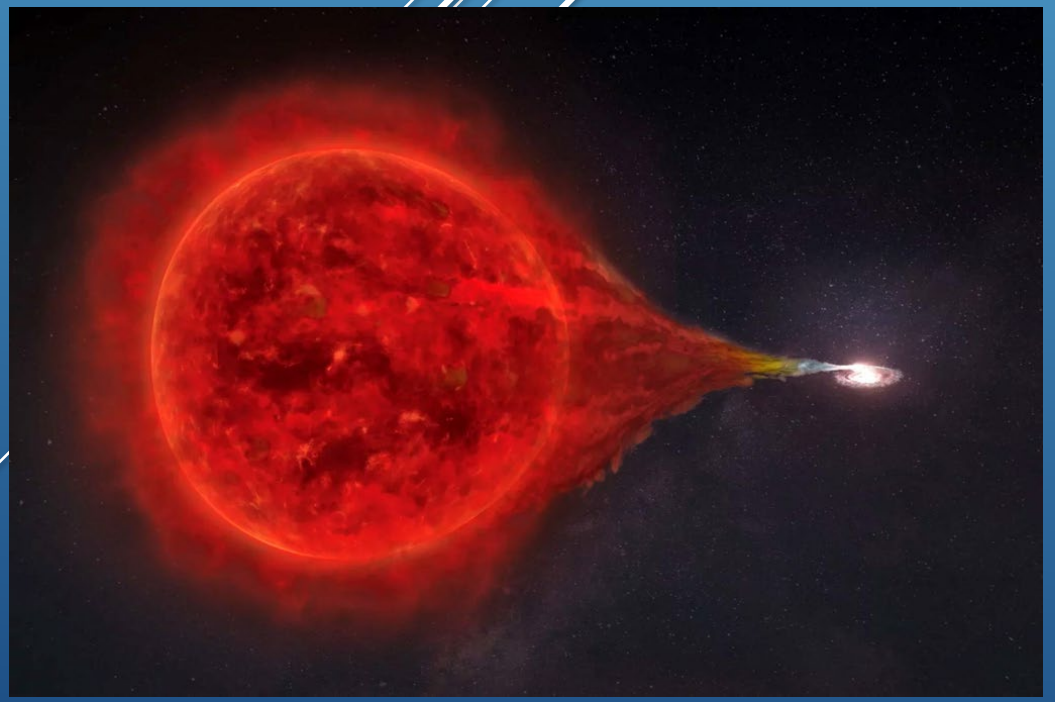
SILICON NUCLEOSYNTHESIS IN CLASSICAL NOVAE

