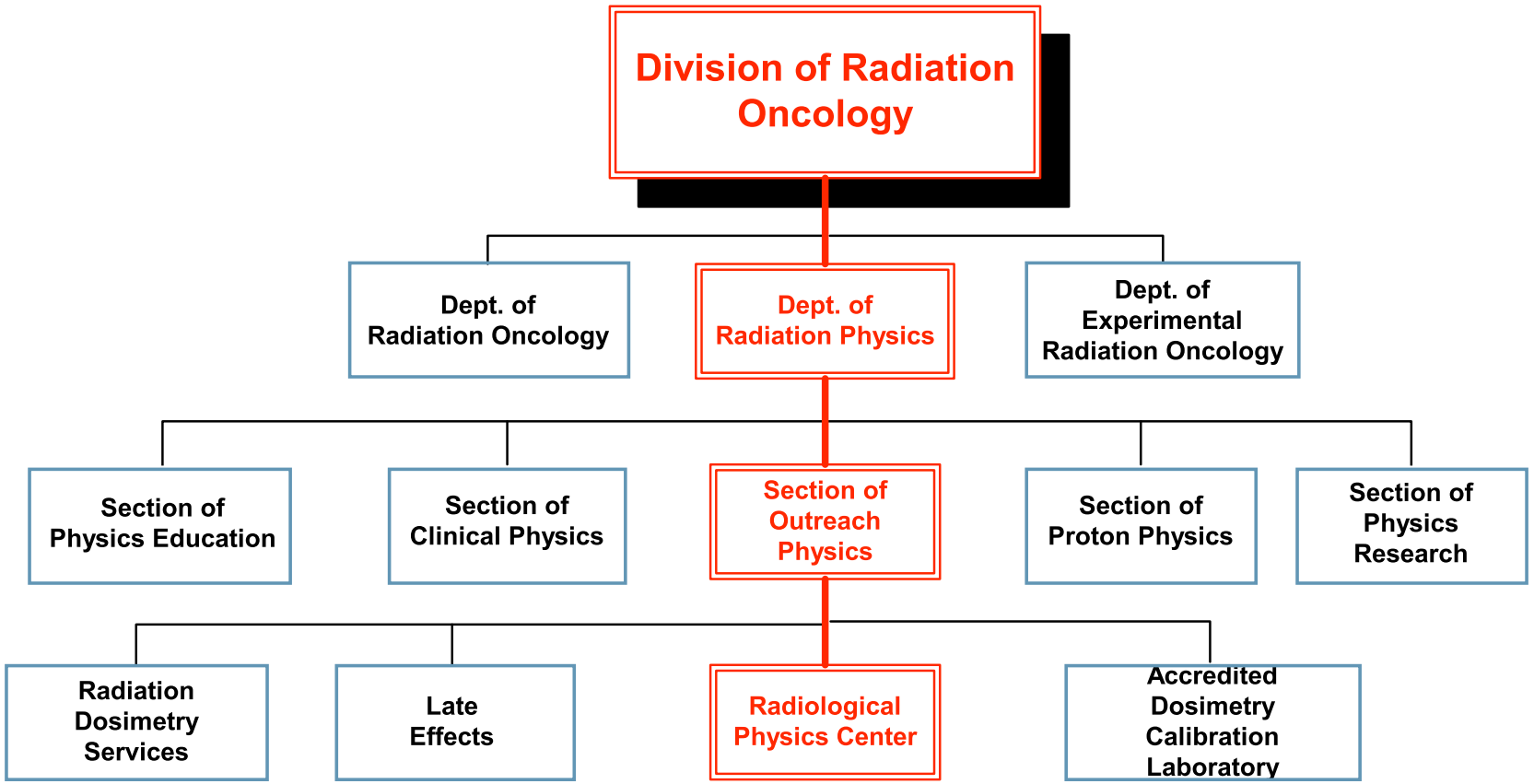
# The RPC's Evaluation of Advanced Technologies


AAPM Refresher Course
July 29, 2008
Geoffrey S. Ibbott, Ph.D. and
RPC Staff


# http://rpc.mdanderson.org

THE UNIVERSITY OF TEXAS
MD ANDERSON
CANCER CENTER
*Making Cancer History®*

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


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

# Division of Radiation Oncology

Section o
Physics Educ

Radiation
Dosimetry
Services

ection of
Physics
Research

# Brief Background

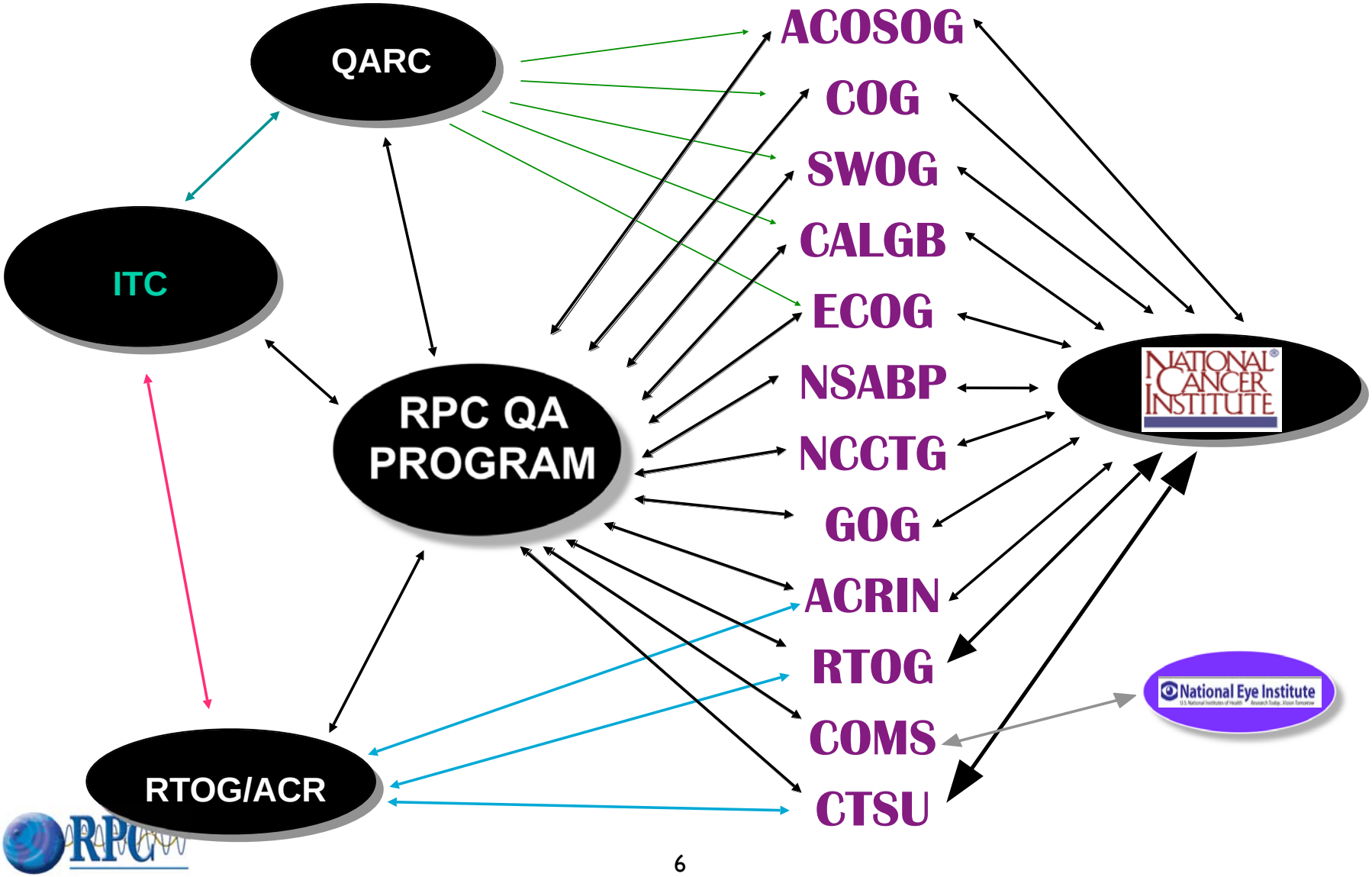
- Formed by agreement between AAPM and CRTS, with funding from NCI
- Founded in 1968 to monitor institution participation in clinical trials
- Funded continuously by NCI as structure of cooperative group programs have changed
- Now 38 years of experience of monitoring institutions and reporting findings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

# 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 all study groups



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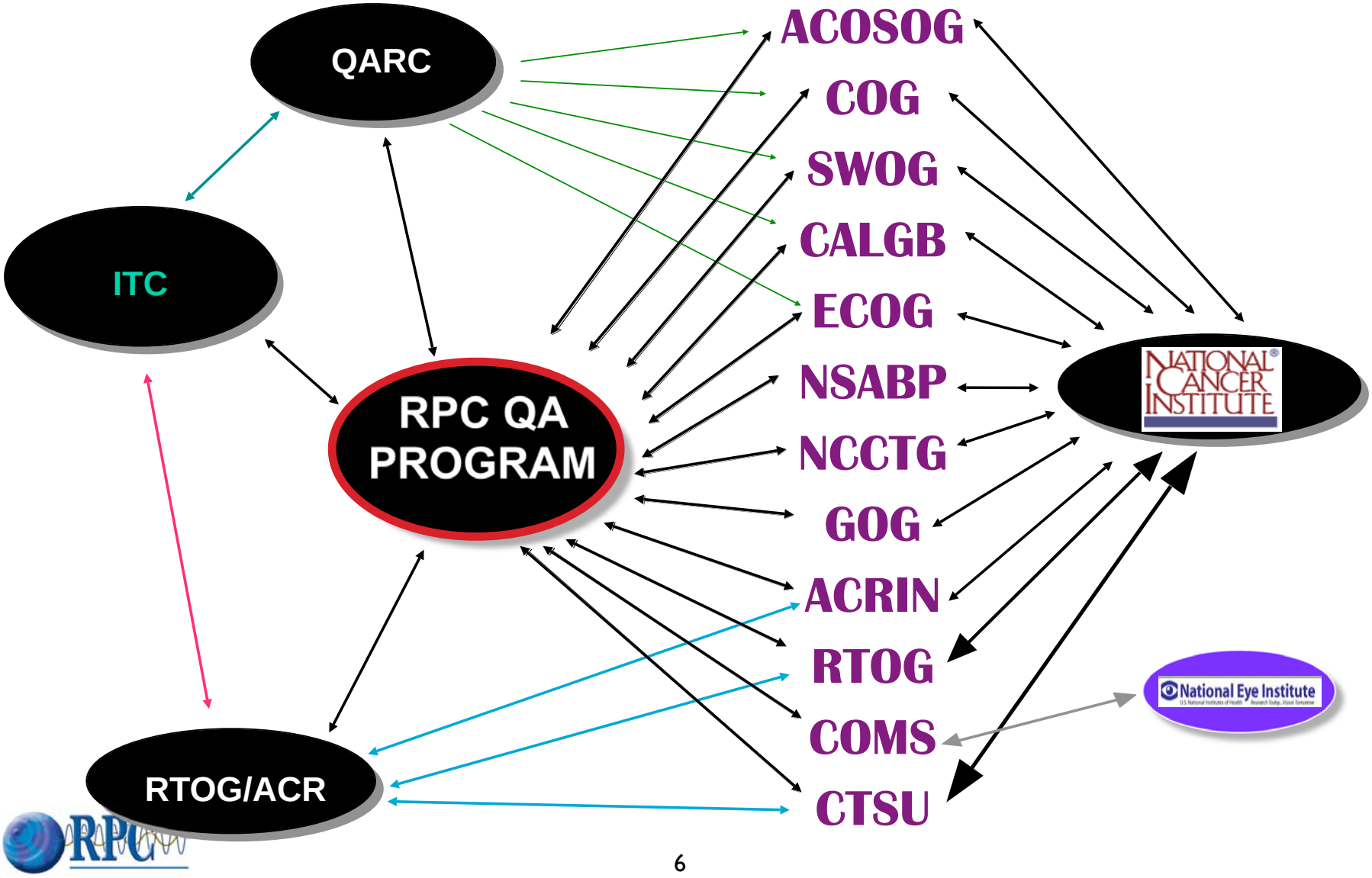

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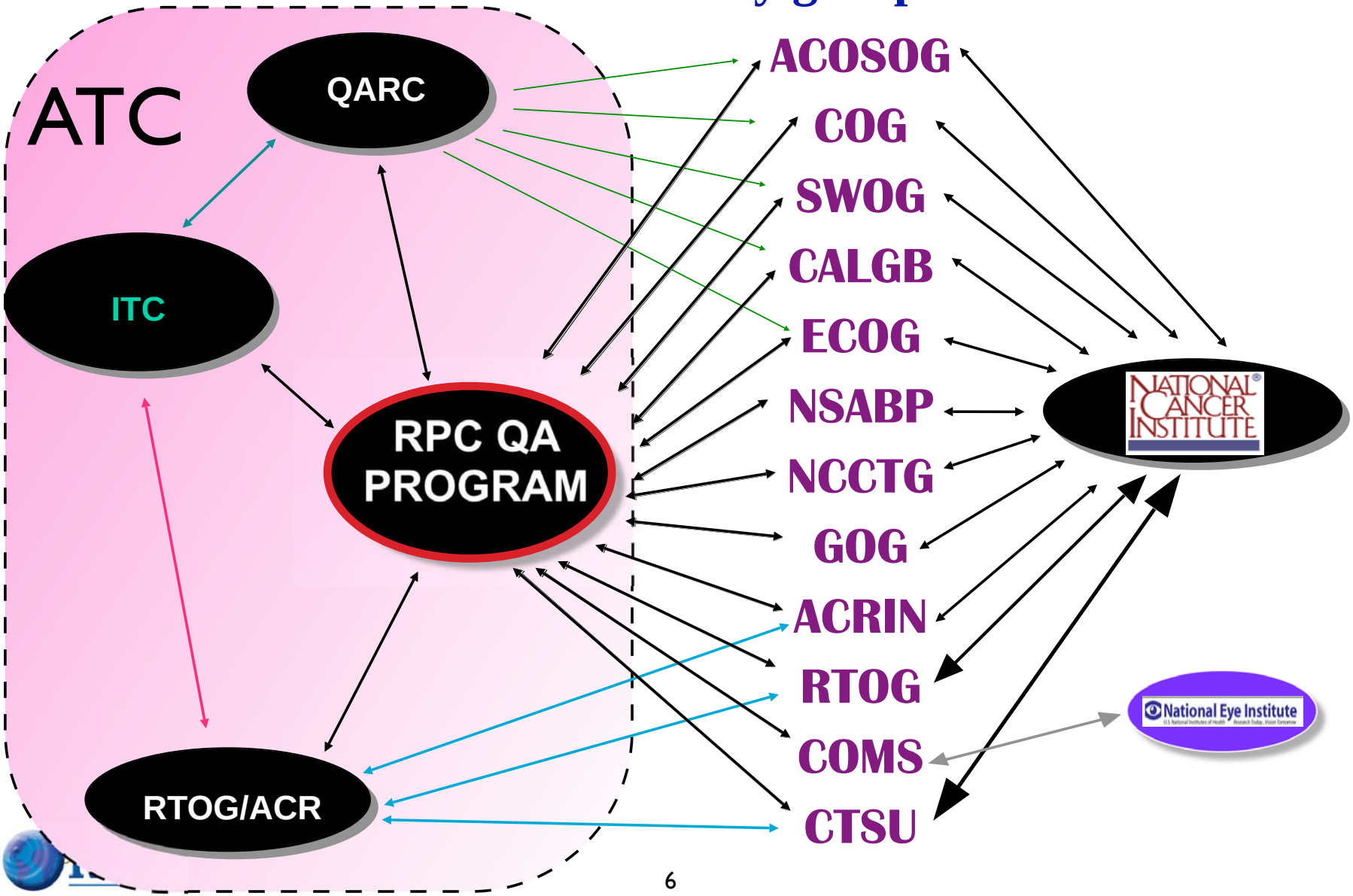


6

# 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

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- Annual checks of machine output
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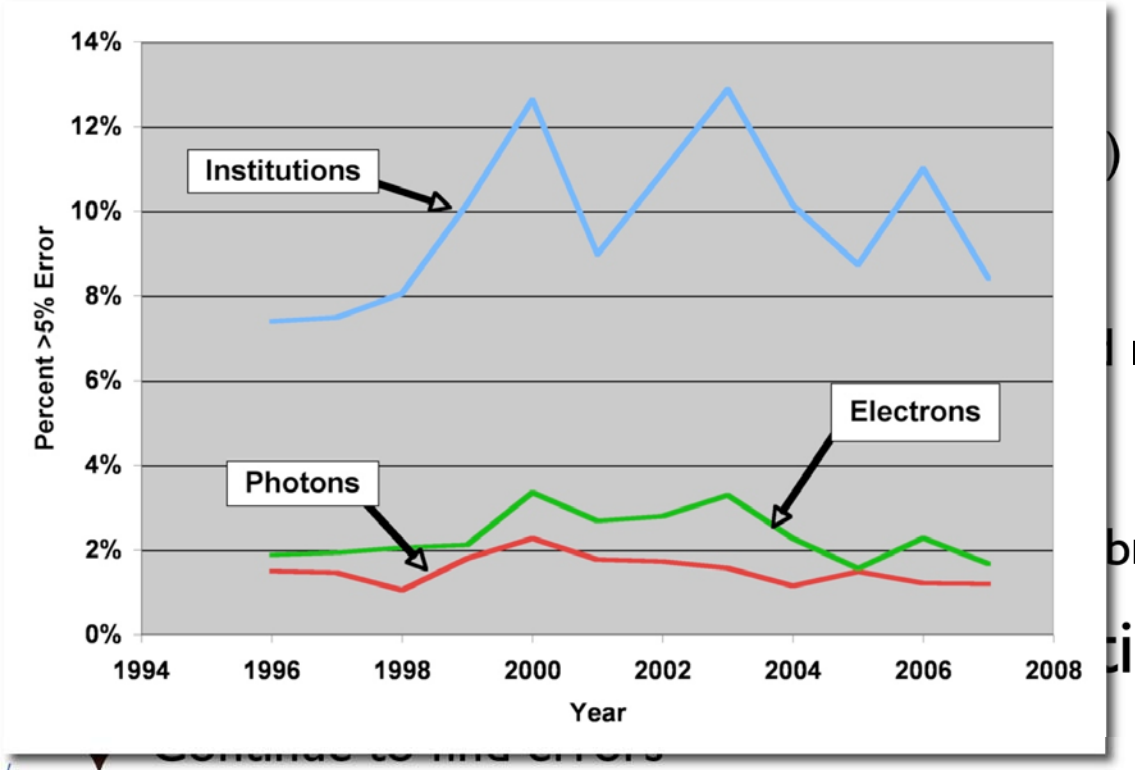


reviews

brachy)

