Summary of Weeks 1 and 2

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OVERVIEW

Exchange Theory
- Bob Palmer
- Dave Neuffer

Bent Solenoids
- Bob Palmer
- Rick Fernow
- Jim Norem
- Paul Lebrun

S-FOFO (→ RFOFO) with Dipoles
- Bob Palmer
- Gail Hanson
- Chun-xi Wang

Bent RF
- Juan Gallardo

Pseudo-Rotate and Bunch = First Attempt
- Dave Neuffer

Helical Channel
- Yaroslav Derbenev
- Valeri Balbekov
- Gregg Penn
- Paul Lebrun
- Daniel Elvira

Bunch Stacking
- Yasuo Fukui
- Don Summers

Ring Cooler
- Valeri Balbekov
- Dejan Trbojevic

Emittance Exchange without Wedges
- Scott Berg

Longitudinal Focusing without RF
- Bruce King

ICOOL Implementations – Rick Fernow
- v2.10 Bent Solenoid with Dipole Field
- v2.11 Bent RF Cavities

Impact of Exchange on Neutrino Factory
- Scott Berg

BENT SOLENOIDS

1. Bob Palmer did a design that produced emittance exchange, but transverse emittance increased.

2. Rick Fernow did ICOOL simulation with rf after bent solenoid to make longitudinal phase space upright before wedges. But problems:
   Longitudinal emittance did not decrease
   Higher order effects, error buildup limits performance

3. Bob Palmer suggested putting rf before bent solenoid ←

No new work at Workshop that I am aware of.

4 Emittance exchange system design

We now consider the design of an actual emittance exchange system. The first half, dealing with dispersion in y, is shown schematically in Fig. 5.

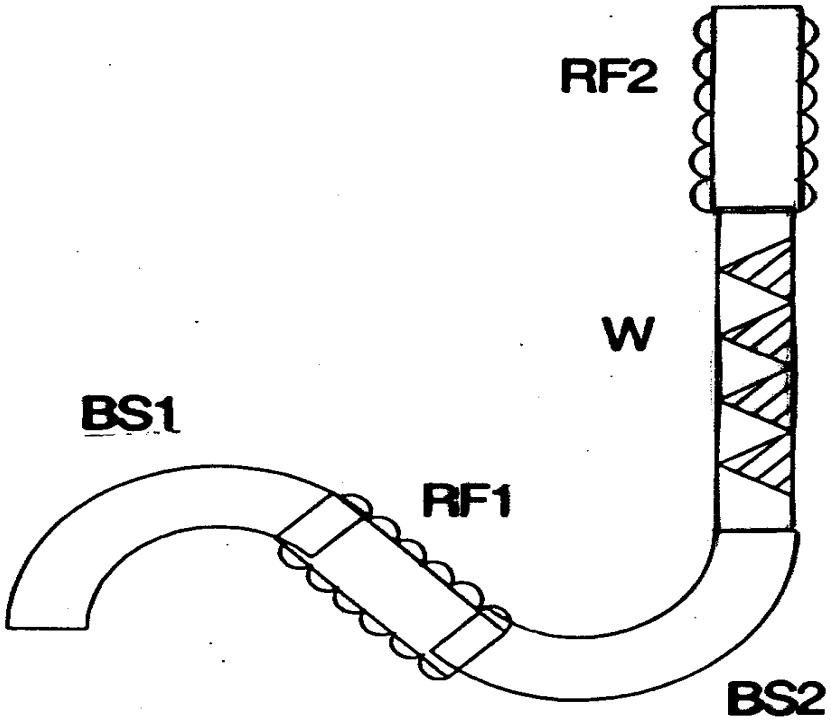


Figure 5. Schematic layout of one half of an emittance exchange system.

