Astrophysics Task Force

Caroline Nesaraja, Michael Smith

ORNL Physics Division

Numerous USNDP institutions are pursuing projects that are beneficial for studies in nuclear astrophysics

These activities include work on both nuclear reactions & nuclear structure

Recent Activities include

- Compilations & Evaluations (ANL, McMaster, ORNL)
- Computational Infrastructure for Nuclear Astrophysics (ORNL)
- Nuclear Theory (LANL)

Argonne NATIONAL LABORATORY Los Alamos NATIONAL LABORATORY EST.1943 McMaster University Inspiring Innovation and Discovery OAK RIDGE National Laboratory

Compilations & Evaluations

ANL (F. Kondev)

- Structure information for states above long-lived isomer ^{186}Re

McMaster (A. Chen)

- Evaluation closely coupled to experimental program of McMaster –TRIUMF $^{26}Al(p,\gamma)^{27}Si$ & $^{40}Ca(\alpha,\gamma)^{44}Ti$

ORNL (C. Nesaraja)

- Focus on reactions involving radioactive nuclei important for stellar explosions - coupled to HRIBF measurements

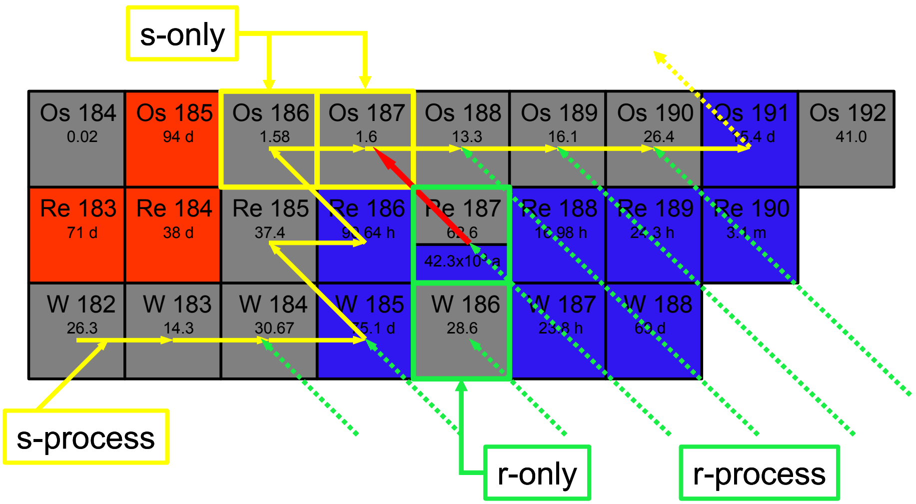
$^{18}F(p,\alpha)^{15}O$ & $^{18}F(p,\gamma)^{19}Ne$, $^{30}P(p,\gamma)^{31}S$,

$^{17}O(p,\gamma)^{18}F$ & $^{17}O(p,\alpha)^{14}N$, & $^{25}Al(p,\gamma)^{26}Si$

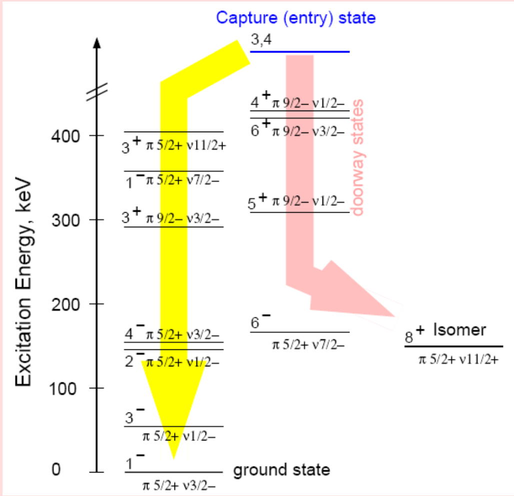
Compilations & Evaluations

ANL

$^{186}W(d,2n)\,^{186}Re$
& γ-ray coincidence



New structure information were assigned above the (8+) isomer



Important for determining accuracy of the $^{187}Re/^{187}Os$ cosmo chronometer that can be used for dating r-process events

