Study 2a Front End Simulations

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NuFact04
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Study 2a

- outline
  - part of 2004 APS study on physics of neutrinos
  - study 2a: configuration described in the report
  - files available at http://www.cap.bnl.gov/mumu/study2a/
  - study 2b: further variations on that design
- acknowledgements
  - collaborators on the front end design
    - R. Palmer, J. Gallardo, H. Kirk (BNL)
    - D. Neuffer (FNAL)
    - K. Paul (Illinois)
  - also thanks to
    - S. Berg, Y. Fukui, M. Zisman and others

Study 2a Front End

- objective: achieve significant cost reduction from FS2 neutrino factory
- major new elements

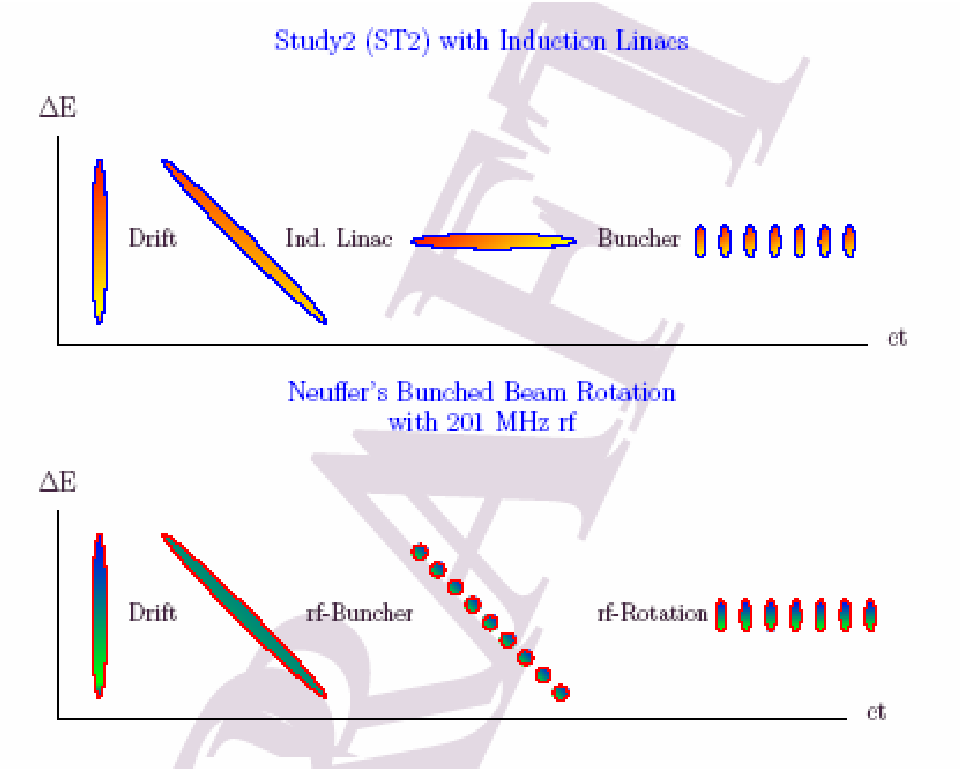
  (1) adiabatic RF bunching and phase rotation (D. Neuffer, FNAL)
    - eliminate induction linacs

  (2) new linac front end with A_{TN} = 30 mm acceptance (R. Palmer et al)

  (3) new simplified cooler design (R. Palmer)
    - fewer components
    - lower peak magnetic field

Adiabatic buncher and phase rotation

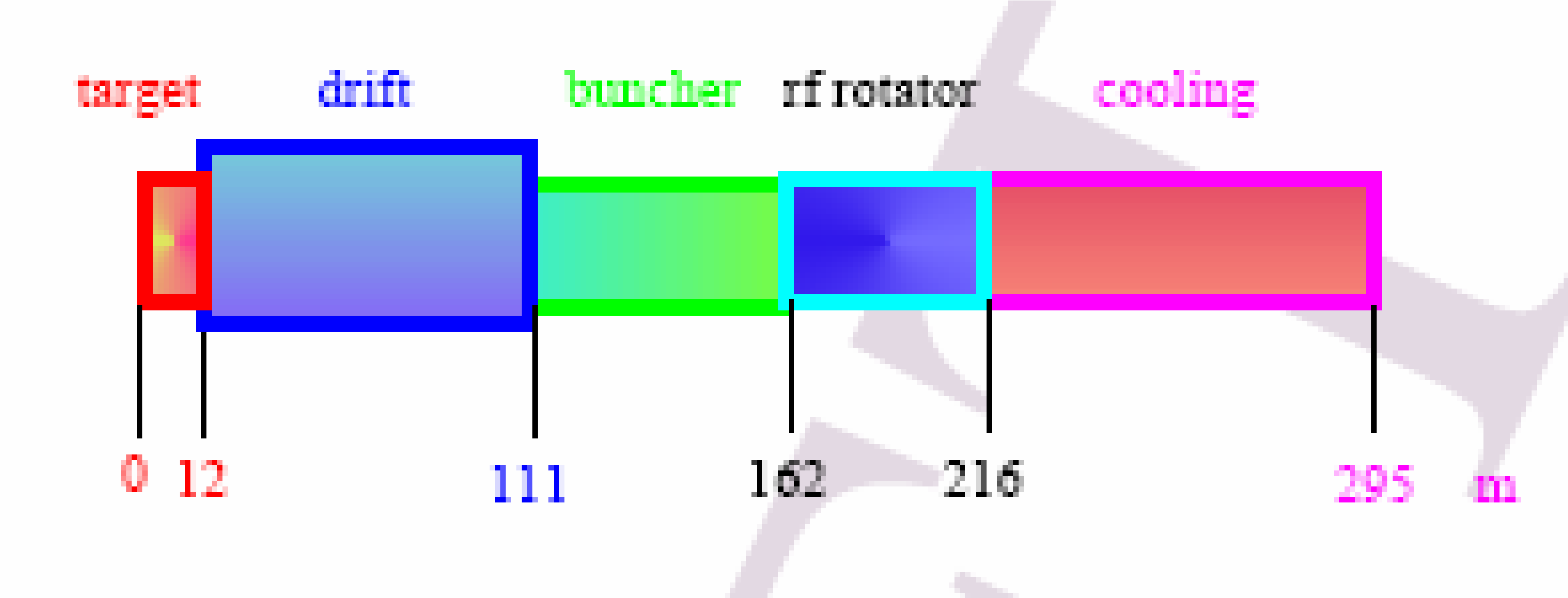
- this new concept had major influence on front end design