configuration

P_z vs t

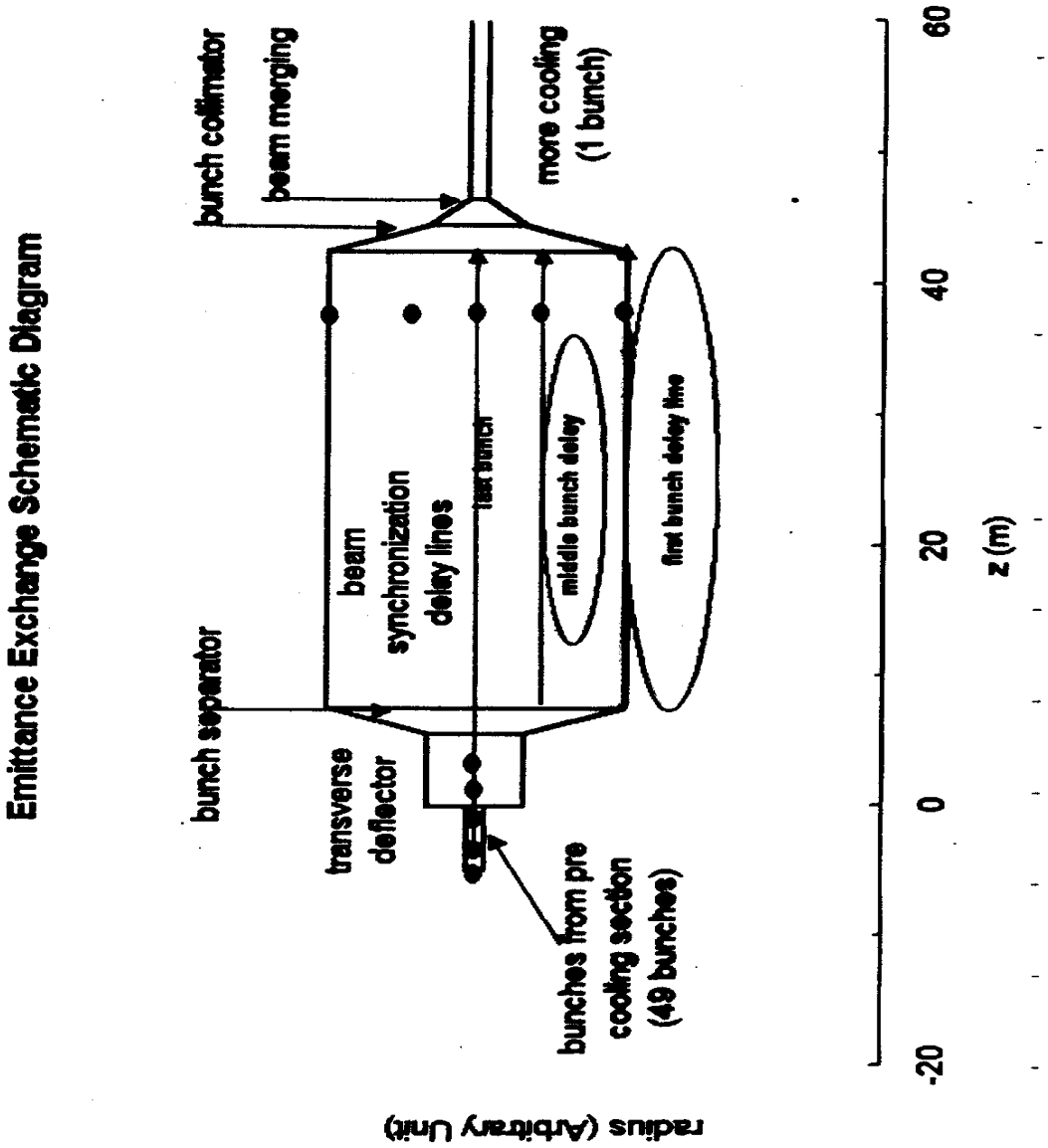
BUNCH STACKING

1. Yasuo Fukui showed his ideas (original work by Charles Kim). Working on ICOOL simulation.

2. Don Summers looking into kickers.

Status reports later this week.

Figure 1


Emittance Exchange Schematic Diagram
bunch collimator
beam merging
more cooling
(1 bunch)
beam
synchronization
delay lines
last bunch
middle bunch delay
first bunch delay line
bunch separator
transverse
deflector
bunches from pre
cooling section
(49 bunches)
radius (Arbitrary Unit)
-20
0
20
40
60
z (m)

HELICAL CHANNEL

1. Theory – Yaroslav Derbenev
   Solenoid + dipole that rotates along length (+ quadrupoles, sextupoles, etc.)

2. Simulation by Valeri Balbekov:
   Found longitudinal perturbation due to nonlinear effects limits performance
   Introducing E-p_T correlation for injected beam brought improvement. However, 6D emittance is increased and transmission is decreased compared with no emittance exchange. (See Table.)

