$^{57}Fe(n,\alpha)^{54}Cr$ and $^{63}Cu(n,\alpha)^{60}Co$ **cross sections in the MeV region**

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Outline

- Introduction
- Measurements
- Results

I. Introduction

JINR-PKU Protocol

北京大学
PEKING UNIVERSITY

Memorandum between
the Joint Institute for Nuclear Research and Peking University

Protocol

of the collaboration on carrying out joint studies on the mechanism of interaction of neutrons with nuclei and on the properties of high excited nuclear states between the Joint Institute for Nuclear Research, Dubna, Russia and Peking University, Beijing, China.

As of 15.03.2005

The collaboration between the two institutions has been fruitful and successful, and the period of validity of the Protocol is extended once for four years until December 31, 2012. At present, both sides would like to continue the collaboration and to extend the period of validity of the above Protocol for another four years until December 31, 2016.

Director of the Joint Institute for Nuclear Research

Prof. V.A. Matveev

Dec. 20, 2012

President of Peking University

Prof. ZHOU Qifeng

Nov. 22, 2012

Results of cooperation

- (n,α) reactions measured:

Light — Medium — Heavy

^{6}Li ^{10}B ^{35}Cl ^{40}Ca ^{54,57}Fe ^{58}Ni ^{63}Cu ^{64,66,67}Zn ^{95}Mo ^{143}Nd ^{144,147,149}Sm

triton production

Reactor control

Structural materials
Fast reactor, Fusion reactor, ADS

Fission products

Nuclear energy

Nuclear physics nuclear astrophysics

- Combined with theoretical calculations, systematic results are obtained.

$^{57}Fe(n,\alpha)^{54}Cr$

- No measurement data exist
- Data exist in all evaluated data libraries with significant discrepancies
- ^{57}Fe abundance in natural iron: 2.119%
- Cross section is small, and in MeV region increase rapidly
- ^{54}Cr stable, so activation method unavailable
- ^{54}Cr separate levels:

0, 0^+; 834.855, 2^+; 1823.93, 4^+ ; 2619.68 2^+;…keV

$^{63}Cu(n,\alpha)^{60}Co$

- 19 measurement data, in 40^{+} years
- In MeV region mainly two measurements, with discrepancy
- ^{63}Cu abundance in natural copper: 63.17%
- Cross section is small, and in MeV region increase rapidly
- ^{60}Co is radioactive, activation method available
- ^{60}Co levels are dense:

  0, 5^{+}; 58.59, 2^{+}; 277.2, 4^{+}; 288.4,3^{+}; 435.7, 5^{+}… keV

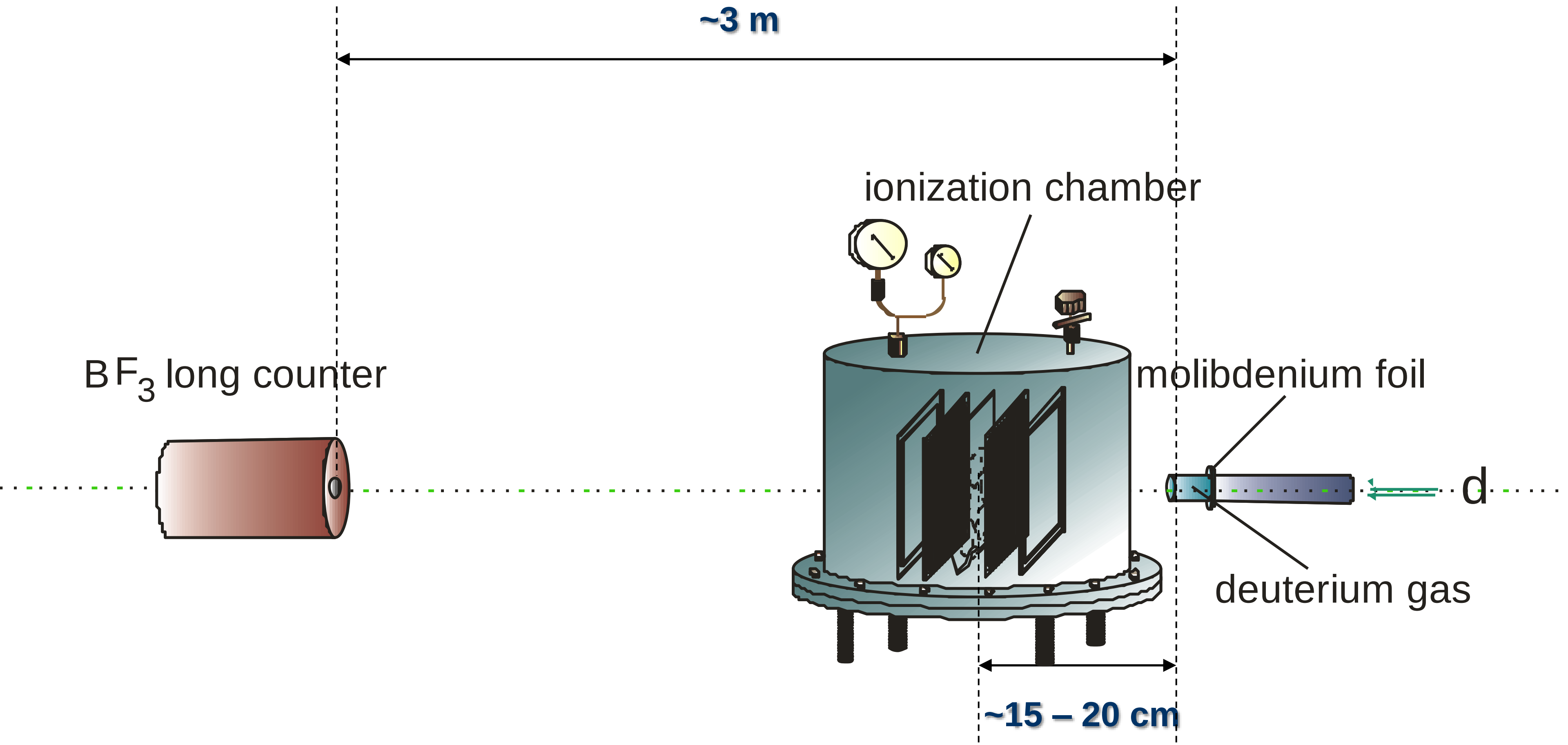
^{57}Fe & ^{63}Cu(n,α) comparison

	^{57}Fe(n,α)	^{63}Cu(n,α)
Exp. data	No data	19 measurements
Activation method	unavailable	available
Natural abundance	2.119%	63.17%
obtained results	(n,α)(n,α_0)(n,α_1)	only (n,α)

II. Measurements.

4.5 MV Van de Graaff Accelerator
Institute of Heavy Ion Physics in Peking University

Setup of experiment



3 parts:

③	②	①
flux measurement	**particle detector**	**neutron source**
BF_3 + $^{238}U(n,f)$	GIC	d-d

Neutron source

- 4.5 MV VDG @PKU
- D-d reaction
- Deuterium gas target (3.0atm, 2.0cm)
- d beam ~ 3 μA
- E_n=5.0±0.16, 5.5±0.14, 6.0± 0.12, 6.5±0.10 MeV

