The Copper Trilogy: exploring ^{61}Cu, ^{64}Cu and ^{67}Cu at the Bern Medical Cyclotron

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ICI 2026

12TH INTERNATIONAL CONFERENCE ON ISOTOPES

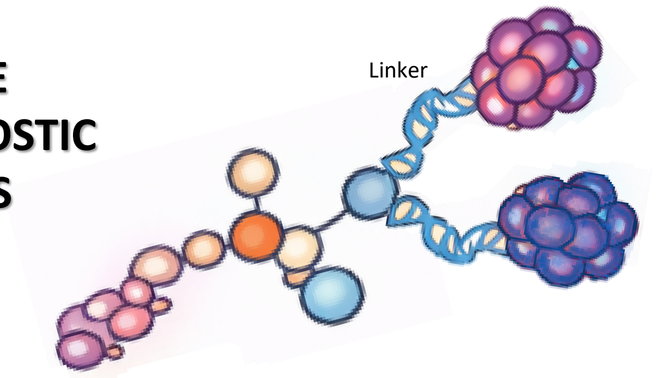
Copper radioisotopes in nuclear medicine

Cu-61
3.339 h
ec,β^+: 100%

Cu-64
12.7006 h
ec,β^+: 61.5%
β^-: 38.5%

Cu-67
61.83 h
β^-: 100%

TRUE THERANOSTIC PAIRS



DIAGNOSTICS

THERAPY

Production routes

Cu-61
3.339 h
ec,β^+: 100%

- **Low-energy protons***: ^{61}Ni(p,n)^{61}Cu
- **Low-energy protons***: ^{64}Zn(p,α)^{61}Cu

Cu-64
12.7006 h
ec,β^+: 61.5%
β^-: 38.5%

- **Low-energy protons***: ^{64}Ni(p,n)^{64}Cu
- **Neutrons:** ^{64}Zn(n,p)^{64}Cu; **c.a.** ^{65}Cu(n,2n)^{64}Cu
- **Low-energy protons***: ^{67}Zn(p,α)^{64}Cu; **c.a.** ^{65}Cu(p,pn)^{64}Cu

Cu-67
61.83 h
β^-: 100%

- **Neutrons:** ^{67}Zn(n,p)^{67}Cu
- **Spallation process:** ^{75}As(p,spall)^{67}Cu
- **High-energy protons:** ^{68}Zn(p,2p)^{67}Cu
- **Low-energy protons***: ^{70}Zn(p,α)^{67}Cu

$^*E_p \leq 20$ MeV

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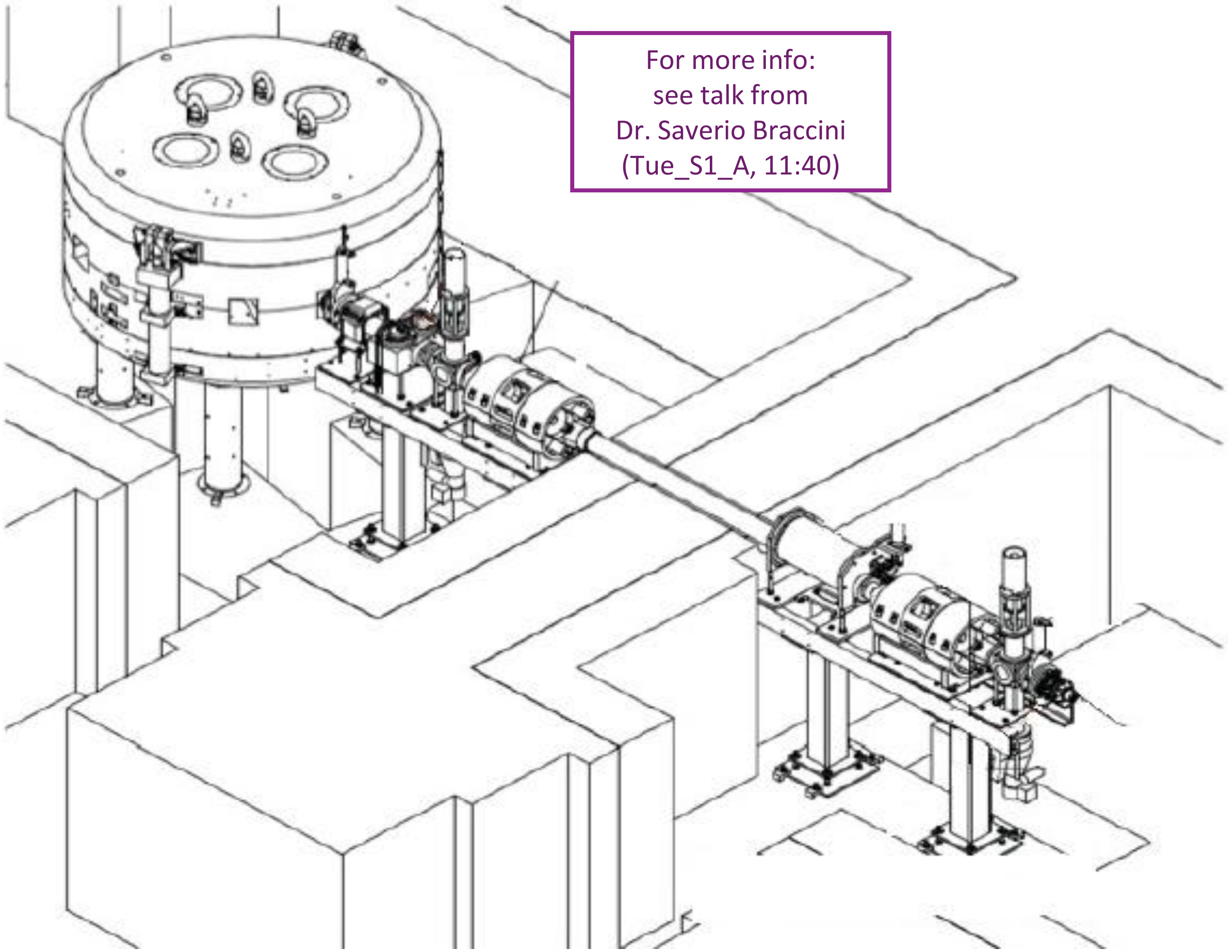

For more info:
see talk from
Dr. Saverio Braccini
(Tue_S1_A, 11:40)

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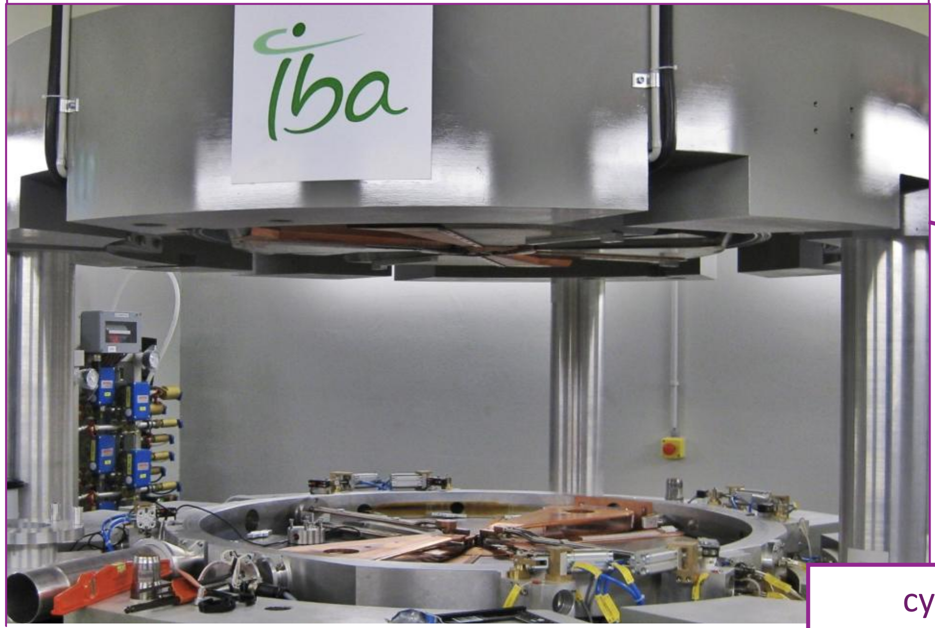
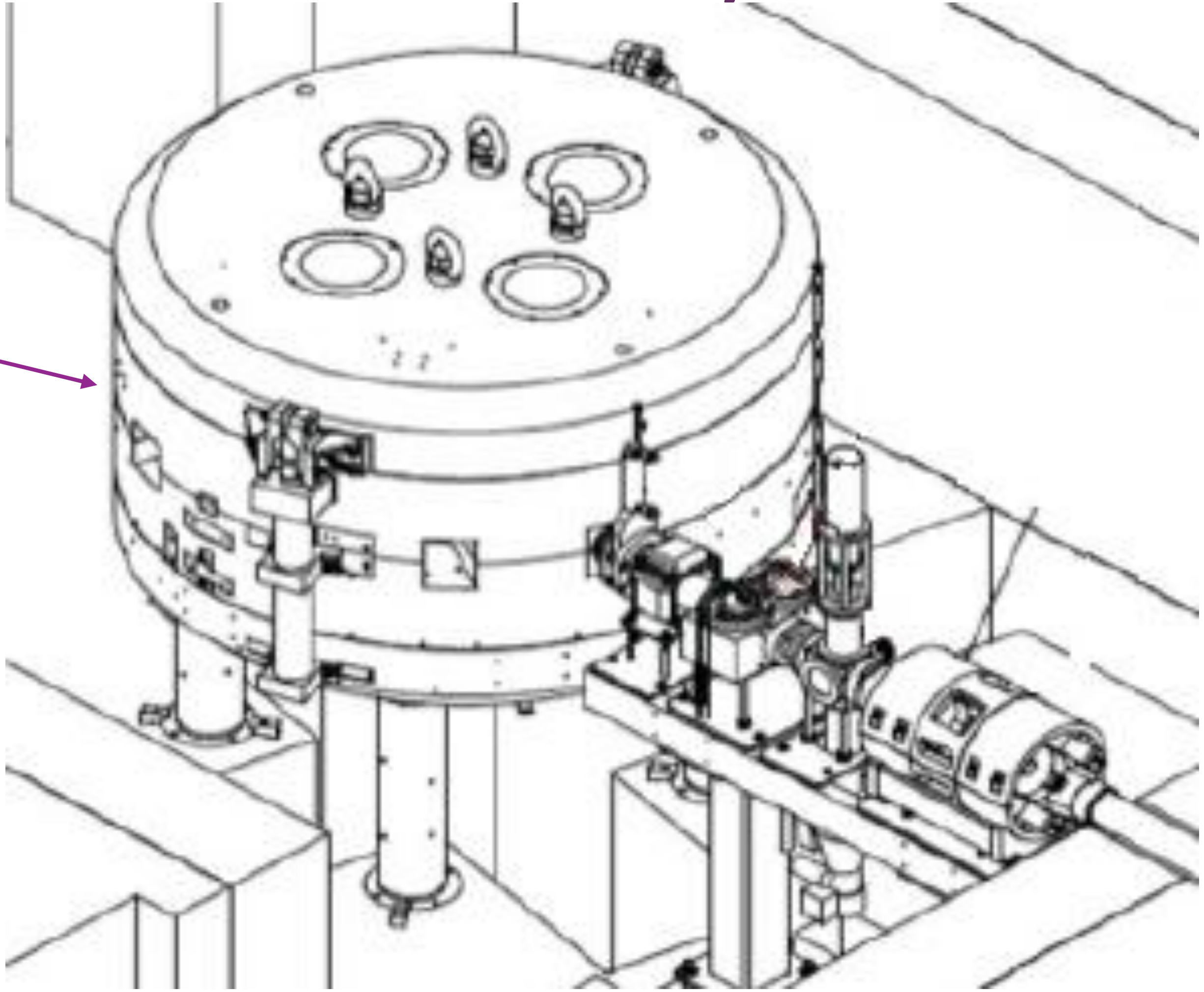
IBA 18/18 HC cyclotron





