Clinical Implementation of the TG-51 Protocol

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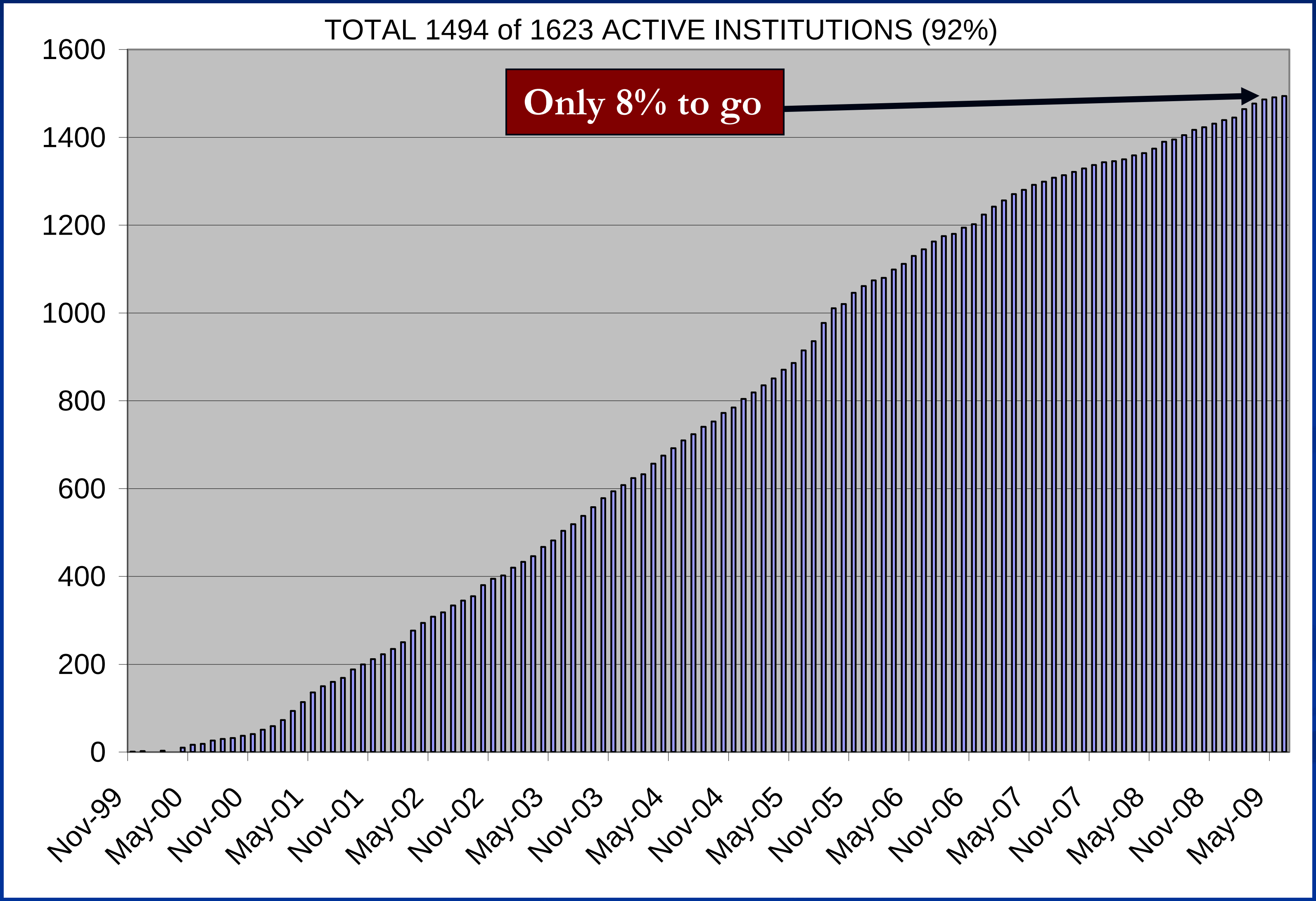
Current Implementation Status



What's the Holdup?

- New Air Kerma standard
  - TG-51 ≈ TG-21 depending on the chamber
- Time and effort required (everyone is very busy)
- New equipment requirements (chambers and phantoms)

Equipment Needs

- Properly sized "liquid" water phantom (30x30x30 cm^3)
  - Don't use the scanning tank
  - Adequate scatter conditions
  - Easy reproducible setup

Chamber Holder and Positioner

- Holder
  - Versatile to hold different chambers
  - Rigid (sensitive volume perpendicular to water surface)
  - No lateral displacement with depth
  - Accurate sub-millimeter placement at any depth
  - Verify accuracy prior to initial use
  - Remote electronic control is nice

Ion Chambers

- TG-51 ion chambers vs NEW ion chambers
  - Most are similar in design but now waterproof
    1. Wall material
    2. Radius of air cavity
    3. Presence of Al electrode
    4. Wall thickness
  - AAPM working group to determine the k_Q, $k_{R_{50}}$, k_{ecal} for new chambers

Ion Chambers - Photons

- ADCL calibrated 0.6 cm^3
  - Smaller volume chambers (> 0.1cm^3) okay if traceable to another 0.6 cm^3
  - **NO parallel plate chambers**
  - Waterproof (Go ahead and get one)
    - Most common: Exradin A12, PTW 30013
  - Non waterproof needs a 1mm PMMA sleeve that does not leak!

Ion Chambers - Electrons

- Parallel-plate or cylindrical chambers okay
  - Cylindrical for energies > 6 MeV per protocol ($R_{50} \geq 2.6$ cm)
  - Cylindrical = parallel plate if care in placement

	P11	PTW Roos	Welhoffer Roos	Marcus
5	1.008 (n=1)			
6	1.002 ± 0.1% (n=3)	1.000 (n=1)	0.996 ± 0.3% (n=2)	1.002 (n=1)
7	1.009 (n=1)			
8	1.006 (n=1)			
9	1.003 ± 0.1%(n=2)	0.998 (n=1)	0.996 (n=1)	1.000 (n=1)
12	1.000 ± 0.1%(n=3)	0.997 ± 0.2% (n=2)	0.996 (n=1)	1.004 ± 0.1% (n=3)
16	1.003 ± 0.2%(n=3)	0.998 ± 0.2 % (n=2)	1.001 ± 0.0% (n=2)	1.001 ± 0.2% (n=2)
20	1.000 ± 0.1%(n=4)	1.000 (n=1)	1.000 ± 0.1% (n=2)	1.000 (n=1)