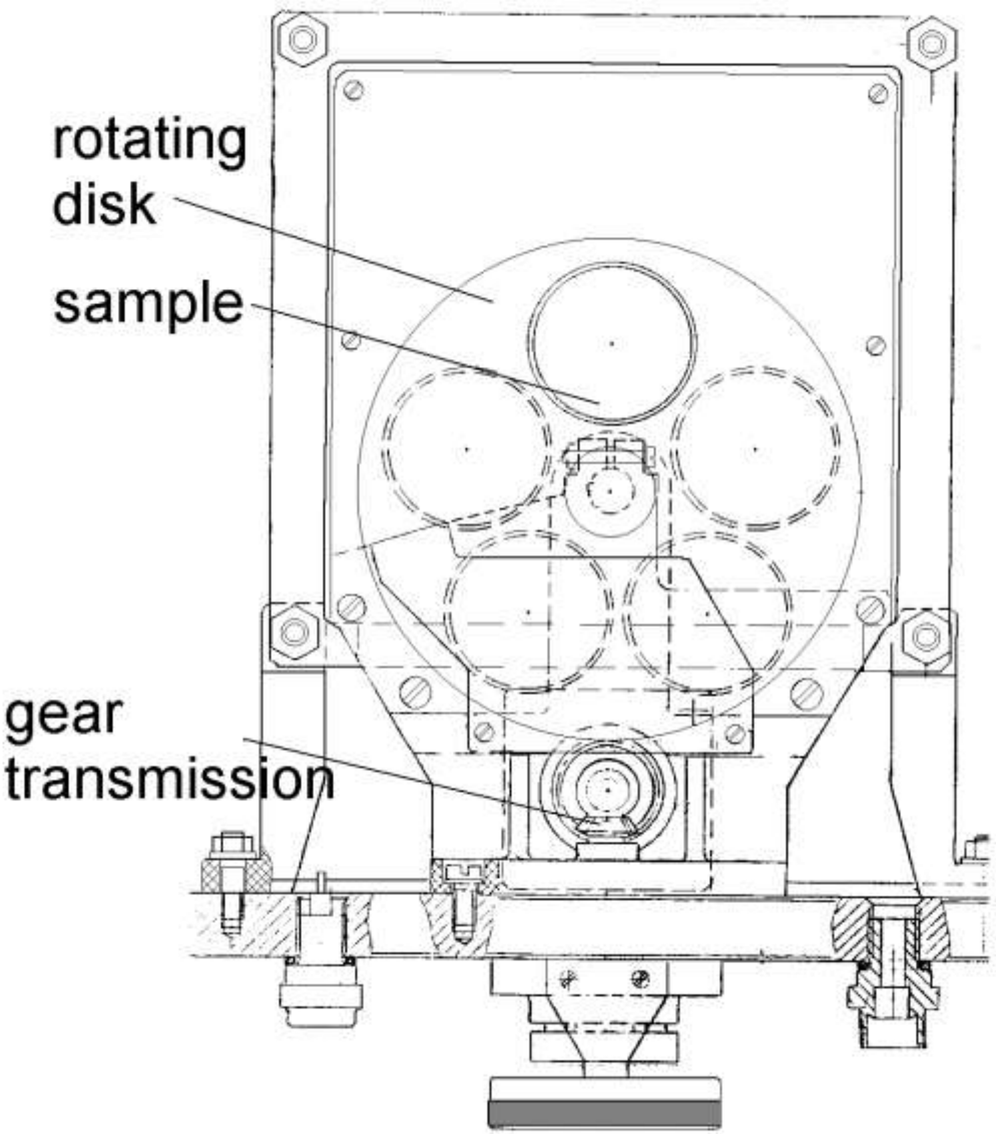
GIC

- Twin GIC

  back to back: ~4π
- 5 back-to-back sample positions
- Working gas: Kr+2.82%CO_2, 1 atm
- distances:

  cathode-grid 61.0 mm
  grid-anode 15.0 mm
  anode-shield 9.0 mm
- Va=+750, Vg=0, Vc=-1500 V

Sample changer

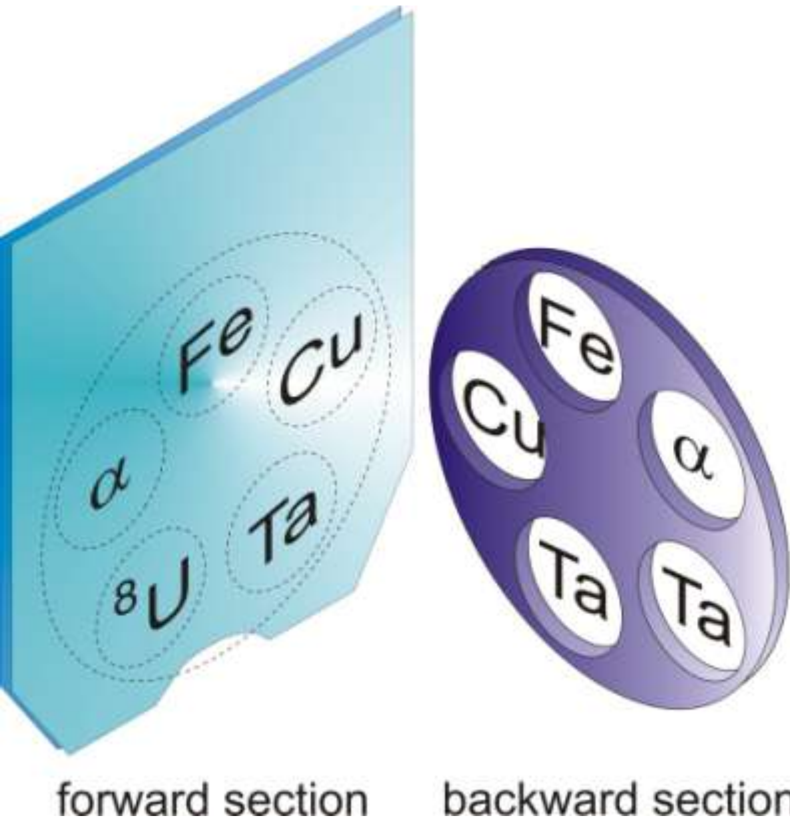


Samples

^{63}Cu

^{57}Fe

Sample positions



^{57}Fe: Event ~10h, background ~6h, flux ~4-6h.   20h for each energy point

^{63}Cu: Event 10--20h

Sample position	Forward direction	Backward direction	Utility
I	^{57}Fe sample #2	^{57}Fe sample #1	②Foreground measurement
II	^{63}Cu sample #2	^{63}Cu sample #1	③Foreground measurement
III	Ta sheet	Ta sheet	④Background measurement
IV	^{238}U	Ta sheet	⑤Neutron flux calibration
V	compound α source	compound α source	① Electronics adjustment and energy calibration

