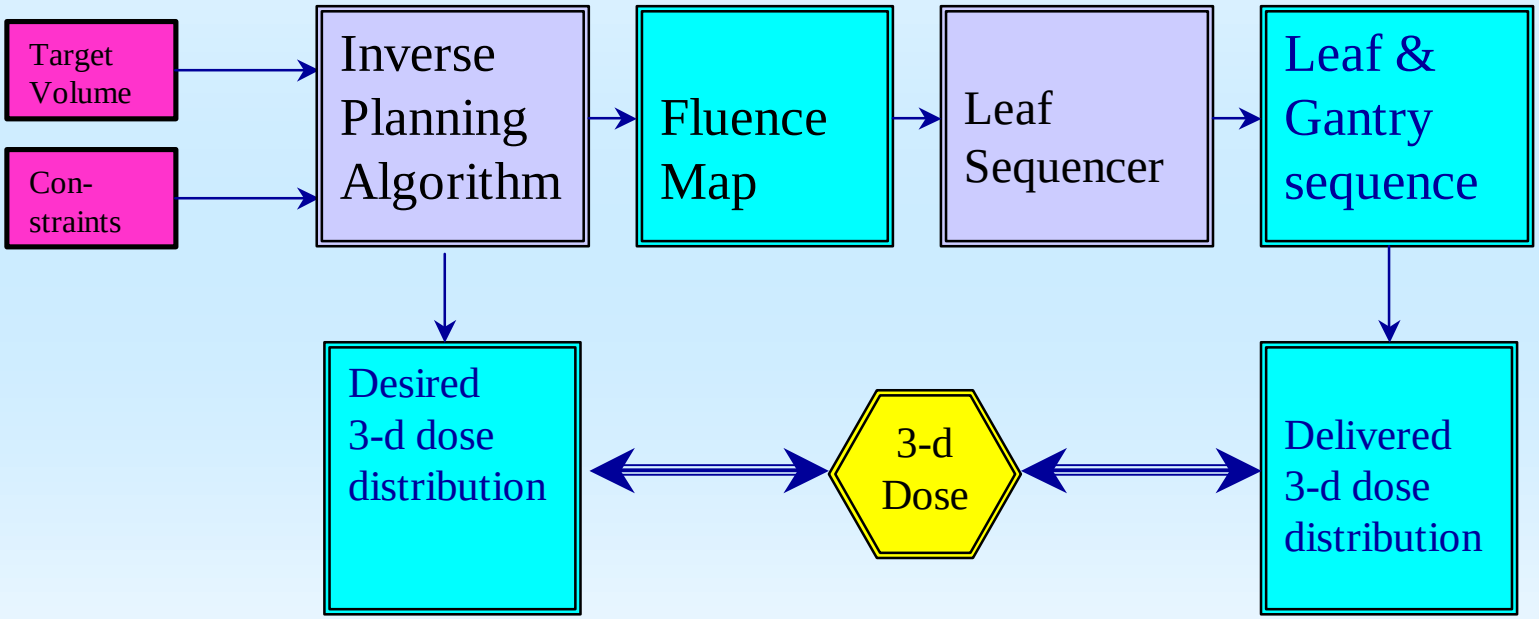
Qalitätssicherung an Multileafkollimatoren

Dr. Lutz Müller

Würzburg jan 2004

IMRT Verification - present



Workflow of Film Verification

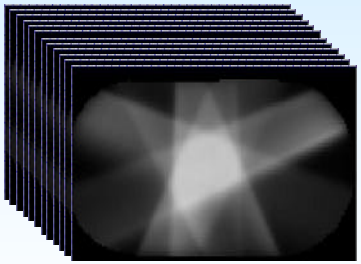
CT scan of phantom

Apply patient‘s plan to phantom

Calculate dose dis-tribution in Phantom

Irradiate patient‘s plan to phantom

Process film



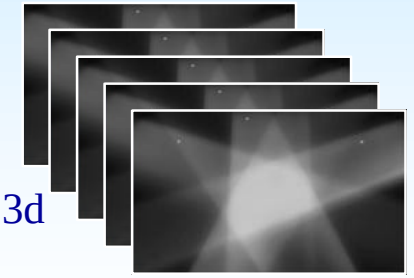
read in 3D data

OmniPro - IMRT

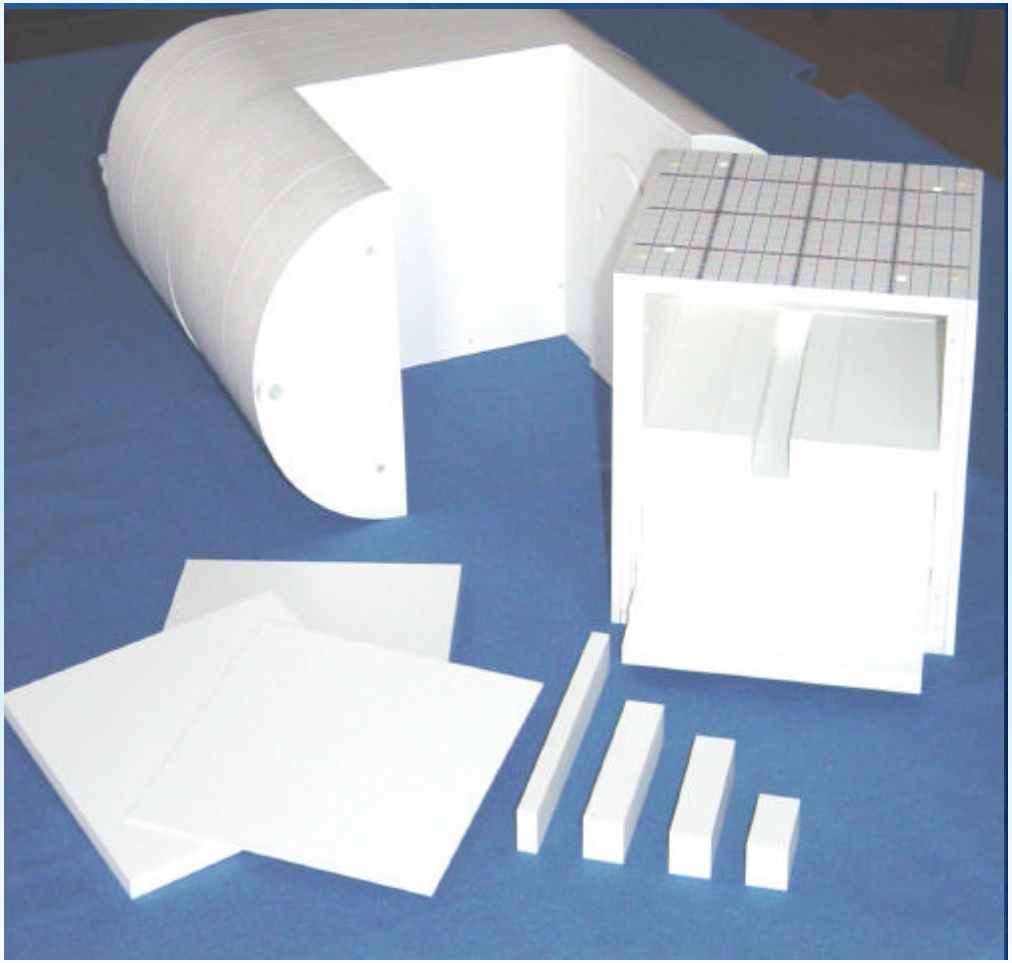
COMPARE AND EVALUATE DATA:

isodoses, + - * /, ?

Scan Film calibrate register reconstruct 3d



Equipment: Body Phantom



Film application fields:

1. Universal body
2. Head & Neck
3. Stereotactic

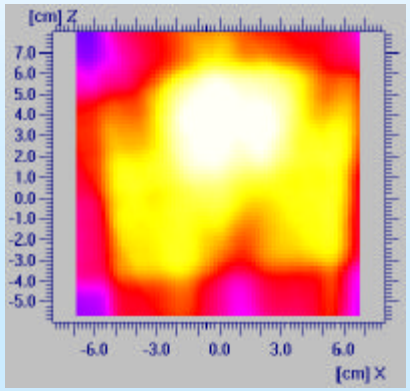
Material: water-equivalent RW3 (polystyrene)

Dimensions:

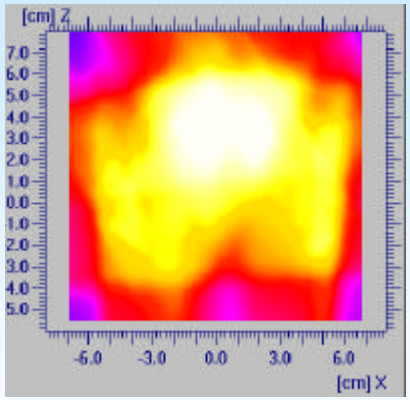
U: 36 (W) x 18 (H) x 33 (D)
H&N: 18 x 18 x 18 cm

Royal Marsden (UK) Testing

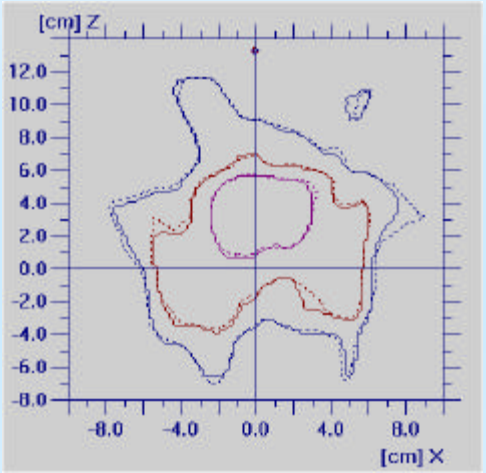
Case: Prostate & Pelvic Nodes in Alderson Phantom



