Updated results for bunch length measurements using streak camera

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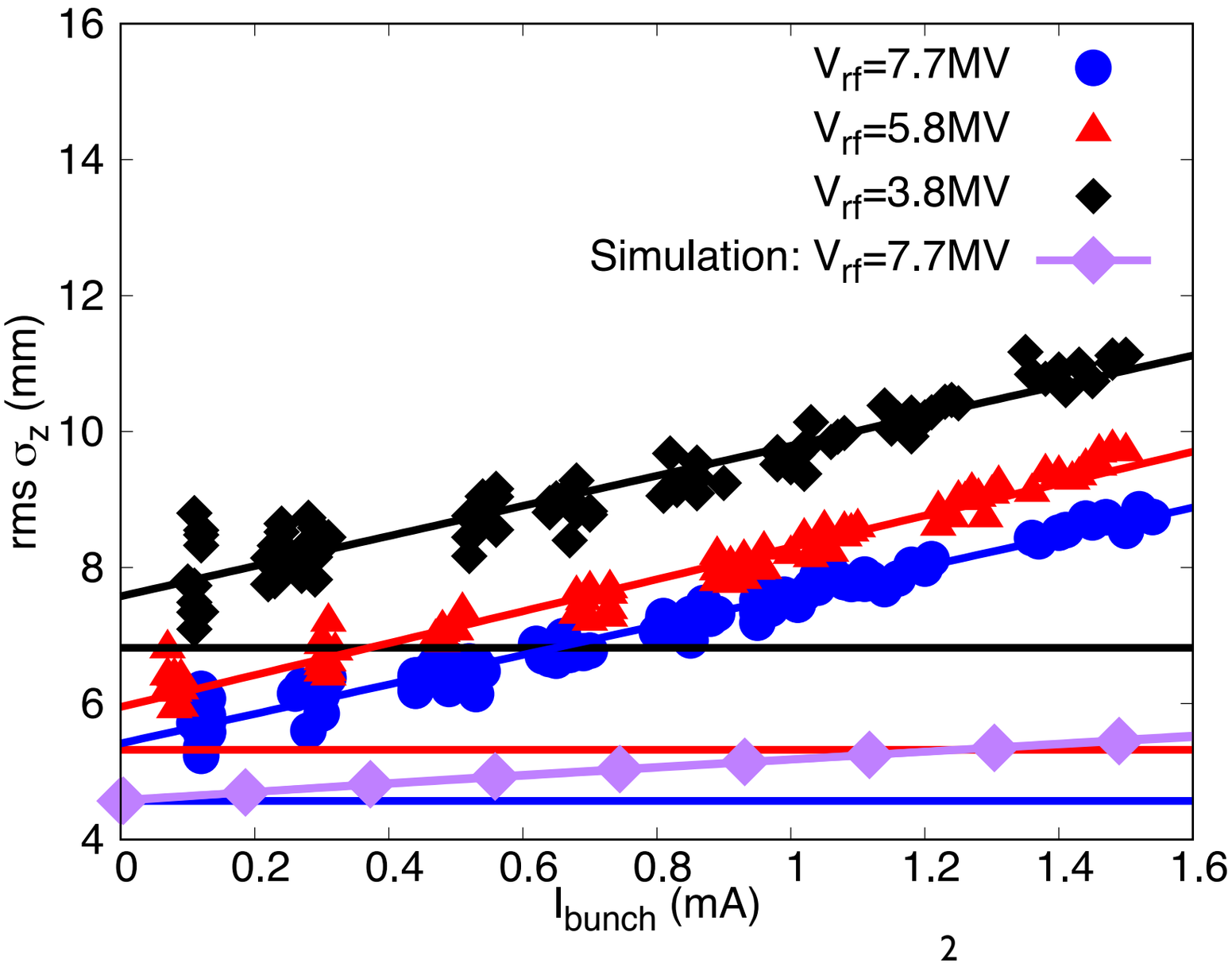
Thanks: M. Nishiwaki, T. Kobayashi, J. Flanagan, M. Tobiyama, K. Ohmi

SuperKEKB mini optics meeting, Sep. 08, 2016

1. LER

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

- **Fitting model: $f(I_b)=a*I_b+b$**
- **σ_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**



