Muon Collider R&D Status

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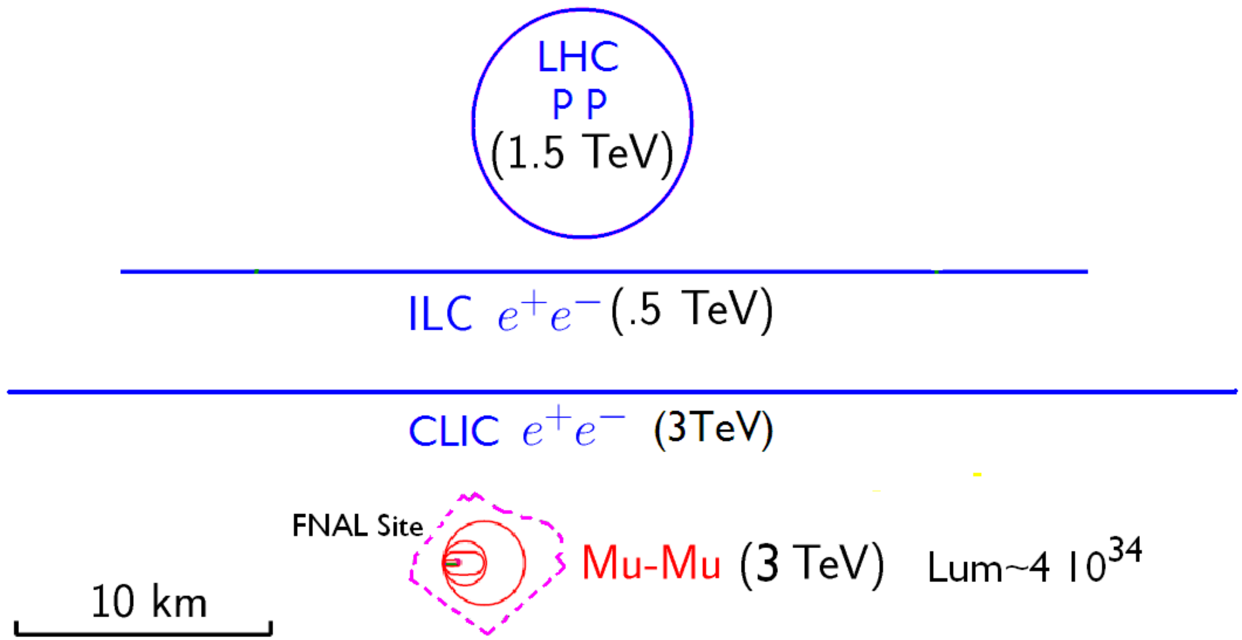
30th Anniversary

Kona, Hawaii 10/21/10

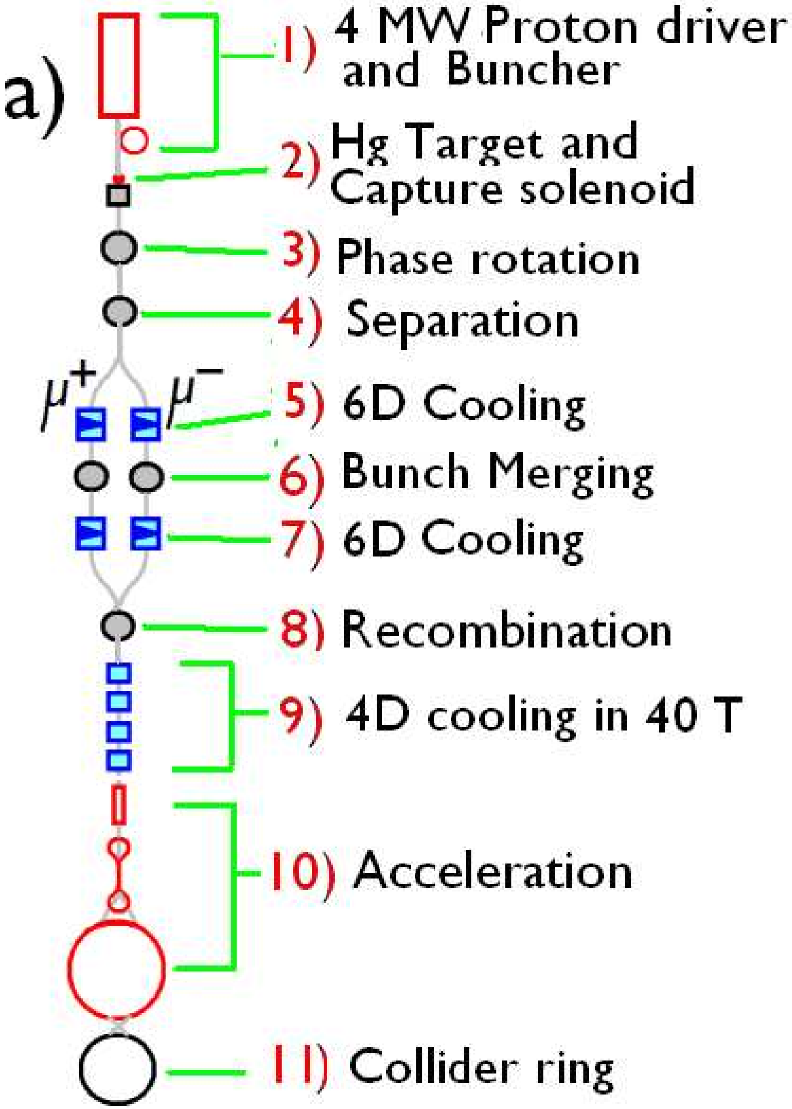
- Why a Muon Collider?
- Scheme
  - Cooling
  - Acceleration and Ring
- R&D
  - Hg Target (MERIT)
  - Cooling (MICE)
  - Cooling components (MuCool)
  - 40 T solenoid
- Muon Accelerator Program (MAP)
- Conclusion

