Commissioning a Linac: How hard could that be?

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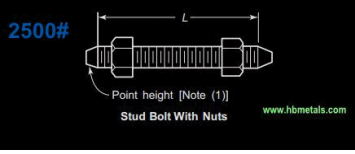
Landauer Medical Physics and Levine Cancer Institute

Disclosures

- I have no conflicts of interest to disclose. Believe me.
- I am employed by Landauer Medical Physics
  - LMP has a commissioning division that does not include me. I'm in the division that takes care of patients in clinics.
  - It has been about 5 years since I personally commissioned a new linac.
  - LMP, my employer, is paying my way to be here today.

Nuts and bolts

See the detailed talk in the Virtual Library:
http://www.aapm.org/education/VL/vl.asp?id=2404
(Think of this as the sequel.)



What we're going to chat about…

- Scope of commissioning
- Staffing the project
- "Precision creep"
- Equipment – especially detectors
- Edges, a deep dive
- IGRT and other localizations
- Documentation

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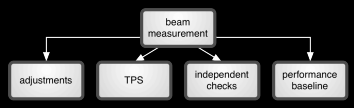
Scope

What you're trying to accomplish:

- Learn how your personal linac behaves
- Gather machine-specific beam data



Scope

Schools of thought:

- It beeps, we're good. Standard data has got to be safe and effective.
- The devil is in the details. Close only counts with horseshoes and hand grenades.

Scope

The quality of the commissioning work pays forward to every one of the ~3000* patients who will be treated with the linac.

* 300 patients/year for 10 years – your mileage may vary

Scope

The "Duke Effect" – a variant of Murphy's Law

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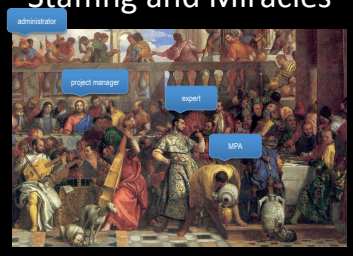
Staffing

- You may not be qualified to do this work.
- Qualified help is available.
- Qualified help might seem expensive.
- You'll be glad you insisted.

Staffing and Miracles



Paolo CALIARI, AKA VÉRONÈSE, Les Noces de Cana, 1563

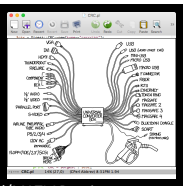
Staffing and Miracles

With 2.1 seconds remaining in overtime, defending national champion Duke trailed 103–102; Christian Laettner, "The Shot," March 28, 1992

Staffing

- But seriously, commissioning is a specialty.
- Any one of us, with enough tech support and manuals, can plug the parts together and make some lines on the screen.
- Fractions of percents matter very much in this work.

Staffing



How qualified help might can help:

- Experience operating a linac flat-out
- Understanding how to operate the scanner
- Knowledge of detectors
- Experience with efficient work sequencing
- Pre-existing spreadsheets and homebrew perl/MATLAB scripts
- A box of parts and tools, souvenirs of prior surprises
- An "educated eye" on setups and results – "that's odd"
- Someone to meet the pizza delivery guy over in the main lobby because Papa John has no idea where the cancer center is going to be.

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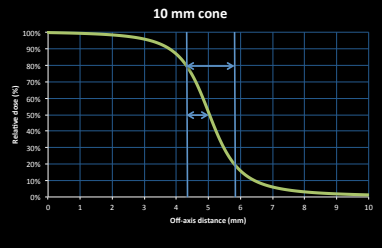
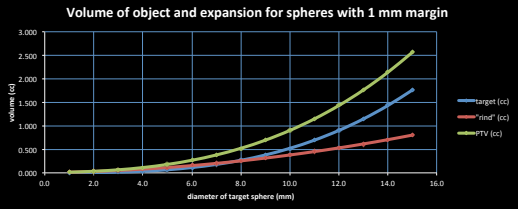
Precision creep

