The Radiological Physics Center's QA Activities

AAPM Refresher Course
July 25, 2007
Geoffrey S. Ibbott, Ph.D. and
RPC Staff

http://rpc.mdanderson.org

Supported by NCI grants CA10953 and CA81647, and educational grant from Varian

Division of Radiation Oncology

- Dept. of Radiation Oncology
- **Dept. of Radiation Physics**
  - Section of Physics Education
  - Section of Clinical Physics
  - **Section of Outreach Physics**
    - Radiation Dosimetry Services
    - Late Effects
    - **Radiological Physics Center**
    - Accredited Dosimetry Calibration Laboratory
  - Section of Proton Physics
  - Section of Physics Research
- Dept. of Experimental Radiation Oncology

Brief Background

- Formed by agreement between AAPM and CRTS
- Founded in 1968 to monitor institution participation in clinical trials
- Funded continuously by NCI as structure of cooperative group programs have changed
- Now 38 years of experience of monitoring institutions and reporting findings to study groups and community

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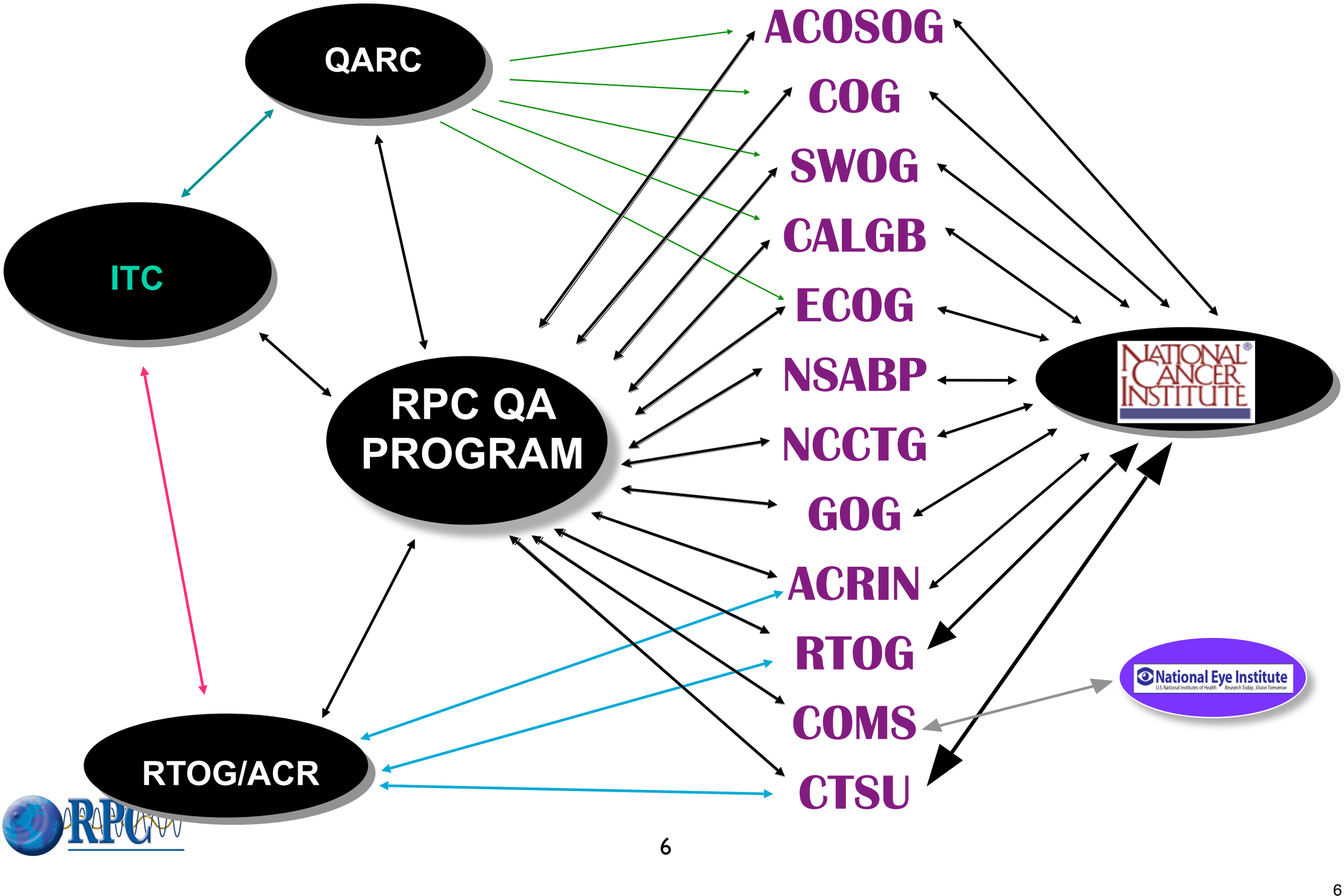
Mission

The mission of the Radiological Physics Center is to assure NCI and the Cooperative Groups that institutions participating in clinical trials deliver prescribed radiation doses that are clinically comparable and consistent. We do this by assessing the institution's radiotherapy programs, helping the institutions implement remedial actions, assisting the study groups in developing protocols and QA procedures, and informing the community of our findings.

Only QA Office with relationships with <u>all</u> study groups



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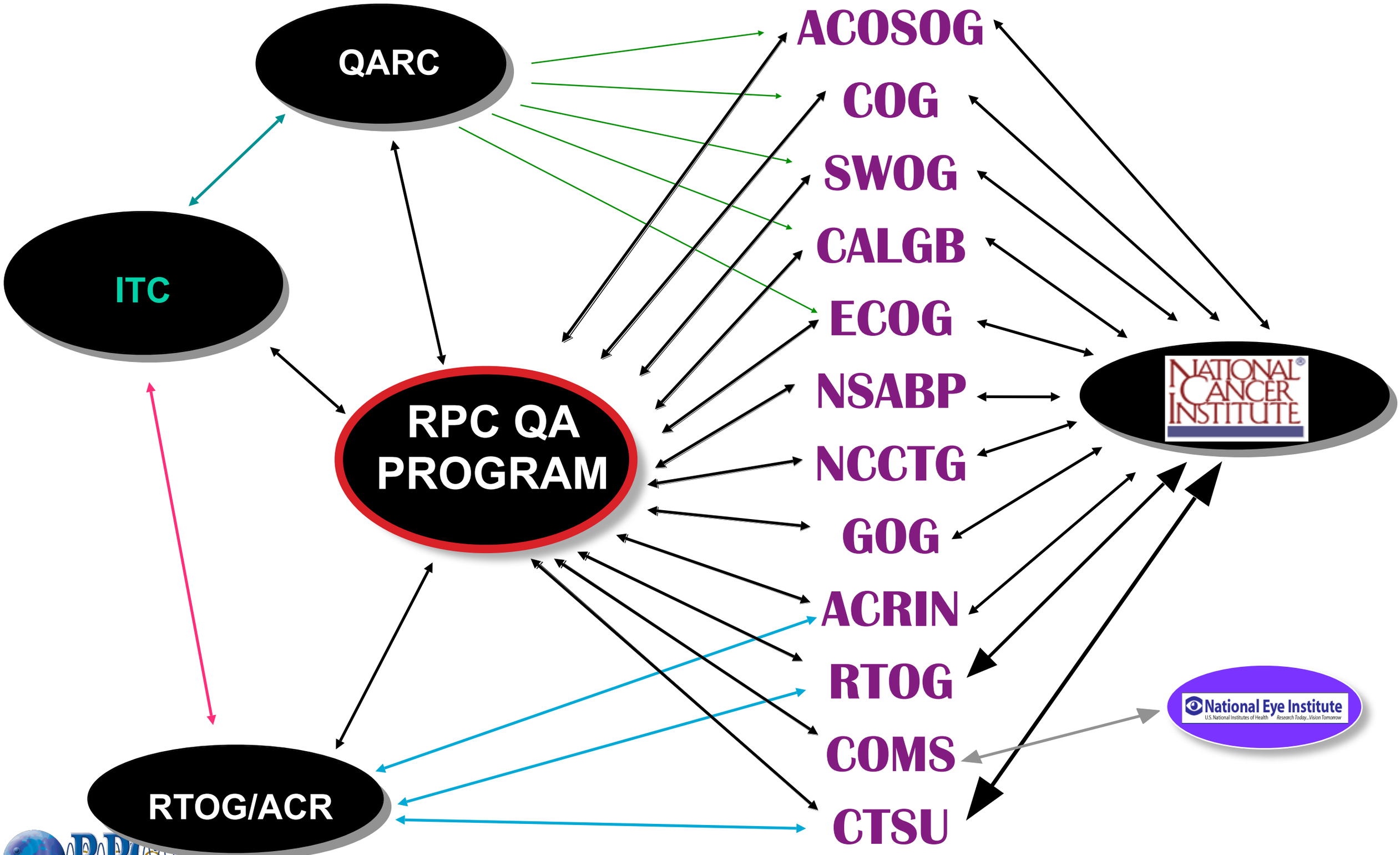
Only QA Office with relationships with <u>all</u> study groups



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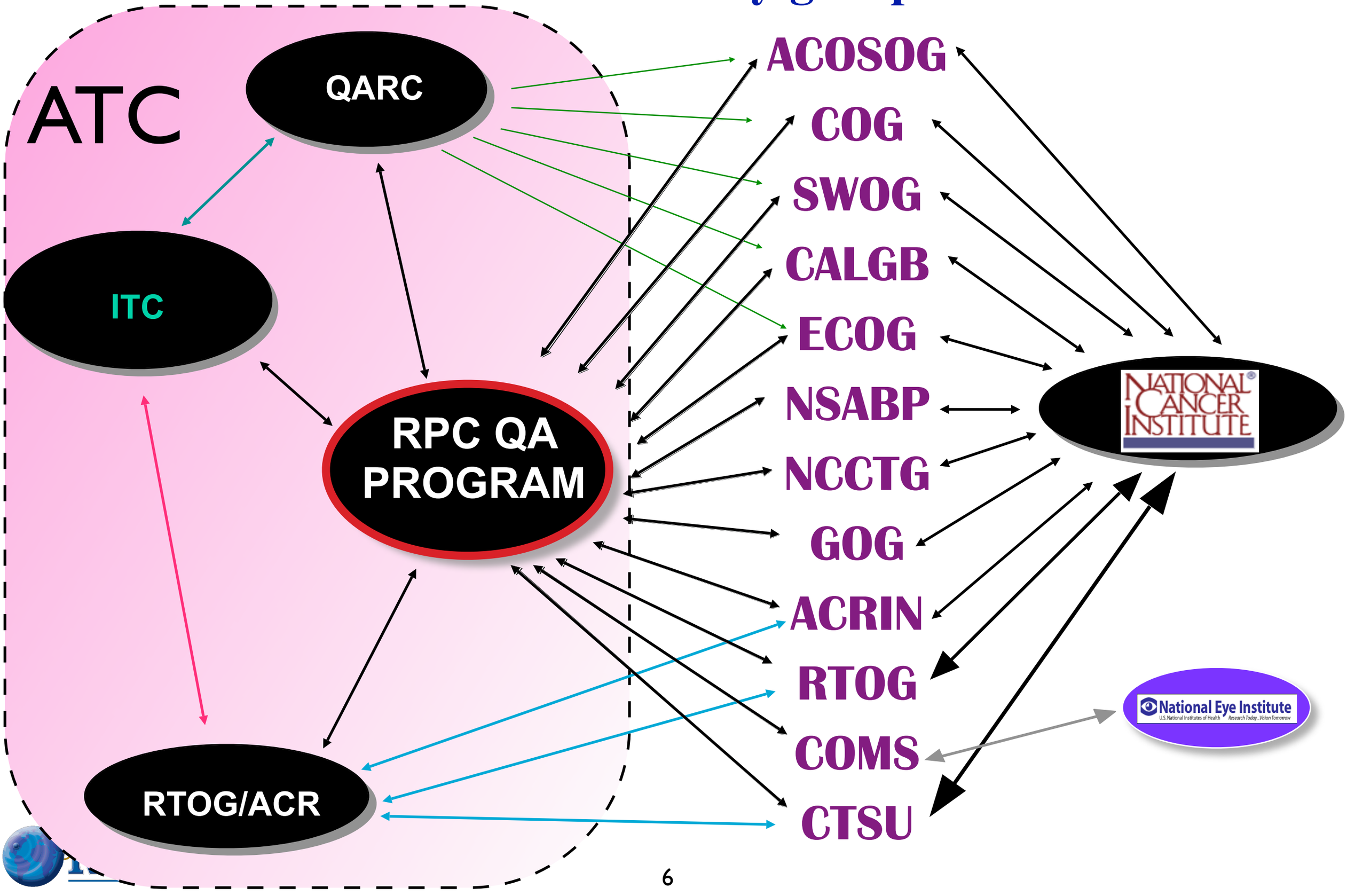
Only QA Office with relationships with <u>all</u> study groups



6

Verification of Delivery of Tumor Dose

Reference calibration
(NIST traceable)

×

Correction Factors:
Field size & shape
Depth of target
Transmission factors
Treatment time

↓

Tumor Dose

7

Verification of Delivery of Tumor Dose

Reference calibration (NIST traceable)

×

Correction Factors:
Field size & shape
Depth of target
Transmission factors
Treatment time

↓

Tumor Dose

Evaluated by RPC Dosimeters

Evaluated by RPC visits and chart review

Evaluated by RPC phantoms

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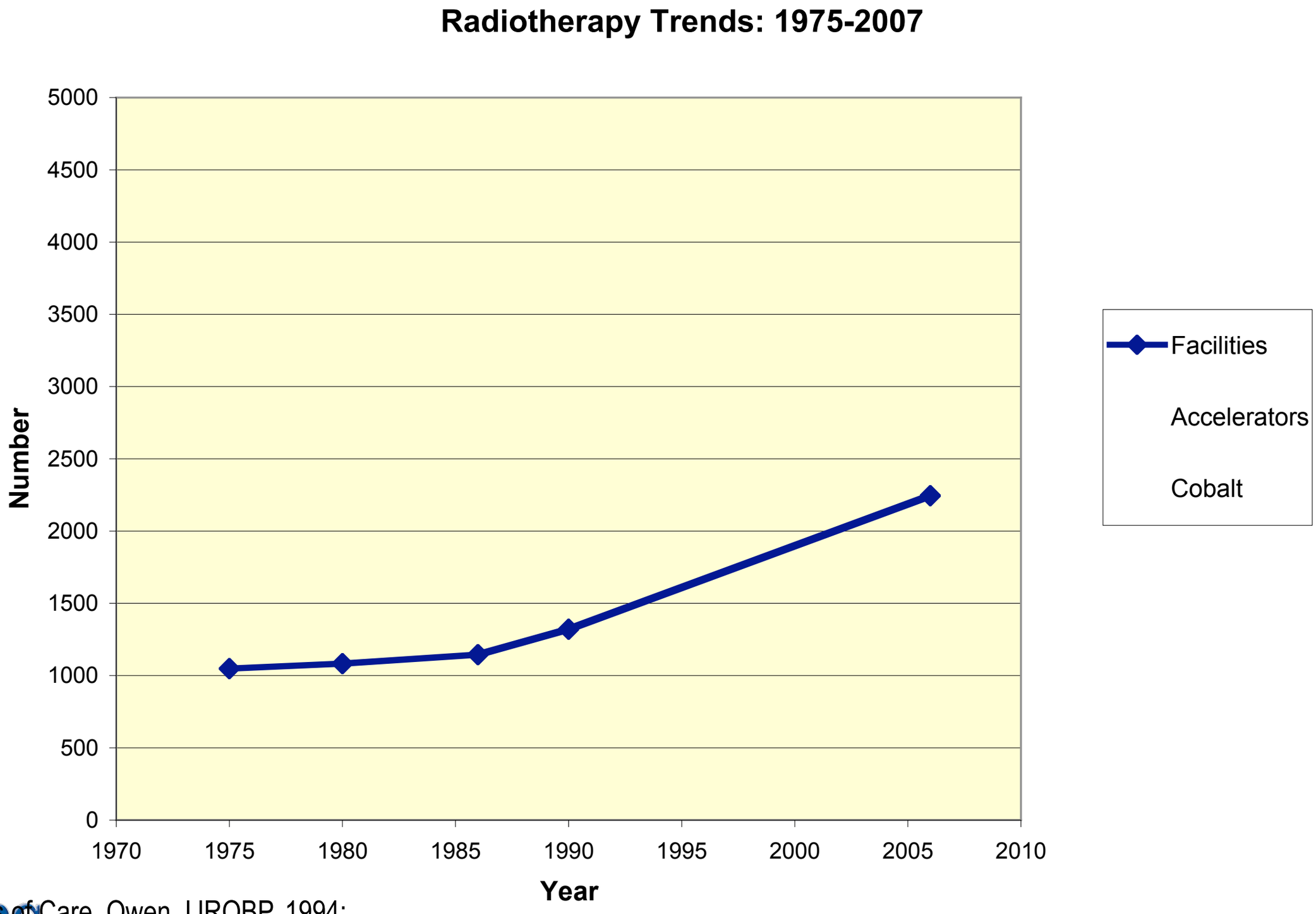
RPC's Conventional Monitoring

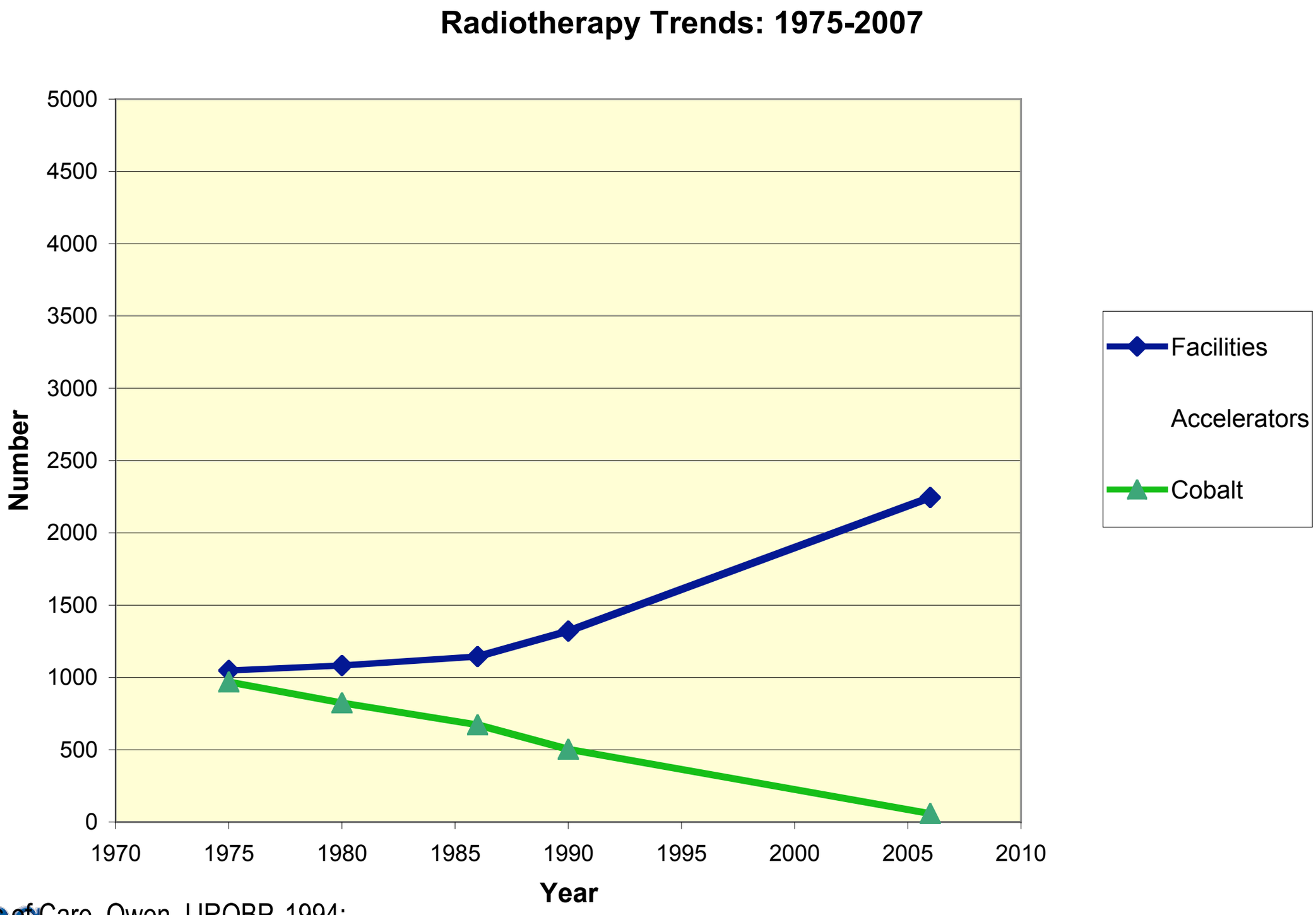
- Annual checks of machine output
  - 1,532 institutions, 13,729 beams measured with TLD (2006)
- On-site dosimetry reviews
  - 19 institutions visited (144 beams measured)
- Credentialing
  - Phantoms, benchmarks, questionnaires, rapid reviews
- Treatment record reviews
  - Review for GOG, NSABP, NCCTG, RTOG (brachy)
- Independent recalculation of patient dose
  - Continue to find errors

US Institutions & Machines



Patterns of Care, Owen, IJROBP, 1994;
Ballas, Int. J. Radiation Oncology Biol. Phys. **66**, 2006