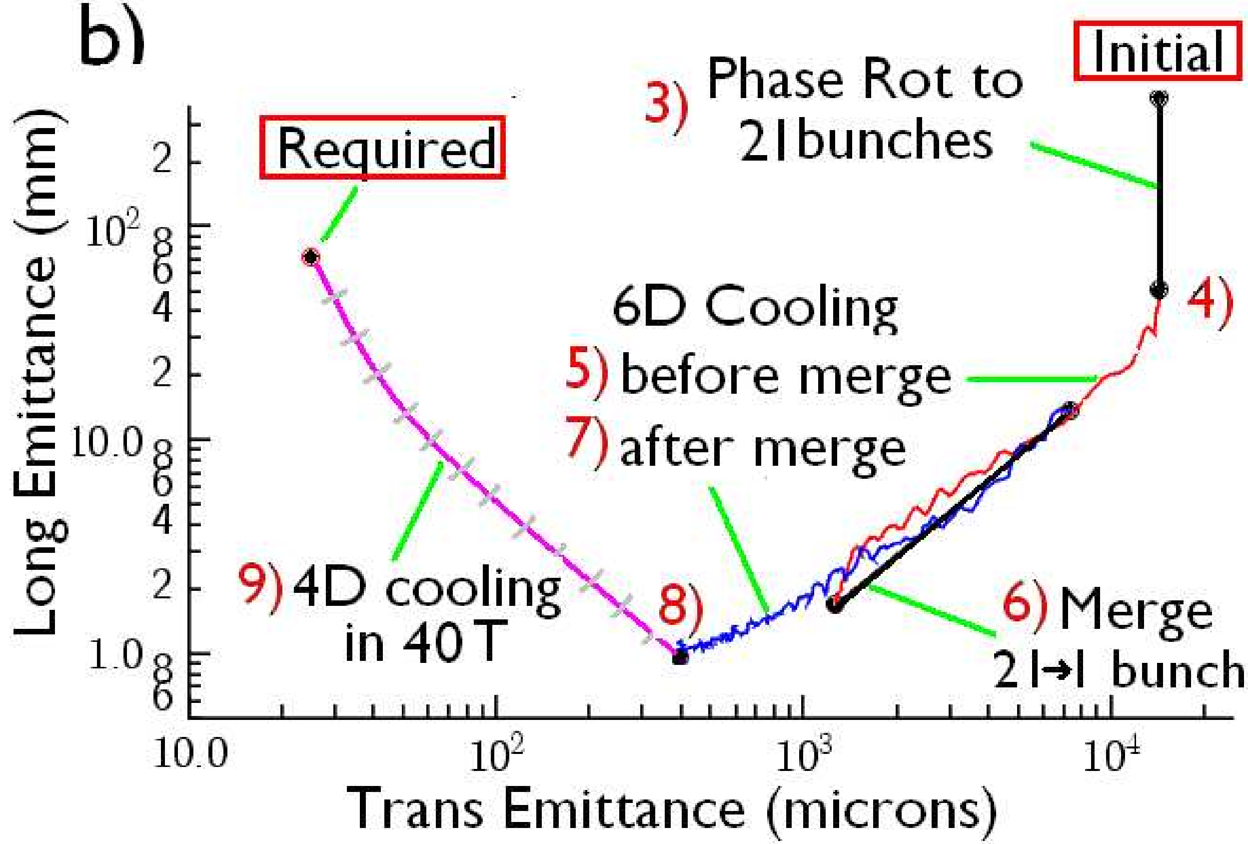
Why a Muon Collider?

- Point like interactions as in linear e^+e^-
- Negligible synchrotron radiation:
  Acceleration in rings Small footprint Less rf Hopefully cheaper
- Collider is a Ring
  $\approx$ 1000 crossings per bunch Larger spot Easier tolerances 2 Detectors
- Negligible Beamstrahlung Narrow energy spread
- 40,000 greater S channel Higgs Enabling study of widths



