Recent Activities & Initiatives in the ORNL Nuclear Data Program – USNDP 2014

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NUCLEAR DATA ACTIVITIES

Nuclear Structure Data

(C. Nesaraja, M. Martin, C. Smith)

- A-chain Evaluations
- XUNDL compilations

Nuclear Astrophysics Data

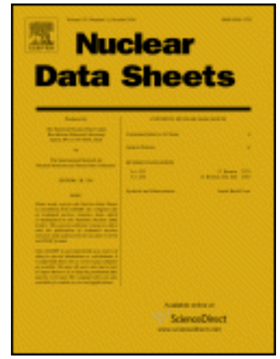
(M. Smith, C. Smith, S. Zhang)

- Assessments of reactions & structure critical for stellar explosion studies
- Determination of thermonuclear reaction rates from USNDP or other nuclear data sets
- Calculation of rates with theoretical models

Online Software Systems

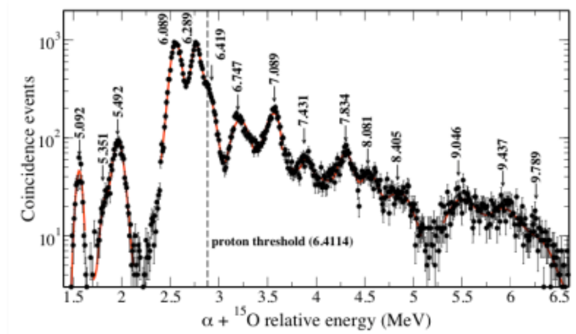
(M. Smith, E. Lingerfelt, C. Smith)

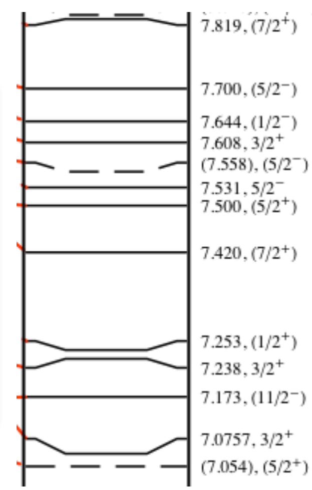
- Recent enhancements to nucastrodata.org and the Computational Infrastructure for Nuclear Astrophysics (CINA)
- Recent enhancements to nuclearmasses.org and the Nuclear Masses Toolkit (NMT)

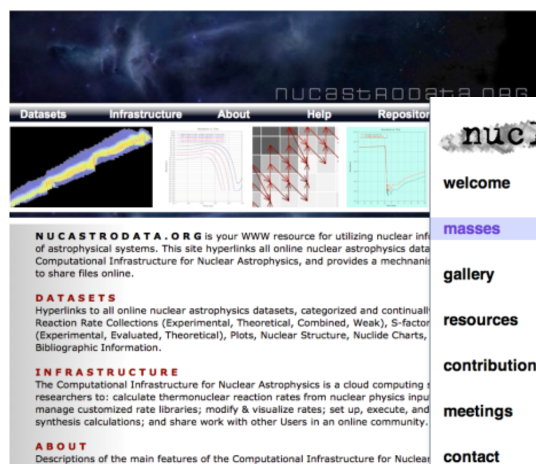


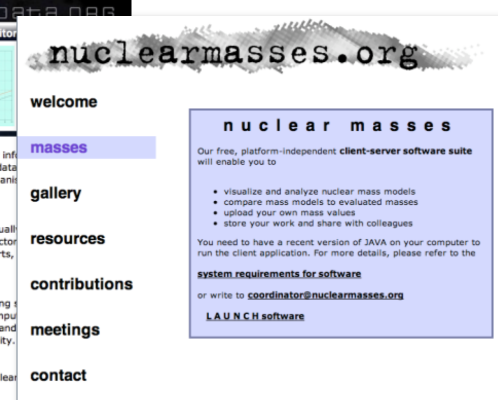
NNDC

Evaluated Nuclear Structure Data File (ENSDF)









NUCLEAR STRUCTURE DATA

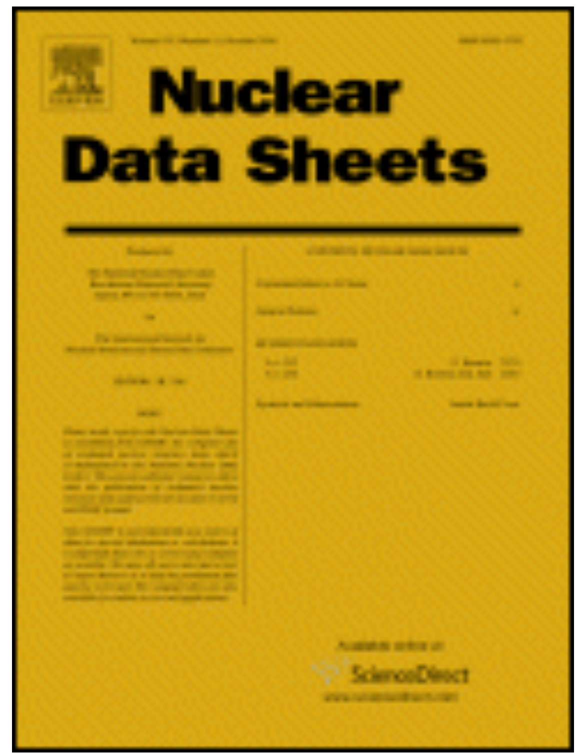
Responsibility:
Actinide Evaluations **A=241 – 249** or others requested from NNDC

Activities:

1. ENSDF – Finalized Mass Chain Evaluation

   A=248 (M. Martin) – 8 nuclides, 22 datasets

   A=241 (C. Nesaraja) – 8 nuclides, 28 datasets



2. ENSDF – Reviewed Mass Chain Evaluation

   A=209 (M. Martin)