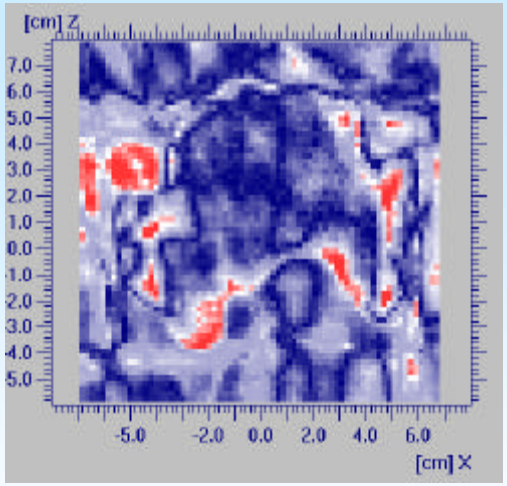
DICOM imported plan



calibrated film



isodose comparison



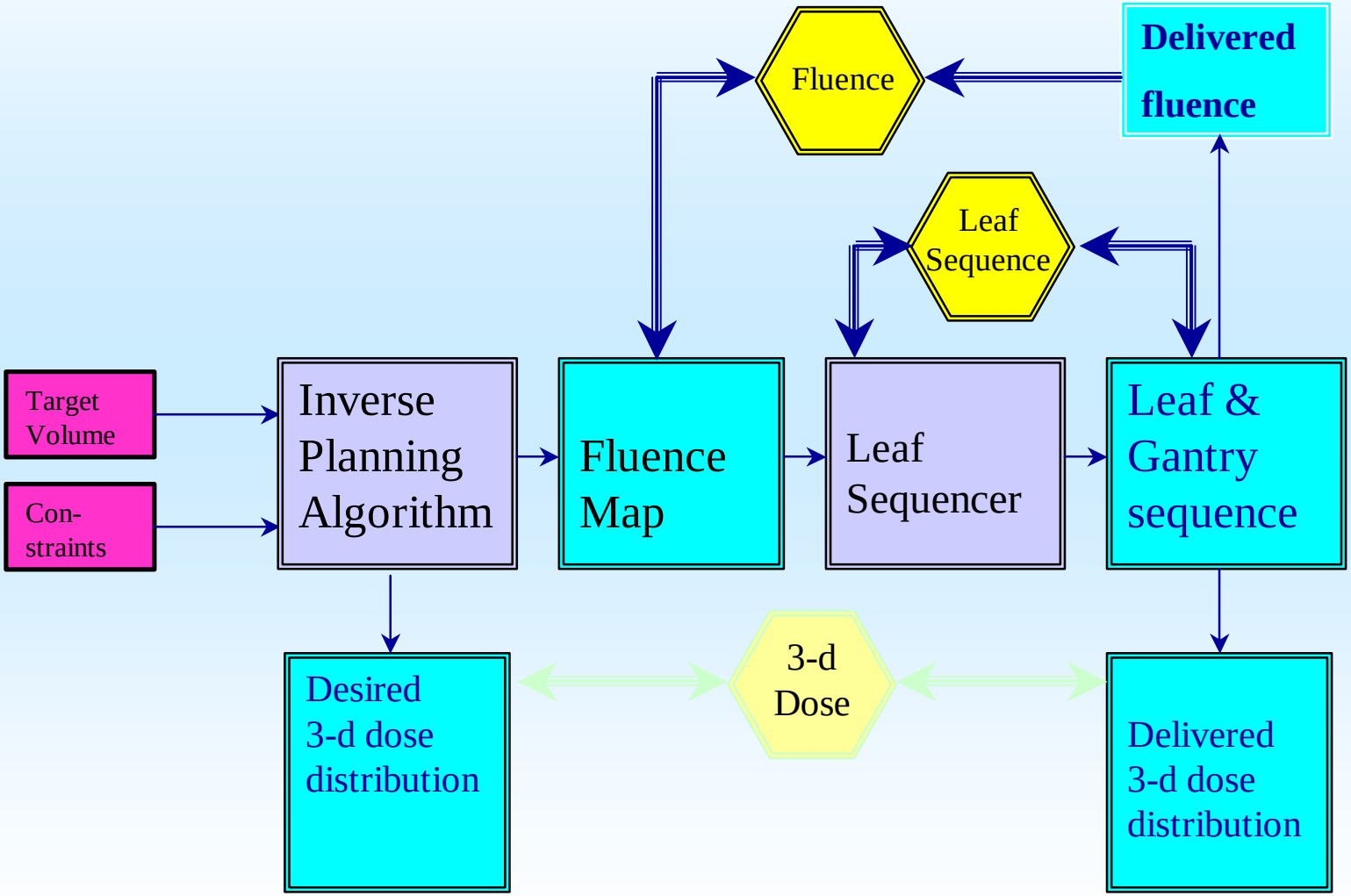
gamma evaluation

Routine IMRT Verification

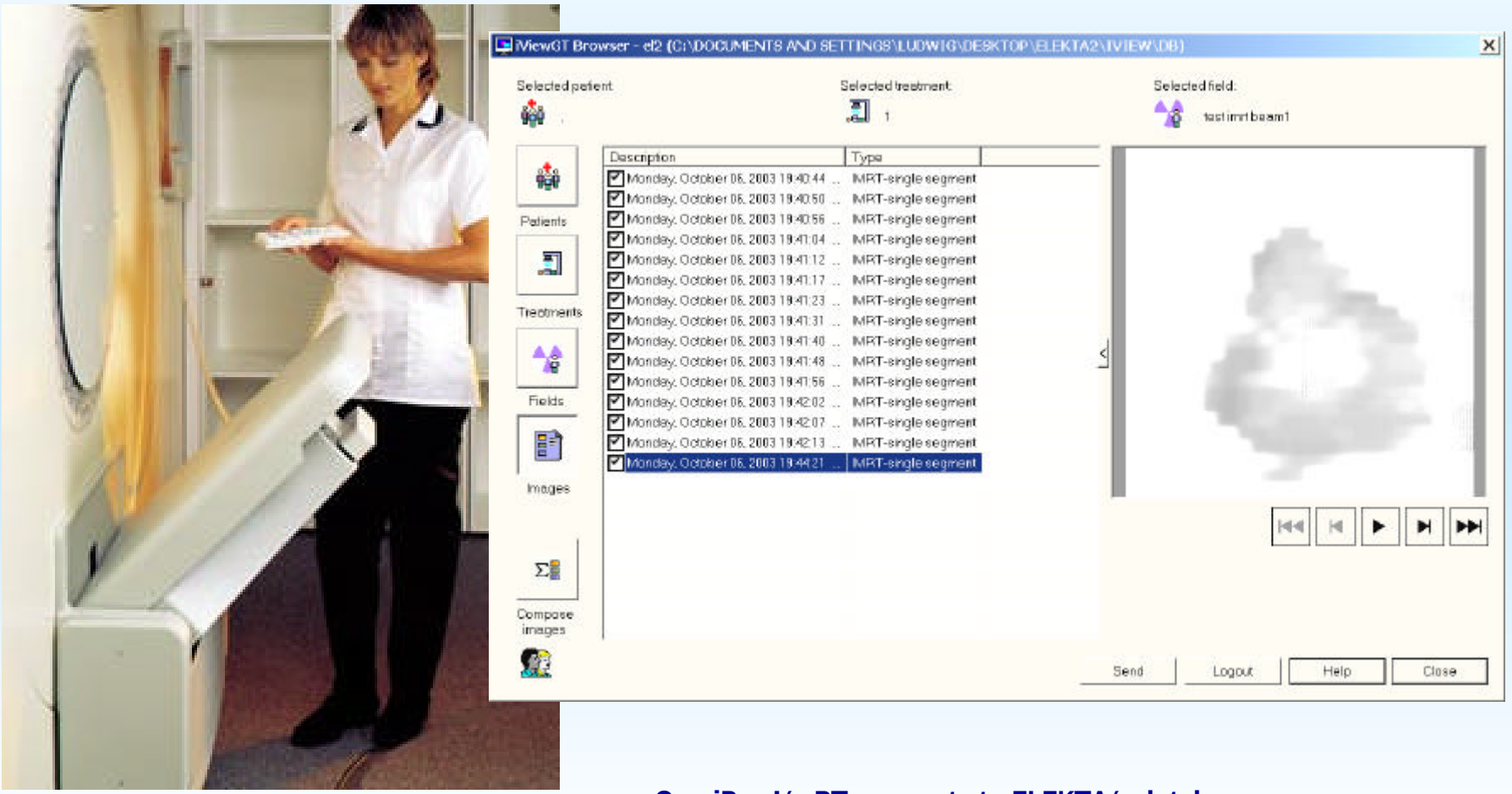
- 3D/ 2 ½D Dosimetry checks the quality of treatment planning process and of the delivery process

- In routine applications, only the delivery needs to be verified
- Check it: measure fluence/sequence offline or online
- Trust it: accurate, frequent QA, specially of MLC, is a MUST

IMRT Verification – 2D



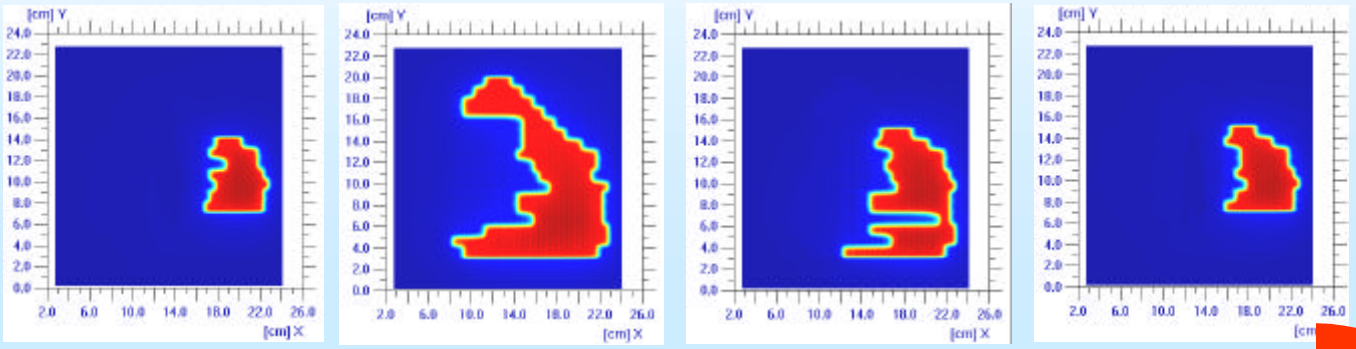
Usage of a-Si EPID (Elekta i-View)



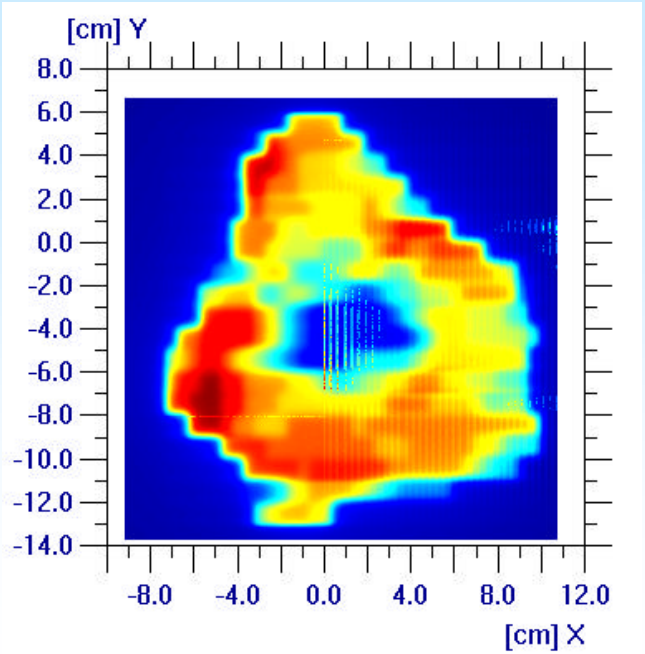
OmniPro-I ‘mRT connects to ELEKTA ‘s database

recalibrates images (linear response)

Step-and-shoot delivery w/ EPID

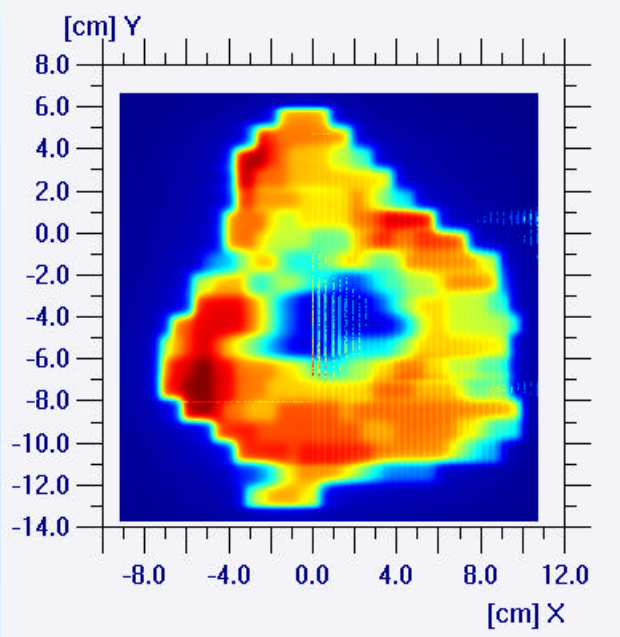


individual segments (integration w/o dead-time)

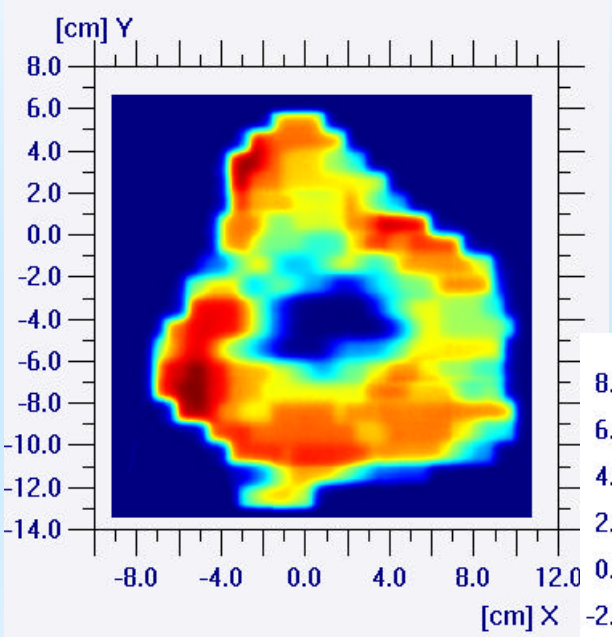


composed image

EPID vs. Film



integrated EPID (normalized)

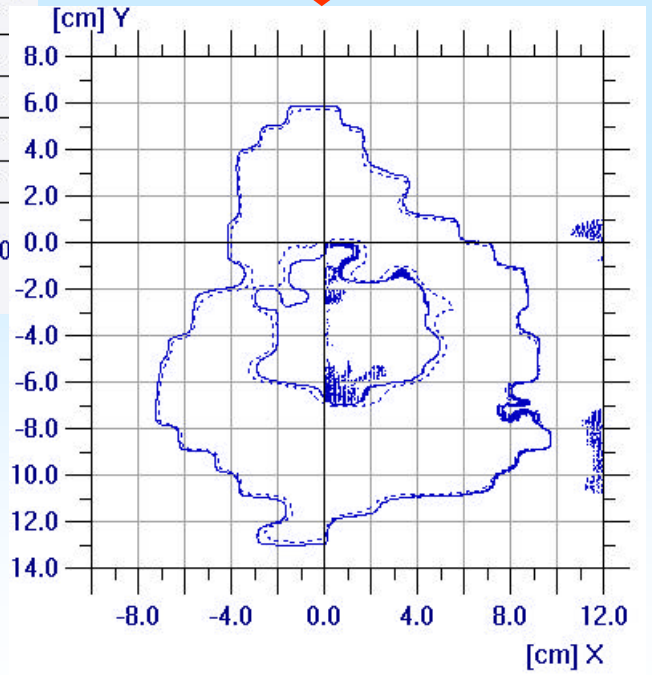


calibrated Film

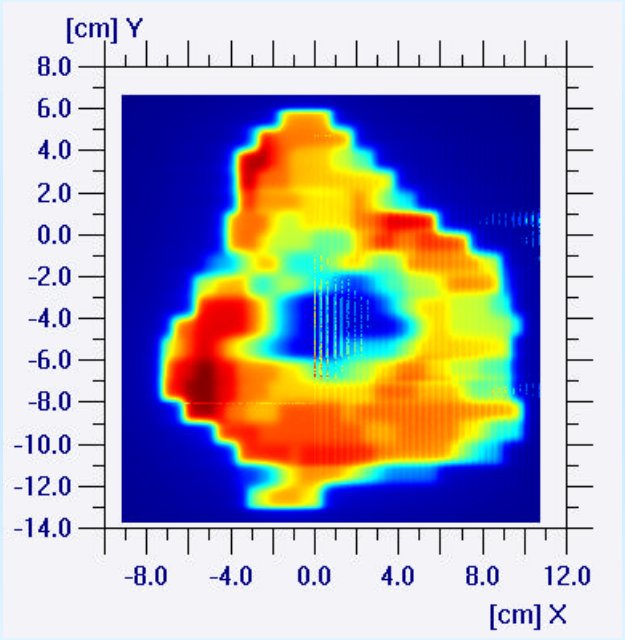
50% isodoses

_____ EPID

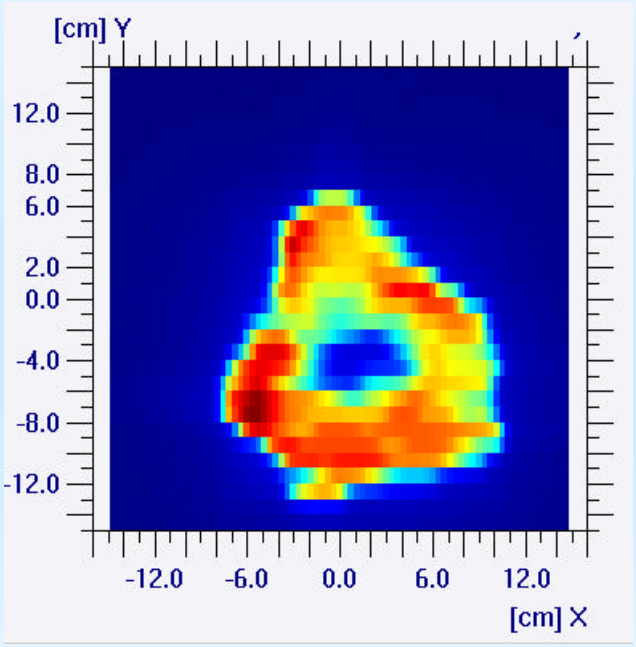
..... Film



EPID vs. Plan (Helax TMS)

