# The $^{16}O(p,\alpha)^{13}N$ reaction in Type 1a supernovae

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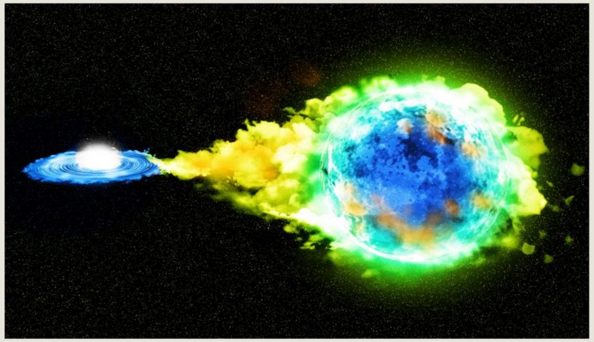
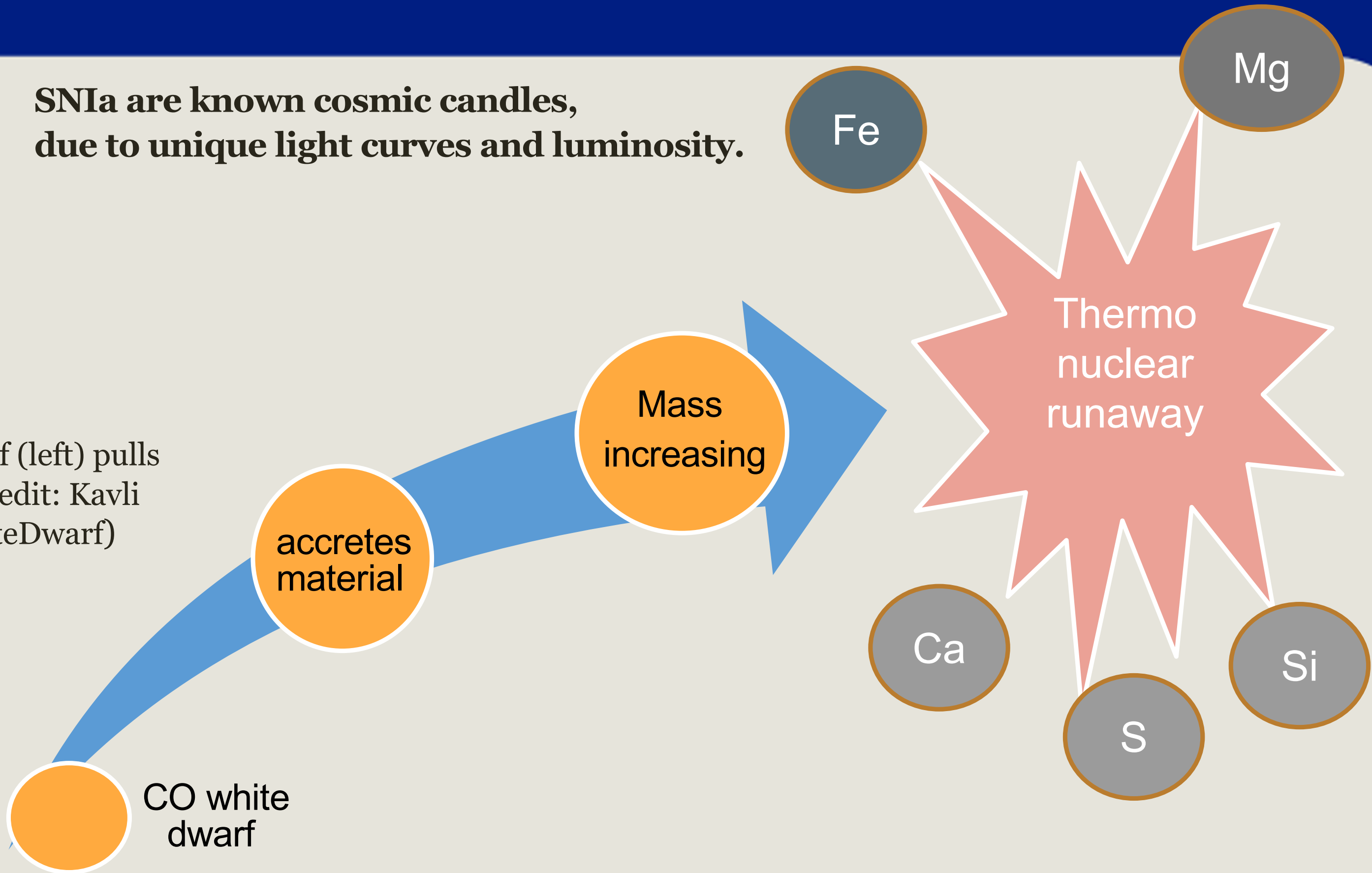
# Type 1a supernovae

**SNIa are known cosmic candles, due to unique light curves and luminosity.**



An illustration of a Type Ia supernova, a white dwarf (left) pulls material from a nearby companion star(right). (Credit: Kavli IPMU:https://www.ipmu.jp/en/20180921-WhiteDwarf)



# Production of intermediate elements

Recent observations of calcium, sulphur and argon interpreted as metallicity-dependent oxygen burning.

Studies have shown how the oxygen burning nucleosynthesis differs with alphas:

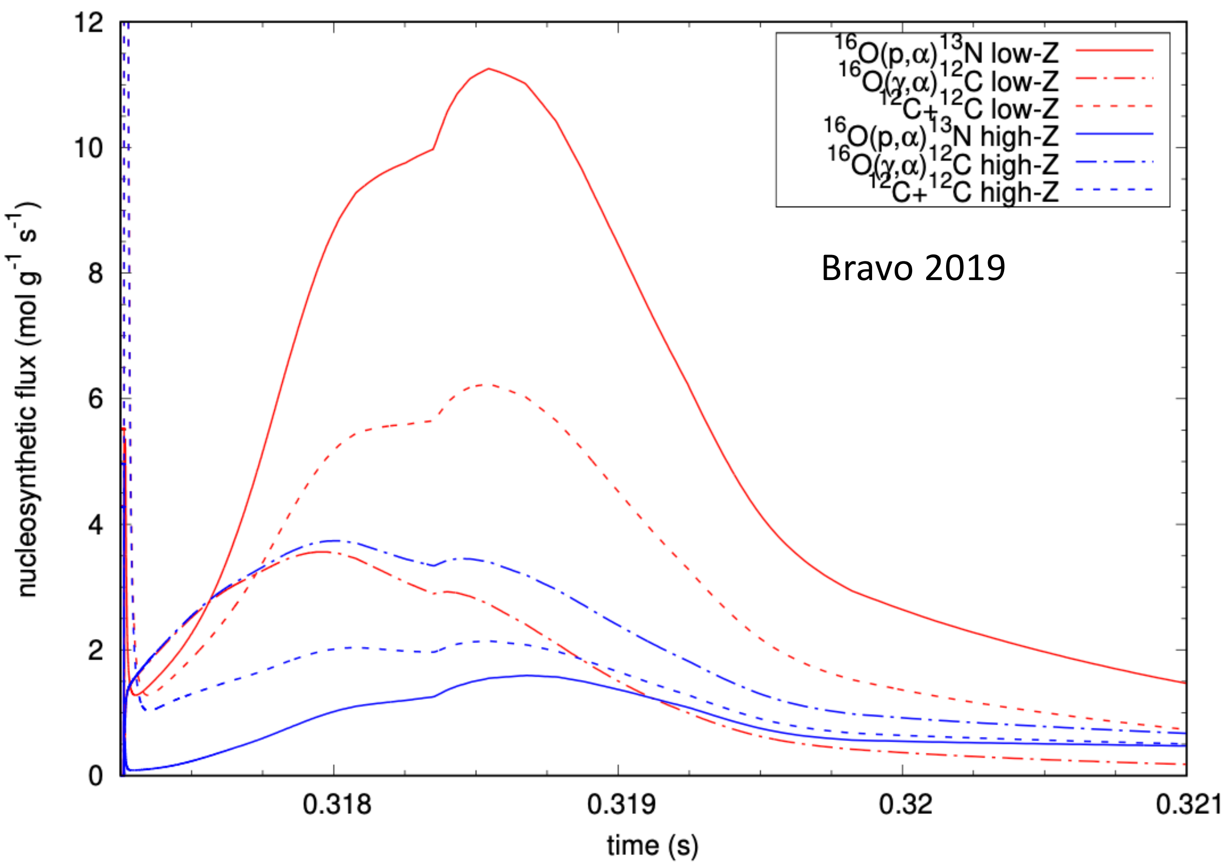
- Alpha-poor leads to more sulphur ($^{32}S$) production relative to calcium ($^{40}Ca$) .