(figure, R. Palmer & J. Gallardo)

Study 2a front end design

- overall configuration designed by R. Palmer



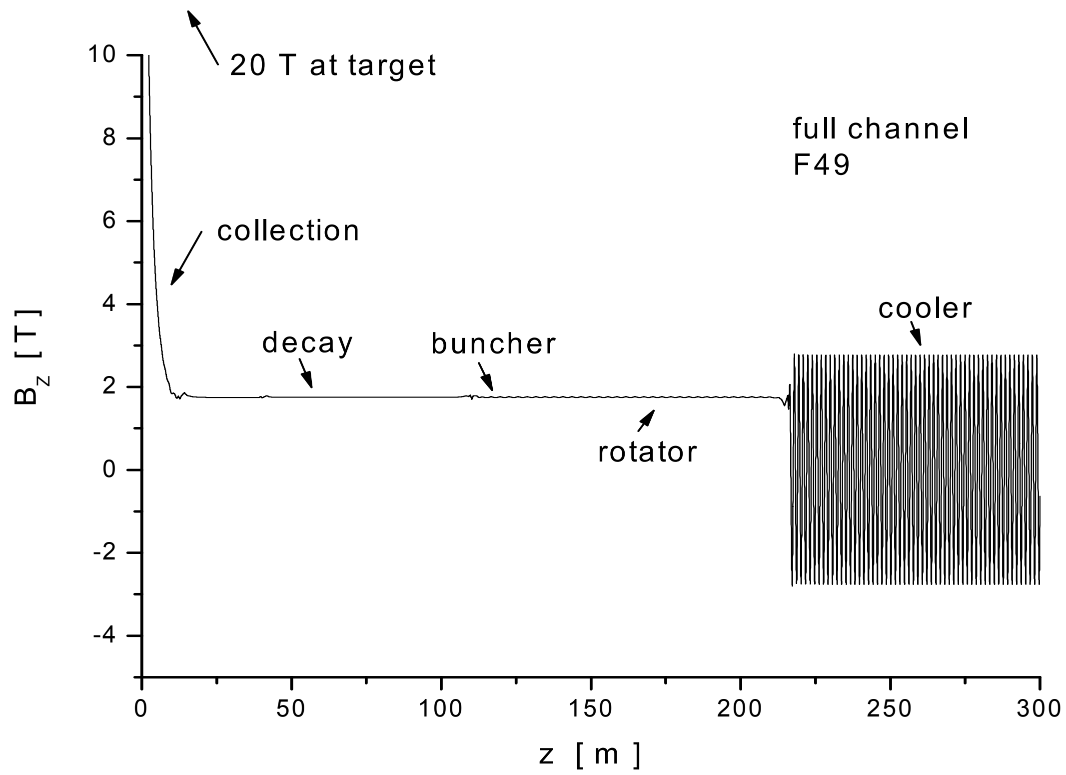
(figure, J. Gallardo)

Realistic design

- Mawellian field from table of coils
  - constant fields → periodic solenoids
  - careful matching at transitions
  - coils near the target moved radially for extra lifetime
  - optimized collection profile
- radial constraint from tapered beam pipe
- RF windows in buncher
- discrete frequency buncher and rotator cavities
- cooler frequency exactly at 201.25 MHz
- Be coating over LiH absorbers
- new beam distribution using new B over target

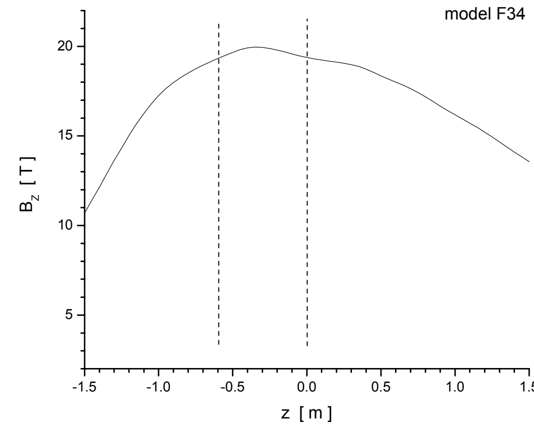
Field configuration

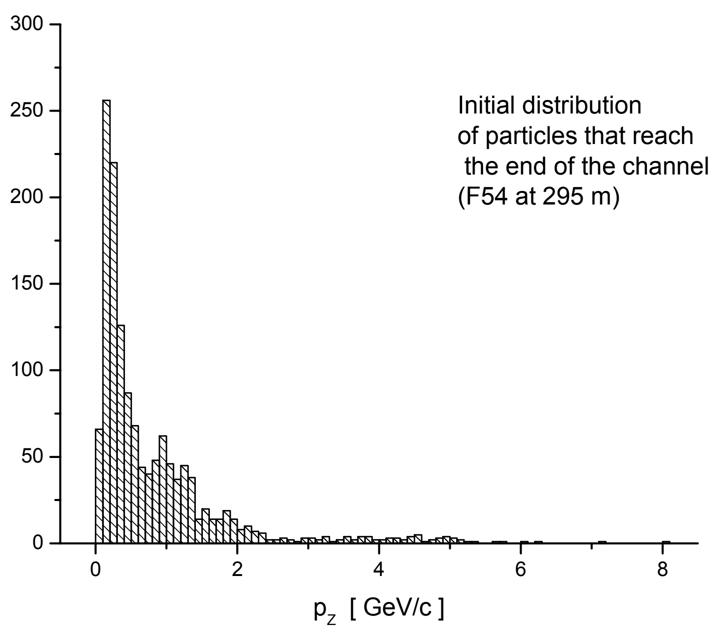
- front end uses 460 solenoid magnets
- most of the channel has ~constant 1.75 T field
- field reversals start at cooler

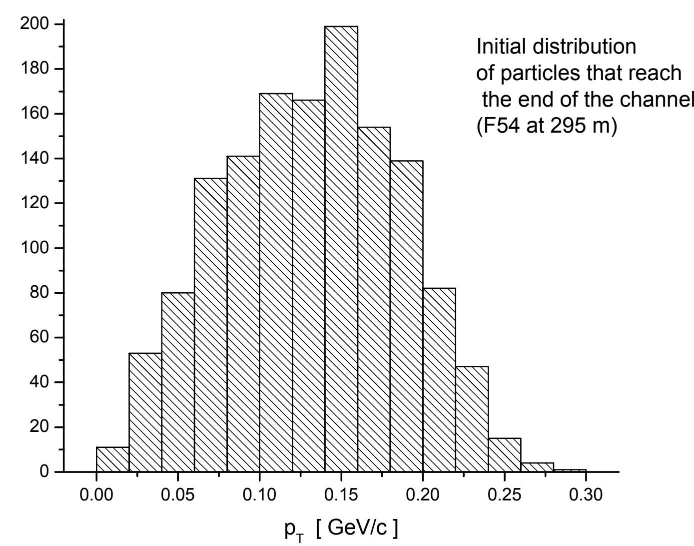


Target

- similar to FS2 design
- 24 GeV protons on Hg jet
- jet at 100 mr from B axis, beam 67 mr from B axis
- particle creation using MARS (H. Kirk)

