Abstract Submitted
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Investigation of "White" Neutron Sources for Efficiency Calibration[1] T. N. MASSEY, A. SALAS BACCI, N. BOUKHAROUBA, C. E. BRIENT, S. M. CALHOUN, S. M. GRIMES, D. JACOBS, J. E. O'DONNELL, J. E. OLDENDICK, R. T. WHEELER, *Ohio University* , S. I. AL-QURASIHI, *King Fahd University of Petroleum and Minerals, Saudi Arabia* , W. E. PARKER, S.A. KREEK, K. RASCHKE, T. F. WANG, *Lawrence Livermore National Laboratory* — We have measured the neutrons spectrum produced by stopping targets of Al, B, BN, and Be with a deuteron beam using fission detectors and lithium glass detectors. The results of these measurements from 0.2 to 20 MeV will be presented. The limitations to accuracy of the determination of the neutron flux will be discussed. The advantages and disadvantages of targets to be used to produce a neutron spectrum to be used as a secondary standard will be discussed. The application to the measurement of the source reactions Be(p,n) and Be(d,n) will be demonstrated.

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Investigation of “White” Neutron Sources for Efficiency Calibration

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Why Use a White Neutron Source for Calibration?

- Time – Previous procedure took 1 week.
- Accuracy – Previously used gas target reactions with at best 10% accuracy.
- New applied Physics, medical and neutron interogation, required better than 5% determination.
- This work is intended to generate an international secondary neutron standard.

Characteristic of an Ideal Source Reaction

- Lack of structure needed to avoid resolution dependent efficiencies.

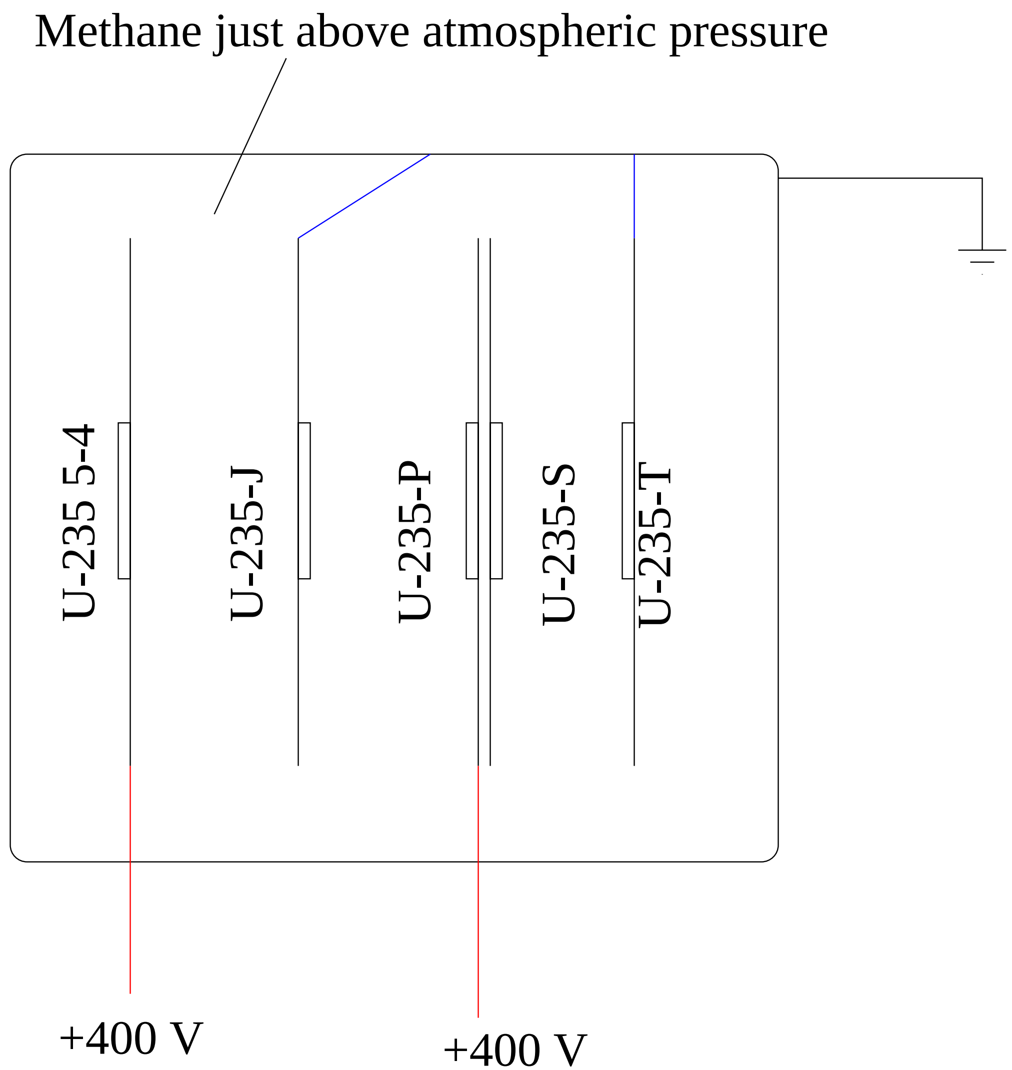
- Need good neutron yield $> 10^5$ neutrons/(MeV μC sr).

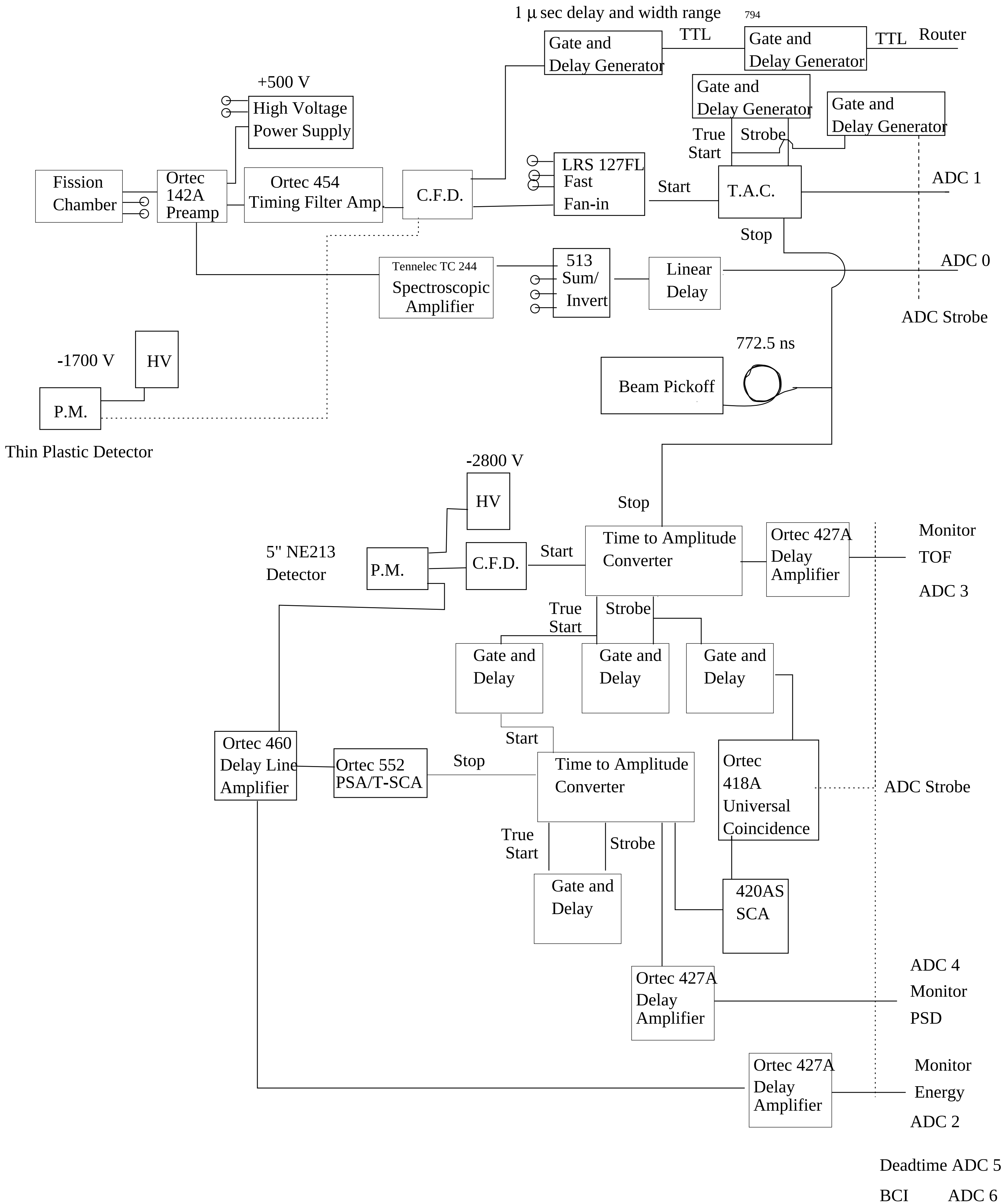
- A positive (d,n) Q-value is needed to cover the neutron energy range.

