Inelastic Scattering of Alphas on ^{24}Mg as a Surrogate for Stellar Carbon Burning

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Hydrogen Burning

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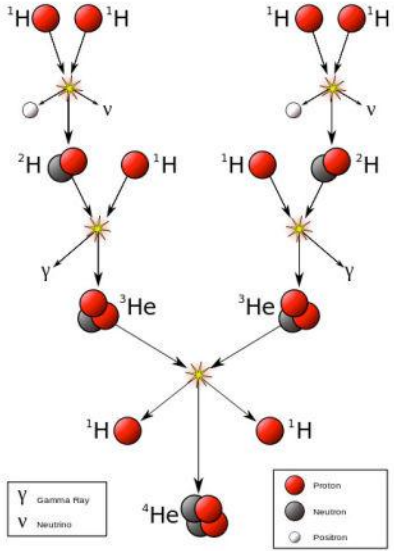
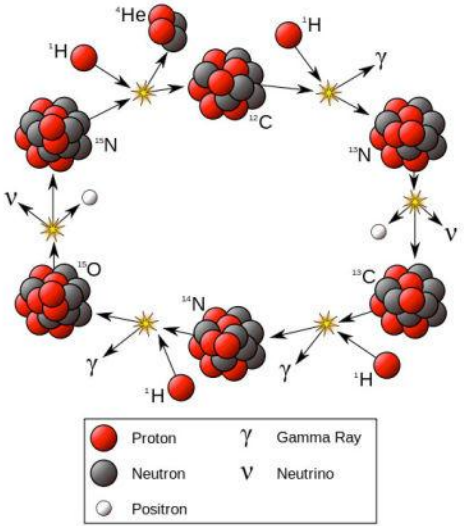
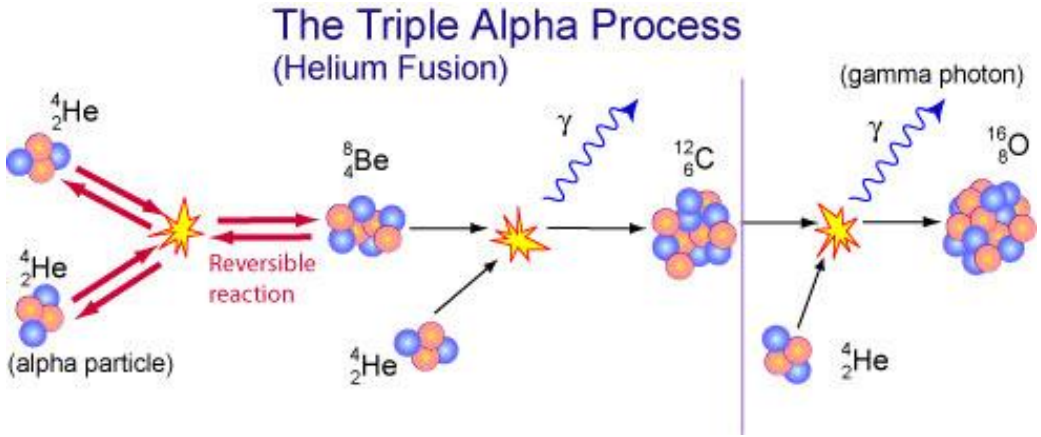


