Proposta di studio n + ^{63,65}Cu a n_TOF

n + rame = ramen

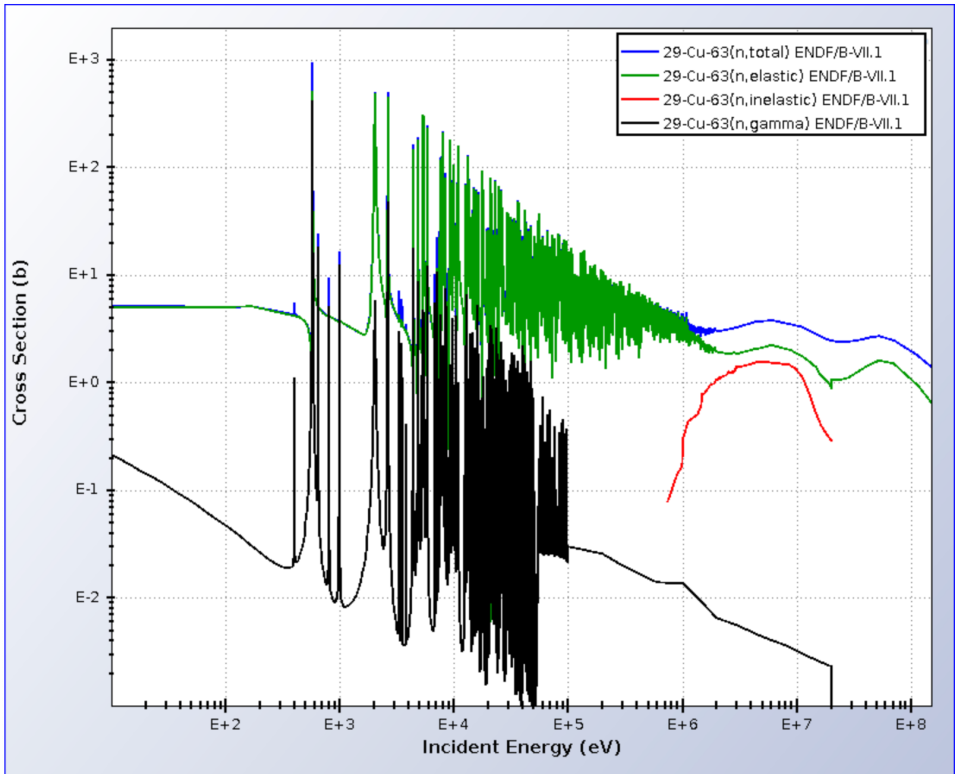
(proposal INFN + ENEA in APRENDE)

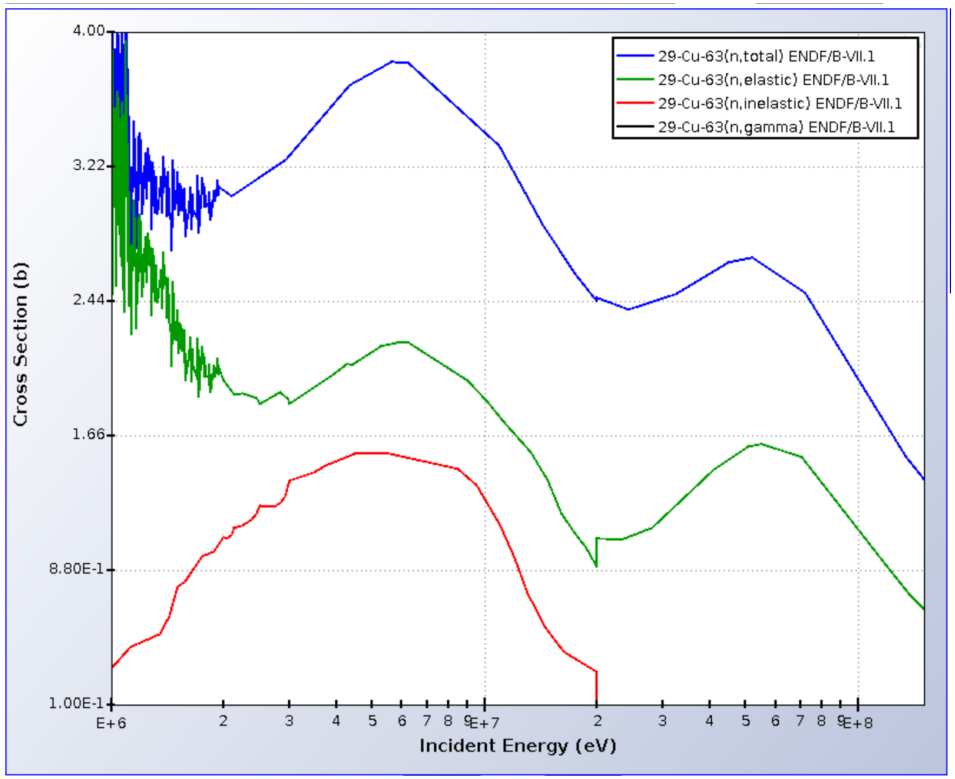
Sezioni d'urto n + ^{63}Cu

$\Gamma_n >> \Gamma_\gamma$

$\sigma_{el} > \sigma_{anel}$

Prodotti della reazione	*Q-valore* (keV)
$^{63}Cu + n$	0
$^{64}Cu + \gamma$	7915.9 ± 0.6
$^{60}Co + \alpha$	1717.0 ± 0.6
$^{63}Ni + p$	715.4 ± 0.6



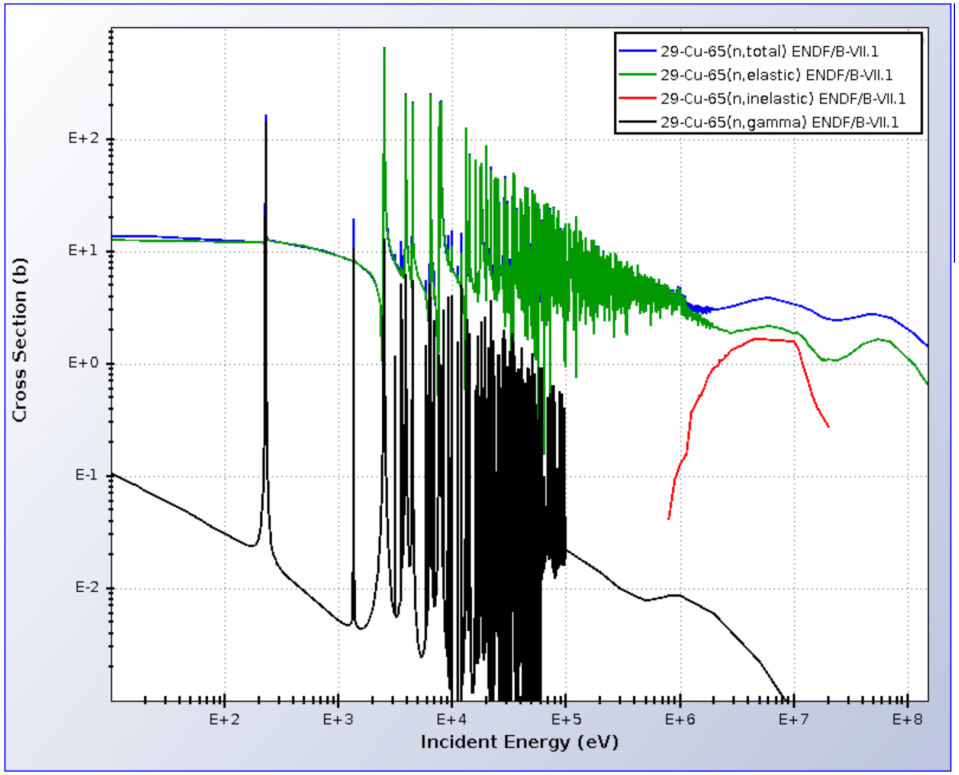


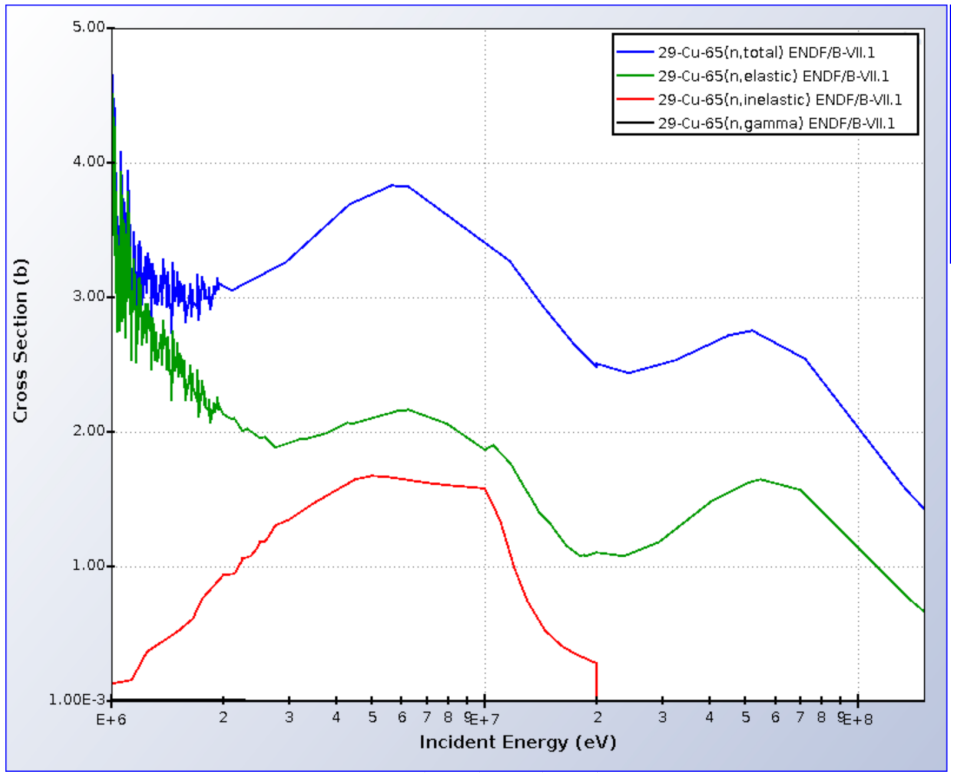
Sezioni d'urto n + ^{65}Cu

$\Gamma_n >> \Gamma_\gamma$

$\sigma_{el} > \sigma_{anel}$

Prodotti della reazione	*Q-valore* (keV)
$^{65}Cu + n$	0
$^{66}Cu + \gamma$	7065.9 ± 0.9
$^{62}Co + \alpha$	-193 ± 18
$^{65}Ni + p$	-1355.5 ± 0.8





