The Need for Standards: ADCLs in Medical Dosimetry

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What are Standards

- Standards are a systematic method to measure a quantity, such as dose, to a primary quantity, such as amount of ionization in air, Kerma.
- These standards, for the most part are maintained at NIST
- Sometimes since it is an involved process, an interim standard is necessary

Standards

- Uniformity among clinics doing radiation therapy starts with the measurement of the quantity that gives dose.
- There needs to be a standard so all clinical doses can be compared.
- This is uniform for external beam but not necessarily for small fields

Standards

- Standards changing Absorbed dose to water (TG 51) was done with precision and uniformly.
- Calibration of chambers and sources essential for radiation therapy: Majority traceable through Cobalt and Cesium.
- Unfortunately, some manufacturers improvise dosimetry to market their product - prevalent for brachytherapy

Manufacturers

- Manufactures put a machine out before there is a standard
- Clinics find it useful and then after it works, clinics find out they have variation in results although they think they are giving the same dose; there is a need for a standard.

NIST

- Problem is that NIST, who is responsible for standards, takes a long time to establish standards. They have to make sure it is done right.
- ADCLs can perform the research more quickly since we have graduate students

Standards

- There is a proposal going through the AAPM that ADCLs be allowed to establish interim standards until NIST can do it.
- HDR standards are an example when NIST doesn’t have a standard and an interim standard set up by ADCL

15 years of Measurement

- The classic Nucletron source has been measured over a 15 year period.
- Each individual source has been compared to the other via 3 well chambers
- The value for the well chamber after measurement by the 7 distance technique is always within $\pm$ 0.5%

Average for Source Comparisons

Type of Source / Manufacturer	Average Percent Difference to Old Nucletron Source
New Nucletron	0.40%
Varisource	-0.52%
GammaMed	0.75%

Conclusion HDR Sources

- The result of the uncertainty analysis for HDR calibrations is 2.14% at k=2 (2σ=2.14%)
- The VariSource, redesigned MicroSelectron source and GammaMed source fall within the expressed uncertainty of the 7-distance calibration
- Actually the measured Air Kerma Strengths of all sources are within 1% of each other
- The new sources and the 1991 standard calibrations all lie within the 2σ uncertainty of the measurement

Address 2 Questions for Medical Dosimetry

- 1. What happens when manufacturers improvise for Standards? A and B
  - Errors! NIST, ADCLs, AAPM should insist on a standard
- 2. What happens when there is a standard but it doesn't fully apply?
  - Apply standards with understanding.

Acknowledgements: Influential People

- John Cameron
- Herb Attix
- Paul De Luca

“If I have seen further than others, it is by standing upon the shoulders of giants” — Sir Isaac

John R. Cameron, Founder of Medical Physics at University of Wisconsin - TLD researcher

(1922 - 2005)

Accredited Dosimetry Calibration Laboratories

- NBS petitioned AAPM to create “Regional Calibration Laboratories” in 1975- In 1983 called ADCLs.
- NBS acknowledges traceability to primary standards (Proficiency tests)
- Agreement for Proficiency tests and round robins $\leq 0.5\%$
- UWADCL founded 1981 by LAD
- Now 3 Labs: UW, M.D. Anderson and K&S

AAPM - ADCL Program

- **The ADCLs have proven track records of providing precise calibrations of equipment for Therapy and Diagnostic applications**
- **Safety and treatment delivery or imaging is improved because of ADCL calibration and research.**

Herb and Paul Members of UWADCL Advisory Board

Establishing Standards

- 1. What happens when manufacturers improvise for Standards?
  - There is a need to have traceability delivered by the Accredited Dosimetry Calibration Laboratories
  - Hospital Physicists generally have requests
  - Users must insist on traceable standards from NIST through the ADCLs

Manufacturers improvise

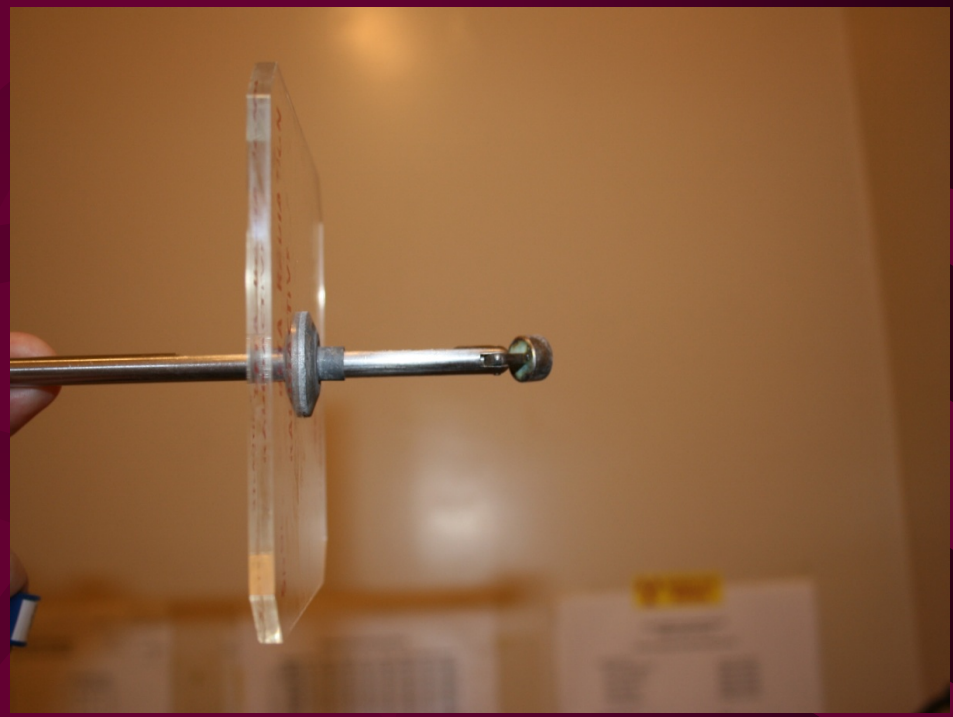
Case A. Sr-90 Ophthalmic Applicators 1983-2001

