

Potential US Testing Opportunities for Muon Collider Capabilities

Workshop on Muon Collider Testing Opportunities

Brookhaven National Laboratory

*Drawing on work conducted by:
the US Muon Accelerator Program (MAP),
the International Design Study for a Neutrino Factory (IDS-NF), and
the International Muon Ionization Cooling Experiment (MICE)*



U.S. DEPARTMENT OF
ENERGY

Office of
Science

BROOKHAVEN
NATIONAL LABORATORY

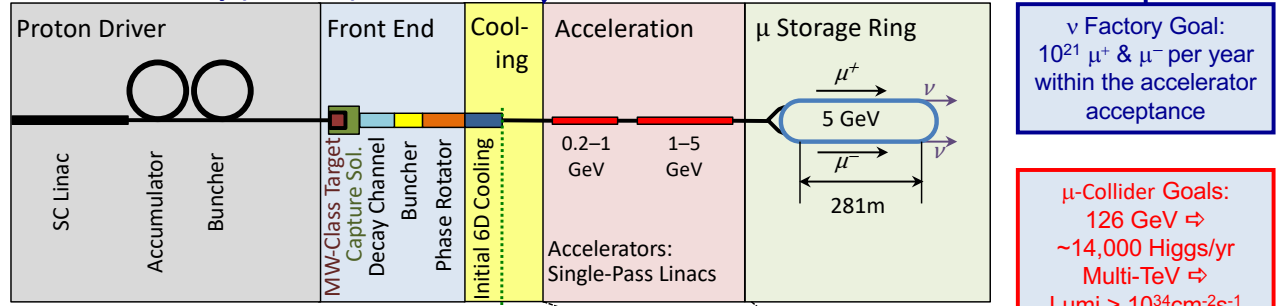


Introduction

- Looking towards the possibility that MC activities may resume in the US after the conclusion of the upcoming US Snowmass process
- Examples are based on areas of engagement identified during the US Muon Accelerator Program
 - No commitments can presently be made
- New opportunities may also appear...
- Focus on:
 - Magnet Demonstration Capabilities
 - RF Demonstration Capabilities
 - Beam Demonstration and Beam Test Capabilities (including beam analogue tests)
Of course, there has been considerable interest in the past on facility options such as nuSTORM

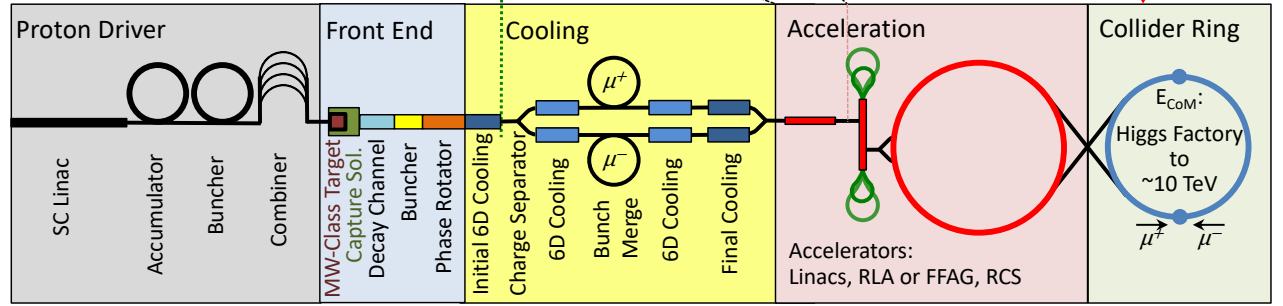
The basic elements

Neutrino Factory (NuMAX)



Share same complex

Muon Collider



μ -Collider Goals:
126 GeV \Rightarrow
 $\sim 14,000$ Higgs/yr
Multi-TeV \Rightarrow
Lumi $> 10^{34} \text{cm}^{-2}\text{s}^{-1}$

