ISINN-31 seminar

Energy distributions and absolute yields measurements of the long-range alpha particles and the tritons in thermal neutron induced ternary fission of ^{235}U using a twin-gridded ionization chamber

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2025.05.29

Report Outline

1. Introduction
2. Experiment Setup
3. Result
4. Conclusion

1 Introdution

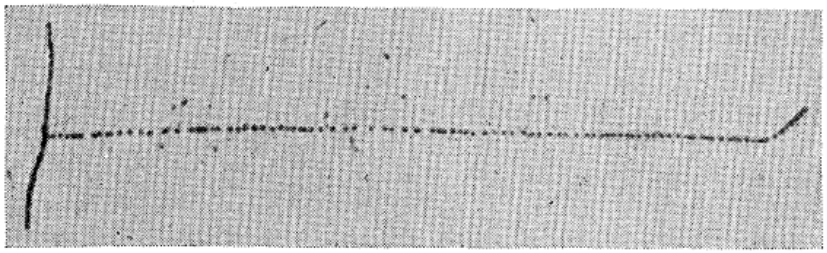
Research status：

Heavy nuclei fission

binary fission： two fission fragments that are emitted in the opposite direction

1947	Tsien San-Tsiang Ho Zah-Wei	Confirm ternary fission

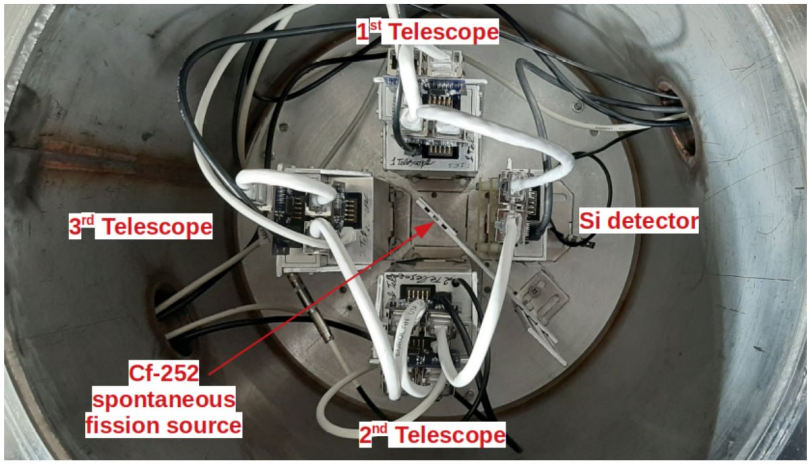
ternary fission： Light charged particles （such as alpha, triton）

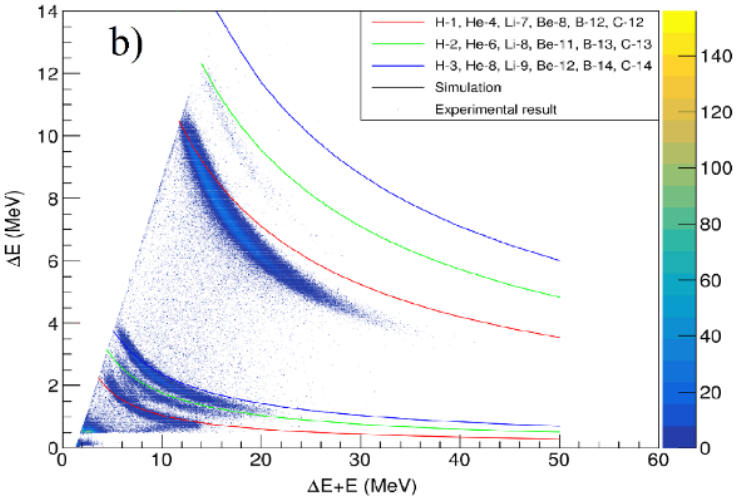


1 Introdution

Research status：

- Most of the light charged particles emitted in the ternary fission are alpha particles **(~90%)**, there are ^{1}H, ^{2}H, **^{3}H,** ^{6}He, ^{7}Li, ^{8}Li, ^{9}Li, ^{9}Be and ^{10}Be in addition, It's just that these accounts for a very small share.

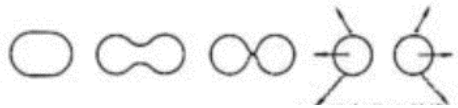


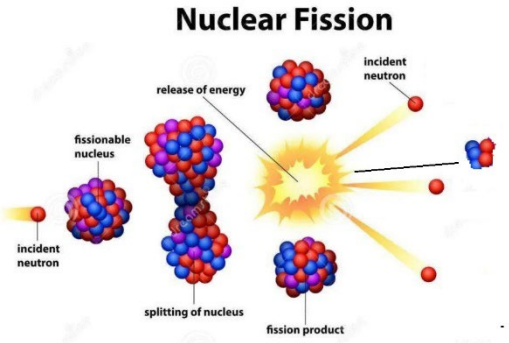


1 Introdution

- The absolute yield of the long-range α particles and tritons in ternary fission of ^{235}U are **important nuclear reaction data**.