- The target should be stopping to avoid uncertainties due to target thickness.

- The target should be inexpensive, in high purity and stable in composition.

- Initial candidate targets were Be, B, BN, and Al.


Methane just above atmospheric pressure
U-235 5-4
U-235-J
U-235-P
U-235-S
U-235-T
+400 V
+400 V



1 μ sec delay and width range
794
Gate and Delay Generator
TTL
Gate and Delay Generator
TTL
Router
+500 V
High Voltage Power Supply
Gate and Delay Generator
Gate and Delay Generator
True Start
Strobe
Fission Chamber
Ortec 142A Preamp
Ortec 454 Timing Filter Amp
C.F.D.
LRS 127FL Fast Fan-in
Start
T.A.C.
ADC 1
Stop
Tennelec TC 244 Spectroscopic Amplifier
513 Sum/ Invert
Linear Delay
ADC 0
ADC Strobe
772.5 ns
Beam Pickoff
-1700 V
HV
P.M.
Thin Plastic Detector
-2800 V
HV
Stop
5" NE213 Detector
P.M.
C.F.D.
Start
Time to Amplitude Converter
Ortec 427A Delay Amplifier
Monitor
TOF
ADC 3
True Start
Strobe
Gate and Delay
Gate and Delay
Gate and Delay
Start
Ortec 460 Delay Line Amplifier
Ortec 552 PSA/T-SCA
Stop
Time to Amplitude Converter
Ortec 418A Universal Coincidence
ADC Strobe
True Start
Strobe
Gate and Delay
420AS SCA
Ortec 427A Delay Amplifier
ADC 4
Monitor
PSD
Ortec 427A Delay Amplifier
Monitor
Energy
ADC 2
Deadtime ADC 5
BCI ADC 6

