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

TECHNISCHE UNIVERSITÄT DRESDEN

HZDR HELMHOLTZ ZENTRUM DRESDEN ROSSENDORF

Nuclear Data for Astrophysics - ChETEC-INFRA

ChETEC INFRA

IAEA Consultancy Meeting
April 25, 2023

Axel Boeltzig
HZDR Dresden, Germany

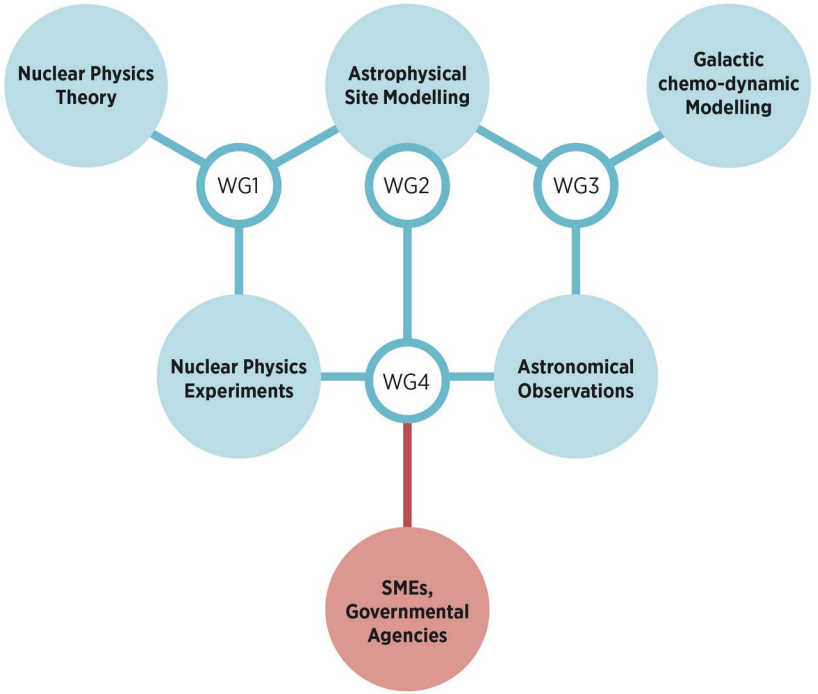
Institute of Radiation Physics · Nuclear Physics Division · Dr. Axel Boeltzig · a.boeltzig@hzdr.de / chetec-infra@hzdr.de · www.hzdr.de

DRESDEN concept

COST action ChETEC [ketek] on Nuclear Astrophysics

Chemical Elements as Tracers of the Evolution of the Cosmos

A network to bring European research, science and business together to further our understanding of the early universe



http://www.chetec.eu
http://nebula.kis.keele.ac.uk:8080/chetec

- ~160 k€/year 2017-2021
- 30 European countries

Chair:

- Raphael Hirschi, Keele/UK

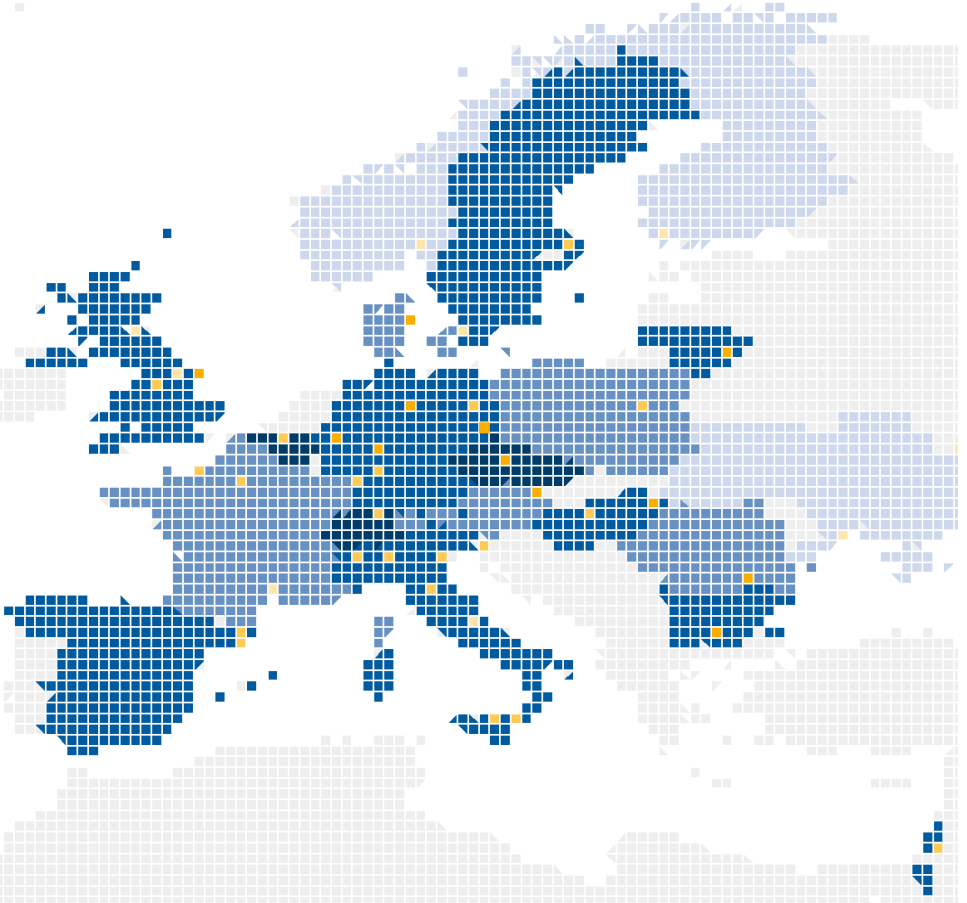
ChETEC-INFRA project for nuclear astrophysics [ketek-infra]

- EU Horizon 2020 **Starting Community** of research infrastructures to serve nuclear astrophysics
- H2020-INFRAIA-2020-1
- **32 partners** in 17 EU+ countries
- 1 May 2021 – 30 April 2025
- 5.0 M€ support by EU
- **13 research infrastructures** offer EU-supported transnational access, selection based on scientific merit


2nd General Assembly (June 2022, Padova)

https://www.chetec-infra.eu

32 partners in ChETEC-INFRA



EU-supported Starting Community of Research Infrastructures for Nuclear Astrophysics

5.0 M€ EU HORIZON2020 support (2021-2025)		
TA Transnational Access	JRA Joint Research Activities	NA Networking Activities
Infrastructure **access** • 8 nuclear laboratories • 4 telescopes • 1 computing cluster	Infrastructure **usability** • Targets • Neutron detectors • Abundance corrections • Analysis pipelines	Infrastructure **networking** • Complementary Experiments • Solar fusion+model • Geochemistry/Astrophysics • Nuclear astrophysics schools • Outreach
32 partners, 17 countries, largest EU project for nuclear astrophysics yet		

WP6 / NA1: “Comprehensive Nuclear Astrophysics”
PI: Jordi José, UPC

WP8 / NA3: “Astronuclear Library”
PI: Aldo Serenelli, ICE-CSIC

Transnational Access to 13 Infrastructures via ChETEC-INFRA

HZDR Felsenkeller underground / DE

HZDR DREAMS AMS / DE

Vienna University VERA AMS / AT

IANAO National Astronomical Observatory / BG

ASU Perek Telescope / CZ

Nordic Optical Telescope La Palma / ES (Arhus / DK)

