Final 50 T cooling with matching & 40 T SBIR Demo.

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Work supported by Particles Beams Lasers (PBL)

MCTF Thursday

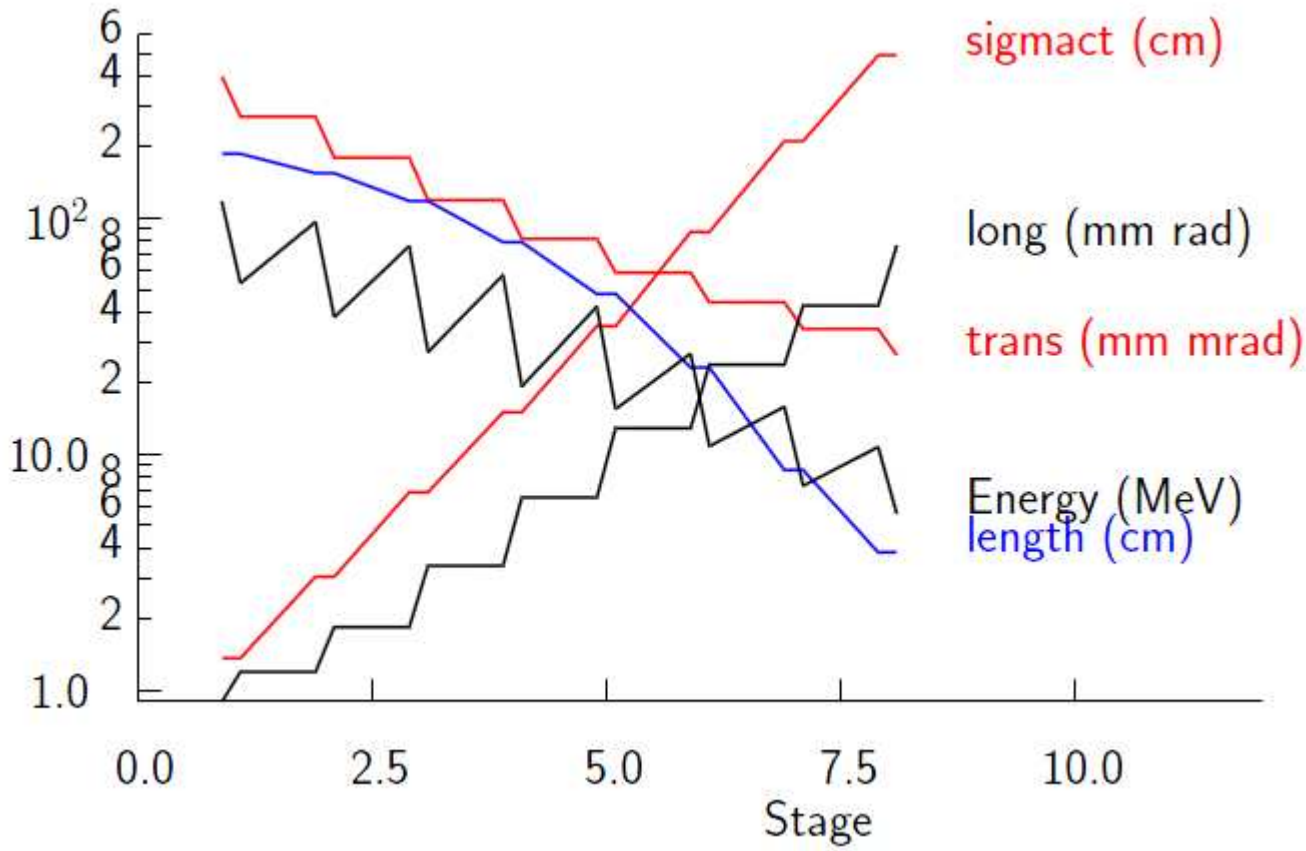
April 23 2009

- Introduction
- ICOOL Simulations of last 2 50 T stages with match
- Next steps

- SBIR Proposal for 40 T
- Conclusion

Introduction

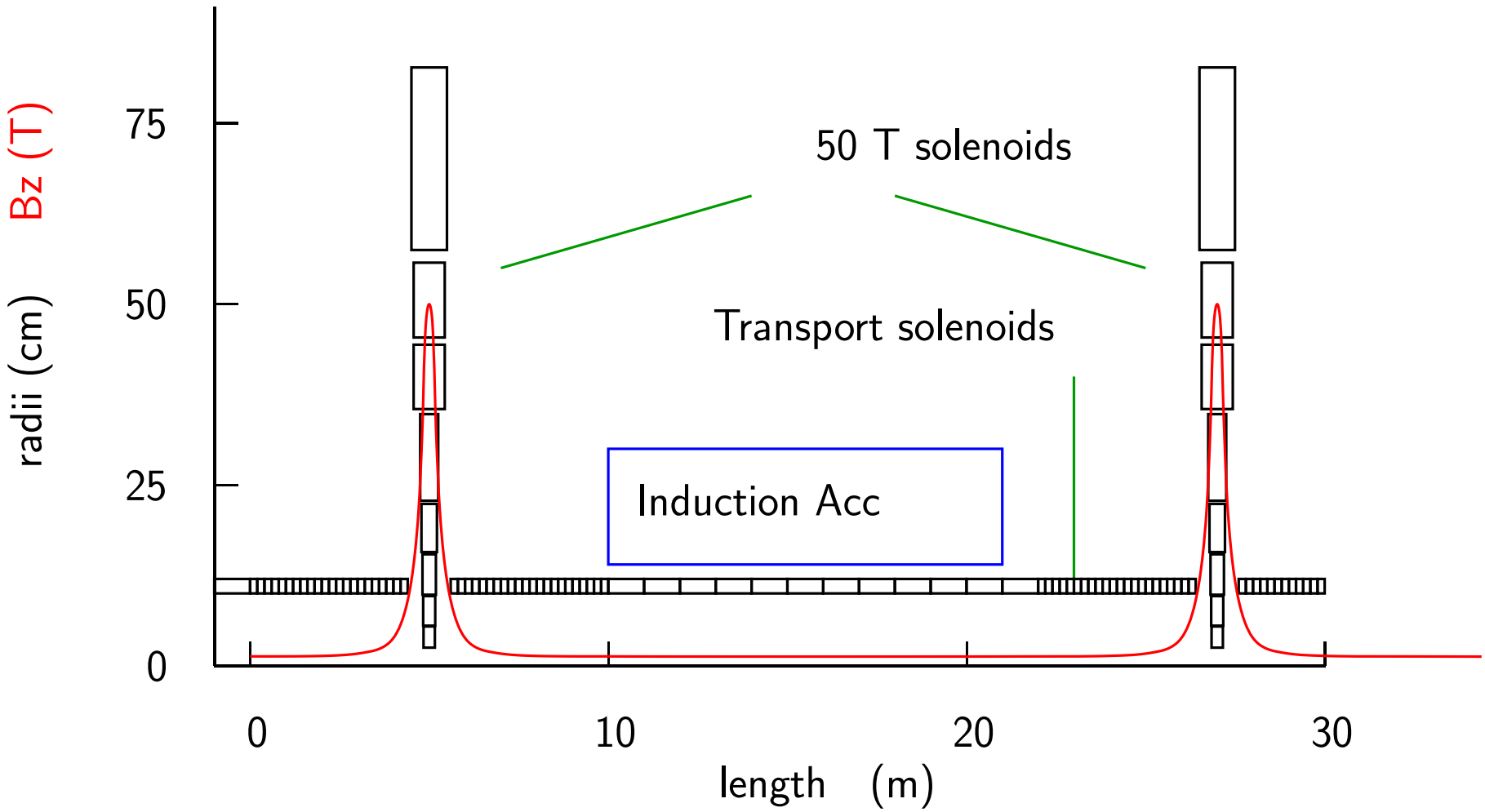
Possible sequence of 50 T Cooling Stages