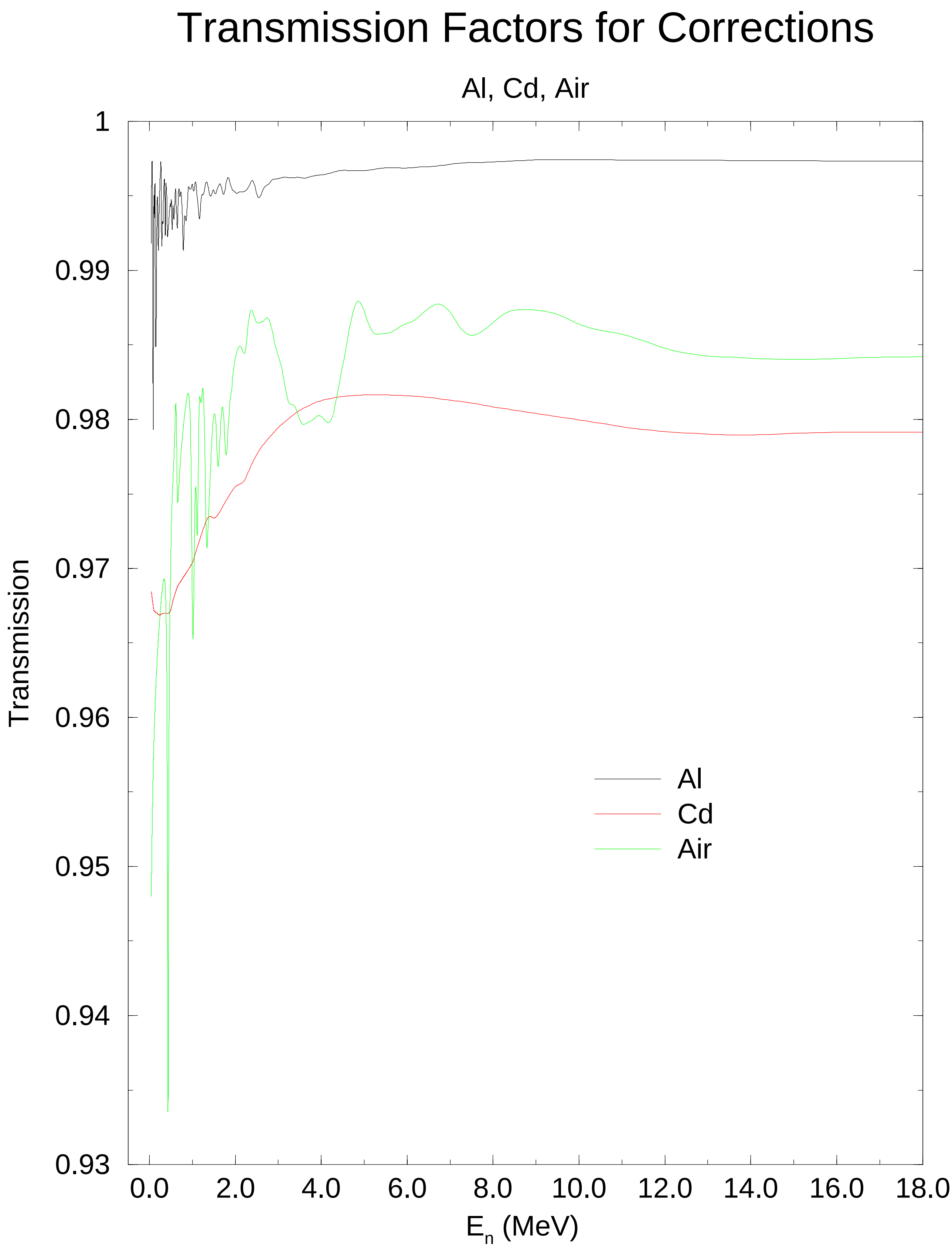
Data Reduction and Error Estimates

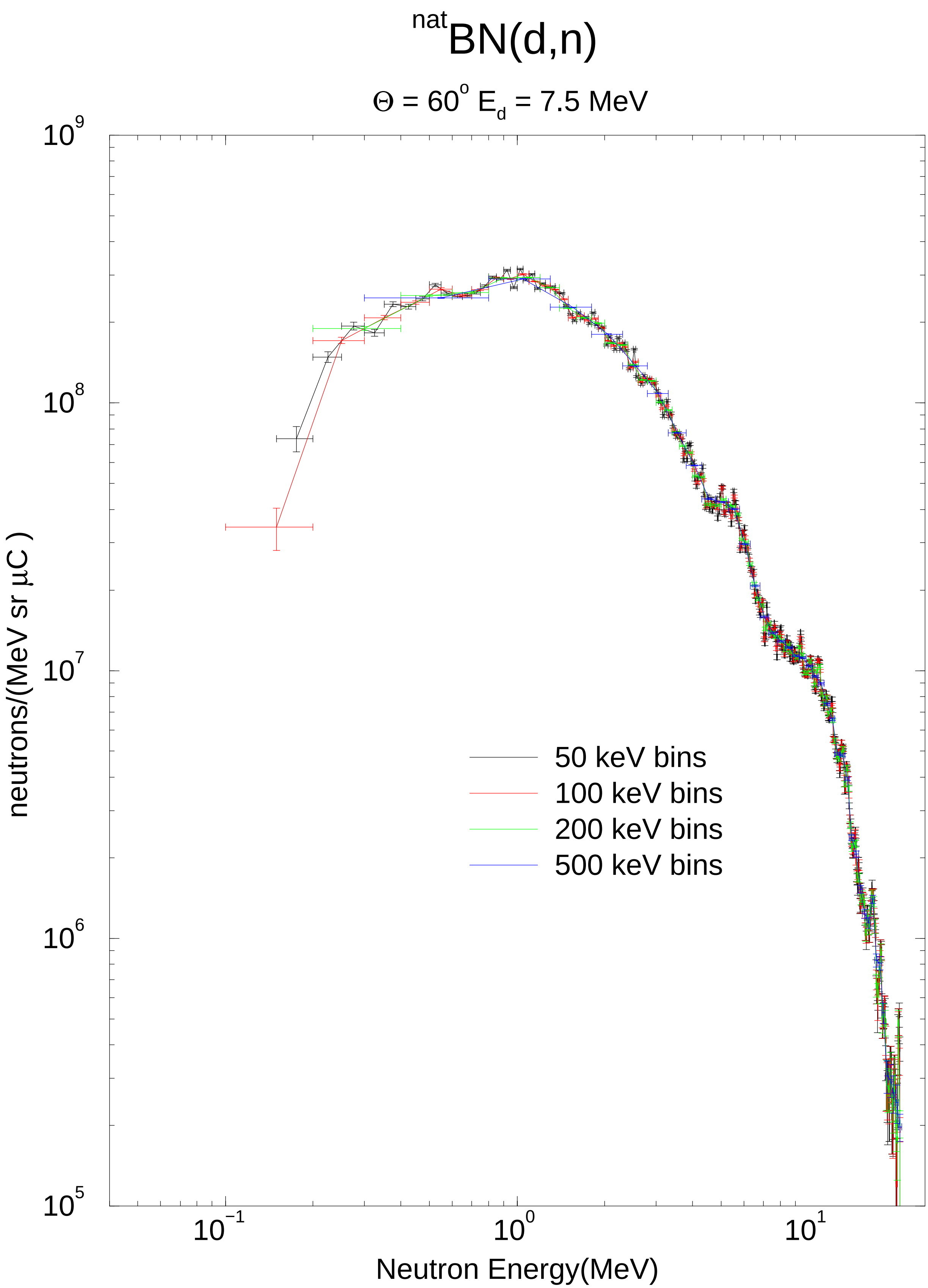
- The fission chamber with four thick ^{235}U foils (0.9% ^{234}U, 93.3% ^{235}U, 0.3% ^{236}U, 5.5% ^{238}U) was used for determination of the relative neutron flux and a thin ^{235}U foil (1.0% ^{234}U, 98.5% ^{235}U, 0.43% ^{236}U, 0.09% ^{238}U) was used for absolute yield determination.

- ENDF/B-VI cross sections used to obtain average cross sections for correction factors and average fission cross sections. All cross sections used were convoluted with the resolution of the fission chamber.

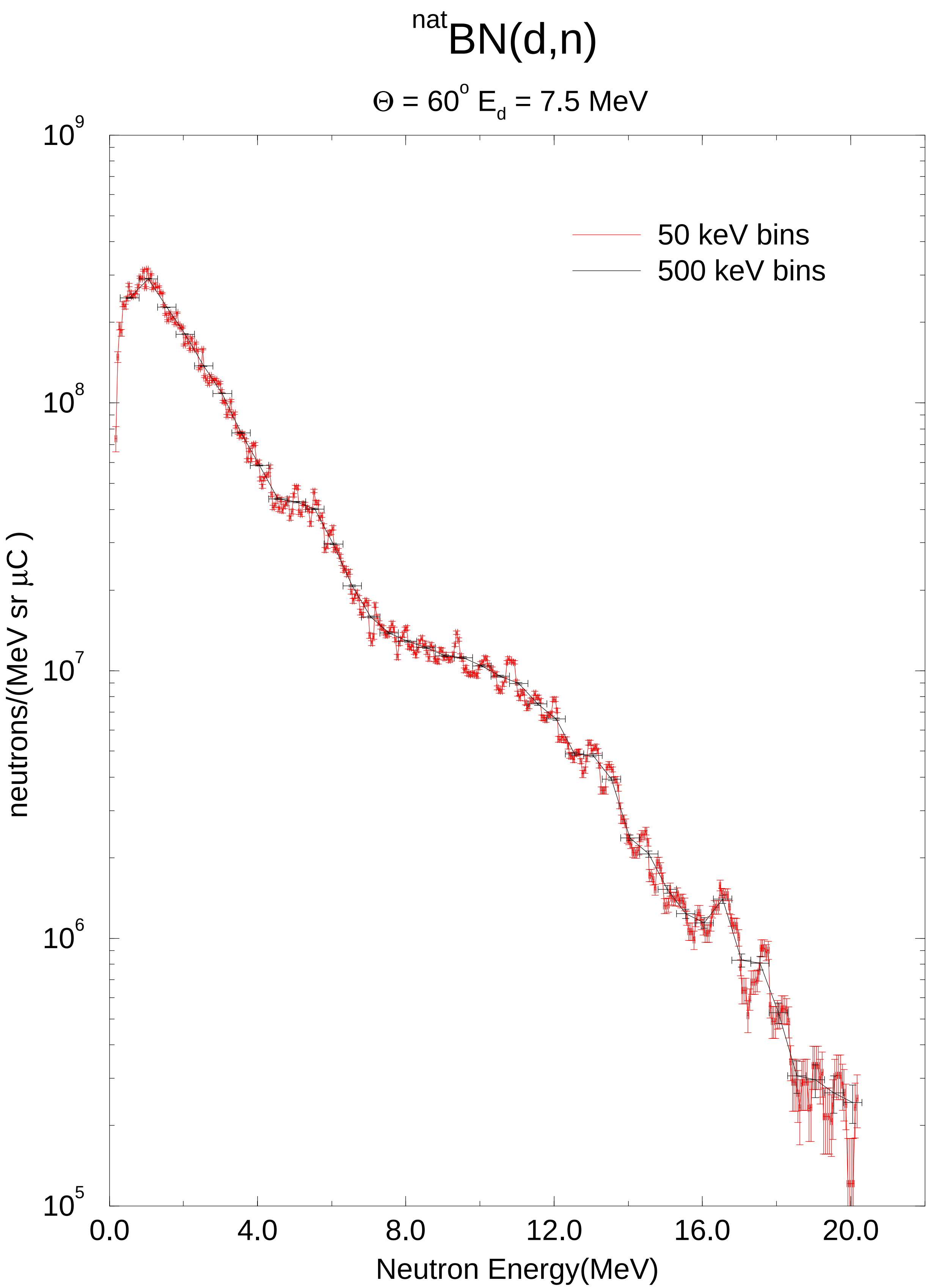
- An additional effort was made to confirm the results of a previous mass spectroscopy result with an assay with gamma-rays. Contribution to the error in relative yield from the uncertainty in isotopic composition was less than 0.25%.

- The error (5%) in the absolute yield is dominated by the counting statistics of the thin standard ^{235}U foil.