- Small is the new typical
- Less than 15 mm aperture is small, and less than 10 mm is *really* small.
- Small IMRT/VMAT segments don't get a free pass

Precision creep



Precision creep



Precision creep

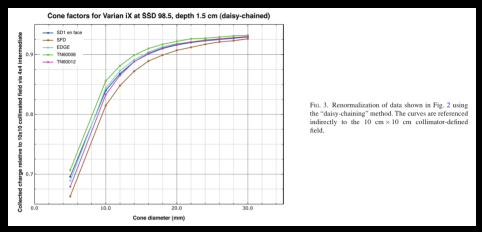


FIG. 3. Renormalization of data shown in Fig. 2 using the "daisy-chaining" method. The curves are referenced indirectly to the 10 cm × 10 cm collimator-defined field.

Dieterich and Sherouse, Medical Physics, Vol. 38, No. 7, July 2011

Precision creep

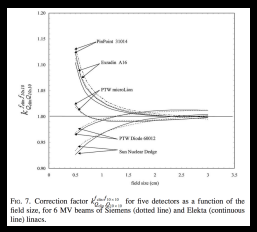
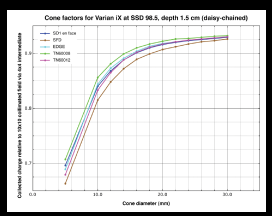
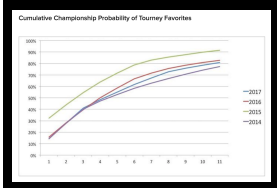


FIG. 7. Correction factor $k_{Q_{msr},Q_0}^{f_{msr},f_0}$ for five detectors as a function of the field size, for 6 MV beams of Siemens (dotted line) and Elekta (continuous line) linacs.

Francescon et al, Medical Physics, Vol. 38, No. 12, December 2011

By the way…





Dieterich and Sherouse, Medical Physics, Vol. 38, No. 7, July 2011

http://www.cbssports.com/college-basketball/news/bracket-voodoo-most-likely-teams-to-win-the-2017-ncaa-tournament/

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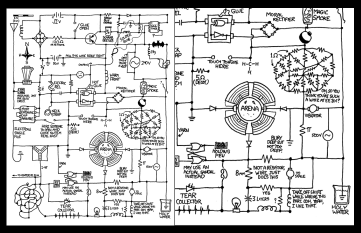
Equipment

- The time to get everything you need is when the linac is *ordered*.
- Short list, not complete:
  - 3D scanner, detectors and holders
    - Parallel plate chamber, microdetector, "small" chamber(s)
    - High capacity water tap and drain, cables permanently in the wall
    - Conditioned power
  - 1D tank, 2 calibrated electrometers, 2 calibrated chambers, lead sheet, certified thermometer and barometer for TG-51
  - Stack of water-equivalent plastic phantom, anthropomorphic phantoms for intended services
  - High quality levels, 3 point leveling plate
  - Mechanical QA device
  - "Morning check" devices for output, beam steering, and imaging mechanicals
  - Detector array for physics QA and associated phantoms
  - Imaging phantoms for physics QA
  - Analysis software and robust computer(s)
    - Admin rights
    - Network connectivity

Equipment and Miracles



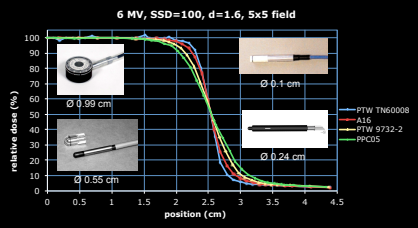
xkcd.com

Equipment

With regard to the 3D scanner and detectors:

- AAPM Report 106 (TG-106) is an excellent reference
- AAPM Report 155 (TG-155) will be another useful reference, probably
- QA of the devices is on you
- Redundant and/or overlapping measurements with different detectors are useful