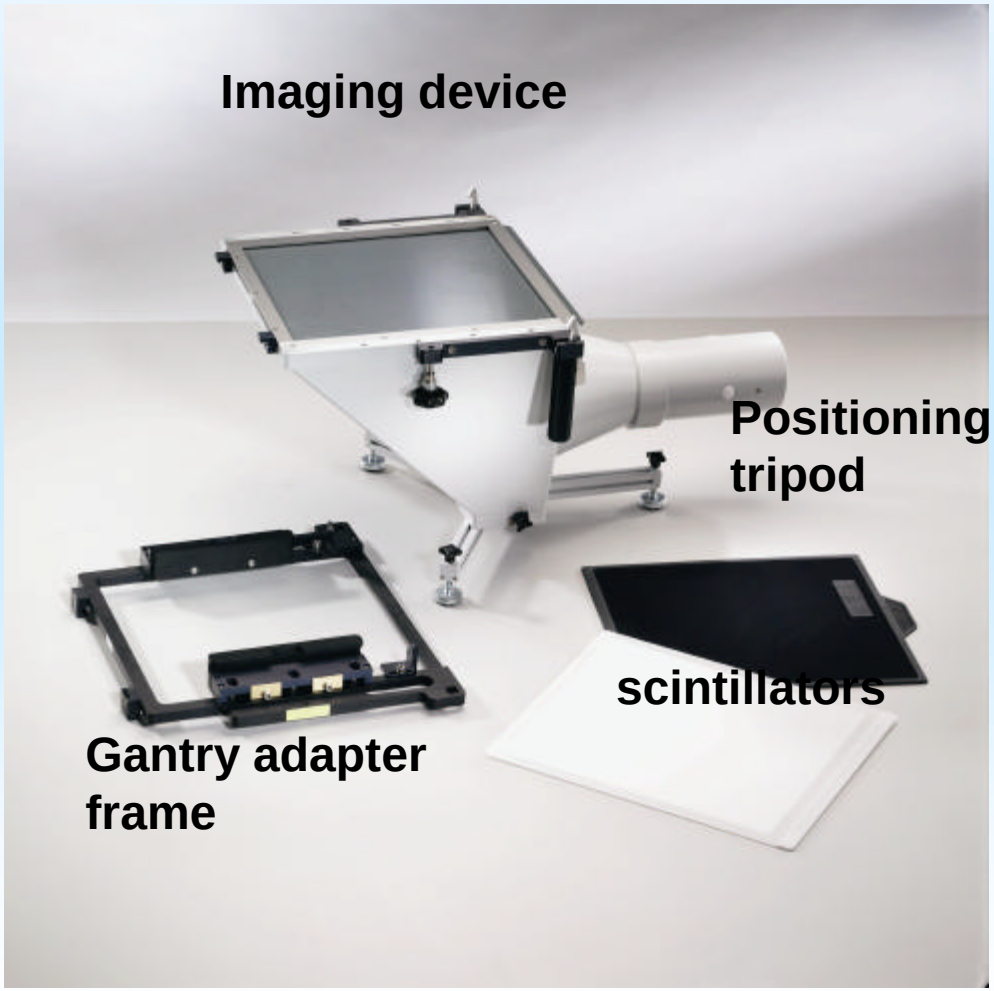


integrated EPID (normalized)

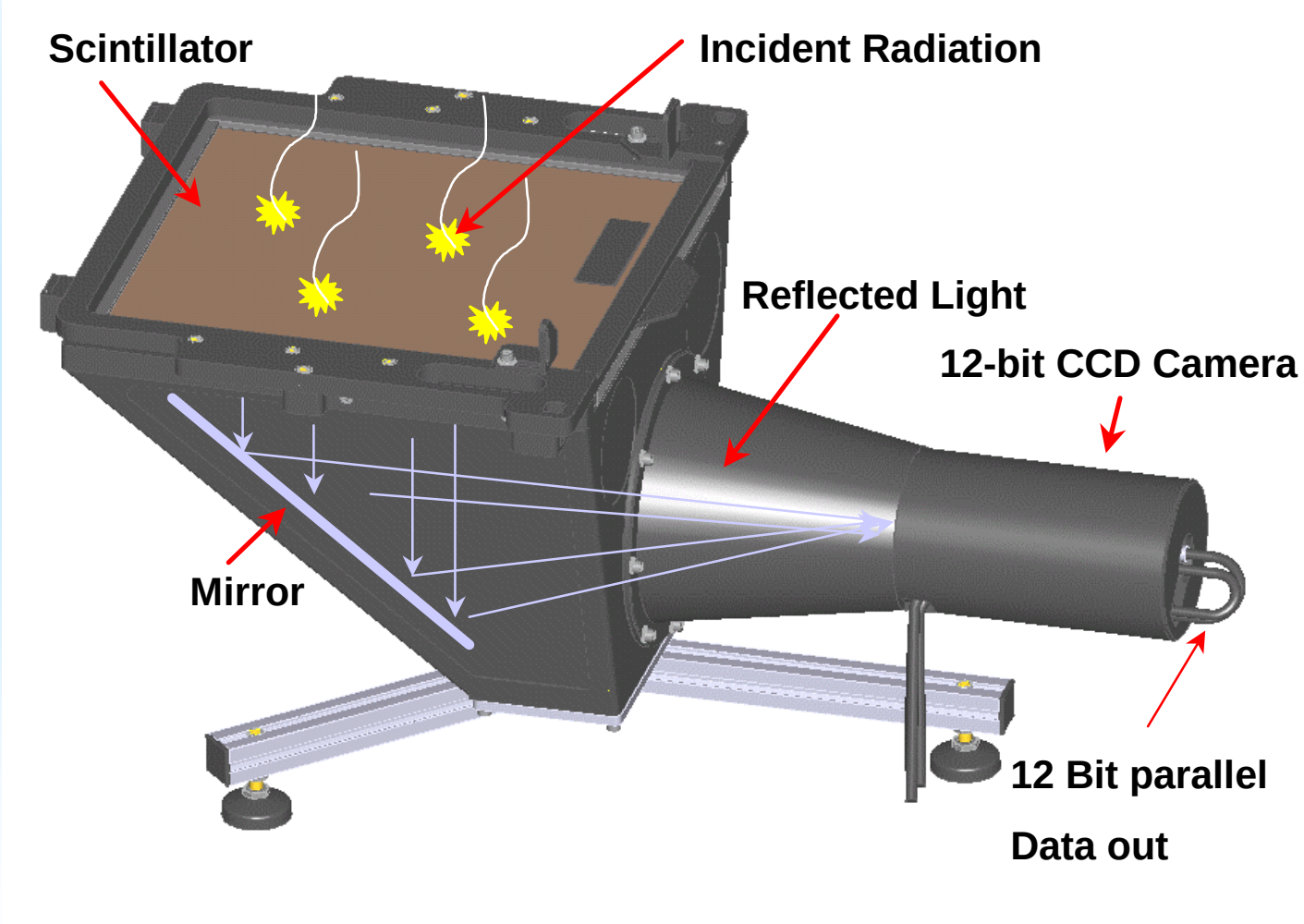


calculated plan data

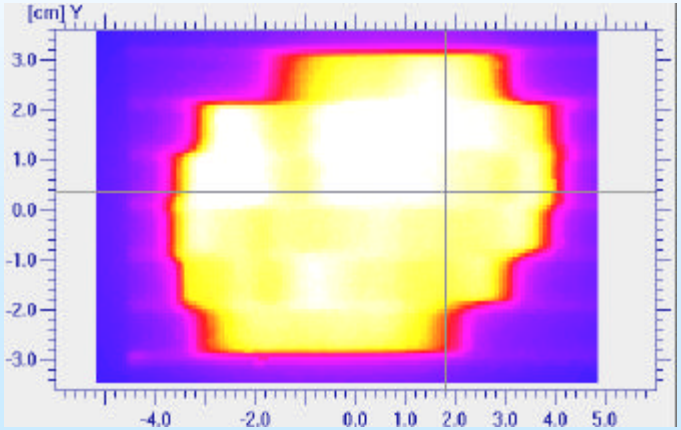
I ‘m*RT* – QA Device



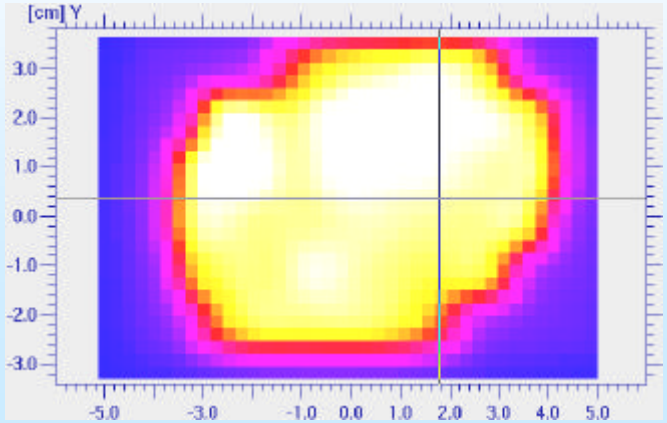
I'm*RT* – QA: Operating Principle



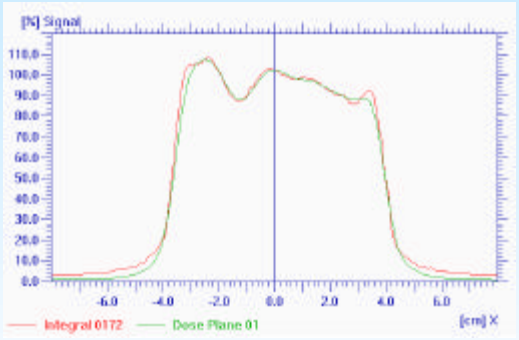
Complex IMRT Field



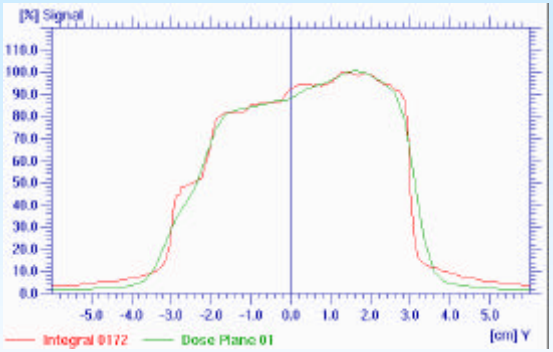
BIS Measurement



Eclipse Calculation



x profile



y profile

_____ I'm*RT* – QA _____ Eclipse

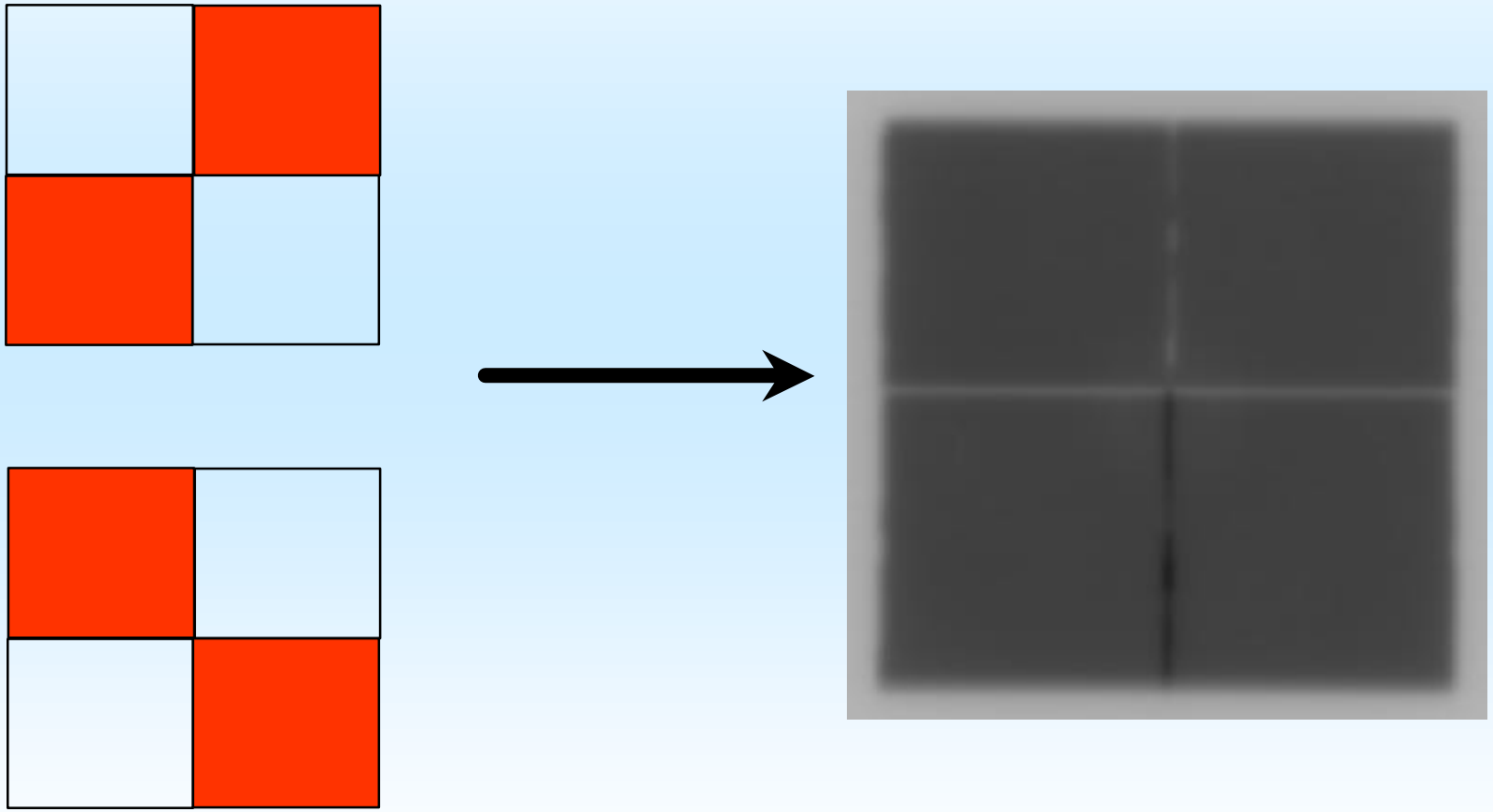
MLC QA

precise measurement

of all leaf positions is needed !

