Karlsruhe Institute of Technology

Federal Ministry of Education and Research

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ANKA THZ GROUP

Time-resolved energy spread studies at the ANKA storage ring

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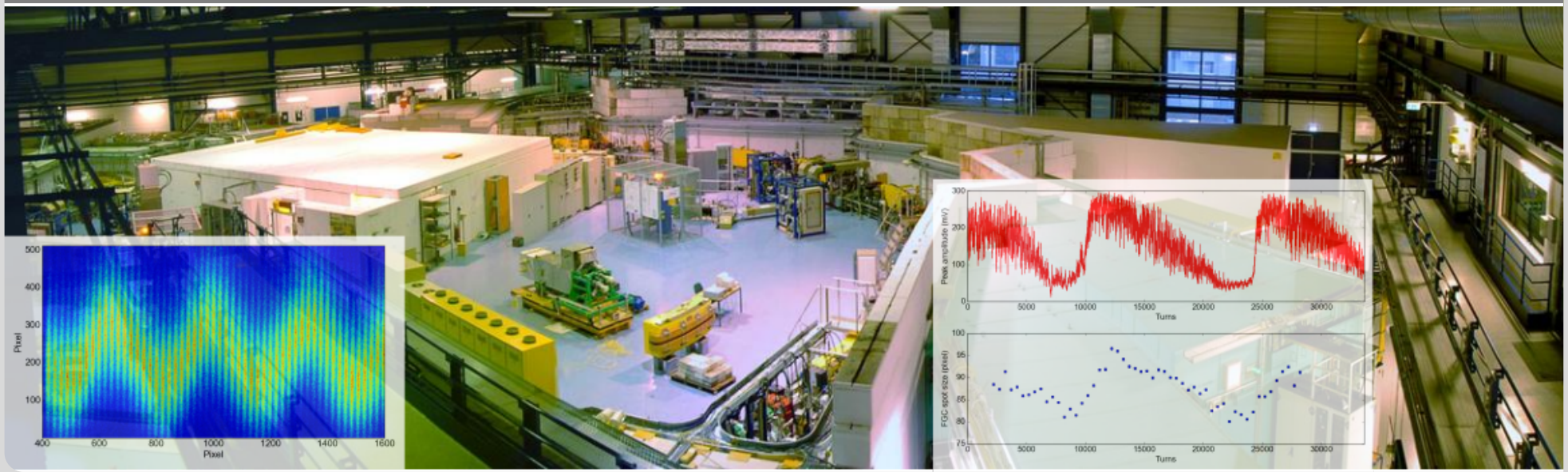
Institute for Beam Physics and Technology (IBPT)



Outline

Introduction

Setup and DAQ
- Fast-gated intensified camera (FGC)
- Schottky diodes + DAQ

Synchronous measurements

Short bunch-length bursting

Summary and outlook

Micro-bunching instabilities

- Self-interaction of bunch with its own field

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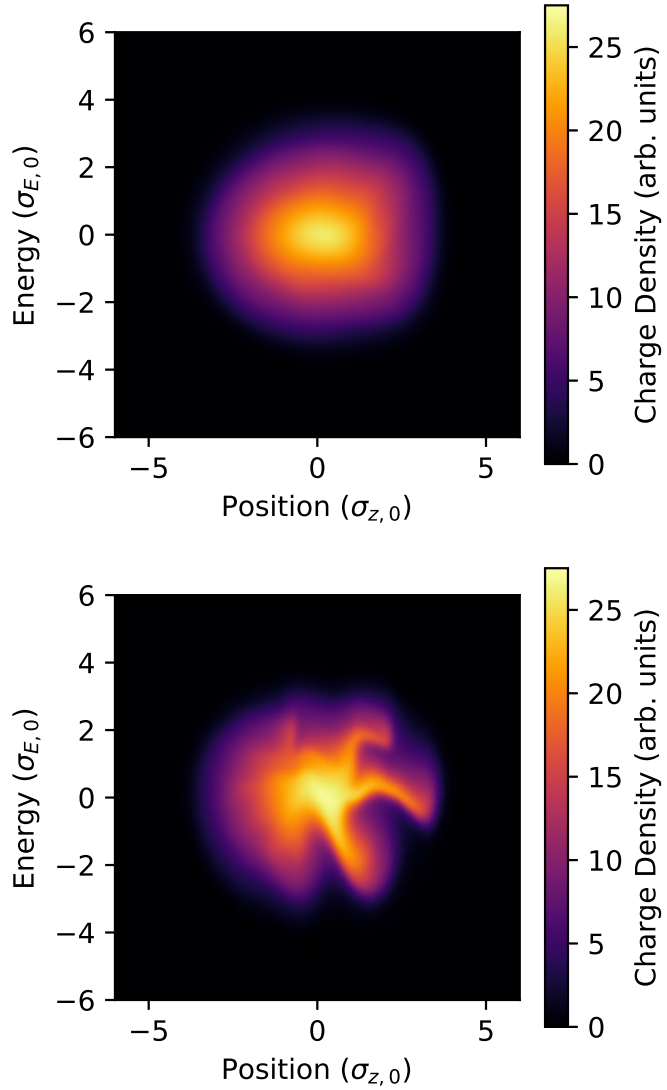

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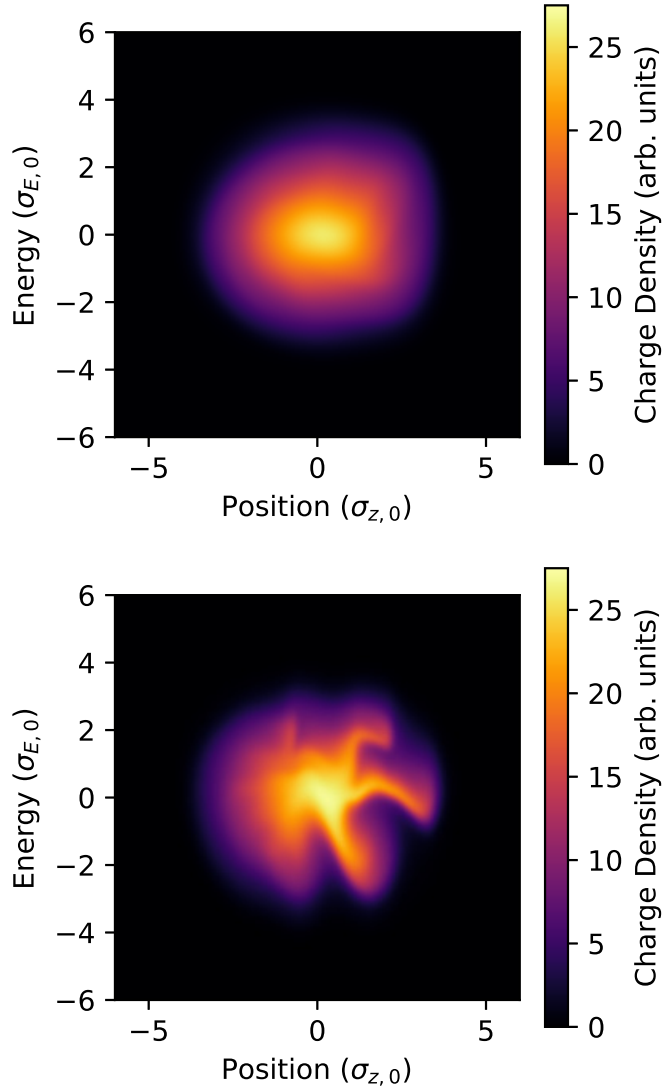
- Self-interaction of bunch with its own field
- Deformation of longitudinal phase space
- Occurs above the *bursting* threshold



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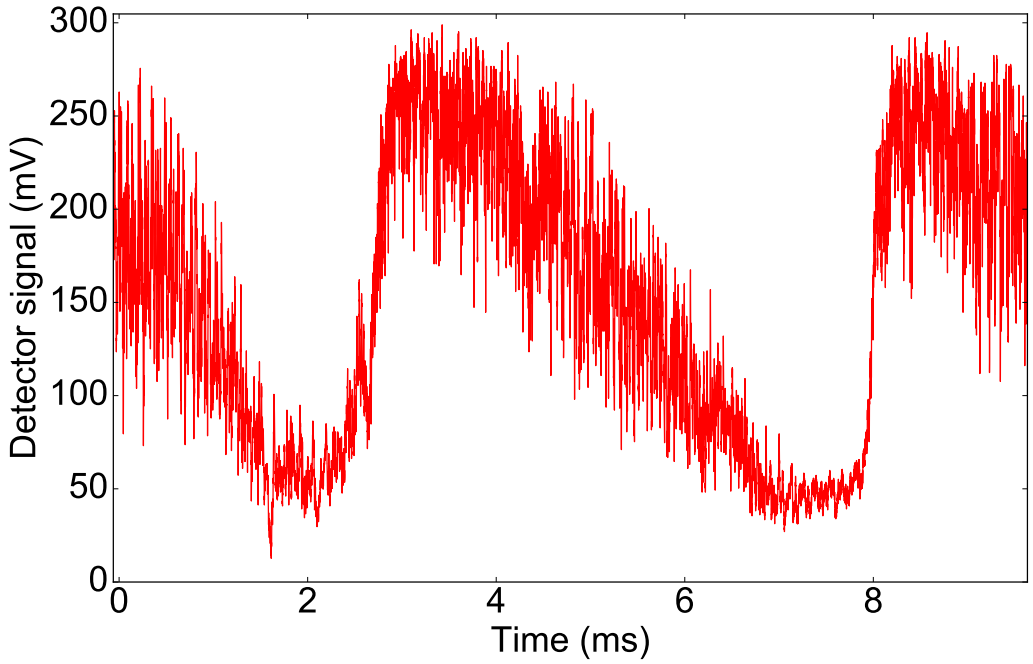
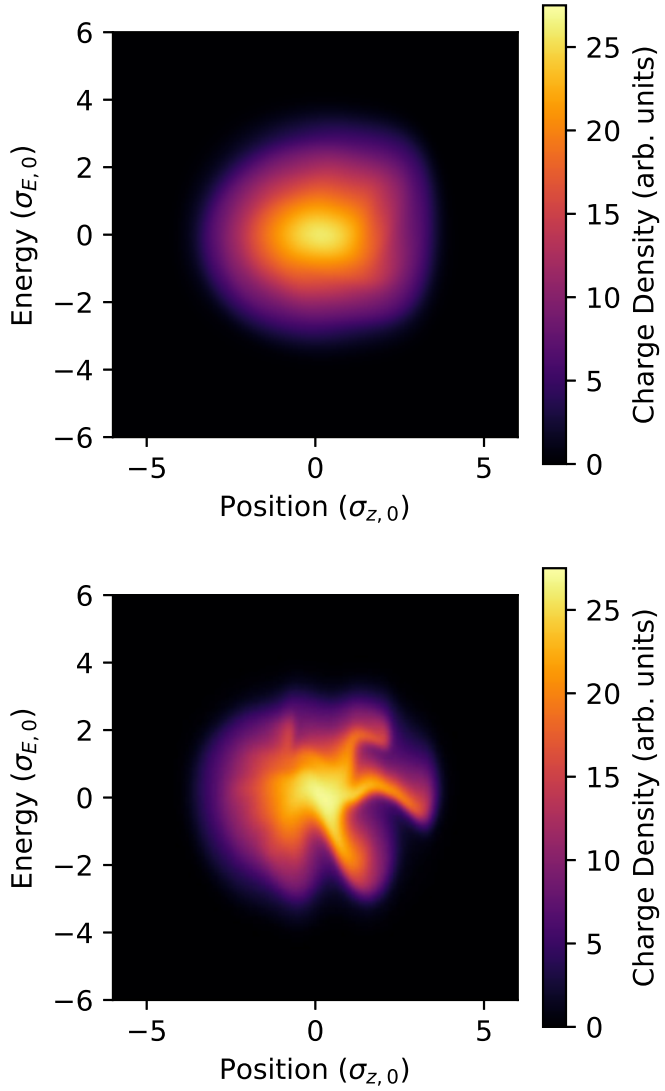
- Self-interaction of bunch with its own field
- Deformation of longitudinal phase space
- Occurs above the *bursting* threshold
- CSR emission (THz range) in *bursts*





Examples of previous studies

- Measurements
  - Energy spread above bursting threshold
    $\rightarrow$ Increases with bunch current[1]

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- Idea: Time-resolved energy spread studies with single-turn resolution and benchmark against CSR

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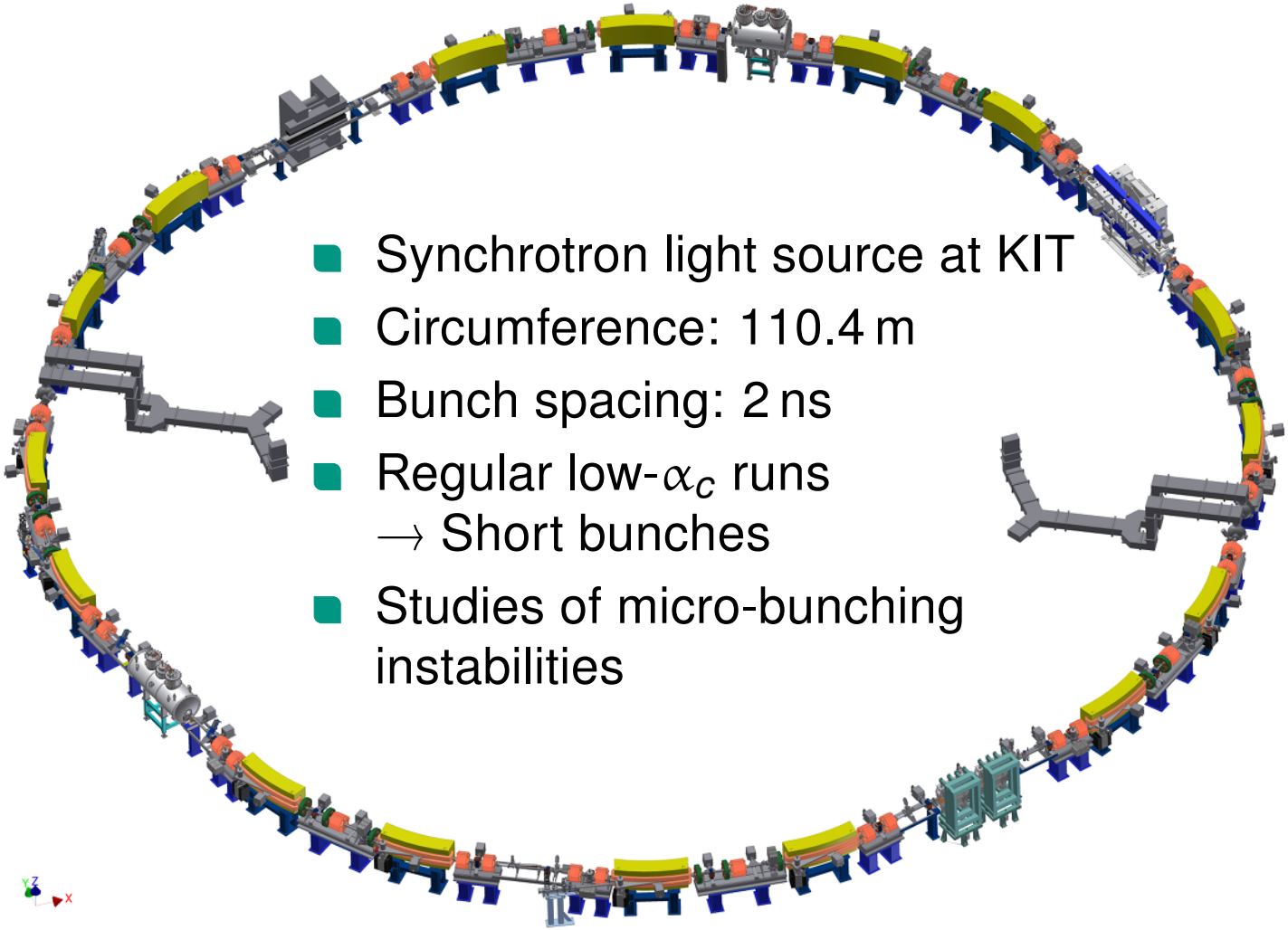

- Synchrotron light source at KIT
- Circumference: 110.4 m
- Bunch spacing: 2 ns
- Regular low-α_c runs
  $\rightarrow$ Short bunches
- Studies of micro-bunching instabilities

Measurement principle

- Energy spread σ_δ
  - Measure the horizontal bunch size σ_x in dispersive section of storage ring

$$\sigma_\delta = \frac{1}{D_x}\sqrt{\sigma_x^2 - \beta_x \cdot \epsilon_x}$$

  - Single turn base?
    $\rightarrow$ Use a fast-gated intensified camera

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  - In-house developed DAQ (KAPTURE)

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- Synchronisation
  - Hardware synchronisation scheme[4]
  - Triggered beam based calibration

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[4] **B. Kehrer et al.; IPAC'16 (MOPMB014).**

Fast-gated intensified camera (FGC)

- Setup at visible light diagnostics beamline[5,6]
- Based on previous works of J. Corbett, W. Cheng[7] and A. Fisher[8]

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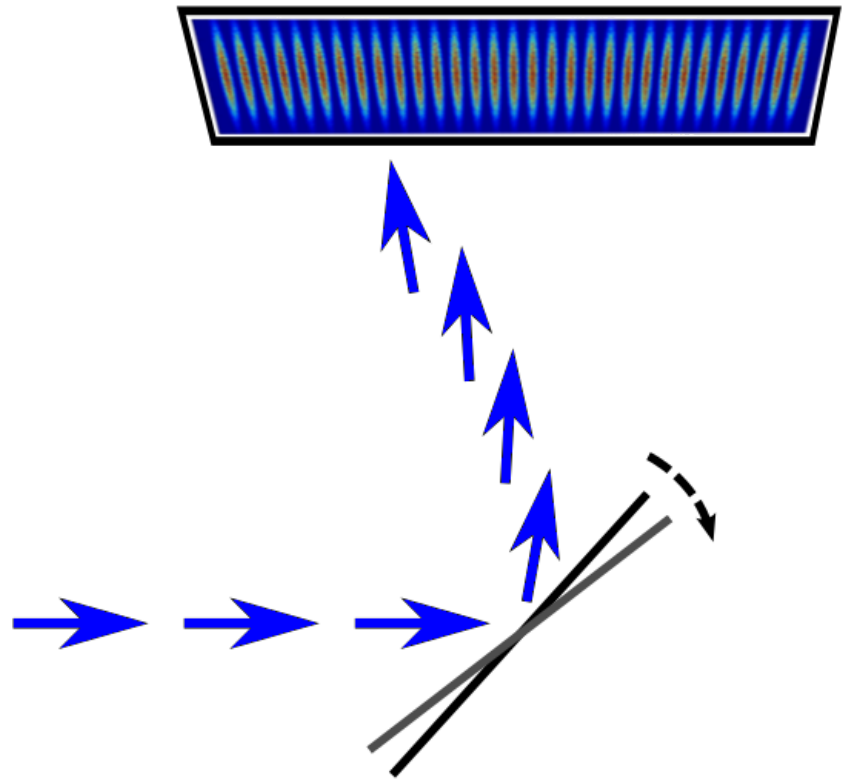