- **Sr-90 applicators introduced in 1950. Plane or concave. 28 year half life**
- **Typical 8mm diameter with a beta shield**
- **Extremely high dose rate**
- **Calibrated by each mfr *wrt* Bragg-Gray theory**
- **Bizarre units like “reps, beta-Roentgens”**
- **Hospitals asked UW ADCL accuracy of dose**

Pterygium and Sr-90 Beta Applicators

- **“Wing-like” growth in conjunctiva**
- **Requires surgery to remove**
- **Surgery fails 90% of time**
- **One dose with Sr-90 prevents recurrence in roughly 90% of patients treated**

Ophthalmic Beta Therapy Source



How to measure?

- At my prompting, Steve Goetsch, contacted Chris Soares, NIST
- One Chicago hospital had an Amersham Model SIA-20 applicator calibrated at NBS: calibrations differed by 38%. Each lab stood by their calibration!

How to measure?

- Sr-90 sources had only been inter-compared IN AIR at distances of 20 to 30cm
- Desired “dose rate” is IN CONTACT with Sr-90 on surface of silver matrix
- Chris Soares developed an extrapolation chamber for calibration.

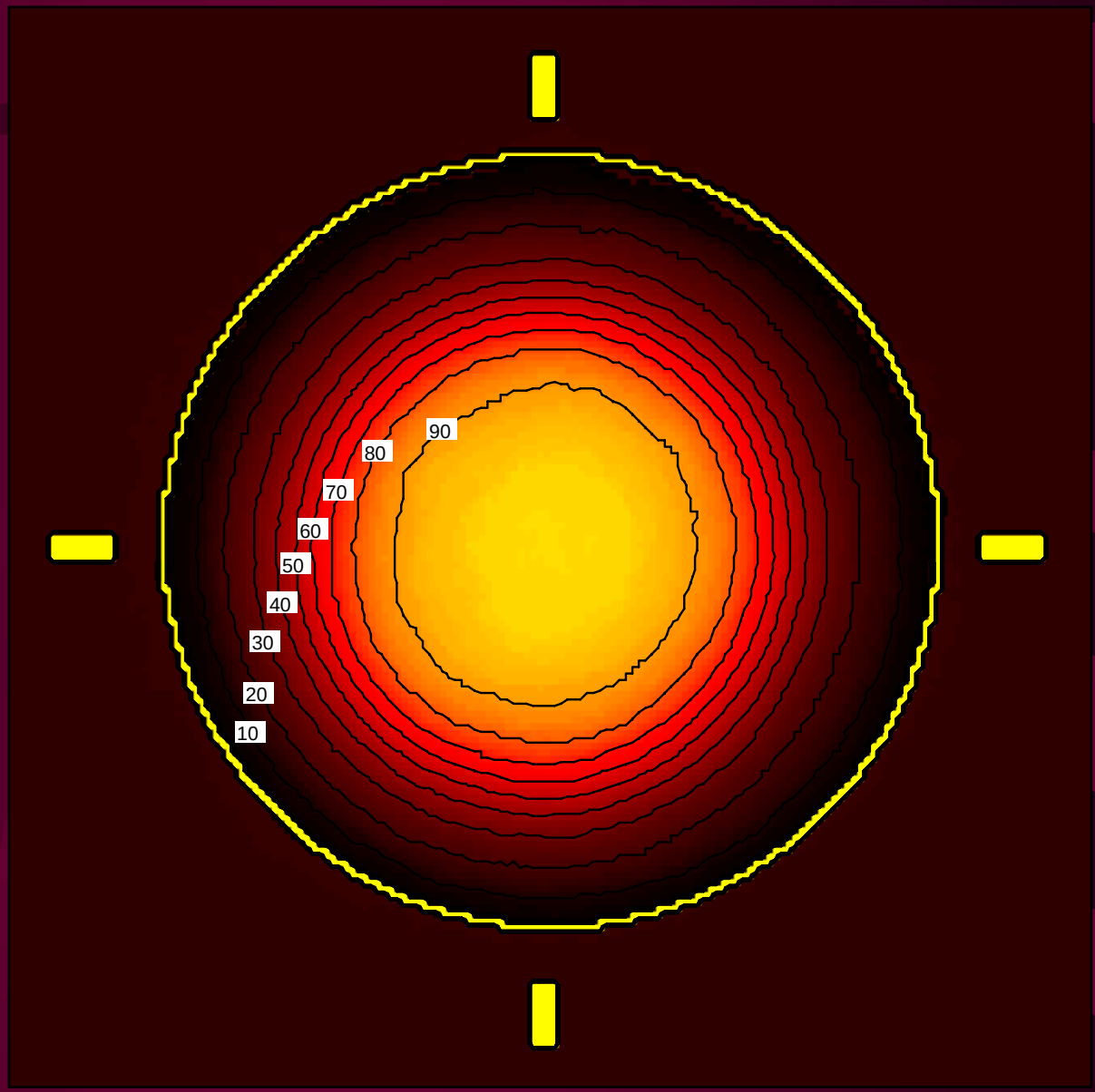
Present status

- Routine ADCL calibrations from UW ADCL using radiochromic film began in 1996.
- NIST quotes uncertainty of 7 %
- Calibration disagreement (old versus new) average 30 %.

