Bunch-by-bunch detection of coherent beam-beam modes with digitized beam position monitor signals

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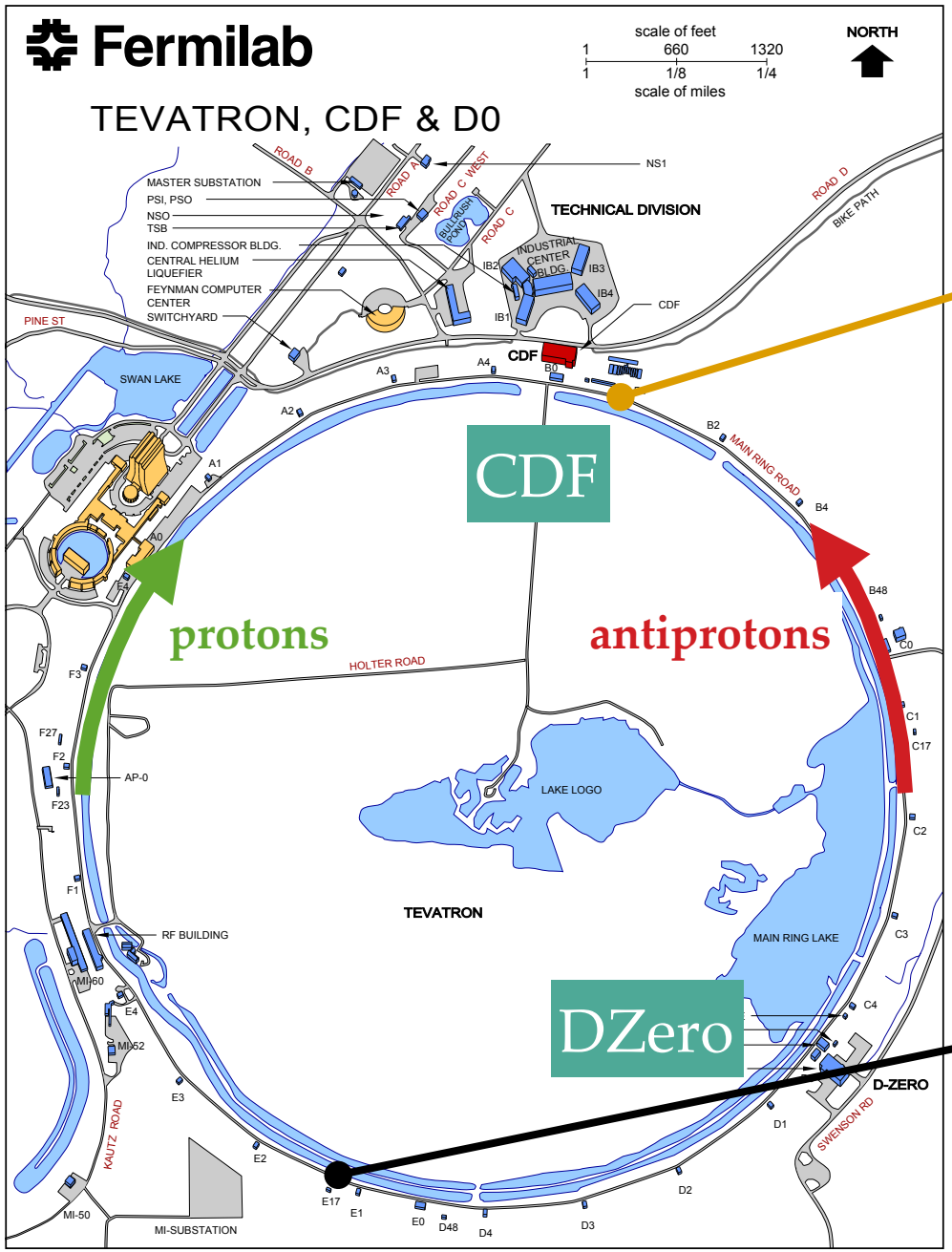
Motivation

- develop new bunch-by-bunch diagnostic for tune distributions
- complement Schottky detectors
- assess effects of Gaussian electron lens for beam-beam compensation
- provide experimental basis for numerical codes

