Update on the MCTF Scenario(s)

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(FNAL)

Parameters of Different MC options

	Low Emit.	High Emit.	MCTF07
$\sqrt{s}$ (TeV)		1.5	
Av. Luminosity ($10^{34}/cm^2/s$) *	2.7	1	1.33-2
Av. Bending field (T)	10	6	6
Mean radius (m)	361.4	500	500
No. of IPs	4	2	2
Proton Driver Rep Rate (Hz)	65	13	40-60
Beam-beam parameter/IP	0.052	0.087	0.1
β^* (cm)	0.5	1	1
Bunch length (cm)	0.5	1	1
No. bunches / beam	10	1	1
No. muons/bunch (10^{11})	1	20	11.3
Norm. Trans. Emit. (μm)	2.1	25	12.3
Energy spread (%)	1	0.1	0.2
Norm. long. Emit. (m)	0.35	0.07	0.14
Total RF voltage (GV) at 800MHz	$407\times10^3\alpha_c$	0.21**	0.84**
Muon survival $N\mu/N\mu0$	0.31	0.07	0.2
μ+ in collision / proton	0.047	0.01	0.03
8 GeV proton beam power	3.62***	3.2	1.9-2.8

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*) Luminosity calculated taking account of the hour-glass factor but ignoring the dynamic beta effect.

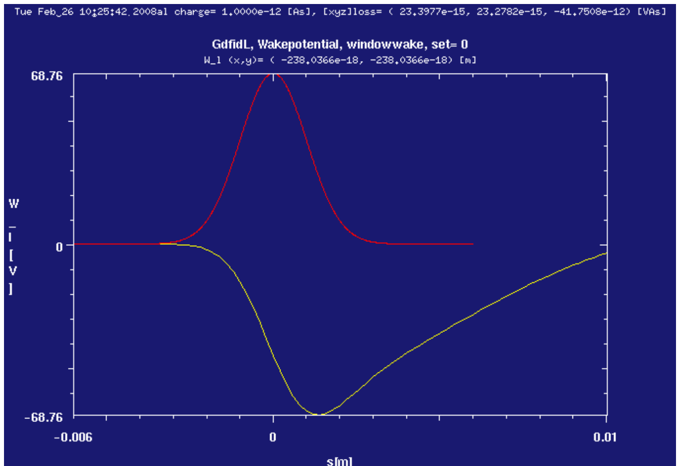
**) Momentum compaction in the present ring design $\alpha_c=1.5\times10^{-4}$. Note that it would be better to assume f=1.3GHz to keep the RF voltage at a reasonable level (0.52GV for MCTF07 set)

***) Assumes μ /p ratio of 0.15 after capture and precooling, and only decay losses afterwards. Positive and negative muons are assumed to be produced independently (from different protons).

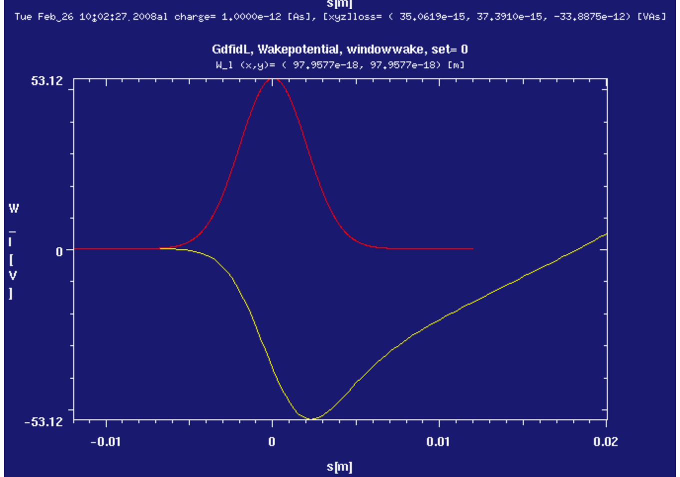
Beam loading in the RF structure.

1. Short range longitudinal wake per unit length:

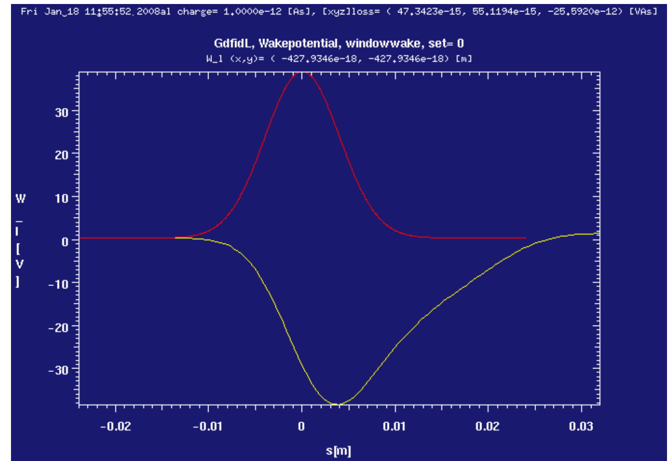
W_{max} ~ $q/(\lambda\sigma)$ for a "long" bunch ($\lambda\sigma > a^2$, a - aperture).



