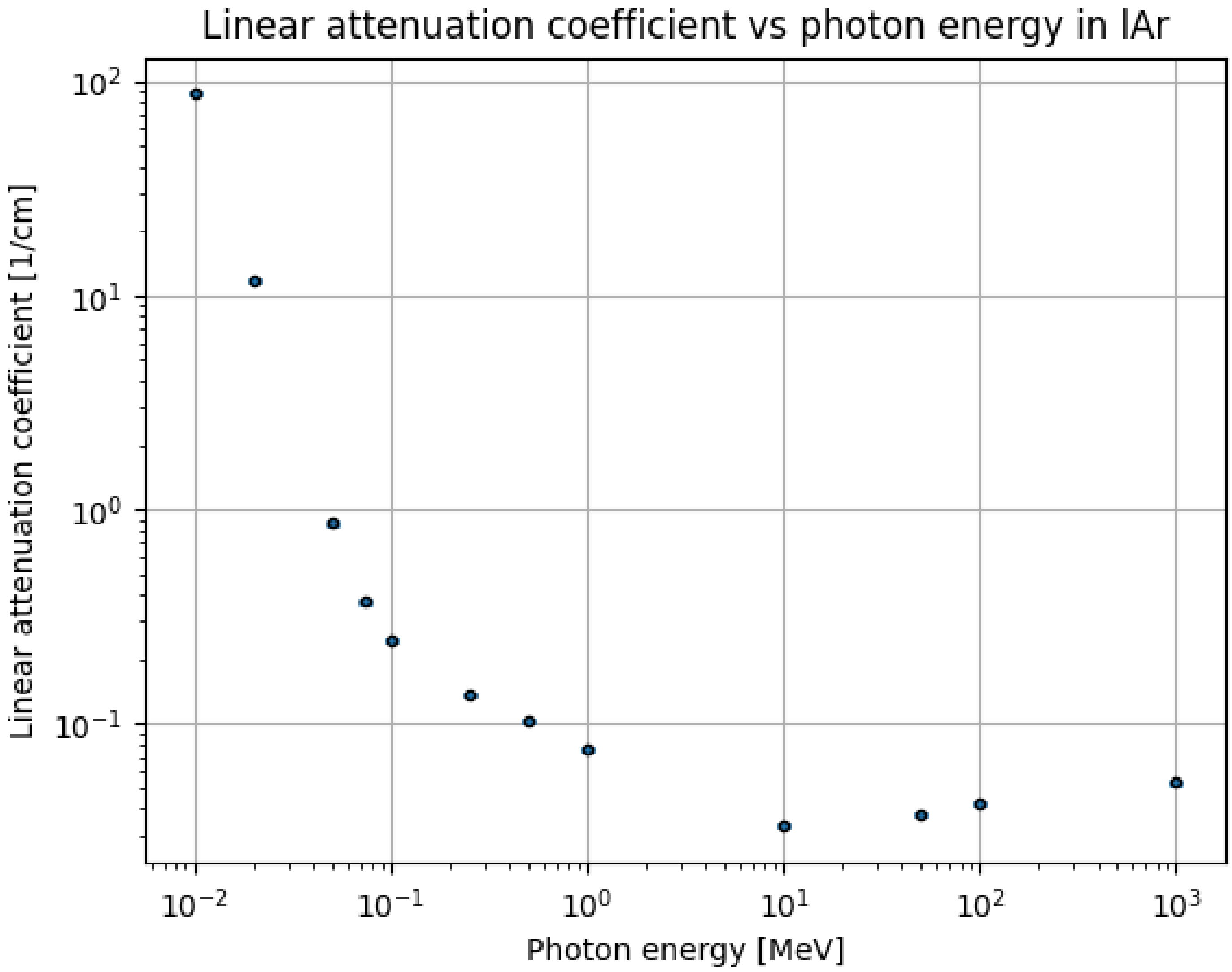
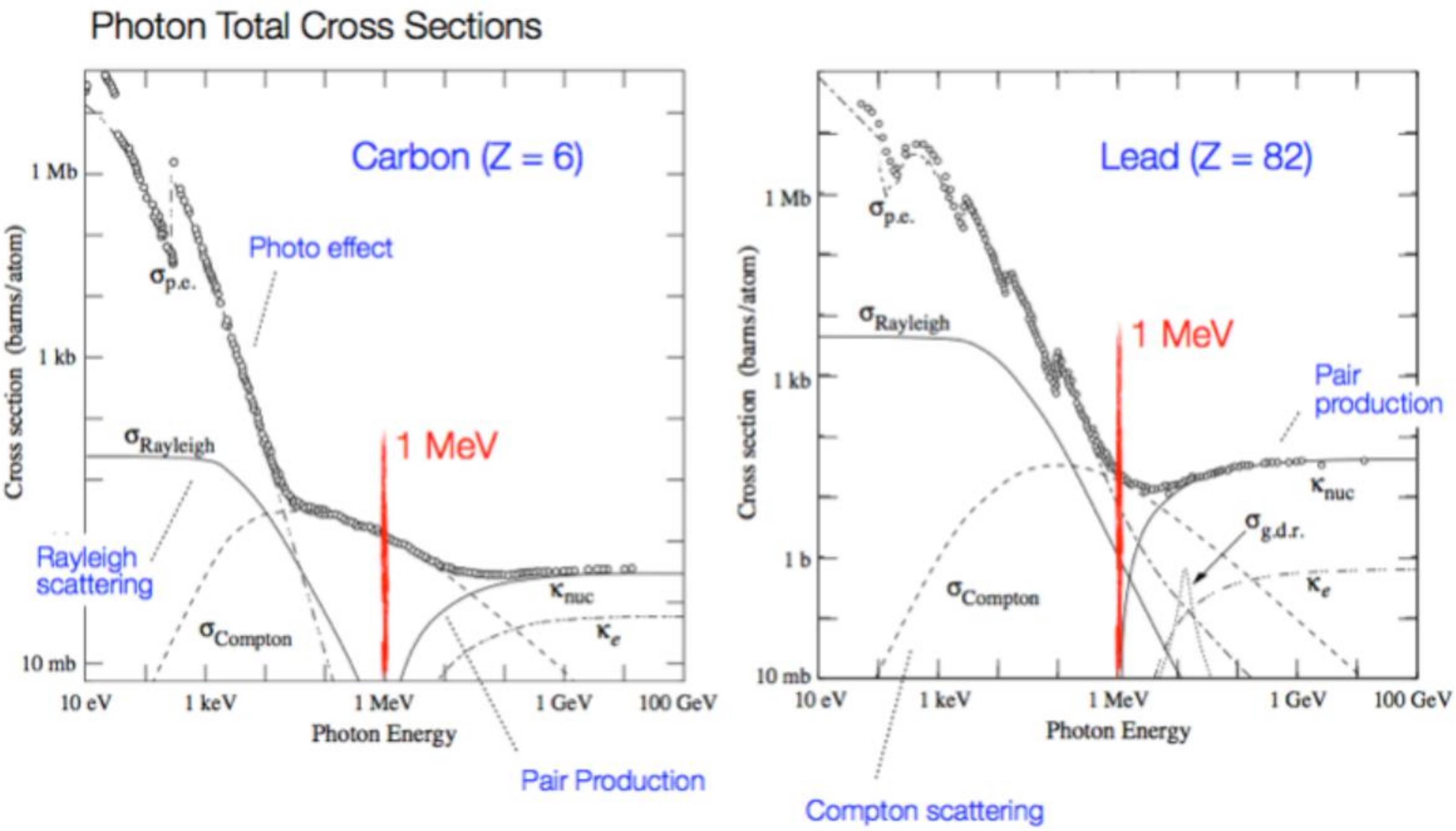
Photon Attenuation Coefficient In Liquid Argon

