Cross section measurement of the $^{3}He(\alpha,\gamma)^{7}Be$ reaction with γ-spectroscopy

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ChETEC-INFRA - Schools on Nuclear Astrophysics Questions
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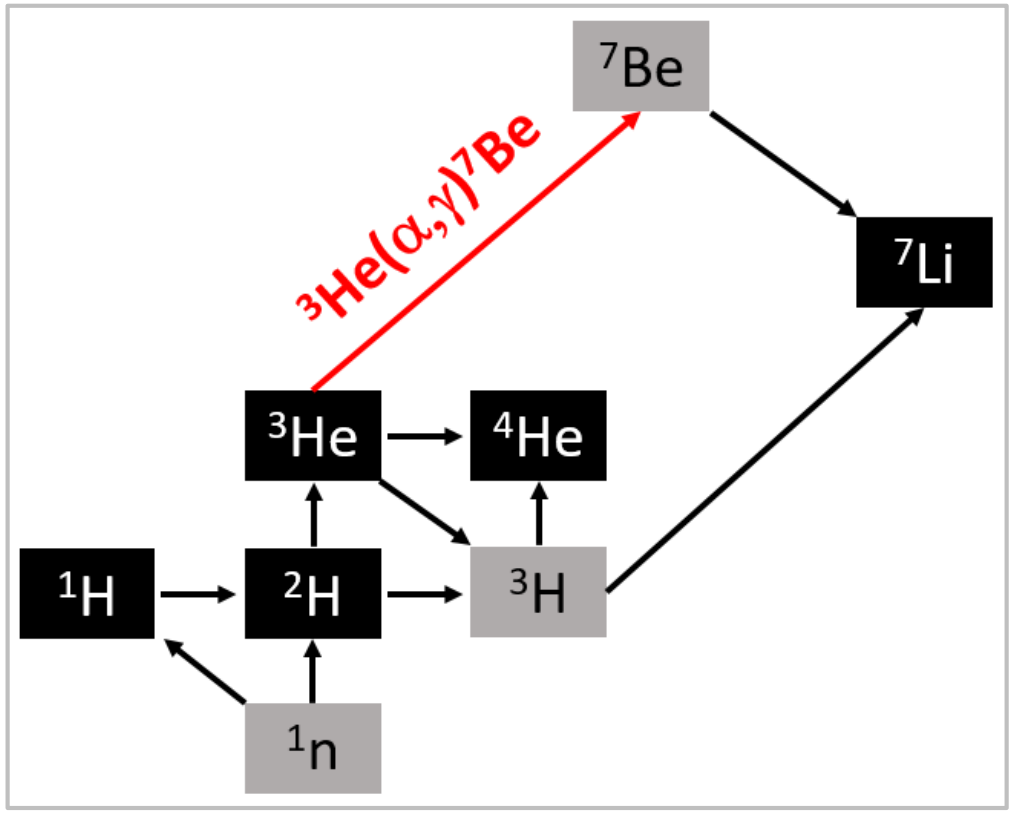
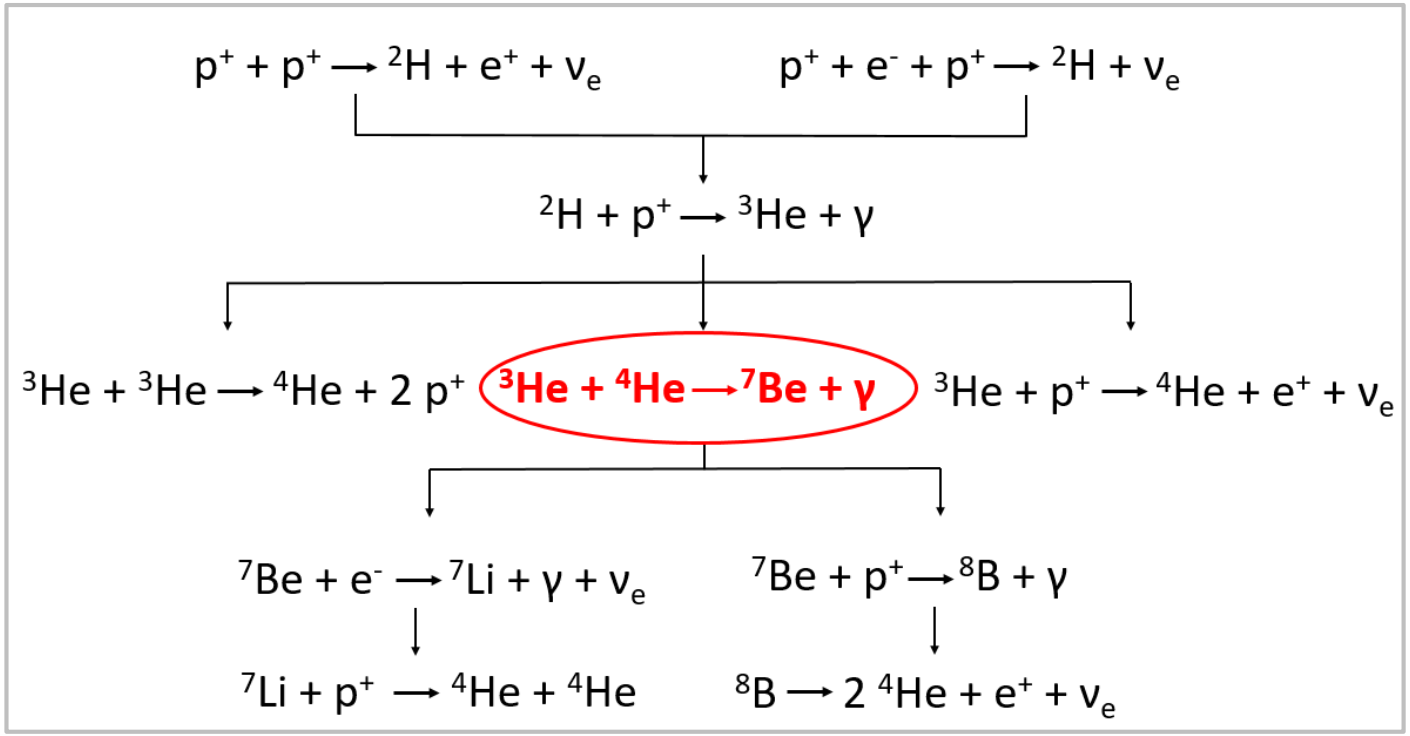
Introduction I.

Why is the $^{3}He(\alpha,\gamma)^{7}Be$ reaction interesting?