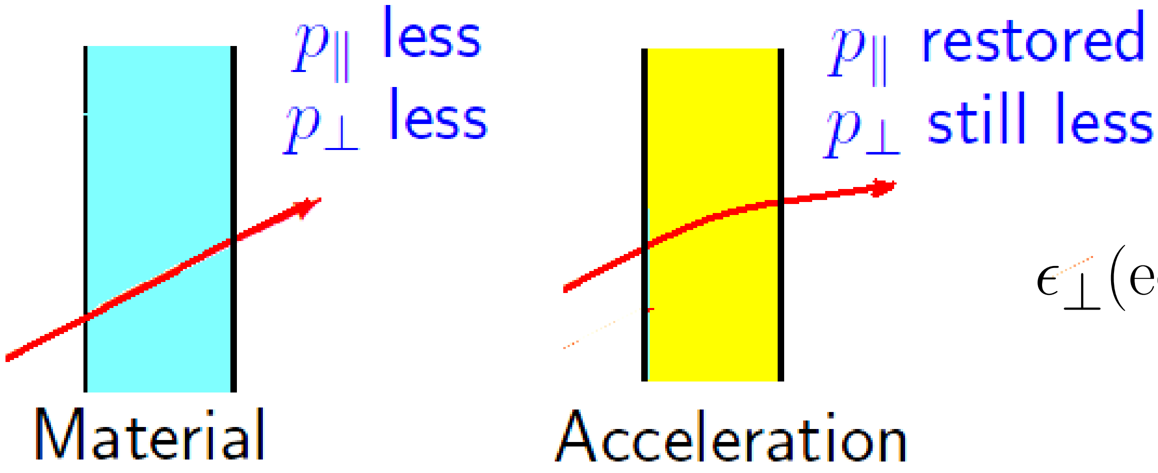
Scheme & Emittances vs. Stage





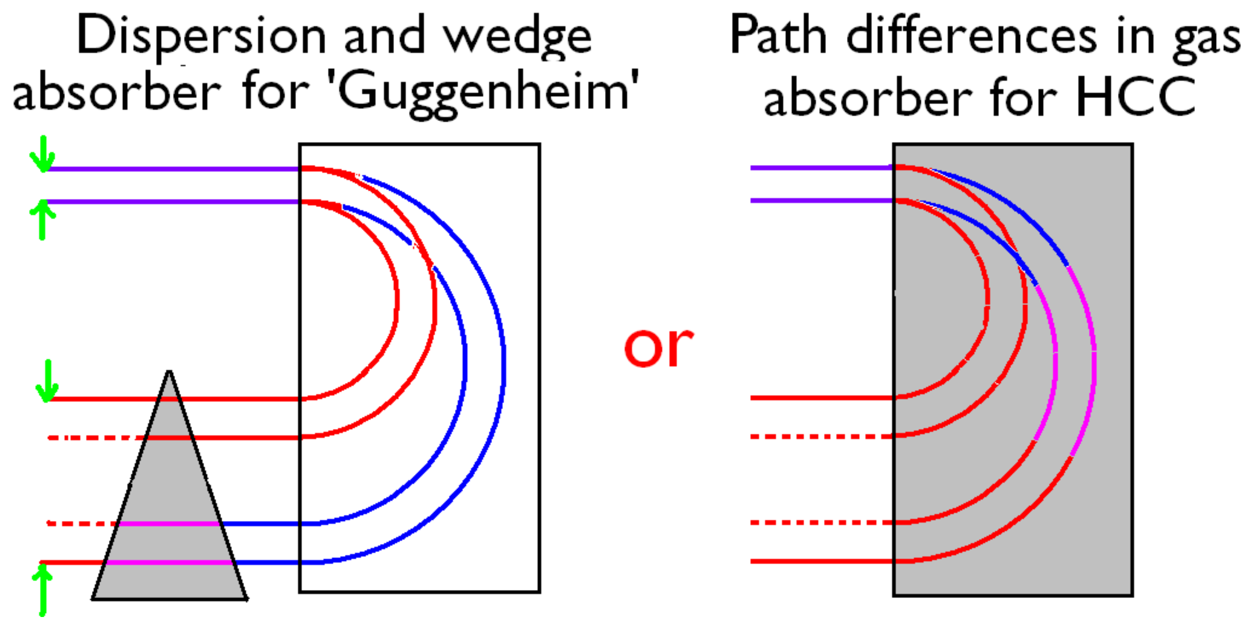
Emittances shown above are from simulations of one example but still less than full end-to-end

Ionization Cooling



$$\epsilon_{\perp}(\text{equilib}) \propto \frac{\beta_{\perp}}{\epsilon_v} \frac{1}{dE/dx\ L_x}$$

- Best Material is Hydrogen
- For 6D cooling we require Emittance Exchange
- Best energy to avoid blow up of dp/p $\approx$ 130 MeV
- But for final cooling, best energy $\approx$ 6 MeV

