The wall effect of the sample position well for neutron induced fission fragments

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Content

1. Introduction

1). **The measurement of neutron induced fission fragments is highly concerned.**

a. **To monitor the neutron flux**
b. **It is important in nuclear physics and application**

2). **Gridded ionization chamber is widely used to measure the neutron induced fission fragments.**

a. **High detection efficiency (solid angle ≈ 4π)**
b. **Gama insensitive**
c. **Radiation resistant**

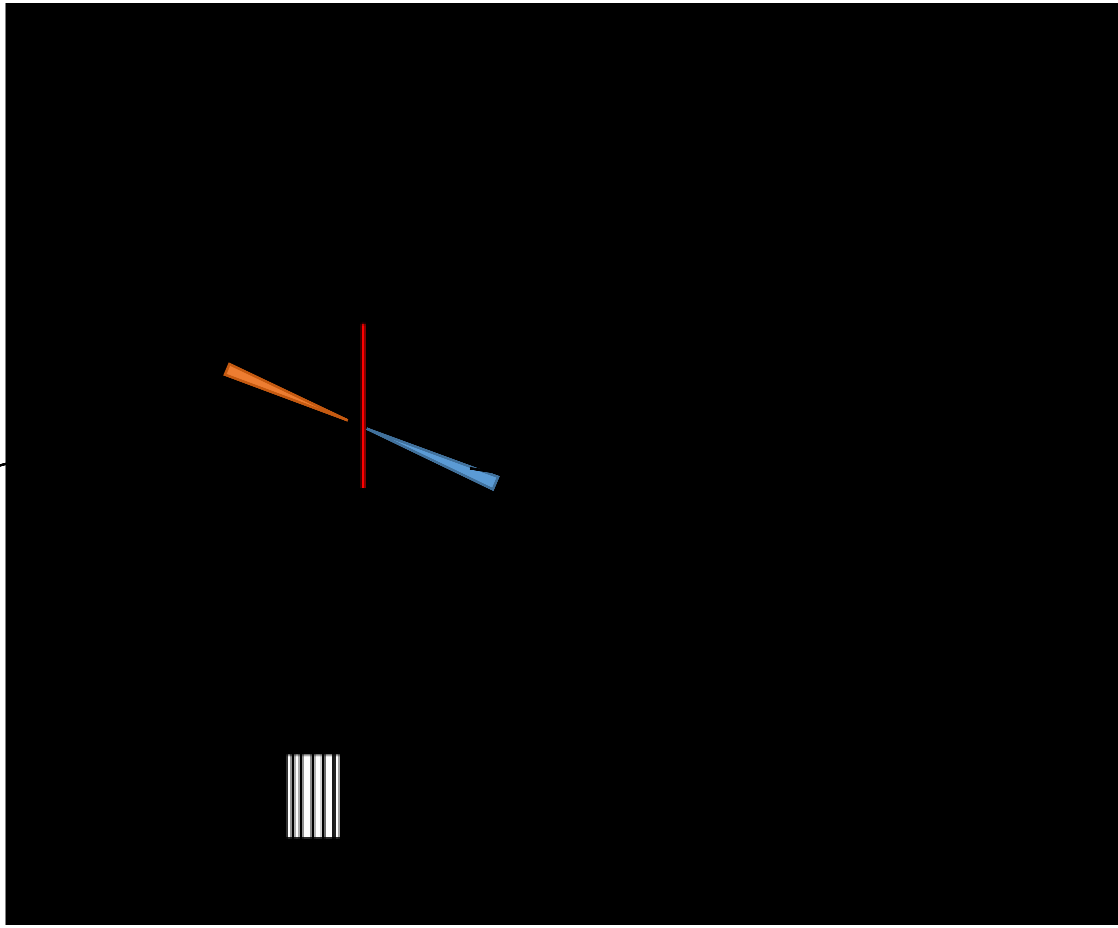
1. Introduction

3). The sample is commonly mounted in a sample position well of the cathode.

a. **To simultaneously measure the emitted fission fragments in both the forward and the backward directions**

b. **To conveniently replace the samples**

Fragment 2



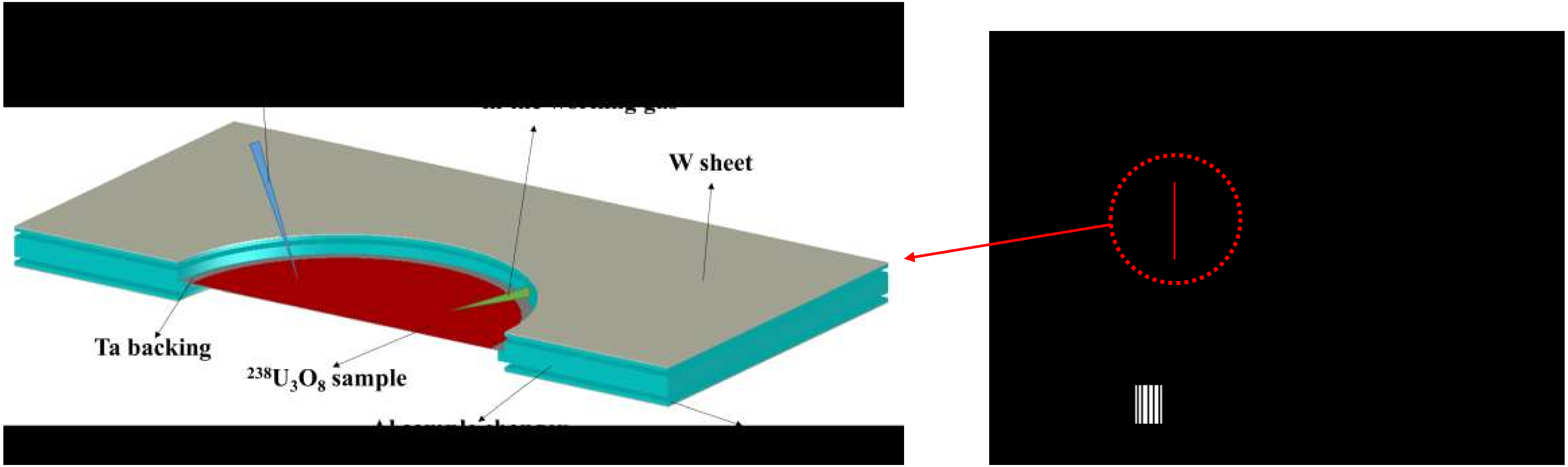
The structure of the ionization chamber

1. Introduction

4). The fission fragment may collide with the inner wall of the sample position well.

Only part of it's kinetic energy can be deposited in the working gas

Wall effect of the sample position well



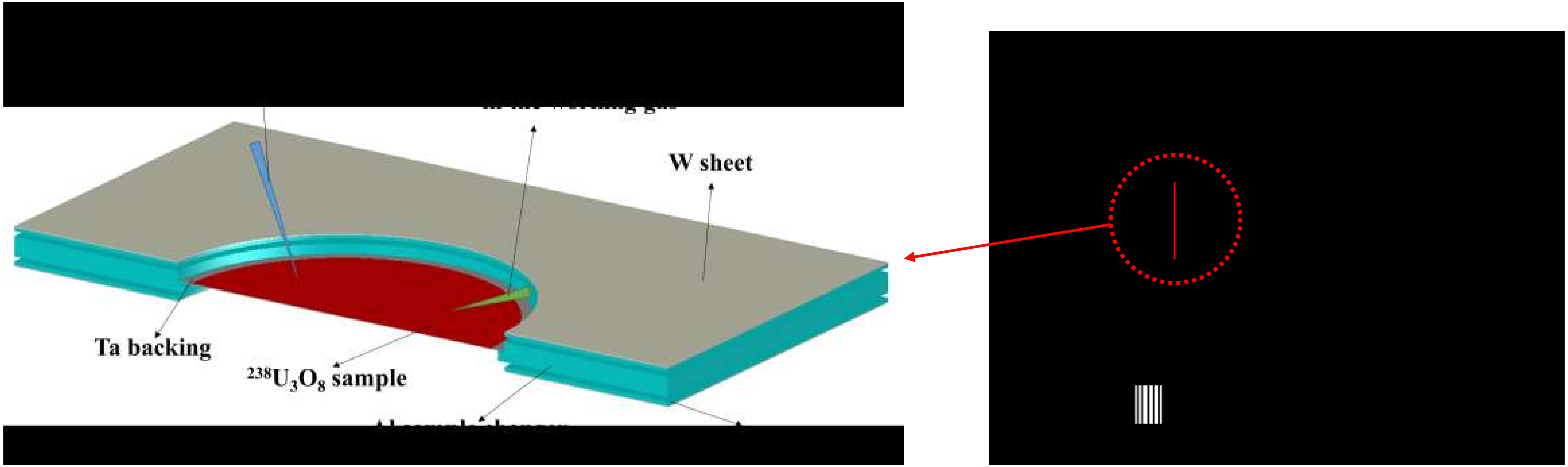
The sketch of the wall effect of the sample position well