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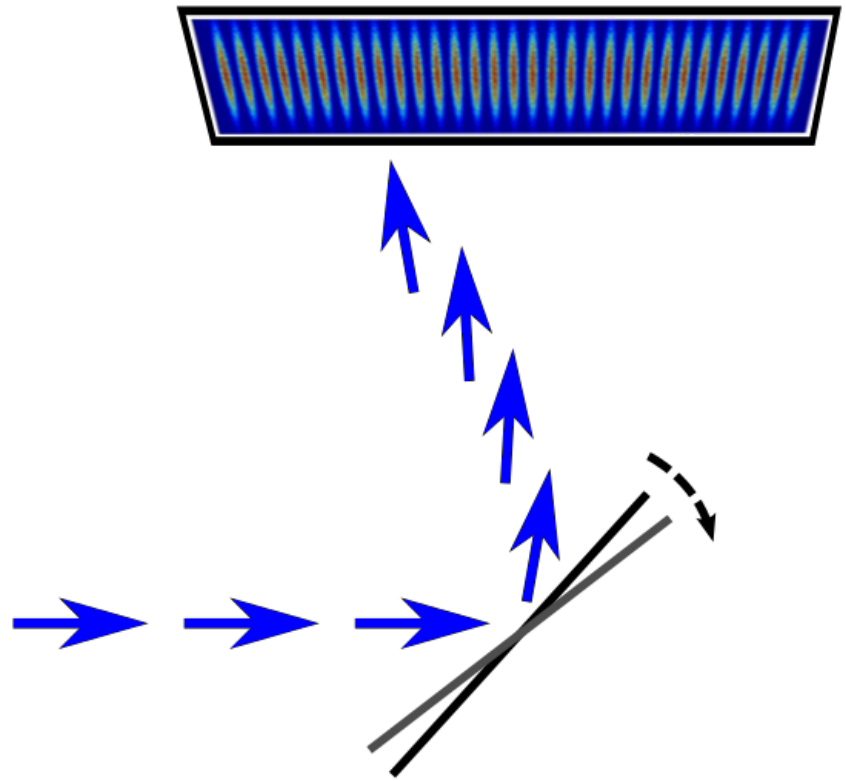
- Drawback: compromise between resolution and time range
- Ideal: Continuous turn-by-turn data



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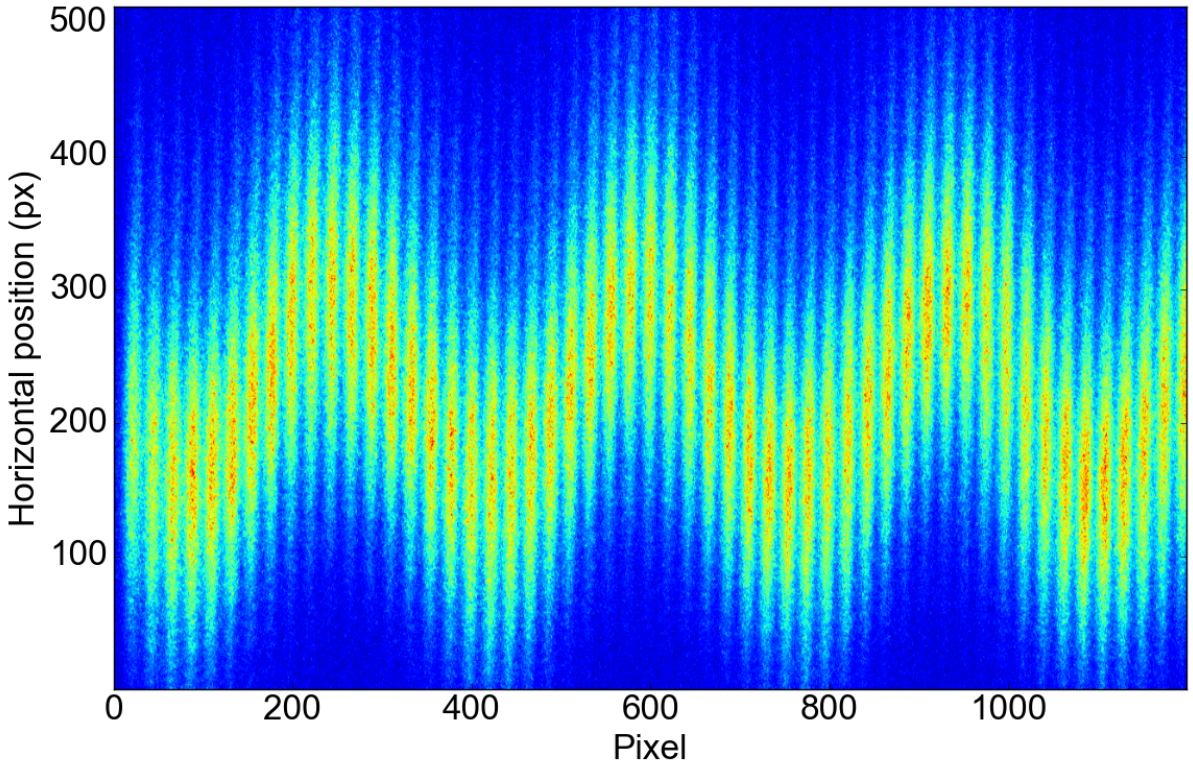
FGC: Data analysis

- FGC raw image



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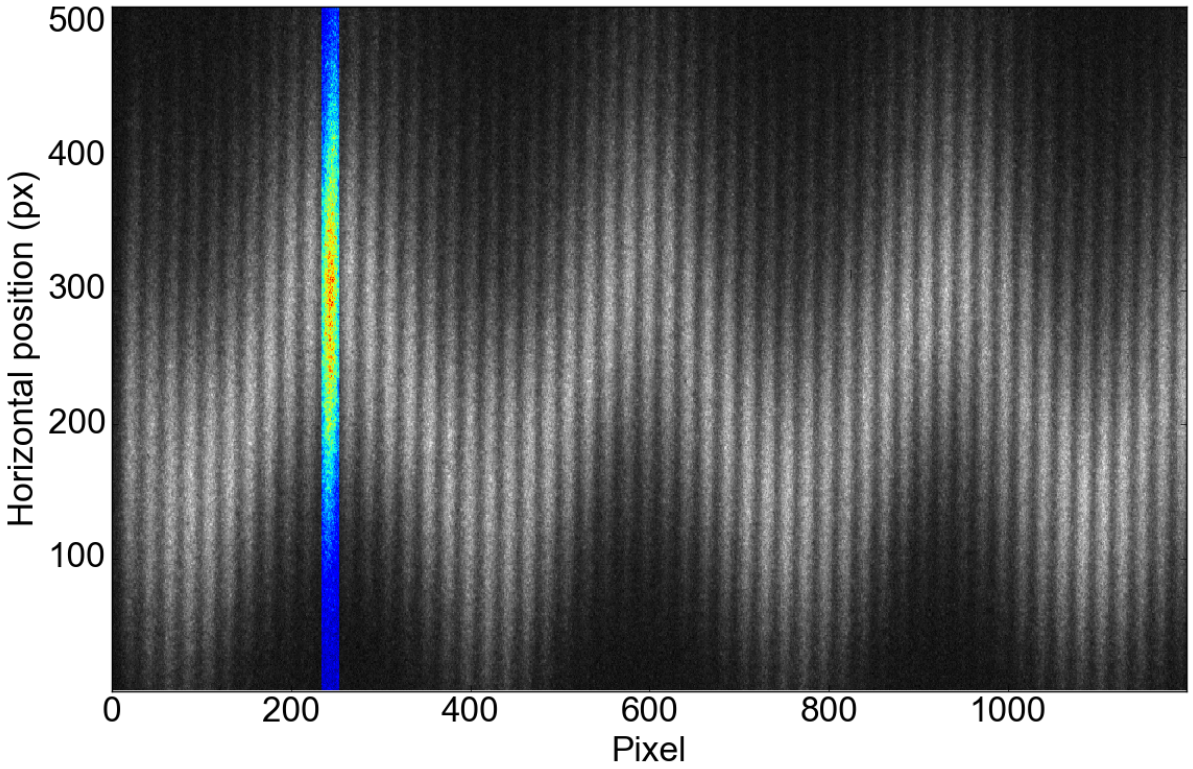

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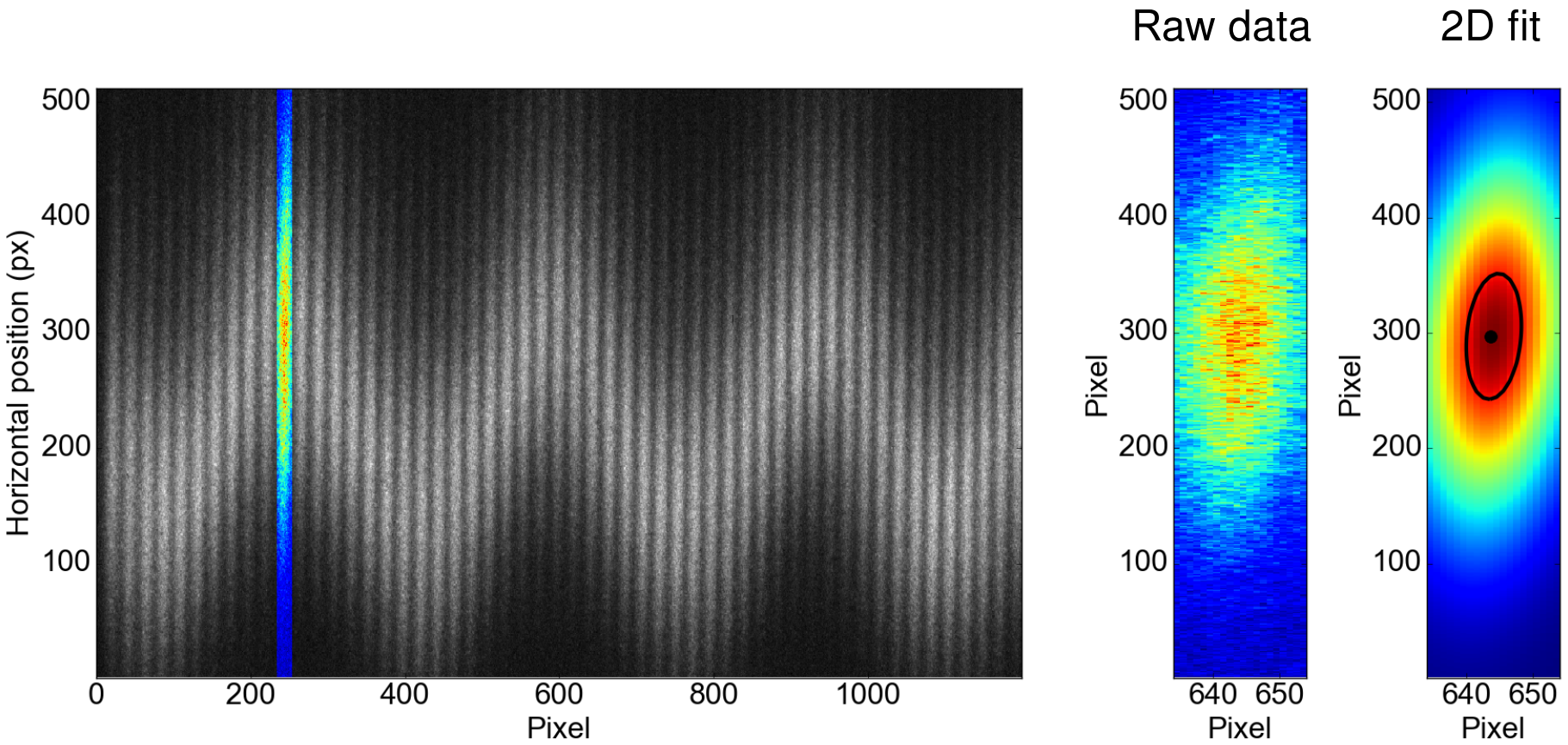

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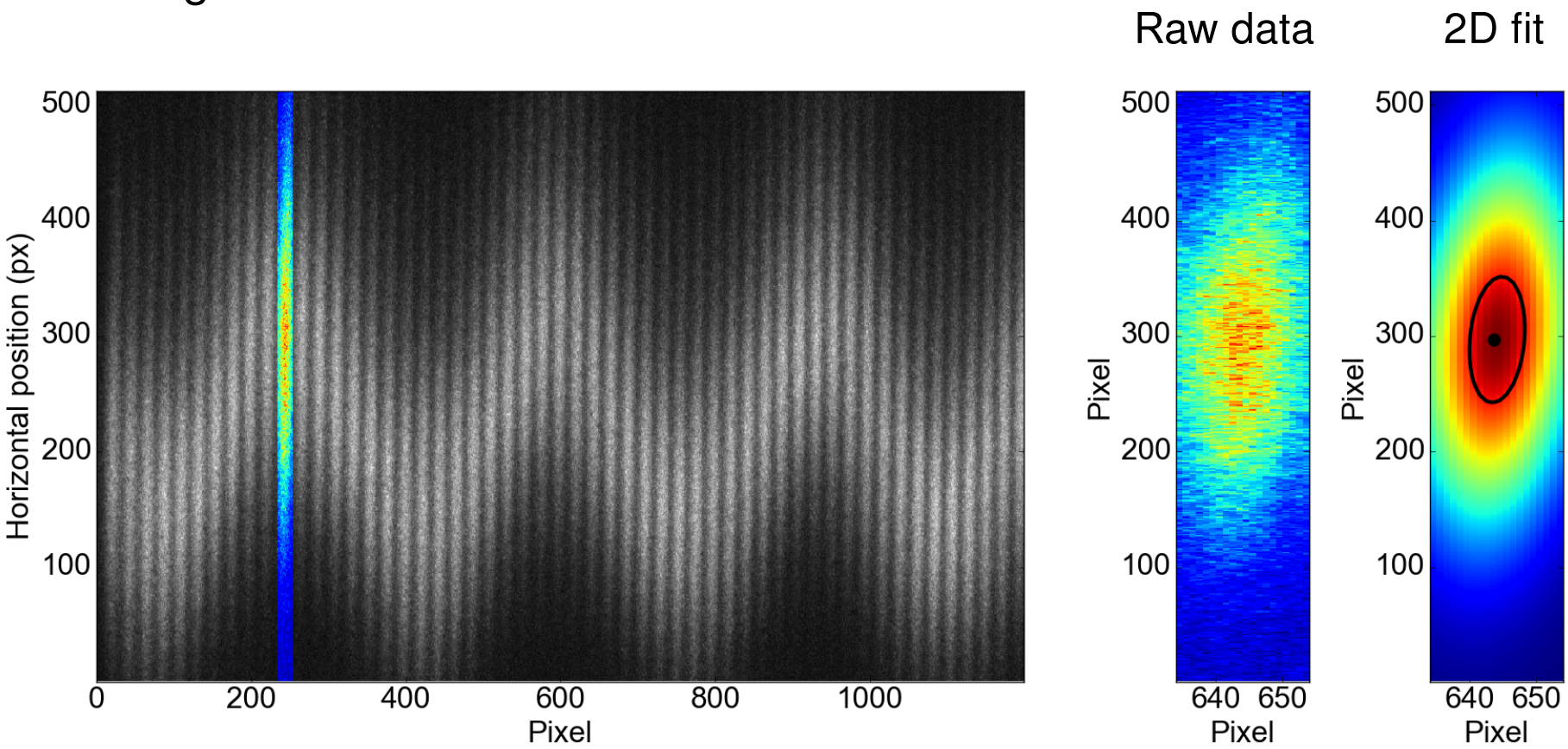

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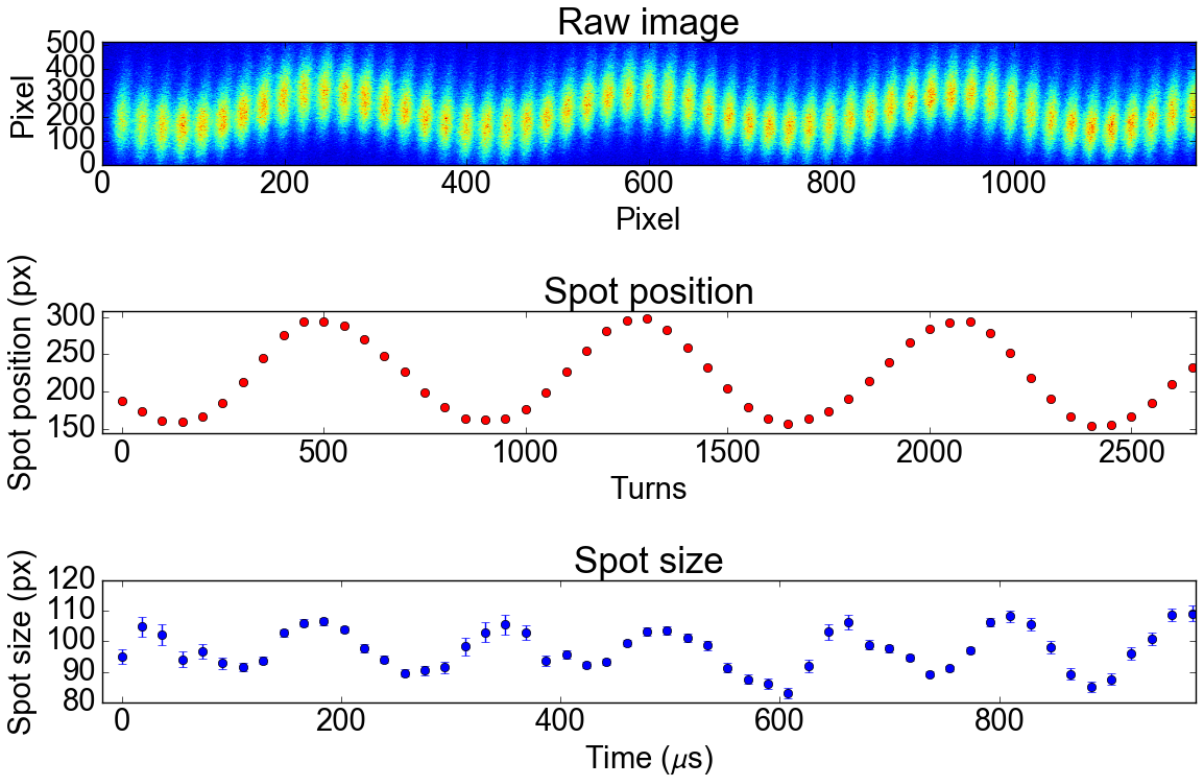

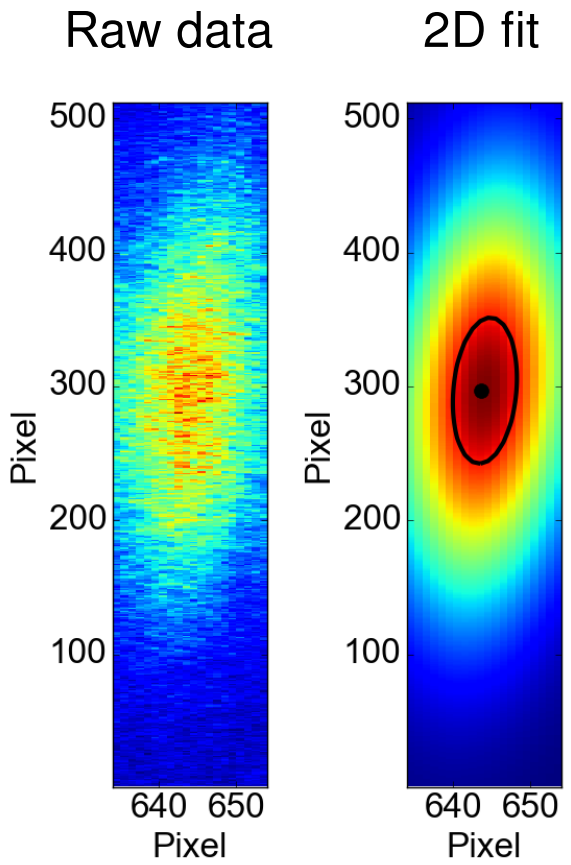

Schottky diodes + KAPTURE

Required: CSR intensity once per bunch and turn

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Schottky diodes + KAPTURE

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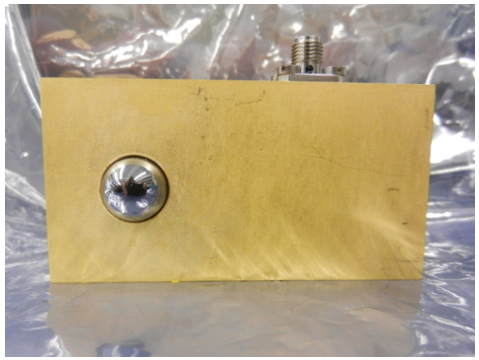
- Detectors: Schottky barrier diodes
  - Room temperature
  - Response time $< 200\,\mathrm{ps}$
  - 50 GHz up to 1 THz + narrowband detectors
  - Commercially available (ACST, VDI)