- Needs long bunch at end ($\sigma z = 5$ m)
- Needs long drift before phase rotation
- Causes significant ($\approx 15\%$) decay loss
- So tried using somewhat higher energy that requires shorter bunches for same longitudinal emittance

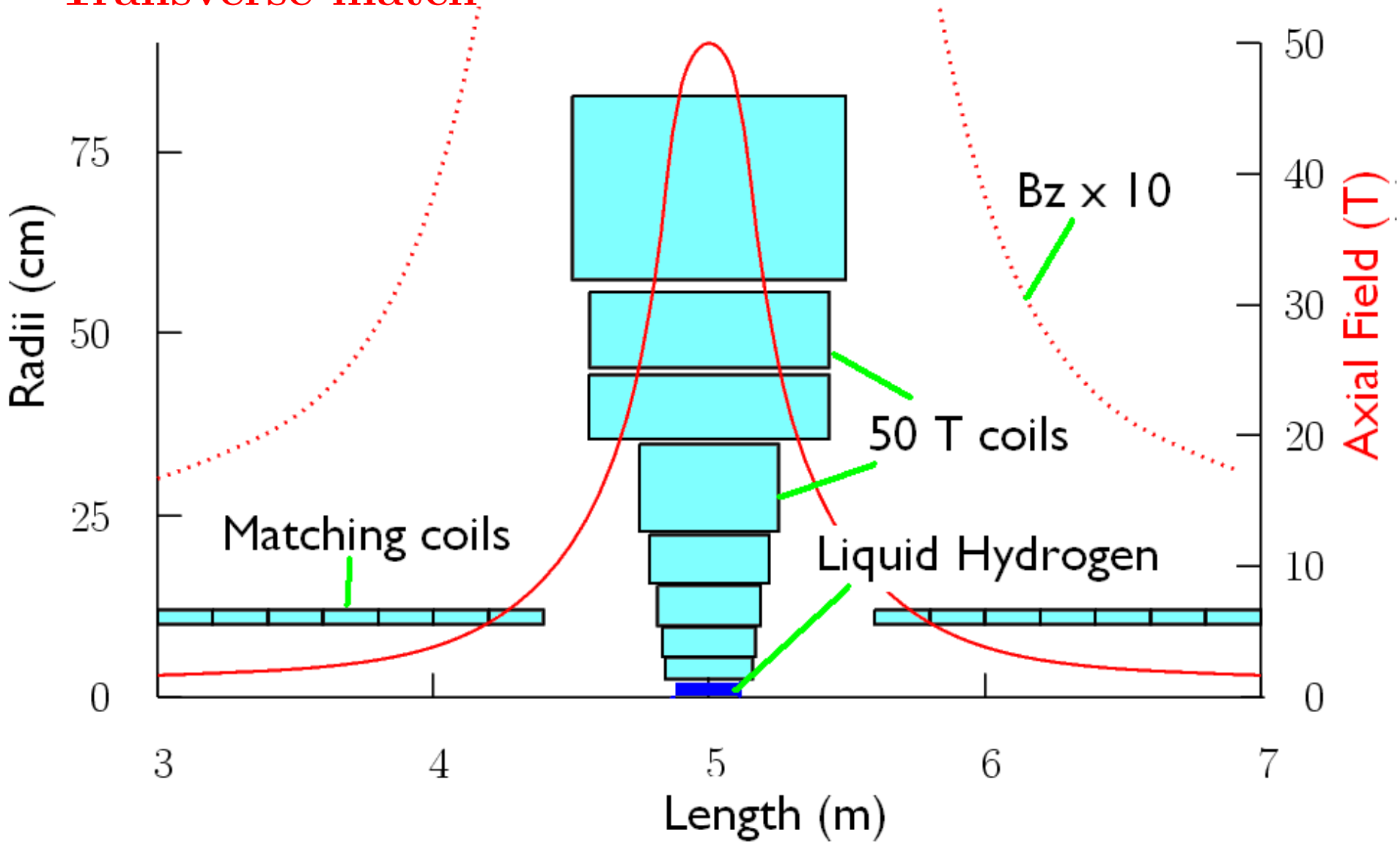
Final Cooling in 50 T Solenoids

ICOOL simulation, including matching, of last two solenoids



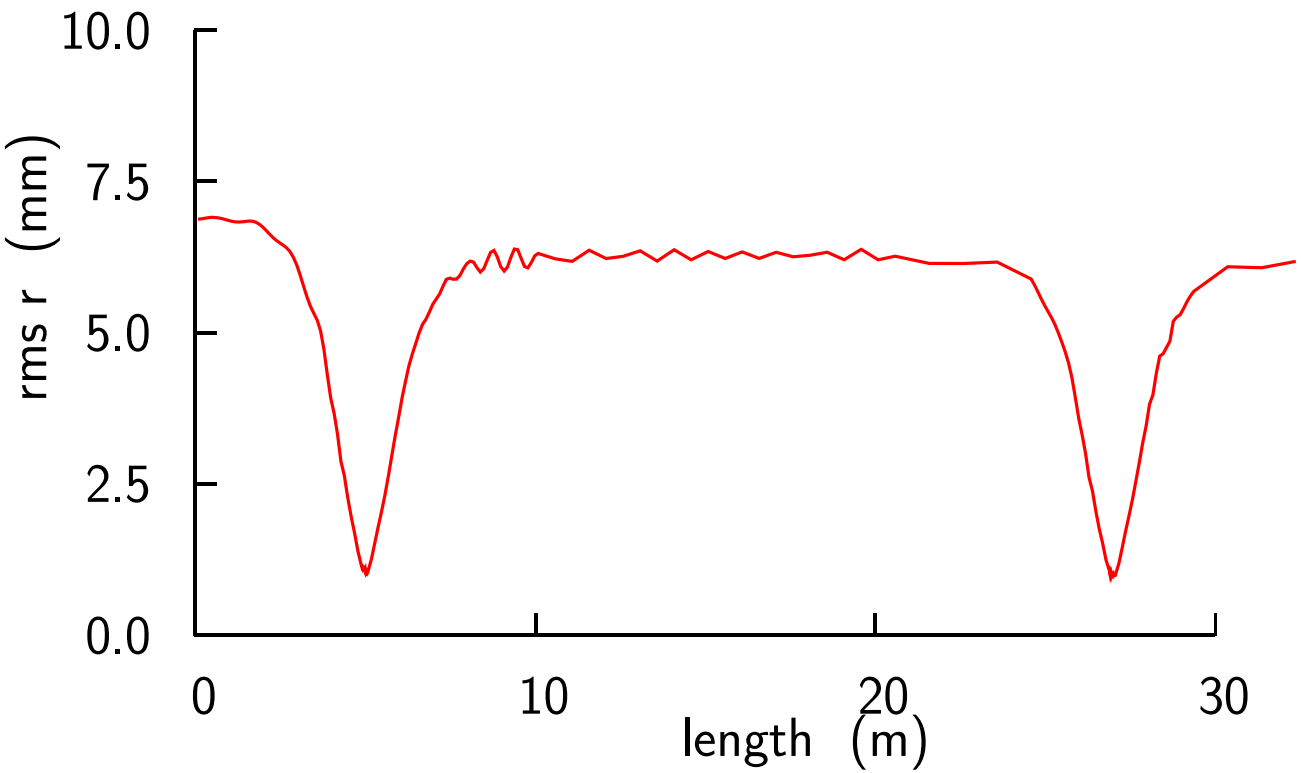
- 50 T design from PBL SBIR phase 1
- Matching part of this SBIR

Transverse match



Condition for adiabatic match: $\frac{d\beta}{dx} \leq 0.25$

