



SATIF – 12

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# BEAM-LOSS CRITERIA FOR HEAVY-ION ACCELERATORS

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# Content

## BEAM-LOSS CRITERIA FOR HEAVY-ION ACCELERATORS.

.motivation

.review of previous results | FLUKA 2008.3.6

.new results | FLUKA 2011.2b.5

.conclusion

# Motivation

SIMULATIONS & EXPERIMENTS.

- . Beam-loss criteria
- . „Hands-on“ maintenance
- . FLUKA verification
- . Previous experiments at GSI
- . Preparation work at FAIR



# Motivation

## SIMULATIONS & EXPERIMENTS.

- . Beam-loss criteria
- . „Hands-on“ maintenance
- . FLUKA verification
- . Previous experiments at GSI
- . Preparation work at FAIR

Target	Beam energy	Beam
Stainless steel	1 GeV/u	U
Stainless steel, Cu, Al, Pb	950 MeV/u	U
Stainless steel, Cu, Al, Pb , Graphite, Carbon-composite	500 MeV/u	U
Pb	345 MeV/u	U
Al	300 MeV/u	U
<b>Al, Cu</b>	<b>200 MeV/u</b>	<b>U</b>
Carbon-composite	100 MeV/u	U
Cu, Al, Pb	500 MeV/u	Ta
Cu	700 MeV/u	N
Cu, Al, Pb	500 MeV/u	N
Cu, Al	1 GeV/u	Ar
Cu, Al	500 MeV/u	Ar

# Beam-loss criteria

N. V. MOKHOV AND W. CHOU (EDS.), BEAM HALO AND SCRAPING, THE 7<sup>TH</sup> ICFA MINIWORKSHOP ON HIGH INTENSITY HIGH BRIGHTNESS HADRON BEAMS, WISCONSIN, USA, 13-15 SEPTEMBER 1999

- . the tolerable beam-loss level of **1 W/m**
- . proton beam
- . energy above 100 MeV
- . uniformly distributed along the beam line
- . 100 days of operation
- . at 30 cm (1 foot) from the component surface
- . 4 hours after shutdown
- . Dose rate below 1 mSv/h

# Beam-loss criteria

. beam-loss criteria for heavy-ion accelerators

Ion 1GeV/u	Number of particles/s equivalent to 1W
$^1\text{H}$	<b>6.24E+09</b>
$^4\text{He}$	1.56E+09
$^{12}\text{C}$	5.20E+08
$^{20}\text{Ne}$	3.12E+08
$^{40}\text{Ar}$	1.56E+08
$^{84}\text{Kr}$	7.43E+07
$^{132}\text{Xe}$	4.73E+07
$^{197}\text{Au}$	3.17E+07
$^{238}\text{U}$	2.62E+07

# Previous simulations

FLUKA 2008.3.6

I.STRASIK, E.MUSTAFIN, M.PAVLOVIC: RESIDUAL ACTIVITY INDUCED BY HEAVY IONS AND BEAM-LOSS CRITERIA FOR HEAVY-ION ACCELERATORS, PHYS. REV. ST ACCEL. BEAMS 13, 071004 (2010)

- . target materials: stainless steel, cooper
- . primary beams:  $^1\text{H}$ ,  $^4\text{He}$ ,  $^{12}\text{C}$ ,  $^{20}\text{Ne}$ ,  $^{40}\text{Ar}$ ,  $^{84}\text{Kr}$ ,  $^{132}\text{Xe}$ ,  $^{197}\text{Au}$ ,  $^{238}\text{U}$
- . beam energies: 200MeV/u ÷ 1GeV/u
- . target geometry: beam-pipe, bulky target
- . normalized induced activities | beam power of 1 W | 3 months of irradiation
- . several time points after irradiation

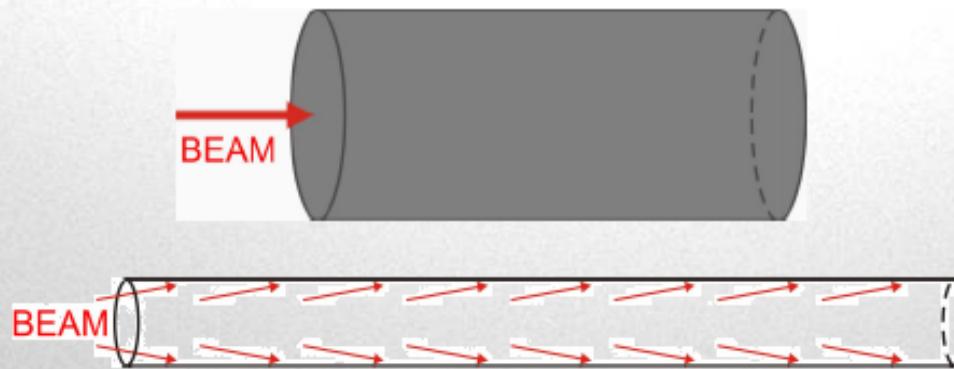


Fig. 6.4. Models of the bulky target (up) and the beam pipe (bottom).

# Previous simulations

FLUKA 2008.3.6

BULKY TARGET.

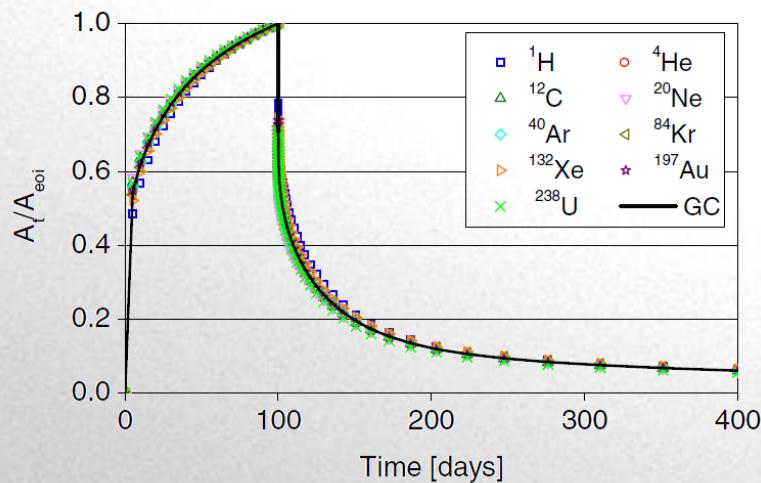
- . target materials: cooper
- . diameter 20 cm
- . length 60 cm



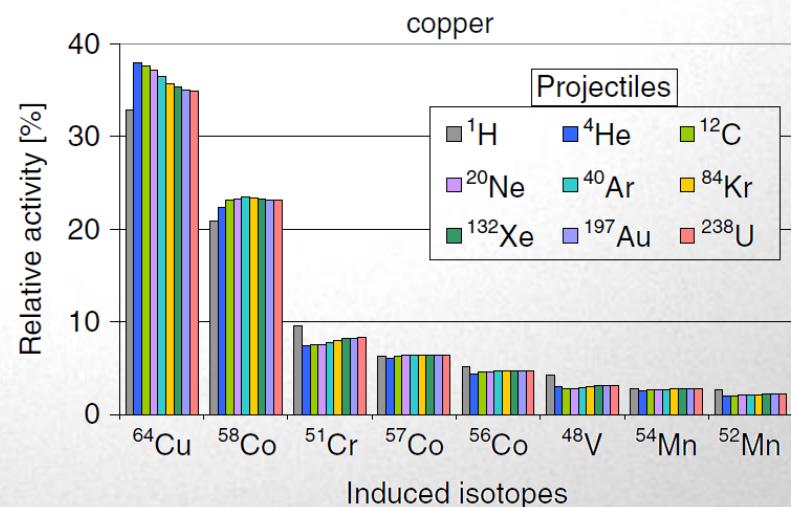
# Generic curve

FLUKA 2008.3.6

- . time evolution of the activity
- . independent from the projectile mass
- . activity normalized to the activity at the end of irradiation
- . obtained by averaging the data points of the individual curves corresponding to different primary ions



. Time evolution of the relative activity in the Beam pipe by different projectiles at 500 MeV/u



. Inventory of nuclides produced in the Beam pipe by different projectiles at 500 MeV/u

# Scaling law

FLUKA 2008.3.6

## SCALING LAW FOR BEAM-LOSS TOLERANCE.

### . relative activities

- . are not strongly depend on the projectile species
- . dependent on the target material  
(isotopes produced mostly by secondary particles)

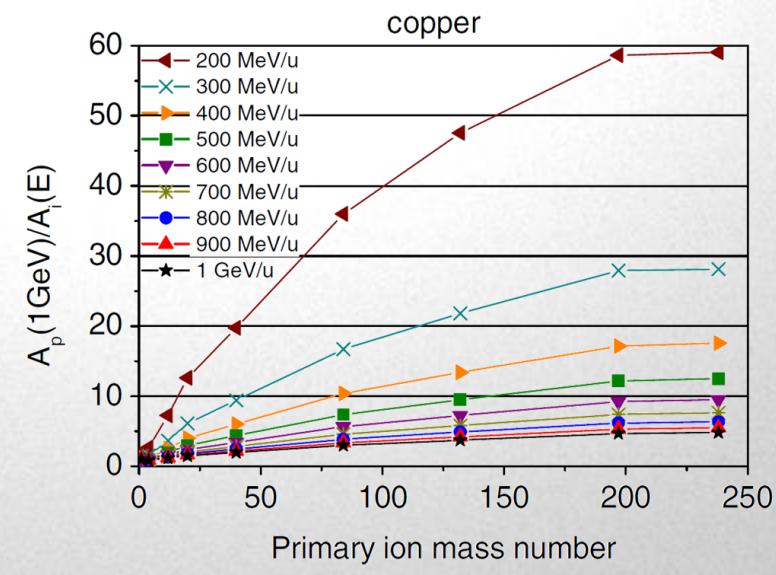
### . the activity induced by 1 W/m of beam losses is decreasing

- . with increasing ion mass
- . with decreasing energy

. The Scaling factor is represented by the ratio of the normalized activity induced by 1GeV proton beam,  $A_p(1\text{GeV})$ , to the normalized activity induced by the beam of interest at given energy,  $A_i(E)$ .

. The activities were calculated by FLUKA at the end of Irradiation.

. The relative standard uncertainty of the presented data is less than 0.76%.



# FLUKA versions

## FLUKA 2008.3.6

- . beam energies:  $200\text{MeV/u} \div 1\text{GeV/u}$
- . threshold for inelastic nucleus-nucleus interaction =  $100\text{MeV/u}$

## FLUKA 2011.2b.5

- . new version allows a treatment below  $100\text{MeV/u}$  for heavy ion

# New simulations

FLUKA 2011.2b.5

- . target materials: **cooper**
- . primary beams:  $^1\text{H}$ ,  $^4\text{He}$ ,  $^{12}\text{C}$ ,  $^{20}\text{Ne}$ ,  $^{40}\text{Ar}$ ,  $^{84}\text{Kr}$ ,  $^{132}\text{Xe}$ ,  $^{197}\text{Au}$ ,  $^{238}\text{U}$
- . beam energies: **25 MeV/u ÷ 1GeV/u**
- . target geometry: **bulky target**
- . normalized induced activities | beam power of 1 W | 3 months of irradiation
- . several time points after irradiation



# New simulations

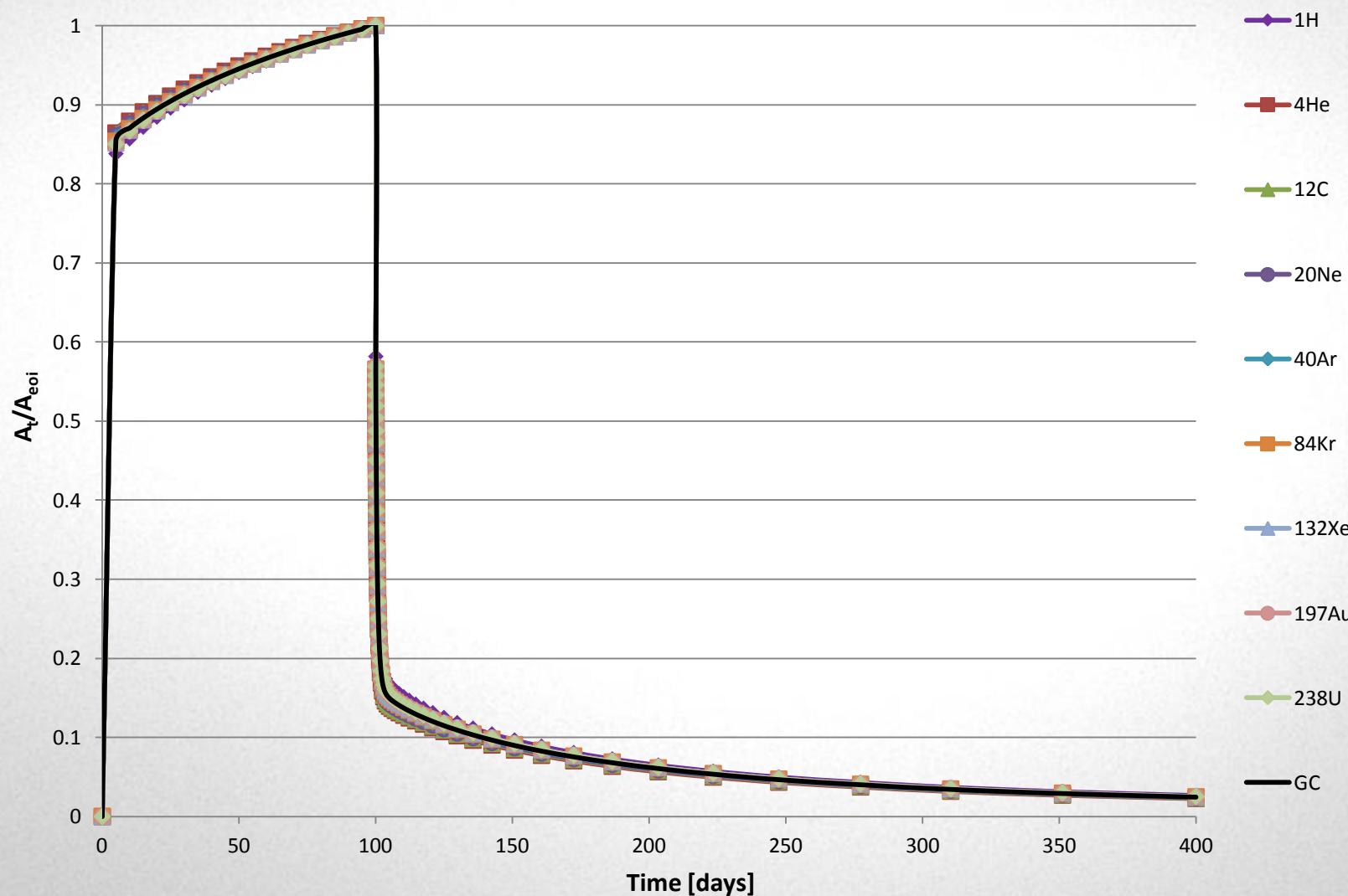
FLUKA 2011.2b.5

INPUT FILES.

