Evaluation of Lung Heterogeneity Corrections for Clinical Trials Using the RPC Lung Phantom

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THE UNIVERSITY OF TEXAS
MD ANDERSON
CANCER CENTER

RPC History Lesson

Originated through agreement between AAPM and CRTS

Founded in 1968 to monitor institution participation in clinical trials (Bob Shalek)

Funded continuously by NCI as structure of cooperative group programs have changed

Now 39 years of experience of monitoring institutions and reporting findings to study groups and community

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Mission

1. Assure NCI and cooperative groups that institutions participating in clinical trials deliver prescribed doses that are comparable and consistent.
2. Help institutions to make any corrections that might be needed.
3. Report findings to the community.

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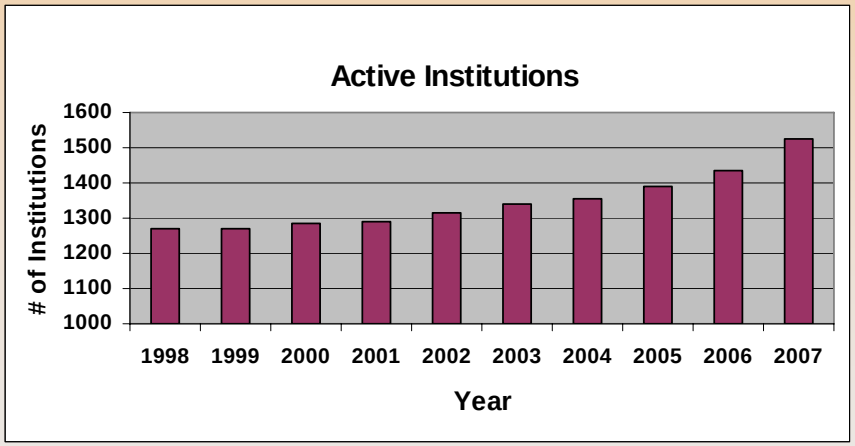
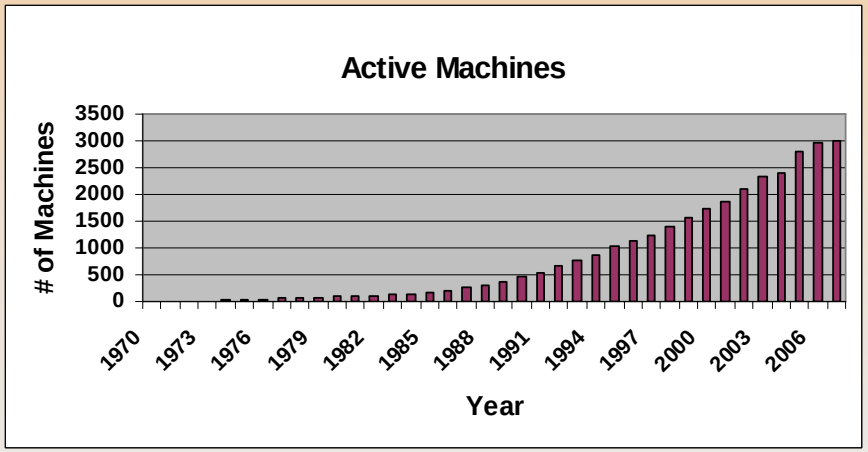
Clinical Trial Participants

- Number of Active Institutions – 1,527
  - 2,989 megavoltage machines
  - 17,605 active megavoltage beams





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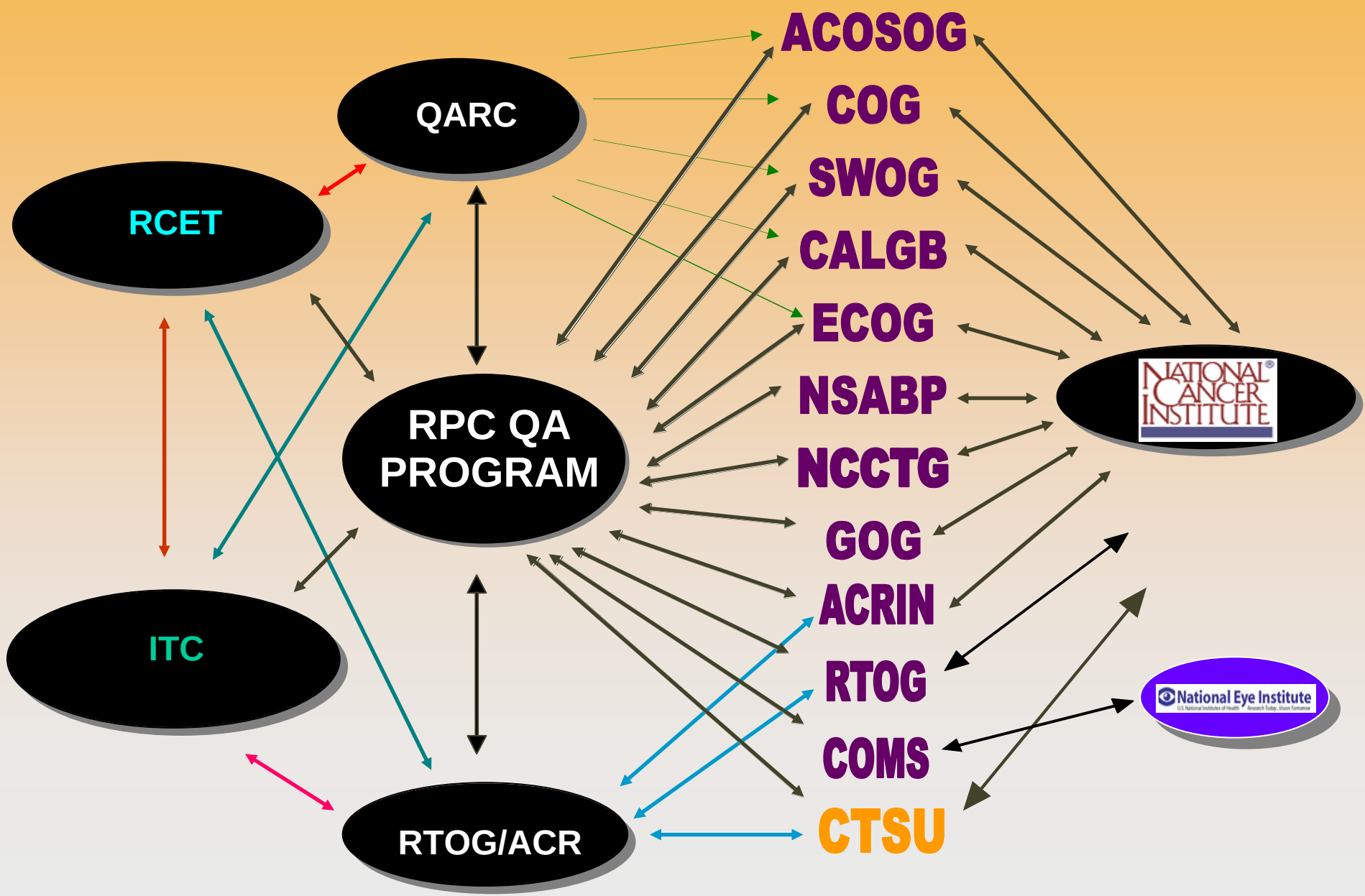
Only QA Office with relationships with all study groups



RPC QA Activities

1. Remote TLD Reviews
2. Patient Dosimetry
3. On-site Reviews
4. Credentialing
   - Benchmark cases
   - Phantoms

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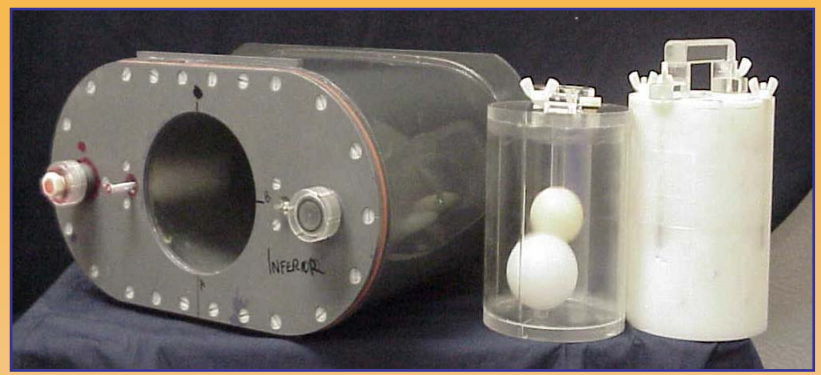
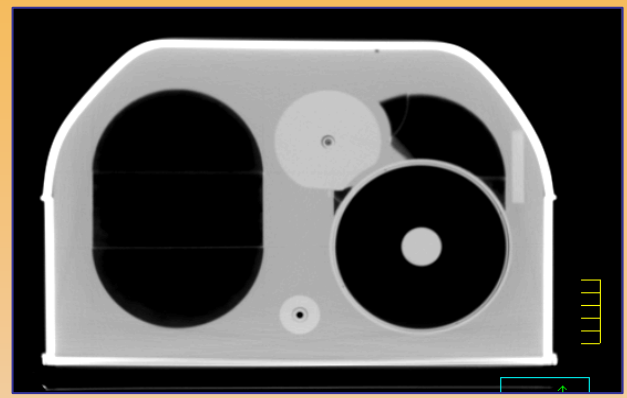
RPC Phantoms



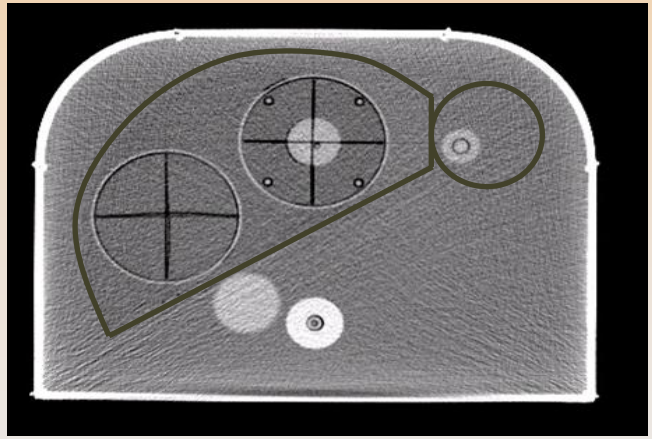
4 prostate phantoms (IMRT)



9 thorax phantoms (SBRT)