Beam size



- some mismatch visible which could be improved
- rms 1 mm in magnet 1.2 cm pipe is 6 sigma
- rms 7 cm in induction 10 cm pipe is 7 sigma

Longitudinal Match

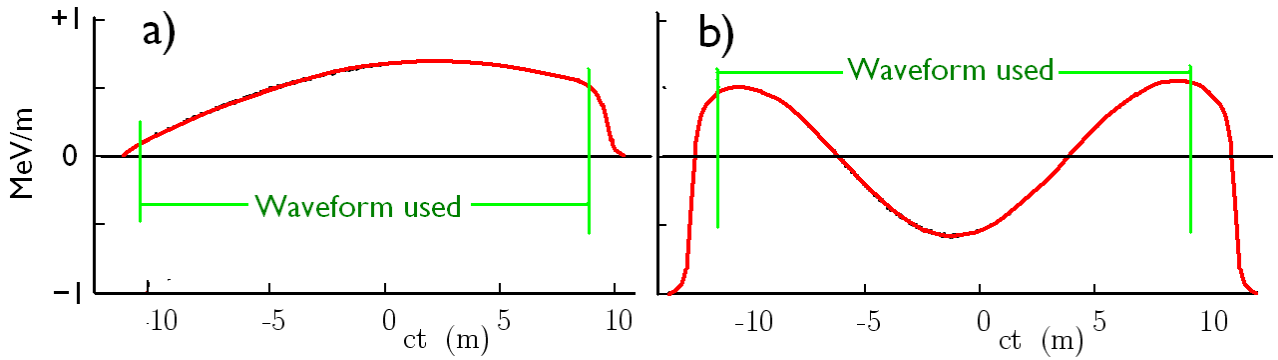
- Attempts using a matrix phase rotation and acceleration gave $\approx$ 30 % longitudinal emittance growth

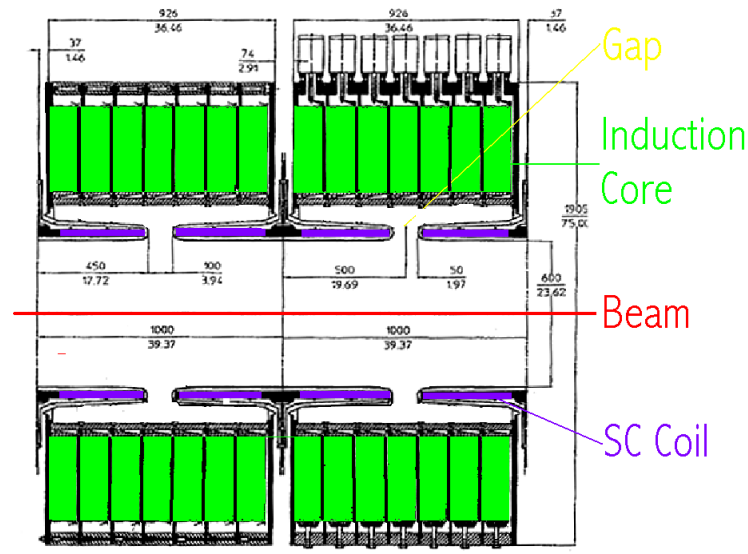
- Then tried real particle simulation with linear induction waveforms
- But particle phase distributions developed banana shapes
- Giving longitudinal emittance growth of the order of 30%

