Berkeley Lab 88-Inch Cyclotron Status

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BASE Facility Layout & Capabilities

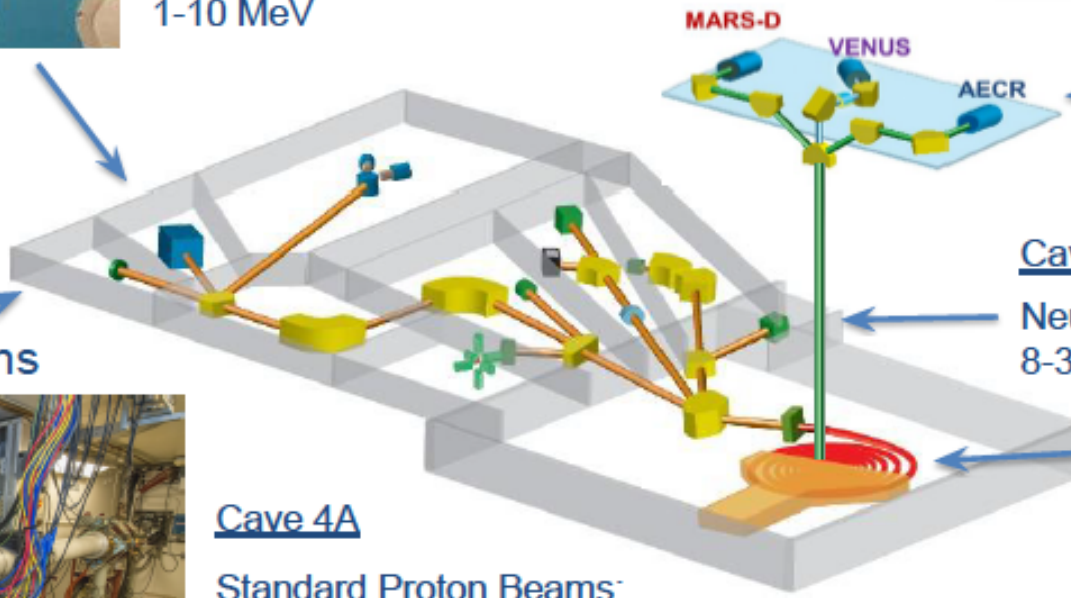
Heavy Ions, Low Energy Protons, Microbeams

Cave 4B

Standard Cocktail Beams:
4.5, 10, 16, & 20 AMeV

Low Energy Protons:
1-10 MeV

BASE Facility Beams:
- Heavy Ions
- Light Ions
- Protons
- Low Energy Protons
- Neutrons
- Microbeams

