

Characterization, Commissioning and Evaluation of Delta⁴ IMRT QA System

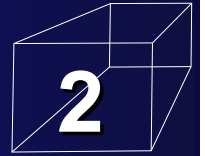
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Acknowledgements

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



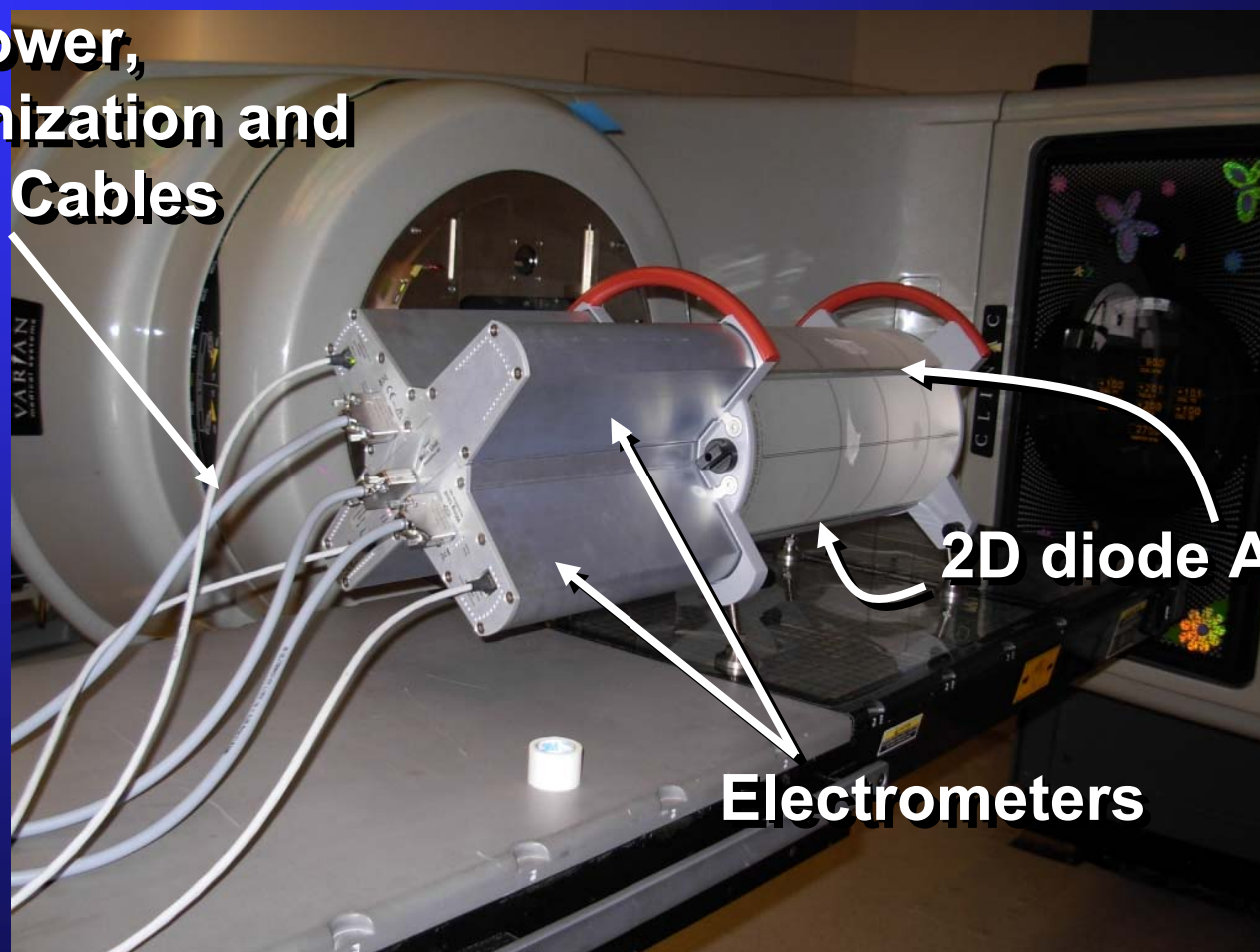
Introduction

- **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 DELTA⁴ system potentially address these drawbacks?

Delta⁴ Device Fully Assembled

**Power,
Synchronization and
Data Cables**



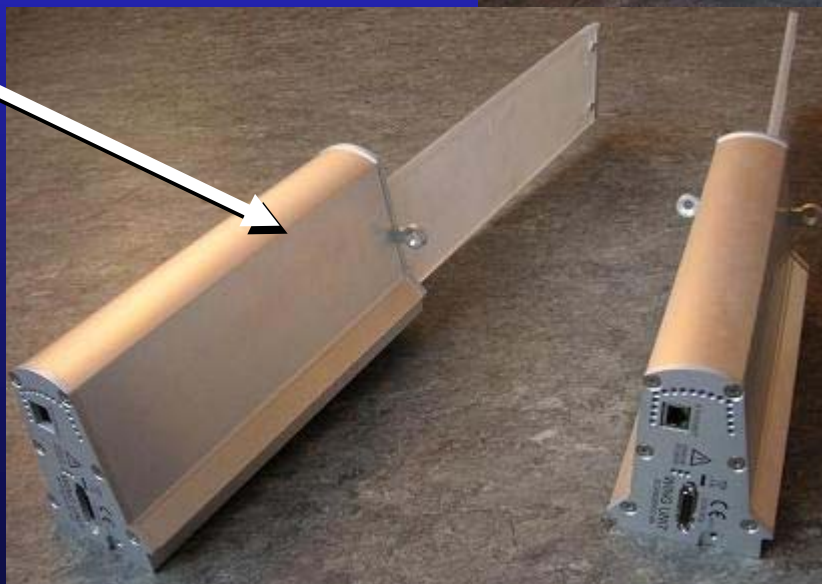
2D diode Arrays

Electrometers

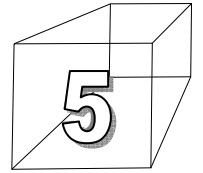
Currently commercially available

2D Detector Arrays Units

- **Main Unit**
- **Detection Area 20x20 cm²**
- **Sensitivity 5nC/Gy**
- **Wing Unit**

