# Preliminary results on proton inelastic scattering cross-sections on $^{24}$Mg

Daniela-Mihaela Chiriac

Horia Hulubei National Institute for Physics and Nuclear Engineering (IFIN-HH)
Bucharest-Magurele, Romania

4 July 2023


# Presentation outline

# Introduction/Motivation

**Main objective**:

- provide nuclear data for the community
- calculate differential and angle-integrated $\gamma$-production cross sections for the first transition on $^{24}$Mg as a function of the incident energy

**The motivation of the experiment**: study to which extent it is possible to infer the neutron cross sections from the corresponding proton ones.

# Experimental setup

The experiment was performed at the 9 MV Pelletron Tandem facility of IFIN-HH Bucharest.

- Target: $^{24}$Mg $\rho_S = 0.22$ mg/cm$^2$
- 2 HPGe detectors placed at 110°and 150°
- $E_{protons}$: 3 – 15 MeV with 25 keV steps
- efficiency measurement using a $^{152}$Eu calibration source
- beam monitoring using a Faraday cup

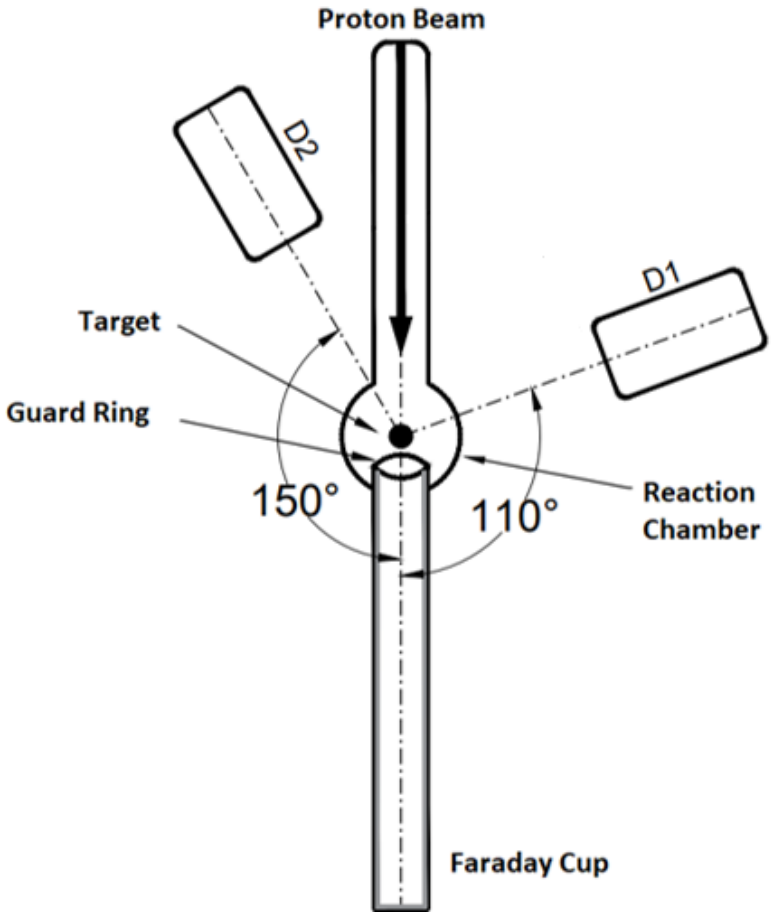



Figure: A schematic drawing of the experimental setup

# Data analysis

**Reaction: $^{24}$Mg (p, p'$\gamma$) $^{24}$Mg**

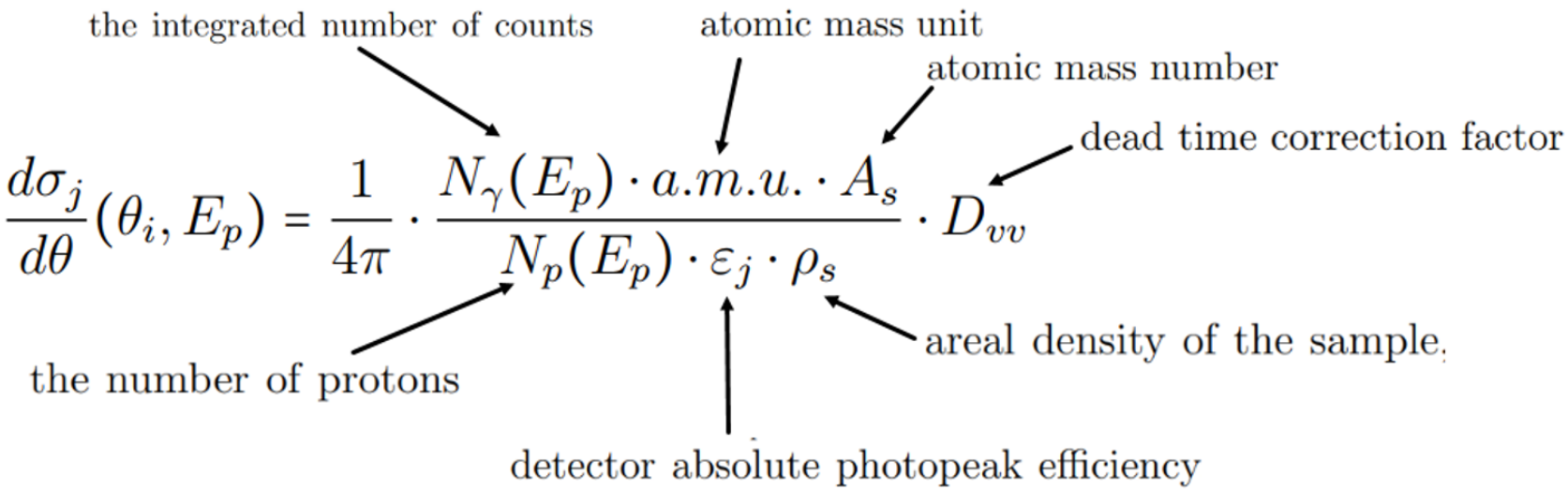
**gamma spectroscopy techniques $\longrightarrow$ absolute cross sections**

**Main extracted quantity**: angle integrated $\gamma$-production cross section

**Data corrections**: dead time and energy loss

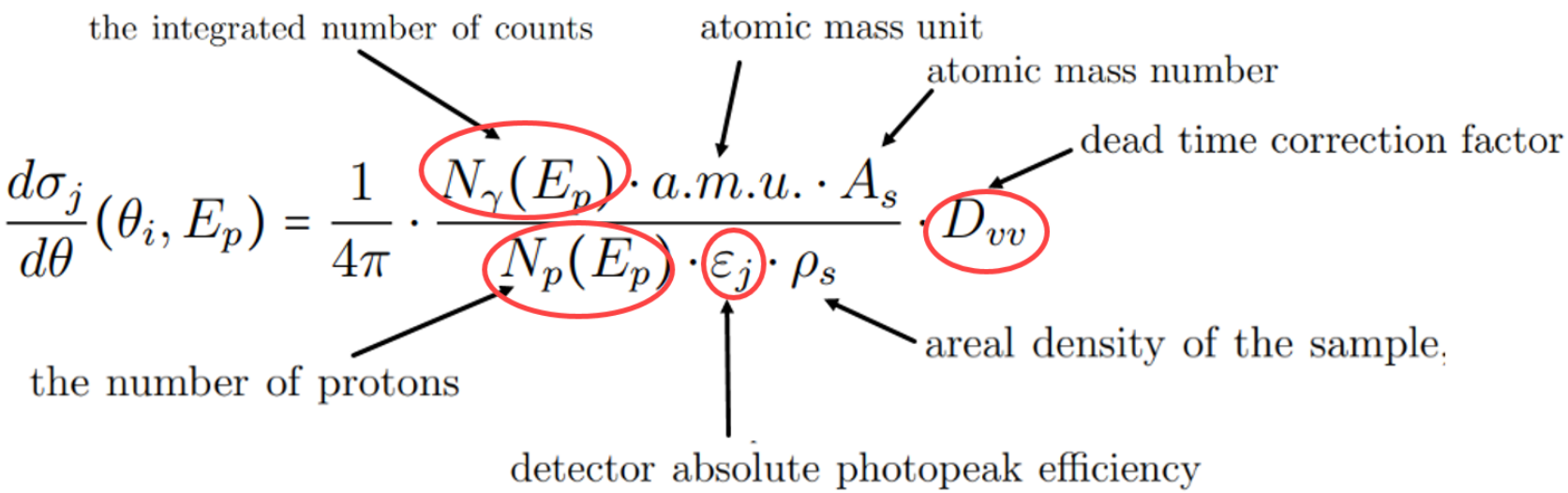
# Differential cross section

For determining the differential $\gamma$-production cross sections for different incident protons, we use this formula:



# Differential cross section

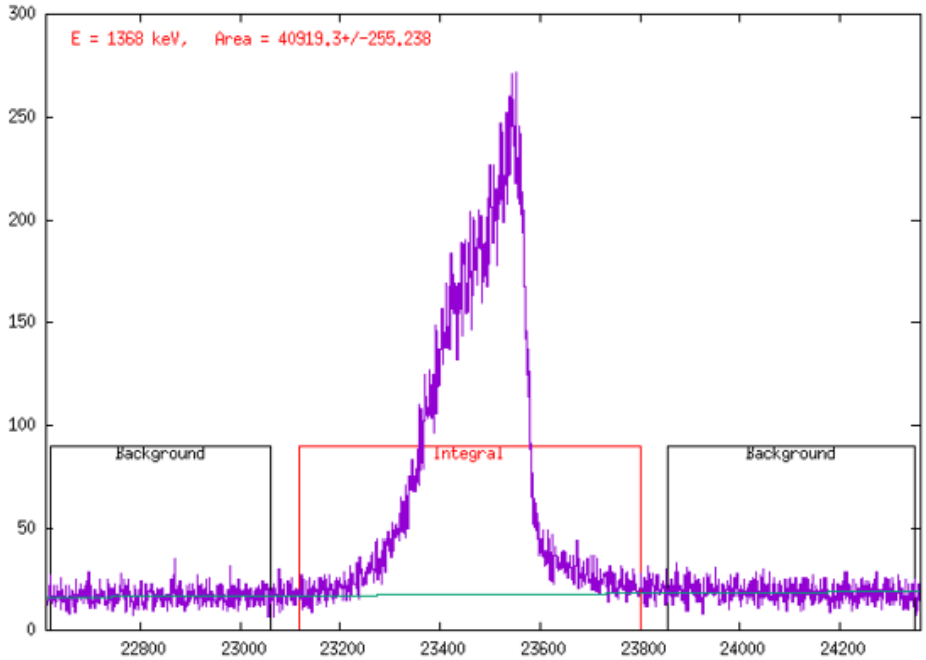
For determining the differential $\gamma$-production cross sections for different incident protons, we use this formula:

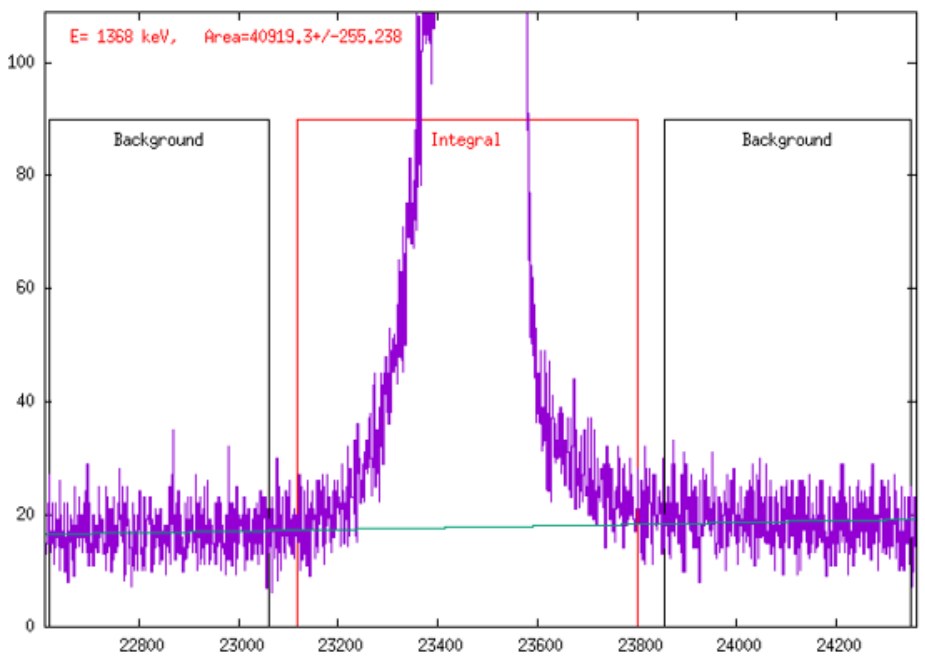



$$\frac{d\sigma_j}{d\theta}(\theta_i, E_p) = \frac{1}{4\pi} \cdot \frac{N_\gamma(E_p) \cdot a.m.u. \cdot A_s}{N_p(E_p) \cdot \varepsilon_j \cdot \rho_s} \cdot D_{vv}$$

# Integration process

In the integration process, the two values of the background on the left and on the right and the integration limits were taken.



# The total number of protons

A Faraday cup was placed after the target in order to collect the protons that passed through it.

The cup was read-out by a charge integrator that gave a output signal at every $10^{-10}$ C of collected charge.

$$N_p = \frac{N_{counts} \cdot 10^{-10} C}{1.6 \cdot 10^{-19} C}$$

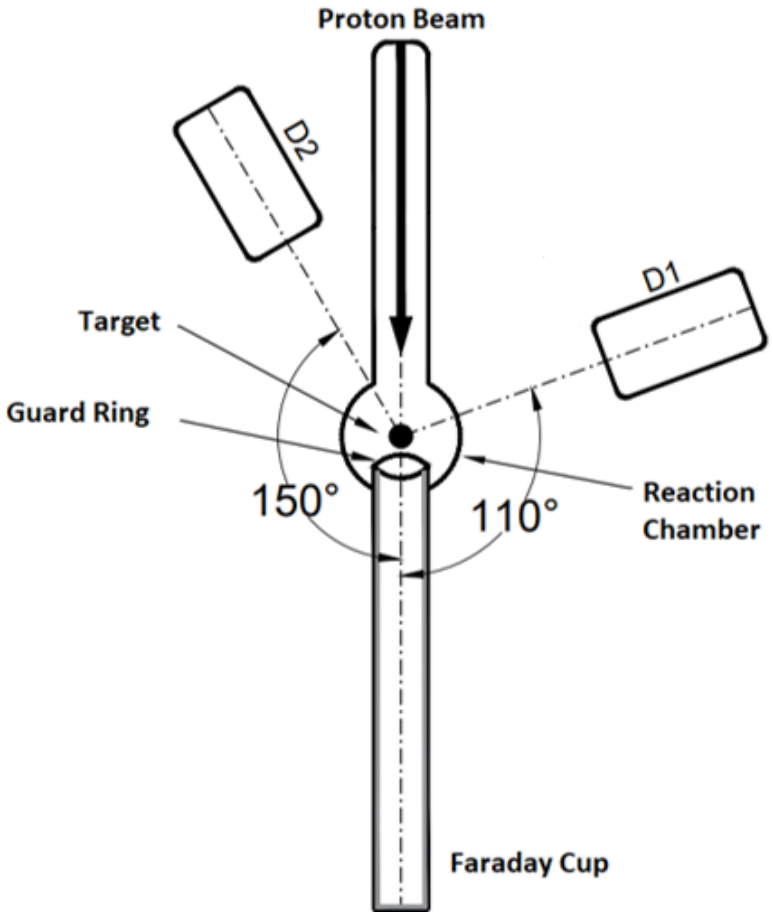



Figure: A schematic drawing of the experimental setup

# Detectors efficiency

For the proton-induced experiment a strong Eu-152 energy calibration source was used.

