Characterization, Commissioning and Evaluation of Delta^4 IMRT QA System

Ram Sadagopan
[1]UTMD Anderson Cancer Center Houston, TX.

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Acknowledgements

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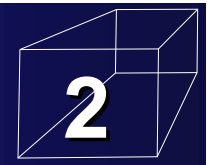
- Jose Bencomo, Rafael. M. Landrove, Peter Balter, Sastry Vedam and Görgen Nilsson
- Core Physics group at MDACC for their support

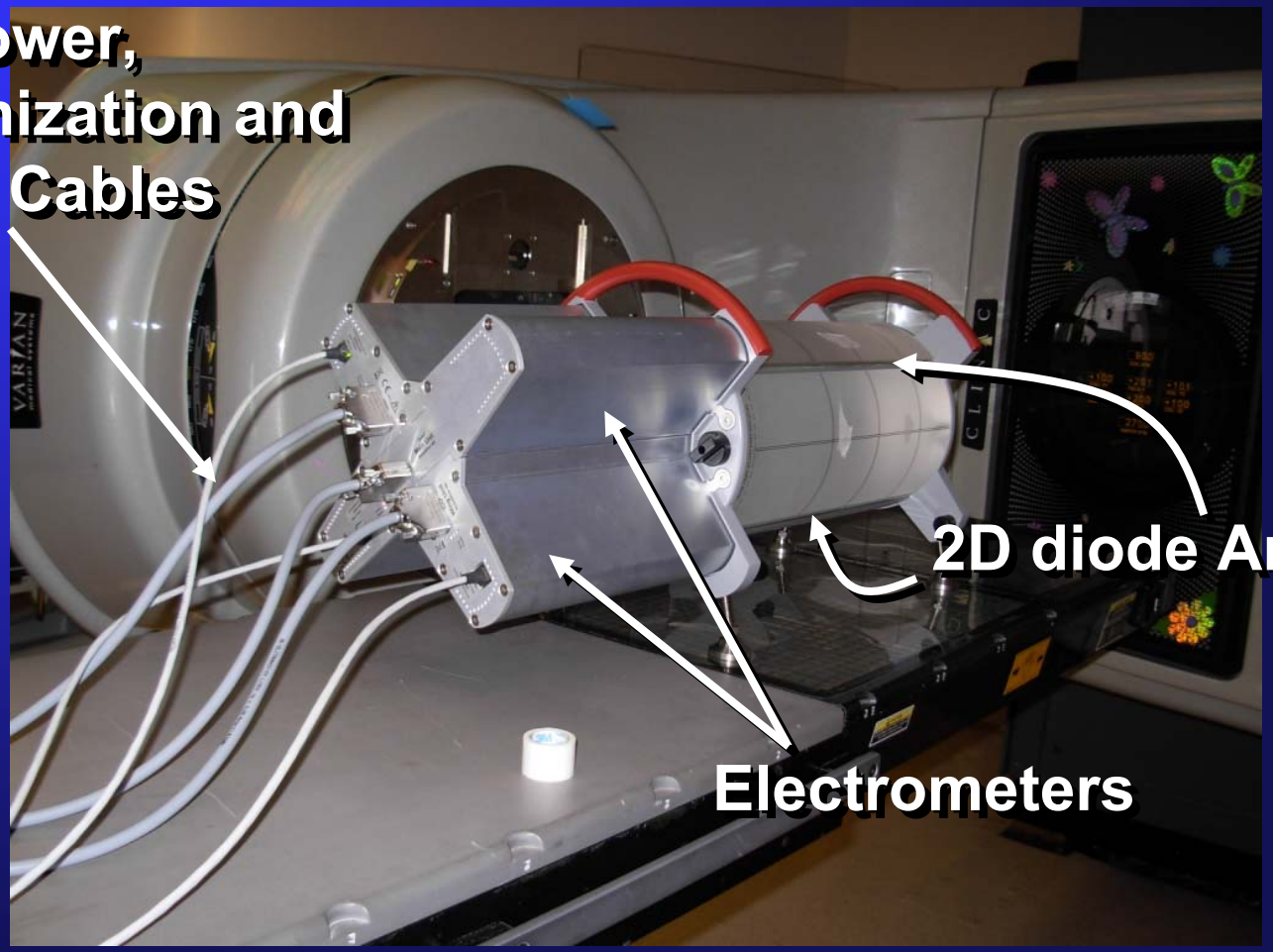
Introduction



- IMRT dose distribution is complex and requires QA
- Current IMRT QA provides limited points and planes and the Gamma analysis is only 2D
- Labor intensive
- Leaves voids in the evaluation of plan and its delivery
- Field by Field and Segment by Segment analysis is typically not possible
- Does not readily extend to 4D

