Physical characteristics of annihilation and related background photons produced in X-ray irradiation with medical linear accelerator

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BACKGROUND & OBJECTIVE

- In external X-ray irradiation by a medical linear accelerator (LINAC), annihilation photons are generated by pair production. From literature, for using annihilation photons produced in X-ray irradiation, the annihilation photon peak is not visible in the energy spectra measured with coincidence pairs of scintillation detectors, because of additional background radiations[1,2].
- In this study, to investigate the effective detection and use of annihilation photons, we analyzed the physical characteristics of the detected photons with a focus on the background components.

METHODS

◆ EXPERIMENT

- Targeted LINAC: TrueBeam (Varian Medical Systems)
- Phantom (Thickness: 20 cm, water equivalent) was placed at the isocenter.
- A pair of scintillation detectors was placed in the opposite position.
- LINAC was operated at 10 and 6 MV X-ray mode with several field sizes (1 cm × 1 cm to 10 cm × 10 cm) and dose rates (100 to 600 MU/,min).
- The energy spectrum was obtained from the irradiation.
- A ^{137}Cs source was placed near the detector in the beam irradiation to measure the pulse measurement.

◆ SIMULATION

- Monte Carlo (MC) simulation code: Geant 4 Ver. 10.3.
- A primary collimator, X-ray target, flattening filter and jaws of LINAC (TrueBeam), couch, and floor were modeled.
- X-rays were produced by simulating electron beams impinging on the X -ray target, and by using IAEA-formatted phase-space files.
- The simulation results of percentage depth dose (PDD) and off-axis ratio (OAR) were compared with actual data to confirm the consistency of the simulation.
- MC simulation was used to investigate the physical characteristics of the annihilation and related background photons.

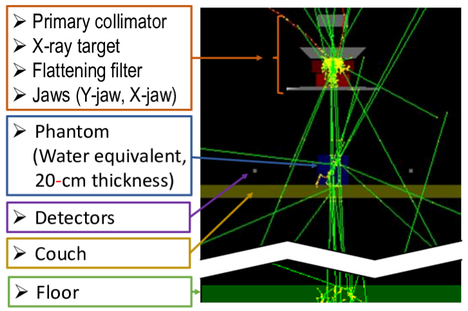

Figure 1 Simulated LINAC geometry consisting of target, primary collimator, jaws, couch, floor and detectors.

RESULTS

◆ EXPERIMENT

- Figure 2 shows the energy spectra from 6- and 10-MV X-ray irradiation as well as ^{137}Cs source measurements with 10-MV X-ray irradiation.
- A peak structure was identified at 500 keV in the energy spectra from the 10-MV x-ray irradiation.
- The signal to background ratio around the 500-keV peak was slightly improved in a smaller field size.

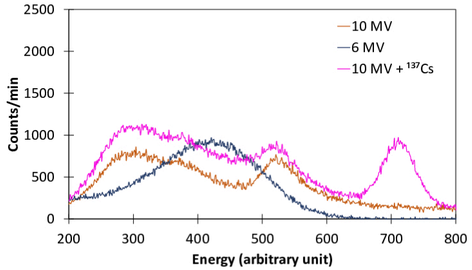

Figure 2 Energy spectra from 10- and 6-MV X-ray irradiations, and ^{137}Cs source at 10-MV irradiation.

- The dose rate dependence of the measured count rates was approximately linear (Figure 3) .
- The count rates in the ＜10-MV and around 500 keV showed a dependence on the field size (Fig .4).

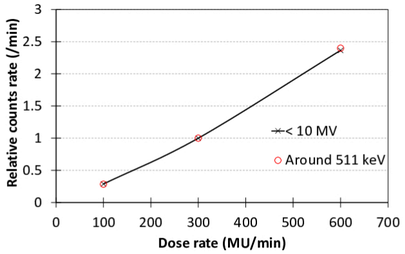

Figure 3 Measured dose rate dependence of count rates.

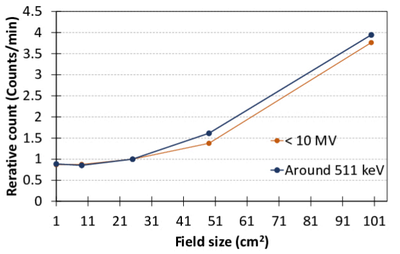

Figure 4 Measured field size dependence of count rates.

◆ SIMULATION CONSISTENCY

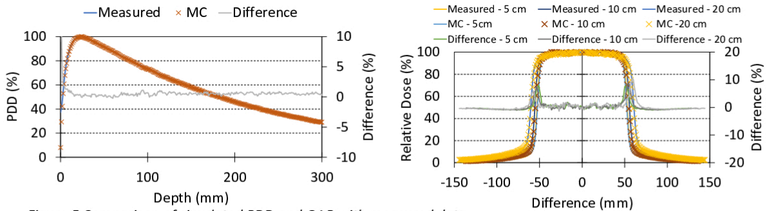

Figure 5 Comparison of simulated PDD and OAR with measured data.

- A PDD field size of 10 cm is consistent (in 1%) with measurement for 99% confidence interval.
- An OAR's depth of 5 cm to 20 cm is consistent (in 2%) with measurement for 95% confidence interval.

◆ 2-D DISTRIBUTION

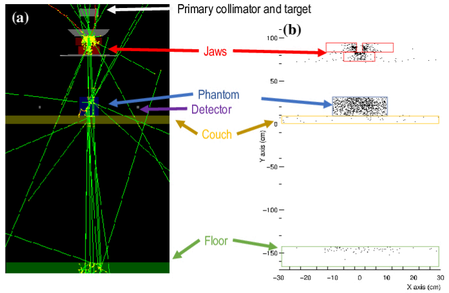

Figure 6 (a) Simulated LINAC geometry and (b) simulated distribution of source positions for the detected photons.

- Figure 6 shows simulated geometry and the distribution of source positions of detected photons obtained by the MC simulations.
- **Most background** photons from the LINAC head were emitted from the edge of jaws.
- The measured energy spectra included the background contribution that was not simulated in this study.

CONCLUSIONS

- We observed a peak structure around 500 keV in the measured energy spectrum from X-ray irradiation of medical LINAC.
- Regarding the physical characteristics of the annihilation and related background photons, we obtained **details about** its emission and distribution.

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◆ BACKGROUND COMPONENTS

Table 1 Simulated relative contribution of detected photons.

Source	<10 MeV	511 keV
Phantom	1.00	1.00
Jaws	0.42	0.90
Couch	0.07	0.06
Floor	0.07	0.17

- The relative contribution of annihilation photons from the jaws was comparable to that from the phantom. The background from the couch and floor was less than 20%, as shown in Table 1.