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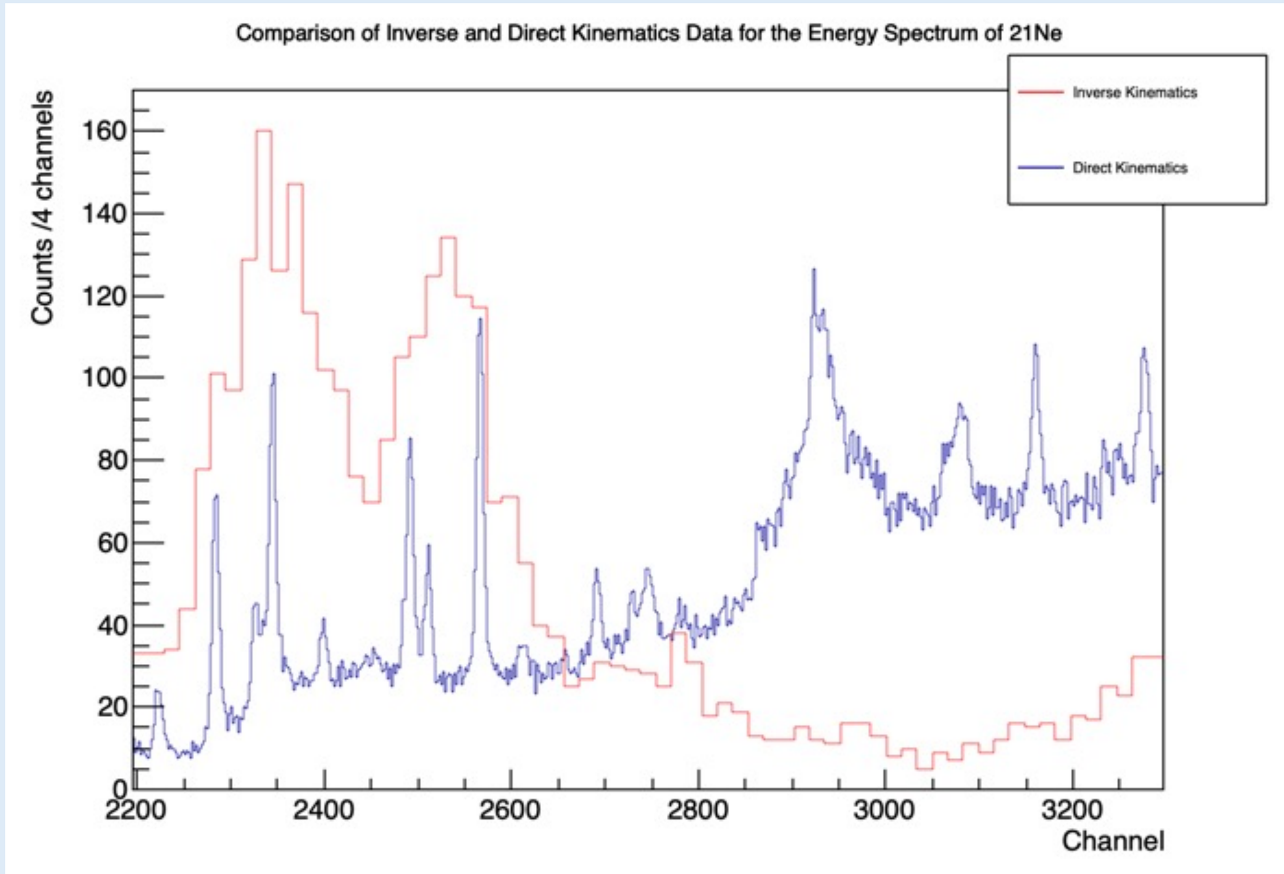
The Energy Levels of ^{21}Ne and the s-process in Rapidly-Rotating Metal Poor Stars

