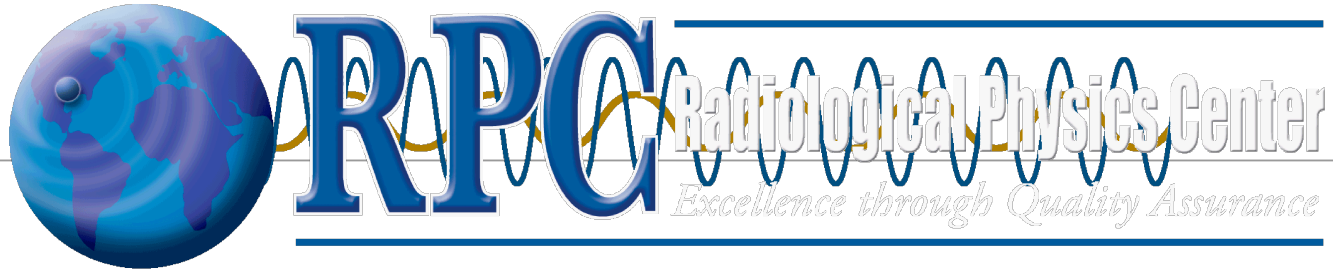
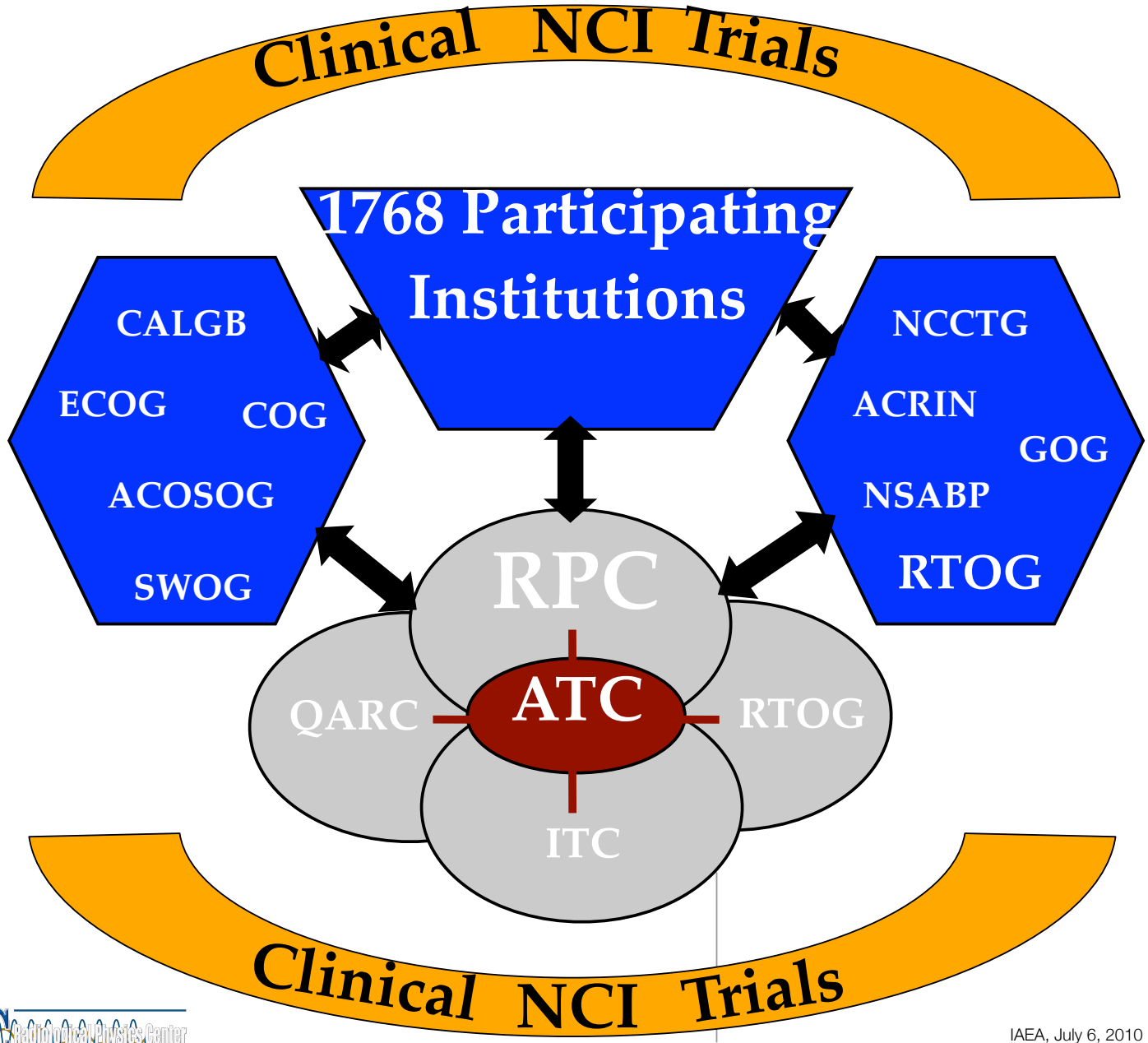
What Can Go Wrong in Radiation Treatment:

Results from RPC Audits



Geoffrey S. Ibbott, Ph.D.
and RPC Staff


Clinical NCI Trials
1768 Participating Institutions
CALGB
ECOG
COG
ACOSOG
SWOG
NCCTG
ACRIN
GOG
NSABP
RTOG
RPC
QARC
ATC
RTOG
ITC
Clinical NCI Trials

Mission

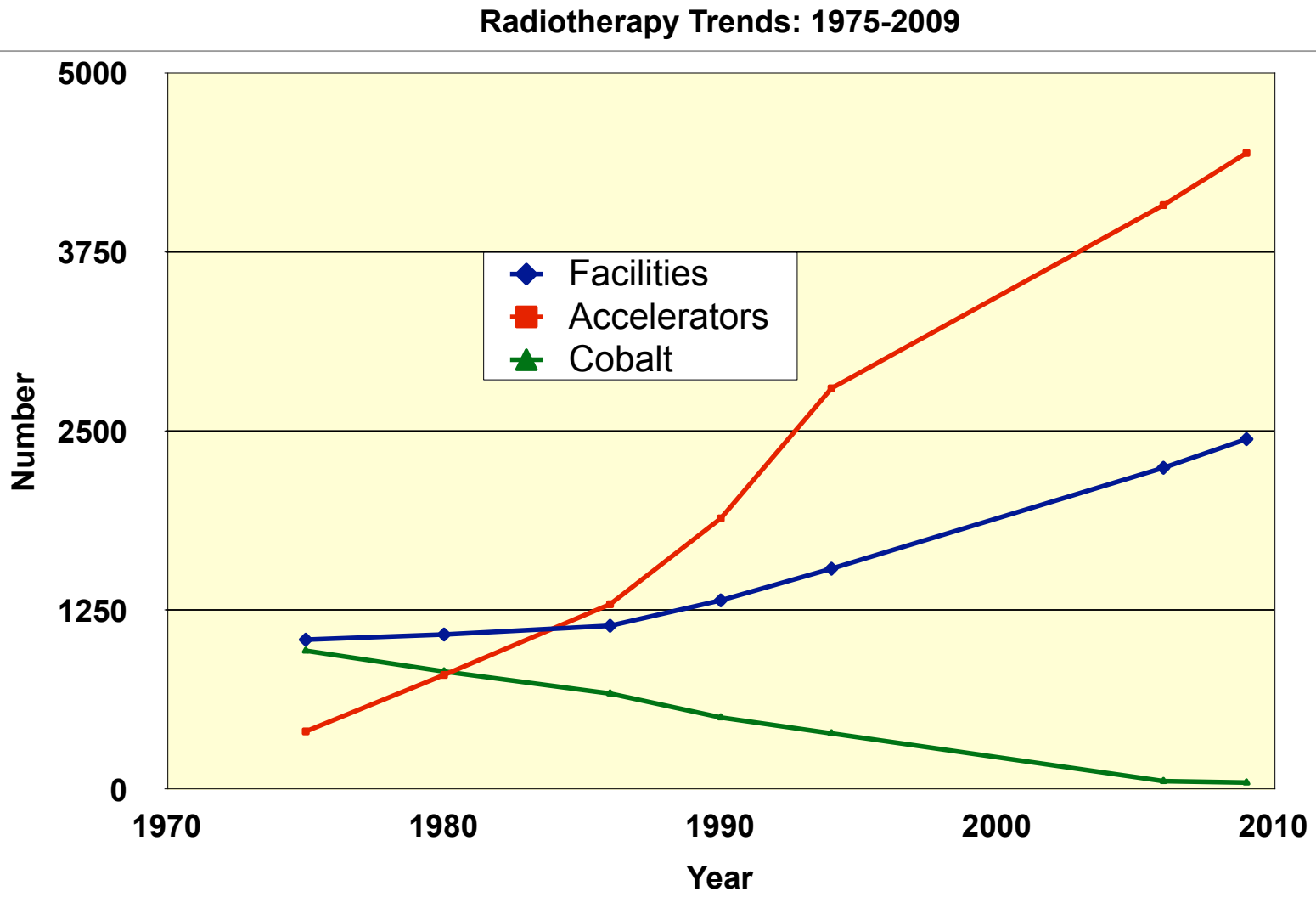
The mission of the Radiological Physics Center is to assure NCI and the Cooperative Groups that institutions participating in clinical trials deliver prescribed radiation doses that are clinically comparable and consistent.

Now 42 years of experience of building an infrastructure, establishing communications with institutions, developing relationships with study groups and QA offices, and adding value to the clinical trials program

Where do we find errors?

- **Remote audits of machine output**
  - 1,768 institutions, ~14,000 beams measured with TLD (2009)
- On-site dosimetry reviews
  - 50 institutions visited (~150 accelerators measured)
- Treatment record reviews
  - Review for GOG, NSABP, NCCTG, RTOG (brachy)
- Independent recalculation of patient dose
  - Continue to find errors
- Credentialing
  - Phantoms, benchmarks, questionnaires, rapid reviews

US Institutions & Machines



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

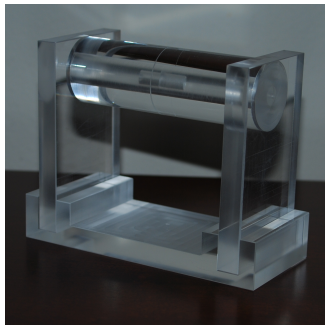
TLD Irradiation

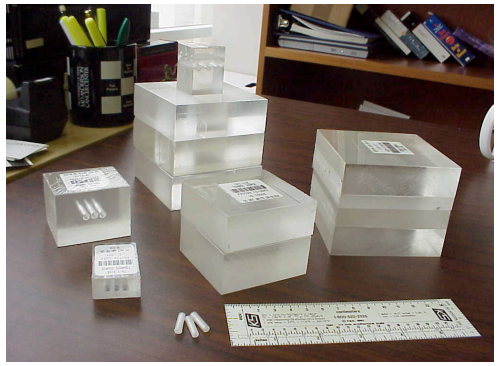
Institutions receive acrylic block containing dosimeters

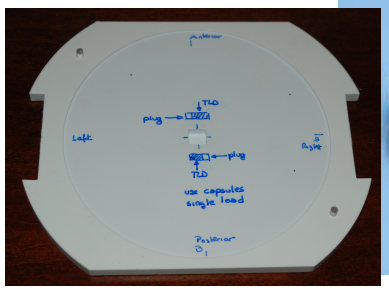
Radiological Physics Center

Verification of Standard Output

- **Photon and electron beams from conventional linear accelerators**
- **CyberKnife**
- **TomoTherapy**
- **Gamma Knife**
- **Protons**





