РОСАТОМ

ГОСУДАРСТВЕННАЯ КОРПОРАЦИЯ ПО АТОМНОЙ ЭНЕРГИИ «РОСАТОМ»

The status and prospects of nuclear physics research at IPPE

Khryachkov V.

State scientific center of the Russian Federation –
Institute for physics and power engineering named after A. I. Leypunsky

IPPE in nuclear data community

IPPE was establish in 31 May 1946!

Neutron nuclear data important for nuclear reactor is one of the first task of IPPE.

G.Smirenkin
B.Kuzminov
D.Shpak
A.Soldatov
B.Maksutenko
G.Lovchikova
B.Fursov
N.Kornilov
S.Simakov
V.Kononov

Yu.Grigoryev
D.Tambovchev
L.Kozlovsky
V.Malinovsky
V.Piksaykin
A.Goverdovski
V.Tolstikov
A.Sergachev
B.Zhuravlev
et al.

Fission cross section, fission fragments yield, prompt neutron spectra, prompt neutron multiplicity, elastic and inelastic neutron scattering, neutron capture, ternary fission, (n,α) reaction, benchmark, neutron capture, delay neutron, cold fission, angular distribution of fission fragments , level density, et alia.

IPPE Accelerators

IPPE accelerator complex

KG-2,5

EGP-15

EG-1

EG-2,5

Nuclear physics
Radiation materials science
Nuclear microanalysis

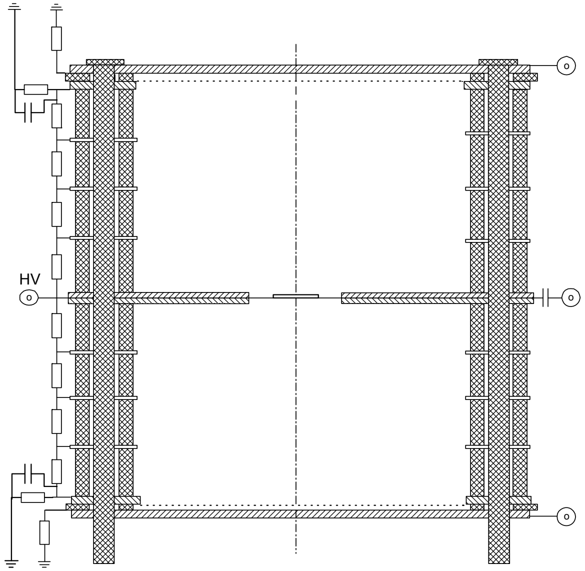
EG-0,3

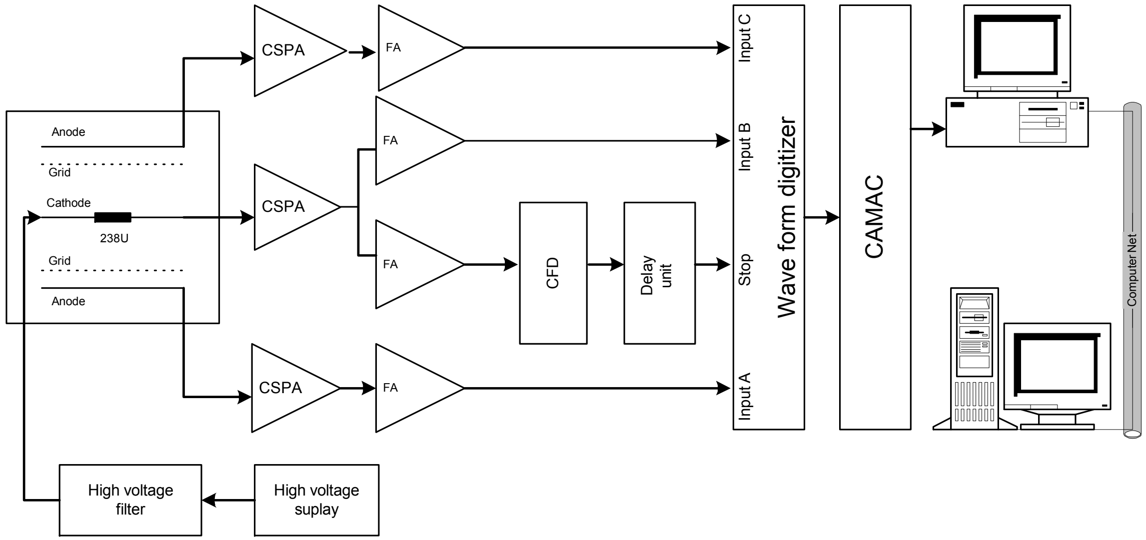
Energy region (p^+)	-0,1…13	MeV
Current	-0,01…2000	μA
Ion mass	-1…100	a.m.u.

Accelerators parameters

Accelerator	Ions energy (MeV)	Ions	Operating mode	Current parameters
EG-2,5 (1961 г.)	0,2 – 2,7	H, D, He, N, Ar, O	DC	0,1 – 30,0 μA 0,01 – 10,0 μA
EG-1 (1958 г.)	0,9 – 4,5	H, D	DC ——— Pulsed	1,0 – 20,0 μA ——— Amplitude 2 -3 mA Pulse duration 1 – 2 ns Frequency 1 – 5 MHz
EGP-10M (1968 г.)	3,5 – 9,0	H, D	DC ——— Pulsed	1,0 – 10,0 μA ——— Amplitude 0,4 mA Pulse duration 1 – 2 ns Frequency 1 – 5 MHz
KG-2,5 (1968 г.)	0.3 – 2,2	H, D	DC	0,1 – 2,0 mA
KG-0,3 (1968 г.)	0,05 – 0,3	H, D	DC ——— Pulsed	0,01 – 2,0 mA ——— Amplitude 3 -5 mA Pulse duration 1 – 3 ns Frequency 0,5 – 2,5 MHz
EGP-15 (1993)	4,0 – 12,0 (p, d)	H, D ---------- F, C, O, Al, Si, Cl, Ni, Fe, Zr	DC ——— Pulsed ———	0,01 – 5,0 μA ——— Amplitude 0,3 -0,5 mA Pulse duration 1 – 3 ns Frequency 1,0 – 5 MHz ---------- 0,01 – 1,0 μA

Fission fragments spectrometer





Ionization chamber: d=120 мм, height – 90 mm.

Working gas: Ar+10%CH_4, Pressure – 0.75 atm.

Digitizer: LeCroy 2262, 40 MHz, Time scale – 7 mks.

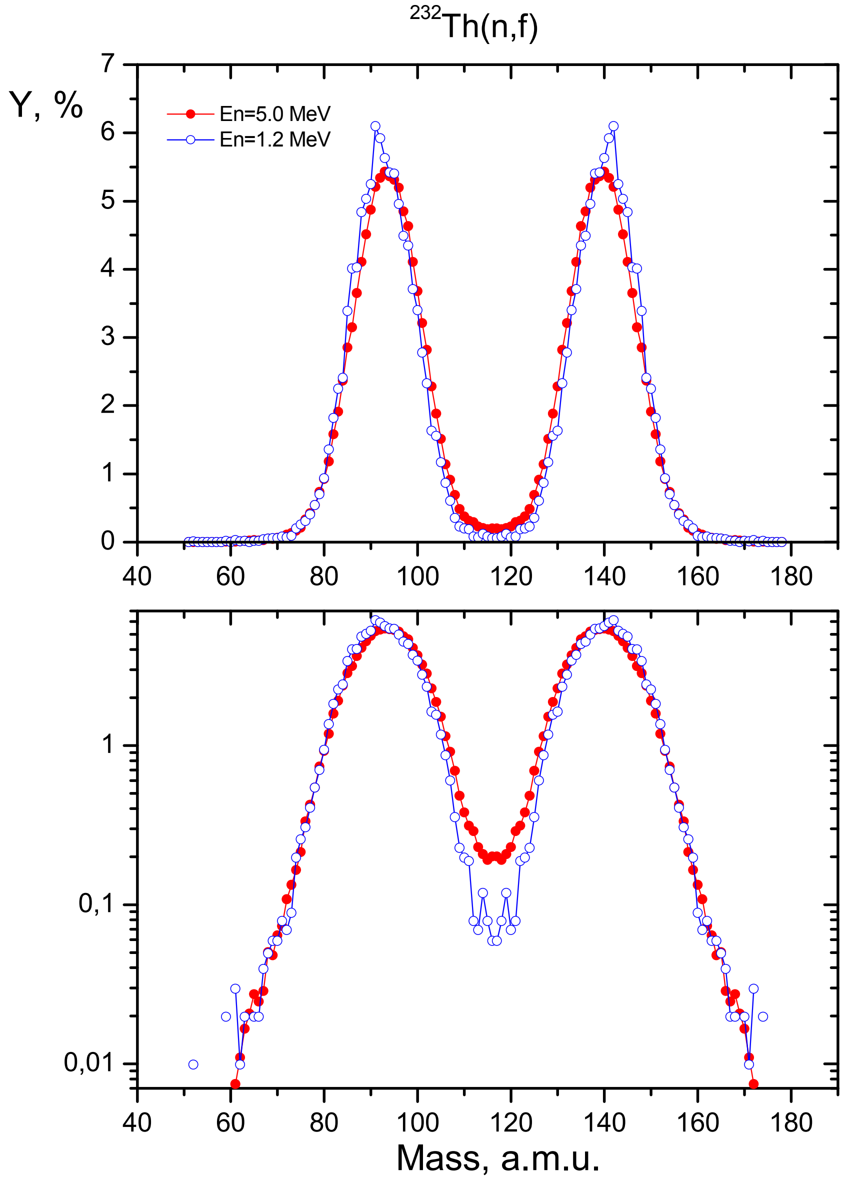
^{238}U sample sizes: Diameter - 60 mm. Thickness 250 mkg/cm^2.

Energy resolution 40 keV for 6 MeV α-particles.

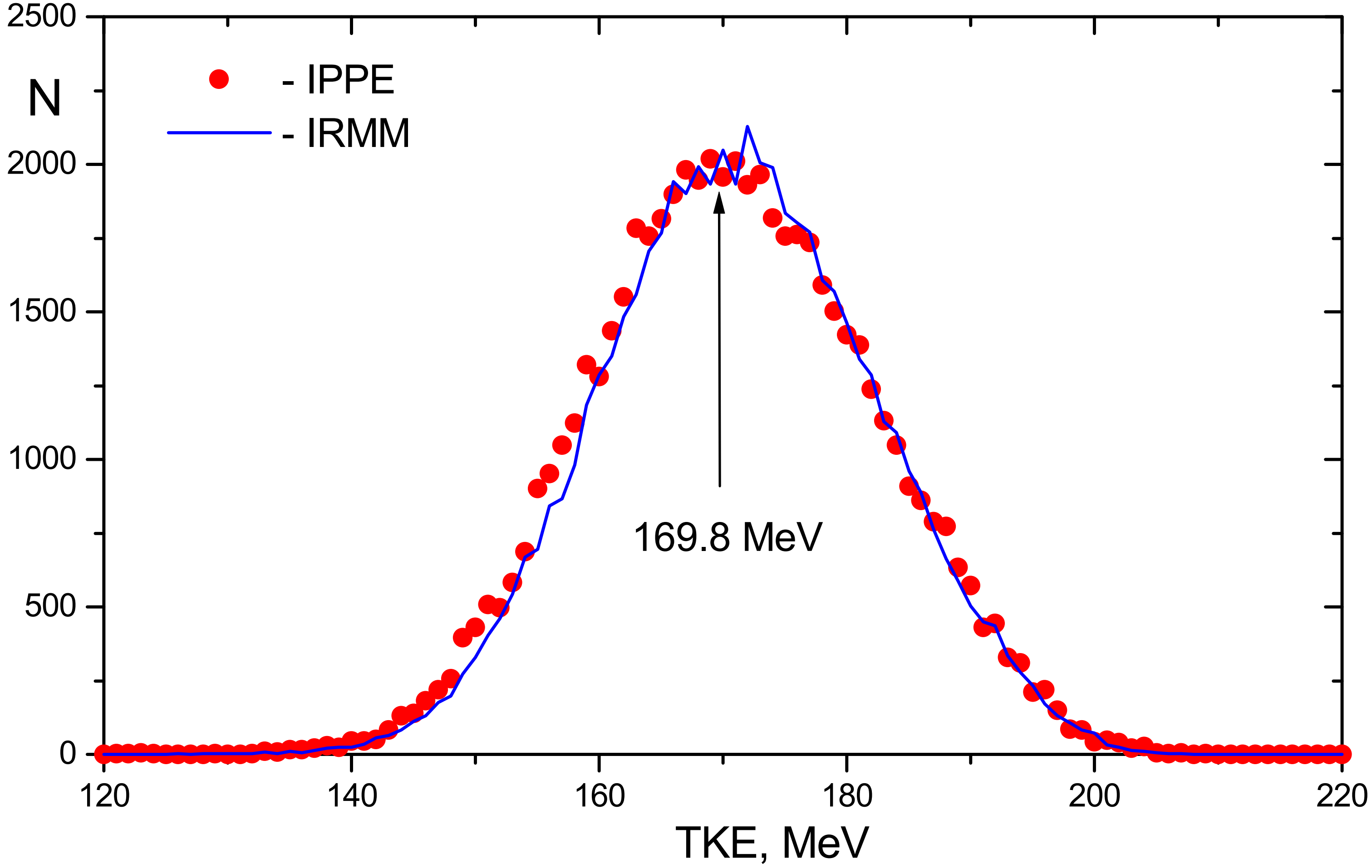
Angular resolution - 0.065 (in cos(θ) unit).

Mass resolution ~1 a.m.u.