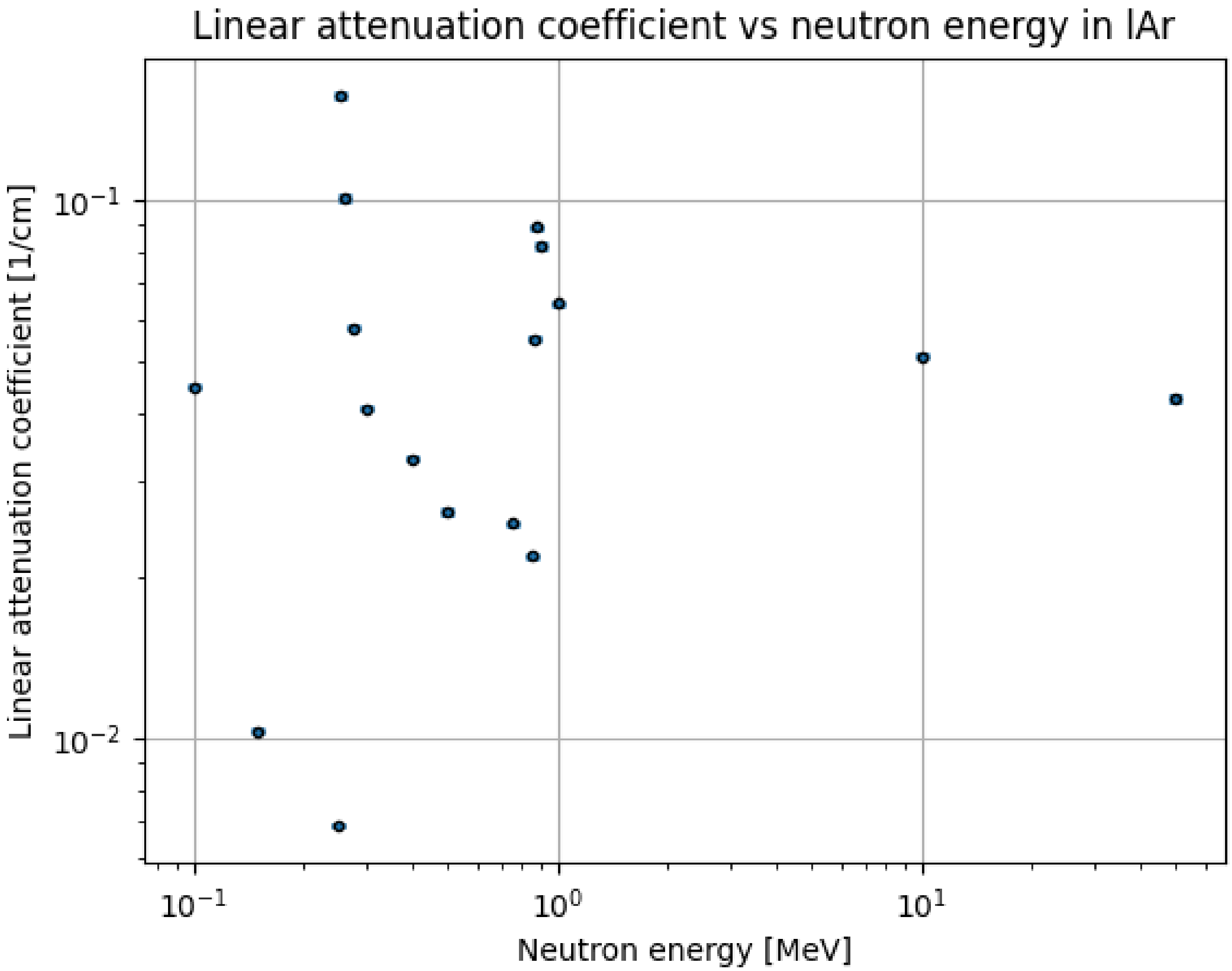


In the graph we can see a small rise in the attenuation coefficient starting around 1MeV, and after checking out photon cross section in the literature, this makes sense, since photon cross section and photon attenuation length are highly correlated.



Argon has a Z =18, and so it lies somewhere between Carbon and Lead, where we see a rise around 50 MeV and 5MeV respectively. Seeing as we have a rise around 10MeV, it seems to fit with the literature.

Neutron Attenuation Coefficient In Liquid Argon



n – ^{40}Ar Cross Sections

- We simulate neutron interaction in liquid argon of 1mm thickness (thin target, $t \ll \frac{1}{\mu}$)
- Now we aim to find the cross sections of the different interactions between neutrons and argon.

First we will show how the cross section is extracted from the geant4 simulation results:

We define –

$N_{incident} = number\ of\ incident\ particles$
$N_{events} = number\ of\ neutron\ - liquid\ argon\ interactions$

$n = number\ of\ argon\ atoms\ per\ unit\ volume = \frac{\rho N_{avogadro}}{A}$ where A=40 is the atomic mass number of argon, and ρ = 1.4 g/cm^3 is the mass density of liquid argon.

$x = thickness\ of\ the\ liquid\ argon$

Thus, we can write $N_{events} = N_{incident} \cdot nx \cdot \sigma$

And so

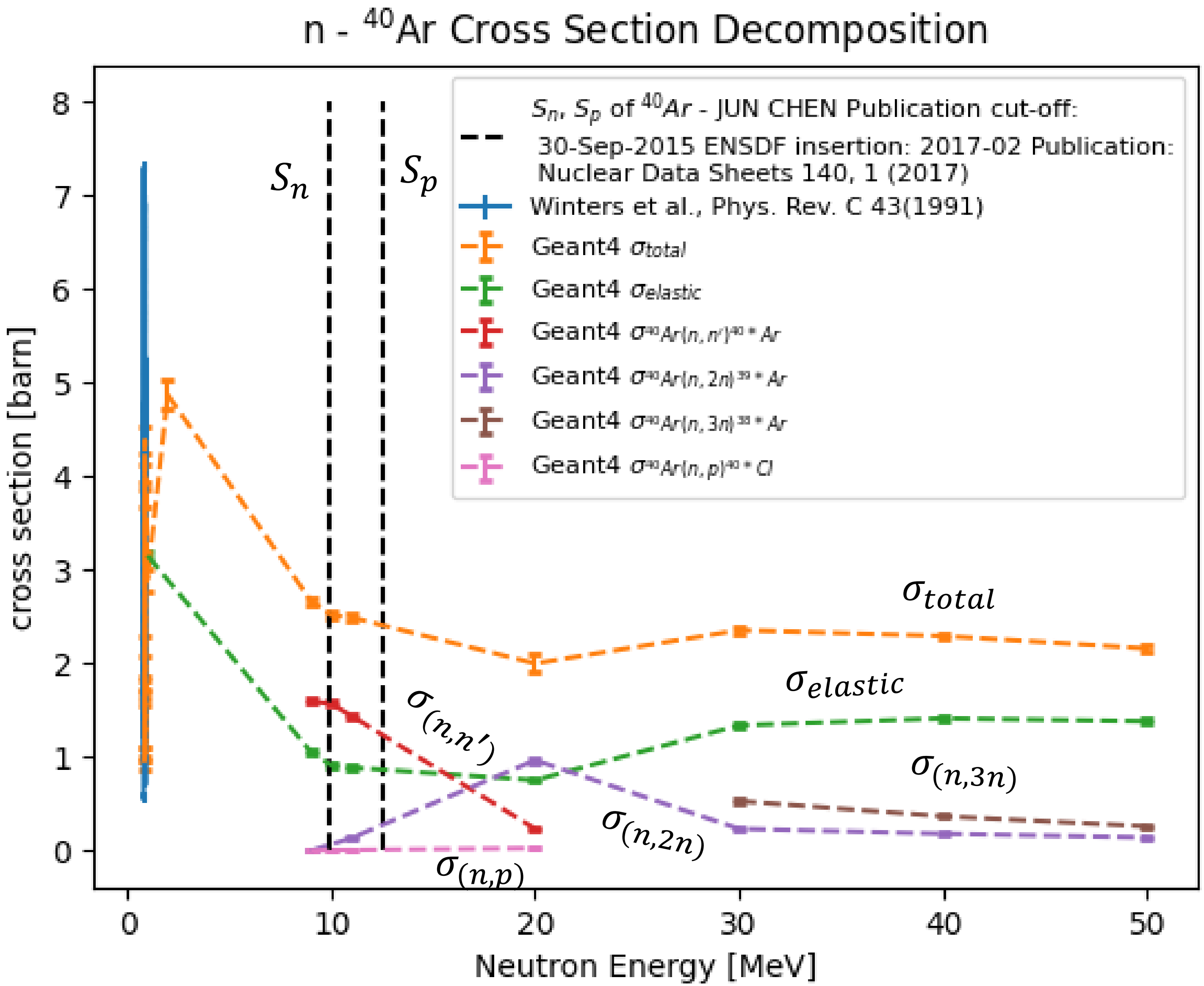
$$\sigma[barn] = 10^{24} \frac{N_{events} A}{N_{incident} \rho x N_{avogadro}}$$

$$d\sigma[barn] = 10^{24} \cdot \frac{A}{N_{avogadro} \rho x} \cdot \frac{N_{events}}{N_{incident}} \cdot \sqrt{\frac{1}{N\_events} + \frac{1}{N\_incident}}$$

