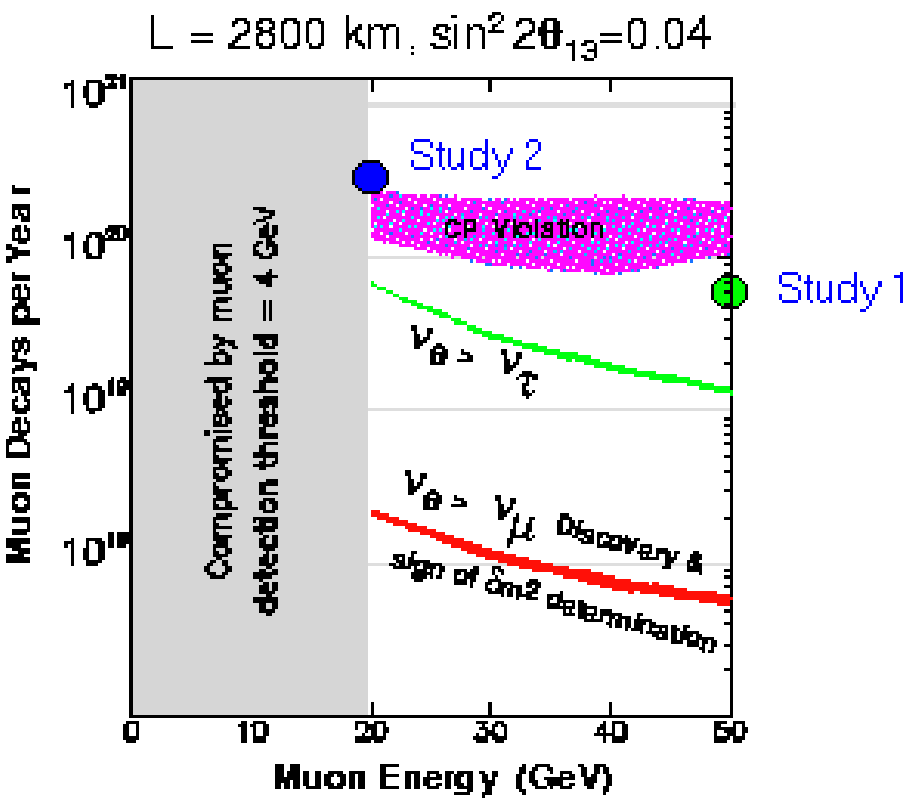
US ν Factory Studies

R.B. Palmer

LBL /5/00

- **Study I**
  - sponsored by Fermi
  - finished March 00
  - 50 GeV
  - "Entry Level" ($\approx 6\ 10^{19}\ \mu/2\ 10^{7}$sec)
- **Study II**
  - sponsored by BNL
  - finished April 01
  - 20 GeV
  - "Higher Flux" ($\approx 3\ 10^{20}\ \mu/2\ 10^{7}$sec)



muon decays in straight section / $2\ 10^{7}$ sec

Performance Required by Study 2 Charge

- **AGS Driver 1 MW at 24 GeV**
- **20 GeV storage ring**
- $2\ 10^{20}\mu$**'s per** (10^7 **sec) year**

- **If 40 % straight, then**
- **≈0.2** μ**/p at 24 GeV**

- **equiv. to ≈.13** μ**/p at 16 GeV**
- **c.f. Study 1: ≈0.018** μ**/p at 16 GeV**
- **Need ≈7 × study 1 efficiency**

Designs under study

A Baseline

- no low freq RF near target
- little polarization ($\approx$ 20%)

B With low freq RF

- RF at 9 m from target
- more polarization ($\approx$ 40% ??)

C Lower initial cost

- reduced initial performance
- but with ugrade path

D Higher performance

- add emittance exchange ??
- other improvements ??

Initial Parameters for Study 2

Design A

R.B. Palmer, S. Berg, R. Fernow, Y. Fukui,
J Gallardo, C. Kim, E. Kim, H. Kirk, J. Miller,
N. Mokhov, G. Penn, R. Weggel, J. Wurtele

10/4/00

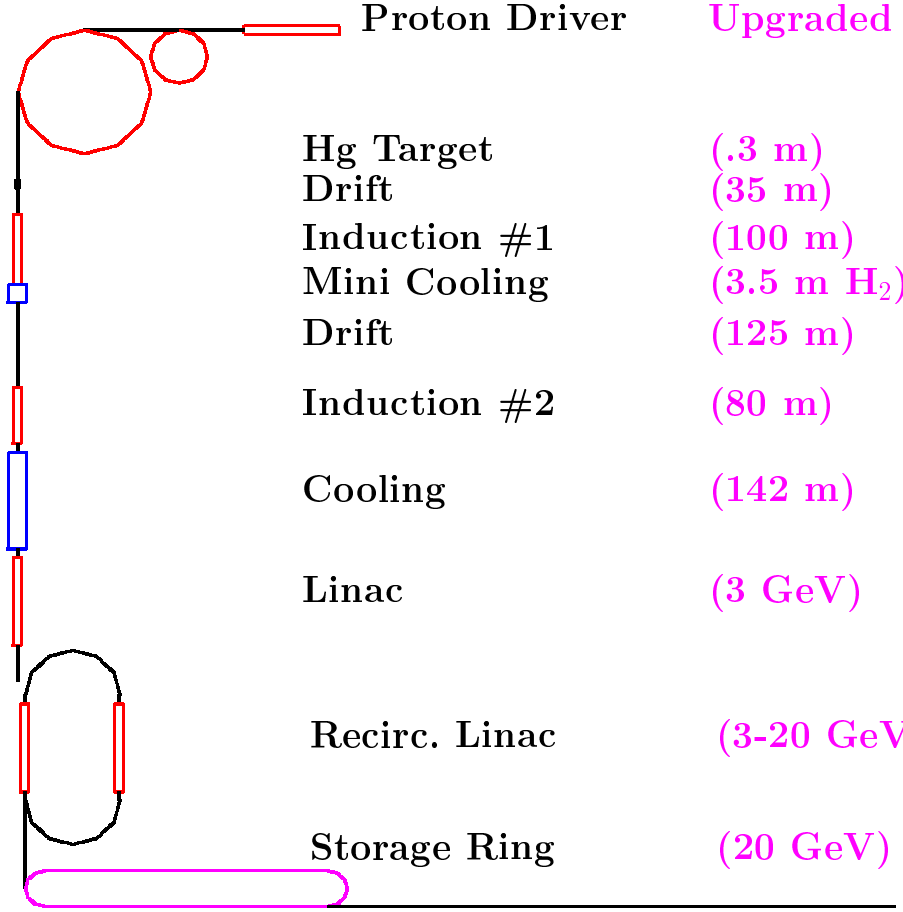
Text of "Initial Parameters" at

http://pubweb.bnl.gov/people/palmer/nu/study2/paramsA.ps

input files for ICOOL (vs 2.08) simulation at

http://pubweb.bnl.gov/people/palmer/nu/study2/icool208/

Schematic



c: aaprog scheme nupict.td

Proton driver

Energy	**24**	**GeV**
protons per bunch	$\approx$ **1.7** 10^{13}	
bunches per fill	**6**	
time between extracted bunches	$\approx$ **20**	**ms**
repetition rate	**2.5**	**Hz**
rms bunch length	$\leq$ **3**	**ns**
beam power	$\geq$ **1**	**MW**

AGS Upgrades

For 1 MW:

- **Accumulator at injection energy**
- **New Magnet power supplies**
  for 2.5 Hz rep rate
- **Increased RF**
  for 2.5 Hz rep rate
- **1/4 diameter 24 GeV SC buncher ring**
  for 3 ns bunches

For 2 MW:

- **Increase linac energy**
  200 to 600 MeV

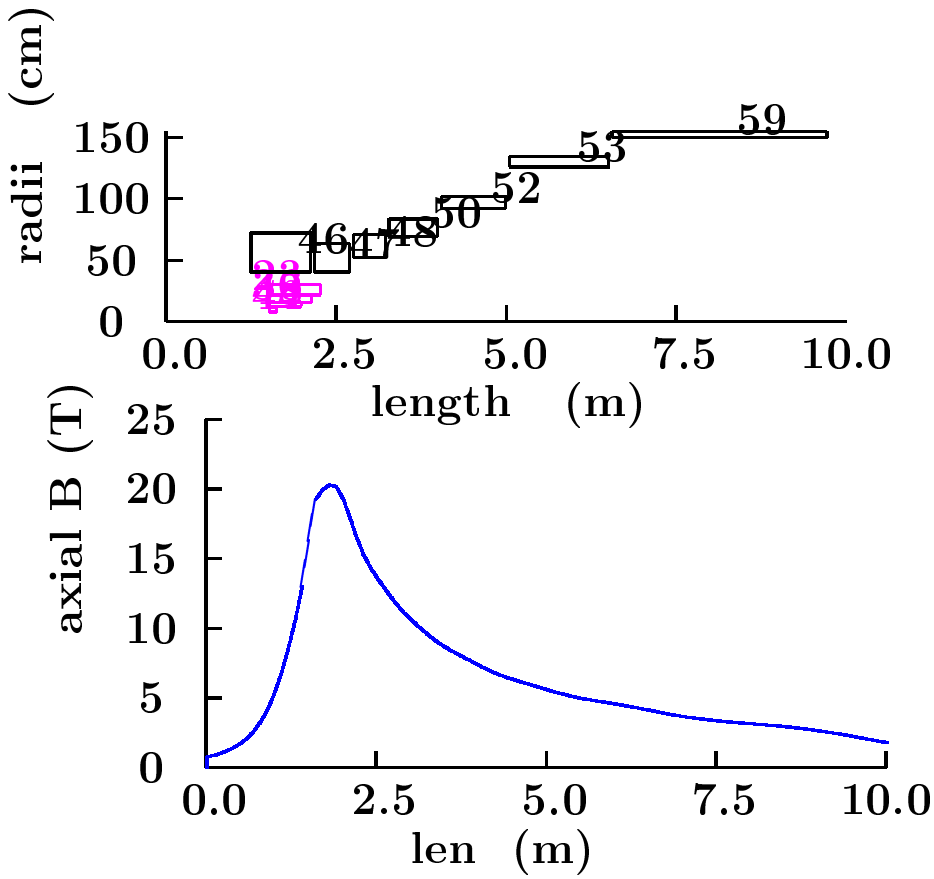
Alternative to Accumulator

- **2 GeV SC Linac**

1 Target

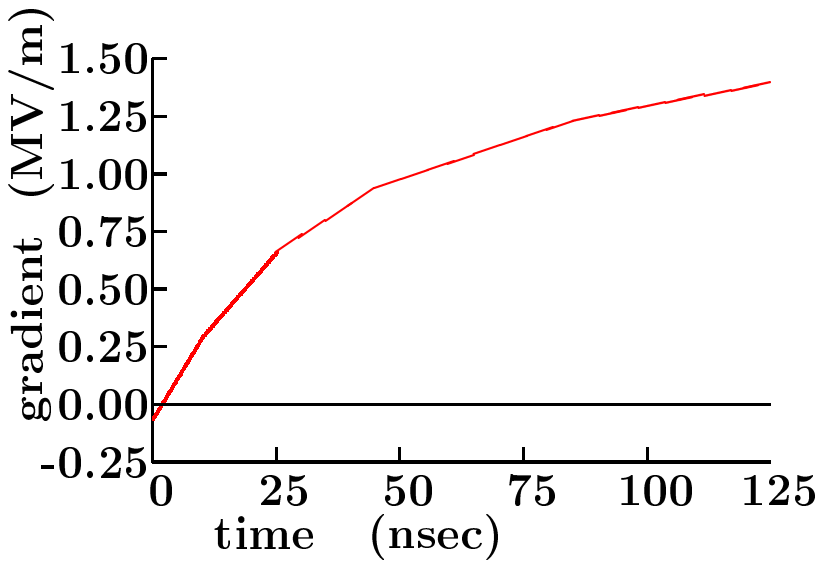
material	**mercury**	
velocity	**$\approx$ 20**	**m/sec**
length	**30**	**cm**
diameter	**1**	**cm**
angle to muon axis	**100**	**mrad**
displacement of front from axis	**$\approx$ 1**	**cm**

2 Capture and matching Solenoids



3 Induction Linac 1

length	100	m
inner radius	30	cm
Solenoid field	1.25	T
maximum gradient	1.4	MV/m
pulse length	125	nsec



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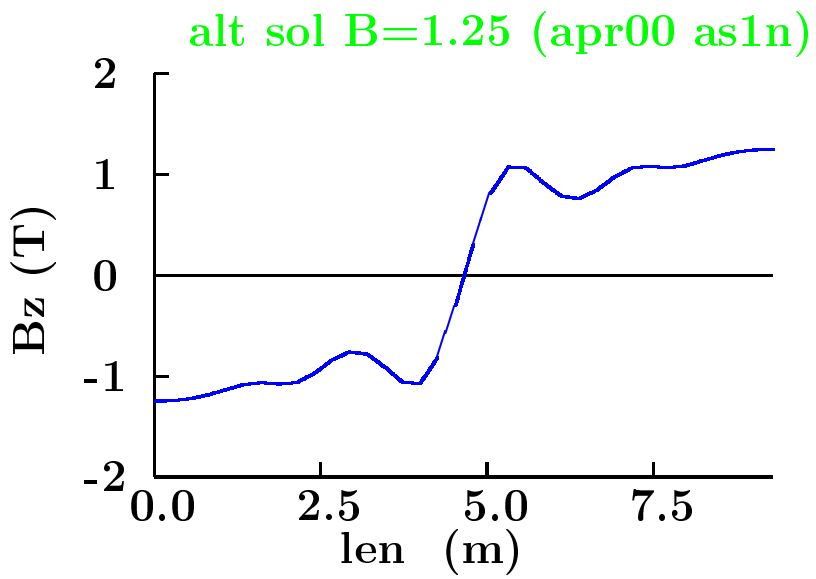
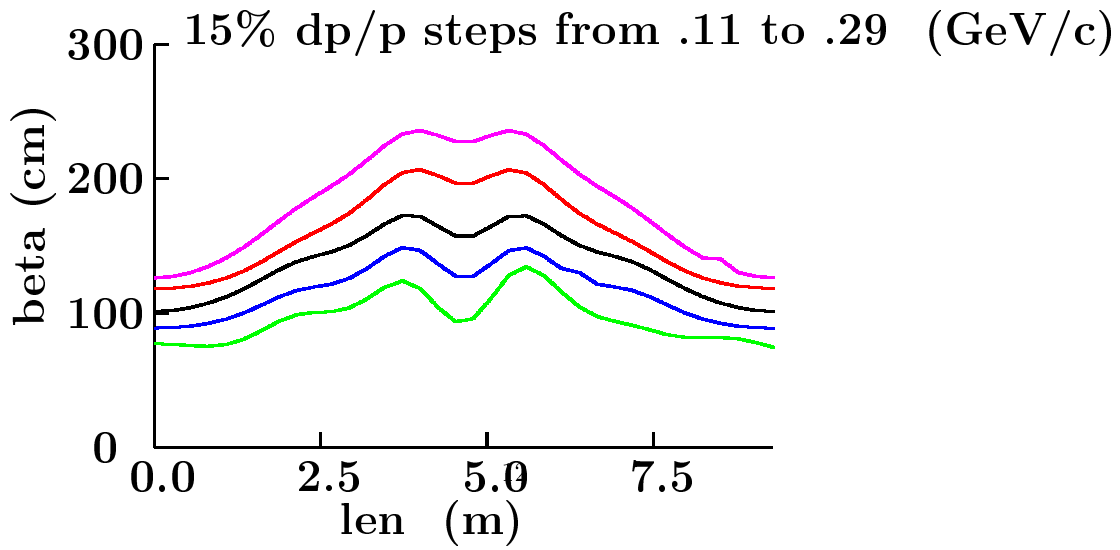
4 Mini-cooling & B reversal

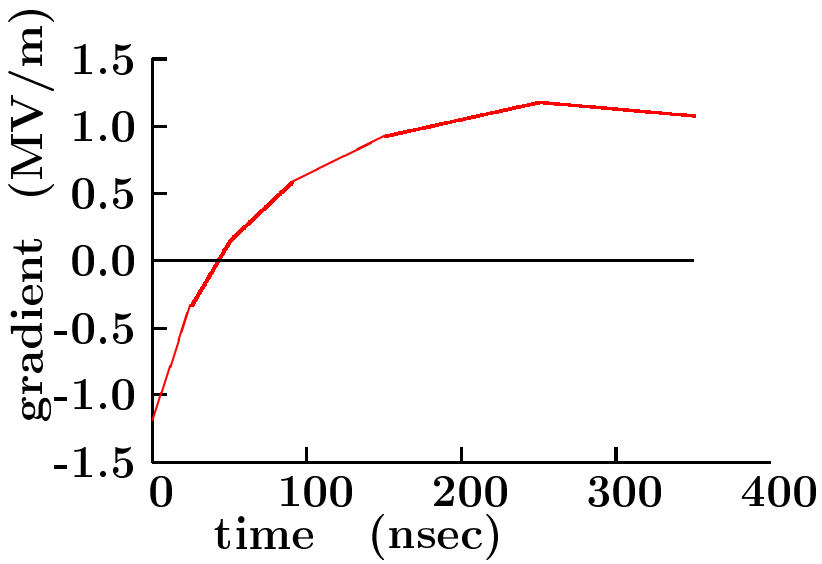
hydrogen length	2×1.75	m
hydrogen radius	30	cm
Solenoid fields	1.25	T



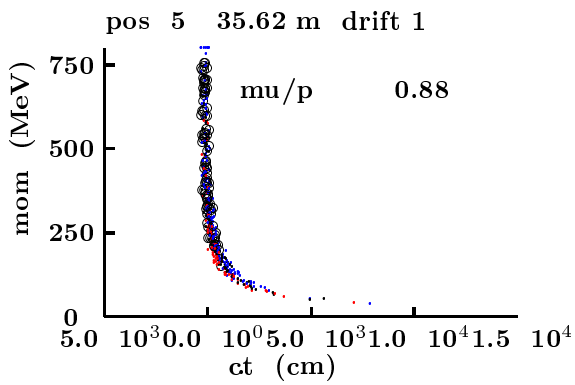


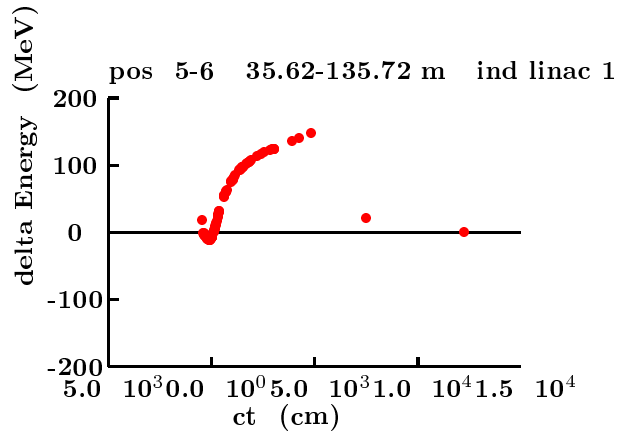
5 Induction Linac 2

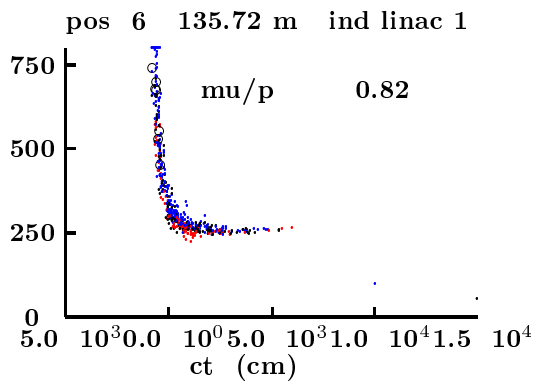
length	80	m
inner radius	30	cm
Solenoid field	1.25	T
maximum gradients	-1.10 to +1.03	MV/m
pulse length	350	nsec

