

# Activation of $^{69,71}\text{Ga}$ and $^{63,65}\text{Cu}$ with 25 and 90 keV neutrons

Clemens Beinrucker

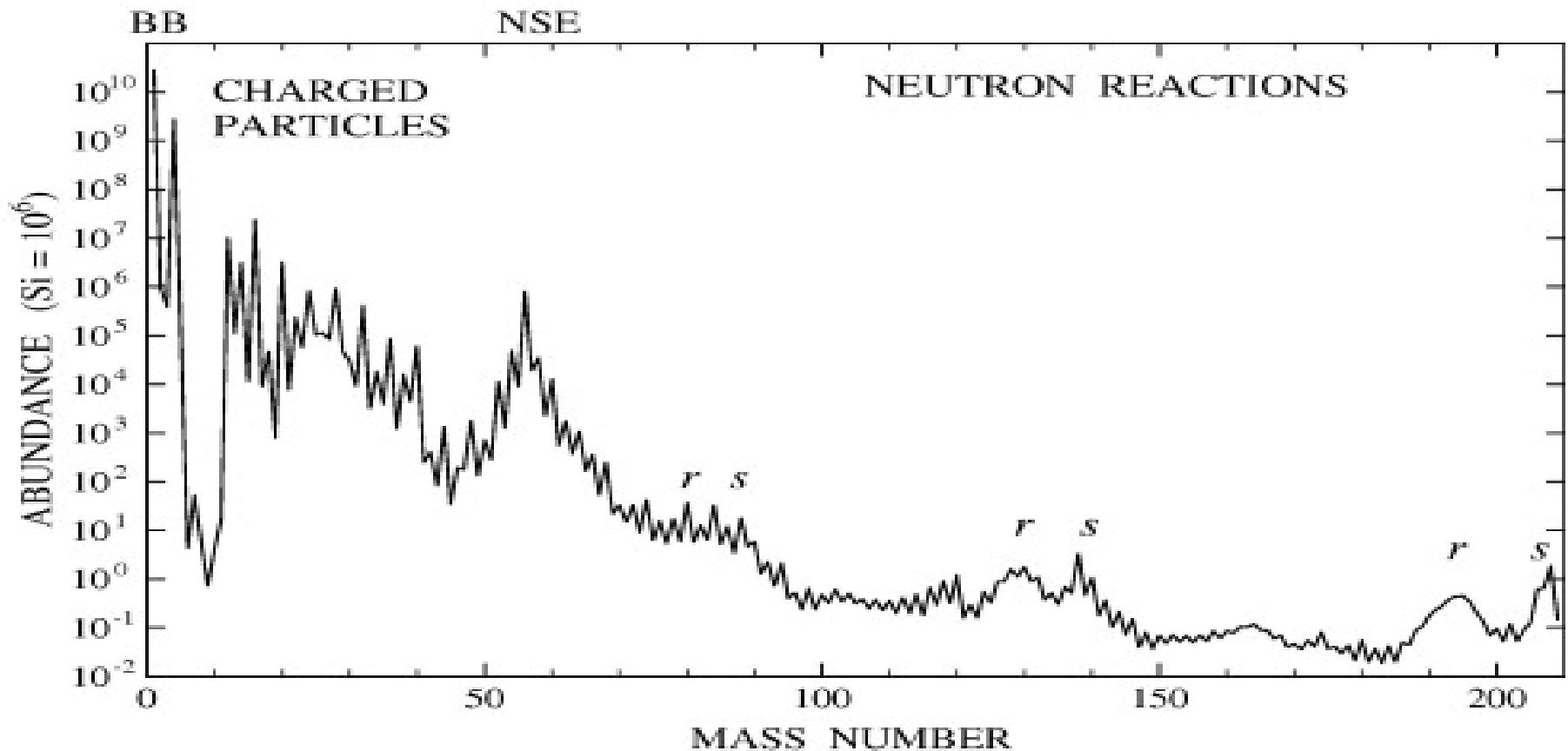
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13.05.15 UCANS V INFN Laboratori Nazionali di Legnaro



# Nucleosynthesis



Käppeler, Nucl. Instr. and Meth. in Phys. Res. B 259 (2007)



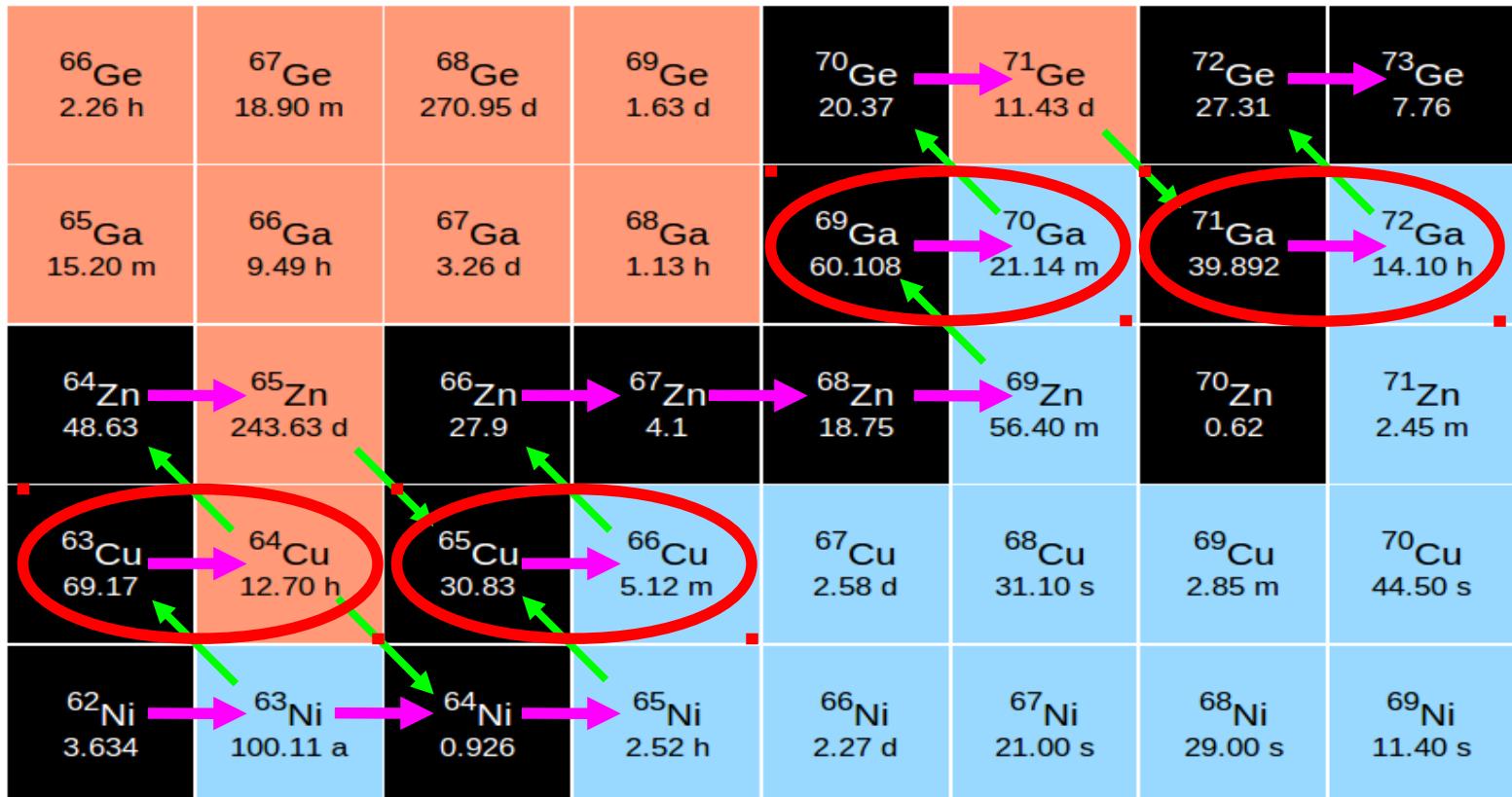
# s-process

	weak component	main component
mass number	$A = 56 - 90$	$A = 85 - 210$
scenario	massive stars of $20\text{-}25 M_{\odot}$	TP-AGB stars of $1\text{-}3 M_{\odot}$
neutron source	$^{22}\text{Ne}(\alpha, n)$	$^{13}\text{C}(\alpha, n), ^{22}\text{Ne}(\alpha, n)$
temperature	$2 \cdot 10^8 - 10^9 \text{ K}$	$10^7 - 3 \cdot 10^8 \text{ K}$
neutron density	$10^6 - 10^{11} \text{ cm}^{-3}$	$10^8 - 10^{12} \text{ cm}^{-3}$