NUCLEAR STRUCTURE DATA

Activities (continued):

3. XUNDL Compilations

C. Nesaraja (1 October 2013 – 19 August 2014) 24 datasets:

* Co-compiled with B. Singh

*154Ho: 141Pr(16O,3n)154Ho	*84Ge: 84Ga β decay	*83Ge: 84Ga β-n decay
*123Cs: 96Zr(32S,Xγ)	*124Ba: 96Zr(32S,Xγ)	*146Eu:146Gd EC decay
*44Ti: 40Ca(α,γ)44Ti	*142Sm: 116Cd(31P,p4n)	*26Mg: 18O(13C,αnγ)
*208Pb:208Pb(p,p’)	*208Pb:207Pb(d,p)	254Md: 258Lr α decay
258No: 258Lr e decay	258Lr: 262Db α decay	262Db: 248Cm(19F, 5n)
*238U: 238U(n,nγ’)	133Sn:9Be(132Sn,8Be)	209Pb:9Be(208Pb,8Be)
131Sn:9Be(132Sn,10Be)	177Hf:Ta(p,Xγ)	180Hf:Ta(p,X)
23Mg:1H(22Na,p)Res	97Rb:241Pu(n,Fγ)	*97Sr: 97Sr IT decay

C. Nesaraja & C. Smith (19 August 2014 – 30 September 2014) 6 datasets:

199At: 165Ho(40Ar,6n) (2014AuAA)	201At: 165Ho(40Ar,4n) (2014AuAA)
78Kr: Coulomb Excitation (2014KU10)	86Kr: Coulomb Excitation (2014KU10)
82SR: 12C(78Kr,2$\alpha\gamma$) (2014KU10)	90SR: 12C(86Kr,2$\alpha\gamma$) (2014KU10)

NUCLEAR STRUCTURE DATA

Future Activities

ESNDF

A=41 mass chain evaluation Caroline Nesaraja with Libby McCutchan (NNDC)

A=242 mass chain evaluation by Murray Martin

XUNDL

Compile / process 1 paper / week – Caroline Nesaraja, Chris Smith

Experimental Work

Collaboration with NNDC

- Cross section measurements of Pt irradiated samples (NNDC-BLIP)
- Gamma ray measurements of PET imaging radionuclides using Gammasphere (NNDC-BLIP)

Possible Collaboration with K. Rykaczewski (ORNL)

- Total absorption spectrometry measurements with the MTAS system

NUCLEAR ASTROPHYSICS DATA

Processing data sets for use in astrophysical models

- improve techniques
- process recent published data sets

Available online at www.sciencedirect.com

ScienceDirect

ELSEVIER

Nuclear Physics A 841 (2010) 31–250

NUCLEAR PHYSICS A

www.elsevier.com/locate/nuclphysa

Charged-particle thermonuclear reaction rates: II. Tables and graphs of reaction rates and probability density functions

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Available online 28 April 2010

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

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Abstract

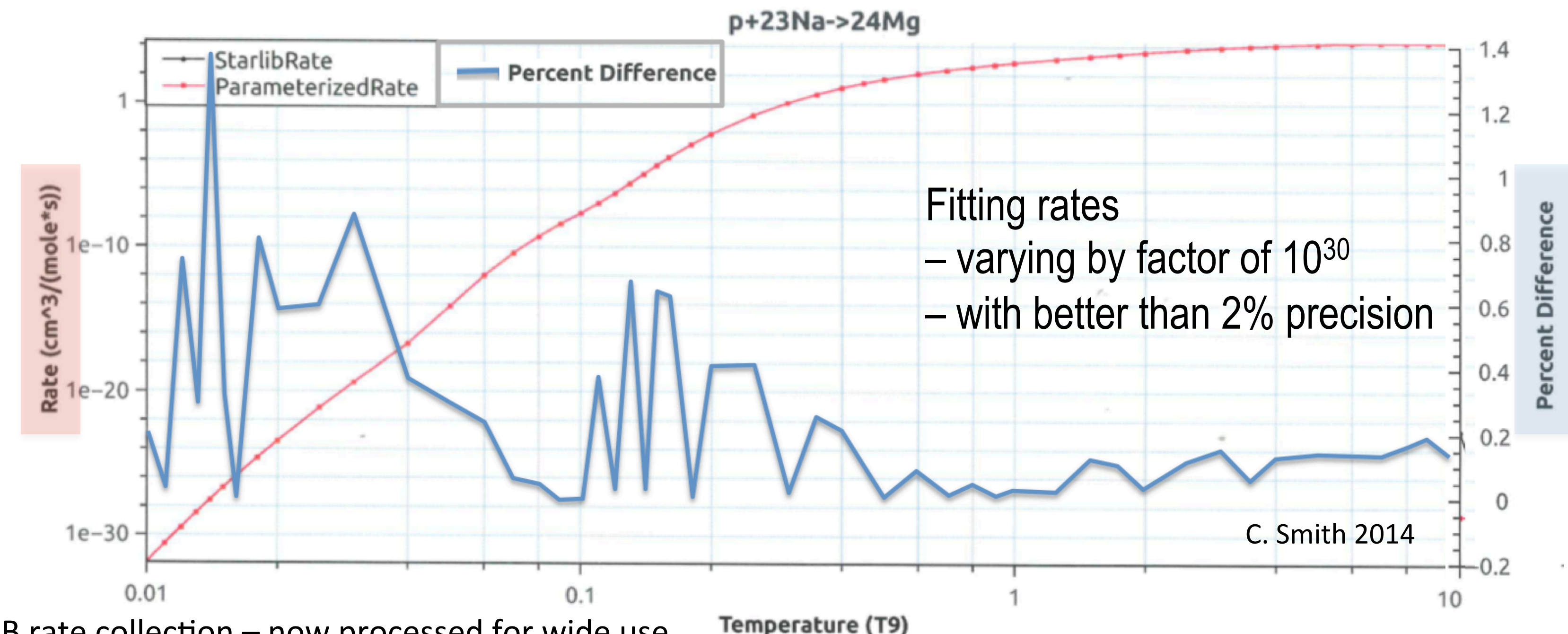
An update of the NACRE compilation [Angulo et al., Nucl. Phys. A 656 (1999) 3] is presented. This new compilation, referred to as NACRE II, reports thermonuclear reaction rates for 34 charged-particle induced, two-body exoergic reactions on nuclides with mass number $A < 16$, of which fifteen are particle-transfer reactions and the rest radiative capture reactions. When compared with NACRE, NACRE II features in particular (1) the addition to the experimental data collected in NACRE of those reported later, preferentially in the major journals of the field by early 2013, and (2) the adoption of potential models as the primary tool for extrapolation to very low energies of astrophysical S-factors, with a systematic evaluation of uncertainties.

