Cross sections of the ^{144}Sm(n, α)^{141}Nd reaction at 5.5 and 6.5 MeV

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(*n*, *α*) reaction investigations

Motivation:

basic physics

- *nuclear structure*
- *nuclear reaction mechanism*

nuclear astrophysics

- *test nuclear statistical models*
- *α+nucleus potential,*
- *p-nuclei*

nuclear engineering

- *nuclear heating*
- *radiation damage*

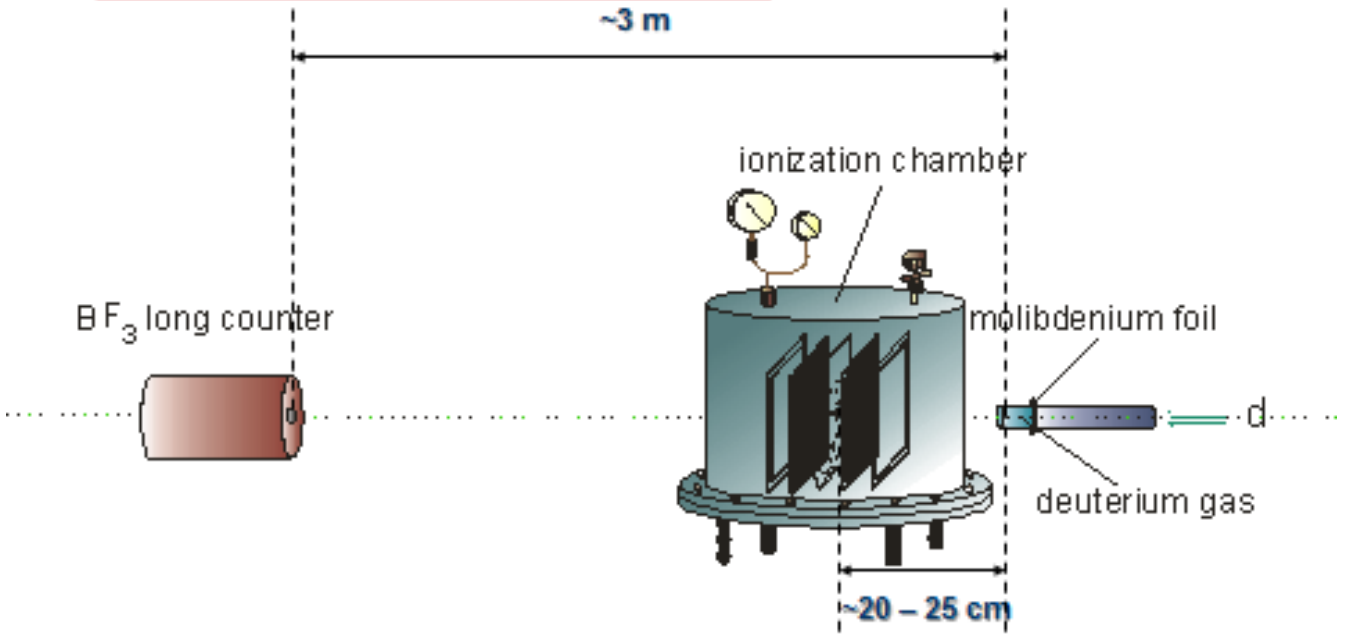
$^{144}Sm(n, \alpha)^{141}Nd$

- For En=3-7 MeV no data except ours
- Around 14 MeV 3-times differences
- More than ten times discrepancies among evaluated nuclear data libraries
- Need more isotopes for analyses

Q value =7.874 MeV

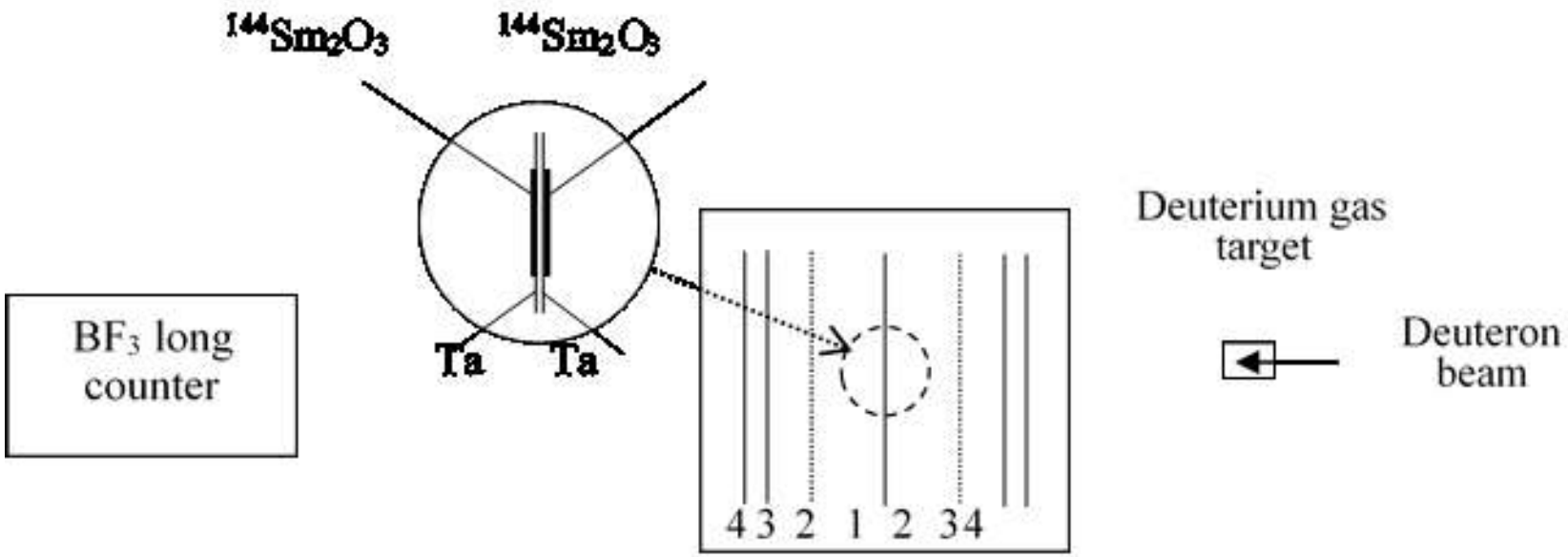
^{144}Sm	^{147}Sm	^{148}Sm	^{149}Sm	^{150}Sm	^{152}Sm	^{154}Sm
3.07%	*14.99%*	*11.24%*	*13.82%*	*7.38%*	*26.75%*	*22.75%*

