RFOFO Cooling Rings

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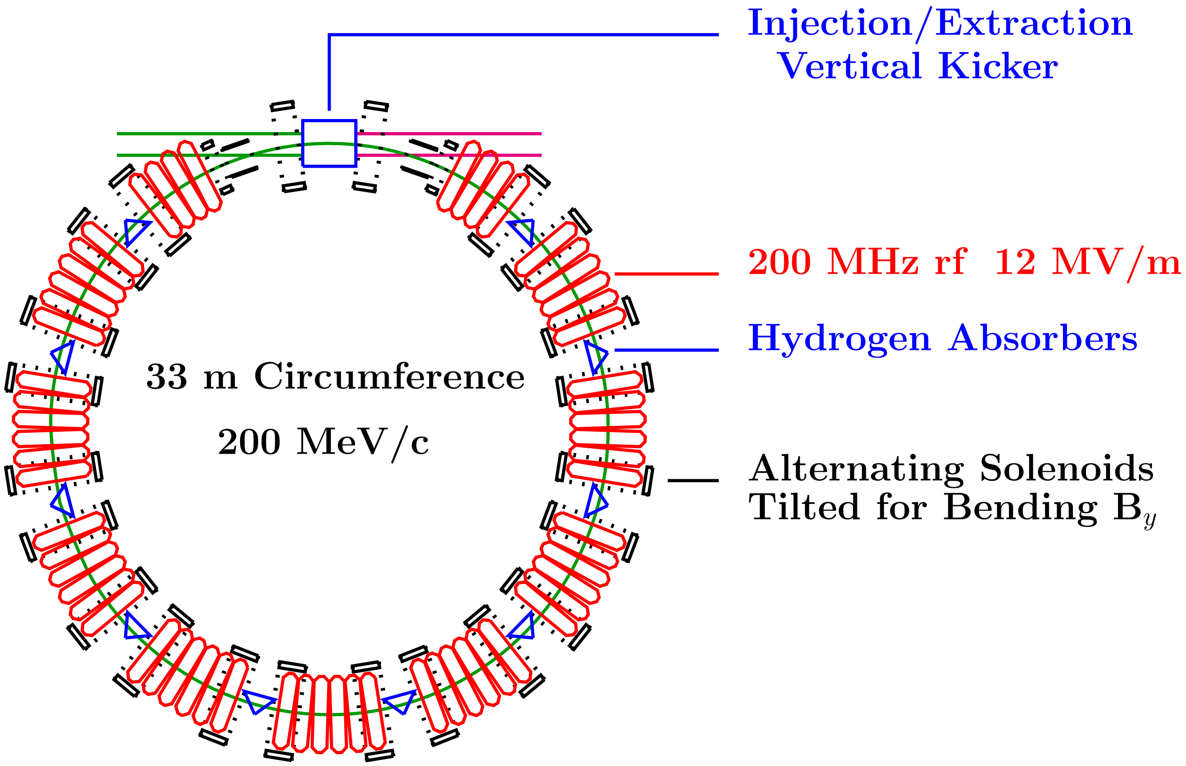
LBNL (Oct 2002)

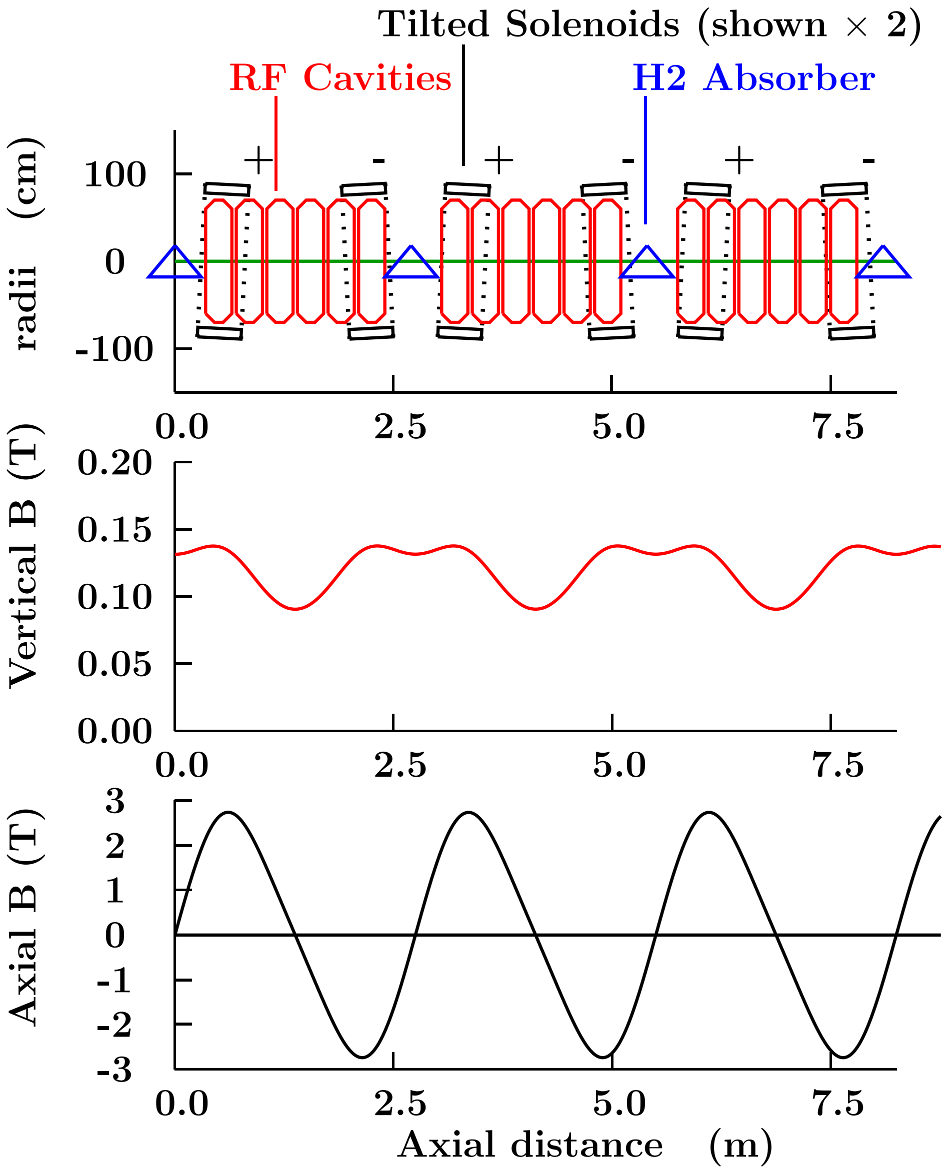
1. Recap First 200 MHz FOFO Ring
2. 10 MHz Ring for First Cooling ?
3. 200 MHZ Low Beta Ring for later Cooling ?