First experimental constraints on nonresonant $^{29}Si(p,\gamma)^{30}P$ capture

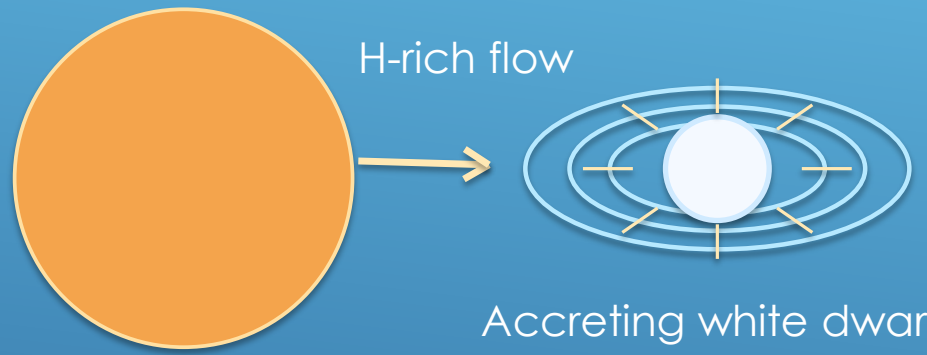


Zs. Mátyus · Gy. Gyürky

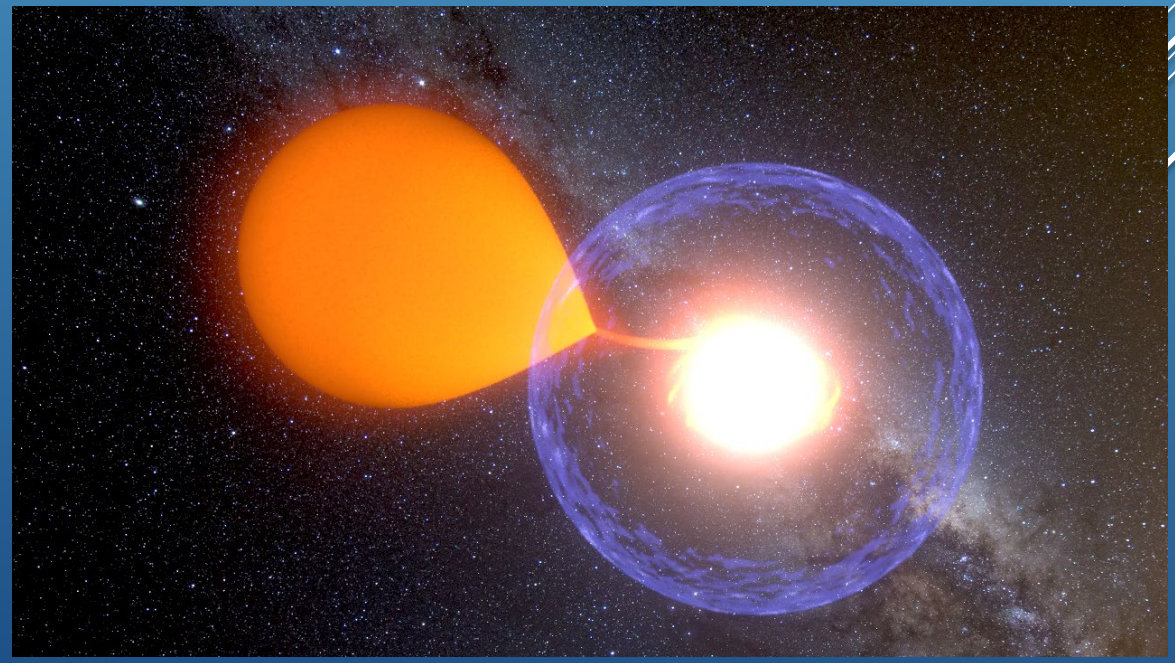
University of Debrecen | HUN-REN ATOMKI

CLASSICAL NOVAE: MATTER PROCESSED AND EJECTED

- Hydrogen-rich matter accretes onto a white dwarf in a binary system.
- Thermonuclear runaway triggers an explosive outburst.
- The ejected material carries newly processed isotopic signatures.



Companion star

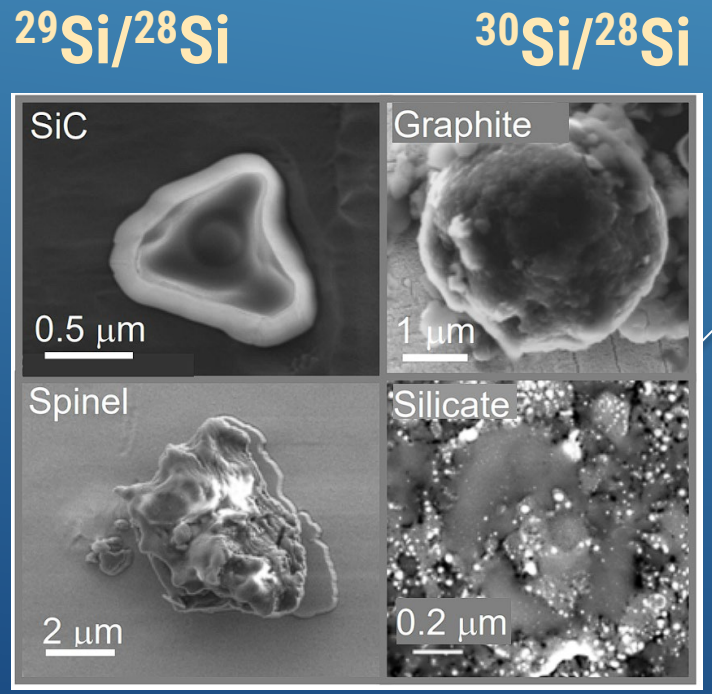


José & Hernanz, J. Phys. G 34 (2007).