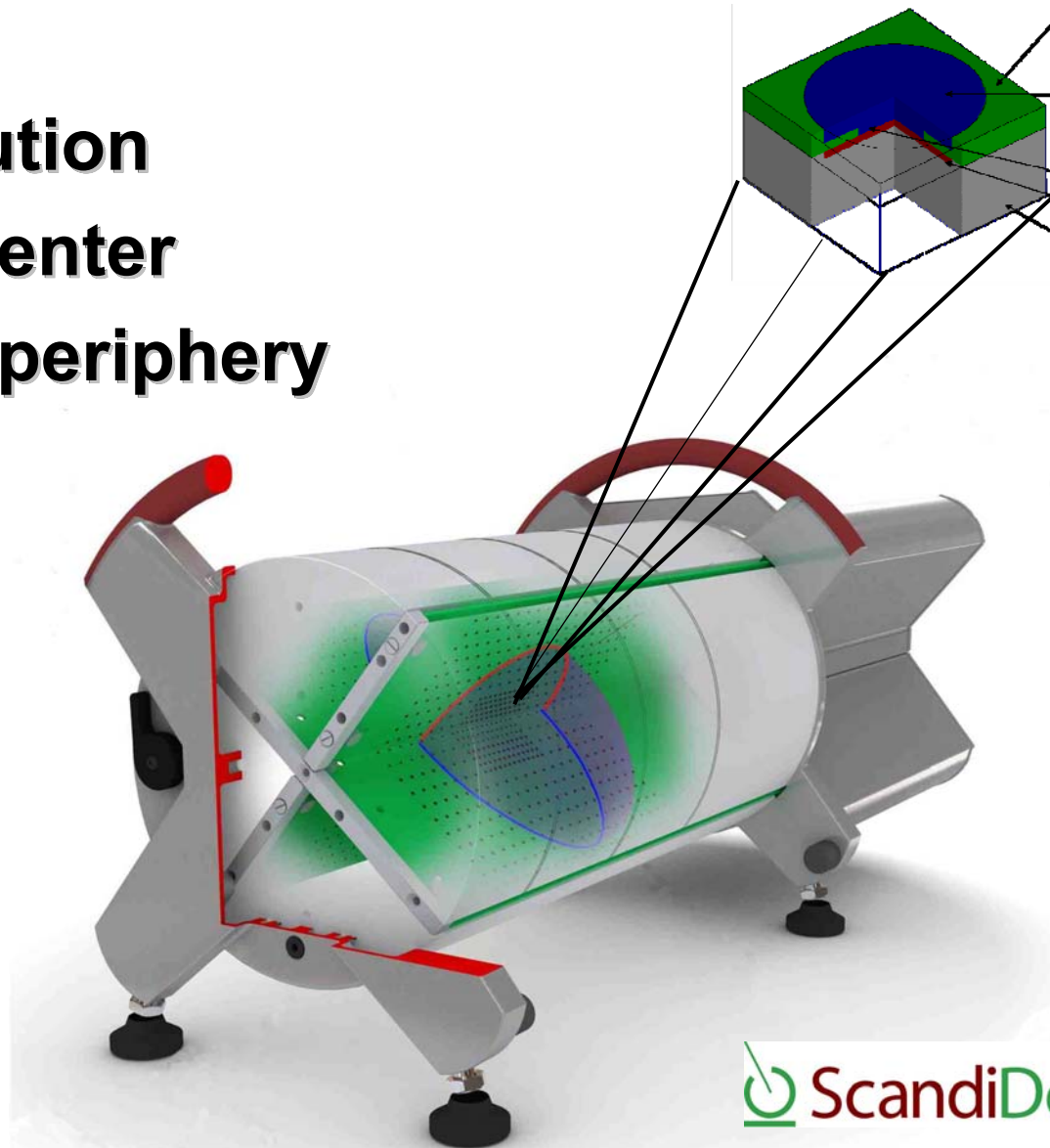


Detector Arrays



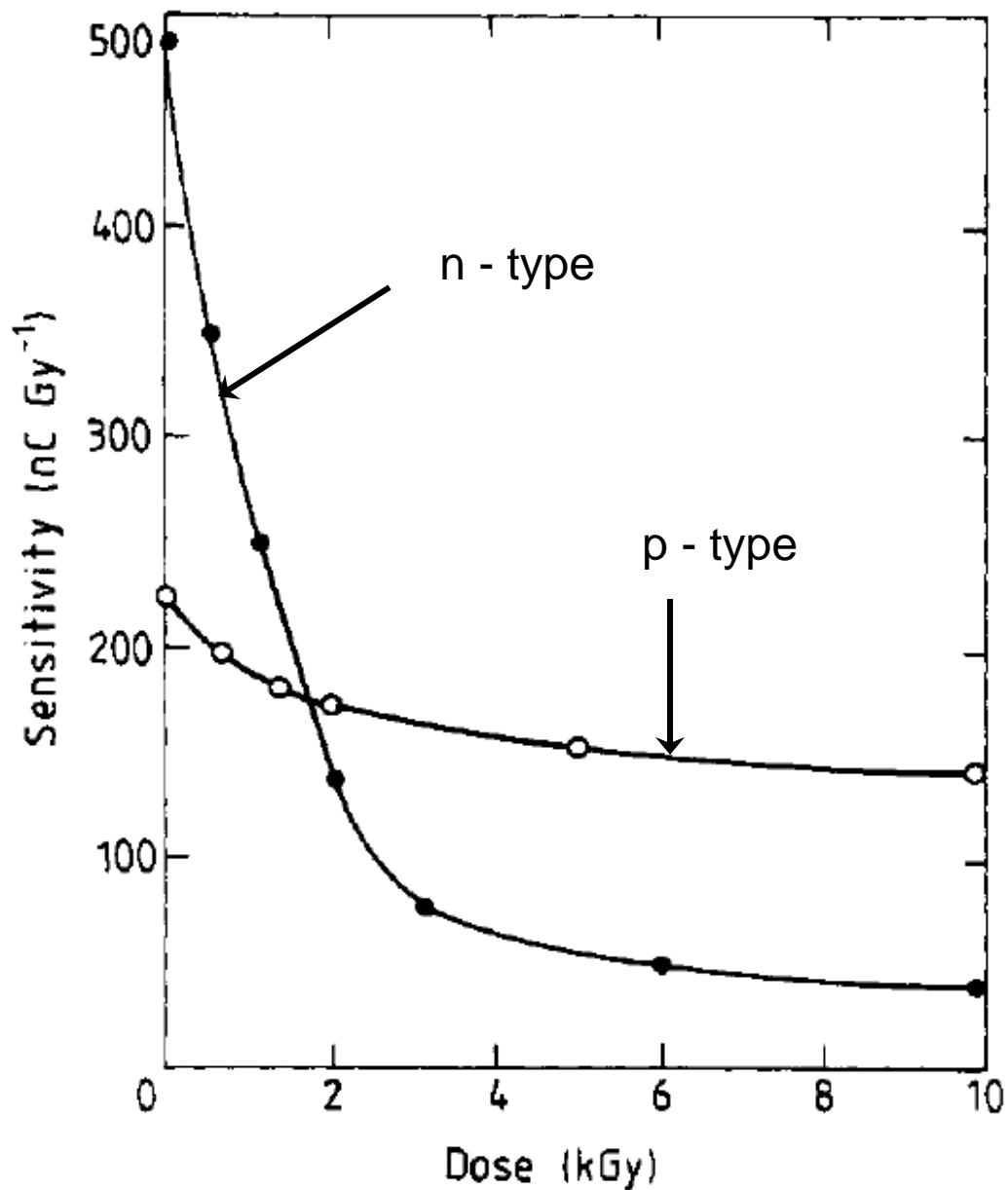
Area: 0.78 mm²
Height: 0.05 mm

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



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.

