Future Cooling Experiments

R. B. Palmer (BNL)

FNAL

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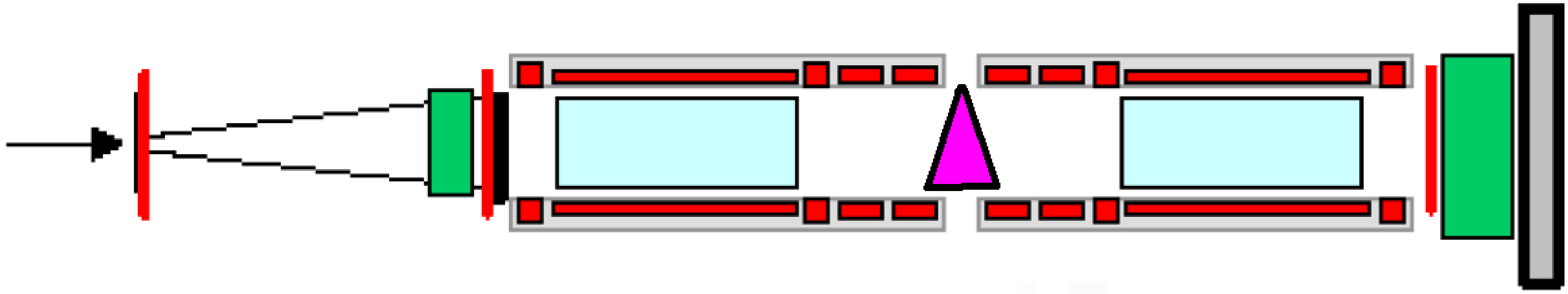
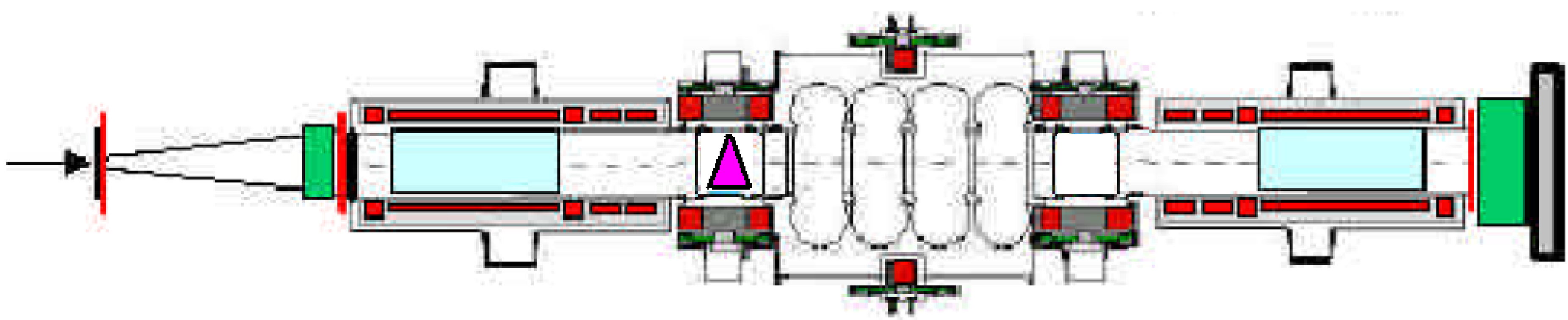
Short Term 6D cooling Experiments

Demonstrate 6D cooling without acceleration using a wedge at MICE

Tracks can be selected off line to represent a beam with dispersion at the wedge absorber. Reconstruction of emittances before and after the LiH or polyethylene wedge will show 6D cooling