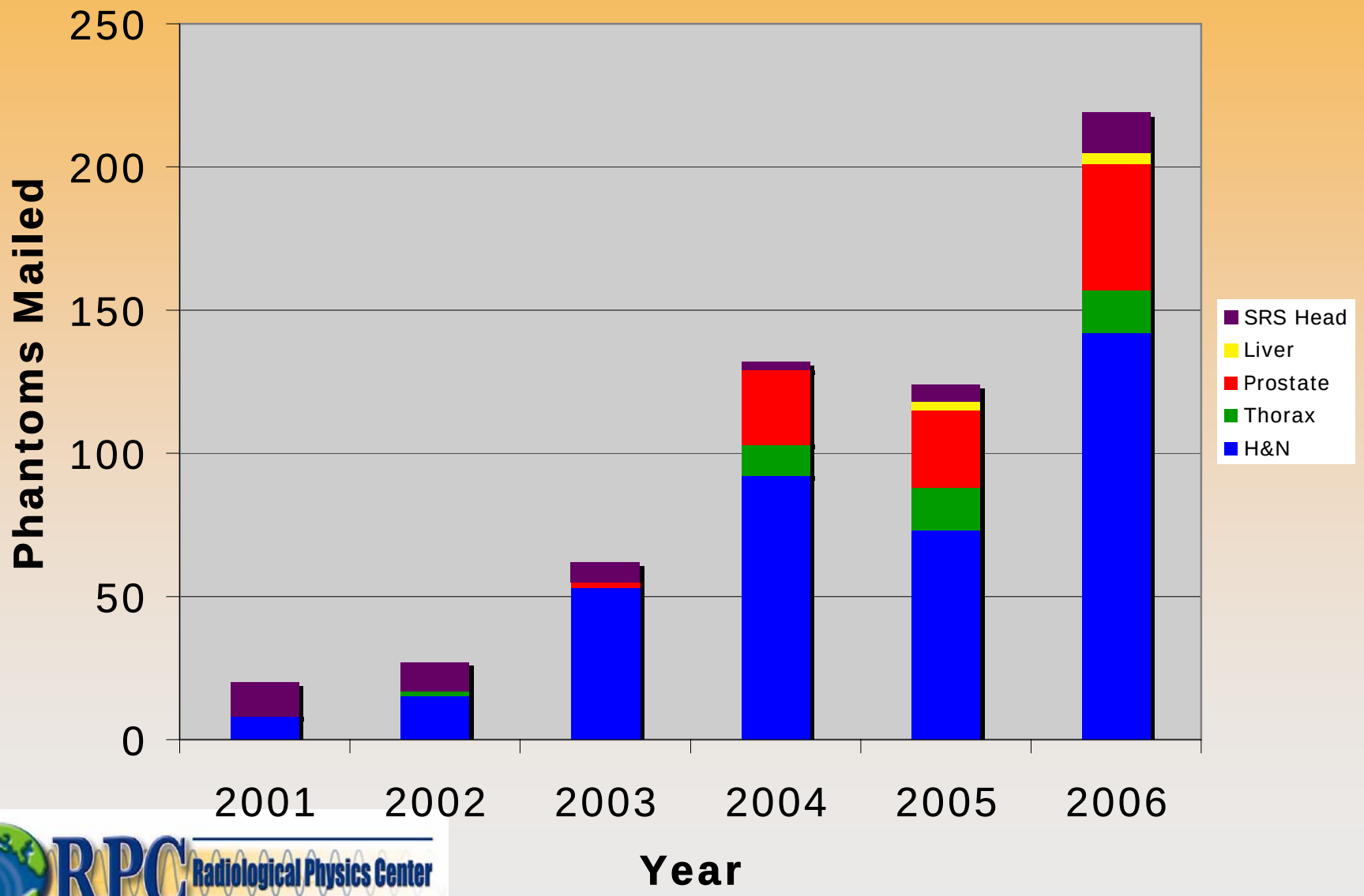
25 H&N phantoms (IMRT)

SRS



2 liver phantoms (SBRT)

Number of H&N Phantom Mailings



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Phantom Credentialing Process

Call the RPC and get placed on the request list

Phantom is shipped

Phantom is imaged

Treatment plan developed by inst. per instructions

Treatment is delivered to the phantom

Phantom is returned to the RPC for data analysis

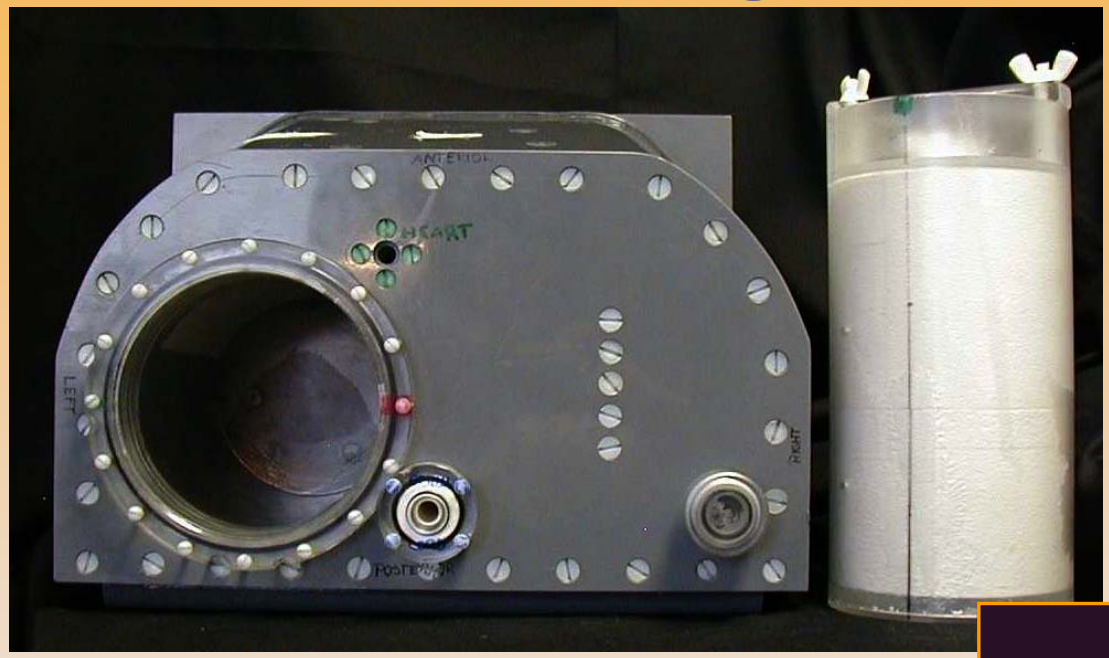
Treatment plan is submitted electronically to the ITC

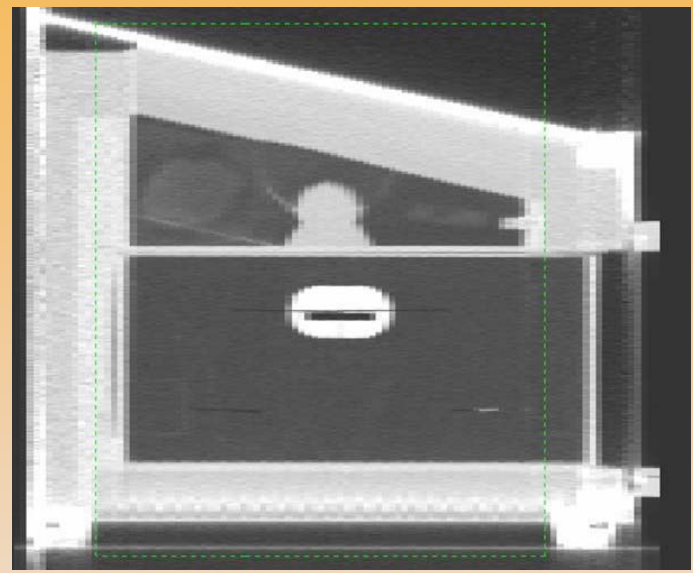
The phantom is to be treated as if it were a patient.

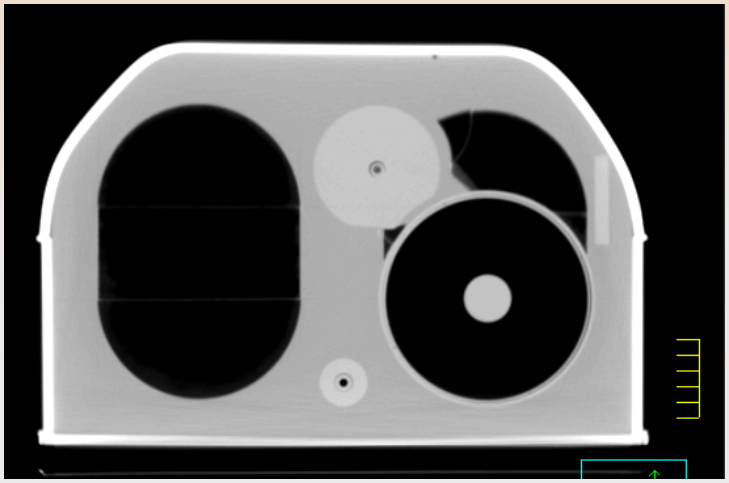
Some institutions go overboard!!

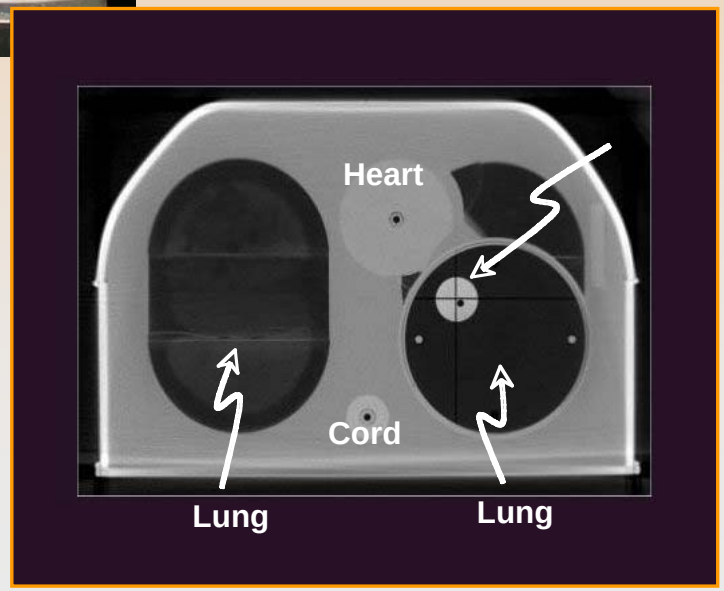
Some patients just want to better understand their treatment.