$f_1(I_b)=5.41+2.17I_b$

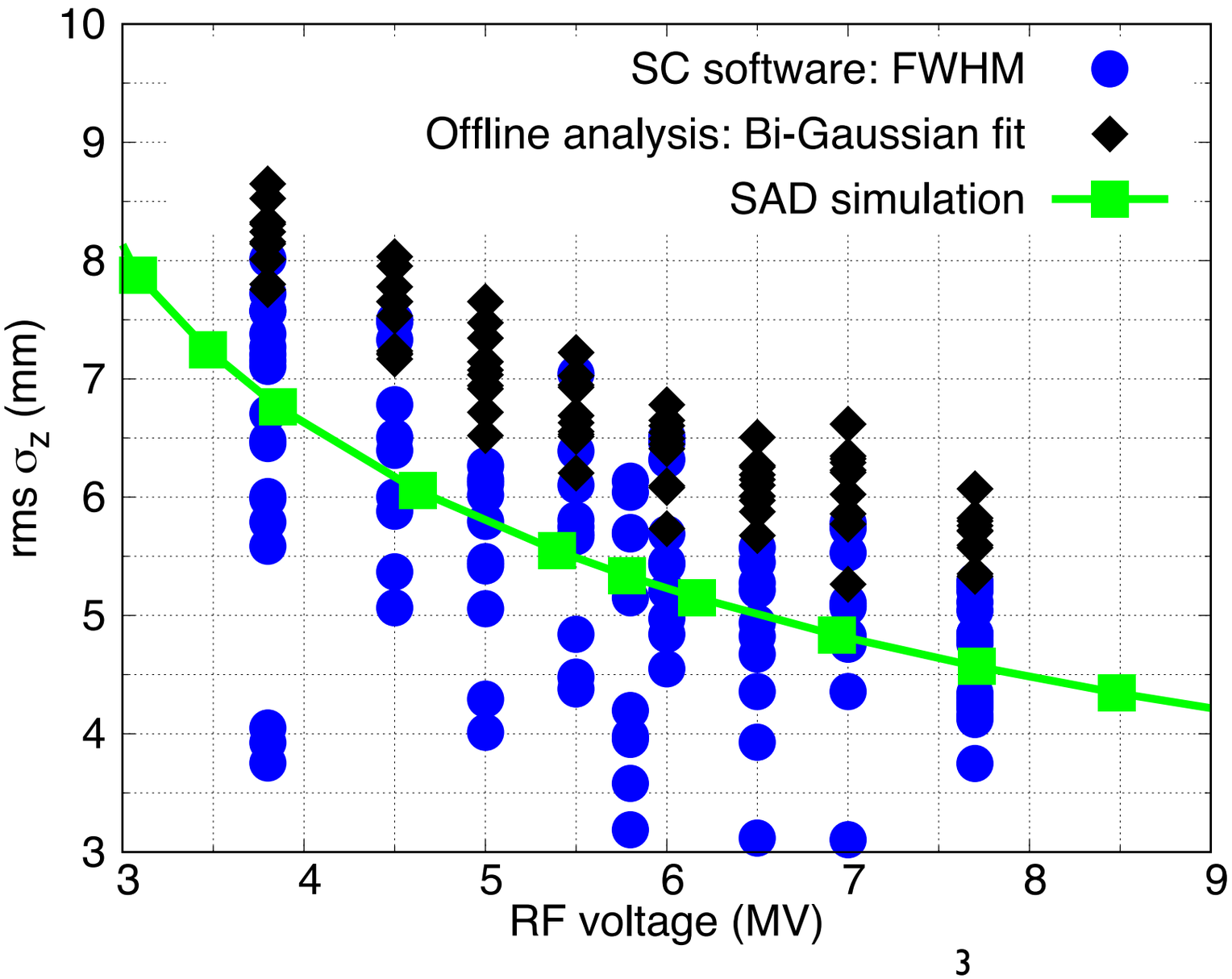
$f_2(I_b)=5.95+2.35I_b$

$f_3(I_b)=7.58+2.21I_b$

$f_4(I_b)=4.58+0.59I_b$

1. LER

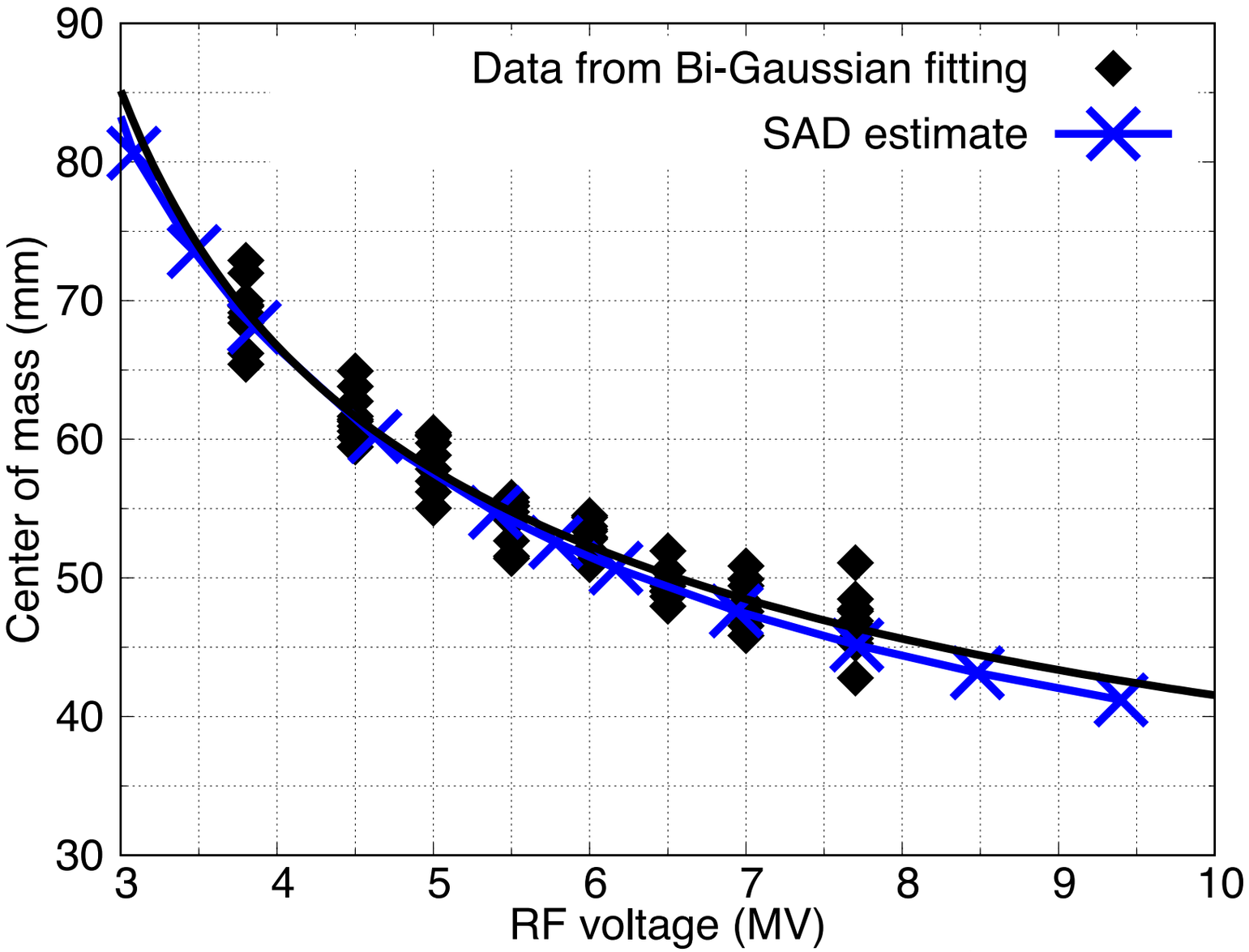
- **Bunch length as function of RF voltage**
- **Bunch current 0.25->0.11mA (Vrf=3.8->7.7MV)**