3. Simulations by Gregg Penn (ICOOL), and Paul Lebrun and Daniel Elvira (GEANT4) ongoing. Status report(s) this week?

$$B_x = B_t\left(\sin\frac{2\pi z}{L} + O\left(\frac{r^2}{L^2}\right)\right) \quad (1)$$

$$B_y = B_t\left(\cos\frac{2\pi z}{L} + O\left(\frac{r^2}{L^2}\right)\right) \quad (2)$$

$$B_z = B_0\left(1 + O\left(\frac{B_t r}{B_0 L}\right)\right) \quad (3)$$

Table 1: Parameters of cooled beam in different approximations.

	Transverse emit. (cm)	Longitudinal emit. (cm)	6D emit.(cm^3)	Transmission
Linear approximation	0.59	1.9	0.67	0.92
Trans. nonlinearities	0.63	1.9	0.75	0.93
All nonlinearities	0.64	2.6	1.07	0.60
With $E - p_t$-correlation	0.75	2.4	1.35	0.81
Without emittance exchange	0.52	3.5	0.95	0.92

RING COOLER

Valeri Balbekov found emittance exchange in two versions. (See tables).

Other simulations? Future work?

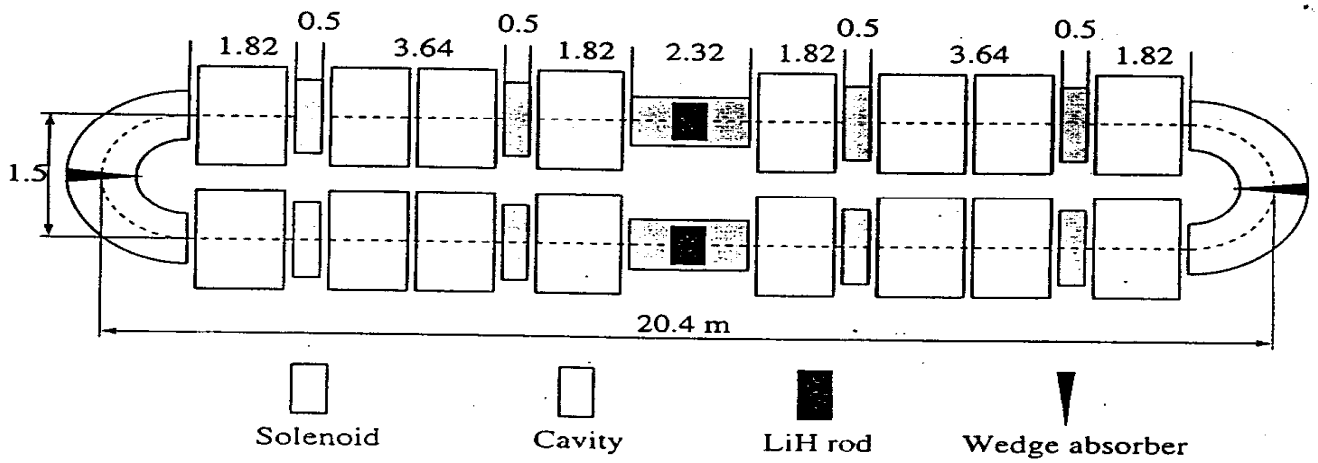
Emittance exchange in ring coolers

V.Balbekov, Fermilab

Emittance exchange workshop, BNL, September 2000

Part A: Low frequency ring cooler (RF = 13.5 MHz, single bunch cooling)

A1. Schematic of the cooler (all sizes in meters)



Motivation:

- Cost
- Easy emittance exchange

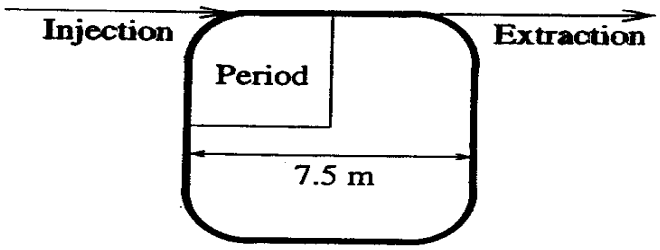
Low Frequency Ring Cooler

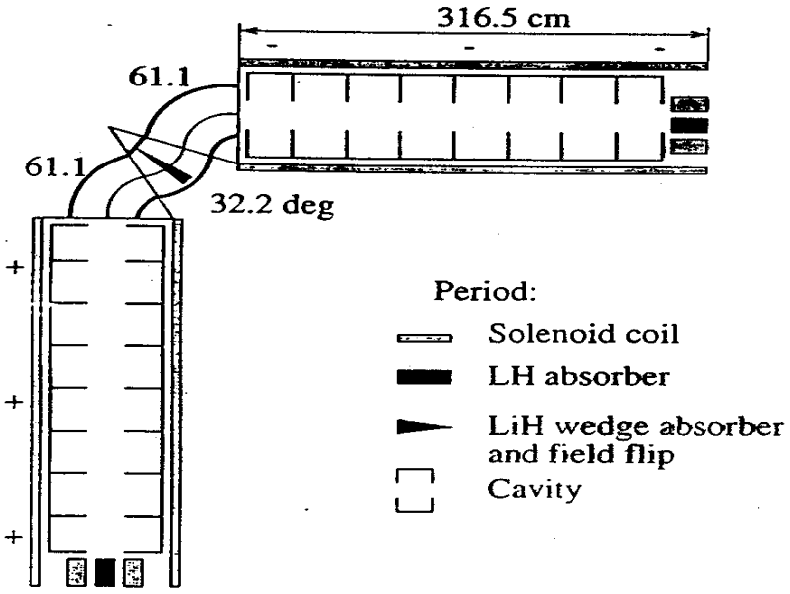
A8. Summary; effect of different factors on the cooling and emittance exchange (beam emittance and transmission after 30 tutns)

	ε_x (mm)	ε_y (mm)	ε_z (mm)	ε_6 (mm^3)	Trans.(%)
Injected beam	12	12	150	21600	100
Paraxial approximation	2.6	2.0	5.0	26	55 (decay)
+ Chromaticity	5.3	4.2	5.8	129	45
+ Transverse nolinearity	6.1	4.6	10	280	40
+ Longitudinal nonlinearity	5.7	4.7	44	1180	36

Part B: High frequency ring cooler (RF = 201.25 MHz, multibunch cooling)

B1. Schematic of the cooler





High Frequency Ring Cooler

B7. Summary; effect of different factors on the cooling and emittance exchange (beam emittance and transmission after 10 tutns)

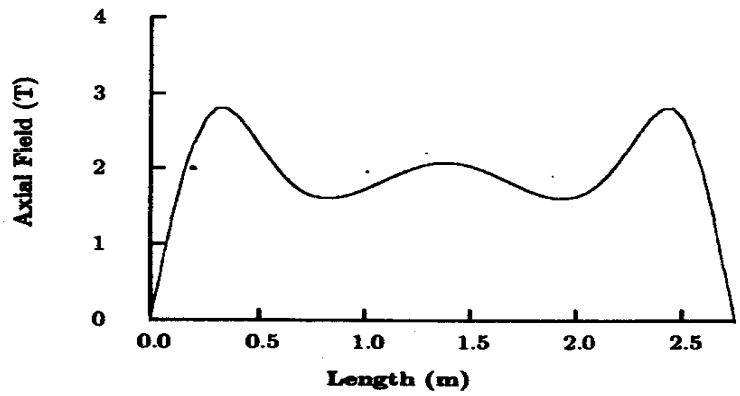
	ε_x (mm)	ε_y (mm)	ε_z (mm)	ε_6 (mm^3)	Trans.(%)
Injected beam	12	12	15	2160	100
Paraxial approximation	2.5	2.3	6.6	38	68
+ Transverse nolinearity	2.5	2.5	7.1	44	50
+ Longitudinal nonlinearity	2.6	2.8	8.8	64	33

