VLHC Round/Flat Working Group Report

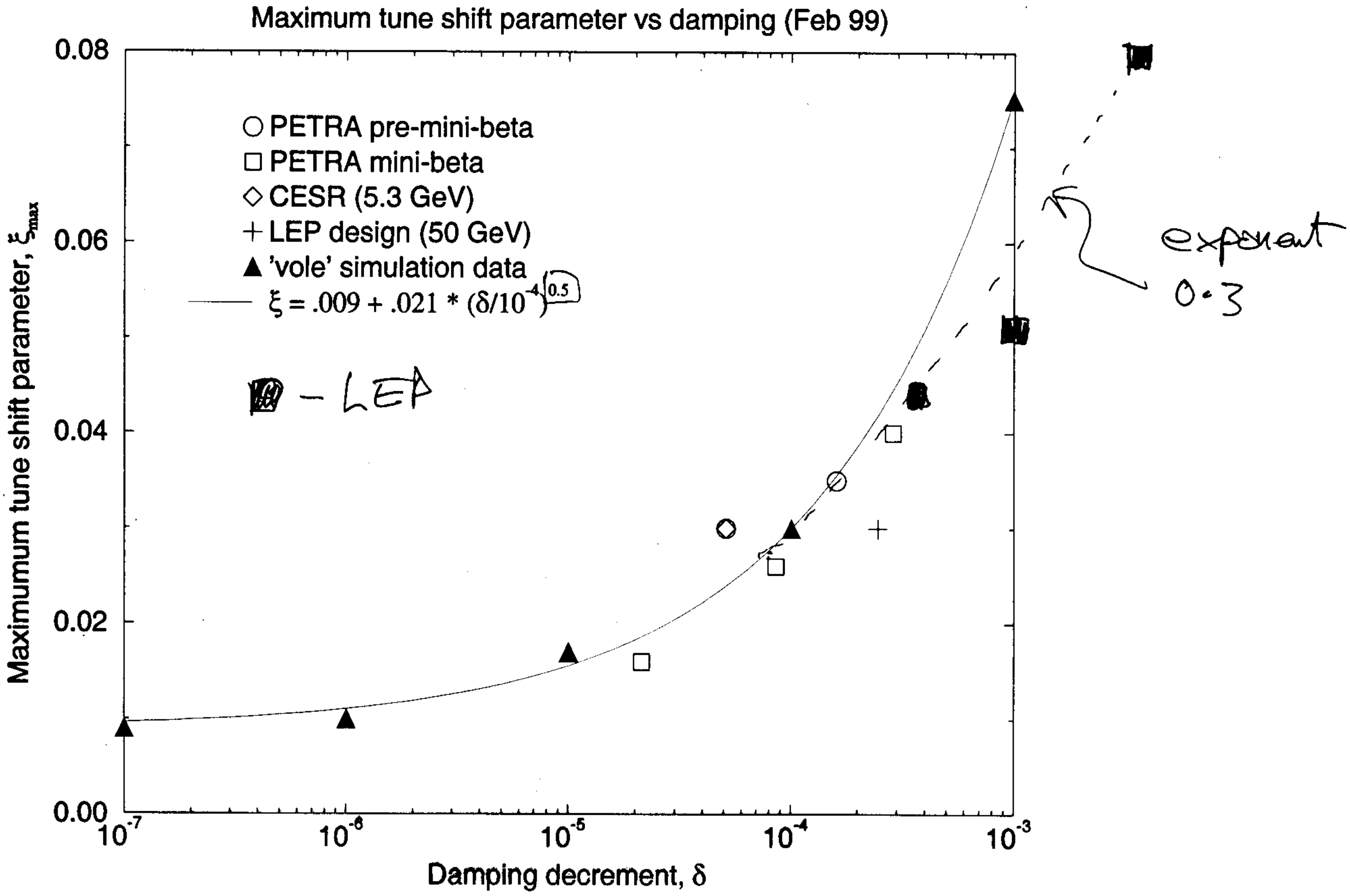
R. Talman, 20 Sep 2000

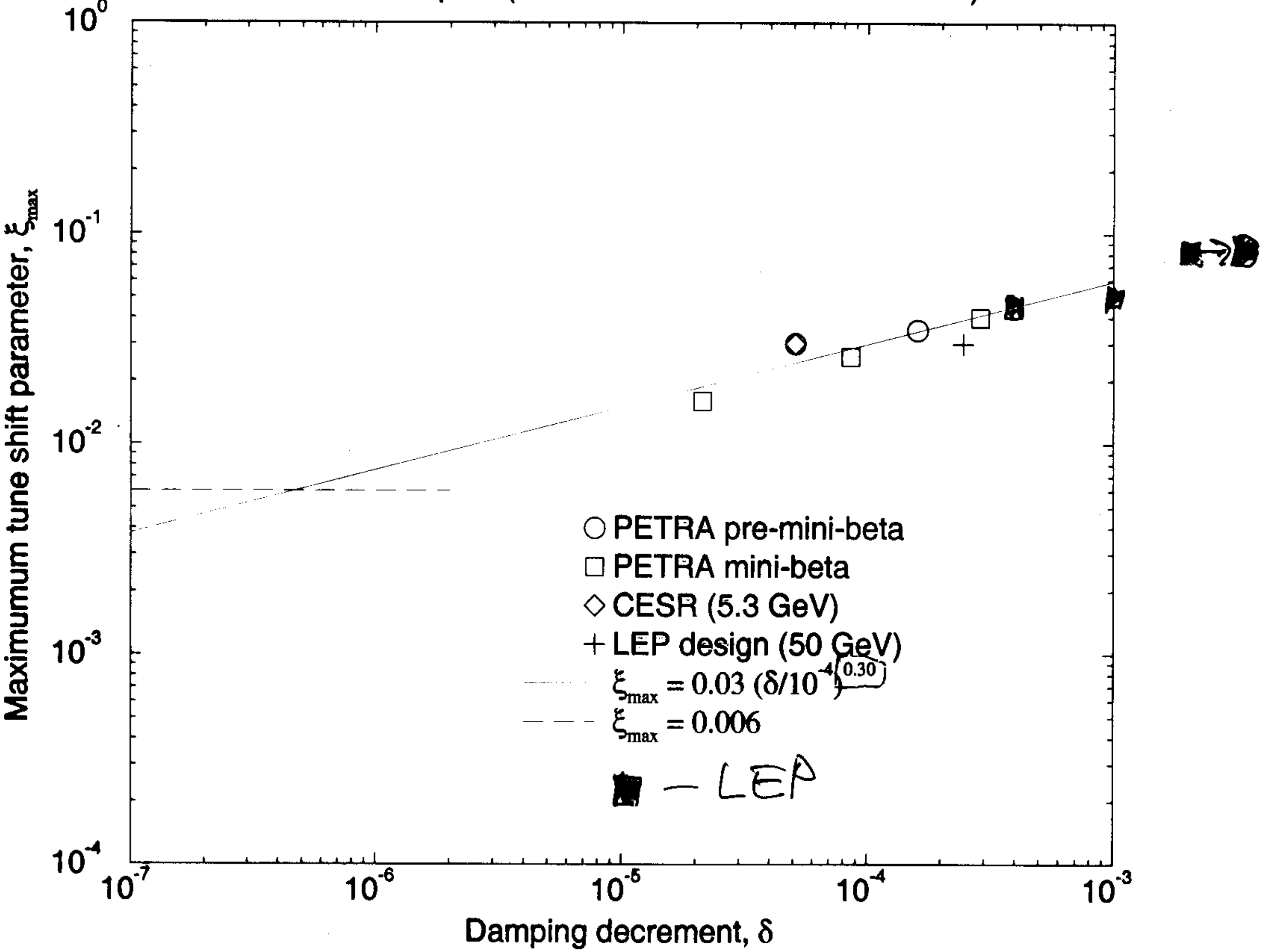
Topics

- flat is good. A Chao will report (I hope).
  if $K \gtrsim 0.1$ Failing that Steve Peggs.
- synch. radiation heat load economy
- attempt to reconstruct G. Dugan wiggler suggestion
- key issues for future investigations both experimental and theoretical

$$\left.\frac{\epsilon_y}{\epsilon_x}\right|_{min} \left\{ \begin{array}{l} \bullet \text{ due to intrabeam scattering} \\ \bullet \text{ due to noise, etc} \end{array} \right.$$

- $\frac{\mathcal{L}_{flat,max}}{\mathcal{L}_{rnd,max}} \overset{?}{\approx} 5$ (AC will discuss).
- damping decrement due to SR seems <u>not</u> to increase ξ_{max}?