- Always use a parallel plate chamber for 4 MeV beams

Caution as to where the inside surface of the front window is located

Ion Chambers - Electrons

- All chambers must have an ADCL calibration coefficient EXCEPT PARALLEL PLATE CHAMBERS
  - AAPM recommendation is to cross calibrate parallel plate chamber with cylindrical chamber in a high energy electron beam (worksheet C *a la* TG-39)
  - ADCL $N_{D,w}$ – **good** TG-51 k_{ecal} – **bad**
  - Use of ($N_{D,w} \bullet k_{ecal}$) results in an error of 1-2%

  ONE EXCEPTION – Exradin P11 seems to be okay

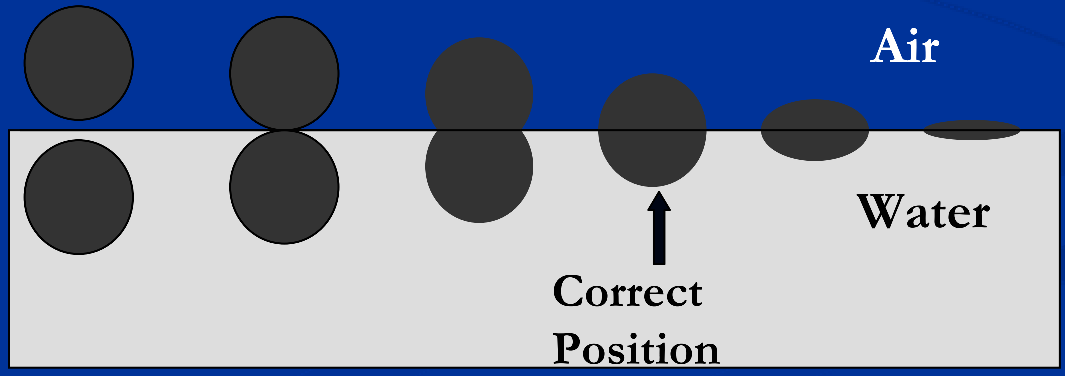
  - AAPM working group determining new k_{ecal} values

Measurement Techniques

- Accurate placement of cylindrical ion chamber at depth
  - Whether manual or electronic motor driven there must be a starting reference point

