Updated results for bunch length measurements using streak camera

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1. LER

- Fitting model: $f(I_b) = a*I_b + b$
- $\sigma_z$ from SAD simulation: 4.6, 5.3, 6.8mm at zero current
- Large discrepancy in zero-current bunch length between SAD simulation and measurements

$$\psi(z) = I_0 * e^{-\frac{(z - \bar{z})^2}{2[1 + \text{sign}(z - \bar{z}) \cdot A]^2 \sigma^2}} + I_1$$

![Graph showing $\sigma_z$ vs. $I_{bunch}$ for different $V_{rf}$ values]
1. LER

- Bunch length as function of RF voltage
- Bunch current 0.25->0.11mA (Vrf=3.8->7.7MV)
1. LER

- Centre of mass (phase shift) as function of RF voltage
- Bunch current 0.25->0.11mA (Vrf=3.8->7.7MV)
- Fitting model:

\[ f_3(V_{rf}) = 14.38 + 77.84 / \sqrt{V_{rf} - 1.79} \]

Note: SAD data offsetted to fit the measurements at low RF voltage
2. HER

- Fitting model: \( f(I_b) = a * I_b + b \)
- \( \sigma_z \) from SAD simulation: 5.3, 6.2, 7.8mm at zero current
- Large discrepancy in zero-current bunch length between SAD simulation and measurements

\[ f_1(I_b) = 6.13 + 1.44I_b \]
\[ f_2(I_b) = 7.03 + 1.54I_b \]
\[ f_3(I_b) = 8.69 + 1.71I_b \]
\[ f_4(I_b) = 5.34 + 0.88I_b \]
2. HER

- Bunch length as function of RF voltage
- Bunch current 0.11->0.1mA (Vrf=6.2->12.48MV)
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- Bunch length as function of RF voltage
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2. HER

- Centre of mass (phase shift) as function of RF voltage
- Bunch current 0.11->0.1mA (Vrf=6.2->12.48MV)
- Fitting model:

\[ f_3(V_{rf}) = 99.91 - 70.92 / \sqrt{V_{rf} - 2.97} \]

Note: SAD data offsetted to fit the measurements at low RF voltage
3. RF tuning

➤ From T. Kobayashi

● RF voltages are measured via power meter. The uncertainty of RF voltage for each cavity is $\sim \pm 5\% \Rightarrow$ The error in total RF voltage should be in the order of $\pm 5\%$.

● The RF phase for each cavity is tuned to maximise the measured synchrotron tune (coherent synch. tune?). This phase optimisation procedure has no relation to incoherent or coherent synch. tune.

● The RF phase is automatically determined by the balance between RF acceleration and SR+HOM loss.

● After RF phase optimization, measured synch. tune (coherent?) is compared with analytic formula $\Rightarrow$ Good agreement at low bunch current (see next 2 pages).
3. RF tuning

➤ HER (from T. Kobayashi)

- Number of bunch: 826 (2016.03.16)

3. RF tuning

➤ LER (from T. Kobayashi)
- **Number of bunch: 1182 (2016.03.11)**

4. KEKB

➤ HER (2009.10.26): nominal bunch length 5.2mm
- Single-shot measurement (100 shots per current) by J. Flanagan
- Average over different number of shots: Converge to same results
- Shot noise and timing jitter are small

\[
\begin{align*}
\text{f}_1(I_b) &= 6.42 + 1.48I_b \\
\text{f}_2(I_b) &= 6.76 + 1.25I_b \\
\text{f}_3(I_b) &= 6.79 + 1.23I_b \\
\text{f}_4(I_b) &= 6.80 + 1.24I_b \\
\text{f}_5(I_b) &= 6.81 + 1.24I_b \\
\text{f}_6(I_b) &= 6.84 + 1.24I_b
\end{align*}
\]
4. KEKB

➤ LER (2009.10.26): nominal bunch length 4.6mm
- Single-shot measurement (128 shots per current) by J. Flanagan
- Average over different number of shots: Converge to same results
- Shot noise and timing jitter are small

\[
\begin{align*}
    f_1(l_b) &= 5.03 + 2.28l_b \\
    f_2(l_b) &= 5.45 + 2.04l_b \\
    f_3(l_b) &= 5.48 + 2.03l_b \\
    f_4(l_b) &= 5.49 + 2.03l_b \\
    f_5(l_b) &= 5.51 + 2.02l_b \\
    f_6(l_b) &= 5.51 + 2.02l_b \\
    f_7(l_b) &= 4.62 + 1.65l_b
\end{align*}
\]
5. Summary

➤ Bi-Gaussian (asymmetric Gaussian) fitting is used to analyse the SC data offline
➤ But results are different from Gauss fit of SC software (Why?!)
➤ At low current, the measured bunch length is systematically larger than SAD calculation. Possible reasons:
  ● There is systematic error in streak camera system
  ● The RF settings (Voltage and/or phase) are different from SAD model (likely not possible?)
➤ The current-dependent phase shifts from measurements have large errors. Therefore estimate of loss factors is not good enough. We may have to design two-bunch method using the streak camera.
5. Summary

➤ RF tuning looks OK, measured bunch length at low current should converge to SAD model (?)

➤ Possible errors in streak camera system
  • Low Shot noise and timing jitter at the photocathode [Ref. SLAC-PUB-13248, 2008]? [Likely not important in SuperKEKB]
  • Calibration in vertical time scale of streak camera? [Usually calibration is necessary]
  • Space-charge effects at the photocathode of the streak camera system [Ref. THPME080, IPAC2014]? [Likely space-charge broadening is possible]