cyclotron configuration in 2023

- Two H^- ion sources
- High current (max 150 µA)
- 8 out ports:
  - 6 ^{18}F liquid targets [industrial production]
  - **Beam Transport Line (BTL) [research]**
  - **Solid Target Station (STS) [research]**

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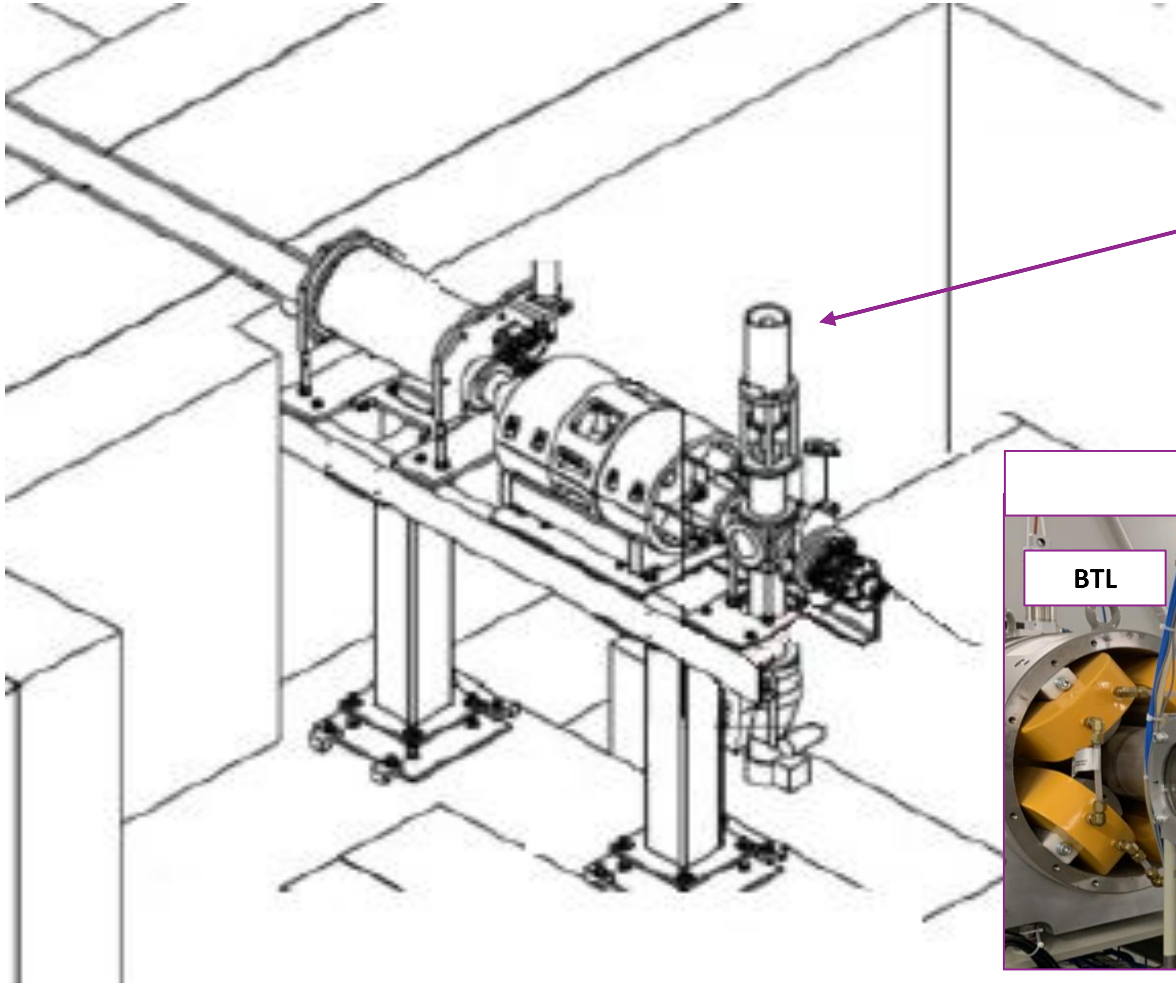
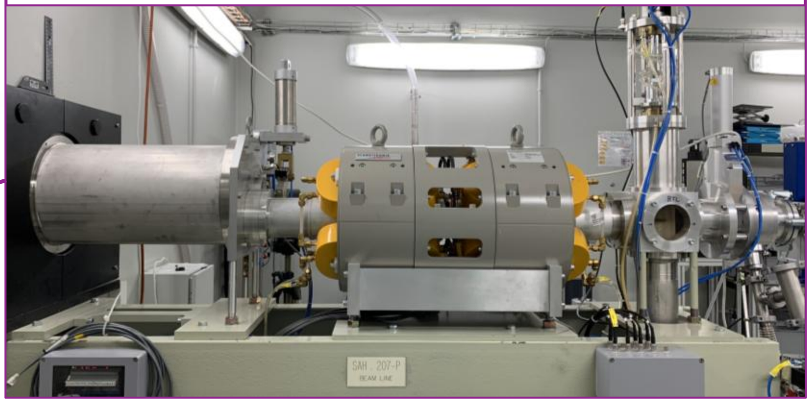
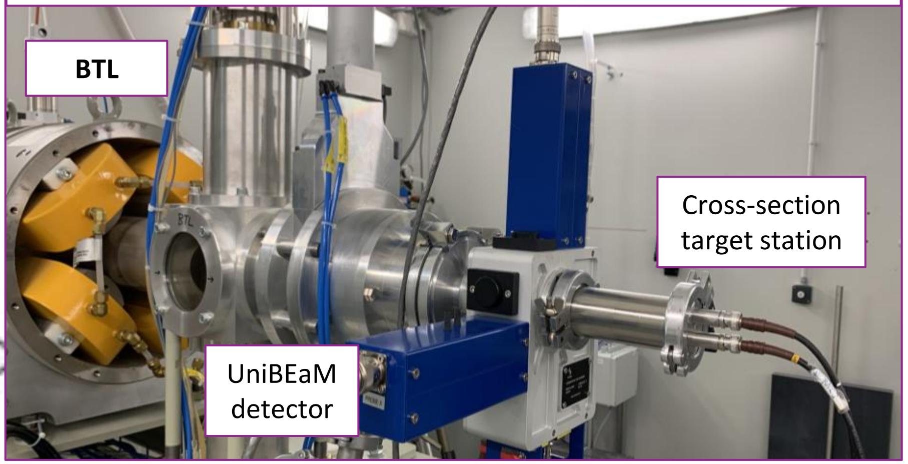