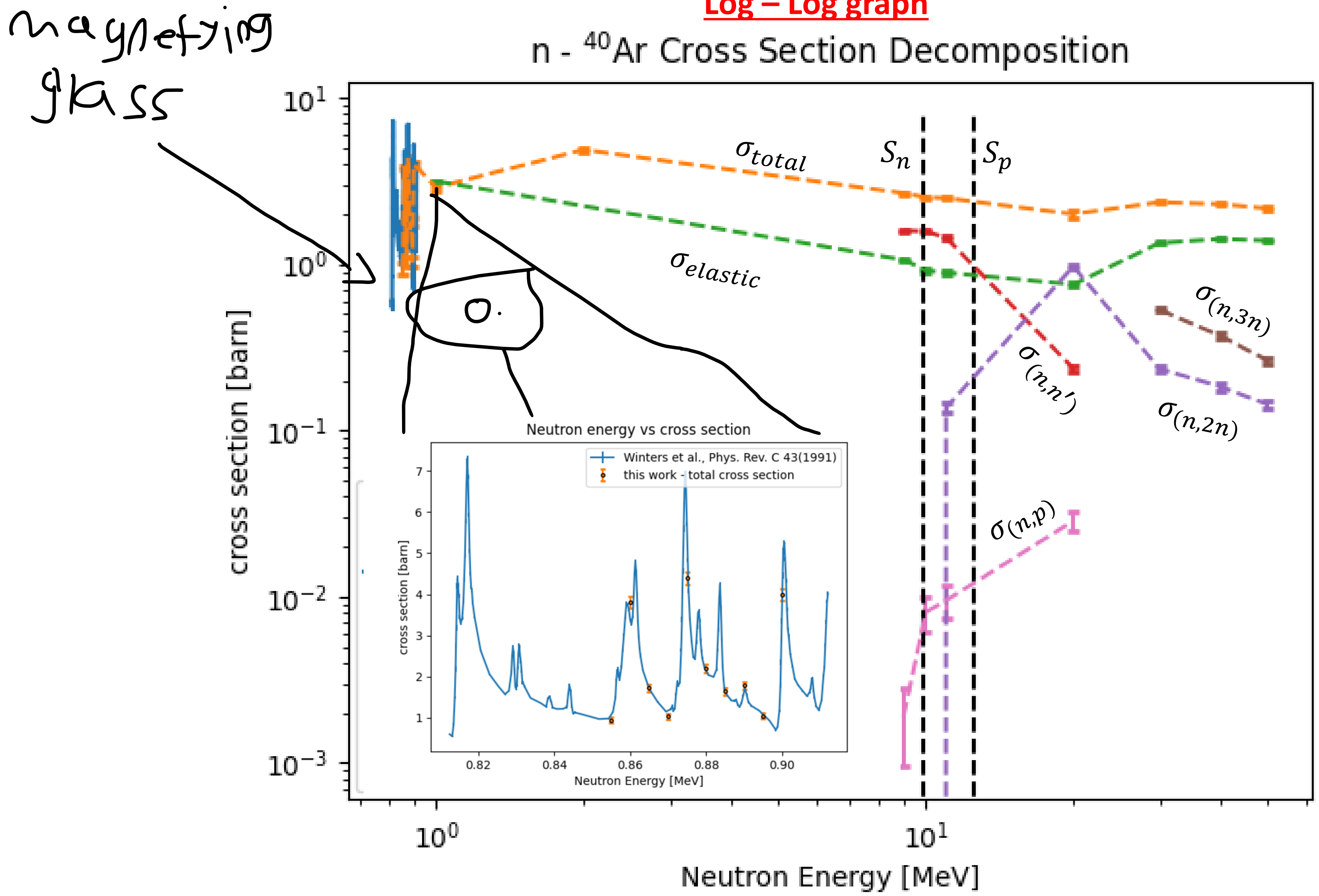
- Note that these equations hold only if the target is thin enough, and so we set the argon thickness such that each neutron interacts once at most.

$n - {}^{40}Ar$ Cross Sections

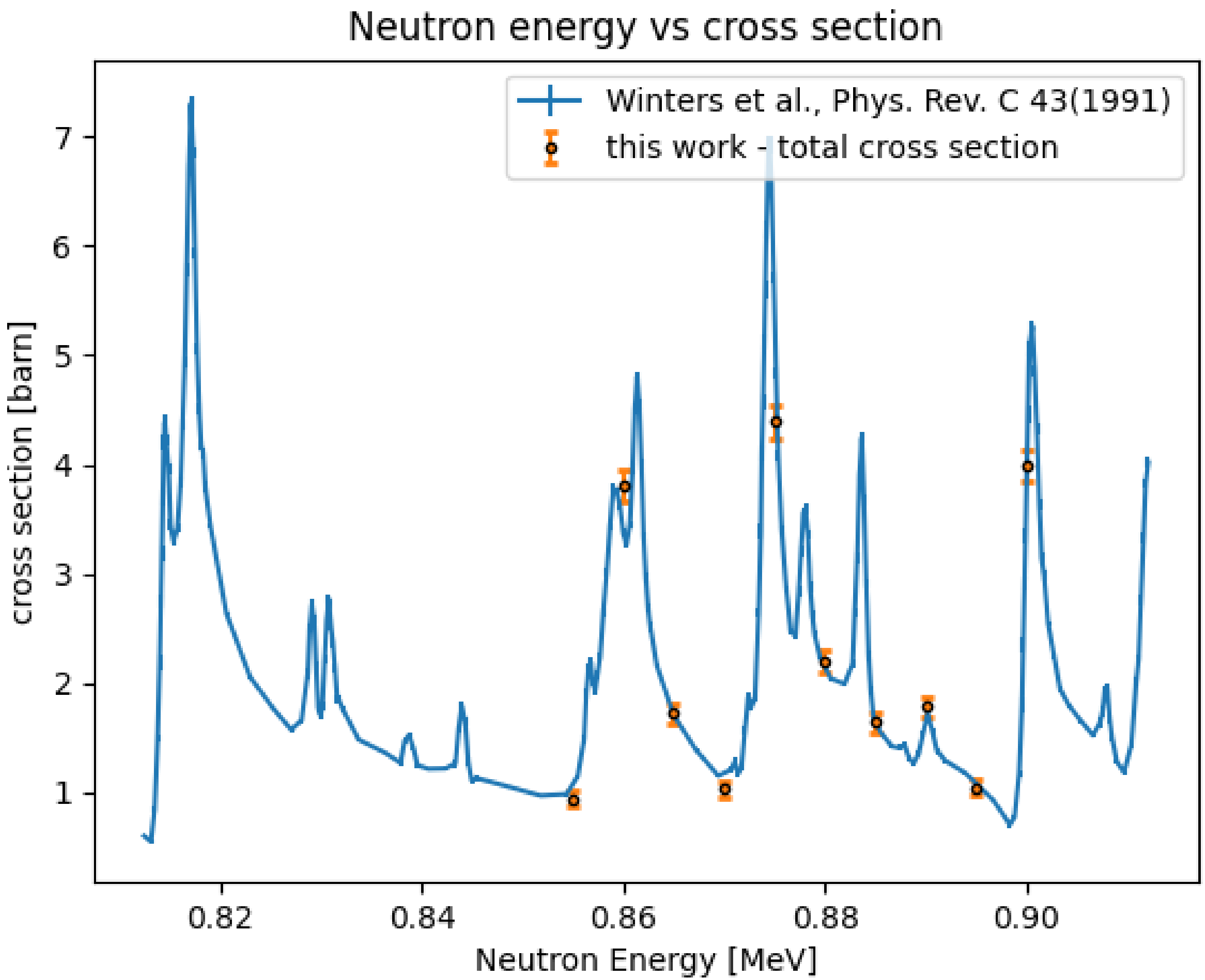
Dashes line aren't interpolation – only used to guide the eye