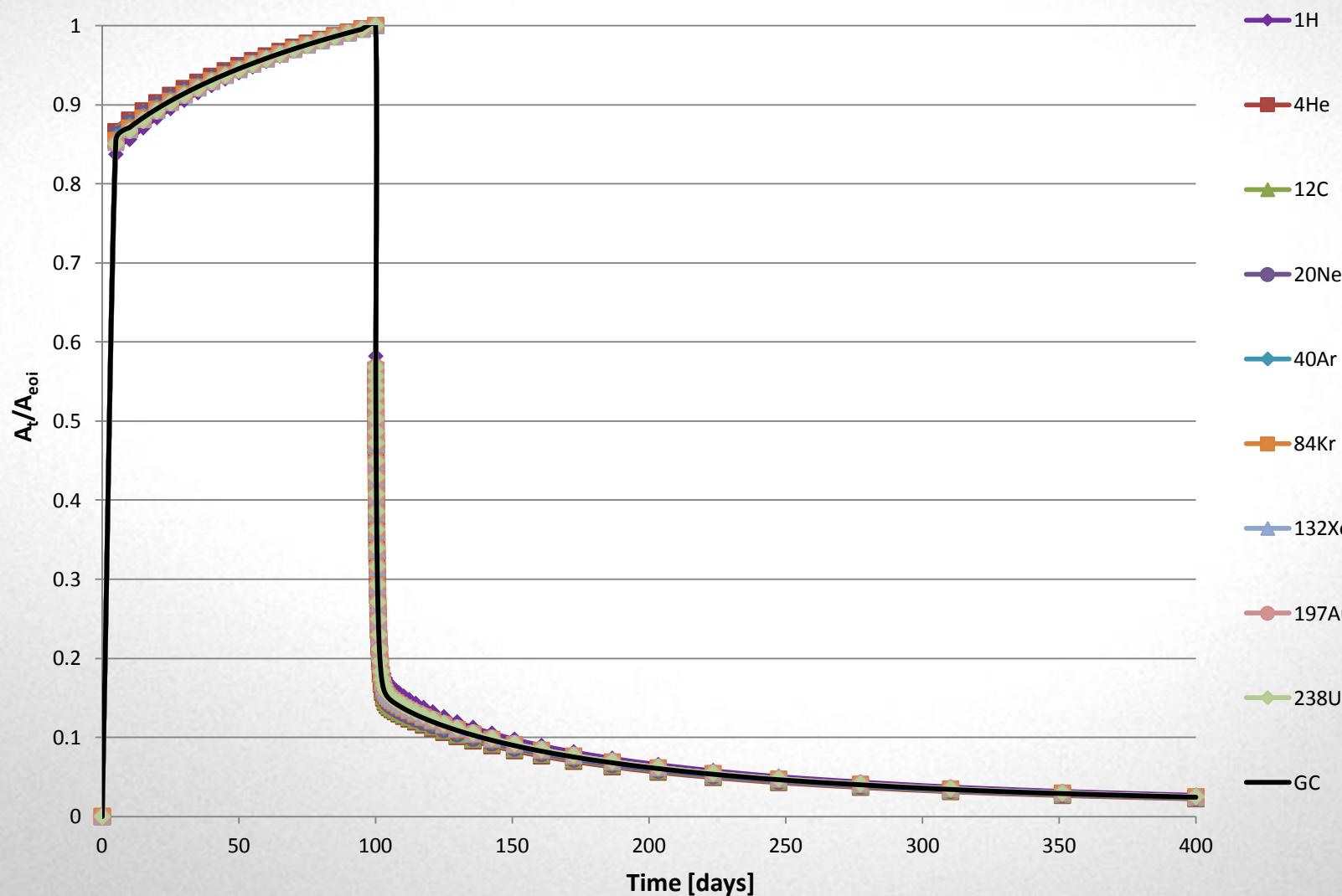
DEFUALTS							NEW-DEFA
BEAM	-2.0	0.0	0.0	-0.58875	-0.58875		<u>4-HELIUM</u>
BEAMPOS	0.0	0.0	-31.0				
PHYSICS	3.						EVAPORAT
PHYSICS	1.						COALESCE
PHYSICS	2.						EM-DISSO
<u>IONTRANS</u>	<u>4-HELIUM (HEAVYION, 0.0)</u>						
GEOBEGIN							COMBNAME

- . evaporation model with heavy-fragment evaporation
- . emission of high-energy light fragments through the coalescence mechanism
- . ion electromagnetic dissociation
- . the heavy-ion transport with nuclear interactions
- . low-energy neutron transport was simulated down to thermal energies
- . residual nuclei from low-energy neutron interactions were scored

