Precision Measurement of the ^{15}N(d, p) Angular Distribution and Spectroscopic Factors of Low-lying ^{16}N Levels

Xinyue Li, China Institute of Atomic Energy

Contents

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Background

中國原子能科學研究院
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- The puzzle of fluorine abundance.
  - The only stable fluorine isotope ^{19}F.
  - Asymptotic giant branch (AGB) stars.
  - Enhancements cannot be reproduced by model calculations.

Background

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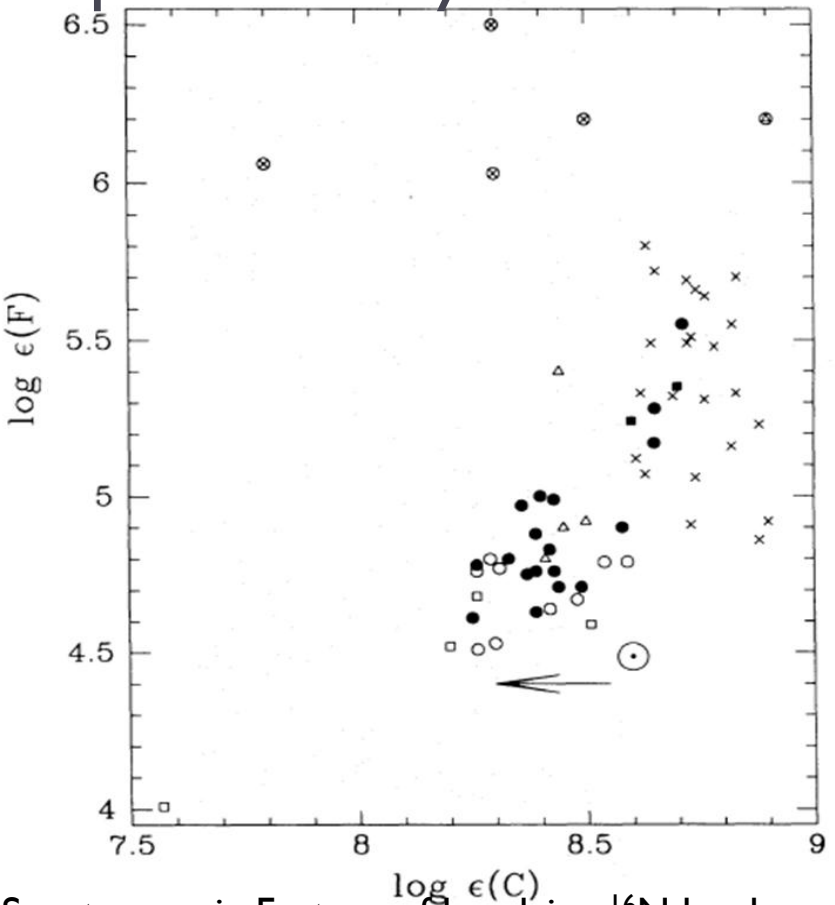
- The puzzle of fluorine abundance.
  - Enhancements cannot be reproduced by model calculations.
    - Factors of up to 30 with respect to solar abundances.
      - A&A 261, 164 (1992).
      - University of Texas.



Background

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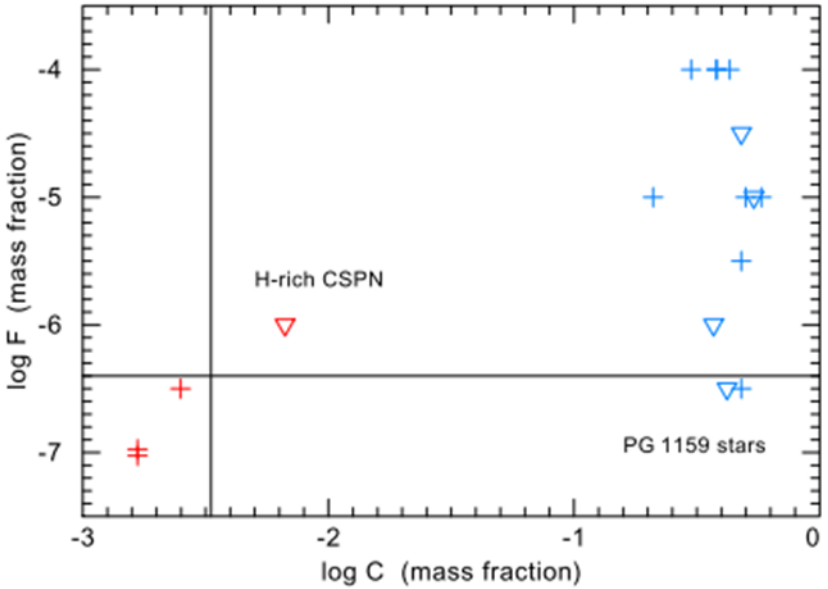
- The puzzle of fluorine abundance.
  - Enhancements cannot be reproduced by model calculations.
    - Up to 250 times solar in some extremely hot post-AGB stars.
      - A&A 433, 641 (2005).
      - Universität Tübingen.



