

# Addendum to the Proposal INTC-P-208 - Measurement of the neutron capture cross section of

**64Ni**  
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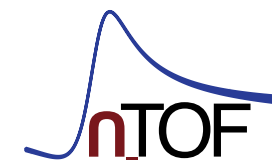
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n\_TOF

The neutron time-of-flight facility (n\_TOF) studies neutron-nucleus interactions for neutron energies ranging from a few meV to several GeV

Alberto Mengoni  
on behalf of the n\_TOF Collaboration

[www.cern.ch/n\\_TOF](http://www.cern.ch/n_TOF)



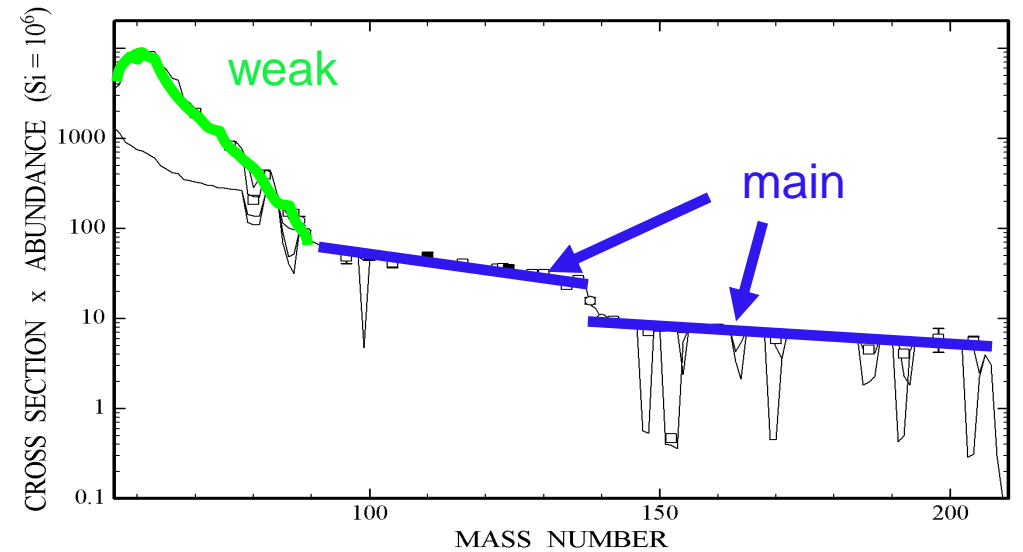
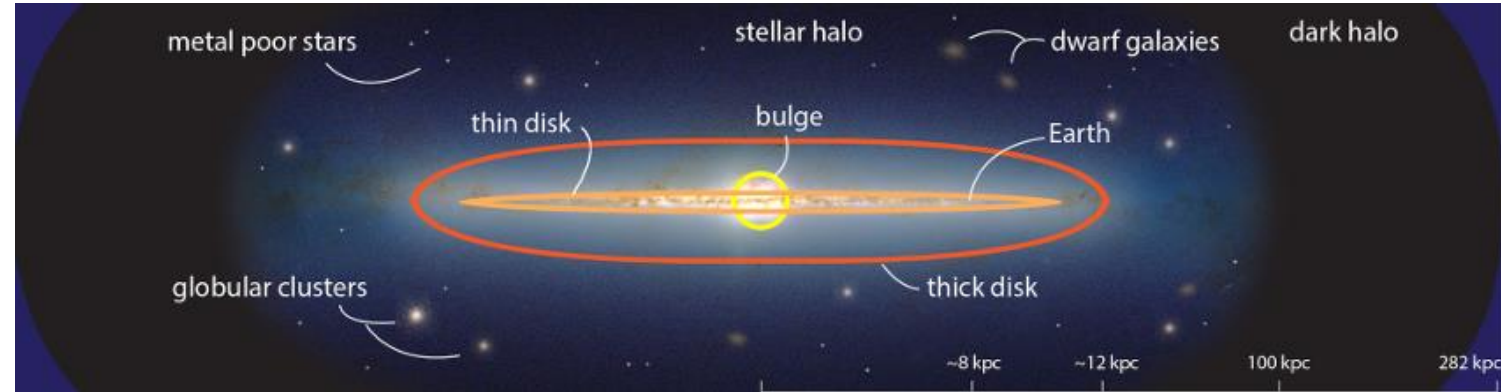
**The role of Fe and Ni**  
**for *s*-process nucleosynthesis in the early Universe**  
**and for innovative nuclear technologies**

J.L. Tain\*,<sup>1</sup> C. Domingo-Pardo,<sup>1</sup> F. Bečvář,<sup>2</sup> E. Berthoumieux,<sup>3</sup> F. Calviño,<sup>4</sup> D. Cano-Ott,<sup>5</sup>  
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The n\_TOF Collaboration

**Abstract**

The early universe was enriched in heavy elements by massive stars via their *s*- and *r*-process contributions. Ultra metal-poor stars were found to show abundance patterns that scale exactly with the solar *r* component. While this holds exactly for elements heavier than barium, there is still confusion about significant discrepancies in the mass region below  $A \leq 120$ . It is known that massive stars contribute significantly to the abundances between Fe and Zr. This so-called weak *s*-process component was found to exhibit large uncertainties due to the poorly known cross sections, especially in the Fe-Ni region. In view of this problem it is proposed to perform accurate state-of-the-art measurements on highly enriched samples of the stable Fe and Ni isotopes at the n\_TOF facility. Transformation of these results into significantly improved stellar cross section rates will allow to disentangle the *s* and *r* contributions observed in the oldest stars for a reliable comparison with galactic chemical evolution models. These results are also very important for the design of advanced reactor concepts.



source: F Käppeler (Prog. Part. Nucl. Phys. 43, 1999)

**weak:** core He burning in massive stars (e.g. 8 solar masses)  
**main:** He shell flashes in low mass TP-AGB stars



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Requested:  
2 x 10<sup>18</sup> protons/isotope to reach ~3% statistical uncertainty



*$^{62}\text{Ni}(n,\gamma)$  and  $^{63}\text{Ni}(n,\gamma)$  cross sections measured at the  $n_{\text{TOF}}$  facility at CERN*  
 C. Lederer, C. Massimi, E. Berthoumieux, N. Colonna, R. Dressler, C. Guerrero, F. Gunsing, F. Käppeler, N. Kivel, M. Pignatari, et al. (The  $n_{\text{TOF}}$  Collaboration)

