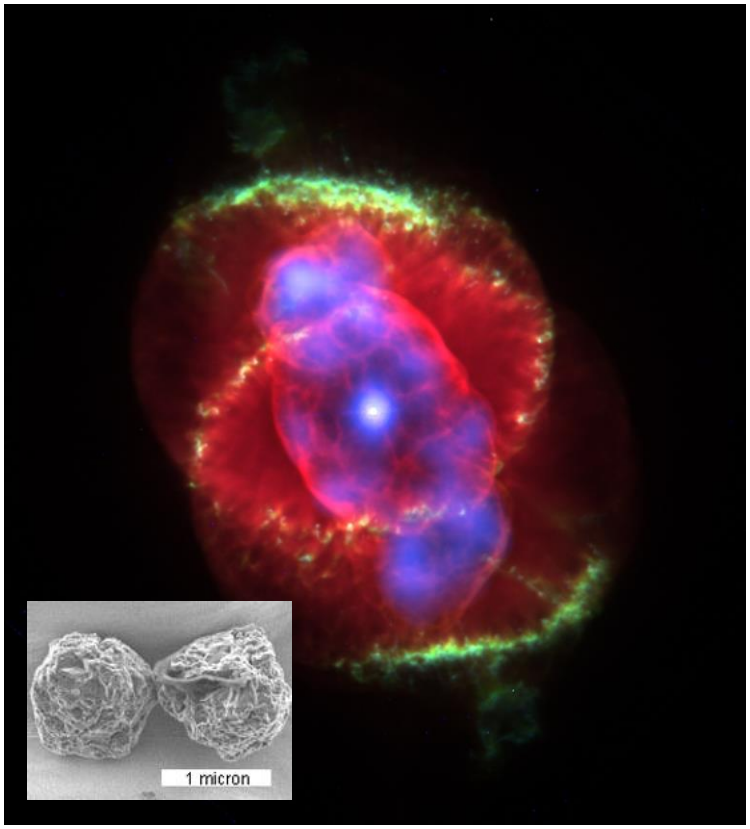
The University of Edinburgh

Measurement of ^{28,29,30}Si(n, γ) capture cross sections to explain isotopic abundances in presolar grains

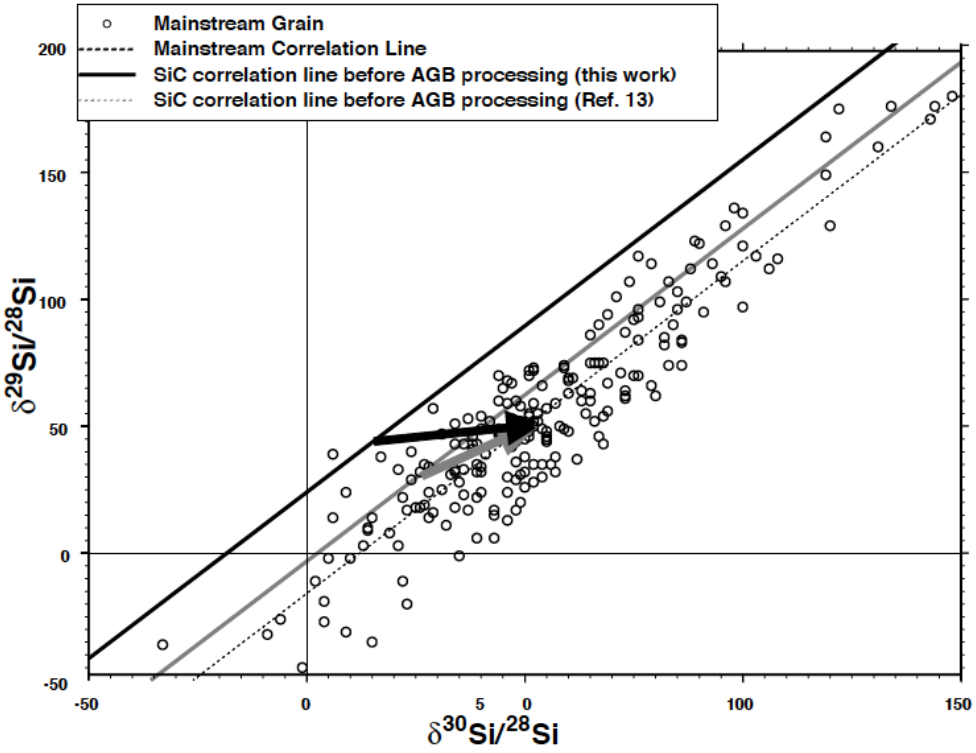
CERN-INTC-2023-009 / INTC-P-653



C. Lederer-Woods, A. Mengoni, *J. Andrzejewski, M. Boromiza, A. Casanovas, S. Cristallo, M. Dietz, C. Domingo-Pardo, A. Gawlik-Ramiega, G. Gervino, A. Gugliemelli, C. Gustavino, T. Heftrich, J. Lerendegui, A. Manna, C. Massimi, A. Negret, N. Patronis, J. Perkowski, C. Petrone, M. Pignatari, T. Rauscher, R. Reifarth, A. Rooney, N. Sosnin, O. Straniero, S. Tosi, P. Ventura, D. Vescovi, P.J. Woods and the n_TOF Collaboration*

Mainstream SiC Grains

- form in circumstellar envelope of AGB stars
- Si abundances: neutron capture nucleosynthesis (s process) superimposed on initial composition
- isotopic ratios measured with 5% accuracy

