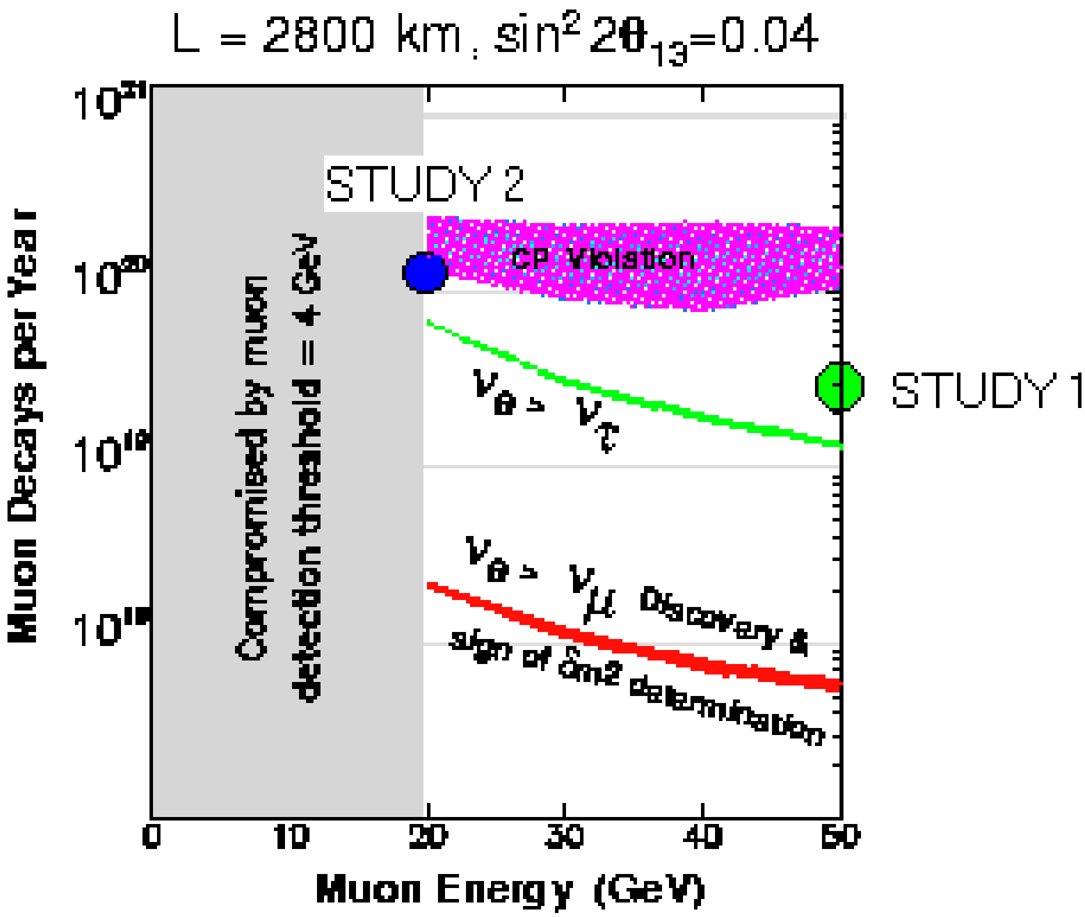
PARAMETERS and SIMULATIONS

Editors & Collaboration at BNL

1/28/01 & 2/1/01

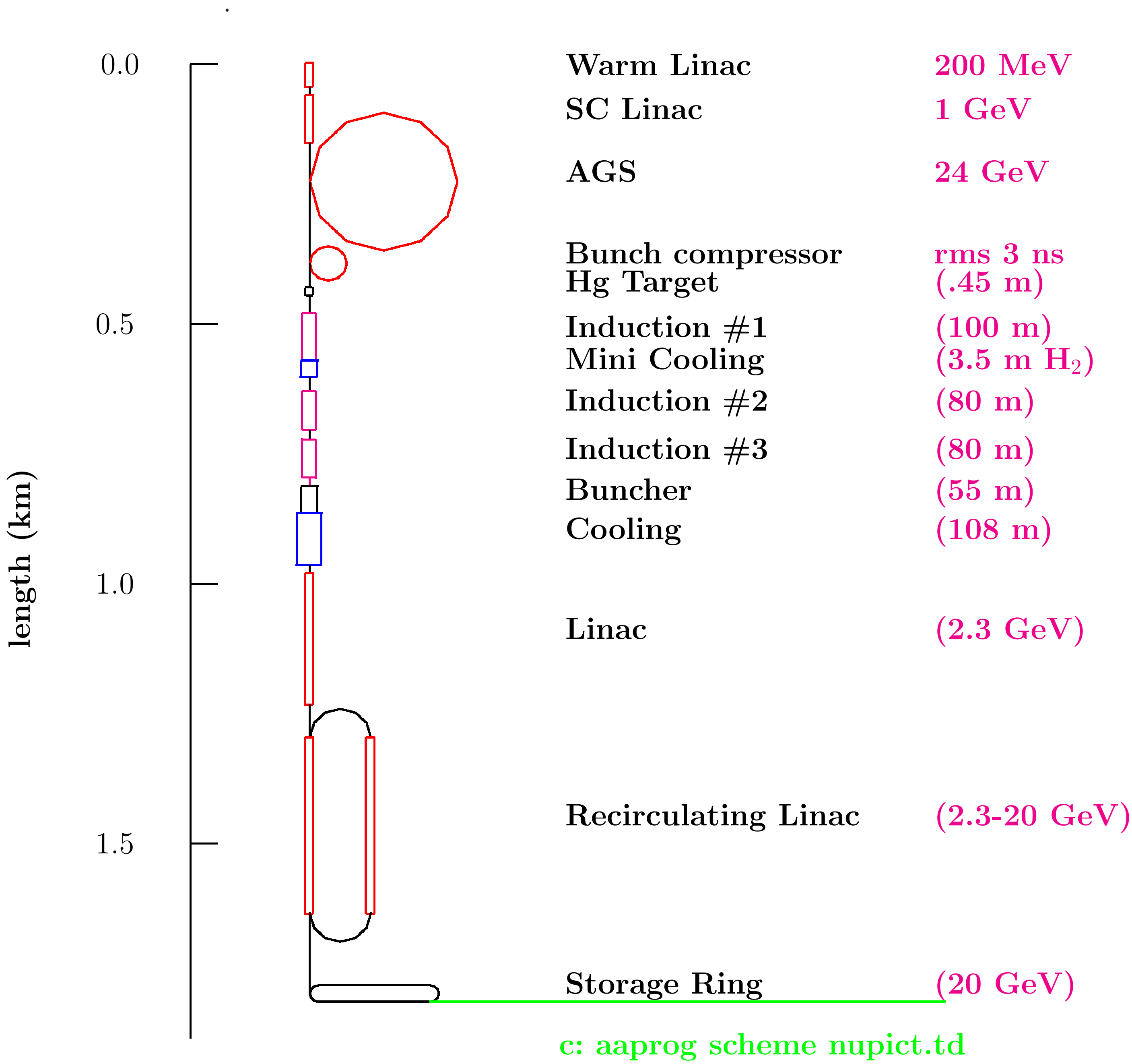
Increased Yield

1) liquid mercury target
2) non-distorting phase rotation
3) tapered cooling system



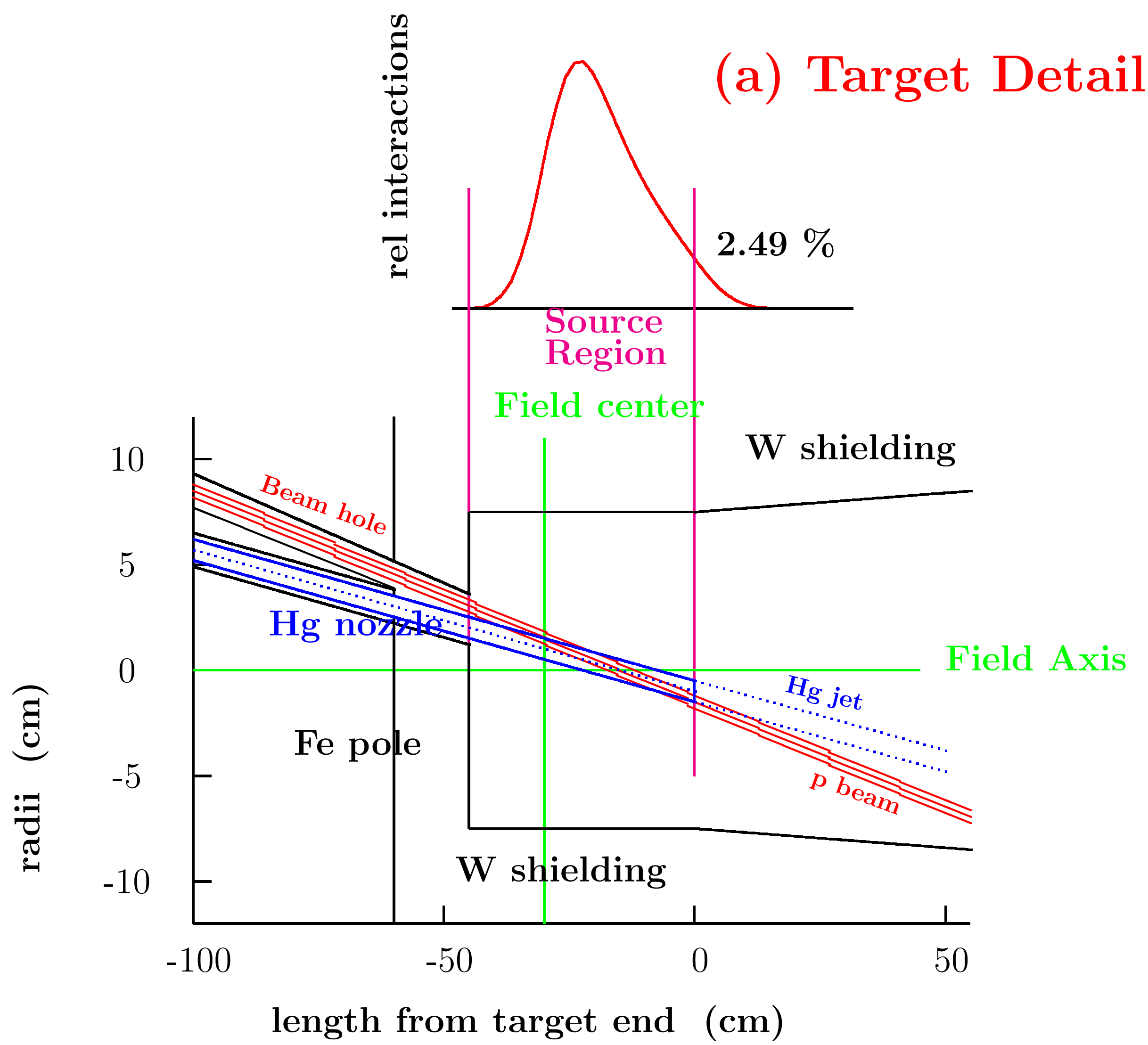
muon decays in straight section / 2 10^7 sec