As in NACRE, the rates are presented in tabular form for temperatures in the $10^6 \lesssim T \leq 10^{10}$ K range. Along with the 'adopted' rates, their low and high limits are provided. The new rates are available in electronic form as part of the Brussels Library (BRUSLIB) of nuclear data. The NACRE II rates also supersede the previous NACRE rates in the Nuclear Network Generator (NETGEN) for astrophysics. [http://www.astro.ulb.ac.be/databases.html.]

Keywords: thermonuclear reaction rates, nuclear astrophysics, potential model, dwba model

NUCLEAR ASTROPHYSICS DATA

Processing data sets for use in astrophysical models



STARLIB rate collection – now processed for wide use

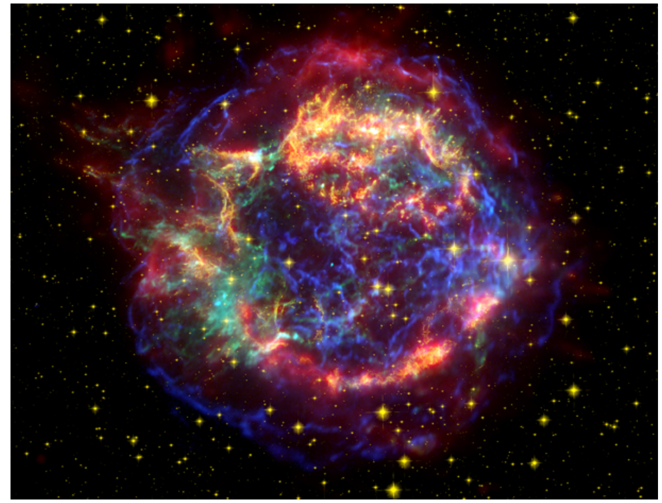
^{14}C(p, γ)^{15}N	^{18}O(α, γ)^{22}Ne	^{21}Na(p, γ)^{22}Mg	^{26}Mg(p, γ)^{27}Al	^{30}Si(p, γ)^{31}P	^{35}Cl(p, α)^{32}S
^{14}C(α, γ)^{18}O	^{17}F(p, γ)^{18}Ne	^{22}Na(p, γ)^{23}Mg	^{23}Al(p, γ)^{24}Si	^{27}P(p, γ)^{28}S	^{34}Ar(p, γ)^{35}K
^{14}N(α, γ)^{18}F	^{18}F(p, γ)^{19}Ne	^{23}Na(p, γ)^{24}Mg	^{24}Al(p, γ)^{25}Si	^{29}P(p, γ)^{30}S	^{35}Ar(p, γ)^{36}K
^{15}N(α, γ)^{19}F	^{18}F(p, α)^{15}O	^{23}Na(p, α)^{20}Ne	^{25}Al(p, γ)^{26}Si	^{31}P(p, γ)^{32}S	^{36}Ar(p, γ)^{37}K
^{15}O(α, γ)^{19}Ne	^{19}Ne(p, γ)^{20}Na	^{22}Mg(p, γ)^{23}Al	^{26}Al^{g}(p, γ)^{27}Si	^{31}P(p, α)^{28}Si	^{35}K(p, γ)^{36}Ca
^{16}O(p, γ)^{17}F	^{20}Ne(p, γ)^{21}Na	^{23}Mg(p, γ)^{24}Al	^{27}Al(p, γ)^{28}Si	^{30}S(p, γ)^{31}Cl	^{39}Ca(p, γ)^{40}Sc
^{16}O(α, γ)^{20}Ne	^{20}Ne(α, γ)^{24}Mg	^{24}Mg(p, γ)^{25}Al	^{27}Al(p, α)^{24}Mg	^{31}S(p, γ)^{32}Cl	^{40}Ca(p, γ)^{41}Sc
^{17}O(p, γ)^{18}F	^{21}Ne(p, γ)^{22}Na	^{24}Mg(α, γ)^{28}Si	^{26}Si(p, γ)^{27}P	^{32}S(p, γ)^{33}Cl	
^{17}O(p, α)^{14}N	^{22}Ne(p, γ)^{23}Na	^{25}Mg(p, γ)^{26}Al^{t}	^{27}Si(p, γ)^{28}P	^{31}Cl(p, γ)^{32}Ar	
^{18}O(p, γ)^{19}F	^{22}Ne(α, γ)^{26}Mg	^{25}Mg(p, γ)^{26}Al^{g}	^{28}Si(p, γ)^{29}P	^{32}Cl(p, γ)^{33}Ar	
^{18}O(p, α)^{15}N	^{22}Ne(α, n)^{25}Mg	^{25}Mg(p, γ)^{26}Al^{m}	^{29}Si(p, γ)^{30}P	^{35}Cl(p, γ)^{36}Ar	