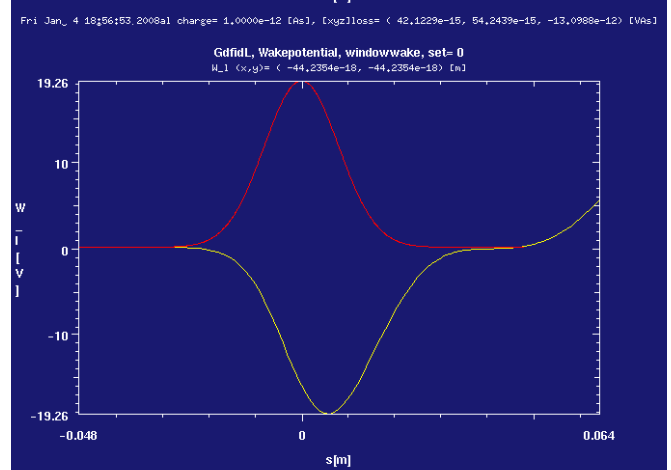
σ=1 mm



σ=2 mm



σ=4 mm



σ=8 mm

For N=2e12, f=1.3 GHz (ILC-like structure) and σ=8 mm W_{max}= 6.2 MV/m!

Ongoing effort

Make High Emittance option more attractive:

- magnetically insulated open cell RF for cooling channel
- high power p-driver (Project-X linac + MI + coalescing ring, recirculating ILA)
- Dielectric Wall Accelerator for strong μ bunches

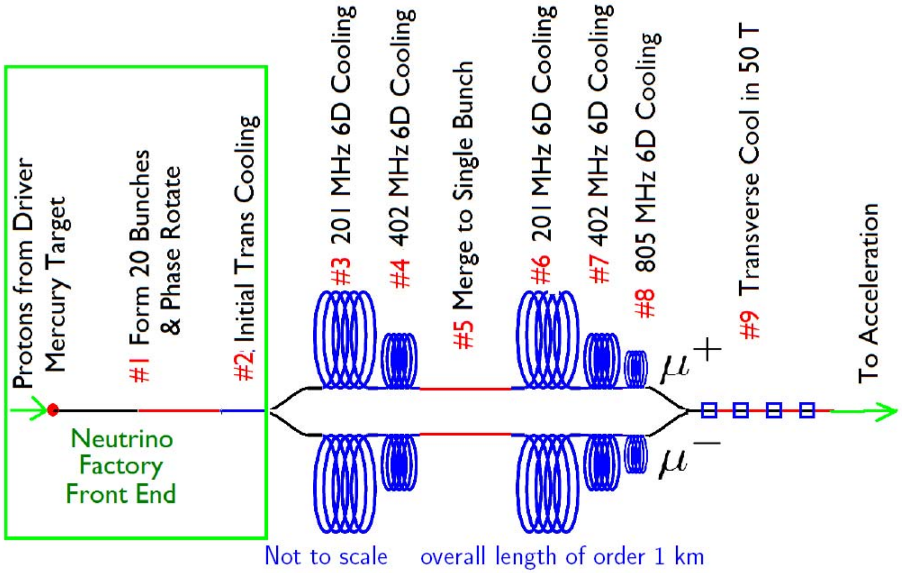
Reduce emittance to that of MCTF scenario and improve transmission:

- faster 6D cooling by using HCC and/or FOFO snake
- avoid bunch merging at low energy (make it at 20-30GeV)
- additional cooling using Fernow lattice or PIC (may become possible due to later bunch merging and lower total intensity)
- increase reprate to compensate for reduction in peak luminosity (Chuck's 8GeV p-driver scheme)

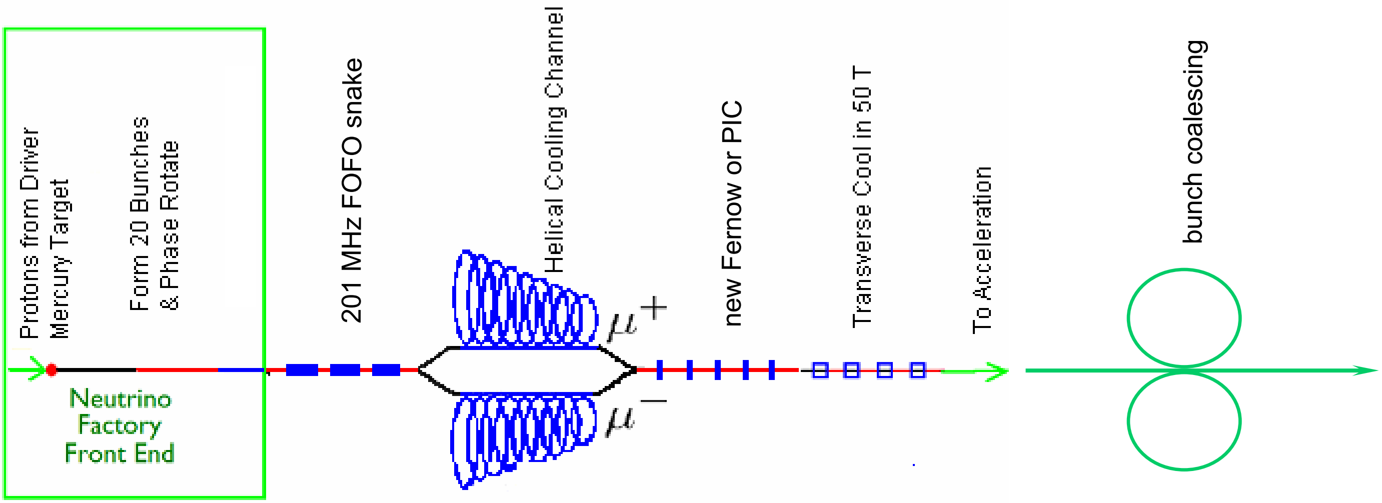
Note: Why cooling in HCC is faster?