Physical Review C **89**, 025810 (2014)

[10.1103/PhysRevC.89.025810](https://doi.org/10.1103/PhysRevC.89.025810)

Erratum: Physical Review C **92**, 019903 (2015)

[10.1103/PhysRevC.92.019903](https://doi.org/10.1103/PhysRevC.92.019903)

*Measurement of the  $^{54,57}\text{Fe}(n,\gamma)$  Cross Section in the Resolved Resonance Region at CERN  $n_{\text{TOF}}$*

G. Giubrone, C. Domingo-Pardo, J.L. Tain, C. Lederer, S. Altstadt, J. Andrzejewski, L. Audouin, M. Barbagallo, V. Bécaries, F. Bečvář, et al. (The  $n_{\text{TOF}}$  Collaboration)

Nuclear Data Sheets **119**, 117-120 (2014)

[10.1016/j.nds.2014.08.033](https://doi.org/10.1016/j.nds.2014.08.033)

*Experimental neutron capture data of Ni-58 from the CERN  $n_{\text{TOF}}$  facility*

P. Žugec, M. Barbagallo, N. Colonna, D. Bosnar, S. Altstadt, J. Andrzejewski, L. Audouin, V. Bécaries, F. Bečvář, F. Belloni, et al. (The  $n_{\text{TOF}}$  Collaboration)

Physical Review C **89**, 014605 (2014)

[10.1103/PhysRevC.89.014605](https://doi.org/10.1103/PhysRevC.89.014605)

*Neutron Capture Reactions on Fe and Ni Isotopes for the Astrophysical  $s$ -process*

C. Lederer, G. Giubrone, C. Massimi, P. Žugec, M. Barbagallo, N. Colonna, C. Domingo-Pardo, C. Guerrero, F. Gunsing, F. Käppeler, et al. (The  $n_{\text{TOF}}$  Collaboration)

Nuclear Data Sheets **120**, 201-204 (2014)

[10.1016/j.nds.2014.07.046](https://doi.org/10.1016/j.nds.2014.07.046)

*Neutron Capture Cross Section of Unstable Ni-63: Implications for Stellar Nucleosynthesis*

C. Lederer, C. Massimi, S. Altstadt, J. Andrzejewski, L. Audouin, M. Barbagallo, V. Bécaries, F. Bečvář, F. Belloni, E. Berthoumieux, et al. (The  $n_{\text{TOF}}$  Collaboration)

Physical Review Letters **110**, 022501 (2013)

[10.1103/PhysRevLett.110.022501](https://doi.org/10.1103/PhysRevLett.110.022501)

*The Role of Fe and Ni for  $s$ -process Nucleosynthesis and Innovative Nuclear Technologies*

G. Giubrone, J. L. Tain, C. Lederer, A. Pavlik, A. Wallner, S. Andriamonje, M. Brugger, M. Calviani, F. Cerutti, E. Chiaveri, et al. (The  $n_{\text{TOF}}$  Collaboration)

Journal of the Korean Physical Society **59**, 2106-2109 (2011)

[10.3938/jkps.59.2106](https://doi.org/10.3938/jkps.59.2106)