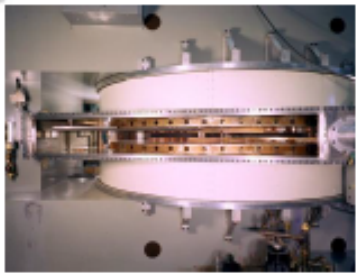


Light Ions, Protons

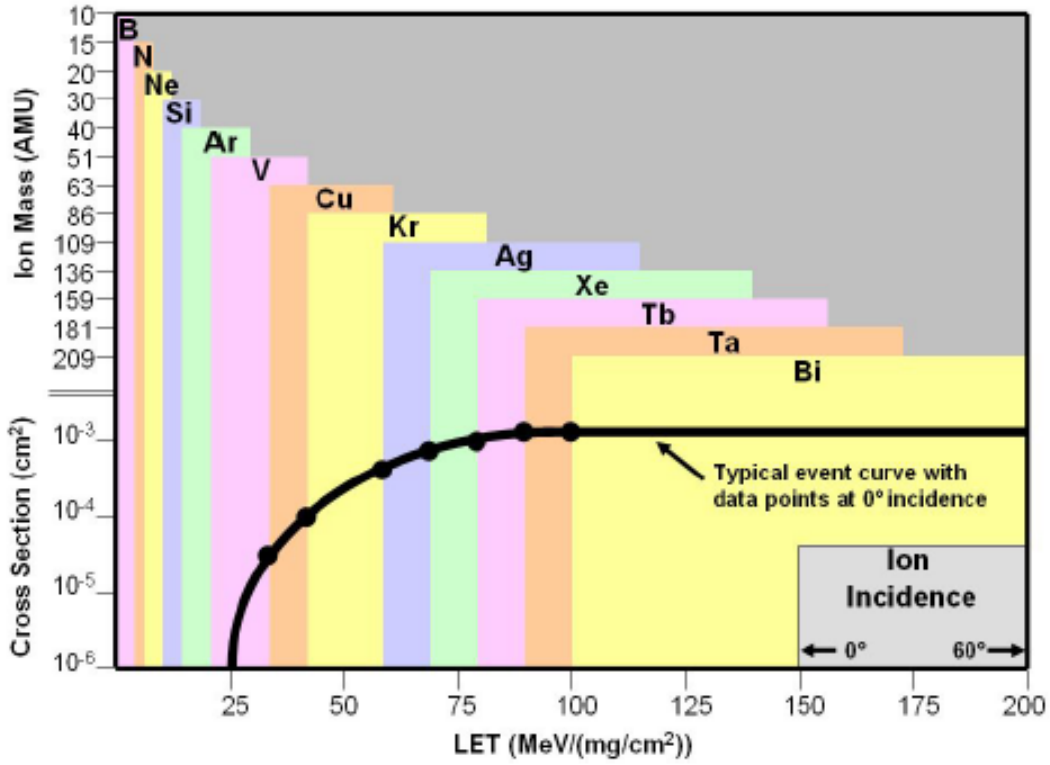
Cave 4A

Standard Proton Beams:
10-60 MeV

Light Ion Cocktails:
30 and 32.5 AMeV



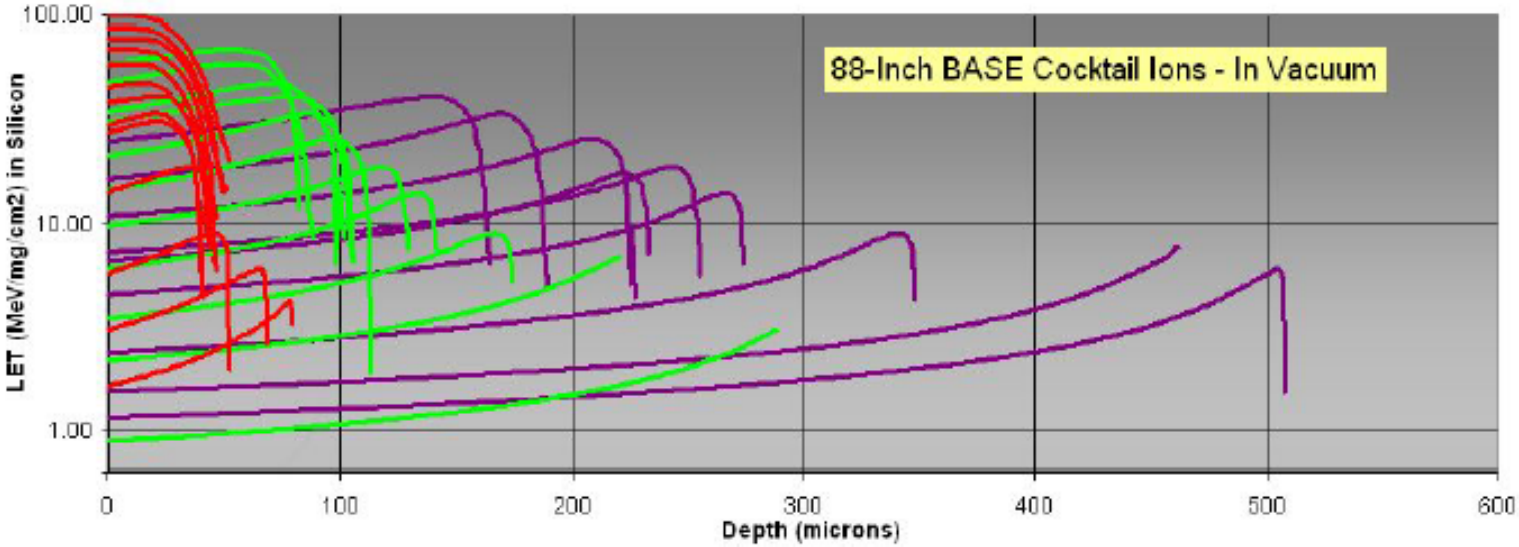
BASE Cocktails



What is a 'cocktail'?

- Multiple ion species are injected into the Cyclotron simultaneously, which are then selected and separated by simply changing the frequency.
- Normally, it would take hours to retune the Cyclotron to a new ion. With our ion sources, we can change ions in less than 3 minutes.

BASE Cocktails



Legend:

4.5 AMeV

10 AMeV

16 AMeV

All three are refined and running smoothly

NEW:

20 AMeV

Still a few growing pains

- Cocktails allow users to deposit the right amount of energy at the desired depth.
- High LET ions are the most difficult to tune out of the machine, but thanks to ion source and Cyclotron improvements, we can achieve very high fluxes for even our heaviest ions.

88-Inch Cyclotron Cocktail Ions

	Ion	Cocktail (AMeV)	Energy (MeV)	Z	A	Chg. State	% Nat. Abund.	LET 0° (MeV/mg/cm2)	LET 60°	Range (Max) (µm)
4.5 AMeV	B	4.5	44.90	5	10	+2	19.9	**1.65**	3.30	78.5
	N	4.5	67.44	7	15	+3	0.37	**3.08**	6.16	67.8
