LINAC and MLC QA for IMRT

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Note: MSKCC receives Varian research support

Learning objectives

- To understand the effects of QA
  on IMRT delivery accuracy.

- To identify planning system weaknesses
  and commissioning uncertainties,
  which may be interpreted as IMRT delivery problems.
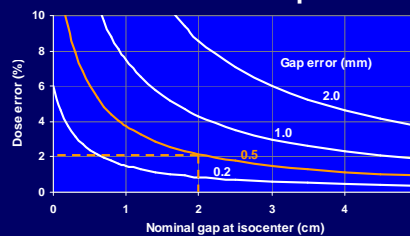

IMRT delivery
- Gap width – relative leaf position
- Gap position – absolute leaf position
- Leaf speed
- Beam characteristics for small MU

Planning system design and commissioning
- Leaf offset
- MLC transmission
- Interleaf effects
- Source function

$$\text{Dose error} \propto \frac{\text{Gap error}}{\text{Gap width}}$$

- This graph is applicable to Siemens, Elekta, and Varian MLC
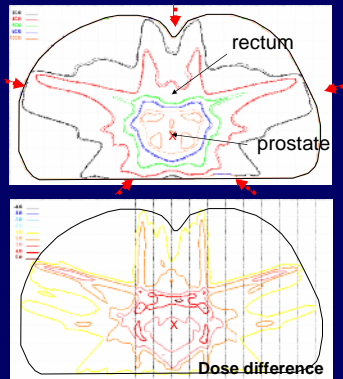 for SMLC and DMLC deliveries.

Prostate

**Gap –
1 mm too wide**
(dotted line)

Dose ↑2-5%

**Largest increase
is at the target-rectum
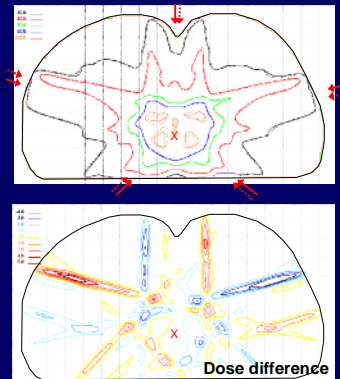interface where
the field narrows
to sharpen
the dose falloff.**

rectum

prostate

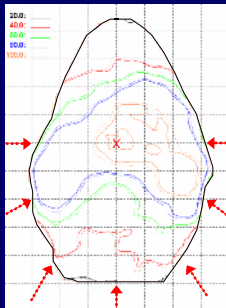**Dose difference**

Prostate

**MLC - offset
1 mm from
beam axis**
(dotted line)

**Gap position,
Gantry mechanical
isocenter**

**Hot and cold
regions are seen
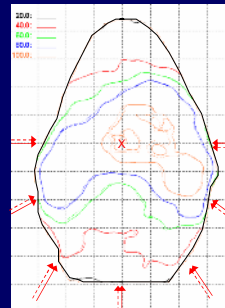at the perimeter
of the target**

Dose difference

Nasopharynx

Dose difference
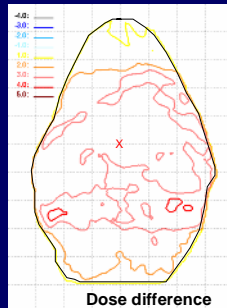
Gap - 1 mm too wide (dotted line)　　**Dose ↑ 2-4%**
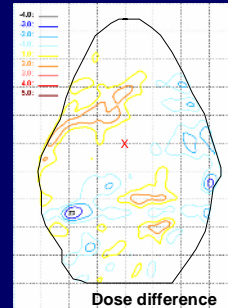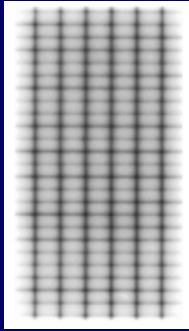

Nasopharynx

Dose difference

MLC offset 1 mm from beam axis (dotted line)
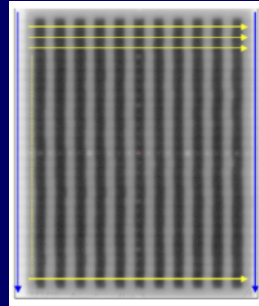
Picket fence pattern