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:

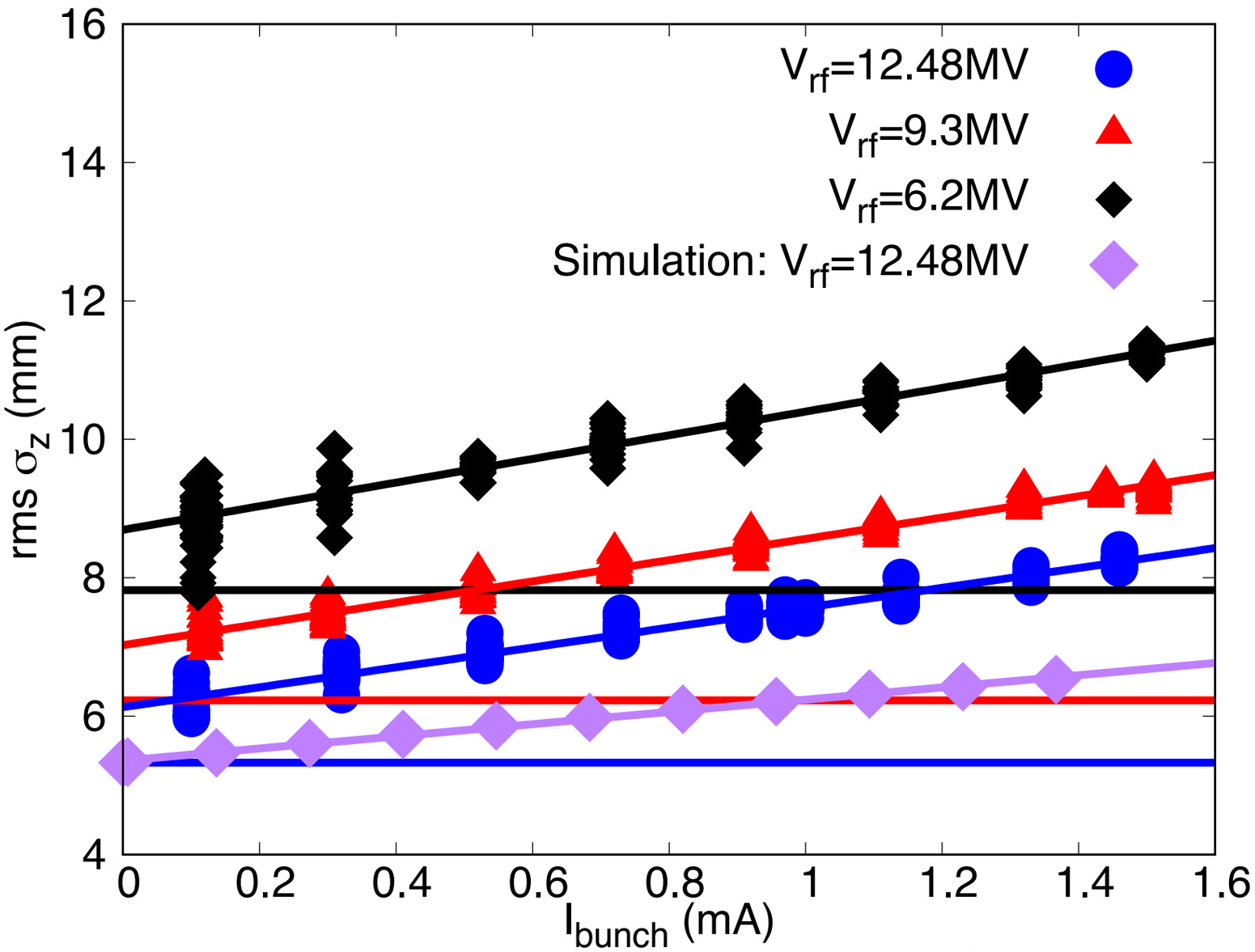
$$f_3(V_{rf})=14.38+77.84/\mathrm{Sqrt}[V_{rf}-1.79]$$



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

2. HER

- Fitting model: $f(I_b)=a*I_b+b$
- σ_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