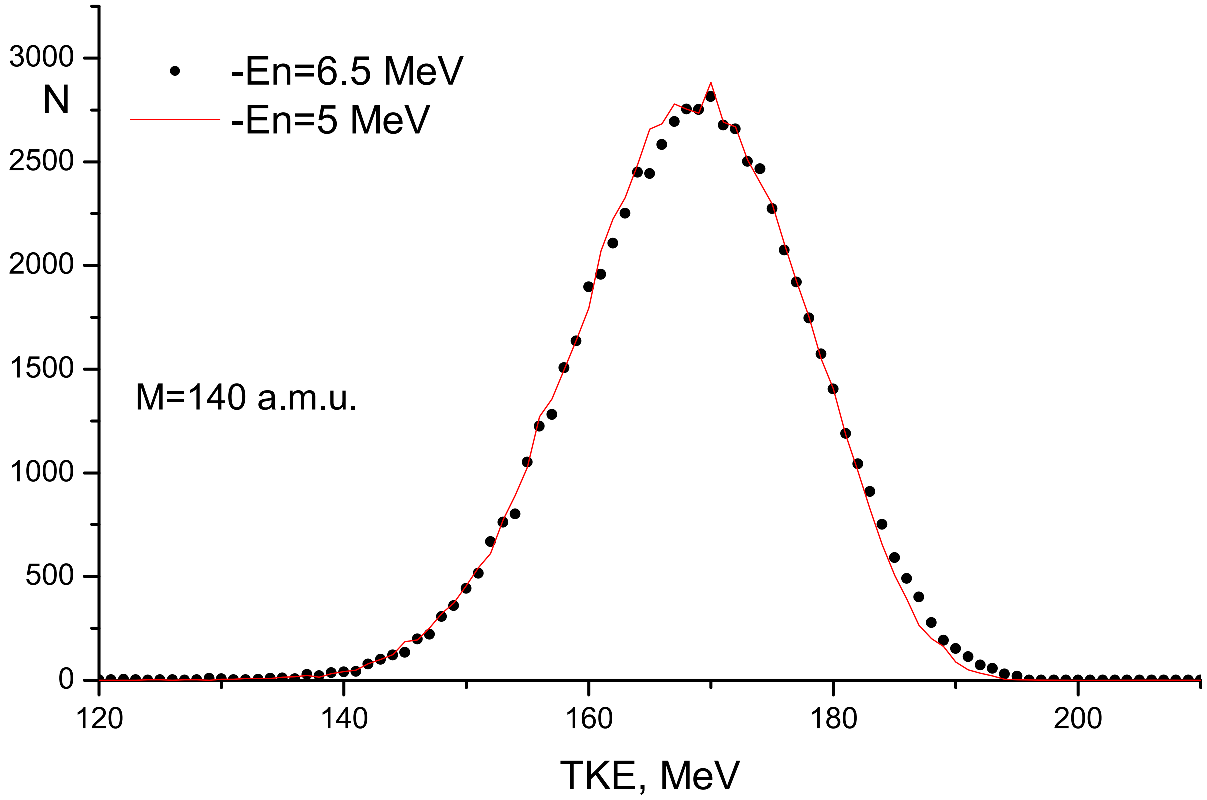
$^{232}Th(n,f)$, En=1,2 and 5 MeV



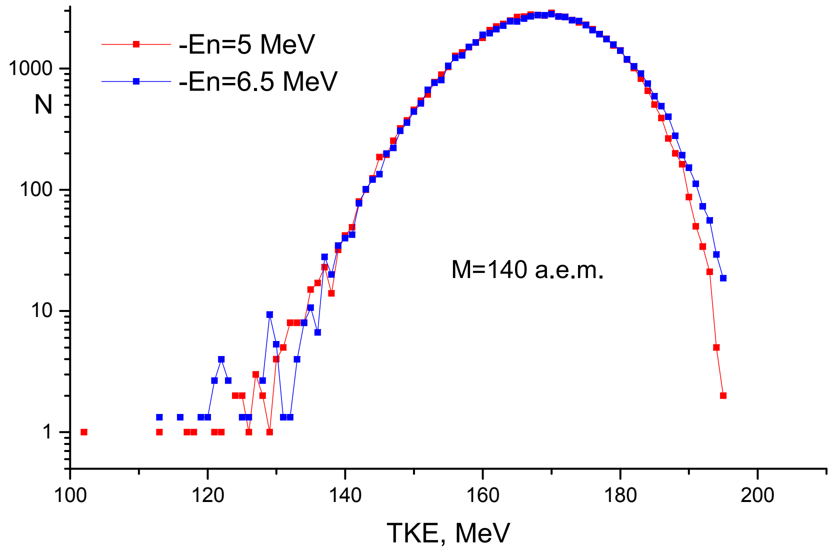
Fission fragments yield

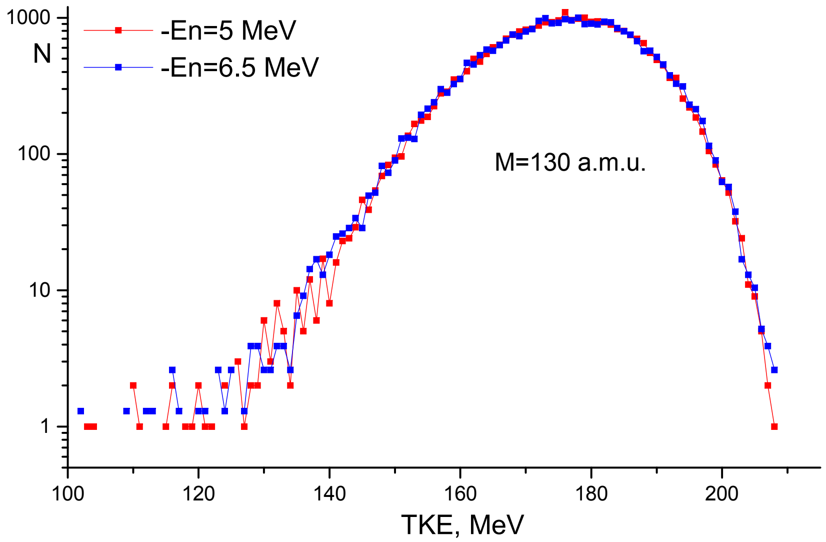


TKE distributions for mass 140 a.m.u.

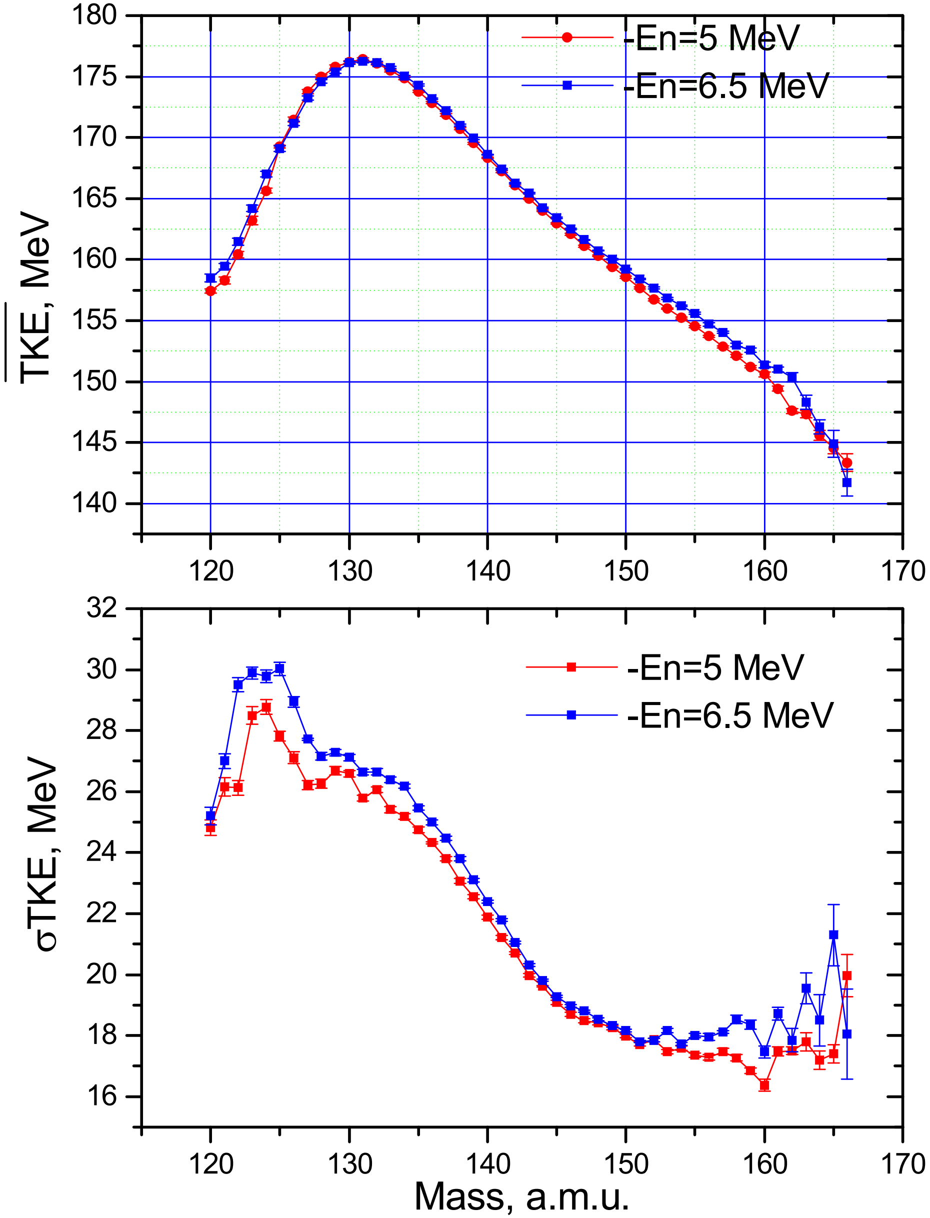


TKE distributions for mass 140 a.m.u.

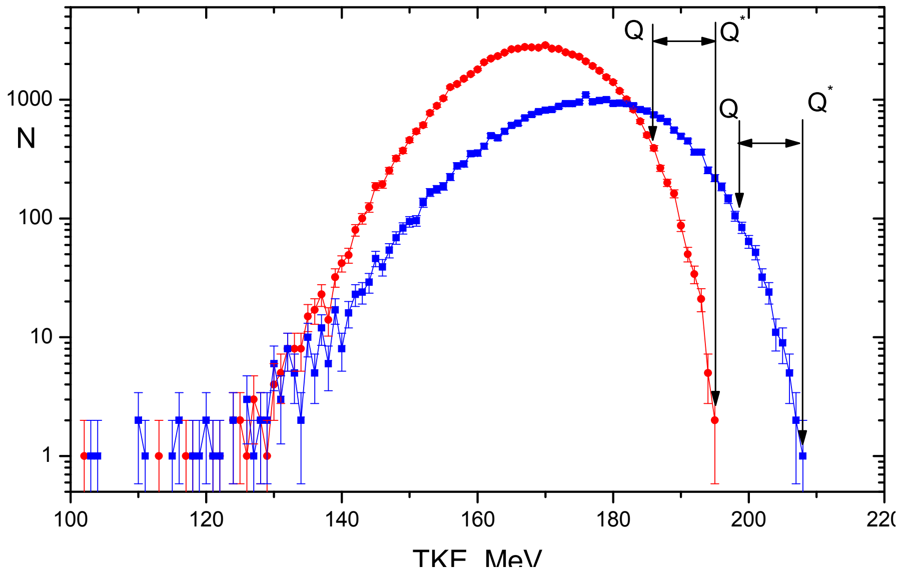




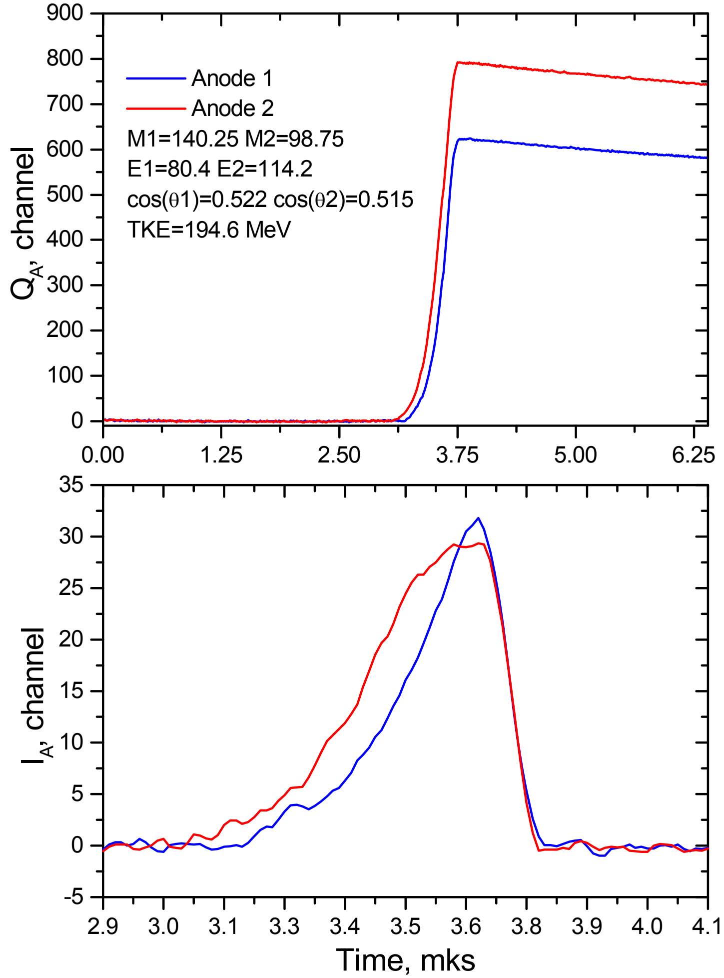
TKE and TKE dispersion for $^{238}U(n,f)$ by 5 and 6,5 MeV neutron



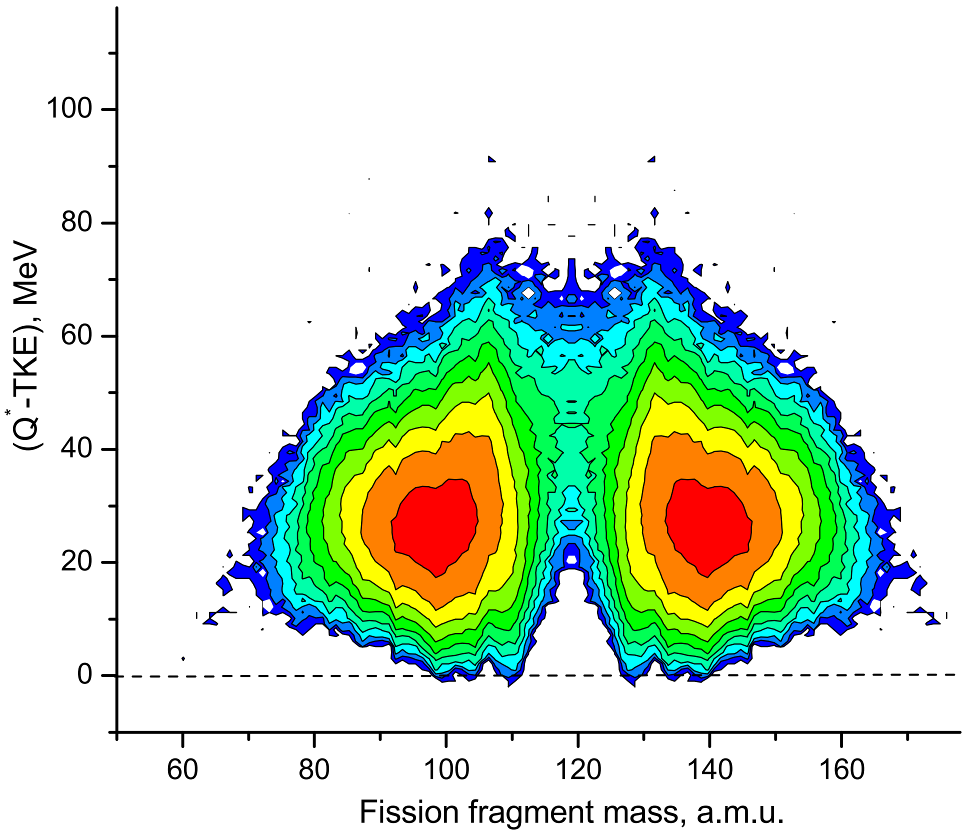
True cold fragmentation observation for ^{238}U fission by 5 MeV neutrons

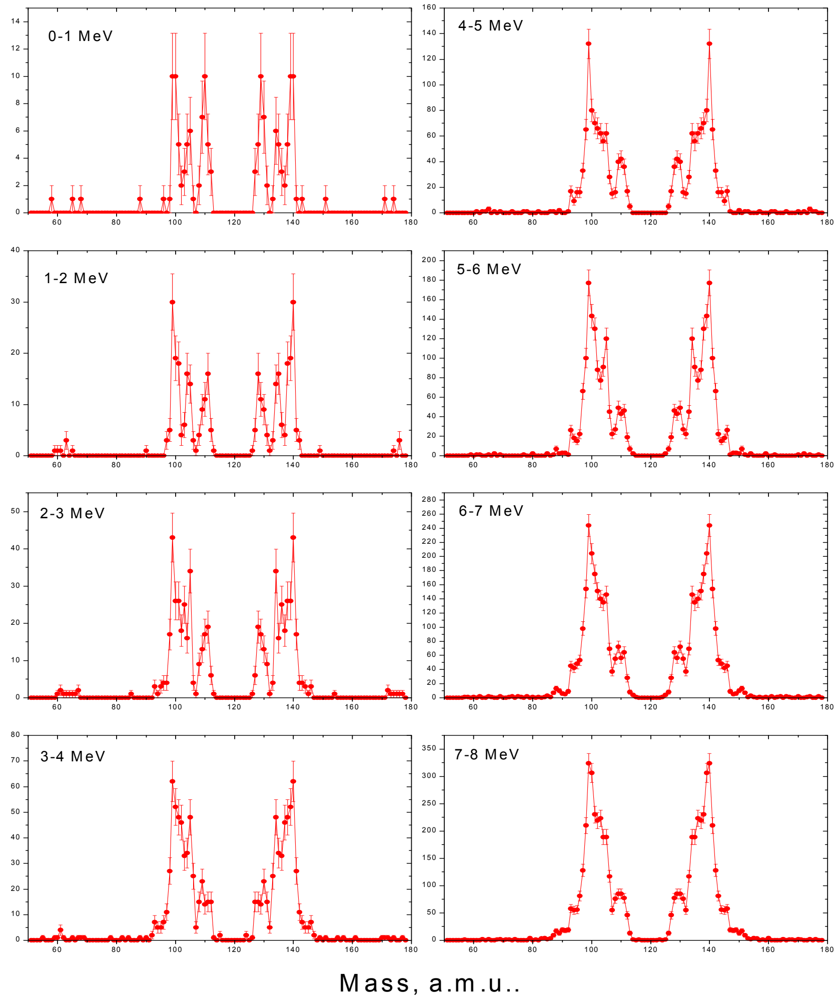


Fission fragments yields dependence from TKE value. (□) – mass 130 a.m.u., (●) – mass 140 a.m.u.