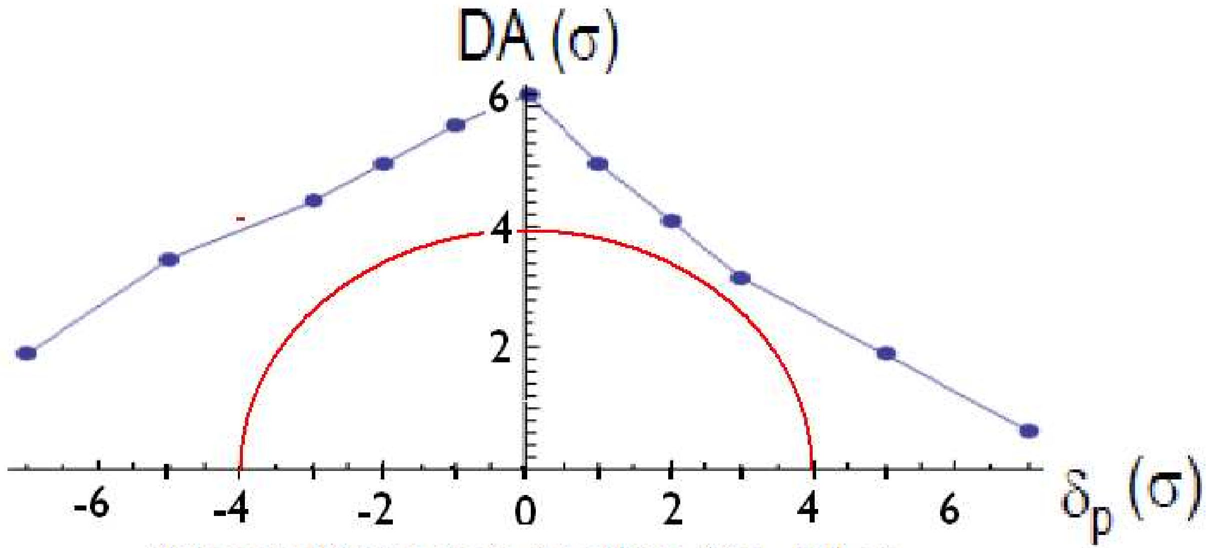


Acceleration

- Initial acceleration in linacs
- Then recirculating linacs (RLA)
- Finally in Pulsed Synchrotrons (RCS)
- Last RCS uses hybrid 8T SC and -1.8 to +1.8 T pulsed dipoles
- rf initally warm, then SCRF at 201$\rightarrow$1300 MHz

Collider Ring

- For 1.5 TeV (c of m)
- $\epsilon_\perp$= 25 μm
- dp/p=0.1%
- β^*=1 cm
- circ=2.5 km

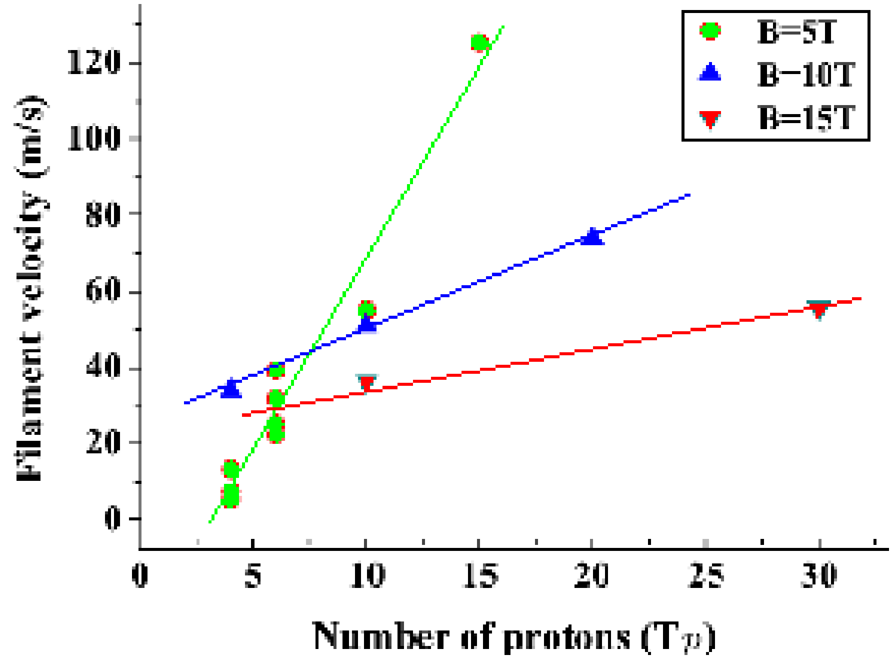


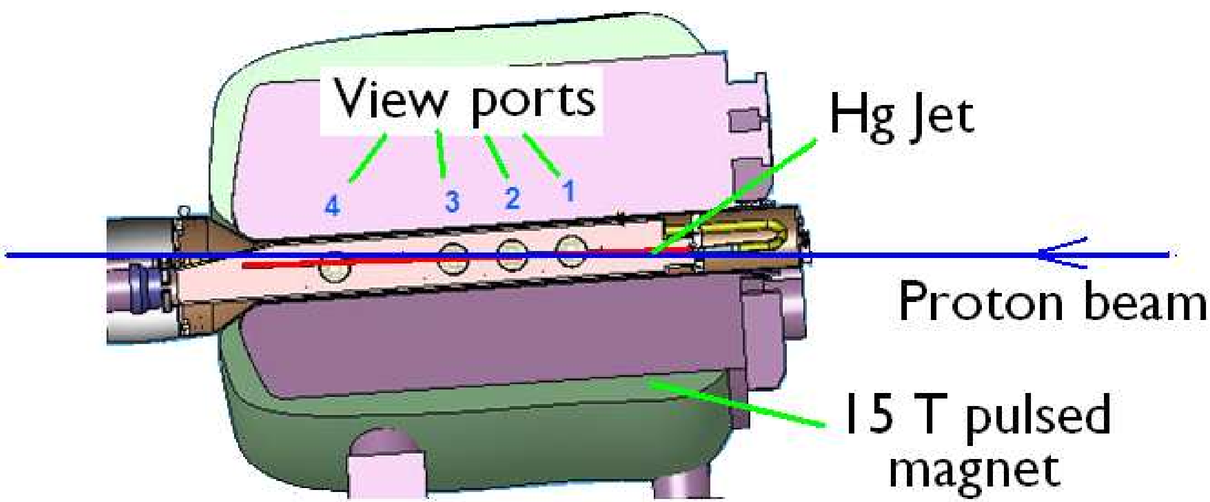
"Diagonal" Dynamic Aperture (Ax=Ay) vs. (constant) momentum deviation in the presence of beam-beam effect (ξ = 0.09/IP) for normalised emittance $\varepsilon_{\perp N}$= 25 μm

