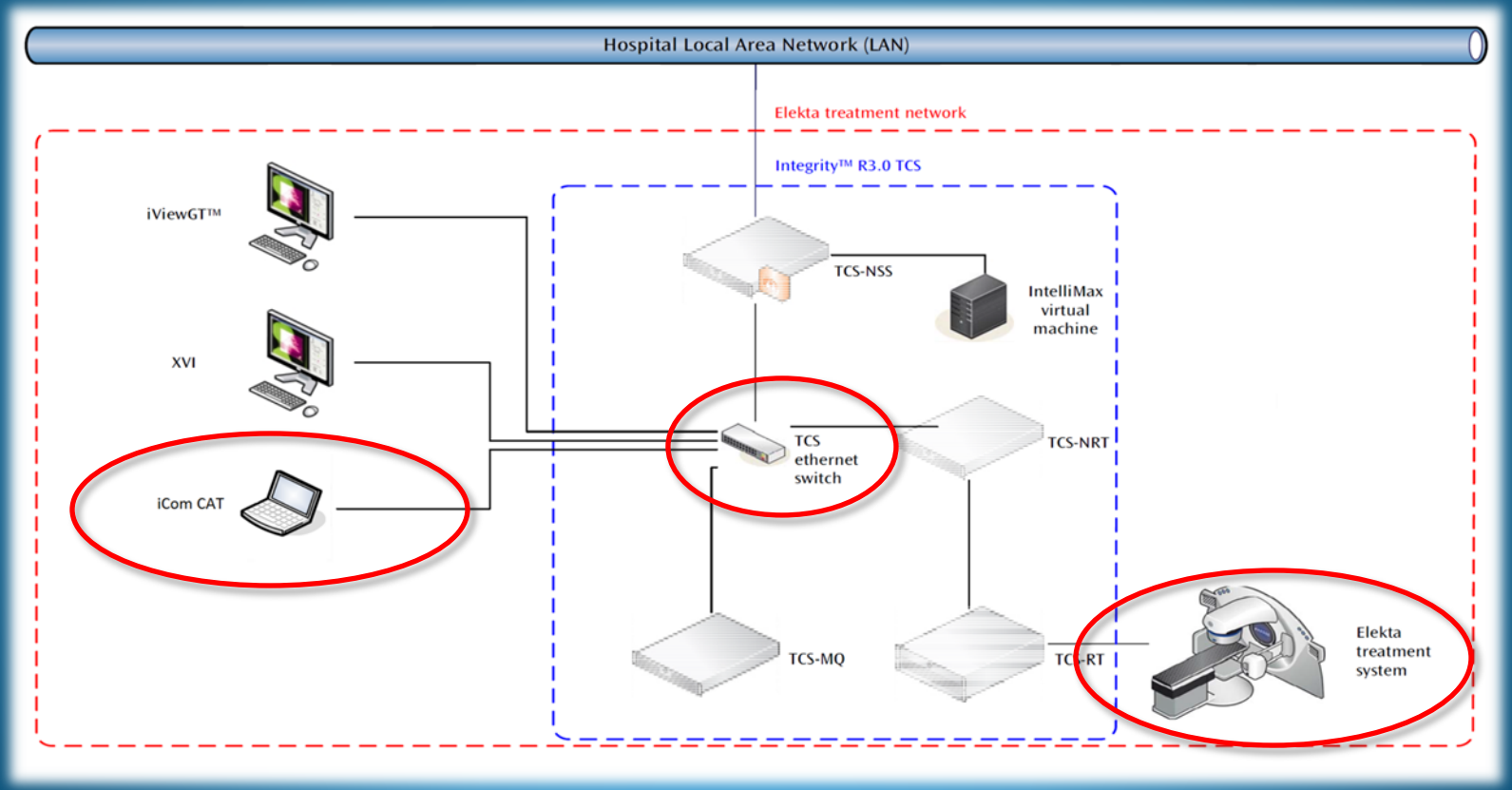


Acceptance Procedure

- iComCAT
  - Application that enables an external system to transmit a treatment prescription to the treatment control system (TCS)
  - Create and send fields with customized segments
  - Useful for creating QA test fields.
    - Picket fence
    - Leaf speed