RPC Lung Phantom









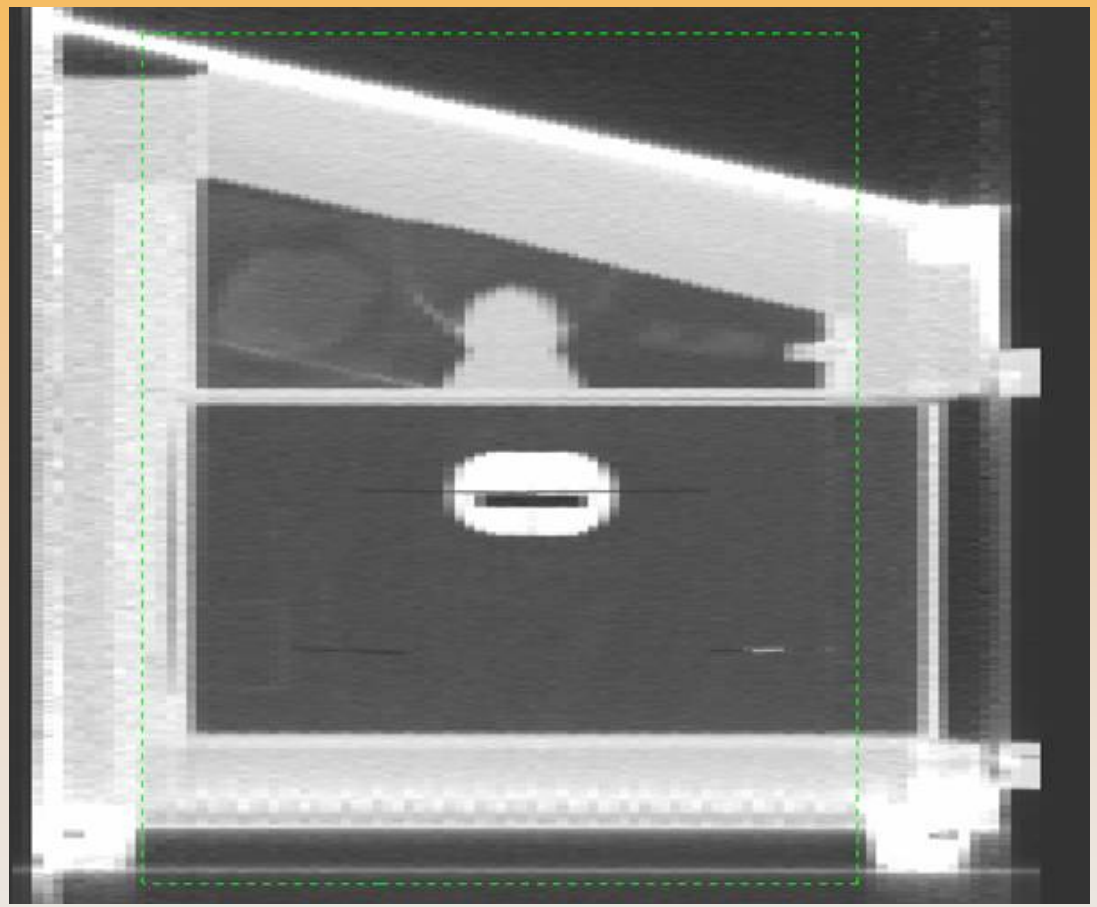
RPC Phantom

Target dimension

Ovoid shape

3 cm diameter

5cm long



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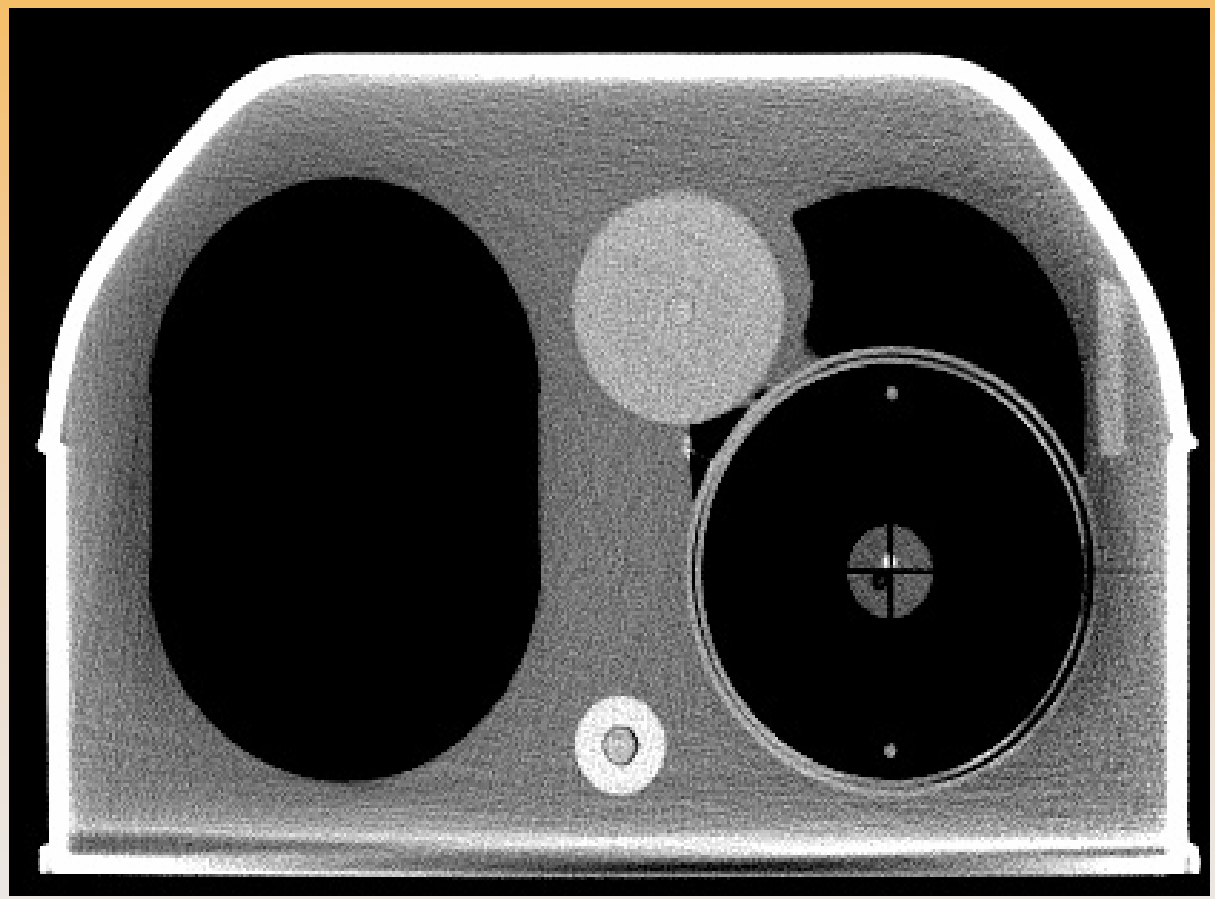
RPC Phantom (cont.)



Densities

Lung = 0.33g/cm^3

Heart, cord = 1.1 g/cm^3

Cord = 1.31 g/cm3

Tumor = 1.04 g/cm^3

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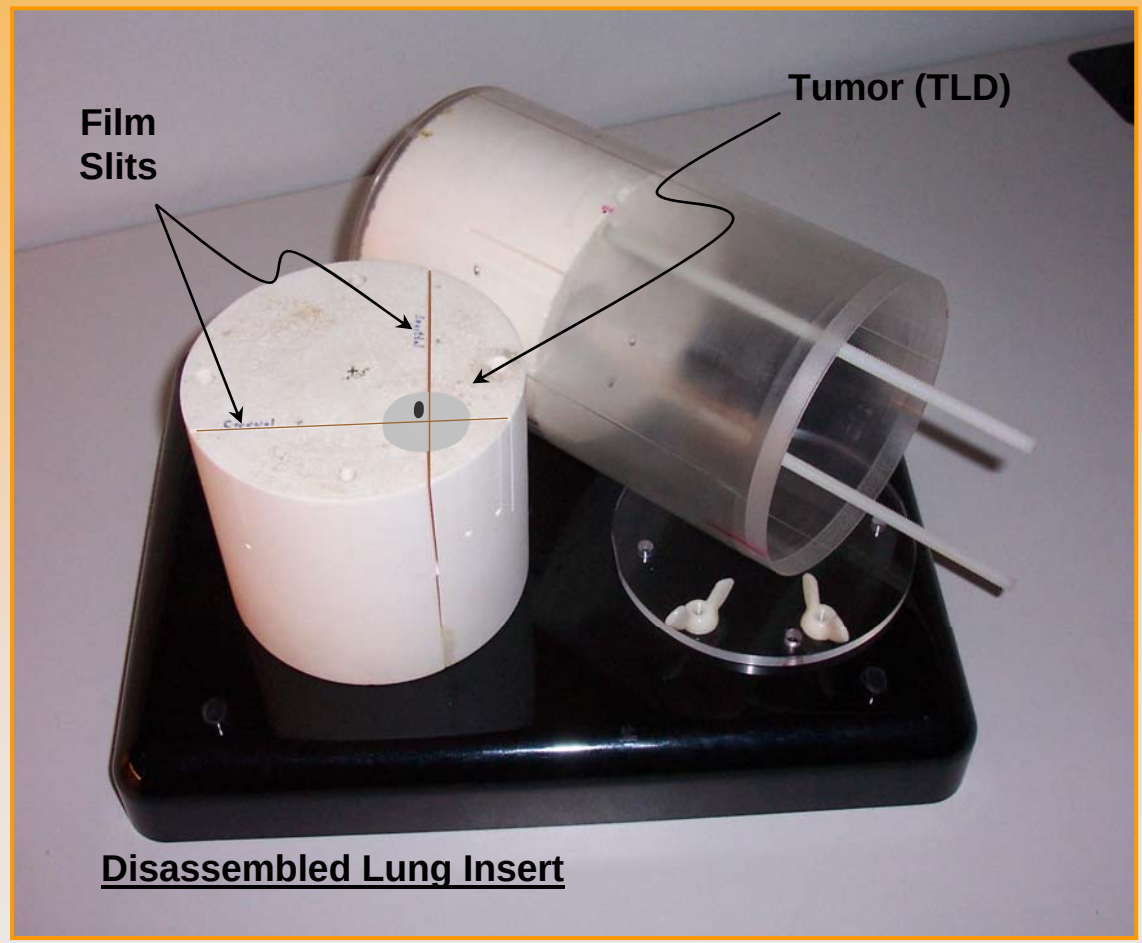
RPC Phantom (cont.)



Dosimeters

TLD and Gafchromic film

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Prescription

- Based on RTOG 0236 (SBRT Radioablation study)

- Energies: 4 – 10 MV
- ≥ 7 non-opposing static fields or ≥ 340° arc rotation technique.
- SBRT technique.
- 20 Gy/fx to 95% of the PTV
- Homogeneous planning and calculation of M.U.
- Must submit heterogeneous plan based on homogeneous M.U. set

Phantom Results

- A total of 30 irradiations were analyzed
- The 6 MV photon beam was used most often
- The TPSs used to plan the cases were:
  Pinnacle, BrainLab, XiO, Precise, Eclipse, Ergo and RenderPlan.
- Convolution Superposition algorithm was used most often.