R&D
1) MERIT Experiment

(Harold Kirk, Kirk McDonald)

- MERIT demonstrated liquid mercury target for multi-megawatt beams
- Splash velocities moderate and reduced by magnetic field
- Remaining need to improve jet quality

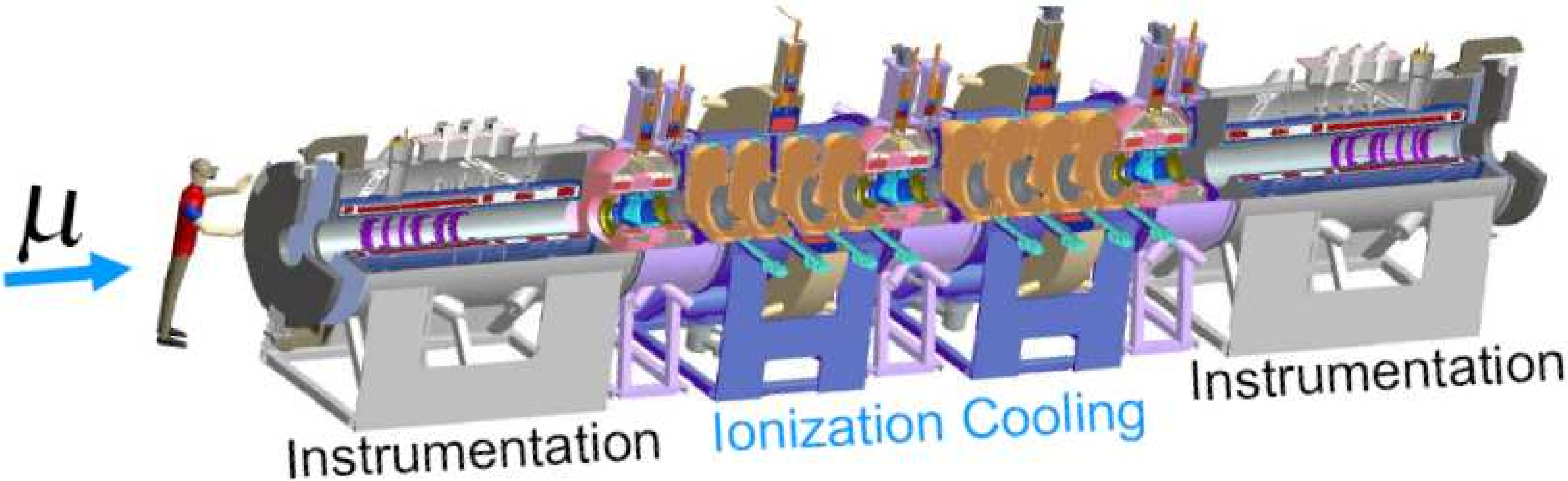




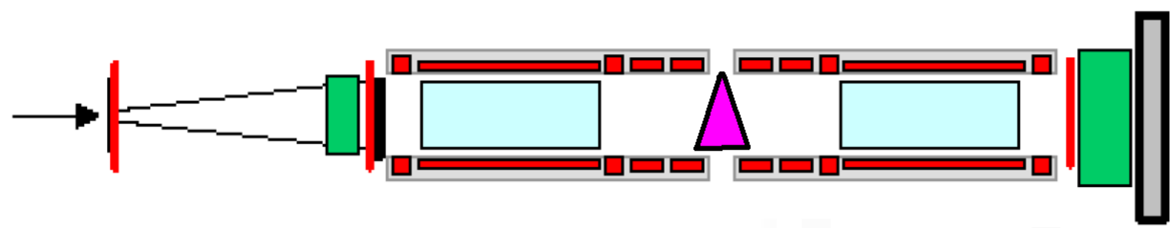
2) Muon Ionization Cooling Experiment (MICE)

International collaboration at RAL, US, UK, Japan (Blondel)

- Will demonstrate transverse cooling in liquid hydrogen, including rf re-acceleration
- Uses a different version of 'Guggenheim' lattice



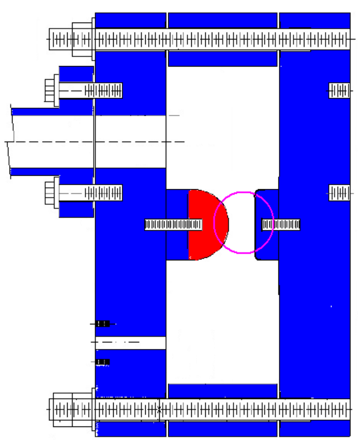
- Early Experiment to demonstrate Emittance Exchange
  - Dispersion by weighting
  - Cooling in all dimensions
  - But no re-acceleration

