A novel method of verifying the field irradiated by therapeutic X-ray beam

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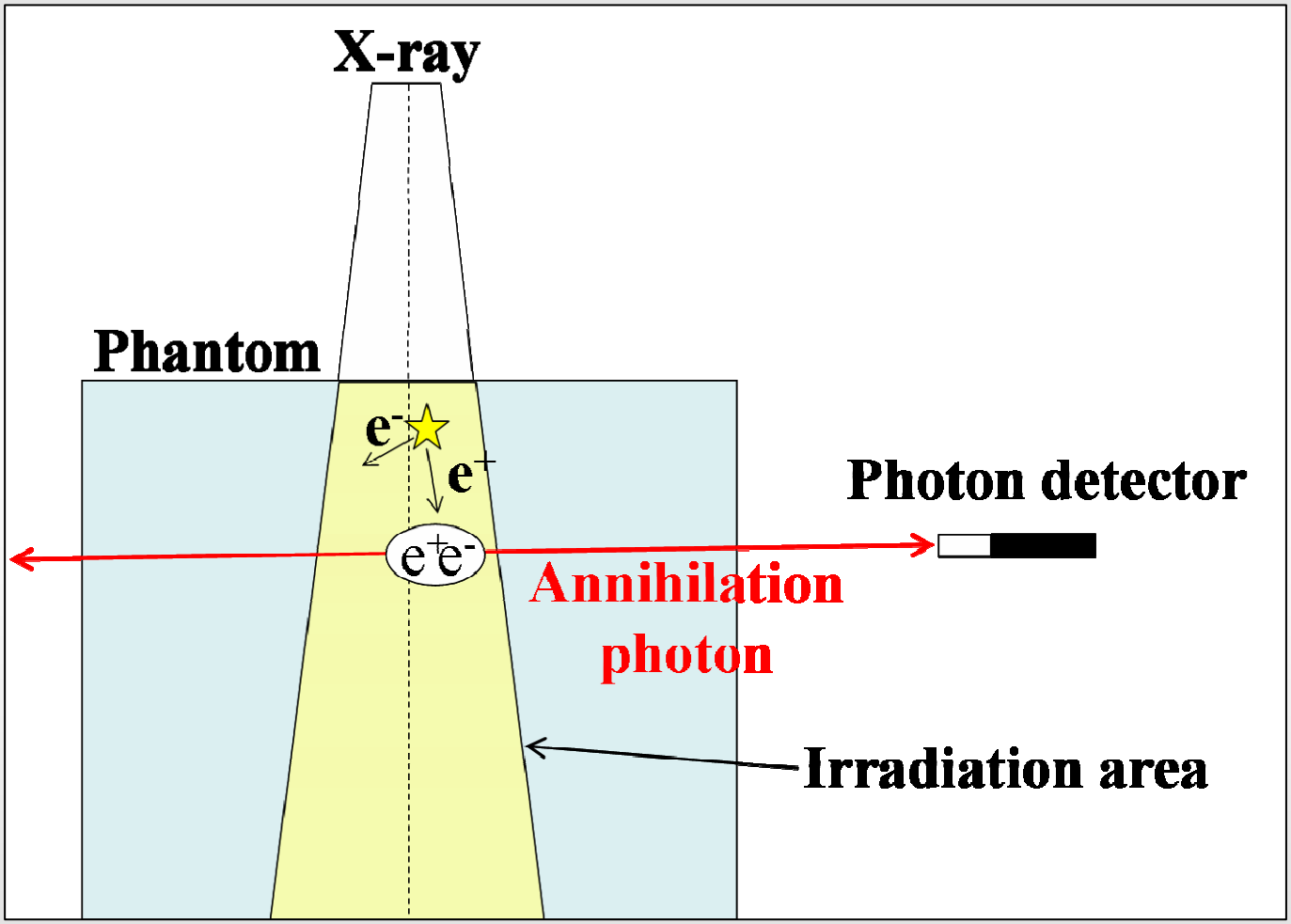
Background