1. Introduction

Wall effect of the sample position well

a. **The detection efficiency will be decreased: The detected energy may be degraded below the measurement threshold**

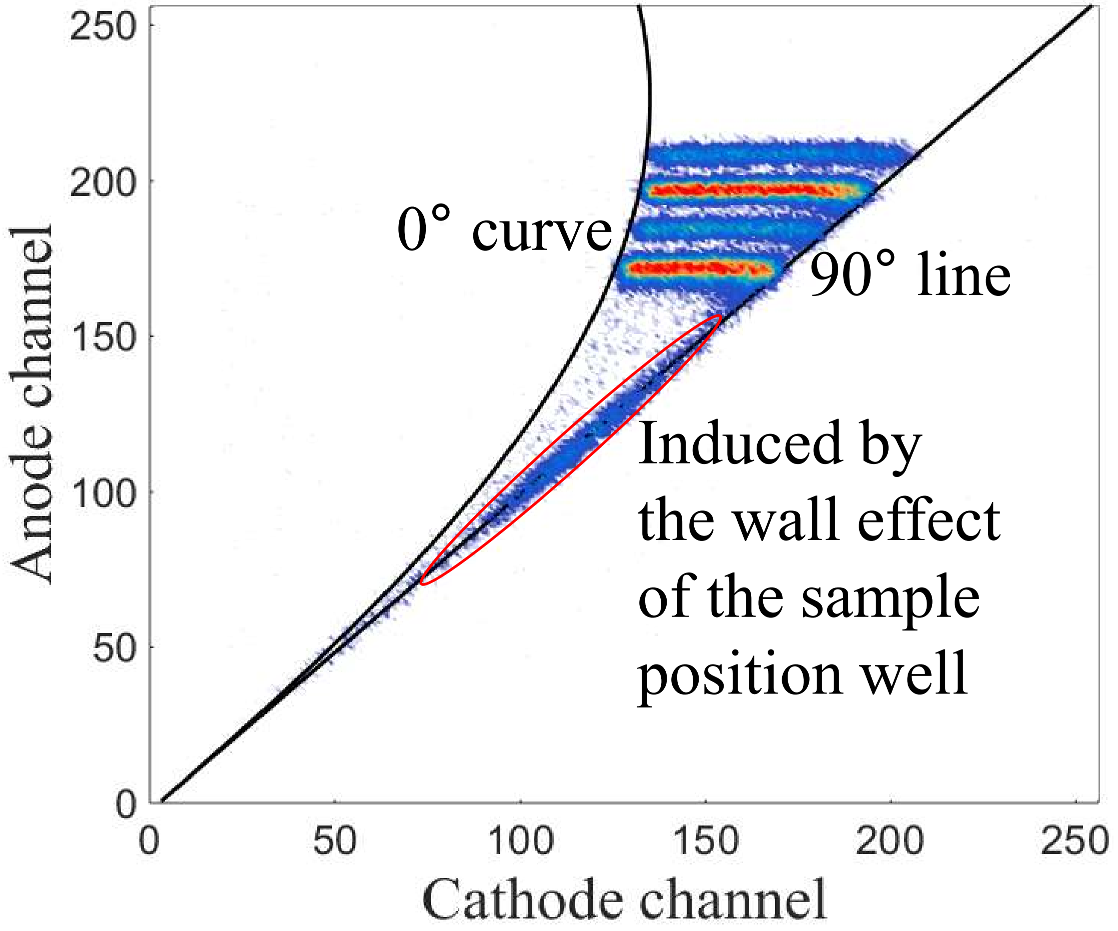
b. **The measured angular distribution may be incorrect: Emission angle dependence**



The sketch of the wall effect of the sample position well

1. Introduction

Wall effect of the sample position well



The wall effect of the sample position well on measured α particles.

Besides the fission fragments, the detection of the other charged particles using the ionization are also affected by the wall effect of the sample position well. And the wall effect of the sample position well can easily be seen in the measurement of the compound *α* source (Bai, 2017; Zhang, 2005).

2. Experiment and simulation

To obtain correct measured results, the wall effect of the sample position well on neutron induced fission fragments should be considered.

Solution: Monte Carlo simulation.

Universal: Through changing some input parameters, the wall effect of the sample position well in different situations can be known.

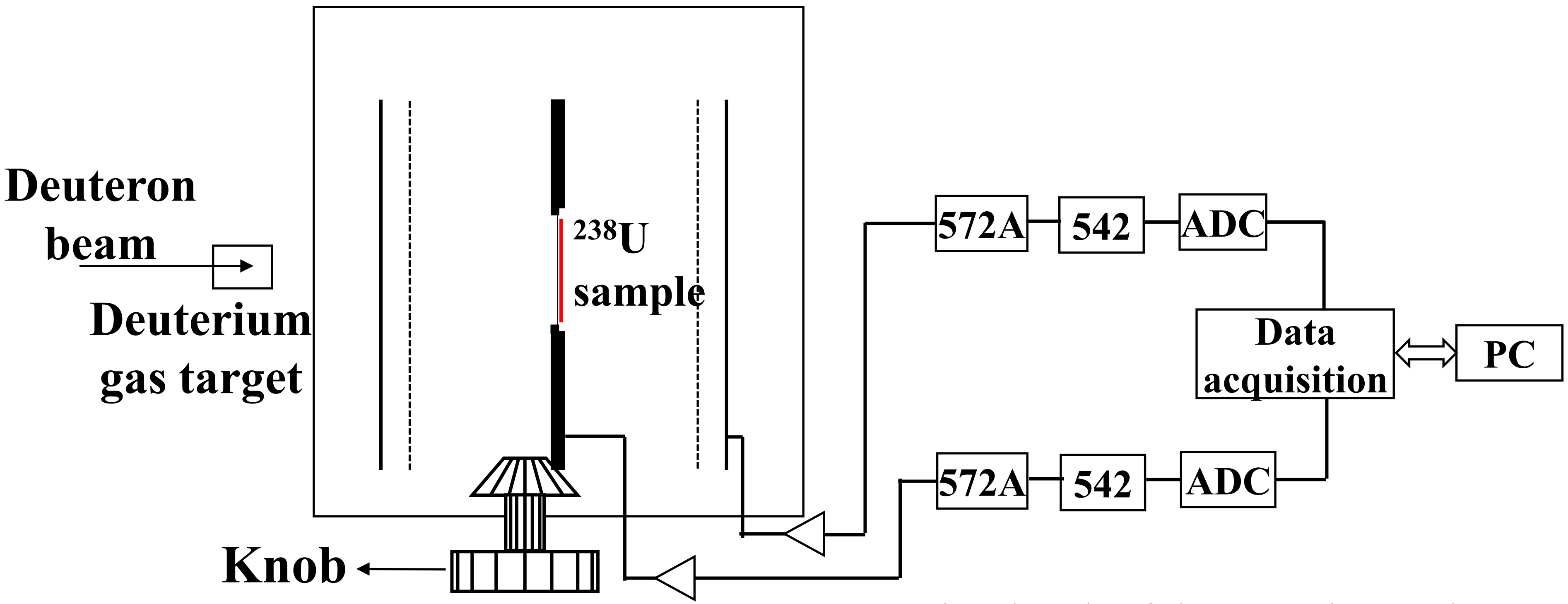
The reliability of the simulation should be checked by experiment first!