$f_1(I_b)=6.13+1.44I_b$

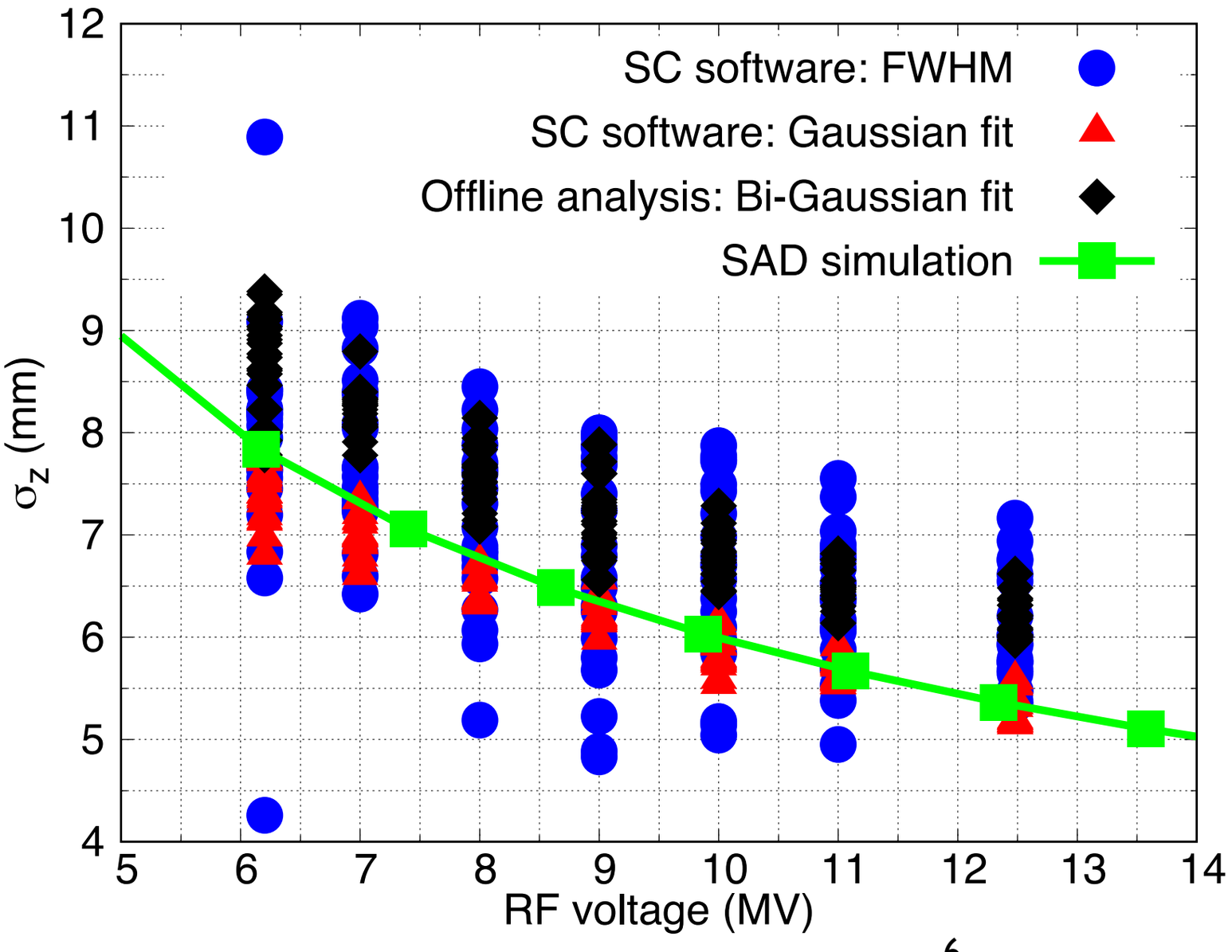
$f_2(I_b)=7.03+1.54I_b$

$f_3(I_b)=8.69+1.71I_b$

$f_4(I_b)=5.34+0.88I_b$

2. HER

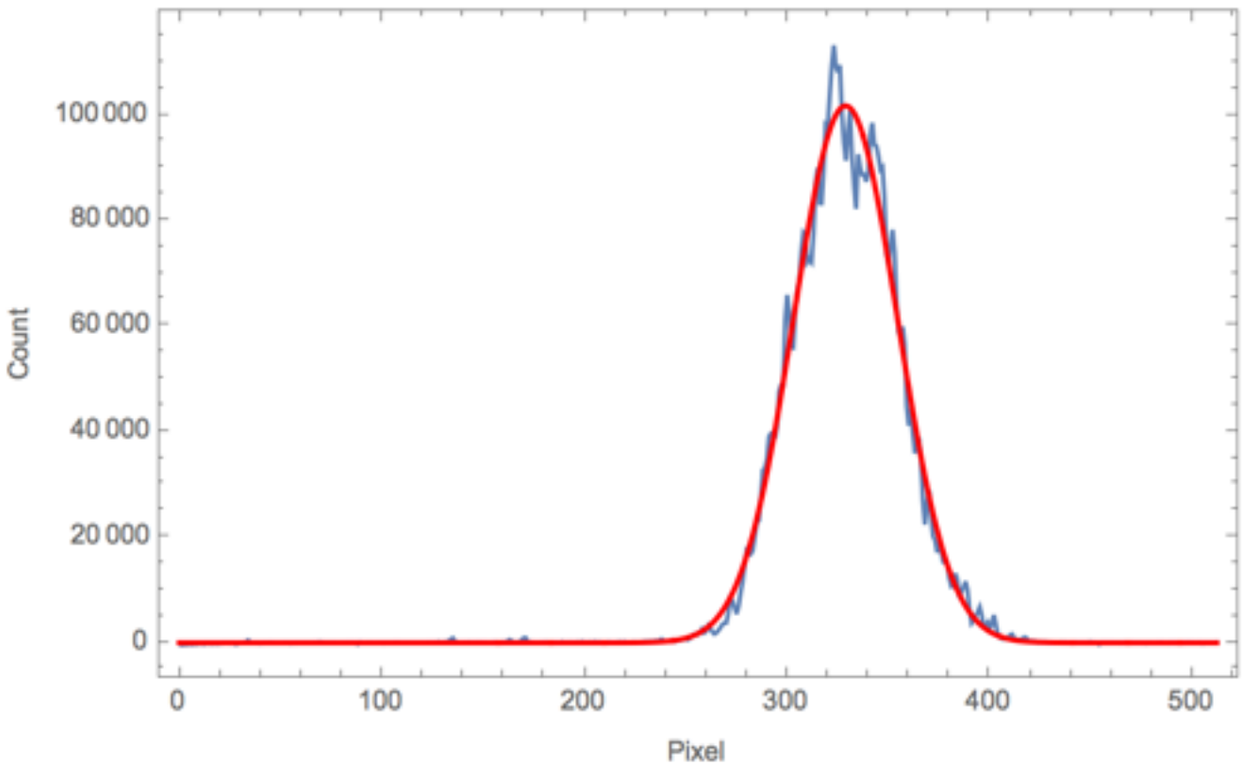
- **Bunch length as function of RF voltage**
- **Bunch current 0.11->0.1mA (Vrf=6.2->12.48MV)**