Original 200 MHz RFOFO Ring



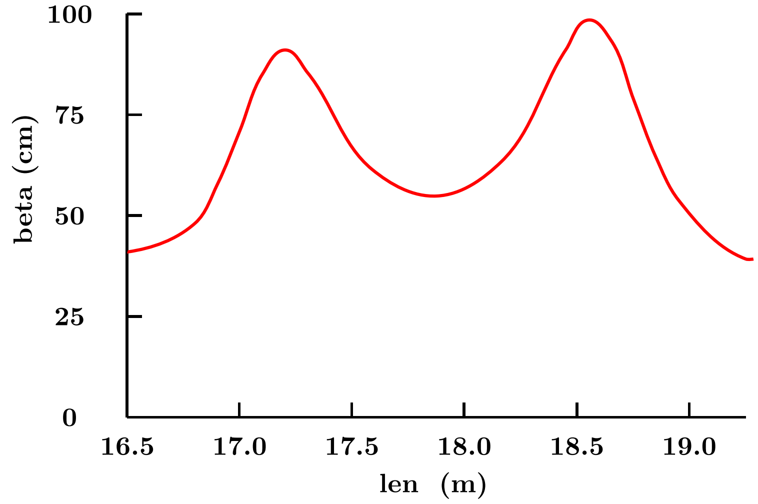
- Rf in dispersive location
- Bending Field Index n=0 i.e. $\beta_x \neq \beta_y$

