This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101008324 (ChETEC-INFRA).

NA3/WP8: Astronuclear Library

ChETEC-INFRA 5th General Assembly

Dresden, 17th-18th September 2025

17/09/2025

Aldo Serenelli, Institute of Space Sciences (ICE, CSIC), aldos@ice.csic.es, chetec-infra.eu

NA3/WP8 Overarching goals

- Development of procedures to evaluate sets of individual results to obtain curated and community supported values: **STANDARDS** (Tasks 8.1 and 8.2)

- Creation of data libraries (Tasks 8.3) based on experimental data as raw as possible to facilitate reutilization for newer analysis
  - 'Big Three' for Helium burning: $^{12}C+\alpha$, $^{12}C+^{12}C$, $^{22}Ne+\alpha$ (T8.1)
  - Hydrogen burning (T8.2)
  - Neutron capture reactions for s-process (T8.3)

- Development and maintenance of ChETEC-INFRA Webpage (T8.4): access to infrastructures, public access to all data obtained in the NAs and JRAs and other data obtained as part of ChETEC-INFRA as well as any other activities related to the project

NA3/WP8 – Task 8.1 – leader: Aurora Tumino (UKE, INFN, UMIL, CNRS, HZDR, GUF, HULL)

Our Big-Three for
- helium **$^{12}C(\alpha,\gamma)^{16}O$**
- carbon **$^{12}C+^{12}C$**
- neutron capture processes **$^{22}Ne(\alpha,n)^{25}Mg$**

Work towards consensus within the community

D8.3: Report to GA on plans for two workshops to discuss complementary reaction studies

1st Workshop – April 2022 (IReNA FA1, Rome)

2nd Workshop – May 2024 (Strasburg)

NA3/WP8 – Task 8.1 – leader: Aurora Tumino (UKE, INFN, UMIL, CNRS, HZDR, GUF, HULL)

D8.7: Key publications with description of methods and results for analysis of Big-Three

Two papers published in EpJA Vol. 61, Topical Issue, ed. D. Bemmerer

Eur. Phys. J. A (2025) 61:70
https://doi.org/10.1140/epja/s10050-025-01537-1

THE EUROPEAN PHYSICAL JOURNAL A

Review

The $^{12}C(\alpha, \gamma)^{16}O$ reaction, in the laboratory and in the stars

R. J. de Boer[1,a], A. Best[2,3], C. R. Brune[4], A. Chieffi[5,6,7], C. Hebborn[8,9,10], G. Imbriani[2,3], W. P. Liu[11,12], Y. P. Shen[11], F. X. Timmes[13], M. Wiescher[1]