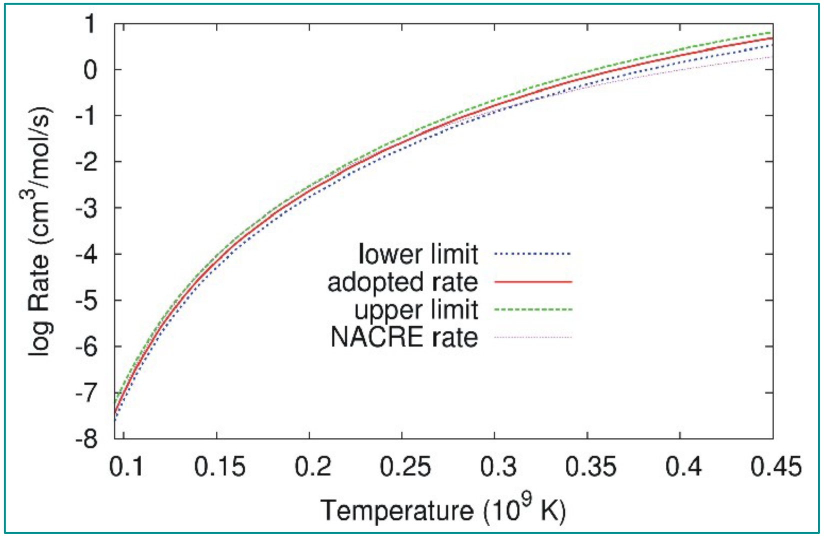
F. Kondev

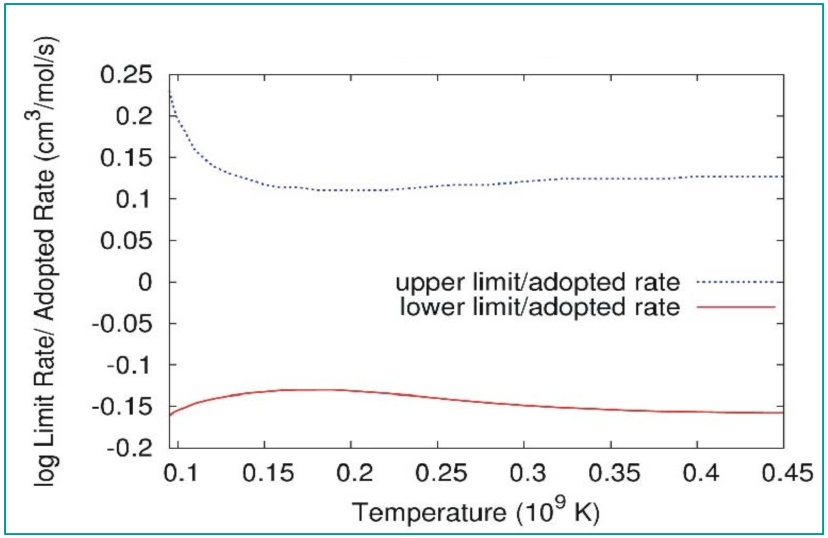
Compilations & Evaluations

McMaster

Evaluation of the $^{26}Al(p,\gamma)^{27}Si$ reaction rate

Incorporated new data from recent measurement of key resonance for the reaction rate at TRIUMF-ISAC using DRAGON (Ruiz et al. PRL (2006))





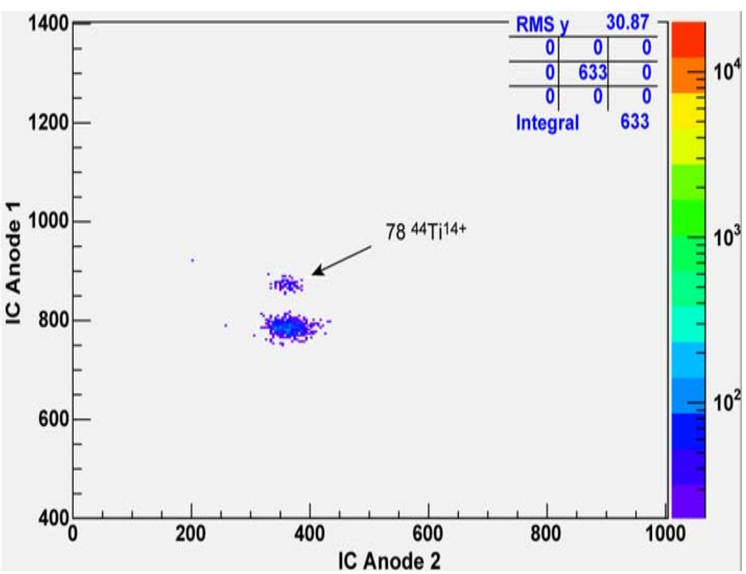
A.Chen

Compilations & Evaluations

McMaster

Evaluation of the $^{40}Ca(\alpha,\gamma)^{44}Ti$ reaction rate

Important in production of the observed gamma emitter ^{44}Ti in supernova explosions (E_γ = 1.16 MeV)