CNO



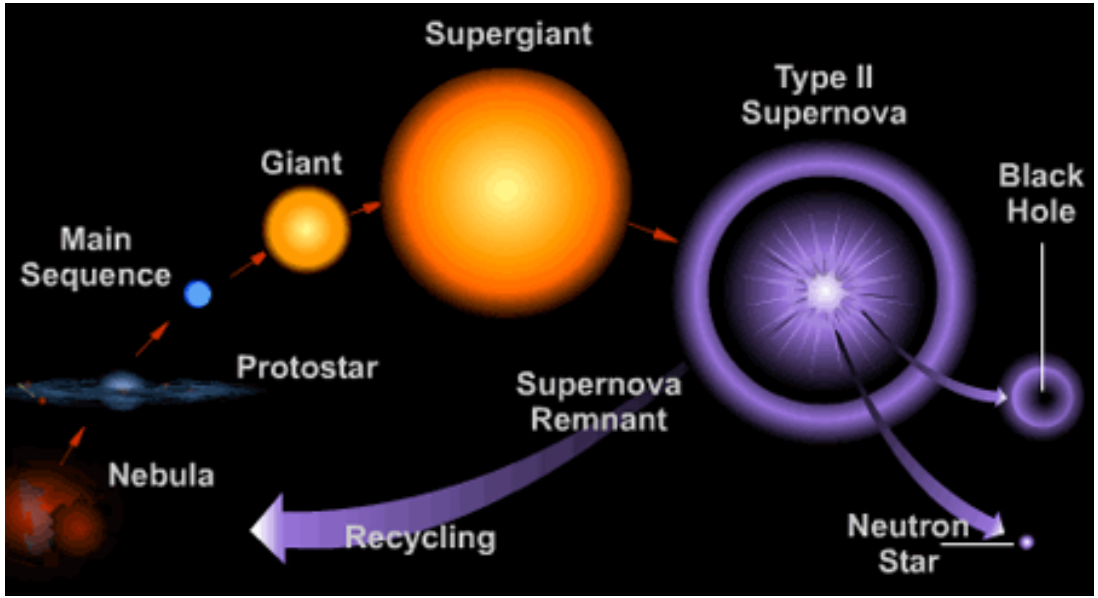
Helium Burning

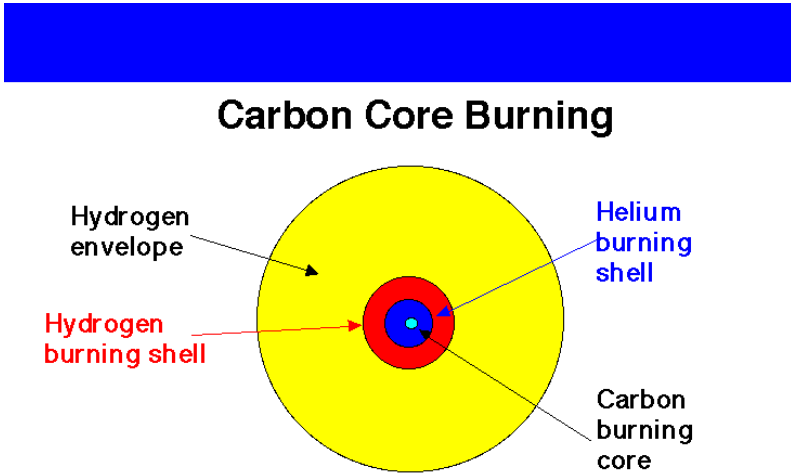


$^{12}C+^{12}C$

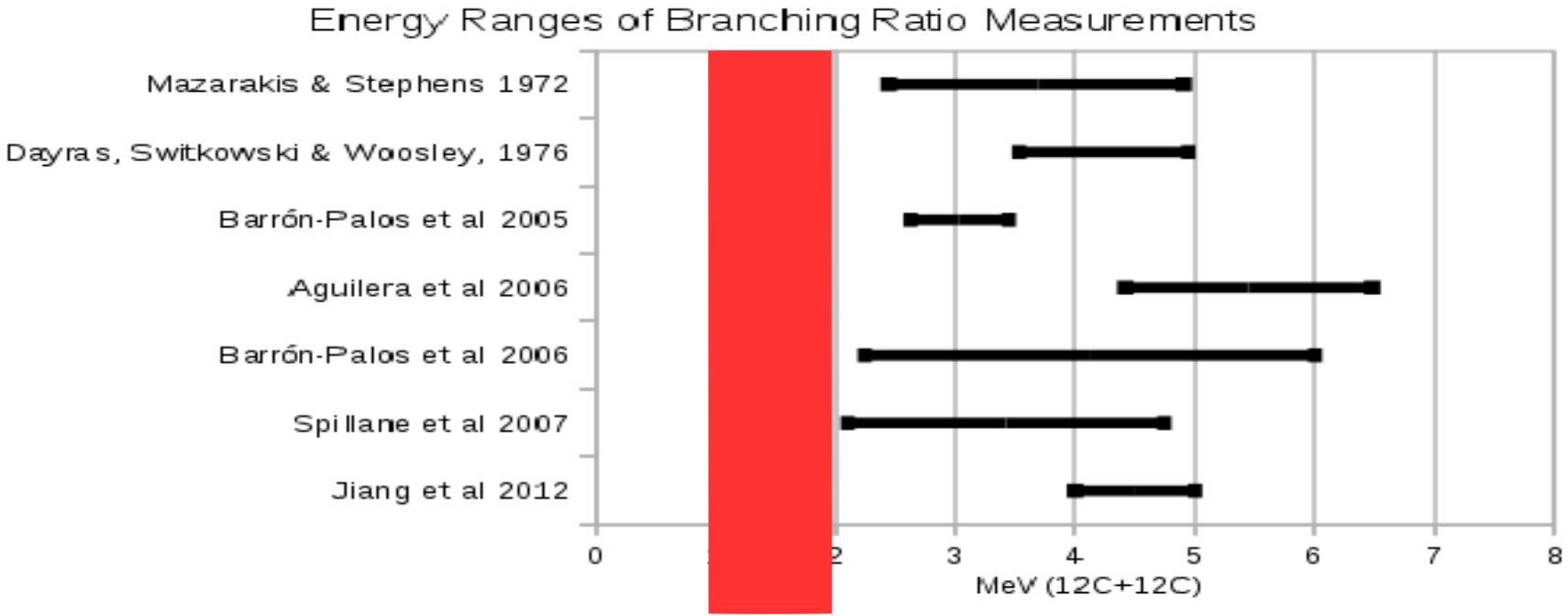
- Carbon burning occurs in several scenarios for later stellar evolution
  - Larger stars experience a static carbon burning stage (around 300 years for a 25 solar mass star)
  - Smaller stars just over one solar mass may develop a degenerate carbon/oxygen core and eventually undergo a Type I supernova explosion - *Used As "Standard Candles" to determine galactic distances*

Massive star evolution



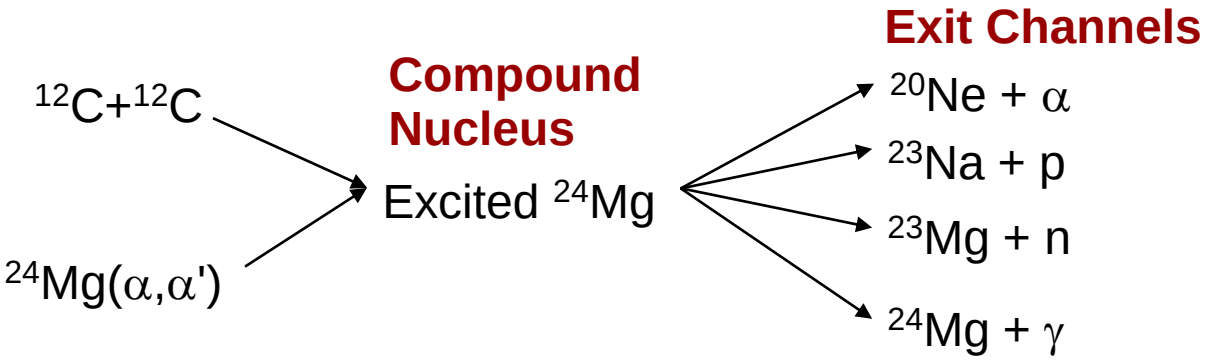


Previous direct measurements of $^{12}C + ^{12}C$



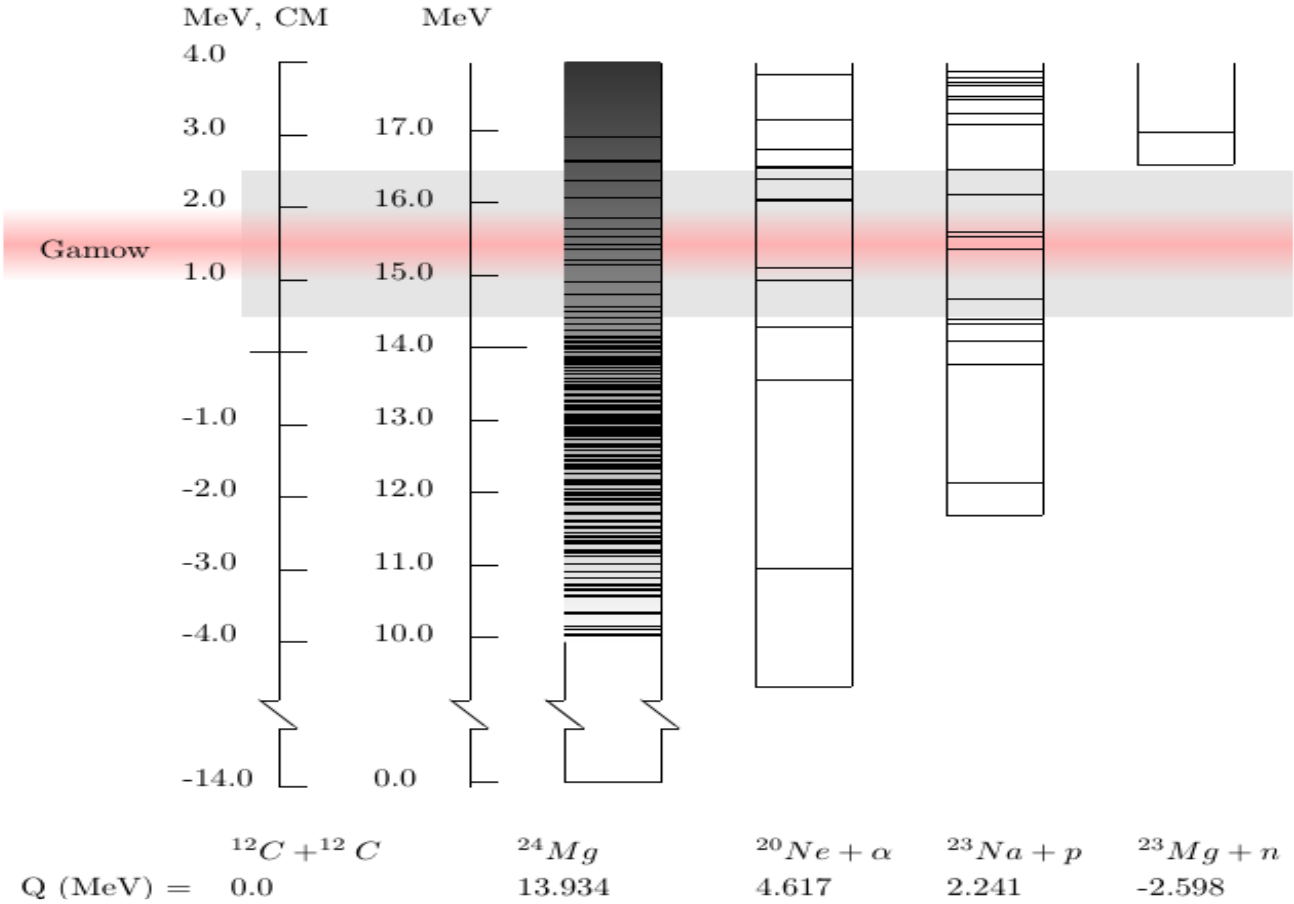
Gamow Window (T= $5x10^8$ K)