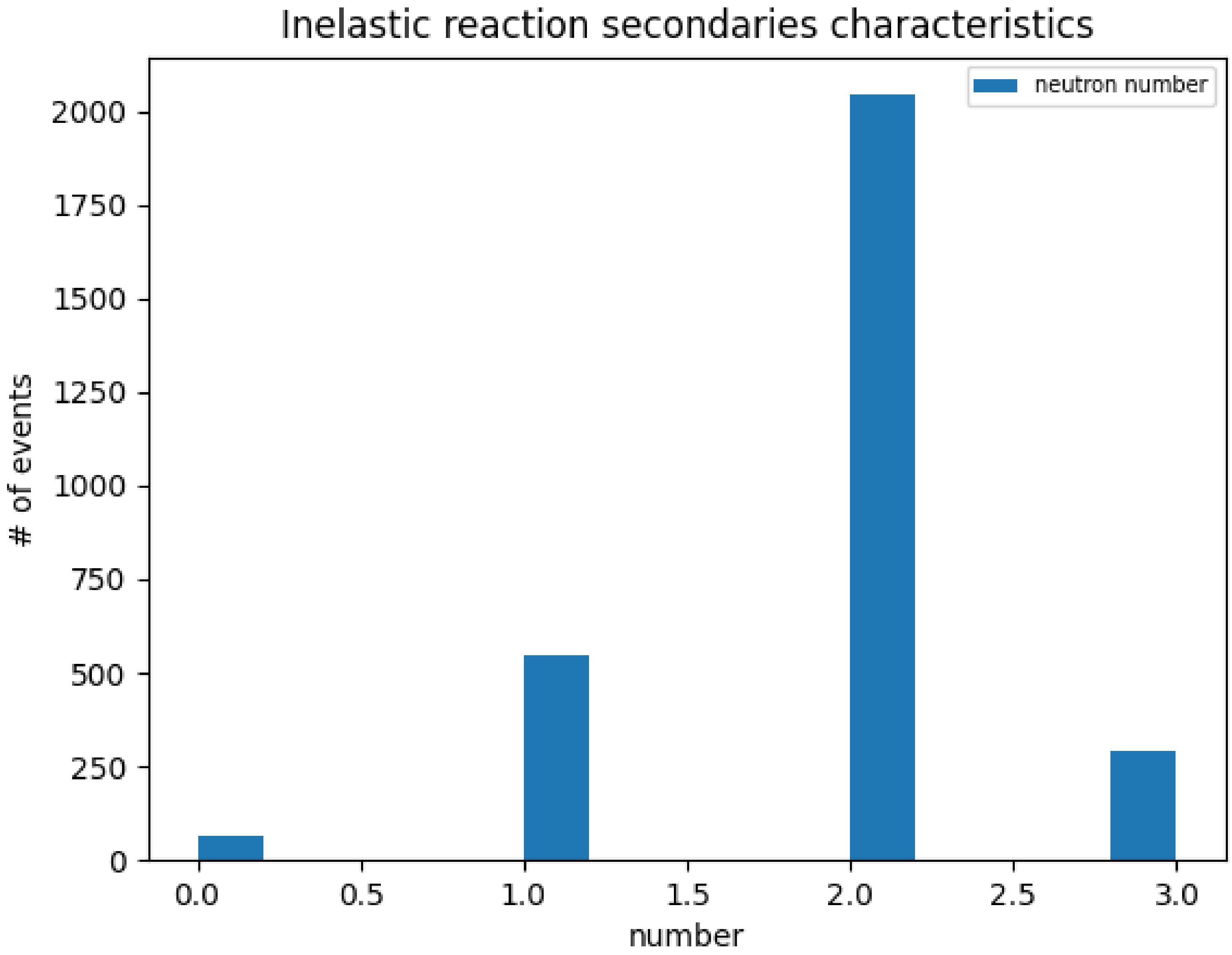
Log – Log graph

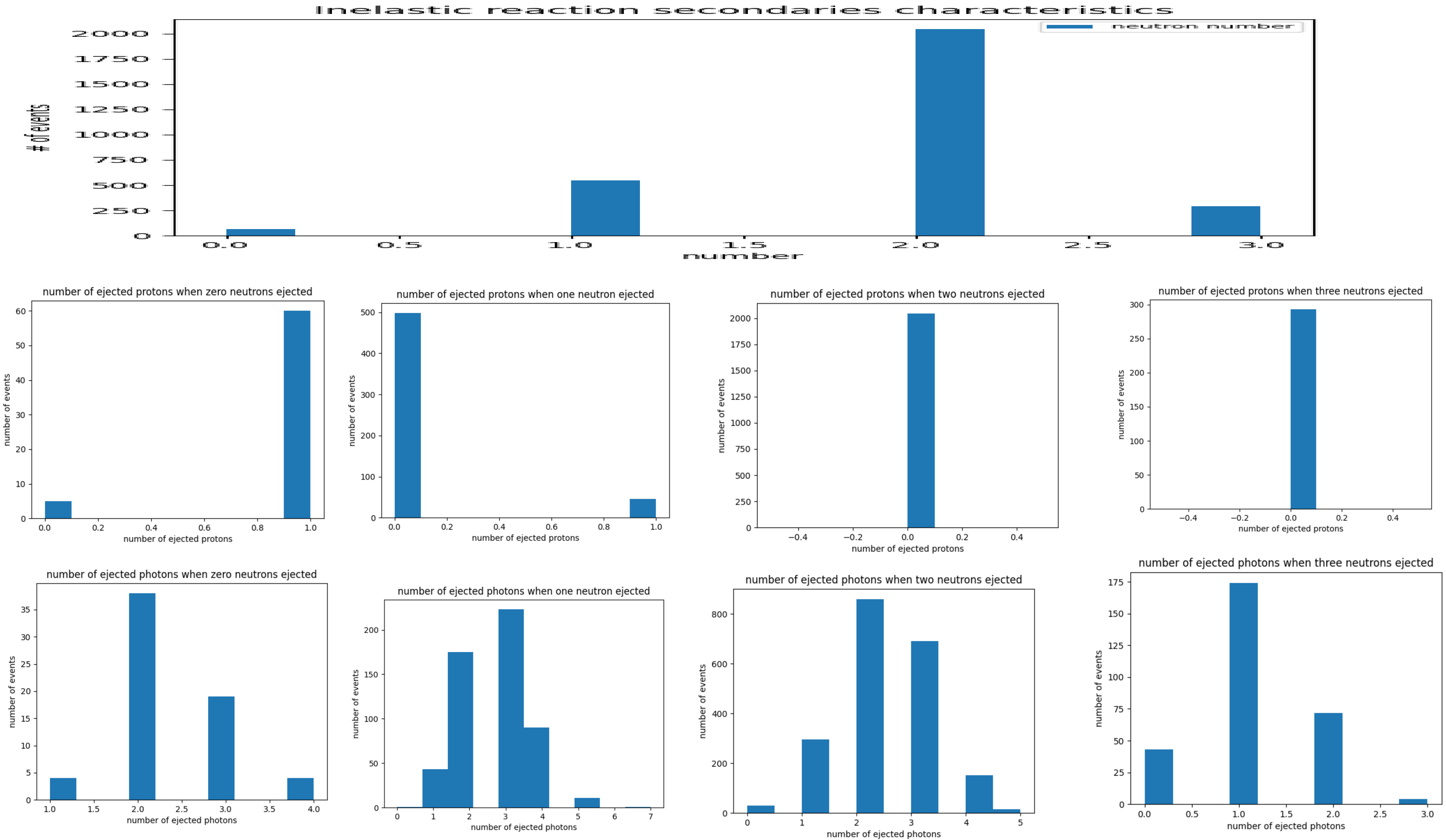


$n - {}^{40}Ar$ Total Cross Section Comparison

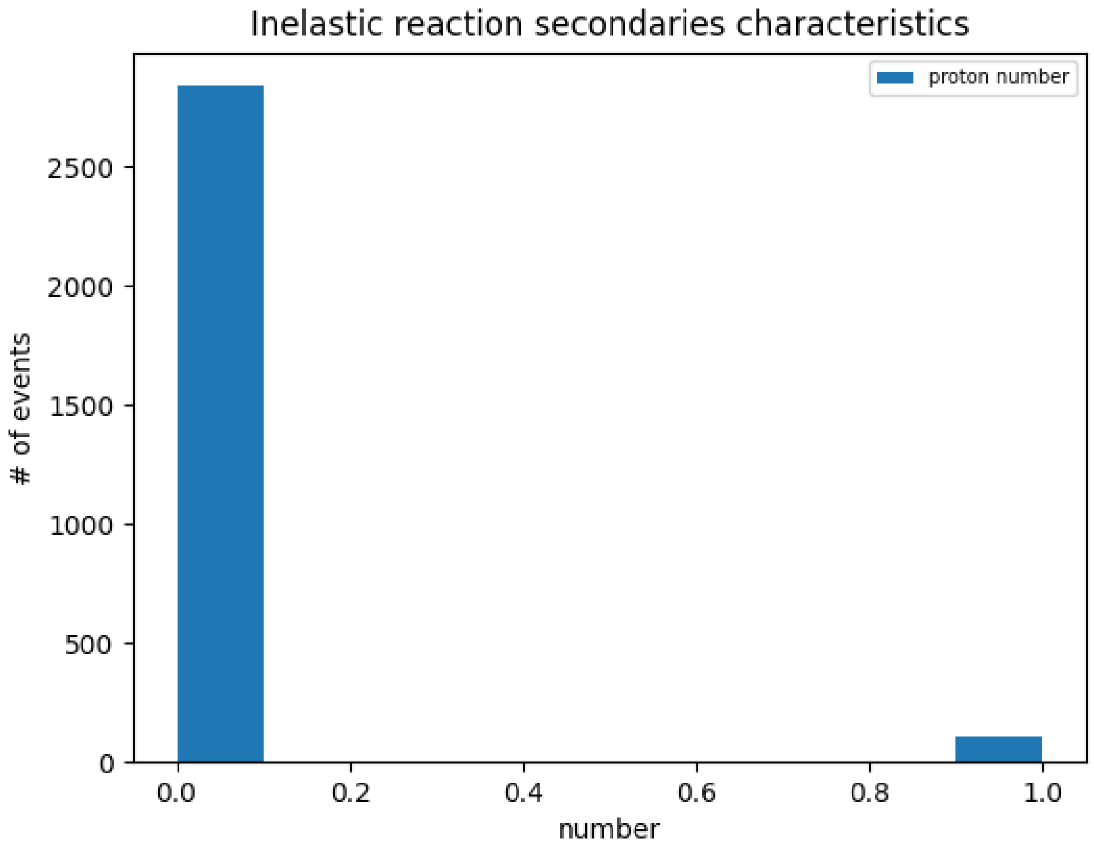


Number of ejected neutrons from Ar40 when hit by 20MeV neutrons

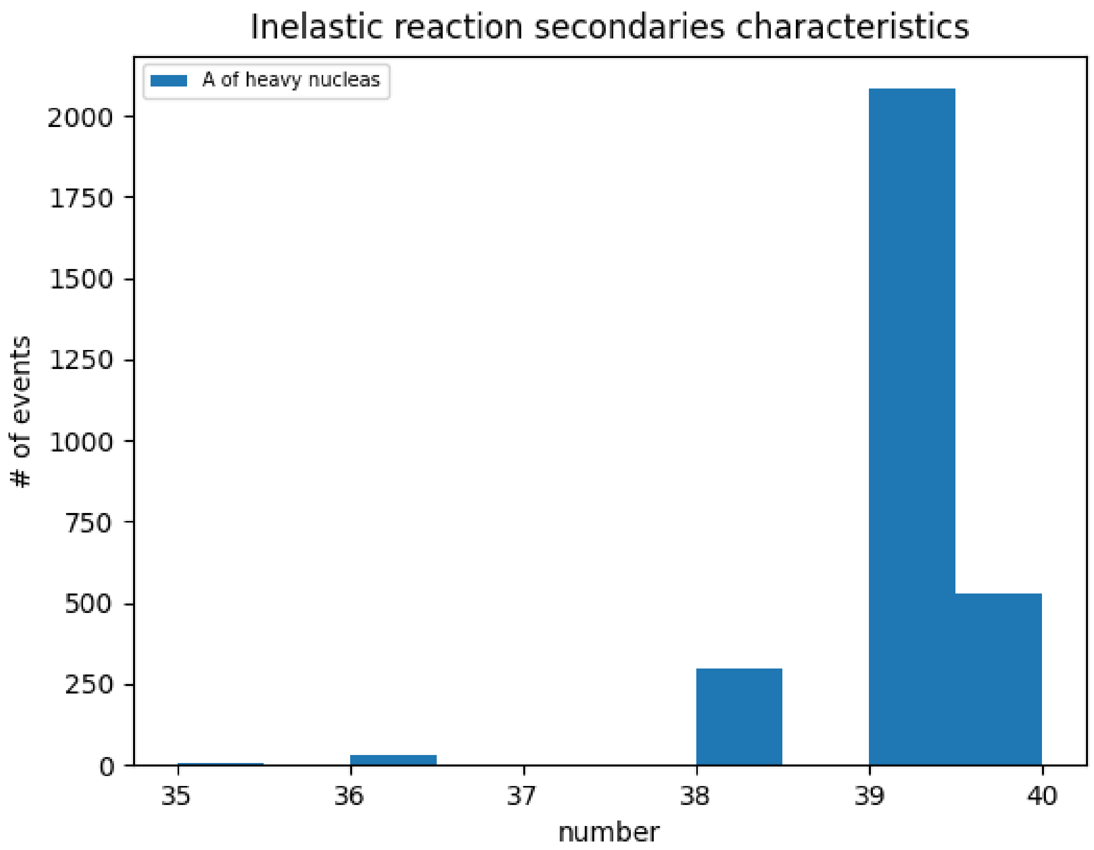



Inelastic reaction secondaries characteristics
neutron number
# of events
number
number of ejected protons when zero neutrons ejected
number of ejected protons when one neutron ejected
number of ejected protons when two neutrons ejected
number of ejected protons when three neutrons ejected
number of ejected protons
number of ejected photons when zero neutrons ejected
number of ejected photons when one neutron ejected
number of ejected photons when two neutrons ejected
number of ejected photons when three neutrons ejected
number of ejected photons
number of events