Data analysis & rate evaluation in progress (Ph.D. thesis, C. Ouellet, McMaster University)

E-ΔE spectrum from ionization Chamber (energy in a.u.)

A.Chen

Compilations & Evaluations

ORNL Focus on structure & reactions involving radioactive nuclei important for stellar explosions

experiments

$^{18}F(p,p)^{18}F$
$^{18}F(p,\alpha)^{15}O$
$^{18}F(d,p)^{19}F$

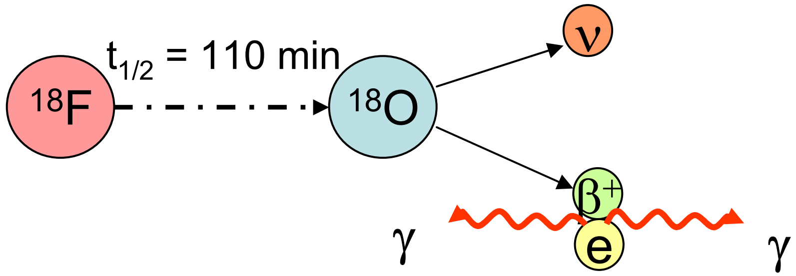
evaluations

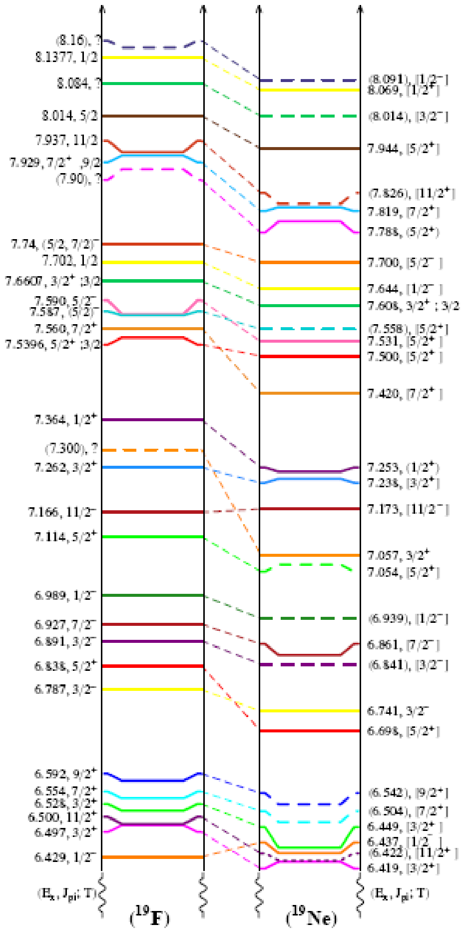
Level Structure of ^{19}Ne

processing

$^{18}F(p,\alpha)^{15}O$ & $^{18}F(p,\gamma)^{19}Ne$ reaction rates

Important for determining synthesis of ^{18}F in novae and heavy element production in X-ray bursts





C.Nesaraja

Compilations & Evaluations

ORNL

Focus on structure & reactions involving radioactive nuclei important for stellar explosions

experiments

$^{32}S(p,d)^{31}S$

evaluations

Level Structure of ^{31}S

processing

$^{30}P(p,\gamma)^{31}S$ reaction rate

Plays crucial role in the synthesis of heavier (A>30) nuclear species in nova outburst on ONe White dwarfs

- A total of 26 levels observed
- 5 observed levels not previously reported
- J $^{\pi}$ determined or constrained for the first time
- Evaluated 44 levels