How to generate By

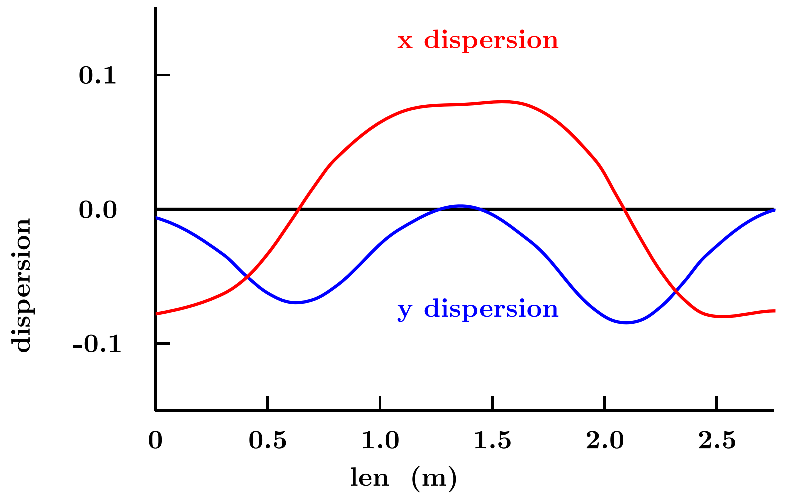


- Approx 0.026 Rad tilts
- Insensetive to By details
- But sensetive to Bz

Beta and Dispersion

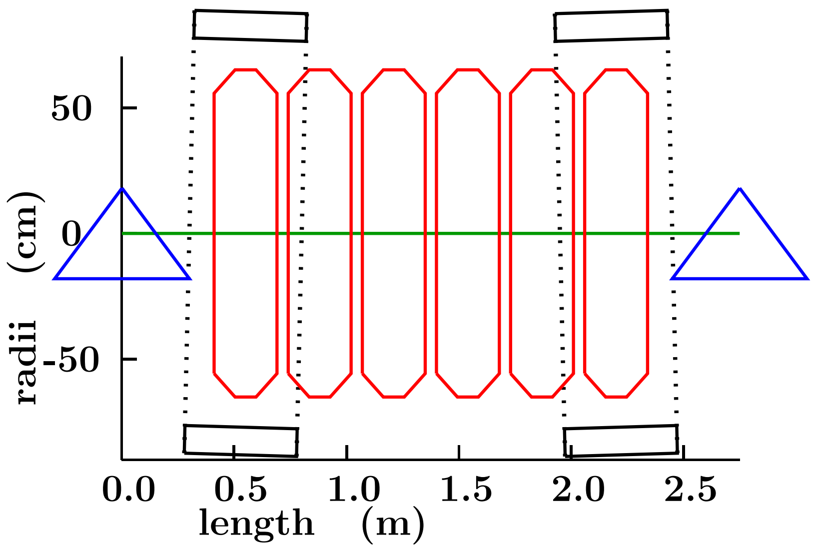


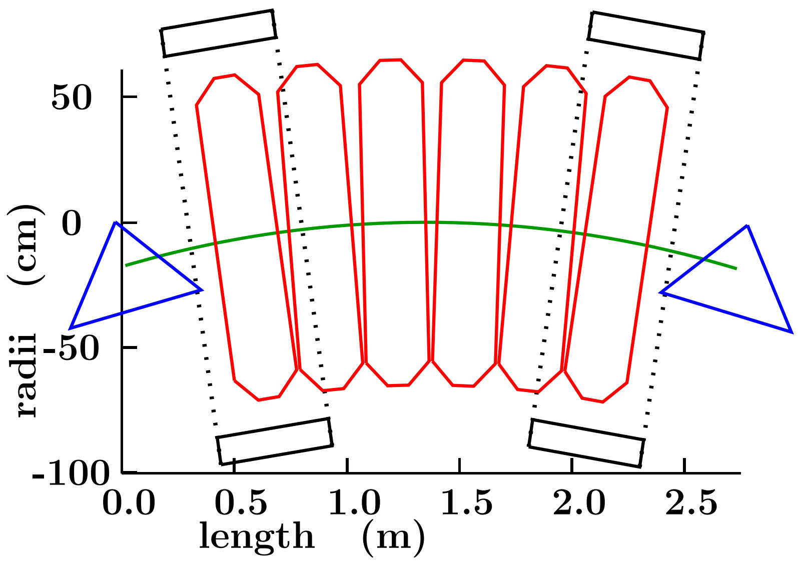
beta is ≈ straight case



Dispersion is rotating back and forth

RF & Absorber Layout



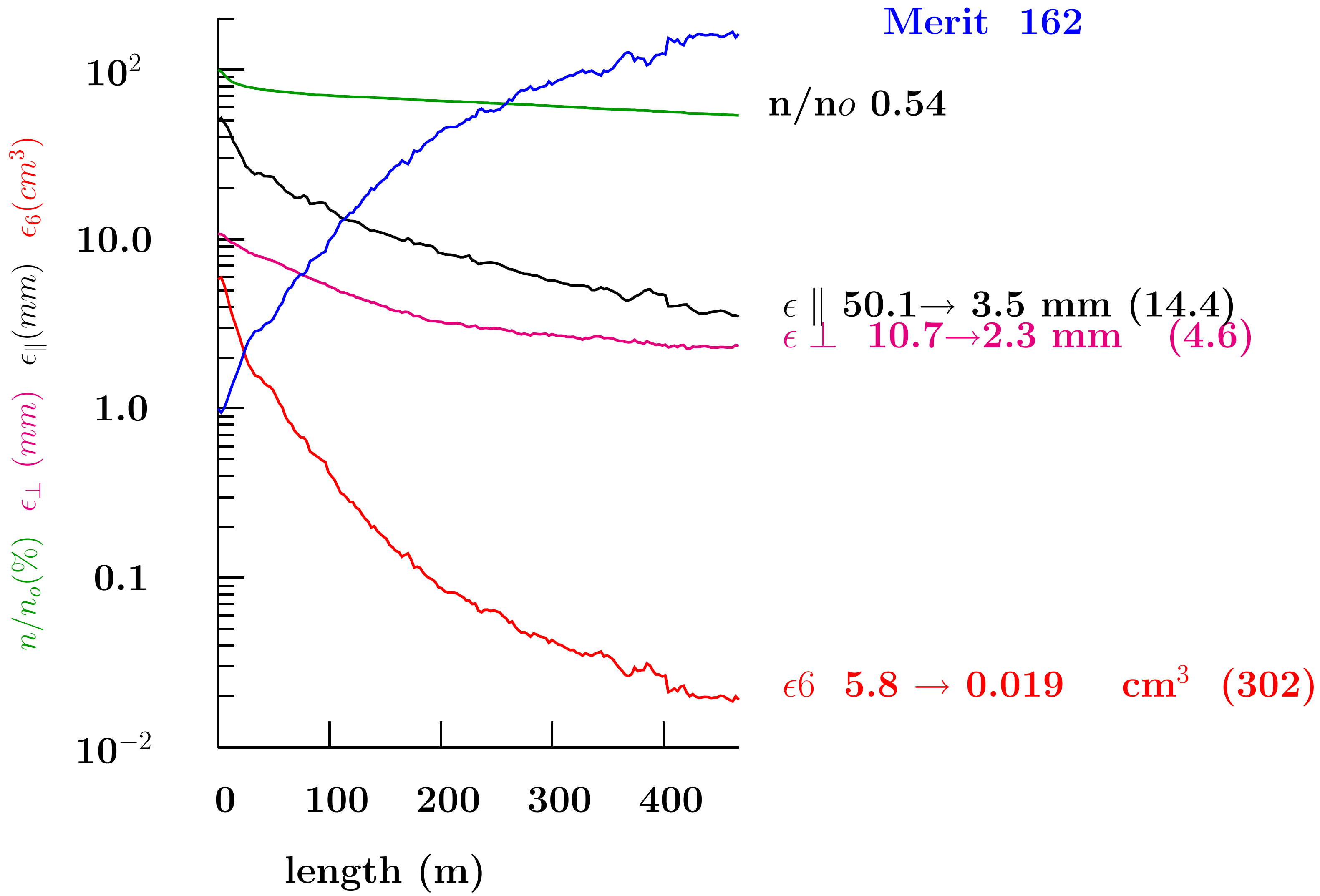


- RF 12 MV/m
- H2 Absorber
- 100 deg
- Wedges shown 0 and 90 deg.
  true angle 30 deg from horizontal
- No windows

ICOOL Simulation

Input From Study 2 Phase Rotation & Bunching

60deg wedge nogap acc11 tilts fs2 33m RFOFO 100deg s&s (2.38 ng3a)



Hydrogen Absorber Windows

ICOOL Run with smaller wedge opening angle
No RF or Saftey Windows

Absorber	window	center thickness mm	Merit	Maximum Q
Hydrogen	none		92	20
”	Conventional	0.5	31	7
”	Bellows	0.25	41	10
”	Bellows	0.125	61	18
LiH	none		19	7

- Rings are more sensitive to windows than linear cooling
- Maximum Efficiency is less damaged than Merit
- Implies use of more rings: Expensive
- Even 125 micron Al degrades Merit 92 $\rightarrow$ 61
- Must Condider AlBemet, Li, LiH as window materials

200 MHz Conclusion

- **Better than Quad Rings**
- **Similar to Balbakov's**
- **But Maxwellian & Realistic Fields**

Need to Study

- **Integration in a system**
  Front end, E, freq etc
- **Wedge absorber design**
- **Thin H2 windows,**
  e.g. AlBemet
- **Thin Be Windows,**
  e.g. Nitrogen Temp RF
- **Injection Extraction Tracking**
- **Kicker**

Integration in System

- **Required Bunch Train only 20 m Long**
  c.f. Study-2 100 m
- **Three Front end solutions:**
  1. **Capture a single bunch (a la CERN), then Initial LF Pre-Cooling**
  2. **Phase Rotate with LF RF → 20 m bunch, then Conventional Bunch**
  3. **Neuffer Bunch to 20 m train (may be hard)**

Look at option # 1

10 MHz RFOFO Ring

The RFOFO ring used was identical to Don's version as shown at shelter Island, except:

RF Cavities

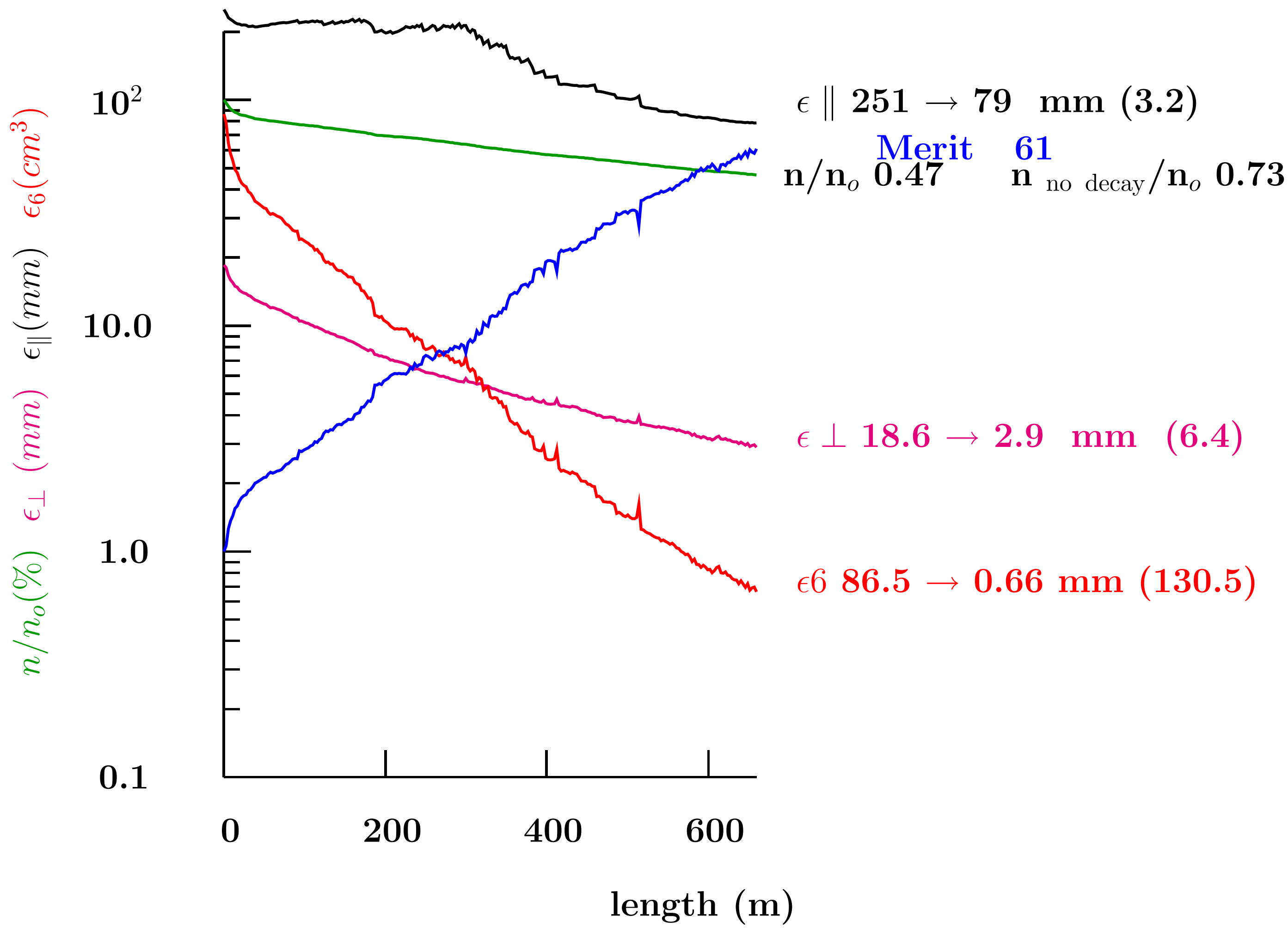
No attempt was made to design real cavities, but I used:
Frequency=10 MHz
Gradient=2 MV/m

Initial Beam

Transverse Emittance=18 mm
RMS Bunch Length=1.6 m
RMS dp/p=8 %
Longitudinal Emmittance=250 mm

10 MHz Performance

10 MHz nogap acc2 tilts 33m RFOFO 51deg s&s (2.41 ng4g)



10 MHz

	len	trans	$\epsilon_\perp$	$\epsilon_\parallel$	ϵ_6	max Q	merit
	m	%	mm	mm	cm^3		
final	660	47	2.9	79.1	0.663	10	61
initial			18.6	251.2	86.531		
ratio			6.4	3.2	130.5		

200 MHz

	len	trans	$\epsilon_\perp$	$\epsilon_\parallel$	ϵ_6	max Q	merit
	m	%	mm	mm	cm^3		
final	468	54	2.3	3.5	0.019	24	162
initial			10.7	50.1	5.787		
ratio			4.6	14.4	302.0		

10 MHz Conclusion

- Good Transverse Cooling
- Much less longitudinal Cooling Needs more Dispersion
- Slower Cooling because low Grad
- Merit less
- Posible Cooling for FFAG ?
- Pre-Cooler for 200 MHz ?
- Needs More Work

Acceleration Cost Reduction
OR
For Muon Collider

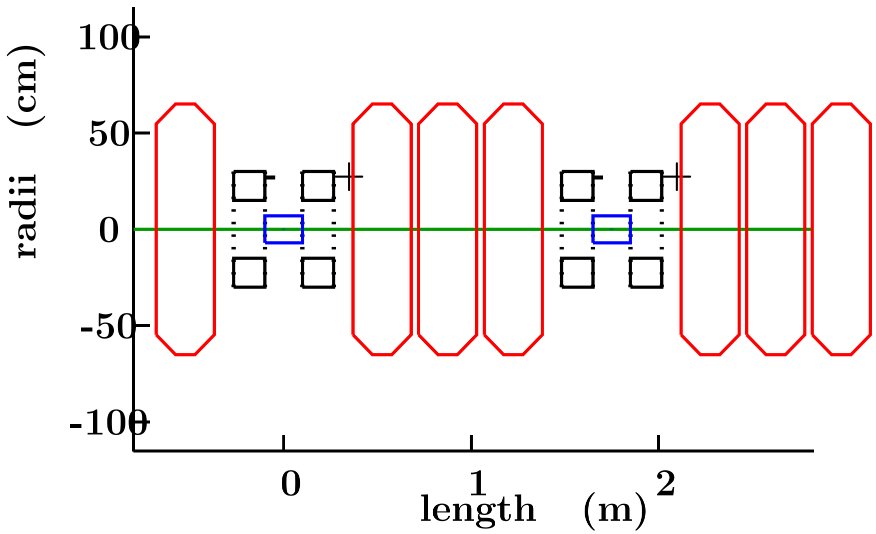
- **Need Further Cooling**
- **Need Lower beta**

