Injector Linacs

- Prelinac
- \( e^+ \) drive \( \rightarrow \) S band \( e^+ \) booster \( \rightarrow \) L band
- e- booster

- Most severe problem: multi-bunch beam break-up (BBU)
- Tolerance on emittance growth (especially in Prelinac), and bunches at large amplitudes

Is detuning alone sufficient? Advantage: simpler than ODS

Nominal bunch spacing \( \Delta t = 2.8 \mu s \)

- \( \frac{d\Delta}{d\Delta s} \) uniform, \( \frac{\Delta f}{f_s} = 10\% \), \( f_s = 4.0126 \text{ Hz} \)

- 2 structure types \( \Rightarrow \) eliminates bounce at \( s \geq 20 \text{ m} \)
  - results less sensitive to errors

For both bunch spacings 2.8\( \mu \)s, 1.4\( \mu \)s

- \( \frac{\Delta f_s}{f_s} = -2.5\% \)
- Tilt top of distribution \( \alpha = -0.3 \)
- Cost: 7\% in accelerating gradient
taken to be mono-energetic. The analytic BBU results and those of LIAR, at the end of the four injector linacs, are compared in Table 4. Results are given for one or two structure types, and for bunch spacings of 1.4 and 2.8 ns. Under the heading “Analytic” are given the rms of the sum wake $S_{rms}$, the rms of the growth factor $\gamma_{rms}$, the maximum (within the bunch train) of the growth factor $\gamma$, and the relative normalized emittance growth according to Eq. 4, $\delta \epsilon$. Under the heading “Numerical” we give the LIAR results; the maximum (within the bunch train) growth in normalized phase space $\xi$ and the relative normalized emittance growth $\delta \epsilon$.

Table 4: Multi-bunch beam break-up calculation results for a bunch train with an initial offset in $y$ of $\sigma_{y0}$. Results are given for different number of structure types $N_s$ and bunch spacing $\Delta t$. Given are the rms of the sum wake $S_{rms}$ (in units of $V/pC/mm/m$), the rms and the peak of the strength parameter, $\gamma_{rms}$ and $\gamma$, respectively, and the analytically obtained relative normalized emittance growth in $y$, $\delta \epsilon$. Also shown are the LIAR obtained peak blow-up in normalized phase space, $\xi$, and the projected emittance growth.

<table>
<thead>
<tr>
<th>$N_s$</th>
<th>$\Delta t$</th>
<th>Name</th>
<th>Analytical</th>
<th>Numerical</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>$S_{rms}$</td>
<td>$\gamma_{rms}$</td>
<td>$\gamma$</td>
</tr>
<tr>
<td>1</td>
<td>2.8ns</td>
<td>Prelinac</td>
<td>.53</td>
<td>.80</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$e^+$ Drive</td>
<td>.53</td>
<td>2.83</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$e^-$ Booster</td>
<td>.53</td>
<td>1.16</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$e^+$ Booster</td>
<td>.12</td>
<td>.14</td>
</tr>
<tr>
<td>2</td>
<td>2.8ns</td>
<td>Prelinac</td>
<td>.02</td>
<td>.02</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$e^+$ Drive</td>
<td>.02</td>
<td>.08</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$e^-$ Booster</td>
<td>.02</td>
<td>.04</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$e^+$ Booster</td>
<td>.12</td>
<td>.14</td>
</tr>
<tr>
<td>2</td>
<td>1.4ns</td>
<td>Prelinac</td>
<td>.58</td>
<td>.62</td>
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<tr>
<td></td>
<td></td>
<td>$e^+$ Drive</td>
<td>.58</td>
<td>2.11</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$e^-$ Booster</td>
<td>.58</td>
<td>.89</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$e^+$ Booster</td>
<td>.30</td>
<td>.24</td>
</tr>
</tbody>
</table>

From the table we see that the analytical $\gamma$ correlates well with the numerical $\xi$, and the analytical emittance correlates well with the numerical one. In fact, when $\gamma$ is not too large the corresponding analytical and numerical results agree rather well. The remaining discrepancies are likely
- if we go to 5\% phase advance, we can recover some gradient (?)

Resulting BBU tolerances OK, worst for e+ drive linac

largest amplification is $\frac{\Delta}{\varphi} = 0.3$ - energy spread very

- $\Delta = \text{structure misalignment}$

- two types need to be well aligned with each other

analytical

- tolerance for 10\% emittance growth

- need to do C/A/R runs

\[
\begin{array}{|c|c|}
\hline
\text{tol} & \text{gridtol} \\
\hline
25\,\mu m & 0.85\,mm \\
0.67\,mm & 2.4\,cm \\
1\,mm & 3.7\,cm \\
66\,cm & 66\,cm \\
\hline
\end{array}
\]

DDS?
- more complicated

suppose we want $\frac{1}{e} \text{ at } 20\,m \Rightarrow Q = 800$

- for 1 structure type, $Q=1000$ simulation obtains $S_{\text{eff}} = S_{\text{lim}} = 0.0466/\text{cm}$

- for BBU, 2\% worse than DT with 2 structure types
- misalignment tolerance 10x larger!...
$S$-band scaled to X-band

Approx DDS by taking $Q=1000$, 1 structure type