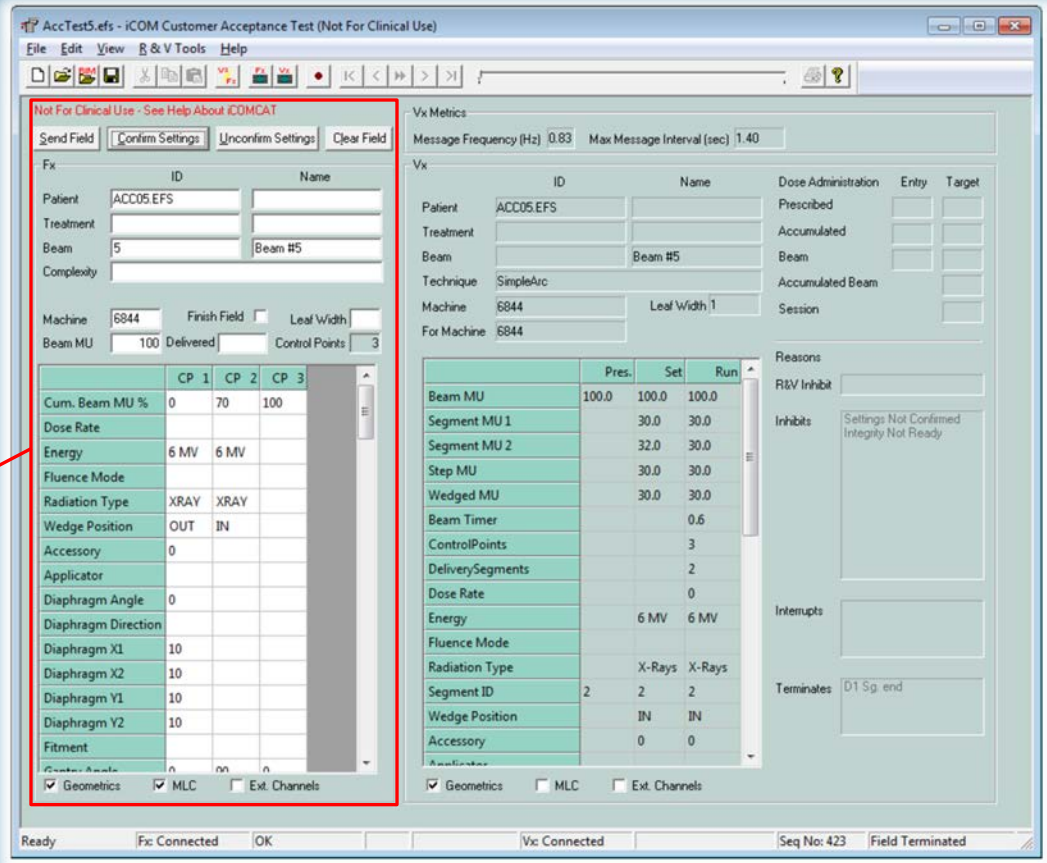
Acceptance Procedure

- iComCAT
  - Connects to the Elekta Treatment Network



Acceptance Procedure

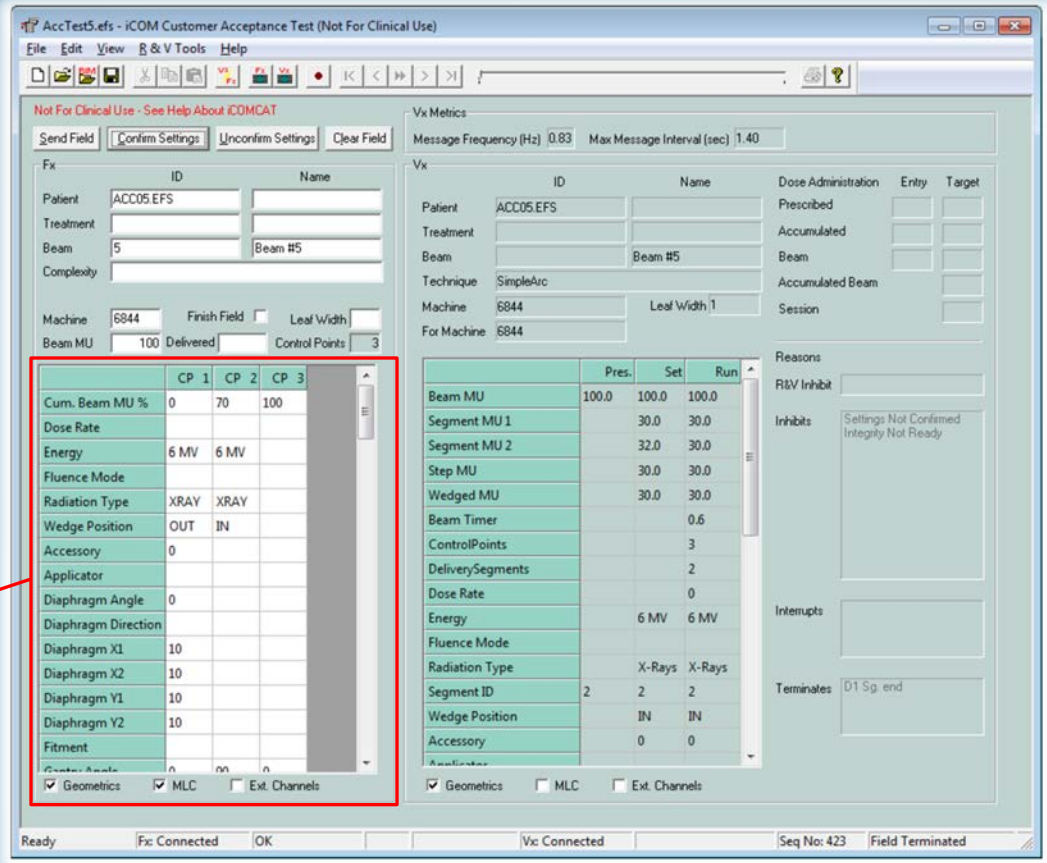
- iComCAT



Field and control point definitions (send to linac)

Acceptance Procedure

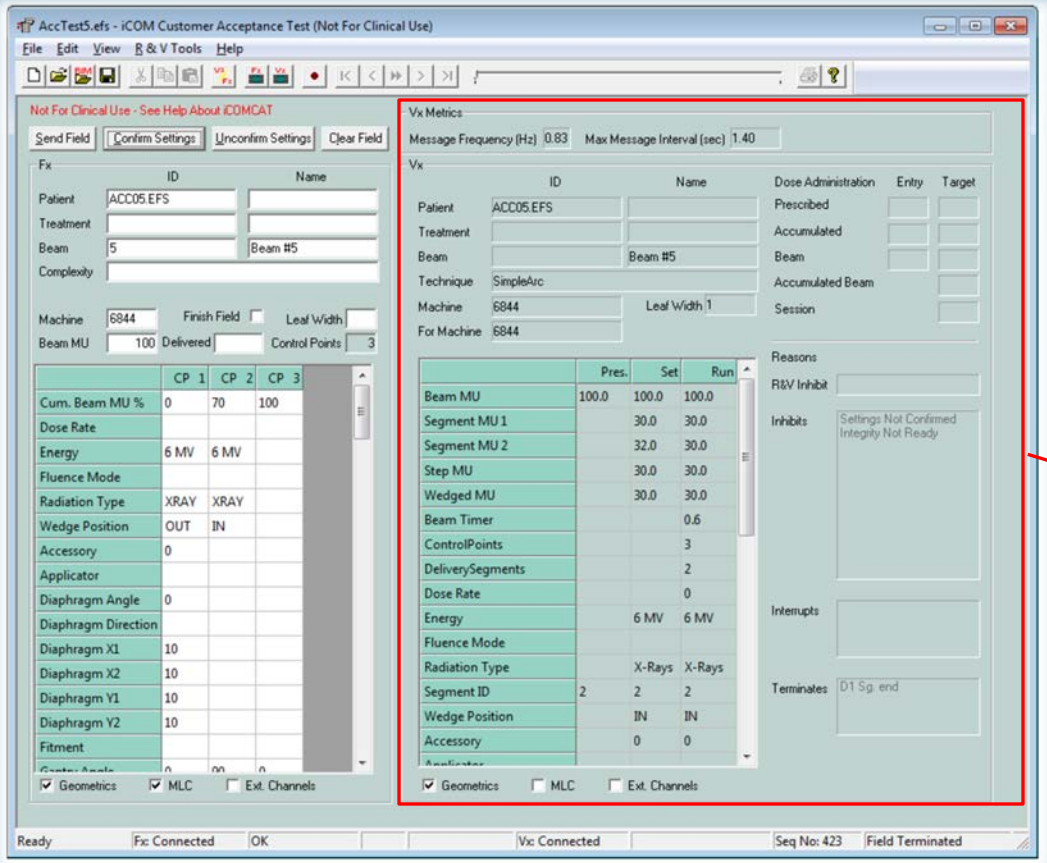
- iComCAT



Control point definitions

Acceptance Procedure

- iComCAT



Record and verify
(return from linac)

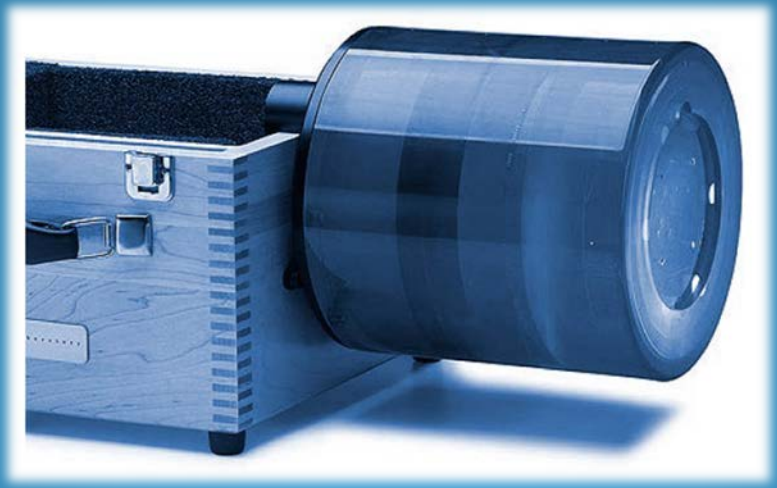
Acceptance Procedure

- 3D kV Imaging
  - Uniformity
  - Low contrast visibility
  - Spatial resolution
  - Transverse scale
  - Sagittal geometry