2. Experiment and simulation

1). Experiment

a. Neutron source

- **Accelerator: 4.5 MV Van de Graff accelerator of Peking University**
- **Beam: Deuteron (≈ 2.5 μA)**
- **Target: Deuterium gas target (0.30 MPa)**



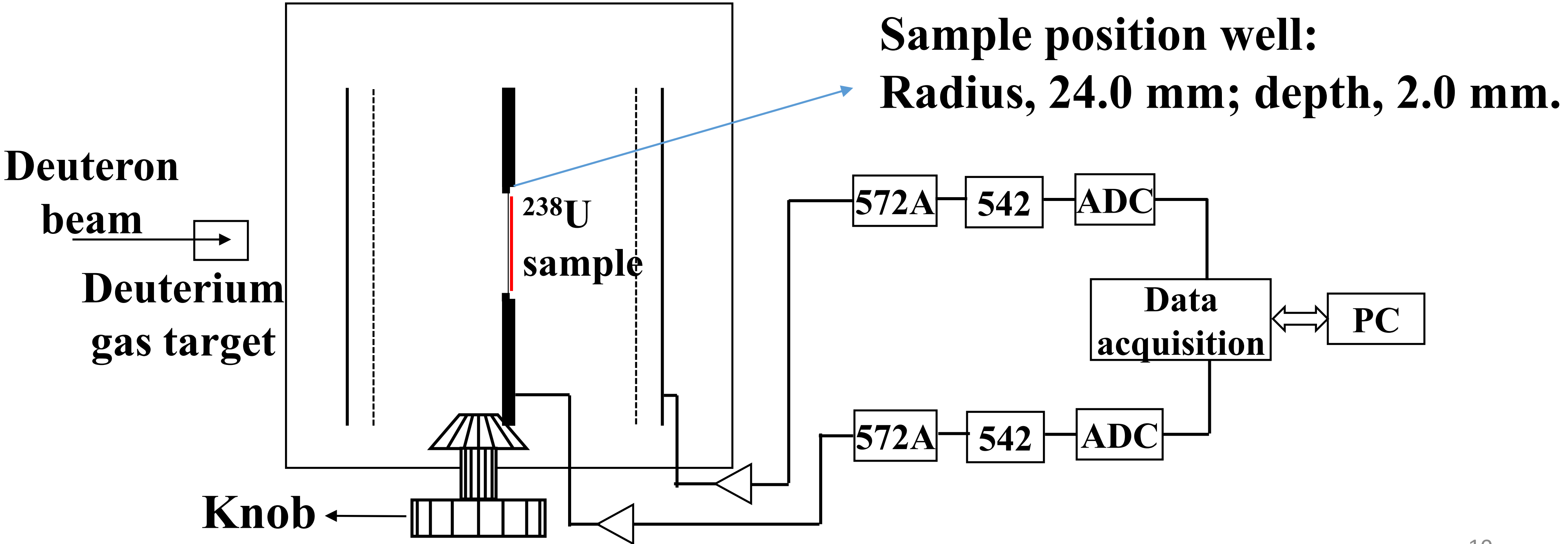
The sketch of the experimental setup.

2. Experiment and simulation

1). Experiment

b. GIC

- **Working gas: Kr + 2.7% CO_2 (0.052 MPa)**
- **Separation: D_{cg}, 61 mm; D_{ag}, 15 mm**
- **HV: cathode, -1100 V; anode, +550 V; grid, 0 V**
- **Data acquisition system: DAqS (Zhang, 2010)**



The sketch of the experimental setup.

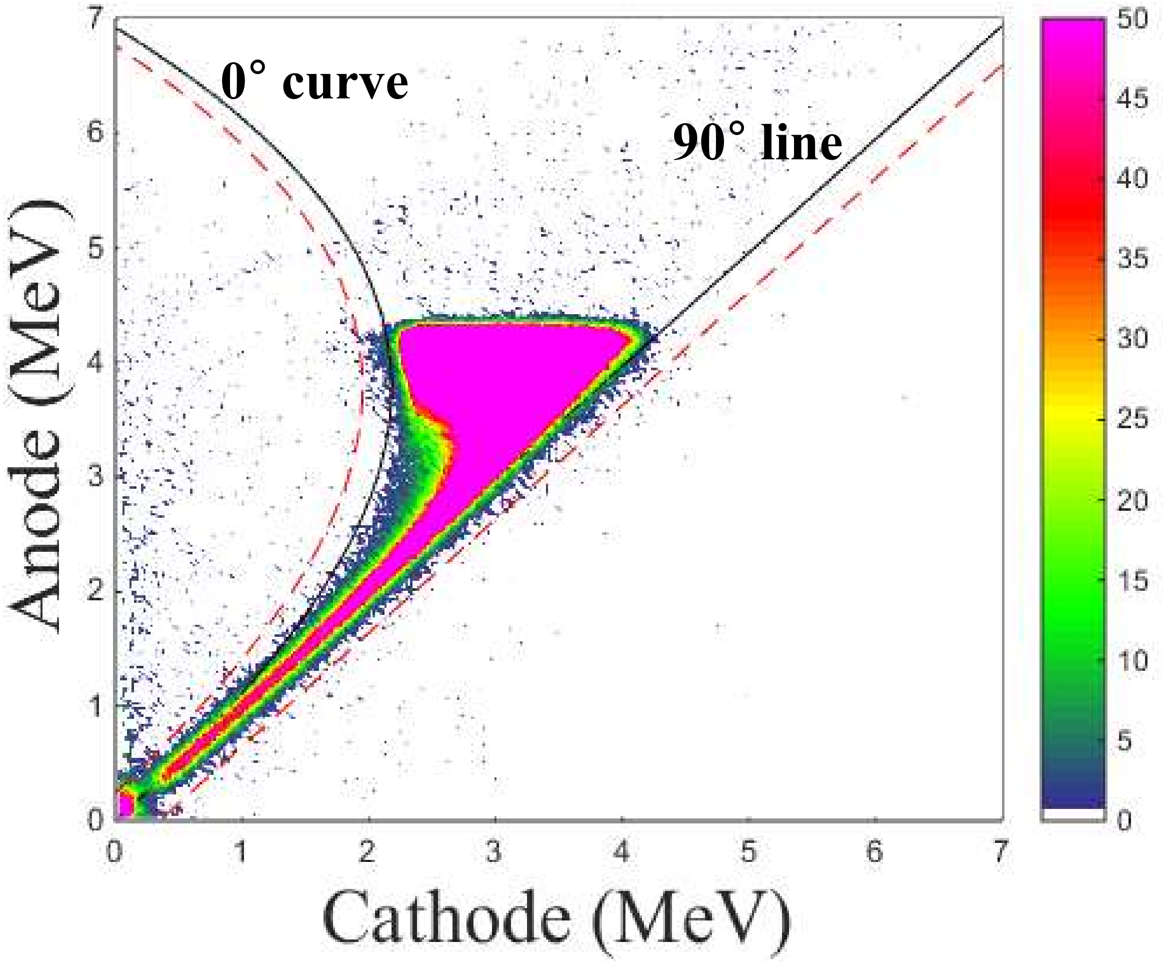
2. Experiment and simulation

1). Experiment

c. $^{238}U_3O_8$ sample

- **Radius: 22.5 mm**
- **Thickness: 605 μg/cm^2**
- **Non-uniformity: 1.00±0.05**

The photo of the $^{238}U_3O_8$ sample.