Background

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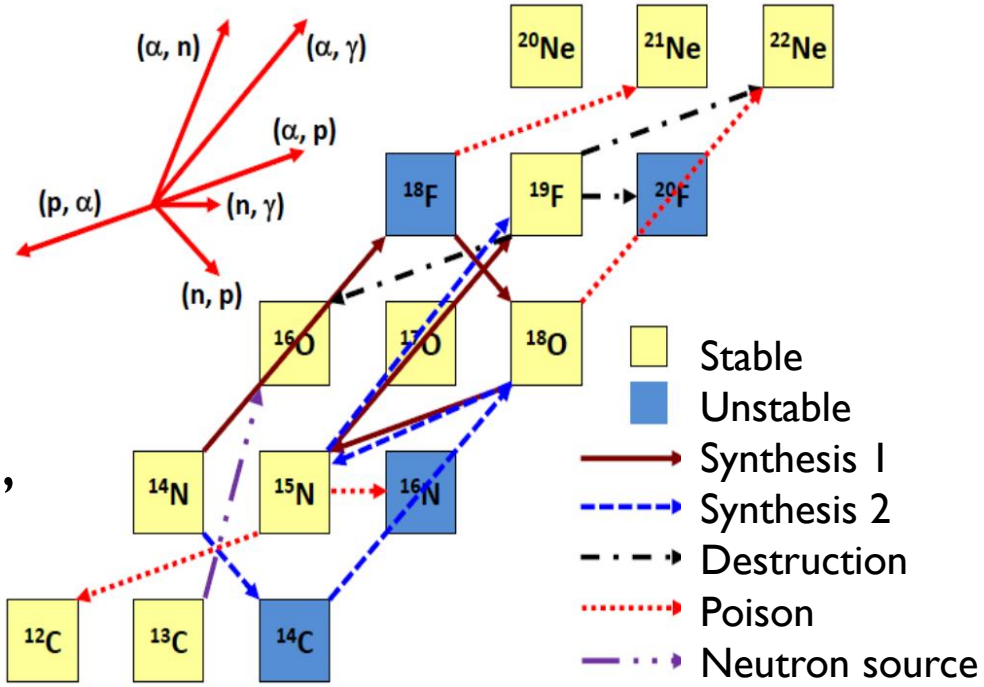
- The puzzle of fluorine abundance.
  - Enhancements cannot be reproduced by model calculations.
    - Planetary nebulae (PNe) ejected from AGB stars.
      - ApJ 631, L61 (2005).
      - ApJ 682, L105 (2008).

Background

- ^{19}F production in AGB stars
  - He intershell.
  - Reaction chains.
    - $^{14}N(\alpha, \gamma)^{18}F(\beta^+)^{18}O(p, \alpha)^{15}N(\alpha, \gamma)^{19}F$
    - $^{14}N(n, p)^{14}C(\alpha, \gamma)^{18}O(p, \alpha)^{15}N(\alpha, \gamma)^{19}F$

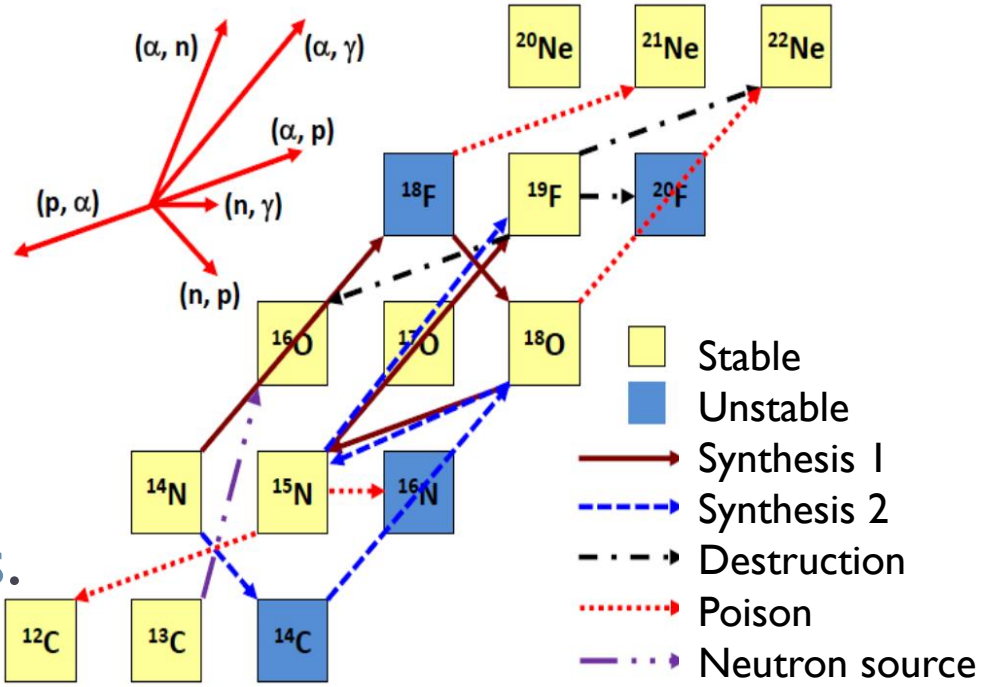
- Network of ^{19}F production.