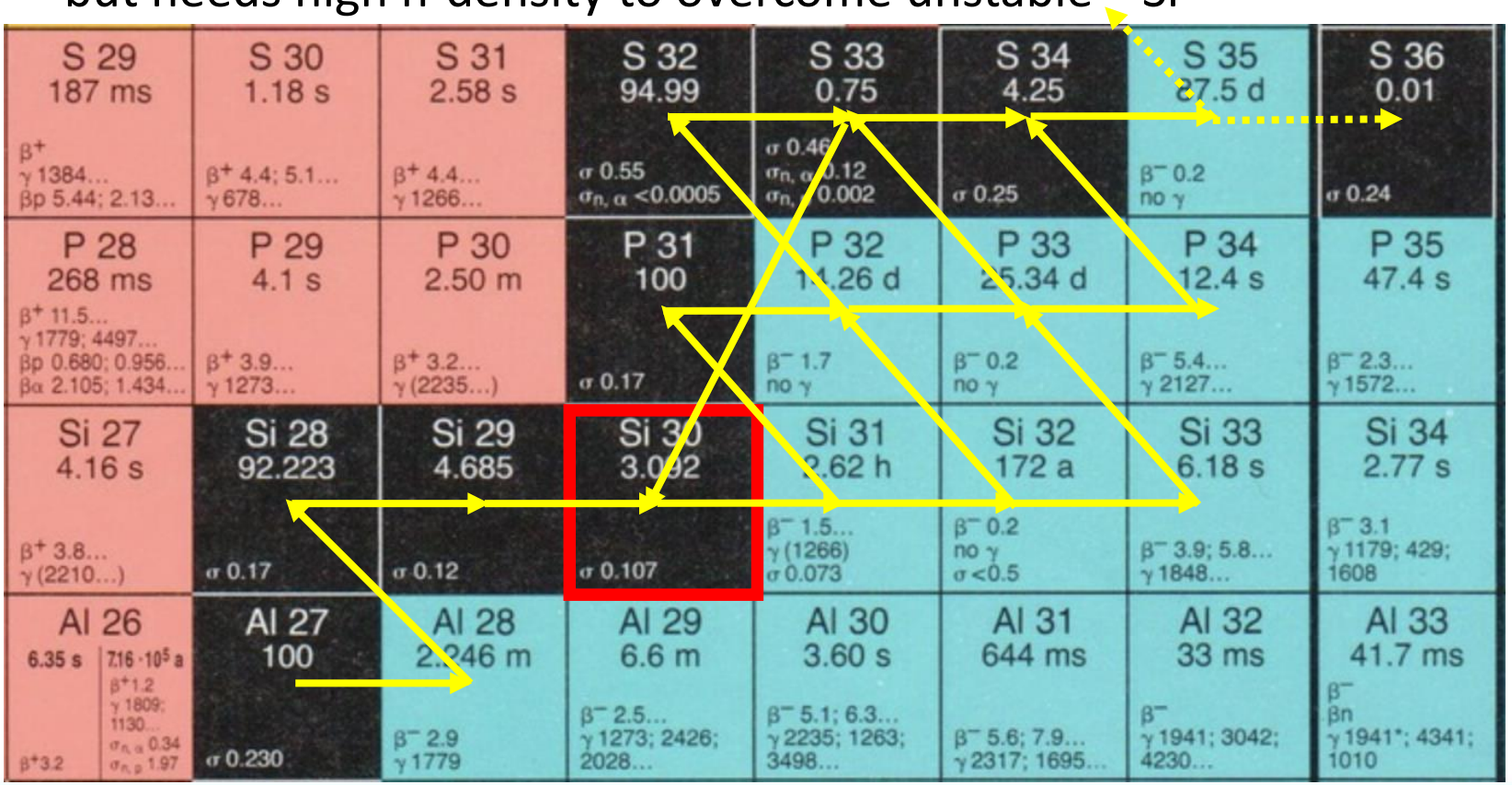


PHYSICAL REVIEW C 67, 062802R(2003)

→ need equally accurate neutron capture cross sections on $^{28,29,30}Si$

SiC Grains Type C

- C-type sub-group
- likely Supernova origin
- peculiar enhancement of ^{32}S that can be explained by presence of unstable ^{32}Si in the SN ejecta
- but needs high n-density to overcome unstable ^{31}Si



Galactic Chemical Evolution

- bulk of the ^{29}Si and ^{30}Si present today in the Milky Way and in the Sun are made in the convective carbon-shell in massive stars at about 1 GK
- ^{28,29,30}Si neutron capture cross sections are crucial to shape the final yields and the relative abundances of ^{29}Si and ^{30}Si

MACS data on ^{28}Si

KADoNiS database, used in stellar models

Recommended MACS30 (Maxwellian Averaged Cross Section @ 30keV)

$$^{28}Si\ (n,\gamma)^{29}Si$$

Total MACS at 30keV: 1.42 ± 0.13 mb

Cross sections do not include stellar enhancement factors!

History

Version	Total MACS [mb]	Partial to gs [mb]	Partial to isomer [mb]
0.2	1.42 ± 0.13	-	-
0.0	2.9 ± 0.3	-	-

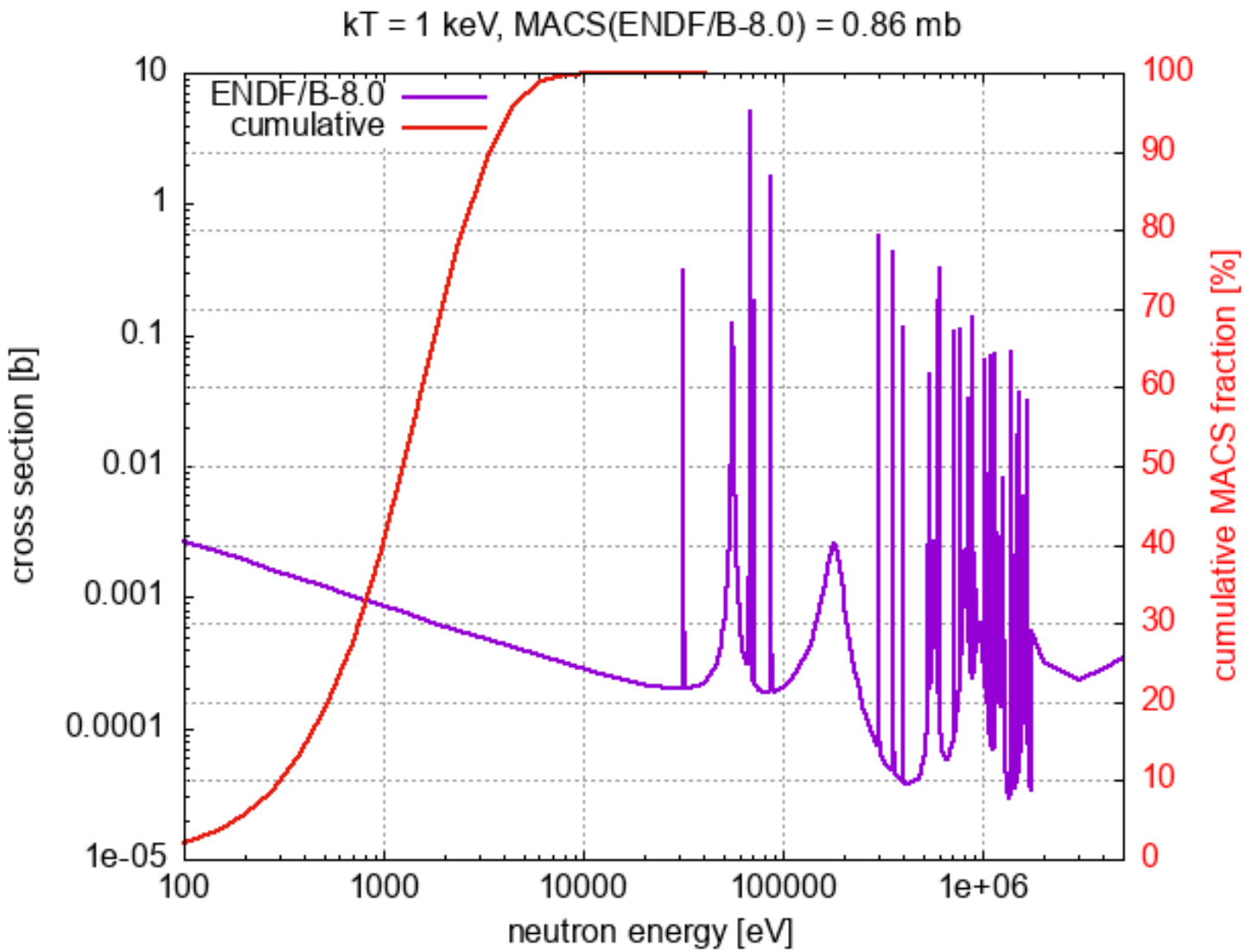
(Version 0.0 corresponds to Bao et al.)