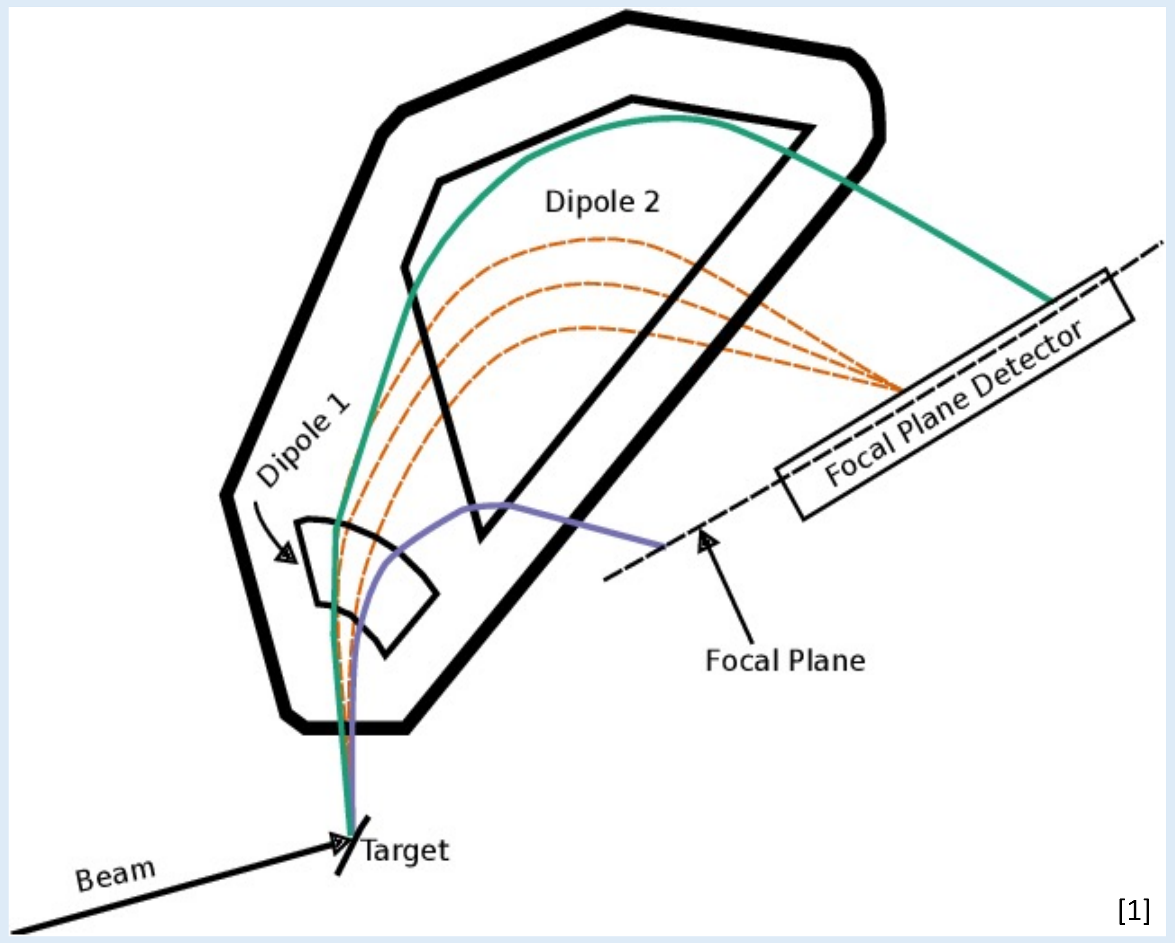
Experimental Aims

To determine the spin-parity and neutron widths of ^{21}Ne states that fall between 7.0 – 8.2 MeV using the reaction: ^{20}Ne(d,p)^{21}Ne studied in both inverse and direct kinematics over the course of two experiments and to use the results to constrain the predictions for the ratio of the rates of reaction: (α,n)/(α,γ) on ^{17}O at astrophysical energies of $0.2 \leq T_9[GK] \geq 0.3$