Eur. Phys. J. A (2025) 61:99
https://doi.org/10.1140/epja/s10050-025-01572-y

THE EUROPEAN PHYSICAL JOURNAL A

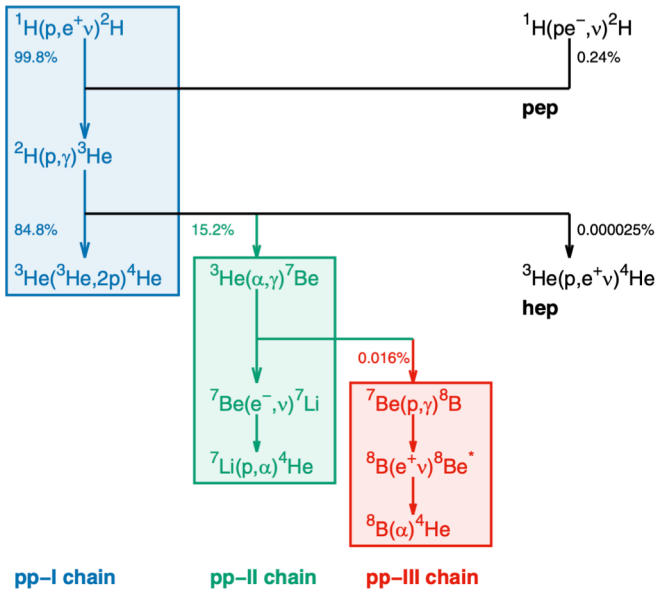
Review

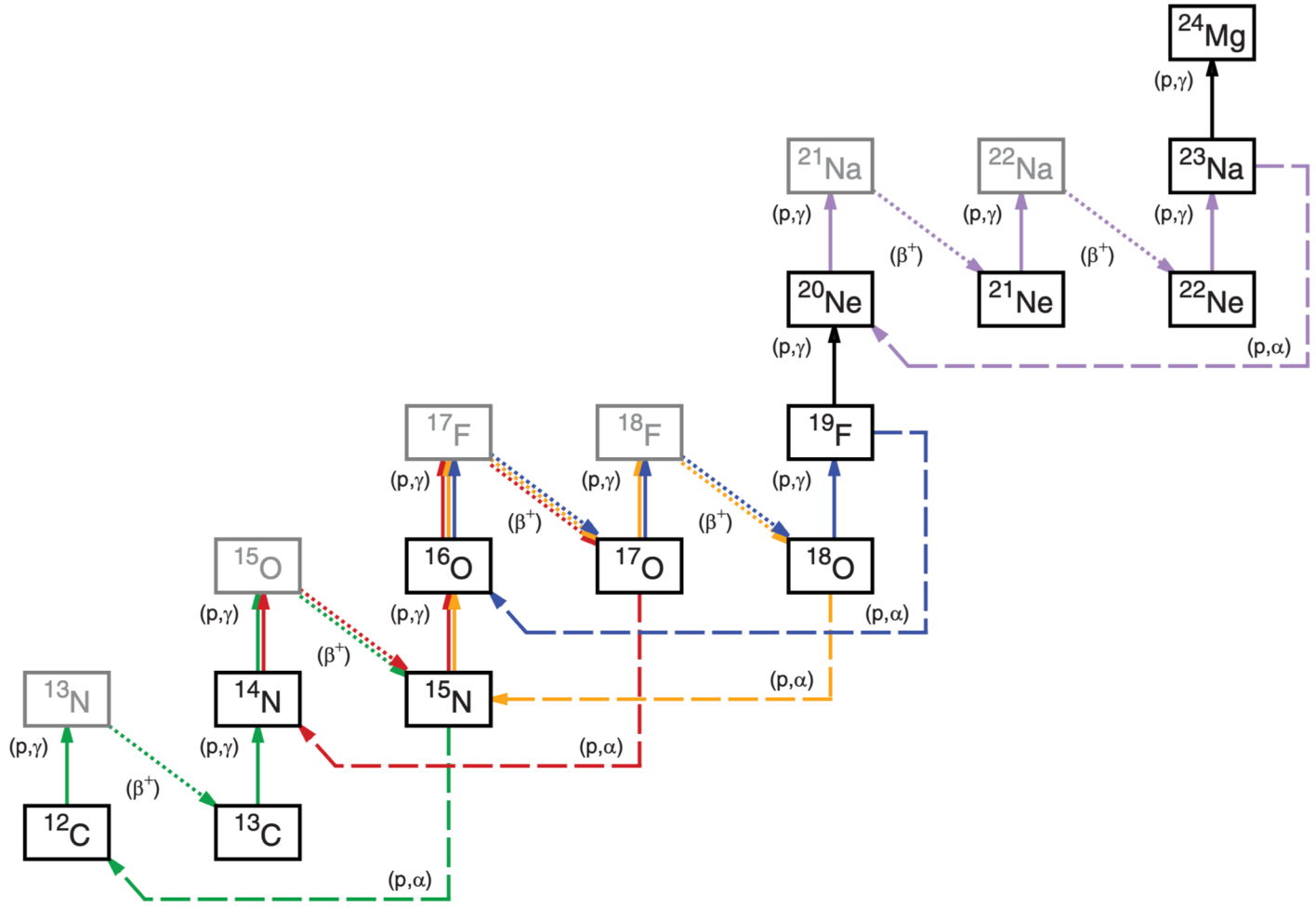
The $^{22}Ne(\alpha,n)^{25}Mg$ reaction - state of the art, astrophysics, and perspectives

Andreas Best[1,2,a], Philip Adsley[3,4], Ryan Amberger[3,4], Umberto Battino[1,5], Thomas Chillery[6], Marco La Cognata[7], Richard James deBoer[8], Daniela Mercogliano[1,2], Shuya Ota[9], David Rapagnani[1,2], Ragandeep Singh Sidhu[10], Roberta Spartà[7,11], Aurora Tumino[7,11], Michael Wiescher[8]

Third paper ($^{12}C+^{12}C$ under revision)

Hydrogen burning reactions





Aldo Serenelli, Institute of Space Sciences (ICE, CSIC), aldos@ice.csic.es, chetec-infra.eu

NA3/WP8 – Task 8.2 – leader: A. Serenelli (CSIC, UMIL, HZDR, TUD)

Hydrogen burning reactions

D8.6: Solar Fusion III published in Sept. 2025

Reaction	S_{ij}	$S(0)$ (MeV b)	$S'(0)$ (b)	$S''(0)$ (MeV^{-1} b)	Section
$^{1}H(p,e^{+}\nu)^{2}H$	S_{11}	4.09×10^{-25}	4.5×10^{-24}	9.9×10^{-23}	III
$^{2}H(p,\gamma)^{3}He$	S_{12}	2.03×10^{-7}	See the text		IV
$^{3}He(^{3}He,2p)^{4}He$	S_{33}	5.21	−4.90	22.42	V
$^{3}He(\alpha,\gamma)^{7}Be$	S_{34}	5.61×10^{-4}	-3.03×10^{-4}	⋯	VI
$^{3}He(p,e^{+}\nu)^{4}He$	S_{hep}	8.6×10^{-23}	⋯	⋯	VII
$^{7}Be(p,\gamma)^{8}B$	S_{17}	2.05×10^{-5}	⋯	⋯	IX
$^{14}N(p,\gamma)^{15}O$	S_{114}	1.68×10^{-3}	⋯	⋯	X F
$^{12}C(p,\gamma)^{13}N$	S_{112}	1.44×10^{-3}	2.71×10^{-3}	3.74×10^{-2}	XI A 1
$^{13}C(p,\gamma)^{14}N$	S_{113}	6.1×10^{-3}	1.04×10^{-2}	9.20×10^{-2}	XI A 2
$^{15}N(p,\gamma)^{16}O$	S^{γ}_{115}	4.0×10^{-2}	1.07×10^{-1}	1.84	XI B 1
$^{15}N(p,\alpha)^{12}C$	S^{α}_{115}	73	3.37×10^{2}	1.32×10^{4}	XI A 3
$^{16}O(p,\gamma)^{17}F$	S_{116}	1.09×10^{-2}	-4.9×10^{-2}	3.11×10^{-1}	XI B 2
$^{17}O(p,\gamma)^{18}F$	S_{117}	4.7×10^{-3}	⋯	⋯	XI B 3
$^{18}O(p,\gamma)^{19}F$	S_{118}	2.30×10^{-2}	⋯	⋯	XI C 1
$^{20}Ne(p,\gamma)^{21}Na$	S_{120}	6.78	⋯	⋯	XI D 1
$^{21}Ne(p,\gamma)^{22}Na$	S_{121}	$\approx 2.0 \times 10^{-2}$	⋯	⋯	XI D 2
$^{22}Ne(p,\gamma)^{23}Na$	S_{122}	0.415	⋯	⋯	XI D 3
$^{23}Na(p,\gamma)^{24}Mg$	S_{123}	1.80×10^{-2}	0	0	XI D 4