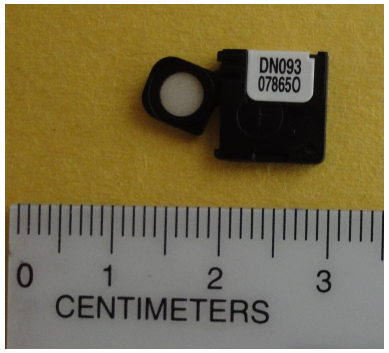


TLD vs OSL

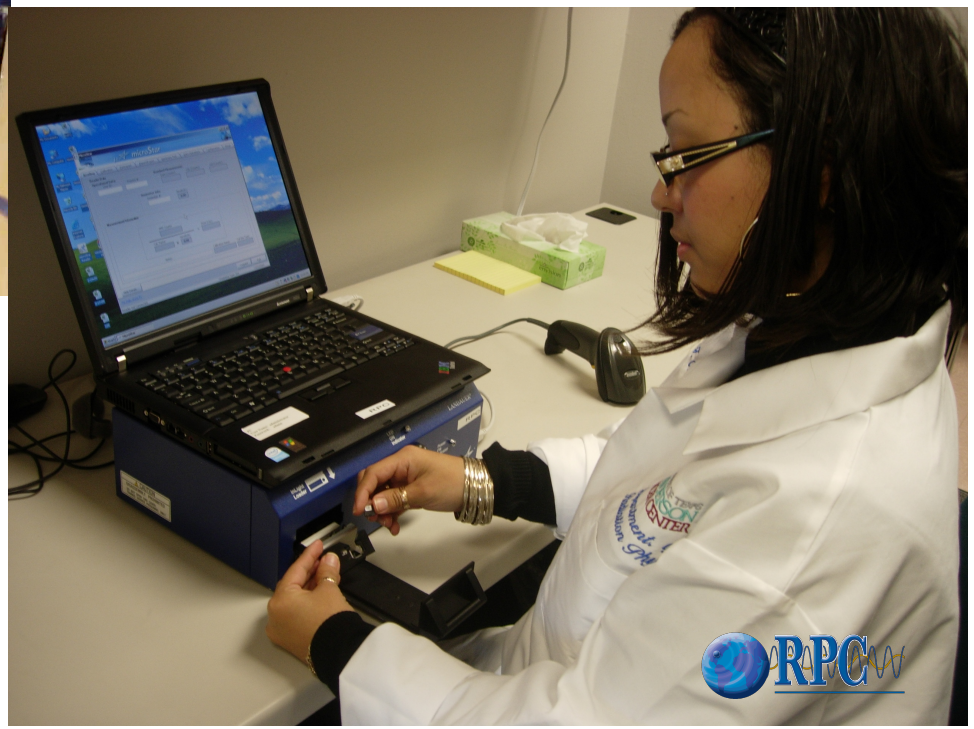
- LiF:Mg,Ti (TLD-100) capsules
- Disposable
- One reading
- Temperature and weight control
- 3 dosimeters per point
- 6 min reading time
- Dosimeter cost per check $2.40

- (Al_2O_3:C) nano dots
- Reusable (dose limit ~ 10Gy)
- Re-readable
- No temp/weight ctrl, light tightness
- 2 dosimeters per point,
- ~ 2 min reading time
- Dosimeter cost per check $1.00