Frankfurt University van de Graaf n-source / DE

PTB Ion Accelerator Facility / DE

University of Cologne 10 MV Tandem / DE

ATOMKI Cyclotron / HU

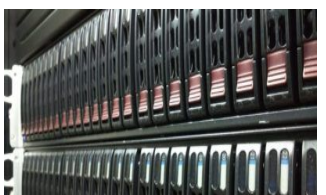
laboratories

supercomputers

telescopes

Vilnius University Moletai Astronomical Observatory / LT

IFIN-HH 3 MV Tandetron accelerator / RO



Hull University VIPER cluster

Nuclear Astrophysics Networks Worldwide

IReNA

IReNA is a National Science Foundation AccelNet Network of Networks

JINA-CEE

EMMI

NUGRID

ChETEC INFRA

IANNA
IBERO AMERICAN NETWORK OF NUCLEAR ASTROPHYSICS

ChETEC Action

UKAKUREN/JaFNA

CaNPAN

BRIDGCE
UK NETWORK

ChETEC INFRA

TECHNISCHE UNIVERSITÄT DRESDEN

DRESDEN concept
SCIENCE AND INNOVATION CAMPUS

HZDR

Nuclear Astrophysics

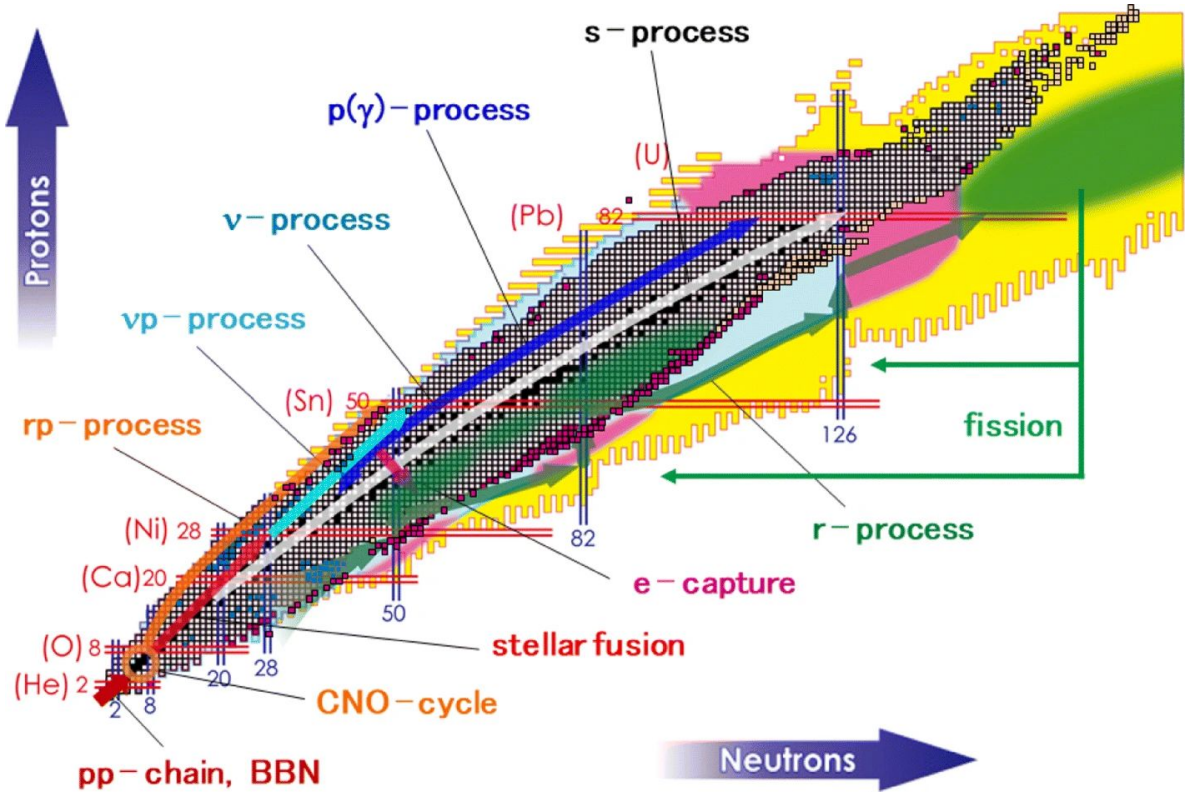
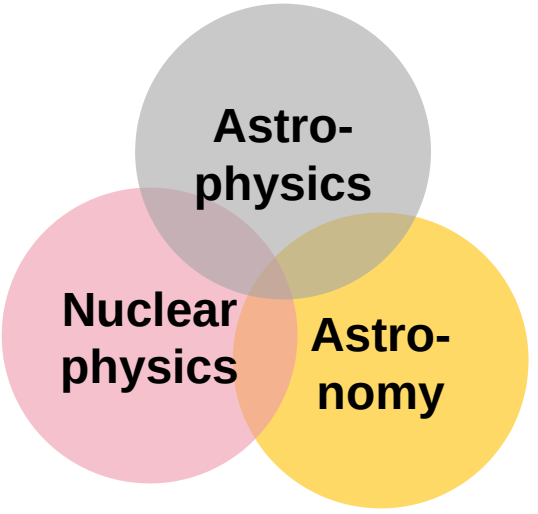
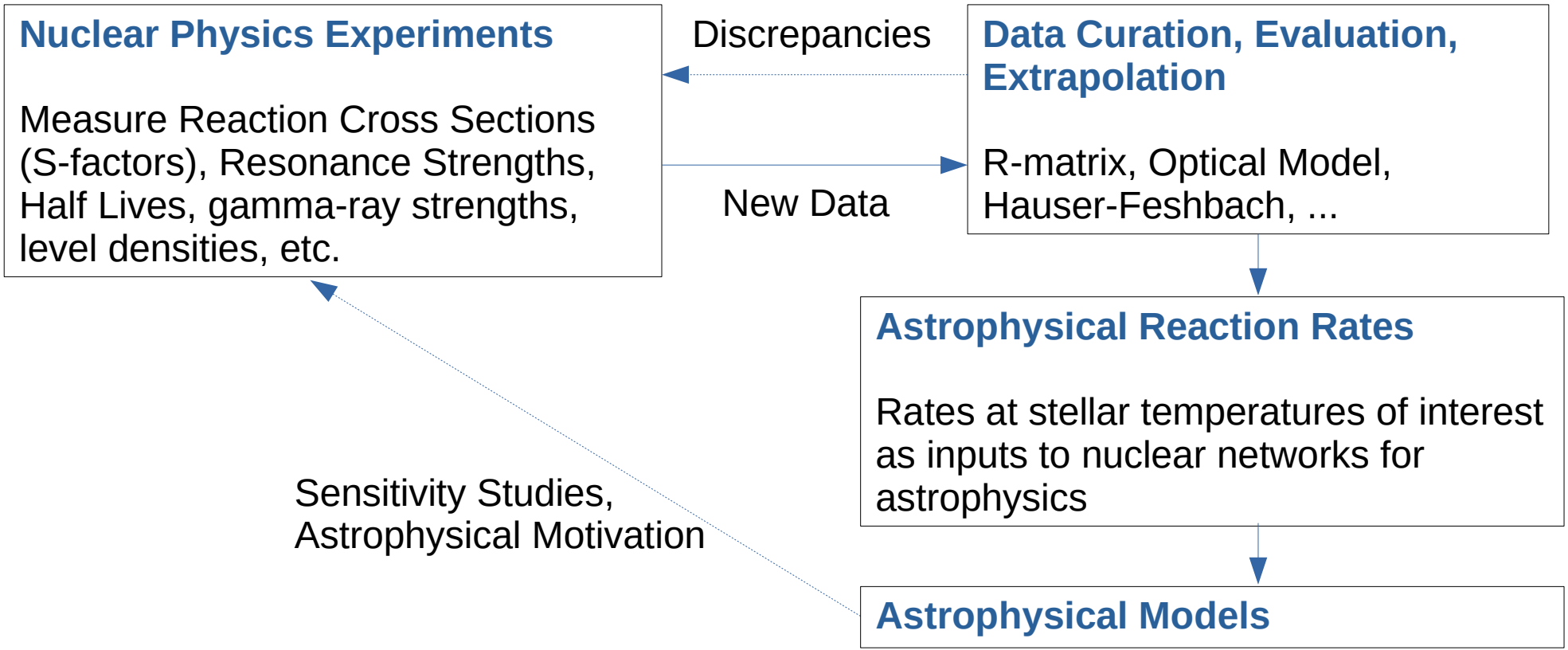