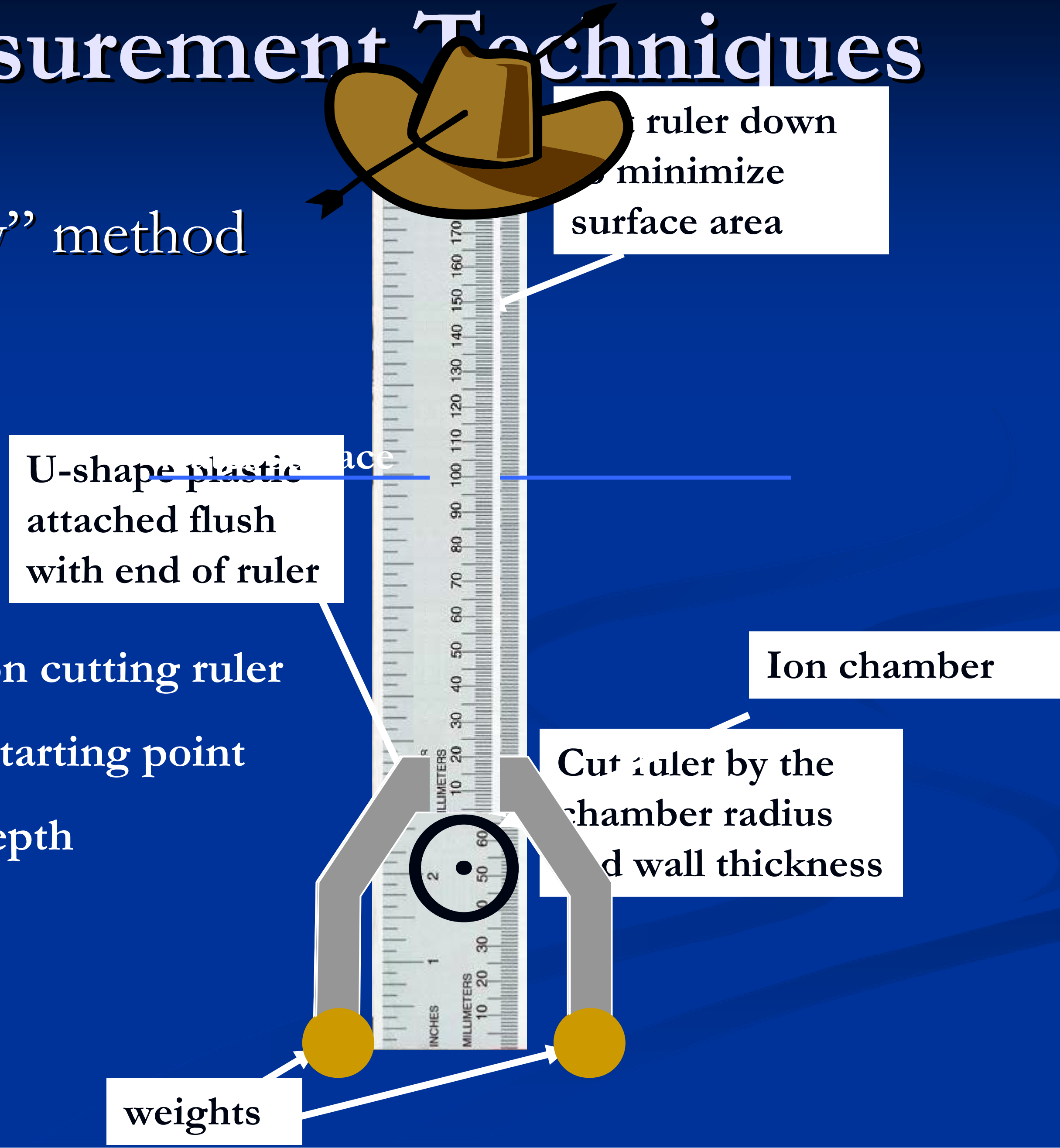
Two techniques

1. Surface method



Measurement Techniques

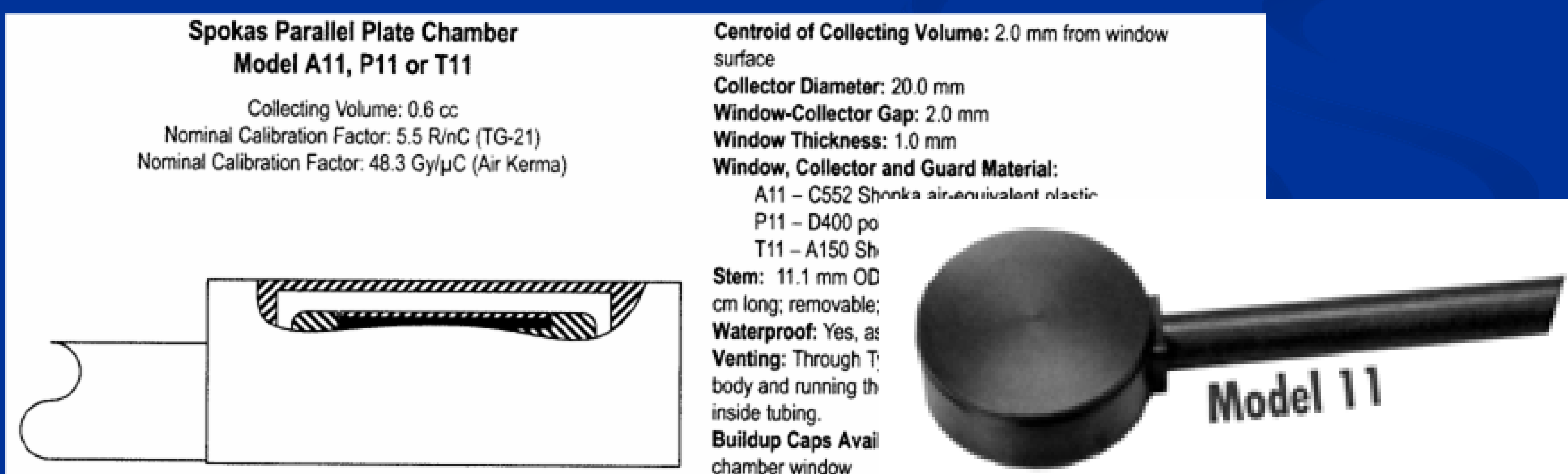
2. "Cowboy" method



- Accuracy depends on cutting ruler
- Used for reference starting point
- Periodic check of depth

Measurement Techniques

- Parallel plate ion chambers
  1. Flat surface makes it easy to measure depth
  2. Accurate ruler needed
  3. Must know where the inside surface of the front window is located



Effective Point of Measurement and Beam Quality

Photons		Electrons
10 cm	calibration depth	d_{ref}

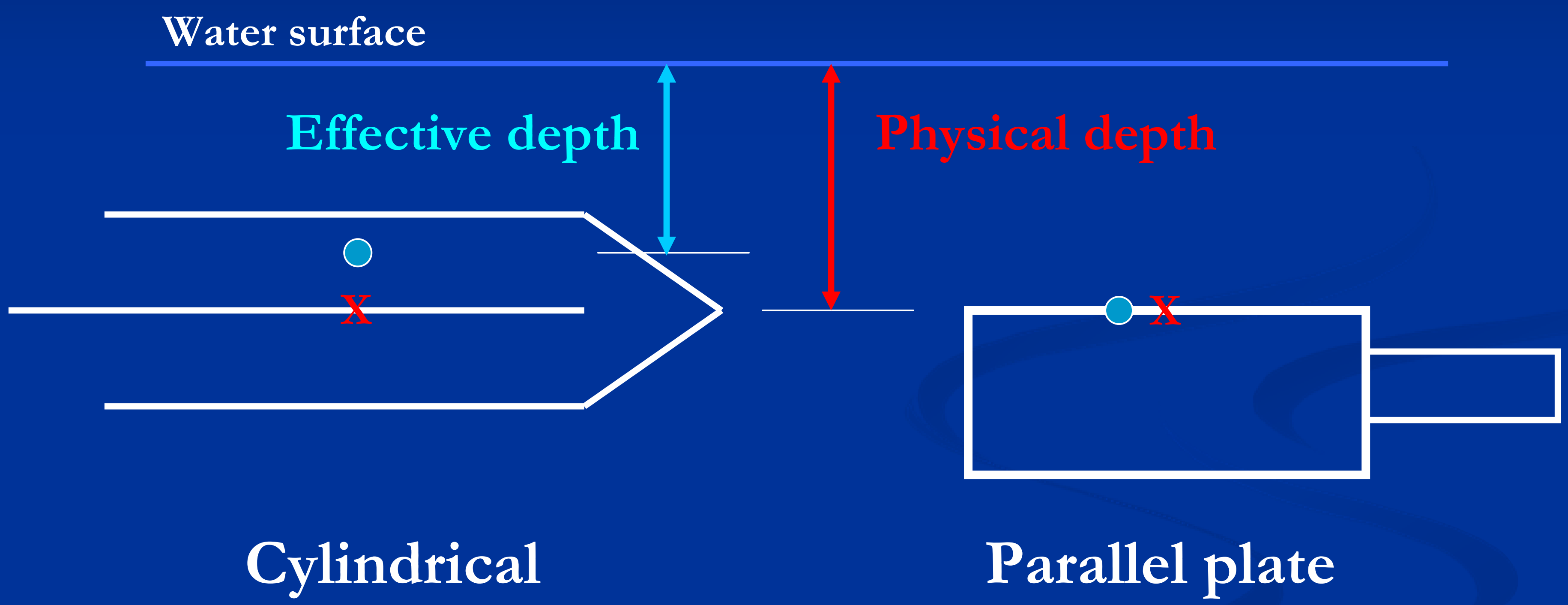
"point of measurement" is the center electrode of a cylindrical chamber and the front window of a parallel plate chamber

$\%dd(10)_x$	beam quality	R_{50}

Beam quality should always be measured using the "effective point of measurement"

$0.6r_{cav}$	shift to effective point	$0.5r_{cav}$
100 cm	beam quality SSD	100 cm
10×10 cm^2	field size	$\geq 10 \times 10$ cm^2

