The Joint Institute for Nuclear Astrophysics

# Measurements of rp-process rates at the NSCL

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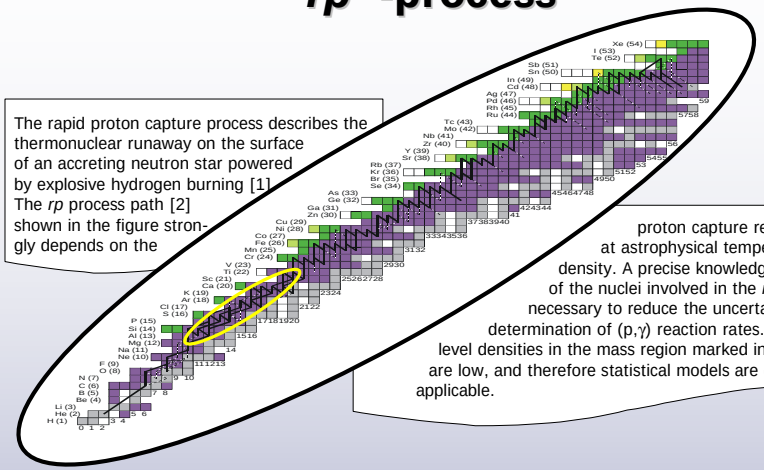
## rp -process



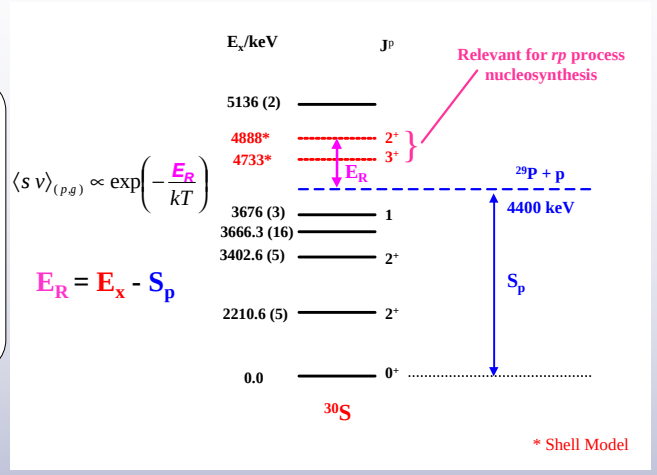
The rapid proton capture process describes the thermonuclear runaway on the surface of an accreting neutron star powered by explosive hydrogen burning [1]. The *rp* process path [2] shown in the figure strongly depends on the proton capture reaction rates at astrophysical temperatures and density. A precise knowledge of masses of the nuclei involved in the *rp* process is necessary to reduce the uncertainties in the determination of (p,γ) reaction rates. In addition, level densities in the mass region marked in the caption are low, and therefore statistical models are generally not applicable.

## Resonant reaction rates

The astrophysical (p,γ) reaction rate at a given temperature, $\langle\sigma v\rangle_{(p,g)}$, depends exponentially on the resonance energy $E_R$, which depends on the proton separation energy $S_p$ and the energy of excited levels above the proton threshold of the final nucleus.