$^{54,57}\text{Fe}(n,\gamma)$

$^{58,62,63}\text{Ni}(n,\gamma)$  already measured and published

Zn 58 84 ms $\beta^+$ $\gamma$ 203; 848 $\beta$ 7	Zn 59 182 ms $\beta^+$ 8.1 $\gamma$ 491; 914 $\beta$ 1.78; 2.09; 1.82; 1.38...	Zn 60 2.4 m $\beta^+$ 2.5; 3.1... $\beta$ 670; 61; 273; 334...	Zn 61 1.5 m $\beta^+$ 4.4... $\gamma$ 475; 1660; 970...	Zn 62 9.13 h $\epsilon$ $\beta^+$ 0.7 $\gamma$ 41; 597; 548; 508...	Zn 63 38.1 m $\beta^+$ 2.3... $\gamma$ 670; 962; 1412...	Zn 64 48.268 $\sigma$ 0.74 $\sigma_{n,\alpha}$ $1.1E-5$ $\sigma_{n,p}$ $<1.2E-5$	Zn 65 24.39 d $\beta^+$ 0.3 $\gamma$ 1115... $\beta$ 66 $\sigma_{n,\alpha}$ 2.0	Zn 66 27.975 $\sigma$ 0.9 $\sigma_{n,\alpha}$ $<2E-5$	Zn 67 4.102 $\sigma$ 6.9 $\sigma_{n,\alpha}$ 0.0004	Zn 68 19.024 $\sigma$ 0.072 + 0.8 $\sigma_{n,\alpha}$ $<2E-5$	Zn 69 13.8 h 56 m $\beta$ 439 $\gamma$ (574) $\beta$ 0.9 $\gamma$ (319...)	Zn 70 0.631 $\sigma$ 0.0081 + 0.083	Zn 71 2.4 m $\beta^+$ 1.5; 2.5; $\beta$ 386; 487; 620; $\beta$ 2.8; 910; 390
Cu 57 199 ms $\beta^+$ 7.7... $\gamma$ 1112	Cu 58 3.20 s $\beta^+$ 7.5... $\gamma$ 1454; 1448; 40...	Cu 59 82 s $\beta^+$ 3.8... $\gamma$ 1302; 878; 339; 465...	Cu 60 23 m $\beta^+$ 2.0; 3.9... $\gamma$ 1332; 1792; 826...	Cu 61 3.4 h $\beta^+$ 1.2... $\gamma$ 283; 656; 67; 1186...	Cu 62 9.74 m $\beta^+$ 2.9... $\gamma$ (1173...)	Cu 63 69.15 $\sigma$ 4.5	Cu 64 12.700 h $\beta^+$ 0.7 $\gamma$ (1346) $\sigma$ 270	Cu 65 0.85 $\sigma$ 2.17	Cu 66 5.1 m $\beta$ 2... $\gamma$ 1039; (834...)	Cu 67 61.9 h $\beta$ 0.4; 0.6... $\gamma$ 185; 93; 91...	Cu 68 3.8 m 30 s $\beta$ 526; 85; 111; $\beta$ 1.7; 4.4; $\gamma$ 1077; 1261	Cu 69 3.0 m $\beta$ 2.5; $\gamma$ 1007; 834; 531...	Cu 70 33 s 44.5 s $\beta$ 886; 3.6; $\beta$ 885; 101; 902; 1252
Ni 56 6.075 d $\epsilon$ ; no $\beta^+$ $\gamma$ 158; 612; 750; 480; 270...	Ni 57 36.0 h $\epsilon$ $\beta^+$ 0.8... $\gamma$ 1378; 1920; 127...	Ni 58 68.0769 $\sigma$ 4.6 $\sigma_{n,\alpha}$ $<0.00003$	Ni 59 $7.5 \cdot 10^4$ a $\epsilon$ ; $\beta^+$ ... no $\gamma$ ; $\sigma$ 77.7 $\sigma_{n,\alpha}$ 14; $\sigma_{n,p}$ 2 $\sigma_{abs}$ 92	Ni 60 26.2231 $\sigma$ 2.9	Ni 61 1.1399 $\sigma$ 2.5 $\sigma_{n,\alpha}$ 0.00003	Ni 62 3.6345 $\sigma$ 15	Ni 63 100 a $\beta$ 0.7 $\sigma$ 20	Ni 64 9256 $\sigma$ 1.6	Ni 65 2.52 h $\beta$ 2.1... $\gamma$ 1482; 1115; 366...	Ni 66 54.6 h $\beta$ 0.2 no $\gamma$	Ni 67 21 s $\beta$ 3.8... $\gamma$ (1937; 1115; 822...)	Ni 68 29 s $\beta$ 758; 84 g	Ni 69 11.4 s $\beta$ 1871; 680; 1213; 1483...
Co 55 17.54 h $\beta^+$ 1.5... $\gamma$ 931; 477; 1409...	Co 56 77.26 d $\epsilon$ ; $\beta^+$ 1.5... $\gamma$ 847; 1238; 2558; 1771; 1038...	Co 57 271.79 d $\epsilon$ $\gamma$ 122; 136; 14	Co 58 8.94 h 70.86 d $\beta^+$ 0.5; 1.3 $\sigma$ 140000 $\sigma$ 1900	Co 59 100 $\sigma$ 20.7 + 16.5	Co 60 10.5 m 5.272 a $\beta$ 1.2... $\gamma$ 1332; 1173; $\sigma$ 58 $\sigma$ 9.9	Co 61 1.65 h $\beta$ 1.2... $\gamma$ 67; 909...	Co 62 14.0 m 1.5 m $\beta$ 2.8... $\beta$ 4.1... $\gamma$ 1173; 1173; 1103; 2302; 2303; 1129...	Co 63 27.5 s $\beta$ 3.6... $\gamma$ 87; 982...	Co 64 0.3 s $\beta$ 7.0... $\gamma$ 1346; 931	Co 65 1.14 s $\beta$ 6.0... $\gamma$ 1142; 311; 964...	Co 66 0.18 s $\beta$ 7.2; 8.5... $\gamma$ 1426; 1246; 1805	Co 67 425 ms $\beta$ 8.0... $\gamma$ 694...	Co 68 1.6 s 0.23 s $\beta$ 2033; 478; 2745... $\beta$ 2030; 815
Fe 54 5.845 $\sigma$ 2.9 $\sigma_{n,\alpha}$ $1E-5$	Fe 55 2.73 a $\epsilon$ no $\gamma$ $\sigma$ 13 $\sigma_{n,\alpha}$ 0.01	Fe 56 91.754 $\sigma$ 2.8	Fe 57 2.119 $\sigma$ 1.4	Fe 58 0.282 $\sigma$ 1.3	Fe 59 4.503 d $\beta$ 2.9... $\gamma$ 847; 1811; 2113...	Fe 60 1.5 $\cdot 10^6$ a $\beta$ 0.1 $\gamma$ 1099; 1292... $\sigma$ 13	Fe 61 1.65 h $\beta$ 2.6; 2.8... $\gamma$ 1205; 1027; 298...	Fe 62 68 s $\beta$ 2.5 $\gamma$ 506 g	Fe 63 6.1 s $\beta$ 6.7... $\gamma$ 995; 1427; 1299...	Fe 64 2.0 s $\beta$ 3.11	Fe 65 0.45 s $\beta$ 7.2	Fe 66 0.44 s $\beta$ 8.0	Fe 67 0.47 s $\beta$ 573... gn
Mn 53 $3.7 \cdot 10^8$ a $\epsilon$ no $\gamma$ $\sigma$ 70	Mn 54 312.2 d $\epsilon$ $\gamma$ 835 $\sigma$ $<10$	Mn 55 100 $\sigma$ 13.3	Mn 56 2.58 h $\beta$ 2.9... $\gamma$ 847; 1811; 2113...	Mn 57 1.5 m $\beta$ 2.6... $\gamma$ 14; 122; 692...	Mn 58 55.3 s 3.0 s $\beta$ 3.9... $\gamma$ 811; 1303; $\beta$ 6.1... $\gamma$ 1447; 2433...	Mn 59 4.6 s $\beta$ 4.4; 4.8... $\gamma$ 726; 473; 571...	Mn 60 0.28 s $\beta$ 5.7... 6.1... $\gamma$ 828; $\gamma$ 828; $\beta$ 8.2... 1150; $\beta$ 6.4... $\gamma$ 629; 207...	Mn 61 0.71 s $\beta$ 8.77; $\gamma$ 877; 942; 1299...	Mn 62 92 ms 625 ms $\beta$ 8.77; 942; 1299...	Mn 63 0.25 s $\beta$ $>3.7$ $\gamma$ 356	Mn 64 88.8 ms $\beta$ 7.46...	Mn 65 92 ms $\beta$ 366 gn	Mn 66 64.4 ms $\beta$ 573... gn
Cr 52 83.789 $\sigma$ 0.8	Cr 53 9.501 $\sigma$ 18	Cr 54 2.365 $\sigma$ 0.36	Cr 55 3.50 m $\beta$ 2.6 $\gamma$ (1528...)	Cr 56 5.9 m $\beta$ 1.5 $\gamma$ 83; 26	Cr 57 21.1 s $\beta$ 5.1... $\gamma$ 83; 850; 1752; 1535...	Cr 58 7.0 s $\beta$ 683; 126; 290; 520... m	Cr 59 1.05 s $\beta$ 1238; 1900; 112; 663...	Cr 60 0.49 s $\beta$ 6.7... $\gamma$ 349; 410; 758 g	Cr 61 0.27 s $\beta$ 285; 355; 640... m	Cr 62 209 ms $\beta$ 250 - 3454	Cr 63 129 ms $\beta$ 188	Cr 64 43 ms $\beta$ 272; 1368 gn	Cr 65 27 ms $\beta$ 272; 1368 gn