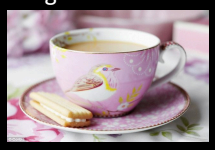
Equipment



Equipment

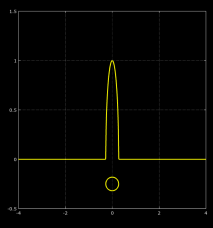
Remain calm. I'm about to use scary signal processing words. Please remain calm. Here's a soothing list by way of fair warning:

- Impulse response
- Signal
- Convolution
- Response



http://www.dailymail.co.uk/sciencetech/article-2337545/An-end-storm-teacup-British-scientists-work-make-perfect-cup-tea.html

Equipment



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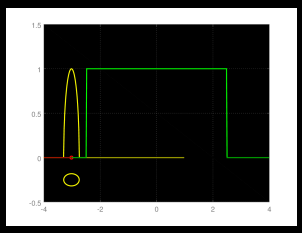

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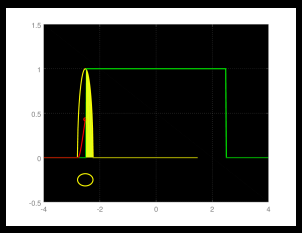

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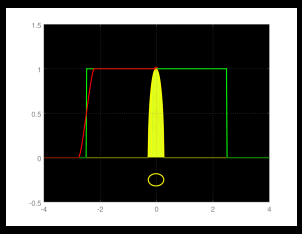

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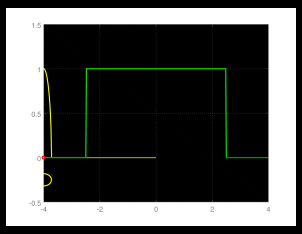

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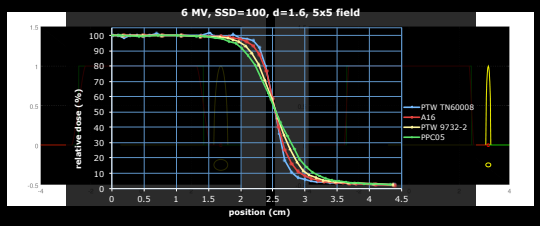

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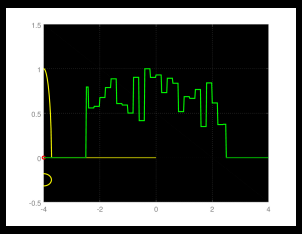

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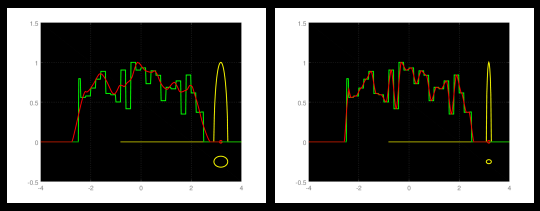

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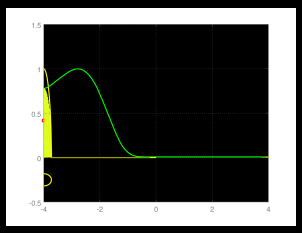

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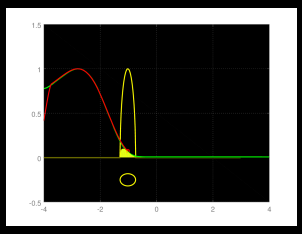

Equipment

http://pixyink.com/free-lunch-tomorrow-funny-metal-novelty-sign.html

Detectors - Some things to know

- Diodes
  - Can have temperature dependence
  - Can have (instantaneous) dose rate dependence
  - Can get torn up pretty quickly by irradiation, especially particles
  - Almost certainly have directional dependence
- Microchambers
  - Low signal can mean noise problems
  - At very small scale the impulse response can be problematically asymmetric
  - At least one model has a metal central electrode that causes problems for very small fields
  - Extracameral signal (stem effect) is a thing

Detectors - Some things to know (cont.)

- PPCs
  - Designs vary significantly – understand your trade-offs
  - Water pressure can cause volume (sensitivity) change
  - Waterproof, water-resistant, cap or no cap; tricky business
  - For very small plate gap a lower bias is appropriate, like maybe 150V

Detectors - Some things to know (cont.)