Big Bang Nucleosynthesis

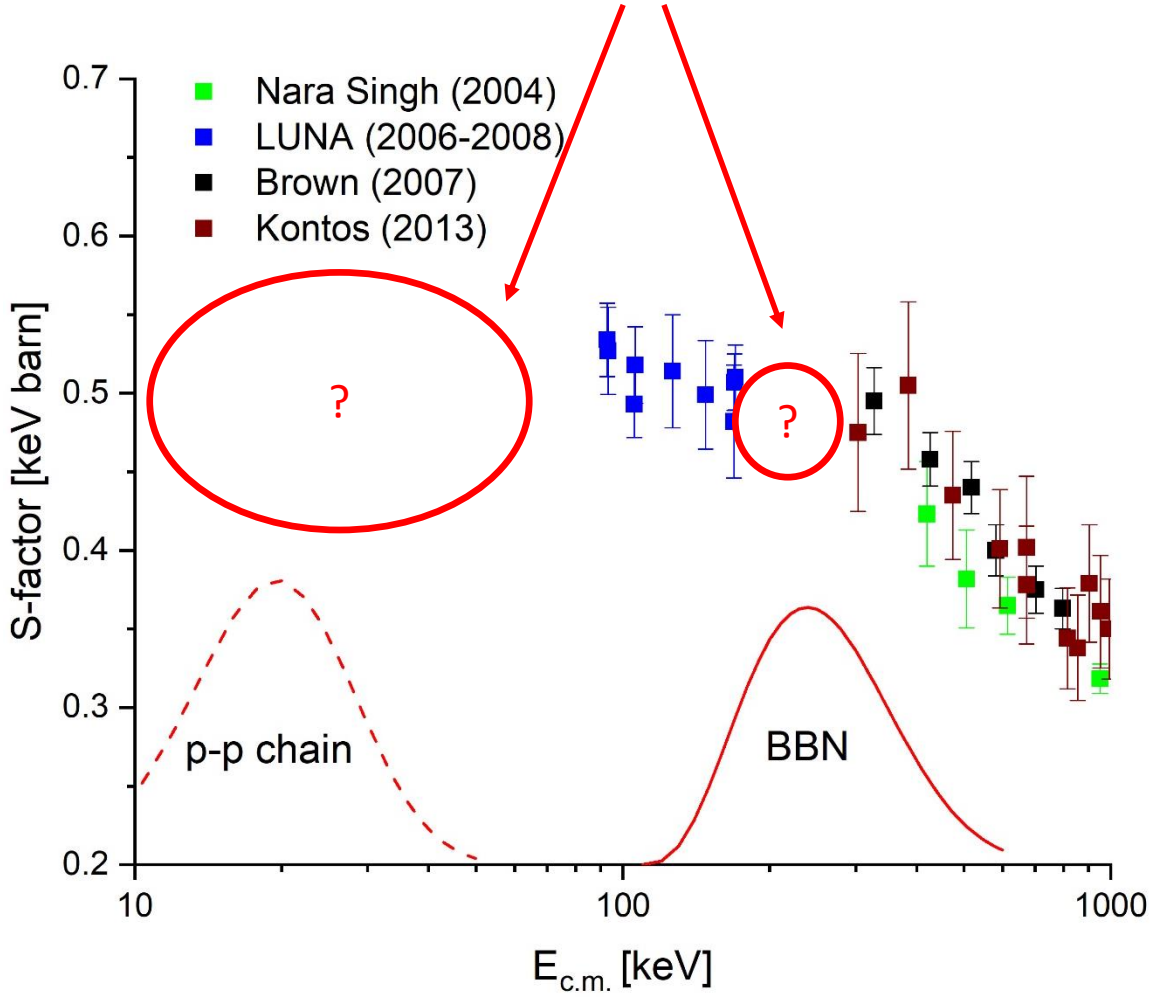


p-p chain in the Sun

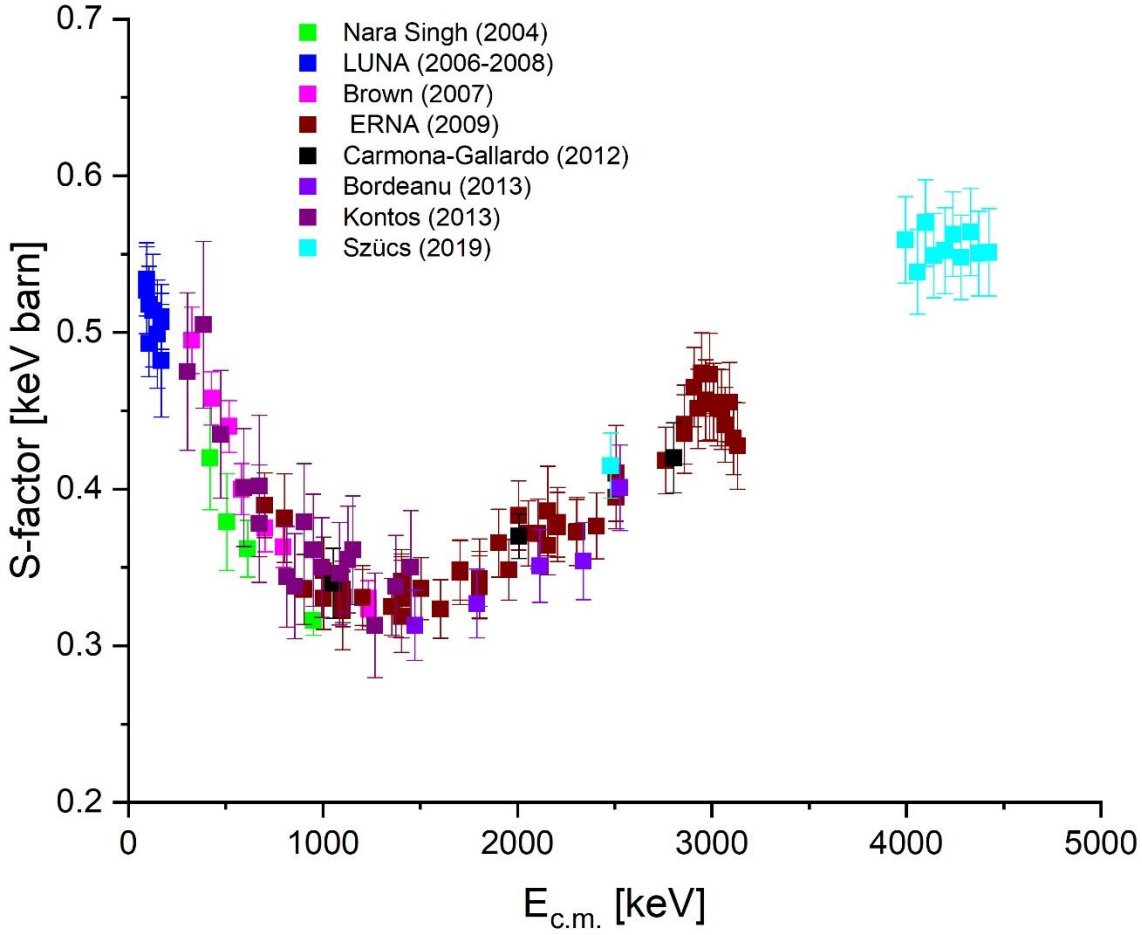


Introduction II.

No modern experimental data



Several experimental data



Extrapolation

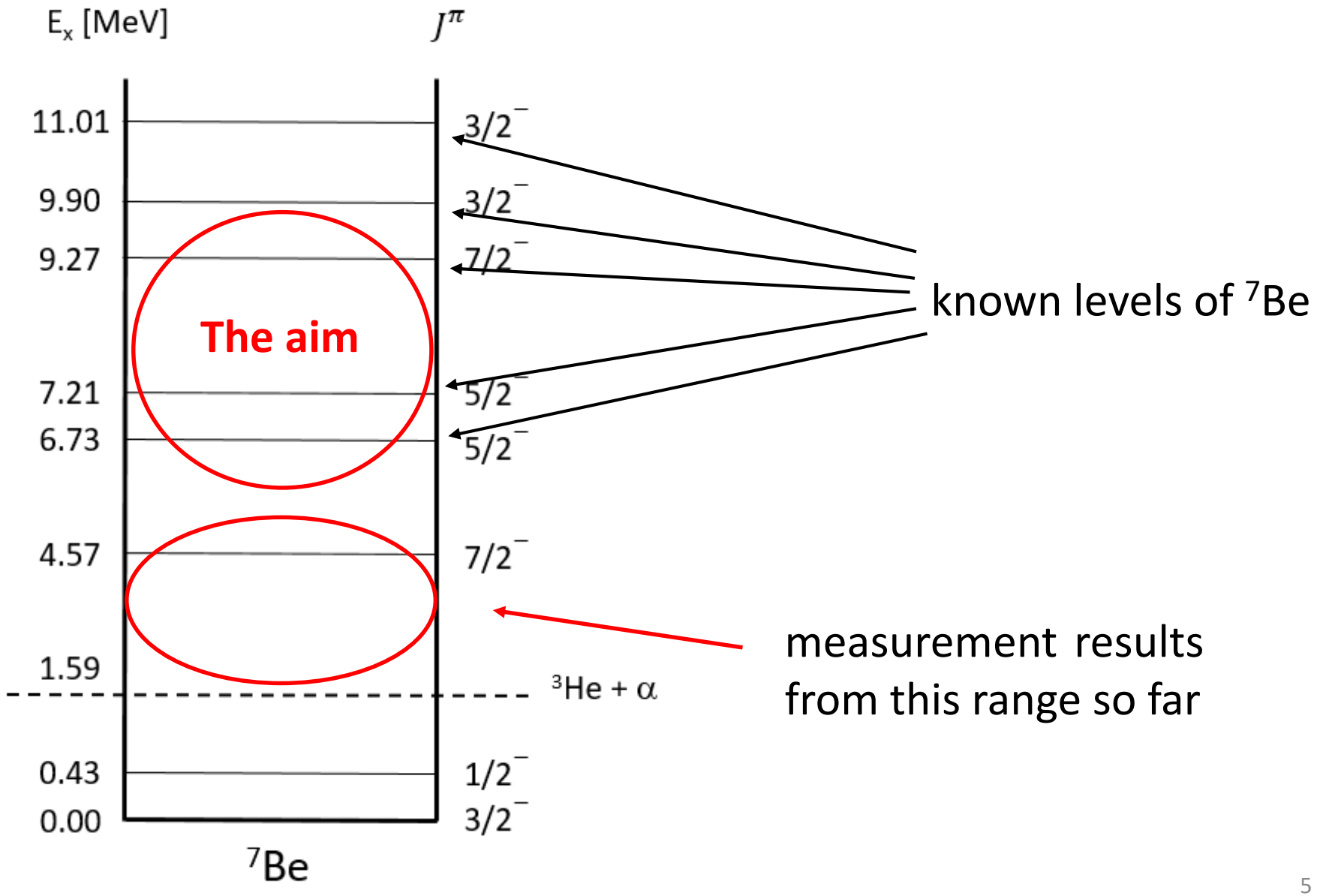
Needed for extrapolation:

Measured points:
low energy points and higher energy points too

The extrapolation and its uncertainty are influenced by the precision of the experimental data.

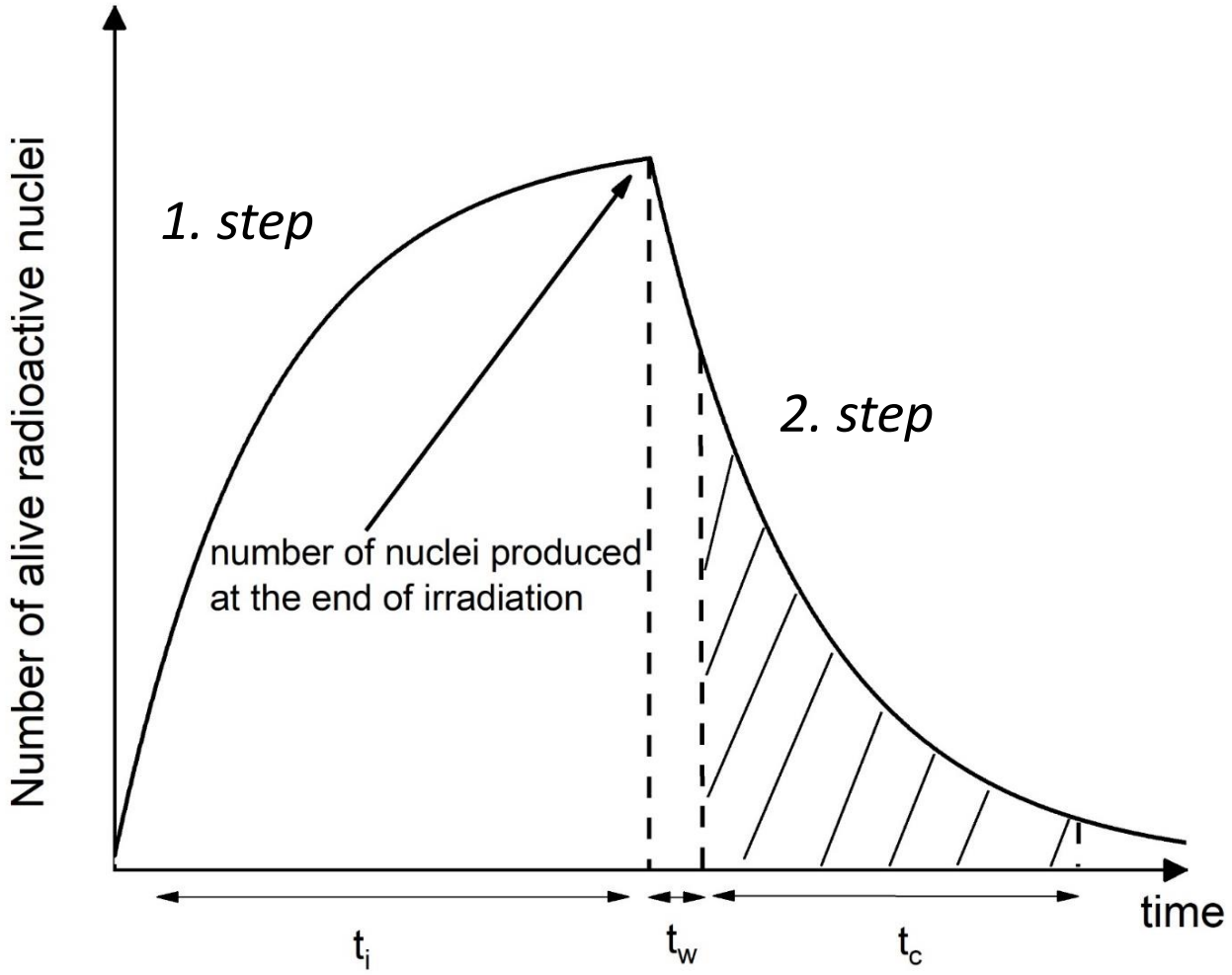
One way of extrapolation is the R-matrix approach, which is based on experimental data.

Motivation


E_x [MeV]
J^π
11.01
9.90
9.27
7.21
6.73
4.57
1.59
0.43
0.00
$3/2^-$
$3/2^-$
$7/2^-$
$5/2^-$
$5/2^-$
$7/2^-$
$1/2^-$
$3/2^-$
The aim
$^3He + \alpha$
^7Be
known levels of ^7Be
measurement results
from this range so far