***Question**: Does the DELTA^4 system potentially address these drawbacks?*

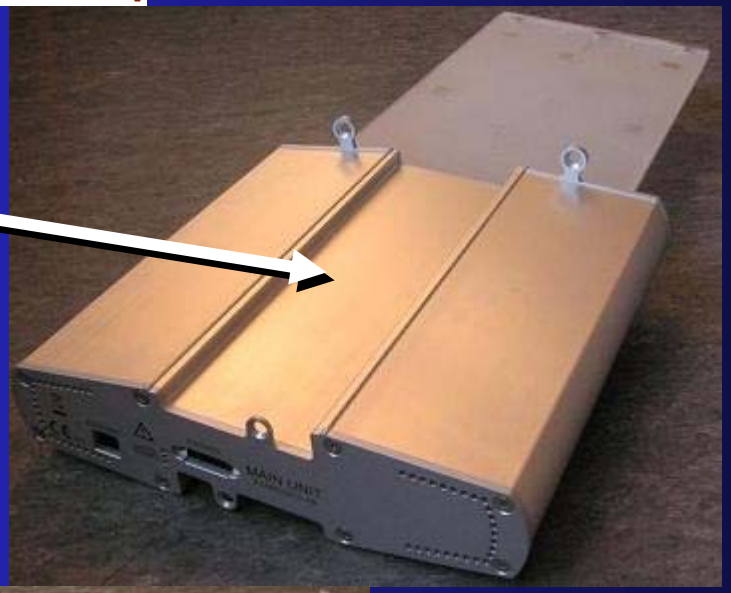
Delta^4 Device Fully Assembled

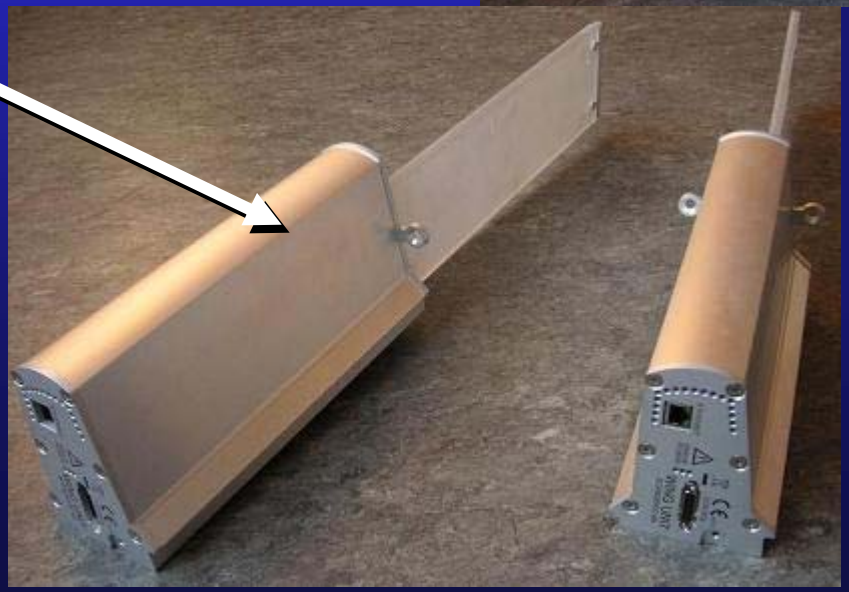


Currently commercially available

2D Detector Arrays Units

- Main Unit
- Detection Area 20x20 cm^2
- Sensitivity 5nC/Gy
- Wing Unit



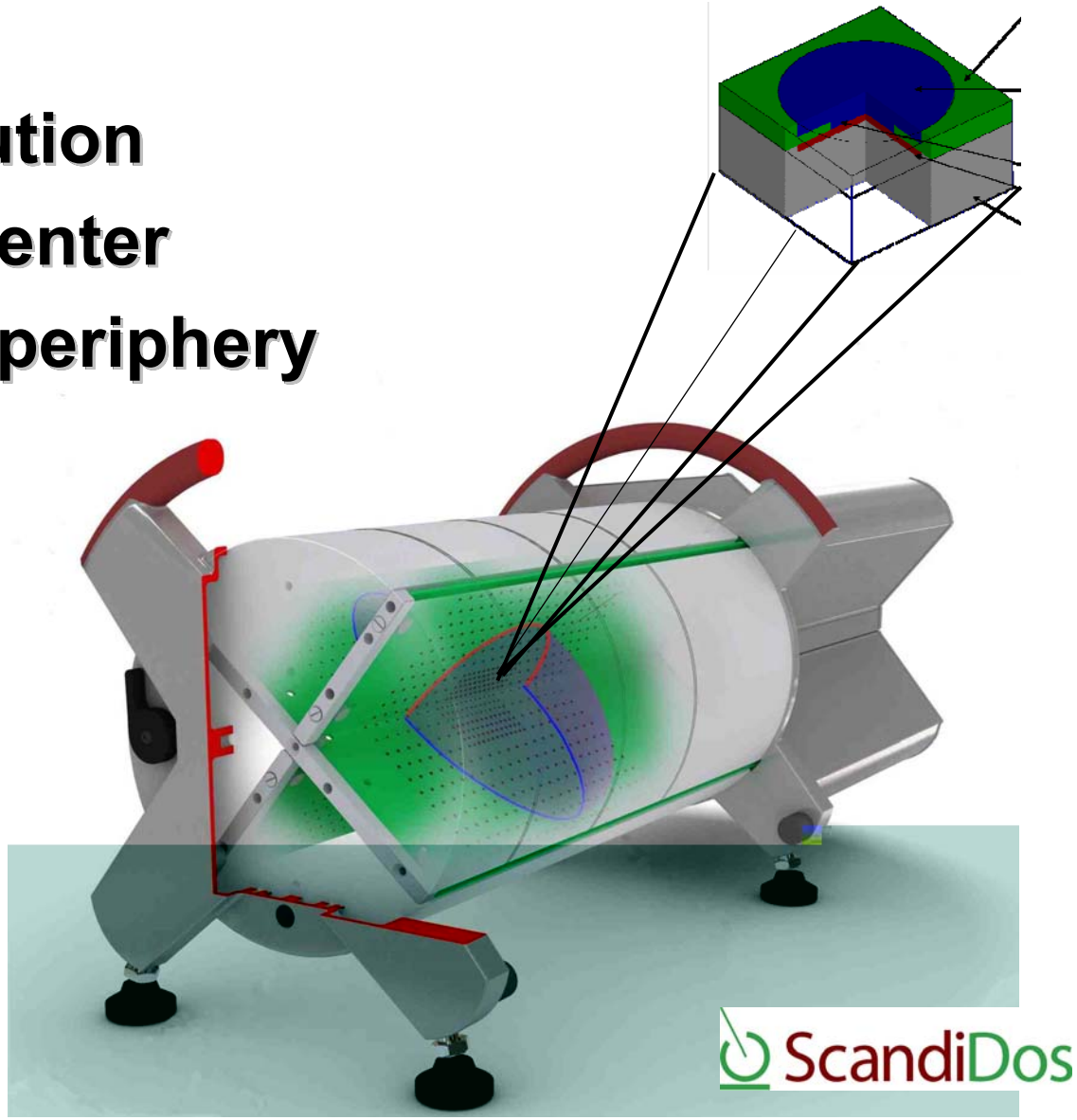


ScandiDos

Detector Arrays

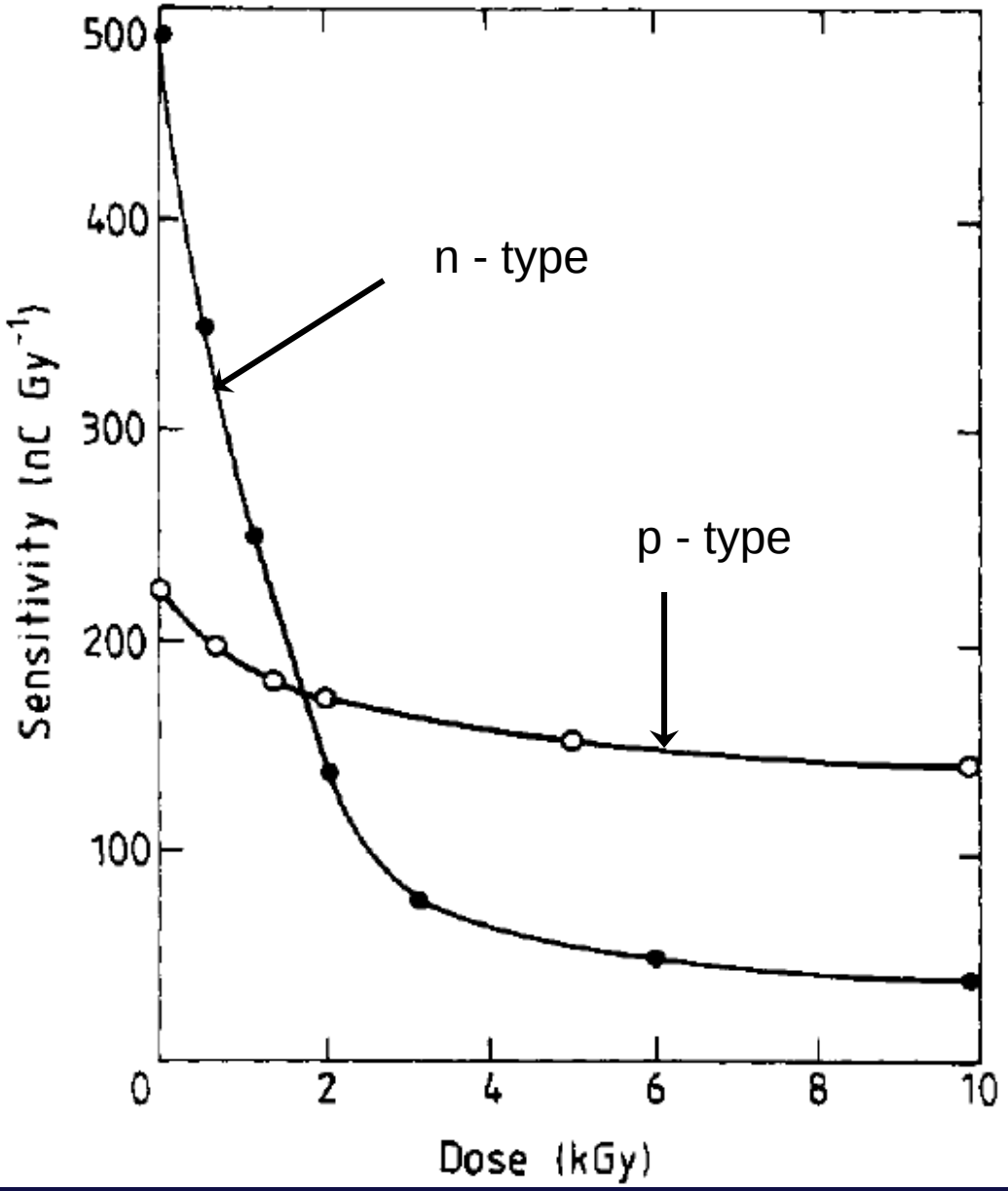
- p-diodes in absolute dose mode
- High spatial resolution
- 5 mm spacing at center
- 10 mm spacing at periphery
- 1069 diodes

Area: 0.78 mm^2
Height: 0.05 mm



G Rikner and E Grusell

Phys. Med. Biol., 1987, **Vol. 32,** No 9, 1109-1117.



