6D Cooling Simulations for the Muon Collider

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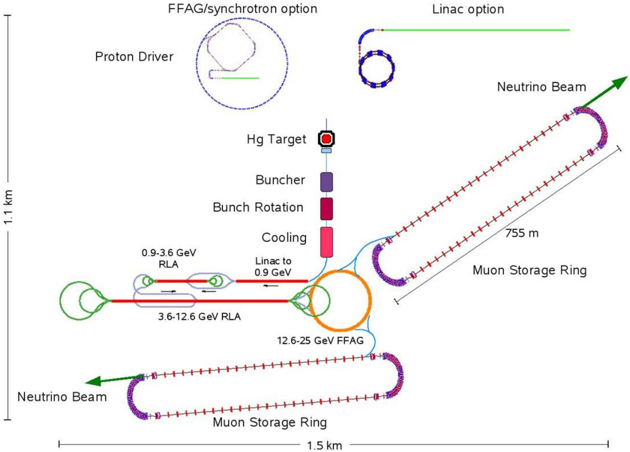
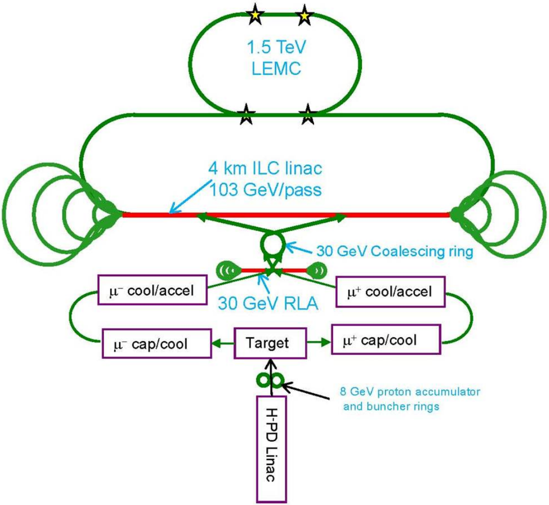
1. Introduction
2. Cooling lattices
3. RF in magnetic field
4. Magnetically insulated lattice
5. Wedge absorber in MICE