Maximum tune shift parameter vs damping (Feb 99)
Maximum tune shift parameter, ξ_{max}
Damping decrement, δ
0.08
0.06
0.04
0.02
0.00
10^{-7}
10^{-6}
10^{-5}
10^{-4}
10^{-3}
○ PETRA pre-mini-beta
□ PETRA mini-beta
◇ CESR (5.3 GeV)
+ LEP design (50 GeV)
▲ 'vole' simulation data
$\xi = .009 + .021 * (\delta/10^{-4})^{\boxed{0.5}}$
■ - LEP
exponent
0.3



Keil-Talman plot (Particle Accelerators 1983 Vol.14)

Accounting for Synch. Rad Heat Load

Luminosity lifetime $\rightarrow$ $\overset{\text{minimum}}{\wedge}$ Number of circulating particles, N_{min}

$\tau_{\mathcal{L}}$ ($\overset{e.g}{=}$ 24 hrs)

$\sigma_{tot}(E)$ = total cross section for proton loss by nuclear collisions

$\overset{e.g}{=}$ 130 mb.

$$N_{min} = \overset{2\ IP's\ \downarrow}{2} \times \underset{\leftarrow \mathcal{L} \propto N^2}{2}\, \mathcal{L}\, \sigma_{tot}\, \tau_{\mathcal{L}} \left(\overset{e.g}{=} 4\times10^{34} \times 1.3\times10^{-25} \times \overset{\text{sec/day}}{\overbrace{0.86\times10^{5}}} \right)$$

$$= 4.5\times10^{14}\left(\frac{\mathcal{L}}{10^{34}}\right) @\ \tau_{\mathcal{L}} = 24\,\text{hrs}$$

$$r_{ex} = \frac{N}{N_{min}} \left(\overset{e.g}{=} \frac{2.5\times10^{14} \leftarrow \text{Peggs, Harrison, Pilat, Syphers}}{4.5\times10^{14}} = 0.55 \right)$$

i.e. lifetime doesn't meet spec.

$r_{ex} > 1 \Rightarrow$ wasted radiation

SR Power

$$U_0 = \frac{C_\gamma E^4}{R} = \text{SR loss per particle per turn}$$

$$C_\gamma = 0.778\times10^{-17}\, m\, GeV^{-3} \text{ (protons)}$$

$\mathcal{C}$ = circumference

P_{SR} = power lost to SR

$$= N U_0 \frac{\mathcal{C}}{c} \quad \left(\overset{e.g.}{=} 0.49\,MW \quad PHPS\right)$$

$$= \left(N_{min} U_0 \frac{\mathcal{C}}{c}\right) r_{ex}$$

Refrigeration Efficiency

η_{mask} = fraction of SR energy extracted at high temp $(0 < \eta_{mask} < 1)$
Less than one because of photons not absorbed by mask and because of heat leaking from mask to cold bore.
$\overset{e.g.}{=} 0.95$ (ie. fairly high even with substantial contact)

$$\eta_{refrig,warm} = \frac{80}{300} 0.25 = 0.67 \times 10^{-1}$$

$$\eta_{refrig,cold} = \frac{4}{300} 0.25 = 3.33 \times 10^{-3}$$

$$P_{wall} = \left(\frac{1 - \eta_{mask}}{\eta_{refrig,cold}} + \frac{\eta_{mask}}{\eta_{refrig,warm}} \right) P_{SR} = \frac{P_{SR}}{\eta_{eff}}$$

$$\eta_{eff} = \left(\frac{.05}{3.33 \times 10^{-3}} + \frac{0.95}{0.67 \times 10^{-1}} \right)^{-1}$$

$$= (15 + 14)^{-1}$$

$$\approx \frac{1}{30}$$

Combine Factors

$$P_{wall} = \underbrace{\left(N_{min} U_0 \frac{c}{C} \right) r_{ex}}_{\overset{e.g.}{=} 5.9 \frac{W}{m} \times 89 km} \frac{1}{\eta_{eff}} \overset{e.g.}{=} 0.49 \times 10^6 \times 30$$

$$= 15 MW$$

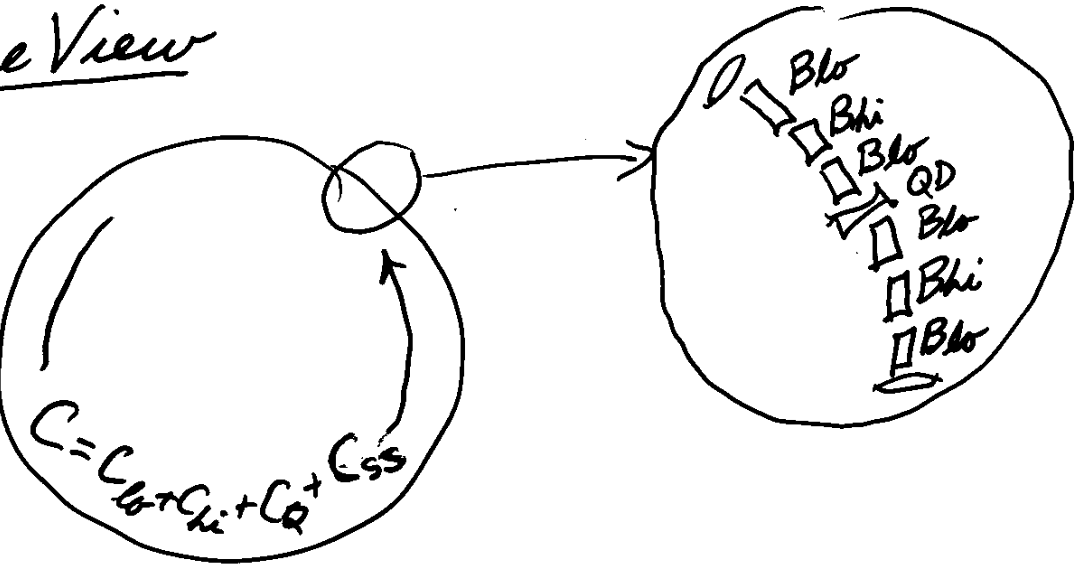
= "tolerable"