# Chart of nuclei

→  $(n, \gamma)$

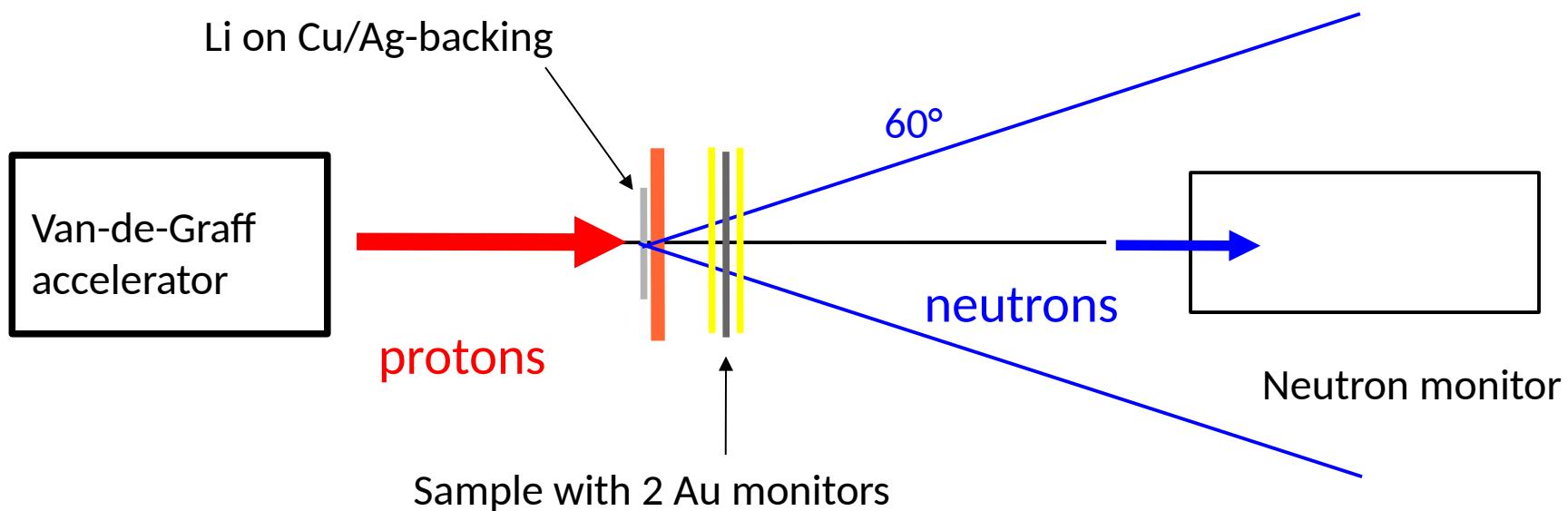
→  $\beta$  decay



Kadonis.org



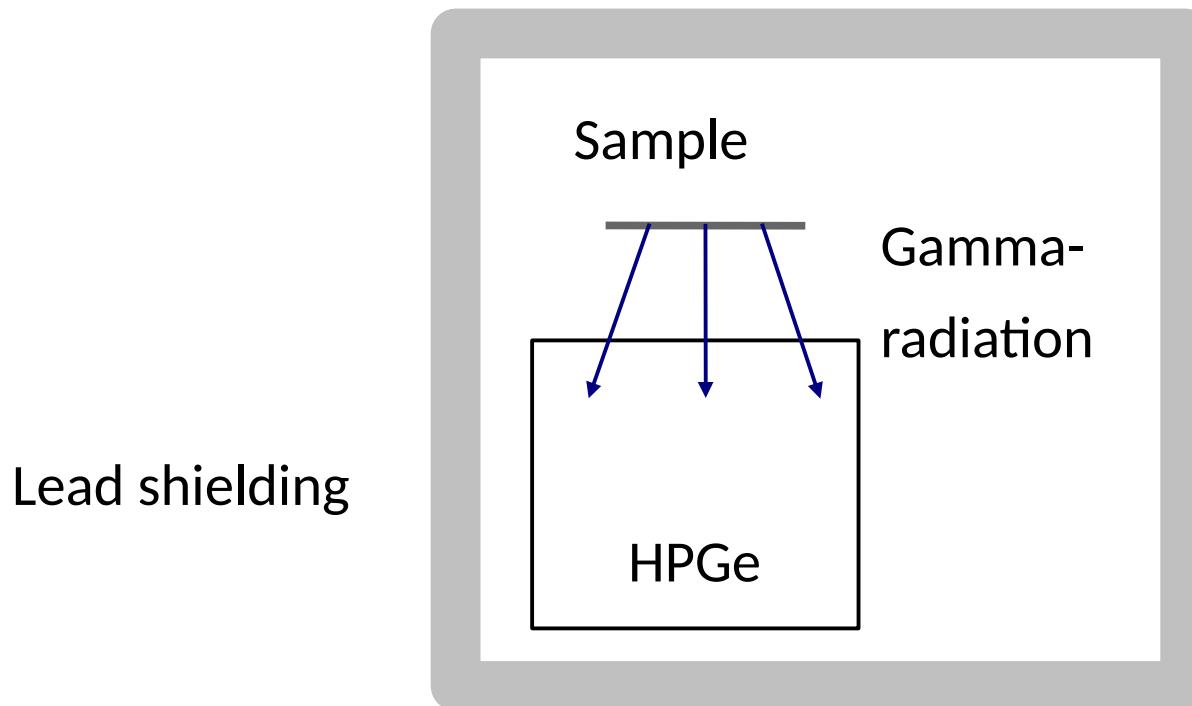
# 1. Activate Sample



Institute for Reference Materials and Measurement, Geel, Belgium

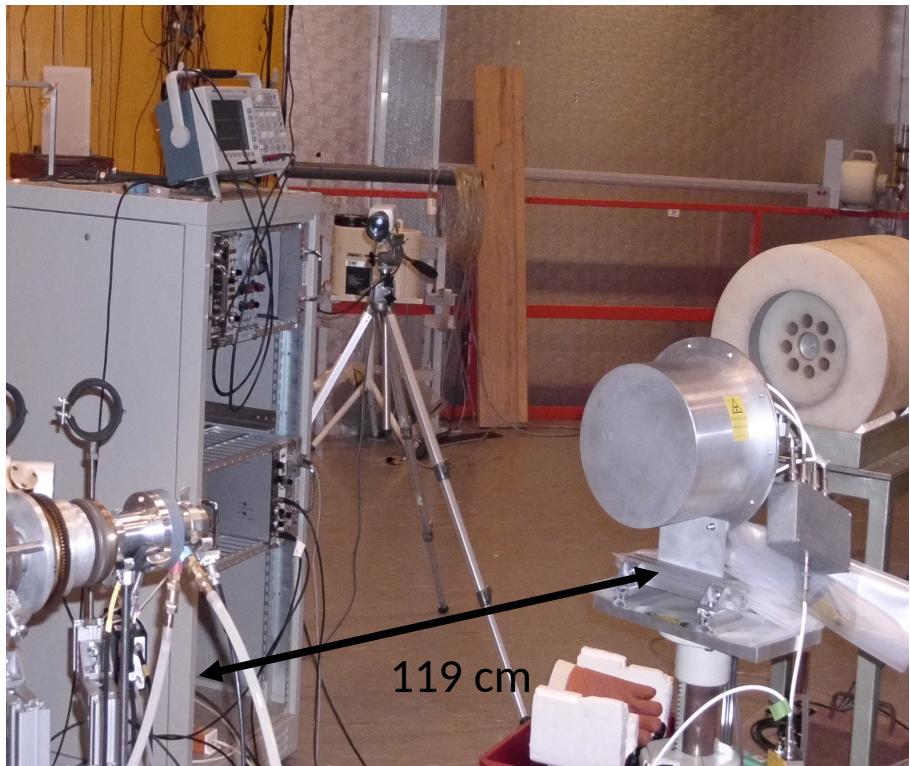
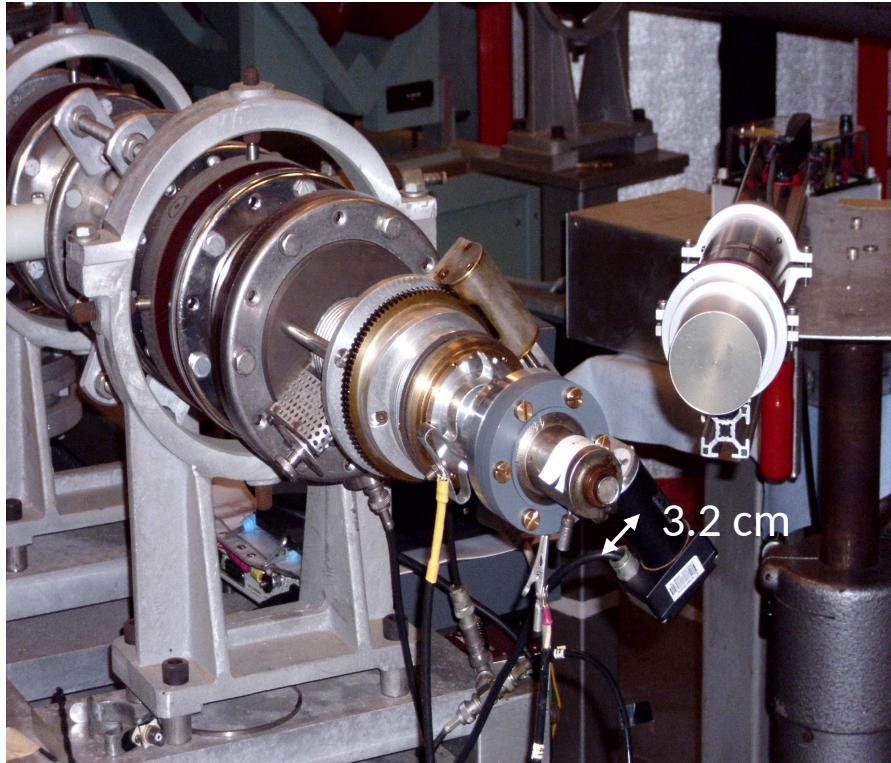