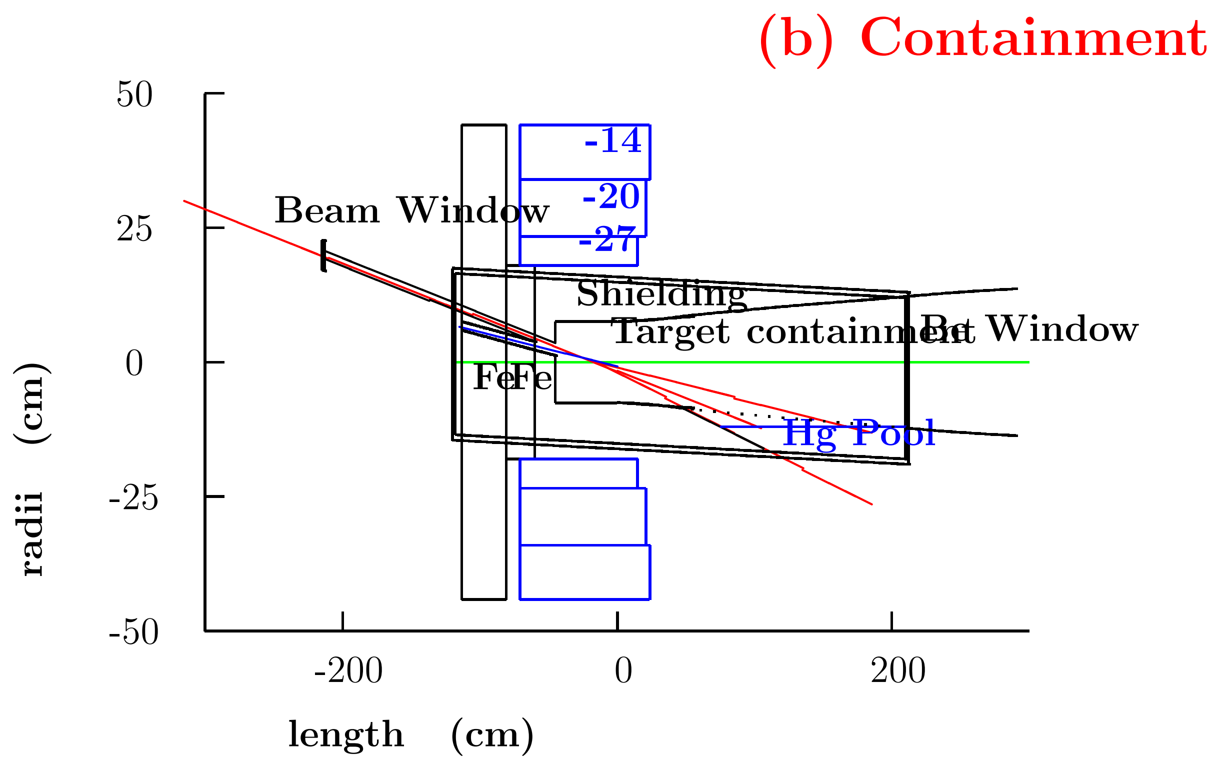
Scheme

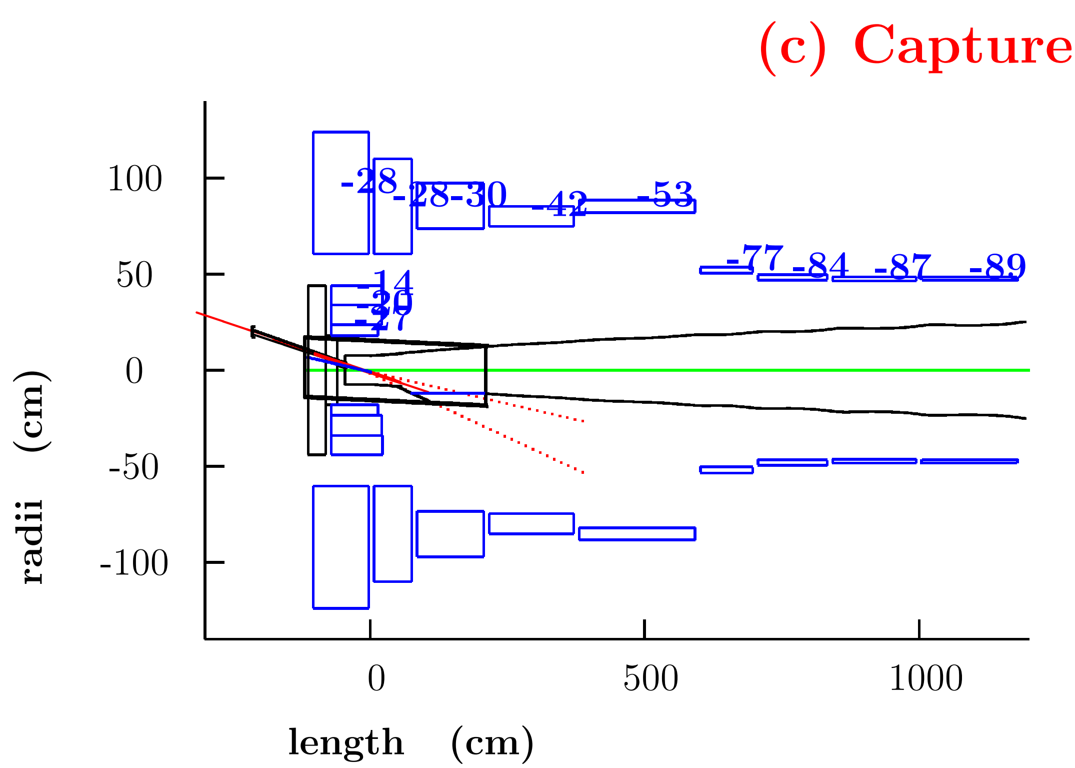


0.0
0.5
1.0
1.5
length (km)
Warm Linac
200 MeV
SC Linac
1 GeV
AGS
24 GeV
Bunch compressor
rms 3 ns
Hg Target
(.45 m)
Induction #1
(100 m)
Mini Cooling
(3.5 m H_2)
Induction #2
(80 m)
Induction #3
(80 m)
Buncher
(55 m)
Cooling
(108 m)
Linac
(2.3 GeV)
Recirculating Linac
(2.3-20 GeV)
Storage Ring
(20 GeV)
c: aaprog scheme nupict.td

Target

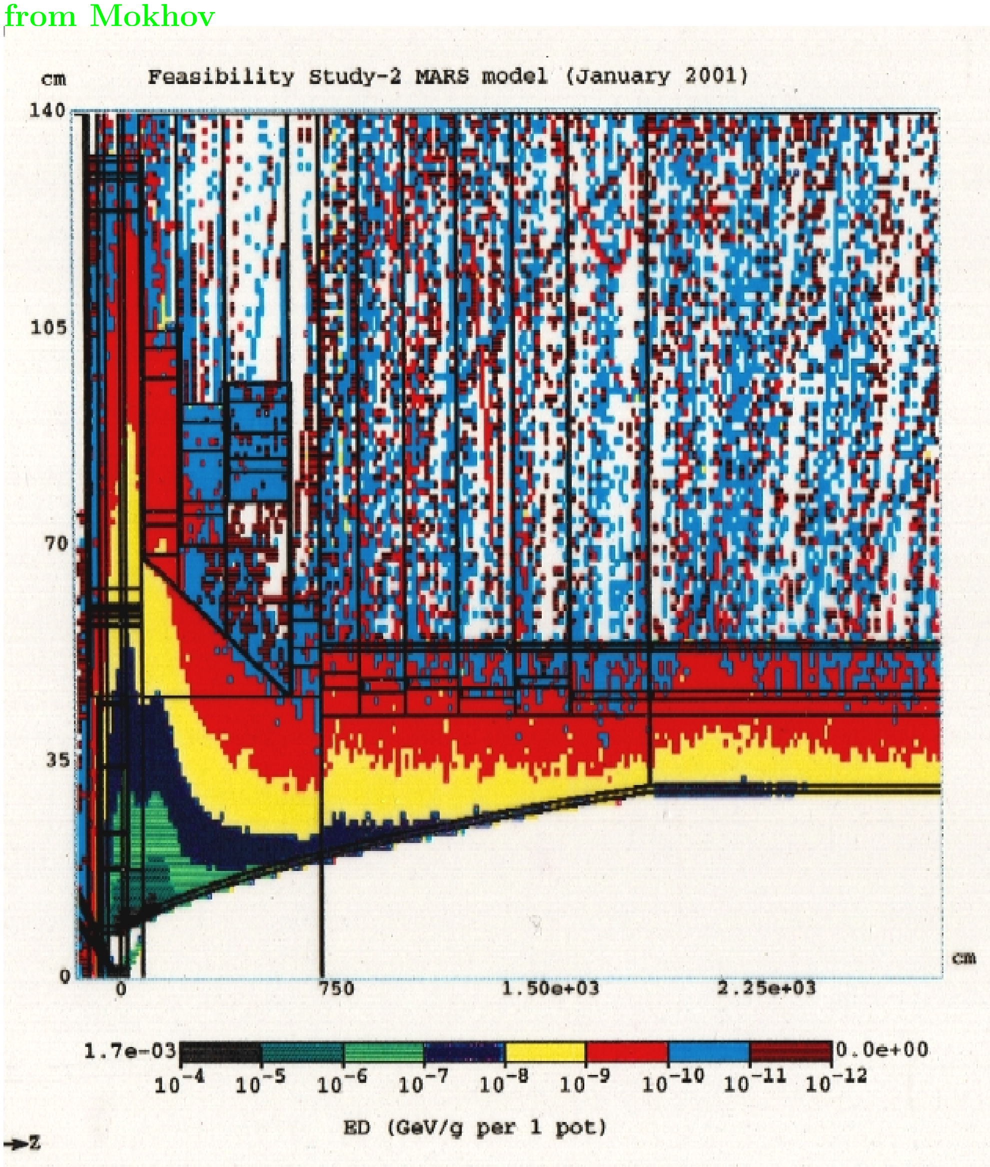

(a) Target Detail
rel interactions
2.49 %
Source
Region
Field center
W shielding
Beam hole
Hg nozzle
Field Axis
Hg jet
Fe pole
p beam
W shielding
10
5
0
-5
-10
-100
-50
0
50
radii (cm)
length from target end (cm)


(b) Containment
50
25
0
-25
-50
radii (cm)
-200
0
200
length (cm)
Beam Window
-14
-20
-27
Shielding
Target containment
Be Window
FeFe
Hg Pool


(c) Capture
100
50
0
-50
-100
radii (cm)
0
500
1000
length (cm)
-28
-28-30
-42
-53
-77
-84
-87
-89
-14
-20
-27

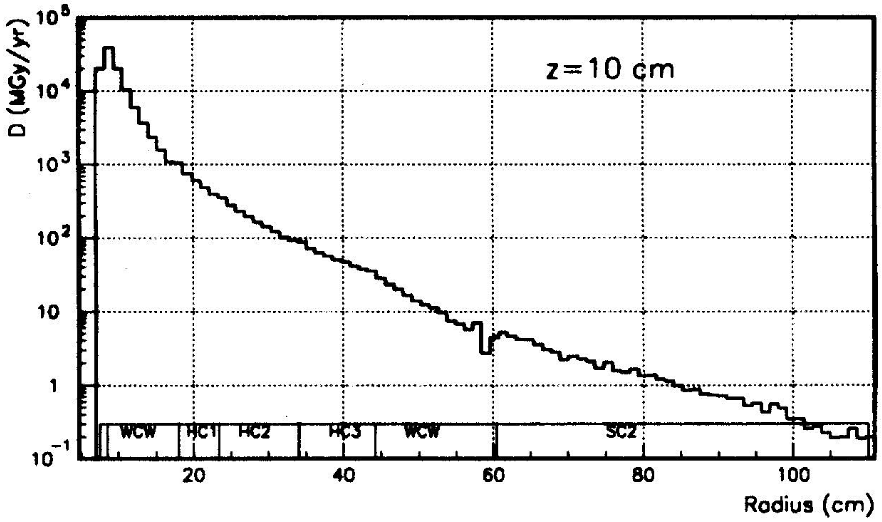
Energy Deposited

from Mokhov



Radiation vs. r at worst z

from Mokhov



Note that the above figure is for a 2 10^7 sec year, but in the following table the year is takeen as 1 10^7 sec.