G. Rikner and E. Grussell

General specifications for silicon semiconductors for use in radiation dosimetry

Phys. Med. Biol., 1987, **Vol. 32,** No 9, 1109-1117.

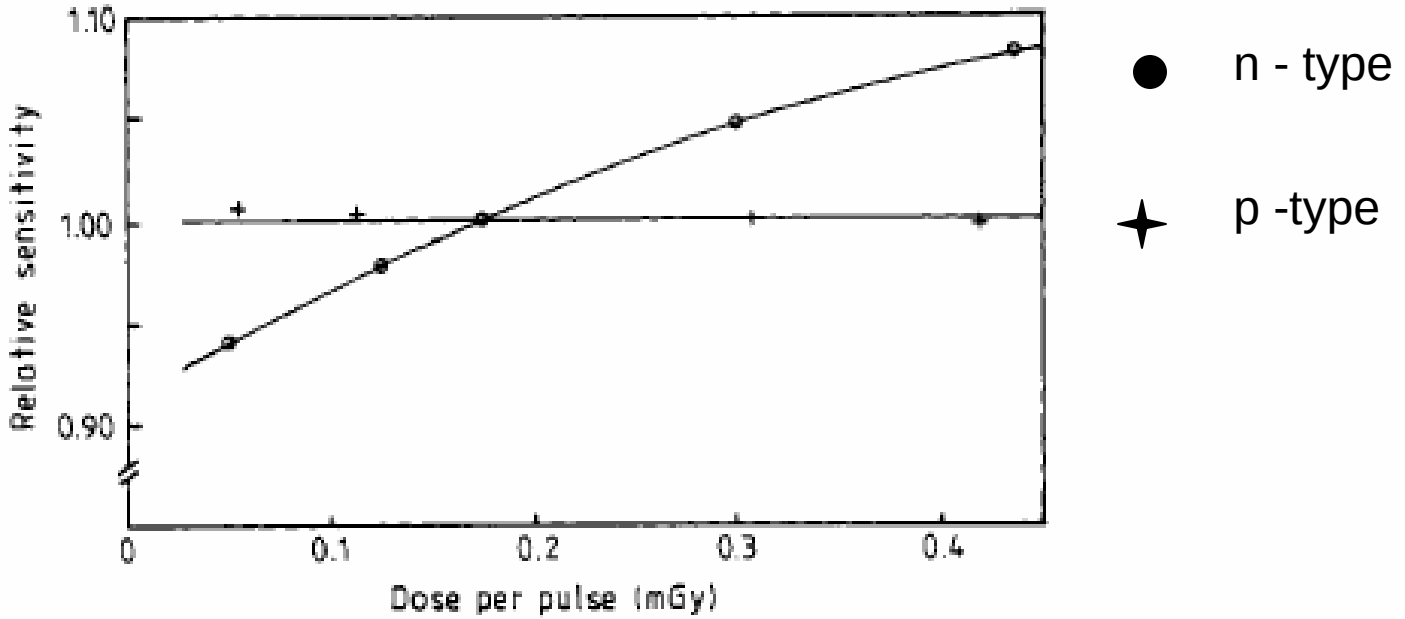
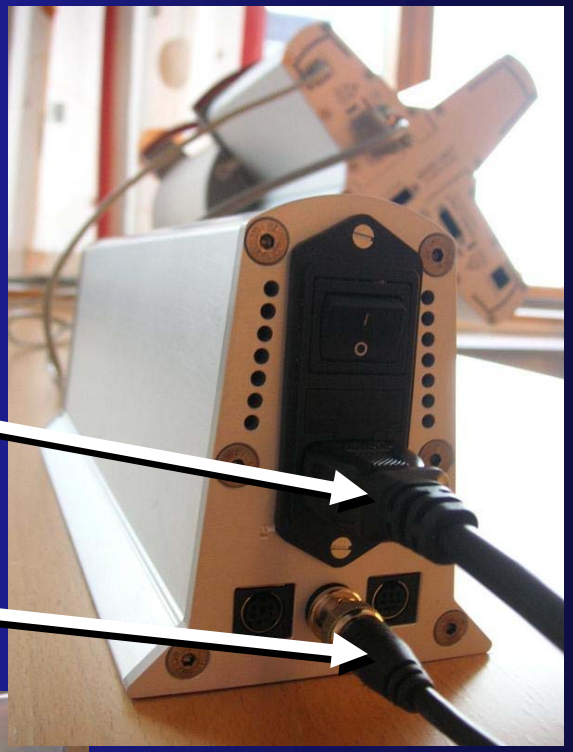
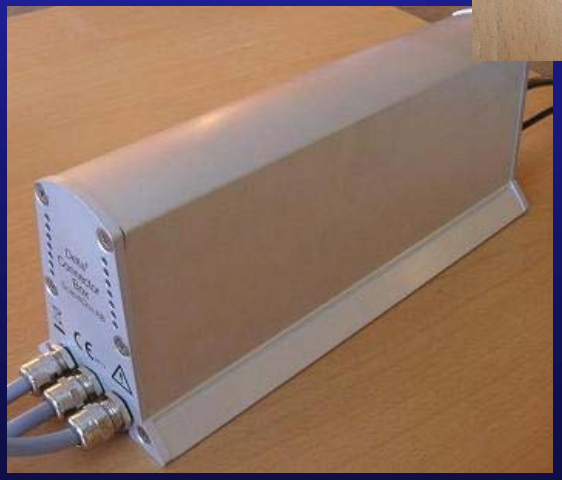


Figure 4. Ratio between signals from a semiconductor detector and an ionisation chamber, measured in 8 MV x-rays, as a function of dose per pulse. Data for p-type detectors pre-irradiated to 25 kGy (+) and n-type detectors pre-irradiated to 10 kGy with 20 MeV electrons (⊖) are shown (from Grusell and Rikner 1984).

Power Distribution System

- Provides each detector unit with power
- Provides (external) synchronization signals to detector units

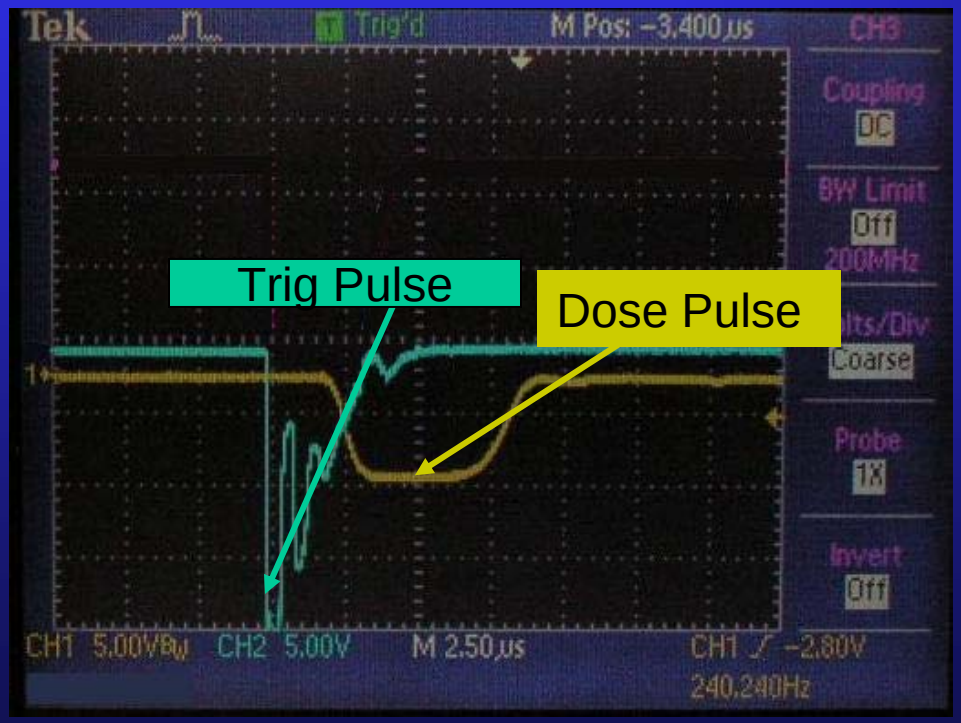




ScandiDos

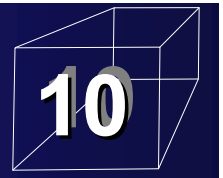
Pulse by Pulse Measurements

- All diodes readings are recorded with time stamp and reset after each pulse



- Segment by Segment and 4D measurements possible
- Approximate pulse separation is 3ms and width is 3ms
- No measurement between pulses, results in a high signal to noise ratio