1 cm Gap **0.5mm means 5% error**

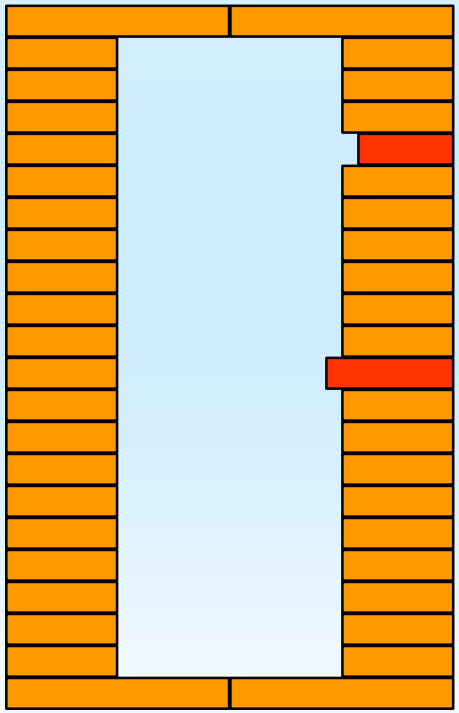
MLC QA with Film – Abutting Fields

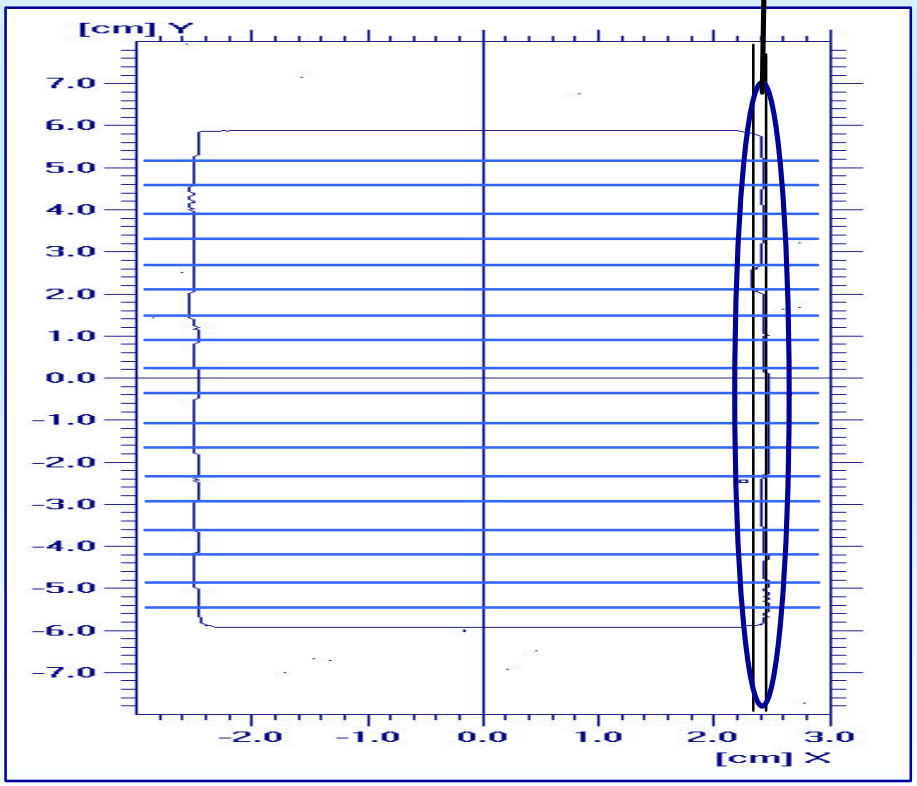


Positioning precision of ? -MLC (3D-LINE)

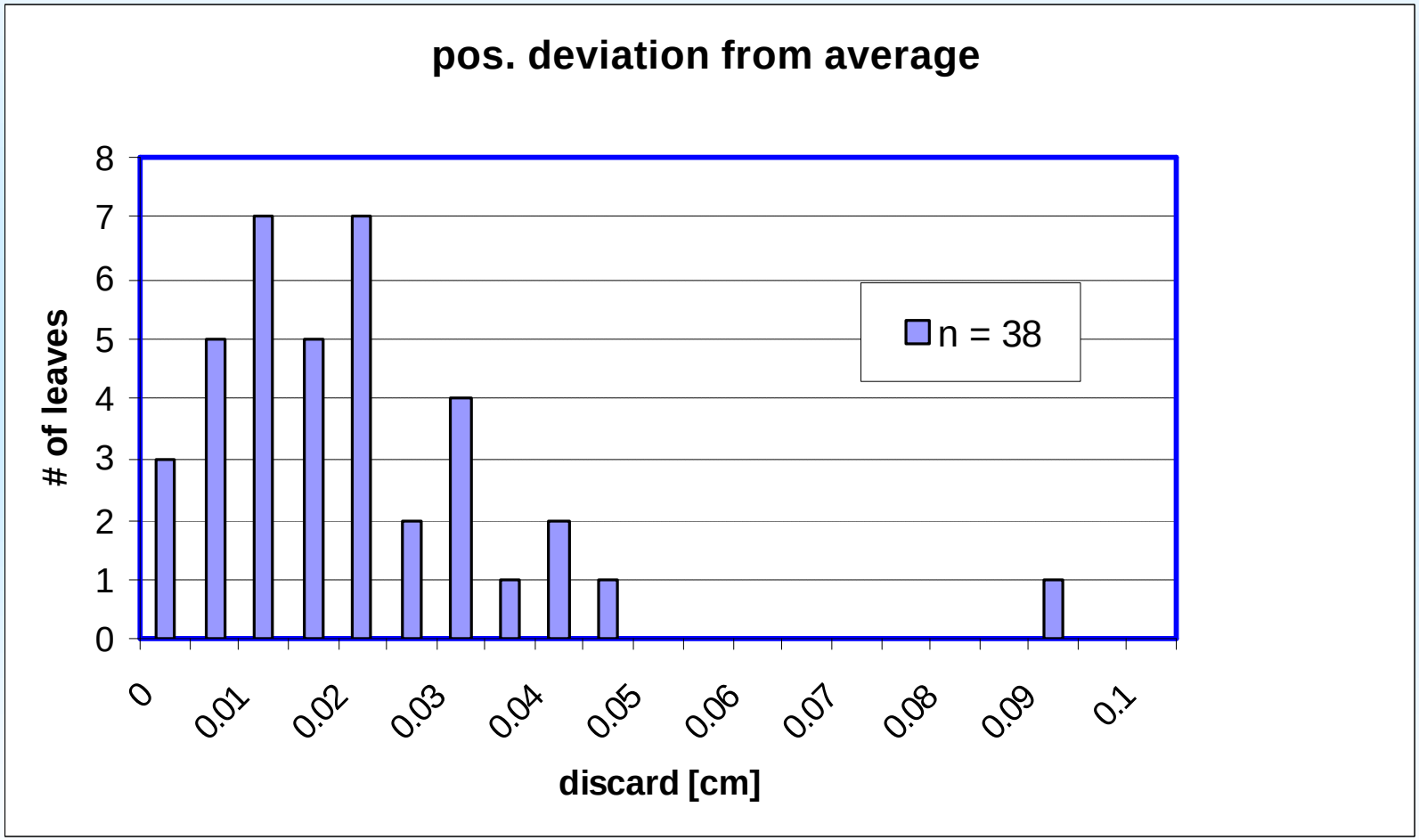
Avg. Pos = 24.6 mm

Std. Dev. = 0.36 mm

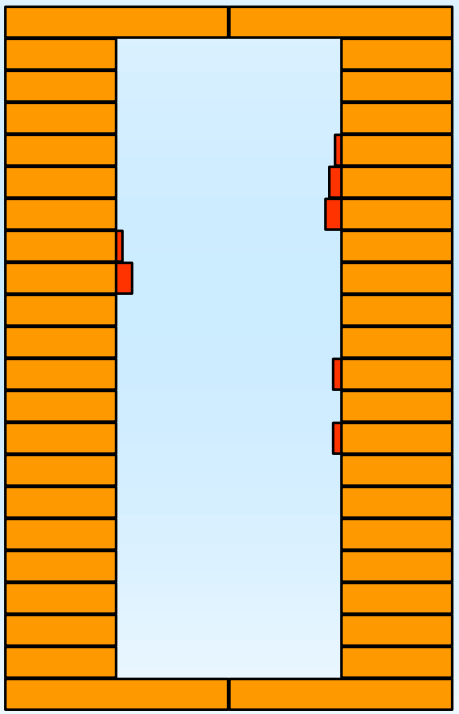


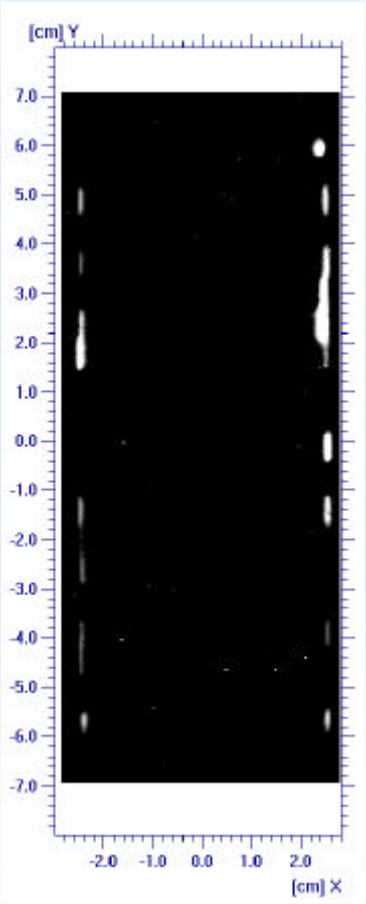


Positioning precision of ? -MLC (3D-LINE)