Detection of collective oscillations with single beam position monitor



CDF

DZero

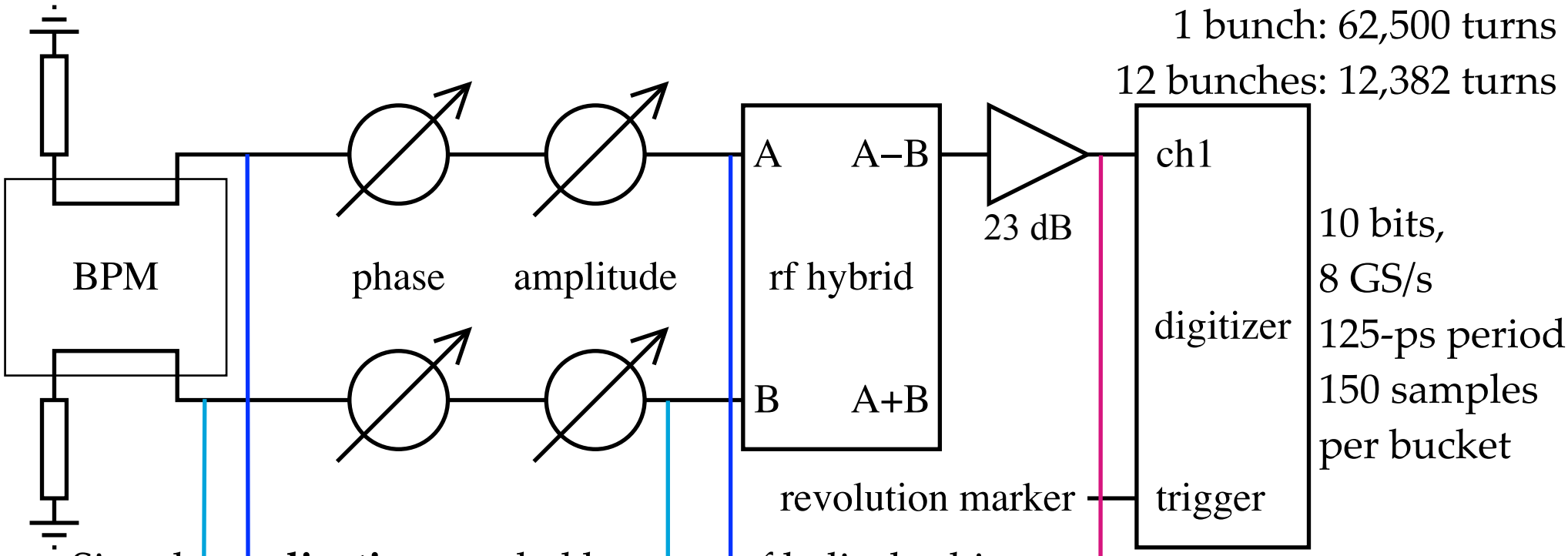
VB11 BPM

Vertical strip-line pickup

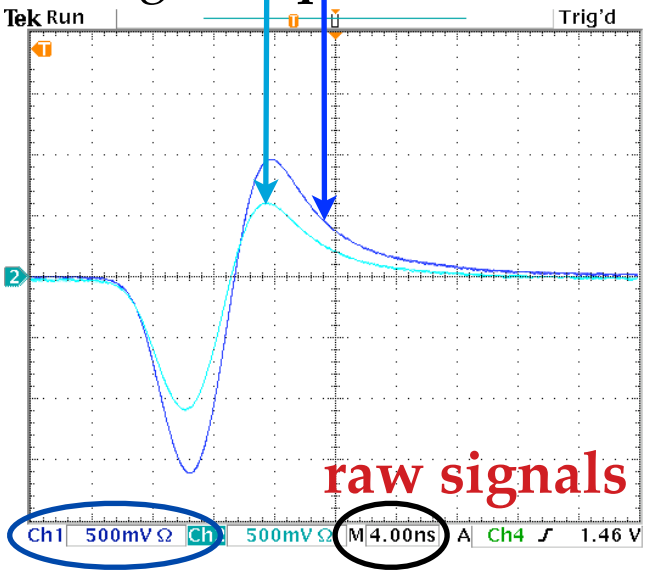
$\beta_y = 880$ m

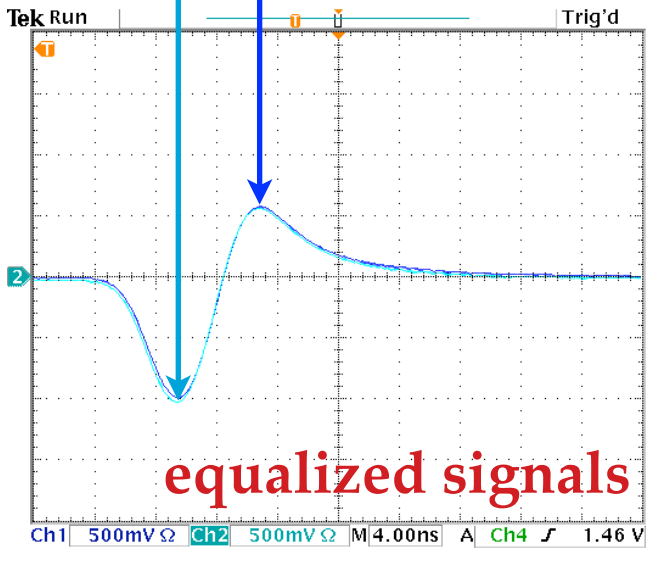
If necessary, signal enhanced by a few watts of band-limited noise applied for 1 s
(No adverse effects on beams even at high luminosity)

