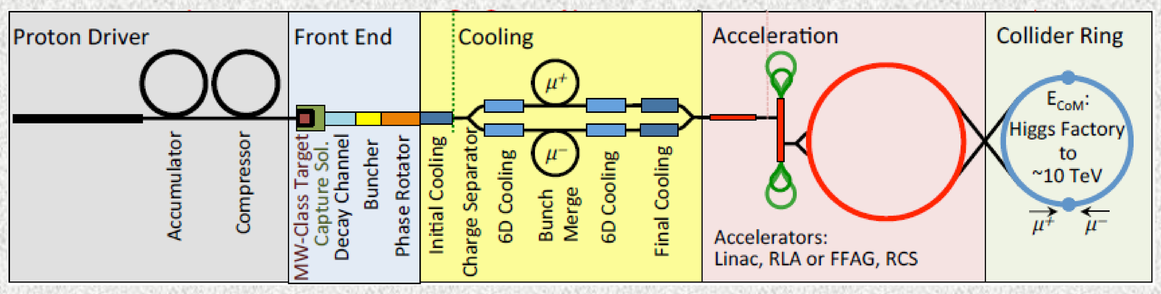
FERMILAB-POSTERP24-0067-AD

An Engineering Prototype of a late stage ionization cooling cell for a Muon Collider

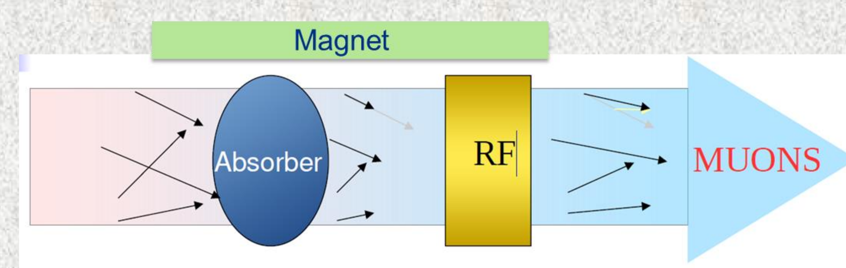
J. S. Berg, Brookhaven National Laboratory, *Upton, NY, U.S.A*
D. Stratakis, K. Badgley, S. Gourlay, S. Krave, A. Zlobin, Fermilab, *Batavia, IL, U.S.A*
T. Luo, Berkley Lab, *Berkley, CA, U.S.A*
E. Nanni, SLAC National Accelerator Laboratory, *Menlo Park, CA, U.S.A*

INTRODUCTION

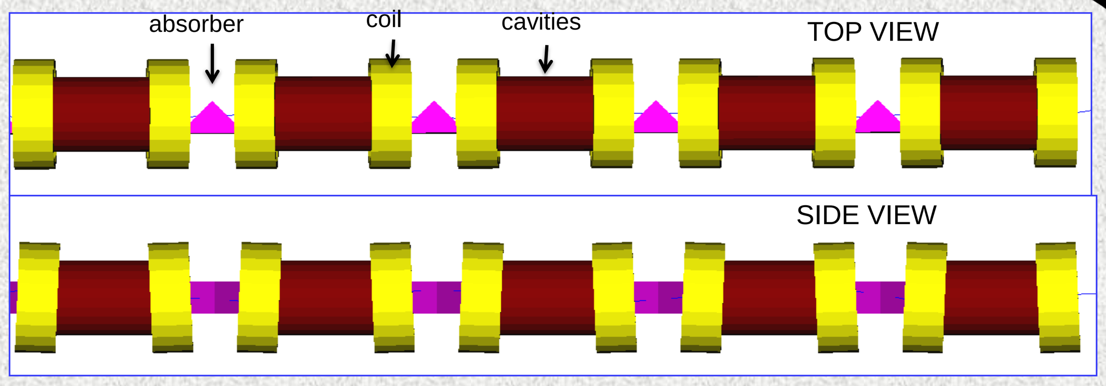
Achieving the low emittances required for a muon collider requires ionization cooling. Much of that cooling occurs in compact cooling cells where superconducting coils and conventional RF cavities are closely interleaved. The real challenges for these cooling cells reside in their engineering challenges: high field solenoids, RF cavities, and absorbers, often designed near technological limits, placed in close proximity to each other. We thus propose to build a prototype ionization cooling cell to demonstrate the capability of constructing an ionization cooling channel reaching the lowest emittances and to provide engineering input for the design of such beamlines.