Surrogate Approach

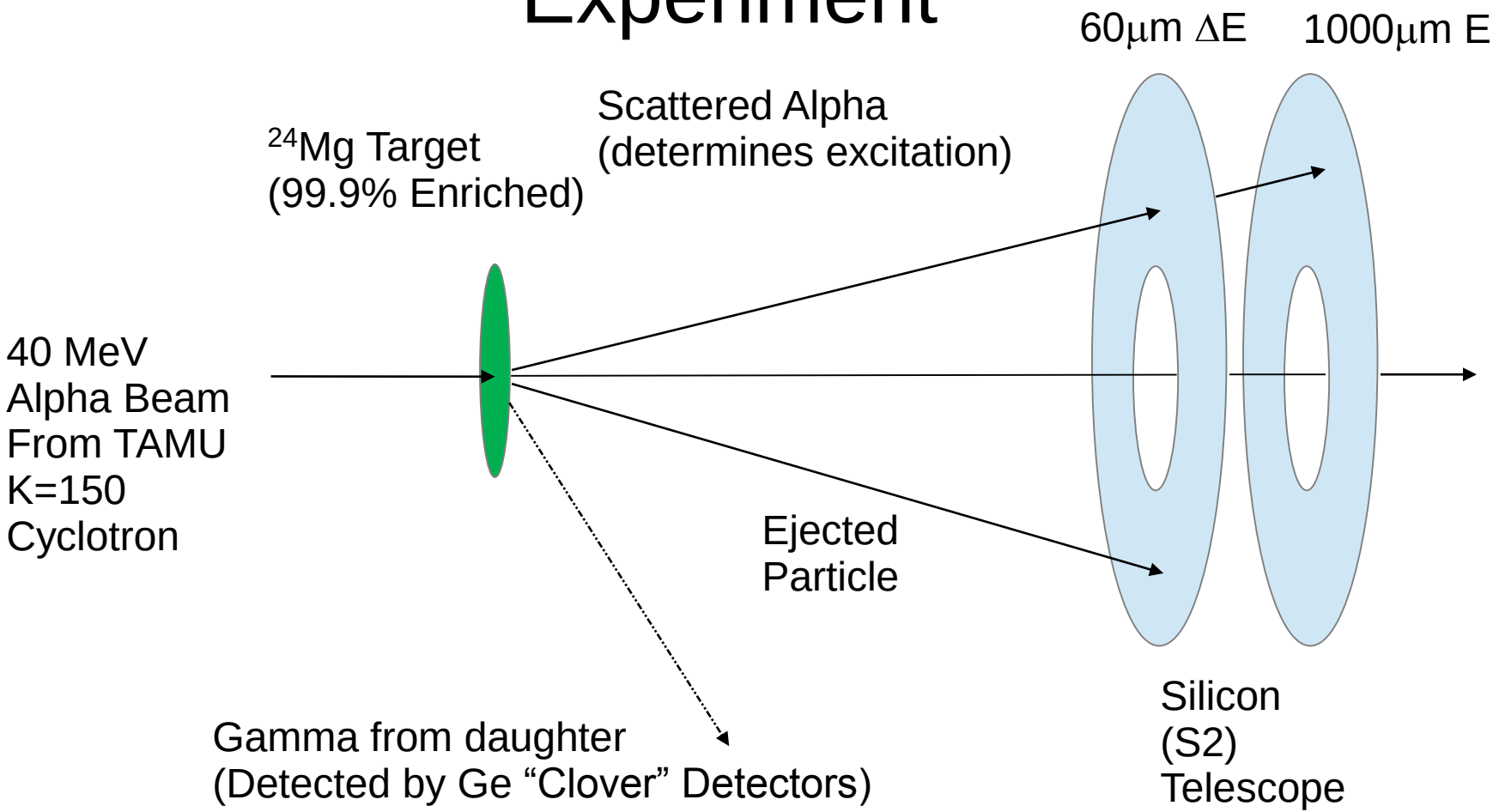


- Energy – Use the scattered alpha to identify the ^{24}Mg Excitation
- Parity – ^{12}C, ^{24}Mg, and alpha particles are all 0^+ particles and should preferentially populate natural parity states.
- Spin – This surrogate reaction is able to bring in slightly higher spins than $^{12}C+^{12}C$. Not ideal, but manageable.