	Ne	4.5	89.95	10	20	+4	90.48	**5.77**	11.54	53.1
	Si	4.5	139.61	14	29	+6	4.67	**9.28**	18.56	52.4
	Ar	4.5	180.00	18	40	+8	99.6	**14.32**	28.64	48.3
	V	4.5	221.00	23	51	+10	99.75	**21.68**	43.36	42.5
	Cu	4.5	301.79	29	63	+13	69.17	**29.33**	58.66	45.6
	Kr	4.5	378.11	36	86	+17	17.3	**39.25**	78.50	42.4
	Y	4.5	409.58	39	89	+18	100	**45.58**	91.16	45.8
	Ag	4.5	499.50	47	109	+22	48.161	**58.18**	116.36	46.3
	Xe	4.5	602.90	54	136	+27	8.9	**68.84**	137.68	48.3
	Tb	4.5	724.17	65	159	+32	100	**77.52**	155.04	52.4
	Ta	4.5	805.02	73	181	+36	99.988	**87.15**	174.30	53.0
	Bi*	4.5	904.16	83	209	+41	100	**99.74**	199.48	52.9
10 AMeV	B	10	108.01	5	11	+3	80.1	**0.89**	1.78	305.7
	O	10	183.47	8	18	+5	0.2	**2.19**	4.38	226.4
	Ne	10	216.28	10	22	+6	9.25	**3.49**	6.98	174.6
	Si	10	291.77	14	29	+8	4.67	**6.09**	12.18	141.7
	Ar	10	400.00	18	40	+11	99.6	**9.74**	19.48	130.1
	V	10	508.27	23	51	+14	99.75	**14.59**	29.18	113.4
	Cu	10	659.19	29	65	+18	30.83	**21.17**	42.34	108.0
	Kr	10	885.59	36	86	+24	17.3	**30.86**	61.72	109.9
	Y	10	928.49	39	89	+25	100	**34.73**	69.46	102.2
	Ag	10	1039.42	47	107	+29	51.839	**48.15**	96.30	90.0
	Xe	10	1232.55	54	124	+34	0.1	**58.78**	117.56	90.0
	Au*	10	1955.87	79	197	+54	100	**85.76**	171.52	105.9

