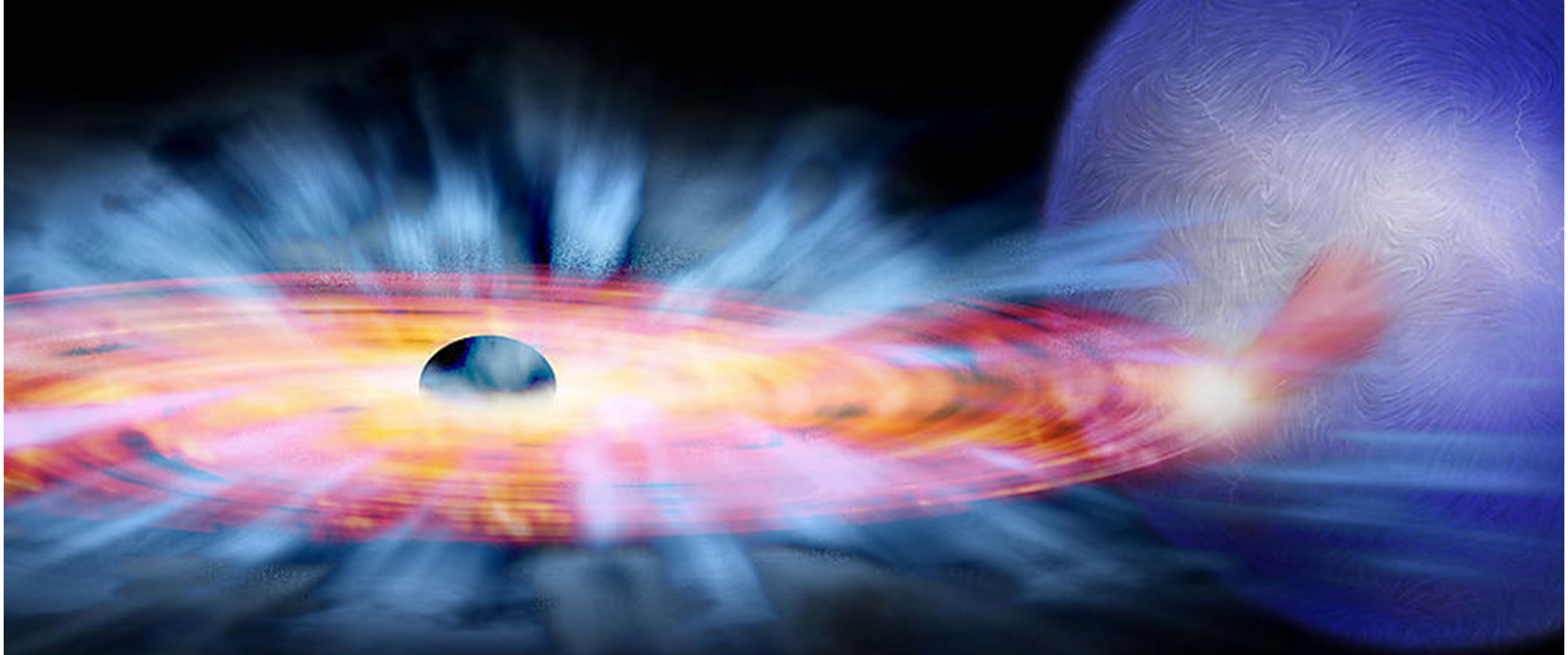
Indirect measurement of the $^{18}Ne(\alpha, p)^{21}Na$ reaction rate



Liyong Zhang

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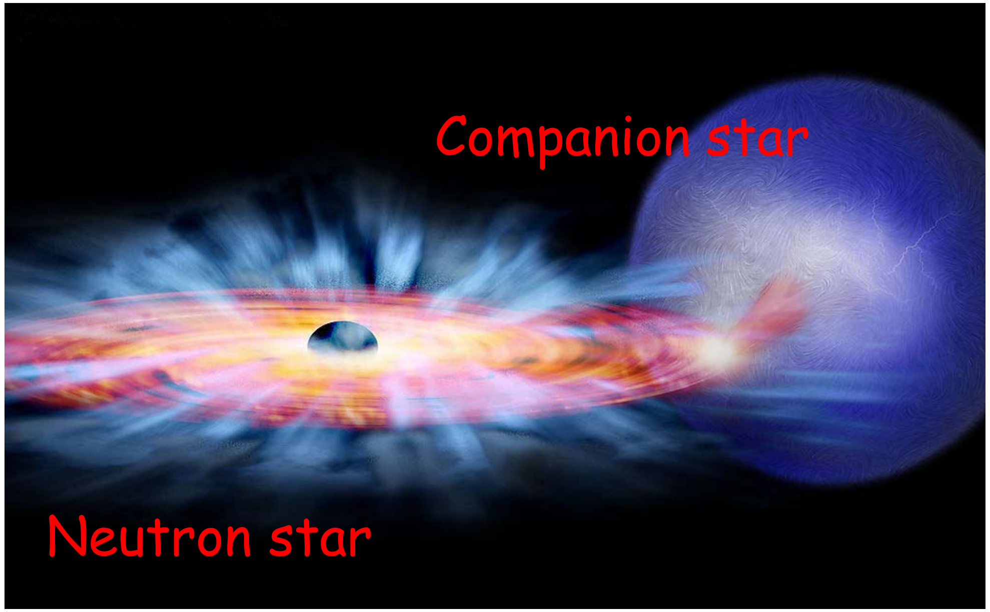
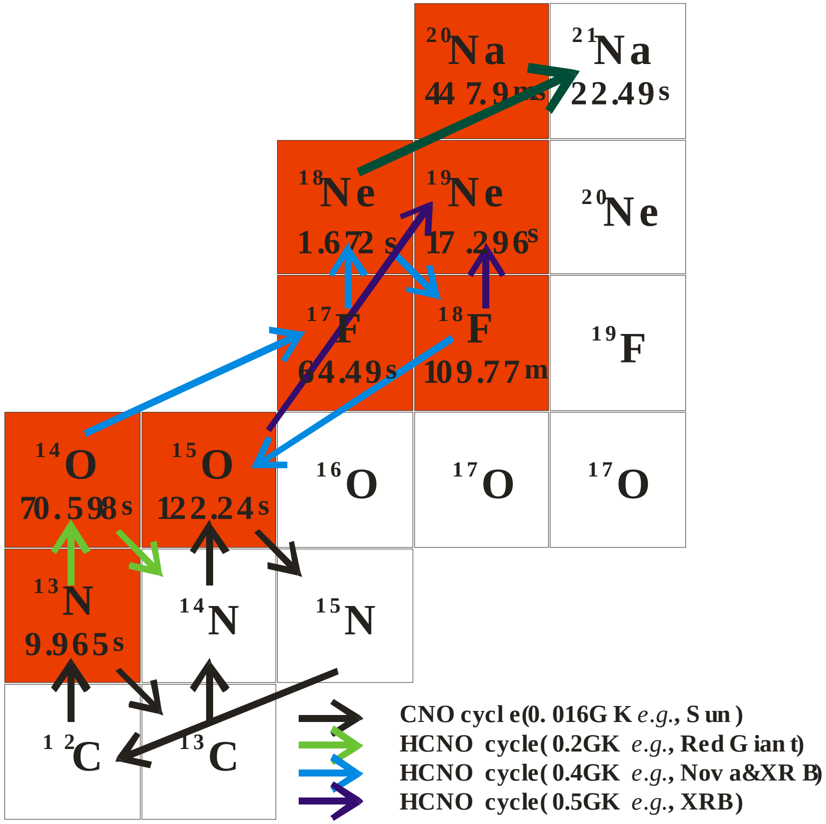
Scientific Motivation