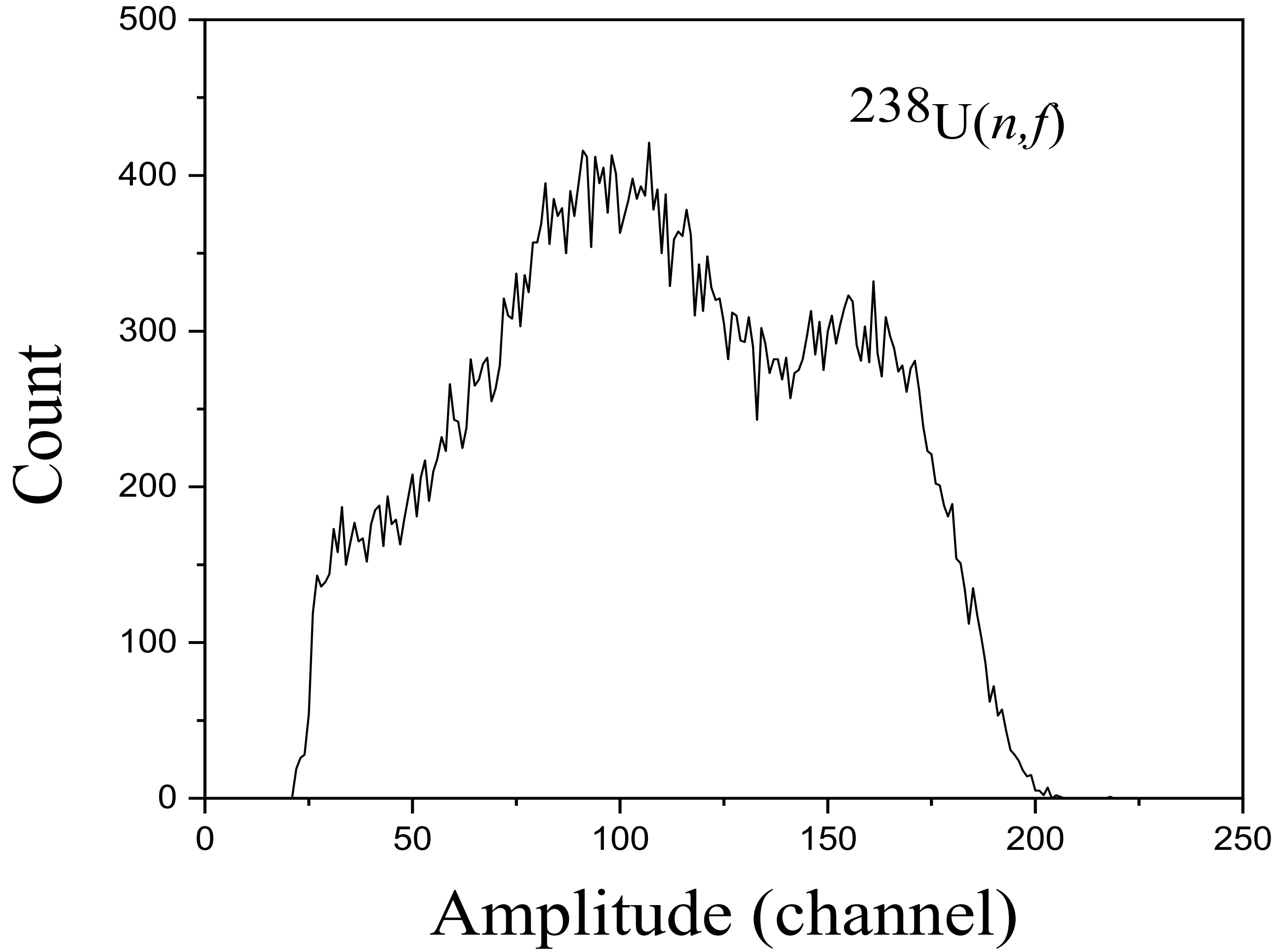


The measured cathode-anode two dimensional spectrum of the α particles emitted from the $^{238}U_3O_8$ sample.

2. Experiment and simulation

1). Experiment

d. Results



The measured energy spectrum of neutron induced fission fragments.

2. Experiment and simulation

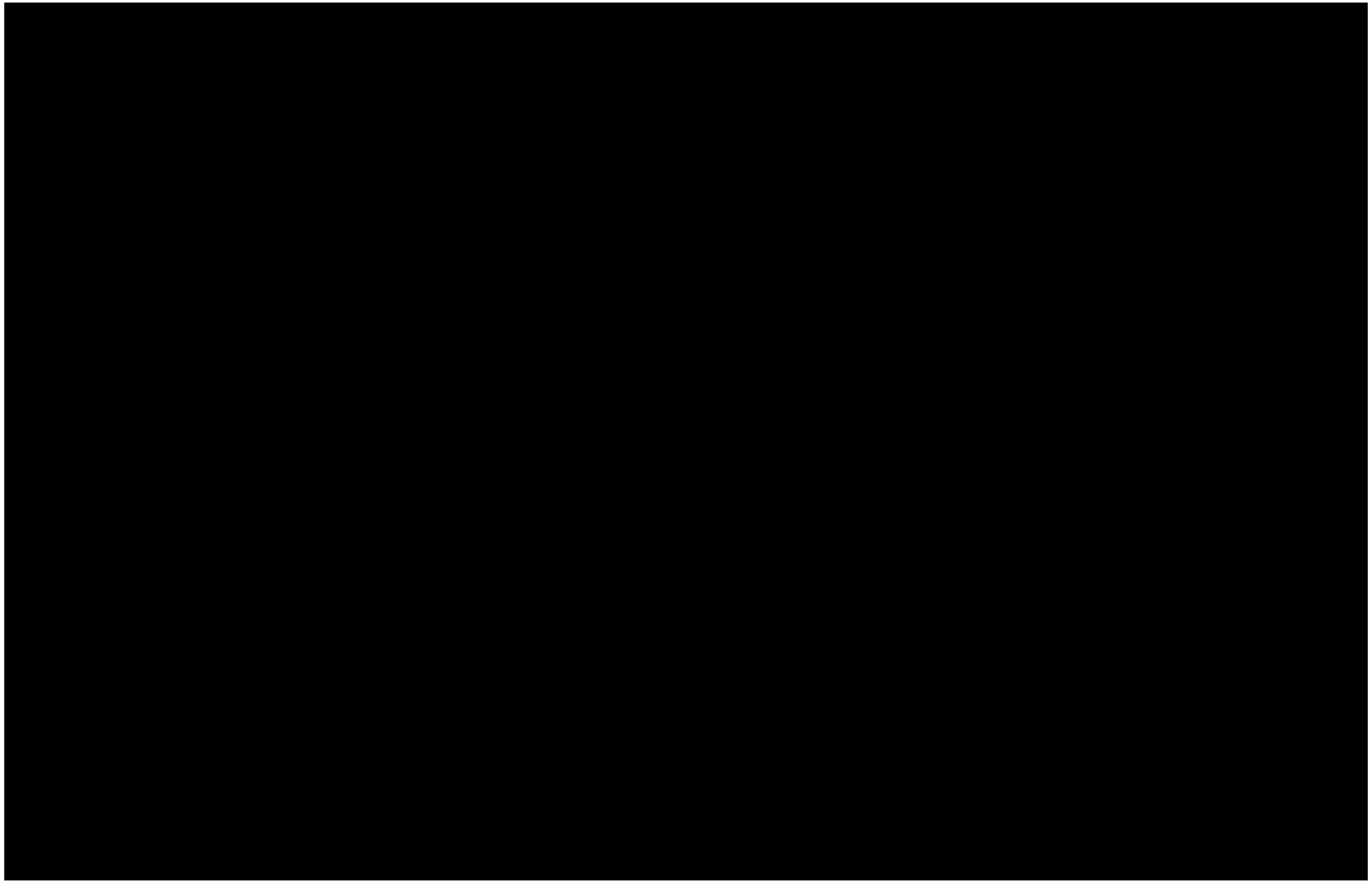
2). Simulations

a. **Based on Monte Carlo method**

b. **Two fission fragments are tracked in one fission event**

c. **The fission fragments are tracked step by step with energy loss of 0.05 MeV**

d. **10^5 fission events are tracked in each runs**



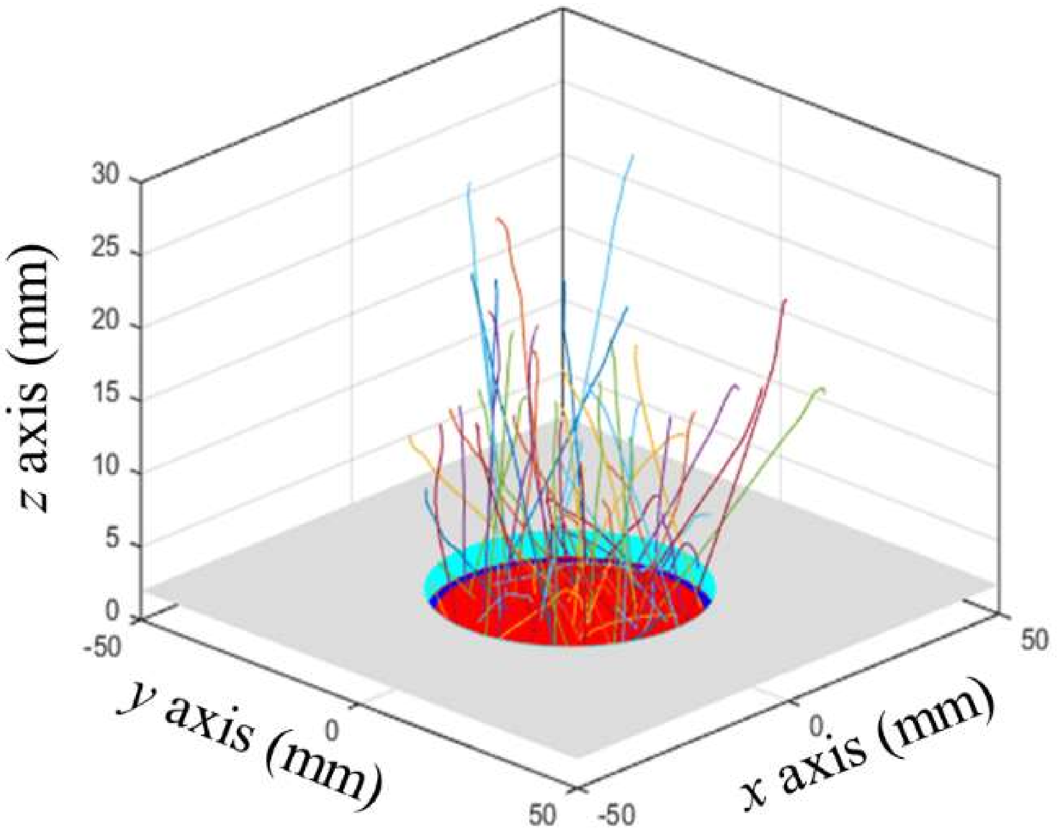
The flowchart of the simulation of the fission energy spectrum.

