Optimization of baseline front end for a neutrino factory

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FNAL

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Outline

- **Front End for the Neutrino Factory/MC**
  - Study 2A – ISS baseline
  - Shorter front end example-
  - other variants (88MHz, Induction Linac)
- **Rf cavities in solenoids?**
  - high gradient cavities may not work in ~2T fields
  - Options
    - Use lower fields (B, V')
  - Boulder Workshop
    - Be cavities – magnetic focusing will not heat cavities enough for Breakdown ? R. Palmer
- **Need baseline design for IDS**
  - need baseline for "5-year Plan"

Baseline Front End

Capture in 20 T solenoid with adiabatic taper

Drift in ~1.5 T, ~100 m solenoid

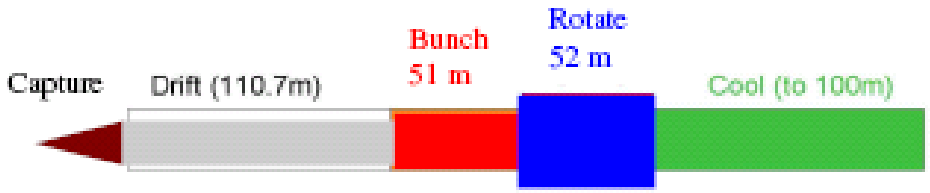
Adiabatically bring on RF voltage to bunch beam

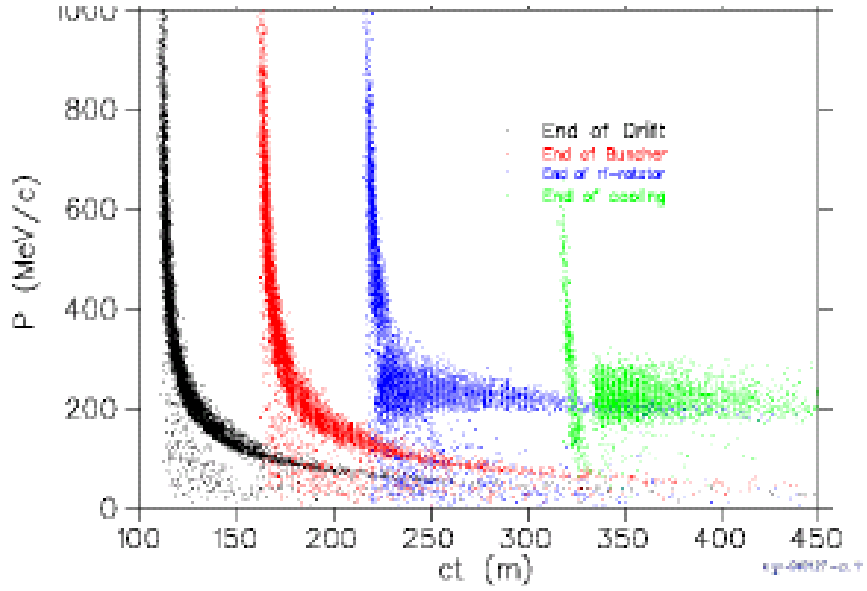
Phase rotation using variable frequencies

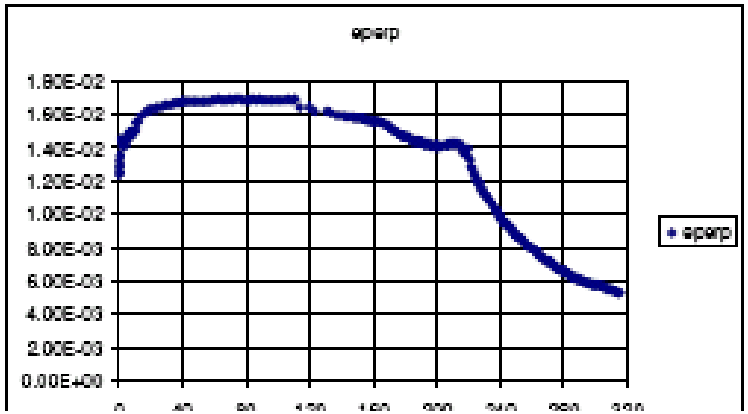
- High energy front sees -ve E
- Low energy tail sees +ve E
- End up with smaller energy spread

