Calibration of Miniaturized Tissue Equivalent Proportional Counter with Monte Carlo Simulations with Function Fitting

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Introduction

- A tissue equivalent proportional counter (TEPC) has good performance at microdosimetry in the mixed radiation fields [1].
- A miniaturized TEPC (mini-TEPC), whose the size is smaller 10 times than the conventional TEPC, is helpful for the intense radiation fileds like clinical beams because it prevents the pile-up of signals [2].
- Indirectly ionizing radiation sources like photon and neutron are required to calibrate the mini-TEPC using the 'edge' of their secondary particles.
- This study investigated the proper calibration method using ^{137}Cs and ^{252}Cf with Monte Carlo simulation codes, Geant4 and MCNP6.

Materials & Methods

1) Monte Carlo simulation setup

- A simple cylindrical mini-TEPC whose height and diameter are 1 mm was constructed with propane-based TE gas and A-150 TE plastic.

- ^{137}Cs simulation : 1×10^{10} photons of 0.662 keV
- ^{252}Cf simulation : 1×10^{9} neutrons from Watt spectrum
  2.2×10^{9} photons from LLNL fission model

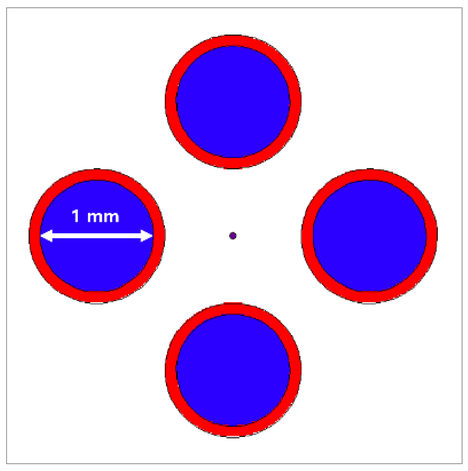


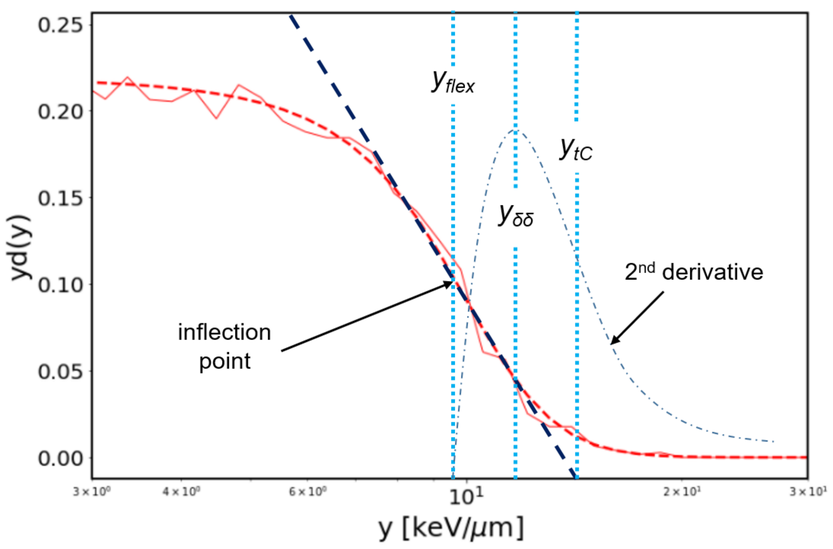
Fig. 1. Four identical detectors surrounding the point source in the middle point. The blue circle is the propane-based TE gas and the red ring is the A-150 TE plastic.

2) Calibration method

- The secondary particles, electron from photon and proton from neutron, have their edges in the dose distribution spectrum.

- Selection of the appropriate calibration point from Fermi-like function fitted at the edge region [3]

$$f(h) = \frac{A}{1 + e^{B(h-c)}}$$



$$y_{flex} = C$$
$$y_{\delta\delta} = \frac{\ln(2+\sqrt{3})}{B} + C$$
$$y_{tC} = \frac{2}{B} + C$$

Fig. 2. Three possible calibration points in *yd(y)* spectrum

Results

- ^{137}Cs simulation results - Electron edge formed at ~ 10 keV/μm.
- Geant4 and MCNP6 results are in good agreement showing that the electron edge markers are similar.
- The second marker ($y_{\delta\delta}$) is closest to the analytical electron edge, which was calculated using the NIST electron range dataset.