US Institutions & Machines



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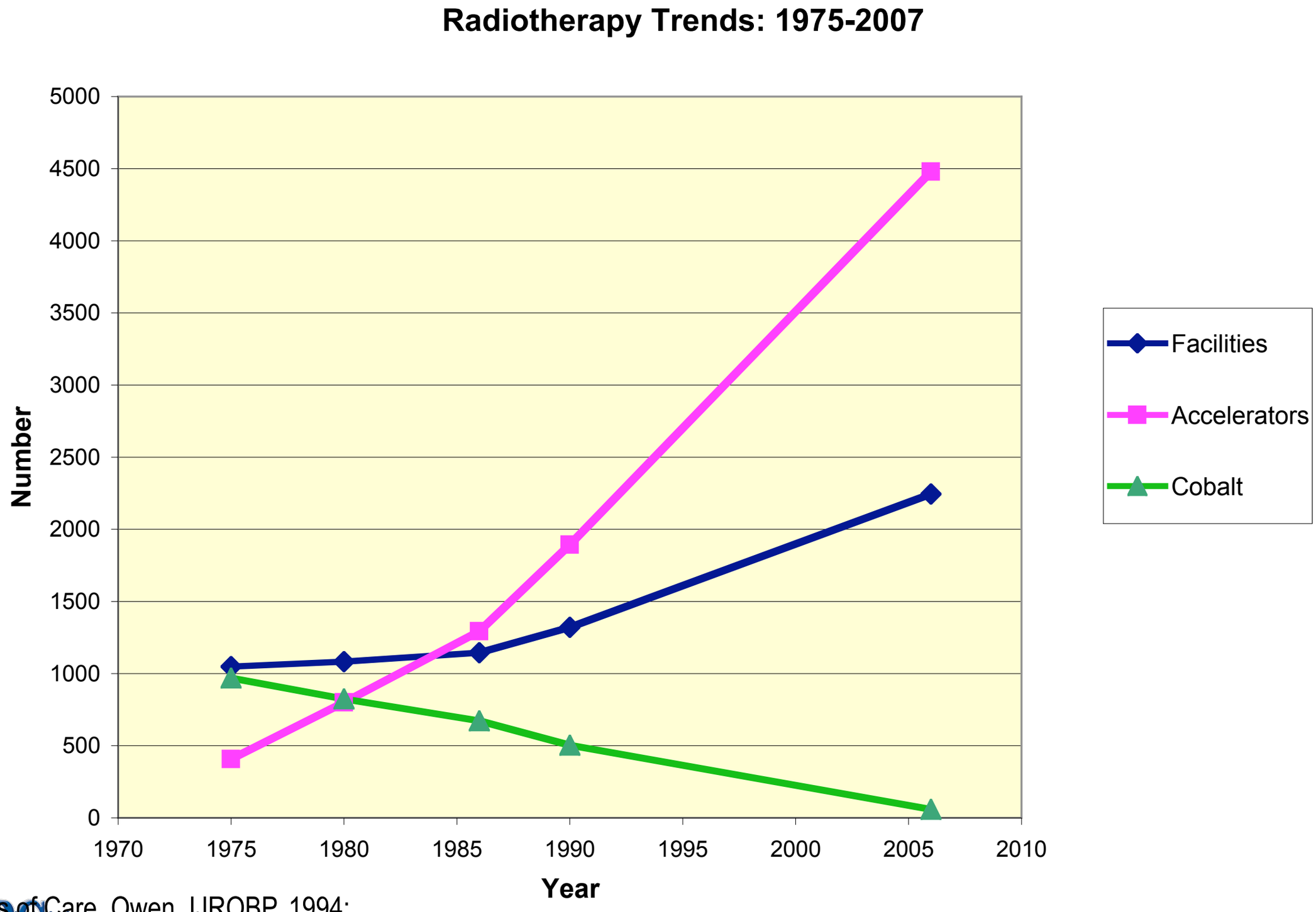
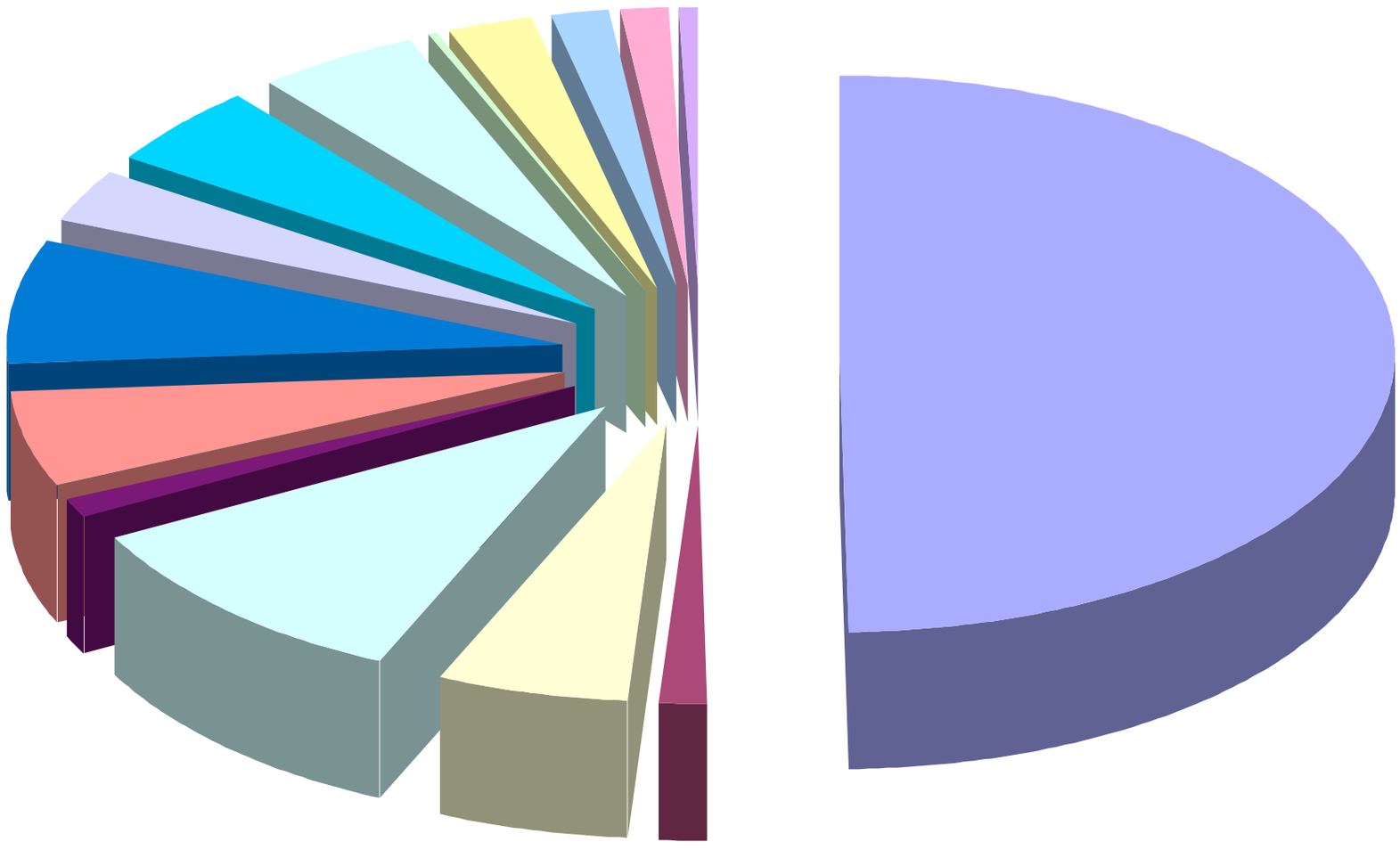
US Institutions & Machines



Patterns of Care, Owen, IJROBP, 1994;
Ballas, Int. J. Radiation Oncology Biol. Phys. **66**, 2006

2,979 US Treatment Machines Monitored by the RPC



TLD Remote Audit Program

- 30 years in operation
- Largest of its kind
- Other programs (IAEA, ESTRO, RDS)

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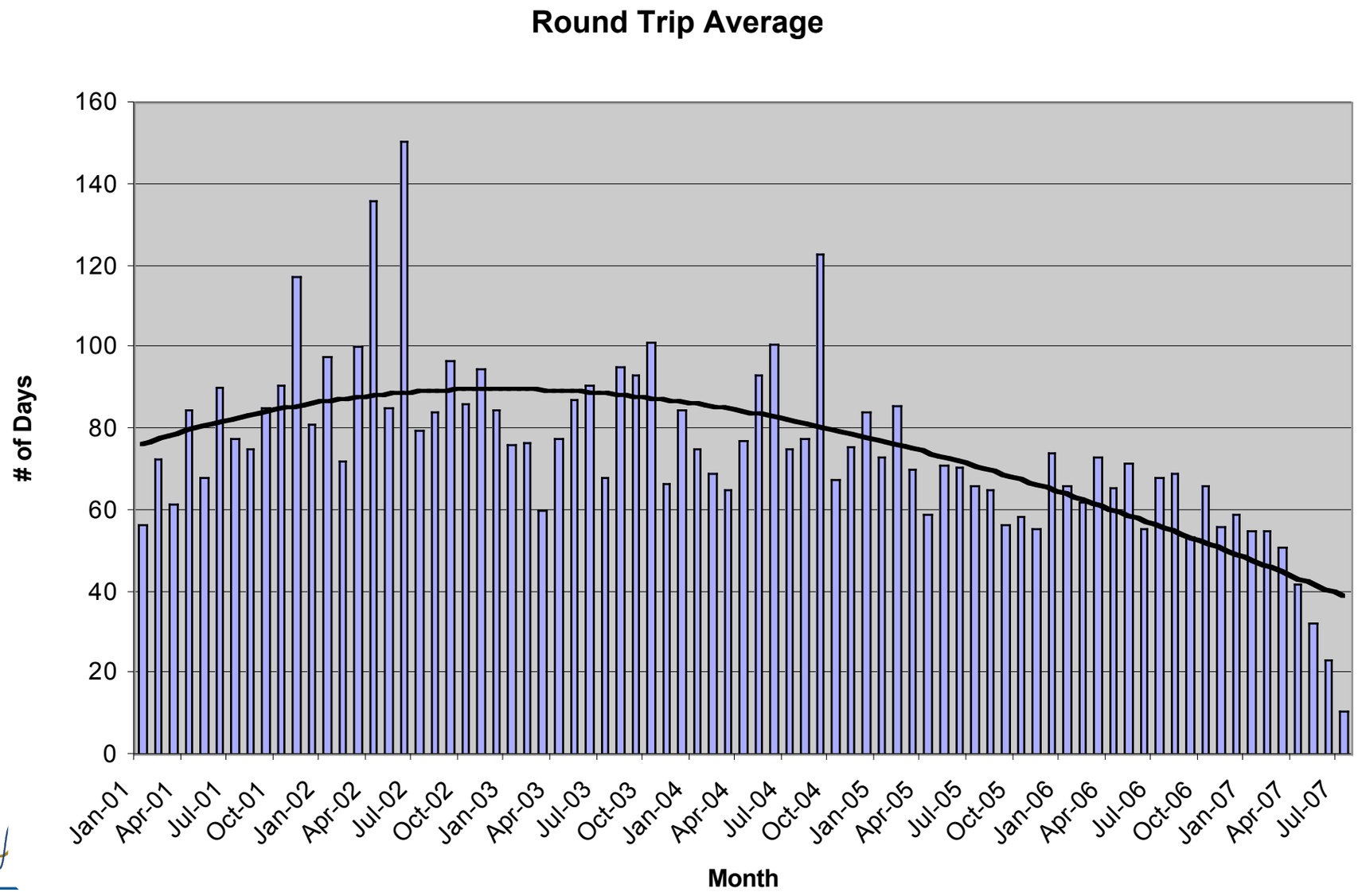
TLD Remote Audit Program [2]

- Improvements in "round-trip" time
- Improvements in reporting time



TLD Remote Audit Program [2]

- Improvements in "round-trip" time
- Improvements in reporting time
- Reduced "receipt-to-read time from 2 months to 4 days
- Reduced "receipt-to-report" time to 11 days

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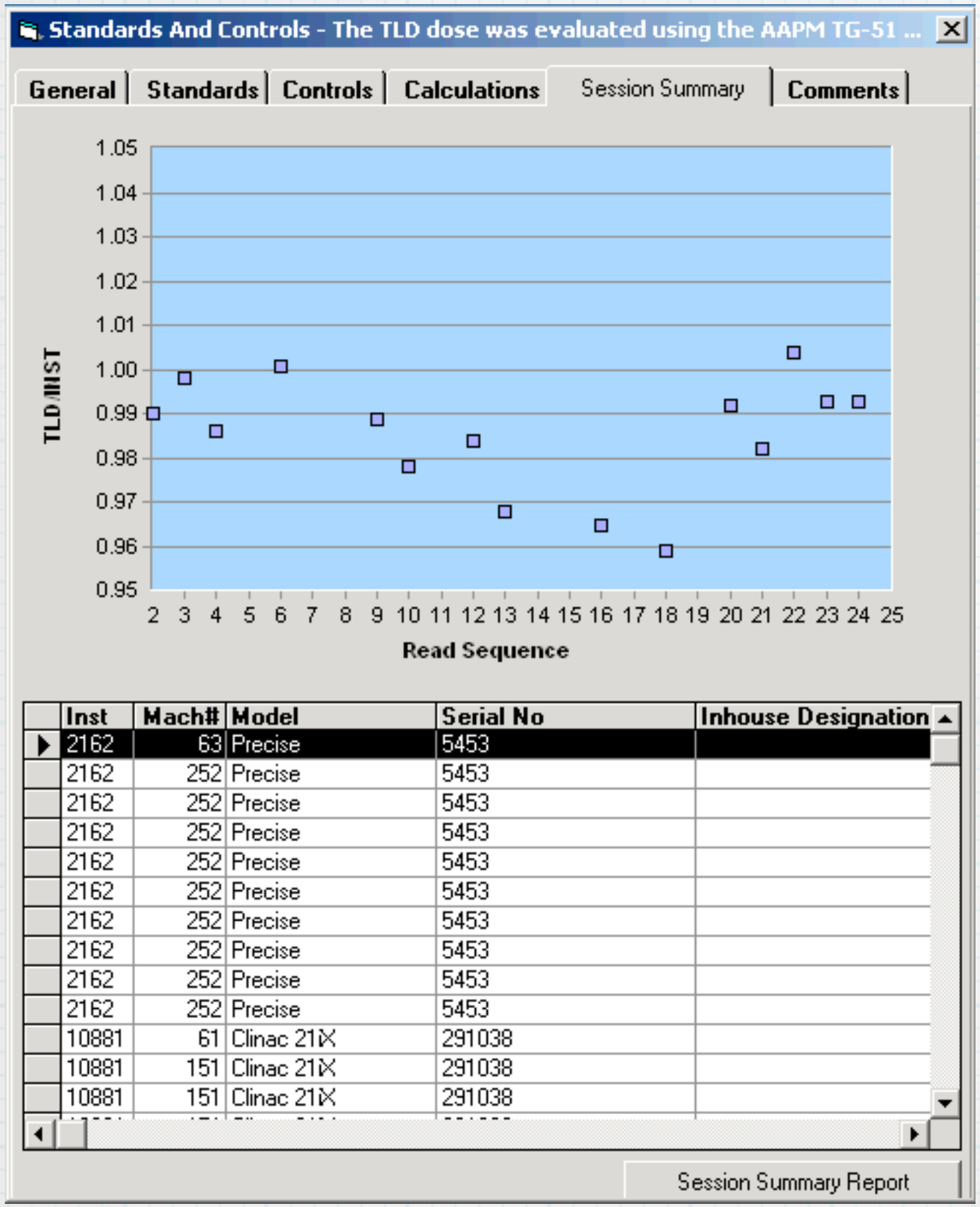
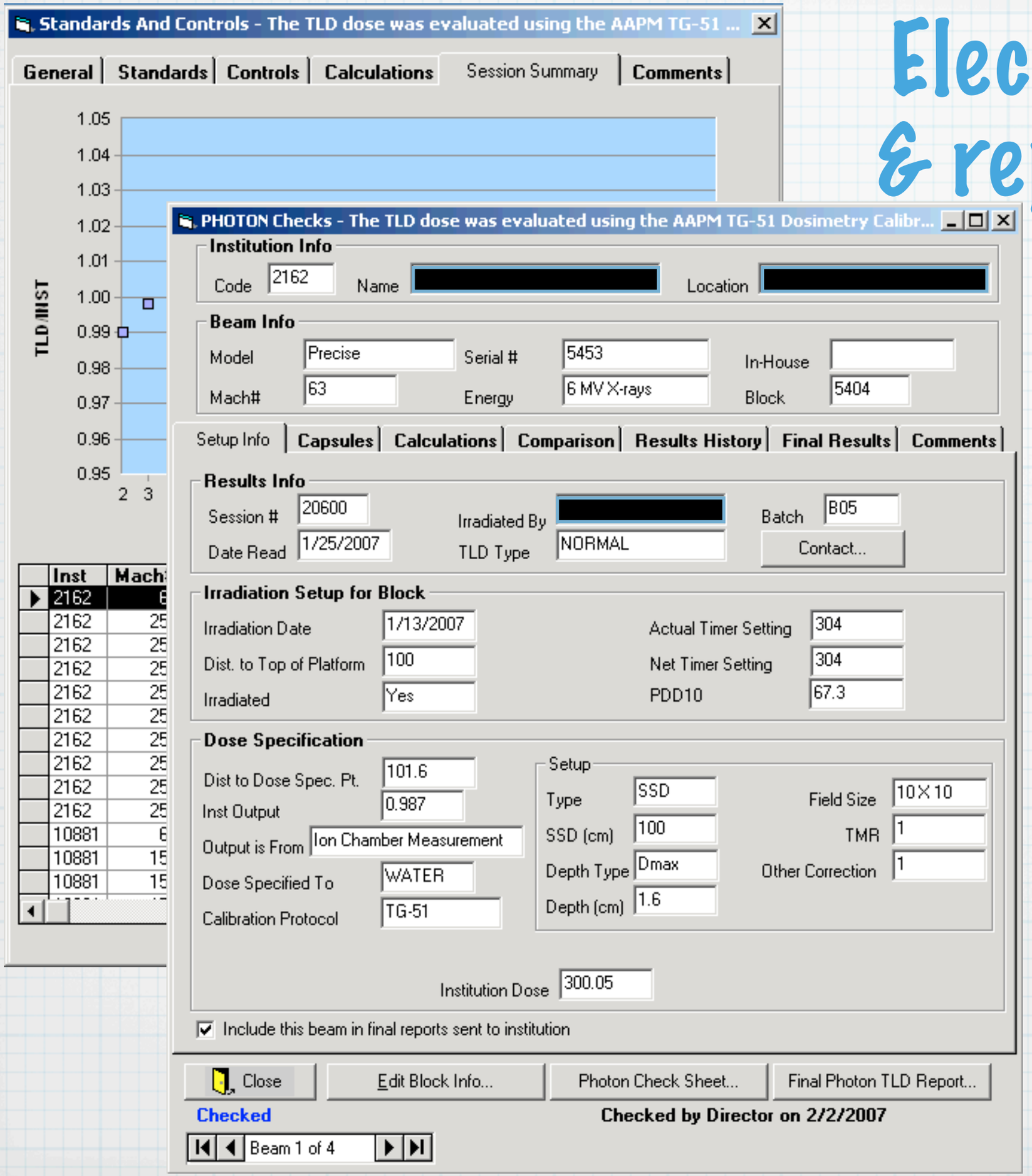
Electronic review & reporting of TLD results



Electronic review & reporting of TLD results



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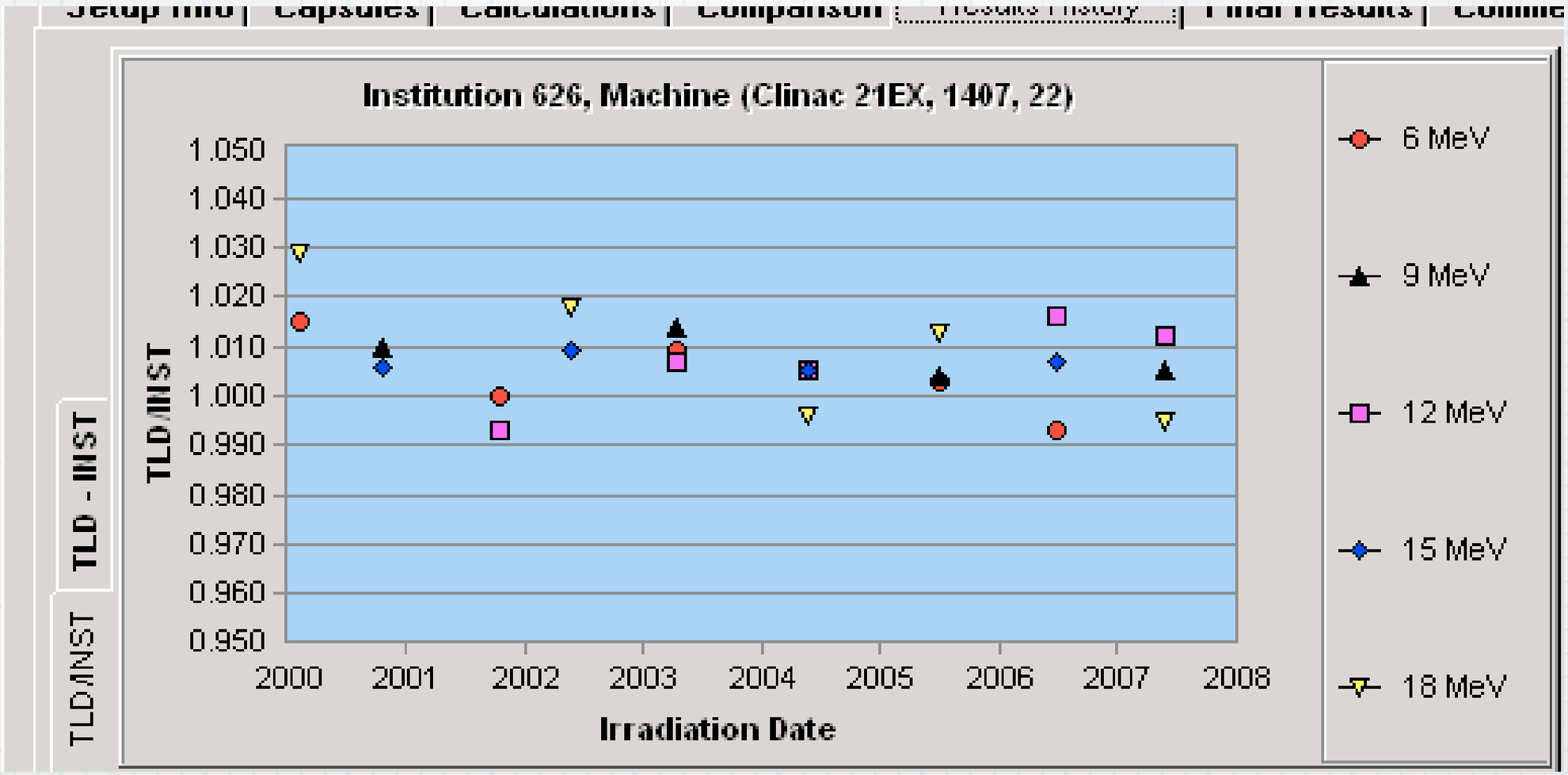