E_x(keV) re-evaluated	Observed in this work	ℓ_n	J^π	C^2S	E_x(keV) ^{31}P mirror
4085 ± 2	4085 ± 2	2	$5/2^+$	0.77	4190
4204 ± 7			$(1/2-7/2)^+$		
4451 ± 0.4	4446 ± 6	3	$7/2^-$	0.15	4431
4525 ± 8			$3/2^+$		
4584 ± 0.3			$7/2^+$		
4711 ± 2	4707 ± 3	2	$5/2^+$	0.40	4783
4866 ± 7					
4976 ± 4	4988 ± 8		$3/2^-$		5015
5027 ± 5					
5156 ± 3	5155 ± 5	0	$1/2^+$	0.11	5256
5301 ± 0.3	5331 ± 5		$9/2^+$		5343
5408 ± 9					
5440 ± 11					
5515 ± 4	5497 ± 10	2	$3/2^+$	0.10	5559
5679 ± 4					
5779 ± 3	5781 ± 5	2	$5/2^+$	0.17	5892
5826 ± 10					
5890 ± 4	5959 ± 10 [a]	2	$(3/2,5/2)^+$	0.15	
5978 ± 0.8	5959 ± 10 [a]	2	$(9/2^+)$		
6160.2 ± 0.7			$5/2^-$		6399
6263 ± 3	6267 ± 5	0	$1/2^+$	0.12	6337
6279.5 ± 2			$3/2^+$		6381
6350 ± 11			$5/2^+$		6461
6376.9 ± 0.5			$9/2^-$		6501
6393.8 ± 0.5	6411 ± 9		$11/2^+$		6454
6544 ± 9	6546 ± 15		$5/2^-$		6594
6593 ± 15			$3/2^-$		6610
6636.2 ± 1.5			$9/2^-$		6793
6712 ± 11			$(3/2-7/2)$		
6748 ± 10			$(3/2-7/2)$		
6796 ± 25			$(3/2-7/2)$		
6833.4 ± 0.3	6848 ± 9 [b]		$11/2^-$		6825
6870 ± 10	6848 ± 9 [b]		$(3/2^-,5/2^+)$		7080
6921 ± 25			$5/2^+$		6932
6969 ± 5			$1/2^+$		
7006 ± 5			$1/2^+$		
7038 ± 4	7044 ± 6	2	$5/2^+$	0.79	7158 [d]
7112 ± 25			$(1/2,3/2)^-$		7214
7156 ± 4			$(3/2,5/2)^+$		
7199 ± 13					
7303 ± 0.7			$11/2^+$		
7445 ± 25					
7511 ± 5	7510 ± 6				
7600 ± 30					
7660 ± 30					
7726 ± 3	7728 ± 4	0+2			
7768 ± 25					
7850 ± 25					
7911 ± 5	7912 ± 5	0	$1/2^+$	0.06	
7985 ± 25	8049 ± 6 [c]	0+2	$(1/2,3/2,5/2)^+$		
8082 ± 25	8049 ± 6 [c]	0+2	$(1/2,3/2,5/2)^+$		
8174 ± 11	8171 ± 12				
8362 ± 25					
8461 ± 0.5			$(13/2^-)$		
8517 ± 13	8517 ± 13	0	$1/2^+$	0.05	
8789 ± 6	8789 ± 6	2	$(3/2,5/2)^+$	0.13	
9154 ± 1.2			$13/2^+$		
9207 ± 5	9207 ± 5				
9423 ± 7	9423 ± 7	2	$(3/2,5/2)^+$	0.19	
9606 ± 14	9606 ± 14				
9853 ± 12	9853 ± 12				
10146 ± 1.0			$(13/2^-)$		
10577 ± 13	10577 ± 13				

[a,b,c] unresolved doublets

Z. Ma

ORNL Focus on structure & reactions involving radioactive nuclei important for stellar explosions

Evaluations / Compilations

$^{17}O(p,\alpha)^{14}N$ → Level Structure of ^{18}F → $^{17}O(p,\gamma)^{18}F$ & $^{17}O(p,\alpha)^{14}N$ reaction rates in Red Giant Stars

B. Moazen

$^{28}Si(p,t)^{26}Si$ → Level Structure of ^{26}Si → $^{25}Al(p,\gamma)^{26}Si$ reaction rate in novae