PRESOLAR GRAINS AND SILICON ISOTOPE RATIOS

- Presolar grains in meteorites preserve isotope ratios from earlier stellar environments.
- $^{29}Si/^{28}Si$ and $^{30}Si/^{28}Si$ help test a possible nova origin.
- Reliable comparison requires accurate nucleosynthesis predictions.

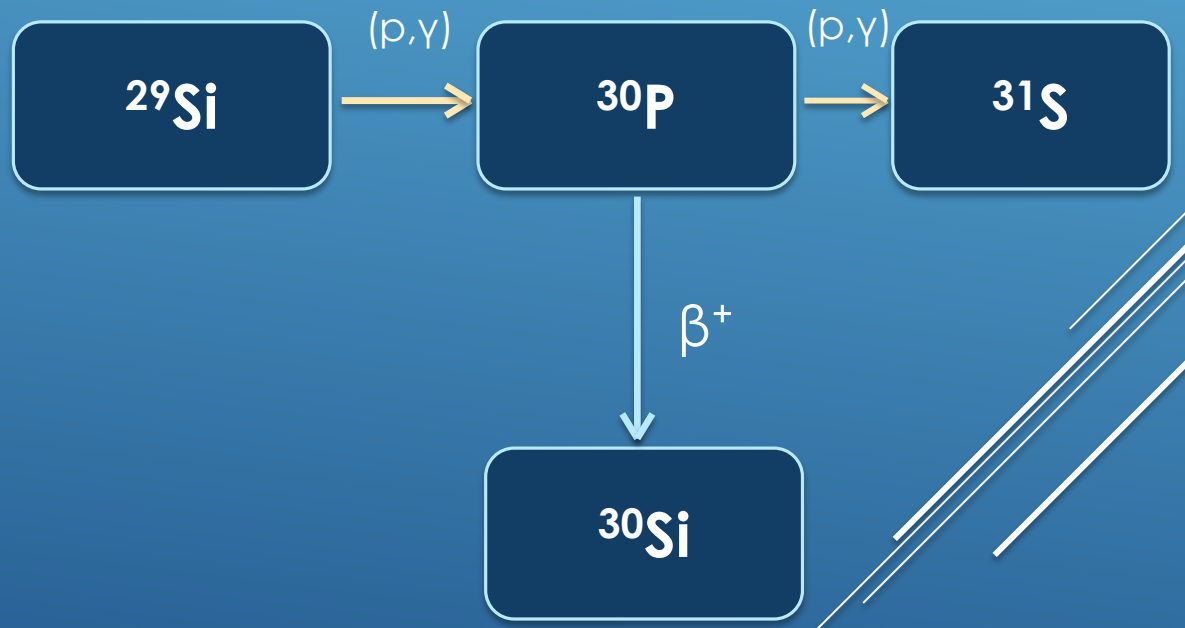




José et al., ApJ 611 (2004); Downen et al., ApJ 928 (2022); P. Hoppe, Proceedings of Science (2010).

WHY $^{29}Si(p,\gamma)^{30}P$ MATTERS

- Proton capture destroys ^{29}Si and produces radioactive ^{30}P.
- ^{30}P can capture a proton or decay into ^{30}Si.
- The reaction network affects the final silicon abundances.



Iliadis et al., ApJS 142 (2002); José et al., ApJ 560 (2001).

RESONANT AND NONRESONANT CAPTURE

- At nova peak temperatures (0.1-0.4 GK), low-energy resonances dominate.
- Several resonance strengths had recently been improved experimentally.
- Nonresonant capture previously relied on theoretical estimates alone.