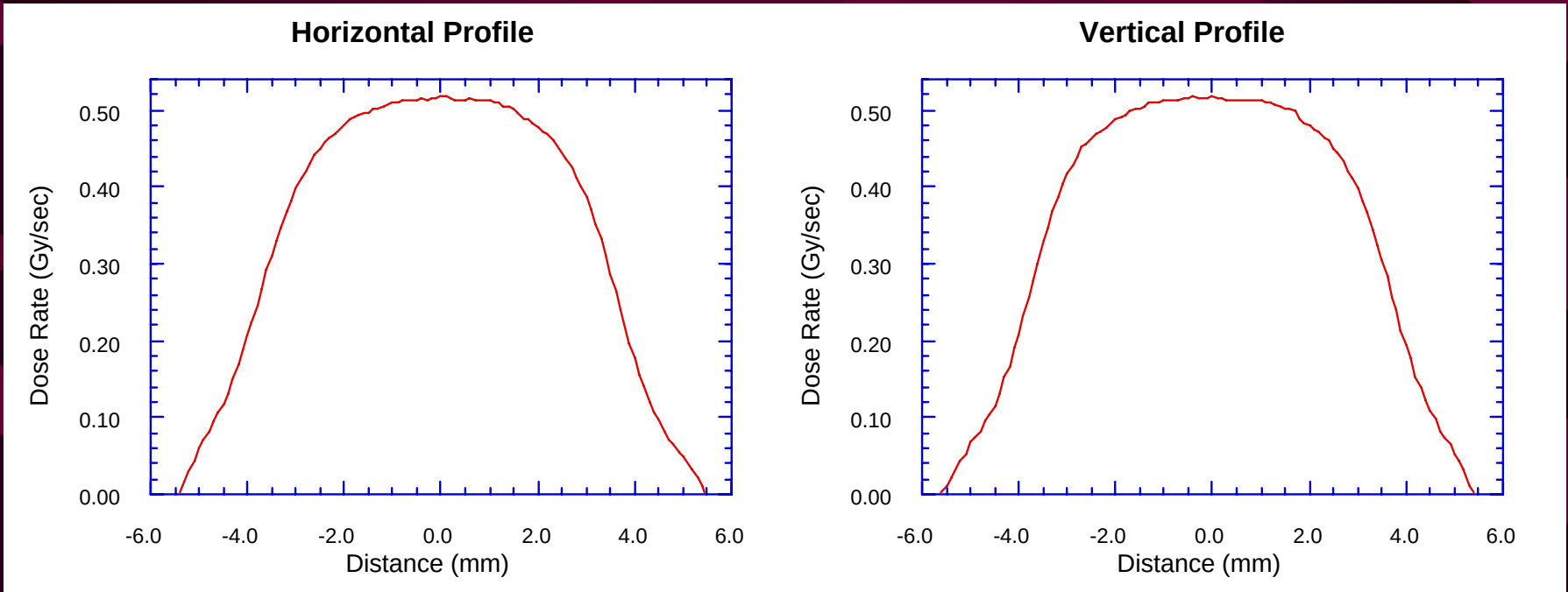
Sr-90 Ophthalmic Applicator Calibration with Radiochromic Film

NIST traceable determination of the absorbed dose to water rate in the central 4 mm of the applicator including color enhanced contour plots and two dimensional dose profiles.

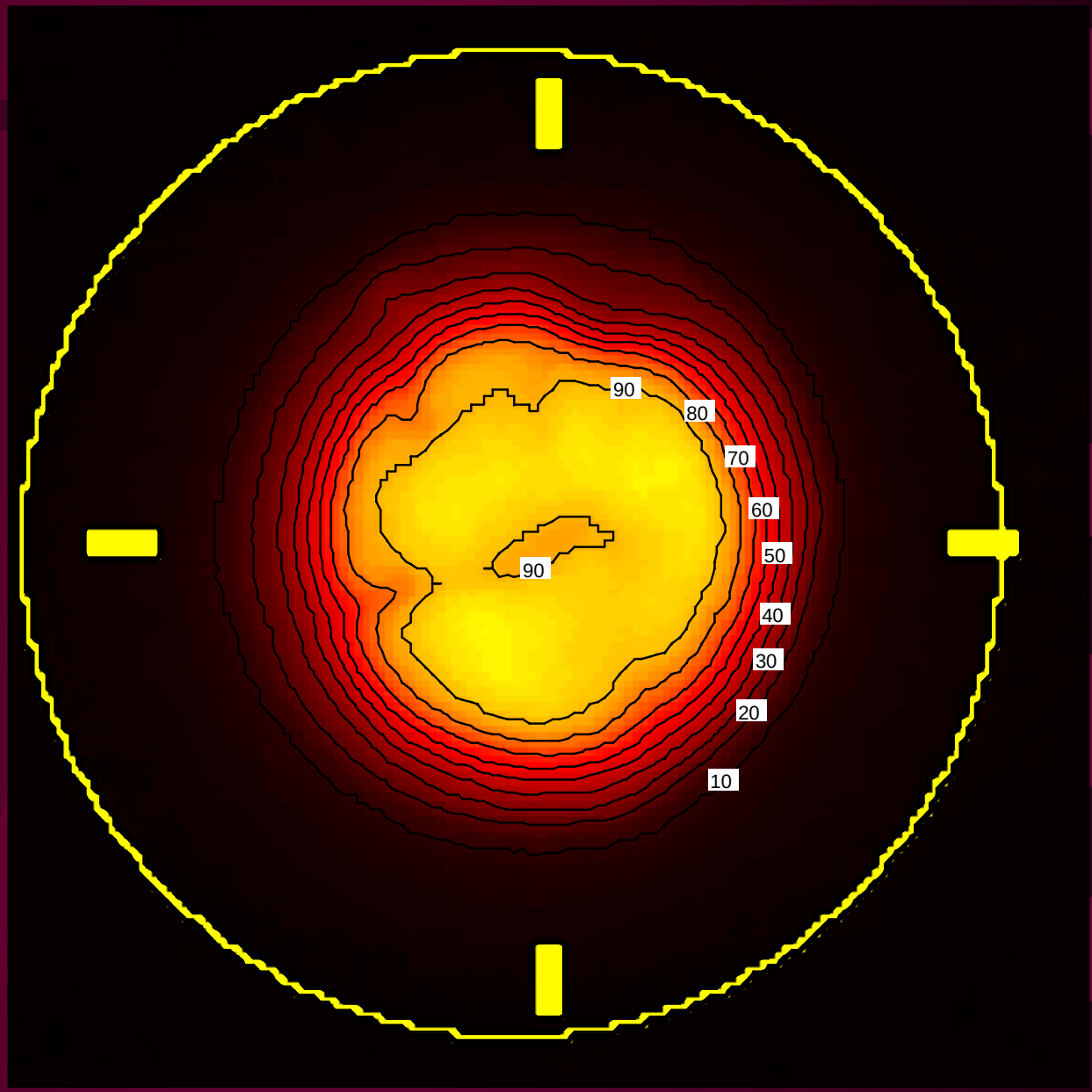
Example of a color enhanced contour plot of a uniform Sr-90 ophthalmic applicator. The dose weighted isocenter is equidistant from the hash marks. The outer circle represents the source physical diameter.