Comment

Rec. value is from GKD03. MACS vs. kT table from GKD03, but extended above kT= 50 keV with norm. energy dependence from KAB76,BAM75b.
Last review: February, 2013

List of all available values

original	renorm.	year	type	Comment	Ref
1.42 ± 0.13		2003	c	Linac, TOF, Au: Sat.; DC component is 0.23 (11) mb	GKD03
2.9 ± 0.3		1976	r	Linac, TOF, ^{6}Li, Au:Sat. Recalcul. including data of MDH81	KAB76,BAM75b
[illegible] ± 1.0		1971	e		AGM71
3.61 ± 0.80		2011	e	ENDF/B-VII.1 plus covariances	endfb71
3.61		2011	e	JENDL-4.0	jendl40
3.61		2004	e	JEFF 3.1	jeff31
1.69		2002	e	JENDL-3.3	jendl33
5.81		2015	t	TENDL-2015 using the TALYS code	tendl15
18.9		2005	t	MOST 2005	Gor05
30.8		2002	t	MOST 2002	Gor02
5.48		2000	t	NON-SMOKER	RaT99
2.4		1978	t		WFH78


kT = 1 keV, MACS(ENDF/B-8.0) = 0.86 mb
ENDF/B-8.0
cumulative
cross section [b]
cumulative MACS fraction [%]
neutron energy [eV]
10
1
0.1
0.01
0.001
0.0001
1e-05
100
1000
10000
100000
1e+06
100
90
80
70
60
50
40
30
20
10
0

The University of Edinburgh

MACS data on ^{29}Si

Recommended MACS30 (Maxwellian Averaged Cross Section @ 30keV)

$$^{29}Si\ (n,\gamma)^{30}Si$$

Total MACS at 30keV: 7.56 ± 0.59 mb

Cross sections do not include stellar enhancement factors!

History

Version	Total MACS [mb]	Partial to gs [mb]	Partial to isomer [mb]
1.0	7.56 ± 0.59	-	-
0.2	6.58 ± 0.66	-	-
0.0	7.9 ± 0.9	-	-

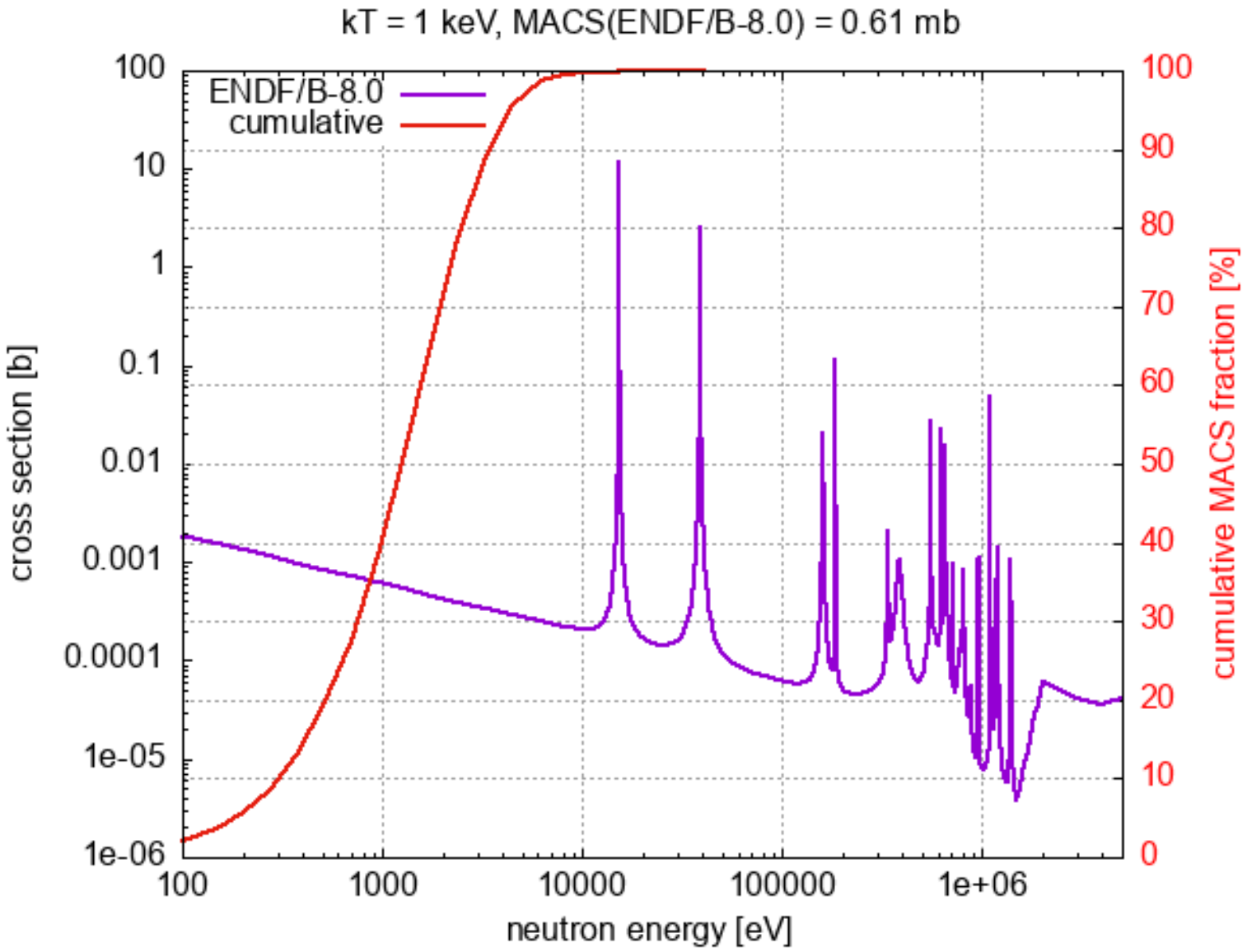
(Version 0.0 corresponds to Bao et al.)