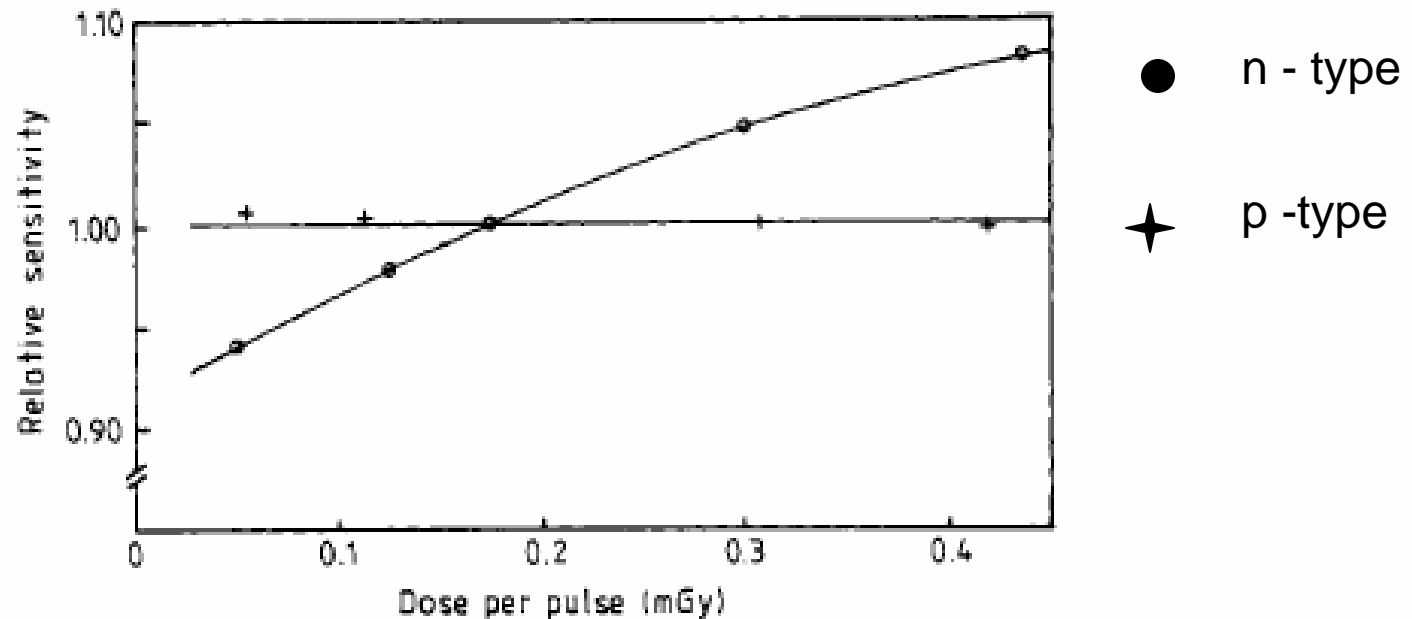
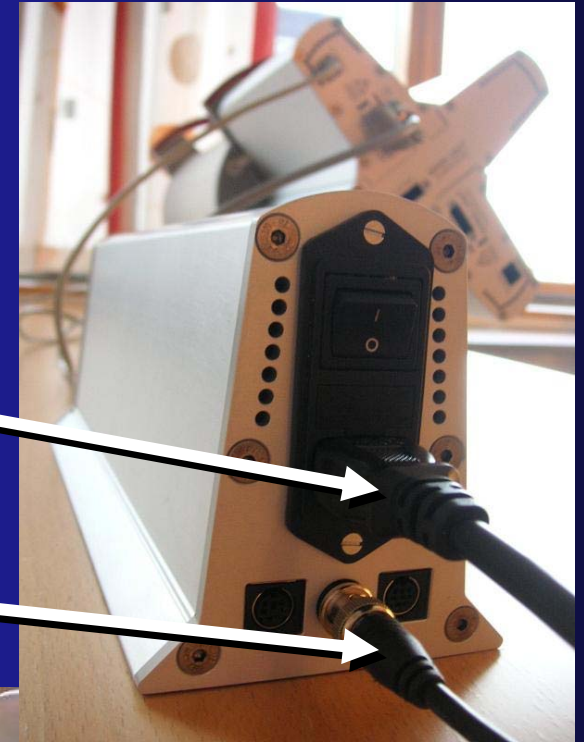


Figure 4. Ratio between signals from a semiconductor detector and an ionisation chamber, measured in 8 MV x-rays, as a function of dose per pulse. Data for p-type detectors pre-irradiated to 25 kGy (+) and n-type detectors pre-irradiated to 10 kGy with 20 MeV electrons (\ominus) are shown (from Grussell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