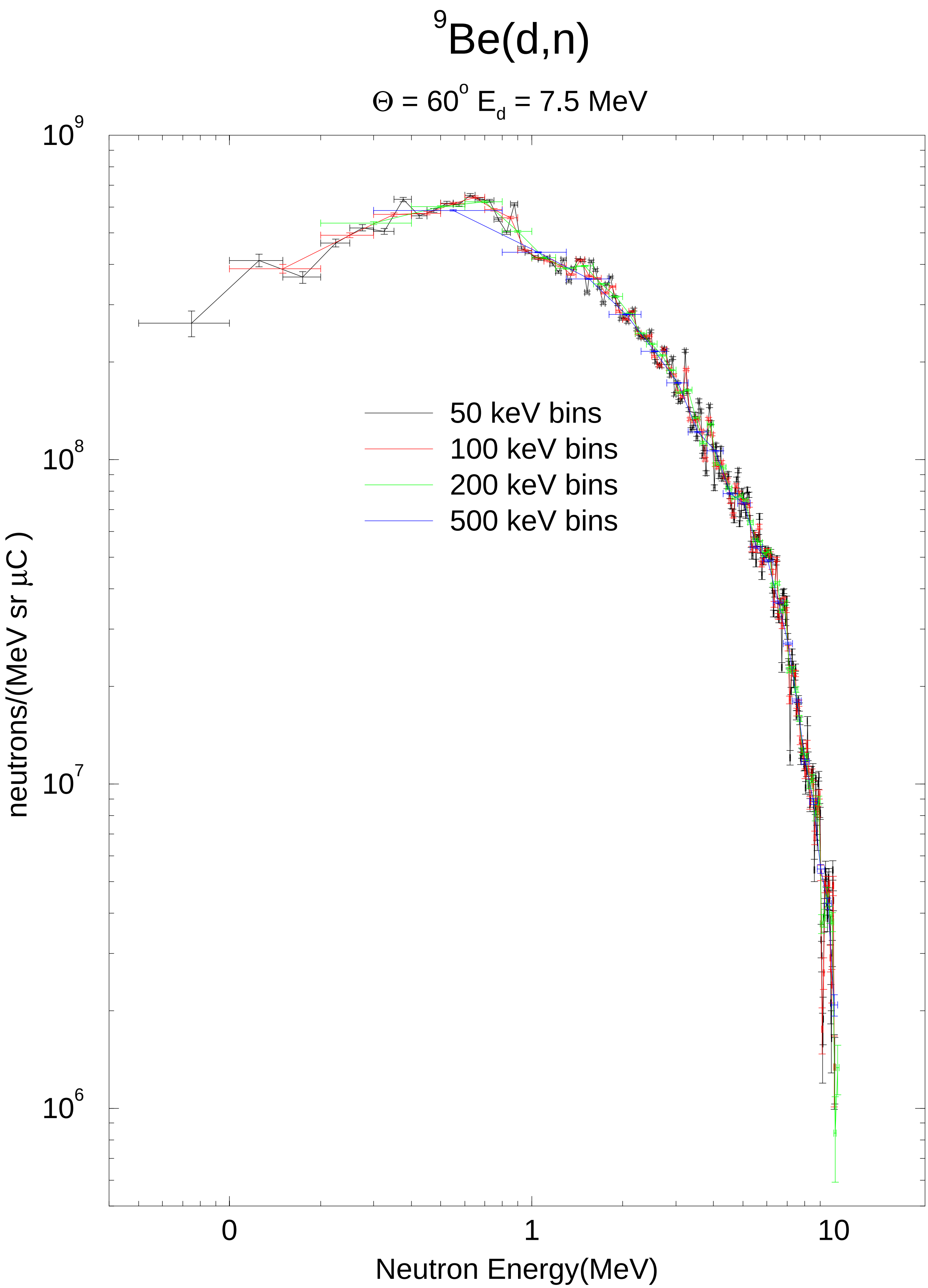

Transmission Factors for Corrections
Al, Cd, Air
Transmission
1
0.99
0.98
0.97
0.96
0.95
0.94
0.93
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
E_n (MeV)
Al
Cd
Air



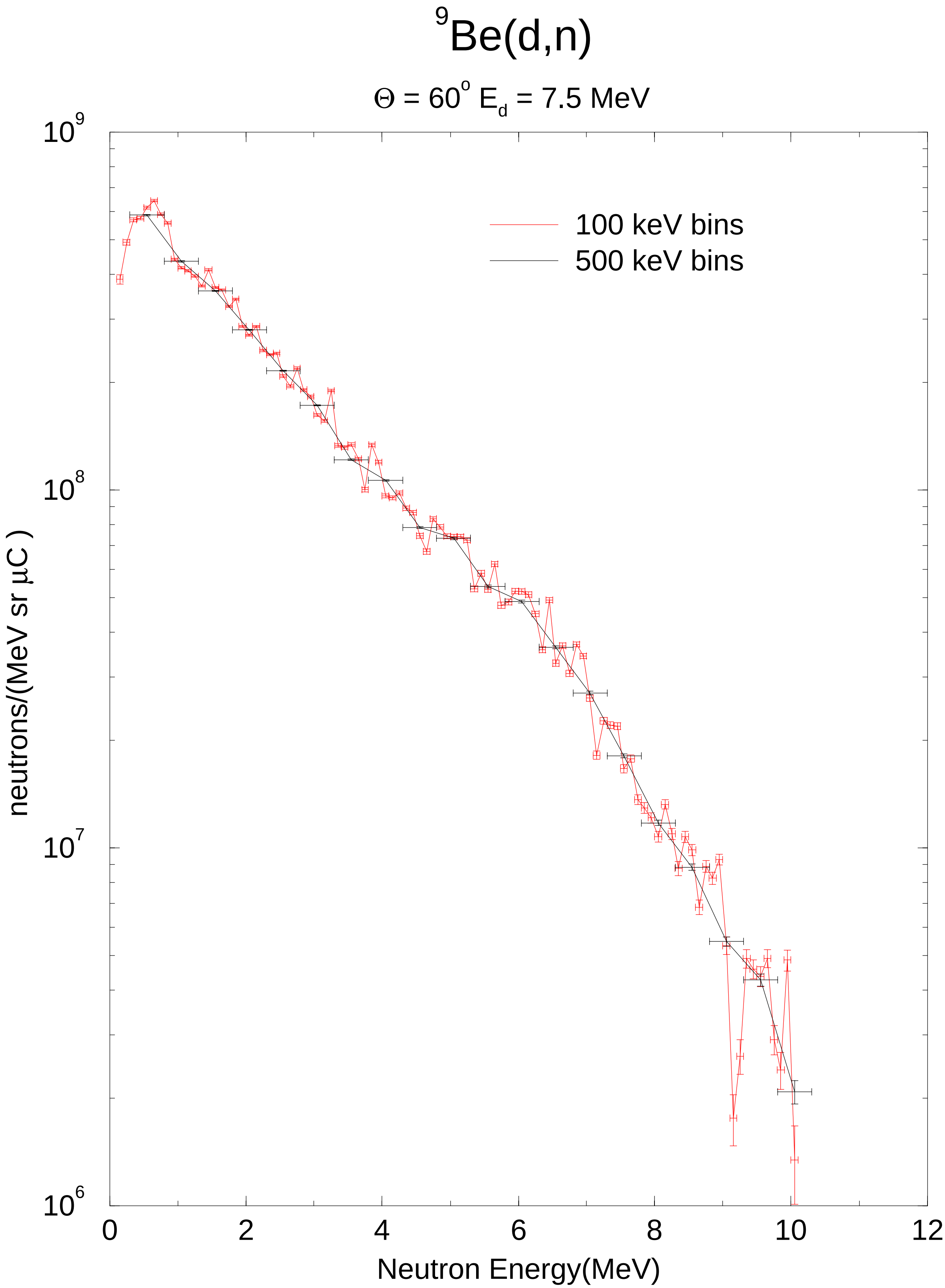
natBN(d,n)
Θ = 60° E_d = 7.5 MeV
neutrons/(MeV sr µC)
Neutron Energy(MeV)
50 keV bins
100 keV bins
200 keV bins
500 keV bins