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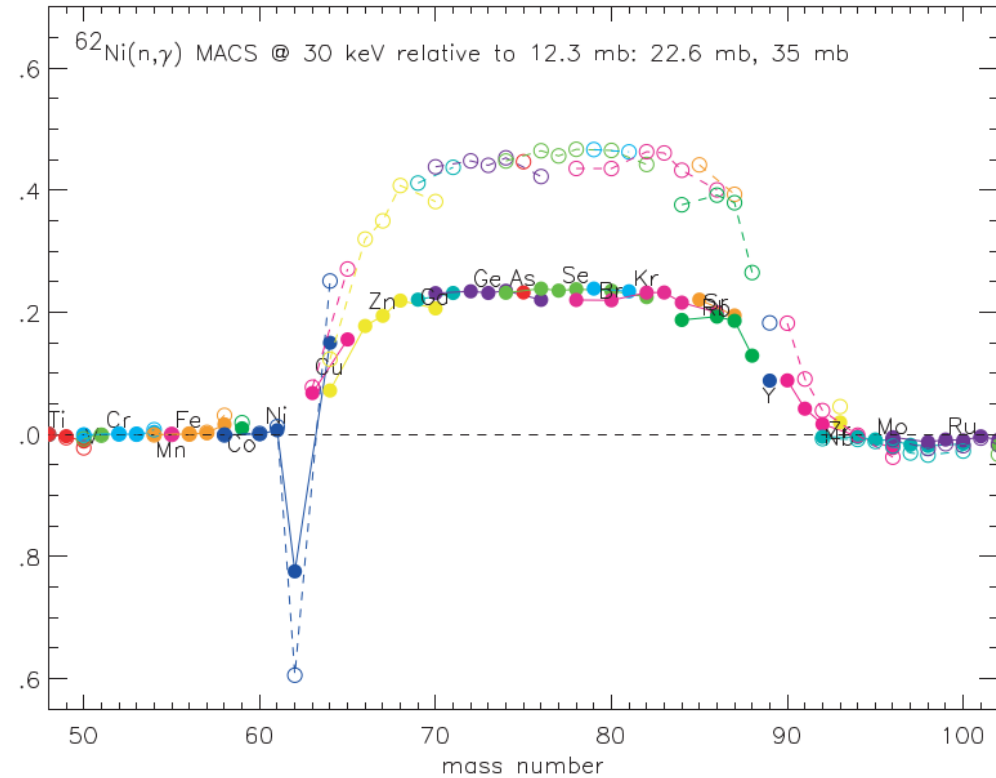


FIG. 3: The effect of cross section uncertainties on the *s*-process efficiency in massive stars illustrated at the example of  $^{62}\text{Ni}$  [13] (see text).

Requested:

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# Addendum to the Proposal INTC-P-208 - Measurement of the neutron capture cross section of $^{64}\text{Ni}$

## EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

### Addendum of the Proposal INTC-P-208

#### Measurement of the neutron capture cross section of $^{64}\text{Ni}$

G. Tagliente<sup>1</sup>, G. Cescutti<sup>2,3</sup>, N. Colonna<sup>1</sup>, S. Cristallo<sup>4,5</sup>, D. Diacono<sup>1</sup>, C. Lederer-Wood<sup>6</sup>, C. Massimi<sup>7,8</sup>, M. Mastromarco<sup>1,9</sup>, A.M. Mazzone<sup>1,10</sup>, P.M. Milazzo<sup>3</sup>, N. Sosnin<sup>11</sup>, D. Vescovi<sup>12</sup>

The following document is an addendum to the proposal INTC-P-208 [1], approved in 2006, concerning the measurement of the neutron capture cross-section of highly enriched samples of the stable Fe and Ni isotopes. The proposed measurements aimed at improving the existing cross section data of interest for the *s*-process nucleosynthesis in *Massive* stars and for innovative nuclear technologies.

In the past years the neutron capture cross sections of the  $^{54,57}\text{Fe}$ ,  $^{58,62,63}\text{Ni}$  isotopes has been successfully performed at the n\_TOF experimental area 1 (EAR1), the results of this work together with the astrophysical implications are reported in several publications and conference proceedings [2,3,4].

The measurement of the  $^{64}\text{Ni}(n,\gamma)$  has been postponed in the past due to the cost of the sample, while now it can be performed using small quantities of  $^{64}\text{Ni}$ , taking advantage of the higher neutron flux available in the n\_TOF experimental area 2 (EAR2).

Together with the astrophysical motivations exhaustively mentioned in the original proposal [1], a further important reason for measuring neutron capture reactions of the  $^{64}\text{Ni}$  is that the Maxwellian Averaged Cross Section (MACS) suffers for severe discrepancies, amongst the databases available in literature, as showed in Fig 1.



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Moreover, recent magnetic Asymptotic Giant Branch models [5] were found to be in disagreement with respect to nickel isotopic ratios measurements in presolar SiC grains (see Fig. 2). Note that other nickel isotopic ratios are well matched by theoretical models.