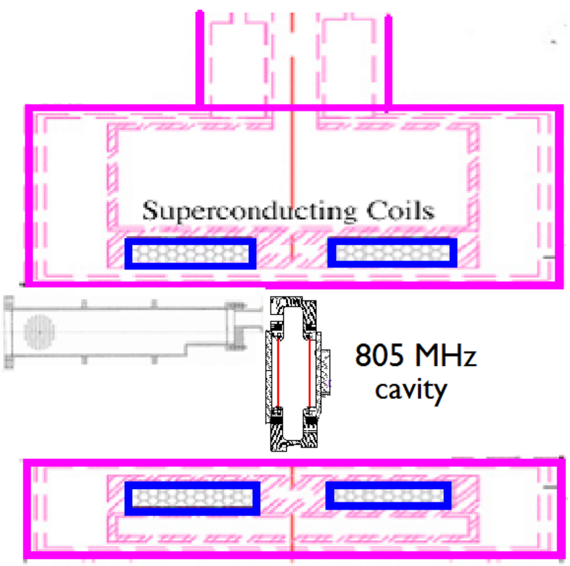


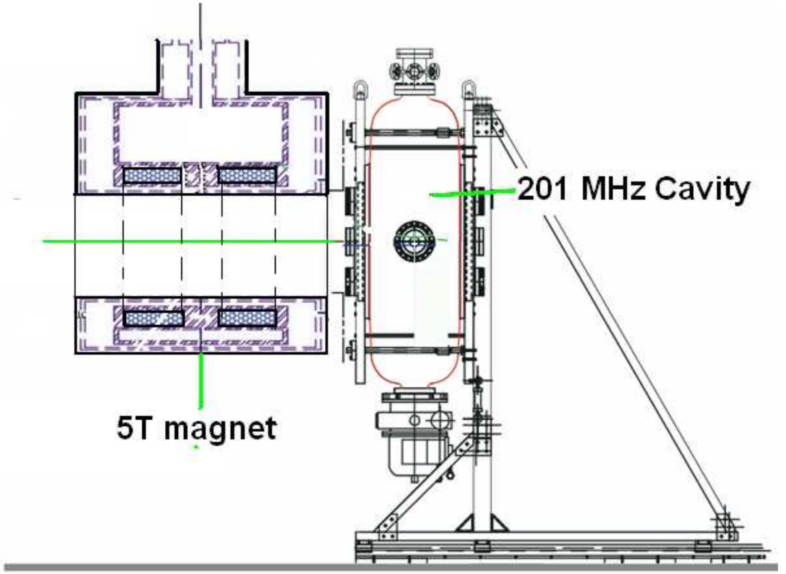
3) MuCool, and MuCool Test Area (MTA) at FNAL

International collaboration US, UK, Japan (Bross)

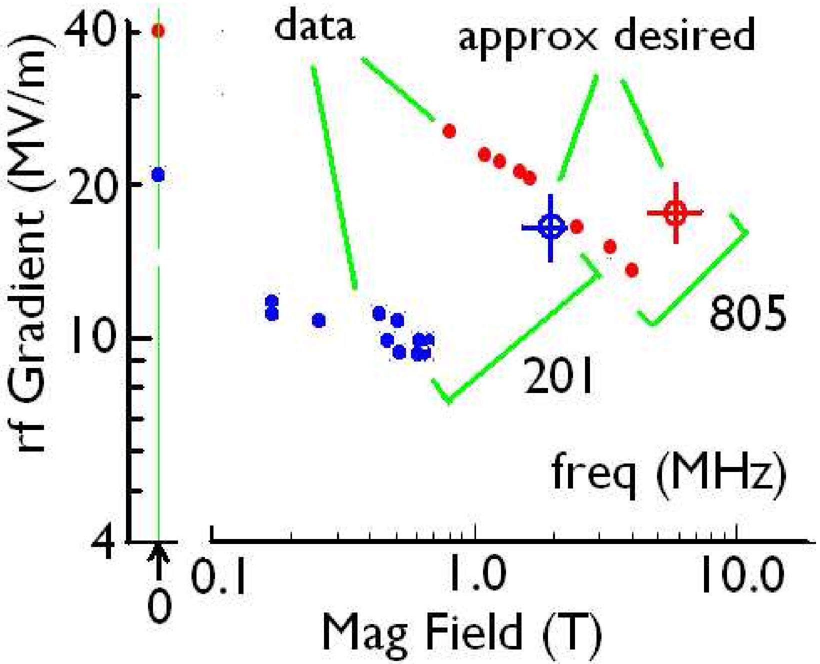
- Liquid hydrogen absorber tested Supported by US-Japan Funds
- Open & pillbox 805 MHz cavities in magnetic fields to 4 T
- 201 MHz cavity tested in stray magnetic field of 0.7 T
  Later, with coupling coil, to 2T
- High pressure H2 gas 805 MHz pillbox cavity tested
- Soon: 805 MHz gas Cavity with proton beam