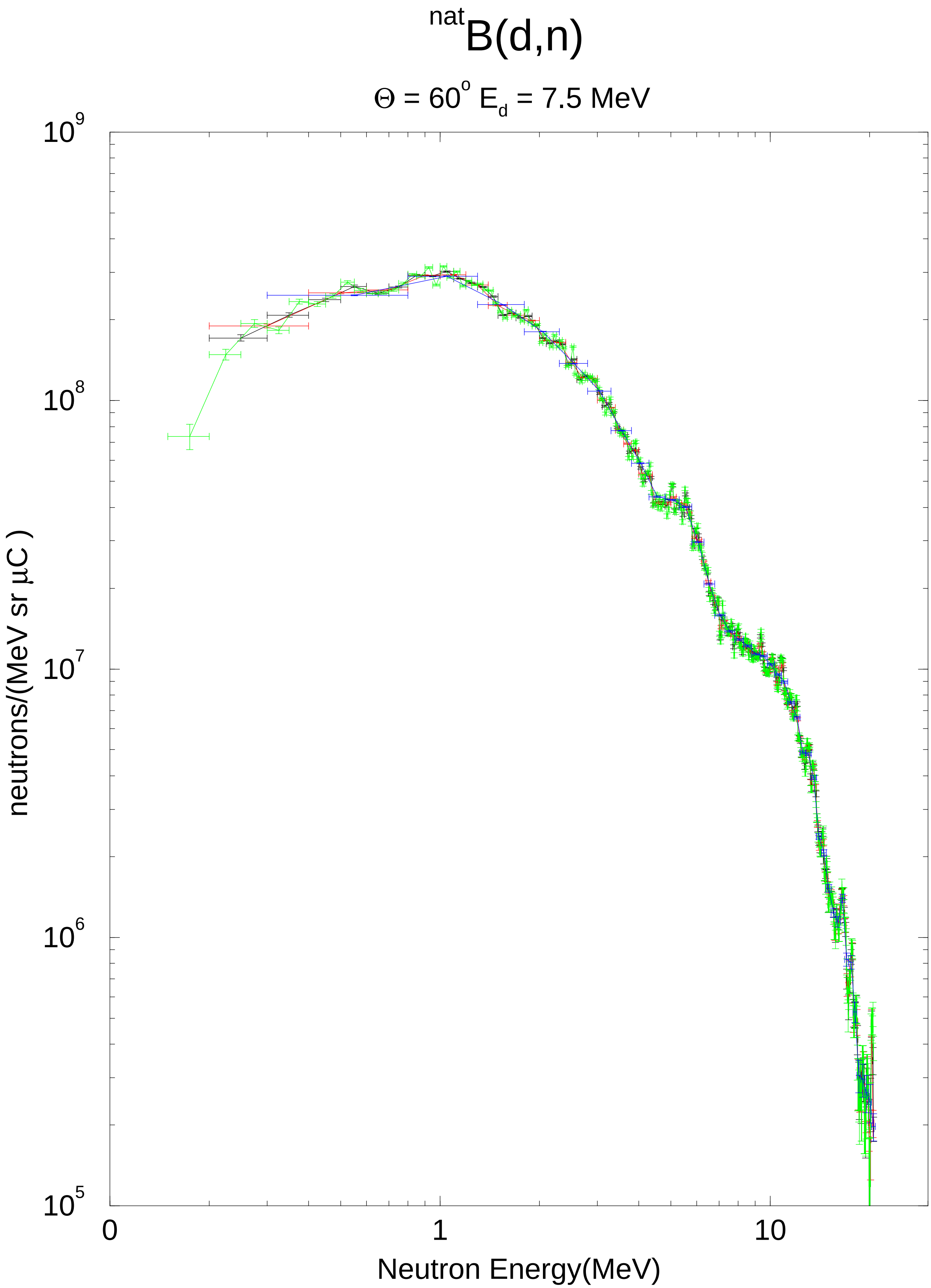
natBN(d,n)
Θ = 60° E_d = 7.5 MeV
50 keV bins
500 keV bins
neutrons/(MeV sr μC)
Neutron Energy(MeV)
10^9
10^8
10^7
10^6
10^5
0.0
4.0
8.0
12.0
16.0
20.0



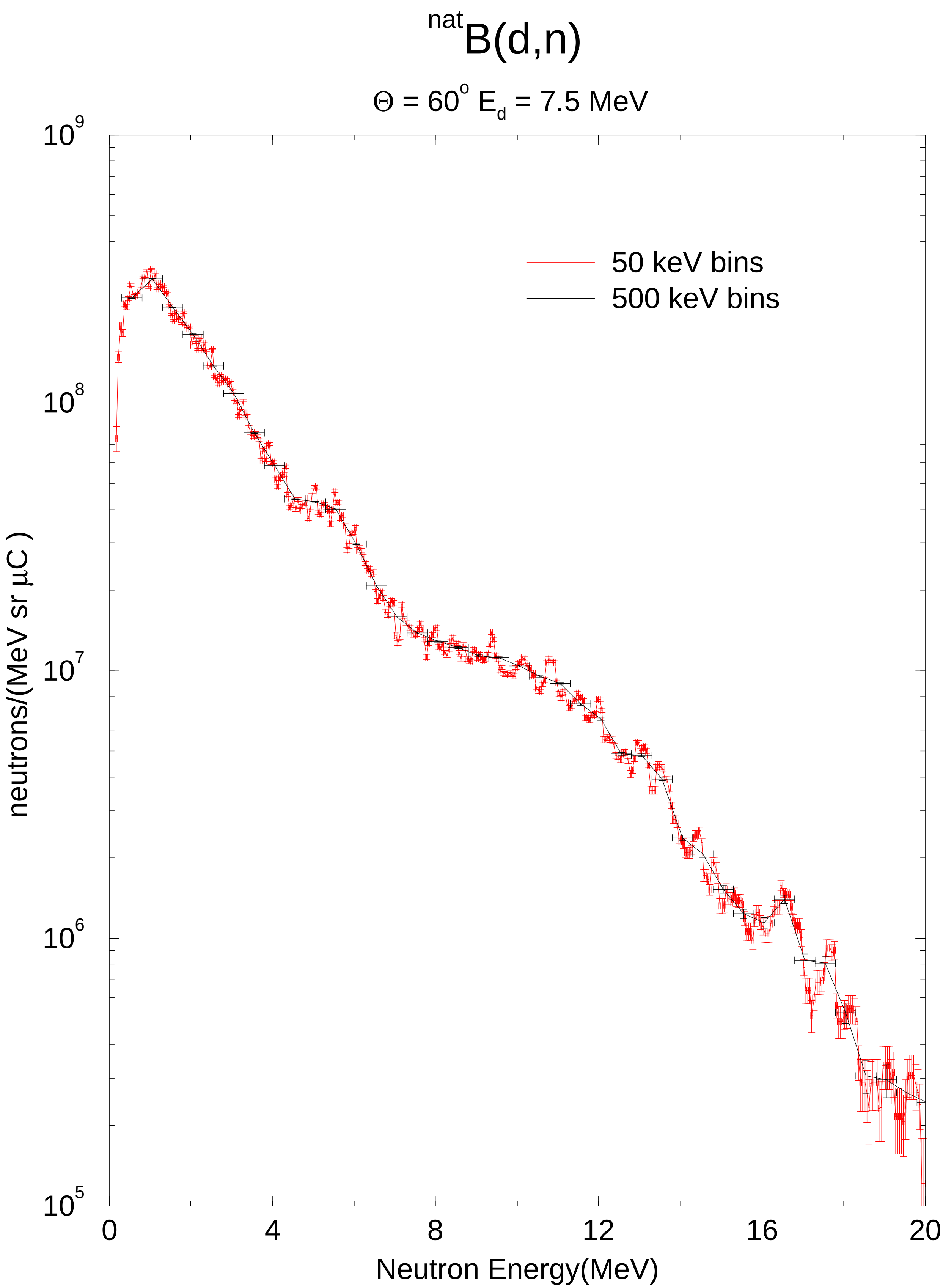
^{9}Be(d,n)
Θ = 60^o E_d = 7.5 MeV
50 keV bins
100 keV bins
200 keV bins
500 keV bins
neutrons/(MeV sr µC)
Neutron Energy(MeV)
10^9
10^8
10^7
10^6
0
1
10