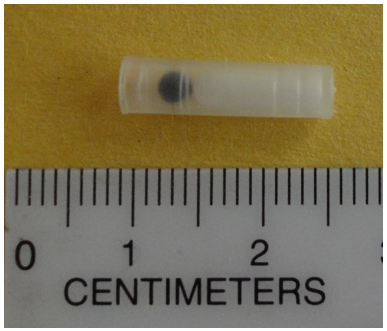
Equipment



OSL



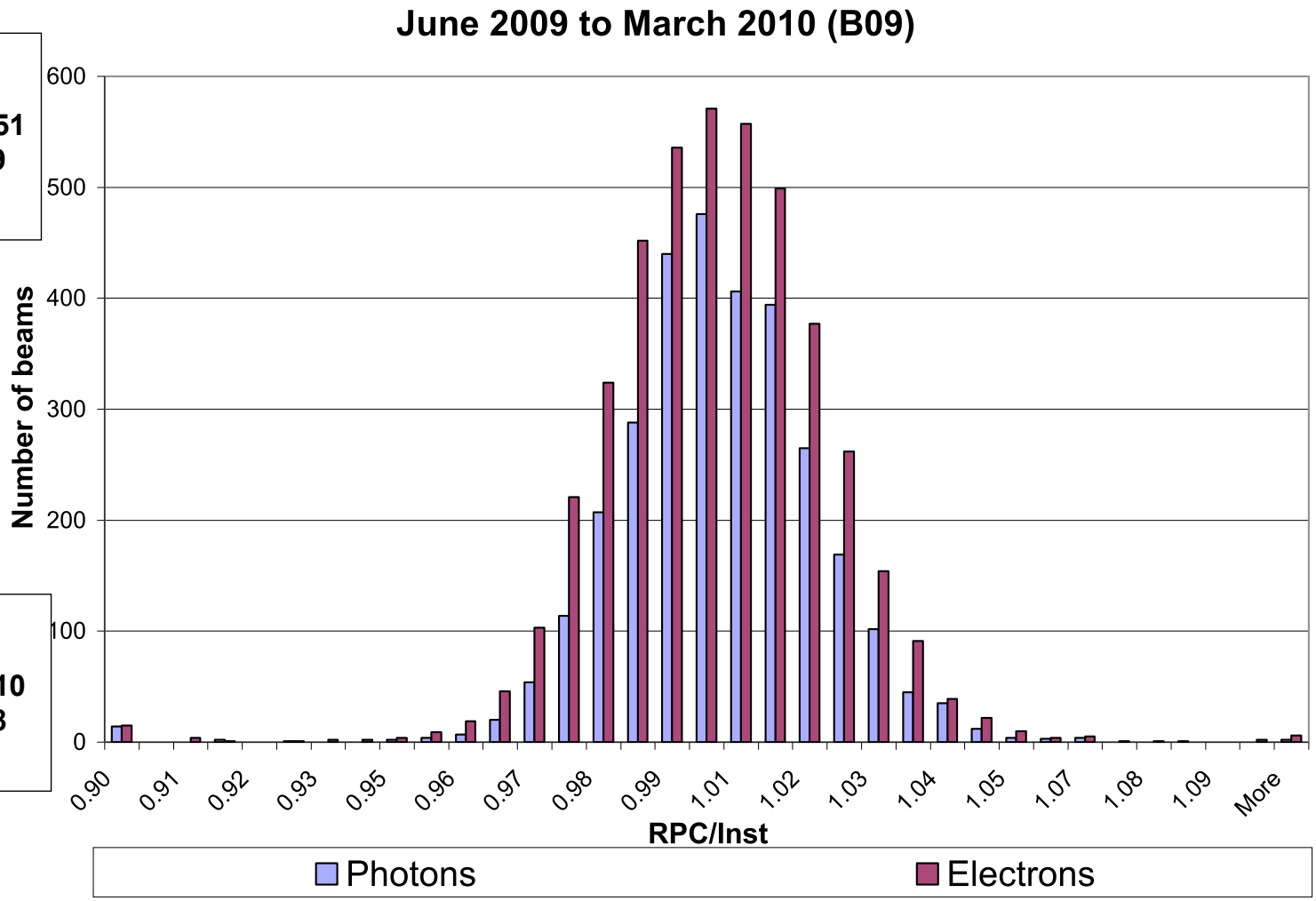
TLD



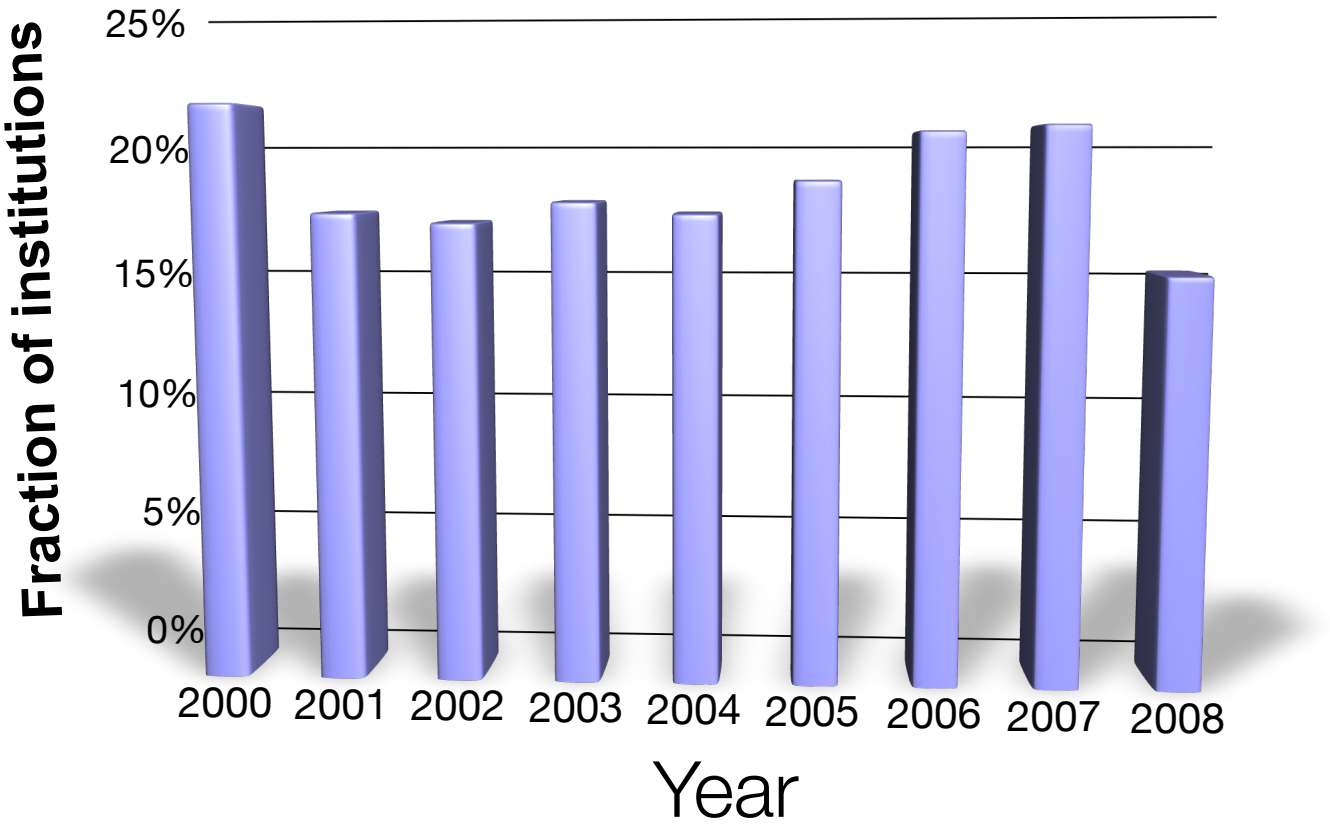
Distribution of TLD results

Photons beams within 7%
Number of beams: 3051
Avg. RPC/Inst.: 0.999
Stdev.: 1.6%

Electrons beams within 7%
Number of beams 4310
Avg. RPC/Inst: 0.998
Stdev.: 1.7%



Institutions with One or More Unacceptable TLD Measurements



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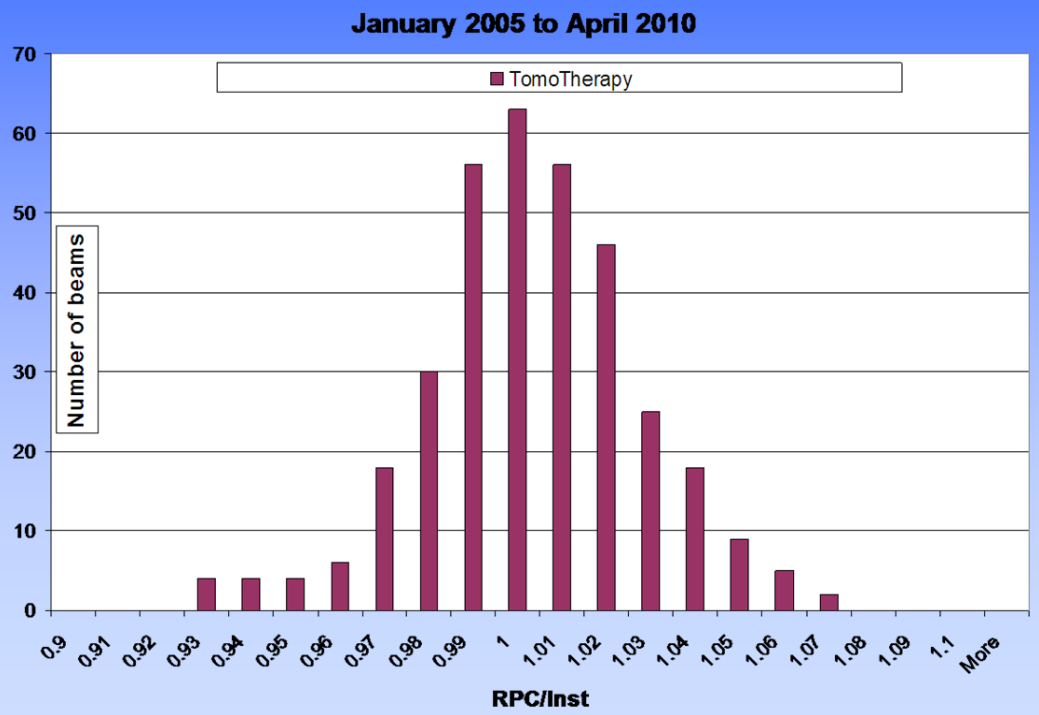
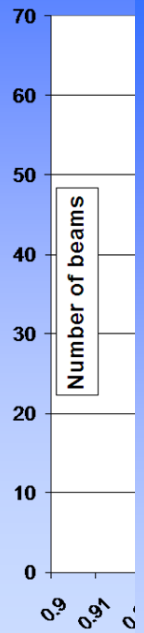
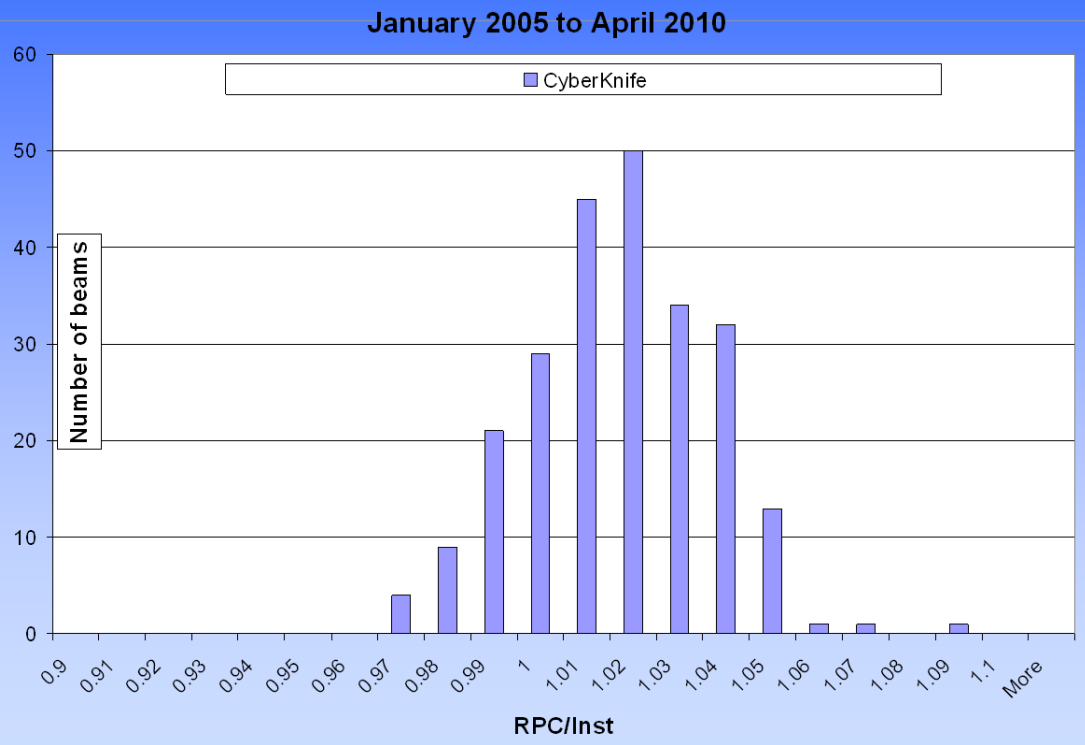
Distribution of TLD results



Distribution of TLD results



Distribution of TLD results



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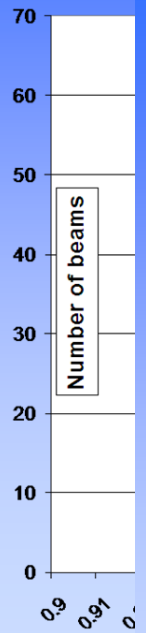

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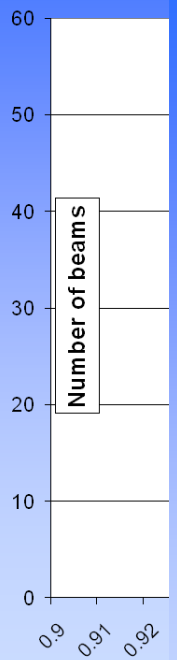

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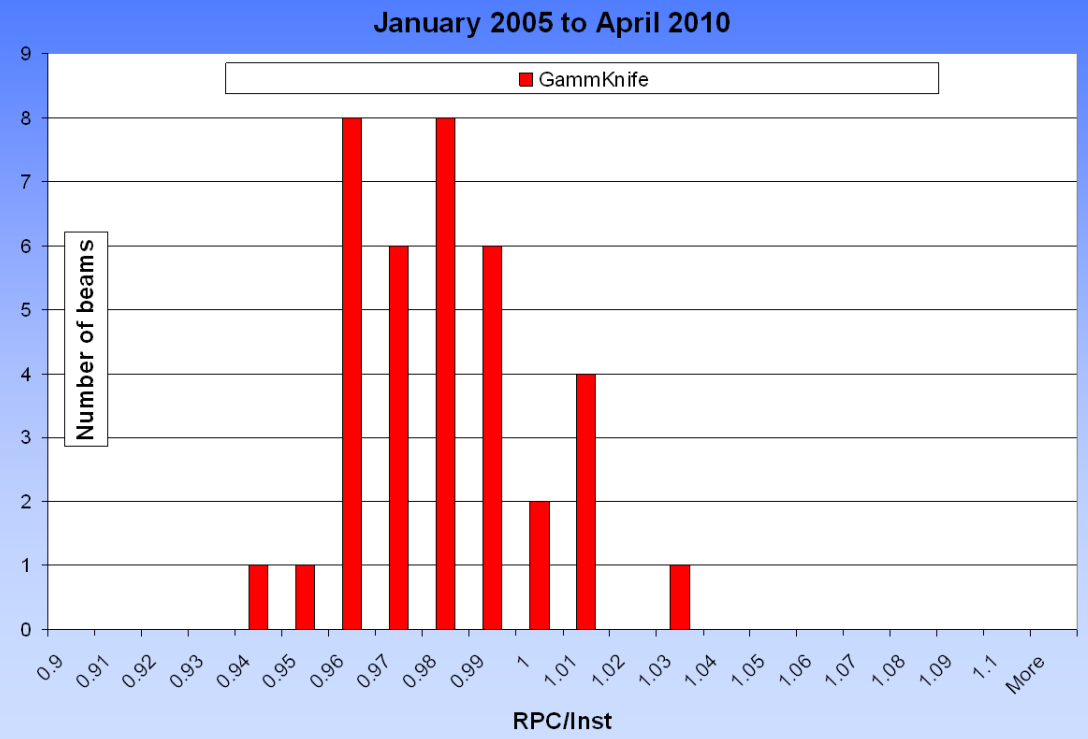
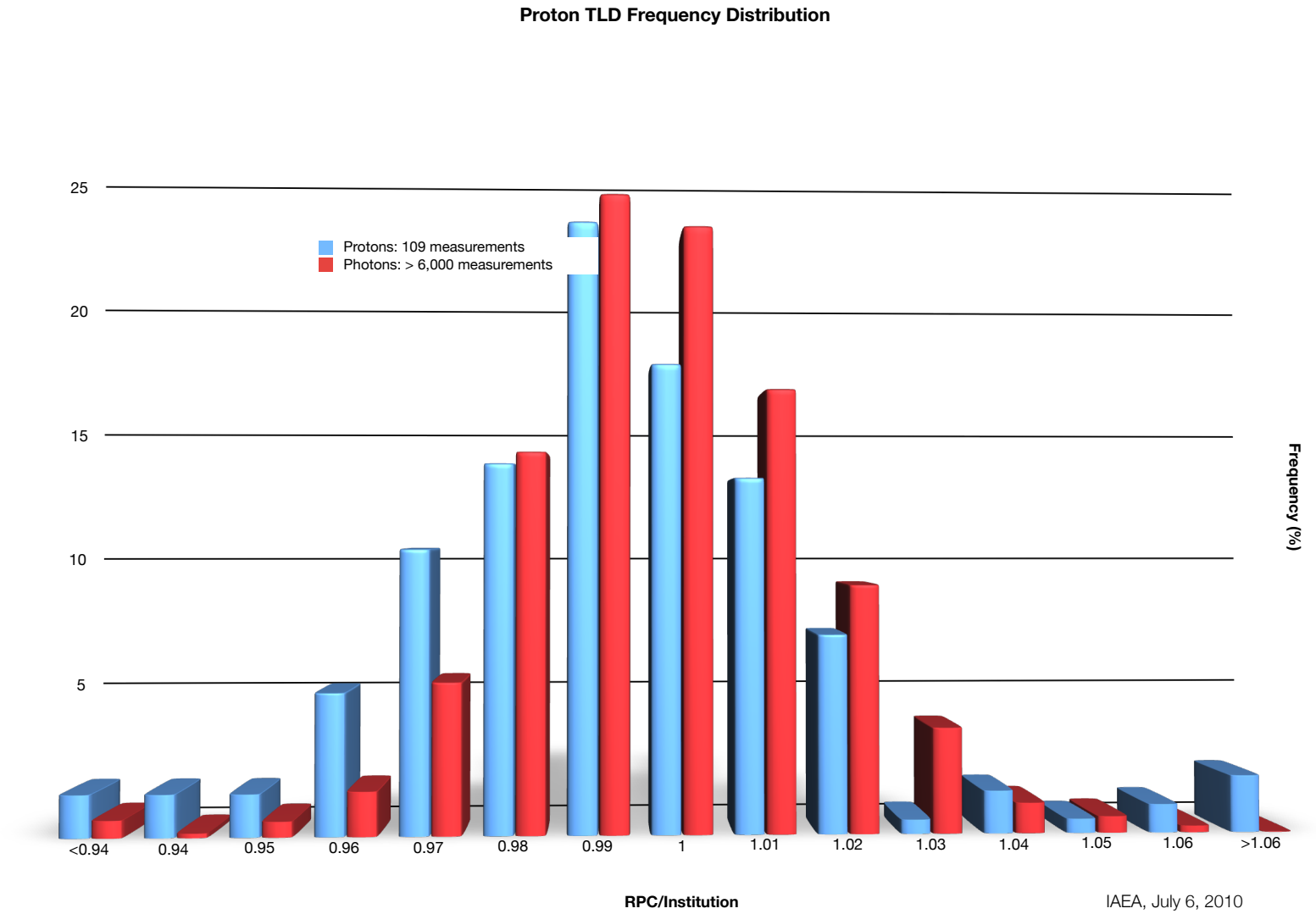