Enge Split-Pole Spectrograph (Triangle Universities Nuclear Laboratory, USA)

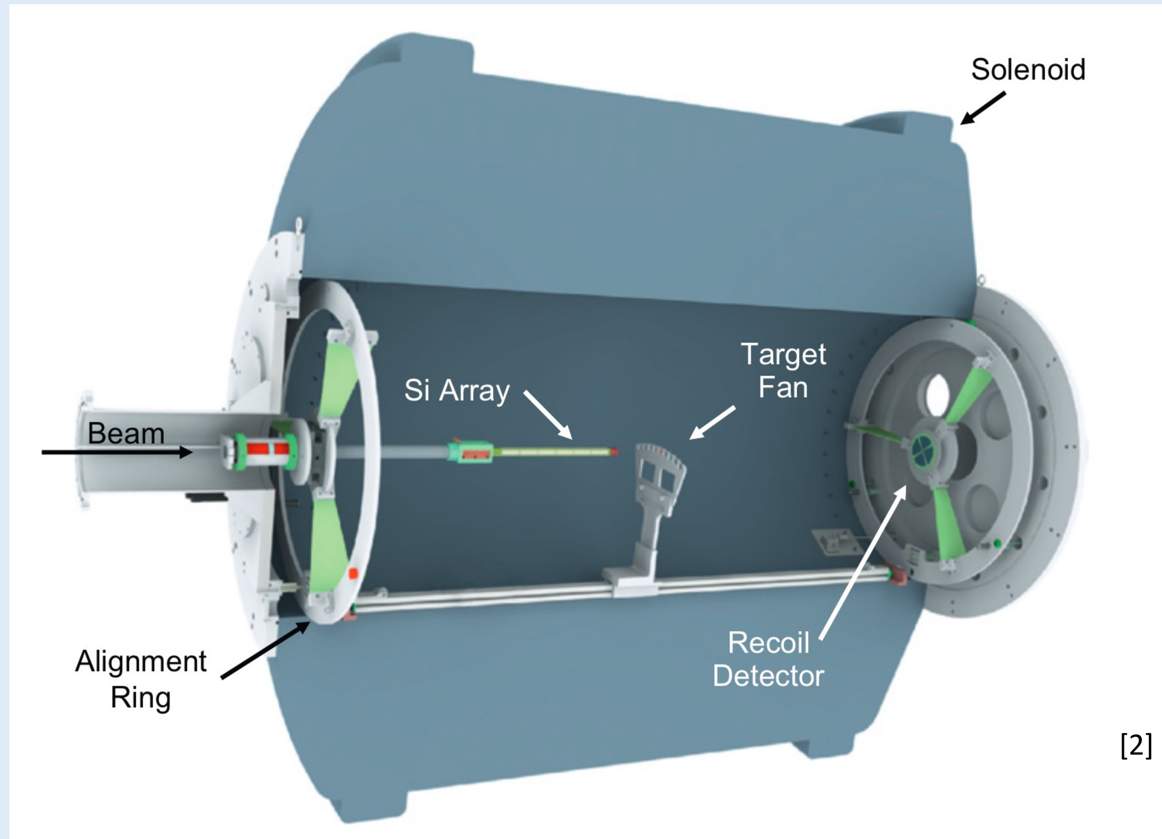
- Type: direct kinematics [3]
- Beam: ^{2}H at 14MeV
- Target: carbon foil implanted with ^{20}Ne
- Pros: good resolution
- Cons: contaminants pose a problem
- Results: this experiment did constrain the predicted rates of reaction however ^{17}O contamination obscured several important energy levels and so lead to the experiment being repeated in inverse kinematics



[1]

Helical Orbital Spectrometer (Argonne National Laboratory, USA)