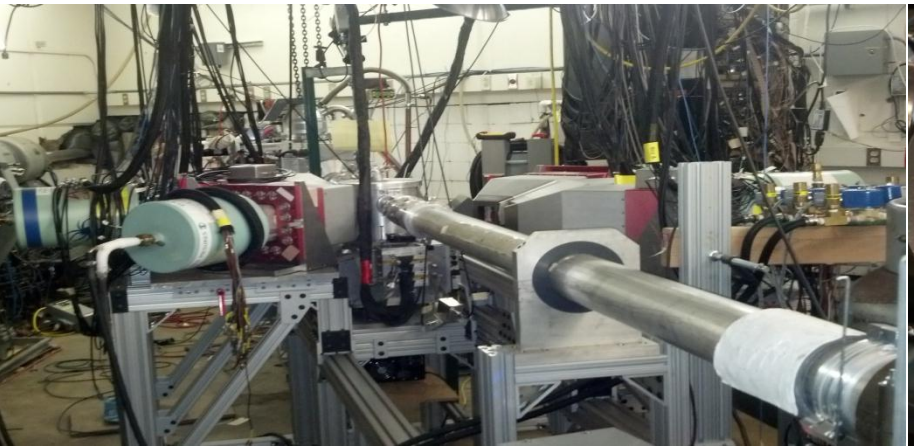
A= 24 Energy Level Diagram

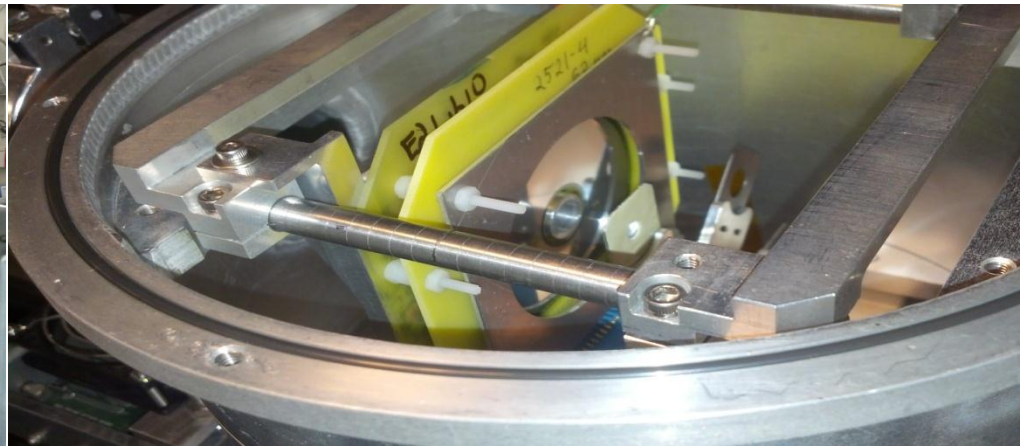


Experiment


60μm ΔE
1000μm E
Scattered Alpha
(determines excitation)
^{24}Mg Target
(99.9% Enriched)
40 MeV
Alpha Beam
From TAMU
K=150
Cyclotron
Ejected
Particle
Gamma from daughter
(Detected by Ge “Clover” Detectors)
Silicon
(S2)
Telescope

Experimental Setup at Texas A&M

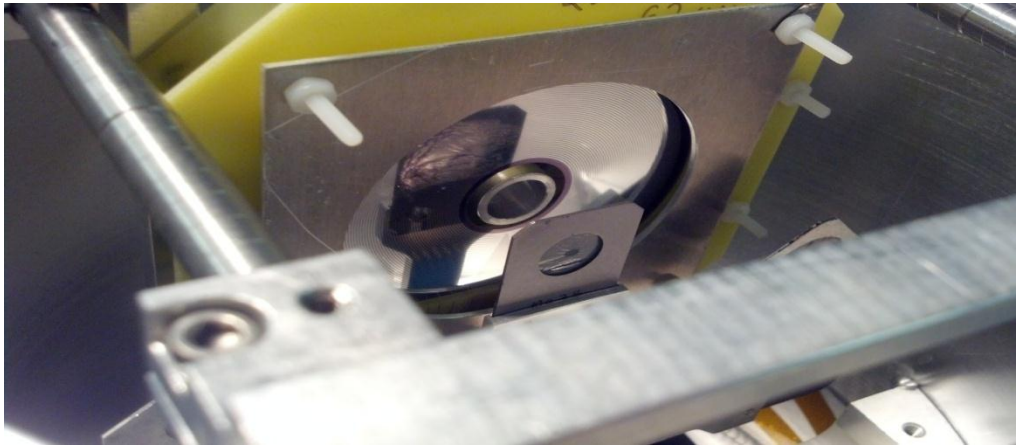




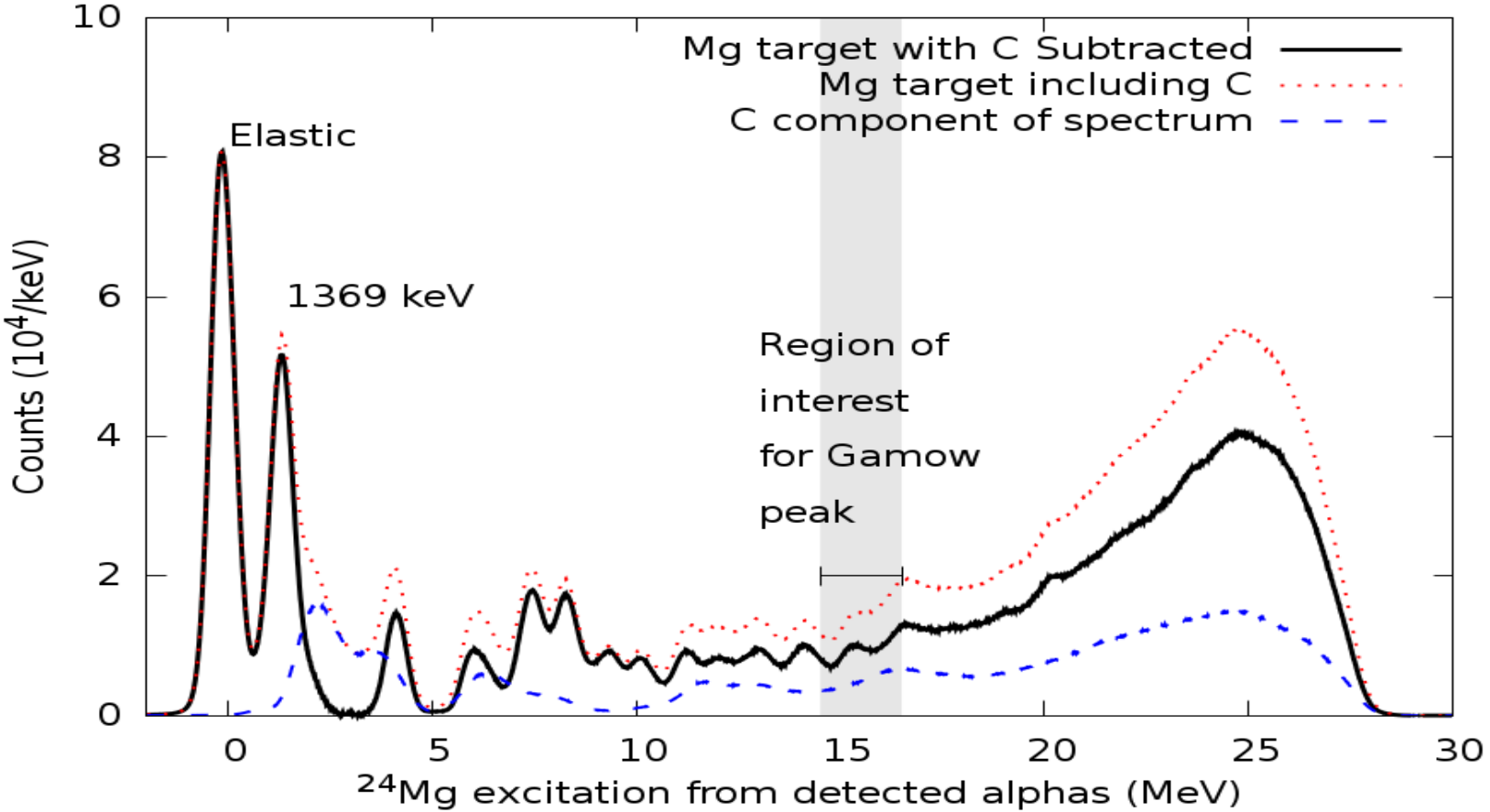
Above Left: Looking upstream from the beam dump towards the target chamber