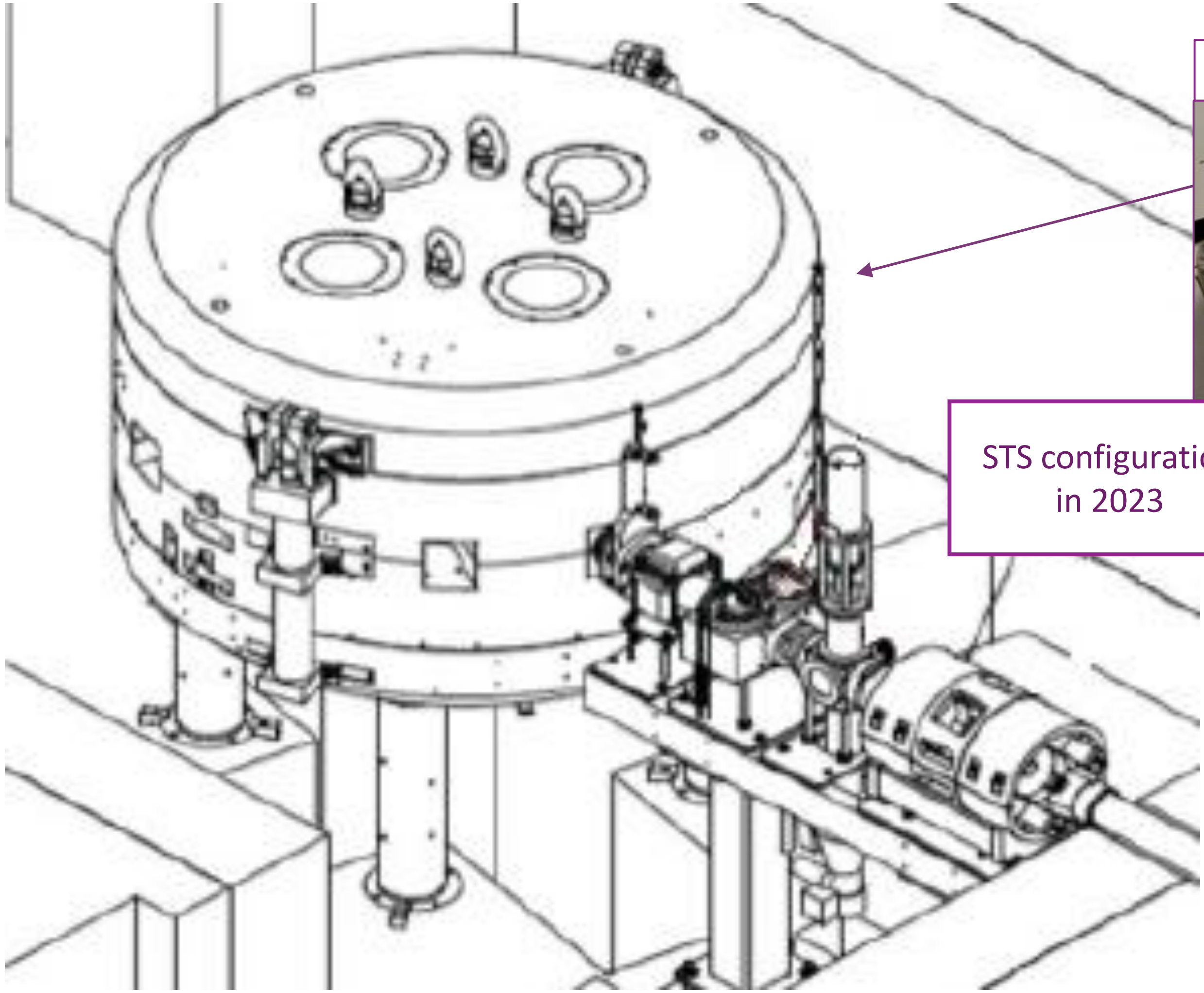
Beam Transport Line (BTL)



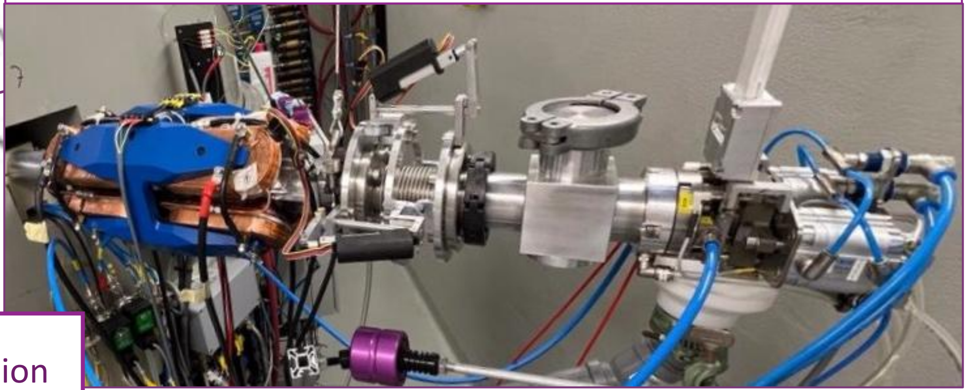
Cross-section measurement setup



The Bern Medical Cyclotron laboratory

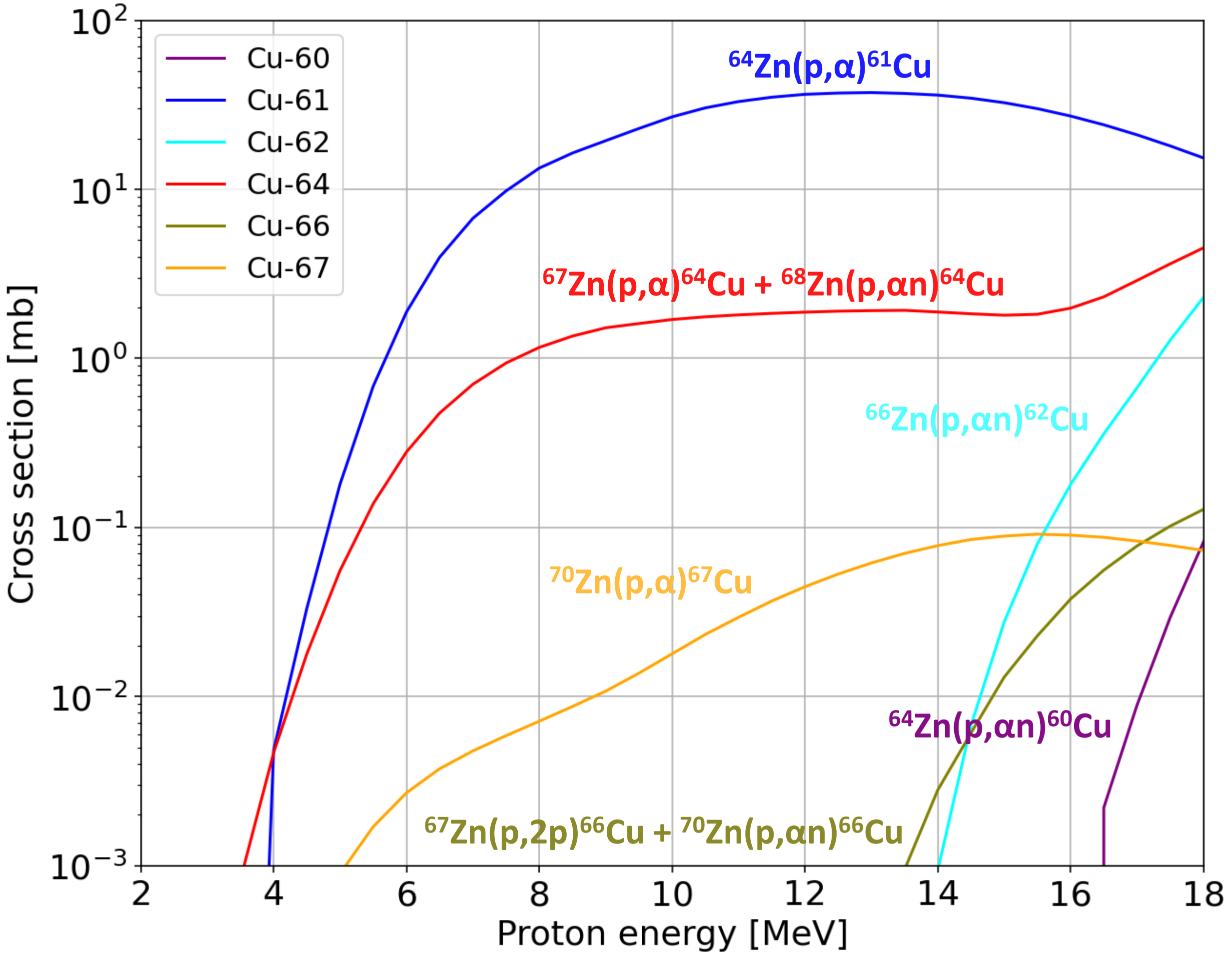


Solid Target Station (STS)



STS configuration in 2023

Proton irradiation of natural Zinc



	^{64}Zn	^{66}Zn	^{67}Zn	^{68}Zn	^{70}Zn
Nat Zn [%]	49.17	27.73	4.04	18.45	0.61
Enr. ^{64}Zn [%]	**99.40**	0.39	0.04	0.17	<0.01
Enr. ^{67}ZnO [%]	1.56	3.88	**89.60**	4.91	0.05
Enr. ^{68}Zn [%]	0.99	0.81	0.38	**97.80**	0.02
Enr. ^{70}ZnO [%]	0.02	0.01	0.02	1.20	**98.75**