Phantom Results

TPS	Dose Calc. Algorithm	# irradiations	Center of Tumor TPS D_{hetero}/D_{homo}
Precise	Scatter Int. Clarkson	2	1.19 ± 2.6%
BrainLab	Clarkson & Pencil beam	5	1.20 ± 2.2%
Eclipse	Pencil Beam	5	1.18 ± 4.3%
Ergo	3D Convol. Pencil Beam	2	1.19 ± 0.1%
RenderPlan	Change in primary attenuation	1	1.20
Pinnacle	Adaptive convolve	10	1.13 ± 2.1%
XiO	Superposition/Convolution	5	1.11 ± 2.3%

Clearly, there are two groupings

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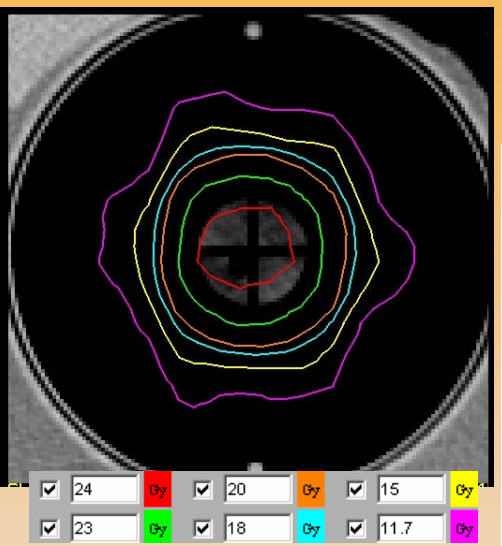
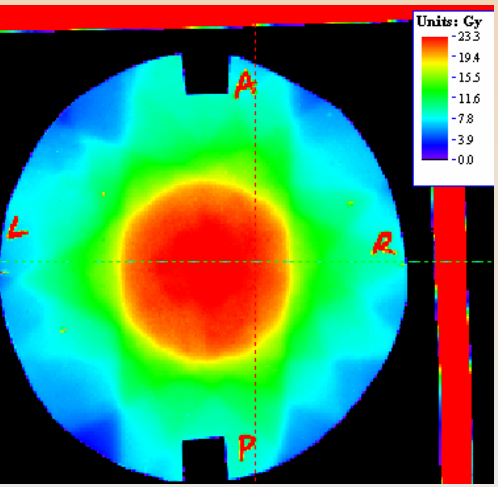
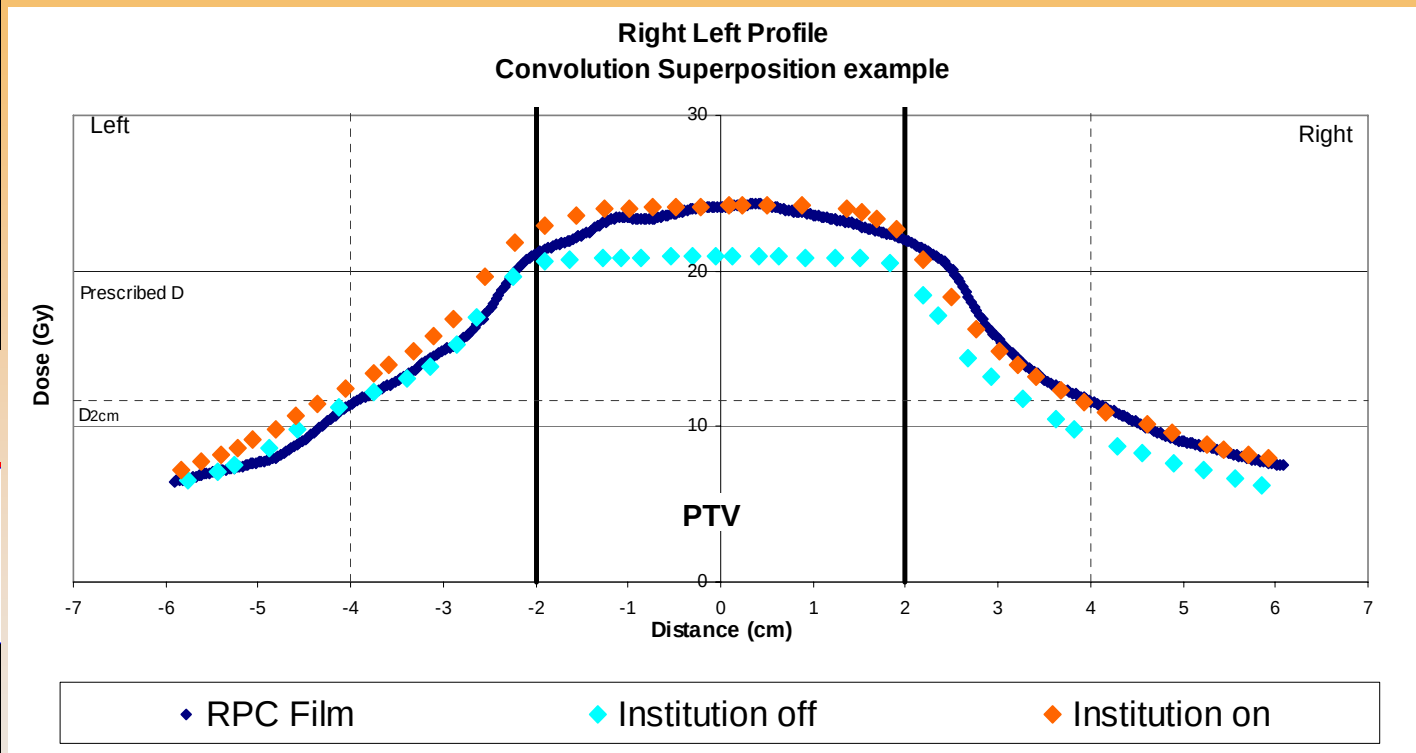
Phantom Results (cont'd)

TPS	Dose Calc. Algorithm	# irradiation	Center of Tumor Measured D_{TLD}/D_{hetero}
Precise	Scatter Int. Clarkson	2	0.99 ± 3.1%
BrainLab	Clarkson & Pencil beam	5	0.96 ± 2.4%
Eclipse	Pencil Beam	5	0.96 ± 1.8%
Ergo	3D Convol. Pencil Beam	2	0.98 ± 3.2%
RenderPlan	Change in primary attenuation	1	0.92
Pinnacle	Adaptive convolve	10	0.99 ± 2.1%
XiO	Superposition/Convolution	5	0.96 ± 2.0%