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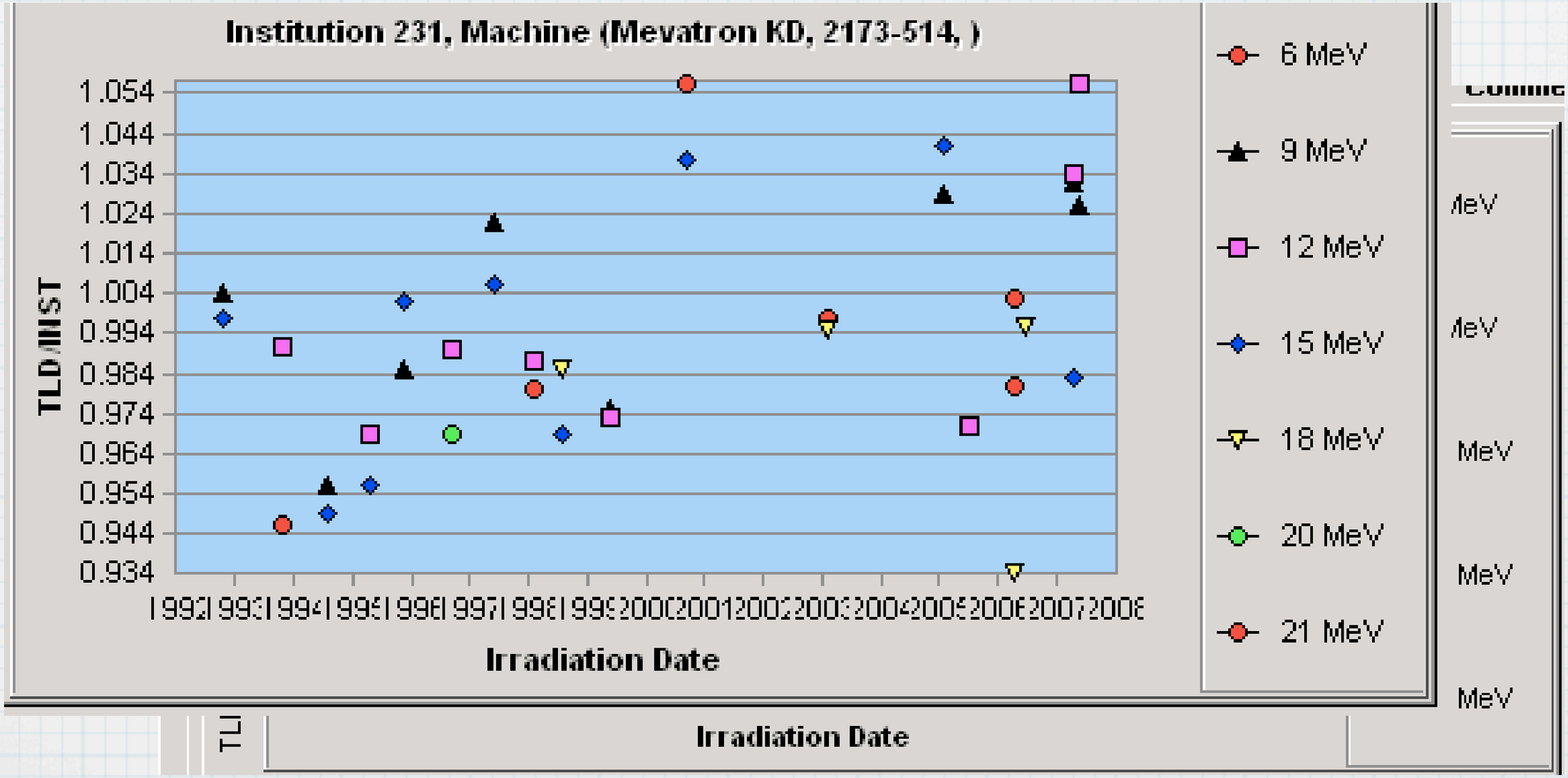
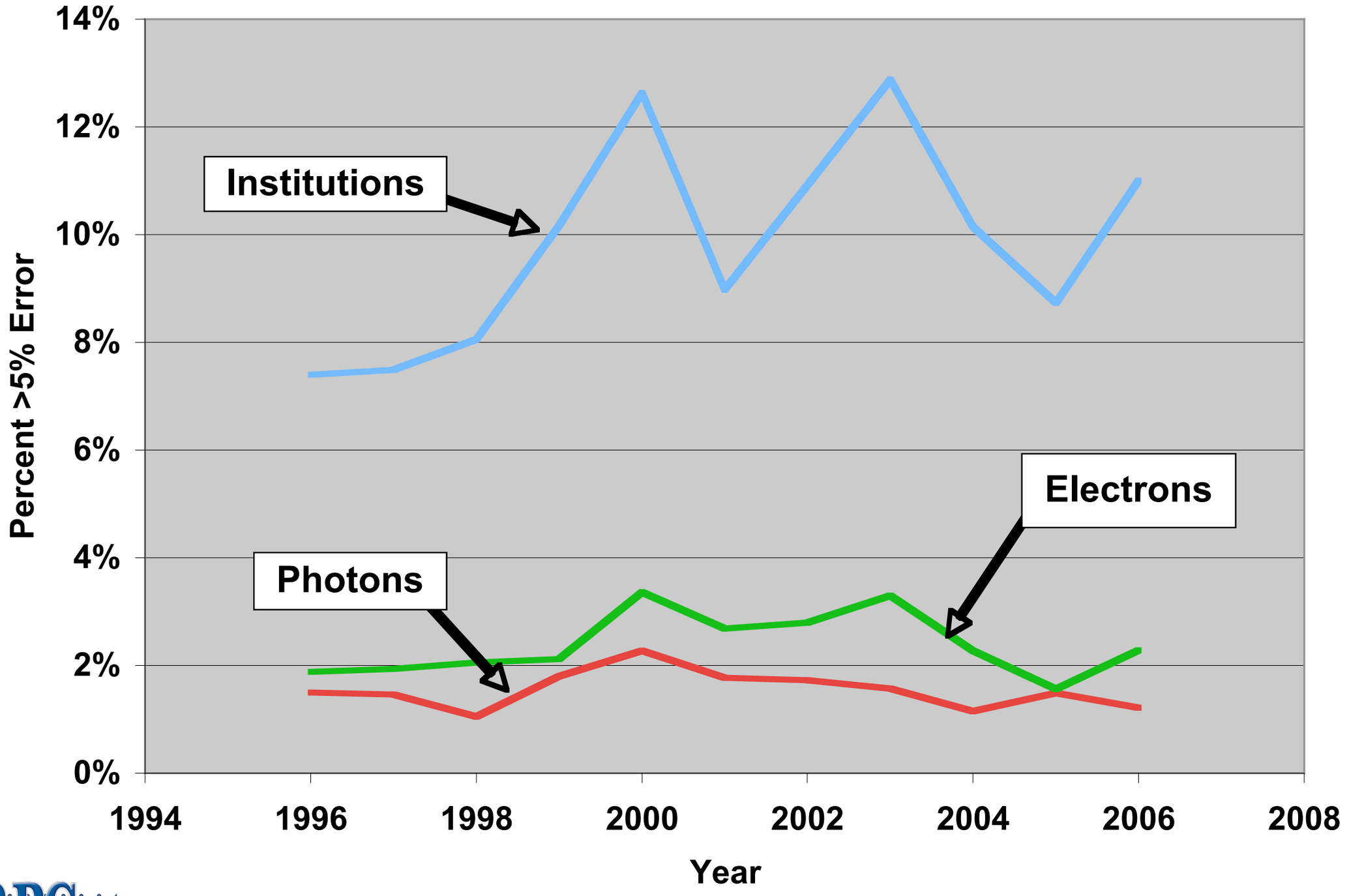
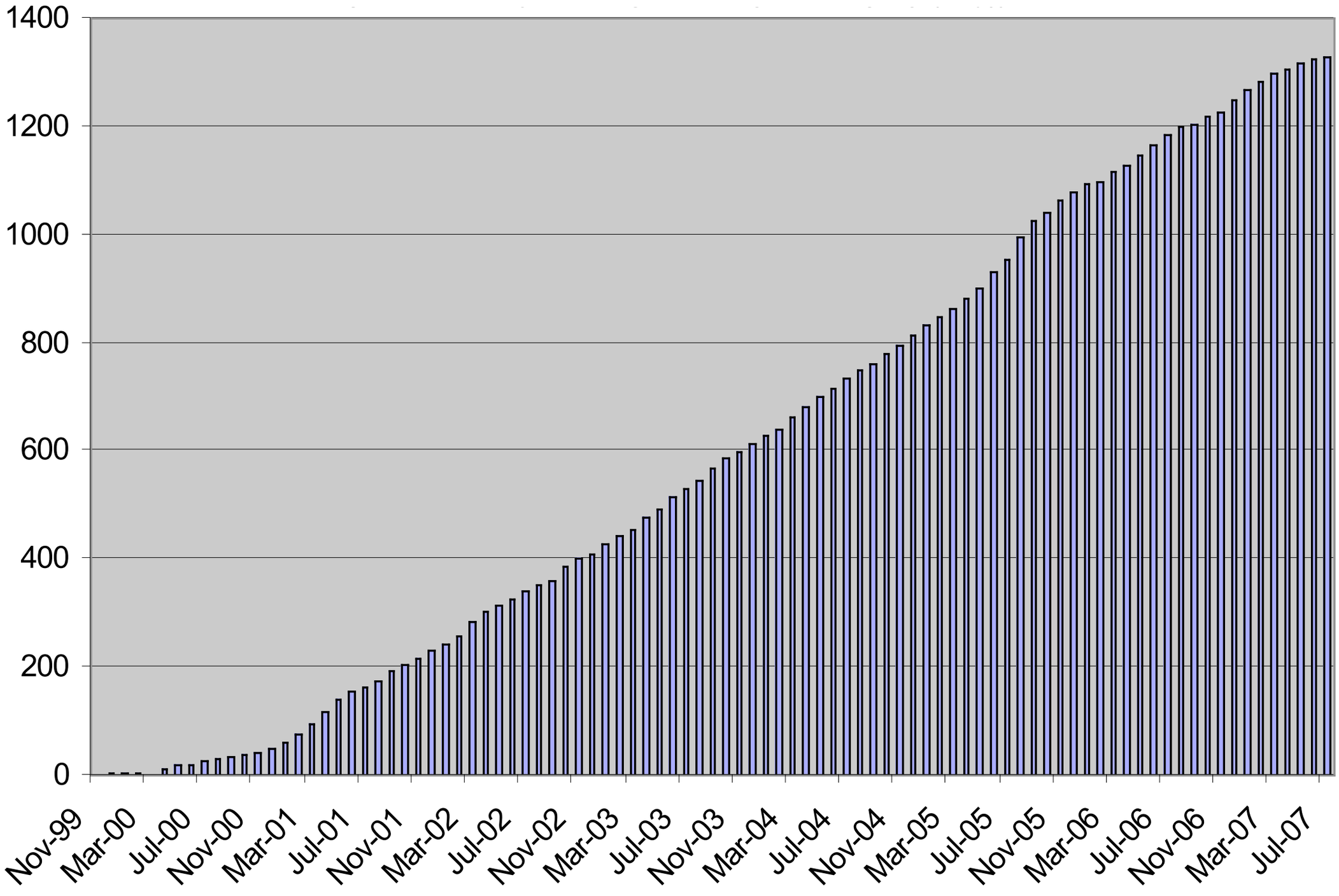


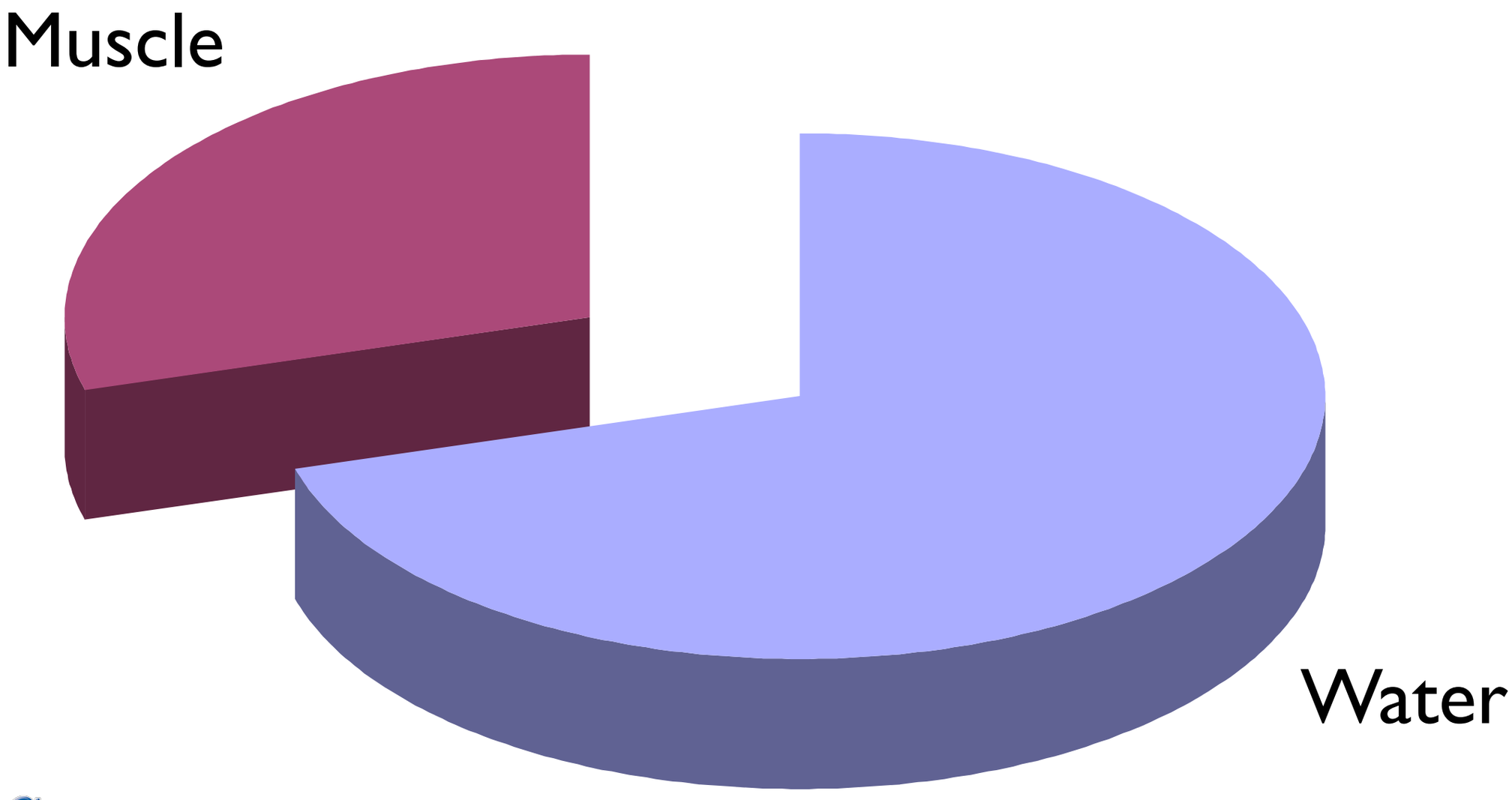
TLD Out of Criteria



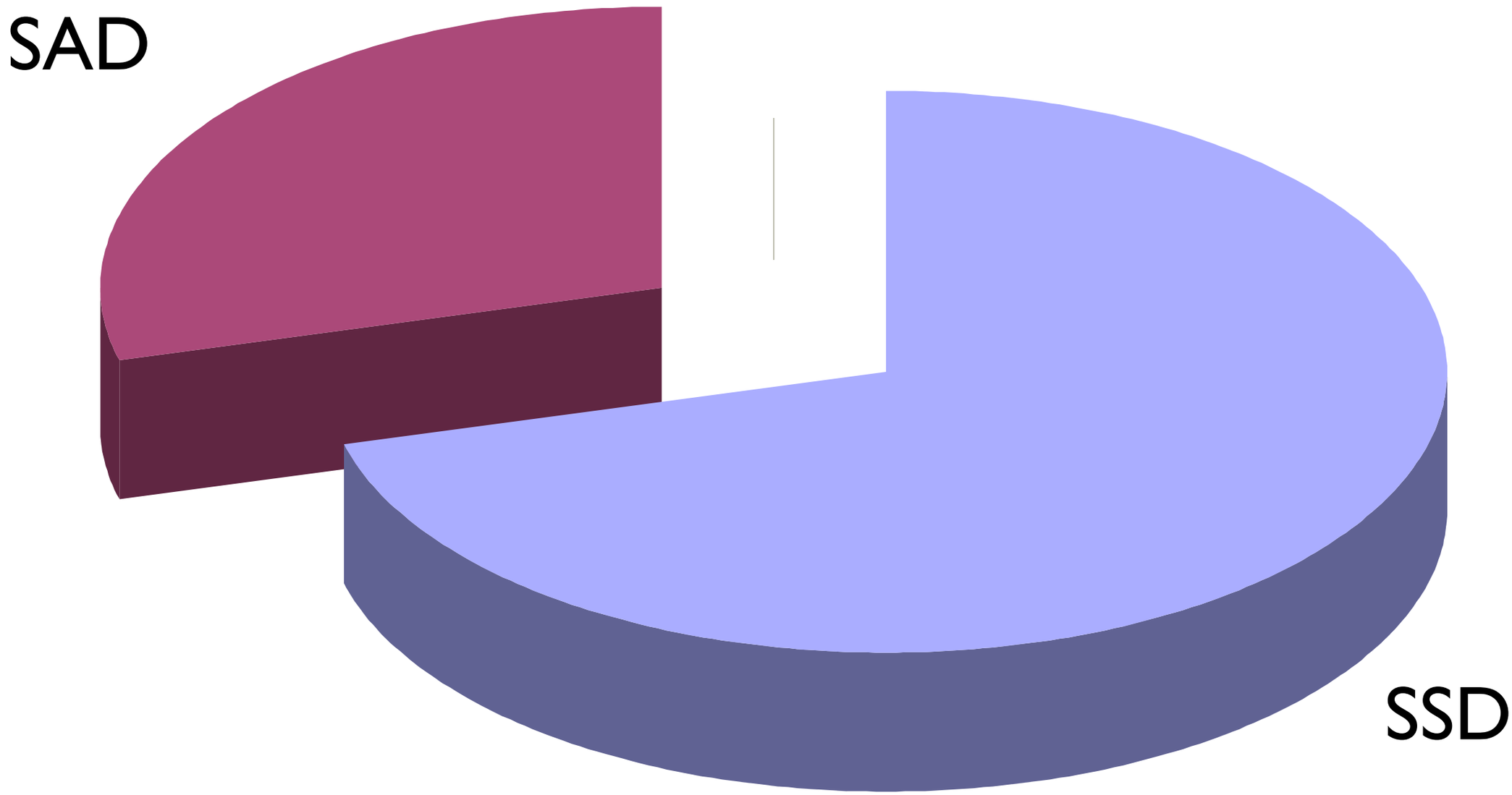
TG-51 Conversions



Calibration in Water vs. Muscle



Calibration at SSD vs. SAD



Benefits of the TLD Program

- Helps institutions stay vigilant
- Problems contribute to priorities for visits
- May satisfy state/local requirements for independent review
- Identifies problems that have direct impact on every patient treated
- It is a model for other remote programs

RPC's Conventional Monitoring

- Annual checks of machine output
  - 1,532 institutions, 13,729 beams measured with TLD (2006)
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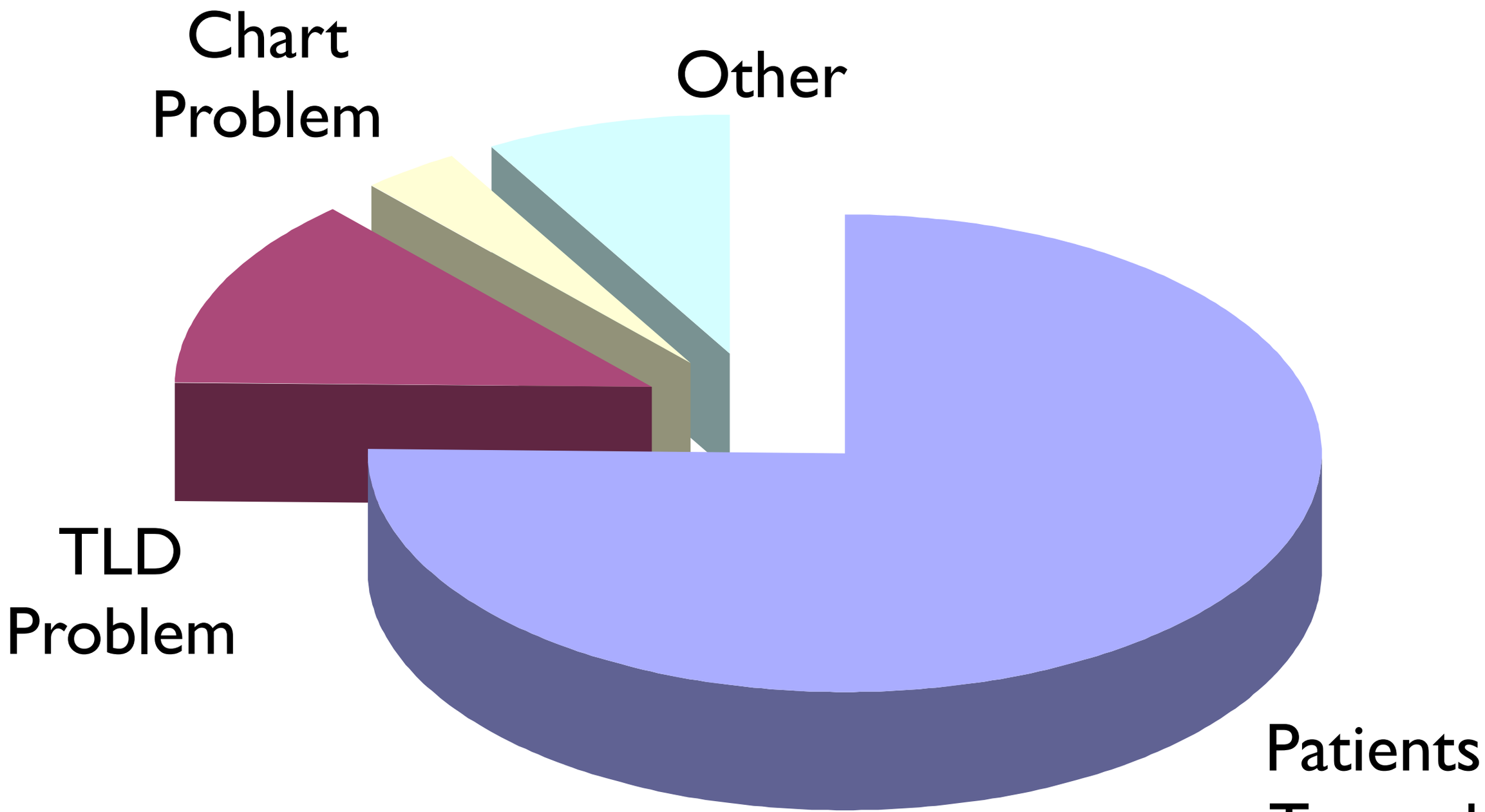
Visit Priority



On-Site
Dosimetry Review Visit

- **The <u>only</u> completely independent comprehensive radiotherapy quality audit in the USA and Canada**
  - Identify errors in dosimetry and QA program and suggest methods of improvements.
  - Collect and verify dosimetry data needed to review patient charts.
  - Improve quality of patient care for all patients.