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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
  - 50 institutions visited (~150 accelerators measured)
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  - Phantoms, benchmarks, questionnaires, rapid reviews
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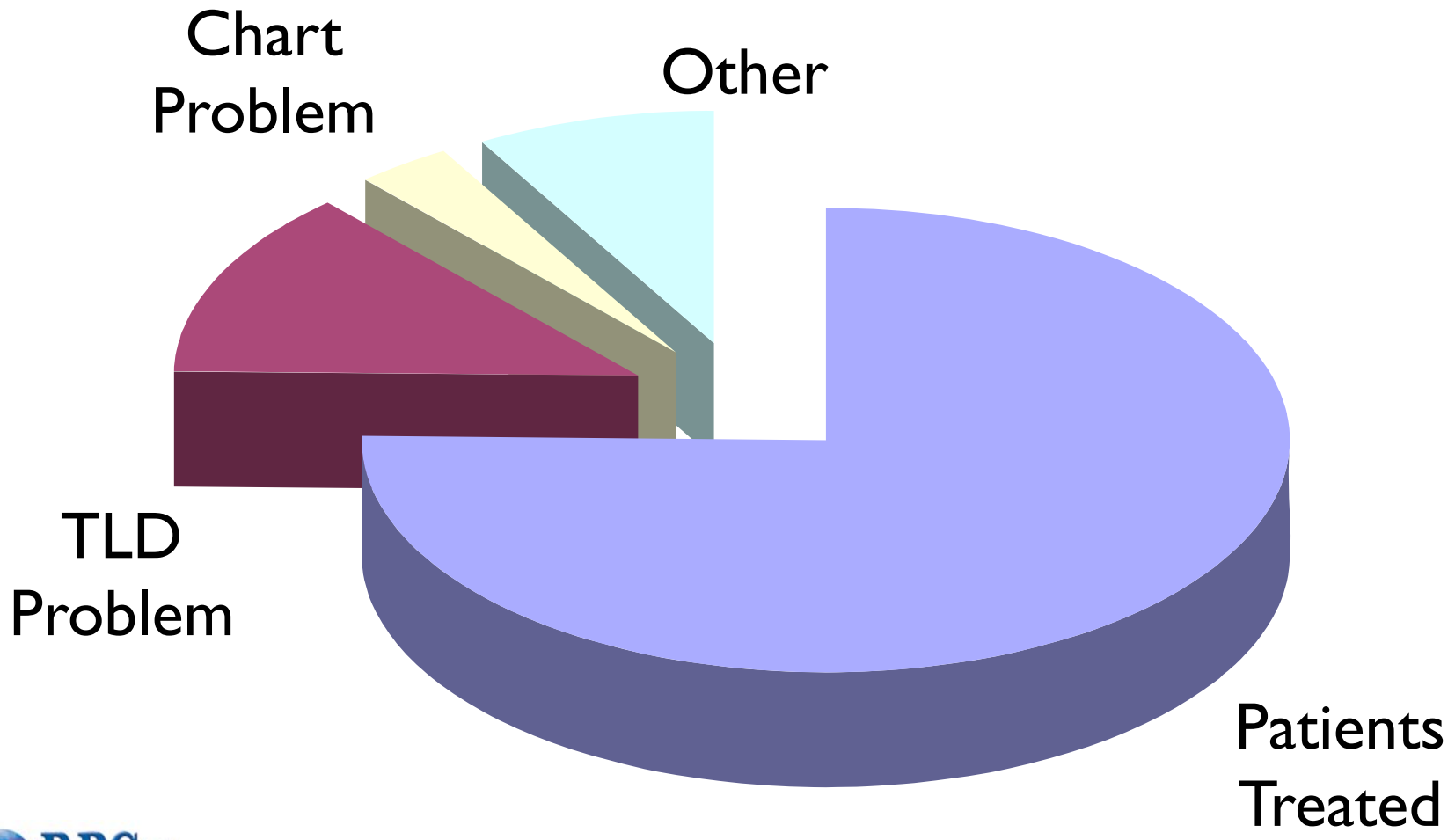
# Visit Priority



# 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.

# On-Site Dosimetry Review

**Selected discrepancies discovered during 2006**

| 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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# Credentialing


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

**Reduce deviation rate**

# 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

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# RPC Website Revisions

RPC Radiological Physics Center
Excellence through Quality Assurance

Search RPC by Google GO

Tel: 713-745-8989

Home | About us | Newsletter | Credentialing | Institutions Monitored | On-Site Audits | FAQ | Contact us | Links | Site map

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

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

**Credentialing Open:** RTOG 0617 Phase III intergroup trial randomizing NSCLC patients to conventional RT versus high-dose conformal RT. Also: RTOG 0618 , RTOG 0621, RTOG 0622, RTOG 0623, RTOG 0630 and GOG 0238 are ready for you to become credentialed.

**Proton Therapy Questionnaire** New requirement of all proton facilities participating on NCI sponsored clinical trials

**New Phantom Requirements:** The RPC has begun requiring electronic submissions of all phantom irradiations. [more]

**NCI Guidelines:** Click here for the latest NCI guidelines on the use of protons and IMRT in clinical trials.

**Radiation exposures from CT:** A new article in the New England Journal by David Brenner and Eric Hall calls attention to the recent increase in utilization of CT and the corresponding increase in dose.[more]

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

40th Anniversary 1968 2008

**AAPM 2008**
**abstracts**

**Challenges in Credentialing Institutions and Participants in Advanced Technology Multi-institutional Clinical Trials** Geoffrey S. Ibbott Ph.D., David S. Followill Ph.D., H. Andrea Molineu M.S., Jessica R. Lowenstein M.S., Paola E. Alvarez M.S. and Joye E. Roll C.M.D.

**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.

**Short Courses** Physics courses related to therapeutic radiology offered at the University of Texas M. D. Anderson Cancer Center.

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

Contact us rpc@mdanderson.org

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NATIONAL CANCER INSTITUTE

aapm online

Updated on: 11/2/2007
You are visitor #44115.