Ionisation Cooling

- Try to reduce transverse beam size

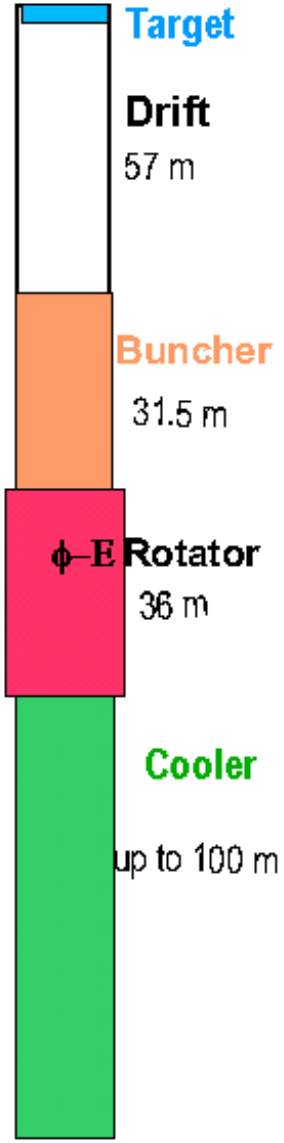


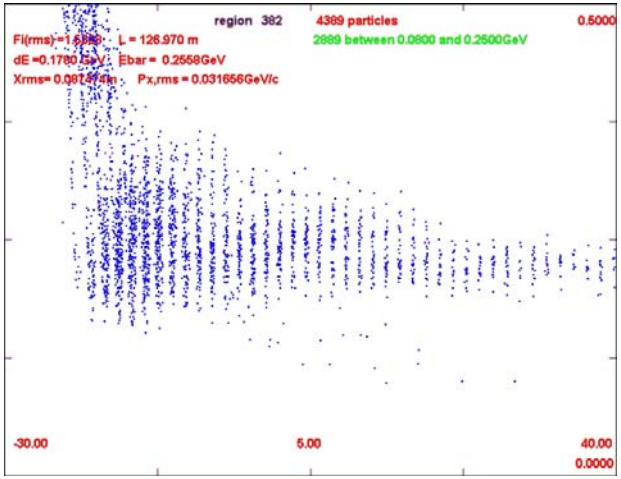


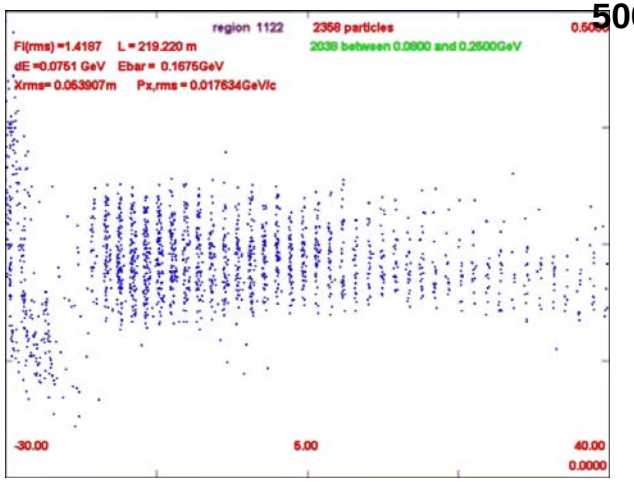


IDS - Shorter Version

- Reduce drift, buncher, rotator to get shorter bunch train:
  - 217m ⇒ 125m
  - 57m drift, 31m buncher, 36m rotator
  - Rf voltages up to 15MV/m (×2/3)
- Obtains ~0.26 μ/p_{24} in ref. acceptance
  - Similar or better than Study 2B baseline
- Better for Muon Collider
  - 80+ m bunchtrain reduced to < 50m
  - Δn: 18 -> 10