Sample data

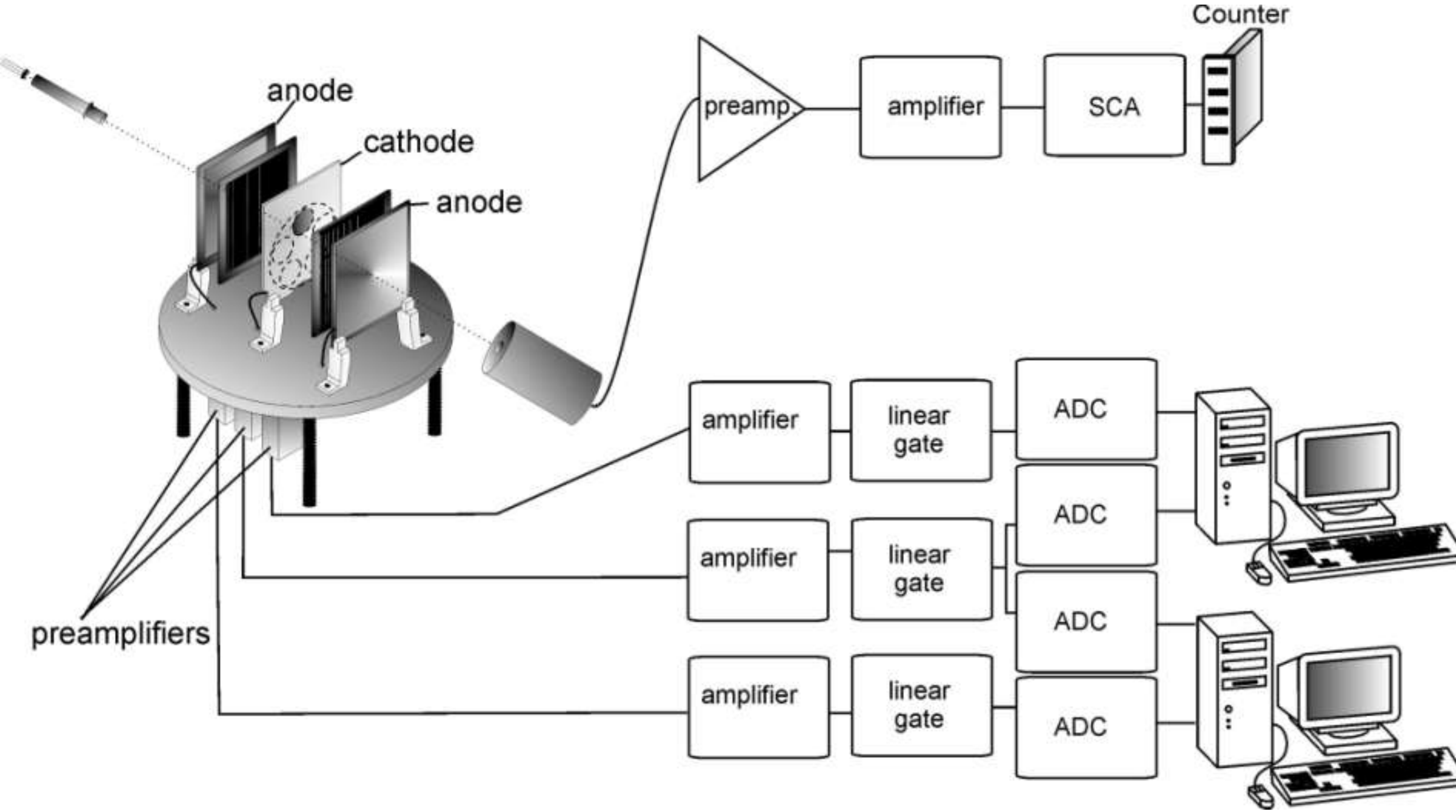
	^{57}Fe Samples	^{63}Cu Samples	^{238}U Sample
Sample material	Enriched ^{57}Fe	Enriched ^{63}Cu	$^{238}U_3O_8$
Isotopic abundance	^{57}Fe 95.9%	^{63}Cu 99.8%	^{238}U 99.999%
Sample thickness	582.5[a] and 599.1[b] μg/cm^2	770[a] and 781[b] μg/cm^2	493.6 μg/cm^2 (^{238}U only)
Sample diameter	45.0[a] and 41.0[b] mm	48.0[a] and 43.5[b] mm	45.0 mm
Backing	Ta sheet	Ta sheet	Ta sheet

[a] forward sample, [b] backward sample

Sample preparation method: press

Russian material, China CIAE preparation

Electronics

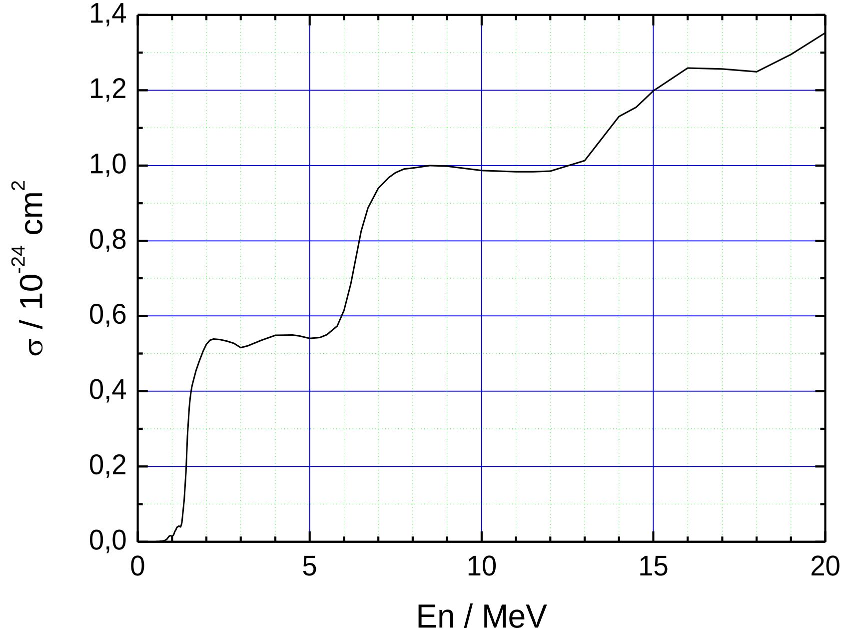


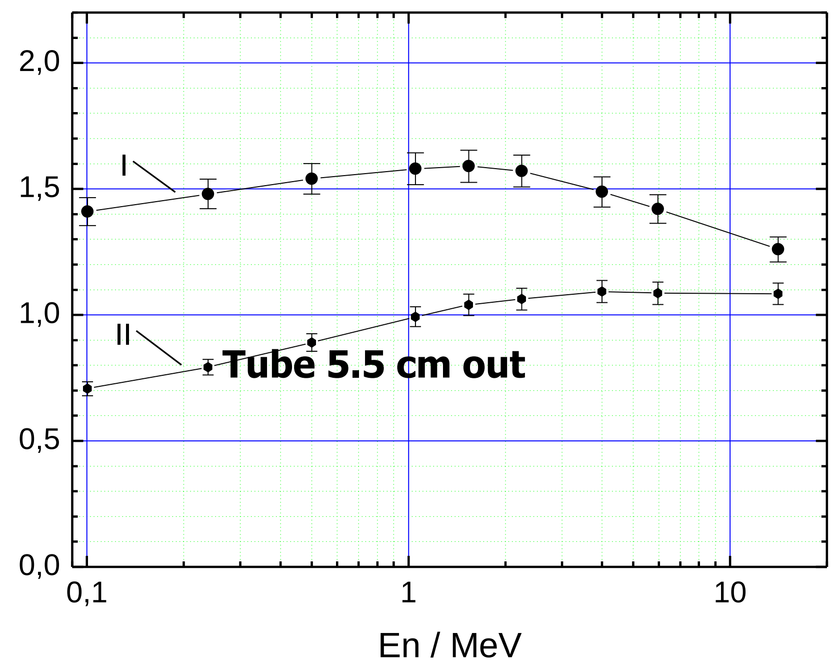
Block diagrams of the electronics.