- Scintillator (W1)
  - There's rumor going around that some very capable people can't make them work reliably. Are you the lucky one?
  - Requires specific electrometer – 2 channel, high bias
  - User community still small
- Diamond
  - Still expensive
  - User community still small

Detectors - Some things to know (cont.)

- EBT
  - The high spatial resolution, 3% dose standard in expert hands
- OSLD
  - If you loved TLD you'll swoon over OSLD
- Gel
  - Same advantages and challenges as EBT, but in 3D mucous form. Still not prime time. Call me. Mean it.

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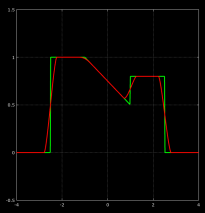
Edges

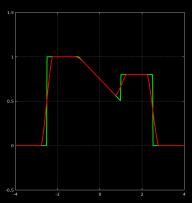


Edges

This gets tricky – what is the effect of poorly-measured edges on your treatment planning accuracy?

Illustration by John Tenniel

Edges



1. Put this measurement in your planning system's physics space.
2. Tune your model to produce a best fit.
3. Henceforth, every calculation will have a detector blur baked in.

Edges

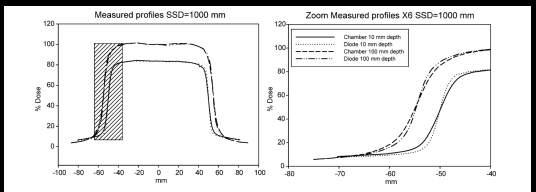


Fig. 1. Measurement of a profile with a PFD^{3G} Scanditronix diode and a PTW-32001 ionisation chamber. The measurements were performed with both detectors at 10 and 100 mm depth on a 6 MV beam from a Saturno 43 linac with a 10 cm×10 cm field size. The rectangle indicates the region enlarged.

F. García-Vicente et al., Radiotherapy and Oncology 74 (2005) 315–322

Edges

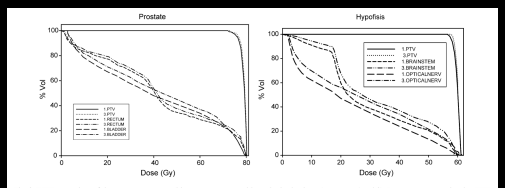


Fig. 3. DVH comparison of the treatments computed in prostate cancer and hypophysis chordoma (treatments 1 and 3). In prostate case, notice that PTV coverage is almost identical but OAR are more irradiated in treatment 3 at any dose level, specially at dose levels above 40 Gy. In hypophysis chordoma case, notice that PTV coverage is almost identical, but sensitive structures are more irradiated at any dose level for treatment 3. The structure labelled as 6+9 represents the sum of the two optic nerves.

F. García-Vicente et al., Radiotherapy and Oncology 74 (2005) 315–322

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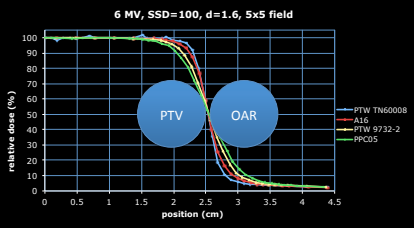

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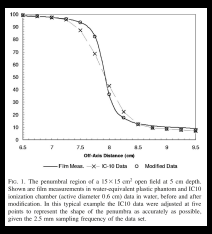

FIG. 1. The penumbral region of a 15×15 cm^2 open field at 5 cm depth. Shown are film measurements in water-equivalent plastic phantom and IC10 ionization chamber (active diameter 0.6 cm) data in water, before and after modification. In this typical example the IC10 data were adjusted at five points to represent the shape of the penumbra as accurately as possible, given the 2.5 mm sampling frequency of the data set.