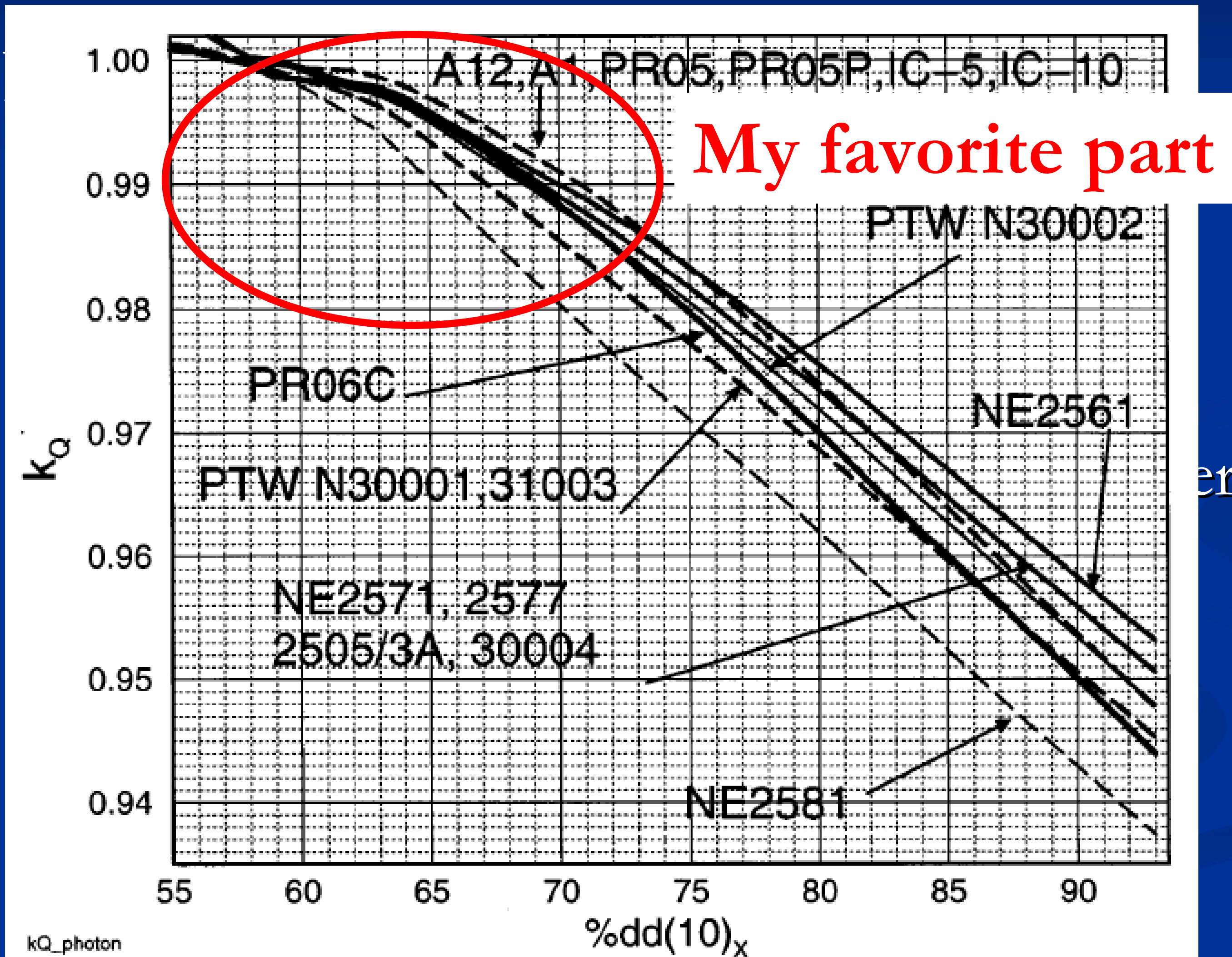
Effective Point of Measurement



“Get the lead out”

- Photon beams (≥ 10 MV)
  - Lead sheet 1 mm ± 0.2 mm
  - 30 or 50 cm from phantom surface
  - Determine $\%dd(10)_{Pb}$ (percent values not fractional)
    - $\%dd(10)_{x}$ should be within 2.5% of $\%dd(10)_{Pb}$
  - Interim alternative (No Lead Sheet) 
    - Measure %dd(10) without lead and use TG-51 eq 15
    - Introduces only 0.1-0.2% error in k_Q
    - Saves time and minimizes chance of damage to chamber