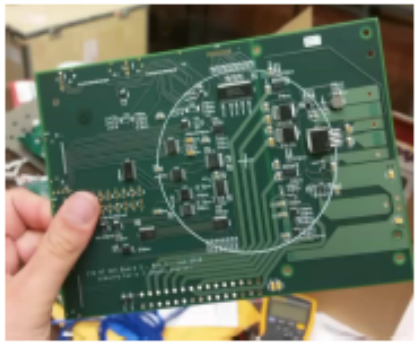
	Ion	Cocktail (AMeV)	Energy (MeV)	Z	A	Chg. State	% Nat. Abund.	LET 0° (MeV/mg/cm2)	LET 60°	Range (Max) (µm)
16 AMeV	He*	16	43.46	2	3	+1	0.000137	**0.11**	0.22	1020.0
	N	16	233.75	7	14	+5	99.63	**1.16**	2.32	505.9
	O	16	277.33	8	17	+6	0.04	**1.54**	3.08	462.4
	Ne	16	321.00	10	20	+7	90.48	**2.39**	4.78	347.9
	Si	16	452.10	14	29	+10	4.67	**4.56**	9.12	274.3
	Cl	16	539.51	17	35	+12	75.77	**6.61**	13.22	233.6
	Ar	16	642.36	18	40	+14	99.600	**7.27**	14.54	255.6
	V	16	832.84	23	51	+18	99.750	**10.90**	21.80	225.8
	Cu	16	1007.34	29	63	+22	69.17	**16.53**	33.06	190.3
	Kr	16	1225.54	36	78	+27	0.35	**24.98**	49.96	165.4
	Xe*	16	1954.71	54	124	+43	0.1	**49.29**	98.58	147.9
20 AMeV	C	20	240.00	6	12	+5	98.900	**0.72**	1.44	813.1
	Ne	20	400.00	10	20	+8	90.480	**2.00**	3.99	504.5
	Al	20	540.00	13	27	+11	100.000	**3.36**	6.72	428.7
	Ar	20	800.00	18	40	+16	99.600	**6.27**	12.53	356.5
	Cu	20	1260.00	29	65	+25	30.830	**14.12**	28.24	288.4
	Kr	20	1560.00	36	78	+32	0.350	**22.62**	45.24	221.7
	Y	20	1780.00	39	89	+36	100.000	**24.82**	49.64	229.2
	Ag	20	2180.00	47	109	+44	48.161	**34.24**	68.48	212.9
	Xe	20	2480.00	54	124	+47	0.100	**45.40**	90.80	193.8
30 AMeV	N	30	425.45	7	15	+7	0.370	**0.76**	1.52	1370.0
	O	30	490.22	8	17	+8	0.04	**0.98**	1.96	1220.0
	Ne	30	620.00	10	21	+10	0.27	**1.48**	2.96	1040.0
	Ar	30	1046.11	18	36	+17	0.337	**4.87**	9.74	578.1

*Special request only. **Ion isotopes and charge states subject to change without notice.
LETs calculated with SRIM using a silicon target in vacuum.