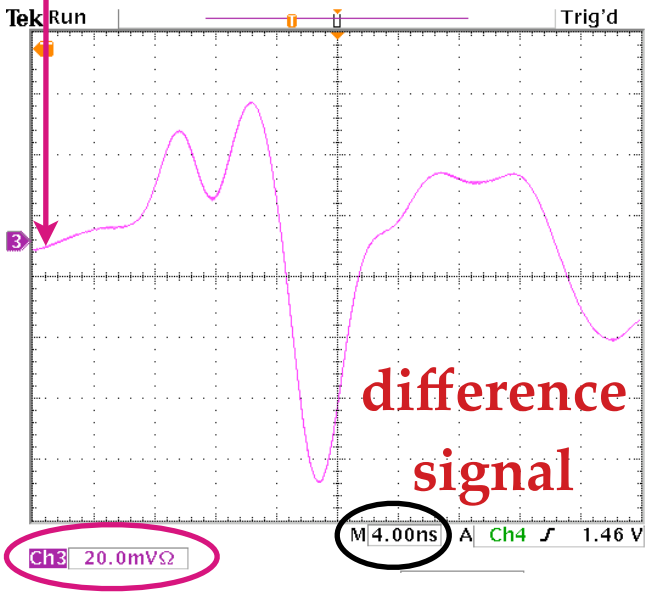
Apparatus



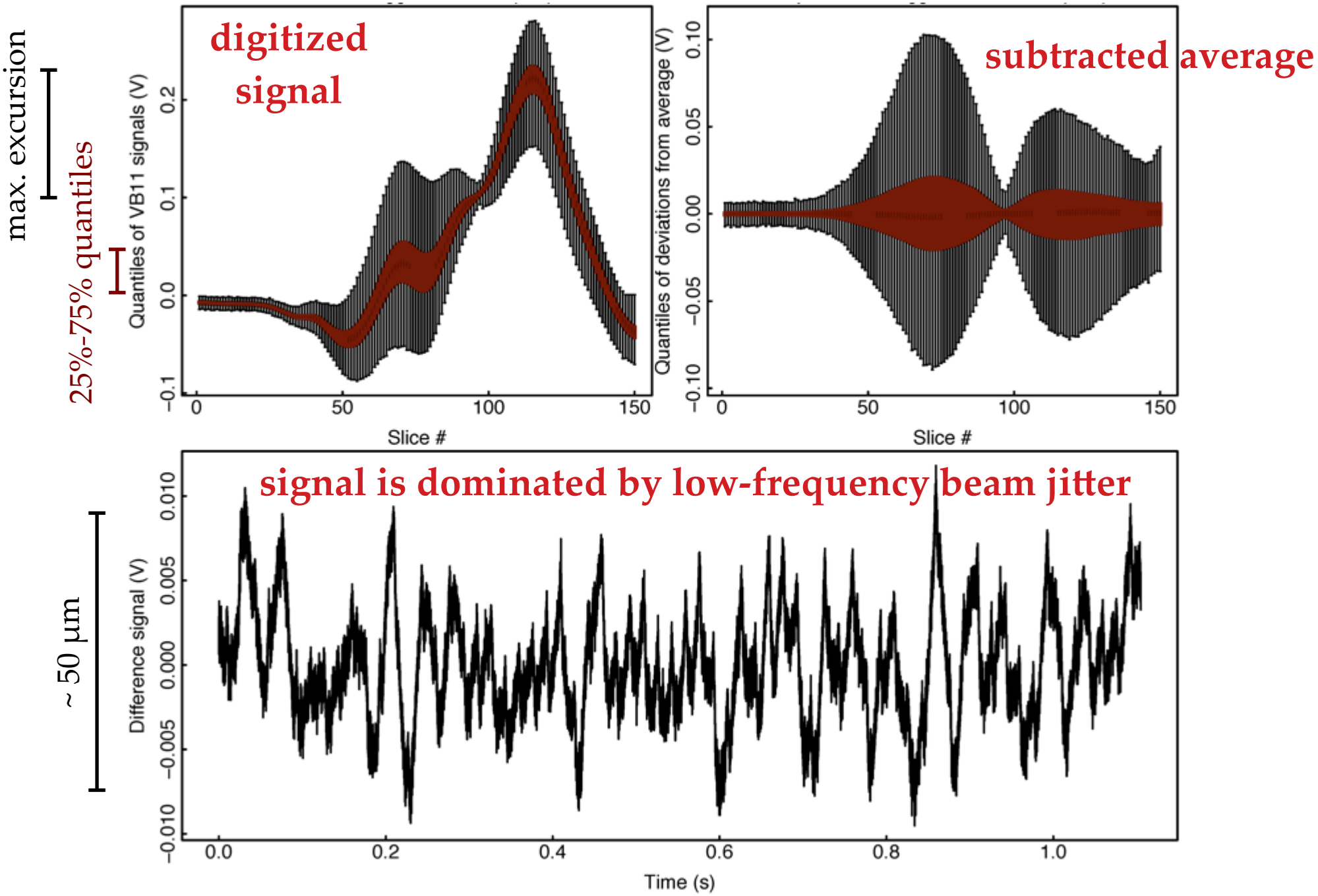
Signal **equalization** needed because of helical orbits