^{60}Cu: $t_{1/2}$ = 23.7 *(4)* min

^{61}Cu: $t_{1/2}$ = 3.339 *(8)* h

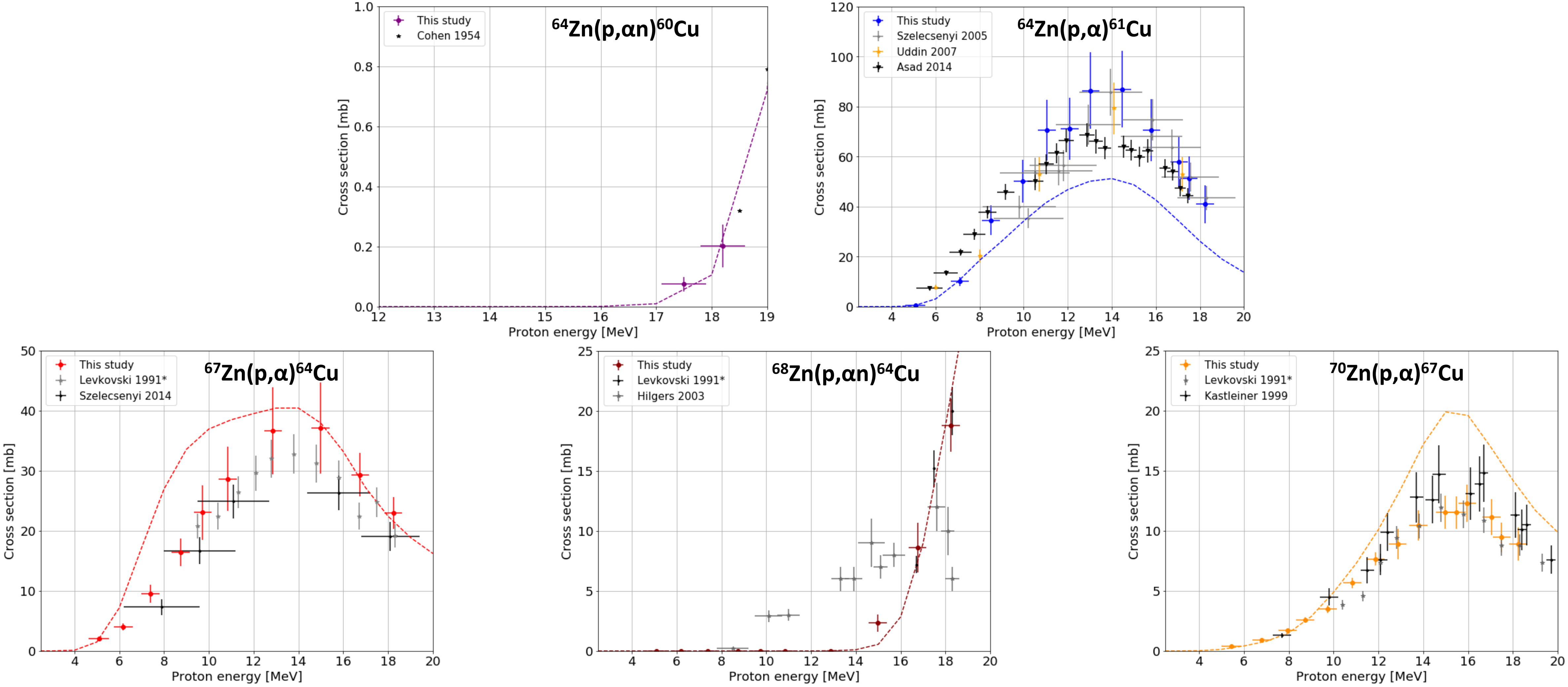
^{62}Cu: $t_{1/2}$ = 9.67 (3) min

^{64}Cu: $t_{1/2}$ = 12.7006 (20) h

^{66}Cu: $t_{1/2}$ = 5.120 (14) min

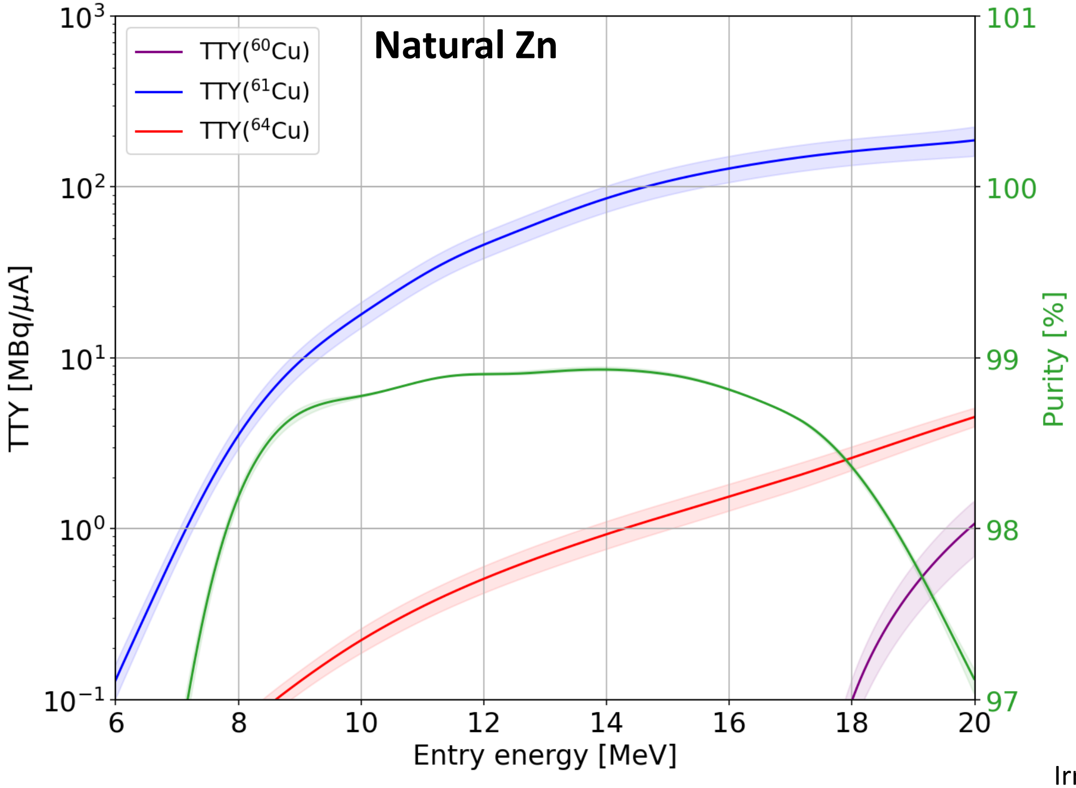
^{67}Cu: $t_{1/2}$ = 61.83 (12) h

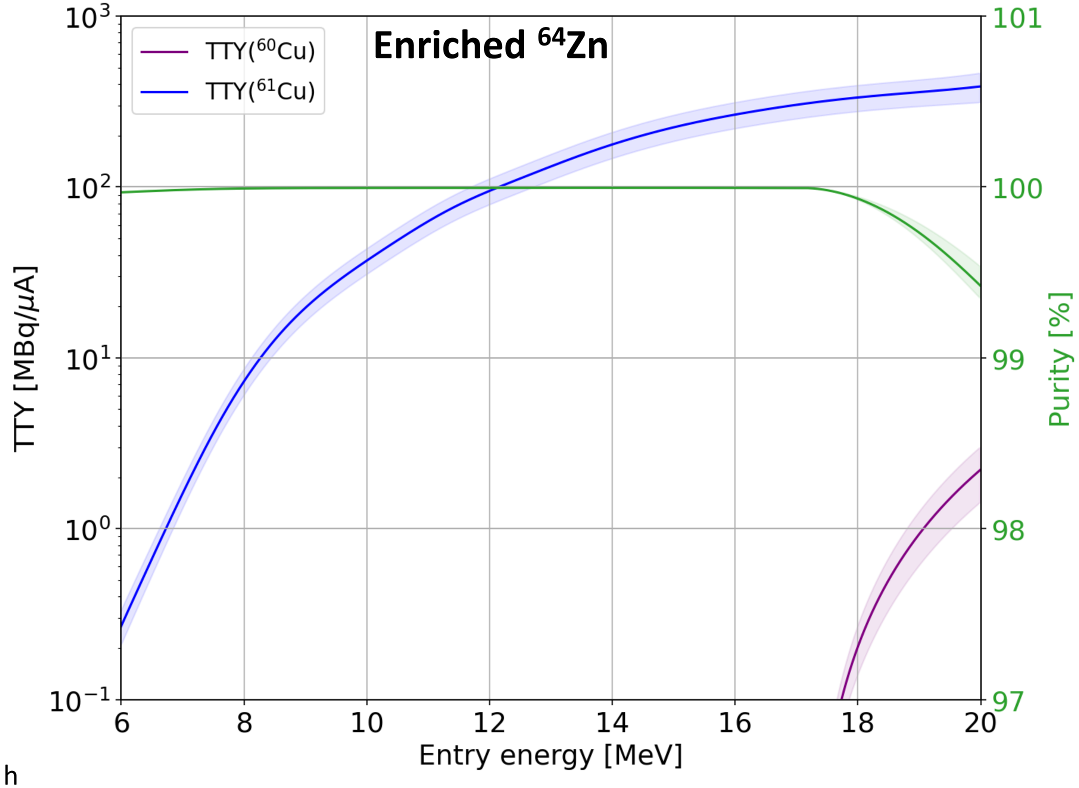
Cross-section results



^{61}Cu production: natural vs enriched ^{64}Zn

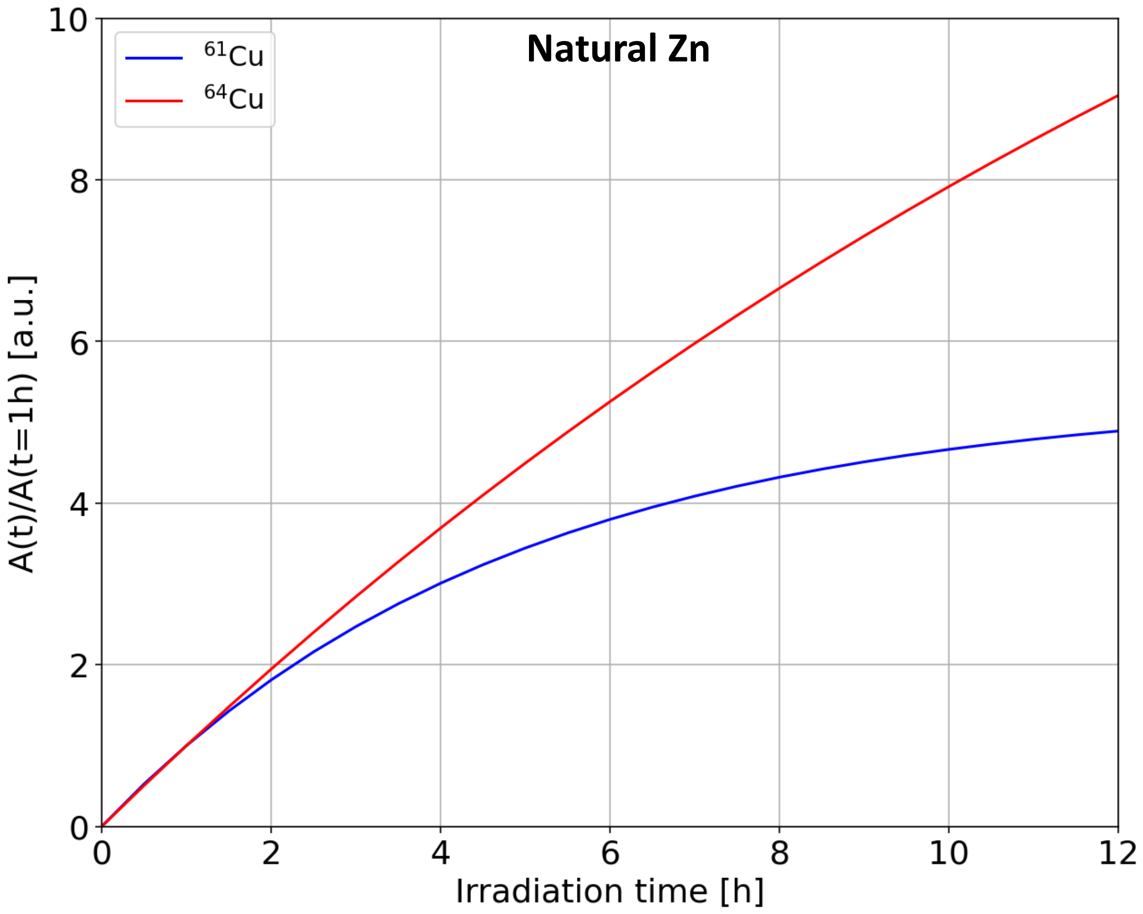
	^{64}Zn	^{66}Zn	^{67}Zn	^{68}Zn	^{70}Zn
Nat Zn [%]	**49.17**	27.73	4.04	18.45	0.61
Enr. ^{64}Zn [%]	**99.40**	0.39	0.04	0.17	<0.01