Acceptance Procedure

- 3D kV Imaging
  - CATPHAN 503 or 600 is required
  - Our institution uses CATPHAN 503, which has 3 modules
    - CTP404, CTP528, CTP486

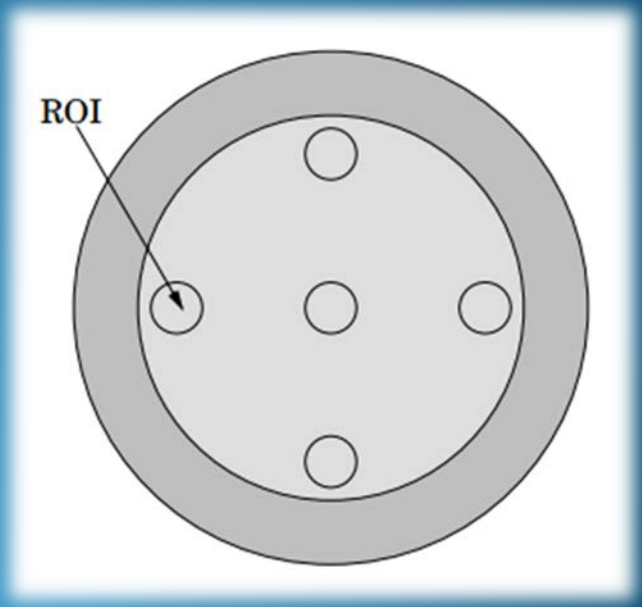
CATPHAN 503



Acceptance Procedure

- 3D kV Imaging Uniformity
  - Module is made of uniform material (approx. water)
  - Contains 5 uniform ROIs
  - Mean pixel value of each ROI is recorded using XVI software
  - Percentage difference of max and min is calculated
  - Tolerance is 2%

CTP486 Module



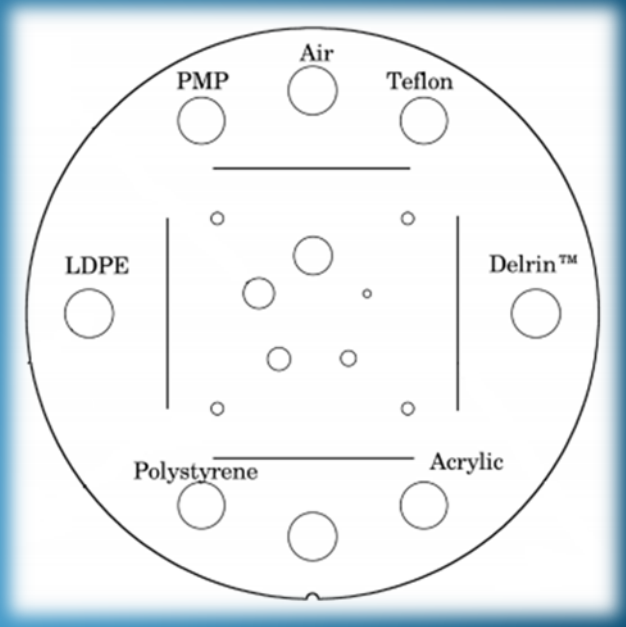
Acceptance Procedure

- 3D kV Low Contrast Visibility
  - Module made of several inserts of varying electron densities
  - Mean pixel value and standard deviation of Polystyrene and LDPE inserts are recorded using XVI software

$$\frac{(CT_{polystyrene} - CT_{LDPE})/10}{\left\{\frac{(Mean_{polystyrene} - Mean_{LDPE})}{(SD_{polystyrene} + SD_{LDPE})/2}\right\}}$$

  - Tolerance is ≤ 1.5%

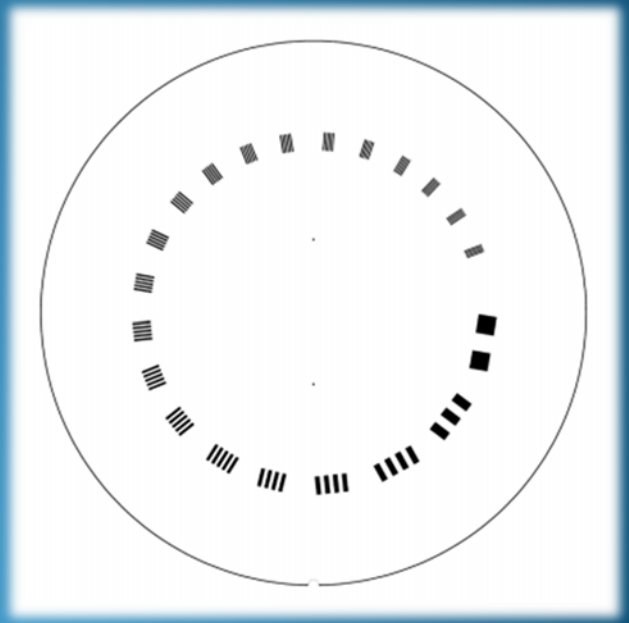
CTP404 Module



Acceptance Procedure

- 3D kV Spatial Resolution
  - 1 through 21 lp/cm
  - Highest number lp/cm that can be seen is recorded
  - Tolerance is ≥ 10 lp/cm

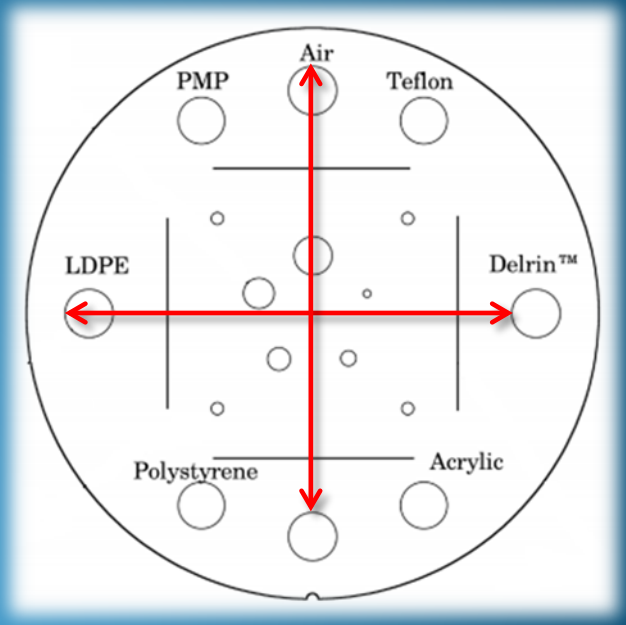
CTP528 Module



Acceptance Procedure

- 3D kV Transverse Scale
  - The distance between 2 sets of inserts is measured
  - Tolerance is ± 1mm

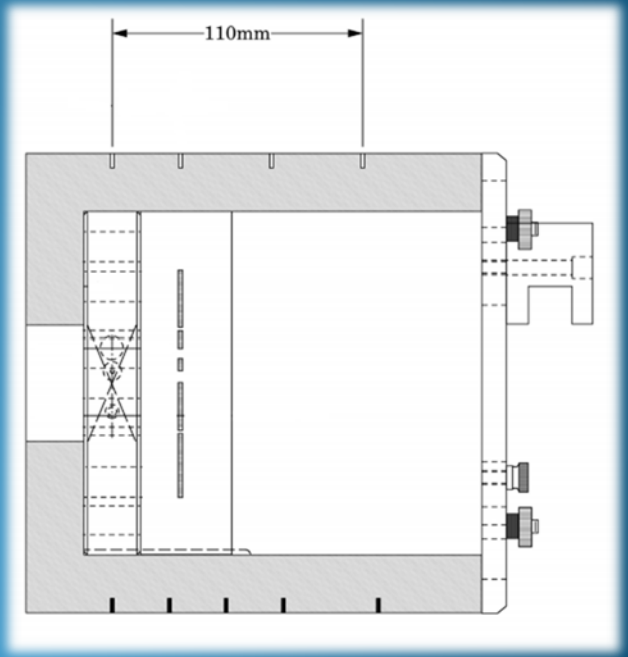
CTP404 Module



Acceptance Procedure

- 3D kV Sagittal Geometry
  - The distance between 2 alignment markers is recorded
  - Tolerance is ± 1mm