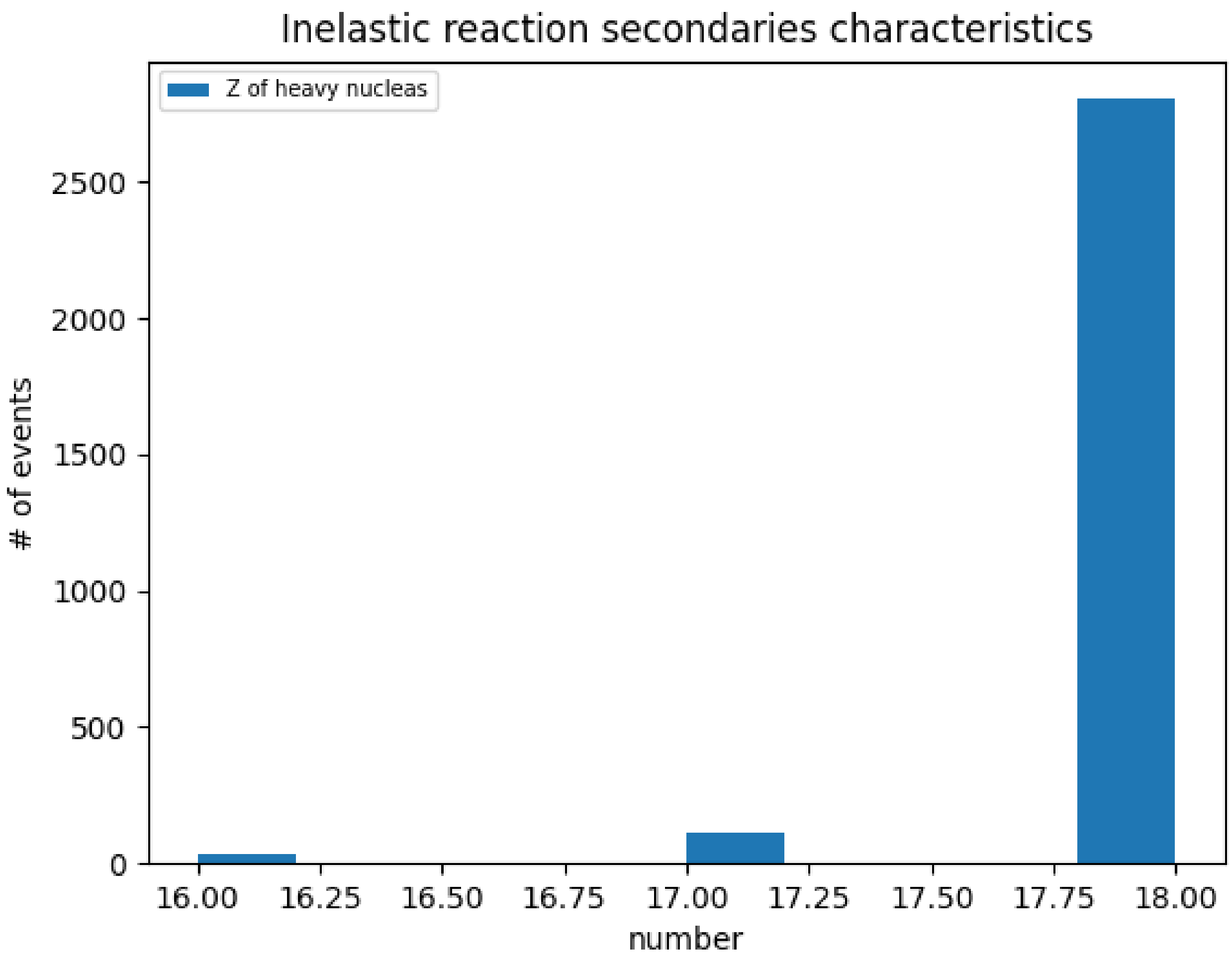
Number of ejected protons distribution



Atomic mass number of heavy nucleus distribution

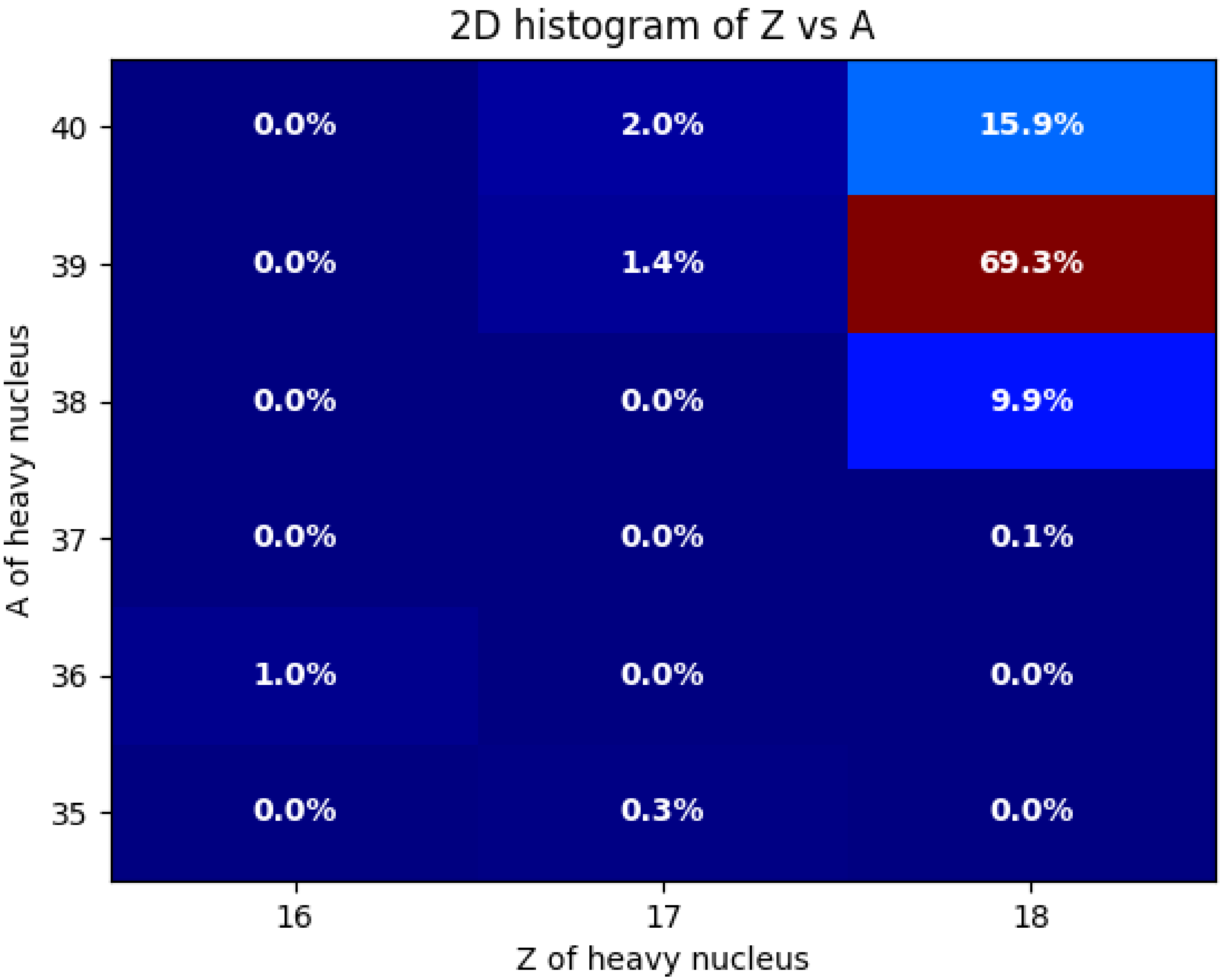


Atomic number of heavy nucleus distribution



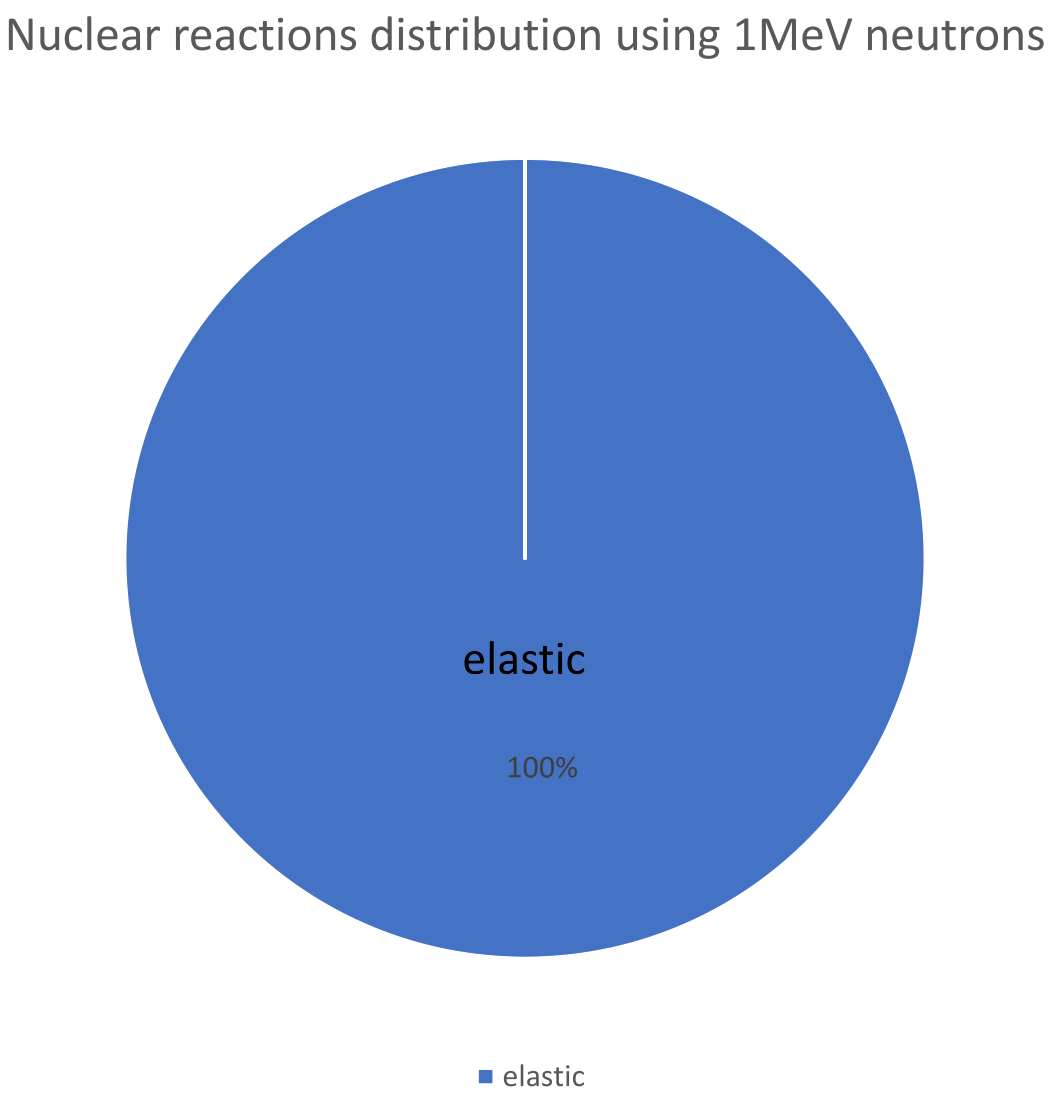
20MeV neutron primaries

Note:
lAr in Geant4 also contains other isotopes of argon in their natural abundance in nature



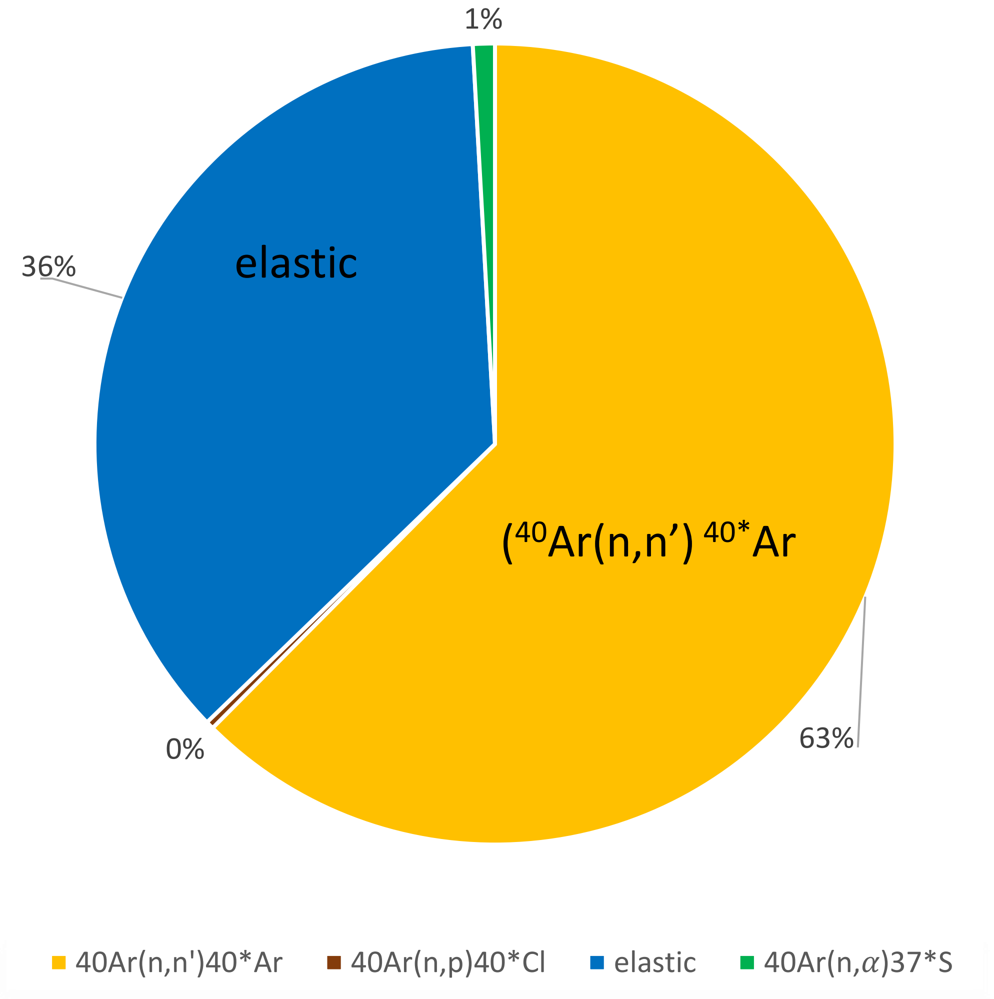
- All Following pie charts represent the distribution of the **first reaction** between the neutrons and the argon.
- In order to simulate only a single reaction the argon target was set to be thin -

