Open Issues Accelerator

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IDS CERN
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1. Proton Driver
2. Target
3. Phase Rotation and Cooling
4. Acceleration
5. Storage Ring
6. General
7. Conclusion

- There may be overlap with Mike Zisman
- These are my views - not necessarily ISS views

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1) Proton Driver

Baseline

- Energy: 5-15 GeV
- Bunch length $\approx$ 2 nsec
- Structure: $\approx$ 4 bunches over:
  - $\leq$ 40 micro sec (for mercury target)
  - $\geq$ 70 micro sec (for solid target)
- Repetition: 50 Hz

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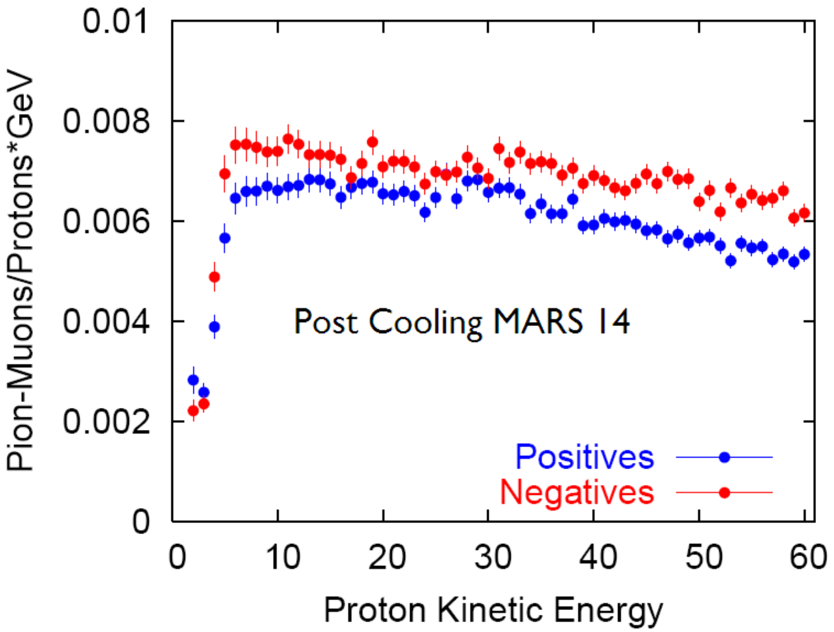
Questions



- Is 5 GeV the correct minimum
  Codes show rapid change vs. energy
  Codes could be wrong

- Is the use of multiple bunches necessary/desirable ?
  Their use requires larger circumference and cost of storage ring
  If a higher energy p driver were chosen (eg JPARC, AGS), space charge would not preclude the higher charge for single bunches and smaller storage rings
  Muon collider needs fewer intense bunches

- What type of p driver should be chosen?
  Site dependent

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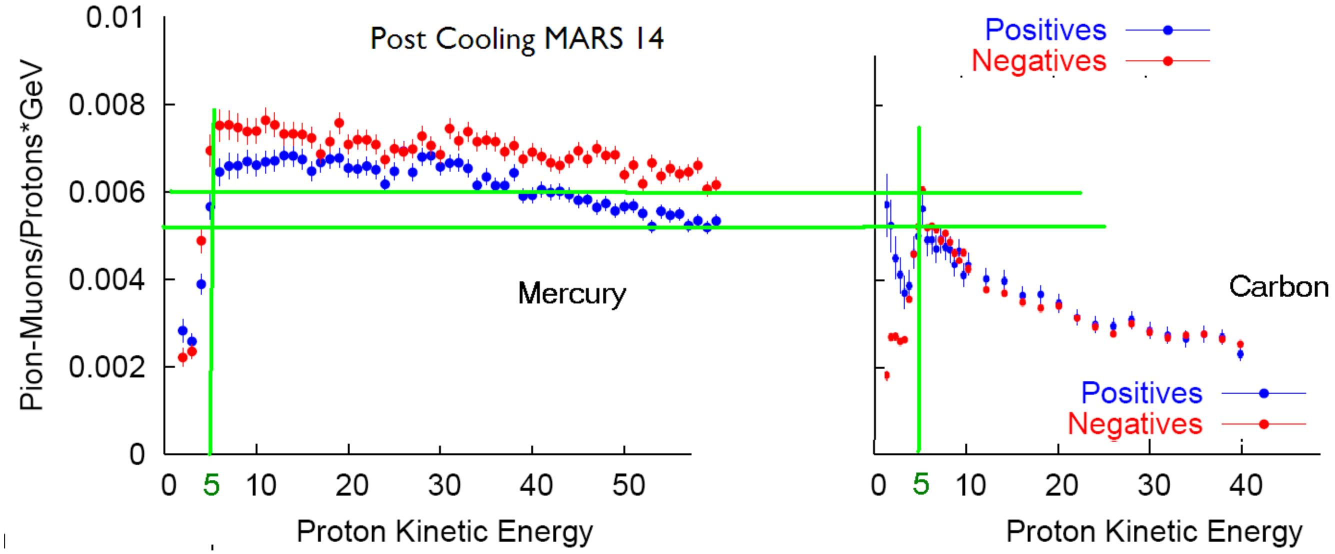
Needed Experimental Work