Setup of experiment



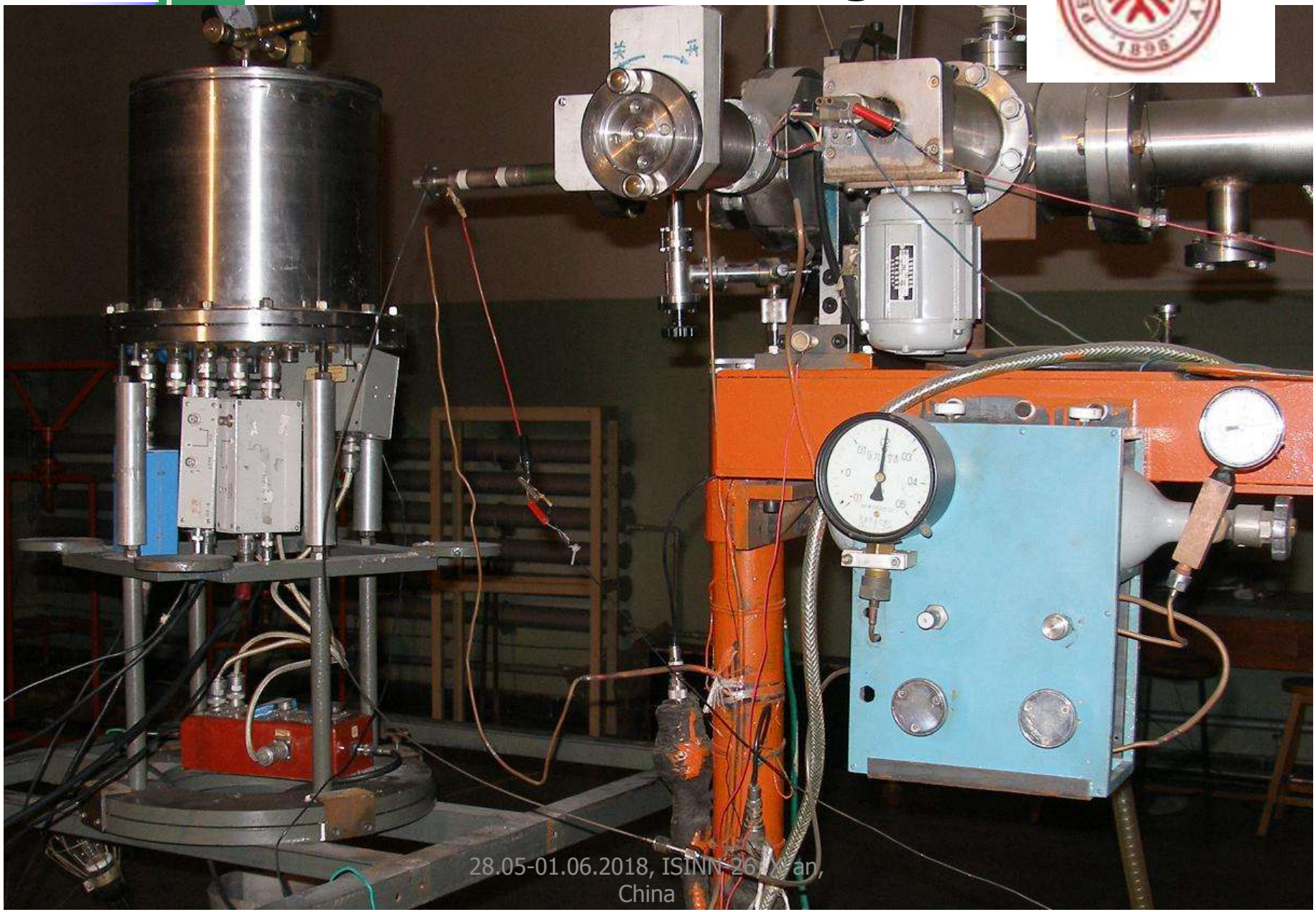
3 parts: ③ ② ①

flux measurement	**particle detector**	**neutron source**
BF_3 + $^{238}U(n,f)$	GIC	d-d