Our goal: the first experimental cross section measurement in a resonance-free region

RESONANT CAPTURE

nova peak temperatures: 0.1-0.4 GK

NONRESONANT CAPTURE

dominant below about 30 MK

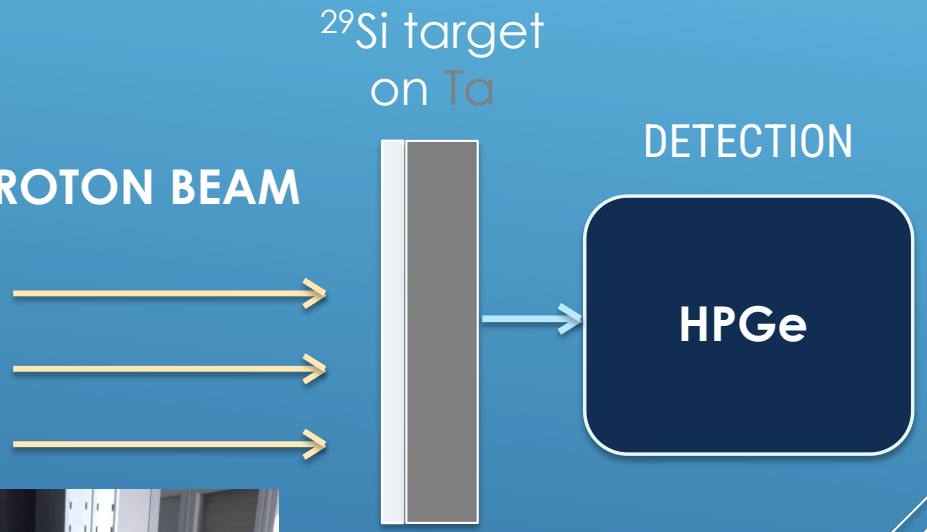
Downen et al., PRC 105 (2022); Mátyus et al., EPJA 60 (2024).

EXPERIMENTAL SETUP

- 99.34% enriched ^{29}Si was evaporated onto tantalum backings.
- The Atomki Tandetron supplied a proton beam.
- Four energies were selected to avoid known resonances.

E_p = 1.0, 1.1, 1.247, 1.43 MeV

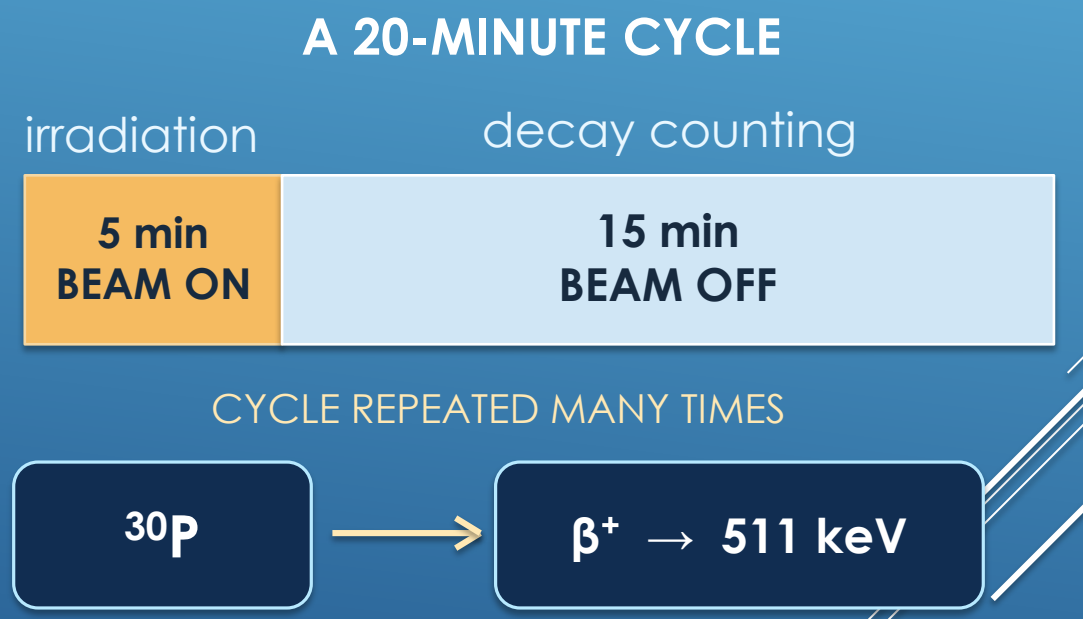




Measured energies selected from Vavrina et al., PRC 55 (1997).