Flux calibration

- ^{238}U fission & BF_3 long counter

ENDF/B-VII





^{238}U fission cross section as a function of the neutron energy.

Relative efficiency of the BF_3 long counter.

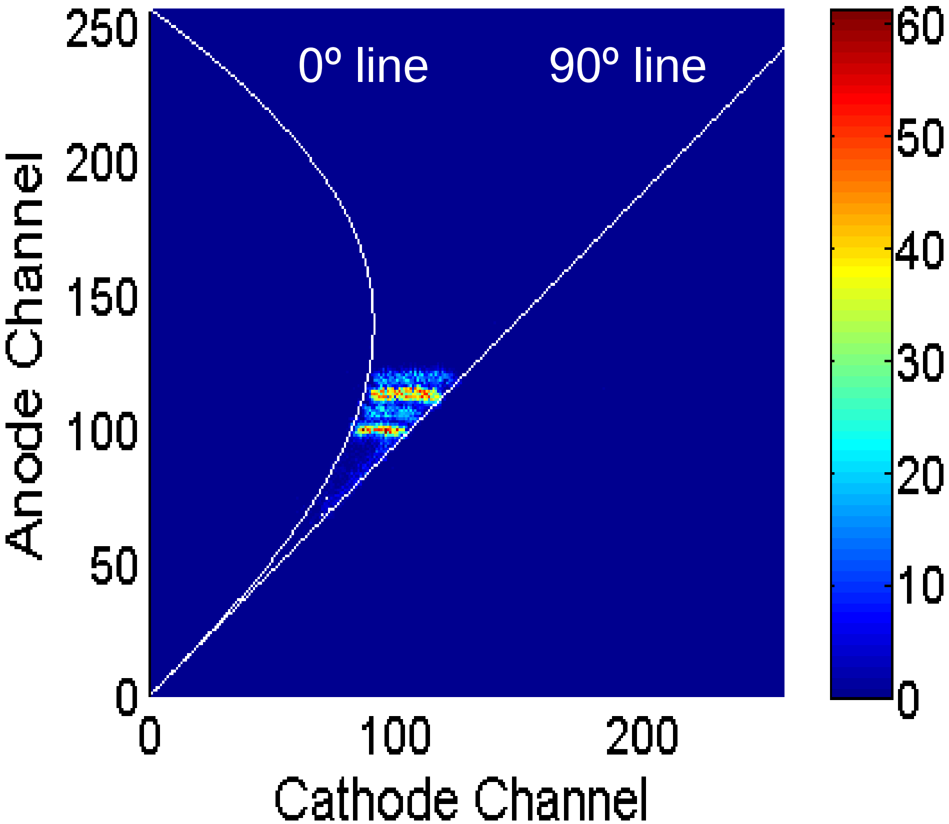
Data Processing

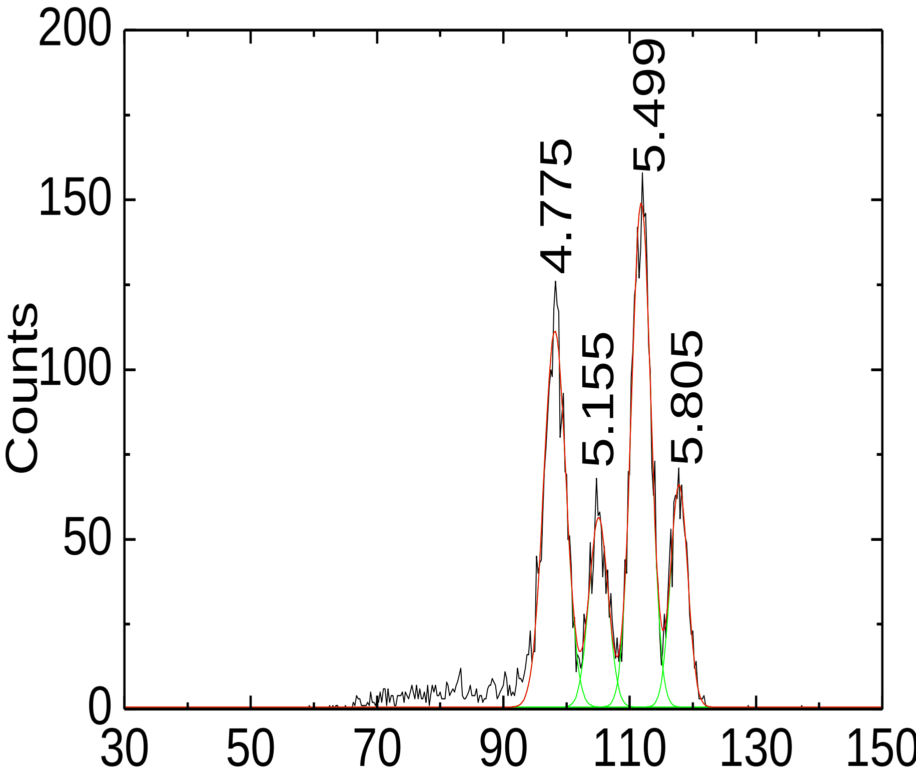
- Energy calibration
- 0/180°, 90° line determination
- Background subtraction (E loss correction)
- Spectrum projection
- Counts determination
- Flux determination
- Theoretical and Monte Carlo calculations
- Self absorption and threshold loss correction (fission & alpha counts)
- Correction for alpha loss from higher excited states (R)

III. Results

Energy calibration

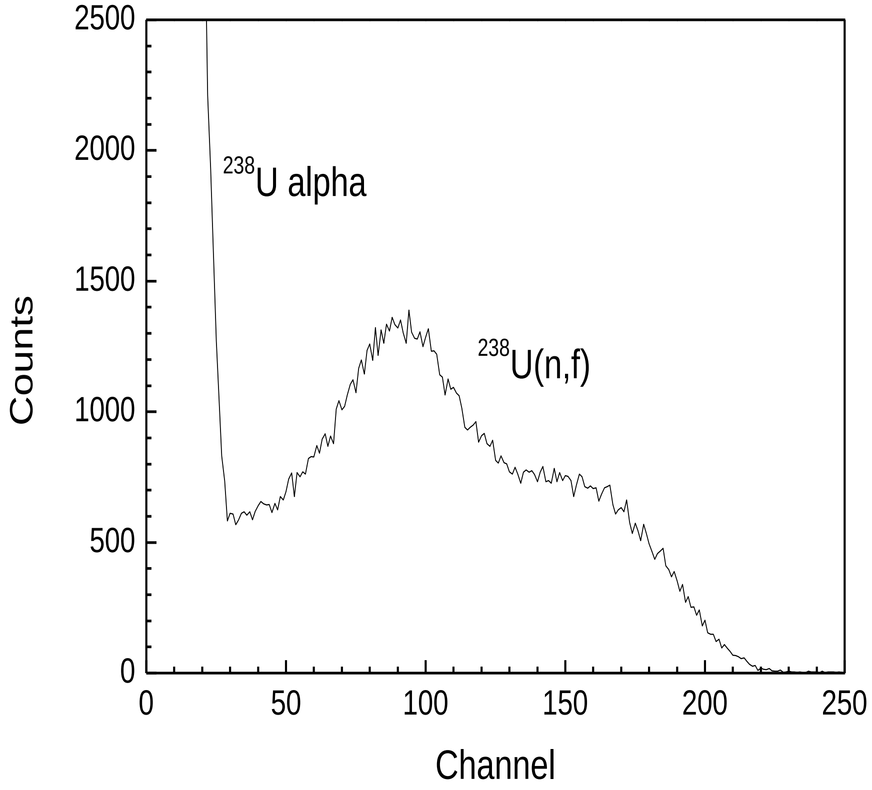
0/180º , 90º line determination





Spectrum of alpha sources.