Background

- $^{15}N(n, \gamma)^{16}N$
  - Poison reaction.
  - Consuming both ^{15}N and neutron.
  - The direct capture rate depends on the spectroscopic factors of low-lying ^{16}N levels.

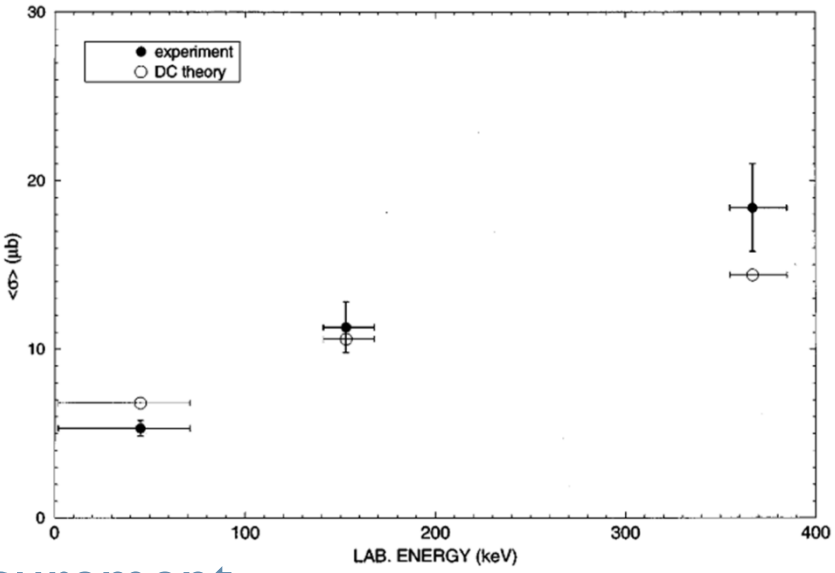
- Network of ^{19}F production.



Background

- Direct measurement.
  - $^{15}N(n,\gamma)^{16}N$.
    - 25, 152, 370keV.
      - PRC 53, 977 (1996).
- Transfer reaction.
  - $^{15}N(d,p)^{16}N$ (1972)
    - ^{16}N spectroscopic factors
      - NPA 196, 41 (1972).
    - Agree with the direct measurement.
    - Disagree with shell model predictions.
      - PRC 53, 977 (1996).

- Excitation curve of $^{15}N(n,\gamma)^{16}N$.



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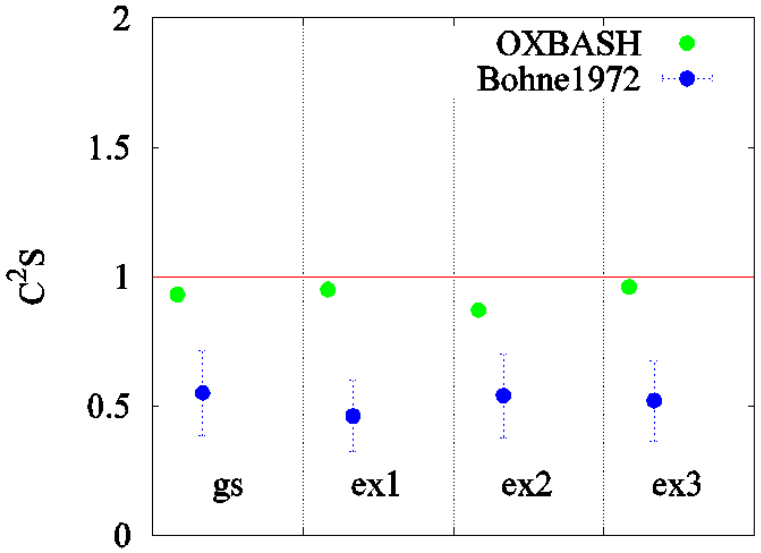
- Spectroscopic factors of low-lying ^{16}N levels.