## 2. Gammaspectroscopy



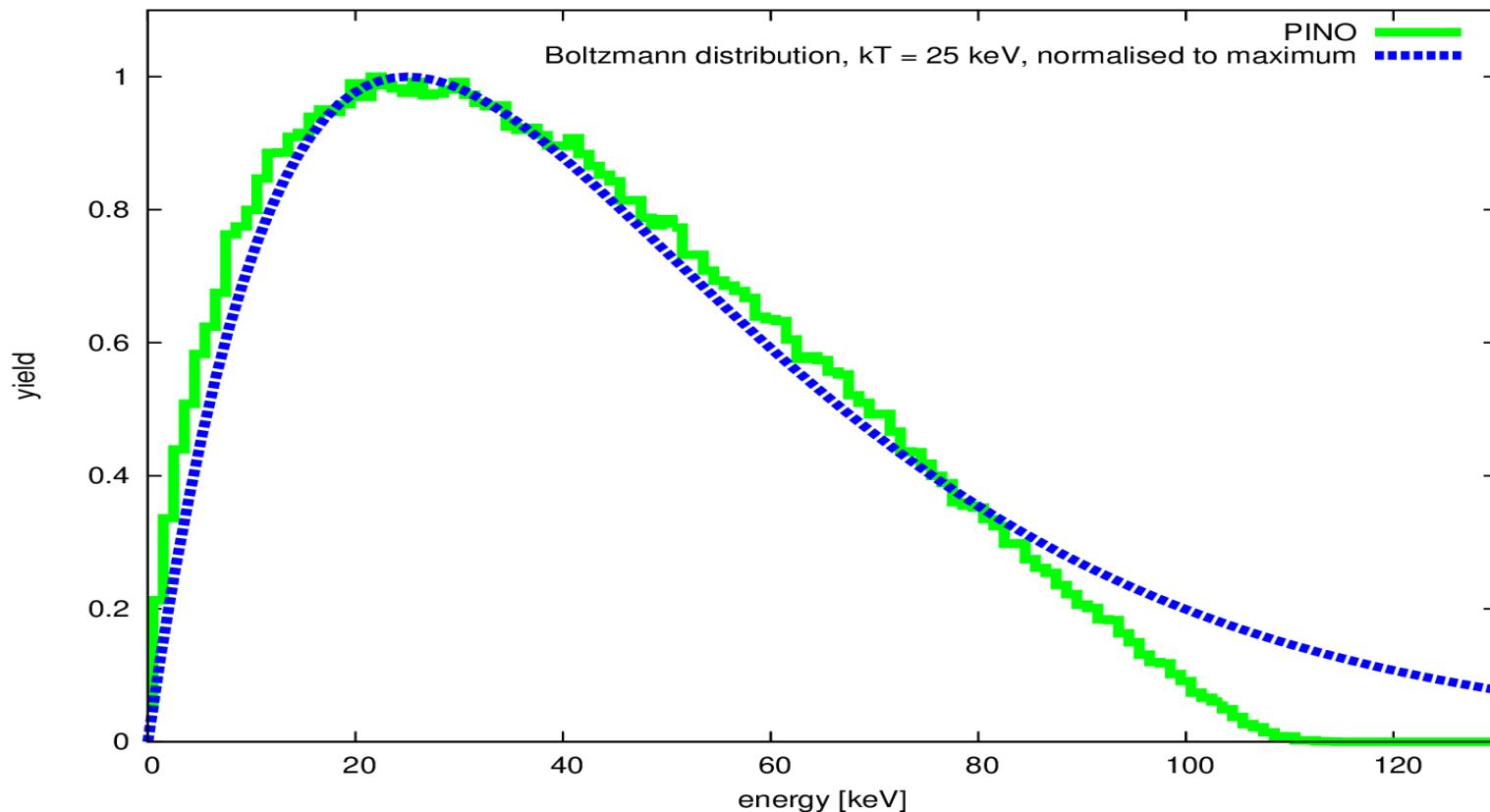


# Li target



# Neutronspectrum at 25 keV

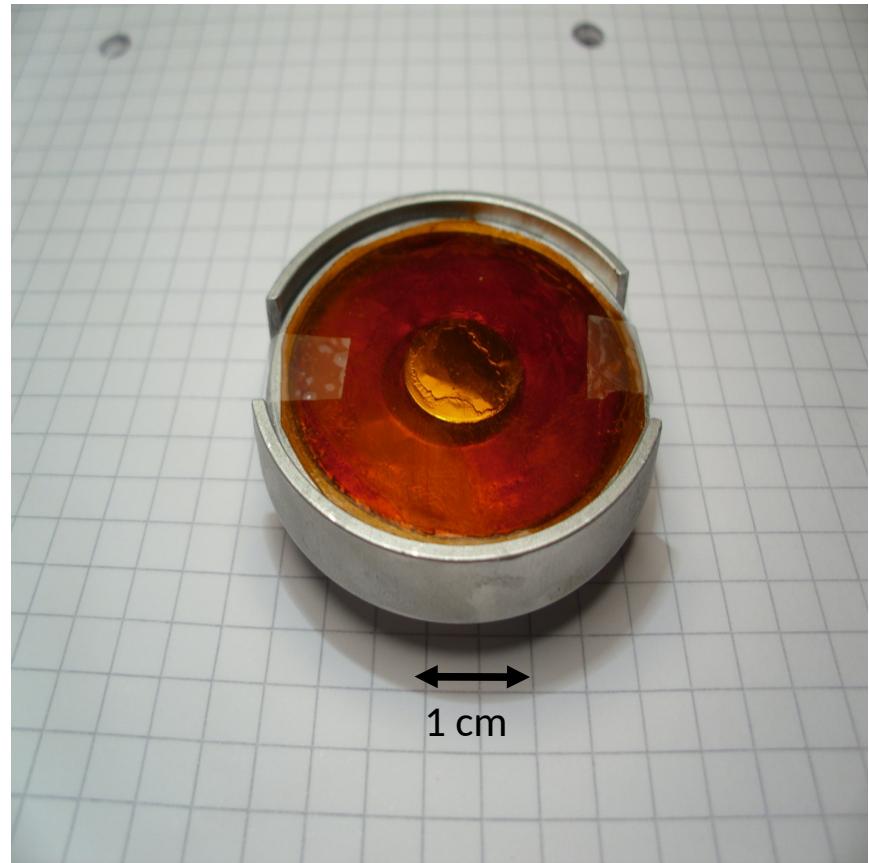
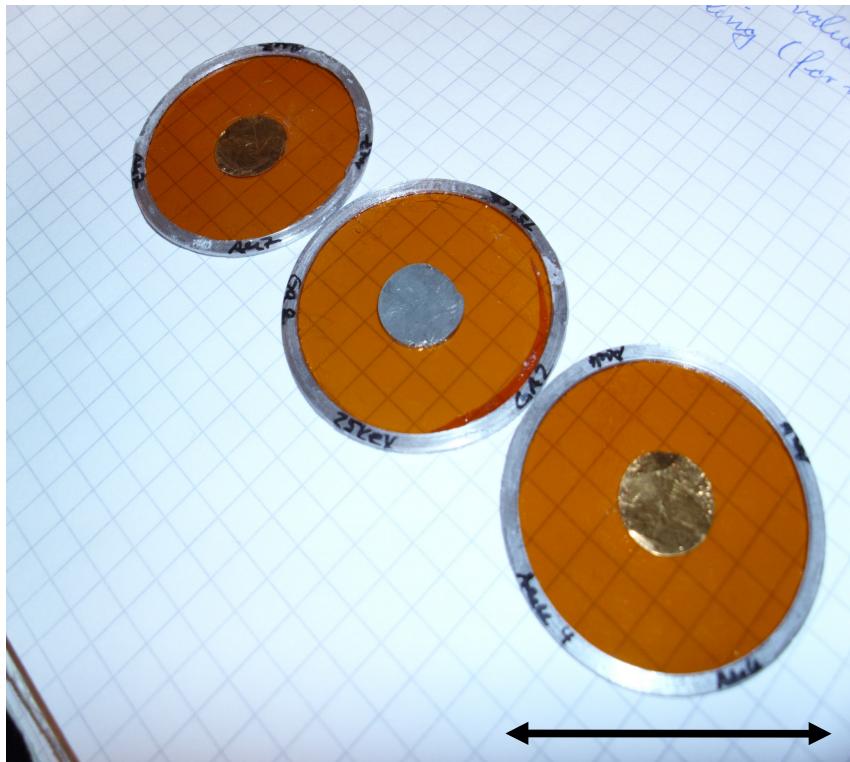
$E_p = 1912$  keV; thickness Li: 27.5  $\mu\text{m}$ ; distance Li-sample: 0.5 mm



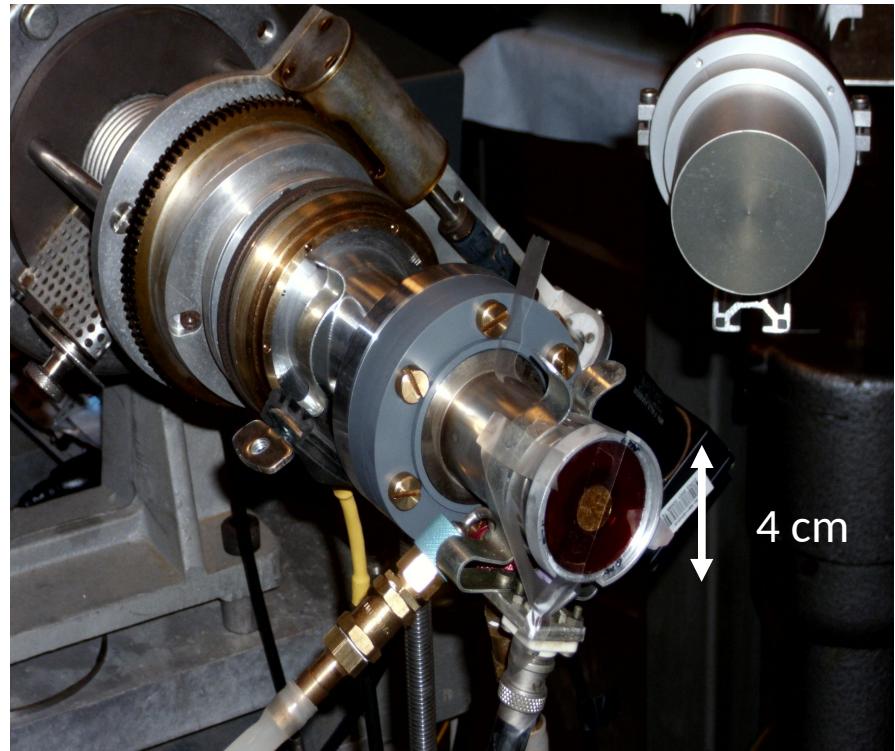
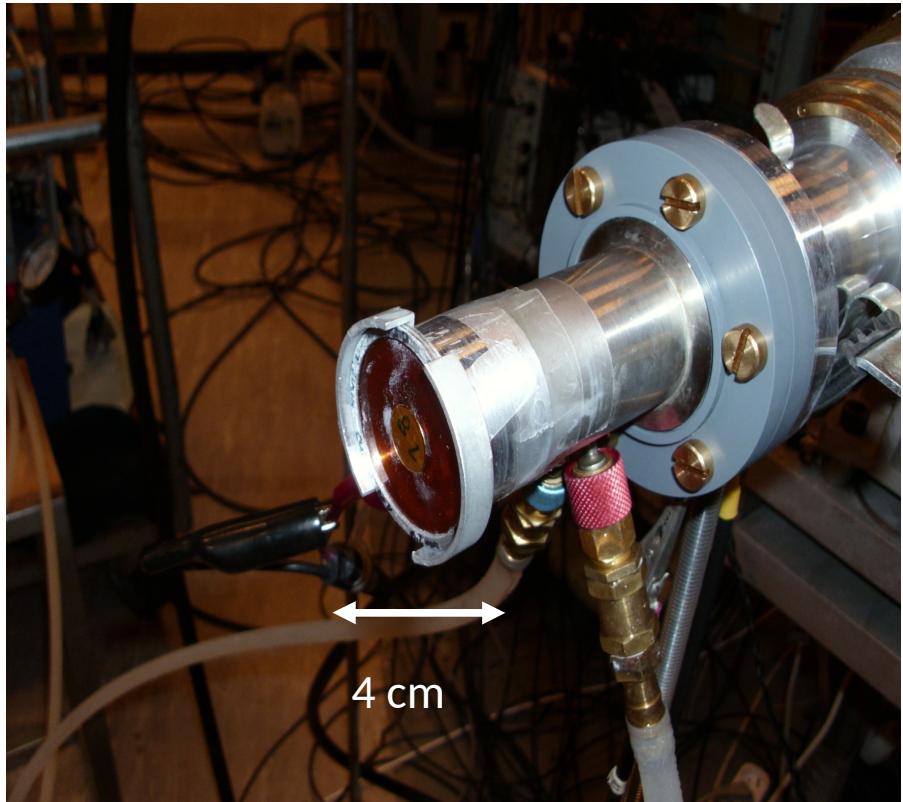
<http://exp-astro.physik.uni-frankfurt.de/pino/>