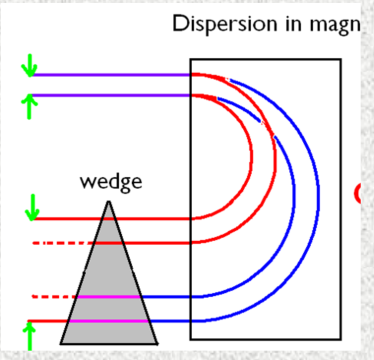
Muon Collider main components



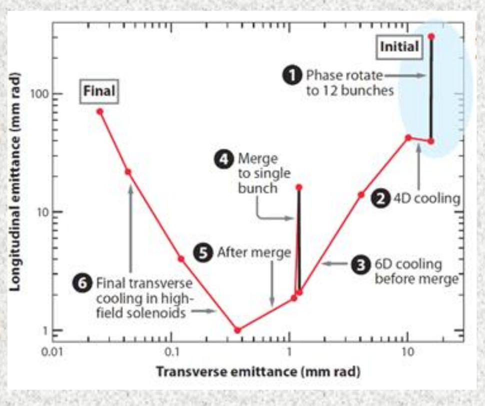
Ionization Cooling: By alternating absorbers with acceleration, the p⊥ of each particle can be reduced.



Proposed 6D Cooling Channel: Rectilinear channel with tilted alternating solenoids and wedge absorbers



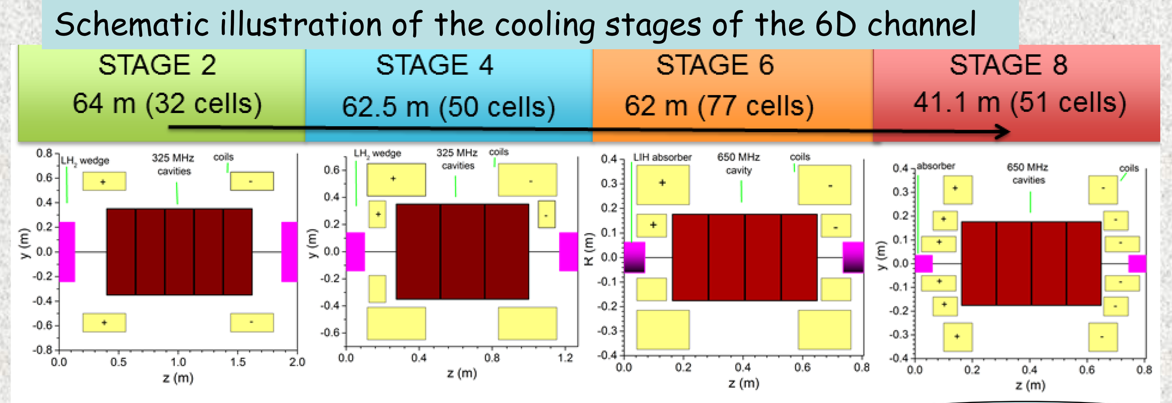
Longitudinal Cooling: Cooling to the longitudinal dimension requires emittance exchange. Dispersion is arranged so higher momentum particles have a longer path in the absorber.