- alpha-rich leads to more calcium ($^{40}Ca$) production relative to sulfur ($^{32}S$) .

$$M_{Ca}/M_{S} \propto X_{\alpha}^{2}$$ (De et al. 2014)

**!->increasing Ca/S ratio related to decreasing metallicity and vice versa**

# $^{16}O(p,\alpha)^{13}N$ reaction and metallicity




In alpha-rich oxygen burning

- $^{16}O$ -> $^{12}C$ then $^{12}C+^{12}C$

If sufficient proton abundance then $^{16}O(p,\alpha)^{13}N$ occurs:

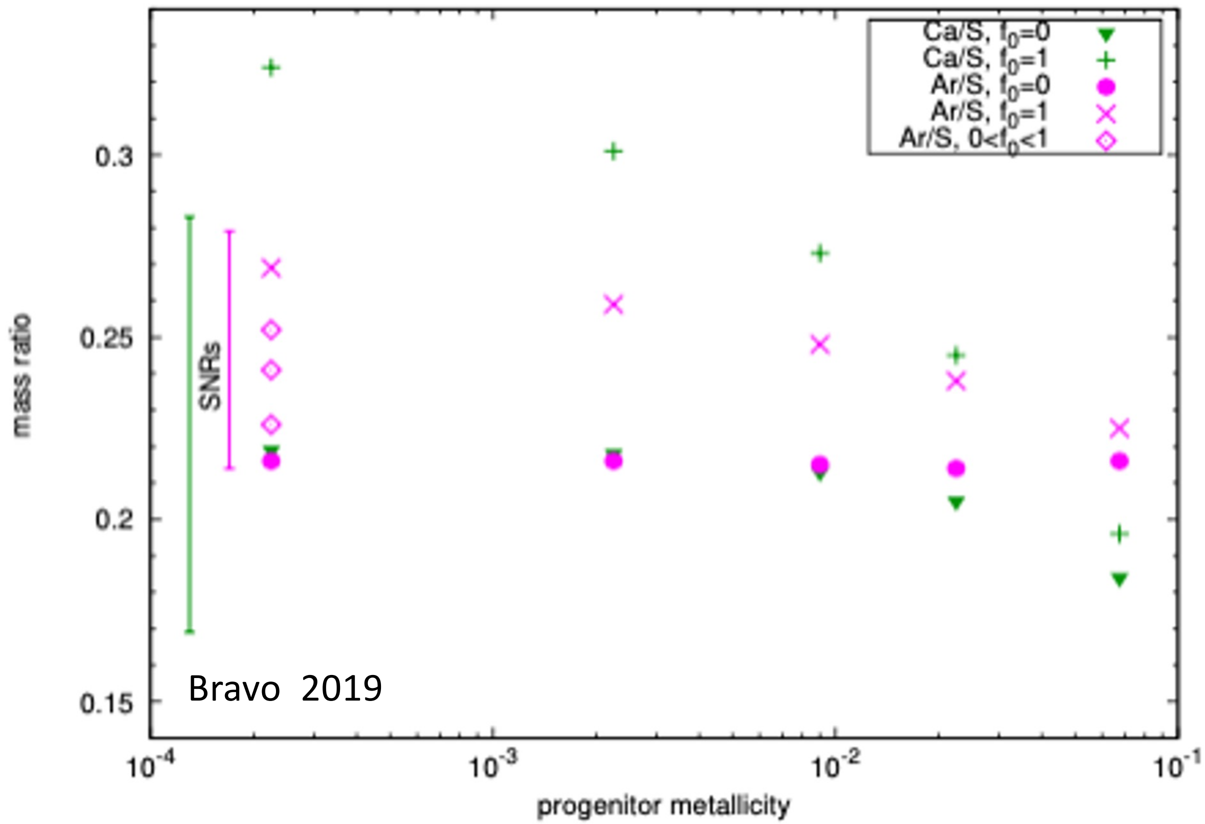
- Increases alphas
- $^{13}N(\gamma,p)^{12}C$ enhances the $^{12}C+^{12}C$
- More intermediate elements

Higher proton availability at lower metallicities

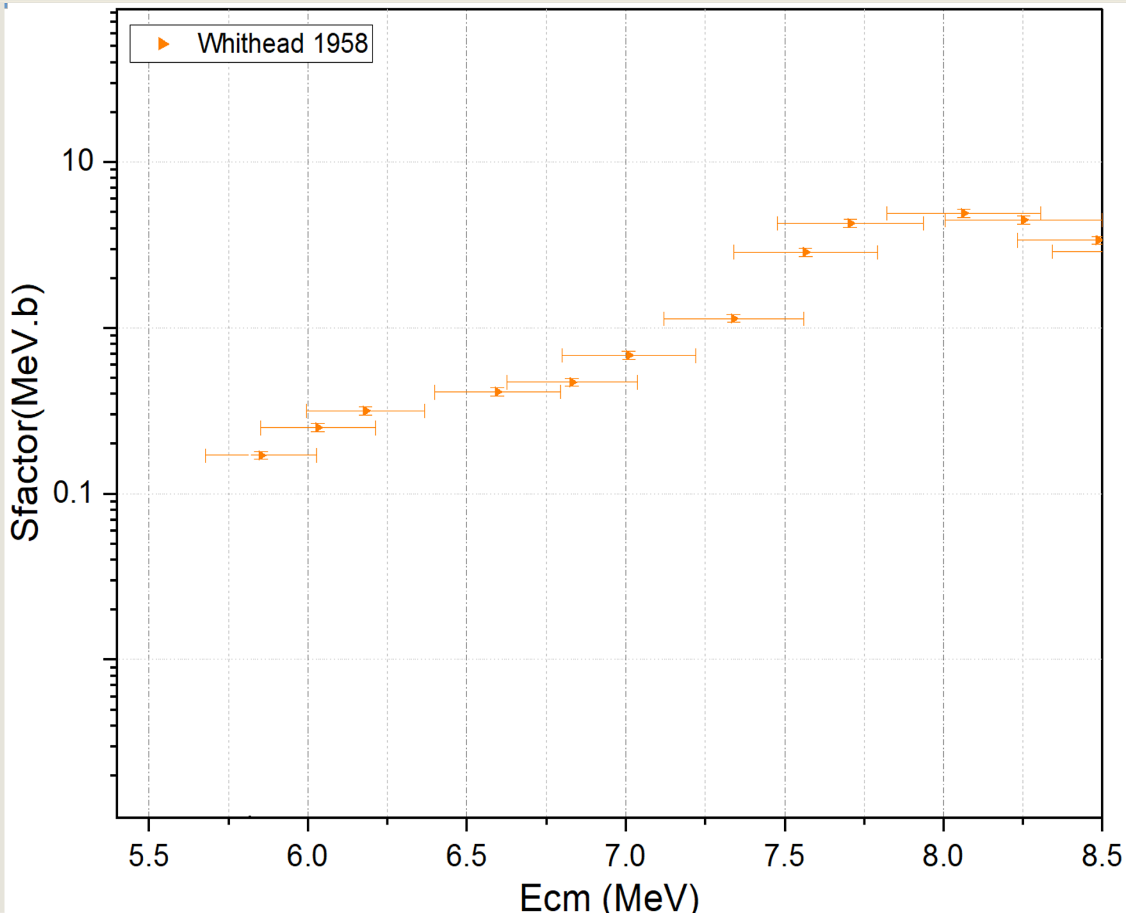
# $^{16}O(p,\alpha)^{13}N$ or $^{16}O + ^{12}C$ rate?