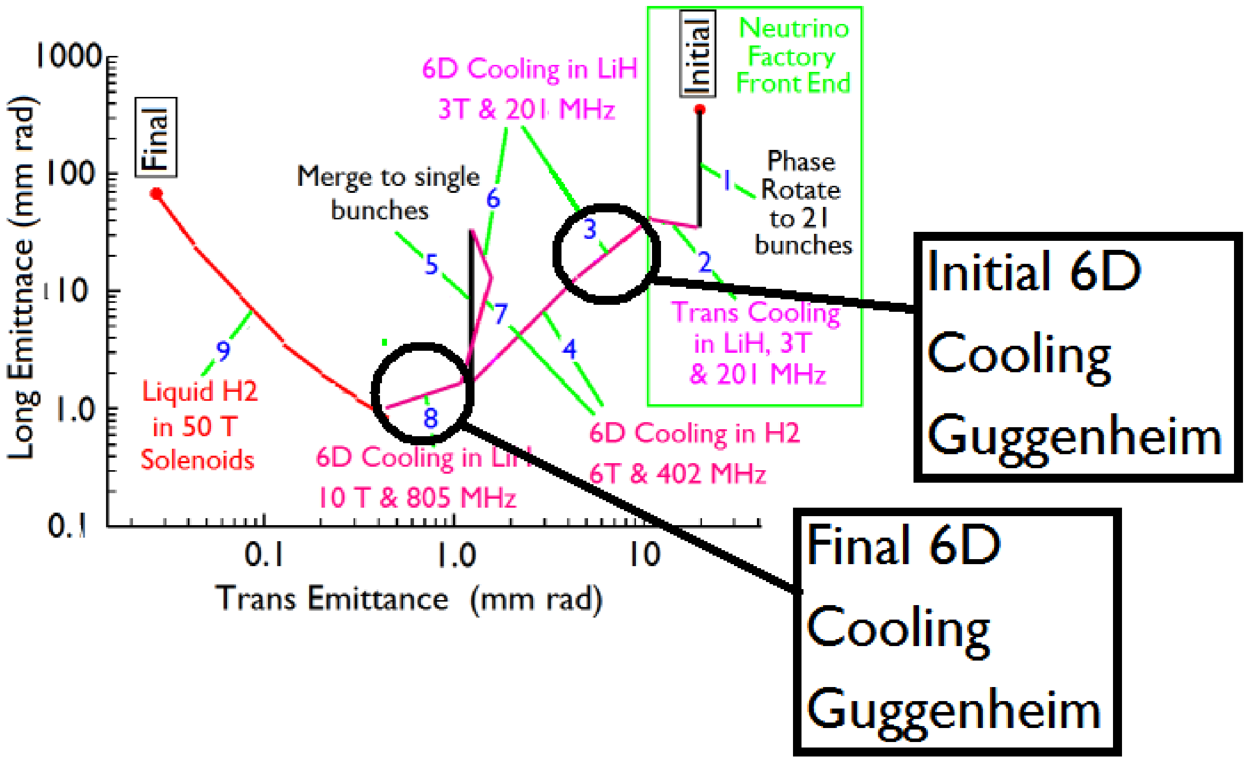
Later re-acceleration can be included





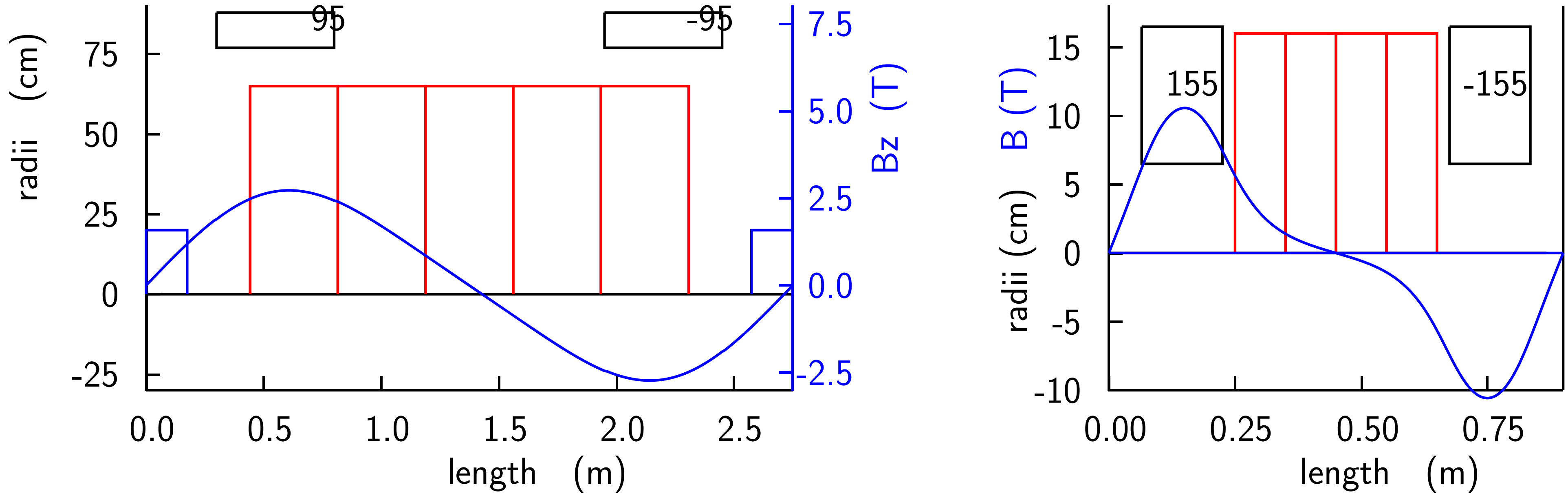
Long Term 6D Cooling Experiments

- We must decide which part of the cooling should be tested
  The last stage of 6D cooling differs most from MICE technology



- We must first address magnetic field problems
  and decide how we will solve them
- Until we know we have a solution for any such problems
  it is premature to decide on or design the cooling experiment

Lattices used in above scheme

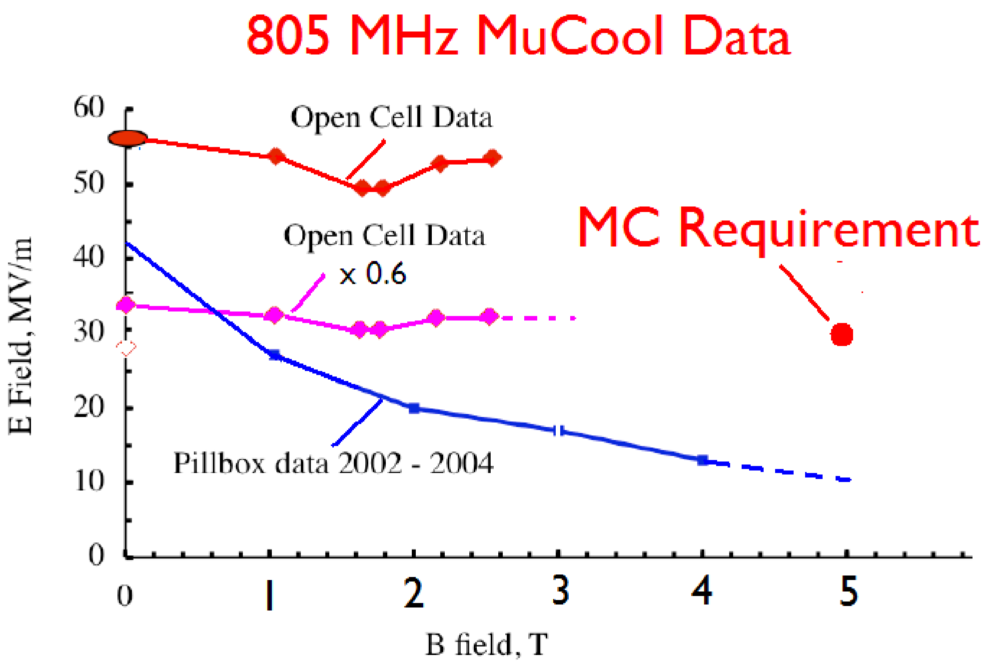


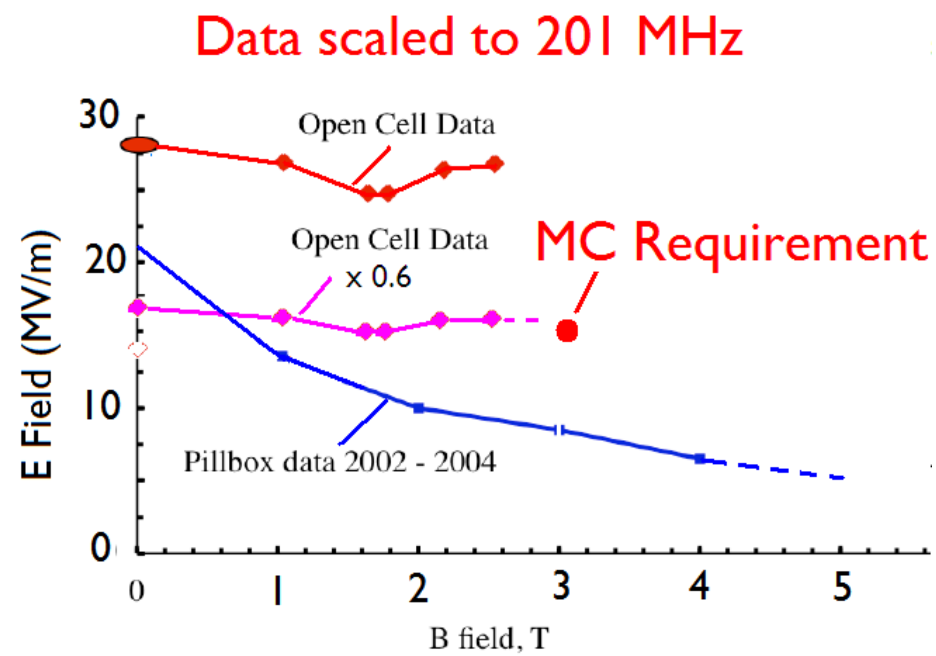
First RFOFO Lattice

Last RFOFO Lattice

	First RFOFO Lattice	Last RFOFO Lattice
RF frequency (MHz)	201	805
RF Gradient (MV/m)	15	30
B Field on RF (T)	3	5