Review Modern Physics Vol. 97
doi:10.1103/8lm7-gs18

REVIEWS OF MODERN PHYSICS, VOLUME 97, JULY–SEPTEMBER 2025

Solar fusion III: New data and theory for hydrogen-burning stars

B. Acharya
Oak Ridge National Laboratory, Oak Ridge, Tennessee 37831, USA

M. Aliotta
SUPA, School of Physics and Astronomy, University of Edinburgh, Edinburgh EH9 3FD, United Kingdom

A. B. Balantekin
Department of Physics, University of Wisconsin–Madison, Madison, Wisconsin 53706, USA

D. Bemmerer
Helmholtz-Zentrum Dresden-Rossendorf, 01328 Dresden, Germany

C. A. Bertulani
Department of Physics and Astronomy, Texas A&M University–Commerce, Commerce, Texas 75429-3011, USA

A. Best
University of Napoli Federico II, 80126 Napoli, Italy and Istituto Nazionale di Fisica Nucleare–Napoli, 80126 Napoli, Italy

C. R. Brune
Edwards Accelerator Laboratory, Department of Physics and Astronomy, Ohio University, Athens, Ohio 45701, USA

R. Buompane and L. Gialanella
Dipartimento di Matematica e Fisica, Università degli Studi della Campania "Luigi Vanvitelli," 81100 Caserta, Italy and Istituto Nazionale di Fisica Nucleare–Napoli, 80126 Napoli, Italy

F. Cavanna
Istituto Nazionale di Fisica Nucleare–Torino, 10125 Torino, Italy

J. W. Chen
Department of Physics and Center for Theoretical Physics, National Taiwan University, Taipei 10617, Taiwan and Physics Division, National Center for Theoretical Sciences, Taipei 10617, Taiwan

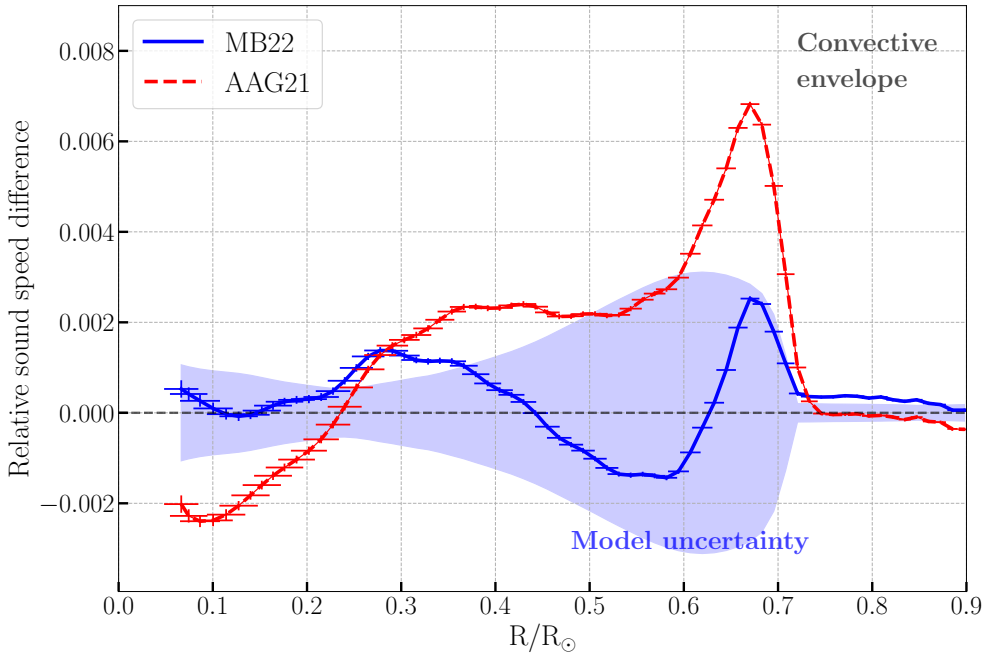
J. Colgan
Los Alamos National Laboratory, Los Alamos, New Mexico 87545, USA

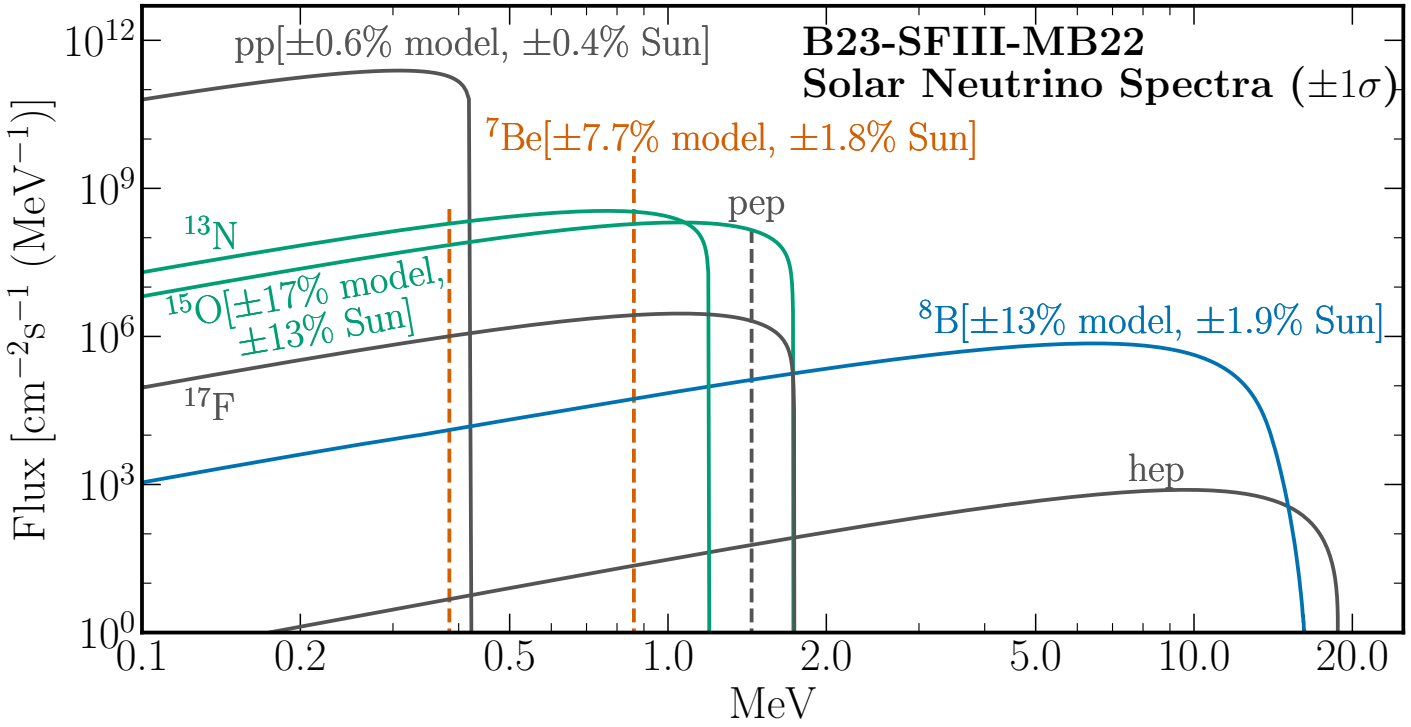
A. Czarnecki
Department of Physics, University of Alberta, Edmonton, Alberta T6G 2E1, Canada