Research on nuclear fission mechanism

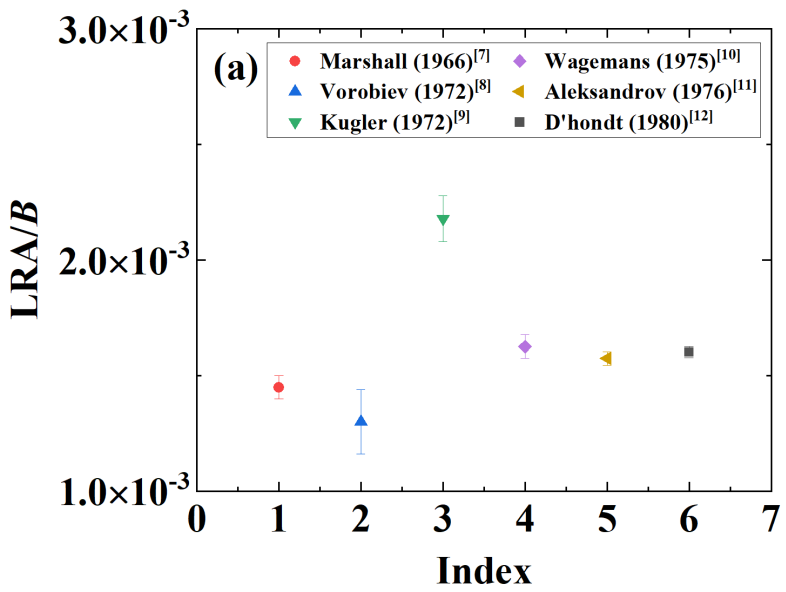


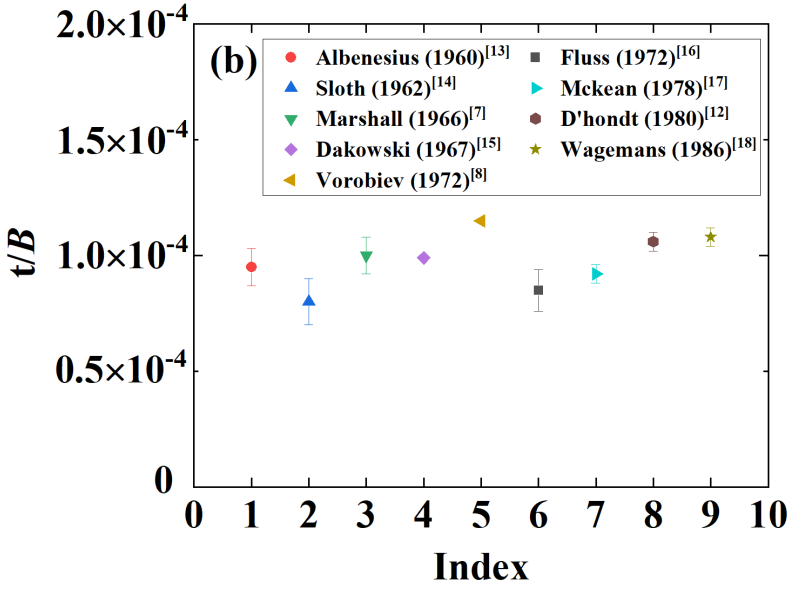


Accurate measurement of the yield data of the long-range α particles and tritons in ternary fission of ^{235}U are of great significance

1 Introdution

- The deviation of the yield of the long-range α particles and tritons in neutron-induced ternary fission of ^{235}U **is very large (about 20%)**.



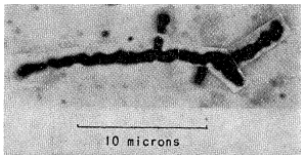


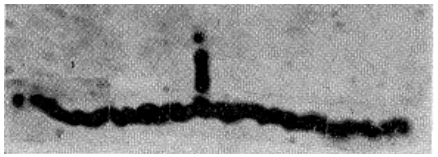
Most of the above measurements are based on the **△E-E telescopes or the radiochemical method**

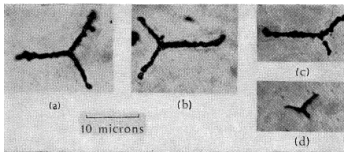
1 Introdution

Method for determining light charged particles (LCP) in ternary fission:

Nuclear emulsion



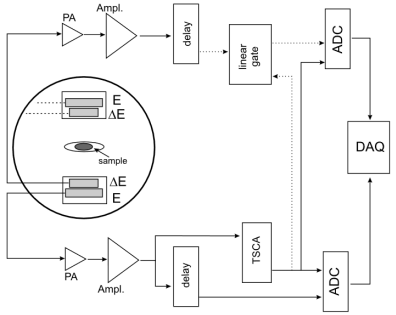


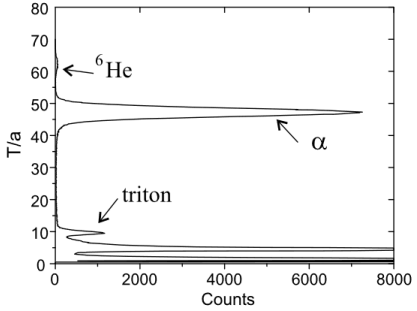


T/B

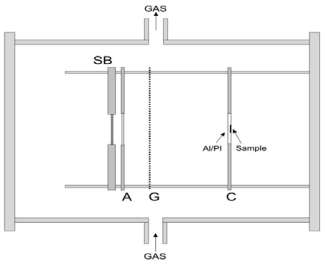
△E-E Telescope (but the solid angle is small)

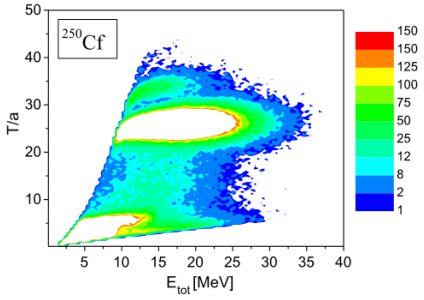
1. Si/Si △E/E telescope





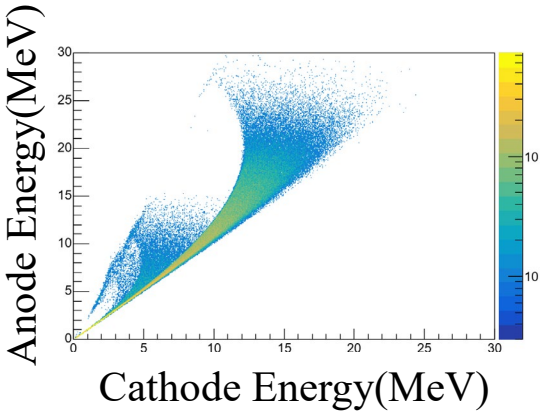
2. GIC/Si △E/E telescope





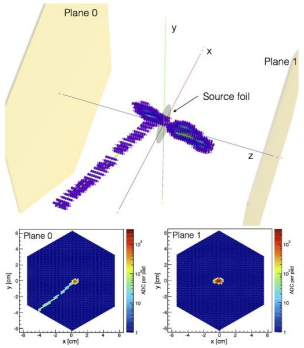
1 Introdution

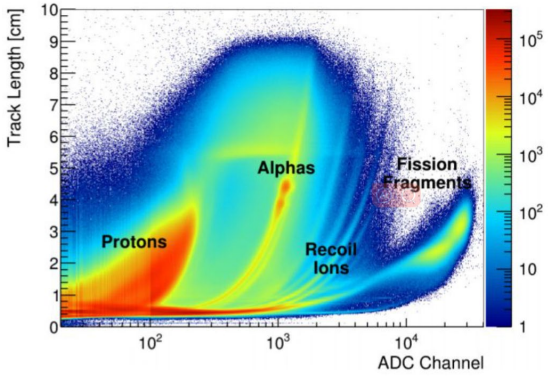
➢ **Grid-ionization Chamber (GIC) (High pressure, film):** New method, high efficiency, probably having a chance to measure the ternary particles **in high neutron energy region**

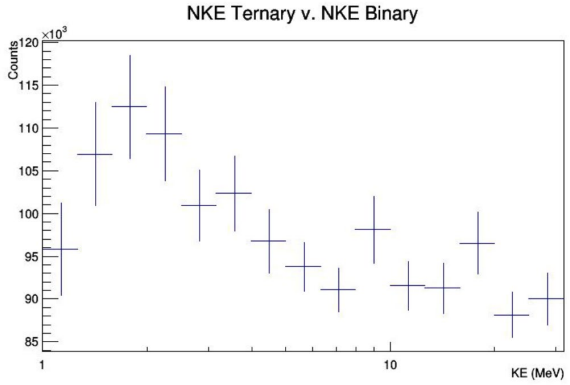


➢ **Time Projection Chamber (TPC)**

➢ NIFFTE has obtained a series of T/B results in different neutron energy at the white neutron source, but the sample is ^{235}U and ^{238}U mixed sample.







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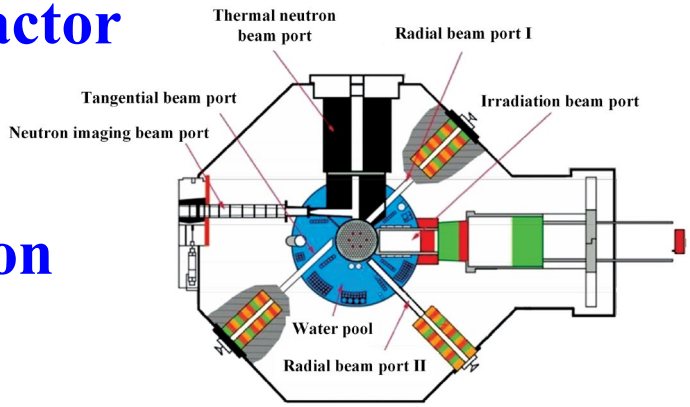
2 Experiment Setup