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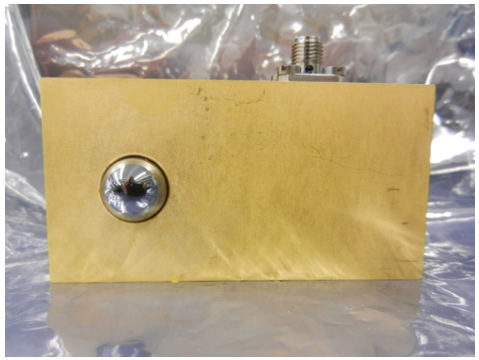

- DAQ: KAPTURE
  - In-house developed DAQ system[9]
  - 4 ADC with turn-by-turn and bunch-by-bunch capability (sampling with fixed phase)
  - Continuous streaming

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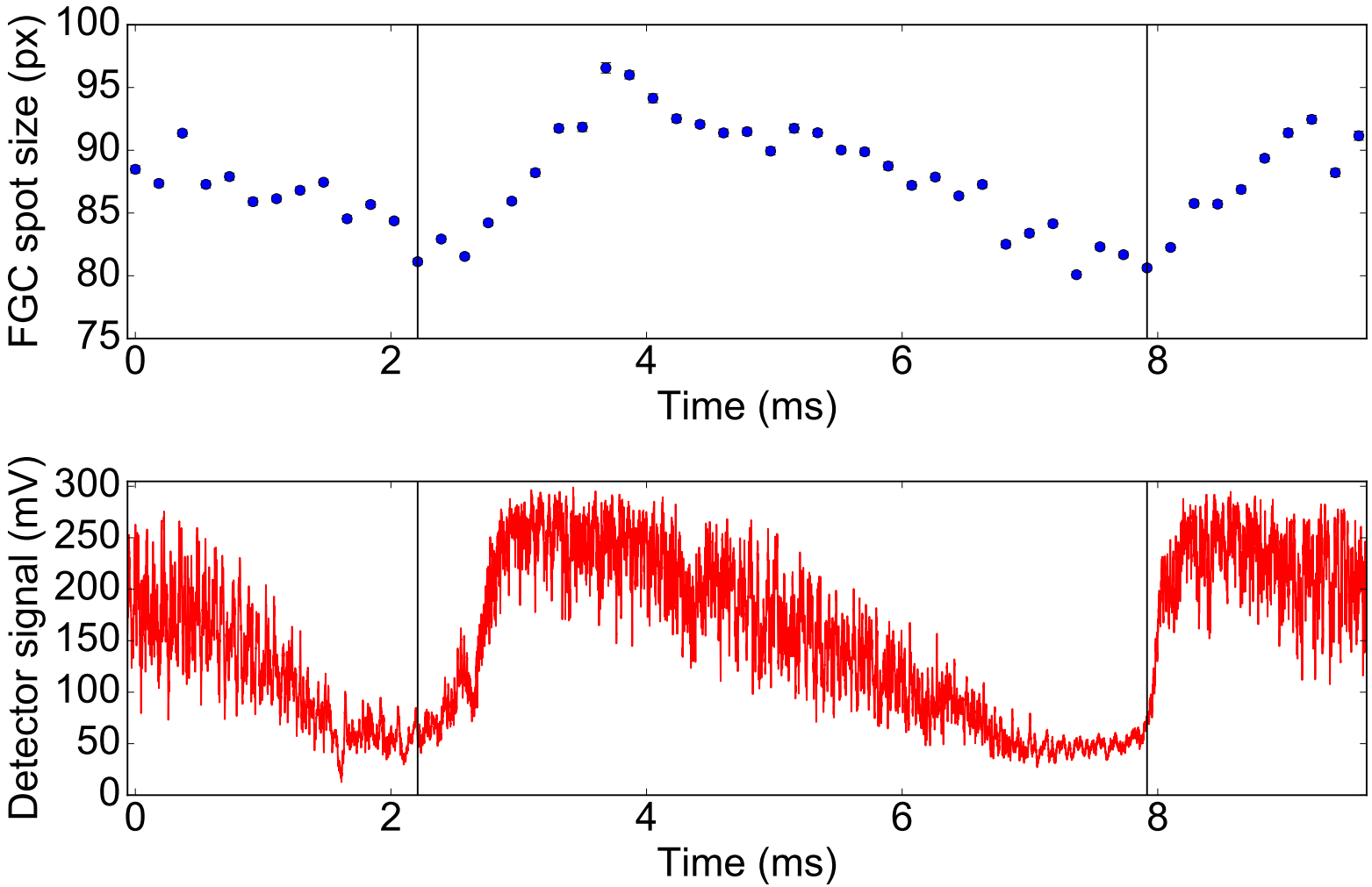
Horizontal bunch size and CSR: Example I



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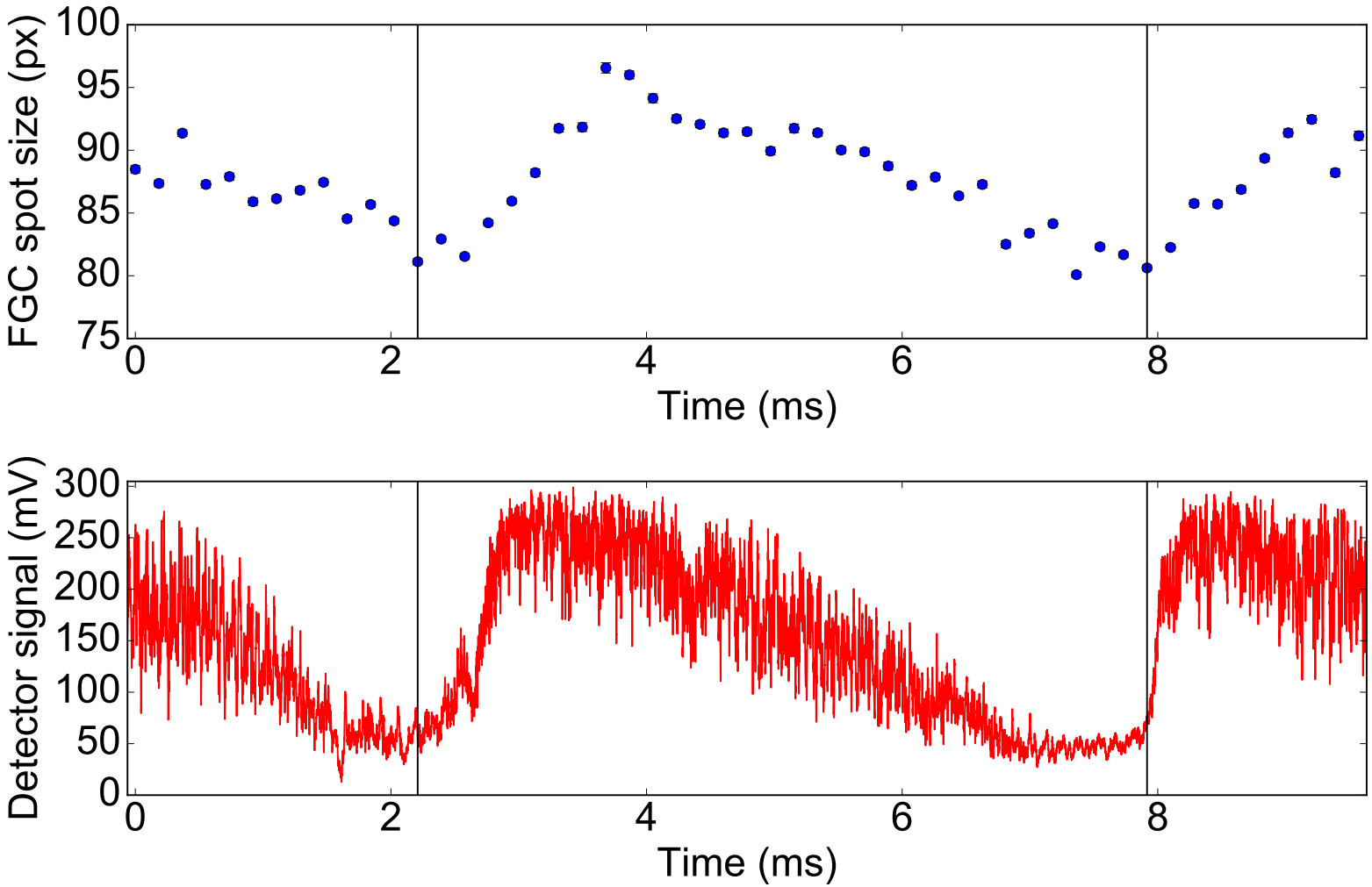
Energy spread with same modulation pattern as CSR



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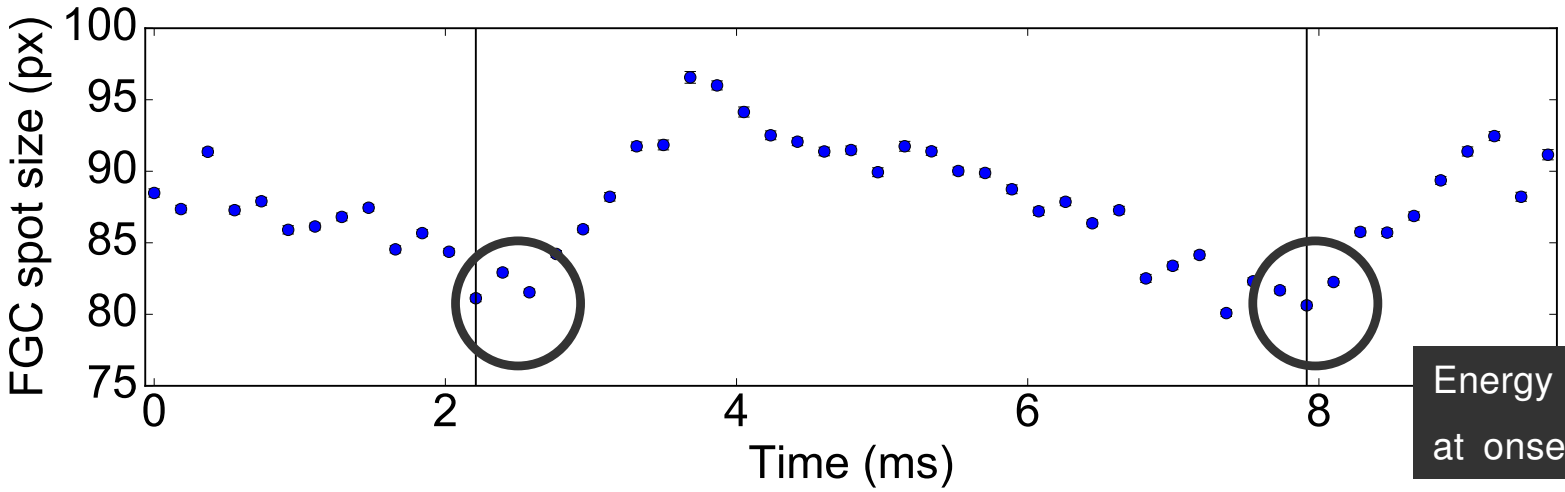
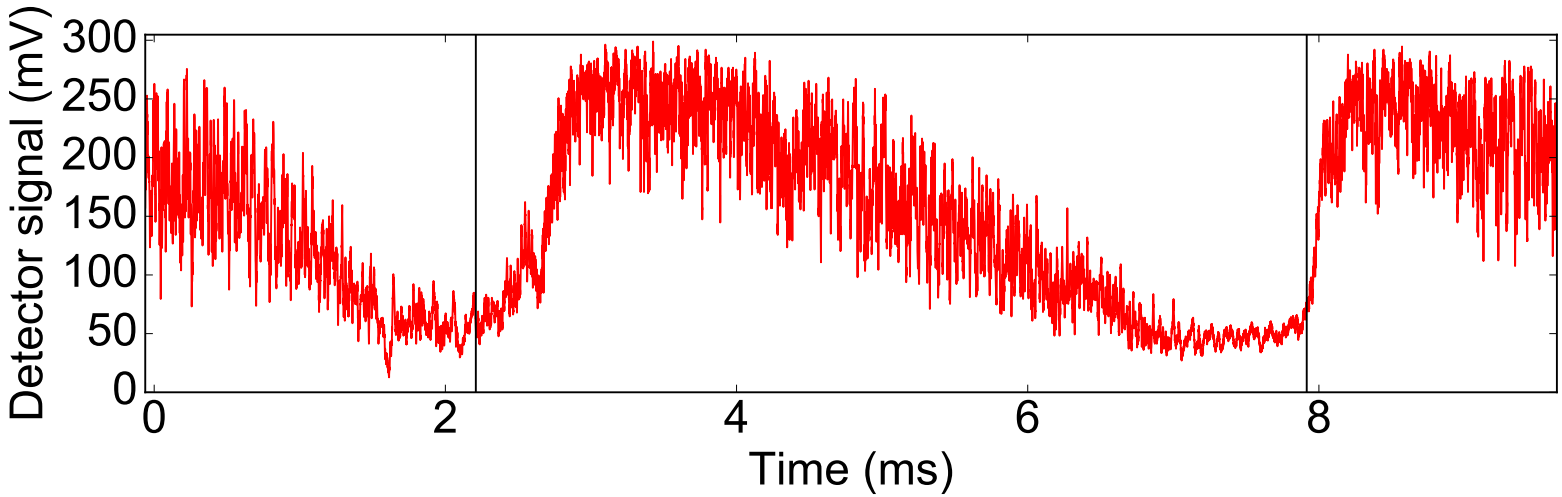


Energy spread rises at onset of burst



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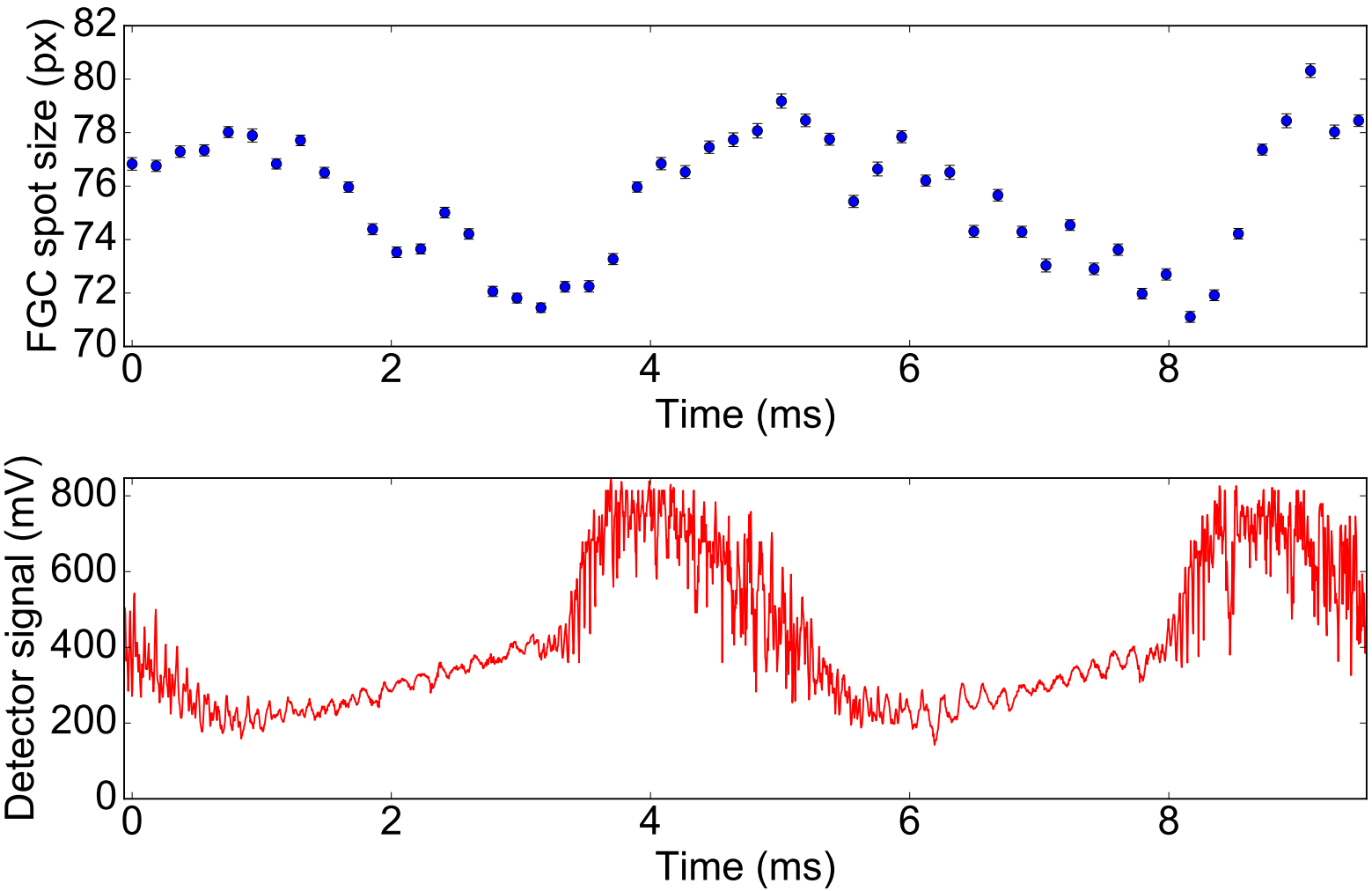