Background

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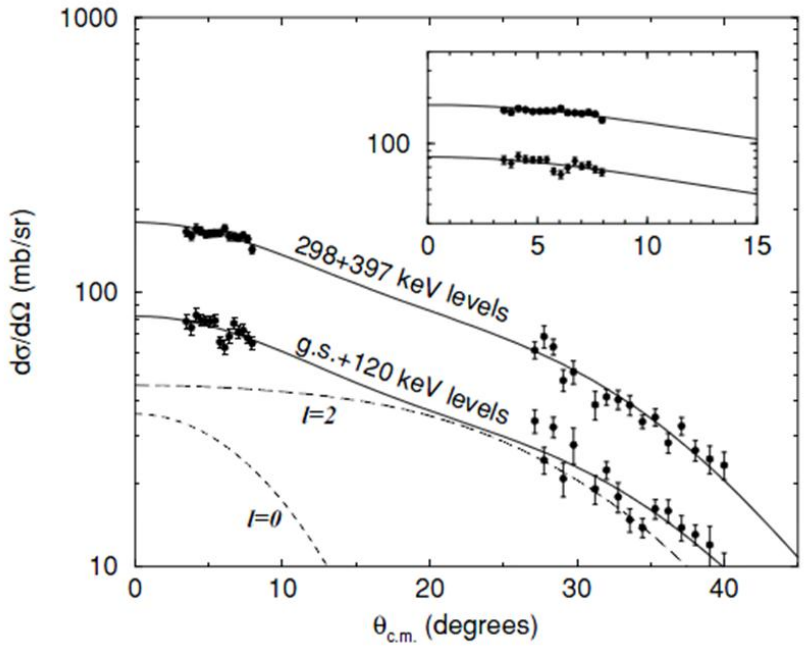
- Transfer reaction.
  - $^{2}H(^{15}N, p)^{16}N$ (2008)
    - PRC 78, 052801(R) (2008).
    - Inverse kinematics.
    - Closely-spaced levels not be resolved.

- Differential cross section of $^{15}N(d, p)^{16}N$.



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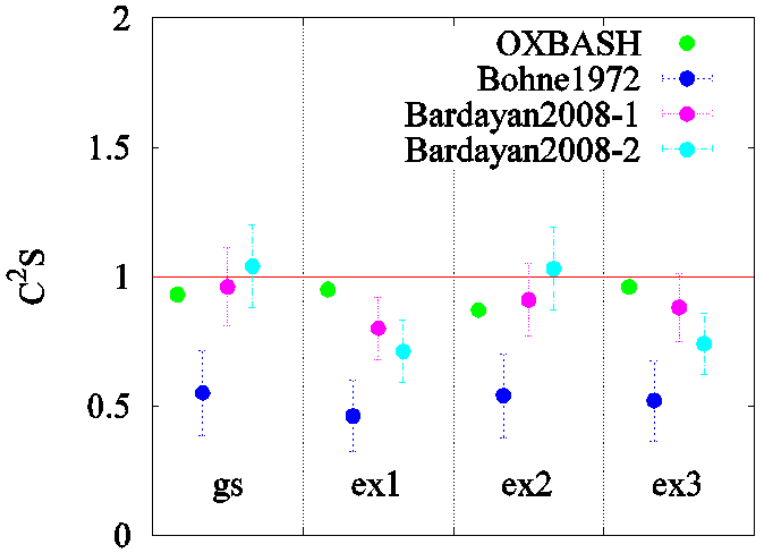
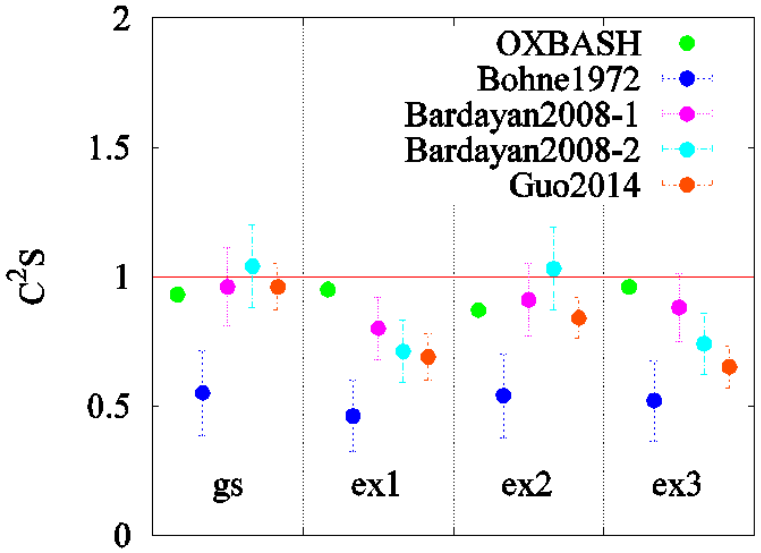


Background

- Transfer reaction.
  - $^{15}N(^{7}Li, ^{6}Li)^{16}N$ (2014)
    - PRC 89, 054315 (2014).
  - Need to do: $^{15}N(d, p)^{16}N$
    - Precision measurement.
    - The discrepancies of the existing results.