Neutron source → **Samples** → **Detector**

Xi'an Plused Reactor (China)

thermal neutron beam port



- A standard Maxwell's thermal neutron field after being fully moderated by graphite
- The neutron flux was about 1×10^5 neutrons/(cm2·s) when the reactor operates at 2 MW
- The ratio of thermal neutrons to epithermal and fast neutrons was about 2×10^3
- The ratio of neutron flux over gamma flux is greater than 10

2 Experiment Setup

Neutron source → Samples → Detector

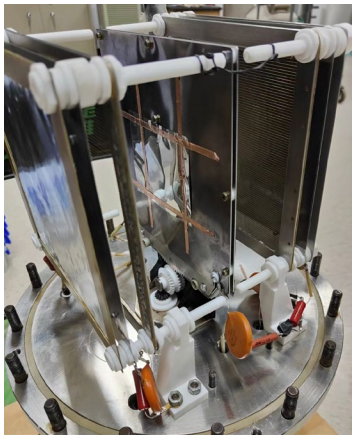
^{235}U sample

^{197}Au sample
(Thermal neutron flux monitor)

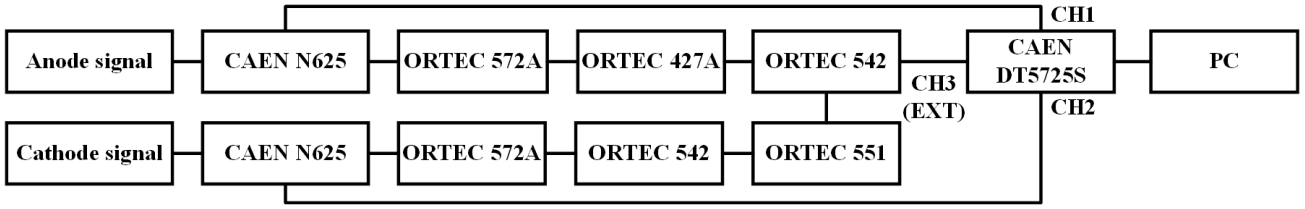
2 Experiment Setup

Neutron source → Samples → Detector

Grid-ionization Chamber(GIC)



Data acquisition System (DAQ)



Report Outline

1、Introduction

2、Experiment Setup

3、Result

4、Conclusion

3 Result

Absolute yields of the long-range alpha particles and the tritons

$$Y = \frac{N}{t\eta N_{235}\sigma\phi}$$

- N: Total counts
- t: measurement duration
- η: detection efficiency
- N_{235}: the number of the ^{235}U nuclei
- σ: Cross section of the ^{235}U(n, f) reaction
- ϕ: Thermal neutron flux

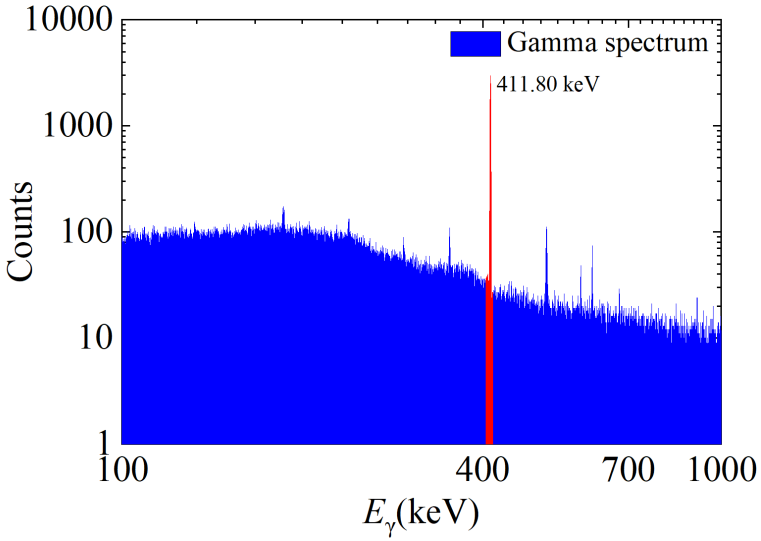
- The measurement of the thermal neutron flux
- The measurement of the absolute yield of the long-range alpha particles and the tritons in thermal neutron induced ternary fission of ^{235}U

3 Result

1) The measurement of the thermal neutron flux:

- The cross section of ^{197}Au(n, γ) ^{198}Au reaction is standard
- A high purity germanium (HPGe) detector was used to measure the radioactivity of the ^{198}Au offline

$$\Phi_{th} = \frac{C\lambda t_3}{N_{Au}\sigma\varepsilon_\gamma I_\gamma (1-e^{-\lambda t_1})\, e^{-\lambda t_2}\, (1-e^{-\lambda t_3}) t_4}$$

