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COMPARISON OF EXPERIMENTAL AND THEORETICAL CSR-DRIVEN INSTABILITY THRESHOLDS AT ANKA

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ABSTRACT: **The Vlasov-Fokker-Planck equation is solved numerically with the simple model of electrons circulating between parallel plates and interacting through their radiation. The theoretical results for the longitudinal stability of the bunches are in good agreement with the observations at ANKA. The study was focused on the exotic parameter region where bunches can become stable again above a lower instability threshold. Remaining discrepancies could be related to the experimental conditions or could indicate limitations of the simple model.**

MOTIVATION

Thanks to the improvements in the data taking process detailed measurements were reported for the longitudinal stability of short bunches in the storage ring ANKA, see poster „Systematic Studies of Short Bunch-length Bursting at ANKA". This triggered the theoretical studies for the characteristic parameters of the ANKA ring and with the corresponding experimental conditions. Following IPAC2013, a single experiment performed at ANKA was simulated and a close to perfect agreement between the observations and the theoretical predictions was found. The hope was to find a similarly good agreement for the more detailed and very recent measurements.

SIMULATION

Numerical solution of the Vlasov-Fokker-Planck equation:

$N>10^9$ electrons per bunch → smooth distribution in phase space
→ distribution function:

$$f(q,p,\tau) \qquad q = z/\sigma_z \quad p = -\Delta E/\sigma_E \quad \tau = \omega_s t$$

$$\beta = \frac{T_{syn}}{2\pi\cdot\tau_{long}}$$

$$\frac{\partial f}{\partial\tau} + p\frac{\partial f}{\partial q} - \left[q + F_c(q,\tau,f)\right]\frac{\partial f}{\partial p} = 2\beta\frac{\partial}{\partial p}\left(pf + \frac{\partial f}{\partial p}\right)$$

(M. Venturini)

RF focusing Collective Force Damping Quantum Excitation

→ Numerical solution based on
M. Venturini, et al., Phys. Rev. ST-AB 8, 014202 (2005)
Other numerical solutions:
R.L. Warnock, J.A. Ellison, SLAC-PUB-8404, March 2000
S. Novokhatski, EPAC 2000 and SLAC-PUB-11251, May 2005

OTHER KEY REFERENCES

[1] J.B. Murphy, et al., "Longitudinal wakefield for an electron moving on a circular orbit", Part. Accel. **57**, 9 (1997)
[2] K.L.F.Bane, et al., „Threshold studies of the microwave instability in electron storage rings", PRST-AB 13, 104402 (2010)
[3] P. Kuske, "CSR-driven longitudinal single bunch instability thresholds", Proceedings IPAC2013, Shanghai, China, WEOAB102
[4] P. Kuske, "CSR-driven longitudinal instability - comparison of theoretical and experimental results", talk at the 3rd Low Emittance Ring Workshop, July, 2013, Oxford, UK
[5] P. Kuske, ,"Calculation of longitudinal instability threshold currents for single bunches" Proceedings ICAP2012, Rostock- Warnemünde, Germany, THSDC3

EARLY RESULTS – COMPARISON OF EXPERIMENT AND THEORY

Parameters for the calculation: σ = 1.953 ps, ρ = 5.593 m, h = 0.016 m, 1.3 GeV,α = 2.033 10^{-4}, V_{rf} = 1.8 MV, T_{long} = 10.6 ms, F_{syn} = 7.8 kHz, β = 1.93 10^{-3}, shielding parameter (à la Bane, et al.): $c\cdot\sigma\cdot\rho 1^{/2}\cdot h^{-3/2}$ = 0.684:

A.S. Müller, et al., IPAC2013, TUXB201

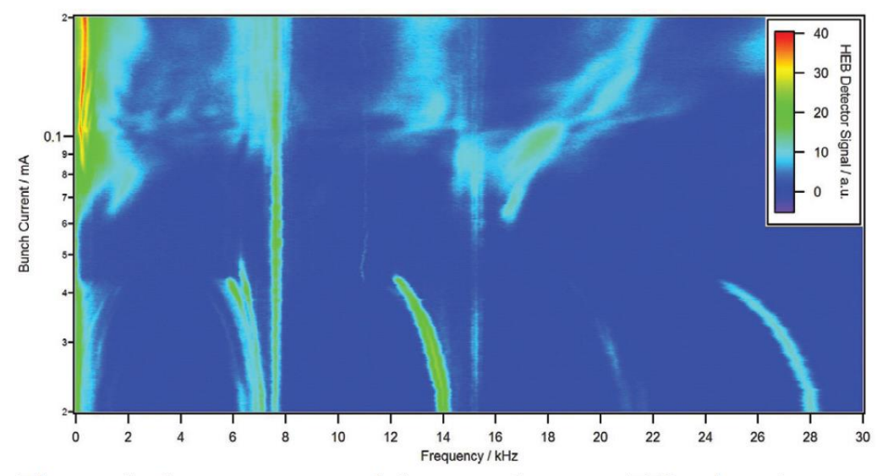
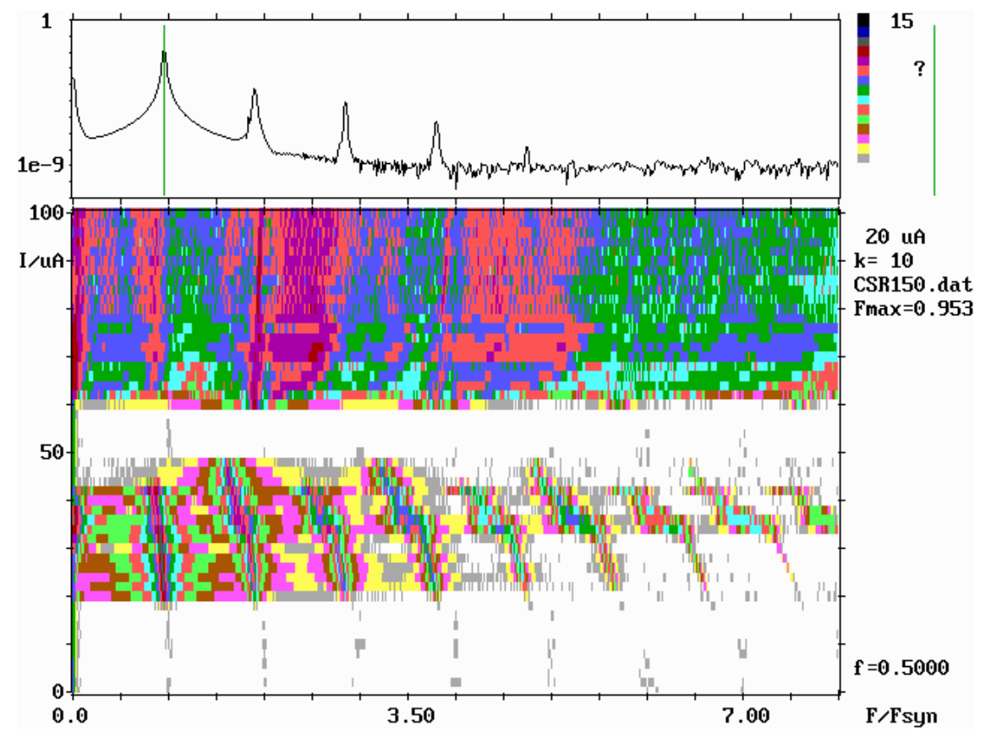
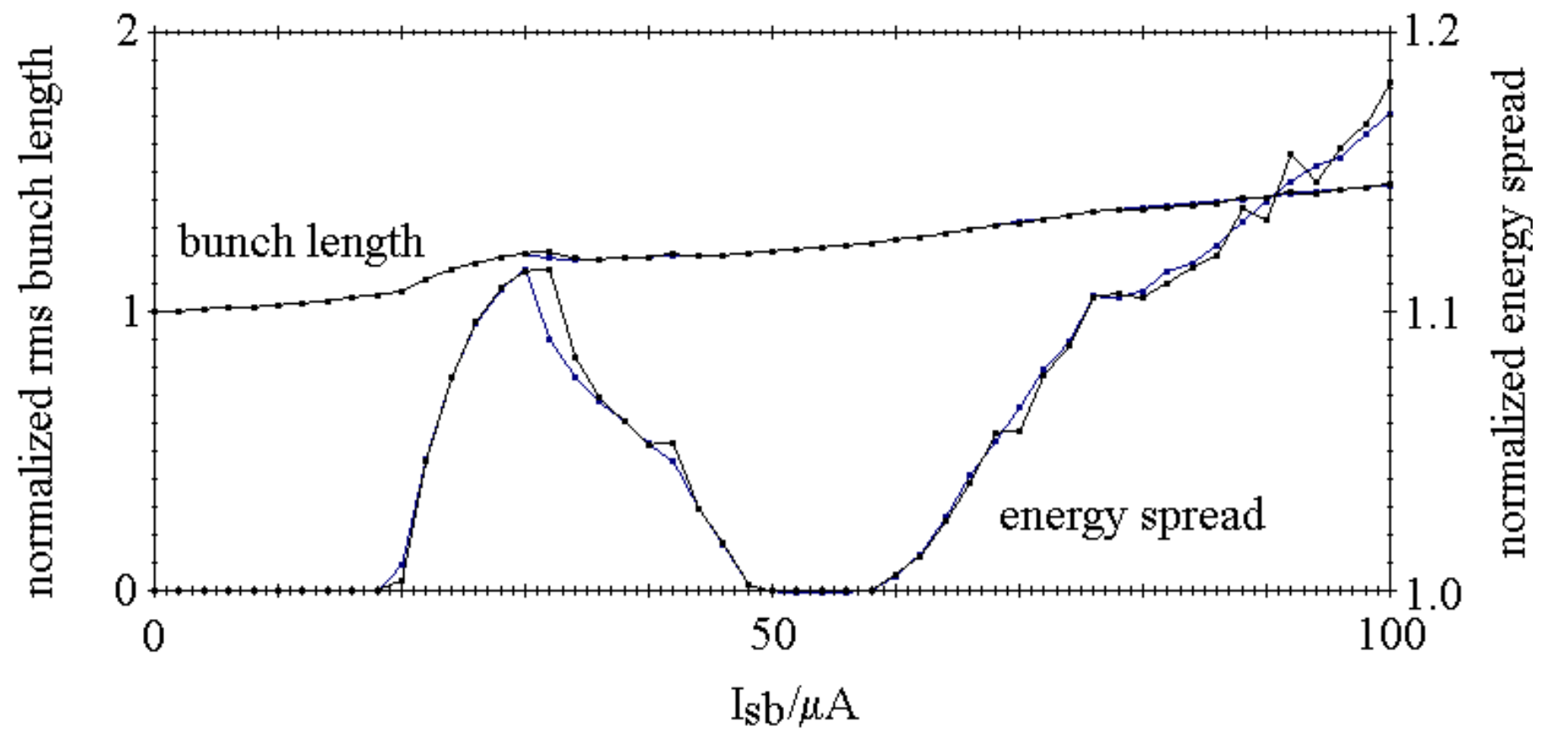


Figure 5: Spectrogram of the turn-by-turn THz signal measured with the HEB detector system at ANKA as a function of the single bunch current [24].