# Samples

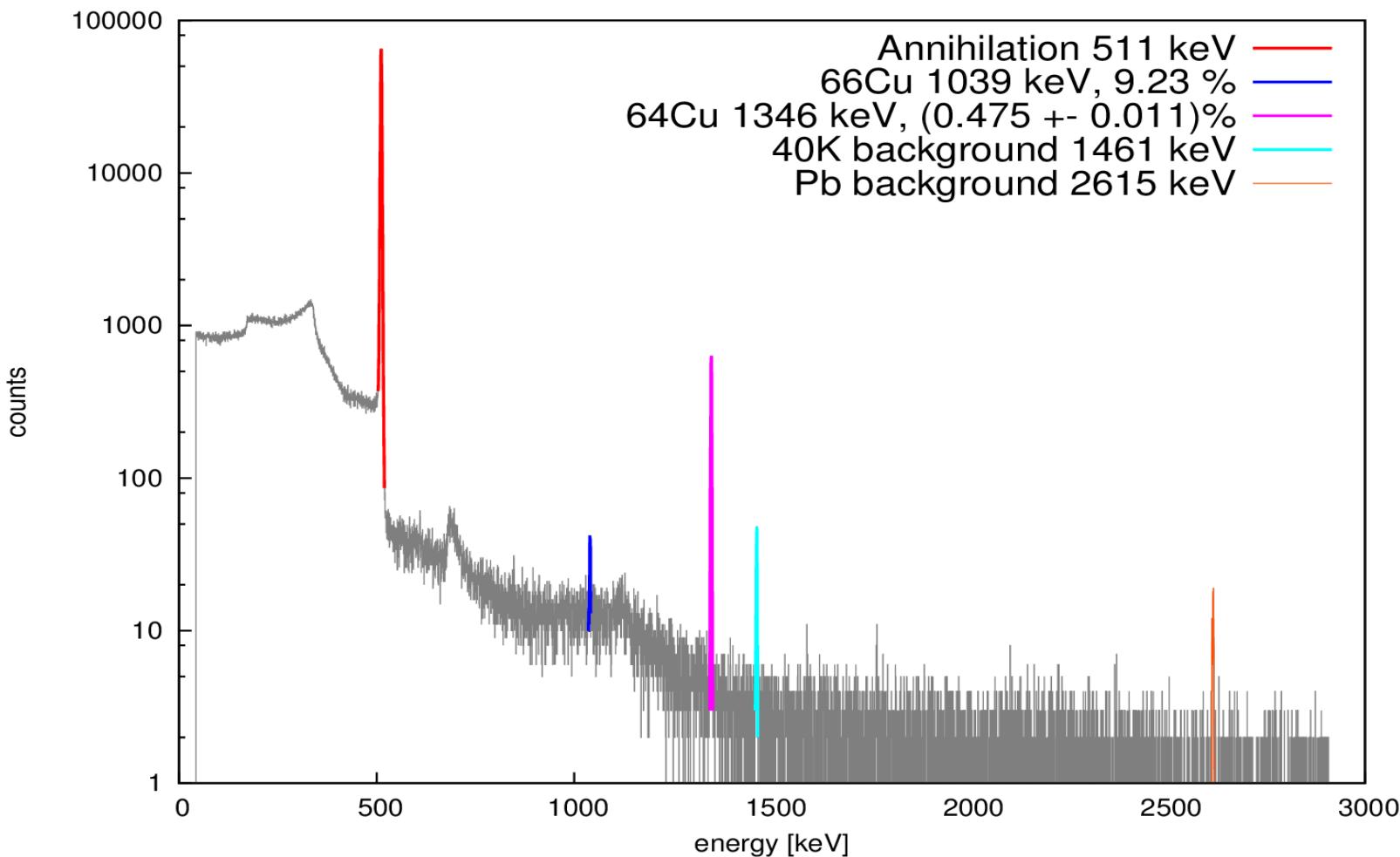


# Sample on beam pipe



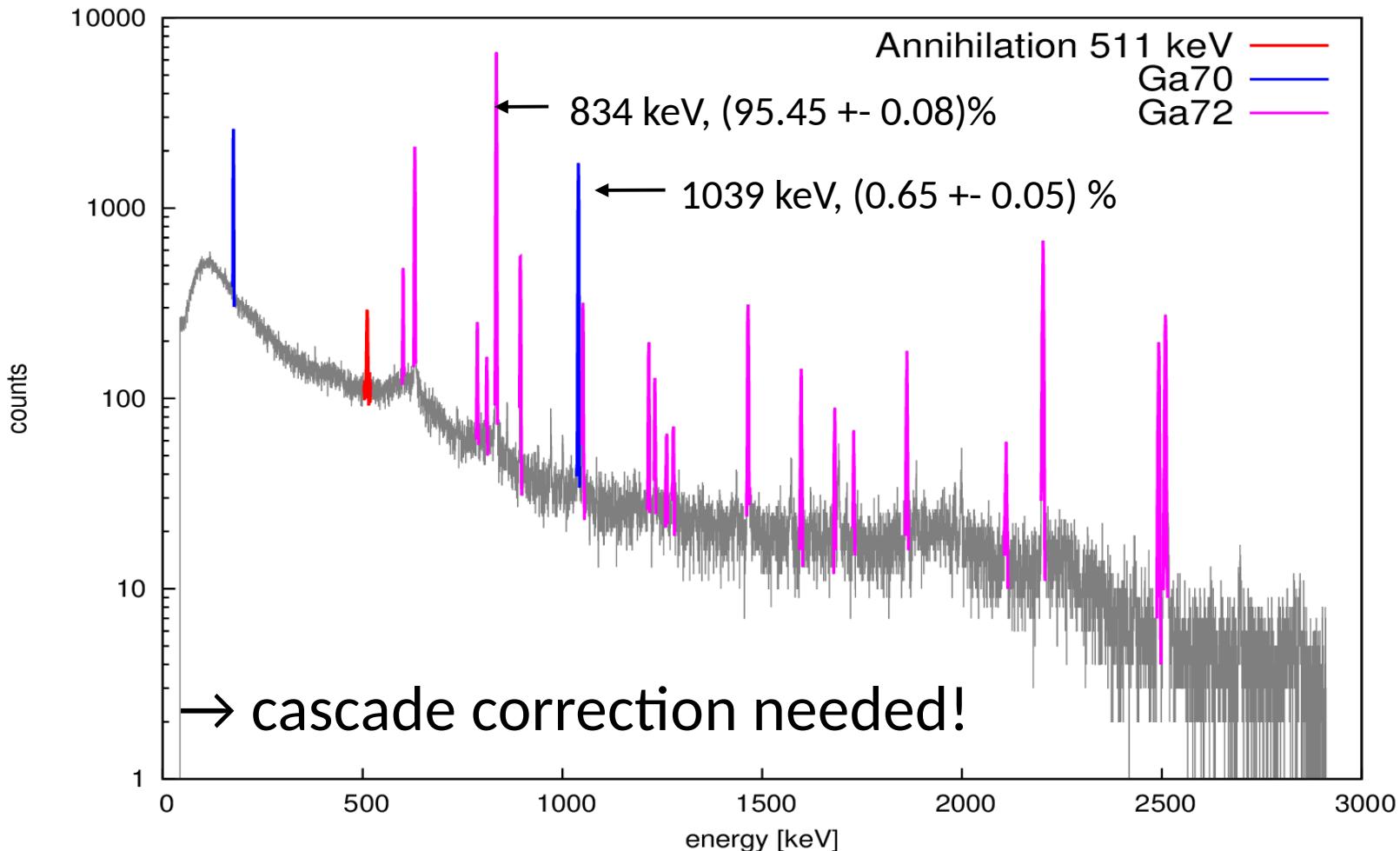


# Measured spectrum



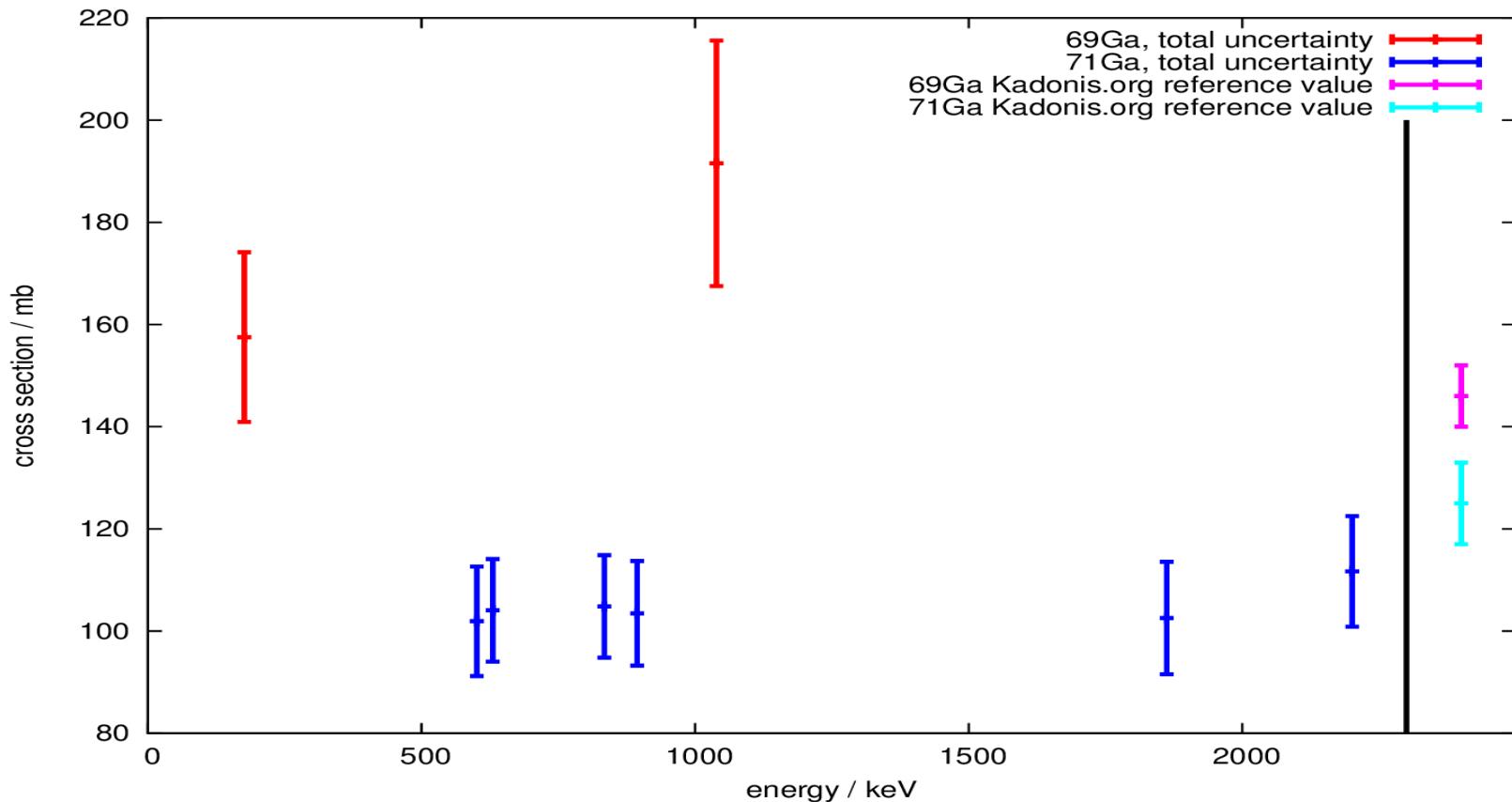


# Measured spectrum





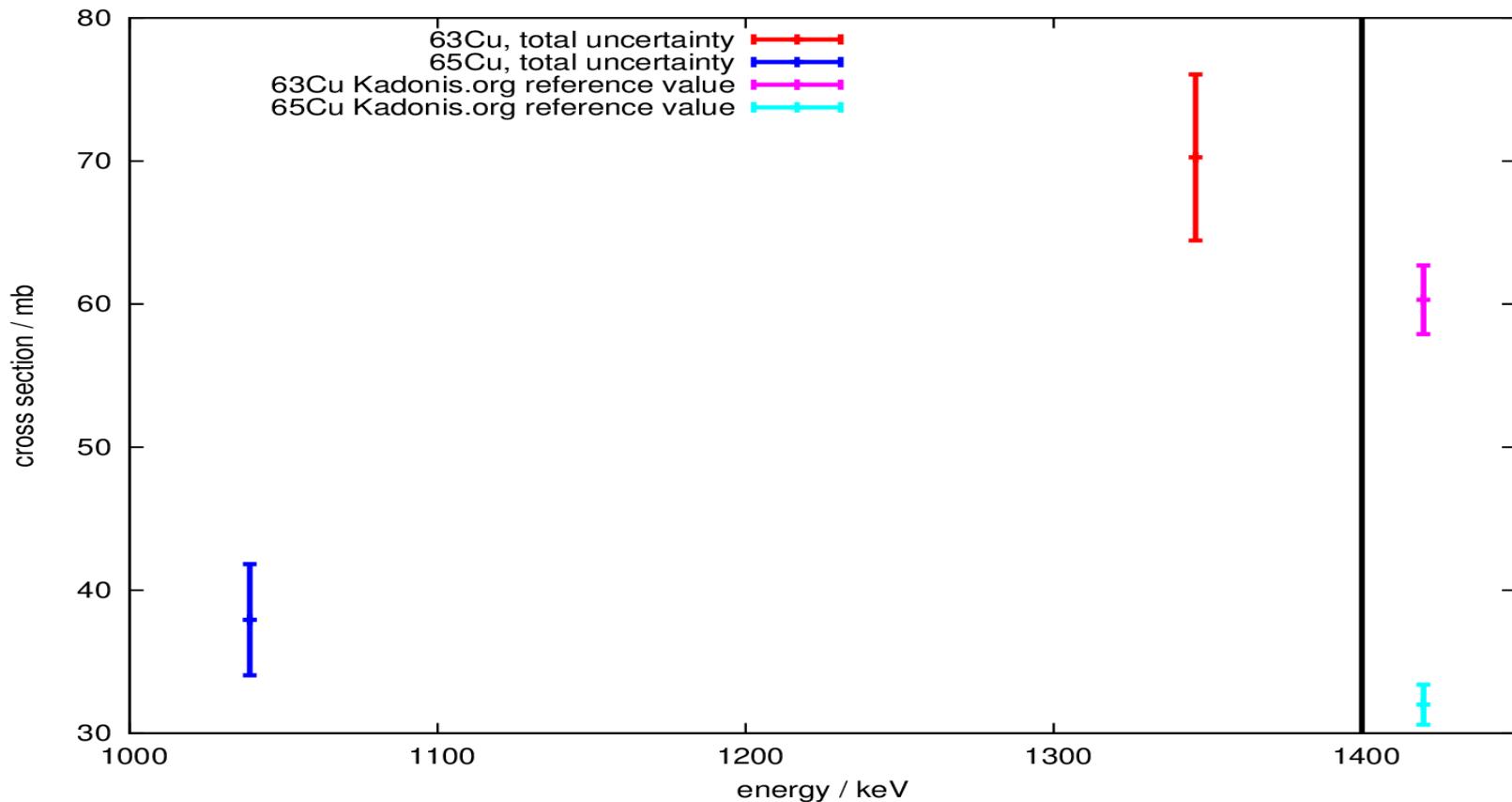
## Ga Cross sections $kT = 25$ keV



Main uncertainty: detector efficiency  $\sim 4\%$ , neutron flux  $\sim 6.5\%$ ,  
cascade simulation  $\sim 6\%$ ;  $^{69}\text{Ga}$ : gamma intensity  $\sim 7.7\%$