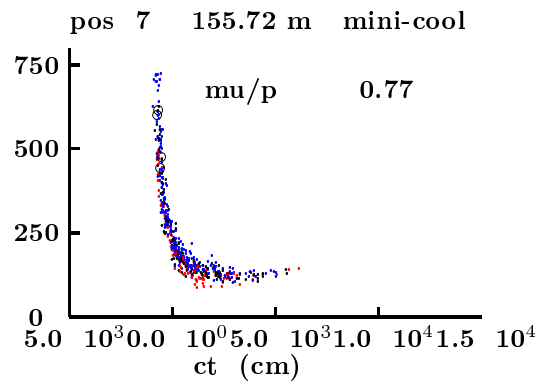


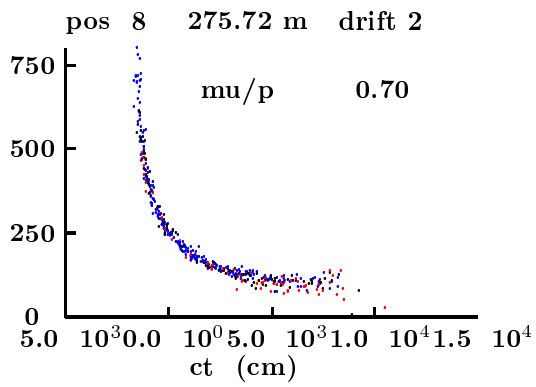
6 Phase Rotation

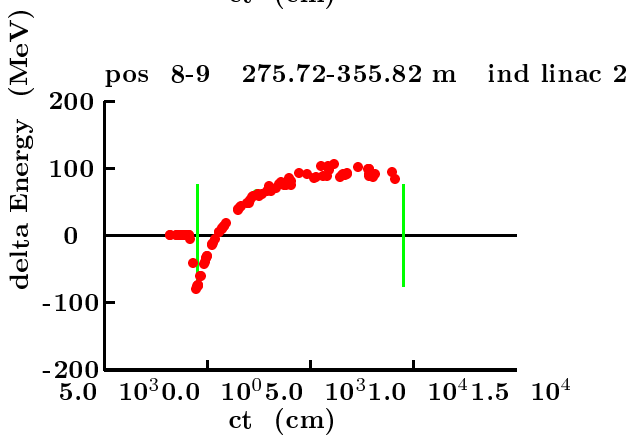


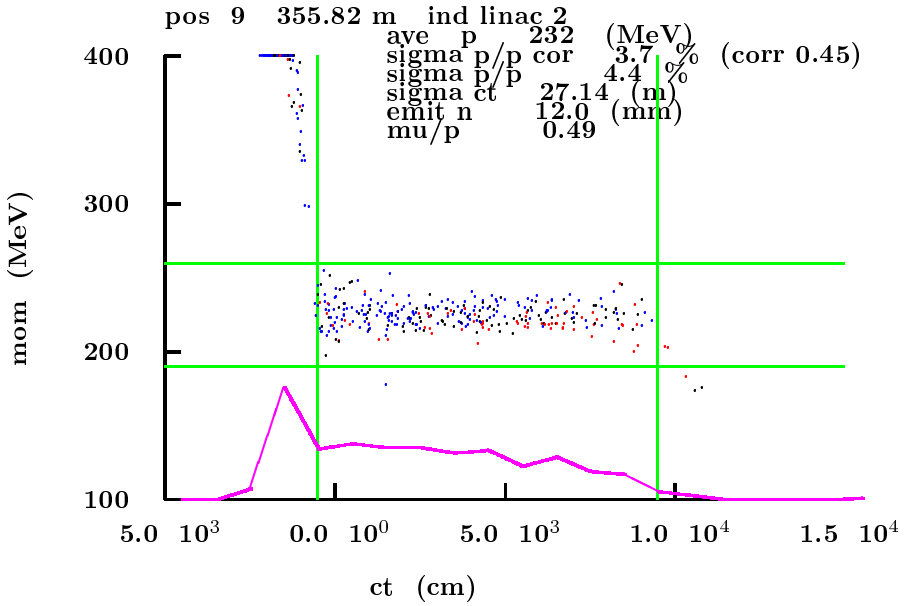


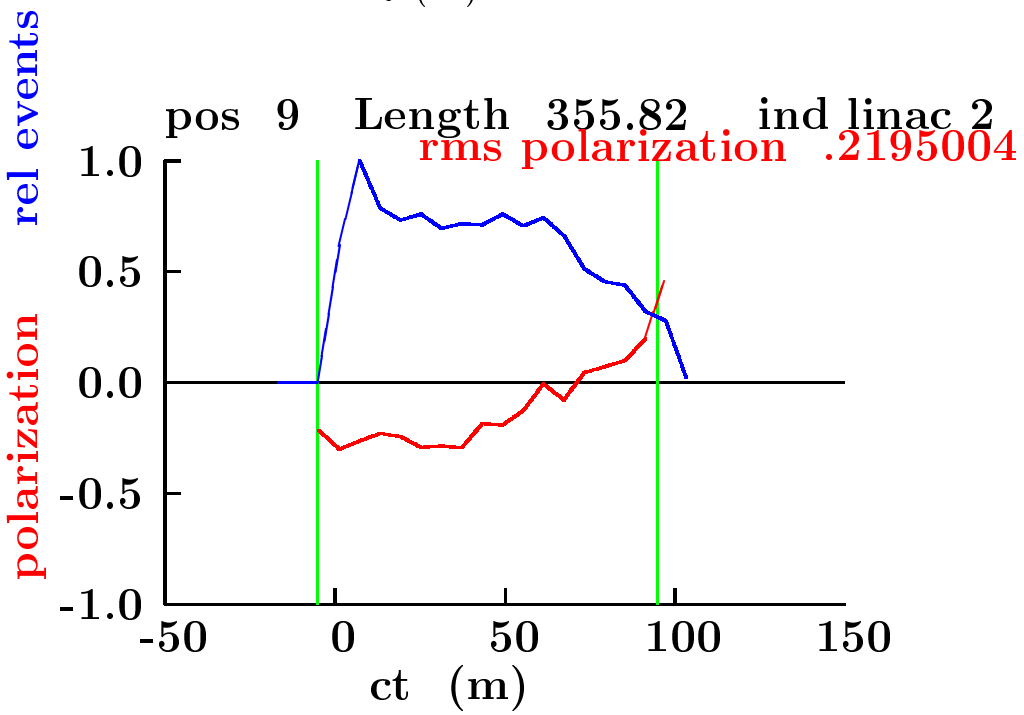


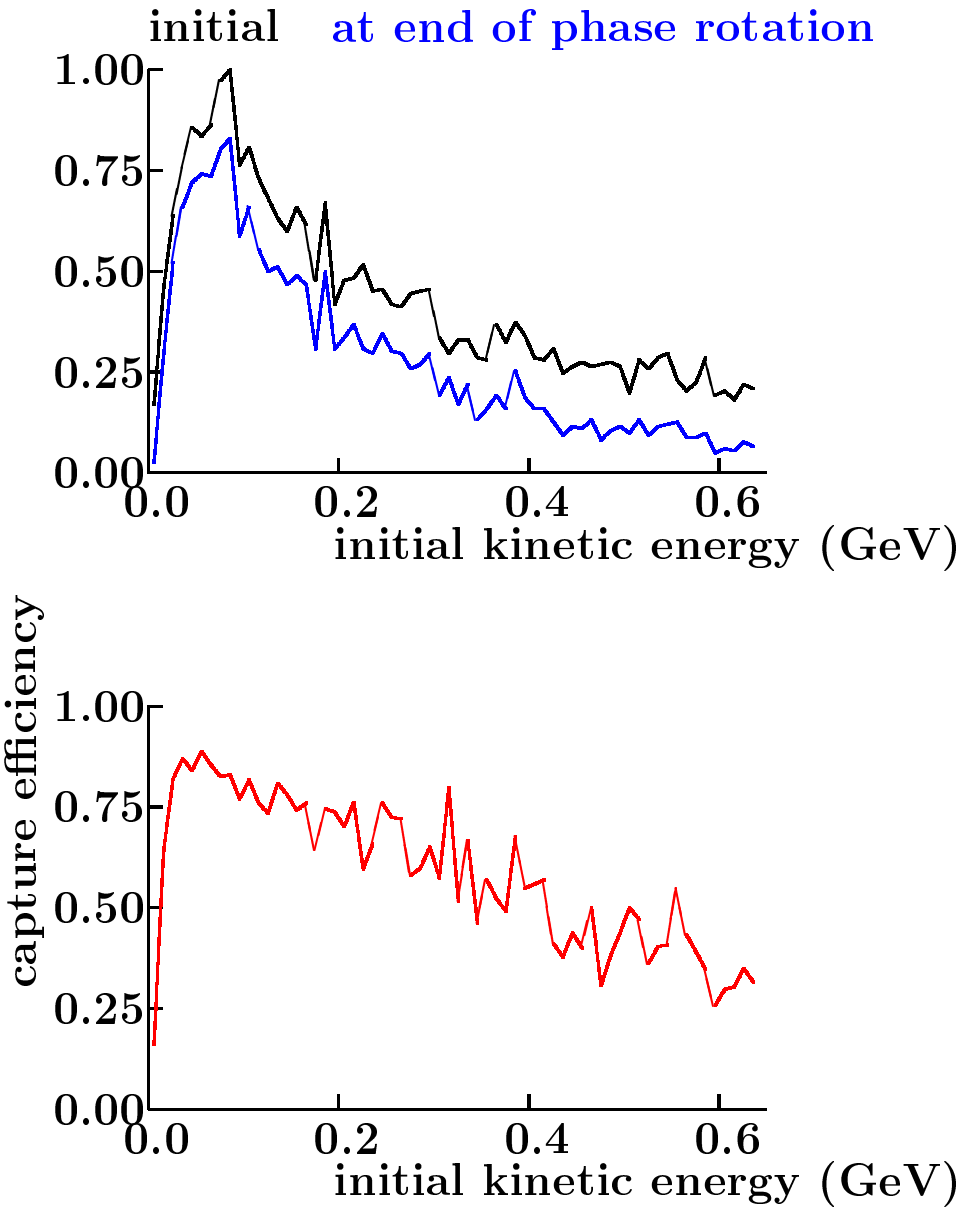






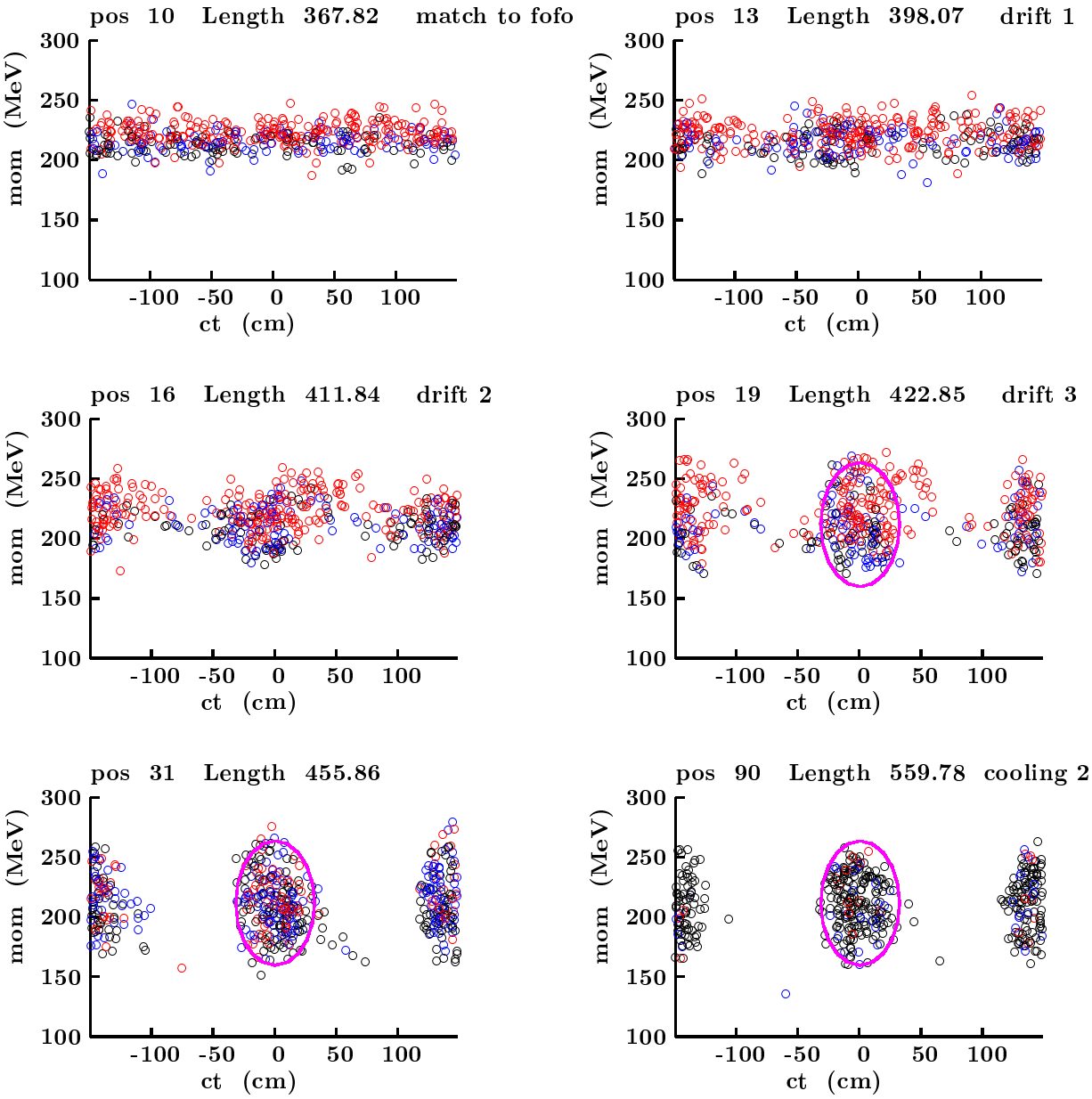

pos 9 355.82 m ind linac 2
ave p 232 (MeV)
sigma p/p cor 3.7 % (corr 0.45)
sigma p/p 4.4 %
sigma ct 27.14 (m)
emit n 12.0 (mm)
mu/p 0.49
mom (MeV)
400
300
200
100
5.0 10^3
0.0 10^0
5.0 10^3
1.0 10^4
1.5 10^4
ct (cm)


pos 9 Length 355.82 ind linac 2