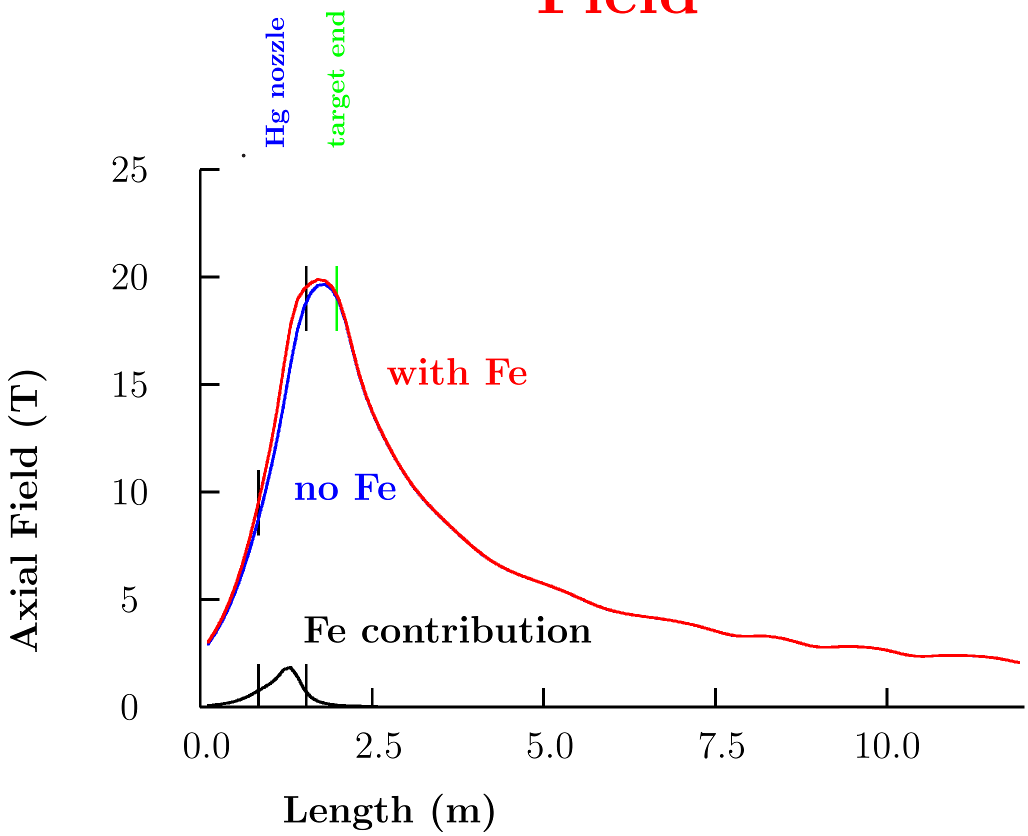
Component	radius cm	Dose/yr Grays/10^7 sec	Max allowed Dose Grays	Lifetime years
Inner Shielding (Fe)	7.5	2.5 10^{10}	10^{11} ?	4 ?
Containment (SS)	15	2 10^9	10^{11}	50
Hollow conductor Coil (SS))	18	5 10^8	10^{11}	200
Superconducting Coil (Polyamid)	60	2.5 10^6	10^8	40

We note that Cu is rated for 10 times more radiation than SS, and would thus last for 40 years as the inner shield, but cannot be used because it is n ot compatible with Hg.

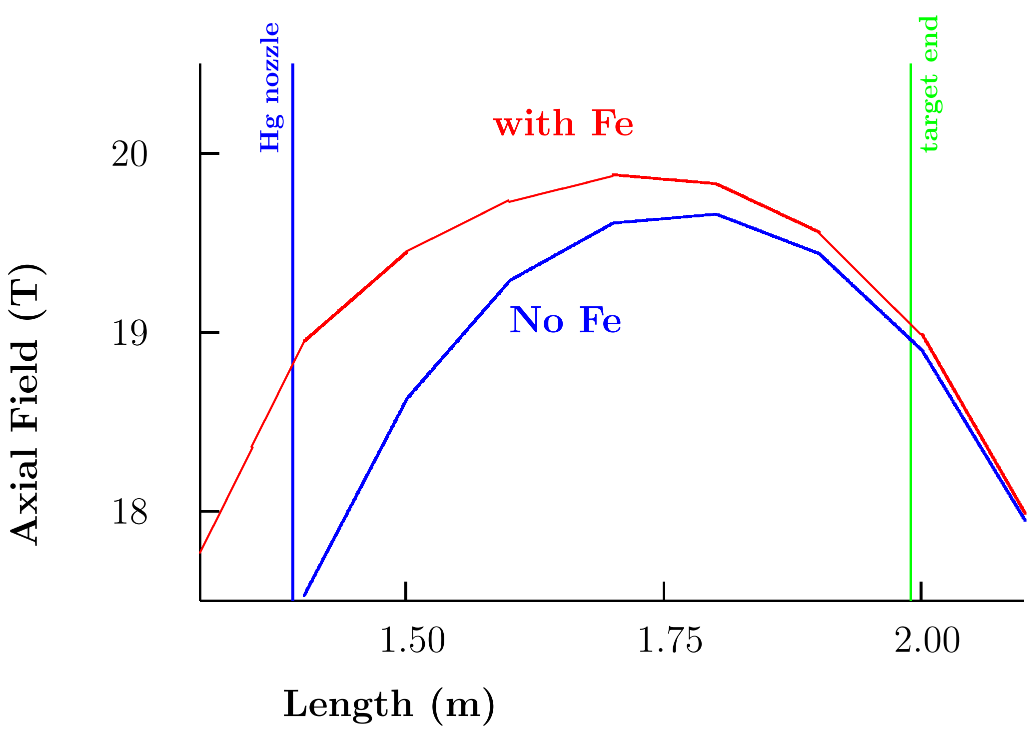
Questions

- Can the SS inner shielding take more radiation if it is not stressed ?
- Is there another material?

Field



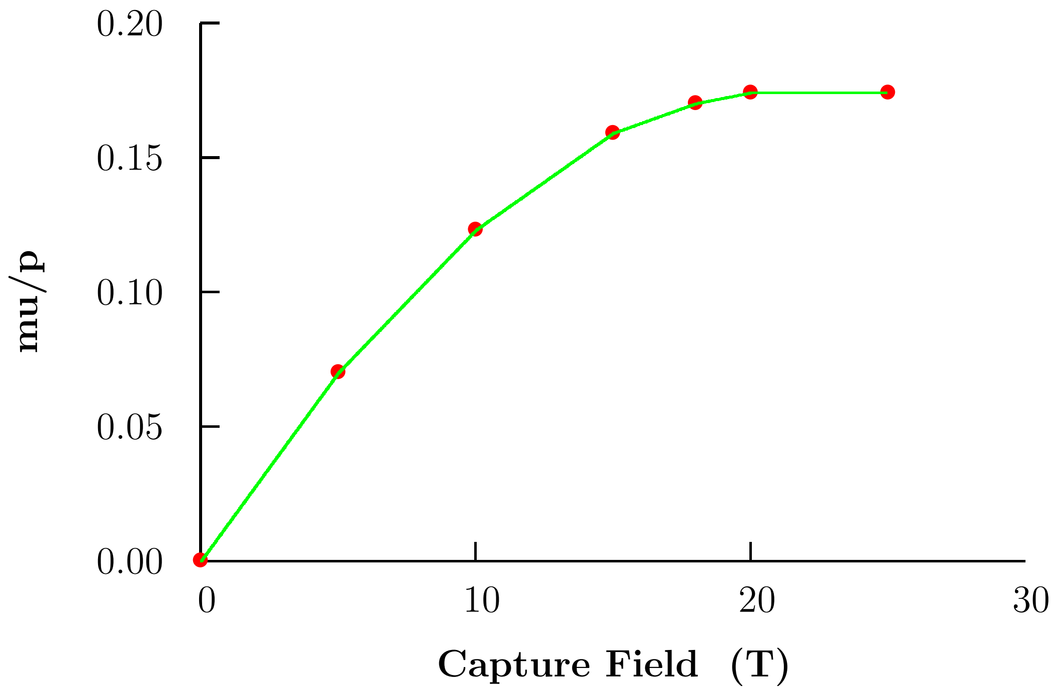
Hg nozzle
target end
25
20
15
10
5
0
Axial Field (T)
with Fe
no Fe
Fe contribution
0.0
2.5
5.0
7.5
10.0
Length (m)