D. Bardayan

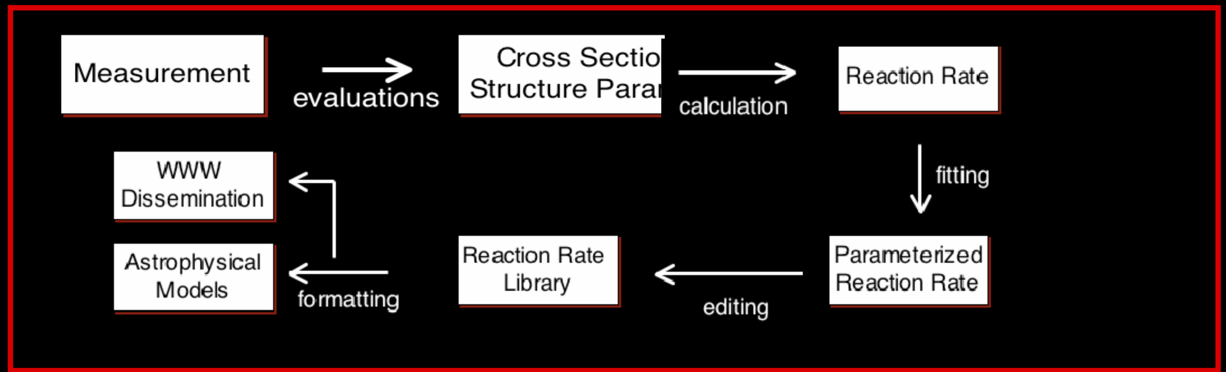
$d(^{7}Be,t)^{6}Be$ → Level Structure of ^{6}Be → $^{3}He(^{3}He,2p)^{4}He$ reaction rate in stars

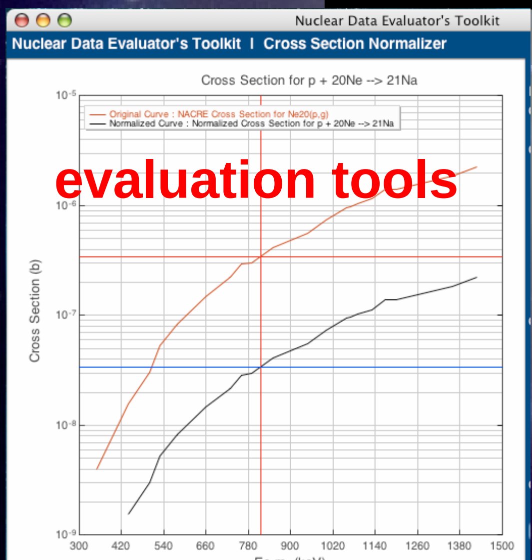
A. Chae

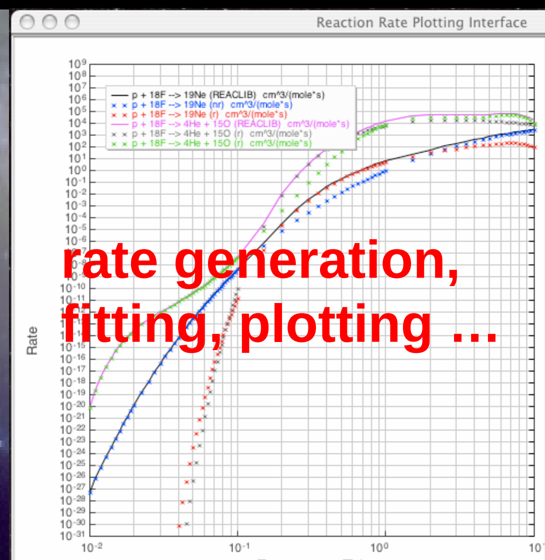
$^{7}Be(p,p)^{7}Be$ & $^{7}Be(p,p')^{7}Be^{*}$ → Level Structure of ^{8}B → Extrapolation $^{7}Be(p,\gamma)^{8}B$ astrophysical S-factor to stellar energies