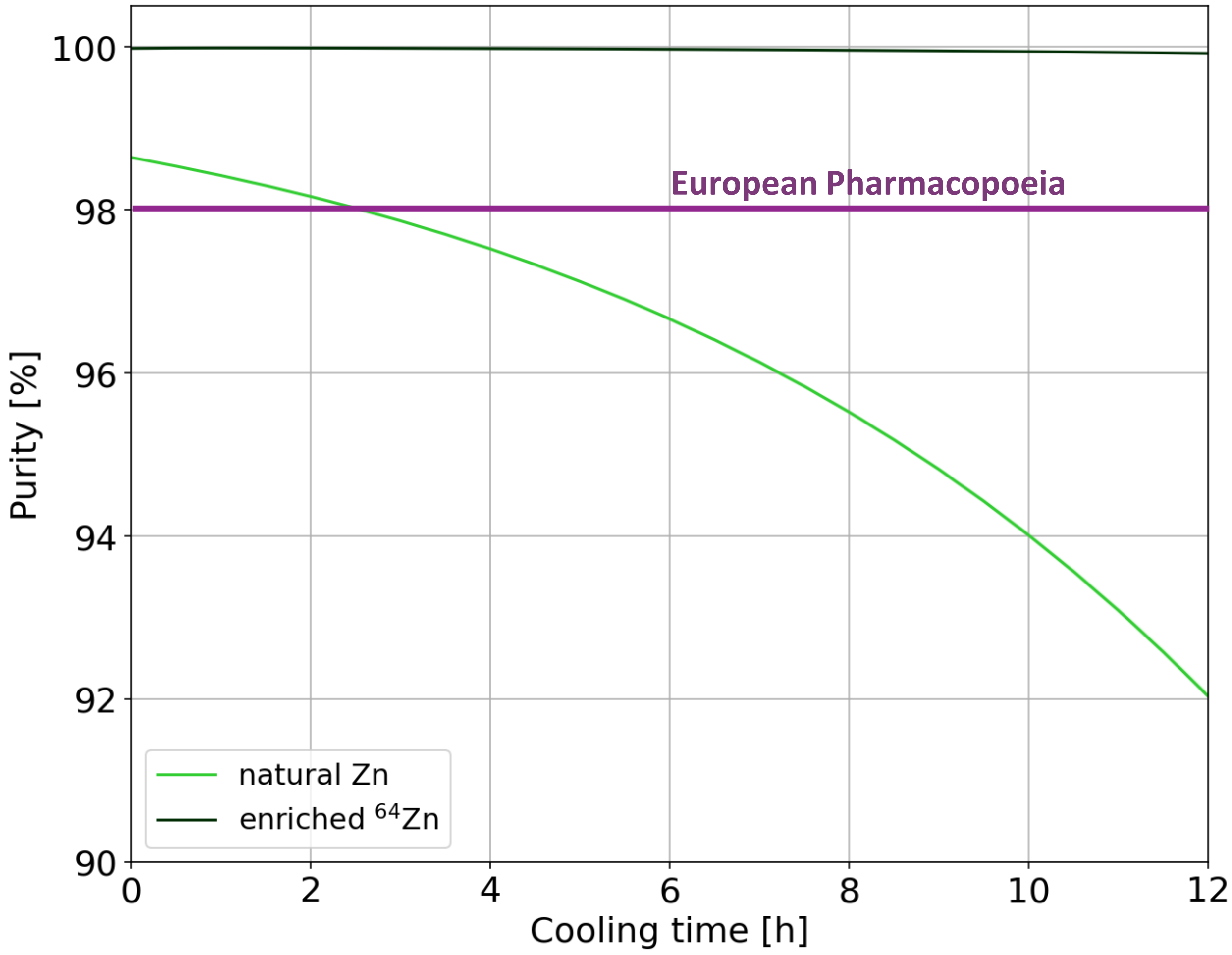
Irradiation time = 1 h

^{61}Cu production: natural vs enriched ^{64}Zn

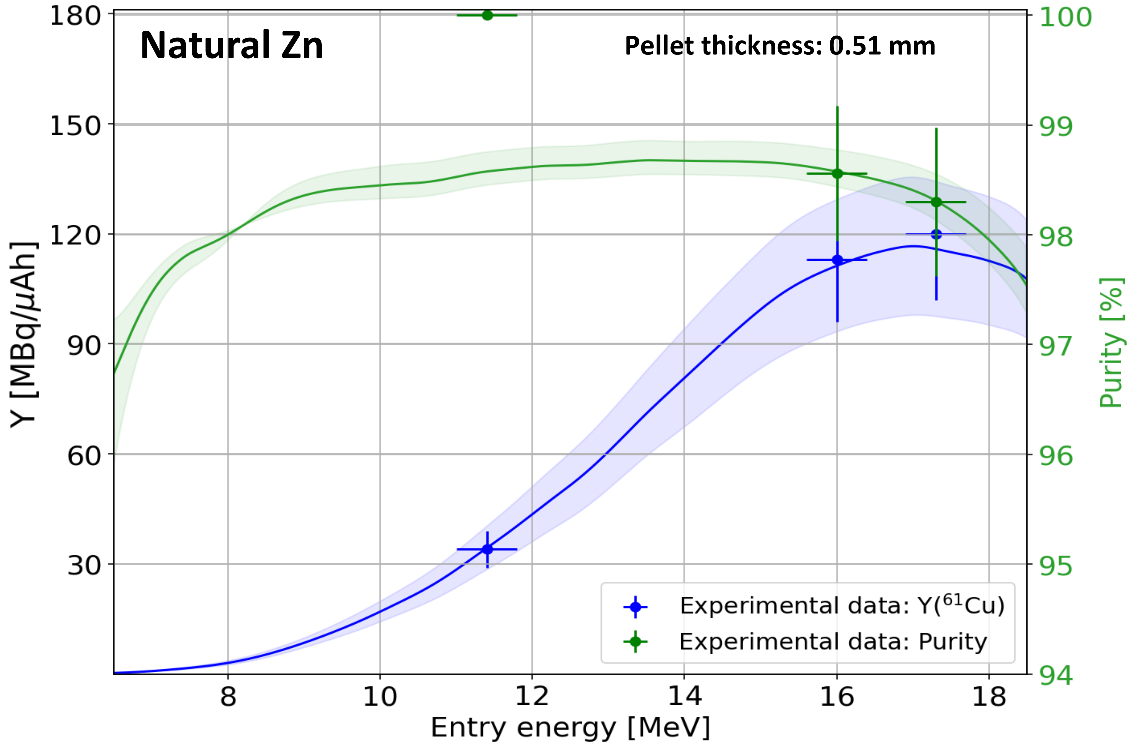


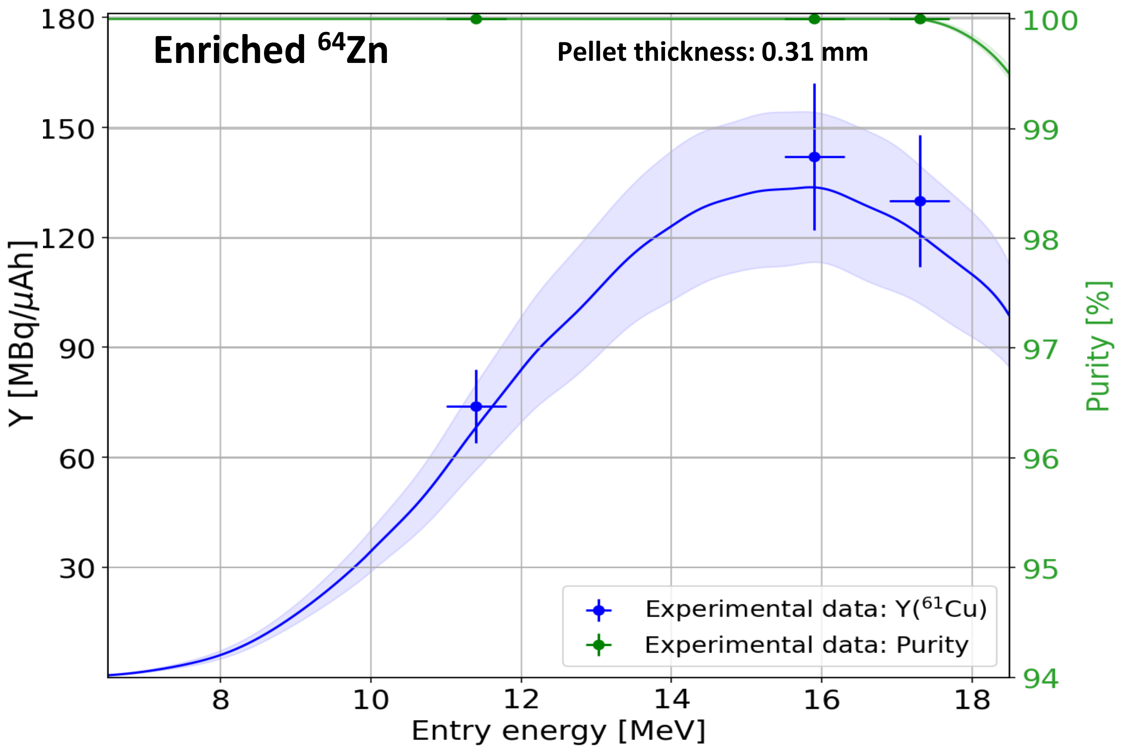
^{61}Cu production: natural vs enriched ^{64}Zn