Breakdown vs. Magnetic Field

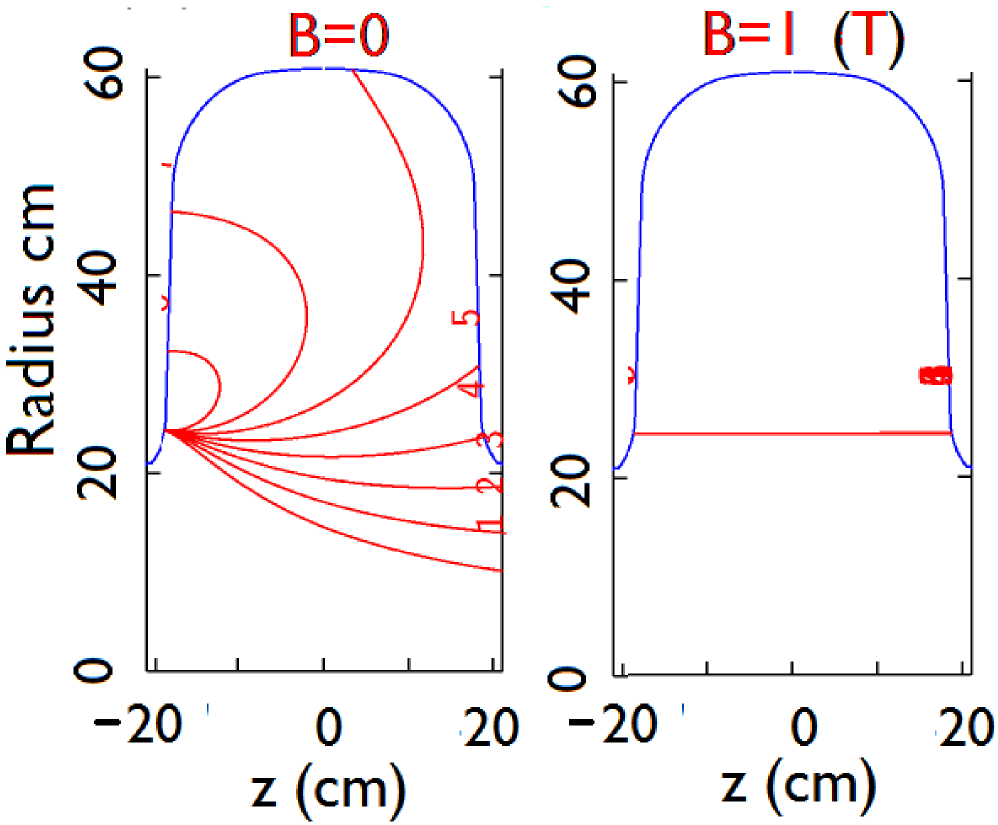


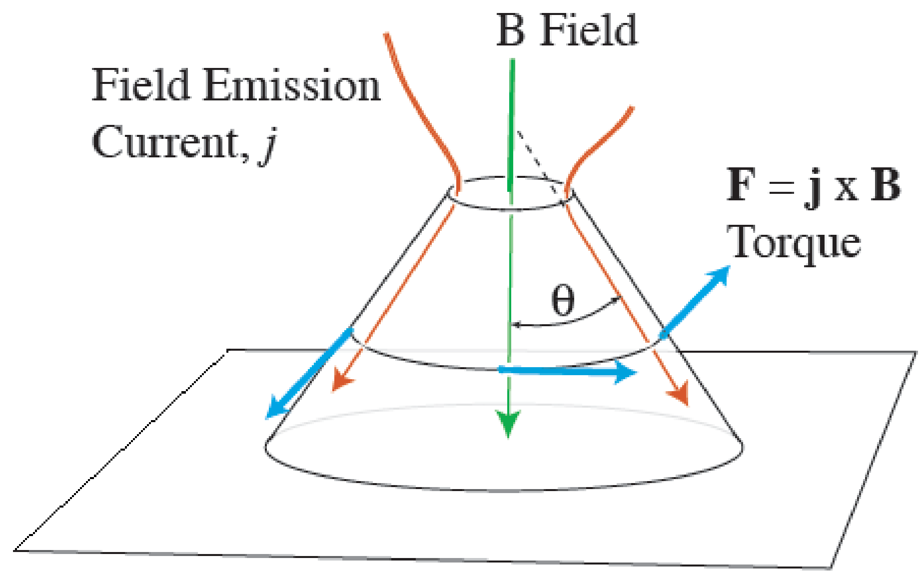


- Open cavity achieved specified field, but suffered unacceptable damage
- So 805 MHz clearly has a problem

- Scaling to 201 MHz assumed ($\propto \sqrt{f}$)
- So 201 MHz probably has a problem

Do we understand the effect?





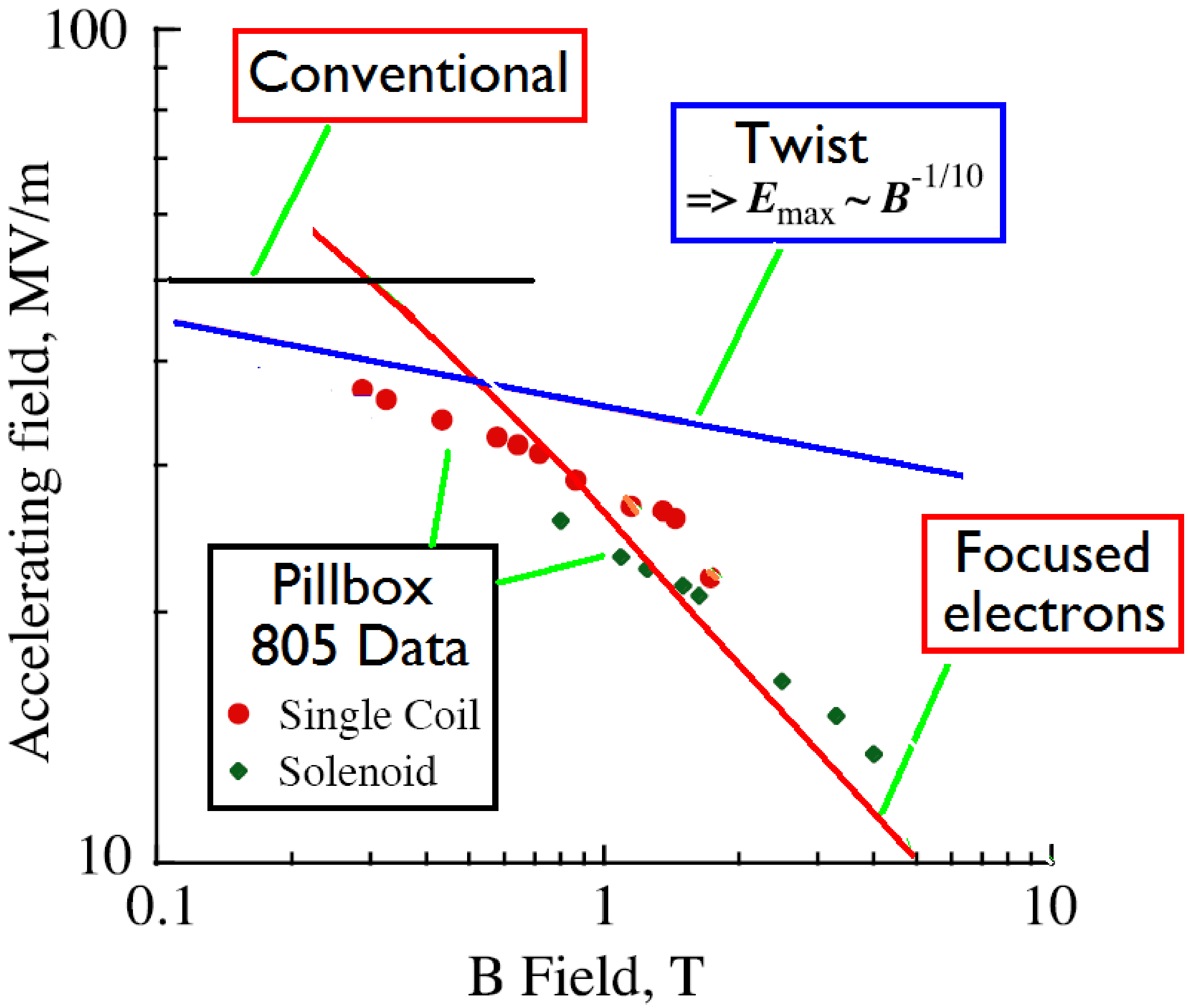
Focused Electrons (Palmer et al)