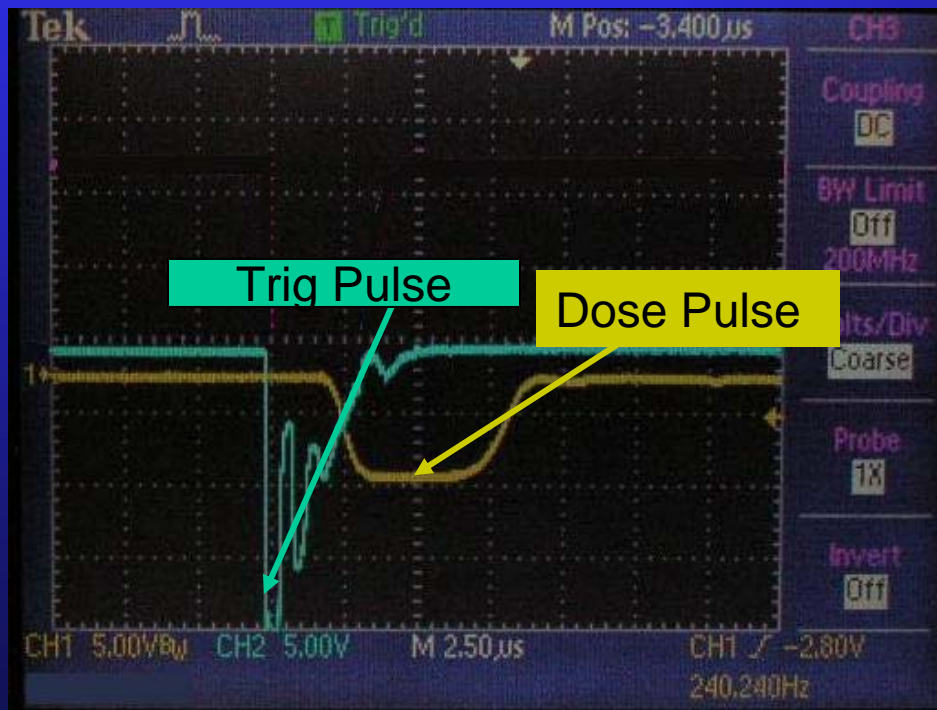
Power Distribution System

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



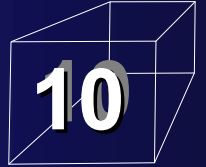
Pulse by Pulse Measurements

- 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



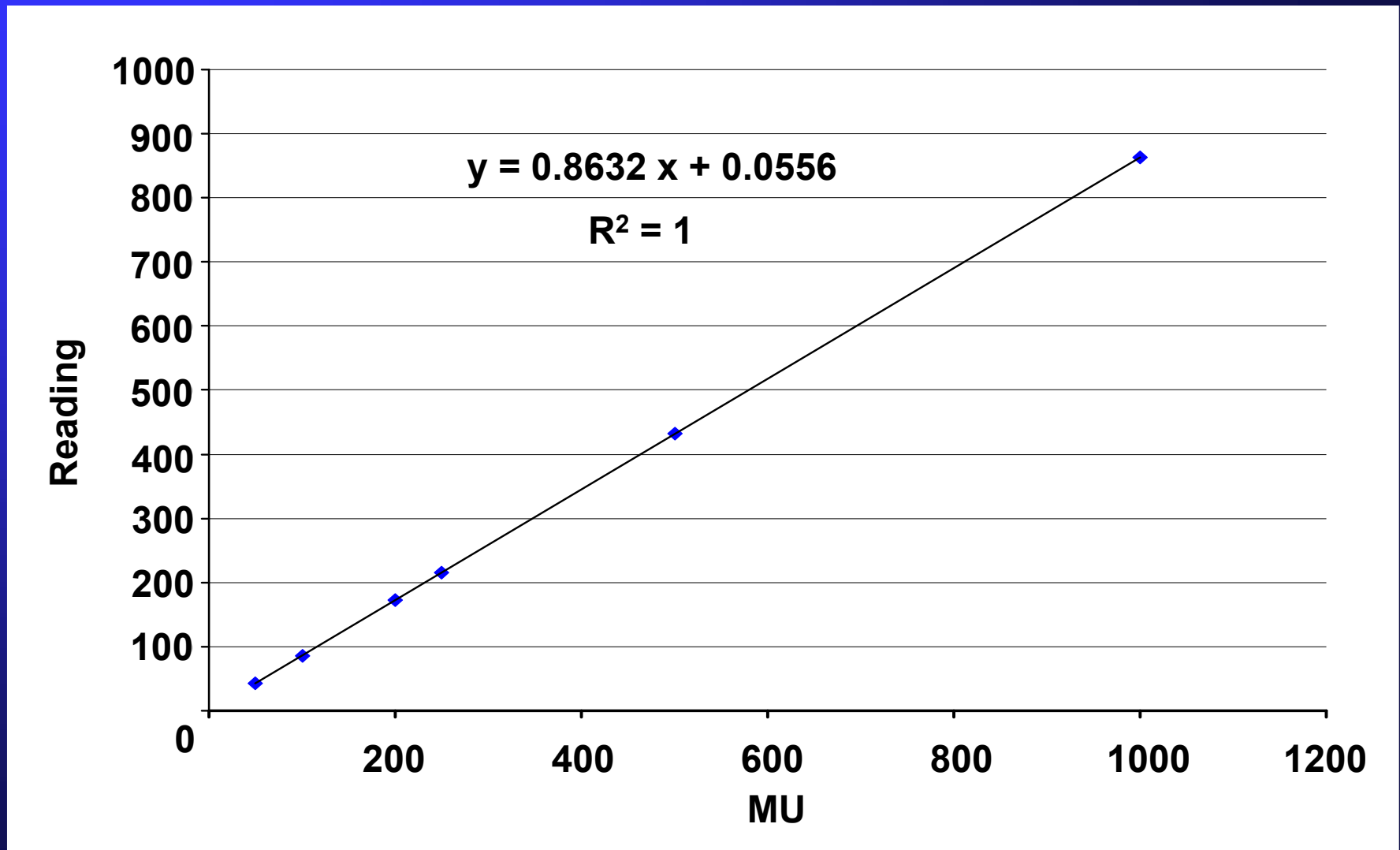
- **Precision**
- **Stability**
- **Linearity**
- **Dose rate (pulse rate) dependence**
- **Dose per pulse rate dependence**
- **Beam directional dependence**
- **Energy dependence**
- **Interpolation at non detector location**
- **Sensitivity change – about 1% kGy**

Results

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

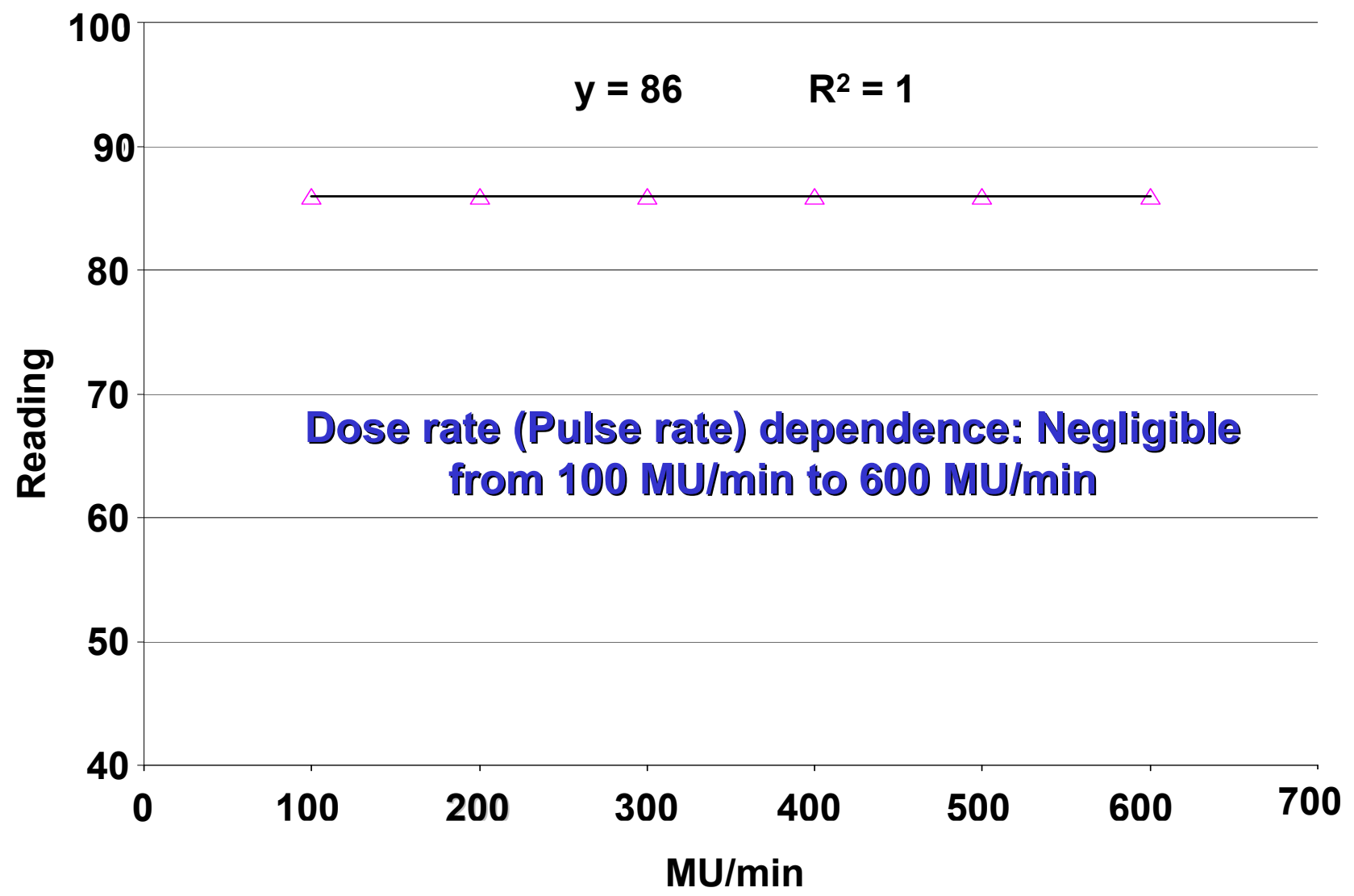
No ion chamber measurements are necessary

