RFOFO cooling ring: simulation results

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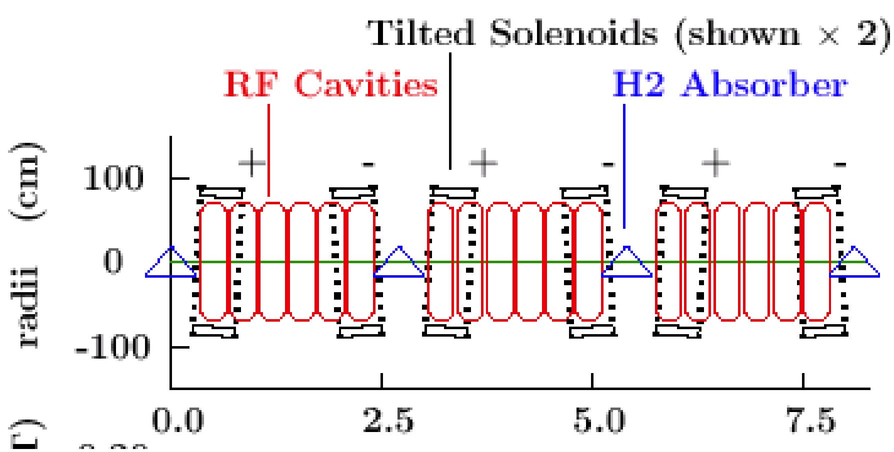
Basic idea

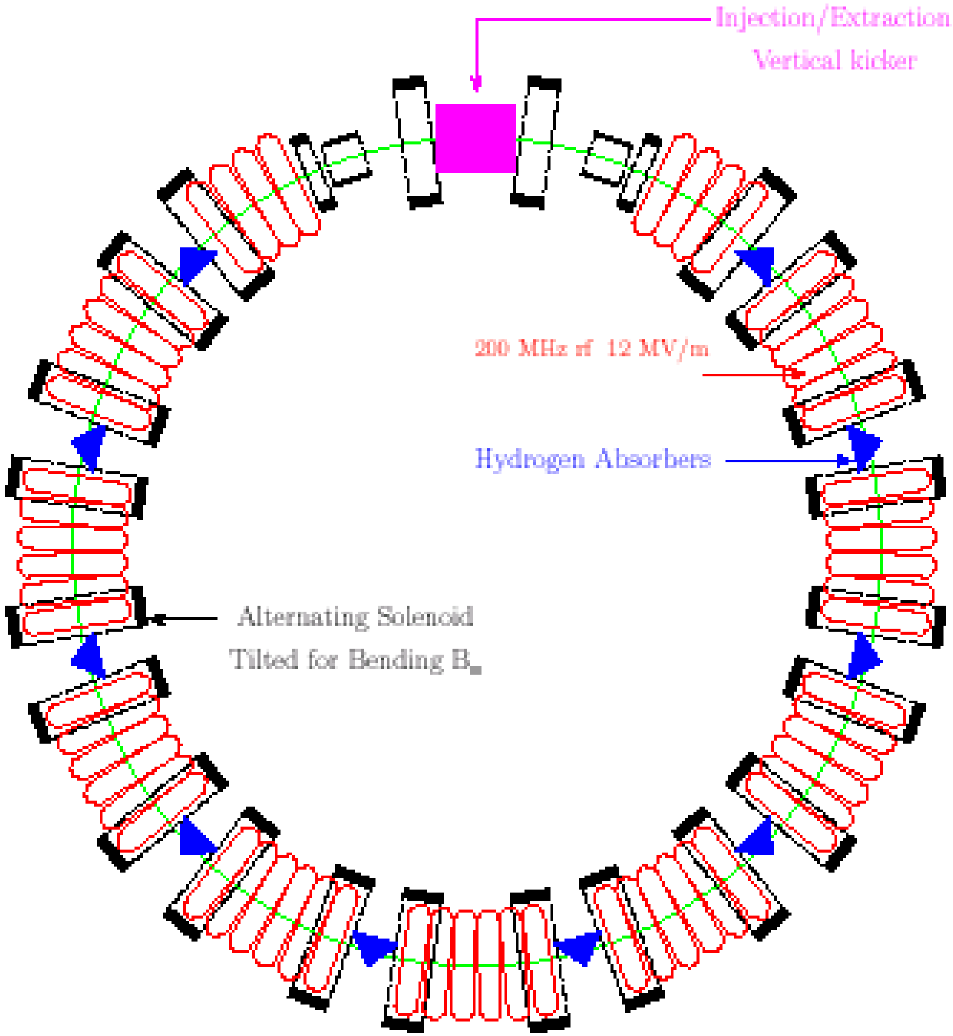
- use alternating solenoid focused lattice
  - large angular acceptance
- identical repeating cells => RFOFO
  - magnetic cell = geometric cell
  - eliminates resonances in momentum acceptance
- short cell length => get low β_T at absorber with moderate field
  - leave RF in dispersive region
  - all cooling in wedge absorbers



