Well-type ionization chamber measurements and simulations with an electronic brachytherapy source

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Outline

- Pressure-temperature correction
- Previous work on air density corrections with well chambers
- Application to Xoft Axxent® electronic brachytherapy source
- Monte Carlo simulations and well chamber measurements
- Conclusions
- Future work

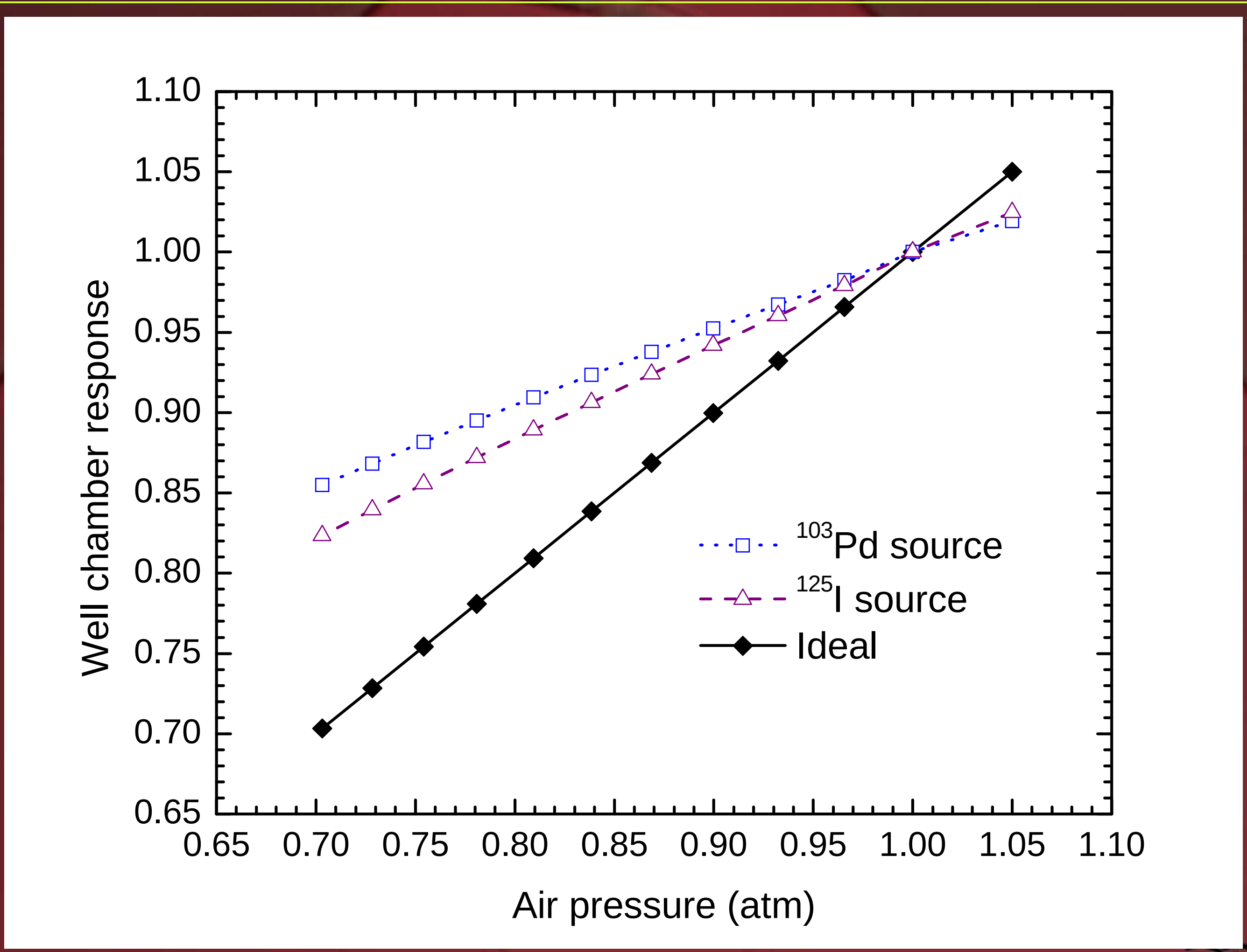
