New Attempt on Measurement of $^{19}F(p,\alpha)^{16}O$ Reaction at Relevant Astrophysical Energy

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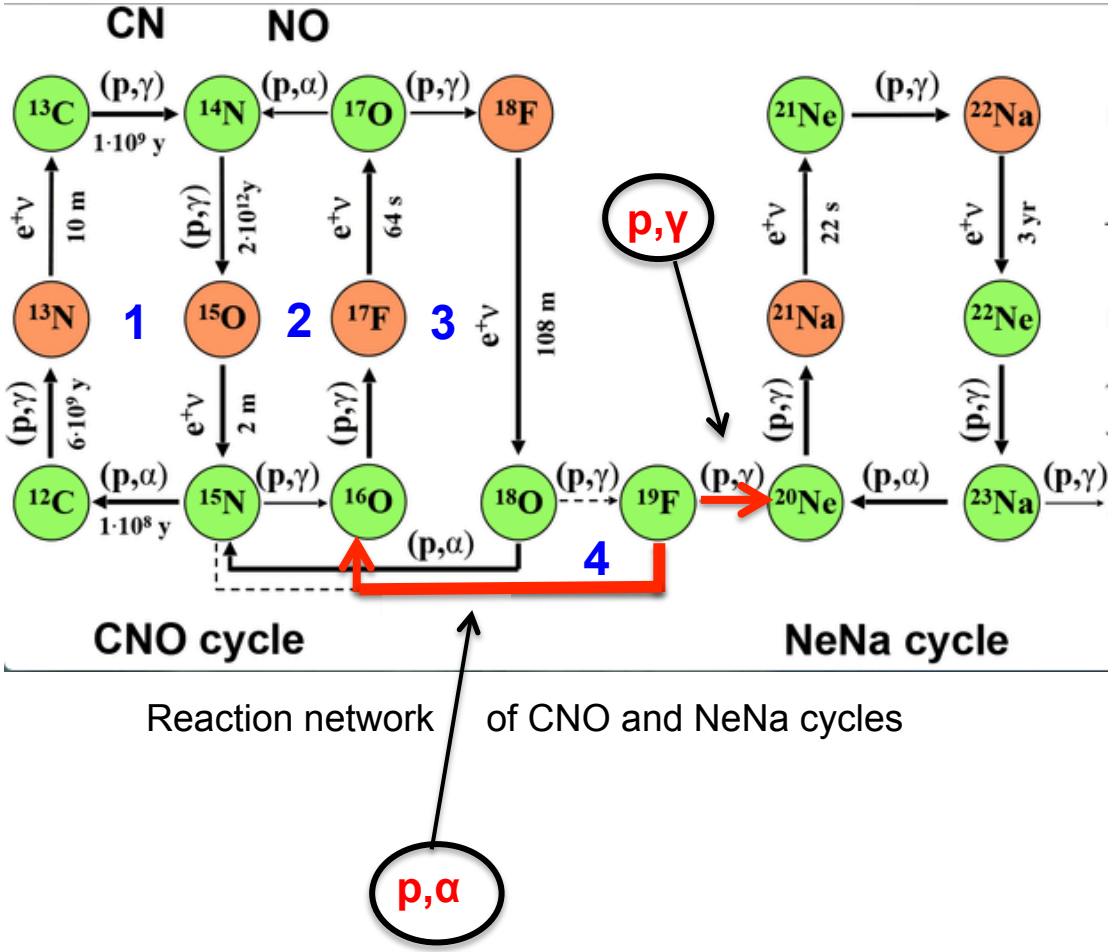
Overview

- Introduction
- Motivation
- Experiment
- Data Analysis
- Results

Astrophysical Background

$^{19}F+p->\alpha+^{16}O$

- Closes the CNOF cycle in the H-burning phase of massive stars
- Competition between (p,α) & (p,γ) determines the amount of catalytic material that goes from CNO to Ne-Na cycle
- Important Fluorine destruction channel in H-rich stellar environments (AGB stars)
- F abundance sensitive to physical conditions in stars



Reaction network of CNO and NeNa cycles

A.Boeltzig et al (2016)

Why $^{19}F(p,\alpha)^{16}O$?