RPC

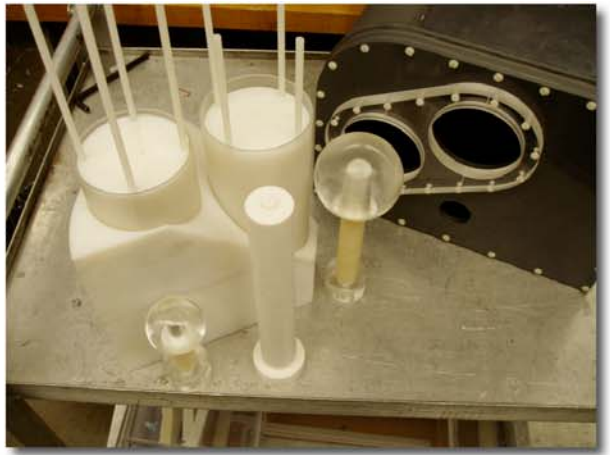
# RPC Phantoms

prostate IMRT: 8, incl. prosthesis

thorax SBRT: 9 phantoms

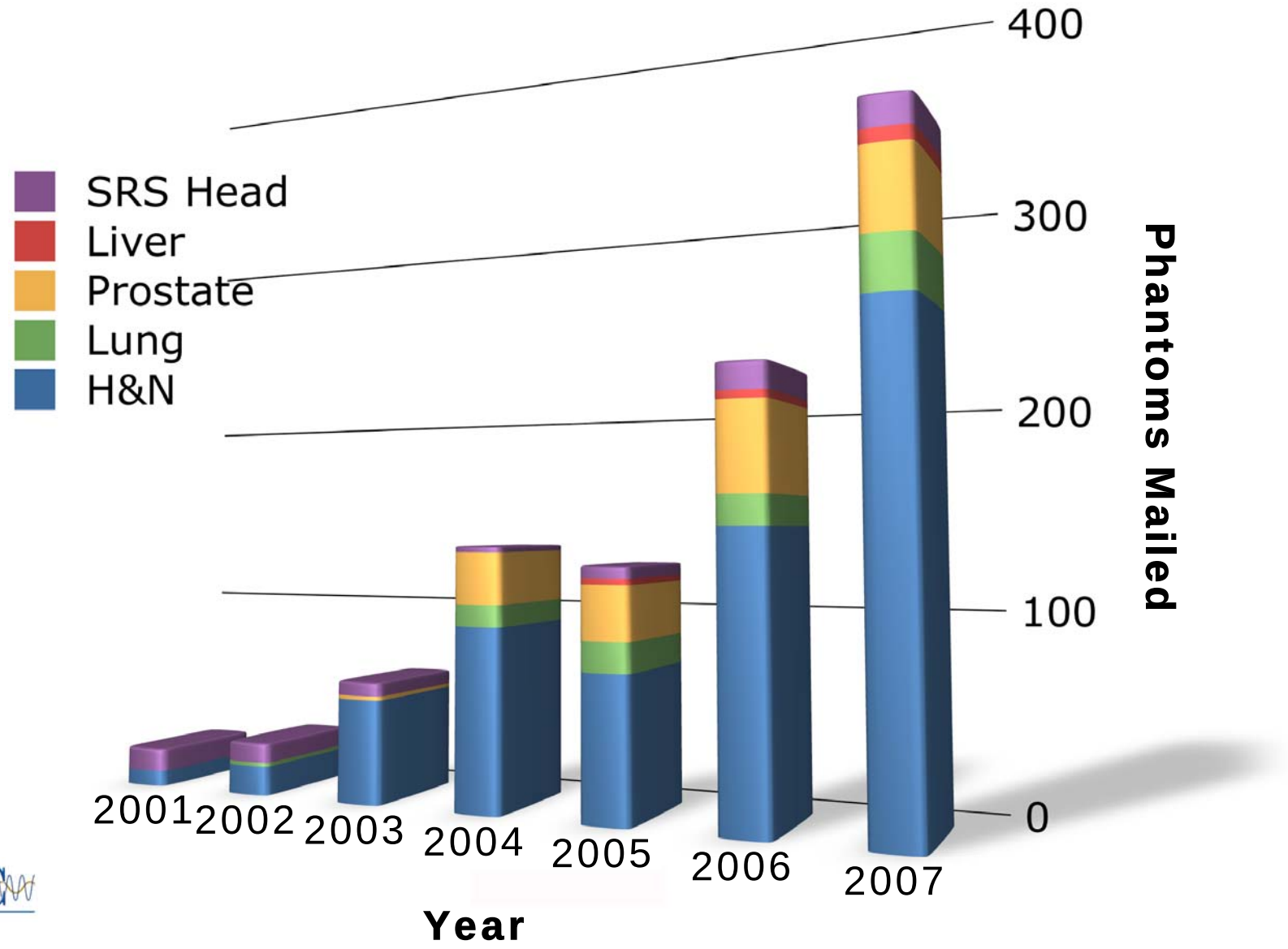
H&N IMRT: 31 in service

SRS: 2 in service, others sent by RDS



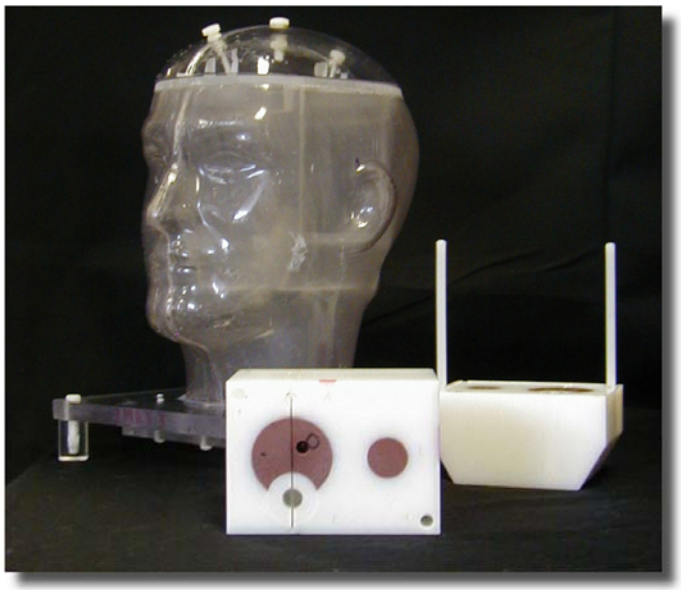
liver SBRT: 3, incl. motion

# Number of phantom mailings

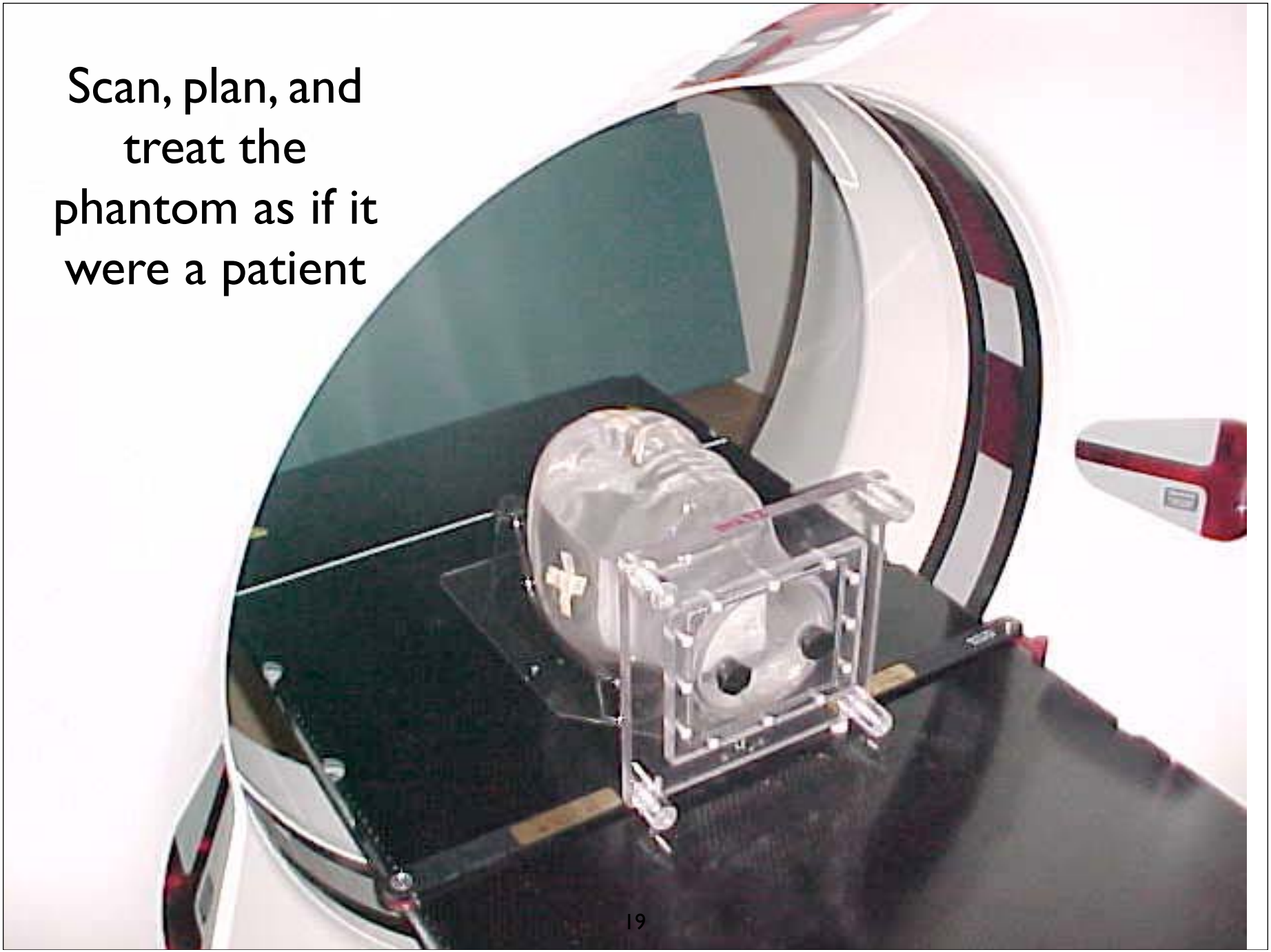


# IMRT Credentialing

500+ institutions have successfully irradiated an RPC IMRT or SBRT phantom



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

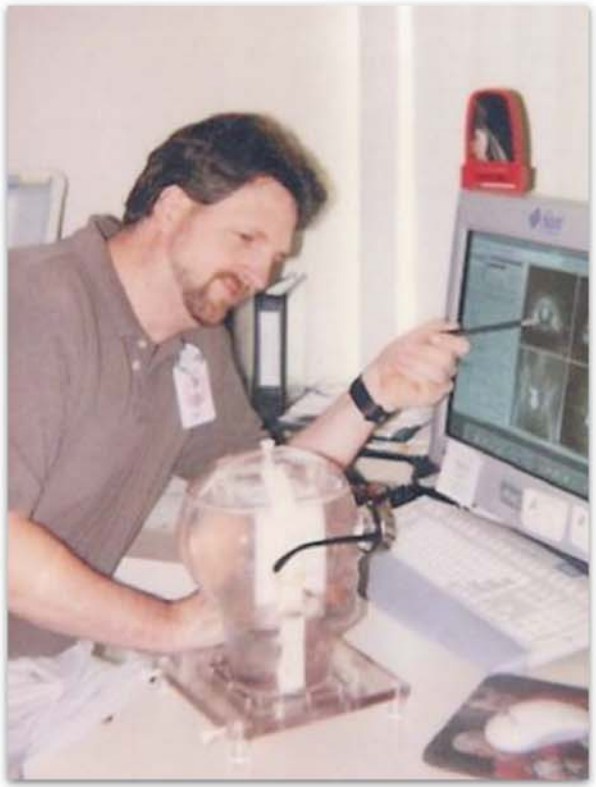


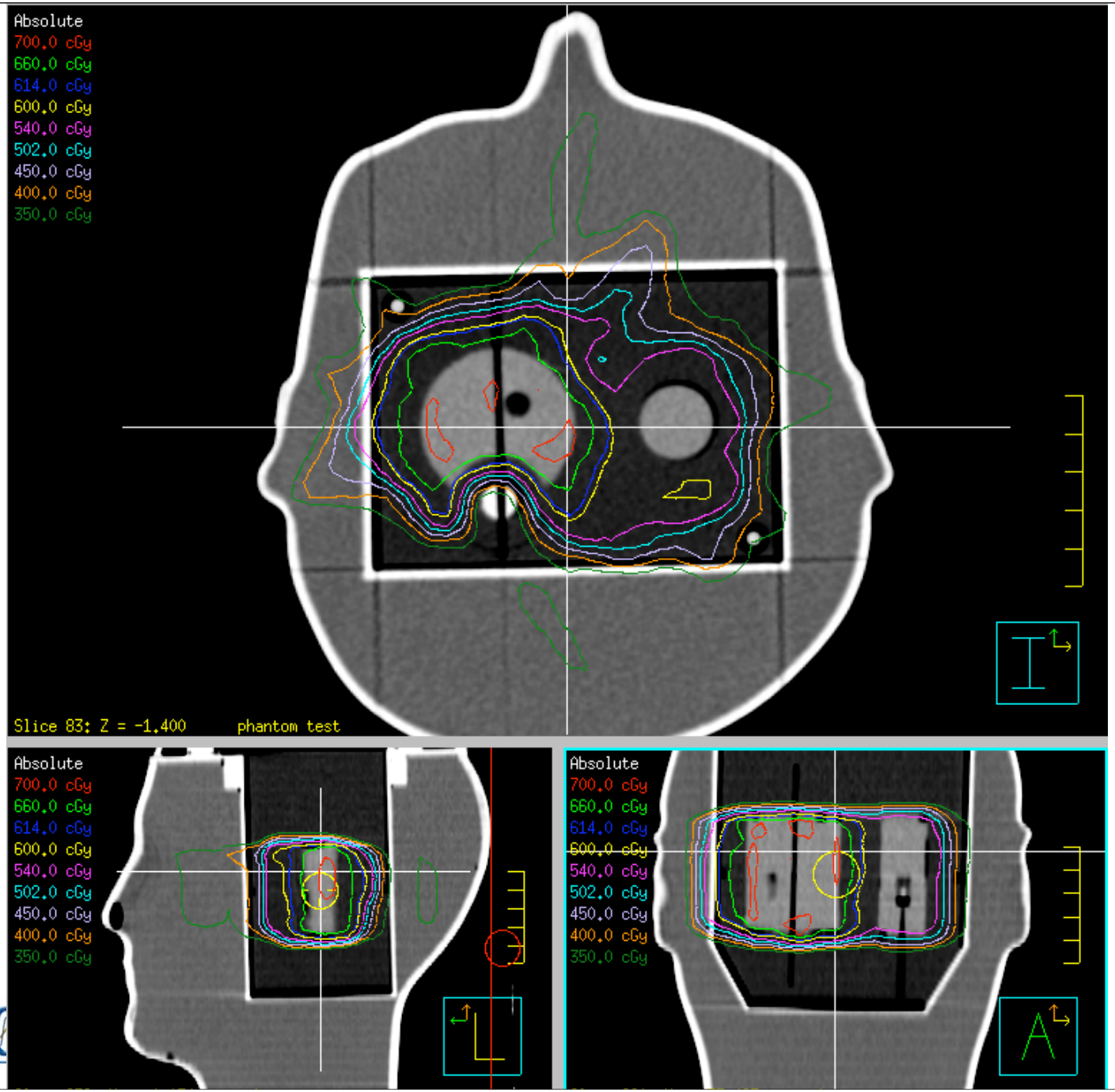
# Treat the phantom like a patient

**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
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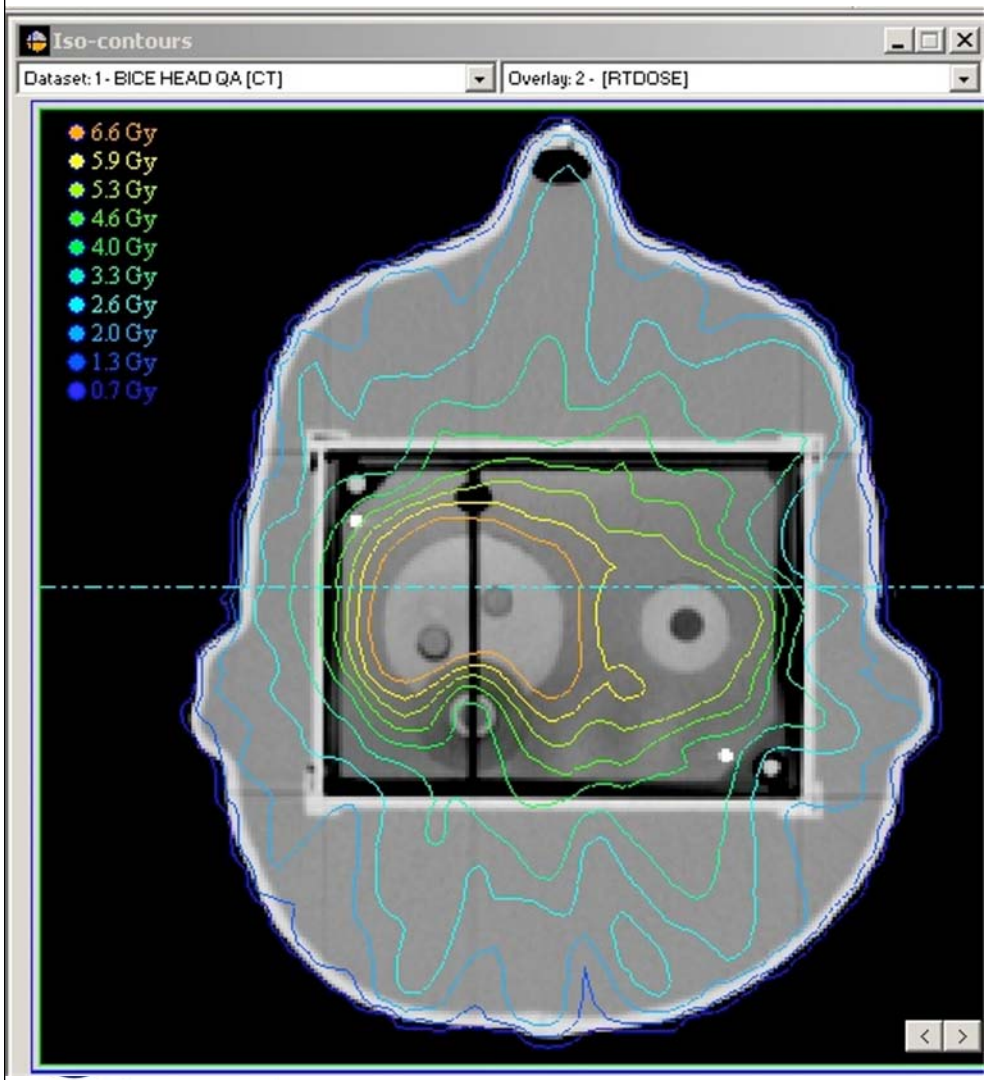
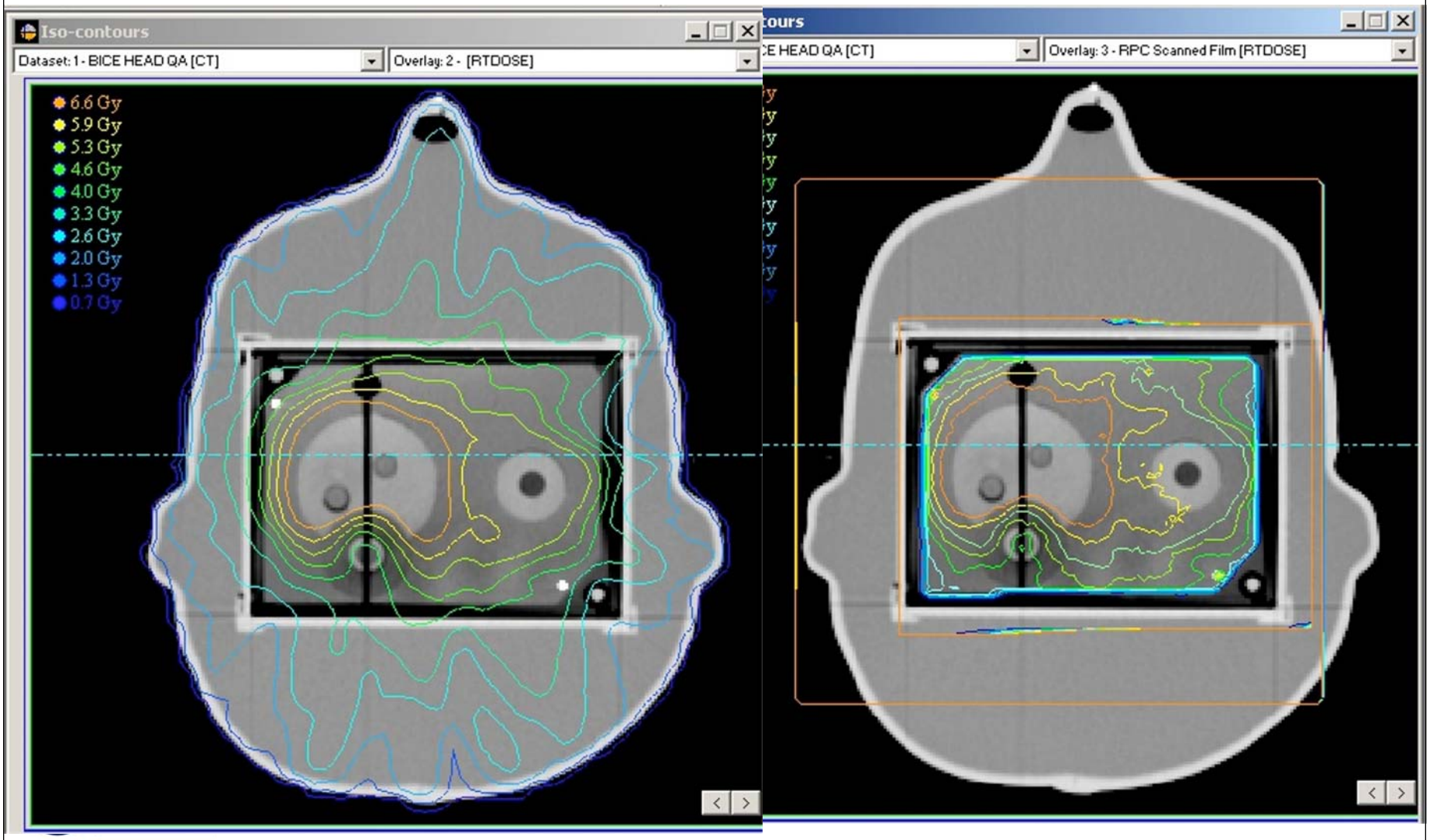

Iso-contours
Dataset: 1 - BICE HEAD QA [CT]
Overlay: 2 - [RTDOSE]
6.6 Gy
5.9 Gy
5.3 Gy
4.6 Gy
4.0 Gy
3.3 Gy
2.6 Gy
2.0 Gy
1.3 Gy
0.7 Gy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6.6 Gy
5.9 Gy
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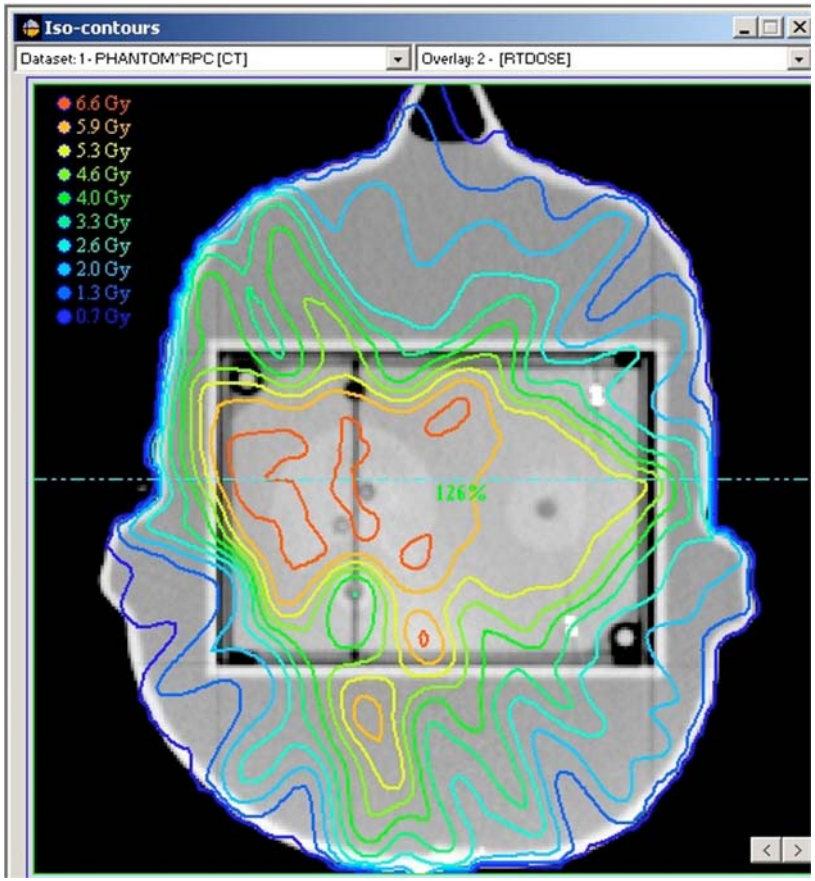
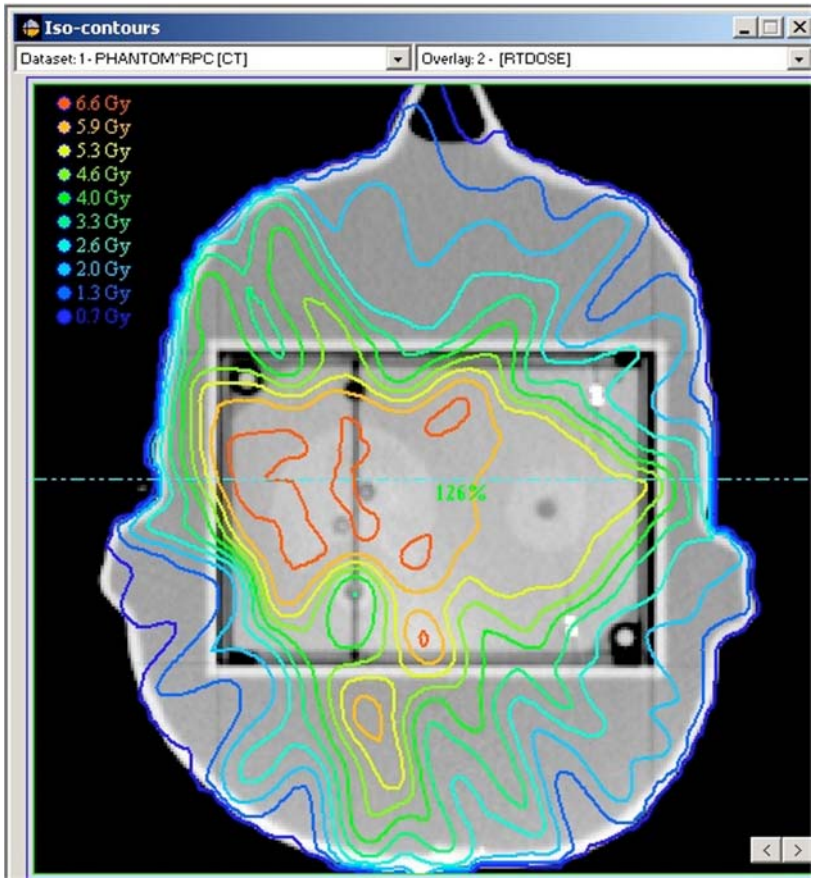
4.6 Gy
4.0 Gy
3.3 Gy
2.6 Gy
2.0 Gy
1.3 Gy
0.7 Gy
Overlay: 3 - RPC Scanned Film [RTDOSE]

# Phantom Results

**Comparison between institution's plan and delivered dose.**
**Criteria for agreement: 7% or 4 mm DTA (or 5%/5mm)**

| Site | Technique | Irradiations | Acceptable irradiations | Institutions acceptable |
|---|---|---|---|---|
| H&N | IMRT | 558 | 425 | 377 |
| Pelvis | IMRT | 109 | 89 | 74 |
| Lung | SBRT/ IMRT | 55 | 42 | 35 |
| Liver | SBRT | 13 | 6 | 6 |
| Bench-mark | IMRT | 89 (19) | 55 (18) | |


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%


Iso-contours
Dataset: 1 - PHANTOM^RPC [CT]
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6.6 Gy
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4.0 Gy
3.3 Gy
2.6 Gy
2.0 Gy
1.3 Gy
0.7 Gy
126%

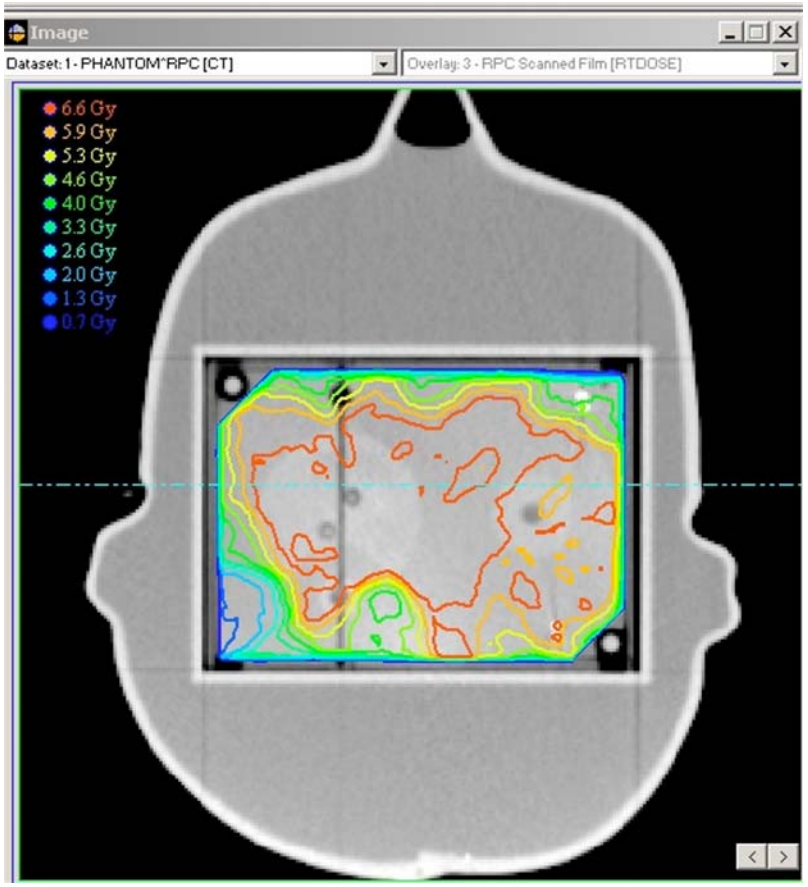
Image
Dataset: 1 - PHANTOM^RPC [CT]
Overlay: 3 - RPC Scanned Film [RTDOSE]
6.6 Gy
5.9 Gy
5.3 Gy
4.6 Gy
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3.3 Gy
2.6 Gy
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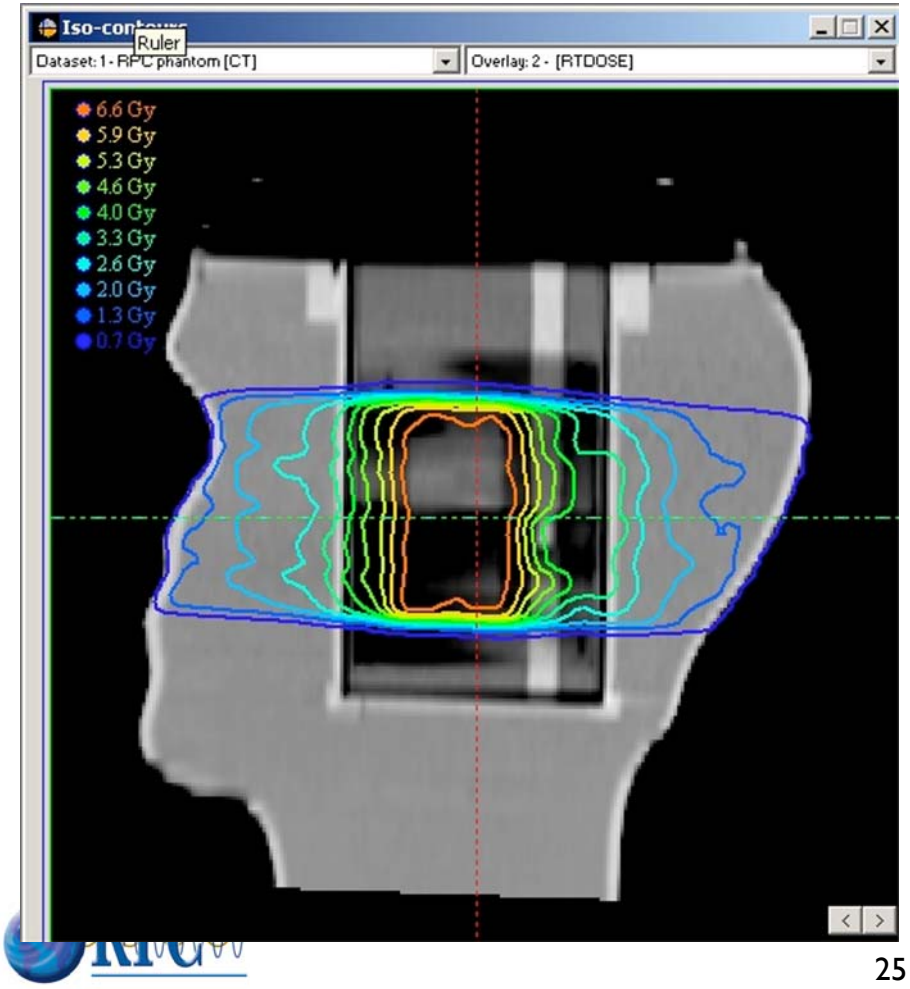
0.7 Gy