- Field emitted electrons
- Focused by field
- Melts spot on opposite$\longrightarrow$ liquid squirt
- Heated by emission
- Vapourized & ionized$\longrightarrow$ breakdown

Twist of point (Norem et al)

- $E \times B$ twists anomally
- Broken tip leaves
- Heated by emission
- Vapourized & ionized$\longrightarrow$ breakdown

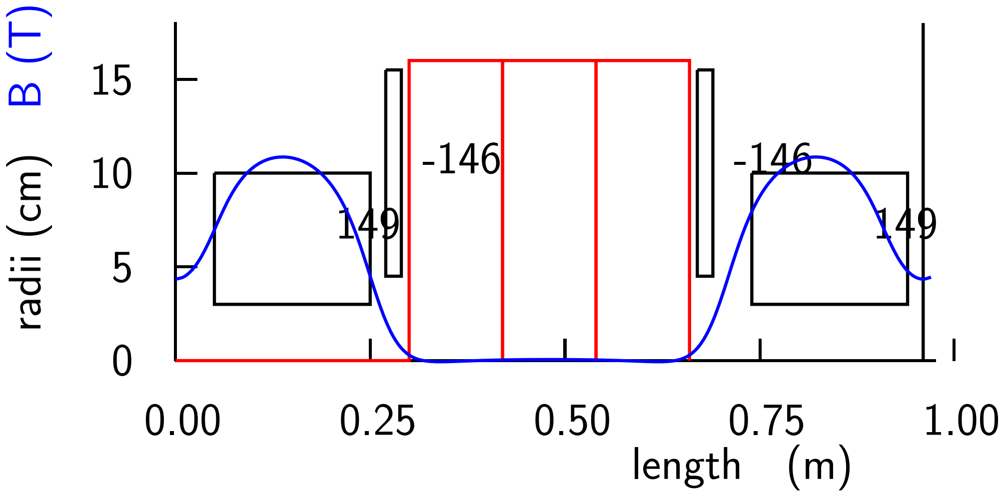
Predictions



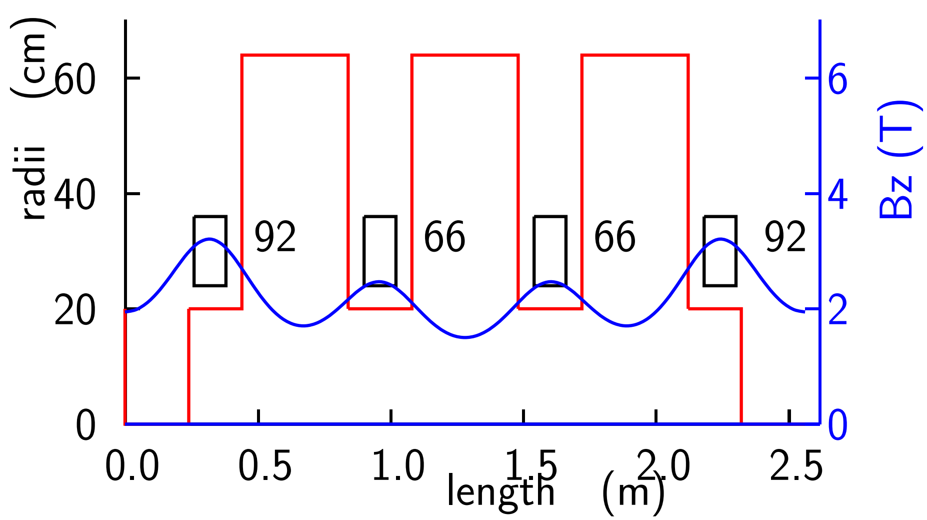
- Horizontal normalization are fit to data
- Fit of Focus model is far better than for "twist" model

Possible Solutions

1. Use high pressure gas
   - Alvin predicts field distruction by plasma electrons from $\geq 10^{12} \mu s$
   - It is anyway unsuitable in final stage because we must use a local focus to get $\beta_\perp$ low enough
2. Removing the fields at the RF with bucking coils
3. Use open rf, coils in irises, and "Magnetic Insulation"