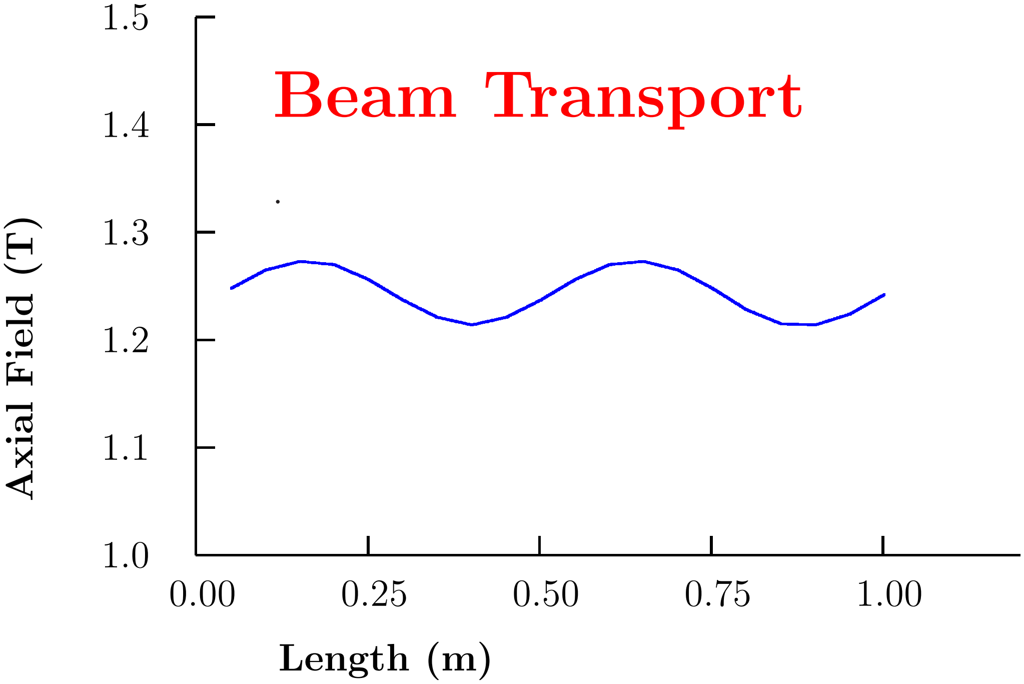


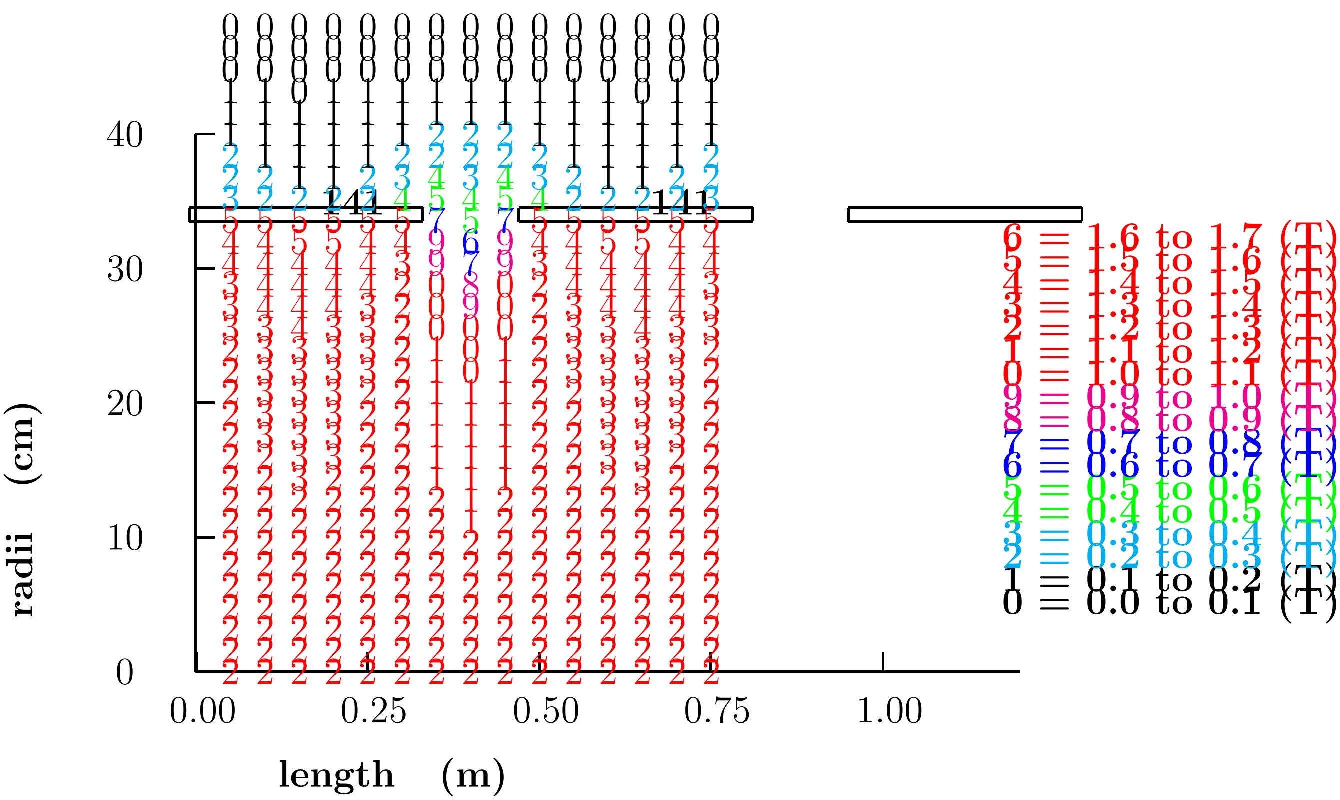
Hg nozzle
target end
with Fe
No Fe
20
19
18
Axial Field (T)
1.50
1.75
2.00
Length (m)

. Alternative

. Efficiency vs. Capture Field

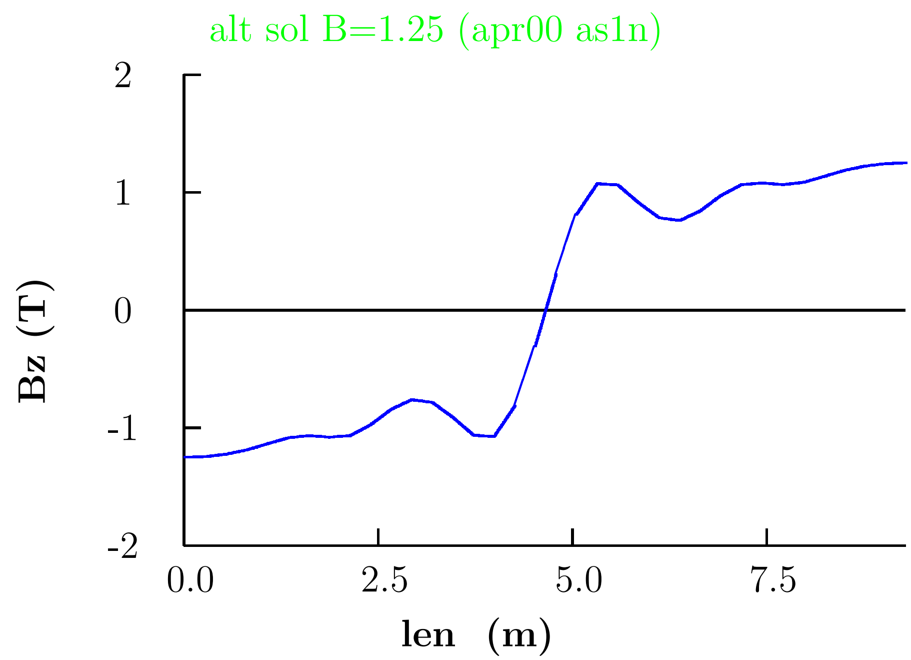


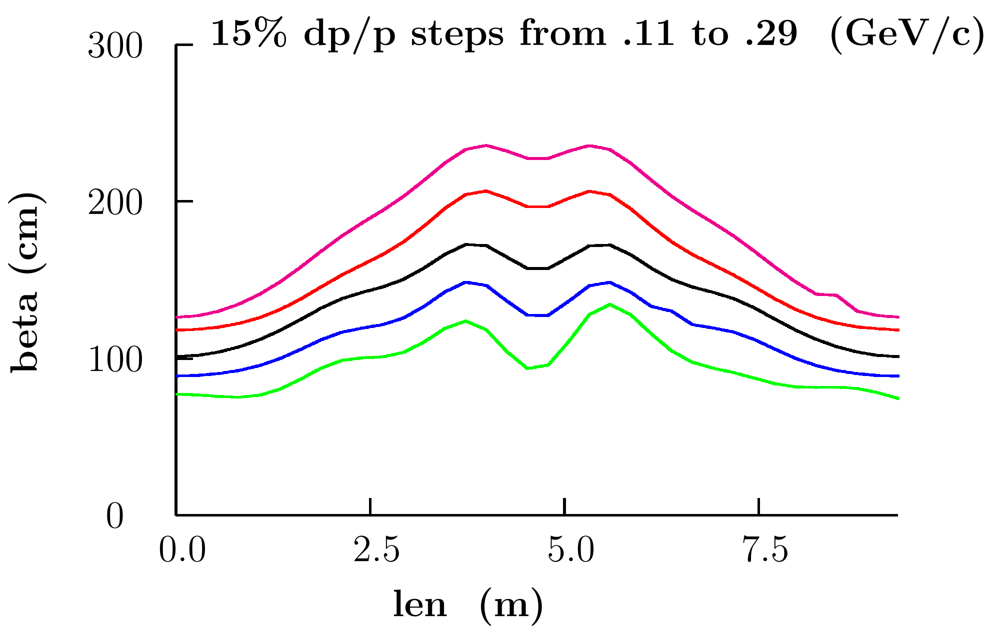

Beam Transport
Axial Field (T)
1.0
1.1
1.2
1.3
1.4
1.5
0.00
0.25
0.50
0.75
1.00
Length (m)


radii (cm)
0
10
20
30
40
0.00
0.25
0.50
0.75
1.00
length (m)
6 ≡ 1.6 to 1.7 (T)
5 ≡ 1.5 to 1.6 (T)
4 ≡ 1.4 to 1.5 (T)
3 ≡ 1.3 to 1.4 (T)
2 ≡ 1.2 to 1.3 (T)
1 ≡ 1.1 to 1.2 (T)
0 ≡ 1.0 to 1.1 (T)
9 ≡ 0.9 to 1.0 (T)
8 ≡ 0.8 to 0.9 (T)
7 ≡ 0.7 to 0.8 (T)
6 ≡ 0.6 to 0.7 (T)
5 ≡ 0.5 to 0.6 (T)
4 ≡ 0.4 to 0.5 (T)
3 ≡ 0.3 to 0.4 (T)
2 ≡ 0.2 to 0.3 (T)
1 ≡ 0.1 to 0.2 (T)
0 ≡ 0.0 to 0.1 (T)

Field Reversal

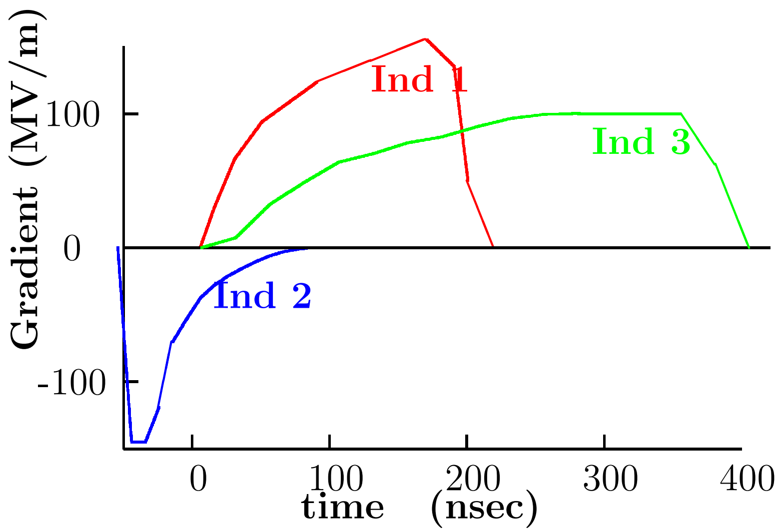
- Avoid generating angular momentum in Mini-cool
- Make delta ct independent of angular momentum