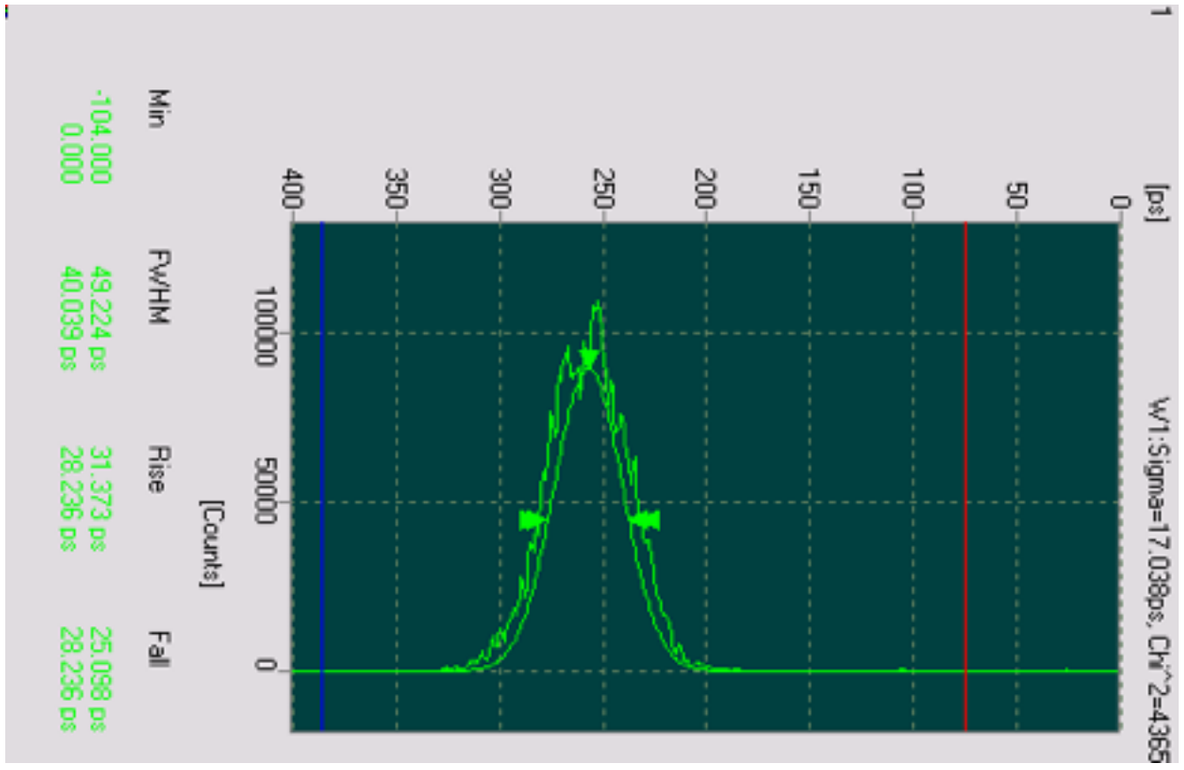
2. HER

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

Mathematica Bi-Gauss fitting



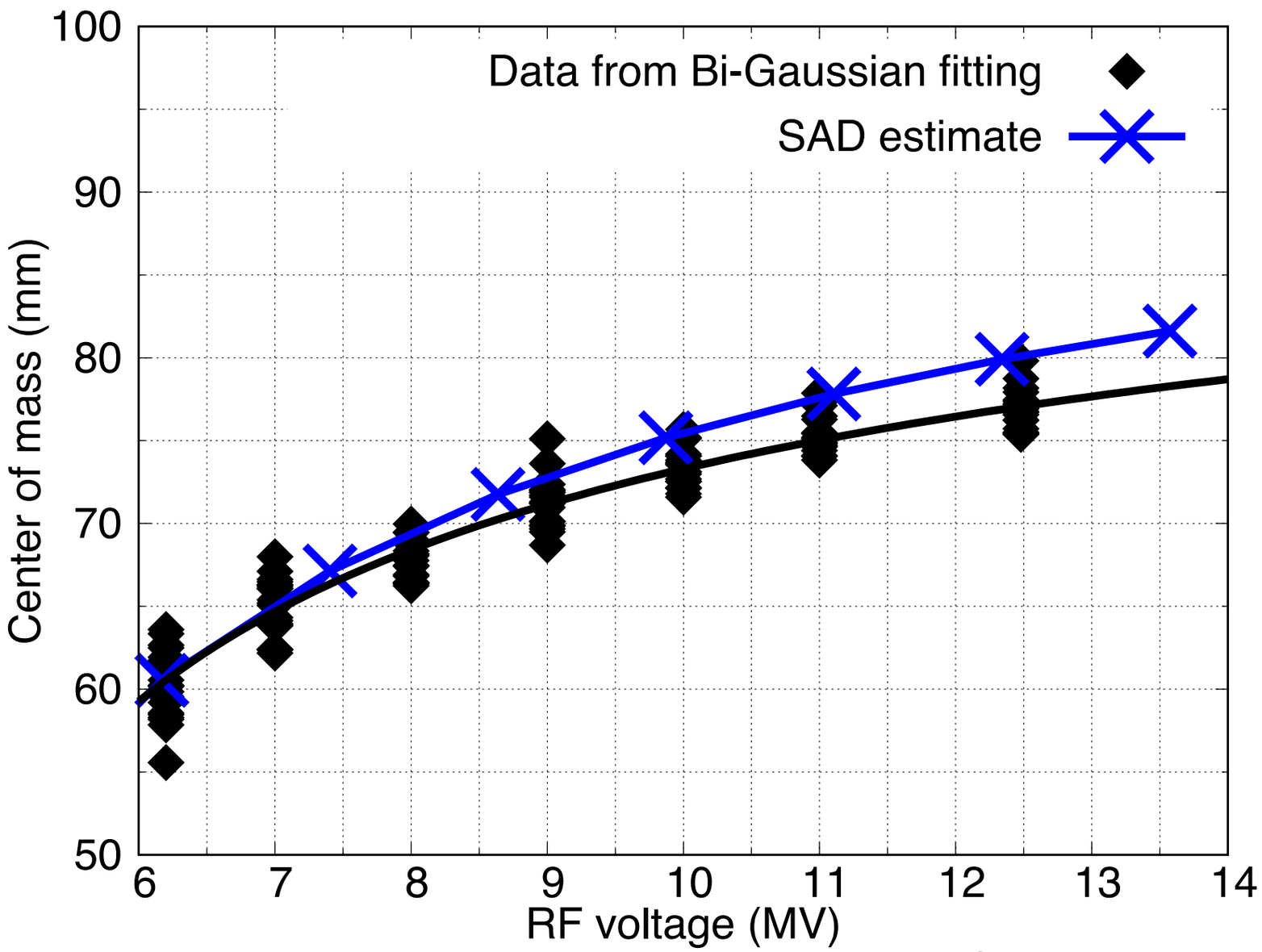
Streak camera software



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

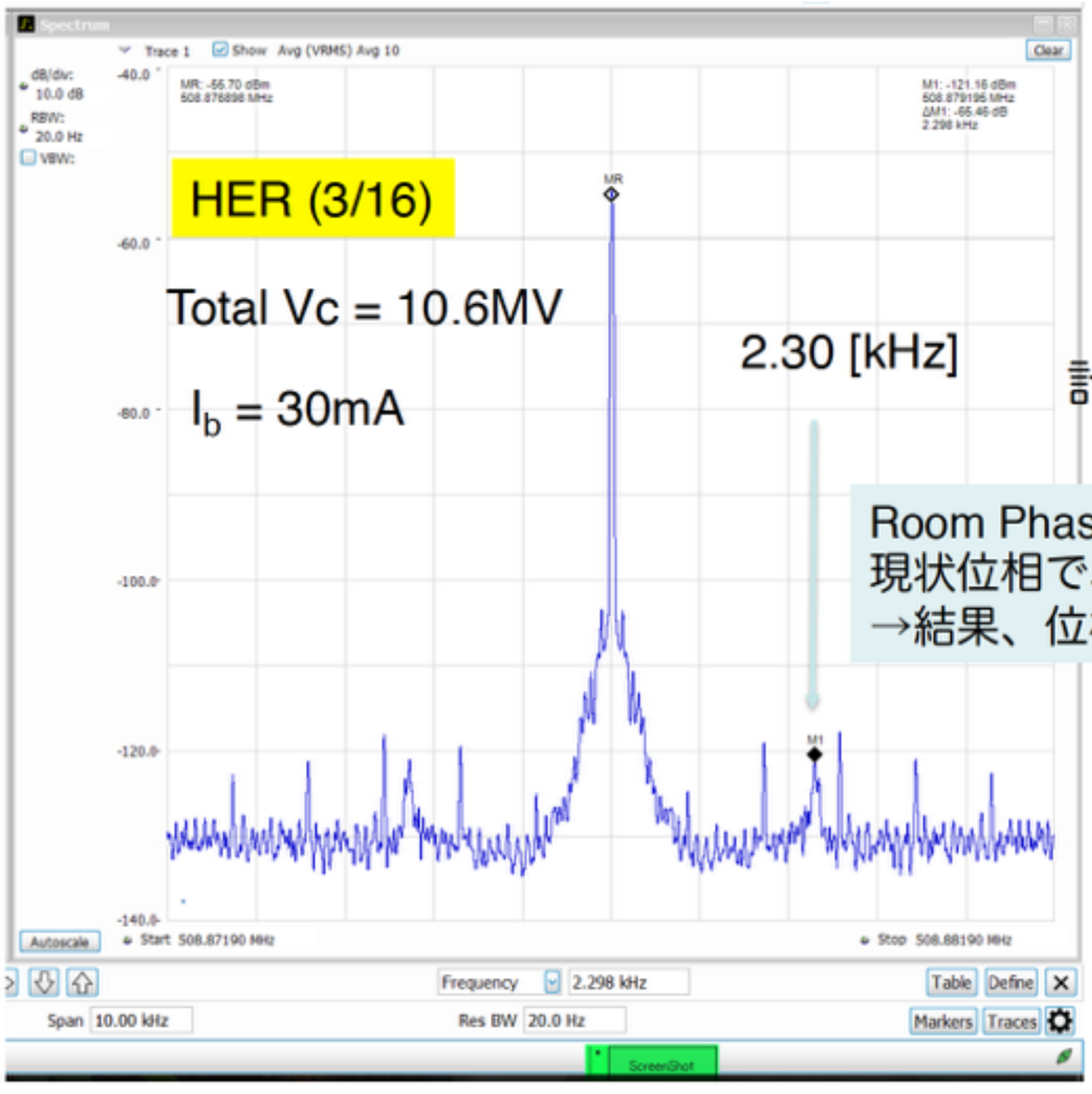
➤ From T. Kobayashi

- RF voltages are measured via power meter. The uncertainty of RF voltage for each cavity is ~±5% => The error in total RF voltage should be in the order of ±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 => Good agreement at low bunch current (see next 2 pages).

3. RF tuning

➤ HER (from T. Kobayashi)