Figure: Aziz et al., 2022 (10.1007/s43673-021-00018-z)

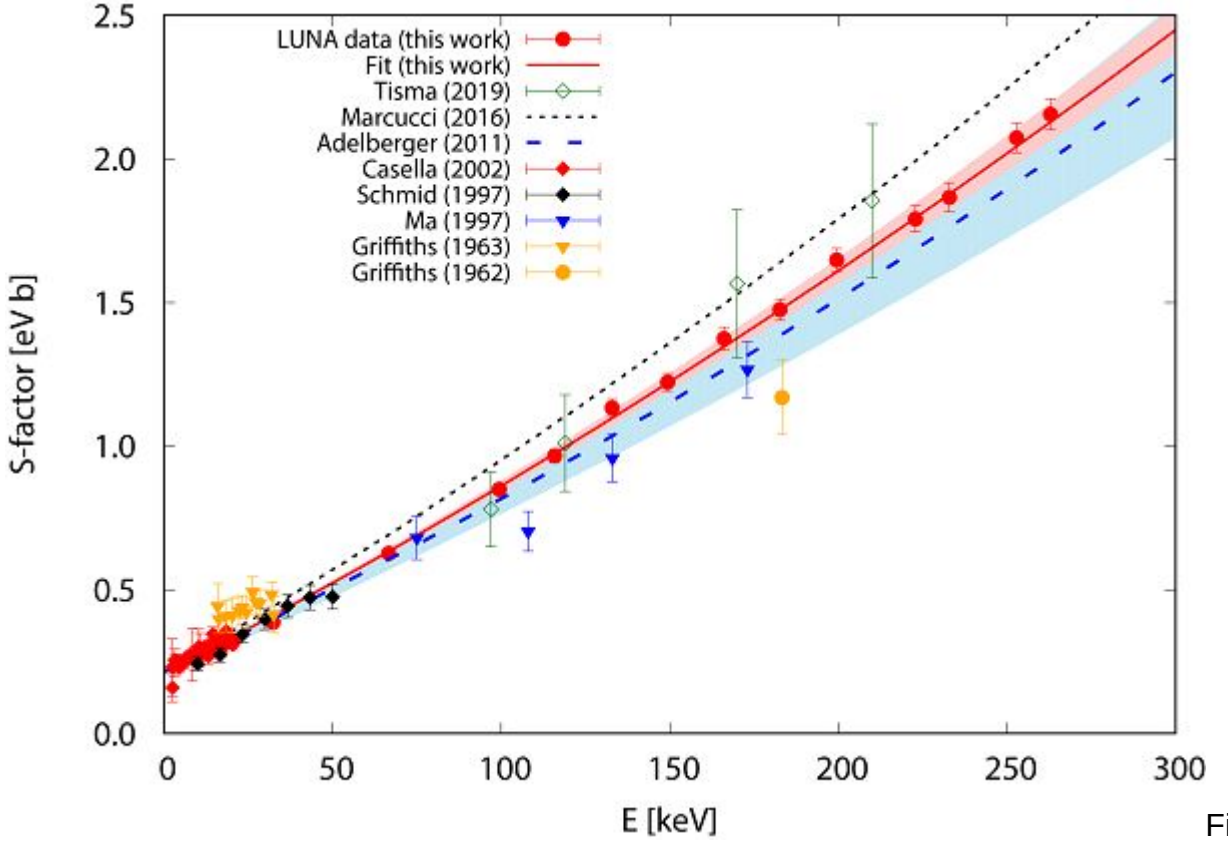


Interdisciplinary field to study the the chemical evolution of the elements in the Universe