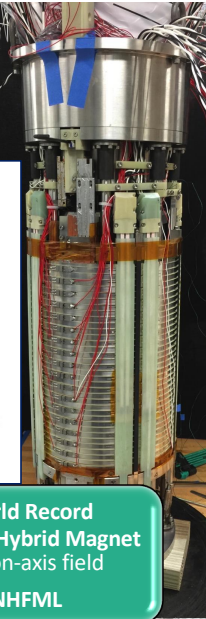
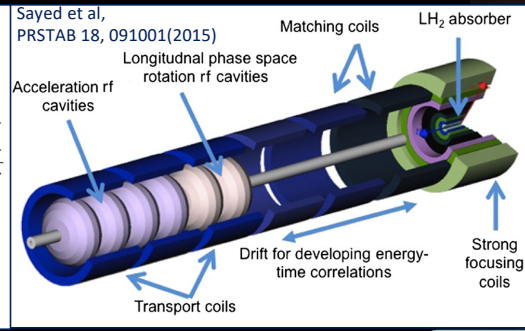
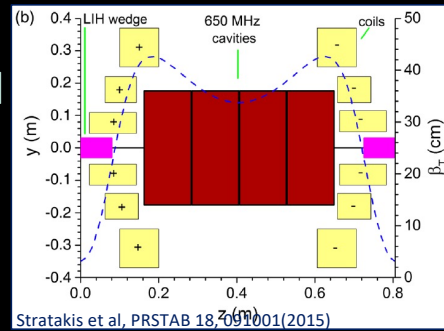


Key R&D Challenges (from MAP Study)

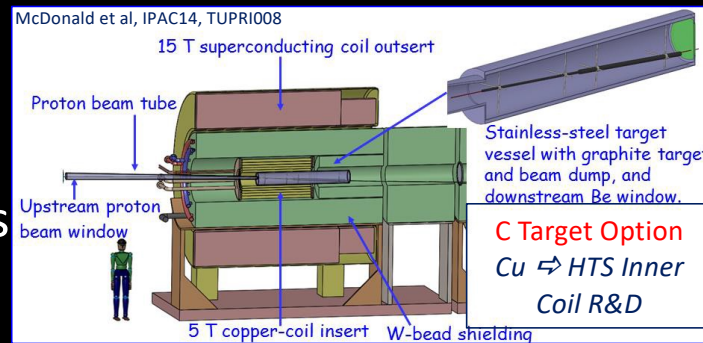
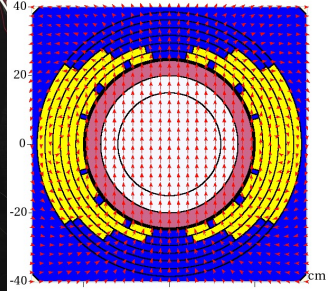
	Issues	Status
Target	<ul style="list-style-type: none">Multi-MW TargetsHigh Field, Large Bore Capture Solenoid	<ul style="list-style-type: none">Ongoing >1 MW target developmentChallenging engineering for capture solenoid
Front End	<ul style="list-style-type: none">Energy Deposition in FE ComponentsRF in Magnetic Fields (see Cooling)	<ul style="list-style-type: none">Current designs handle energy deposition
Cooling	<ul style="list-style-type: none">RF in Magnetic FieldHigh and Very High Field SC MagnetsOverall Ionization Cooling Performance	<ul style="list-style-type: none">MAP designs use 20 MV/m → 50 MV/m demo>30 T solenoid demonstrated for Final CoolingCooling design that achieves most goals
Acceleration	<ul style="list-style-type: none">AcceptanceRamping SystemSelf-Consistent Design	<ul style="list-style-type: none">Designs in place for accel to 125 GeV CoMMagnet system development needed for TeV-scaleSelf-consistent design needed for TeV-scale
Collider Ring	<ul style="list-style-type: none">Magnet Strengths, Apertures, and ShieldingHigh Energy Neutrino Radiation	<ul style="list-style-type: none">Self-consistent lattices with magnet conceptual design up to 3 TeV> ~5 TeV – ν radiation solution required
MDI/Detector	<ul style="list-style-type: none">Backgrounds from μ DecaysIR Shielding	<ul style="list-style-type: none">Further design work required for multi-TeVInitial physics studies at 1.5 TeV promising