CATPHAN 503 Sagittal View



Acceptance Procedure

- 2D kV Imaging
  - Low contrast visibility
  - Spatial resolution

TOR 18FG Leeds Phantom

Acceptance Procedure

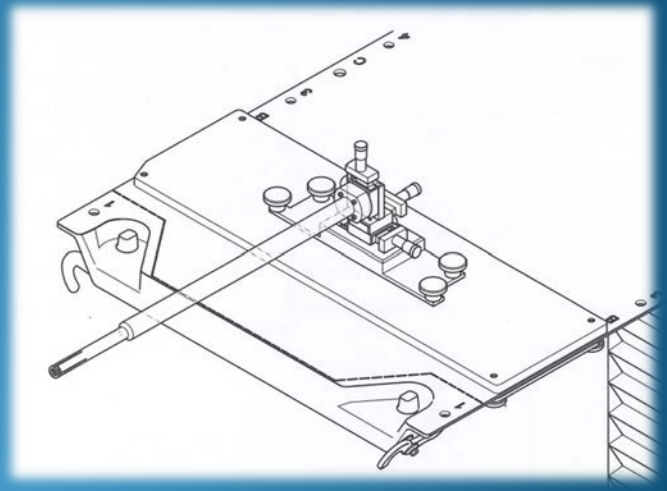
- 2D kV Imaging
  - Low contrast visibility
    - Count number of disks visible
    - A minimum of 12 disks must be seen
  - Spatial resolution
    - Count number of line pairs visible
    - Tolerance is ≥ 1.4 lp/mm

TOR 18FG Leeds Phantom

Acceptance Procedure

- kV and MV Registration Accuracy
  - Register CBCT to reference CT and apply shifts to ball-bearing phantom using vernier scale
  - Acquire MV images at 4 cardinal angles each at 0° and 180° collimator rotation
  - XVI software calculates registration accuracy
  - Tolerance is ≤ 1mm

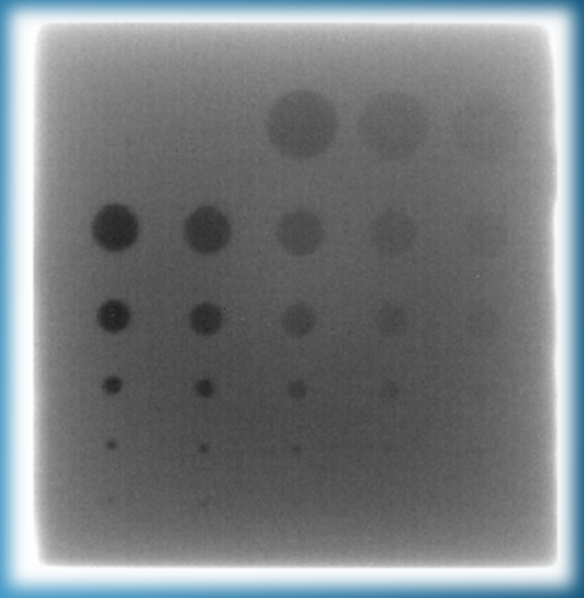
Ball-bearing phantom



Acceptance Procedure

- MV Image Quality
  - Contrast-detail phantom
  - Holes have varying thickness and diameter
  - Certain specified holes are required to be discernable in image

Las Vegas phantom

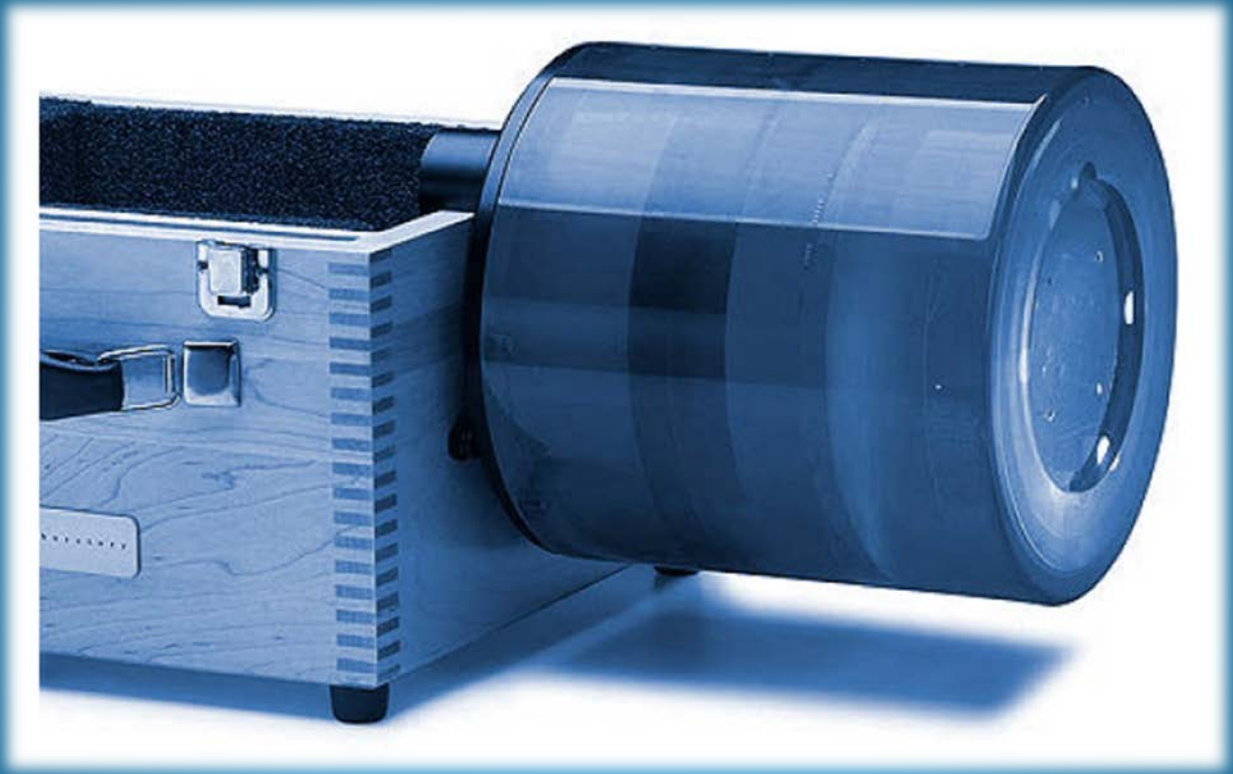


Acceptance Procedure

- Imaging QA Baselines
  - Following acceptance, imaging baselines should be established using the methods that will be used for routine QA
  - Our institution uses Mobius Medical Systems DoseLab with Sun Nuclear ImagePro phantoms
  - Baselines include spatial resolution, contrast, CBCT HU constancy, uniformity and noise.