Activation method

2 steps: irradiation and gamma-ray counting

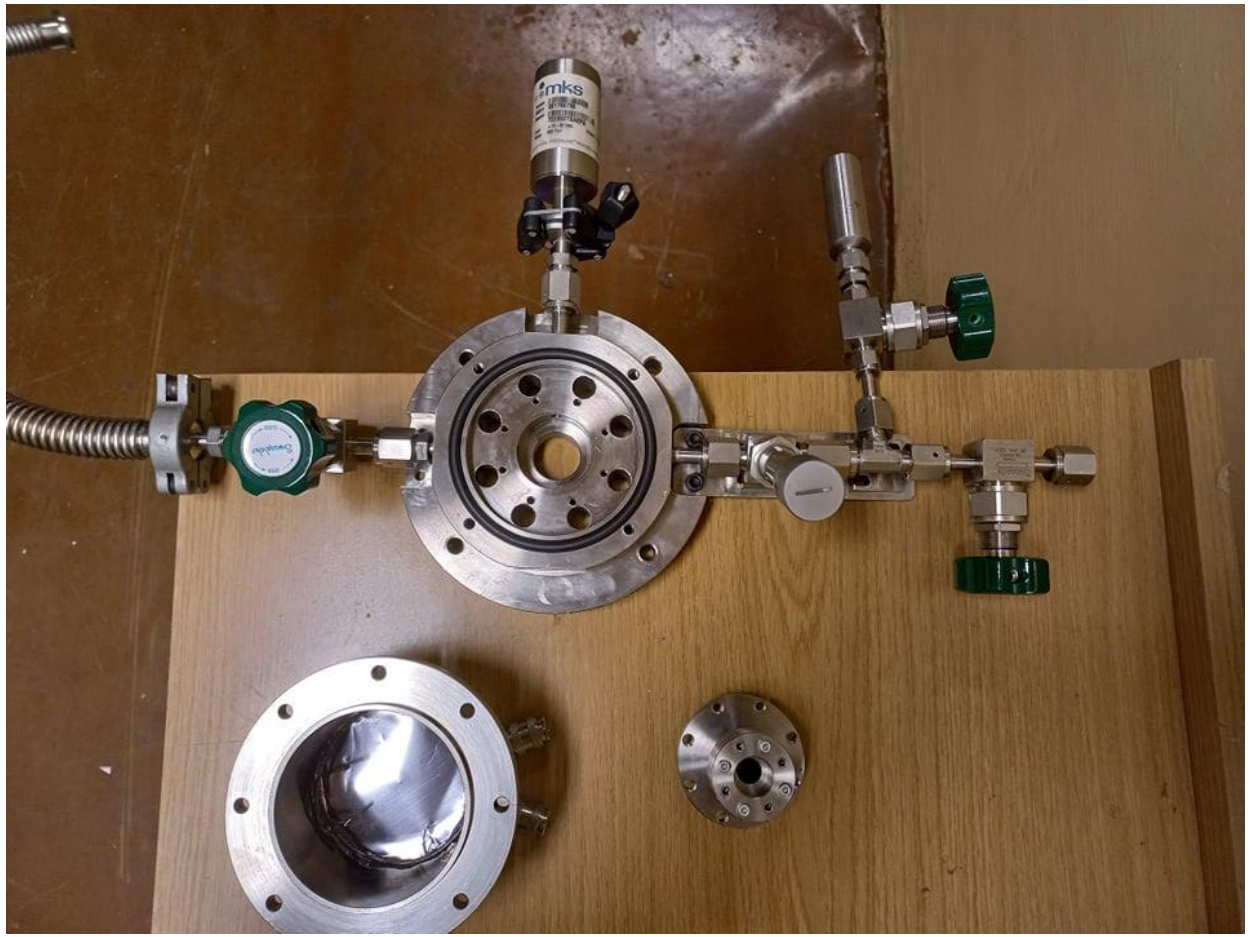


$$N_{reactions} = \sigma_{reaction} \cdot N_{target} \cdot \phi_b \cdot \frac{1 - e^{-\lambda \cdot t_i}}{\lambda}$$

$$N_{decay} = N_{reactions} \cdot e^{-\lambda t_w} \cdot \left(1 - e^{-\lambda \cdot t_c}\right) \cdot \varepsilon \cdot I$$

The gas cell

Length: 4.19 cm



Entrance Al foil thickness: 10 μm
Exit Al foil thickness: 10,15 or 20 μm

Typical impurities:
Si (1.96 ppm), Mg (1.57 ppm), Fe(1.01 ppm)

High purity (99.999%) ^{3}He target

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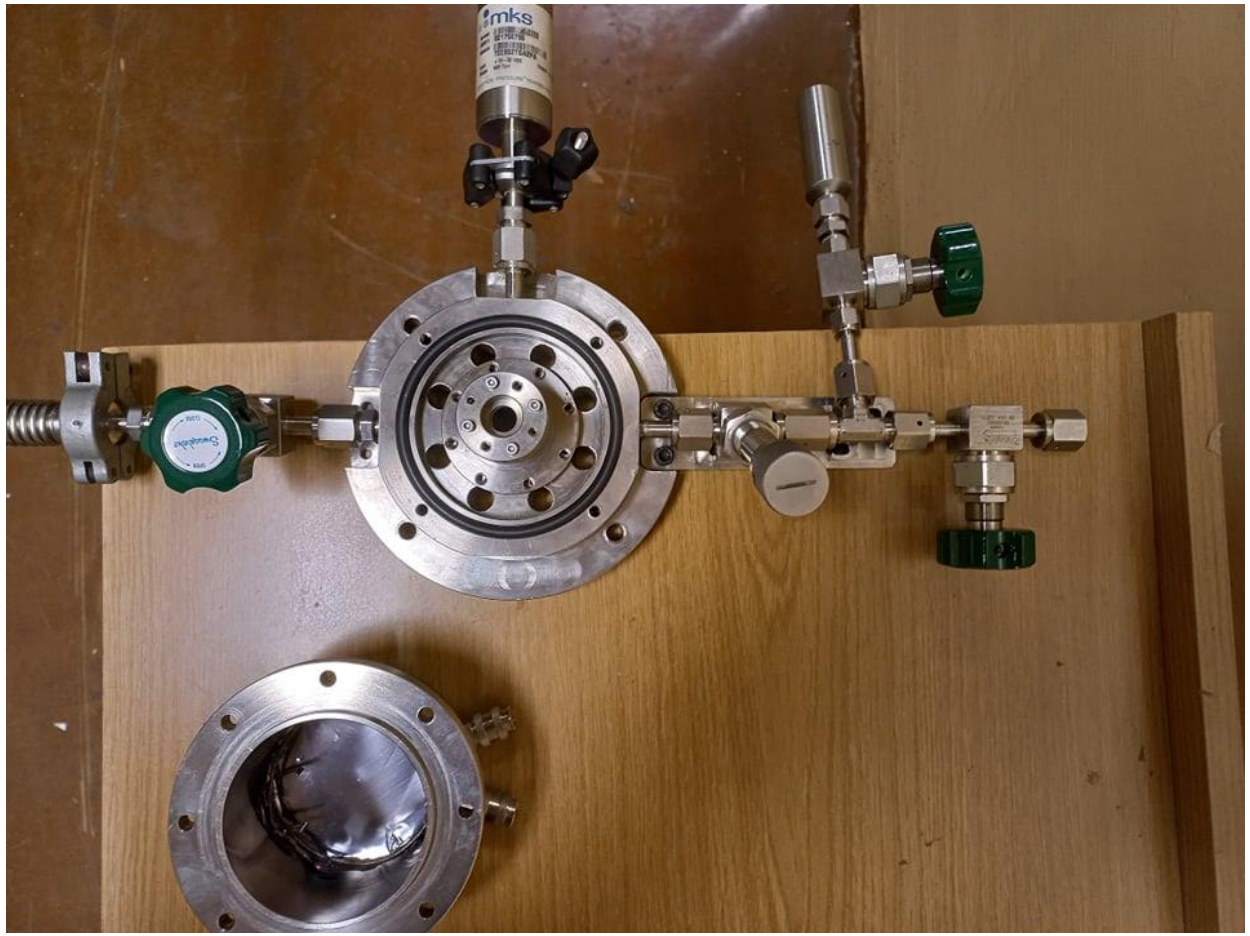

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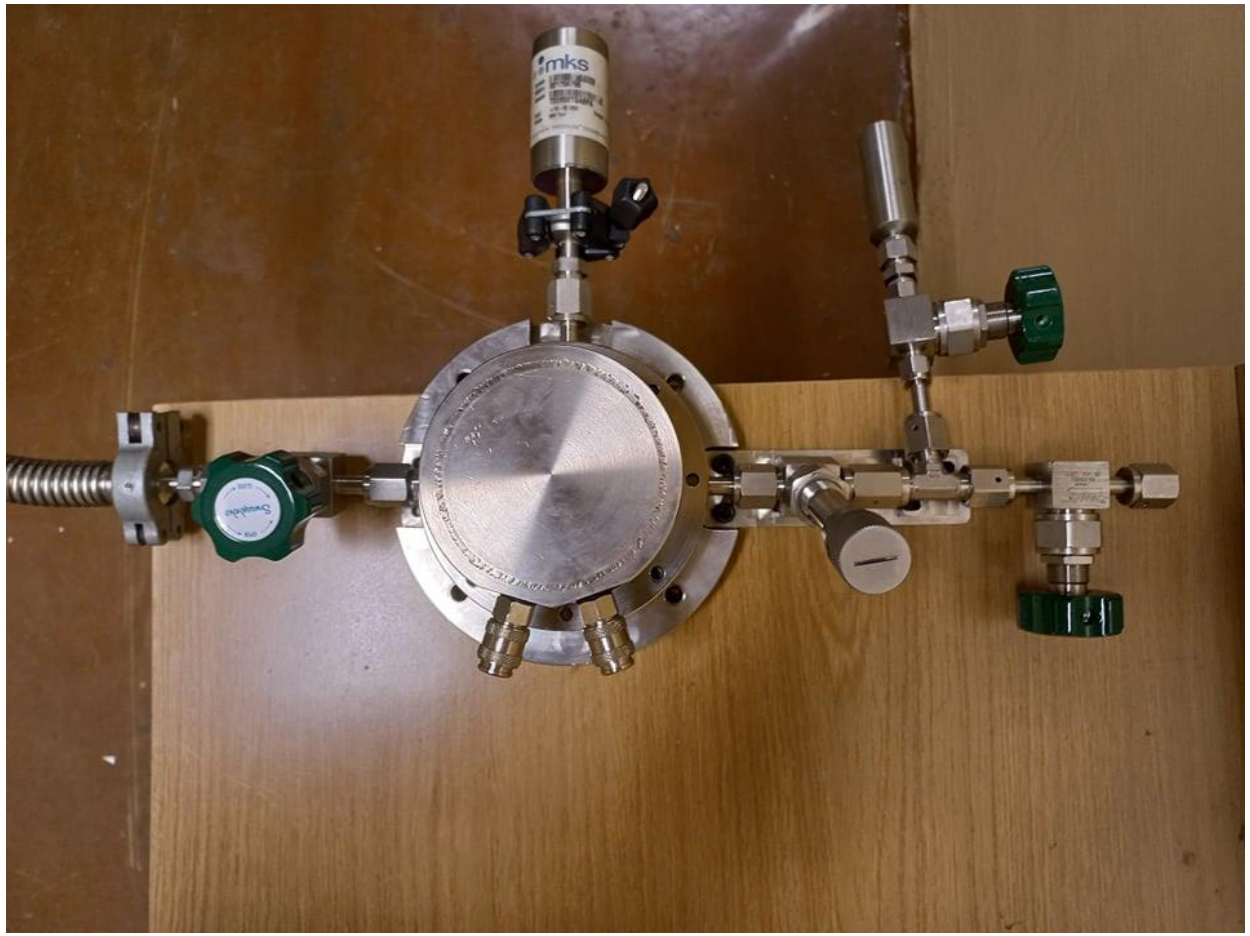