CYCLIC ACTIVATION: IRRADIATION AND DECAY COUNTING

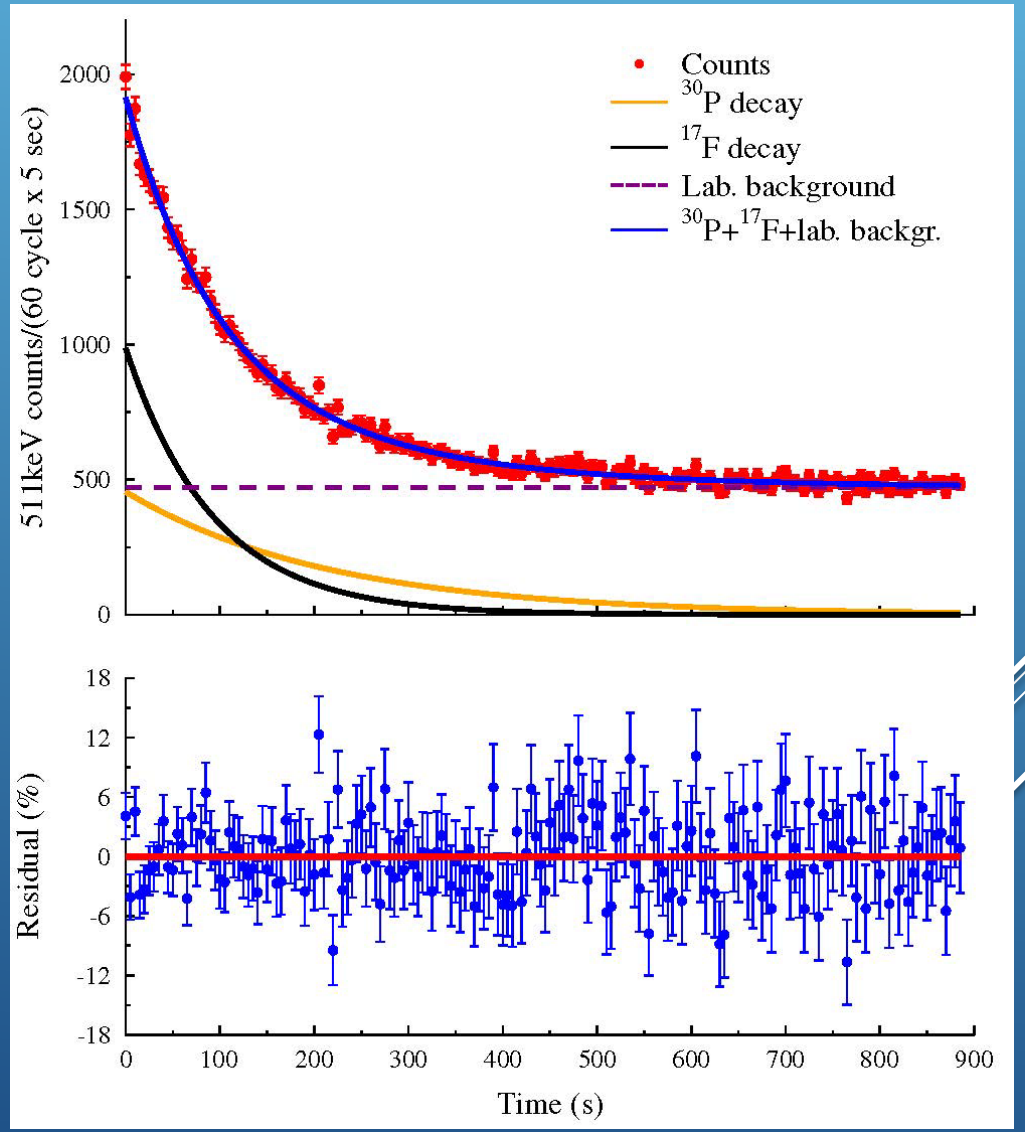
- ^{30}P is radioactive with a half-life of 2.498 minutes.
- Each cycle: 5 min irradiation followed by 15 min counting.
- The HPGe detector records 511 keV annihilation γ rays.