NA3/WP8 – Task 8.2 – leader: A. Serenelli (CSIC, UMIL, HZDR, TUD)

D8.8: Sun as a benchmark

Solar models, structures, neutrino fluxes & production profiles, codes for sensitivity studies
https://doi.org/10.5281/zenodo.10174170



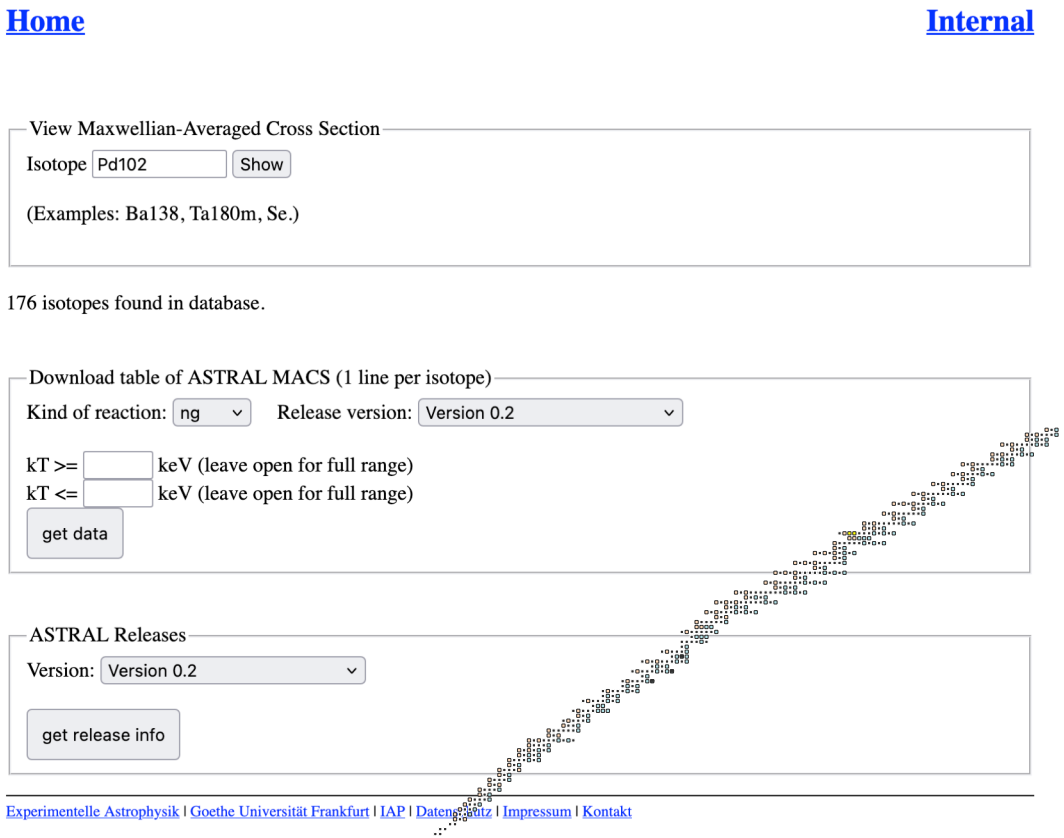


NA3/WP8 – Task 8.3 – leader: Tanja Heftrich/Rene Reifarth (GUF, HZDR, TUD, CSIC)

D8.4: s-process library and raw data distribution

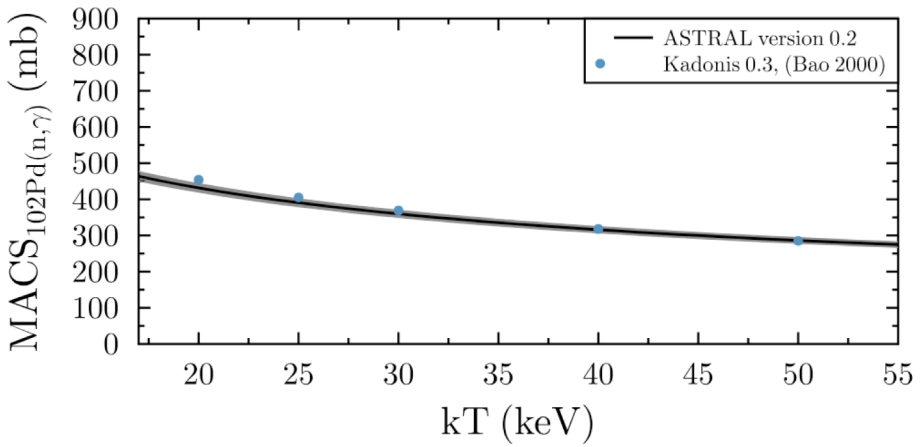
- Publicly available ASTRAL v0.2 - 176 isotopes
  but 243 already included – to be released
  further extension will also happen
- User front-end MACS
- Backend – raw data for easy reevaluation when needed