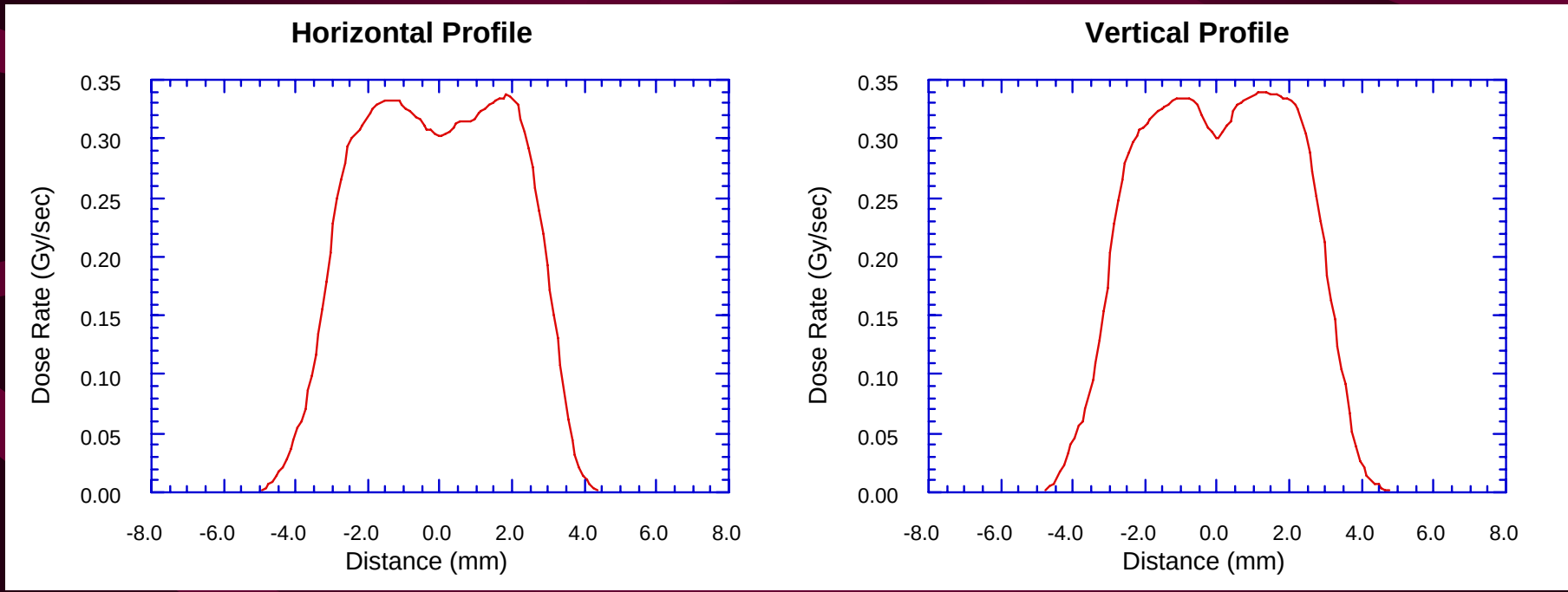
2-Dimensional dose profiles for a uniform source.



Example of a color enhanced contour plot of a *non*-uniform Sr-90 ophthalmic applicator. Notice the offset or shift of the dose weighted isocenter from the physical source center, and the non-uniform dose distribution.

