Energy Upgrade

Damon Todd

88 Inch Cyclotron, Nuclear Science Division

Lawrence Berkeley National Laboratory

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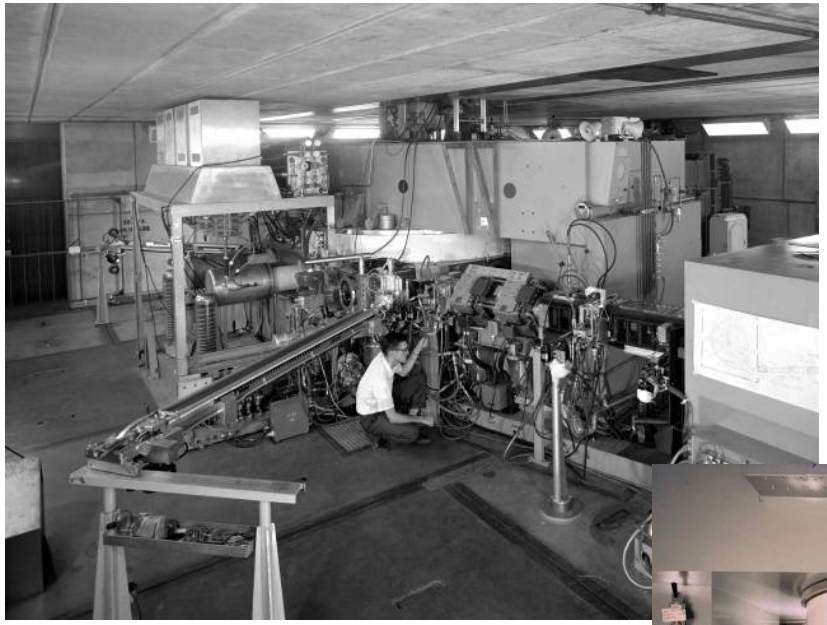
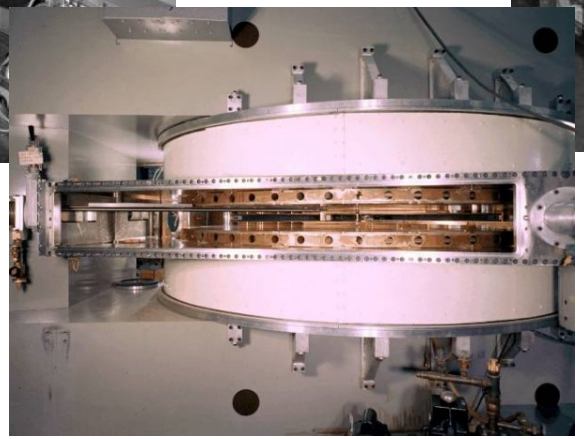
88 Inch Cyclotron





Designed for use as a flexible, light ion accelerator

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Most common users of beams from 88 Inch Cyclotron

	Mass numbers	Currents	Energies/nucleon
Super-heavy elements	~40-60	20-40 umA	~5 MeV/u
Neutrons	1-2	<10 umA	~10-60 MeV/u
BASE	~10-208	pA to nA	~5-20 MeV/u

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Neutrons

Neutron beams

- Pulsed, high-intensity
- Broad spectral range (0.05 to 62 MeV)
- Variable flux up to $2.75 \cdot 10^{12}$ $n_O/sr/s$

Recent work

- Isotope production (e.g. ^{225}Ac for cancer treatment)
- Scintillator characterization
- Neutron damage studies
- Measurements of:
  - Cross-sections
  - Fission yields
  - Inelastic scattering

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Expand capabilities:

- More current
- More neutron-rich metals
- Higher energies

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Expand capabilities:

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- More neutron-rich metals
- Higher energies

→ Ion source/ovens

→ Ion source and/or …

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Using ion sources to produce higher energy ion beams

Increase accelerated charge state:

Cyclotrons	Linear Accelerators
$KE \propto Q^2$	$KE \propto Q$

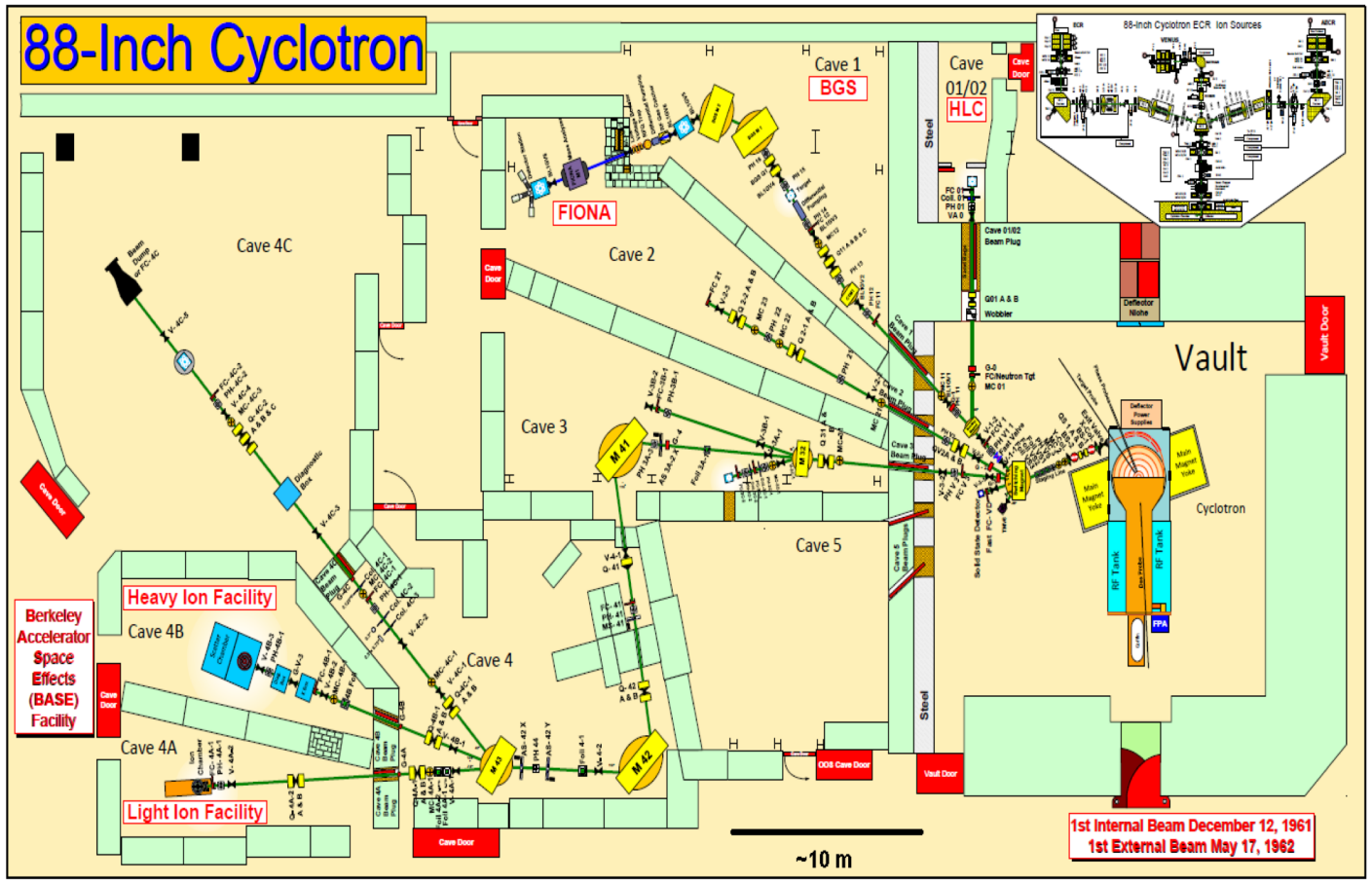
Cyclotron kinetic energy increases:

100s of MeV in 1960s to > 2.5 GeV today with VENUS

Addition of MARS will give both higher charge states and and higher currents

➔ However, a hard limit is fully-stripped ions

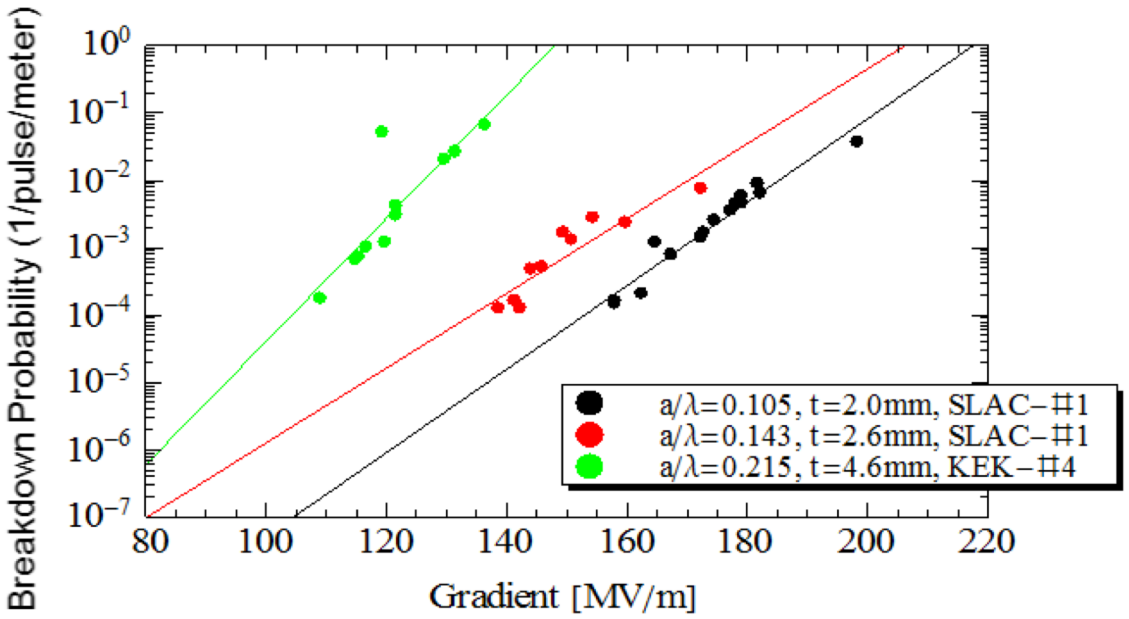
Higher energy ion beams via post-acceleration