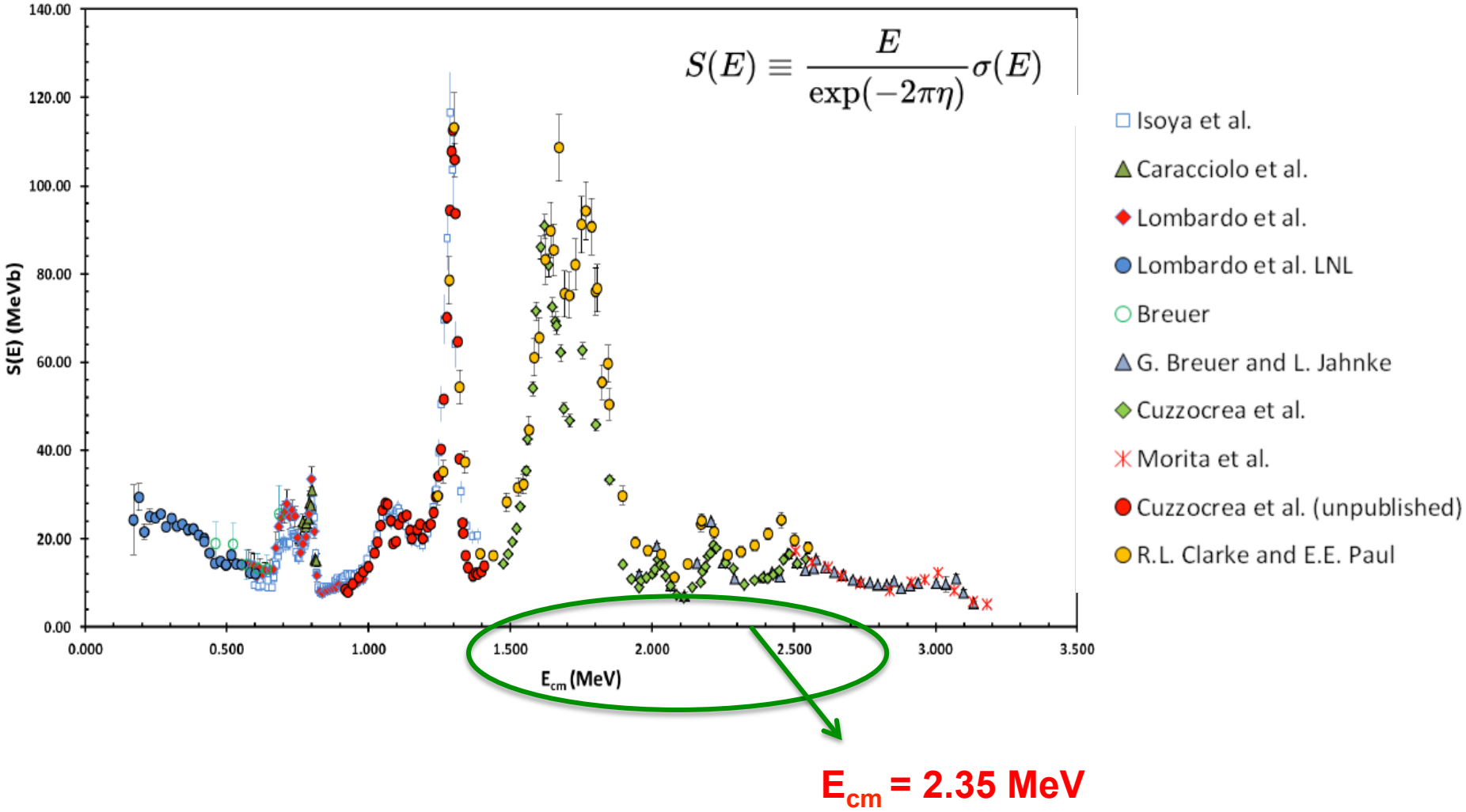
- To correct for overestimation of Galactic Fluorine Abundance
  - ❏ theoretical models overproduce F abundances

- To Probe different nucleosynthesis scenarios
  - ❏ helpful in constraining chemical & stellar evolution models

- To study mixing processes in AGB stars
  - ❏ dredge ups

- To study the s-factor at relevant energy
  - ❏ $^{19}F(p,\alpha)^{16}O$ is the main F-destruction channel