rms polarization .2195004
rel events
polarization
1.0
0.5
0.0
-0.5
-1.0
-50
0
50
100
150
ct (m)

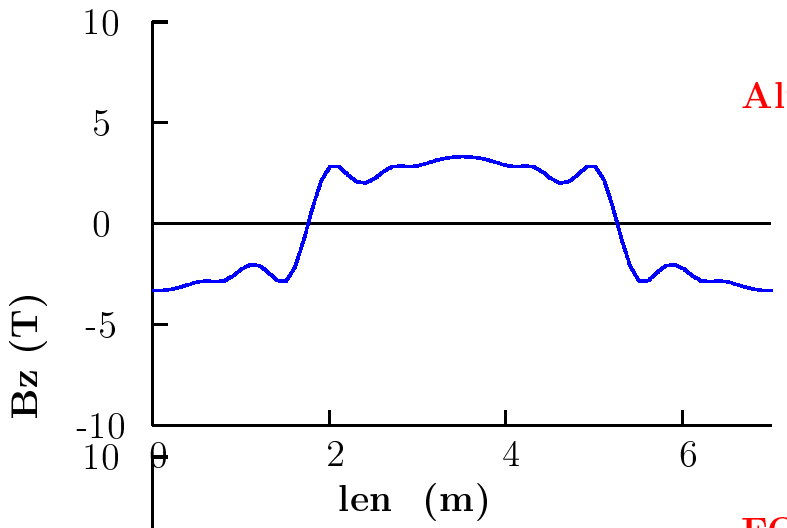

initial
at end of phase rotation
1.00
0.75
0.50
0.25
0.00
0.0
0.2
0.4
0.6
initial kinetic energy (GeV)
capture efficiency
1.00
0.75
0.50
0.25
0.00
0.0
0.2
0.4
0.6
initial kinetic energy (GeV)

7 Buncher

nd phase rotation with minicool 200 MHz 4 2 CAV (2.06 nd6)

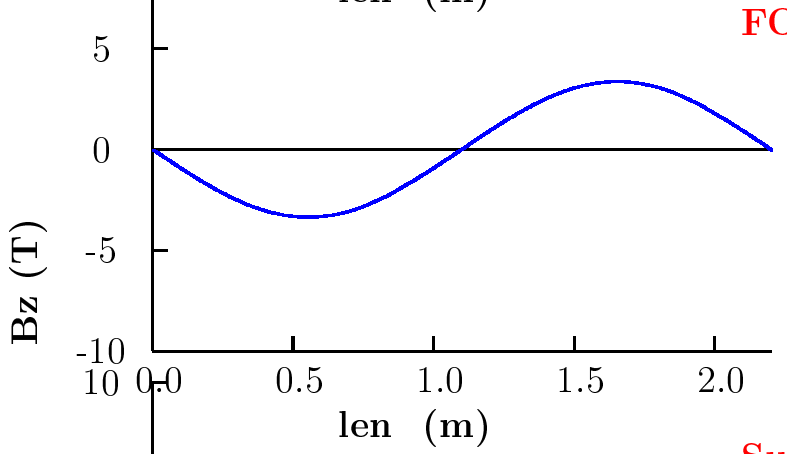


Cooling Lattices



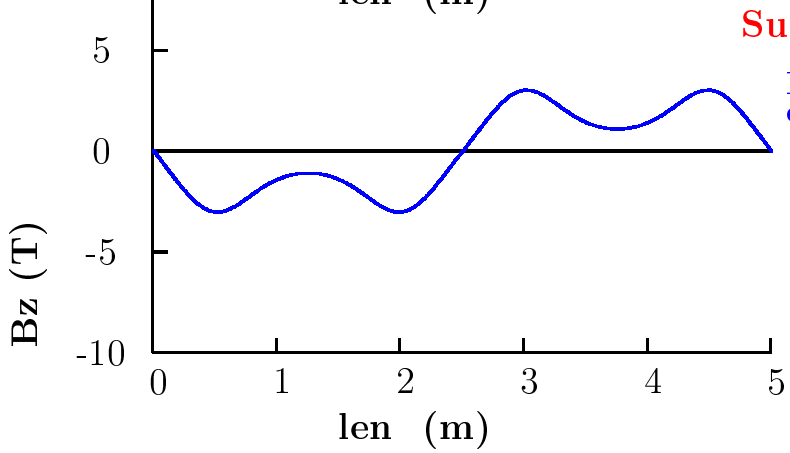
Alternating Solenoid

$B_z(\max) = 3.4$ (T)
$dB_z/dz(\max) = 15$ (T/m)