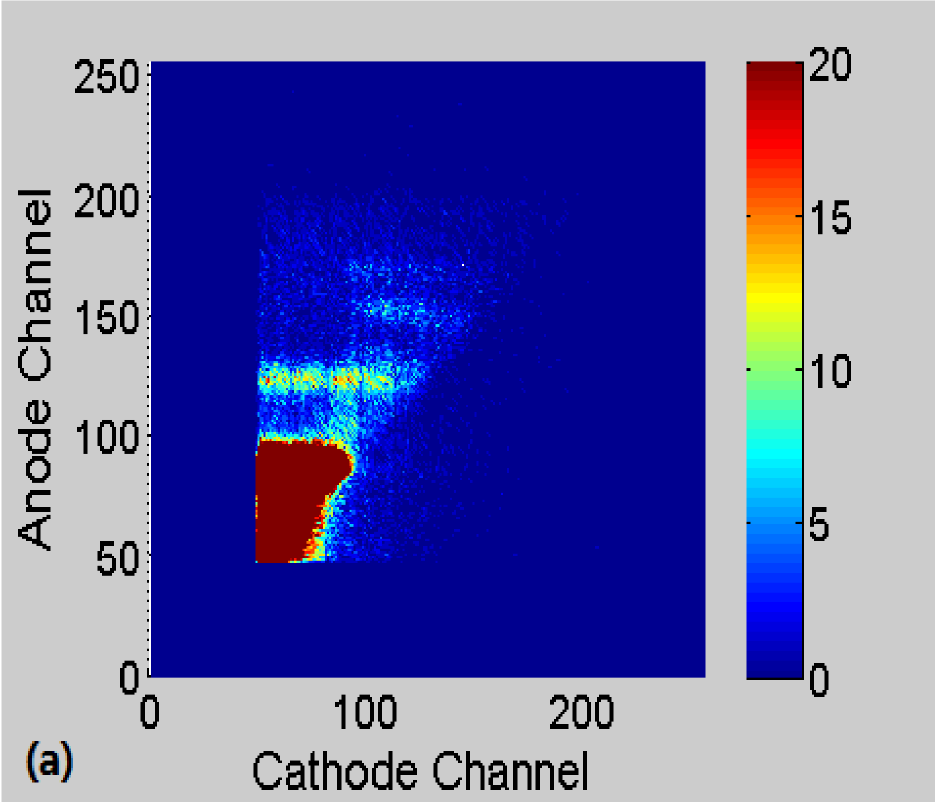
Flux determination

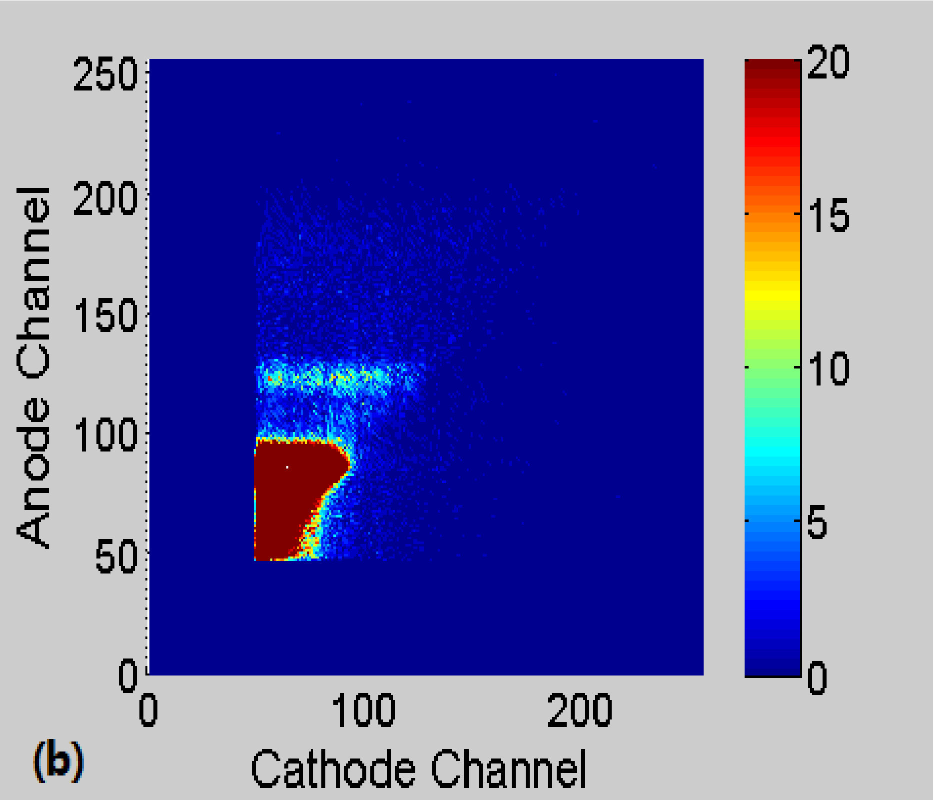


^{238}U Fission spectrum at E_n=6.5 MeV.