Experimental setup

Gas target

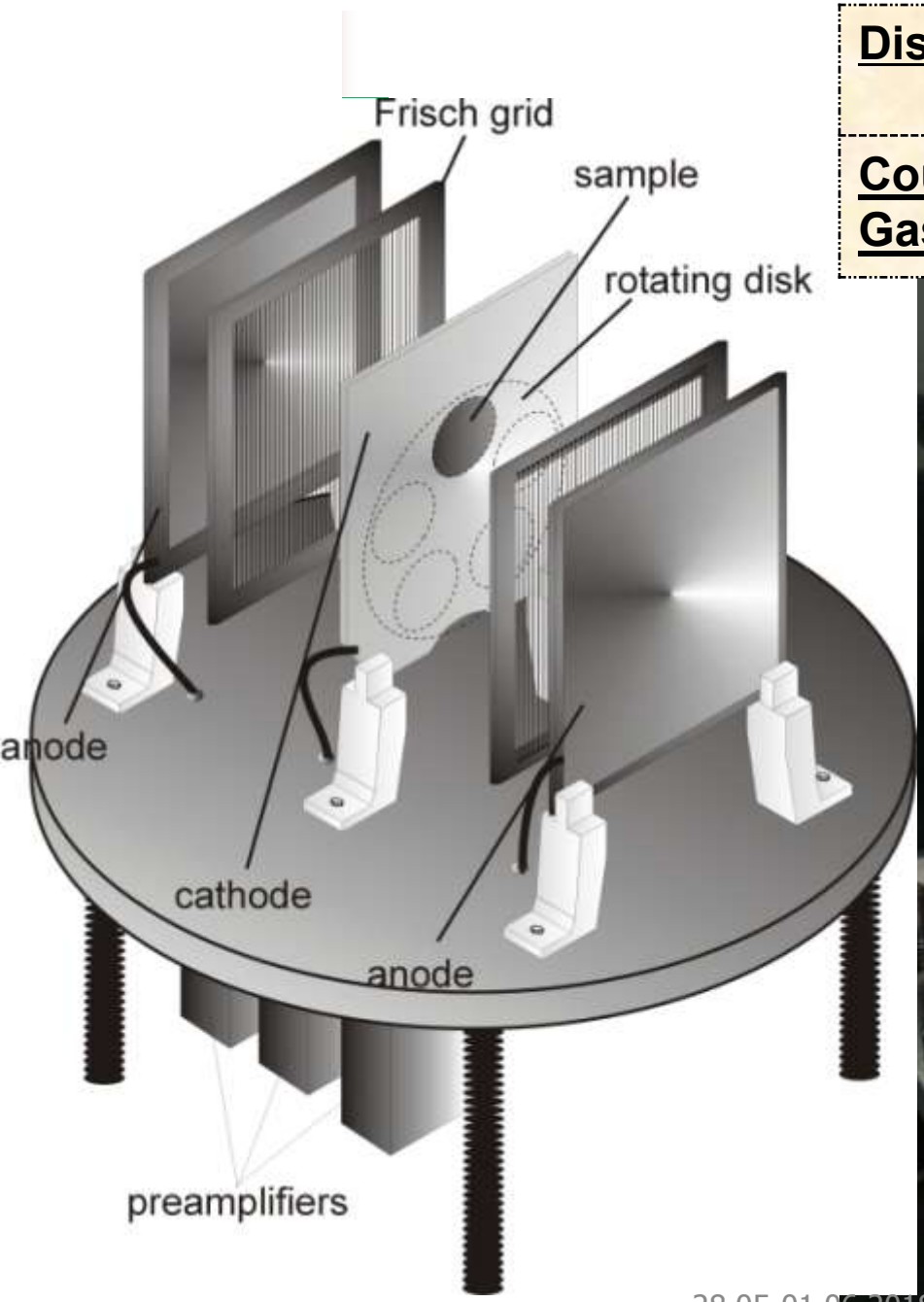


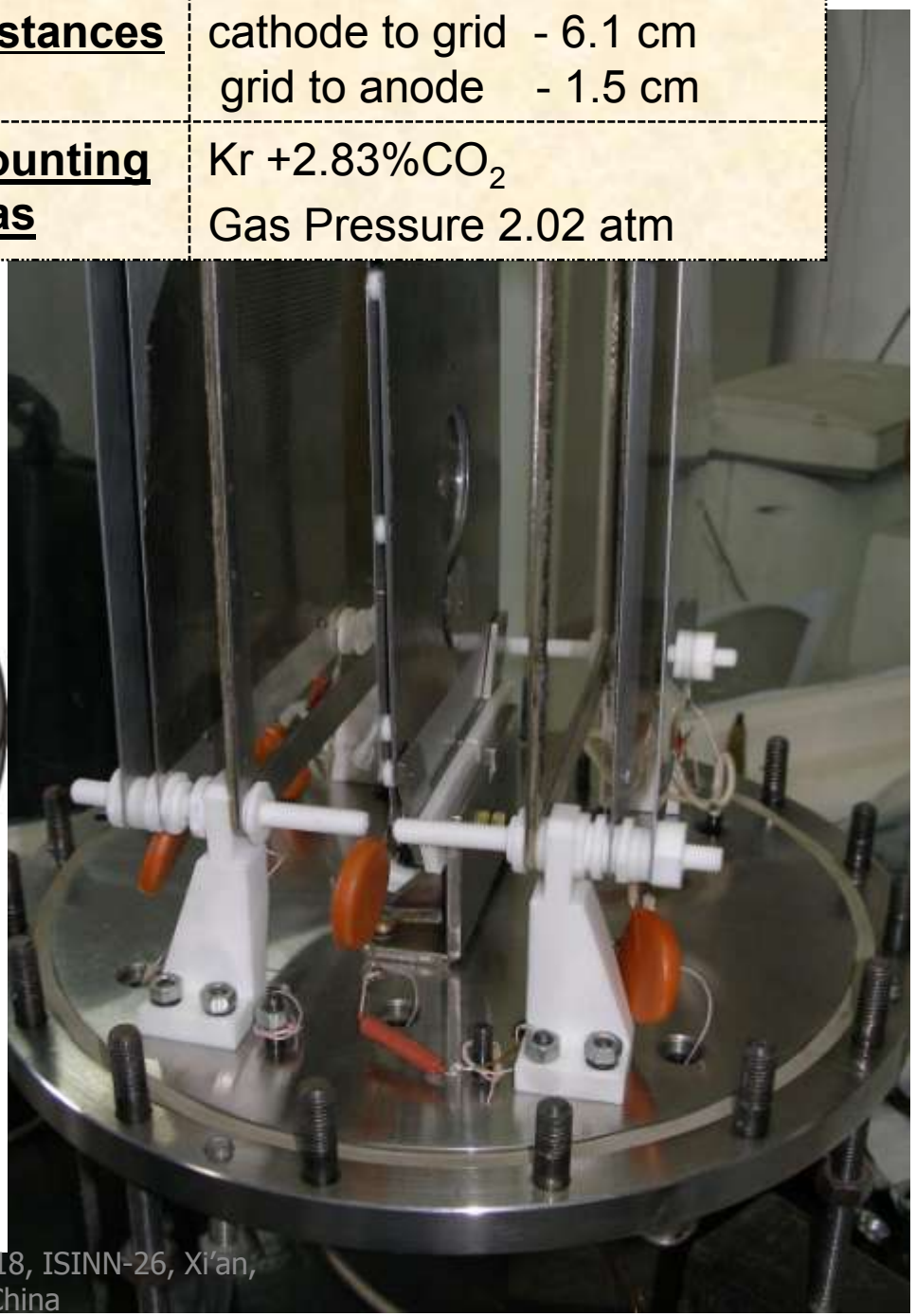
Van de Graaff accelerator EG-4.5 in IHIP PU, Beijing, China;