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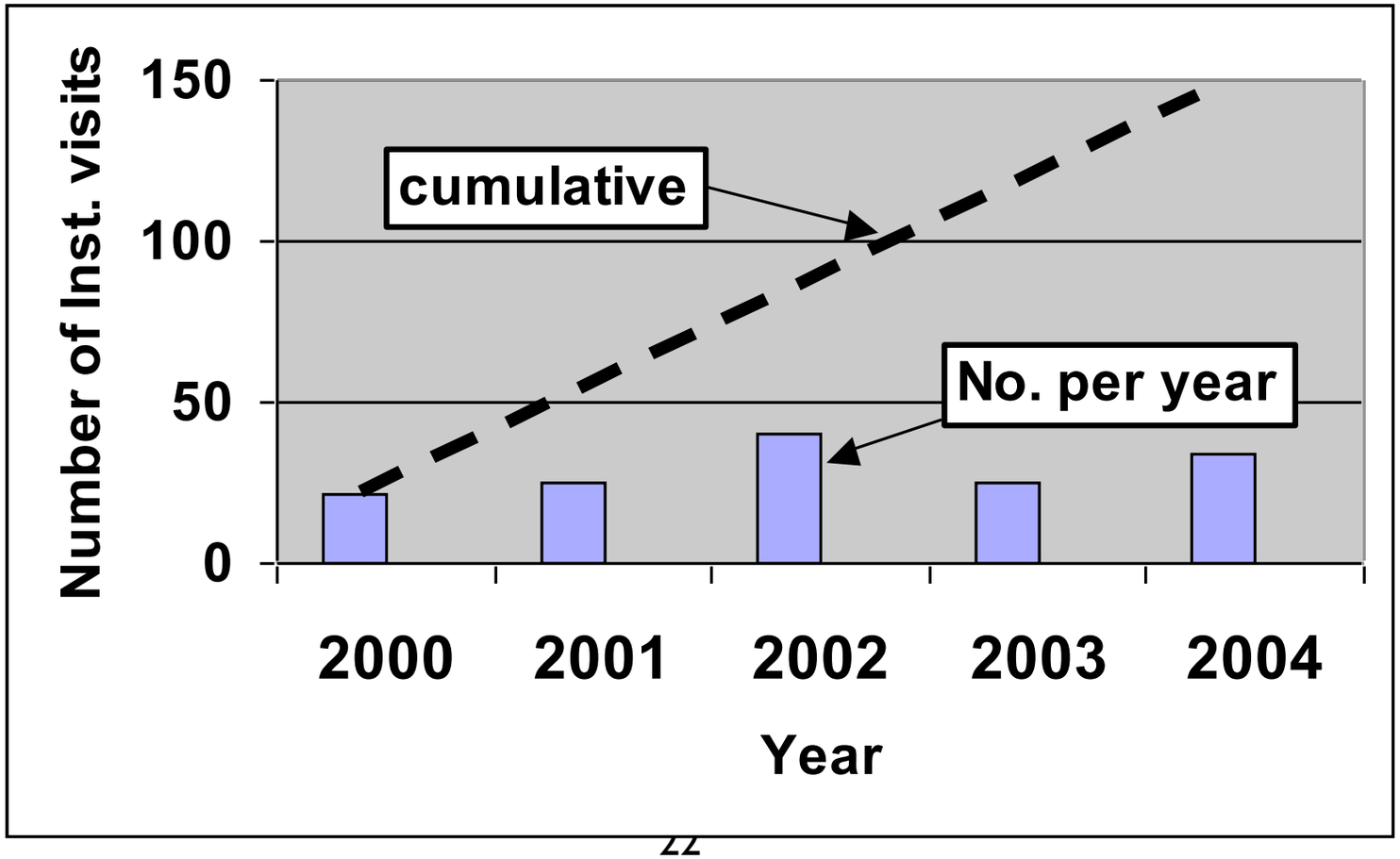
Dosimetry Review Visit

1474 institutions participating in clinical trials

	visited	not visited yet
Institutions:	715	672
Patient accrual:	20,130 (95%)	1,095 (5%)



Dosimetry Review Visit

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On-Site Dosimetry Review Visit Errors

Over 500 errors and 85 lapses in QA programs were identified at institutions visited by the RPC during the past 5 years.

These errors potentially impacted all patients treated at these institutions.

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On-Site Dosimetry Review

Selected discrepancies discovered during 2004

Errors Regarding:	Percent of Institutions
Review QA Program	(84%)
*Photon Depth Dose	(30%)
Switch to TG-51	(24%)
*Wedge Transmission	(24%)
*Photon Calibration & FSD	(24%)
*Electron Calibration	(22%)
*Off-axis Factors	(16%)

*70% of institutions received at least one of the significant dosimetry recommendations.

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Remote Review of Institution's Dosimetry Program

How can we evaluate institutions and find errors for the nearly 700 institutions that have a low priority for a visit?

25

Remote Review of Institution's Dosimetry Program

How can we evaluate institutions and find errors for the nearly 700 institutions that have a low priority for a visit?

Use the RPC standard data.

25

RPC Standard Data

Compilation of RPC measured **average** data

- 2350 photon beams
- 81 accelerator model/ energy combinations
  - Specific to make/model/energy
  - ≥ 5 sets of RPC measured data

Analyses of these data indicate that machines of same make/model/energy have same radiation characteristics.

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RPC Remote Data Review

Can standard data discover errors?

(analysis of 7,864 data points from 150 institutions)

		Std. Data indicates discrepancy: Yes	Std. Data indicates discrepancy: No
Dosimetry review visit found discrepancy	Yes	6890 (87.7%)	**450 (5.7%)**
	No	**378 (4.8%)**	146 (1.9%)

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Credentialing

Why?

- Education
- Evaluate ability to deliver dose
- Improve understanding of protocol

Reduce deviation rate

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General Credentialing Process

- Previous patients treated with technique
- Facility Questionnaire
- Knowledge Assessment Questionnaire
- Benchmark case or phantom
- Electronic data submission
- RPC QA & dosimetry review
- Clinical review by radiation oncologist

30

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Feedback to Institution

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Grandfathering

- New procedure this year (Section 5.1)
- Institution completes on-line questionnaire
  - Demographic information
  - Protocols previously participated in
  - Credentialing procedures completed
- RPC determines remaining procedures to be completed, if any

RPC Website Revisions

Radiological Physics Center – RPC Website

http://rpc.mdanderson.org/RPC/home.htm

RPC | MDA VPN | Apple | AAPM | Continental Airlines | News (345) | Physics Groups | MD Anderson | Personal | .Mac | Amazon | eBay | Yahoo! | Apple (43)

Radiological Physics Ce... | Map of 1515 Holcombe ...

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Excellence through Quality Assurance

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Tel: 713-745-8989

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Office Hours:
8 A.M. to 5 P.M.
M-F Central time.
Holidays

- Services
- Forms
- Publications
- Brachy Sources
- Research/TG-51
- Upcoming Meetings

Welcome During March 5 and 6, 2007, an ad hoc working group of the AAPM Therapy Physics Committee (TPC) will meet at the RPC headquarters.During these two daysselected RPC staff will present summaries of the overall activities of the RPC during the previous year, and plans for future activities. A report on the site visit to the RPC will be presented by the ad hoc committee chairman during the regular spring meeting of the TPC for March 6 – 7, 2007.

The RPC has presented at several scientific meetings recently, including AAPM, ESTRO, ASTRO, CIRMS, QANTRM and RSNA. Our presentations and posters are available on our web page under the RPC Presentations link in the Publications section.

NCI Guidelines for IMRT The 2006 NCI IMRT letter and guidelines.

NEW RPC March 2007 Newsletter.

Third party checks of iodine and palladium seeds: Click here to display the AAPM's recommendations for 3rd party brachytherapy seed calibrations and physicist responsibilities.

Publication on Physics of Clinical Trials
We recommend AAPM Report 86 for physicists who want to know more about the conduct of clinical trials and their physics and QA requirements.

RDS Radiation Dosimetry Services offers mailed dosimeters and anthropomorphic phantoms for dosimetry QA.

ADCL The ADCL at M. D. Anderson Cancer Center is fully accredited for external beam and brachytherapy calibrations. FAQ about ADCL.

THE UNIVERSITY OF TEXAS MD ANDERSON CANCER CENTER

NATIONAL CANCER INSTITUTE

aapm online

Updated on: 12/19/2006
You are visitor #16907.

Credentialing Status Inquiry

CREDENTIALING FOR ADVANCED TECHNOLOGY PROTOCOLS

This questionnaire is will help determine if your institution is credentialed to participate on a protocol. If there are any questions please contact the RPC at (713) 745-8989 or rpc@mdanderson.org

Facility Name:_____

Provide the Facility's member number: RTOG #:_____ RTF#[1]:_____

Name of person completing this form: _____

Email address: _____

Are you a: ☐ Radiation Oncologist ☐ Physicist ☐ Dosimetrist ☐ Clinical Coordinator

Which protocol are you interested in being credentialed for? _____

Has your institution successfully irradiated an RPC phantom? ☐ Yes ☐ No

If yes, which phantom?

☐ IMRT Head & Neck ☐ IMRT Pelvis ☐ Stereotactic Lung ☐ Stereotactic Liver

Questionnaires

- Facility Questionnaire determines if equipment and QA procedures are adequate
- Knowledge Assessment tests physician knowledge about the protocol

Web-based forms

RPC Radiological Physics Center
Excellence through Quality Assurance

Search RPC by Google GO

Tel: 713-745-8989

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CREDENTIALING FOR NSABP/RTOG PBI PROTOCOL KNOWLEDGE ASSESSMENT FORM

This questionnaire is intended to evaluate your understanding of the protocol. If there are any questions please contact the RPC at (713) 745-8989 or rpc@mdanderson.org
Quotes are not allowed.

Facility Name:

Check the appropriate box and provide the Facility's member number: ☐ RTOG#: ☐ NSABP#:

Fill in the Facility's identification: NCI#: RTF#:[1] [1]RTF# is required and may be obtained by clicking here

Name of Radiation Oncologist completing this form: First Last

CTEP# of Radiation Oncologist completing this form

Identify the PBI Technique(s) to be used: ☐ MammoSite ☐ Multi-catheter Brachy ☐ 3D Conformal EBRT

(Complete this section and the appropriate sections(s) on pages 2 - 4.)

Data to submit: List the digital data to be submitted for each patient:

-

3D CONFORMAL RADIATION THERAPY (3D CRT)

- Evaluate 3D treatment planning process and ability to provide documentation
- ~700 institutions credentialed to date
  - 545 through NSABP/RTOG partial breast irradiation protocol

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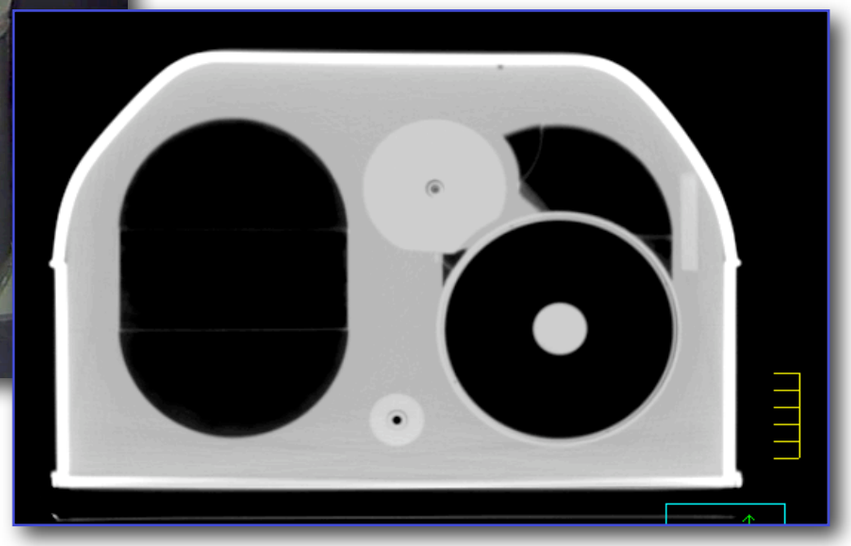
RPC Phantoms