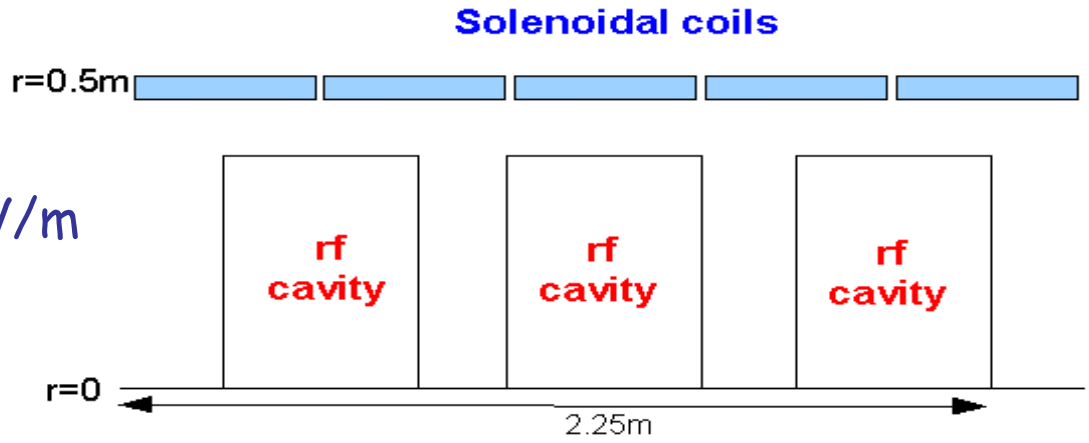


500MeV/c

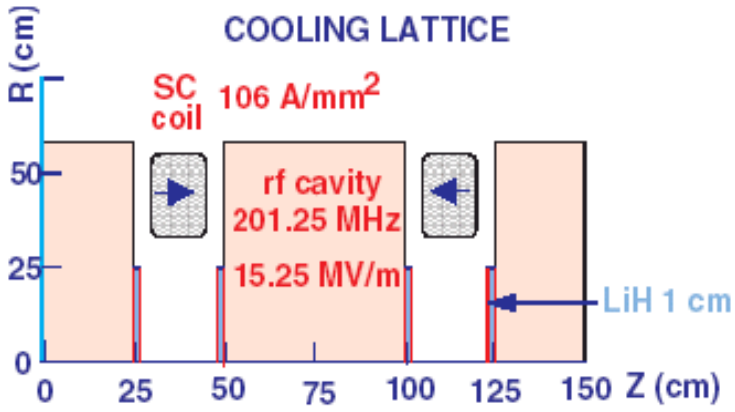
-30 40m

Buncher-Rotator settings

- **Buncher and Rotator have rf within ~2T fields**
  - rf cavity/drift spacing same throughout (0.5m, 0.25)
  - rf gradient goes from 0 to 15 MV/m in buncher cavities
- **Cooling baseline**
  - ASOL lattice
  - 1 cm LiH slabs (3.6MeV/cell)
  - ~15MV/m cavities
  - **also consider H_2 cooling**
- Simulated in G4Beamline
  - **optimized to reduce # of frequencies**
- Shorter version has 20% higher gradient