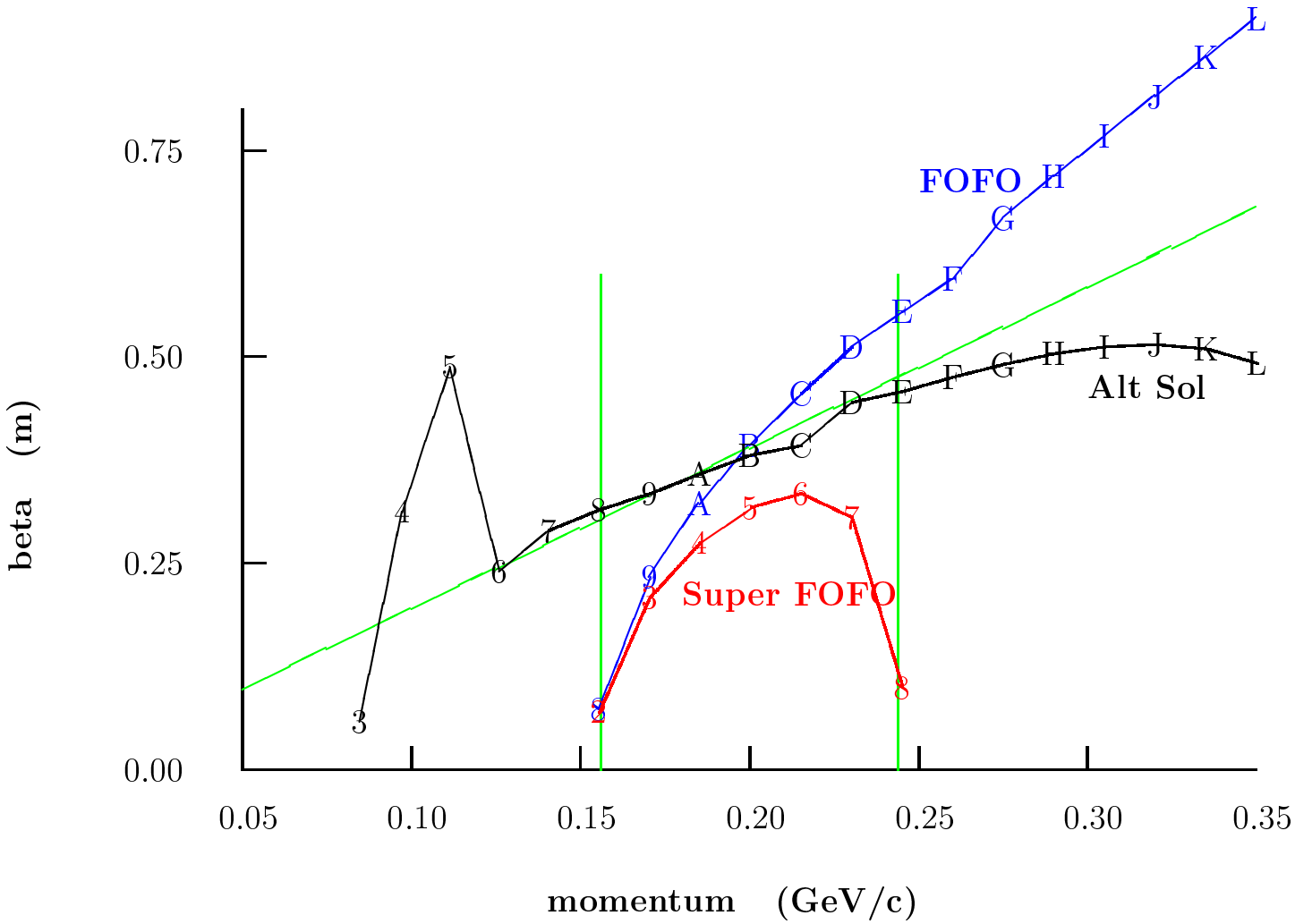
FOFO

$B_z(\max) = 3.4$ (T)
$dB_z/dz(\max) = 9.4$ (T/m)