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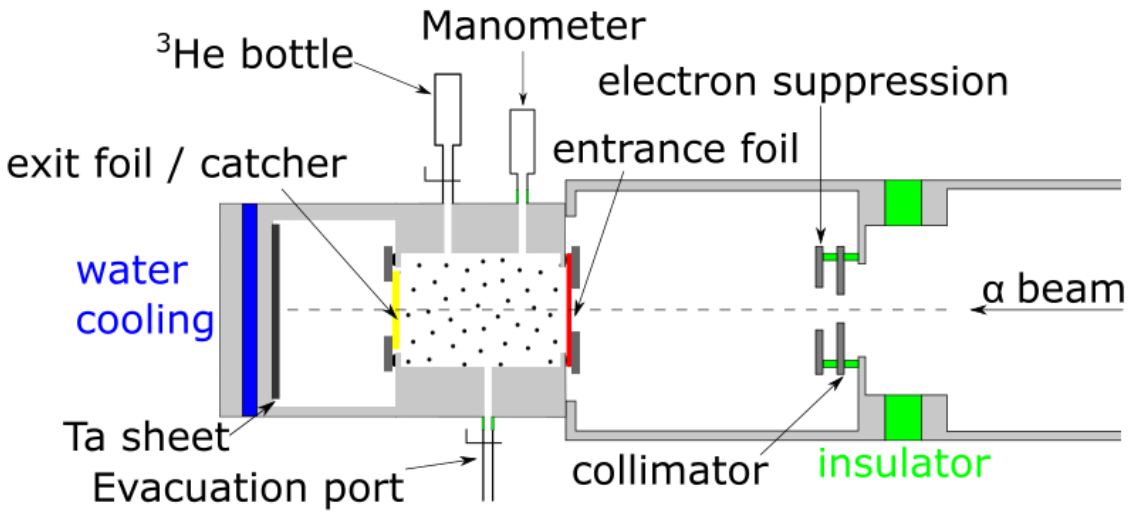
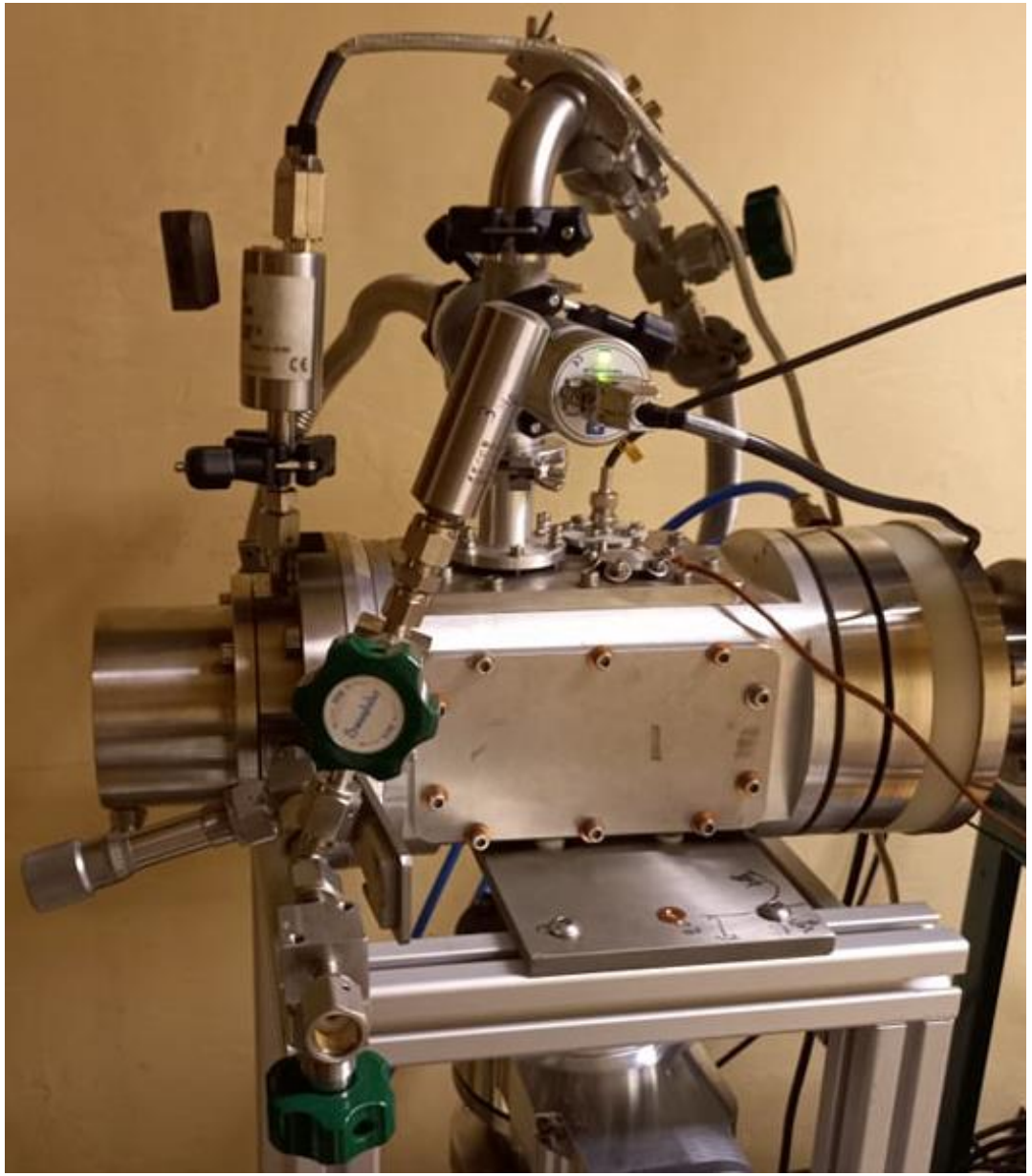
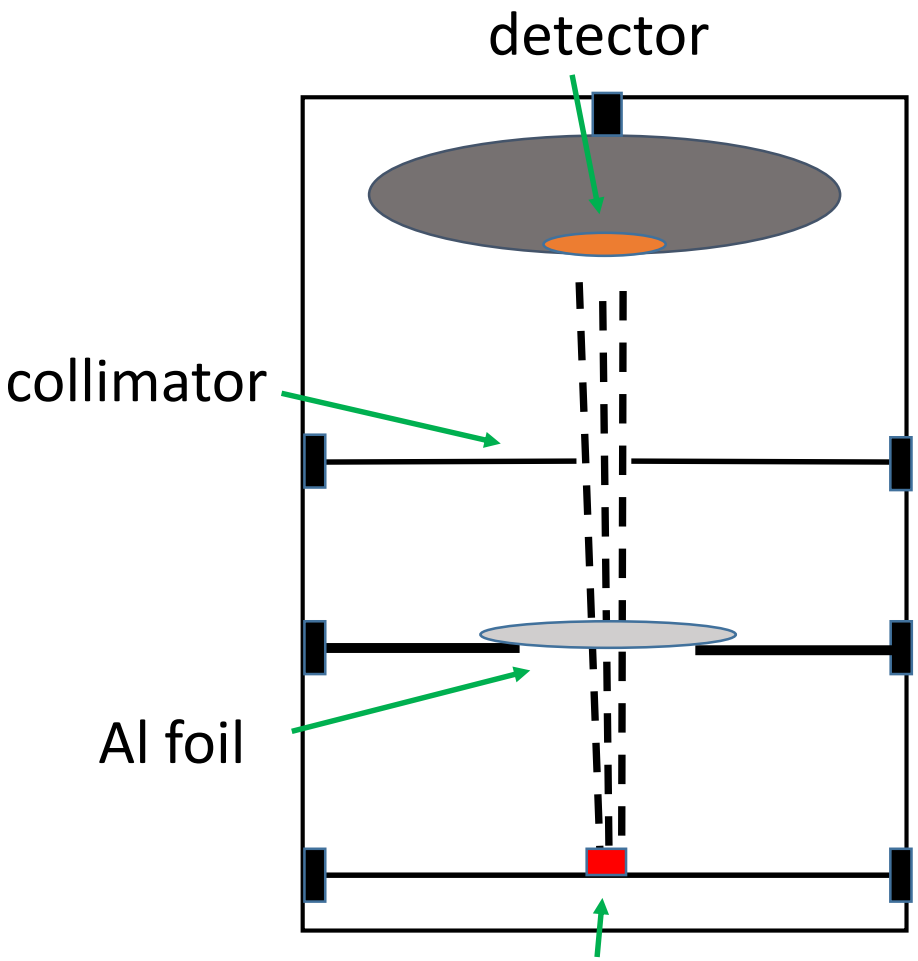
Irradiation