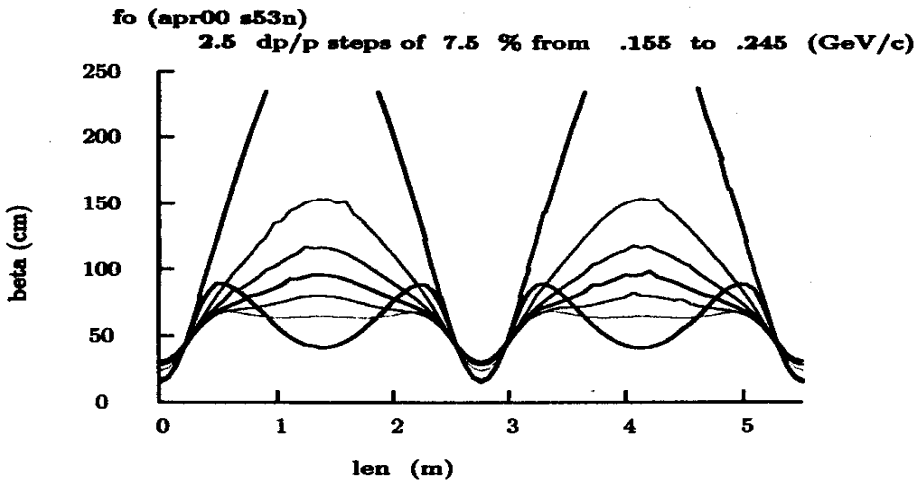
S-FOFO (R-FOFO) WITH DIPOLES

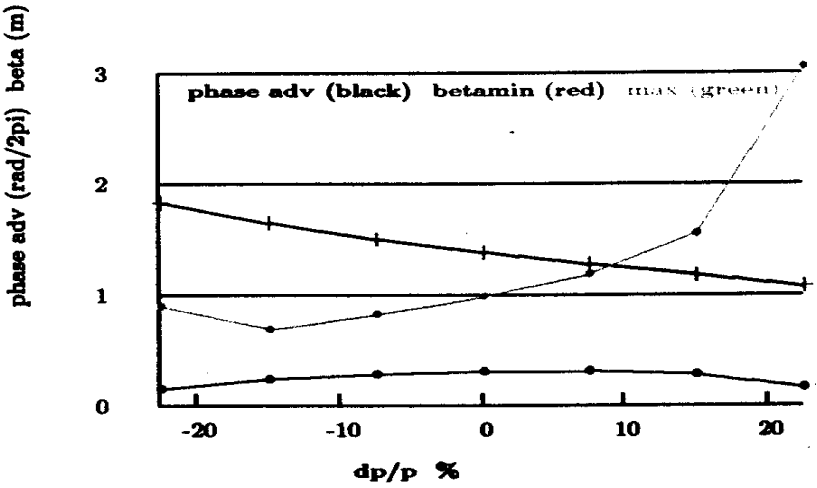
1. S-FOFO from Study 2 Design A (Bob Palmer's original note).
   Dispersion produced by bending in dipole
   Focusing from dipole gradient
   Bob Palmer replaced S-FOFO with R-FOFO.

2. Analytical solution by Chun-xi Wang.

3. Simulations (ICOOL) by Bob Palmer and Gail Hanson ongoing.
   Status reports this week.

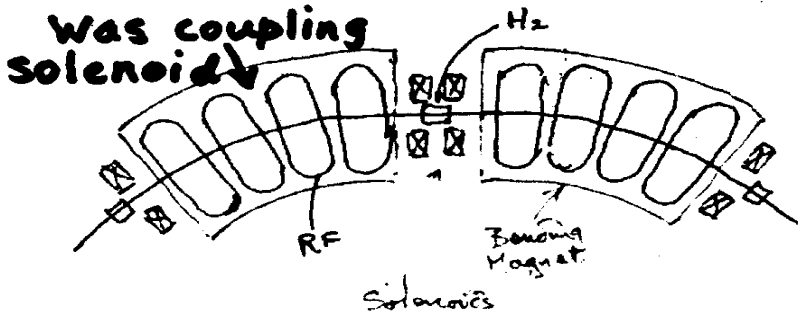

Axial Field (T)
4
3
2
1
0
0.0
0.5
1.0
1.5
2.0
2.5
Length (m)


fo (apr00 s53n)
2.5 dp/p steps of 7.5 % from .155 to .245 (GeV/c)
beta (cm)
250
200
150
100
50
0
0
1
2
3
4
5
len (m)