Interesse scientifico

- Tecnologie nucleari

TECNOLOGIE NUCLEARI

- Astrofisica Nucleare

ASTROFISICA NUCLEARE

TECNOLOGIE NUCLEARI

Tecnologie nucleari: TAPIRO

TAratura Pila Rapida Potenza ZerO

- 5 kW Potenza
- Combustibile U-Mo
- Core = cilindro retto di 12 cm
- Arricchimento ^{235}U = 93.5%
- $4x10^{12}$ n/s
- Non moderato

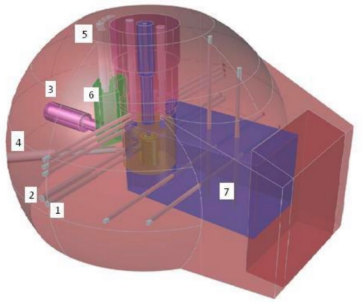
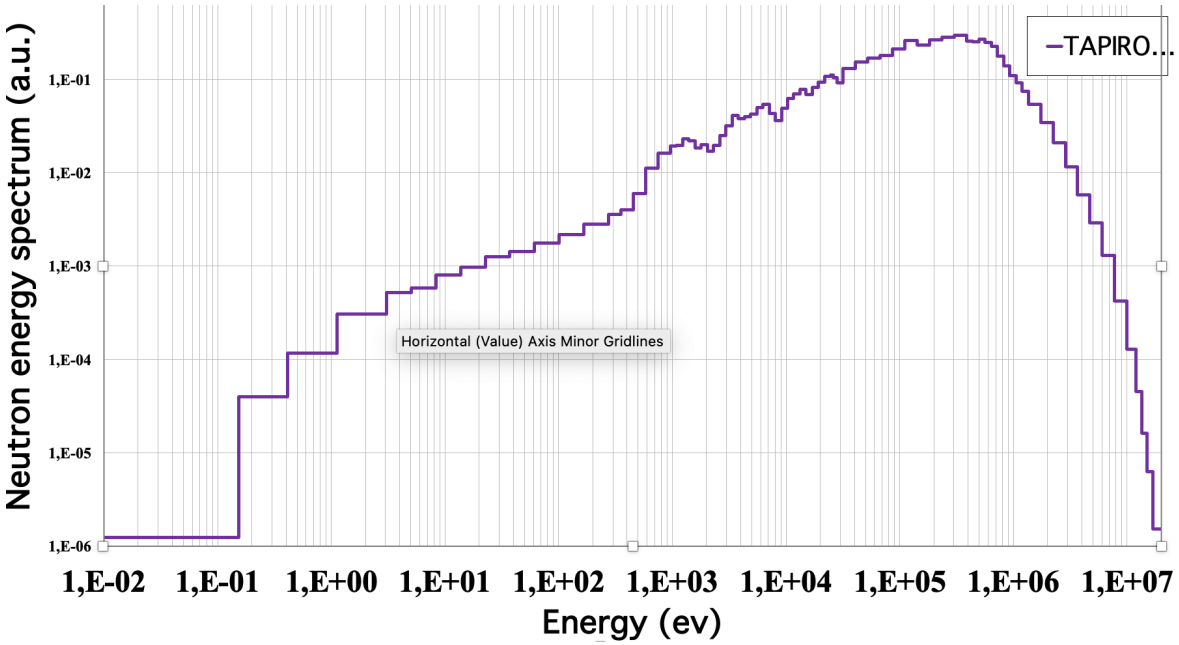


Figura 1.8: Componenti del reattore TAPIRO: 1) Canale diametrale, 2) Canale tangenziale, 3) Canale radiale 1, 4) Canale radiale 2, 5) Canali rilevatori, 6) Paraffina, 7) Colonna termica [9].

Tecnologie nucleari: TAPIRO



Tipico spettro di fissione, con massimo a E_n=820 keV
Ideale per studi di reattori veloci:

- test di materiali
- Validazione di dati nucleari

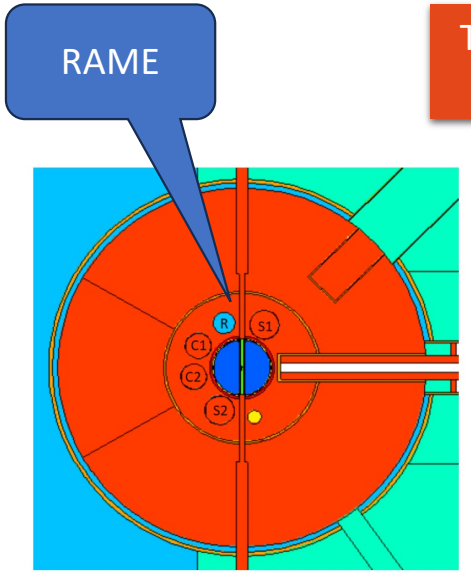
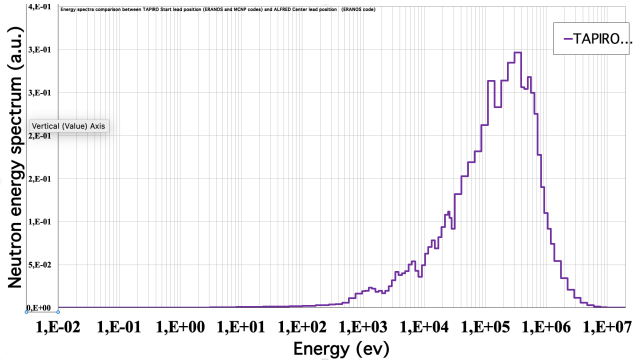
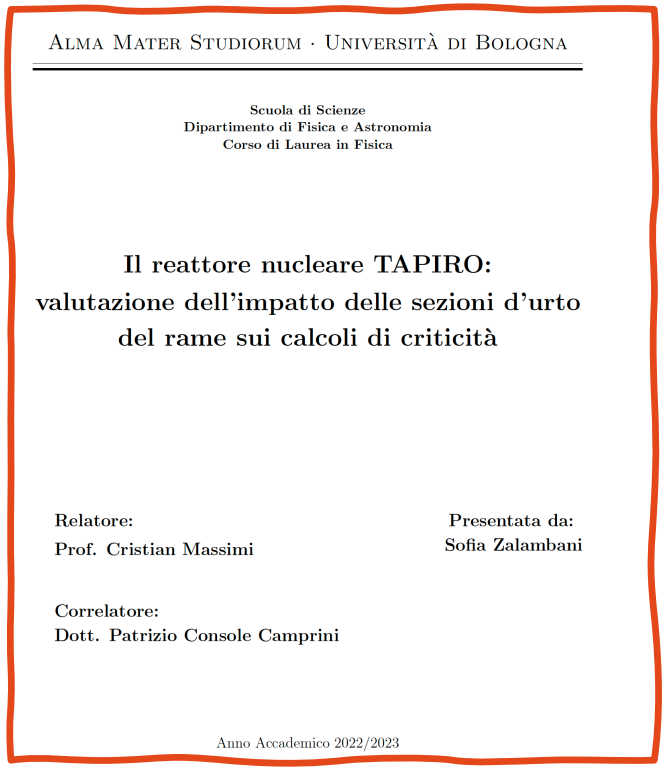


Figura 2.25: Sezione del reattore TAPIRO realizzata grazie al programma VISED. Nella figura si possono osservare in arancione il riflettore in rame, che si estende per un diametro di circa 80 cm, e in blu il nocciolo, costituito dalla lega di uranio e molibdeno, con diametro pari a 12 cm. Sono inoltre evidenti le 5 barre: 1 di regolazione (R), 2 di controllo (C1 e C2) e 2 di sicurezza (S1 e S2).