$^{57}Fe(n,\alpha)^{54}Cr$

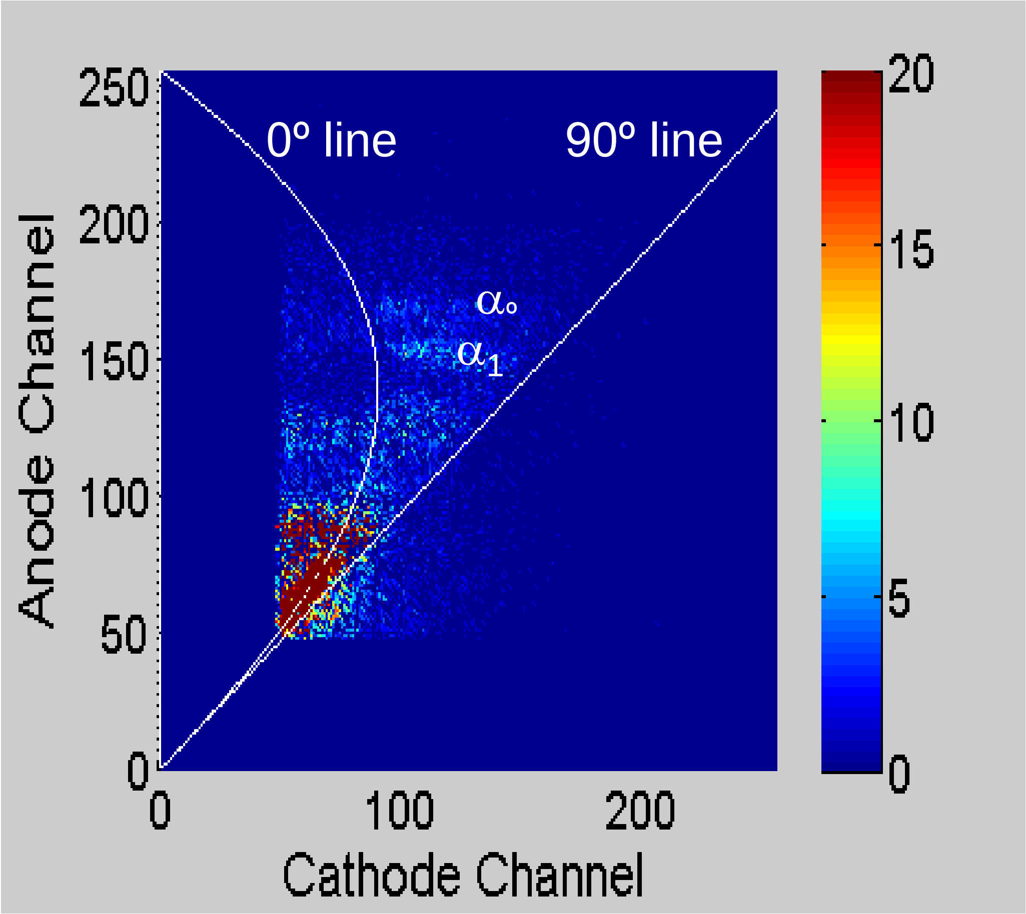
foreground **background**





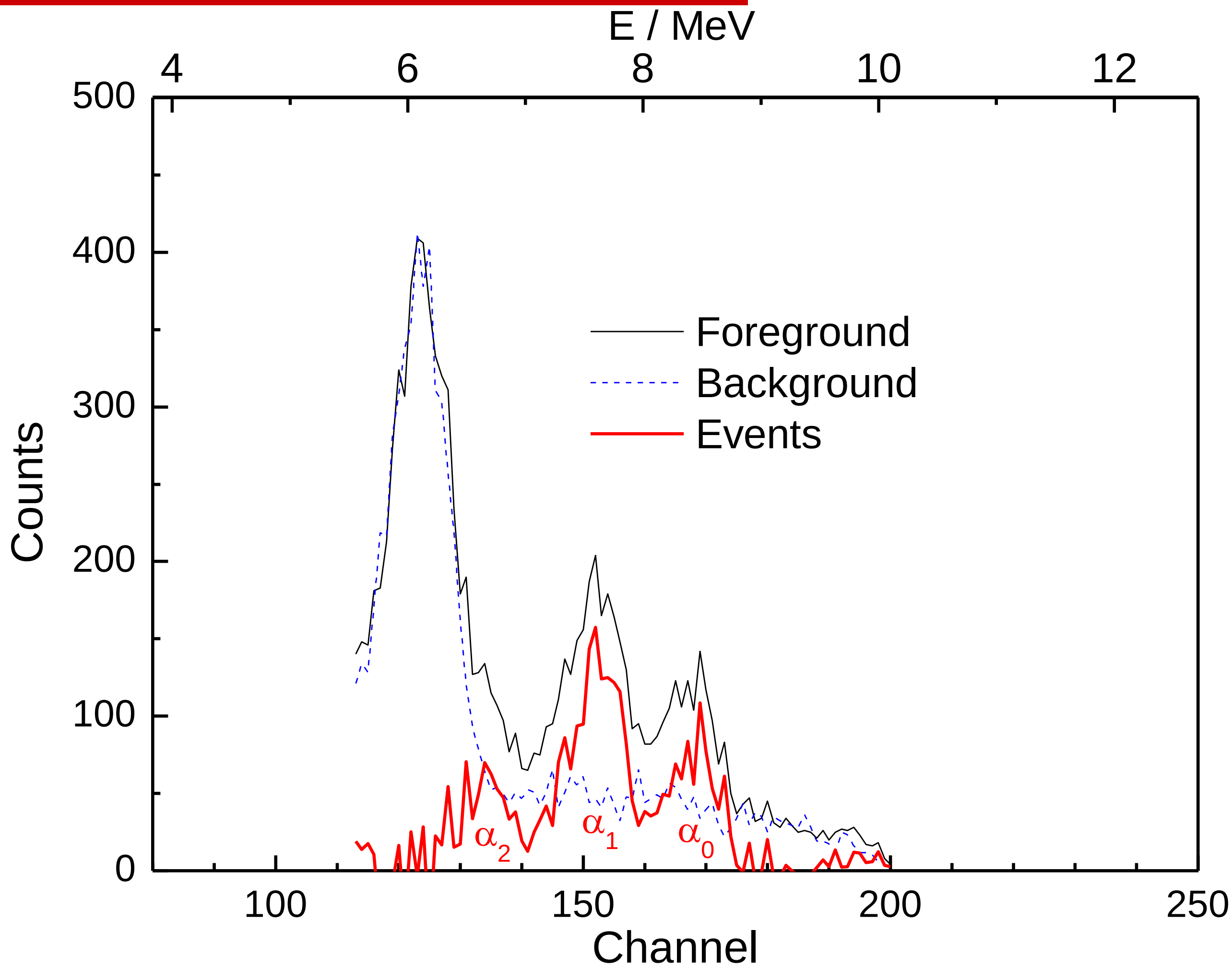
Cathode-anode two dimensional spectrum for the forward direction at E_n = 6.5 MeV.