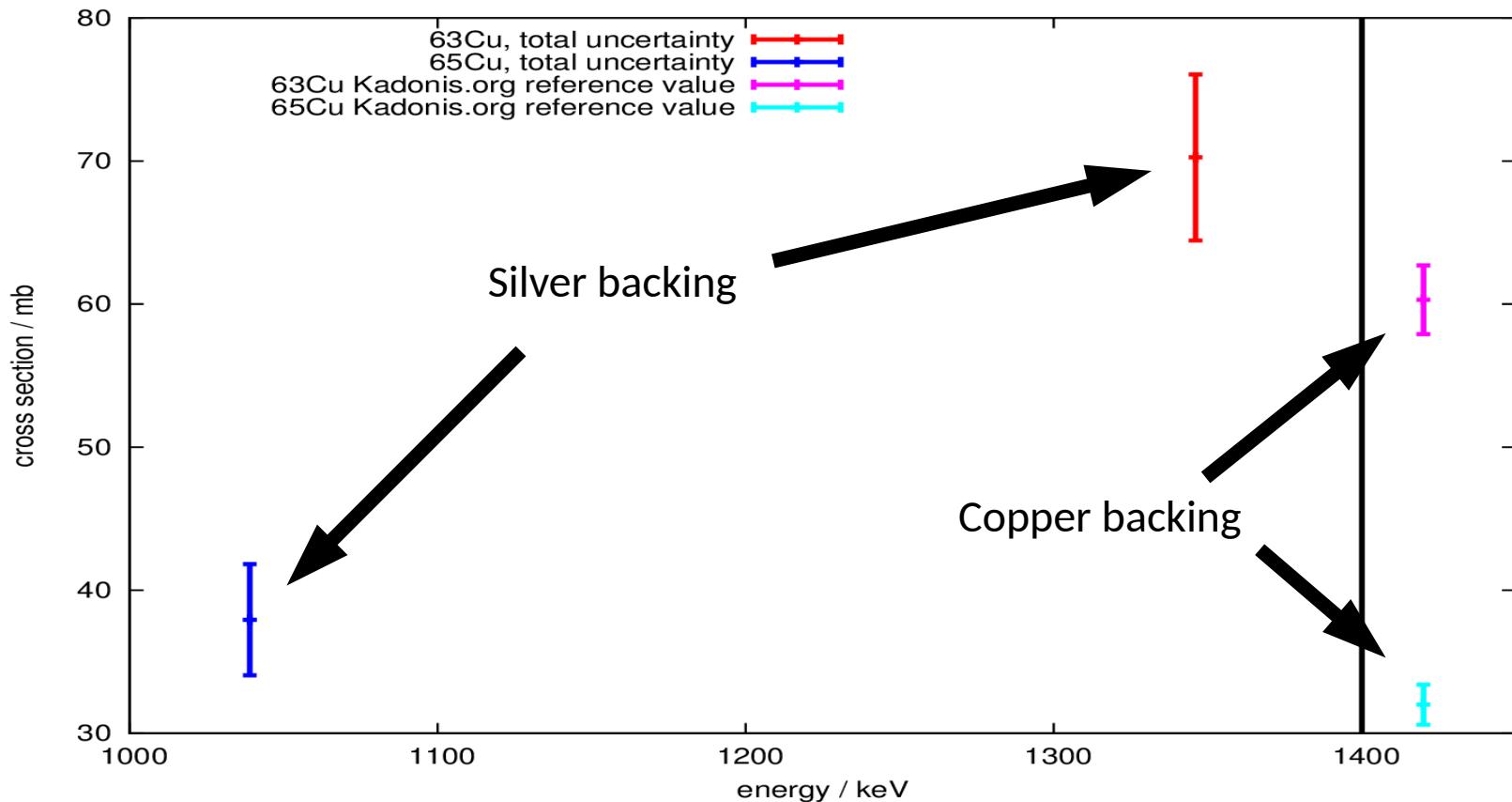


## Cu Cross sections $kT = 25$ keV



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cascade simulation  $\sim 6\%$ ;

# Cu Cross sections $kT = 25$ keV



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cascade simulation  $\sim 6\%$ ;



# Cu/Ag backing simulation

- Idea / possible explanation:

Capture neutrons in Cu backing at resonance energies

→ measured integrated cross-sections decrease

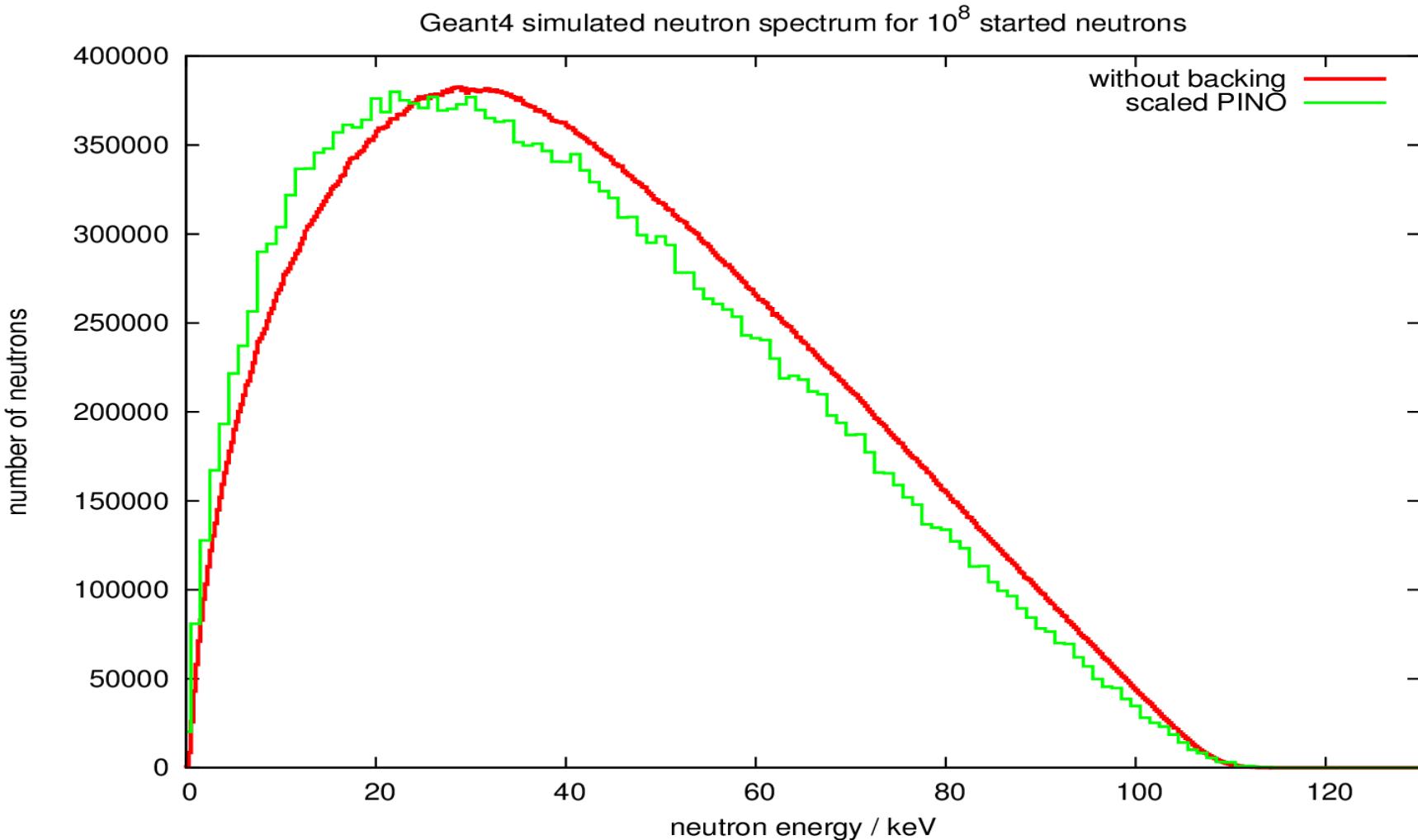
- correction factor:

$^{63}\text{Cu}$ : 0.8206

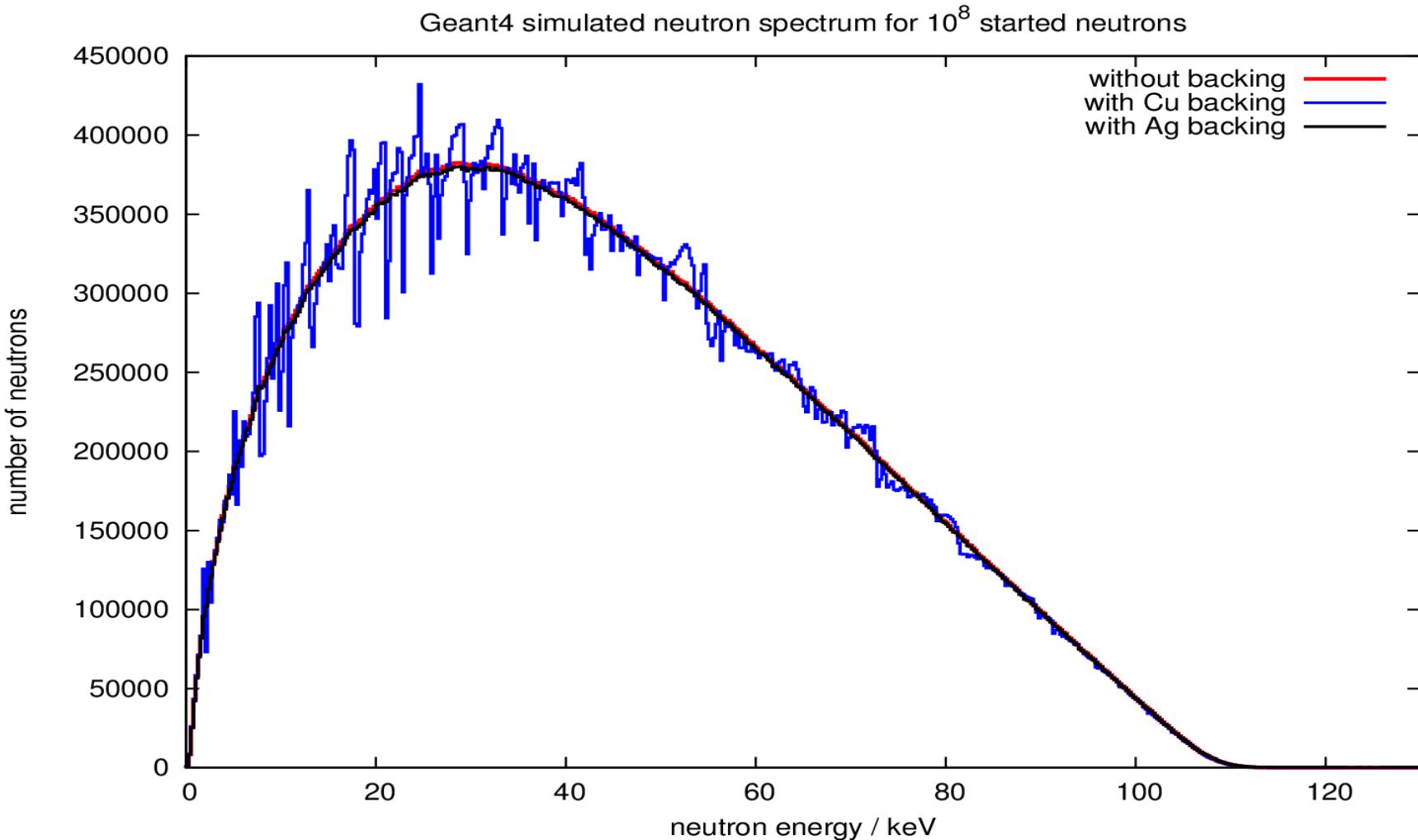
$^{65}\text{Cu}$ : 0.8778

$$\frac{\left( \frac{\# \text{Cu}_i}{\# \text{Au}} \right)_{\text{Cu backing}}}{\left( \frac{\# \text{Cu}_i}{\# \text{Au}} \right)_{\text{Ag backing}}}$$