Bucked field coil

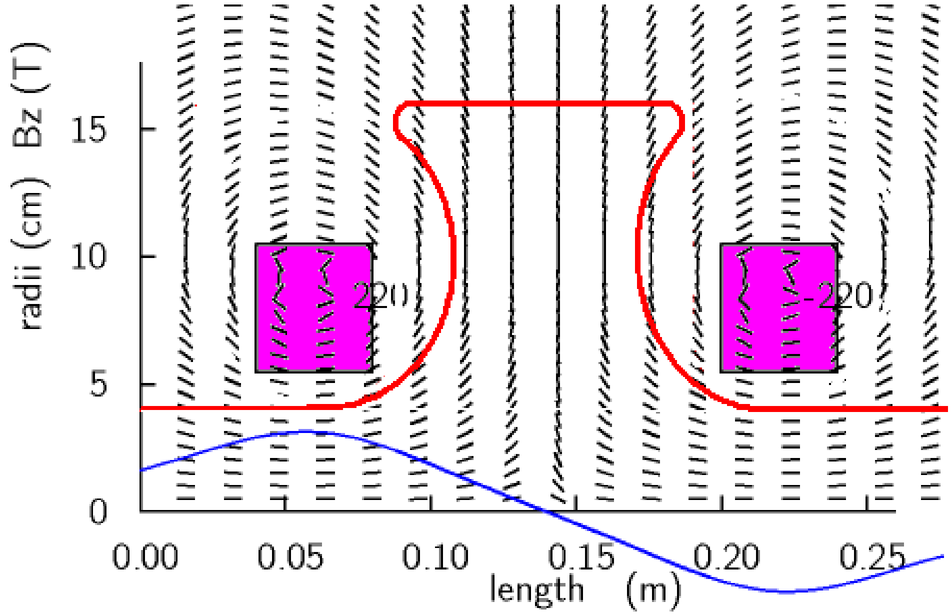


Magnetic Insulation

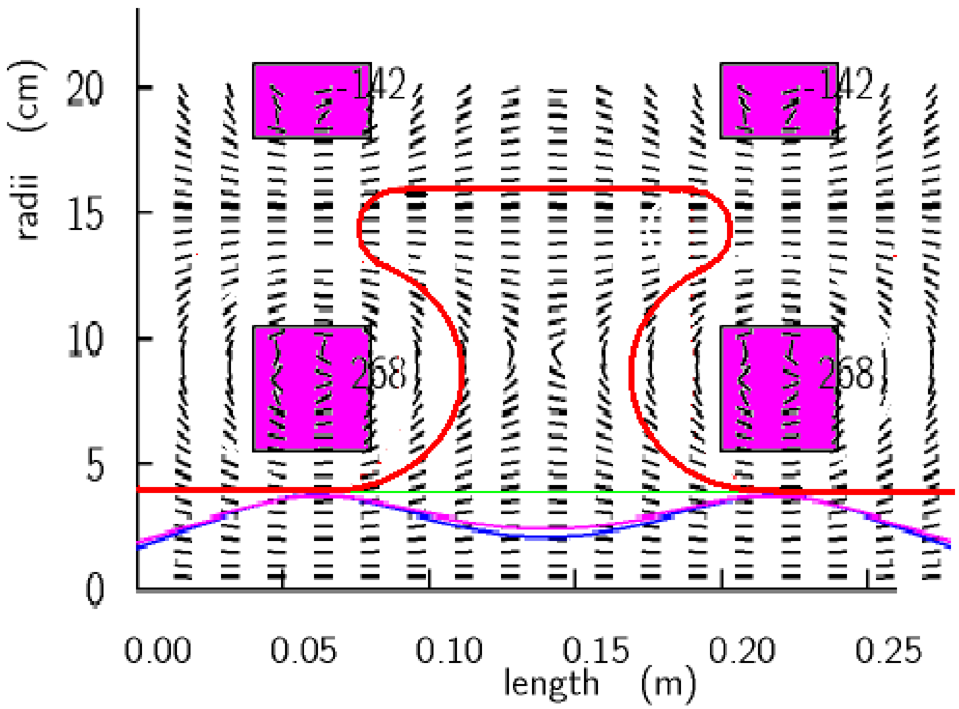
Magnetic Insulation with all high field surfaces $\parallel$ B

Put coils in the irises

- If the currents can be alternated

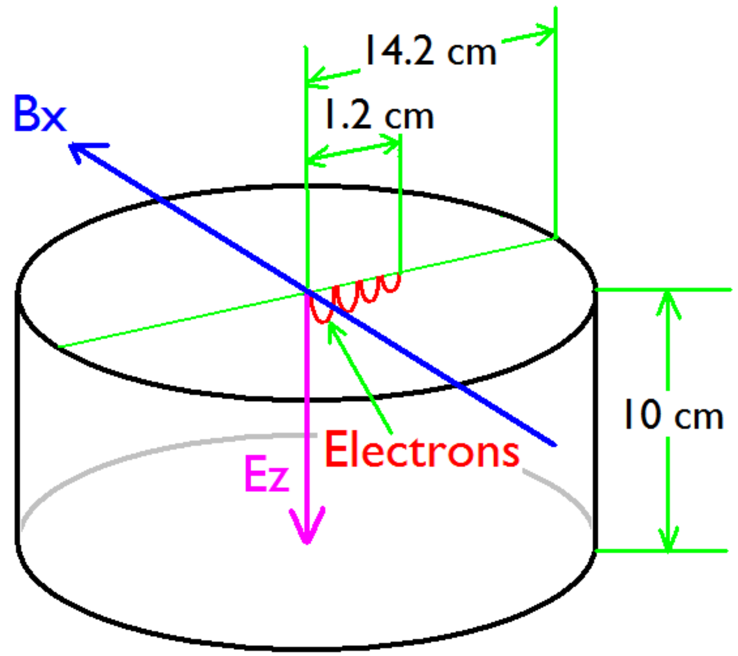


- For same polarity, requires reverse outer coils



Magnetic insulation in a simple pillbox at 90 degrees

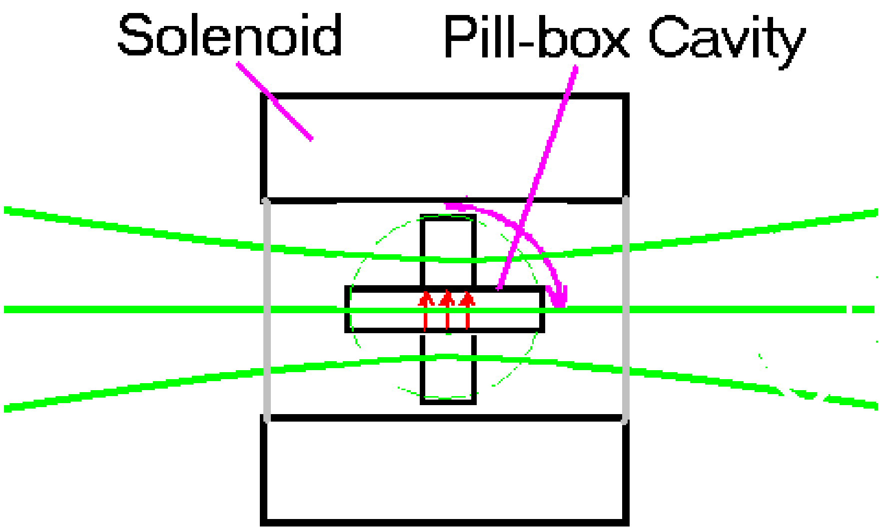
CAVEL Simulation of 10 cm long simple 805 MHz cavity with 1 T magnetic field $\perp$ axis



- Electrons move perpendicularly to field
- remaining close to surface
- Distance traveled depend on initial rf phase