- HP RF: Emax >50 MV/m @ 800MHz (is there frequency dependence?)
- homogeneous optics $\rightarrow$ large DA $\rightarrow$ low p=100MeV/c (not demonstrated yet)
- continuous RF (may be unrealizable)

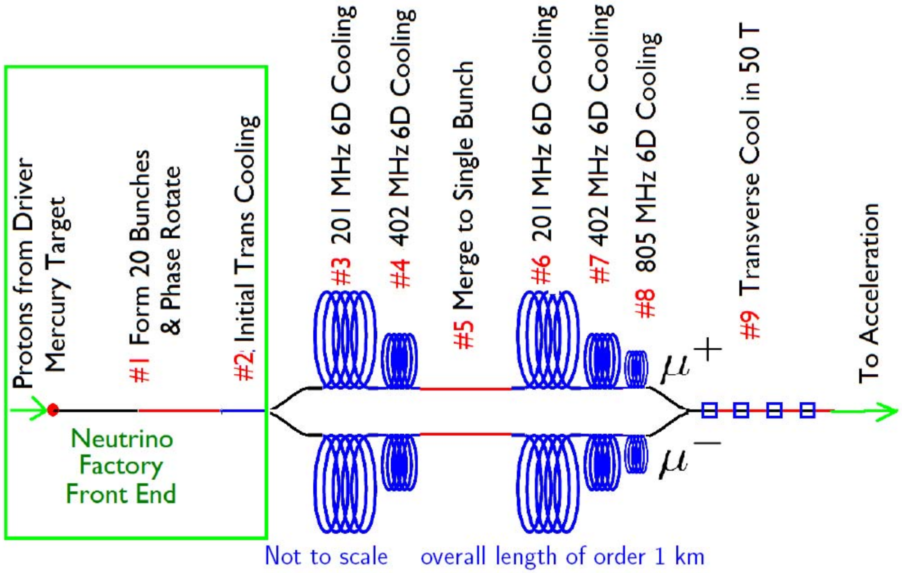
Cooling Schemes in HE and MCTF Scenarios



The alternative scheme below should have made (almost) everybody happy: it provided room for various cooling ideas, but...

