SuperB: Ring Issues

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Content

- Basic parameter estimate
- Examples of some lattices
- S.R. Handling
- Bunch length
- Collective effects incl beam lifetime
- Summary

This presentation will deal with the LER only, assumed to operate at 4 GeV

Fundamental Parameters

- The first fundamental parameter is the damping time, determining energy loss/turn U_0:

$$\tau_{d,x} = \frac{2}{J_x}\frac{E}{U_0}\tau_{rev} = \frac{2}{J_x}\frac{\rho}{88.5E^3}\tau_{rev}$$

- For 10 ms damping and 2200 m length:
  - LER (4GeV): U_0=5.6 MeV, HER (7 GeV): 9.9 MeV
  - bending radii: 21.5 m (1.1T) 4 m (3.3T) (assuming no wigglers or other "tricks")
- S.r. power:
  - 15+8.5=23.5 MW for 1.5 A in each ring
  - > "Wal-plug power" ≈ 47 MW for the rf

Scaling with Ring Size

- τ_d scales with R for fixed ρ
  - If spec. for τ_d independent of τ_{rev} this strongly discourages large rings
- If we let τ_d go up as R goes up then s.r. power is independent of size
  - One may argue this is the correct scaling (bunches collide less often).
- In the following, the latter scaling is assumed to hold.

The Beam Emittance

- The desired emittance sets the bending angle/cell:
  - $$\varepsilon_x \geq \frac{1}{4\sqrt{15}} C_q \frac{\gamma^2 \Theta_D^3}{J_x}$$ (“=“ for a TME cell)
- We want about 0.4 nmr for each beam
  - > Θ/cell ≈ 3.5° (4 GeV, again, TME assumed)
    2.5° (7 GeV, TME)
  - > length is ≈1 m for the HER but ≈.26 m for the LER
    B ≈ 1.1 T ≈ 3.3 T
- The HER magnet looks reasonable
  The LER magnet might be buildable as superferric magnet

Lattice Issues

- TME cells have been built for light sources
  - small dispersion => strong sextupoles => bad acceptance
  - dipoles can get rather short & strong, can become hard to build
- Alternative: use wigglers
  - low emittance by weak, long dipoles, wiggler sets damping time
  - wigglers have nonlinearities => acceptance issues
  - high E-loss in wiggler(s) => s.r. handling issues (MW power)
- Alternative 2: "mini wigglers" at each dipole
  - realistic dipole fields & lengths, s.r. more manageable
  - small dispersion & acceptance problems remain.

Lattice Example 1: ILC DR PPA

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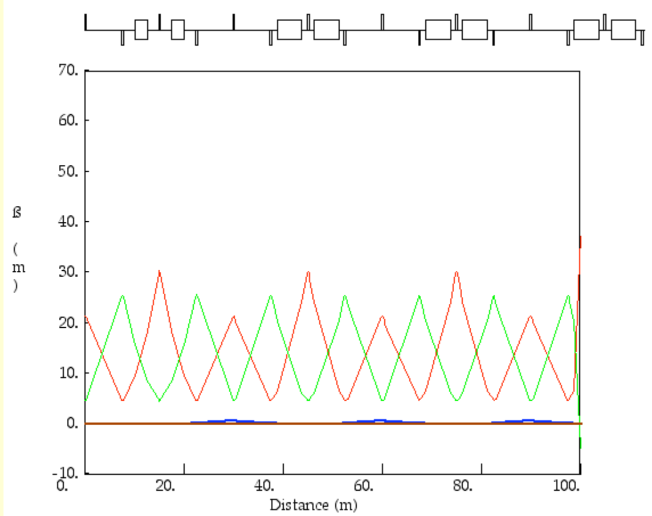
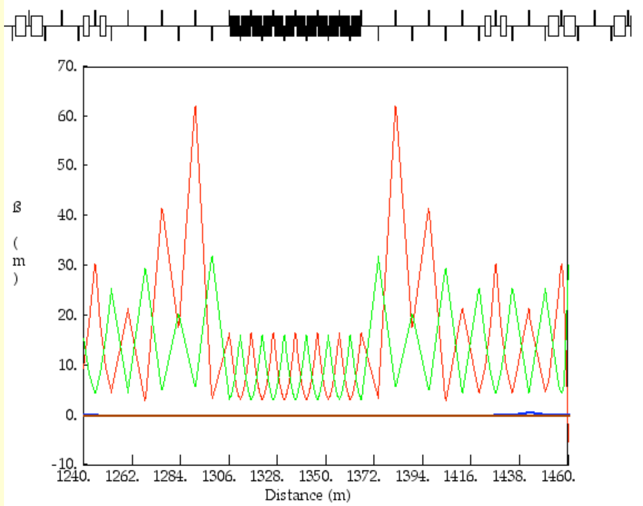
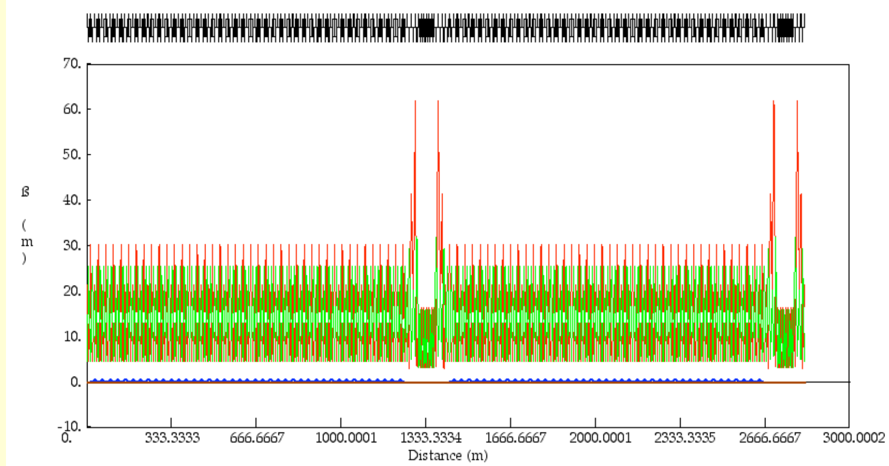