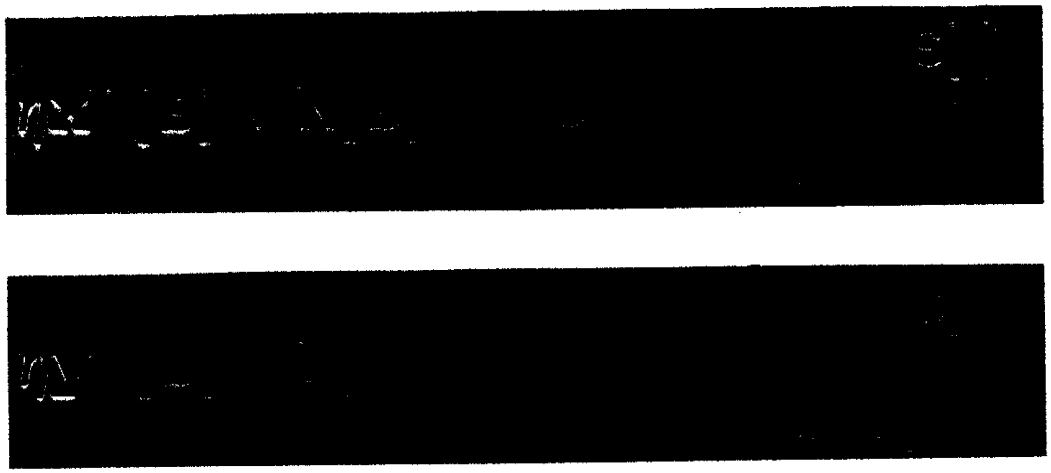


0.2 Add a Bend

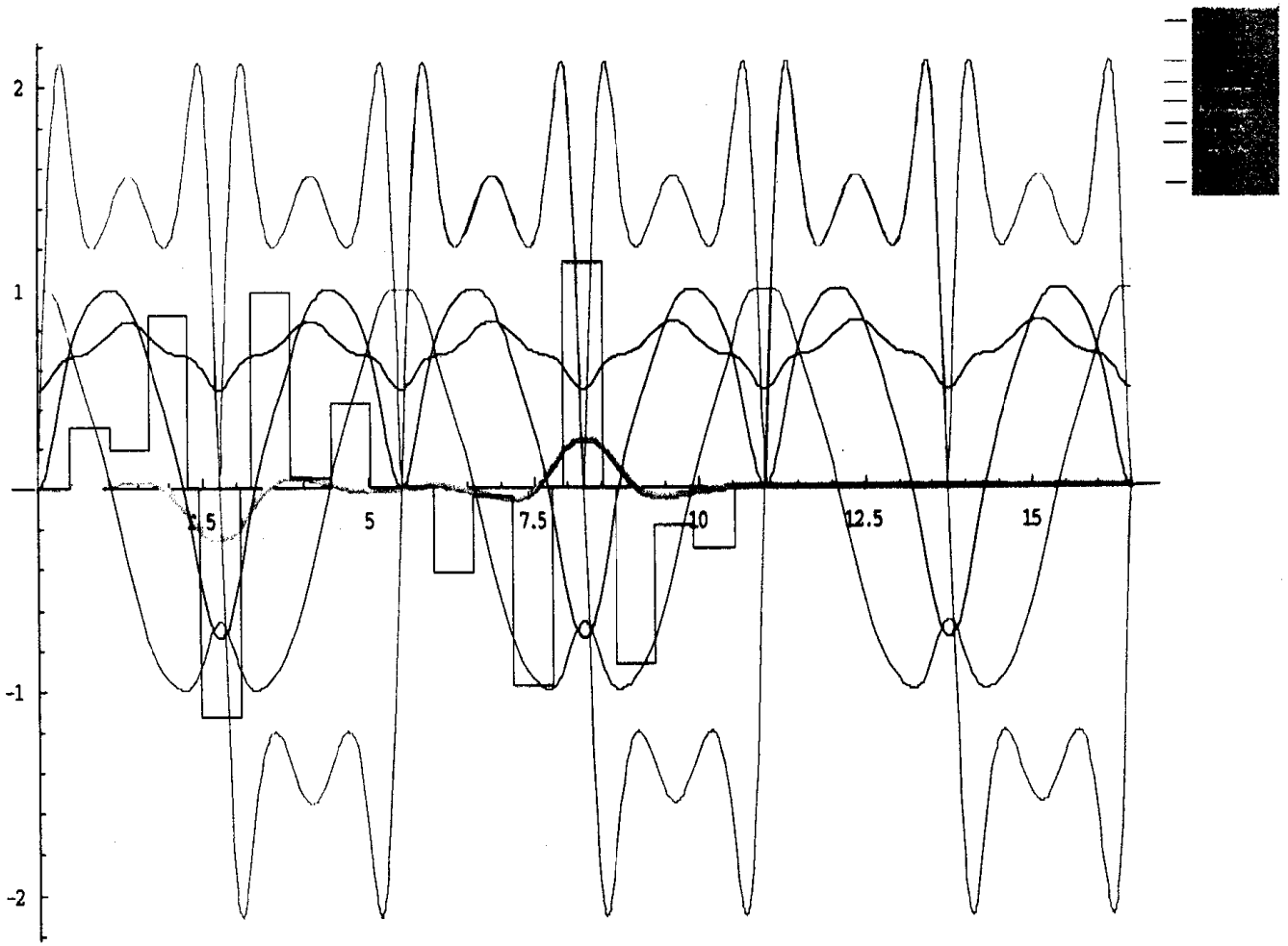
In order to use this lattice for emittance exchange we must add some bending to generate dispersion at the absorber. The absorber can then be made wedge like and the required exchange obtained. Consider putting the bend in the center of the cell¿ It now falls on top of the coupling solenoid, which is uncomfortable. But bening magnets have focussing: perhaps it can replace this solenoid.