Characterization Measurements



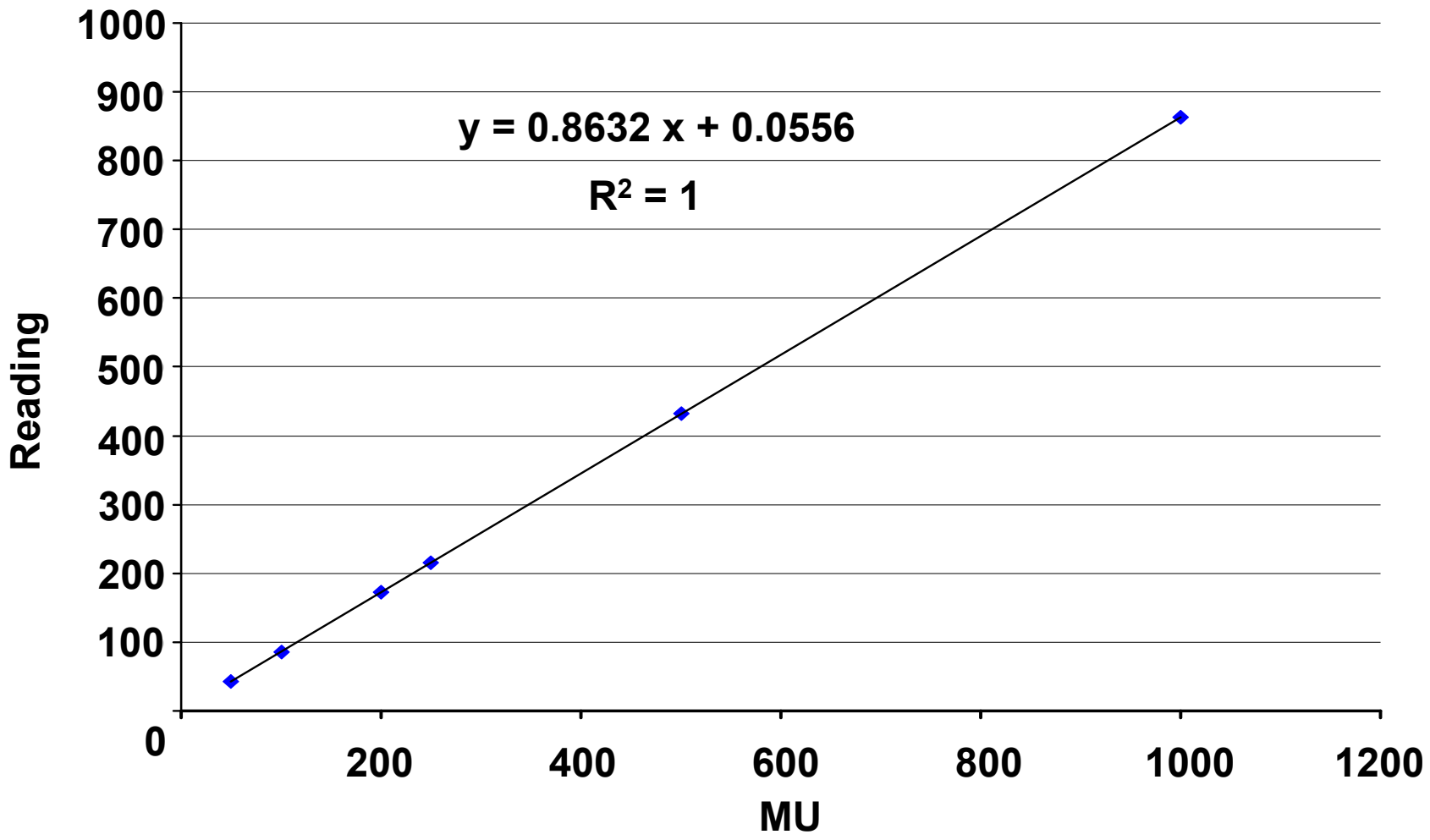
- Precision
- Stability
- Linearity
- Dose rate (pulse rate) dependence
- Dose per pulse rate dependence
- Beam directional dependence
- Energy dependence
- Interpolation at non detector location
- Sensitivity change – about 1% kGy

Results

- **Precision**
  - 1σ = 0.1%, Range from 0 to 1% measured exposing single field 10 times in a 6 MV beam
- **Stability**
  - 1σ = 0.6%, Range from 0 to 0.5% (Five measurements of 4 Field box distribution over a 3 month period)

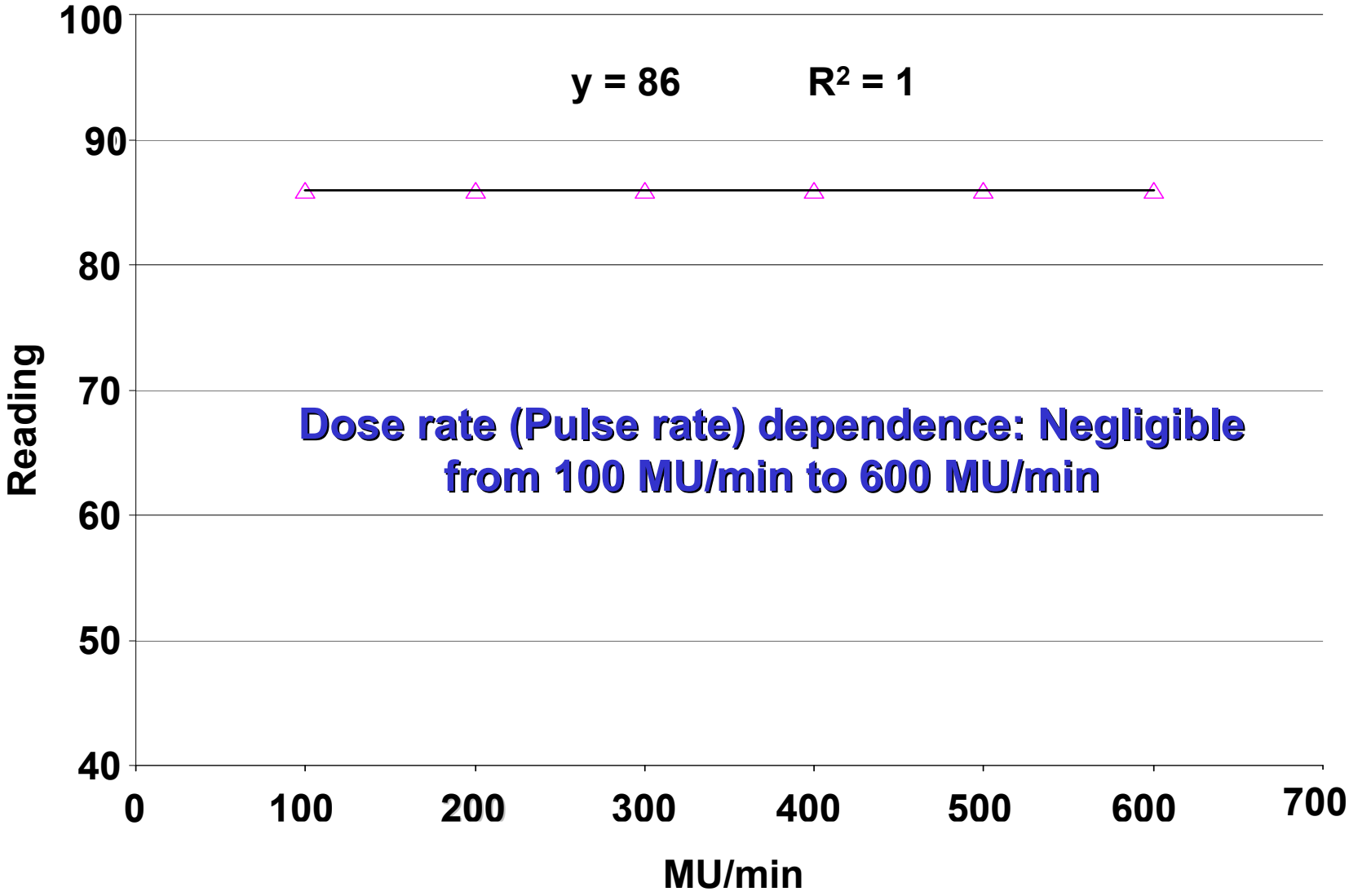
No ion chamber measurements are necessary