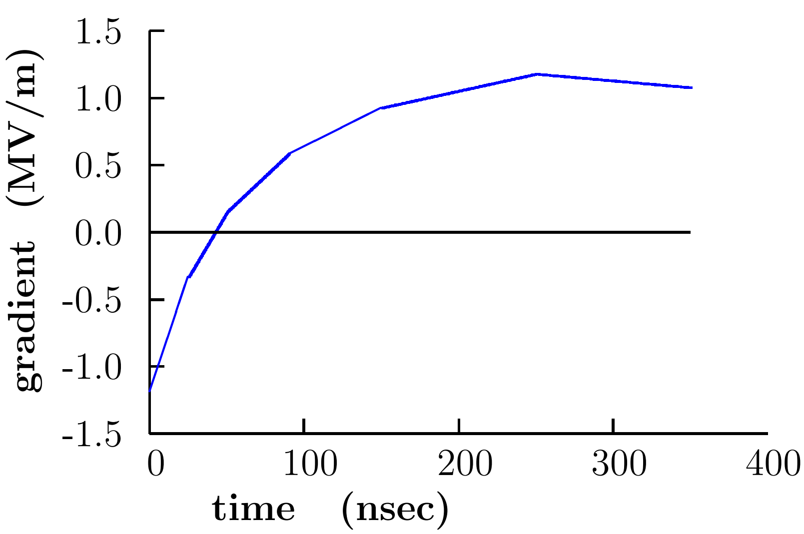




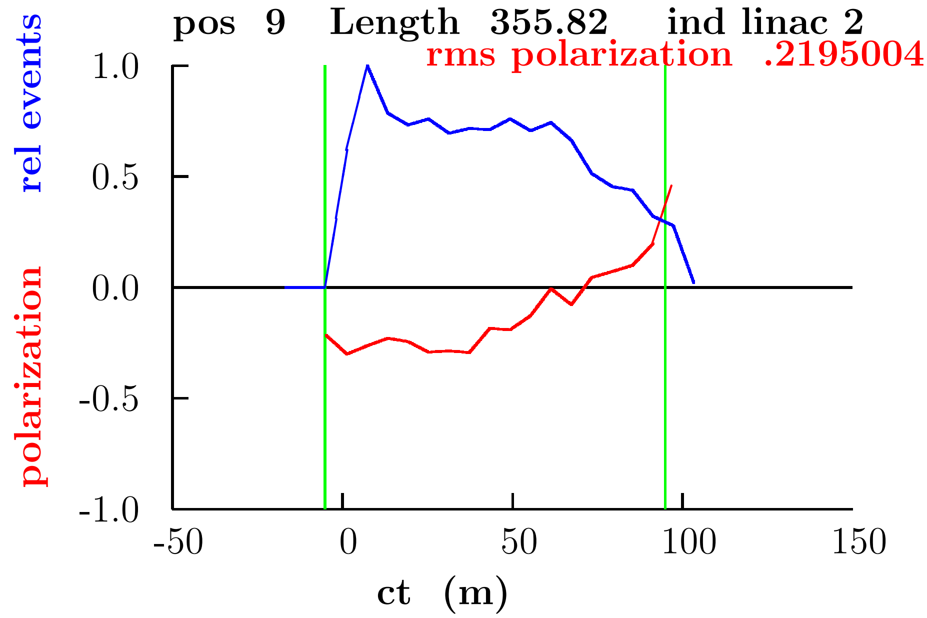
Phase Rotation

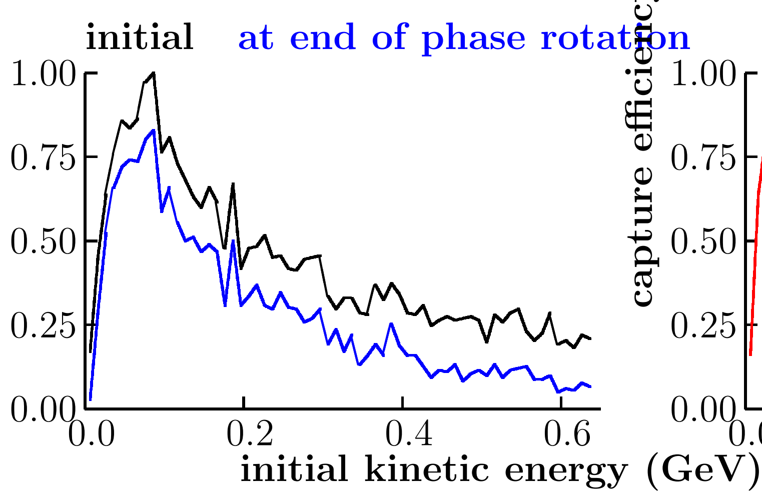
		1	2	3
length	m	100	80	80
inner radius	cm	30	30	30
Solenoid field	T	1.25	1.25	1.25
maximum gradient	MV/m	1.55	1.45	1.0
pulse length	nsec	190	100	360