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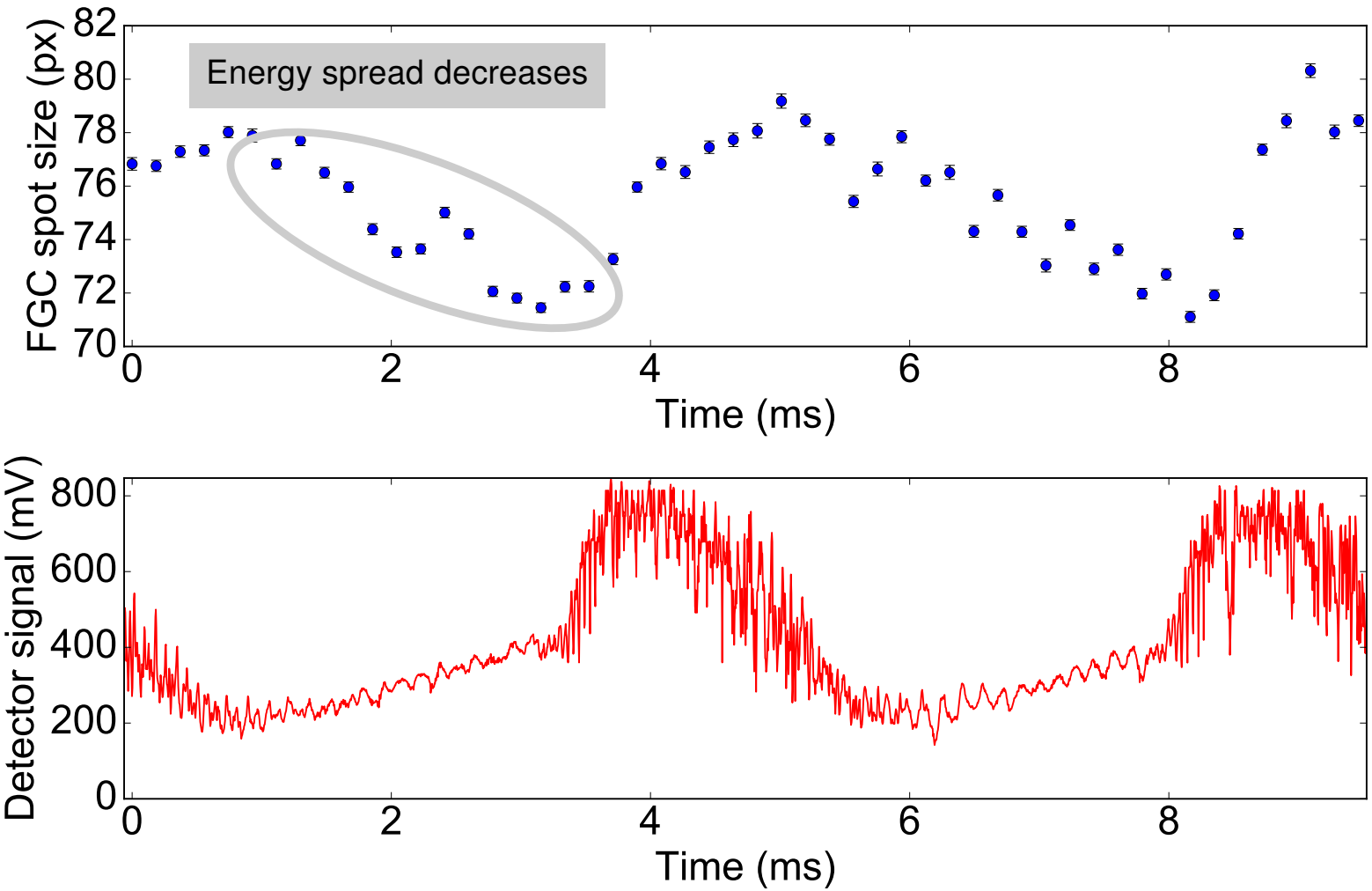

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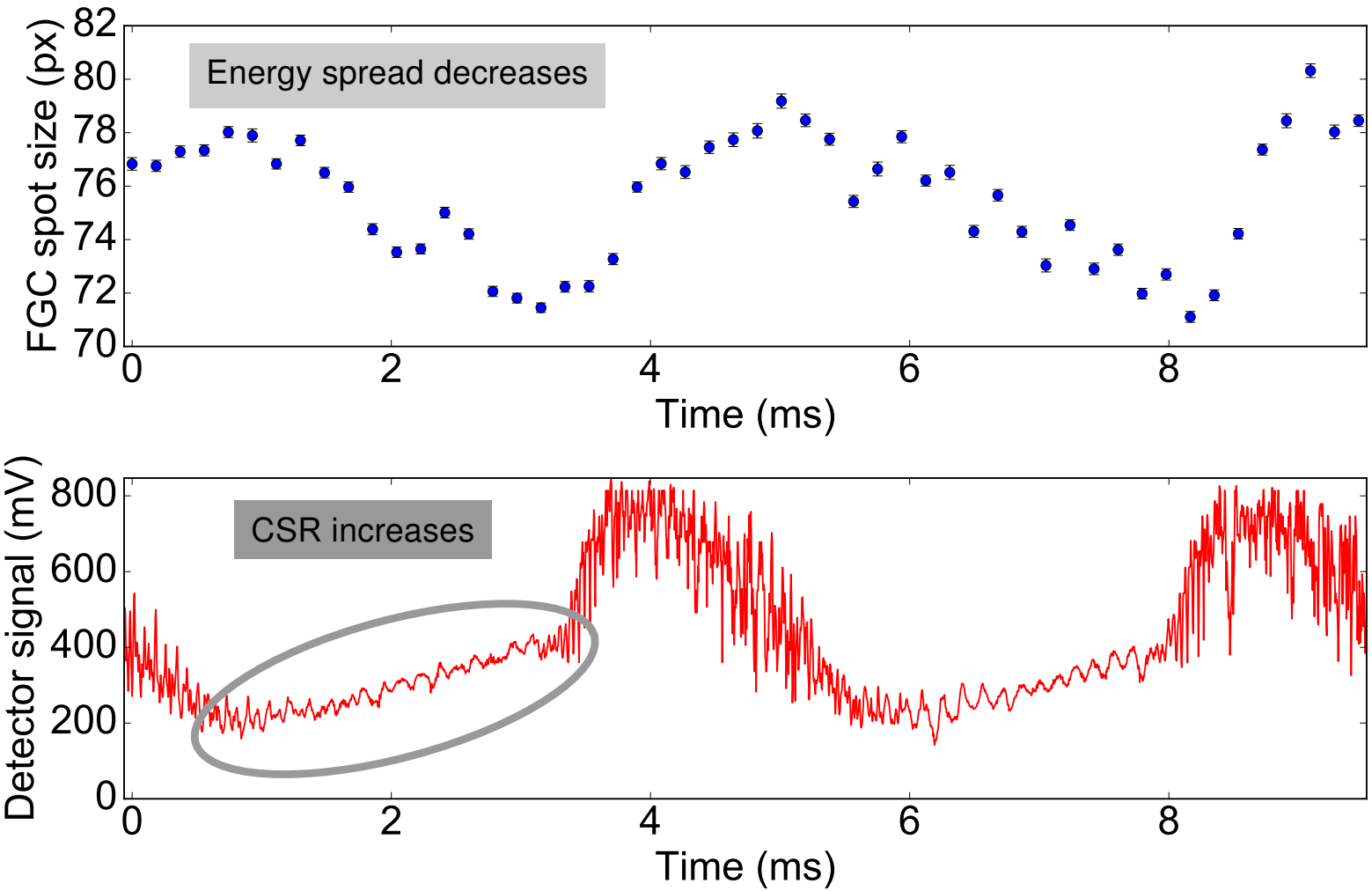

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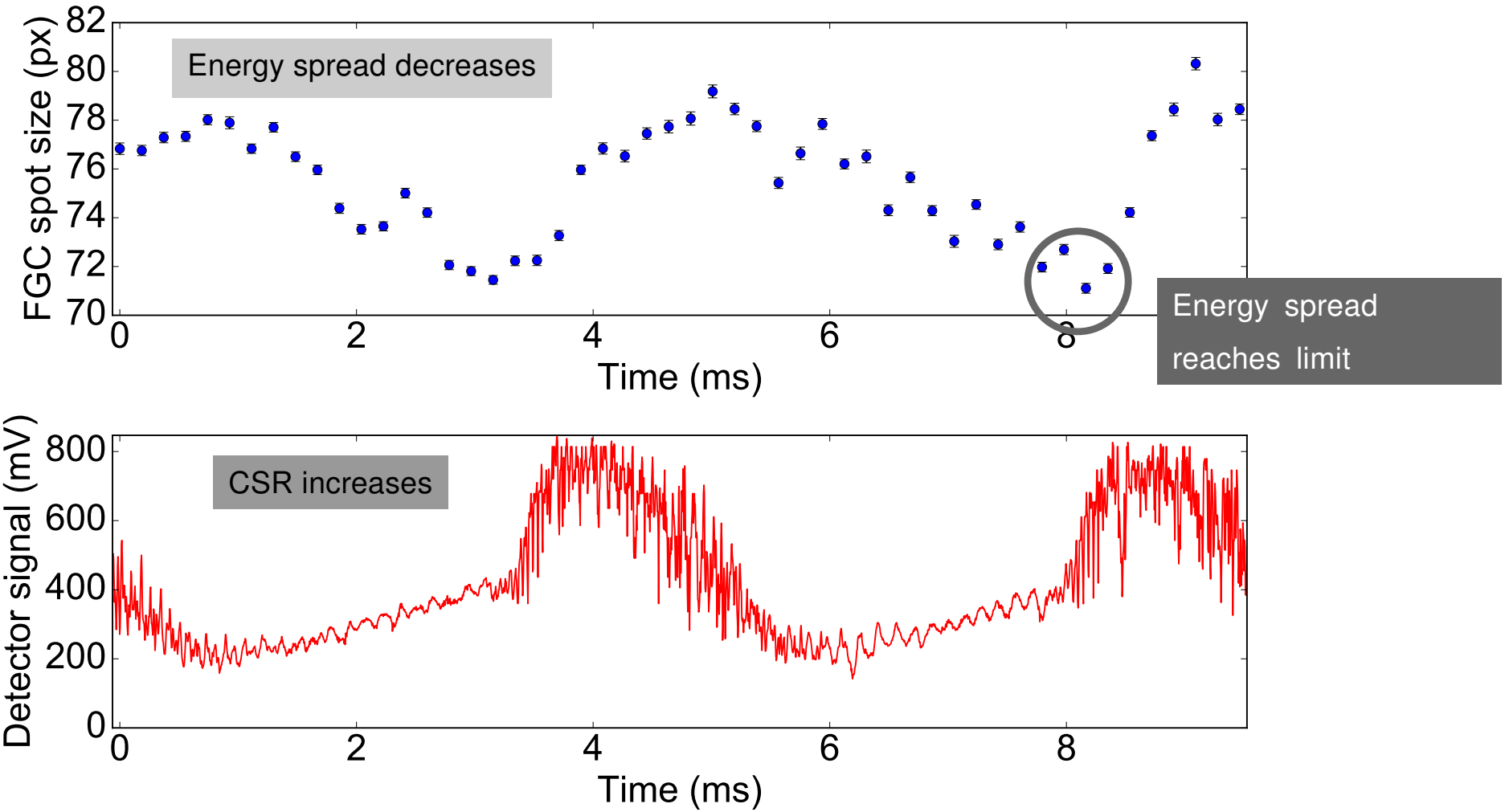

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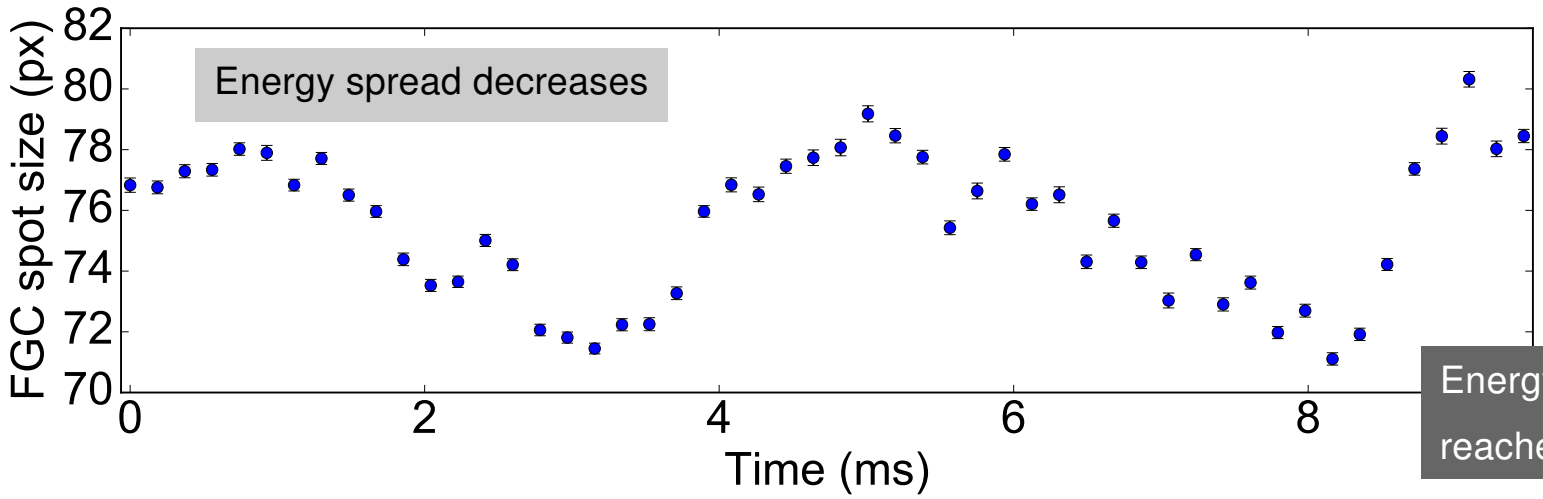
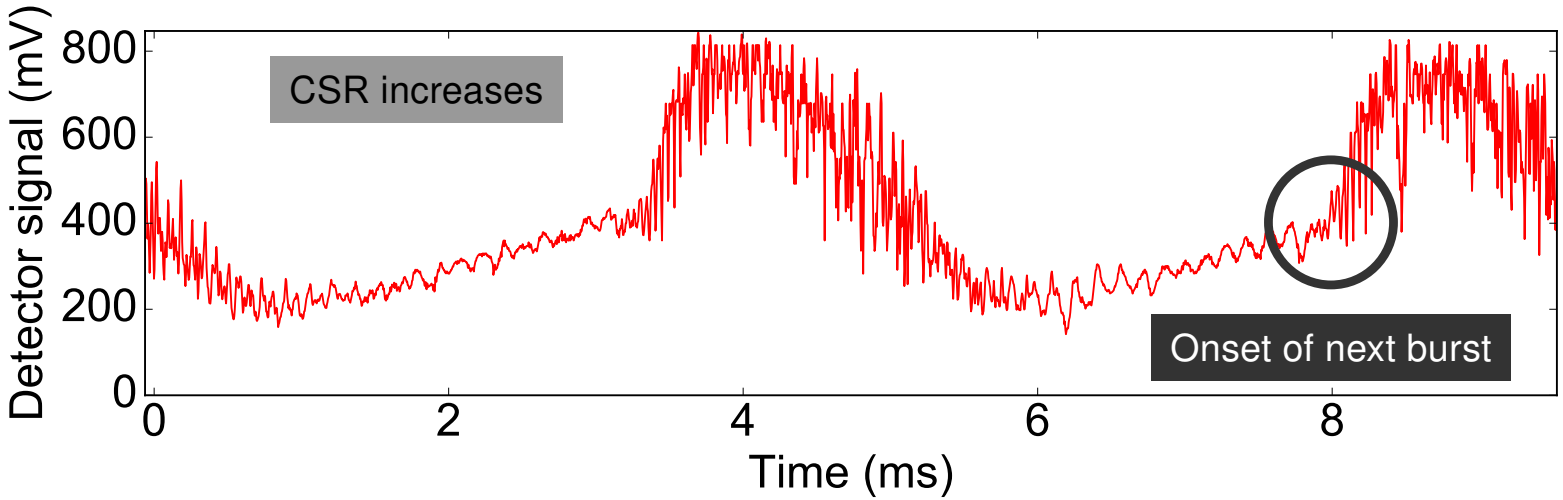
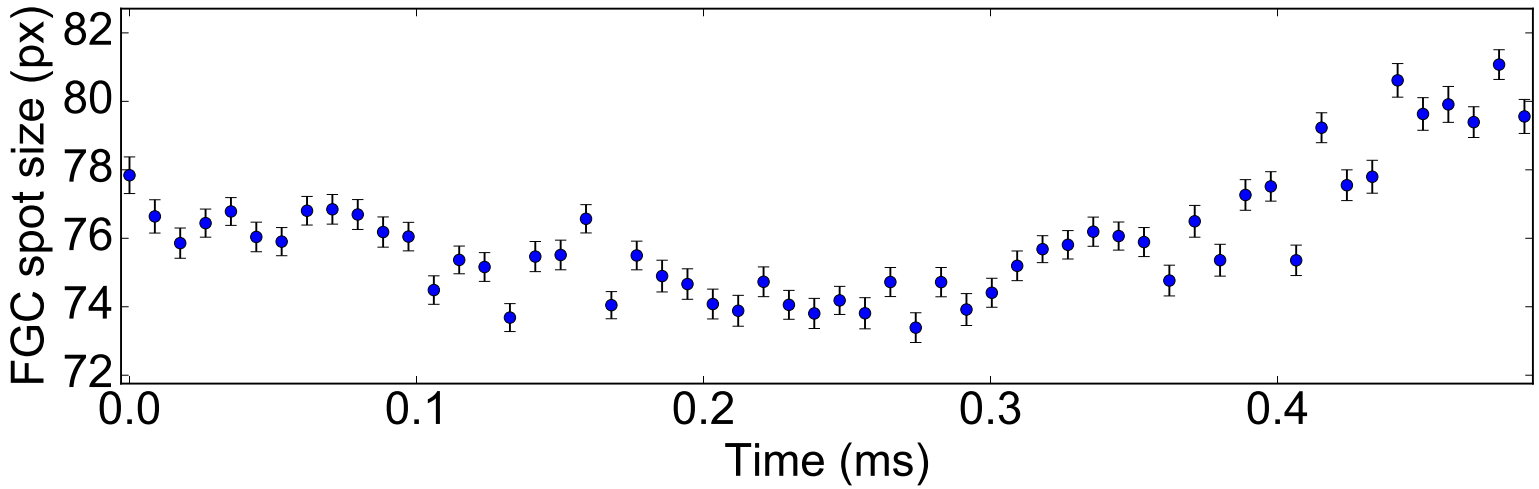