Arnfield et al., Med. Phys. 32 (1), January 2005, pp. 12-19

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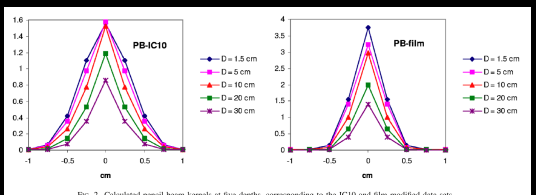

FIG. 2. Calculated pencil beam kernels at five depths, corresponding to the IC10 and film-modified data sets.

Arnfield et al., Med. Phys. 32 (1), January 2005, pp. 12-19

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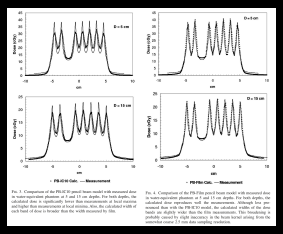

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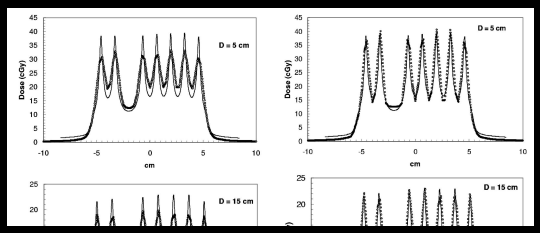

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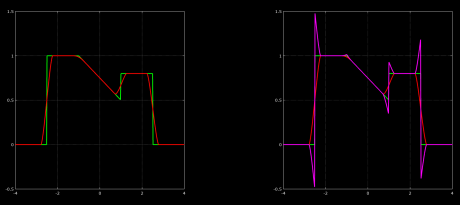

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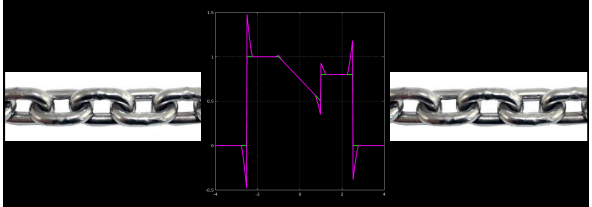

Edges

VARIAN medical systems

Clinical perspectives | Varian Photon Beam Source Model

USING VARIAN PHOTON BEAM SOURCE MODEL FOR DOSE CALCULATION OF SMALL FIELDS

Tuomas Torsti, Laura Korhonen, Viljo Petäjä
Varian Medical Systems Finland Oy, Paciuksenkatu 21, FIN-00270 Helsinki, Finland (Dated: September 2013)

RAD 1093A

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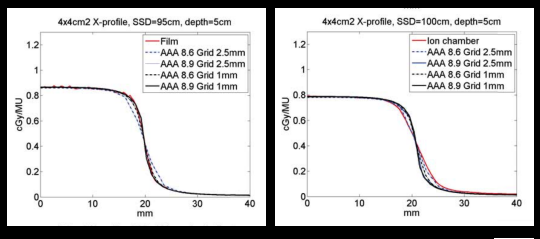

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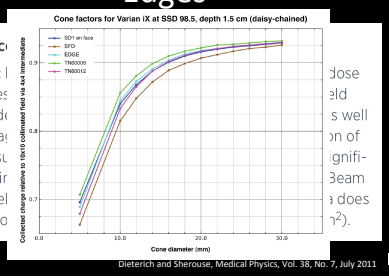

Dieterich and Sherouse, Medical Physics, Vol. 38, No. 7, July 2011

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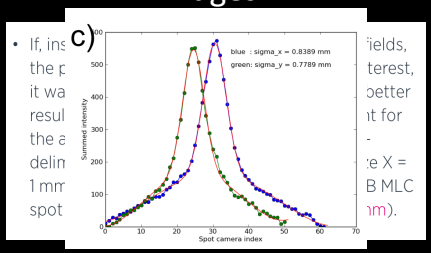

Sawkey, et al., http://radiotherapyresearchtools.com/montecarlo/presentations.html

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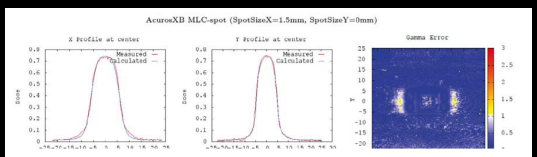


FIGURE 9: Illustrating the choice of the spot size for 10 x 10 mm² MLC-delimited field in a 60 x 60 mm² jaw-opening. All calculations performed with 11.0 versions and 1 mm calculation grid size.