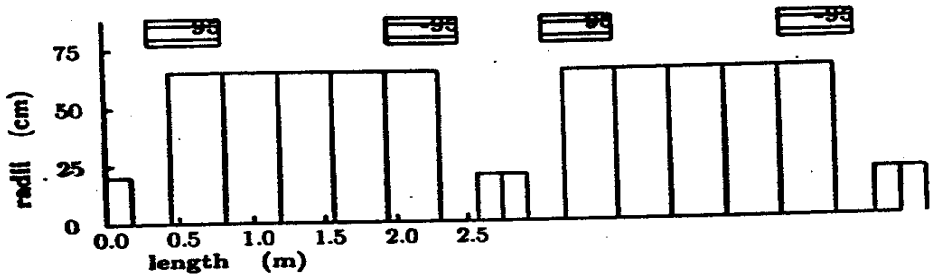
Equations for dispersion function

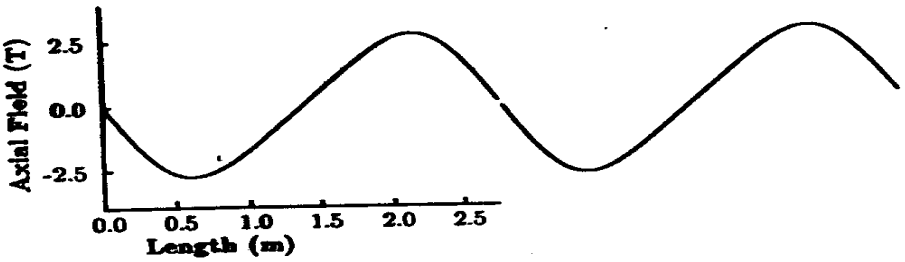


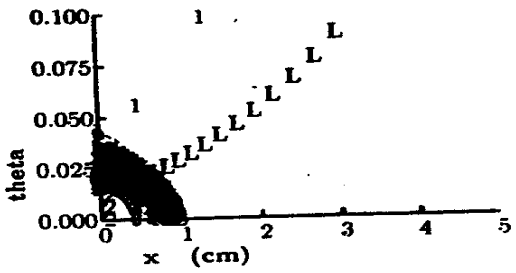
Example Solution

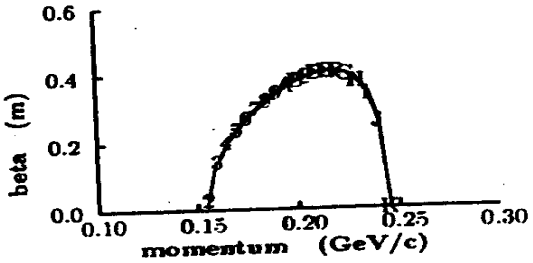


R FOFO


radii (cm)
75
50
25
0
0.0
0.5
1.0
1.5
2.0
2.5
length (m)


Axial Field (T)
2.5
0.0
-2.5
0.0
0.5
1.0
1.5
2.0
2.5
Length (m)


theta
0.100
0.075
0.050
0.025
0.000
0
1
2
3
4
5
x (cm)