200 MHz RFOFO has beta=42 cm
cools $\epsilon_\perp$**: 12**$\rightarrow$ **2.3 (mm)**

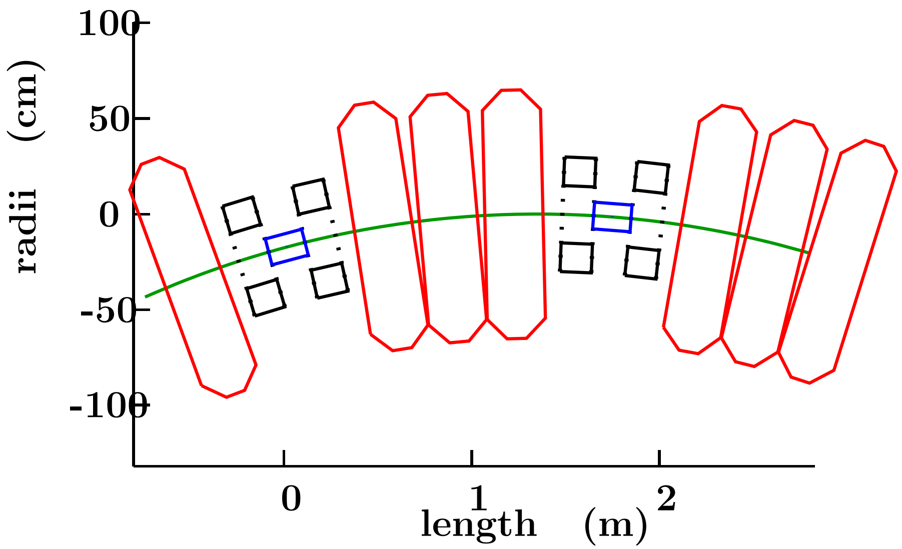
Try
200 MHz RFOFO has beta=5 cm
cooling $\epsilon_\perp$**: 2.3**$\rightarrow$ **.3 (mm)**

Low Beta Ring

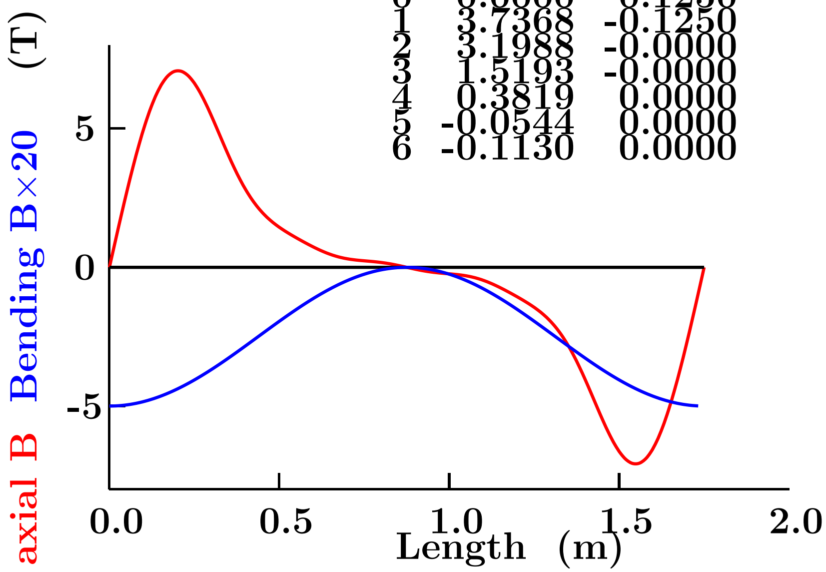
Just Started



- RFOFO
- Shorter Cell (1.75 m)
- Coils in close



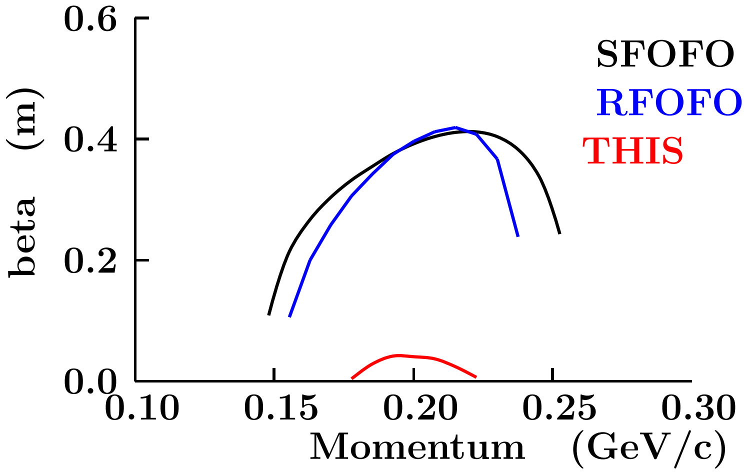
B Fields



n	Az	By
0	0.0000	0.1250
1	3.7368	-0.1250
2	3.1988	-0.0000
3	1.5193	-0.0000
4	0.3819	0.0000
5	-0.0544	0.0000
6	-0.1130	0.0000