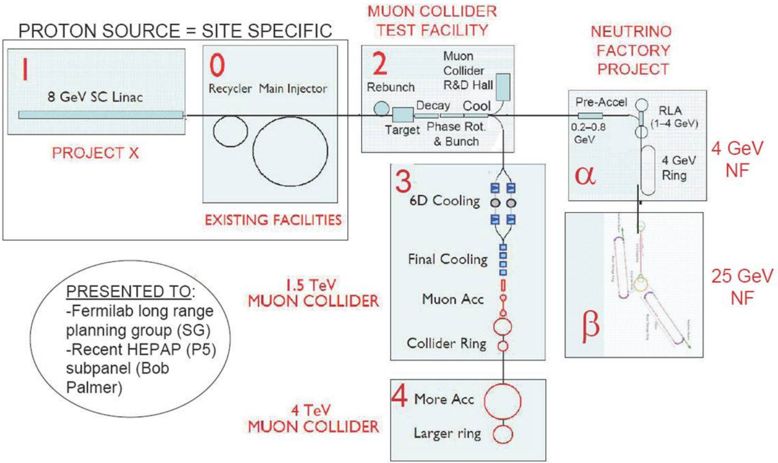
Schematics of the Neutrino Factory



Schematics of the Muon Collider



νFactory as a stepping stone for the μCollider



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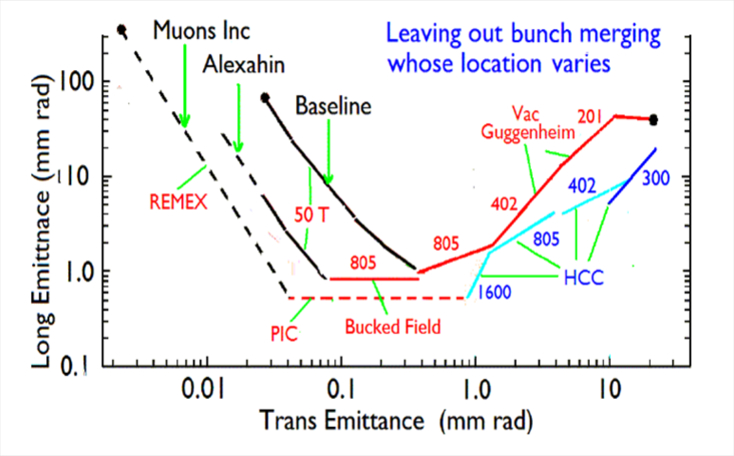
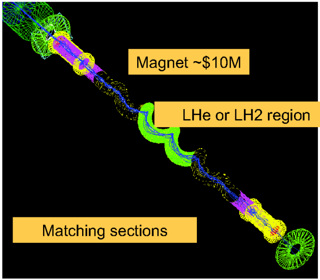
Muon Collider cooling scheme

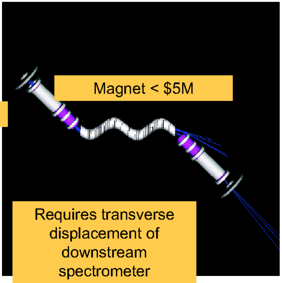


Helical Cooling Channel

PHASE III?

MANX, a possible6D cooling experiment using an helicoidal solenoid

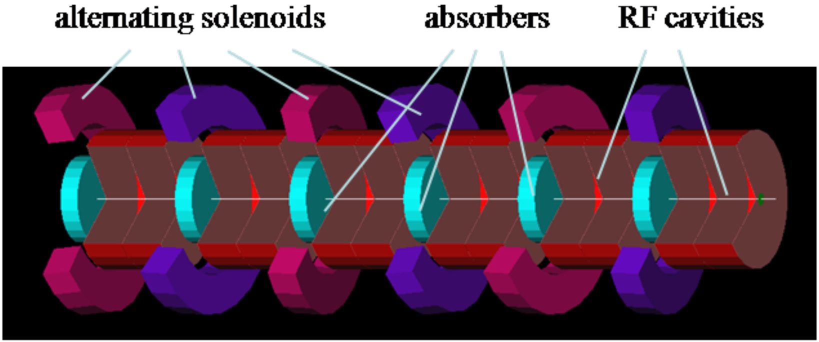




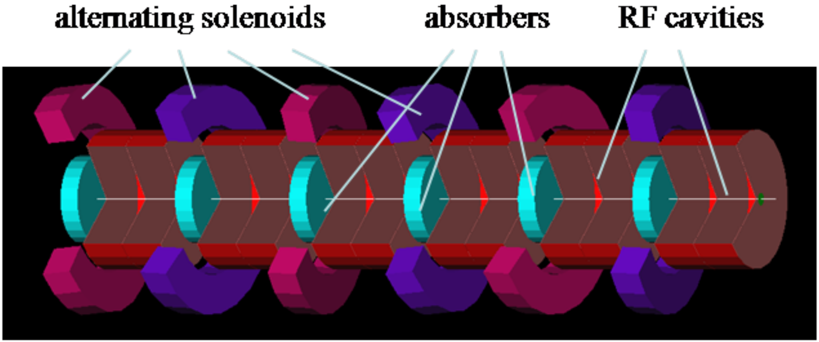
Very interesting … but still a lot of work to do!