DECAY-CURVE ANALYSIS

- The 511 keV signal contains more than the ^{30}P decay.
- The product of $^{16}O(p,\gamma)^{17}F$ also decays by positron emission.
- A constant background also contributes to the decay curve.

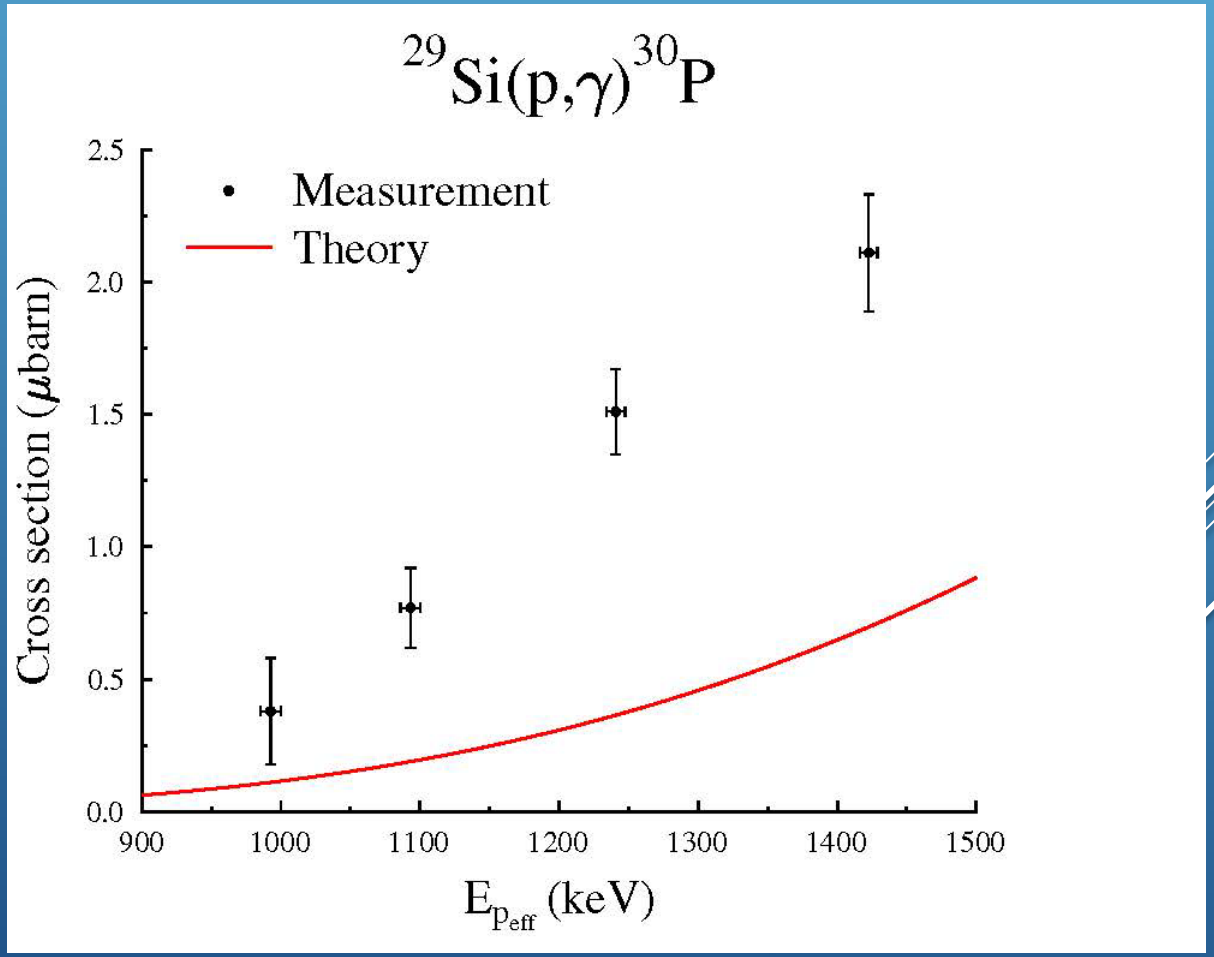
$t_{1/2}=^{30}P$: 2.50 min $t_{1/2}=^{17}F$: 64.49 s



FIRST NONRESONANT CROSS SECTIONS

Four effective proton energies from 0.993 to 1.423 MeV

- Measured σ rises with increasing energy.
- All four points include statistical and systematic uncertainties.
- $^{16}O(p,\gamma)^{17}F$ agrees with earlier measurements: a consistency check.