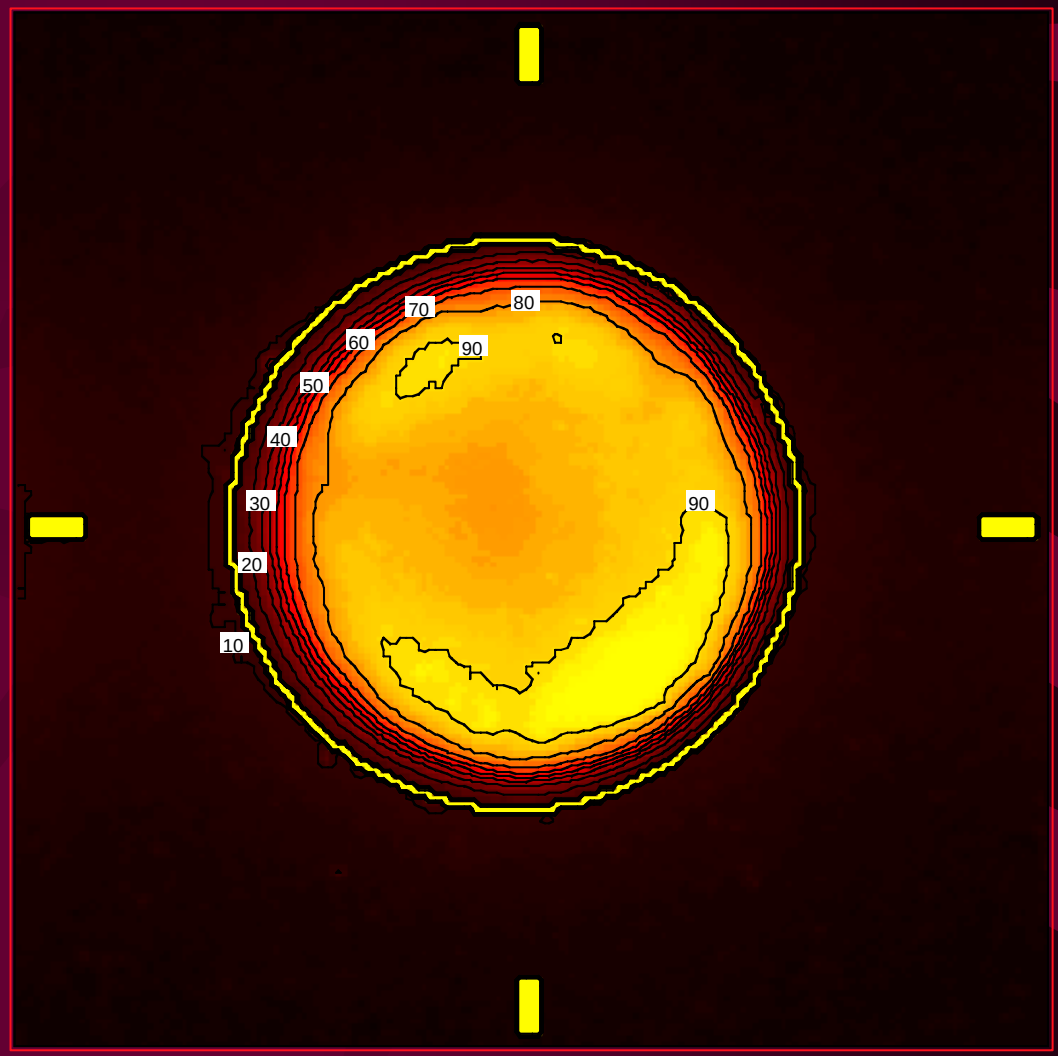


2-Dimensional dose profiles for a *non*-uniform source.