- Apparently the problem is intrinsically non-linear

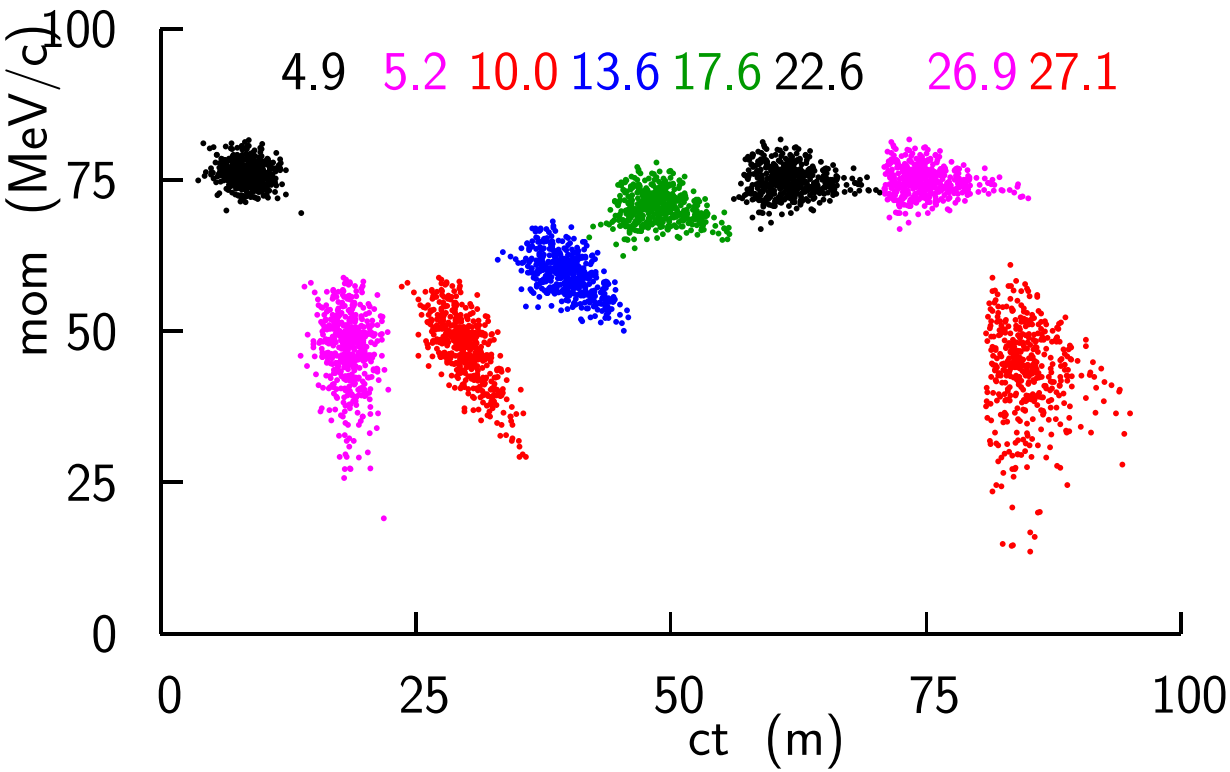
Using sinusoidal waveforms

Uses two Induction Linac Waveforms



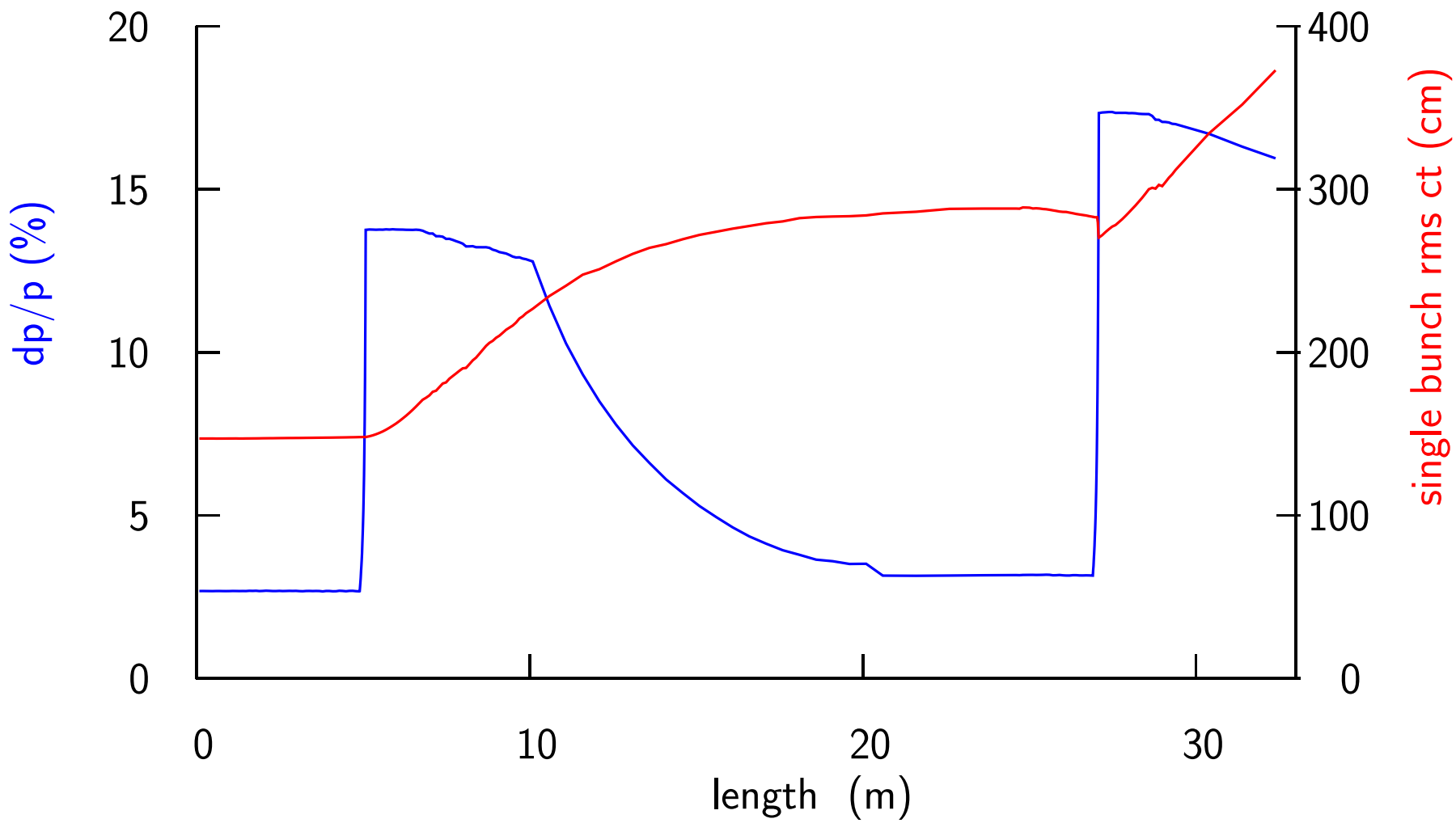


Study II Induction design

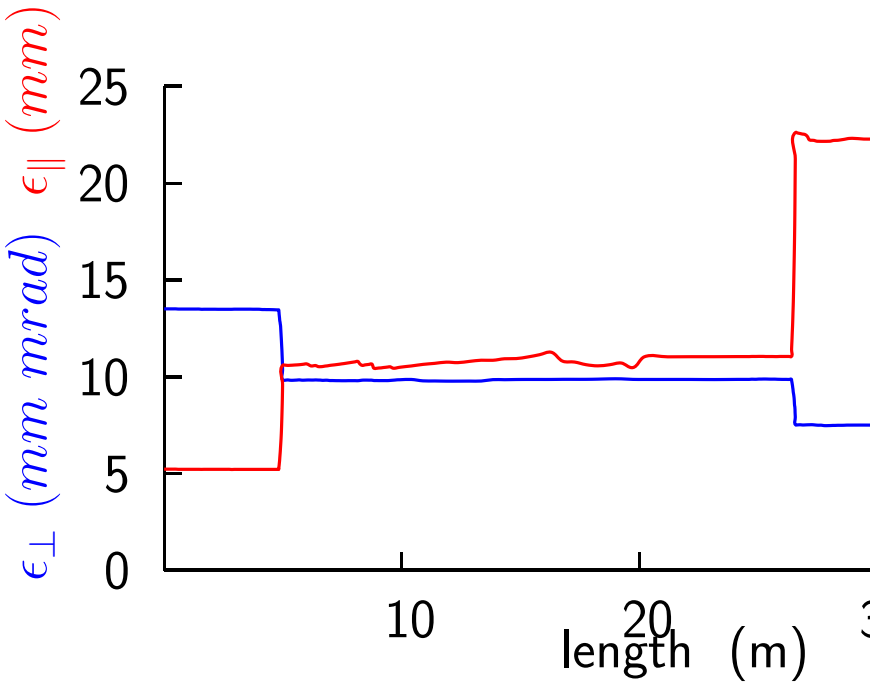


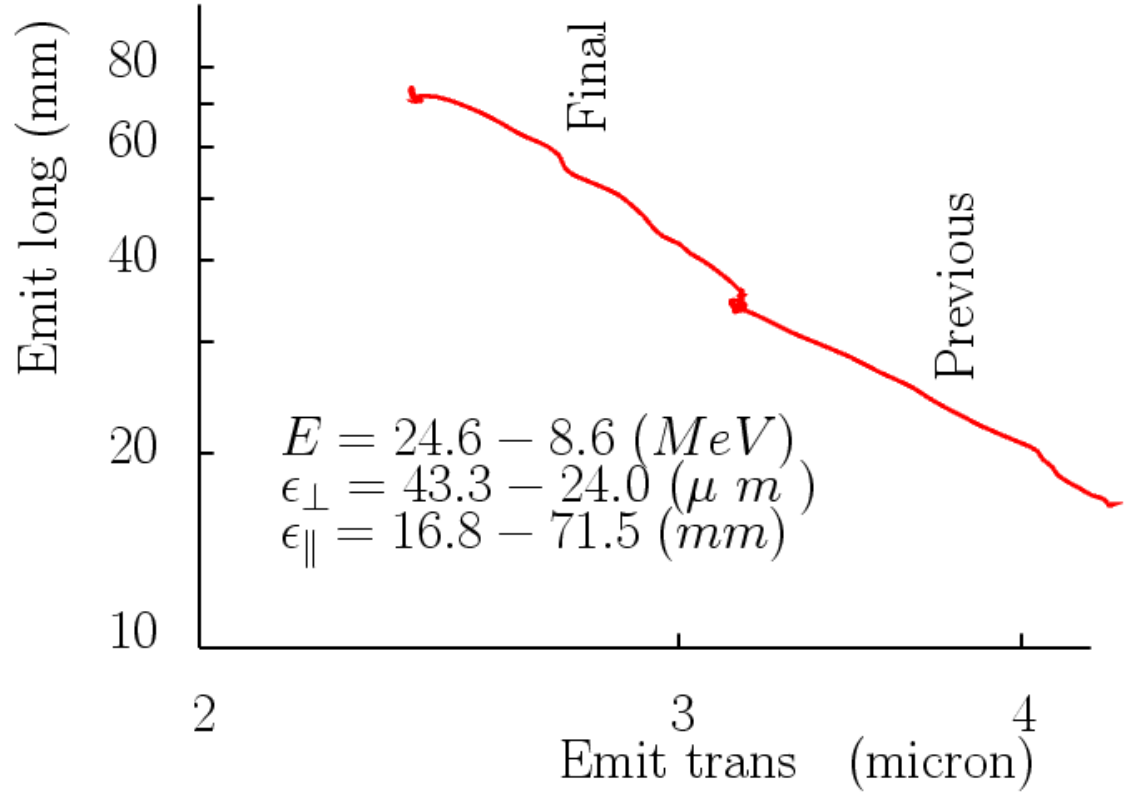
- Good results
- No banana shape

dp/p and sigma z



Emittances

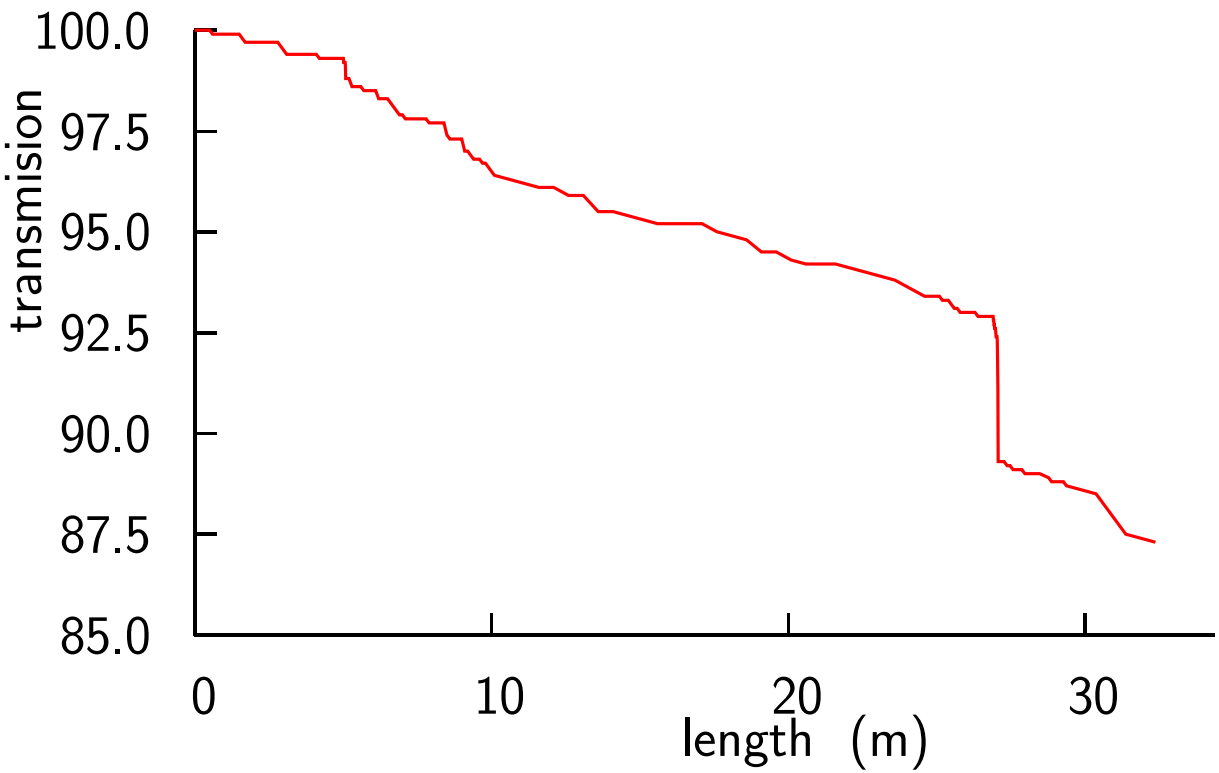




In matching:

- Negligible increase in transverse emittance
- Only 2% increase in longitudinal emittance

Transmission



In both cooling stages and match between them:

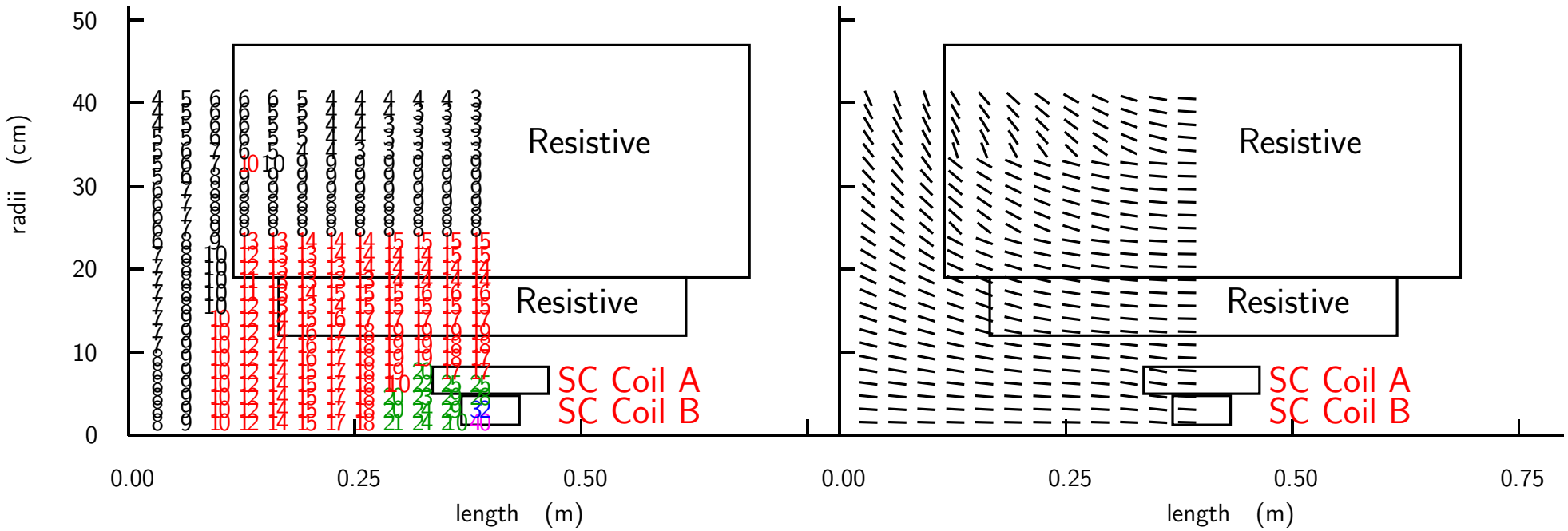
- 12.5 % loss
- 5 % from decay
- Rest from 4 sig cut, stopping muons etc

Next steps

- Simulate ever earlier stages
- Will eventually run into known problem:
  - Bunches too short to propagate without rf through a 50 T magnet and matching
  - Will need to use lower magnetic fields, shorter magnets, more rf
- Re-optimize energies
- Somebody should really try simulating REMEX
  - Use a low κ 40-50 T helix
    (A Kashikin helix with small bore & required thick coils will have low κ)
  - Use low energies, as here, to get low betas
  - Add LiH wedges
  - One could hope for fewer stages and less loss

PBL SBIR Phase II Proposal to test 40 T magnet

Weggel, Gupta, Palmer, Scanlan (PBL)