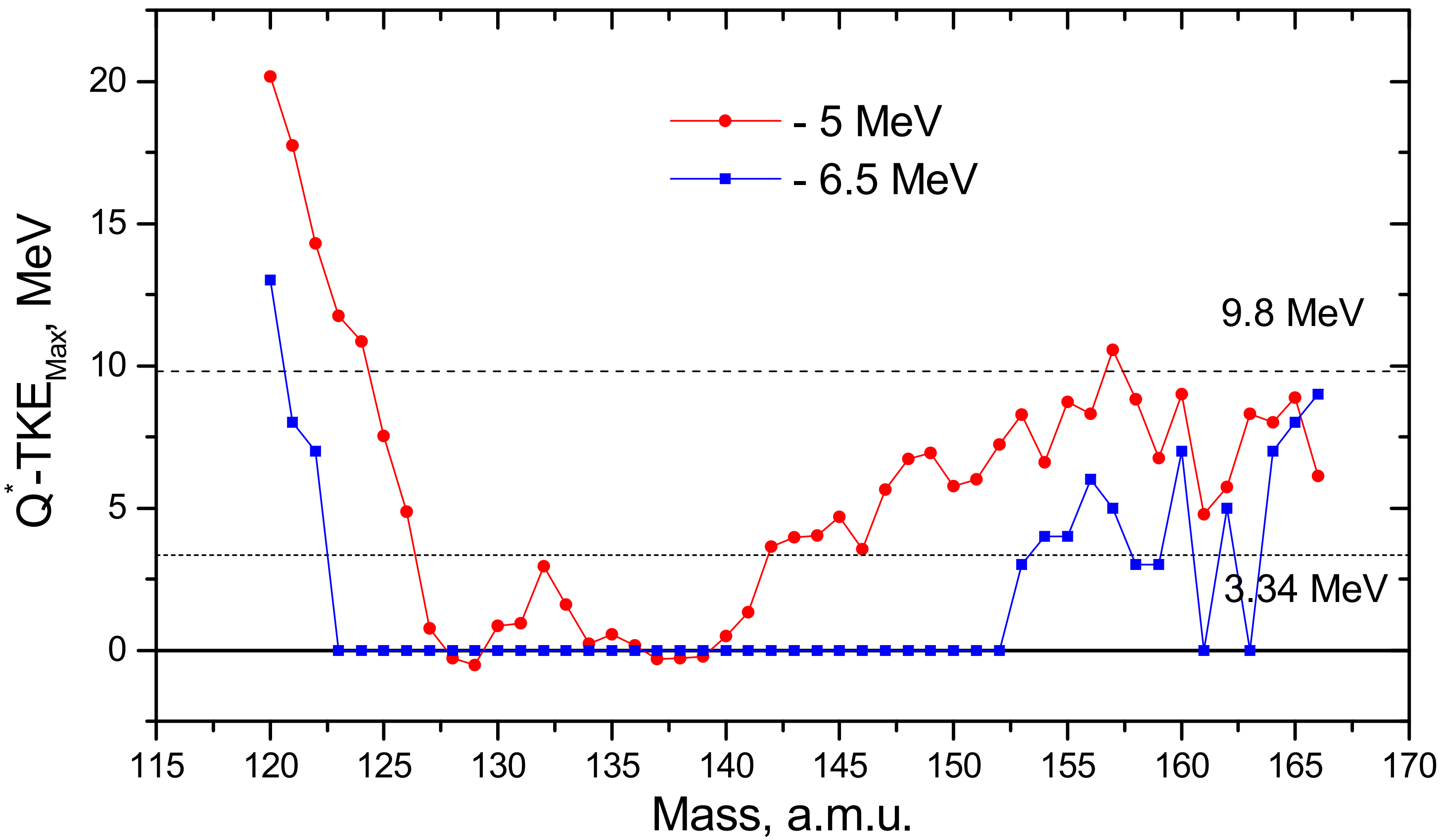


$^{238}U(n,f)$, En=5 MeV

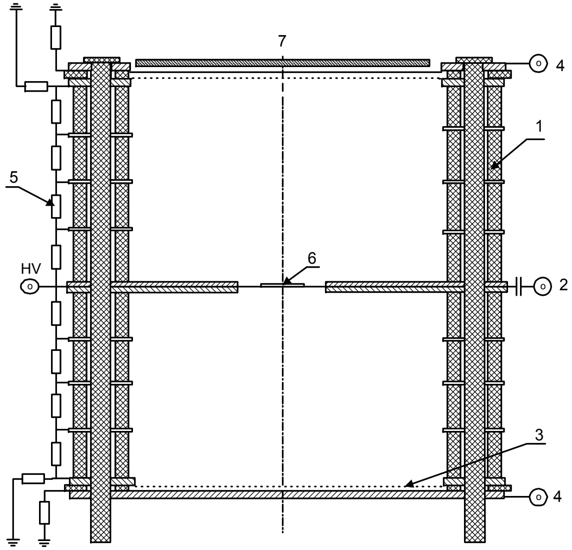


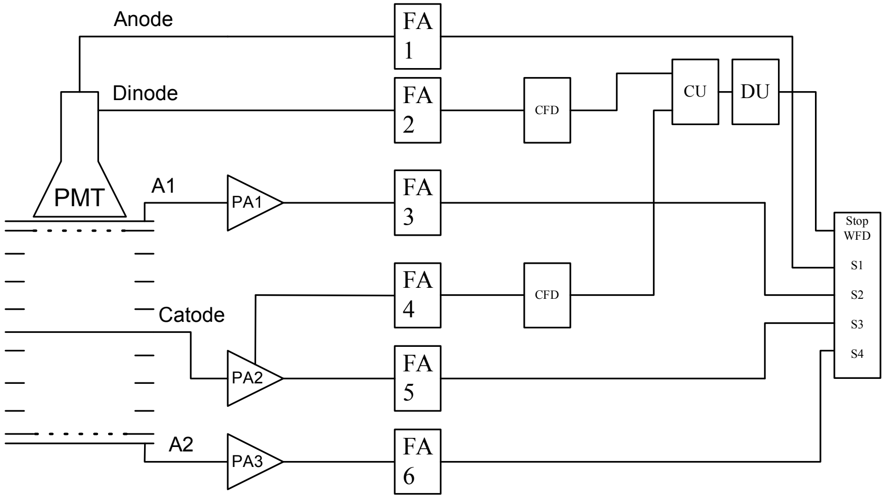


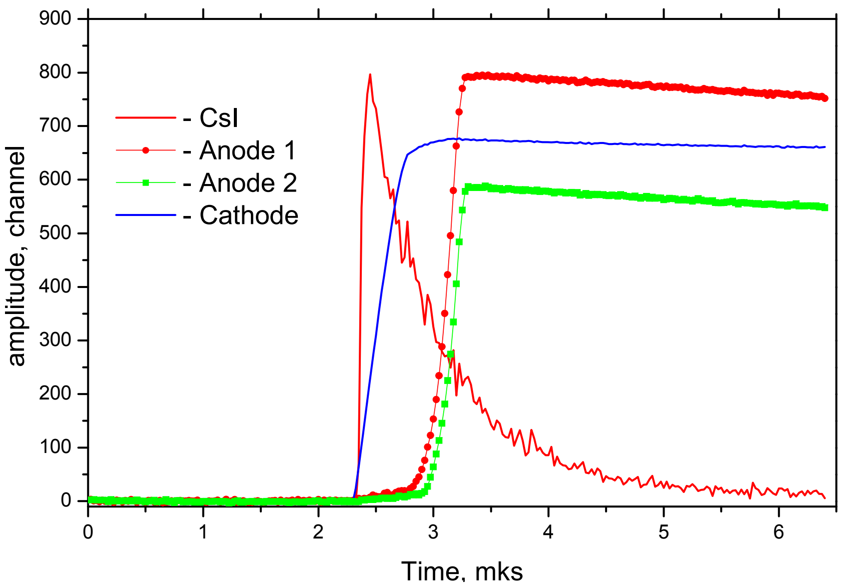
Maximal available TKE for different mass