Beam Quality Conversion Factors



Beam C

- Electron
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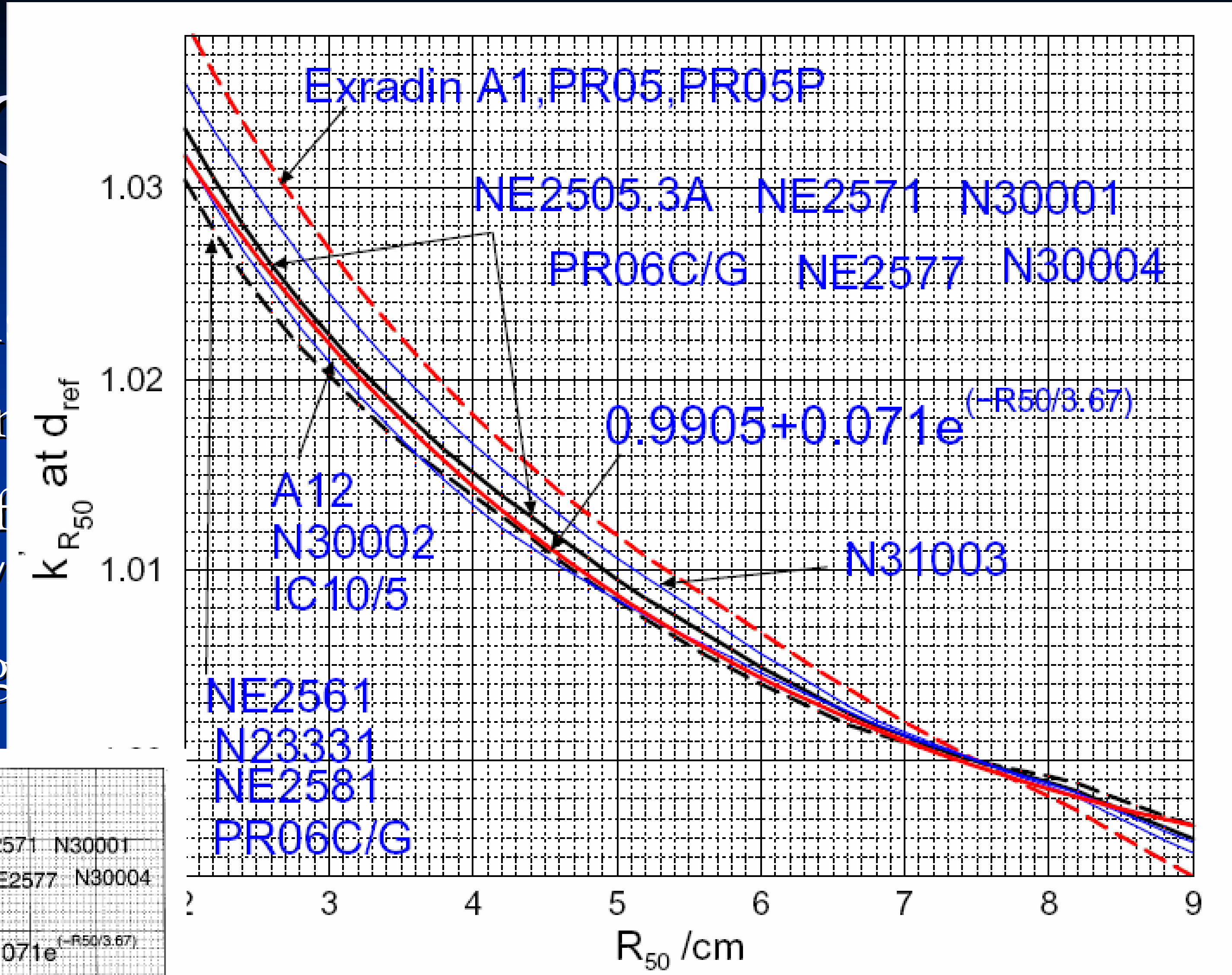
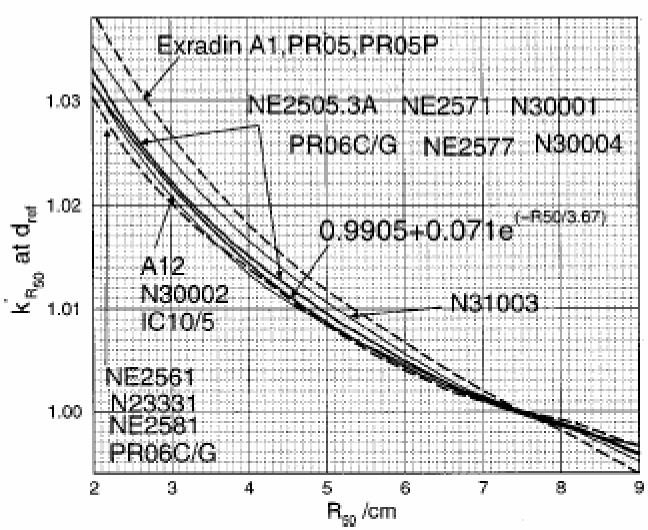
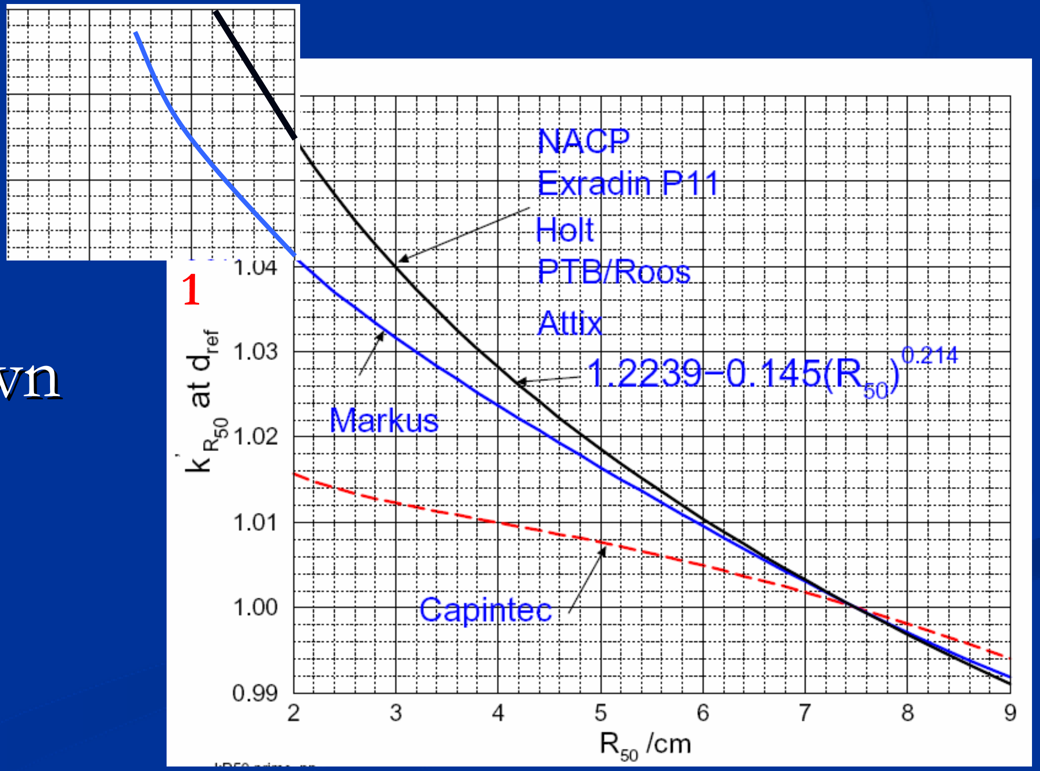




Beam Quality Conversion Factors

- Electrons – 4 MeV beams ($R_{50} < 2.0$ cm)
  - Only use parallel plate chamber
  - Need to extrapolate curve
  - Equation good down to 1 cm



Charge Measurements

$$M = P_{ion} \bullet P_{TP} \bullet P_{elec} \bullet P_{pol} \bullet M_{raw}$$

- P_{TP} correction factor
  - Mercury thermometers and barometers most accurate (but they are no longer kosher)
  - Hg barometers T&G corrections needed
  - Quality aneroid or digital can be used
    - Check annually against a standard
    - Digital purchased with a calibration does not mean accurate but rather what it read at certain pressures or temperatures