- Bombarded particles: alpha
- Target: ^{3}He with 99.999% pure
- A thin window gas cell with Al foils
- Length of gas cell: 4.19 cm
- Beam current: ~ 1 μA
- Initial pressure: ~ 100 mbar
- Temperature: ~ 23 ^{o}C
- Length of irradiation: ~ 20 hours

Energy loss in Al foil



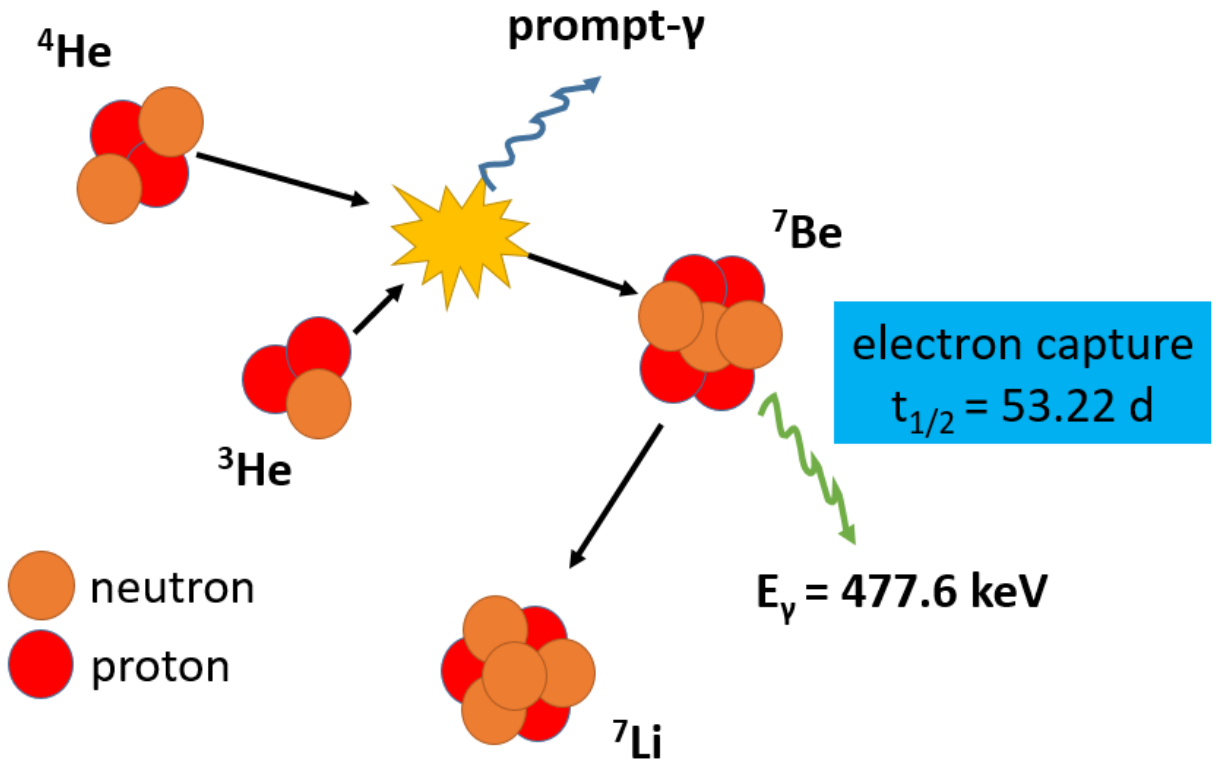
SRIM program

Energy loss in the range of
E_α = 11 – 20 MeV

–> 1 – 0.6 MeV

Gamma-counting

HPGe detector with lead shielding



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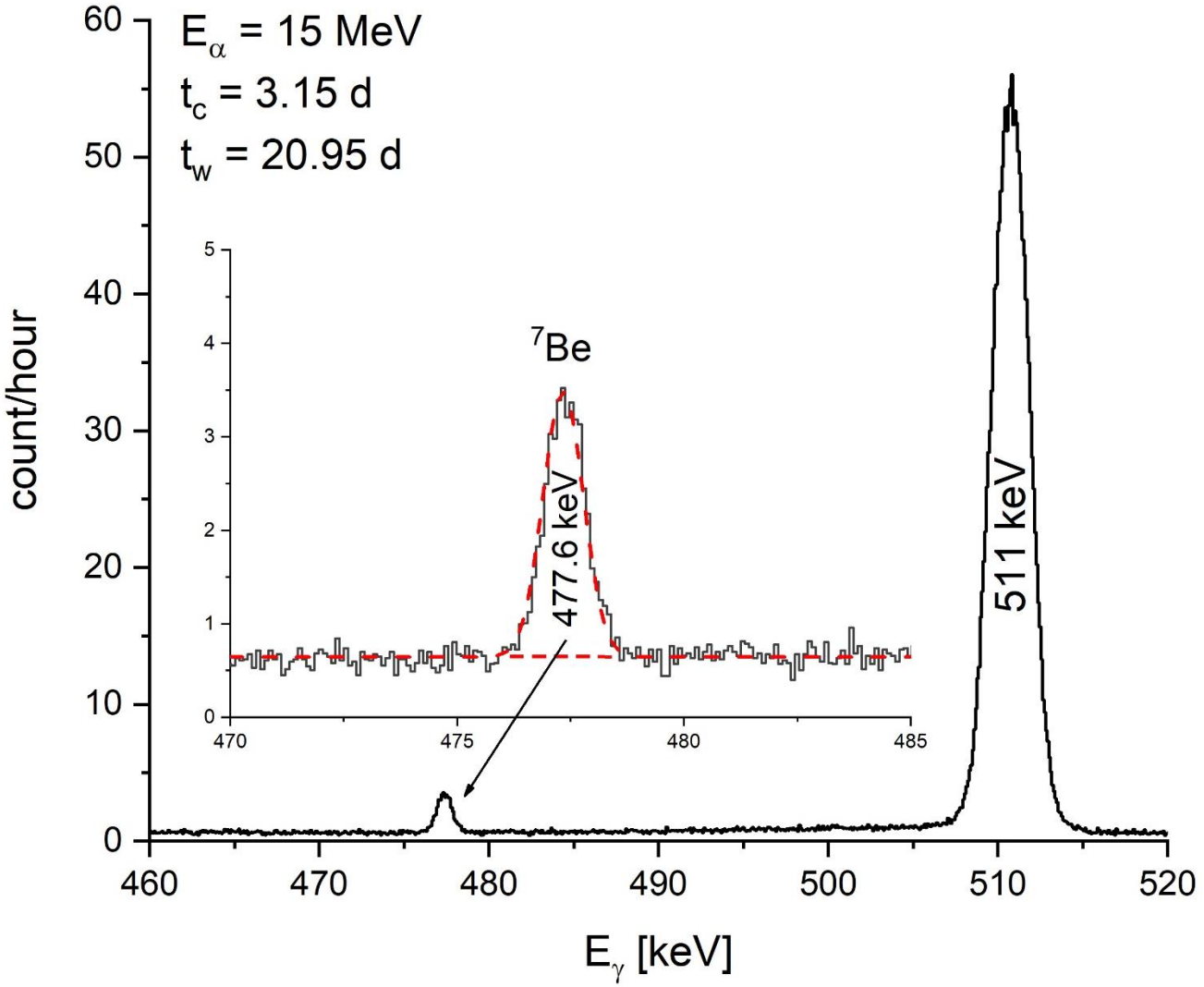