- **Radiations used in external radiotherapy**
  - ✓ **X-rays**, gamma-rays, electrons, heavy ion
- **Verification of the irradiation area**
  - ✓ There is no method to verify the irradiation area
- **Therapeutic X-ray irradiation**
  - ✓ Positrons are produced in electron-positron pair productions
  - ✓ Positrons annihilate into two photons (annihilation photons)

Use the annihilation photons for the verification

- **A novel method to verify the irradiation area**



We measure the annihilation photons

Purpose

Examine the feasibility of the proposed method

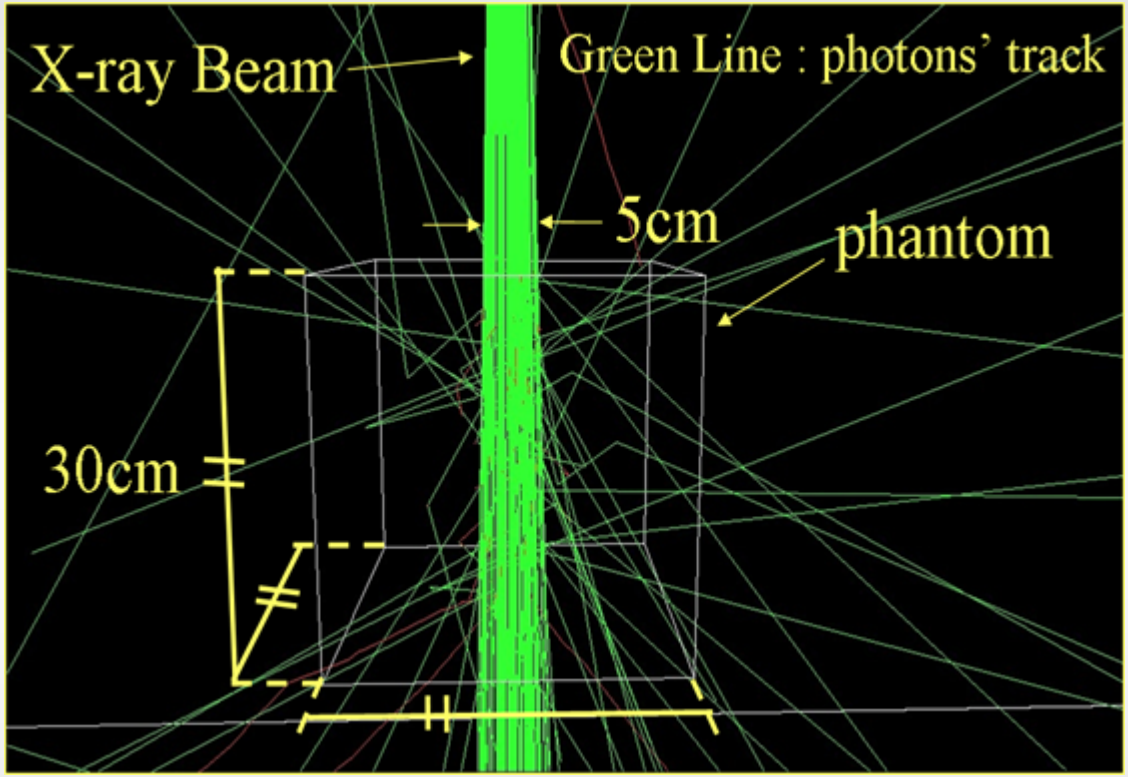
- ✓**Estimation of the number of the generated positrons**
- ✓**Annihilation positions of the positrons**

GEANT4 Monte Carlo simulation

- ✓**Detection of annihilation photons**

Experimental test

Monte Carlo simulation



✓GEANT4 : version 4.7.1

✓ Irradiated 6MV_X-ray on water phantom

✓Number of X-ray photons : 5.0×10^7 histories

- **The number of the positrons produced in the phantom**
- **Distribution of the number of the annihilated positrons**