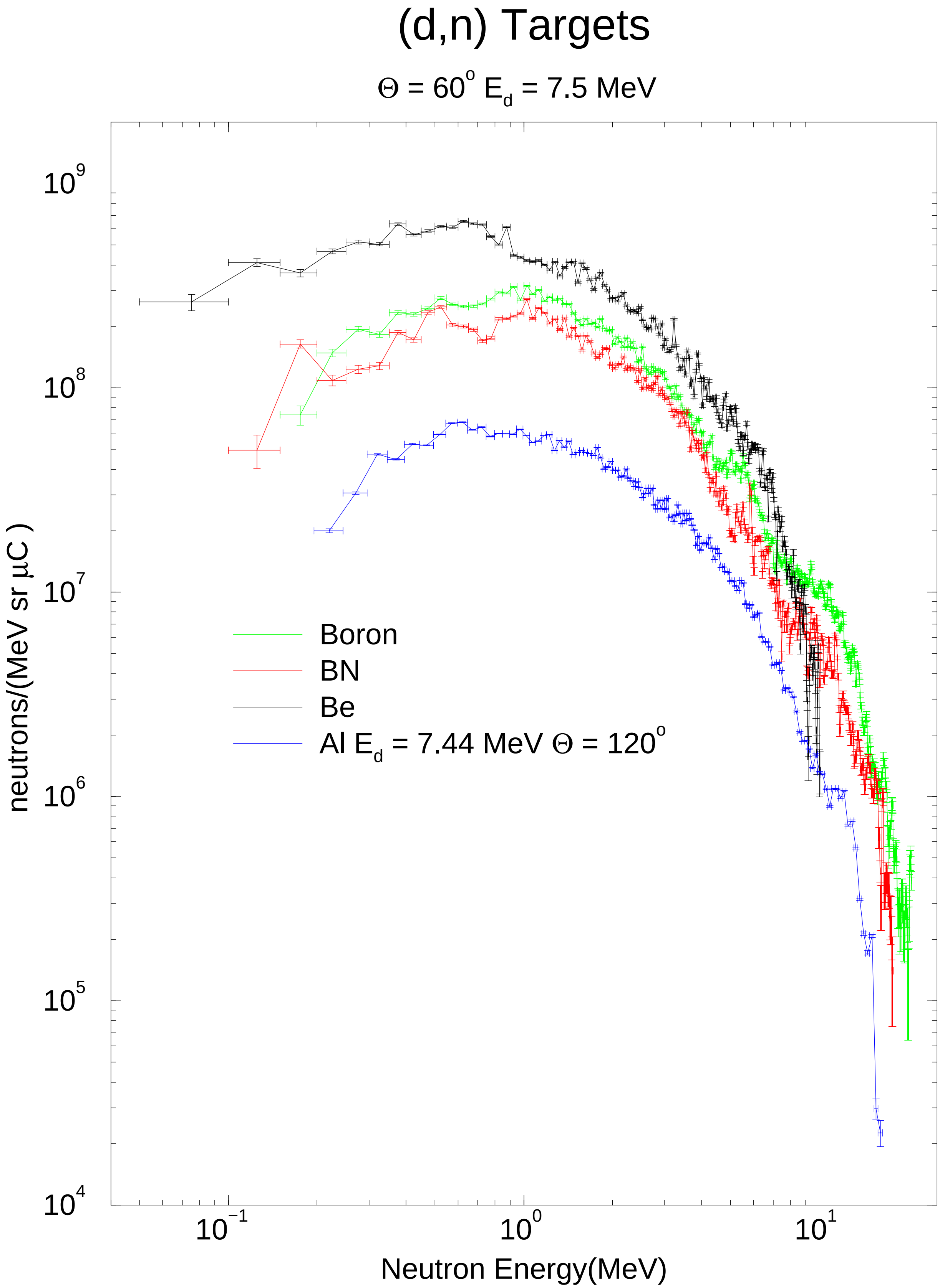


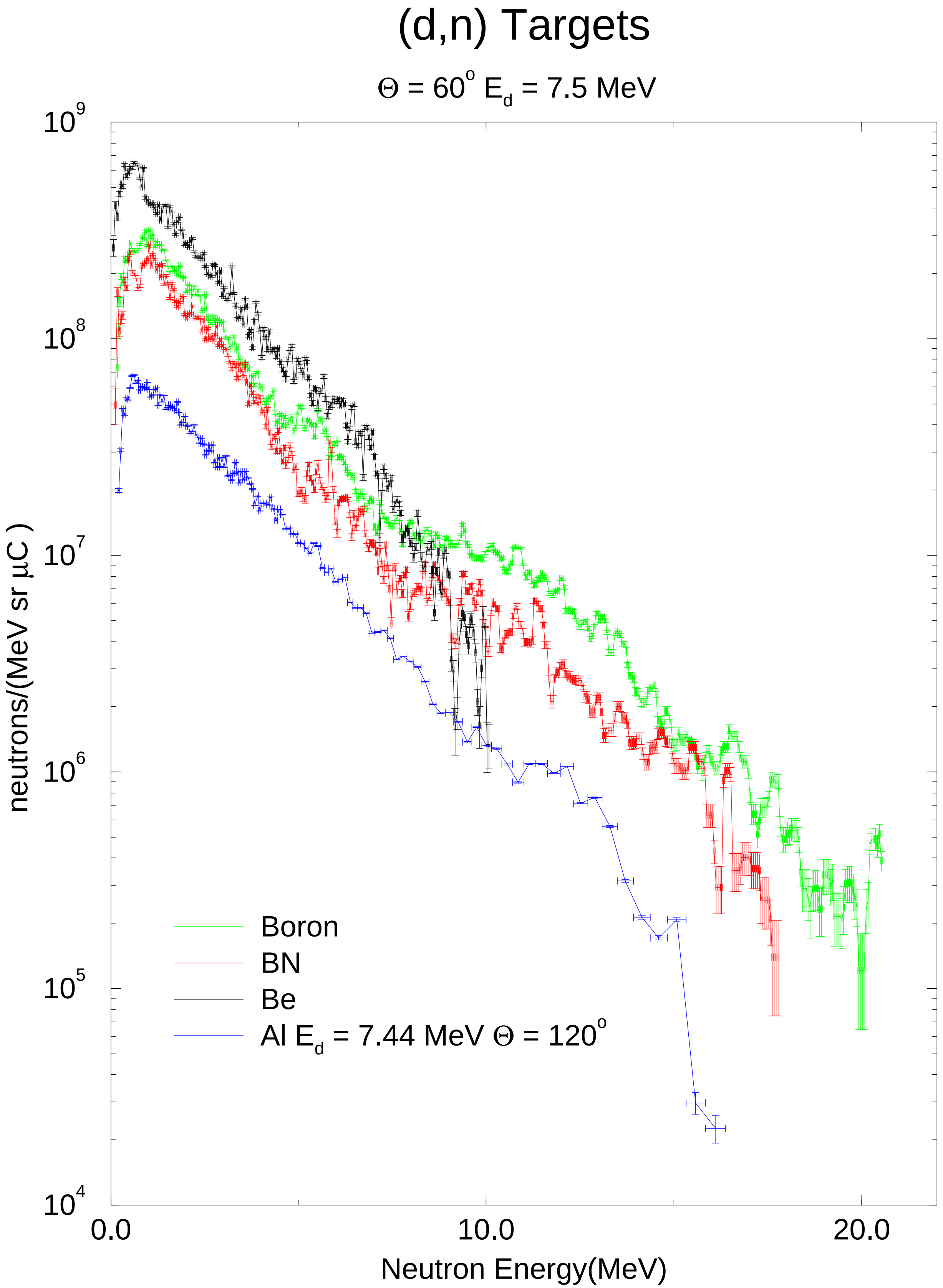
⁹Be(d,n)
Θ = 60° E_d = 7.5 MeV
100 keV bins
500 keV bins
neutrons/(MeV sr μC)
Neutron Energy(MeV)
10^9
10^8
10^7
10^6
0
2
4
6
8
10
12



natB(d,n)
Θ = 60° E_d = 7.5 MeV
10^9
10^8
10^7
10^6
10^5
neutrons/(MeV sr μC)
0
1
10
Neutron Energy(MeV)


natB(d,n)
Θ = 60° E_d = 7.5 MeV
50 keV bins
500 keV bins
neutrons/(MeV sr µC)
Neutron Energy(MeV)
10^9
10^8
10^7
10^6
10^5
0
4
8
12
16
20


(d,n) Targets
Θ = 60° E_d = 7.5 MeV
neutrons/(MeV sr µC)
Neutron Energy(MeV)
10^4
10^5
10^6
10^7
10^8
10^9
10^−1
10^0
10^1
Boron
BN
Be
Al E_d = 7.44 MeV Θ = 120°