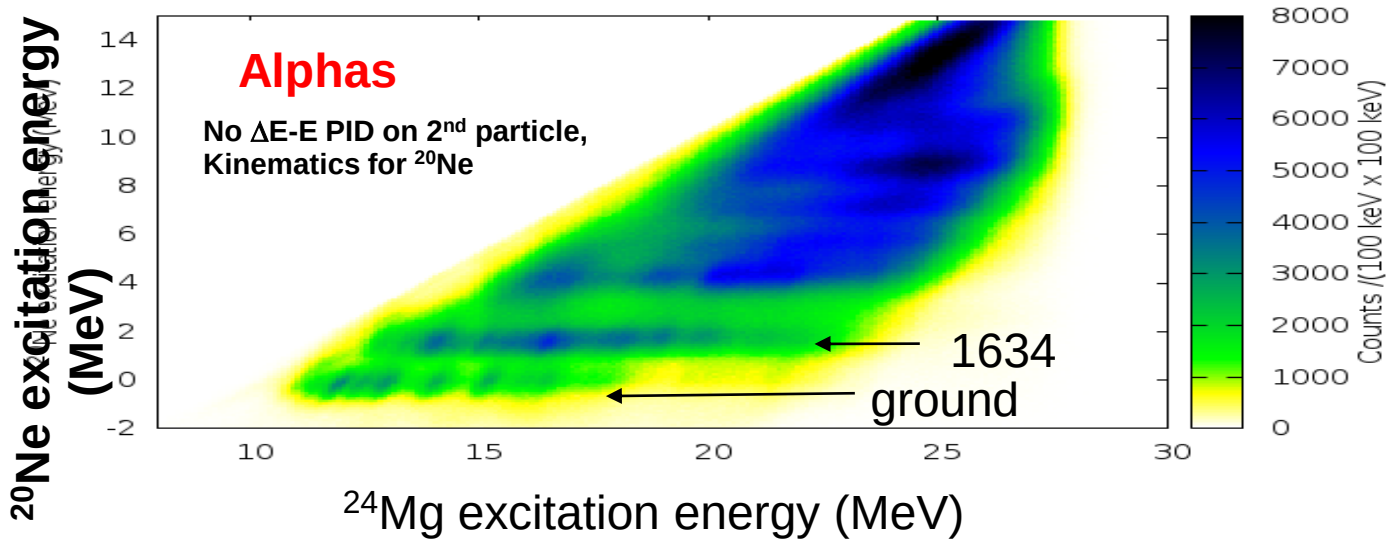
Above Right: Target chamber showing the detector pack and a tuning phosphor

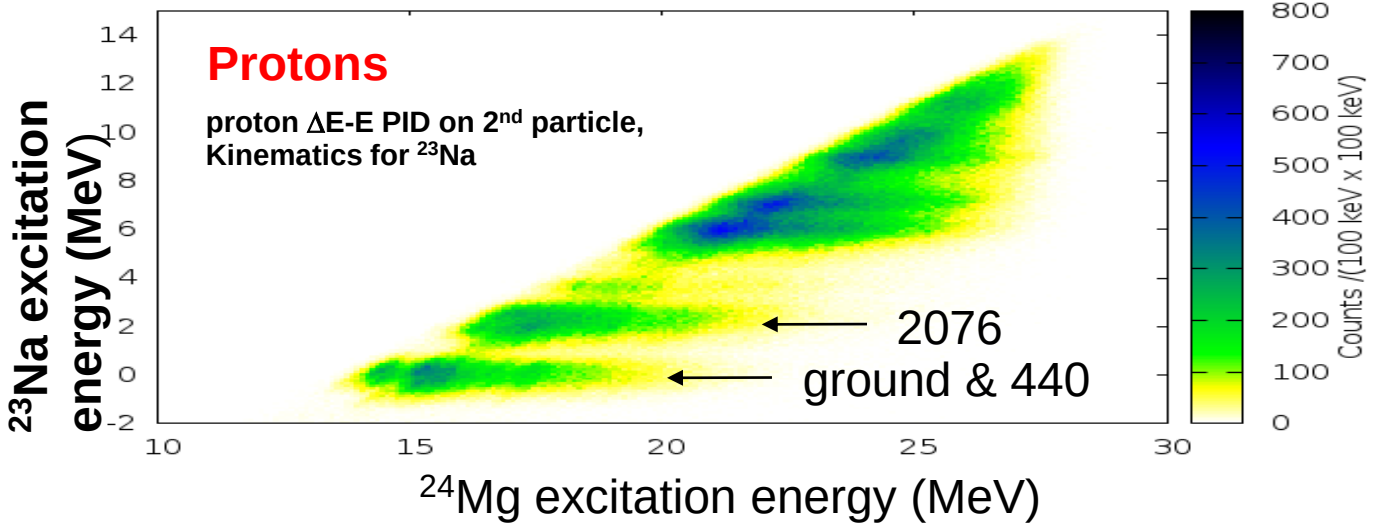
Lower Right: ^{24}Mg target in chamber. The hole in the frame is ½” diameter.