2. Experiment and simulation

2). Simulations

e. The fission products yields (ENDF/B-VII.1), the energy of the fission fragments (Birgersson, 2009), and the stopping powers of the fission fragments calculated using SRIM-2013 code (Ziegler, 2013) are used

f. The angular differential scattering cross sections are calculated using Rutherford scattering equation (Chu, 1978.)



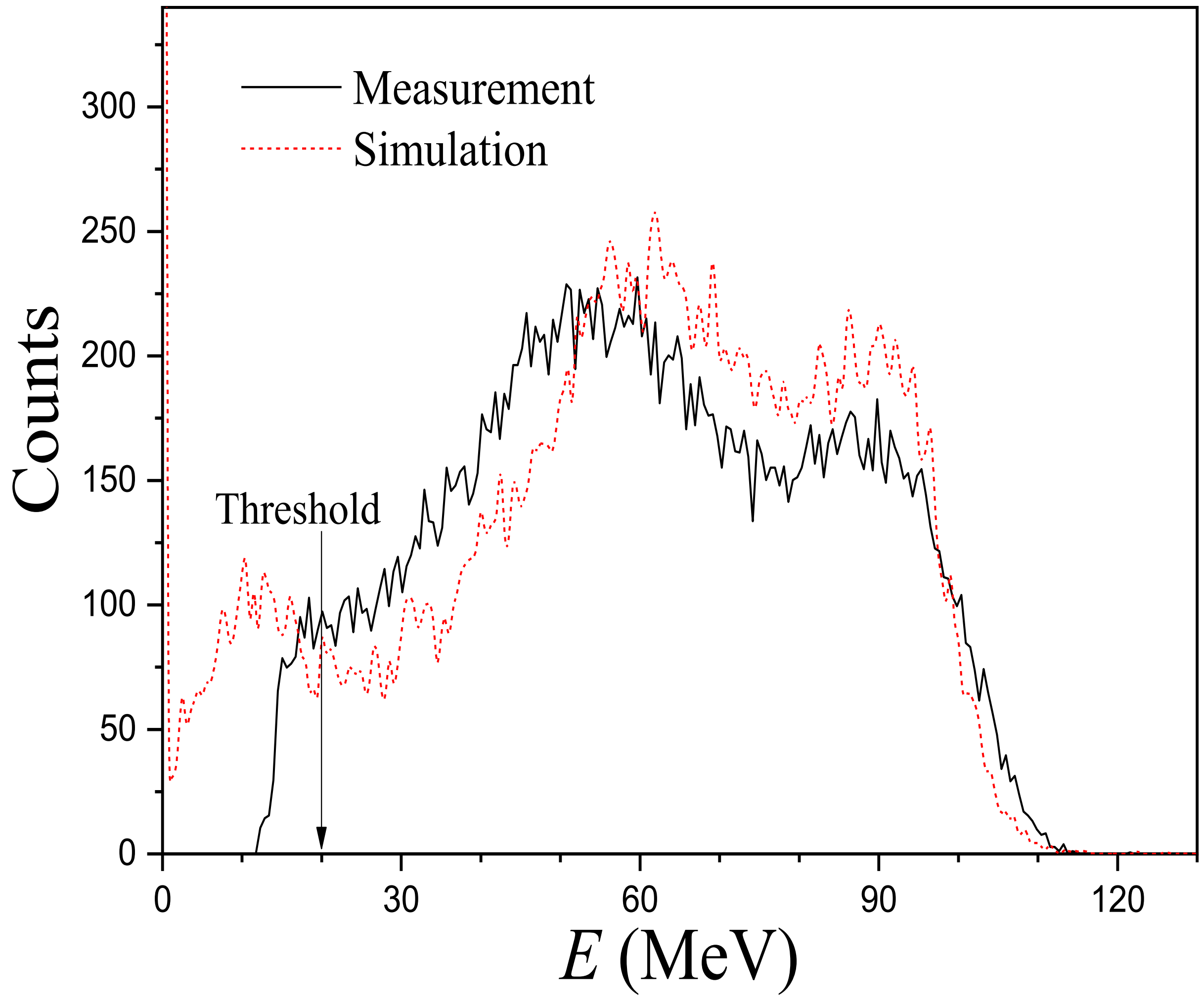
The simulated tracks of 100 fission events.

2. Experiment and simulation

2). Simulations

g. The energy of the higher energy peak is about 90 MeV

h. The energy of the simulated lower energy peak is higher than that of the measured one because the pulse height defect (PHD) effect is not considered



The energy spectra of neutron induced fission fragments.

2. Experiment and simulation

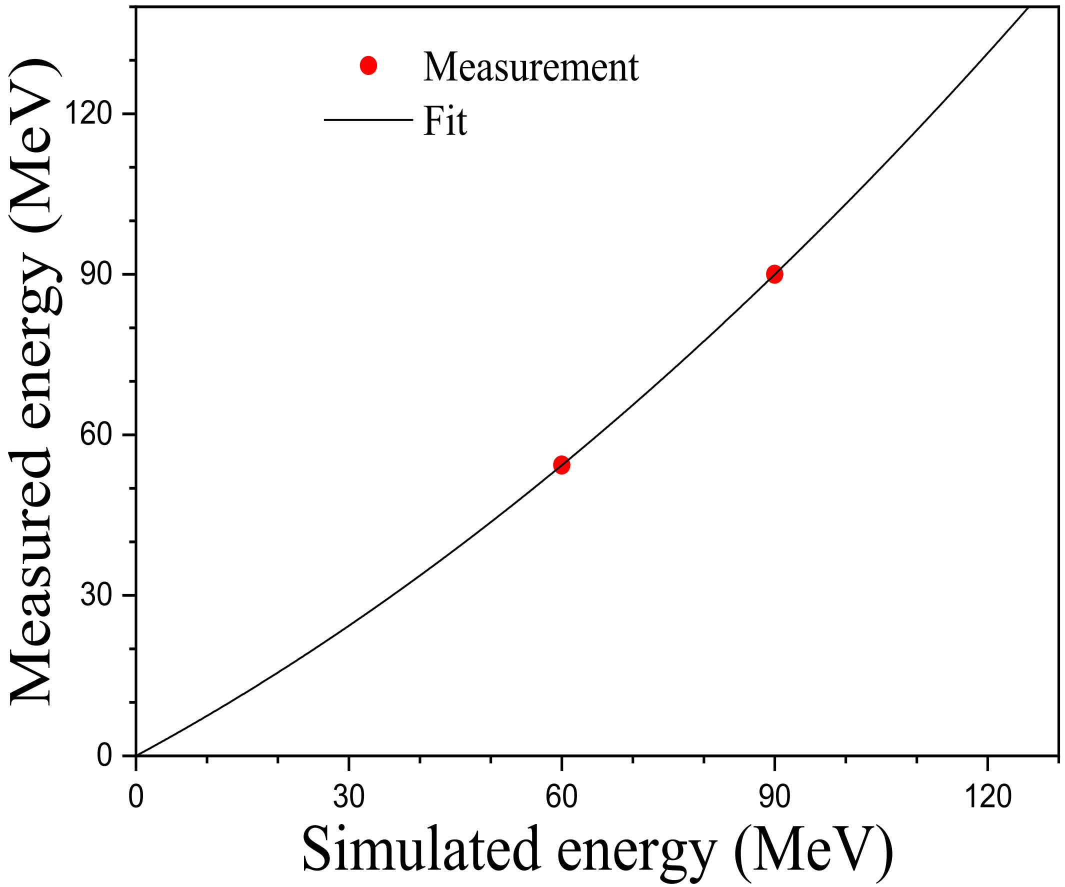
2). Simulations

i. **No related data about the PHD effect can be used**

j. **The energy scaling method is adopted**

$$E_M = aE_s + bE_s^2$$

Although it is not the best and basic resolution, the energy scaling is reasonable because the PHD effect is more significant for heavier fission fragments.



The relationship between the simulated energy and the measured energy of the fission fragments.