- Spectroscopic factors of low-lying ^{16}N levels.



Experiment

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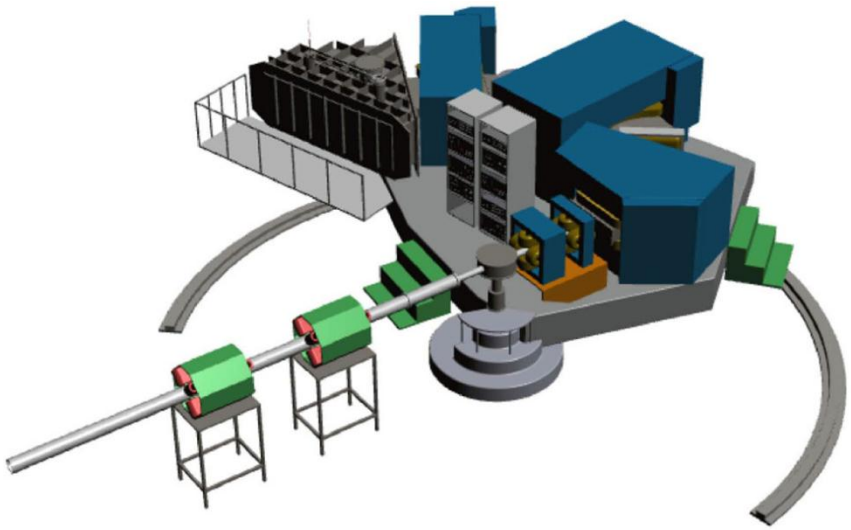
- Set up.
  - HI-13 tandem accelerator, CIAE, Beijing.
  - Target: $C_3N_3(^{15}NH_2)_3$.
  - Beam: d, 15MeV.
  - Q3D magnetic spectrograph.
  - Silicon detectors.

- Q3D magnetic spectrograph.



Experiment

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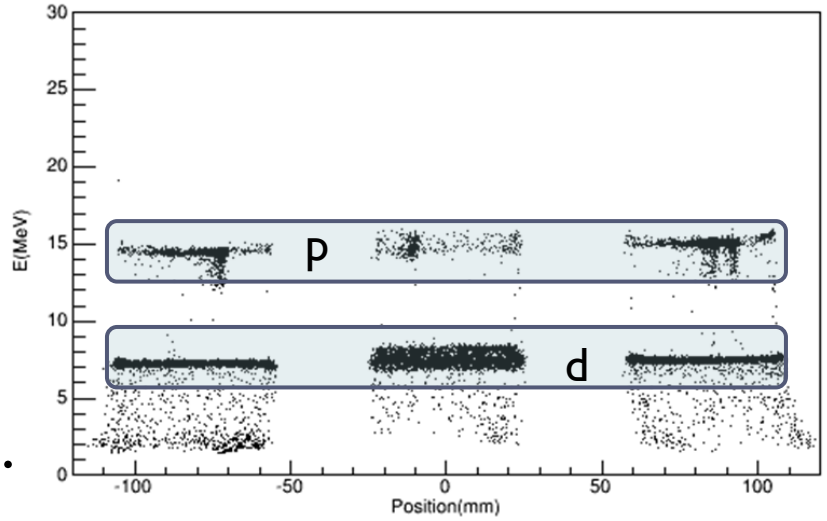
- Selecting the outgoing particles.
  - Q3D magnetic spectrograph.
    - Bρ=mv/Q (magnetic rigidity).
    - Magnetic rigidity => Position on the focal plane.
  - Silicon detectors.
    - Energy.
    - Position on the focal plane.

- Detected energy vs. position, $\theta_{lab}=8^{\circ}$.



Experiment

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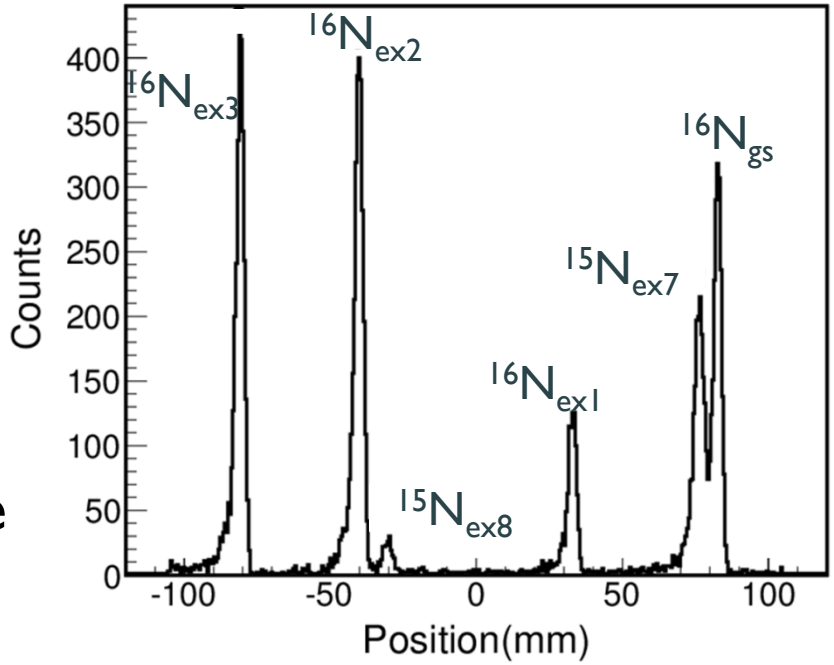
- Selecting the outgoing particles.
  - Q3D magnetic spectrograph.
    - Bρ=mv/Q (magnetic rigidity).
    - Magnetic rigidity => Position on the focal plane
  - Silicon detectors.
    - Energy.
    - Position on the focal plane.