Nuclear Astrophysics



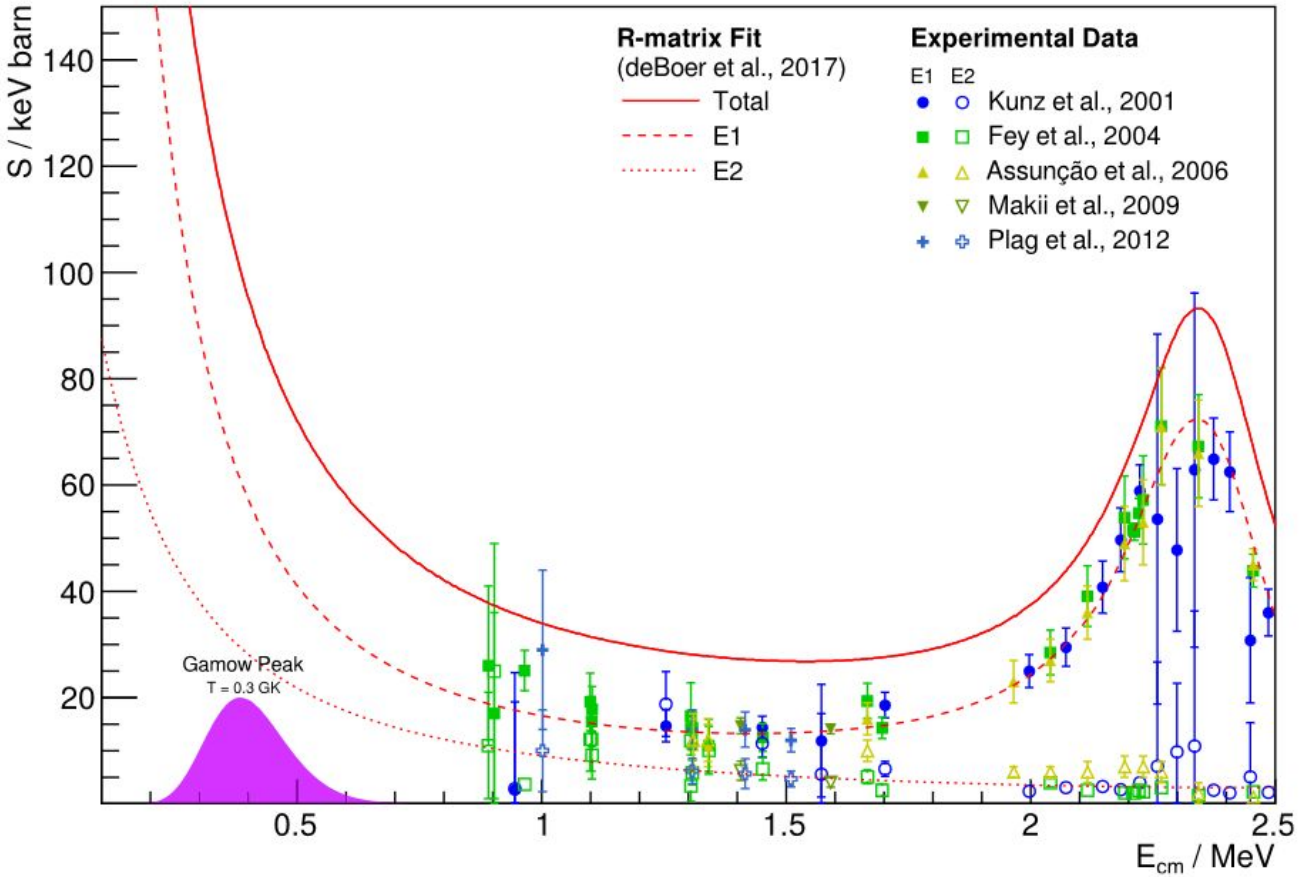
Examples for Data Sets



$^{2}H(p,g)^{3}He$

Figure: Mossa et al., 2020

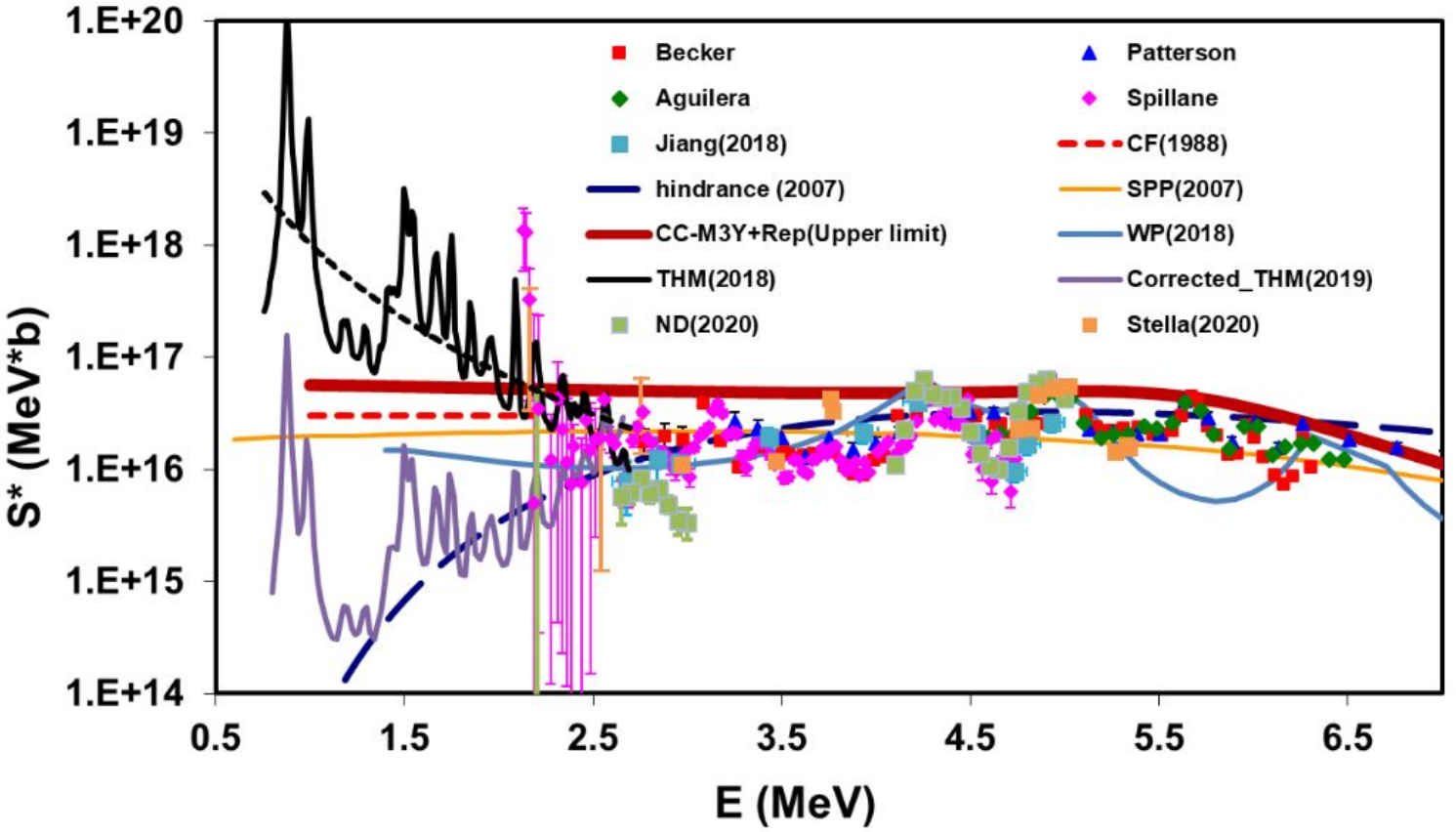
Examples for Data Sets



$^{12}C(a,g)^{16}O$

Figure: Ferraro et al., 2021

Examples for Data Sets



$^{12}C + {}^{12}C$

Figure: Tang et al., 2022

Nuclear Library for Astrophysics Applications

Energy Levels of Light Nuclei, A = 3 - 20

Nuclear Data Evaluation Project
Triangle Universities Nuclear Laboratory

TUNL Nuclear Data Evaluation Home Page

Information on mass chains and nuclides

3	4
5	6
7	8
9	10
11	12
13	14
15	16
17	18
19	20

- Group Info
- Publications
- HTML
- General Tables
- Level Diagrams
- Tables of EL's
- NSR Key# Retrieval
- ENSDF
- Excitation Functions

• TUNL Nuclear Data Group: Who we are and what we do.

Our publications on Energy Levels of Light Nuclei, A = 5 - 20:

• Publications: TUNL evaluations of A = 3 - 20, and modified versions of Fay Ajzenberg-Selove's publications of A = 5 - 20, are available here in PDF format. The most recent HTML documents of A = 3 - 20, and EL diagrams of A = 4 - 20 are also available here. Some reprints and preprints may be requested by mail.

• HTML for Nuclides: HTML documents are available for individual nuclides found within the TUNL or FAS evaluations.

Resources relating to our publications:

• Energy Level Diagrams are available for A = 4 - 20 nuclides.

• Tables of Energy Levels: a brief listing of tables of energy levels from the most recent publication for each nuclide A = 4 - 20.