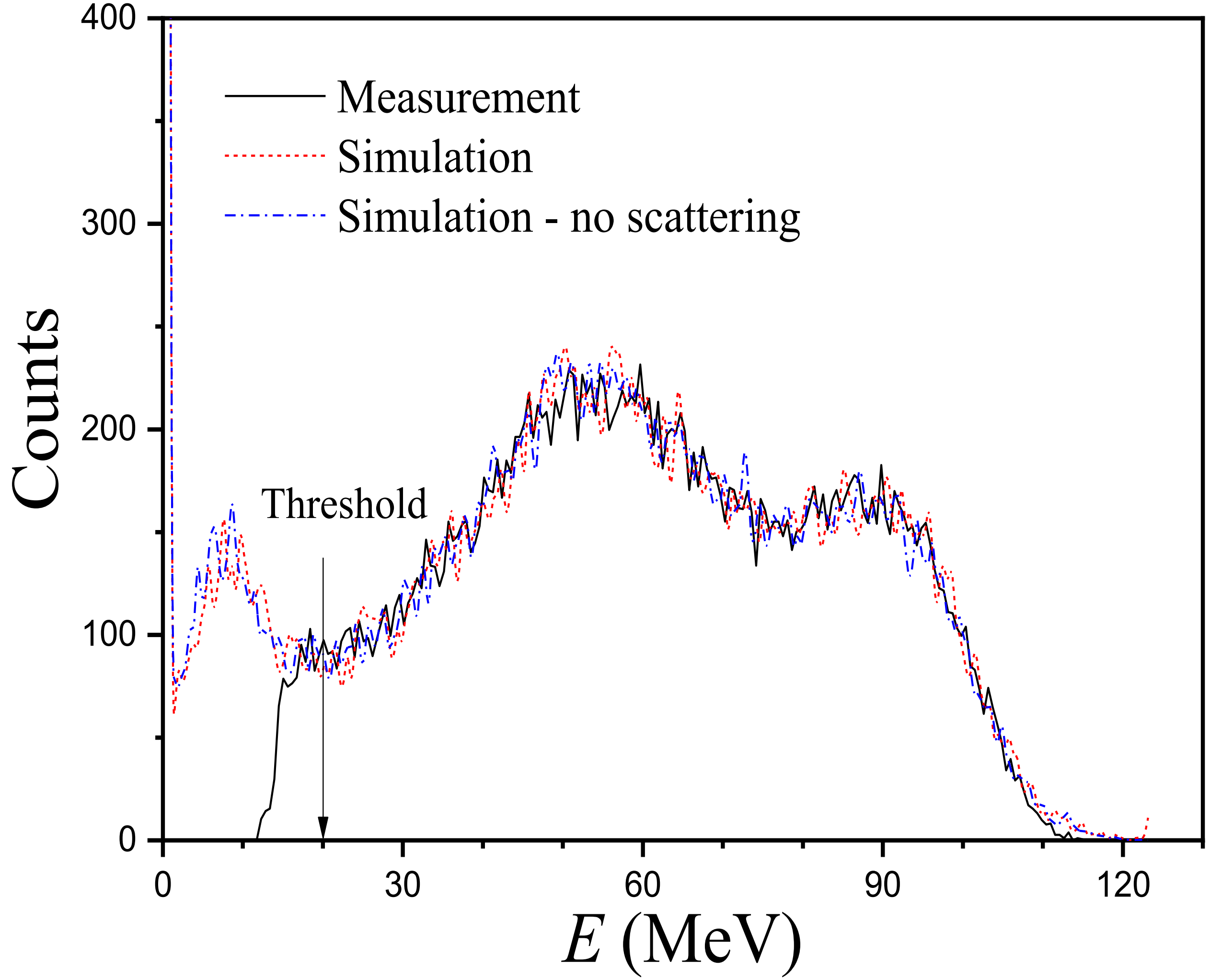
2. Experiment and simulation

2). Simulations

j. After the energy scaling, the simulated energy spectrum of the fission fragments coincidence with the measured one

k. The simulation is reliable

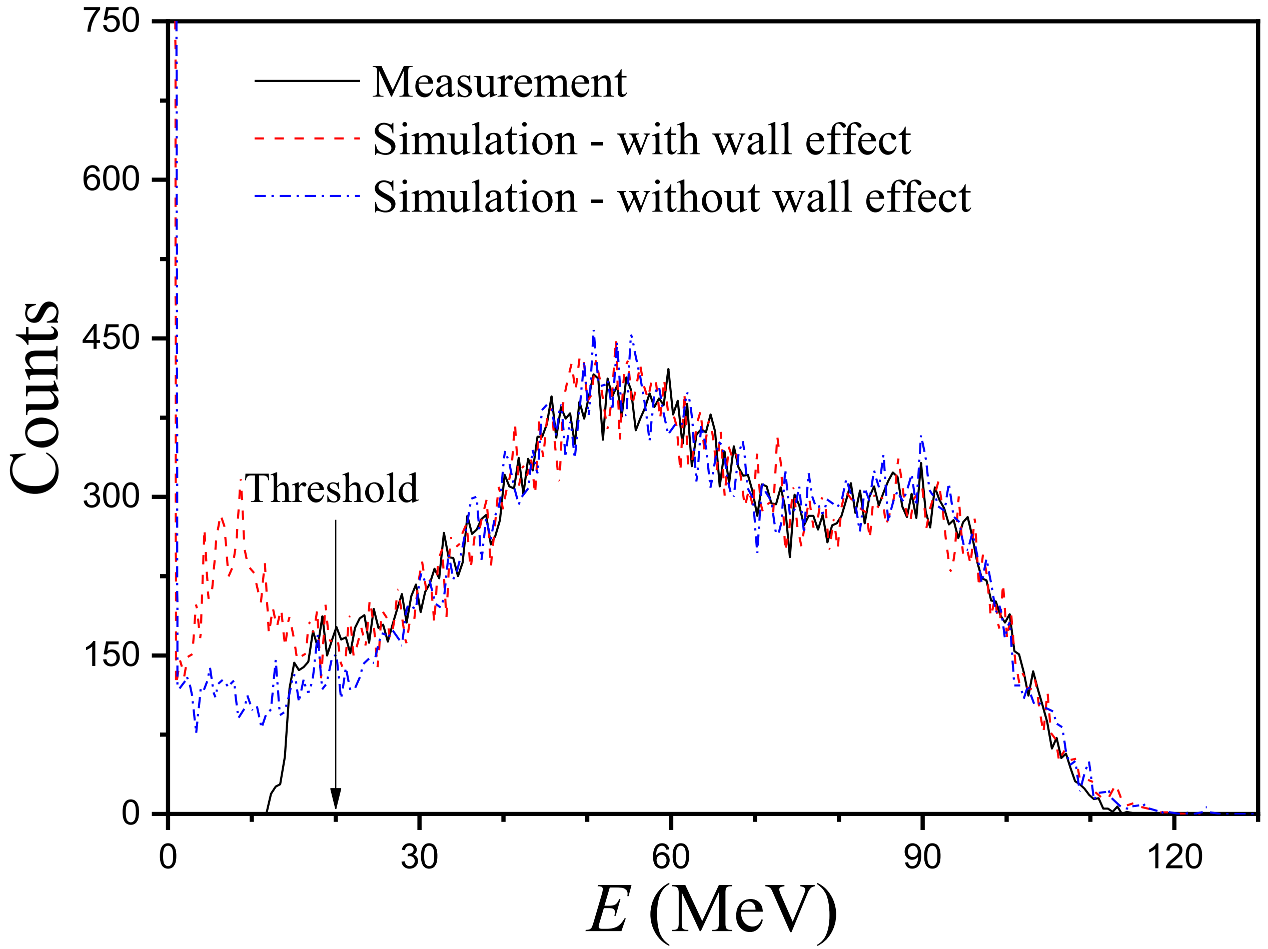
l. The effect of the scattering can be ignored



The energy spectra of neutron induced fission fragments.