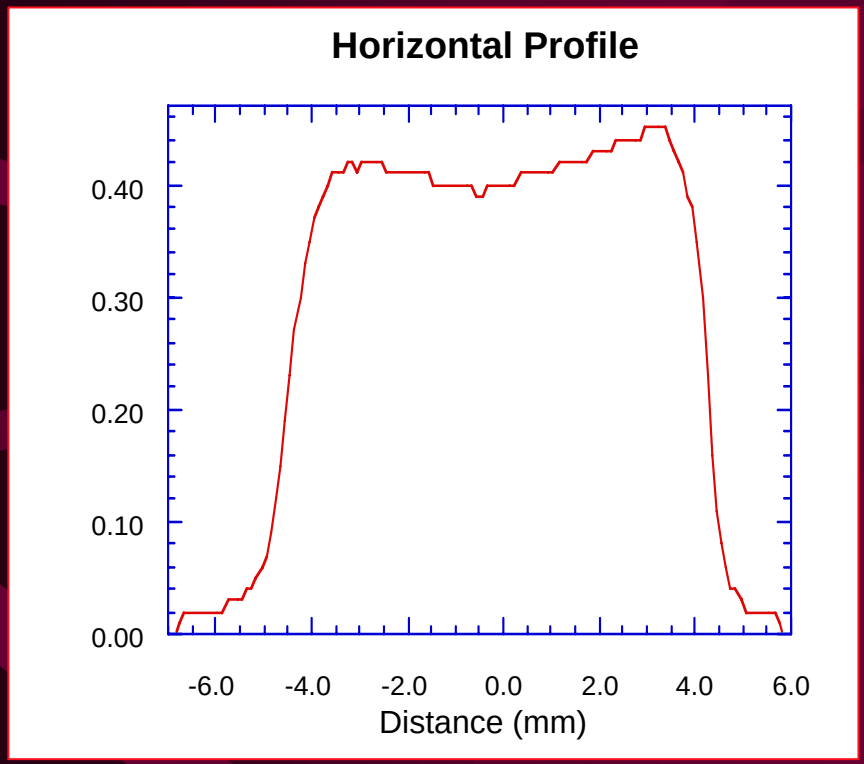


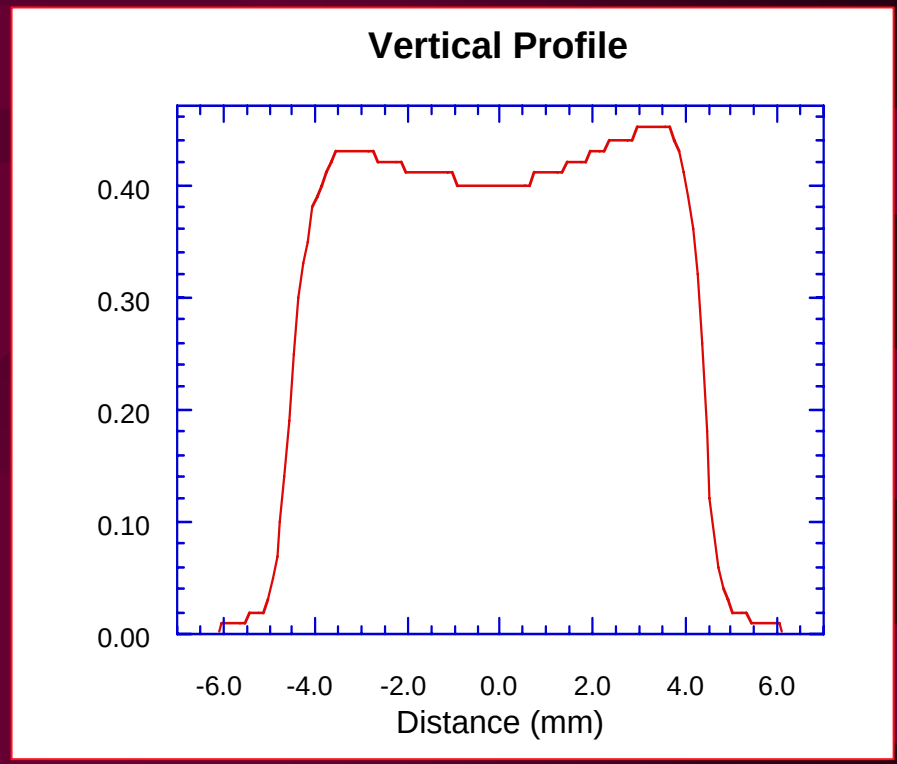
Skewed Dose Sr-90 Source

Example of a color enhanced contour plot of a *skewed*-Sr-90 ophthalmic applicator. Notice the offset or shift of the dose weighted isocenter from the physical source center, and the non-uniform dose distribution.



2-Dimensional dose profiles for a *skewed* source.