Detection efficiency

Calibrated sources:

- ^{60}Co
- ^{133}Ba
- ^{152}Eu

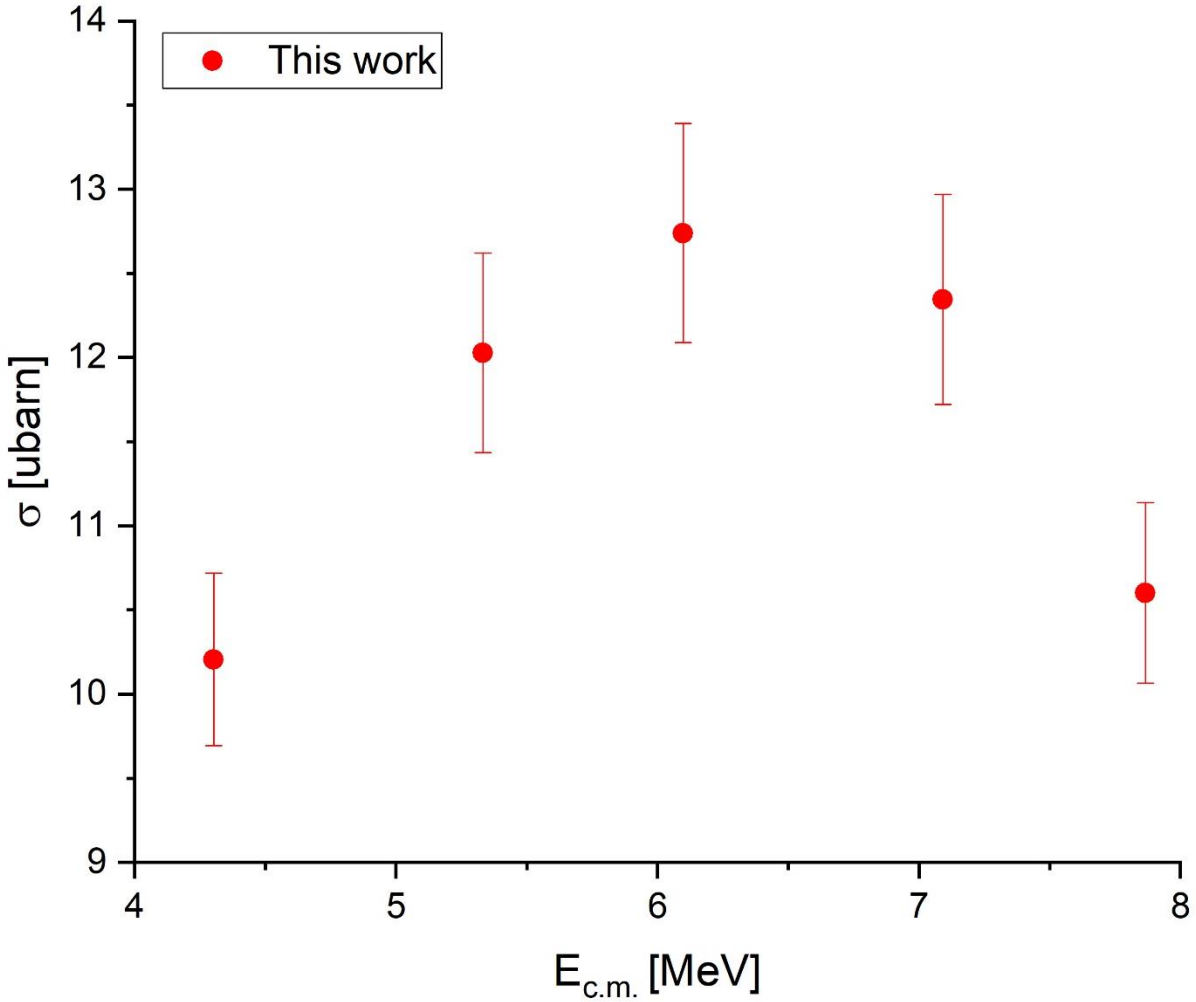
+

- ^{7}Be

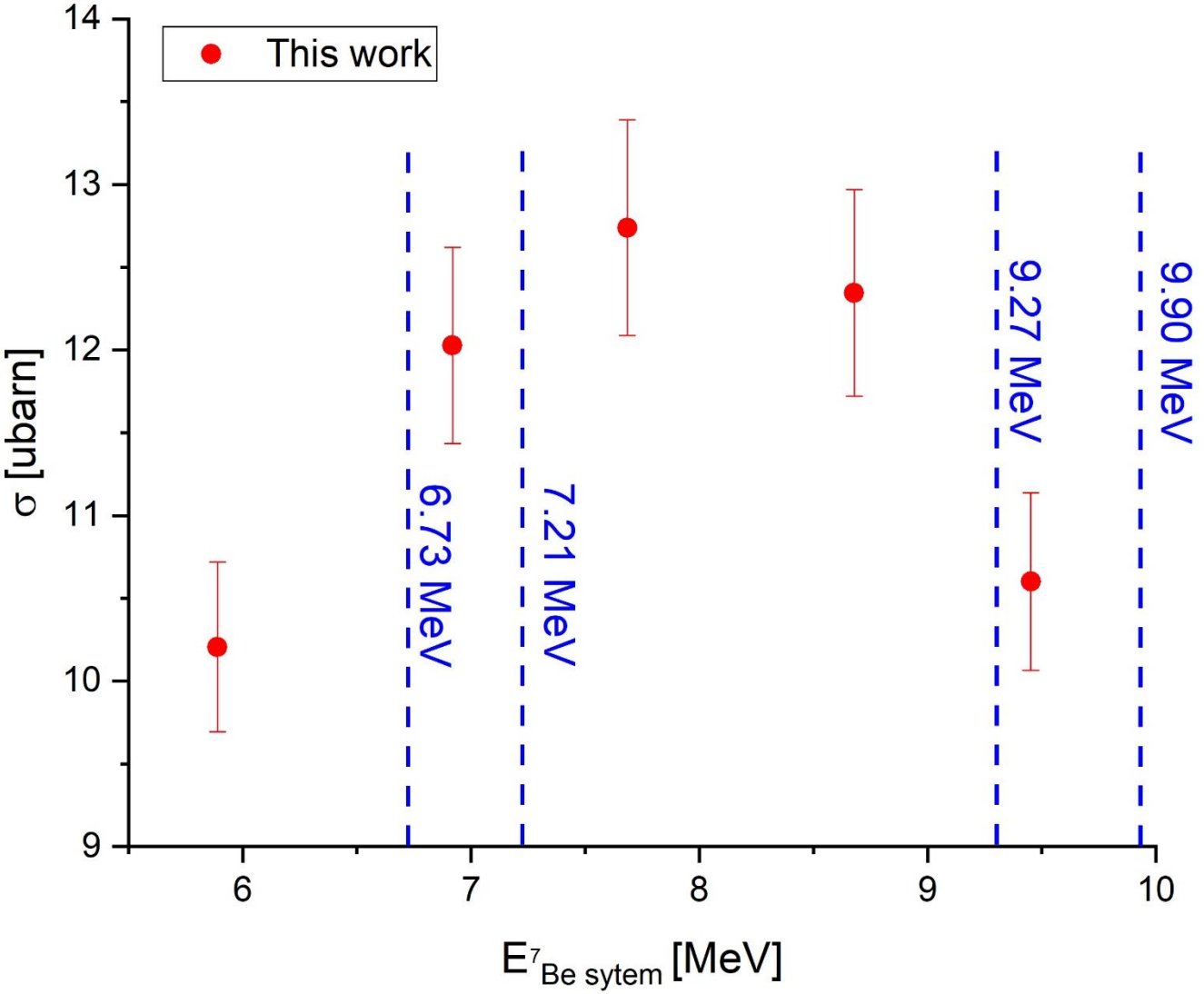
Far geometry:
Efficiency at 10 and 27 cm source-detector distance
(from the detector end cap)