Possible simple pillbox Experiment in MTA

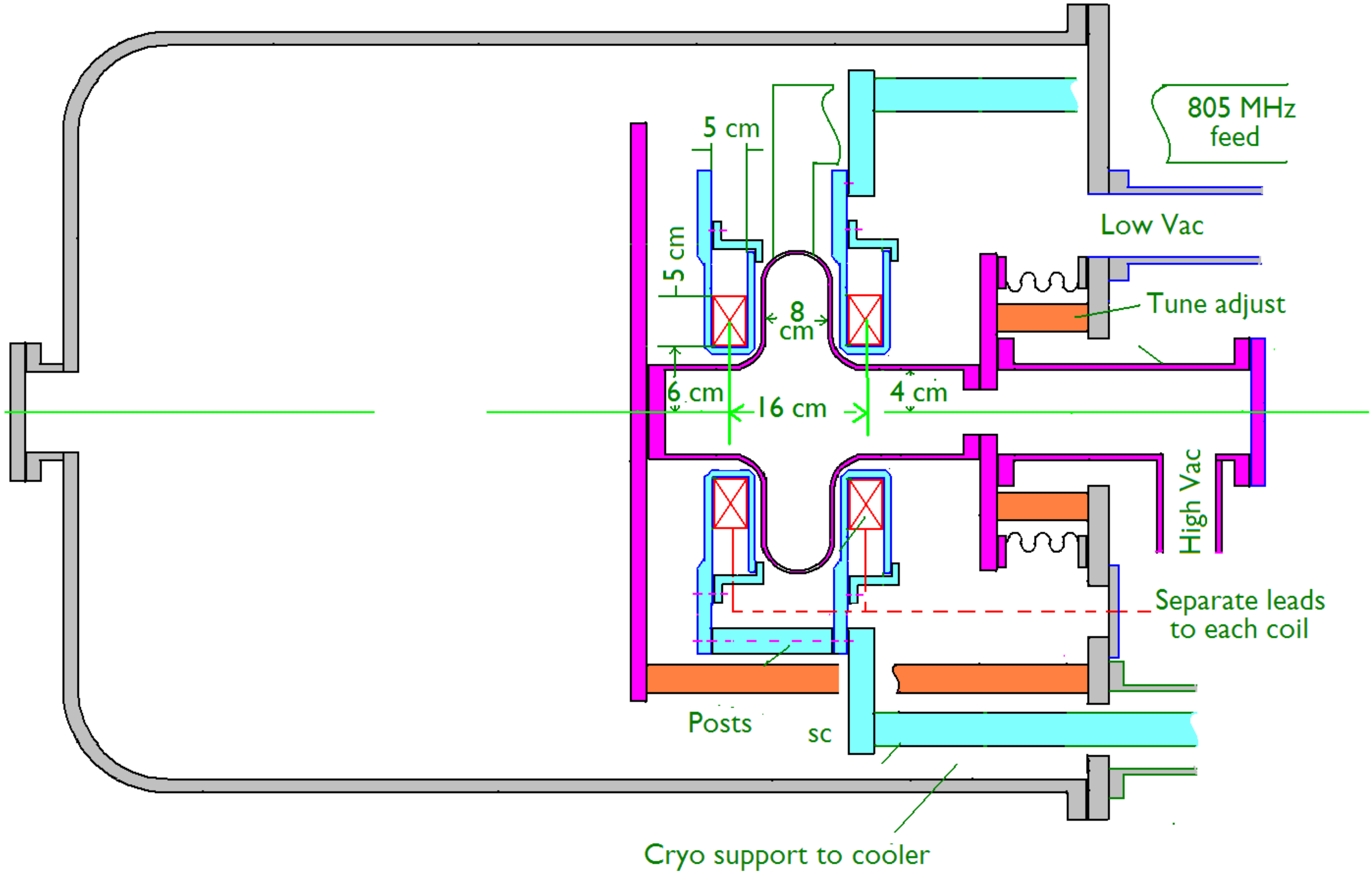
- Using lab G Magnet and new simple pillbox cavity at multiple angles



This will be a better test of 'magnetic insulated rf

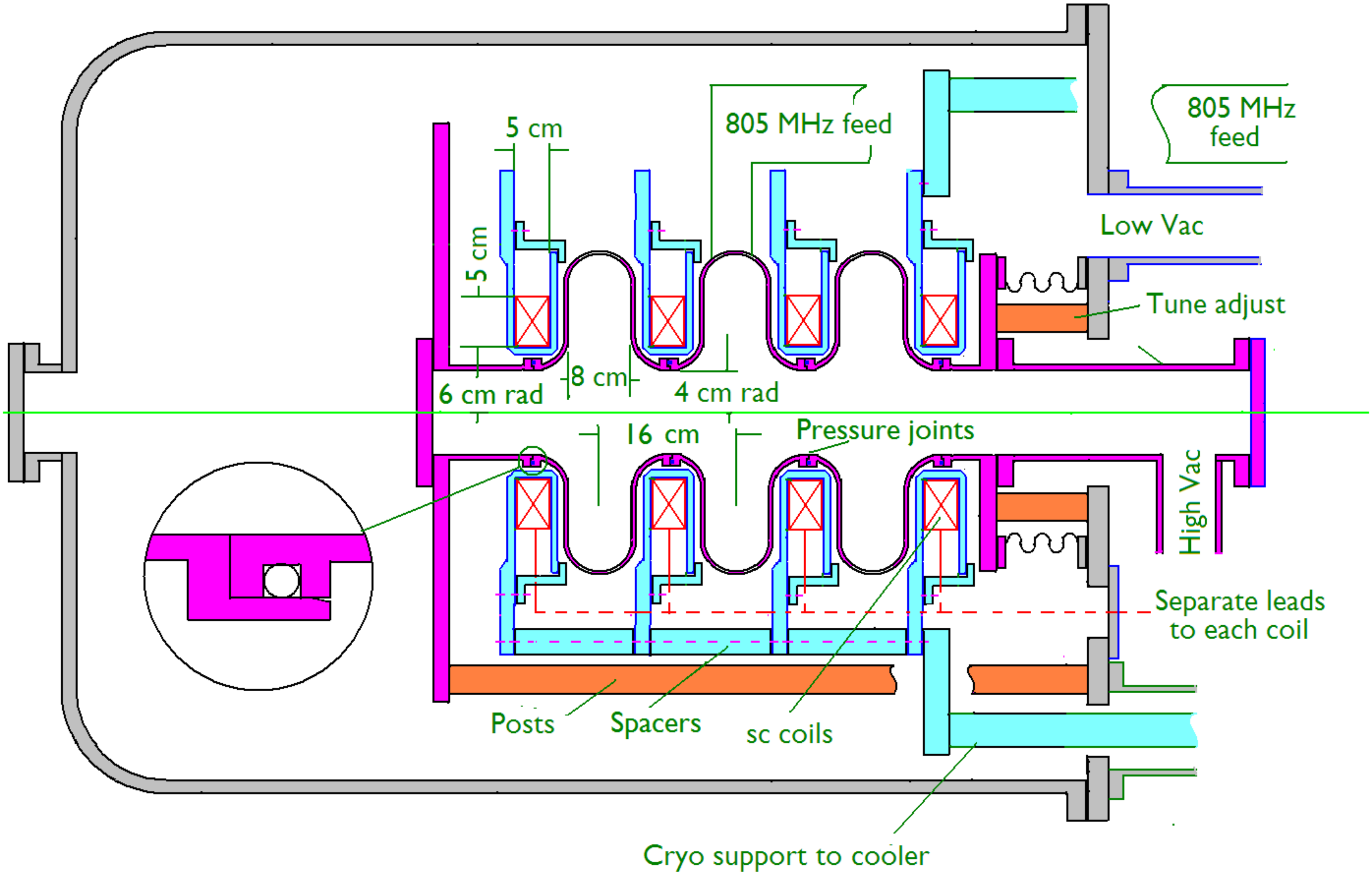
But angles should be good to a fraction of a degree, or adjustable over such a range, to see the sensetive angle dependence