- Much work to achieve 4 MW
  But this work is ongoing at several labs
- Results on pion production
  Needed to settle proton driver specifications

2) Target

Baseline is Mercury

Questions



- At 5 GeV, Carbon similar to Mercury
  And could be higher (predictions rapidly changing)
  But lifetime of carbon target at 4 MW unclear
- Use of Pb-Bi instead of Mercury may be safer

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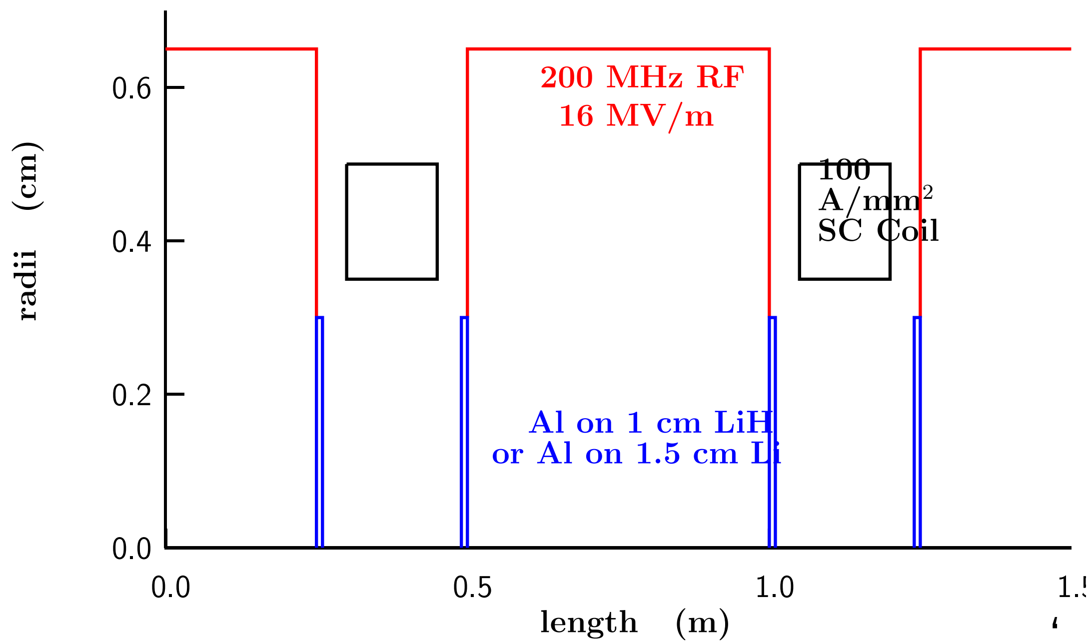
Needed Experimental Work

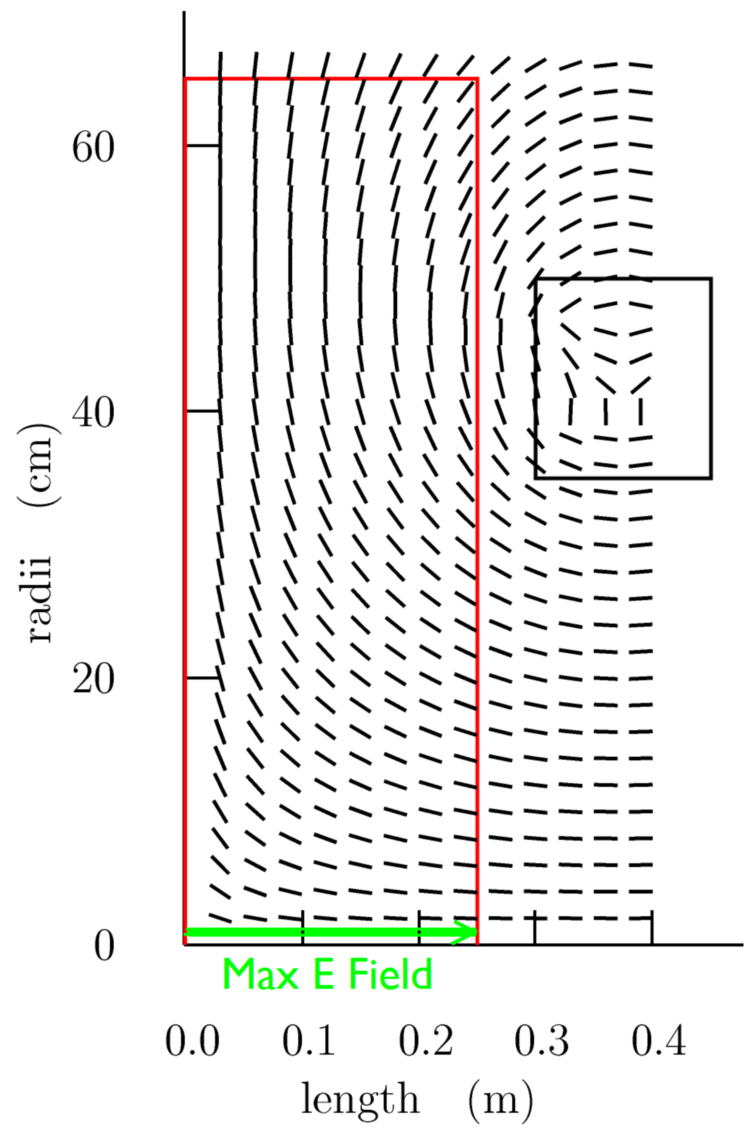
- Results of pion production experiments
  To settle Carbon vs. Mercury question
- MERIT
  Demonstrate feasibility
- MERIT with Pb-Bi ?
  If Safety considerations prefer it
- Study of carbon?
  Needed anyway for superbeams