Total length 2.8 km
Wiggler: 0.4 m period, 120 m total length

At 4 GeV:
 td = 40 ms
 ex = .27 nmr

(t_d=20 ms @ 5GeV in original design)
For SuperB need to shorten dipoles
and possdily strengthen the wiggler





Lattice Example 2: ILC DR OTW

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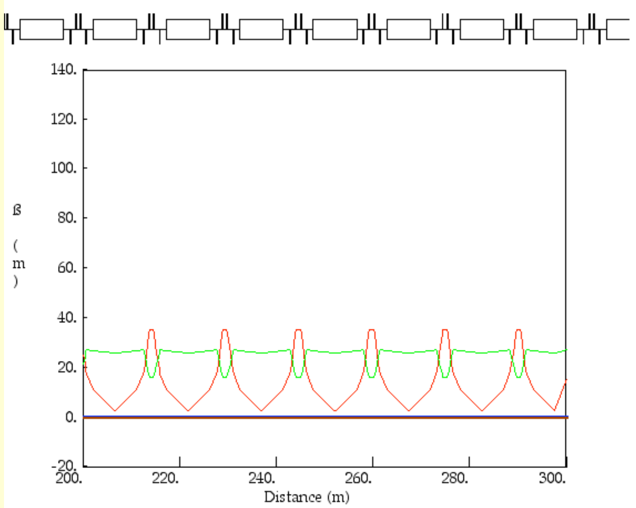
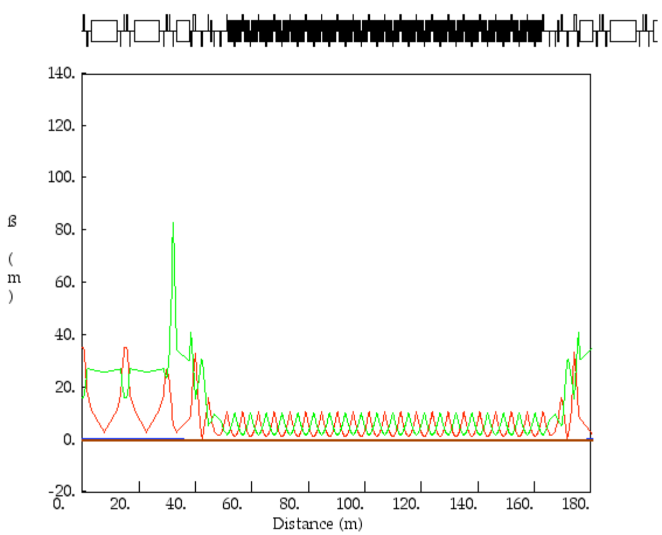
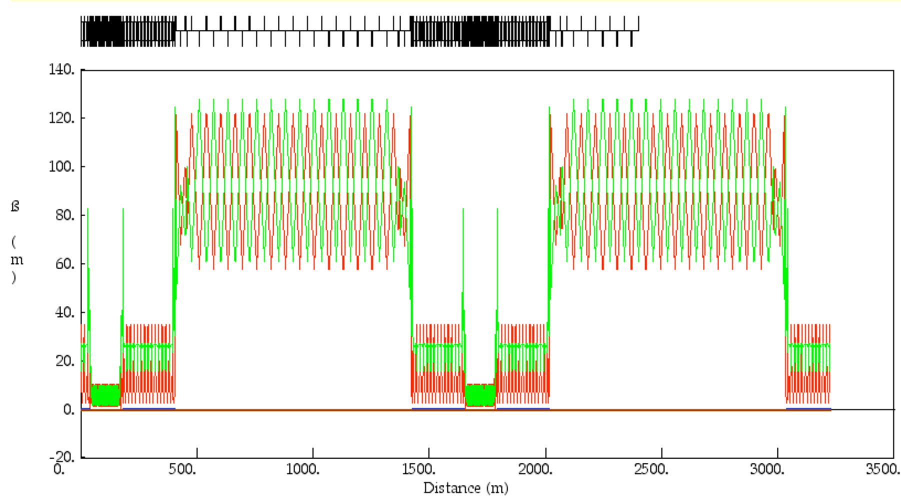