Routine QA

- kV CBCT
  - CATPHAN 503 is used

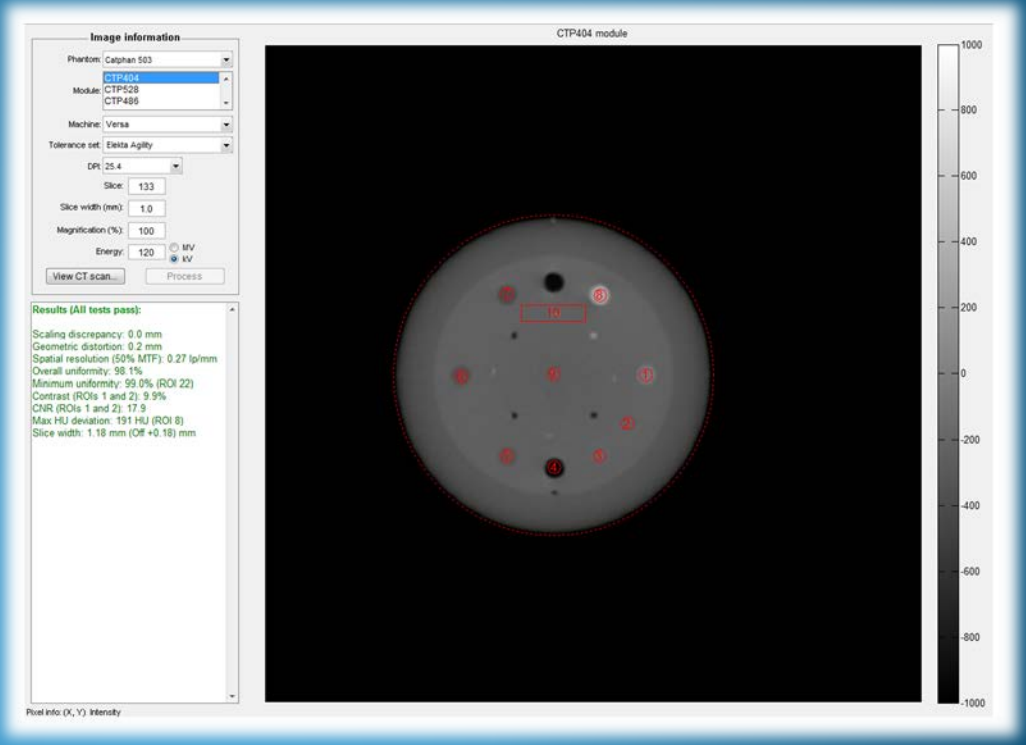


Routine QA

- kV CBCT
  - DoseLab software automatically analyzes the CT data set and compares results to tolerances and baselines

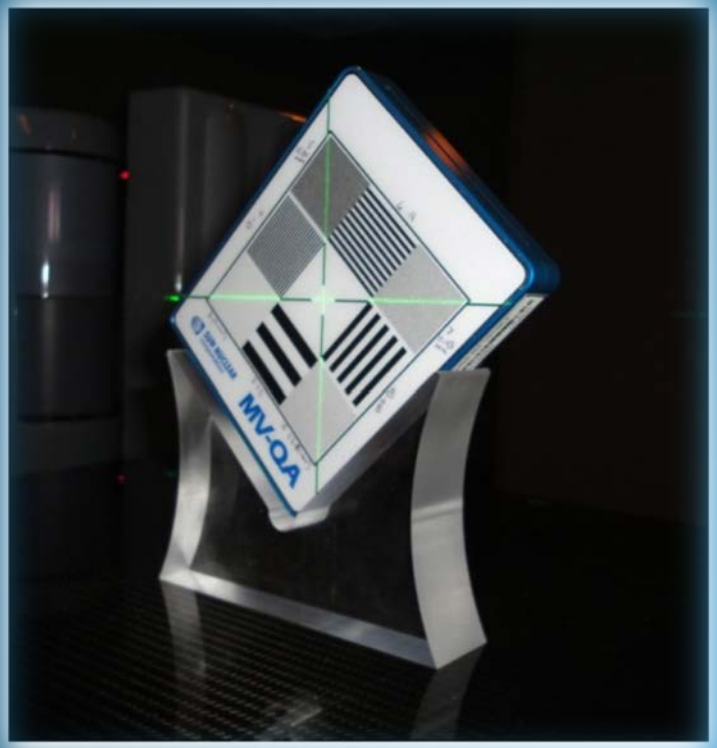
Results (All tests pass):

Scaling discrepancy: 0.0 mm
Geometric distortion: 0.2 mm
Spatial resolution (50% MTF): 0.27 lp/mm
Overall uniformity: 98.1%
Minimum uniformity: 99.0% (ROI 22)
Contrast (ROIs 1 and 2): 9.9%
CNR (ROIs 1 and 2): 17.9
Max HU deviation: 191 HU (ROI 8)
Slice width: 1.18 mm (Off +0.18) mm



Routine QA

- MV Imaging
  - Sun Nuclear MV-QA phantom is used



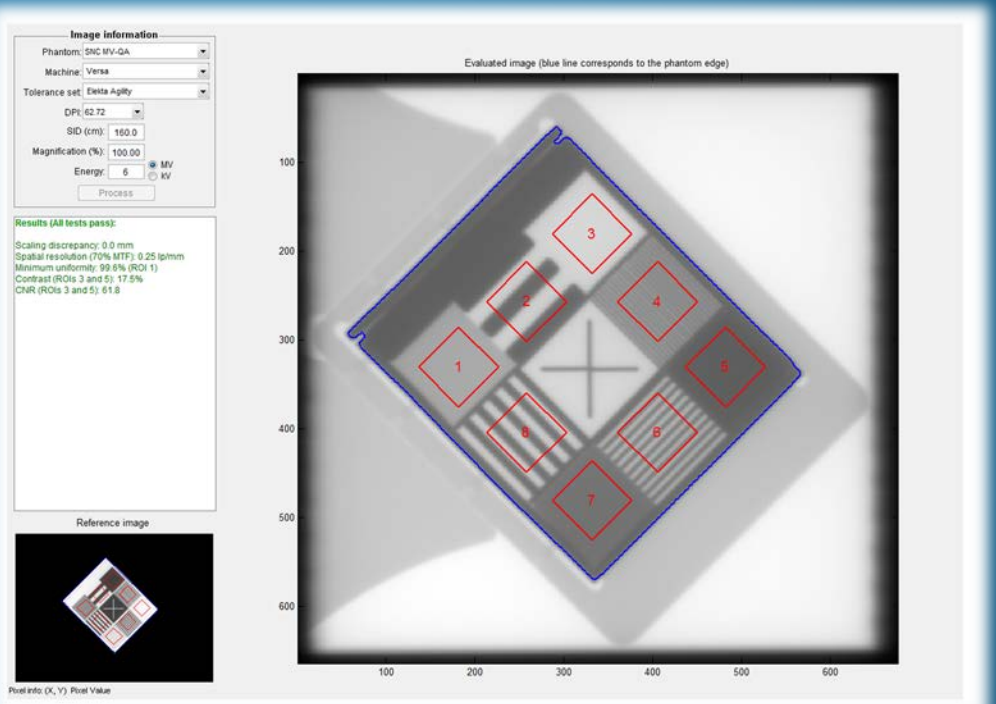
- 4 spatial resolution ROIs (0.1, 0.2, 0.5, 1.0 lp/mm)
- 4 contrast ROIs