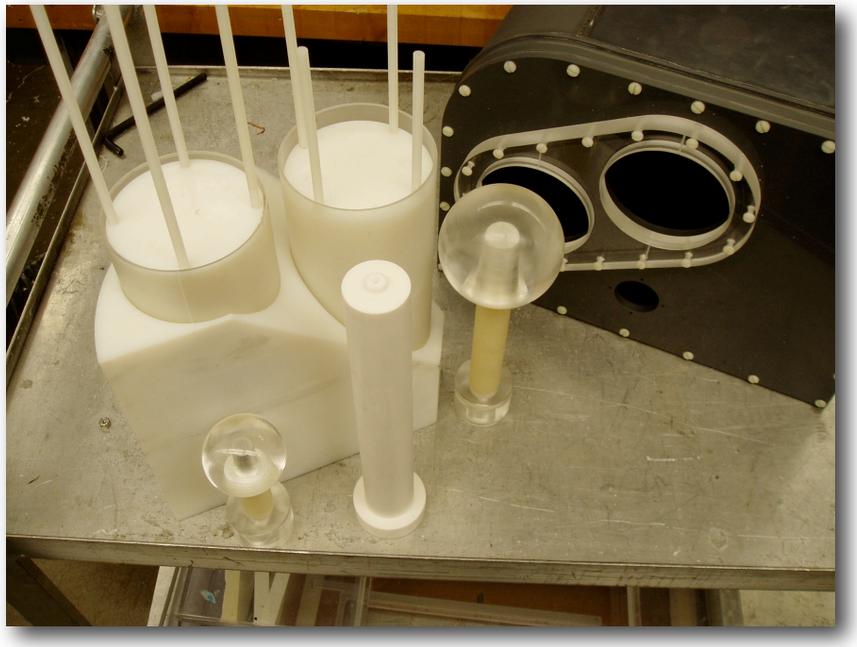
prostate IMRT: 8, incl. prosthesis



thorax SBRT: 9 phantoms

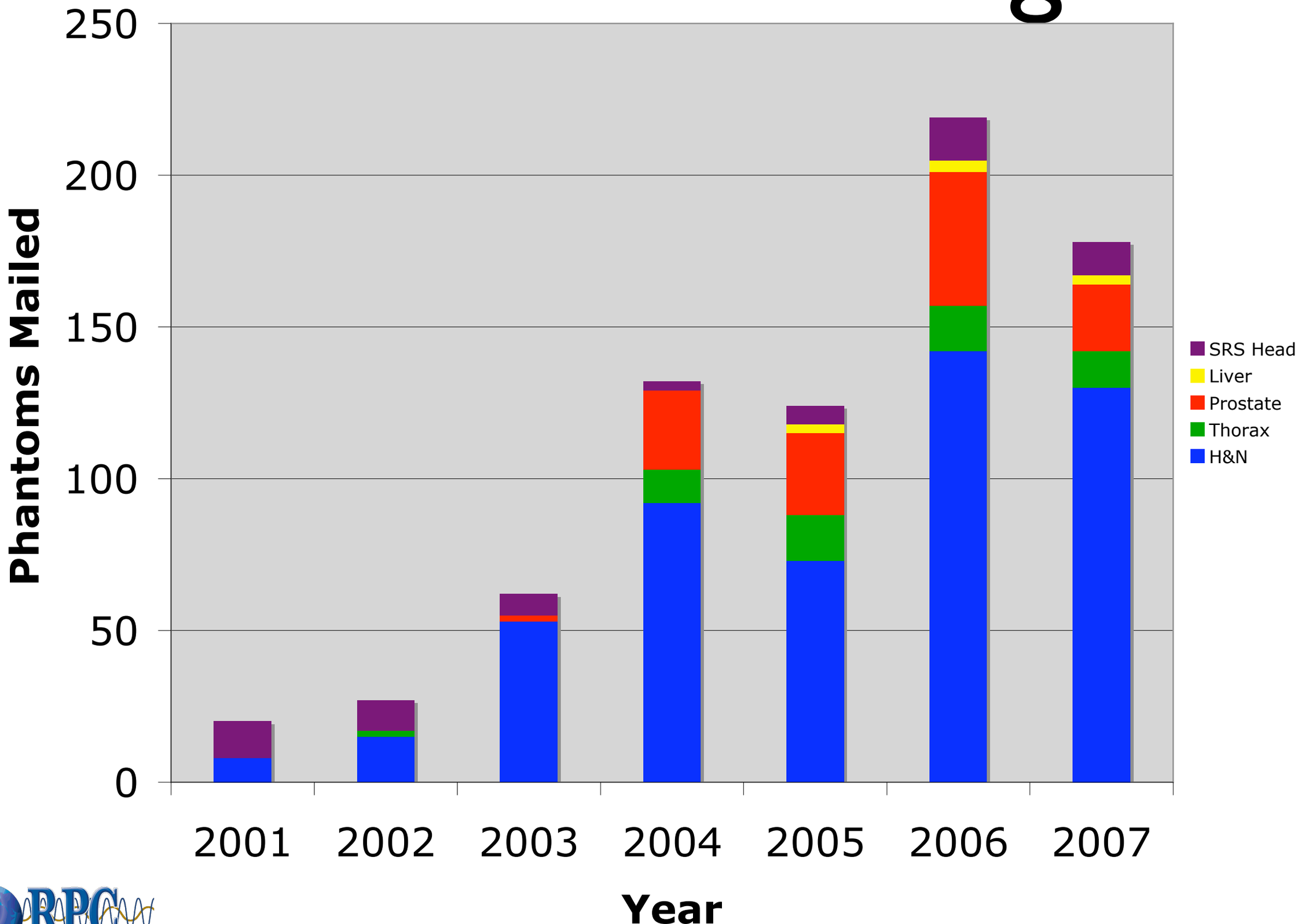
H&N IMRT: 25 in service

SRS: 2 in service, others sent by RDS



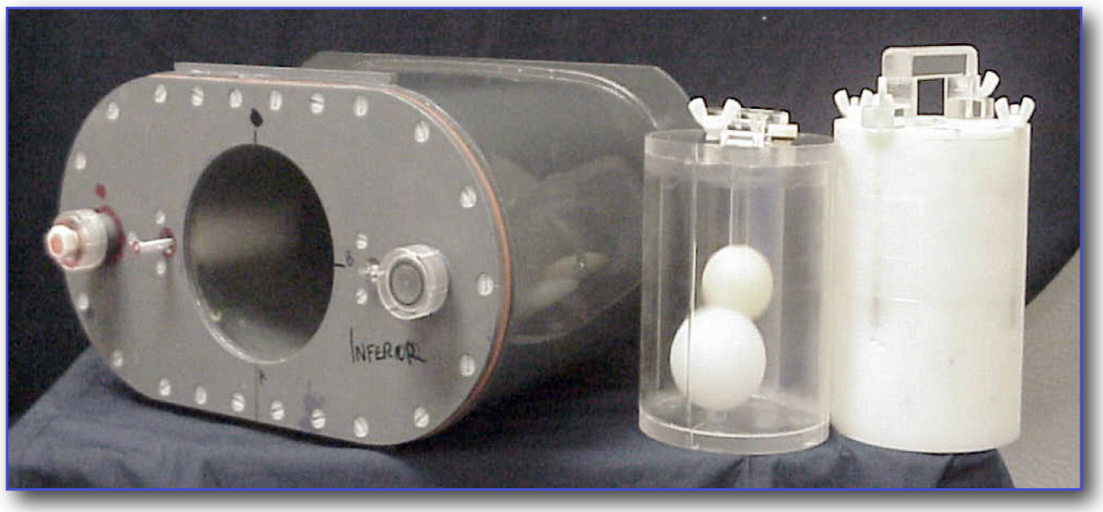
liver SBRT: 3, incl. motion

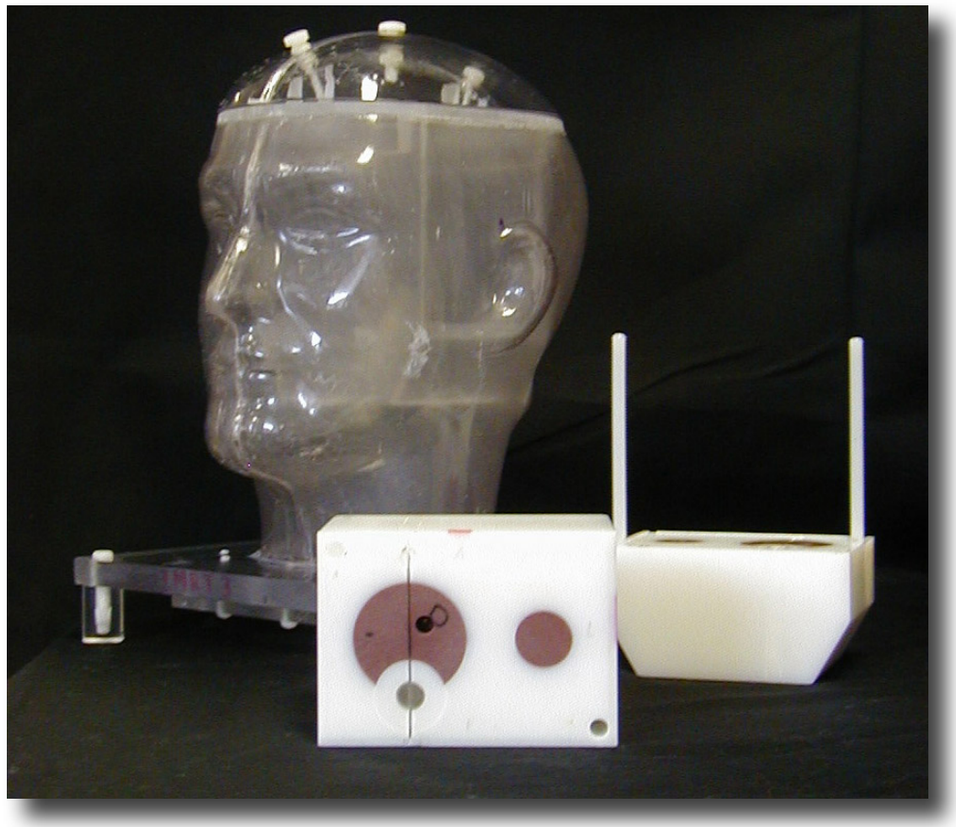
Phantom Mailings



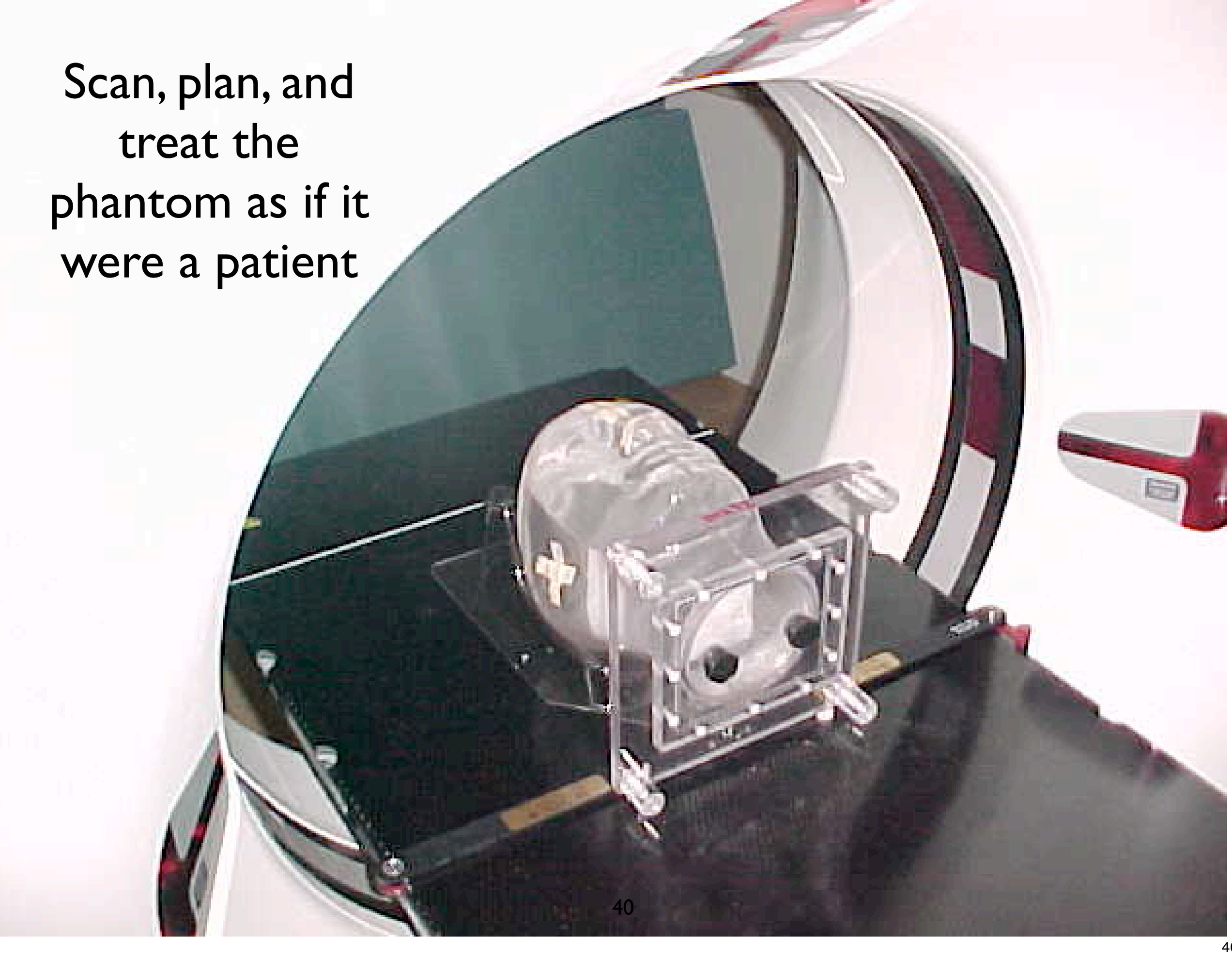
IMRT Credentialing

300+ institutions have successfully irradiated an RPC IMRT phantom





Scan, plan, and treat the phantom as if it were a patient



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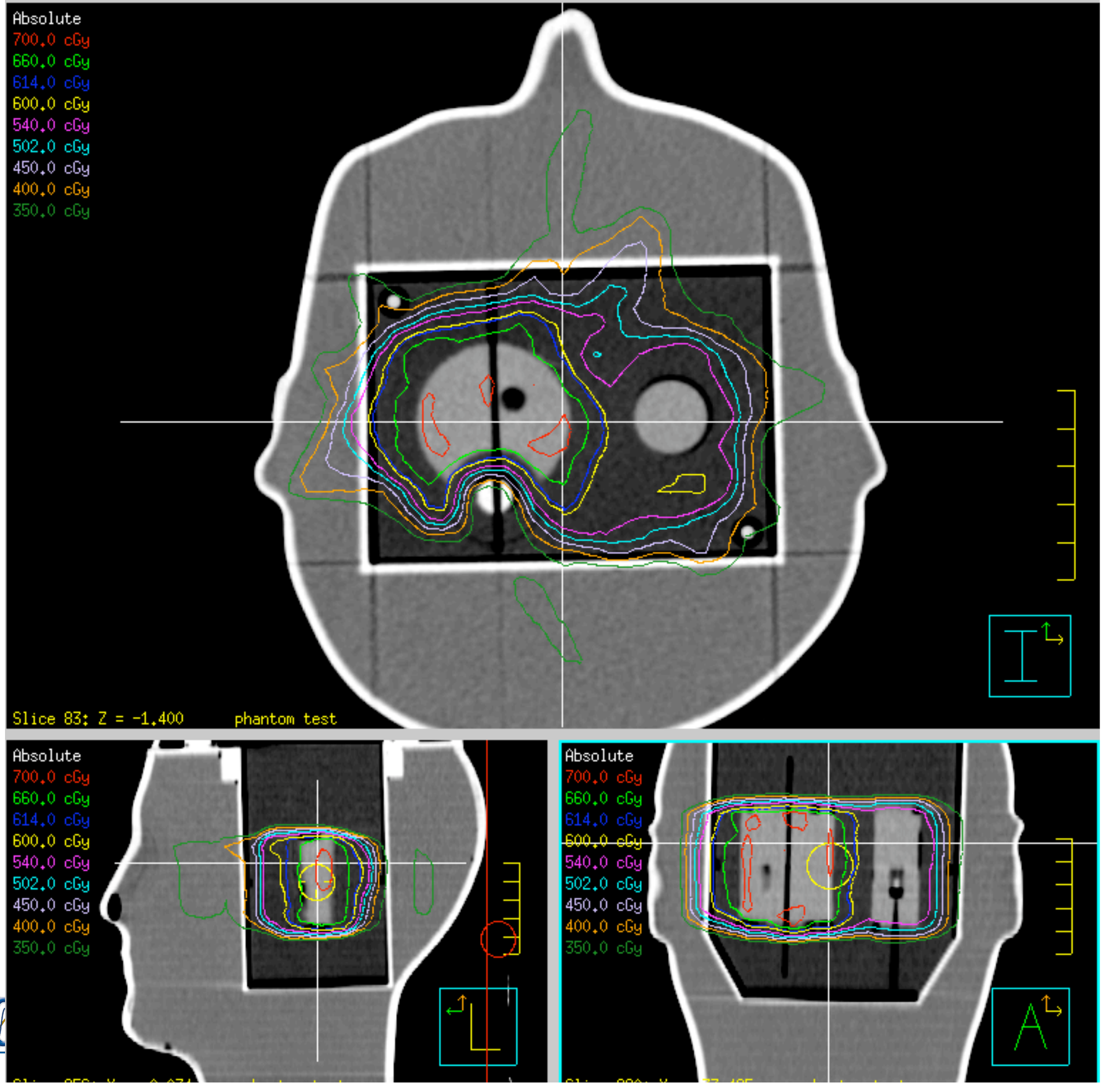
Treat the phantom like a patient

Some institutions go overboard

Treat the phantom like a patient

Some patients want to know more


Absolute
700.0 cGy
660.0 cGy
614.0 cGy
600.0 cGy
540.0 cGy
502.0 cGy
450.0 cGy
400.0 cGy
350.0 cGy
Slice 83: Z = -1.400
phantom test
Absolute
700.0 cGy
660.0 cGy
614.0 cGy
600.0 cGy
540.0 cGy
502.0 cGy
450.0 cGy
400.0 cGy
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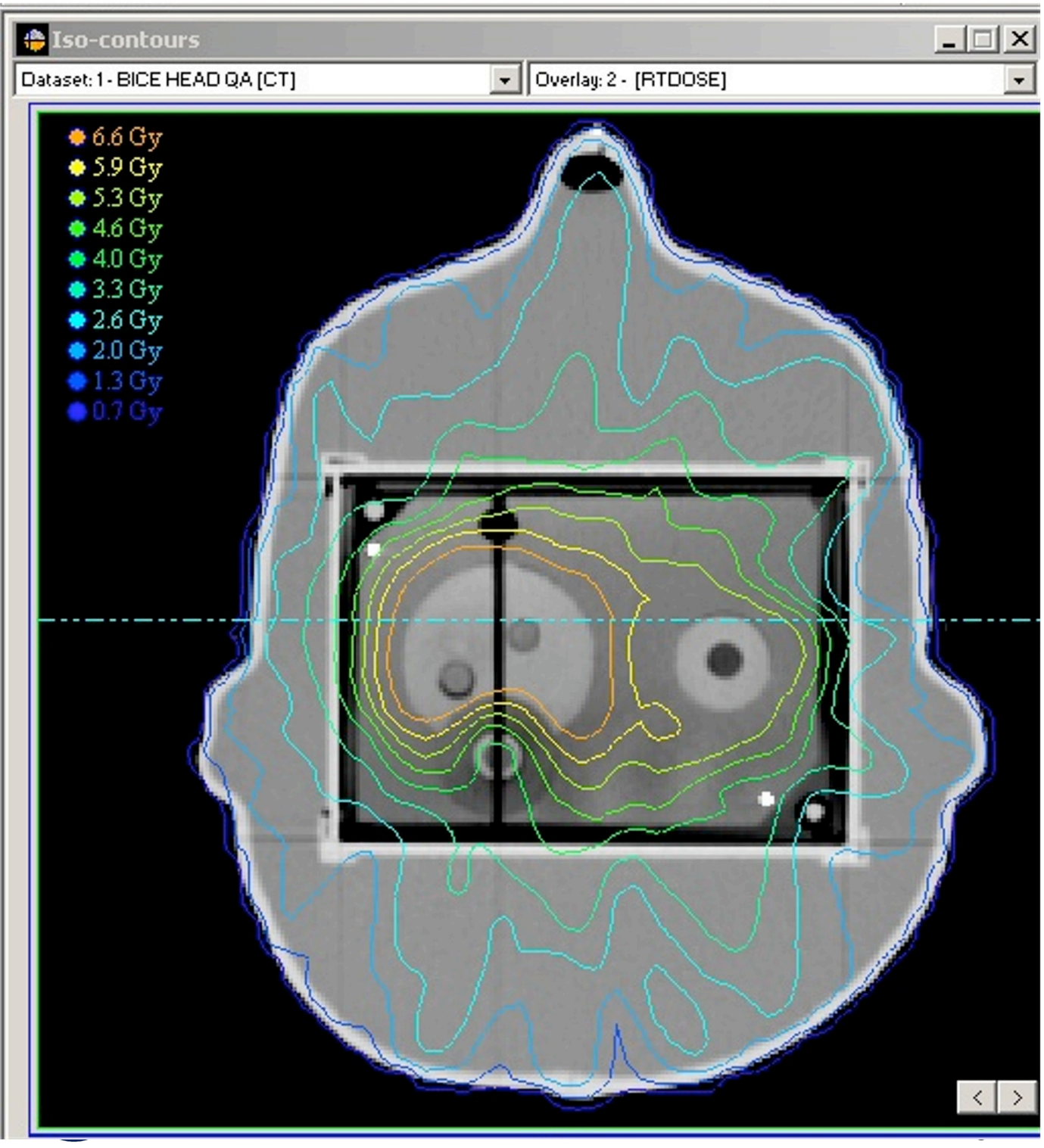
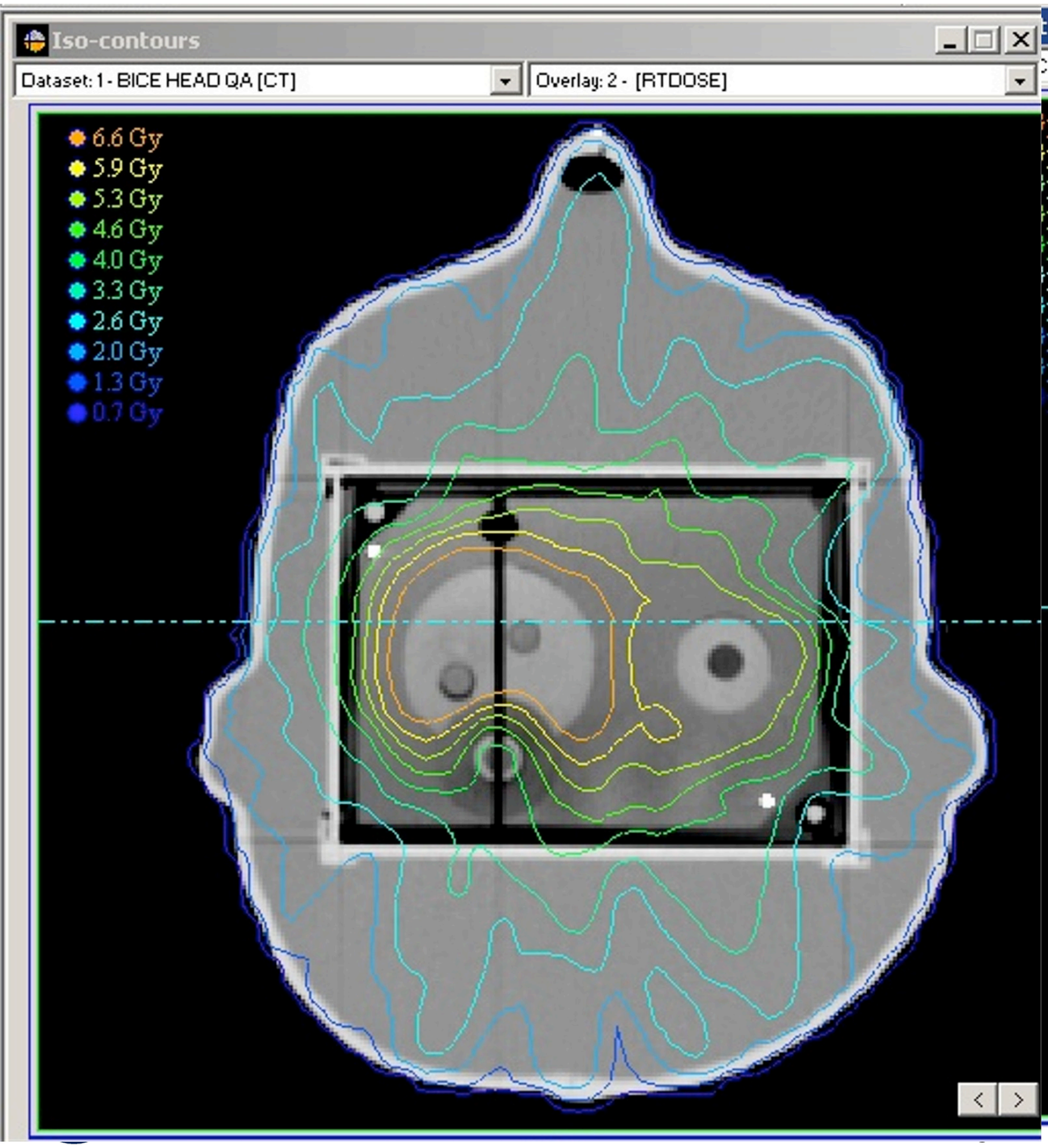

Iso-contours
Dataset: 1 - BICE HEAD QA [CT]
Overlay: 2 - [RTDOSE]
6.6 Gy
5.9 Gy
5.3 Gy
4.6 Gy
4.0 Gy
3.3 Gy
2.6 Gy
2.0 Gy
1.3 Gy
0.7 Gy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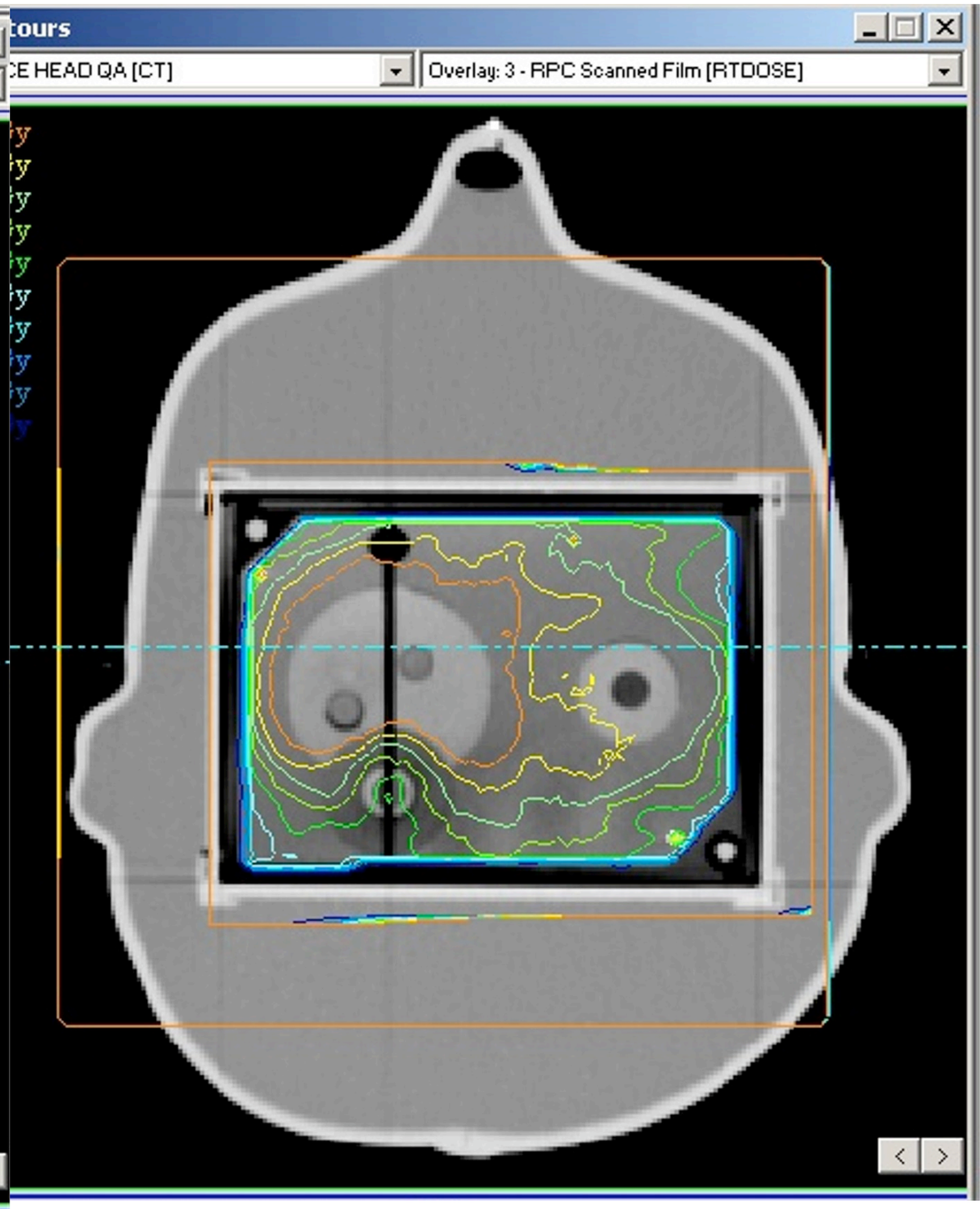
2.0 Gy
1.3 Gy
0.7 Gy