TECNOLOGIE NUCLEARI

Tecnologie nucleari: TAPIRO



ALMA MATER STUDIORUM · UNIVERSITÀ DI BOLOGNA

Scuola di Scienze
Dipartimento di Fisica e Astronomia
Corso di Laurea in Fisica

Il reattore nucleare TAPIRO: valutazione dell'impatto delle sezioni d'urto del rame sui calcoli di criticità

Relatore:
Prof. Cristian Massimi

Presentata da:
Sofia Zalambani

Correlatore:
Dott. Patrizio Console Camprini

Anno Accademico 2022/2023

Libreria	k_{eff}
JEFF3.3	1.00637 ± 0.00001
JENDL-5	1.00147 ± 0.00001
TENDL-2021	1.00102 ± 0.00001

^{63}Cu

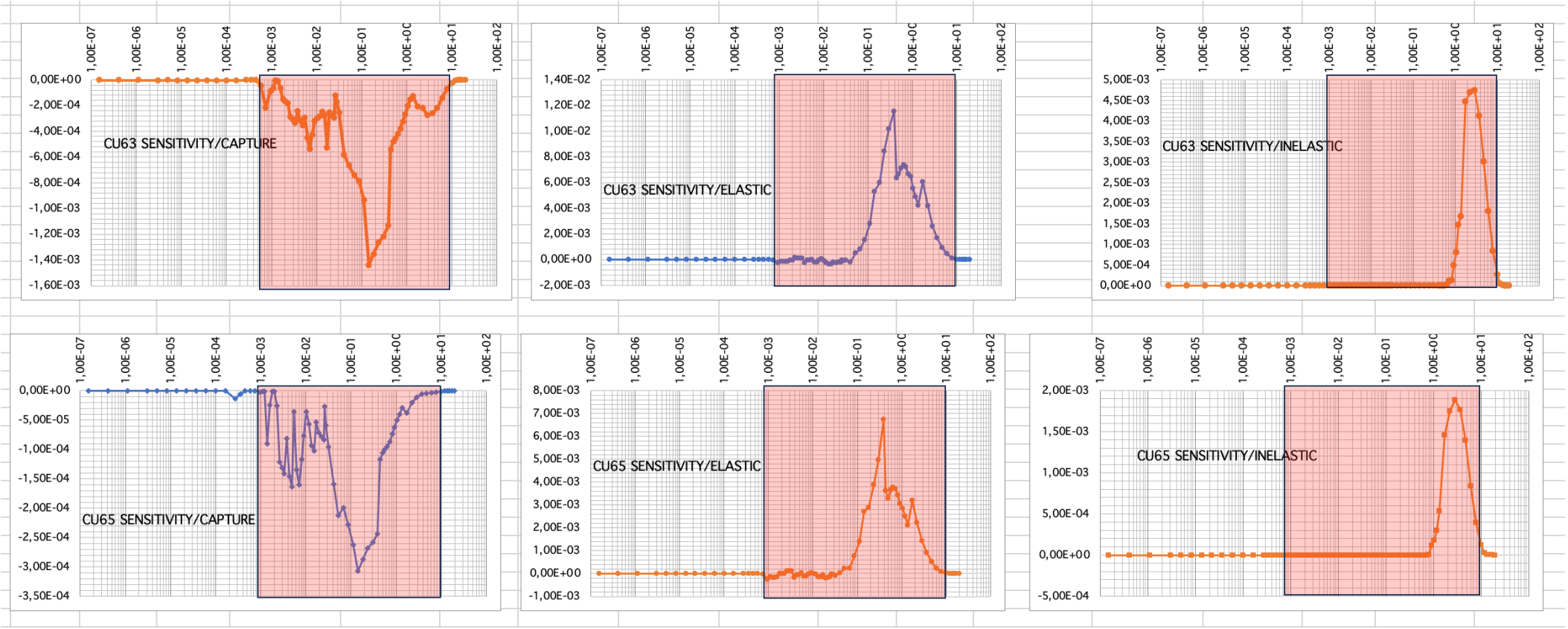
Libreria	k_{eff}
JEFF3.3	0.99980 ± 0.00001
JENDL-5	0.99782 ± 0.00001
TENDL-2021	1.00017 ± 0.00001

^{65}Cu

In entrambi i casi:
barre regolate affinché ENDF/B-VIII.0 → k_{eff} = 1.00000

TECNOLOGIE NUCLEARI

Tecnologie nucleari: TAPIRO



ERANOS Sensitivity studies by **Donato Castelluccio**

ASTROFISICA NUCLEARE

Come si è prodotto il rame?

- Weak s process
- SNIa

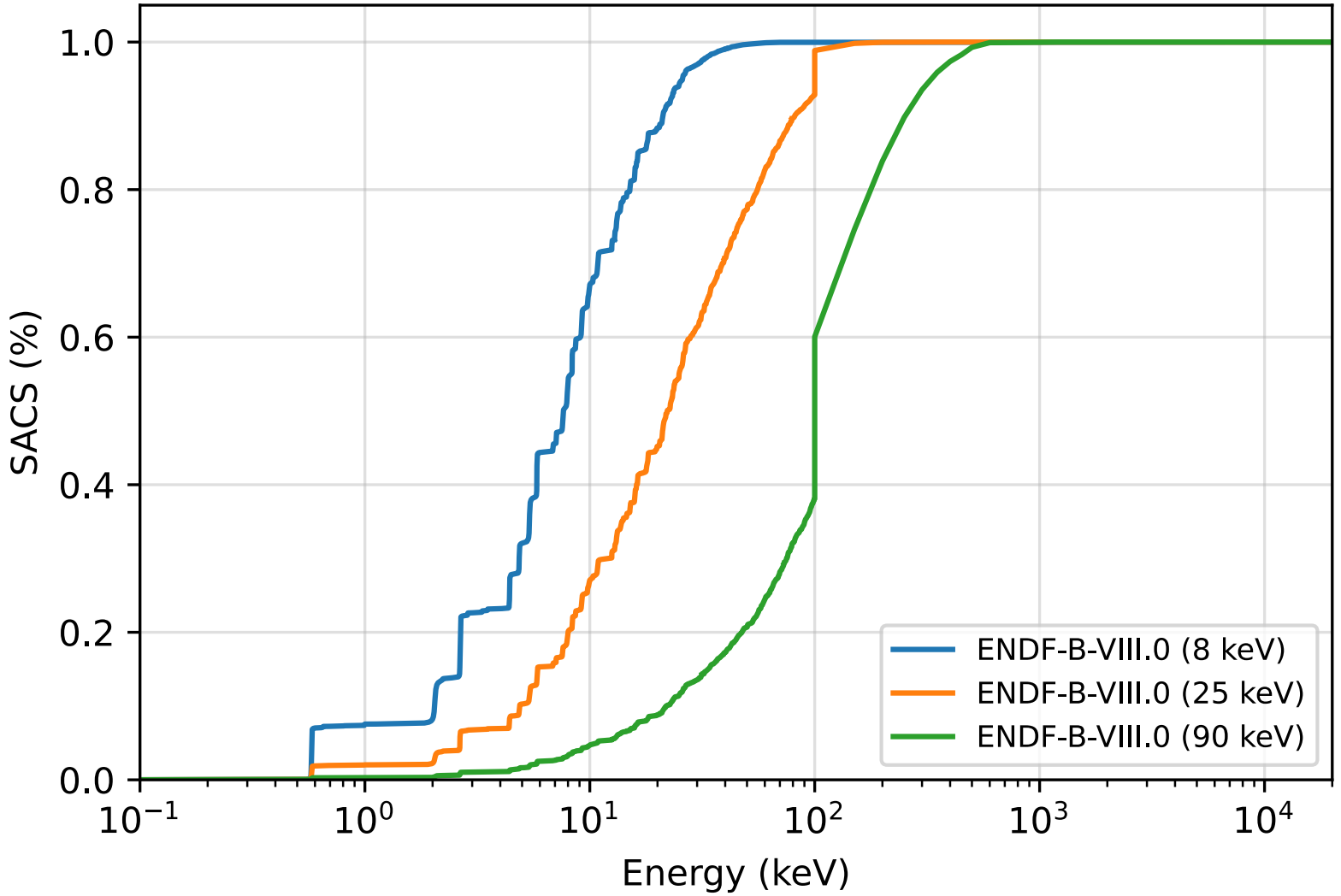
→ MACS @ kT= 25 keV
→ MACS @ kT= 90 keV

^{62}Ga 116.00 ms β$^+$	^{63}Ga 32.40 s β$^+$	^{64}Ga 2.63 m β$^+$	^{65}Ga 15.20 m β$^+$	^{66}Ga 9.49 h β$^+$	^{67}Ga 3.26 d β$^+$	^{68}Ga 1.13 h β$^+$
^{61}Zn 1.48 m β$^+$	^{62}Zn 9.19 h β$^+$	^{63}Zn 38.47 m β$^+$	**^{64}Zn 48.63 59 mb**	**^{65}Zn 243.63 d 162 mb, β$^+$**	**^{66}Zn 27.9 35 mb**	**^{67}Zn 4.1 153 mb**
^{60}Cu 23.70 m β$^+$	^{61}Cu 3.33 h β$^+$	^{62}Cu 9.67 m β$^+$	**^{63}Cu 69.17 94 mb**	^{64}Cu 12.70 h β$^+$	**^{65}Cu 30.83 41 mb**	^{66}Cu 5.12 m β$^-$
^{59}Ni 75.99 ka 87 mb, β$^+$	**^{60}Ni 26.223 30 mb**	**^{61}Ni 1.14 82 mb**	**^{62}Ni 3.634 22.3 mb**	**^{63}Ni 100.11 a 31 mb, β$^-$**	**^{64}Ni 0.926 8.7 mb**	^{65}Ni 2.52 h β$^-$
^{58}Co 70.86 d β$^+$	**^{59}Co 100 38 mb**	^{60}Co 5.27 a β$^-$	^{61}Co 1.65 h β$^-$	^{62}Co 1.50 m β$^-$	^{63}Co 27.40 s β$^-$	^{64}Co 300.00 ms β$^-$
^{57}Fe 2.119 40 mb	**^{58}Fe 0.282 12.1 mb**	^{59}Fe 44.50 d β$^-$	^{60}Fe 1.50 Ma β$^-$	^{61}Fe 5.98 m β$^-$	^{62}Fe 1.13 m β$^-$	^{63}Fe 6.01 s β$^-$