Explosive hydrogen and helium burning



$^{12}\mathrm{C}(p,\gamma)^{13}\mathrm{N}(p,\gamma)^{14}\mathrm{O}(\alpha,p)$

$^{17}\mathrm{F}(p,\gamma)$ $^{18}\mathrm{Ne}(\alpha,p)^{21}\mathrm{Na}$

Reaction Mechanism:

- Resonance reaction rate:

$$N_A < \sigma v > = 1.54 \times 10^{11} \ (\mu T_9)^{-3/2} \sum_i (\omega\gamma)_i \times exp(-11.605\, E_i/T_9)\ [cm^3\ s^{-1}\ mol^{-1}]$$

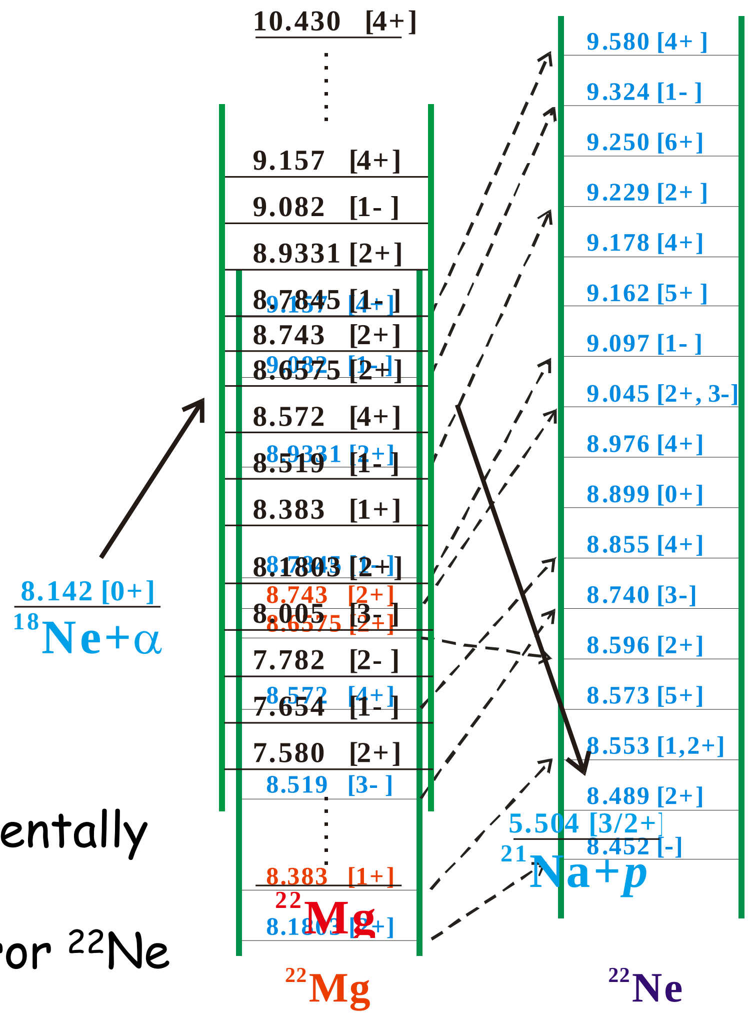
$$\omega\gamma \approx \frac{2J_{^{22}Mg}+1}{(2J_p+1)(2J_{^{21}Na}+1)}\Gamma_\alpha$$

$$\Gamma_\alpha = \frac{3\hbar^2}{\mu R_n^2} C^2 S_\alpha \times P_l(E_i)$$

- Indirect measurement:

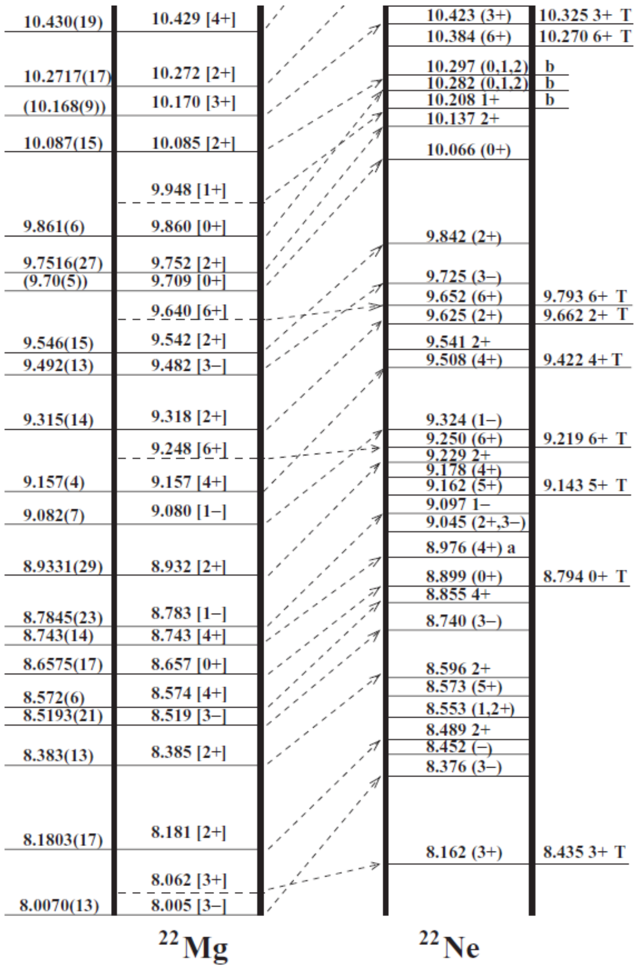
1. Determine E_i and J^π of ^{22}Mg levels experimentally