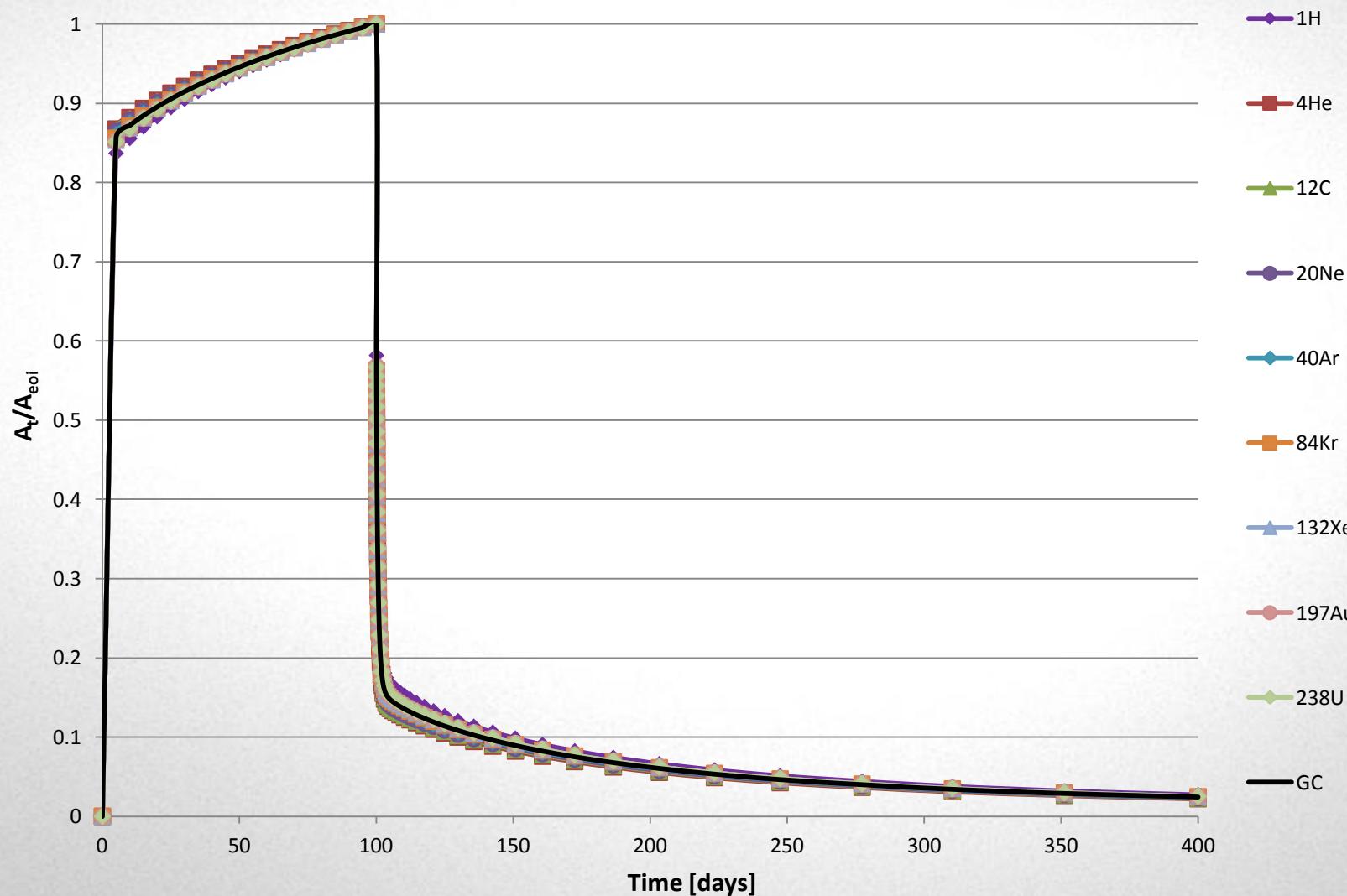
# Generic Curves | 1 GeV/u



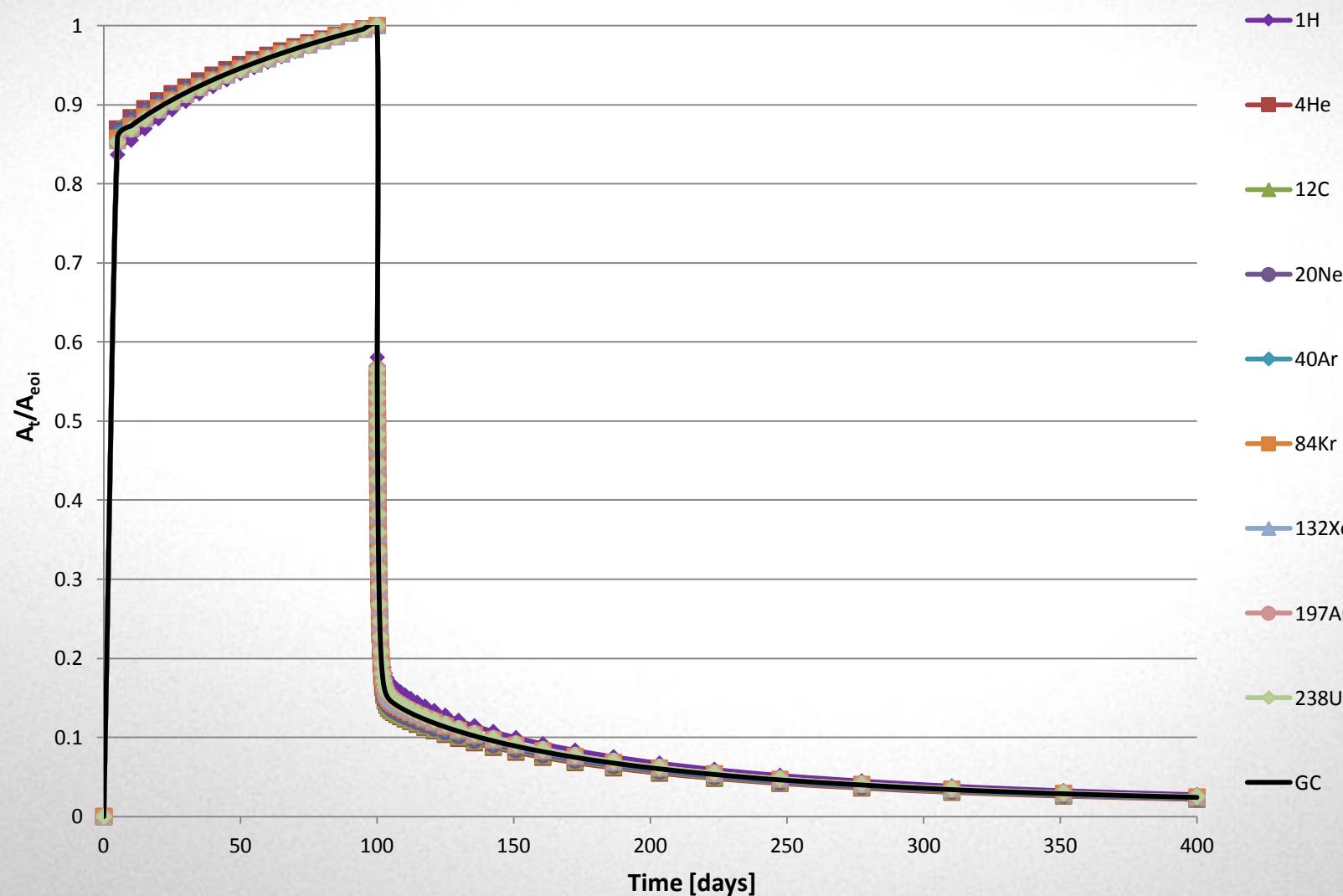
# Generic Curves | 900 MeV/u



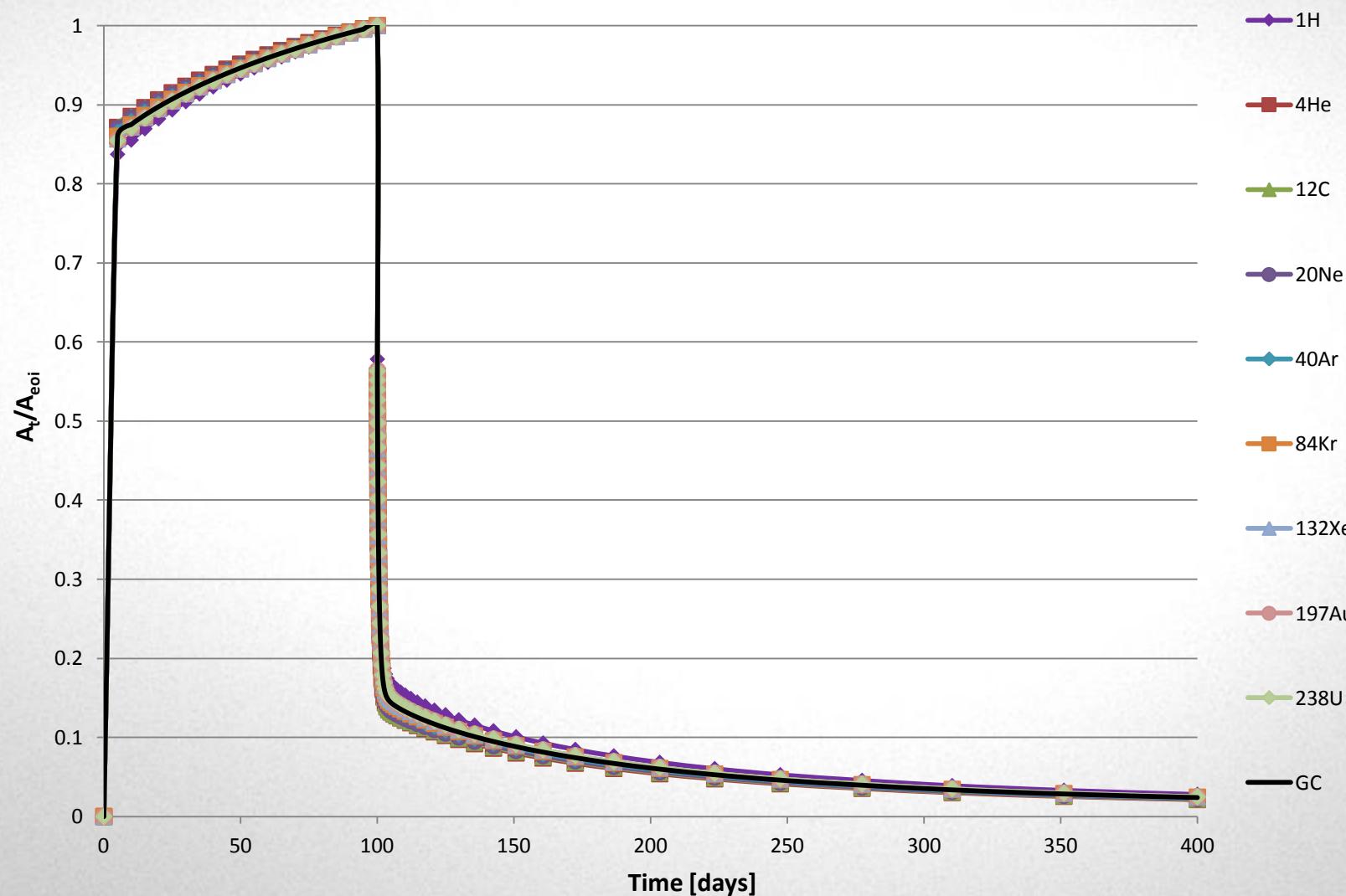
# Generic Curves | 800 MeV/u



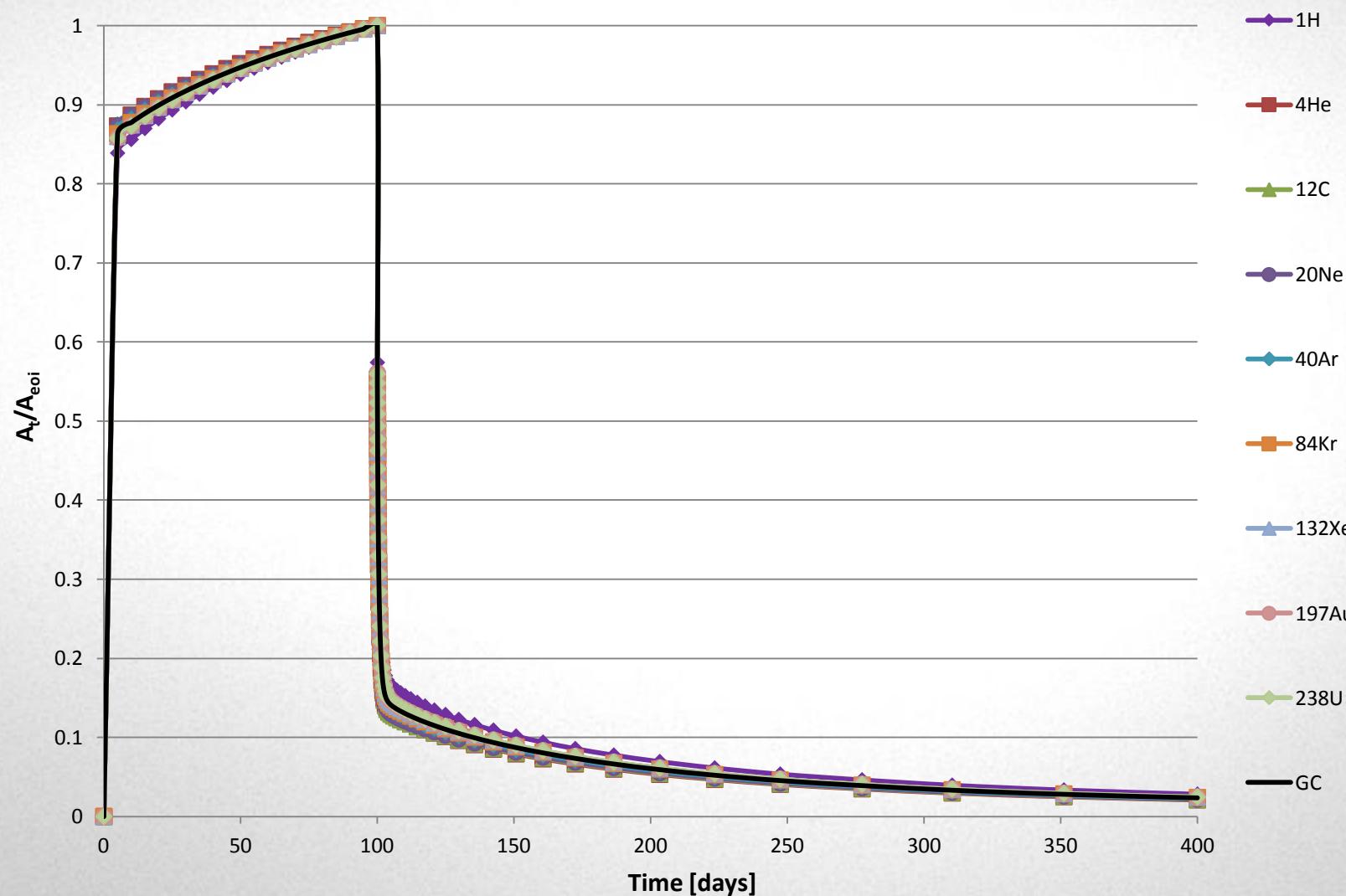
# Generic Curves | 700 MeV/u



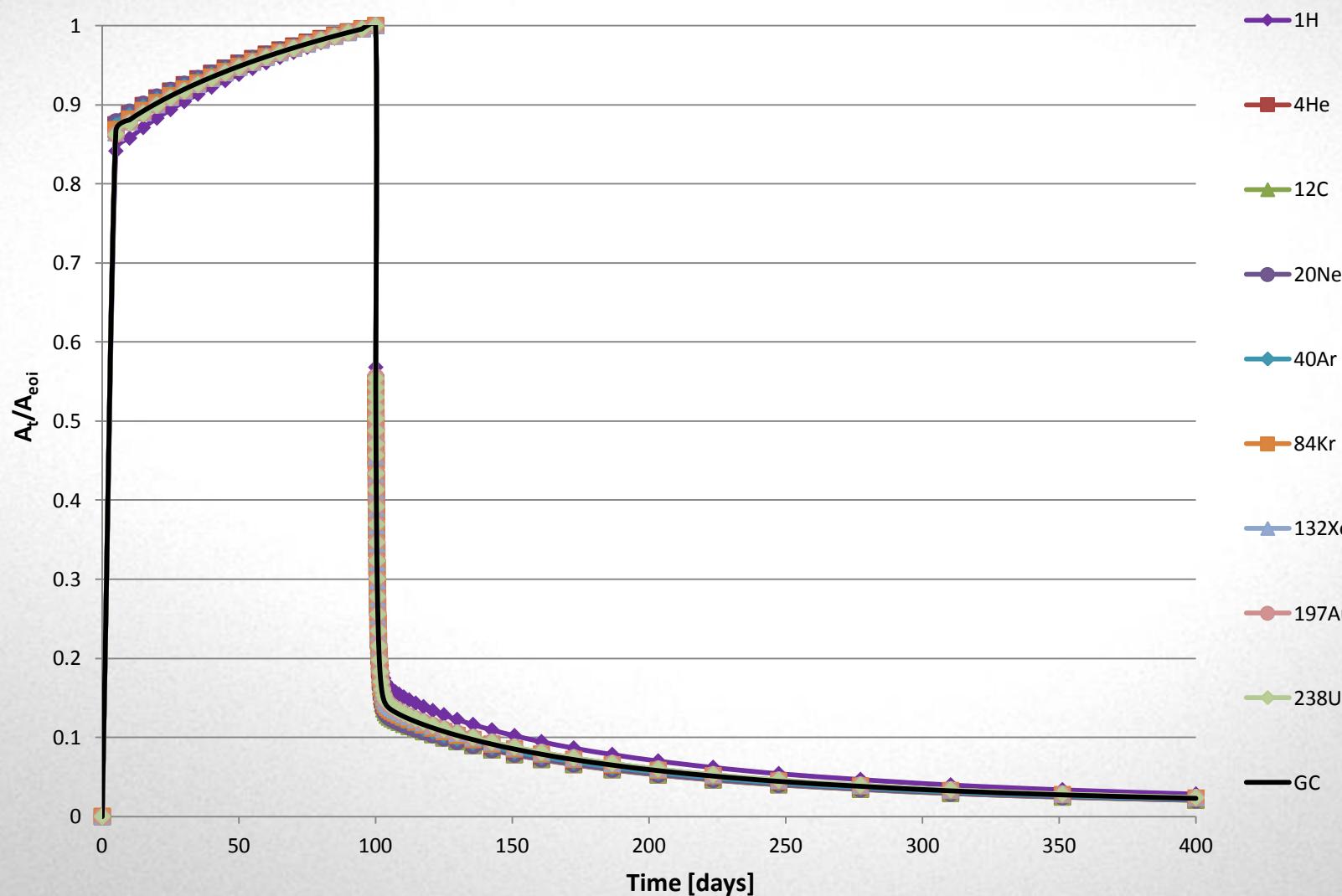
# Generic Curves | 600 MeV/u



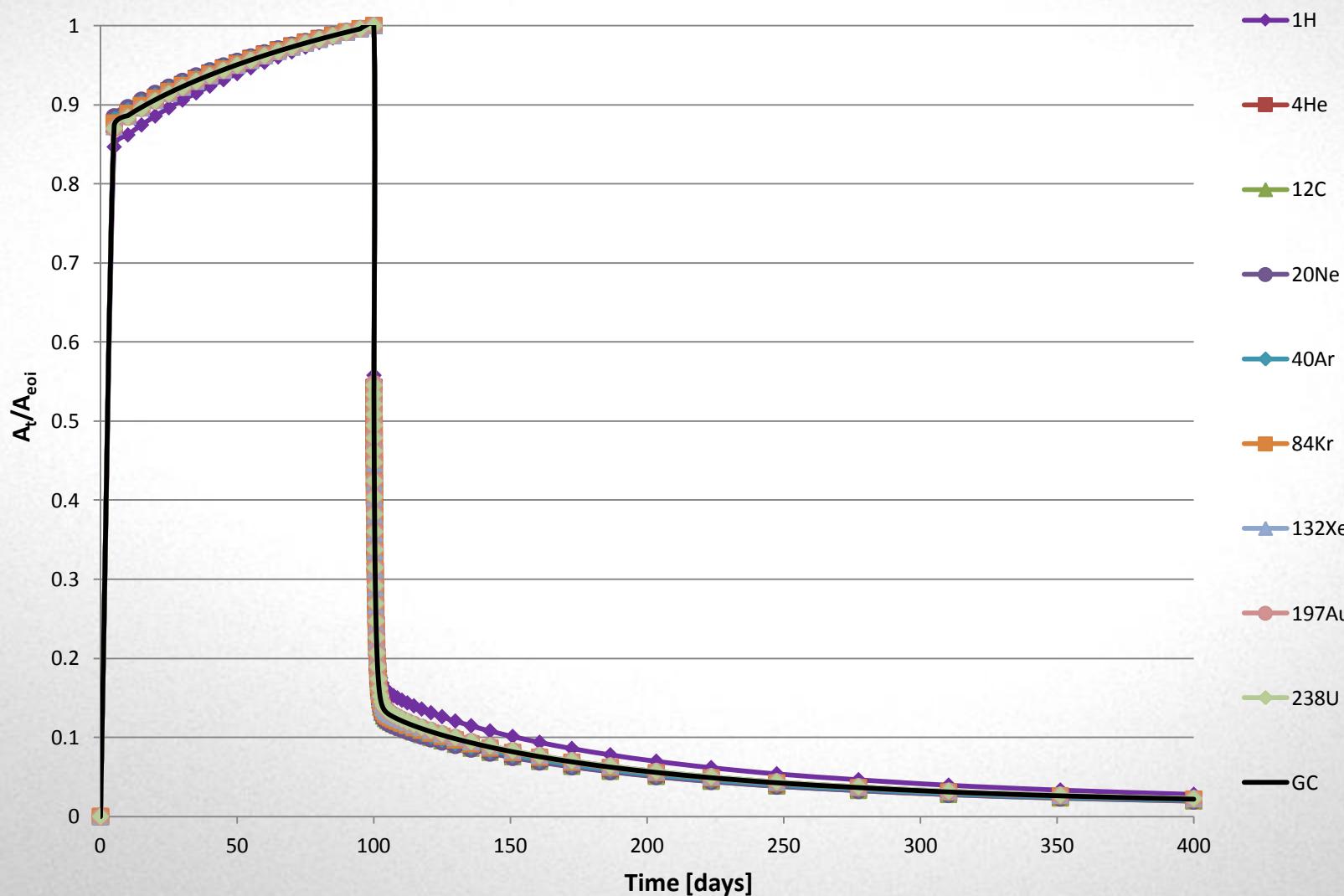
# Generic Curves | 500 MeV/u



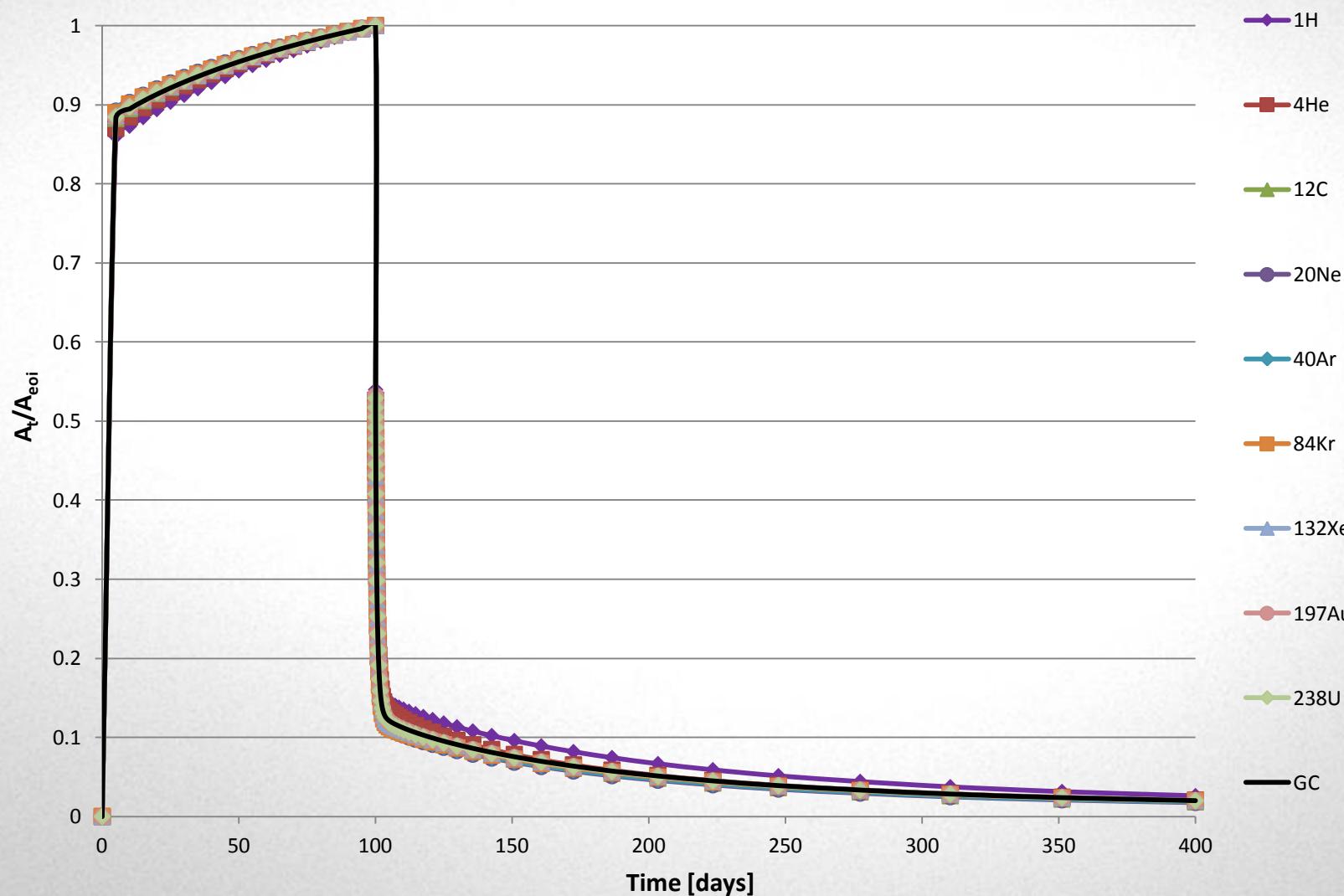