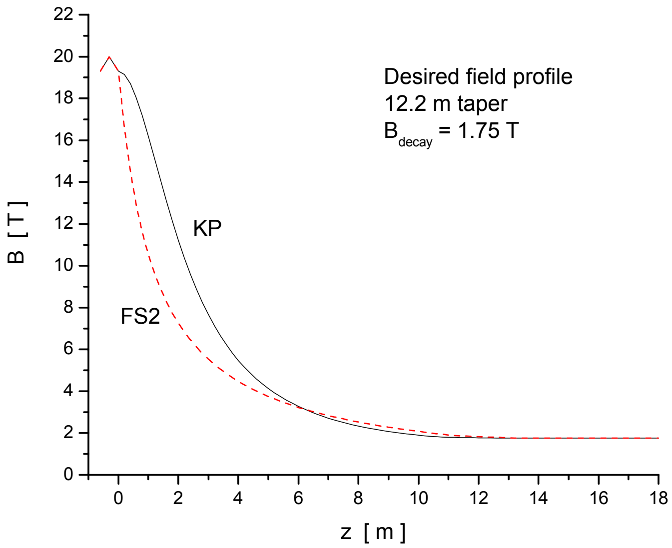


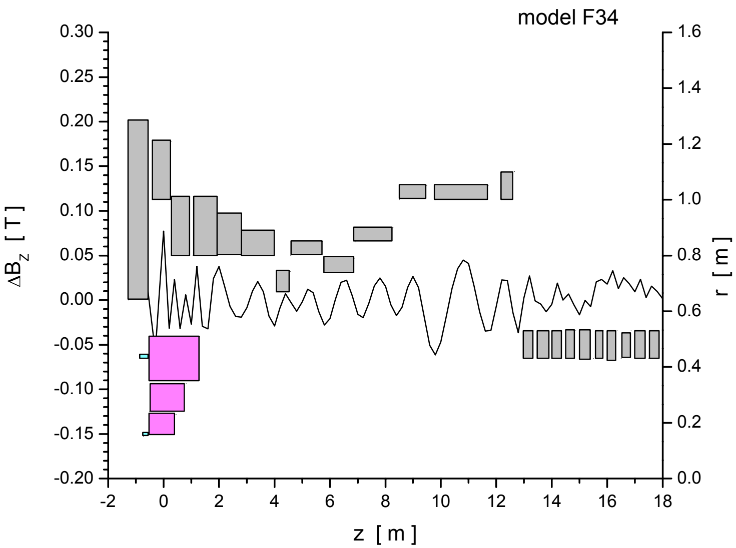




Pion/muon collection

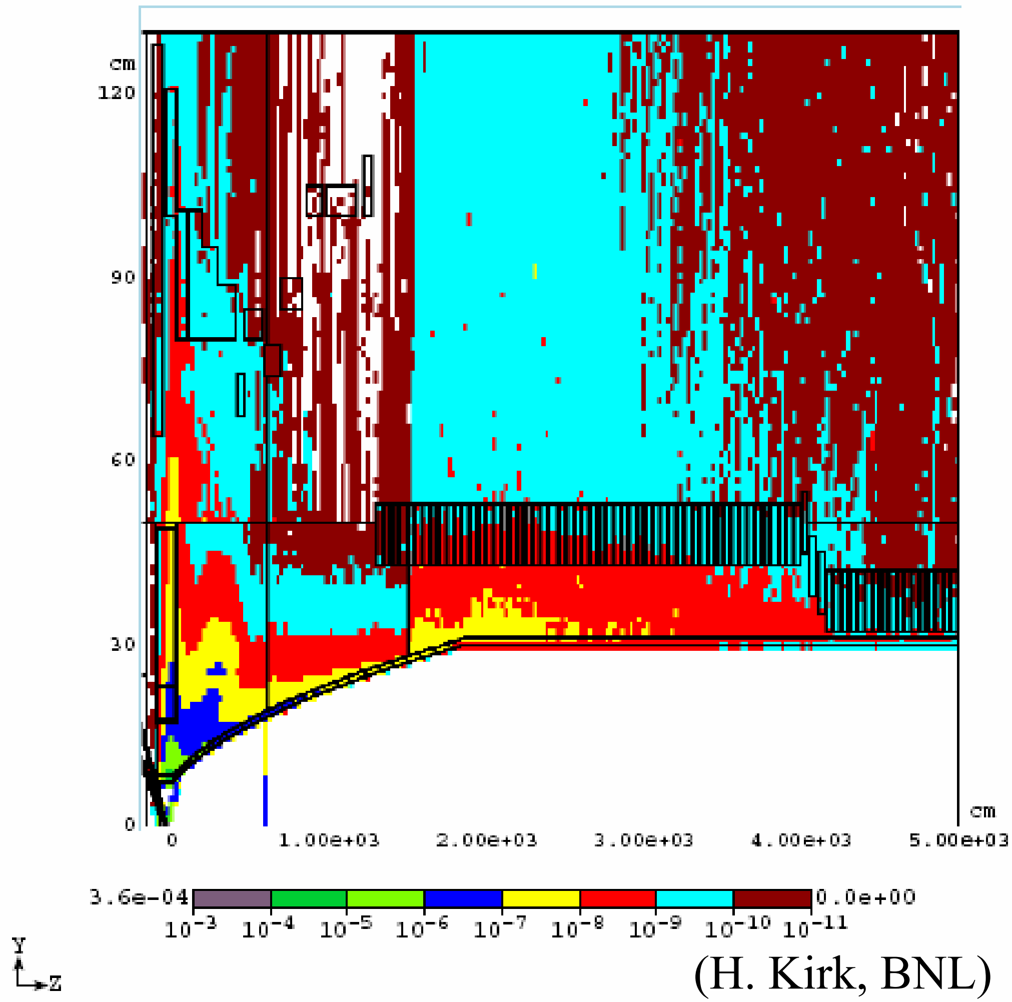
- 12.2 m taper from 20 T to 1.75 T
- improved collection design (K. Paul, U. Illinois)
- increased accepted μ / p by ~10%