TLD measurements in proton beams



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On-Site Dosimetry Review Visit

- **The only completely independent comprehensive radiotherapy quality audit in the USA and Canada**

- Identify errors in dosimetry and QA and suggest improvements.
- Collect and verify dosimetry data for chart review.
- Improve quality of patient care.

On-Site Dosimetry Review Visit

New audit techniques:

1. TomoTherapy
2. CyberKnife
3. Small field dosimetry
4. MLC dosimetry
5. Image guidance (in development)

On-Site Dosimetry Review Visit

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As radiotherapy treatment techniques change, so do the visit audit techniques

On-Site Dosimetry Review Visit

Reference Beam Calibration

Percent of Beams out of Criteria

(since 2000)

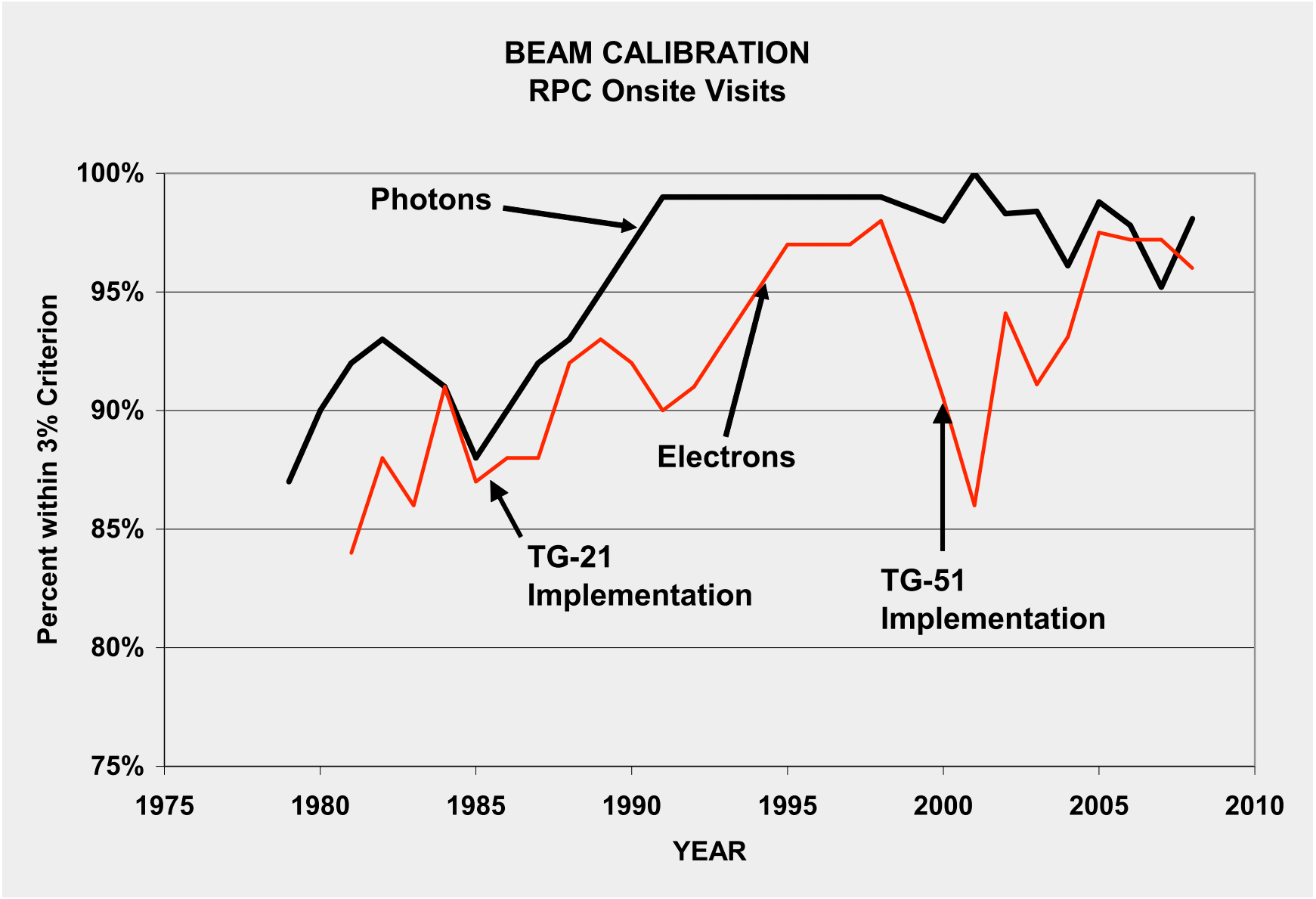
	Photons	Electrons
TLD (±5%)	3-5%	5-8%
Visits (±3%)	2-4%	3-14%

On-Site Dosimetry Review Visit

Reference Beam Calibration
Percent of Inst. with ≥ 1 beam out of criteria
(since 2000)

	Photons	Electrons
TLD (±5%)	7-11%	6-12%
Visits (±3%)	~13%	~15%

On-Site Dosimetry Review Visit



On-Site Dosimetry Review

Selected discrepancies discovered 2004 – 2008

Errors Regarding	Number of Institutions (%)
Review QA Program	127 (77%)
*Wedge Transmission	53 (32%)
*Photon FSD (small fields)	46 (28%)
Off-Axis, Beam Symmetry	42 (25%)
*Photon Depth Dose	34 (21%)
*Electron Calibration	25 (15%)
*Photon Calibration	22 (13%)
*Electron Depth Dose	19 (12%)

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

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  - Calculation errors, reporting errors
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RPC Patient Dose Review

- Independent calculation of tumor dose
- Agree within 5% (15% for implants)
- Verify dose, time, fractionation per protocol
- Notify institution if major deviation seen during review to prevent further deviations

Without RPC review 36% of the doses used by the study group would be incorrect

- 1% Systematic errors
- 8% Individual errors
- 27% Reporting errors

Exmples of Systematic Errors > 5% (>15%)

Error	Magnitude
TPS used wrong depth when head frame used	27%
TPS did heterogeneity corrections incorrectly	8.5%
Institution ignored effects when >50% of the field was blocked	5%
Point of calculation near edge of field	6-7%
Non-measured output with average TLD > 5%	7%
Lung correction used, not allowed on protocol	9-13%
TPS wedge factor differs from clinical wedge factor	9%

Examples of Individual Errors > 5% (>15%)

Problem	Magnitude
Addition error	9%
Hand written daily treatment record differed from Record and Verify for one field	145%
Institution treated 180 cGy/field rather than 180 cGy/day	291%
Dose reported under block for parametrial boost	21%
Inhomogeneity corrections used (not allowed on protocol)	5 – 7%
Brachytherapy shielding error	23%
Incorrect prescription points on brachytherapy	Up to 553%
Magnification error on brachytherapy	144%
Combined with incorrect prescription point	208%
Reported dose rates rather than dose for brachytherapy	Up to 480%

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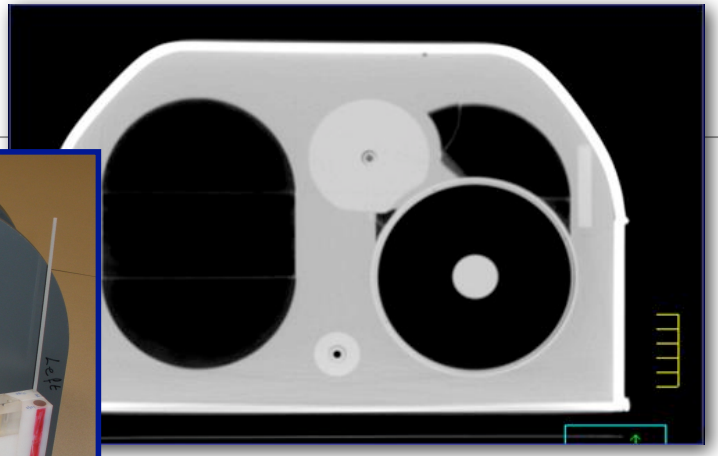
RPC Phantoms

Pelvis (10)

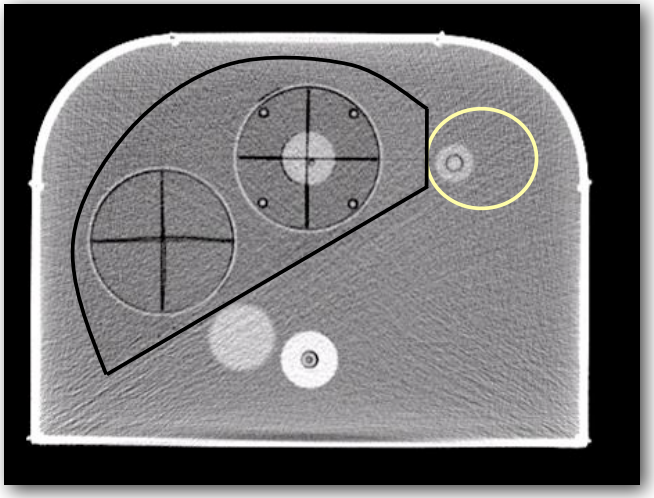
Spine (3)



Thorax (13)

H&N (31)

SRS Head (4)



Liver (2)