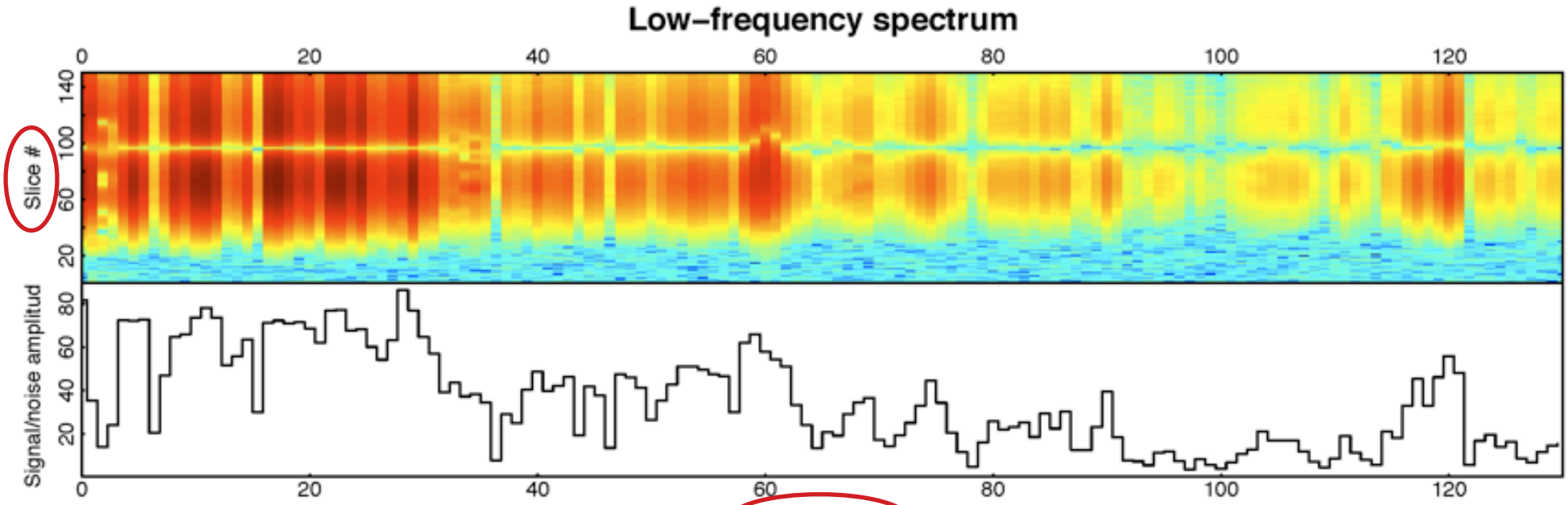




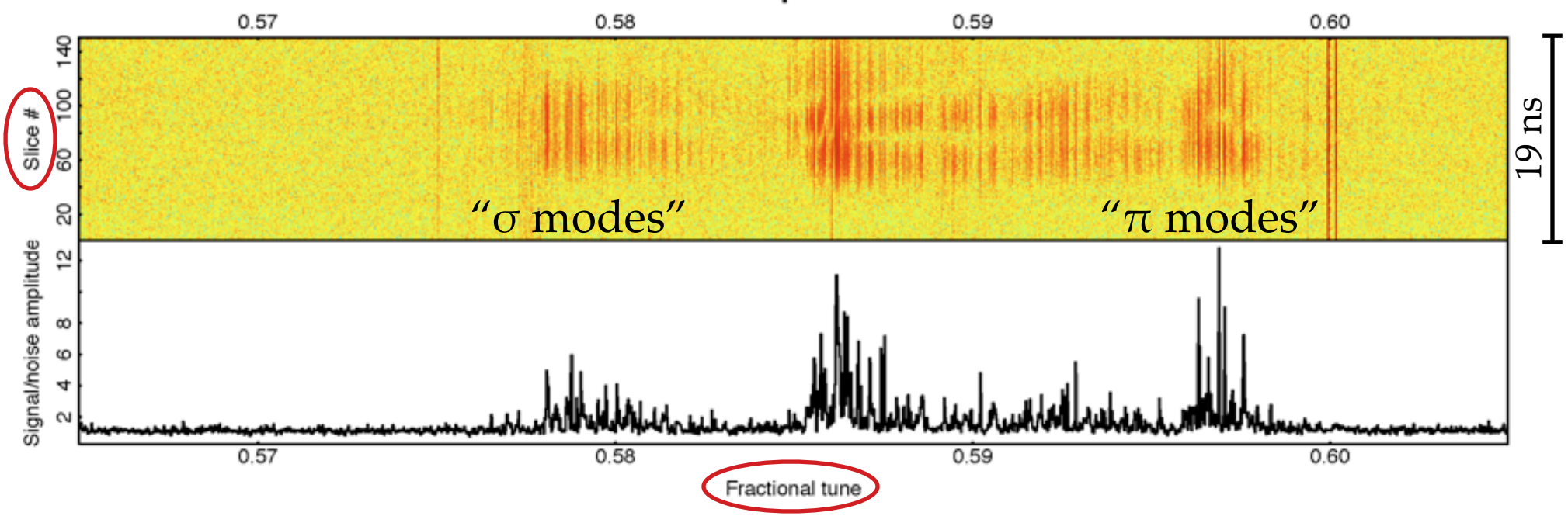
Data analysis