History

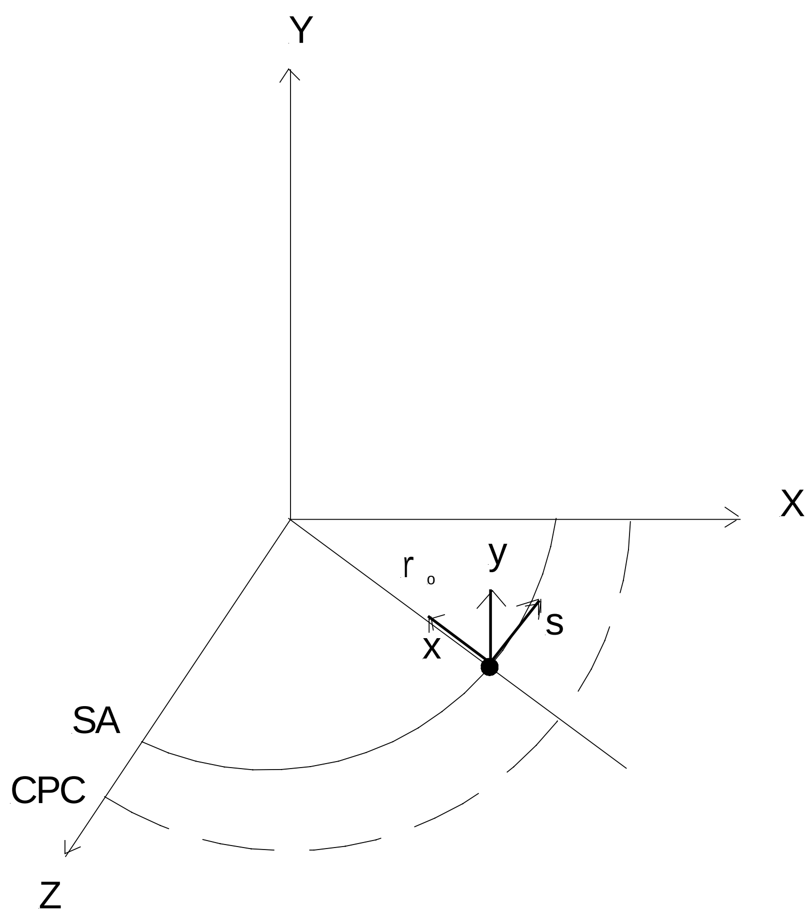
- idea introduced by R. Palmer at BNL EmEx WS (9/00)
- first promising results at LBL EmEx WS (10/01)
- first detailed design by BFG&P MC239 (3/02)
  superimposed gradient dipole field
- dipole field from tilted solenoids at Shelter Island (5/02)
- ring cooler and EmEx WS at FNAL (11/02)
- studies of fields from tipped solenoids
  MC265 (11/02), MC268(1/03), MC271(3/03)
- first simulations using realistic fields by V. Balbekov MC264 (11/02)
- ICOOL ring simulations MC273 (4/03)
- Geant ring simulations are under way

Present ring design [MC273]



