Measurements of the $^{6}Li(n,\alpha)^{3}H$ reaction in the neutron energy range E_n=3.3-5.1 MeV.

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MOTIVATION

Studies of neutron reactions with charged particle emission is important for:

Nuclear physics: understanding the structure of atomic nuclei and the mechanisms of nuclear reactions.

Astrophysics: refining the parameters of the optical potential used in astrophysical calculations.

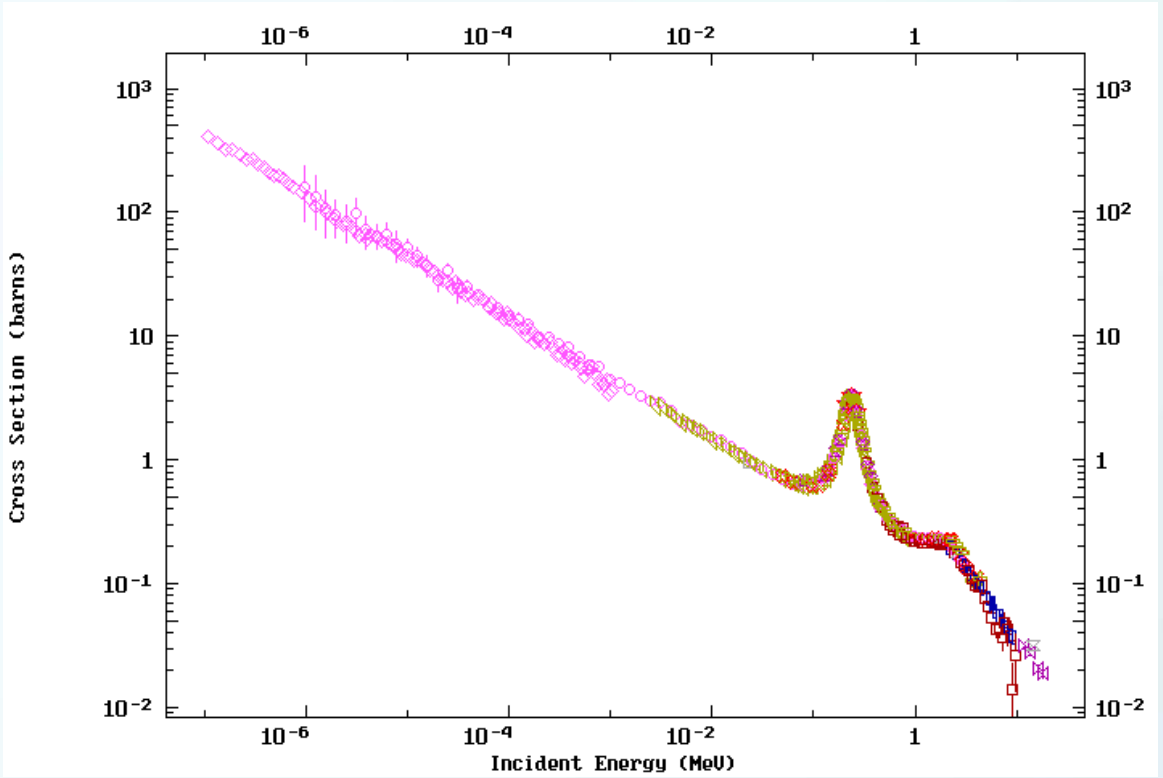
Reactor technology: assessing radiation damage caused by the accumulation of hydrogen and helium in structural materials.

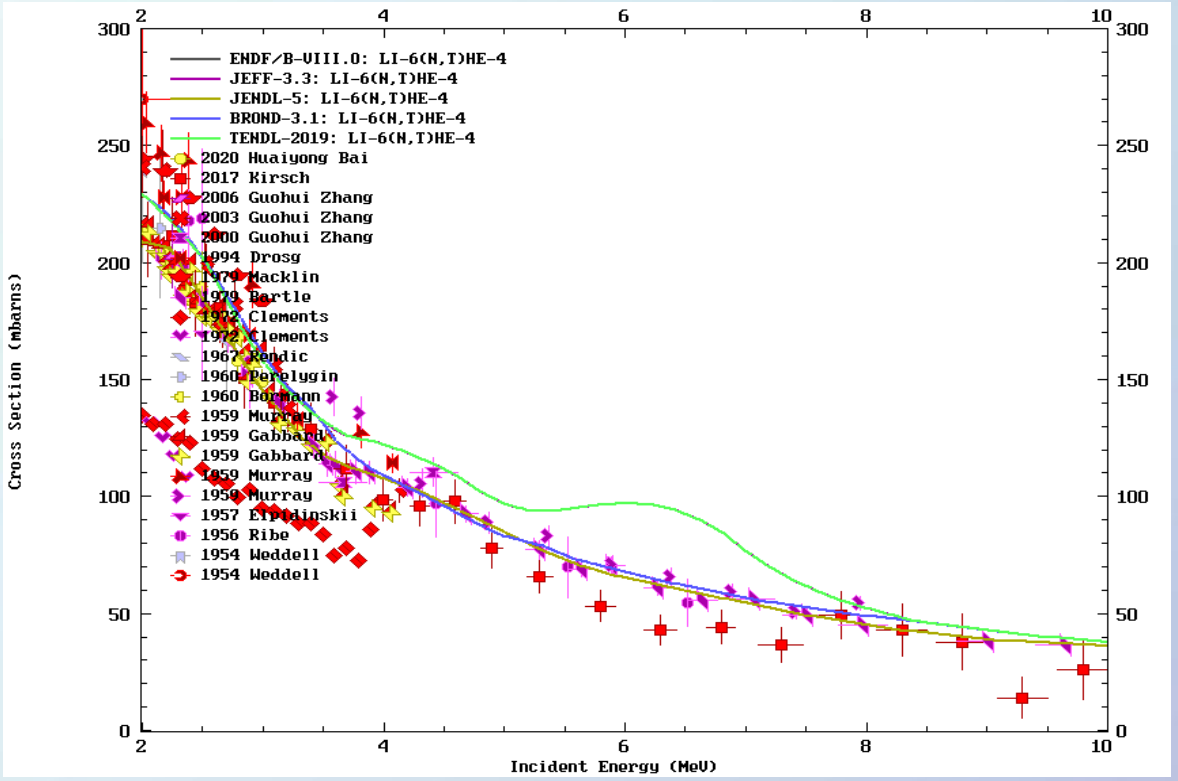
The reaction cross section $^{6}Li(n,\alpha)^{3}H$:

- Used for tritium production.
- Used for neutron flux monitoring.
- Serves as a standard for neutron cross section from thermal energy to 100 keV due to its large Q-value, large thermal cross section of 940 barns, and 1/v energy dependence below 10 keV.

However, there are significant discrepancies in both experimental and evaluated data in the neutron energy range of several MeV.

MOTIVATION


Cross Section (barns)
Incident Energy (MeV)


ENDF/B-VIII.0: LI-6(N,T)HE-4
JEFF-3.3: LI-6(N,T)HE-4
JENDL-5: LI-6(N,T)HE-4
BROND-3.1: LI-6(N,T)HE-4
TENDL-2019: LI-6(N,T)HE-4
2020 Huaiyong Bai
2017 Kirsch
2006 Guohui Zhang
2003 Guohui Zhang
2000 Guohui Zhang
1994 Drosg
1979 Macklin
1979 Bartle
1972 Clements
1972 Clements
1967 Kondic
1960 Perelygin
1960 Bormann
1959 Murray
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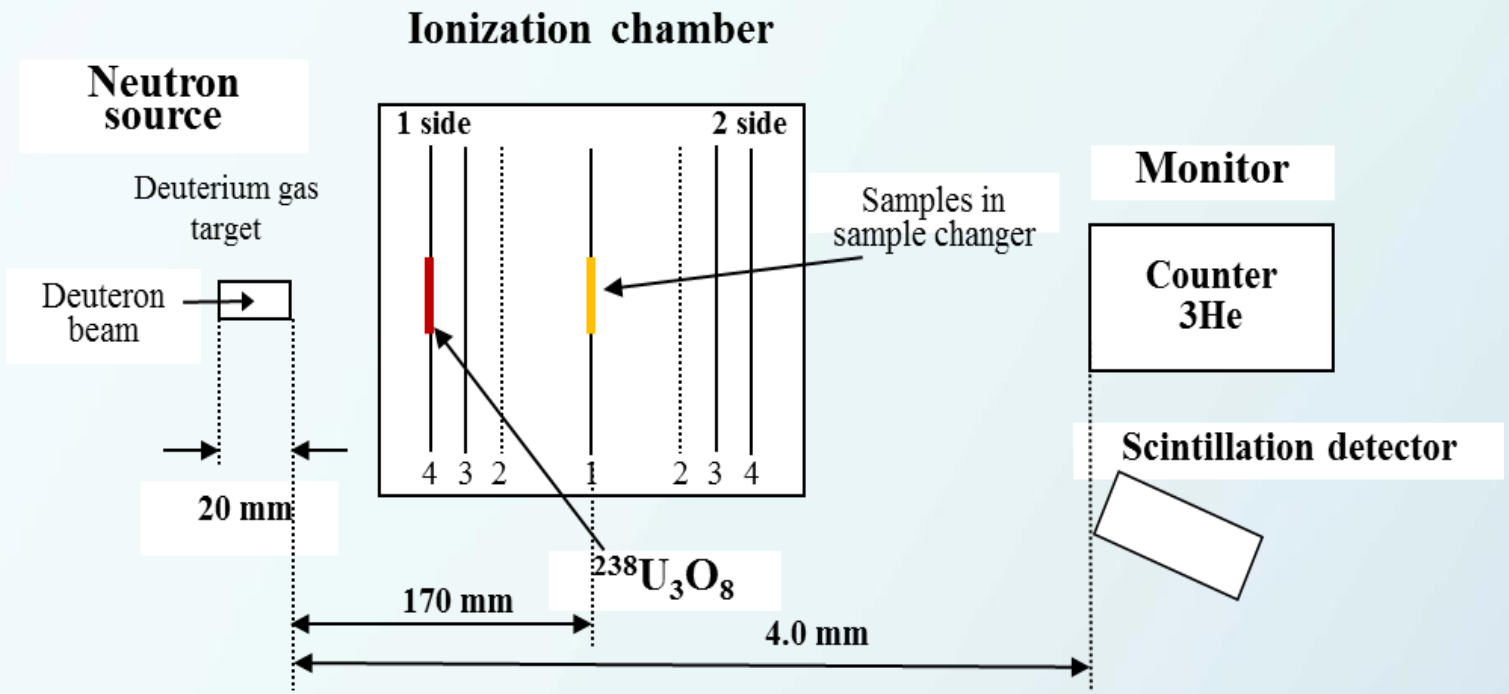
Cross Section (mbarns)
Incident Energy (MeV)