Radiation

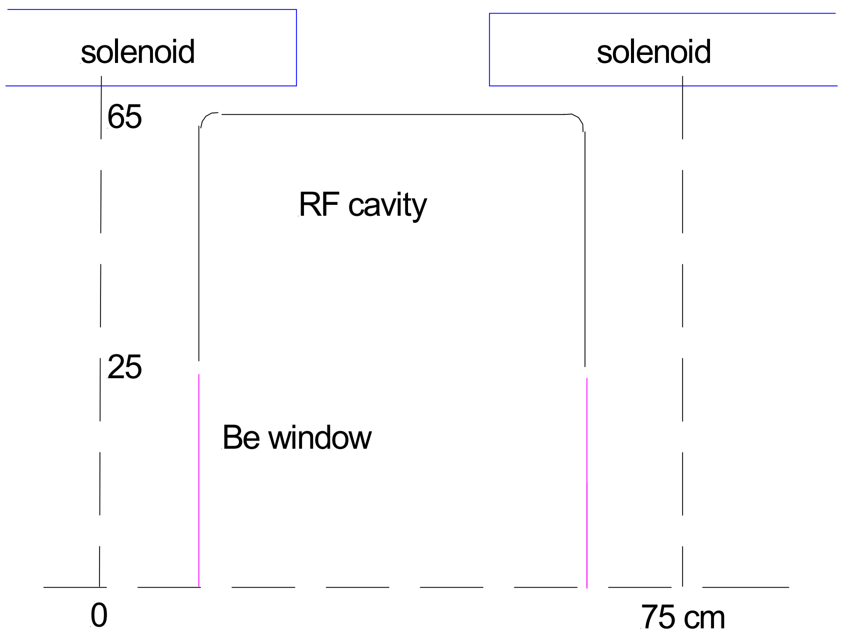
- MARS calculations
  of absorbed dose (H. Kirk)
- peak deposition in SC coils
  is ~ 1MGy/yr
- no problem with SC lifetime

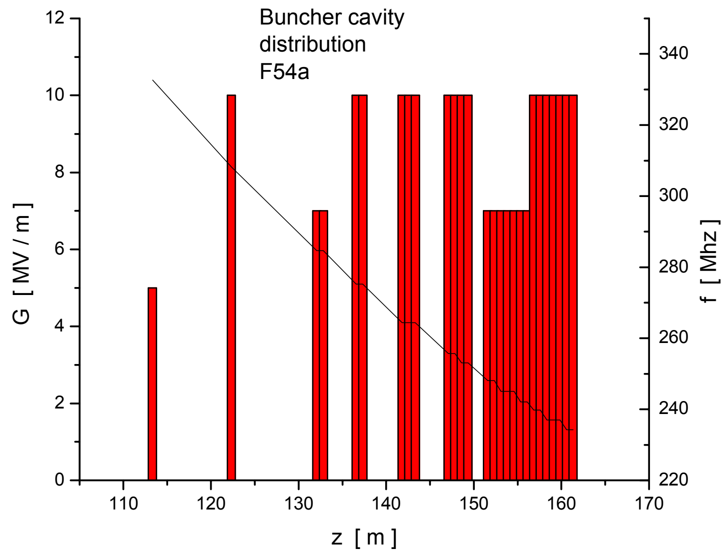


(H. Kirk, BNL)

Buncher configuration

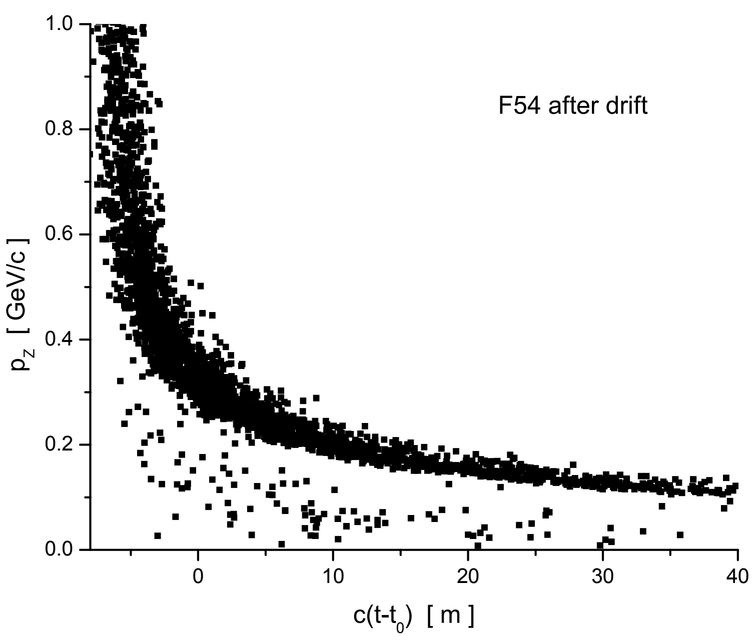
- 51 m long
- 27 cavities with 13 different frequencies (333→234 MHz)
- gradients (5 → 10 MV/m)
- window thickness (200 – 395 μm)