Linearity

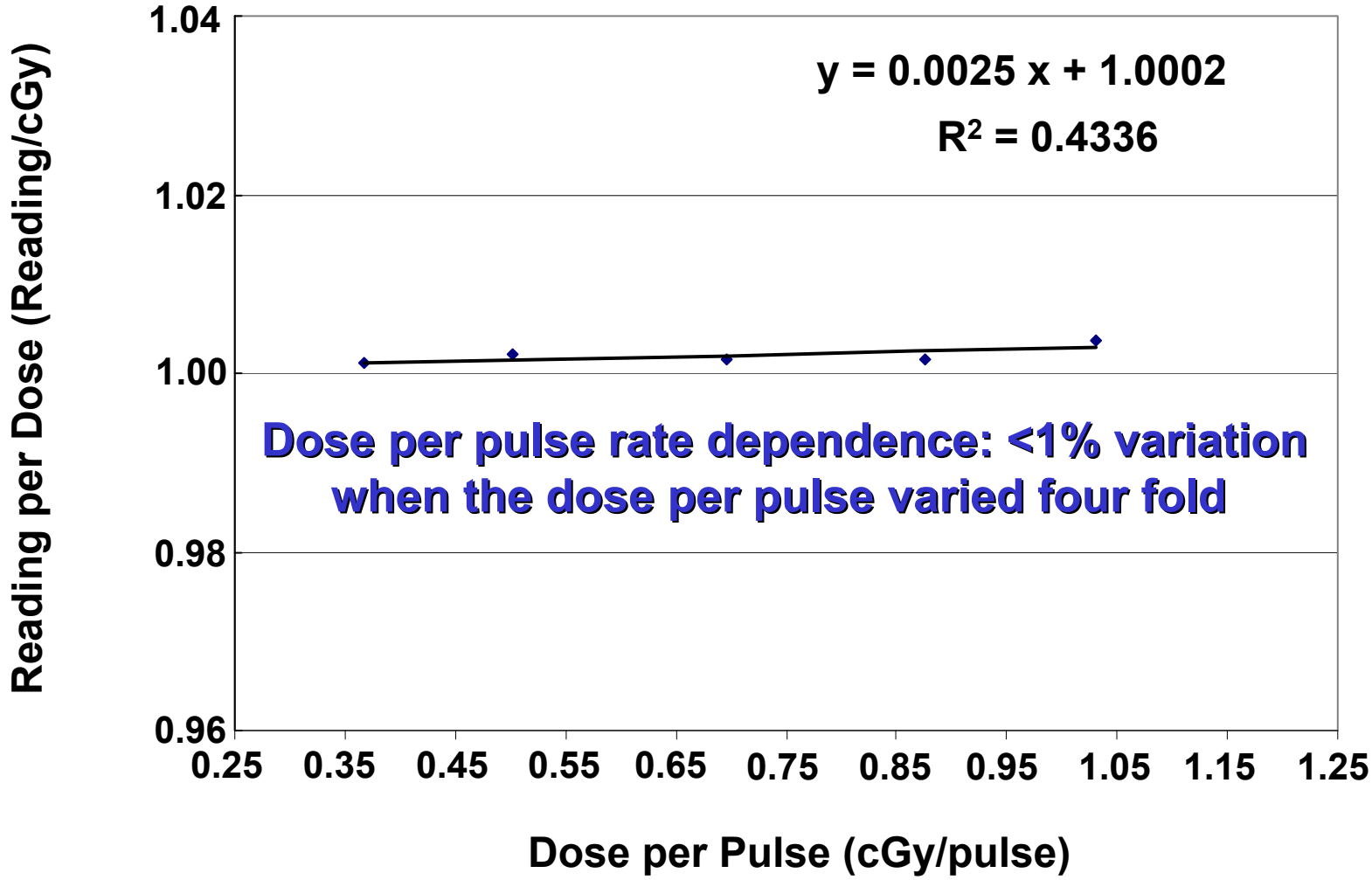


Dose response of the central detector from 50 to 1000 MU

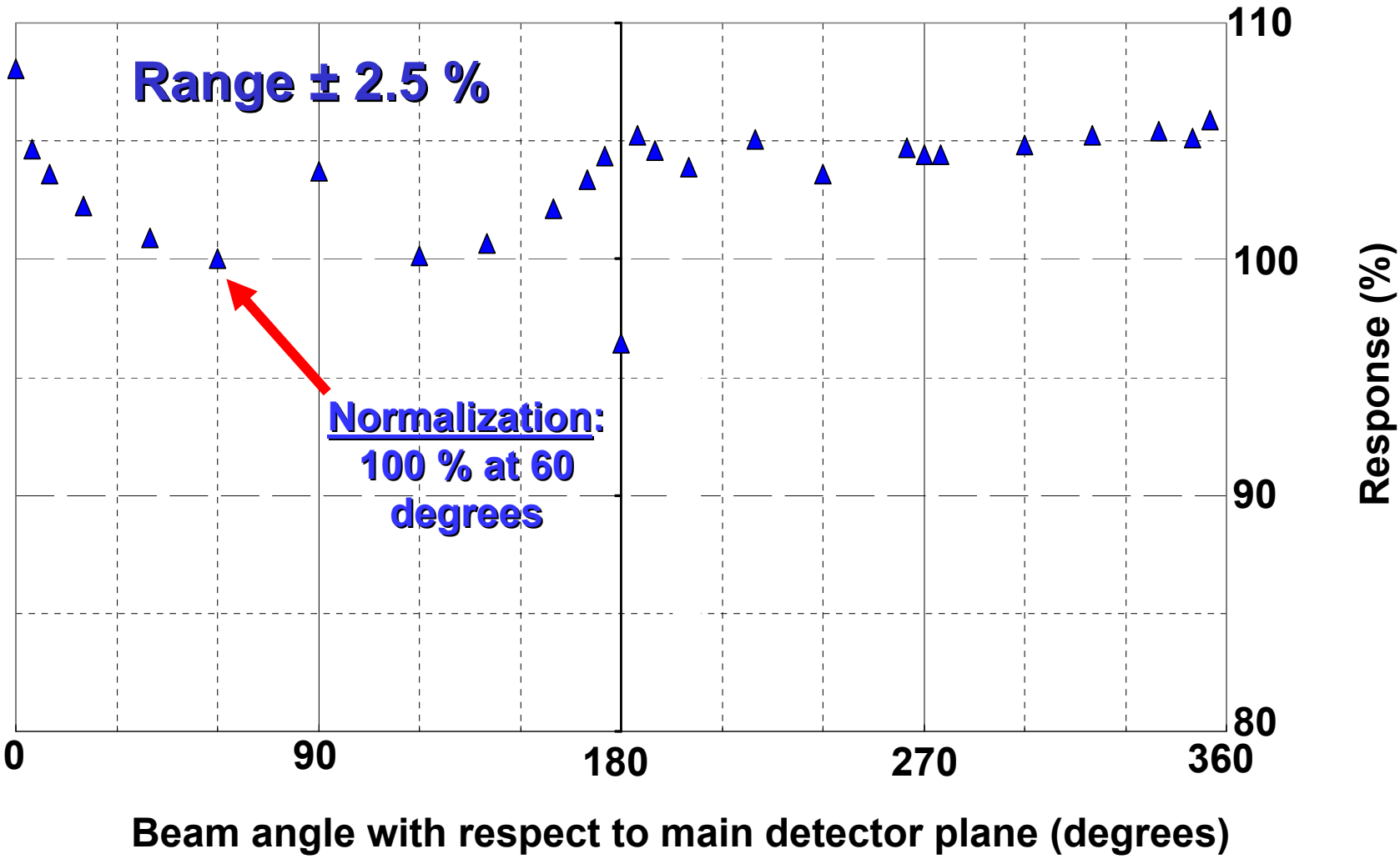
Dose Rate Dependence



Dose per Pulse Dependence



Directional dependence 6 MV beam



Response to Scatter and Leakage Radiation

MLC FS	JAW FS	DIST. FieldEdge	DELTA^4 6 MV	IC CC04 6 MV	DELTA^4 18 MV	IC CC04 18 MV
2 X 2	3 X 3	1	0.030	0.020	0.040	0.040
2 X 2	3 X 3	2	0.009	Lo Signal	0.009	Lo Signal
4 X 4	5 X 5	1	0.050	0.040	0.060	0.060
4 X 4	5 X 5	2	0.020	0.020	0.018	0.019
10 X 10	11x11	1	0.080	0.080	0.090	0.100
10 X 10	11x11	2	0.045	0.041	0.036	0.038
MLC Leakage	10x10	-	0.016	0.013	0.017	0.013