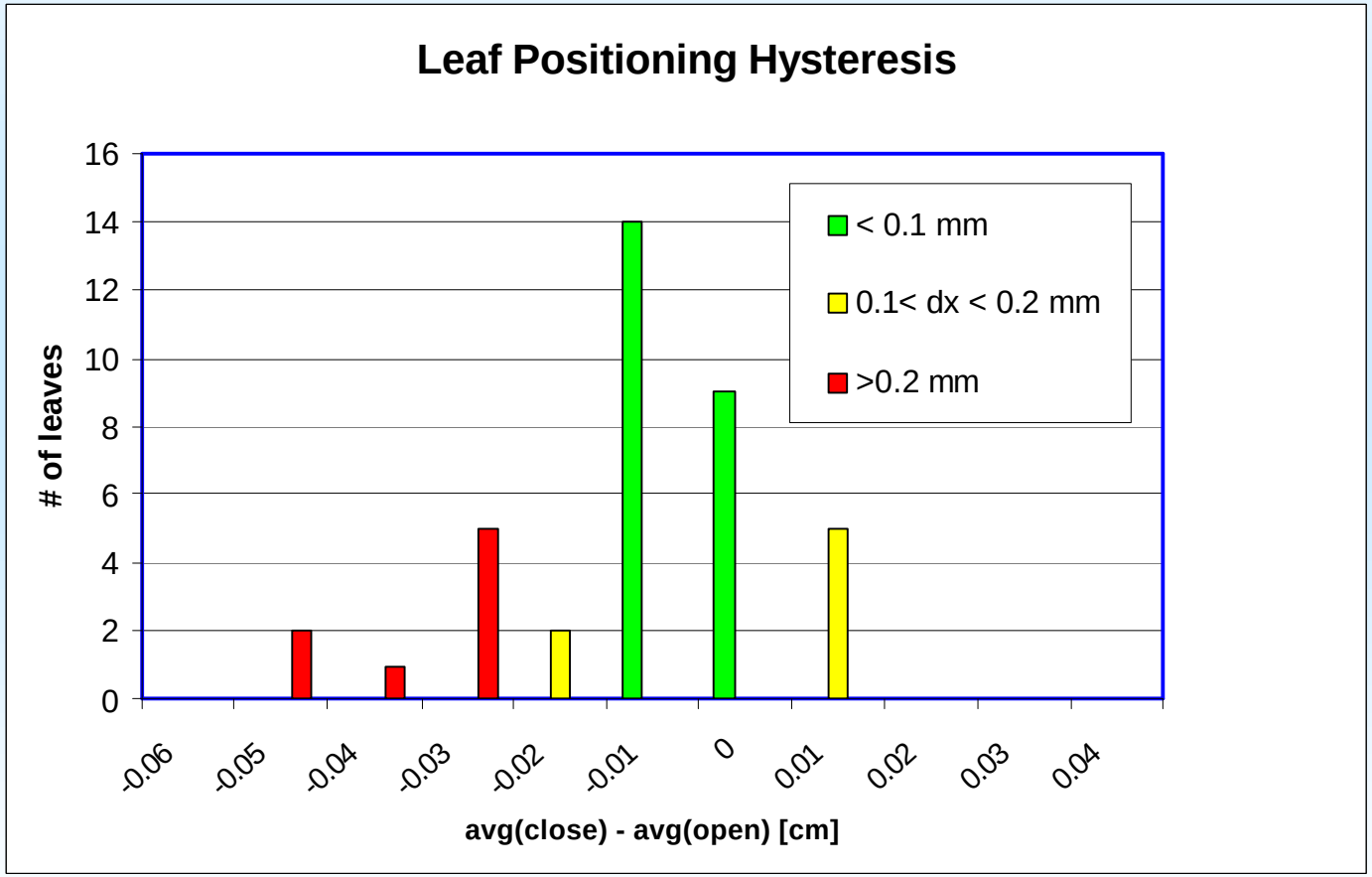


Hysteresis in Leaf Positioning

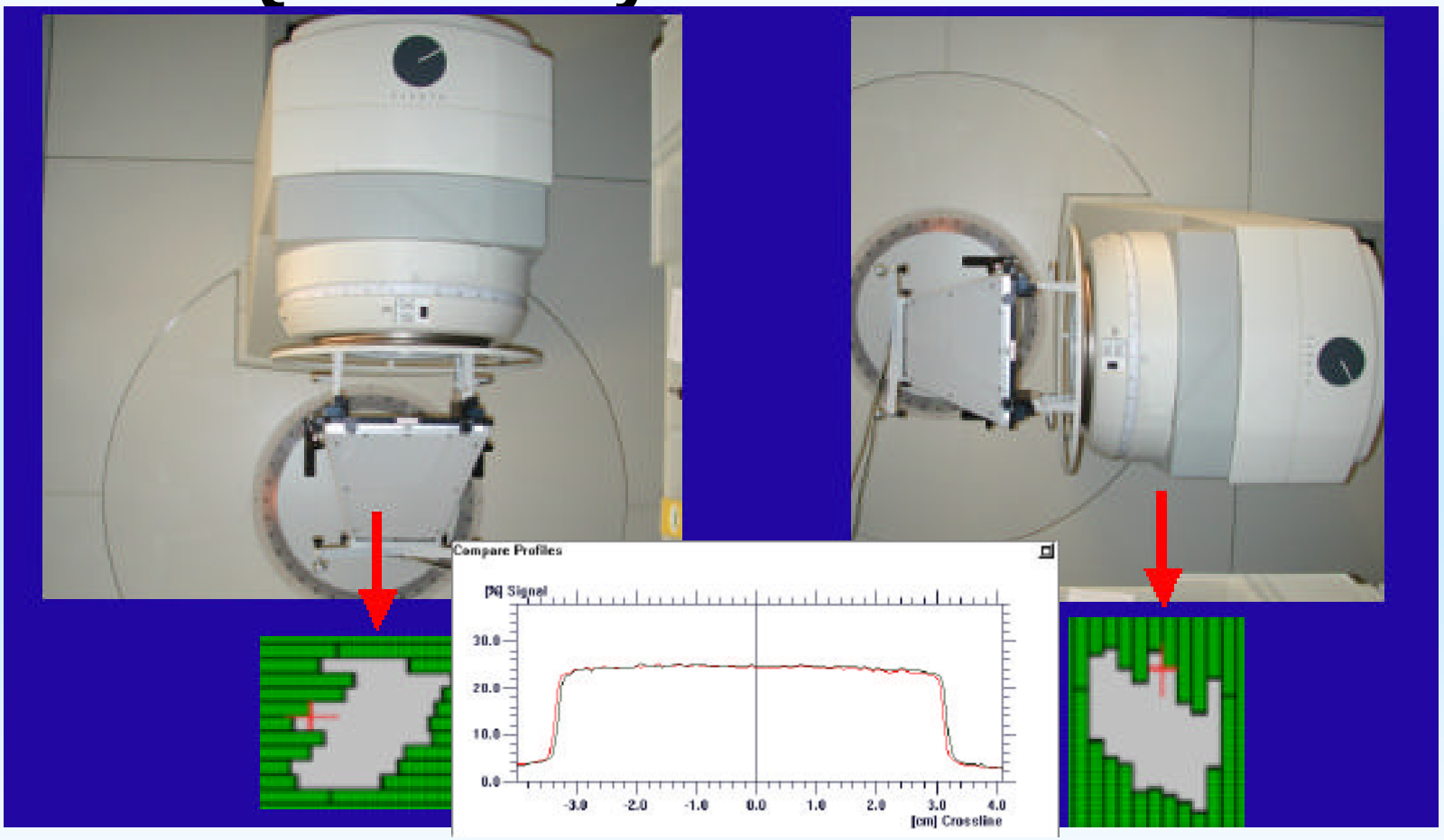




Hysteresis in Leaf Positioning

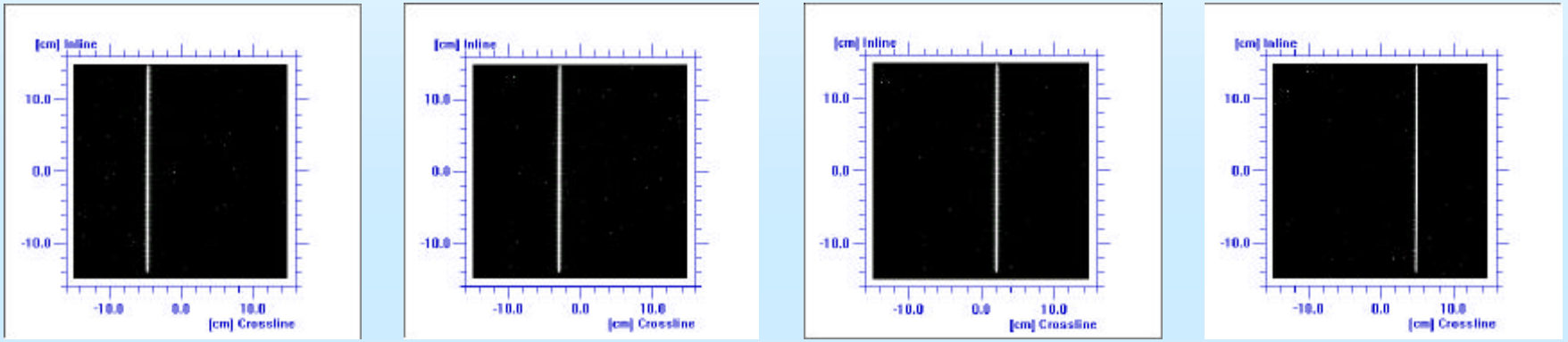


MLC QA - Gravity



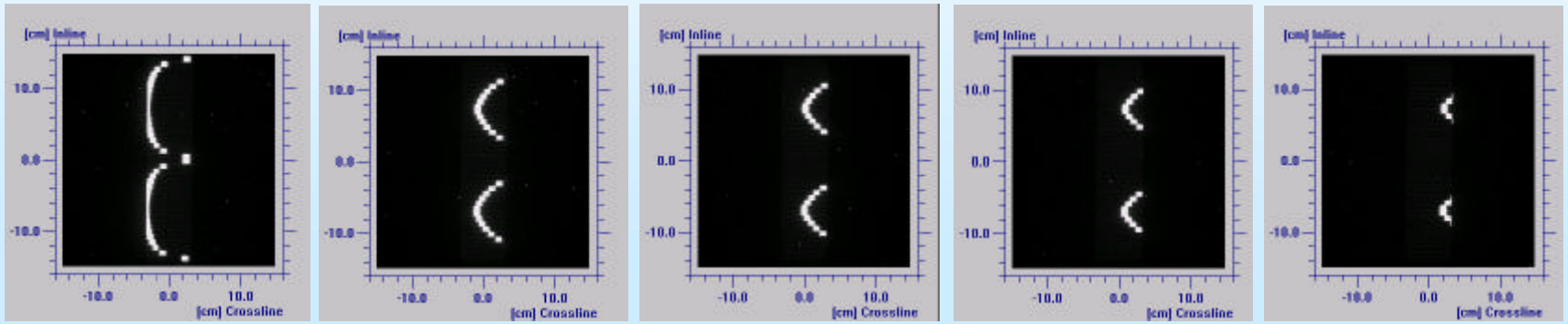
90° Gantry Orientation vs.
270° Gantry Orientation

MLC QA – ‚Picket Fence‘

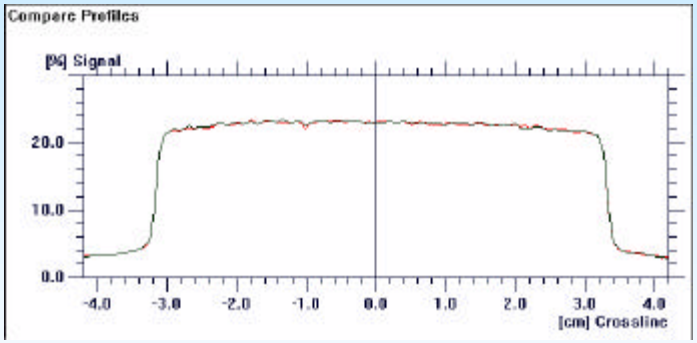


MLC pairs form a narow slot moving across the field, stopping and reaccelerationg at predefined positions

MLC QA –Leaf Speed Test

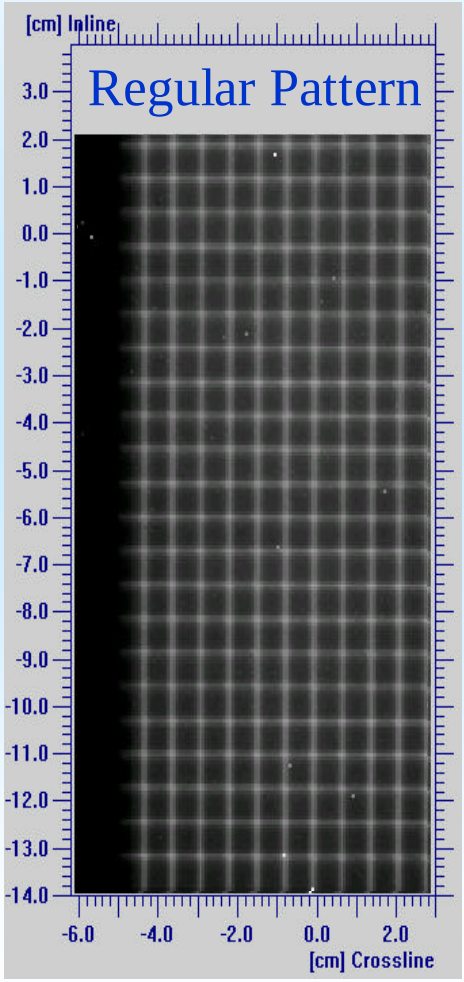


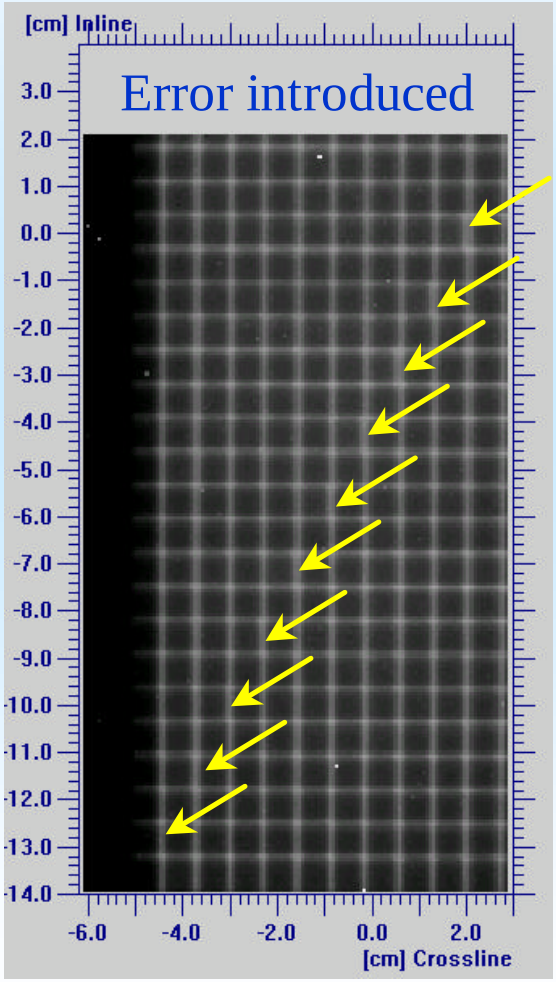
Leaf pairs form gaps moving with different speed