S-FACTORS CALCULATED FROM MEASURED CROSS SECTIONS

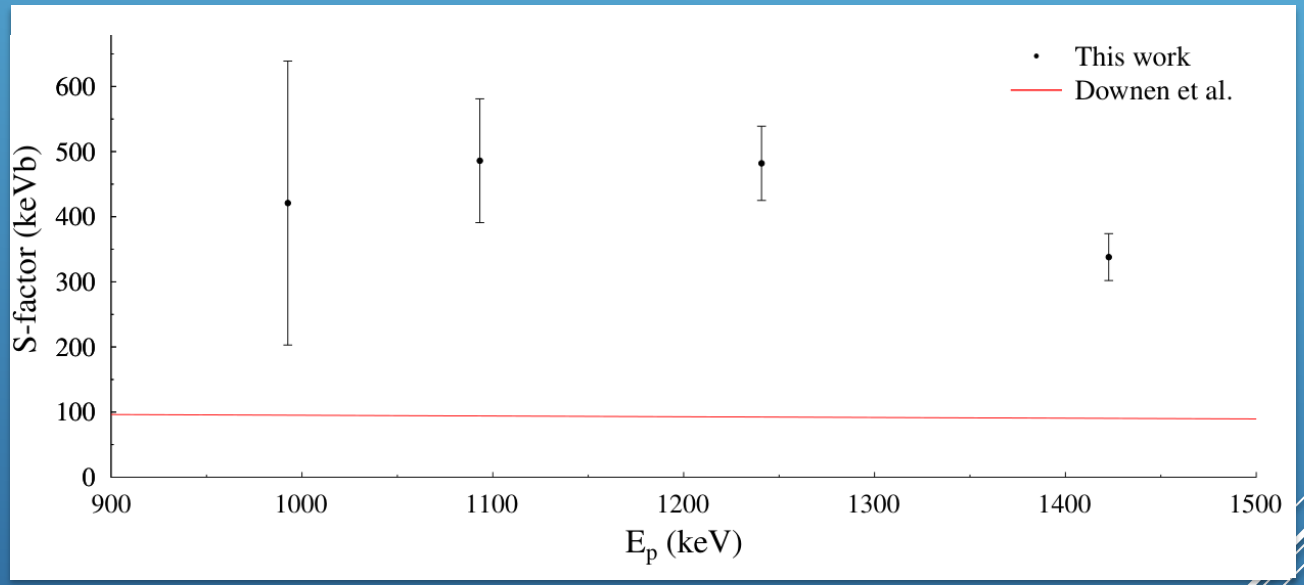
Zs Mátyus et al., J. Phys. G: Nucl. Part. Phys. 52 105201 (2025)

4.3 ± 0.6

times higher than the prior direct-capture prediction

The energy dependence is broadly consistent with the theoretical curve.

S(E) is calculated from σ(E).



„... For most reactions, we estimated the DC by scaling single-particle calculations with spectroscopic factors (or ANCs) from transfer experiments. So, there will be a lot of interest in your work, showing that these calculations maybe off by large factors. ..."
C. Iliadis

Downen et al., PRC 105 (2022).

CONCLUSIONS AND OPEN QUESTIONS

- The $^{29}Si(p,\gamma)^{30}P$ nonresonant cross section now has an experimental constraint.
- The derived S-factors are 4.3 ± 0.6 times above one published DC prediction.
- Weak unknown resonances or broad resonance tails cannot yet be ruled out.
- Further work is needed to quantify the impact on nova isotope ratios.

Better nuclear inputs → more reliable tests of the stellar origins of presolar grains.

Key references: José et al., ApJ 611 (2004); Downen et al., ApJ 928 (2022), PRC 105 (2022); Mátyus et al., EPJA 60 (2024), J. Phys. G: Nucl. Part. Phys. 52 105201 (2025).