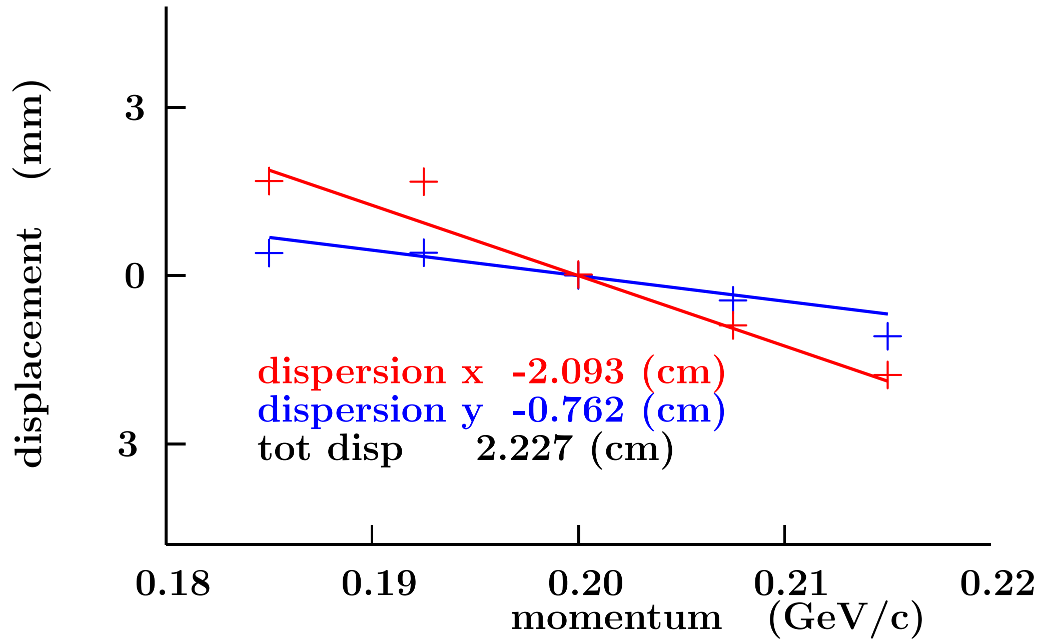
- 33m Circumference
- Bending field shape arbitary (1-cos)
- Will try tilts later

Beta vs p



- Required Beta achieved, but
- Less Momentum Acceptance +/− 12 % (c.f +/− 24 %)