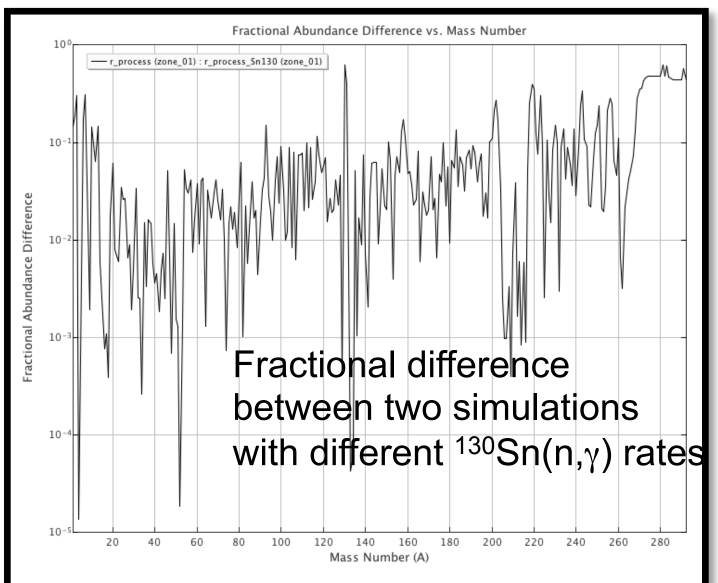
NUCLEAR ASTROPHYSICS DATA

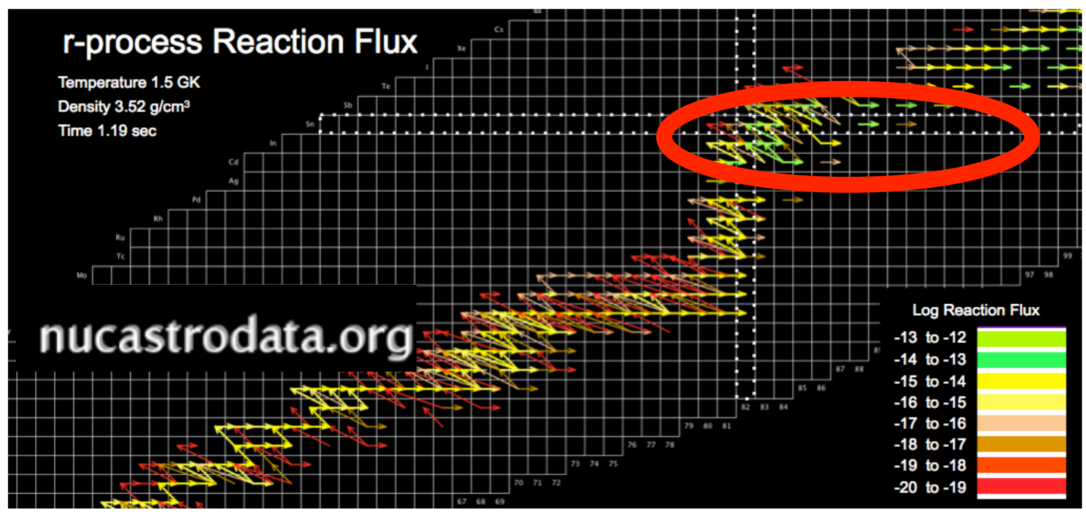
Assessment of neutron captures on Exotic Sn nuclei lying in / near the r-process path

Motivation: variations in ^{130}Sn(n,γ) shown to make **global** changes in r-process abundances

Approach: **data assessments** combined with nuclear structure and reaction **calculations** leading to improved neutron capture rates

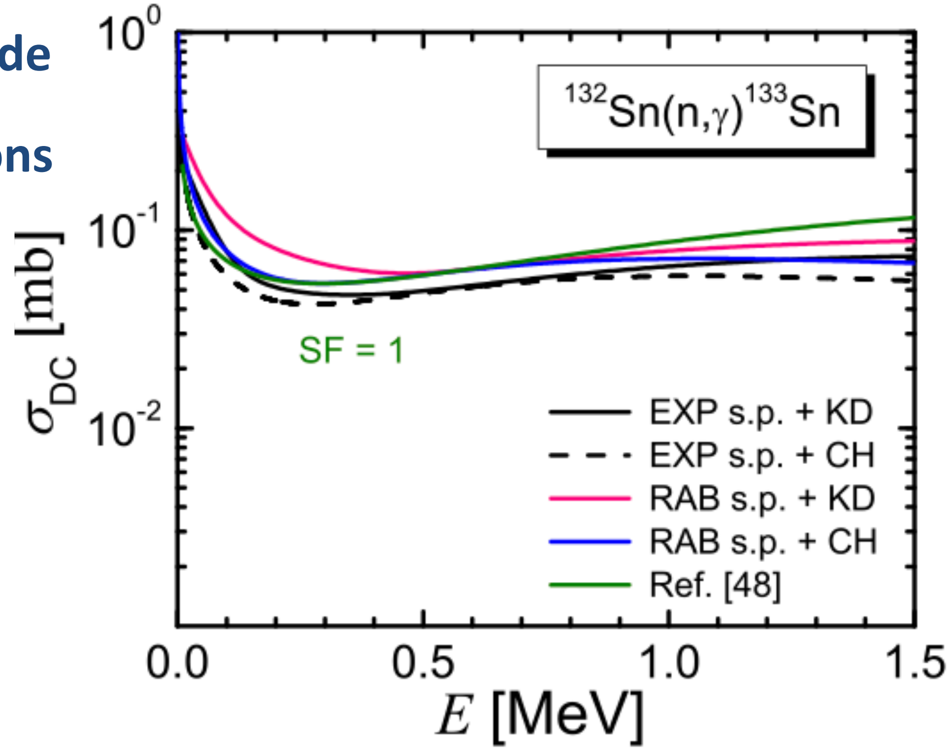






NUCLEAR ASTROPHYSICS DATA

Project: benchmark FRESCO reaction code and RMF-based structure calculations for direct neutron capture cross sections