Previous Measurements



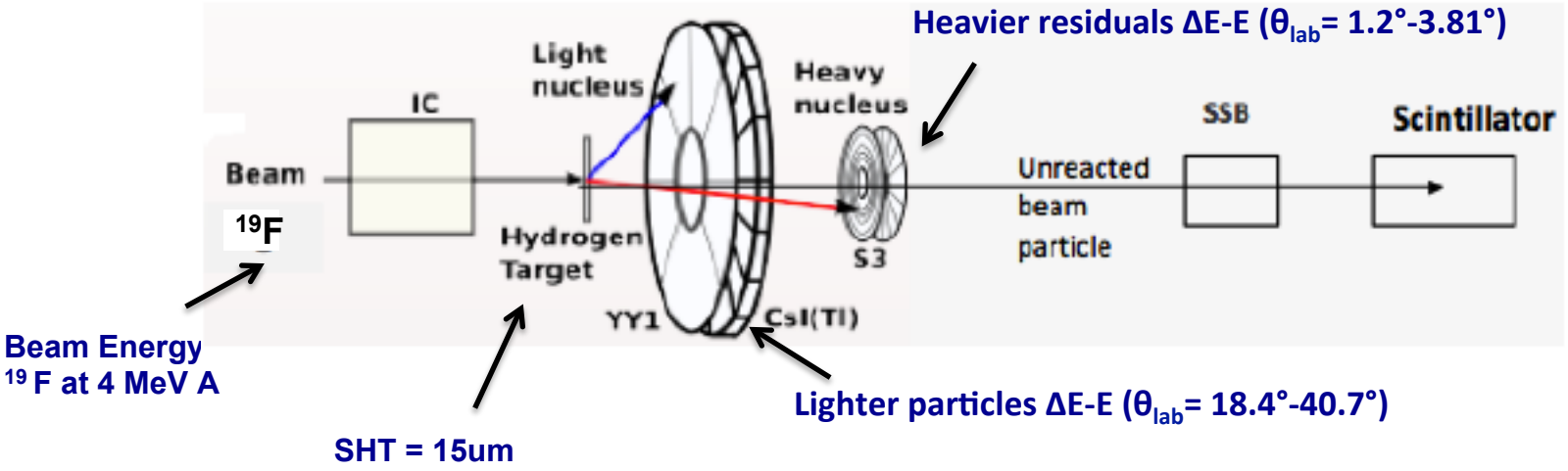
E_{cm} = 2.35 MeV

$^{19}F(p,\alpha)^{16}O$ S-factor data sets in 0.2 MeV- 3.3 MeV E_{cm} energy range

D.Dell' Aquila and I. Lombardo 2015

Measuring $^{19}F(p,\alpha)^{16}O$ by *Missing Mass Technique*

IRIS = ***I****SAC Cha****R****ged Part****I****cle* ***S****pectroscopy Station*



$^{19}F+p->\alpha+^{16}O$

$$Q = (M_{19F} + m_p) - (m_\alpha + M_{16O})$$

E_{cm} = 2.35 MeV

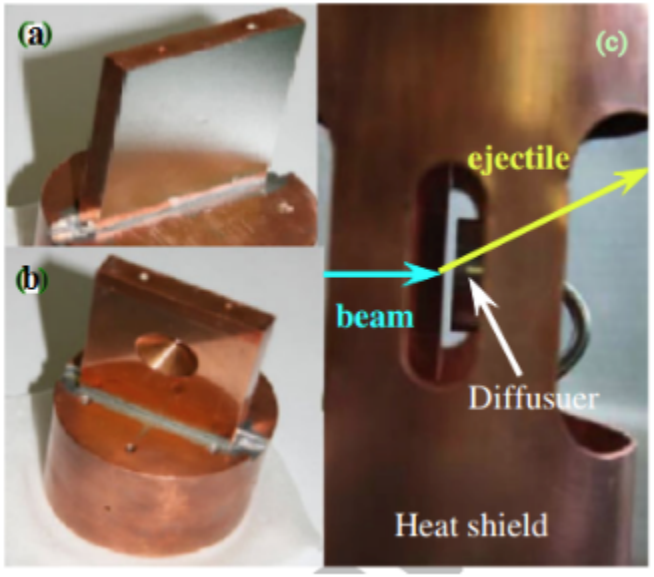
Quantities that can be measured in the experiment :