Comment

Rec. value is from GKD03 (previous rec. value included no DC component). MACS vs. kT table from GKD03, but extended above kT= 50 keV with norm. energy dependence from KAB76,BAM75b.
Last review: February, 2013

List of all available values

original	renorm.	year	type	Comment	Ref
7.56 ± 0.59		2003	c	Linac, TOF, Au: Sat.; DC component is 0.98 (69) mb	GKD03
7.9 ± 0.8		1976	r	Linac, TOF, ^{6}Li, Au:Sat. Recalcul. including data of MDH81	KAB76,BAM75b
10.4		1971	s		AGM71
7.77 ± 0.83		2011	e	ENDF/B-VII.1	endfb71
7.77		2011	e	JENDL-4.0	jendl40
5.75		2002	e	JENDL-3.3	jendl33
6.44		2015	t	TENDL-2015 using the TALYS code	tendl15
63.8		2005	t	MOST 2005	Gor05
89.2		2002	t	MOST 2002	Gor02
8.82		2000	t	NON-SMOKER	RaT99
5.4		1978	t		WFH78


kT = 1 keV, MACS(ENDF/B-8.0) = 0.61 mb
ENDF/B-8.0
cumulative
cross section [b]
cumulative MACS fraction [%]
neutron energy [eV]
100
10
1
0.1
0.01
0.001
0.0001
1e-05
1e-06
100
1000
10000
100000
1e+06
90
80
70
60
50
40
30
20
10
0

MACS data on ^{30}Si

Recommended MACS30 (Maxwellian Averaged Cross Section @ 30keV)

$$^{30}Si\ (n,\gamma)^{31}Si$$

Total MACS at 30keV: 1.82 ± 0.33 mb

Cross sections do not include stellar enhancement factors!

History

Version	Total MACS [mb]	Partial to gs [mb]	Partial to isomer [mb]
0.2	1.82 ± 0.33	-	-
0.0	6.5 ± 0.6	-	-

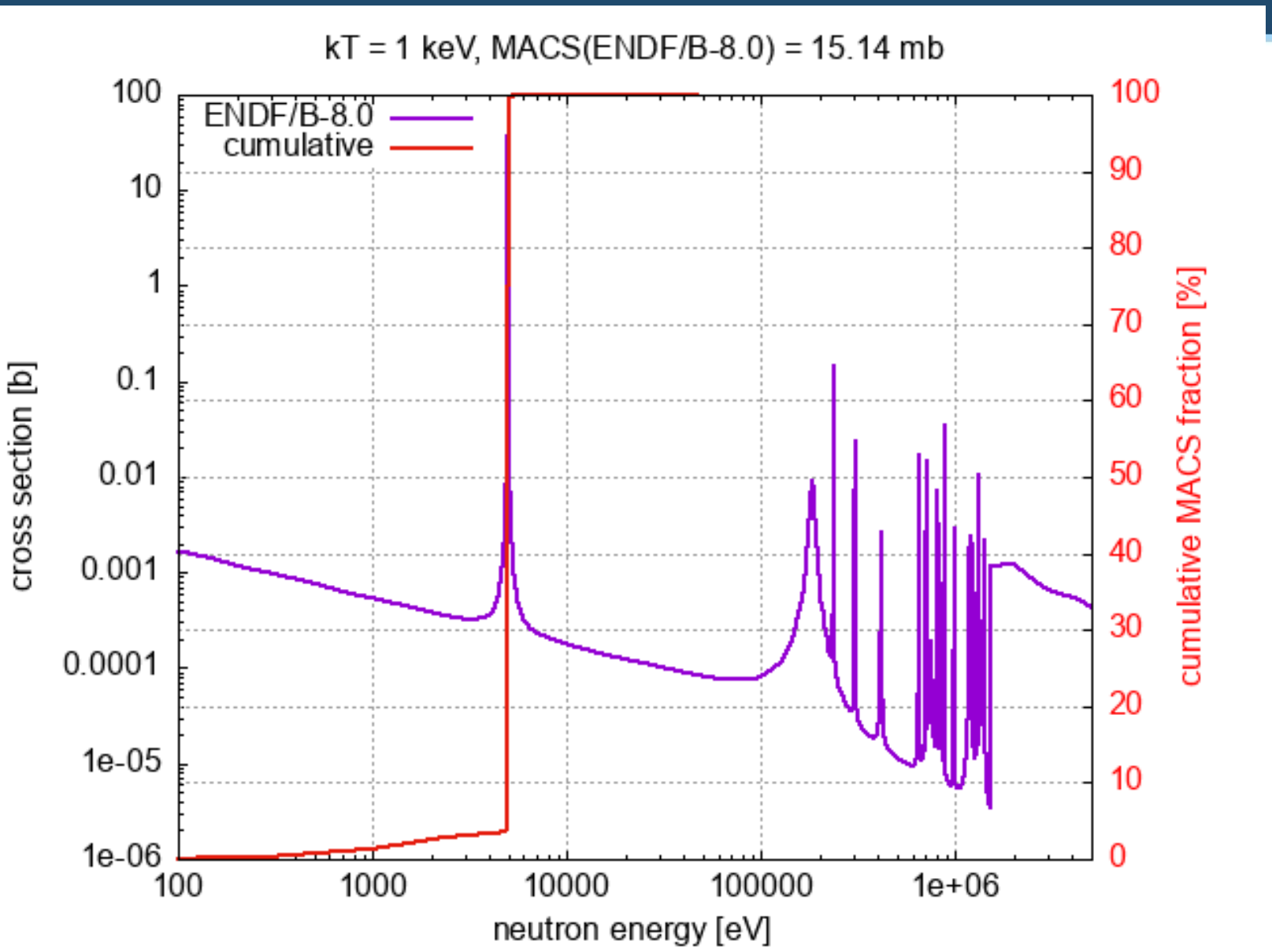
(Version 0.0 corresponds to Bao et al.)