NUFACT09 IIT Chicago 20-07-2009 Alain Blondel

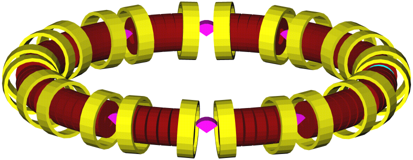
FOFO snake



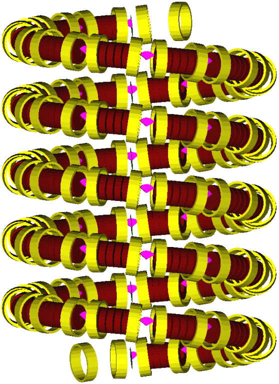
FOFO snake



RFOFO ring and Guggenheim helix

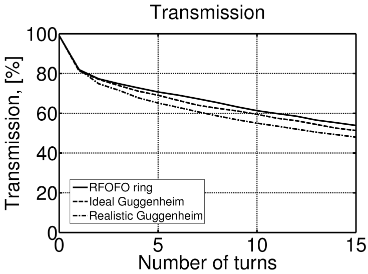


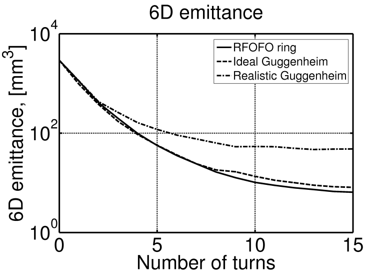
- RFOFO ring
- Issues: absorber overheating, injection/extraction, continuous operation



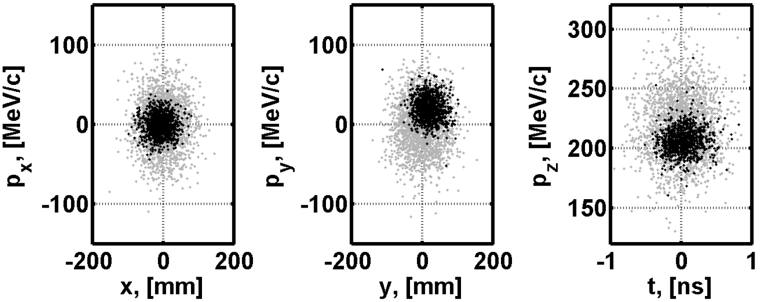
- RFOFO-based Guggenheim helix

Performance studies





Phase space reduction



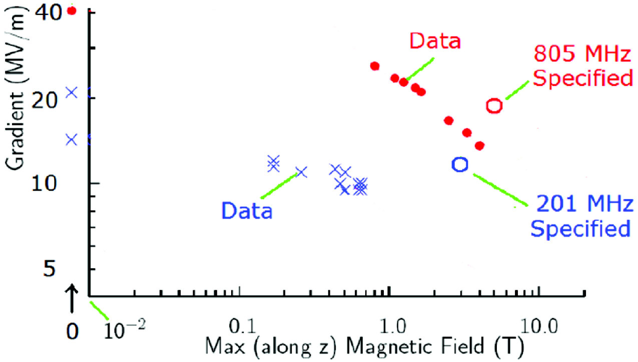
RF in magnetic field: issues and remedies

Jim Norem on RF in magnetic field

Gradient limits are vital to accelerator performance.

- Muon cooling might be limited by gradients.
- MICE might be limited by field emission.
- ILC had major problems with gradient.
- CLIC is uncertain about gradient.
- SNS is not reaching its design gradient.
- JPARC is intensity limited by gradient in its RFQ.
- ERLs are gradient limited by power consumption.

Experimental results



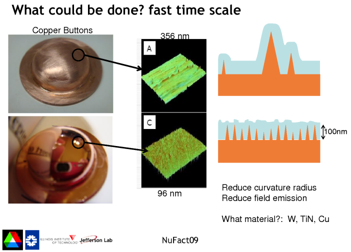
Possible breakdown mechanism

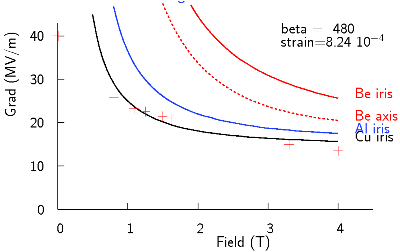
II) A Be Cavity test

With Steve Virostek, Mike Zisman, Derun Li

- RF Breakdown in magnetic fields probably due to focused emitted electrons
- Damage caused by cyclic heating from electron dE/dx
- Damage less if:
  - density low so less dE/dx
  - Radiation length high so electrons not scattered back
  - Thermal expansion low so less stress from heating
  - Thermal conductivity high so heat distributed
- Be is better than copper on all counts
- Cold (77 deg) Be is even better
- Explains lack of observed damage on Be window even opposite a button with enhanced field
- A cavity with Be walls is the surest solution to the problem
- Cold (77 deg) Al may also be a solution, but less assuredly so.