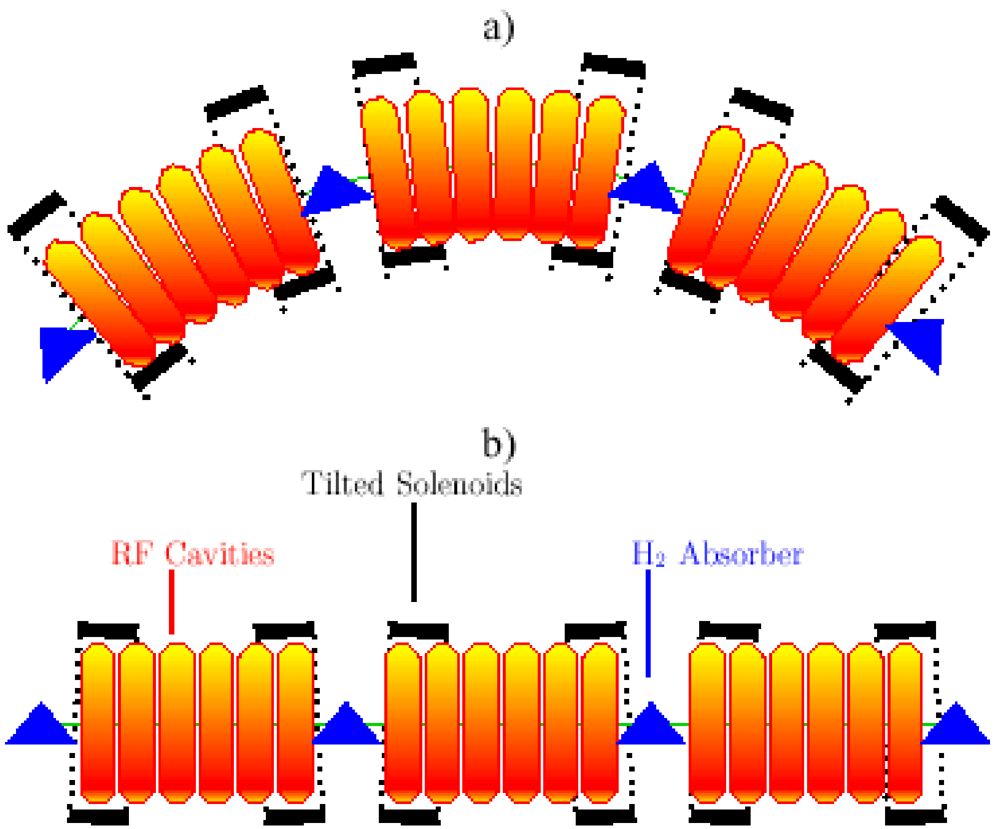
C	33 m
cells	12
cell length	2.75 m
wedge mat	LH_2
wedge angle	100^o
wedge thick	25.4 cm
wedge azim	270^o
rf freq	201.25 MHz
rf grad	12 Mv/m
rf phase	25^o

Solenoid displacement



- to minimize B_X on-axis center of coils are displaced radially

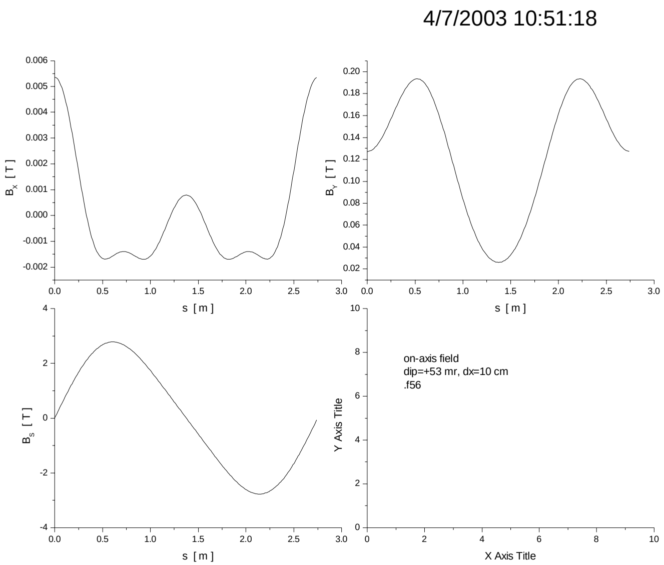
Cell layout



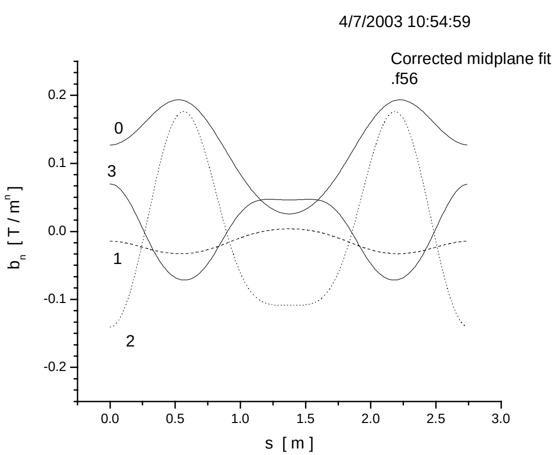
plan view
(distorted wedges)