Iso-contours
Ruler
Dataset: 1 - RPC phantom [CT]
Overlay: 2 - [RTDOSE]
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4.6 Gy
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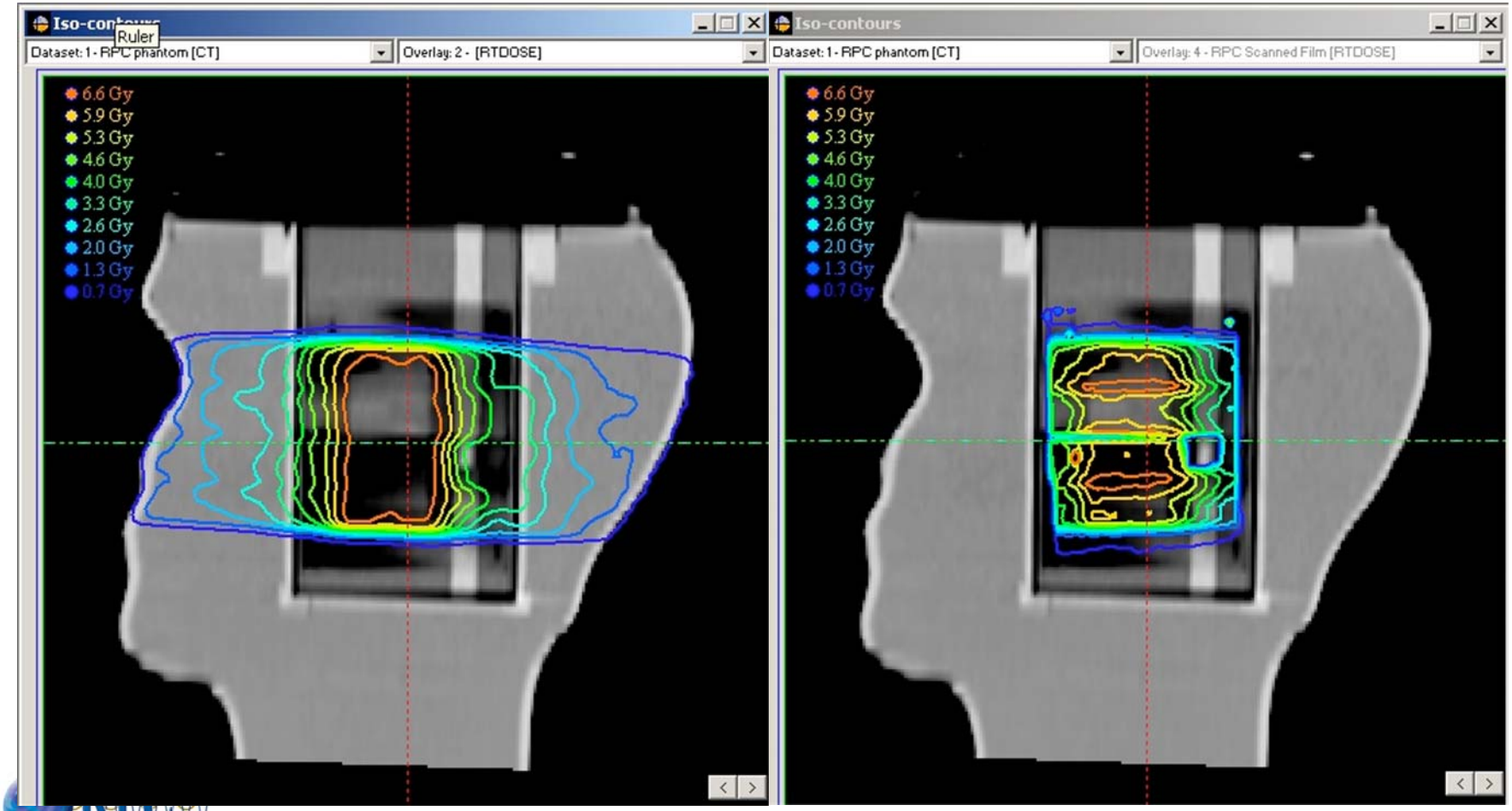
0.7 Gy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Overlay: 2 - [RTDOSE]
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4.6 Gy
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3.3 Gy
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1.3 Gy
0.7 Gy
Iso-contours
Dataset: 1 - RPC phantom [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

# HN results grouped by accelerator manufacturer

| Linear Accelerator Manufacturer | Pass Rate (%) | Attempts | Criteria Failed | | |
|---|---|---|---|---|---|
| | | | Dose | DTA | Dose and DTA |
| BrainLab | 100 | 5 | 0 | 0 | 0 |
| Elekta | 60 | 35 | 11 | 2 | 1 |
| Siemens | 71 | 56 | 10 | 2 | 4 |
| TomoTherapy | 73 | 22 | 5 | 1 | 0 |
| Varian | 80 | 301 | 39 | 8 | 14 |
| Total | | 419 | 65 | 13 | 19 |

# HN results grouped by TPS

| Treatment planning system | Pass Rate (%) | Attempts | Criteria Failed | | |
|---|---|---|---|---|---|
| | | | Dose | DTA | Dose and DTA |
| Corvus | 75 | 32 | 7 | 0 | 1 |
| Eclipse | 85 | 114 | 10 | 4 | 3 |
| Pinnacle | 73 | 168 | 33 | 4 | 8 |
| TomoTherapy | 73 | 22 | 5 | 1 | 0 |
| XiO | 73 | 59 | 7 | 4 | 5 |
| Other | 79 | 24 | 3 | 0 | 2 |
| Total | | 419 | 65 | 13 | 19 |

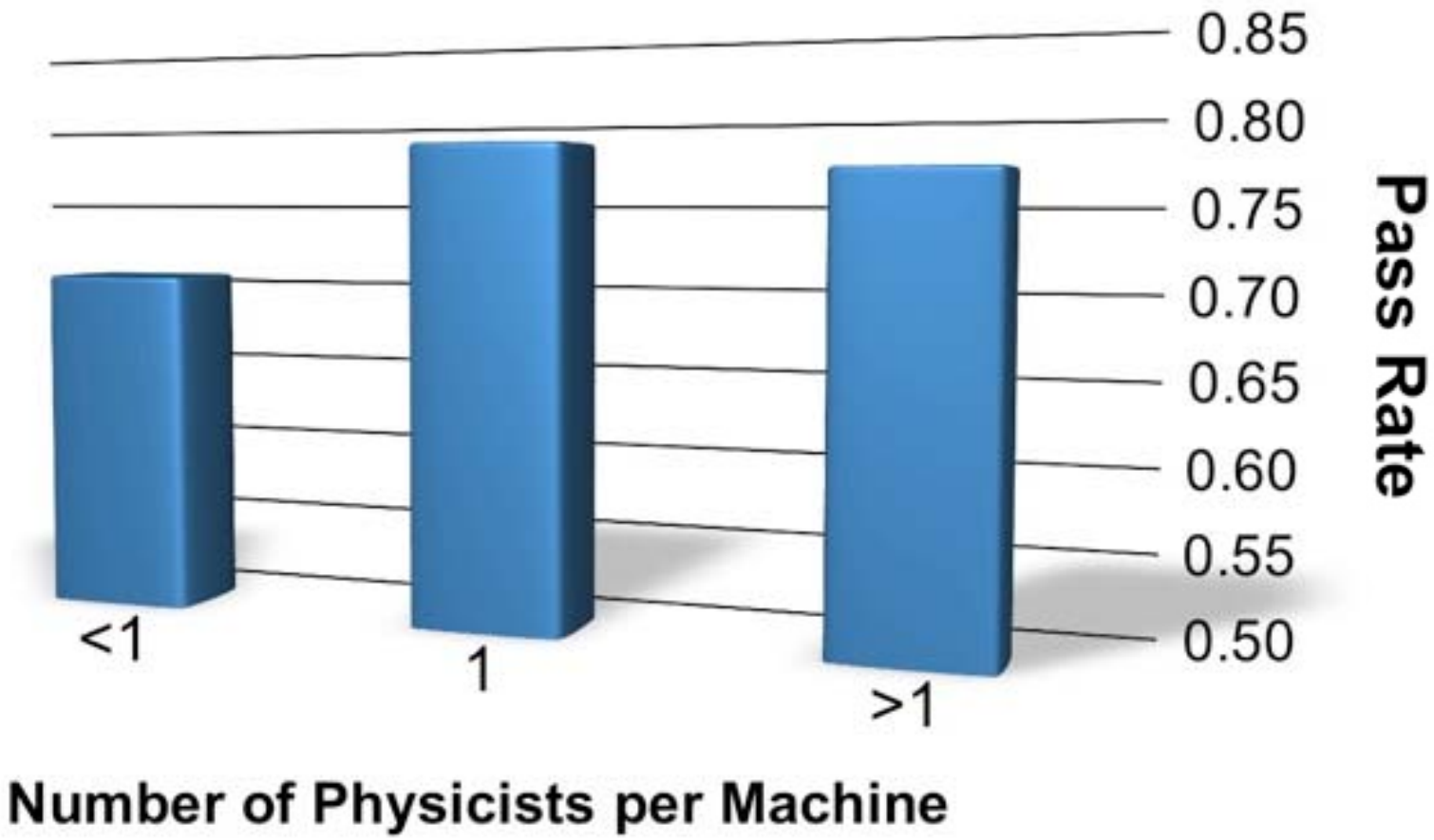
# HN results grouped by machine/TPS

| Manufacturer/TPS Combination | Pass Rate (%) | Attempts | Criteria Failed | | |
|---|---|---|---|---|---|
| | | | Dose | DTA | Dose and DTA |
| Elekta/Corvus | 0 | 1 | 1 | 0 | 0 |
| Elekta/Pinnacle | 67 | 21 | 6 | 1 | 0 |
| Elekta/XiO | 56 | 9 | 2 | 1 | 1 |
| Elekta/Other | 50 | 4 | 2 | 0 | 0 |
| Siemens/Corvus | 88 | 8 | 1 | 0 | 0 |
| Siemens/Pinnacle | 70 | 27 | 5 | 0 | 3 |
| Siemens/XiO | 77 | 13 | 1 | 1 | 1 |
| Siemens/Other | 67 | 6 | 1 | 1 | 0 |
| Varian/Corvus | 73 | 22 | 5 | 0 | 1 |
| Varian/Eclipse | 86 | 110 | 9 | 3 | 3 |
| Varian/Pinnacle | 75 | 121 | 22 | 3 | 5 |
| Varian/XiO | 76 | 37 | 4 | 2 | 3 |
| Varian/Other | 77 | 13 | 1 | 0 | 2 |
| Other | 77 | 26 | 5 | 1 | 0 |
| Total | | 418 | 65 | 13 | 19 |

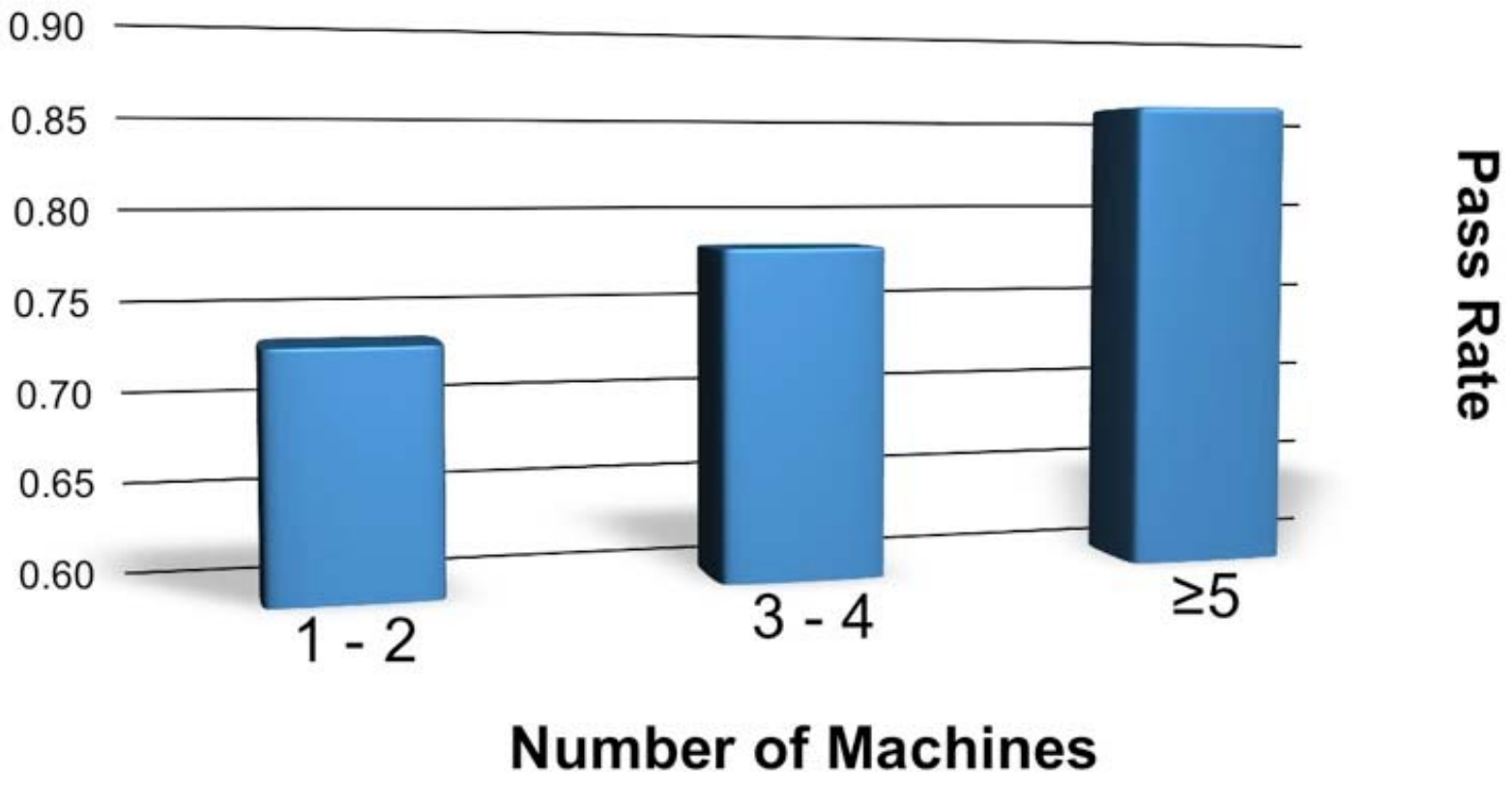
# HN results grouped by technique

| IMRT technique | Pass Rate (%) | Attempts | Criteria Failed | | |
|---|---|---|---|---|---|
| | | | Dose | DTA | Dose and DTA |
| Dynamic MLC | 87 | 110 | 9 | 2 | 3 |
| IMAT | 50 | 12 | 5 | 0 | 1 |
| Segmental | 74 | 279 | 47 | 10 | 15 |
| TomoTherapy | 76 | 17 | 3 | 1 | 0 |
| Experimental | 0 | 1 | 1 | 0 | 0 |
| Total | | 419 | 65 | 13 | 19 |