	Nat Zn	**Enr -^{64}Zn**
E [MeV]	16.0	17.8
Irrad time [h]	3	12
TTY [MBq/µA]	317	1606
P_{EOB} [%]	98.64	99.98



^{61}Cu production tests





	E [MeV]	**Q [10^{-4} μAh]**	**Y(^{61}Cu) [MBq/μAh]**	**P(^{61}Cu) [%]**	**Q [10^{-4} μAh]**	**Y(^{61}Cu) [MBq/μAh]**	**P(^{61}Cu) [%]**
Test 1	17.3 ± 0.4	3.3 ± 0.3	120 ± 18 *(115)*	98.3 ± 0.7 *(98.3)*	2.3 ± 0.2	130 ± 18 *(123)*	100 *(100)*
Test 2	16.0 ± 0.4	3.1 ± 0.3	113 ± 17 *(111)*	98.6 ± 0.6 *(98.6)*	2.7 ± 0.3	142 ± 20 *(131)*	100 *(100)*
Test 3	11.4 ± 0.4	1.1 ± 0.1	34 ± 5 *(35)*	100 *(99)*	1.1 ± 0.1	74 ± 10 *(70)*	100 *(100)*

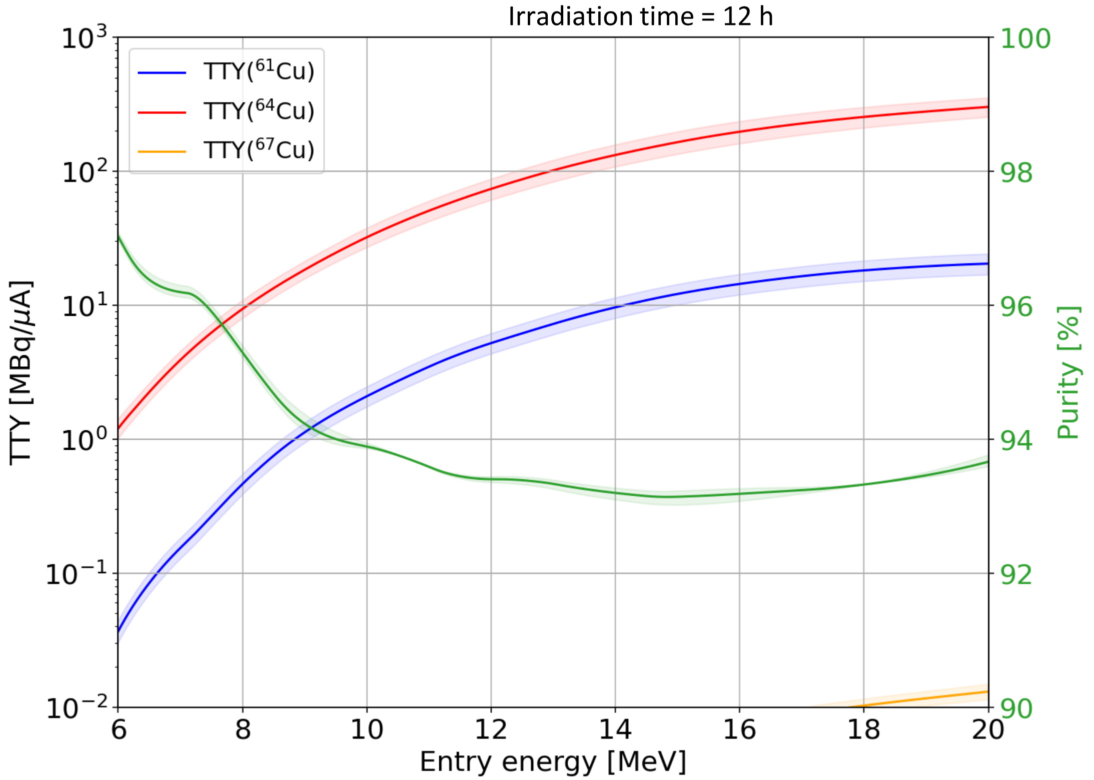
G. Dellepiane et al, *Appl Radiat Isot 2022, 190*, 110466

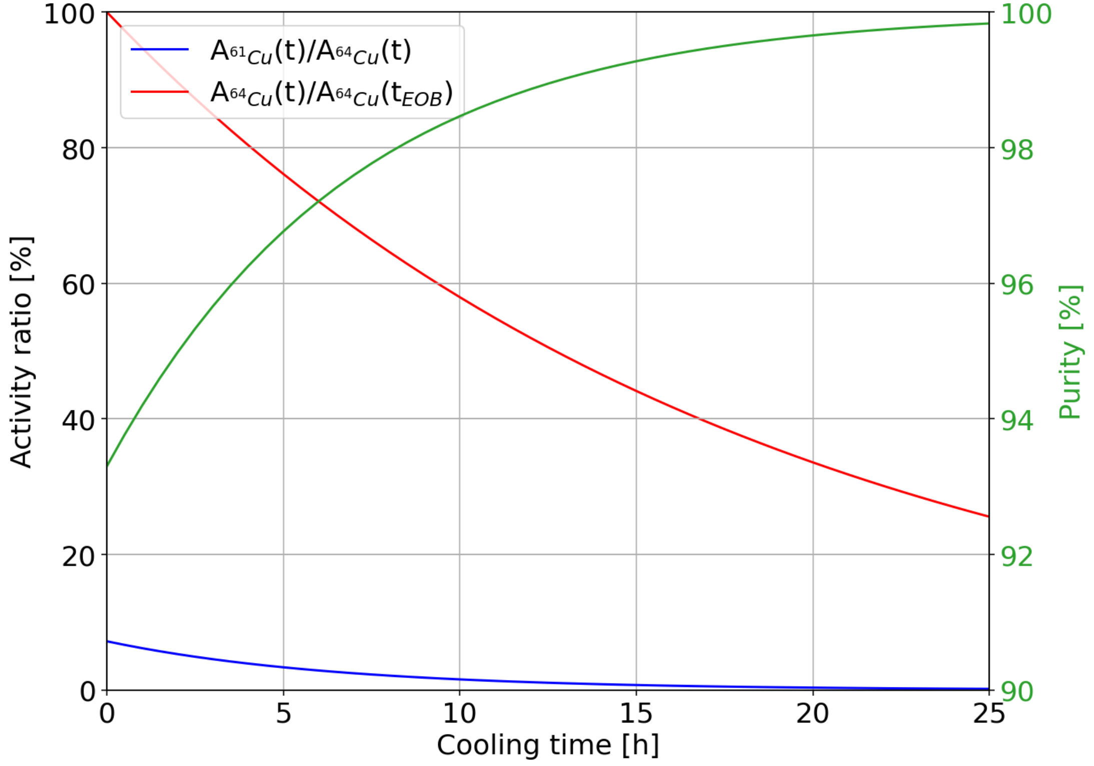
^{64}Cu production

	^{64}Zn	^{66}Zn	^{67}Zn	^{68}Zn	^{70}Zn
Enr. ^{67}ZnO [%]	1.56	3.88	**89.60**	4.91	0.05