Correction for pressure and temperature

$$P_{TP} = \frac{273.15 + T(°C)}{273.15 + 22} \cdot \frac{760}{P(\text{Torr})}$$

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

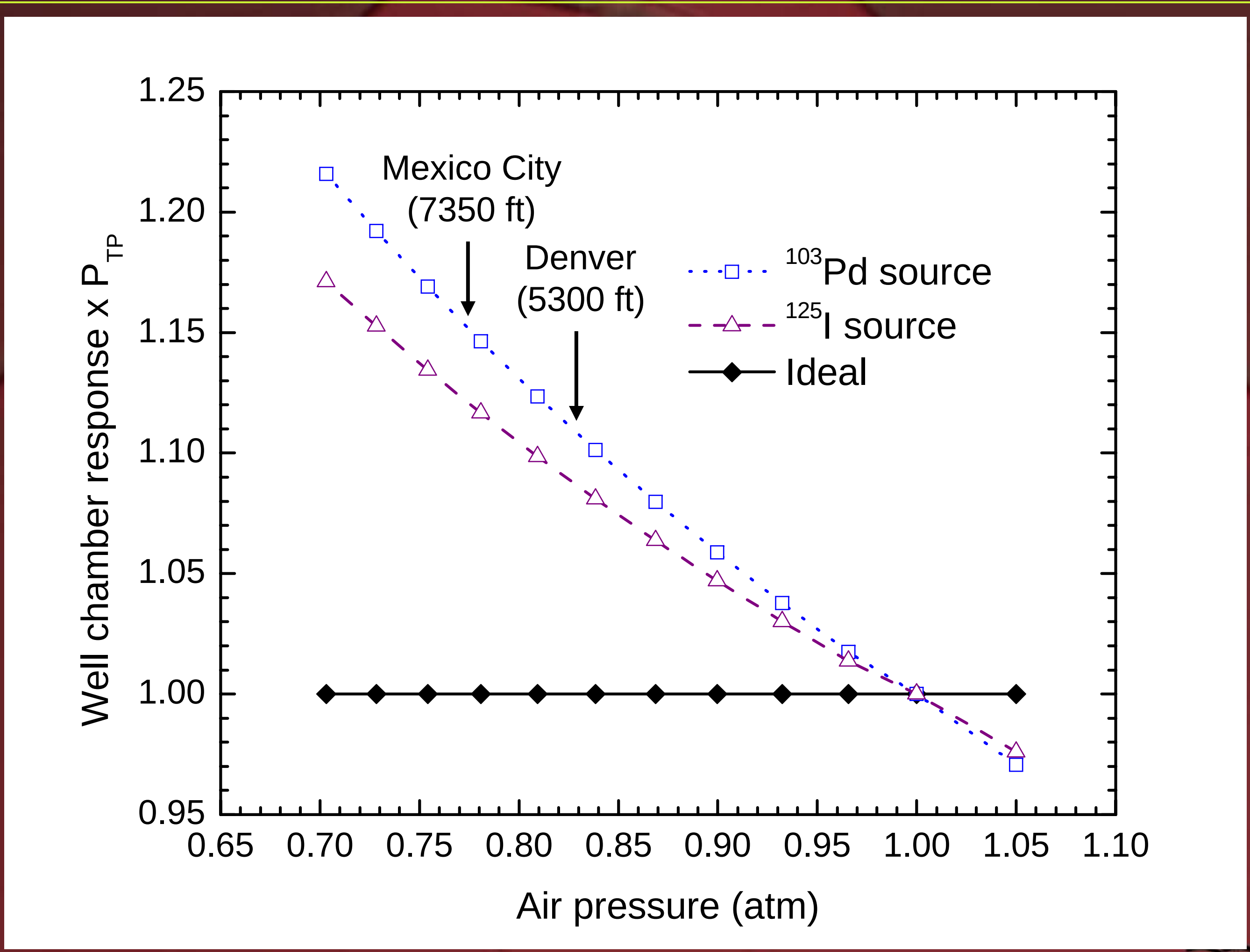
- Used for all types of air-communicating ionization chambers
- Assumes the active volume of the chamber acts as a Bragg-Gray cavity
  - Cavity is small compared with the range of the charged particles
  - Photon interactions in the cavity are negligible