Comment

Rec. value is from GKD03. MACS vs. kT table from GKD03, but extended above kT= 50 keV with norm. energy dependence from endfb71. Note that there is discrepancy between the activation measurement from BSR02b and the TOF value from GKD03. **A further investigation is required!!!**
Last review: August 2014

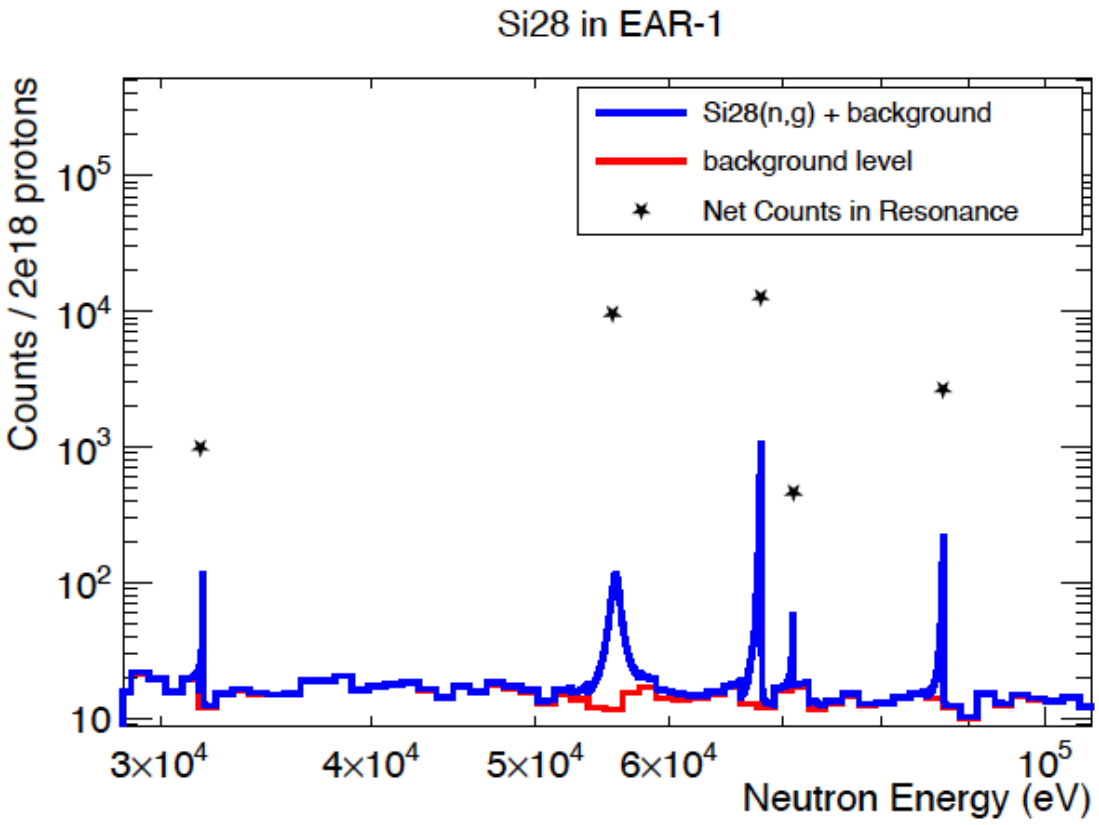
List of all available values

original	renorm.	year	type	Comment	Ref
1.82 ± 0.33		2003	c	Linac, TOF, Au: Sat.; DC component is 0.48 (30) mb; no res. at 2.235 keV found	GKD03
3.51 ± 0.15 kT= 25 keV	3.64 ± 0.14	2002,2015	c	VdG, Act., Au:RaK88 corrected by 632 mb/586 mb= 1.0785; DC component at kT= 30 keV is 0.36 mb	BSR02b
0.72 ± 0.07 kT= 52 keV		2002	c	VdG, Act., Au:RaK88	BSR02b
6.5 ± 0.6		1975	r	Linac, TOF, ^{6}Li, Au:Sat. Recalcul. including data of MDH81	BAM75b
1.81		2015	e	TENDL-2015 using the TALYS code	tendl15
4.43 ± 1.52		2011	e	ENDF/B-VII.1 plus covariances	endfb71
4.43		2011	e	JENDL-4.0	jendl40
5.75		2004	e	JEFF-3.1	jeff31
5.75		2002	e	JENDL-3.3	jendl33
1.9		1971	e		AGM71


kT = 1 keV, MACS(ENDF/B-8.0) = 15.14 mb
ENDF/B-8.0
cumulative
cross section [b]
cumulative MACS fraction [%]
neutron energy [eV]
100
10
1
0.1
0.01
0.001
0.0001
1e-05
1e-06
100
1000
10000
100000
1e+06
90
80
70
60
50
40
30
20
10
0

Measurement at EAR-1

- 1g of isotopically enriched material
- Legnaro type C_6D_6 Detection Setup
- 20% cascade efficiency assumed
- 2E18 protons