ASTROFISICA NUCLEARE

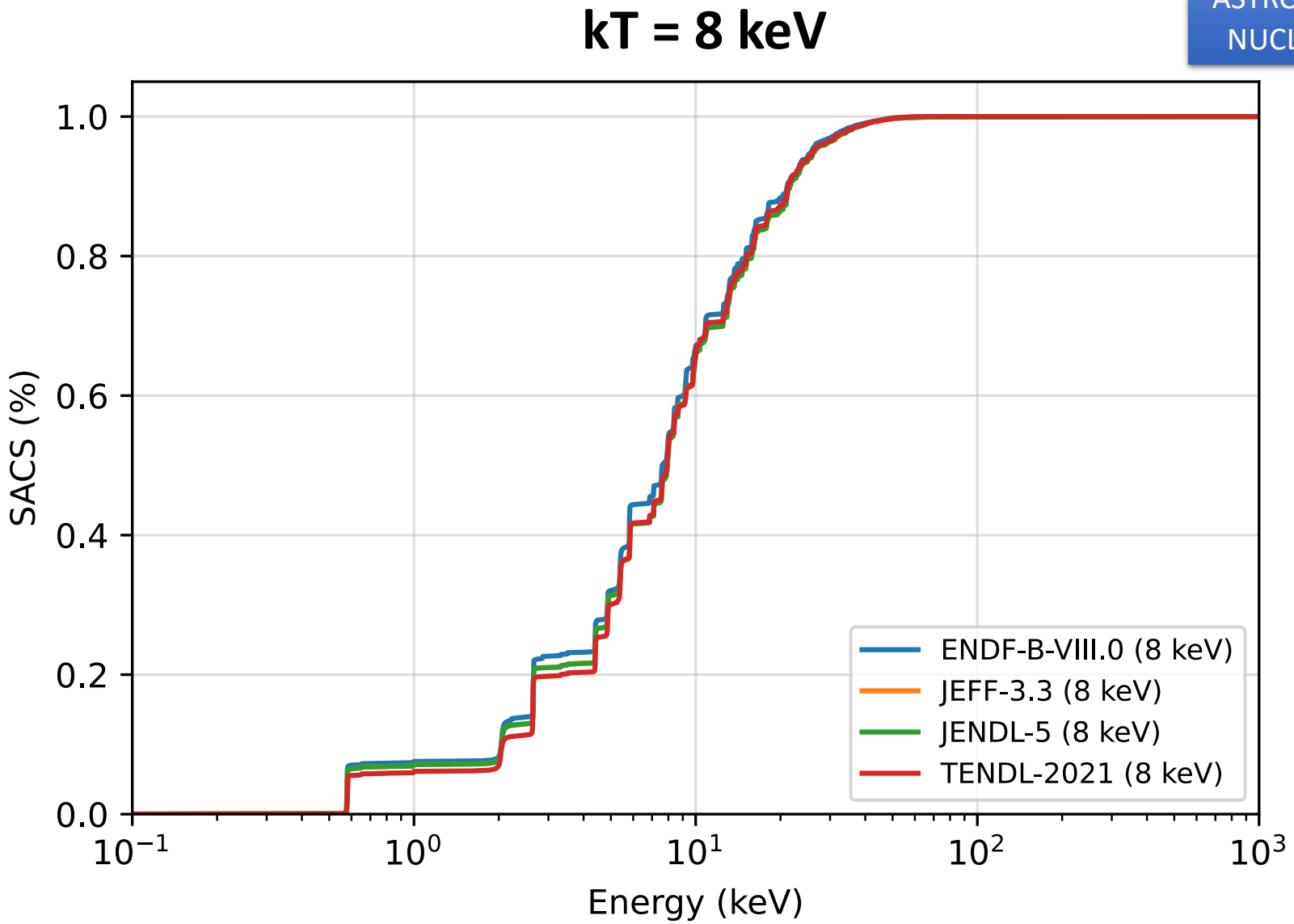
^{63}Cu

% della MACS



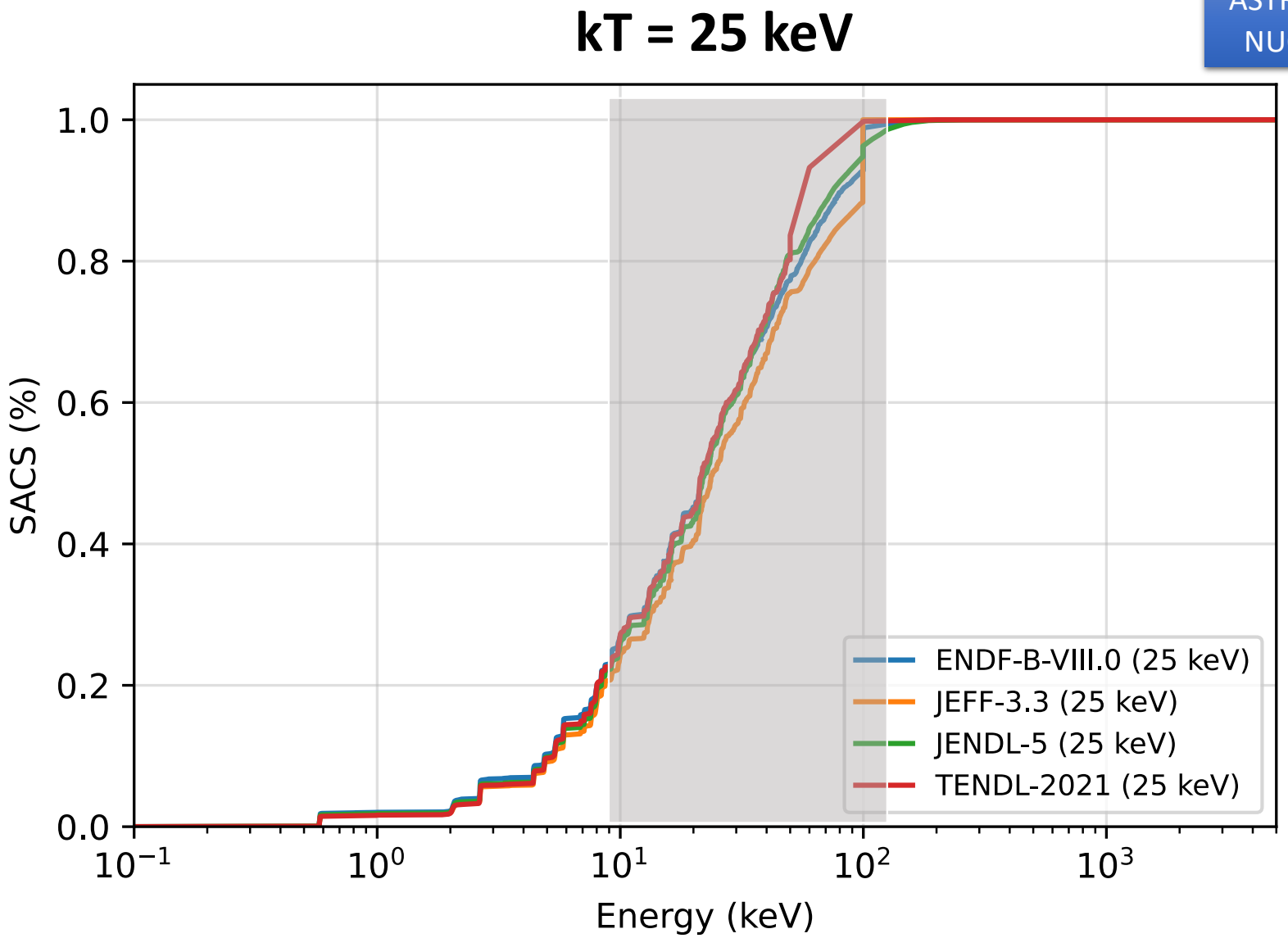
ASTROFISICA NUCLEARE

^{63}Cu



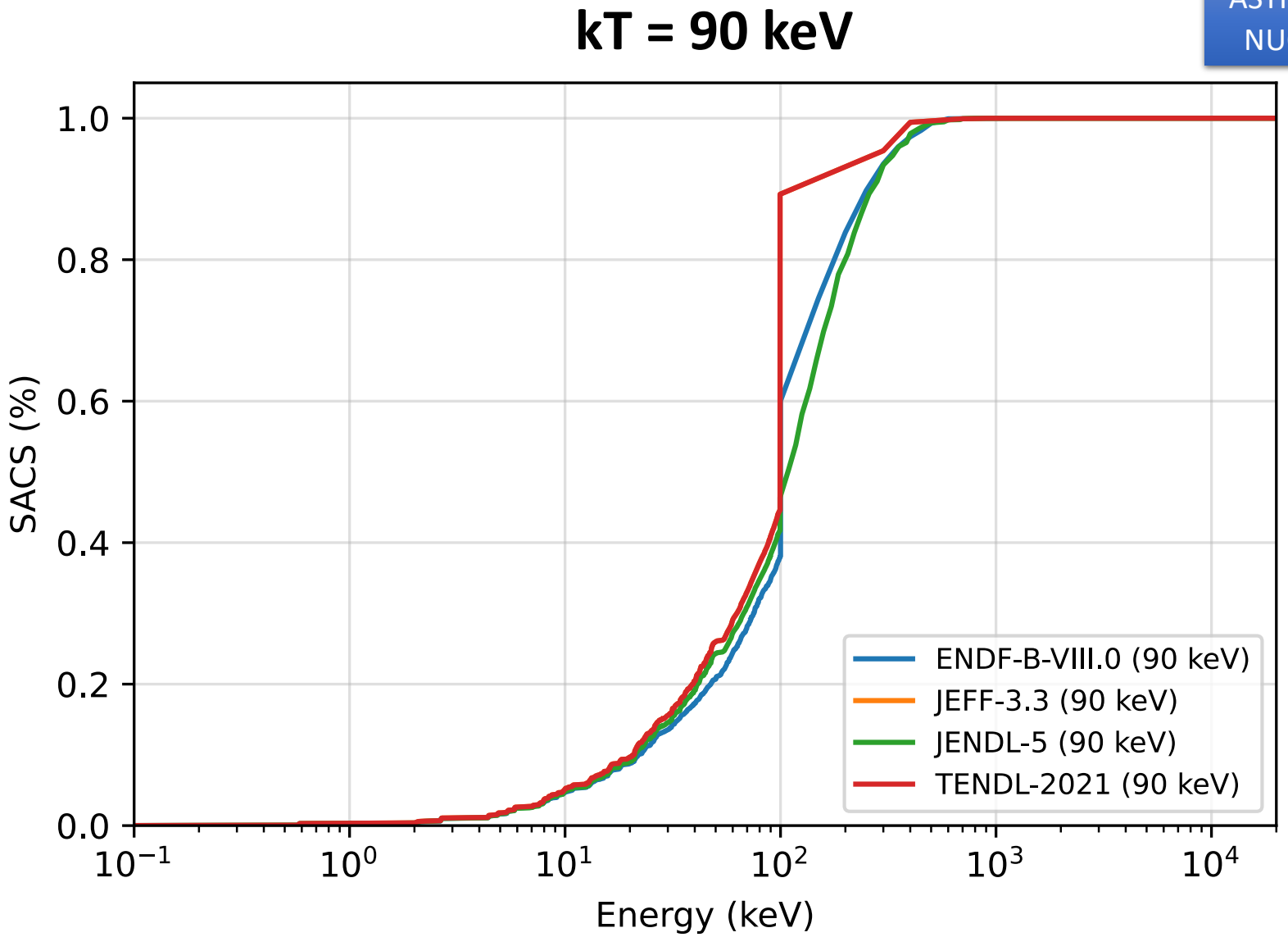
ASTROFISICA NUCLEARE

^{63}Cu



ASTROFISICA NUCLEARE

^{63}Cu



ASTROFISICA NUCLEARE

^{63}Cu

Recommended MACS30 (Maxwellian Averaged Cross Section @ 30keV)

$$^{63}Cu\ (n,\gamma)^{64}Cu$$

Total MACS at 30keV: 60.1 ± 6.2 mb

Cross sections do not include stellar enhancement factors!

History

Version	Total MACS [mb]	Partial to gs [mb]	Partial to isomer [mb]
1.0	60.1 ± 6.2	-	-
0.3	55.6 ± 2.2	-	-
0.0	94 ± 10	-	-

(Version 0.0 corresponds to Bao et al.)

Comment

New rec. value is from HKU08, renormalized by 632 mb/586 mb = 1.0785, and recalculated with normalized energy dependencies of tendl15,endfb71,jendl40. Uncertainty is the deviation between different evaluations plus 4% exp. uncertainty from HKU08. **Note the large deviation between the activation measurement and the TOF measurements. More investigation needed!**
Last review: April 2017

ASTROFISICA NUCLEARE

^{63}Cu

TOF - DANCE

List of all available values

original	renorm.	year	type	Comment	Ref
84.0 ± 7.8		2017	c	TOF; W Spall., Au	WBC17
60.3 ± 2.4 kT= 25keV	60.1	2016	r	VdG, Act., Au:RaK88 corrected by 632/586= 1.0785; en. dep. from endfb71,jendl40,tendl15	HKU08
60.3 ± 2.4 kT= 25keV	55.6 ± 2.2	2008	c	VdG, Act., Au:RaK88; en. dep. from Bao00	HKU08
94 ± 10		1977	r	Linac, TOF, ^{6}Li, Au:Sat., Recalc. incl. data of Alt75 at 50 < E(n) < 300 keV	PGM77
56 ± 7 E(n)= 25 (5) keV		1979	c	F.N.B., Act., 1/v(E), ^{127}I:832 mb 5 keV)	AJB79
21		1970	c	Sb-Be, Act., 1/v(E), Au:640 mb keV)	ChP70