- Type: inverse kinematics
- Beam: ^{20}Ne at 220MeV
- Target: Deuterated polyethylene
- Pros: contaminants do not impact results
- Cons: resolution is much lower
- Status: analysis is proceeding using the direct kinematics results to inform the fitting of the energy levels in the ^{21}Ne spectrum (top-centre) once complete, the results will be used to constrain the ratio of reaction rates

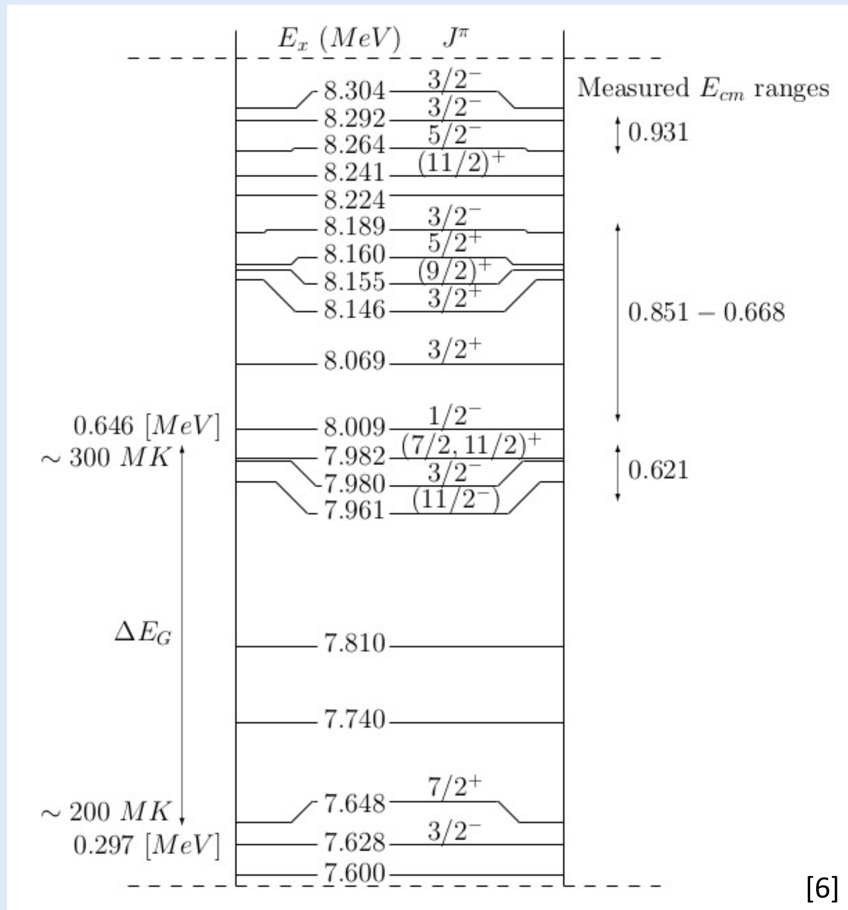


[2]

Astrophysical Motivation

Observations of old Ultra Metal Poor stars have shown that current models of early nucleosynthesis underproduce elements in the range of 26 < Z < 47 [4], suggesting that there is more than just the r-process operating at early times. One source of these elements could be the s-process in Rapidly-Rotating Metal Poor Stars.

^{16}O(n,γ) ^{17}O competes strongly for neutrons with the s-process. Those neutrons could be recycled by the reaction ^{17}O(α,n)^{20}Ne however ^{17}O+α branches with ^{17}O(α,γ)^{21}Ne. The ratio of these reactions will determine the efficiency of the s-process in rapidly-rotating metal poor stars but, that ratio is highly uncertain and ^{17}O+α cannot be directly measured due to low cross-sections [5] at the relevant energies. Calculated predictions for the ratio are used instead but these depend upon the energy levels of ^{21}Ne – some of which have unknown parameters (right).



[6]

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[1] Marshall, C. *et al*. (2019) "*The Focal-Plane Detector Package on the TUNL Split-Pole Spectrograph*". IEEE T INSTRUM MEAS 68, 533-546.
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