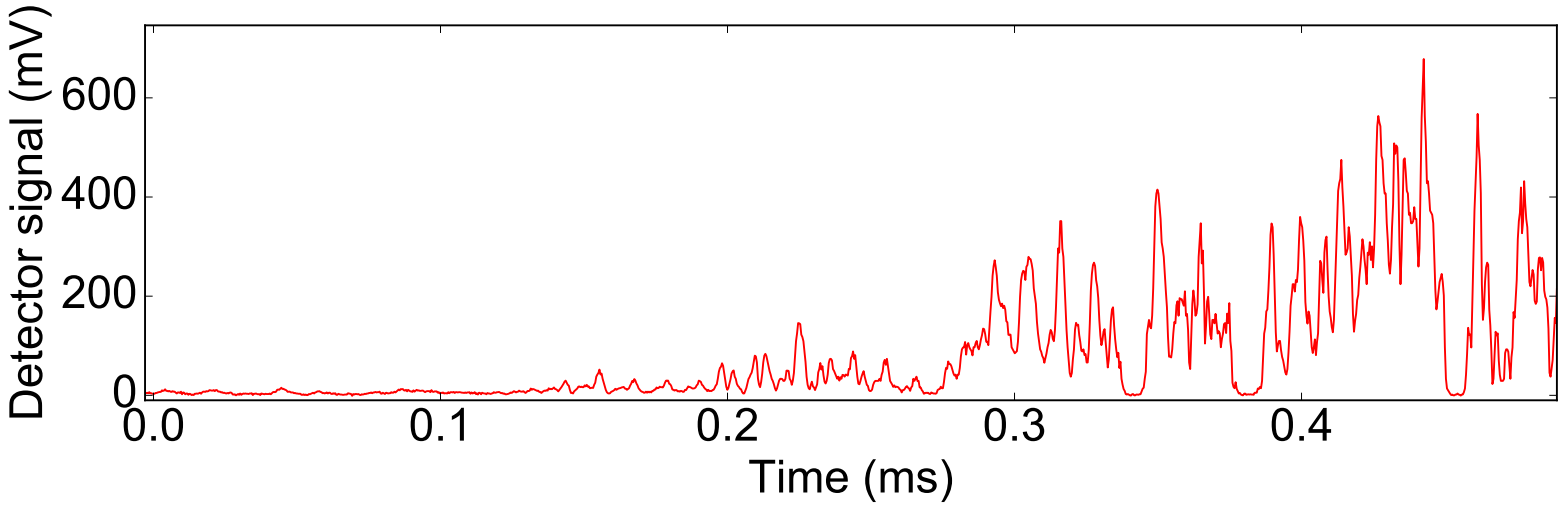
Energy spread reaches limit



Horizontal bunch size and CSR: Example III

Study in more detail $\rightarrow$ 24 turns gate separation, 500 μs time range





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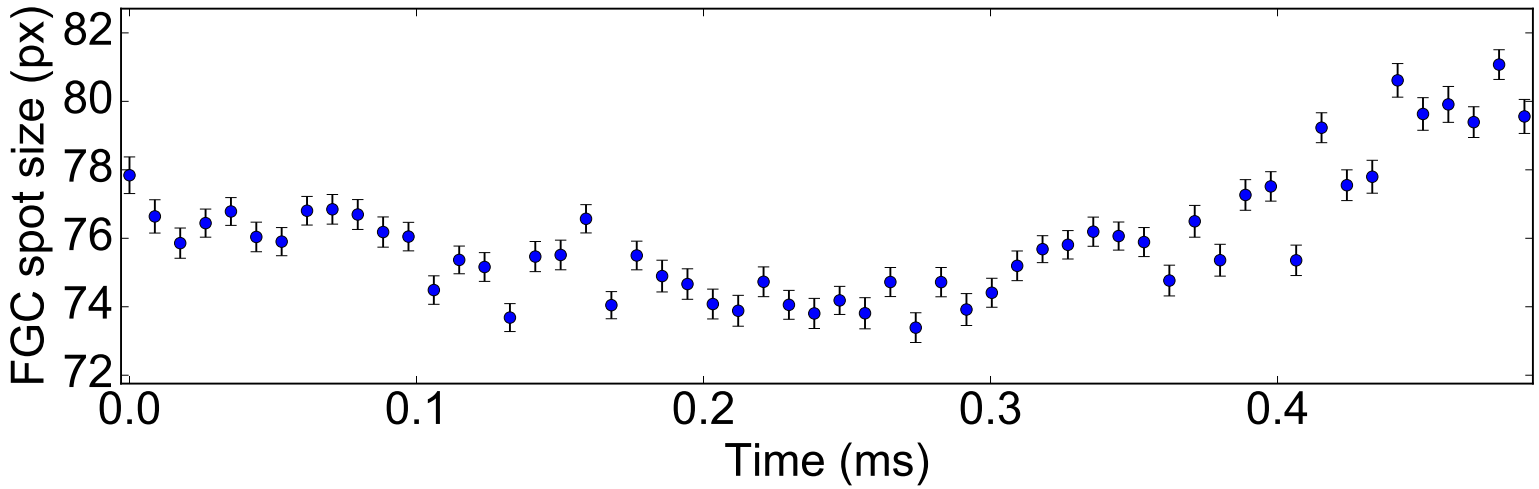

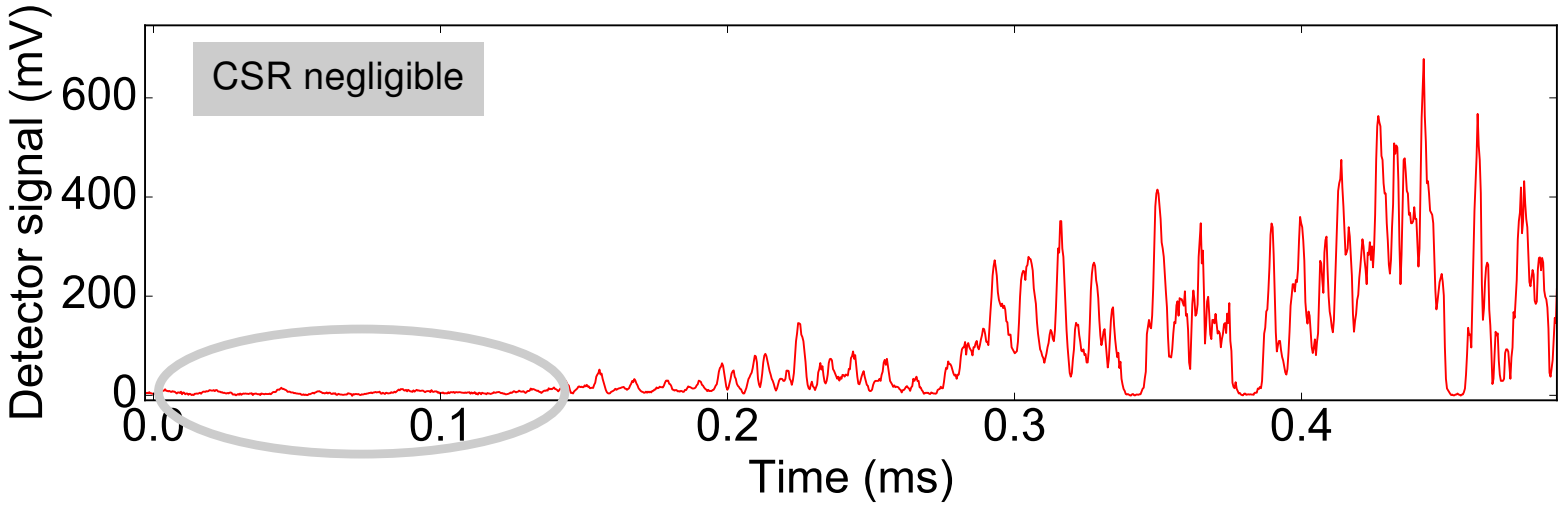

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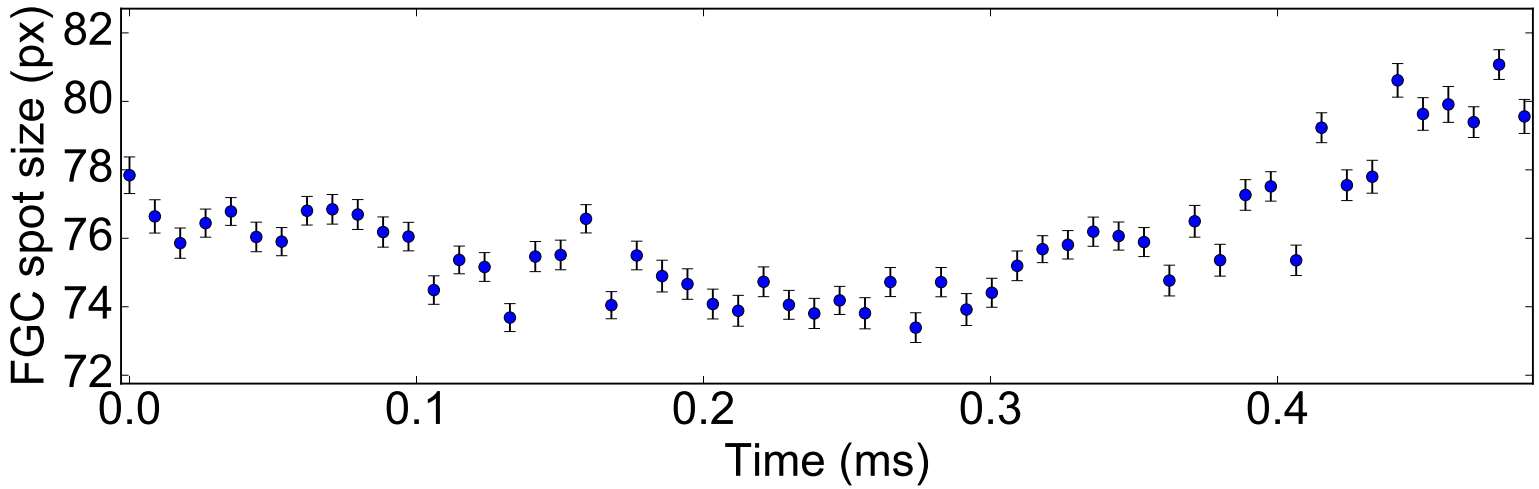

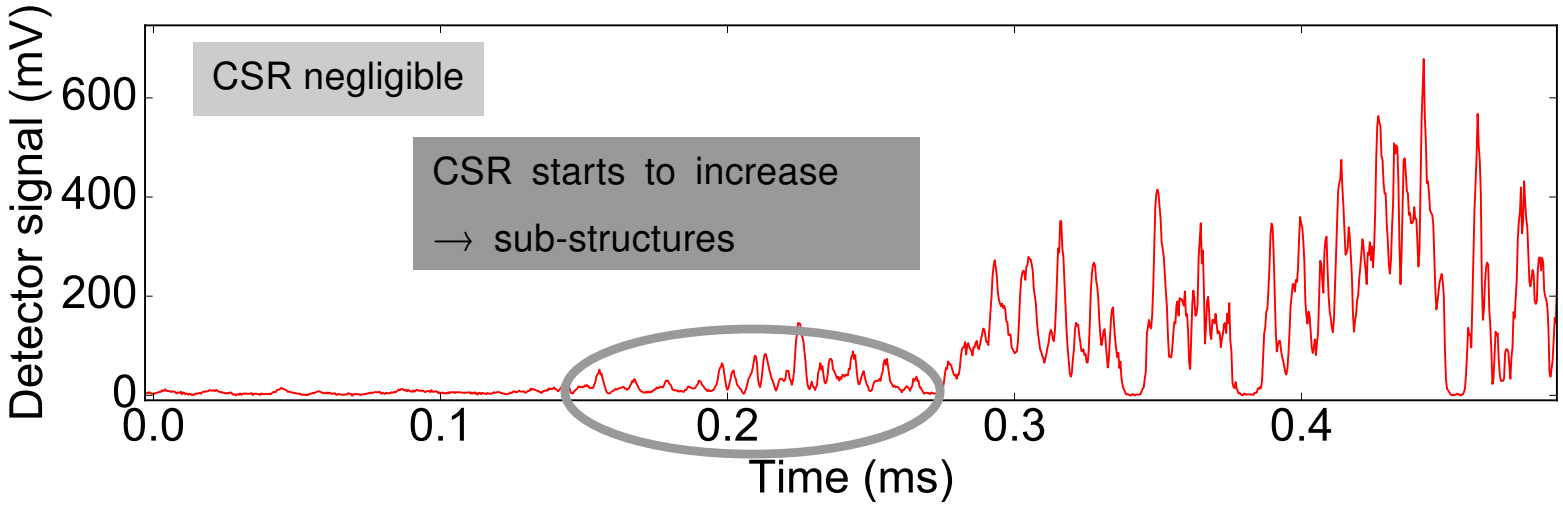

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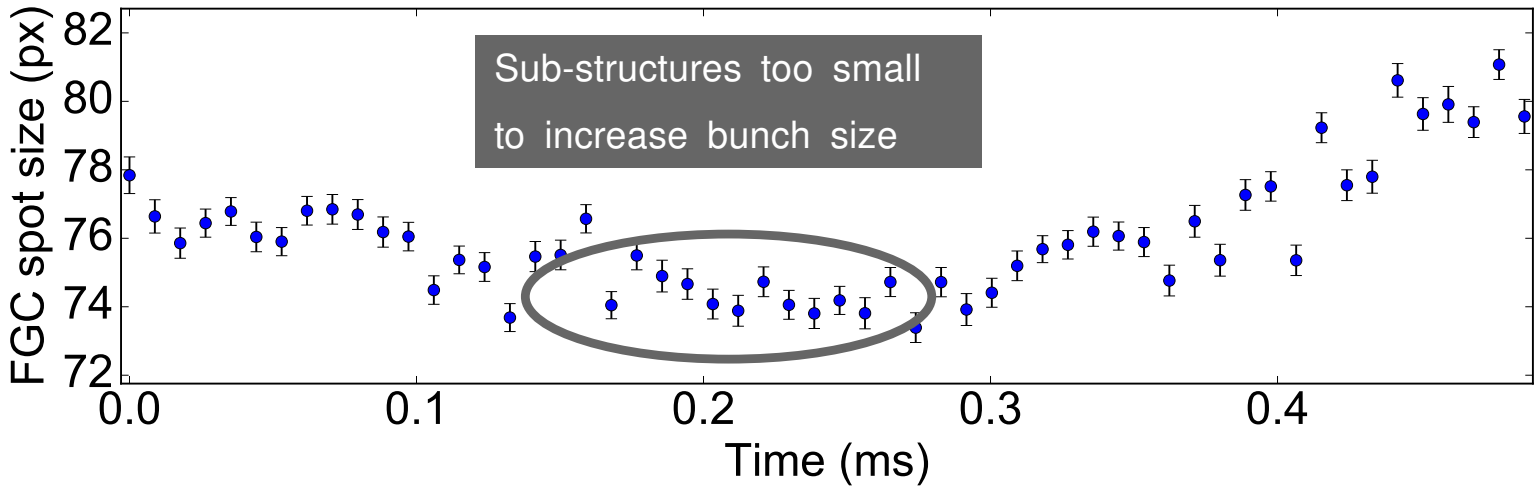

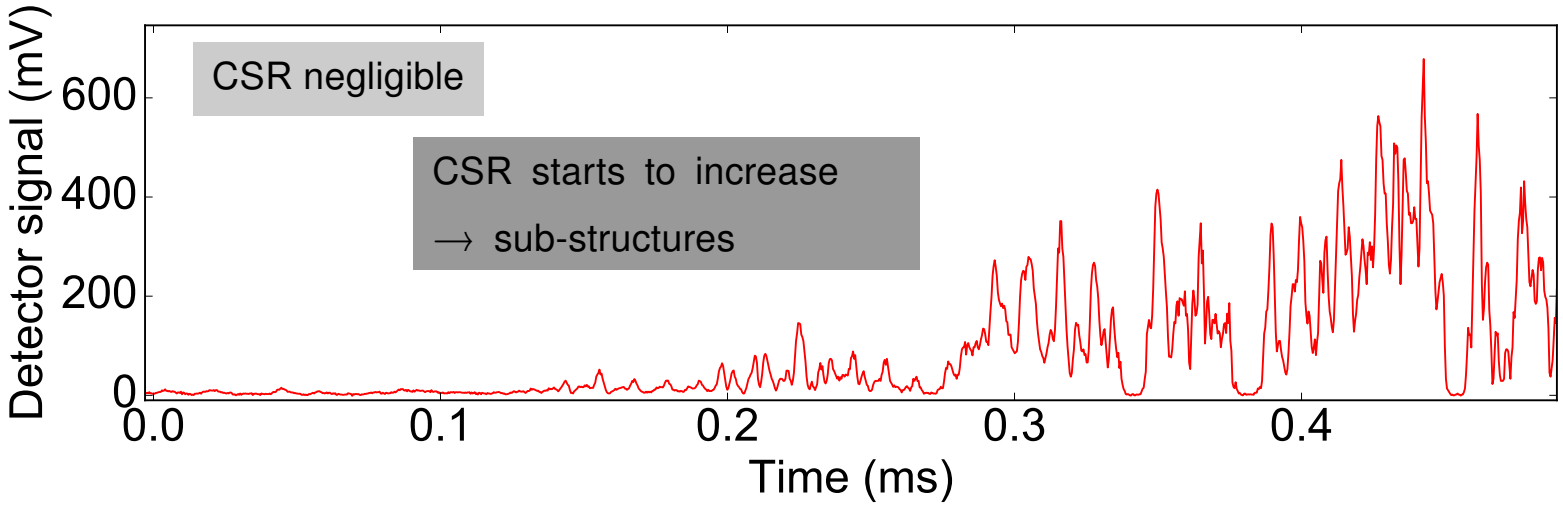

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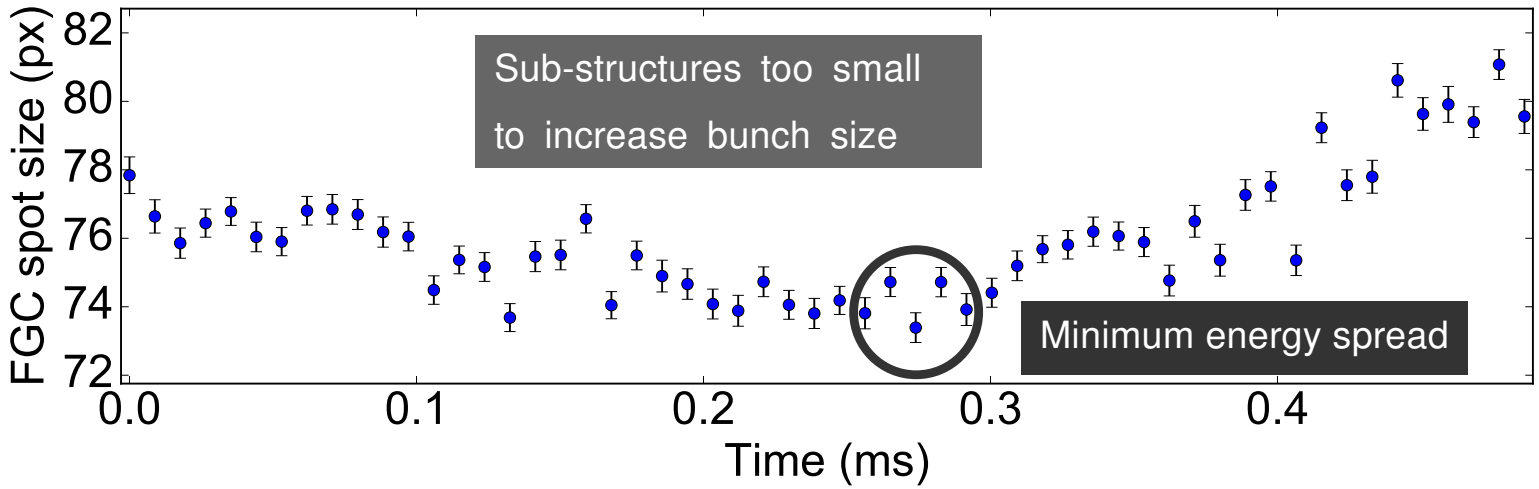