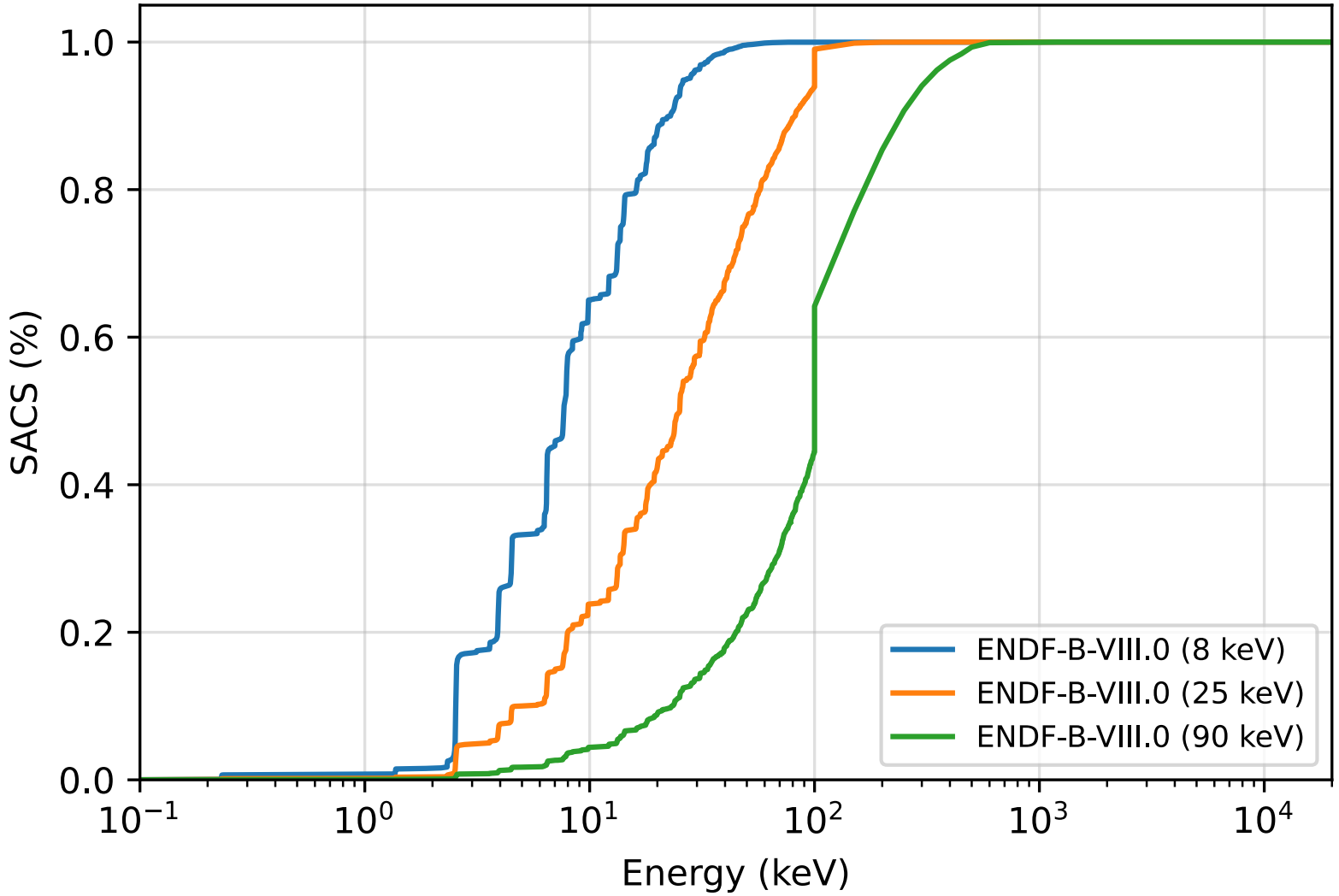
Attivazione - FZK

TOF - ORELA

^{65}Cu

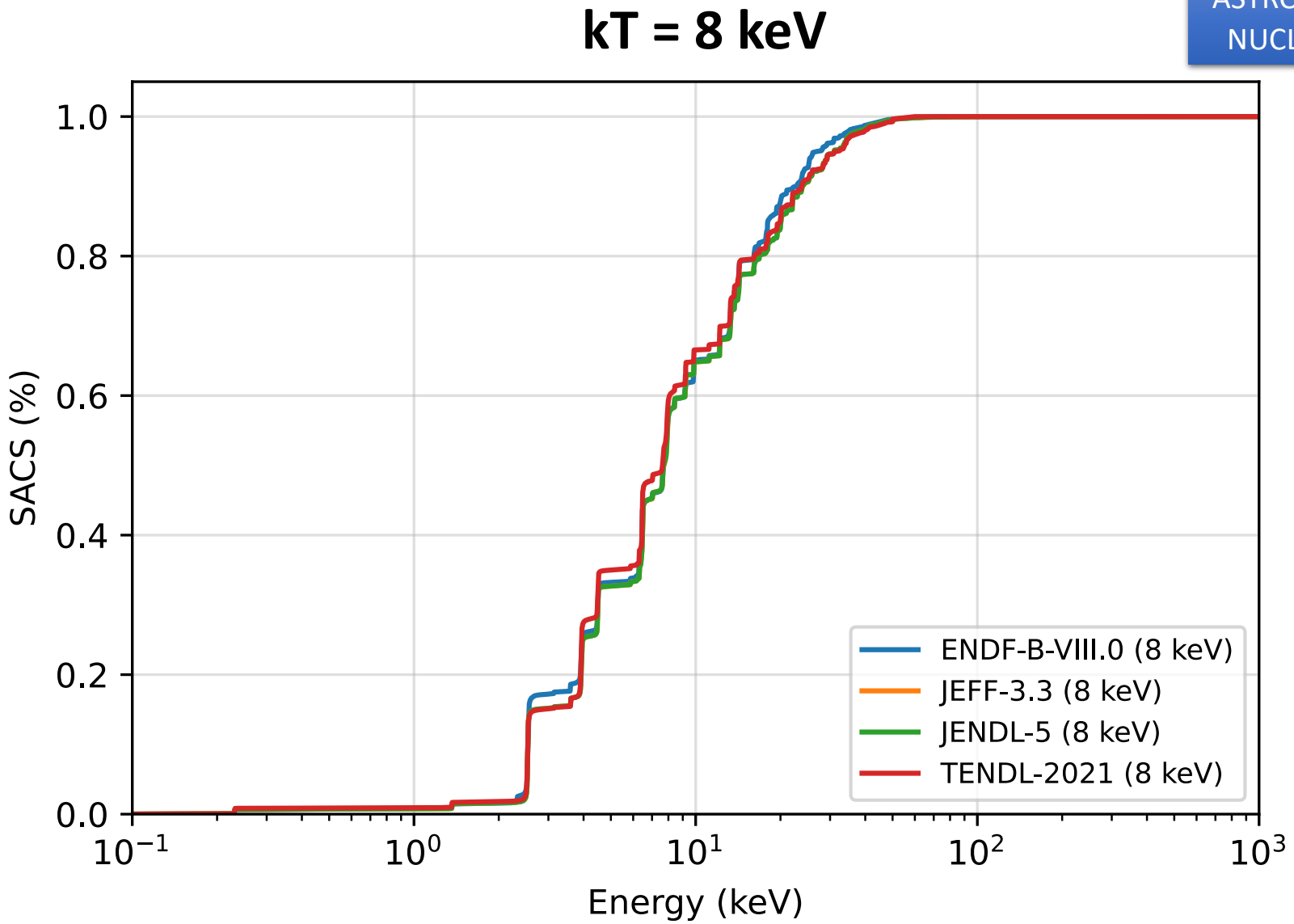
ASTROFISICA NUCLEARE

^{65}Cu



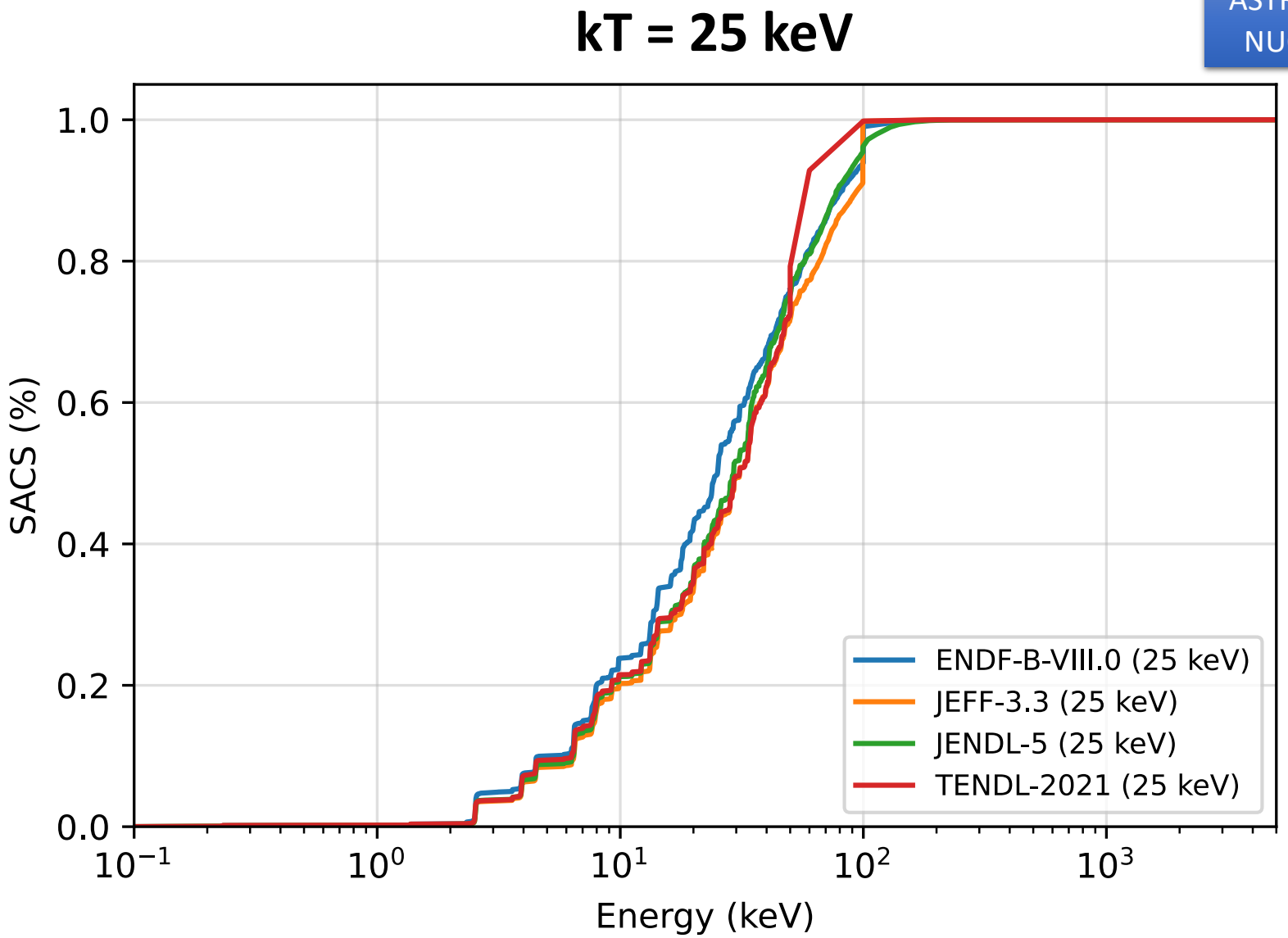
ASTROFISICA NUCLEARE

^{65}Cu



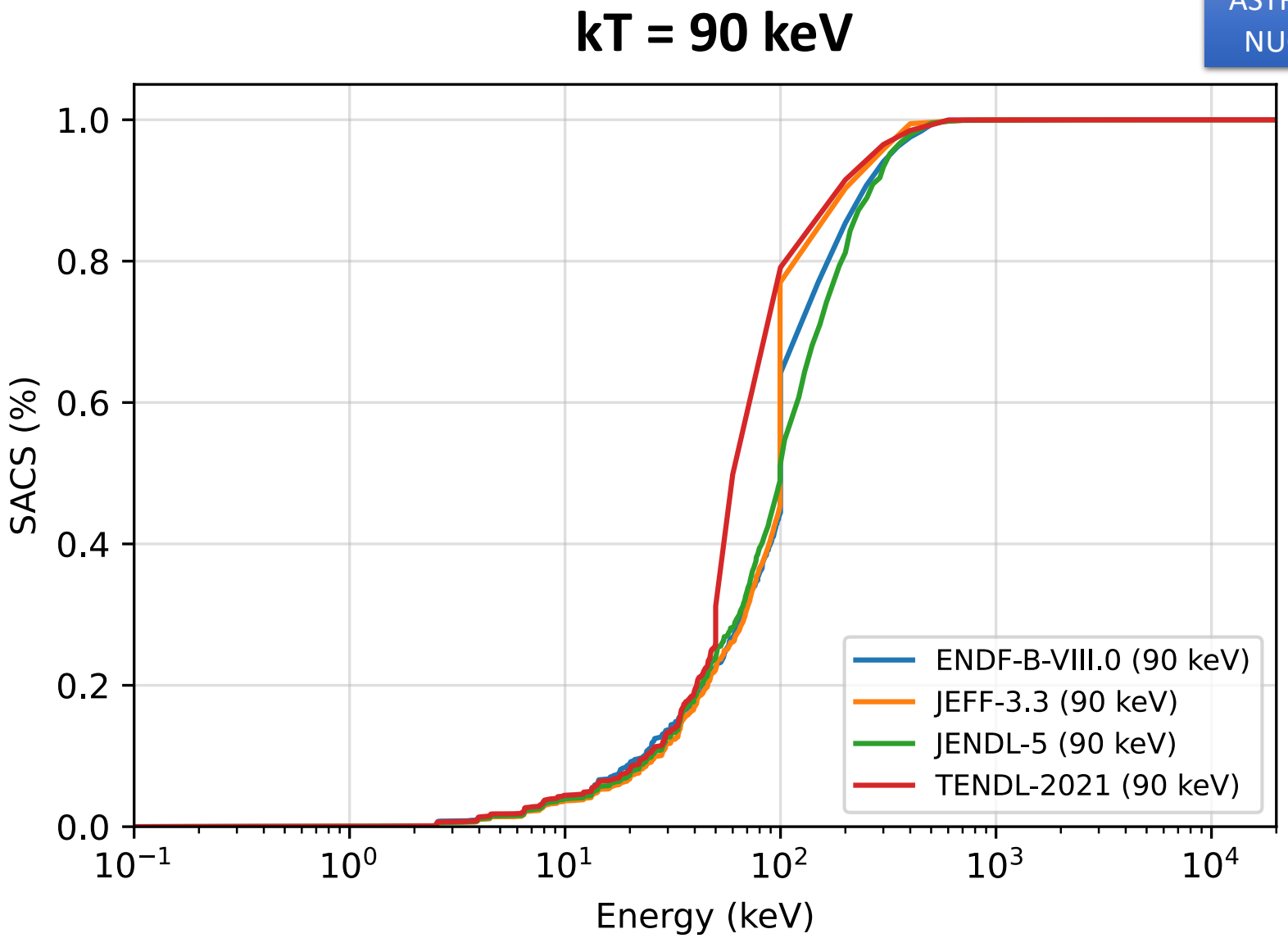
ASTROFISICA NUCLEARE

^{65}Cu



ASTROFISICA NUCLEARE

^{65}Cu



ASTROFISICA NUCLEARE

^{65}Cu

Recommended MACS30 (Maxwellian Averaged Cross Section @ 30keV)

$$^{65}Cu\ (n,\gamma)^{66}Cu$$

Total MACS at 30keV: 31.2 ± 1.7 mb

Cross sections do not include stellar enhancement factors!

History

Version	Total MACS [mb]	Partial to gs [mb]	Partial to isomer [mb]
1.0	31.2 ± 1.7	-	-
0.3	29.8 ± 1.3	-	-
0.0	41 ± 5	-	-

(Version 0.0 corresponds to Bao et al.)