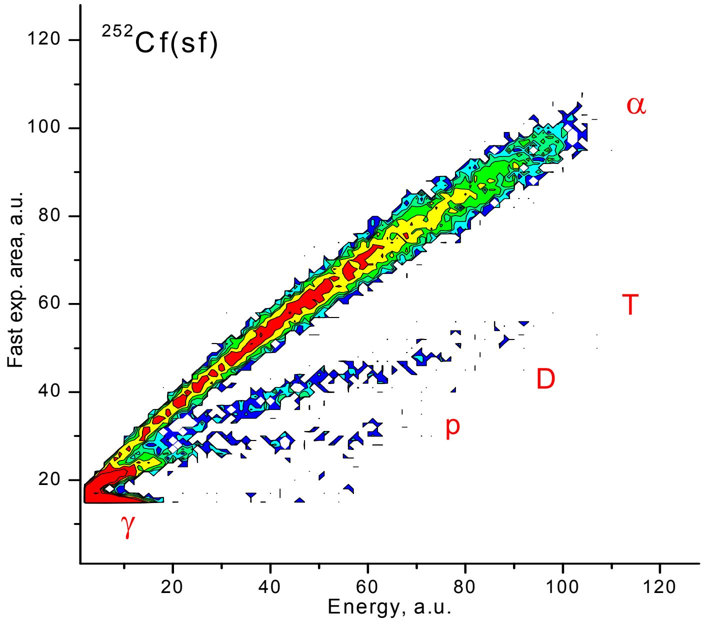


^{252}Cf and ^{233}Th ternary fission

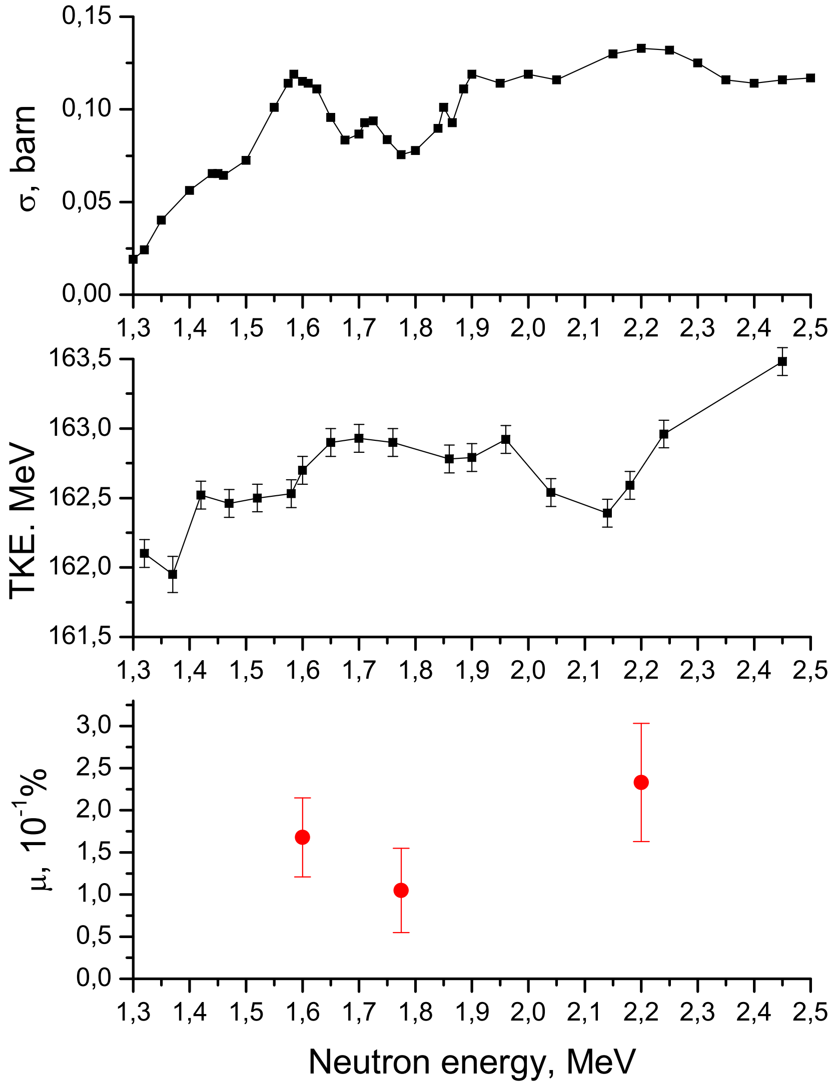






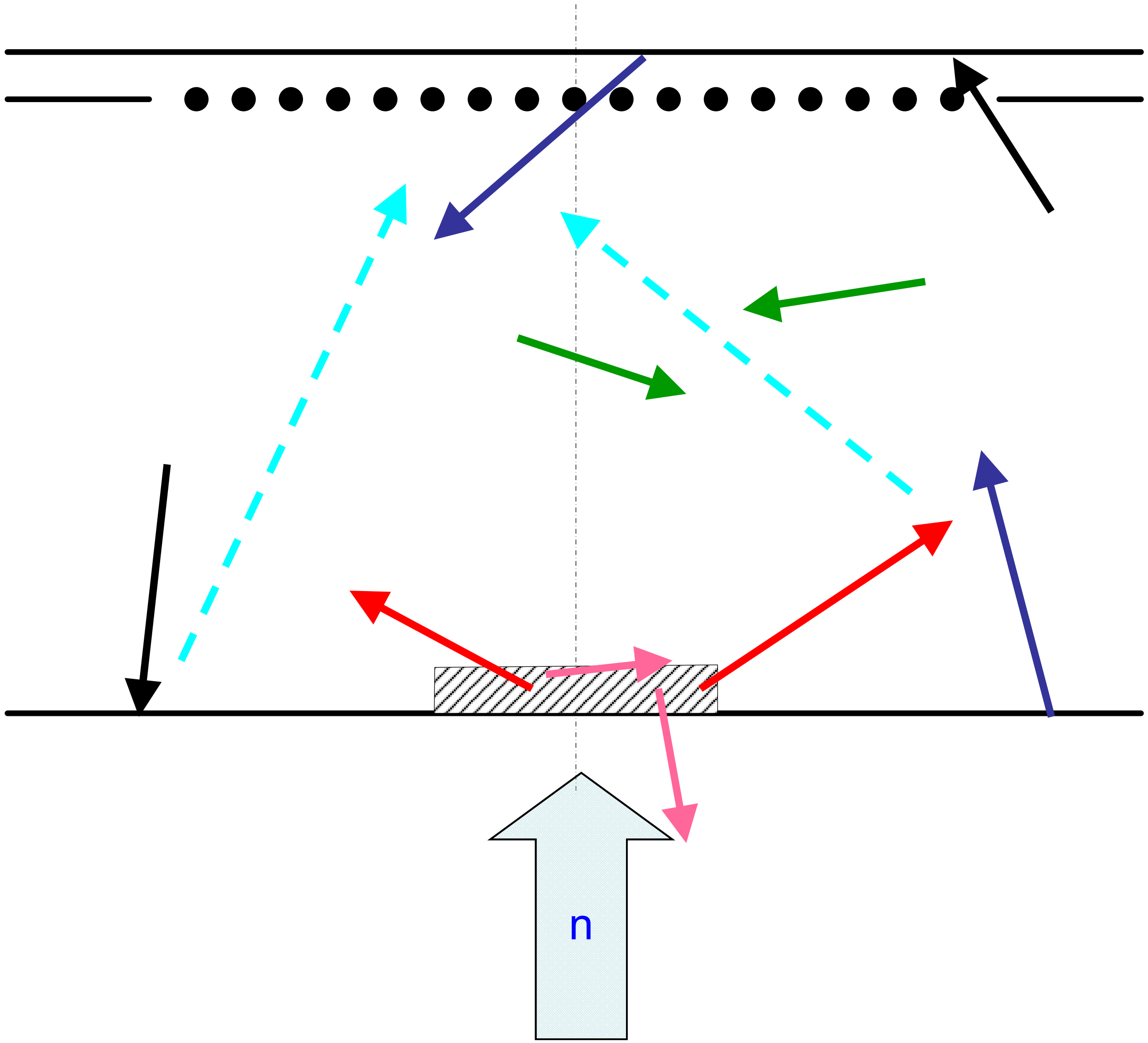


Energy dependence of ternary fission probability for $^{232}Th(n,f)$

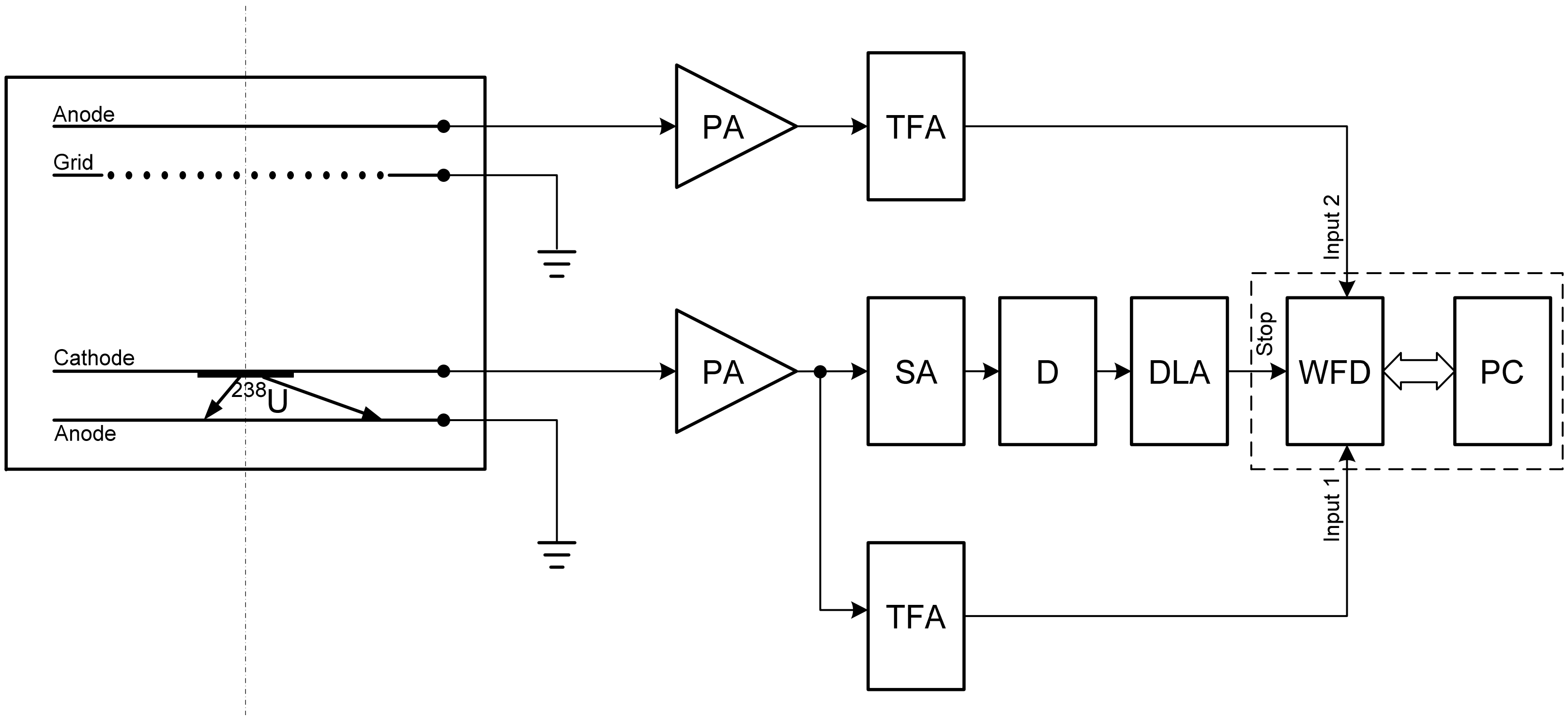


Classical spectrometer events classification

1. Target
2. Full absorption
3. Electrodes
4. Gas a-particles
5. Protons
6. Wall effect

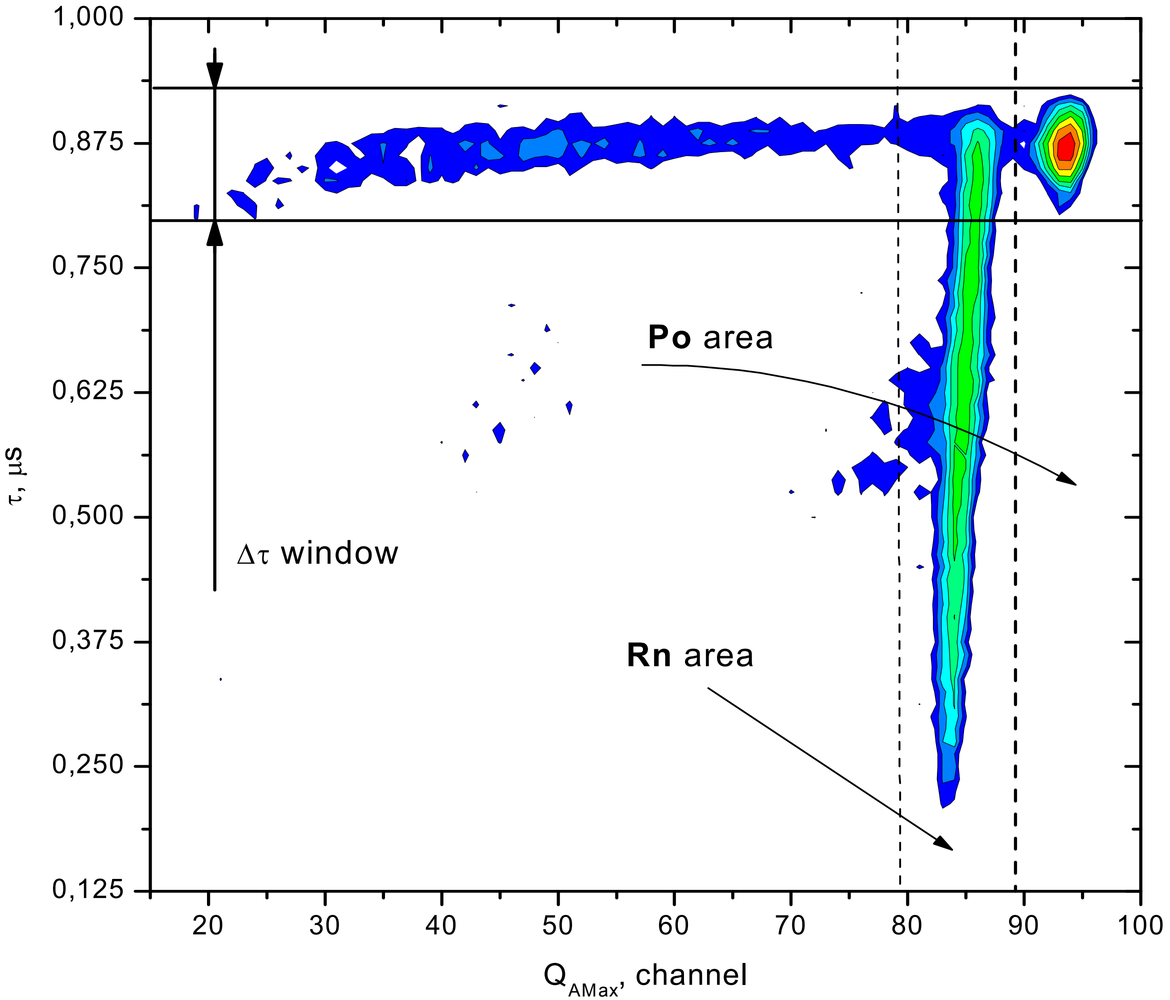


Scheme of the IPPE experimental setup

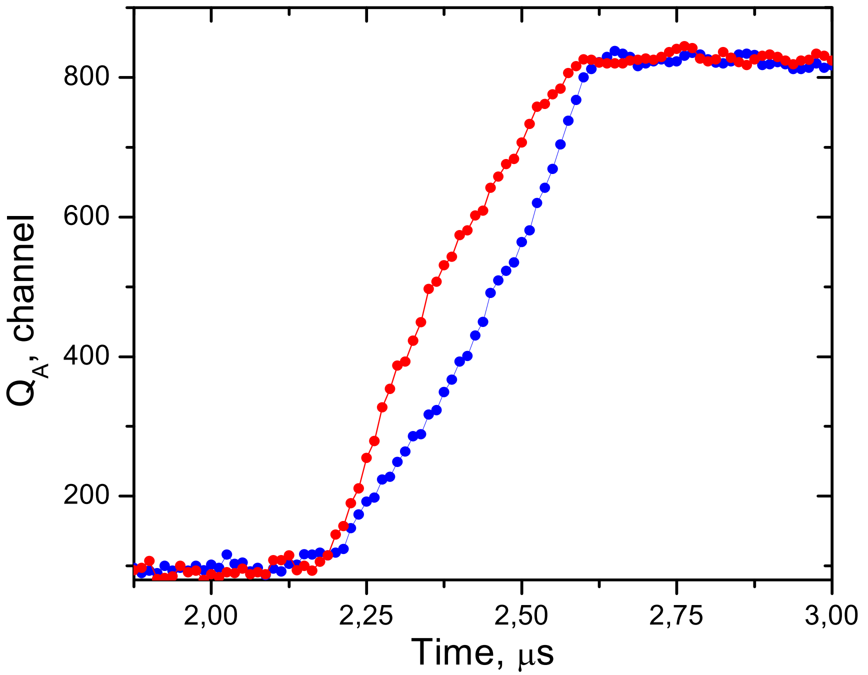


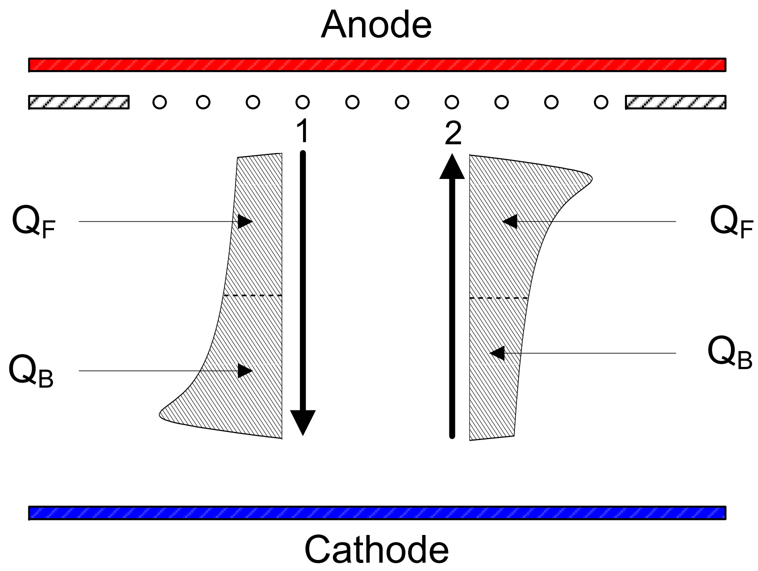
PA – preamplifier, TFA – timing filter amplifier,
D – discriminator,
SA – spectroscopy amplifier, DLA – delay line amplifier,
WFD – waveform digitizer, PC – personal computer.