Results

- **The number of produced positrons**

The number of X-ray photons(N_γ)	The number of produced positrons (N_{e^+})
5.0×10^7	6.2×10^5

$$\frac{N_{e^+}}{N_\gamma} = 1.2[\%]$$

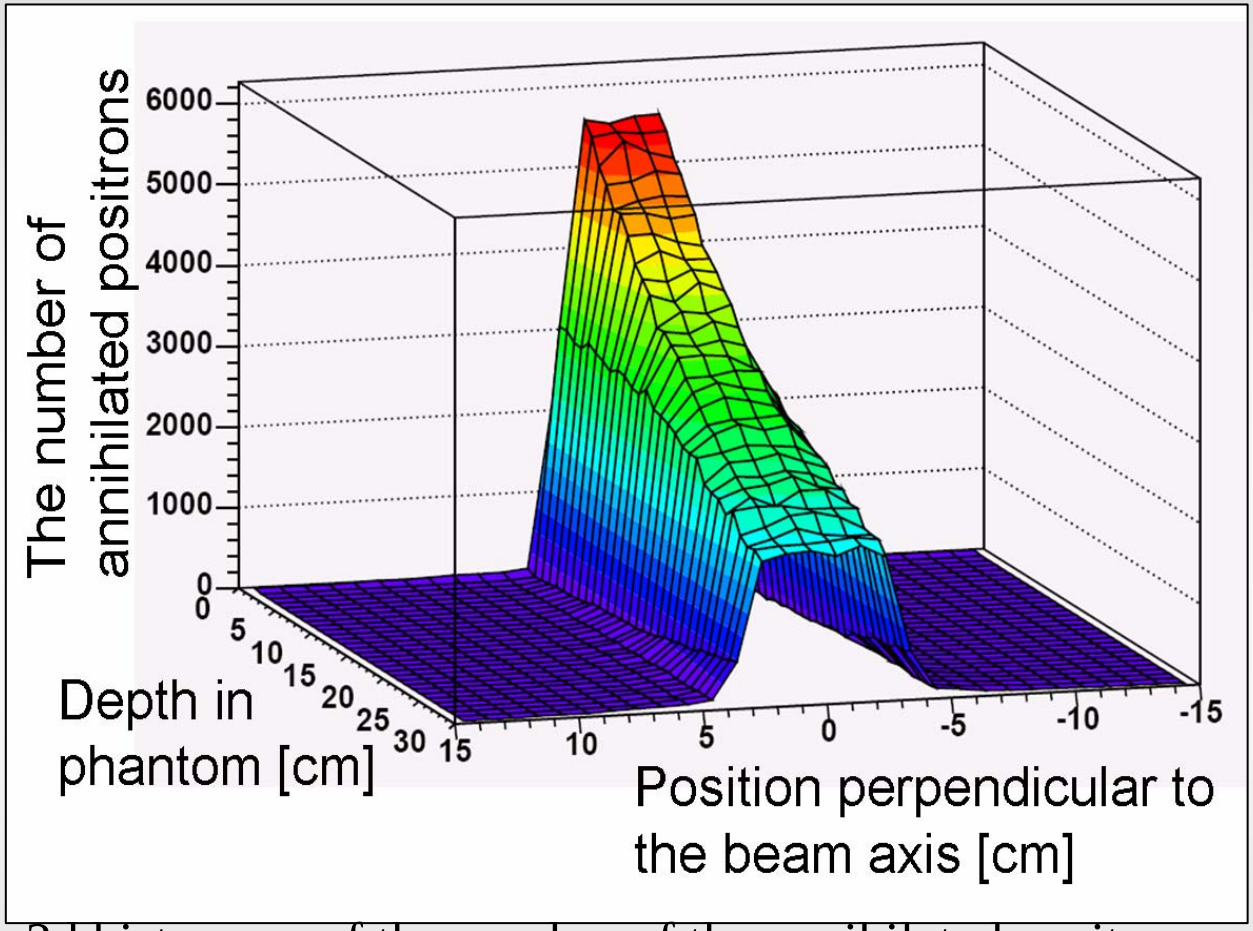
10^{10}~10^{11} photons are generated in one X-ray pulse from Linac