HDR 1000 Plus well chamber response



Data derived from the results of Griffin *et al.* (2005)

Measured well chamber response x P_{TP}



Data derived from the results of Griffin *et al.* (2005)

Air density (altitude) correction - P_A

$$M = M_{\text{raw}} P_{\text{TP}} P_{\text{ion}} P_{\text{pol}} P_{\text{elec}} \boxed{P_{\text{A}}}$$

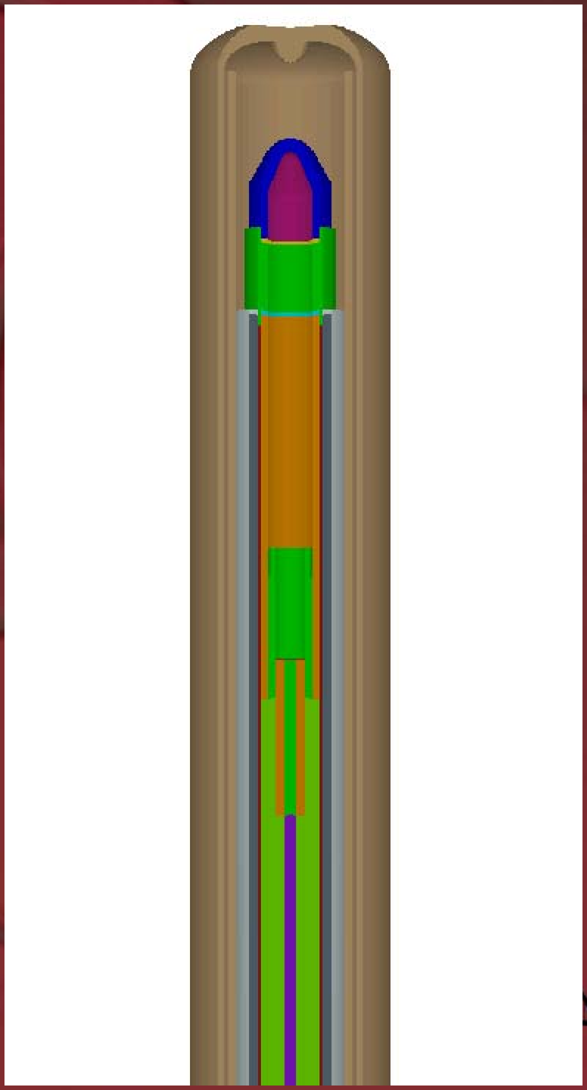
- More pronounced over-correction as photon energy decreases
- Bohm *et al.* (2005 and 2007) have shown that effect decreases if chamber walls are air-equivalent
- Bohm demonstrated that MCNP5 was accurate for modeling the air density effects in well chambers
- LaRussa *et al.* (2006) have calculated similar effects for several type of ionization chambers used for external beam kilovoltage dosimetry

Xoft Axxent® miniature x-ray source

- HDR 1000 Plus well chamber is used to measure the air-kerma strength
- 50 kV photon spectrum with average energy ~27 keV
- Need to determine P_A correction
- Difficult to measure air density effects directly