# Pass Rate vs. Physicists



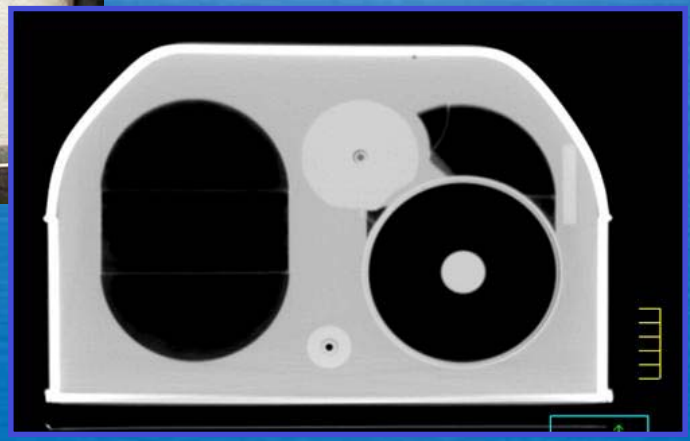
# Pass Rate vs. Machines



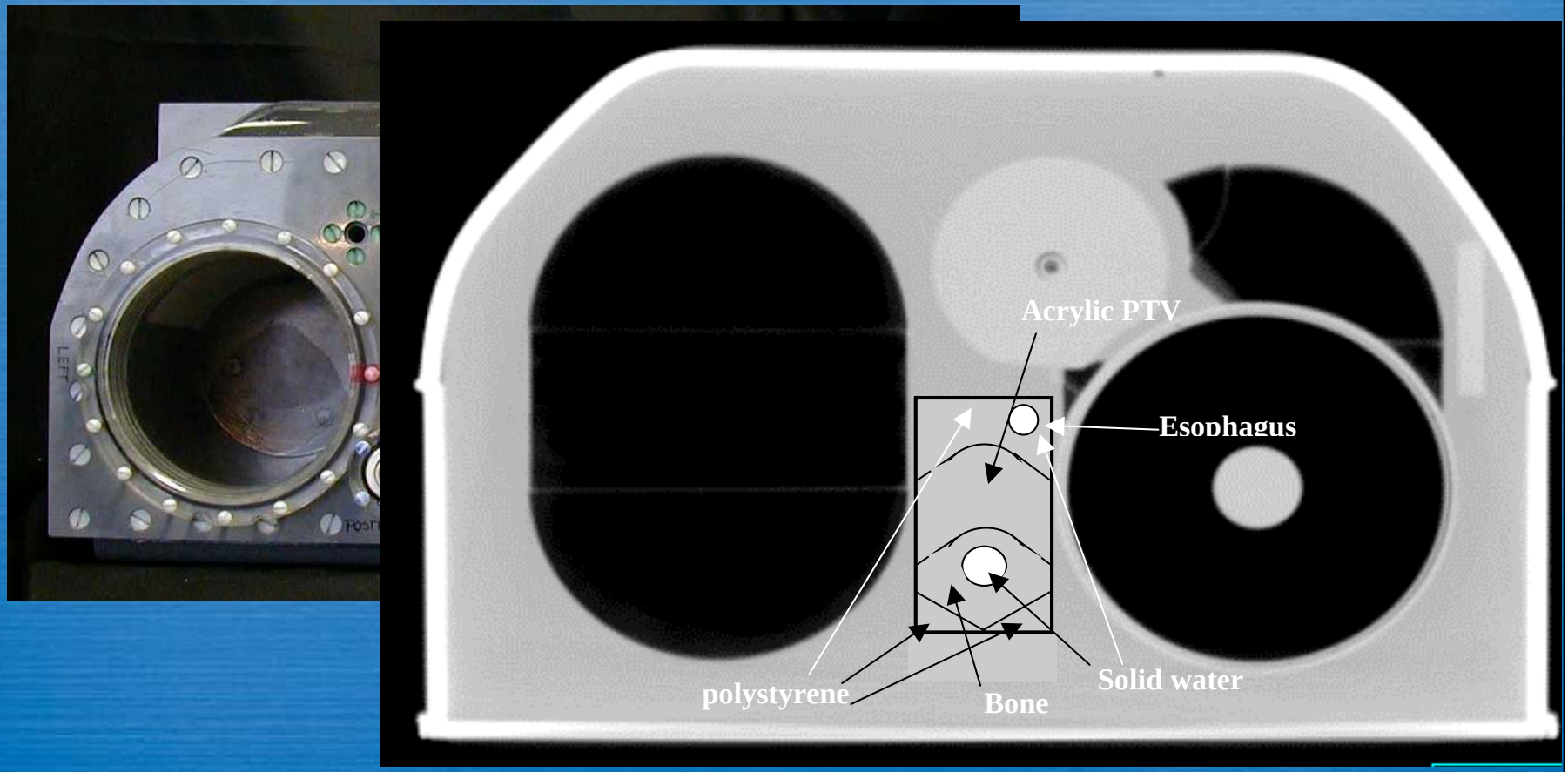
# Explanations for Failures

| Explanation | Minimum # of occurrences |
|---|---|
| incorrect output factors in TPS | 1 |
| incorrect PDD in TPS | 1 |
| IMRT Technique | 3 |
| Software error | 1 |
| inadequacies in beam modeling at leaf ends (Cadman, et al; PMB 2002) | 14 |
| QA procedures | 3 |
| errors in couch indexing with Peacock system | 3 |
| equipment performance | 2 |
| setup errors | 7 |