• SiteMap and Complete List of Available TUNL Documents: Trying to find a specific TUNL evaluation or preliminary report, HTML document, General Table, Update List or Energy Level Diagram? Click here for a complete list of what's available on our website.

Applications and databases relating to the A = 3 - 20 nuclides:

• NSR Key Number Retrieval

• ENSDF: Information for A = 2 - 20 nuclides available through the National Nuclear Data Center (NNDC) site.

• Excitation Functions: Compilation of the excitation functions for various (p, X) and (α, X) reactions.

• Thermal Neutron Capture Data: Summary of level and branching intensity data measured in Thermal Neutron Capture.

• Ground-State Decay Data: Summary of half-life, branching intensity, and mass excess data measured in ground state beta- and charged-particle-decay.

• Half-Lives Table: List table of nuclear decay half-lives.

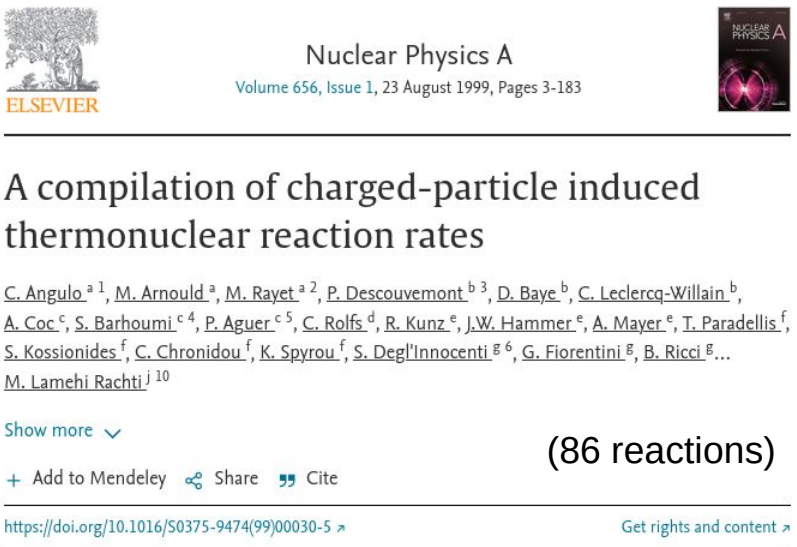
• Live Chart of Nuclides - IAEA: Allows to search and plot nuclear structure and nuclear decay data interactively.

• AME-Viewer: Java utility for interacting and comparing atomic mass data from the Atomic Mass Data Center 2020 mass evaluation.

Helpful links:

https://nucldata.tunl.duke.edu/

Nuclear Astrophysics Compilation of Reaction Rates (NACRE)



ELSEVIER

Nuclear Physics A

Volume 656, Issue 1, 23 August 1999, Pages 3-183

A compilation of charged-particle induced thermonuclear reaction rates

C. Angulo [a 1], M. Arnould [a], M. Rayet [a 2], P. Descouvemont [b 3], D. Baye [b], C. Leclercq-Willain [b], A. Coc [c], S. Barhoumi [c 4], P. Aguer [c 5], C. Rolfs [d], R. Kunz [e], J.W. Hammer [e], A. Mayer [e], T. Paradellis [f], S. Kossionides [f], C. Chronidou [f], K. Spyrou [f], S. Degl'Innocenti [g 6], G. Fiorentini [g], B. Ricci [g]... M. Lamehi Rachti [j 10]

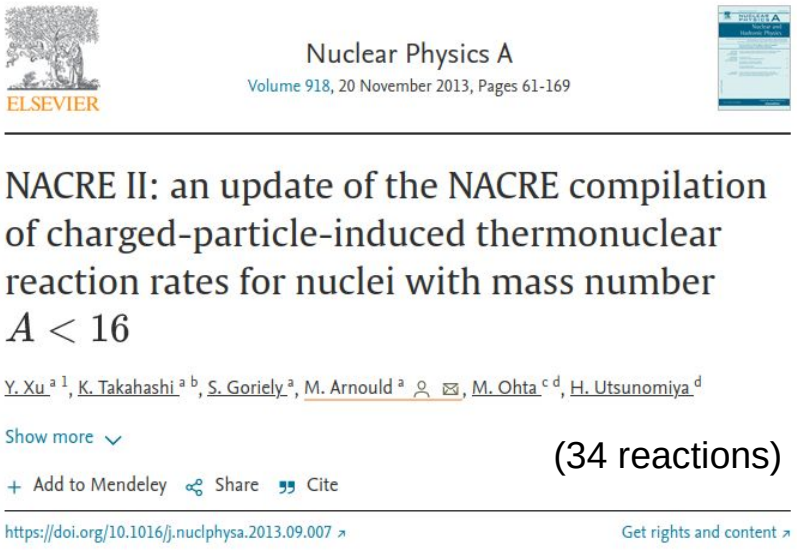
Show more

+ Add to Mendeley Share Cite

(86 reactions)

https://doi.org/10.1016/S0375-9474(99)00030-5

Get rights and content



ELSEVIER

Nuclear Physics A

Volume 918, 20 November 2013, Pages 61-169

NACRE II: an update of the NACRE compilation of charged-particle-induced thermonuclear reaction rates for nuclei with mass number $A < 16$

Y. Xu [a 1], K. Takahashi [a b], S. Goriely [a], M. Arnould [a], M. Ohta [c d], H. Utsunomiya [d]

Show more

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(34 reactions)

https://doi.org/10.1016/j.nuclphysa.2013.09.007

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NACRE (1999) and NACRE II (2013) still widely used as baseline for reaction rates

http://www.astro.ulb.ac.be/nacreii/

BRUSLIB Database for Nuclear Astrophysics Applications

Free Access

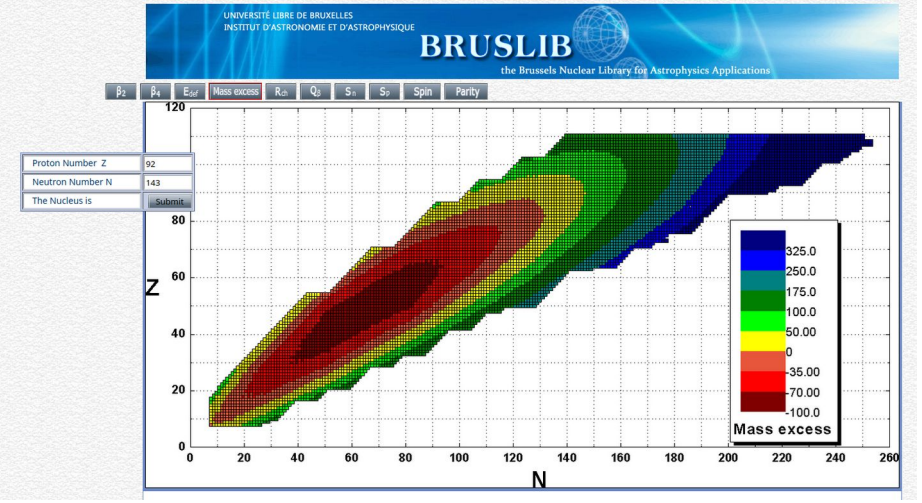
Issue	A&A **Volume** 549, January 2013
Article Number	A106
Number of page(s)	10
Section	Atomic, molecular, and nuclear data
DOI	https://doi.org/10.1051/0004-6361/201220537
Published online	07 January 2013