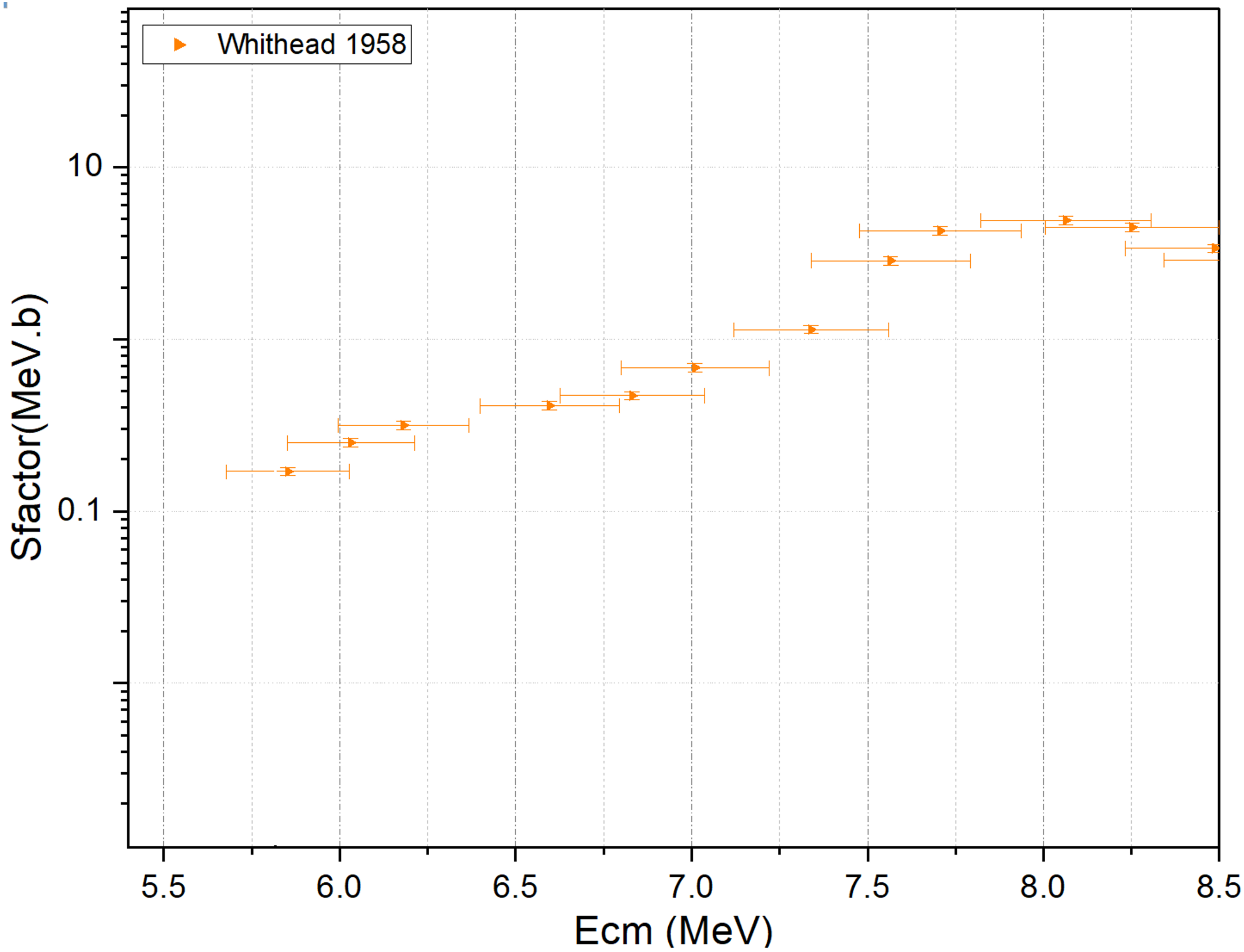
To match observations, scaling the $^{12}C + ^{16}O$ reaction rate by a factor 0.1 suggested by Martínez-Rodríguez et al. (2017)

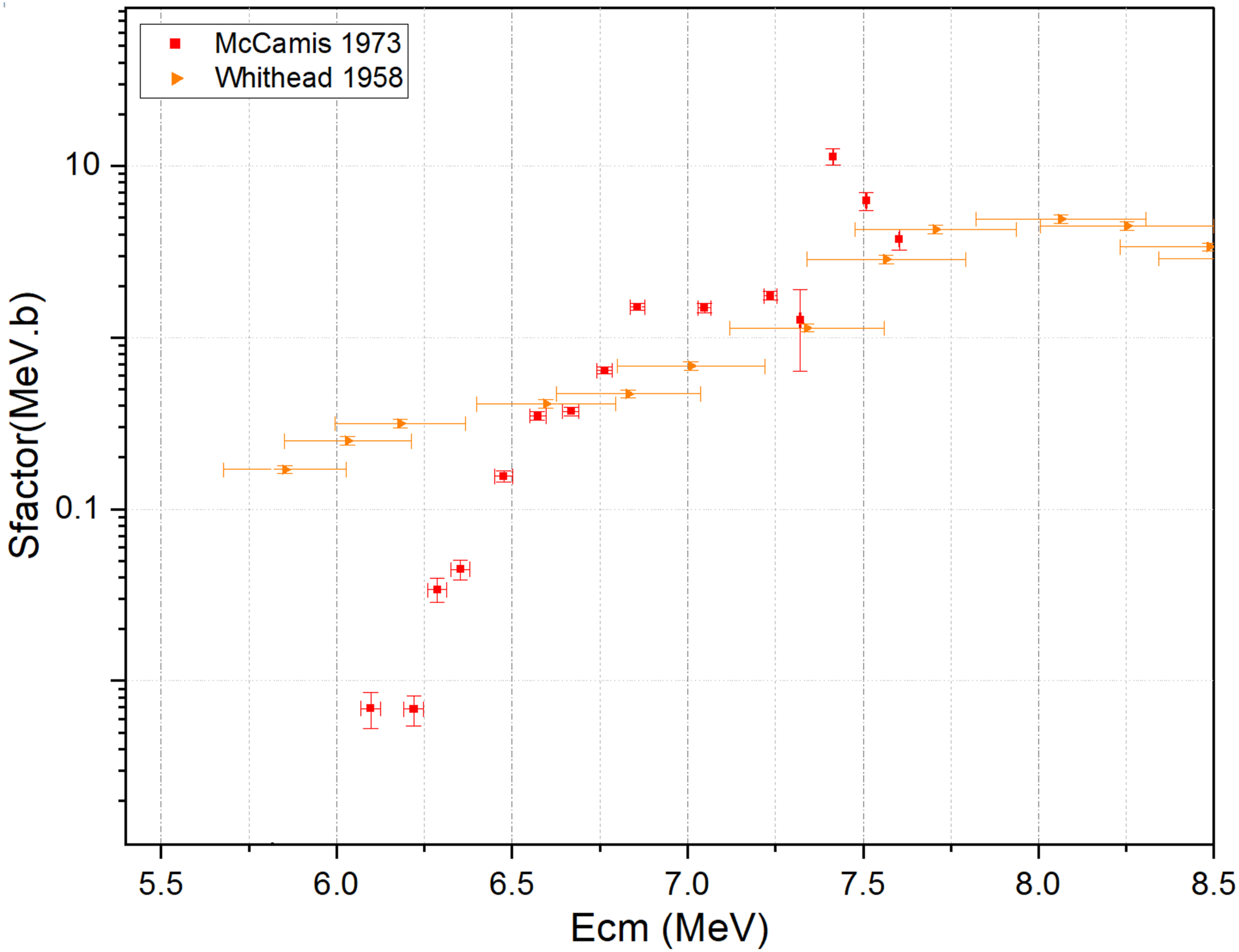
$^{12}C + ^{16}O$ reaction rate in its standard value, but enhanced $^{16}O(p,\alpha)$ by 7 was suggested by Bravo (2019)