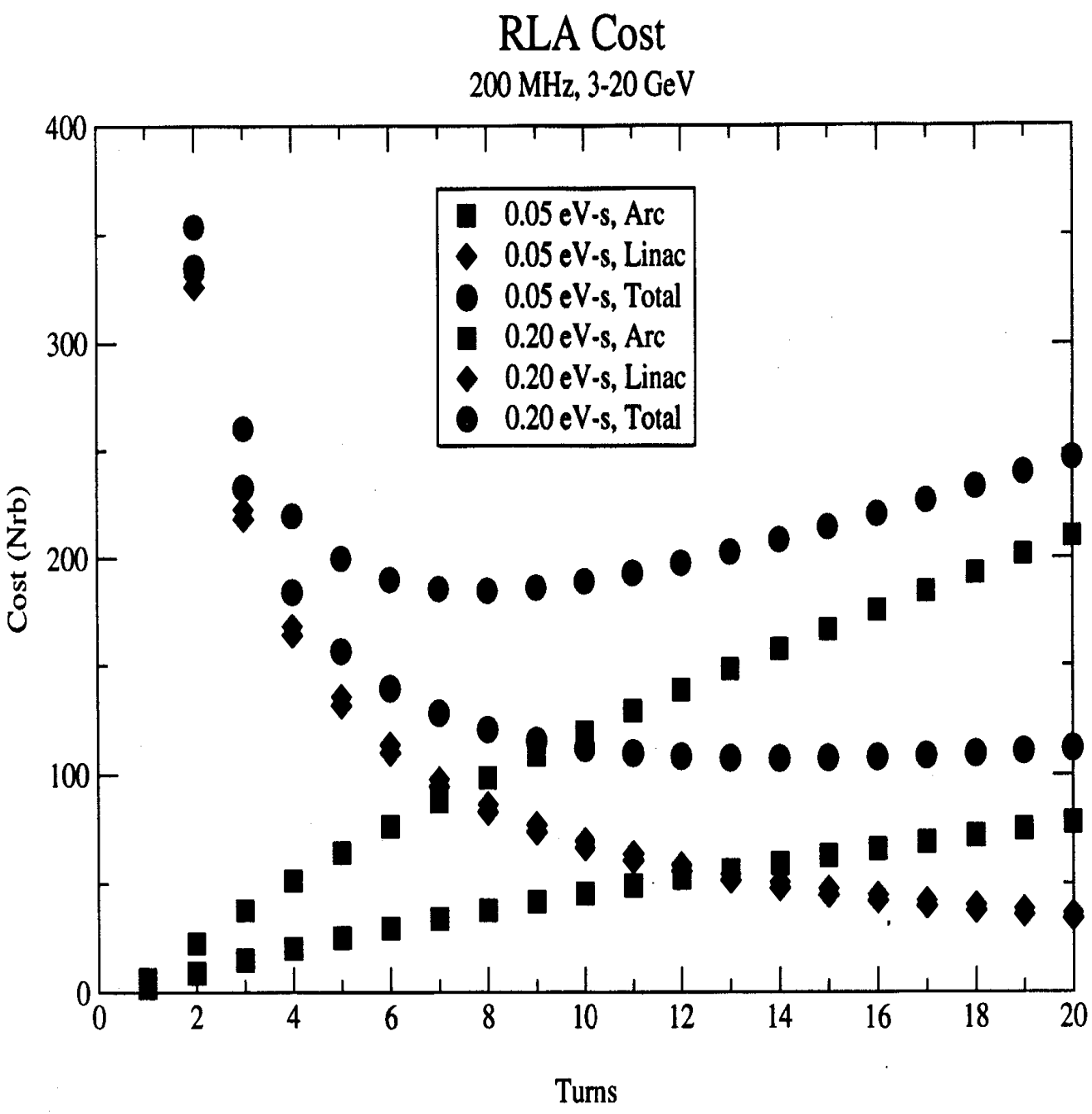

beta (m)
0.6
0.4
0.2
0.0
0.10
0.15
0.20
0.25
0.30
momentum (GeV/c)

COST BENEFITS OF LOW LONGITUDINAL EMITTANCE

Scott Berg showed analysis during Week 1.
- Easier arcs
- Lower frequency better
- Savings of 10% of total machine for X4 emittance reduction

PSEUDO-ROTATE AND BUNCH – FIRST ATTEMPT "BETTER BUNCHER"

Dave Neuffer discussed scheme that uses 150-300 MHz rf varying frequency in z (tunable rf cavities?)
- Replaces induction linac and low-frequency rf.
- 75% of μ's captured.


RLA Cost
200 MHz, 3-20 GeV
0.05 eV-s, Arc
0.05 eV-s, Linac
0.05 eV-s, Total
0.20 eV-s, Arc
0.20 eV-s, Linac
0.20 eV-s, Total
Cost (Nrb)
Turns
0
100
200
300
400
0
2
4
6
8
10
12
14
16
18
20