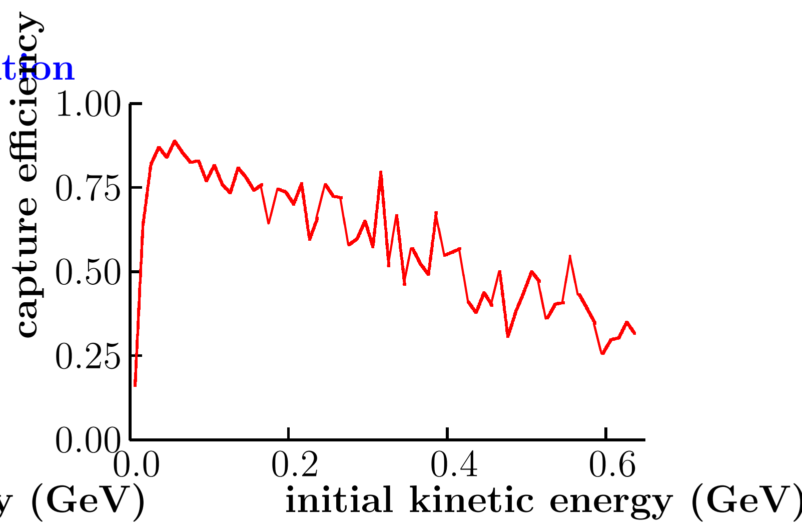




. Rotation Performance

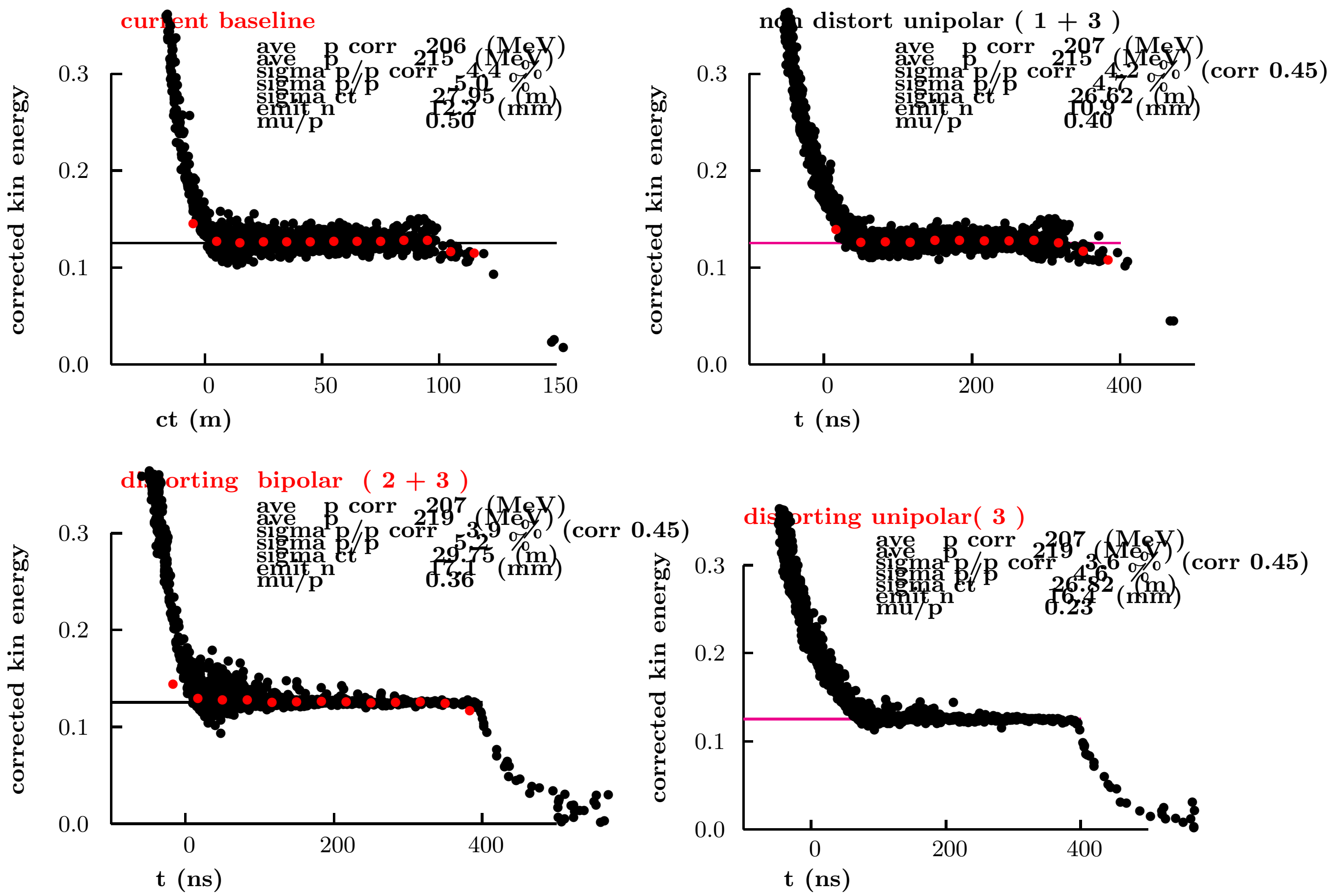


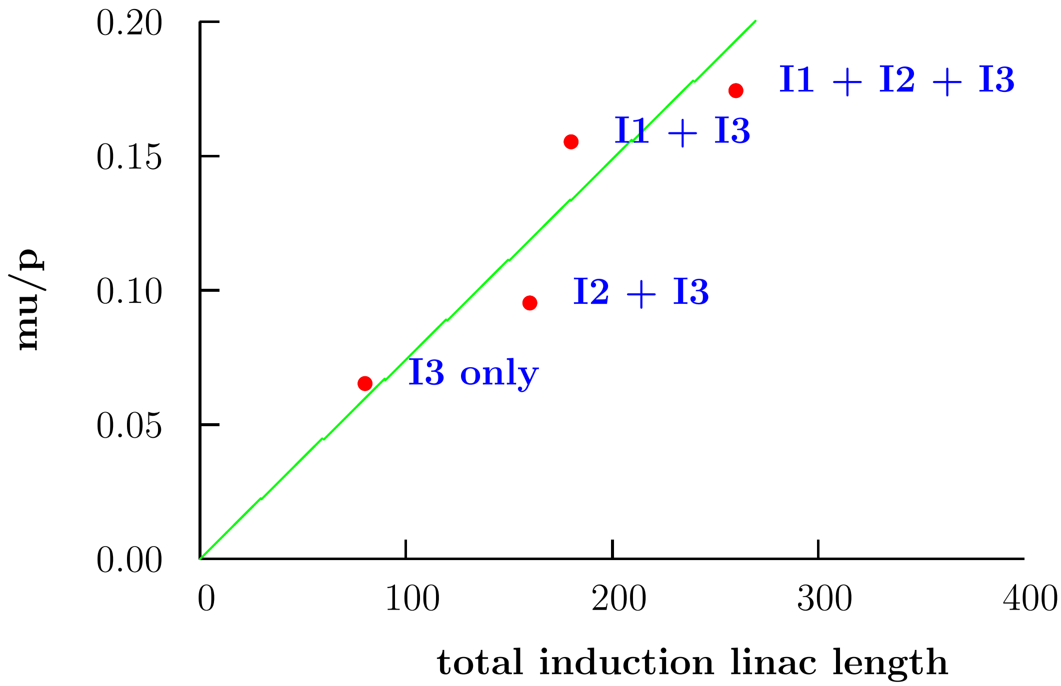




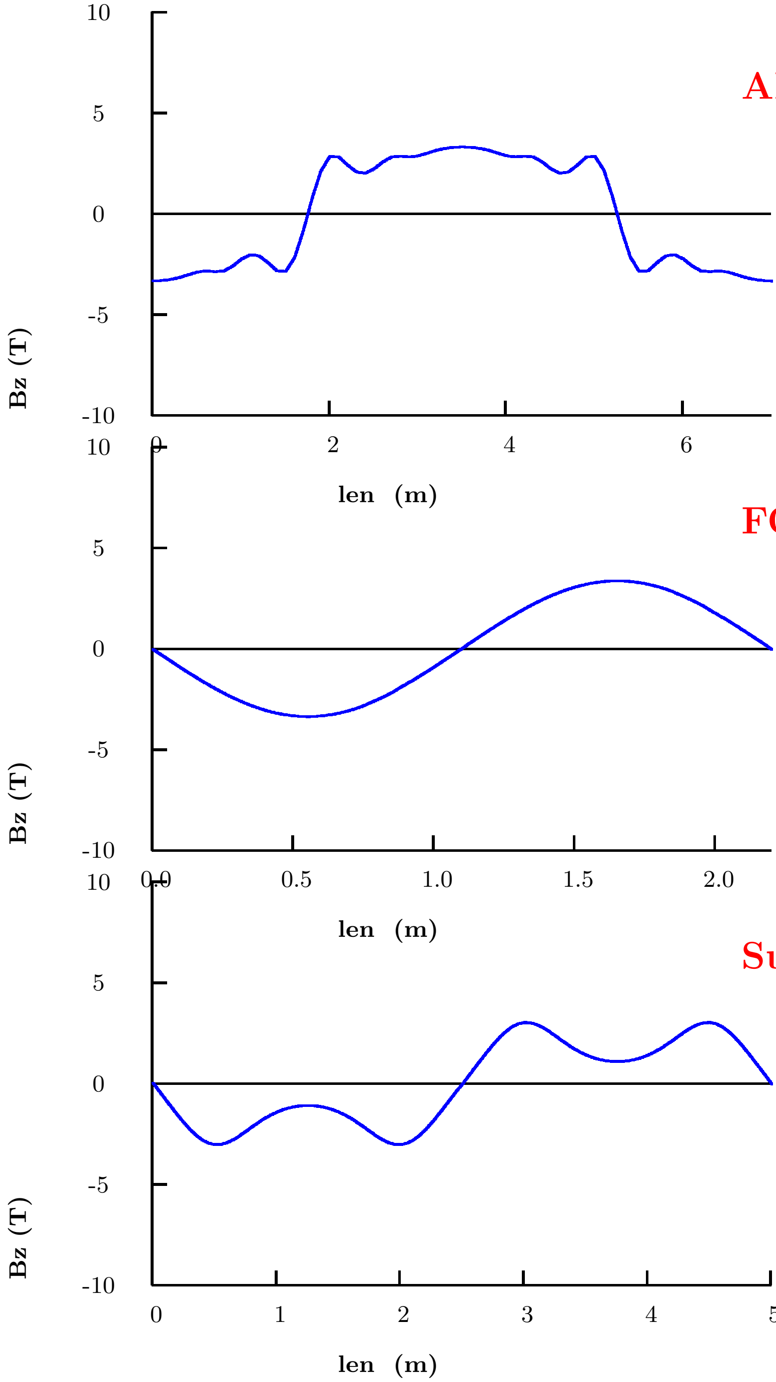
. Alternative

. Less Induction Linac




0.20
0.15
0.10
0.05
0.00
mu/p
0
100
200
300
400
total induction linac length
I1 + I2 + I3
I1 + I3
I2 + I3
I3 only

Cooling Lattices



Alternating Solenoid

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

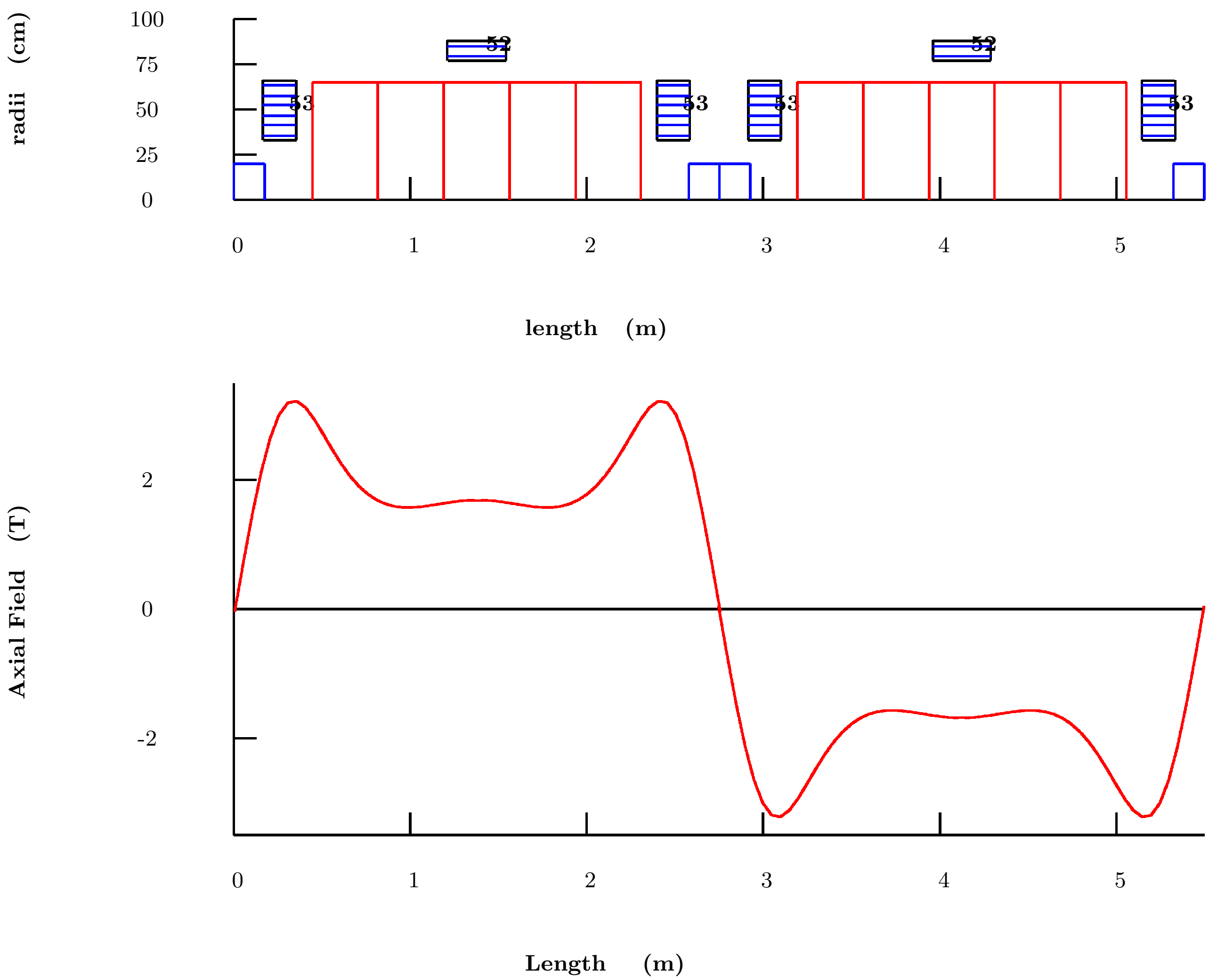
FOFO

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

Super FOFO

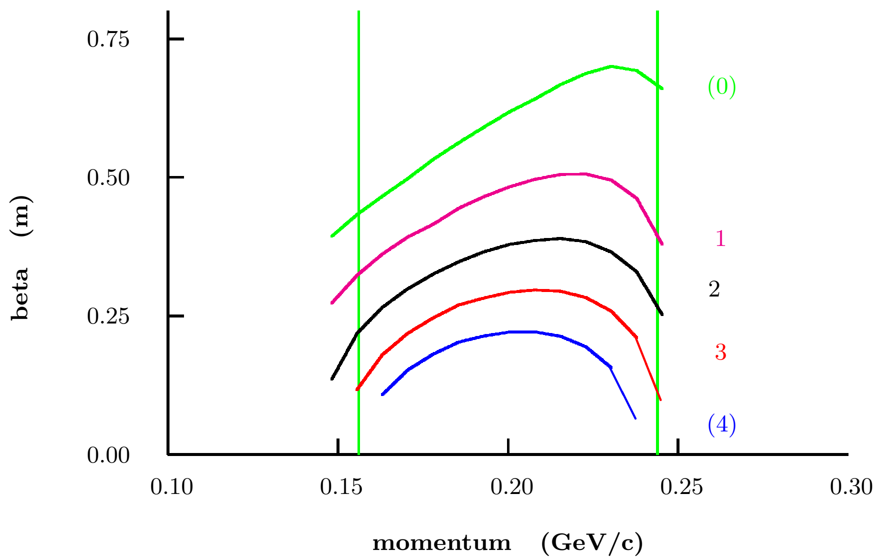
$B_z(\max) = 2.6$ (T)
$dB_z/dz(\max) = 7$ (T/m)

Super FOFO

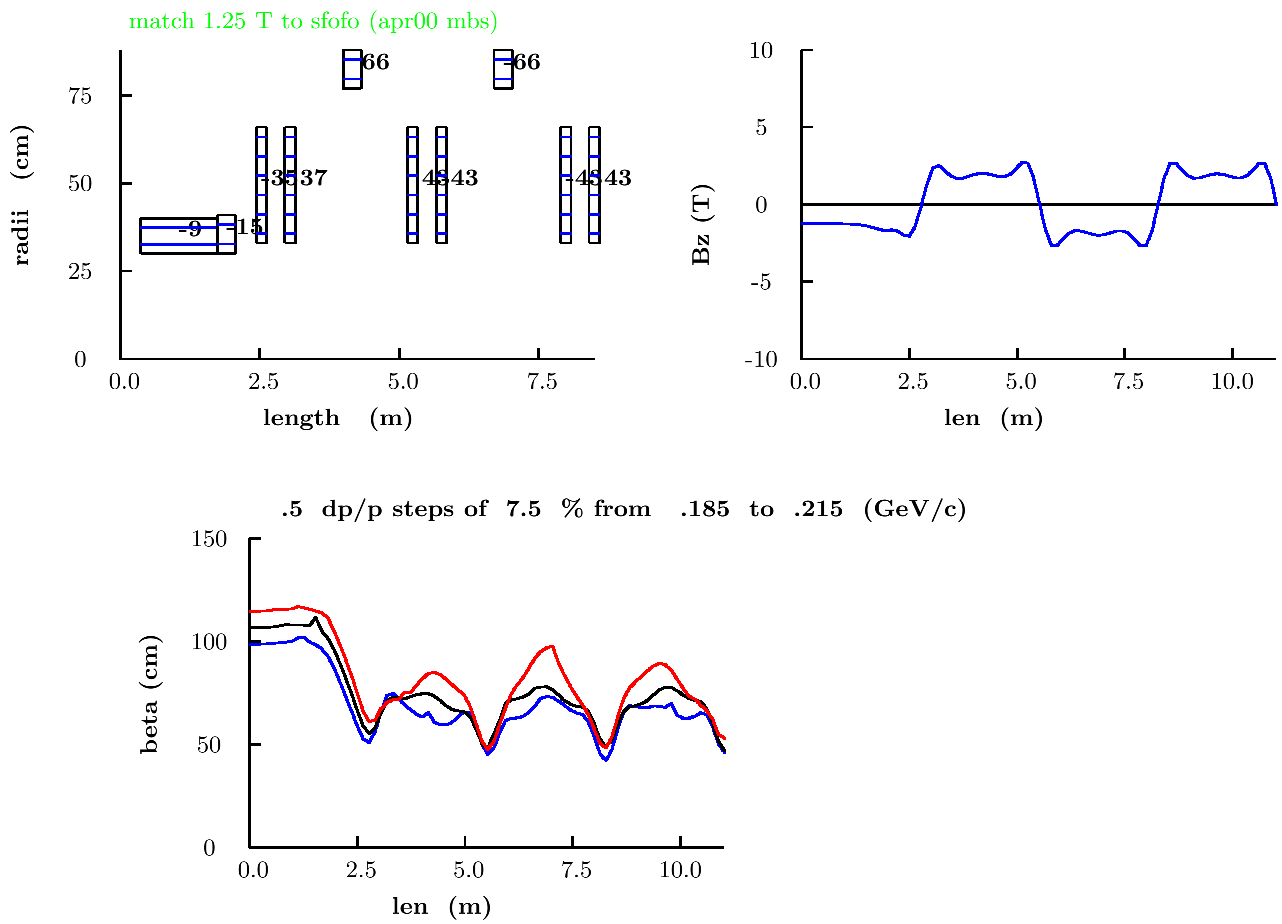


radii (cm)
100
75
50
25
0
52
53
0
1
2
3
4
5
length (m)
Axial Field (T)
2
0
-2
0
1
2
3
4
5
Length (m)