Total length 3.3 km
Wiggler: 0.4 m period, 240 m total length

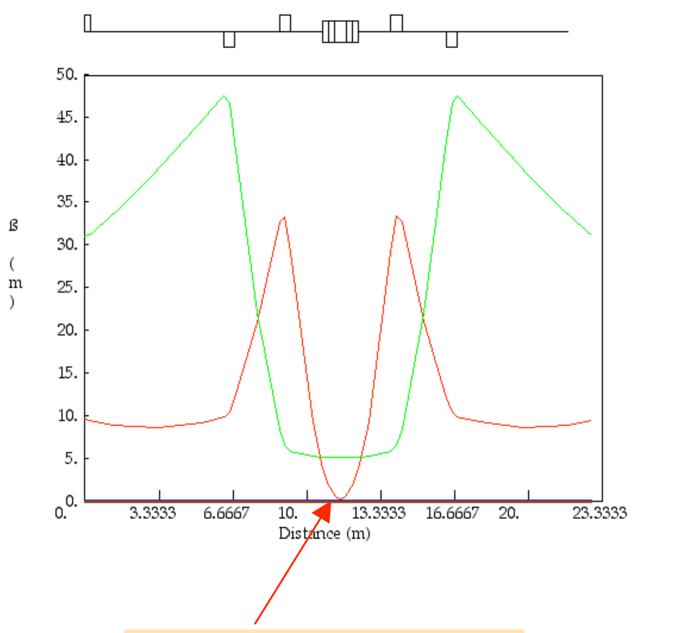
At 4 GeV:
td = 24 ms
ex = .26 nmr

(t_d=12 ms @ 5 GeV in original design)
For SuperB need to shorten dipoles
and possibly strengthen the wiggler