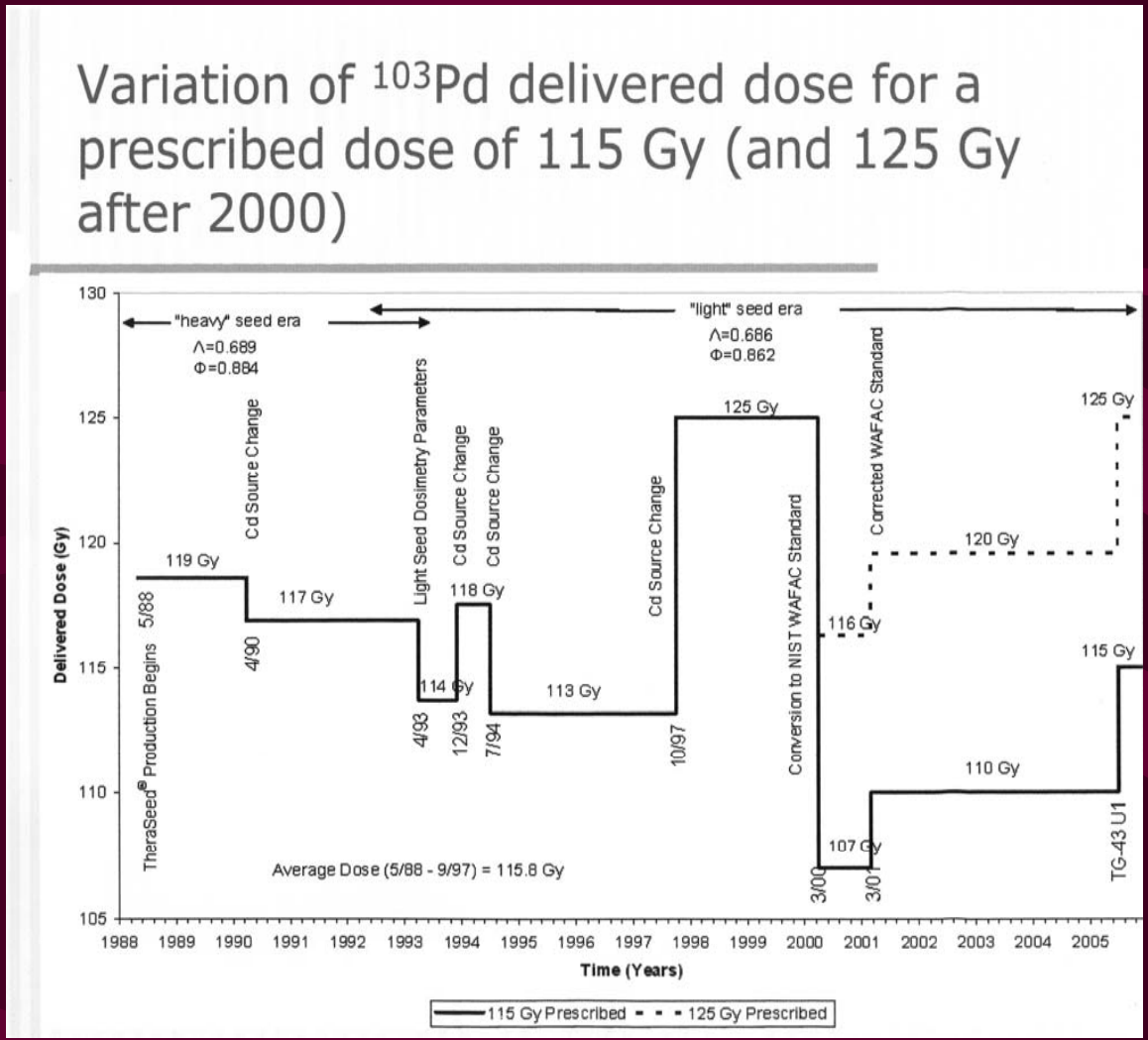




Part B Palladium-103 seeds for brachytherapy 1987-2001

- Palladium 103 introduced in 1987 with NO NIST standard
- Pd-103 has very short half-life (17.0 d) so NIST traceable ^{109}Cd source (half-life of 463.2d) was used as a reference source for 12 years, then replaced in 1997
- However, self-shielding of the source encapsulation was different between these two isotopes
- This resulted in a sudden 9% shift in calibration by letter to users in 1997

Analysis of calibration variation over the years by Wayne Butler, Wheeling Hospital



Brachytherapy struggles to catch up

- AAPM issued TG43 brachytherapy protocol in 1995
- AAPM issues Ad Hoc Committee report in 1998 recommending at least 2 external evaluations BEFORE new radioactive seeds distributed
- NIST developed the WAFAC

Catch up

- NIST releases Pd-103 national standard in 1999
- AAPM recommended in 2000 that all vendor calibrations be traceable to NIST WAFAC
- DeWerd, et al published ADCL recommendations for mfrs and users in 2004 (13 I-125 and 7 Pd-103 seeds by that time)

Present Status

- Pd-103 seed calibrations transferred to ADCL and there is an ongoing calibration check.
- Well chamber calibrations available from UW, MD Anderson and K&S ADCLs
- Traceable to primary national standards.

Conclusion for Question 1

- There can be significant errors
- If traceable to NIST, even if wrong, everyone is consistent if traceable standard- at least traceable through ADCL, interim standard
- NIST and ADCLs need to insist upon standards.
- Manufacturers try hard but they need to rely on NIST and ADCLs for standards

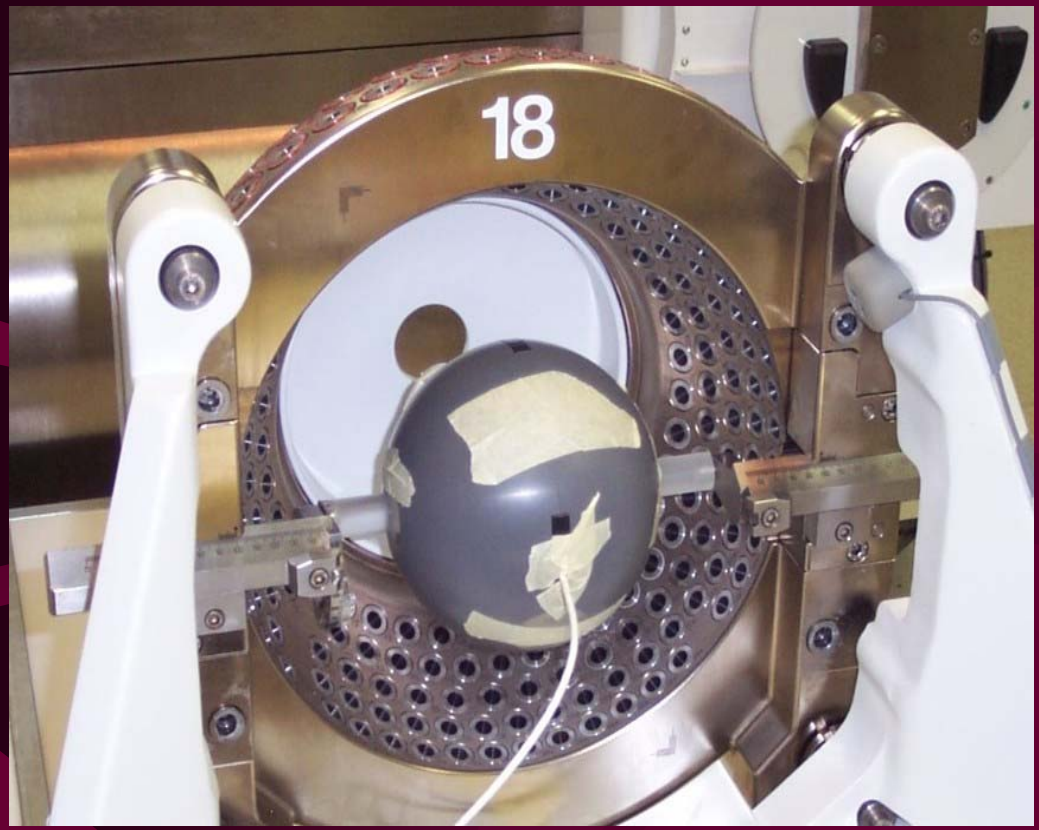
The need to use standards correctly

- 2. What happens when there is a standard but it doesn't fully apply?
  - Absorbed dose to water, air kerma standards modified to fit small fields
  - Modification may not be correct
  - Majority of Medical Radiation Therapy depends on Cobalt or Cesium standard.