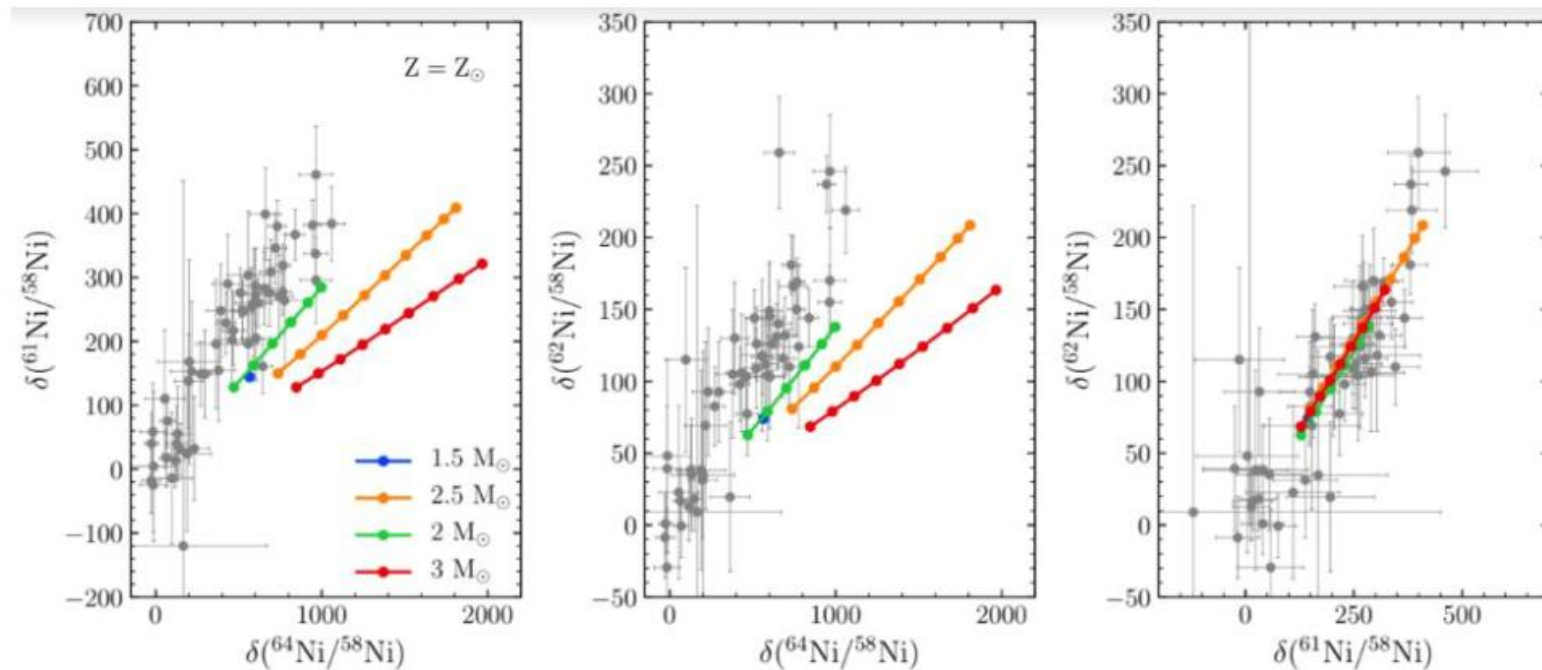


Figure 2 Comparison between theoretical AGB models and presolar grain measurements.

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Availability of Ni-64 sample material

**ISOFLEX USA**

*Isotopes for Science, Medicine and Industry*

P.O. Box 29475  
San Francisco CA 94129 USA  
Tel: 415-440-4433 Fax: 415-563-4433  
Email: [iusa@isoflex.com](mailto:iusa@isoflex.com)  
FEIN: 20-8066748

## QUOTATION

*Confidential Business Matter*

DATE: June 30, 2021  
QUOTE NUMBER: 210630-I/R  
SELLER CONTACT: Allan Pashkovski

**BUYER:**

Attn: Dr. Giuseppe Tagliente  
INFN Bari  
Via Orabona, 4  
Bari 70125  
Italy  
[giuseppe.tagliente@ba.infn.it](mailto:giuseppe.tagliente@ba.infn.it)  
Tel. +390805442351

**CONSIGNEE / SHIP TO:**

TBD

**QUOTATION SUMMARY**

DESCRIPTION	PROPOSED DELIVERY	QUANTITY	UNIT PRICE	SUBTOTAL
Nickel-64 (Ni-64), metal powder Isotopic Enrichment: 99,33atom% Harmonized Code: - 2845.90.0000 (USA)	~4 weeks ARO	2000 mg	\$31.50 per mg	\$63,000.00

## EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

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Istituto Nazionale di Fisica Nucleare, Sez. di Bari, Italy

Università di Trieste, Dipartimento di Fisica, Trieste, Italy

Istituto Nazionale di Fisica Nucleare, Sez. Trieste, Italy

Istituto Nazionale di Astrofisica, Osservatorio Astronomico d'Abruzzo, Teramo, Italy

Istituto Nazionale di Fisica Nucleare, Sez. di Perugia, Italy

School of Physics and Astronomy, University of Edinburgh, United Kingdom

Istituto Nazionale di Fisica Nucleare, Sez. di Bologna, Italy

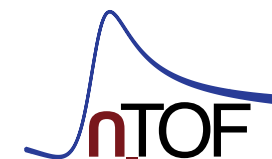
Università di Bologna, Dipartimento di Fisica e Astronomia, Bologna, Italy

Università degli Studi di Bari, Dipartimento Interateneo di Fisica, Bari, Italy

CNR, Istituto di Cristallografia, Bari, Italy

University of Manchester, United Kingdom

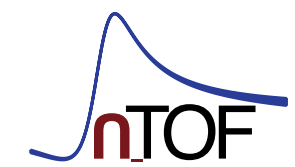
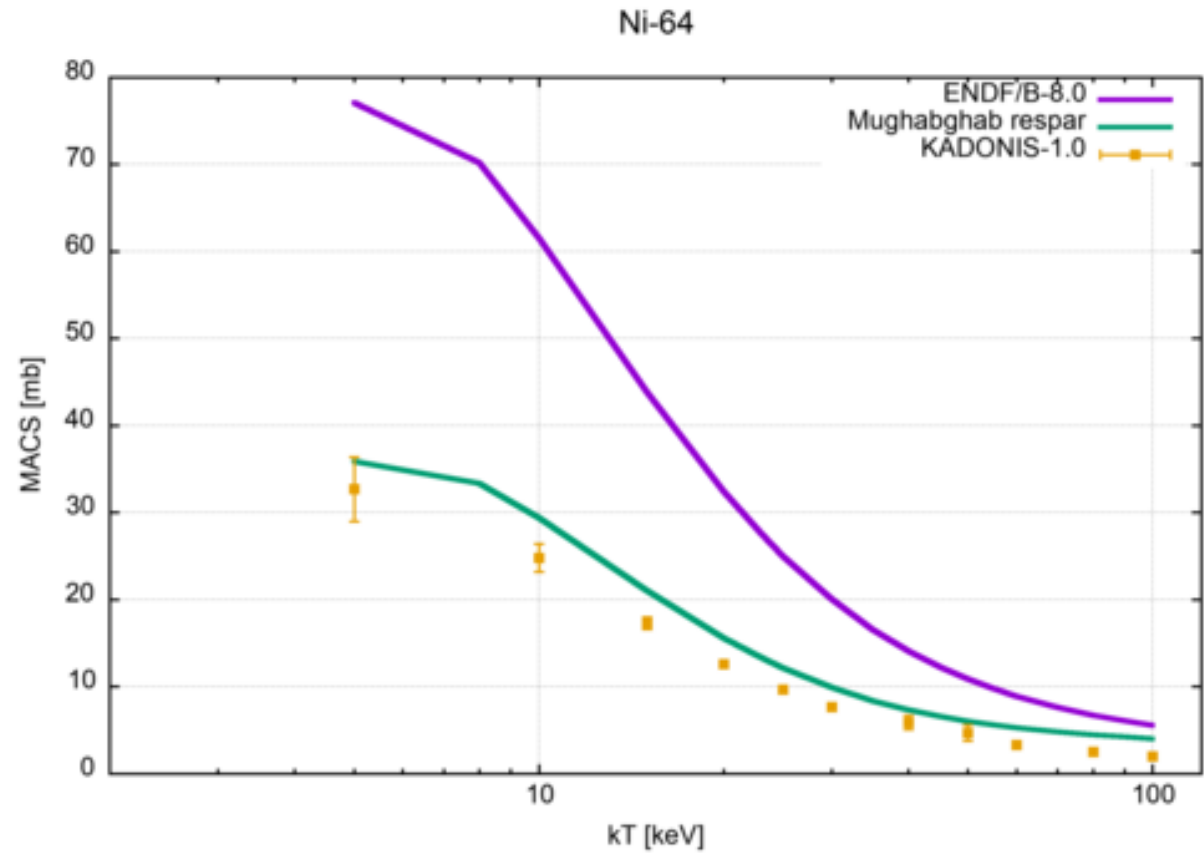
Goethe University Frankfurt, Max-von-Laue-Strasse 1, Frankfurt am Main 60438, Germany