**1 mm wide strips
at 2 cm intervals**

**Provides a quick
visual check
of relative leaf positions**

Guidance document … Ezzell et al 2003
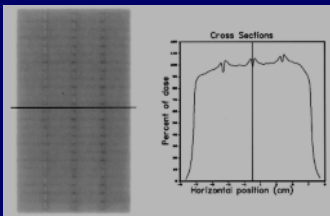
Leaf position calibration

MLC test pattern

**1 cm wide strips
used to locate
the 50% dose value**

**This works for
focussed leaves.
(Siemens)**

Bayouth 2003

Leaf position calibration

**"Create a test sequence that abuts irradiated strips at different
locations across the field, adjusted to account for any offset so
that the 50% decrement lines superimpose."**

**"This positional
variation
will produce
a dose variation
of about ± 5%
in the matchline…"**

**Guidance document…
Ezzell et al 2003**

Leaf position calibration

**"Create a test sequence that abuts irradiated strips at different
locations across the field, adjusted to account for any offset so
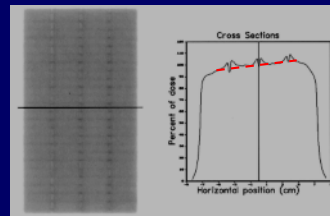that the 50% decrement lines superimpose."**

**"This positional
variation
will produce
a dose variation
of about ± 5%
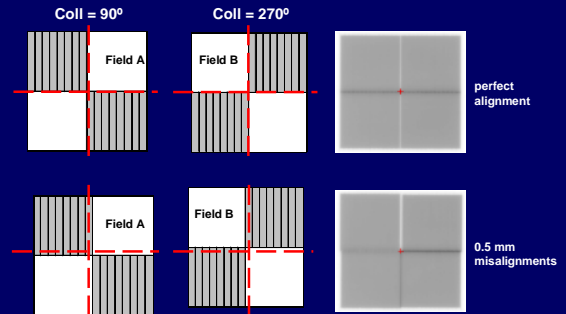in the matchline…"**

**Guidance document…
Ezzell et al 2003**

Field Alignment Tool - Varian

**Used with a feeler gauge
to adjust leaf gap, centering, and skewness**

MLC Alignment

Coll = 90° Coll = 270°

Field A   Field B   perfect alignment

Field A   Field B   0.5 mm misalignments

**This double exposure detects misalignment
relative to the CAX**

Dosimetric verification of gap width

5 mm slit/ 10x10

0.175
0.170
0.165
0.160
0.155

J-02 J-03 J-04 J-05 J-06 J-07 J-08 J-09

0-0
90-0
270-0
180-0
90-90
270-90

0.2mm – 1%
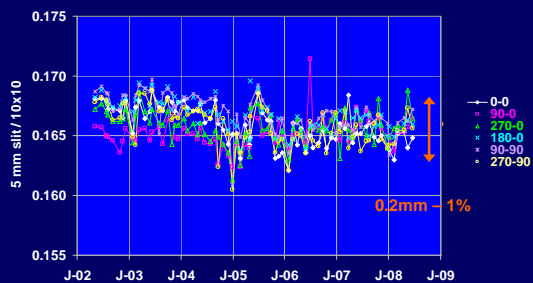
**Output for a 5 mm slit relative to an open field
is a sensitive measure of gap variation over time
and as a function of gantry and collimator angle.**

Leaf speed – DMLC (Varian)

- Causes
  - dirt, grease between leaves
  - deterioration of motor components

- Tests
  - pulse width modulation (PWM)
  - RMS errors - Dynalog File Viewer (DFV)

Leaf speed - pulse width modulation test

(minimum PWMs to move leaves -2.000 from indicated positions (rel. to crg.) before 2 second timeout)