- **Number of bunch: 826 (2016.03.16)**



計算値(2.31kHz)に合う

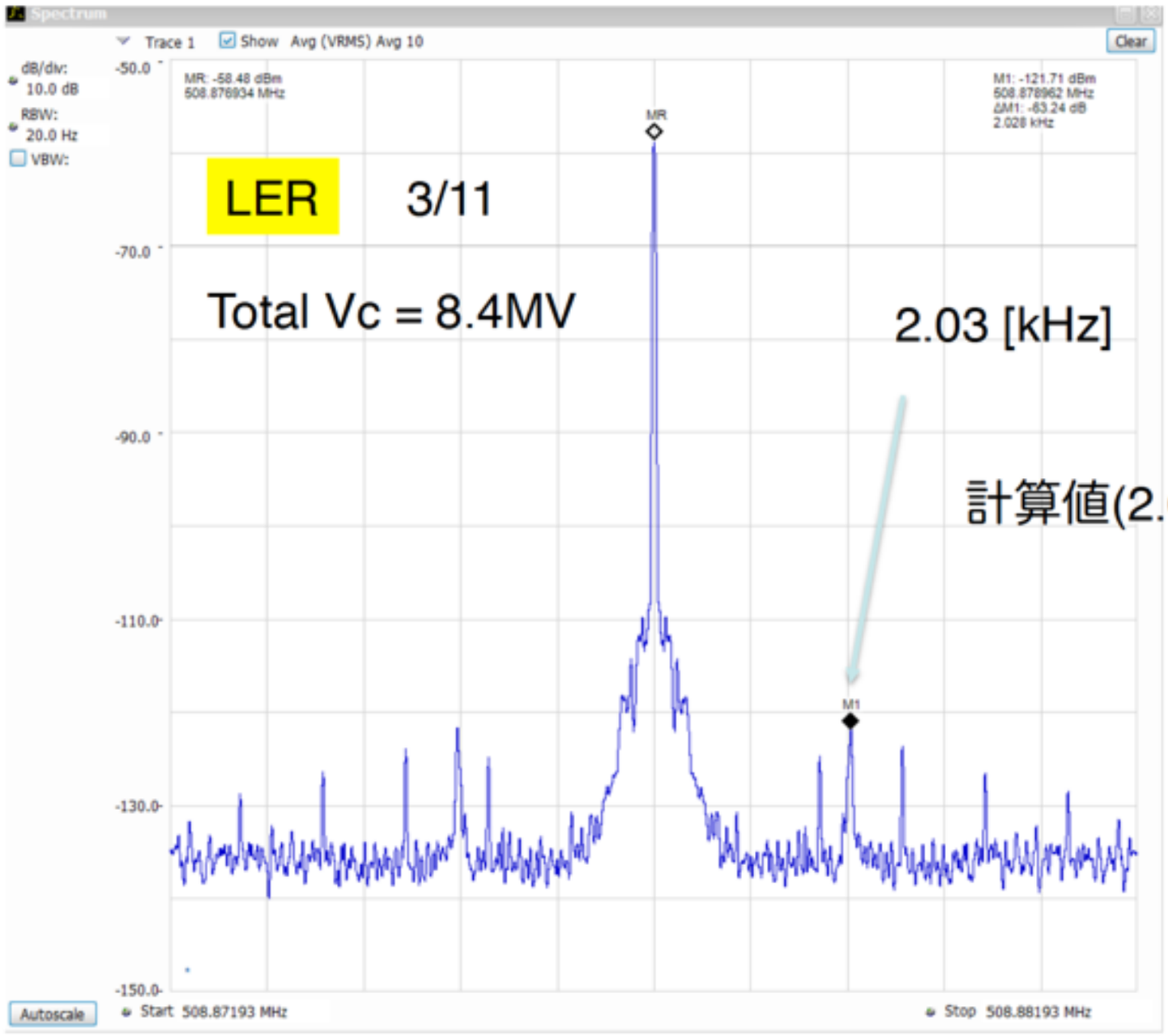
Room Phaseを振ってfs再確認。
現状位相で、ほぼfs最大。
→結果、位相変更なし（元に戻した）。

 Ref. SuperKEKB shift report, Mar. 16, 2016

3. RF tuning

➤ LER (from T. Kobayashi)