Linearity



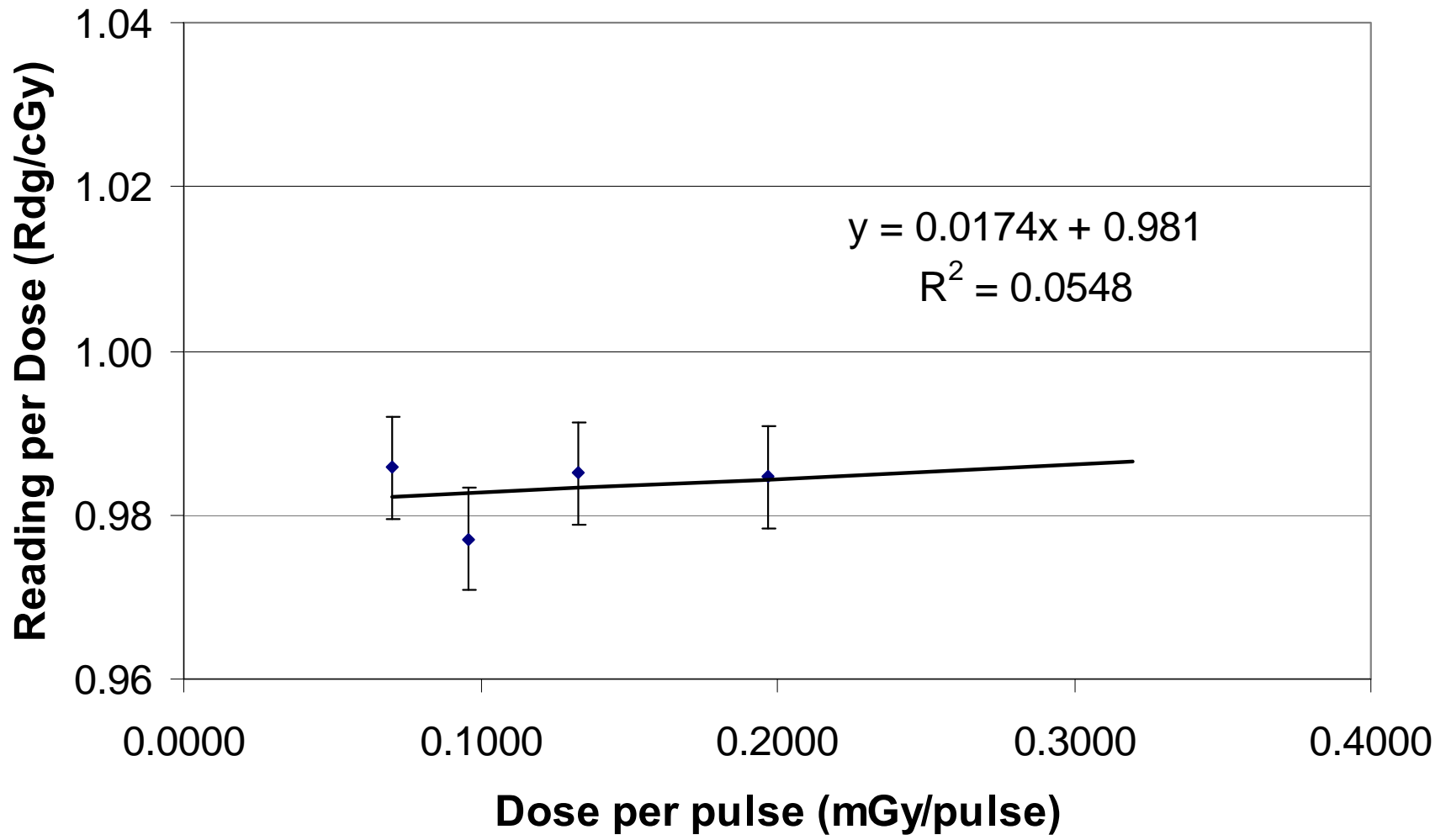
Dose response of the central detector from 50 to 1000¹³ MU