Lattice Example 3: mini Wiggler



$\beta_{x,\min} \approx 0.8 * l_d / 2$

Total length 2.2 km
mWiggler: 0.6 m period, 120 m total length

At 4 GeV:
- td = 7 ms
- ex = 1.2 (0.5) nmr

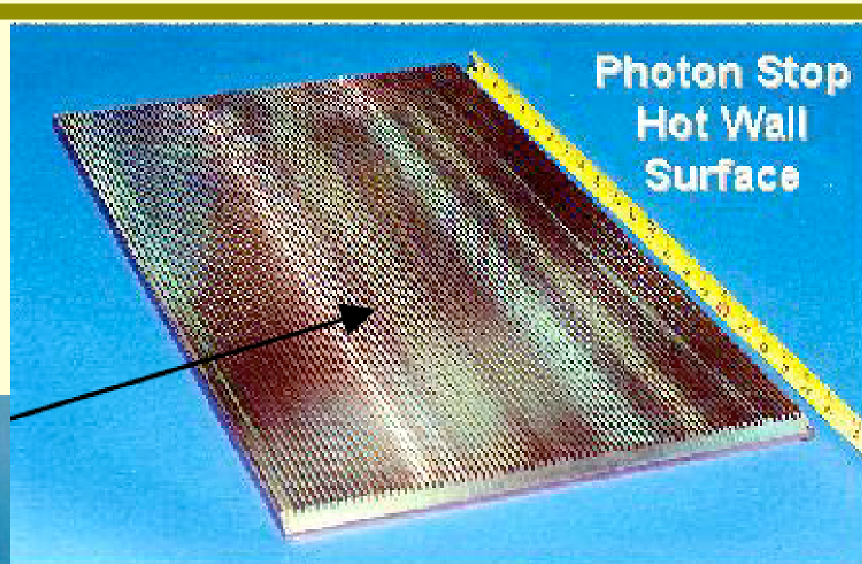
Note to Examples

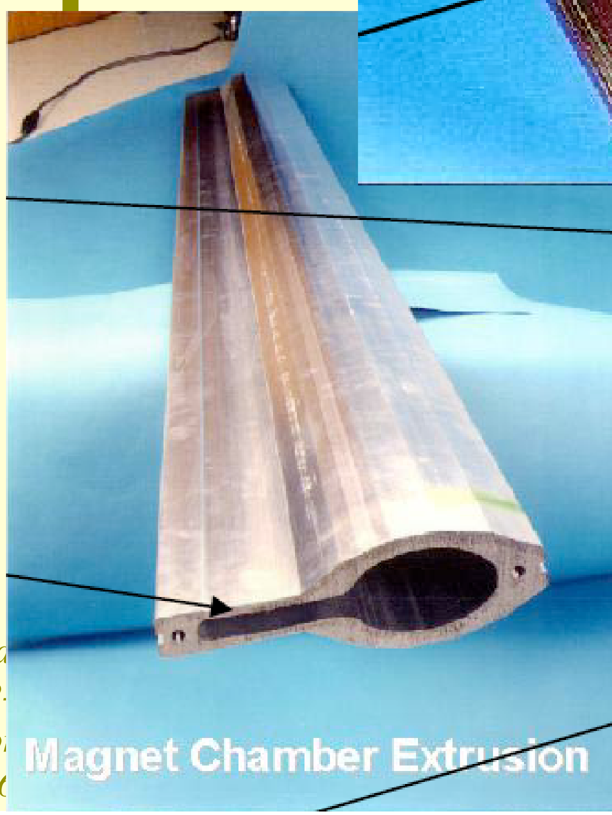
- None of these are fully worked SuperB-parameter lattices.
  - ILC lattices re-run at 4 GeV
  - True scaling of the ILC DR lattices to SuperB parameters should straighforward.
- The mini-Wiggler example is only a concept at this stage.