Delivery with beam interrupts

MLC QA – ‚Picket Fence‘

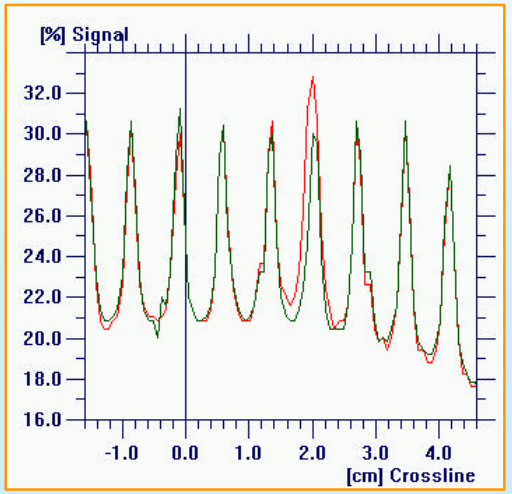




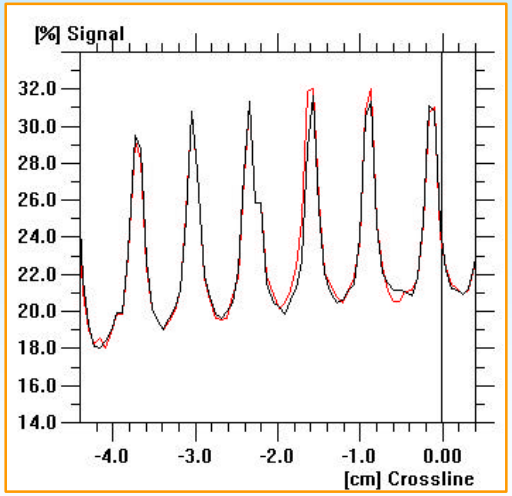
MLC QA – ‚Picket Fence‘

1.0 mm
0.9 mm
0.8 mm
0.7 mm
0.6 mm
0.5 mm
0.4 mm
0.3 mm
0.2 mm
0.1 mm

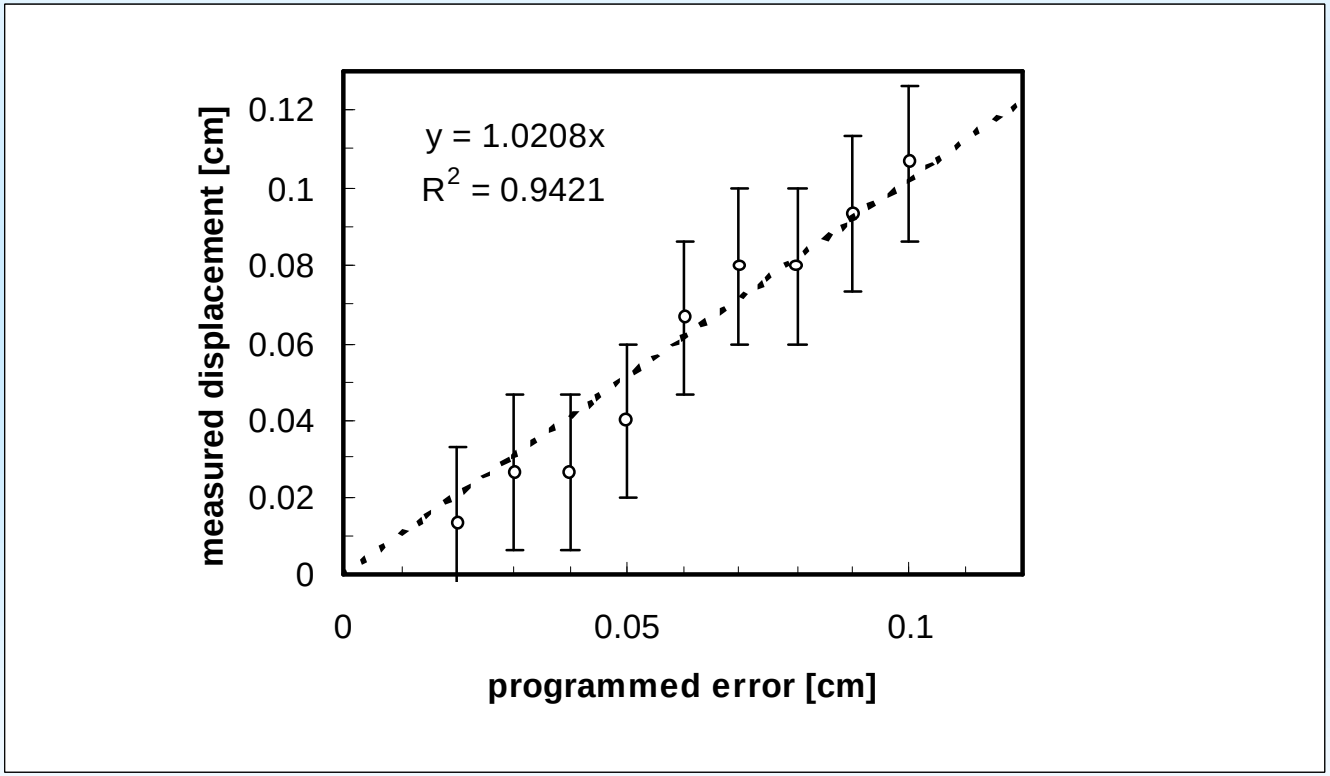
1.0 mm



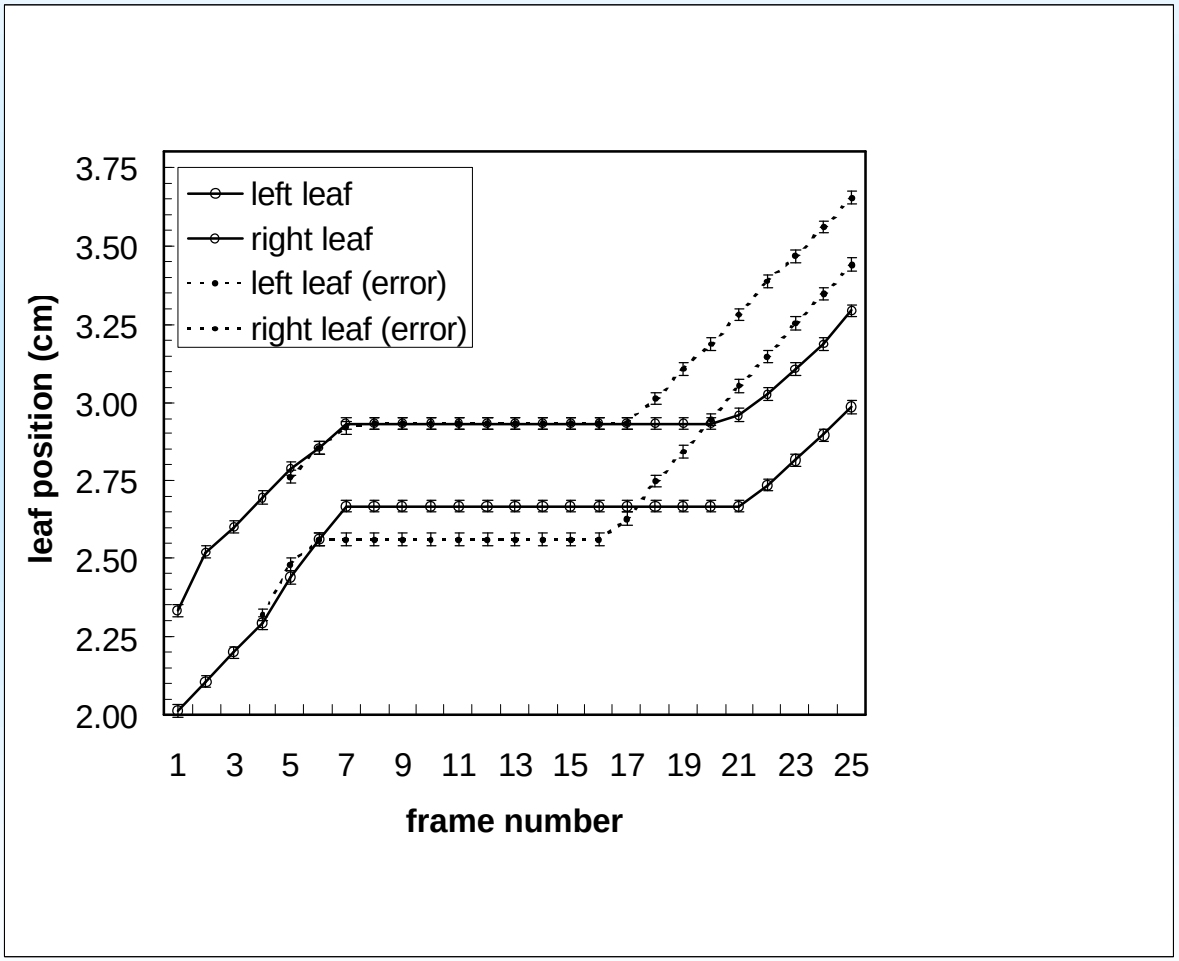
0.5 mm



Leaf Position Readout Precision



Leaf Timing Diagram

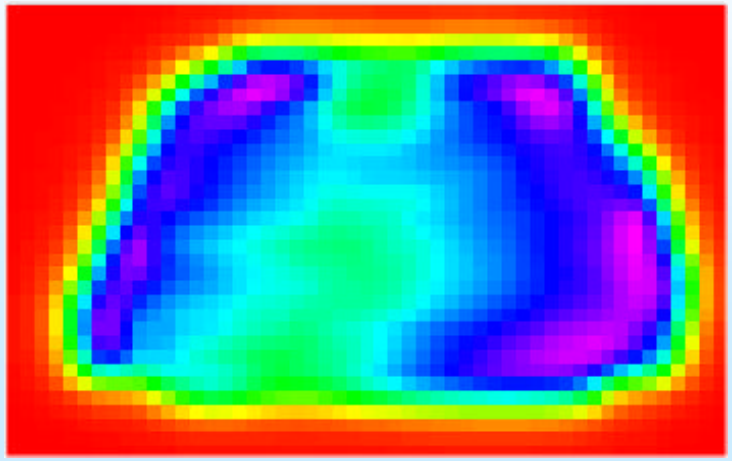



SCANDITRONIX
WELLHÖFER

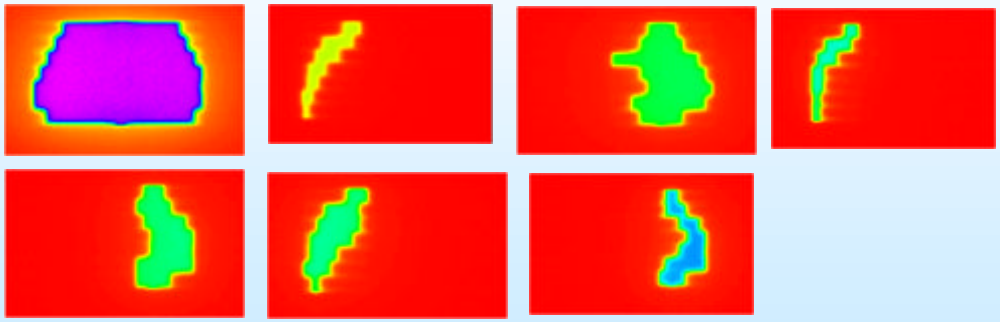
I'mRT - QA Key Features

- Fast and simple set-up: less than 5 minutes.
- Positioning on table or in gantry accessory holder
- Acquisition of individual segments or entire IMRT field
- Minimum acquisition time: 120 msec per 2D image
- Intensity resolution: 12 bit
- Spatial resolution 0.4 x 0.4 mm
- Field size up to 400 x 400 mm
- Acquisition and analysis integrated in OmniPro-IMRT software platform

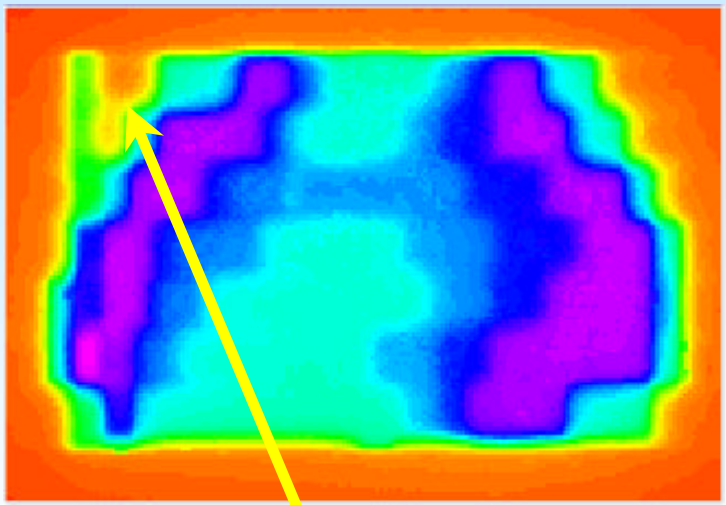
Verification of intensity modulated pattern



calculated plan

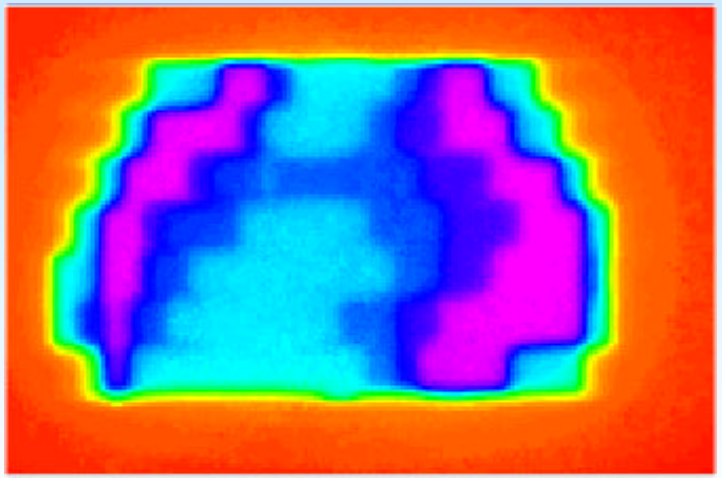


Individual segments



Delivery error!

I'm*RT*-QA



After error analysis & correction

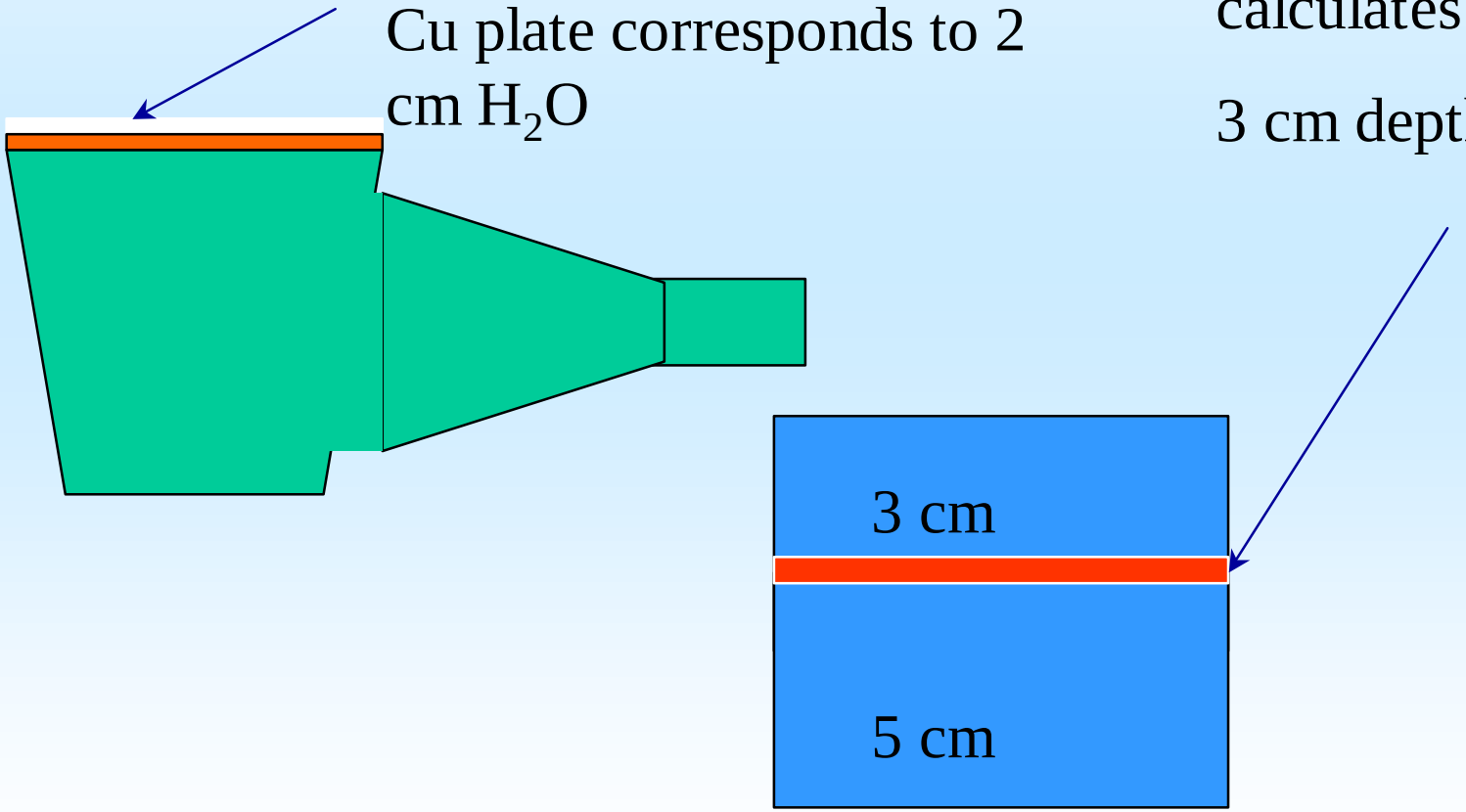
Use of 2-d Dose Distribution for Verification (Measurements at IGR Paris)