# What do we already know?




Whithead 1958
Sfactor(MeV.b)
10
0.1
5.5
6.0
6.5
7.0
7.5
8.0
8.5
Ecm (MeV)



McCamis 1973
Whithead 1958
10
0.1
Sfactor(MeV.b)
5.5
6.0
6.5
7.0
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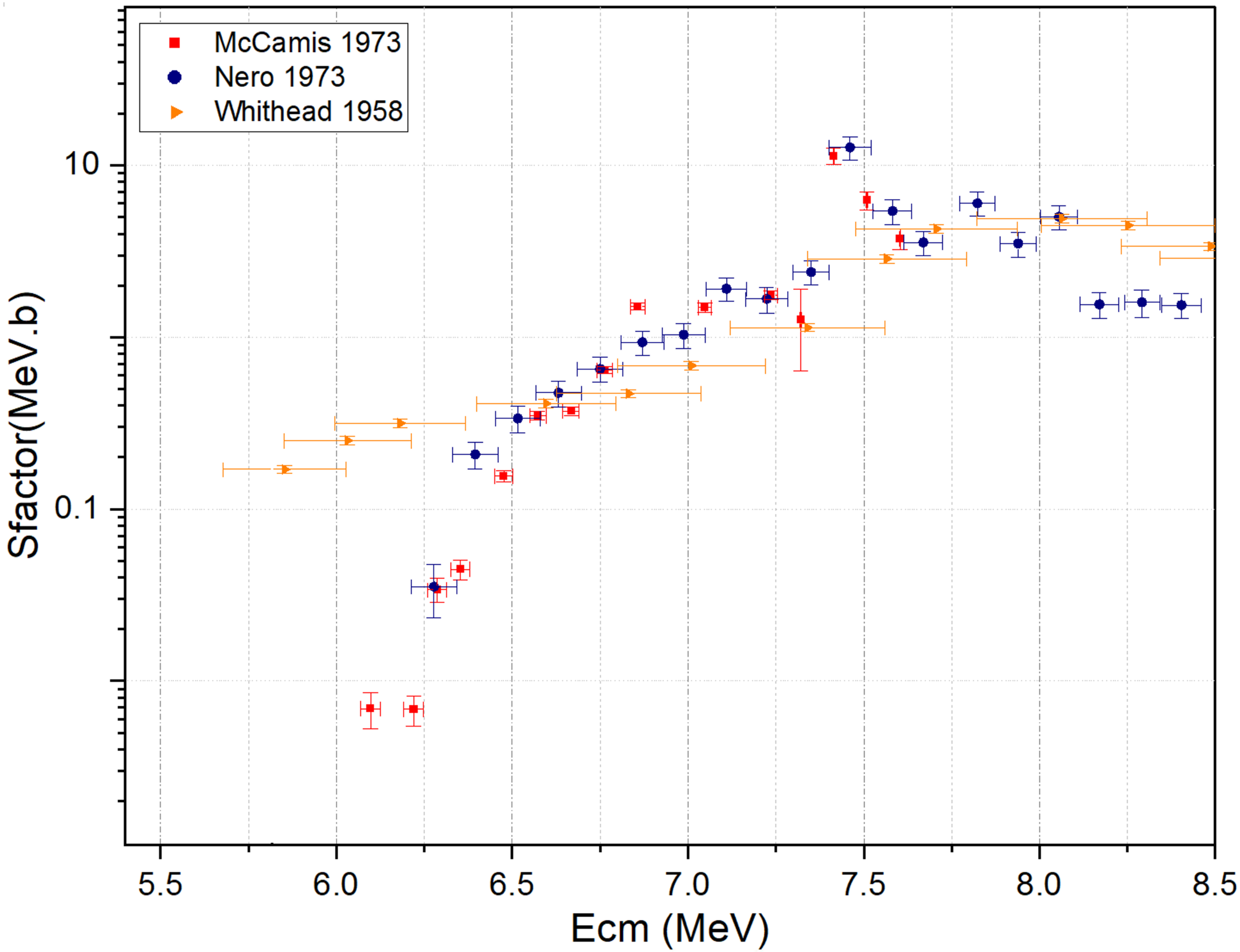
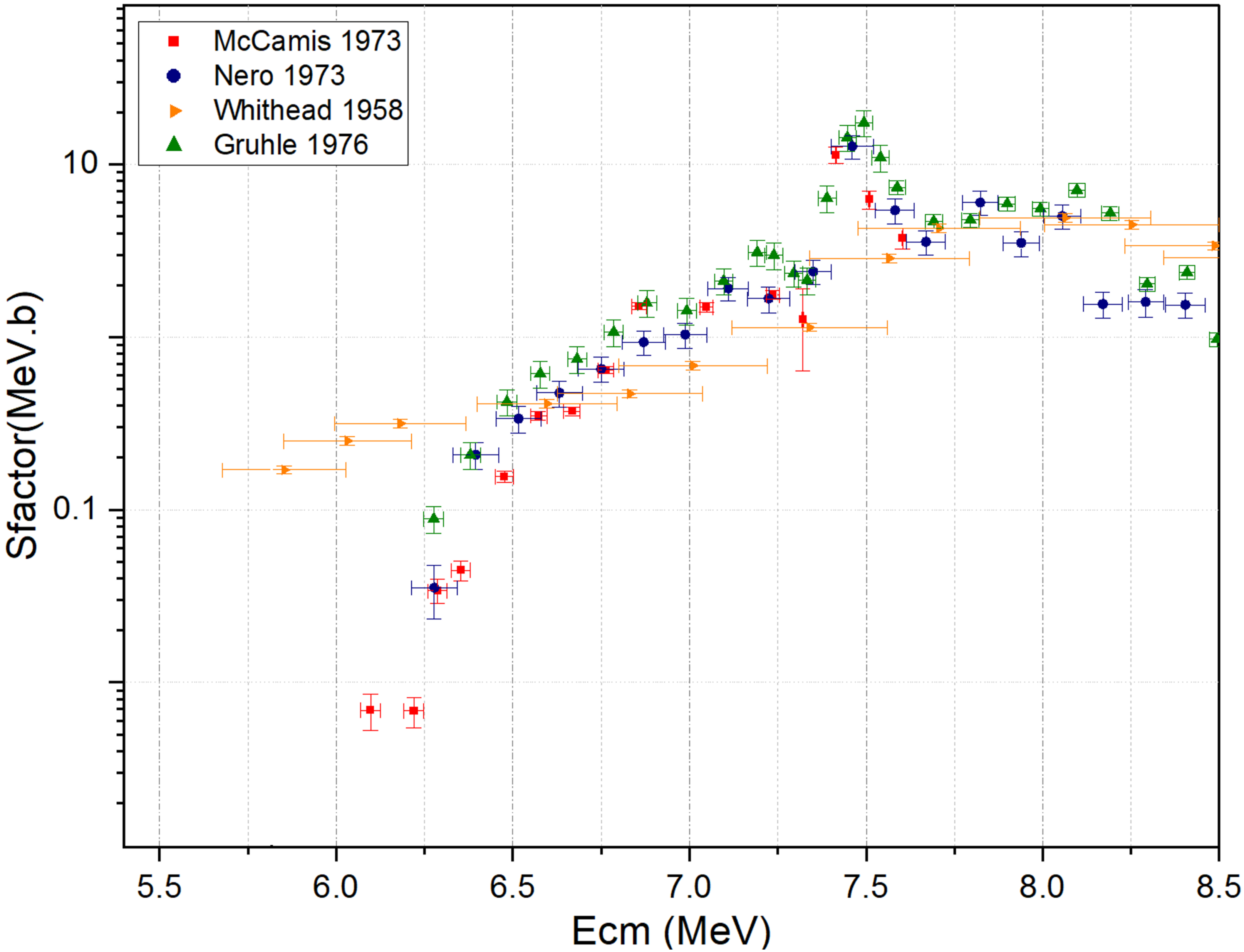
8.0
8.5
Ecm (MeV)