Leaf	0	-25	-50	-75	Leaf	0	-25	-50	-75
A01	10	12	10	8	B01	12	12	12	10
A02	14	12	10	8	B02	10	10	8	8
A03	12	10	12	10	B03	8	8	8	8
A04	8	8	8	8	B04	8	8	8	8
A05	8	8	8	8	B05	10	10	8	8
A06	8	8	8	8	B06	14	12	12	12
A07	12	12	12	10	B07	8	10	10	8
A08	8	8	8	8	B08	8	8	8	8
A09	8	8	8	8	B09	8	8	8	8
A10	8	8	8	8	B10	8	8	8	8
A11	10	10	10	12	B11	12	10	10	12
A12	10	10	10	12	B12	14	12	12	10
A13	10	12	12	12	B13	10	10	10	10
A14	14	12	14	14	B14	12	14	12	14
A15	12	12	12	12	B15	12	12	12	12
A16	10	10	10	10	B16	14	12	14	12
A17	10	10	12	12	B17	16	16	22	26
A18	10	10	10	10	B18	10	10	10	10
A19	10	10	10	12	B19	10	10	12	12
A20	10	10	8	8	B20	12	12	12	10
A21	10	10	12	12	B21	18	24	20	14
A22	12	10	10	10	B22	10	10	10	10
A23	12	10	12	12	B23	16	12	12	14
A24	10	10	10	12	B24	28	14	14	20
	*					*			
	*					*			

At each of four leaf positions, the effort required to move the leaf is recorded

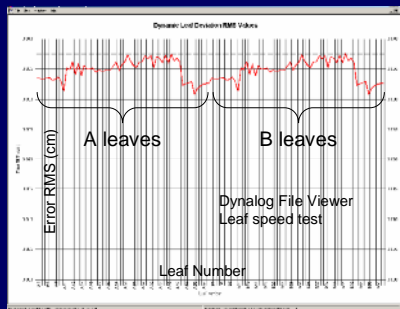**If value exceeds threshold, clean leaf or replace motor.**

Leaf speed test pattern
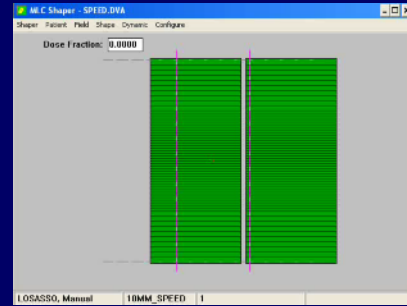
Alternating pairs of leaves move at constant speed. Log file is generated for analysis.
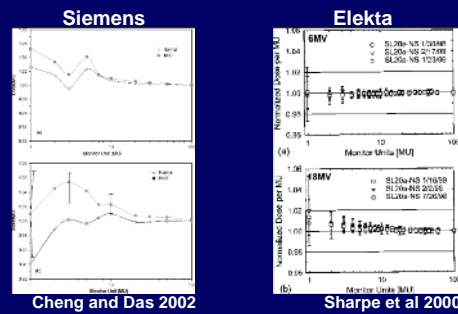
Leaf speed - log file analysis

A leaves   B leaves

Error RMS (cm)

Dynalog File Viewer
Leaf speed test

Leaf Number

Logged leaf positions are compared with prescribed positions

Output / MU

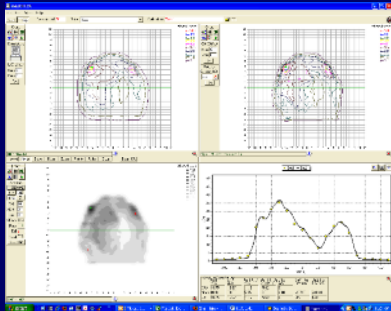Siemens

Elekta

Cheng and Das 2002

Sharpe et al 2000

Siemens - up to 5% variation below 5 MU
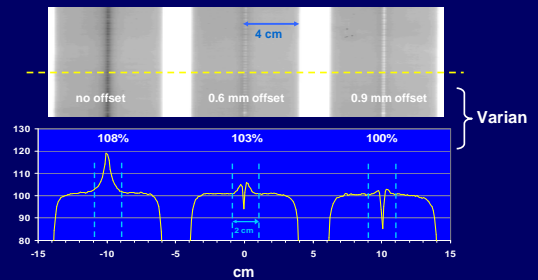**Elekta and Varian - less than 2% variation at 1 MU**

Clinical reference dosimetry

The same data set is planned and measured semi-annually for each linac / MLC.