Gamma Stereotactic Radiosurgery Calibration 1968 to Present

- Lars Leksell invented “Gamma Knife” using 201 cobalt sources with 18 mm, 14 mm, 8 mm and 4 mm helmets.
- Commercial Model U introduced in 1987
- Elekta Corporation invented entire dosimetry chain. Only one manufacturer.
- 16cm diameter “mystery plastic” sphere included
- Physicist must establish absorbed dose rate at center of sphere

Calibration Setup



- Calibrate with 18mm helmet
- Need SMALL ion chamber
- Apply Physics

How to relate to national calibration protocols?

- Gamma Stereotactic Radiosurgery devices are very different:
- 40cm SAD, with hemispherical or cylindrical convergence
- Maximum field size 18 (or 16) millimeters
- 3 dimensional - volume “field”
- Calibration depth fixed at 8cm

Apply Physics Principles

- Calculate absorbed dose rate using physics from old AAPM TG21 protocol
- Made measurements in-air and in-phantom using the physics principles in TG 21 so can move from standard to specialized application.

Calibration Agreement in-air and in PMMA phantom

Location	Media	Measured $\dot{D}_{\text{water}}$ $\frac{\text{Gy}}{\text{min}}$	% difference In-Air to PMMA
Unit A	In-Air	3.918	
	PMMA	3.904	0.37
Unit B	In-Air	2.636	
	PMMA	2.641	-0.18
Unit C	In-Air	3.105	
	PMMA	3.097	0.26
Unit D	In-Air	1.334	
	PMMA	1.334	-0.06

Comparison of 7 centers (Measured vs. TPS)

Location	Measured $\dot{D}_{\text{water}}$ $\frac{\text{Gy}}{\text{min}}$	TPS $\dot{D}_{\text{water}}$ $\frac{\text{Gy}}{\text{min}}$	% difference Measured to TPS
Unit A	3.918	3.828	2.3
Unit B	2.636	2.587	1.9
Unit C	3.105	3.059	1.5
Unit D	1.334	1.303	2.3
Unit E	2.224	2.159	2.9
Unit F	3.068	2.992	2.5
Unit G	2.853	2.796	2.0

New Unit - Perfexion

- Comparison of measurement with the treatment planning system up to 5 % different.
- Manufacturer saying it is basically the same as the old units.
- Just applying a standard without understanding is not appropriate.

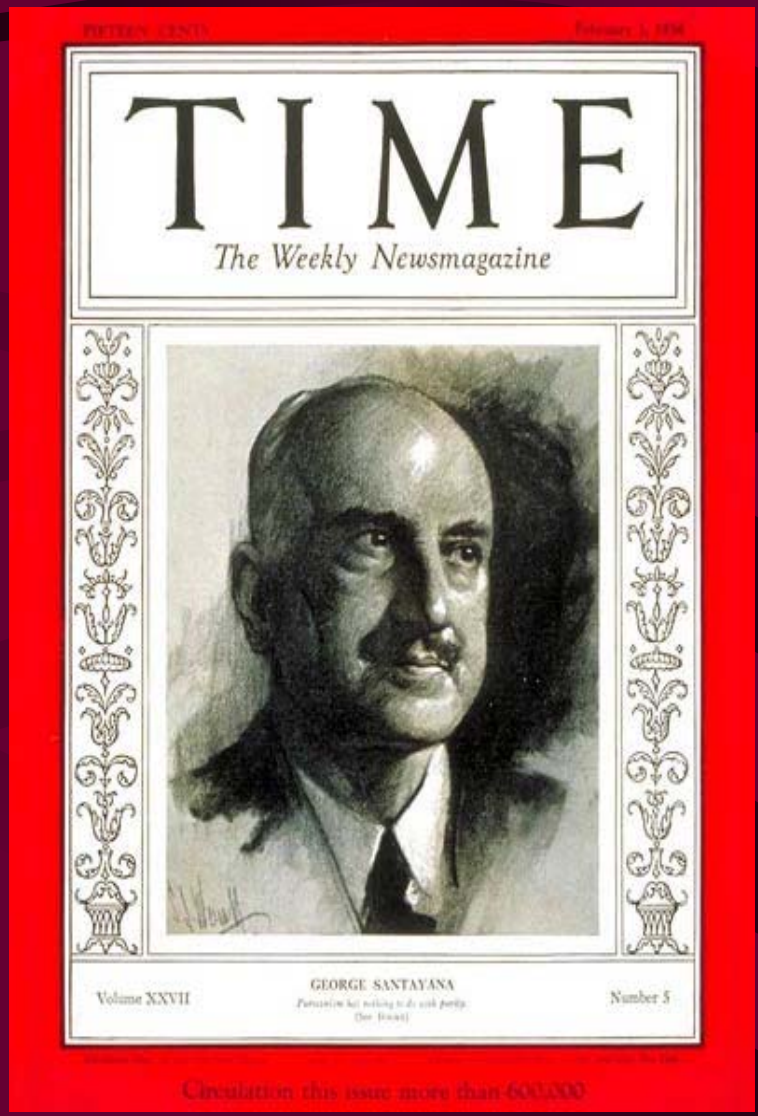
New AAPM Gamma Stereotactic Radiosurgery Task Group

- Chartered last summer by Therapy Physics Committee
- Steve Goetsch, Chair
- Will coordinate dosimetry w Jan Seuntjens Working Group
- Will re-write AAPM Report 54, but JUST for GSR units

Lesson to ponder

"Those who do not remember the past are condemned to repeat it."

George Santayana, Harvard Professor and poet



Conclusions

- **Fools rush in where angels fear to tread**
- **If you can't be right, at least be consistent**
- **NO manufacturer should EVER invent their own standards *("Don't try this at home")***
- **NIST needs more support**
- **ADCLs can play a vital role in resolving calibration problems**

Acknowledgements

- All of my graduate students
- All of the ADCL staff
- All of the ADCL customers