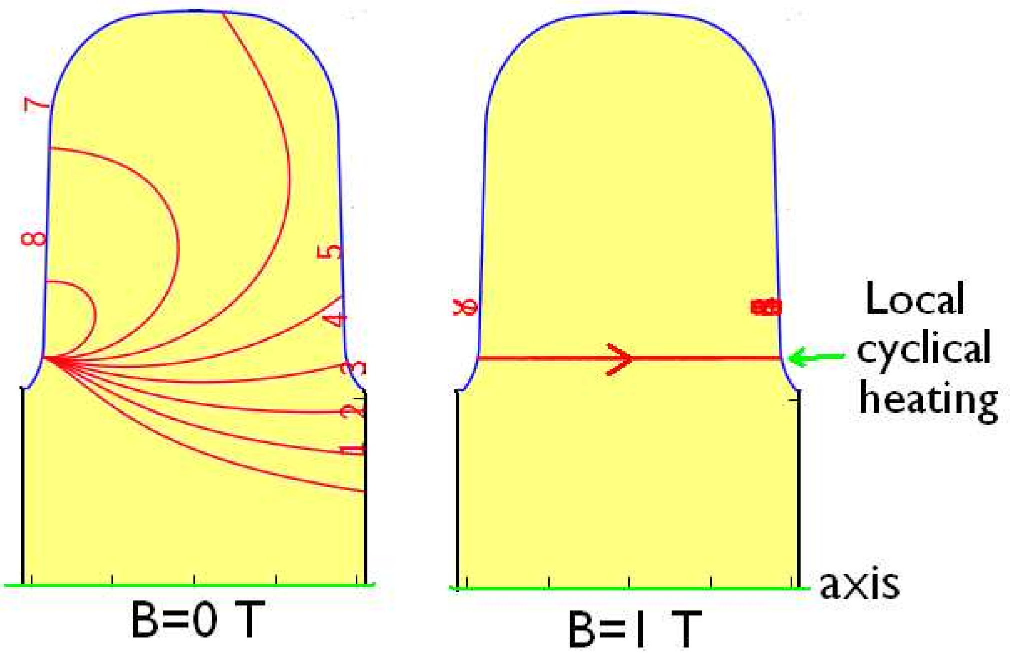






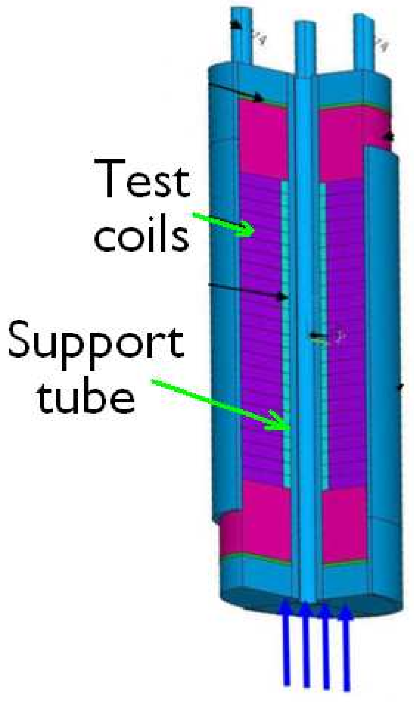
Observed rf breakdown in required magnetic fields

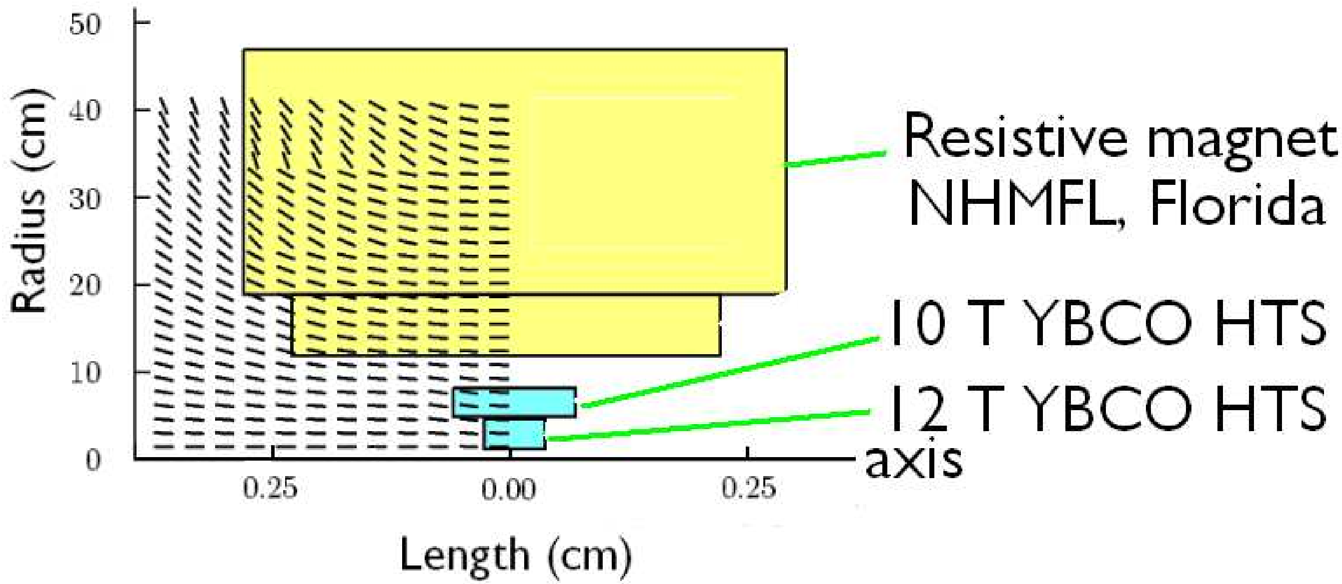




- Theory:
  - Electrons from field emission accelerated to ≈ 1 MeV
  - Focused by field → fatigue damage from cyclical heating of ΔT≈ 50 deg.
- Solutions ?
  - Magnetically insulation, by crossing E & B, reduces effect
  - High pressure gas shows no B effect. Possible rf losses with beam tested soon
  - Beryllium surfaces should suffer smaller ΔT. To be tested soon