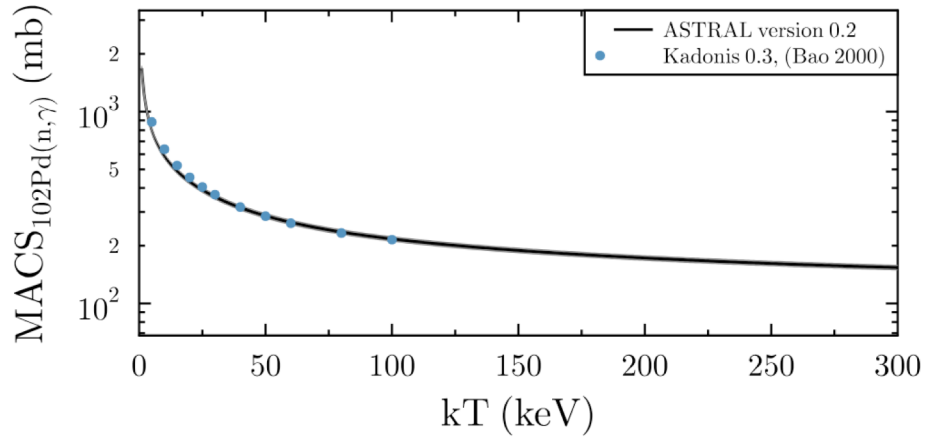
https://exp-astro.de/astral/



NA3/WP8 – Task 8.3 – leader: Tanja Heftrich/Rene Reifarth (GUF, HZDR, TUD, CSIC)