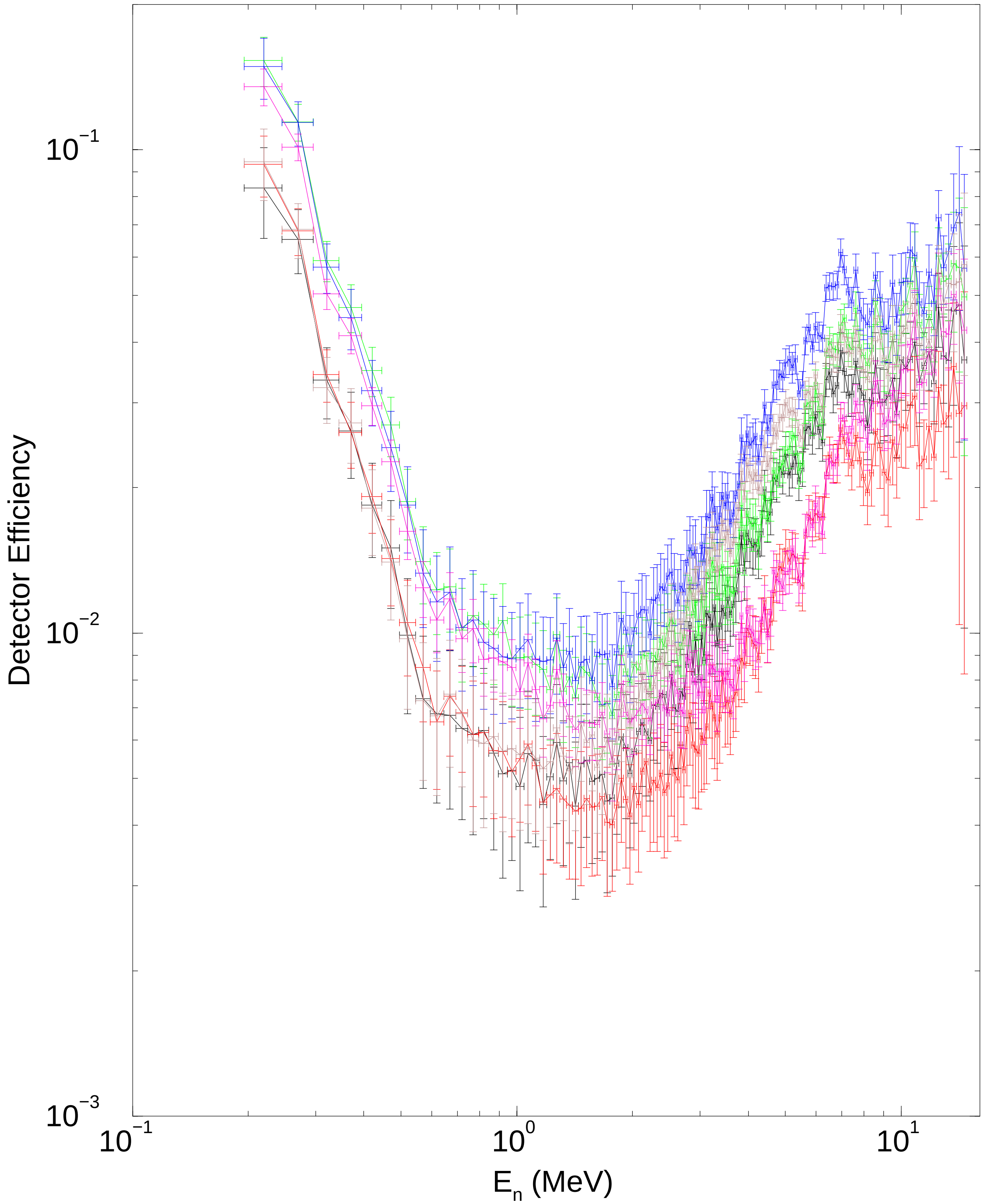
(d,n) Targets
Θ = 60° E_d = 7.5 MeV
neutrons/(MeV sr μC)
Neutron Energy(MeV)
10^9
10^8
10^7
10^6
10^5
10^4
0.0
10.0
20.0
Boron
BN
Be
Al E_d = 7.44 MeV Θ = 120°

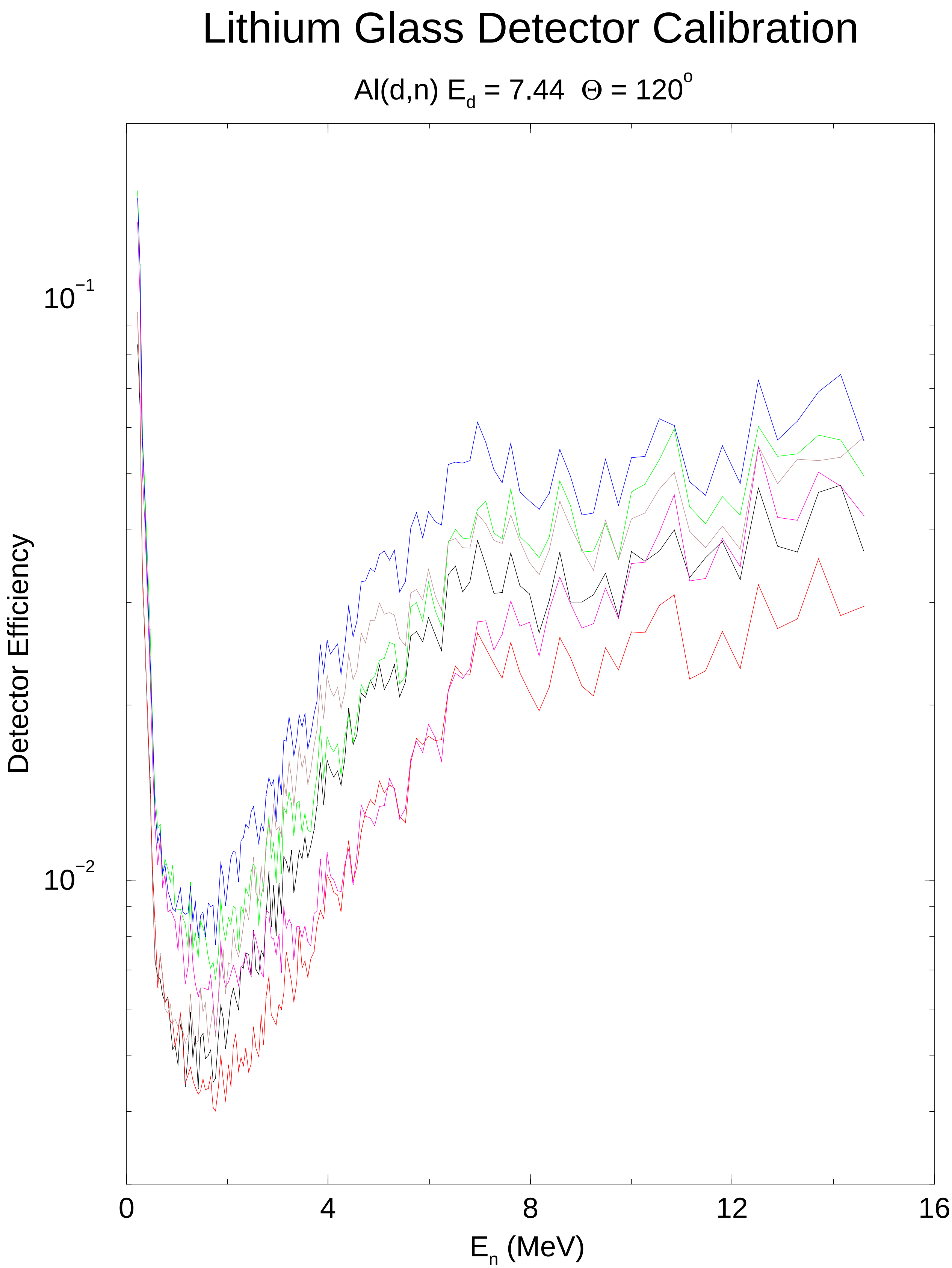
Example Efficiency Determination Using Al(d, n)