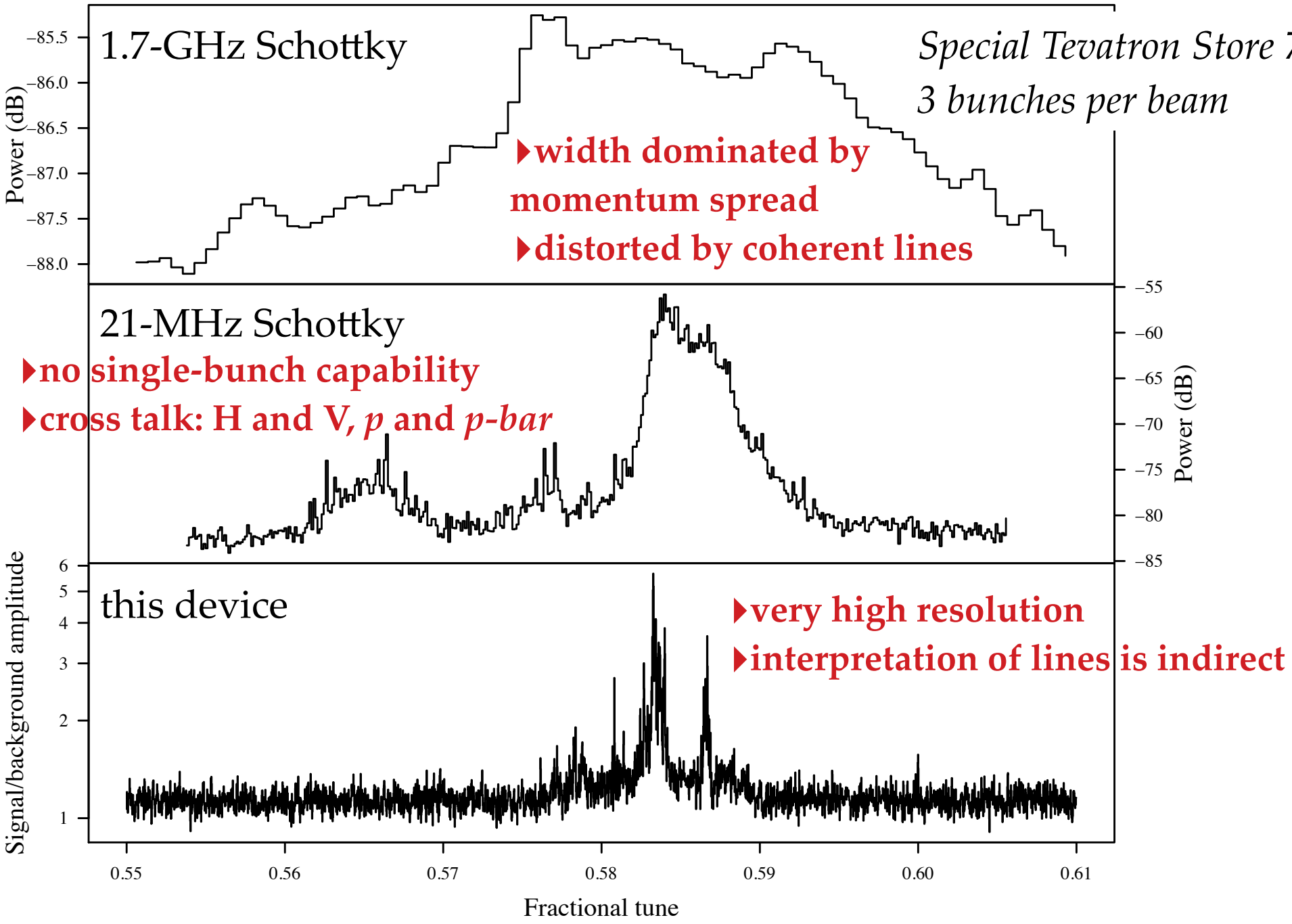
Frequency spectrum of coherent oscillations within a bunch