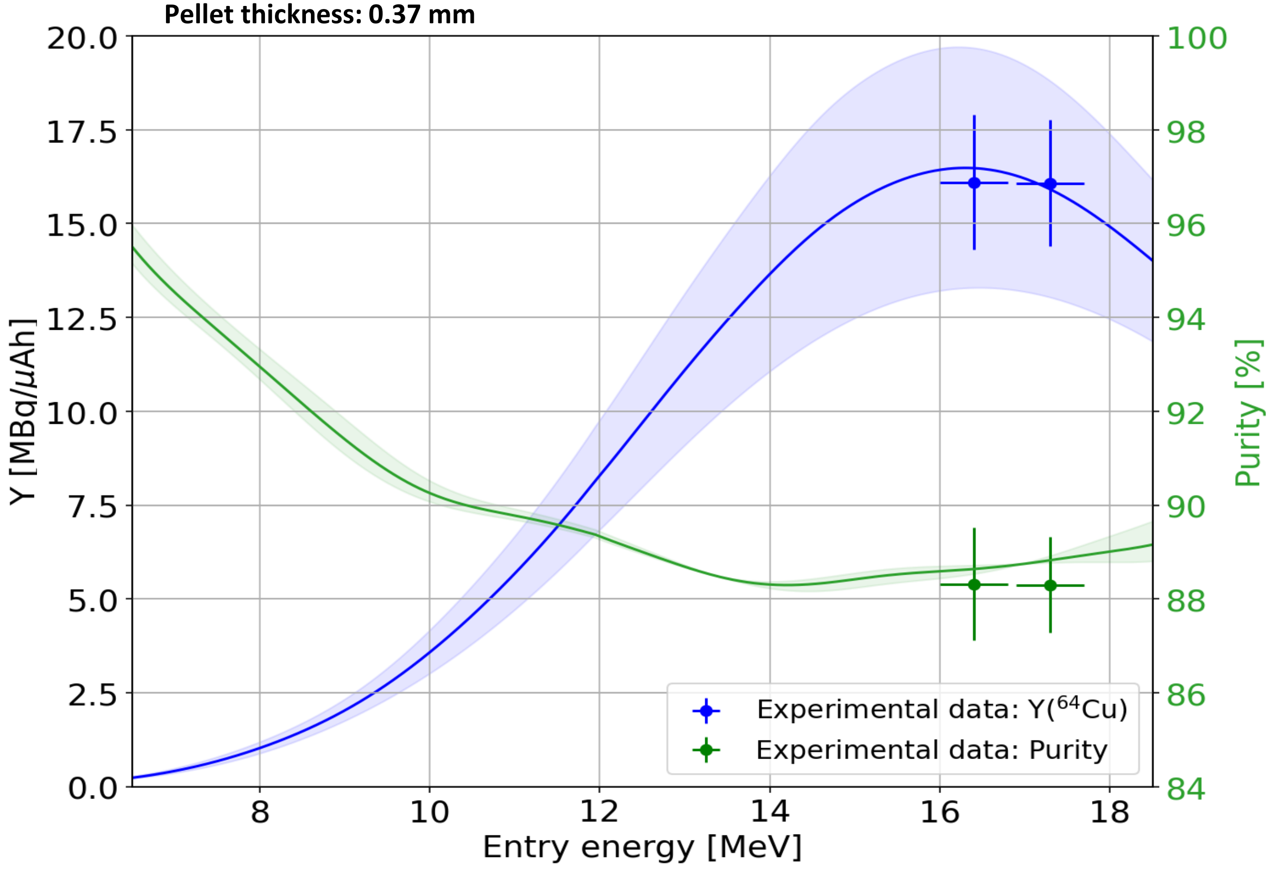
	EOB	**t_c = 10 h**
TTY [MBq/µA]	250	170
P_{EOB} [%]	93.30	98.47

*Proton energy: **17.8 MeV**; Irradiation time: **12 h**





^{64}Cu production tests



	E [MeV]	Q [10^{-4} μAh]	Y(^{64}Cu) [MBq/μAh]	P_{EOB}(^{64}Cu) [%]	P_{10h}(^{64}Cu) [%]
Test 1	17.3 ± 0.4	2.7 ± 0.3	16.1 ± 1.7 *(15.9)*	88.3 ± 1.0 *(88.8)*	97.4 ± 1.0 *(97.4)*
Test 2	16.4 ± 0.4	1.3 ± 0.1	16.1 ± 1.8 *(16.3)*	88.3 ± 1.2 *(88.6)*	97.3 ± 1.3 *(97.3)*

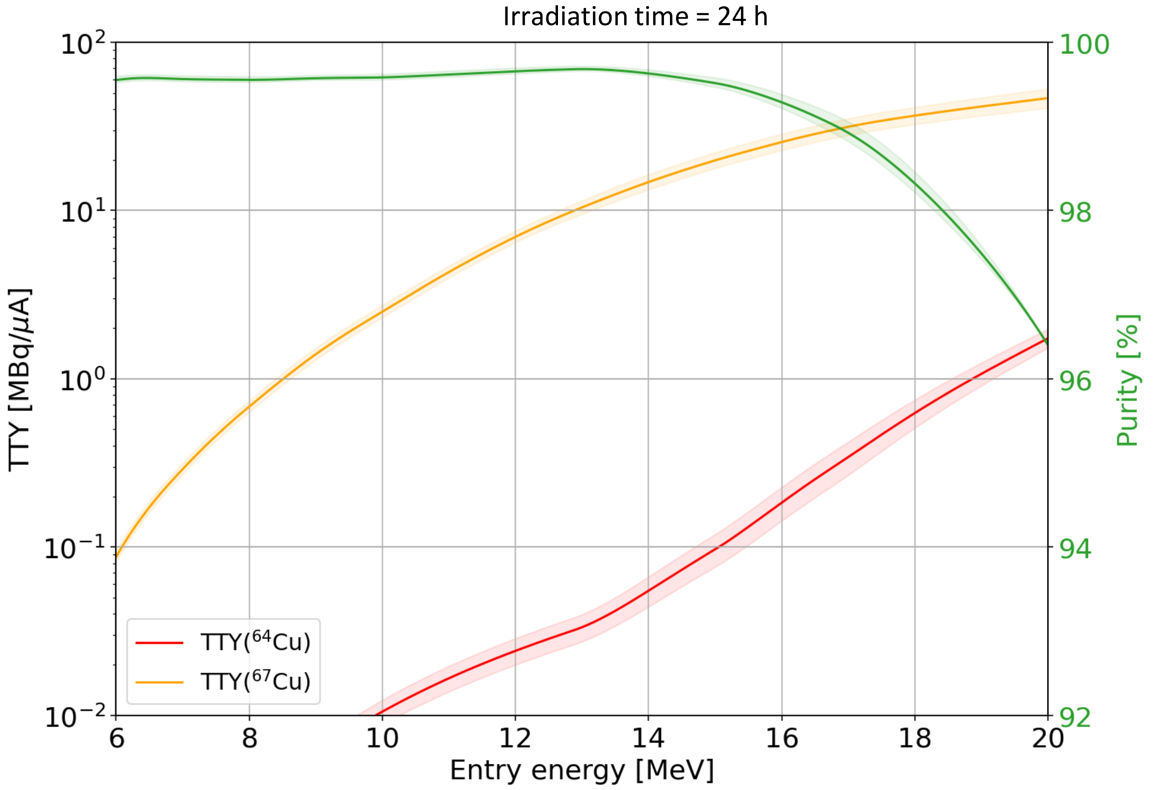
G. Dellepiane et al, *Appl Radiat Isot 2023, 191*, 110518

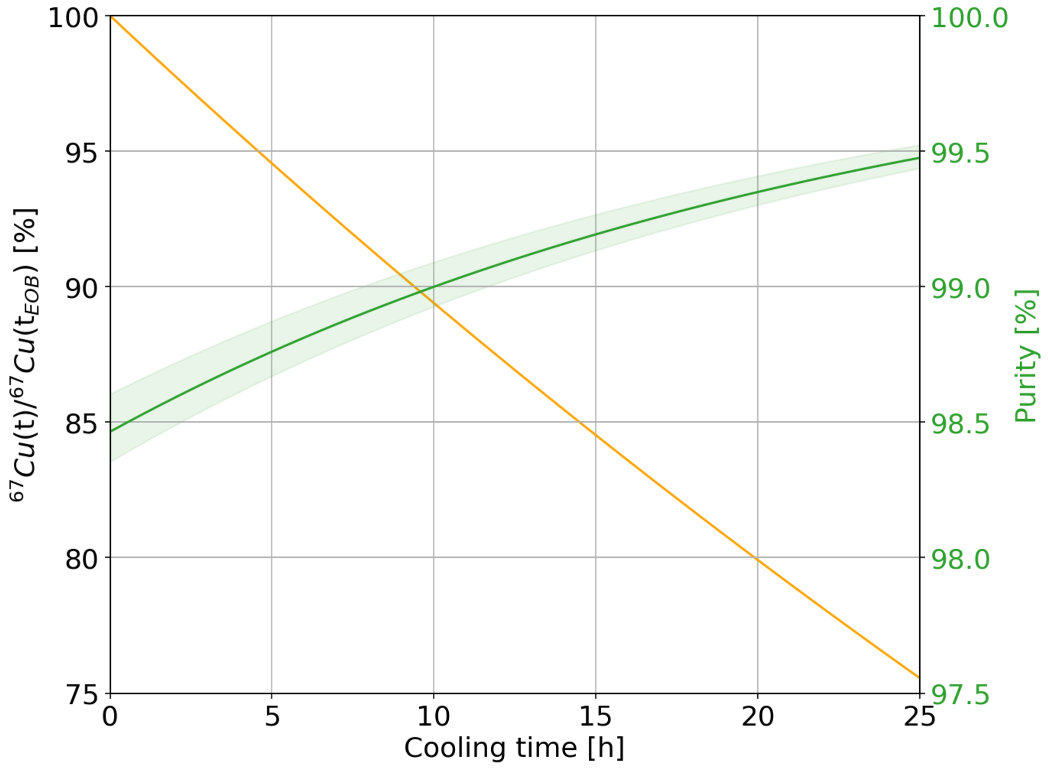
^{67}Cu production

	^{64}Zn	^{66}Zn	^{67}Zn	^{68}Zn	^{70}Zn
Enr. ^{70}ZnO [%]	0.02	0.01	0.02	1.20	**98.75**