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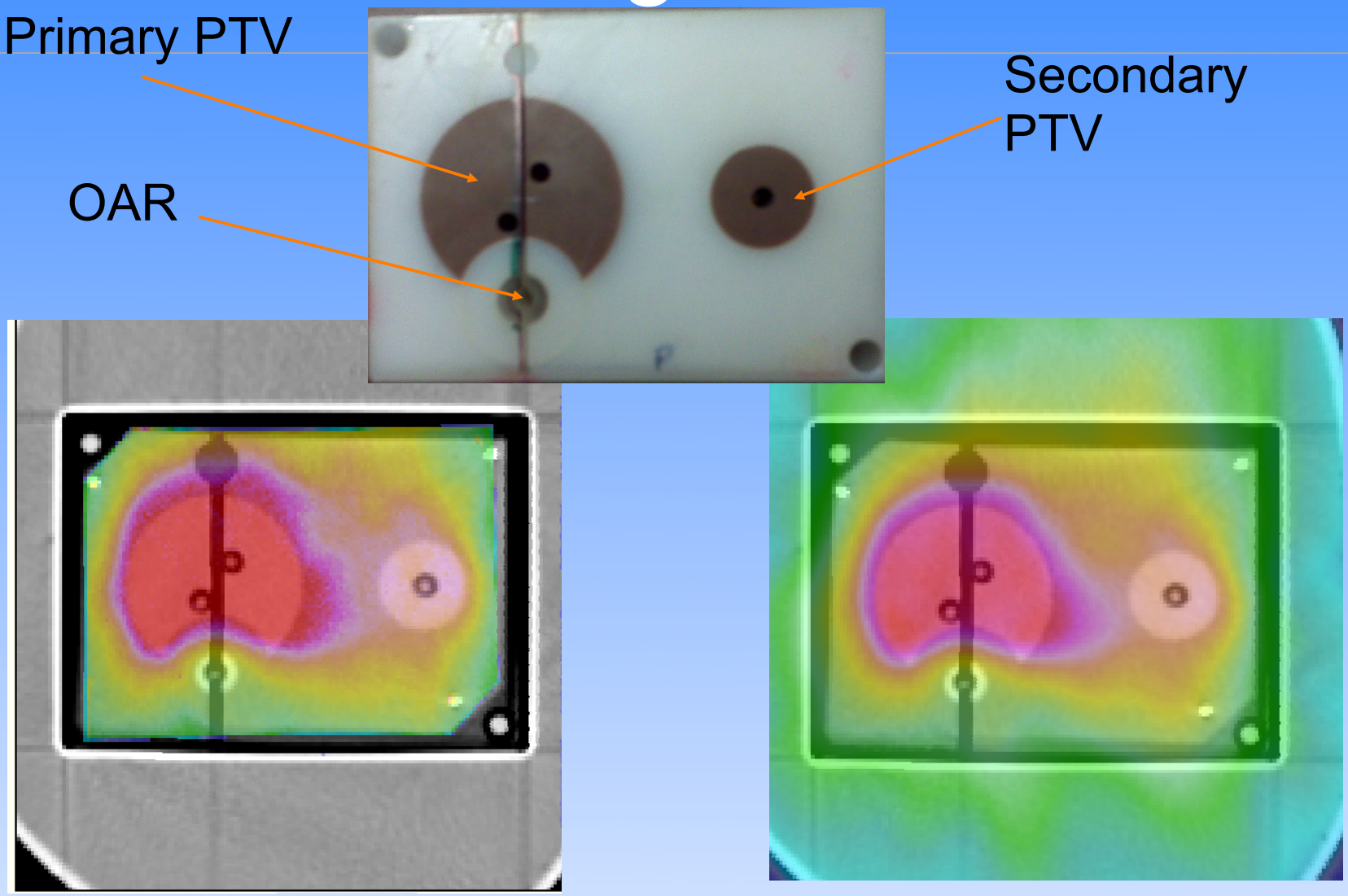
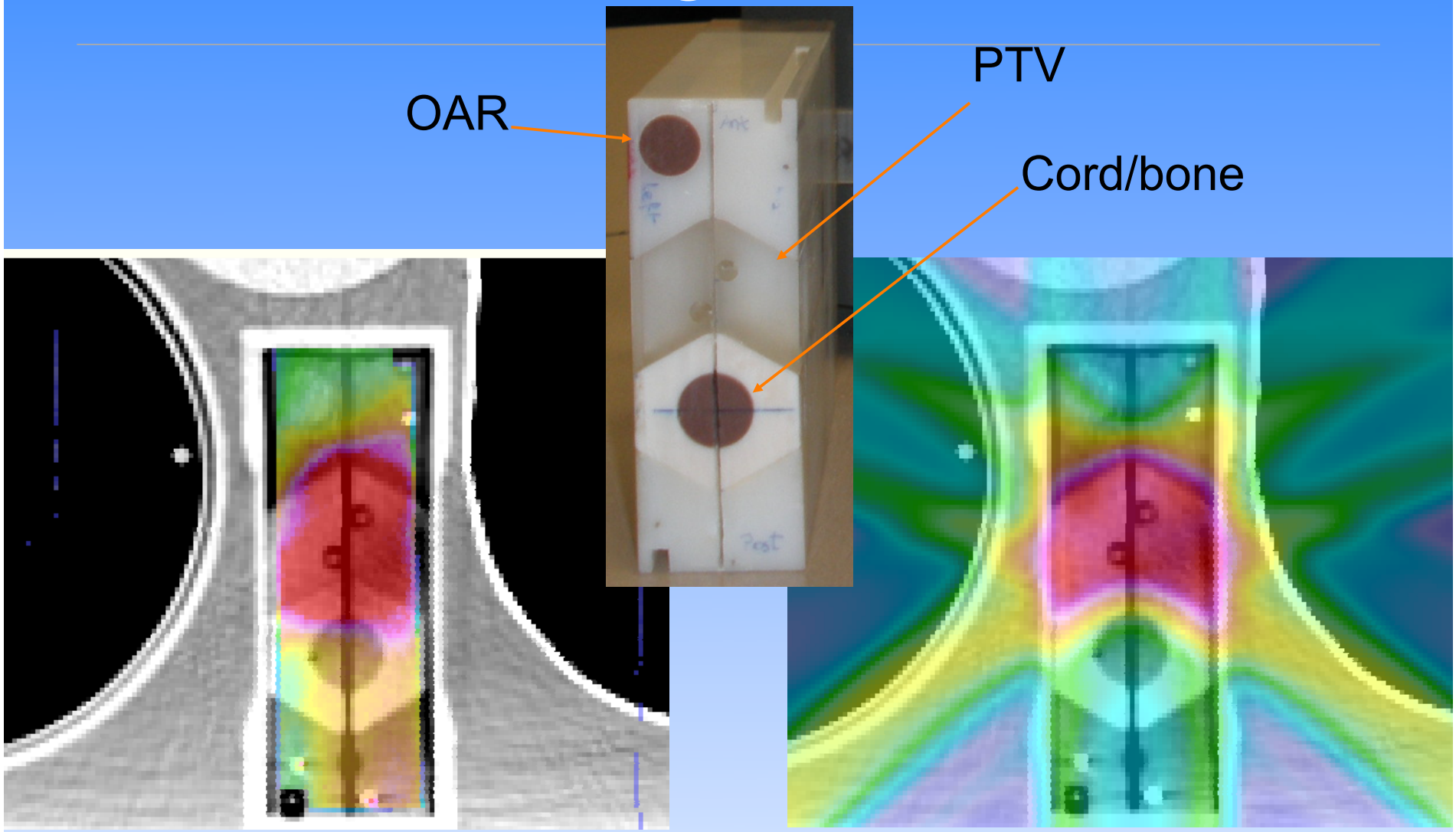
Good Agreement