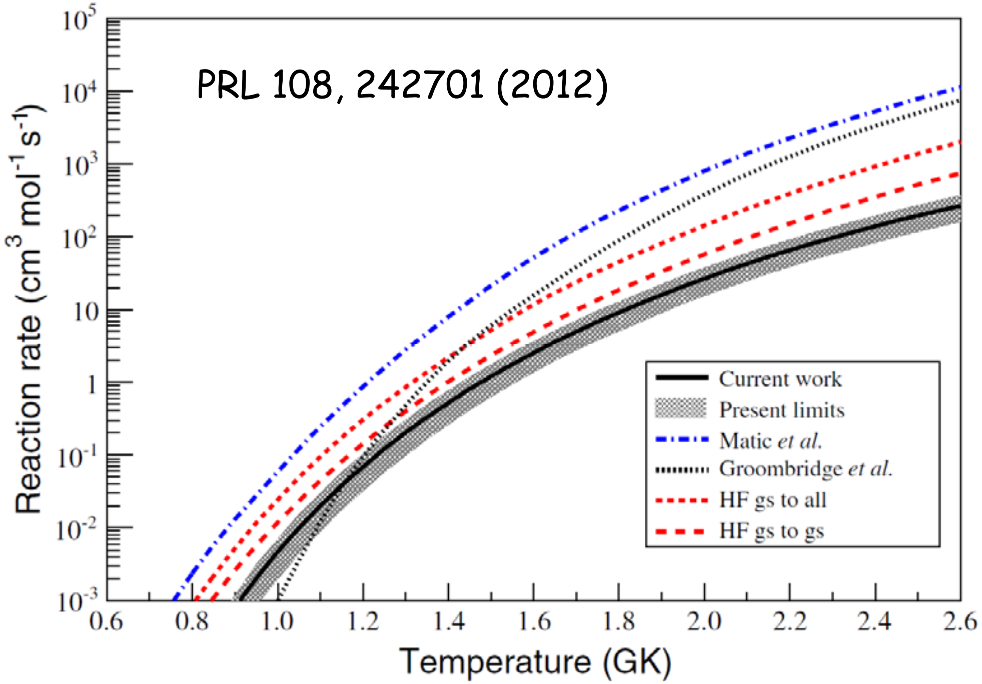
2. The S_α factors were adopted from the mirror ^{22}Ne



Present Status

PRC 80, 055804 (2009)

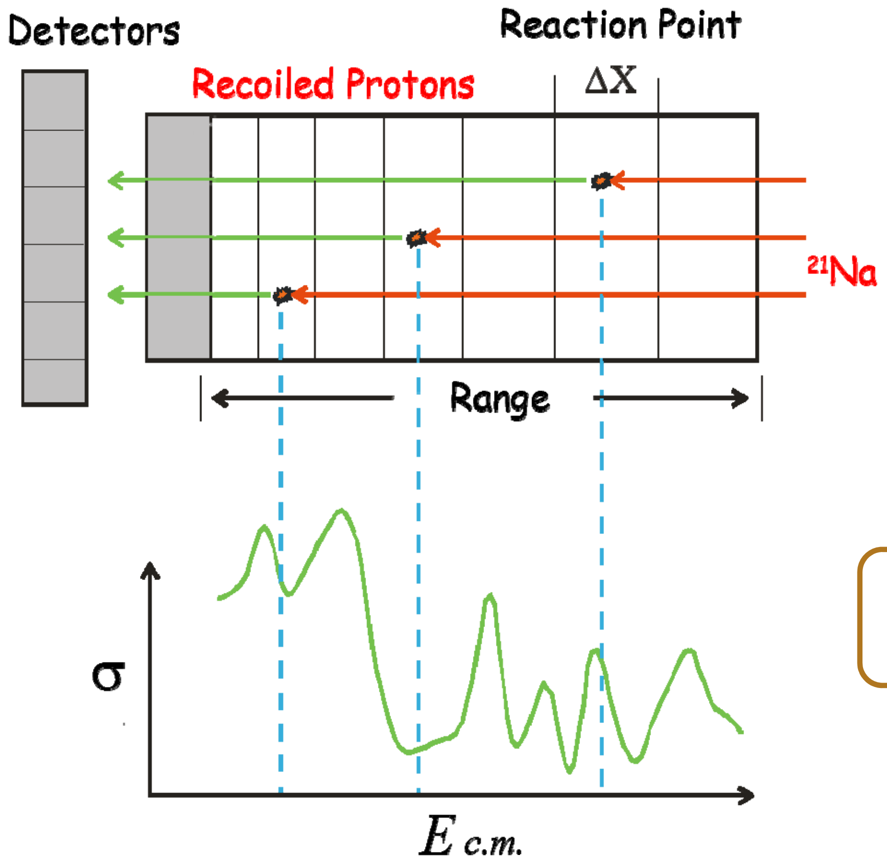




Indirect Measurement
^{24}Mg(p,t)^{22}Mg

Direct Measurement
^{21}Na(p,α)^{18}Ne

Thick Target Method:



^{21}Na beam + CH_2 Target

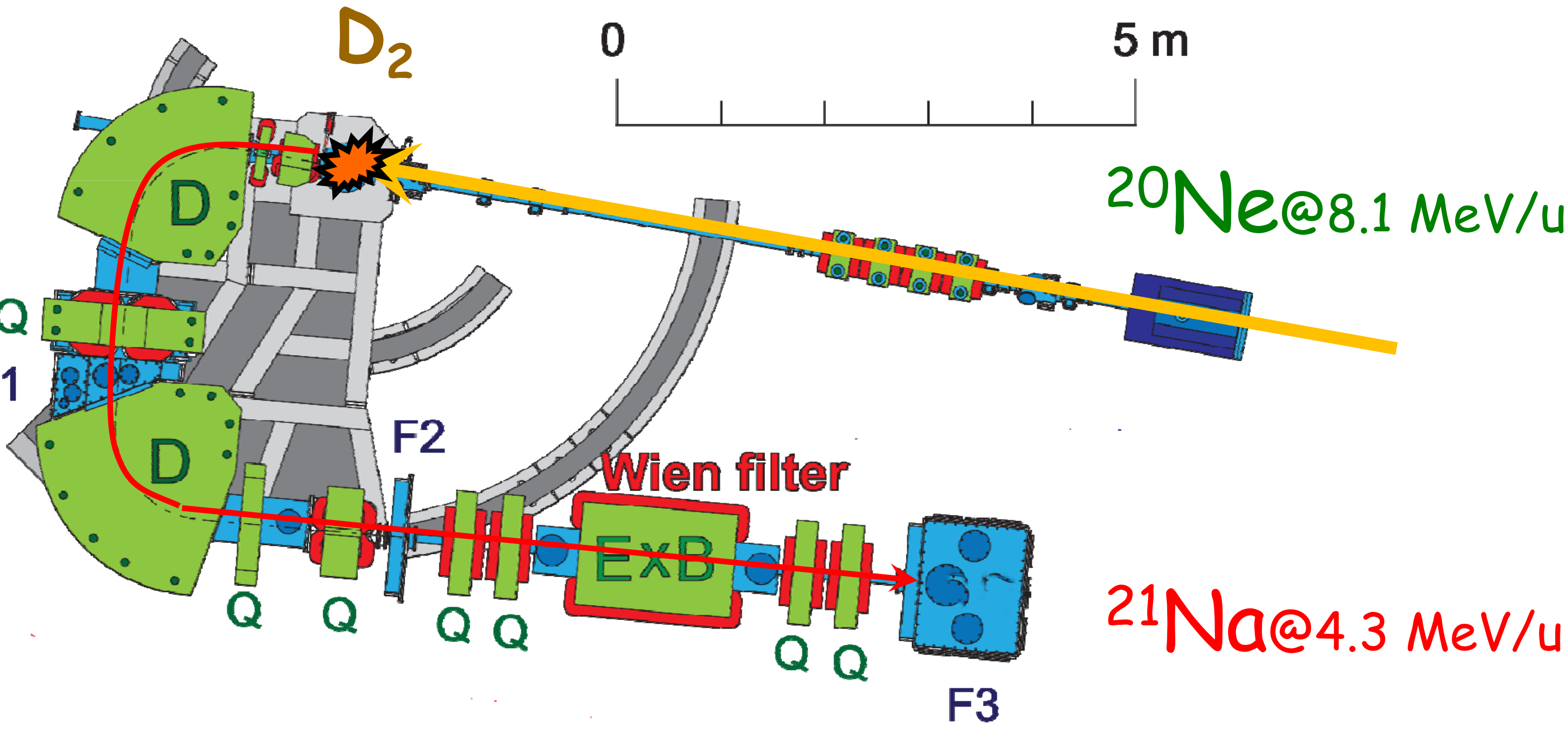
^{21}Na(p,p)^{21}Na cross section

R-Matrix Analysis

E_i and J^{π}

Beam Production

CRIB(CNS low-energy Radioactive-Ion Beam) separator

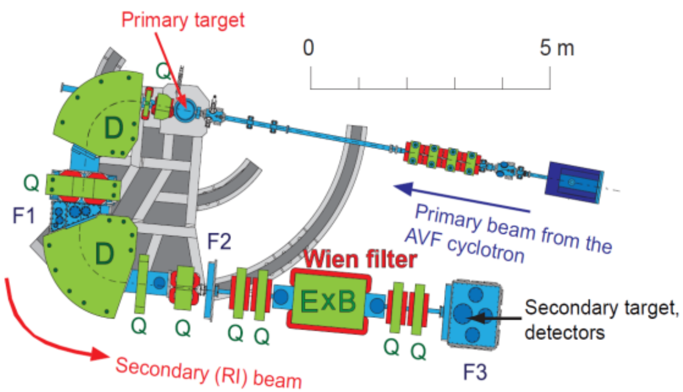


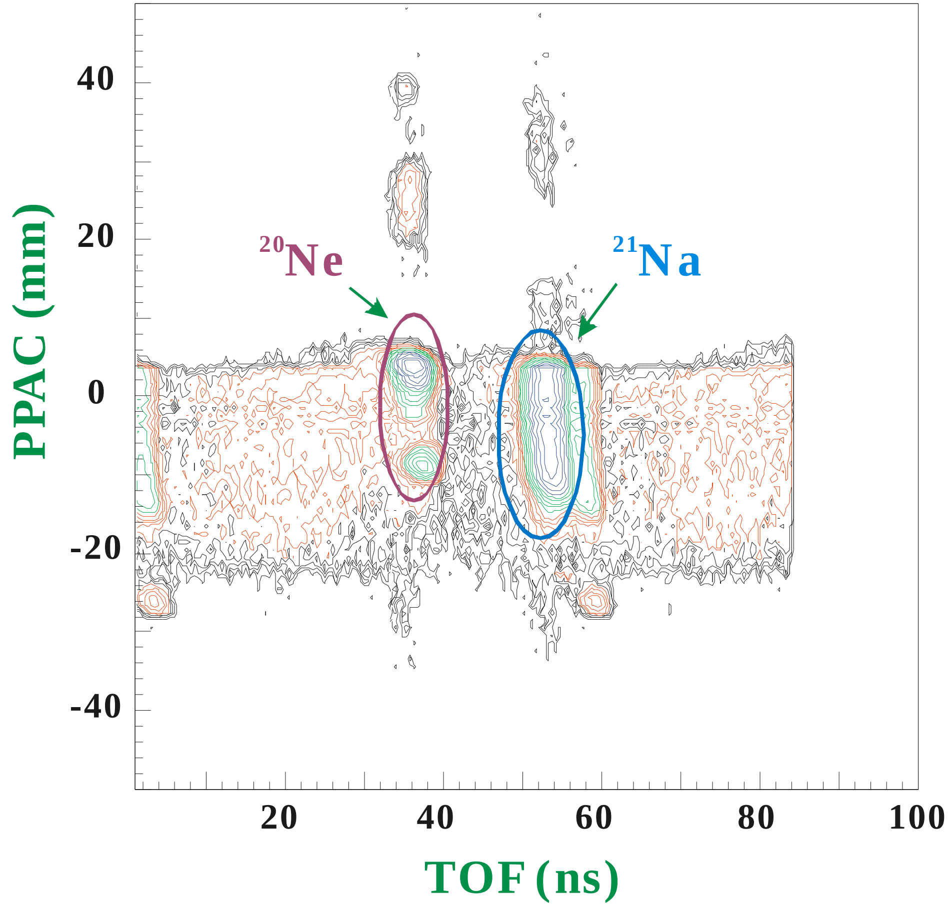
Beam Particle Identification

Beam intensity: 2×10^{5} pps