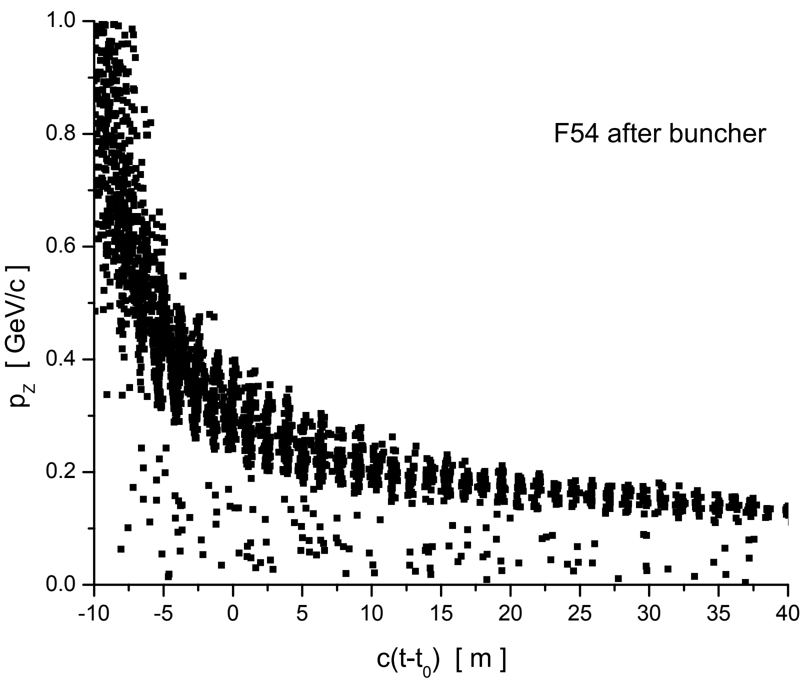




Buncher performance

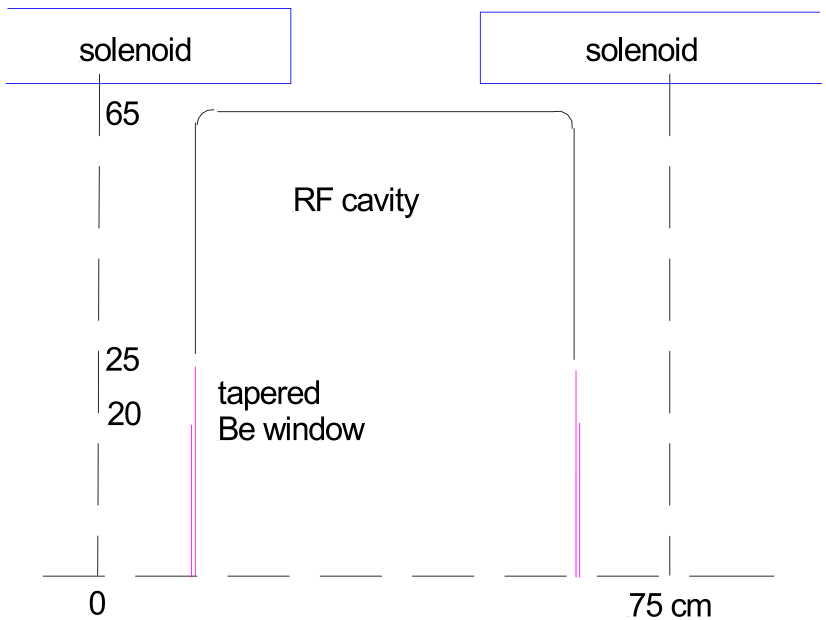
- 92 bunches in train at 295 m

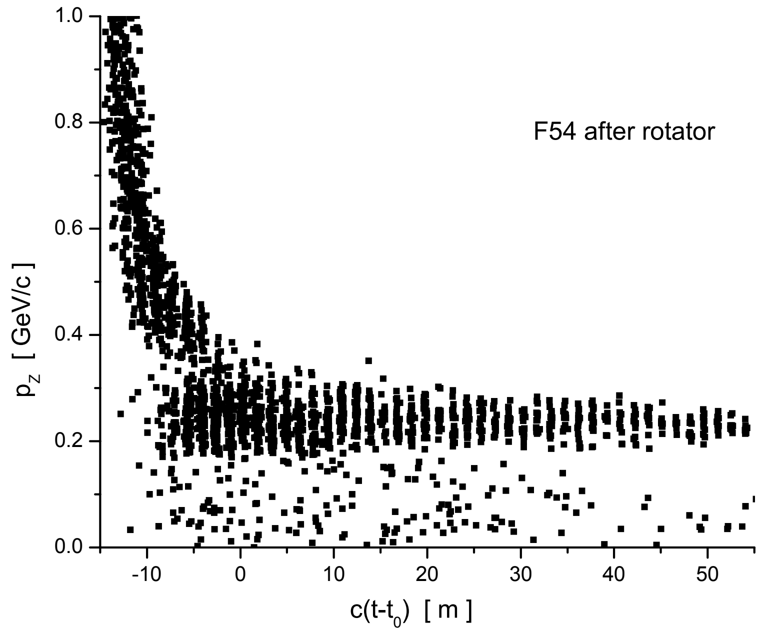




Rotator

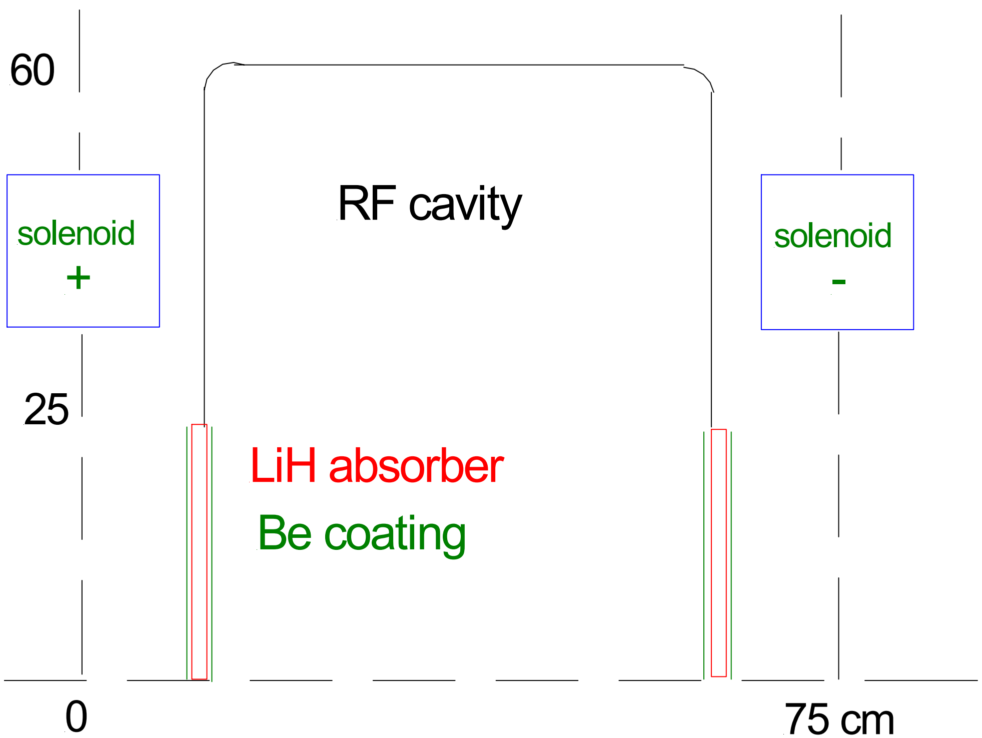
- 54 m long
- 72 cavities with 15 different frequencies (232→201 MHz)
- gradient 12.5 MV/m
- window thickness (750 + 750 μm)