$$t \ll \frac{1}{\mu}$$

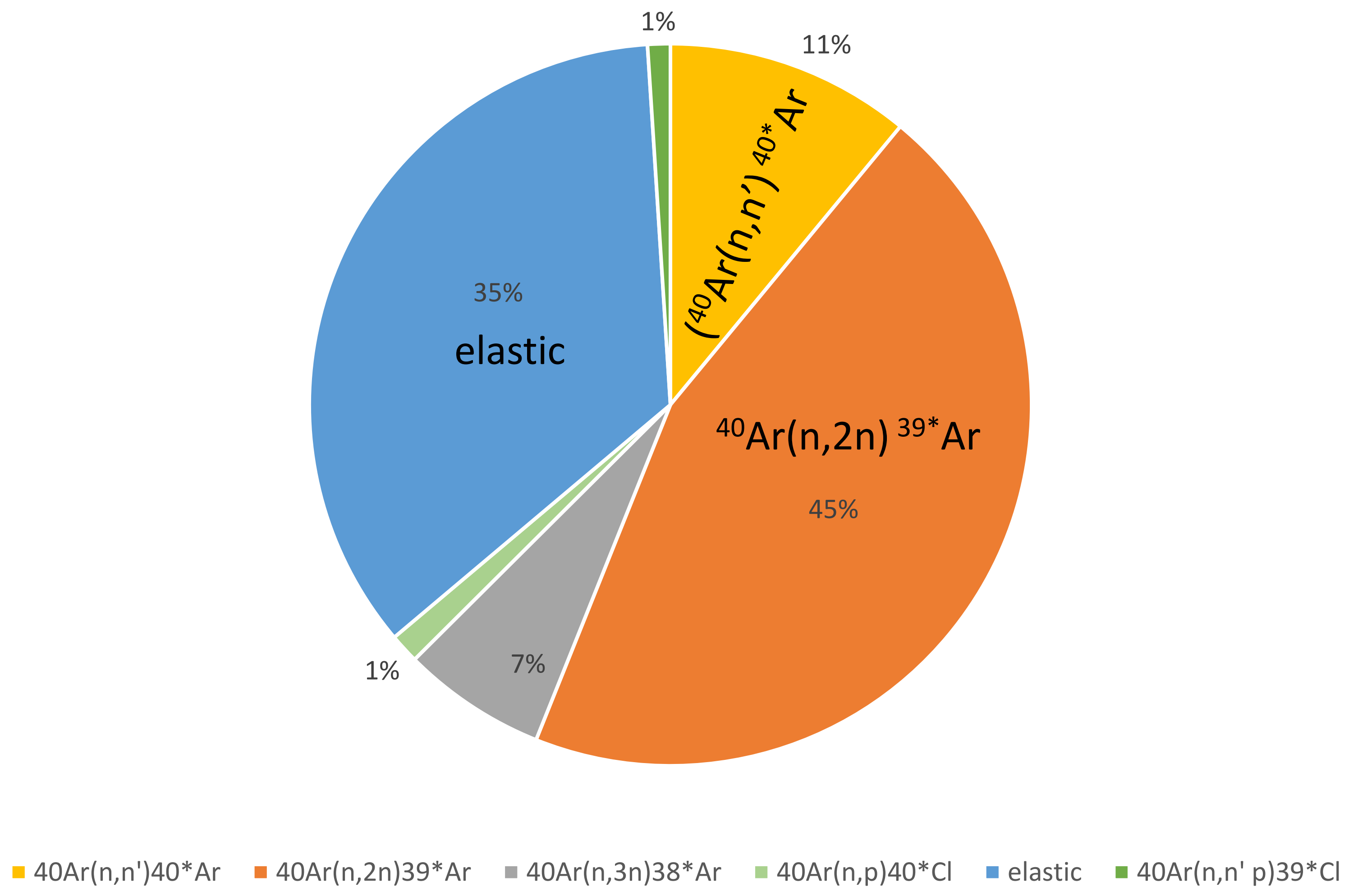


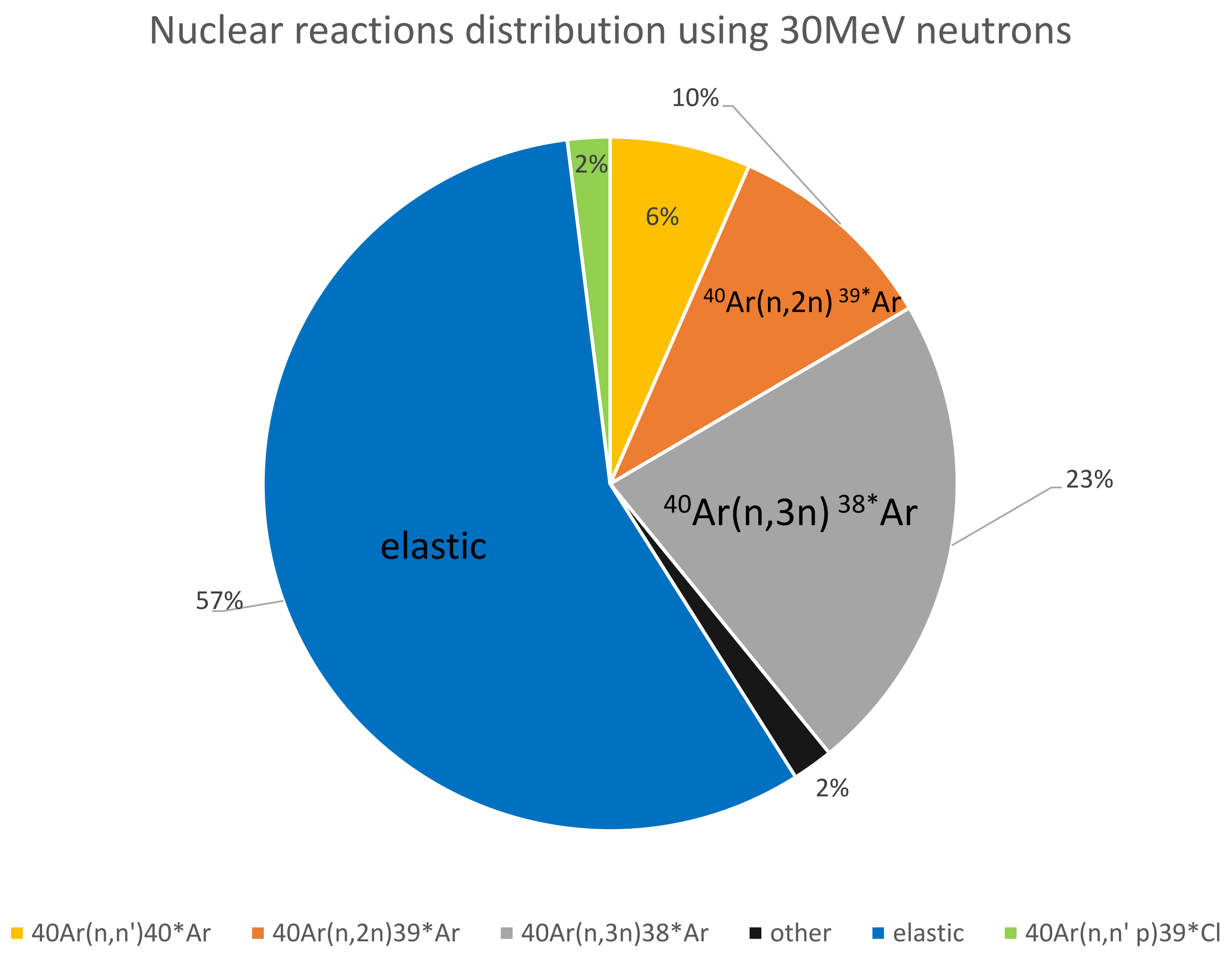
Nuclear reactions distribution using 1MeV neutrons
elastic
100%
elastic