.   Vary beta by currents



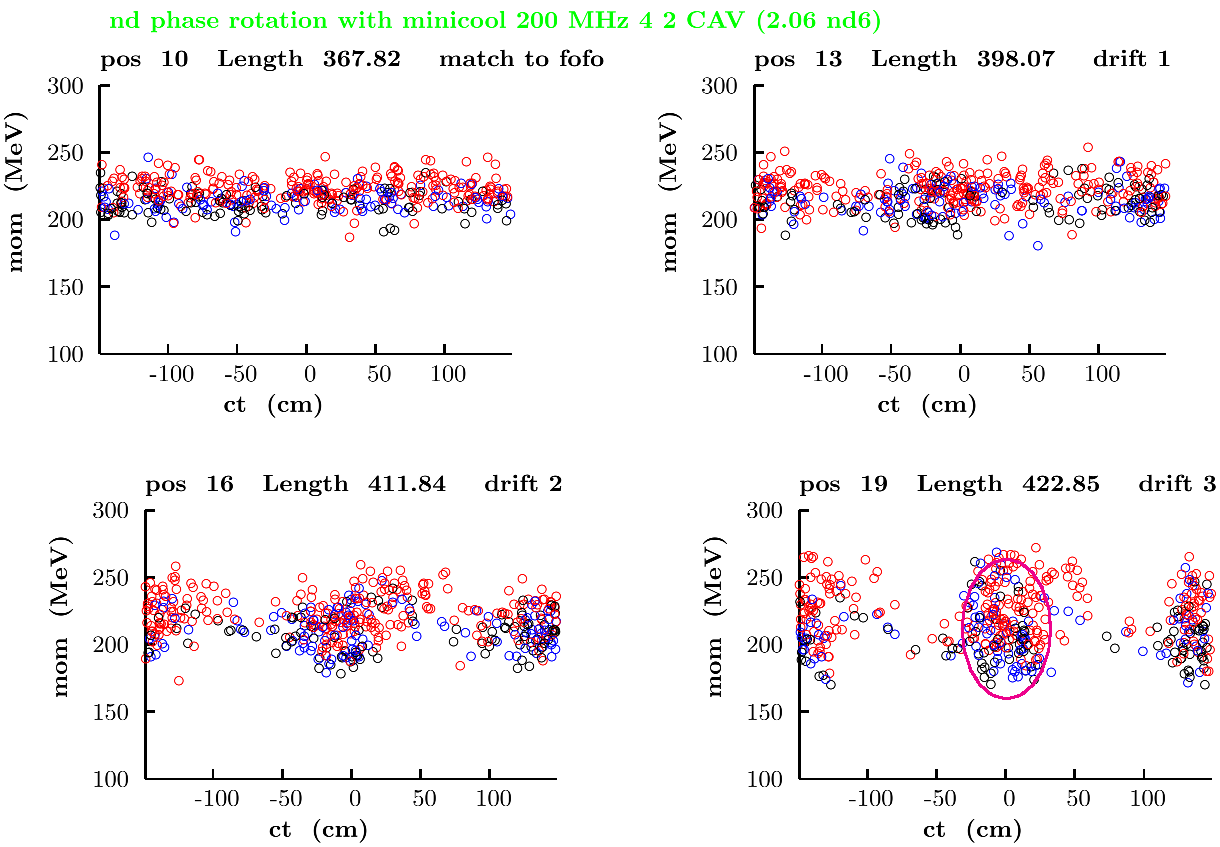
Match form solenoid to super FOFO lattice



Buncher

Three stages:

1. low field 200 MHz rf with 400 MHz harmonic, followed by a long drift (27.5 m)
2. medium field 200 MHz rf with 400 MHz harmonic, followed by a shorter drift (11 m)
3. higher field 200 MHz rf followed by a short drift (5.5 m)

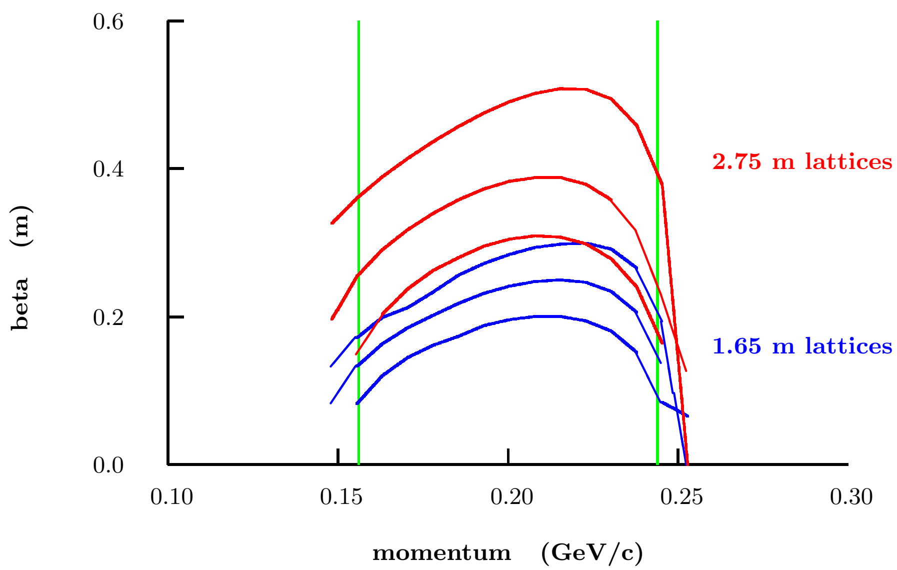


RF windows

	rad m	thickness μm
windows at ends of each 400 MHz cavity	.2	100
windows at end of each set of 4 200 MHz cavities	.21	125
windows between the 4 400 MHz cavities	.25	250

Cooling Sequence

	length	total length
	m	m
cool 1,1	$5 \times 2.75 = 11$	11
cool 1,2	$5 \times 2.75 = 11$	27.5
cool 1,3	$5 \times 2.75 = 16.5$	49.5
cool 2,1	$13 \times 1.65 = 19.8$	73.7
cool 2,2	$9 \times 1.65 = 13.2$	90.2
cool 2,3	$13 \times 1.65 = 19.8$	113.3



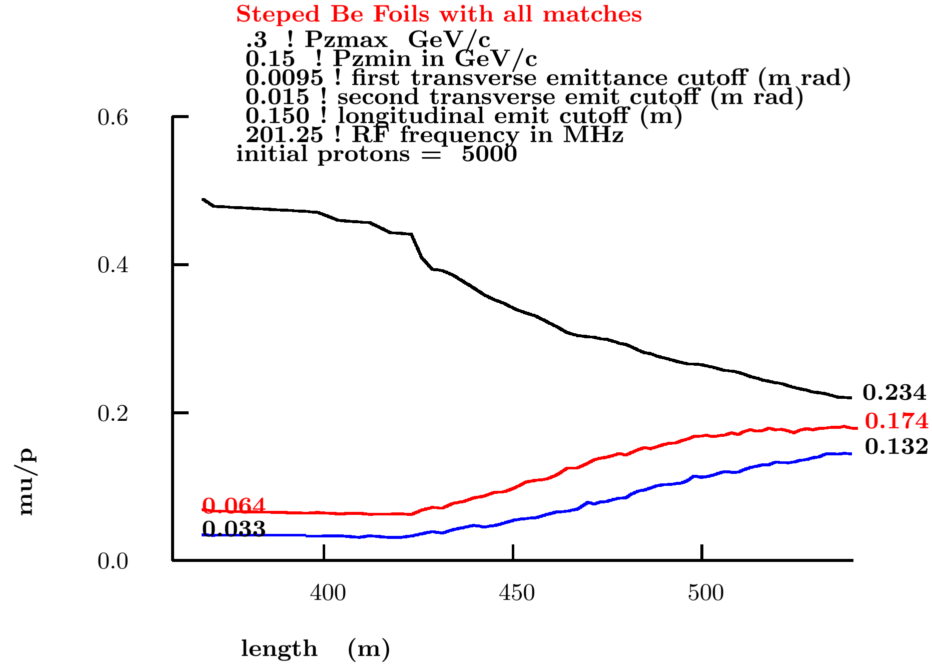
Cooling RF

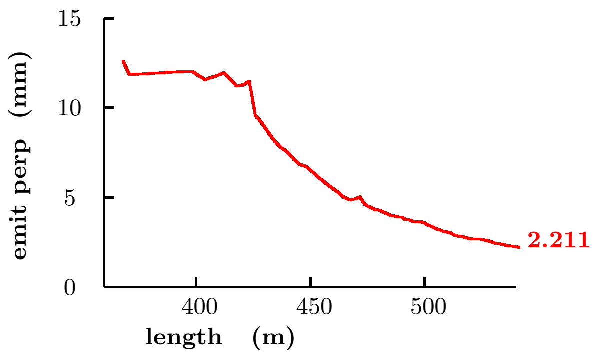
	dl cm	gradient MV/m	phase deg
Hydrogen	35		
RF	4 × 46.6	15.48	40

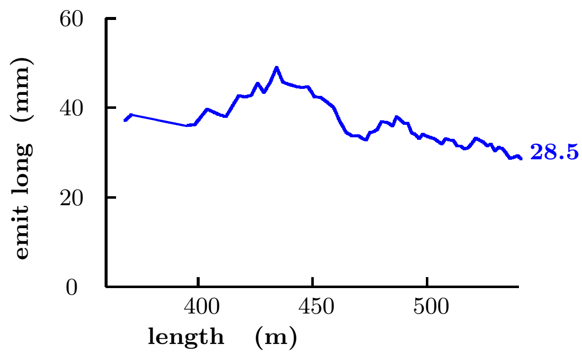
Stepped Be RF Windows

Sec	ends					center				
	t2	t1	r1	r2	mat	t2	t1	r1	r2	mat
	μm	μm	cm	cm		μm	μm	cm	cm	
1,1-3	400	200	12	18	Be	1400	700	14	21	Be
2,1-3	200	100	10	15	Be	760	380	12	18	Be

Cooling Performance



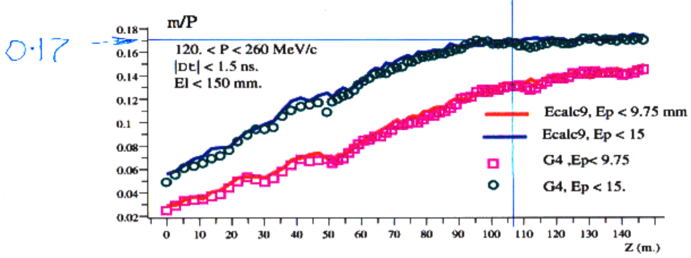




Geant4

Which Emittances ? Ecalc9 vs G4

Muon Collaboration



Correlation and centroid displacements effects can artificially increase the performance by 5, at most 10%, based on ~2600 incoming particles (800 at the end, with cuts.)