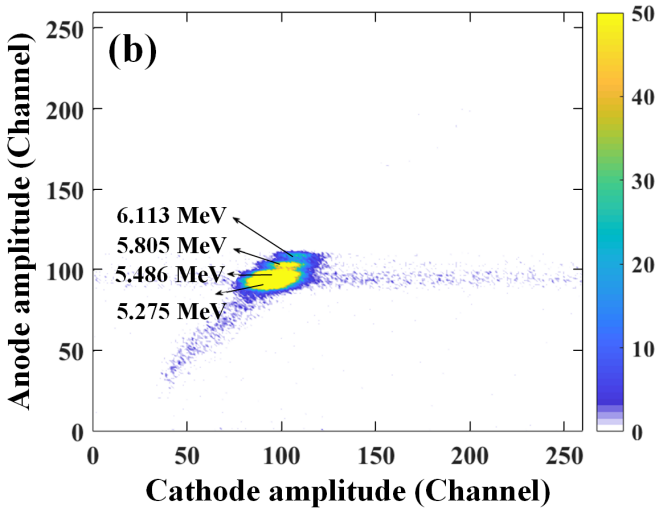


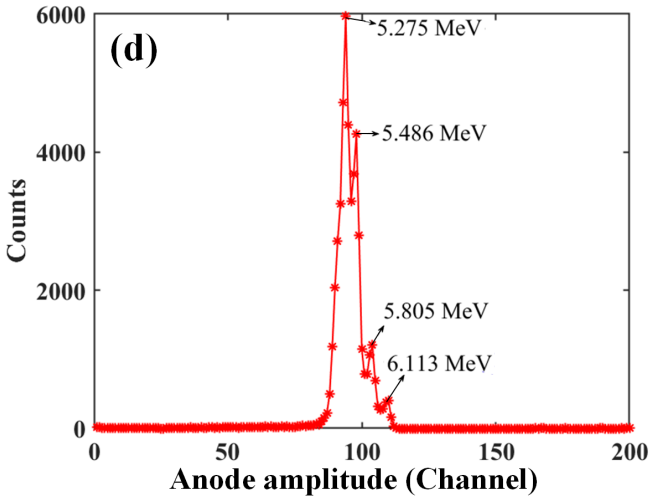
$$\Phi_{th} = 8.98\times10^{4}\,\mathrm{cm^{-2}s^{-1}}$$

3 Result

2) The ternary fission measurement of ^{235}U

Using α source for energy calibration:





α energy: 5.275 MeV (^{243}Am)
5.486 MeV (^{241}Am)
5.805 MeV (^{244}Cm)
6.113 MeV (^{242}Cm)

Energy = 0.0524×Channel + 0.3465 (MeV)

3 Result

2) The ternary fission measurement of ^{235}U

Radioactive source: ^{235}U (30 μm Al film covered)

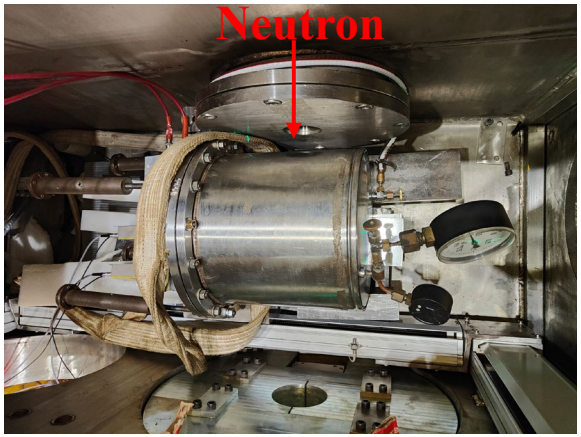
Working gas: 90%Ar+10%CH_4 (8.0 atm)

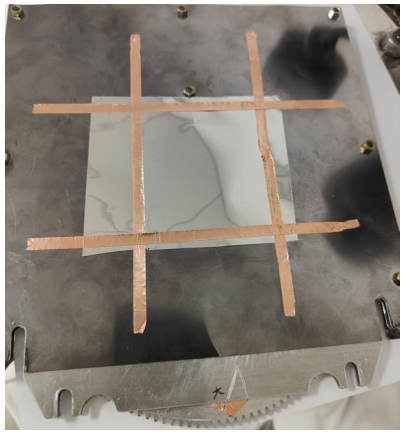
Voltage: +1450 V/ −2900 V (drift velocity≈1.6 cm/μs)