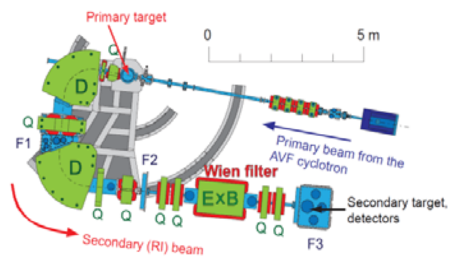
Purity: 70%

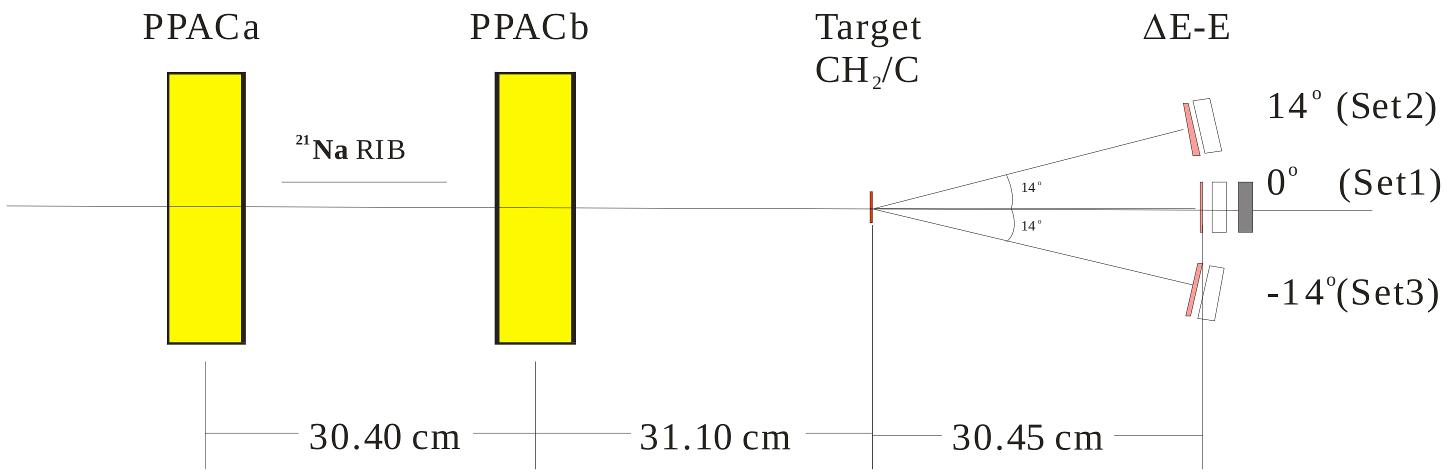
Spot size : 9.5×4.8 mm (FWHM)





Experimental Setup





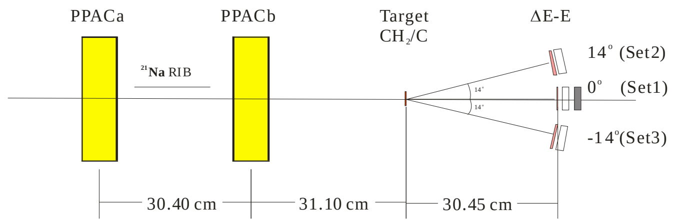
PPACs
Position Resolution: 1 mm
Count Rate: 10^6 pps

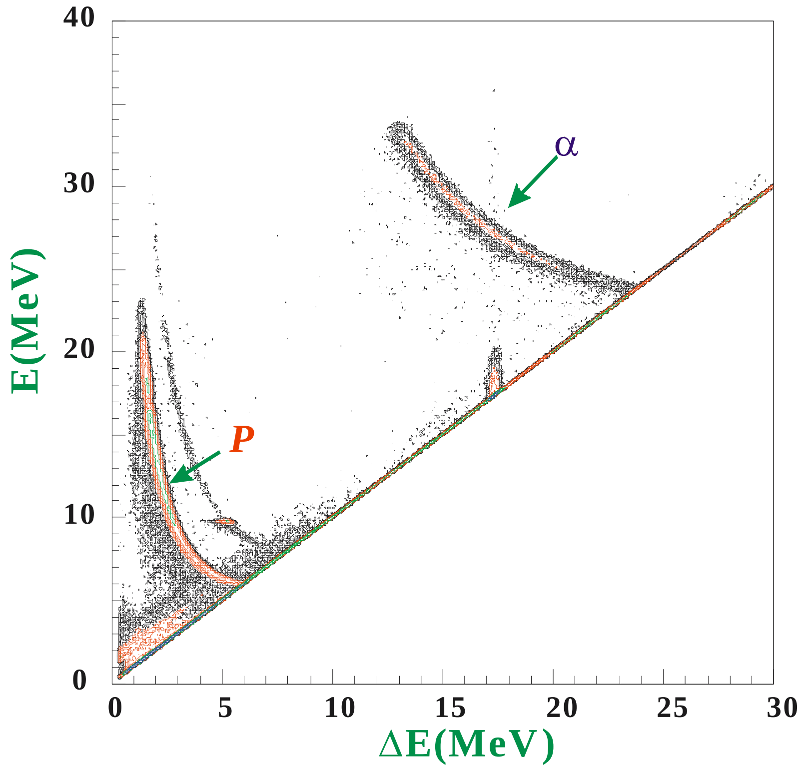
Target
ϕ=30 mm, 90 μm CH_2
ϕ=30 mm, 50 μm C