McCamis 1973
Nero 1973
Whithead 1958
Sfactor(MeV.b)
10
0.1
5.5
6.0
6.5
7.0
7.5
8.0
8.5
Ecm (MeV)


McCamis 1973
Nero 1973
Whithead 1958
Gruhle 1976
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0.1
Sfactor(MeV.b)
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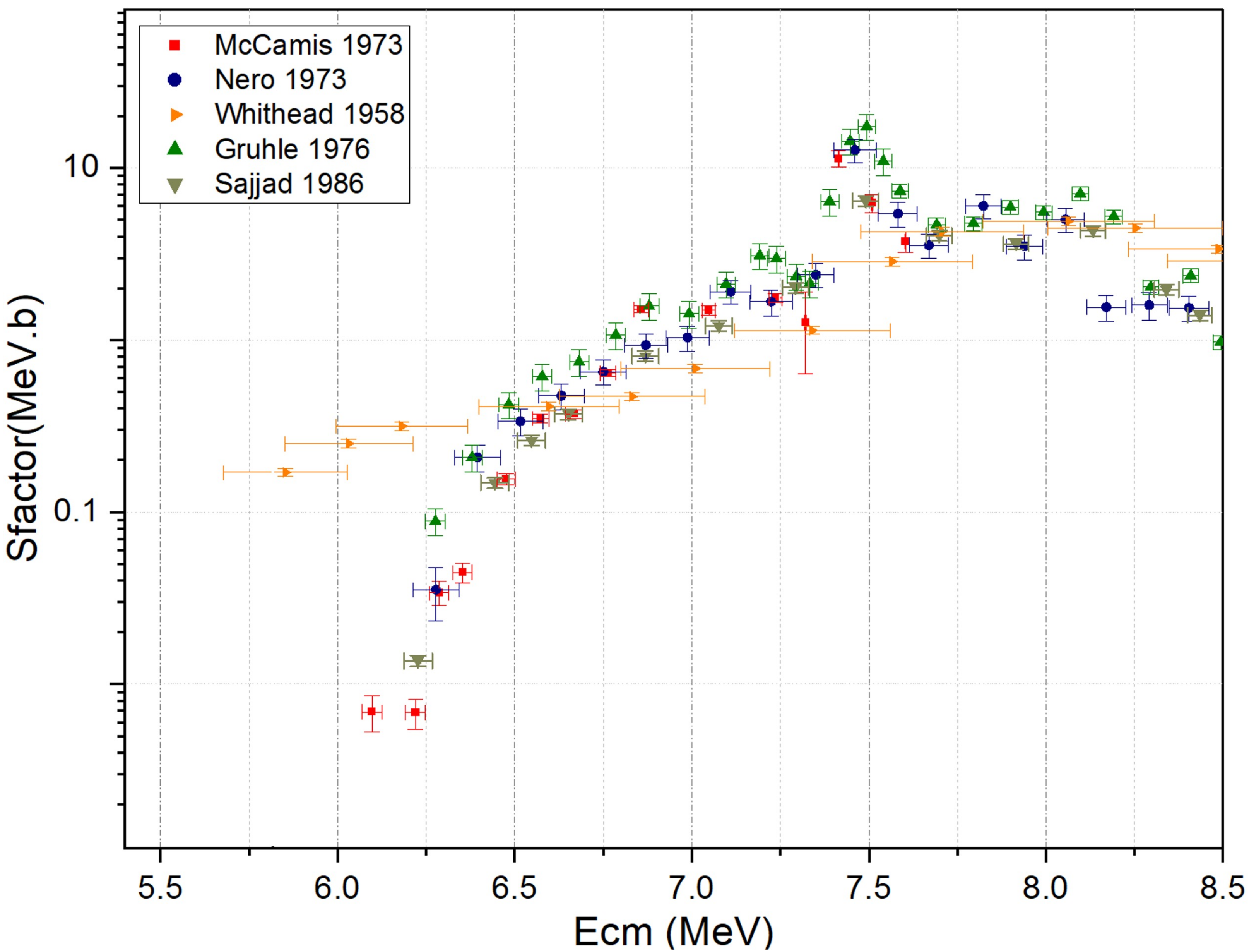
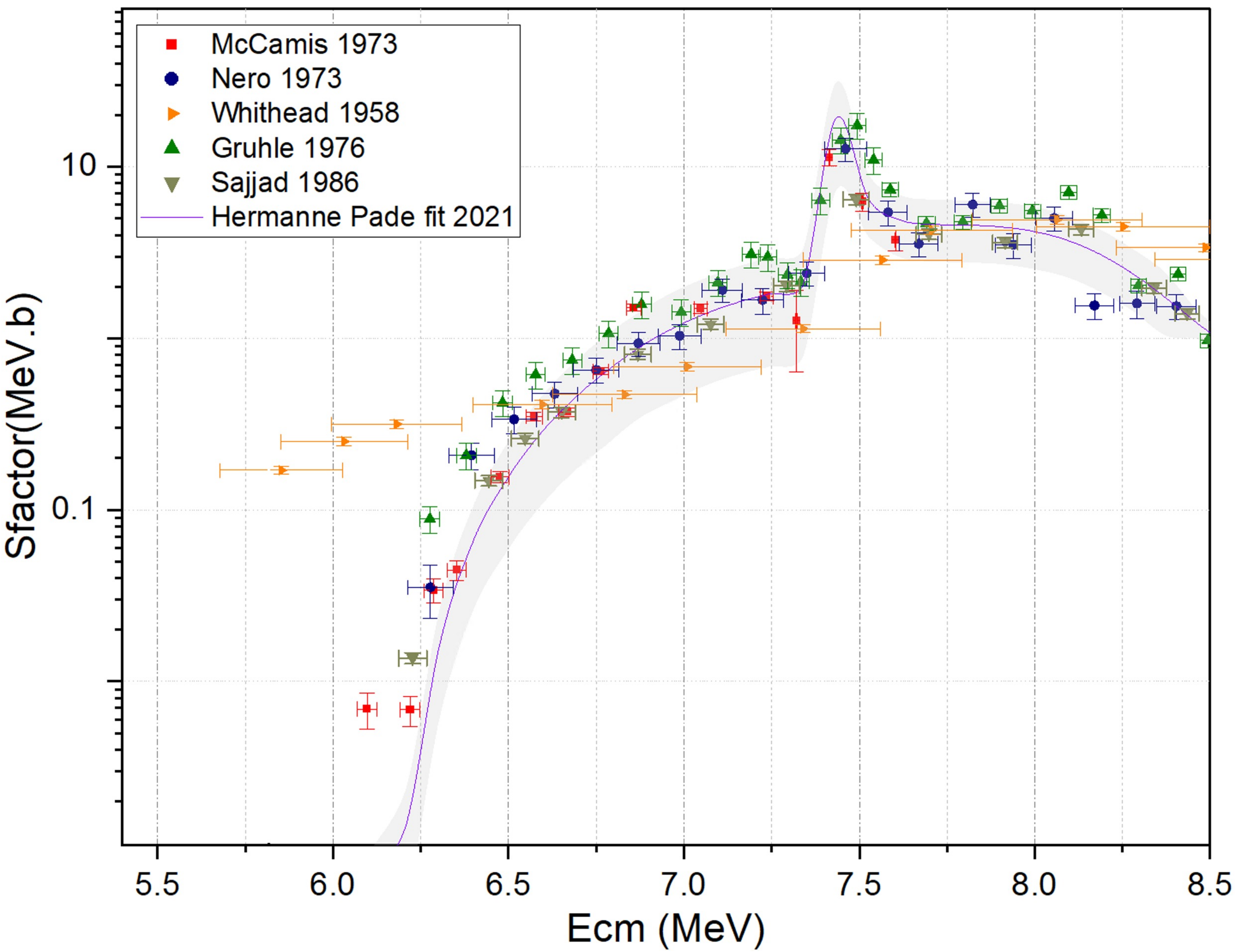
8.5
Ecm (MeV)