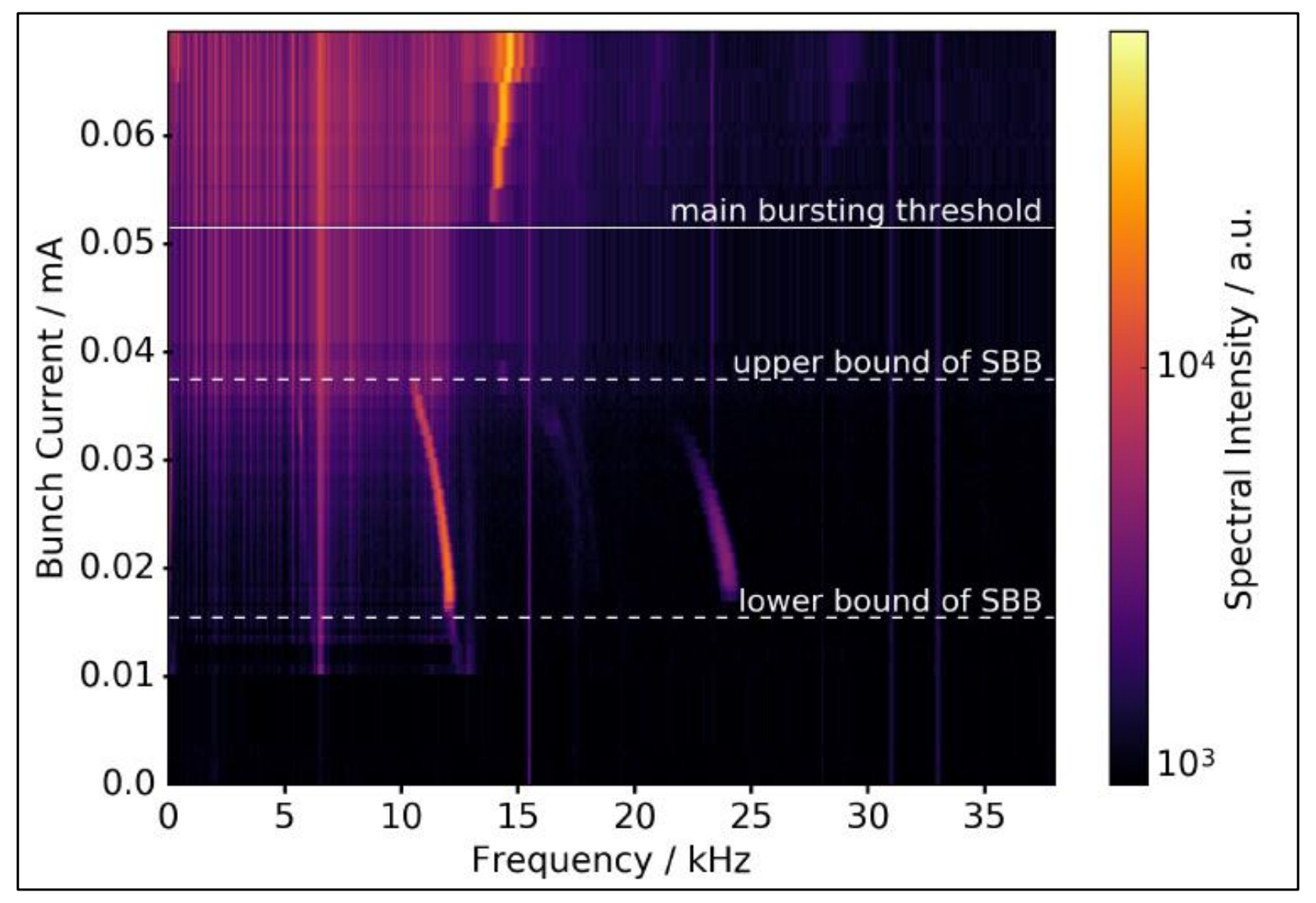


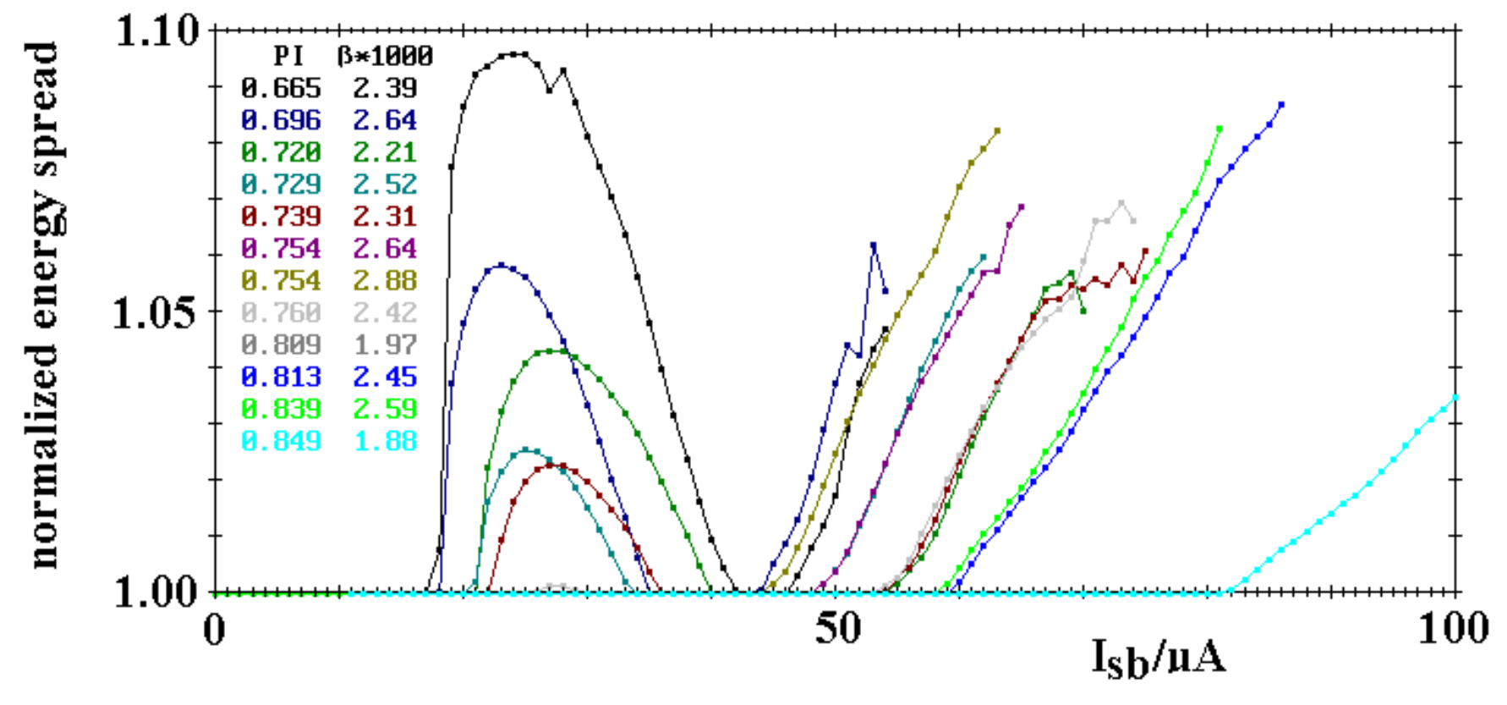


close to perfect agreement between the observations and the theoretical predictions