Distance between cathode and grid: 74 mm

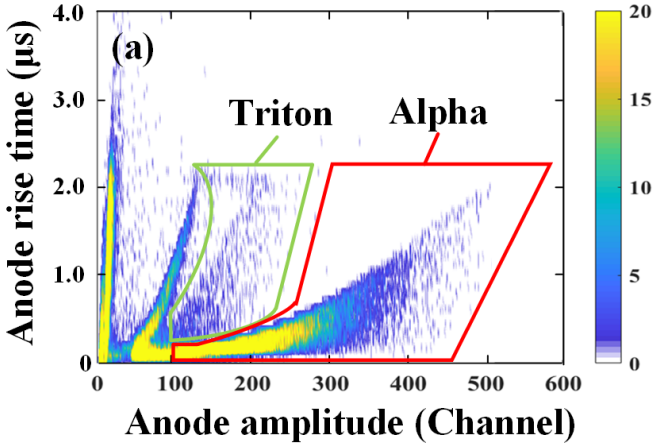
Measuring time: 144346 s

Neutron flux monitor: ^{197}Au

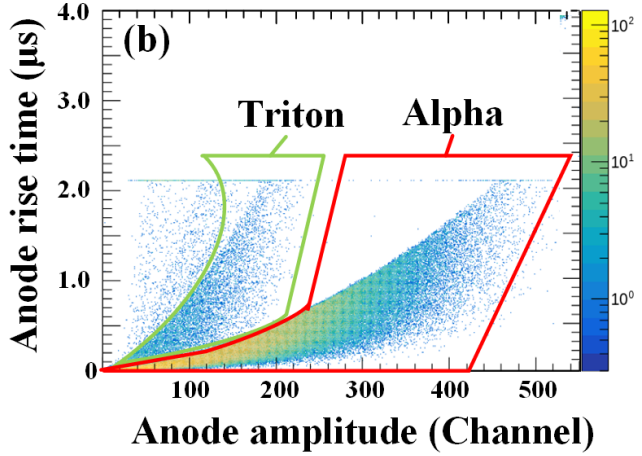




Exp result:



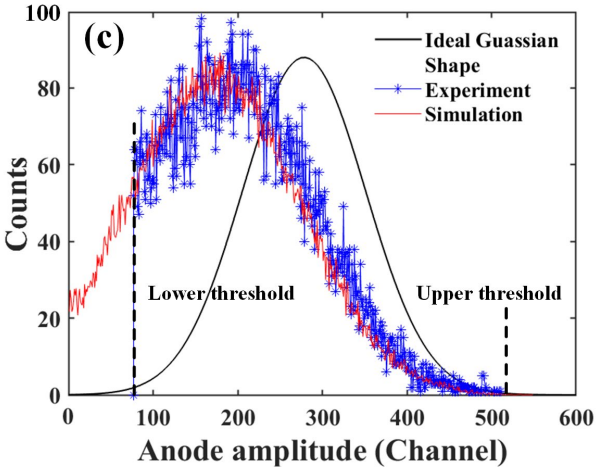
Sim result:



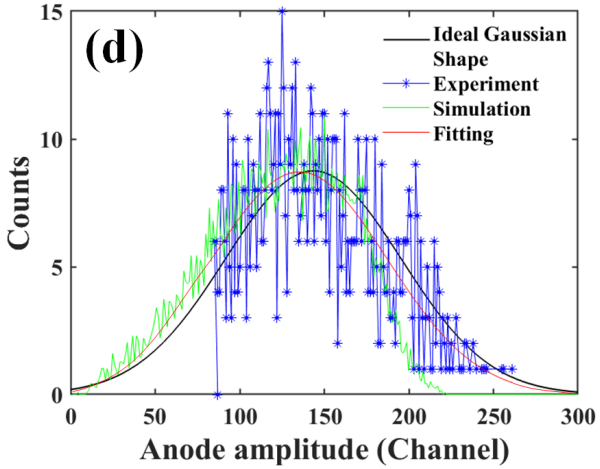
3 Result

2) The ternary fission measurement of ^{235}U

By selecting the event region, the anode projection spectrum of the long-range α particles and the tritons is obtained, and the mean energy and FWHM are obtained by the simulation.



	^{235}U (thermal neutron) exp
LRA/B	$(1.84 \pm 0.10) \times 10^{-3}$
t/B	$(1.13 \pm 0.06) \times 10^{-4}$