Magnet Design Needs

- Major Items
- Target: Capture Solenoid
- 6D Cooling Channel: Integrated RF Cavities
- Final Cooling (Emittance Exchange): Very high field solenoids
- Ramping Magnets for high energy acceleration
- Large aperture shielded collider magnets
- US Magnet Capabilities well-matched to support development program
- BNL, FNAL, LBNL, NHMFL
- Academia
- Industrial partners



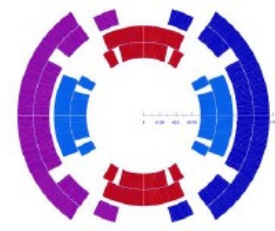
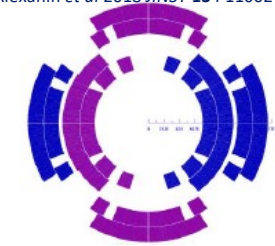
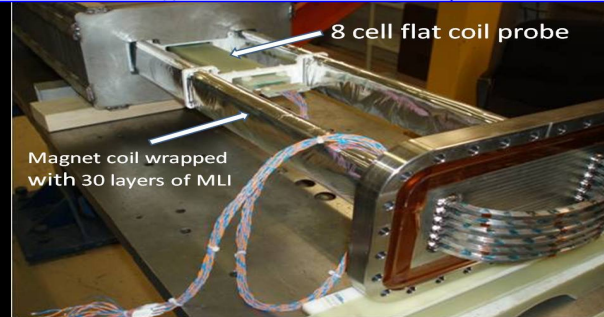
Large Aperture Collider Magnets



World Record
LTS-HTS Hybrid Magnet
32T on-axis field
NHMFL



New HTS fast ramping magnet technology
Piekarz et al., NIM A, Vol 943, 2019, 162490