Amplitude of anode pulse vs electron drift time

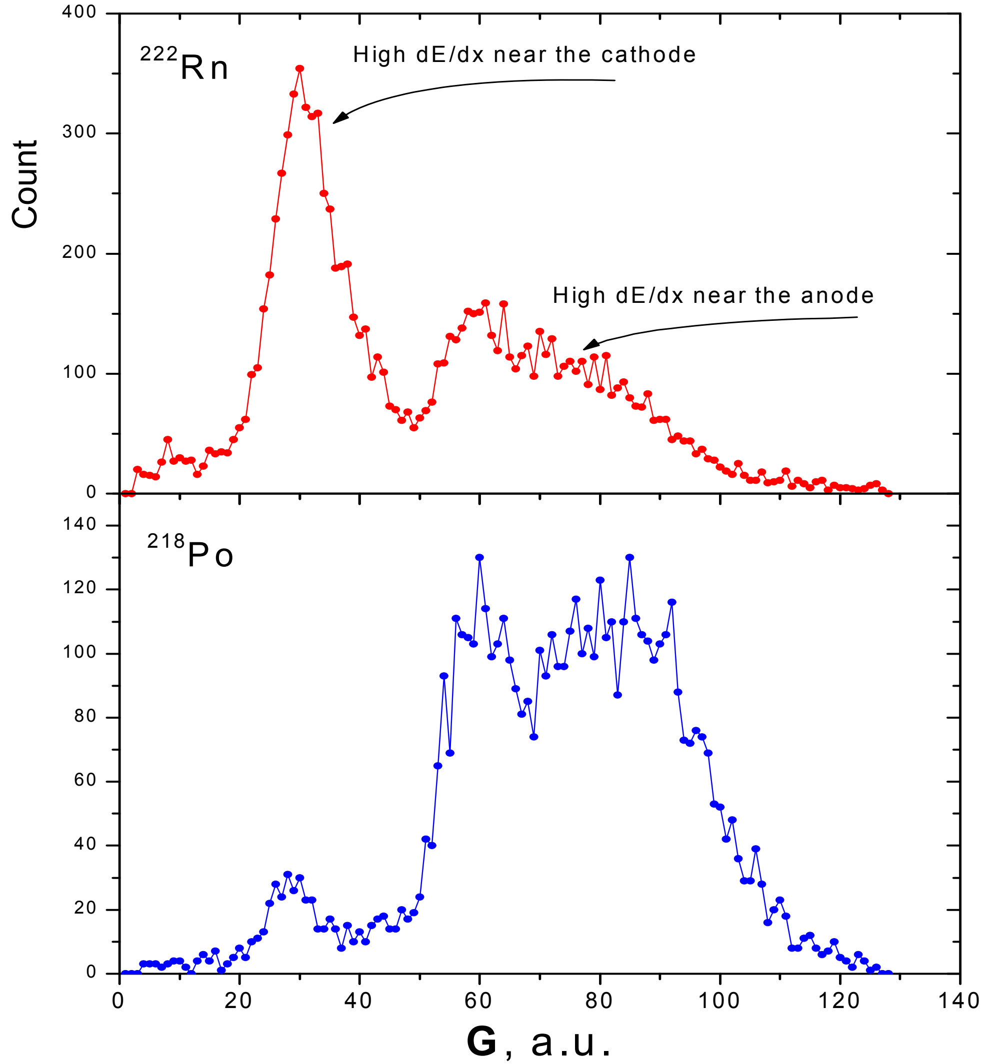


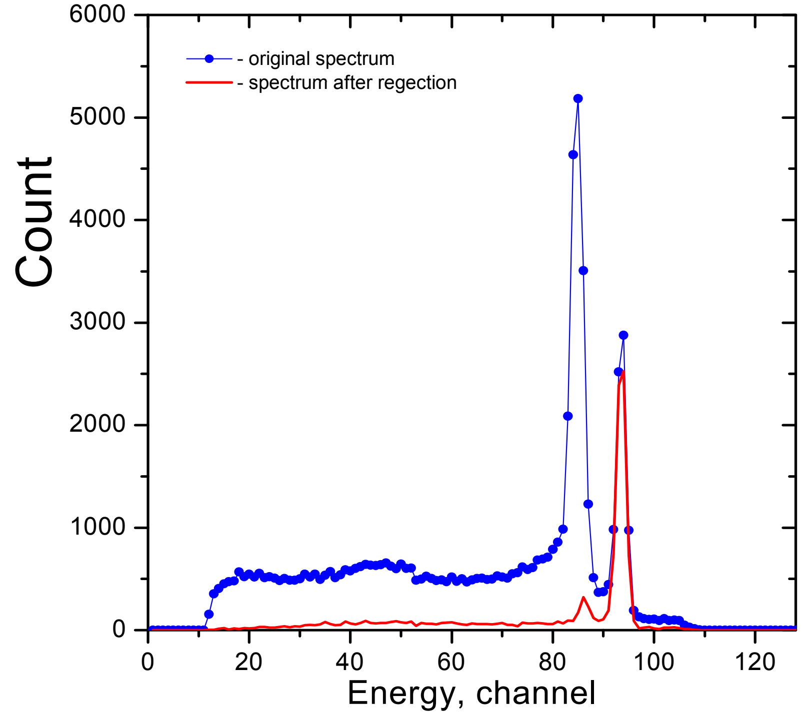
α-particle directionality determination





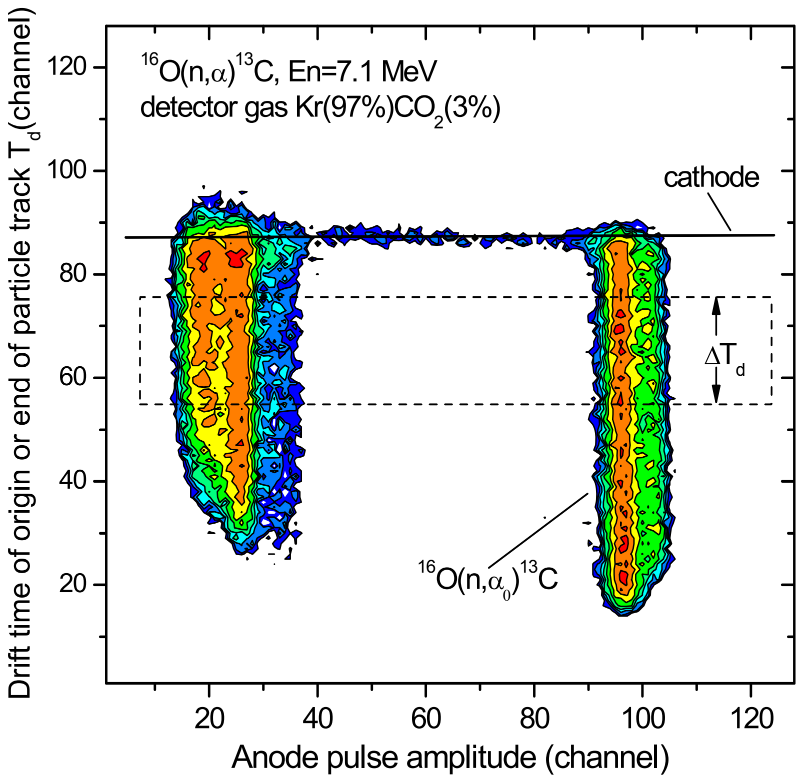
α-particle directionality determination

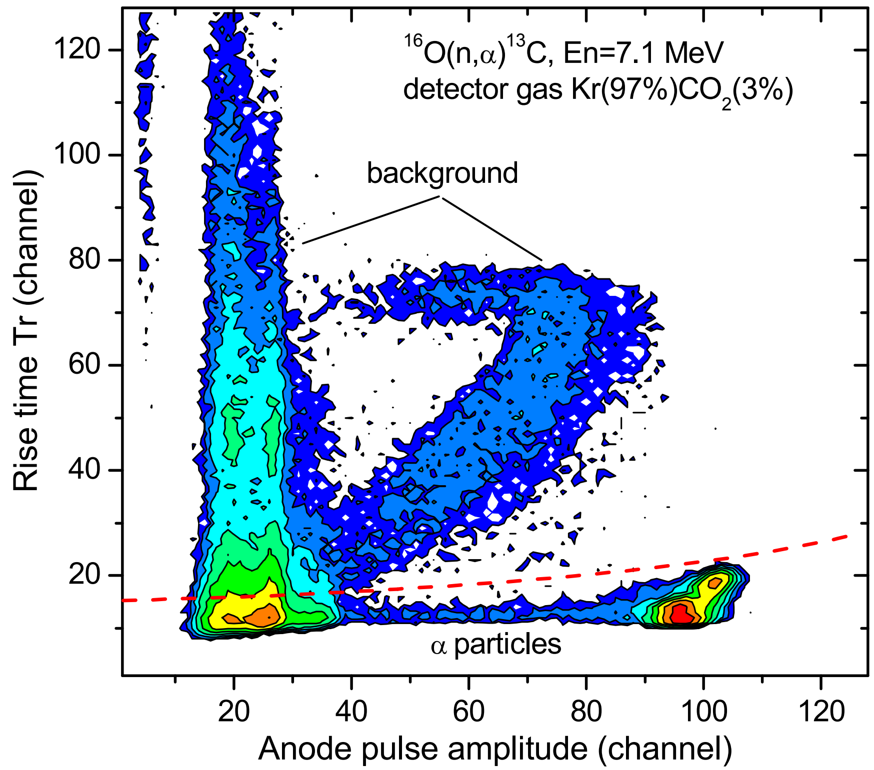




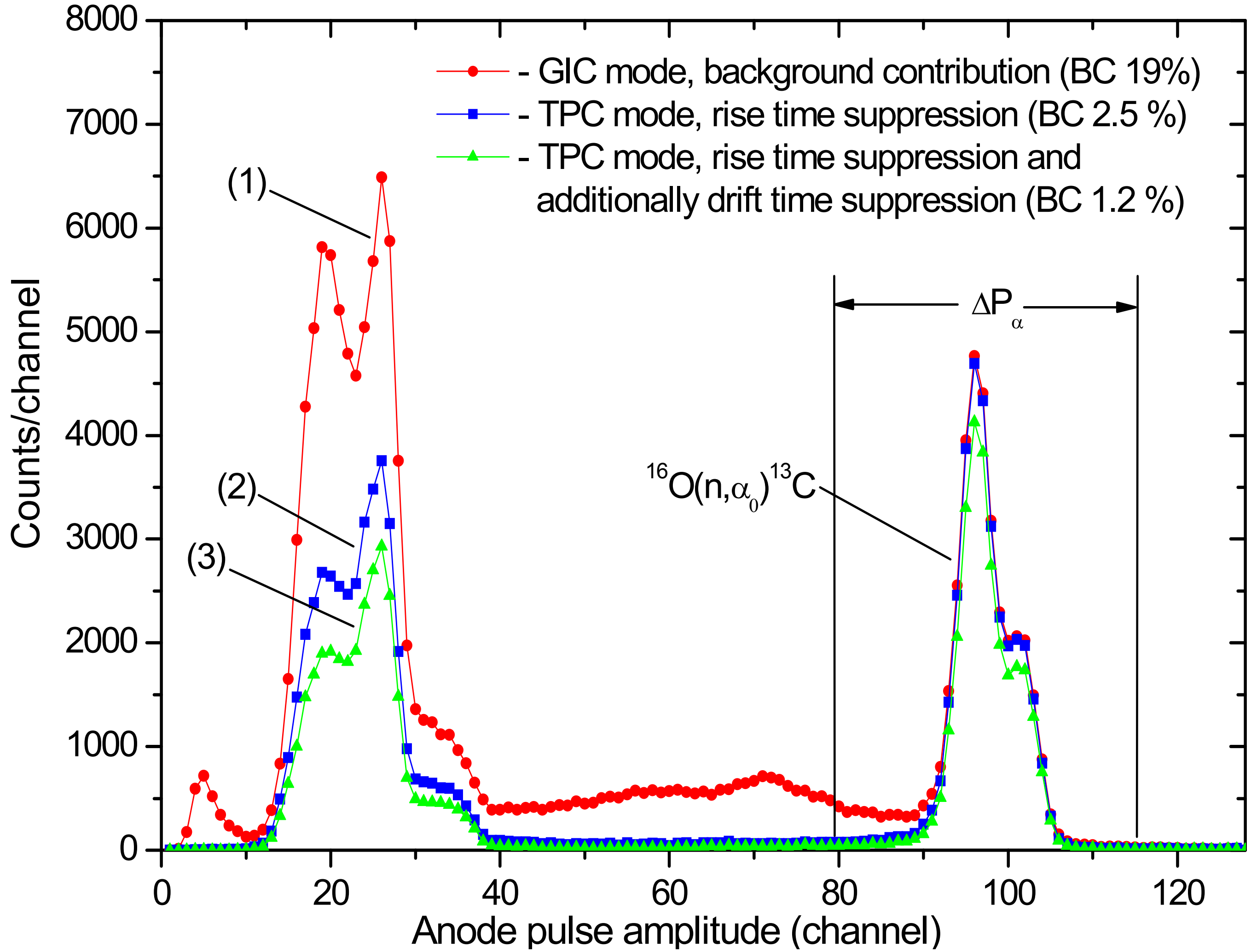
$$G = \frac{\frac{dQ_A(t)}{dt}(begin)}{\frac{dQ_A(t)}{dt}(end)} = \frac{\left(\frac{dE}{dx}\right)_{begin}}{\left(\frac{dE}{dx}\right)_{end}}$$

Particle position and type of particle determination

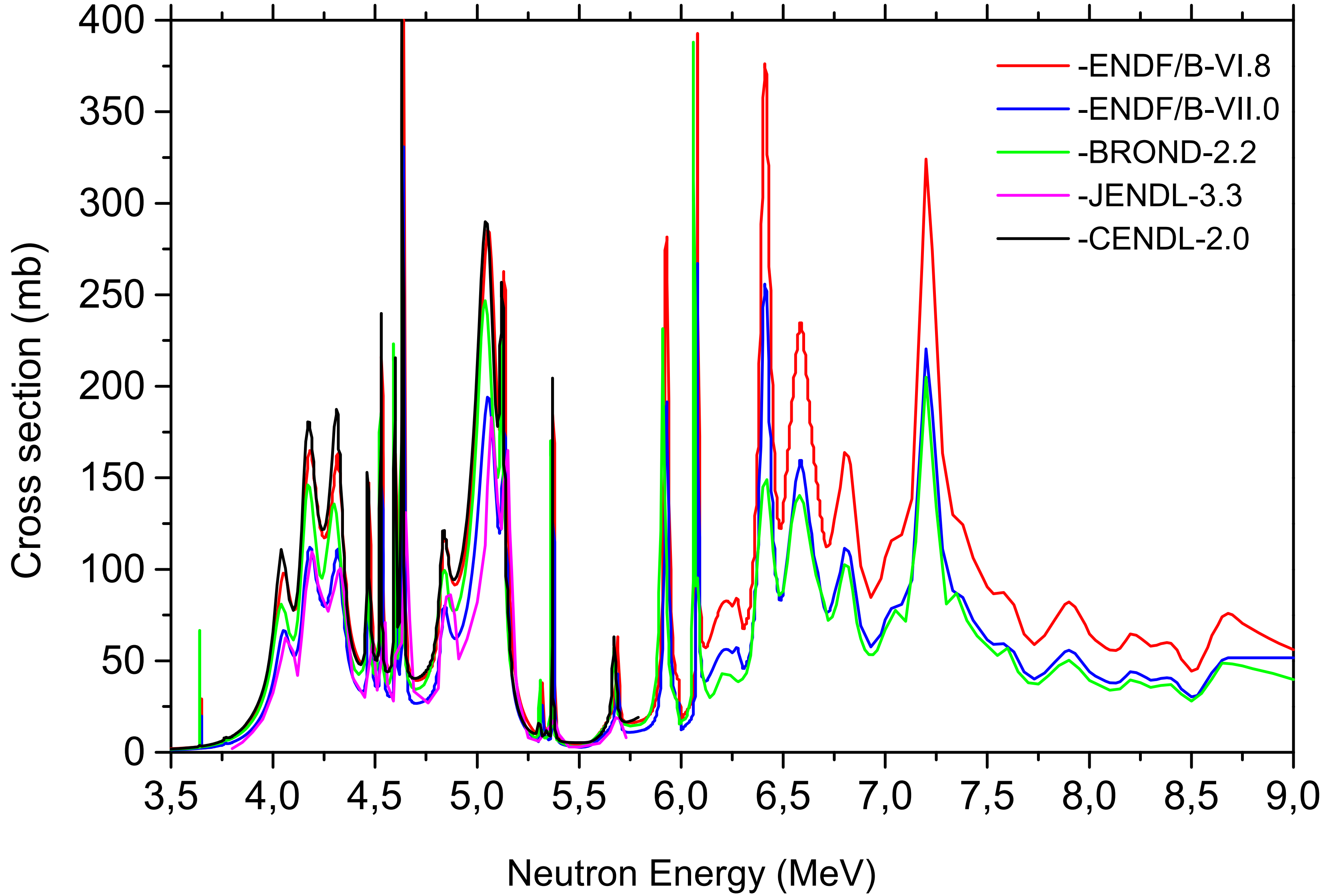




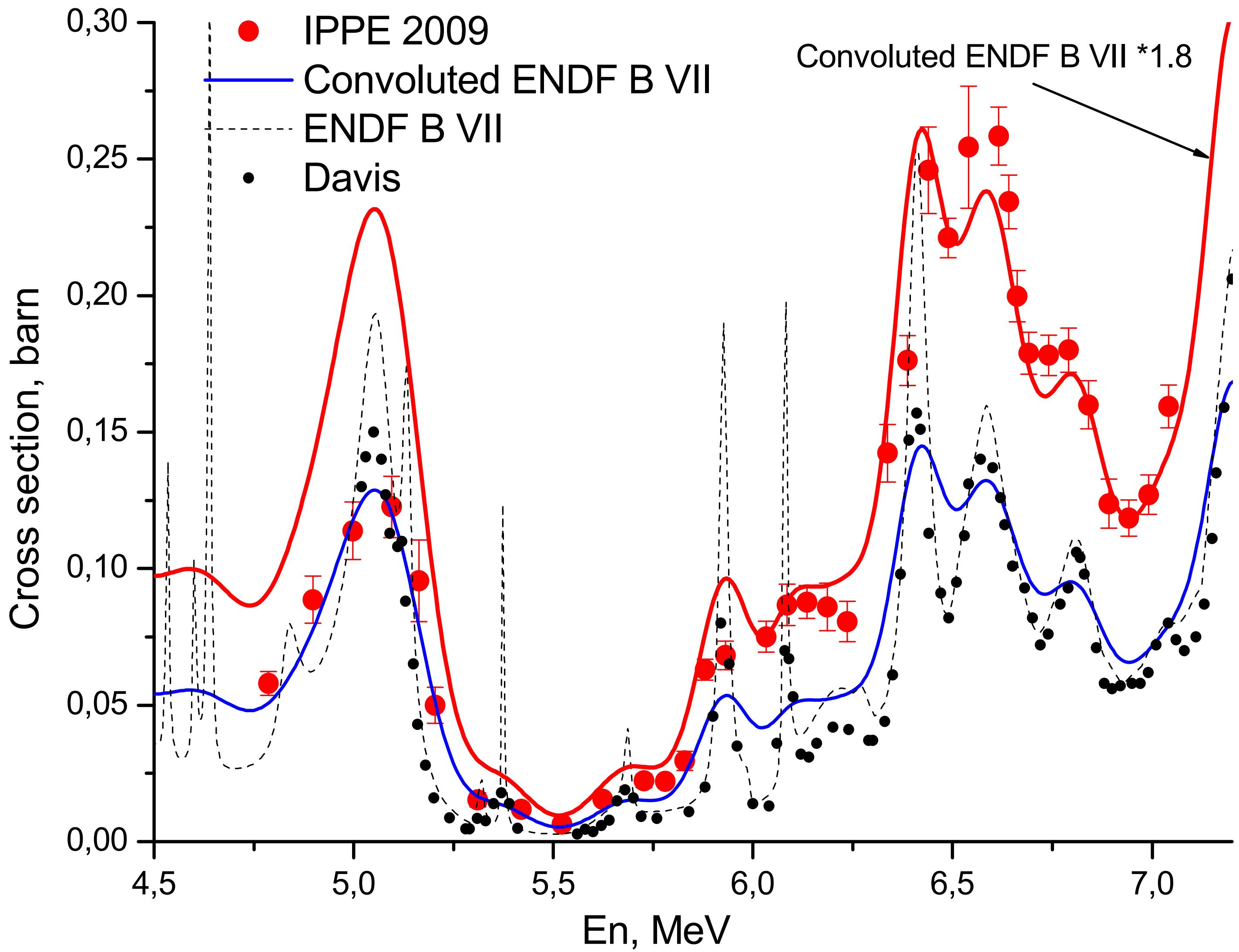
Energy spectrum of α-particles



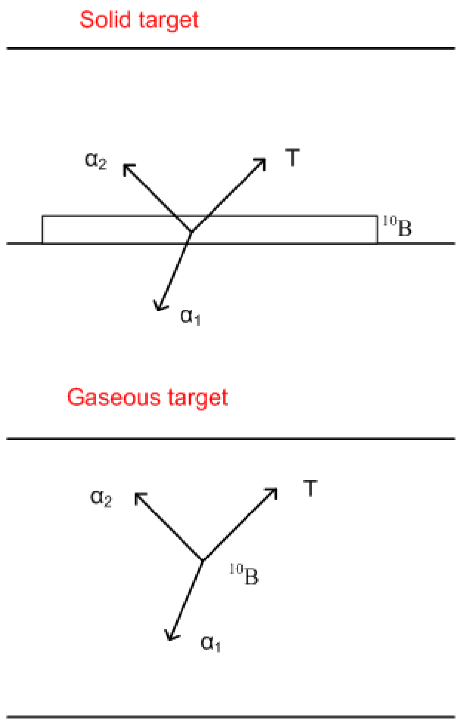
Evaluations for $^{16}O(n,\alpha)$ reaction

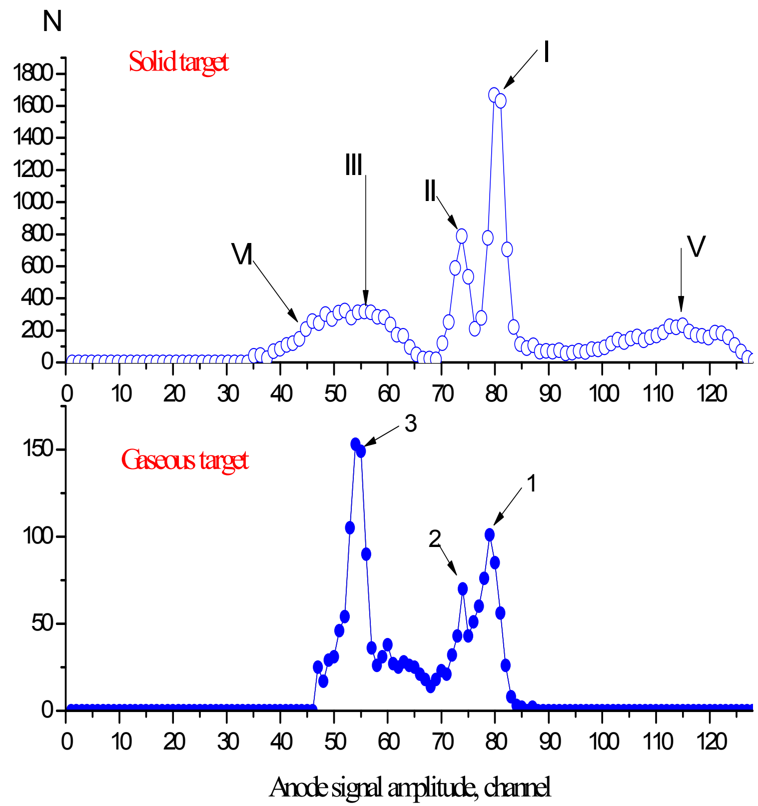


Result for $^{16}O(n,\alpha)^{13}C$



Spectrometer response function for gaseous and solid targets





Solid target:

I – $^{10}B(n,\alpha_0)$;

II – $^{10}B(n,\alpha_1)$;

III – $^{10}B(n,t)$;

VI – ^{7}Li;

V – $^{7}Li+\alpha$

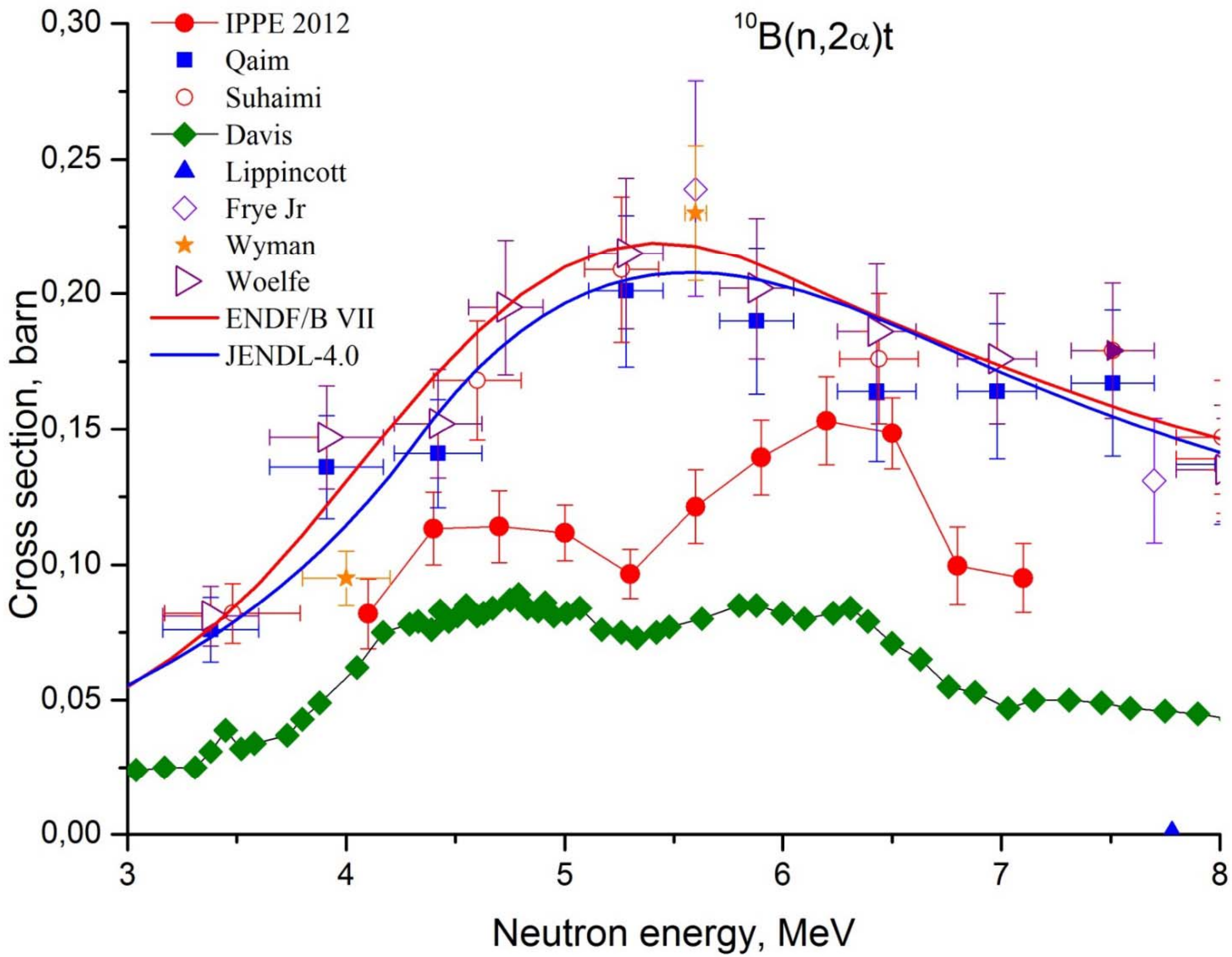
Gaseous target:

1 – $^{10}B(n,\alpha_0)$;

2 - $^{10}B(n,\alpha_1)$;

3 - $^{10}B(n,t)$

Result for $^{10}B(n,2\alpha)t$ reaction



Result for (n,a) reaction cross section for light elements

New data for:

1) $^{10}B(n,t)$,
2) $^{10}B(n, \alpha_0)/^{10}B(n, \alpha_1)$,
3) $^{12}C(n,\alpha)$,
4) $^{14}N(n,\alpha_0)$, $^{14}N(n,\alpha_1)$, $^{14}N(n,\alpha_2)$,
5) $^{14}N(n,t_0)$,
6) $^{16}O(n,\alpha_0)$,
7) $^{19}F(n,\alpha)$,
8) $^{20}Ne(n,\alpha_0)$, $^{20}Ne(n,\alpha_1)$, $^{20}Ne(n,\alpha_2)$, $^{20}Ne(n,\alpha_3)$,
9) $^{36}Ar(n,\alpha_0)$, $^{36}Ar(n,\alpha_1)$, $^{36}Ar(n,\alpha_2)$,
10) $^{40}Ar(n,\alpha_0)$

was measured

Some of structural material isotopes properties

Isotope	Natural abundance, %	(n,α) reaction Q-value, MeV
^{50}Cr, $T_{1/2}>1,8*10^{17}$ y, EC	4,345	+0,3213
^{52}Cr, stable	83,489	-1,2097
^{53}Cr, stable	9,501	+1,7903
^{54}Cr, stable	2,365	- 1,5466

Cr

Isotope	Residual nuclear	Stability
^{50}Cr	**^{47}Ti**	**Stable**
^{52}Cr	**^{49}Ti**	**Stable**
^{53}Cr	**^{50}Ti**	**Stable**
^{54}Cr	^{51}Ti	$T_{1/2}$=5,76 min

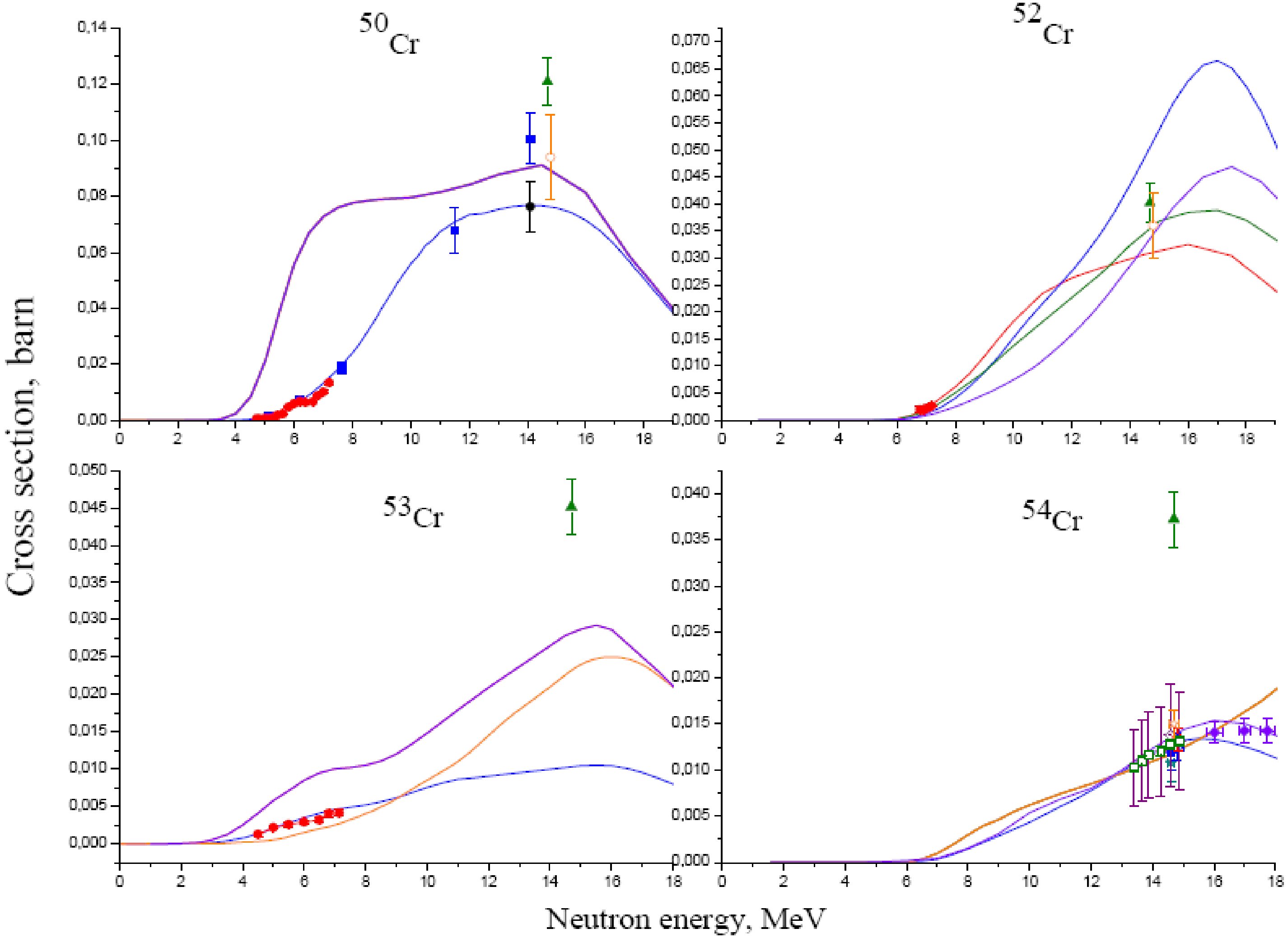
Fe

Isotope	Residual nuclear	Stability
^{54}Fe	**^{51}Cr**	**$T_{1/2}$=27,7 d, ec**
^{56}Fe	**^{53}Cr**	**Stable**
^{57}Fe	**^{54}Cr**	**Stable**
^{58}Fe	^{55}Cr	$T_{1/2}$=3,55 min

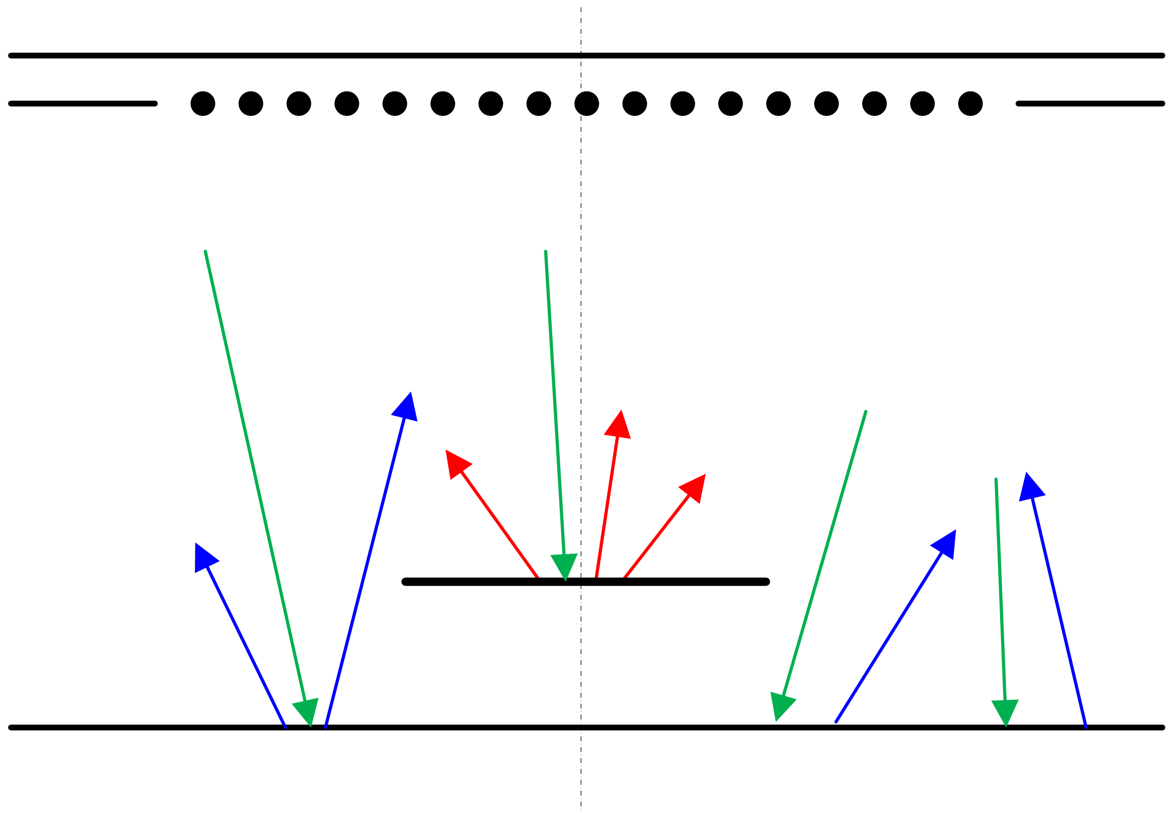
Ni

Isotope	Residual nuclear	Stability
^{58}Ni	**^{55}Fe**	**$T_{1/2}$=2,7 y, ec**
^{60}Ni	**^{57}Fe**	**Stable**
^{61}Ni	**^{58}Fe**	**Stable**
^{62}Ni	^{59}Fe	$T_{1/2}$=44,5 d

Present status of experimental data and evaluation for chromium isotopes

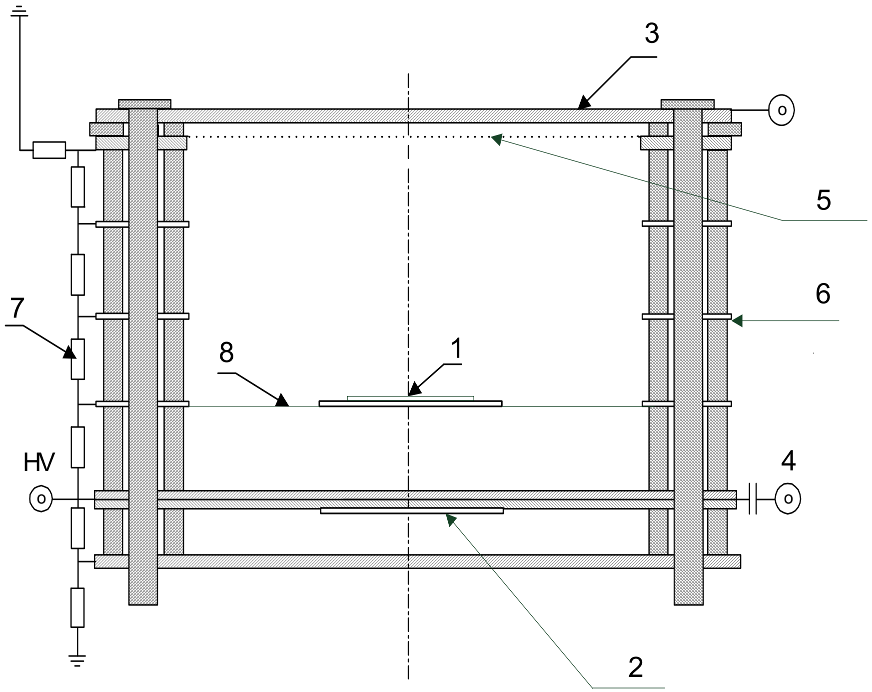


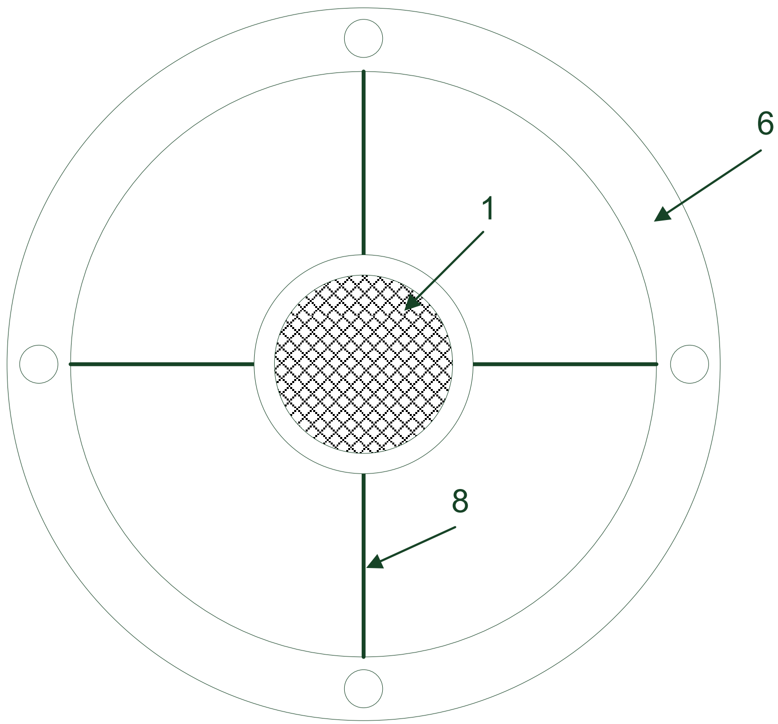
Motivations for removing solid target from cathode surface