Measured outgoing alpha-particle spectrum



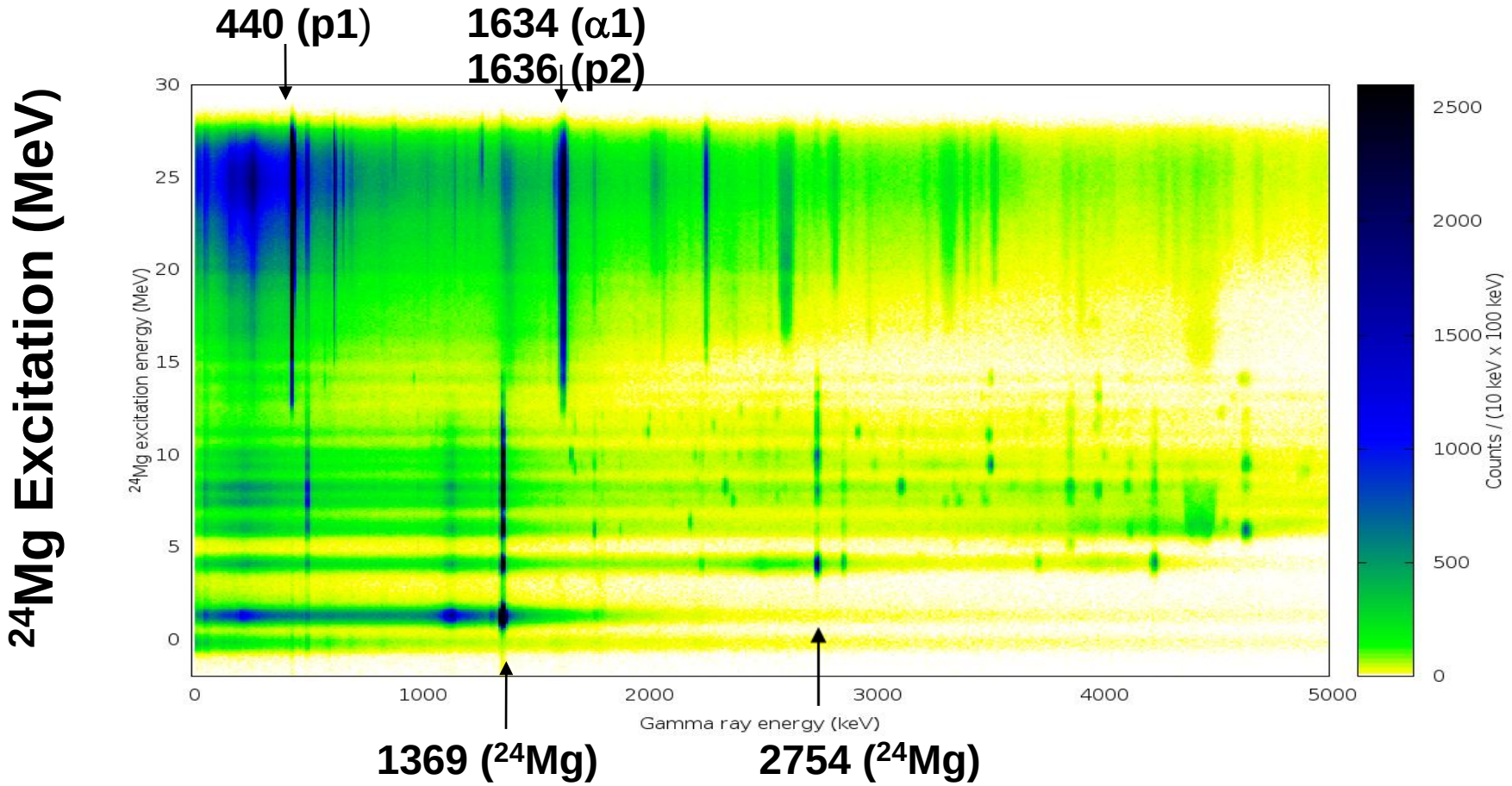




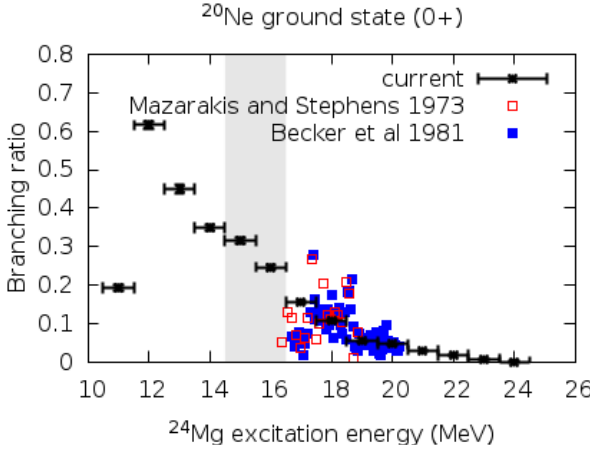
Particle-Particle Coincidence

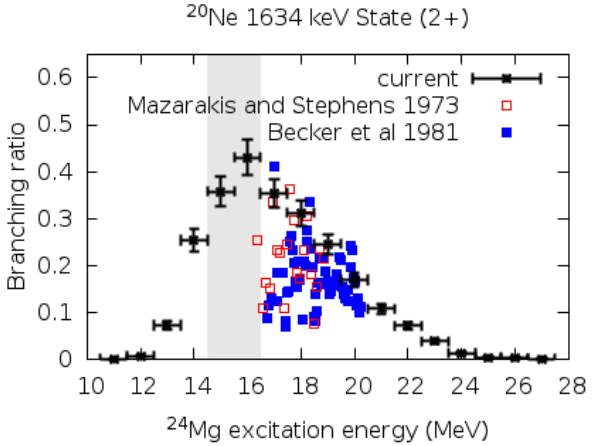
Needed for ground states. Gamma coincidences help with excited states.