EXPERIMENTAL SETUP



Experimental scheme

Neutron source

- $D(d,n)^3He$ reaction
- Gas pressure – 2-2.5 atm.
- Current– 2-3 μA
- F_n~6,5x10^5(n/sm^2*sec);
- E_d = 1.8-2.6MeV.
- E_n=3.3–5.1 МэВ

IC parameters with grid:

- Forward-backward: ~ 4π
- Working gas: Kr + 4% CH_4
- Gas pressure: 0,7-4 atm.

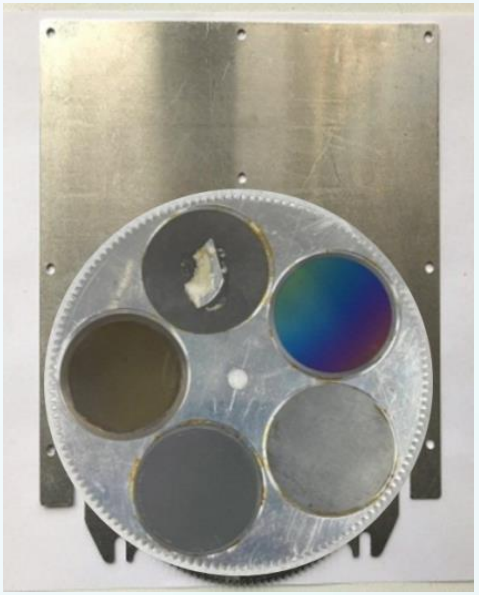
Neutron monitors

- A fission chamber and a long ^{3}He counter were used as neutron flux monitors
- The absolute neutron flux was determined from the registration of ^{238}U fission fragments,
- The Ej309 scintillation detector was used to measure the neutron spectrum.