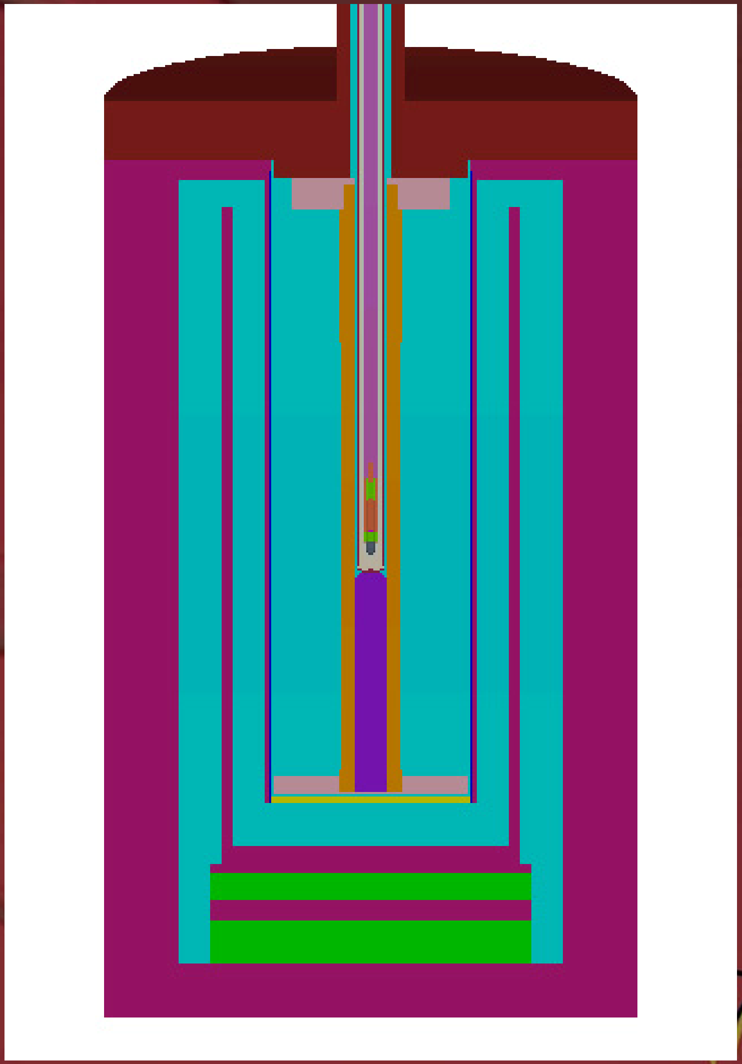
MCNP5 simulations of x-ray source

- Model based on engineering specifications from Xoft, Inc.
- Benchmarked with ionization chamber measurements in water by Rivard *et al.* (2006)