1 cm solid water on BIS,

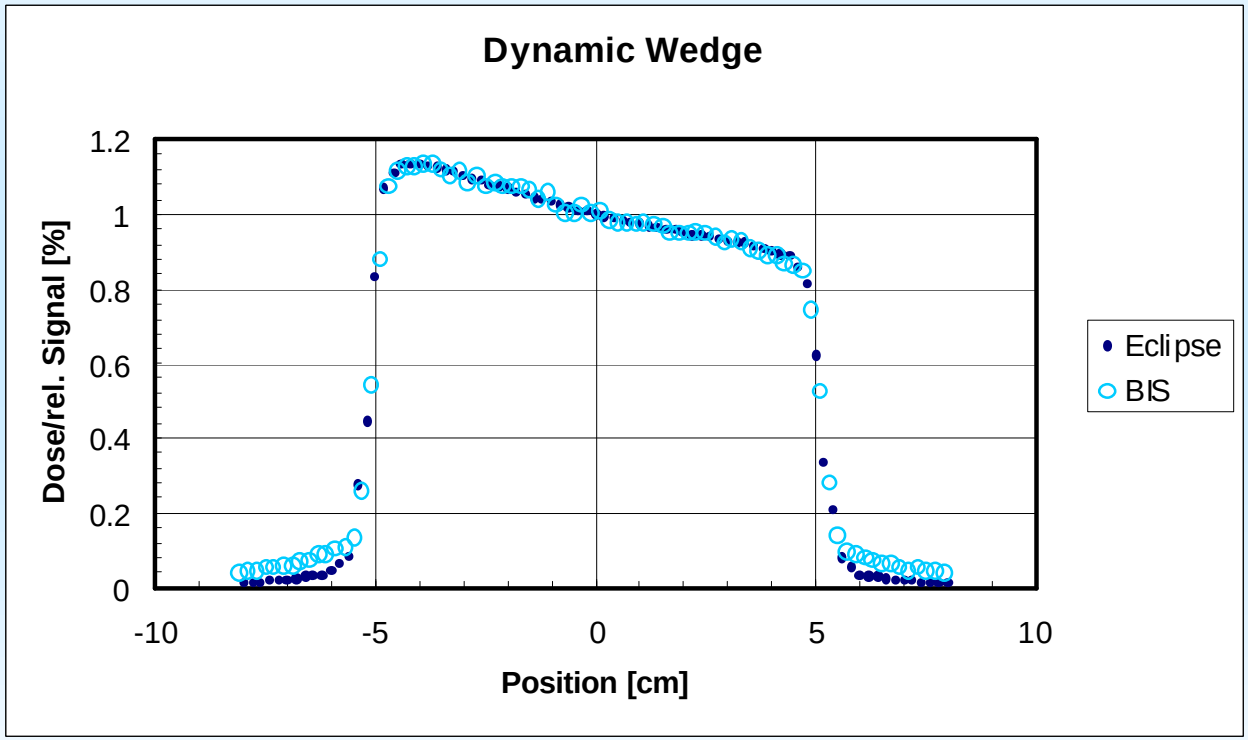
Cu plate corresponds to 2 cm H_2O

CadPlan calculates in

3 cm depth



Dynamic Wedge



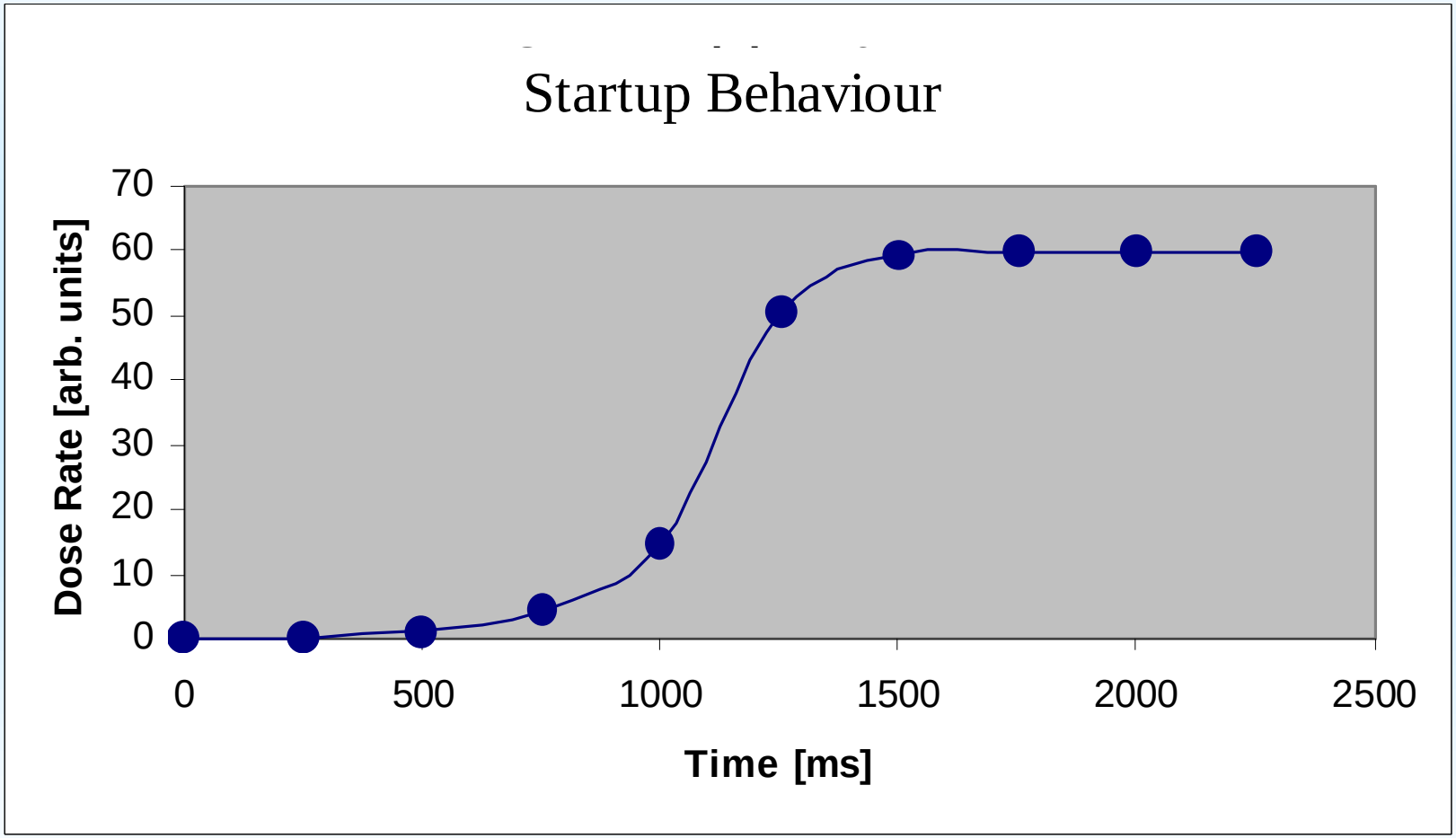
Verification of IMRT

Quantity	Calculation	Measurement
3-D Dose Distribution	Apply Plan to Phantom. Calculate 3-D Dose Distribution	Put Films in the Phantom. Process, Scan, Calibrate Films. Compose 3-D Dose Distribution
2-D Dose/Fluence	Calculate Fluence Pattern or 2-D Dose Distribution	BIS Integrated Fluence Pattern
Leaf Positions MLC QA	Leaf Positions from TPS	Leaf Positions from single BIS Images
MU/Dose Check	Dose in a reference Point	Ion Chamber in Phantom
Penumbra measurement	Needed for TPS Set-up	Small Ion Chamber or Diode in 3-D-Phantom

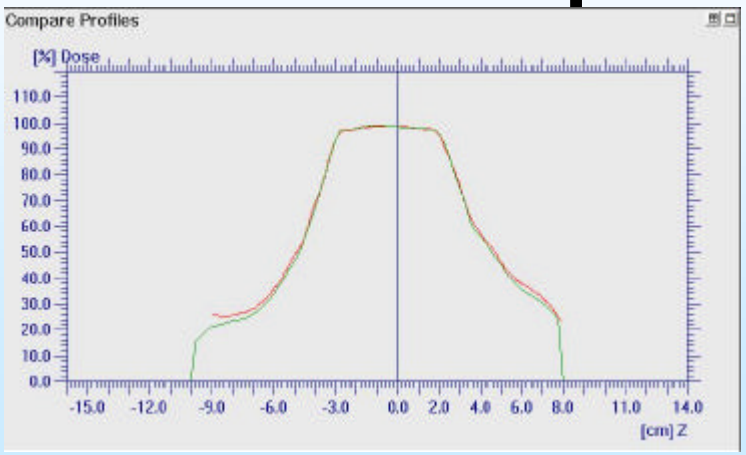
IMRT dosimetry applications

- Verification of the planned versus delivered dose
- Verification of the IMRT delivery prior to a treatment
- MLC QA
- Monitor Unit calculation
- Penumbra measurements

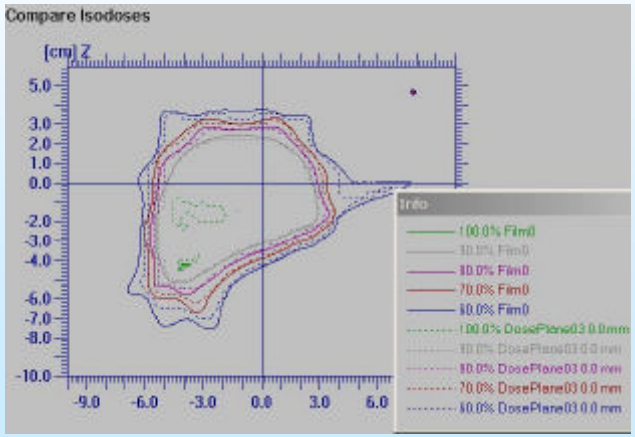
Startup behaviour



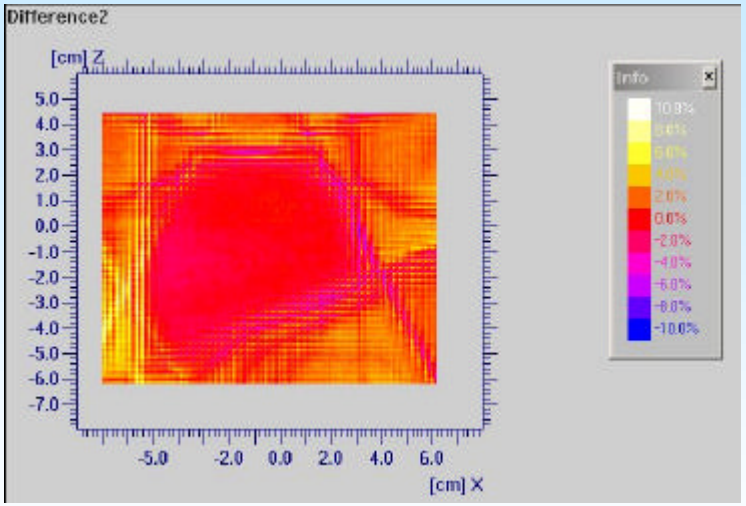
Dose Comparison Methods



Profiles

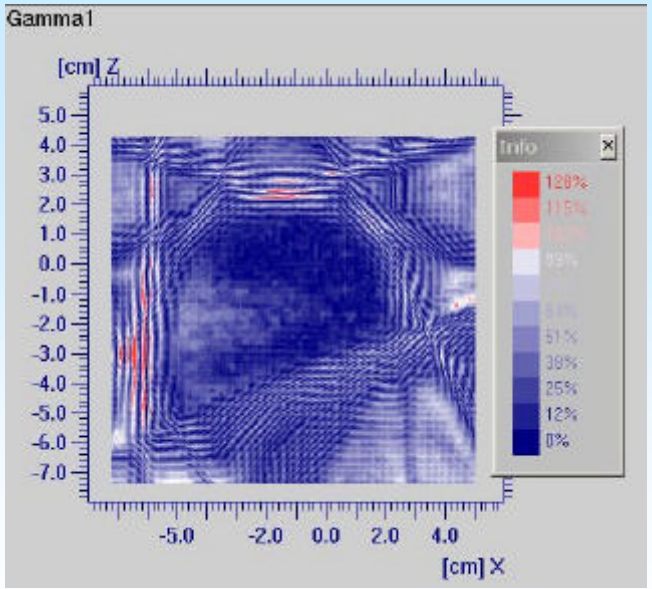


Isodoses

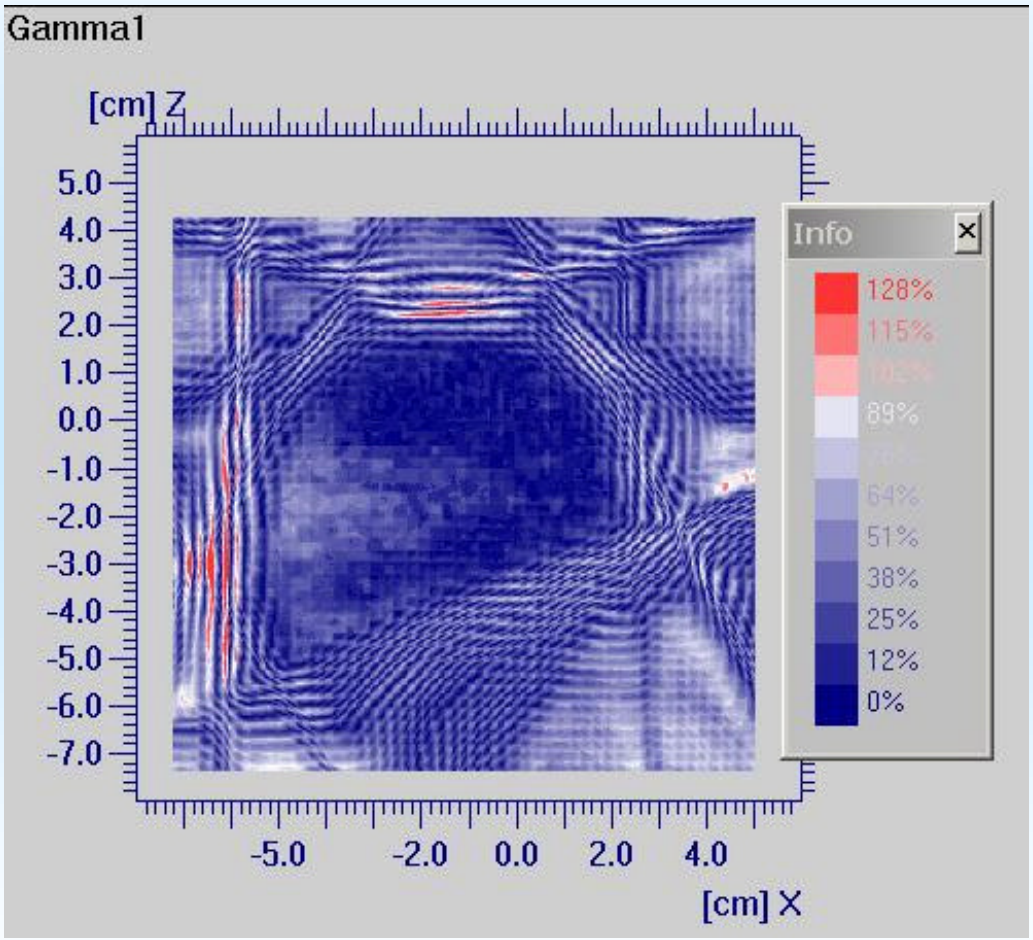


Difference

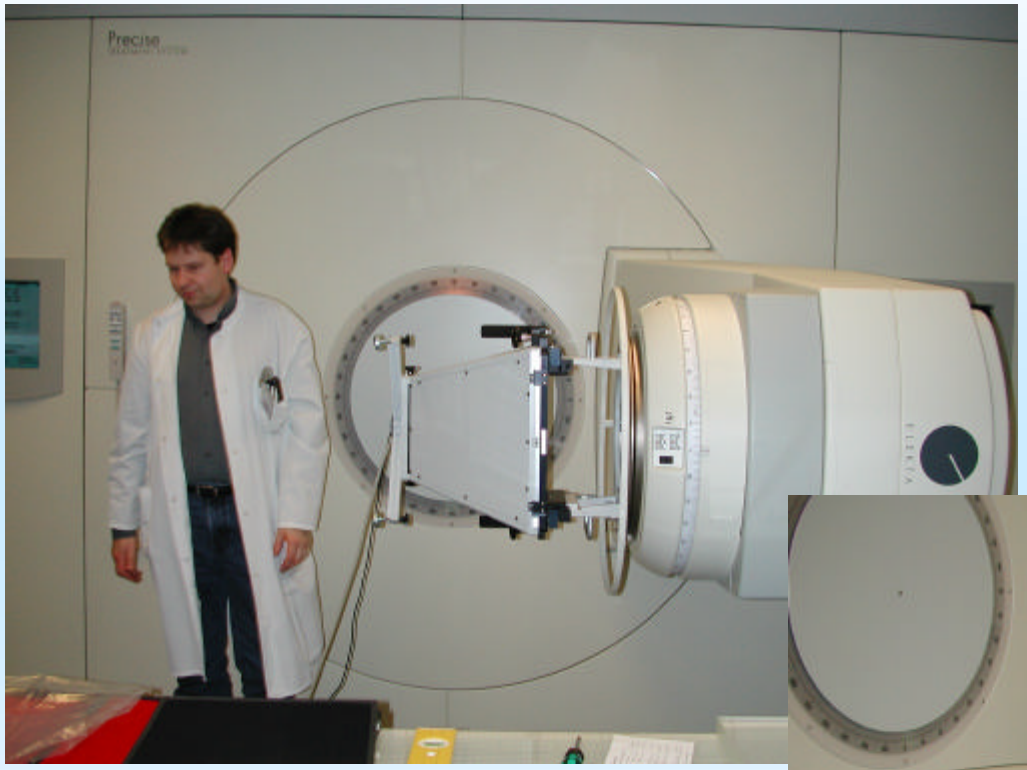
Gamma



Gamma evaluation (3mm/3%)