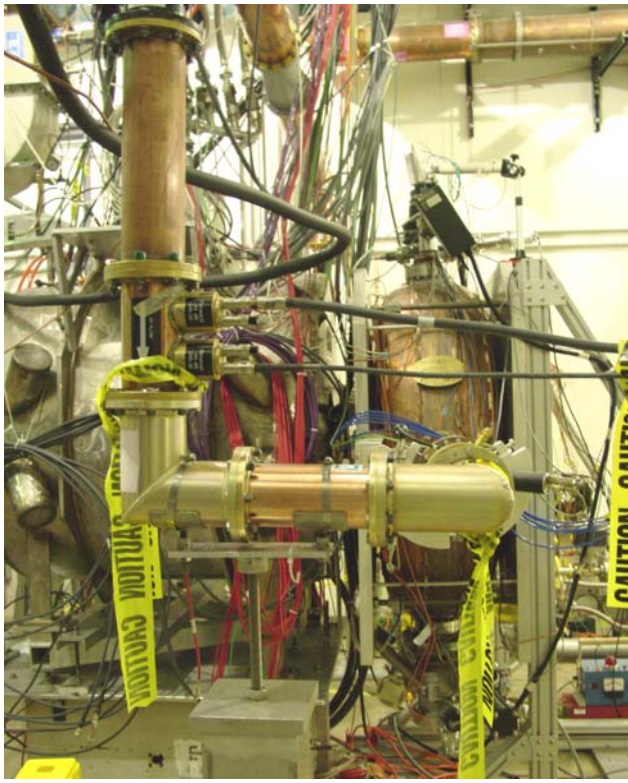
ASOL lattice



Optimizations

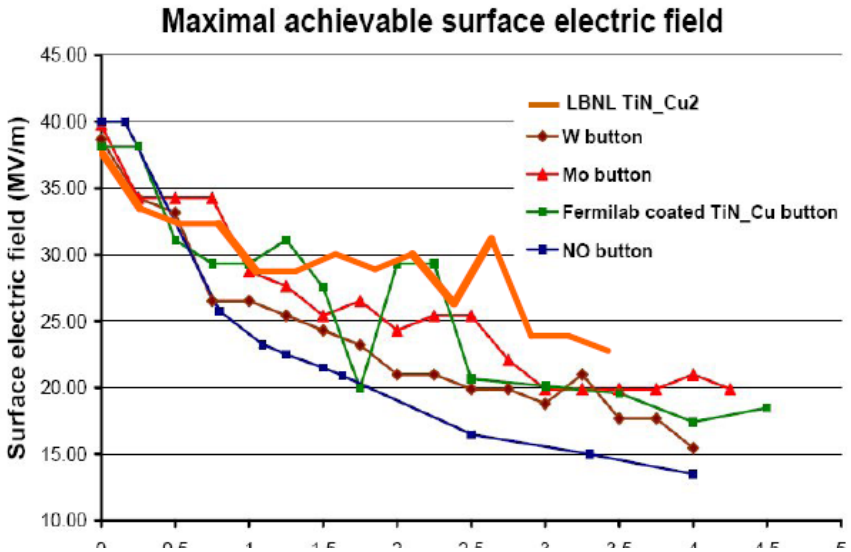
- **Major uncertainty is high-gradient rf within solenoidal fields**
  - $V'_{rf} / B_{solenoid}$???
  - Currently have **B= 1.5 to 2T, V' = 12 to 15 MV/m**
  - baseline frequency is ~200 MHz

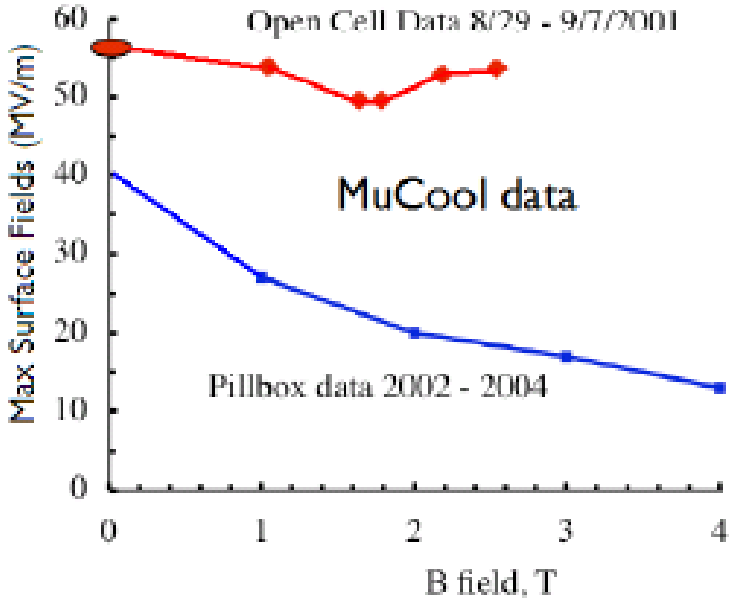
- **Experiments have achieved ~ 14 MV/m at 2.5-T**
  - (~ 0.75-T at nearest thin Be window)
  - Solenoid near 201 MHz cavity