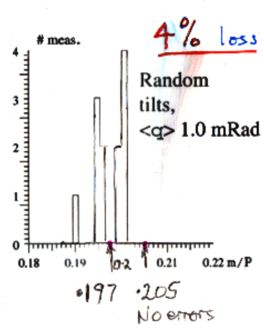
January 29 2000 Paul Lebrun 11

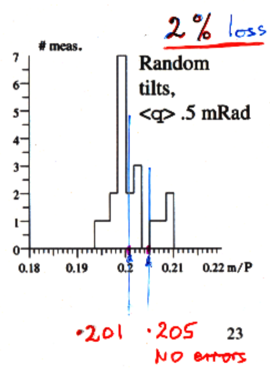
Errors

Buncher + Cooling: Yield in presence on random tilts.

Muon Collaboration

On the standard beam, estimate muon/P at the end.
Nominal value: 20.6 % Mutl. Scat. On, NO DECAY!)





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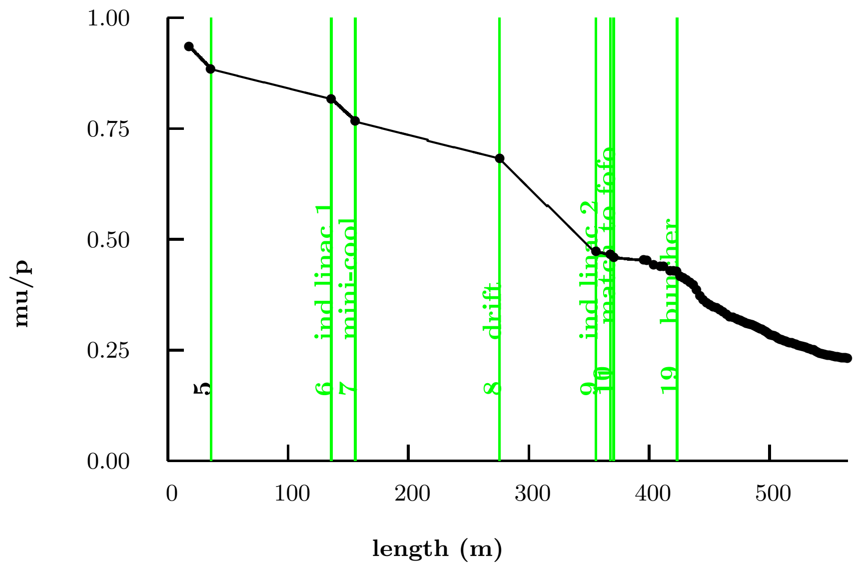
Overall Performance



Muons/year

$$\mu/\text{year} \;=\; 10^{14}{\times}2.5{\times}10^{7}{\times}0.17{\times}0.4 \;=\; 1.7\,10^{20}$$

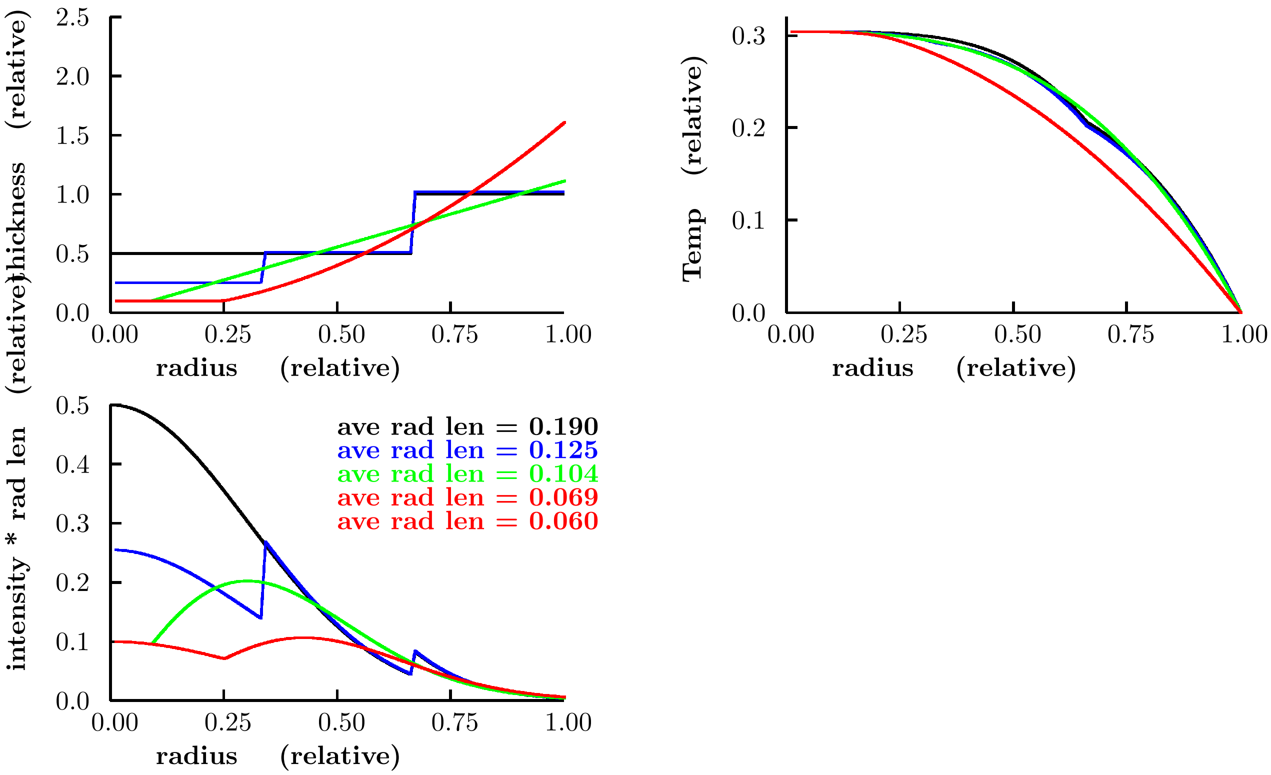
$$(\text{ppp})(\text{Hz})(\text{s/year})(\mu/\text{p})(\%\text{straight})$$

If Loss in acceleration = 30 %, then

$$\mu/\text{year} = 1 \times 10^{20}$$

Alternatives

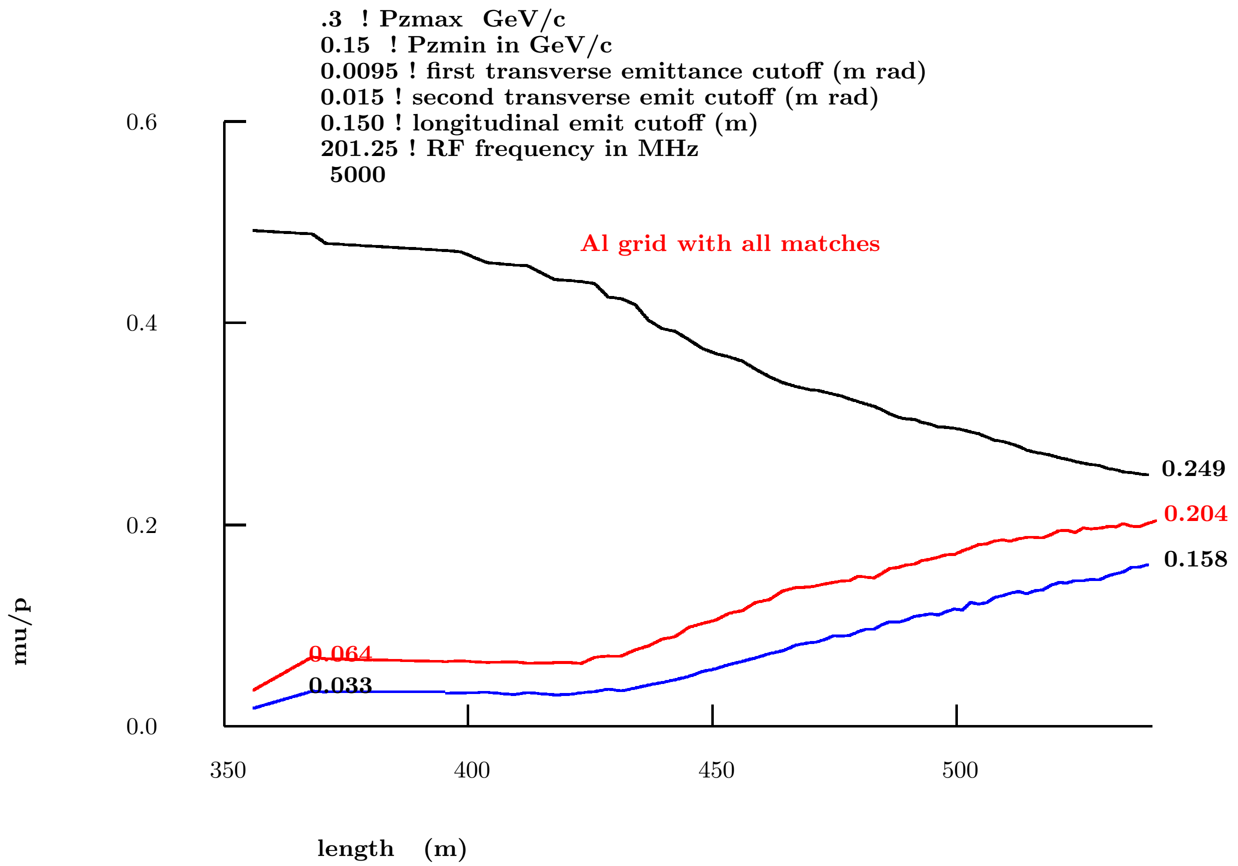
- Differing foil shapes



No Significant changes in mu/p

- Grid of tubes

mu/p=.95 Gain=15%



Compare with Study 1

	p energy GeV	bunch length rms ns	μ/p 15 mm	μ/p 9.75
Hg (Study 2)	24	3	0.17	.13
Hg (Study 2)	16	3	0.12	.08
C (Study 2)	16	3	.06	.05
C (Study 1)	16	3		.018

No change per MW from 24 vs 16 GeV
From cooling design 2.9 $\times$
From use of the mercury 1.9 $\times$
From larger acceptance is 1.2 $\times$

Total efficiency gain = 6.6 $\times$

Study 2 uses 1 MW
(Study 1 used 1.5 MW)

Study 2 1MW: gain = 4.4 $\times$ Study 1

If Study 2 1.5 MW: gain = 6.6 $\times$
If Study 2 4MW: gain = 18 $\times$

Conclusions

- Significant improvement
- Still 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 2 will not be the last