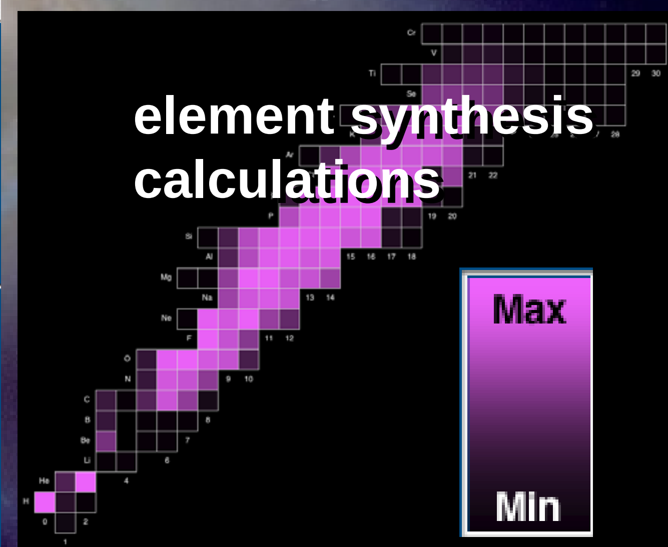
R. Livesay

Computational Infrastructure for Nuclear Astrophysics









Expansion of the **Computational Infrastructure for Nuclear Astrophysics** at nucastrodata.org includes rate locater, improved reaction rate fitting routines, reaction flux animation, faster animation rendering & export of movie files and many other features

Nuclear Theory

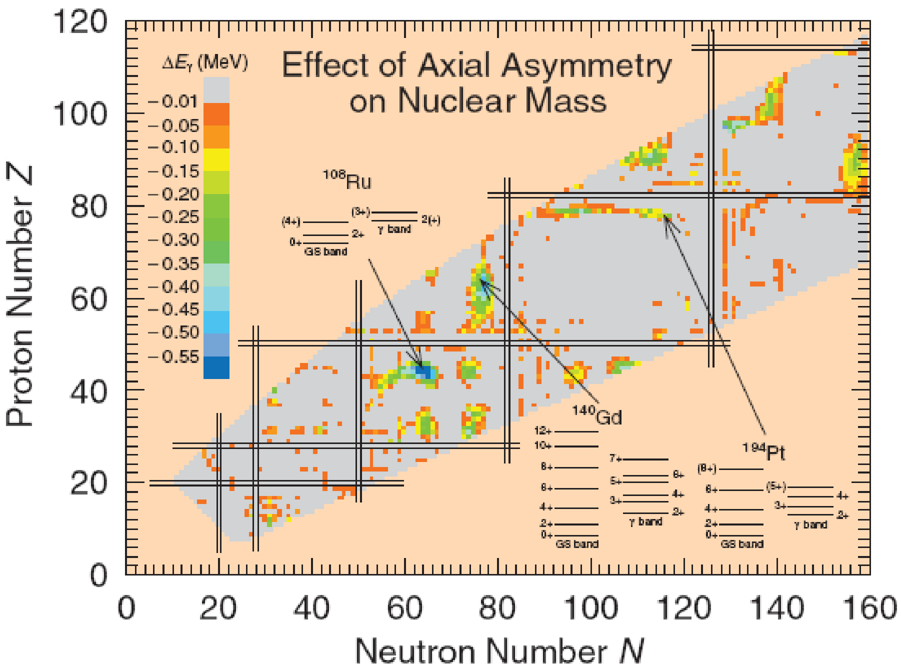
LANL

Global Calculation of Ground State Axial Asymmetry of Nuclei

PRL 97, 162502 (2006) PHYSICAL REVIEW LETTERS week ending 20 OCTOBER 2006

Global Calculations of Ground-State Axial Shape Asymmetry of Nuclei

Peter Möller,[1,*] Ragnar Bengtsson,[2] B. Gillis Carlsson,[2] Peter Olivius,[2] and Takatoshi Ichikawa[3]



First global systematic study of the axial asymmetry of >7000 nuclei

• **characteristic γ bands are observed** experimentally for many nuclei in region where axial asymmetry is calculated