EXPERIMENTAL SETUP

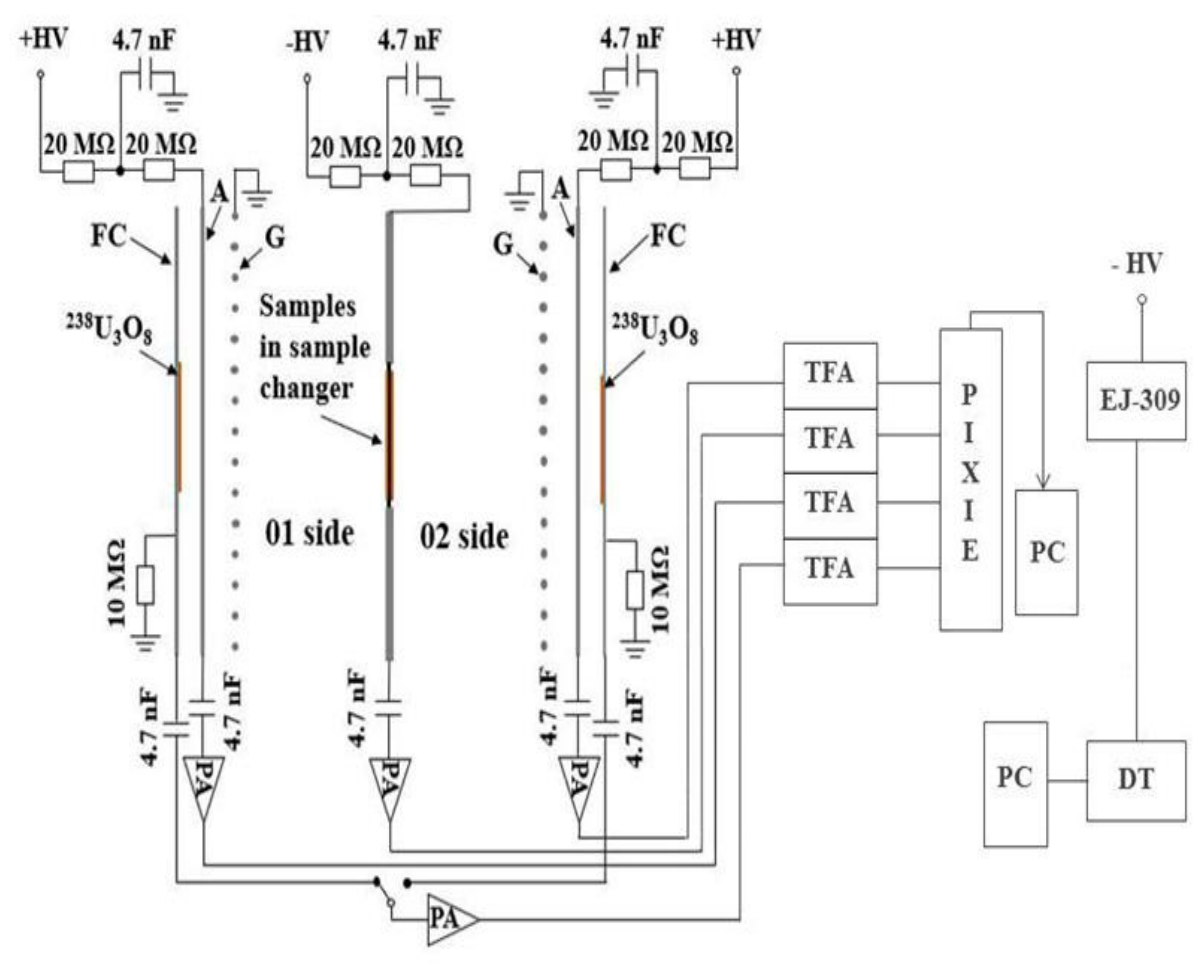
SAMPLES

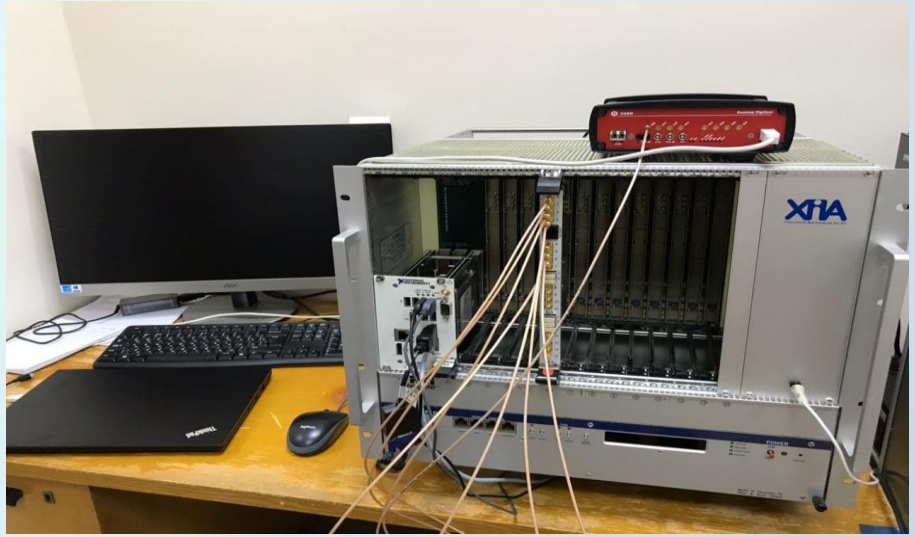
Positions of samples on the cathode and their characteristics

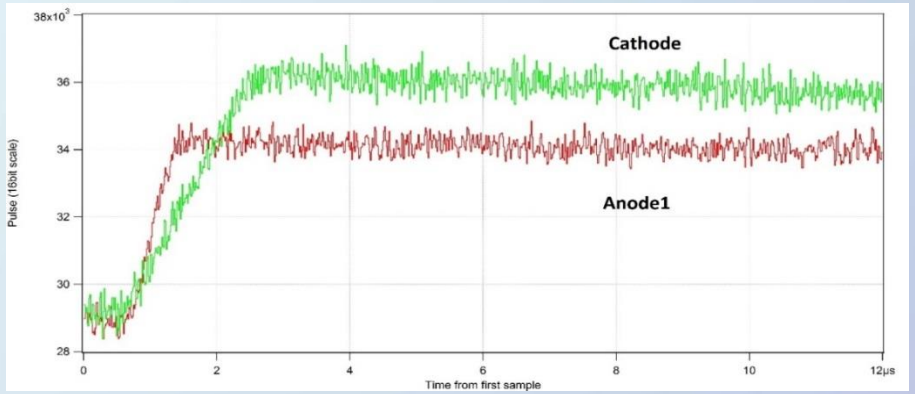


Sample position	Sample (2 side)	Thickness (mg/cm2)	Sample (1 side)	Thickness (mg/cm2)
No.1	α - source	-	α – source	-
No.2	$^{238}U_3O_8$	-	Al	-
No.3	^{6}LiF#I	272,9	^{6}LiF#II	233,5
No.4	^{6}LiF#III	105,3	^{6}LiF#IV	46
No.5	Ta	-	Ta	-

DAQ







Schematic diagram of the ionization chamber with electronics

MEASUREMENTS

Several series of measurements were carried out:

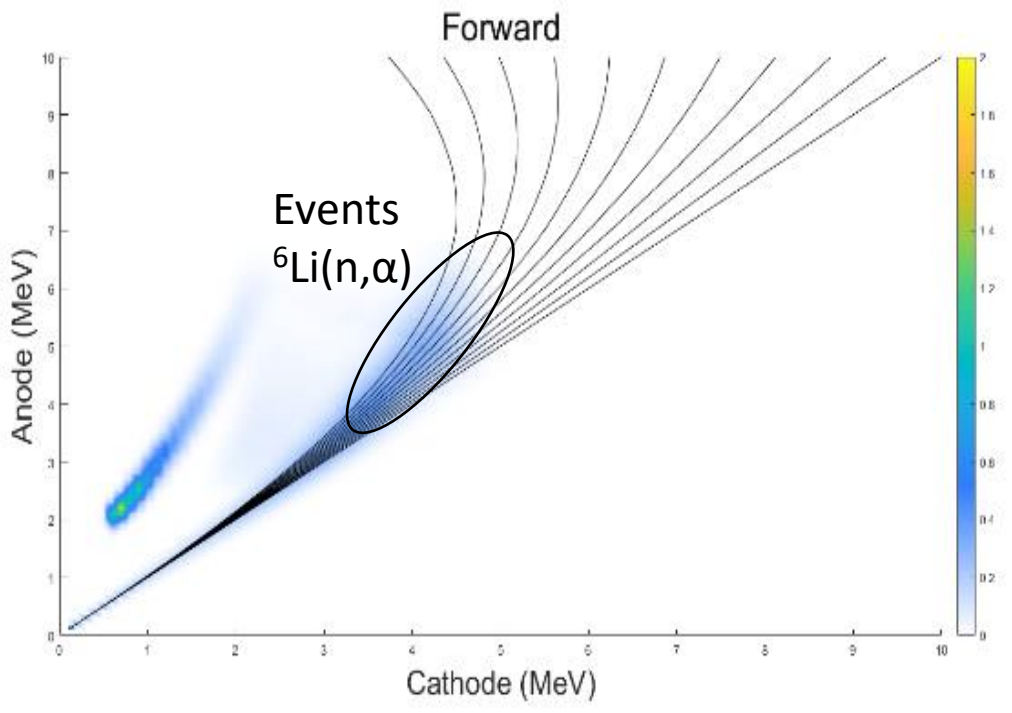
1) Measurement №1 P=1.0 atm, sample №2
2) Measurement №2 P=1.0 atm, sample №3
3) Measurement №3 P=4.0 atm, sample №2
4) Measurement №4 P=4.0 atm, sample №3

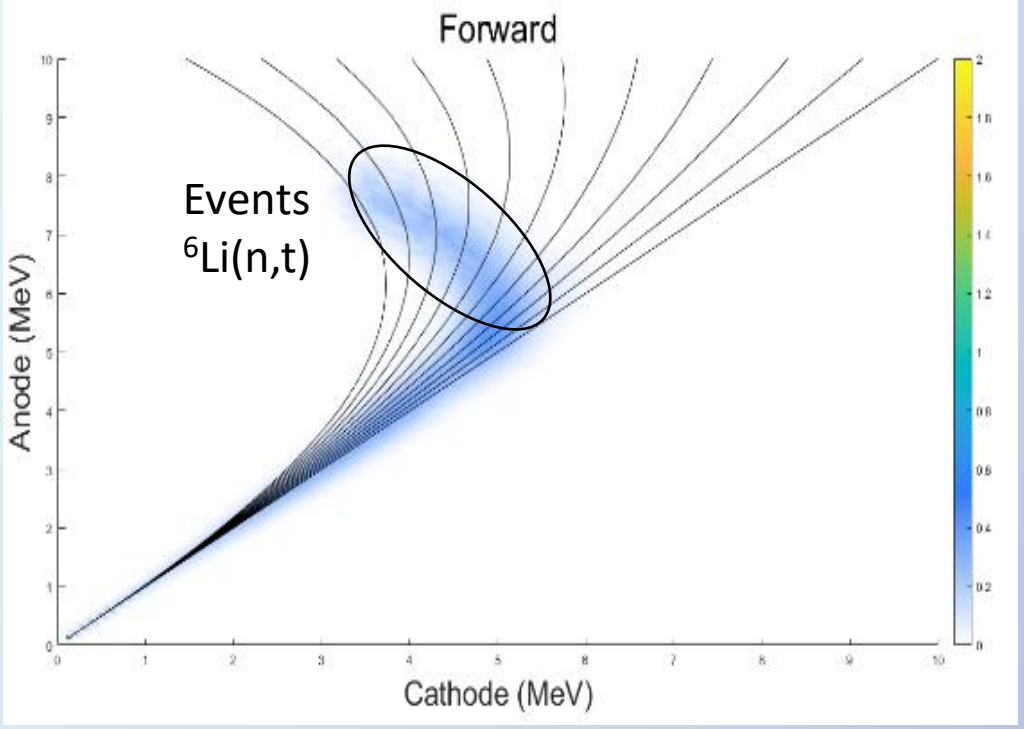
In each series, measurements were carried out at 5-7 values of En in the range of 3.3-5.1 MeV in the following order:

a) calibration of IC using α-sources – 10 minutes;
b) measurement with a lithium sample – 2 hours;
c) background measurement with a clean Ta substrate - 2 hours;
d) measurement with a ^{238}U sample on the IC cathode for flux measurement - 1 hour.