$D(d,n)^3He$ I_d~2-3 μA

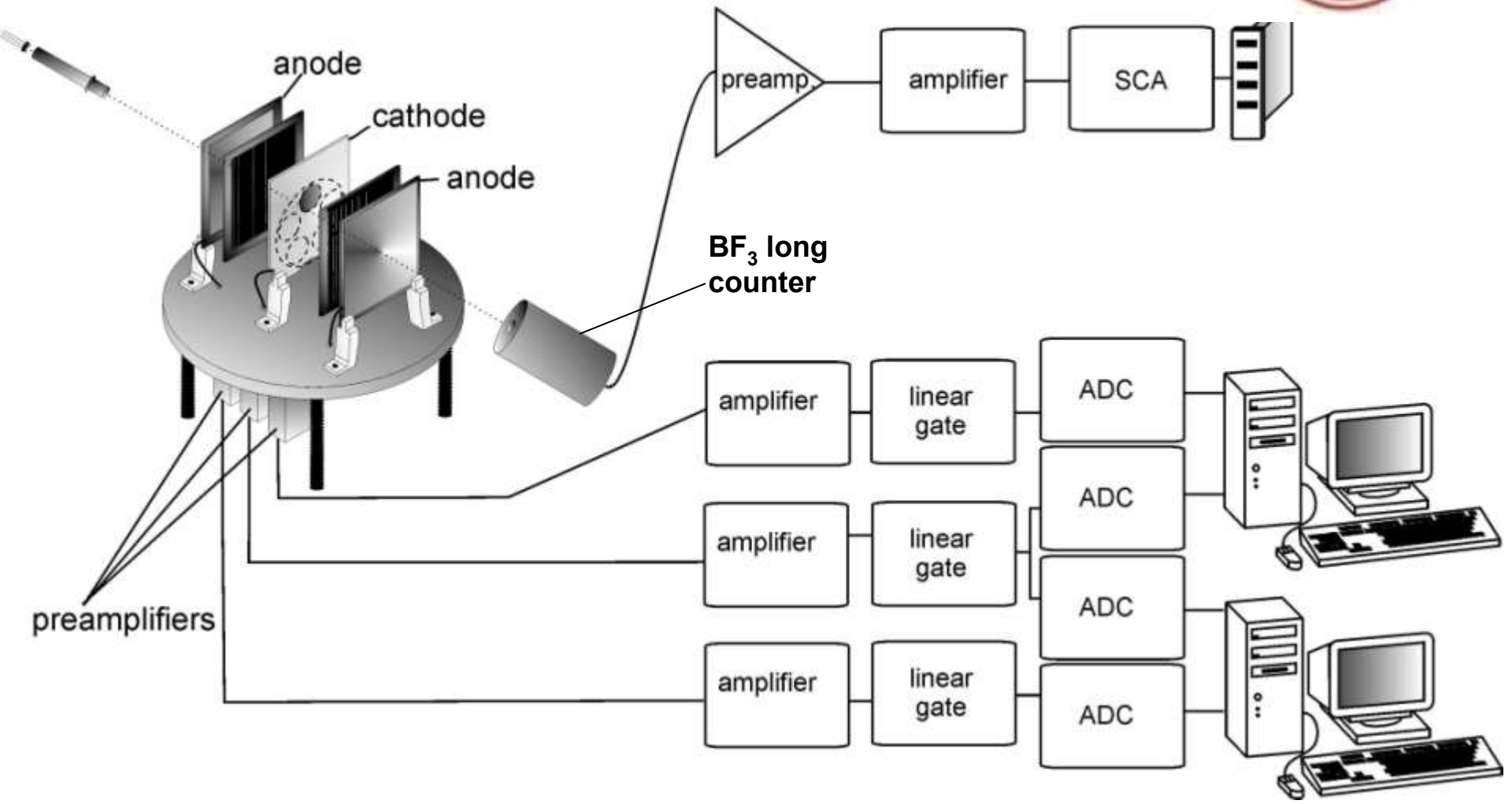
- gas D_2 – target, L=20 mm;
-Mo foil, d=6 μm;
-E_n=3-7 MeV;

Distances	cathode to grid - 6.1 cm grid to anode - 1.5 cm
Counting Gas	Kr +2.83%CO_2 Gas Pressure 2.02 atm





Block scheme



Description of the samples

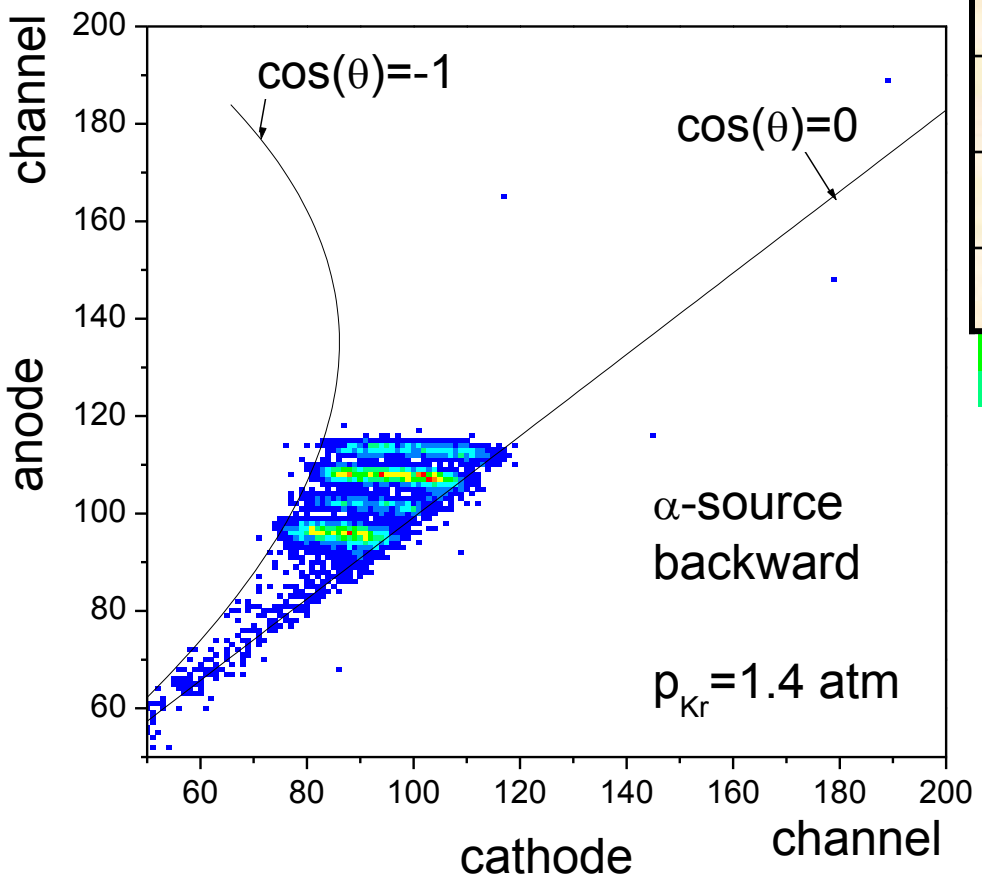
Samples	Material	Isotopic abundance (%)	Thickness ($\mu g/cm^2$)	Diameter (mm)
^{144}Sm	$^{144}Sm_2O_3$	95.0	4240[a] and 2830[b]	44.0[a,b]
^{238}U	$^{238}U_3O_8$	99.999	493.6(^{238}U only)	45.0