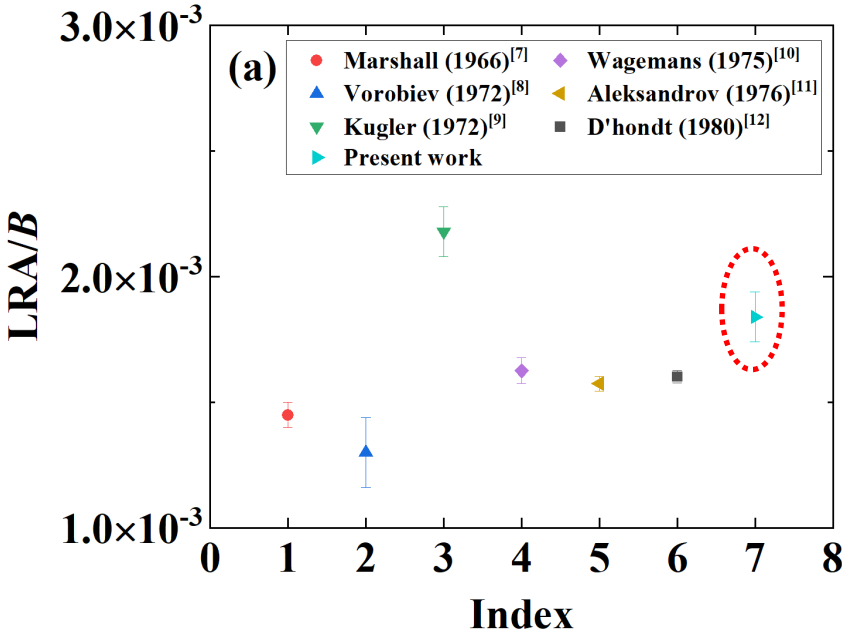
3 Result

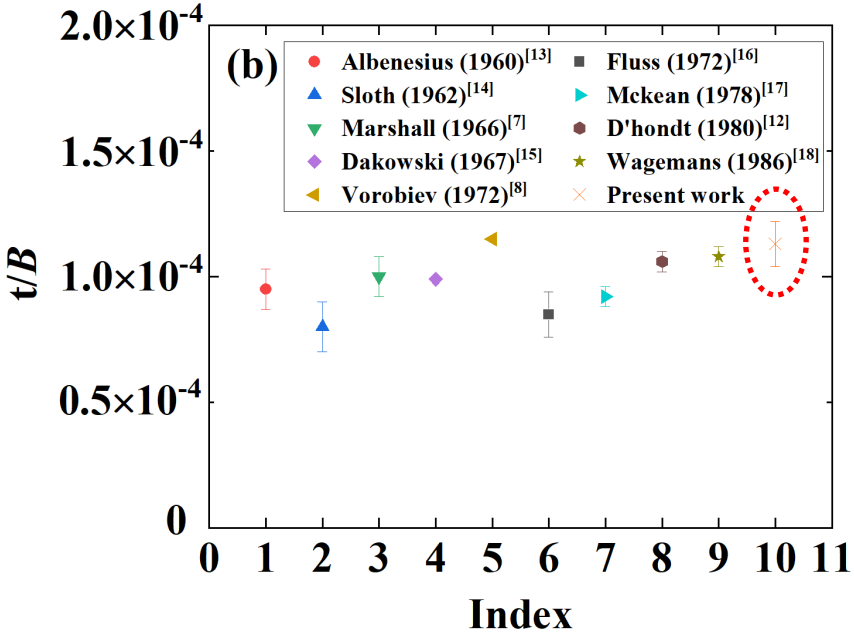
2) The ternary fission measurement of ^{235}U

Reaction	Mean energy of LRA (MeV)	FWHM of LRA (MeV)	Mean energy of triton (MeV)	FWHM of triton (MeV)	Reference
$^{235}U + n_{th}$	15.9 ± 0.1	9.8 ± 0.1	8.2 ± 0.2	6.5 ± 0.2	Vorobiev [8]
	16.0 ± 0.1	9.6 ± 0.1	8.1 ± 0.1	6.7 ± 0.2	D'hondt [12]
	15.7 ± 0.3	9.8 ± 0.4	8.6 ± 0.3	6.7 ± 0.6	Dakowski [15]
	15.8 ± 0.1	9.5 ± 0.1	8.3 ± 0.1	6.8 ± 0.2	Wagemans [18]
	15.7 ± 0.1	9.6 ± 0.1			Bayer [35]
	15.8 ± 0.3	9.5 ± 0.3	8.4 ± 0.3	6.9 ± 0.4	Present work

