Investigation of the CNO-Reaction $^{14}N(p,\gamma)^{15}O$ in Inverse Kinematics at Astrophysically Relevant Energies

E. Krmpotic[1], M. Fey[1], R. Kunz[1], J.W. Hammer[1], B. Pfeiffer[2], A.N. Ostrowski[2], J. Barth[2], K.-L. Kratz[2], H. Beer[3], S. Harissopulos[4] and G. Staudt[5]

[1]Institut für Strahlenphysik, Universität Stuttgart, Germany; [2]Institut für Kernchemie, Universität Mainz, Germany; [3]Institut für Kernphysik, Forschungszentrum Karlsruhe, Germany; [4]Demokritos, Athens, Greece; [5]Physikalisches Institut, Universität Tübingen, Germany

The reaction $^{14}N(p,\gamma)^{15}O$ is the slowest within the CNO-cycle and its reaction rate is determining the energy production and the isotopic abundances of the involved elements. The excitation function of $^{14}N(p,\gamma)^{15}O$ is known only with large uncertainties [1, 2] below the lowest established resonance at $E_{c.m.} = 278\,keV$. Therefore, new measurements with high sensitivity are required in that energy range. Furthermore, a group from TUNL [3] has reported a resonance at $E_{c.m.} = 118\,keV$ (see Fig. 1)whereas another group [4] of the same institution did not find any indication of this resonance.
Missing resonances near the threshold could enhance the reaction rate by orders of magnitude and turn the $^{14}N(p,\gamma)^{15}O$ into a fast process.

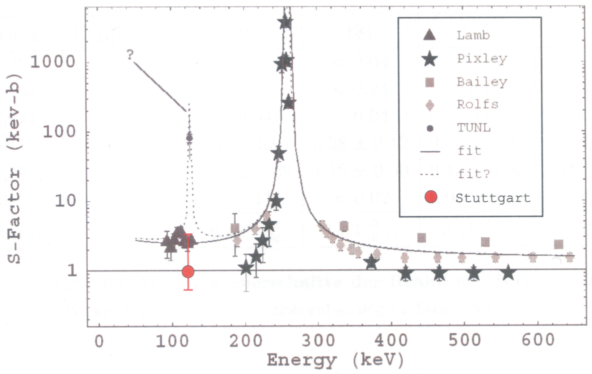

Figure 1: Comparison of the S(E)-factor at 118 keV from Ref. [3] (TUNL) with the result from this measurement (red circle).

Therefore, we have investigated this reaction in inverse kinematics using the gas-target facility RHINOCEROS and an intense ^{14}N-beam of the Stuttgart DYNAMITRON in the energy range $E_{c.m.} = 100-220\,keV$. The target gas was natural hydrogen, as well as hydrogen depleted with respect to deuterium. To obtain a sufficient target thickness of about 15 keV, the target pressure in the reaction chamber was set to 20 mbar and the beam of $30-80\,\mu A$ was transmitting this chamber windowless. The background resulting from the residual deuterium content could be separated well. For further details, see Ref. [5].

In the energy range 119 to 207 keV, no resonance was detected (see, Figs. 1 and 2). An upper limit for the resonance strength at 118 kev of $\omega\gamma \leq 23$ neV instead of the value 5400 neV of Ref. [3] was obtained in accordance with the upper limit of 32 neV of Ref. [4]. In a recent paper of the authors of Ref. [3], no low lying resonance is reported anymore [6].

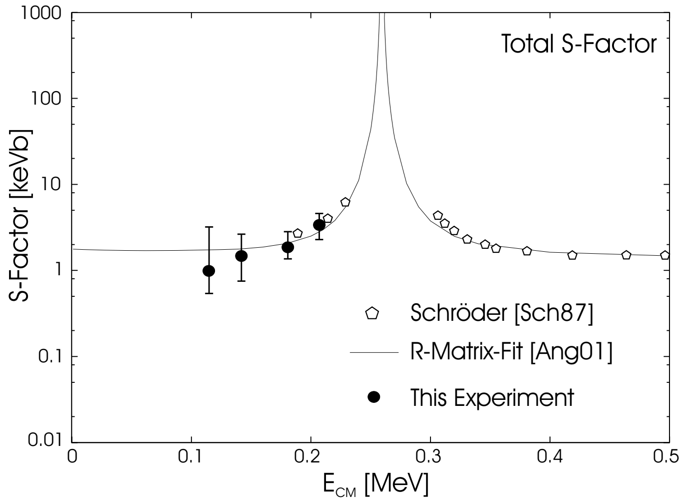

Figure 2: Comparison of the S(E)-factor obtained in this measurement (red circle) with values from Ref. [1] and the R-Matrix fit of Ref. [2].

Table 1: Measured S(E)-factors and cross-sections of [5]

E_{CM} [keV]	S-factor [keV·b]	cross-section [nb]
118	0.96 (+2.31/-0.42)	0.03 (+0.08/-0.01)
142	1.47 (+1.19/-0.72)	0.21 (+0.17/-0.10)
181	1.88 (+0.95/-0.52)	1.53 (+0.76/-0.42)
207	3.26 (+1.40/-0.95)	6.46 (+2.76/-1.88)

The results of this experiment are summarised in Tab. 1 and compared in Fig. 2 to values from literature [1] and an R-Matrix fit of [2]. The S(E)-factor determination in this low energy range will improve the R-matrix description and will allow to better extrapolate the excitation function down to the Gamow peak at 26 keV of astrophysical relevance. The non-observation of the 118 keV resonance confirms the main features of the standard models for stellar evolution [7].

References

[1] U. Schröder et al., Nucl. Phys. **A 467**, 240 (1987).
[2] C. Angulo *et al.*, Nucl. Phys. **A 656**, 3 (1999).
[3] S.O. Nelson et. al., Bull. Am. Phys. Soc. **46**, 64 (2001).
[4] R.C. Runkle et. al., Phys. Rev. C **66**, 022801(R)(2002).
[5] E. Krmpotic, Diploma Thesis, Stuttgart, 2003.
[6] S.O. Nelson et al., Phys. Rev. **C68**, 065804 (2003).
[7] J.N. Bahcall et al., Phys. Rev. Lett. **90**, 131301 (2003).