# Generic Curves | 400 MeV/u



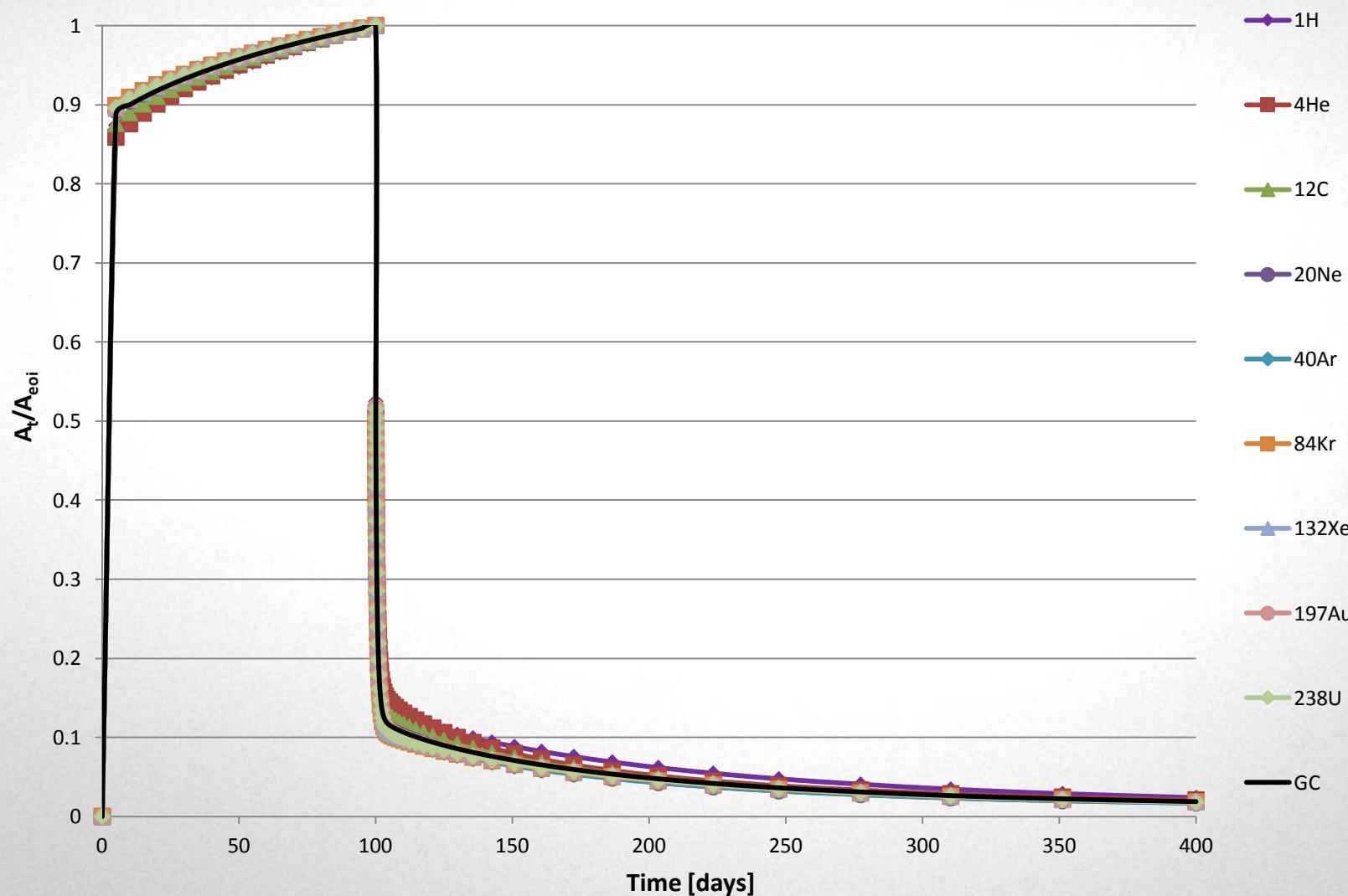
# Generic Curves | 300 MeV/u



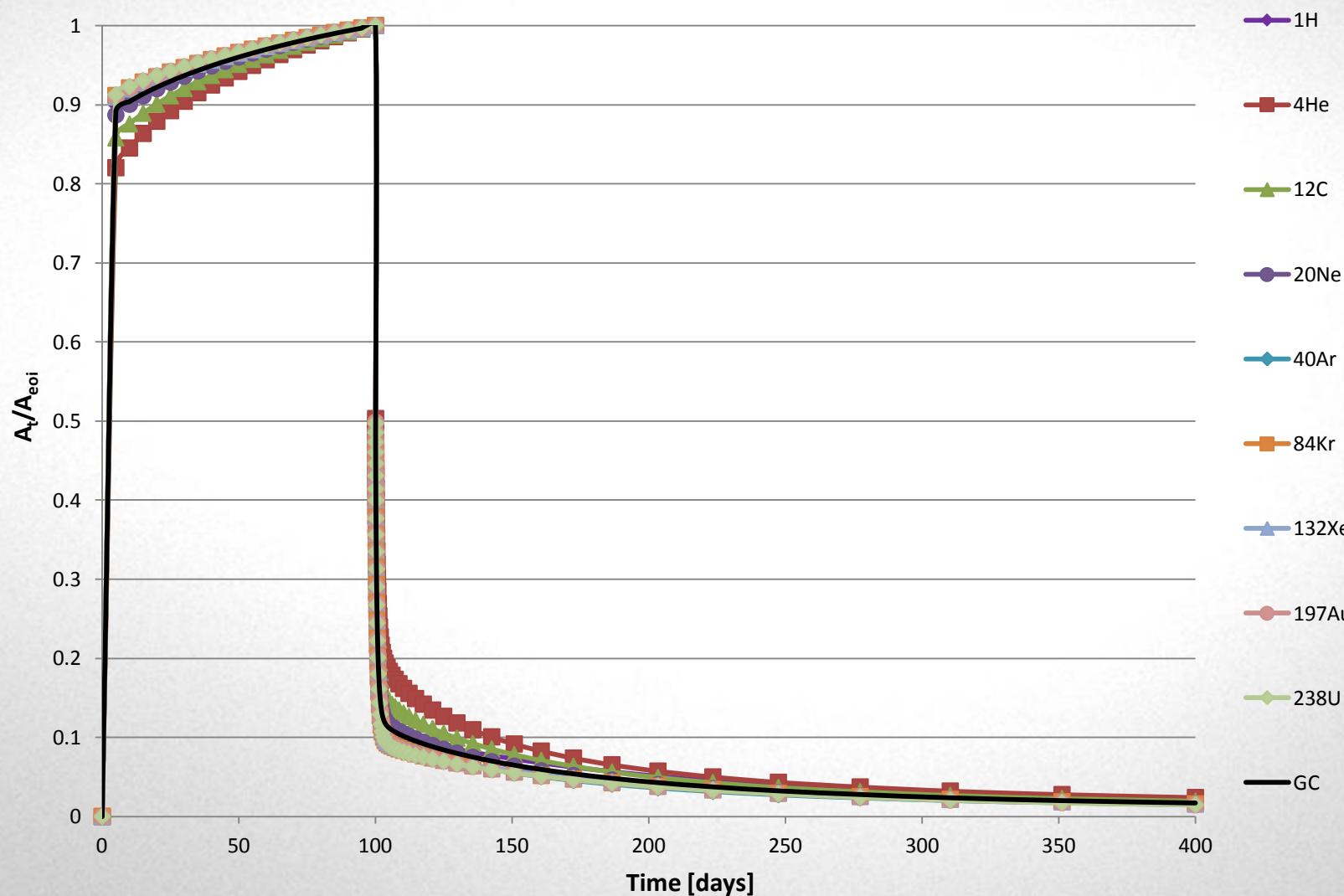
# Generic Curves | 200 MeV/u



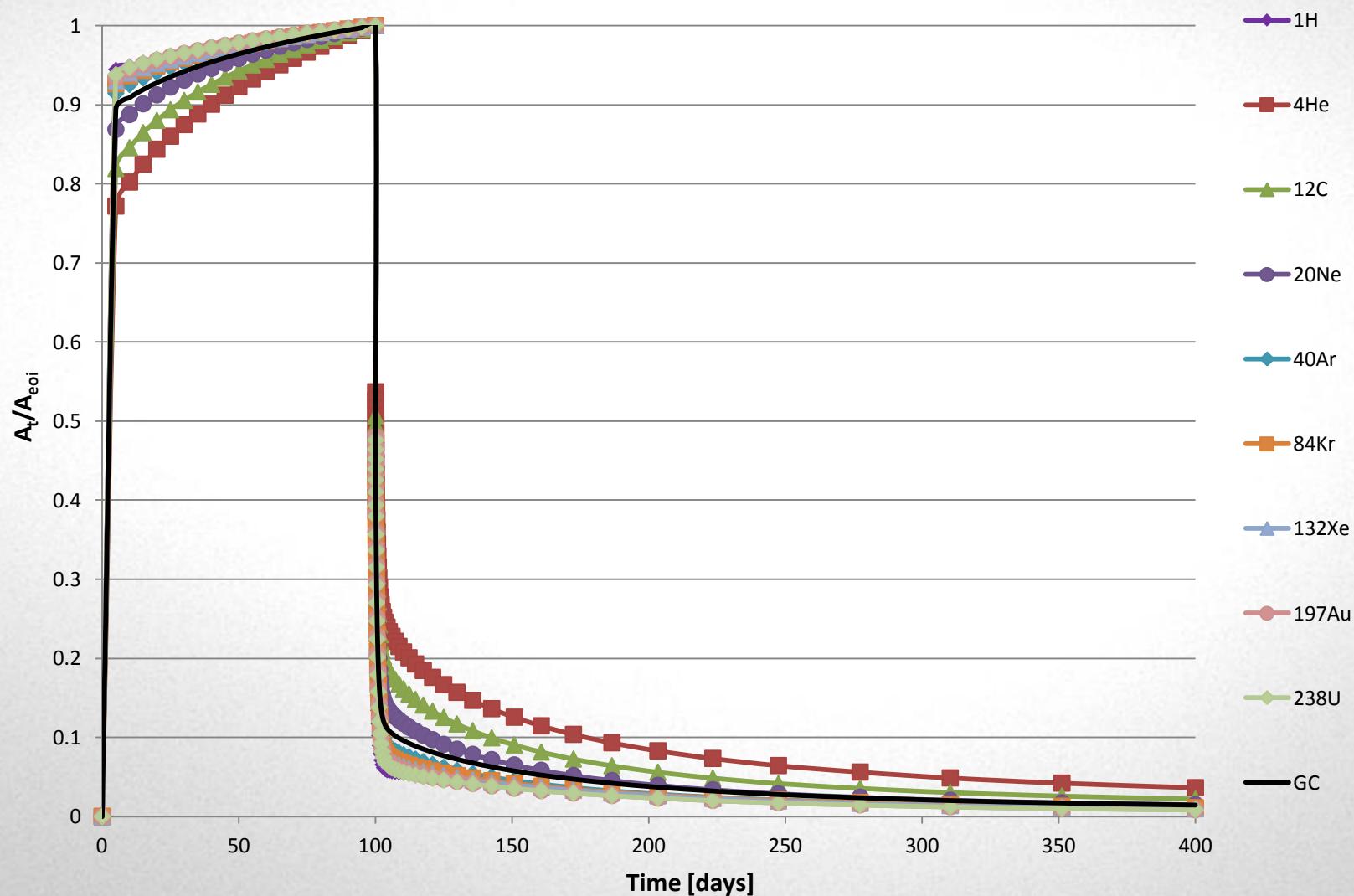
# Generic Curves | 150 MeV/u



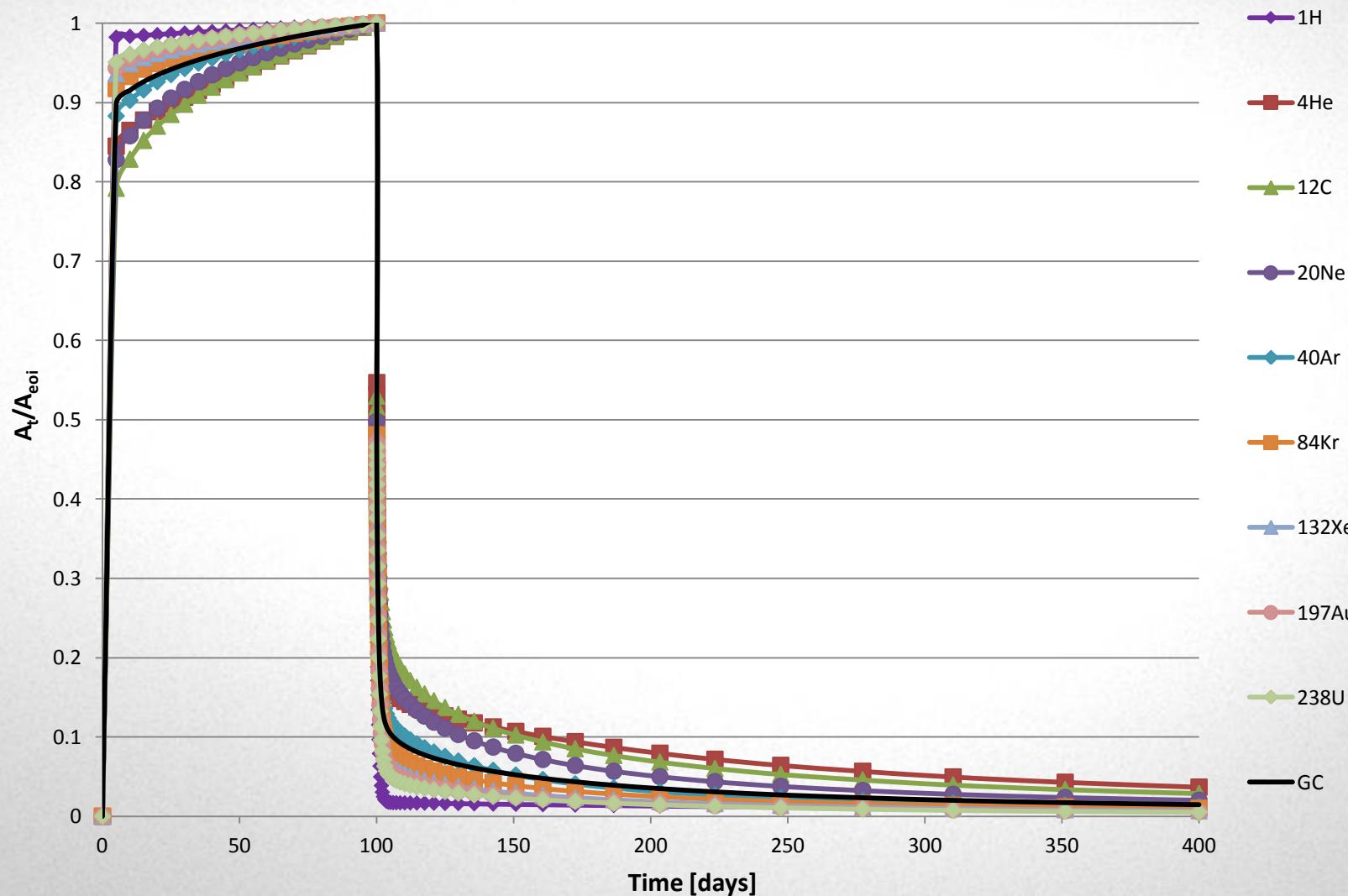
# Generic Curves | 100 MeV/u



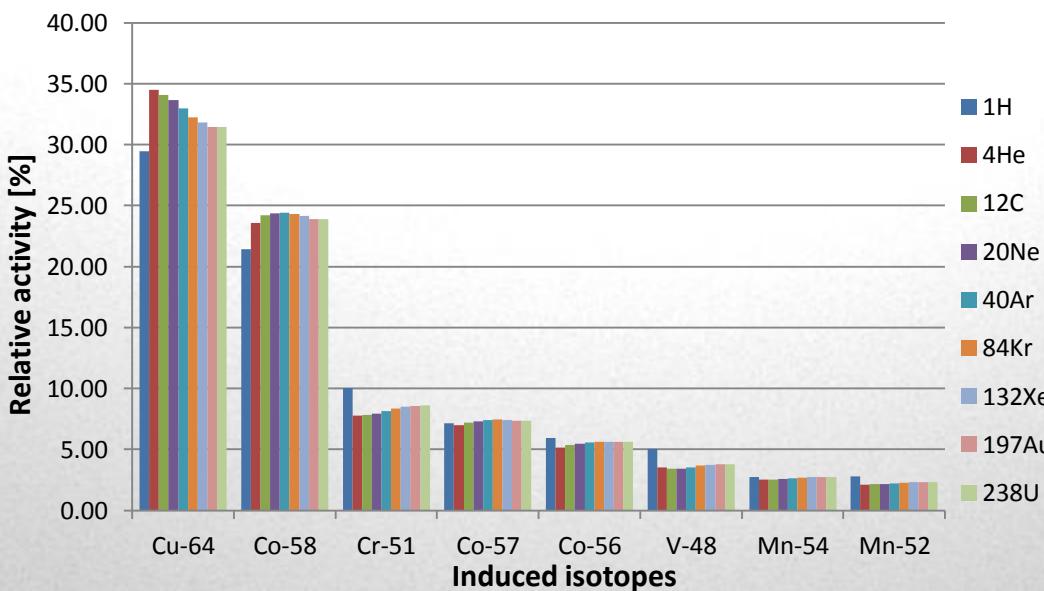
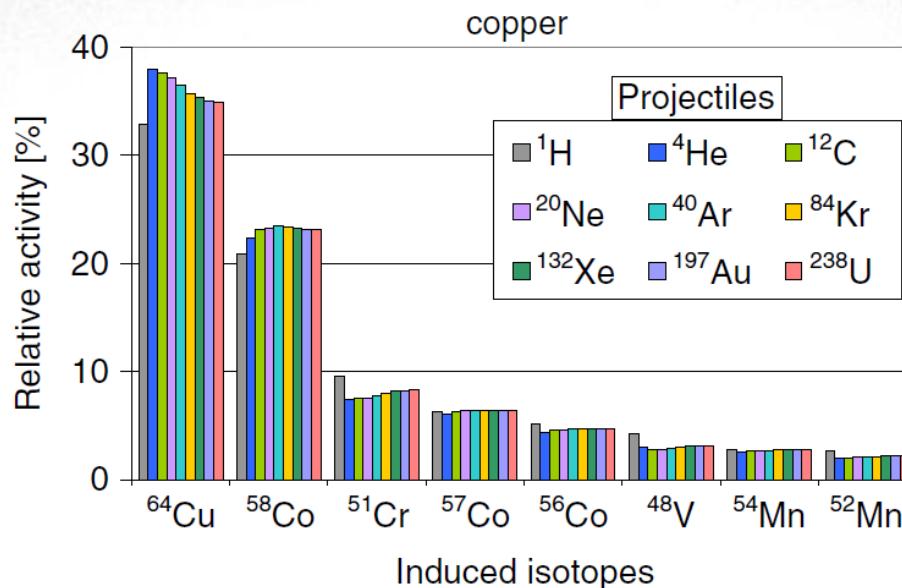
# Generic Curves | 50 MeV/u