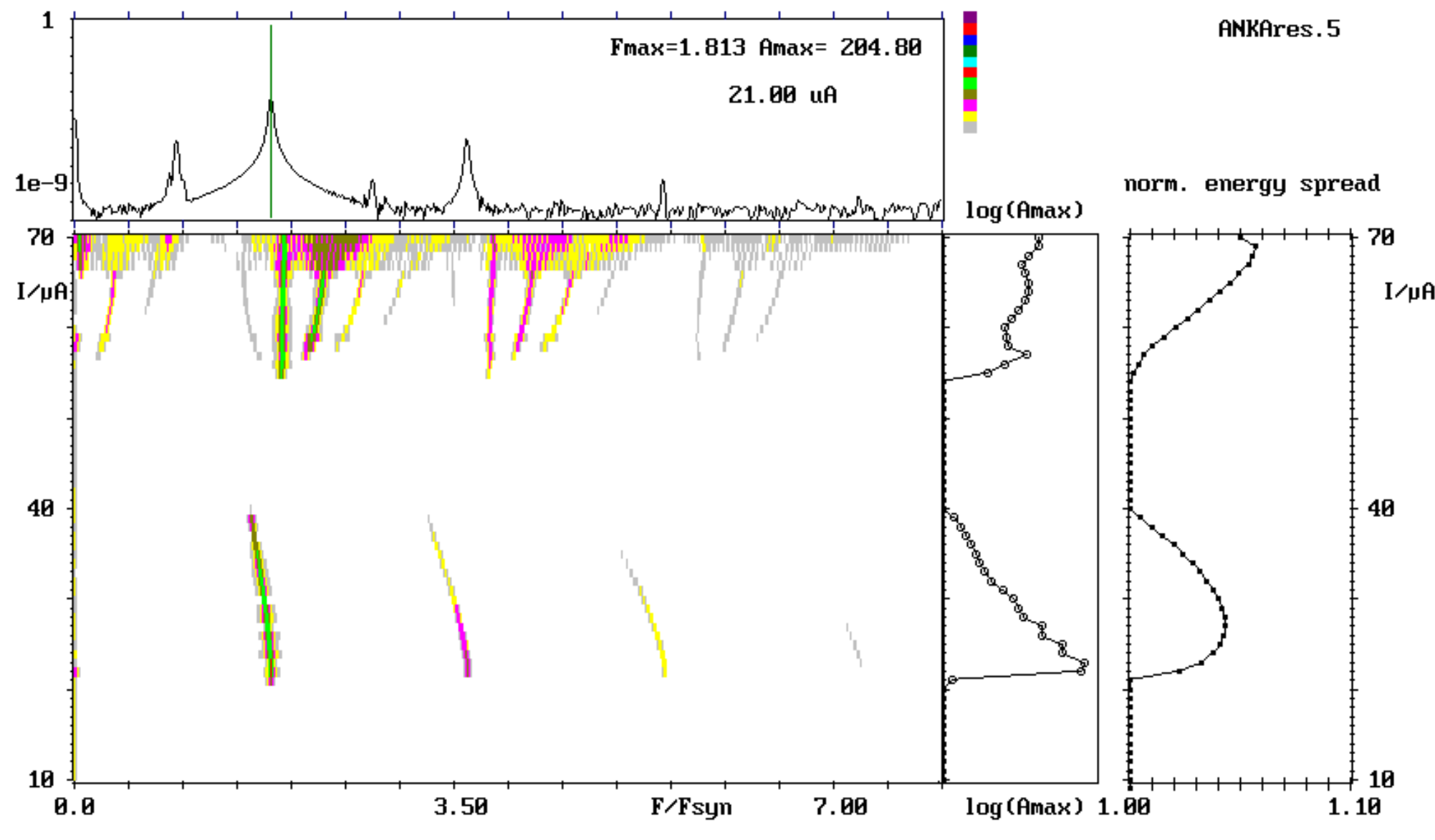
NEW RESULTS

M. Brosi and J. L. Steinmann et. al., IPAC 2016, TUPOR006:

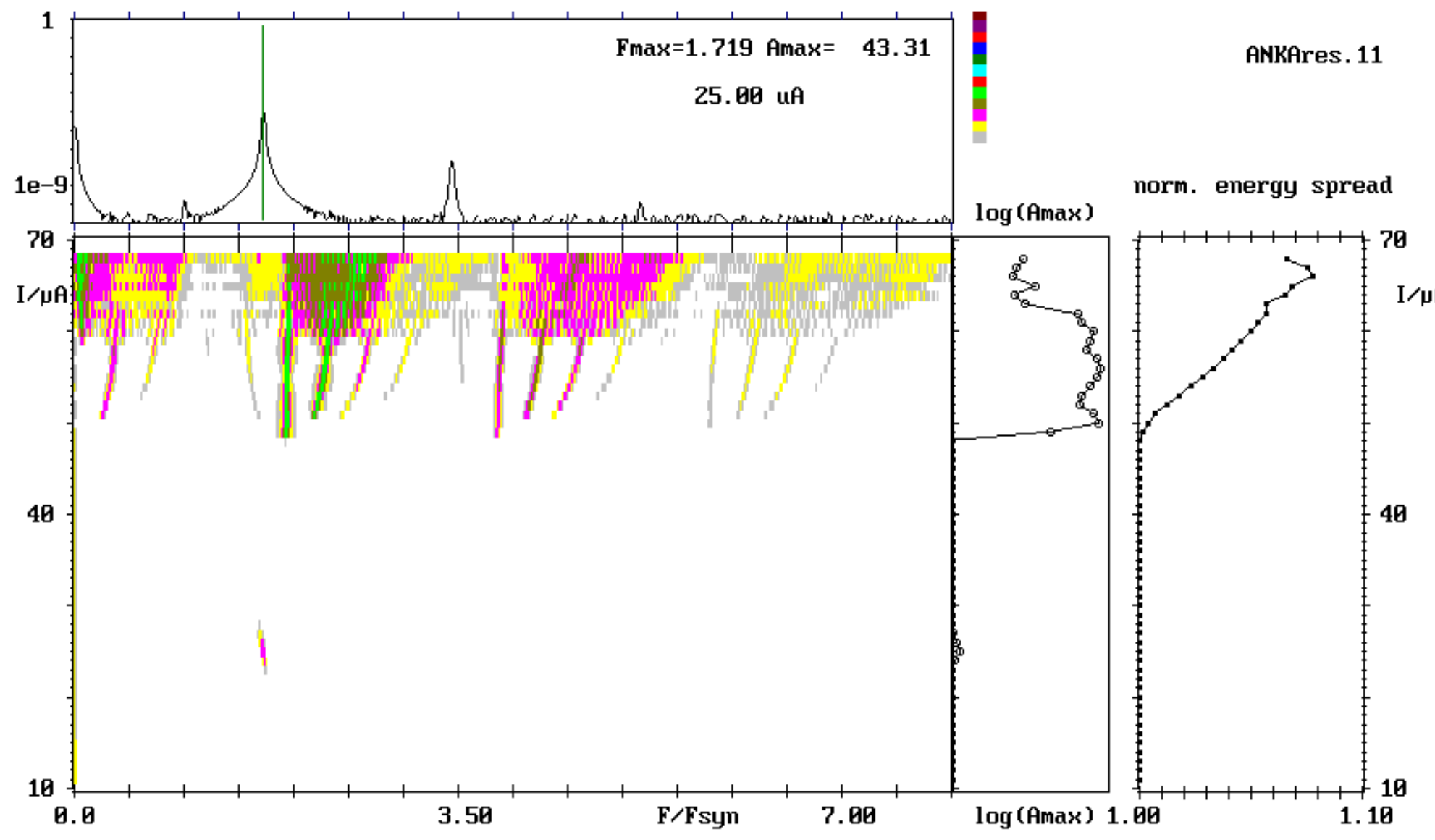




Theoretical relative energy spread for all measurements where more than one threshold was observed – not always in the calculations!