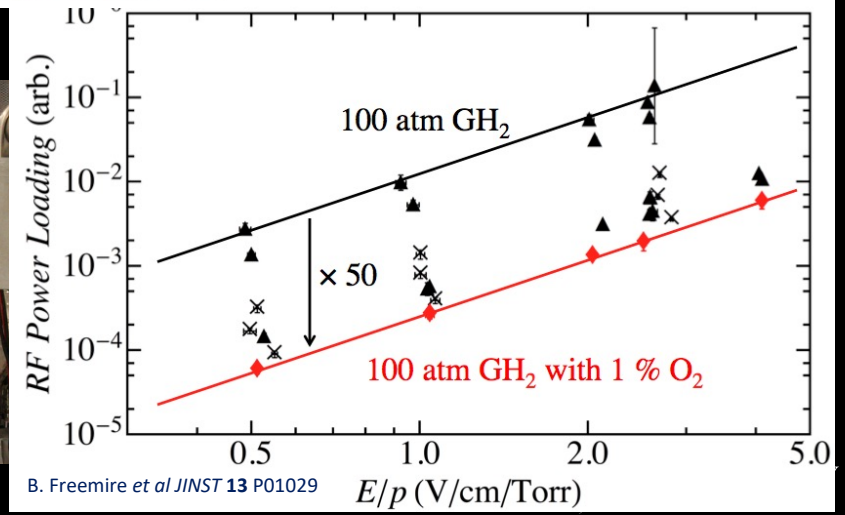
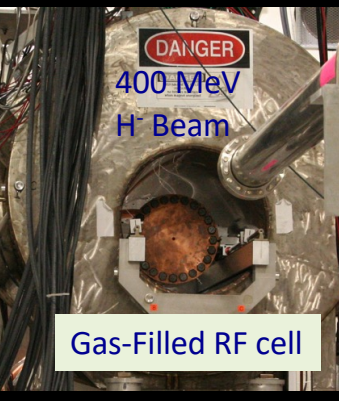
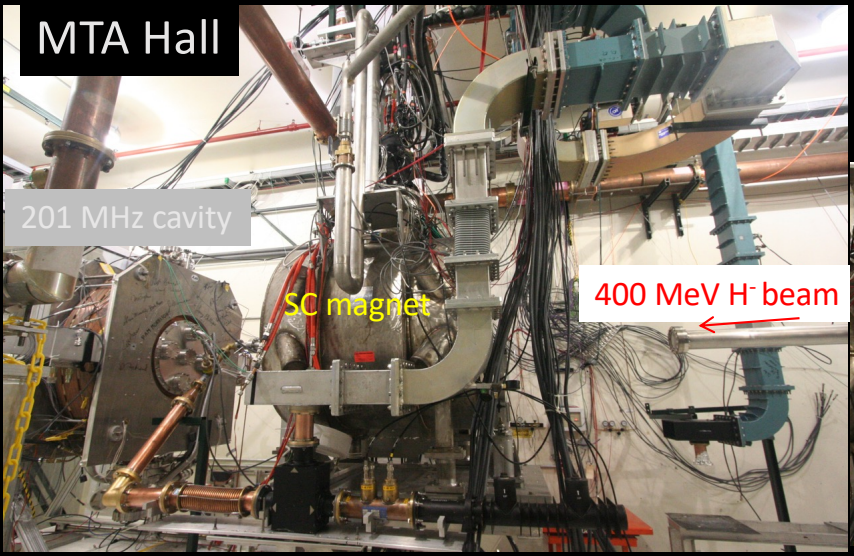
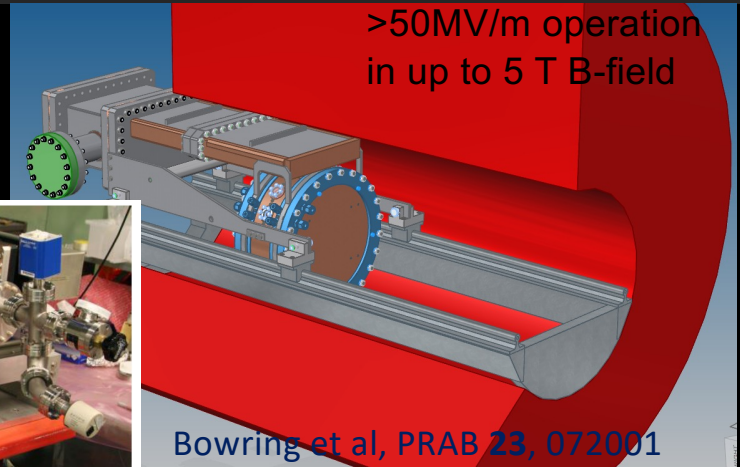




MuCool Test Area (MTA) and NC RF Development



MTA now decommissioned



March 24, 2021

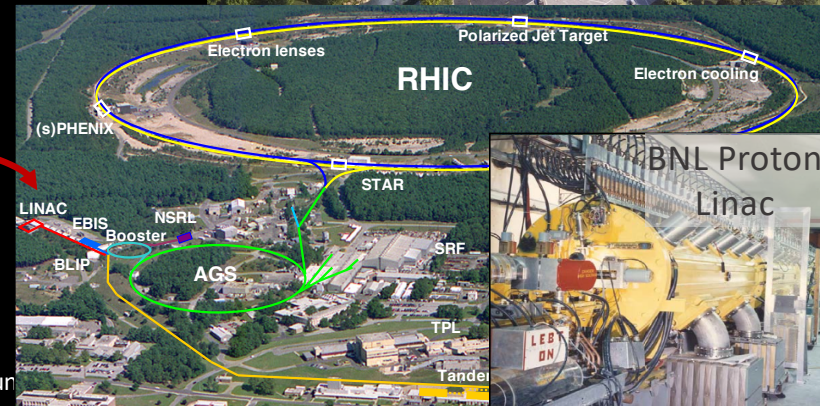
Workshop on Muon Collider Testing Opportunities