Measurement at EAR-1

- 1g of isotopically enriched material
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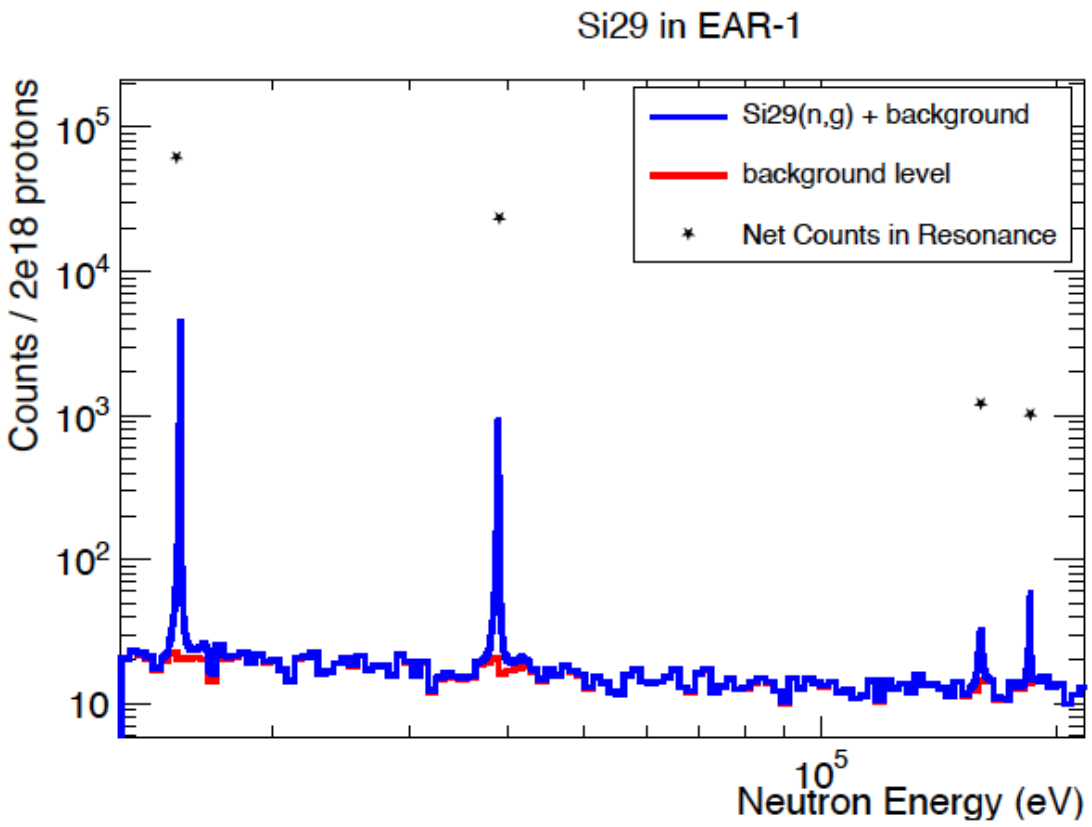
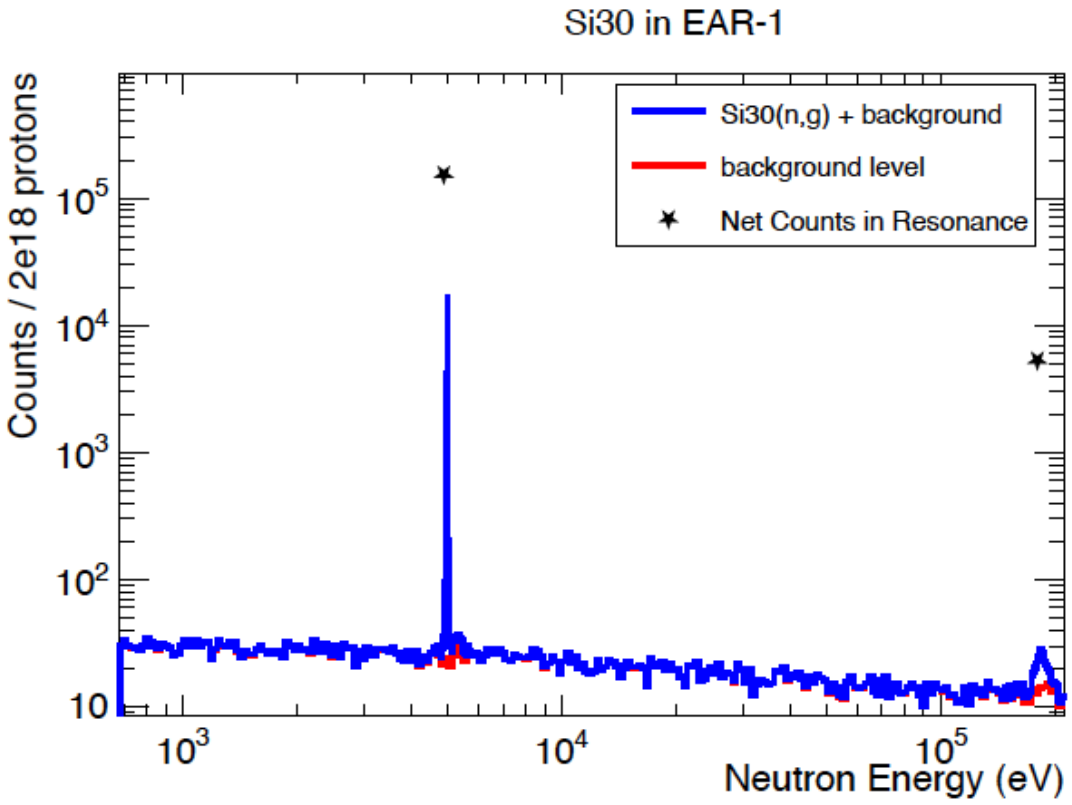
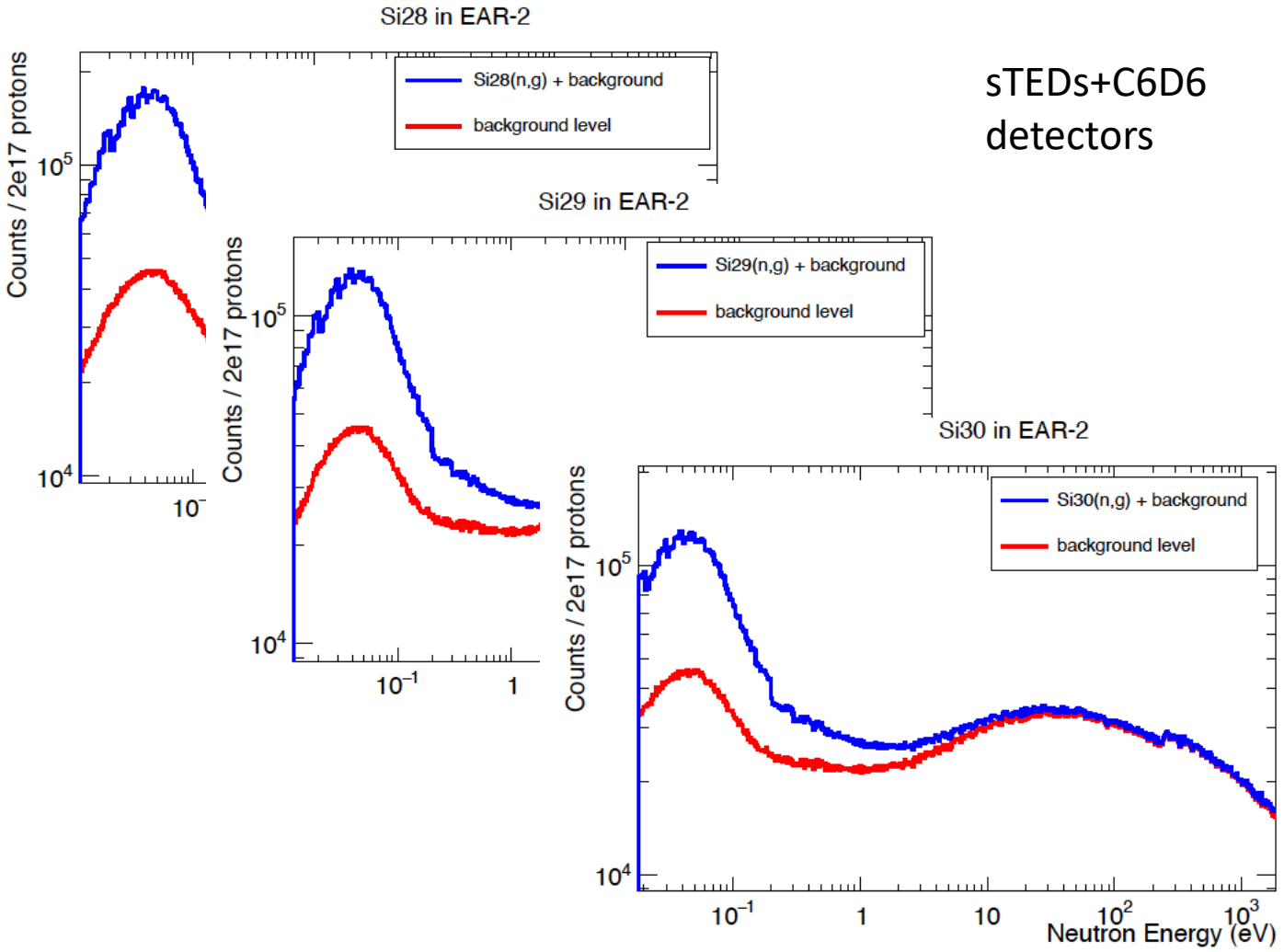