$^{57}Fe(n,\alpha)^{54}Cr$



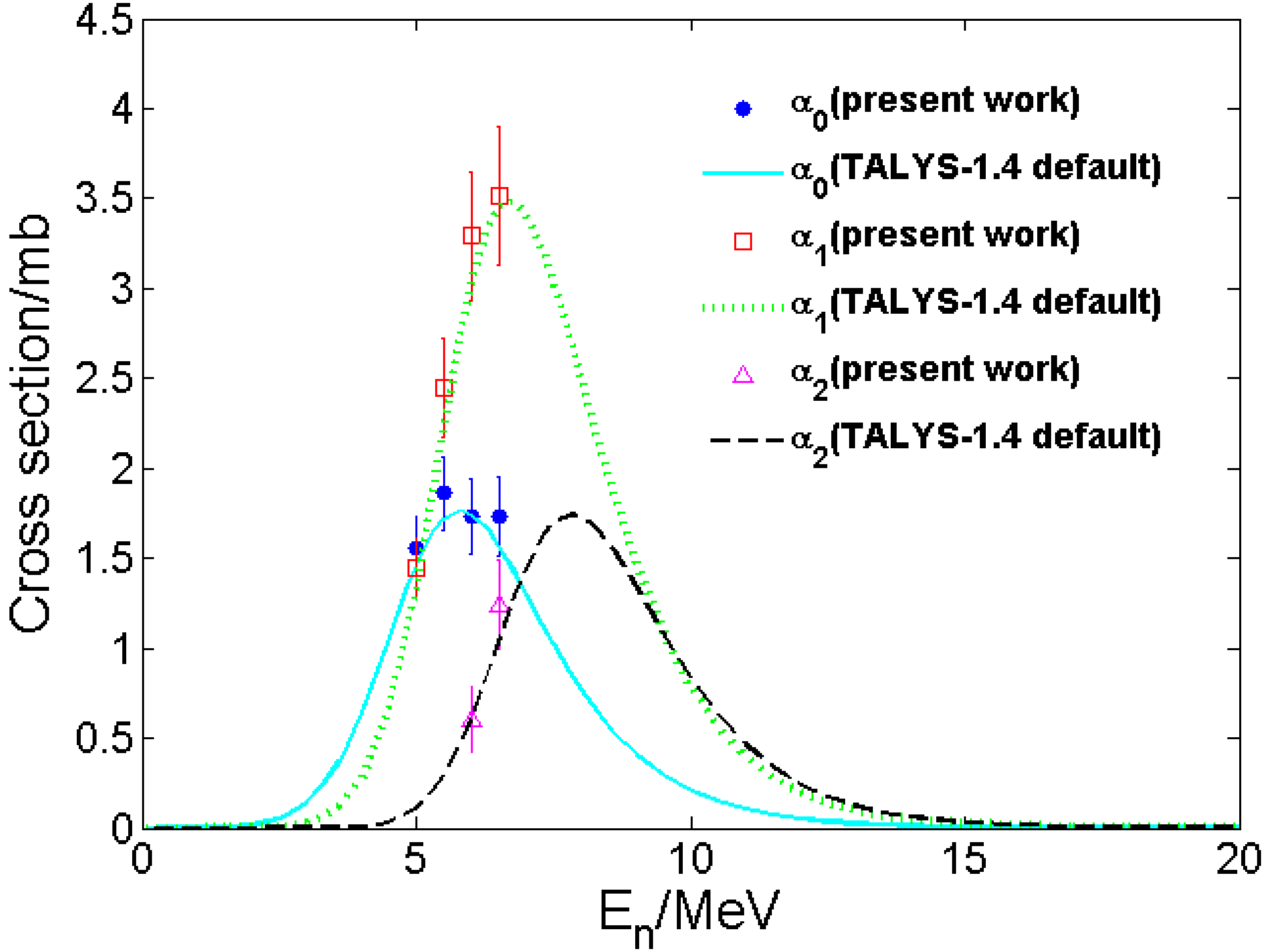
Two dimensional spectrum after background subtraction for the forward direction at E_n = 6.5 MeV.

$^{57}Fe(n,\alpha)^{54}Cr$



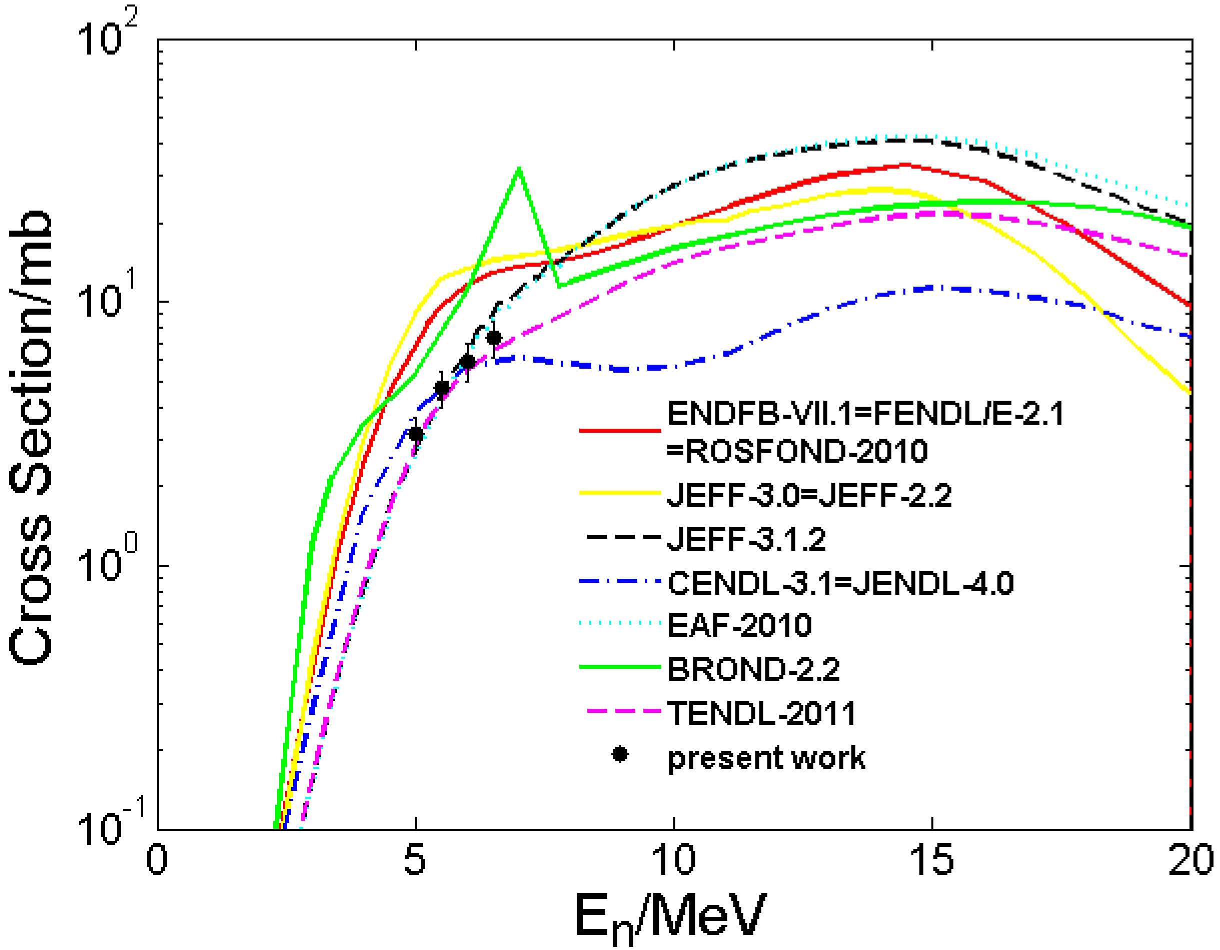
Anode spectrum for the forward direction at E_n = 6.5 MeV.

$^{57}Fe(n,\alpha_0),(n,\alpha_1),(n,\alpha_2)$



Present results compared with TALYS-1.4 calculations.