2. Experiment and simulation

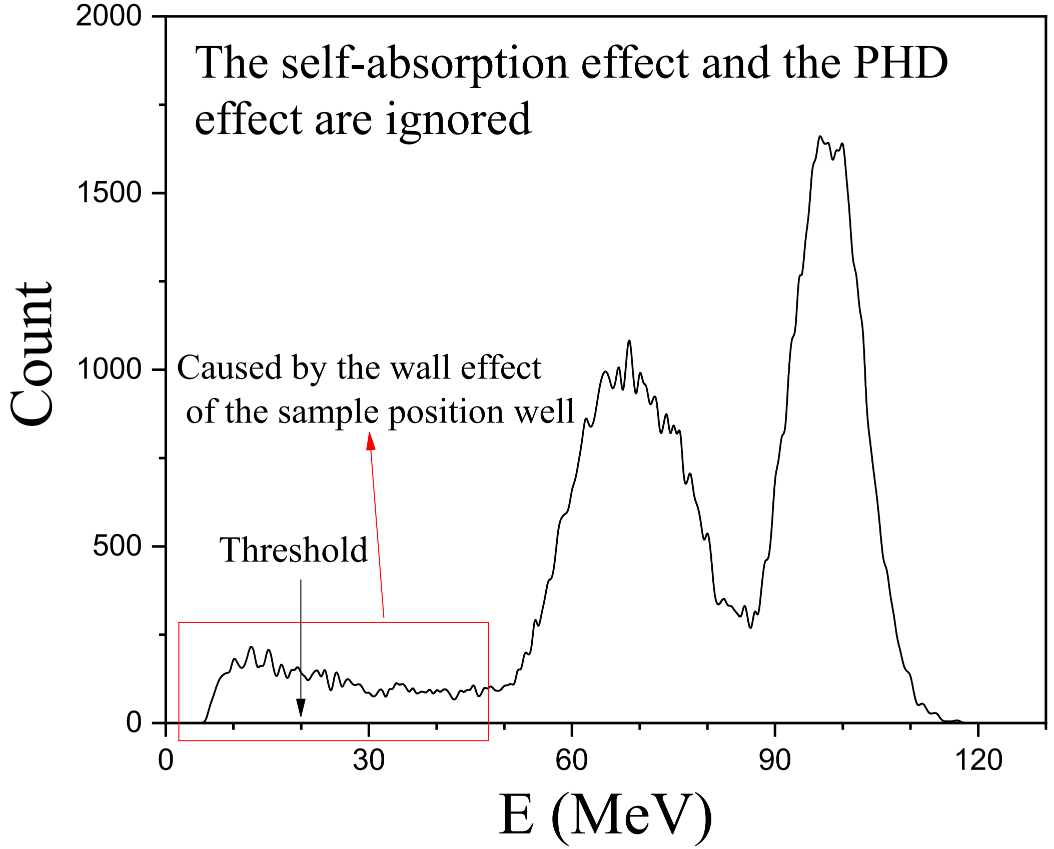
m. Below the measurement threshold, the differences between the simulated results with and without considering the wall effect of the sample position well are apparent (≈5% of the total count).



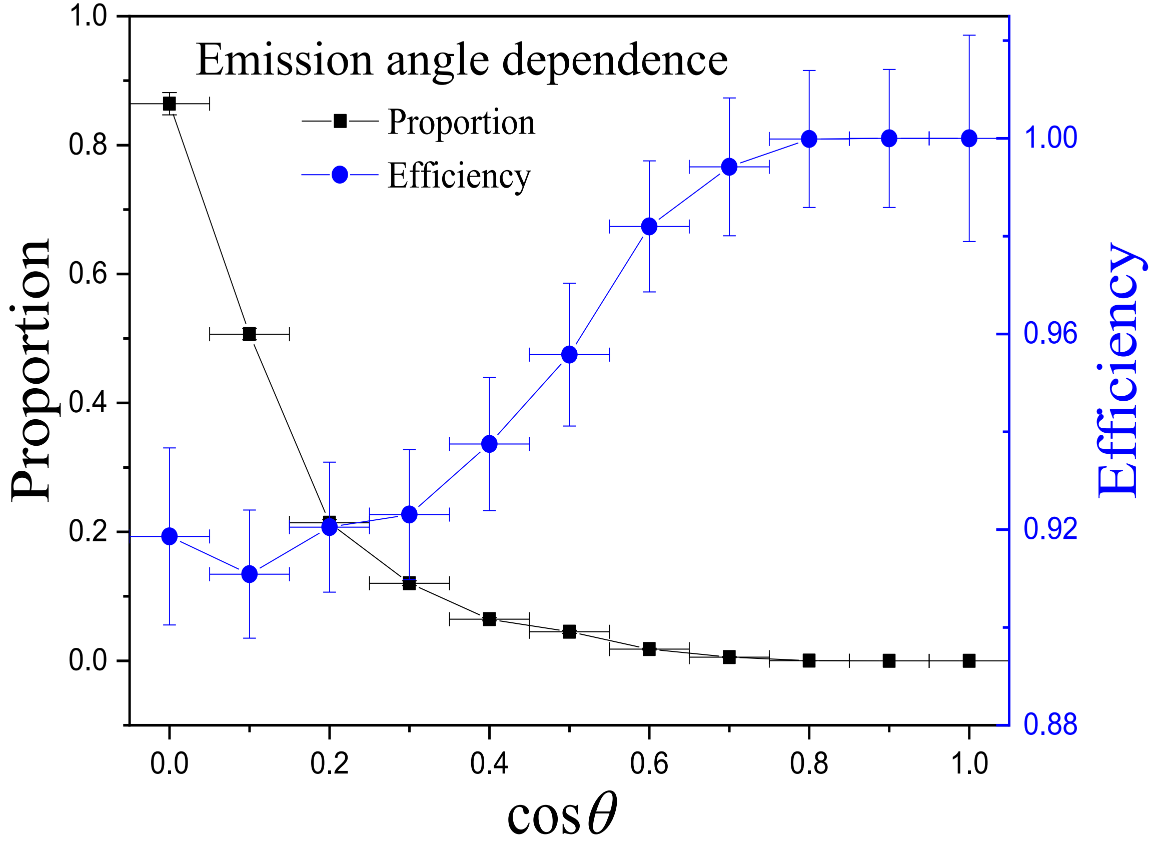
The energy spectra of neutron induced fission fragments.

3. Results

To illustrate the wall effect of the sample position clearly, the self-absorption effect and the PHD effect are ignored: only the wall effect of the sample position well affect the energy deposited in the working gas.



The simulated neutron induced fission fragment energy spectrum without considering the self-absorption effect and PHD effect.

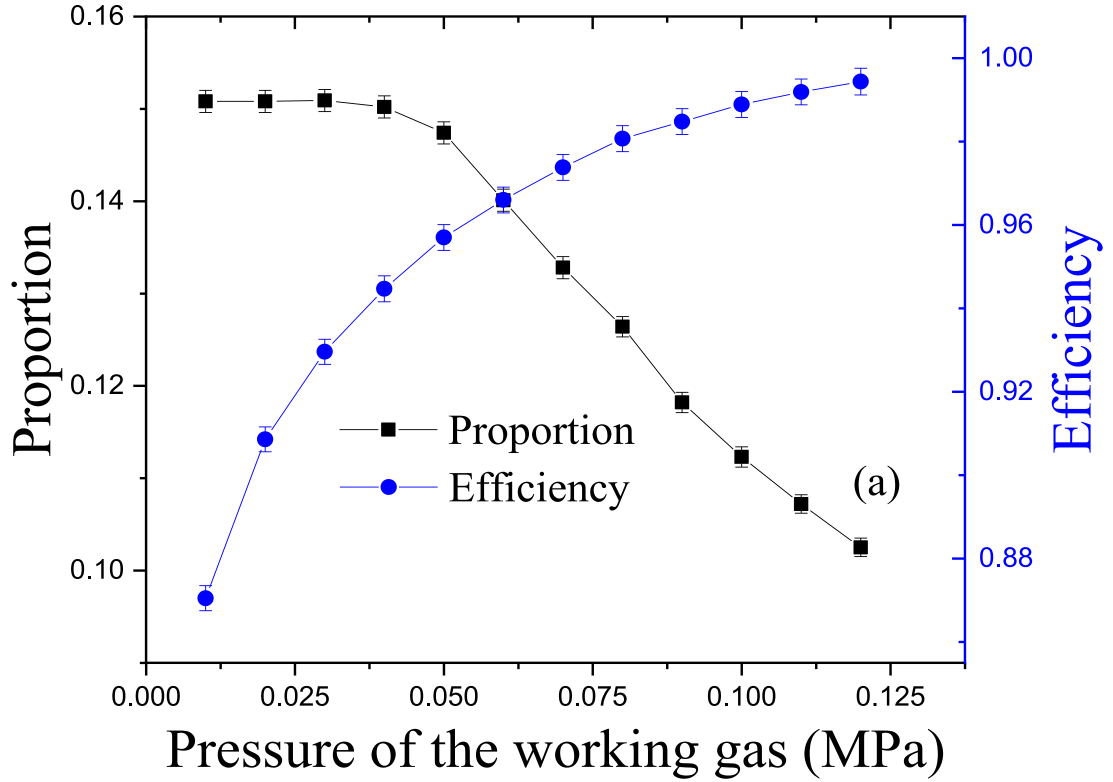


The proportion of the fission fragments with the wall effect of the sample position well as a function of the emission angle, and the detection efficiency of the fission fragments as a function of the emission angle.