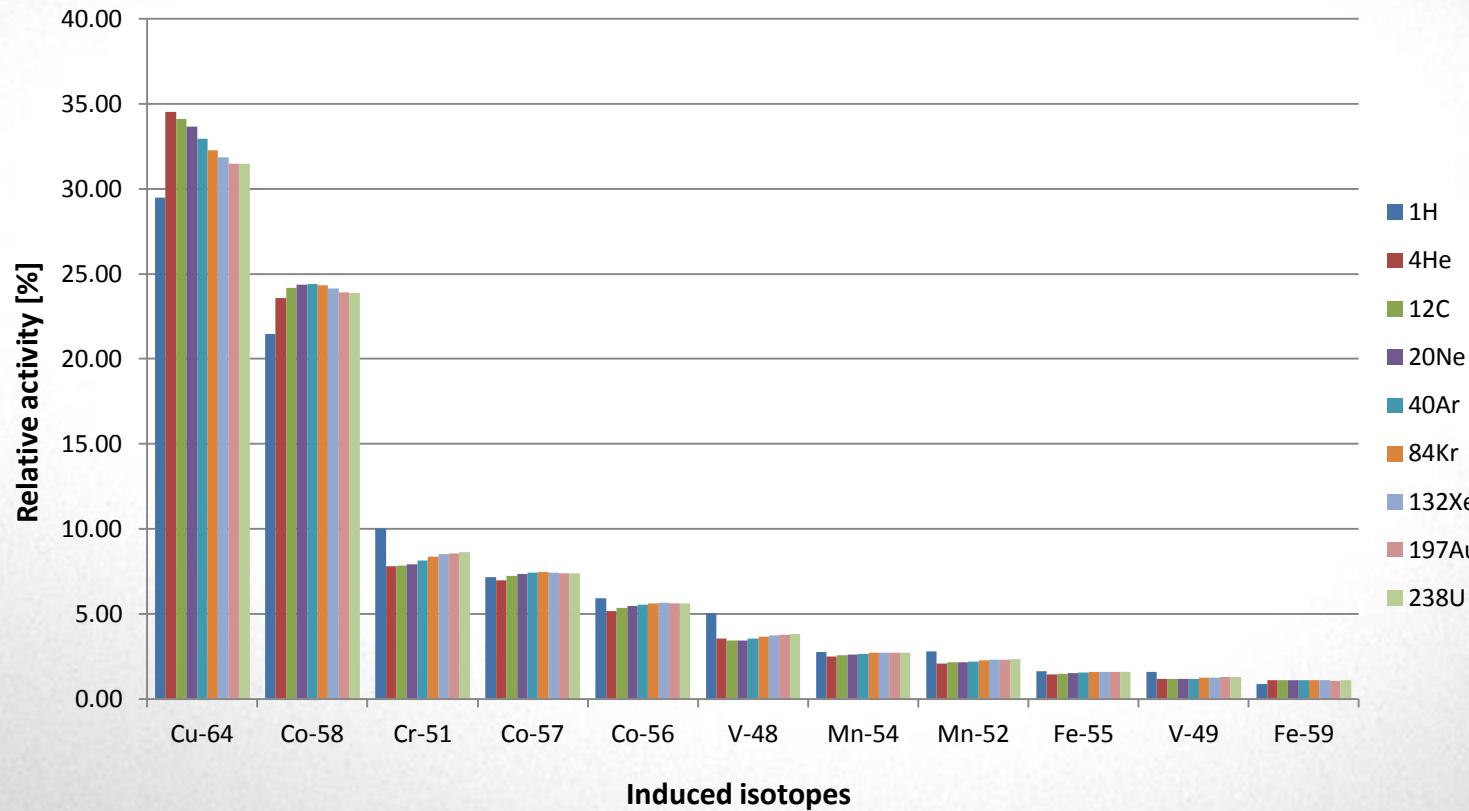
# Generic Curves | 25 MeV/u



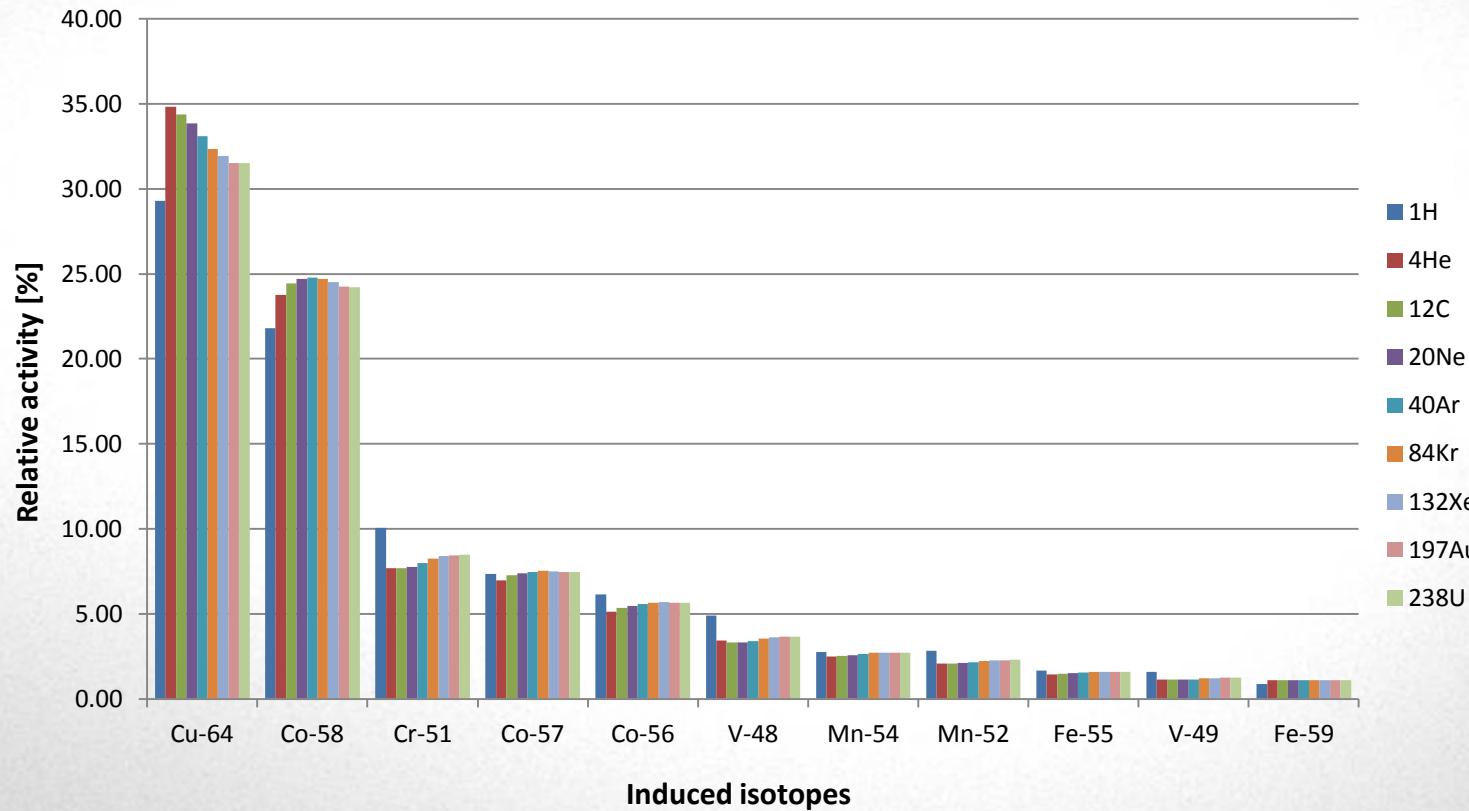
# INDUCED ISOTOPES | 1 GeV/u



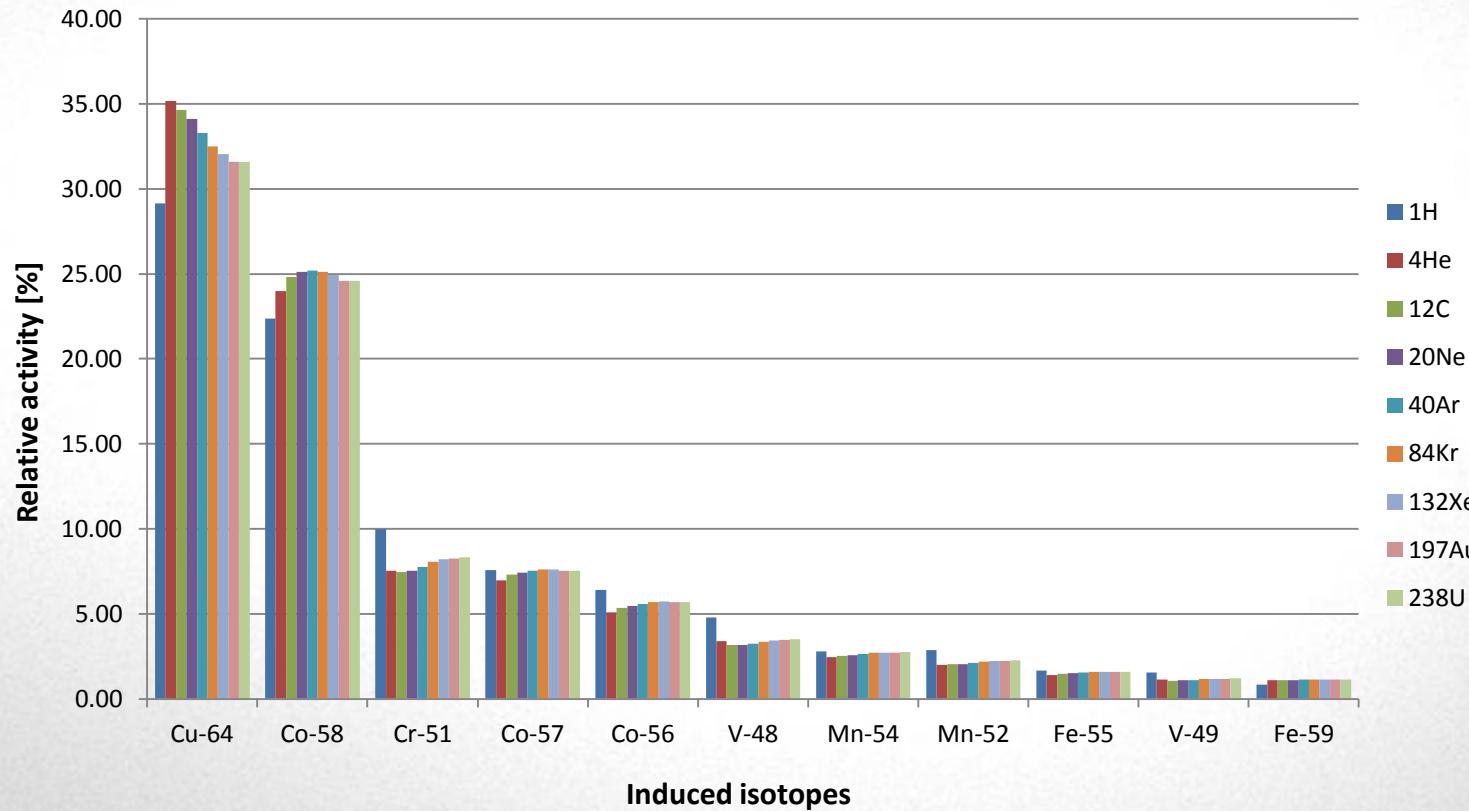
# INDUCED ISOTOPES | 1 GeV/u



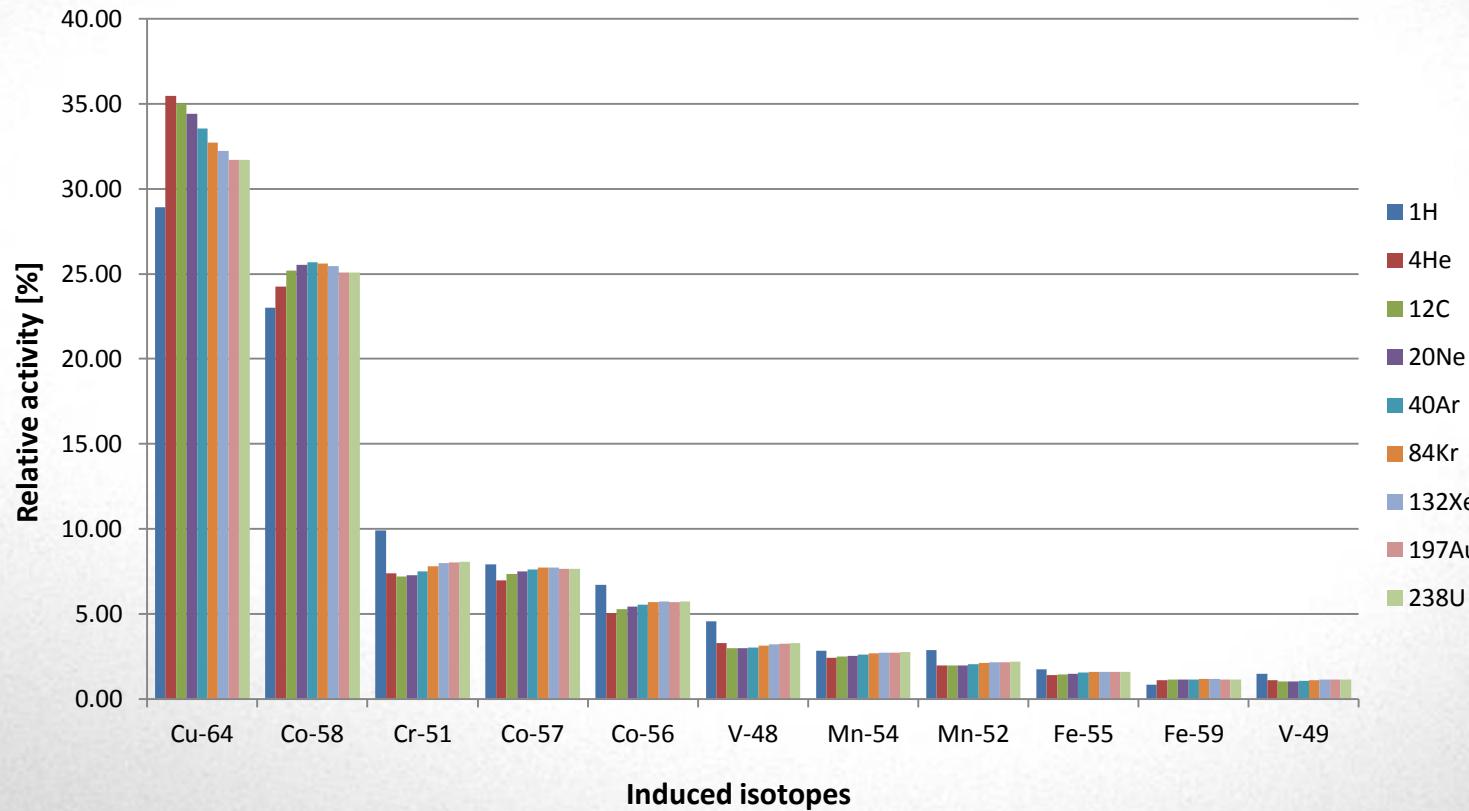
# INDUCED ISOTOPES | 900 MeV/u



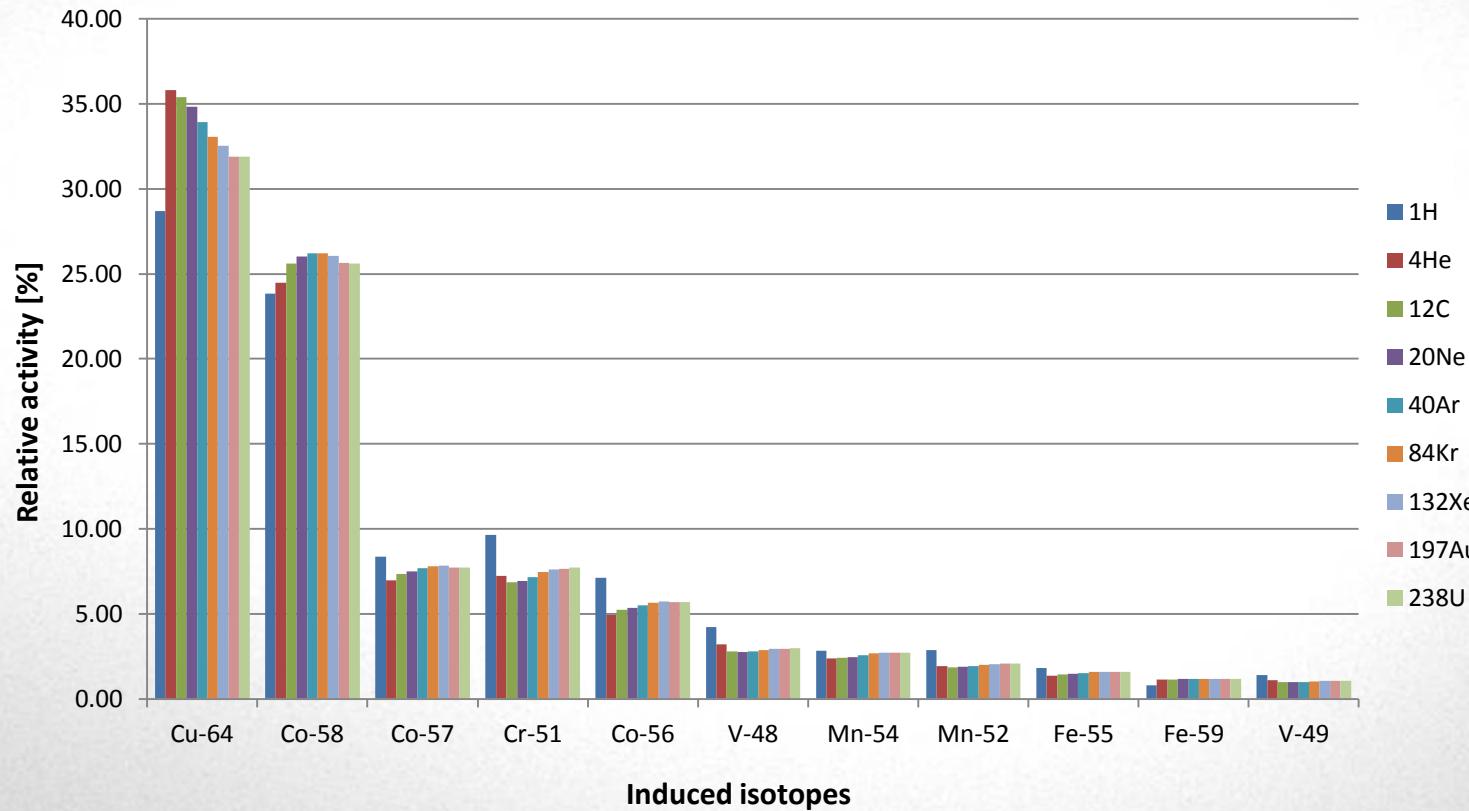
# INDUCED ISOTOPES | 800 MeV/u



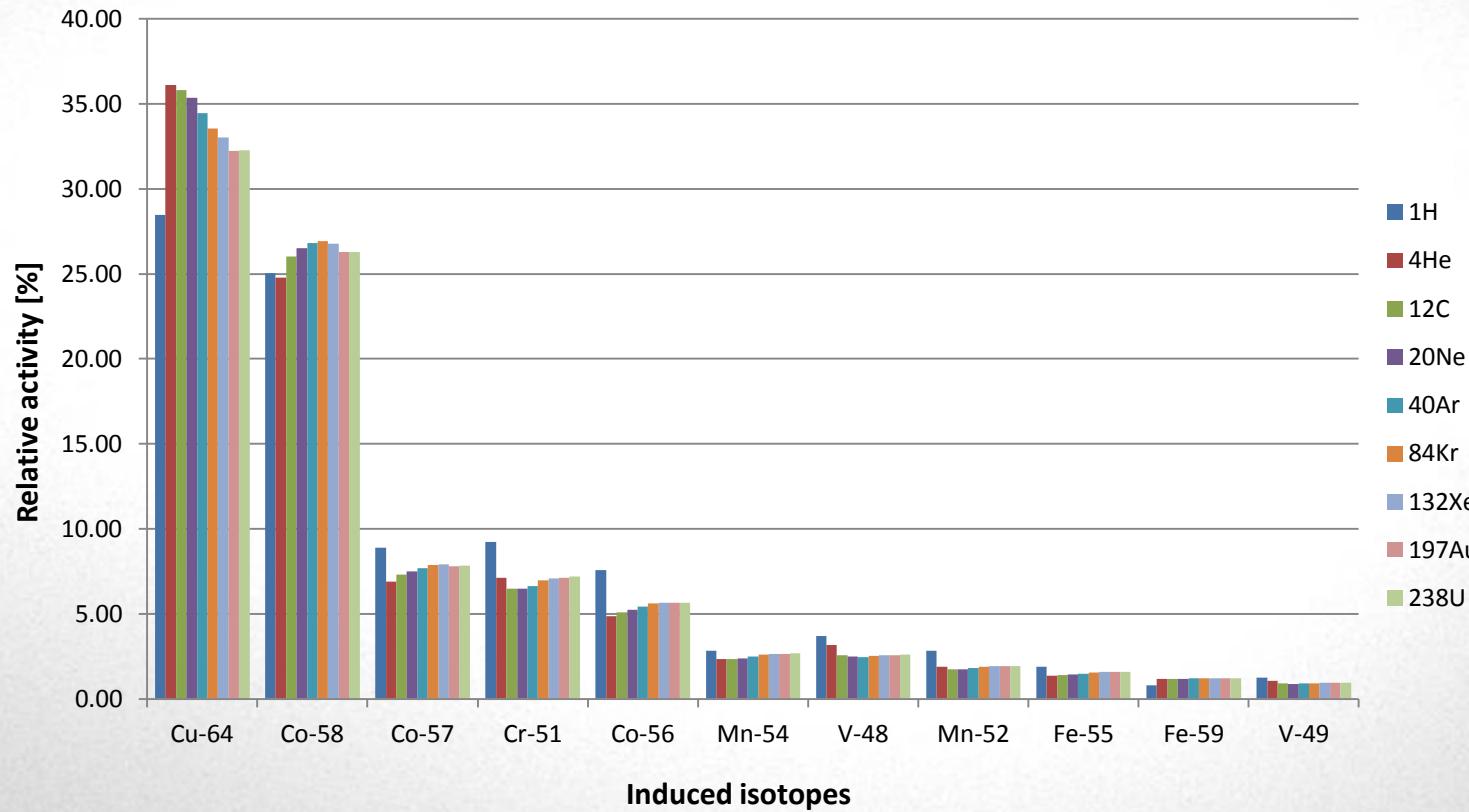
# INDUCED ISOTOPES | 700 MeV/u



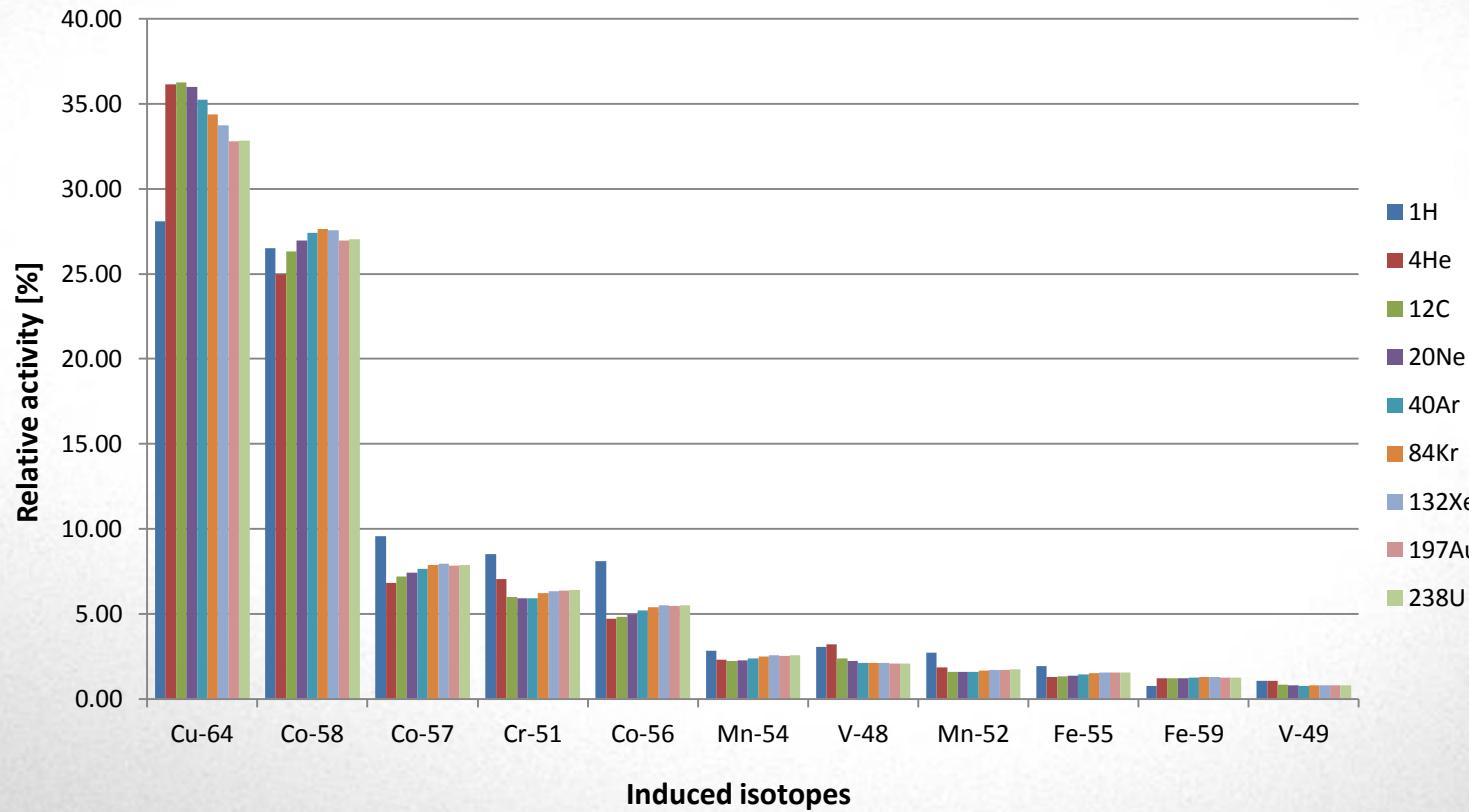
# INDUCED ISOTOPES | 600 MeV/u



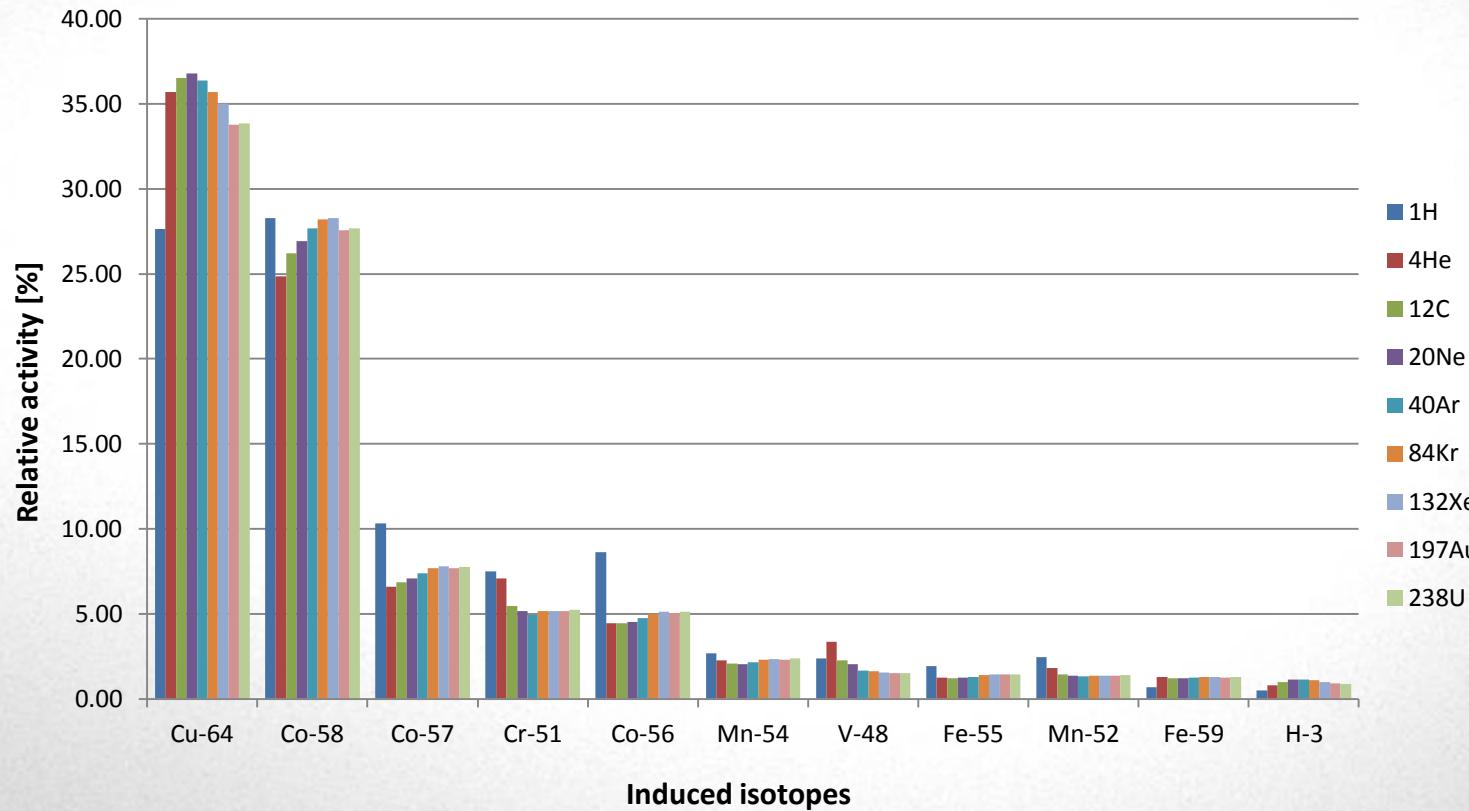
# INDUCED ISOTOPES | 500 MeV/u



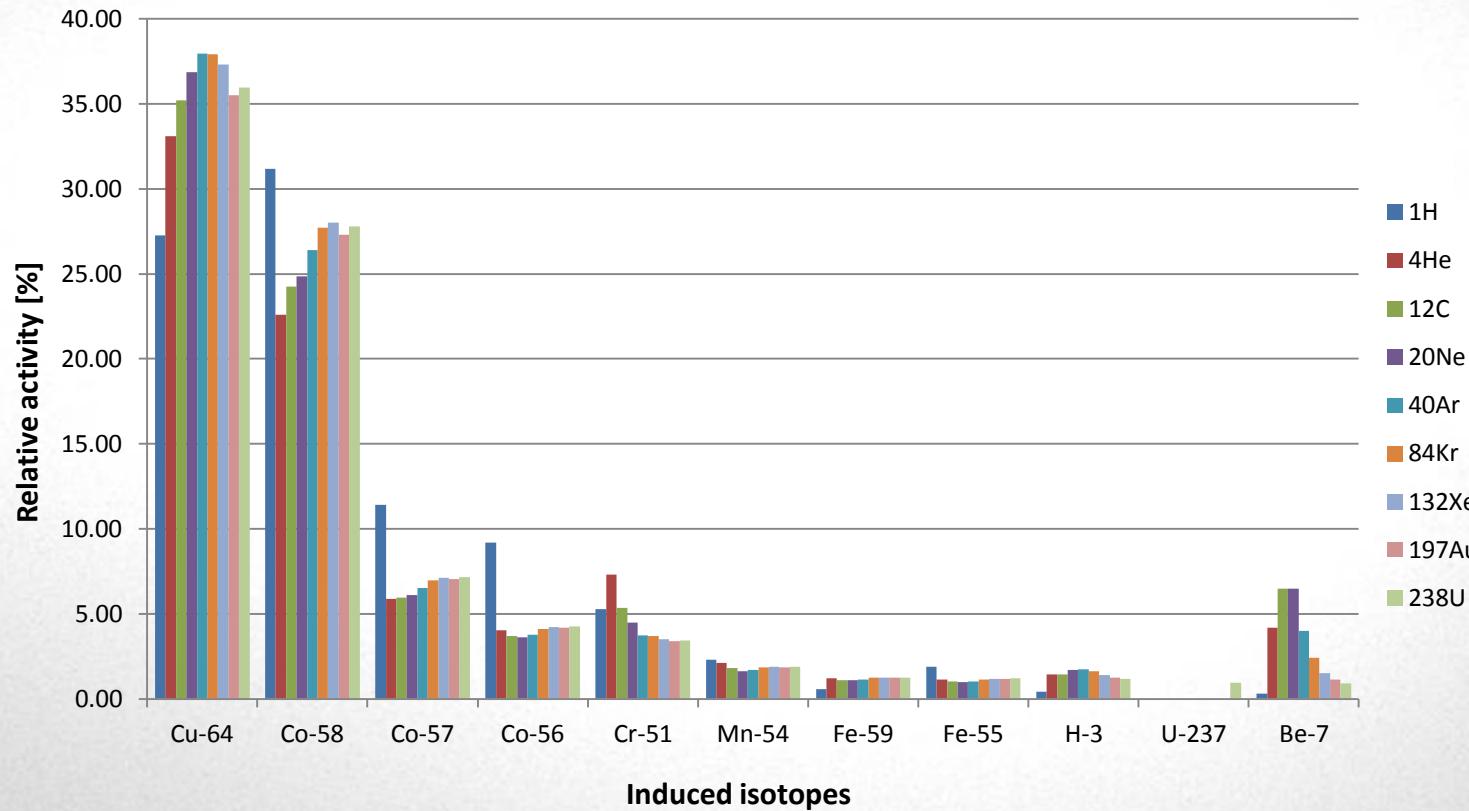
# INDUCED ISOTOPES | 400 MeV/u



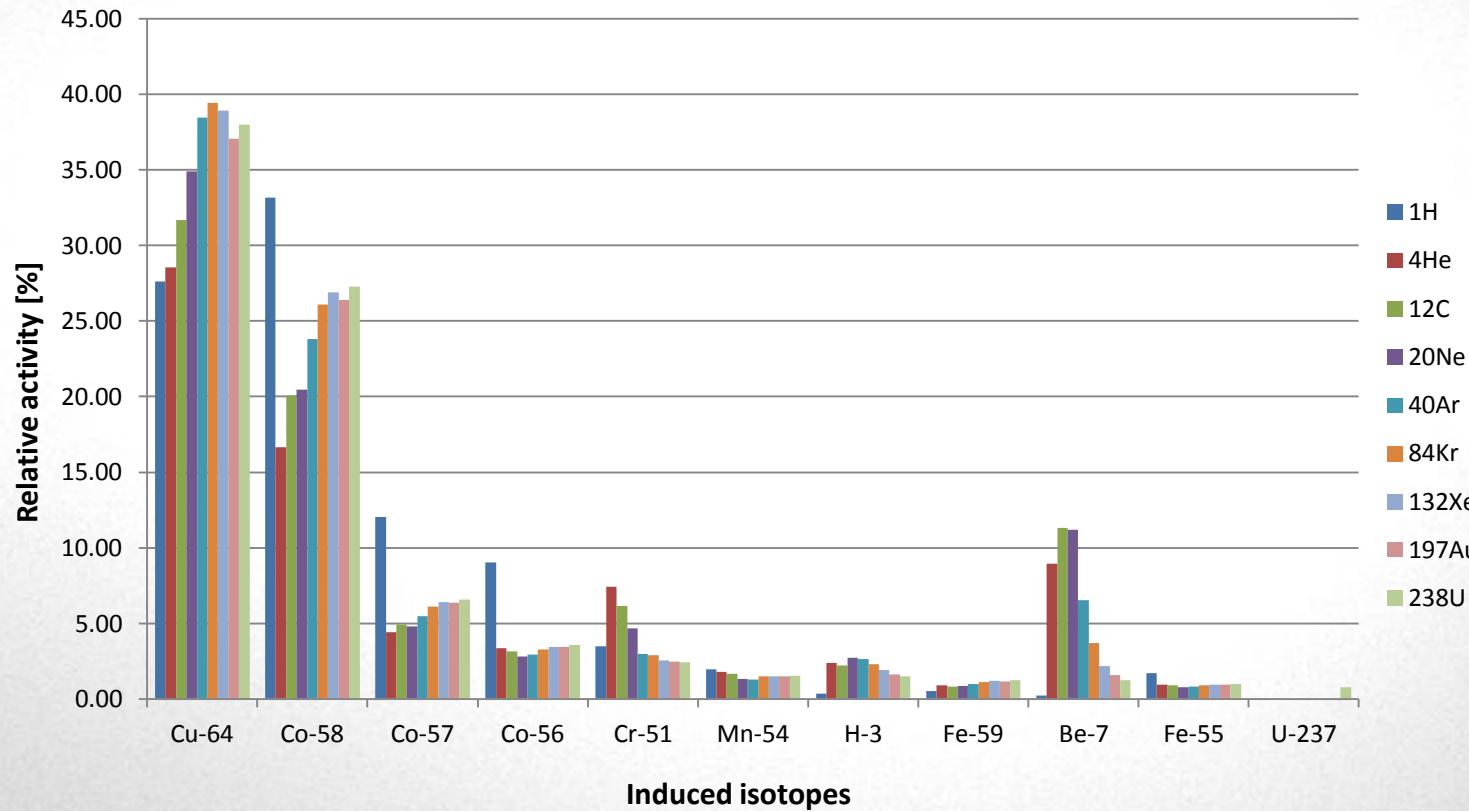
# INDUCED ISOTOPES | 300 MeV/u



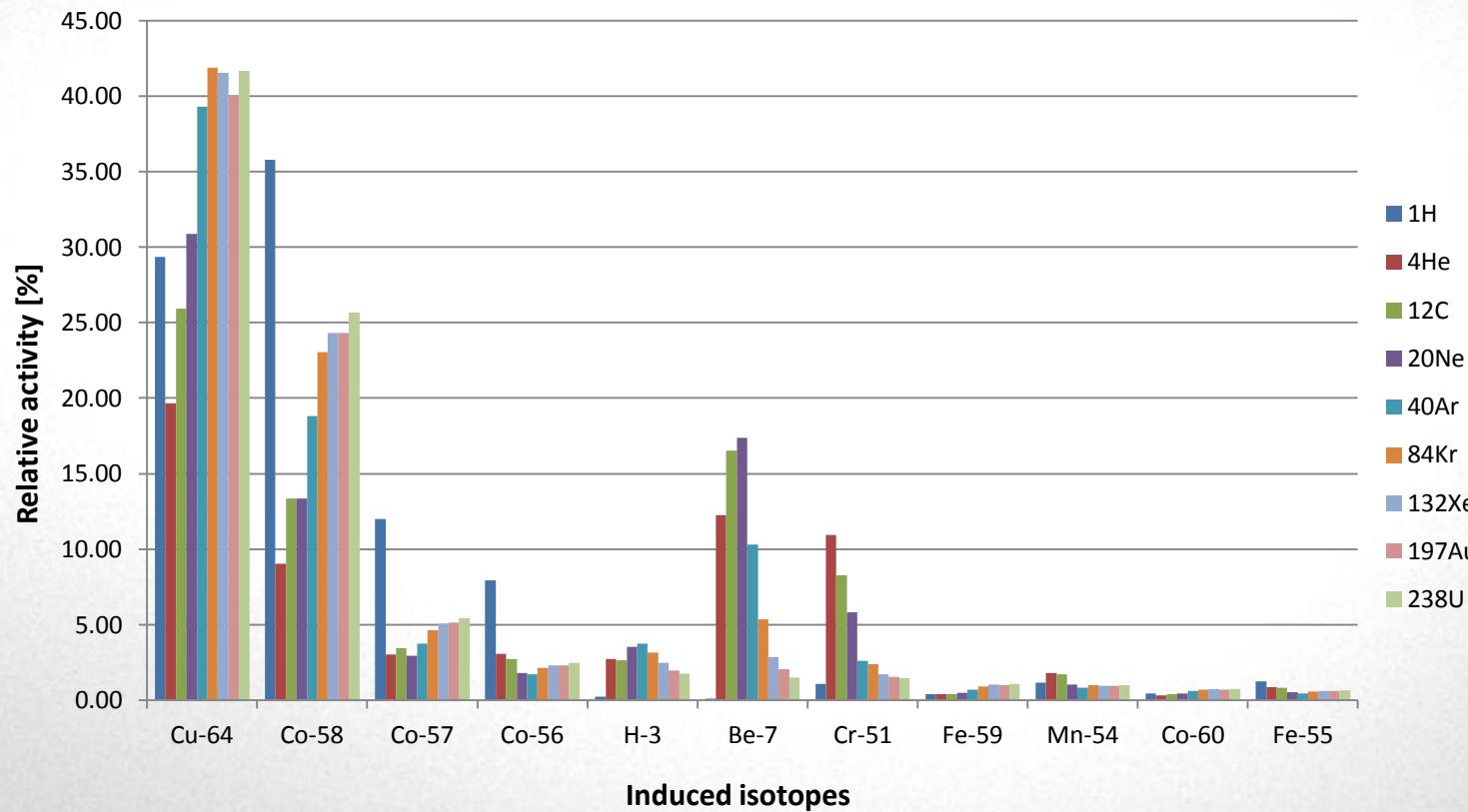