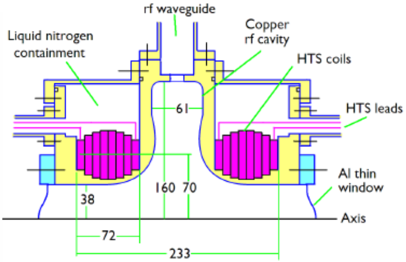
Ways to improve RF gradient

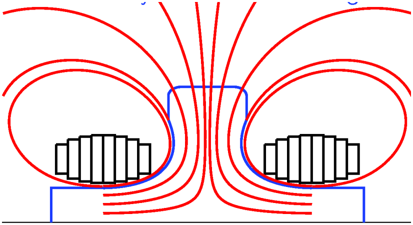


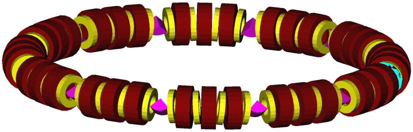


- Atomic layer deposition
- Alternative materials
- Low temperatures
- HPRF

Magnetic insulation

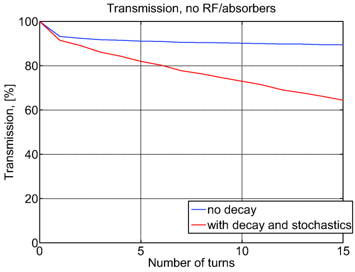


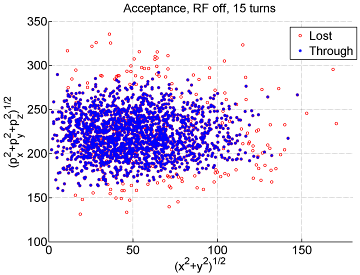




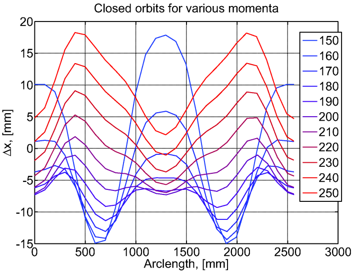
- Open cavity lattice
- Coils in the irises
- Coils are tilted to generate bending field