Dispersion



$$\frac{D}{\beta} = \frac{2.23}{5} = 44.6\ \%$$

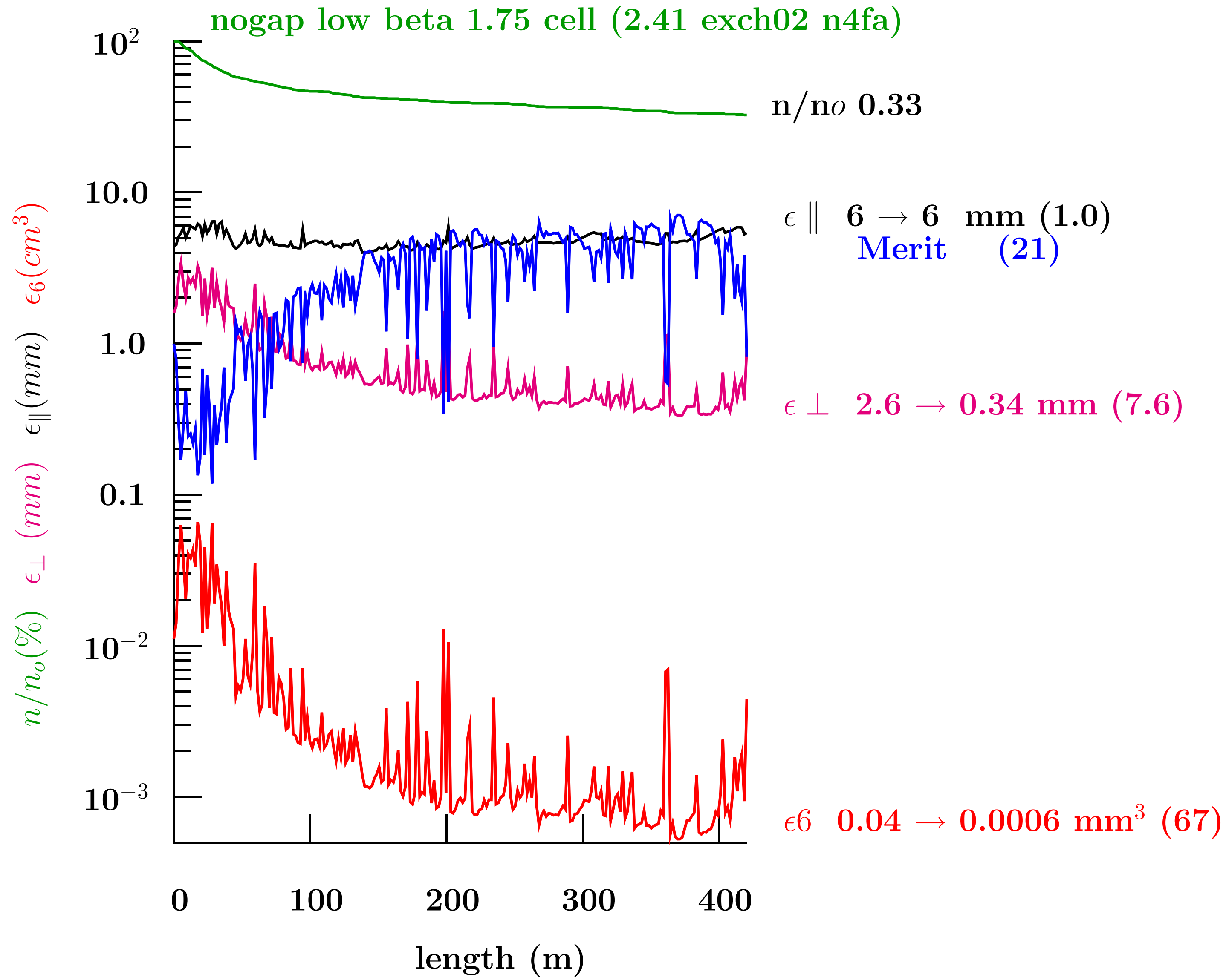
cd regular

$$\frac{D}{\beta} = \frac{8}{42} = 19\ \%$$

Much more relative Dispersion !

Performance

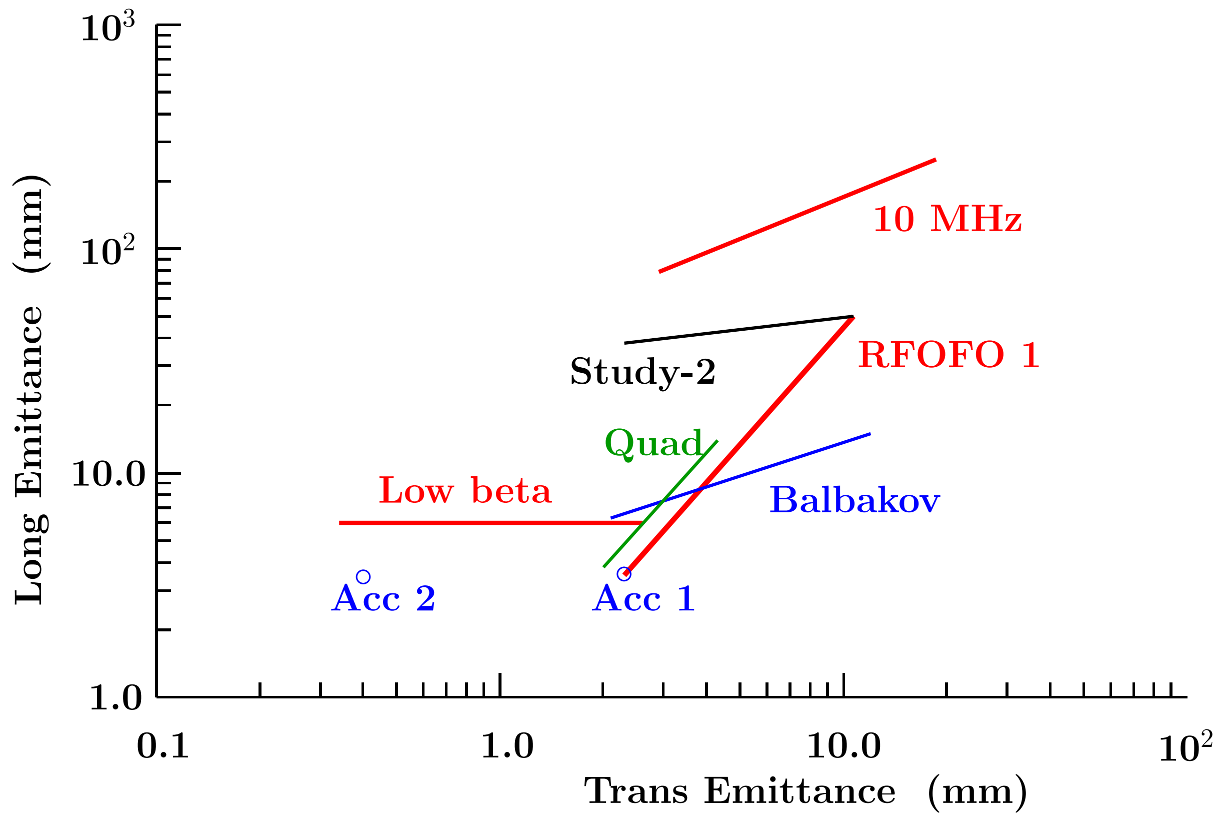
Preliminary - not-optimized



Low beta Conclusions

- Much too much loss
- No longitudinal cooling
- Work in progress

Conclusion



- Progress
- Waiting for 3D fields
  - In GEANT
  - In ICOOL
- More Work on Capture, Phase Rotation, Bunching
- More Work on Low Beta Ring
- More Work on Injection/Extraction