Routine QA

- MV Imaging
  - DoseLab software automatically analyzes the MV image and compares results to tolerances and baselines

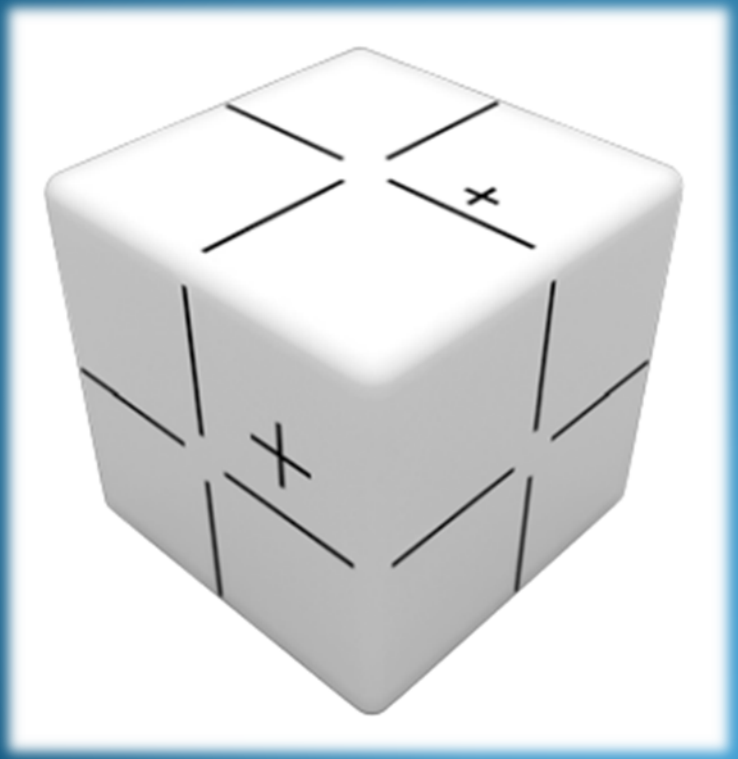
Results (All tests pass):

Scaling discrepancy: 0.0 mm
Spatial resolution (70% MTF): 0.25 lp/mm
Minimum uniformity: 99.6% (ROI 1)
Contrast (ROIs 3 and 5): 17.5%
CNR (ROIs 3 and 5): 61.8



Routine QA

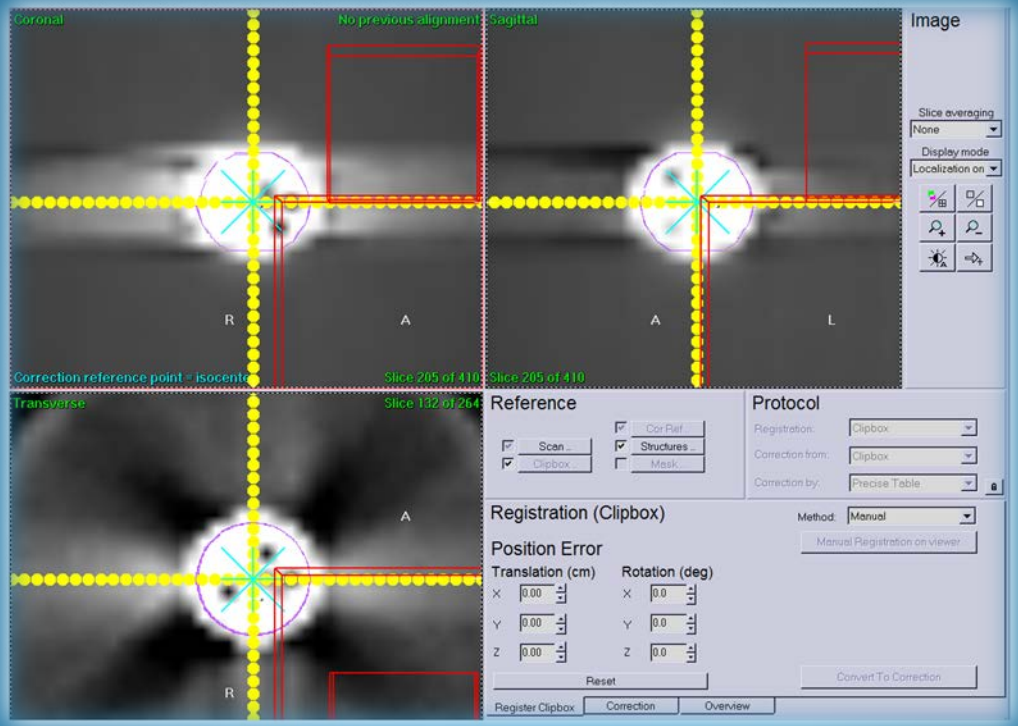
- Imaging and treatment coordinate coincidence
  - Sun Nuclear WL-QA phantom is used



- 6 x 6 x 6 cm^3
- 8.0 mm metal sphere at the cube center

Routine QA

- Imaging and treatment coordinate coincidence
  - A CBCT is acquired and registered to the reference CT to align the sphere with the kV isocenter

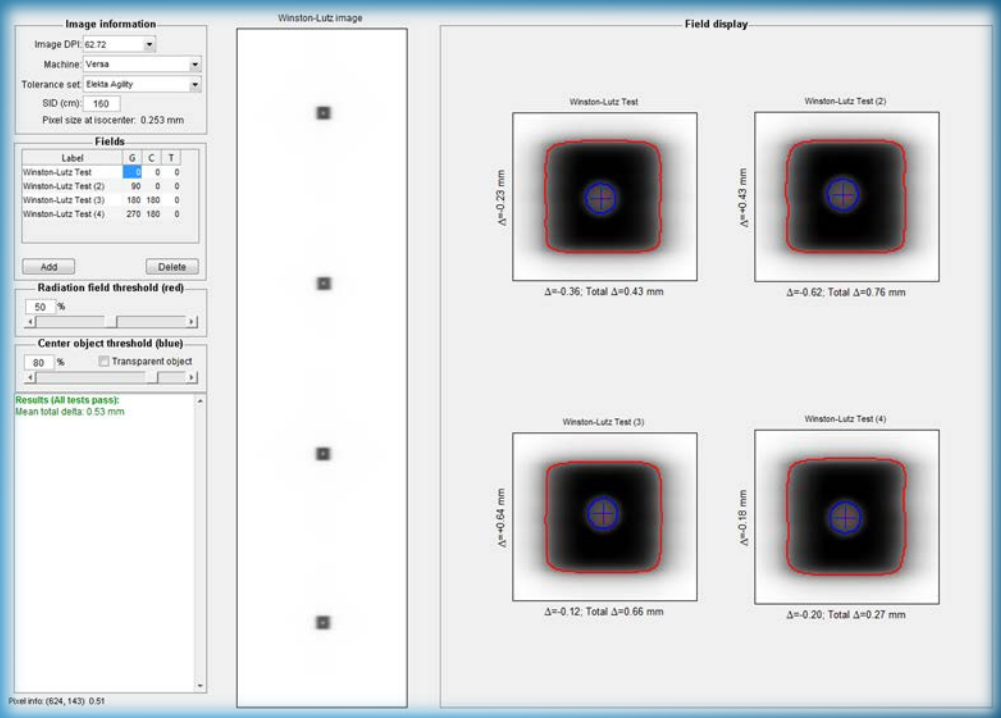


Routine QA

- Imaging and treatment coordinate coincidence
  - Once the sphere is at kV isocenter, four 2 x 2 MV images are collected
  - MV images are measured at the cardinal angles with opposing field collimation rotated 180° apart.