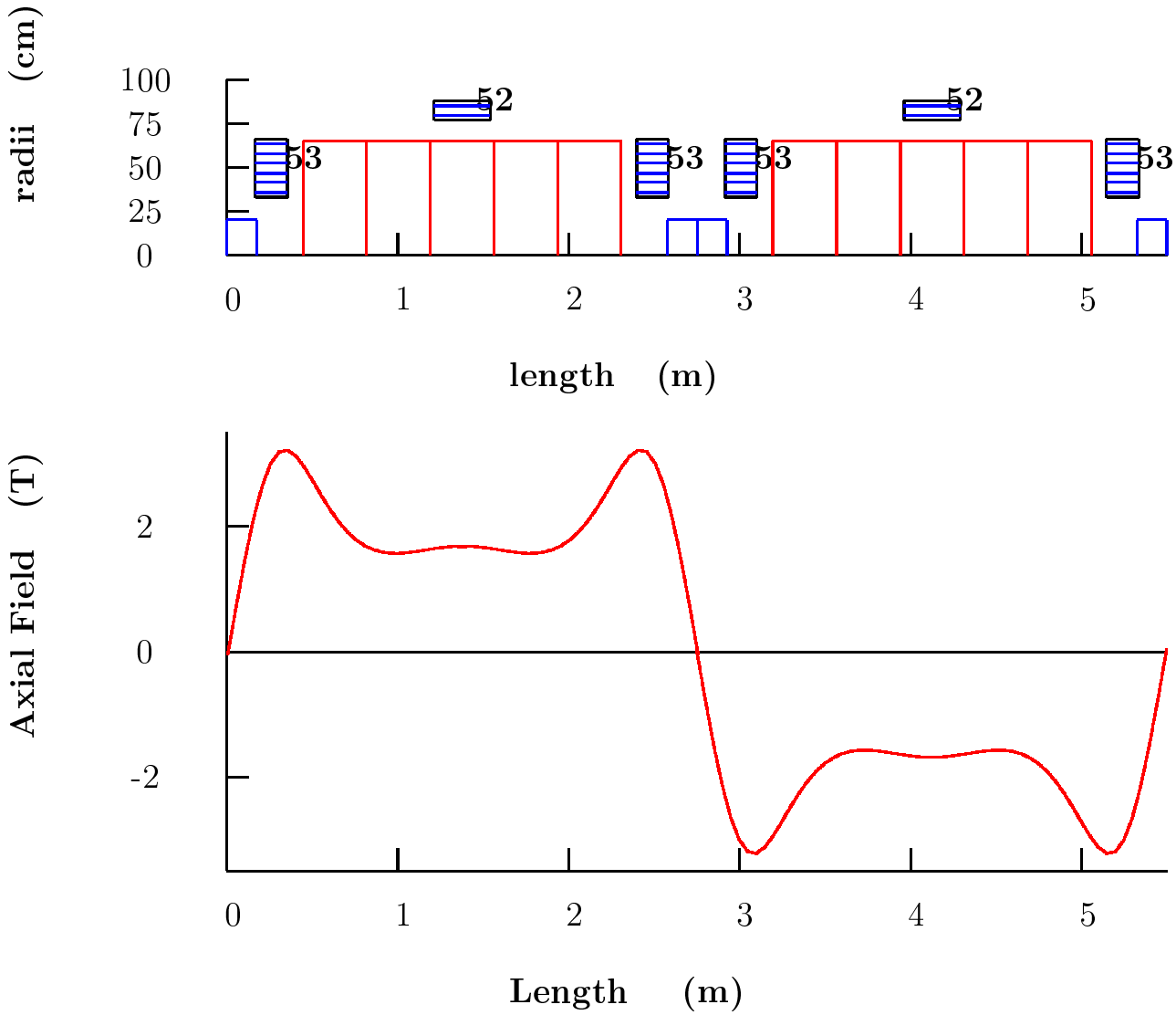


Super FOFO

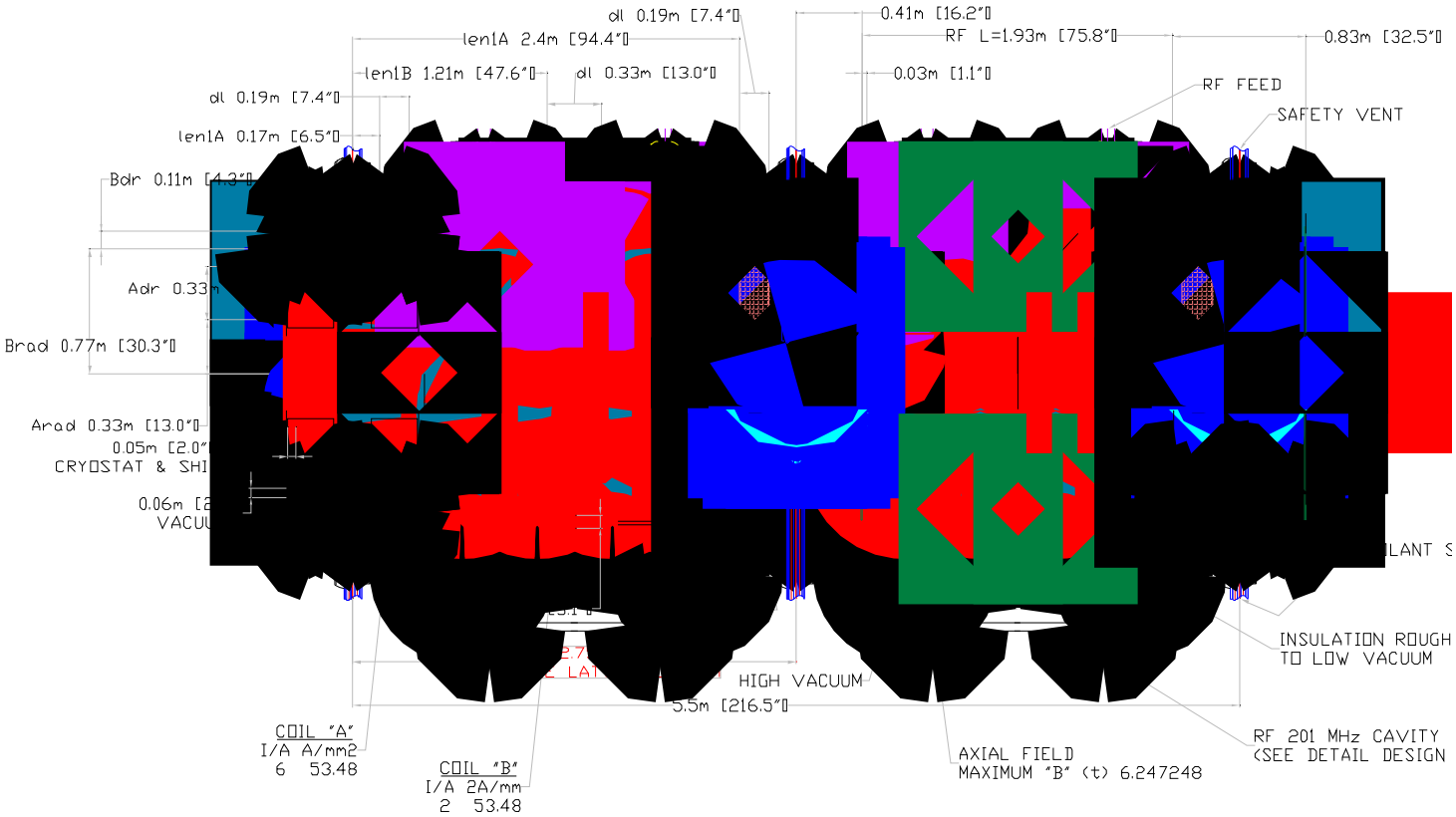
$B_z(\max) = 2.6$ (T)
$dB_z/dz(\max) = 7$ (T/m)


0.75
0.50
0.25
0.00
beta (m)
0.05
0.10
0.15
0.20
0.25
0.30
0.35
momentum (GeV/c)
FOFO
Alt Sol
Super FOFO

Super FOFO


radii (cm)
100
75
50
25
0
52
52
53
53
53
53
0
1
2
3
4
5
length (m)
Axial Field (T)
2
0
-2
0
1
2
3
4
5
Length (m)

Preliminary Engineering

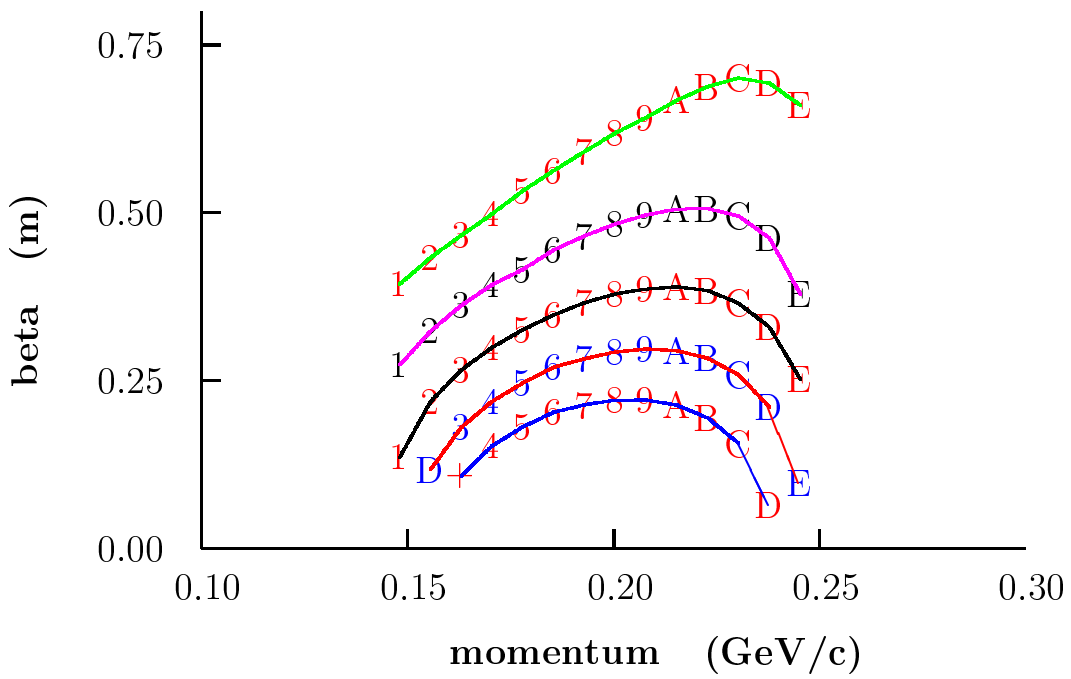


[redacted]

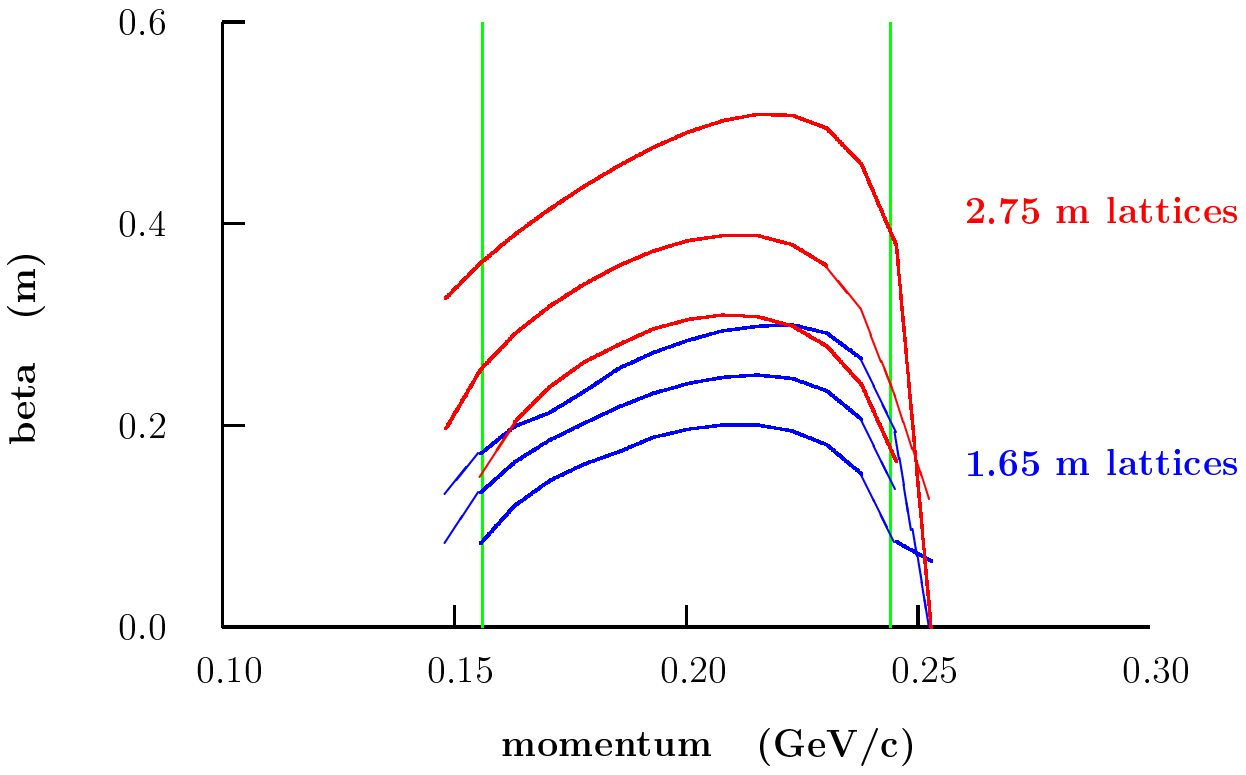
Super FOFO LATTICE
at start of cooling
(PRELIMINAR)

E.L.Black IIT
6/22/2000
6/28/2000 REV.