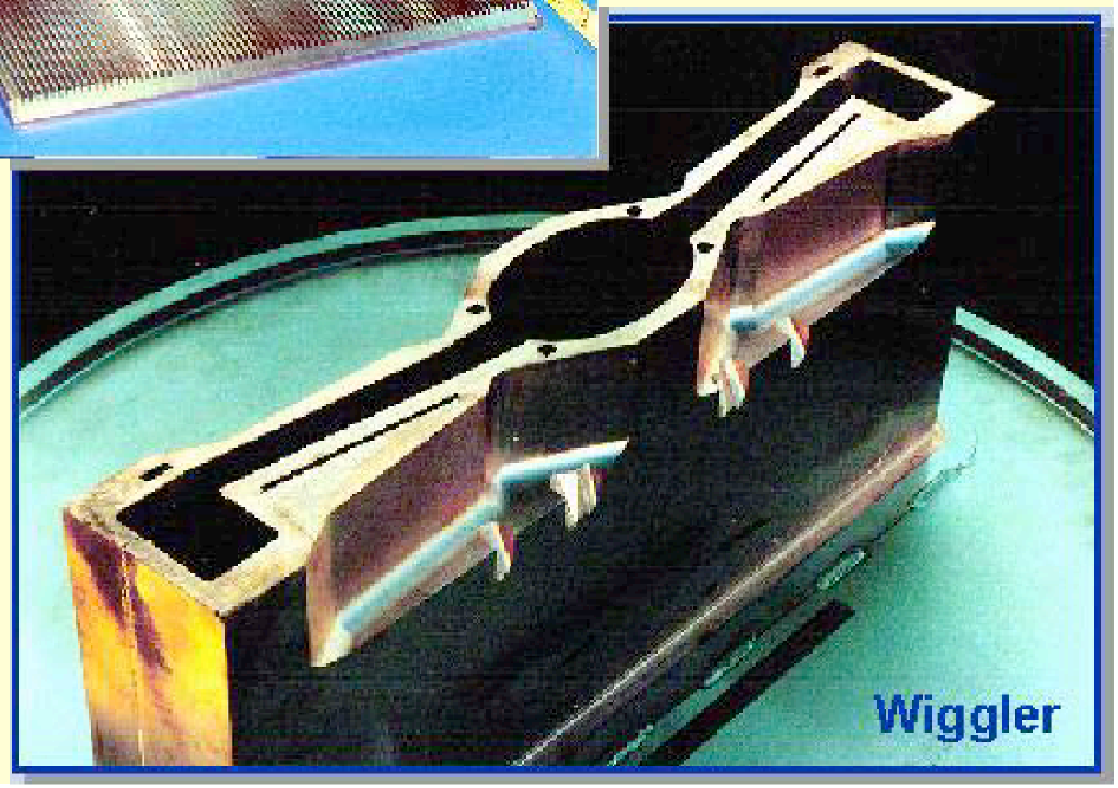
Synchrotron-Radiation Issues

- 8.5 MW total power
- mWiggler lattice: ≈ 100kW/dipole-mWiggler
  - 3 m of absorber assuming 2* power density of present LER photon stops, fairly straightforward (watch that upstream wiggle section!)
- ILC-type wigglers, ≈2.5 MW total
  - 100 m length: 25kW/m: ok
  - problem if opening angle too small
    - ILC wigglers have 10 mr/pole, may want to increase that.

High-S.R.-Power Chambers







Bunch Length

- For ≤4 mm bunch length:
  - wiggler lattices: $\alpha \approx$ 3E-4, $V_{rf} \approx$ 23…30 MV
  - pure TME or mini-wiggler: $\alpha \approx$ 2E-5, $V_{rf} \approx$ 6 MV
- … and synchrotron tune
  - $\nu_s \approx$ .033 (wiggler), .0024 (TME, mini-wiggler)

- The low rf voltage for the TME looks attractive, however, beam-loading maybe overwhelming
  - only .4 MV over voltage (6-5.6)
  - likely need more volts to deal with bunch lengthening