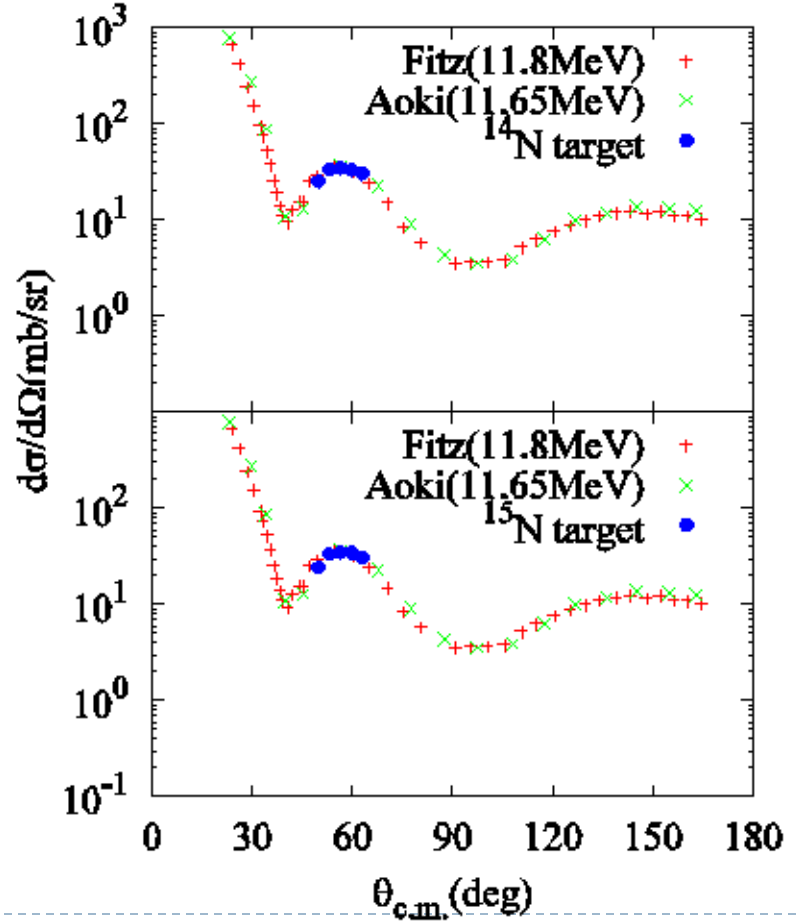
- Focal plane position spectrum, $\theta_{lab}=36^{\circ}$.



Analysis

- Target thickness.
  - ^{14}N.
    - 11.8MeV, d+^{14}N.
      - NPA 101(2), 449 (1967).
      - NPA 322, 117 (1979).
  - ^{15}N.
    - $C_3N_3(^{15}NH_2)_3$.

- Angular distribution of d+^{14}N e.s., 11.8MeV.



Analysis

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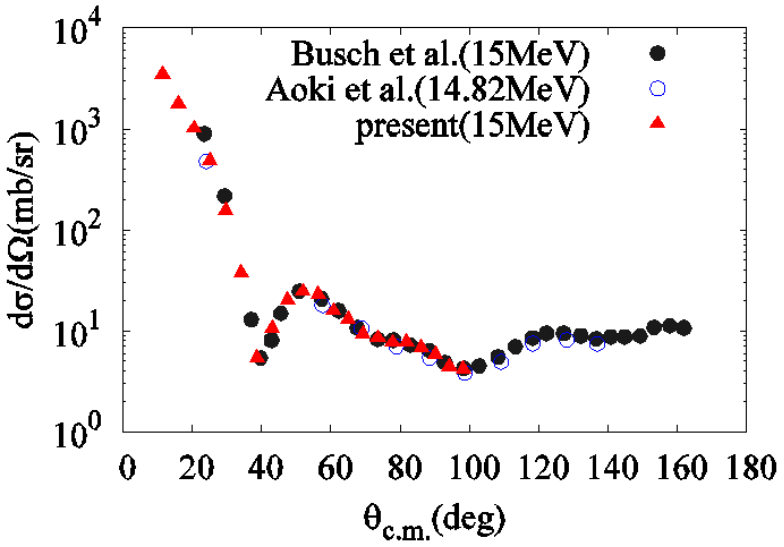
- Elastic scattering.
  - d+^{14}N, 15MeV.
    - Checking the set up.
      - NPA 223, 183 (1974).
      - NPA 322, 117 (1979).