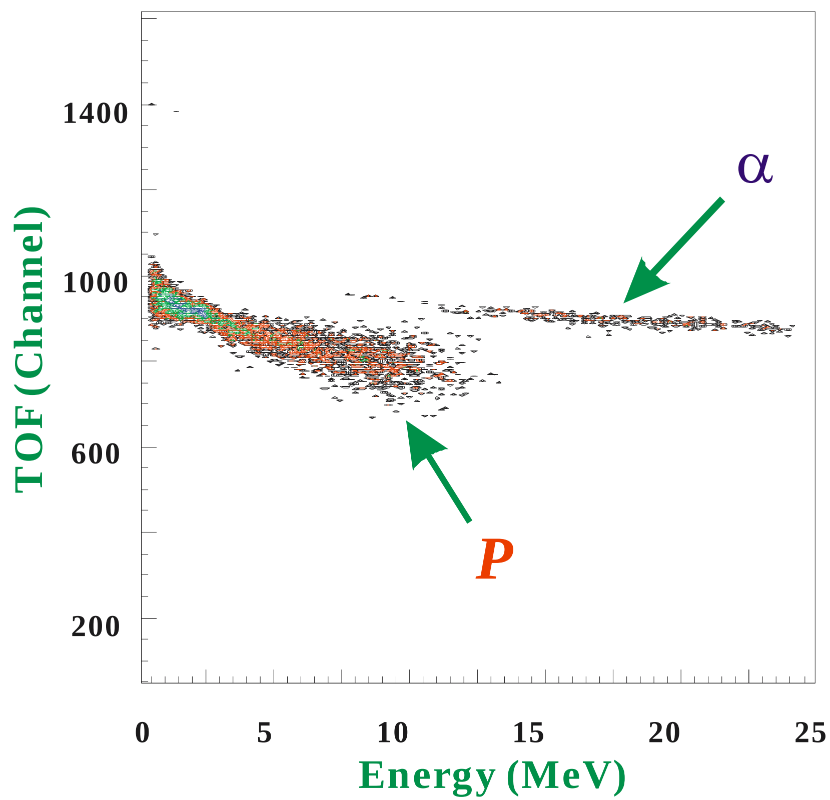
Si Telescopes
Size: 5×5 cm
ΔE: 300/65 μm
E: 1.5 mm