Variation on material, geometry

- **Surface/material changes maximum field**
  - TiN coating (-> 30MV/m)
  - 800 MHz
- **More improvement with ALD?**
- **Open cell cavity**
  - shows no dependence on B
  -



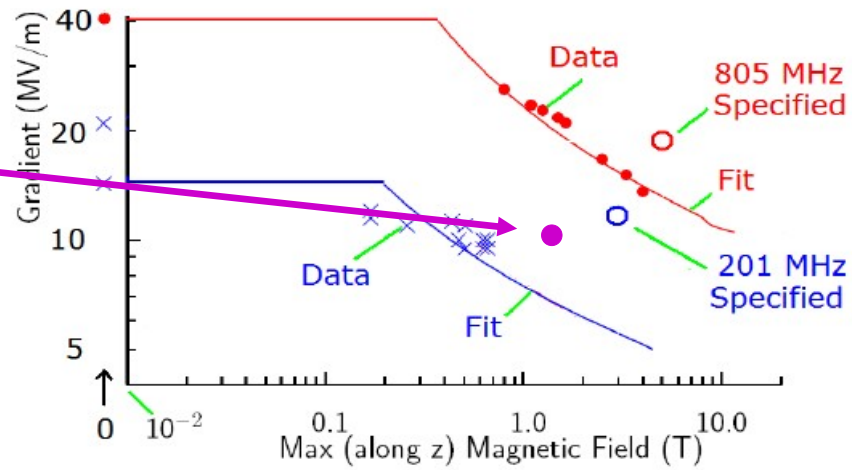


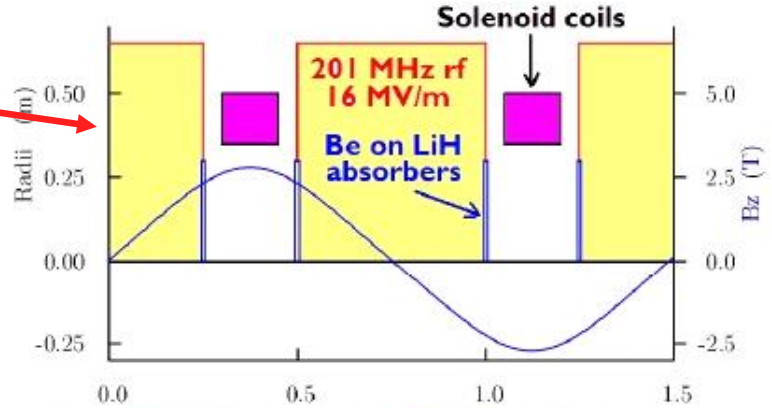
Solutions to possible rf cavity limitations