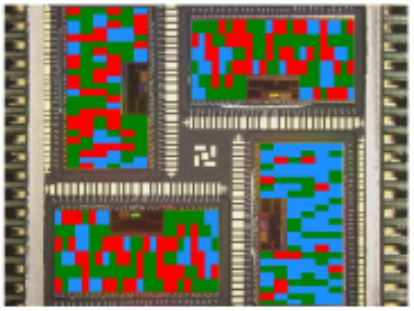
ALICE-LHC Studies at BASE

ALICE Inner Tracking System Upgrade

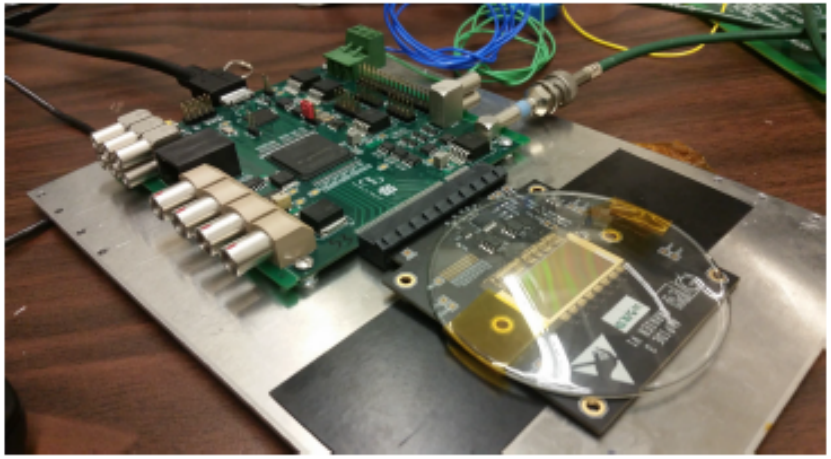
- BASE heavy ions used for MAPS Single Event Latch-up studies.
- BASE protons used for MAPS Single Event Upset studies.
- BASE used for rad hardness studies for power board components.
- SEU detector tests conducted at BASE for use at LHC.

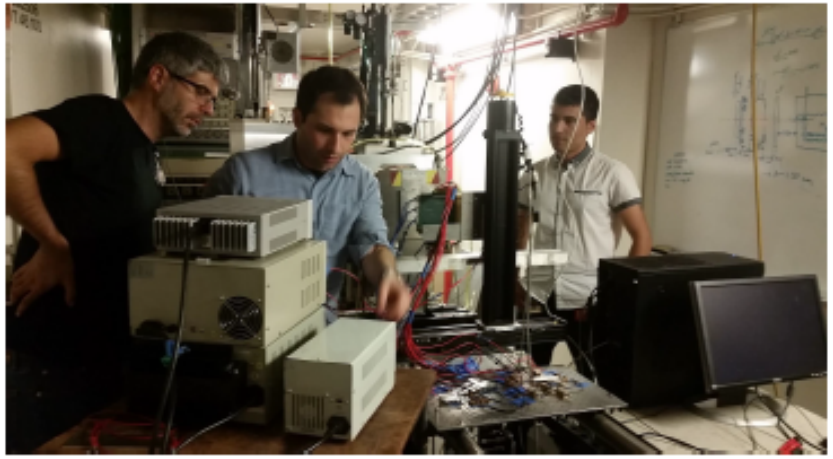


Power Board Components



LHC SEU Detector





88-Inch Contributions to Space Exploration

Apollo 17 (experiment with lunar soil sample)

Solar Terrestrial Relations Observatory (STEREO)

Solar Dynamics Observatory (SDO)

Solar Probe Plus

Genesis (Solar Wind Sample Return)

Messenger (Mercury)

Pioneer Venus

Van Allen Probes

IMAGE/Explorer 78

Landsat

Global Positioning System (GPS)

Lunar Reconnaissance Orbiter (LRO)

Mars Pathfinder

Mars Polar Lander

Mars Climate Orbiter

Mars Exploration Rover (MER) / Spirit & Opportunity Rovers

Mars Science Laboratory (MSL) / Curiosity Rover

Mars Atmosphere & Volatile Evolution (MAVEN)

Mars Odyssey

Phoenix (Mars)

ExoMars

InSight (Mars) Lander

Dawn (Asteroid Belt)

Galileo (Jupiter)

Europa Clipper (Jupiter)

Cassini-Huygens (Saturn)

Voyager (Jupiter, Saturn, Uranus, Neptune)

New Horizons (Pluto)

Stardust (Comet Sample Return)

Deep Space 1 (Comet & Asteroid Flyby)

Atlas Launch Vehicles

Delta Launch Vehicles

Space Shuttle

Orion Multi-Purpose Crew Vehicle

International Space Station (ISS)