Measurement at EAR-1

- 1g of isotopically enriched material
- Legnaro type C_6D_6 Detection Setup
- 20% cascade efficiency assumed
- 2E18 protons



Thermal at EAR-2



sTEDs+C6D6 detectors

Beam time request

EAR-1

$2x10^{18}$ protons per Si isotope
$1x10^{18}$ protons for Au, Empty, C-nat

Total: $7x10^{18}$ protons

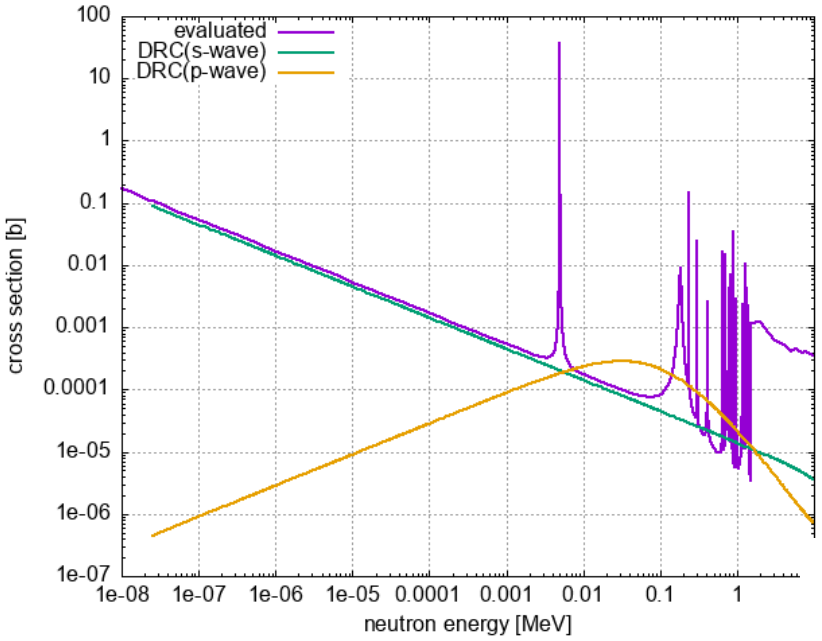
EAR-2

$2x10^{17}$ protons per Si isotope
$5x10^{17}$ protons for Au, Empty, C-nat

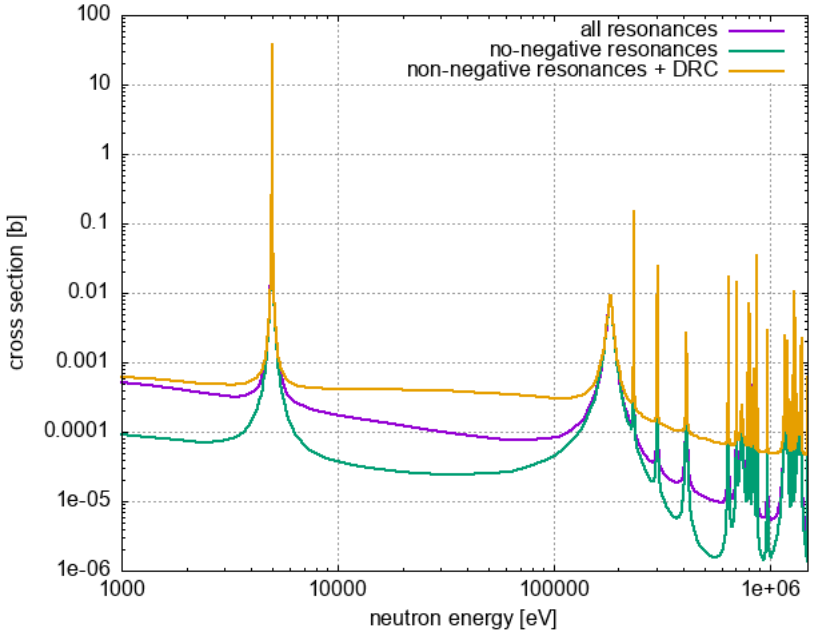
Total: $1.1x10^{18}$ protons

Extra slides

Direct Capture ^{30}Si

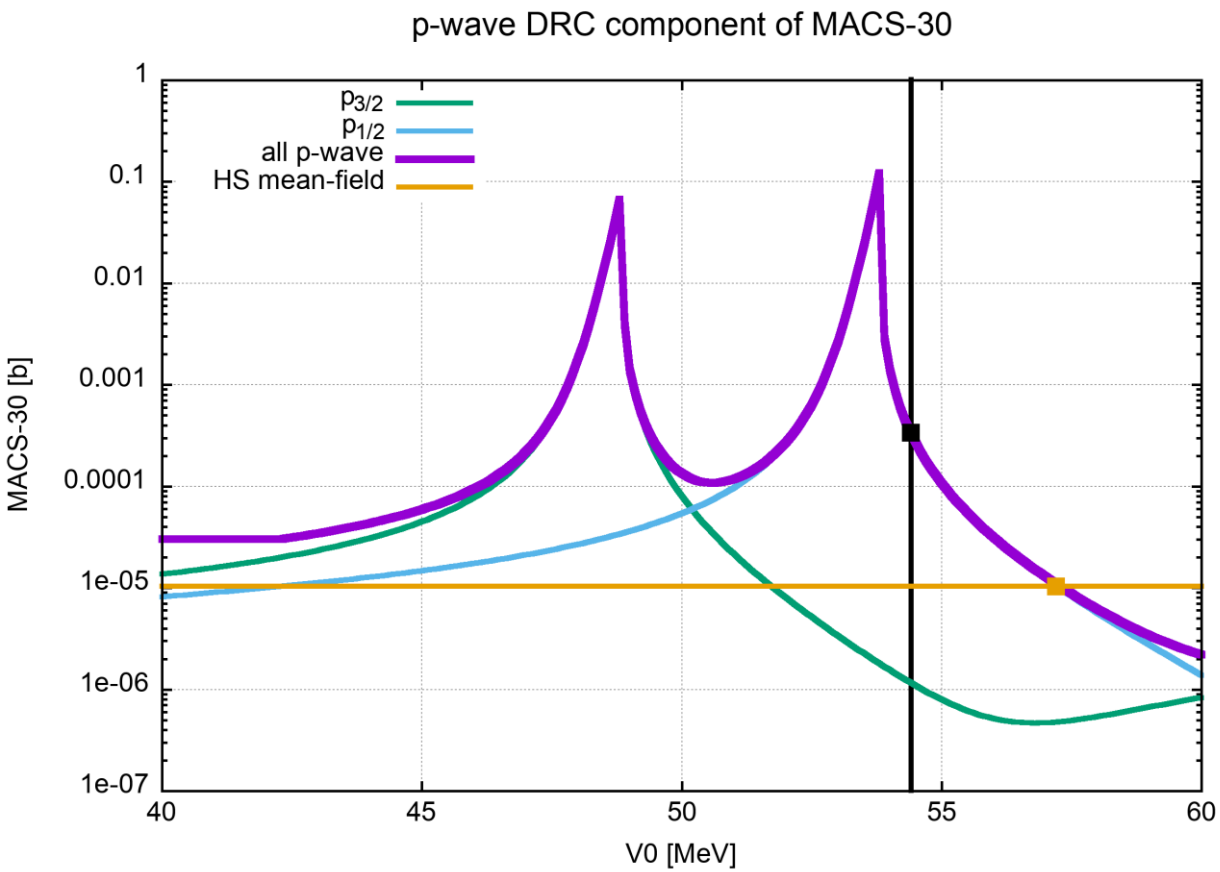


A. Mengoni