Reaction Product PID

ΔE_E and TOF_E method

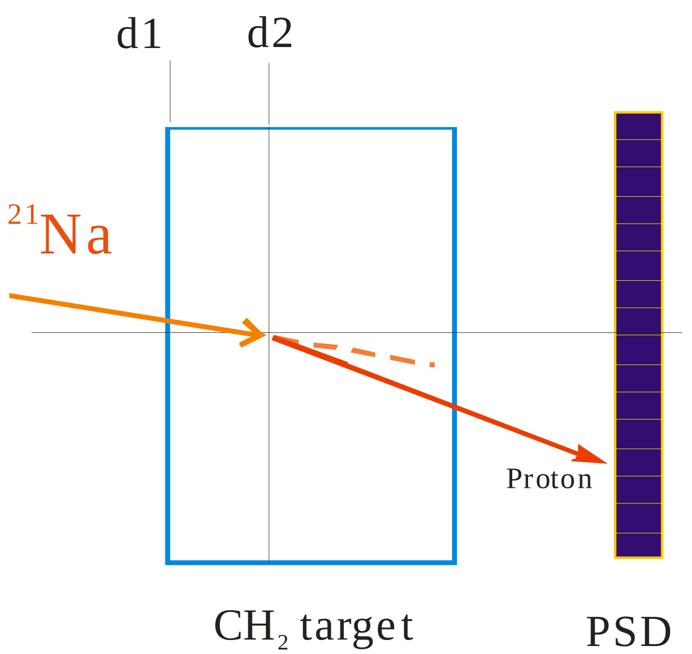


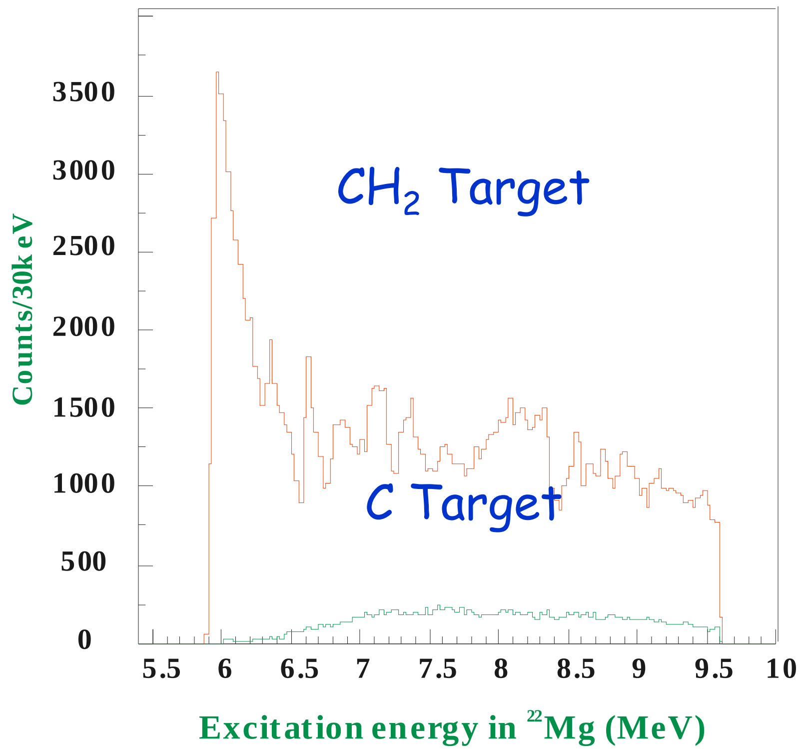




Reconstruction of the $E_{c.m.}$ Spectrum

The reaction point is reconstructed

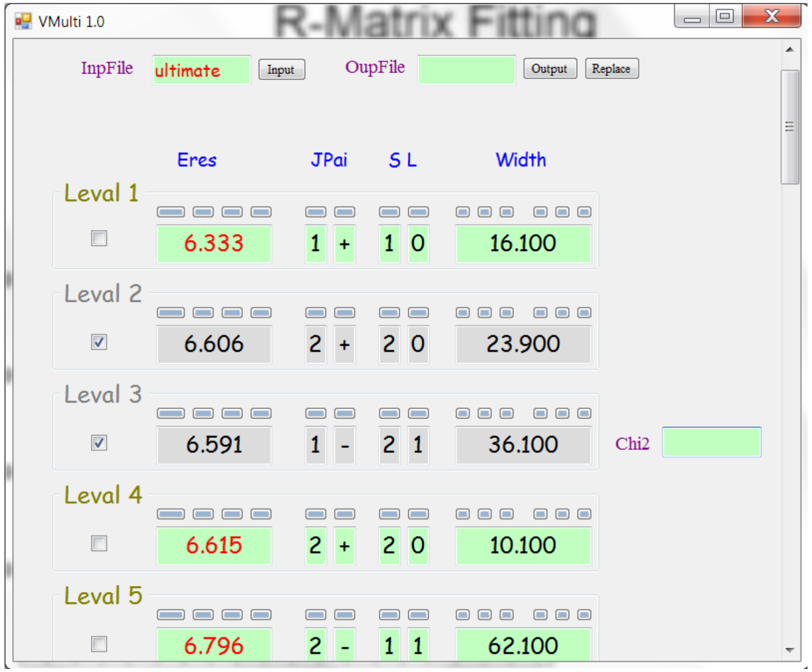


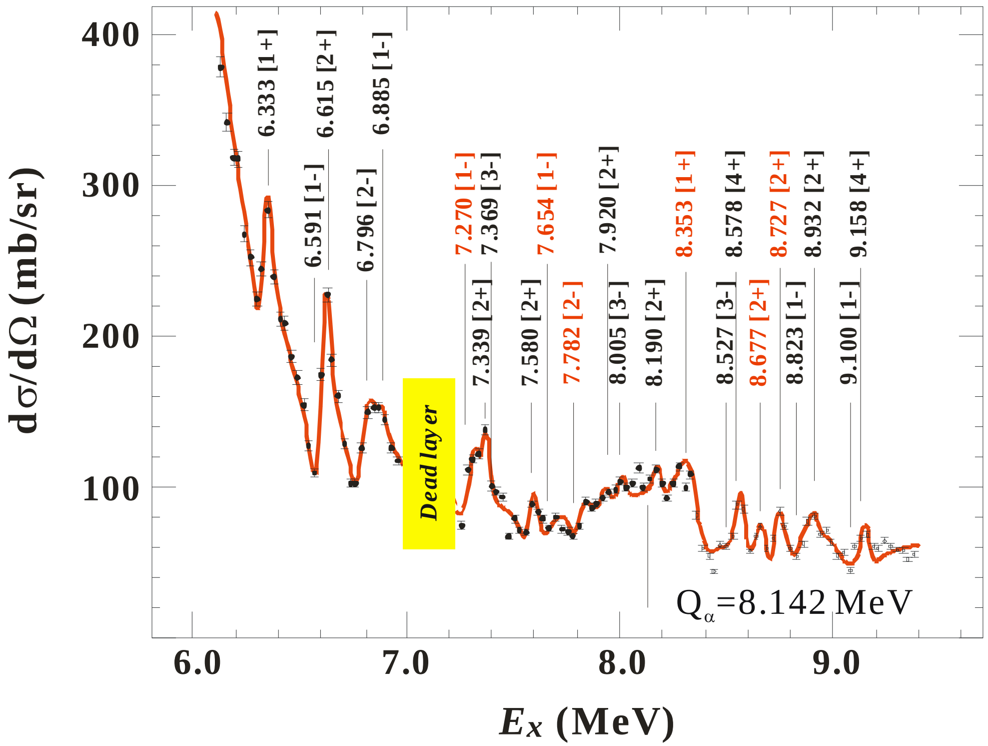


The Carbon background is subtracted

R-Matrix Fitting

The Visual edition of the MULTI Program

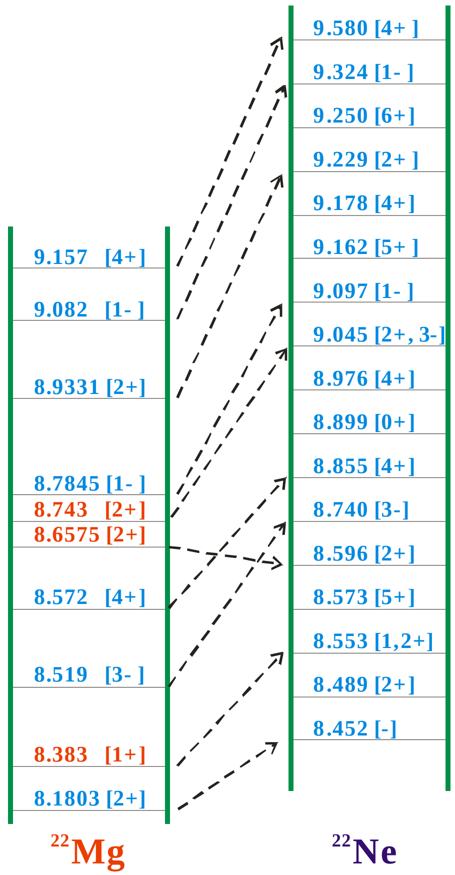


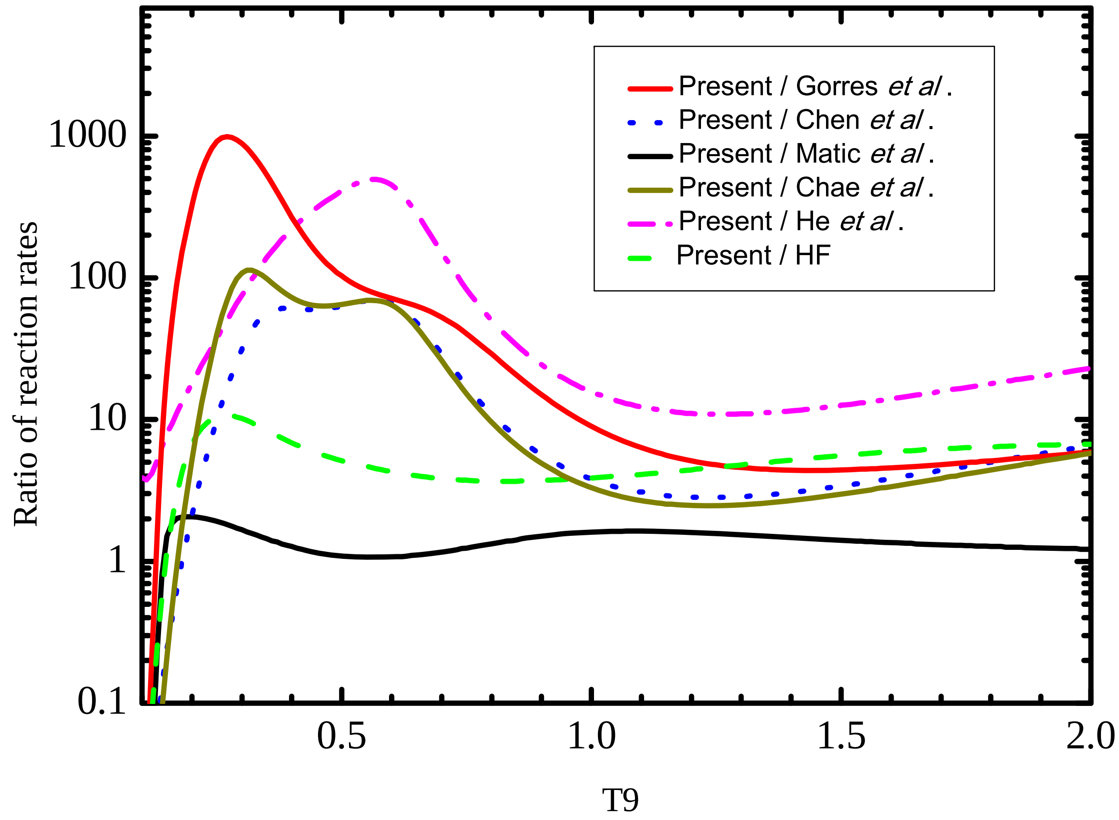


These spin-parity values were used to calculate the $^{18}Ne(\alpha, p)^{21}Na$ rate

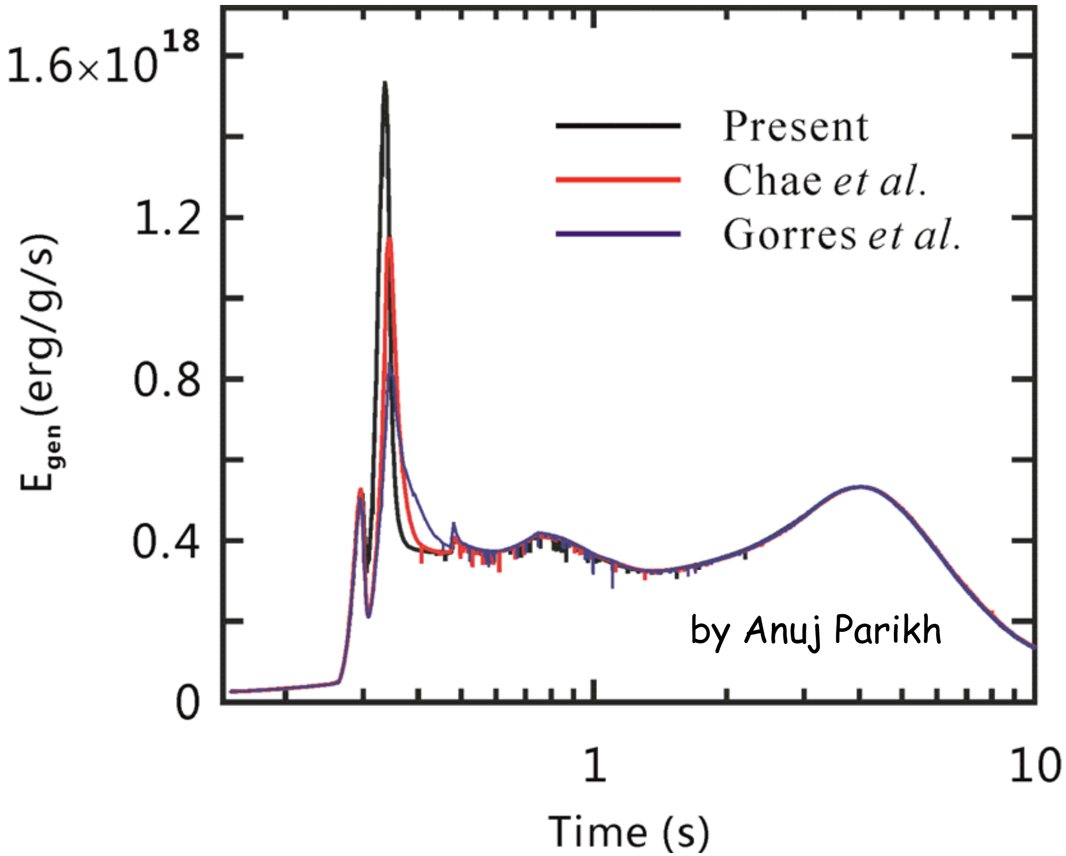
Results: Calculated reaction rate

$$N_A < \sigma v > = 1.54 \times 10^{11} \, (\mu T_9)^{-3/2} \sum_i (\omega\gamma)_i \, \times exp(-11.605 \, E_i / T_9) \, [cm^3 \, s^{-1} \, mol^{-1}]$$





Results: Astrophysical impacts



One-zone postprocessing x-ray burst calculations

The peak energy generation rate increase by a factor of 1.4–1.8

PRC RC and Regular

Summary

- The ^{18}Ne(α,*p*)^{21}Na reaction rate was indirectly measured via a ^{21}Na(*p*,*p*)^{21}Na experiment