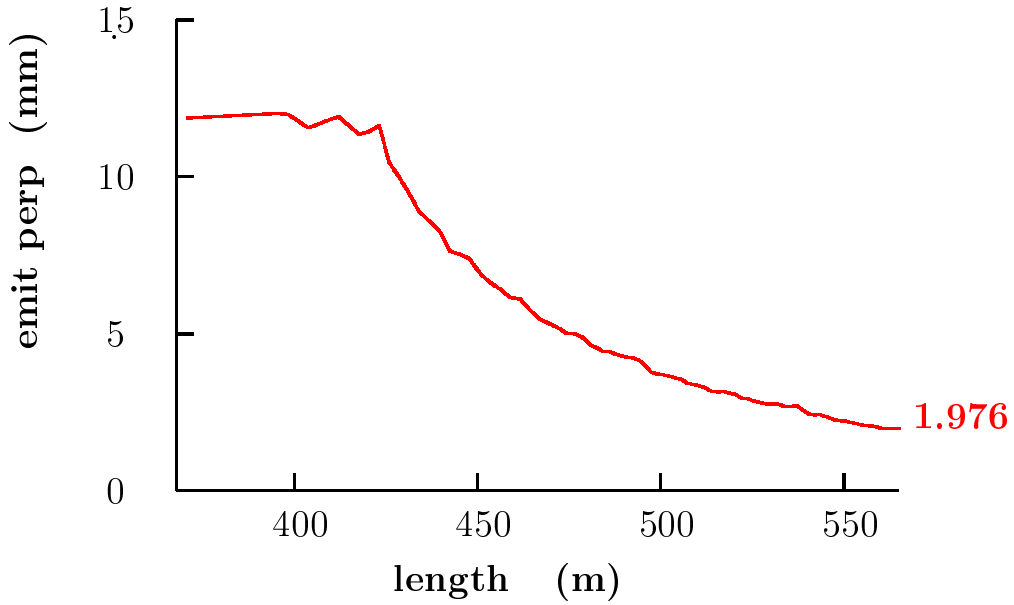
Tapering with Currents

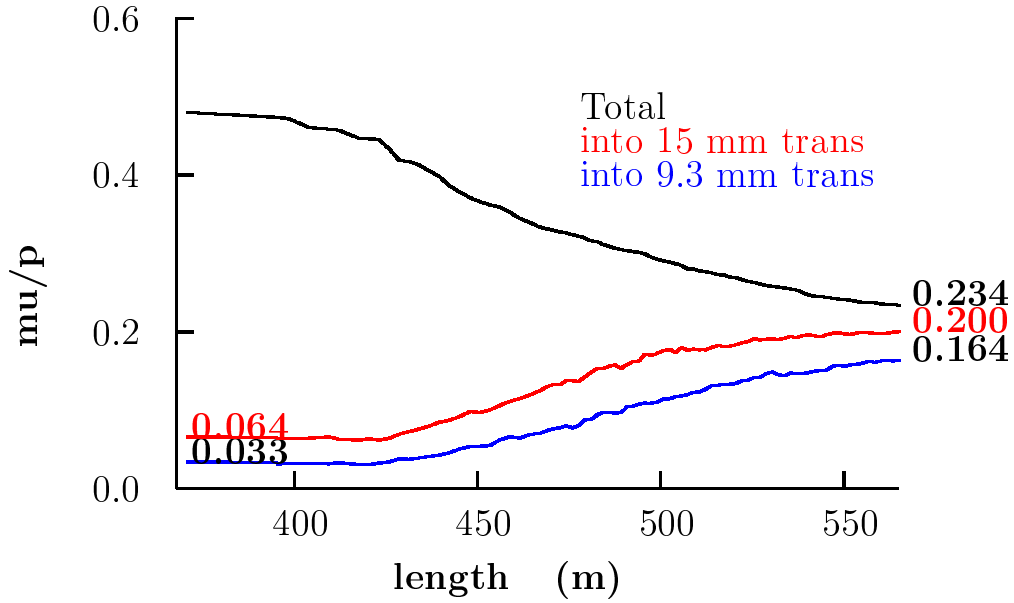


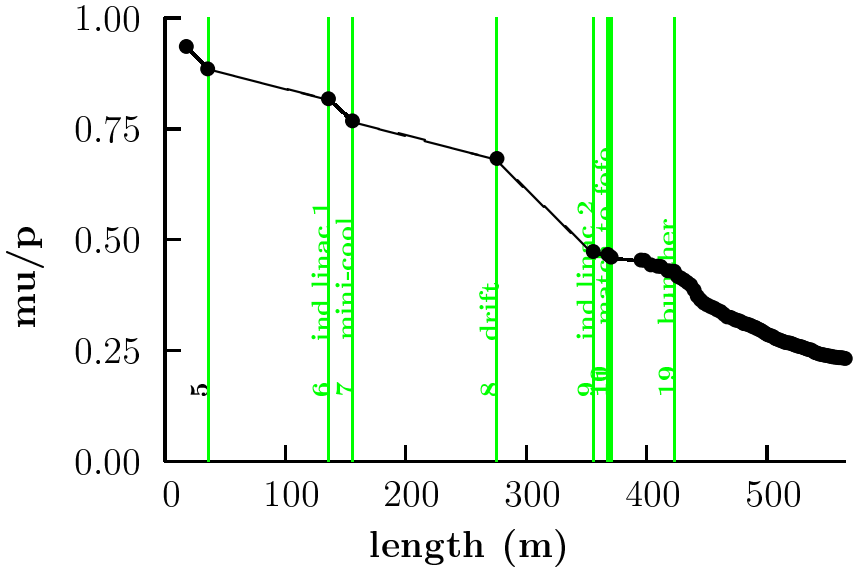
Tapering with Lattice Change

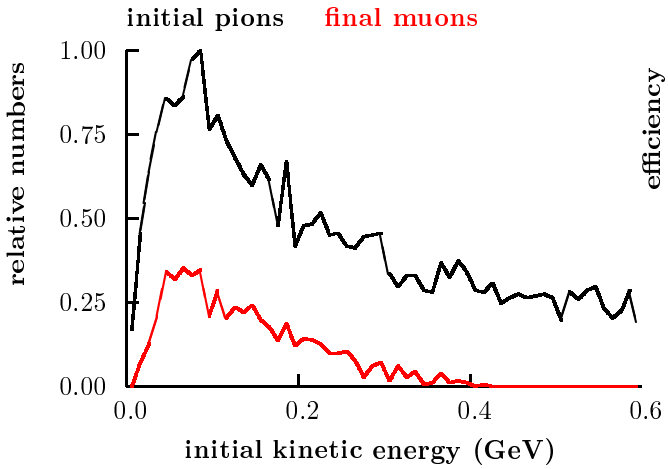


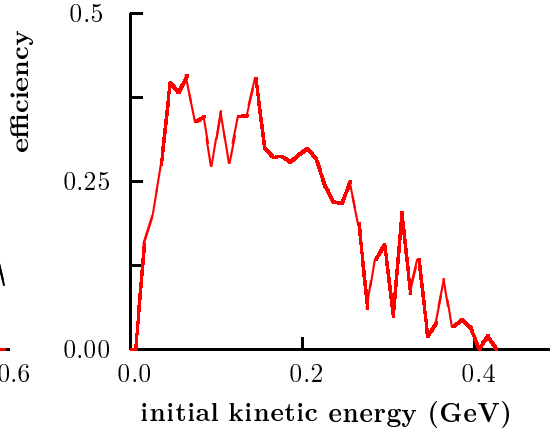
Cooling Performance






1.00
0.75
0.50
0.25
0.00
mu/p
0
100
200
300
400
500
length (m)
5
6
ind linac 1
7
mini-cool
8
drift
9
ind linac 2
10
19
buncher


initial pions
final muons
relative numbers
1.00
0.75
0.50
0.25
0.00
0.0
0.2
0.4
0.6
initial kinetic energy (GeV)


efficiency
0.5
0.25
0.00
0.0
0.2
0.4
initial kinetic energy (GeV)

Compare with Study 1

	p energy GeV	bunch length rms ns	μ/p 15 mm	μ/p 9.75
Hg (Study 2)	24	3	0.20	.164
Hg (Study 2)	16	3	0.13	.11
C (Study 2)	16	3	.069	.057
C (Study 1)	16	3		.018

No change per MW from 24 vs 16 GeV
From cooling design 3.2 $\times$
From use of the mercury 1.9 $\times$
From larger acceptance is 1.2 $\times$