PRELIMINARY DATA

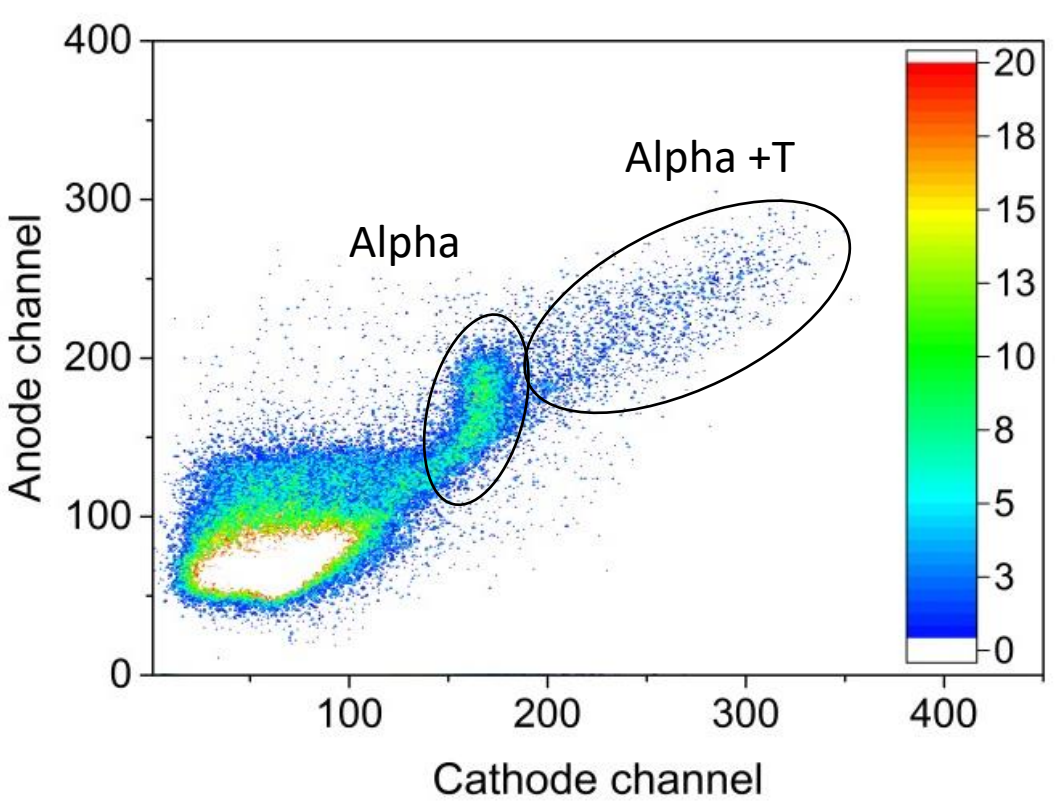
Simulation of measurements of the reaction cross section of $^{6}Li(n,\alpha)^{3}H$ and $^{6}Li(n,t)$