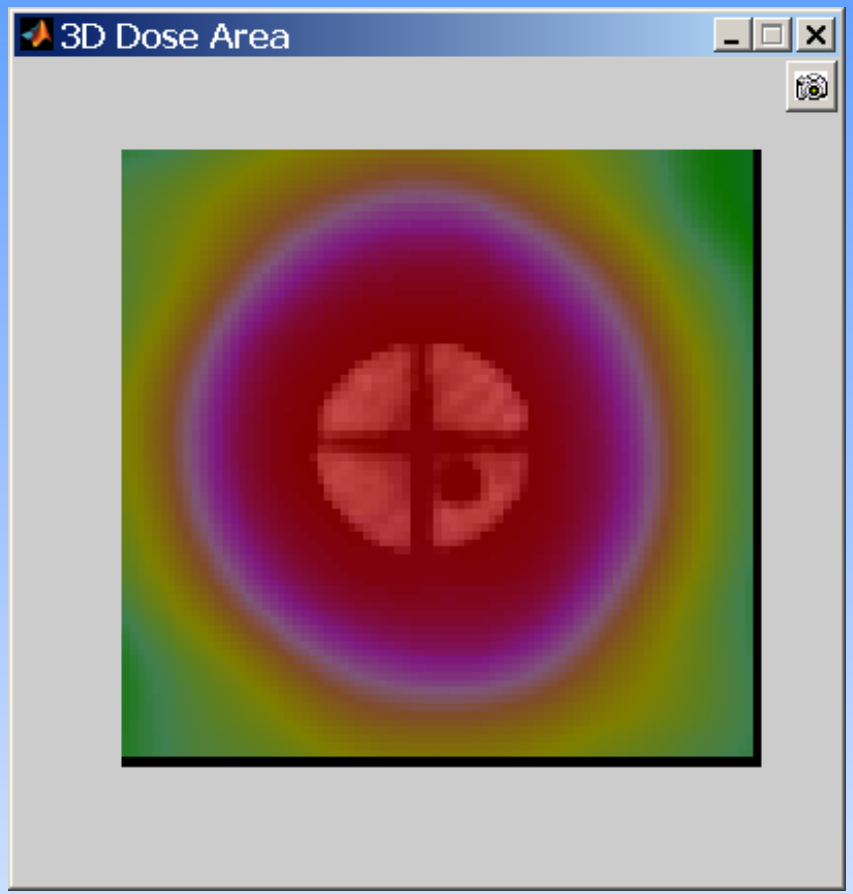
Bad Agreement



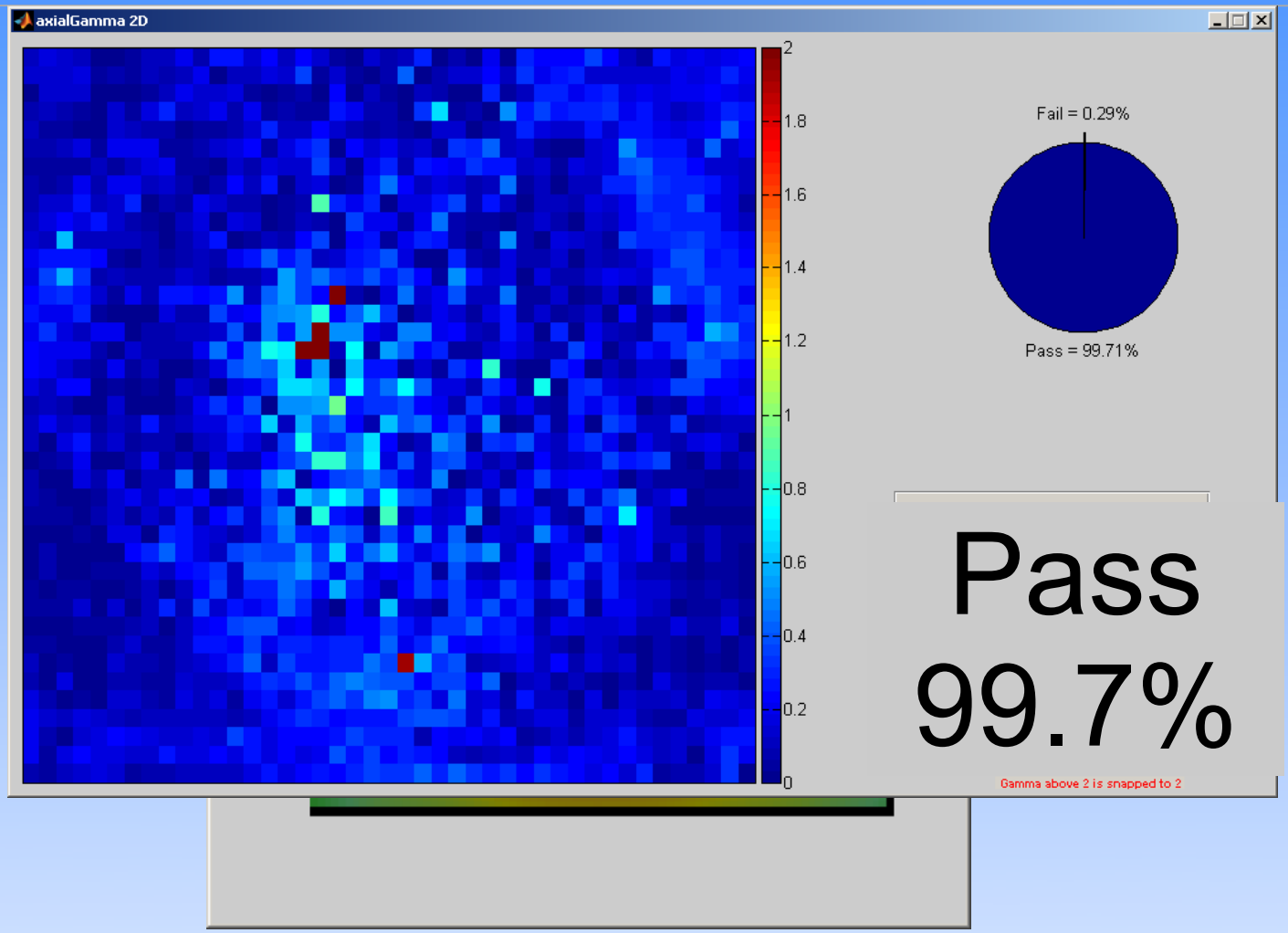
Measurement

Plan

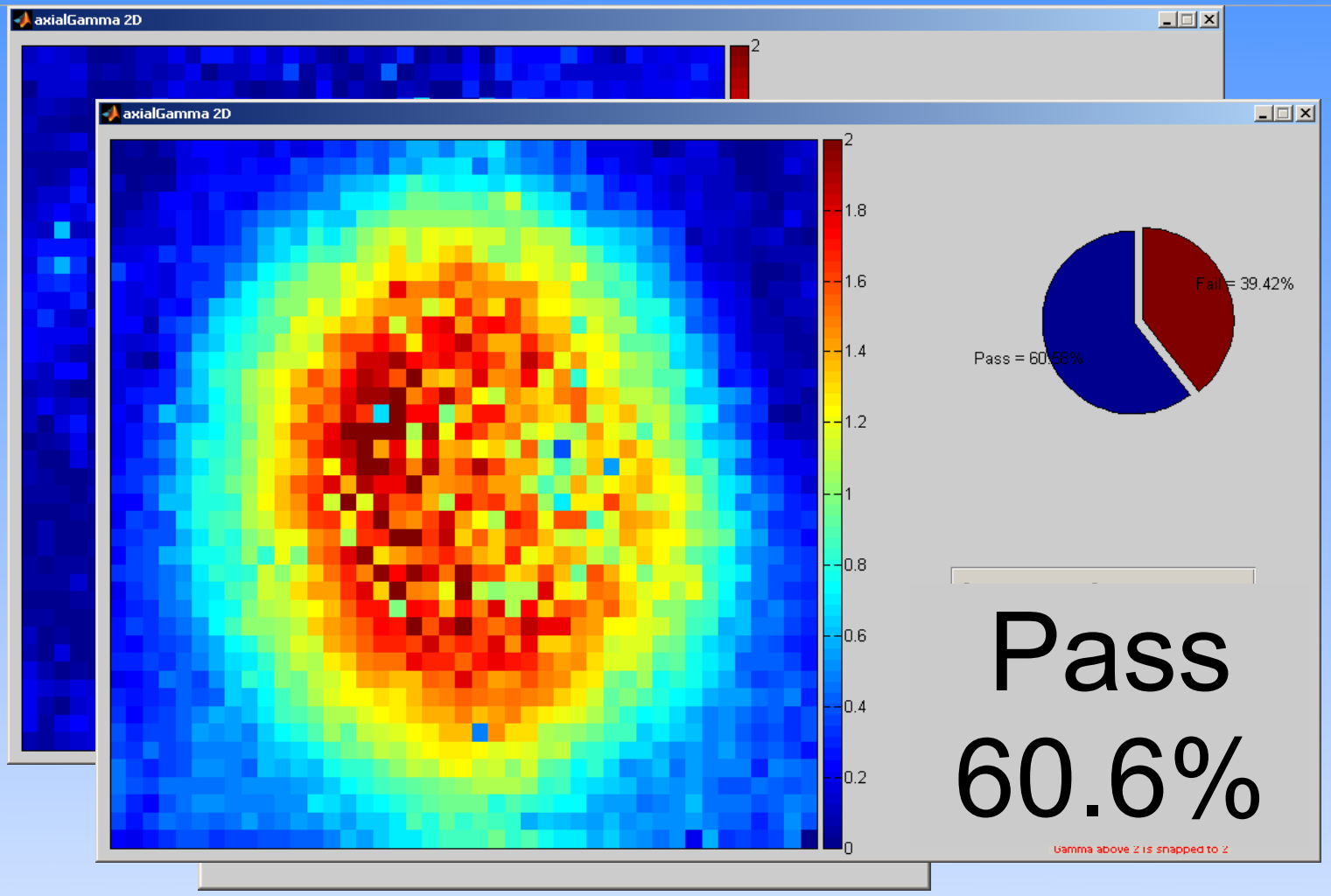
Gamma Analysis results



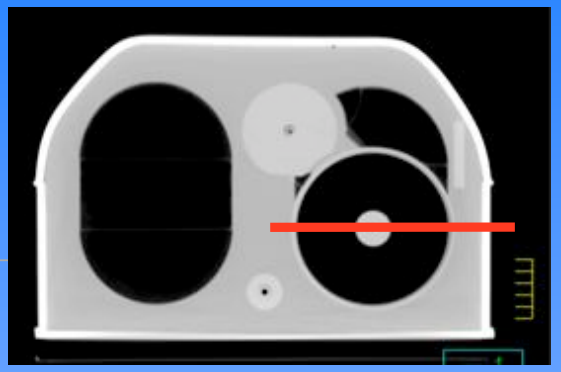
Gamma Analysis results

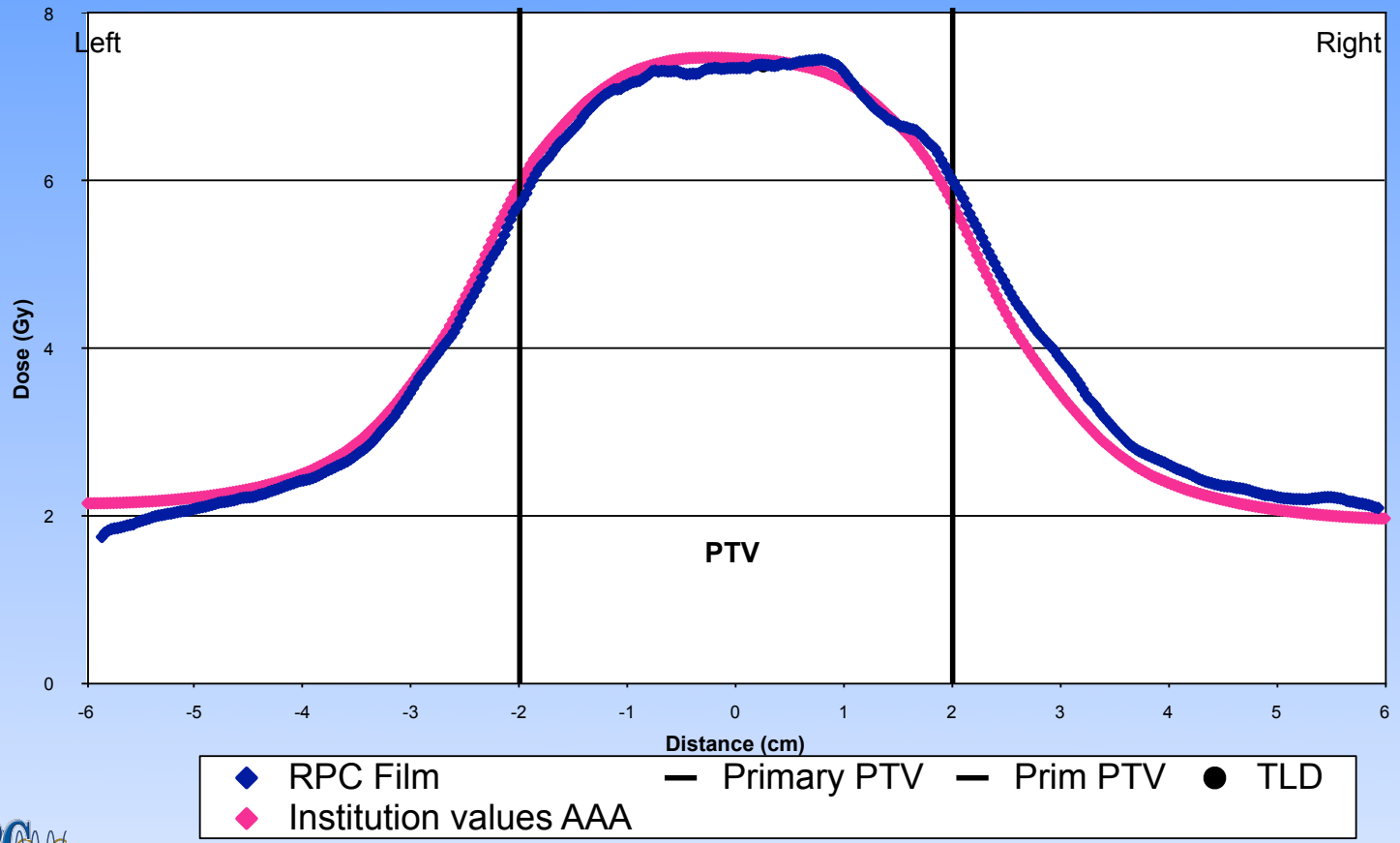


Gamma Analysis results

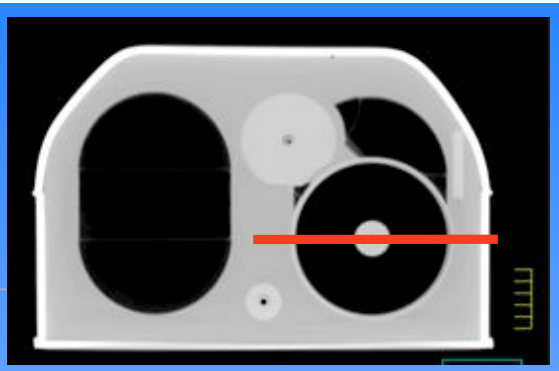


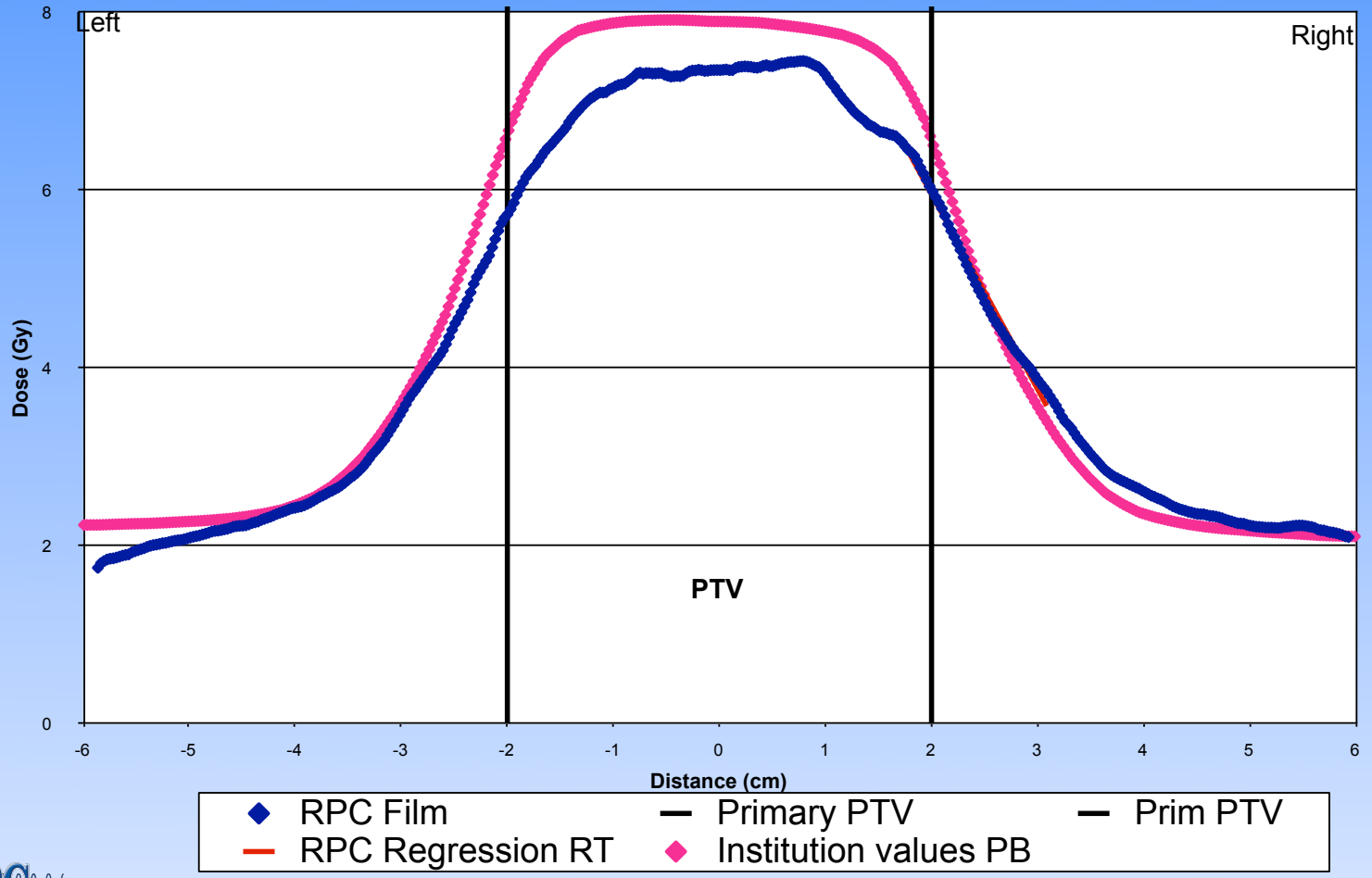
AAA Profile




Left
Right
PTV
Dose (Gy)
Distance (cm)