3) Phase Rotation and Cooling

Baseline

- Designed assuming large (30 pi mm) accelerator acceptance
- LiH absorbers not at beta minima
- Focus-Focus (FOFO) with alternating solenoids
- 15 MV/m 200 MHz rf in magnetic field $\approx$ 3 T

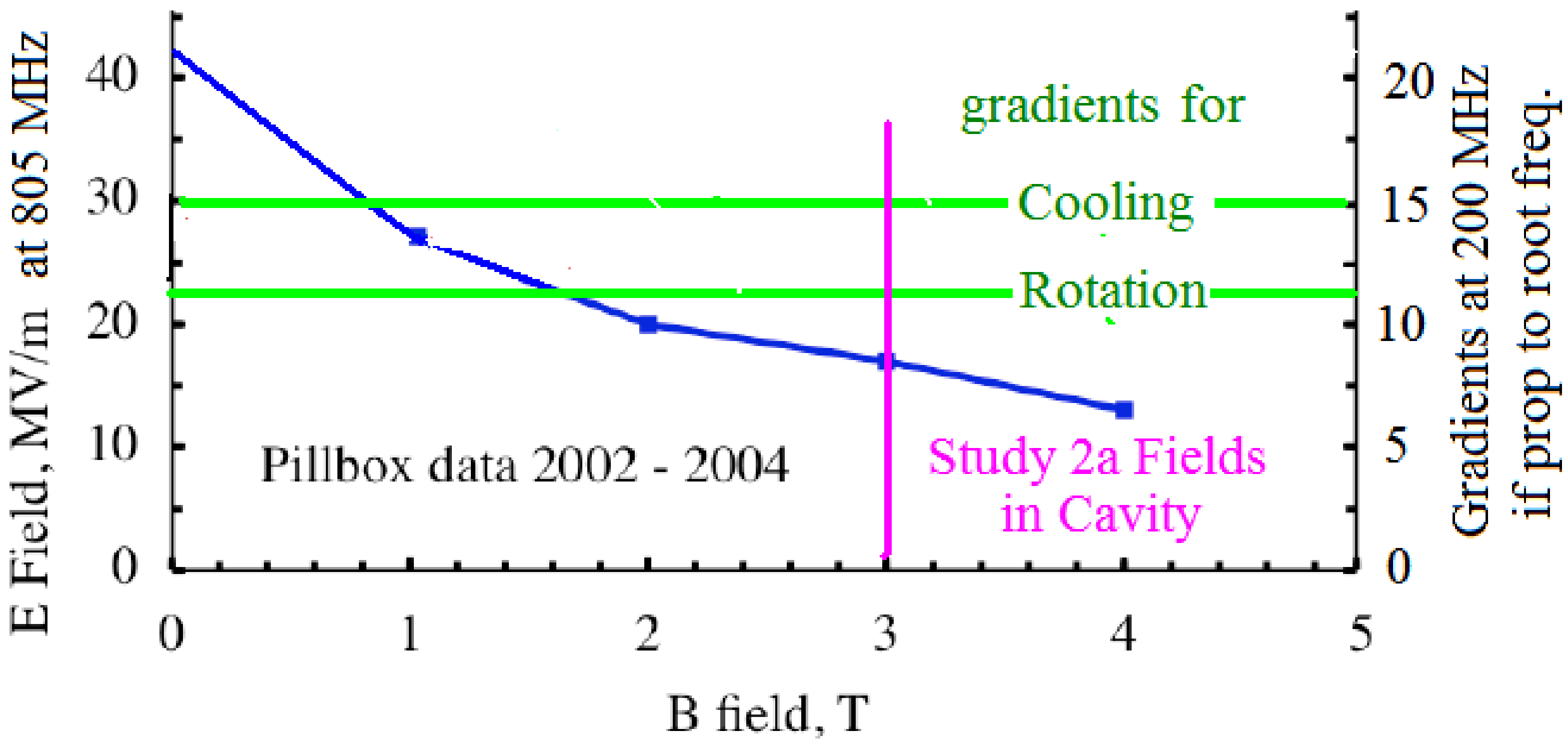




Big Question

- Will 200 MHz pill box cavity operate at 15 MV/m in 3 T field

- Pill-box has maximum electric field (on axis) parallel with magnetic field
  Worst possible geometry
- Perry Wilson's model suggests scaling may be faster than $\sqrt{f}$
  but predicts suppression if magnetic and electric fields are perpendicular
- Experimental results with pillbox at 805 MHz (assuming $\propto \sqrt{f}$)