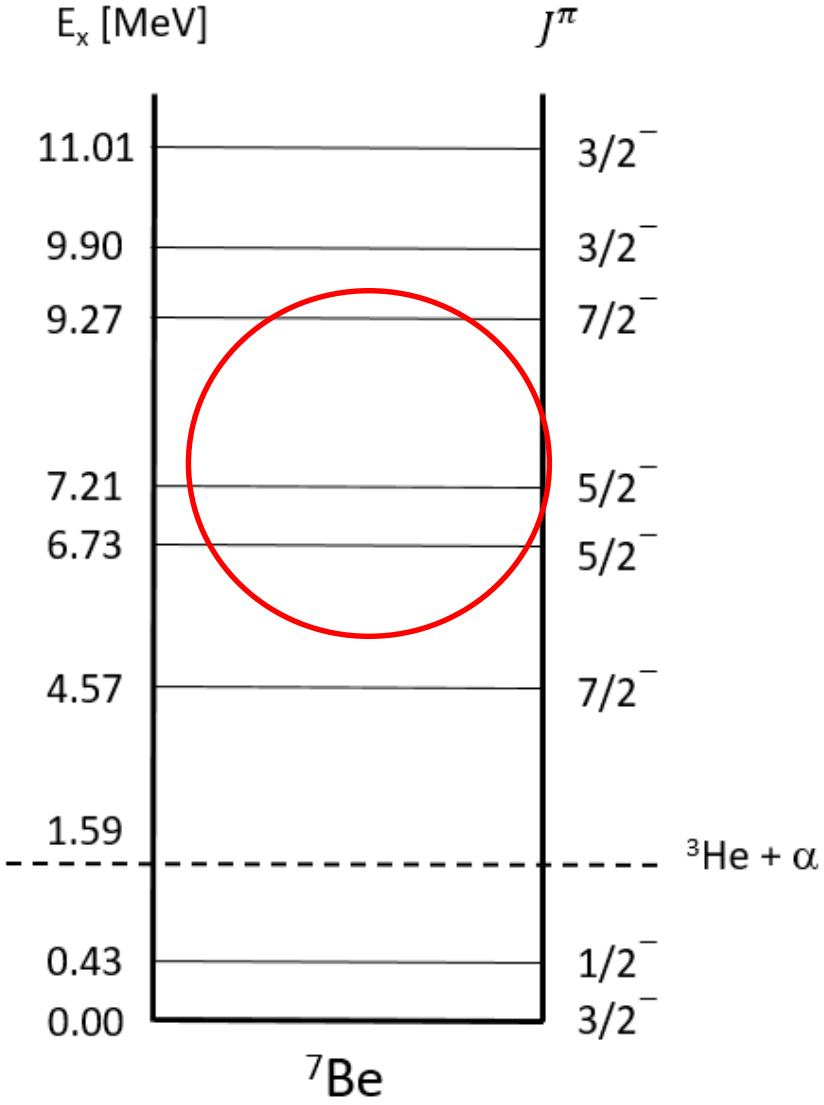
Close geometry:
Efficiency at 1 cm source-detector distance
Efficiency ratio for the close-far geometry

Preliminary results



Preliminary results





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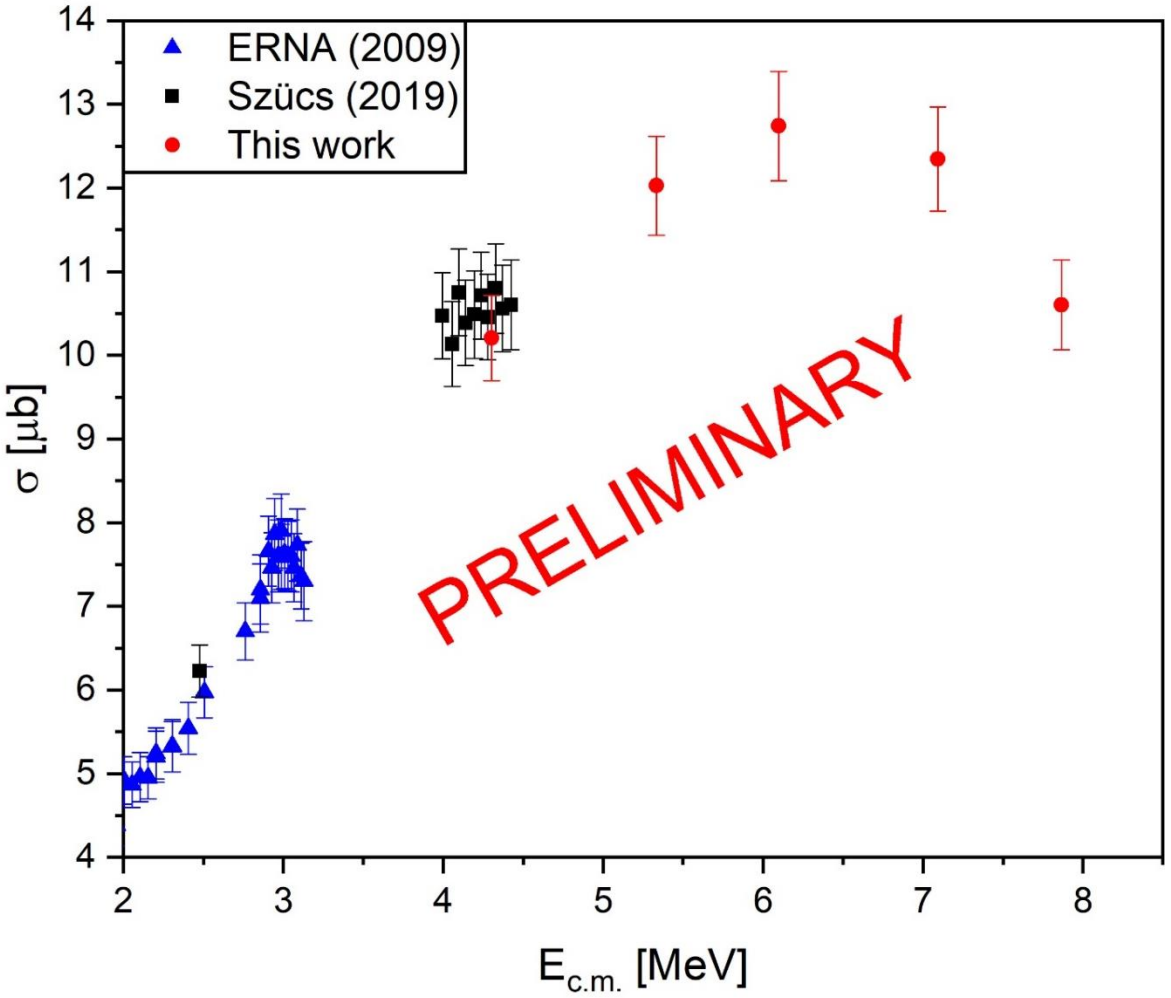

E_x [MeV]	E_α* [MeV]	E_α [MeV]	$E_{c.m.}$ [MeV]	$E_{c.m.}$+ Q value [MeV]
4.57	8.09	11	4.302	5.892
6.73	12.86	13	5.332	6.922
7.21	13.93	15	6.098	7.688
9.27	18.58	17	7.091	8.681
9.9	20.01	19	7.866	9.456
11.01	22.57			
17	36.84			

The ATOMKI cyclotron energy range

Particle	Energy [MeV]	RF harmonic mode	Max. extracted current [μA]
p	2–2.6	3	20
	2.6–18	1	50
d	2.3–5.2	3	20
	5.2–10	1	50
$^3He^{2+}$	4–8.0	3	2
	8.0–27	1	8
$^4He^{2+}$	3.5–10.4	3	5
	10.4–20	1	20

Thank you for your attention!