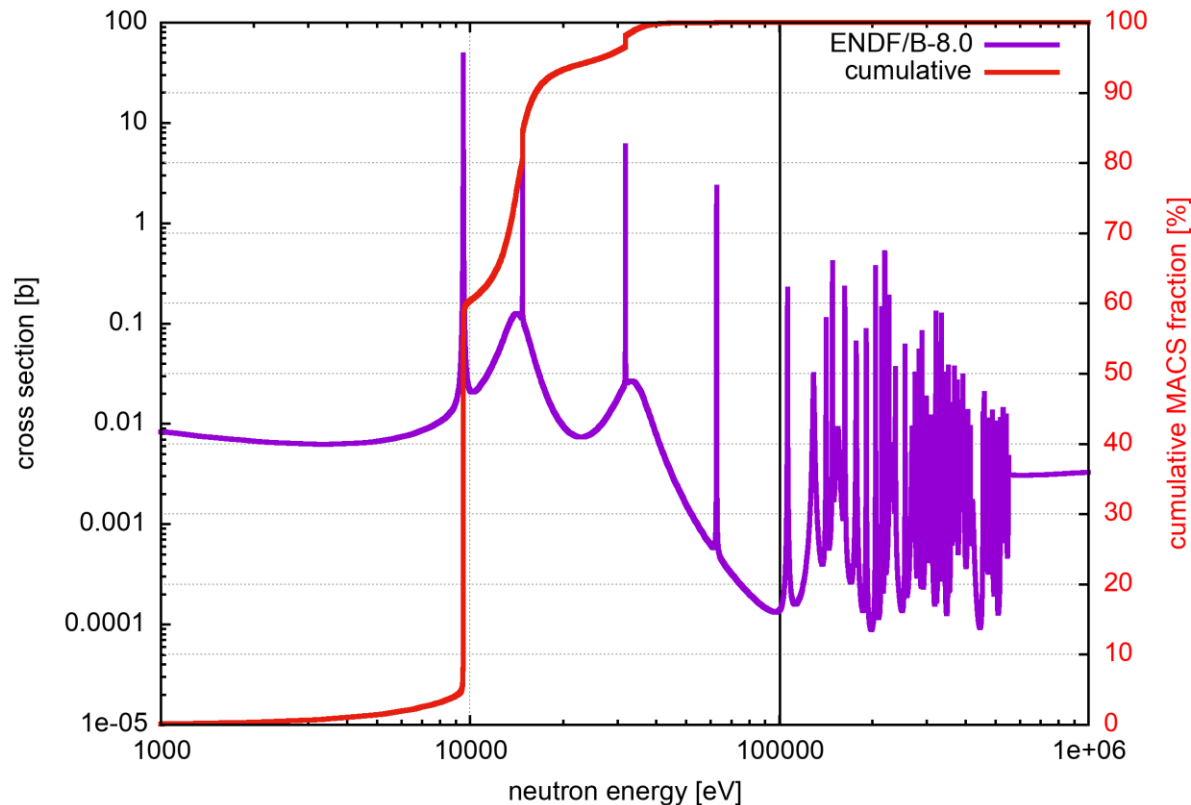
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Significant discrepancies on data previously available