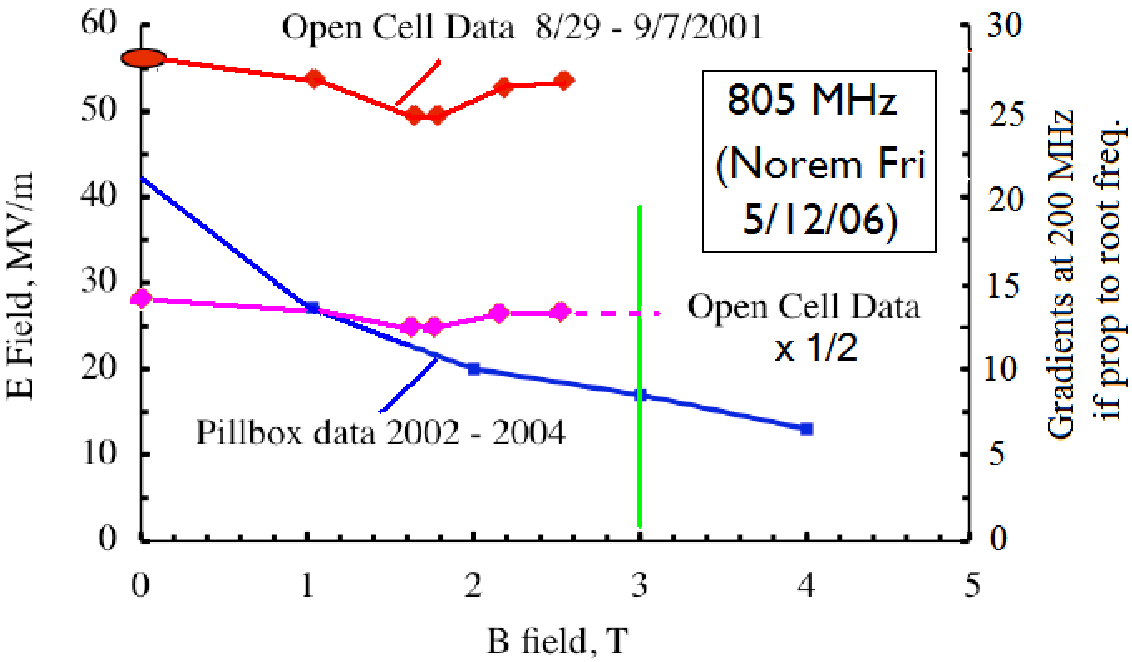


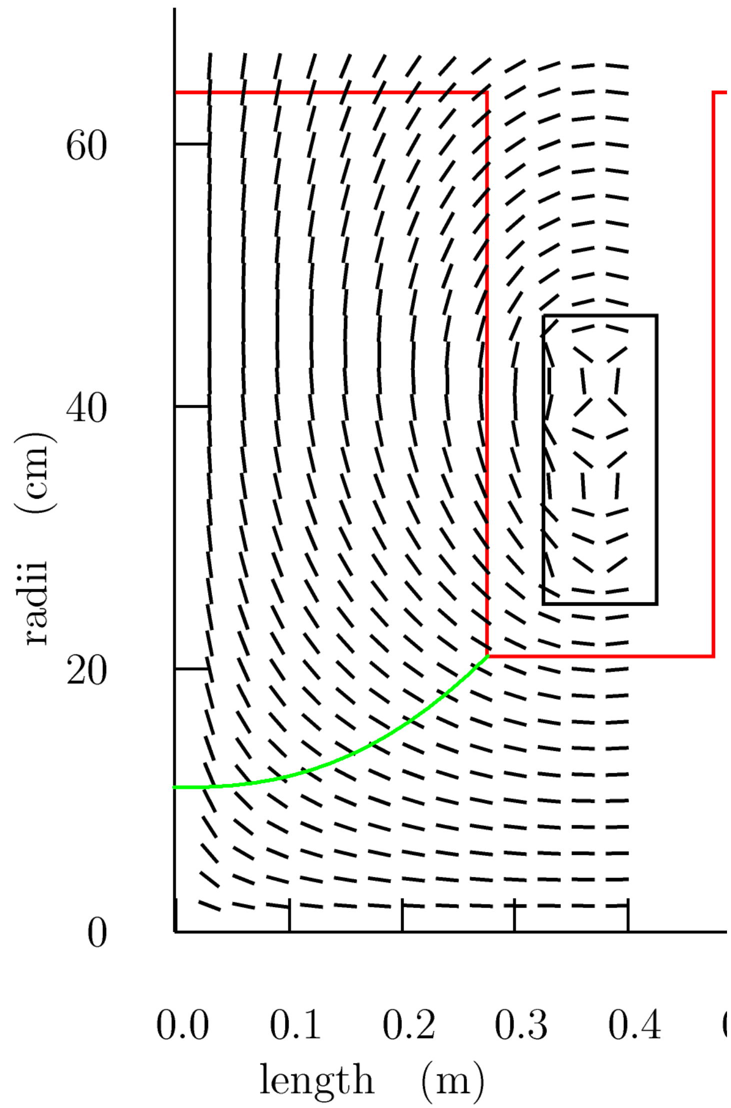
Possible solutions

- Lower fields and lengthen systems
  Increases decay loss
- Fill cavities with high pressure hydrogen gas
  - Neuffer work on rotation, Gallardo on cooling
  - Not known if a beam will cause gas breakdown
  - Safety question (Ignition source in inflammable medium)
- Use open cell cavities
  May be a good solution, but needs R&D

Muon Collider will be studying these options too

Open Cell rf