Nuclear reactions distribution using 10MeV neutrons

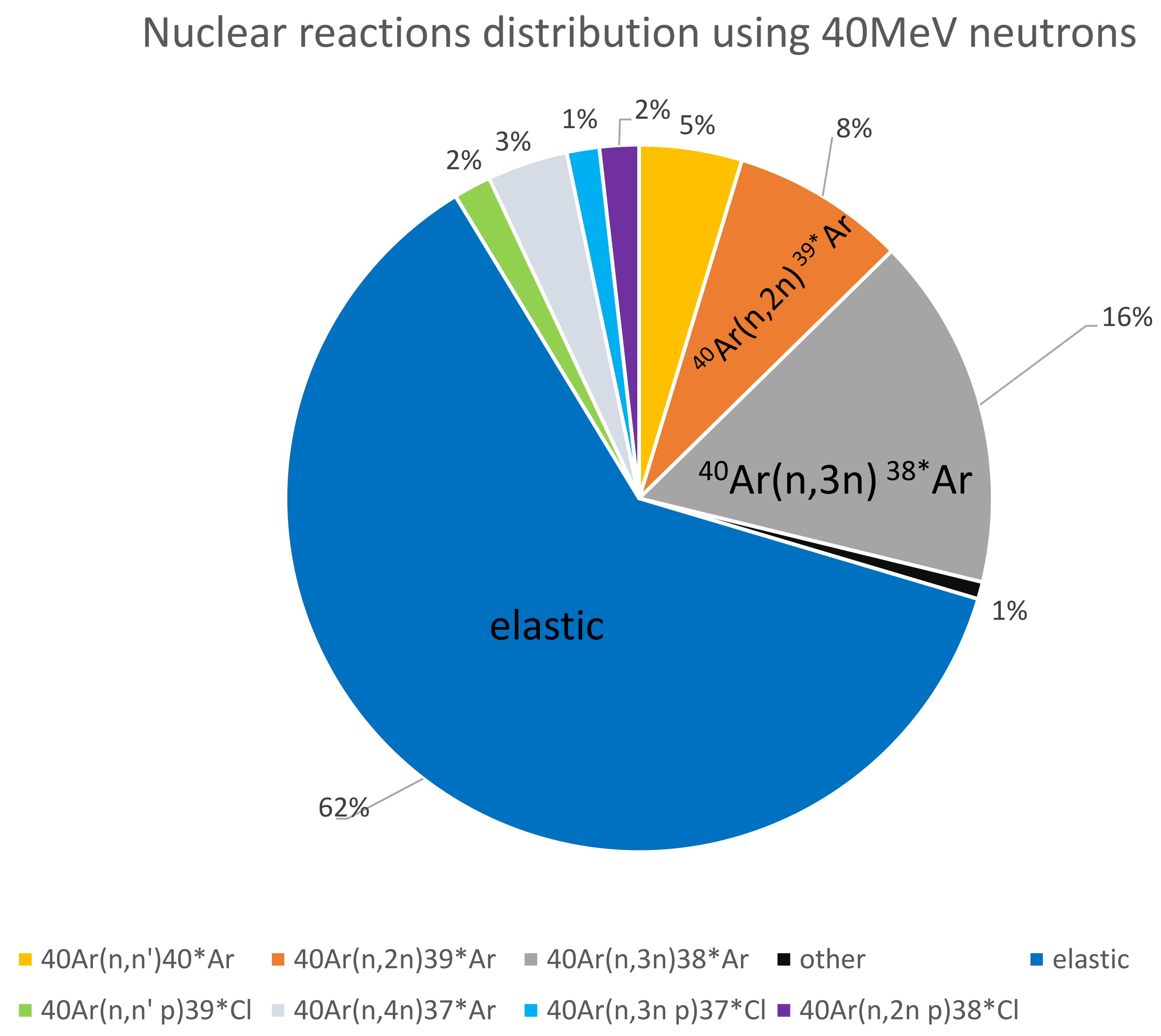


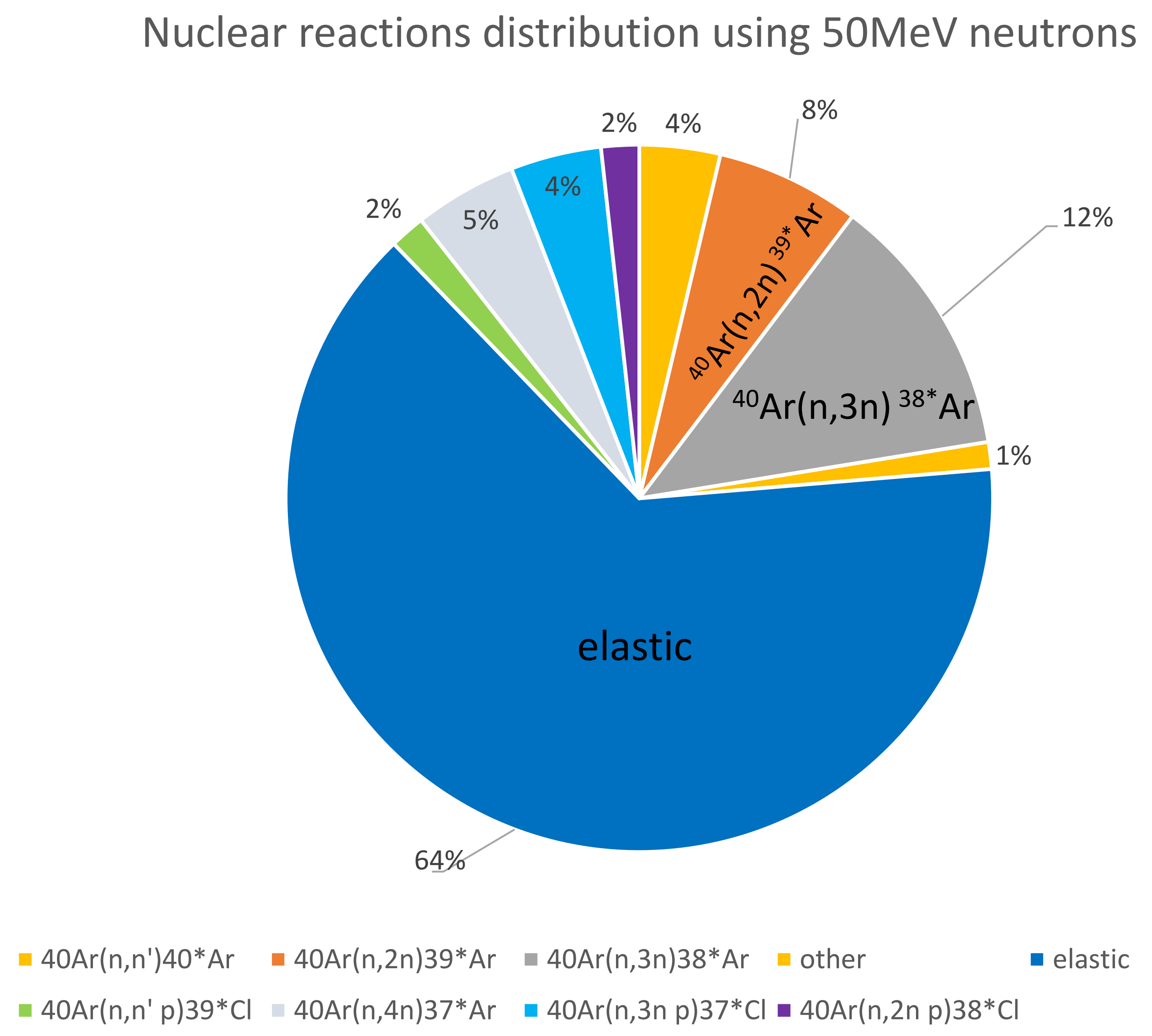
Nuclear reactions distribution using 20MeV neutrons





Nuclear reactions distribution using 30MeV neutrons
10%
2%
6%
^{40}Ar(n,2n) ^{39*}Ar
23%
^{40}Ar(n,3n) ^{38*}Ar
elastic
57%
2%
40Ar(n,n')40*Ar
40Ar(n,2n)39*Ar
40Ar(n,3n)38*Ar
other
elastic
40Ar(n,n' p)39*Cl


Nuclear reactions distribution using 40MeV neutrons
2%
3%
1%
2%
5%
8%
16%
1%
62%
40Ar(n,2n) 39* Ar
40Ar(n,3n) 38*Ar
elastic
40Ar(n,n')40*Ar
40Ar(n,2n)39*Ar
40Ar(n,3n)38*Ar
other
elastic
40Ar(n,n' p)39*Cl
40Ar(n,4n)37*Ar
40Ar(n,3n p)37*Cl
40Ar(n,2n p)38*Cl



Nuclear reactions distribution using 50MeV neutrons
2%
4%
8%
12%
2%
5%
4%
40Ar(n,2n) 39* Ar
40Ar(n,3n) 38* Ar
1%
elastic
64%
40Ar(n,n')40*Ar
40Ar(n,2n)39*Ar
40Ar(n,3n)38*Ar
other
elastic
40Ar(n,n' p)39*Cl
40Ar(n,4n)37*Ar
40Ar(n,3n p)37*Cl
40Ar(n,2n p)38*Cl

Conclusions

- At 1 MeV the dominant interaction is elastic (about 100% of reactions).
- At 10 MeV the dominant interactions are $^{40}Ar(n,n')\,^{40}Ar$ (63% of interactions) and elastic (36% of interactions).
- At 20 MeV the dominant interactions are $^{40}Ar(n,2n)\,^{39*}Ar$ (45% of interactions) , elastic (35% of interactions) and $^{40}Ar(n,n')\,^{40*}Ar$ (10% of interactions.
- Around the resonances ~ 875KeV ……….