# INDUCED ISOTOPES | 200 MeV/u



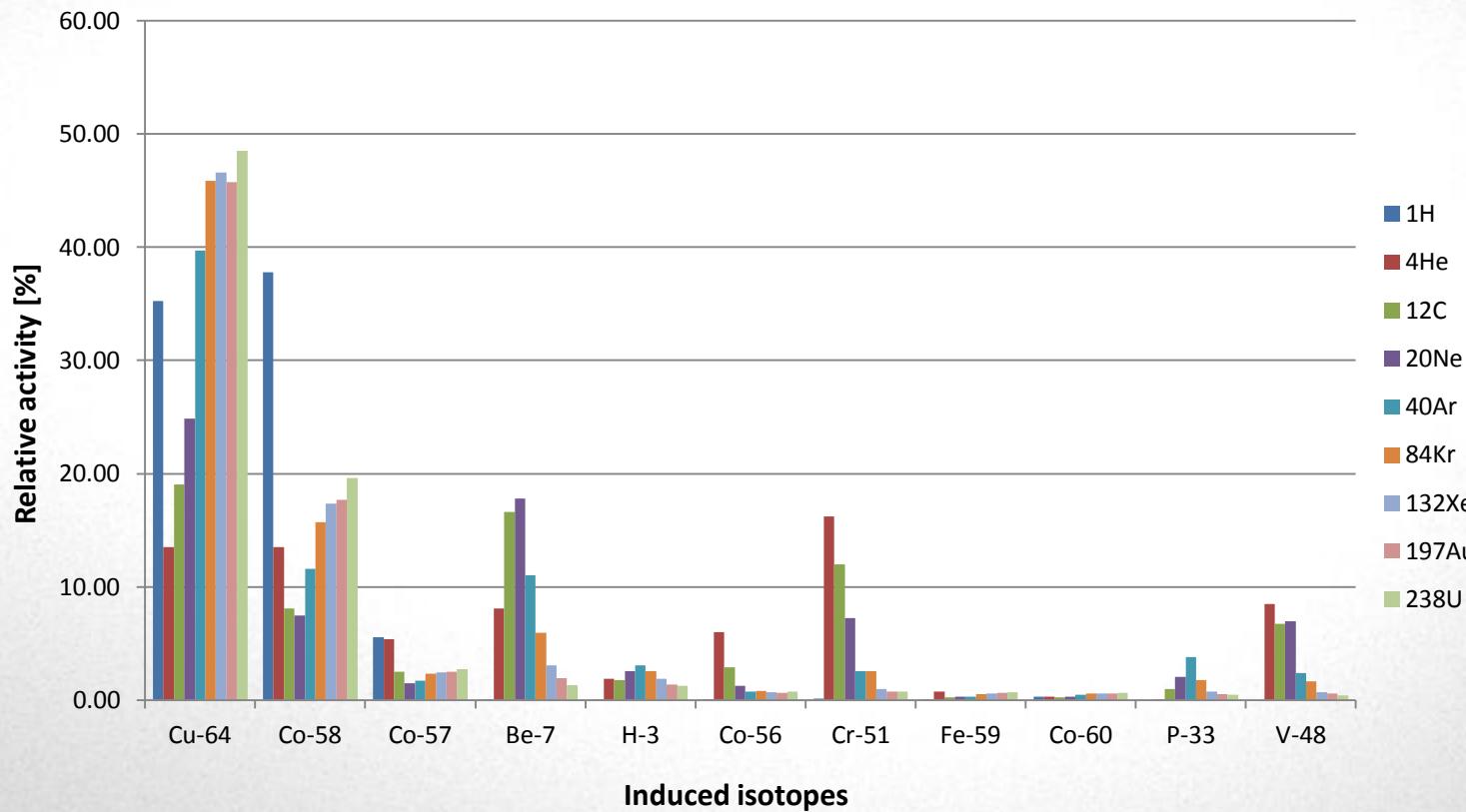
# INDUCED ISOTOPES | 150 MeV/u



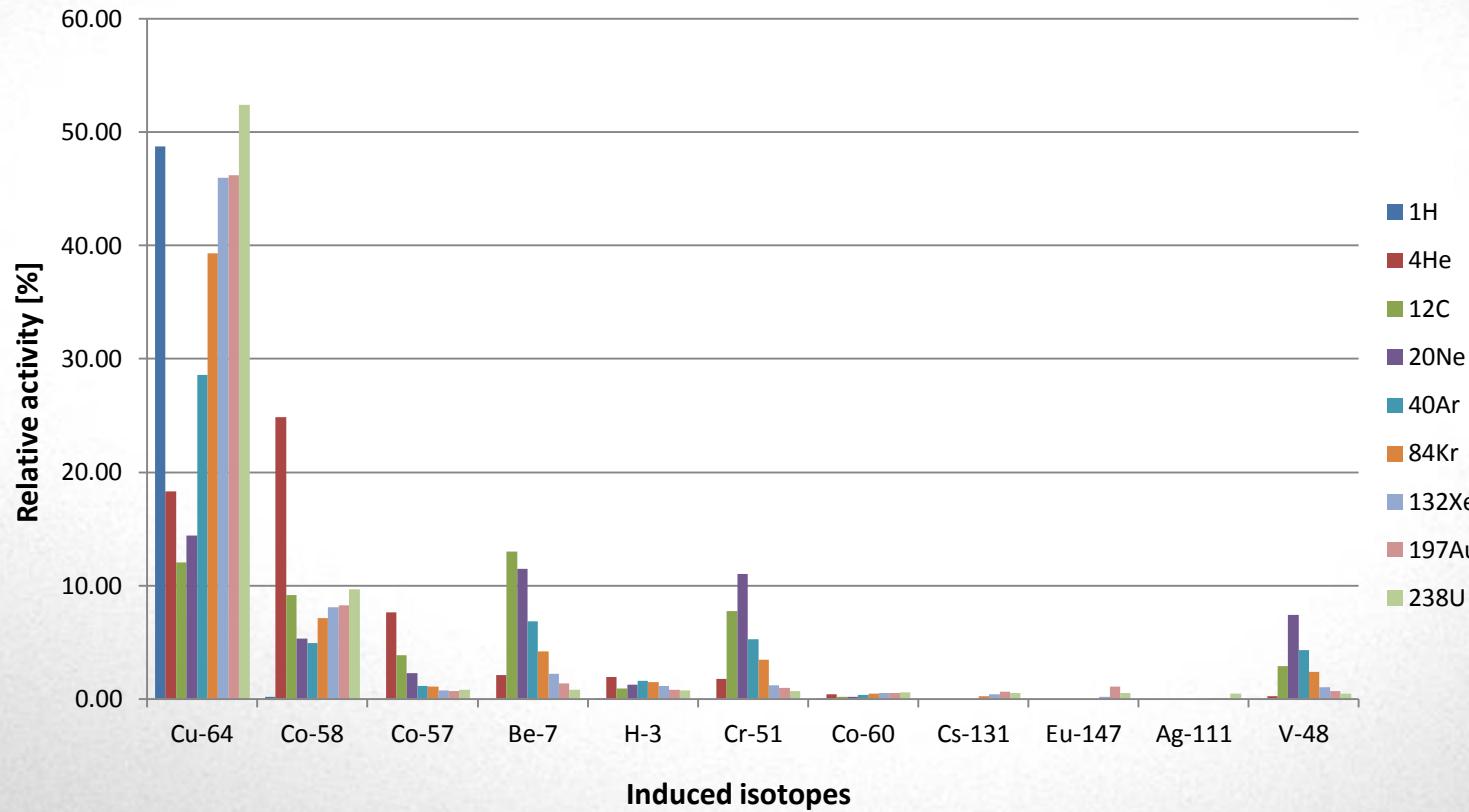
# INDUCED ISOTOPES | 100 MeV/u



# INDUCED ISOTOPES | 50 MeV/u

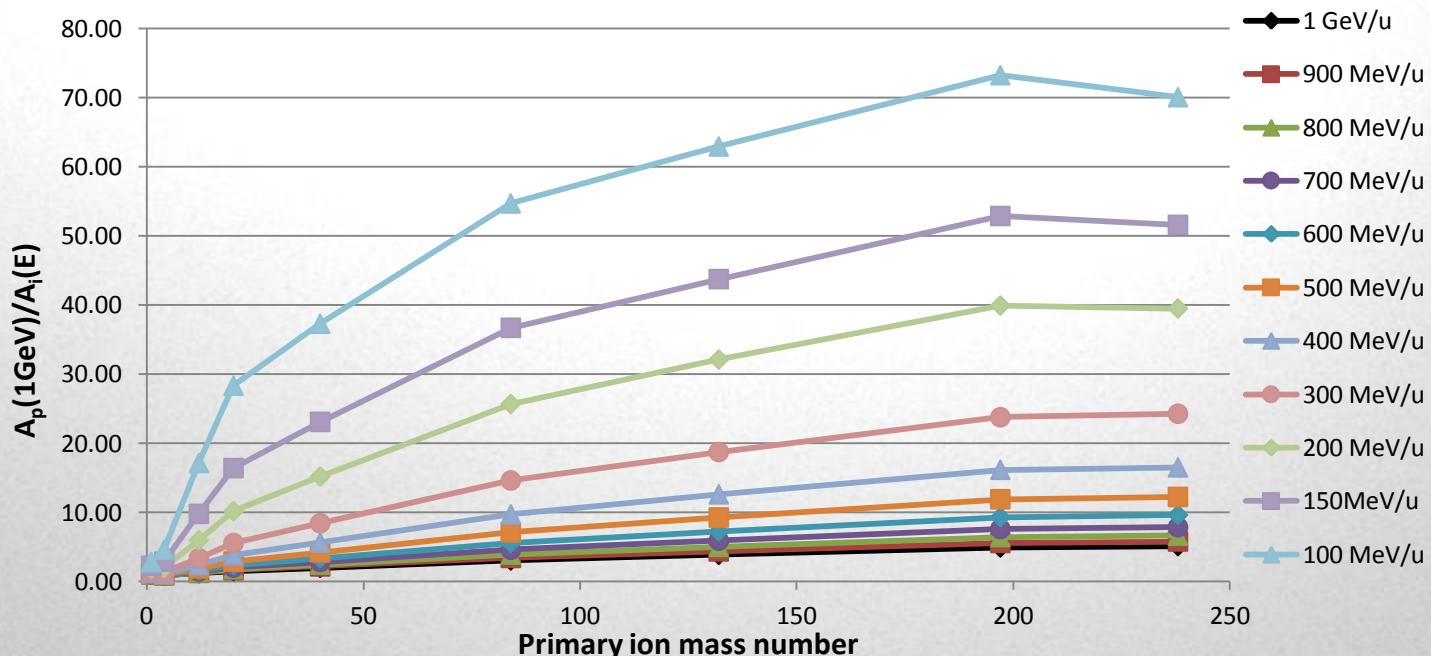


# INDUCED ISOTOPES | 25 MeV/u



# SCALING LAW

Energy	1	900	800	700	600	500	400	300	200	150	100	50	25
Mass	GeV/u	MeV/u	MeV/u										
<sup>1</sup> H	1.00	1.01	1.02	1.05	1.09	1.16	1.28	1.49	1.90	2.25	2.84	4.17	8.54
<sup>4</sup> He	0.87	0.87	0.87	0.88	0.91	0.97	1.09	1.33	1.98	2.85	4.64	9.34	19.86
<sup>12</sup> C	1.18	1.23	1.30	1.42	1.59	1.88	2.37	3.35	5.96	9.76	47.12	35.28	74.36
<sup>20</sup> Ne	1.51	1.61	1.77	2.00	2.34	2.86	3.77	5.54	10.15	16.39	28.33	60.44	138.25
<sup>40</sup> Ar	1.97	2.17	2.42	2.79	3.34	4.19	5.63	8.42	15.17	23.08	37.29	76.62	194.25