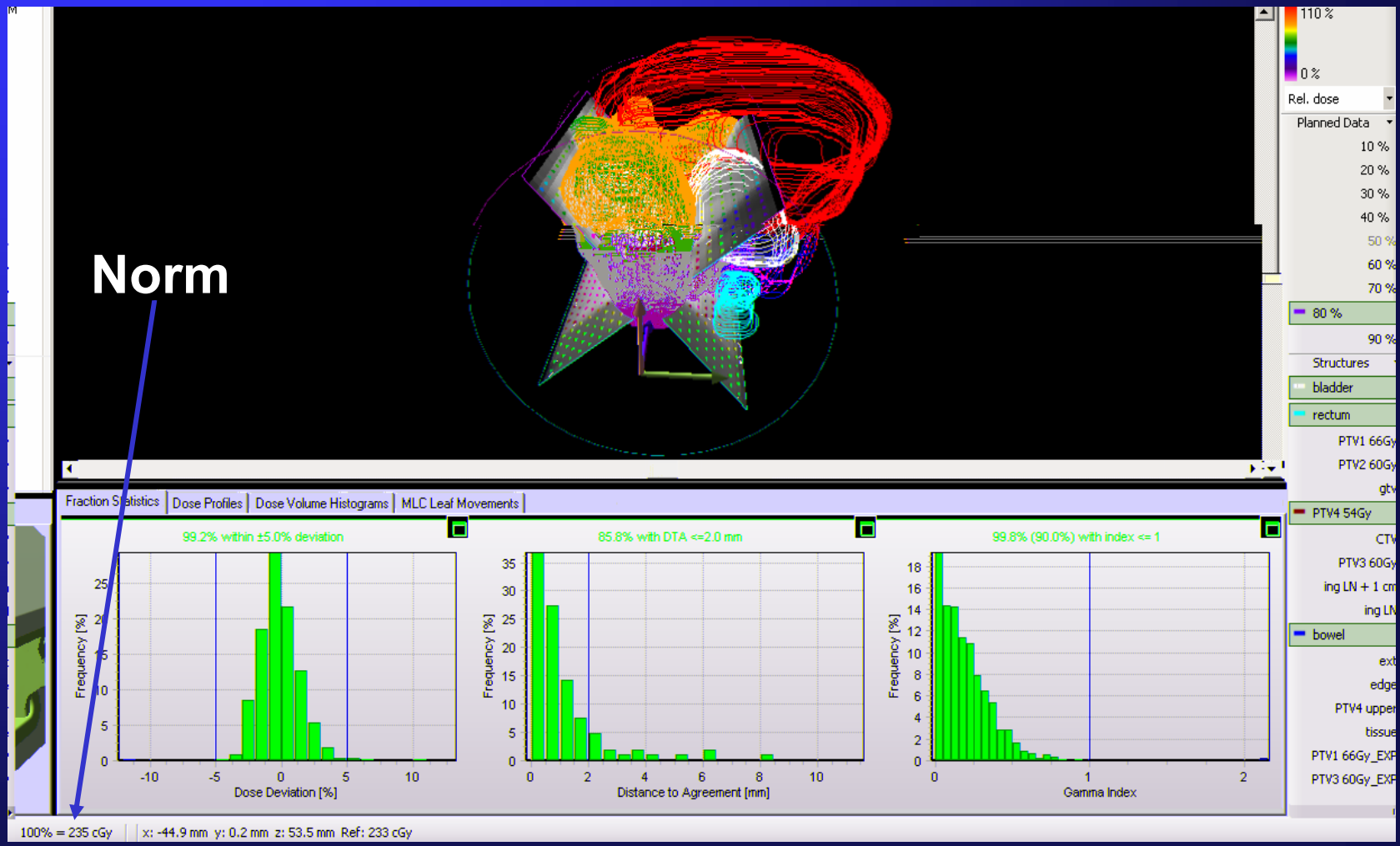
Commissioning

- Absolute dose calibration against calibrated Farmer Type ion chamber in plastic-slab phantom
- Relative dose calibration in a stable beam
- Network, PC and interface with R&V system configuration (if needed)
- Configuring export (from TPS) and import (into Delta^4) of DICOM RT and RTOG formatted files

Evaluation

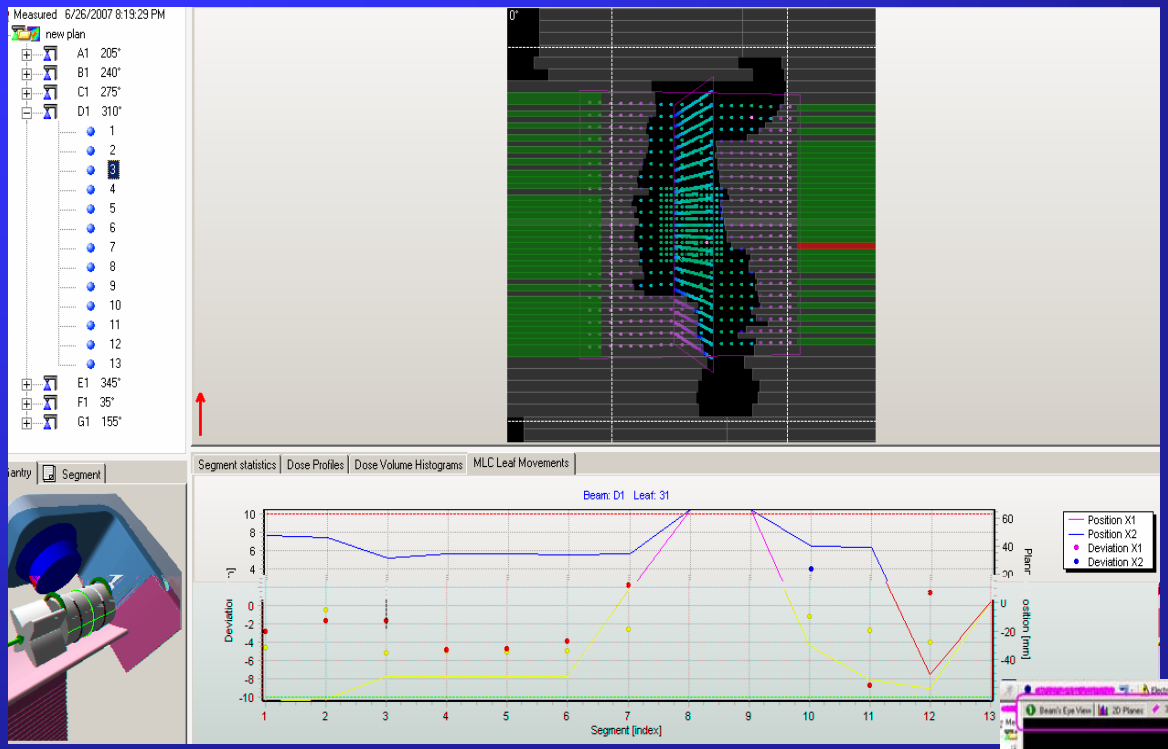
- IMRT QA on Twelve patient plans (HN, CNS, Thoracic, Gyn, GU and GI)
- Plans with Non coplanar beams were also measured
- All plans passed the criteria of Gamma (5% or 5mm) ≤ 1 for more than 97% of points
- Representative analysis presented