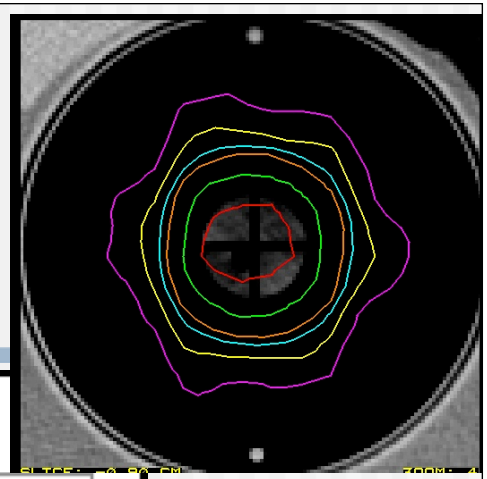
# Thorax Phantom

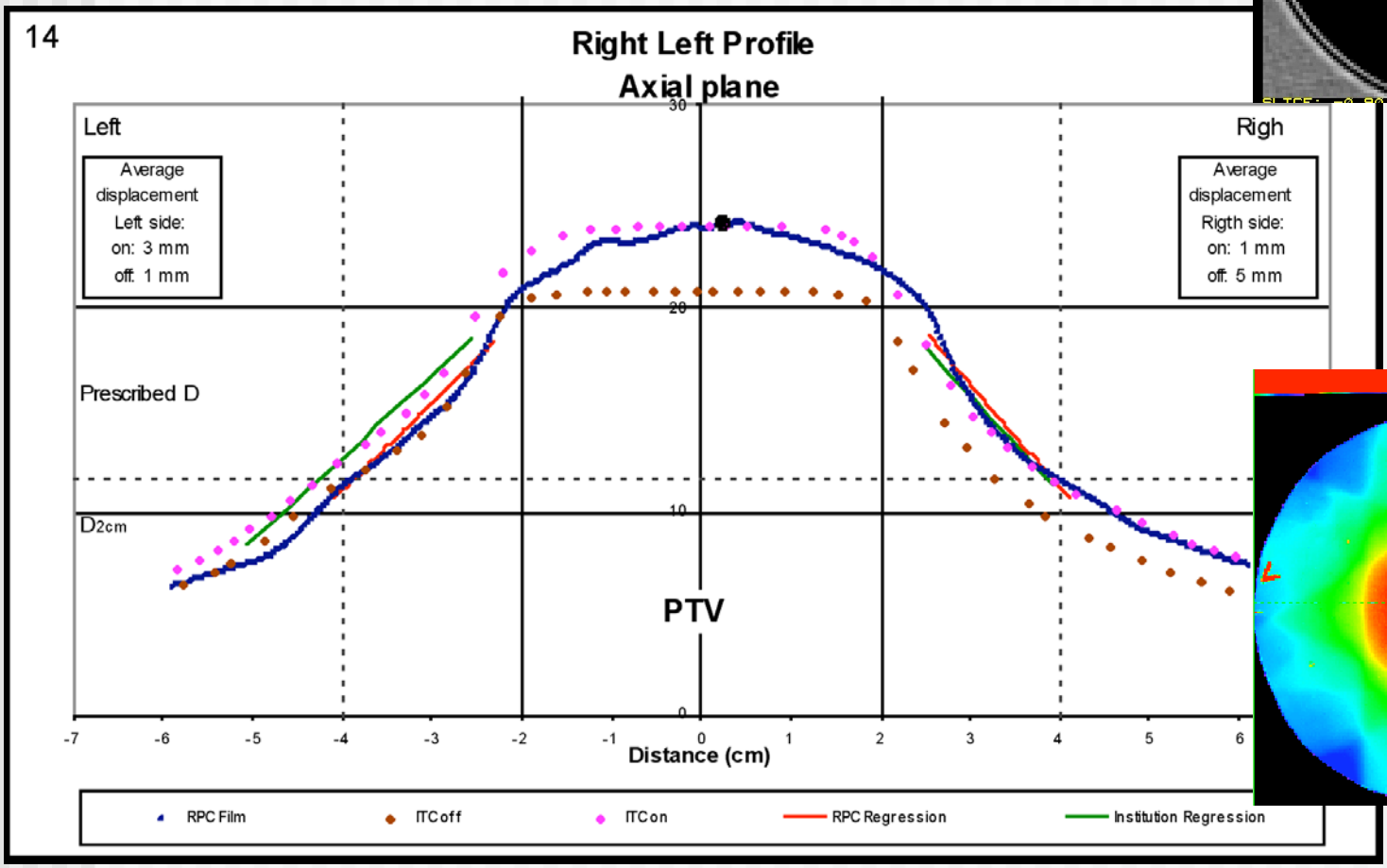



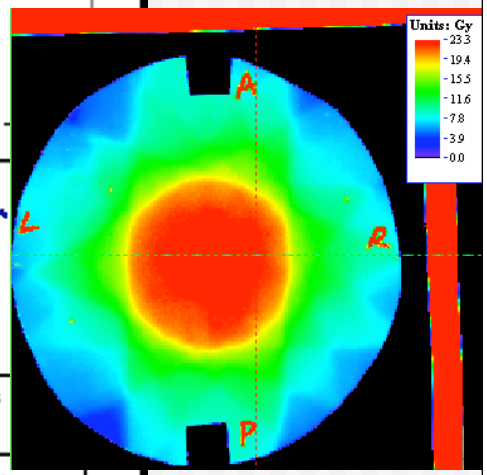
# Spine Phantom



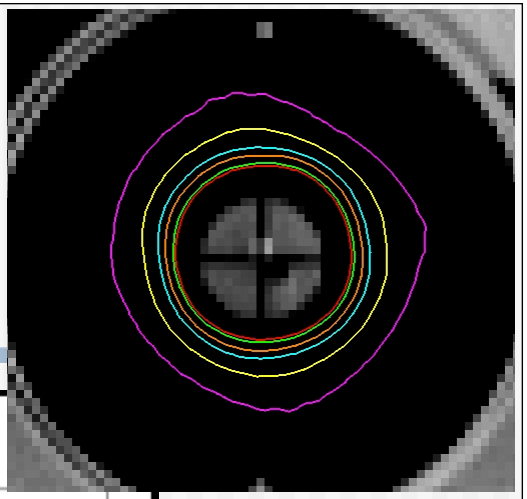
# Convolution R-L Profile

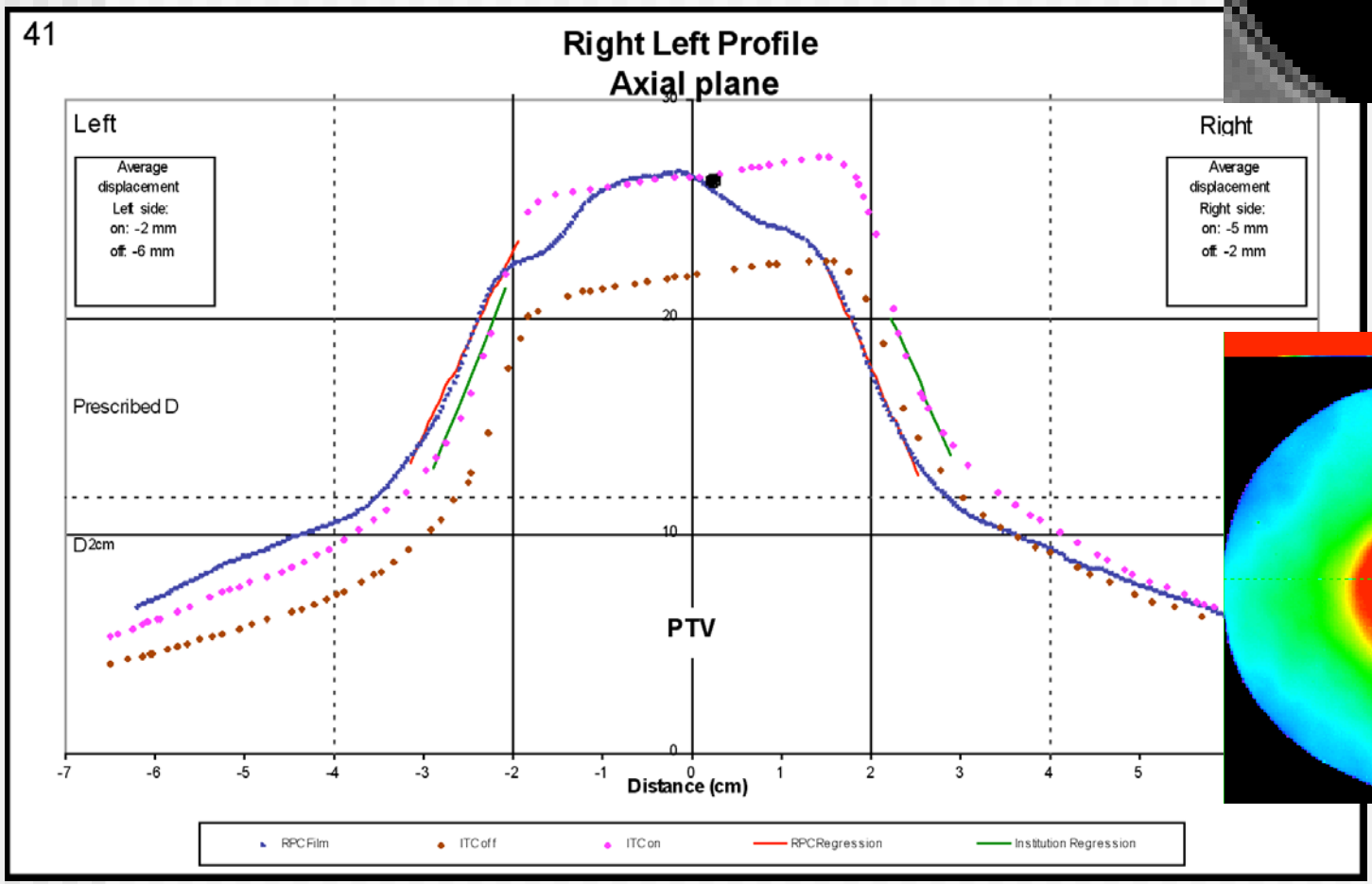


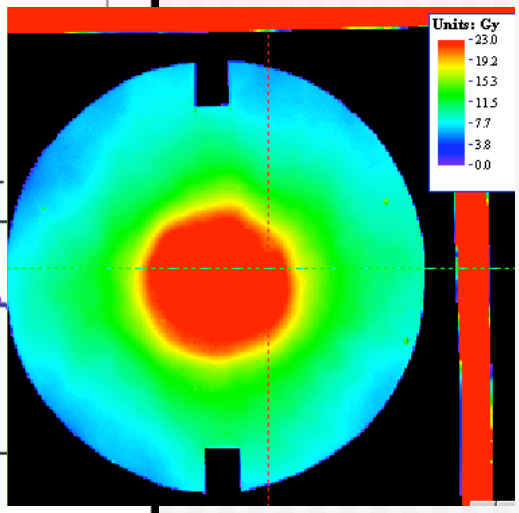


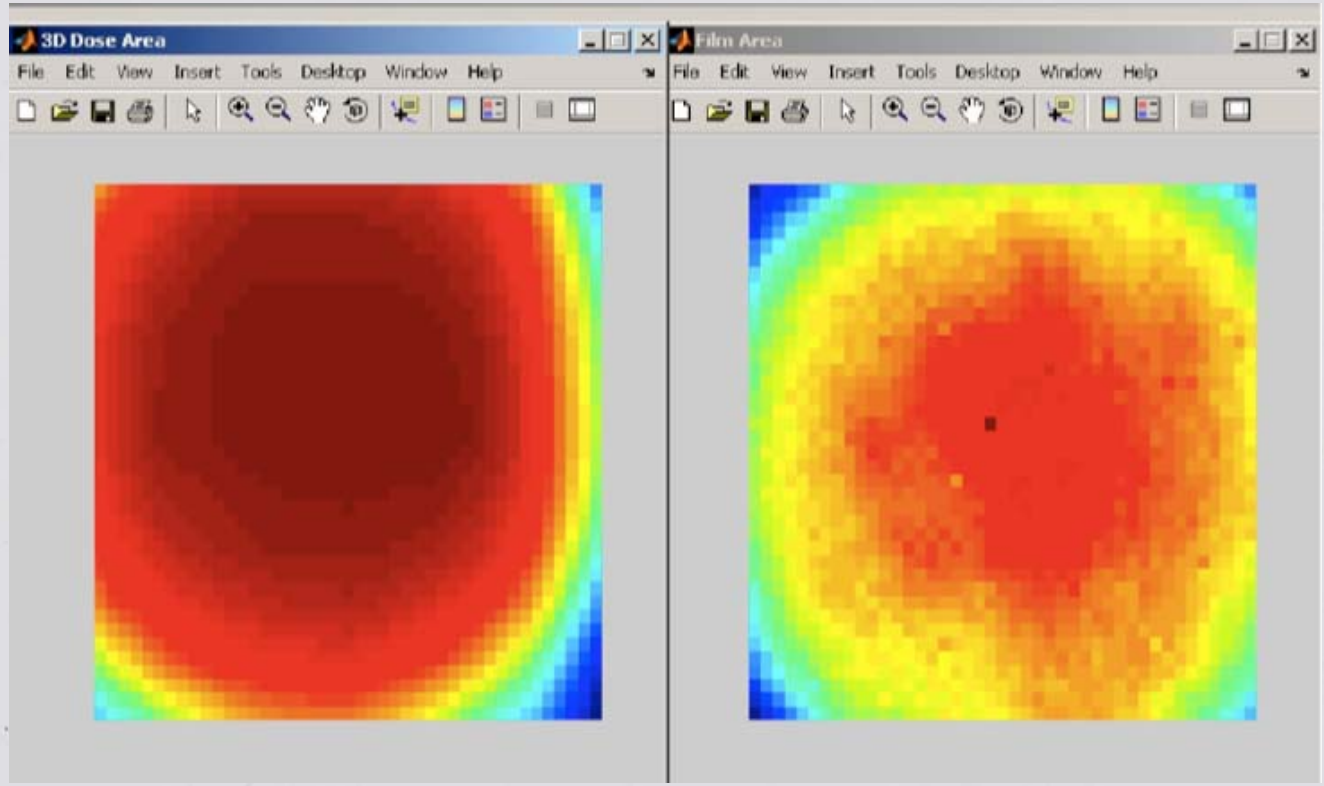
# Pencil-Beam profile



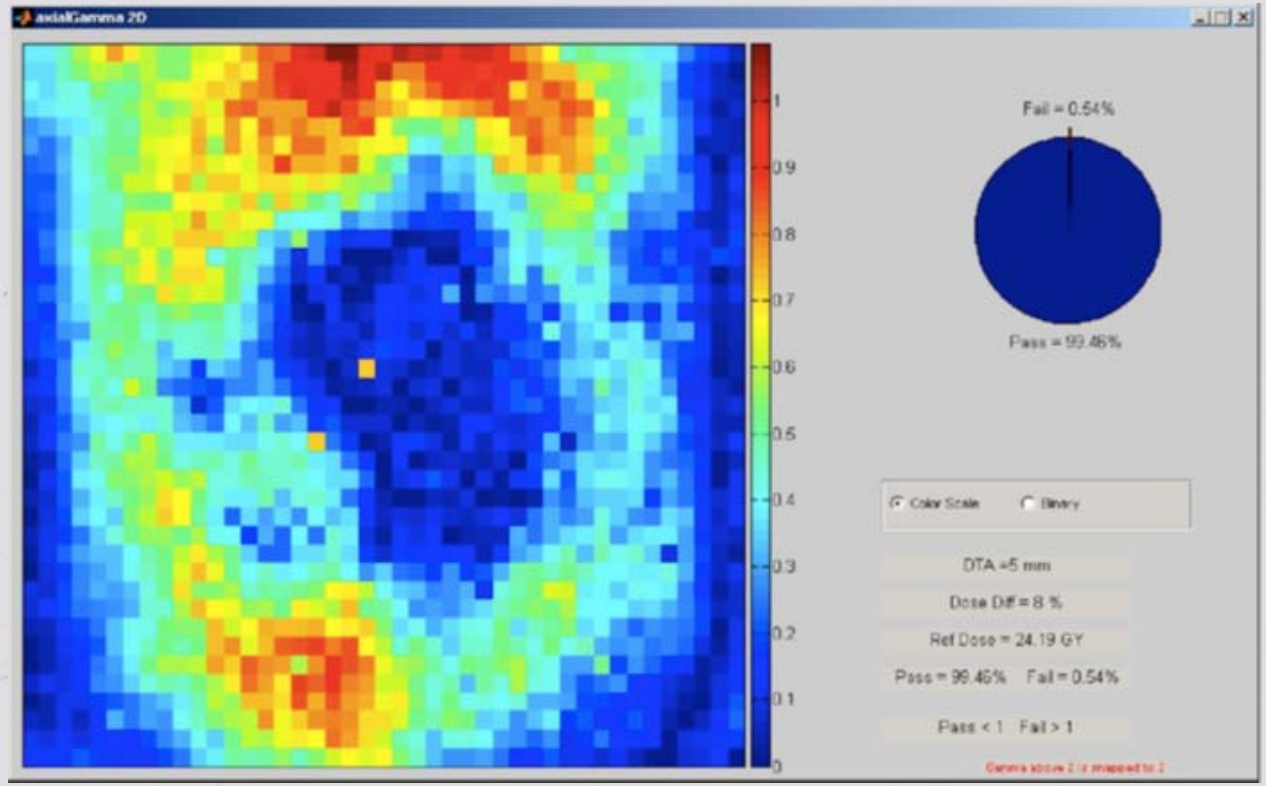


# 2D Gamma Index Evaluation "Good" Irradiation



# 2D Gamma Index Evaluation "Good" Irradiation



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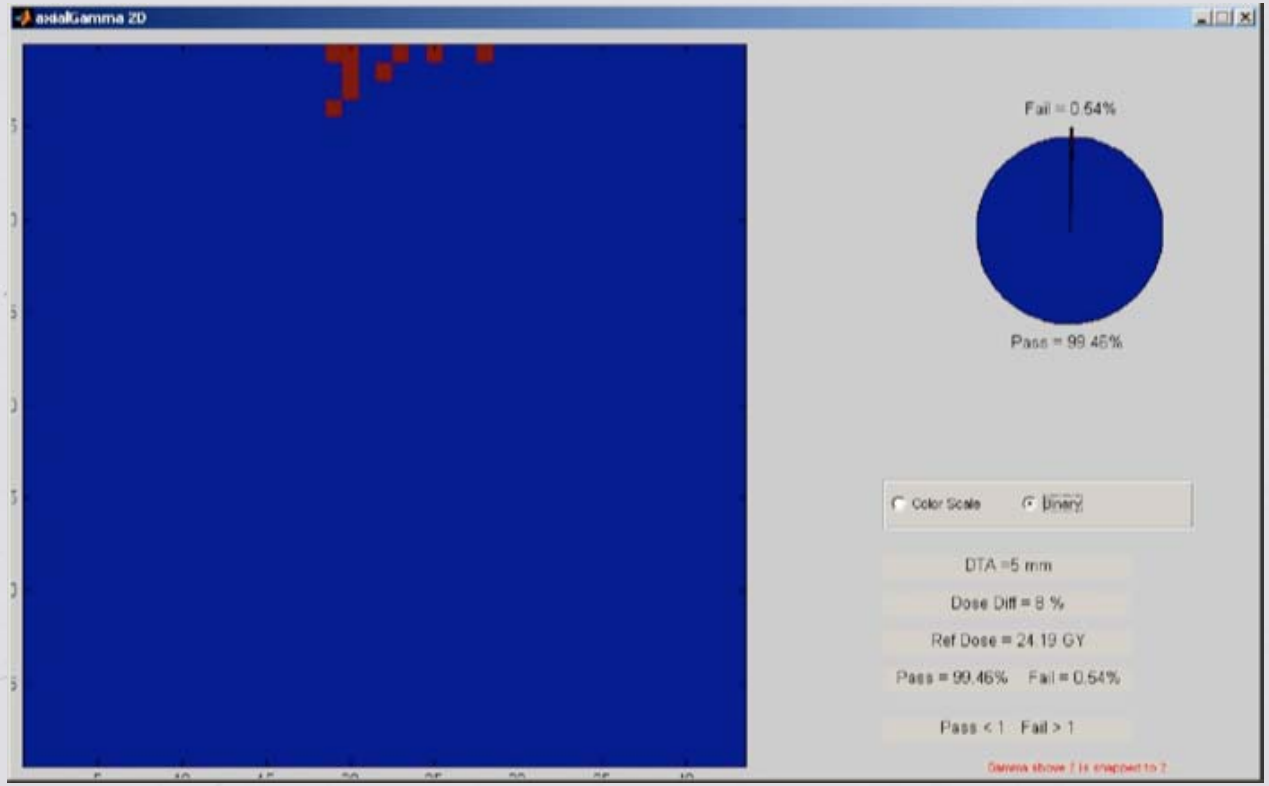

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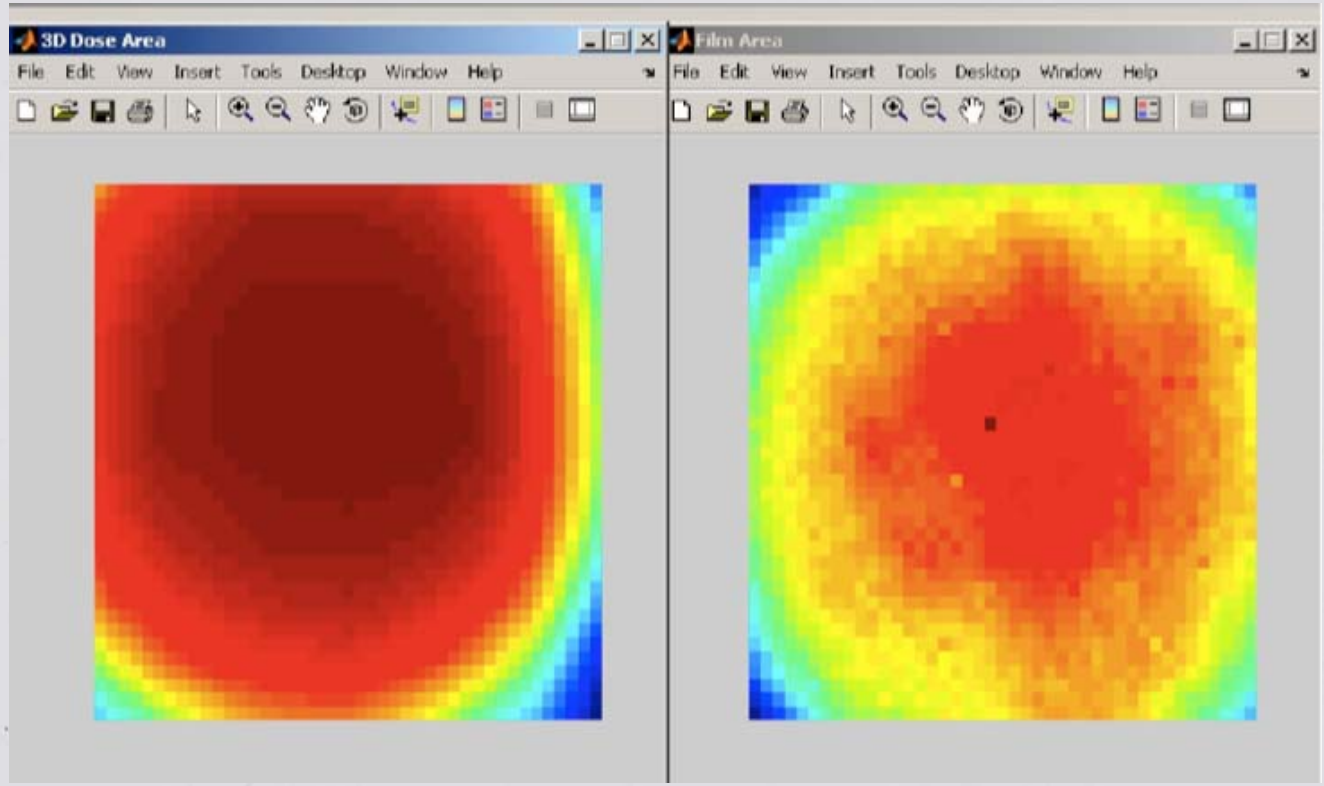

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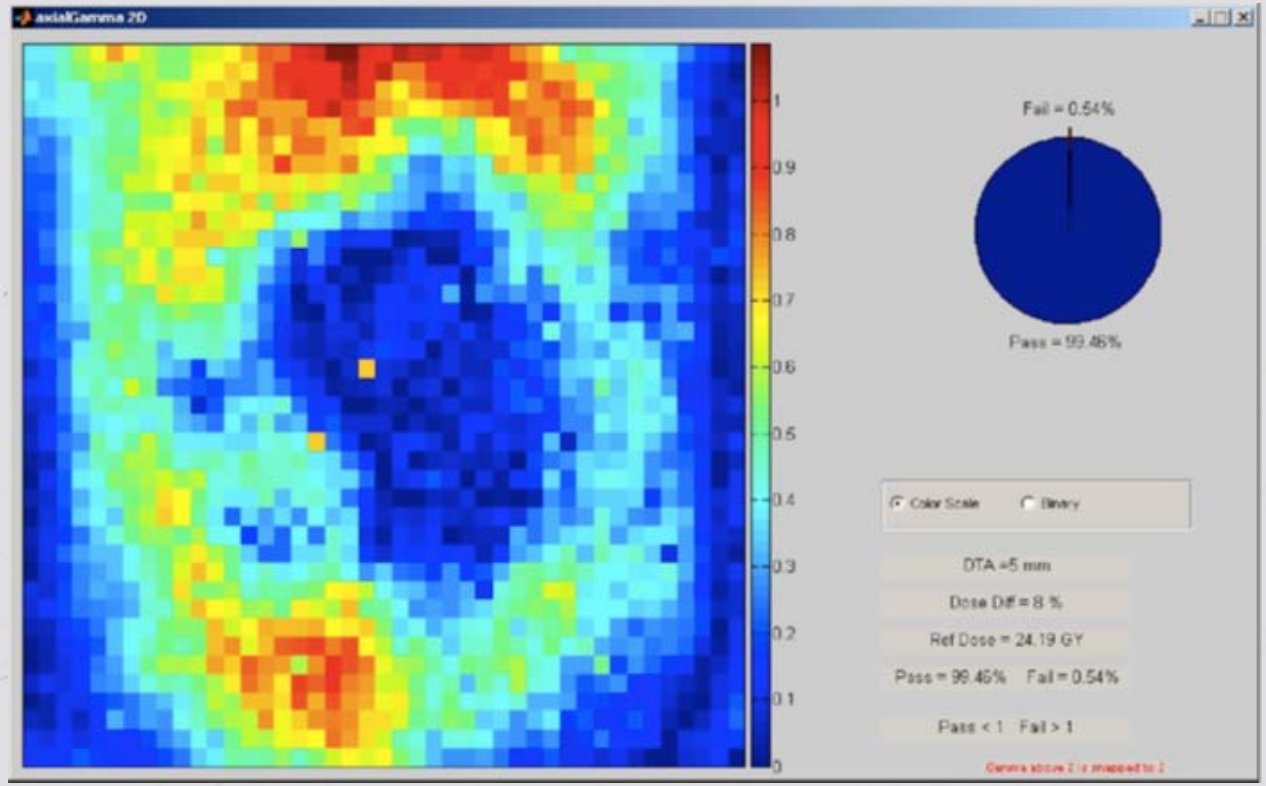

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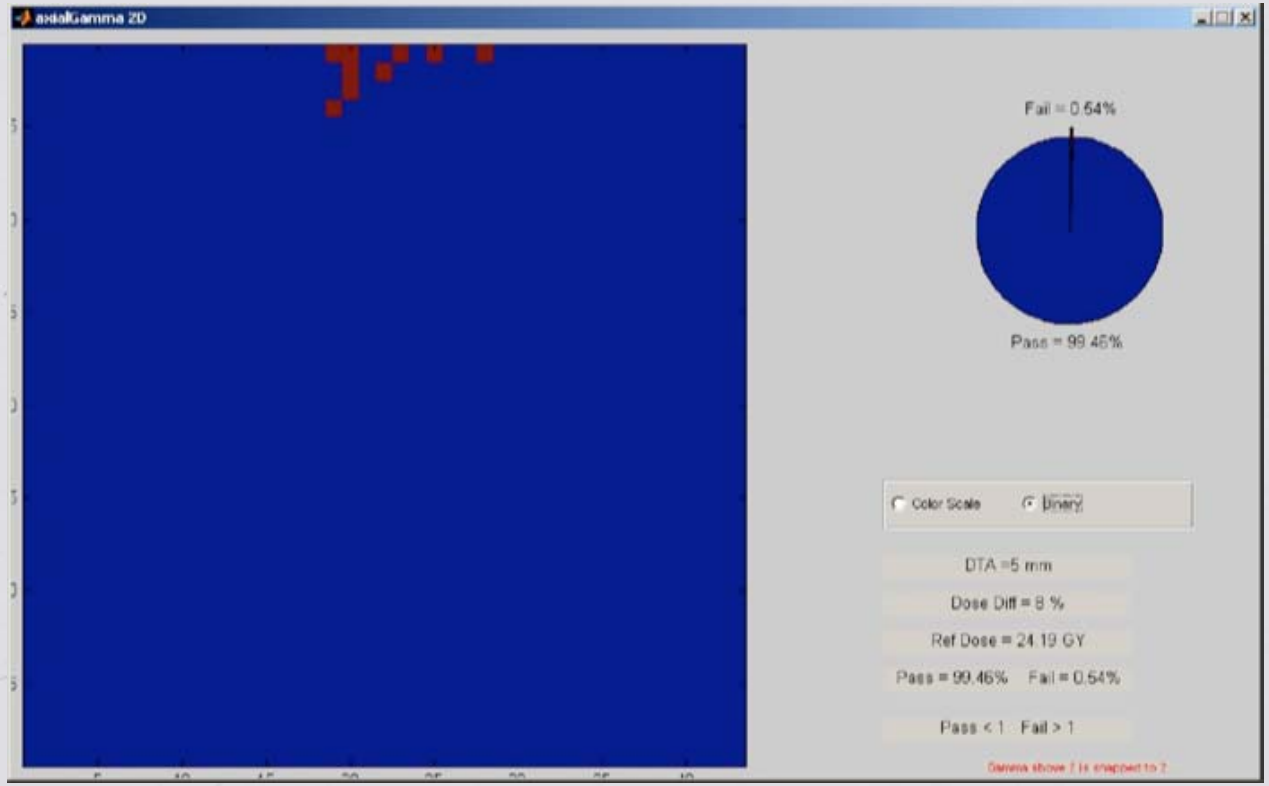