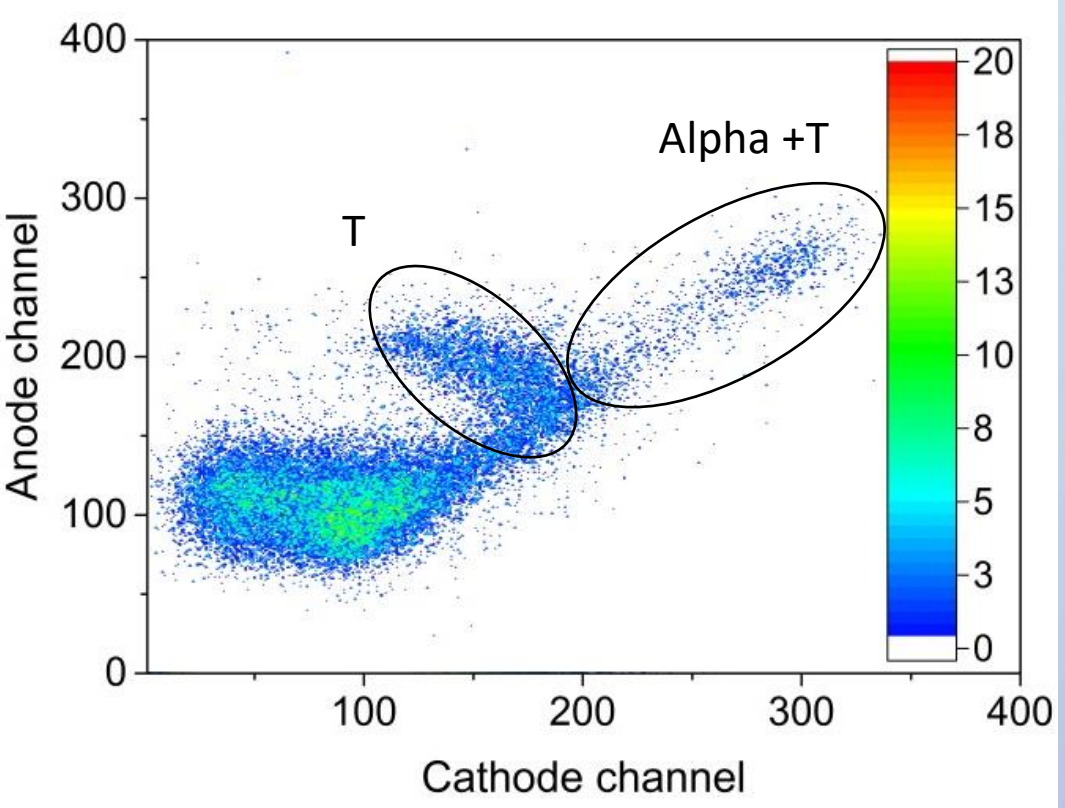




Anode-cathode 2D spectra for a sample of 105 μg/cm^2,
E_n=4.8 MeV, P=1.3 (left) and 4.0 atm. (on right)

PRELIMINARY DATA





Experimental anode-cathode 2D spectra from measurements, sample thickness 233.5 μg/cm^2, pressure P = 1.0 (left) and 4.0 atm. , E_n=4.5 MeV

The cross section for the $^{6}Li(n,\alpha)^{3}H$ reaction for the “forward” and “backward” directions was calculated using the formula:

$$\sigma_{n,\alpha} = \sigma_{n,f} \cdot \frac{N_\alpha}{N_f} \frac{\varepsilon_f}{\varepsilon_\alpha} \frac{N_{238U}}{N_{sample}} \cdot K$$

where $K = \frac{N_{f\,FC}}{N_{f\,IC}}$

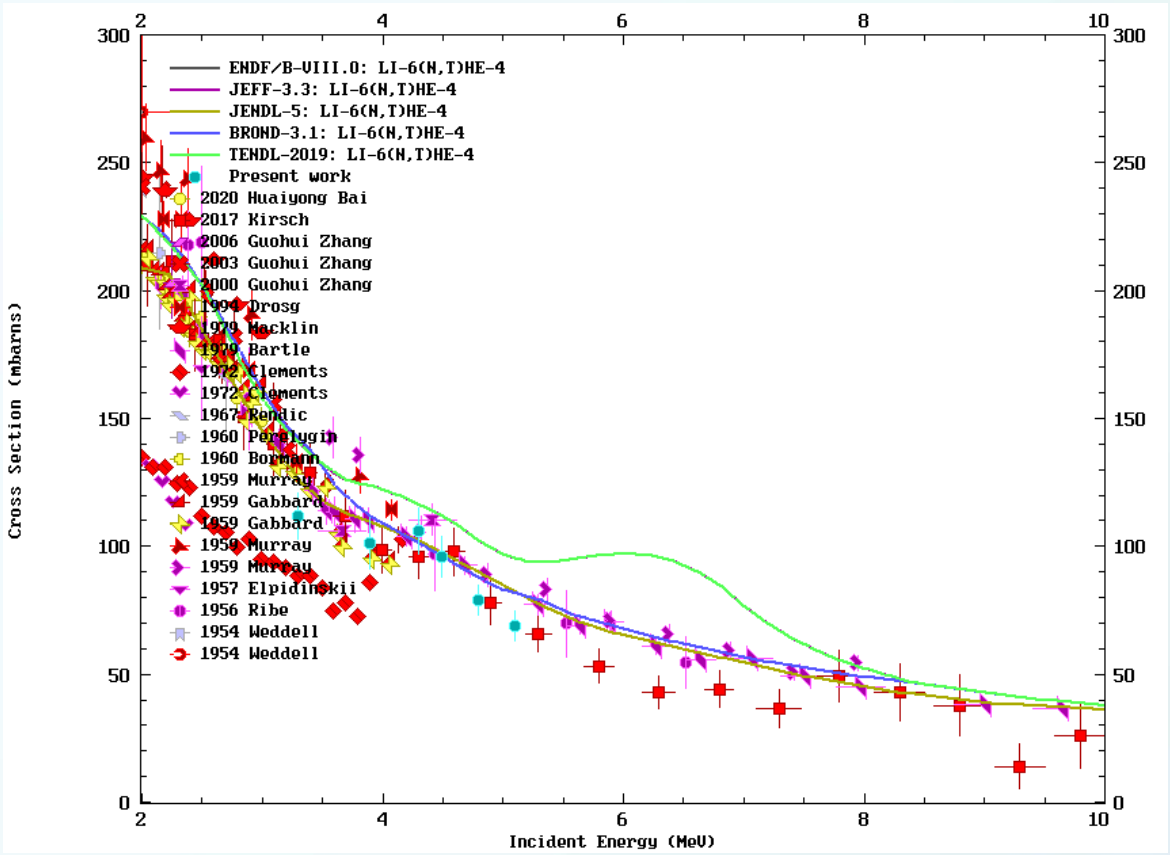
$N_{f\,FC}$ and $N_{f\,IC}$ - readings from the fission chamber and IC when measuring the reactions $^{238}U(n, f)$, and $^{6}Li(n, \alpha)^{3}H$, respectively;