- **Number of bunch: 1182 (2016.03.11)**

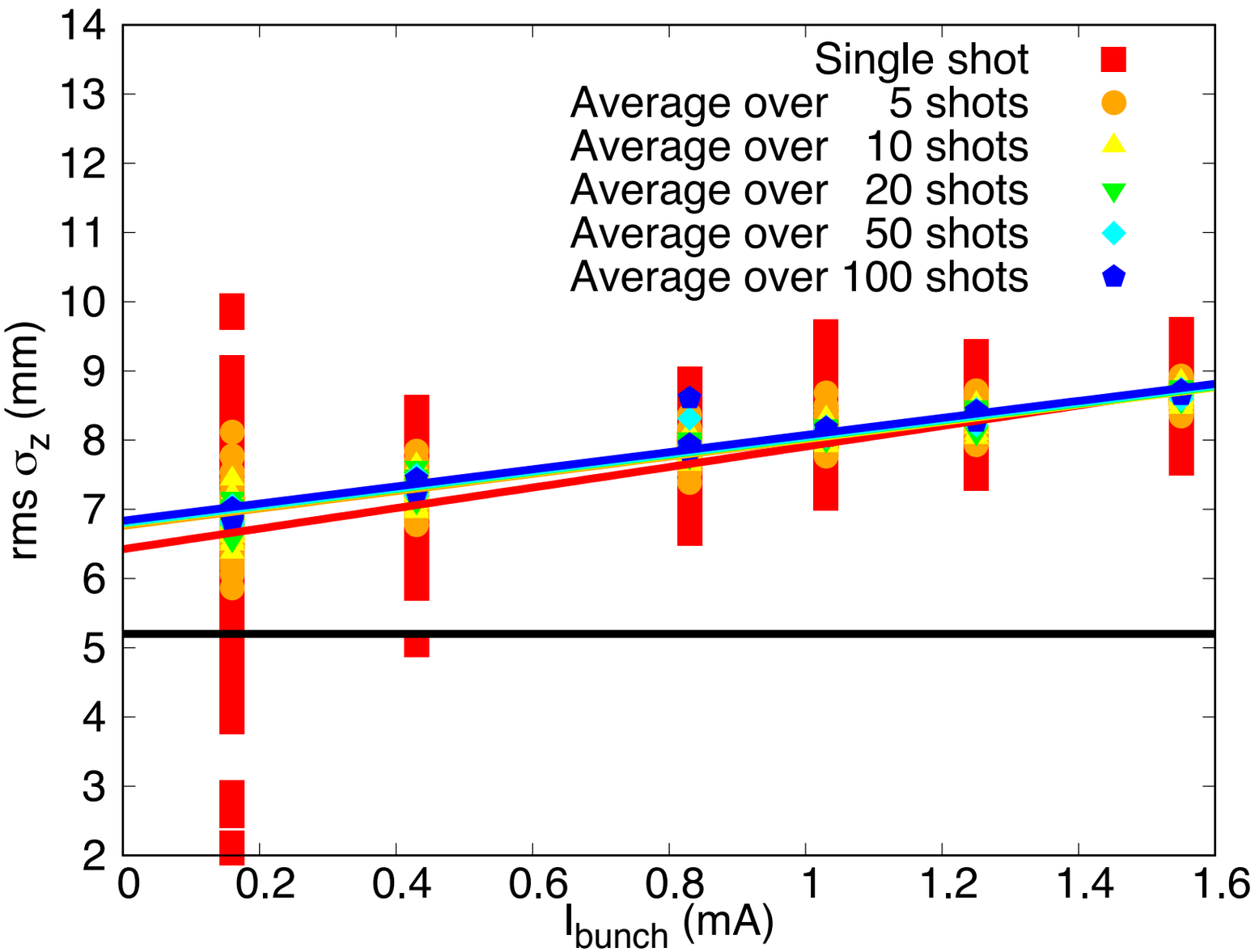


Ref. SuperKEKB shift report, Mar. 16, 2016

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**



$f_1(I_b)=6.42+1.48I_b$

$f_2(I_b)=6.76+1.25I_b$

$f_3(I_b)=6.79+1.23I_b$

$f_4(I_b)=6.80+1.24I_b$

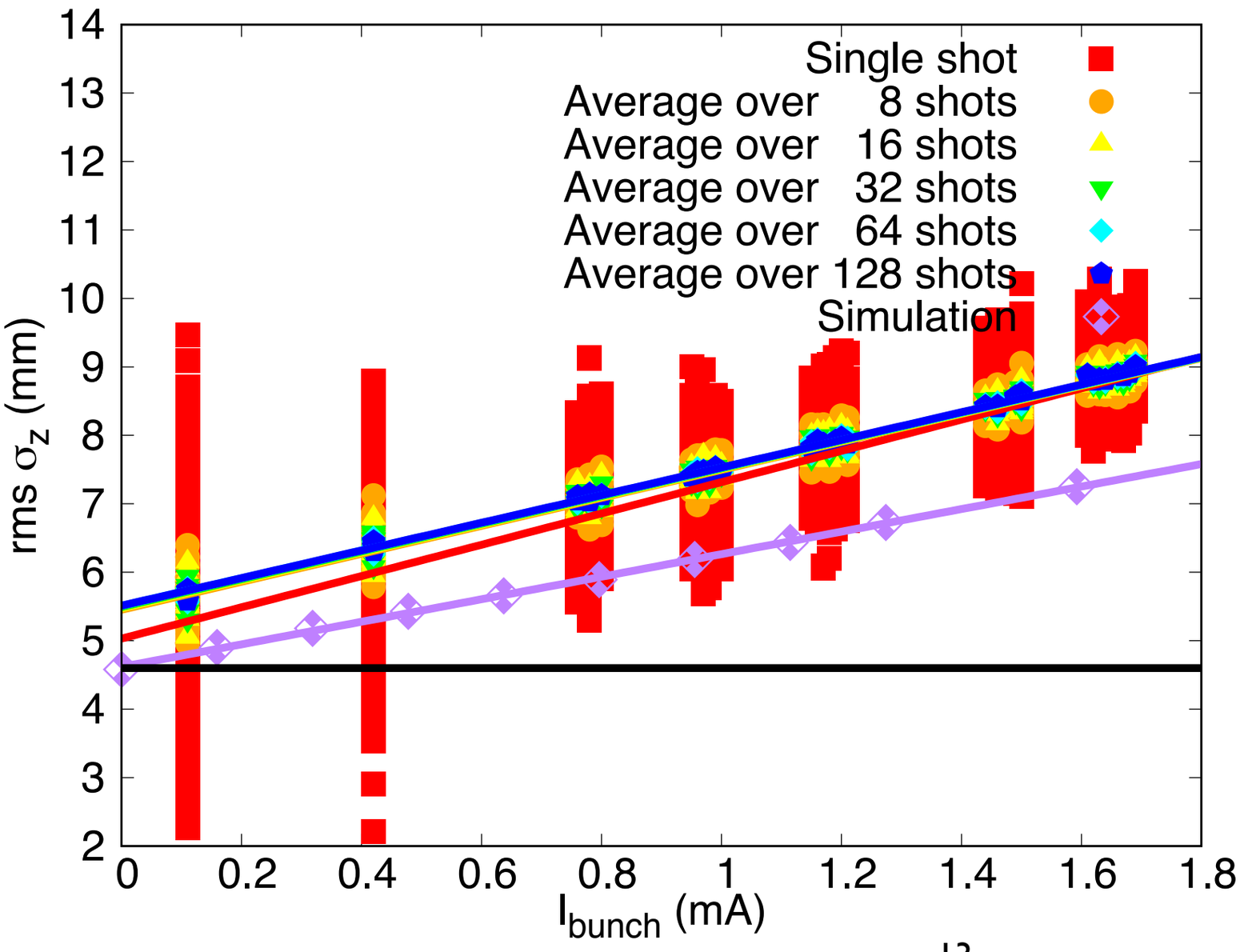
$f_5(I_b)=6.81+1.24I_b$

$f_6(I_b)=6.84+1.24I_b$

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



$f_1(I_b)=5.03+2.28I_b$

$f_2(I_b)=5.45+2.04I_b$

$f_3(I_b)=5.48+2.03I_b$

$f_4(I_b)=5.49+2.03I_b$

$f_5(I_b)=5.51+2.02I_b$

$f_6(I_b)=5.51+2.02I_b$

$f_7(I_b)=4.62+1.65I_b$

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]**