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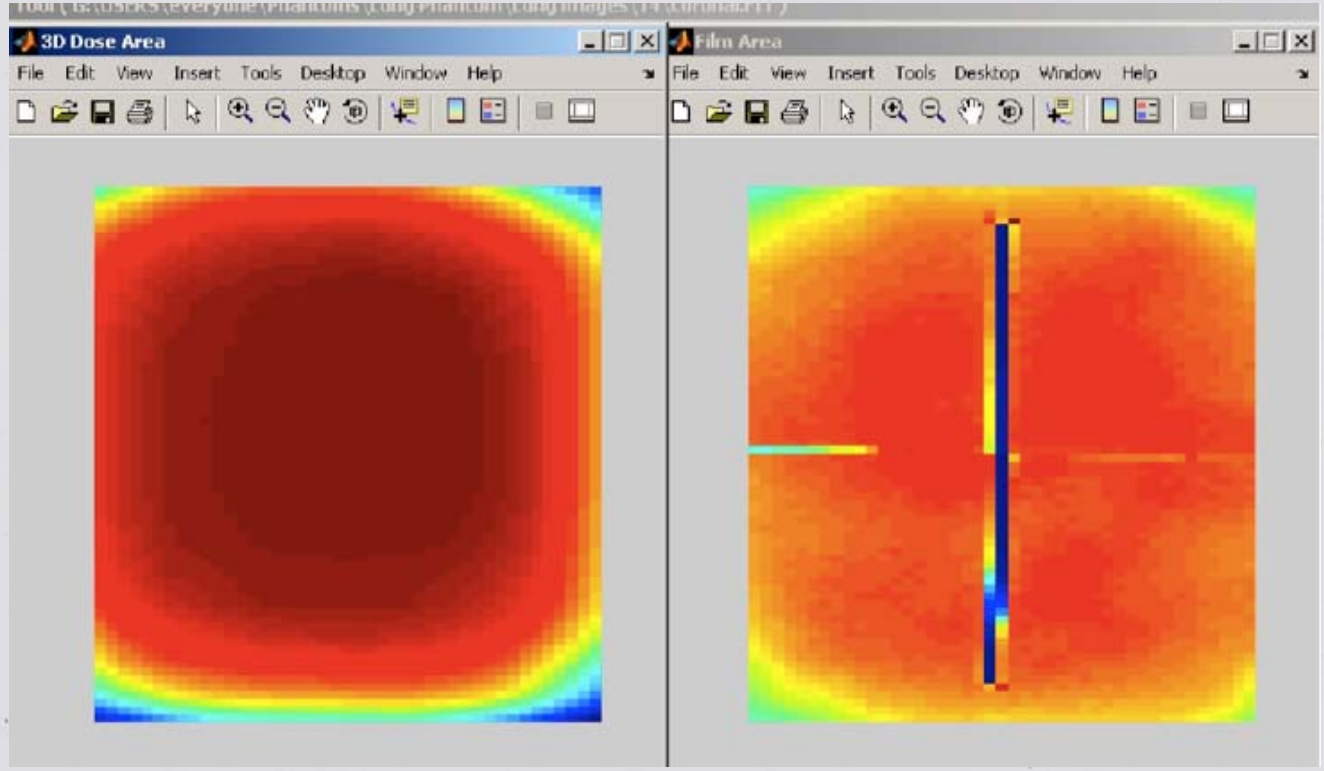
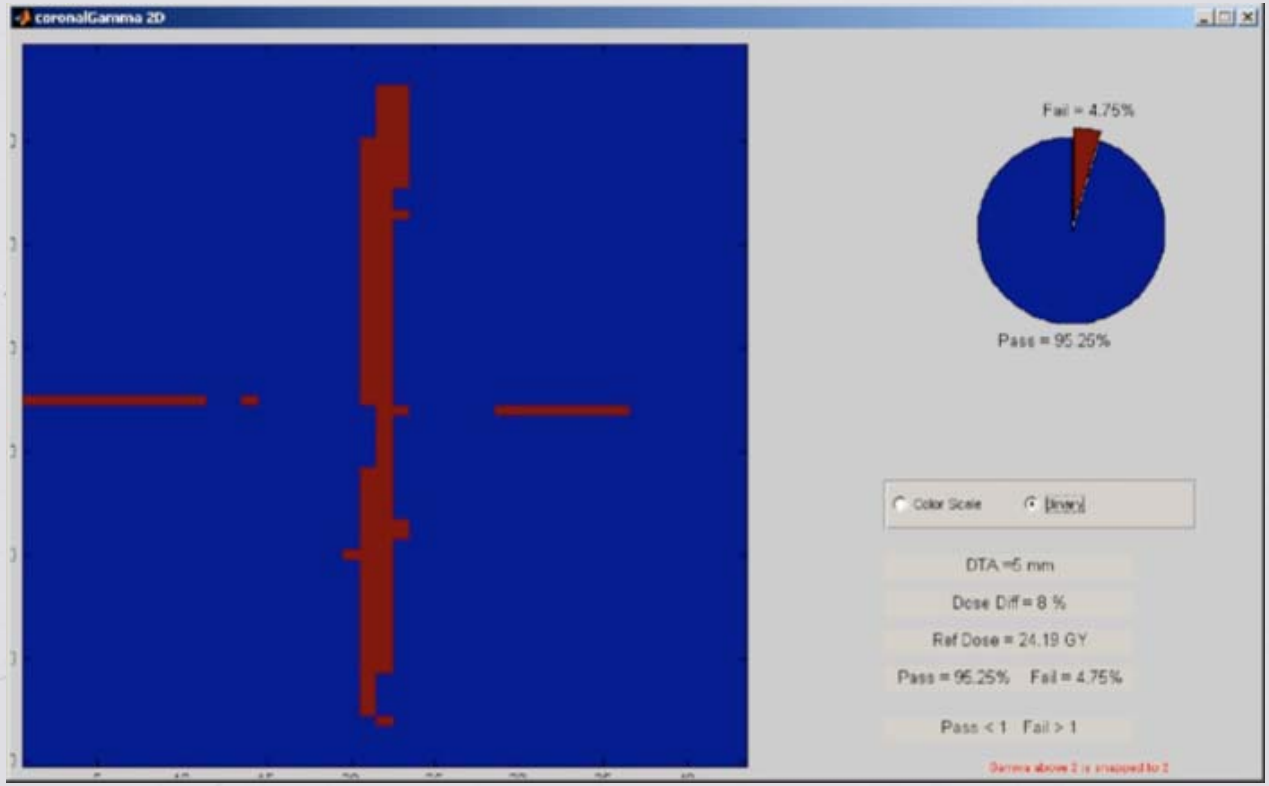
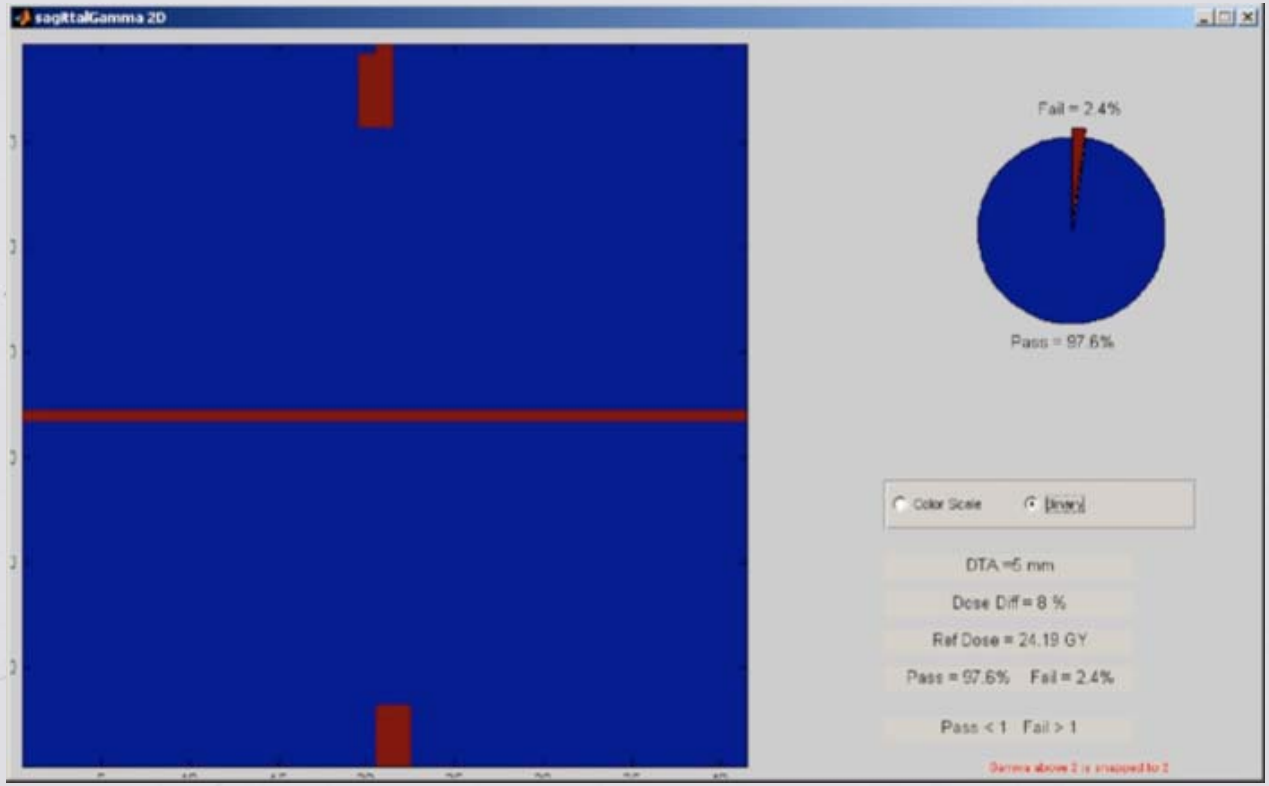


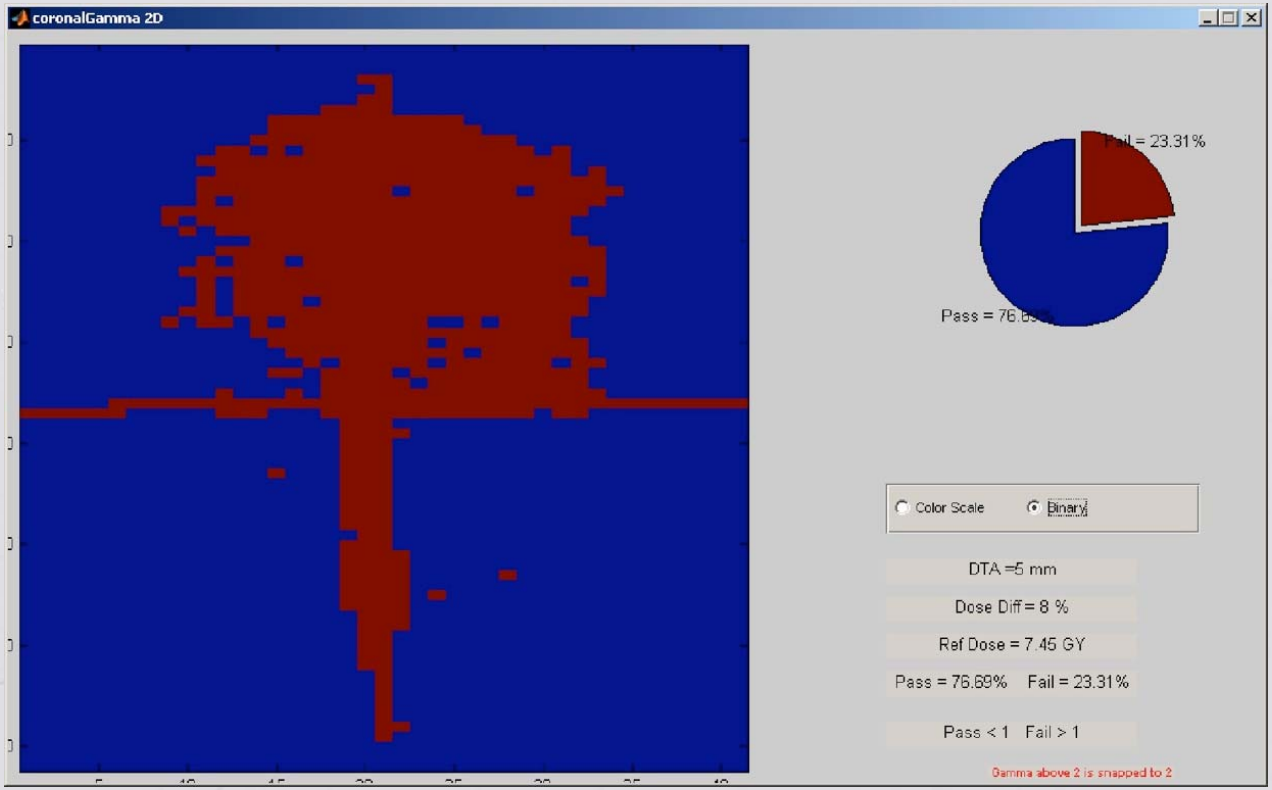
# 2D Gamma Index Evaluation "Good" Irradiation



# 2D Gamma Index Evaluation "Good" Irradiation



# 2D Gamma Index Evaluation Failing Irradiation



# Evaluation

- Criteria: 5% / 5 mm over PTV
- Percent of pixels passing: 90% - Axial
  80% - Coronal
  80% - Sagittal

# Results

- Systems with "good" algorithms, passing original criteria:
  - 25/29 irradiations passed 2D Gamma Index
- Systems with "poor" algorithms, passing original criteria:
  - 3/18 irradiations passed 2D Gamma Index

# Results of Credentialing
## (closed studies)

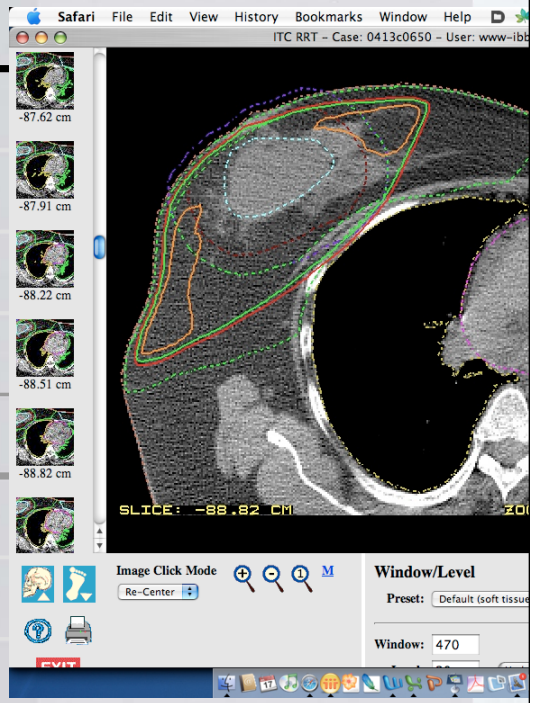
| Study | Major Deviations | Minor Deviations | Number of Patients |
|---|---|---|---|
| GOG 165<br>HDR Cervix<br>Credentialed inst | 0 | 15 | 70 |
| RTOG 95-17<br>HDR & LDR Breast<br>(all) | 0 | 4 | 100 |
| RTOG 0019<br>LDR Prostate<br>(values for dose only) | 0 | 6 | 117 reviewed<br>(total 129 eligible)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

# Results of Credentialing
## (closed studies)

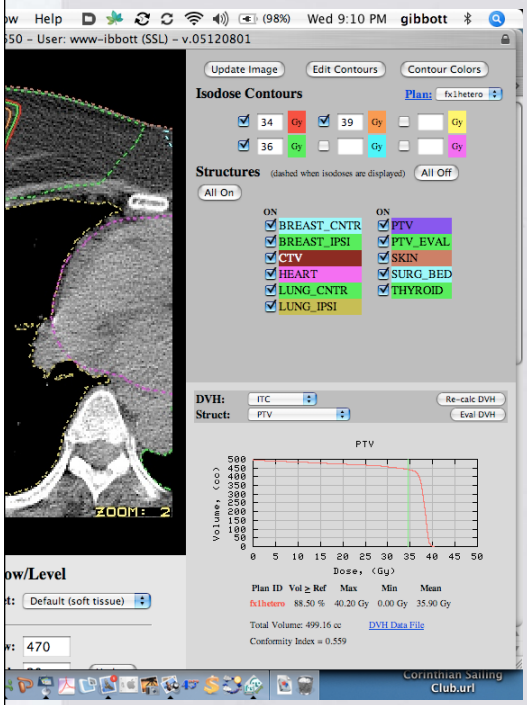
| Study | Major Deviations | Minor Deviations | Number of Patients |
|---|---|---|---|
| GOG 165<br>HDR Cervix<br>Credentialed inst | 0 | 15 | 70 |
| Non-credentialed | 57 | 87 | 275 |
| RTOG 95-17<br>HDR & LDR Breast<br>(all) | 0 | 4 | 100 |
| RTOG 0019<br>LDR Prostate<br>(values for dose only) | 0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

# 0413 / B-39 Reviews

| Review Type | Number |
|---|---|
| PBI | 1566 |
| WBI | 1572 |
| Patients with completed reviews | 1085 |
| Rapid Reviews | 337 |
| Timely Reviews | 565 |
| Open Reviews | 145 |
| Random Reviews | 38 |
| DVA Scores | |
| Per Protocol | 924 |
| Minor corrections | 157 |
| Major corrections | 3 |
| Repeat Timely Reviews | 1 |



# 0413 / B-39 Reviews

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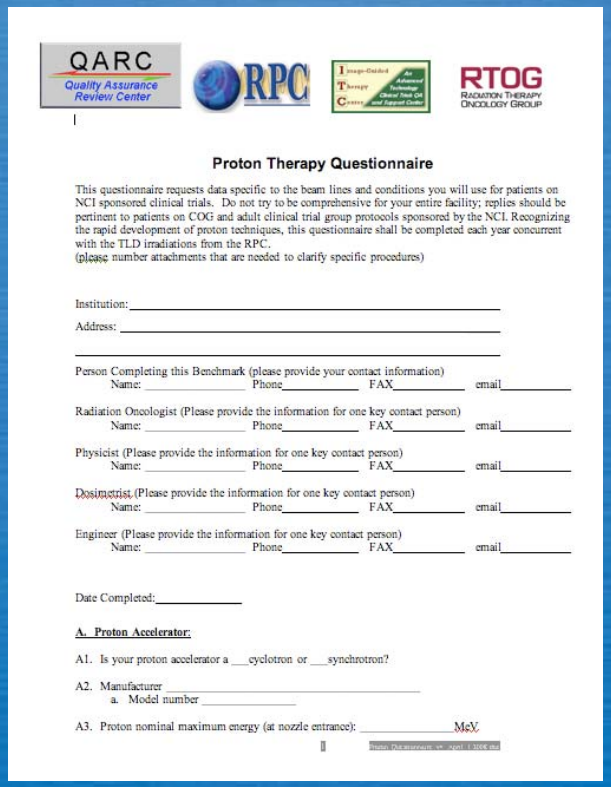
# RPC Monitoring of Proton Facilities

- Questionnaire developed by QARC
- TLD audits of basic calibration
- Dosimetry review visits
- Dose delivery evaluation with anthropomorphic phantoms

# Questionnaire

- Description of accelerator
  - Beam spreading techniques
  - Maximum range, field size, shaping
  - Uniformity of dose in SOBP
- Calibration procedure
- Treatment planning
  - CT -> stopping power
- Treatment delivery
  - Positioning, immobilization



QARC Quality Assurance Review Center · RPC · Image-Guided Therapy Center · RTOG Radiation Therapy Oncology Group

**Proton Therapy Questionnaire**

This questionnaire requests data specific to the beam lines and conditions you will use for patients on NCI sponsored clinical trials. Do not try to be comprehensive for your entire facility; replies should be pertinent to patients on COG and adult clinical trial group protocols sponsored by the NCI. Recognizing the rapid development of proton techniques, this questionnaire shall be completed each year concurrent with the TLD irradiations from the RPC.
(please number attachments that are needed to clarify specific procedures)

Institution: _____

Address: _____

_____

Person Completing this Benchmark (please provide your contact information)
Name: _____ Phone_____ FAX_____ email_____

Radiation Oncologist (Please provide the information for one key contact person)
Name: _____ Phone_____ FAX_____ email_____

Physicist (Please provide the information for one key contact person)
Name: _____ Phone_____ FAX_____ email_____

Dosimetrist (Please provide the information for one key contact person)
Name: _____ Phone_____ FAX_____ email_____

Engineer (Please provide the information for one key contact person)
Name: _____ Phone_____ FAX_____ email_____

Date Completed:_____

**A. Proton Accelerator:**

A1. Is your proton accelerator a ___cyclotron or ___synchrotron?