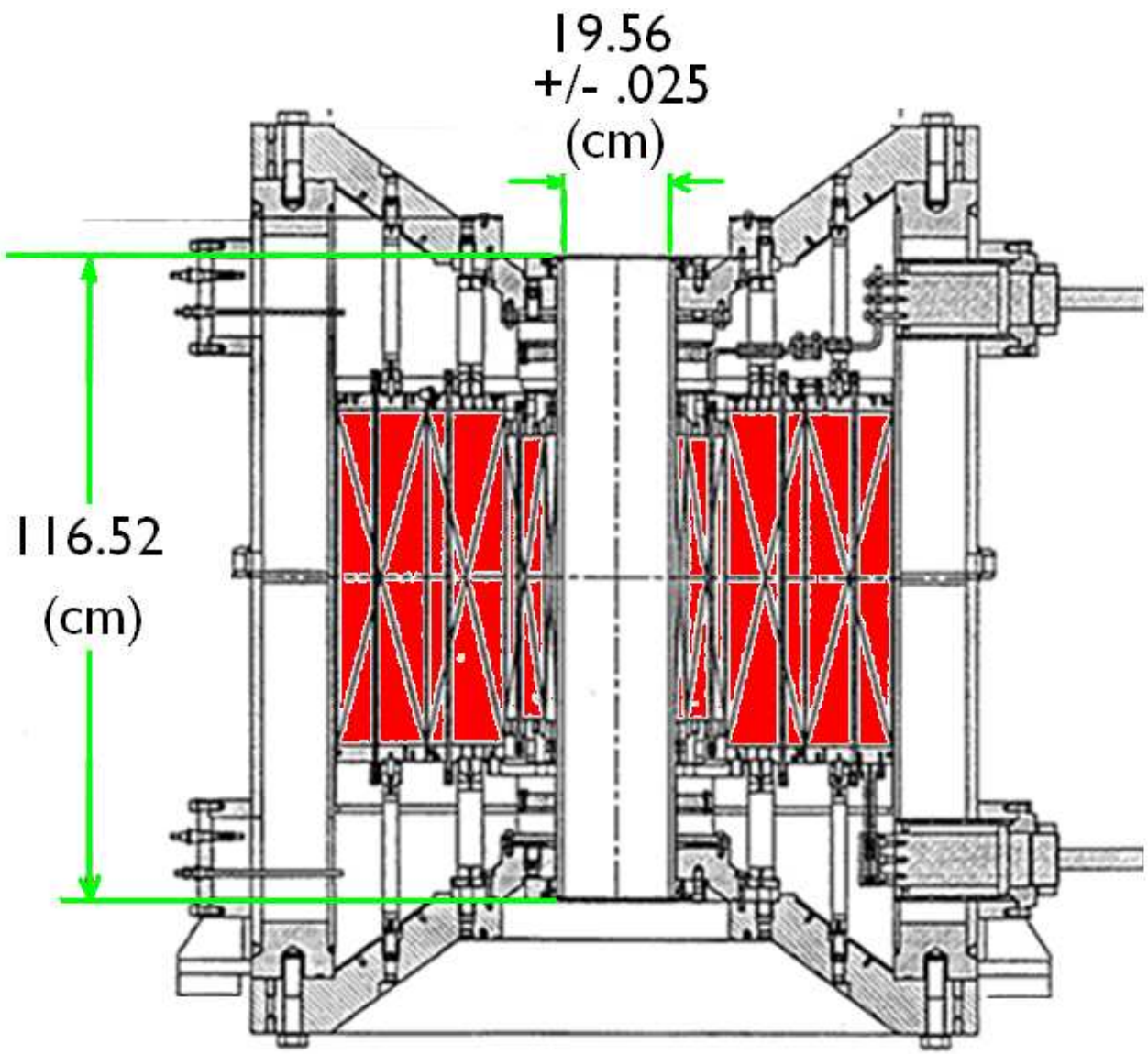


Coil A being built now under active PBL SBIR using SuperPower YBCO tape

New PBL SBIR Proposal:

- Build insert coil B also with SuperPower YBCO tape
- Design quench protection
- Test both coils in NHMFL 19 T resistive solenoid