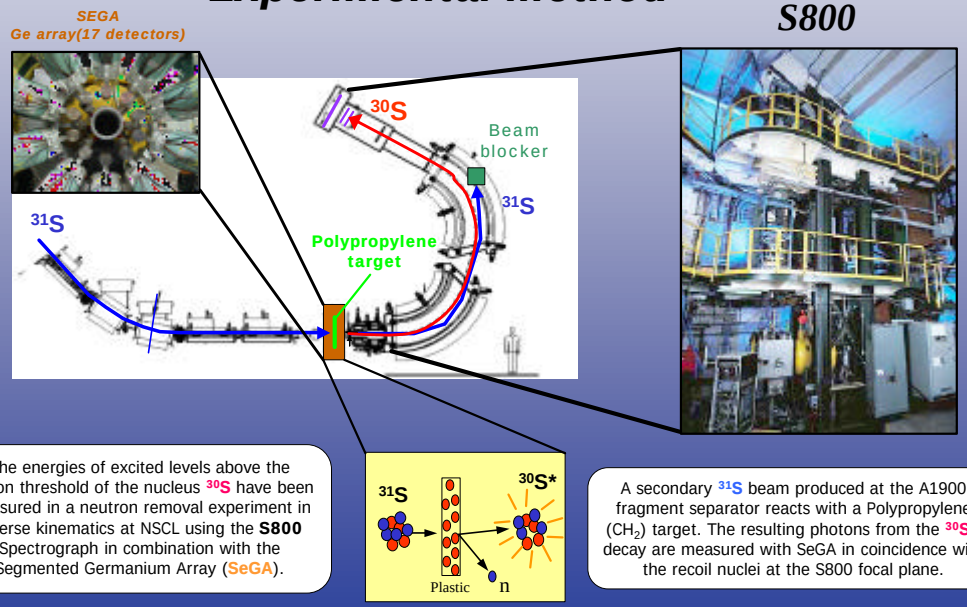
$$\langle s\,v\rangle_{(p,g)} \propto \exp\left(-\frac{E_R}{kT}\right)$$

$$E_R = E_x - S_p$$




The situation for the $^{29}P(p,\gamma)^{30}S$ reaction is shown in the figure. Two levels above the proton threshold are predicted to contribute to the total reaction rate. Uncertainties of about 40 keV in the prediction of level energies [3] translate into several orders of magnitude uncertainty in the reaction rate.

## Experimental method



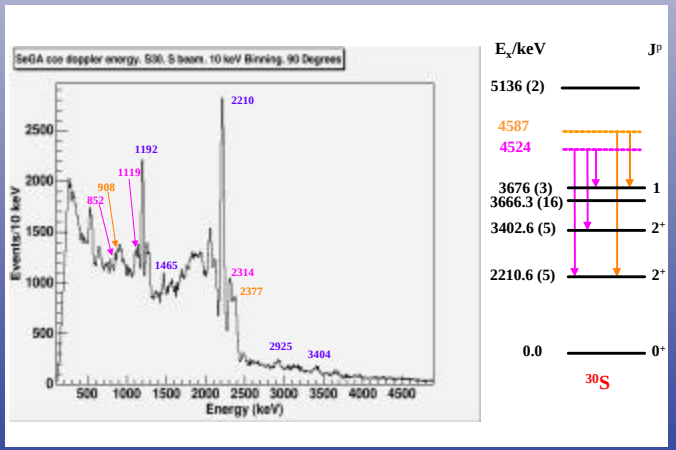




The energies of excited levels above the proton threshold of the nucleus $^{30}S$ have been measured in a neutron removal experiment in inverse kinematics at NSCL using the **S800** Spectrograph in combination with the Segmented Germanium Array (SeGA).

A secondary $^{31}S$ beam produced at the A1900 fragment separator reacts with a Polypropylene ($CH_2$) target. The resulting photons from the $^{30}S^*$ decay are measured with SeGA in coincidence with the recoil nuclei at the S800 focal plane.

## Preliminary results




The Doppler corrected photon spectrum associated to the identified $^{30}S$ nuclei is shown in the figure. In addition to the known lines (blue), several gamma lines can be identified as transitions from two levels located above the proton threshold: 4542 keV (pink) and 4587 keV (orange). The impact of the new resonance energies for the *rp* process is under study. Results of previous measurements using the same technique on the nucleus $^{33}Ar$ can be found in [4].

References:
[1] H. Schatz *et al.*, Phys. Rep. **294**, 167 (1998)
[2] J. L. Fisker *et al.*, Nucl. Phys. **A758**, 447c (2005)
[3] C. Illiadis *et al.*, Ap. J. Suppl. **134**, 151 (2001)
[4] R. R. C. Clement *et al.*, Phys. Rev. Lett. **92**, 172502 (2004)

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