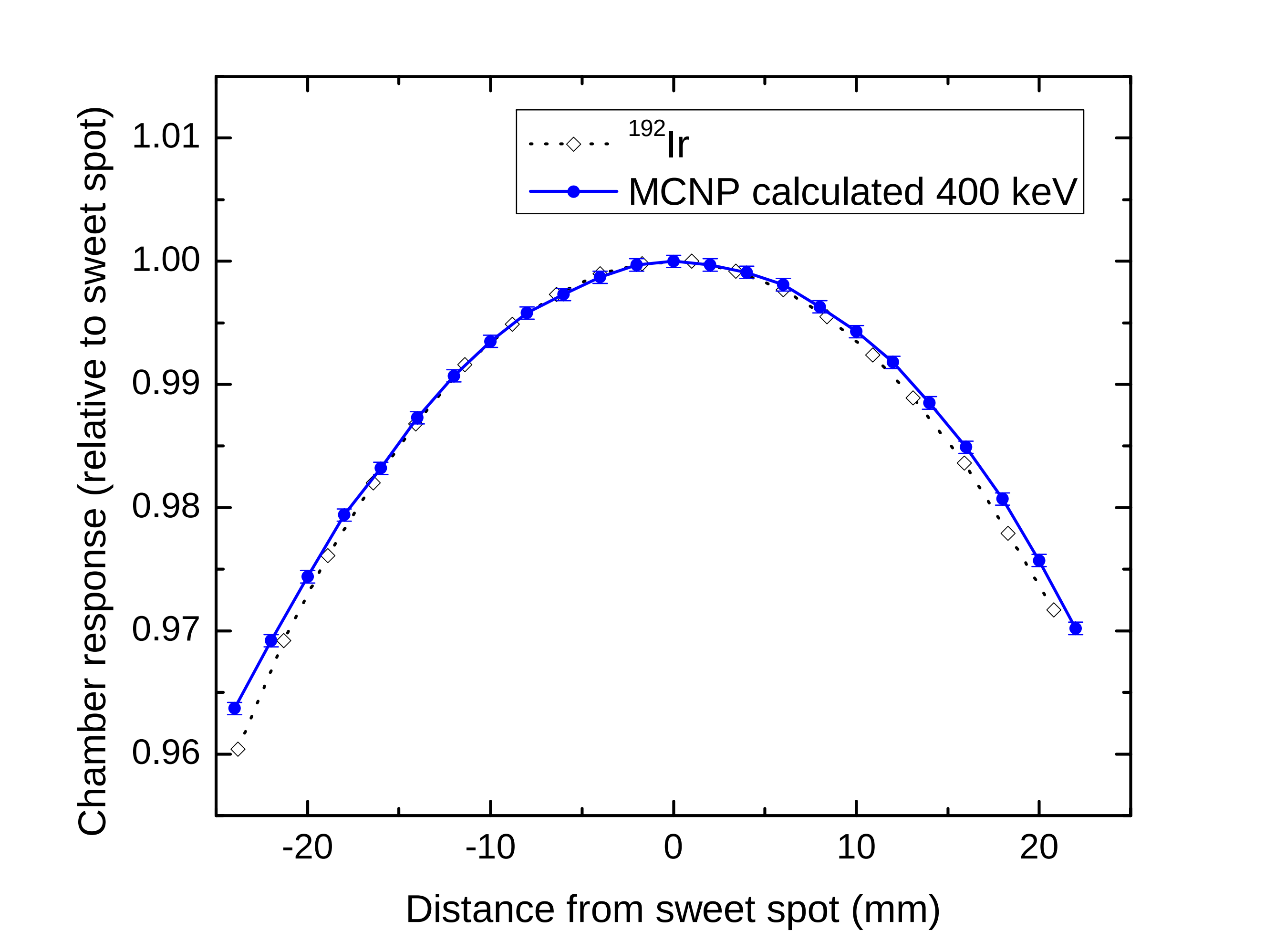


MCNP5 well chamber simulations

- Based on engineering specifications from Standard Imaging, Inc.
- Source is inserted in aluminum source holder
- Separate model is used to simulate Oncura model 6711 ^{125}I measurements