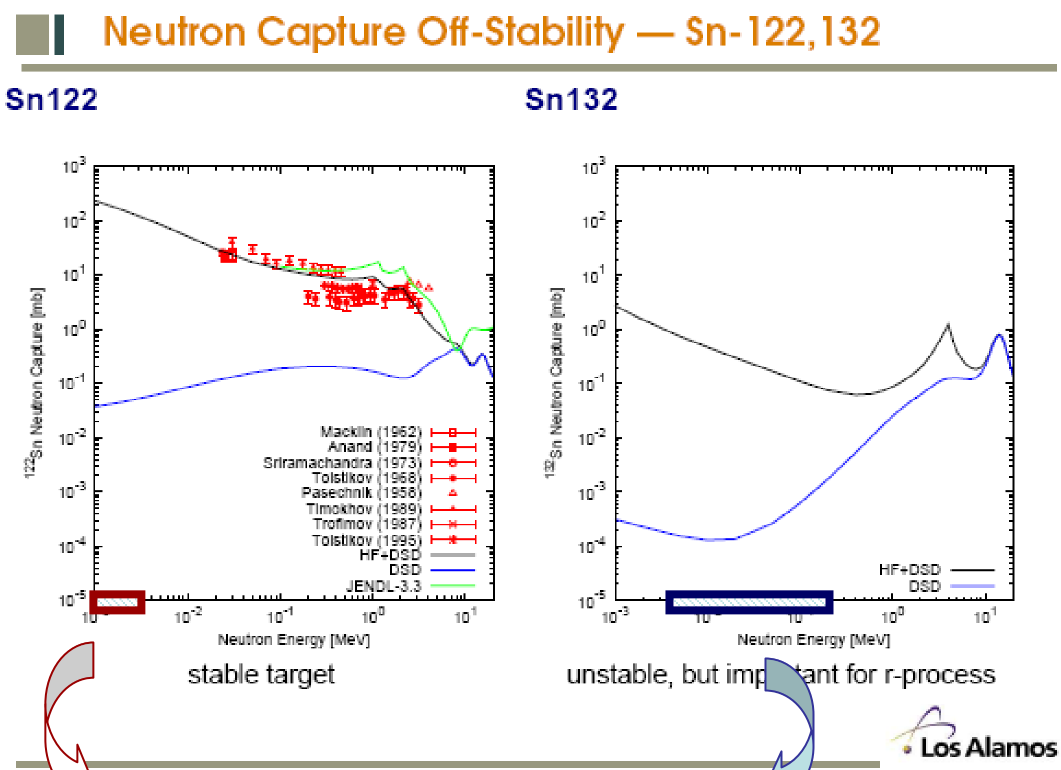
• for nuclei where axial asymmetry is found, a **systematic deviation between calculated and measured masses is removed**

• important application for modeling the properties of nuclei involved in the **r process in supernovae**

P.Möller

Nuclear Theory

LANL Direct & Semidirect Capture of Nucleons with Hartree –Fock BCS Theory



New calculation for neutron direct/semidirect capture on Sn based on Hartree-Fock BCS Theory

Low energy neutron captured in s-process in red giant stars

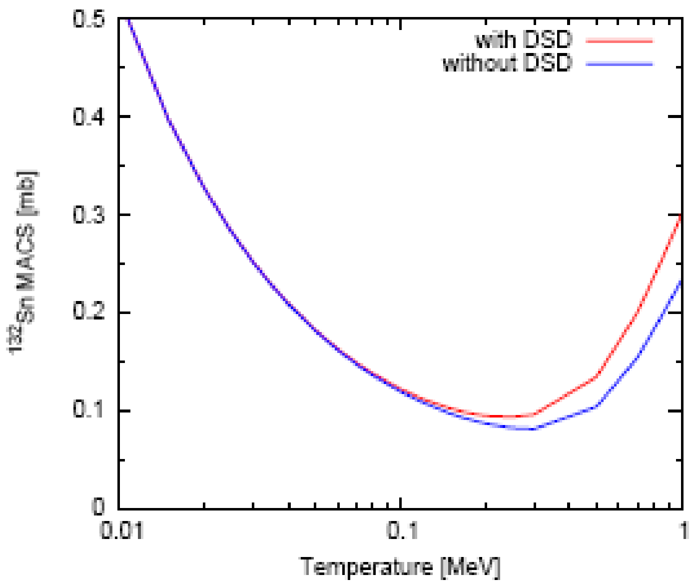
Higher energy neutrons capture in r-process in supernovae

Kawano *et al*.

LANL

Maxwell-Averaged Capture Cross Section for Sn-132

DSD Contribution to MACS



- Because of small CN capture cross sections on ^{132}Sn, DSD capture becomes in the same order as the Hauser-Feshbach cross sections.
- MACS is increased by the DSD cross section, when $kT \geq 100$ keV.
- 23% of MACS is from DSD at $kT = 1$ MeV.

^{132}Sn β^--decays with $T_{1/2}$ of 39.7 s. If nucleo-synthesis takes place in a high temperature environment, uncertainty in the DSD calculation may change the r-process scenario.

Los Alamos

Kawano *et al.*