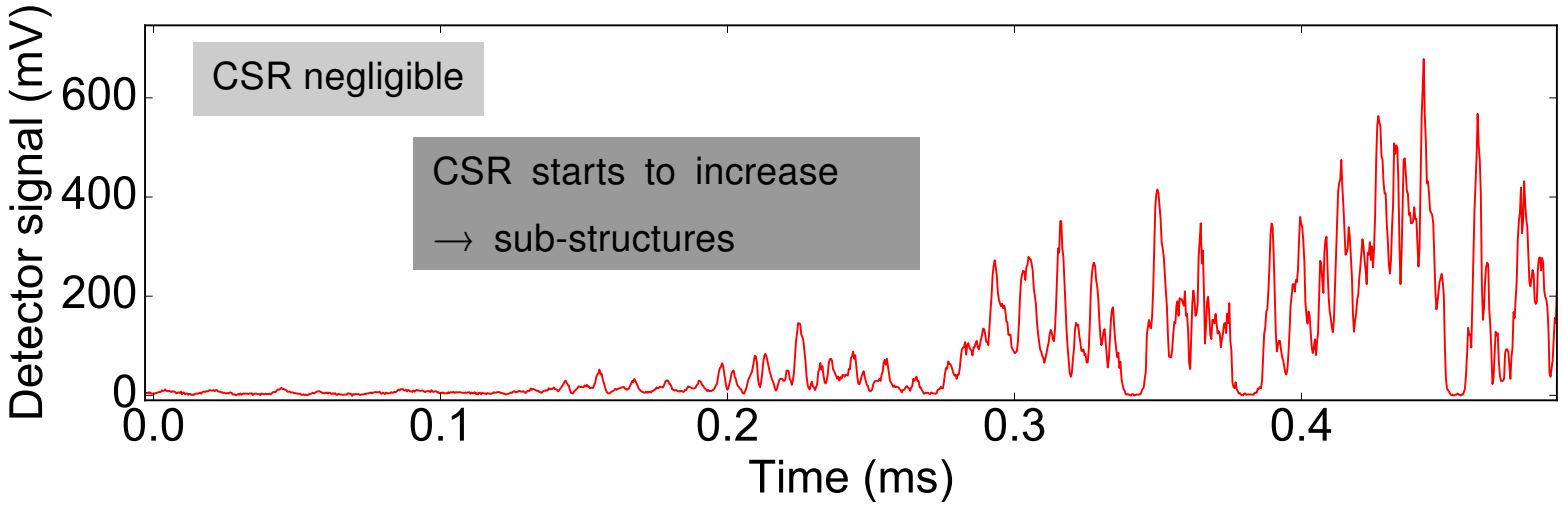

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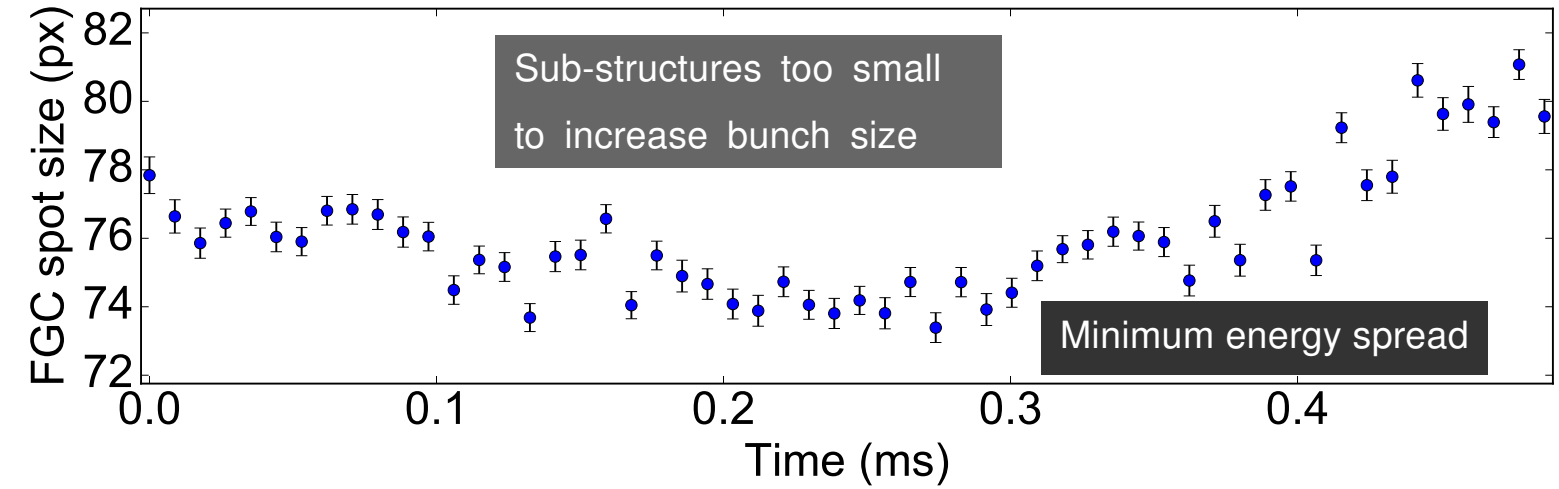
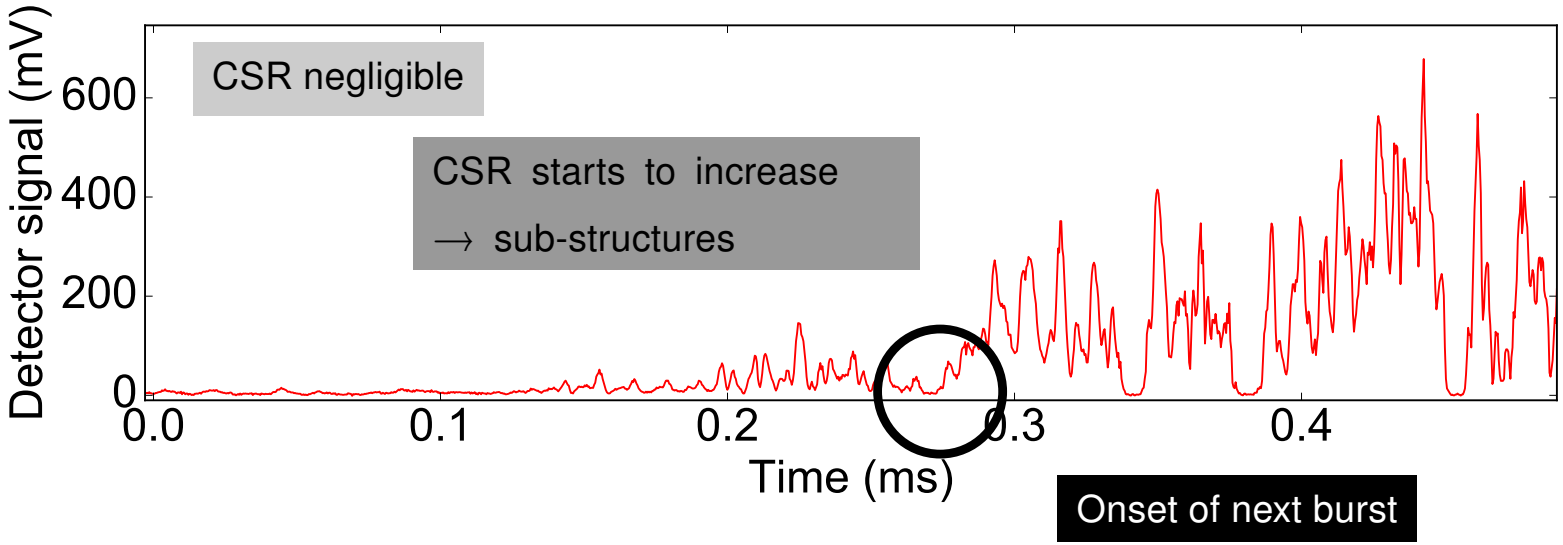
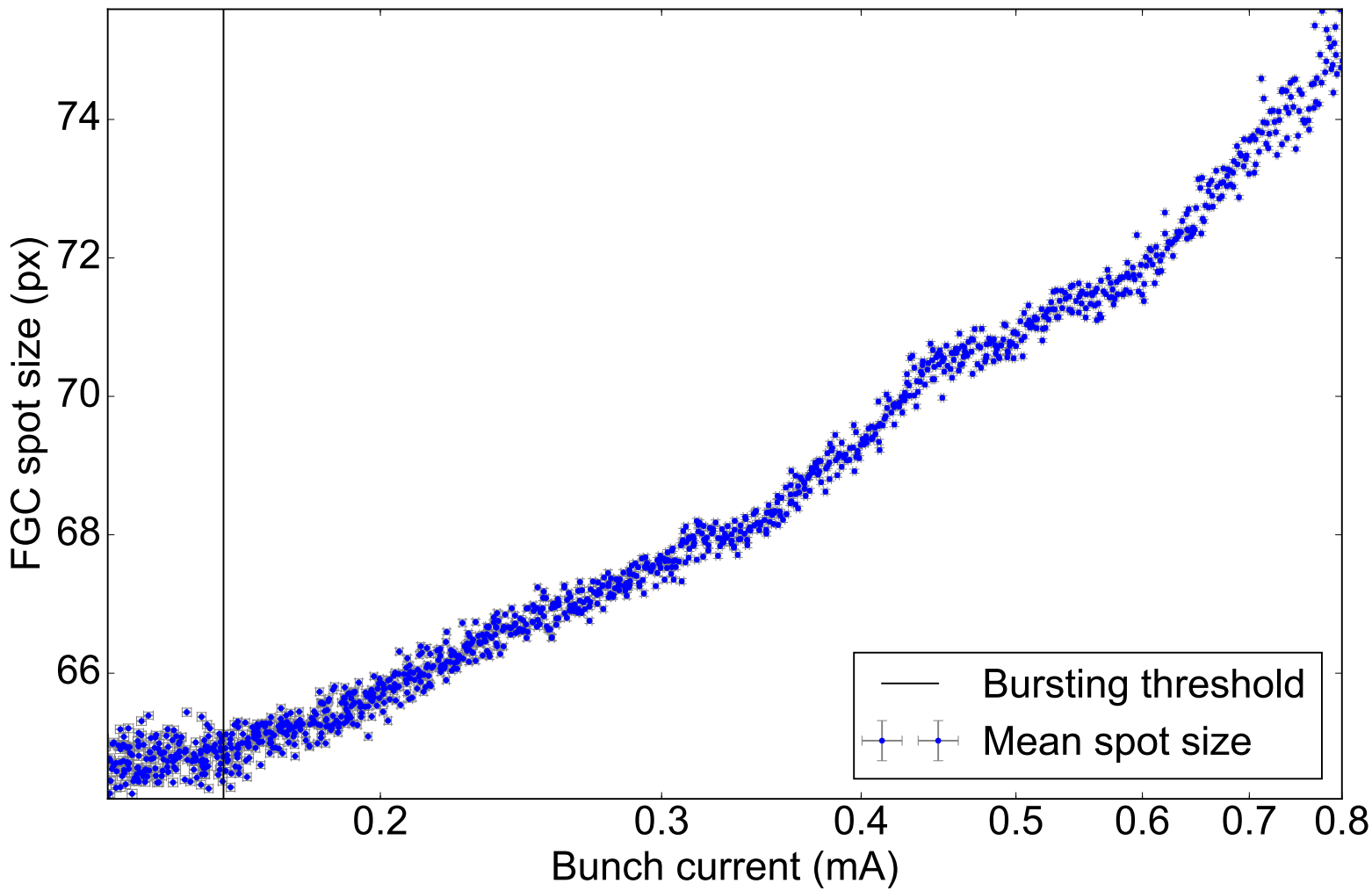




Bursting threshold



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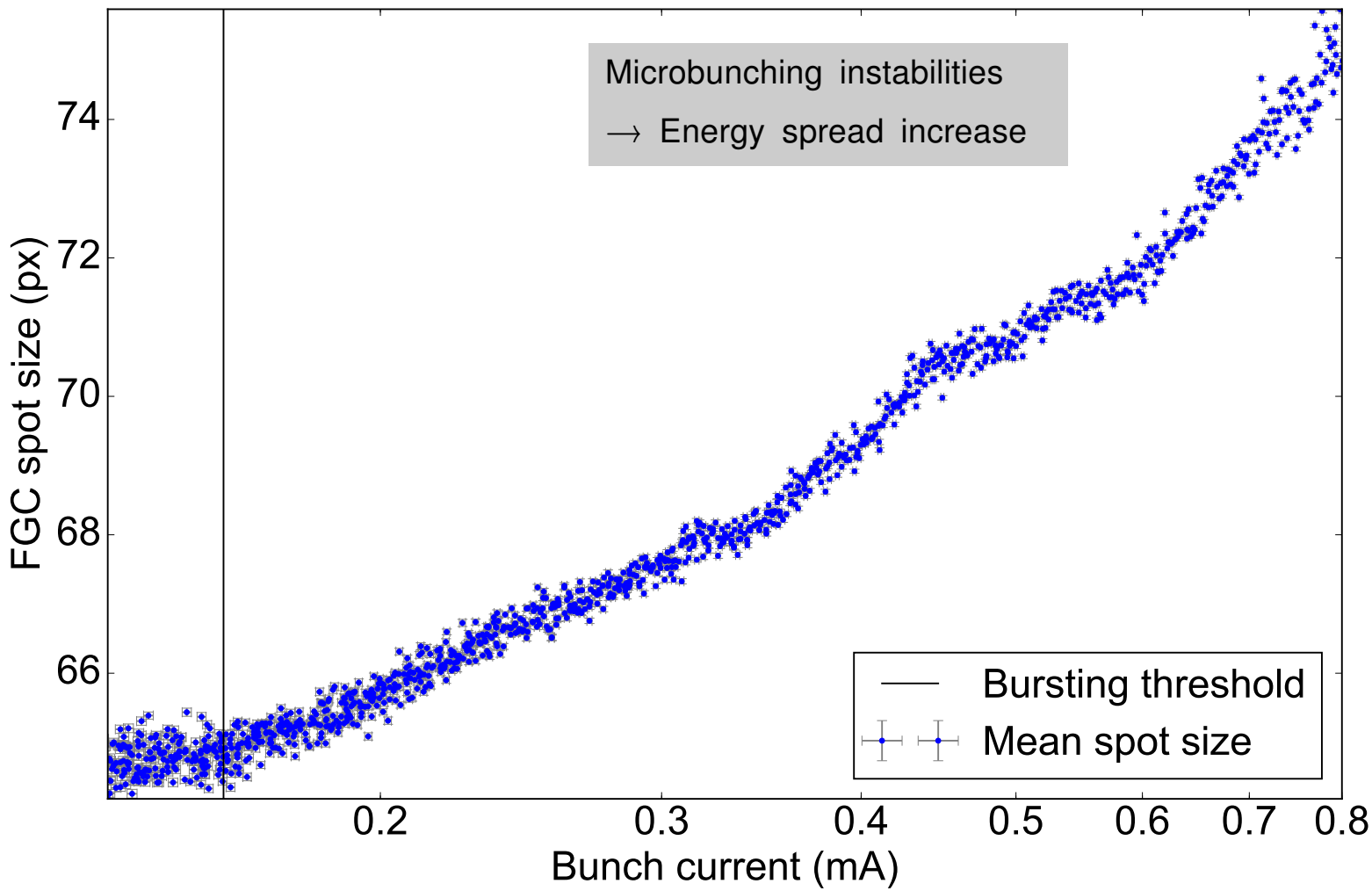
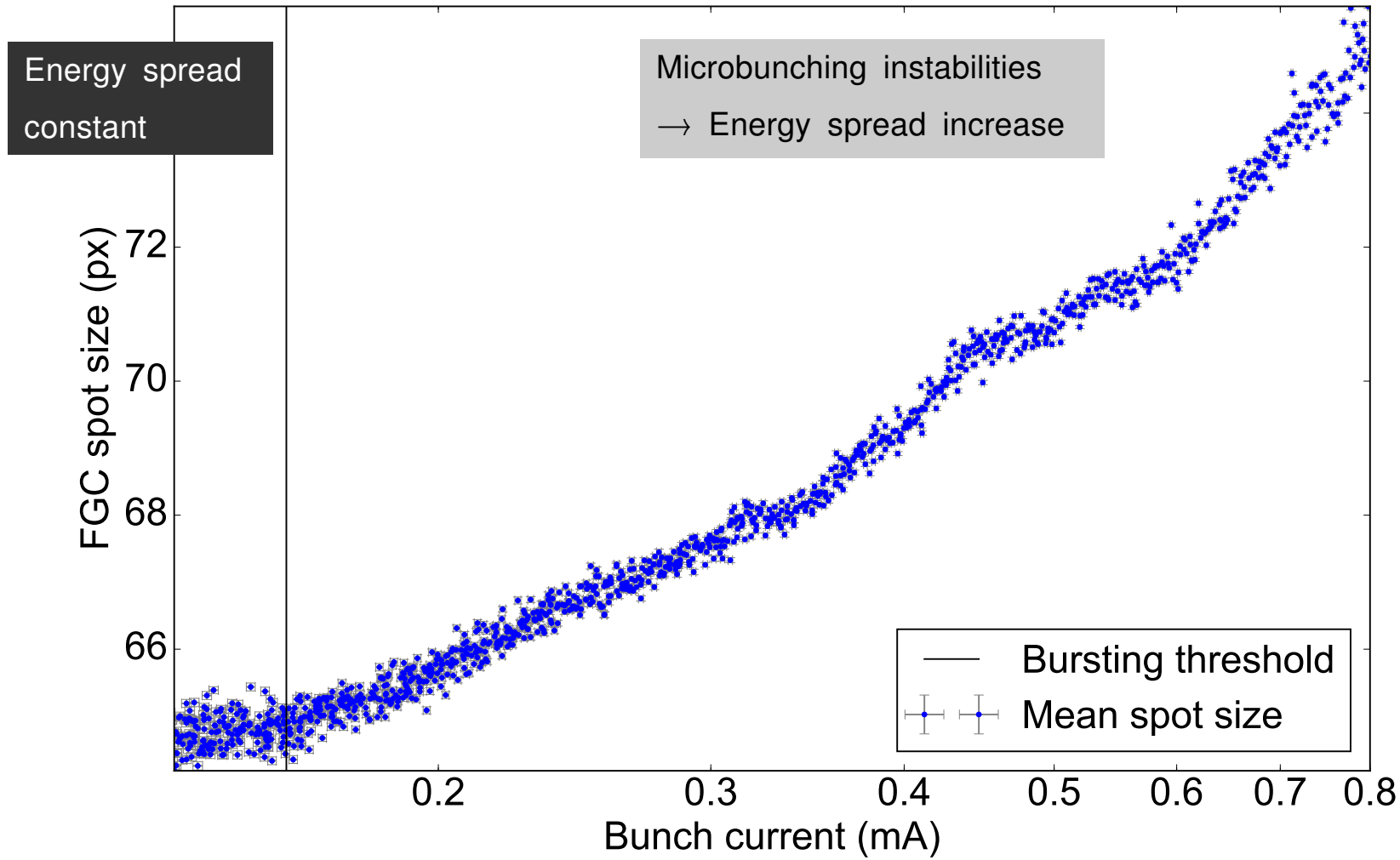


Bursting threshold



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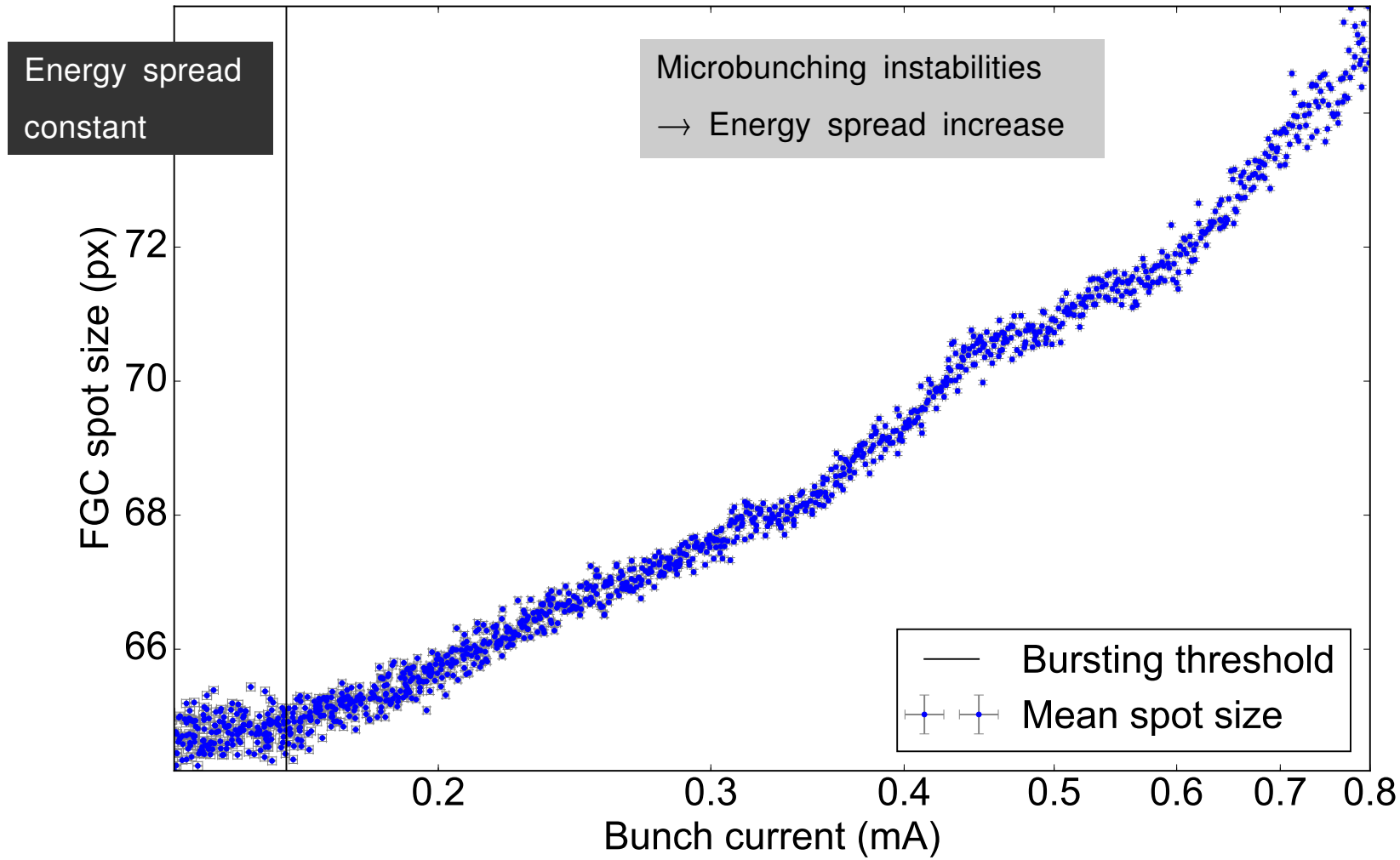