D8.4: s-process library and raw data distribution

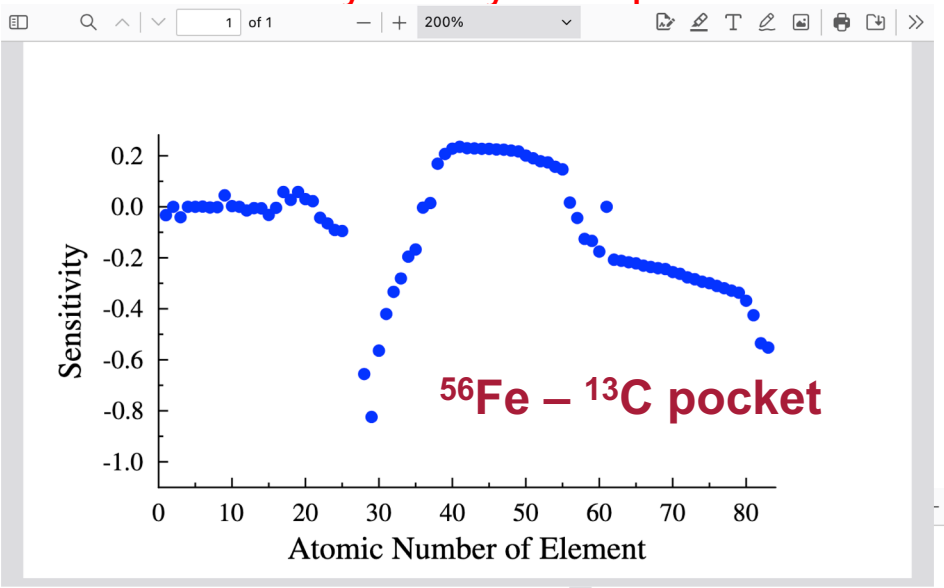


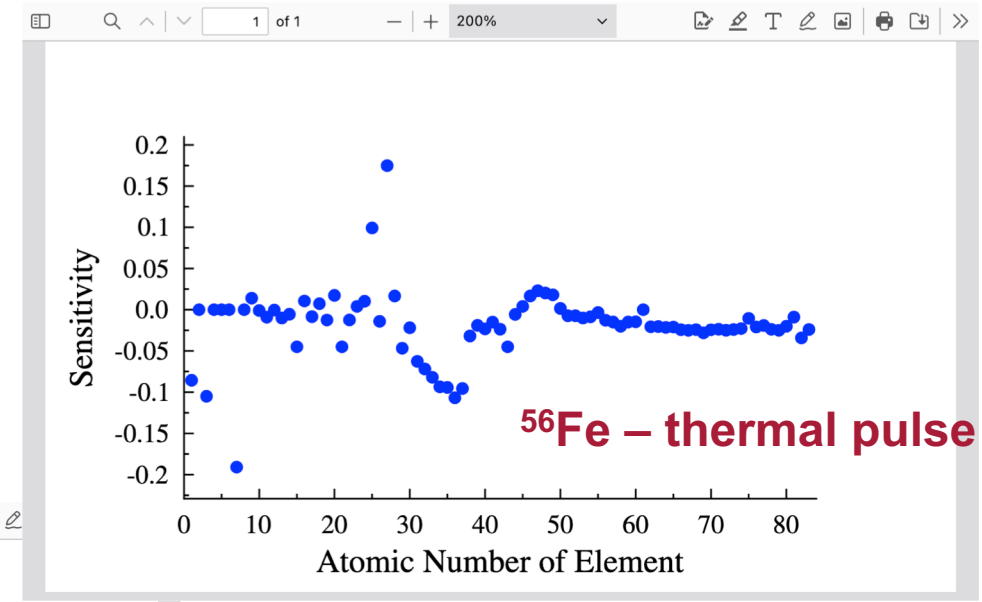


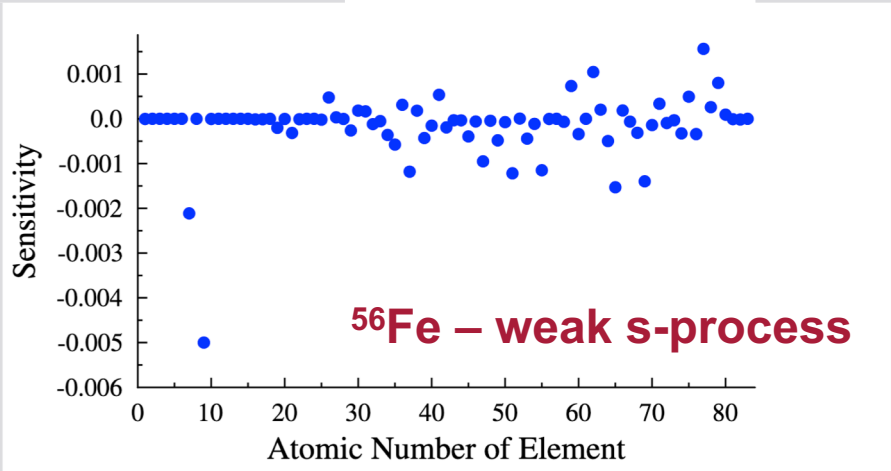
kT (keV)	MACS (mb) +- 1-sigma (abs
1.0	1685.01501 +- 46.4287758
2.0	1224.62439 +- 33.7386627
3.0	1010.85193 +- 27.8469505
4.0	883.429749 +- 24.3342381
5.0	797.205627 +- 21.9574242
6.0	734.009399 +- 20.2155476
7.0	685.101990 +- 18.8677387
8.0	645.722351 +- 17.7823620
9.0	613.065491 +- 16.8822346
10.0	585.366089 +- 16.1189289
11.0	561.436279 +- 15.4595346
12.0	540.456970 +- 14.8814621
13.0	521.841492 +- 14.3685436
14.0	505.157715 +- 13.9088840
15.0	490.070770 +- 13.4930906
16.0	476.334808 +- 13.1145353
17.0	463.760651 +- 12.7681494
18.0	452.183624 +- 12.4493170
19.0	441.471619 +- 12.1542883
20.0	431.521301 +- 11.8802710
21.0	422.247559 +- 11.6249828
22.0	413.564758 +- 11.3858337
23.0	405.417511 +- 11.1614542
24.0	397.753967 +- 10.9504089
25.0	390.529602 +- 10.7515144
26.0	383.700500 +- 10.5634670
465.0	138.351120 +- 3.80848026
466.0	138.282623 +- 3.80659556
467.0	138.214310 +- 3.80471539
468.0	138.146164 +- 3.80284023
469.0	138.078186 +- 3.80096984
470.0	138.010376 +- 3.79910421
471.0	137.942749 +- 3.79724312
472.0	137.875290 +- 3.79538679
473.0	137.807999 +- 3.79353499
474.0	137.740860 +- 3.79168773
475.0	137.673904 +- 3.78984523
476.0	137.607101 +- 3.78800702
477.0	137.540466 +- 3.78617334
478.0	137.473984 +- 3.78434420
479.0	137.407669 +- 3.78251934
480.0	137.341507 +- 3.78069878
481.0	137.275513 +- 3.77888274
482.0	137.209671 +- 3.77707076
483.0	137.143967 +- 3.77526331
484.0	137.078430 +- 3.77345967
485.0	137.013046 +- 3.77166057
486.0	136.947815 +- 3.76986551
487.0	136.882721 +- 3.76807451
488.0	136.817780 +- 3.76628757
489.0	136.752991 +- 3.76450467
490.0	136.688339 +- 3.76272583
491.0	136.623840 +- 3.76095104
492.0	136.559479 +- 3.75918007
493.0	136.495270 +- 3.75741315
494.0	136.431183 +- 3.75565004
495.0	136.367249 +- 3.75389075
496.0	136.303452 +- 3.75213528
497.0	136.239792 +- 3.75038362
498.0	136.176270 +- 3.74863553
499.0	136.112885 +- 3.74689150
500.0	136.049637 +- 3.74515104
500.0	136.049637 +- 3.74515104

NA3/WP8 – Task 8.3 – leader: Tanja Heftrich/Rene Reifarth (GUF, HZDR, TUD, CSIC)