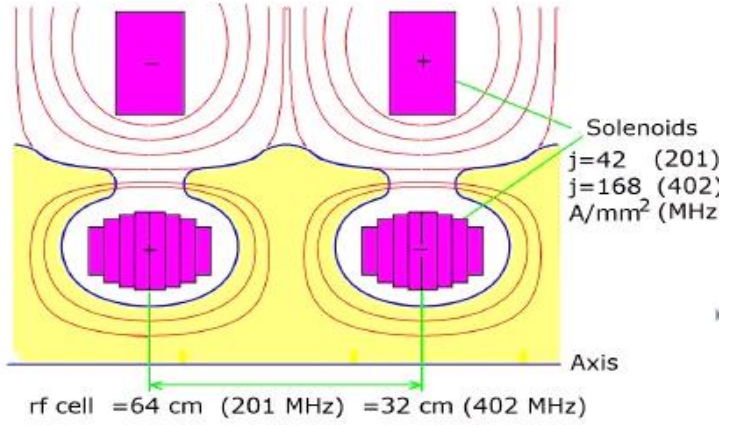
- For IDS, we need an rf cavity + lattice that can work
- Potential strategies:

- Use lower fields (V', B)
  - 10MV/m at 1.5T?
- Use non-B = constant lattices
  - alternating solenoid

- Magnetically insulated cavities
  - Is it really better ???
  - Alternating solenoid is similar to magnetically insulated lattice
- Shielded rf lattices
  - low B-field throughout rf
- Use gas-filled rf cavities
  - same gradient with/without fields
  - but electron effects?

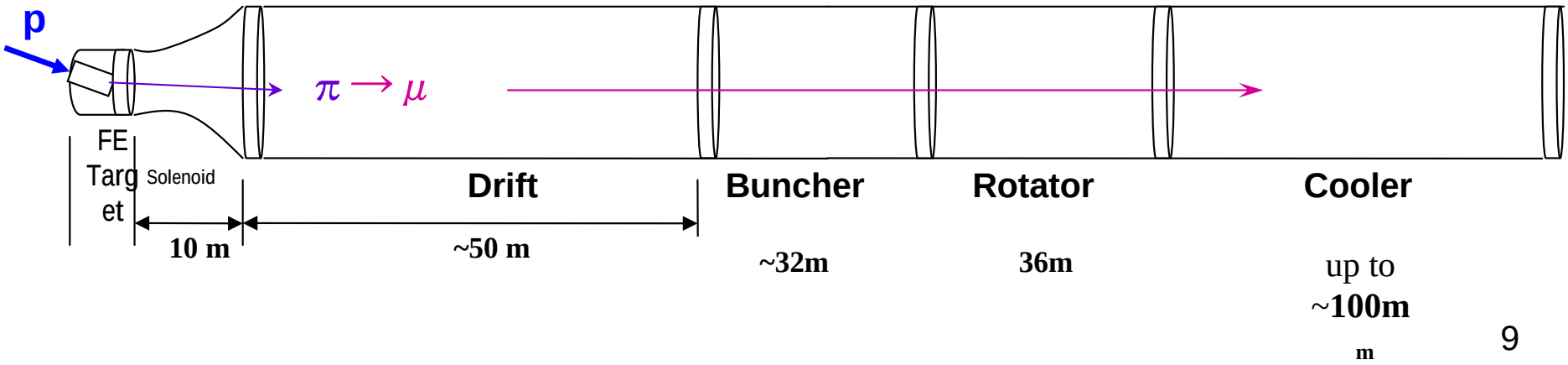






Current study

- **Change magnetic field, V'_{rf} to study limits**
- **Use "short" front end for studies**
  - Baseline had 2T solenoid in drift and buncher
    - 0 to 15 MV/m rf
  - 15 MV/m in rotator; 15 MV/m in cooler
  - vary rotator from 10 to 15 MV/m;
  - Cooler 12 to 18 MV/m



Results

- Muons per 10 8-GeV protons

Cooler/ Rotaters	10	12	14	15	17	18 MV/m
10		0.70		0.73		
12			0.75	0.77		0.80
14				0.80	0.84	
15				0.81	0.85	0.84