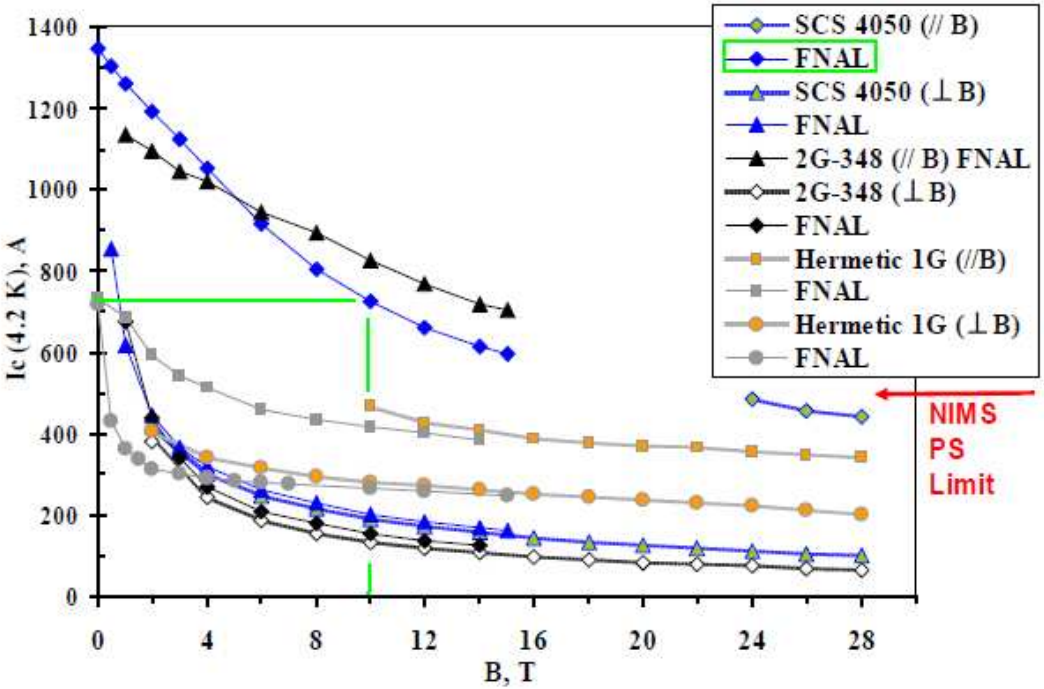
NHMFL 19 T Resistive magnet

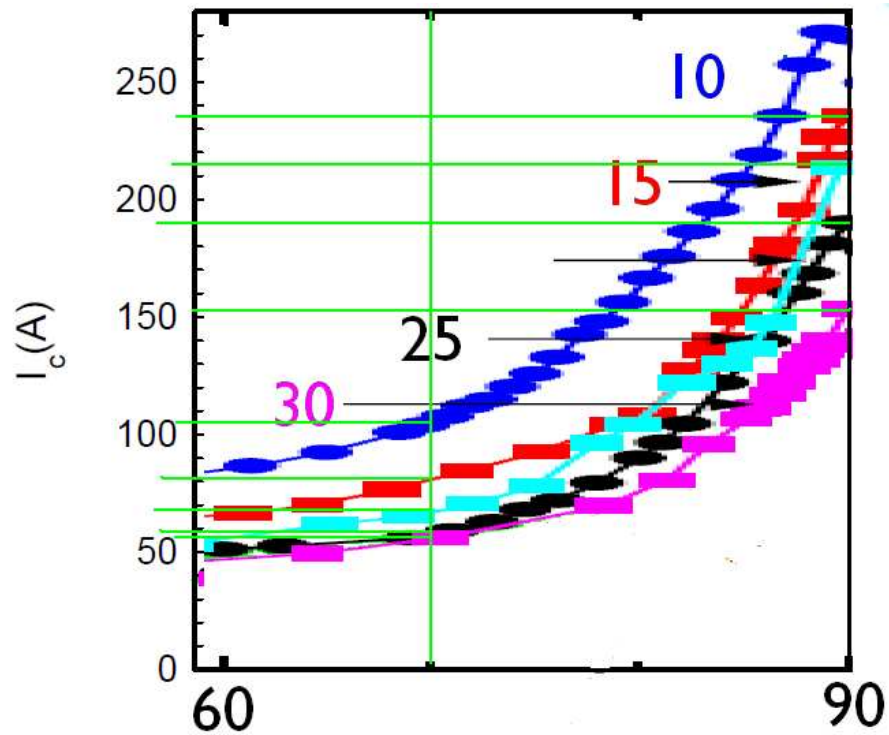


NHMFL has cryostat that we can use

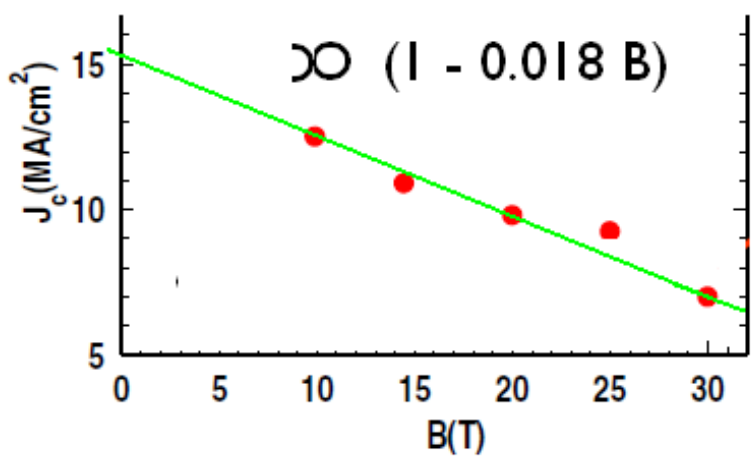
j vs. B and angle for SuperPower YBCO tape

Measured by NHMFL





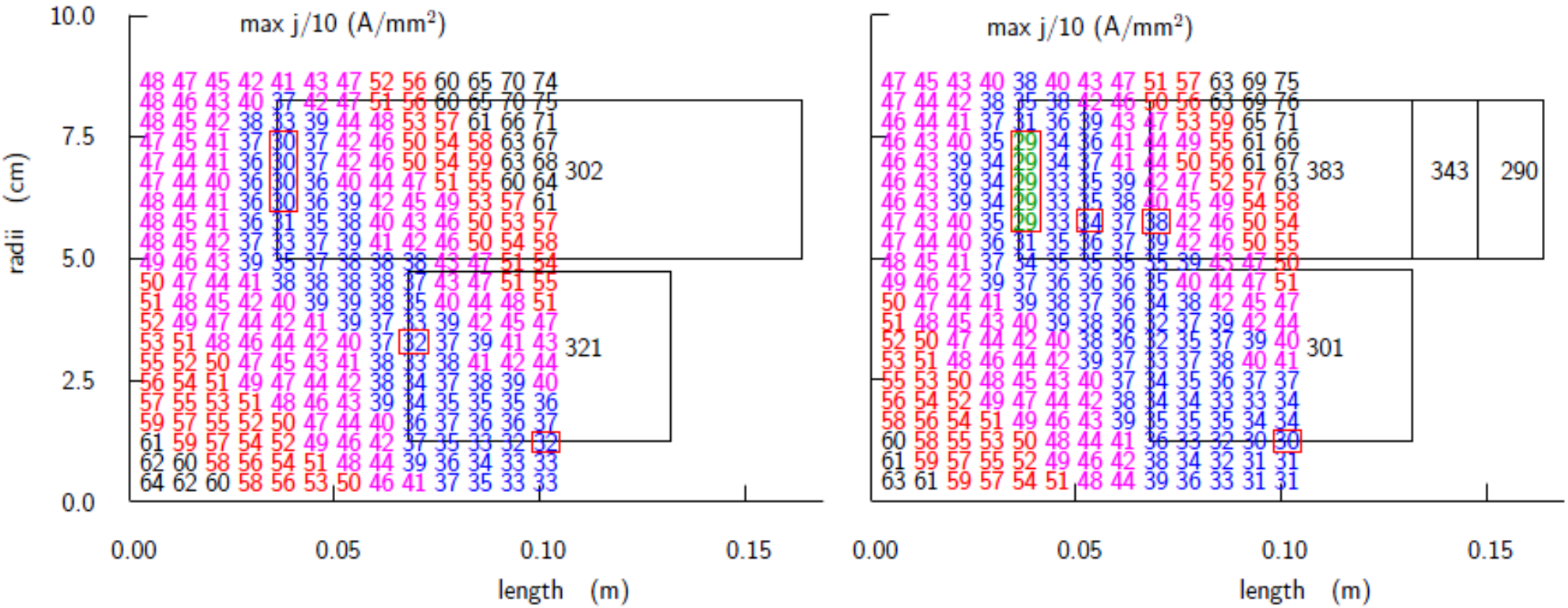
$$j(10) = \frac{720}{(4.4 + \underset{\text{ins}}{0.13})(0.145 + \underset{\text{ins}}{.025})} = 935 A/mm^2$$



- B and angle dependence from NHMFL
- Absolute normalization from Barsi (FNAL)

$$j = 1140\ (1\ -\ 0.018\ B)\ \exp -(0.057 - .0001(B - 20)^2)\ \theta \quad (\mathrm{A/mm^2})$$

Match maximum allowed currents including angle



- Lowest maximums are on coil ends
- If all powered with same current Bmax=38.9 T
- Currents lowered on end 4 pancakes: B→ 39.9 T
- If Bi-2212 coils added: Bmax → 40.5 T

Conclusion

- Several designs of 50 T 'all super conducting' magnets have been published
- Yet doubts remain as to whether they are realistic

- This test will apply the Bob Wilson approach: Start building something

- Designing a 19 T super conducting magnet is straightforward
  and can be done with Nb3Sn at 2 degrees, so

- If this test is successful
  - Practicality of 40 T will be established
- If this test fails
  - We will have learnt a lot

- Demonstrating 50 T will be more expensive
  because there is no resistive magnet big enough to contain the HTS coils to add 31 T to it