3 Result

2) The ternary fission measurement of ^{235}U



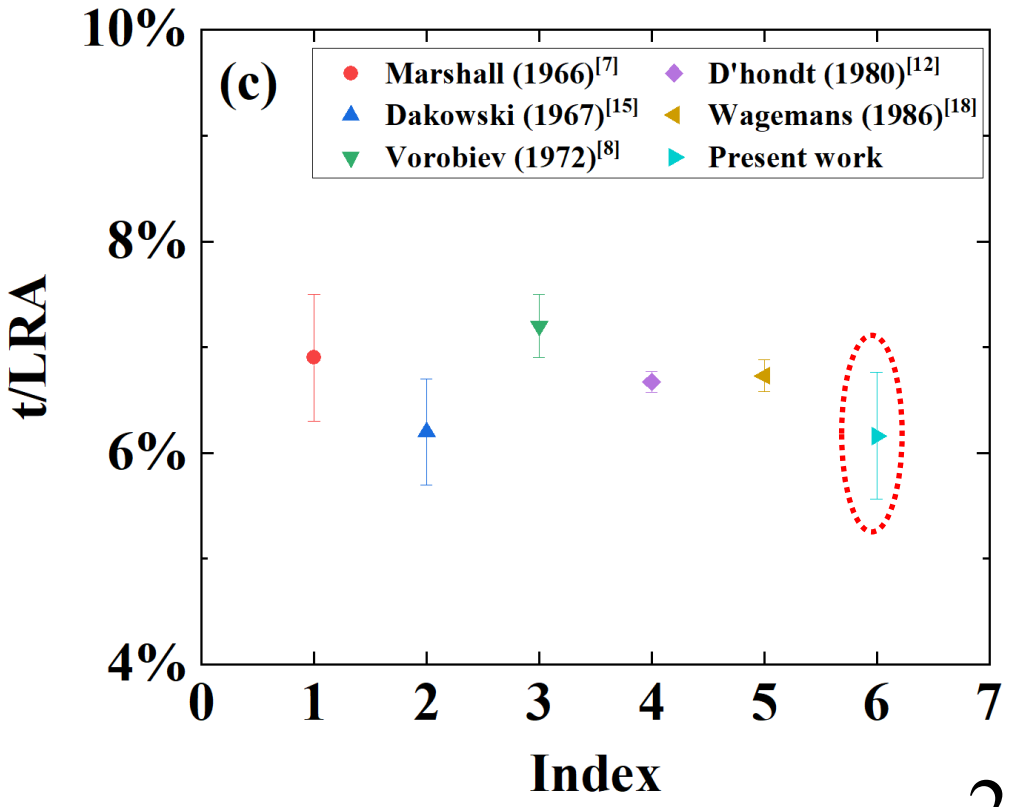


3 Result

2) The ternary fission measurement of ^{235}U

LRt/LRA: **$(6.16 \pm 0.60) \times 10^{-2}$**

	LRt/LRA[%]
^{235}U exp Marshall[5]	6.9 ± 0.50
^{235}U exp Dakowski[1]	6.2 ± 0.5
^{235}U exp Vorobiev[2]	7.2 ± 0.3
^{235}U exp D'hondt[3]	6.67 ± 0.10
^{235}U exp Wagemans[4]	6.73 ± 0.15
^{235}U exp	**6.16 ± 0.60**

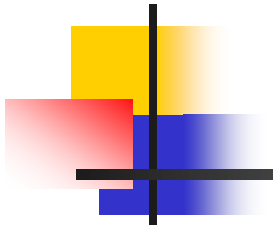


4 Conclusion

1. A method to determine the absolute yields of the long-range alpha particles and the tritons in ternary fission using a twin-gridded ionization (GIC) is proposed. The high-precision simulation of the detection process of the ternary particles in the situation of the fissile sample being shielded with an aluminum film and the working gas with high pressure is used.
2. The energy distributions and the absolute yields of the long-range α particles and the tritons in ternary fission of ^{235}U can be obtained accurately by selecting the event region, which is in good agreement with the literature.
3. For the tritons, the energy spectrum can be obtained more accurately, but the yield of the tritons needs to be modified after deducting the influence of the long-range α particles.
4. This method has the advantage of high detection efficiency and partial particle identification ability such as distinguishing the alpha particles and the tritons from the other ternary particles. The present method can be used to determine the emission probabilities of the long-range alpha particles and tritons in the fast-neutron-induced ternary fission.

Reference

[1] S. Tsien, Z. Ho, R. Chastel et al., Phys. Rev. 71, 382 (1947).
[2] C. Wagemans, A. J. Deruytter, Nucl. Phys. A 212, 556 (1973).
[3] F. Gonnenwein, Nucl. Phys. A 734, 213 (2004).
[4] W.J. Swiatecki, Second UN intern. Conf. on the peaceful uses of atomic energy, 651 (1958).
[5] S.G. Nilsson, Dan. Mat. Fys. Medd. 29, no. 16 (1955).
[6] V.M. Strutinsky, Nucl. Phys. A 95, 420 (1967).
[7] M. Marshall and J. Scobie, Phys. Lett. 23, 583 (1966).
[8] A. Vorobiev, D. Seleverstov, V. Grachov et al., Phys. Lett. 40B, 102 (1972).
[9] G. Kugler and W. Clarke, Phys. Rev. C 5, 551 (1972).
[10] C. Wagemans and A. Deruytter, Z. Phys. A 275, 149 (1975).
[11] B. Aleksandrov, I. Kondurov, A. Krivokhatsky et al., Nejtr. Fiz. Moscow, part 6,97 (1976).
[12] P. Dhondt, C. Wagemans, A. Declercq, G. Barreau and A. Deruytter, Nucl. Phys. A 346, 461 (1980).
[13] E. Albenesius and R. Ondrejcin, Nucleonics 18, 100 (1960).
[14] E. Sloth, D. Horrocks, E. Boyce et al., J. Inorg. Nucl. Chem. 24, 337 (1962).
[15] M. Dakowski, J. Chwaszczewska, T. Krogulski et al., Phys. Lett. B 25, 3 (1967).
[16] M.J. Fluss, N.D. Dudey and R.L. Malewicki, Phys. Rev. C 6, 6 (1972).
[17] I. Mckean and E. Crouch, Nuclear Energy Agency, NEANDC (E), 192-8, 2252 (1978).
[18] C. Wagemans, P. Dhondt and P. Schillebeeckx, Phys. Rev. C 33, 3 (1986).



Thank you for your attention!