But: Not always the case

“Short bunch-length bursting”

- Simulations predicted *weak instability* below the bursting threshold[10]
- Measured on CSR at ANKA[11] for $\alpha_c \leq 2.64 \cdot 10^{-4}$

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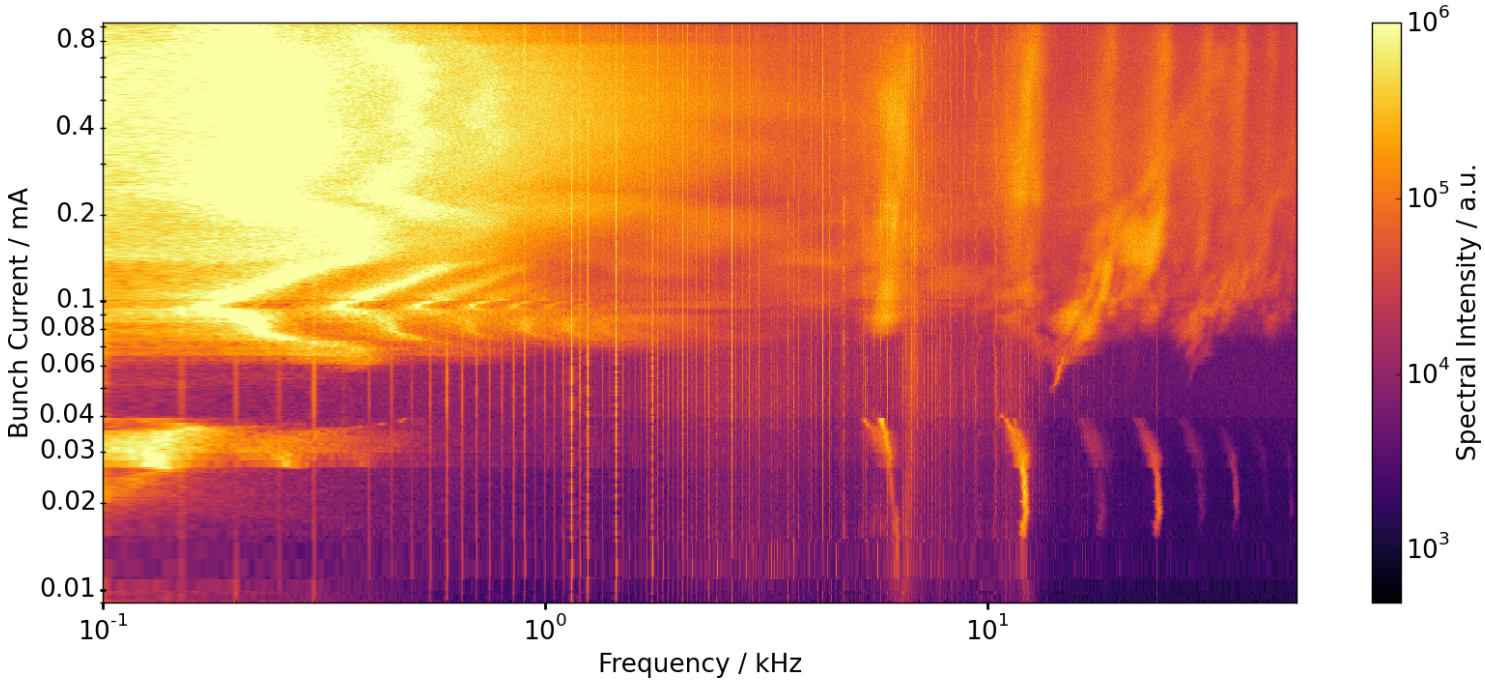

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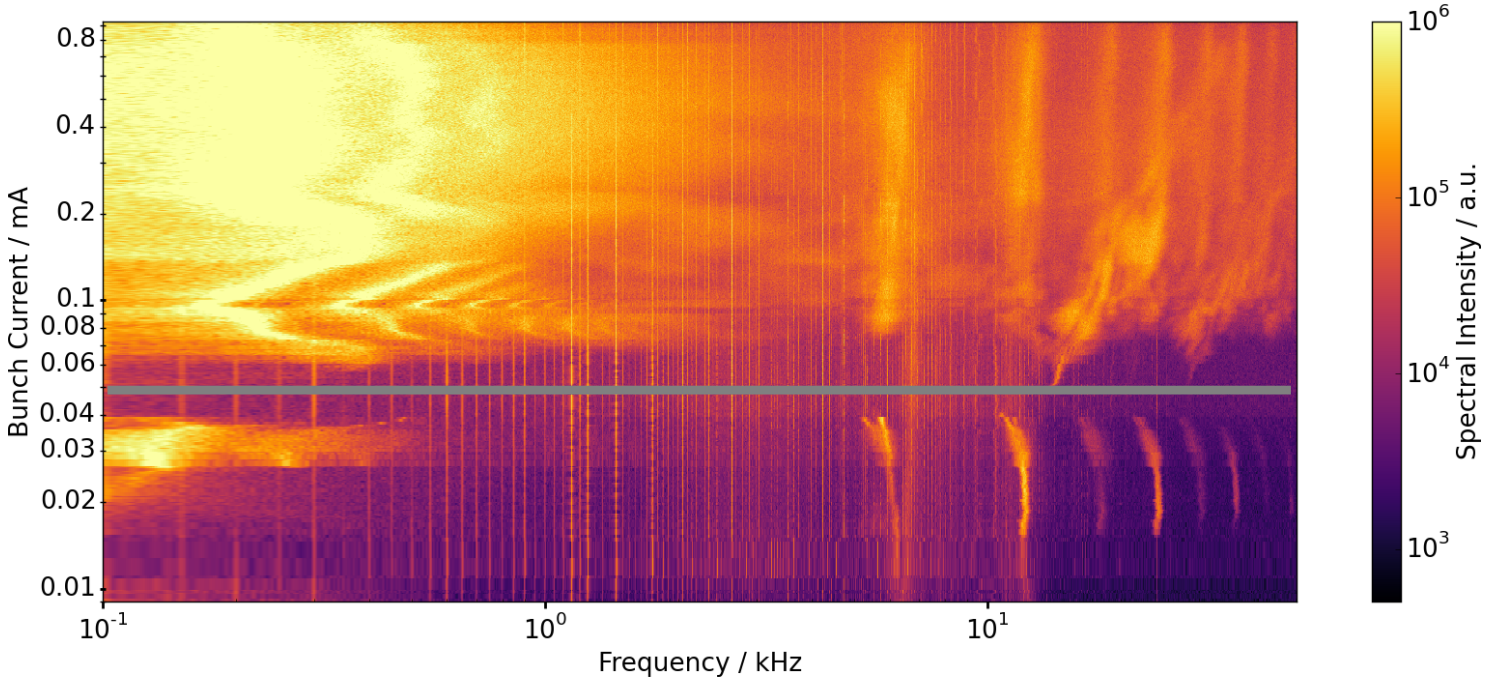

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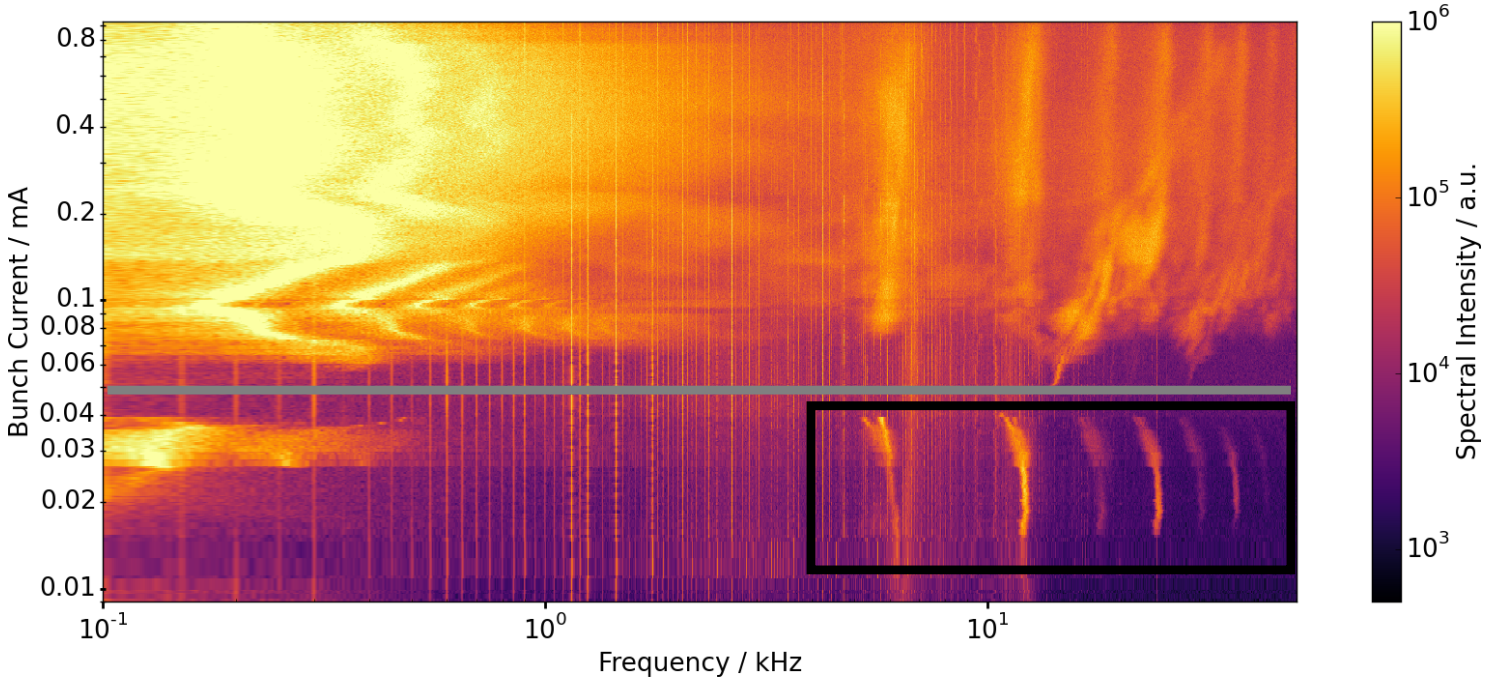

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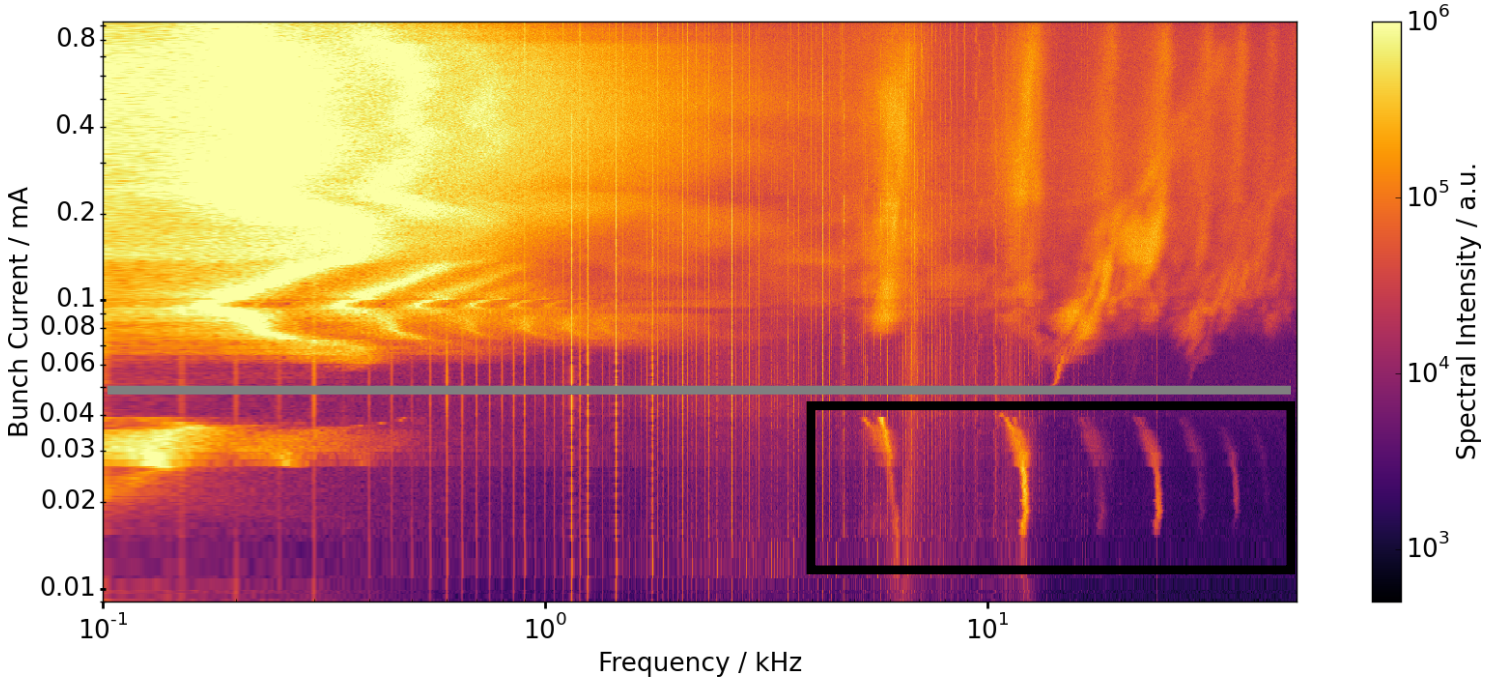

- Instability would lead to energy spread increase

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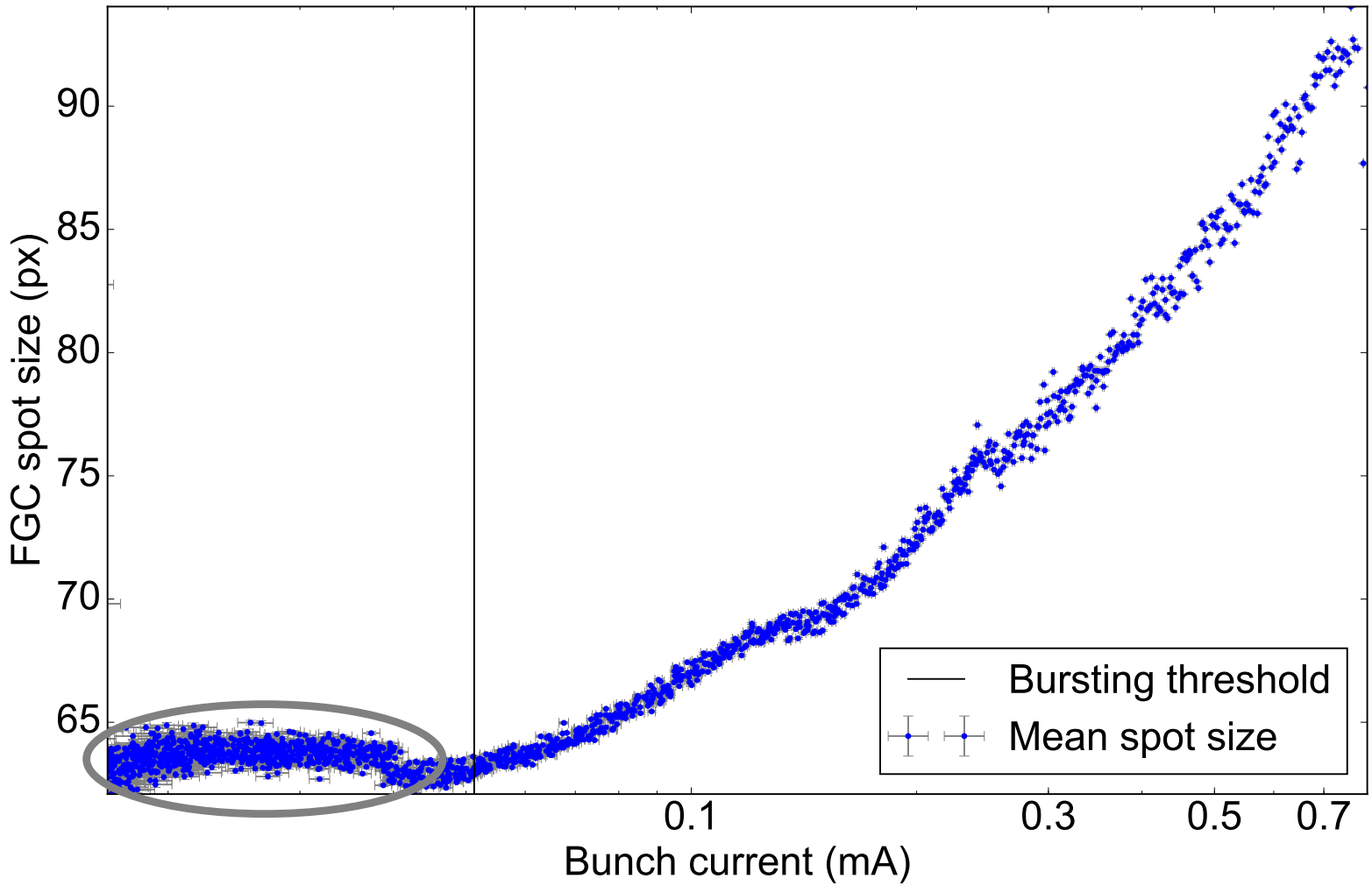