Total efficiency gain = 7.4 $\times$

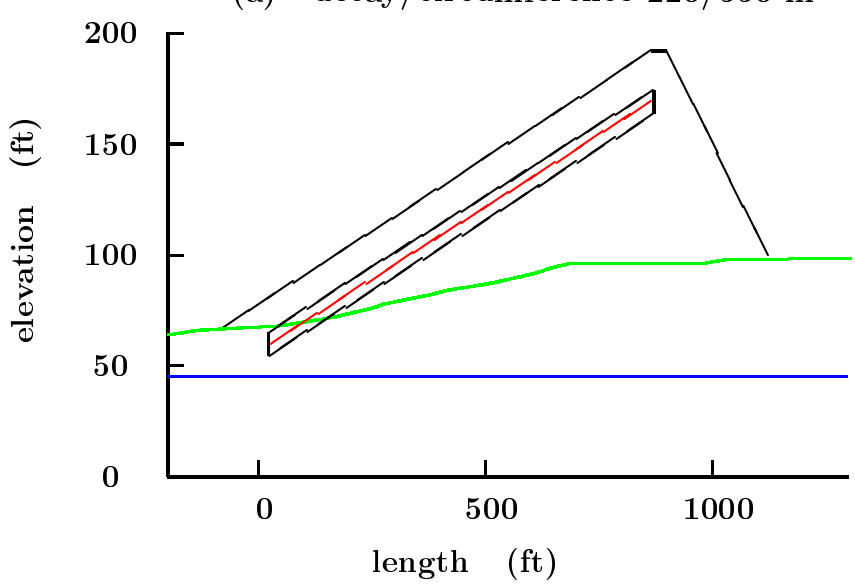
Study 1 used 1.5 MW

If Study 2 1MW: gain = 5 $\times$
If Study 2 2MW: gain = 10 $\times$

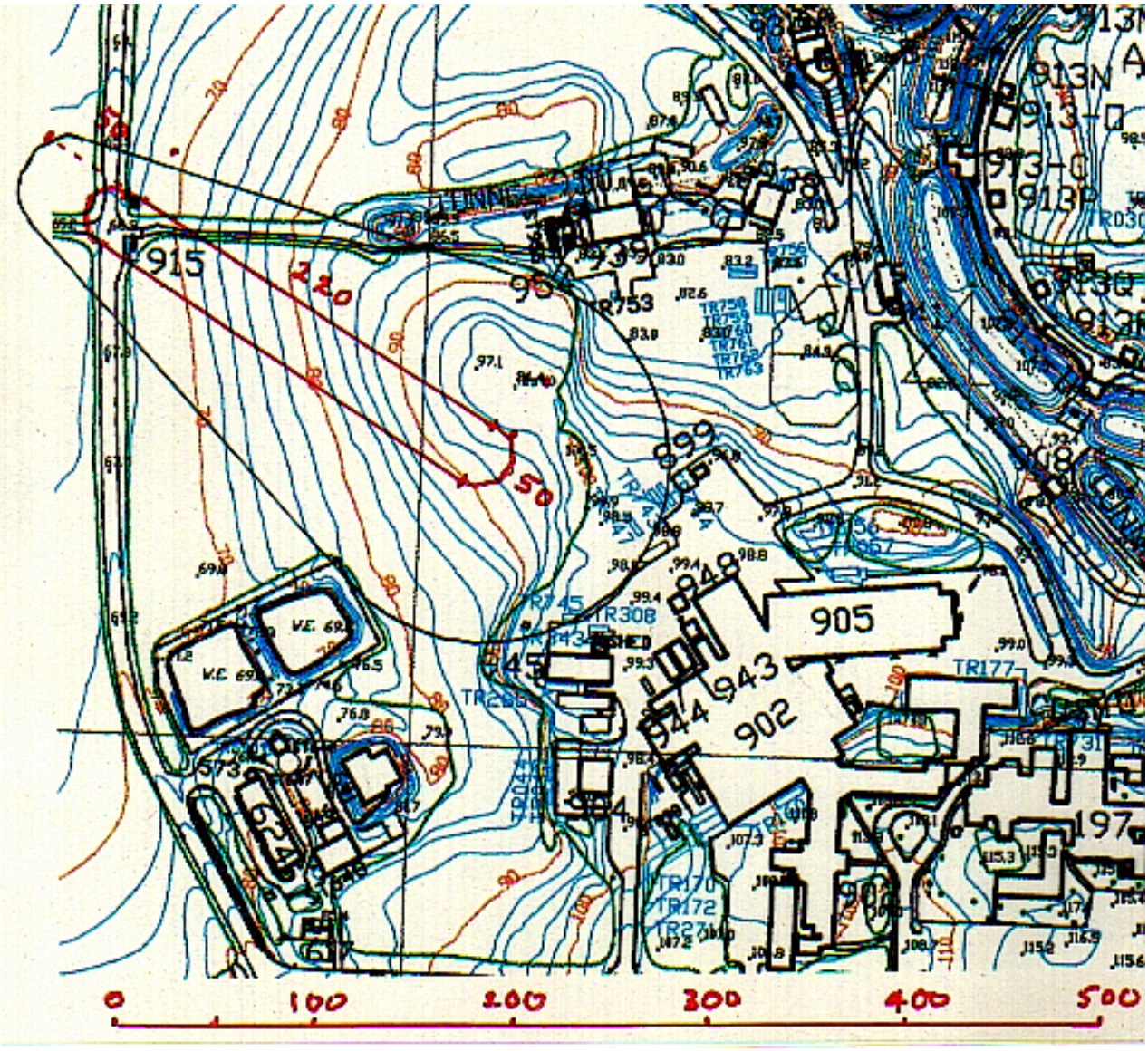
Preliminary Ring Layout

To Soudan	1713	km
Dip angle	7.73	deg
Bearing	303.33	deg
Tunnel diam	10	ft
Cover	20	ft
Burm angle	27	deg
Arc Rad	16	m
Water table	45	ft
Decay len / circ	40	%
Straight	m	210
Circumference	m	525
Hill	m	30
Volume	m^3	250k

(a) decay/circumference 220/550 m = 40 %



40 % Soudan Case



If BNL to Carlsbad

To Carlsbad	2903	km
Dip angle	13.1	deg
Dip angle	.229	rad
Bearing	267.45	deg
straight	m	116
circ	m	332
decay/circ	%	35
hill	m	30
vol	m^3	225

Study 2A Conclusions

- Significant improvement over Study 1
- But only 20 % mu/pi
- And only one sign
- i.e. efficiency only 10 %

But

- Bunch Beam Phase Rotation
  Simulated by Neuffer
  Gives both signs
- Emittance exchange promising
  Several schemes under study
  Could double efficiency

So

- Study 2A will not be the last

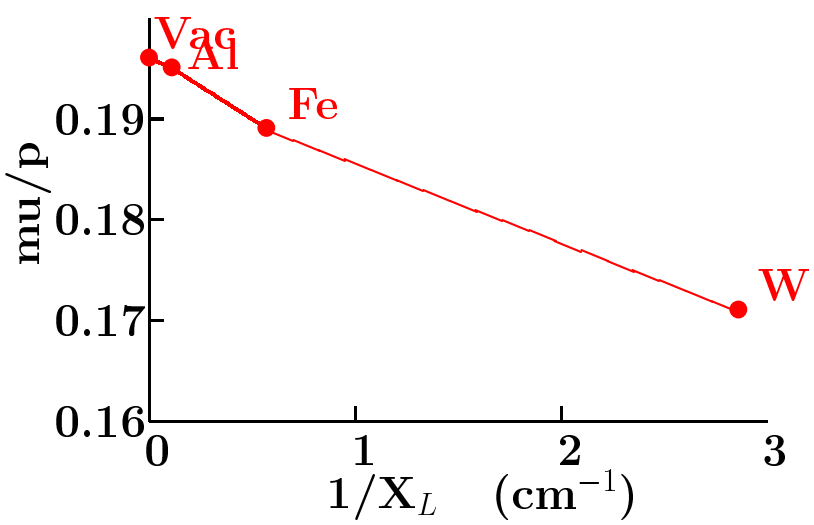
H_2 Window material

Material	Z	X_L^{-1} (cm)$^{-1}$	μ/p	ϵ_n mm rad
Vac	0	0	.196	2.07
Al	13	.11	.195	2.09
Fe	26	.57	.189	2.28
W	74	2.87	.171	2.87

Dan would like to double the Al window thicknesses,

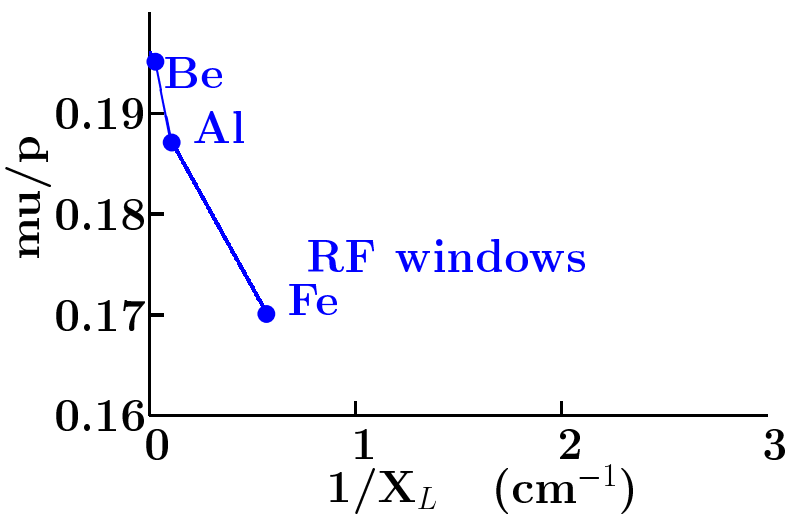
Expected reulting loss $\approx$ 1 %,

which would seem acceptable.



RF Window material

Material	Z	X_L^{-1} (cm)$^{-1}$	μ/p	ϵ_n mm rad
Vac	0	0	.196	2.04
Be	13	.03	.195	2.09
Al	13	.11	.187	2.806
Fe	26	.57	.17	2.32
JC*			.146	1.95

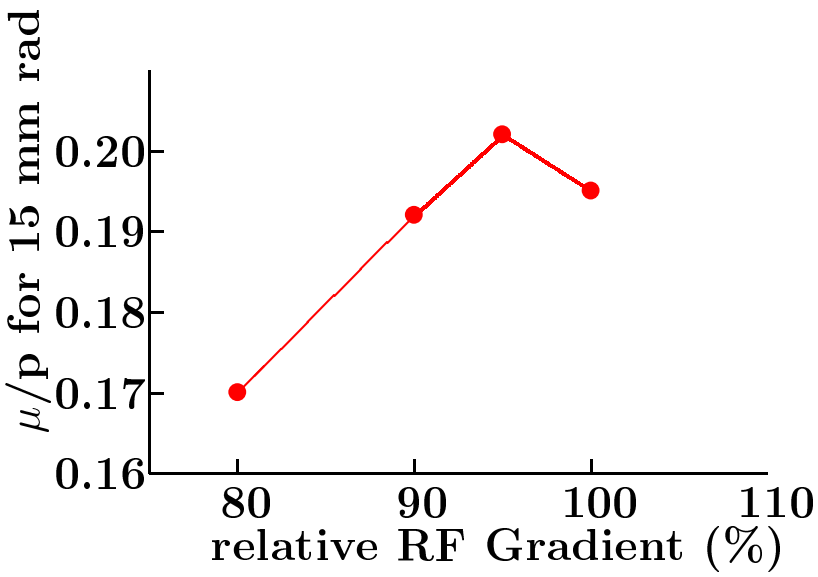


If plane Be windows are used with no gas cooling then John needs to increase the window thicknesses by up to 10 times. With these requirements (JC*) the per-

formance falls by 25 % (from $\approx$ 0.2 to $\approx$ 0.15 - see above).

Options:

- **gas cooling between double windows**
- **reduce maximum radii in a tadeoff to minimize loss**
- **grade the thicknesses**

RF Voltage

V/V_o %	V(1) MV/m	V(2) MV/m	μ/p	ϵ_n mm rad
100	16.29	17.6	.195	2.09
95			.202	1.94
90			.192	1.82
80			.170	1.54