- **Kinetic Energy of the fragments & residuals**
- **Scattering Angle of the fragments & residuals**

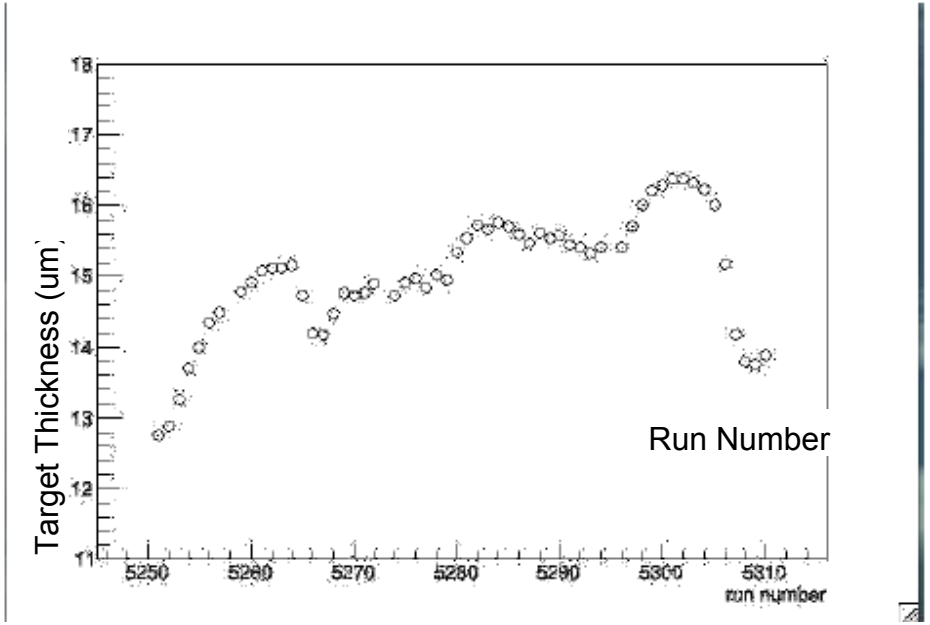
→ Obtained from Si & CsI(Tl) detector

$$Q = m_a+m_b+m_c-\sqrt{m_a^2+m_c^2-m_b^2+2m_b(KE_a+m_a)-2(KE_a+m_a+m_b)(KE_c+m_c)+2P_aP_c\cos(\theta_c)}$$

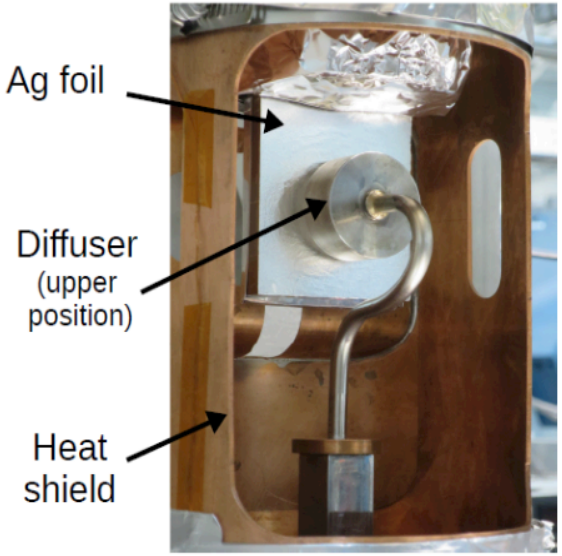
Solid H2 Target



Thin, Windowless Solid target



Target Thickness variation for ~ 48 hours for ^{19}F data



TARGET ASSEMBLY

- ➔ Hole ~ 5mm in the copper cell
- ➔ Silver Foil ~ 4.5 um at the surface
- ➔ Target Cell cooled ~ 4K
- ➔ H2 gas sprayed using a diffuser