Exploration of Direct Neutron Capture with Covariant Density Functional Theory Inputs

Shi-Sheng Zhang,[1,2,3,*] Jin-Peng Peng,[1] M. S. Smith,[2,†] G. Arbanas,[4] and R. L. Kozub[5]

[1] *School of Physics and Nuclear Energy Engineering, Beihang University, Beijing 100191, China*
[2] *Physics Division, Oak Ridge National Laboratory, Oak Ridge, TN 37831-6354 USA*
[3] *Department of Physics and Astronomy, University of Tennessee, Knoxville, Tennessee 37996, USA*
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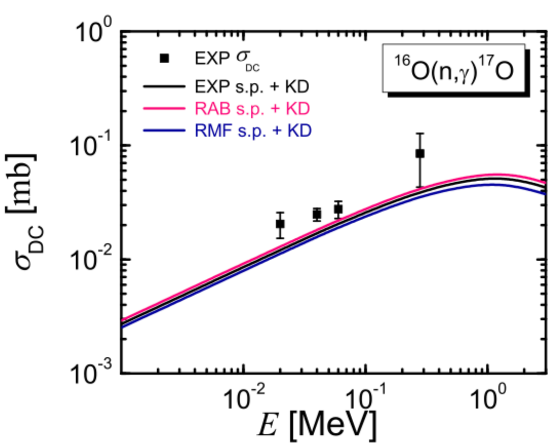
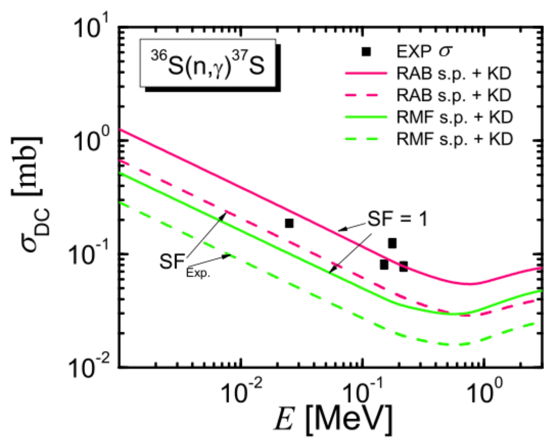
[5] *Department of Physics, Tennessee Technological University, Cookeville, TN 38505 USA*

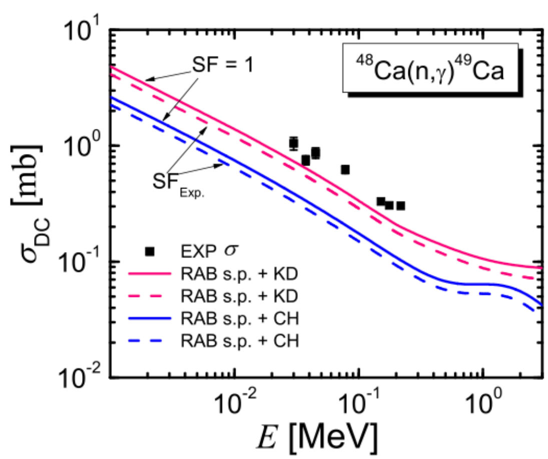
(Dated: October 31, 2014)

Predictions of direct neutron capture are of vital importance for simulations of nucleosynthesis in supernovae, merging neutron stars, and other astrophysical environments. We calculated direct capture cross sections using nuclear structure information obtained from a covariant density functional theory as input for the FRESCO coupled reaction channels code. We investigated the impact of pairing, spectroscopic factors, and optical potentials on our results to determine a robust method to calculate cross sections of direct neutron capture on exotic nuclei. Our predictions agree reasonably well with experimental cross section data for the closed shell nuclei ^{16}O and ^{48}Ca, and for the exotic nucleus ^{36}S. We then used this approach to calculate the direct neutron capture cross section on the doubly magic unstable nucleus ^{132}Sn which is of interest for the astrophysical r-process.

PACS numbers: 21.60.-n, 21.10.-k, 24.10.Jv, 21.10.Ma, 25.85.Ec







ONLINE SOFTWARE SYSTEMS - CINA

Computational Infrastructure for Nuclear Astrophysics

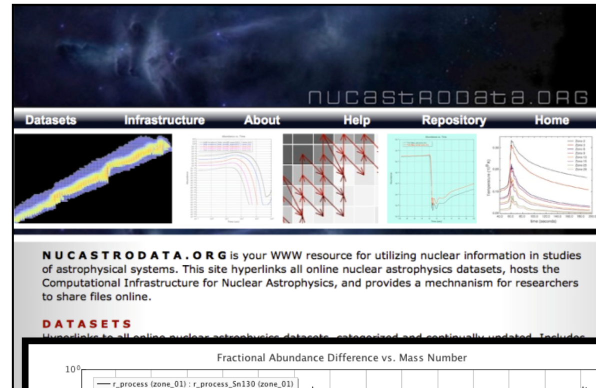
CINA streamlines the incorporation of the latest **NUCLEAR DATA** into astrophysics simulations