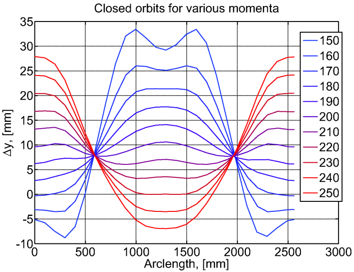
Simulation results: transmission



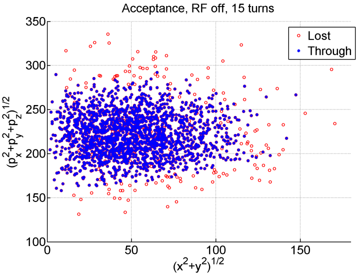


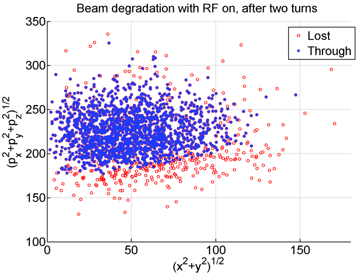
Simulation results: closed orbits





Longitudinal dynamics issue





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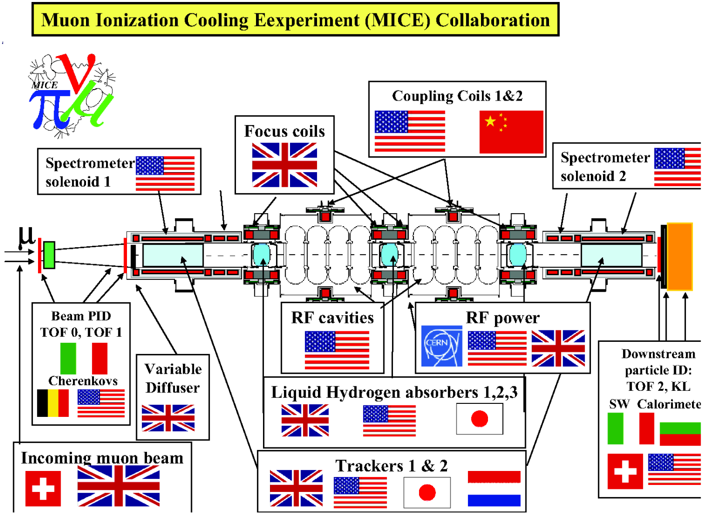
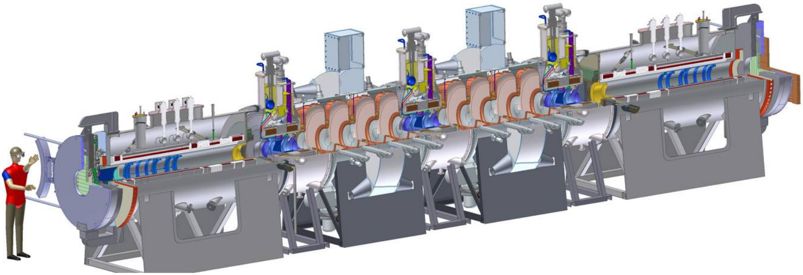
Wedge absorber in MICE Step IV

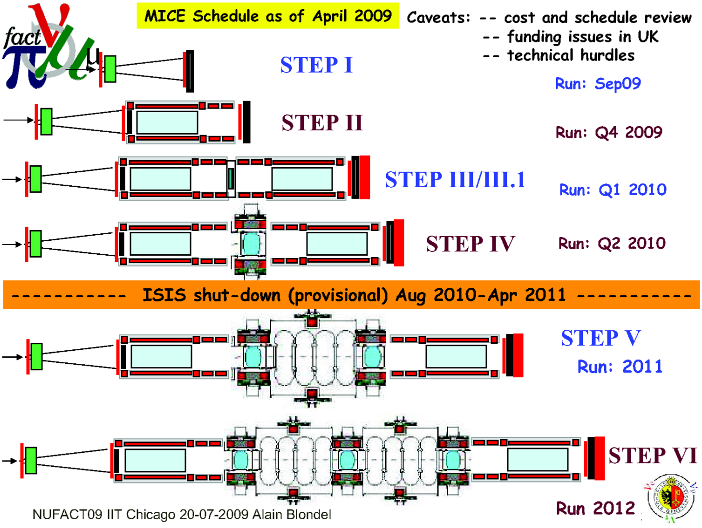
MICE experiment



MICE 3D model

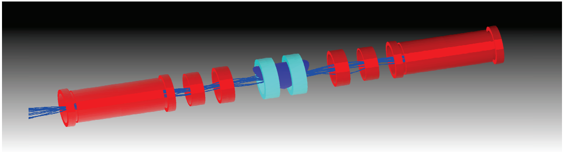


MICE schedule



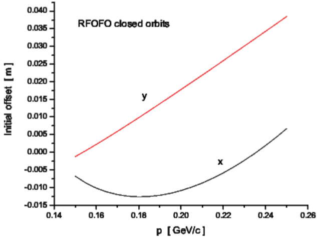
Simple Wedge

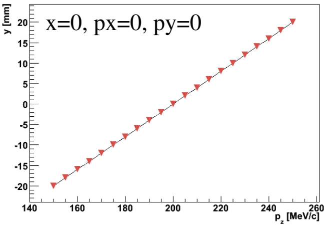
- Simple wedge
  - Induce dispersion in input beam
  - Measure (reverse) emittance exchange
- To what purpose?
  - "Proof-of-principle" - demo for wider community
  - Test material physics model in a different geometry
- Open questions
  - Which material?
  - What opening angle?
  - Can we measure an effect?