Comment

New rec. value is from HKU08, renormalized by 632 mb/586 mb = 1.0785, and recalculated with normalized energy dependencies of tendl15,endfb71,jendl40. Uncertainty is the deviation between different evaluations plus 4.3% exp. uncertainty from HKU08.
Last review: June 2016

ASTROFISICA NUCLEARE

^{65}Cu

List of all available values

original	renorm.	year	type	Comment	Ref
32.0 ± 1.4 kT= 25 keV	31.2	2016	r	VdG, Act., Au:RaK88 corrected by 632/586= 1.0785; en. dep. from endfb71,jendl40,tendl15	HKU08
32.0 ± 1.4 kT= 25 keV	29.8 ± 1.3	2008	c	VdG, Act., Au:RaK88; en. dep. from bao00	HKU08
41 ± 5		1977	r	Linac, TOF, ^{6}Li, Au:Sat., Recalc. incl. data of PGM77 at 0 < E(n) < 50 keV (k= 0.9507) and data of GaK76 at 50 < E(n) < 400 keV	PGM77,GaK76

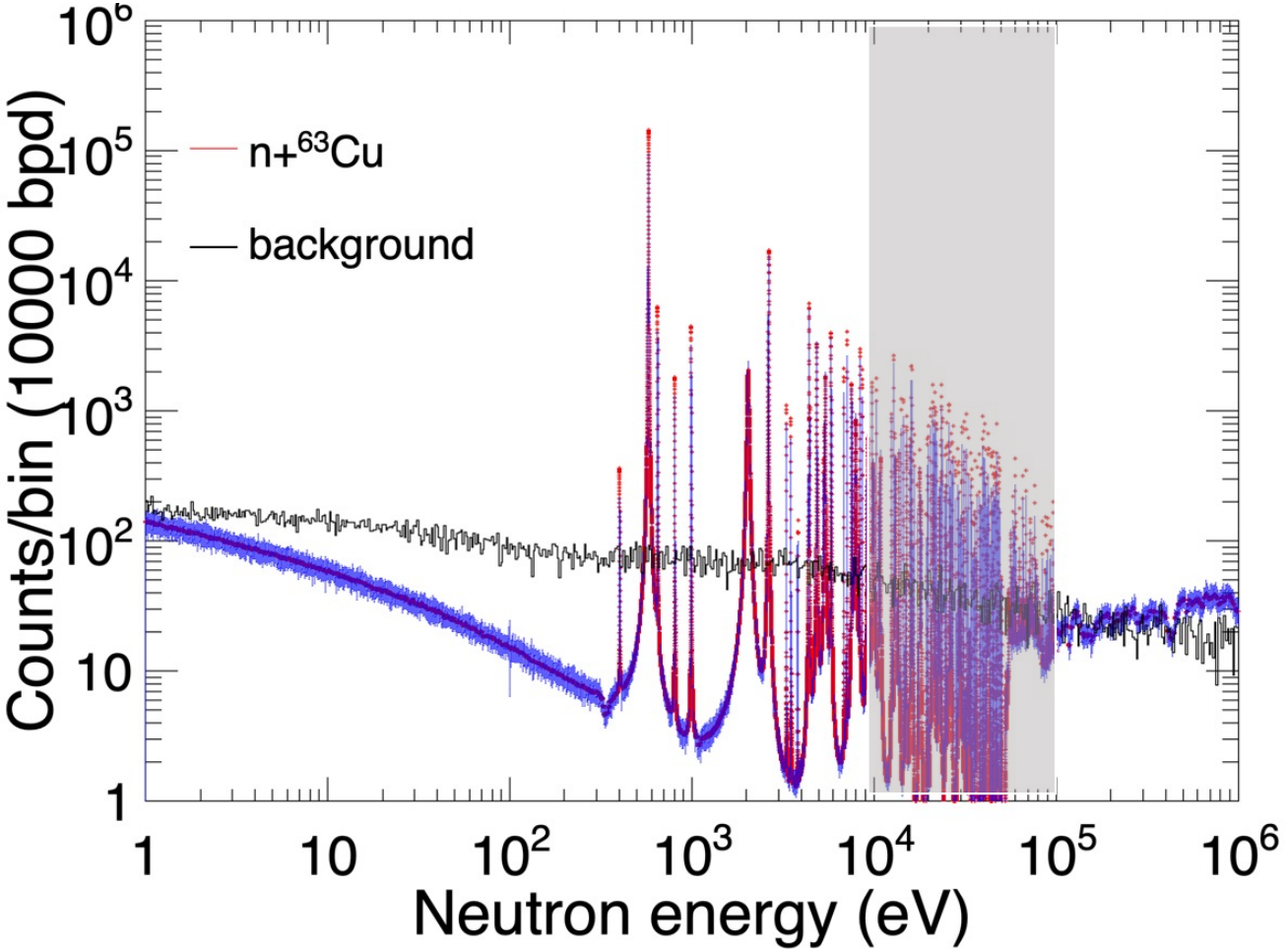
^{63,65}Cu(n,γ) count rate

1 keV < E_n < 300 keV

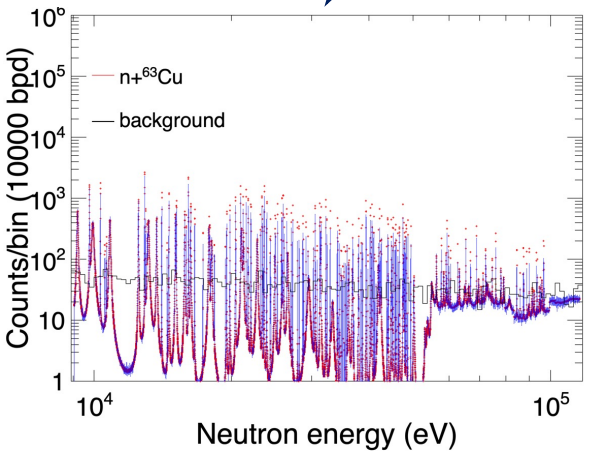
TECNOLOGIE NUCLEARI

ASTROFISICA NUCLEARE

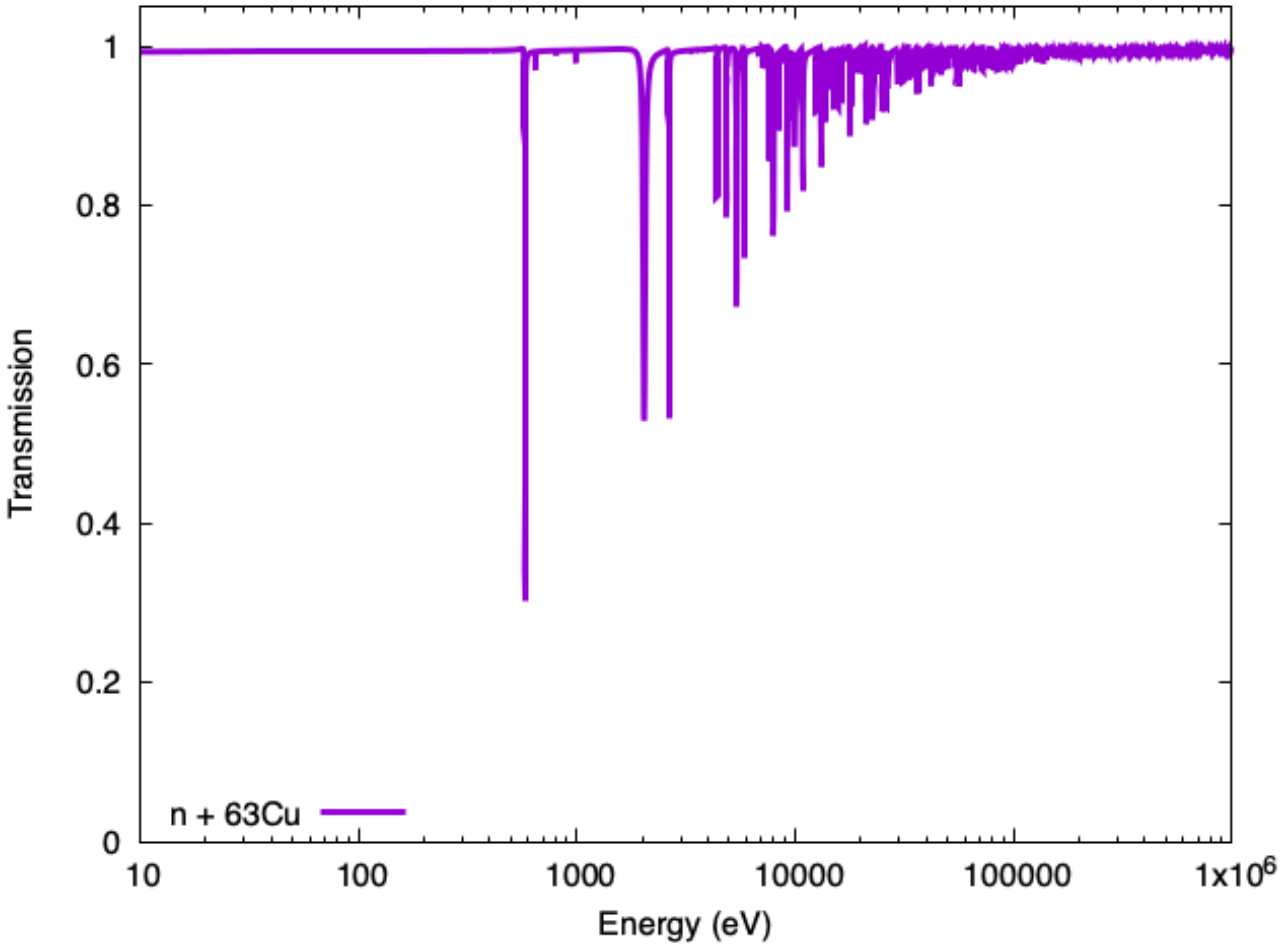
(n,γ) @ EAR 1, 4 C_6D_6, Ø = 3 cm, mass = 1 g



