Intensity Limitations in LEP

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Spectra

External excitation
High chromaticity (10)
200 μA/bunch
Transverse Mode Coupling

\[ I_{th} = \frac{7.88.Q_s.f_{rev}.E}{e.\Sigma \beta_i k_i} \]
Chromaticity and head tail damping
Spectra

NO External excitation
chromaticity 10
200 µA/bunch
Spectra

NO External excitation
chromaticity : 1
420 μA/bunch
\( Q_{\nu} = 0.08 \)
Loss factors

\[ k \]

\[ 10 \quad 20 \]

\[ \sigma_s \text{(mm)} \]

\[ k \text{ in } V/(m.pC) \]

<table>
<thead>
<tr>
<th>( \beta )</th>
<th>( n )</th>
<th>( a )</th>
<th>( b )</th>
<th>( \beta )</th>
<th>( n )</th>
<th>( a )</th>
<th>( b )</th>
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<tbody>
<tr>
<td>40.6</td>
<td>48</td>
<td>0.02703</td>
<td>4.2625</td>
<td>51.3</td>
<td>288</td>
<td>-0.1</td>
<td>11.5</td>
</tr>
</tbody>
</table>

Legend:
- Cu
- S.C
- sep
- SBA
- Bel L
- Bel S
- Bel 200
- Bel 250
- SRM
- SUM
Scaling?

\[(\Sigma k_i B_i)_L = \frac{\langle \beta_{BL}^{\prime} \rangle}{\langle \beta_{BL} \rangle} \cdot \frac{m_{BL}}{m_{BL}} \langle \beta^L \rangle_{BL} \]

\[+ \frac{\langle \beta_{CL} \rangle}{\langle \beta_{CL} \rangle} \frac{U_{RFL}}{U_{RFL}} \langle \beta^L \rangle_{CL} \]

\[= \langle \beta^L \rangle_{BL} + \frac{U_{RFL}}{U_{RFL}} \langle \beta^L \rangle_{CL} \]

\[= \left( \frac{1}{2} + \frac{4}{3} \cdot \frac{1}{2} \right) \langle \beta^L \rangle_{LEN} \]

\[= \frac{7}{6} \langle \beta^L \rangle_{LEN} \]

\[= \frac{7}{6} \langle \beta^L \rangle_{LEN} \]

\[= \left( \frac{5}{6} + \frac{4}{6} \right) \langle \beta^L \rangle_{LEN}. \]
Longitudinal Turbulence

\[ V = F(\sigma_s) \]

\[ \sigma_s = f(V) \]

Leads to shape oscillations, mainly quadrupole.

Less damping of the \( m=1 \) mode (depends on longitudinal phase correlation).
Figure 45.2: Longitudinal spectrum around the $2 \times Q_s$ line for a bunch current of 430 $\mu$A.

Figure 45.3: Frequency of the longitudinal modes as a function of intensity.
Use of Wigglers

- Dynamic range of storage ring: small emittance at high energy $\leftrightarrow$ short bunch length at injection.
- Lower beta at impedances $\leftrightarrow$ short bunch length.
- Stronger damping.
- $V_{rf}/V_{beam}$
  - No turbulence
  - $0_{\beta} > 8 \text{ mm}$
Bunch length > 8mm

• k-factors increase rapidly
• Longitudinal turbulence (less damping of m=1) + cavity stability
• Splitting of m=0 mode
• Cryogenic losses
Ultimate limit: coherent synchro-betatron resonances

Qs > 0.15 Intensity saturated.
Intensity limit with two beams

\[ \sigma \]

\[ \pi \]

\[ Q \]

\[ I \]

\[ 0.5(Q_1+Q_2) \]
Figure 25.8: maximum currents as function of $Q_s$ for nominal separation

Figure 25.9: maximum intensity as function of $Q_s$ with 50% more separation. The lowest curve is the second for $Q'_s=0$. 