Tevatron collider Store 7754

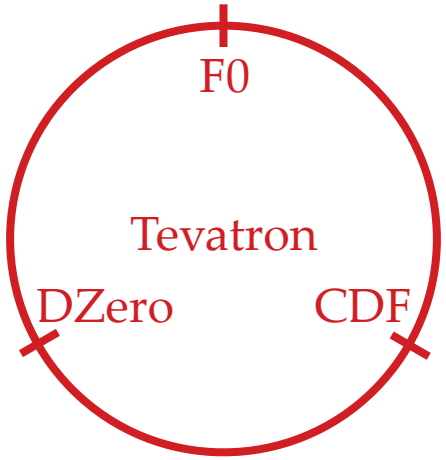


Comparison with Schottky detectors

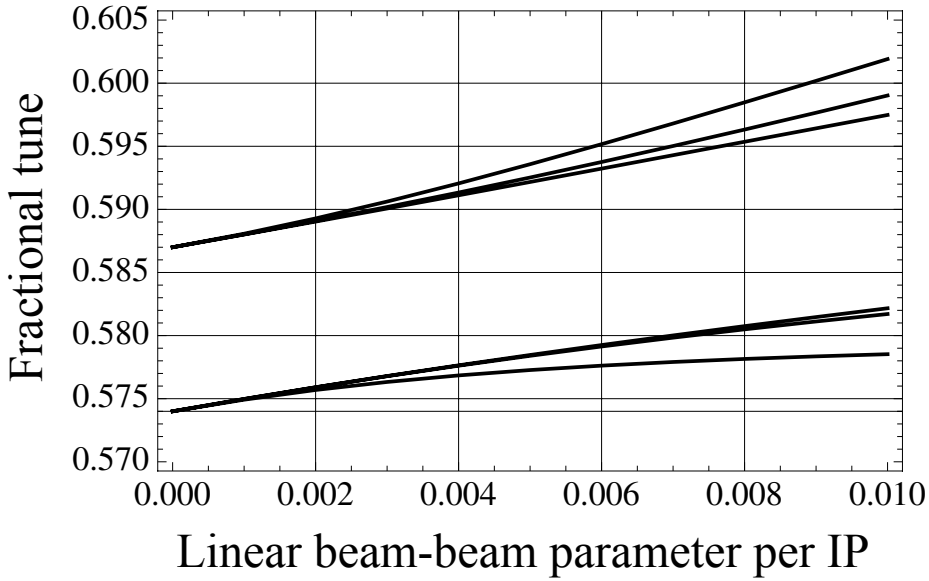


Models of coherent beam-beam oscillations

(a) Rigid-bunch approximation



Normal modes vs. beam-beam strength

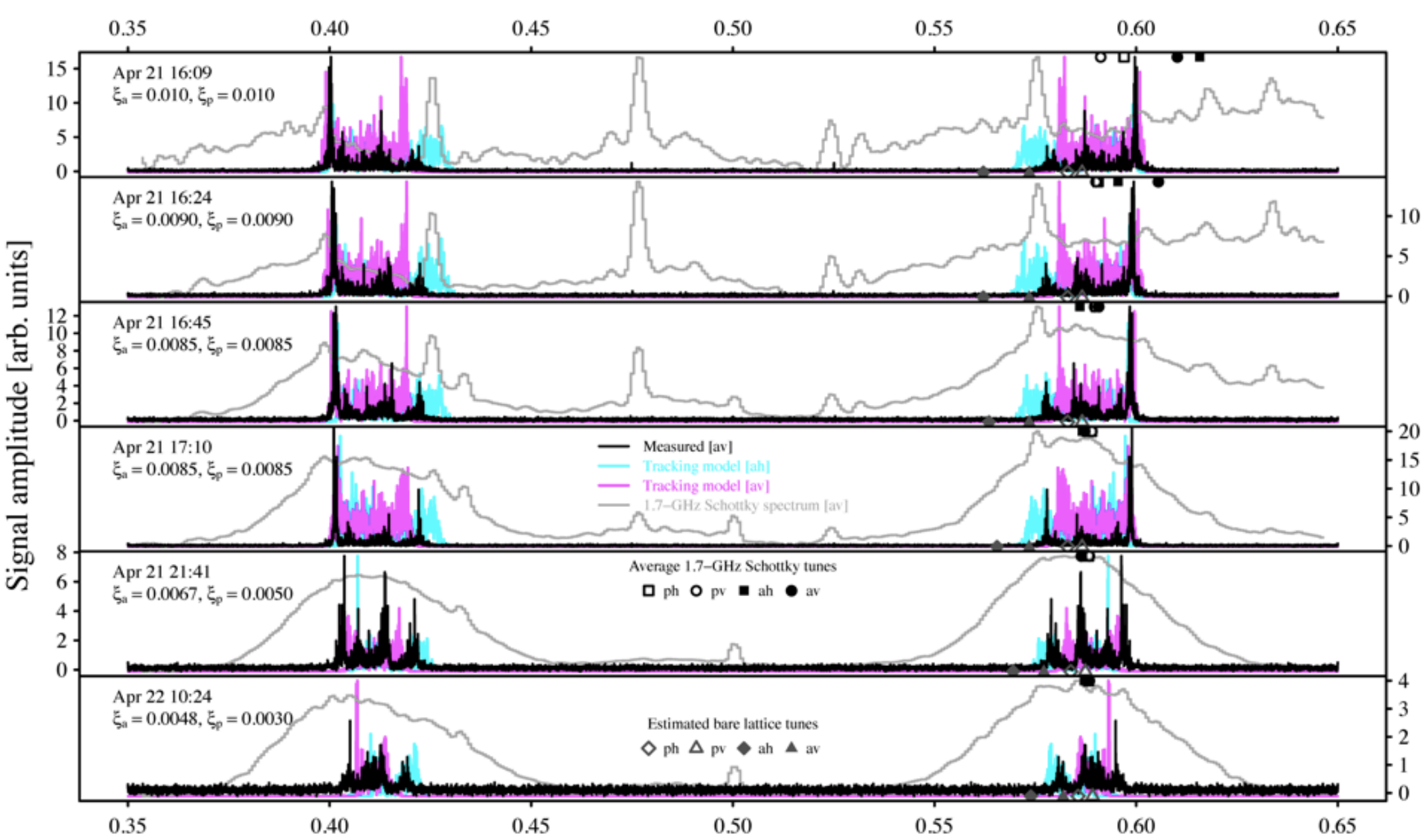


(b) 3D numerical parallel code

BeamBeam3D

- self-consistent field calculations
- multiple bunches
- linear transfer maps between IPs
- no coupling in these examples

Evolution of frequency spectra during collider store (wide span)