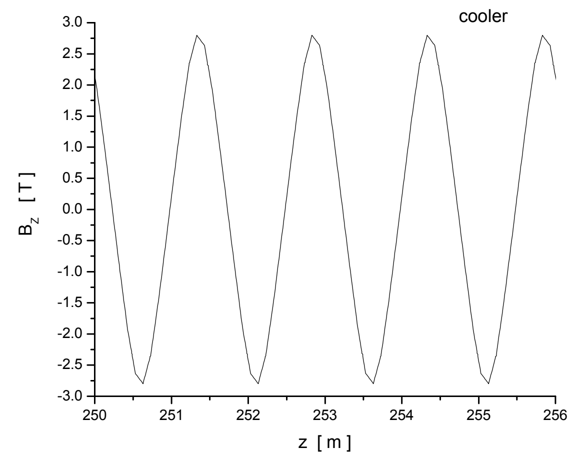


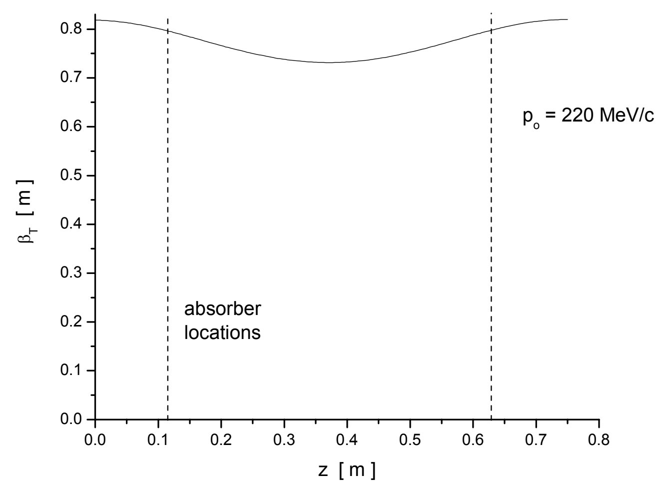


Cooler design

- 80 m long alternating solenoid channel, $B_S = 2.8$ T
- large, relatively flat $\beta_\perp \sim 80$ cm
- use LiH absorbers as RF windows

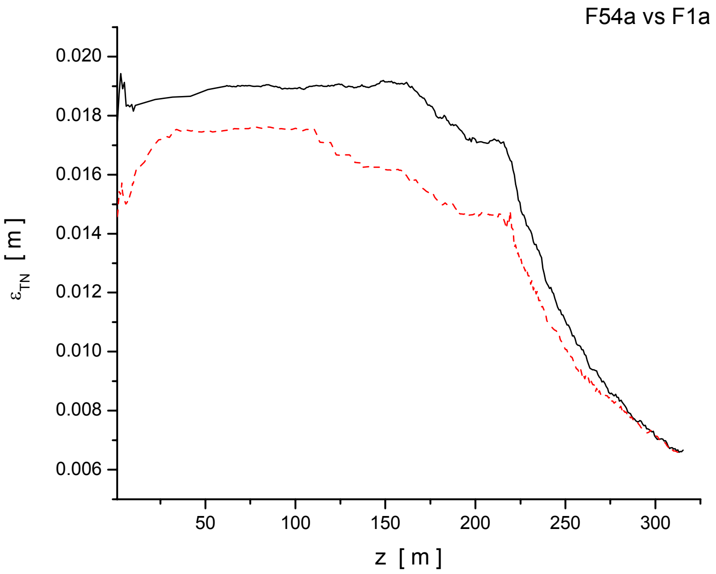


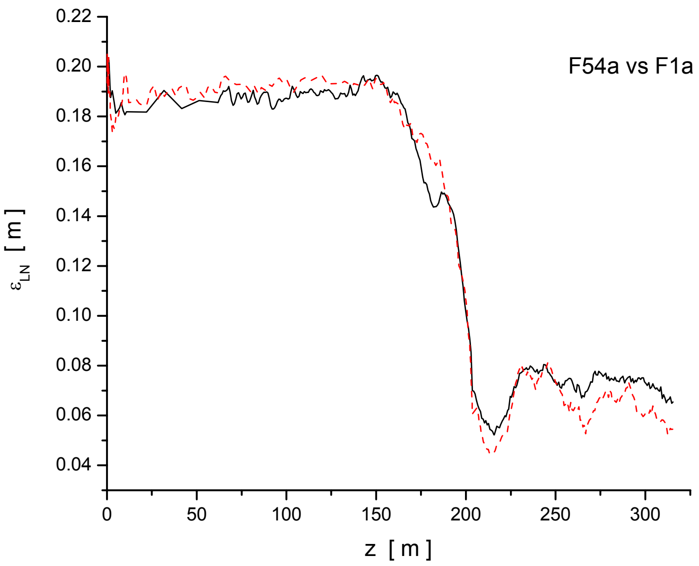




Channel performance (emittance)

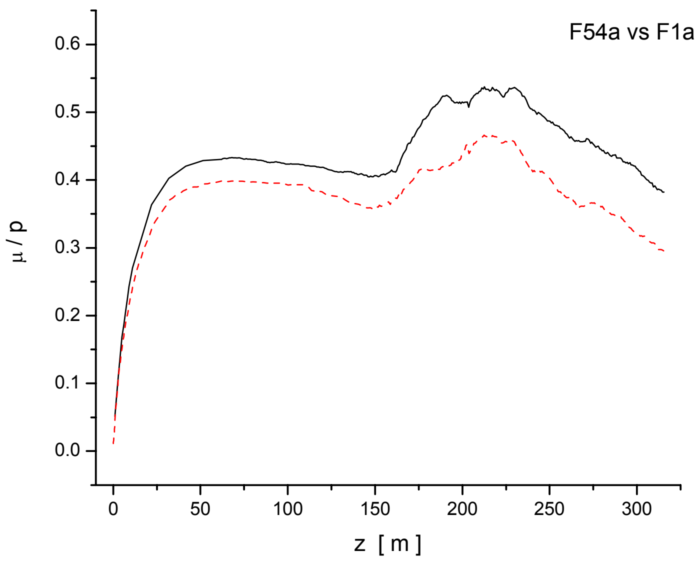
- cools normalized transverse emittance by factor of ~2
- final ε_{TN} = 7.1 mm (equilibrium value for LiH is ~5.5 mm)
- plotted emittances have 100 < p < 300 MeV/c cut