Dose Rate Dependence

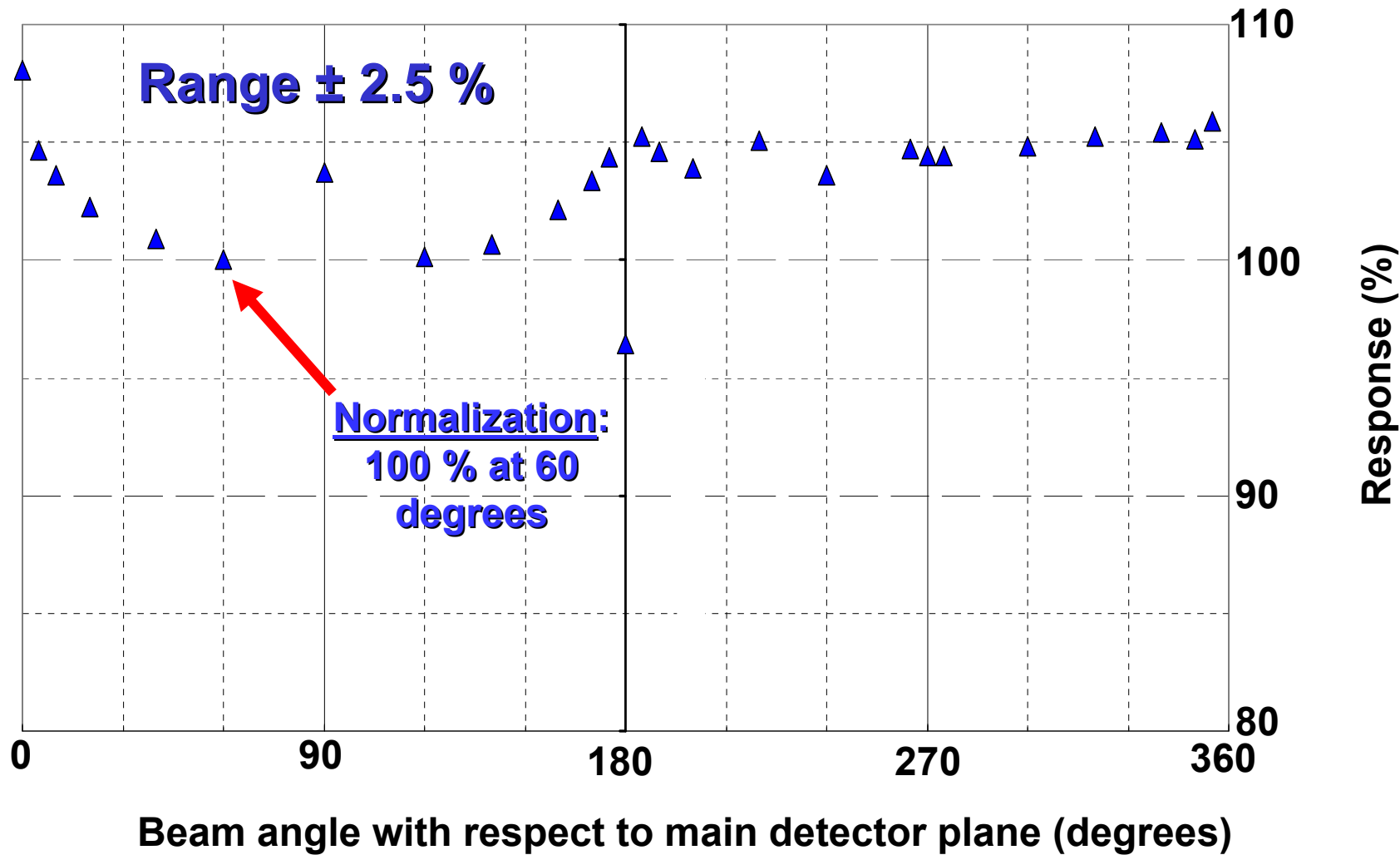


Dose per Pulse Dependence

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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

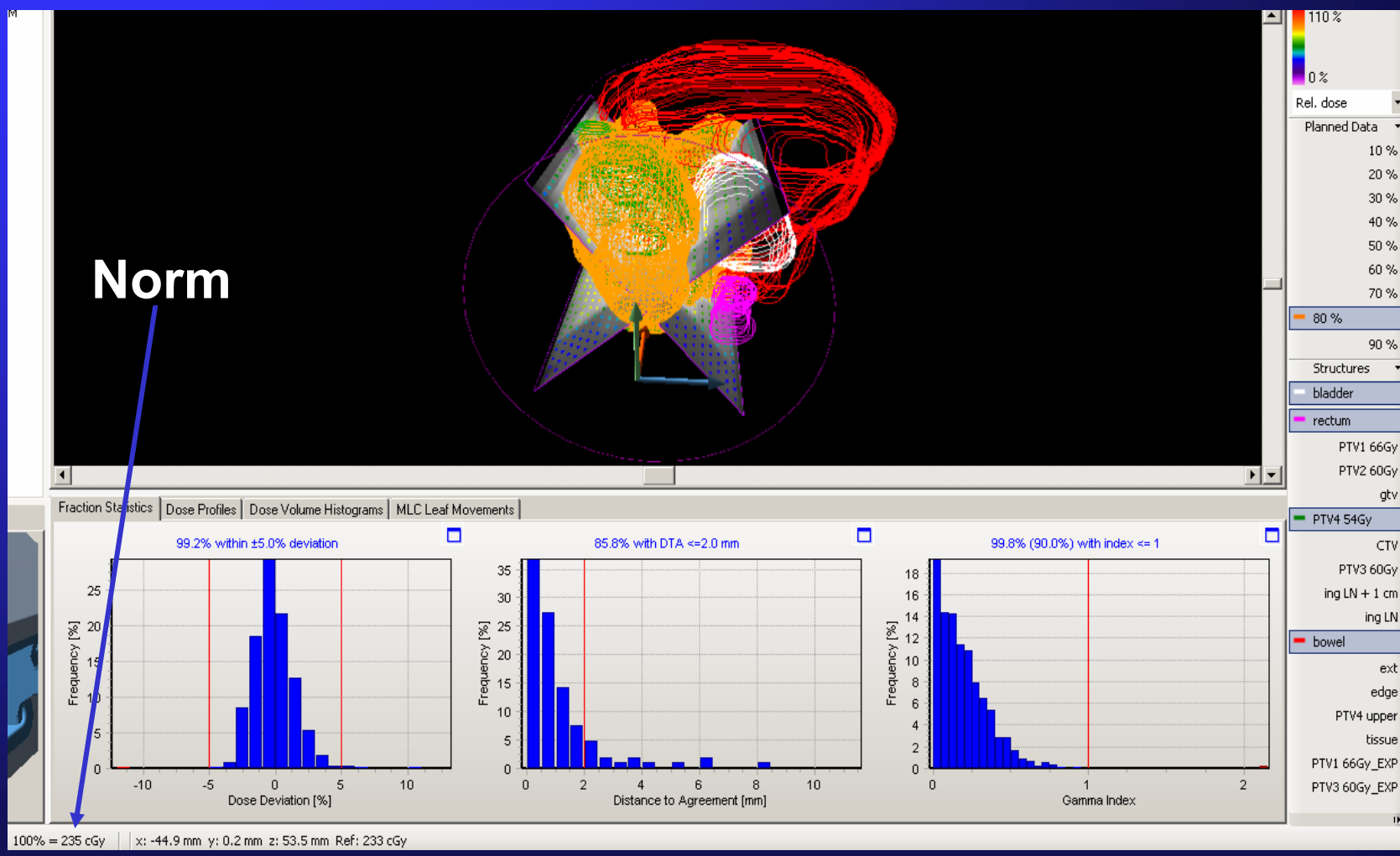
Commissioning

- **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 Delta⁴) of DICOM RT and RTOG formatted files**

Evaluation

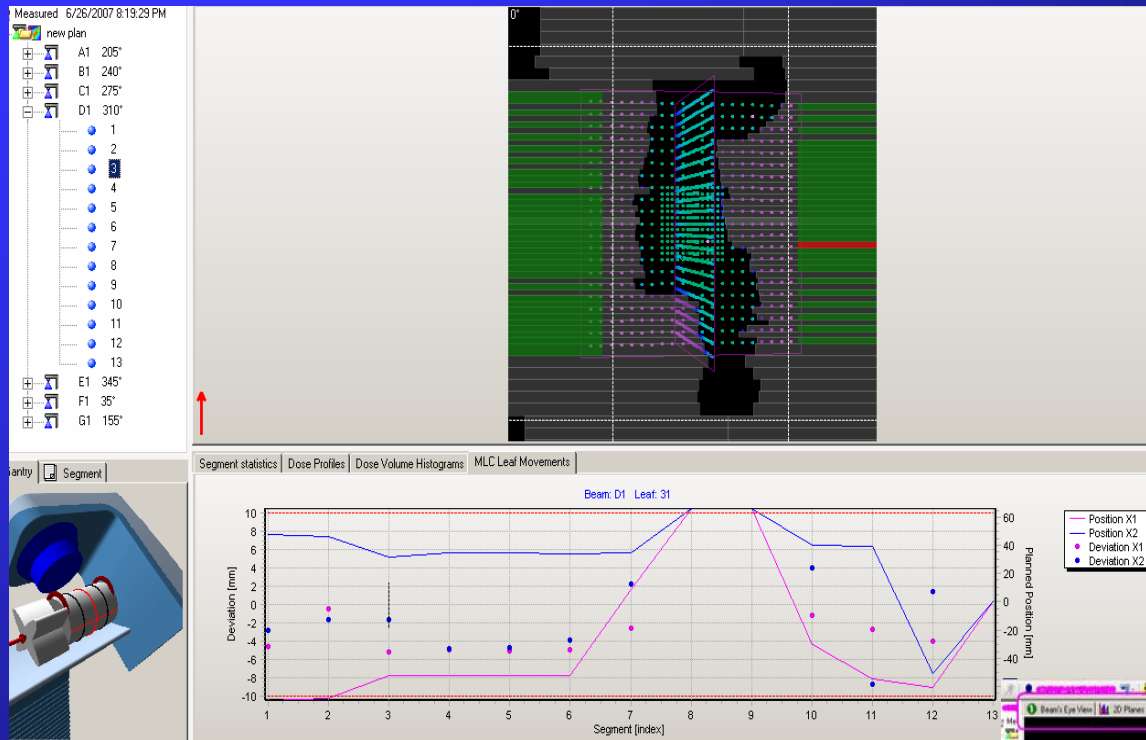
- **IMRT QA on Thirteen patient plans (HN, CNS, Thoracic, Gyn, GU and GI)**
- **Plans with Non coplanar beams were also measured**
- **All plans passed the criteria of Gamma (5% or 5mm) ≤ 1 for more than 97% of points**
- **Representative analysis presented**