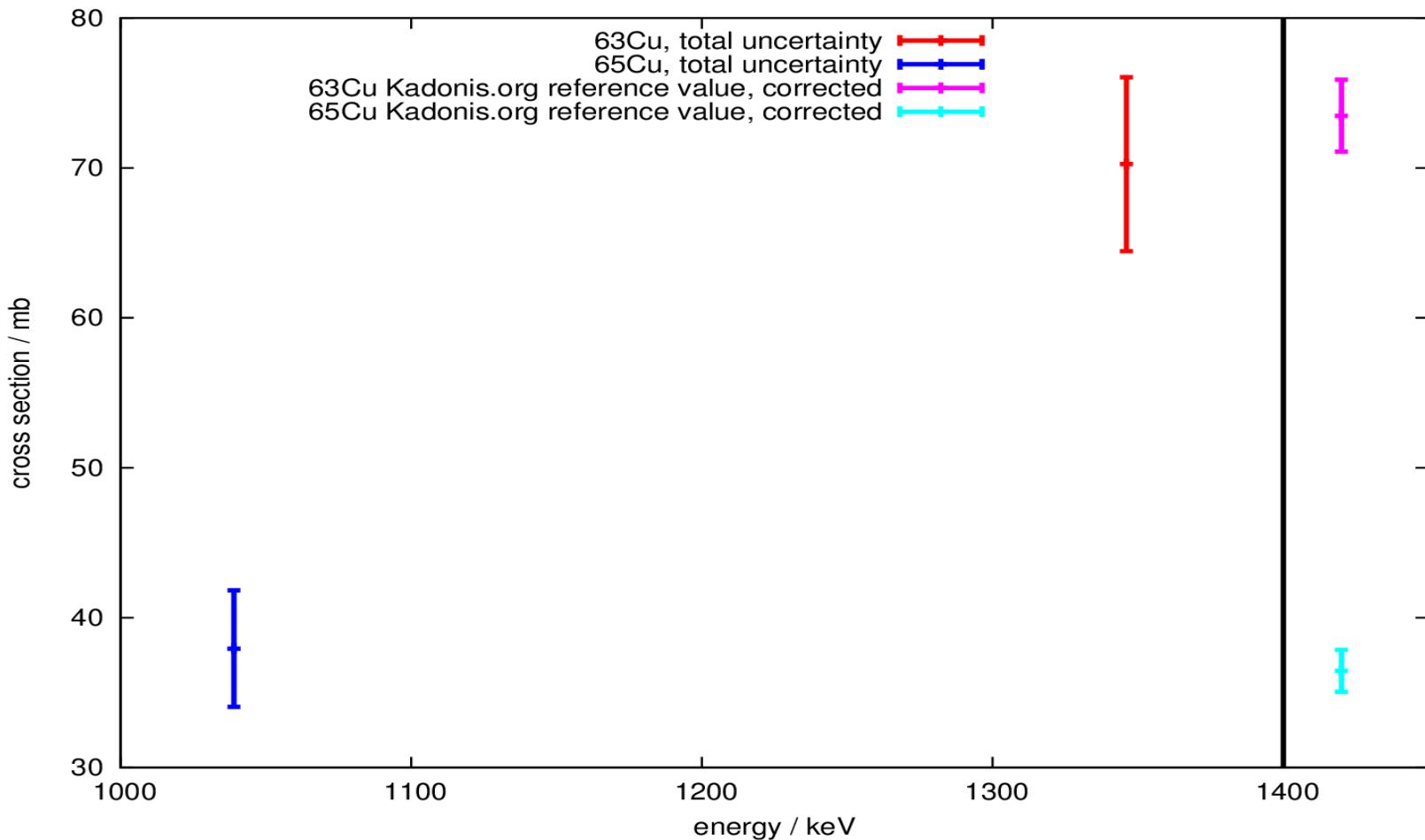
# Cu/Ag backing simulation



# Cu/Ag backing simulation



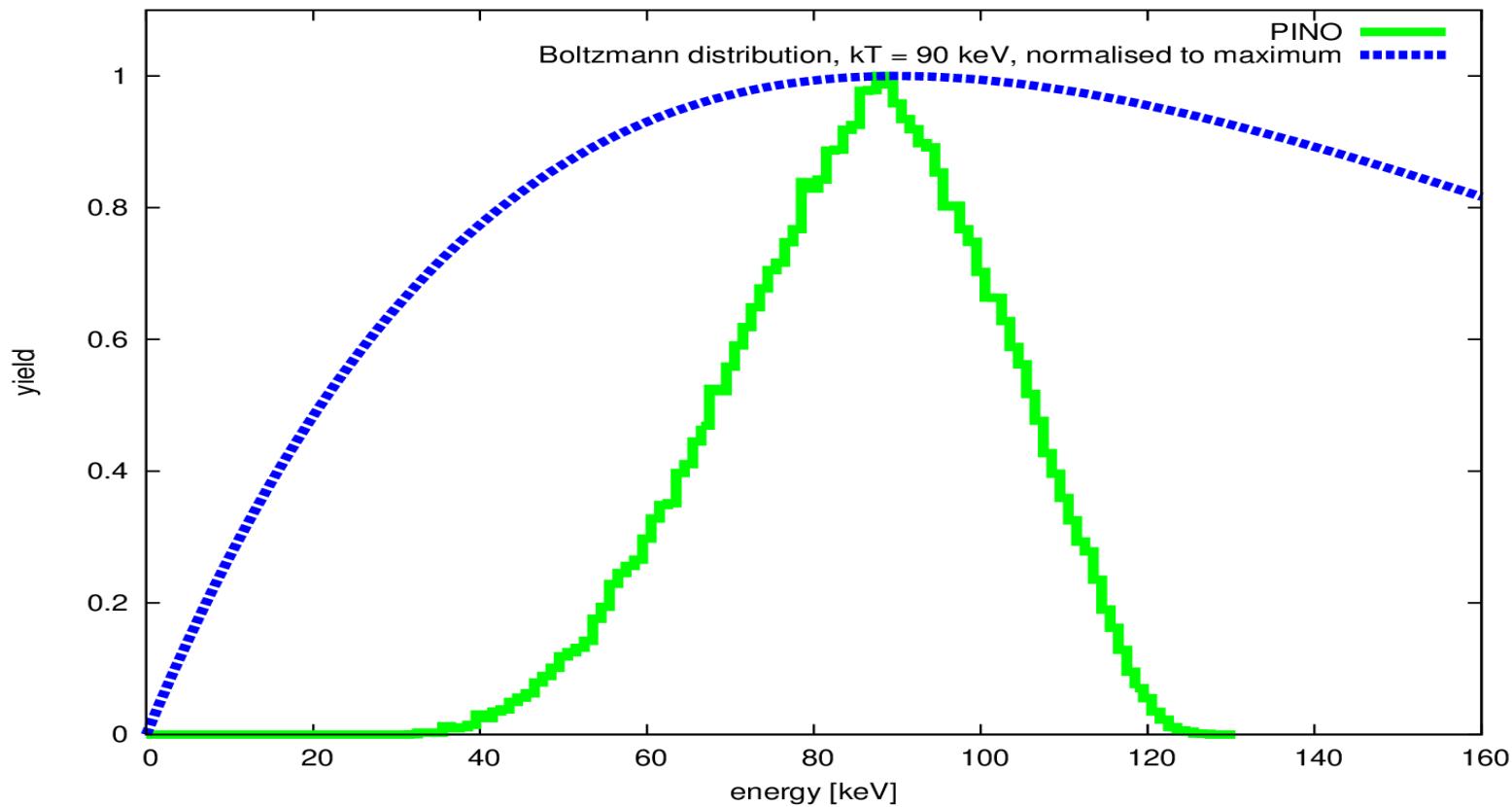
# Cu Cross sections $kT = 25$ keV (corrected)





# Neutronspectrum at 90 keV

$E_p = 1920$  keV; thickness Li: 1  $\mu\text{m}$ ; distance Li-sample: 9.7 mm



<http://exp-astro.physik.uni-frankfurt.de/pino/>



# Neutronspectrum at 90 keV

- Idea:

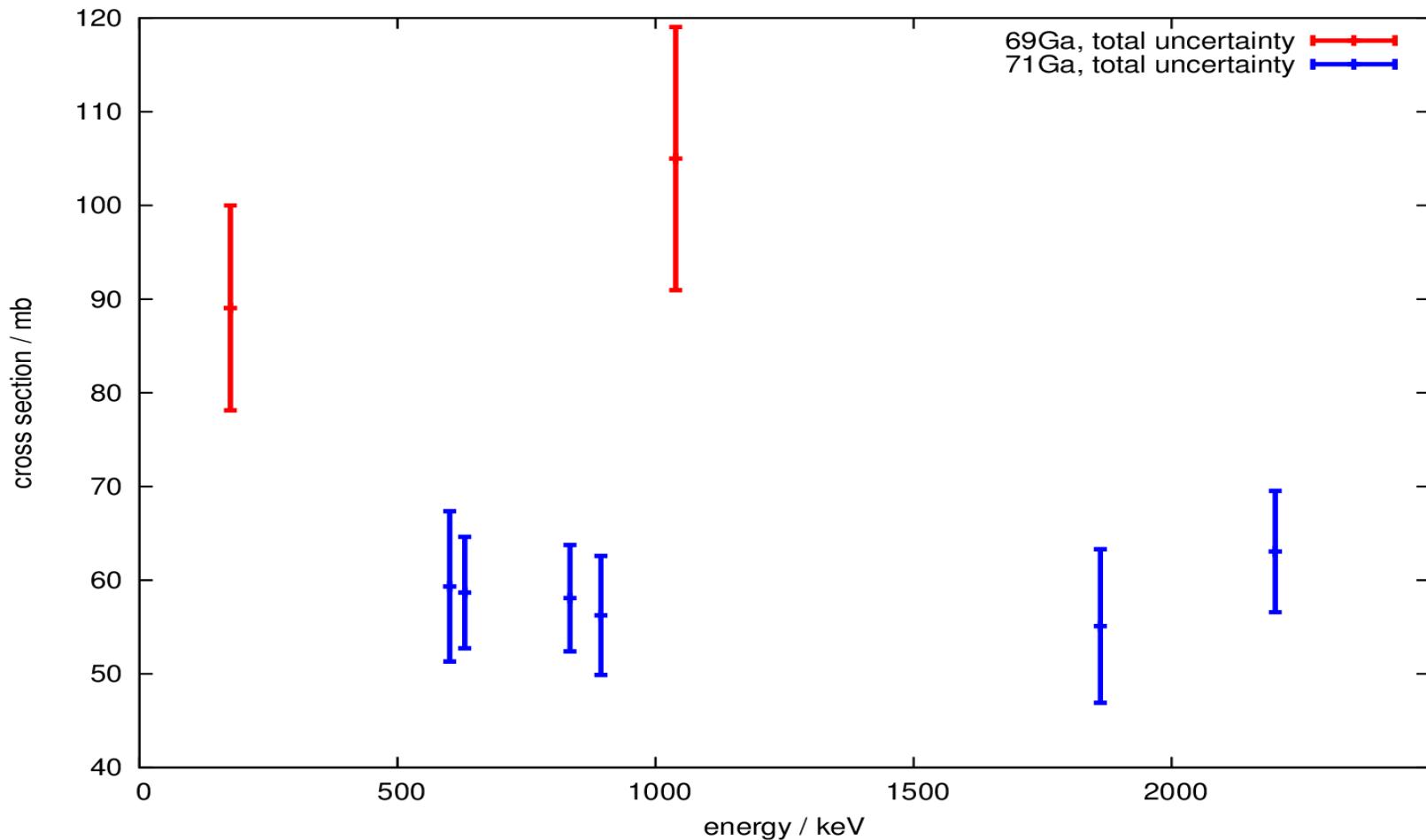
Measure directly in energy range to  
cover possible resonances