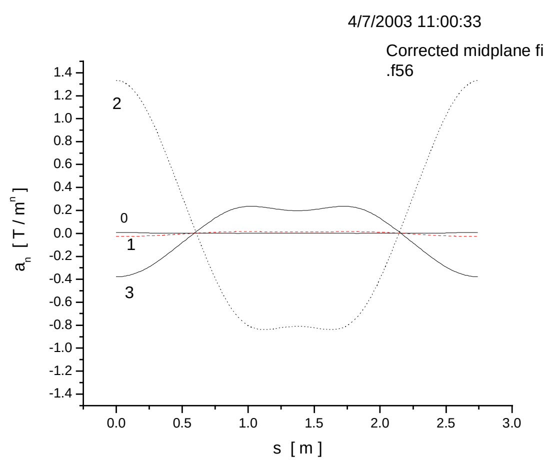
elevation view

Realistic fields from tipped solenoids

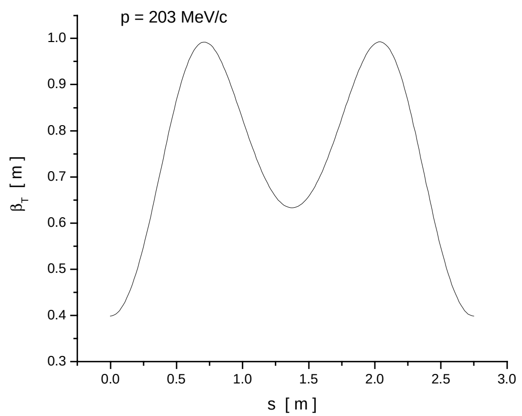


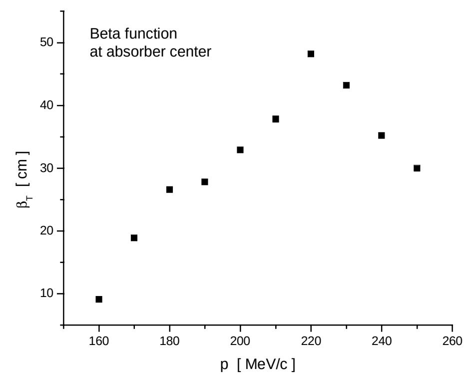
- fields from
  current sheets (elliptic integrals)
  Biot-Savart law
- satisfies ME to ~1 μT/m