- Angular distribution of d+^{14}N e.s., 15MeV.



Analysis

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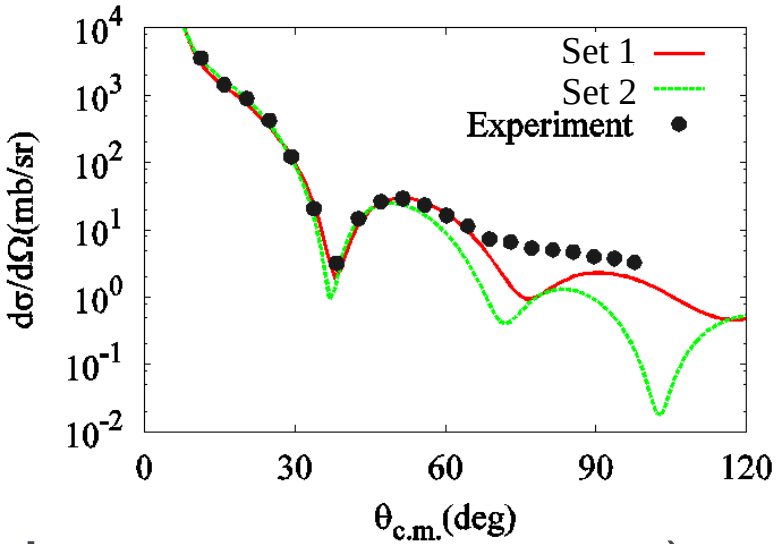
- Elastic scattering.
  - d+^{15}N, 15MeV.
    - Checking the optical model potential (OMP).
- OMP parameters.
  - DWBA.
    - Perey et al., At. Data Nucl. Data Tables **17**, 1(1976).
  - ADWA (adiabatic distorted wave approximation).
    - Varner et al. Phys. Rep. 201(2), 57 (1991).
    - Johnson, Soper. Phys. Rev. C, 1, 976 (1970).
    - Wales, Johnson. Nucl. Phys. A, 274, 168 (1976).

- Angular distribution of d+^{15}N e.s., 15MeV.



Analysis

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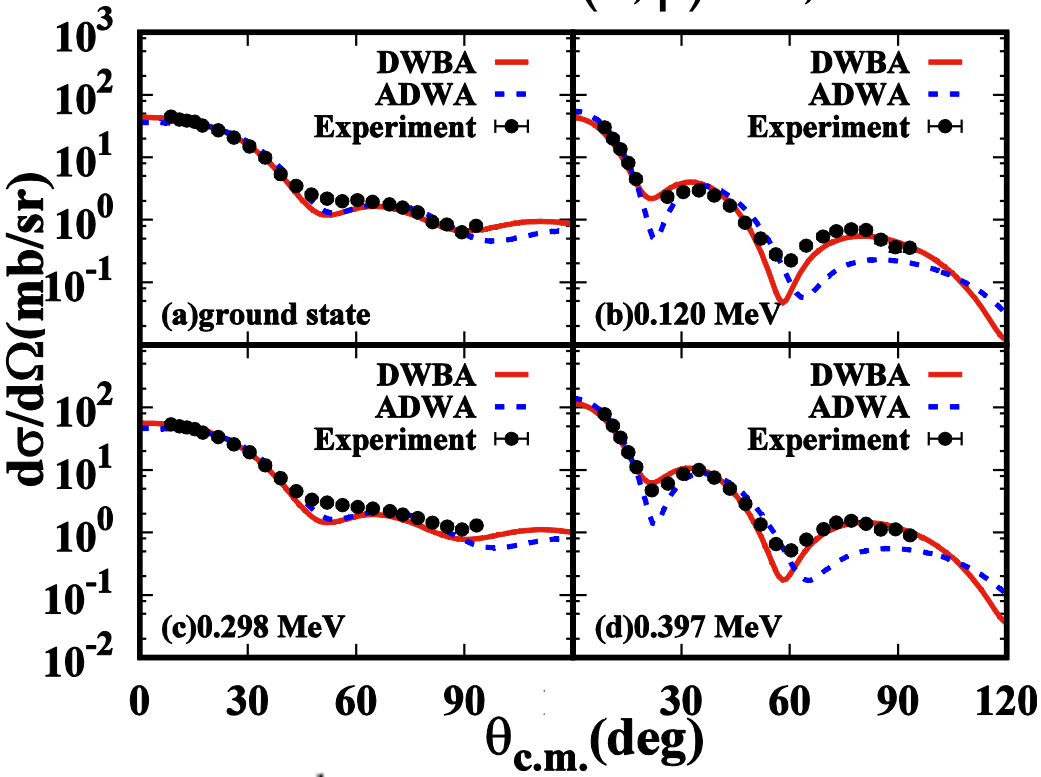
- Spectroscopic factors of low-lying ^{16}N levels.
  - Angular distribution of ^{15}N(d, p)^{16}N, 15MeV.