Delta^4 Software 3D View



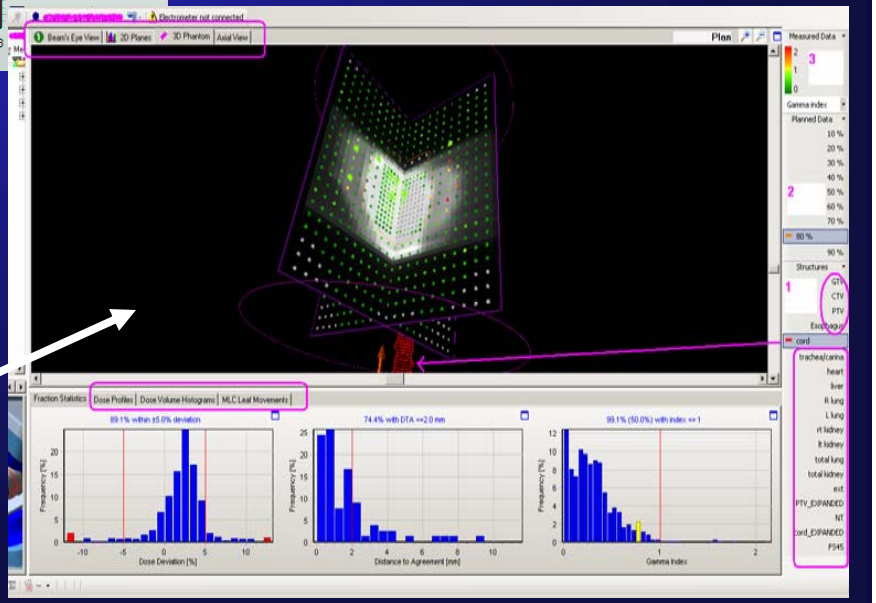
Software provides information on IMRT QA Statistics