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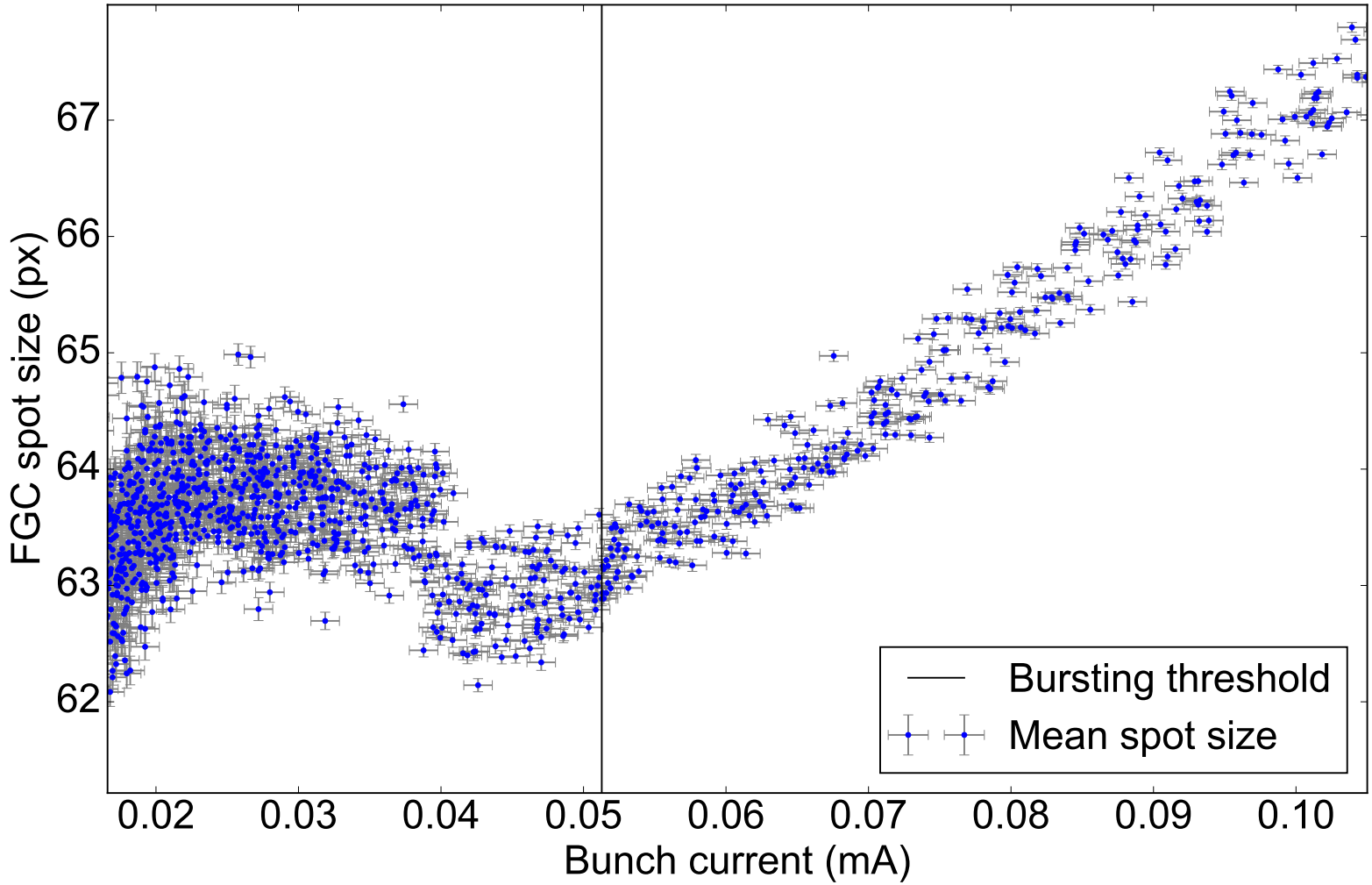

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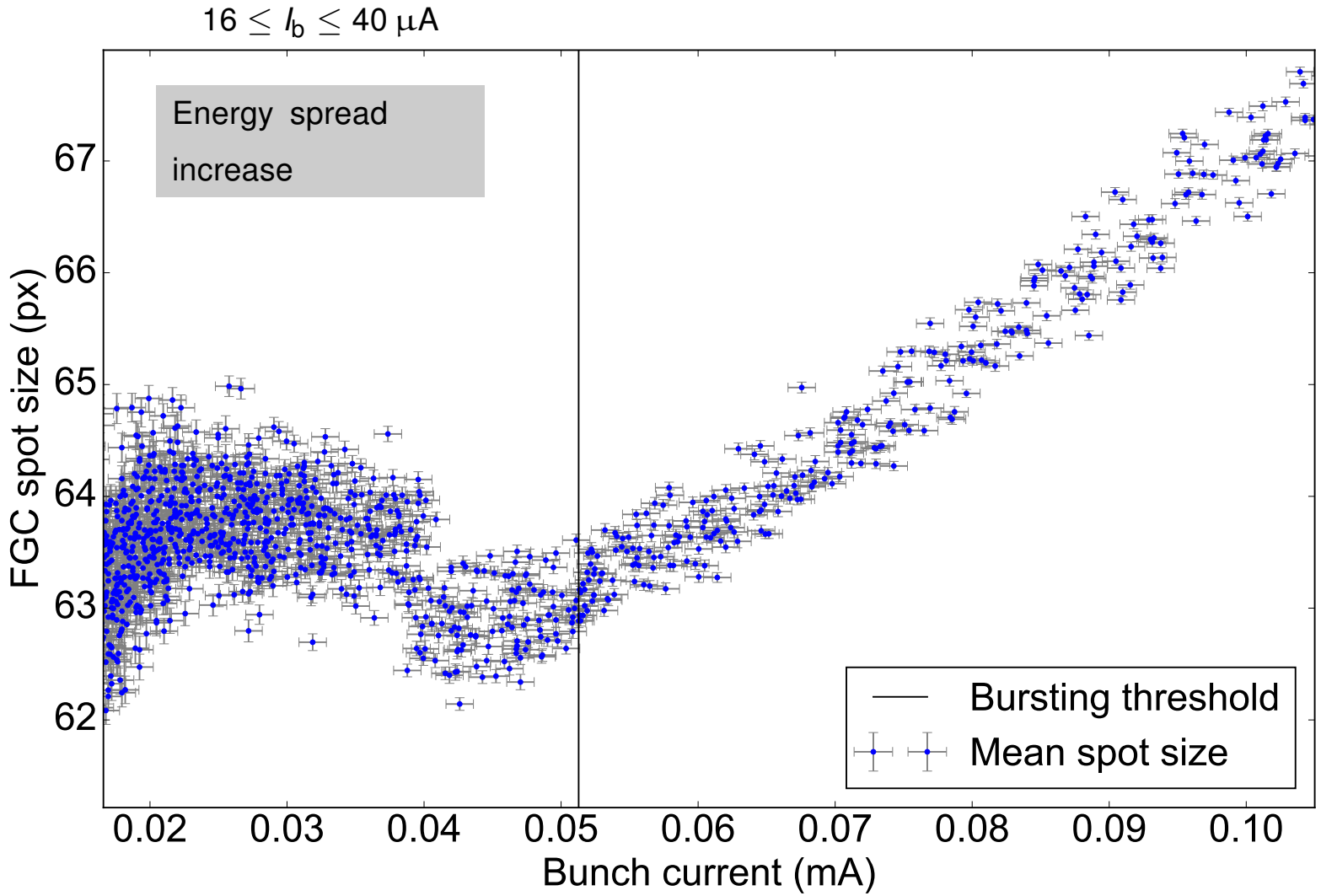

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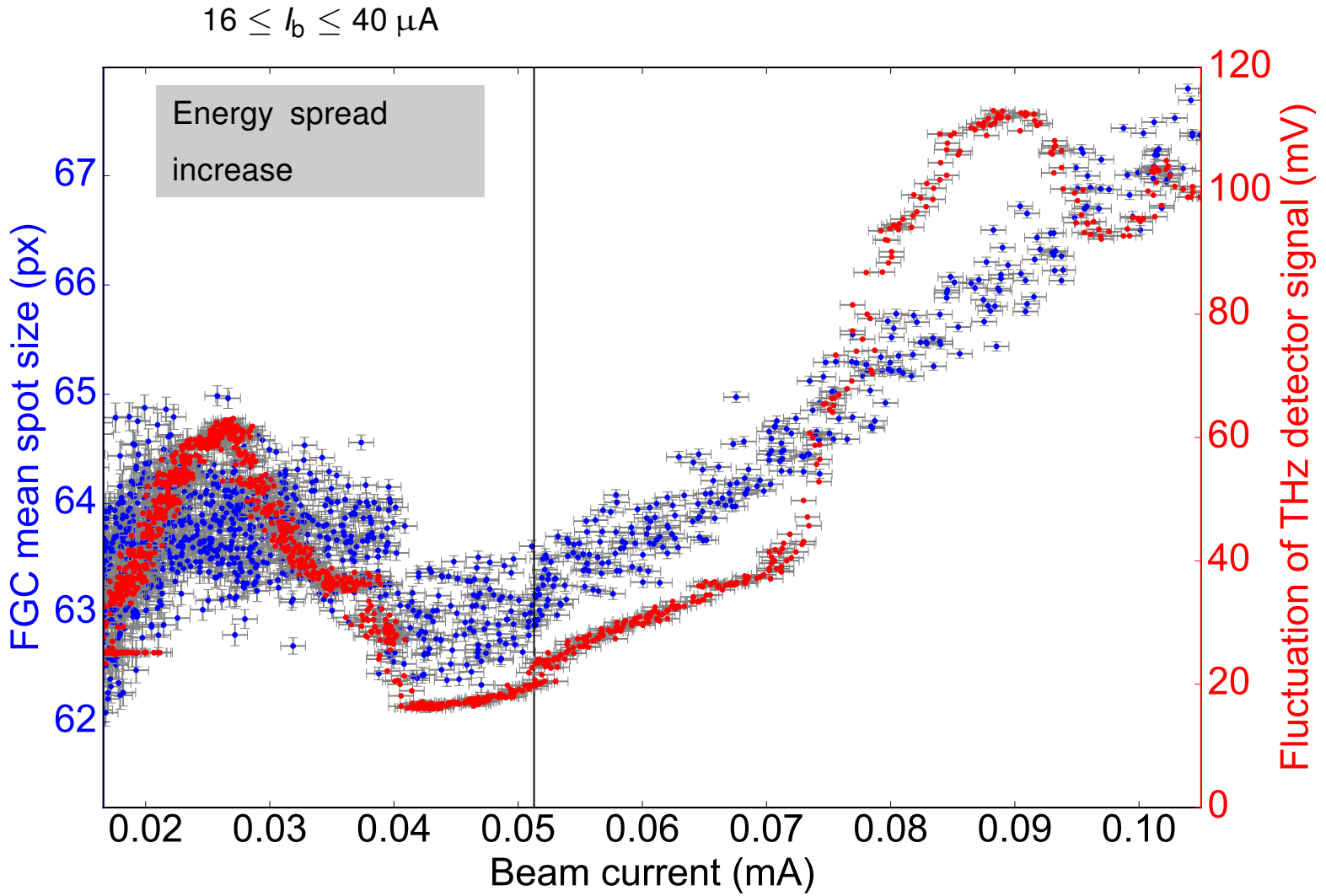

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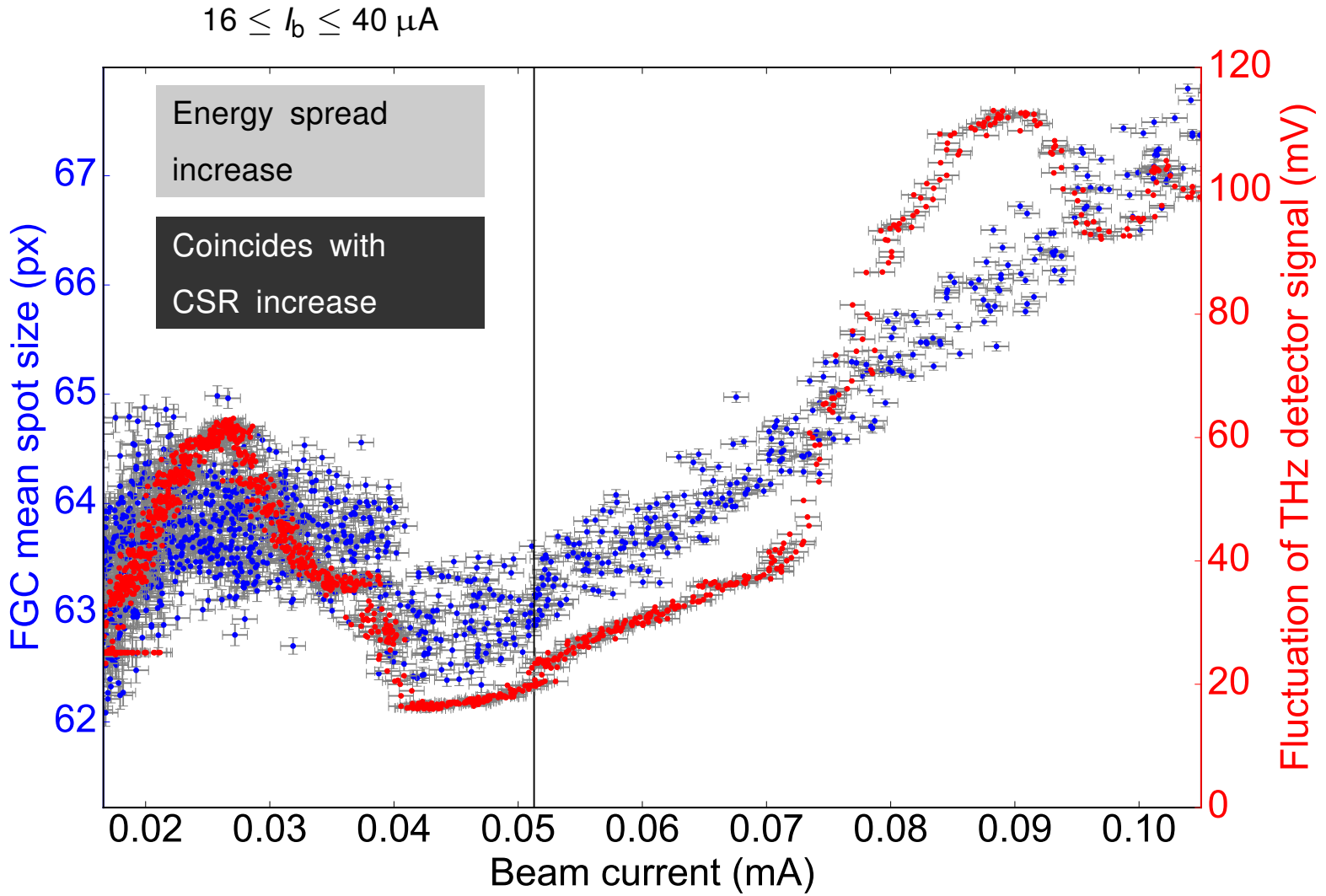

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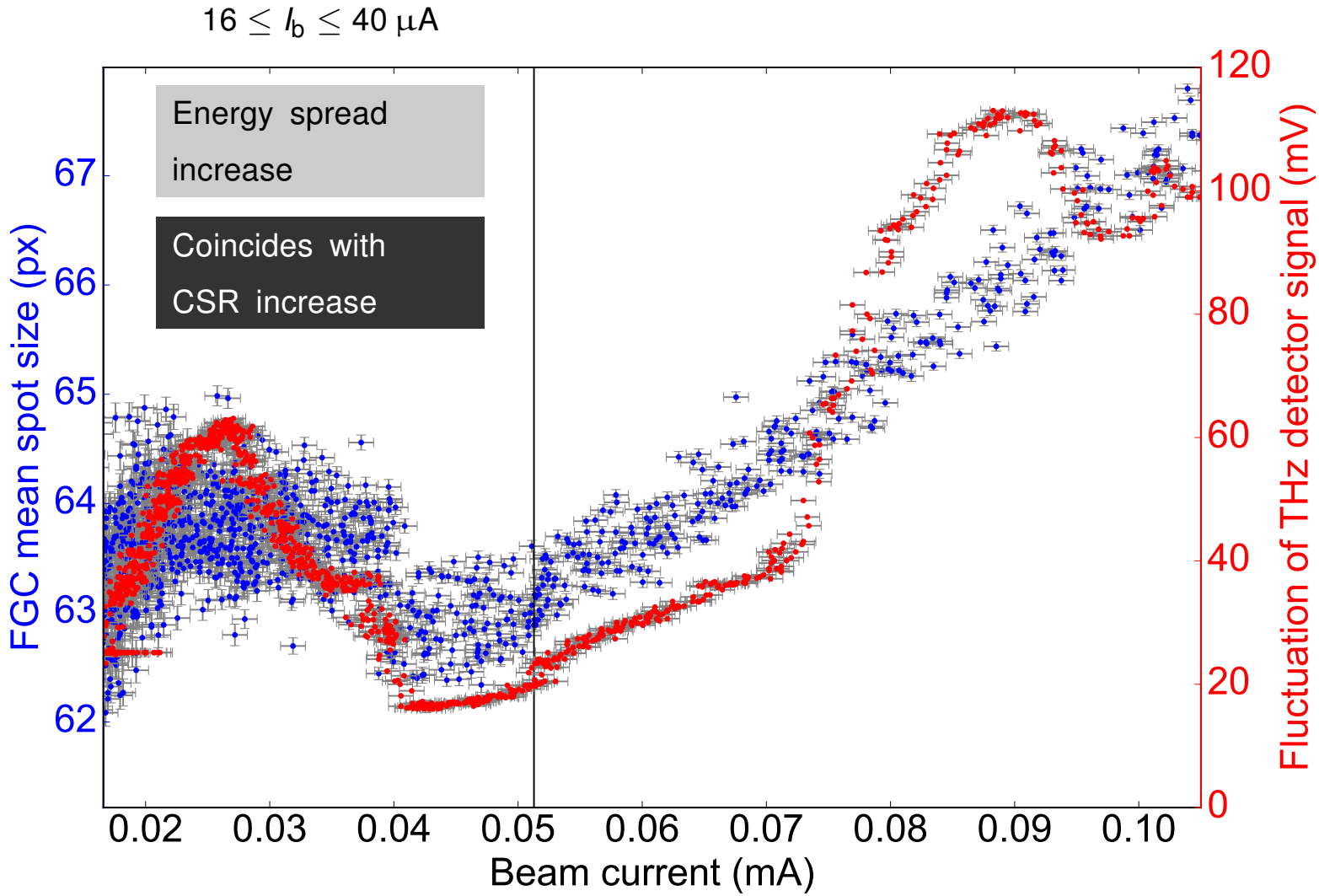

→ Signature of short-bunch length bursting

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- **KIT THz-Team** (from IBPT, IMS, IPE, IPS and LAS):
  M. Balzer, E. Blomley, T. Boltz, A. Borysenko, M. Brosi, E. Bründermann, M. Caselle, C. Chang*, N. Hiller, S. Höninger, M. Hofherr, E. Huttel, K.S. Ilin, V. Judin*, M. Klein*, S. Marsching, Y.-L. Mathis, M.J. Nasse, G. Niehues, A. Plech, J. Raasch, P. Rieger*, L. Rota, R. Ruprecht, M. Schedler, A. Scheuring, P. Schönfeldt, M. Schuh, P. Schütze*, M. Schwarz, M. Siegel, N.J. Smale, B. Smit, J. Steinmann, P. Thoma*, M. Weber, S. Wuensch, M. Yan, and A.-S. Müller
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- Next steps
  - Continuous sampling and data streaming
  - For CSR already possible (KAPTURE)
  - Using a 256-pixel line array for turn-by-turn sampling of a single bunch
  - Longitudinal bunch profile: Electro-Optical Spectral Decoding
  - Horizontal bunch profile: Replace FGC to overcome resolution limit


Thank you for your attention!

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Horizontal plane

Courtesy Paul Schütze