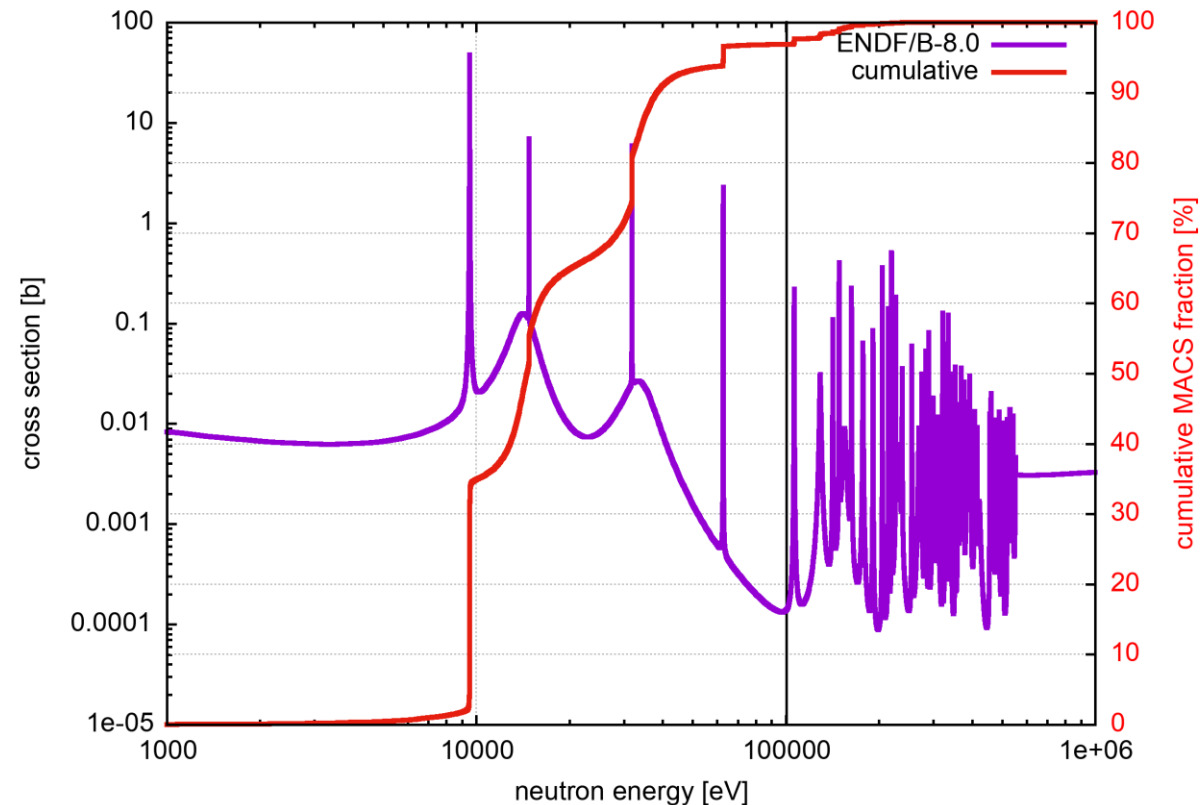


# Addendum to the Proposal INTC-P-208 - Measurement of the neutron capture cross section of $^{64}\text{Ni}$

$kT = 8 \text{ keV}$ ,  $\text{MACS}(\text{ENDF/B-8.0}) = 70.3 \text{ mb}$



$kT = 30 \text{ keV}$ ,  $\text{MACS}(\text{ENDF/B-8.0}) = 20.1 \text{ mb}$



# Addendum to the Proposal INTC-P-208 - Measurement of the neutron capture cross section of $^{64}\text{Ni}$

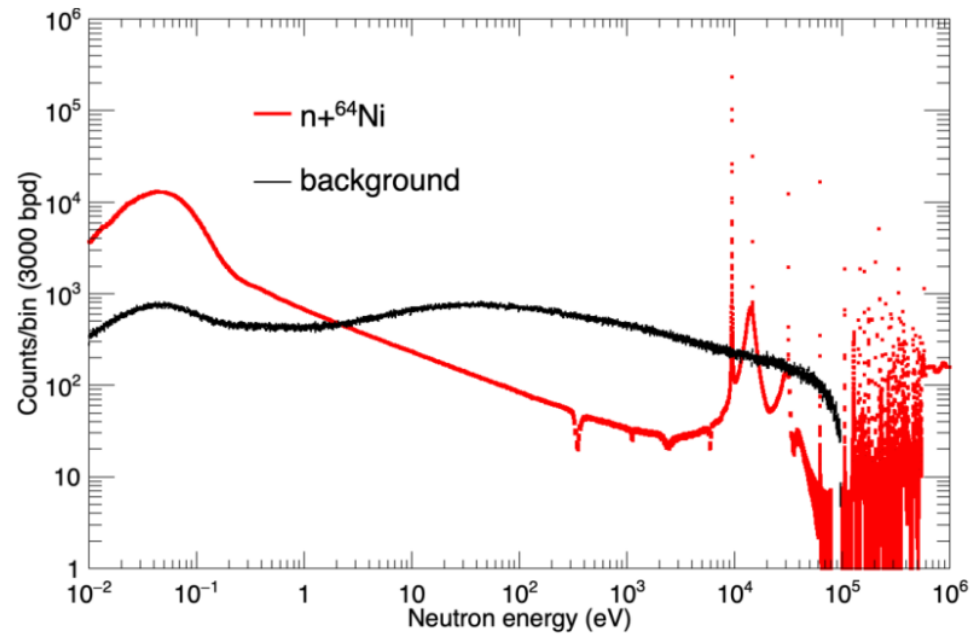


Figure 3. Expected counting rate for the  $^{64}\text{Ni}$  using mono-isotopic sample of 200 mg in EAR2. In the calculation the neutron irradiation corresponds to an intensity of  $1.0 \times 10^{18}$  protons. The black line represents the expected background level during measurement.

## EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH Addendum of the Proposal INTC-P-208

### Measurement of the neutron capture cross section of $^{64}\text{Ni}$

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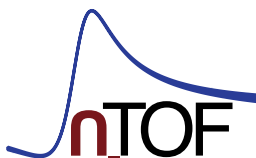
University of Manchester, United Kingdom

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

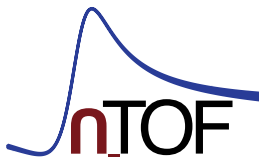
Request:

$1.5 \times 10^{18}$  protons in EAR2 to reach  $\sim 5\%$  statistical uncertainty