$$\left(\frac{d\sigma}{d\Omega}\right)_{\exp} = S^{d}_{l_i j_i} S^{^{16}\mathrm{N}}_{l_f j_f} \sigma^{\mathrm{th}}_{l_i j_i l_f j_f}(\theta)$$

Analysis

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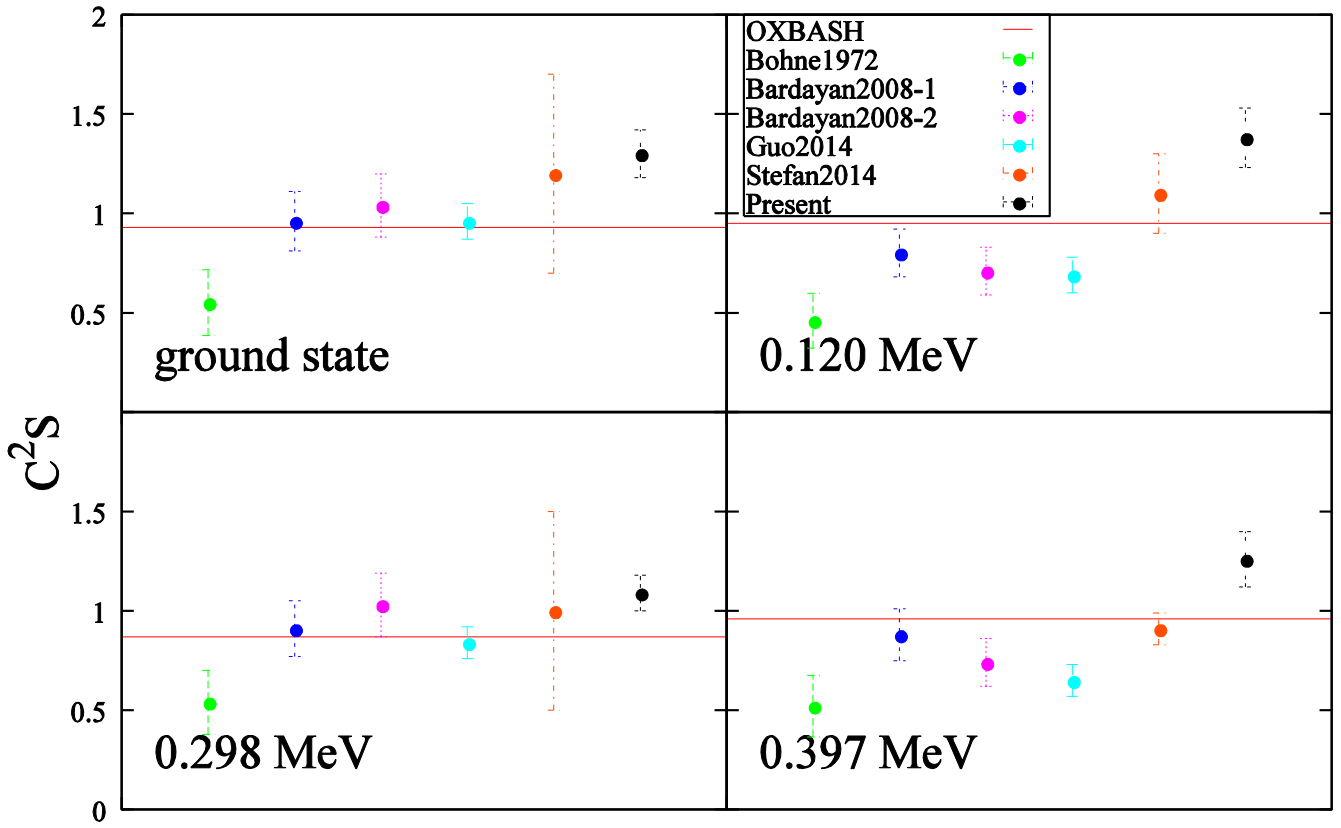
- Spectroscopic factors of low-lying ^{16}N levels.



Summary

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- $^{15}N(n, \gamma)^{16}N$, a poison reaction of the production of ^{19}F.
- ^{16}N spectroscopic factors deduced from $^{15}N(d, p)^{16}N$.
- The levels are good single-particle levels as predicted.
- Differences to be explained.

References

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- Thank you !