Fit energy dependence on data points  
at 25 and 90 keV

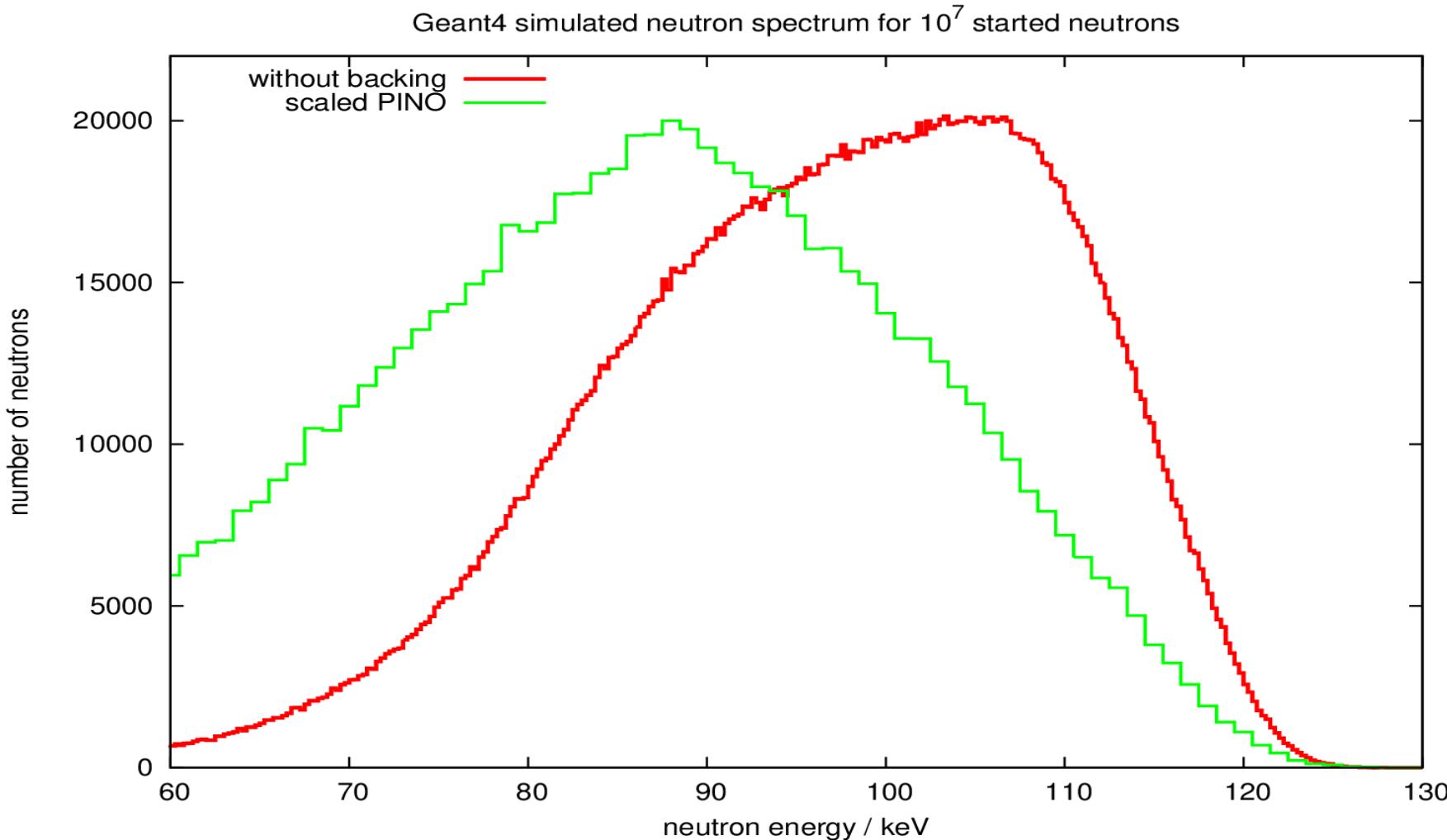
Improve MACS extrapolation



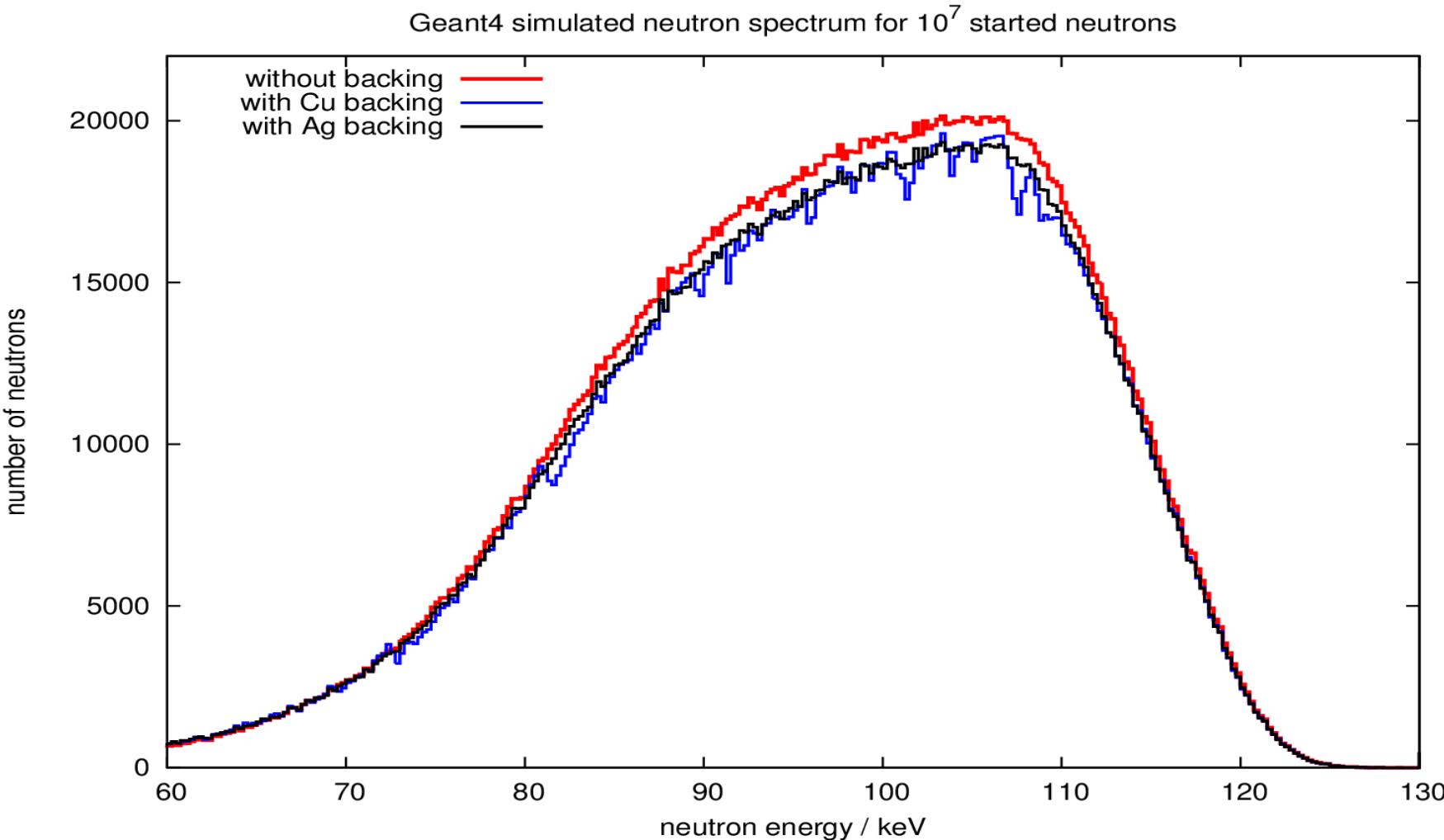
## Ga Cross sections 90 keV



# Cu/Ag backing simulation 90 keV



# Cu/Ag backing simulation 90 keV





# Summary

- performed Cu and Ga activation measurements at 25 keV and 90 keV at IRMM, Geel, to determine  $(n,\gamma)$  cross-sections
- showed influence of backing on neutron spectrum and solved difference between activation and ToF cross-sections of Cu
- presented idea to improve extrapolated MACS



# Next Steps

- solve mentioned issues
- fit of energy dependence on measured values
- calculate Maxwellian Averaged cross sections (MACS)
- network calculations for astrophysical implication of new MACS