<sup>84</sup> Kr	3.03	3.39	3.88	4.58	5.57	7.10	9.69	14.60	25.67	36.69	54.69	107.10	254.56
<sup>132</sup> Xe	3.85	4.34	4.99	5.89	7.23	9.24	12.59	18.71	32.10	43.74	62.94	116.75	261.93
<sup>197</sup> Au	4.92	5.56	6.41	7.58	9.29	11.88	16.15	23.75	39.92	52.88	73.26	124.72	262.71
<sup>238</sup> U	5.12	5.77	6.63	7.84	9.61	12.21	16.50	24.25	39.49	51.59	70.07	113.18	245.72

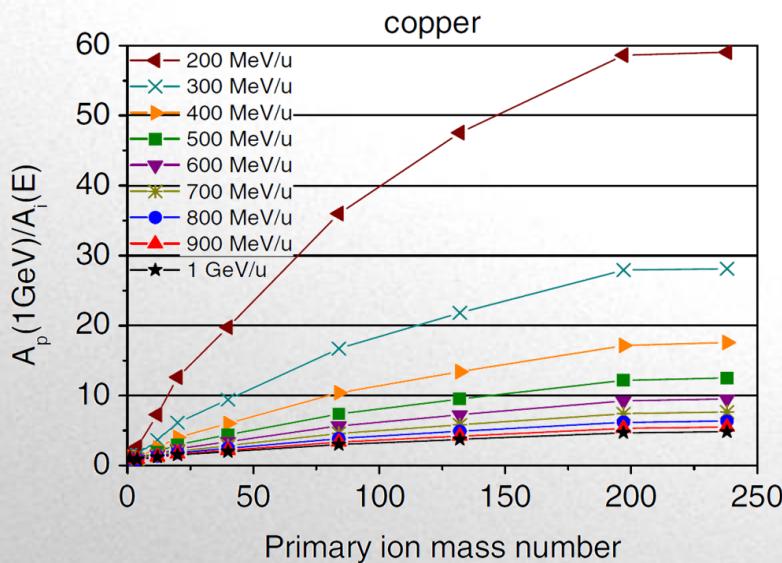


# CONCLUSION

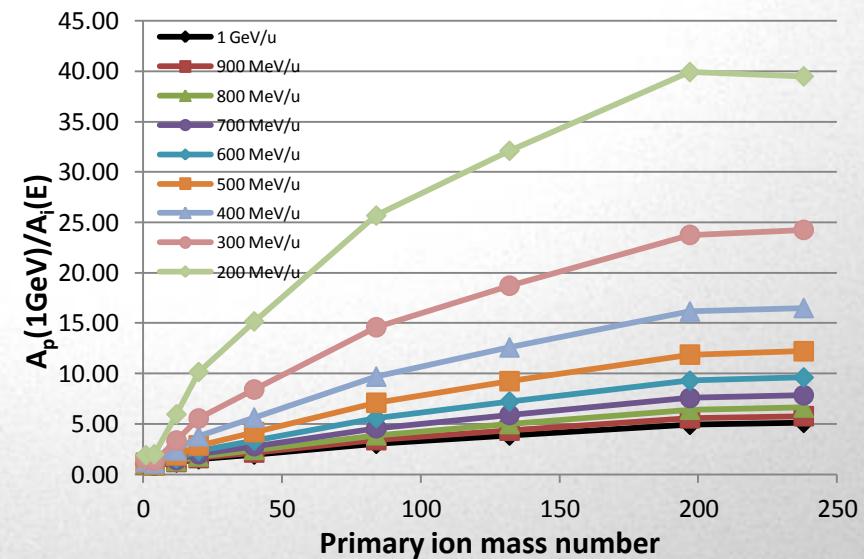
Activity induced by Uranium beam vs. 1GeV protons

Tolerable beam loss for U beam	FLUKA 2008.3.6	FLUKA 2011.2b.5
1GeV/u	5 W/m	5 W/m
500 MeV/u	12 W/m	12 W/m
200 MeV/u	<b>60 W/m</b>	<b>40 W/m</b>
150 MeV/u		52 W/m

FLUKA 2008.3.6



FLUKA 2011.2b.5



**THANK  
YOU**  
for your  
**ATTENTION**

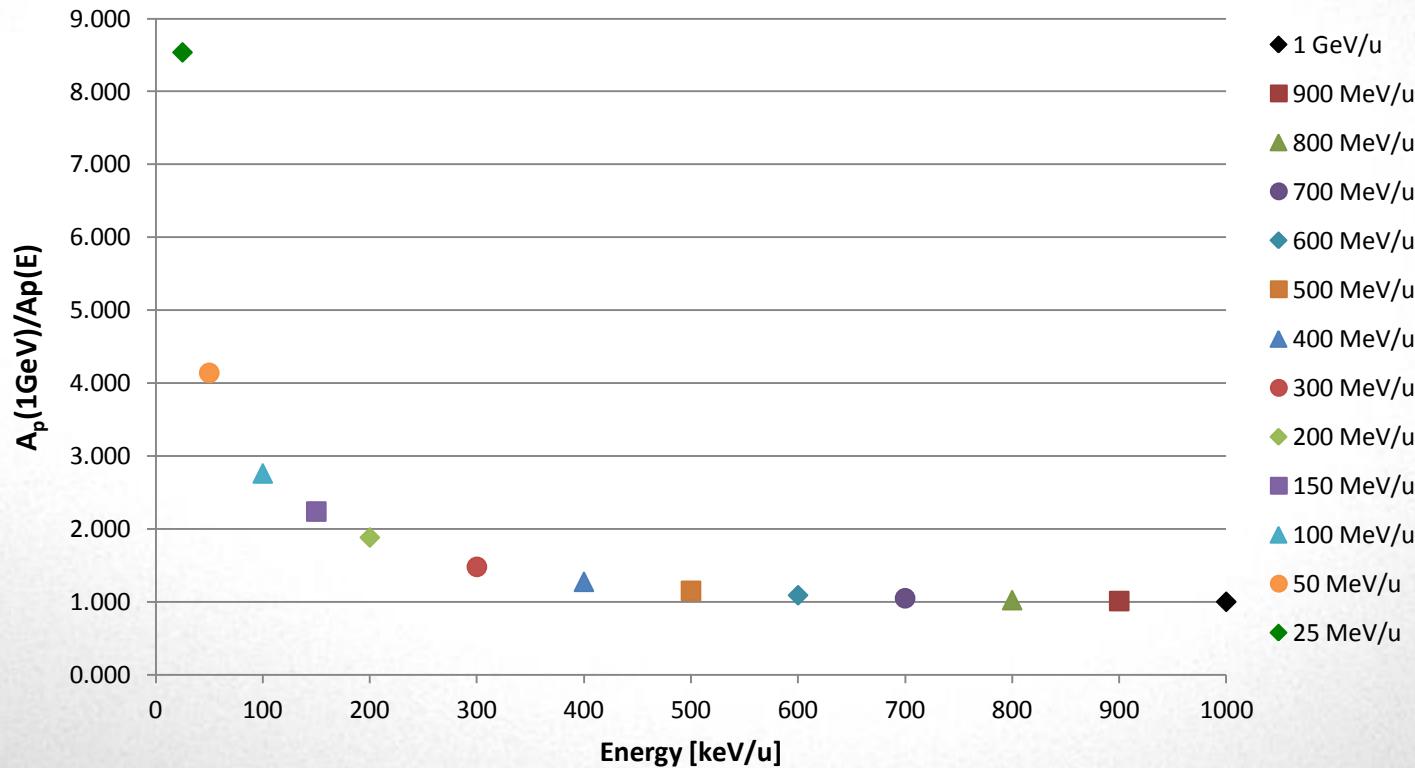
[ p.katrik@gsi.de ]

# BACKUP SLIDE

[ [p.katrik@gsi.de](mailto:p.katrik@gsi.de) ]

# CONCLUSION

Activity induced by protons with different energy



. tolerable beam losses for hydrogen beam could be 9 W/m at 25 MeV/u

# CONCLUSION

Activity induced by Uranium beam vs. 1GeV protons

FLUKA 2008.3.6.

- ~ 5 times lower at 1 GeV/u
- ~ 12 times lower at 500 MeV/u
- ~ **60** times lower at 200 MeV/u

- . tolerable beam losses for uranium beam could be
- . 5 W/m at 1 GeV/u
- . 12 W/m at 500 MeV/u
- . **60 W/m** at 200 MeV/u

FLUKA 2011.2b.5.

- ~ 5 times lower at 1 GeV/u
- ~ 12 times lower at 500 MeV/u
- ~ **40** times lower at 200 MeV/u

- . tolerable beam losses for uranium beam could be
- . 5 W/m at 1 GeV/u
- . 12 W/m at 500 MeV/u
- . **40 W/m** at 200 MeV/u