※ used parameters

pulse current : 100mA, efficiency of photon generations : 30%,
filtered with tungsten

A number of positrons are produced

- **The distribution**

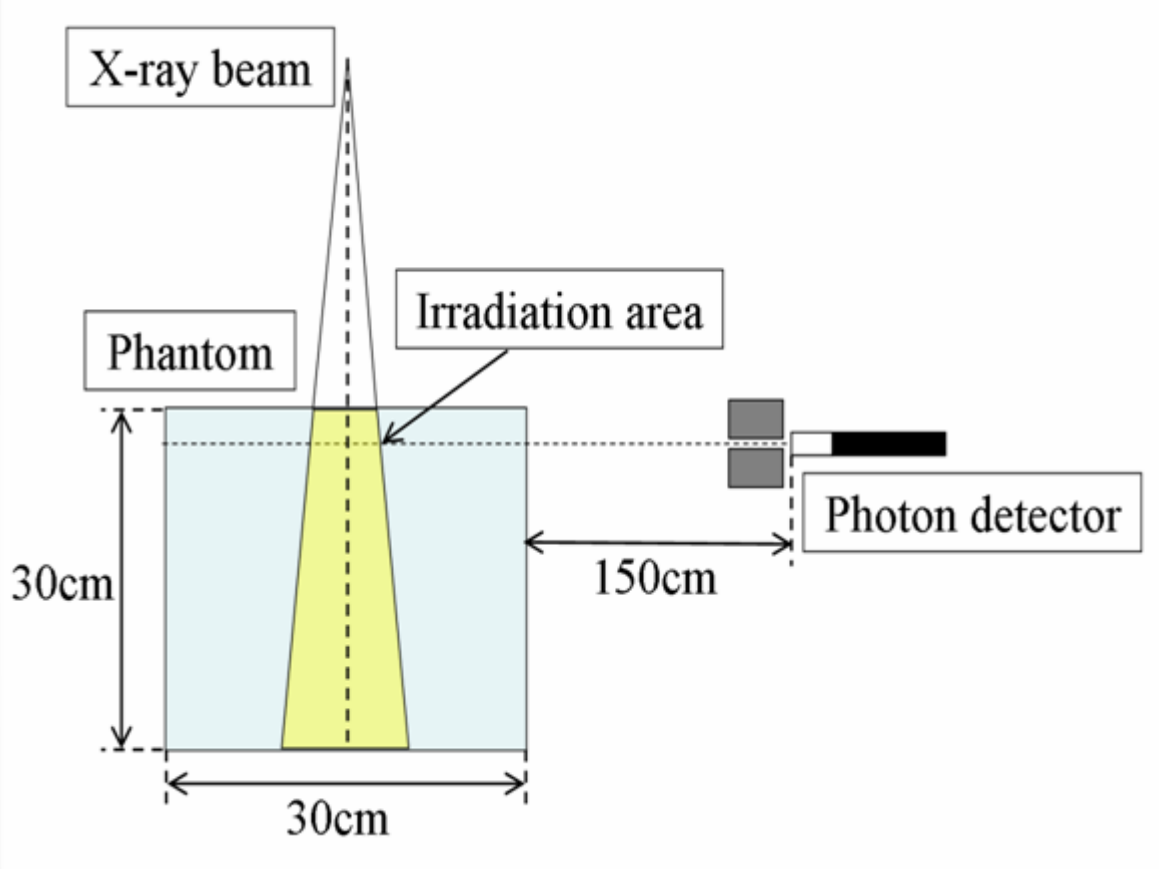


2d histogram of the number of the annihilated positrons

positrons are annihilated in the irradiation area