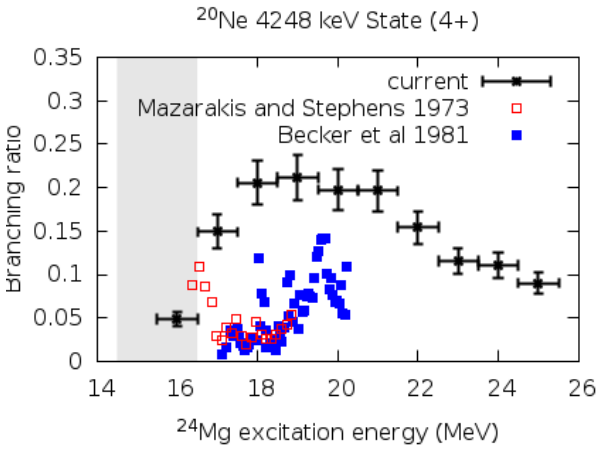
Particle-Gamma Coincidence

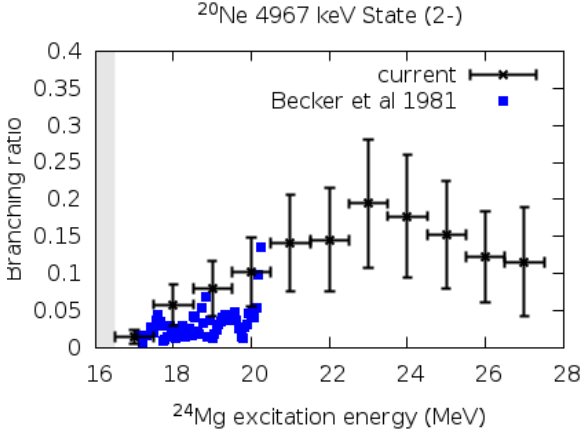


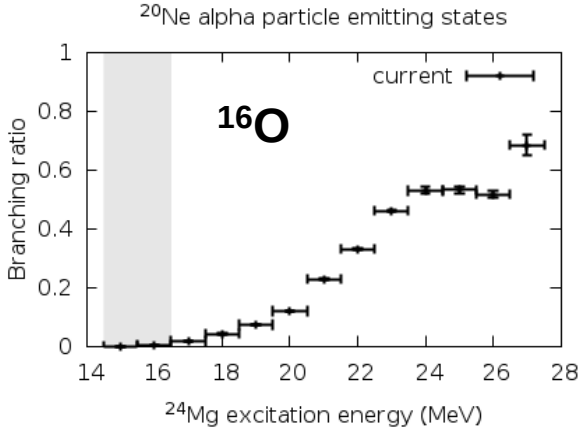
Alpha (^{20}Ne) Branches

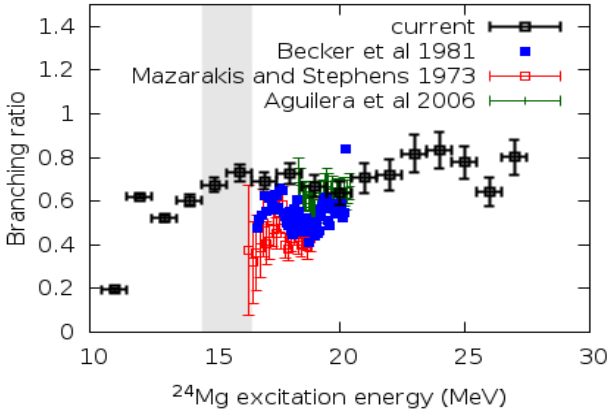






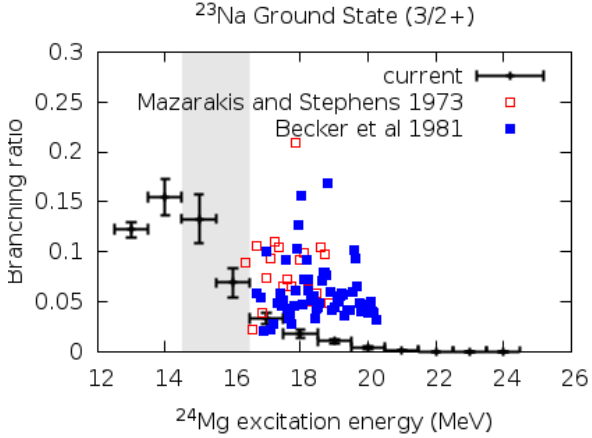


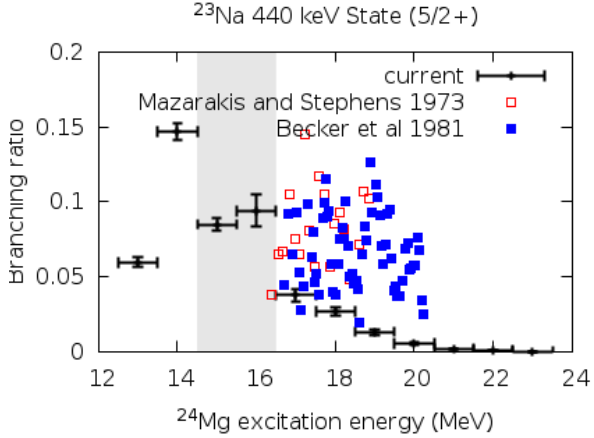


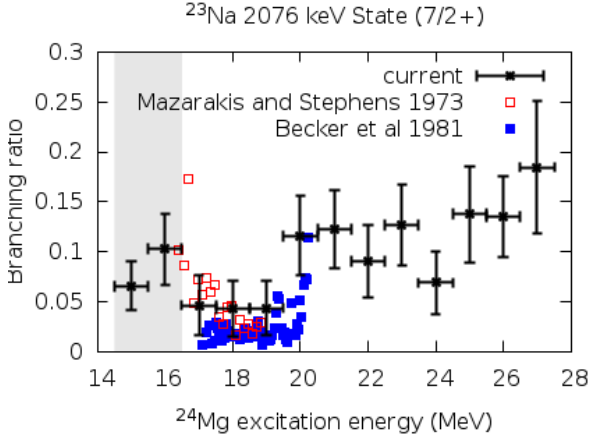


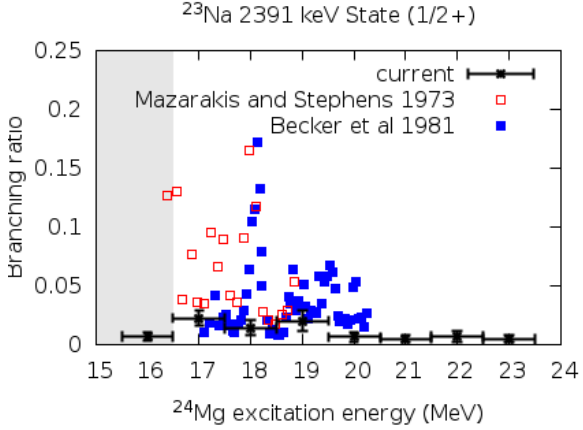
Sum of Alpha Branches

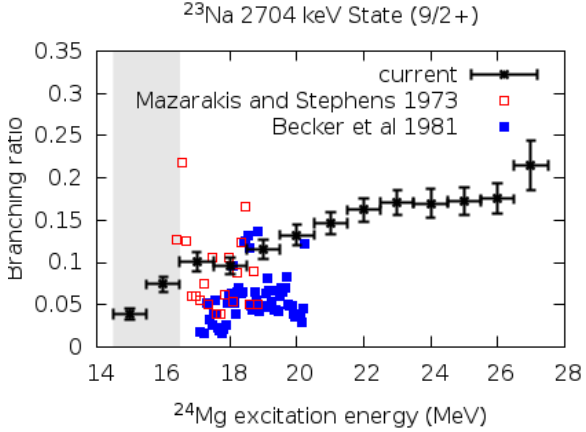
Proton (^{23}Na) Branches

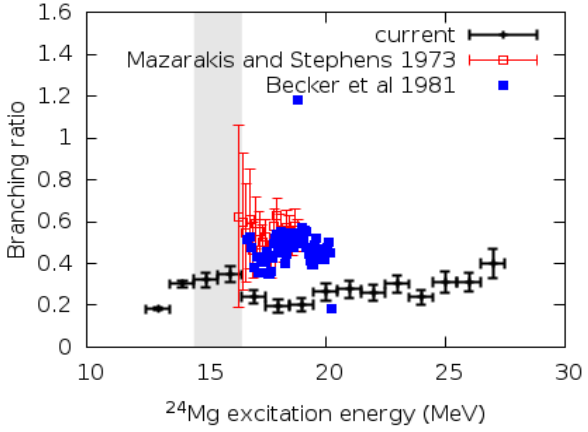






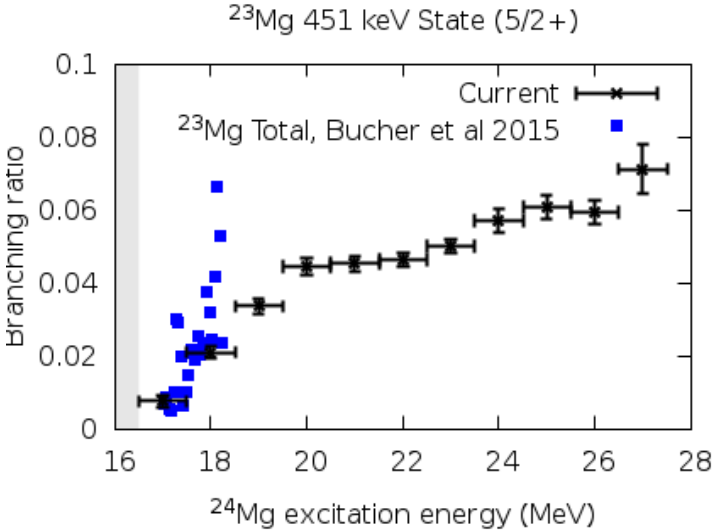


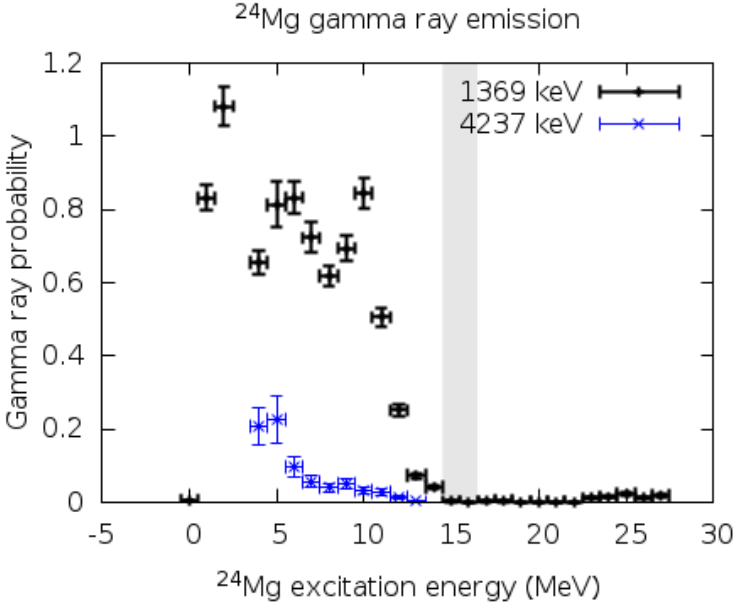




Sum of Proton Branches

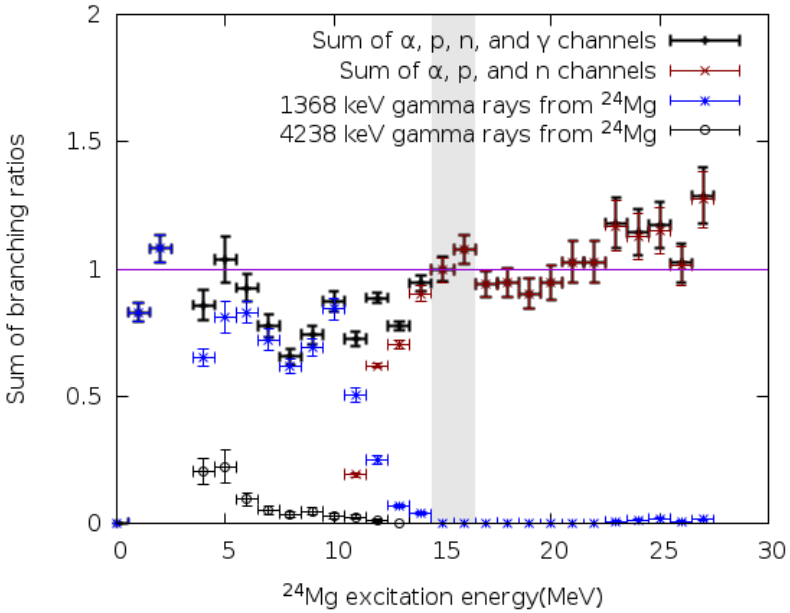
Neutron (^{23}Mg) and Gamma (^{24}Mg) Branches