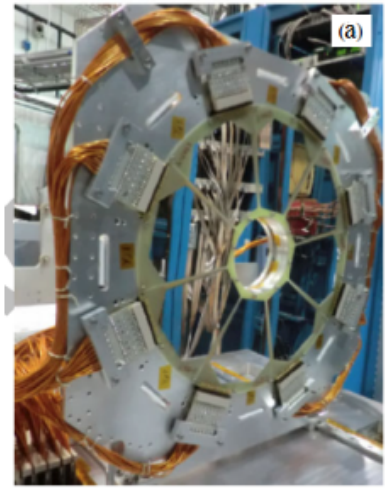
Charged Particle Detectors

- To detect the charged particle reaction products
- To detect both light target-like particles and heavy beam-like reaction residues

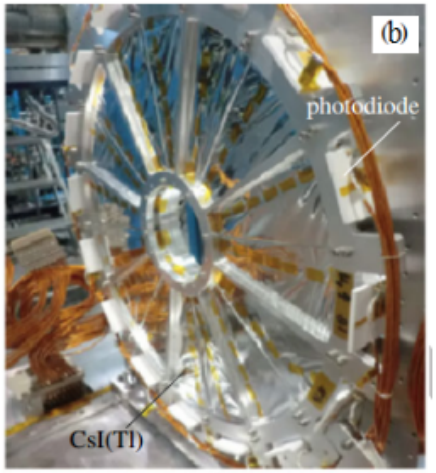
LIGHT PARTICLES: dE-E telescope

Si detector

- 100 um Si detector
- placed downstream
- thin detector
- measures dE
- measures theta
- 8 sectors
- 16 rings in each
- 8*16 detectors



(a)



(b)

CsI(Tl) detector

- 12 mm thick Si detector
- placed behind YY1
- thick detector
- measure E
- theta info from YY1
- 16 sectors
- rings info from YY1
- 16 detectors

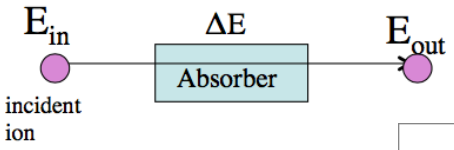
Detectors for target-like nuclei **(a)** Si **(b)** CsI(Tl): **Useful to construct Particle Identification Plots**

△E-E telescope & PID

Particle Identification Spectrum

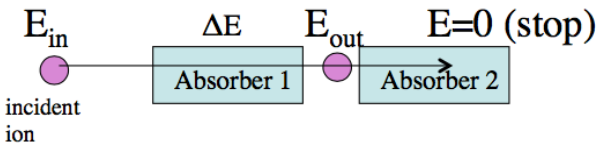
- Identification of atomic number ‘Z’

Energy Loss $\frac{dE}{dx} \propto \frac{z^2}{v^2}$



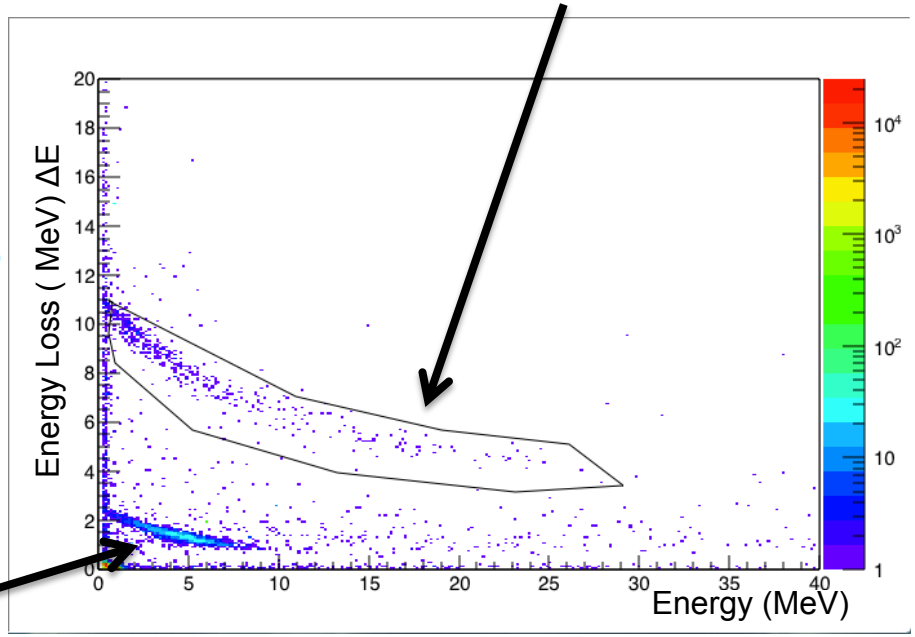
- Identification of mass number ‘A’