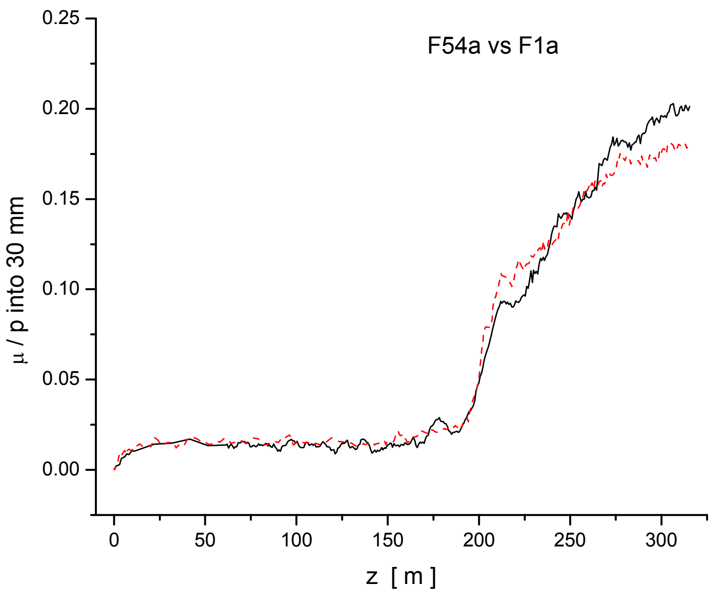




Channel performance (μ density)

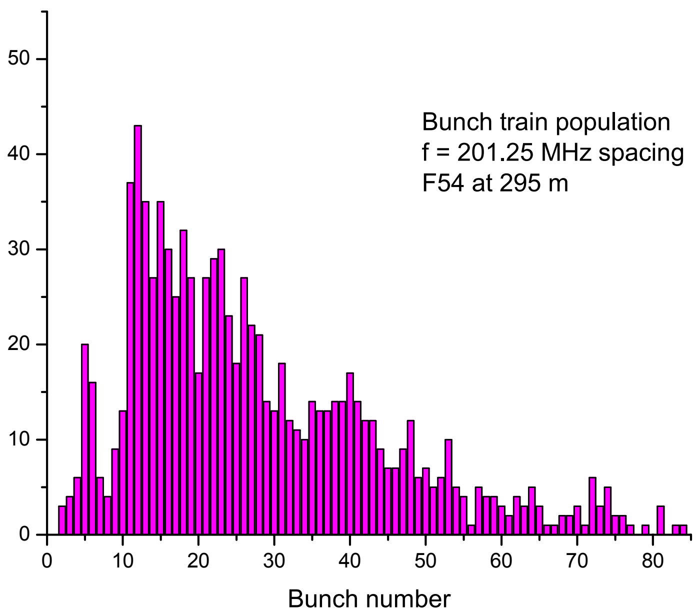
- cooling decreases total μ in Δp band by ~30%
  (decay loss is 6%)
- cooling increases μ density into accelerator acceptance by factor of 1.7

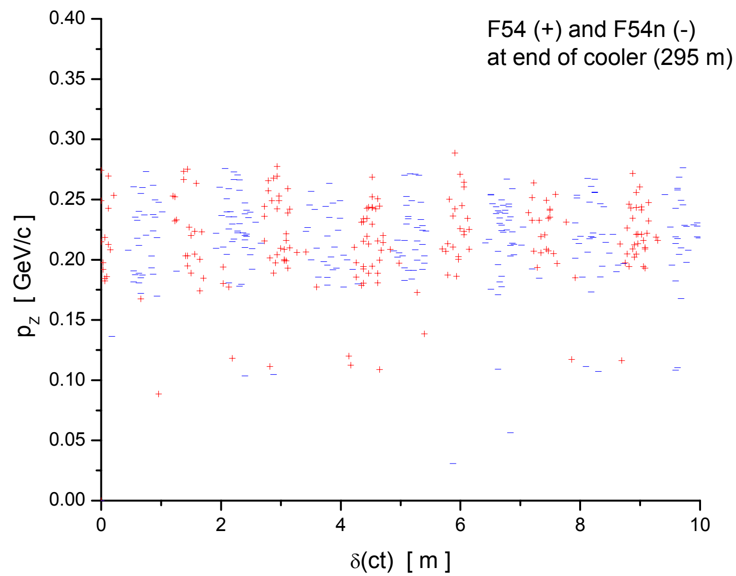




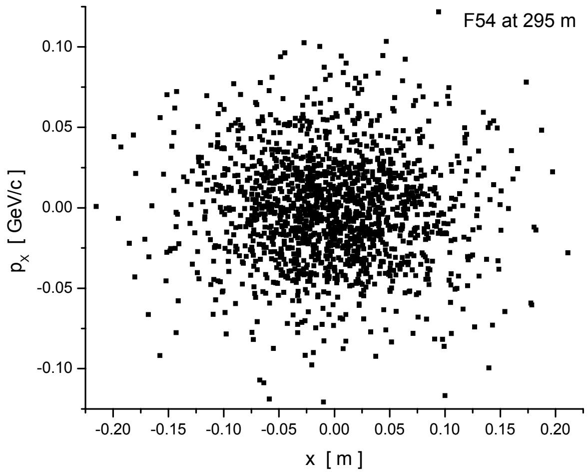
Both signs

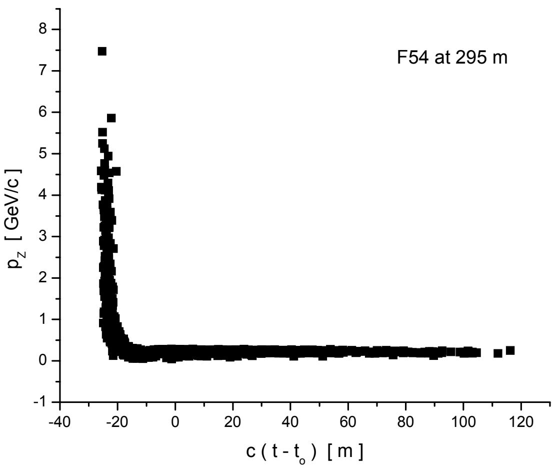
- adiabatic buncher captures both μ^+ and μ^- bunches
- distinguish μ source by timing at detector