Variation is not strong; more rf still means more muons

Next try changing B

- B= 1.33 T (~Study 2)
- match into alternating solenoid

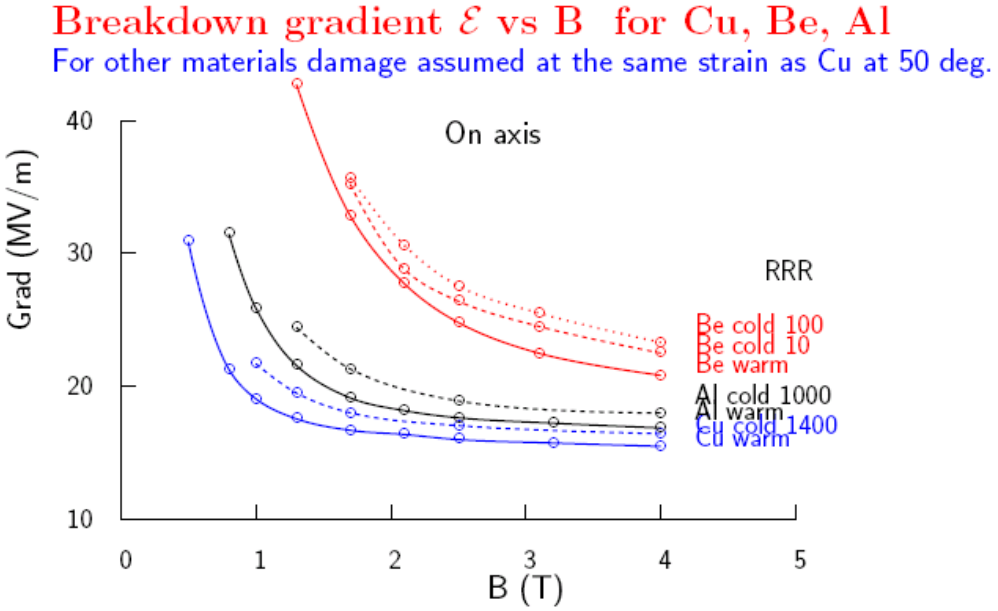
- Tapering focus would help …

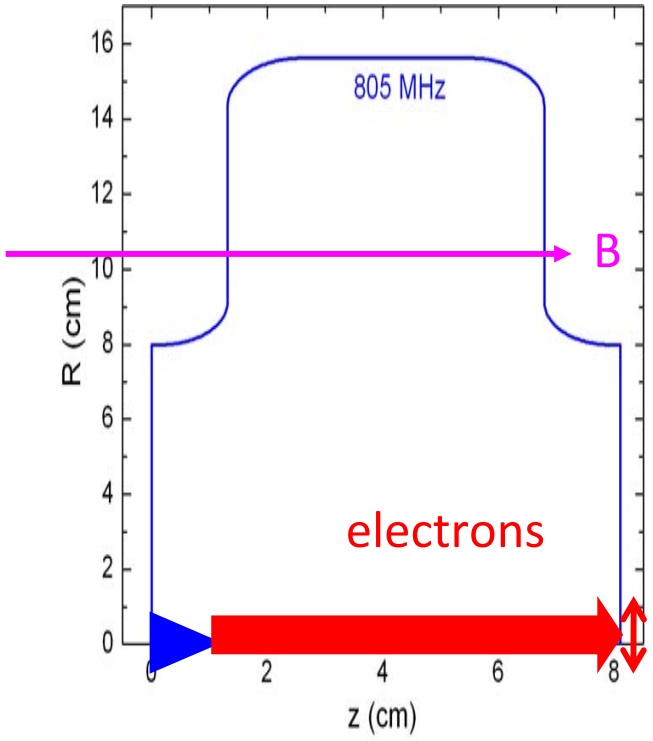
Change cavity material-Palmer

- Tech-X rf breakdown modeling workshop

Bob is convinced Be would solve the Front End Problem ?

Needs experimental tests !!!





Plan for IDS

- **Need one design likely to work for V_{rf}/B-field**
  - rf studies are likely to be inconclusive
- **Hold review to endorse a potential design for IDS**
  - – likely to be acceptable (V_{rf}/B-field)
  - April 2010 ?
- **Use reviewed design as basis for IDS engineering study**