[a]Forward sample. [b] Backward sample.

Measurements

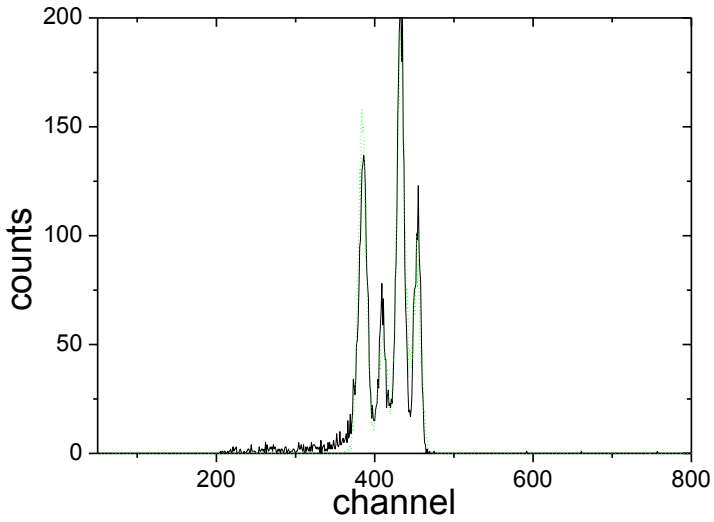
1) compound α source for energy calibration;
2) foreground for α events of the $^{144}Sm(n, \alpha)^{141}Nd$ reaction;
3) background with tantalum foils;
4) ^{238}U fission events for absolute neutron flux calibration;
5) α source for energy calibration again