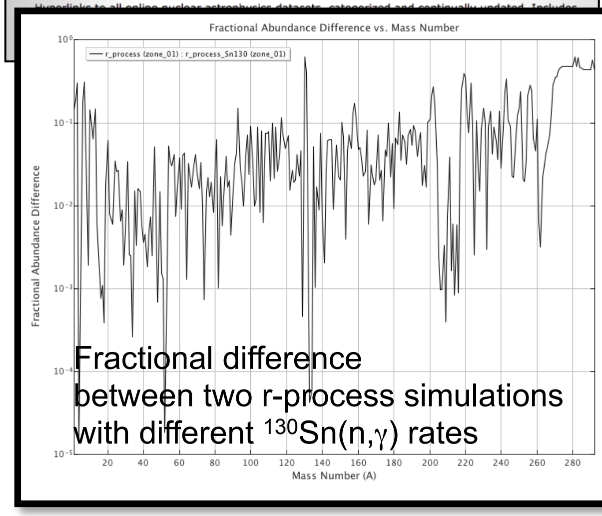
Processing enables USNDP data to be used for astrophysics simulations

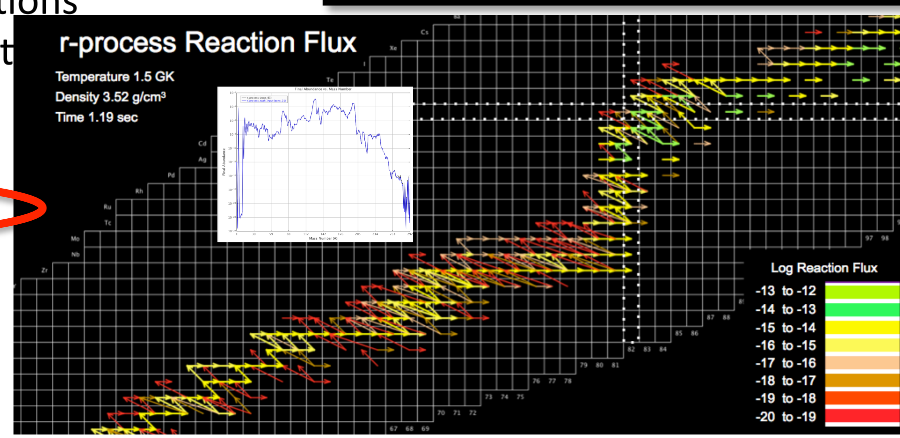
Accessible via an easy-to-use, web-deliverable, cross-platform Java application

Newest feature in CINA: r-process calculations

- Online core-collapse supernova r-process and cold r-process simulations with over 4500 isotopes and > 51,000 thermonuclear reactions rates
- Temperatures and Densities from multi-D supernova simulations
- Plotting of abundances, reaction fluxes, 2-D animations
- Plot fractional abundance difference of two simulat
- Overlay predicted abundances with observations
- Set up custom calculations in 9 steps
- Significant extension of JINA REACLIB library







ONLINE SOFTWARE SYSTEMS - CINA

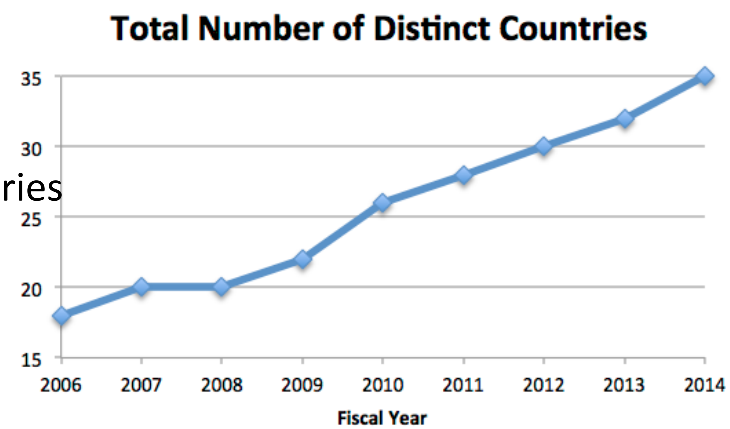
WIDELY UTILIZED community resource for nuclear data in nuclear astrophysics

Registered Users from over 35 countries and 156 institutions with an average of one new User/week over a six year period.

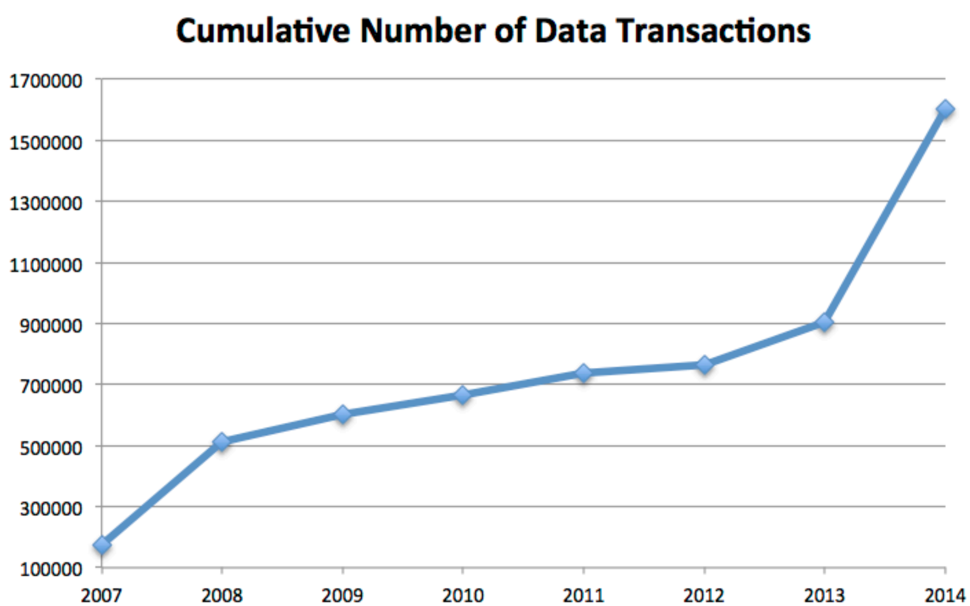
New improvements and content at *nucastrodata.org* include:

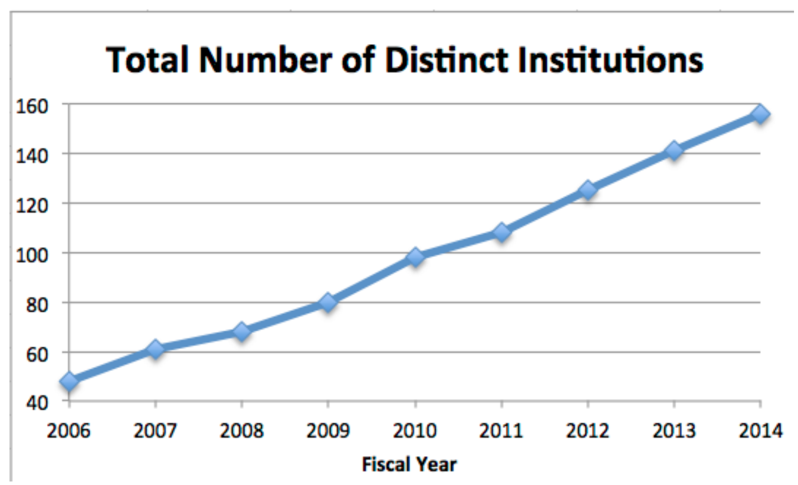
•Redesign of website's "Look and Feel" and menu options

•Updated links to online nuclear astrophysics datasets and libraries



Since the beginning of FY2007, CINA has logged over 1.5M data transactions

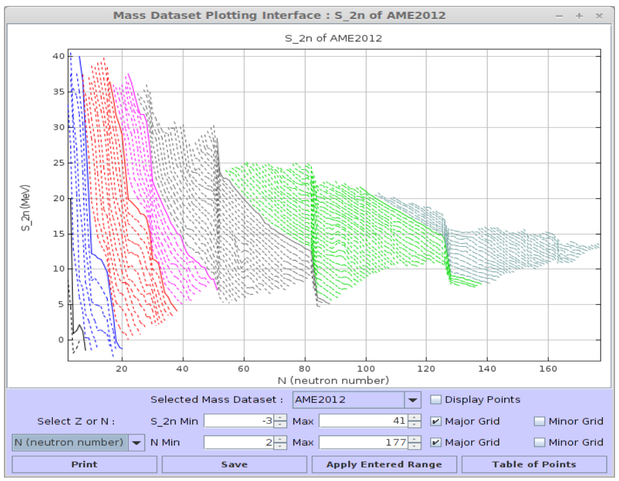


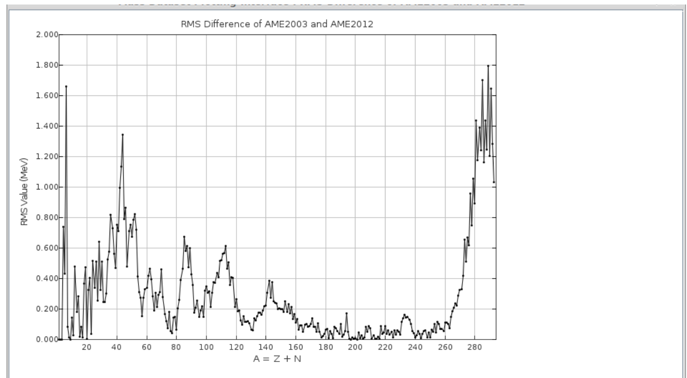


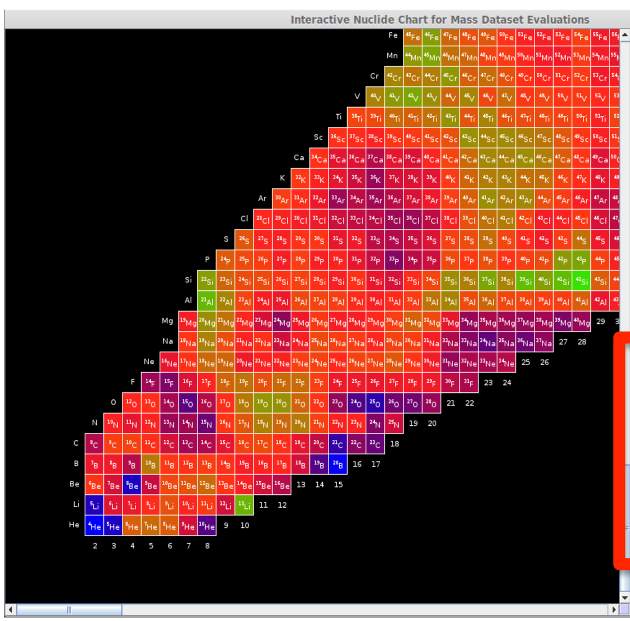
ONLINE SOFTWARE SYSTEMS – Nuclear Mass Toolkit

nuclearmasses.org

COMPONENTS
Java GUI for Users
Secure PHP Web Portal
Data Analysis Codes
MySQL Database
Host Website