0
2
4
6
8
-6
-5
-4
-3
-2
-1
0
1
2
3
4
5
6
RPC Film
Institution values AAA
Primary PTV
Prim PTV
TLD

Pencil-Beam Profile





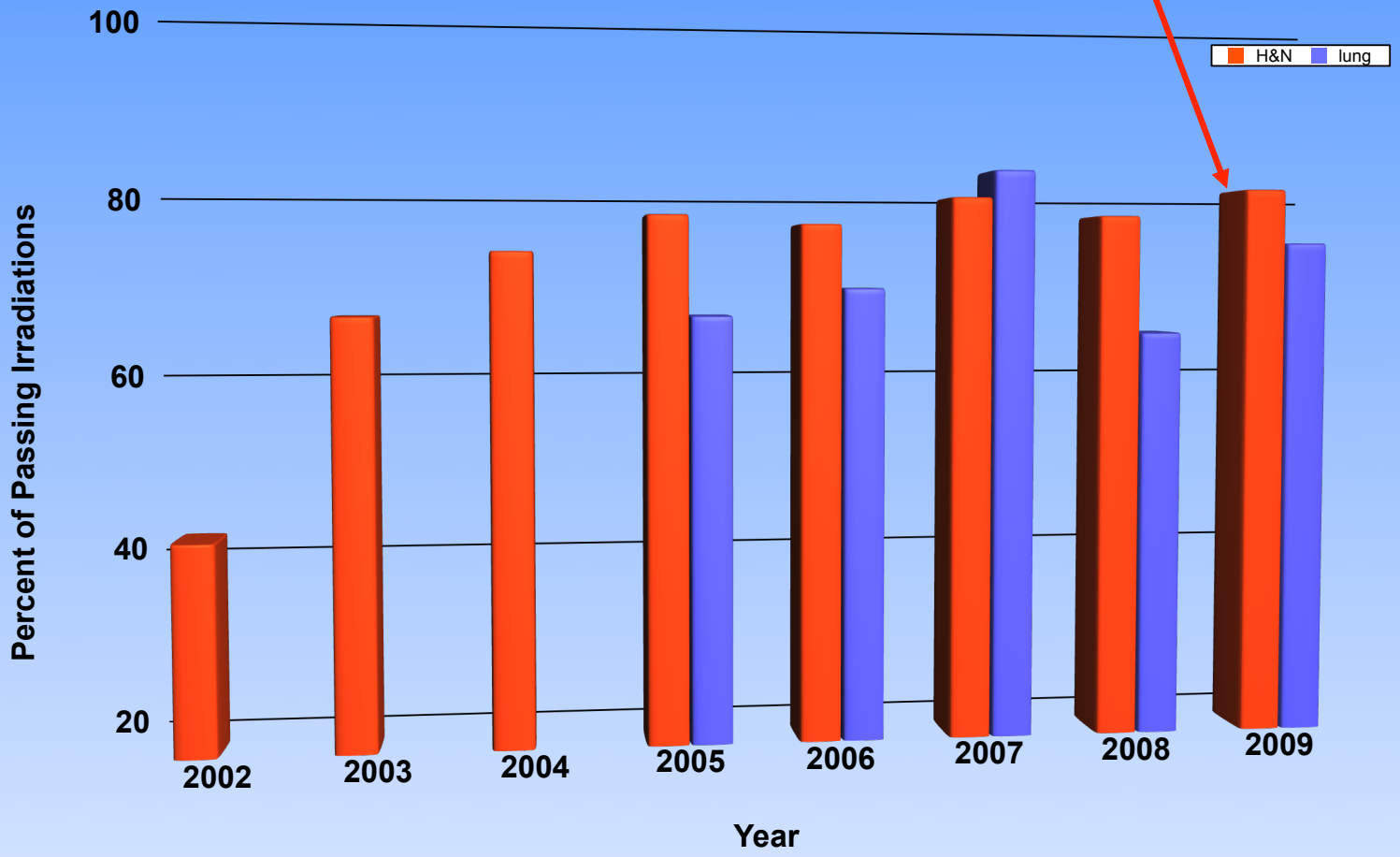
Phantom Results

Comparison between institution's plan and delivered dose.

Phantom	H&N	Prostate	Spine	Lung	Liver
Irradiations	752	174	19	174	23
Pass	585	143	13	124	12
Pass %	78%	82%	68%	71%	52%
Criteria	7%/4mm	7%/4mm	5%/3mm	5%/5mm	7%/4mm
Year introduced	2001	2004	2009	2004	2005