Test of a Magnetic Insulated Cavity



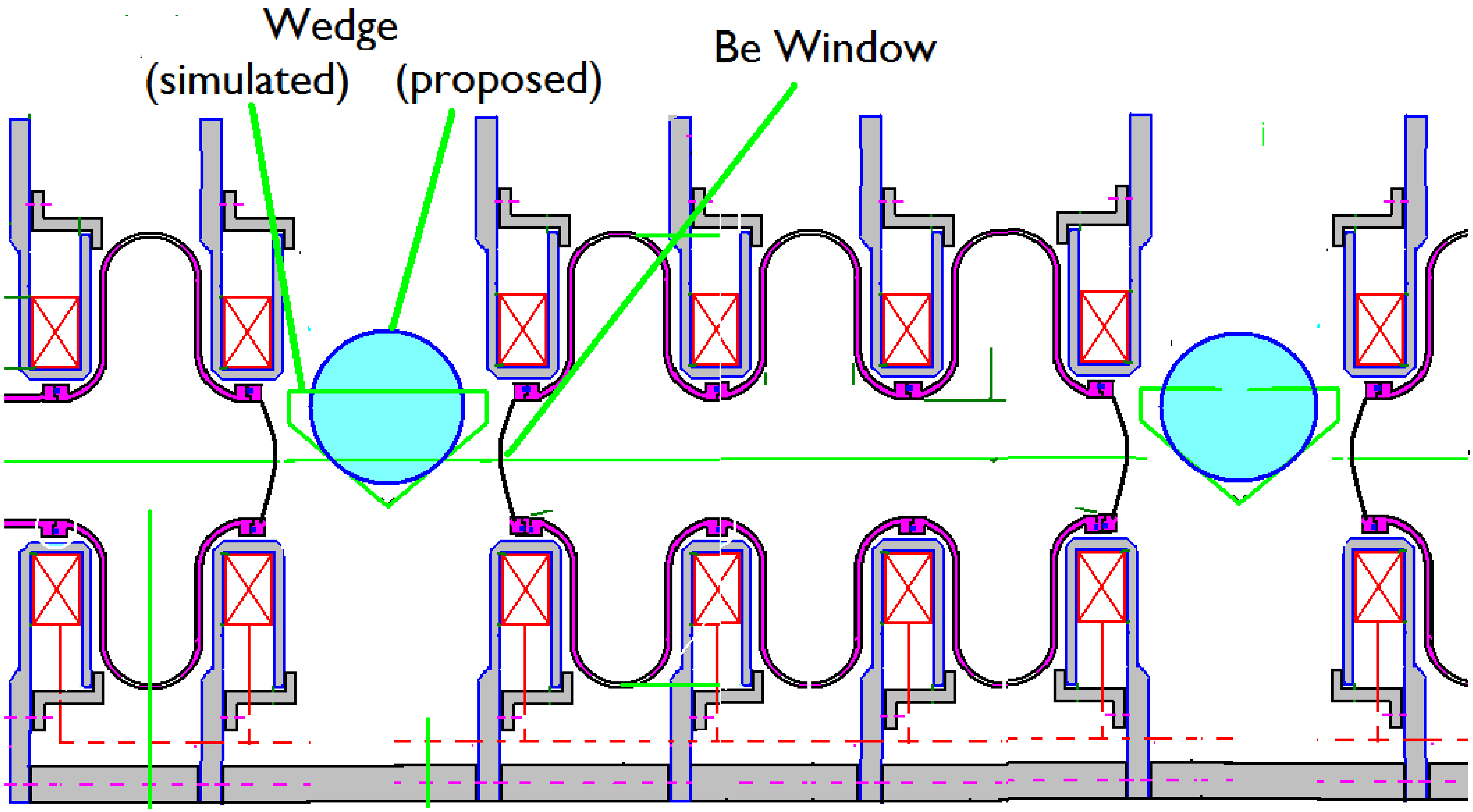
- 805 MHz chosen for early test, although needed first in 201 MHz
- In this and following, the cavities are drawn without the special need shapes

Test of Multi-cell 805 Magnetic Insulation



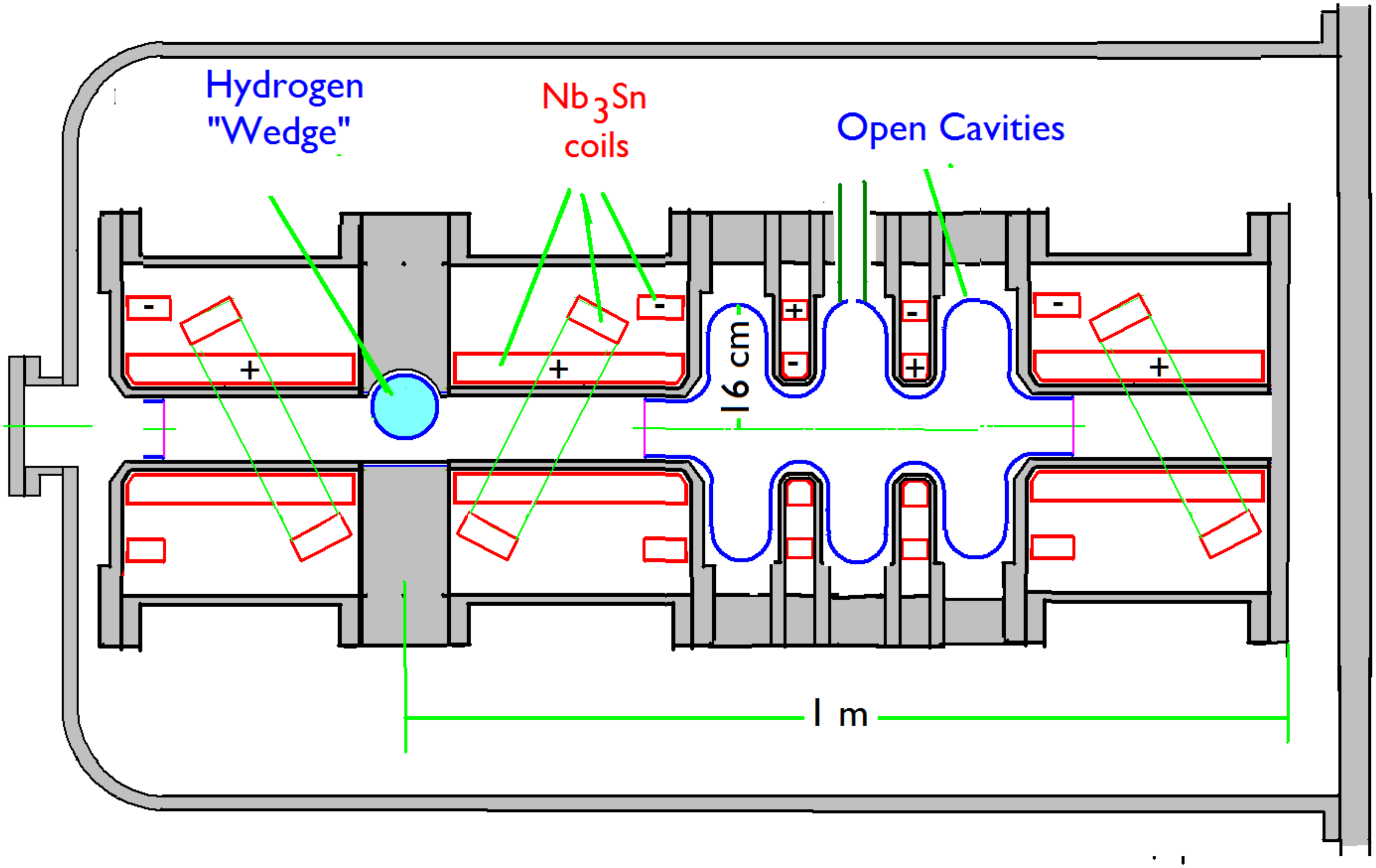
- More realistic E and B fields
- Test concept of pressure flanges for cavity joints
- Geometry of early cooling (201 MHz)

Test of Multi-cell 201 Magnetic Insulation ??