A number of annihilation photons are generated in the irradiation area

Experimental test

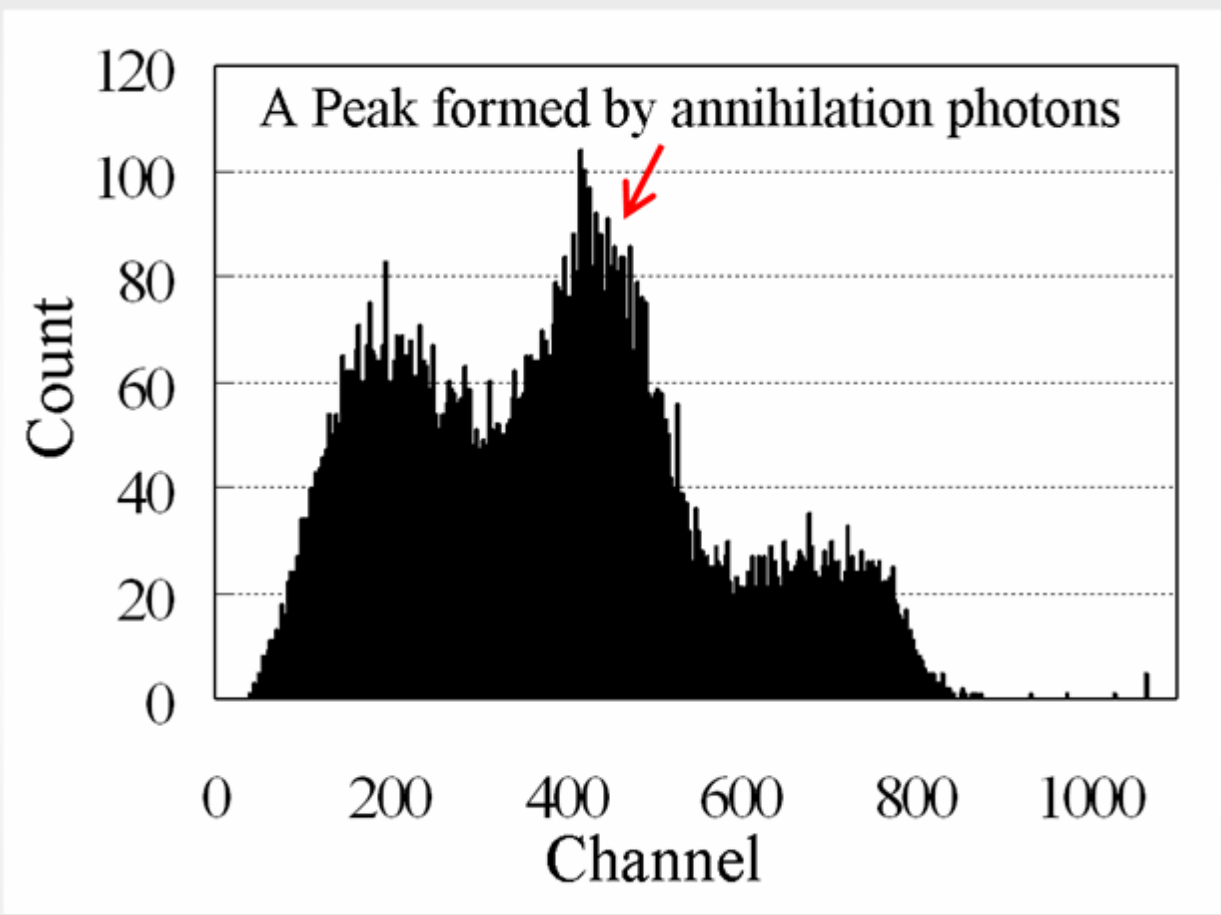


layout of equipments

- ✓Irradiated 6MV_X-ray from Linac on a phantom
- ✓Irradiation field : 5cm* 5cm @surface
- ✓Photon detector : GSO scintillator + PMT