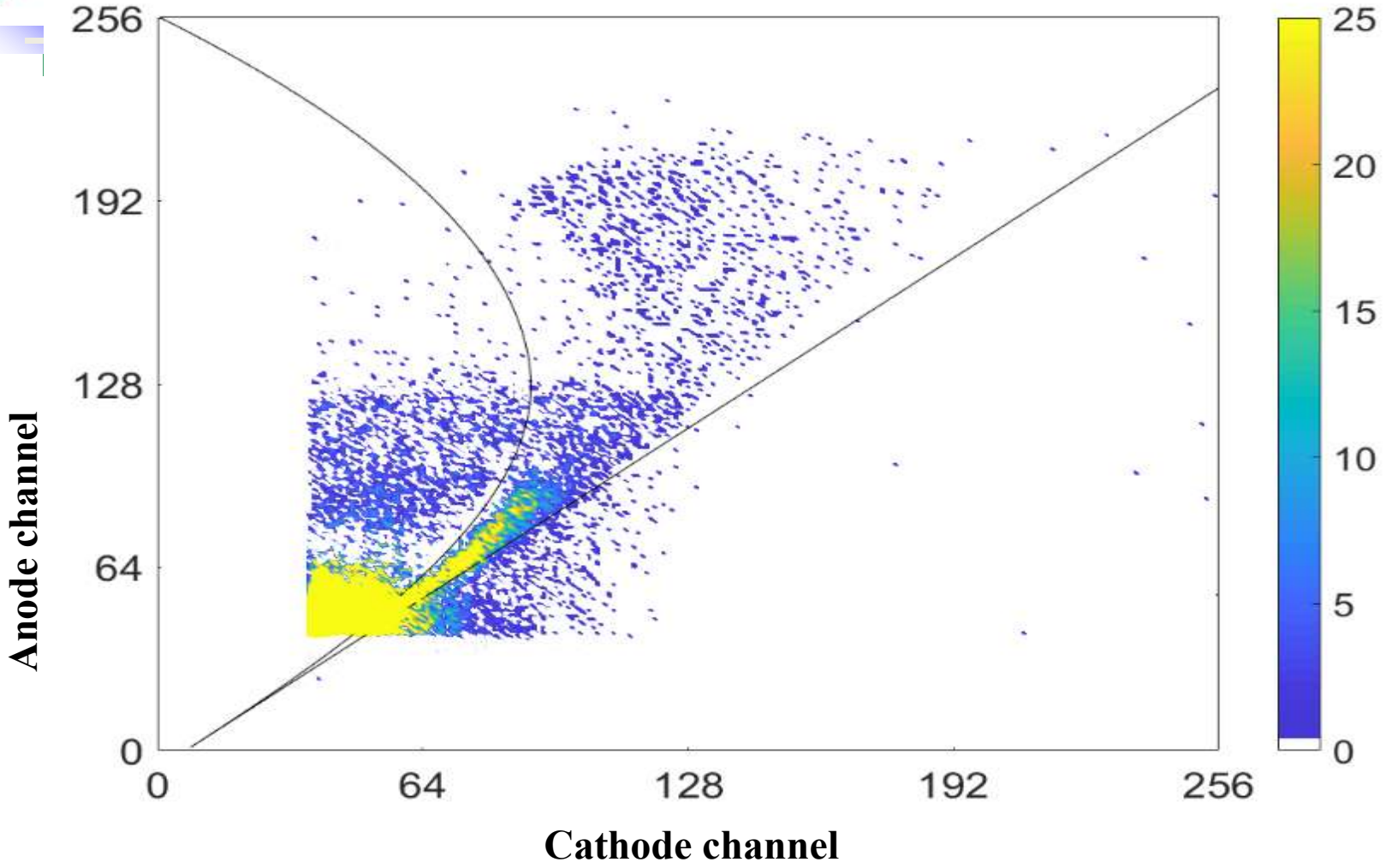
Calibration α-source



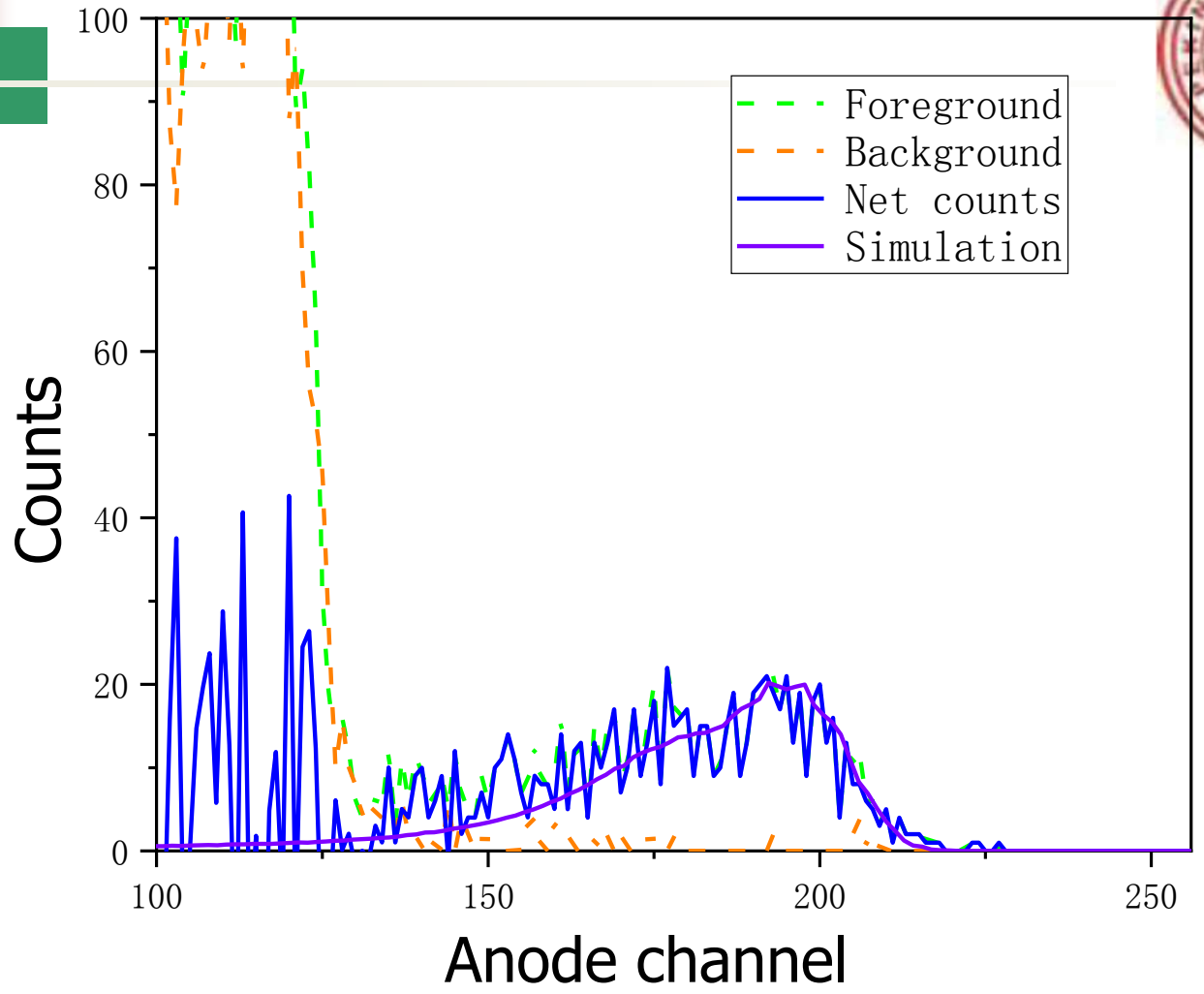
^{234}U	^{238}Pu	^{239}Pu	^{244}Cm
Energies for calibration (MeV)			
α_1	α_2	α_3	α_4
4.775	5.155	5.499	5.805