1) Target surface 10 times less then cathode surface; Probability of gaseous particle absorption is proportional to the surface area.
2) Target material – gold. Low probability for charge particle emission;

New chamber design

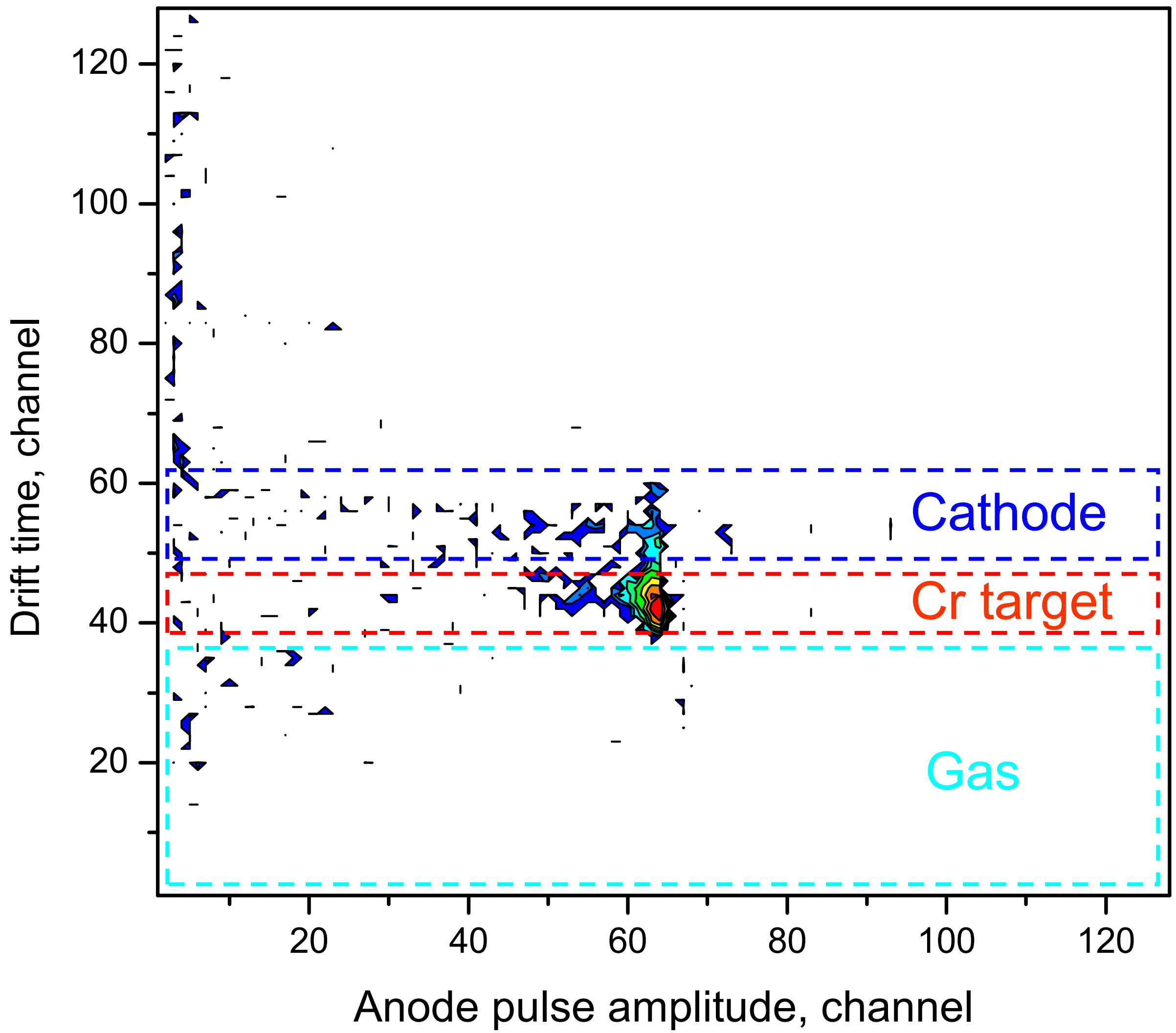




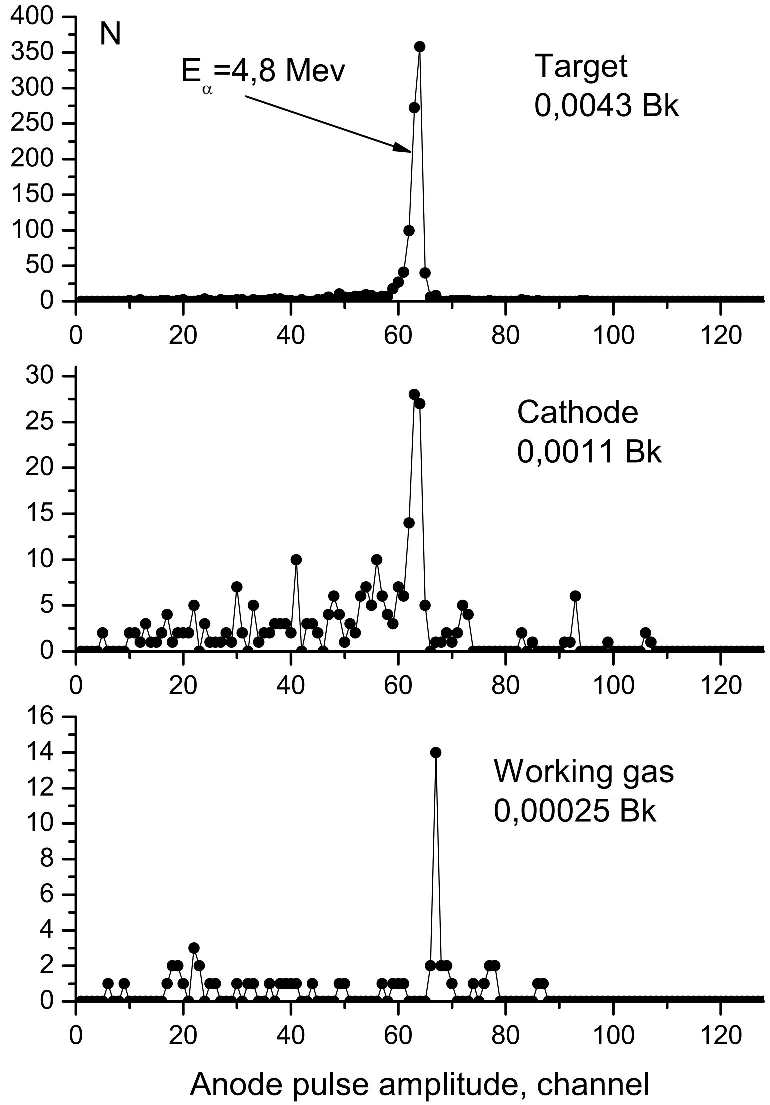
1) Cr target;
2) ^{238}U target;
3) Anode;
4) Anode signal connector;

5. Frisch grid;
6. Guard electrodes;
7. Resistor.
8. Golden threads

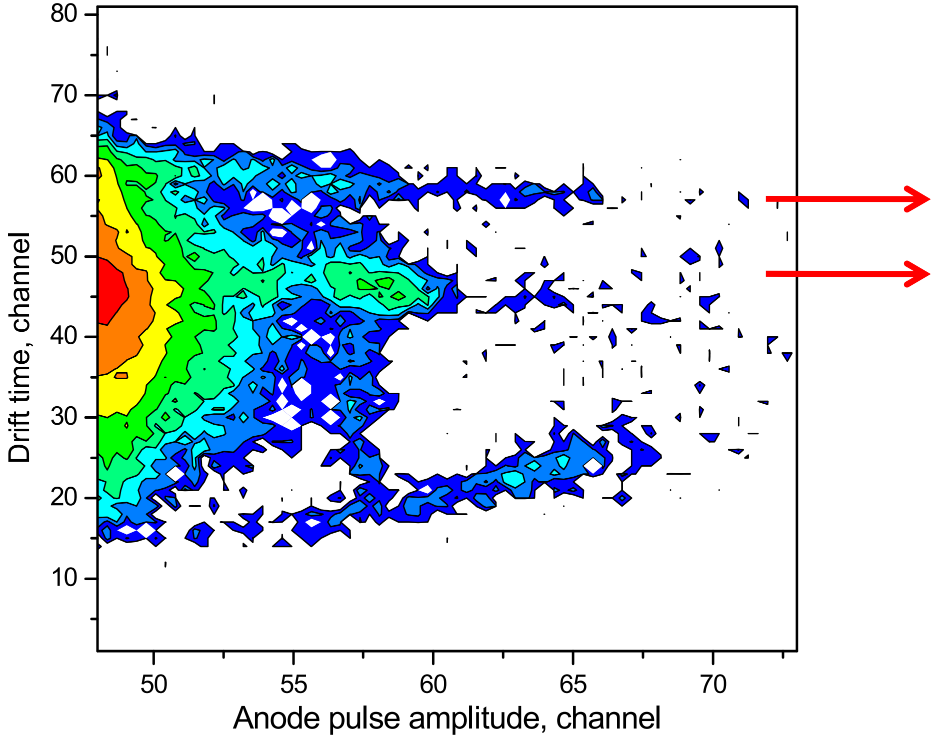
Background (neutron beam off)