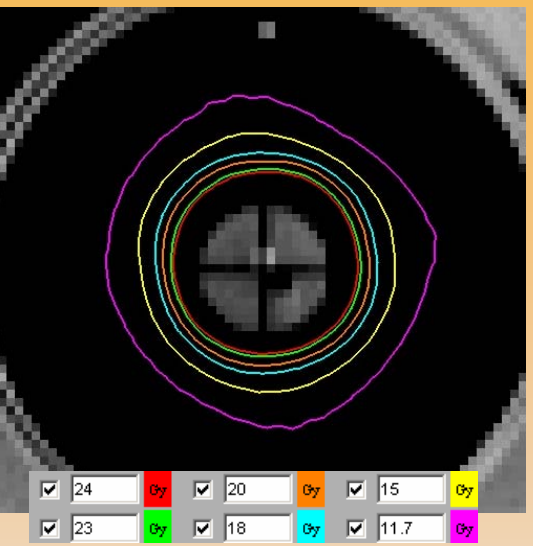
Profile analysis

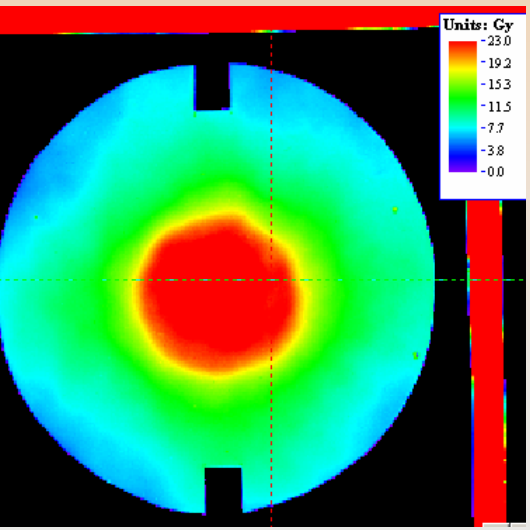


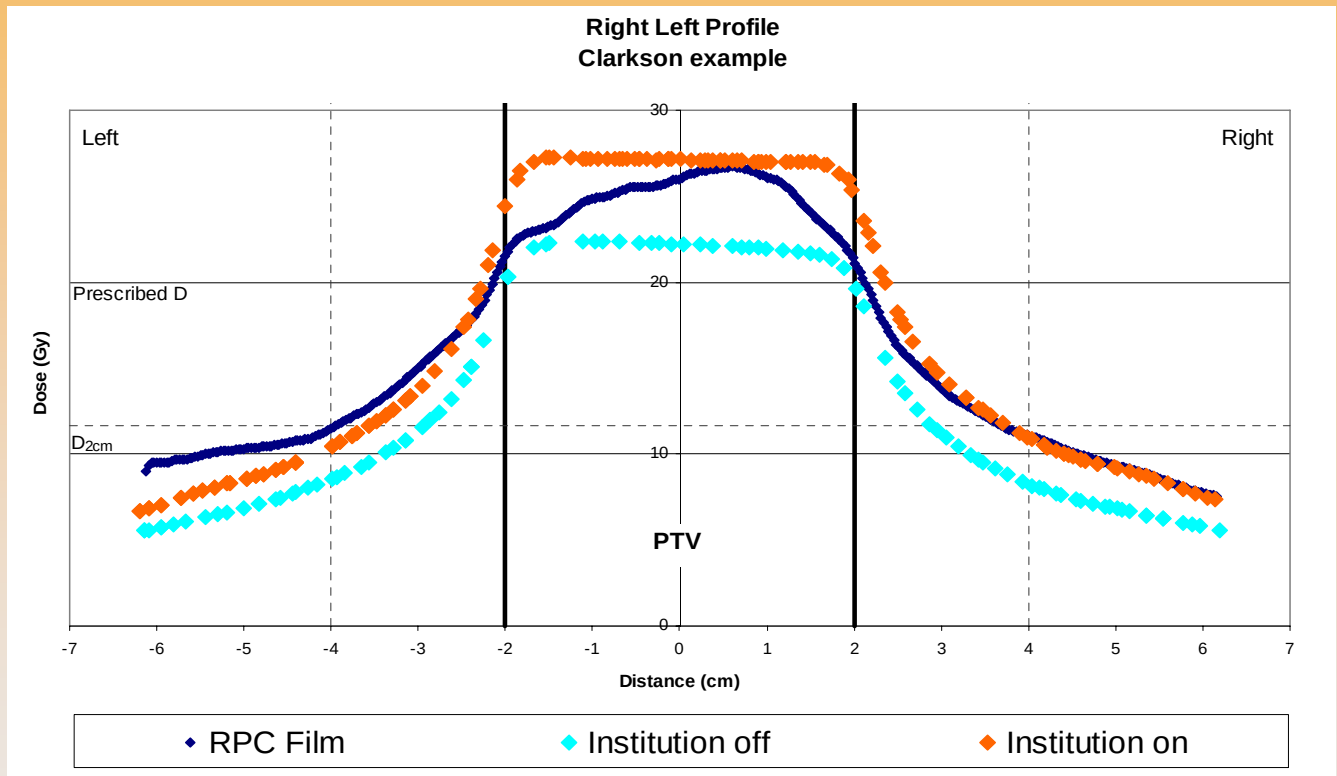




Profile analysis







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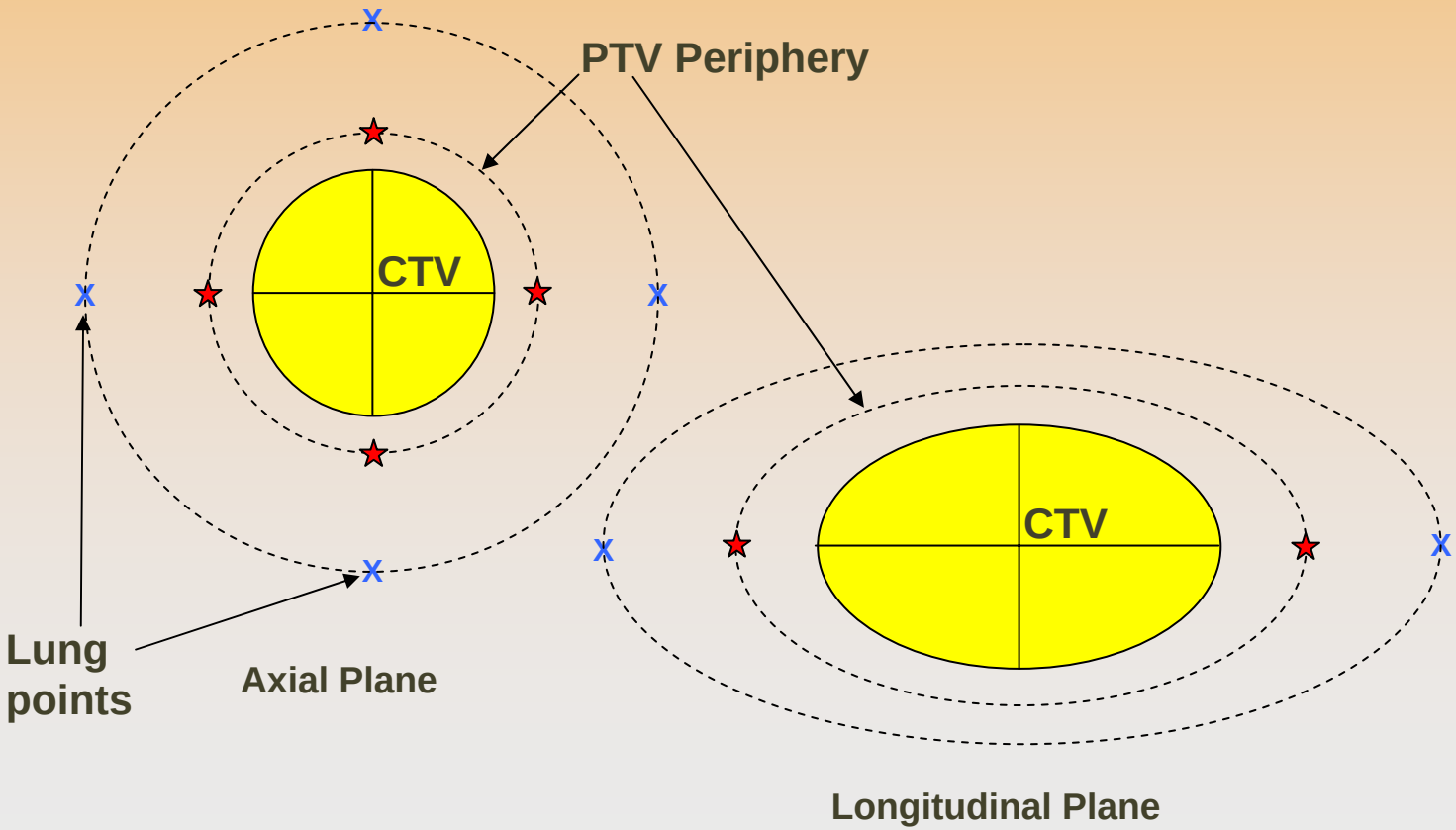
PTV Periphery and Lung Points

PTV = Tumor (CTV) + 0.5 cm in axial plane + 1 cm in longitudinal plane.

Lung constraint: points 2 cm from the PTV



Phantom Results (PTV Periphery)

TPS	Dose Calc. Algorithm	# irradiation	TPS D_{hetero}/D_{homo} Axial plane
Precise	Scatter Int. Clarkson	2	1.20 ± 3.2%
BrainLab	Clarkson & Pencil beam	2	1.17 ± 1.6%
Eclipse	Pencil Beam	5	1.17 ± 4.3%
Ergo	3D Convol. Pencil Beam	2	1.18 ± 1.3%
Pinnacle	Adaptive convolve	10	1.06 ± 4.2%
XiO	Superposition/Convol.	3	1.08 ± 5.3%

Two separate groupings again

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Phantom Results (PTV Periphery) Measurements

TPS	Dose Calc. Algorithm	# irradiation	PTV Periphery measured $D_{TLD/film}/D_{hetero}$
Precise	Scatter Int. Clarkson	2	0.88
BrainLab	Clarkson & Pencil beam	2	0.84
Eclipse	Pencil Beam	5	0.87
Ergo	3D Convol. Pencil Beam	2	0.84
Pinnacle	Adaptive convolve	10	0.97
XiO	Superposition/Convol.	3	0.95

Two separate groupings again

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Phantom Results (Lung points)

TPS	Dose Calc. Algorithm	# irradiation	TPS D_{hetero}/D_{homo} Axial plane
Precise	Scatter Int. Clarkson	2	1.19 ± 4.2%
BrainLab	Clarkson & Pencil beam	2	1.22 ± 5.5%
Eclipse	Pencil Beam	5	1.19 ± 8.3%
Ergo	3D Convol. Pencil Beam	2	1.20 ± 5.3%
Pinnacle	Adaptive convolve	10	1.12 ± 5.8%
XiO	Superposition/Convol.	3	1.12 ± 6.4%