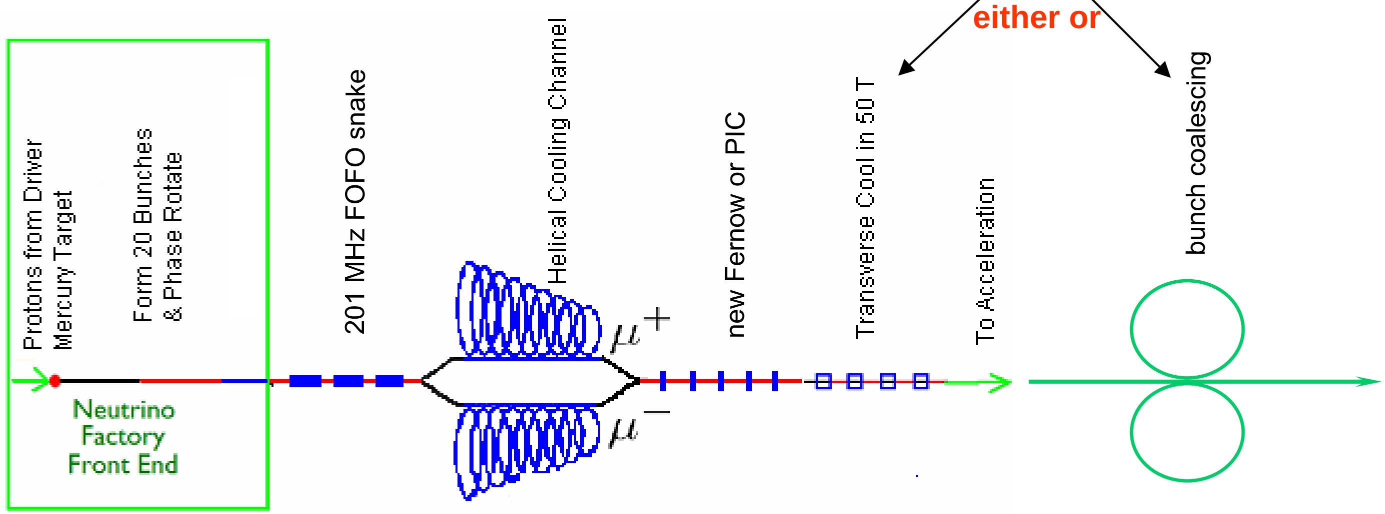


Cooling Schemes in HE and MCTF Scenarios

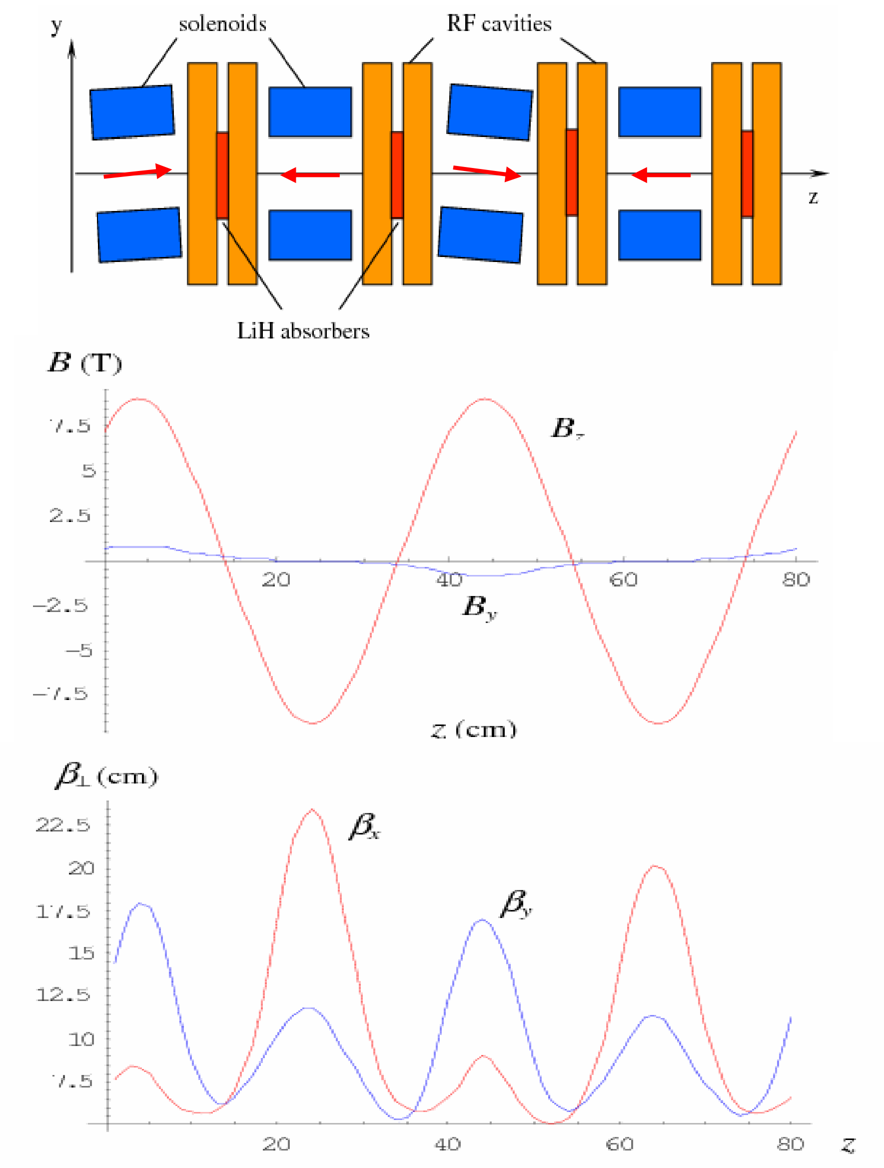


Bob immediately pointed out that REMEX in 50T solenoids and coalescing at high energy are incompatible (see later)

either or



FOFO Snake



800MHz p=100MeV/c case :

Cooling by GH_2 (19% of LH_2) + LiH wedges

Bmax= 9.5T → tunes >1 → α_c > 0

Solenoid tilt ±65mrad → Dmax ~ 6cm

Emax= 50MV/m

$Q_{I,II,III}$ =1.42+0.005i, 1.51+0.005i, 0.19+0.004i

- emittance damping length ~13m

Equilibrium $\varepsilon_\perp$~0.8mm, $\varepsilon_{||}$~0.4mm

Things to do:

- **Check with ICOOL or G4BL**
- **200MHz p=215MeV/c design for initial cooling. Estimated performance:**

$\varepsilon_\perp$, $\varepsilon_{||}$ ~ 2cm → 5mm in 140m (10% decay loss)