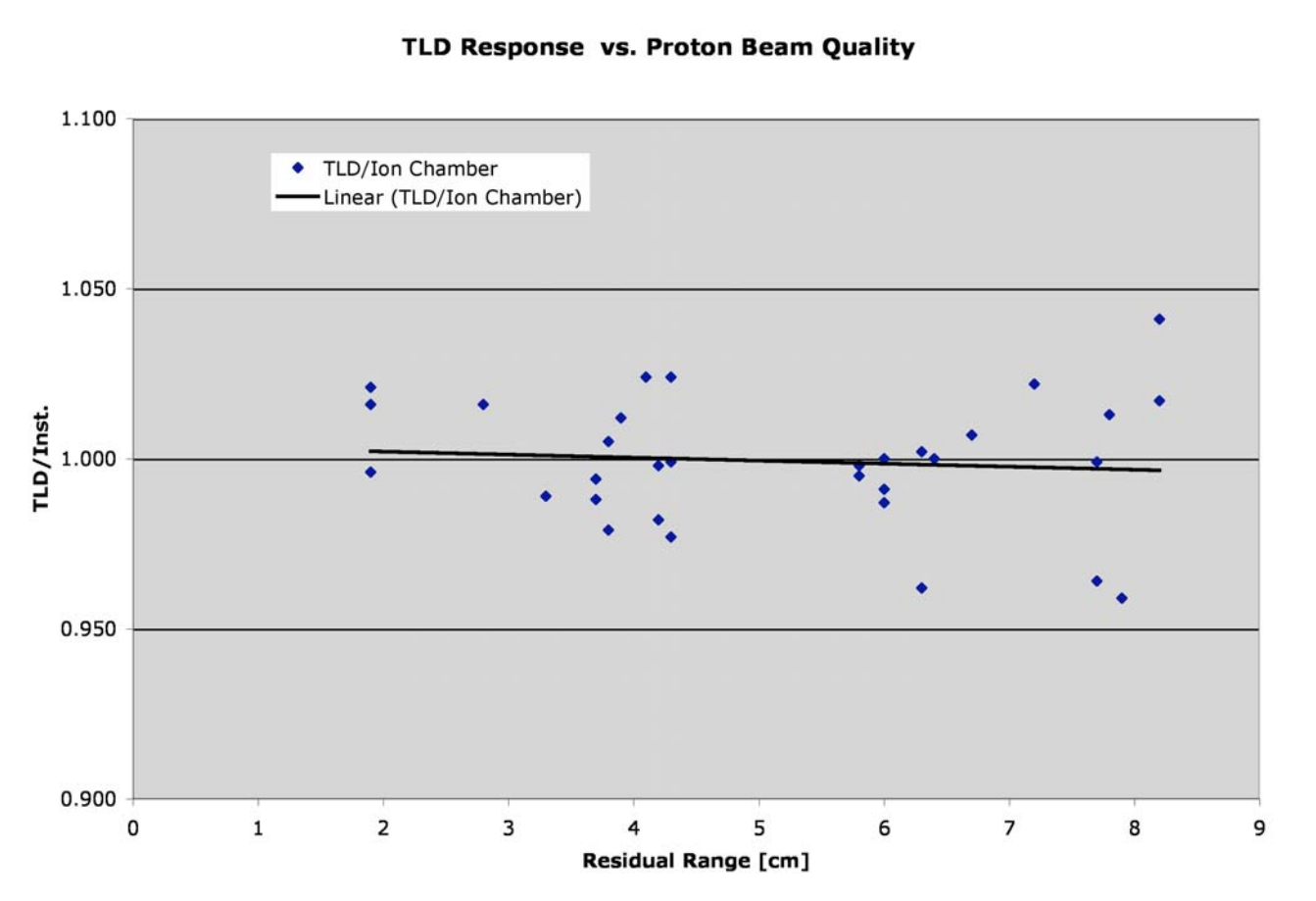
A2. Manufacturer _____
a. Model number _____

A3. Proton nominal maximum energy (at nozzle entrance): _____MeV

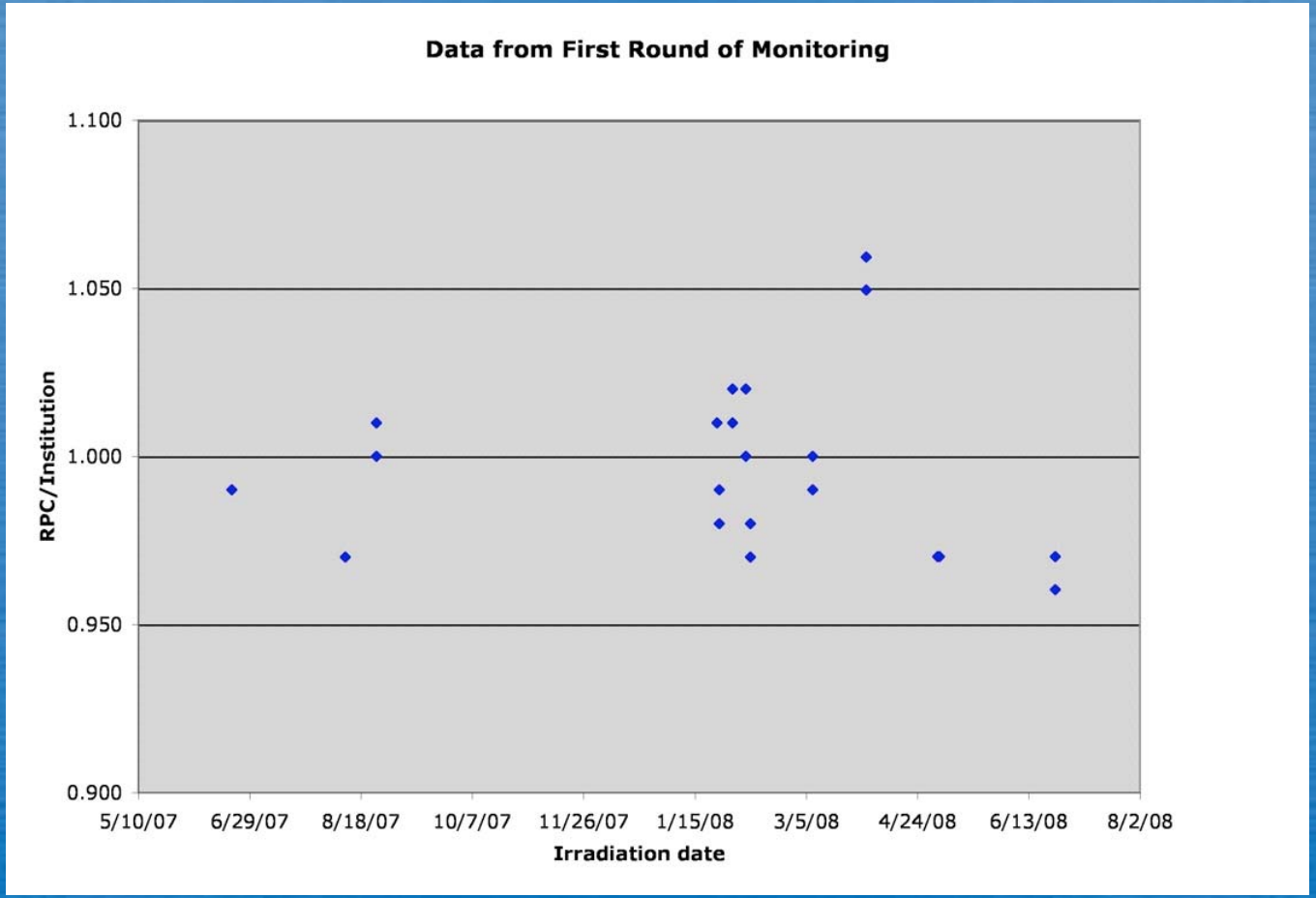
# TLD Audits

- RPC evaluated TLD system under many conditions of energy, modulation, residual range, field size

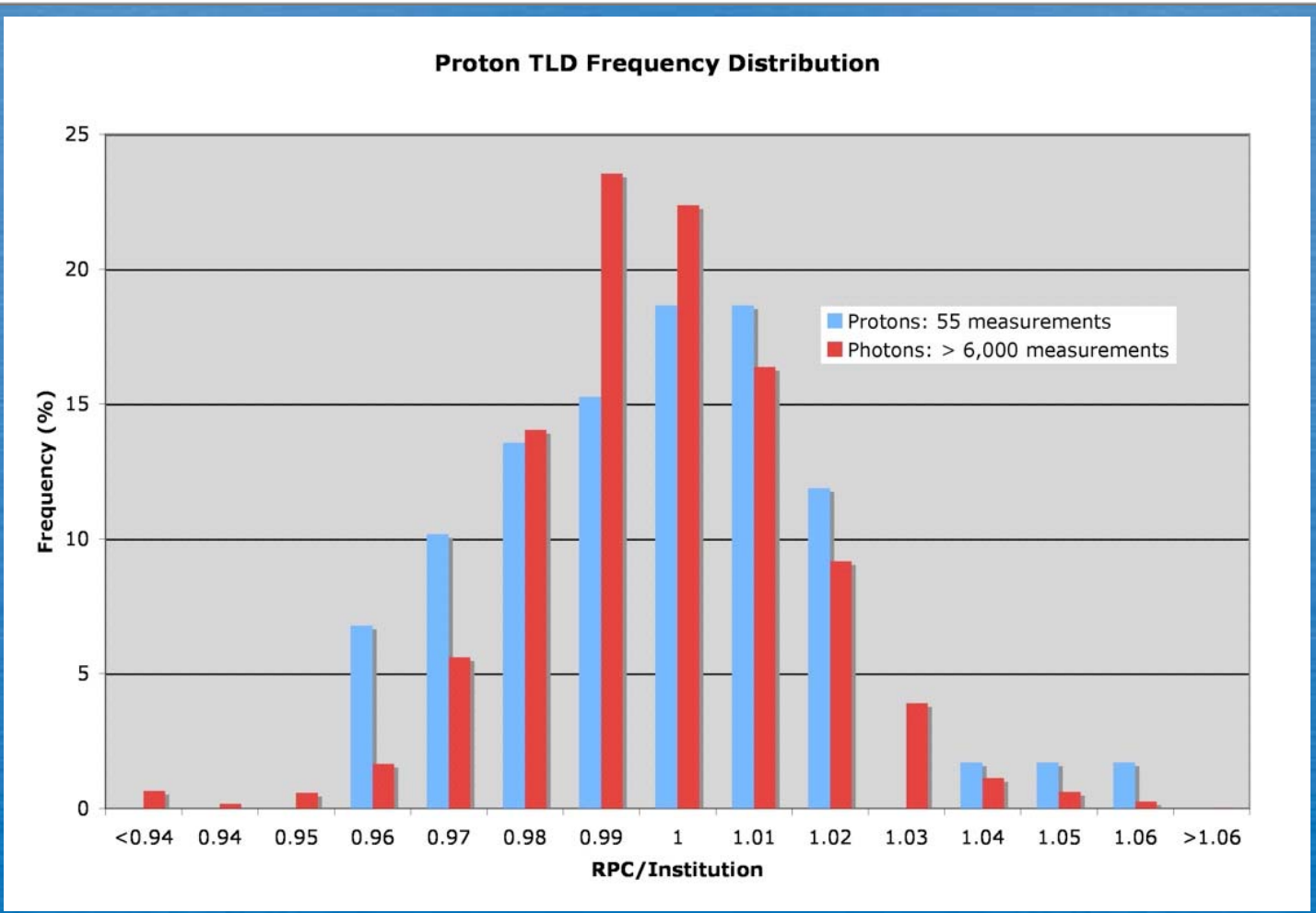
# TLD Response vs Residual Range



# First Round of Monitoring

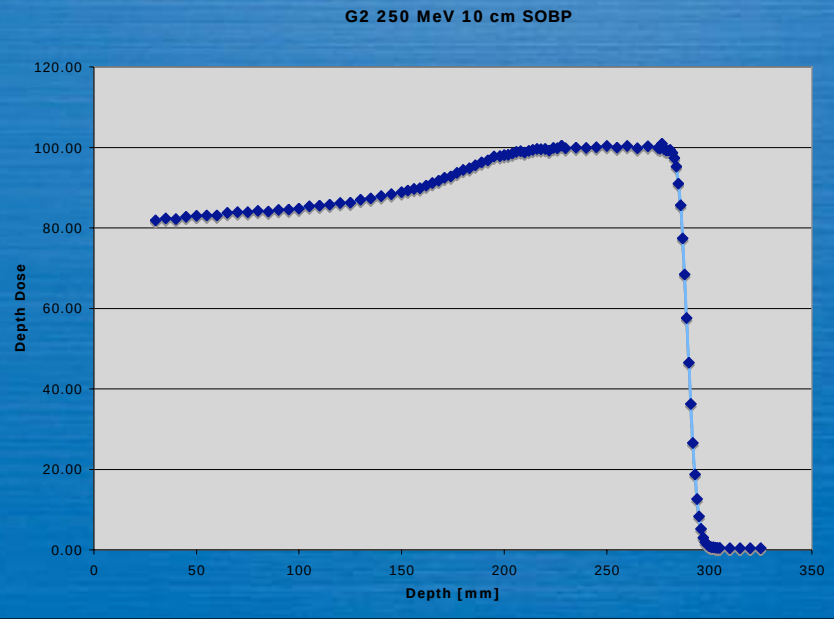


# Distribution



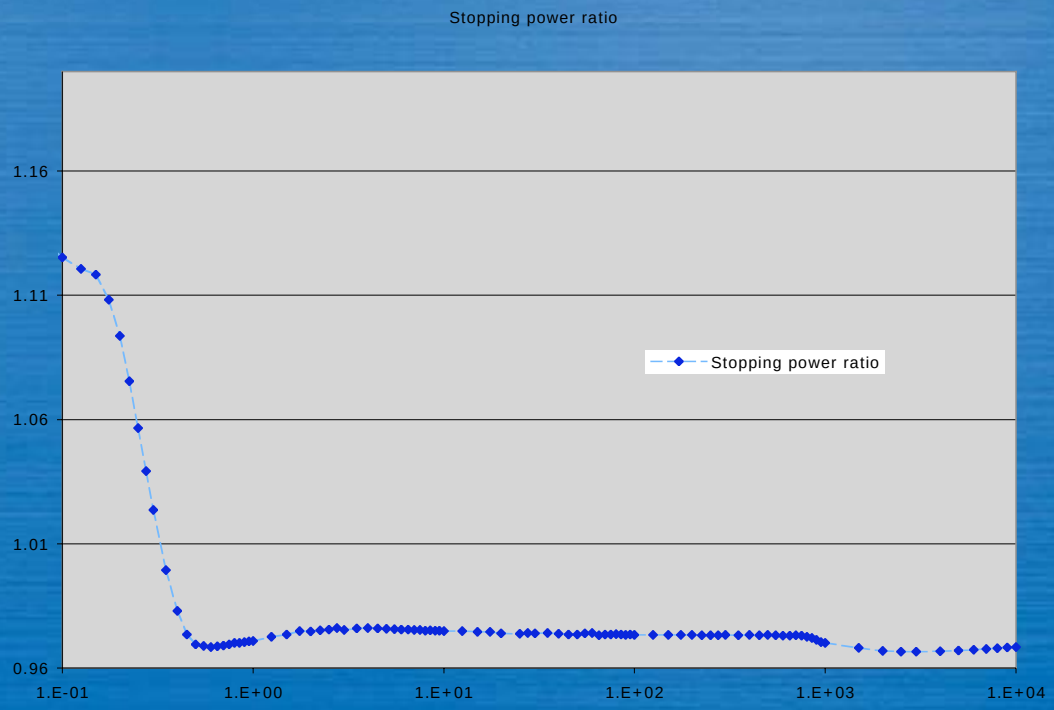
# Dosimetry Review Visits

- Comparison with institution data:
  - Reference calibration
  - Representative %depth dose, range
  - Representative profiles
  - Output dependence on
    - Snout size, distance
    - SSD
    - Aperture size
    - Energy, range shift
    - Modulation



# Dosimetry Review Visits [cont'd]

- Review of CT # - stopping power conversion



# Dosimetry Review Visits [cont'd]

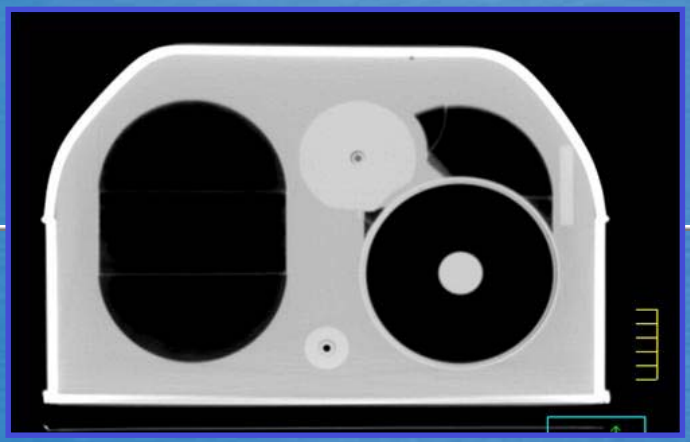
- Image guidance, patient alignment
  - Evaluate imaging system with IGRT phantom
- QA Procedures
  - Daily
  - Monthly

# Schedule for Visits

- Equipment has been received
- Will modify RPC scanner for greater depth, accommodate new chambers
- Test at MDACC during August
- First visit in Fall …

# RPC Phantoms

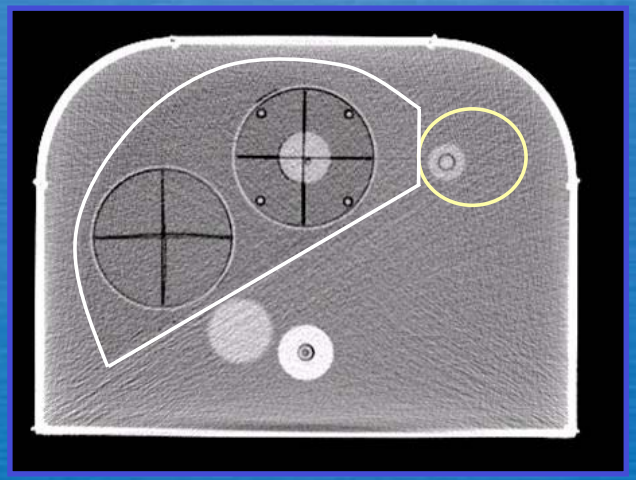
Pelvis (8)



Thorax (9)

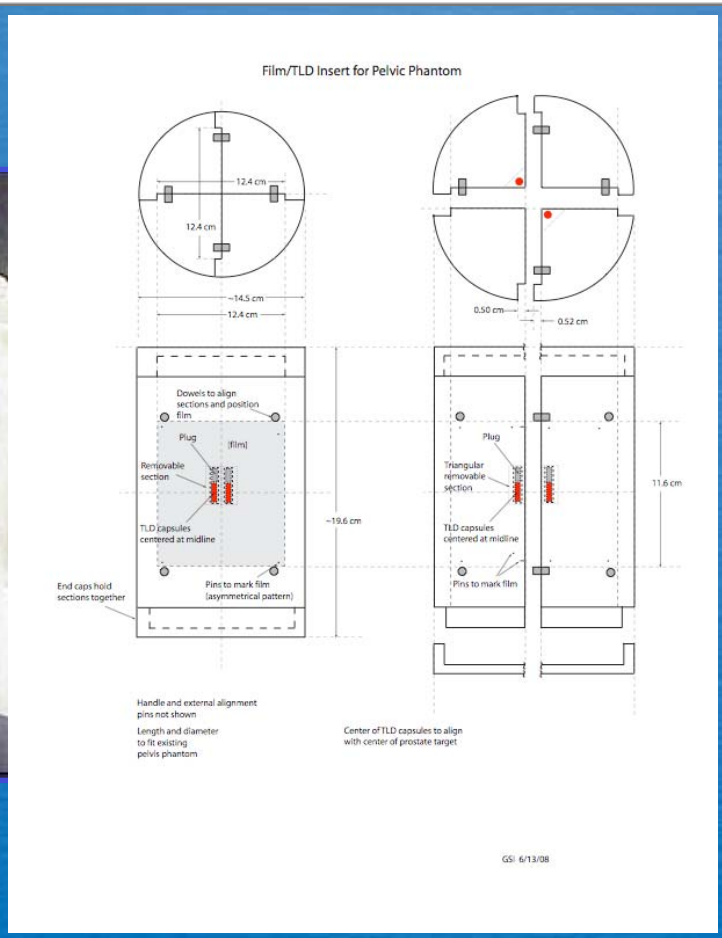
H&N IMRT (30)

SRS Head (4)



Liver (2)

# Anthropomorphic Phantoms

# Thorax Phantom