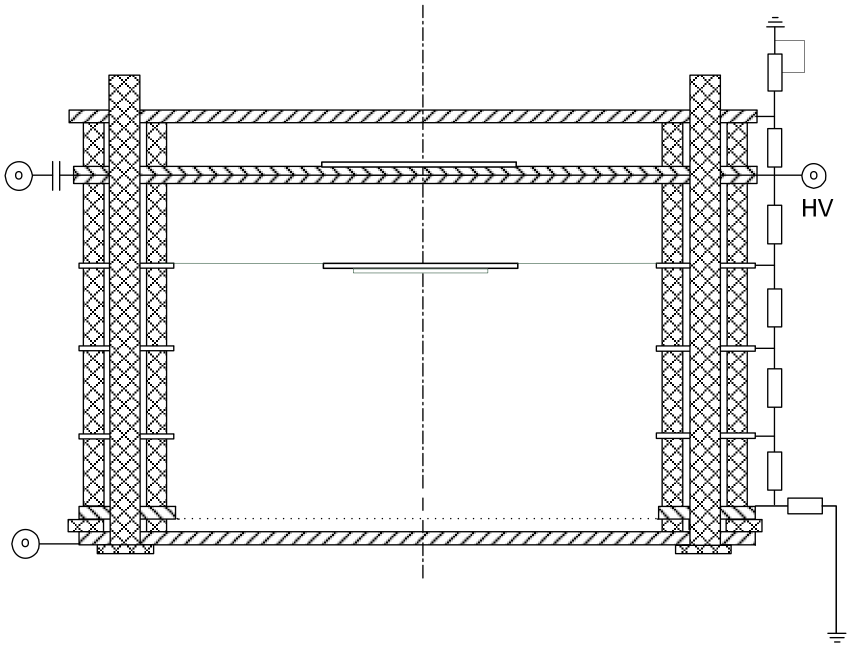


Own α - activity of the detector

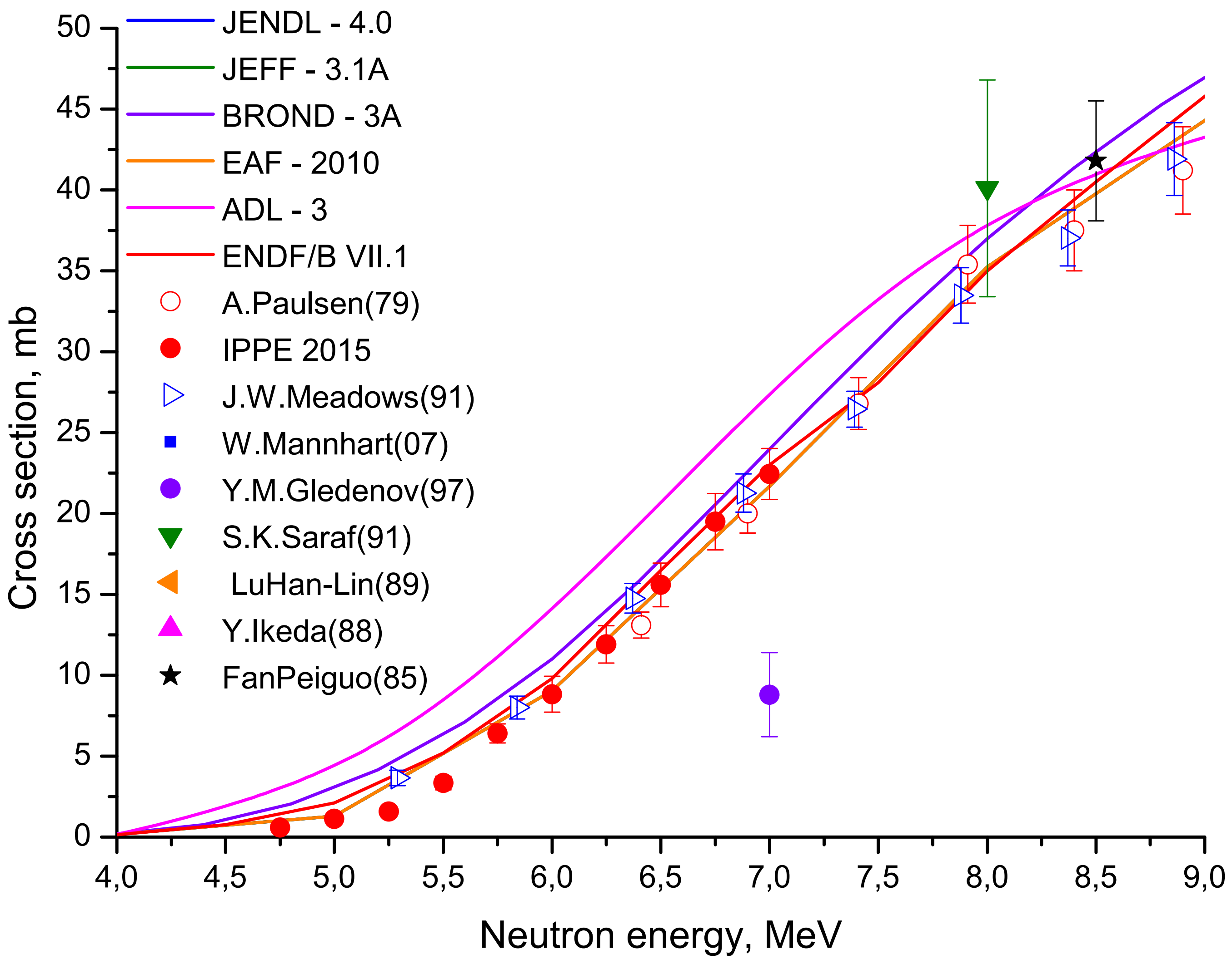


Drift time selection for α-particles only

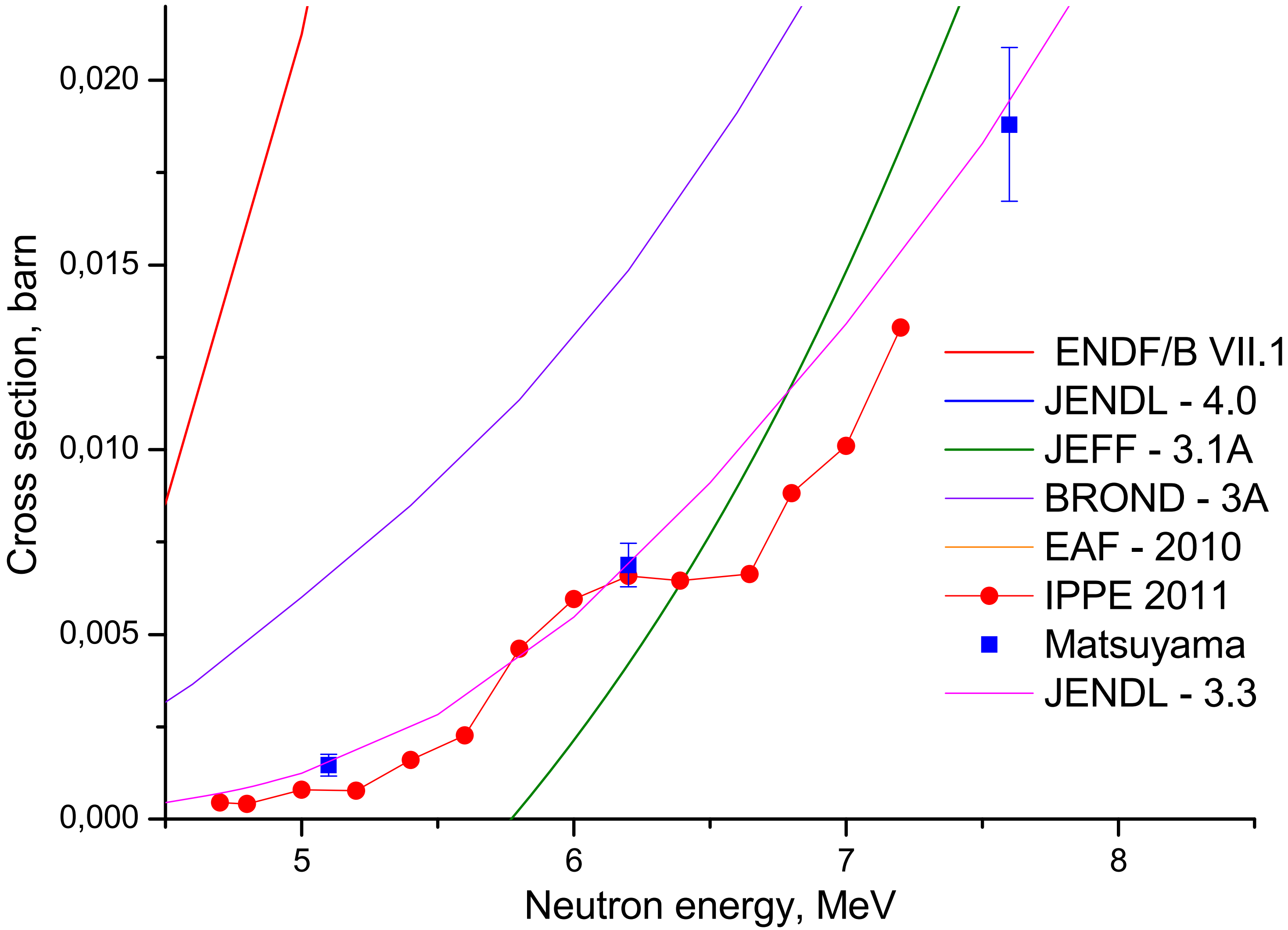




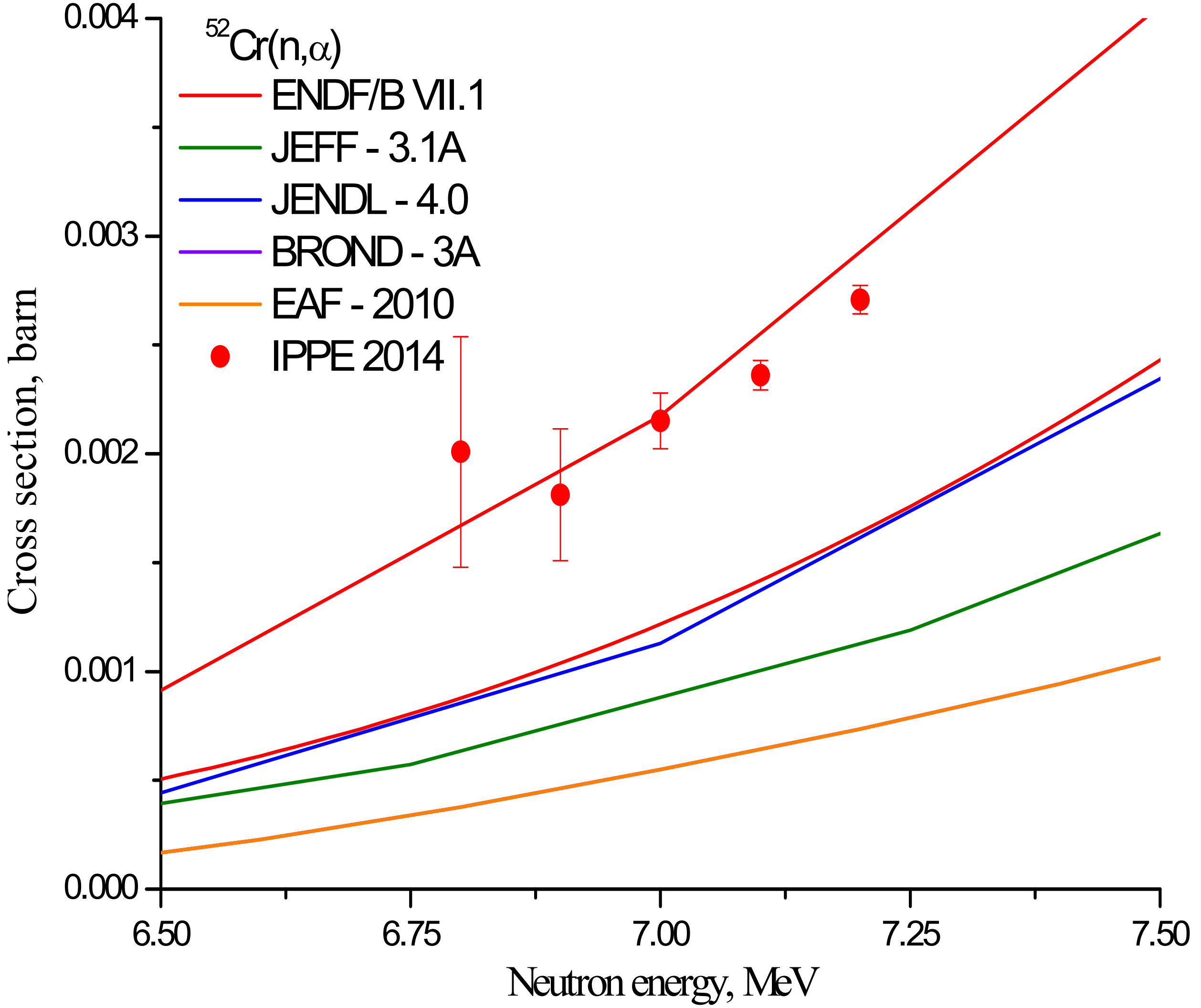
Result for $^{54}Fe(n,\alpha)^{51}Cr$ reaction cross section



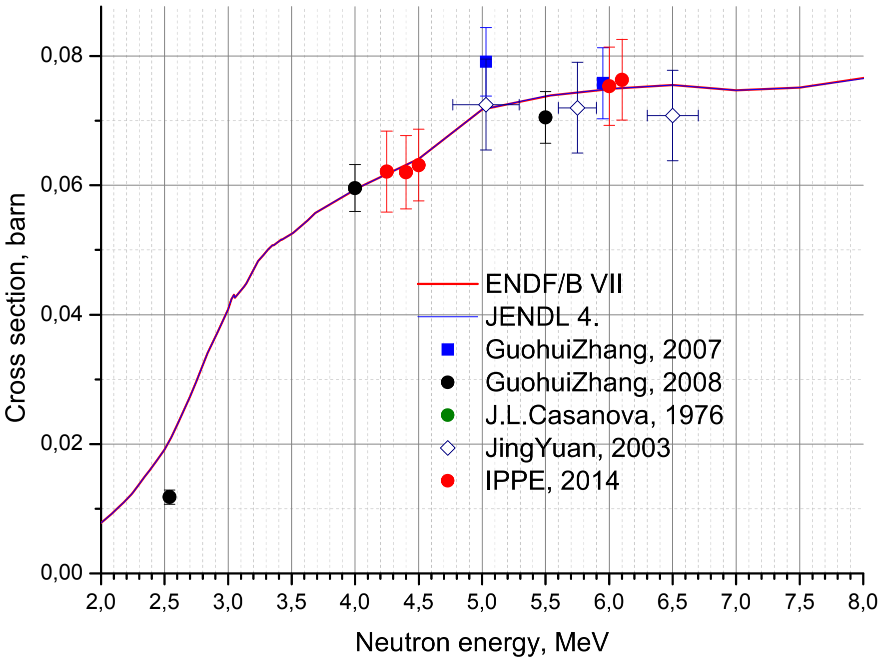
Result for ^{50}Cr

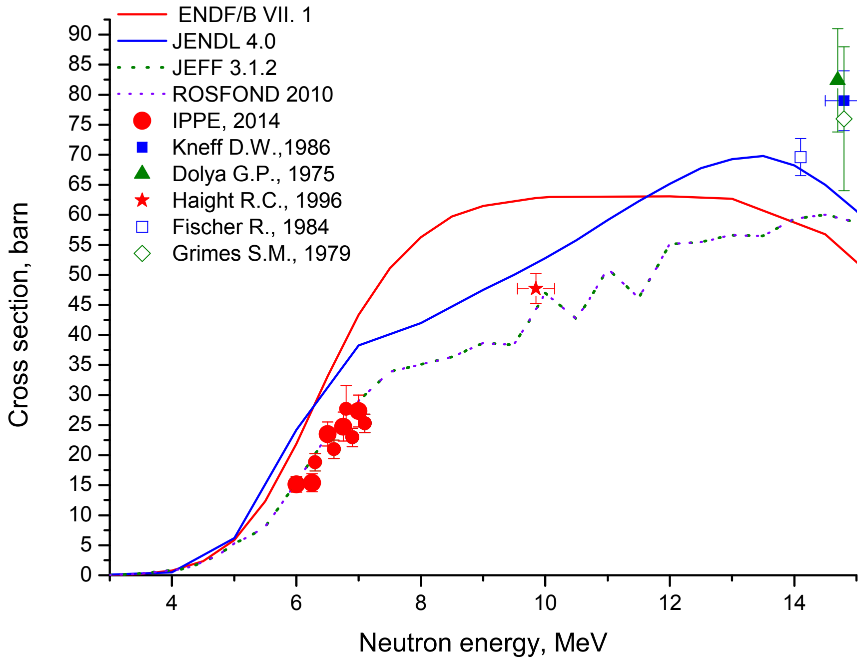


Result for $^{52}Cr(n,\alpha)^{49}Ti$ reaction cross section



Result for $^{64}Zn(n,\alpha)$ and ^{60}Ni (n,α) reaction cross section





Result for (n,a) reaction cross section for light elements

New data for:

1) $^{50}Cr(n, \alpha)$,
2) $^{52}Cr(n, \alpha)$,
3) $^{53}Cr(n, \alpha)$,
4) $^{54}Fe(n, \alpha)$,
5) $^{57}Fe(n, \alpha)$,
6) $^{60}Ni(n, \alpha)$,
7) $^{64}Zn(n, \alpha)$,,

was measured

New 3MV Tandetron 4130 HC accelerator

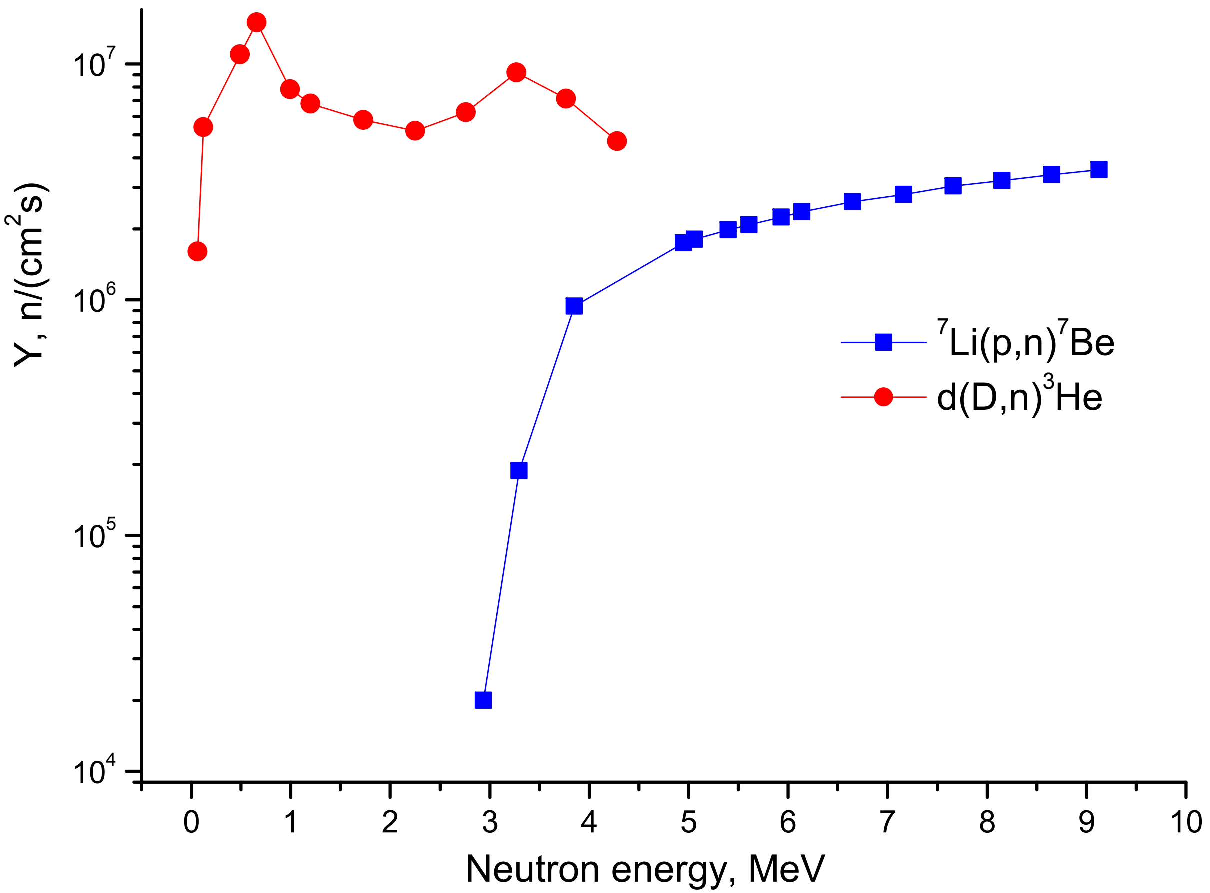
Parameters of the Tandem accelerator 3MV Tandetron 4130 HC

РОСАТОМ

Voltage **0,2 -3,3 MV**
Voltage stability **± 300 V**
Vacuum 4×10^{-7} Torr (oil free)
Pulse regime (hydrogen):
Ion energy - 0,5 - 4 MeV;
Pulse width - 2 ns;
Pulse rate - 125 kHz - 4 MHz
Average current: - 4,8 μA (4 MHz)

Ion	Current, μA	Max. energy, MeV		Ion	Current, μA	Max. energy, MeV
^{1}H(+)	**20**	**6**		^{31}P(3+)	20	12
^{2}D(+)	**15**	**6**		^{28}Si(3+)	48	12
^{4}He(2+)	**4**	**9**		^{58}Ni(3+)	20	12
^{7}Li(2+)	**2**	**9**		^{56}Fe(3+)	2	12
^{11}B(3+)	12	12		^{63}Cu(2+)	8	9
^{12}C(3+)	40	12		^{75}As(2+)	5	9
^{16}O(3+)	40	12		^{197}Au(2+)	20	9

Expected neutron flux



Current 20 μA. Target thickness – 2 mg. Distance from neutron target – 10 cm.

Plane of future investigations.

- Experiments with gaseous targets ($^{16}O(n,\alpha)$, $^{14}N(n,\alpha)$, $^{14}N(n,t)$ и $^{10}B(n,\alpha)$) for neutron energy range from threshold to 9 MeV.
- Prompt neutron spectra for ^{235}U fission by thermal neutrons (fully digital experiment).
- (n,α) reaction cross section for structural material nuclear (up to 9 MeV).
- Benchmarks. Liking neutron spectra from sphere for californium source and 14 MeV source.
- Fission fragment yield for fast neutrons.
- Ternary fission by fast neutron.
- Study of delay neutrons. Spectra. Yield. Timing parameters.
- Elastic and inelastic neutron scattering cross section for structural materials.

Thank you for attention !