A&A 549, A106 (2013)

Databases and tools for nuclear astrophysics applications

BRUSsels Nuclear LIBrary (BRUSLIB), Nuclear Astrophysics Compilation of REactions II (NACRE II) and Nuclear NETwork GENerator (NETGEN)

Y. Xu, S. Goriely, A. Jorissen, G. L. Chen and M. Arnould



http://www.astro.ulb.ac.be/bruslib/

Solar Fusion I & II

Solar fusion cross sections

Eric G. Adelberger *et al.*
Rev. Mod. Phys. **70**, 1265 – Published 1 October 1998

Article | References | Citing Articles (501) | PDF | Export Citation

ABSTRACT

We review and analyze the available information on the nuclear-fusion cross sections that are most important for solar energy generation and solar neutrino production. We provide best values for the low-energy cross-section factors and, wherever possible, estimates of the uncertainties. We also describe the most important experiments and calculations that are required in order to improve our knowledge of solar fusion rates.

DOI: https://doi.org/10.1103/RevModPhys.70.1265

Solar Fusion (1998)

Community-led evaluations, resulting in evaluated reaction rates

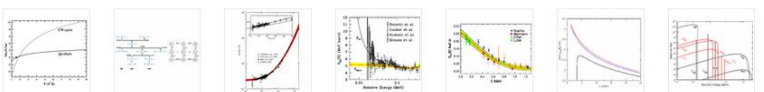
Solar fusion cross sections. II. The *pp* chain and CNO cycles

E. G. Adelberger *et al.*
Rev. Mod. Phys. **83**, 195 – Published 12 April 2011

Article | References | Citing Articles (515) | PDF | HTML | Export Citation

ABSTRACT

The available data on nuclear fusion cross sections important to energy generation in the Sun and other hydrogen-burning stars and to solar neutrino production are summarized and critically evaluated. Recommended values and uncertainties are provided for key cross sections, and a recommended spectrum is given for ^{8}B solar neutrinos. Opportunities for further increasing the precision of key rates are also discussed, including new facilities, new experimental techniques, and improvements in theory. This review, which summarizes the conclusions of a workshop held at the Institute for Nuclear Theory, Seattle, in January 2009, is intended as a 10-year update and supplement to 1998, Rev. Mod. Phys. **70**, 1265.



13 More
Received 21 April 2010

DOI: https://doi.org/10.1103/RevModPhys.83.195

Solar Fusion II (2011)

Solar Fusion III

Solar Fusion Cross Sections III (INT-22-82W)

26-29 July 2022
David Brower Center and UC Berkeley, Berkeley, CA, USA
US/Pacific timezone

* WG1 - S_{11} [^{1}H(p, e^{+} ν)^{2}H] and theory, extrapolations, radiative corrections, electron capture, neutrino spectra

Conveners: L. Marcucci (Univ. Pisa), J.-W. Chen (Natl. Univ. Taiwan)

* WG2 - Solar neutrino observations, helioseismology, asteroseismology

Conveners: F. Villante (Univ. L'Aquila), A. Serenelli (ICE), H. Robertson (Univ. Washington)

* WG3 - S_{114} [^{14}N(p, γ)^{15}O]

Conveners: R. James deBoer (Notre Dame U.), Tamás Szücs (ATOMKI)

* WG4 - S_{12} [^{2}H(p, γ)^{3}He]

Conveners: F. Cavanna (INFN Torino)

* WG5 - S_{17} [^{7}Be(p, γ)^{8}B]

Conveners: L. Gialanella (Univ. Studi Campania)

* WG6 - S_{112} [^{12}C(p, γ)^{13}N], other CNO, NeNa

Conveners: R. Depalo (Univ. Milano), Ch. Iliadis (Univ. North Carolina)

* WG7 - S_{34} [^{3}He(^{4}He, γ)^{7}Be] and S_{33} [^{3}He(^{3}He, 2p)^{4}He]

Conveners: D. Bemmerer (HZDR), K. Nollett (San Diego State)

* WG8 - New facilities: LUNA-MV, JUNA, NIF, etc

Conveners: M. Aliotta (Univ. Edinburgh), A. Tumino (Enna Univ.), M. Wiescher (Notre Dame Univ.)

* WG9 - Opacity, screening

Conveners: T. Nagayama (Sandia), J. Colgan (Los Alamos), B. Balantekin (UW-Madison)

STARLIB: Thermonuclear Rate Library

THE ASTROPHYSICAL JOURNAL
SUPPLEMENT SERIES

ARTICLES

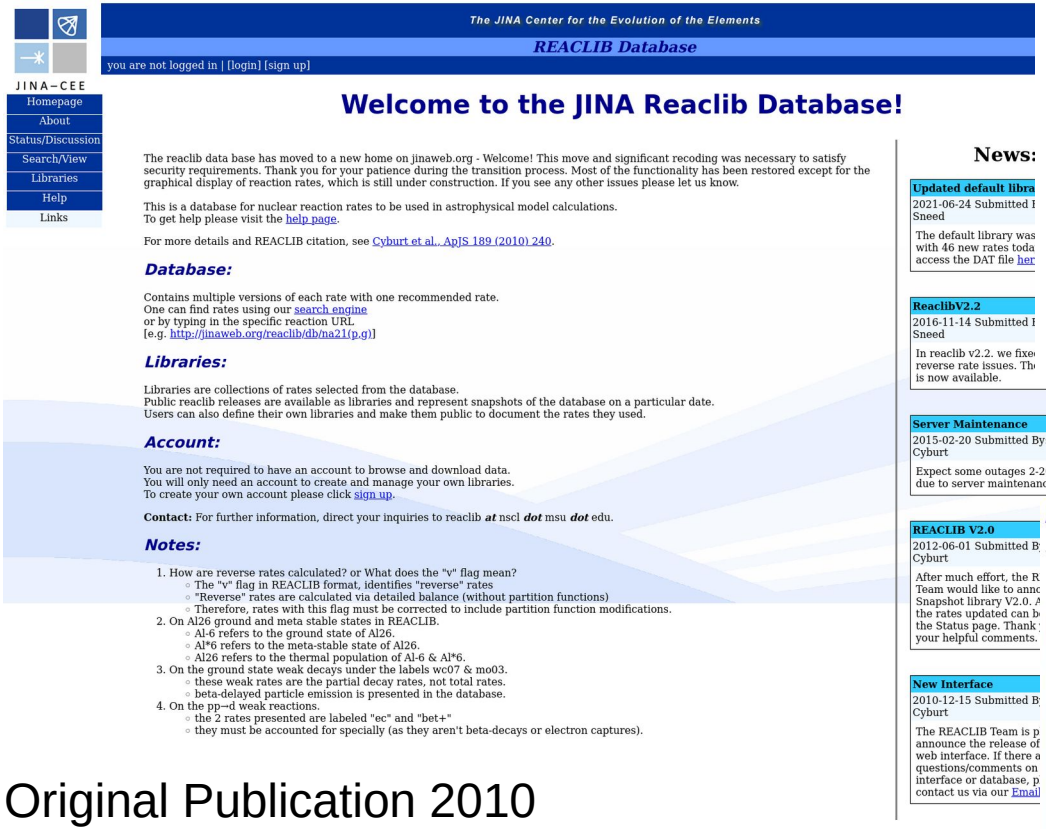
STARLIB: A NEXT-GENERATION REACTION-RATE LIBRARY FOR NUCLEAR ASTROPHYSICS

A. L. Sallaska[1], C. Iliadis[2,3], A. E. Champange[2,3], S. Goriely[4], S. Starrfield[5], and F. X. Timmes[5]

Published 2013 July 2 • © 2013. The American Astronomical Society. All rights reserved.
The Astrophysical Journal Supplement Series, Volume 207, Number 1
Citation A. L. Sallaska *et al* 2013 *ApJS* **207** 18
DOI 10.1088/0067-0049/207/1/18

https://starlib.github.io/Rate-Library/
https://github.com/Starlib/Rate-Library

JINA ReacLib



The JINA Center for the Evolution of the Elements

REACLIB Database

you are not logged in | [login] [sign up]