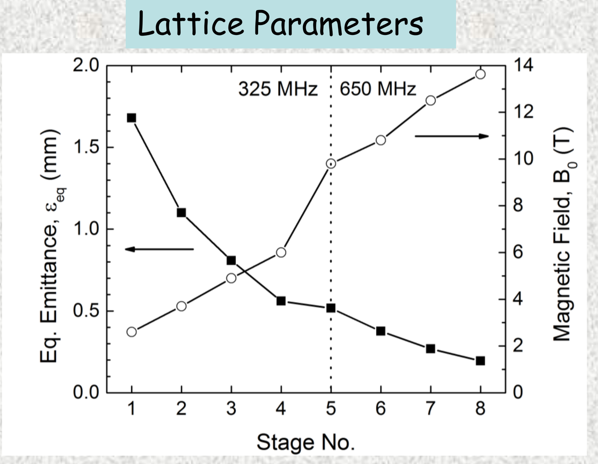
6D COOLING CHANNEL OVERVIEW

- Multi-stage tapered channel; Each stage has a lower equilibrium emittance
- This is achieved by decreasing the beta function for each stage by scaling the cell dimensions and increasing the on-axis field

Schematic illustration of the cooling stages of the 6D channel

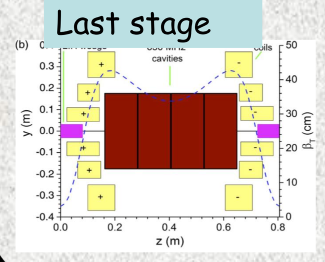


Lattice Parameters

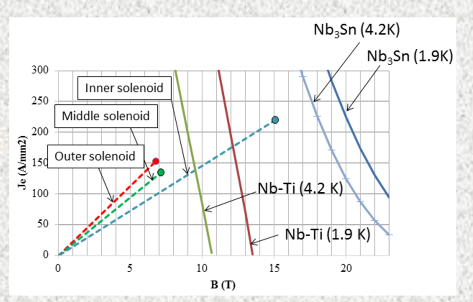


Last Cooling Stage

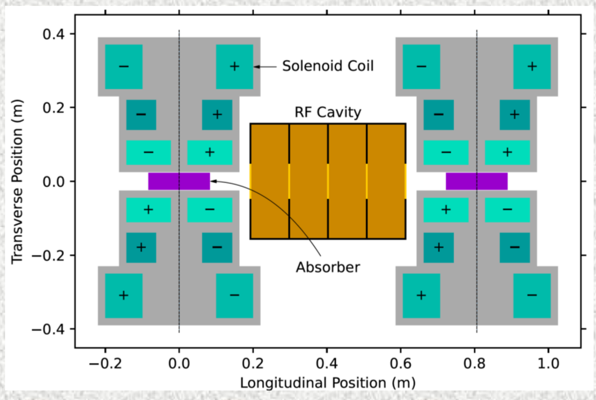
Last stage



- 6 solenoids per cell
- High solenoid fields: 15 T at coils, including a dipole
- SC coils close to RF cavities (28 MV/m RF gradient)
- Some evidence that RF cavities have problems in B-fields



1.5 CELL PROTOTYPE PLAN

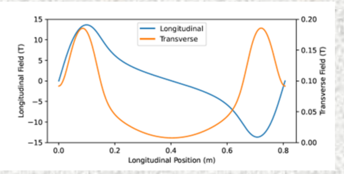


2 cells of magnets, one cell of RF

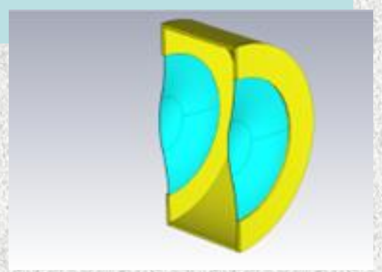
- Magnets will see similar forces to full system
- RF in magnetic field of full system
- Not just solenoids: dipole component

Magnets powered to full current

- RF powered to full voltage
- Demonstrate required gradients in magnetic field



A conceptual structure of the proposed 600-800 MHz cavity



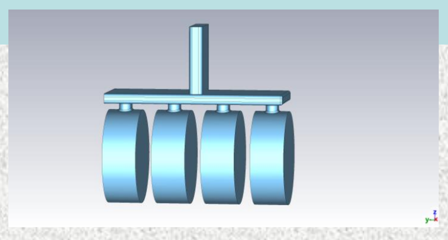
MAGNET PROGRAM

Conceptual design studies and modeling of SC magnets::