Calculated axial well chamber response

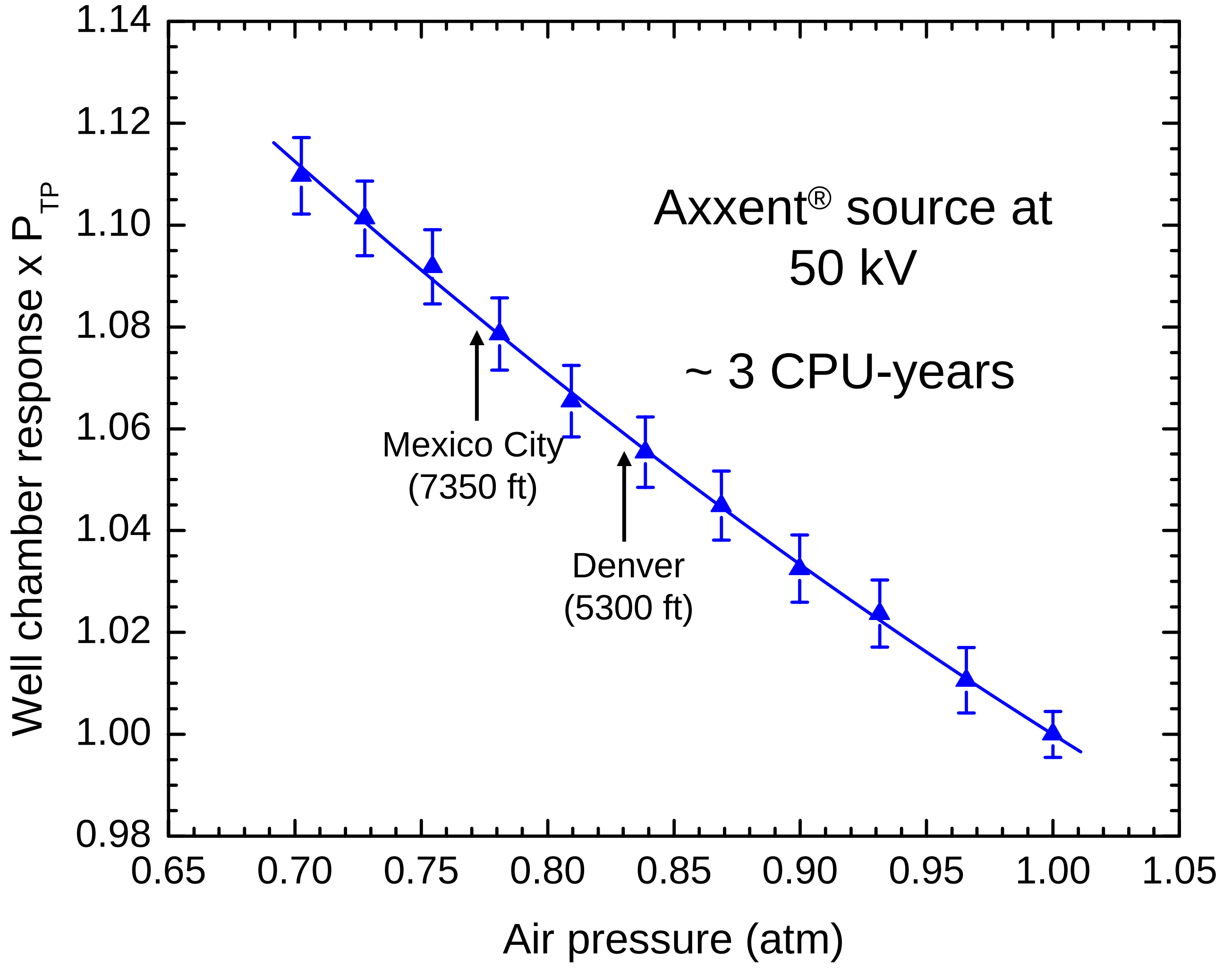


Measurement data from HDR 1000 Plus Manual

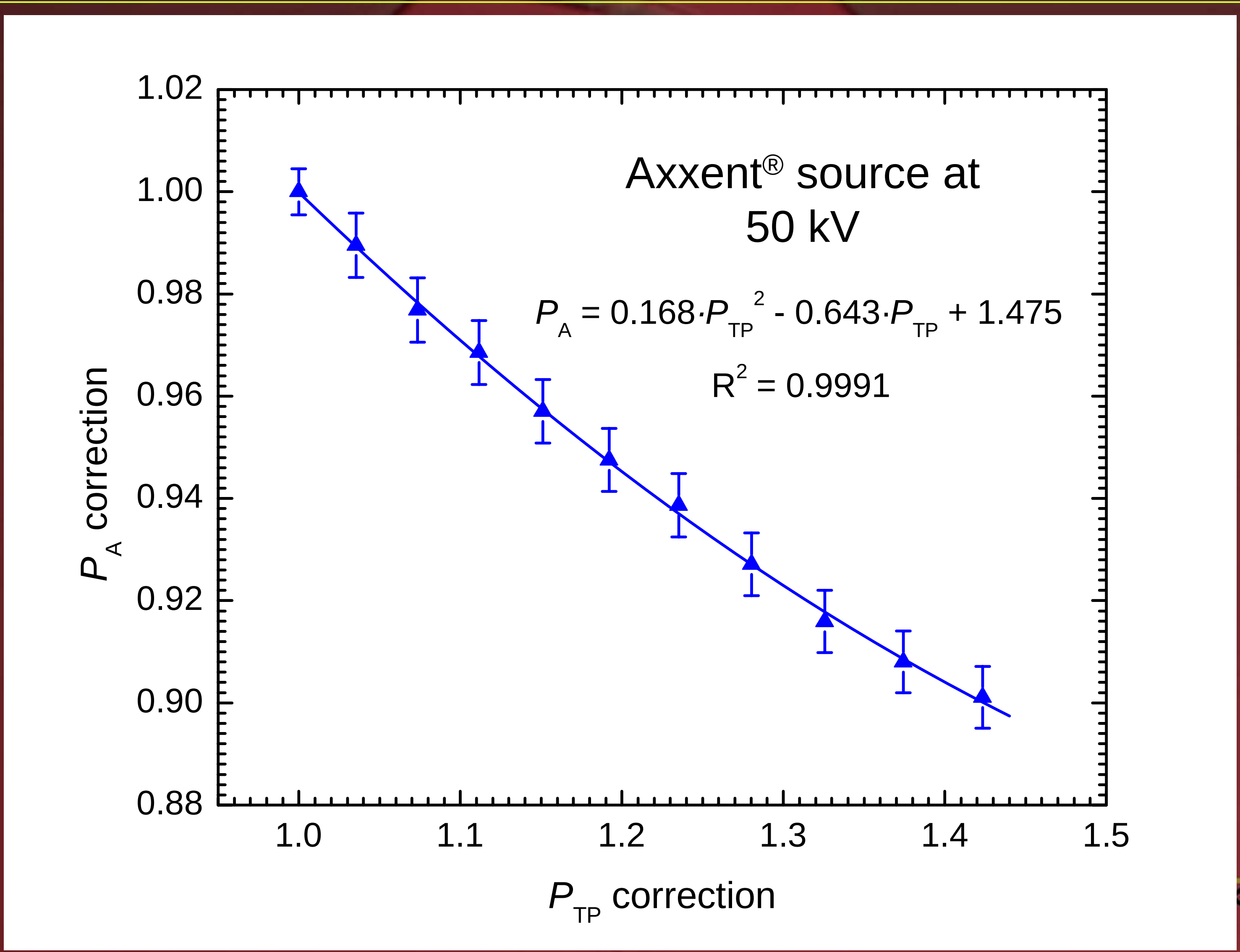
Well chamber calibration coefficient calculations

Source	HDR 1000 Plus N_K (Gy/C) Calculated (MCNP5)	Measured (UW Attix FAC)	% difference
Axxent 40 kV	56.51	55.58	1.7
Axxent 45 kV	41.71	41.72	-0.02
Axxent 50 kV	33.53	34.19	-1.9
6711 seed	19.37	19.21	0.9
50 kV (point source)	30.83	34.19	-9.8
30 keV monoenergetic	10.82	34.19	-68.4