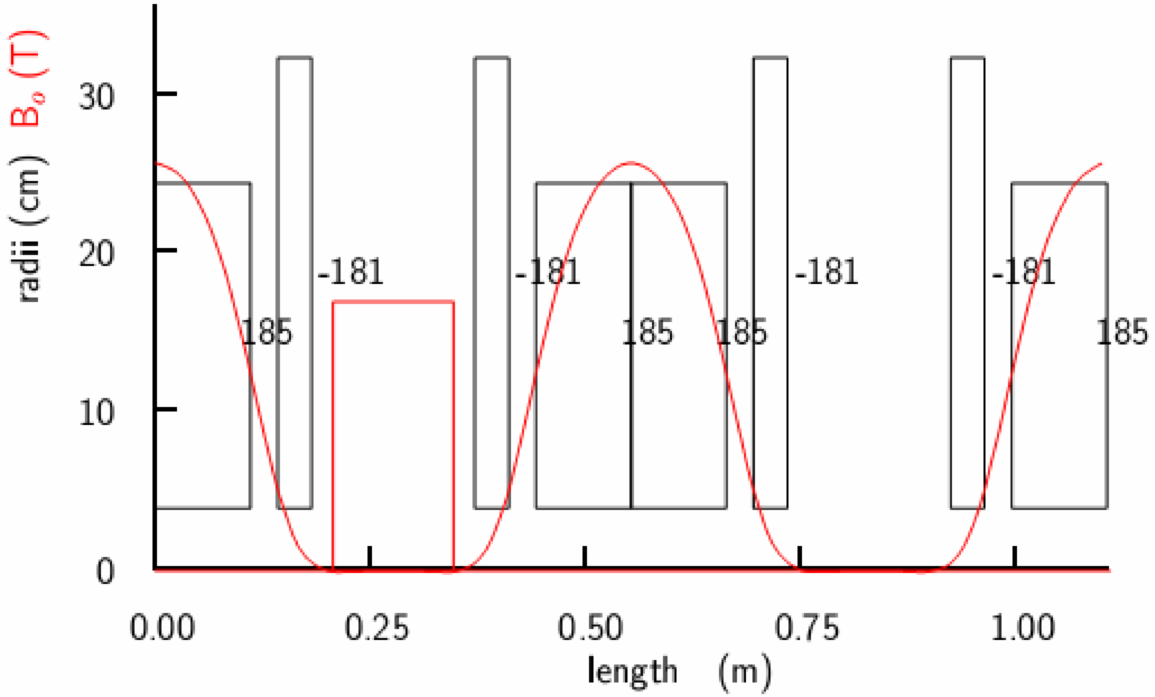
- **Tilt 2nd and 4th solenoids horizontally (and displace all solenoids from axis) to make a helix.**

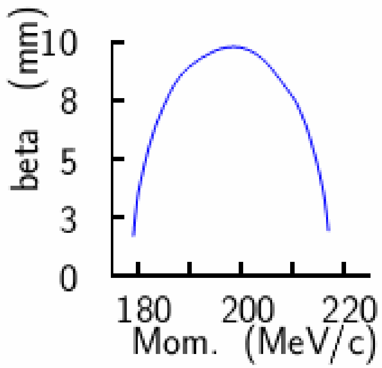
Hopefully α_c will become large enough to discard LiH wedges → smaller emittances

8) THREE COIL PER CELL, 2ND PASS BAND

Fernow's New Lattices + Bucking Coils $< \hat{+} - - \hat{+} - - \hat{+} >_2$

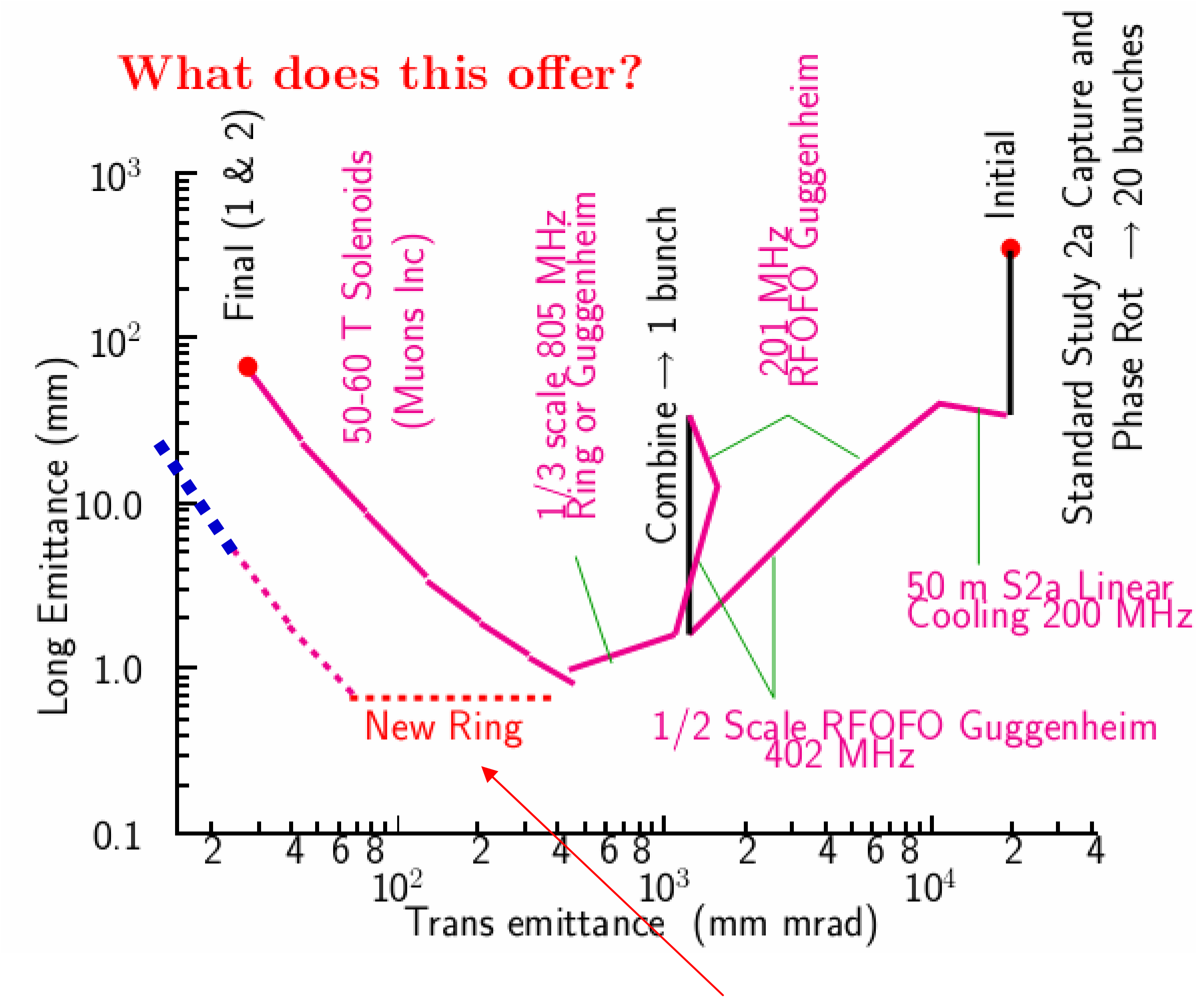
- It may be desirable to add bucking coils to reduce the field on the RF