Delta⁴ Software 3D View



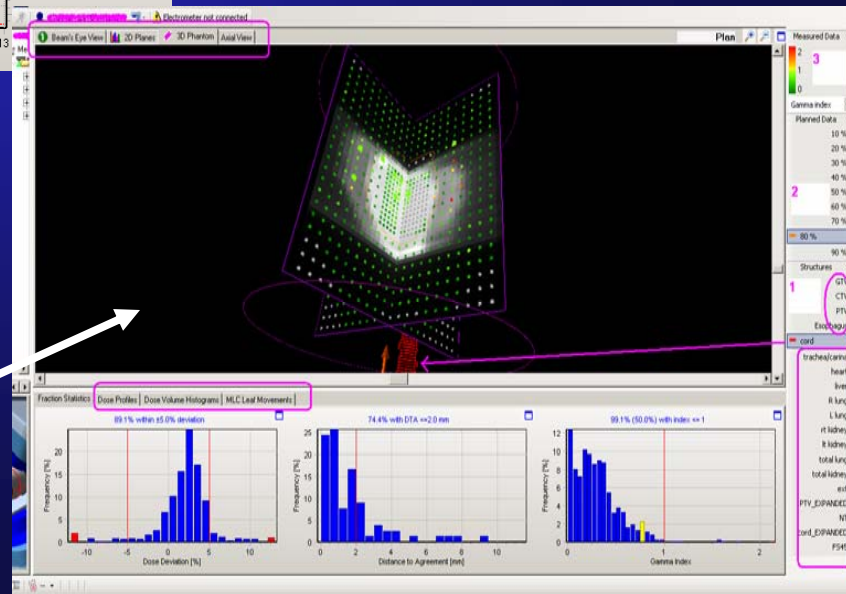
Software provides information on IMRT QA Statistics

Visualization of BEV MLC Deviations

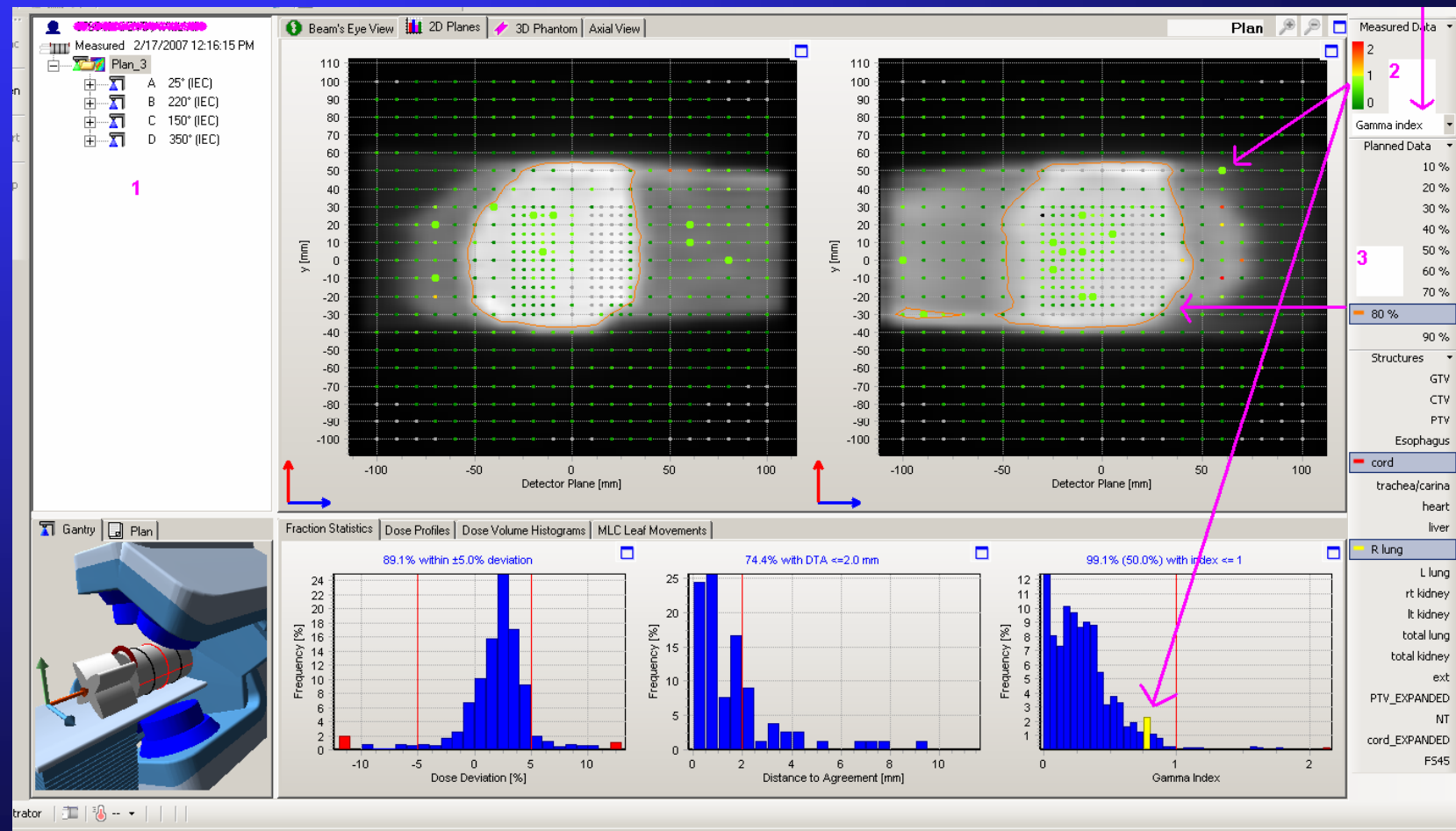


Dose Comparison 3D

Interactive



Dose comparison in 2D and Interactive Statistics



ScandDose Delta4.0 - [Brooks, Brian]