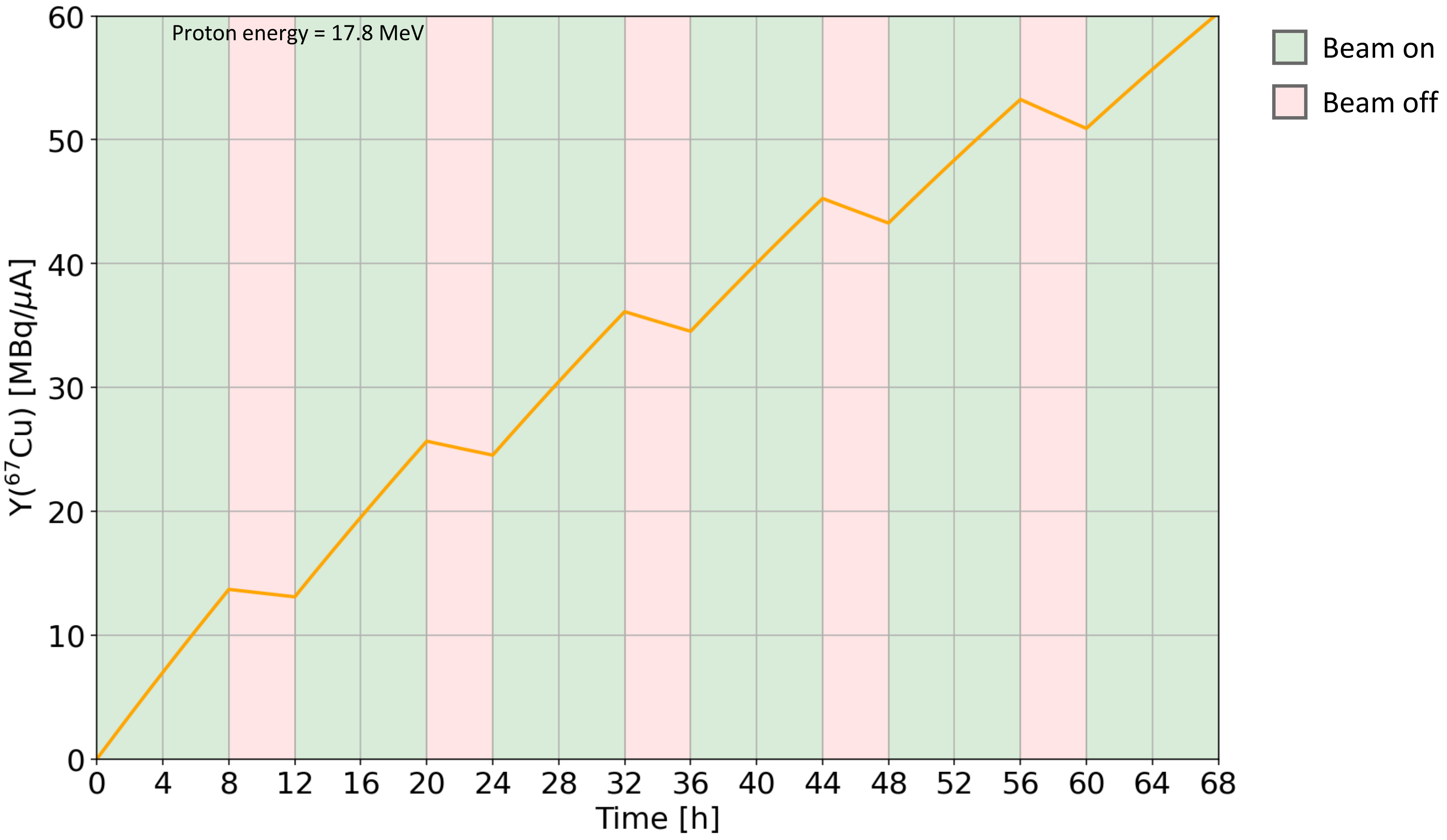
	EOB	**t_c = 10 h**
TTY [MBq/μA]	36	31
P_{EOB} [%]	98.46	99.00

*Proton energy: **17.8 MeV**; Irradiation time: **24 h**

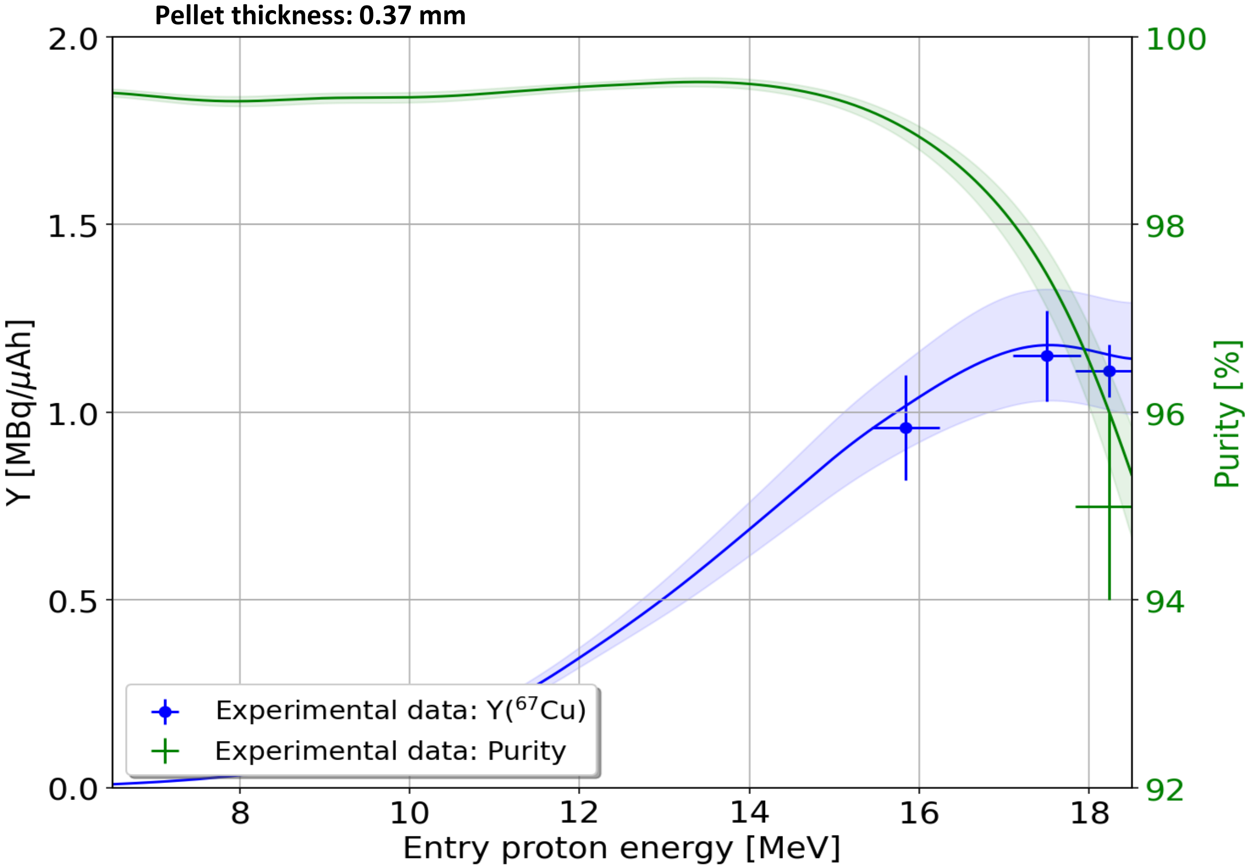




^{67}Cu production

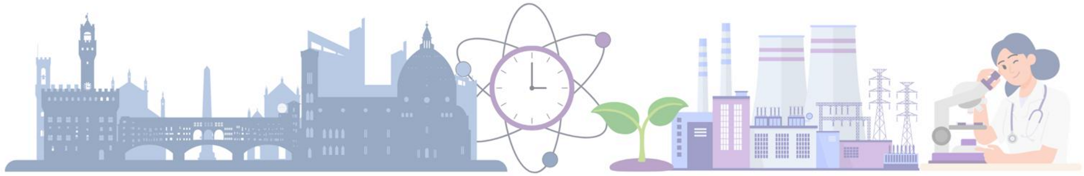


^{67}Cu production tests

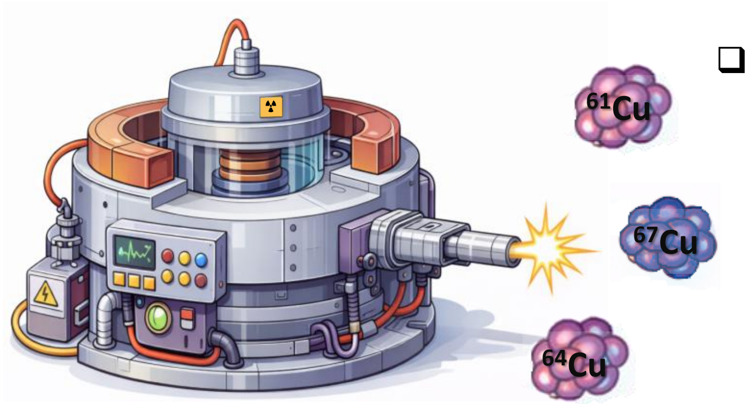


	E [MeV]	Q [10^{-3} µAh]	Y(^{64}Cu) [MBq/µAh]	P_{EOB}(^{64}Cu) [%]
Test 1	11.0 ± 0.4	7.9 ± 0.8	0.96 ± 0.14 *(1.02)*	100 *(99)*
Test 2	13.2 ± 0.4	1.7 ± 0.2	1.15 ± 0.12 *(1.18)*	100 *(98)*
Test 3	14.0 ± 0.4	37.7 ± 1.8	1.11 ± 0.07 *(1.15)*	95 ± 1 *(96)*

G. Dellepiane et al, *Appl Radiat Isot 2023, 195*, 110737



Conclusions and outlook

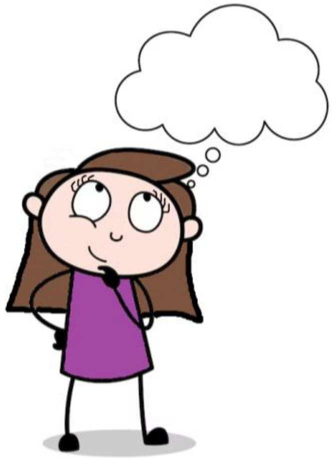


- We demonstrated the feasibility of producing **^{61}Cu, ^{64}Cu** and **^{67}Cu** using a biomedical cyclotron

- **Highly-enriched zinc** targets are essential to achieve **high radionuclidic purity**

  ALTHOUGH **low-cost natural Zn** may be considered for nearby ^{61}Cu PET applications

- For **^{61}Cu** and **^{64}Cu**, the achievable yields are sufficient for pre-clinical and clinical applications



- **^{67}Cu** production requires **high beam currents**

  THEREFORE **further studies** are needed to assess **target robustness** and **thermal performance** under high-current irradiations

Thank you all for your attention!