Direct Capture ^{30}Si

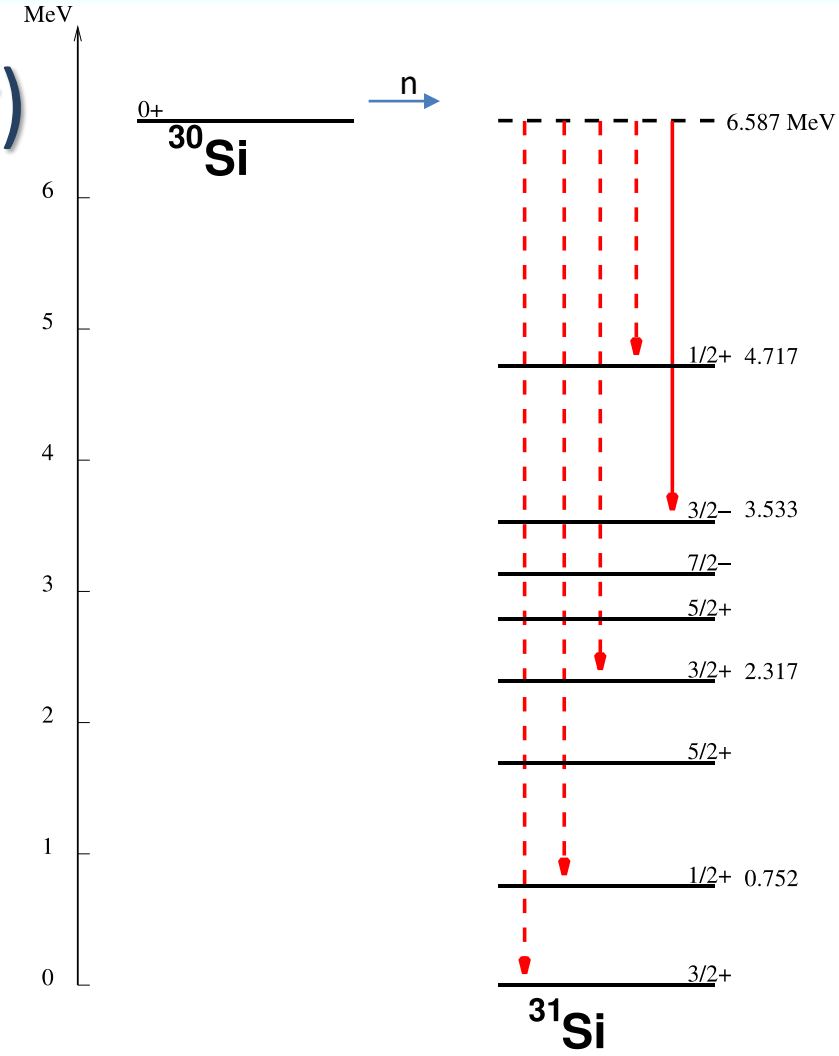
A. Mengoni



p-wave MACS-30 for Si-30. The extremely large sensitivity to the mean-field interacting potential is shown. The splitting of the 2p single-particle orbit is also apparent. The MACS-30 value obtained for a potential strength of 54.4 MeV is show as the interception with a vertical bar, while the value for a hard-sphere potential (independent, of course, on the potential strength) is shown by the horizontal line.

$^{30}Si(n,\gamma)$

$\sigma_\gamma = 107 \pm 2$ mb



s-wave neutrons

M1 transitions

E1 transition

CERN

nTOF