- **Measured counting rates and pulse heights of signals from the detector**

• Energy calibration of the photon detector



Pulse height distribution of ^{22}Na (annihilation photons emission source)

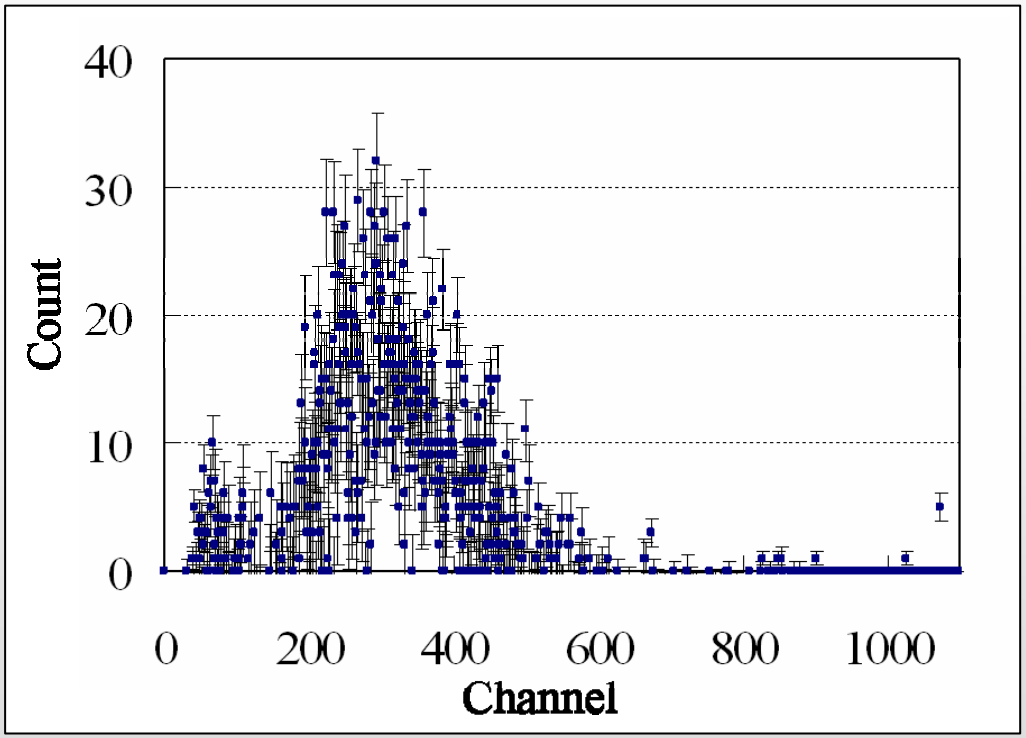
Photo peak of annihilation photons is 450channel

Results

•Detection of the photons generated in the phantom

	Background (Without phantom)	Irradiation area (With phantom)
Count	94277	114325
Time [s]	300	300
Counting rate [cps]	314	381