The experimental efficiency $\epsilon$ was calculated using:

$$\epsilon = \frac{A_{peak}}{\Lambda \; I_\gamma \; t_m}$$

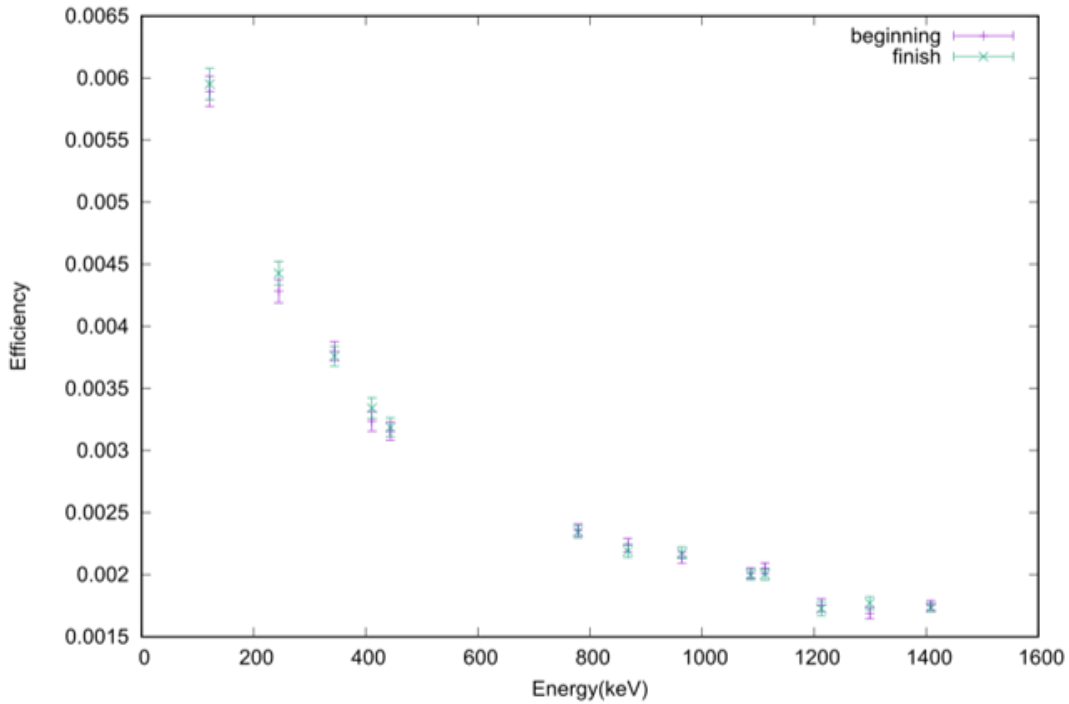



Figure: Experimental absolute efficiency points of one of the HPGe detectors employed during the experiment.

# Dead time corrections

During this experiment, relatively high counting rates were registered. This was due to two factors:

- gaining maximum possible statistics means increasing the rates
- difficulties appear with the stability of the beam intensity at high proton energies rates

| $E_p$ [MeV] | $\overline{R}_{det}$ [counts/s] | $D_{vv}$ |
|---|---|---|
| 3.0 | 329.216 | 1.01687 |
| 5.0 | 760.288 | 1.03981 |
| 7.0 | 2236.310 | 1.12760 |
| 9.0 | 3794.620 | 1.24047 |
| 11.0 | 7757.080 | 1.69485 |
| 13.0 | 8915.380 | 1.96402 |
| 15.0 | 8133.360 | 1.75917 |

Table: The values of the average detected rates and the dead time corrections corresponding to the incident proton energy

# Corrections for the energy loss

The mean proton energy and its associated uncertainty was calculated assuming that the uniform distribution is well suited for this task.

The energy loss was extracted from the SRIM program

| $E_p^{incid}$ [keV] | $(\Delta E)^{tot}$ [keV] | $E_p^{mean}$[keV] | $\sigma$ [keV] |
|---|---|---|---|
| 3000 | 9.53 | 2990.47 | 5.50 |
| 5000 | 6.57 | 4993.43 | 3.79 |
| 7000 | 5.10 | 6994.90 | 2.95 |
| 9000 | 4.21 | 8995.79 | 2.43 |
| 11000 | 3.61 | 10996.39 | 2.08 |
| 13000 | 3.17 | 12996.83 | 1.83 |
| 15000 | 2.83 | 14997.17 | 1.63 |