BPM measurement

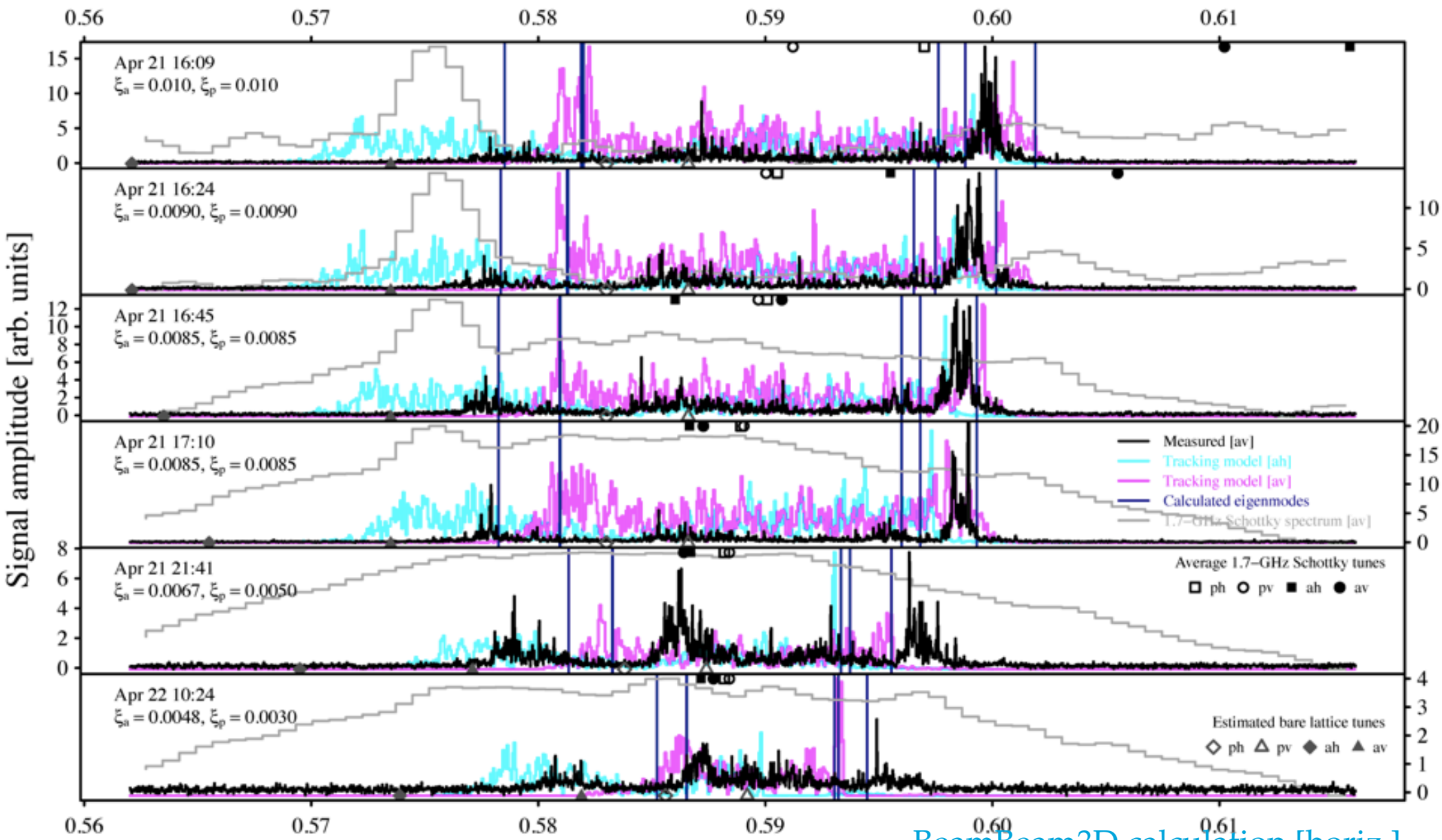
1.7-GHz Schottky

Fractional tune

BeamBeam3D calculation [horiz.]

BeamBeam3D calculation [vert.]

Evolution of frequency spectra during collider store (narrow span)