- magnetic and mechanical design and analysis, ,
- magnet powering powering and quench protection
- Cryostat design and thermal analysis
- System integration

Construct a prototype for the first solenoid for that cell and proceed

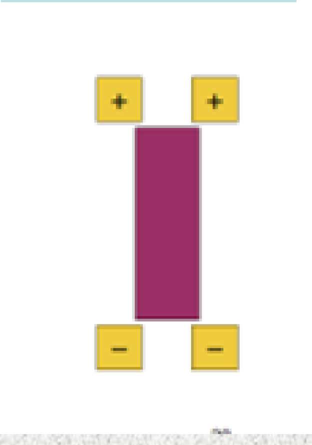
Distributed coupling model for a 4-cell cavity module



RF CAVITY PROGRAM:

- Design and prototype a cavity for a gradient test facility
- Study rf cavity materials and achievable gradients (Cu/Au alloy, cryogenic Cu, aluminum)
- Design the cavity for the 1.5 prototype and its power source
- Optimize the integration between RF and SRF system

Rf test stand

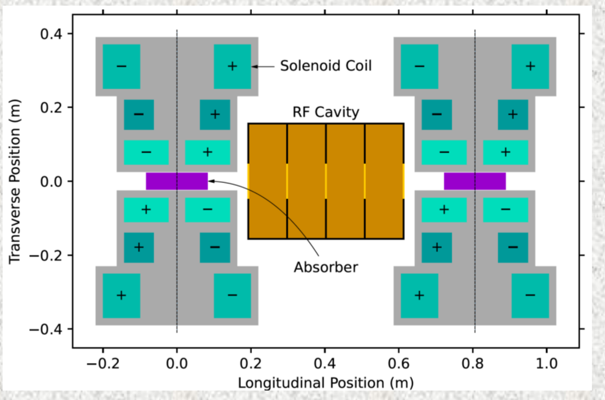


COOLING PROTOTYPING AND DEMONSTRATION

A cooling cell prototype:

- Design, build, and power the most challenging cooling cell
- Should face all the challenging engineering issues
- Convince the community that a cooling channel is buildable
- Engineering design process will provide input to physics design

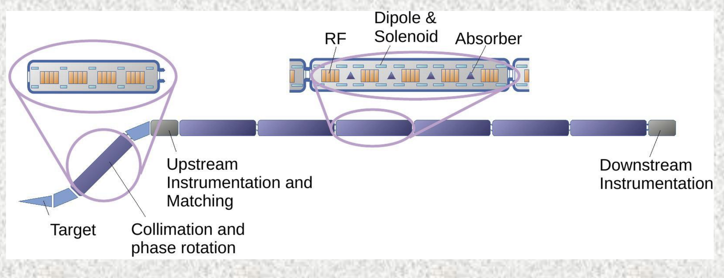
Cooling prototype 1.5 cell



A muon cooling demonstrator:

- Demonstrate significant 6D ionization cooling
- Requires multiple cells, each cell should have reasonable cost
- Use less challenging parameters to drive down the cost and to avoid issues with the dynamic aperture
- Address issues related to delivering and measuring the beam

Cooling demonstrator conceptual design



Conceptual design studies and modeling of all components needs to start now if we like to envision these facilities in the next decade

OUTLOOK

- **Phase 1**: (1) Design components for cavity material/limitation testing, (2) test cavity materials and determine gradient limits: choose technology
- **Phase 2:** (1) Design and test remaining solenoids, (2) full cavities design, (3) integration of all components for the 1.5 cell (4) begin testing…
- **Phase 3:** Proceed to a full demonstrator program with a beam using multiple cells but with less demanding parameters

This manuscript has been authored by Fermi Research Alliance, LLC under Contract No. DE-AC02-07CH11359 with the U.S. Department of Energy, Office of Science, Office of High Energy Physics.