JINA–CEE

Homepage | About | Status/Discussion | Search/View | Libraries | Help | Links

Welcome to the JINA Reaclib Database!

The reaclib data base has moved to a new home on jinaweb.org - Welcome! This move and significant recoding was necessary to satisfy security requirements. Thank you for your patience during the transition process. Most of the functionality has been restored except for the graphical display of reaction rates, which is still under construction. If you see any other issues please let us know.

This is a database for nuclear reaction rates to be used in astrophysical model calculations.
To get help please visit the help page.

For more details and REACLIB citation, see Cyburt et al,. ApJS 189 (2010) 240.

Database:

Contains multiple versions of each rate with one recommended rate.
One can find rates using our search engine
or by typing in the specific reaction URL
[e.g. http://jinaweb.org/reaclib/db/na21(p,g)]

Libraries:

Libraries are collections of rates selected from the database.
Public reaclib releases are available as libraries and represent snapshots of the database on a particular date.
Users can also define their own libraries and make them public to document the rates they used.

Account:

You are not required to have an account to browse and download data.
You will only need an account to create and manage your own libraries.
To create your own account please click sign up.

Contact: For further information, direct your inquiries to reaclib *at* nscl *dot* msu *dot* edu.

Notes:

1. How are reverse rates calculated? or What does the "v" flag mean?
   - The "v" flag in REACLIB format, identifies "reverse" rates
   - "Reverse" rates are calculated via detailed balance (without partition functions)
   - Therefore, rates with this flag must be corrected to include partition function modifications.
2. On Al26 ground and meta stable states in REACLIB.
   - Al-6 refers to the ground state of Al26.
   - Al*6 refers to the meta-stable state of Al26.
   - Al26 refers to the thermal population of Al-6 & Al*6.
3. On the ground state weak decays under the labels wc07 & mo03.
   - these weak rates are the partial decay rates, not total rates.
   - beta-delayed particle emission is presented in the database.
4. On the pp→d weak reactions.
   - the 2 rates presented are labeled "ec" and "bet+"
   - they must be accounted for specially (as they aren't beta-decays or electron captures).

News:

Updated default libra
2021-06-24 Submitted
Sneed
The default library was
with 46 new rates toda
access the DAT file her

ReaclibV2.2
2016-11-14 Submitted
Sneed
In reaclib v2.2. we fixe
reverse rate issues. Th
is now available.

Server Maintenance
2015-02-20 Submitted By: Richard Cyburt
Expect some outages 2-20-2015 due to server maintenance.

REACLIB V2.0
2012-06-01 Submitted B
Cyburt
After much effort, the R
Team would like to annc
Snapshot library V2.0. A
the rates updated can b
the Status page. Thank
your helpful comments.

New Interface
2010-12-15 Submitted B
Cyburt
The REACLIB Team is p
announce the release of
web interface. If there a
questions/comments on
interface or database, p
contact us via our Email

THE ASTROPHYSICAL JOURNAL
SUPPLEMENT SERIES

THE JINA REACLIB DATABASE: ITS RECENT UPDATES AND IMPACT ON TYPE-I X-RAY BURSTS

Richard H. Cyburt[9,1,2], A. Matthew Amthor[1,2,3], Ryan Ferguson[1,2,3], Zach Meisel[1,2,3], Karl Smith[1,2,3], Scott Warren[1,2,4], Alexander Heger[1,5], R. D. Hoffman[6], Thomas Rauscher[7], Alexander Sakharuk[1,2] + Show full author list

Published 2010 June 30 • © 2010. The American Astronomical Society. All rights reserved.
The Astrophysical Journal Supplement Series, Volume 189, Number 1
Citation Richard H. Cyburt *et al* 2010 *ApJS* **189** 240
DOI 10.1088/0067-0049/189/1/240

ReaclibV0.5

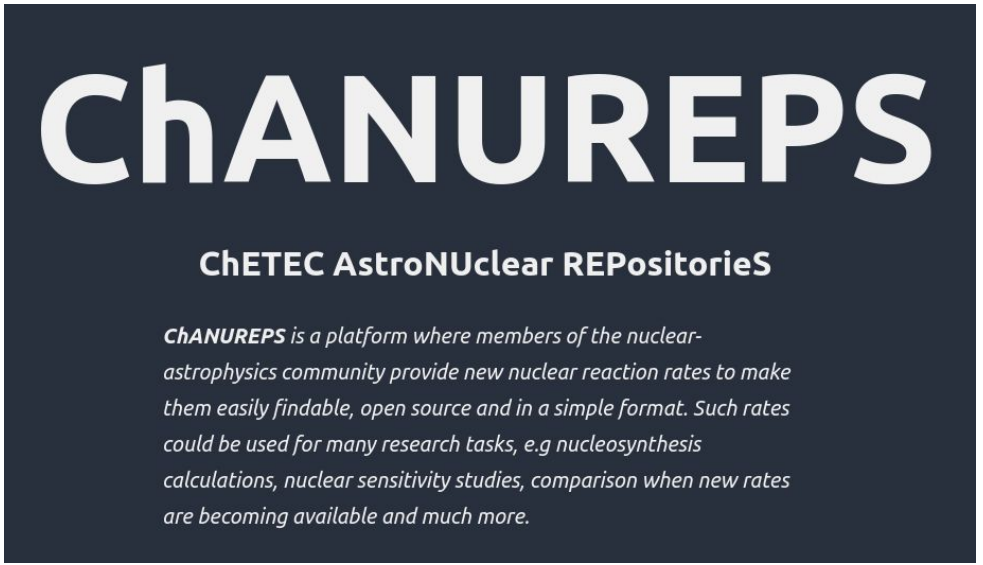
Viewing rates **1-50** *of* **76064**

Page **1** *of* **1522.** 1 2 3 4 5 6 7 ... 1522

Chap	Reaction	Type	Label	Modified	Last Change	Ver	Comments
1	n -> p	exp	wc07	2010-06-11 15:14:12	script	1	Added with weakrates.pl
1	t -> he3	exp	wc07	2010-06-11 15:14:12	script	1	Added with weakrates.pl
1	he3 -> t	exp	ec	2010-06-11 15:14:12	script	1	Updated Q value
1	he6 -> li6	exp	wc07	2010-06-11 15:14:12	script	1	Added with weakrates.pl
1	he8 -> li8	exp	wc07	2010-06-11 15:14:12	script	1	Added with weakrates.pl
1	li9 -> be9	exp	wc07	2010-06-11 15:14:12	script	1	Added with weakrates.pl
1	li11 -> be11	exp	wc07	2010-06-11 15:14:12	script	1	Added with weakrates.pl
1	be7 -> li7	exp	ec	2010-06-11 15:14:12	cyburt	2	