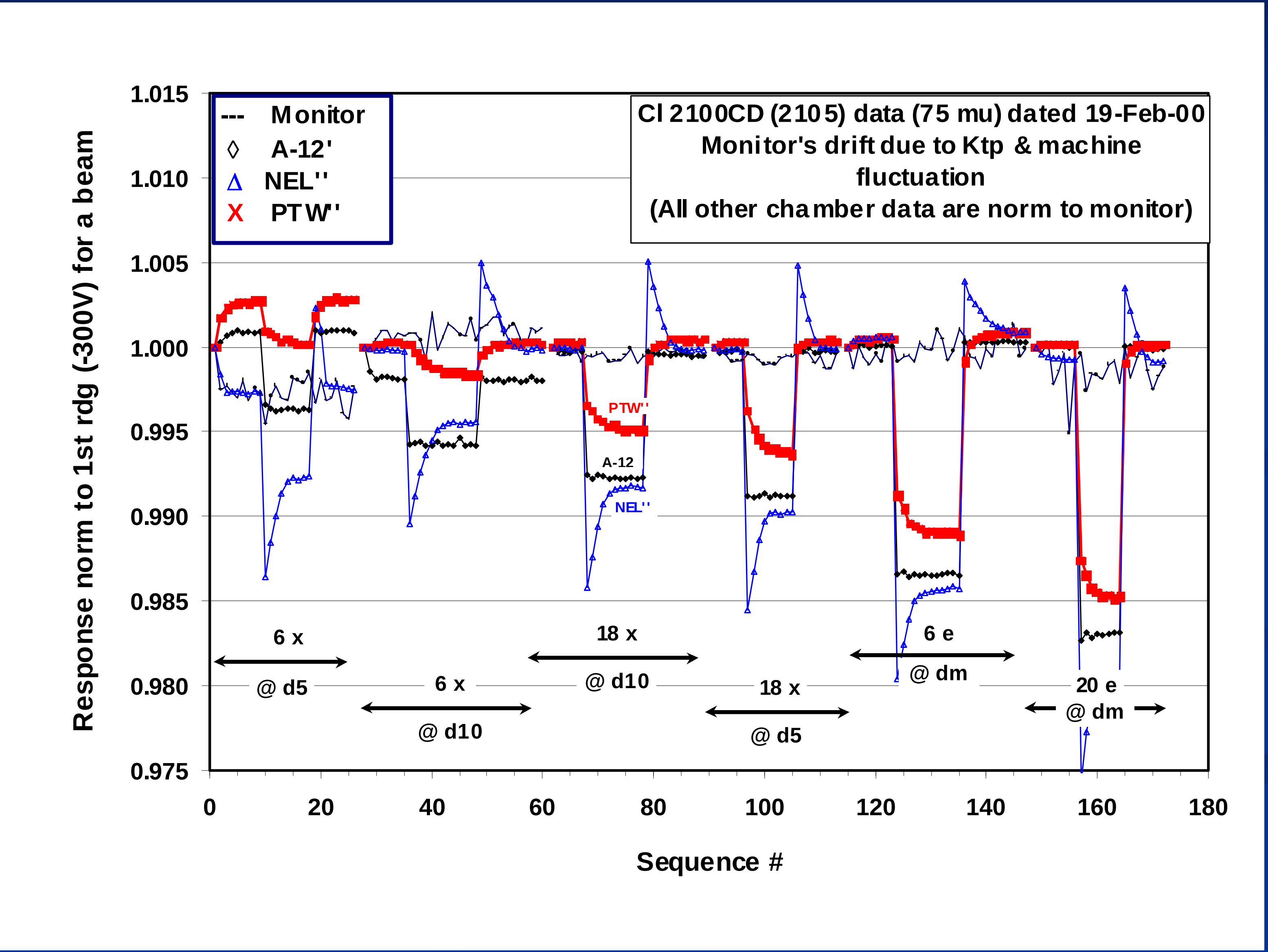
Charge Measurements

- P_{elec} correction factor
  - ADCL calibration for each scale needed
- P_{pol} correction factor
  - Change polarity requires irradiation (600 to 800 cGy) to re-equilibrate chamber
  - Use of eq 9 in TG-51 requires that you preserve the sign of the reading or

$$P_{pol} = \frac{\left|M_{raw}^{+}\right| + \left|M_{raw}^{-}\right|}{2\left|M_{raw}\right|}$$

  - P_{pol} should be near unity for cylindrical chambers and slightly larger correction for parallel plate chambers

Charge Measurements



Charge Measurements

- P_{ion} correction factor
  - Use eqs. 11 and 12 to calculate P_{ion}
  - As a check if using $V_H/V_L = 2$ (within 0.1%)
    - Pulsed beam : $P_{ion} = M_H/M_L$ if $M_H/M_L < 1.02$
    - Continuous beam : $P_{ion} = \{(M_H/M_L - 1)/3\}+1$
  - P_{ion} depends on chamber, beam energy, linac and beam modality
    - Tends to increase with energy

Charge Measurements

- Electron beam gradient (P_{gr}) correction factor
  - No correction for photon beams since correction included in k_Q
  - Only for cylindrical ion chambers
  - Ratio of readings at two depths