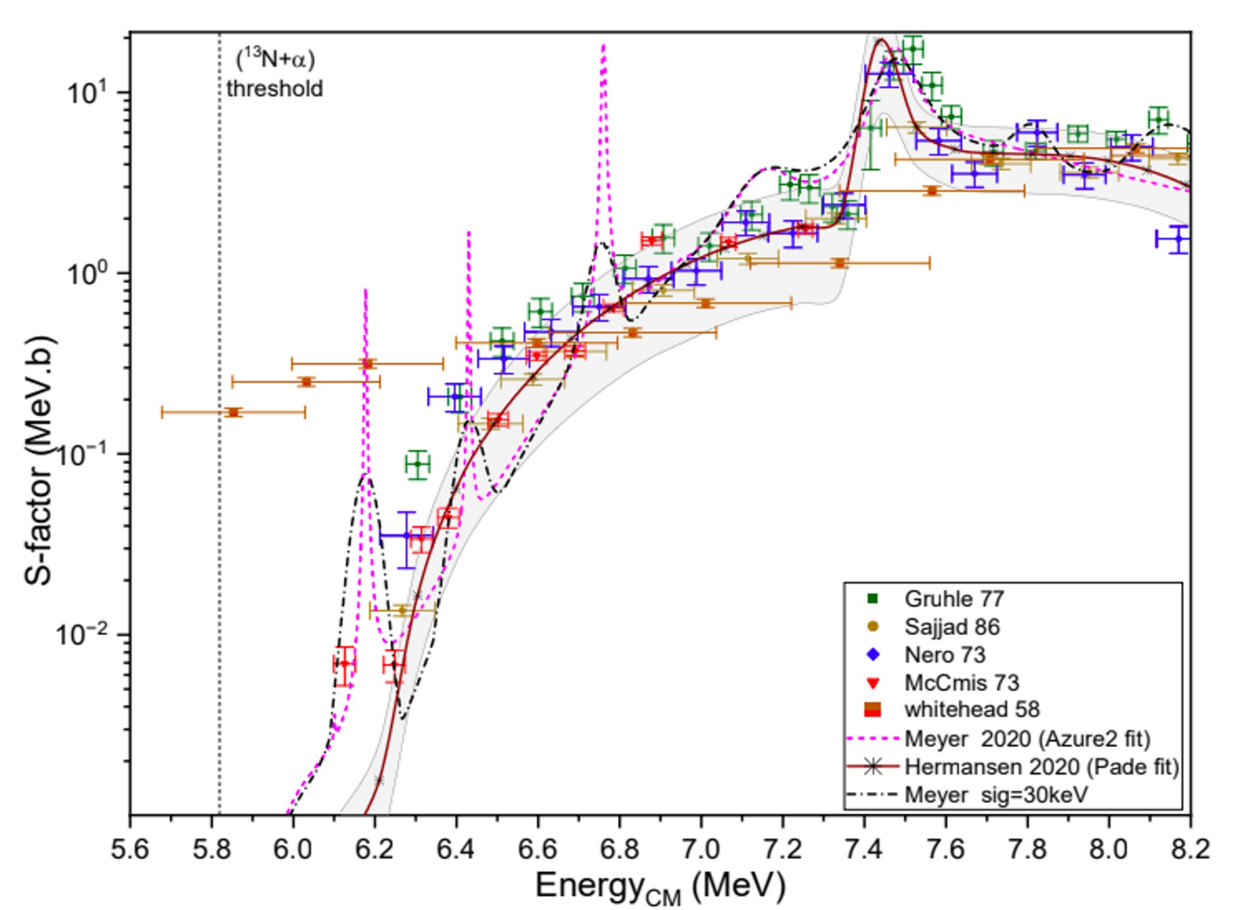


McCamis 1973
Nero 1973
Whithead 1958
Gruhle 1976
Sajjad 1986
Sfactor(MeV.b)
10
0.1
5.5
6.0
6.5
7.0
7.5
8.0
8.5
Ecm (MeV)



McCamis 1973
Nero 1973
Whithead 1958
Gruhle 1976
Sajjad 1986
Hermanne Pade fit 2021
10
0.1
5.5
6.0
6.5
7.0
7.5
8.0
8.5
Sfactor(MeV.b)
Ecm (MeV)