25.00

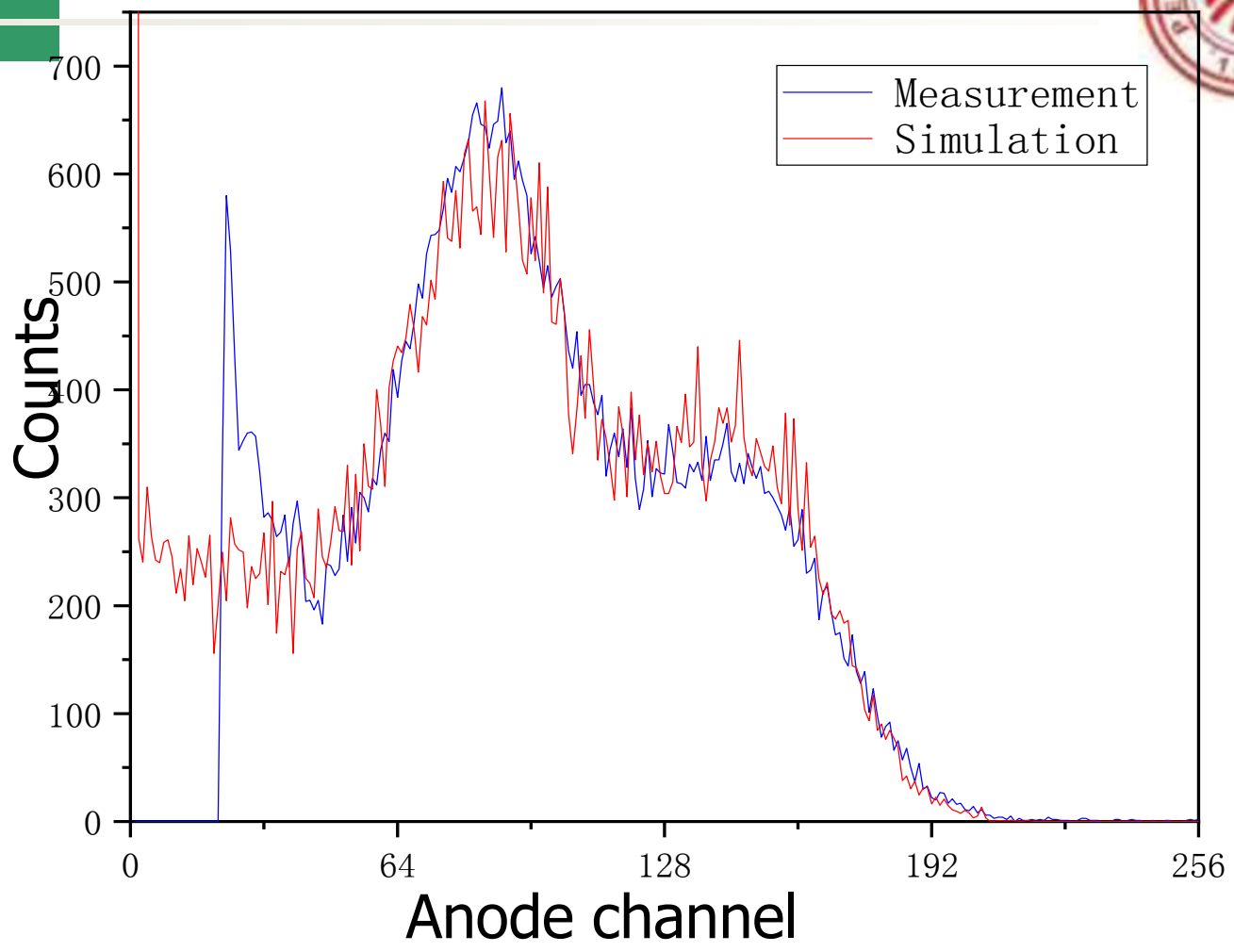




Two-dimensional spectrum of the $^{144}Sm(n, \alpha)^{141}Nd$ reaction at En = 5.5 MeV in the forward direction

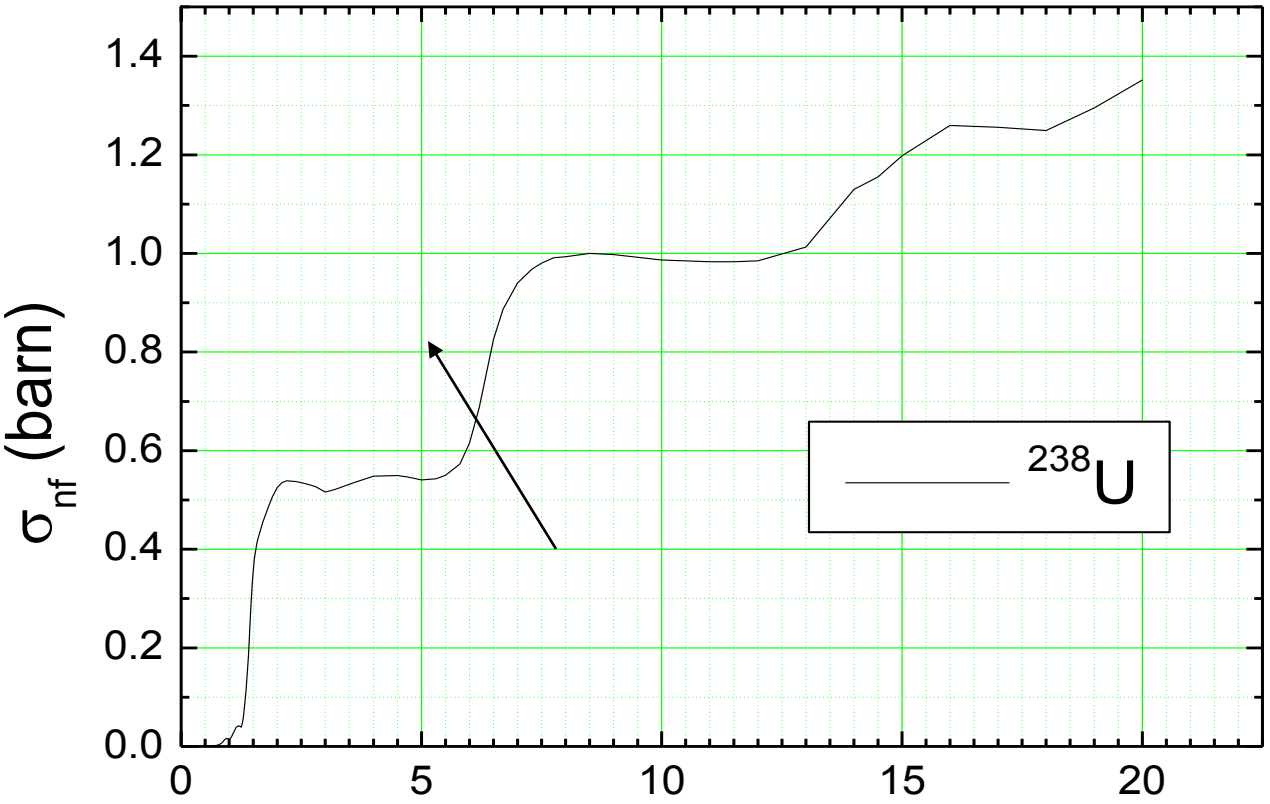


Anode spectrum of the 144Sm(n, α)141Nd reaction at En = 5.5 MeV for the forward direction