$$P_{gr} = \frac{M(d_{ref} + 0.5r_{cav})}{M_{raw}(d_{ref})}$$

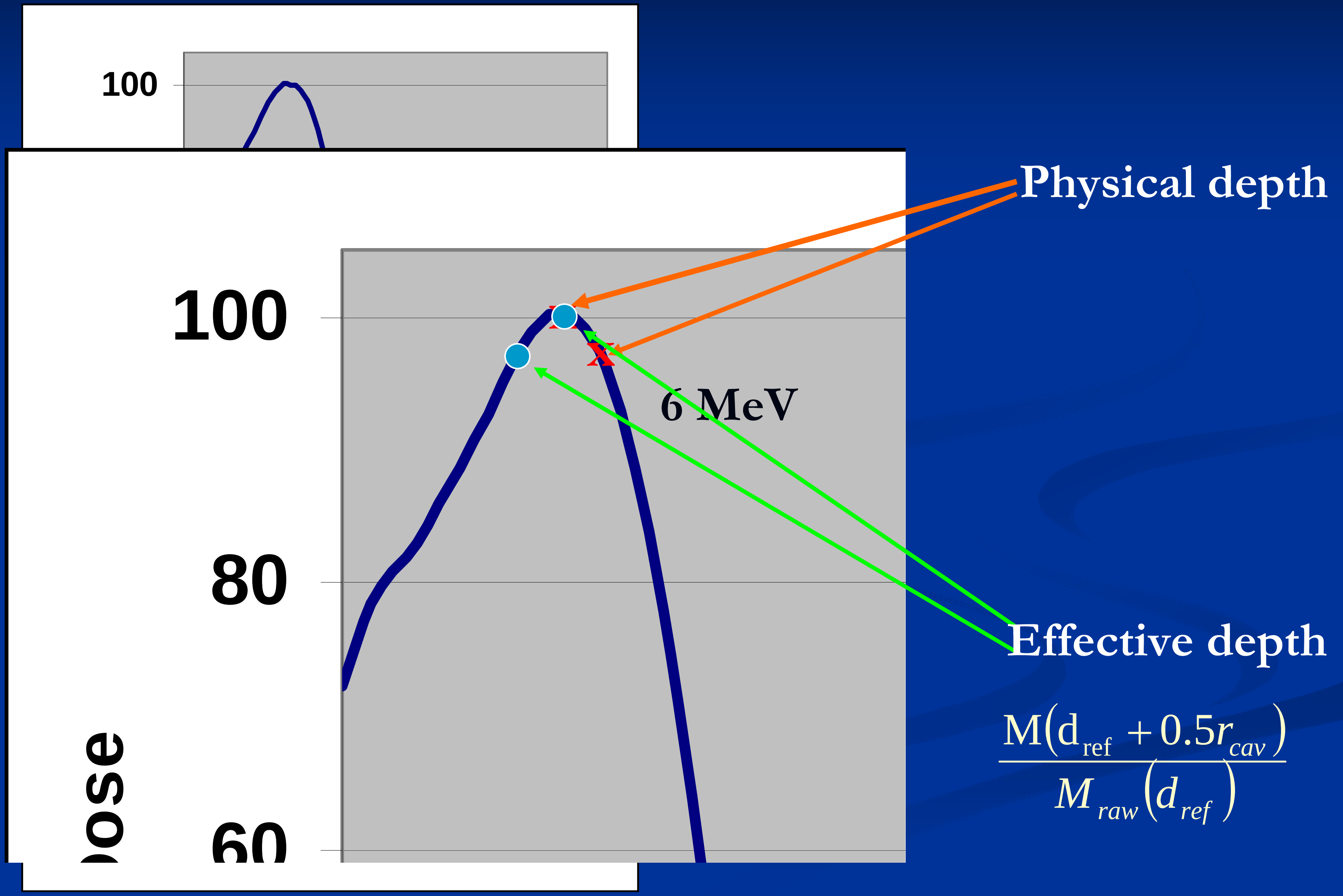
  - The reading at $d_{ref}+0.5r_{cav}$ should have the same precision as the reading at d_{ref} since:

$$\text{Dose} = \cancel{M(d_{ref})} \cdot (\text{many factors}) \cdot \frac{M(d_{ref}+0.5r_{cav})}{\cancel{M(d_{ref})}}$$

Charge Measurements

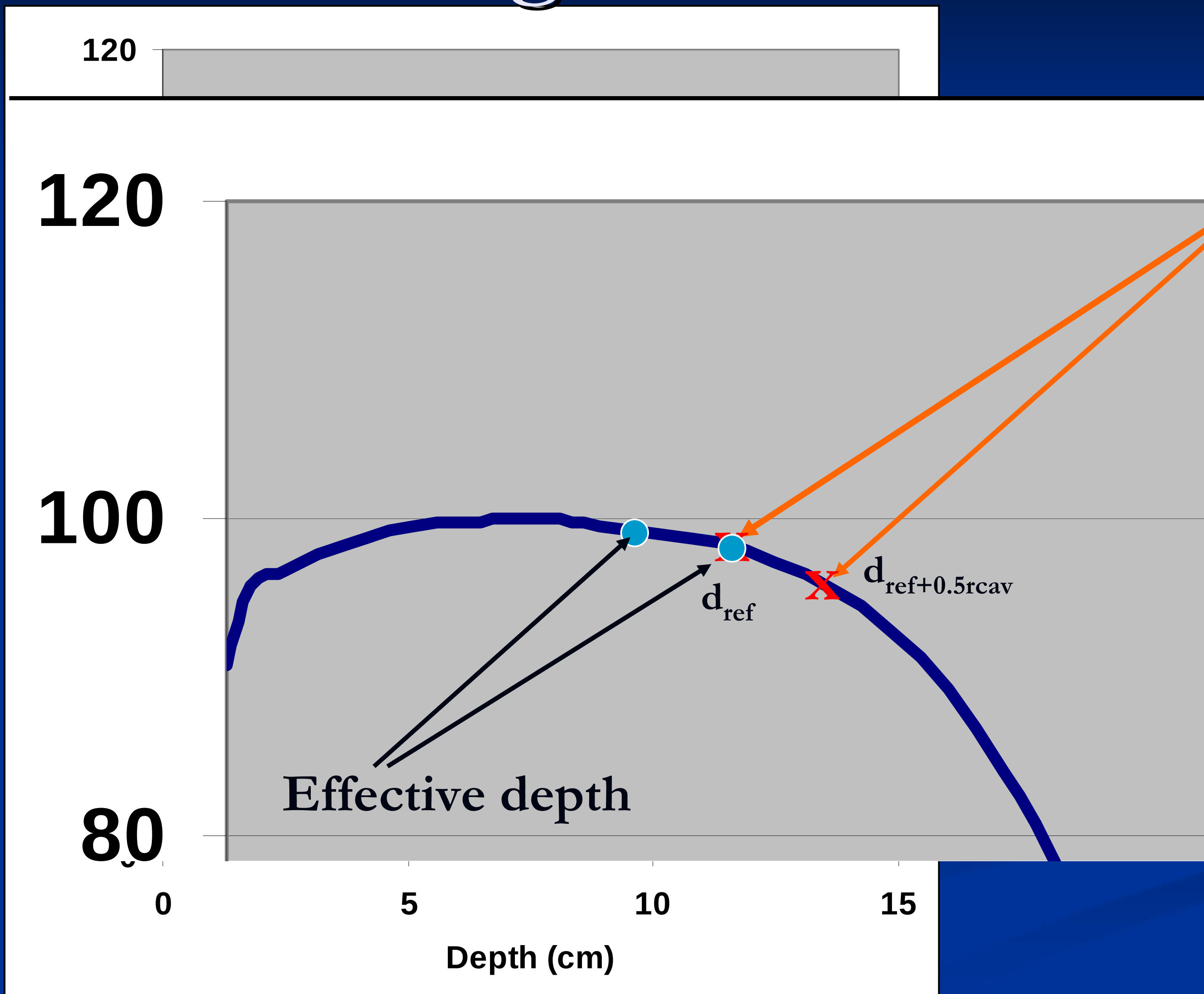
- Electron beam gradient (P_{gr}) correction factor
  - E < 12 MeV; P_{gr} >1.000
  - E ≥ 12 MeV; $P_{gr} \leq 1.000$
  - Why? Because for low electron energies $d_{ref} = d_{max}$ and this places the eff. pt. of measurement in the buildup region thus a ratio of readings greater than 1.000.
  - At higher electron energies d_{ref} is greater than d_{max} and as such the eff. Pt. of measurement is on the descending portion of the depth dose curve thus a ratio of readings less than 1.000.