# What do we already know?



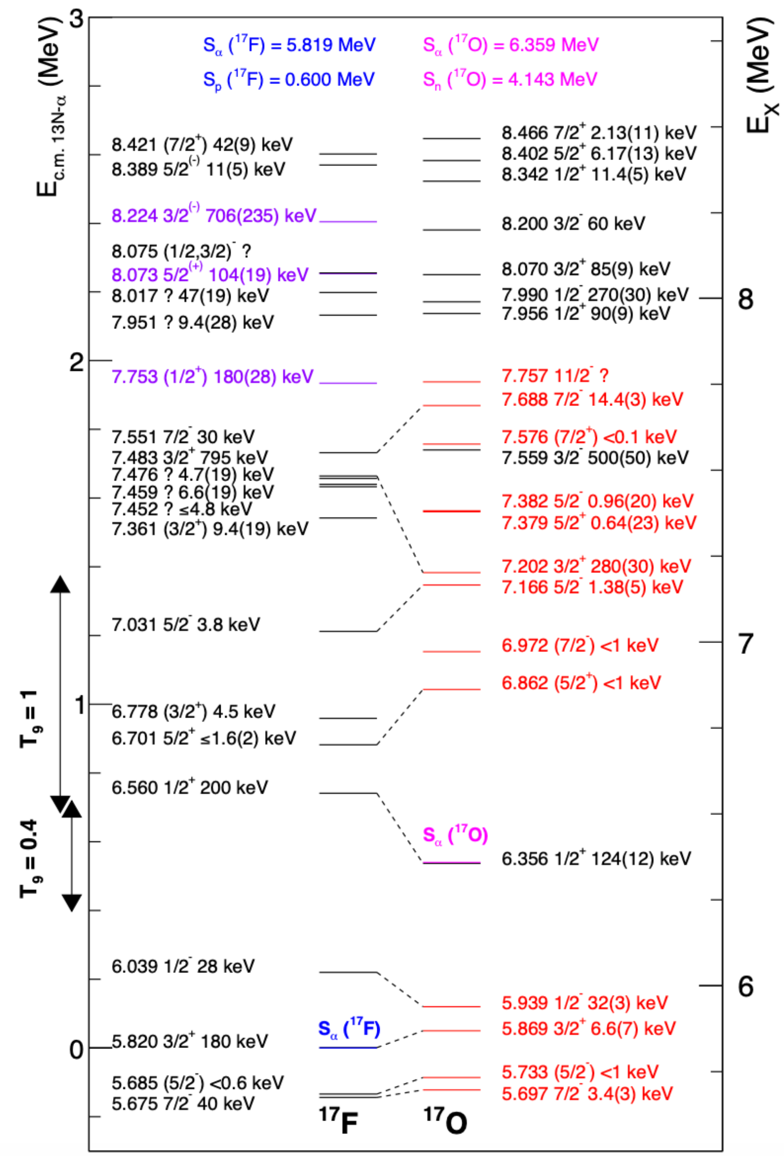

Previous measurements of $^{16}O(p,\alpha)^{13}N$ cross section show significant discrepancies, **and don't agree within uncertainty.**

**All previous measurements were performed using activation techniques.**

# (Brief nuclear aside: the magic of mirrors)

- The compound nucleus is $^{17}$F.
- Its mirror is $^{17}$O
- Which is formed in the $^{13}C(\alpha,n)^{16}O$ reaction

➢ See Meyer et al. Phys. Rev. C 2020



# MUSIC measurement

**active target**

- Gas: detector & target
- Change in energy loss detected
- High efficiency

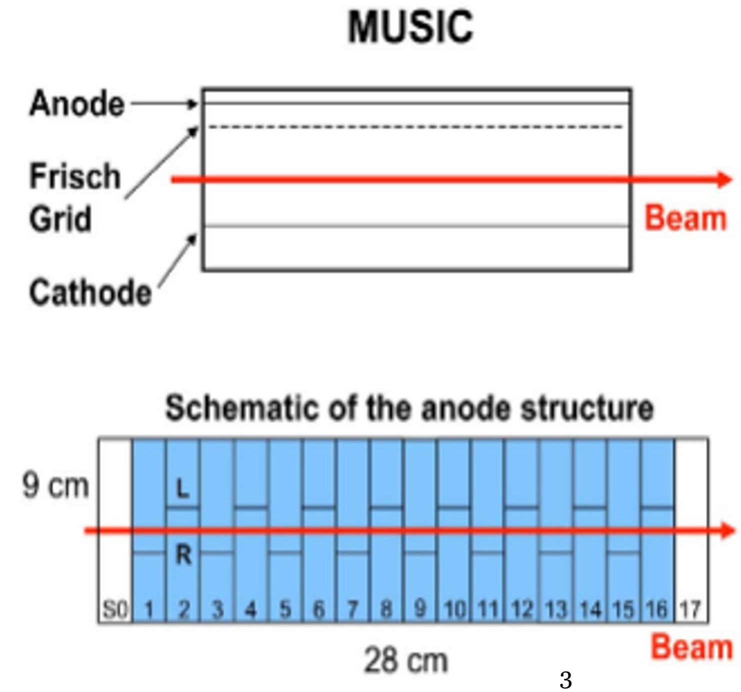
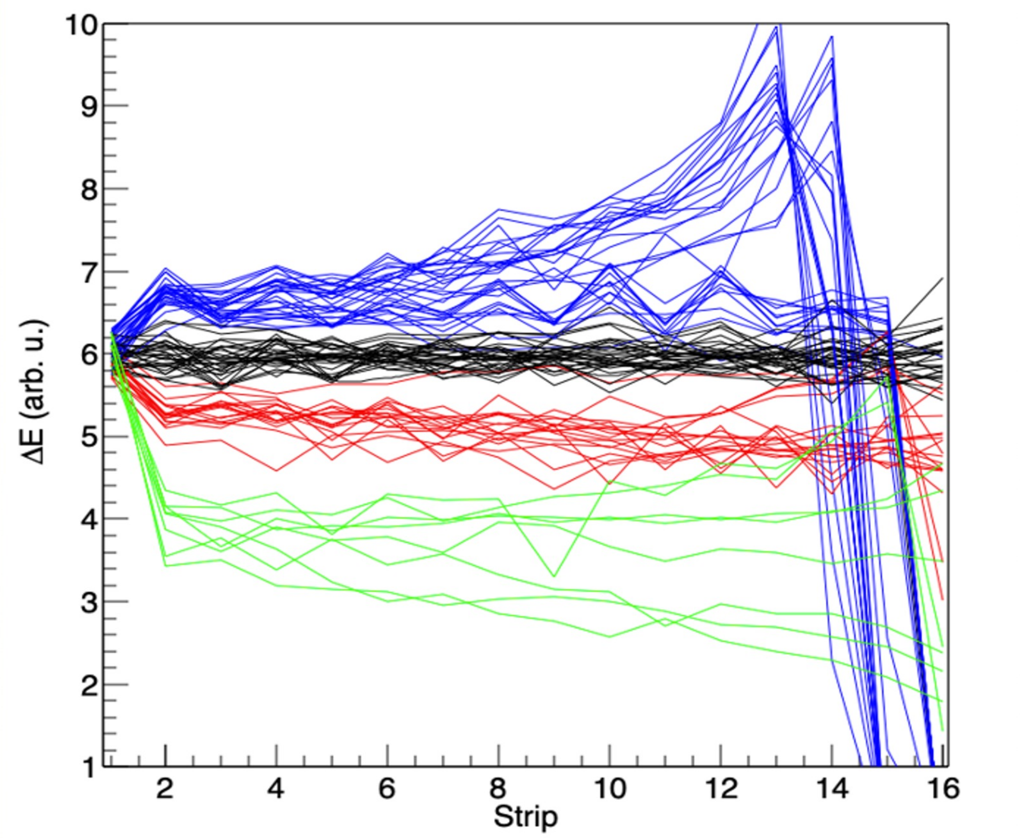