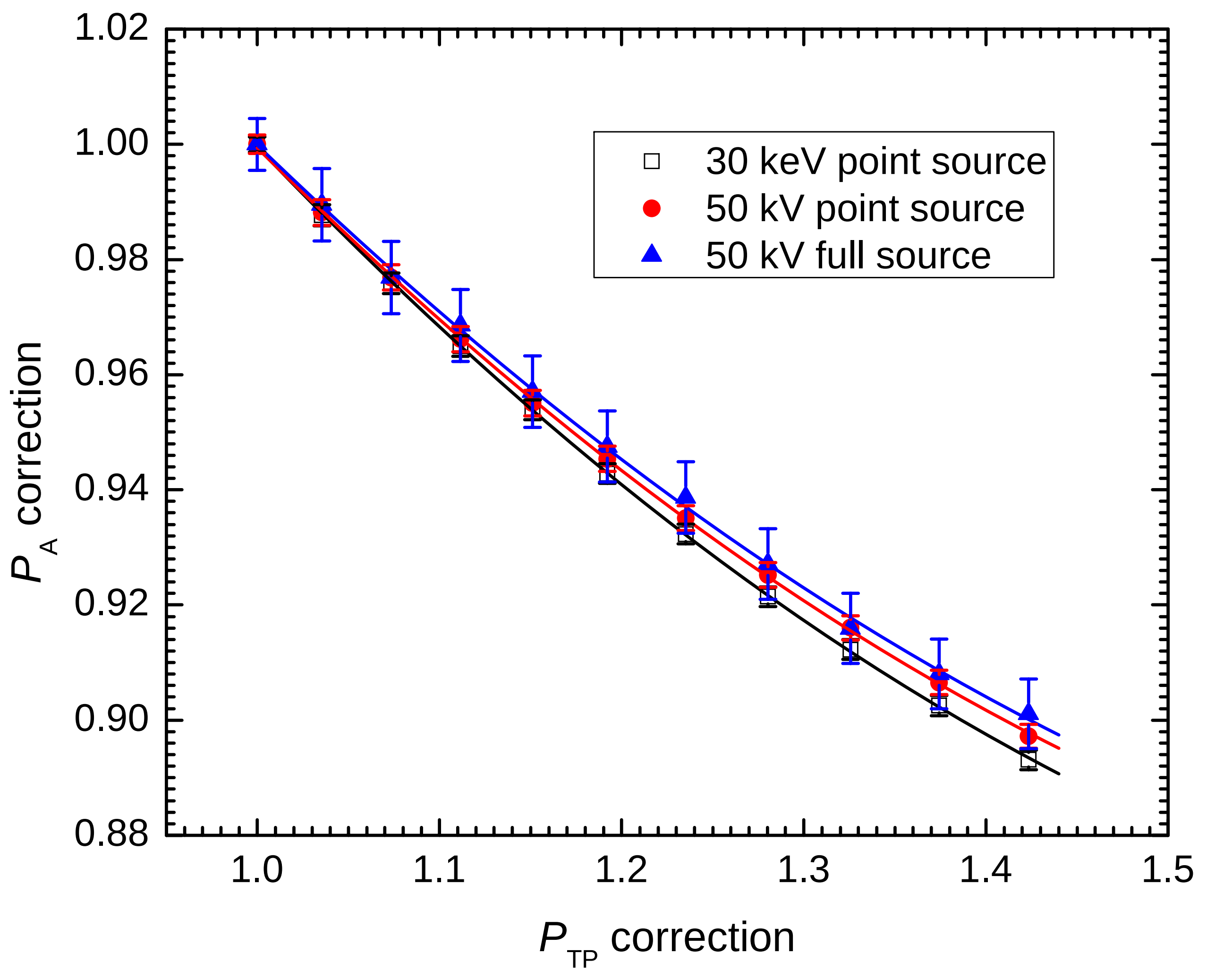
Calculated well chamber response x P_{TP}



P_A correction results



P_A correction results



Conclusions

- Accurate Monte Carlo model of the HDR 1000 Plus well chamber was developed
- Well chamber calibration coefficient simulations require a detailed model of the source for sufficient accuracy
- Air density simulations were less sensitive to the details of the source output
- Air density correction will need to be applied in the clinic for accurate dosimetry at high altitudes

Future work

- Tolerance study of the effect of small changes in geometry (e.g. thickness of aluminum insert)
- Benchmark the well chamber model against measured calibration coefficients for a variety of seed models
- Construct an apparatus to measure the air density effects with the Axxent® sources

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