B. Freemire et al JINST 13 P01029

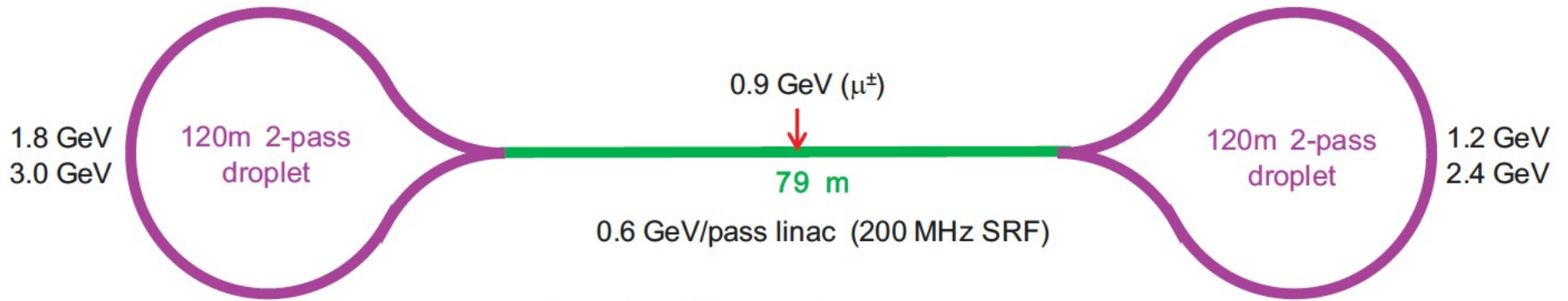


Future End Station Options?

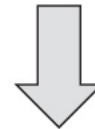
- MTA
 - Hardware decommissioned at the conclusion of MAP
 - End station re-tasked for other studies
 - Plasma interaction studies and impacts on beam dynamics studies were discontinued at the conclusion of MAP \Rightarrow *Studies important to developing an understanding of high intensity muon beams in a cooling channel*
- Fermilab moving to PIP-II (800 MeV SC Linac)
 - Will NC Linac still be available in the relevant time frame?
 - Will suitable testing options become available with
- Alternatives in the US
 - 200 MeV LINAC at BNL
 - Suitable end station would need to be constructed



JEMMRLA

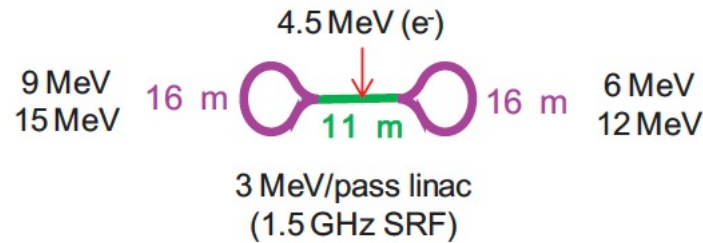


energies reduced by
factor of 200
(m_μ/m_e)



size reduced by
factor of 7.5
(1.5GHz/200MHz)

