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5.3. Compute cross section with constant s-factor

The total reaction cross-section can be expressed in terms of the astrophysical s-factor as

$$\sigma(E) = \frac{S(E)e^{-2\pi\eta}}{E}$$

Where $\eta = \frac{Z_1 Z_2 e^2}{4\pi\epsilon_0 \hbar v}$ is the Sommerfeld parameter. With energy in the center of mass system in units of keV and the reduced mass μ given in atomic mass units:

$$2\pi\eta = 31.29 \times Z_1 Z_2 \sqrt{\frac{\mu}{E}}$$

.

5.3.1. Code

1. Penetrability

   Define a function.

```
def CalculateTwopieta(z1:int, z2:int, m1:float, m2:float, E:float)->float:
    k: float = 31.29
    mu: float = m1*m2/(m1+m2)
    twopieta: float = k * z1 * z2 * np.sqrt(mu / E)
    return twopieta
def CalculatePenetrability(z1:int, z2:int, m1:float, m2:float, E:float)->float:
    twopieta: float = CalculateTwopieta(z1, z2, m1, m2, E)
    penetrability: float = np.exp(-twopieta)
    return penetrability
```

   Call the function to calculate the penetrability with the given parameters.

```
penetrability: float = CalculatePenetrability(zp, zt, mp, mt, energy)
```

In the horizontal setup, a single, water cooled target was mounted at the end of the horizontal tube. This setup allows for a higher neutron detection efficiency and better cooling capacity, and was used for the low-energy measurements where detection efficiency was of particular importance. In addition the moderator was surrounded with 25.3 mm (vertical config) and 50.8 mm (horizontal config) thick layer of 5% borated polyethylene to further reduce the environmental neutron background. In both setups, a cooling loop running deionised water at 5°C is integrated in the target holders for beam power dissipation (~100 W).

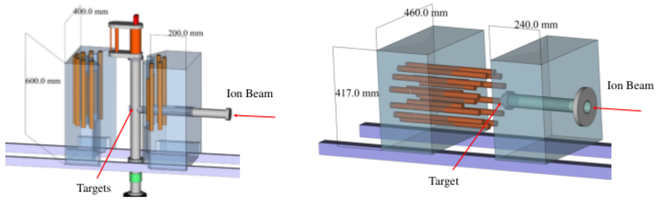

Figure 1: Vertical (left panel) and horizontal (right panel) setup of the LUNA neutron detector array. Dimensions of the moderators, target positions and beam direction are also indicated (see text for more details).

The vertical setup was used to measure the reaction cross section in the energy range $E_{\alpha,lab} = 360 - 400\,keV$, while the horizontal setup was used for the low energy measurements $E_{\alpha,lab} = 300 - 360\,keV$.