Table: *Proton energy loss inside the target*

# Angle-integrated cross section

After obtaining the differential cross sections at 110°and 150°, the angle-integrated cross sections were calculated using:

$$\sigma(E_k) = 2\pi[w_{110^\circ}\frac{d\sigma}{d\theta}(110^\circ, E_k) + w_{150^\circ}\frac{d\sigma}{d\theta}(150^\circ, E_k)]$$

The $w_{110^\circ}$ and $w_{150^\circ}$ coefficients have the values 1.30429 and 0.69571

# Results

# The evaluated transition

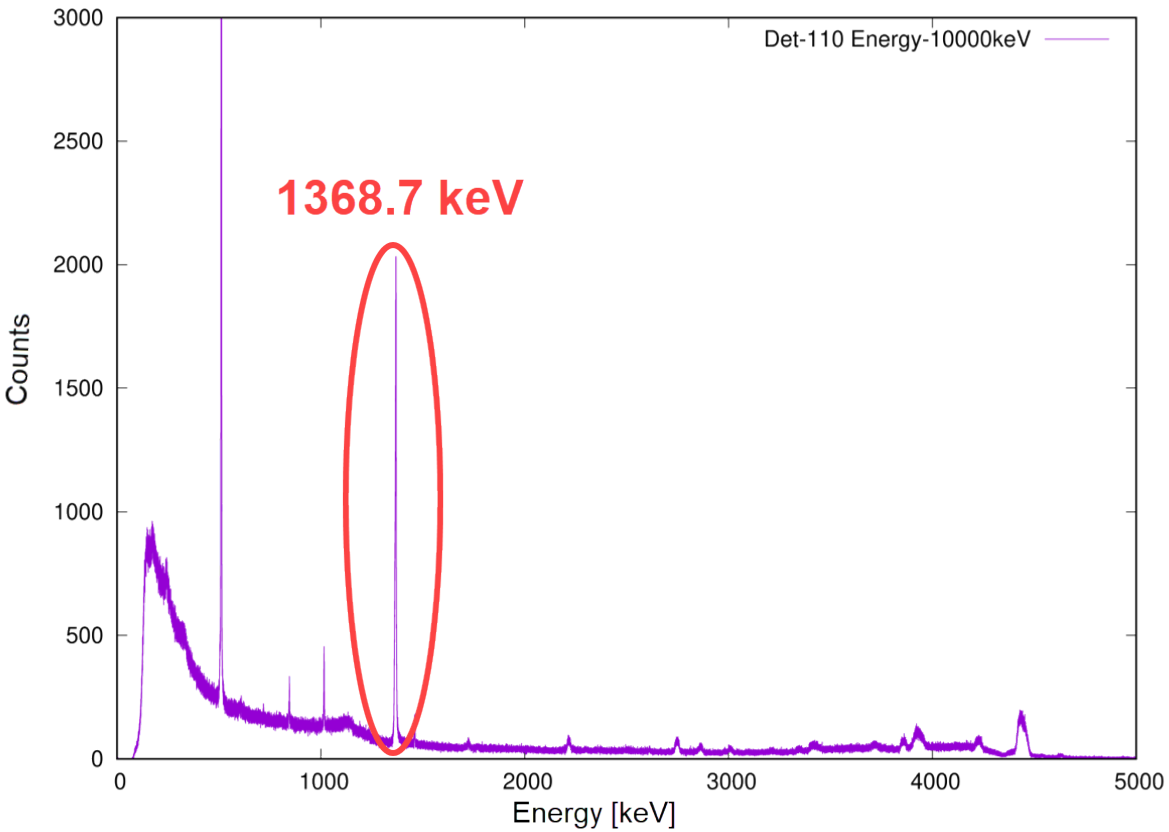



Figure: The amplitude spectrum of $^{24}$Mg


Figure: The partial level scheme

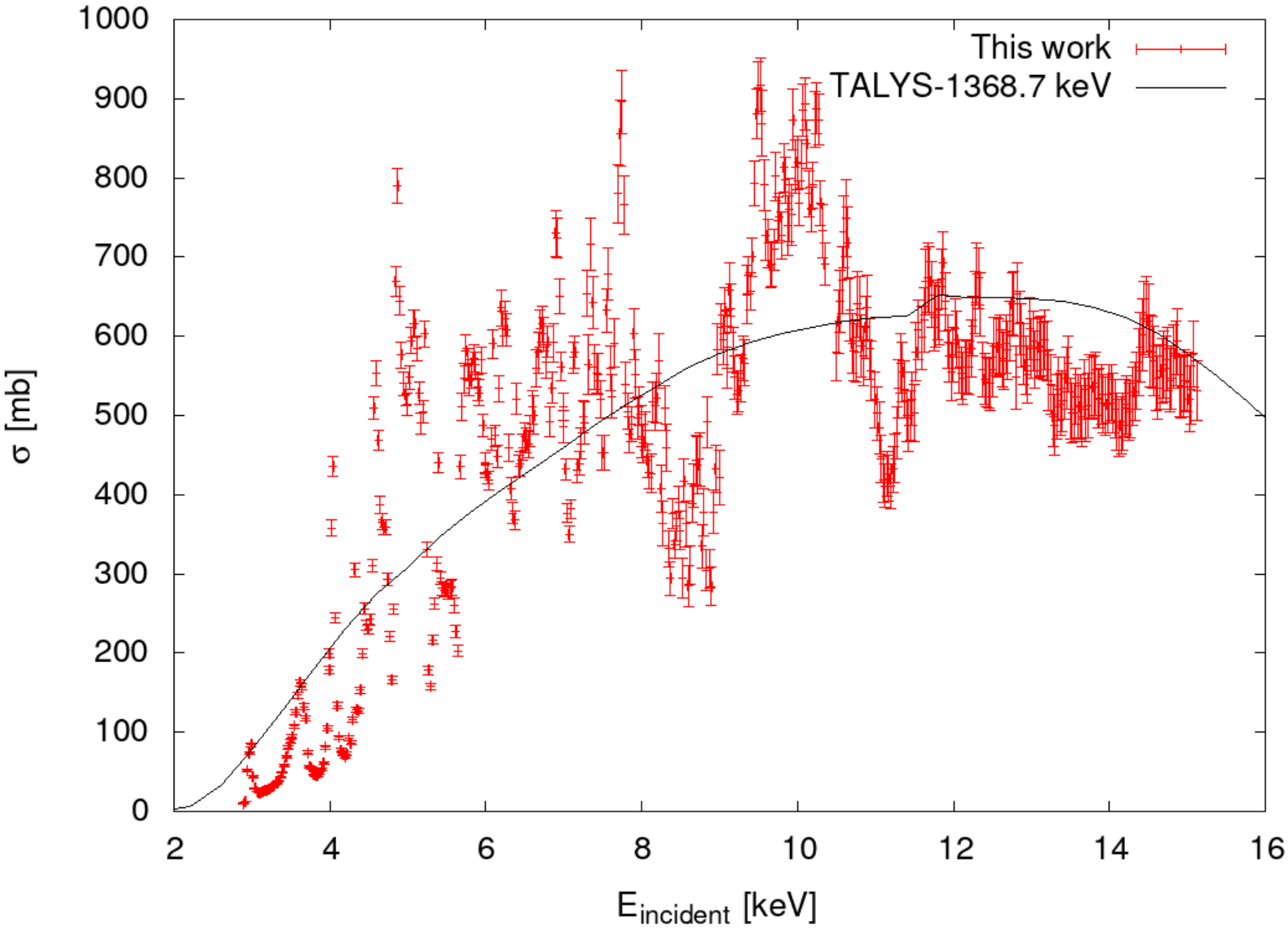



Figure: The proton inelastic integral $\gamma$-production cross section for the 1368.7 keV transition with its associated uncertainty

# Future work

In conclusion, our data analysis involved gamma spectroscopy techniques to extract absolute cross sections. Through careful data corrections, including dead time corrections and energy loss corrections, we accounted for various experimental uncertainties, ensuring the accuracy of our measurements.

Future work:

- Analysing the data for the thick target
- Detailed comparisons and data discussion of the proton and neutron corresponding cross sections (our group's main research)
- Concluding & publishing the $^{24}$Mg results

# Thank you