Anode spectrum of the 238U fission fragments at En = 5.5 MeV

^{238}U fission cross section ENDF library



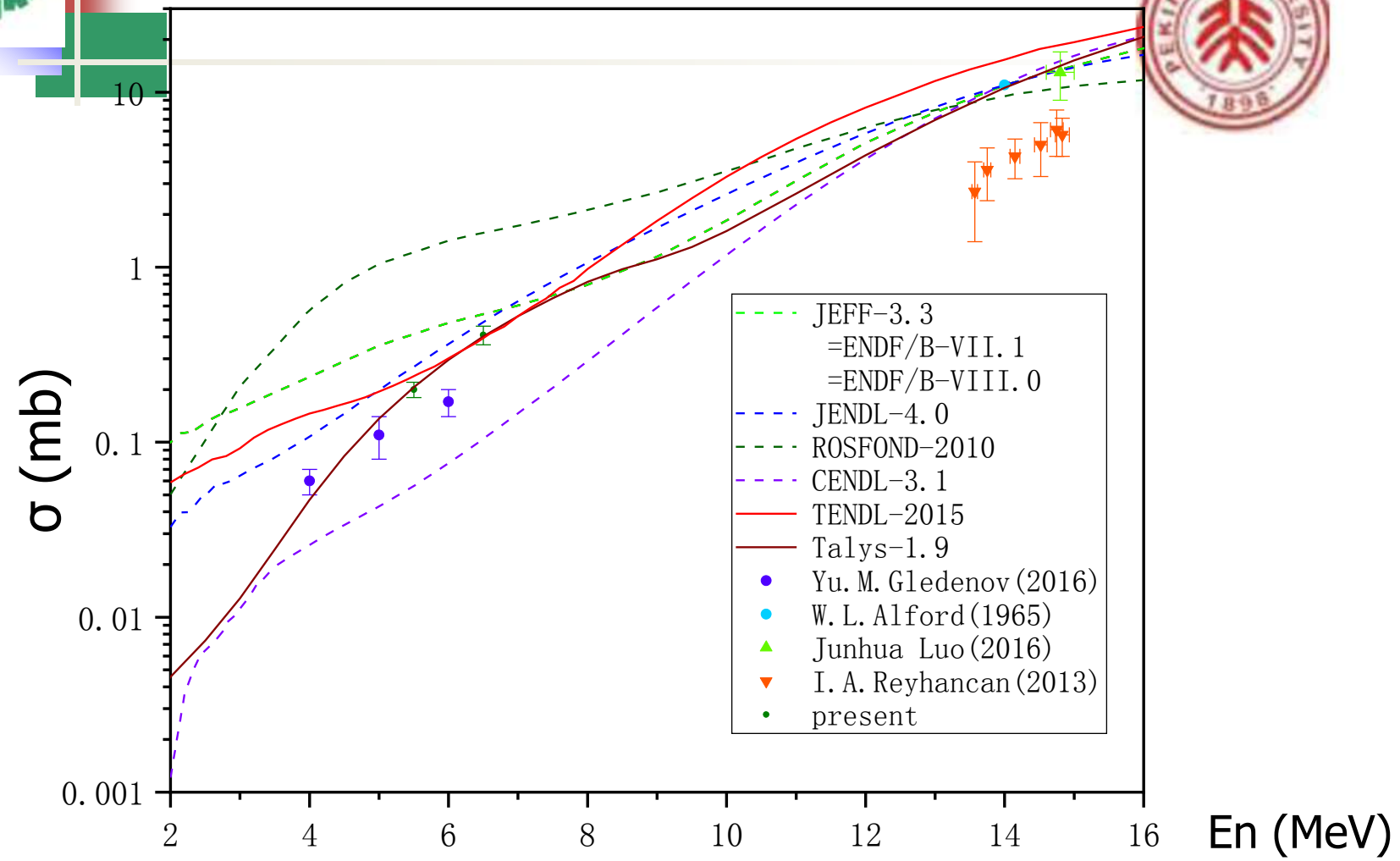
The cross section σ can be calculated by the following equation:

$$\sigma = \frac{k \cdot N_{\alpha}}{D}$$

N_{α} - the detected count of the alpha events,
D - the correction factor,
K - count-to-cross section factor

$$k = \frac{\sigma_f \ N_{^{238}U} N_{BF_3-f}}{N_f \ N_{samp} \ N_{BF_3-\alpha}}$$

σ_f - the standard ^{238}U(n,f) cross sections,
N_f - the number of fission events from the ^{238}U(n,f) reaction,
N_{238U} and N_{samp} - the numbers of ^{238}U and ^{144}Sm atoms in the samples,
$N_{BF3\text{-}f}$ and $N_{BF3\text{-}\alpha}$ - counts of neutron flux monitor of BF_3 counter for (n,α) events
^{238}U fission measurement



Present cross sections of the ^{144}Sm(n, α)^{141}Nd reaction compared with existing measurements, evaluations and Talys-1.9 calculations

Measured $^{144}Sm(n, \alpha)^{141}Nd$ cross sections

E_n(MeV)	$\sigma_{(n, \alpha)}$ (mb)	
	Measurement	Calculation
5.5	0.20±0.02	0.21
6.5	0.41±0.05	0.40

Forward/Backward Ratio
$^{144}Sm(n,\alpha)^{141}Nd$

Isotope	E_n (MeV)	F/B Ratio, exp	F/B Ratio, theor
144Sm	5.5	2.04±0.35	1.02
	6.5	2.70±0.62	1.02
147Sm	5.0	1.65±0.23	1.46
	6.0	2.49±0.32	1.68
149Sm	4.5	1.4±0.35	1.39
	5.0	1.6±0.4	1.51
	5.5	1.9±0.5	1.62
	6.0	2.2±0.6	1.72
	6.5	2.7±0.7	1.81

Conclusion

- Cross sections of the 144Sm(n, α)141Nd reaction were measured at 5.5 and 6.5 MeV
- There are very large differences between different evaluations
- Our results are closer to the data of TENDL-2015 library
- Theoretical analyses using Talys-1.9 code was performed, and agreement was achieved between present measurements and calculations
- Experimental Forward/backward ratios disagree with Talys-1.9 and agree with Talys-1.1 code calculation
- Further measurements are needed

THANK YOU FOR ATTENTION

Pulse-height spectrum from the $^{147}Sm(n,\alpha)$ measurement obtained for the neutron energy E_n~184 eV.