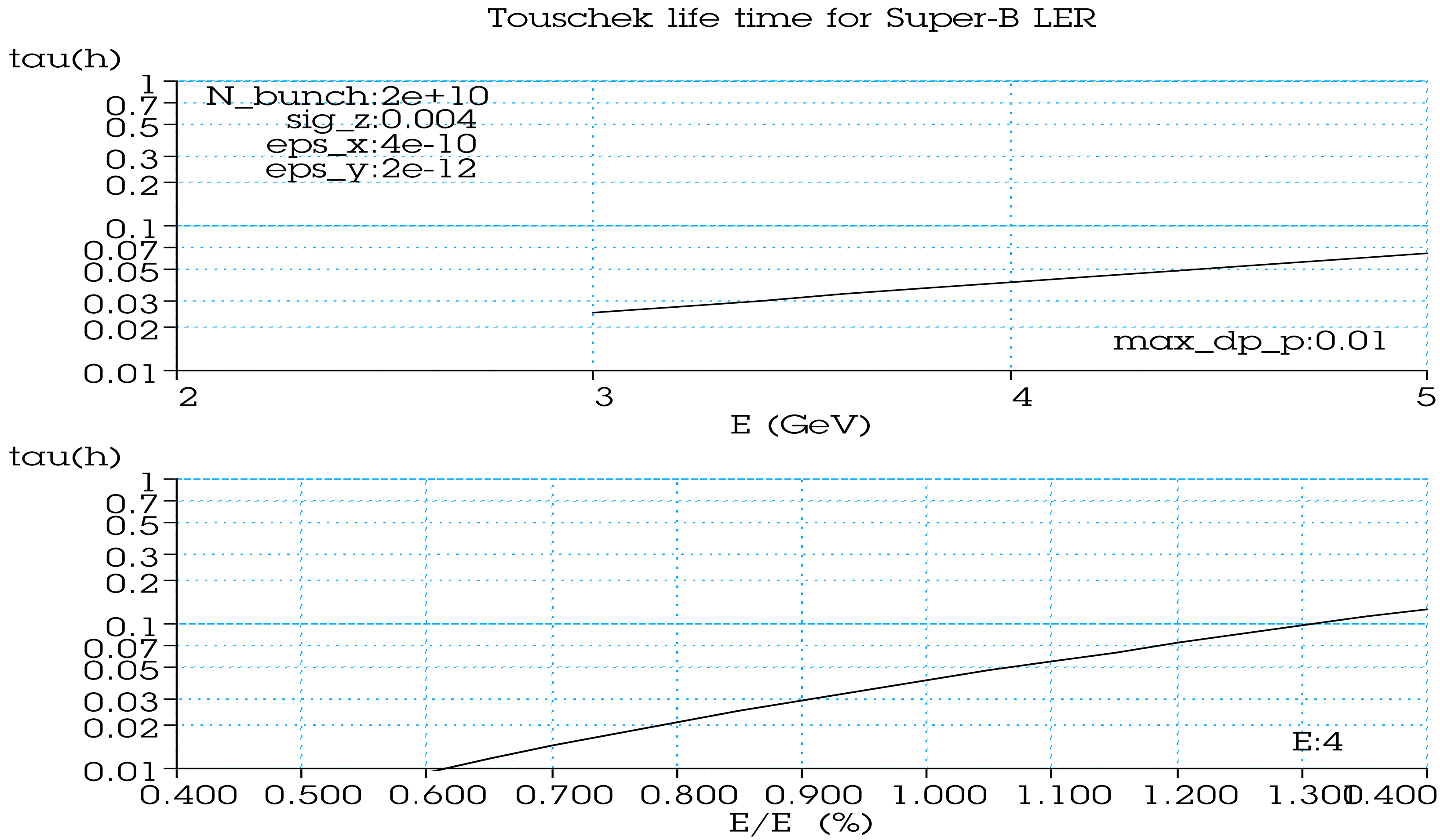
Lattice Comparison

Parameter	at 3.1 GeV PEP-II LER	PPA (Cai)	at 4 GeV OTW (Kuroda)	mWiggler	Unit
circumference	2.2	2.8	3.2	2.2	km
X tune	36	48	45	72	
Y tune	35	48	24	24	
momentum comp.	0.00124	0.00028	0.00036	0.00003	
X damping time	≈65	39	24	7	ms
X emittance	24	0.28	0.26	1 (0.5)•	nmr
dP/P	6.40E-04	1.00E-03	1.10E-03	1.20E-03	
Main dipole field	10	1	1.55	16.7	kG
Arc focusing cells	96	164	120	96	regular cells
Cell type	FODO	FODO	TME	TME	
Vrf for 4 mm bunches	22	17	25	6*	MV
nus for above	0.07	0.025	0.035	0.0024	

***: 3.5 mm bunch length**

•: parameters for 1 nmr cell, 0.5 nmr cell slightly different

Touschek Lifetime



Emittance blow-up from IBS may be of concern as well

Instability Thresholds (comp PEP-II)

- μwave instability (Z/n ≈ 3Ω)

$$I_b = \frac{2\pi|\eta|(E/e)(\beta\sigma_b)^2}{\left|\frac{Z_{||}}{n}\right|_{eff}}$$

  - Ok for PPA, OTW, factor 60 worse than PEP for mWig
- TMCI threshold

$$I_b = \frac{4(E/e)\nu_s}{\langle \mathrm{Im}(Z_\perp)\beta_\perp \rangle R} \frac{4\sqrt{\pi}}{3}\sigma_l$$

  - $Z_\perp \approx 0.5$MΩ/m: factor of 10 worse than PEP, probably ok since I_b less by 4.

Summary

- Wigglers enhance the flexibility of the lattice parameters
  - better chromatic behaviour, flexibility in α
  - can use more units to reduce power density
  - Conclusion for HER may be *different*!
- Size (2, 3, 6 km) not a constraint for rings *per se*
  - But need an IR design to fit.
- Rf voltage could be high for the wiggler lattices
- Short beam lifetime needs powerful injector *e.g*. 5…10 mA/s just to keep up

Some Open Questions for Rings

- We need to make a parameter set (or sets)
  - actual energies, emittances, aspect & current ratio *etc*.
- Need to make lattices so the IR can be fit in
  - Could stay close to ILC designs, *e.g*. PPA
    - but need to adjust for size & energy
  - What is the effect of the IR on emittance??
    - e.g. PEP LER: .6 nmr just from the vertical bends!
- Get some idea if schemes like travelling focus actually work in practice.
  - Ultra-low ß will require local chromaticity correction
  - Residual aberrations from travelling focus
  - beam aspect ratio of 200 may be tough