Demonstration of high
efficiency multi-pass arcs
JLAB Proposal

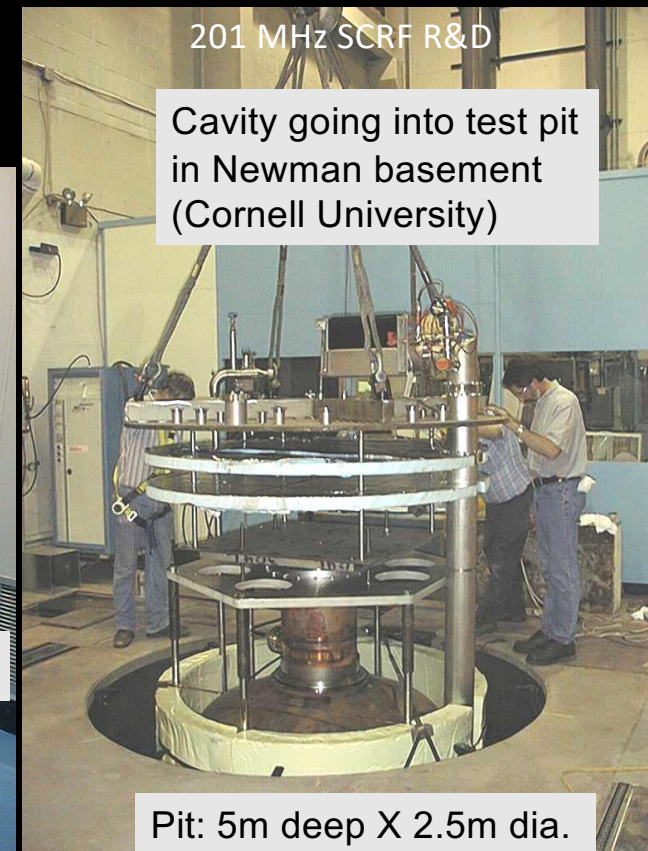
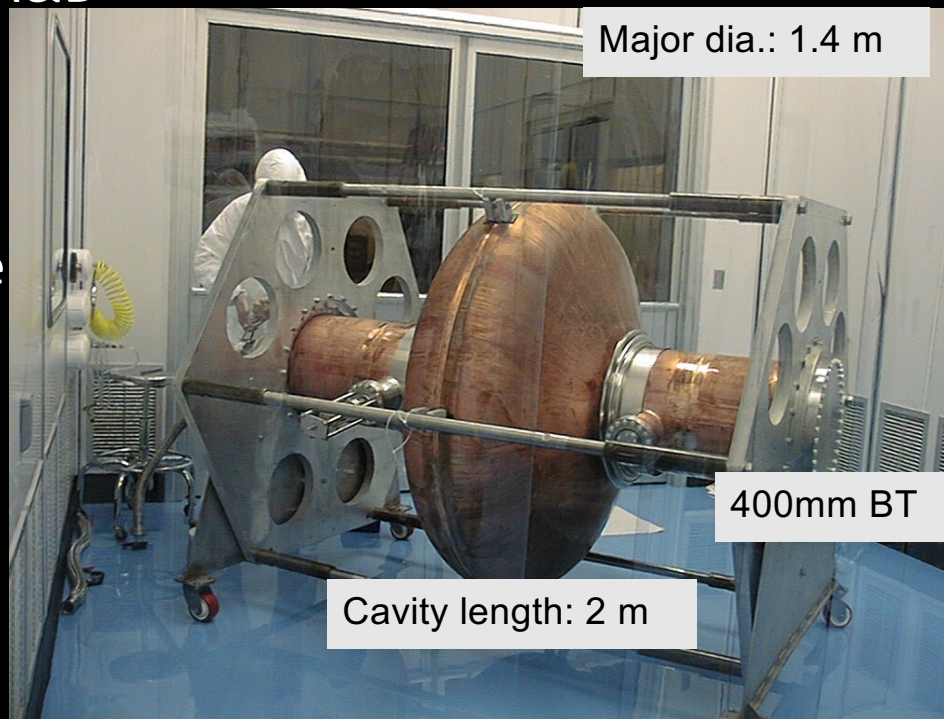