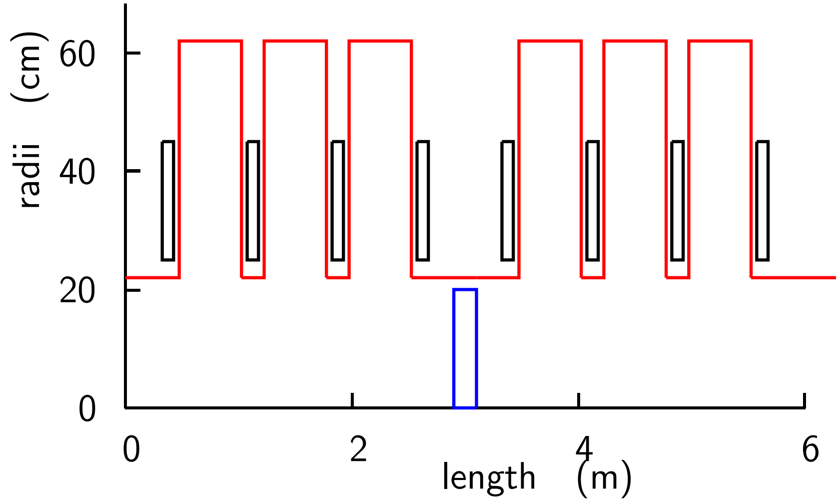




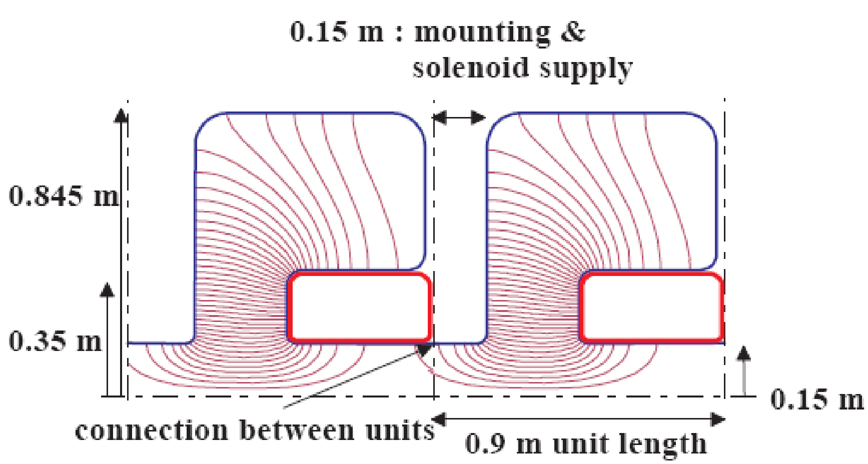
- Surface breakdown fields in open cavity did not fall much with magnetic field
  Similar experience at SLAC e^+ source
- But average/peak acceleration $\approx 1/2$
  $\approx$ 12 MV/m at 200 MHz
- If coils in irises, magnetic fields perpendicular to electric fields probably allows higher gradients (magnetic insulation known effective dc)

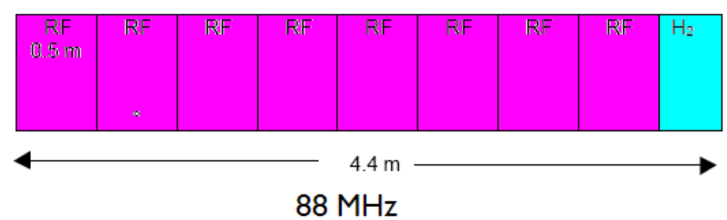
Where is the absorber?