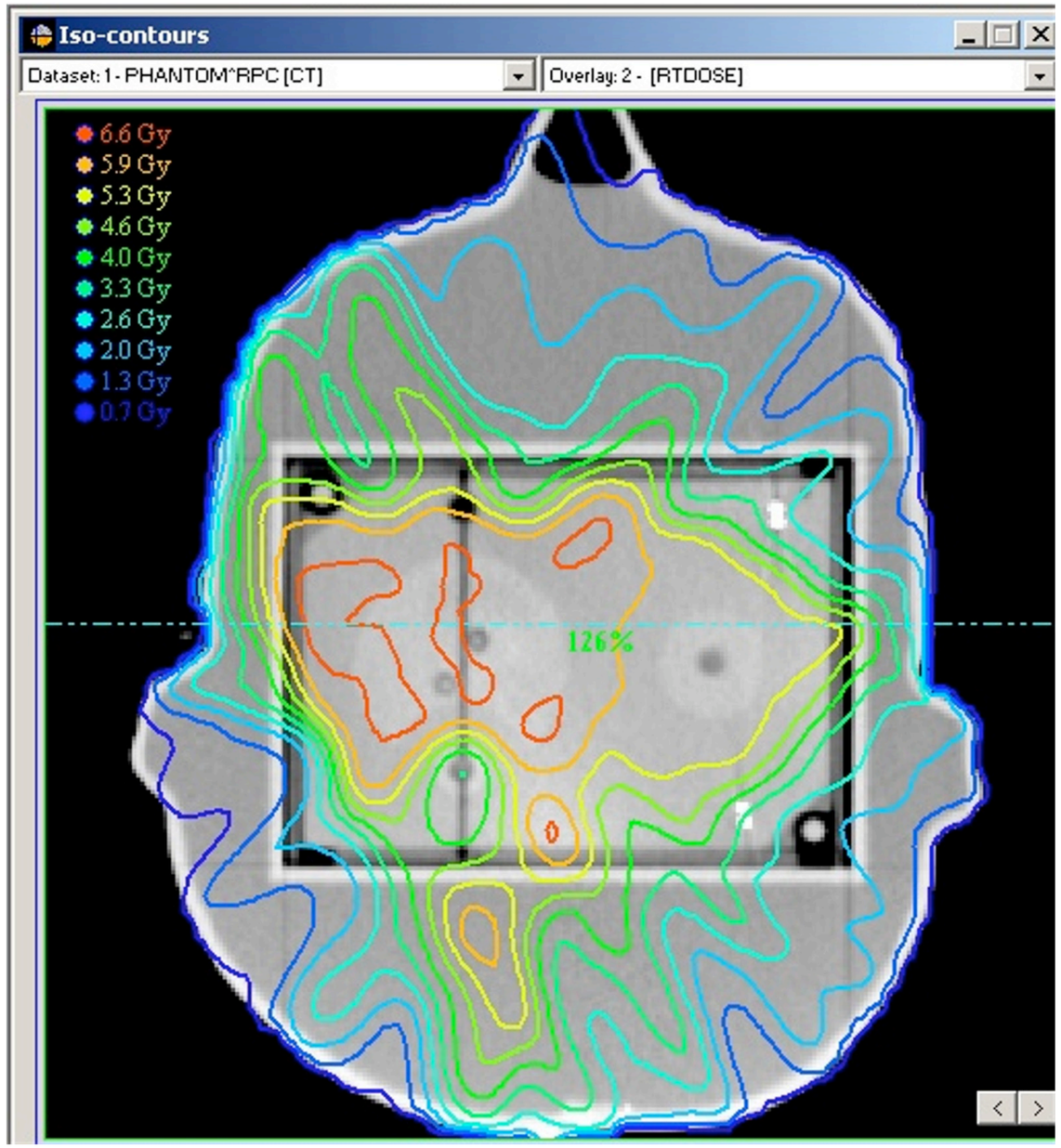

CE HEAD QA [CT]
Overlay: 3 - RPC Scanned Film [RTDOSE]

Phantom Results

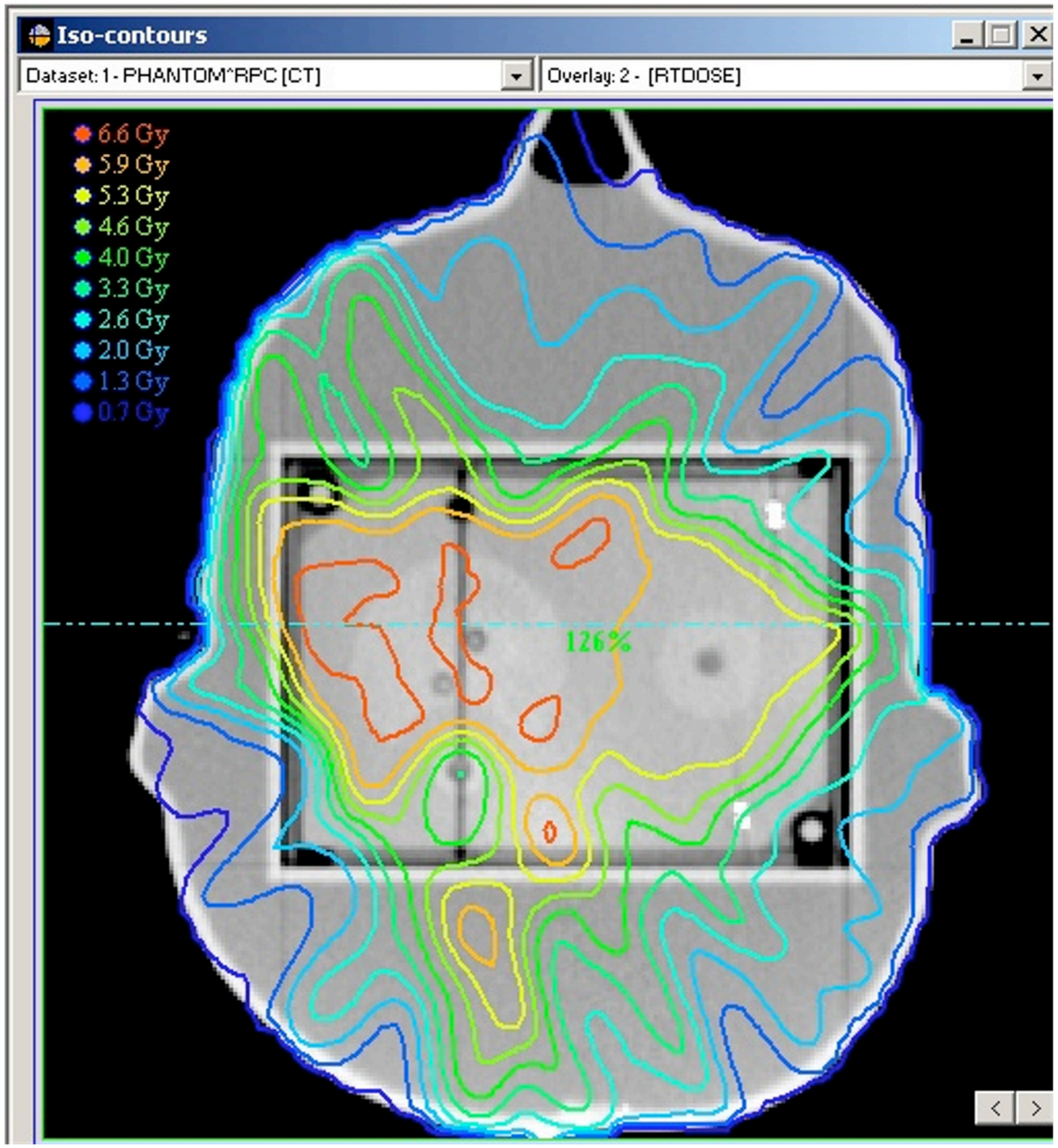
Comparison between institution's plan and delivered dose. Criteria for agreement: 7% or 4 mm DTA

Phantom	H&N	Prostate	Thorax	Liver
Irradiations	254	73	30	6
Pass	179*	55	17	3
Fail	71	9	7	1
Under analysis or at institution	30	6	6	1
Year introduced	2001	Spring 2004	Spring 2004	Spring 2005

*** 30% of institutions failed H&N phantom on the first attempt**


Iso-contours
Dataset: 1 - PHANTOM^RPC [CT]
Overlay: 2 - [RTDOSE]
6.6 Gy
5.9 Gy
5.3 Gy
4.6 Gy
4.0 Gy
3.3 Gy
2.6 Gy
2.0 Gy
1.3 Gy
0.7 Gy
126%

45


Iso-contours
Dataset: 1 - PHANTOM^RPC [CT]
Overlay: 2 - [RTDOSE]
6.6 Gy
5.9 Gy
5.3 Gy
4.6 Gy
4.0 Gy
3.3 Gy
2.6 Gy
2.0 Gy
1.3 Gy
0.7 Gy
126%

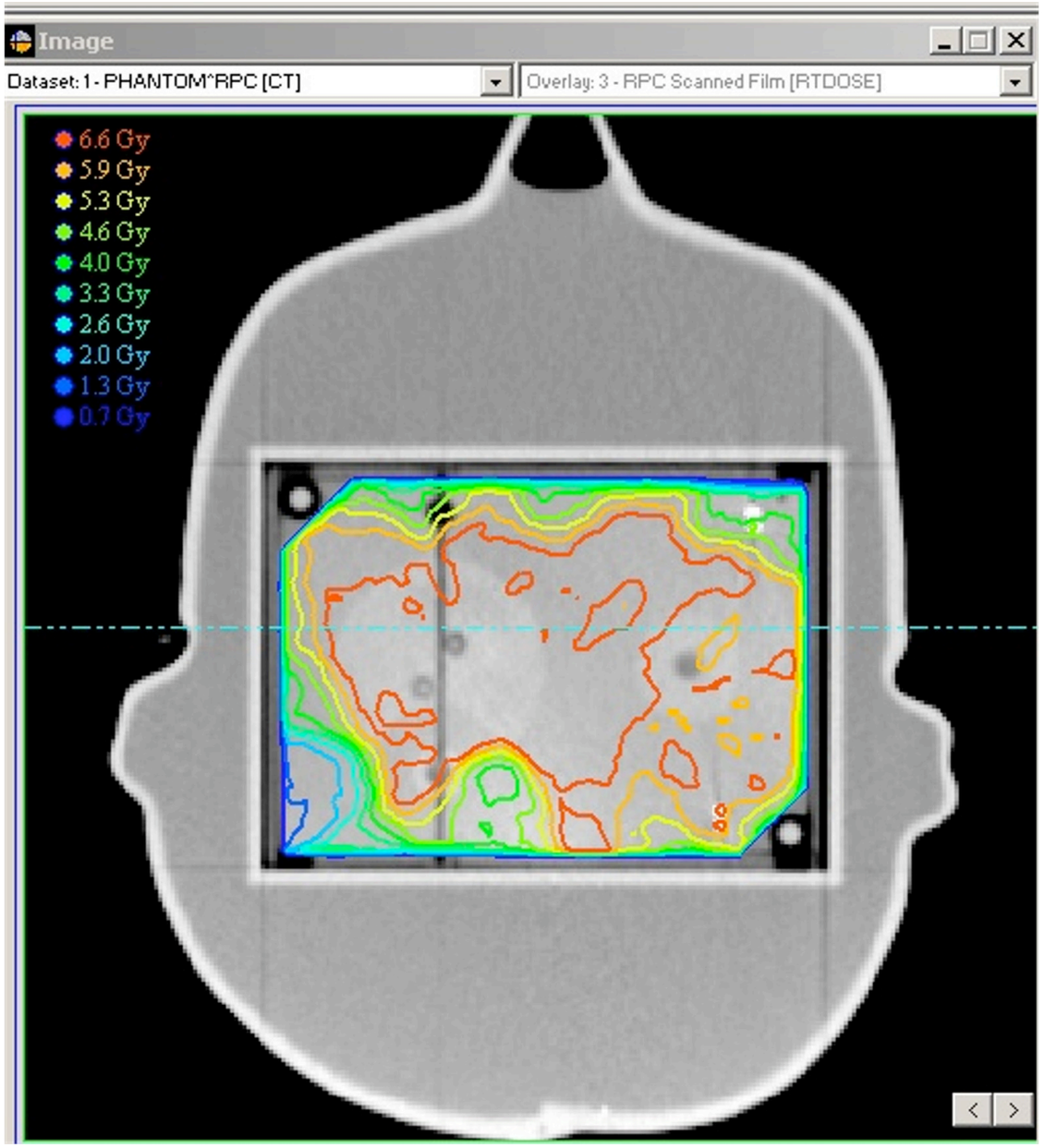
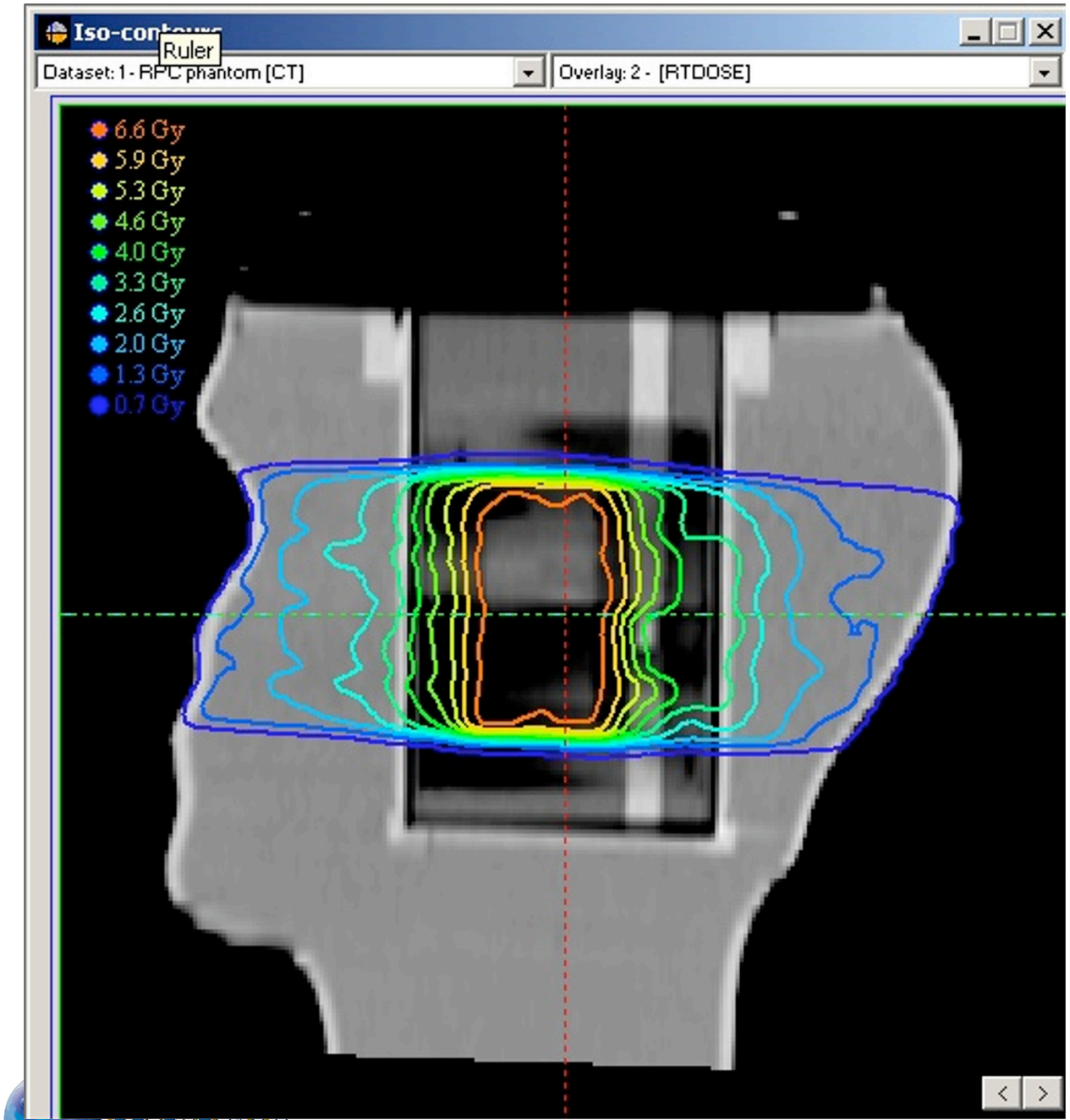
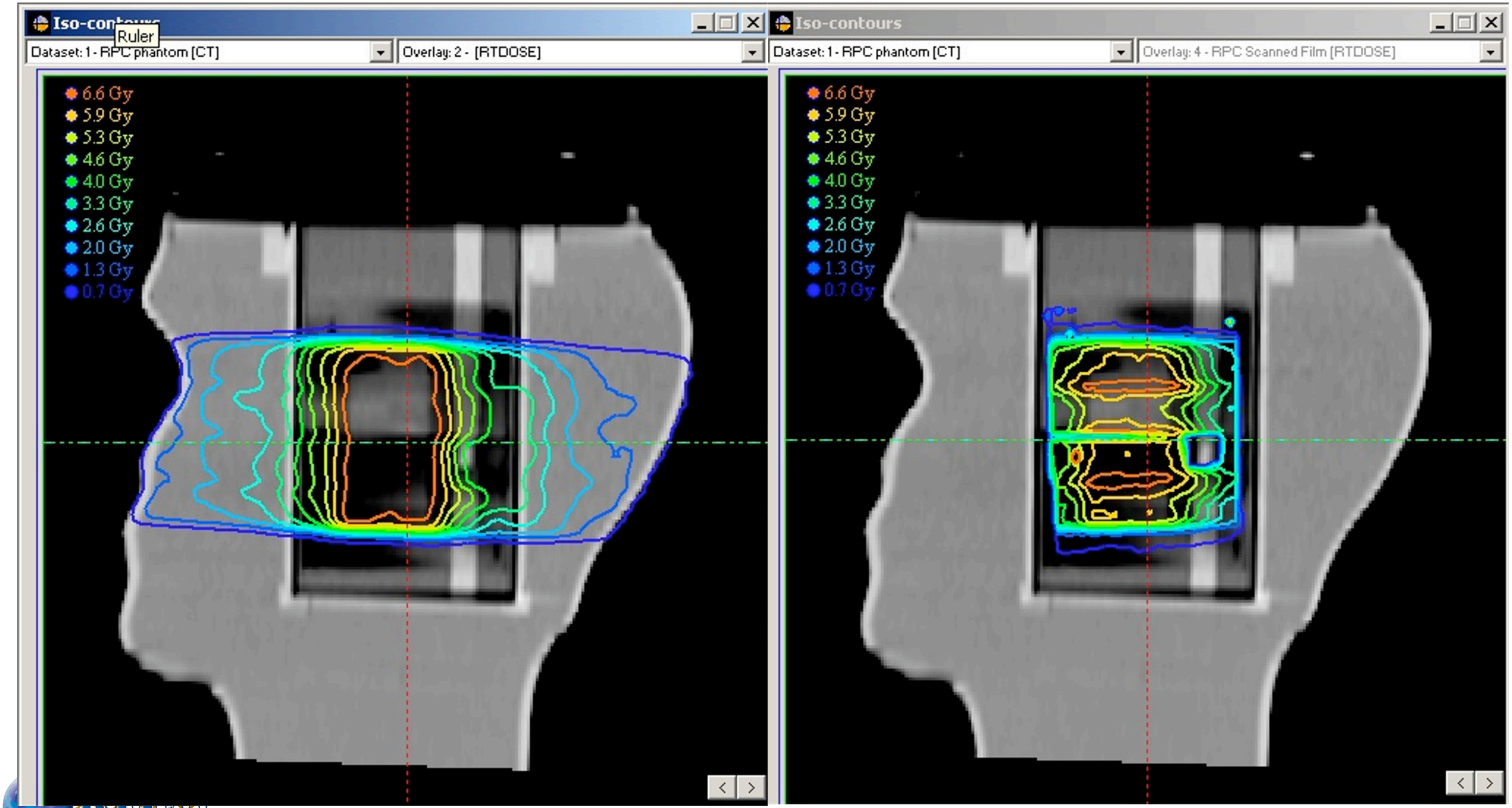


Image
Dataset: 1 - PHANTOM^RPC [CT]
Overlay: 3 - RPC Scanned Film [RTDOSE]
6.6 Gy
5.9 Gy
5.3 Gy
4.6 Gy
4.0 Gy
3.3 Gy
2.6 Gy
2.0 Gy
1.3 Gy
0.7 Gy

45


Iso-contours
Ruler
Dataset: 1 - RPC phantom [CT]
Overlay: 2 - [RTDOSE]
6.6 Gy
5.9 Gy
5.3 Gy
4.6 Gy
4.0 Gy
3.3 Gy
2.6 Gy
2.0 Gy
1.3 Gy
0.7 Gy