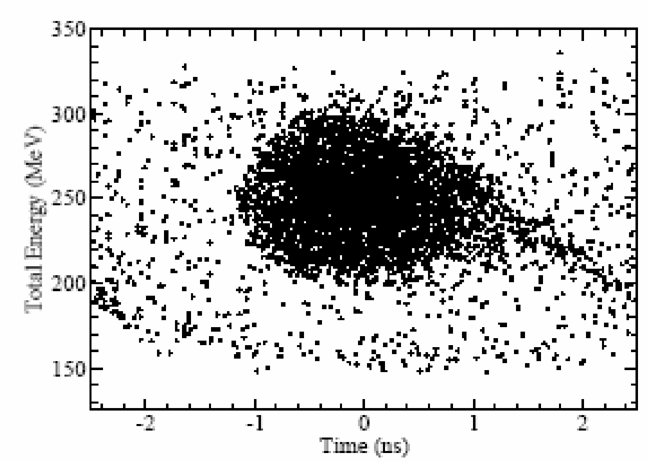




Phase space presented to accelerator







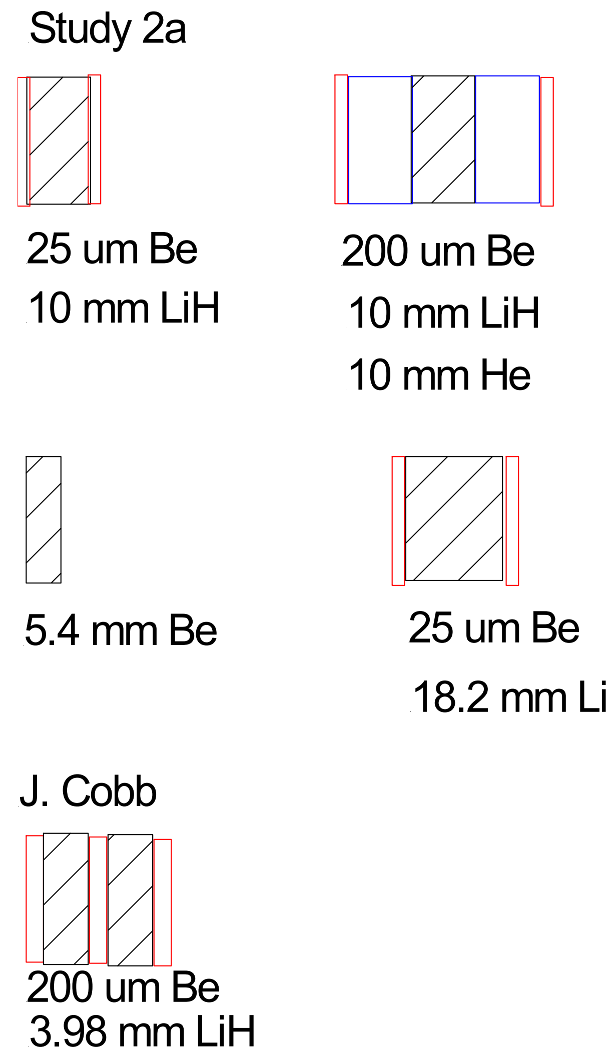
(Scott Berg, BNL)

Status of Study 2a

- current best result is $\mu / p = 0.170 \pm 0.004$ into accelerator acceptance
- achieved same performance claimed in Study 2
- but this design gives muons of both signs
  - potential gain of a factor of 2 in neutrino flux
  - preliminary front end cost estimate: 53% of FS2 (R. Palmer)
- potential problems
  - (1) no margin in delivering the required μ / p
    - reasonable cost/benefit changes drop us below 0.17 μ / p
    - reduce specs for the neutrino factory or
      modify design to increase μ / p performance margin ?
    - give up some of the cost savings from FS2 ?
  - (2) beam and RF heating of the absorber
  - (3) 15.25 MV/m needed in the cooler RF cavities
- need continued R&D

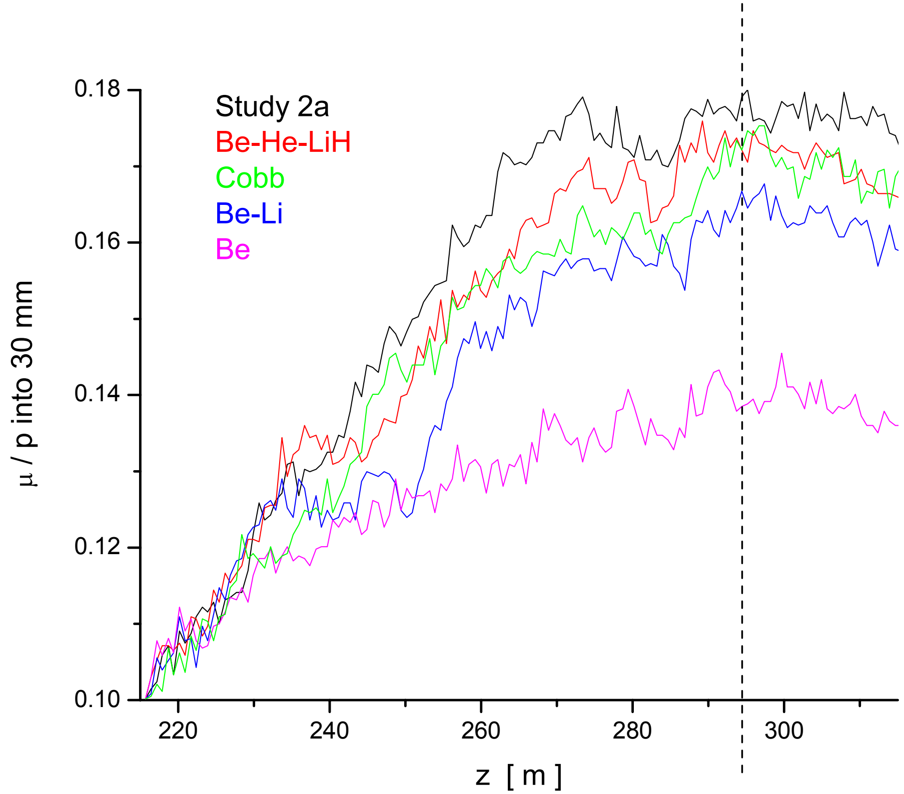
Alternate absorber designs (Study 2b)

- many unresolved issues
- can we "deposit" or bond a thin Be coating on LiH?
- heating, melting, differential stresses
  - $P_{BEAM} = 60$ W
  - $P_{RF} = 220$ W
  - non-uniform deposition
  - FEA studies at Oxford University
- radiation damage
  - degradation of material properties
  - release of H_2 from LiH?



Absorber performance

- Study 2a performance is still the best
- helium-cooled and sandwich arrangements are only slightly worse
- Li may be OK, but Be is probably unacceptable



Other potential studies

- does new field taper really gain 10% in performance?
- need absorber before buncher to stop protons from target?
- try shorter RF cells at start of buncher
  50 cm is inefficient for early, high frequency cavities
- try shorter rotator section
  54 m is long compared to earlier designs
- reexamine old β_T=70 cm match into cooler
- Geant simulation of Study 2a channel