Routine QA

- Imaging and treatment coordinate coincidence
  - DoseLab software automatically analyzes the MV images and compares result to tolerance



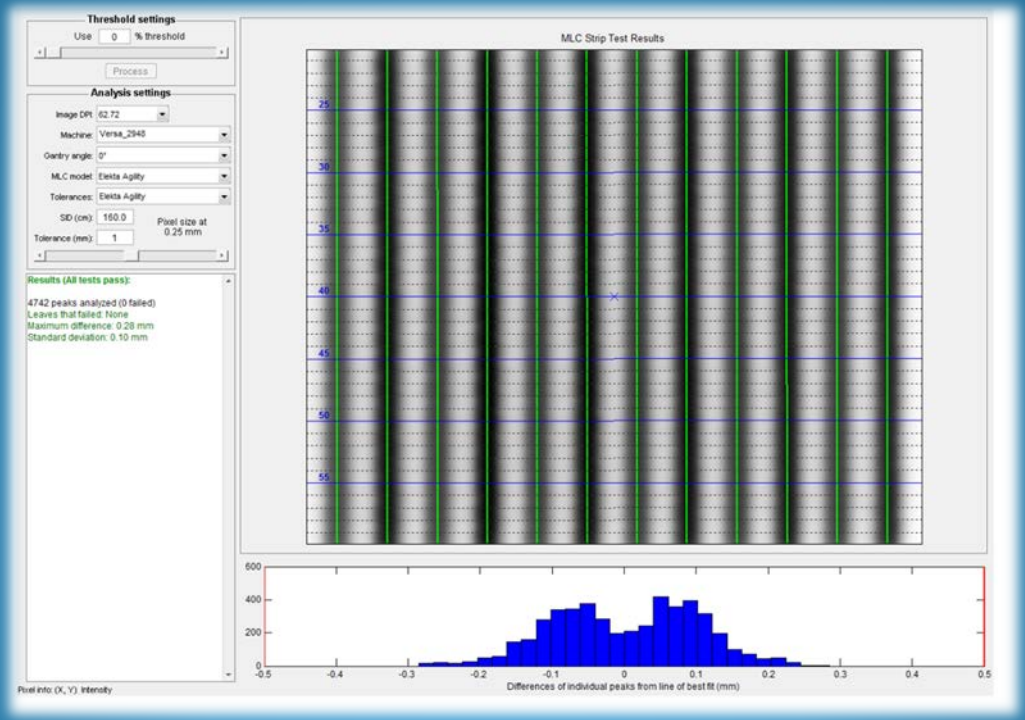
Results (All tests pass):
Mean total delta: 0.53 mm

Routine QA

- Leaf Position Accuracy
  - Picket fence field is used (created in iCom CAT)
  - 12 strips, 1 cm width, 22 cm height, 2 cm center to center, 21 MU per strip
  - Image collected on iViewGT MV panel.

Routine QA

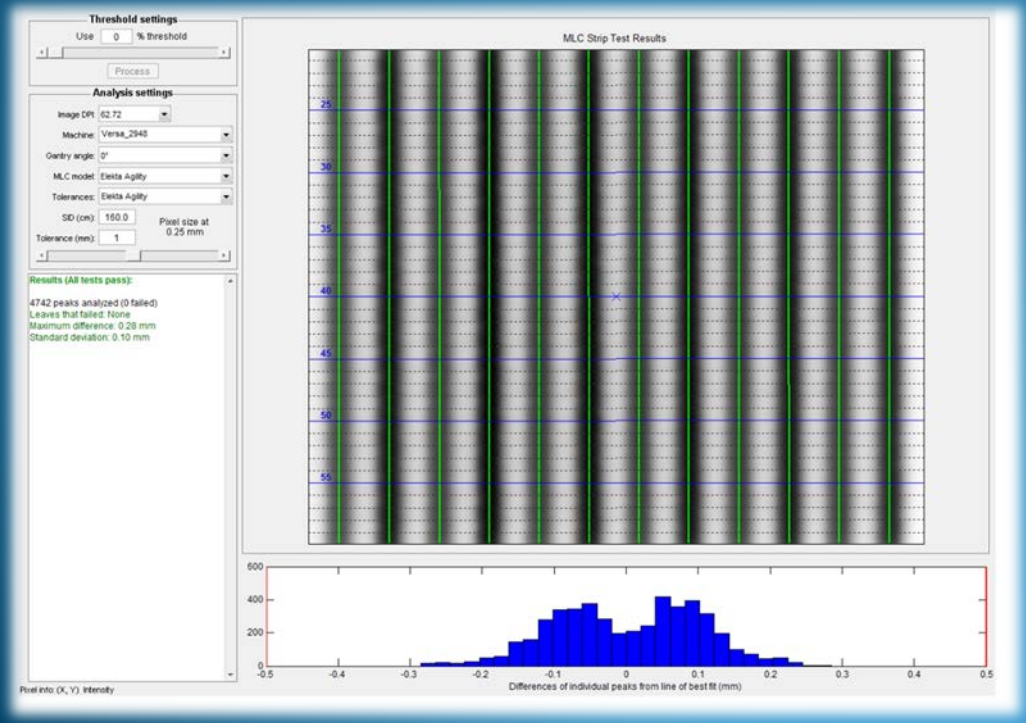
- Leaf Position Accuracy
  - DoseLab software automatically analyzes the MV image and compares the results of each leaf to the tolerance



Leaves that failed: None
Maximum difference: 0.28 mm
Standard deviation: 0.10 mm

Routine QA

- Leaf Position Accuracy
  - DoseLab software automatically analyzes the MV image and compares the results of each leaf to the tolerance