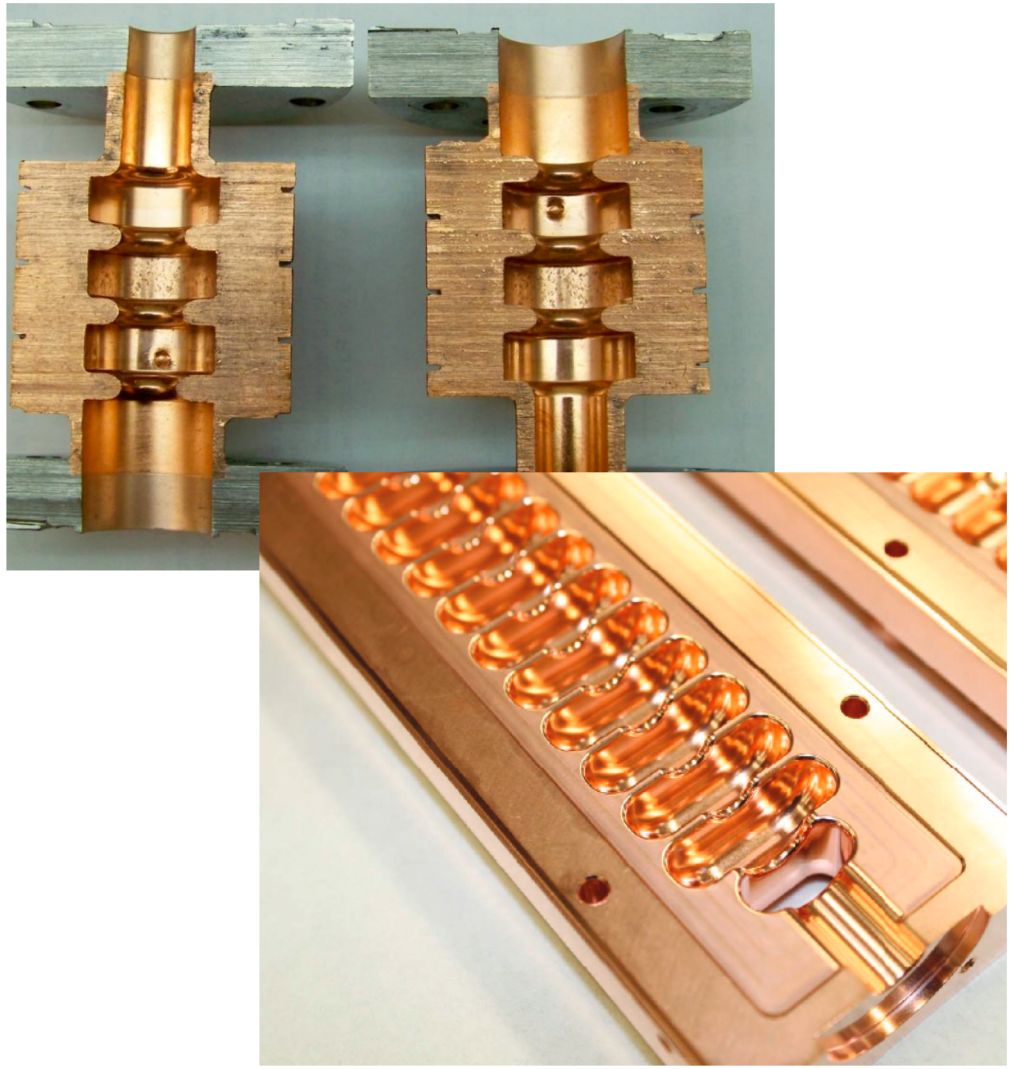


- Concept: use a linear accelerator after the cyclotron to raise beam energies
- Ideally of a size to fit within current building, therefore need high acceleration gradients (e.g. superconducting linac)

Recent advancements in normal-conducting RF cavities

Stanford University has developed high-gradient RF cavities capable of exceeding 100 MV/m





Proposed beam for post-acceleration

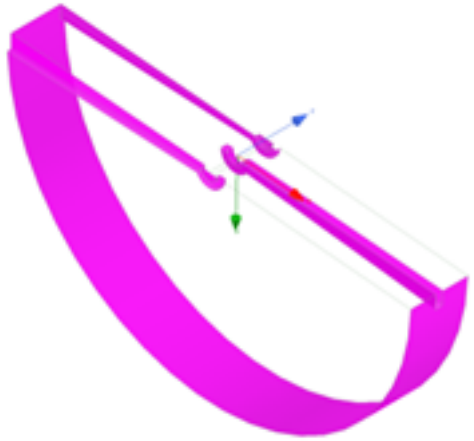
Question for Stanford:
could their high-gradient technology be used to accelerate the 10 MeV/nucleon cocktail beam to 25 MeV/nucleon over 6 m?

Why 10 MeV/u?

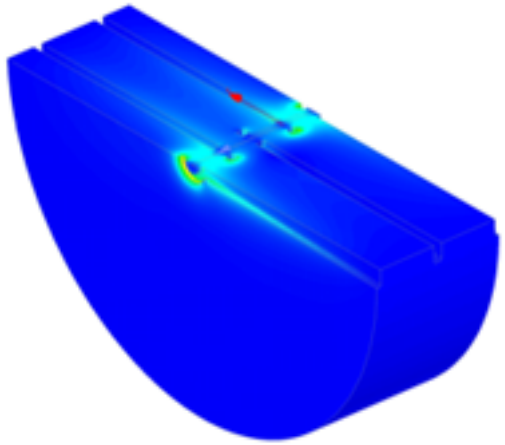
- Spans a very wide mass range:
  - $^{11}B^{3+}$, $^{18}O^{5+}$, $^{22}Ne^{6+}$, $^{40}Ar^{11+}$, $^{65}Cu^{18+}$, $^{86}Kr^{24+}$, $^{124}Xe^{34+}$, and $^{197}Au^{52+}$

- Why 25 MeV/u over 6 m?
  - Small footprint---further acceleration possible
  - Sets a cost for further acceleration
  - Will have produced a beam immediately useful to BASE community (wide mass spectrum can be used at air)

Stanford / LBNL proposal



Physical structure



Electric field magnitude

- 433 MHz traveling wave Interdigital-H (IH) structure
- 29 cm diameter
- 9 MV / m gradient to reach 25 MeV / u over 6 m