$E \propto mv^2$



- $^{19}F+p->\alpha+^{16}O$
- $^{19}F+p->p+^{19}F$

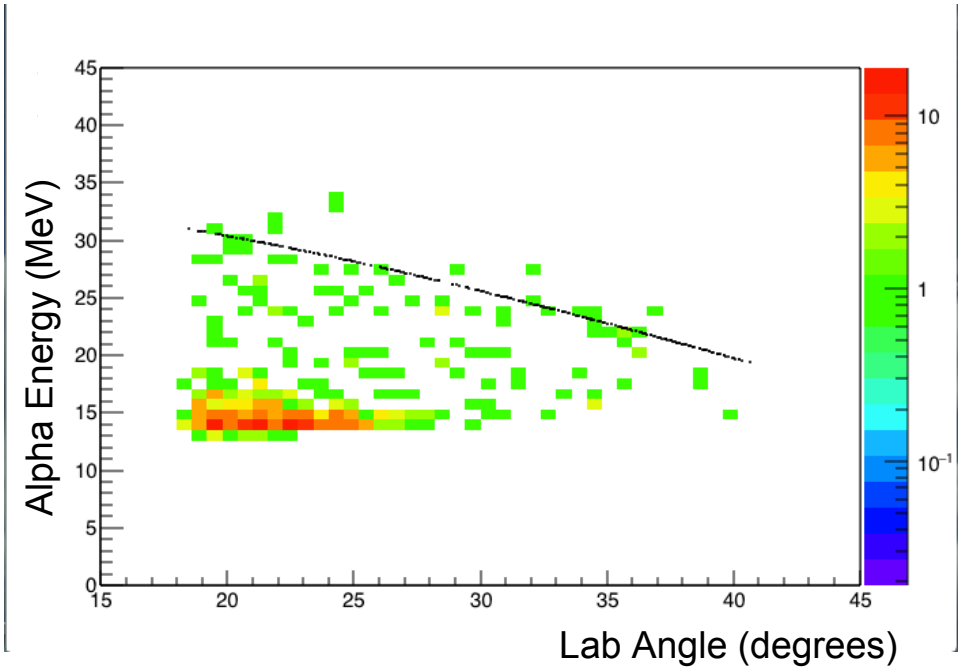
alphas He-4



protons

Particle Identification Spectrum with ^{19}F Beam

Kinematics of alphas from $^{19}F(p,\alpha)^{16}O$



Kinematics of alphas from 19F+p interaction

- This energy information is extracted from the measured energy in Si and CsI(Tl) detector
- The energy of scattered alphas at the middle of solid H2 was reconstructed from the measured energy information
- The figure on left shows reconstructed energy vs the scattering angle for alphas
- This energy and angle information is required to construct the excitation spectrum using missing mass technique

Background from Ag-Foil

- PACE4 calculations

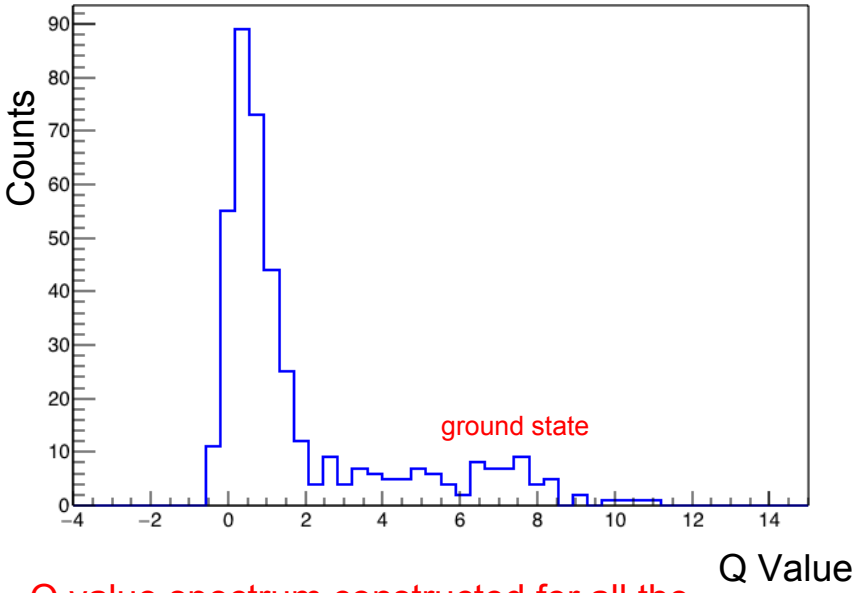
- Angular and energy range for alphas from Fusion-evaporation calculations