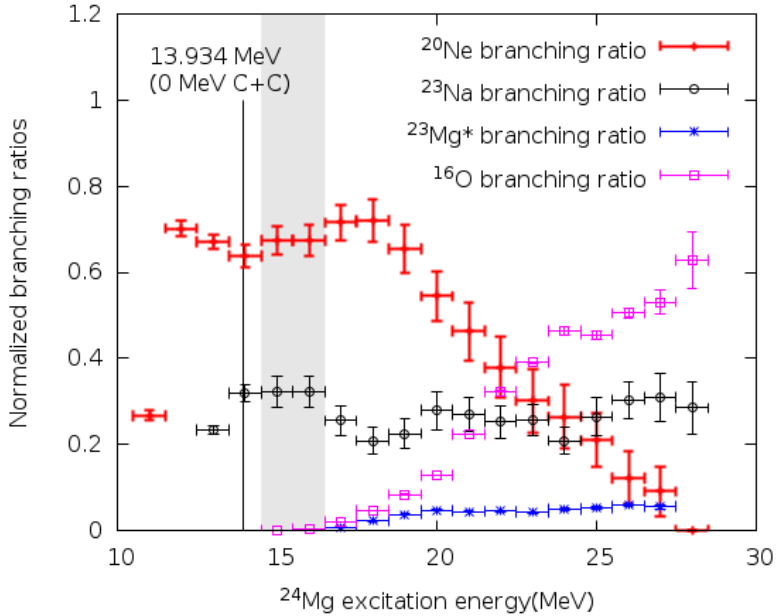


*The current measurement only measured the neutron branch populating the 451 keV state of ^{23}Mg. Bucher *et al*. data is the total (ground and excited) neutron branching ratio.

Summary



The sum of the measured branches serves as a check for the measurement. The sum of the branches should be 1.0



Branching ratios normalized such that the sum of alpha, p, n, and gamma channels is 1. The branching ratio to higher excited states of ^{20}Ne which decay by alpha particle emission is shown here as ^{16}O.

Surrogate measurements suggest ^{12}C+^{12}C → 68% (^{20}Ne) + 32% (^{23}Na)

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Acknowledgements

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