- Skip 1 cavity in 8 and put LiH absorber at center
- Allow energy to saw tooth, scaling fields to keep focusing steady



Remember CERN 88 MHz Proposal: coils in irises absorber every 8 cells

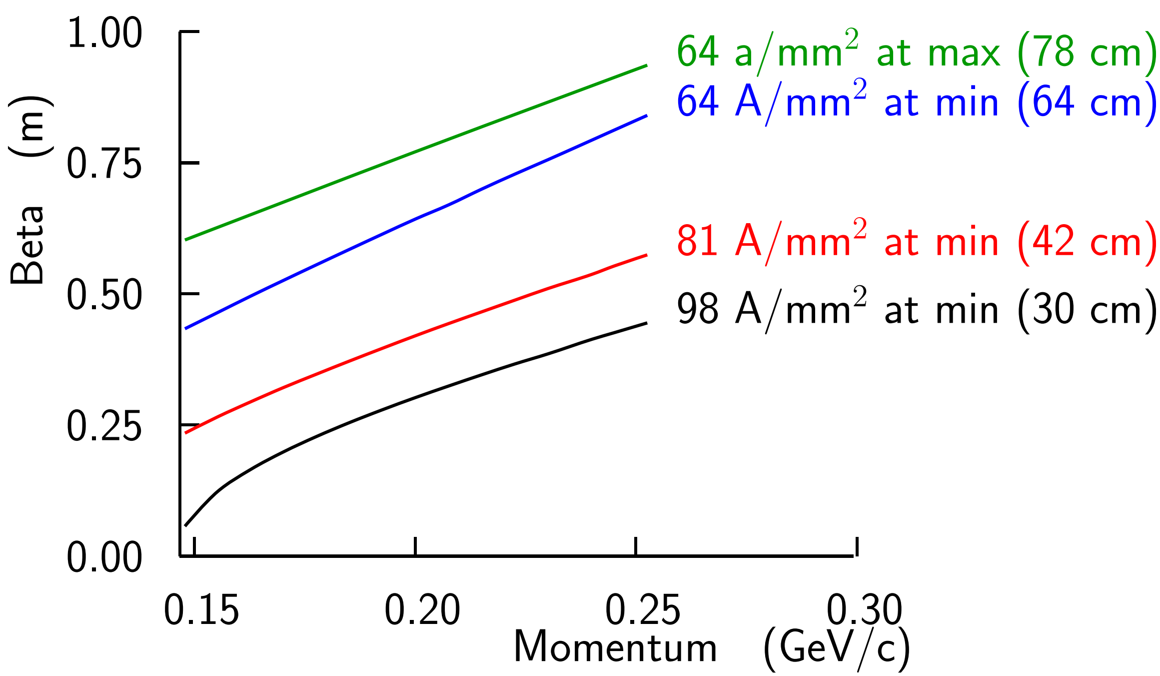




Second Question

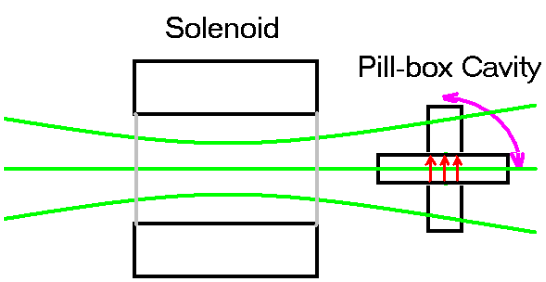
- Should Cooling be improved to ease FFAG acceleration problems

- Open cavity design has absorbers at beta minima
- Higher fields, or SFOFO/RFOFO lattices, would then allow lower betas
- Changing currents vs. length can 'taper' parameters
- Improving performance
- Or allowing smaller accelerator acceptance

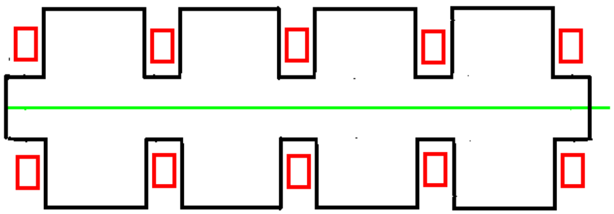


Needed Experimental Work

- MICE demonstration of cooling
- Breakdown studies
  - Breakdown studies at 200 Mhz in a coupling coil
    Planned at MTA
  - Breakdown studies with hydrogen gas and a beam
    Planned at MTA
  - Breakdown vs angle with field (at 805 MHz ?)
    Discussed but not yet scheduled