46

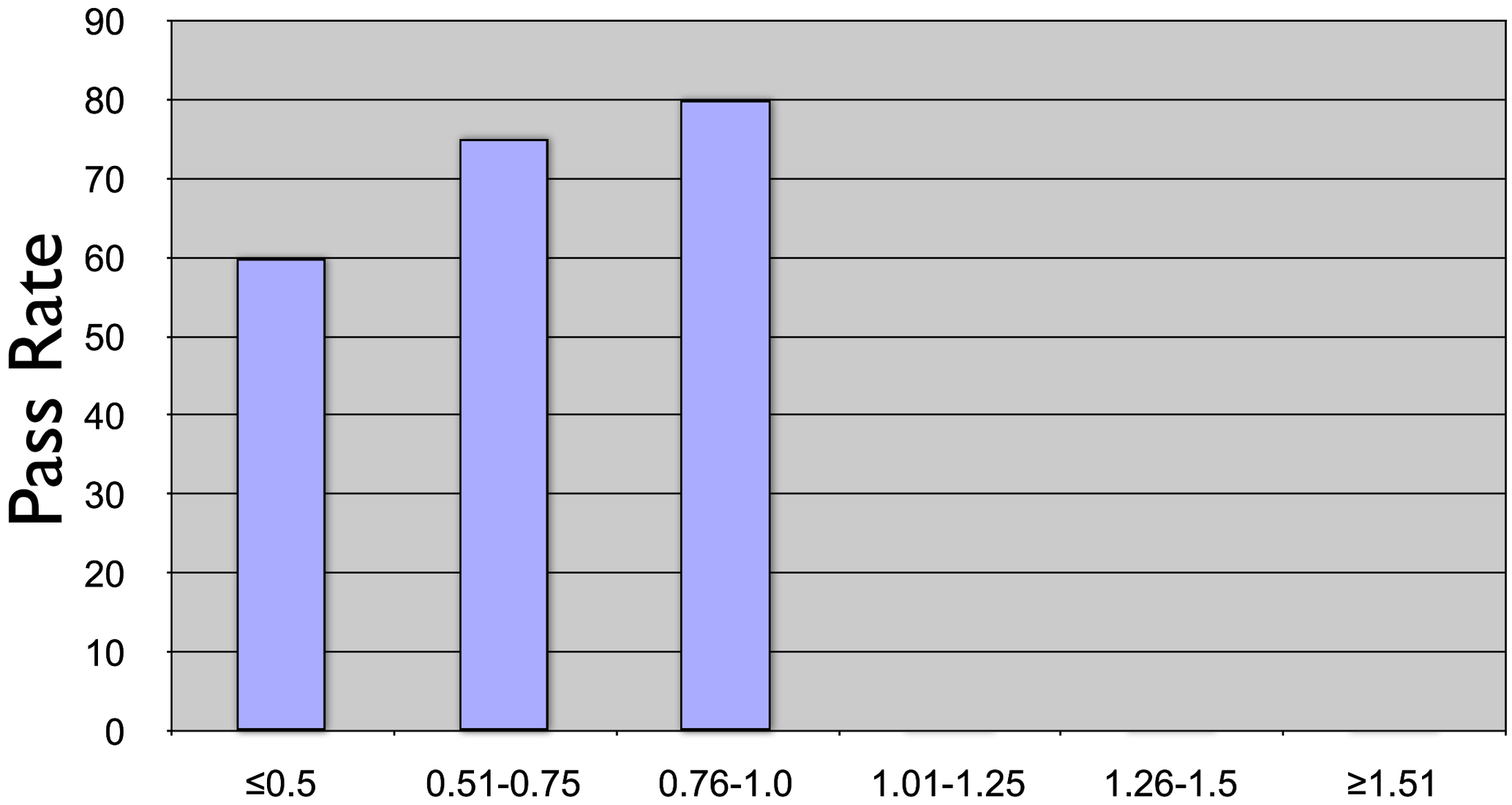

Iso-contours
Ruler
Dataset: 1 - RPC phantom [CT]
Overlay: 2 - [RTDOSE]
6.6 Gy
5.9 Gy
5.3 Gy
4.6 Gy
4.0 Gy
3.3 Gy
2.6 Gy
2.0 Gy
1.3 Gy
0.7 Gy
Iso-contours
Dataset: 1 - RPC phantom [CT]
Overlay: 4 - RPC Scanned Film [RTDOSE]
6.6 Gy
5.9 Gy
5.3 Gy
4.6 Gy
4.0 Gy
3.3 Gy
2.6 Gy
2.0 Gy
1.3 Gy
0.7 Gy

46

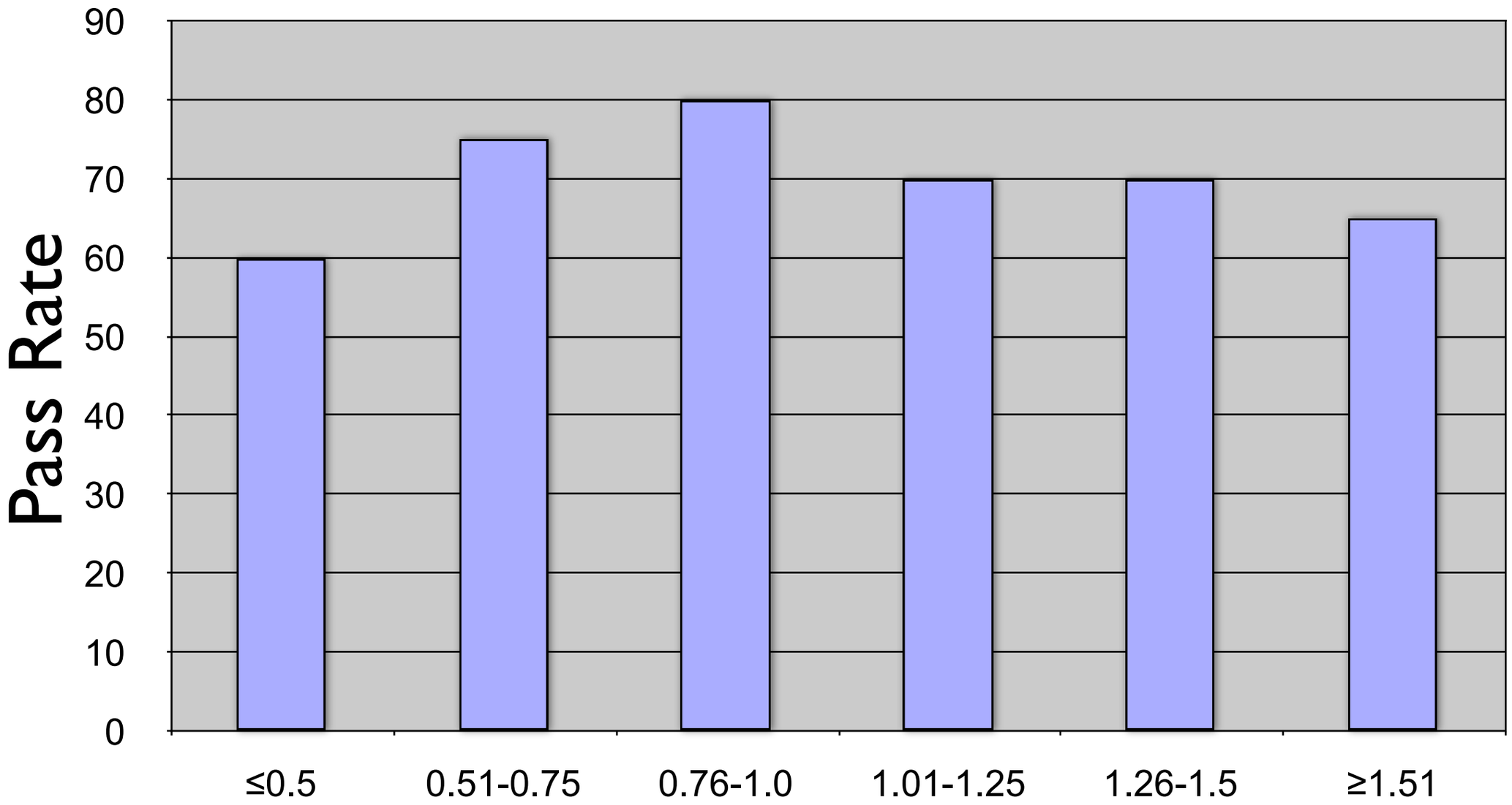
Explanations for Failures

Explanation	Minimum # of occurrences
incorrect output factors in TPS	1
incorrect PDD in TPS	1
Software error	1
inadequacies in beam modeling at leaf ends (Cadman, et al; PMB 2002)	14
not adjusting MU to account for dose differences measured with ion chamber	3
errors in couch indexing with Peacock system	3
2 mm tolerence on MLC leaf position	1
setup errors	7
target malfunction	1

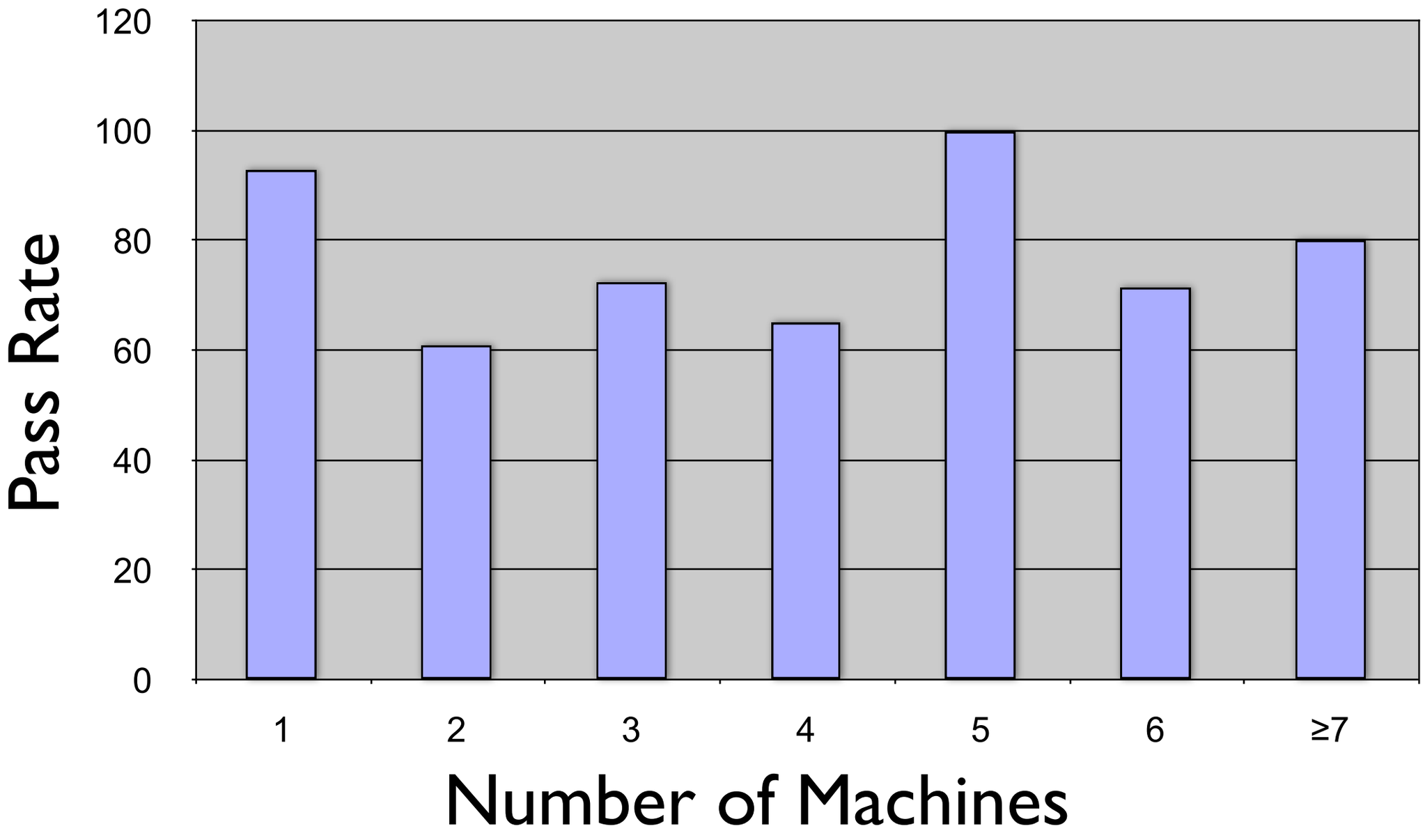
Physicists per machine



Physicists per machine



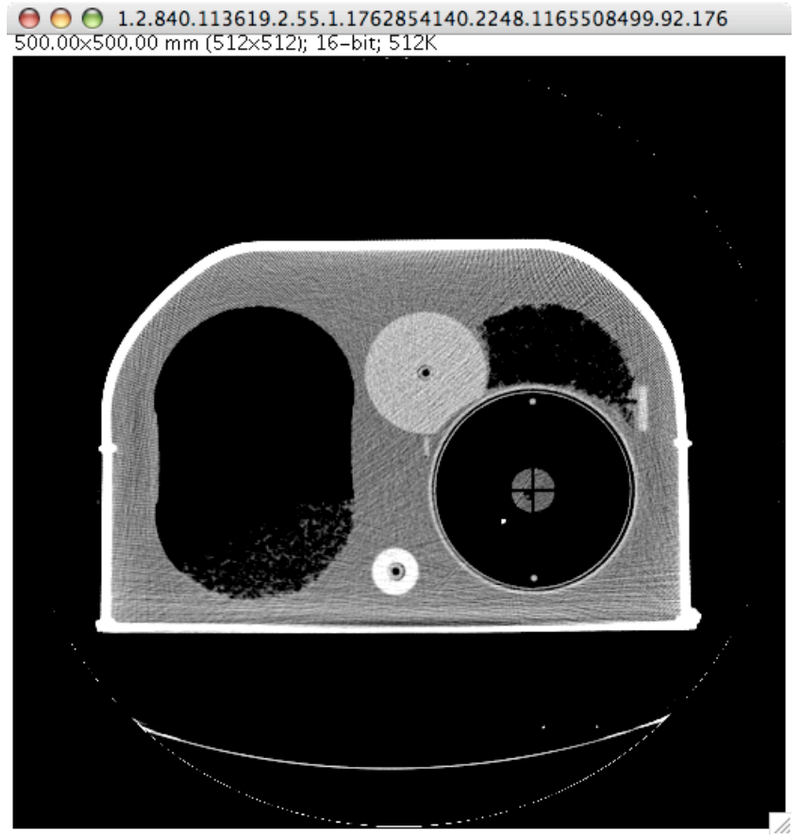
Number of Machines



Results grouped by TPS

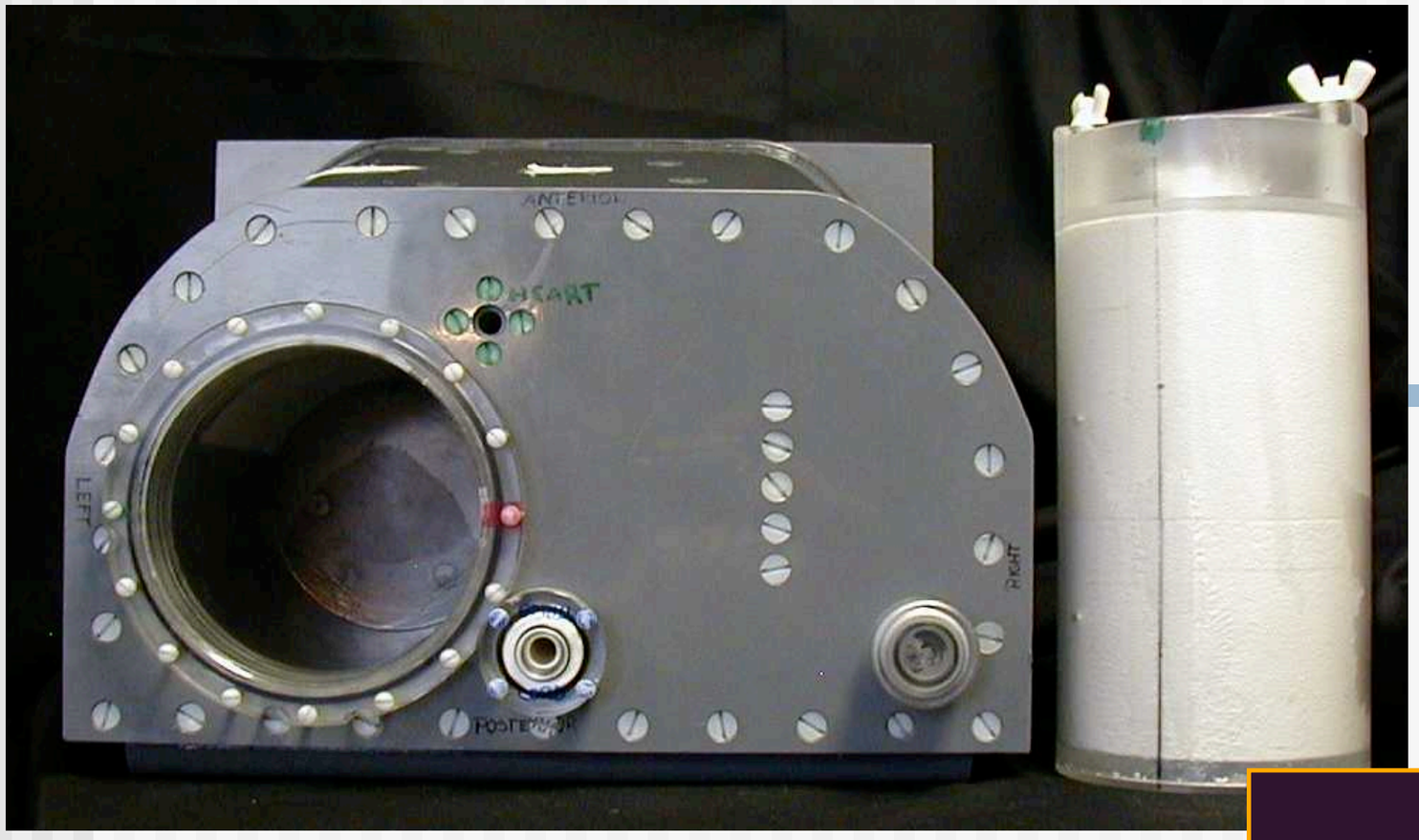
Treatment planning system	Pass Rate (%)	Attempts	Criteria Failed		
			Dose	DTA	Dose and DTA
BrainScan	100	4	0	0	0
Cadplan	67	3	1	0	0
CMS XiO	76	17	1	1	2
Corvus	73	26	6	0	1
Eclipse	84	32	2	2	1
Helax	100	2	0	0	0
Pinnacle	61	69	16	4	7
Radionics XKnife	100	1	0	0	0
Theraplan Plus	0	2	0	0	2
TomoTherapy	67	3	1	0	0
Inst. developed TPS	75	4	1	0	0
total		163	28	7	13