- The range seems to agree well with the back ground range

Alpha spectra in laboratory coordinates 179 events

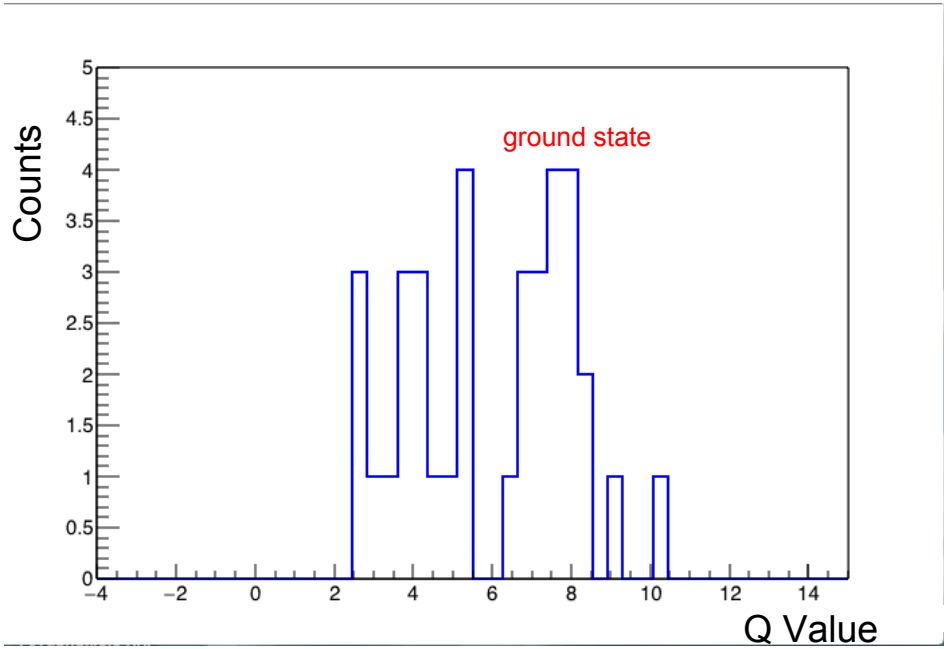
Energy range (MeV)	0 10	10 20	20 30	30 40	40 50	50 60	60 70	A
8.0-9.0								
9.0-10.0								
10.0-11.0							1	
11.0-12.0							1	
12.0-13.0							1	
13.0-14.0							2	
14.0-15.0					2		6	
15.0-16.0	1		2	1	2	4	4	
16.0-17.0		1	3	2		1	2	
17.0-18.0			3	1	3	3	2	
18.0-19.0	1	2	2		2	4		
19.0-20.0	1	1		2		1	1	
20.0-21.0			1					
21.0-22.0		1	1		1			
26.0-27.0			1					
Above 30.0								
Total	3	5	13	6	10	13	20	
dSig/dOmega	0	0	0	0	0	0	0	

Q value spectrum



Q value spectrum constructed for all the measured angles integrated

$\theta_{lab} > 30$



Q value spectrum constructed for measured angles > 30 degree

SUMMARY

- The measurement of $^{19}F(p,\alpha)^{16}O$ in this work shows alphas for ^{16}O gs visible for angle > 30 degrees
- From the Q value spectrum, 17 counts are seen in the ground state peak
- The uncertainty in the number of scattered particles will be reflected as the *statistical* uncertainty in cross-sections & S-factor measurements

Acknowledgements

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Thank You