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How MARS can help

- 10 MeV/nucleon beam chosen because of presence of gold

E_o	^{197}Au charge state	E_f	ΔE
10 MeV/u	52+	25 MeV/u	15 MeV/u

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How MARS can help

- 10 MeV/nucleon beam chosen because of presence of gold

E_o	^{197}Au charge state	E_f	ΔE
10 MeV/u	52+	25 MeV/u	15 MeV/u
15 MeV/u	66+	34.4 MeV/u	19.4 MeV/u

- Currently we have extracted 61+ from cyclotron using VENUS, but we expect much higher charge states from MARS

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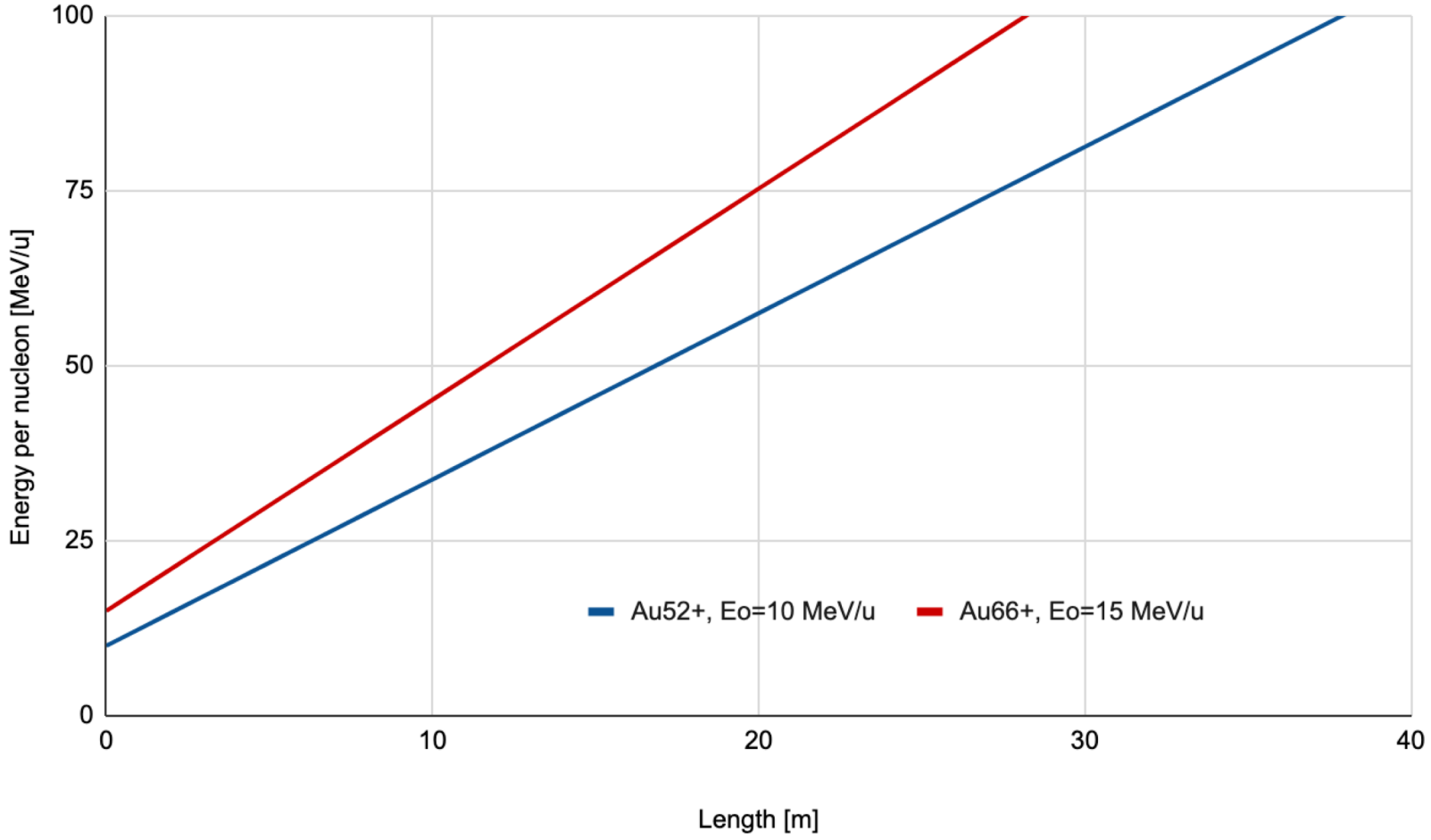
Accelerating to yet higher energies