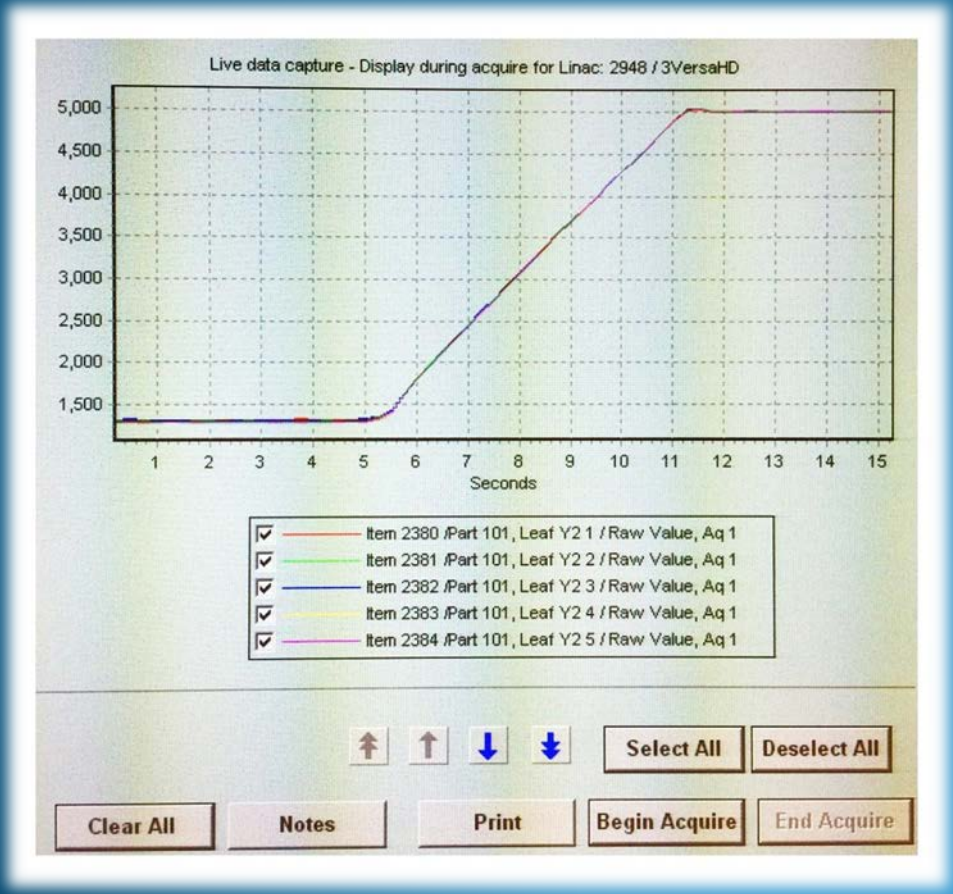
- Recommendations for Elekta machines
  - Use a Gaussian fit instead of a Lorentzian fit
  - Ignore results near leaf junctions

Routine QA

- MLC Leaf Speed
  - Raw leaf positions vs time (seconds) are recorded in service graphing in service mode
  - Raw leaf positions can be converted to cm if leaf travel distance is known
  - At our institution, a single segment, low MU field (20MU) is delivered with all leaves traveling 25cm.

Routine QA

- MLC Leaf Speed



- Data acquisition steps
  - Begin Acquire
  - Beam on (MLCs move 25cm)
  - End Acquire
  - Save file as .xml
  - Import file into Excel and calculate cm/s for each leaf

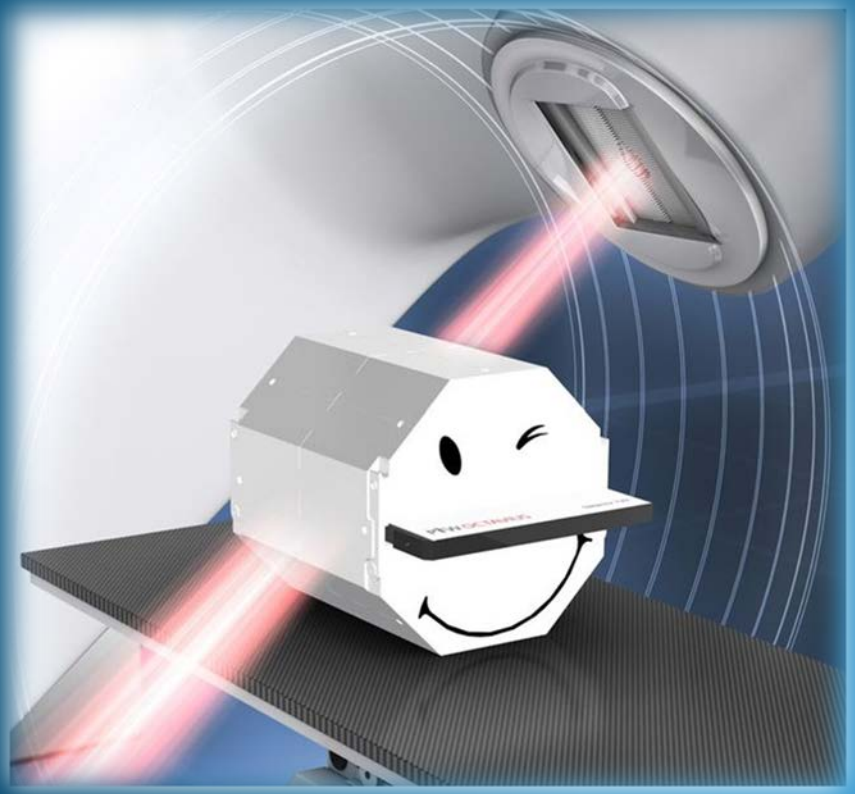
Routine QA

- MLC Leaf Speed
  - Excel results

Leaf	Baseline Speed (cm/s)	Meas. Speed (cm/s)	Abs. Diff. (cm/s)	TG-142 Tol. (cm/s)	Result
Y1 1	3.8	3.8	0.0	0.5	Pass
Y1 2	3.8	3.8	0.0	0.5	Pass
Y1 3	3.8	3.8	0.0	0.5	Pass
Y1 4	3.8	3.8	0.0	0.5	Pass
Y1 5	3.8	3.8	0.0	0.5	Pass
Y1 6	3.8	3.8	0.0	0.5	Pass
Y1 7	3.8	3.8	0.0	0.5	Pass
Y1 8	3.8	3.8	0.0	0.5	Pass
Y1 9	3.8	3.8	0.0	0.5	Pass
Y1 10	3.8	3.8	0.0	0.5	Pass

Routine QA

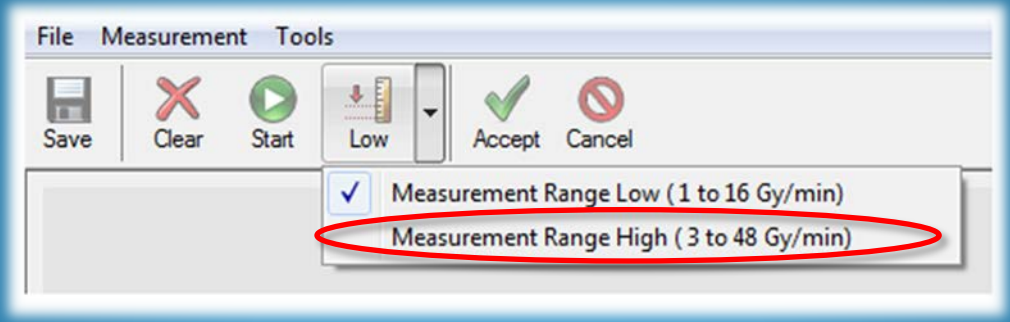
- Patient-specific QA
  - PTW OCTAVIUS II and OCTAVIUS 729 are used



- OCTAVIUS II
  - Polystyrene (~water equiv.)
  - 32 cm diameter
- OCTAVIUS 729
  - 729 vented ion chambers

Routine QA

- Patient-specific QA
  - OCTAVIUS 729 is suitable for dose rates up to 48 Gy/min or 0.8 Gy/s
  - Measuring range must be set to high for FFF in the data collection software



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Thank You!

References

1. “Ion-recombination correction for different ionization chambers in high dose rate flattening-filter-free photon beams”, S. Lang, J. Hrbacek, A. Leong and S. Klock, Phys. Med. Biol. 57, 2819–2827 (2012)

2. “Modeling the instantaneous dose rate dependence of radiation diode detectors”, J. Shi, W.E. Simon, T.C. Zhu, Med. Phys. 30 (9), 2509-2519 (2003)

3. "User's Guide, EDGE Detector™“, Sun Nuclear Corporation., Document 1118011, Rev J-1, 1 July 2013