- The resonance properties were determined via an R-Matrix analysis

- The ^{18}Ne(α,*p*)^{21}Na reaction rate is recalculated, which is 10 to 100 times larger than previous ones

- The peak energy generation rate increased by a factor of 1.4–1.8

Thank you

- typical temperature = 0.4 – 2.0 GK
- Crresponding Energy Region
  - E_{cm}^{α} = 0.7 - 2.1 MeV
  - E_x (^{22}Mg) = 8.8 -10.2 MeV
- LLN, Belgium (Edinburgh Group, PRC)
  - E_{cm}^{α} = 1.7 - 3.01 MeV
  - ^{18}Ne beam + ^{4}He gas target
- ANL, USA (S. Sinha et al., ANL Annu. Report)
  - E_{cm}^{α} = 1.2 – 2.5 MeV,
  - ^{21}Na beam + CH_2 target
- CNS (J.J. He et al., PRC)
  - E_{cm}^{α} ~ 0.76 MeV,
  - ^{21}Na beam + CH_2 target
- Our results: E_{cm}^{α} = 0 – 1.6 MeV

Experimental Setup

- 1 primary beam $^{20}Ne^{8+}$
  - --- Energy: 8.1 **AMeV**
  - --- Intensity: 300 **pnA**
- 2 Production Target: D_2
  - --- Length: 80 **mm**
  - --- Temperature: 80 **K** (液氮冷却)
  - --- Pressure: 500 **Torr**
  - --- Thickness: 2.4 **mg/cm^2**