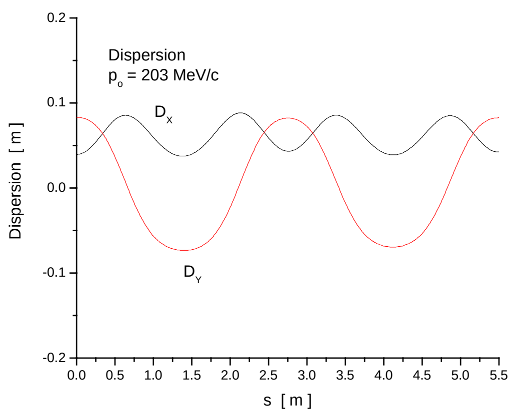


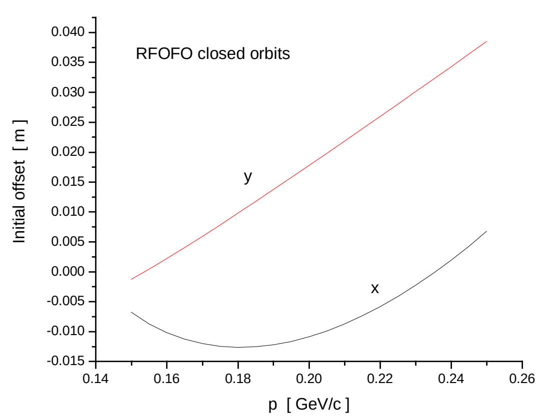
Lattice functions





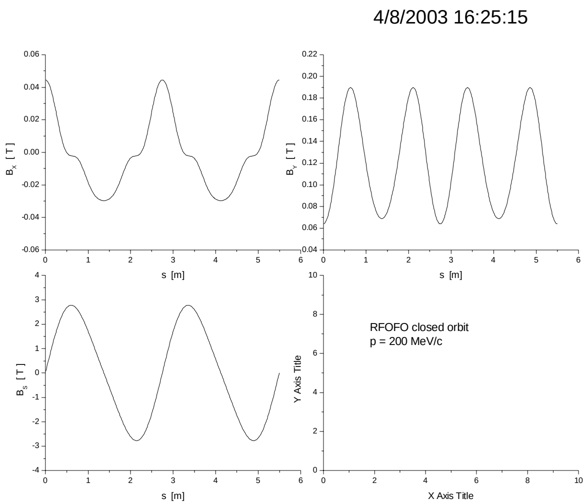
- minimum β_T is at absorber
- min $\beta_T \sim 38$ cm
- transmits over 160-250 MeV/c