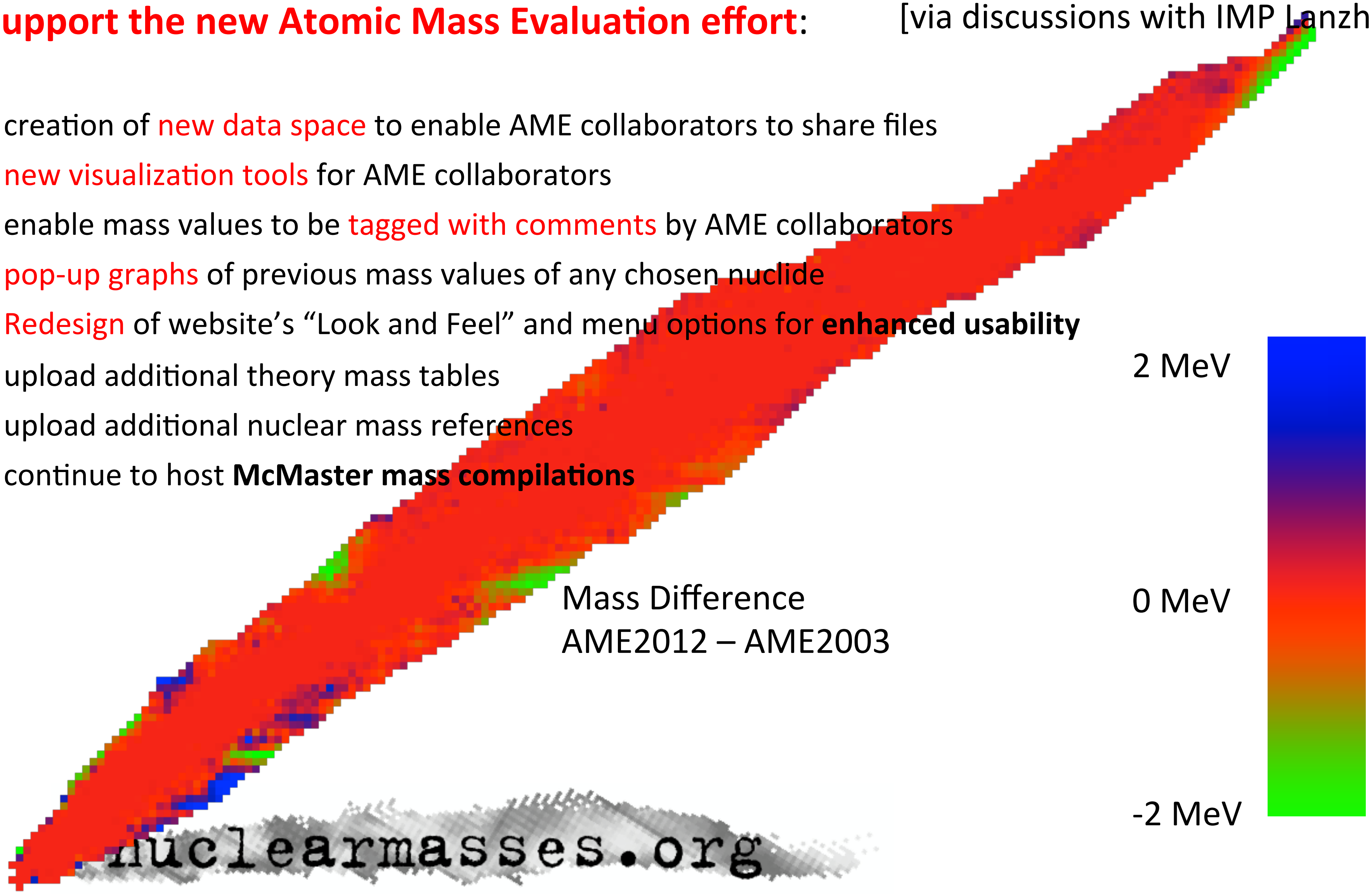


Before Toolkit	Now With Toolkit
Years between publication & use	**UPLOAD** your new mass data in minutes
Dataset searches long & difficult	**INSTANTLY ACCESS** published mass tables in one location
Dataset sharing often determined by author or publisher	**EASILY SHARE** datasets online
Datasets in multiple formats	**STANDARDIZED** format used for all datasets
Visualizations hand-built, usually only experts bother	**QUICKLY GENERATE** customized 1D & 2D plots via easy-to-use JAVA GUI
Difficult to compare datasets	**RAPIDLY COMPARE** datasets with customized visualizations

ONLINE SOFTWARE SYSTEMS – Nuclear Mass Toolkit

New improvements ***planned*** in FY15 for Nuclear Mass Toolkit include work to **support the new Atomic Mass Evaluation effort**: [via discussions with IMP Lanzhou]

- creation of new data space to enable AME collaborators to share files
- new visualization tools for AME collaborators
- enable mass values to be tagged with comments by AME collaborators
- pop-up graphs of previous mass values of any chosen nuclide
- Redesign of website's "Look and Feel" and menu options for **enhanced usability**
- upload additional theory mass tables
- upload additional nuclear mass references
- continue to host **McMaster mass compilations**



Future Work

Nuclear Structure Data Evaluation / Compilation

- Mass chain evaluations A = 41, 242
- Collaborate with evaluators at NNDC
- XUNDL compilations

Experimental Measurements

- Cross section measurements of Pt irradiated samples
- Gamma ray measurements of PET imaging radionuclides with Gammasphere
- Total absorption spectrometry

Nuclear Astrophysics Data

- Systematic calculation of neutron capture on exotic Sn isotopes
- Fits of thermonuclear reaction rates in recent published collections

Computational Infrastructure for Nuclear Astrophysics

- Calculation of rates from resonance parameters
- Incorporate additional rate collections into our system

Nuclear Masses

- Develop tools at nuclearmasses.org for future mass evaluation efforts

Metrics

Effort

- **Permanent staff:** 2 heads (C. Nesaraja, M. Smith), 1.2 FTE
- **Scientific Temporary staff:** 2 heads (M. Martin, S. Zhang), 0.65 FTE
- **Technical/Support staff:** 2 heads (E. Lingerfelt, C. Smith), 1.0 FTE

Evaluations: 16 nuclides across 2 A-chains
Compilations: 30 [XUNDL]
Retrievals (dissemination): 875000
Publications: 9
Reports: 0
Invited talks: 7