



Fig. 1 (color online) The Gamma calibration laboratory.



Fig. 2 (color online) The Control room.

## 8 - 33 Radiation Shielding Design for a 10 MeV Rose-like Electron Irradiation Accelerator

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This article focuses on the radiation shielding research of the coaxial cavity electron accelerator, a petal-shaped electron accelerator independently developed by the Institute of Modern Physics at the Chinese Academy of Sciences. This study aims to provide reference for the radiation shielding design of similar devices in the future. The coaxial cavity electron accelerator mainly consists of an electron gun, a resonant cavity, nine external bending magnets, a 270-degree bending magnet, and a scanning system. Its working principle is shown in Fig. 1. The resonant cavity provides a radial accelerating electric field. After the electron beam is horizontally shot into the resonant cavity from the electron gun, it is accelerated along the radial electric field, and then enters the resonant cavity again through the external bending magnet after being deflected, repeatedly going through nine turns and ten passes of the resonant cavity, and finally ejected from the exit. Each time the electron beam passes through the resonant cavity, it gains 1 MeV of energy. Therefore, the energy of the ejected electron beam is 10 MeV. The ejected electron beam then passes through a 270-degree bending magnet, and its direction changes from horizontal to vertical downward. After being expanded into a parallel plane beam by the scanning system, it completes the irradiation of the object. Table 1 provides the main technical parameters of the coaxial cavity electron accelerator.

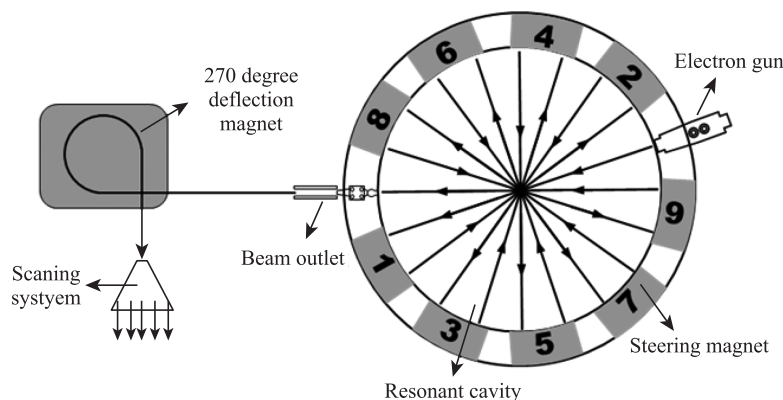


Fig. 1 (color online) Diagram of accelerator main structure and acceleration principle.

According to the design of the coaxial cavity electron accelerator, the beam loss occurs during the electron beam acceleration, ejection, and irradiation processes. Each beam loss point is a radiation source. The beam loss during the acceleration and ejection processes occurs on the nine bending magnets and the exit slit, with the corresponding beam energy ranging from 1 to 10 MeV. The total beam loss intensity is 6  $\mu\text{A}$ , with less beam loss of high-energy

electrons and more of low-energy electrons. During the irradiation process, the entire scanned beam is lost in the beam recovery water tank in the irradiation room, with a corresponding beam energy of 10 MeV and a loss intensity of 10 mA.

Table 1 Main tech parameter of Recotron.

Parameter	Value
Electron beam energy/MeV	10
Electron beam intensity/mA	10
Electron beam power/kW	100
Energy instability/%	$\pm 2$
Beam instability/%	$\pm 2$
Scanning unevenness/%	$\pm 10$

Due to the large number of beam loss points and the diverse forms of beam loss, including concentrated point losses and surface losses after scanning, and each beam loss point having a different beam energy, it is difficult for shielding calculations using empirical formulas. Therefore, this article uses the three-dimensional Monte Carlo program FLUKA for simulation calculations. In the Monte Carlo simulation, the source model is crucial, and its rationality directly determines the credibility of the calculation results. According to the characteristics of the beam loss in the coaxial cavity electron accelerator, source models for the accelerator and irradiation were established, as shown in Figs. 2 and 3. The black dot in the middle of Fig. 3 represents a point electron source located at the center. The dashed arrow indicates the direction of electron emission, with the number it points to indicating the electron energy, and the angle between adjacent dashed lines is  $36^\circ$ . The sampling probability in all directions is equal. The black cylinder surrounding it represents the target at the beam loss point, made of iron and with a thickness of 1 cm. The beam and target are 1.45 m away from the ground. This model ignores the resonant cavity, external bending magnets, electron gun, and makes two approximations: (1) the beam loss along the path in the slit of the bending magnet is equivalent to a concentrated point loss, which is reasonable since the slit of the bending magnet is close to a point relative to the large space of the main room, and its geometric effect on the radiation field is negligible; (2) the beam loss is not related to the electron energy, and the loss current strength at each target location is the same. Since high-energy electrons can produce stronger bremsstrahlung, this approach is also conservative. In Fig. 4, the solid line above represents a uniform plane electron source with a range of 110 cm in length and 10 cm in width, with virtual arrows indicating the emission direction of the electrons. The rectangular box below represents the beam recycling water tank with a thickness of 10 cm, which is greater than the range of electrons with the energy of 10 MeV in water. In addition, to avoid problems such as long calculation time, large calculation errors, or even empty counts for small probability events, the simulation technique of distributed computing was used, which first simulates the interaction between electrons and matter, and then uses the photons generated in the first step as source particles for the transport simulation of the second step.

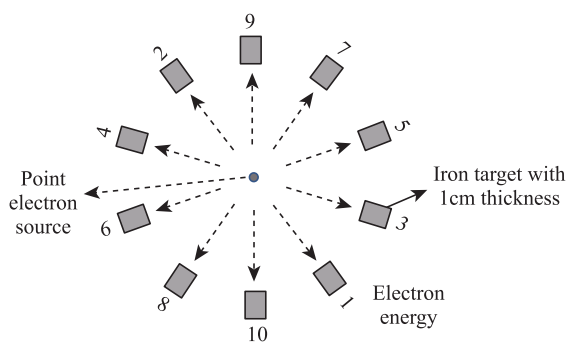


Fig. 2 (color online) Diagram of accelerator radiation source model.

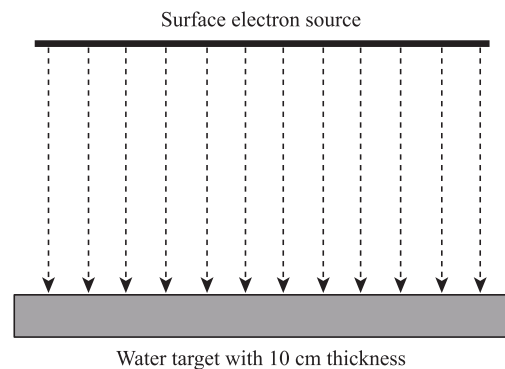


Fig. 3 (color online) Diagram of irradiation radiation source model.

The calculated results show that to meet the dose safety criterion of China, the thickness of side walls and ceiling of accelerator room and ceiling of irradiation room should be at 160~220 cm, 110~150 cm, 150 cm respectively, when ordinary concrete was used as shielding material.