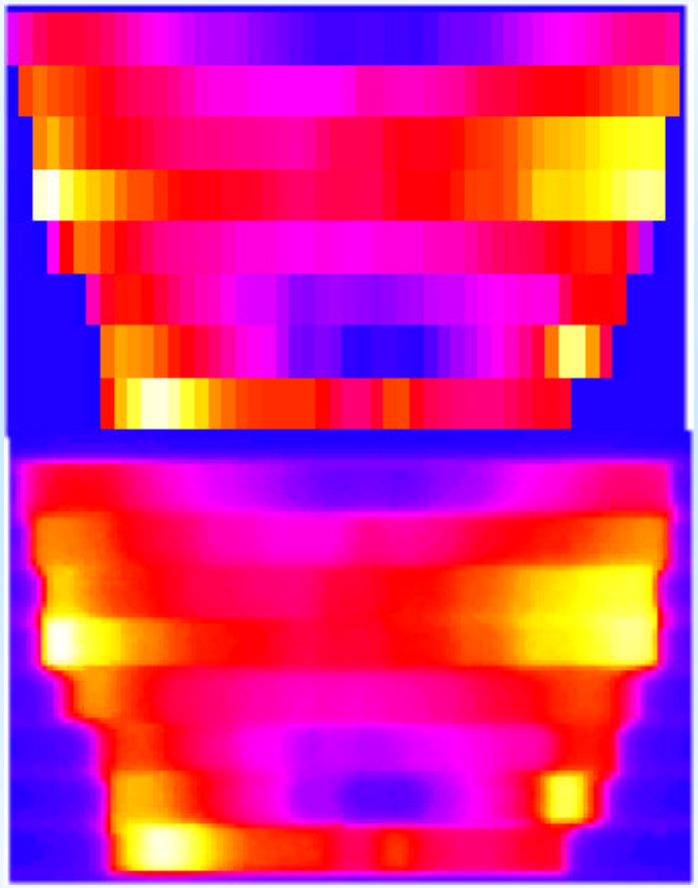
BIS2G attached to the gantry



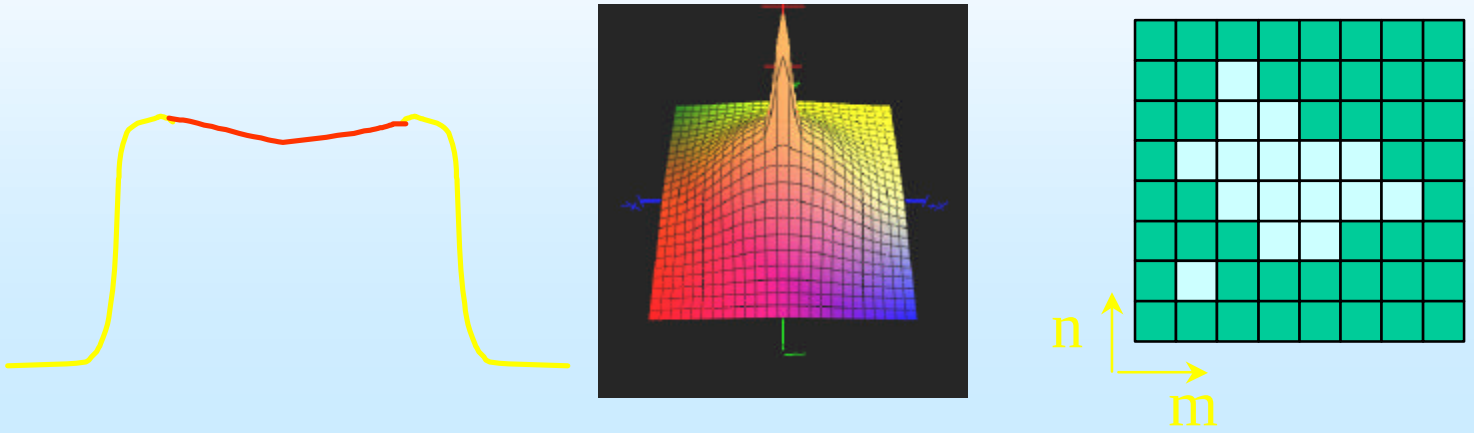
The Gantry is turned around 90 degrees.

BIS-System already assembled into the adapter. The accelerator is turned around 180 degrees.

BIS vs. Cadplan



Fluence reconstruction – more complex



$$? _{x,y} ? ? (x,y) ?? S(x ? x', y ? y') T(x ? x', y ? y') dx' dy'$$

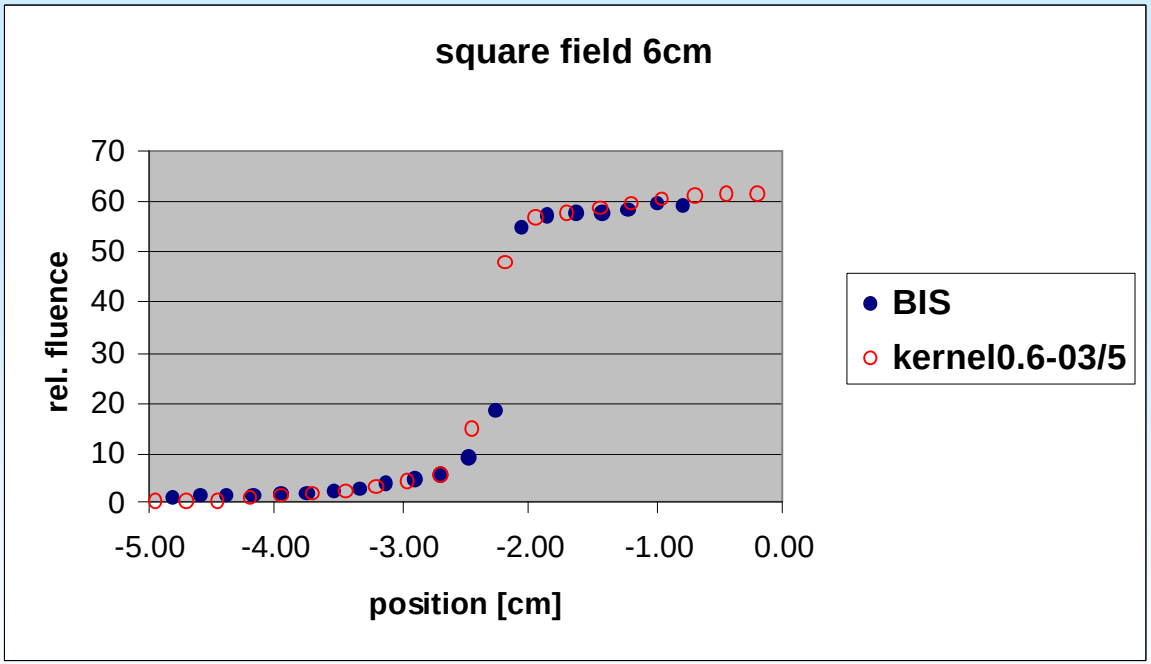
Open field	Double-Gaussian	Transmission
w/o penumbra	Kernel (from penumbra)	through MLC 1 or 0

L.Ma, P.Geis, A.L.Boyer, Med Phys 24(8), 1997

Fit of penumbra region

Double-Gaussian Kernel:

$$I(x_0, y_0) = \sum_{x,y} I_0(x,y) \exp\frac{-(x-x_0)^2 - (y-y_0)^2}{\sigma_1^2} + \exp\frac{-(x-x_0)^2 - (y-y_0)^2}{\sigma_2^2}$$



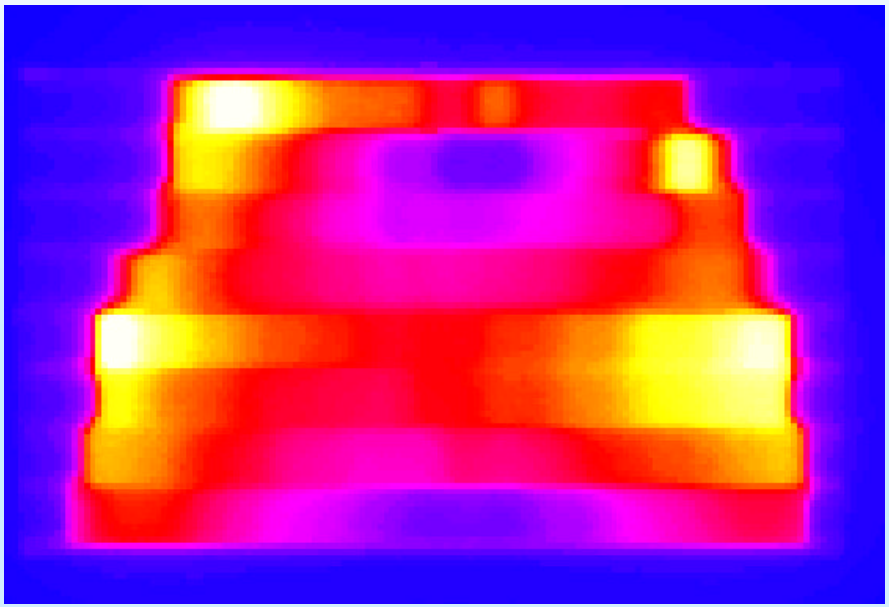
Fit to Penumbra region (square field):

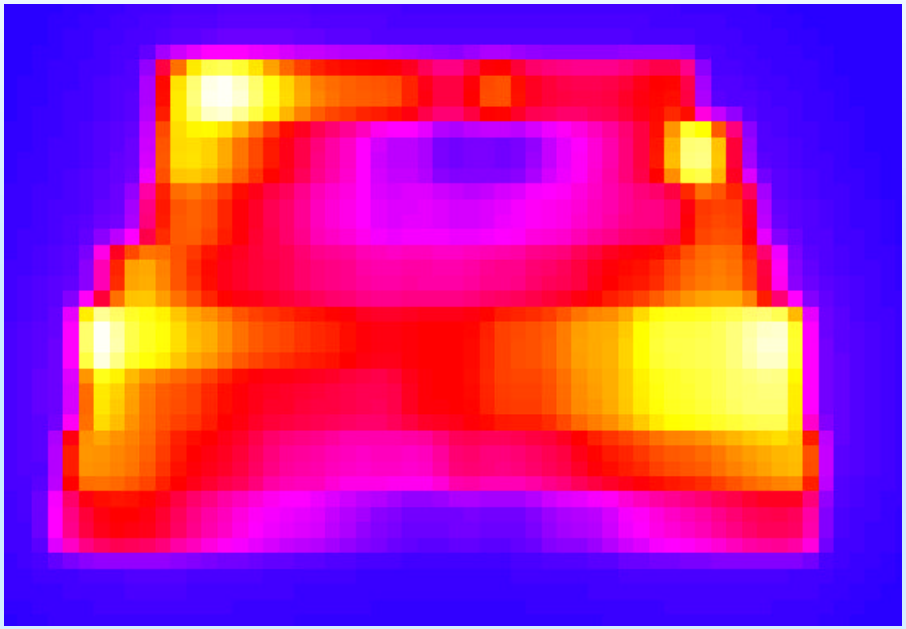
σ_1=0.6mm

σ_2=3 mm

????

Double-Gaussian Kernel

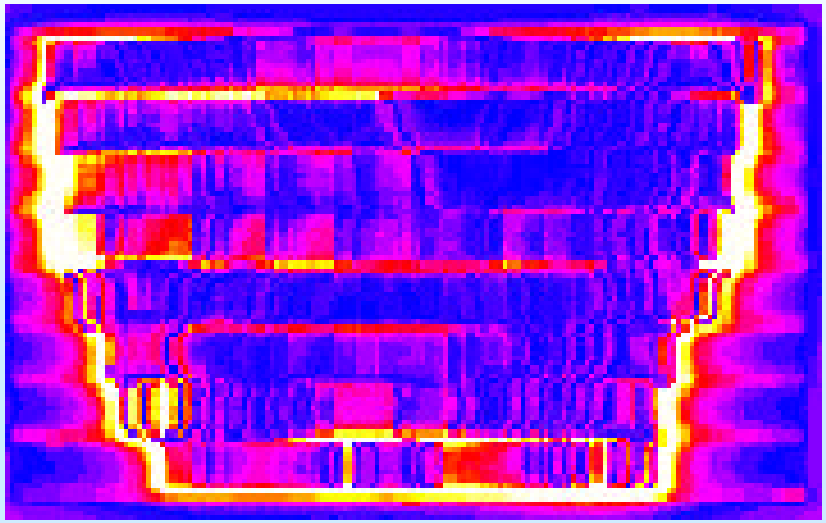




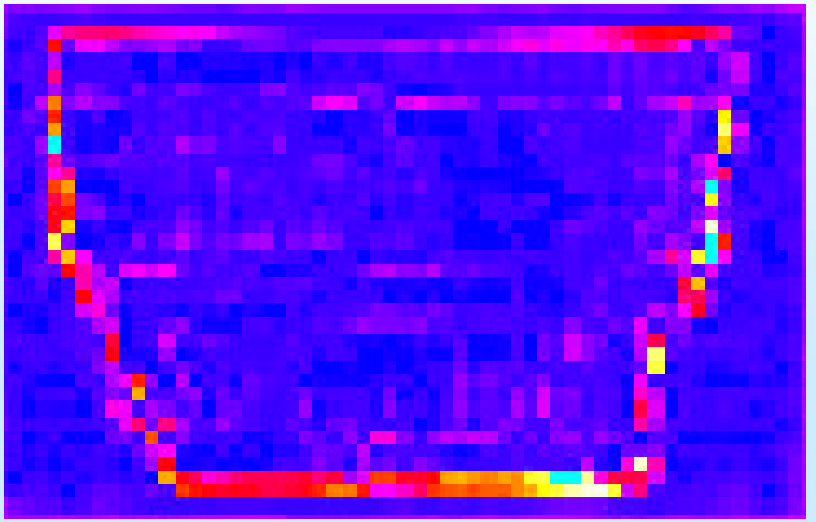
BIS measured

Cadplan / double gaussian kernel

Gamma Index



Cadplan raw fluence



Double Gaussian Kernel

? x = 3mm, ? D = 3%

MLC QA with BIS^{2G}

BIS^{2G} is an ideal tool for accurate and fast MLC QA:

1. High spatial resolution (0.4x0.4mm),
2. High acquisition speed (120ms/frame) and
3. Gantry mount

MLC QA techniques:	leaf positioning accuracy and reproducability
	acceleration and deceleration of leafs
	gravity effect
	leaf transmission (leakage)
	visualization on-line MLC movement

IMRT dosimetry applications

- Verification of the planned versus delivered dose
- Verification of the IMRT delivery prior to a treatment
- MLC QA
- Monitor Unit calculation
- Penumbra measurements