Two separate groupings again

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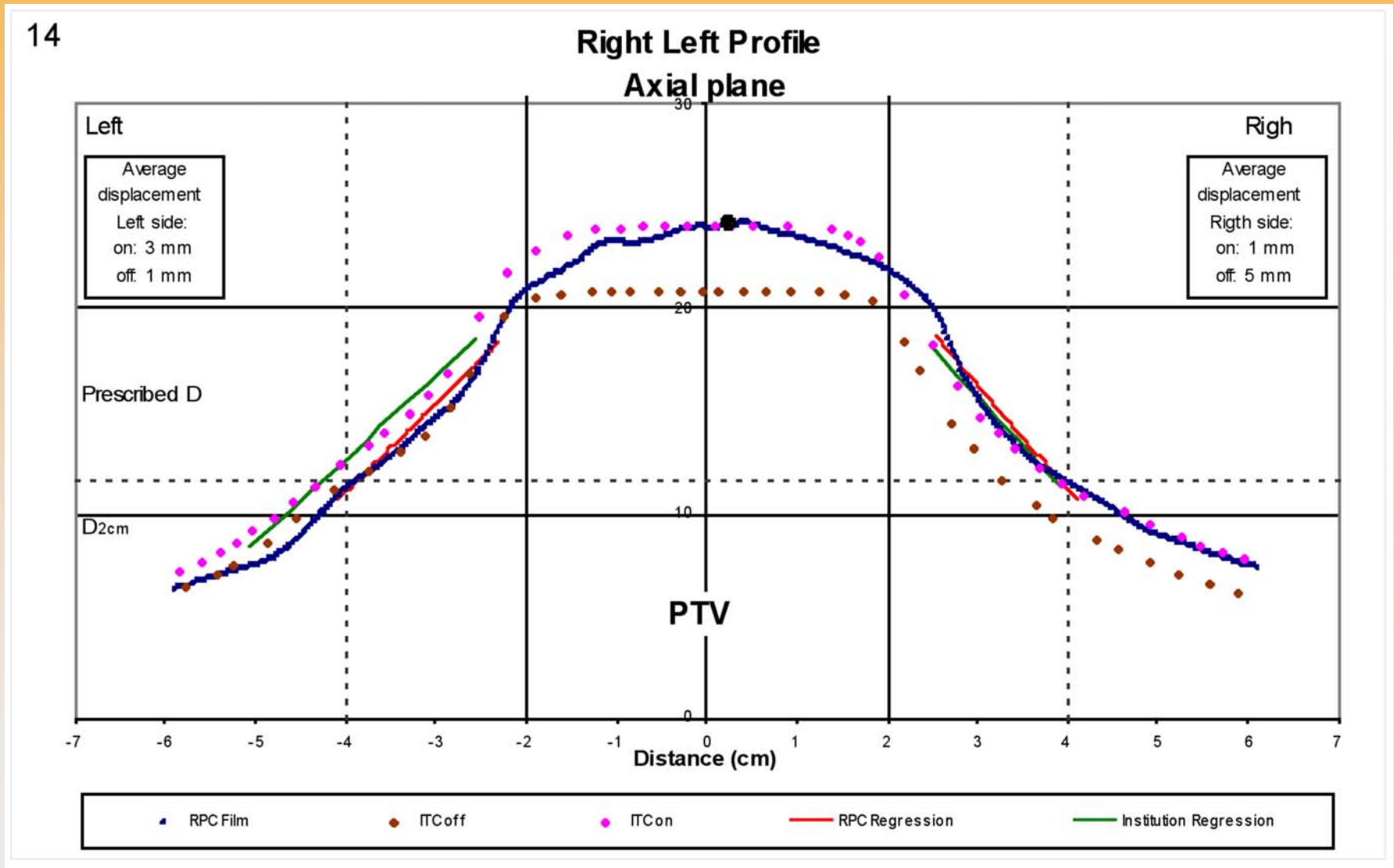
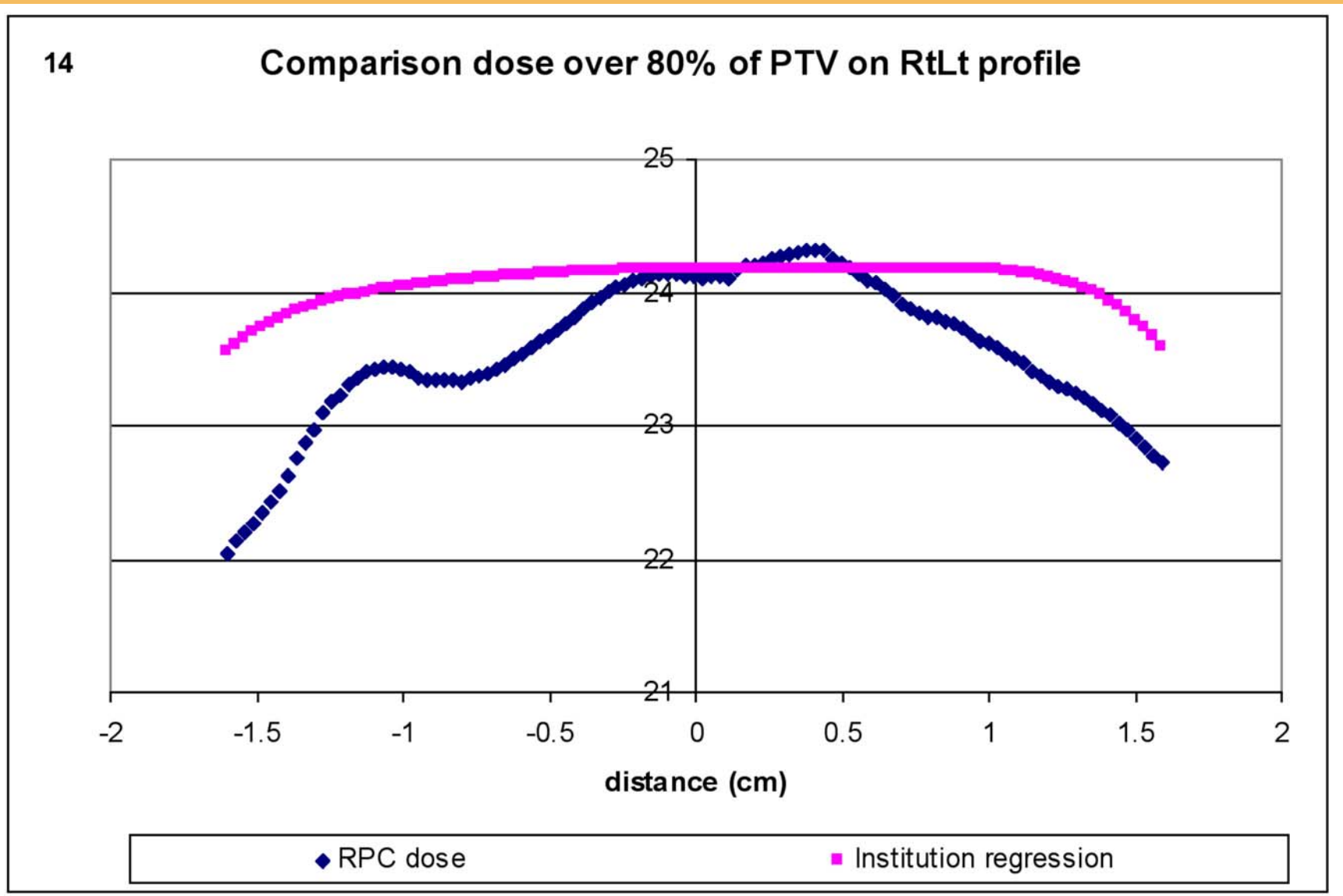
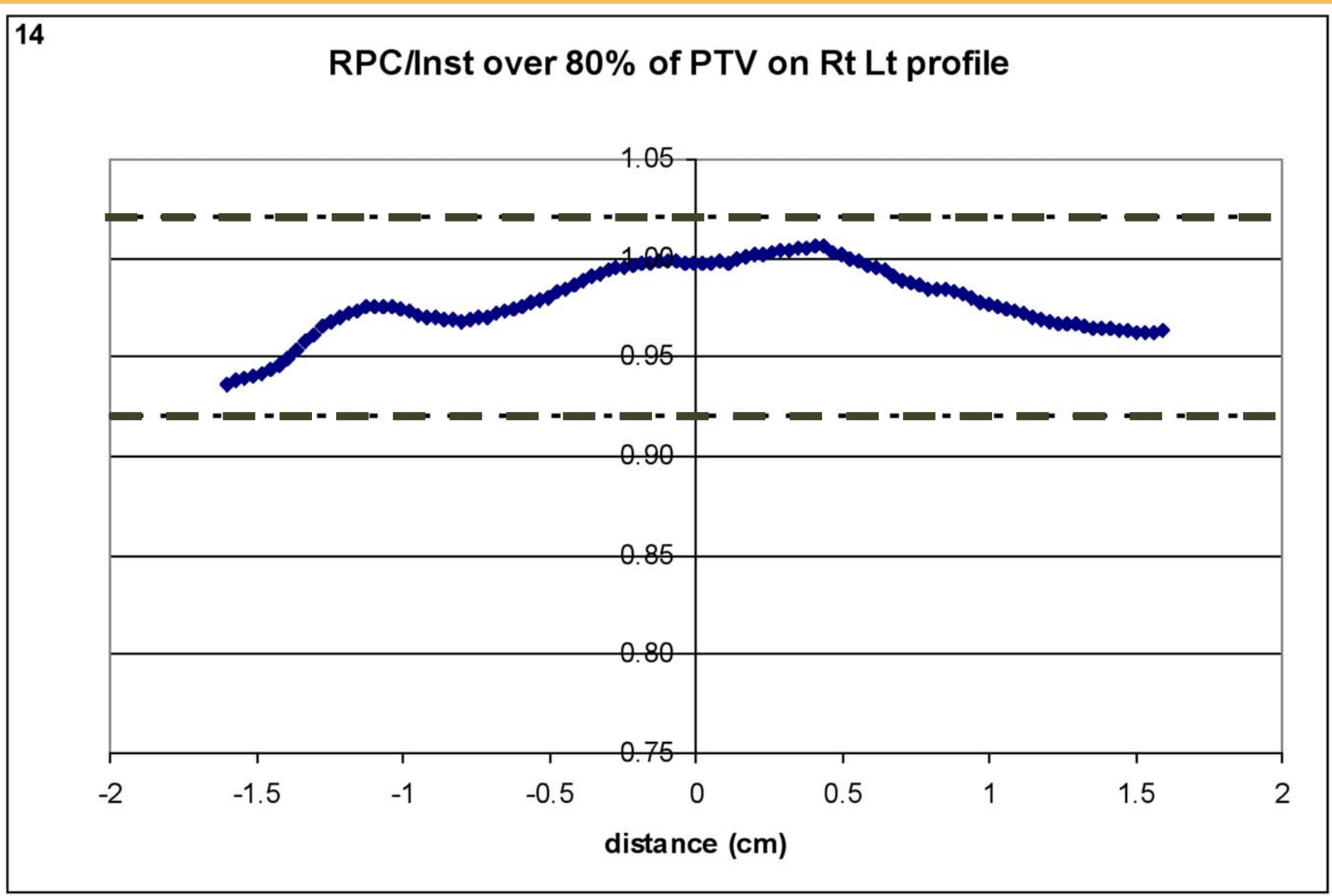
Convolution R-L Profile