Leaf offset – round leaves

4 cm

no offset   0.6 mm offset   0.9 mm offset

Varian

108%   103%   100%

2 cm

- Minimizing the peak-valley dose variation (center) or superimposing the 50% decrement lines is not optimal,
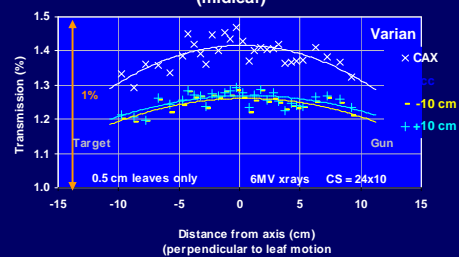- The integral dose in the abutment region (right) should be matched to that in an adjacent region

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MLC Transmission
vs field size and energy

Varian

15X

6X

Transmission (%)

Area defined by jaws @ 100 cm
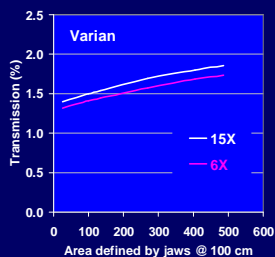
- Jaw openings up to 20x20
  ~ 0.5% (1.5% for IMRT*)

- 6X vs 15X
  ~ 0.15% (0.5% for IMRT*)

* Based upon 25% duty cycle

Off-axis transmission
(midleaf)

Varian

× CAX

– -10 cm

+ +10 cm

1%

Target   Gun

0.5 cm leaves only   6MV xrays   CS = 24x10
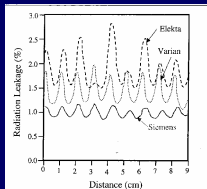
Transmission (%)

Distance from axis (cm)
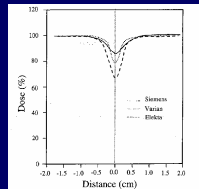(perpendicular to leaf motion)

- 0.2% (0.6% for IMRT*) reduction in transmission at 10 cm off-axis is mainly due to transmission change with off-axis beam spectrum.

Interleaf effects
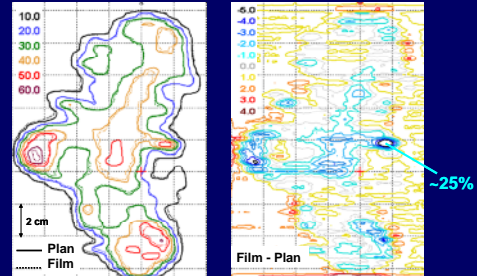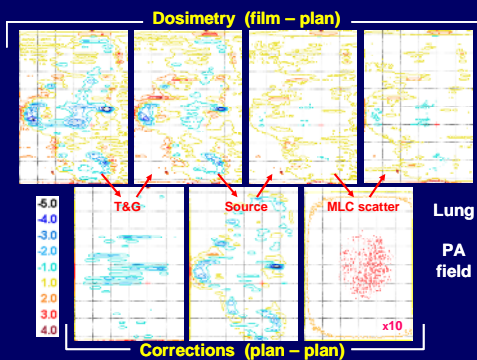

Interleaf transmission　　　　**Tongue and groove**

- Interleaf transmission (up to 4% for IMRT*) and
  T&G underdose (as much as 30%, FWHM 5mm) are greatest for Elekta.
- Siemens MLC has the least interleaf effects.

Huq et al 2002

Improved calculations needed for IMRT fields

Overlay　　　　　　　**Difference**

DMLC lung field - calculation vs film measurement
Maximum deviation – 25% of the mean dose

**Modelling interleaf effects, multi-component source,
and MLC scatter is significant.**

Conclusions

- **QA should target known problems
  for each MLC and delivery type.**

- **Inadequate design and commissioning
  of planning systems
  may be interpreted as delivery problems.**

- **If the above issues are rectified
  or at least understood by the user,
  then both machine QA and patient-specific QA
  can be simplified.**