  - Breakdown studies of Open Cavities with coils in irises (at 805 MHz?)
    Not yet discussed



- Development of 201 MHz rf sources
- Encapsulation and cooling of LiH
  - MUCOOL to study this

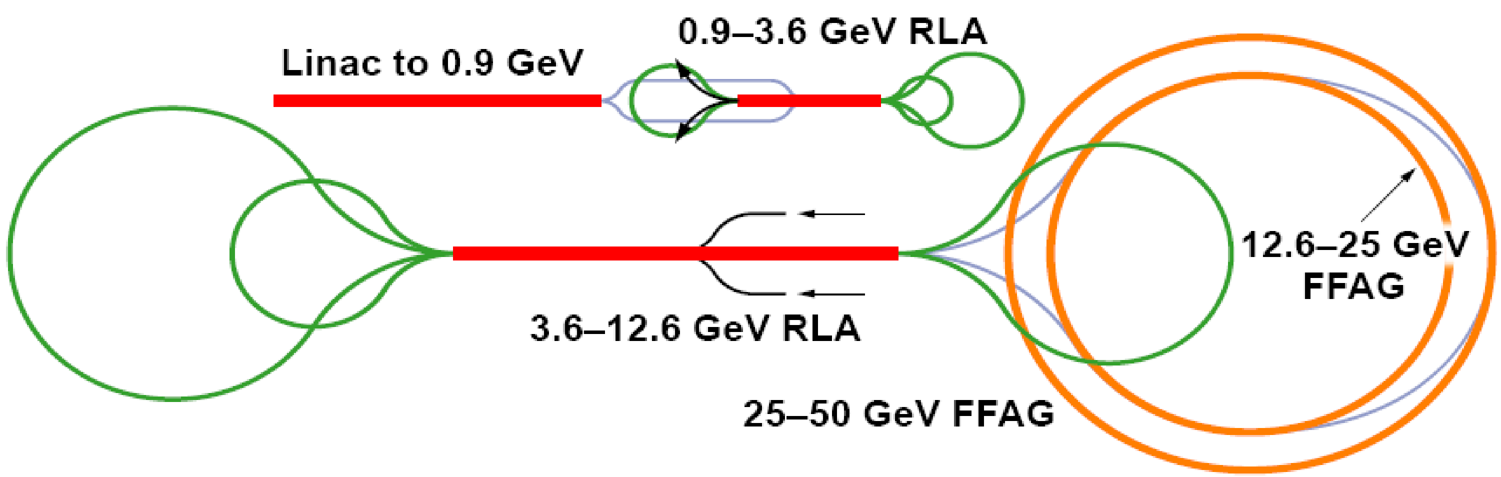
All the above also needed for Muon Collider

4) Acceleration

Baseline

- 0.9 GeV Linac
- 0.9-3.6 GeV Dog Bone RLA
- 3.6-12.6 GeV Dog Bone RLA
- FFAG 12.6-25 GeV

  optional
- FFAG 25-50 GeV



Questions

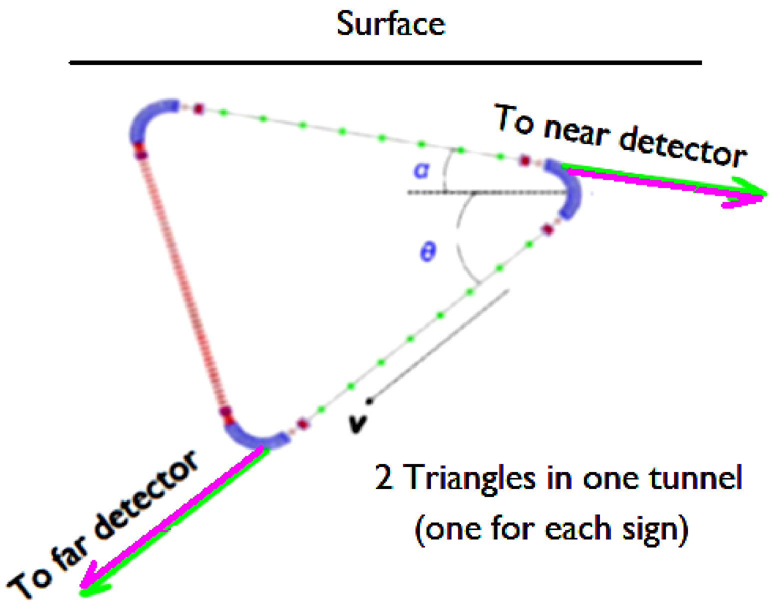
- Accelerating Gradient in 200 MHz SC rf
  - Original design for 17 MV/m (as predicted)
  - Maximum achieved at Cornell 11 MV/m (but they are working on it)
- Final energy specification including possibility of future energy upgrade
  - Amplitude-time effect is cumulative. If upgrade to 50 GeV not required, design for 25 GeV is easier (cheaper)
- Design transfer lines and injection/extraction systems
- Full simulation with amplitude-time effect and errors - not yet done
- Comparison with all RLA solution
  - Old comparison, showing clear FFAG advantage, compared non-optimized RLA with FFAG without amplitude effect
  - Current RLA designs use FODO lattices vs. earlier, more expensive, triplet lattices
  - All RLA solution would always allow addition of further acceleration