RFoFo Model

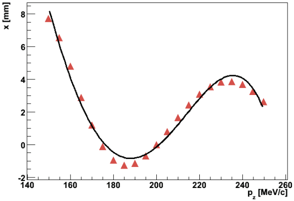
- Induce some y-pz correlation in particles at the wedge
  - Working to approximately follow RFoFo lattice - MUCOOL Note 314

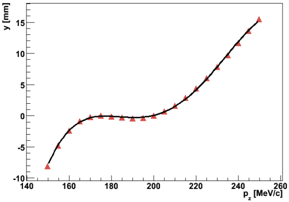




Non-Linearity

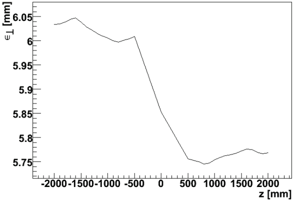
- Look at these particles at tracker
  - Tells us what correlation we need at the tracker to get dispersion at the wedge
- Pretty non-linear
  - Fit using 4th order polynomials
  - Probably needs 5th order...
  - This is probably generated by Larmor angle as a function of p_z
- To get a “non-linear” match
  - Insert beam at wedge center
  - No material processes
  - Transport to tracker
  - Apply px, py, t -> -px, -py, -t
    - Time Parity operator + reflection in z

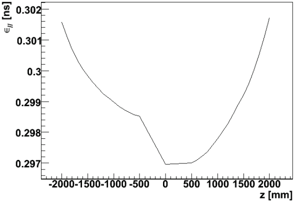


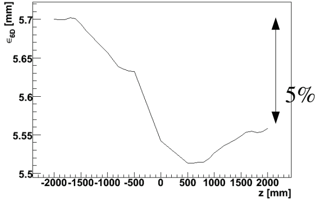


Emittances 100º LH2 Wedge

- D_y = 100 mm
- 100º ~ RFoFo wedge
  - No windows
- Small longitudinal cooling
- Drowned by non-linearities
- Overall ~ 5% 6d emittance reduction

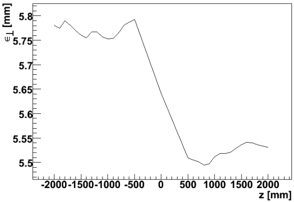


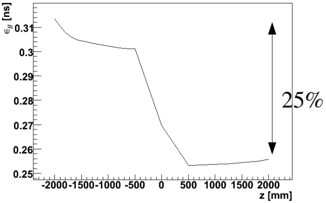


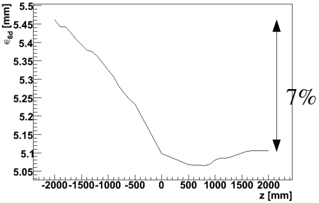


Emittances 90° LiH Wedge

- D_y=200 mm this time
- ~ 25% longitudinal emittance reduction
- 6D emittance reduction
  - 7 % in mm
  - 20 % in mm³
  - lH2 is much worse
  - Plastic is similar







Further studies

Use alternative approach:

- Start with whatever distribution comes from the beamline to the experiment.
- Track the distribution to the absorber plane.
- Analyze the resulting distribution.
- Decide on the shape of the absorber required.

Summary

- RFOFO and Guggenheim studied in detail (except for possible tapering).
- "RF in magnetic field" can possibly be mitigated by magnetically insulating the cavities.
- To test the emittance exchange, wedge absorber test is proposed for MICE Step IV.