D8.9: Sensitivity library for s-process





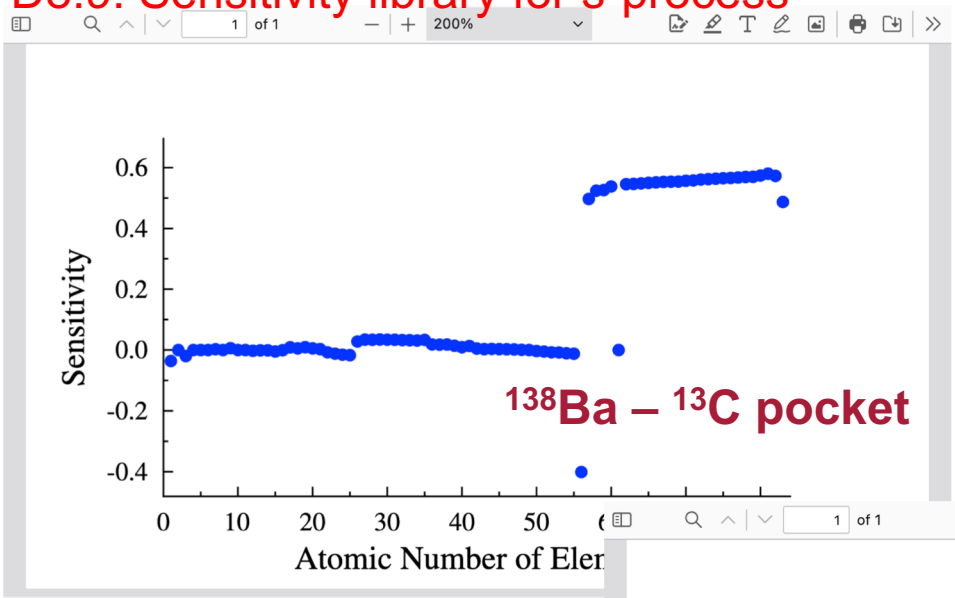


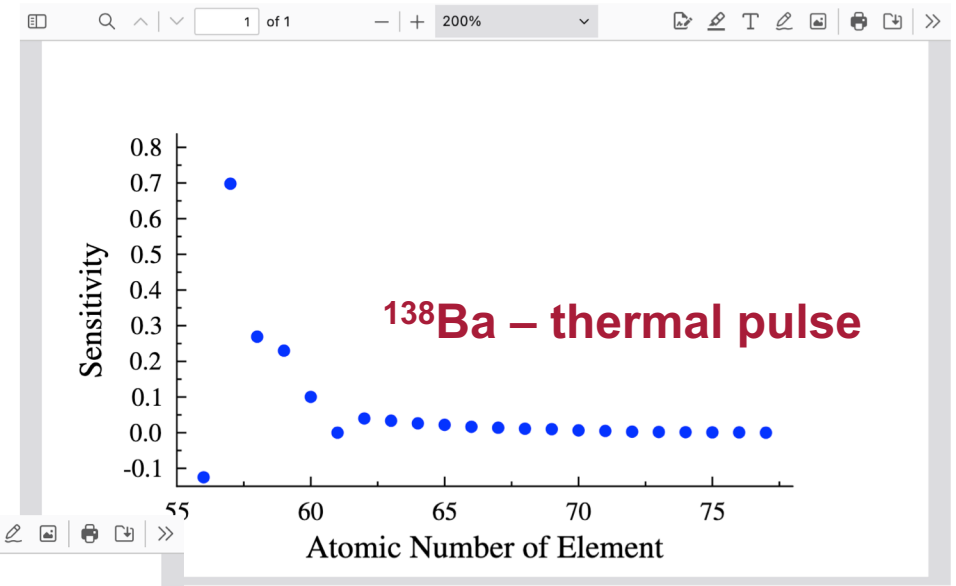
See also connection to WP4 presented by M. Pignatari

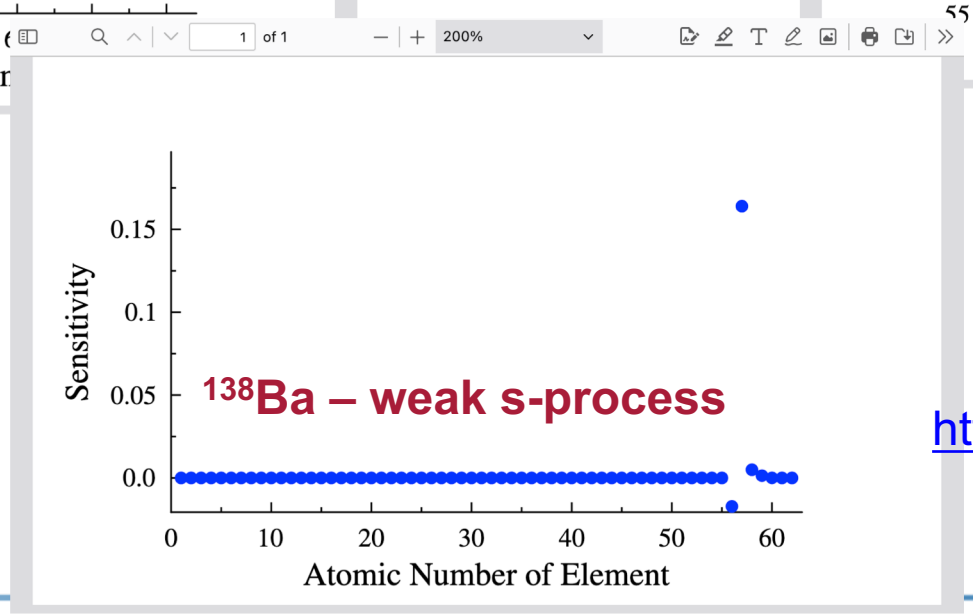
https://exp-astro.de/sensitivities_elements/

NA3/WP8 – Task 8.3 – leader: Tanja Heftrich/Rene Reifarth (GUF, HZDR, TUD, CSIC)

D8.9: Sensitivity library for s-process







See also connection to WP4 presented by M. Pignatari

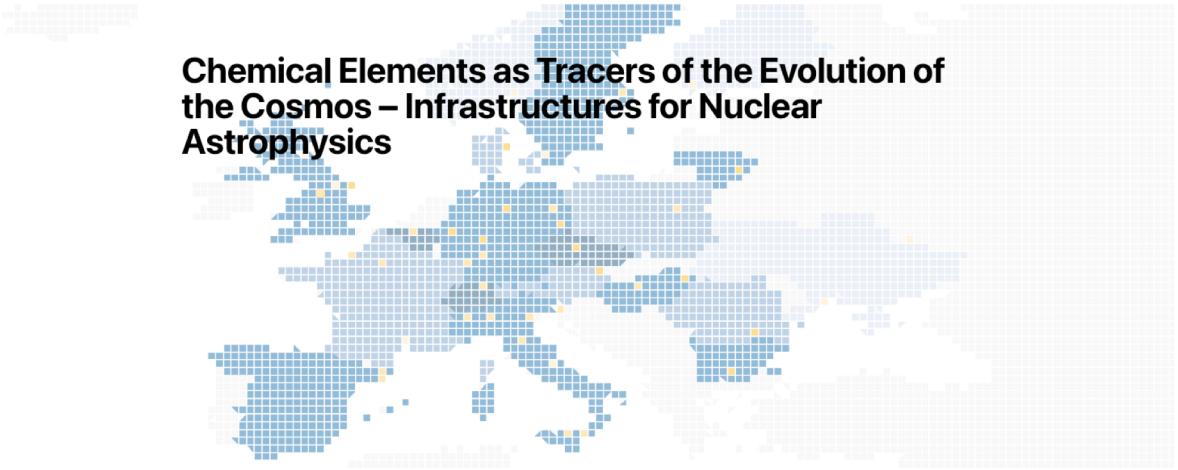
https://exp-astro.de/sensitivities_elements/

NA3/WP8 – Task 8.4 – leader: (Rene Reifarth)/Axel Boeltzig (GUF, HZDR, TUD)

ChETEC-INFRA

About ▾ News ▾ Infrastructures ▾ Institutes Activities ▾ Imprint

ChETEC-INFRA



Nuclear astrophysics studies the origin of the chemical elements: from the Big Bang, to stellar burning, and to neutron star mergers. ChETEC-INFRA networks the three types of infrastructures that, together, provide the capabilities needed for this quest: astronuclear laboratories supply reaction data, supercomputer facilities perform stellar structure and nucleosynthesis computations, and telescopes and mass spectrometers collect elemental and isotopic abundance data. – About ChETEC-INFRA.