James Webb Space Telescope

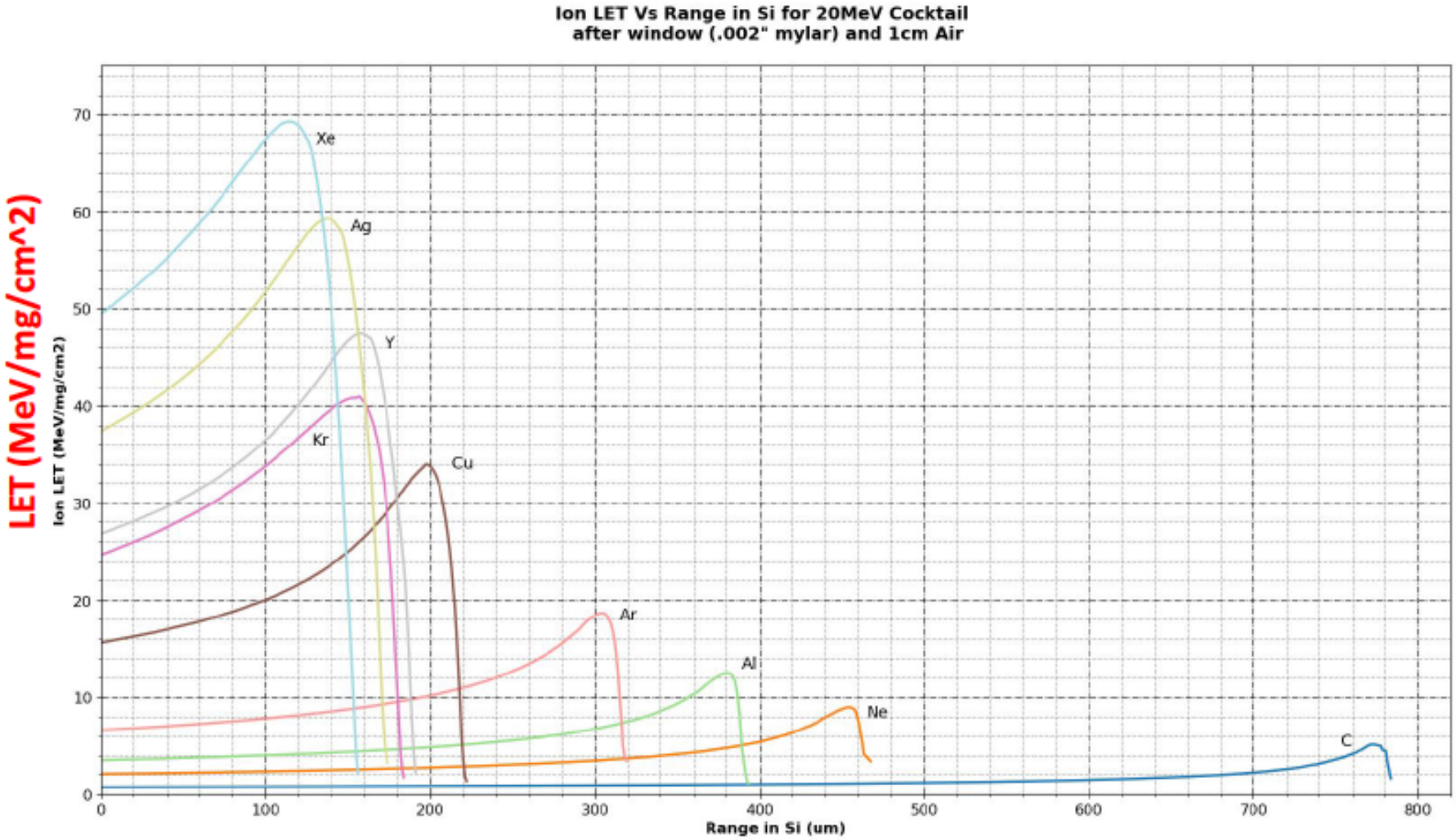
Spitzer Infrared Telescope Facility

Swift Gamma-Ray Burst Mission

Wide Field Infrared Survey Telescope

Restore-L (Robotic Servicing)

Bragg Curves - 20 AMeV (in-air)



LET (MeV/mg/cm^2)

Range (um)