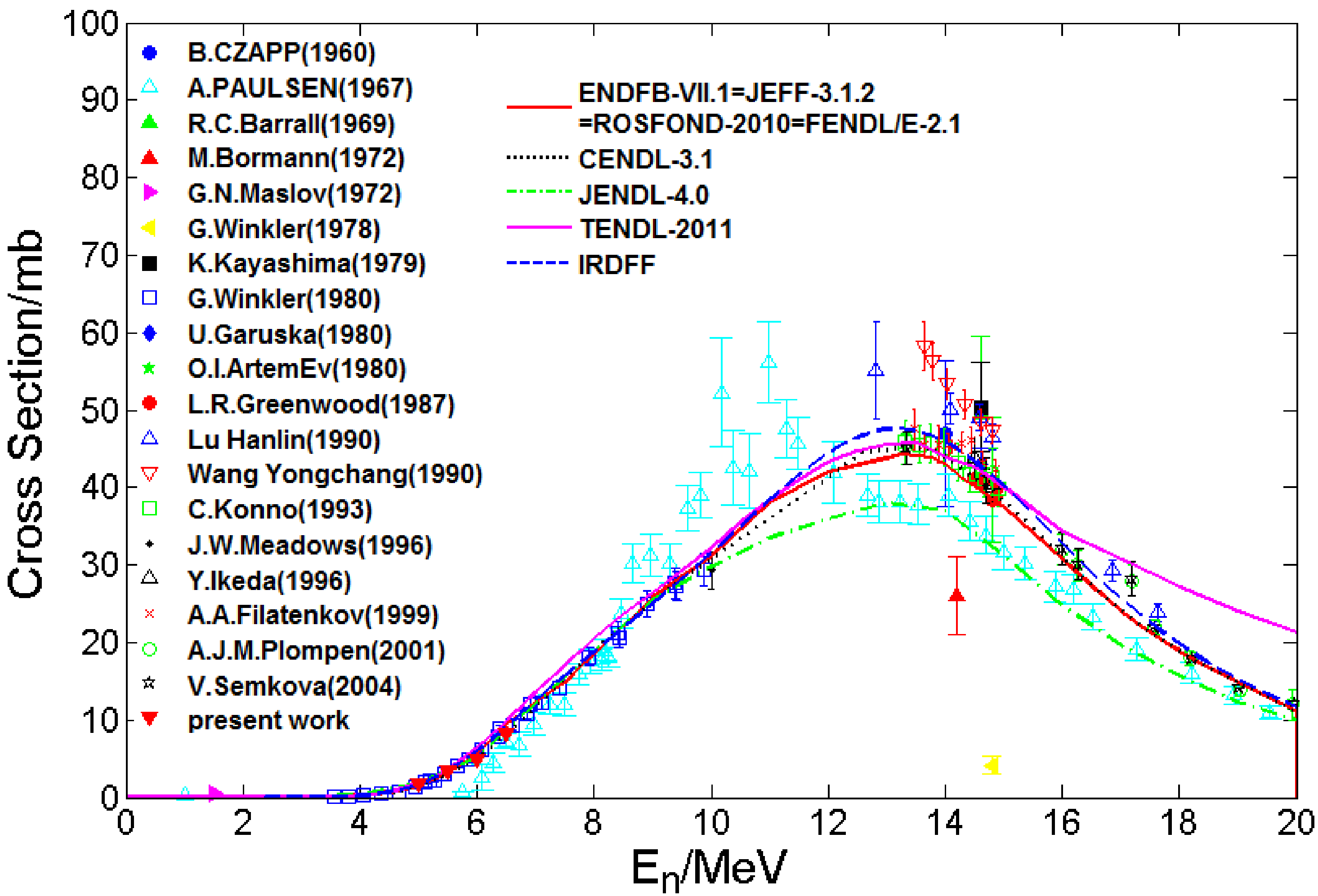
$^{57}Fe(n,\alpha)^{54}Cr$



E (MeV)	σ (mb)
5.0	3.1
5.5	4.7
6.0	5.8
6.5	7.2

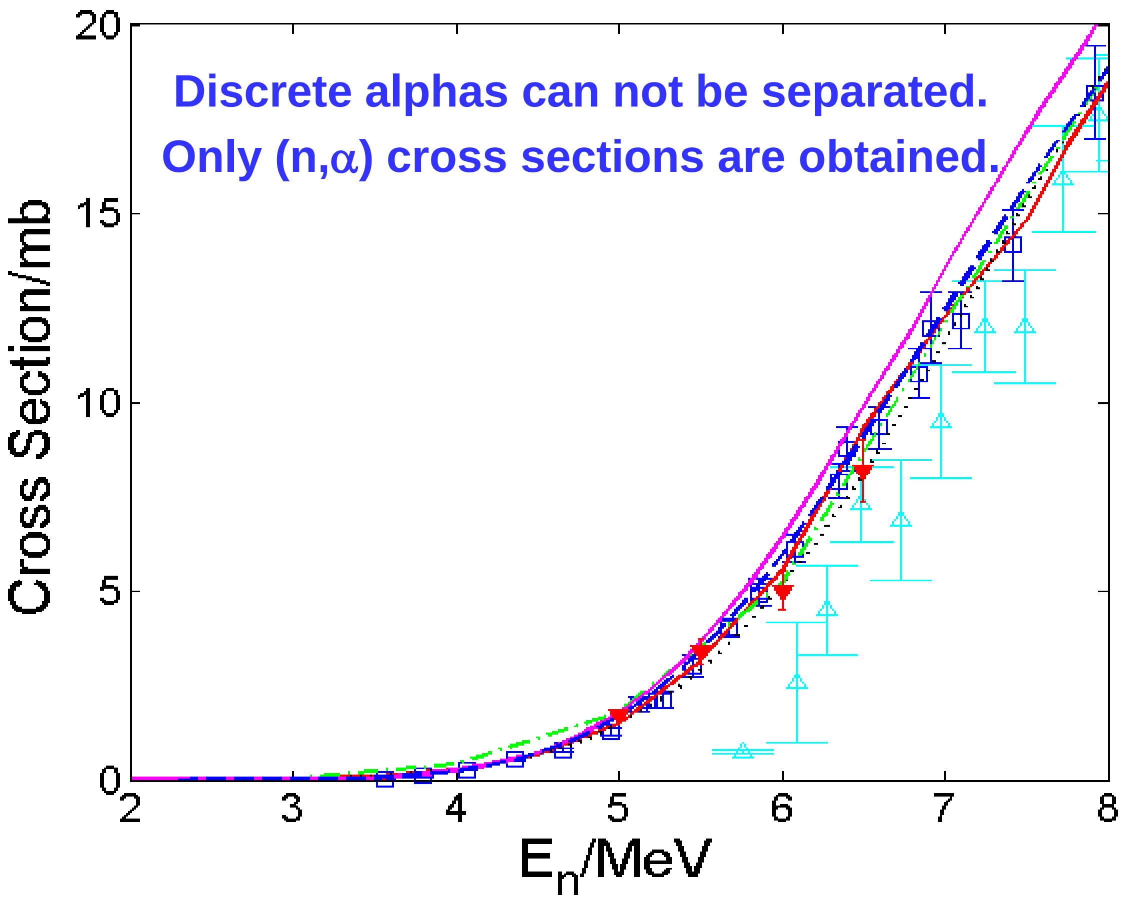
Present results compared with existing evaluations.

$^{63}Cu(n,\alpha)^{60}Co$



Present results compared with other measurements and evaluations.

$^{63}Cu(n,\alpha)^{60}Co$



E (MeV)	σ (mb)
5.0	1.7
5.5	3.4
6.0	5.0
6.5	8.2

Present results compared with other measurements and evaluations.

Summary

- $^{57}Fe/^{63}Cu$ samples are prepared
- $^{57}Fe(n,\alpha)$, (n,α_0), (n,α_1), (n,α_2) cross sections and $^{63}Cu(n,\alpha)$ cross sections are measured @4.5MV VDG PKU
- at E_n= 5.0, 5.5, 6.0, 6.5 MeV
- Data are compared with existing evaluations and TALYS-1.4 calculations
- Results are preliminary, further check, and measurements are needed

Thank you!