- The design gave the same 9.6 % $\Delta p/p$ (c.f. 9.5 %)
- With the same current densities ($<$ 200 A/mm^2)
- And, surprisingly, a lower β = 10 mm (c.f. 12 mm)
- With no field between coils, reversals can be introduced, or left out, without disturbing transverse dynamics

Possible Benefit from R. Fernow's Lattice

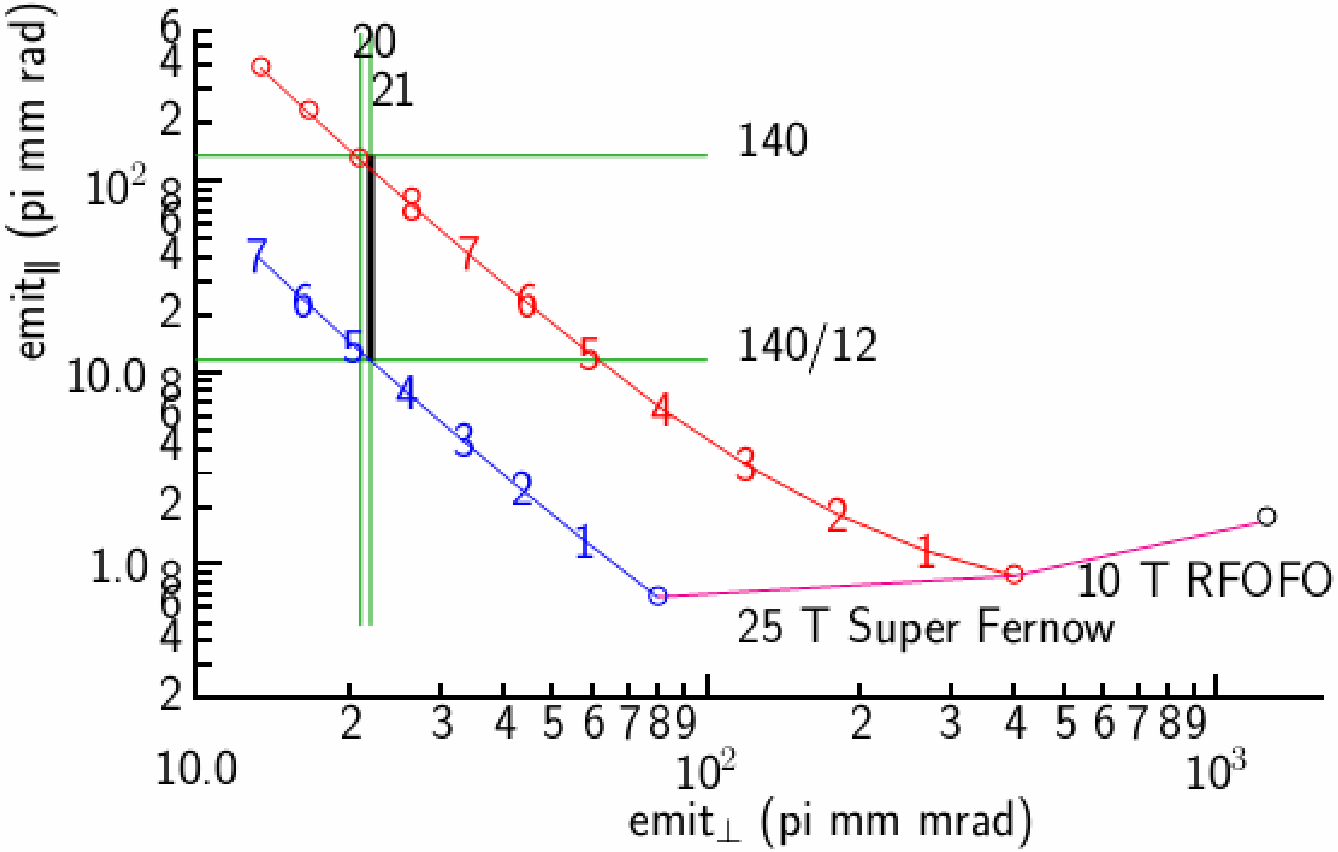


According to Bob, he abandoned the idea of the New Ring employing one of Rick's lattices due to strong Space Charge effects. Will a 10-fold reduction in intensity help?

Starting with much lower transverse emittance, will it be possible to cool it down to ~10 μm without excessive longitudinal blowup in 50T solenoids?