BPM measurement

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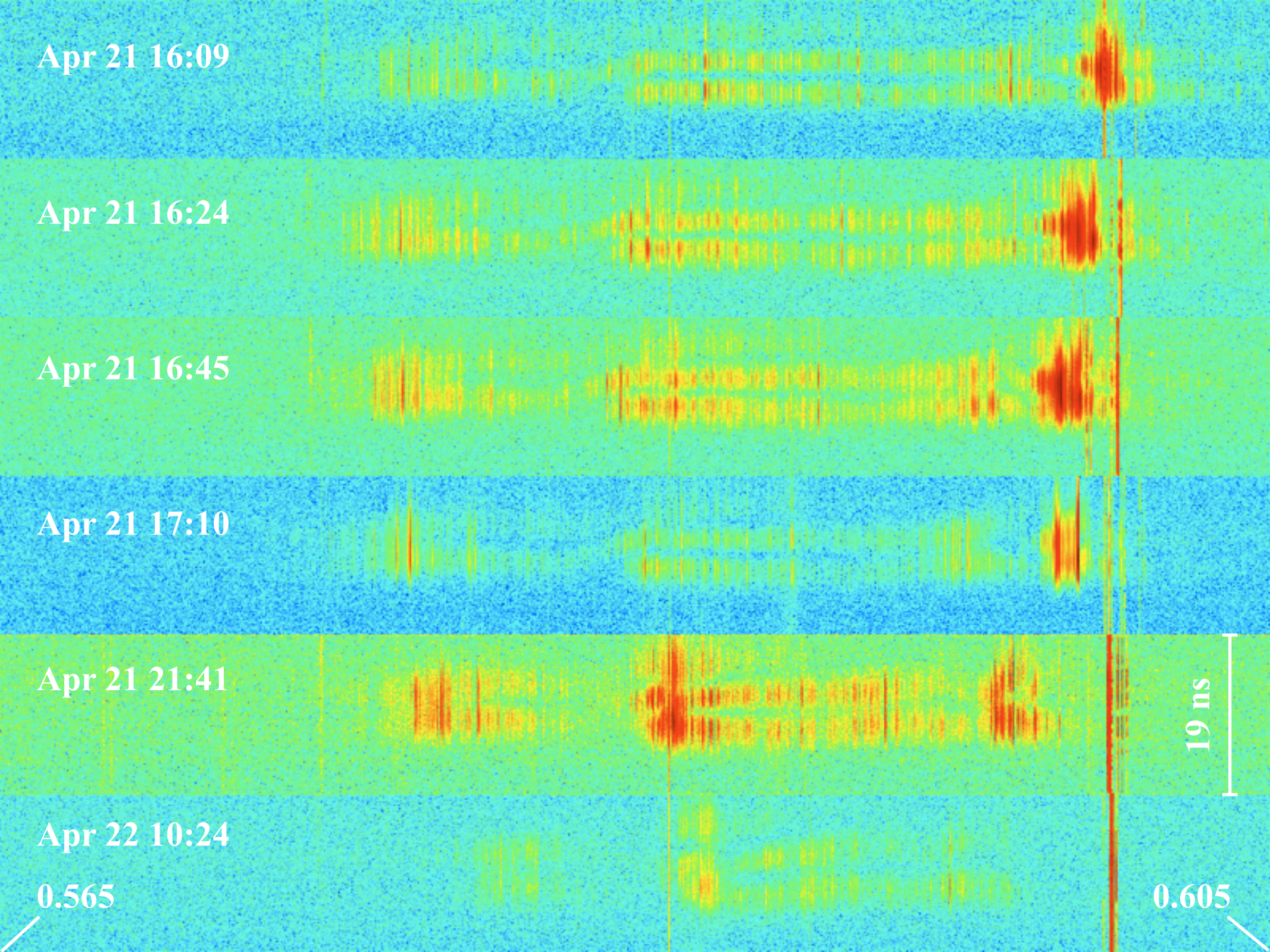
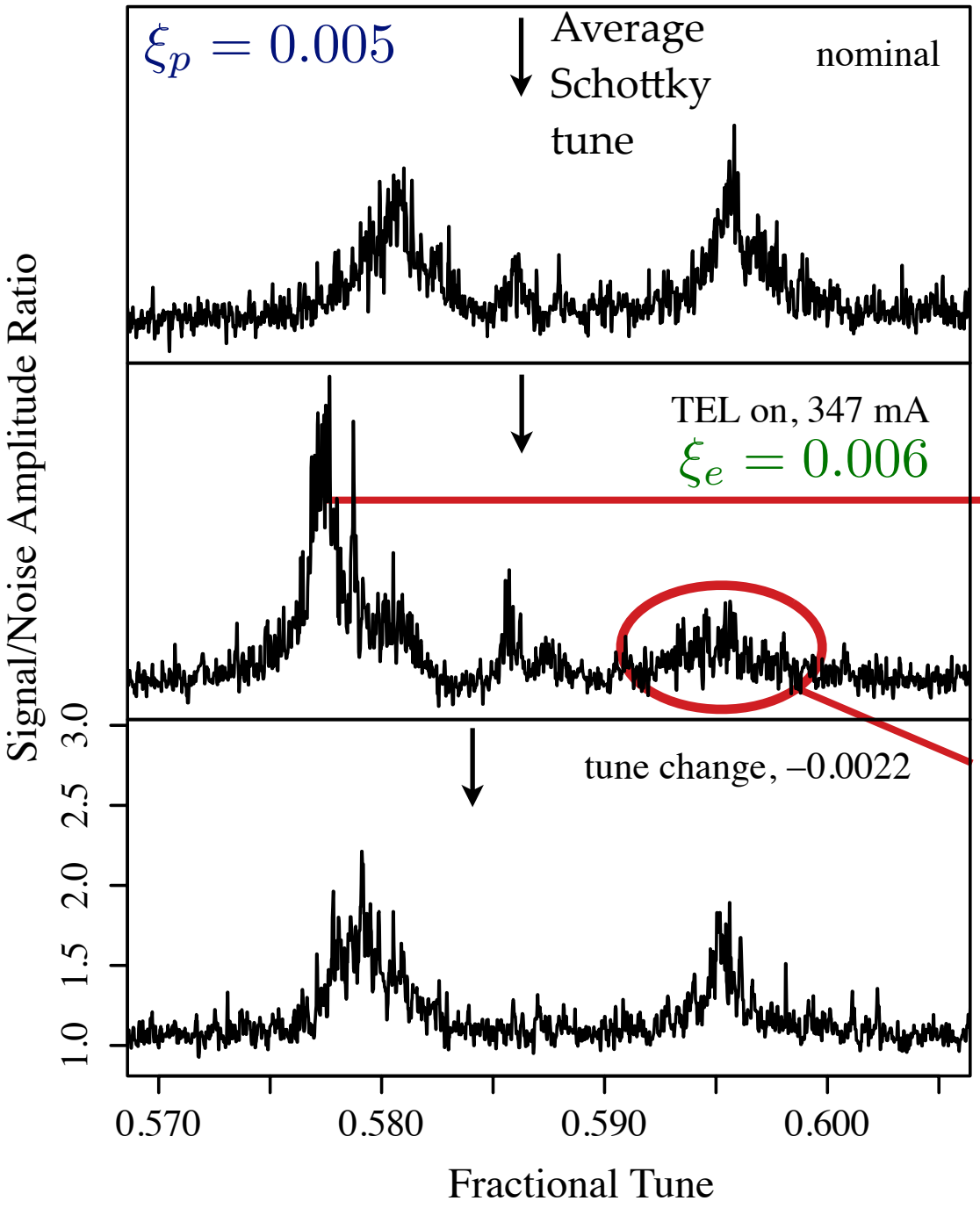
BeamBeam3D calculation [horiz.]

BeamBeam3D calculation [vert.]

Rigid-bunch model


Apr 21 16:09
Apr 21 16:24
Apr 21 16:45
Apr 21 17:10
Apr 21 21:41
Apr 22 10:24
19 ns
0.565
0.605

Effects of Gaussian electron lens in regular collider store



Tune shift of first eigenmode
Change in tune spread?

Suppression of second eigenmode

Interpretation requires calculation of mode strengths and widths

Conclusions

- Developed diagnostic tool for **detection of coherent beam oscillations** based on digitized signals from a **single BPM** in high-amplitude region
- **Features**:
  - short response time (seconds)
  - high frequency resolution (1.6×10^{-5} in fractional tune)
  - high sensitivity (tens of nanometers)
  - low background
  - may require beam excitation with band-limited noise (a few watts)
  - only used manually so far
- Selected **results**:
  - observed evolution of coherent beam-beam modes during collider store
  - coherent oscillations in Tevatron were stable, likely because of asymmetric intensities and tunes, and chromaticity
  - compared with linear rigid-bunch model and strong-strong tracking code
- Observations under other experimental conditions in Stancari and Valishev, Phys. Rev. ST Accel. Beams **15**, 041002 (2012)

Thank you