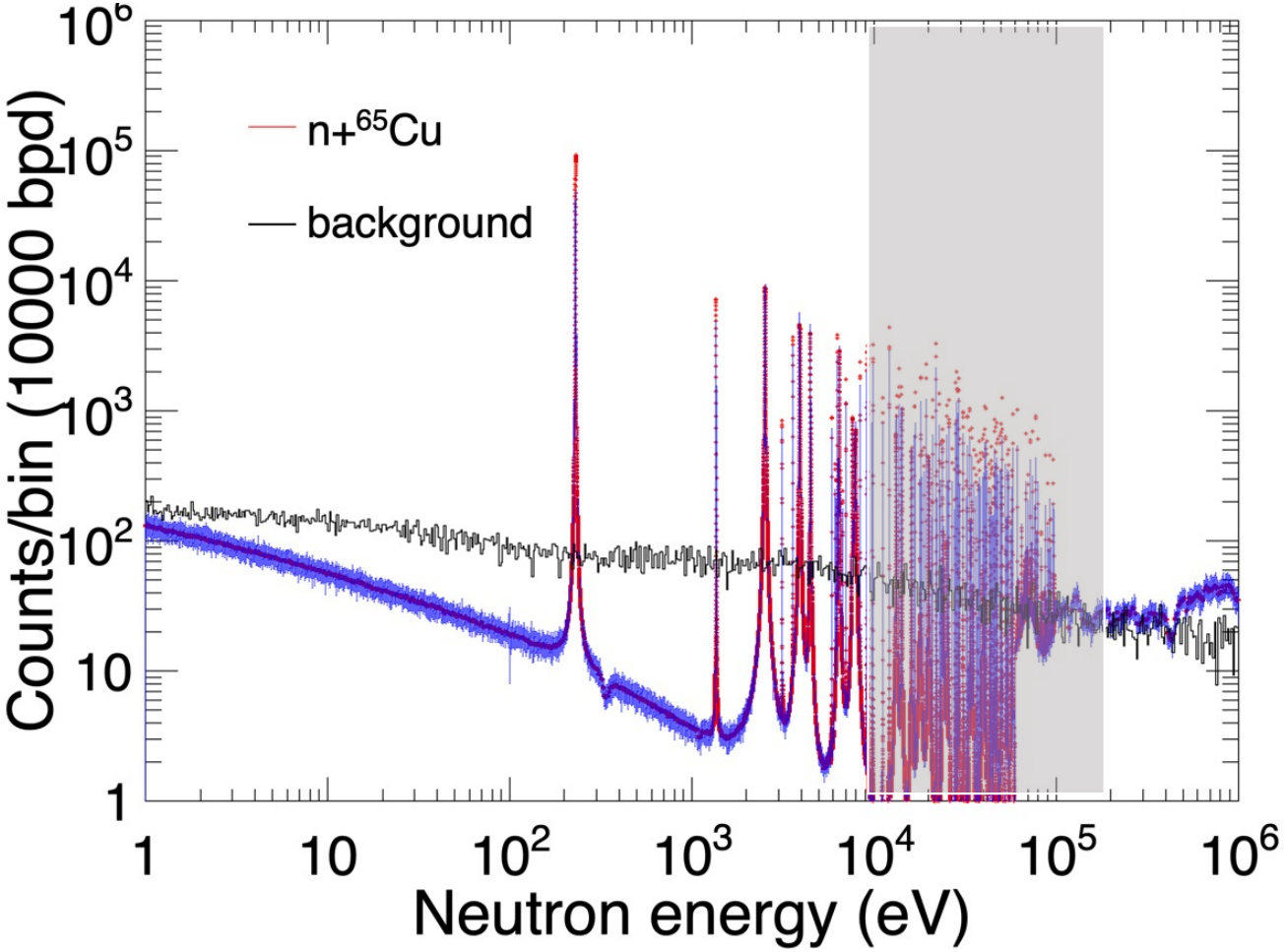
4x10^{18} p



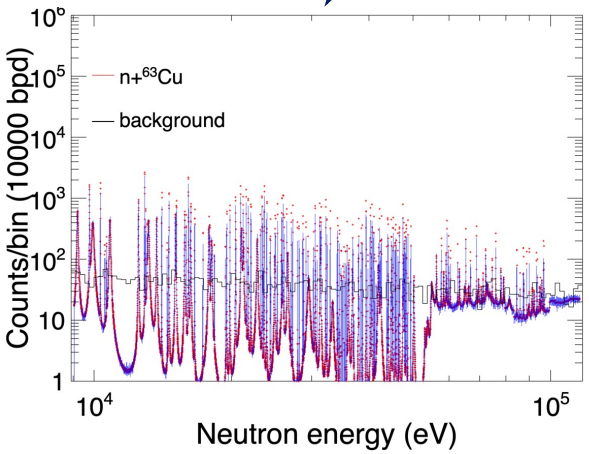
(n,γ) @ EAR 1, 4 C_6D_6, Ø = 3 cm, mass = 1 g



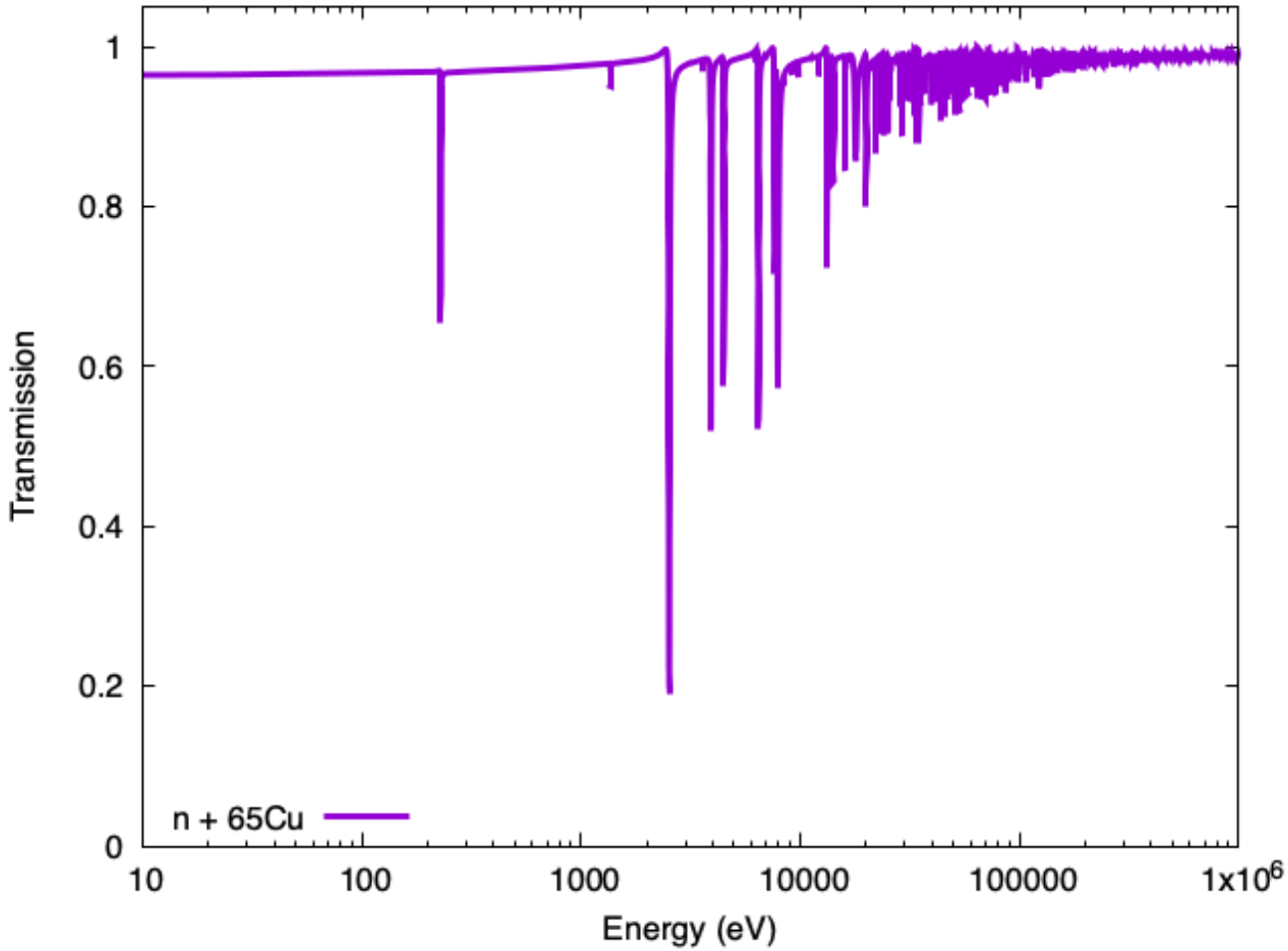
(n,γ) @ EAR 1, 4 C_6D_6, Ø = 3 cm, mass = 2 g



4x10^{18} p



(n,γ) @ EAR 1, 4 C_6D_6, Ø = 3 cm, mass = 2 g



TECNOLOGIE NUCLEARI

^{63,65}Cu(n,n)

50 keV < E_n < 5 MeV

- Misura di trasmissione tra 50 keV e 1 MeV (@ n_TOF)
- Misura con p-stil tra 1 MeV e 10 MeV

TECNOLOGIE NUCLEARI

^{63,65}Cu(n,n')

1 MeV < E_n < 10 MeV

- HPGe/LaBr @ EAR1

TECNOLOGIE NUCLEARI

Discussione:

- Ramen: un caso molto interessante!

- Come organizzare il proposal da sottomettere alla INTC di febbraio?