Counting rate measured in irradiation area was 20% more than background

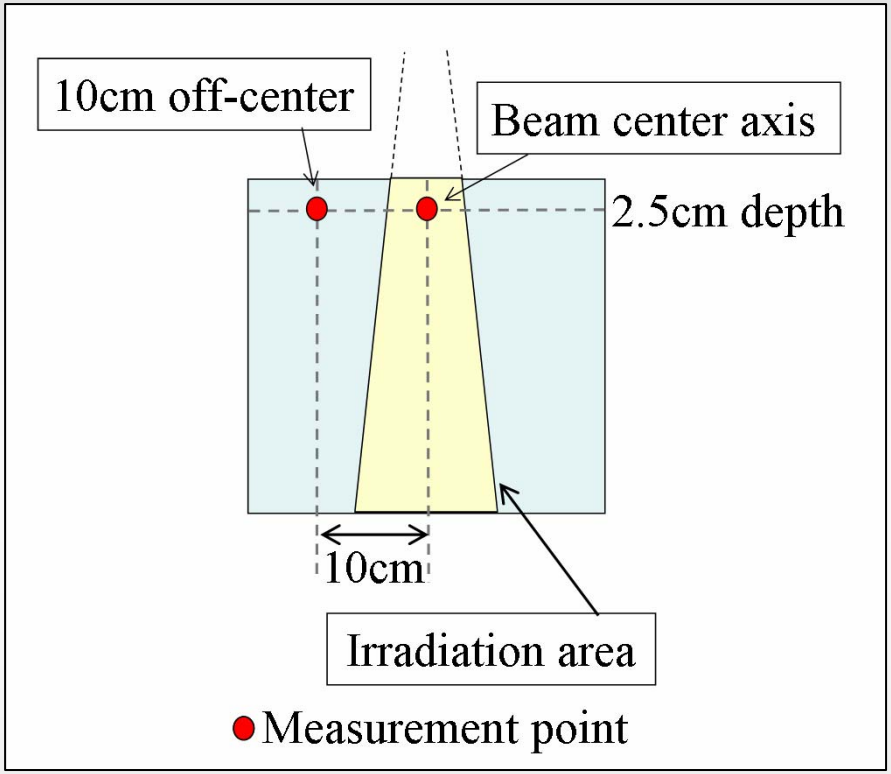


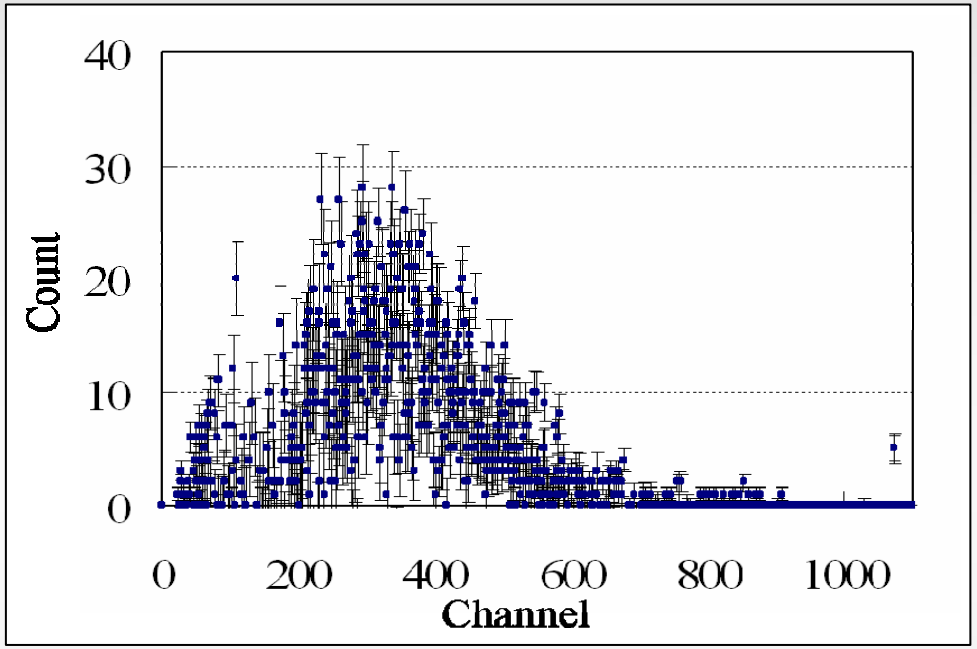
↙ Pulse height distribution (Irradiation area – Background)