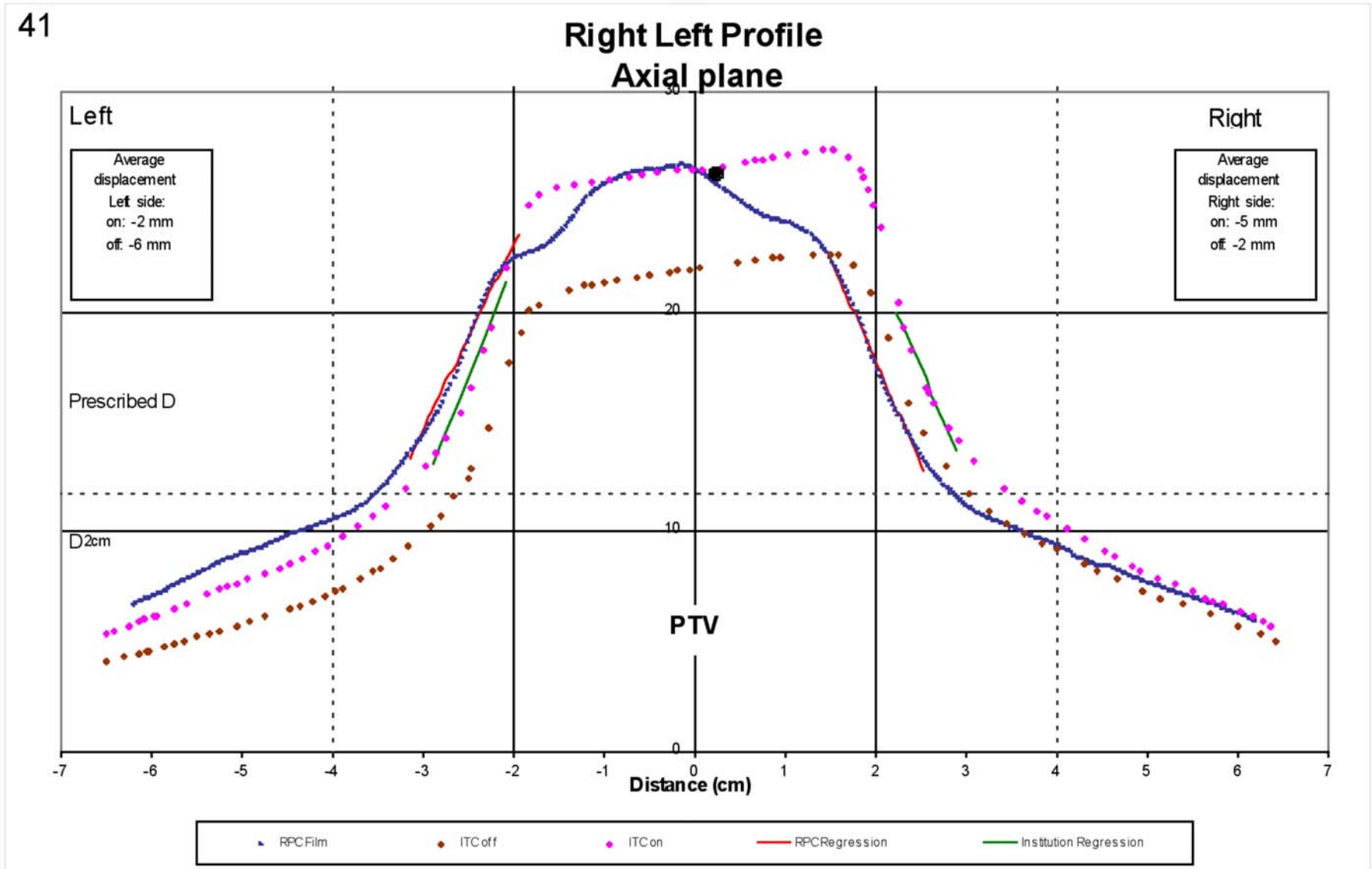
Convolution Central 80 %



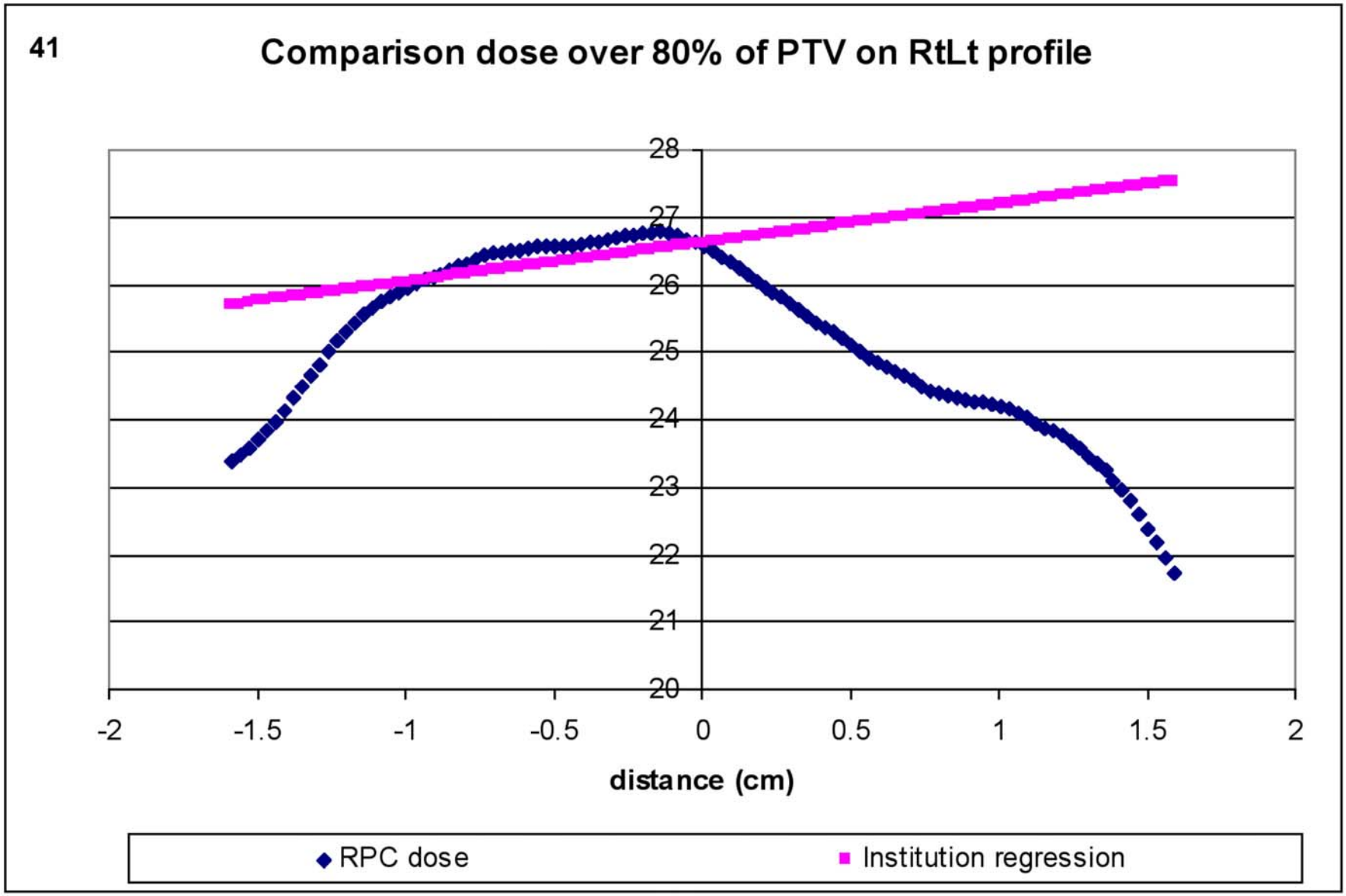
Convolution RPC/Inst.