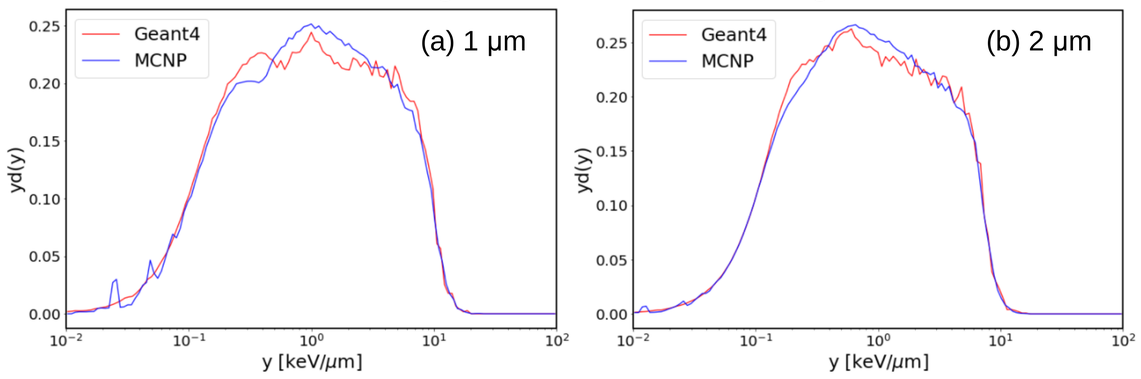


Fig. 3. Dose distribution spectrum of ^{137}Cs simulation for the simulated tissue sizes 1 and 2 μm.

Site size	1 μm			2 μm		
Marker	y_{flex} (keV/μm)	$y_{\delta\delta}$ (keV/μm)	y_{tC} (keV/μm)	y_{flex} (keV/μm)	$y_{\delta\delta}$ (keV/μm)	y_{tC} (keV/μm)
Geant4	9.33	11.63	12.83	6.8	8.64	9.6
MCNP	8.44	11.53	13.13	6.27	8.58	9.78
Analytical		11.15			8.36	

Table 1. Three calculated markers of photon source and analytical electron edge

- ^{252}Cf simulation results – Proton edge formed at ~ 100 keV/μm.
- The proton edge markers from MCNP6 result are smaller than those from Geant4 result.

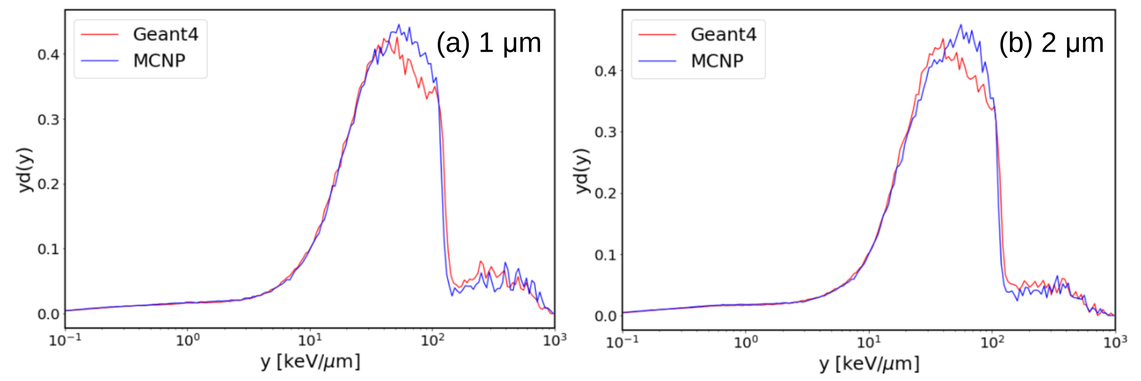


Fig. 4. Dose distribution spectrum of ^{252}Cf simulation for the simulated tissue sizes 1 and 2 μm.

Site size	1 μm			2 μm		
Marker	y_{flex} (keV/μm)	$y_{\delta\delta}$ (keV/μm)	y_{tC} (keV/μm)	y_{flex} (keV/μm)	$y_{\delta\delta}$ (keV/μm)	y_{tC} (keV/μm)
Geant4	127.52	142.6	150.43	117.2	132.17	139.93
MCNP	119.76	129.91	135.17	110.92	121.7	127.29
Analytical		141			146	

Table 2. Three calculated markers of neutron source and analytical proton edge

Discussion & Conclusions

- The major secondary particle of the photon source is the electron only, but heavy charged particles are generated by the neutron, which makes the tail in the spectrum.
- The calibration is possible using photon source and fitting Fermi-like function.
- The alternative methodology is required in case of using the neutron source for the calibration of a mini-TEPC.

References

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