Merging after acceleration (Yuri's proposal)

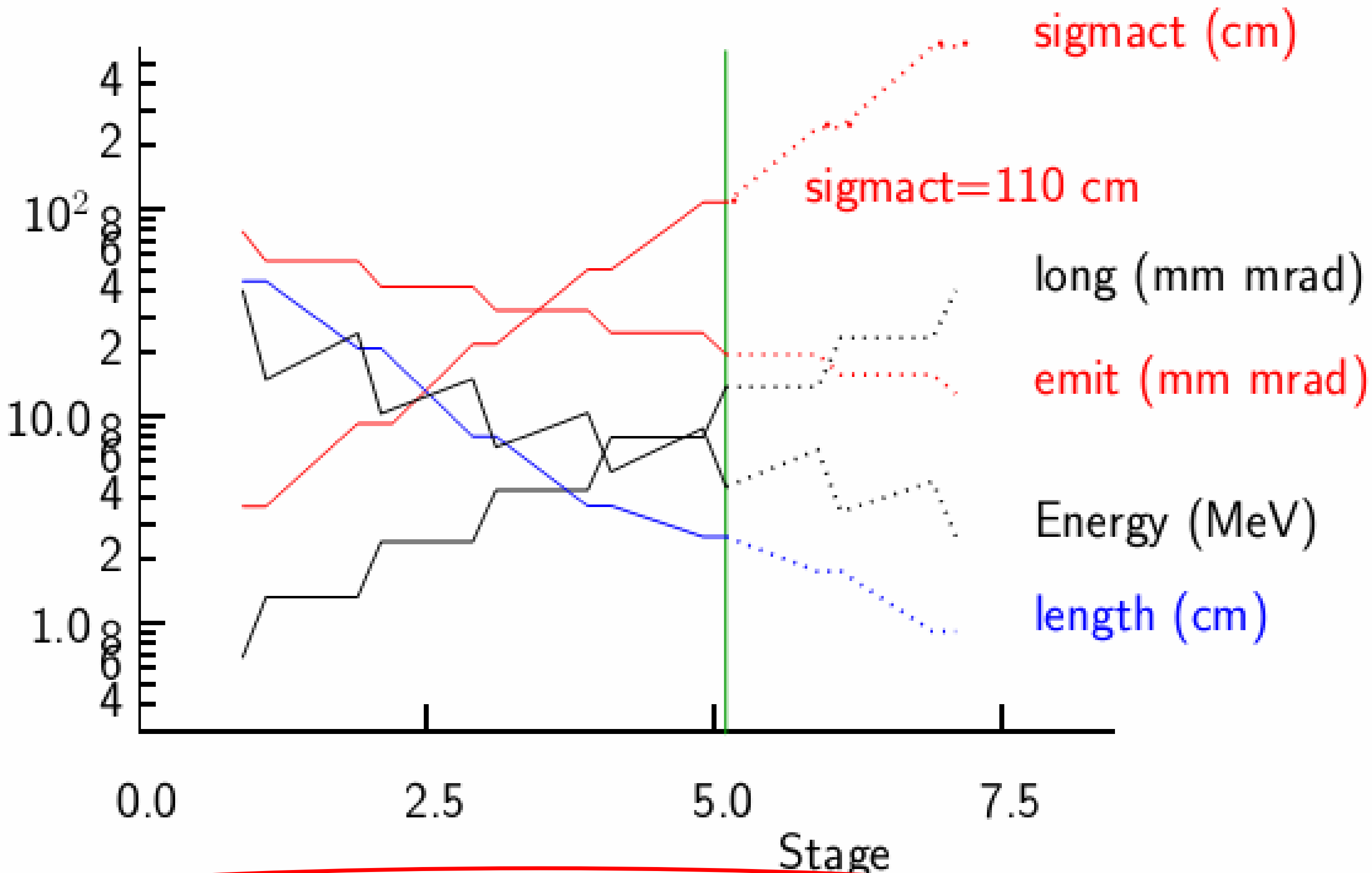
- assume longitudinal emittance 140 pi mm (vs 70 pi mm)
  0.2 % dp/p (vs 0.1%)



- Super Fernow plus merge after acceleration & Conventional merge and re-cool give same final emittance

And merge after acceleration does not work

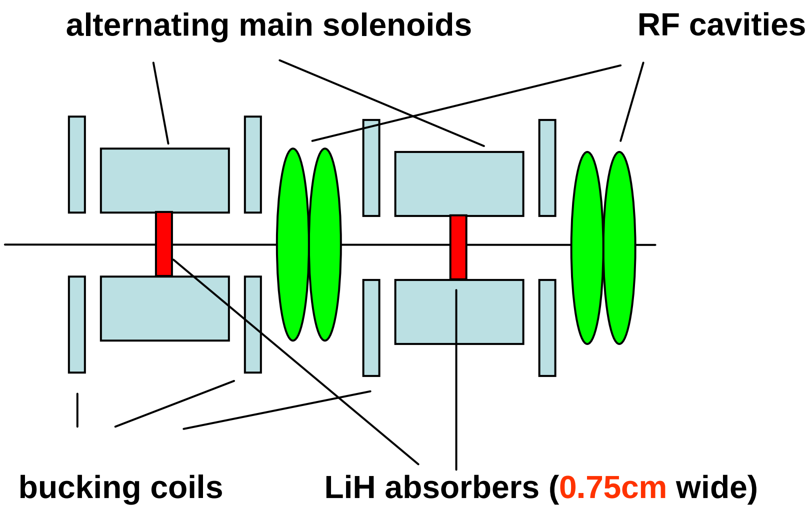
because of bunch length at end of 50 T



- A train of $c\ \sigma_t$ =1.1 bunches cannot have 1.5 m separations in ct

Analytical Study of R. Fernow's Lattice with SC

Bob showed that emittances $\varepsilon_{\perp N}$ ~10μm are feasible, is the space charge really an obstacle?