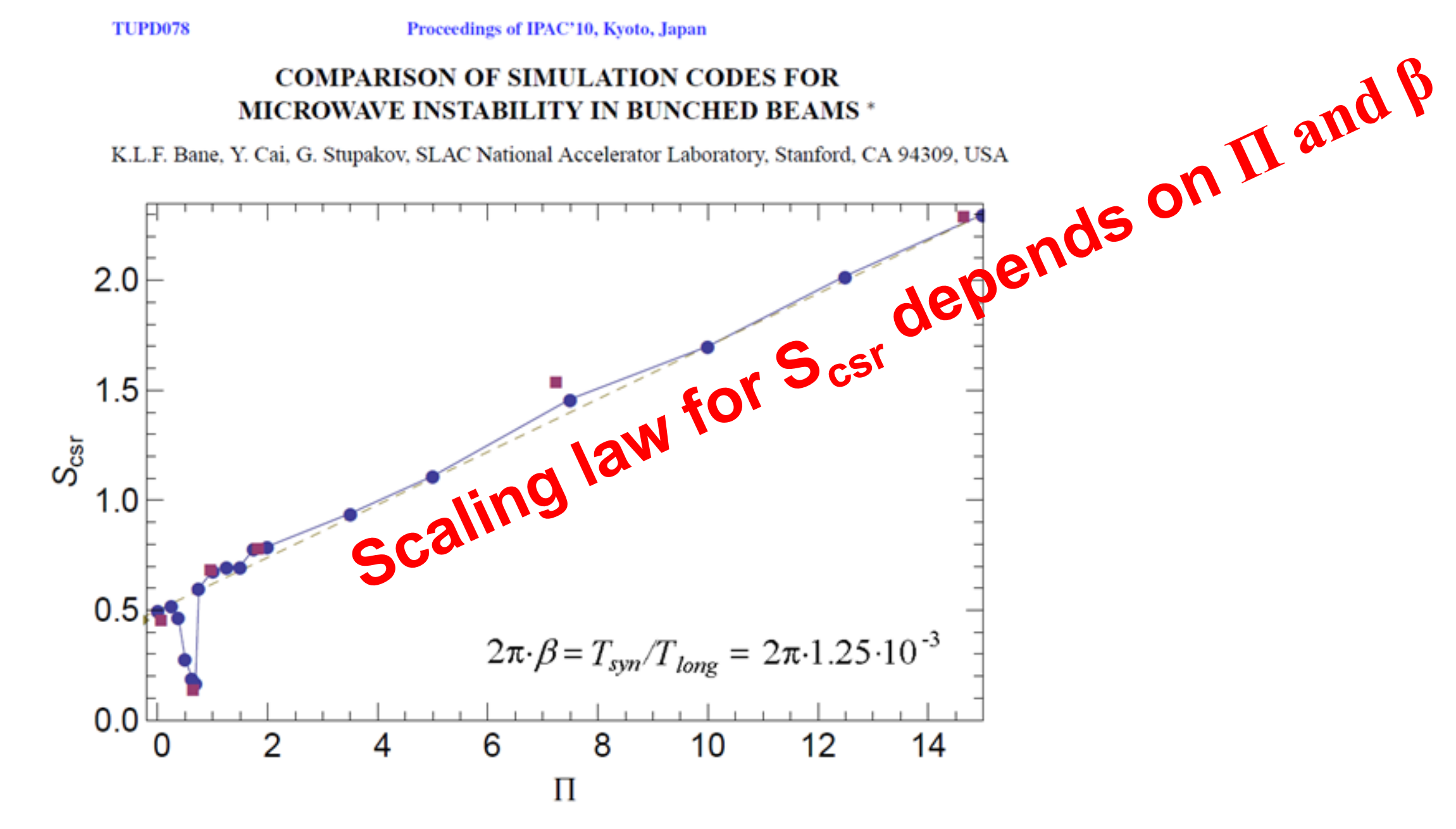


Lines in the CSR-spectrum are related to increased energy spreads



The detection of these lines is very sensitive and due to the low noise of the VFP-solver show up already before energy widening occurs.