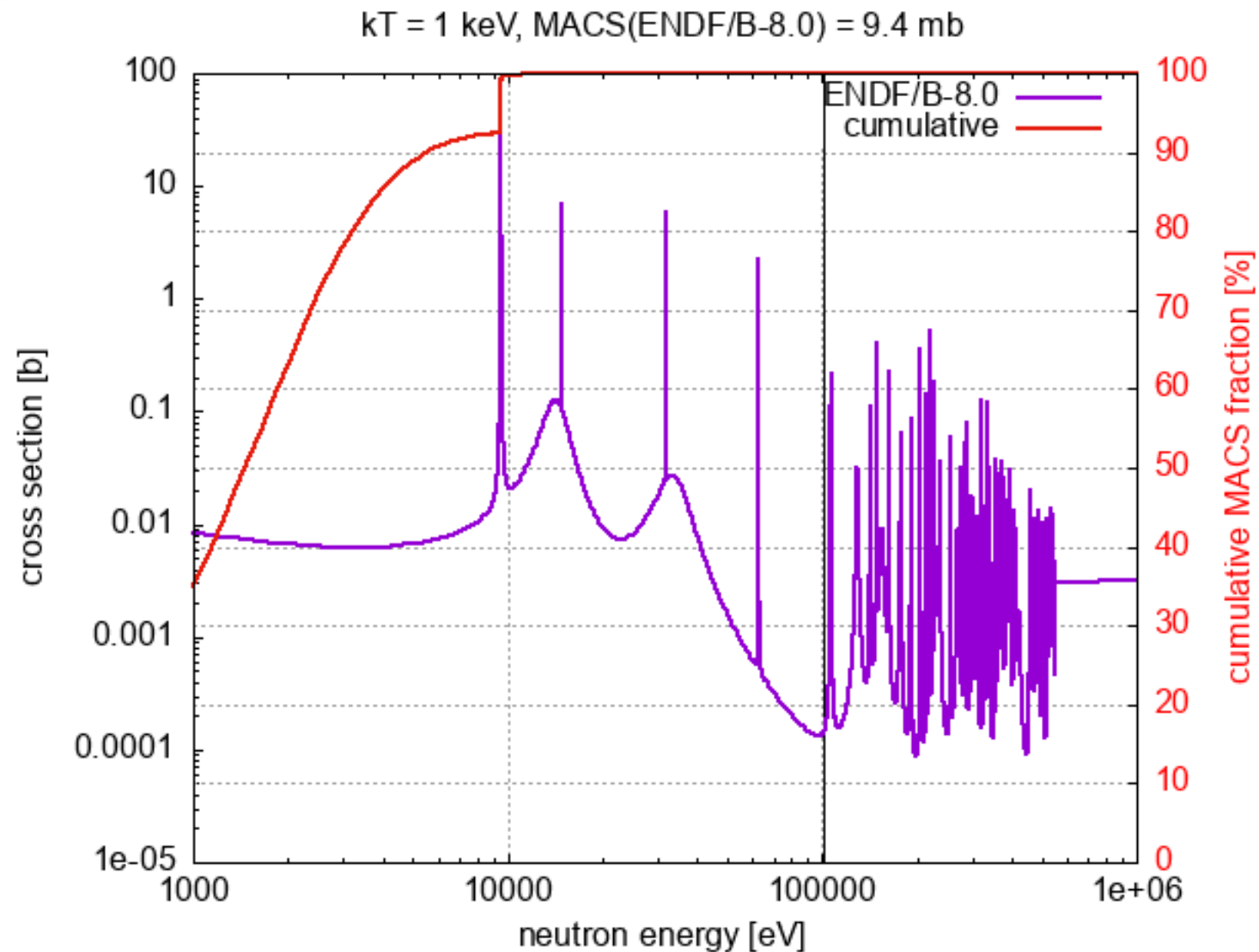
(reduced with respect to the original proposal due to the higher neutron flux in EAR2)



# The End



# Addendum to the Proposal INTC-P-208 - Measurement of the neutron capture cross section of $^{64}\text{Ni}$



# Addendum to the Proposal INTC-P-208 - Measurement of the neutron capture cross section of $^{64}\text{Ni}$

 $^{64}_{28}\text{Ni}$ 

## THERMAL CROSS SECTIONS

$$\begin{aligned}\sigma_{\gamma}^0 &= 1.63 \pm 0.02 \text{ b} \\ \sigma_{\text{s}}^0 &= 0.014 \pm 0.005 \text{ b} \\ \sigma_{\text{t}}^0 &= 1.64 \pm 0.02 \text{ b} \\ b_{\text{coh}} &= -0.38 \pm 0.07 \text{ fm} \\ g_{\gamma} &= 1.004 \\ R^{\gamma} &= 6.97 \pm 0.30 \text{ fm}\end{aligned}$$

## RESONANCE PROPERTIES

$$\begin{aligned}D_0 &= 21.1 \pm 2.0 \text{ keV} \\ D_{\gamma} &= 9.2 \pm 0.6 \text{ keV} \\ S_0 &= 2.6 \pm 0.7 \\ S_{\gamma} &= 0.77 \pm 0.14 \\ I_{\gamma} &= 1.07 \pm 0.15 \text{ b} \\ I_{\gamma}^c &= 0.76 \pm 0.06 \text{ b} \\ \sigma_{\gamma}^c(5 \text{ keV}) &= 26.1 \pm 5.2 \text{ mb} \\ \sigma_{\gamma}(30 \text{ keV}) &= 7.66 \pm 0.26 \text{ mb} \\ \sigma_{\gamma}^c(30 \text{ keV}) &= 8.7 \pm 0.6 \text{ mb}\end{aligned}$$

## RESONANCE PARAMETERS

$$\begin{aligned}I^{\pi} &= 0^+ \\ \sigma_{\gamma}(+) &= 0.72 \text{ b}\end{aligned}$$

$$\begin{aligned}\% \text{Abn} &= 0.926 \\ \sigma_{\gamma}(\text{B}) &= 0.91 \text{ b}\end{aligned}$$

$$\begin{aligned}\text{Sn} &= 6098.09 \pm 0.14 \text{ keV} \\ \sigma_{\gamma}(\text{D}) &= 1.37 \text{ b}\end{aligned}$$

$E_0$ (keV)	J	l	$g\Gamma_n$ (eV)	$\Gamma_{\gamma}$ (eV)	$g\Gamma_n^0$ (eV)	$g\Gamma_n^1$ (eV)	$g\Gamma_n\Gamma_{\gamma}/\Gamma$ (eV)
-1.01	1/2	0		(1.04)	0.19		
9.571 ± 0.100	(3/2)	[1]	(7)	0.4			
14.3 ± 0.2	1/2	0	2900 ± 500	1.01 ± 0.07	24 ± 4		1.01 ± 0.07
14.8 ± 0.1	(1/2)	[1]	(10)	0.25			
31.8 ± 0.1	(3/2)	[1]	(10)	0.41			
33.81 ± 0.04	1/2	0	8900 ± 500	1.16 ± 0.08	48 ± 3		1.16 ± 0.08
62.8 ± 0.4	(3/2)	[1]	(20)	0.44			
106.52 ± 0.08		1	110 ± 30			2.6 ± 0.7	
129.32 ± 0.03	1/2	0	1400 ± 50		3.89 ± 0.14		
141.5 ± 0.1		1	170 ± 20			2.7 ± 0.3	
148.8 ± 0.1	1/2	0	80 ± 20		0.21 ± 0.05		
155.0 ± 0.1	1/2	0	3950 ± 100		10.0 ± 0.3		
163.2 ± 0.1	1/2	0	160 ± 20		0.40 ± 0.05		
177.7 ± 0.1	1/2	0	470 ± 30		1.11 ± 0.07		
191.0 ± 0.2		1	140 ± 30			1.5 ± 0.3	
205.3 ± 0.2	1/2	0	60 ± 20		0.13 ± 0.04		