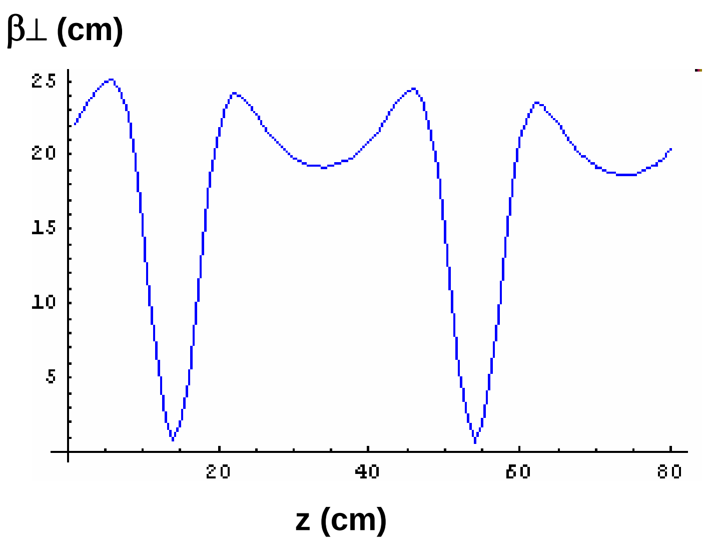


Bmax=17T with p=100MeV/c,

Emax=40MV/m @ 800 MHz

$Q_\perp$=1.4+0.0044i, QL=0.135- 0.004i,

→ 5.4% transverse emittance reduction per cell (0.8m)

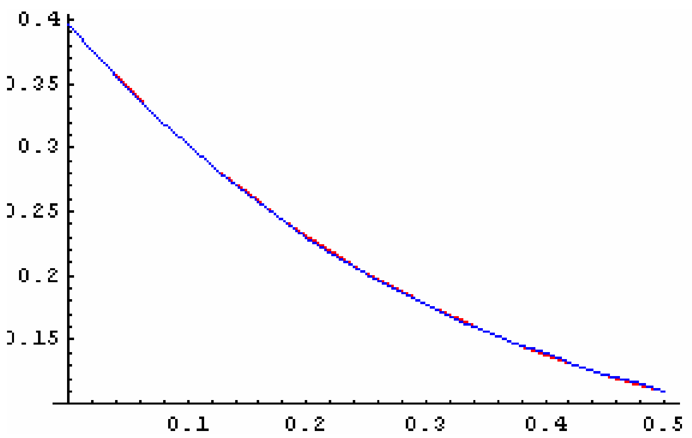


$\beta_\perp$ (min) = 0.76cm →

$\varepsilon_{\perp N}$= 44μm (equilibrium)

Analytical Study of R. Fernow's Lattice with SC

$Q_{I,II}$



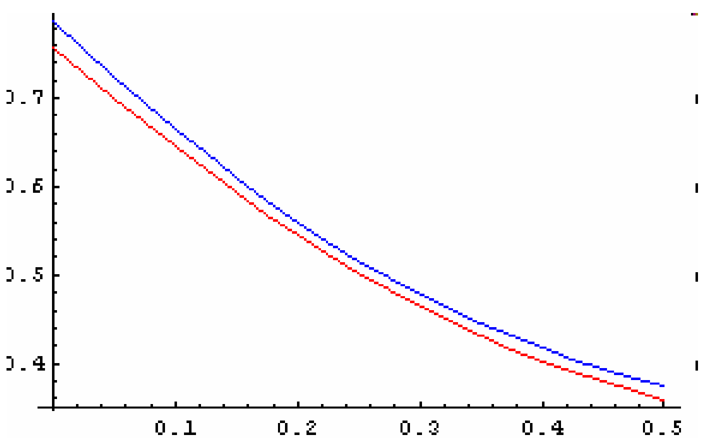
|ΔQ_SC| (linear SC parameter)

The range of linear stability is amazingly large, for cited emittances it corresponds to

Nmu=2.5e12

It looks like the lattice can accept the full intensity bunch of the high-emittance option!

β @ absorber (cm)



|ΔQ_SC|

The "dynamic beta" effect – well known in collider theory – facilitates the cooling!

Can it be employed to obtain smaller emittances?

Two Scenarios with Fernow's Lattice

Original R.Palmer's idea:

201/402 MHz 6D cooling → bunch merging → 201/402/804 MHz 6D cooling → 804 MHz Fernow → REMEX in 50T solenoids → acceleration

with REMEX in Fernow's lattice:

201/402/804/1608 MHz 6D cooling → Fernow 6D cooling → REMEX in 1608 MHz Fernow → acceleration → bunch merging @ 30GeV

Parameters of 1.6 GHz Fernow REMEX channel:
p=50MeV/c, L=0.2m, Bmax=34T →
equilibrium $\varepsilon_{\perp N}$ < 10μm