From the pioneering work of the Stanford group



TUPD078 Proceedings of IPAC'10, Kyoto, Japan

COMPARISON OF SIMULATION CODES FOR MICROWAVE INSTABILITY IN BUNCHED BEAMS *

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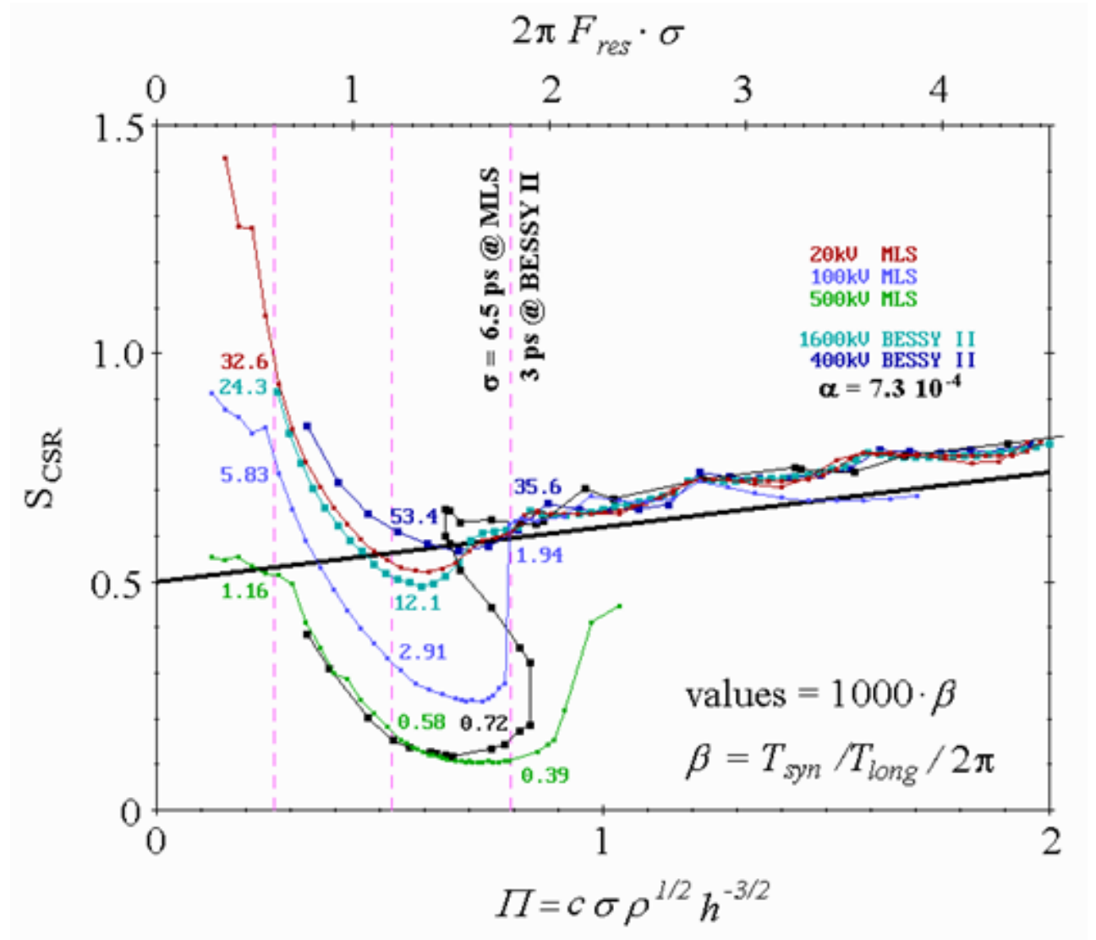
Figure 2: For the CSR wake, threshold value of S_{csr} vs. shielding parameter, $\Pi = \rho^{1/2}\sigma_{z0}/h^{3/2}$. Symbols give results of the VFP solver (blue) and the LV code (red).

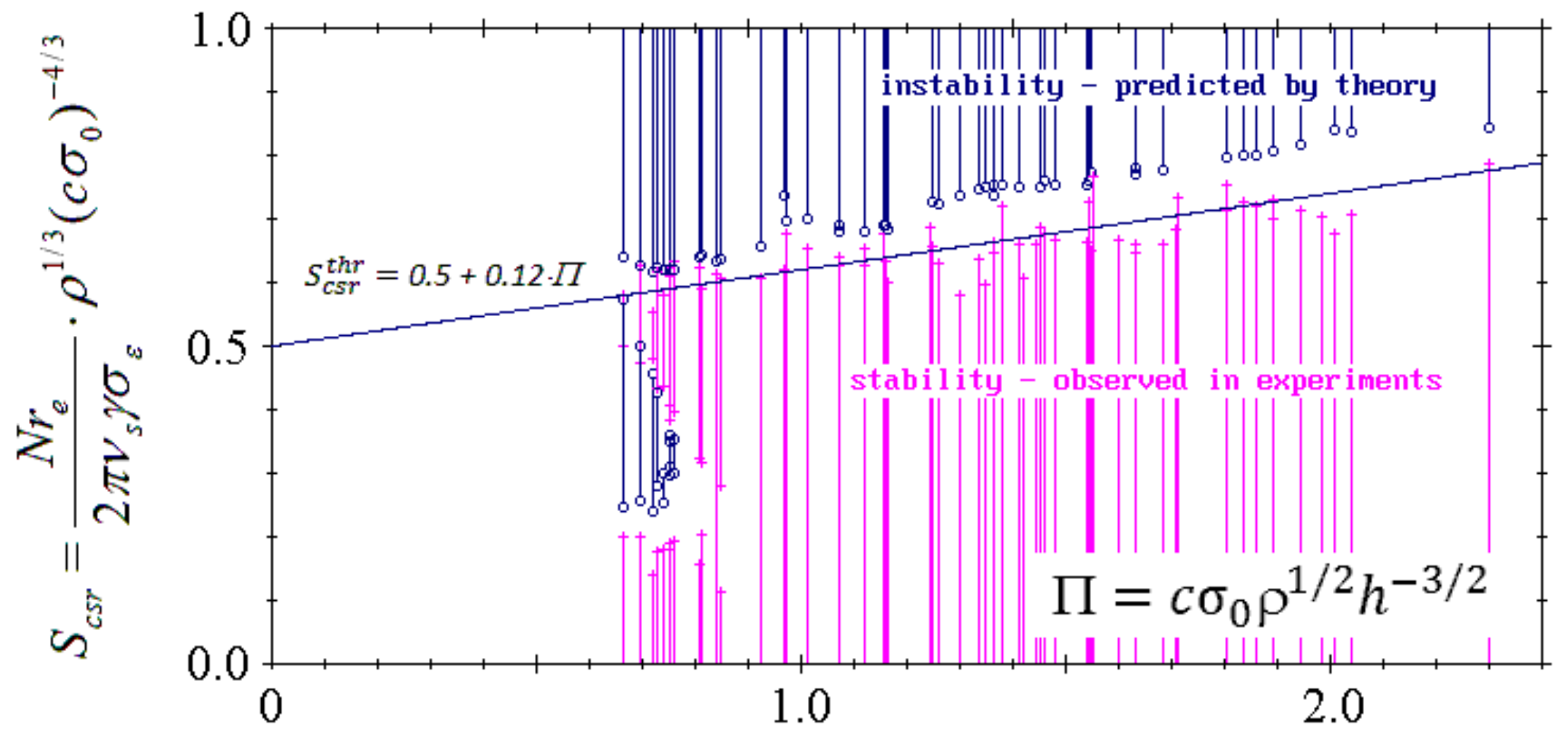
Via the calculations for BESSY II, MLS and BESSY VSR for shorter bunches