Note. Function of mask is more to enable cryopumping than to extract heat.

Tutoritron (all-Wiggler) Lattice

. attempt to reconstruct G. Dugan suggestion. RT alteration — distribute wiggler and use it to ramp energy

Course View



$$\left.\begin{aligned} C_{lo} &\overset{e.g}{=} \overset{\swarrow C_{lo}}{0.85\,C_B} = 85\,km \\ C_{hi} &\overset{e.g}{=} 0.15\,C_B = 15\,km \end{aligned}\right\} C_B = 100\,km$$

$C_Q \overset{e.g}{=} 20\,km$

$C_{SS} \overset{e.g}{=} 10\,km$

$C_{tot} = 130\,km$

Parameters $B_{lo} = \text{fixed} \overset{e.g}{=} 3\,T$

$B_{hi} = b\,B_{hi} = b\,12T$

$-1 < b < 1$

$-12T < B_{hi} < 12T$

Energy Ramping

$$\frac{E(b)}{e} = \frac{cC_B}{2\pi}\left(c_{lo}B_{lo} + c_{hi}B_{hi}\,b\right)$$

$$\frac{E_{max}}{\cancel{e}} = \frac{3\times10^8\times10^5}{2\pi}\left(\overset{2.55}{0.85\times3} + \overset{1.8}{0.15\times12}\right)$$

$$= 20.8\,\text{TeV}$$

$$E_{min} = \frac{3\times10^8\times10^5}{2\pi}\left(2.55 - 1.8\right)$$

$$= 3.6\,\text{TeV}$$

$$3.6\,\text{TeV} < E(b) < 20.8\,\text{TeV}$$

Synchrotron Radiation

$\boxed{E = 3.6\,\text{TeV}}$

U_0 = SR energy per particle per turn

$$= \frac{C_\gamma E^4}{2\pi}\left(\frac{c_{lo}C_B}{R_{lo}^2} + \frac{c_{hi}C_B}{R_{hi}^2}\right)$$

$$= \frac{C_\gamma\left(\frac{pc}{e}\right)^4 C_B}{2\pi}\frac{1}{(\rho c/e)^2}\left[c_{lo}B_{lo}^2 + c_{hi}B_{hi}^2\right]$$

$$= \frac{C_\gamma\left(\frac{pc}{e}\right)^2 C_B}{2\pi}\left[\overset{7.65}{0.85\times3^2} + \overset{21.6}{0.15\times12^2}\right]$$

$$= 4702\,\text{eV}$$

Compared to ring with only R_{lo}, $U_0 = 323\,\text{eV}$

Damping Rate at Injection

$$\text{fractional vertical emittance decrement} = \frac{U_0}{pc/e} \text{ per turn}$$

$$= \frac{U_0}{pc/e}\frac{c}{C} \text{ per second}$$

$$\underline{\underline{\text{e.g}}} \quad \frac{4702 \times 3\times10^8}{3.6\times10^{12}\times1.3\times10^5}\ \overset{\overset{\frac{\text{sec}}{\text{hour}}}{\downarrow}}{3600}$$

$$= 1.08\times10^{-2}\,\text{hrs}^{-1}$$

which is too low to be useful.

Damping Rate at Full Energy

$$U_0 \propto E^2$$

$$E\cancel{U}_0 \propto E$$

$$\frac{\frac{1}{\varepsilon}\frac{d\varepsilon}{dt}(20.8)}{\frac{1}{\varepsilon}\frac{d\varepsilon}{dt}(3.6)} = \frac{20.8}{3.6} = 5.8$$

$$\frac{1}{\varepsilon}\frac{d\varepsilon}{dt}(20.8\,\text{TeV}) = 0.062\,\text{hrs}^{-1} \quad (16 \text{ hours lifetime})$$

Still not very useful. Need more high field length

I am probably missing something