NA3/WP8 – Task 8.4 – leader: (Rene Reifarth)/Axel Boeltzig (GUF, HZDR, TUD)

Resources

Available reports:

- Solid Targets for Astrophysics Research – STAR
- Tests of Solid Targets for Astrophysics Research
- Development of a jet-gas target system
- Development of a cell gas target setup
- Materials and Techniques for Neutron Detection
- Extracting two non-routine AMS isotopes
- Stellar Simulations and Resulting Publications
- Model Industry Day
- Stellar evolution simulations and resulting publications

Databases and datasets:

- Barium Star Repository
- Reaction Network Generator – NetGen
- New Generation of Solar Models
- Nuclear Reaction Rates – ChANUREPS
- Stellar Trajectories – ORChESTRA
- s-process Library – ASTRAL
- Solar Fusion Library (Solar Fusion III)
- 3D NLTE Abundance Correction Grid
- Database of stable isotope anomalies in bulk meteoritic materials
- Example database representing nuclear astrophysics models predictions of correlations between stable/stable abundances of specific isotopes

Courses and Tutorials

- Course on Galactical Chemical Evolution Modelling
- Course on Stellar Nucleosynthesis Tools for HPC Clusters
- Multidisciplinary Guide to Astronuclear Science Cases

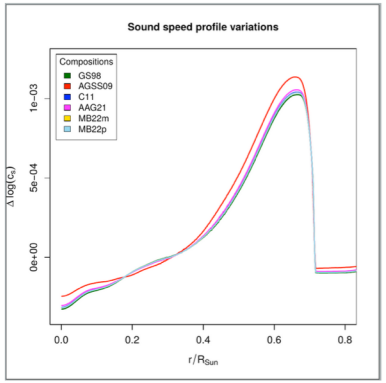
Tools:

- Stellar Analysis Pipeline – webSME
- Stellar Interpretation for Meteoritic data and PLotting – SIMPLE
- Translation of Stellar Yield Predictions for Comparison with the Laboratory Analysis of Meteorites
- Implantation Of Noble Gases In Grains – IONGIG
- Open-source computational tool to calculate the diffusive transport of radioactive nuclei in the interstellar medium (*RadioDiff*)
- Nucleosynthesis Sensitivity Library

Scientific Publications

NA3/WP8 – Task 8.4 – leader: (Rene Reifarth)/Axel Boeltzig (GUF, HZDR, TUD)

New Generation of Solar Models

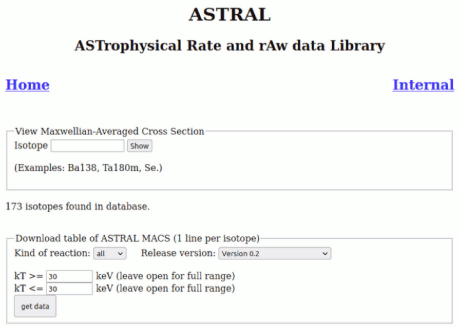


Data from a variety of up-to-date Solar Models is published at

DOI:10.5281/zenodo.10822316

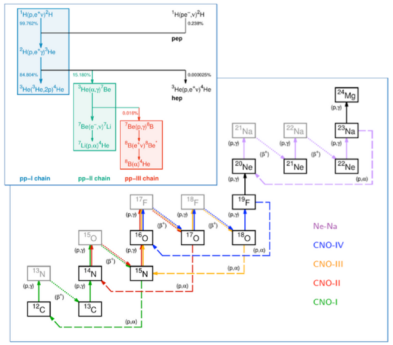
together with a routine to generate variations of them in a Linear Solar Model (LSM) approximation. The provided data includes the solar inner structure for several physical variables and abundances for chemical species of interest, as well as neutrino outflows and distributions from different sources and their correlation matrices.

Maxwellian-Averaged Cross Sections for the s-Process – ASTRAL



ASTRAL, the ASTrophysical Rate and rAw data Library, collects recommended neutron capture cross sections required for s-process nucleosynthesis calculations. As measured data are typically cross section ratios between the isotope under investigation and a reference cross section, ASTRAL does not only store the cross section but also the raw value, allowing to accommodate updates of the reference cross sections.

Solar Fusion Library (Solar Fusion III)



This dataset contains the latest recommendations of astrophysical S-factors for nuclear fusion reactions occurring in hydrogen-burning stars, included in the ***Solar Fusion III*** decadal review article (submitted for publication, e-print available at arXiv:2405.06470).

https://doi.org/10.5281/zenodo.13945119

The data includes S-factors and their derivatives at zero energy (where available). That is, $S(0)$, $S'(0)$, $S''(0)$, in units of MeV·b, b, and b/MeV, respectively. Fractional uncertainties are also provided (marked as *fr_err*). Unavailable data are marked as *NA*

Nuclear Reaction Rates – ChANUREPS

ChANUREPS
ChETEC AstroNUclear REPositorieS

ChANUREPS is a platform where the nuclear-astrophysics community is providing new nuclear reaction rates, and other users can find them easily open source with a simple format. These rates could be used for many research tasks, such as nucleosynthesis calculations, comparison when new rates are becoming available and much more.

NA3/WP8 – Summary

- D8.1: Web page
- D8.2: Data Management Plan
- D8.3: Report to GA on plans for Big-Three meetings
- D8.4: First release of s-process library
- D8.5: Report on expert meeting on shared data formats
- D8.6: Paper on H-burning rates
- D8.7: Paper(s) on methods and results for Big-Three
- D8.8: Release of new generation of standard solar models
- D8.9: First release of sensitivity library for s-process

- D8.10: Report on possible strategy for community wide sharing on raw data

Our thanks go to all the collaborators for their work on this very successful project!