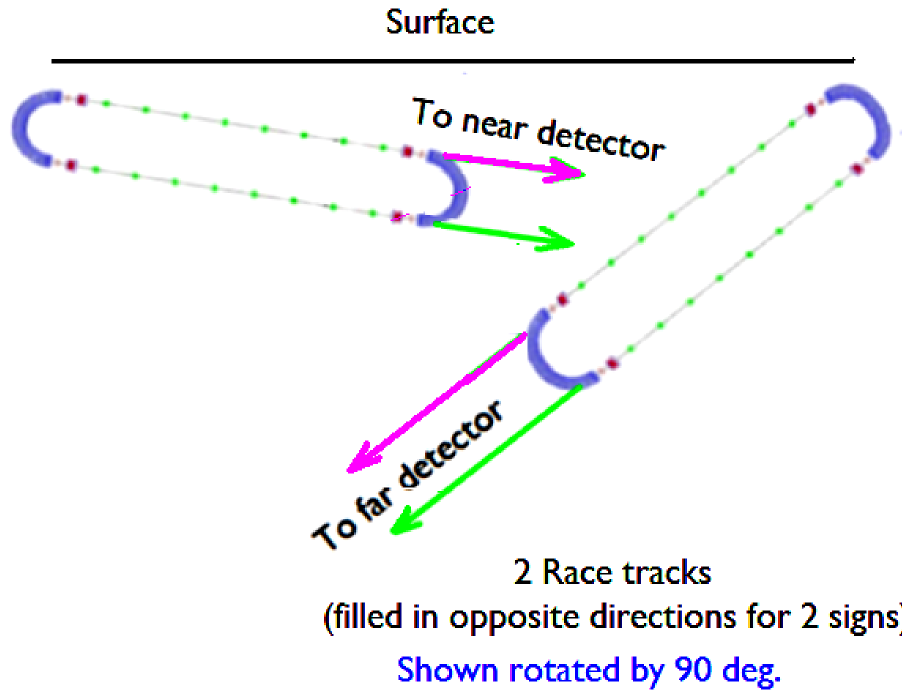
.

Needed Experimental Work

- Work on superconducting cavity Q slope
  Funding for Cornell work at 200 MHz was stopped
  Some work at higher frequencies ongoing
  Need to restart work at 200 MHz
  Also needed for Muon Collider
- EMMA to demonstrate non-scaling FFAG
- May need prototype work on FFAG combined function SC magnets

5) Storage ring(s)





- Baseline   Race tracks   38% of circumference give useful decays
  No constraint on detector location
  More conventional construction

Alternative: Triangular   48% of circumference give useful decays
Requires detectors in opposite directions
Slightly greater required depth
Contains almost vertical section

Questions

- Reconsider triangles ?
  - If Detector locations are known, triangles could be reconsidered
  - But engineering of steep side needs study
- Study cost savings if fewer, eg one, muon trains leading to smaller circumferences
  - Cost estimate in Study 2a was for a much smaller ring using a single bunch train
- Study 4 GeV storage ring
  - 30 pi mm acceptance at 4 GeV implies very large apertures
  - Ring could have much smaller circumference and lower cost, only if a single bunch train used
  - If multiple bunches used then cost may be greater than for 30 GeV ring!

6) General

- End to end simulations
  - Muons have memory
  - eg shape of sensitivity to proton energy depends on cooling
  - Matching losses
  - Effects of lower cavity gradients
- Cost Estimation
  - Dangerous but necessary
  - Relative costs dependent on apertures, gradients, etc
  - Needed to allow cost optimization
- Cost optimization
  - Proton energy and number of bunches (single bunch gives smaller storage ring circumference)
  - Cooling vs accelerator/storage ring acceptance
  - All RLA (allows larger acceptances) vs FFAG (limited acceptance)
- 4 GeV muon energy option
- Synergy with Muon Collider

Conclusion

- 4 MW proton driver requires much development
  But is under study in several labs
- Need pion production results to settle driver and target specifications
  it has been a long time
- Breakdown of rf in magnetic fields may be biggest problem
  Several possible solutions
  Need for experimental work
  Muon Collider must also solve this problem
- Costing is needed for acceleration
  FFAG amplitude problems have increased cost from Study 2a
  Not obvious that an all-RLA solution is unreasonable
- Costing is needed for storage rings
  ISS rings have much larger circumference than single Study 2a ring
  and may have significant cost implications
- Study of 4 GeV storage ring is needed
  If θ_{13} is large, this may be way to go
  It may not be easy or cheap