- 9 MV/m acceleration gradient
- Acceleration of either
  - 10 MeV/u cocktail ($^{197}Au^{52+}$)
  - 15 MeV/u cocktail ($^{197}Au^{66+}$)

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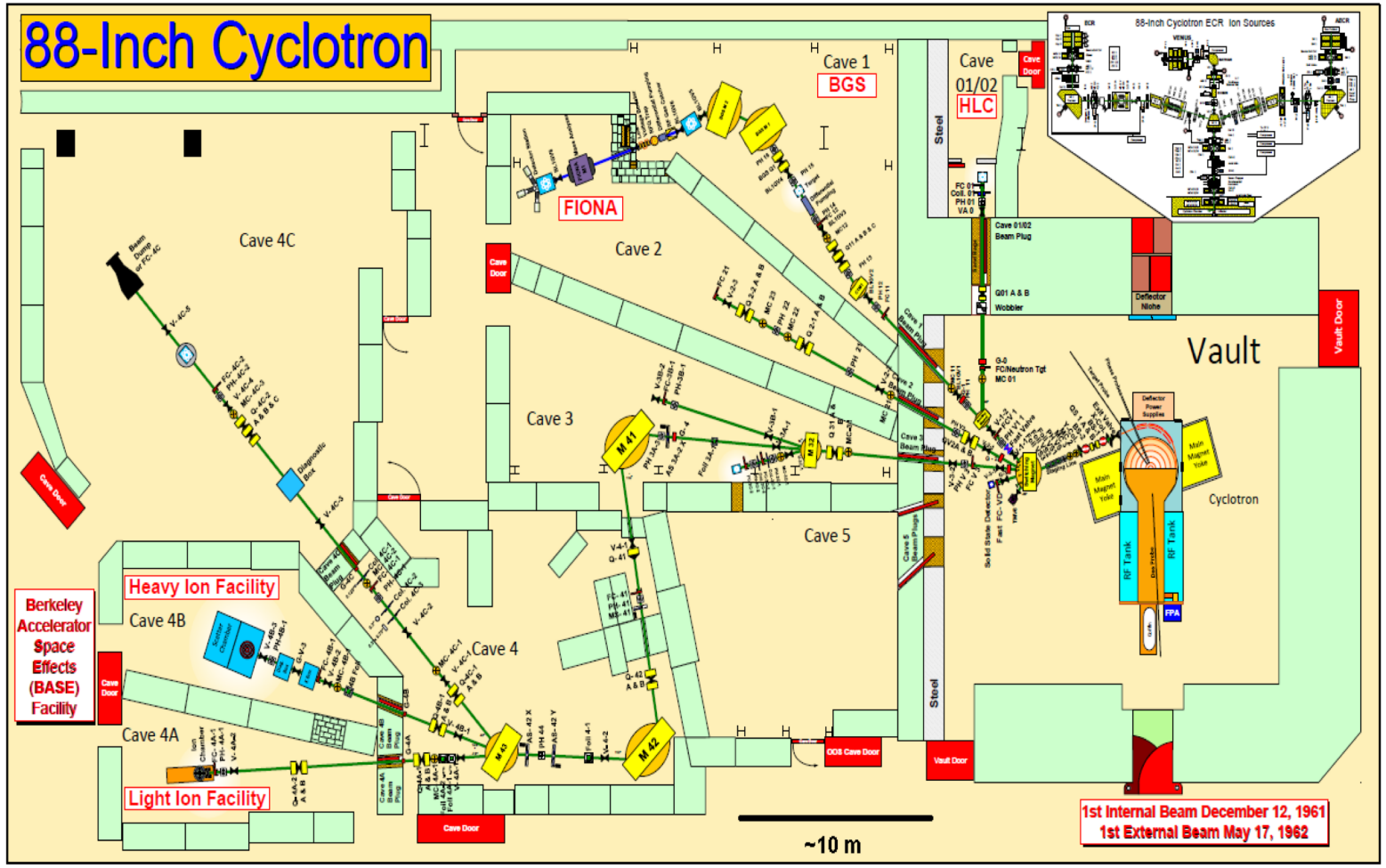
High energy ions with a relatively small footprint

- A 10s-of-meter length booster linac could fit within our walls



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