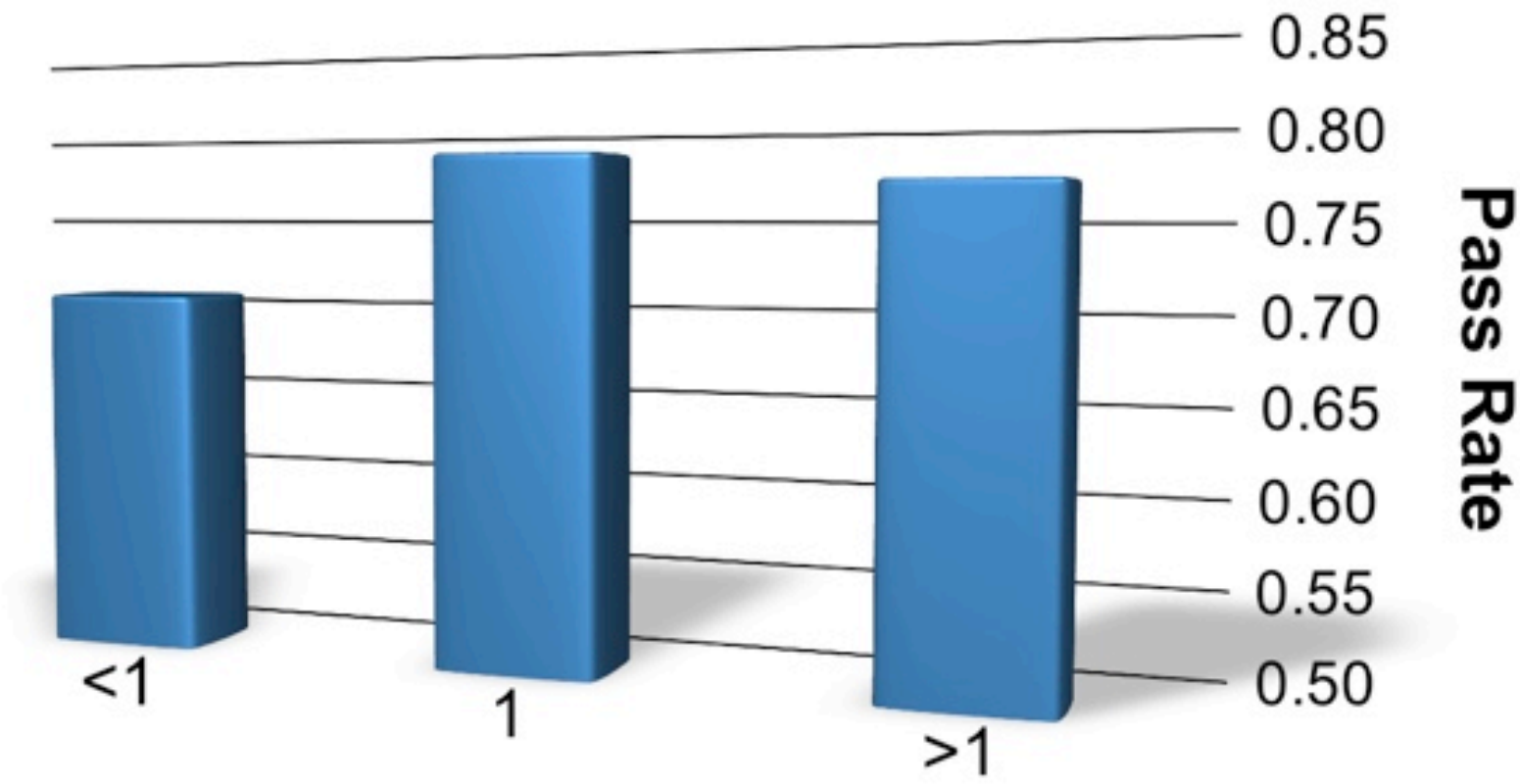
Good News

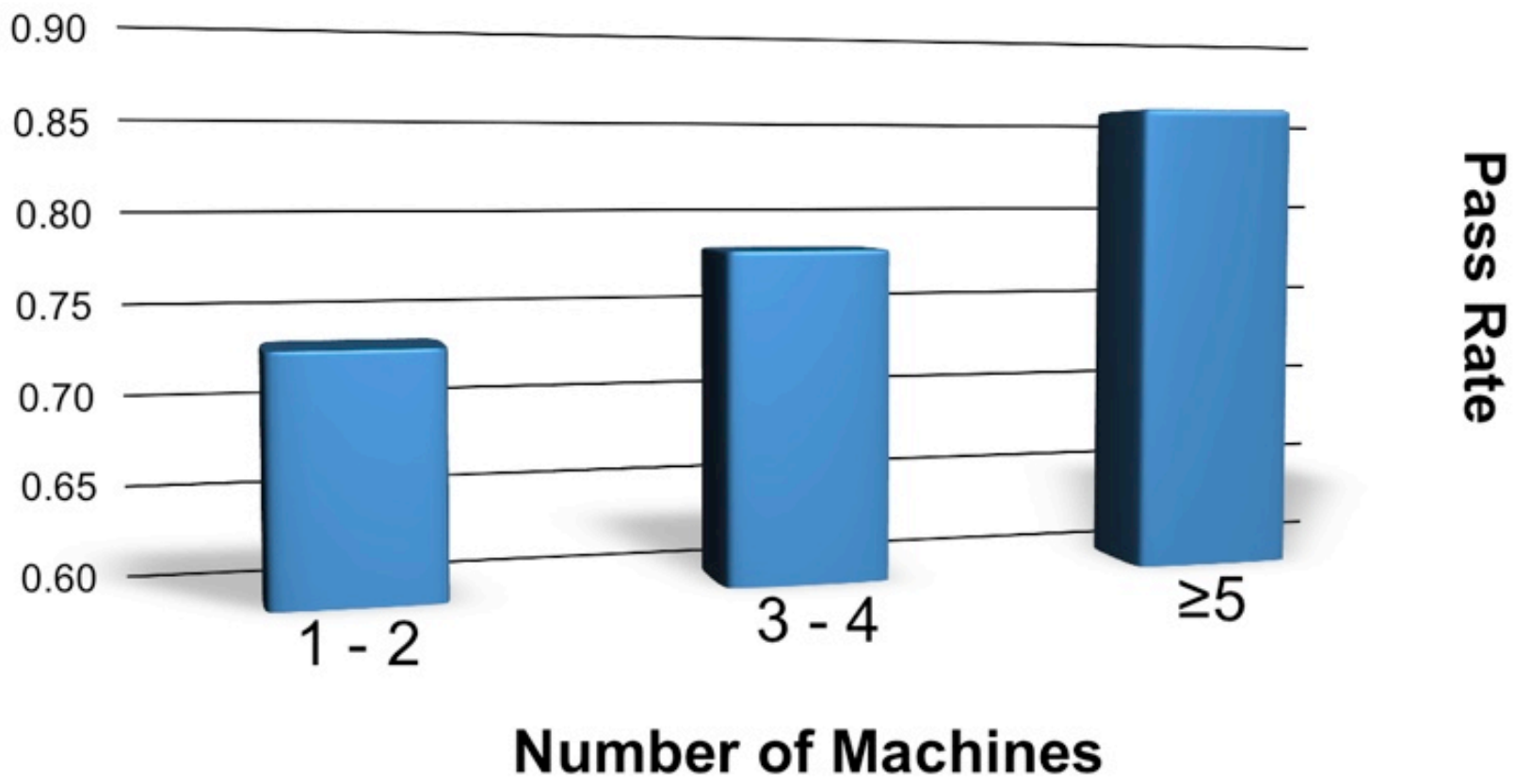
80% Pass Rate



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


0.85
0.80
0.75
0.70
0.65
0.60
0.55
0.50
Pass Rate
<1
1
>1
Number of Physicists per Machine

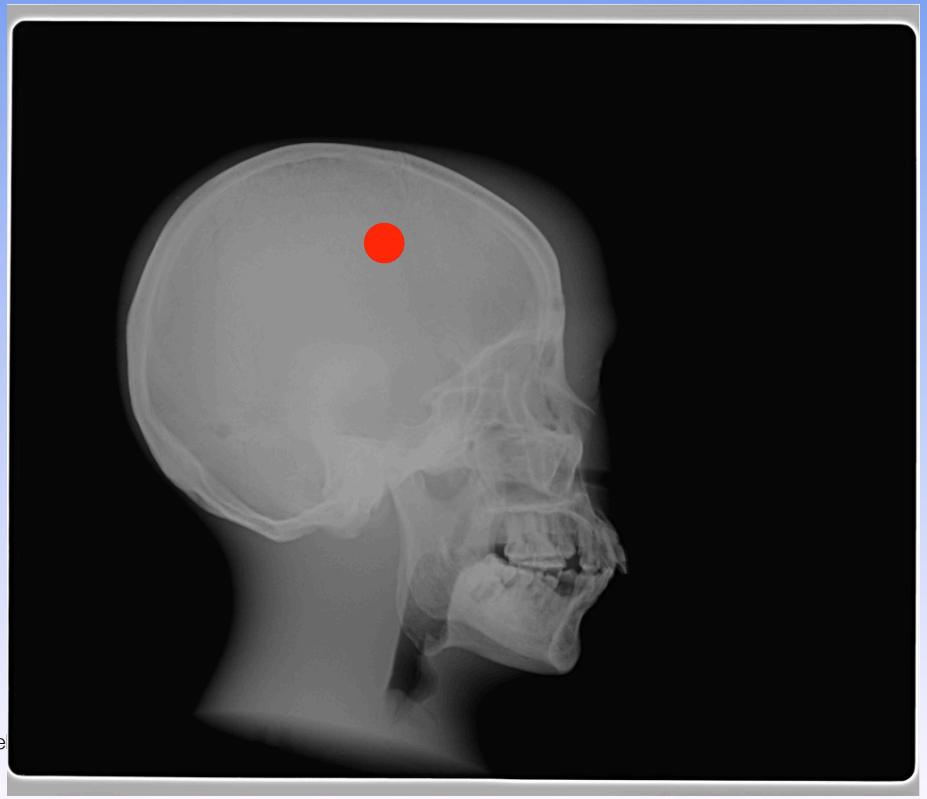

0.90
0.85
0.80
0.75
0.70
0.65
0.60
1 - 2
3 - 4
≥5
Pass Rate
Number of Machines

Explanations for Failures

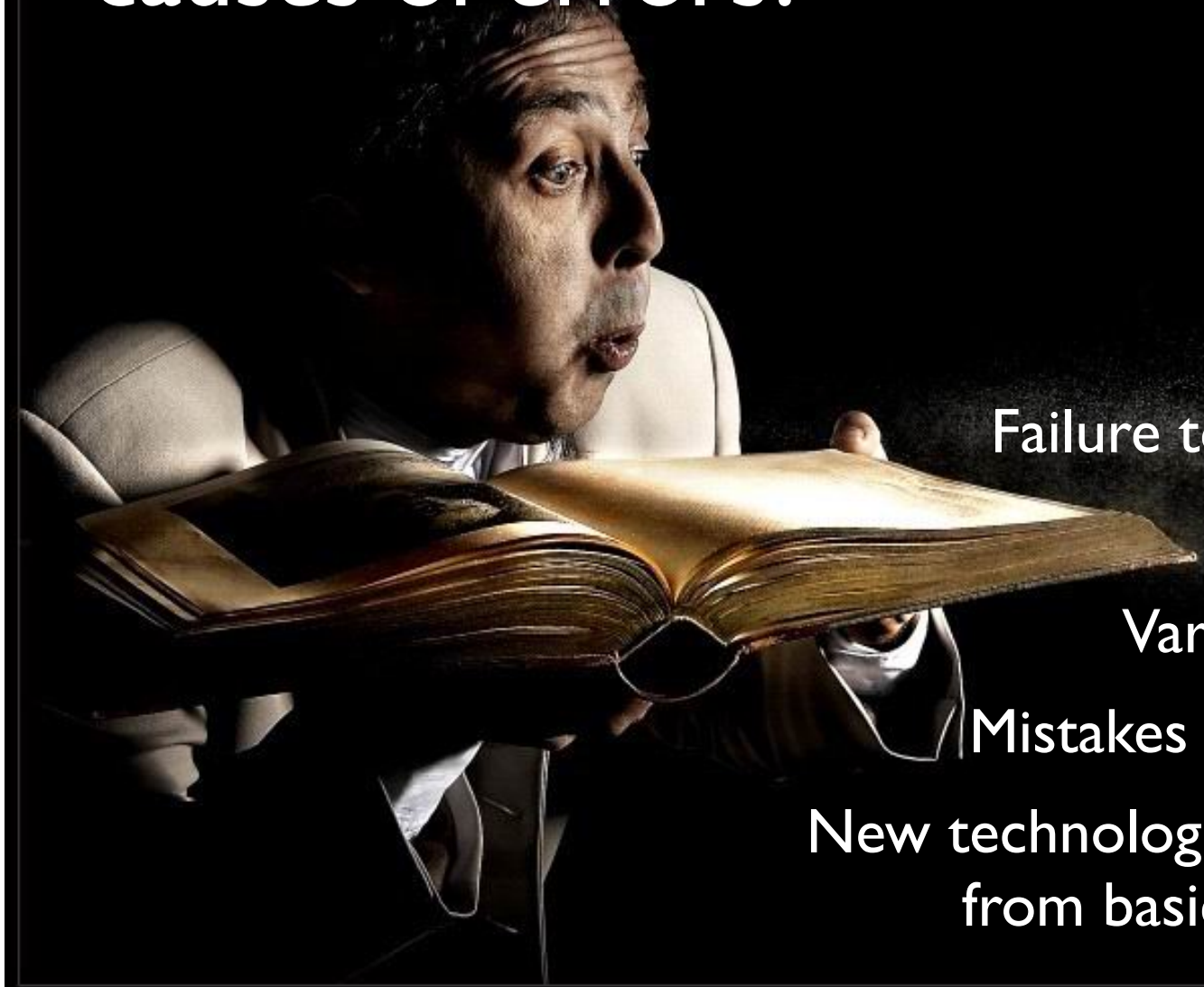
Explanation	Minimum # of occurrences
incorrect output factors in TPS	1
incorrect PDD in TPS	1
IMRT Technique	3
Software error	1
inadequacies in beam modeling at leaf ends (Cadman, et al; PMB 2002)	14
QA procedures	3
errors in couch indexing with Peacock system	3
equipment performance	2
setup errors	7

Brain Phantom

- Selected Phantom Lab “Alderson” phantom
  - Materials fall on CT#-RLSP curve
  - Contains realistic bony anatomy
  - Inserts with target and dosimetry will be constructed



What are the causes of errors?



Failure to learn the basics

Inexperience

Variations in training

Mistakes at commissioning

New technologies pull resources from basic QA procedures

RPC Radiological Physics Center

THE UNIVERSITY OF TEXAS
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