S.A. Bogacz, et al
IPAC2013, WEOAB202



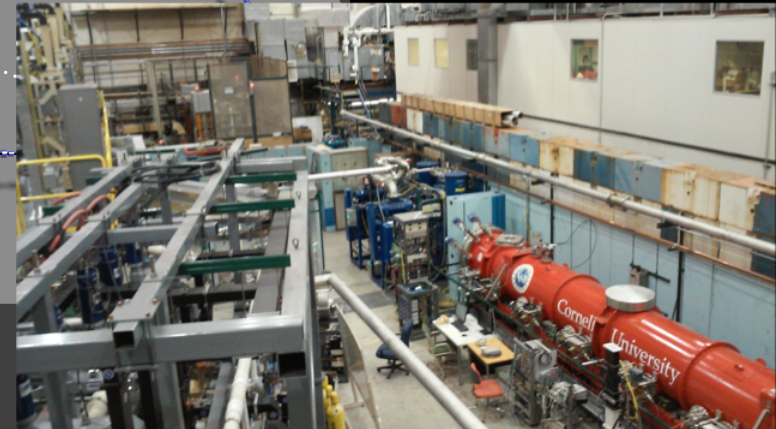
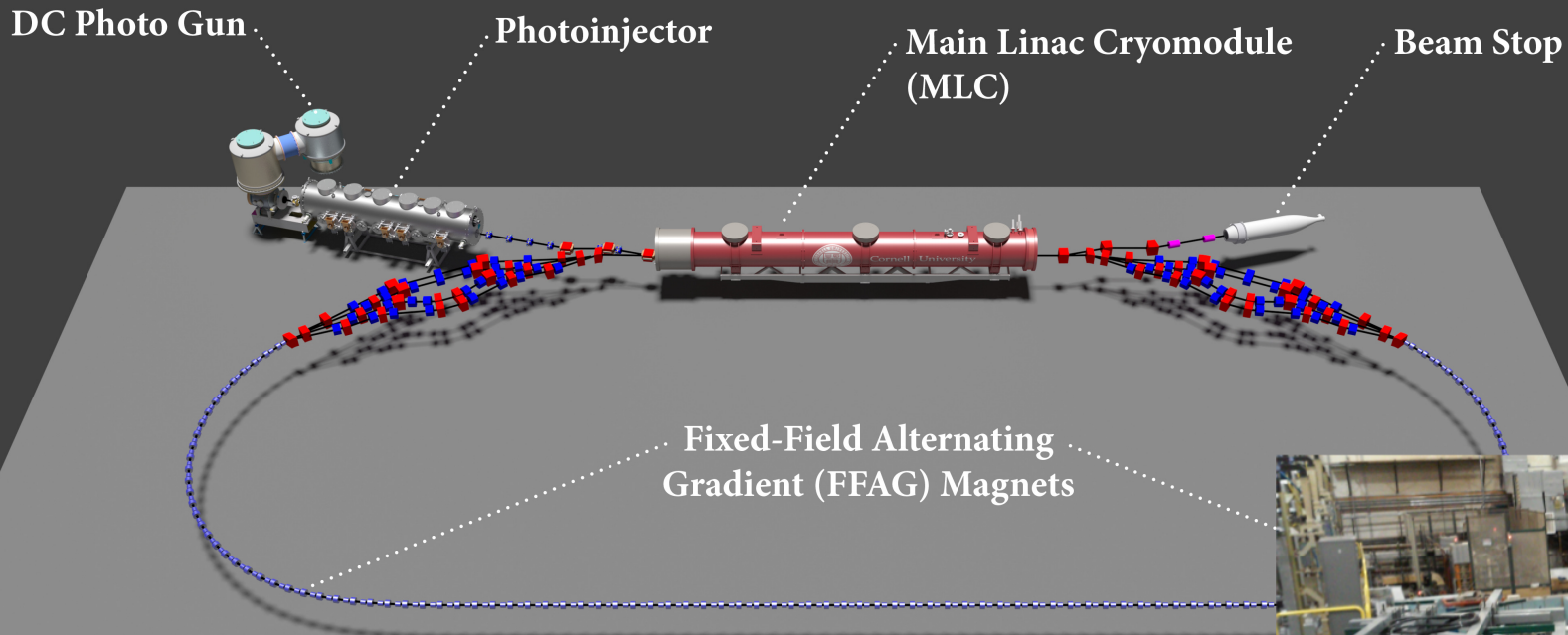
Superconducting RF Development

- Stored energy and aperture are critical issues in the early acceleration stages
- Nb on Cu R&D
- Multiple US Labs could contribute





FFA Demonstration @CBETA (Cornell/BNL)



[arXiv1706.04245](https://arxiv.org/abs/1706.04245)

March 24, 2021

Workshop on Muon Collider Testing Opportunities

10

BROOKHAVEN
NATIONAL LABORATORY



Final Comments and Conclusion

- Additional comments
 - US efforts continue in high power targetry
 - RADIATE Collaboration
 - LBNF/DUNE high power target development (FNAL)
 - Materials studies at BLIP (BNL)
 - Further details on many of these efforts will be discussed in subsequent talks at this workshop
- Concluding Thoughts
 - Interest in the US in technical demonstrations remains strong
 - Further funding and ability to execute significant test programs are dependent on the outcome of the Snowmass Community Planning process in the US



Thank you for your attention!