Visualization of BEV MLC Deviations

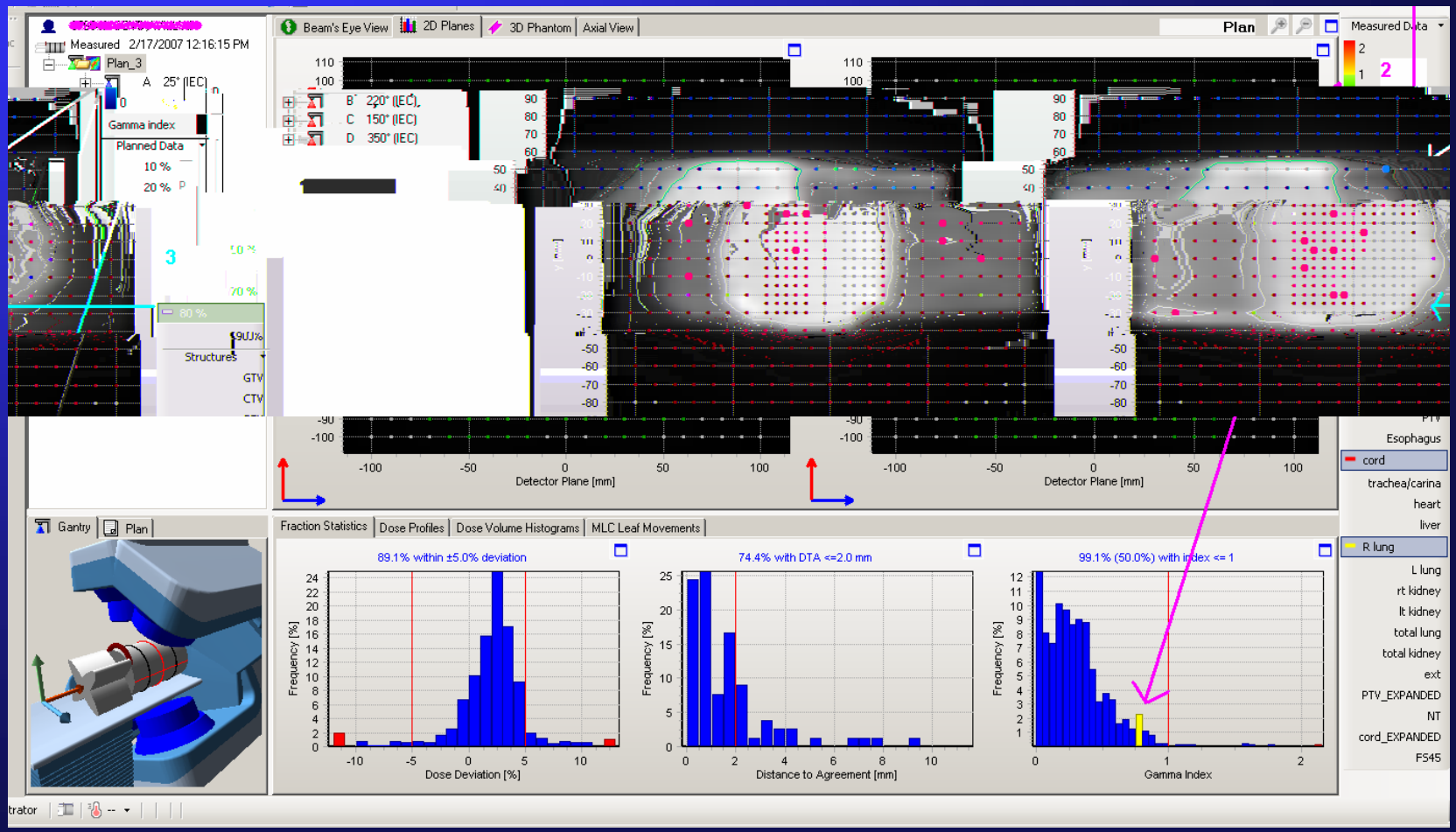


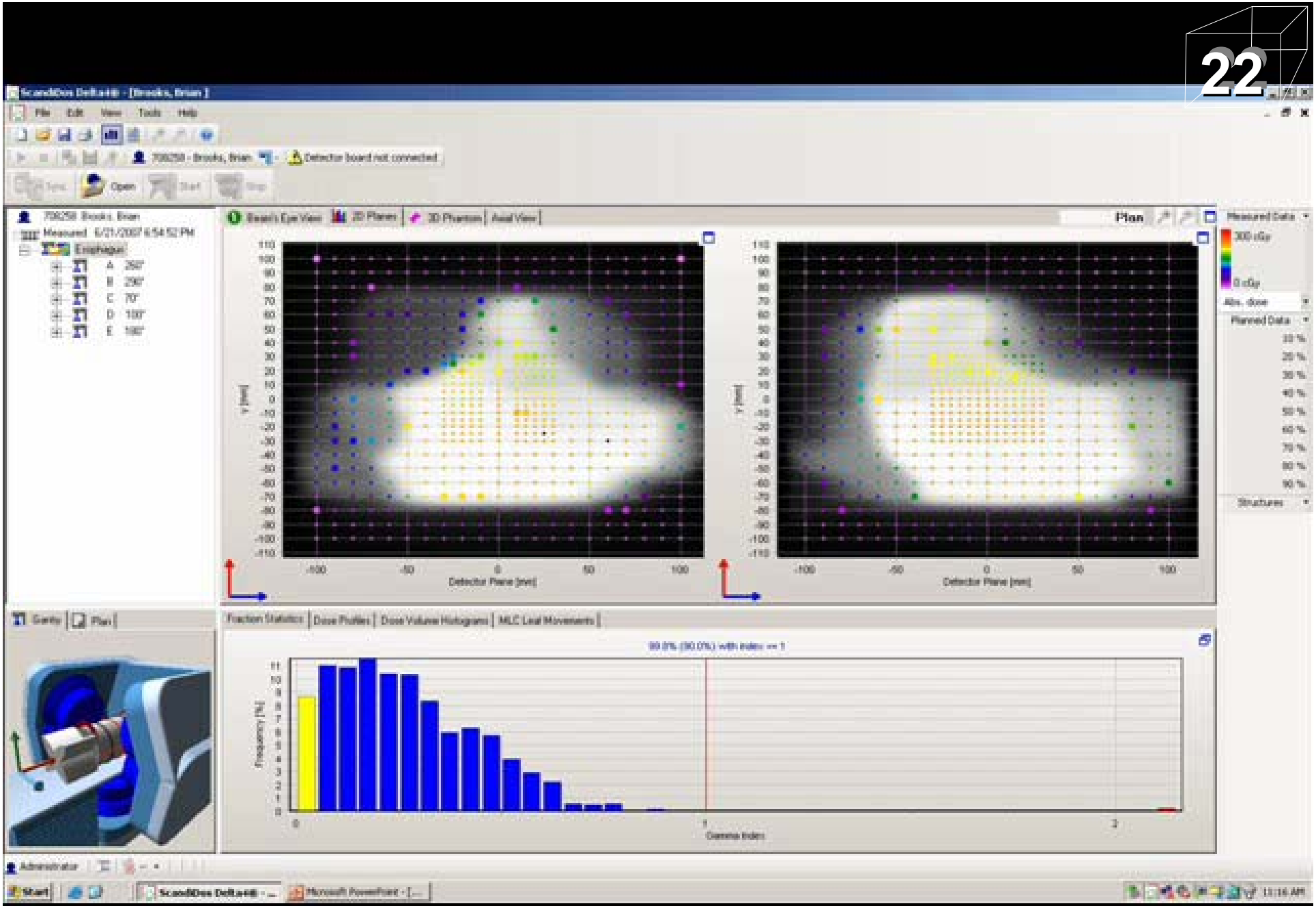
Dose Comparison 3D

Interactive

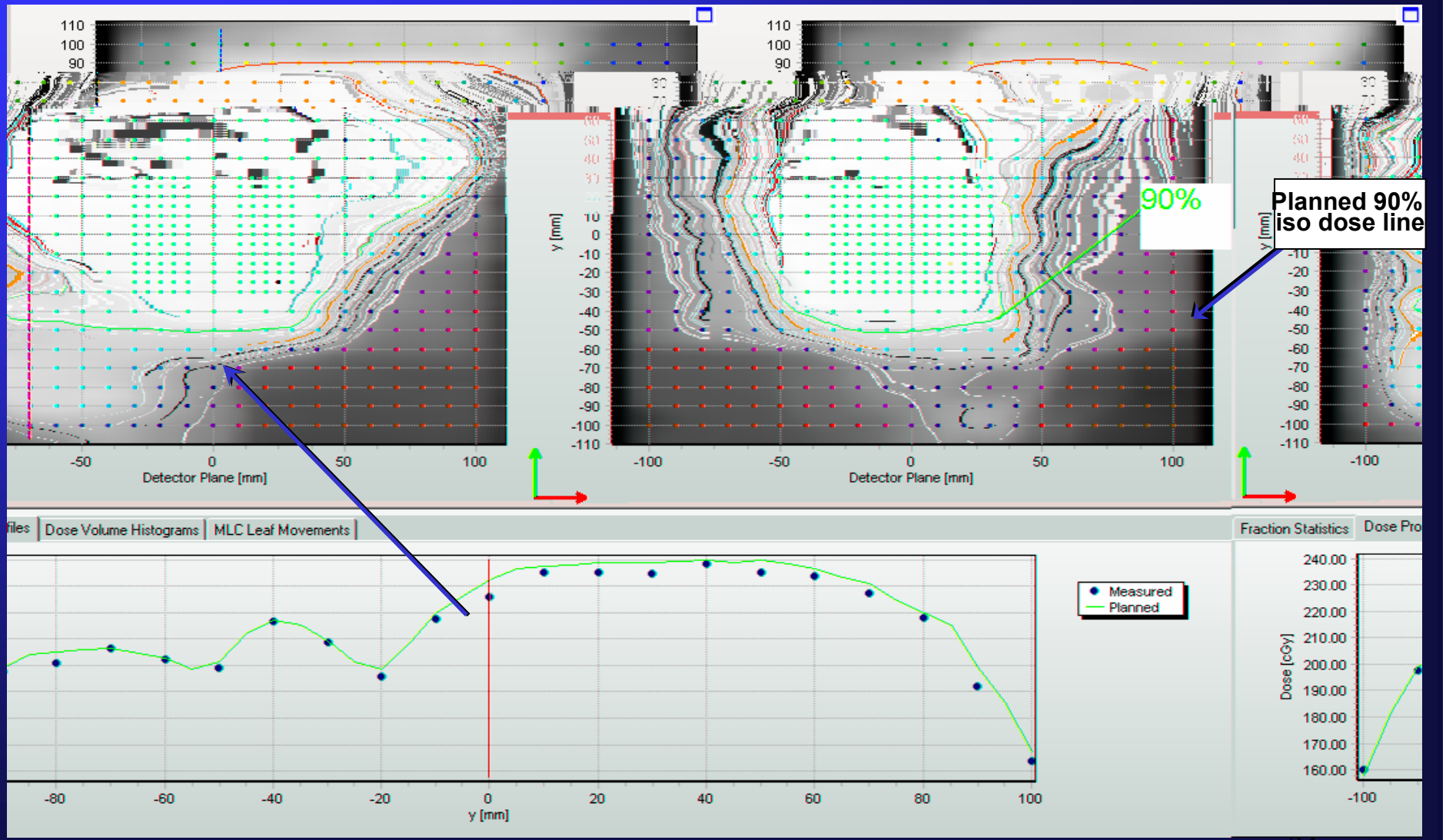


Dose comparison in 2D and Interactive Statistics

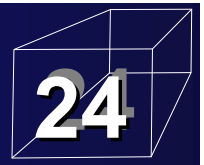



File Edit View Tools Help
Open
Bird's Eye View
2D Planes
3D Phantom
Axial View
Plan
Esophagus
Detector Plane [mm]
Gantry
Plan
Fraction Statistics
Dose Profiles
Dose Volume Histograms
MLC Leaf Movements
Frequency [%]
Gamma Index

Software allows for Profile Comparison – Composite Dose



Conclusions



- Accurate and Precise.
- It is an integrated 3D system with analysis software
- Timeliness: QA prior to treatment
- Powerful: Field by Field and Segment by Segment analysis, display of anatomical contours over the measured distribution
- Efficiency and convenience of central database
- Extension to 4D

Delta^4 system does address the drawbacks in the current QA system

Future Work

- Research possibilities - RPC Head and Neck phantom
- Future work - Breast phantom, 4D lung phantom, Independent algorithm to verify the interpolation method used here, etc.