- Essential if Current design cannot get 15 MV/m
- This could be used at MICE for a cooling experiment
- Introduction of 0.125 T vertical not shown

Test of 10 T 6D cooling components



- Bending can be for Guggenheim or Snake
- Offset hydrogen pipe provides "wedge"
- Preliminary - Not simulated yet

Parameters of 10T 6D cooling Lattice

Cell length	(cm)	90
Hydrogen length	(cm)	10
Wedge angle	(deg)	110
Ave bend field	(T)	0.25
Equilibrium trans emittance	(π mm)	0.4
Frequency	(MHz)	805
Acceleration length	(cm)	48
Average accelerating grad	(MV/m)	12.5
Surface fields	(MV/m)	37
Momentum	(MeV/c)	200
beta minimum	(cm)	5
beta maximum	(cm)	35
Full momentum acceptance	($\pm$%)	9

- Cooling rate per cell is relatively low because only 10 cm hydrogen per cell
- So 5 cells needed to get 4% fractionlal cooling
- But length the same as current MICE

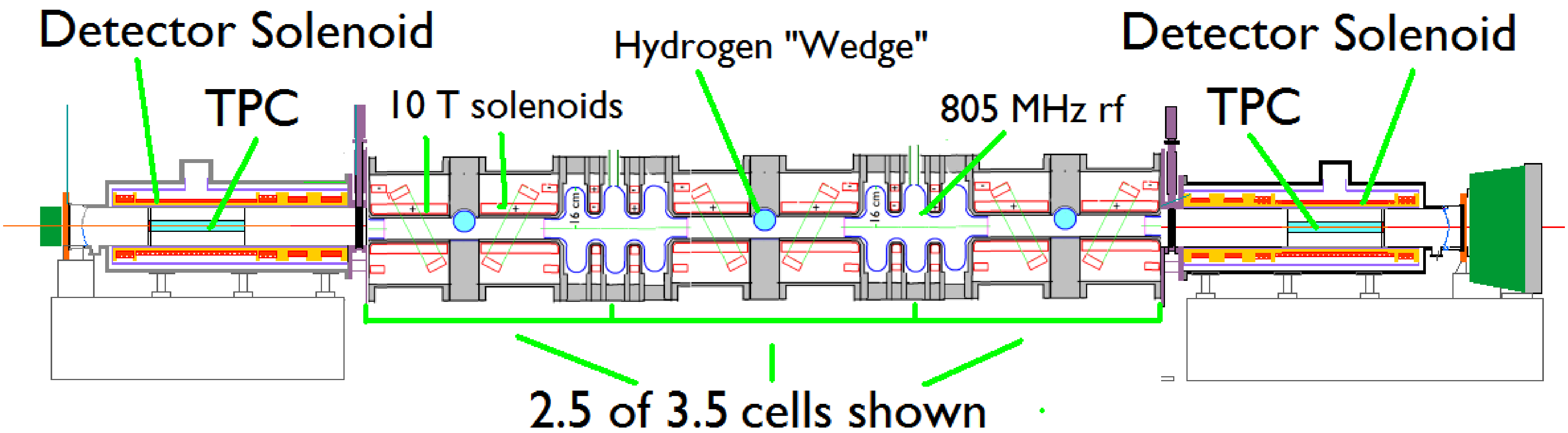
Parameters of 10T 6D Cooling Experiment

Cells		5
Length	(m)	4.5
Initial Emittance	(π mm)	0.8
Fractional transverse cooling	(%)	4
Initial Momentum Spread	(%)	4
Fractional longitudinal cooling	(%)	3

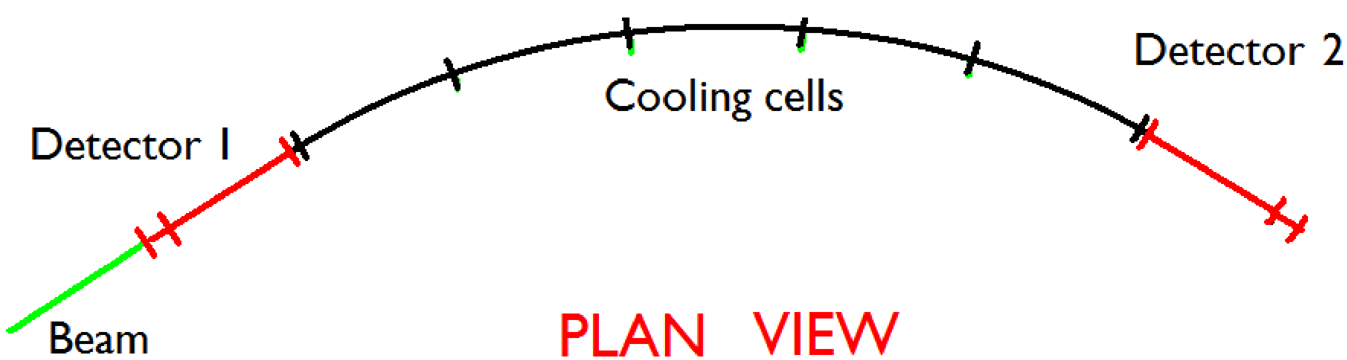
In order to use MICE beam and detectors:

- Fiber tracks have too little resolution and too much scattering
- Use Hydrogen gas TPC ?
- If readout planes face out, scattering should ok
- σ_r in 5 T solenoid $=$ 1 cm
- TPC radius diameter approx 8 cm

Matching into MICE detectors and beam



- Beam should be focused and collimated
- The 5 cells form an arc with bending radius 5.3 m



Questions

- Can MICE detectors measure an emittance of $800 \ \ (\pi \text{ mm mrad})$ to 0.4% ?
  In order to measure 4% cooling to 10%
- What modifications might be needed ?
  We believe only a TPC might do the job
- Can it measure the momentum of such a beam to 10^{-6}% ?
  To measure a 2% change in an rms 3% beam to 10 %
  Probably need to enter solenoids off axis to get significant helix radius
  My guess is that there is no hope of meauring the bunch length to this accuracy
- What would the detector look like if we start from scratch at FNAL ?

Conclusion

- Needed Component Experiments
  1. Test principle of magnetic insulation with simple 805 MHz cavity at 90 degrees
  2. Build single magnetically insulated 805 MHz cavity
  3. Engineer multiple 805 MHz magnetically insulated cavities
  4. Develop compact Nb_3Sn 10 T coils with return coils
     Slomo Caspi had looked at the parameters and proposed pre-compression method
  5. Engineer a hydrogen wedge in the above assembly
  6. Test one complete 10T 805 MHz 6D cooling cell
- Possible Cooling Experiments
  1. Short term 6D demonstration at MICE Worth a Letters article
  2. 6D cooling at 3T and 201 MHz at MICE Not as imortant as:
  3. 6D cooling at 10T and 805 MHz at MICE if possible