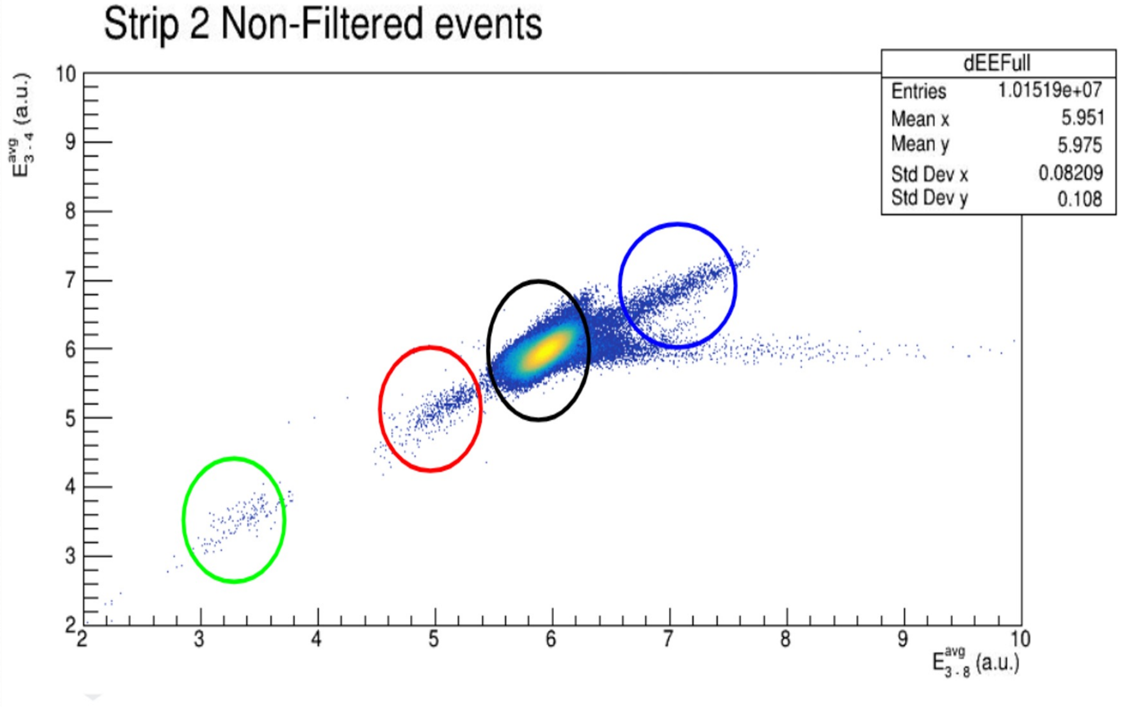

**Fig. 1.** Schematic of the MUSIC detector (from Ref. [5]). Upper panel: lateral view of the detector. Lower panel: anode structure, showing the 18 strips. Strips 1–16 are subdivided into non-symmetric left and right sections.

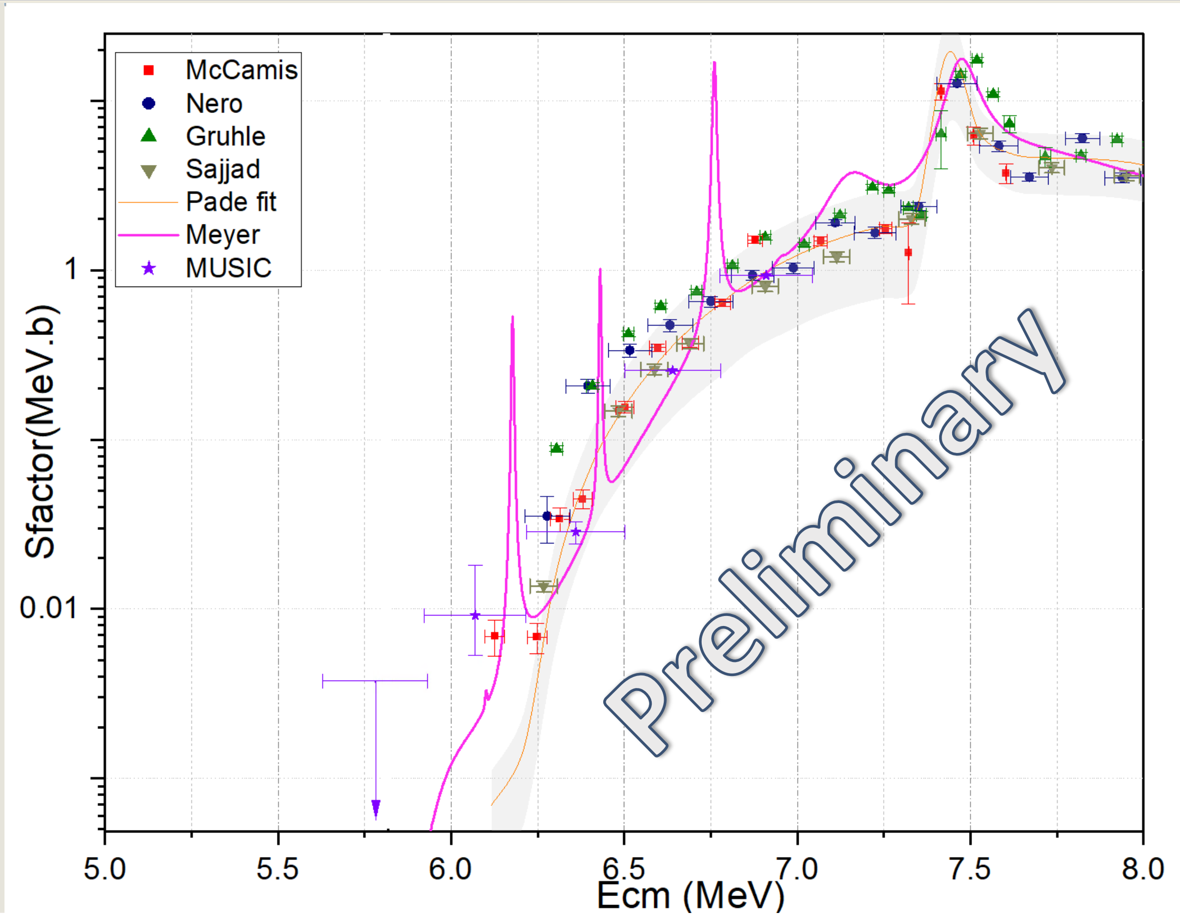
**array of 18 anode**

- Filtering background
- Single Beam wide Ecm range

# Event identification




McCamis
Nero
Gruhle
Sajjad
Pade fit
Meyer
MUSIC
1
0.01
Sfactor(MeV.b)
5.0
5.5
6.0
6.5
7.0
7.5
8.0
Ecm (MeV)
Preliminary

# Summary

- The reaction rate of **16O(p,α)13N**, which is crucial for understanding nucleosynthesis in Type Ia supernovae (SNIa), was poorly constrained.
- Earlier cross-section measurements relied on the activation method, which may have included background from contaminants, particularly at energies lower than **6.8 MeV**.
- Our new measurement using the **MUSIC** detector has provided cross-sections for energies below **6.9 MeV**, significantly improving the constraints on the reaction rate.
- However, our results do not support the previously suggested increase in the **16O(p,α)** rate by a factor of 7

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Thank you!