An important point…

In model-driven dose calculations

- The parameters may have physical-sounding names but may not match measured factors.
- The point of the commissioning exercise is to make the calculation match your careful measurements.
- There is a dilemma when the only way to improve match in a particular experiment is to change inappropriate parameters.

An important point (cont)…

In Eclipse specifically

- Folks have observed large errors in absolute dose measured vs calculated for highly modulated small field RapidArc.
- The only relevant tunable parameters in RapidArc calculation are spot sizes, MLC transmission and DLG.
- Of those DLG is the only one that is somewhat specific to IMRT and is the strongest influencer of dose/MU. Hence tempting to tinker.
- Using DLG as a calibration factor for dose/MU potentially adversely affects all MLC modulation calculations.
- Changing DLG or spot size or leaf transmission changes RMS dose/MU. But so does tinkering the calibration reference. None of those can address a weak model.

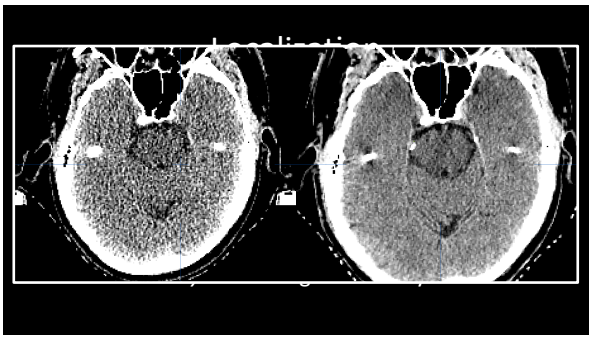
See for instance http://www.wienkav.at/kav/kfj/91033454/physik/eclipse/spotsize.htm and Med. Phys. 39 (10), October 2012, pp. 636-6371

An important point (repeated)…

- The point of the exercise is to make reliable measurements and then try to make the TPS compute absolute and relative doses that match measurement.
- If you commission with blurred data, then calculate with blur-poisoned models, then compare blurred calcs to additional blurred measurements you are at risk of a self-fulfilling elaborate fantasy.
- Model parameters are free parameters, not free lunch.

What we're going to chat about…

- Scope of commissioning
- Staffing the project
- "Precision creep"
- Equipment – especially detectors
- Edges, a deep dive
- IGRT and other localizations
- Documentation



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Documentation

Good "data hygiene" with scanning

- Make sure the clock is right on the scanning PC
- Capture tank orientation properly
- Name and label your detectors properly including orientation
- Make it clear if the point of measurement position is physically shifted
- Use a logical naming convention and storage hierarchy for data files. A table of contents earns points toward sainthood.
- Use the "comments," including "performed by"

Documentation

Full documentation of modeled parameters and validation results

- Print out every screen of physics workspace
- Print every spreadsheet and comparison
- Archive the data files from the TPS, your spreadsheets, and any validation measurements

Documentation

One-stop basics on cover page of data book

- Serial number of the machine
- Who did the work, when
- Which detectors were used for what
- Shifts or no shifts
- Calibration geometry – SSD, depth, field size, cGy/MU
- Known limitations of measurements and models

Documentation

I highly recommend an end-to-end test for every option.

- Every energy
- Every wedge in every orientation
- Every electron cone

Make a plan with each field variant, calculate QA plans, mode up and deliver each, do a QA measurement like IMRT. Save the plan for next time.

Things that we've chatted about…

- Scope of commissioning
- Staffing the project
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- Equipment – especially detectors
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