Counts around 450 channel was more significant

Detection of the annihilation photons is possible

•Variation of the number of the annihilation photons

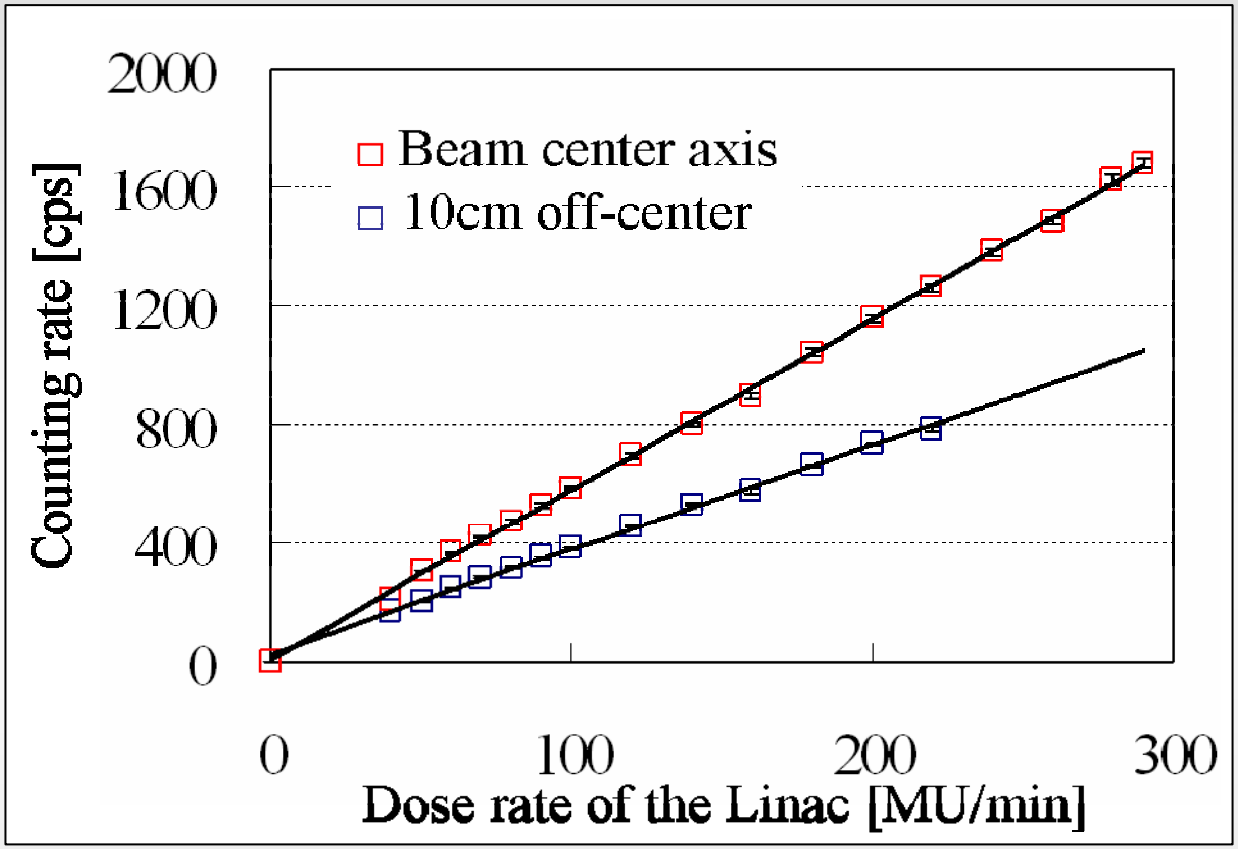




The number of annihilation photons generated in irradiation area is more than 10cm off-center

Measurement of the variation of the number of the annihilation photons is possible

•Variation of the counting rate by changing position



Counting rates measured at beam center axis were 50% more than the counting rates measured at 10cm off-center

We could measure the variation of counting rate

Discussion

- ✓**Annihilation photons are generated in the irradiation area**
- ✓ **The detection of the annihilation photons is possible**
- ✓**Measurement of the variation of the number of the annihilation photons is possible**

⇩

It is possible to verify the irradiation area using this method

Conclusion

- ✓A number of annihilation photons are generated by the therapeutic X-ray beam irradiation in the irradiation field
- ✓We could indicate that it is possible to measure the annihilation photons generated by the beam irradiation
- ✓We could measure the variation of the number of the annihilation photons

It is proved that verification of the irradiation area is possible by the present method