- ^{6}Li Glass Detectors
- Stilbene Detector
- NE213 Detector

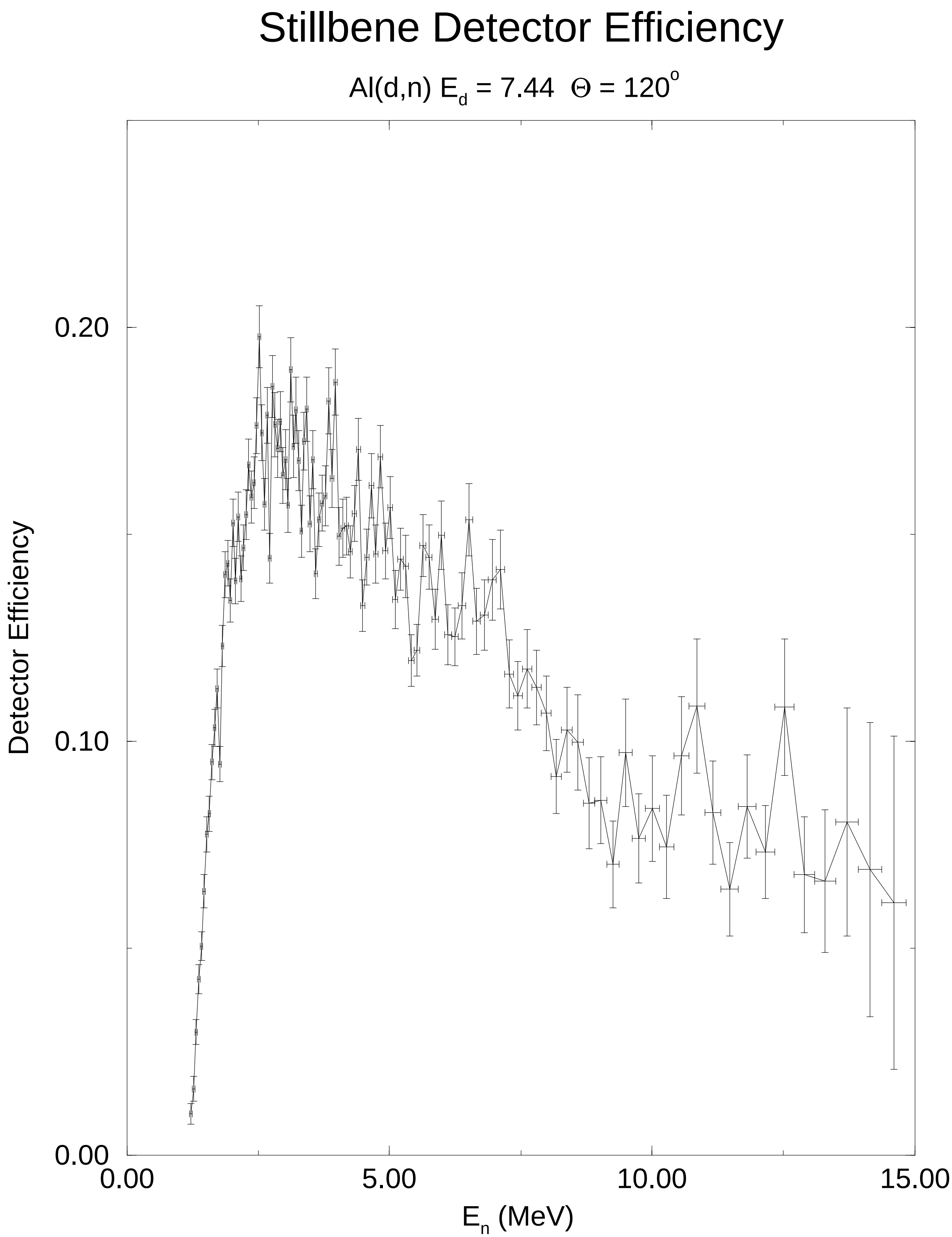
Lithium Glass Detector Calibration

Al(d,n) $E_d = 7.44$ $\Theta = 120^o$

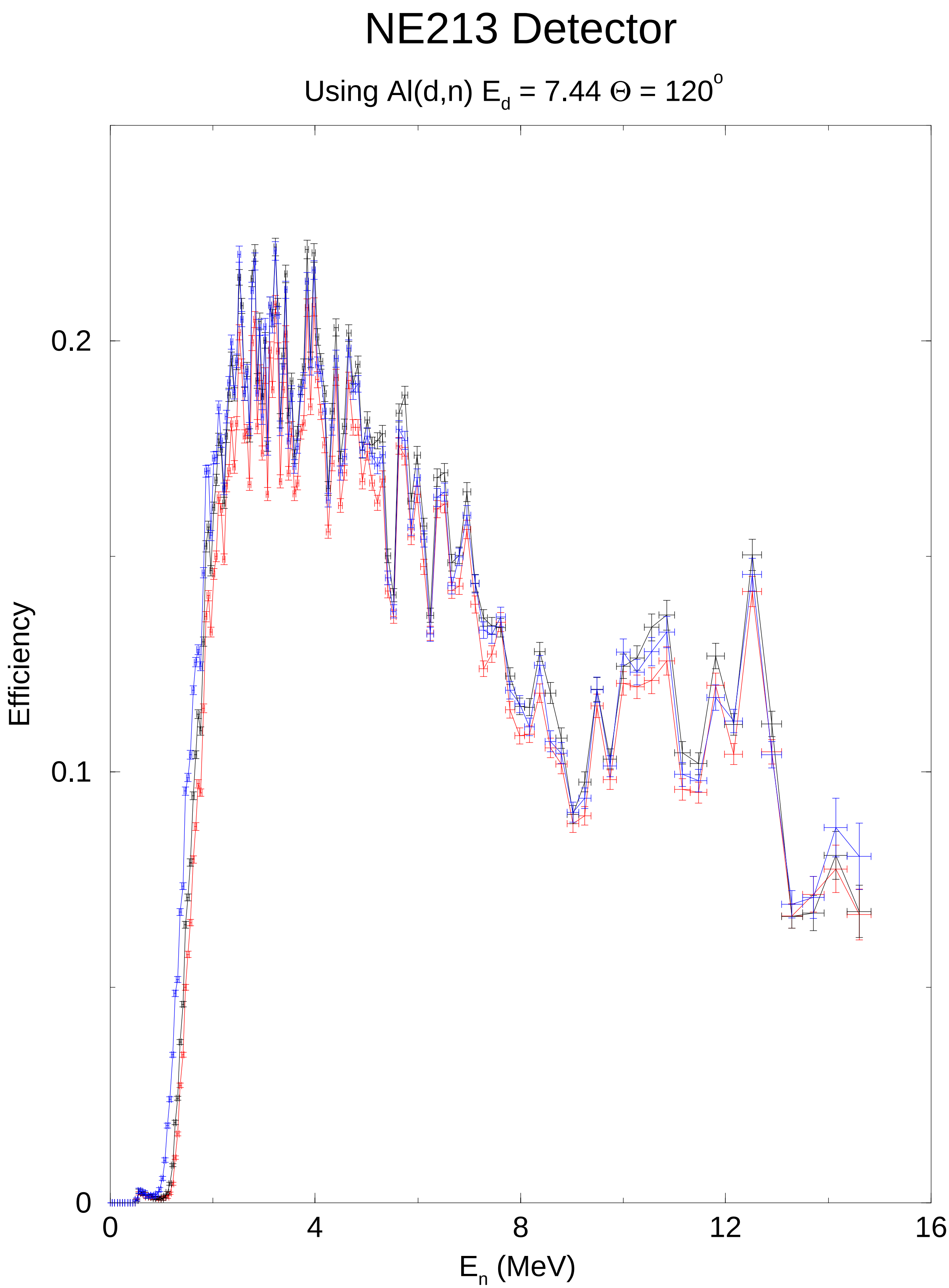




Lithium Glass Detector Calibration
Al(d,n) E_d = 7.44 Θ = 120^o
Detector Efficiency
10^{-1}
10^{-2}
0
4
8
12
16
E_n (MeV)



Stillbene Detector Efficiency
Al(d,n) E_d = 7.44 Θ = 120°
Detector Efficiency
0.20
0.10
0.00
0.00
5.00
10.00
15.00
E_n (MeV)



NE213 Detector
Using Al(d,n) E_d = 7.44 Θ = 120°
Efficiency
0.2
0.1
0
0
4
8
12
16
E_n (MeV)

Conclusions

- We have measured neutron spectra from Be, B, BN and Al targets.

- We have used these results to determine efficiencies of neutron time-of-flight detectors.

- We have used at the beryllium, boron, and aluminum targets to obtain a calibration over the range of 40 keV to 20 MeV.

Target	Useful Energy Range
Be	0.050- 9.0 MeV
B	0.100- 19.0 MeV
BN	None - target deteriorates under irradiation
Al	0.200 - 14.0 MeV

- Resultant efficiencies have been used to determine absolute neutron flux from the Be(p,n) and Be(d,n) reactions. The Be(p,n) reaction is currently being used by Harvard/MIT for Boron Neutron Capture Therapy (BNCT).