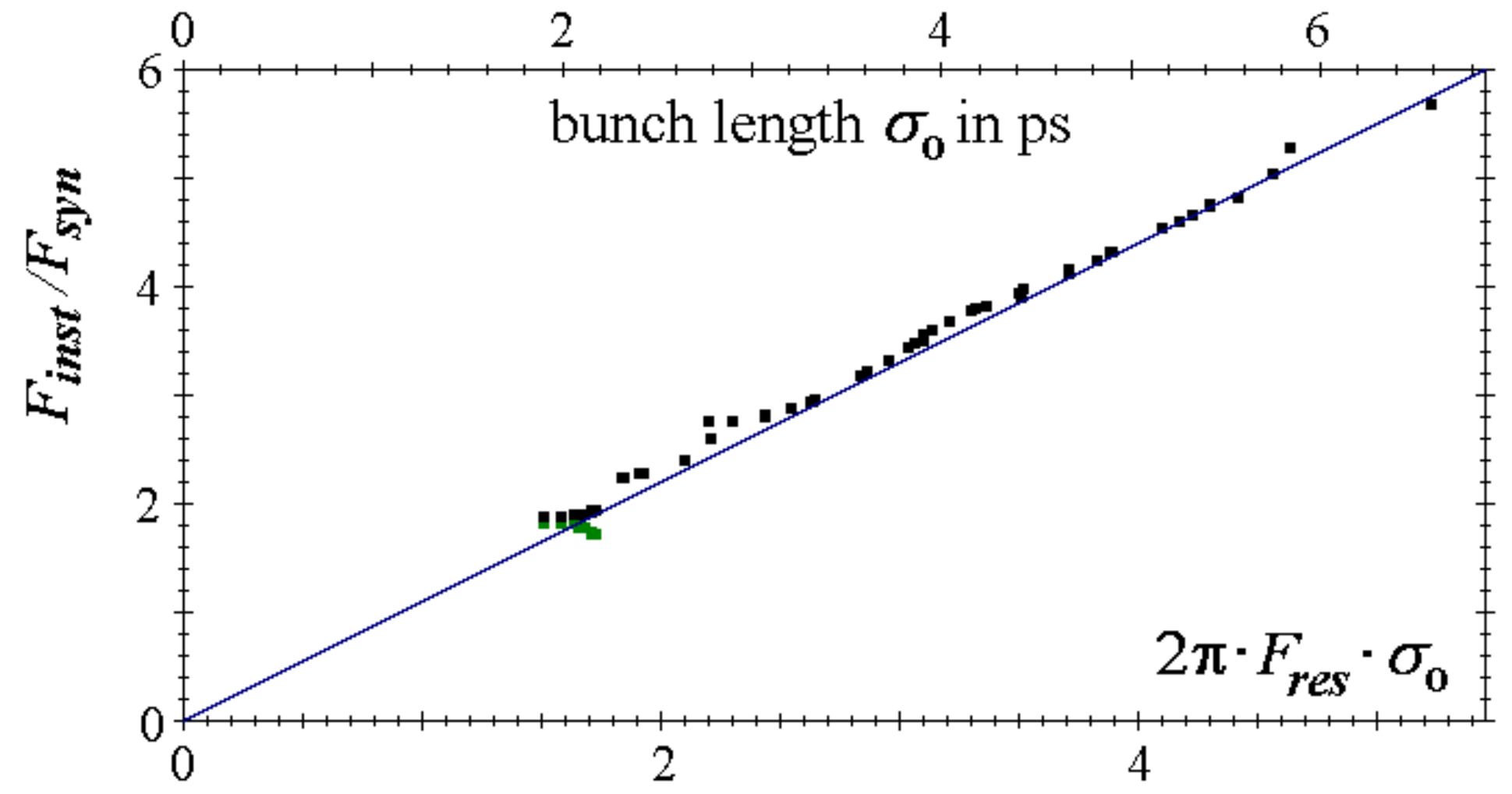
S_{csr} is the dimensionless strength, Π is the shielding factor and ß relates damping time and synchrotron frequency.
Thresholds are a function of both parameters:

$$S_{csr}^{thr} = f(\Pi,\beta) \neq 0.5 + 0.12\cdot\Pi$$

To the simulations for ANKA and the actual operating conditions in the experiments



Comparison of calculated and measured threshold strengths as a function of the shielding factor for ANKA



Frequency of the first unstable mode normalized by the synchrotron frequency as a function of the normalized bunch length

CONCLUSIONS

- good agreement between simple theory and measurements
- However, systematic differences for the new (single shot) measurements
- Could this be an experimental effect – through the interaction of the many bunches?
- Could this be an indication of a stronger CSR-interaction than expected from the simple circular orbit – through an interaction extending into the straights behind the dipoles?