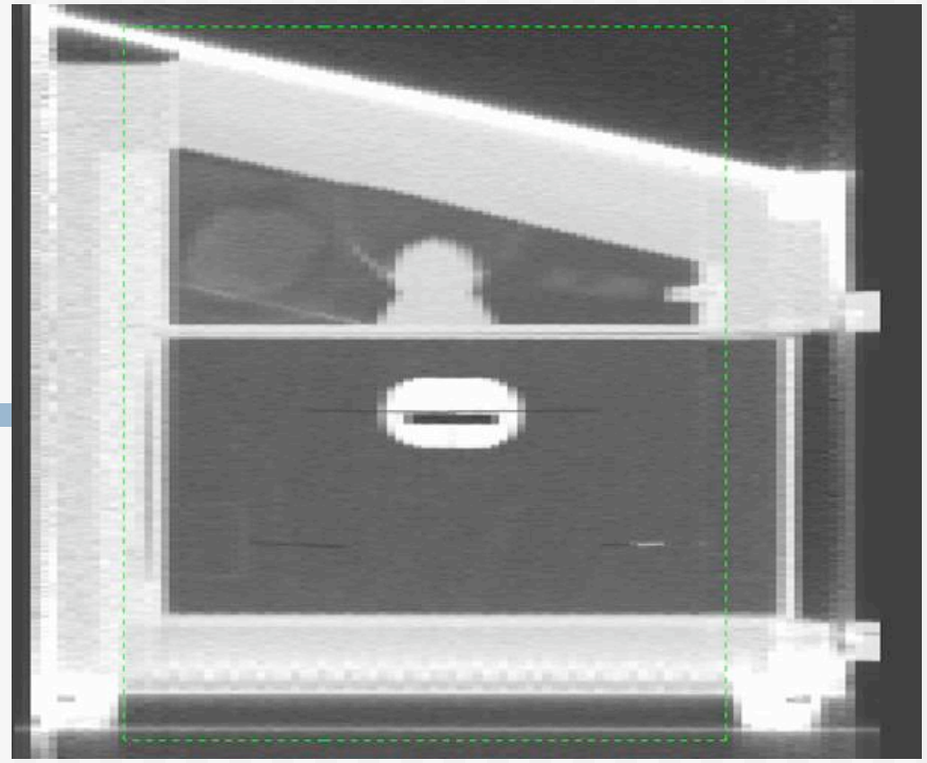
Credentialing for SBRT Lung Protocols

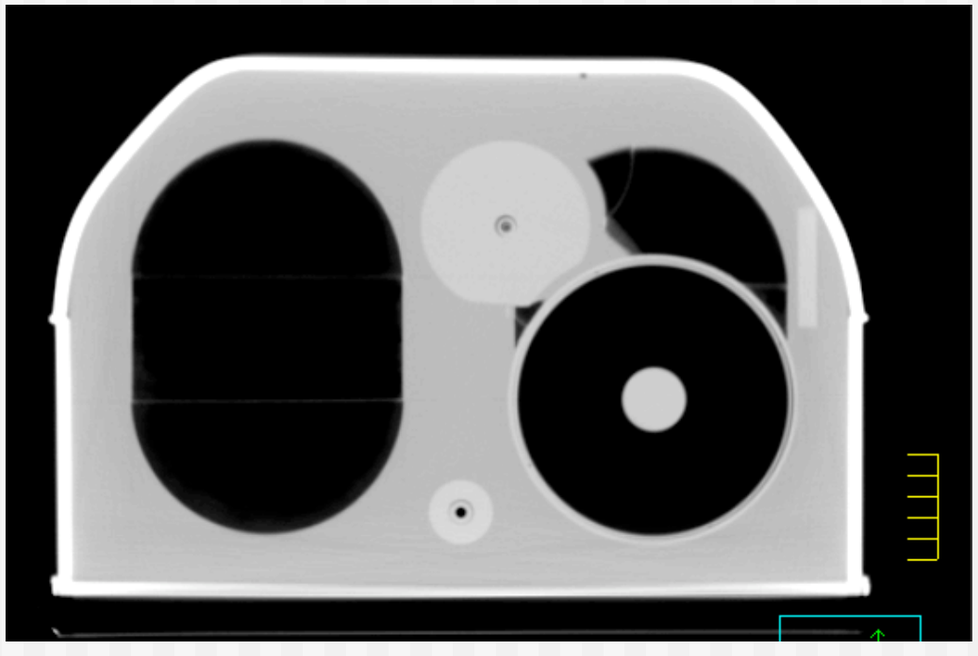


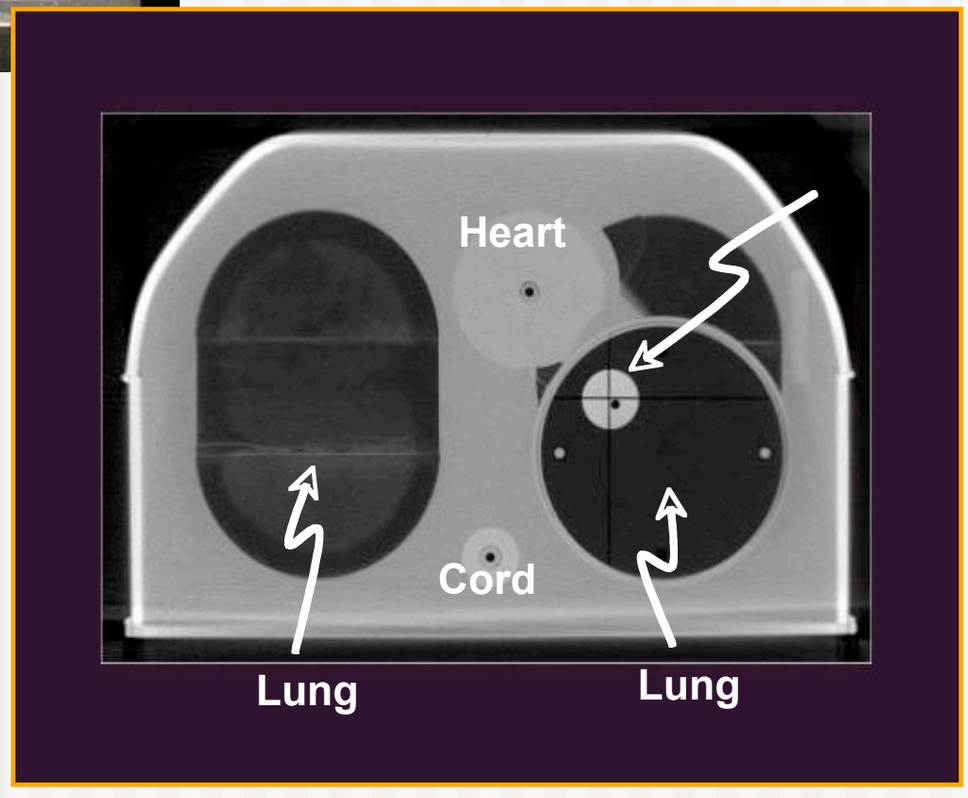
- RPC evaluates dose to TLDs
  - Criteria: ± 0.05
- Evaluate DTA from film data
  - ± 5 mm at all sides of target
- Analysis neglects variation across target
  - RPC has proposed to include evaluation of dose across target

RPC Lung Phantom









Lung Phantom Irradiations

TPS	Dose Calc. Algor correction on	Number of irradiations	D_{hetero}/D_{homo}
Precise v 2.01	Scatter Integ. Clarkson Type	2	1.19 ± 2.6%
BrainLab	Clarkson & Pencil Beam	4	1.21 ± 0%
Eclipse	Pencil Beam	2	1.19 ± 4.6%
Ergo	3D Convolution Pencil Beam	1	1.19 ± 0.1%
Pinnacle v 6.2, 6.4, 7.0g, 7.4f	Adaptative Convolve	8	1.13 ± 2.1%
Render plan	Change in primary attenuation	1	1.20
XiO	Superposition/ Convolution	3	1.12 ± 2.4%
	Total	21	1.18

Lung Phantom Irradiations

TPS	Dose Calc. Algor correction on	Number of irradiations	D_{hetero}/D_{homo}
Precise v 2.01	Scatter Integ. Clarkson Type	2	1.19 ± 2.6%
BrainLab	Clarkson & Pencil Beam	4	1.21 ± 0%
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Ergo	3D Convolution Pencil Beam	1	1.19 ± 0.1%
Pinnacle v 6.2, 6.4, 7.0g, 7.4f	Adaptative Convolve	8	1.13 ± 2.1%
Render plan	Change in primary attenuation	1	1.20
XiO	Superposition/ Convolution	3	1.12 ± 2.4%
	Total	**21**	**1.18**

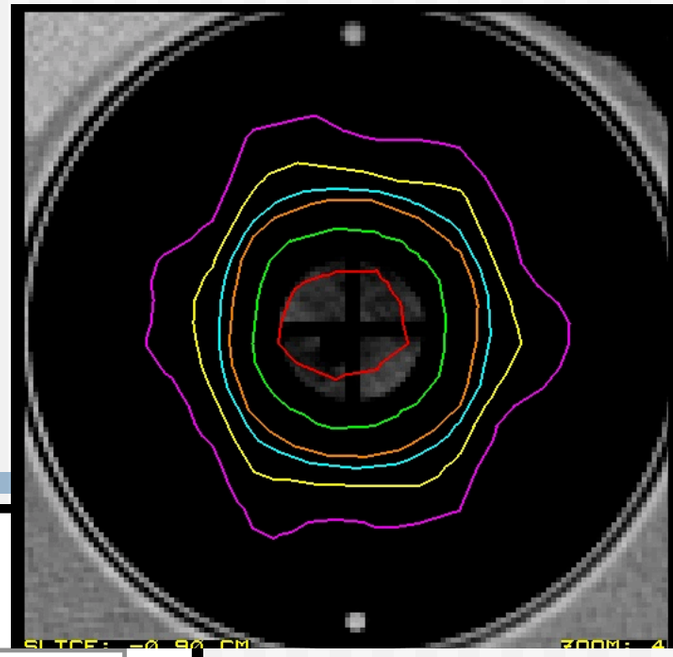
TLD Dose vs. Hetero Corrected Plan

TPS	Dose Calc. Algor correction on	Number of irradiations	D_{TLD}/D_{hetero}
Precise v 2.01	Scatter Integ. Clarkson Type	2	0.99 ± 3.1%
BrainLab	Clarkson & Pencil Beam	4	0.96 ± 2.7%
Eclipse	Pencil Beam	2	0.97 ± 1.6%
Ergo	3D Convolution Pencil Beam	1	0.98 ± 3.2%
Pinnacle v 6.2, 6.4, 7.0g, 7.4f	Adaptative Convolve	8	0.99 ± 2.3%
Render plan	Change in primary attenuation	1	0.92
XiO	Superposition/ Convolution	3	0.96*
	Total	21	0.97

TLD Dose vs. Hetero Corrected Plan

TPS	Dose Calc. Algor correction on	Number of irradiations	D_{TLD}/D_{hetero}
Precise v 2.01	Scatter Integ. Clarkson Type	2	0.99 ± 3.1%
BrainLab	Clarkson & Pencil Beam	4	0.96 ± 2.7%
Eclipse	Pencil Beam	2	0.97 ± 1.6%
Ergo	3D Convolution Pencil Beam	1	0.98 ± 3.2%
Pinnacle v 6.2, 6.4, 7.0g, 7.4f	Adaptative Convolve	8	0.99 ± 2.3%
Render plan	Change in primary attenuation	1	0.92
XiO	Superposition/ Convolution	3	0.96*
	Total	**21**	**0.97**

Convolution R-L Profile



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Right Left Profile
Axial plane

Left

Average displacement Left side: on: 3 mm off: 1 mm

Righ

Average displacement Rigth side: on: 1 mm off: 5 mm

Prescribed D

D_{2cm}

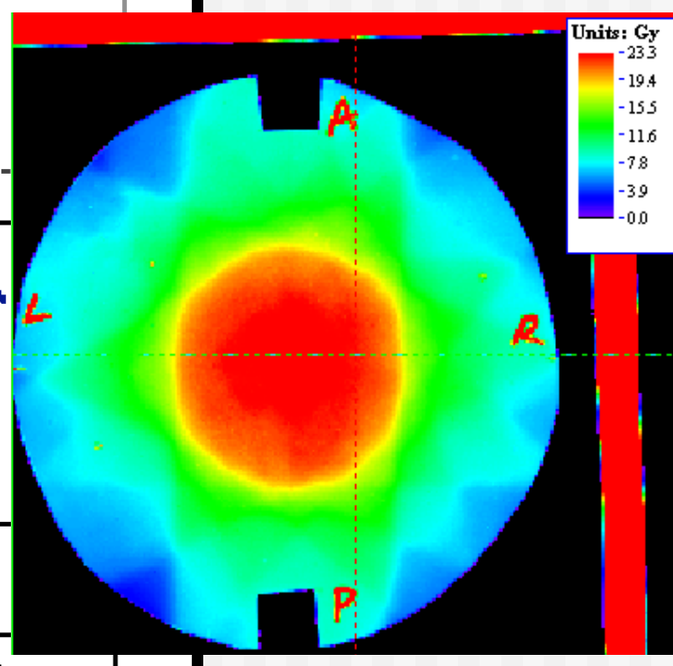
PTV

30
20
10
0

-7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6

Distance (cm)

RPC Film | ITC off | ITC on | RPC Regression | Institution Regression



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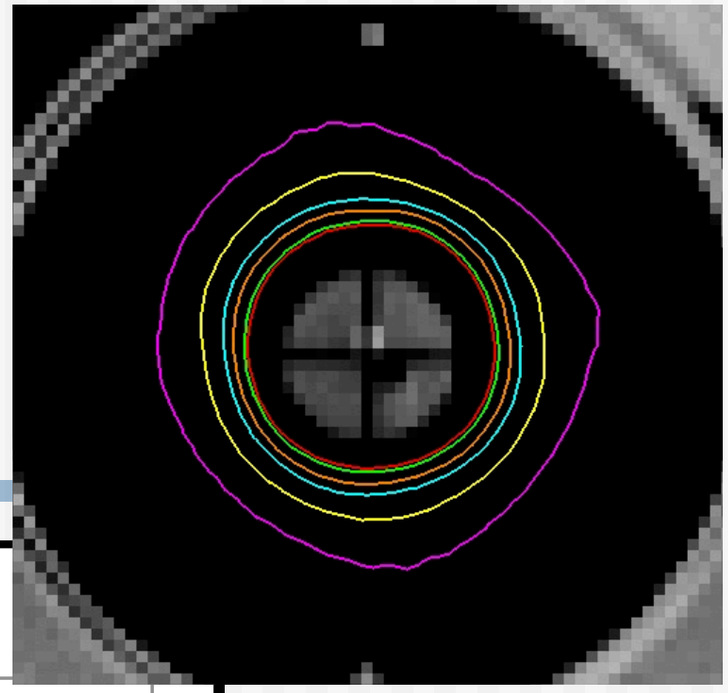
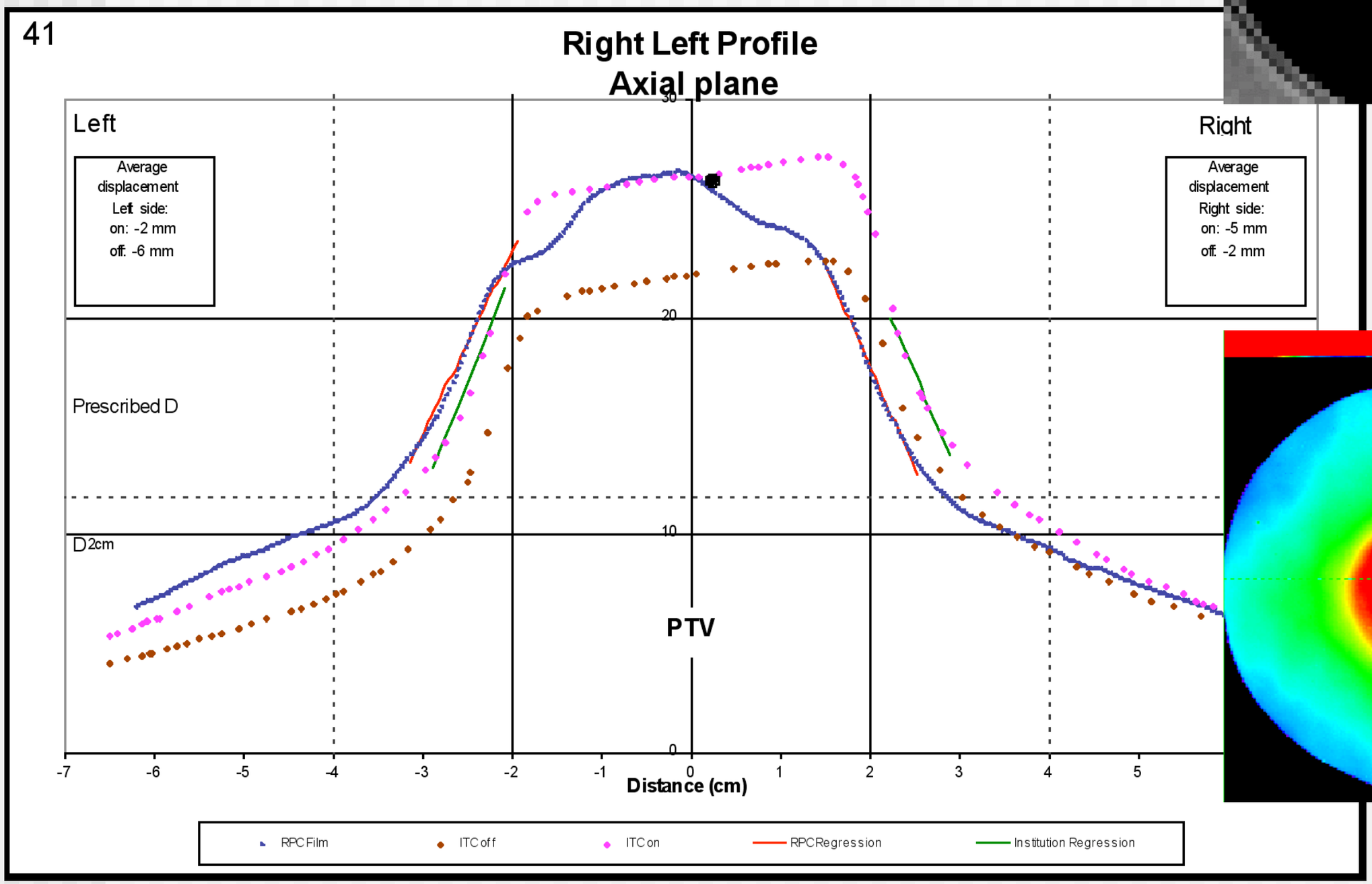
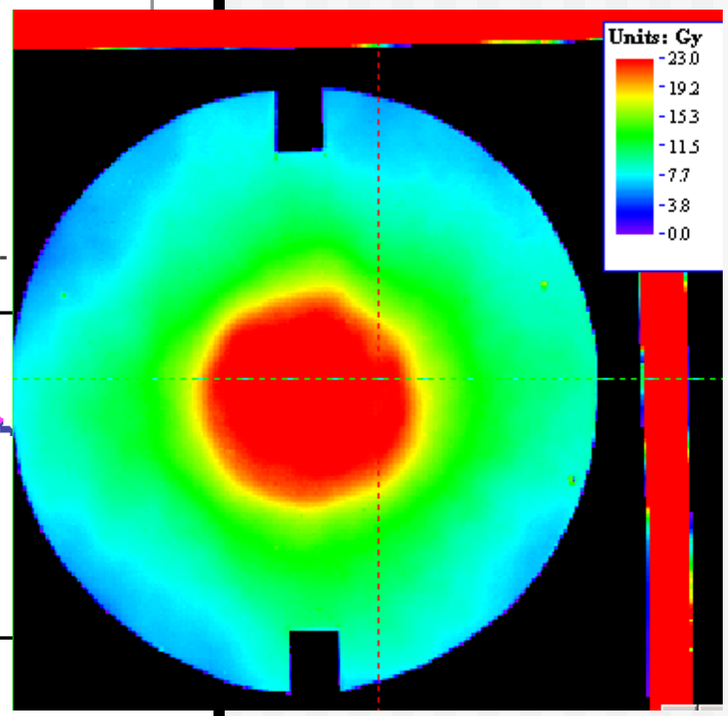
Pencil-Beam profile







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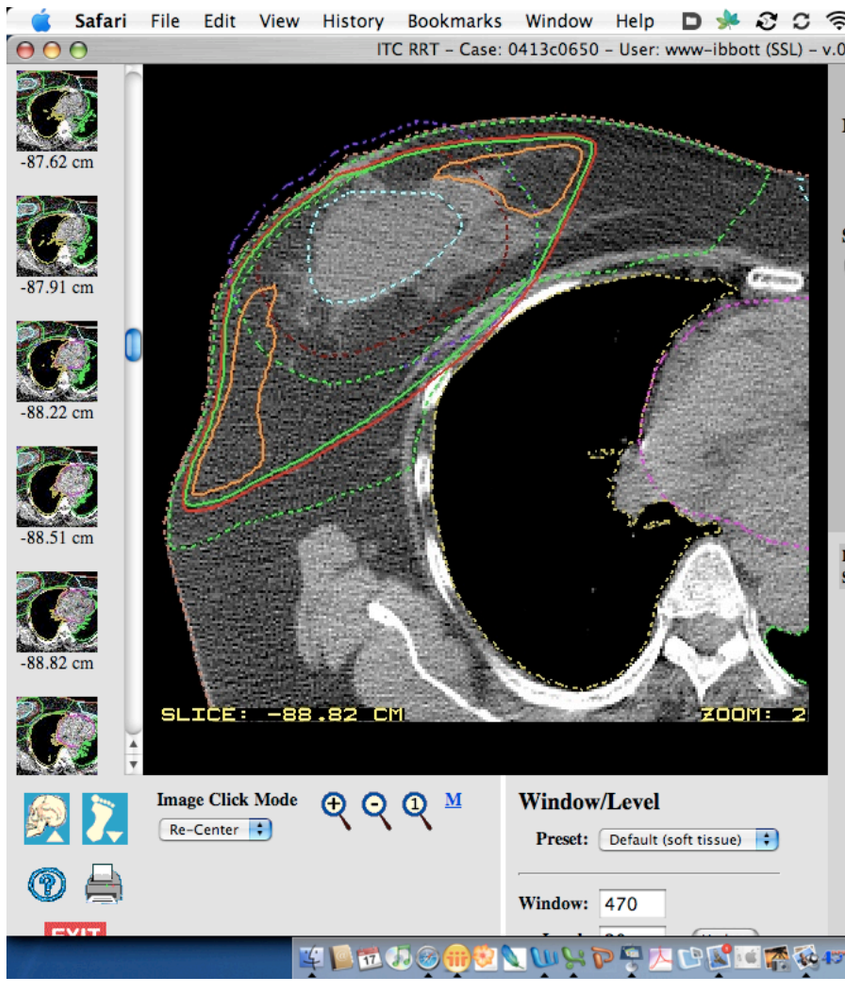
~300 institutions have demonstrated ability to submit digital data to ITC

ATC Support of Protocols

1. Data submission to ITC;
2. Data-quality QA performed by ITC;
3. Contour QA review by study P.I.s online using RRT
4. Dosimetry QA review by RPC online using RRT
5. RPC compares plan and



Results of Credentialing
(closed studies)

Study	Major Deviations	Minor Deviations	Number of Patients
GOG 165 HDR Cervix Credentialed inst	0	15	70
RTOG 95-17 HDR & LDR Breast (all)	0	4	100
RTOG 0019 LDR Prostate (values for dose only)	0	6	117 reviewed (total 129 eligible)

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Results of Credentialing
(closed studies)

Study	Major Deviations	Minor Deviations	Number of Patients
GOG 165 HDR Cervix Credentialed inst	0	15	70
Non-credentialed	57	87	275
RTOG 95-17 HDR & LDR Breast (all)	0	4	100
RTOG 0019 LDR Prostate (values for dose only)	0	6	117 reviewed (total 129 eligible)

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RPC's Conventional Monitoring

- Annual checks of machine output
  - 1,532 institutions, 13,729 beams measured with TLD (2006)
- On-site dosimetry reviews
  - 19 institutions visited (144 beams measured)
- Credentialing
  - Phantoms, benchmarks, questionnaires, rapid reviews
- Treatment record reviews
  - Review for GOG, NSABP, NCCTG, RTOG (brachy)
- Independent recalculation of patient dose
  - Continue to find errors

Status of RPC Preparations for Monitoring Proton Facilities

RPC able to visit PTC-H during construction to learn about facility design and operation

Visits to PTC-H and to UF/Jacksonville to measure and verify beam output, depth dose characteristics

Irradiated TLD at 3 facilities under more than 30 combinations of energy, field size, depth and residual range

Evaluated radiochromic film (2 types) for use in proton beams

Presently testing BANG® gel & Presage™ dosimeters

Agreement with Landauer to evaluate OSL dosimeters in various beams, including protons

RPC's Vision for Support of Proton Clinical Trials

- Encourage uniform adoption of calibration protocol with traceability to NIST
  - Participate on AAPM Work Group on Particle Beams
- Design and implement devices for monitoring beam calibration
  - Proton-specific blocks for TLD or OSL
- Pursue evaluation of gel/Presage™ dosimeters
- Design, evaluate and implement modified anthropomorphic phantoms for evaluating proton beam delivery
- Implement proton planning on RPC's Eclipse workstation for independent review