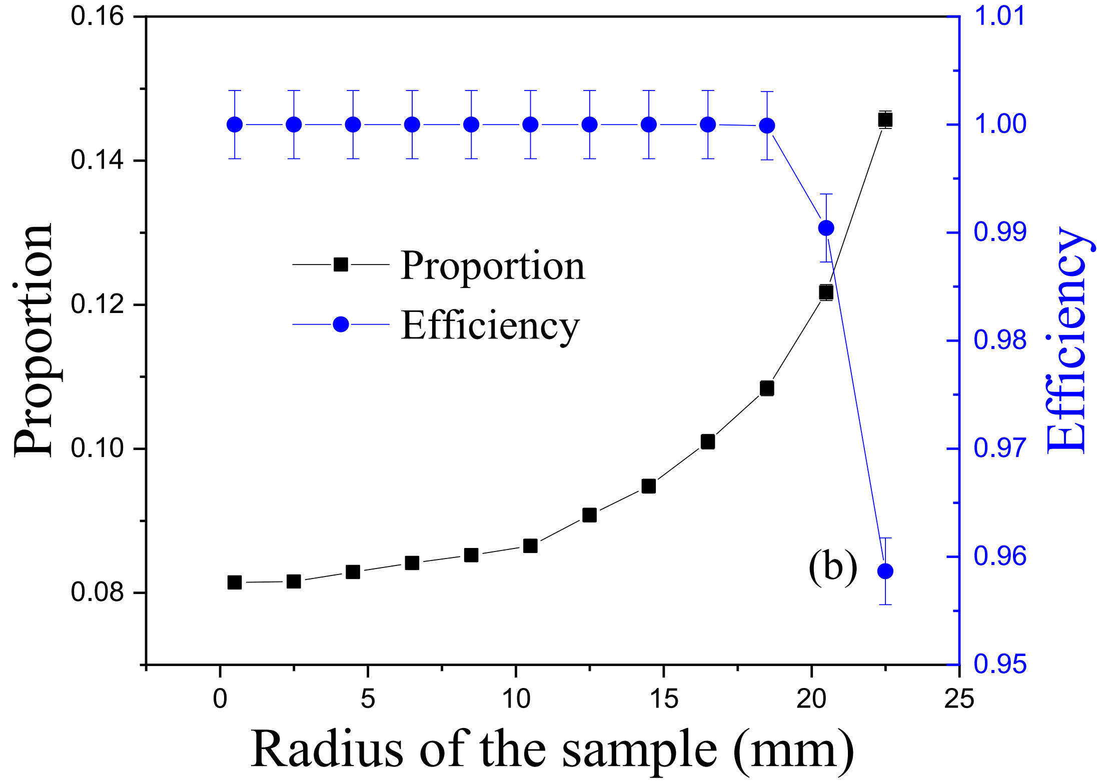
3. Results

The influences on the wall effect of the sample position well

a. The influence of the working gas pressure



b. The influence of the radius of the sample

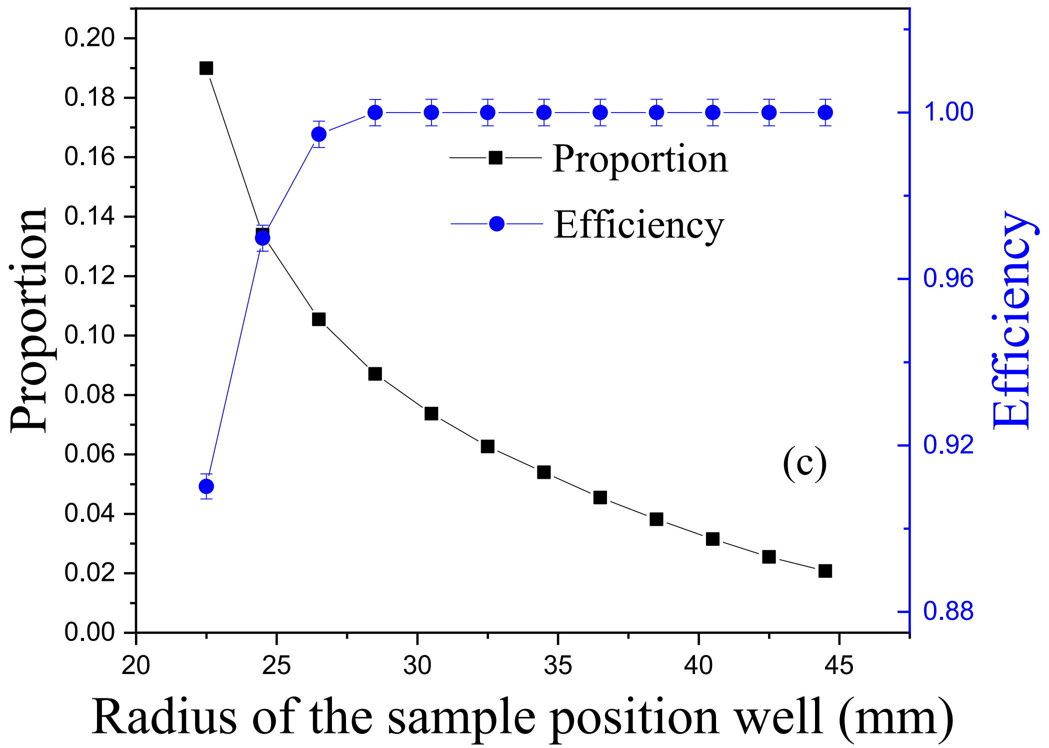


The proportion of the fission fragments influenced by the wall effect of the sample position well (square), and the detection efficiency of the fission fragments (circle). (a), the influence of the working gas pressure; and (b), the influence of the radius of the $^{238}U_3O_8$ sample.

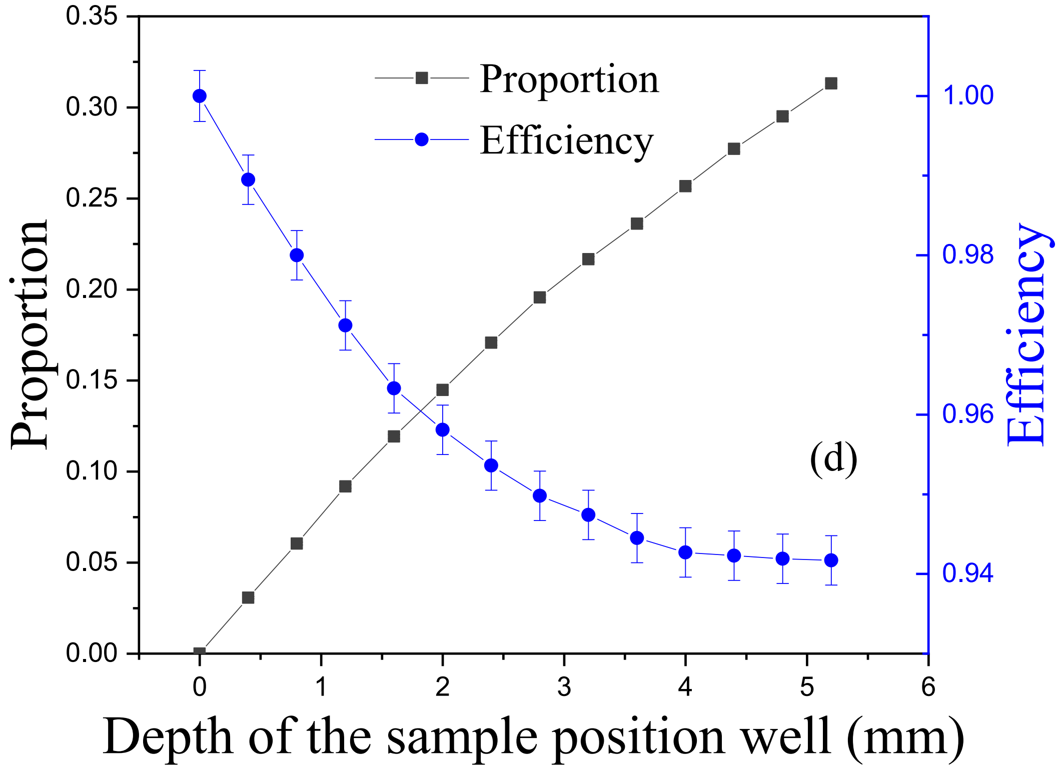
3. Results

The influences on the wall effect of the sample position well

c. The influence of the radius of the sample position well



d. The influence of the depth of the sample position well



The proportion of the fission fragments influenced by the wall effect of the sample position well (square), and the detection efficiency of the fission fragments (circle). (c), the influence of the radius of the sample position well; and (d), the influence of the depth of the sample position well.

4. Conclusions

- The simulation is reliable and it can be used to study the wall effect of the sample position well.
- The proportion of the fission fragments affected by the wall effect of the sample position well can be >10%.
- The detection efficiency of the fission fragments can be overestimated by >5% if the wall effect of the sample position well is ignored.
- The wall effect of the sample position well for fission fragments with larger emission angle are more apparent.
- The wall effect of the sample position well will be more significant if the working gas pressure is lower, or the radius of the sample is bigger, or the radius of the sample position well is smaller, or the sample position well is deeper.

References

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Thanks!