4) HTS R&D towards a 40 T solenoid





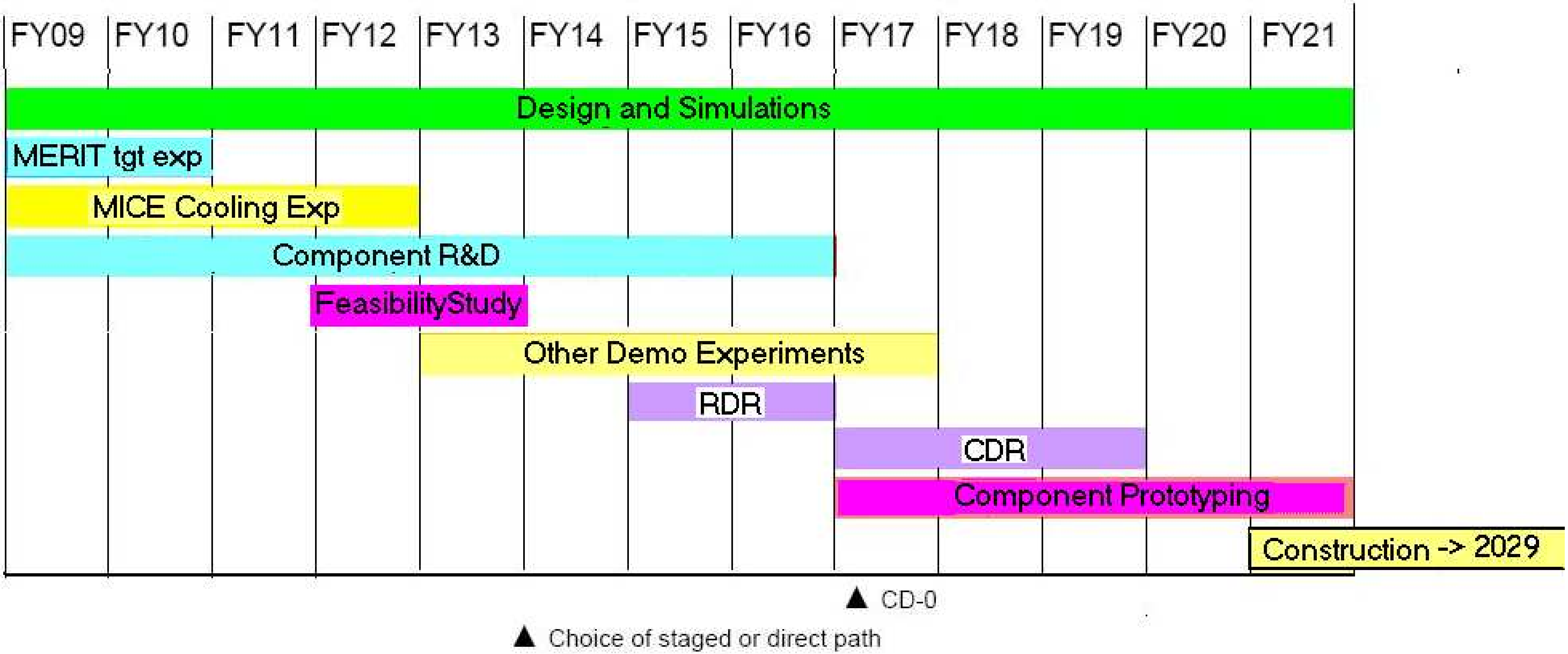
- FNAL program
- Testing multiple small coils in existing 12 T facility
- Fields up to 25 T

- BNL/PBL Program (SBIR)
- Nested YBCO HTS coils under construction
- 12 + 10 T = 22 T stand alone
- 40 T in 19 T NHMFL magnet
- Design for 19 T NbTi + Nb_3Sn design is straightforward

Muon Accelerator Program (MAP) submitted to DoE

Administered by FNAL, but National Program, with International Collaboration

(Interim Directors: Steve Geer, Mike Zisman)



8	11	13	20	25	25	25	35	40	40	R&D Funds M$/year

Delayed 1 year from P5 presentation

Conclusion

- Designs achieve $\mathcal{L} = 10^{34}$ at 1.5 TeV $4\ 10^{34}$ at 3 TeV
- All stages simulated at some level, but many details still to be done
- Hg experiment (MERIT) at CERN has established target technology
- MICE will demonstrate transverse & 6D cooling
- MuCool program at FNAL studying absorber and rf technology
  - Observed breakdown problem in required magnetic fields
  - Several solutions under study
- BNL/SBIR program should demonstrate 40 T using HTS
- Proposed & Reviewed MAP program should increase funding 10$\rightarrow$ 16 M$
- Feasibility study with cost range by 2016

Muon Physics-Detector-Collider Meeting June 21 - July 1 in US
(location to be determined)