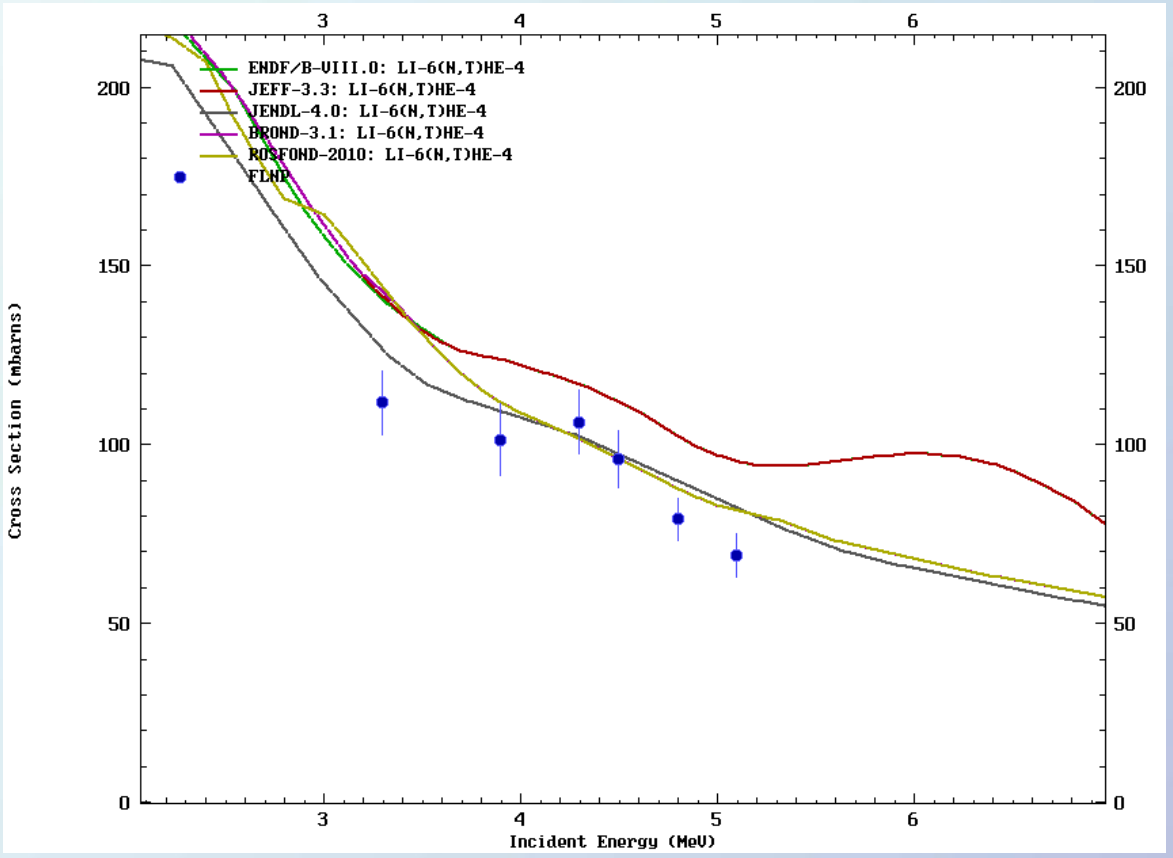
$\sigma_{n,f}$ - standard cross section ^{238}U (n, f) from ENDF/B-VIII.0;

N_α and N_f are the number of events from α particles from the reaction $^{6}Li(n, \alpha)^{3}H$ and fission fragments from ^{238}U (n, f), respectively;

N_{238U} and N_{sample} are the number of atoms in the samples, respectively.

PRELIMINARY DATA





The presented cross sections for the reaction $^{6}Li(n,\alpha)^{3}H$ are compared with existing measurements and estimates

CONCLUSION

- At the EG-5 accelerator FLNP JINR, a charged particle spectrometer with all the necessary equipment was set up.
- Simulation of measurements using various working gases (Kr, CH_4, CO_2) was carried out.
- Made targets (samples) ^{238}U (99.999) with a thickness of ~ 0.5 mg/cm^2, ^{6}LiF (90.5%) of various thicknesses from 50 to 300 μg/cm^2;
- Measurements of the reaction $^{6}Li(n,\alpha)^{3}H$ at E_n=3.3; 3.9; 4.3; 4.5; 4.8; and 5.1 MeV were carried out at EG-5 FLNP JINR. The data we obtained was compared with those available in EXFOR and data libraries.

Thank you for your attention.