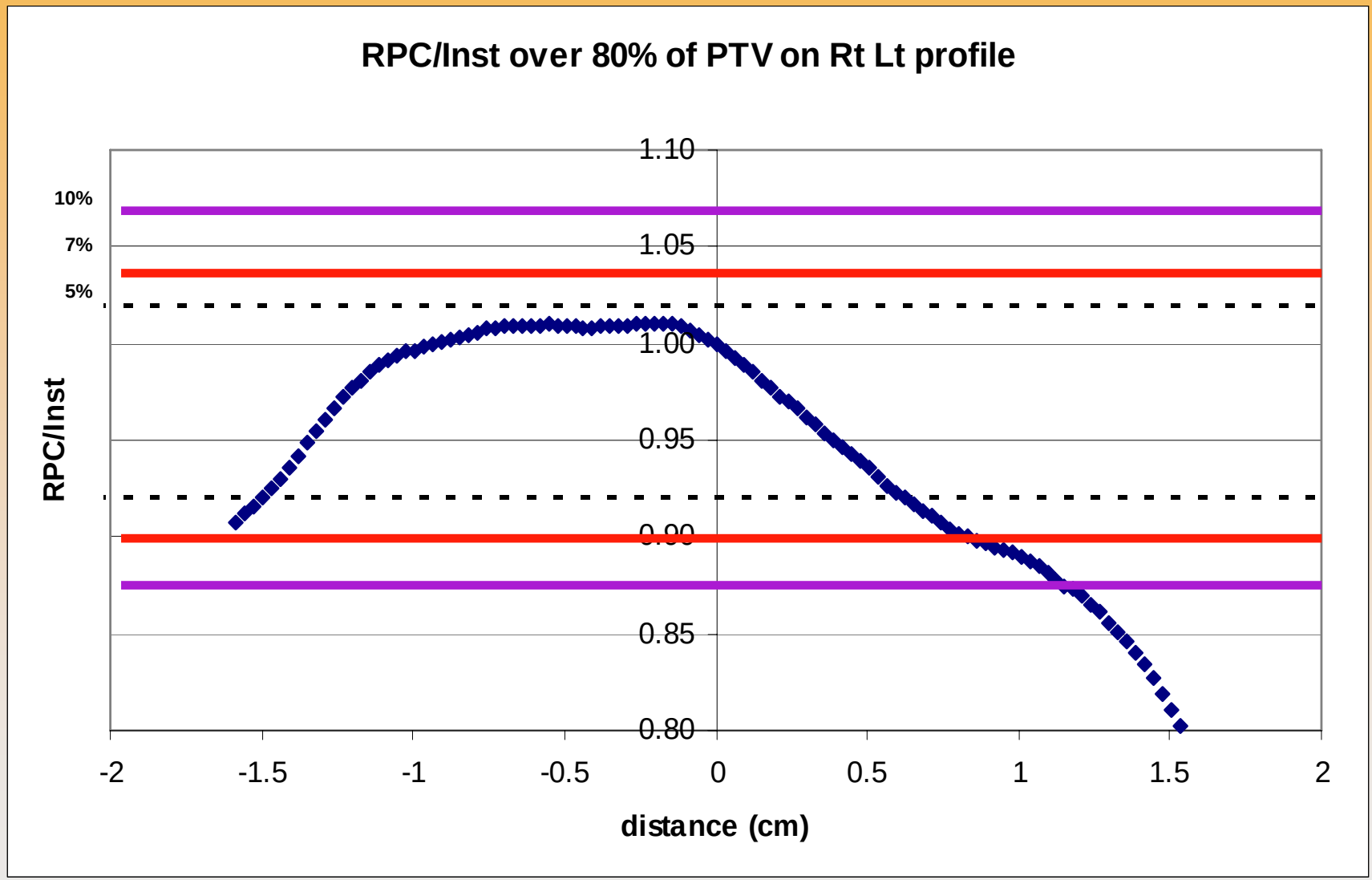
Pencil-Beam profile



Pencil Beam - Central 80%

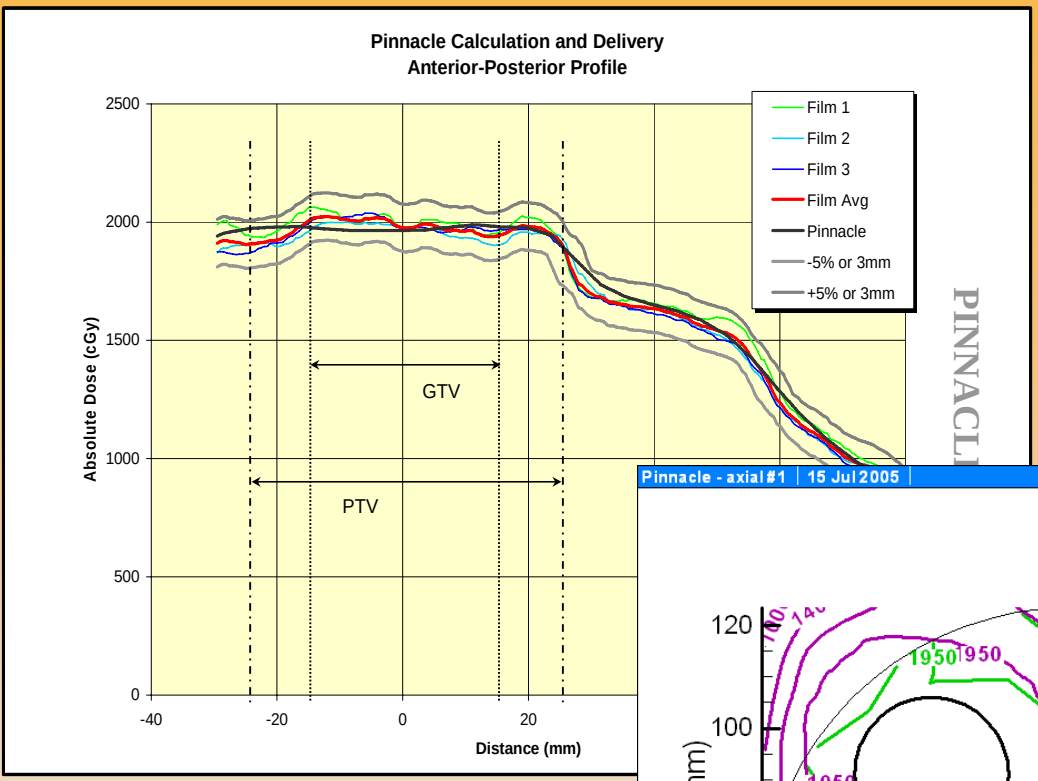


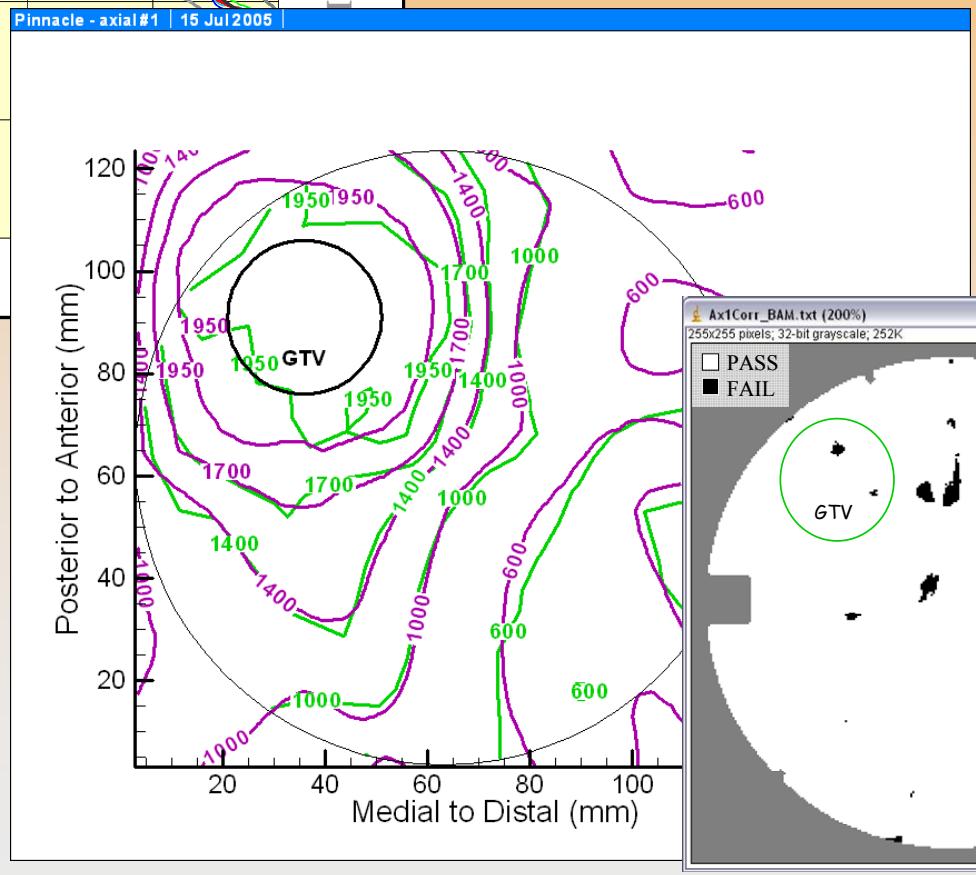
Pencil Beam RPC/Inst



Summary of Systems Passing Existing Criteria

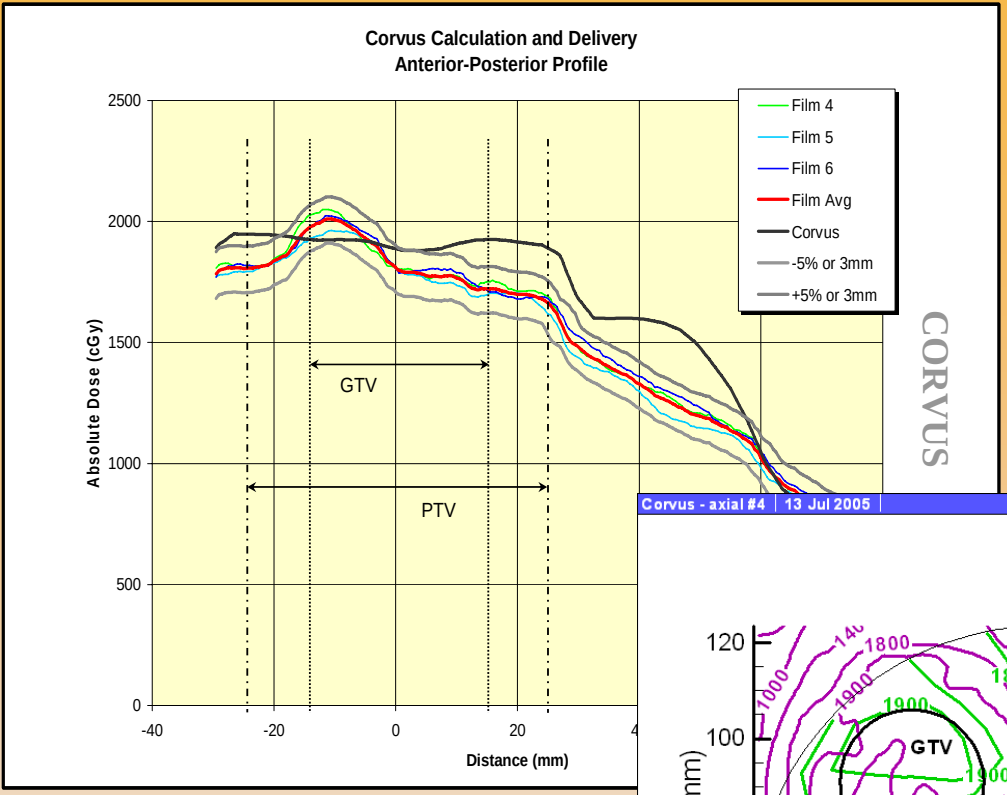
System/Algorithm	Percent of Points Within: 5%	7%	10%
Pencil Beam-Clarkson (n=9)	69 ±27%	83 ±14%	92 ±8%
Convolution-Superposition (n=11)	87 ±20%	95 ±13%	99 ±5%

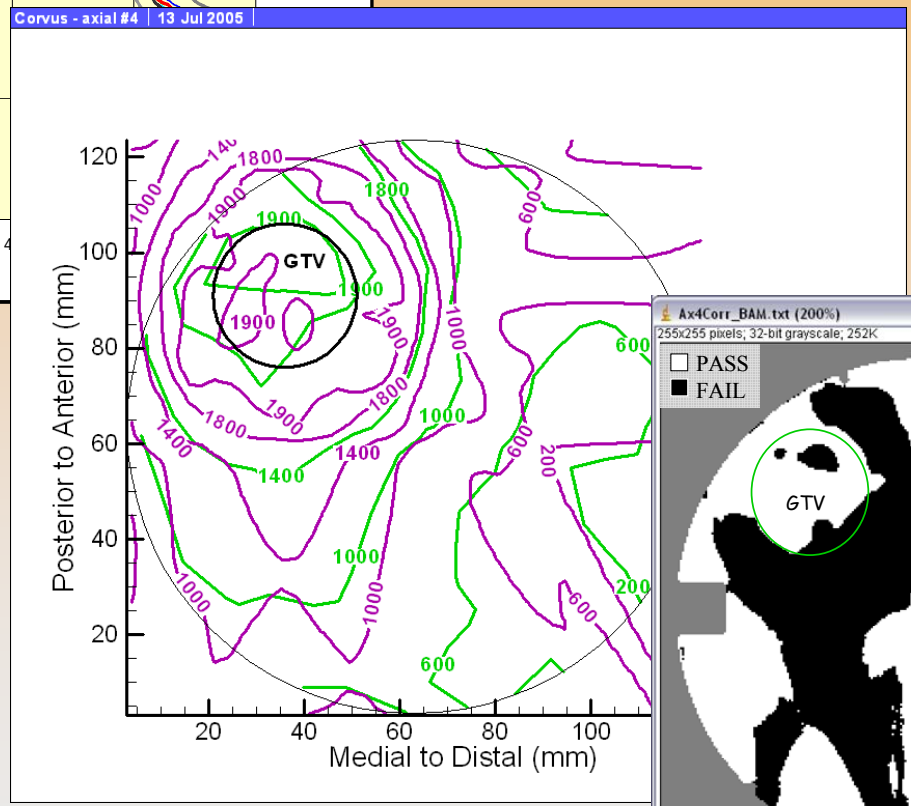

Pinnacle Calculation and Delivery
Anterior-Posterior Profile
Absolute Dose (cGy)
2500
2000
1500
1000
500
0
-40
-20
0
20
Distance (mm)
GTV
PTV
Film 1
Film 2
Film 3
Film Avg
Pinnacle
-5% or 3mm
+5% or 3mm
PINNACL

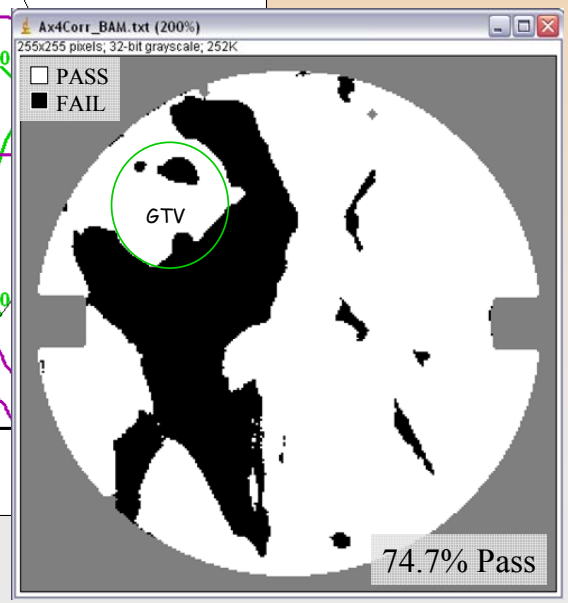

Pinnacle - axial #1 | 15 Jul 2005
Posterior to Anterior (mm)
120
100
80
60
40
20
20
40
60
80
100
Medial to Distal (mm)
GTV
1950
1700
1400
1000
600

Ax1Corr_BAM.txt (200%)
255x255 pixels; 32-bit grayscale; 252K
PASS
FAIL
GTV
98.2% Pass

Pinnacle


Corvus Calculation and Delivery
Anterior-Posterior Profile
Film 4
Film 5
Film 6
Film Avg
Corvus
-5% or 3mm
+5% or 3mm
CORVUS
GTV
PTV
Absolute Dose (cGy)
Distance (mm)


Corvus - axial #4 | 13 Jul 2005
GTV
Posterior to Anterior (mm)
Medial to Distal (mm)


Ax4Corr_BAM.txt (200%)
255x255 pixels; 32-bit grayscale; 252K
PASS
FAIL
GTV
74.7% Pass

CORVUS

Conclusions

- The average target TLD/Inst ratio is 0.97 (range 0.92 to 0.99). Good agreement for Convolution Superposition algorithms in the target.
- Large differences exists between the Convolution Superposition heterogeneity corrected dose calculations and other algorithms (ratios of 1.13 vs. 1.20).
- Heterogeneity corrected doses at the PTV periphery and lung points are higher than uncorrected doses.
- The Convolution Superposition algorithm calculations agree with the RPC measurements.
- New evaluation methods needed to assess each algorithm's accuracy


Thank you