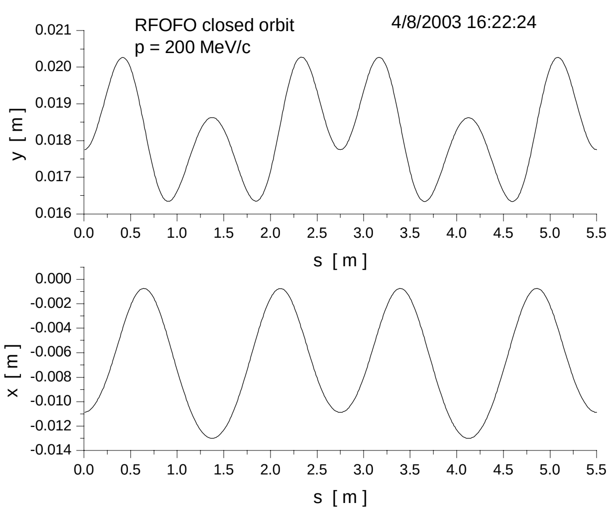




- dispersion angle rotates
- max disp ~ 8 cm
- very linear in y

Closed orbits

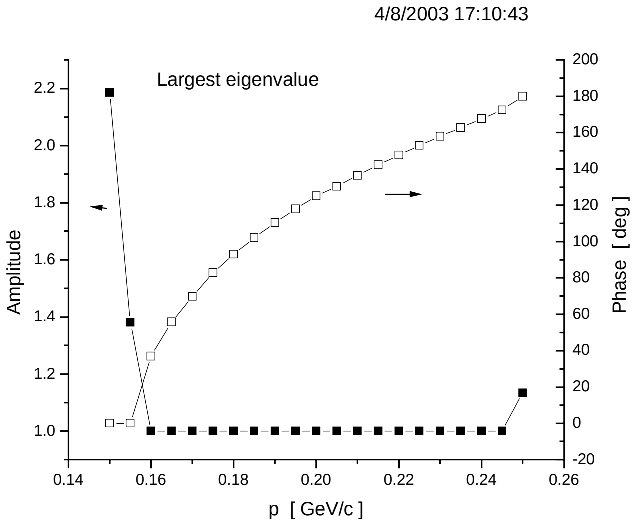




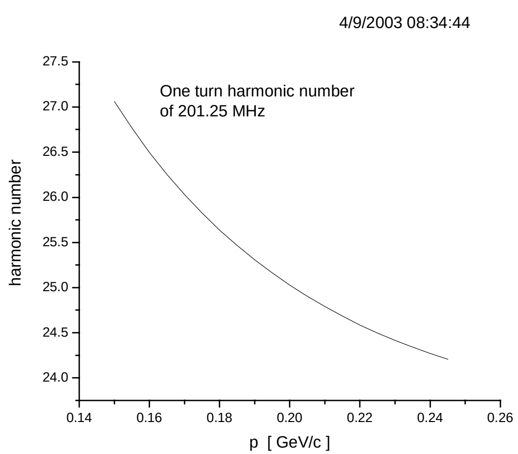
- B_Y more regular

- x varies by ±6 mm
- y varies by ±2 mm

Eigenvalues, harmonic number

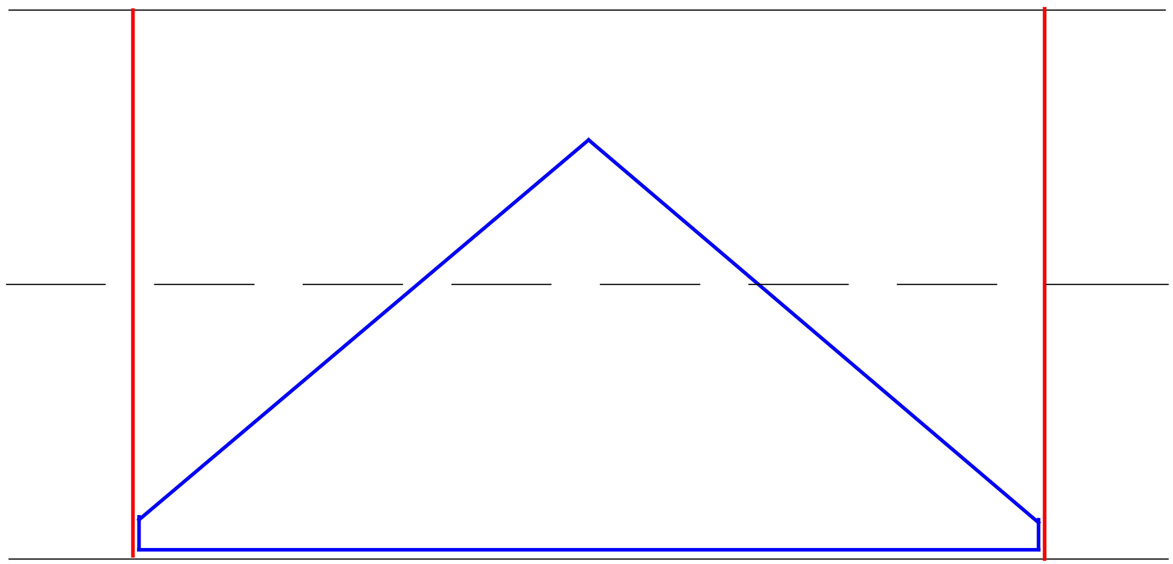


- look at derivative matrix of nearby trajectories over 1 cell (S. Berg)
- extract eigenvalues
- no large resonances over 160-245 MeV/c



- look at propagation time of closed orbits as a function of p
- picking 25th harmonic of 201.25 MHz $\Rightarrow p_{REF} = 203$ MeV/c

Wedge absorber



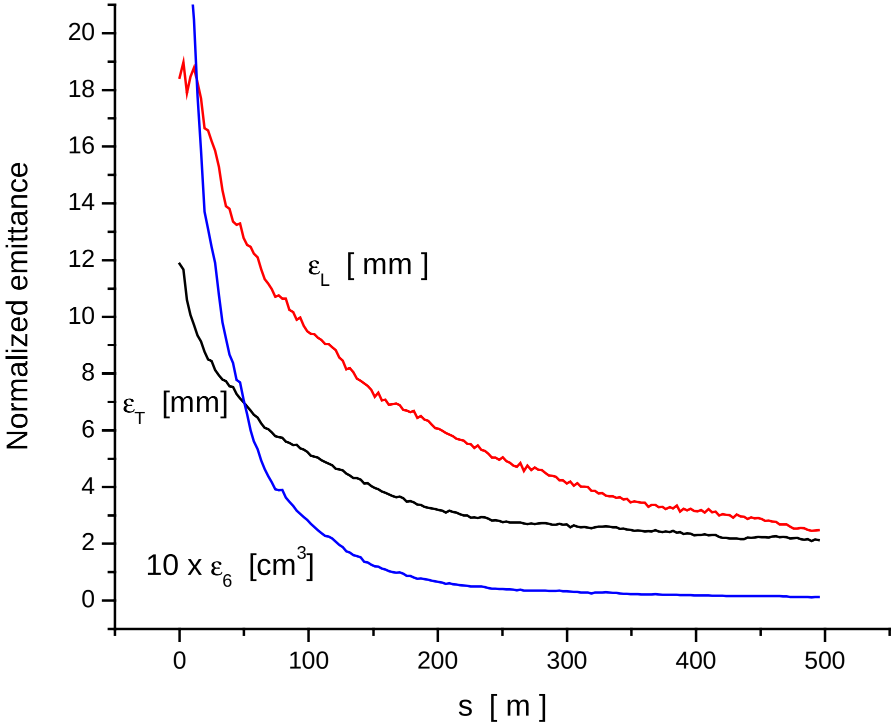
• only covers part of aperture
• note window locations