Original Publication 2010
Updates 2016, 2021

ChANUREPS



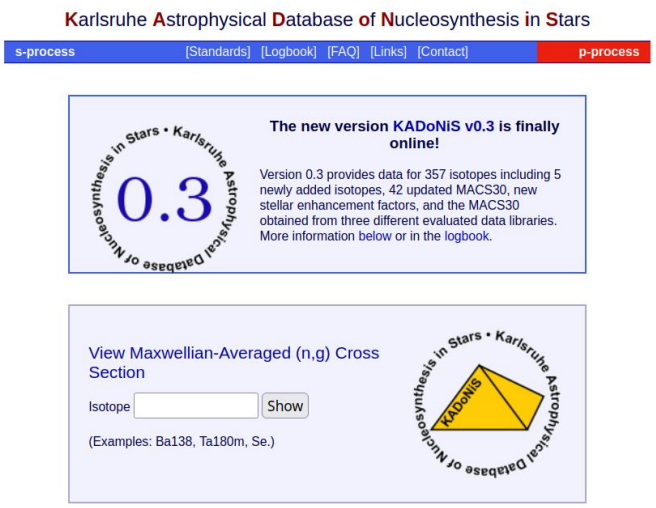
http://chanureps.chetec-infra.eu

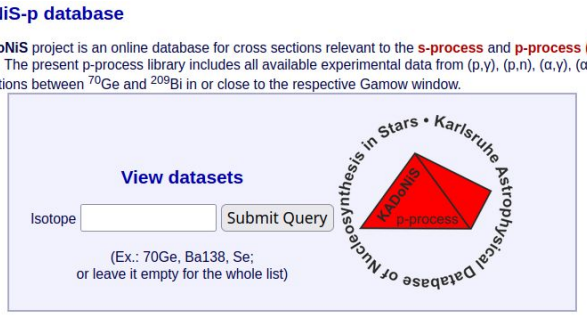
Collection of reaction rates provided by the community.

No evaluated “best” rate, rather “pick & choose”.

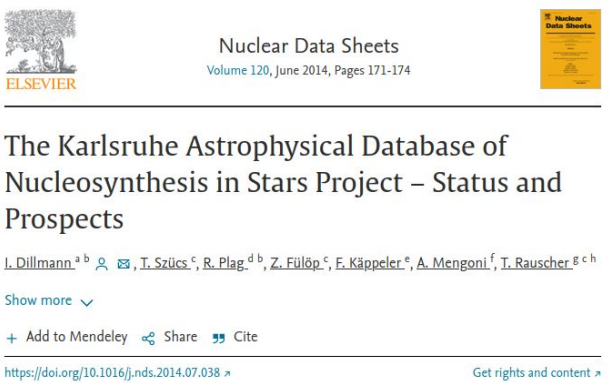
Recently launched and growing (~20 rates).

Neutron-Induced Reactions: MACS – KaDONIS

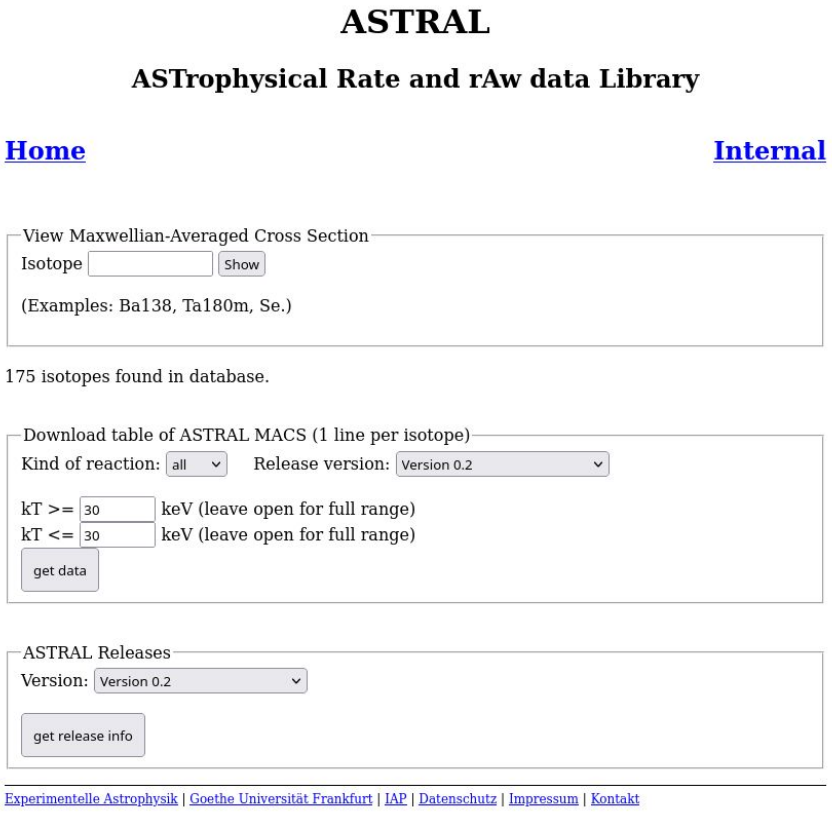




https://www.kadonis.org



Neutron-Induced Reactions: MACS – ASTRAL



Open Access

Issue	EPJ Web Conf. **Volume** 279, 2023 Nuclear Physics in Astrophysics – X (NPA-X 2022)
Article Number	11011
Number of page(s)	5
Section	Nuclear Reactions
DOI	https://doi.org/10.1051/epjconf/202327911011
Published online	22 March 2023

EPJ Web of Conferences **279**, 11011 (2023)
https://doi.org/10.1051/epjconf/202327911011

The ASTRAL database for neutron-capture nucleosynthesis studies

Diego Vescovi*, **René Reifarth, Enis Lorenz and Andreas Elbe**

Goethe University Frankfurt, Max-von-Laue-Strasse 1, Frankfurt am Main 60438, Germany

http://astral.chetec-infra.eu

Summary / Conclusions

Nuclear astrophysics relies on nuclear input for modeling of the galactic chemical evolution - crucially **reaction cross sections** to calculate reaction rates.

Measured reaction cross section data typically need to be **compiled, evaluated, and often extrapolated** to provide the necessary reaction rates.

Evaluation and extrapolation requires modeling, hence **nuclear input parameters**.

Mix of established (literature) compilations and newer (online) databases, between stable references and quick incorporation of new experimental results.
– Require **continuous efforts**, to provide up-to-date data to the community.

Periodic efforts for reaction rate evaluations from **within the nuclear astrophysics community**, supported by different institutions / projects.

Open data in nuclear experiments still in early phase, but could help to investigate / reconcile contradicting data sets found in evaluations.