Charge Measurements



$$\frac{\mathrm{M}\left(\mathrm{d}_{\mathrm{ref}}+0.5r_{cav}\right)}{M_{raw}\left(d_{ref}\right)}$$

Charge Measurements



Physical depth

$$\frac{M\left(d_{ref} + 0.5r_{cav}\right)}{M_{raw}\left(d_{ref}\right)}$$

Clinical Depth Dose

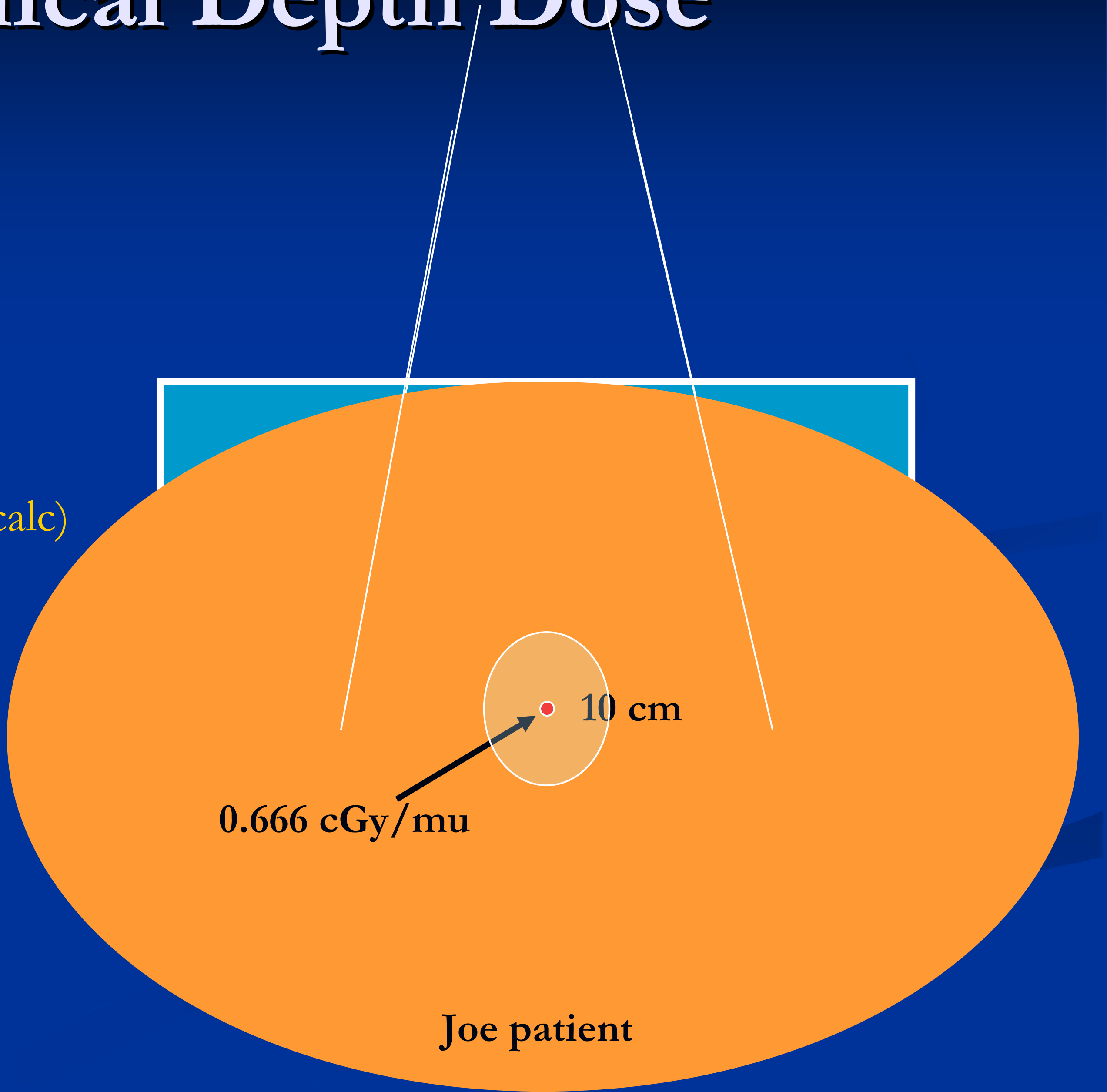
- Always measured using the effective point of measurement
  - Re-measurement not suggested for existing Linacs
  - New Linacs or beams should incorporate shift
- Always use the clinical depth dose to make the correction from the calibration depth to the reference depth
  - Measurement at depth will always equal calculation at the same depth (use same data to go to d_{max} as is used to go back down to reference depth)

Clinical Depth Dose

$\%dd(10)_x = 67.0\%$

Annual QA $\%dd_{10} = 67.4\%$

TPS $\%dd_{10} = 66.6\%$ (mu calc)



Clinical Depth Dose

- For photons – do not use the beam quality value $\%dd(10)_x$ to take dose from 10 cm to d_{max}
- For electrons – depth dose correction for ≥ 16 MeV is significant (~98.5% - 16 MeV and ~95.5% - 20 MeV)
  - Caution!!! Super big problem if you use % depth ionization data (3-5% error for high energy electron beams)

Summary

- Implementation is straightforward
  - Must read the protocol and follow the prescriptive steps
  - Many suggestions to clarify confusion have been made
  - RPC will assist you and answer questions
- Differences between TG-51 and other protocols such as TG-21 and TRS 398 are minimal.