Beam simulations

- used initial beam similar to V. Balbekov MC264
- include amplitude – momentum correlation

$\sigma_X = \sigma_Y$	4.25 cm
σ_{ct}	8 cm
$\sigma_{PX} = \sigma_{PY}$	30 MeV/c
ref, $< p_Z >$	203, 220 MeV/c
σ_E	20 MeV
ε_{TN}	12 mm
ε_{LN}	18 mm

Emittances for ideal ring



ε_{TN} x 5.6

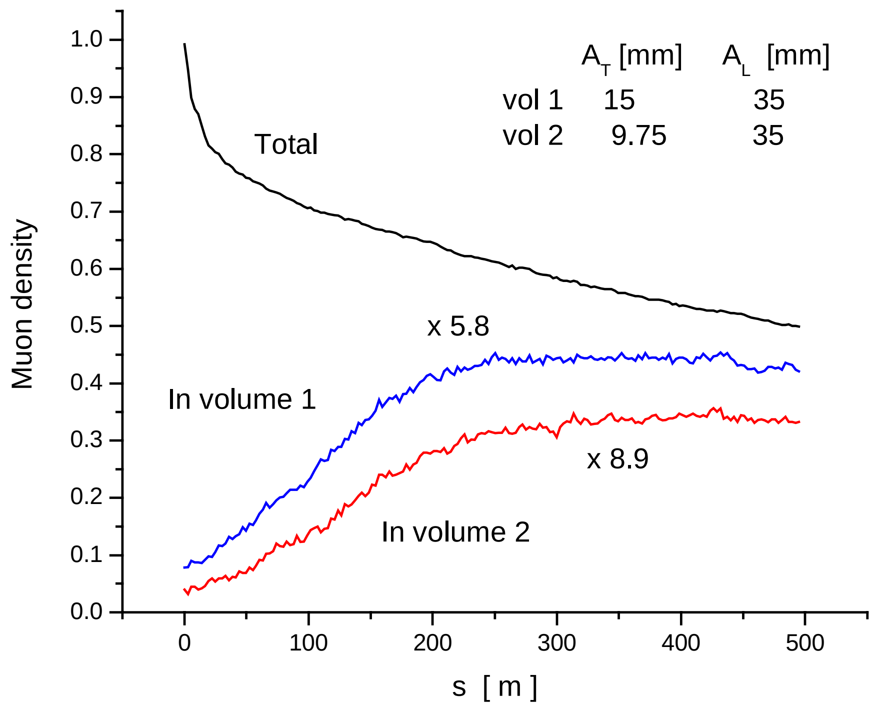
ε_{LN} x 7.4

ε_{6N} x 223

Tr = 0.503 (with decay)

M = 112

Muon density for ideal ring



- measure performance with the D-factor

$$D = (N_\mu(s) / V) \; / \; (N_\mu(0) / V)$$

Real-world perturbations

- FS2 used 360 μm Al absorber windows
  - may be thicker for safety
  - may be thinner for optimized material or shape
- FS2 used 200-400 and 700-1400 μm Be rf windows
  - could be thinner because of
    1. liquid nitrogen operation
    2. lower rf gradient (12 vs 16 MV/m)
- allow 2 empty cells for injection/extraction kickers
  - maintain magnetic periodicity

Perturbations on ideal ring

absorber	abs win	rf win	empty cells	D
LH	none	none	0	8.93
LH	250 μm Al	none	0	7.50
LH	360 μm Al	none	0	6.60
LH	500 μm Al	none	0	6.08
LiH	none	none	0	4.88
LH	none	FS2	0	5.88
LH	none	FS2 / 20	0	7.80
LH	none	none	2	6.73
LH	360 μm Al	FS2 / 20	2	4.25

Conclusions

- good progress so far
  good performance with two codes, third in progress
- plausible ring design can increase muon density by factor of 4
- need further work on modeling realistic absorber windows
- requires preceding bunch compression ring
  cf. V. Balbekov, MC272
- need self-consistent front end design: target through cooling ring
- need design for state of the art kicker for injection