File Edit View Tools Help

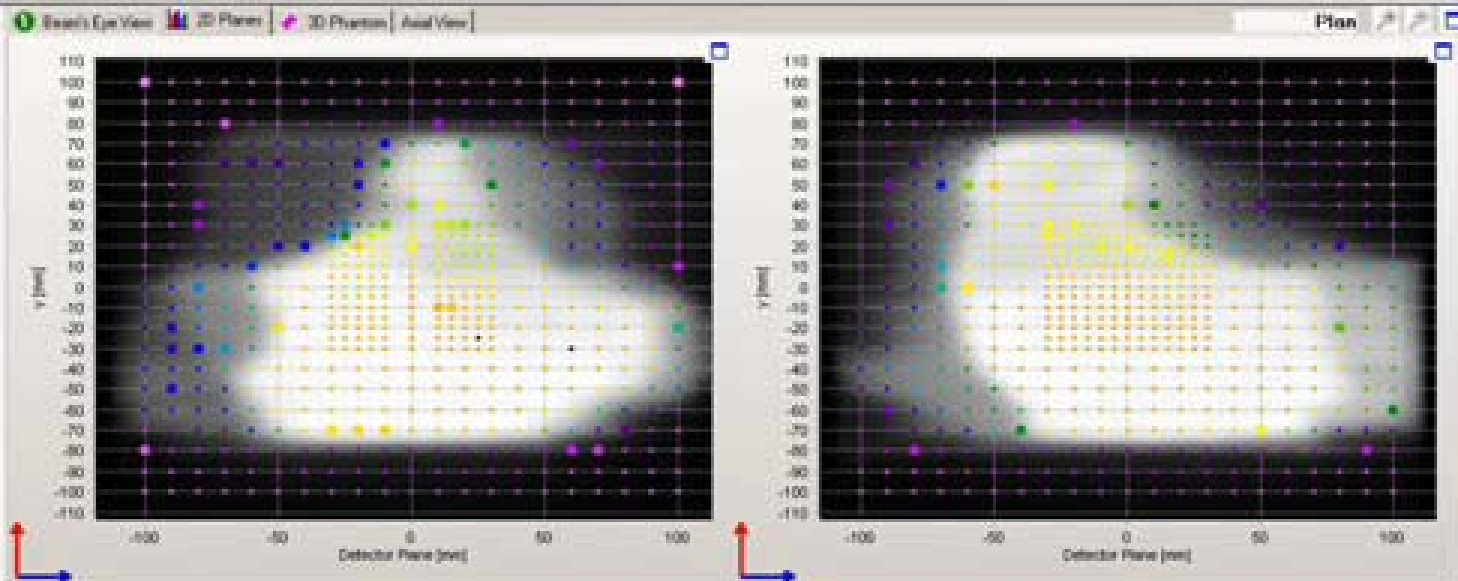
700258 - Brooks, Brian - Detector board not connected

700258 Brooks, Brian

Measured: 6/21/2007 6:54:52 PM

Enthalpaq

- A 20°
- B 20°
- C 70°
- D 100°
- E 100°



Measured Data

0 cGy

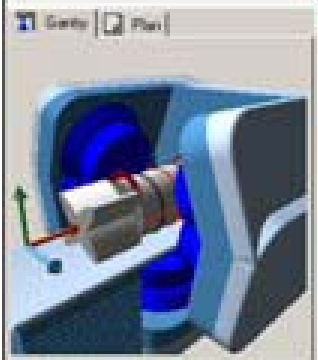
200 cGy

Abs. dose

Planned Data

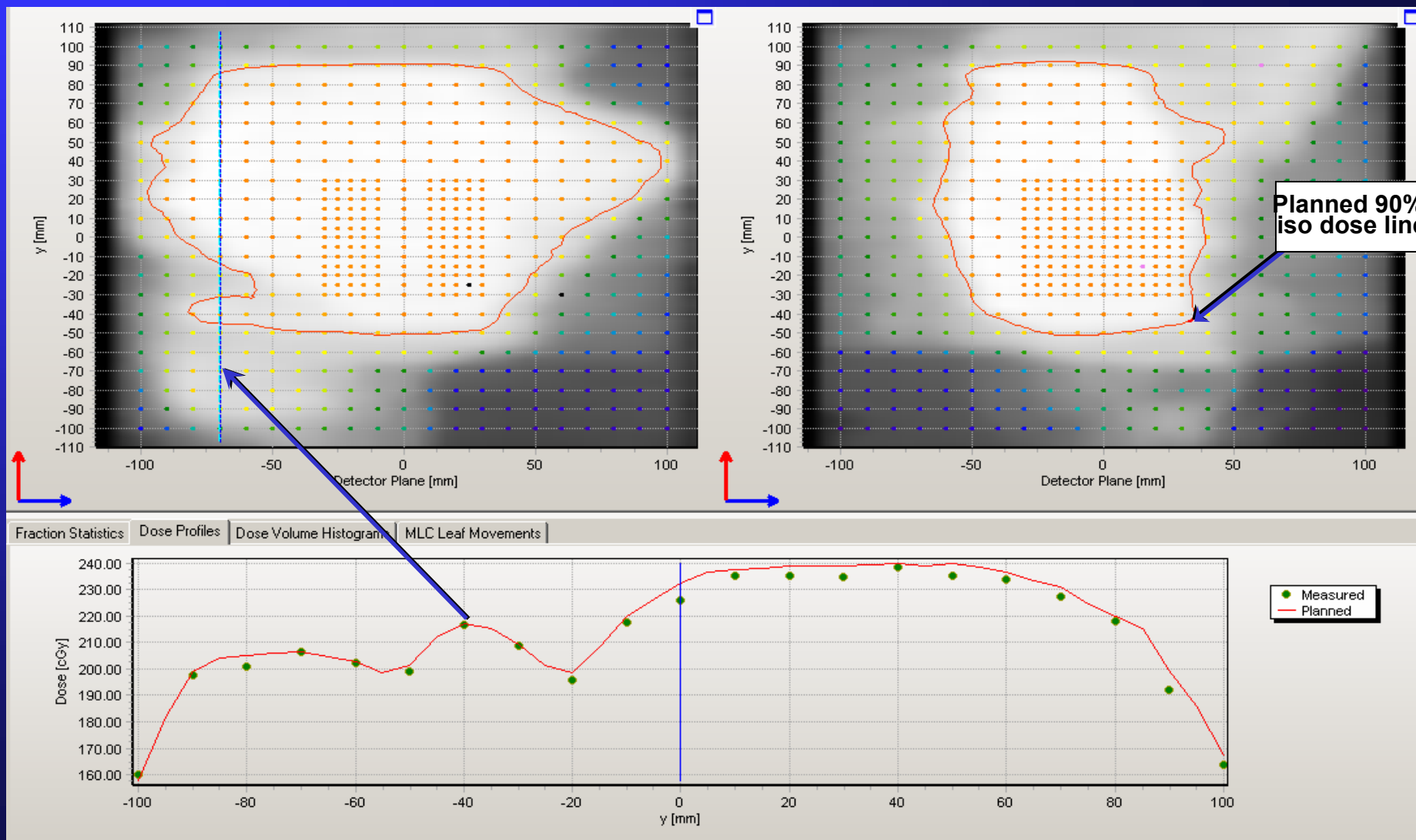
- 10 %
- 20 %
- 30 %
- 40 %
- 50 %
- 60 %
- 70 %
- 80 %
- 90 %

Structures



Software allows for Profile Comparison – Composite Dose

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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**

Delta⁴ 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.**