Instability Observations via Streak Camera and PMT

J. Flanagan

KEKB Review

2003.2.10

Studies of photo-electron cloud induced vertical beam blow-up in the LER

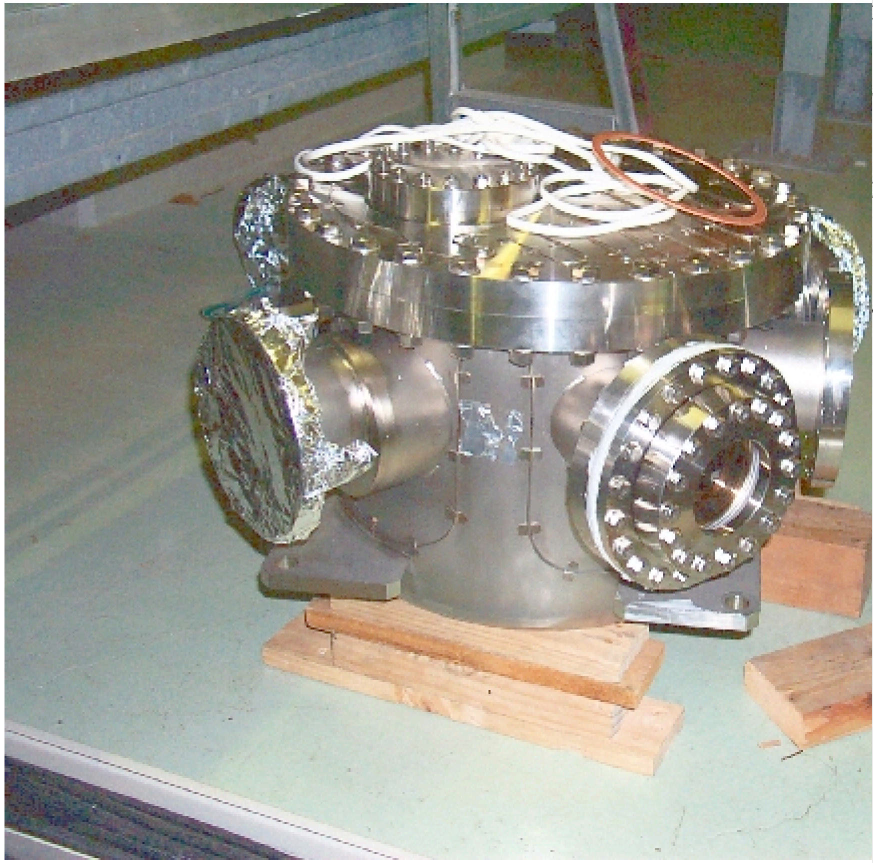
S. Hiramatsu, T. Mitsuhashi, H. Fukuma, H. Ikeda, M. Masuzawa, J. Flanagan

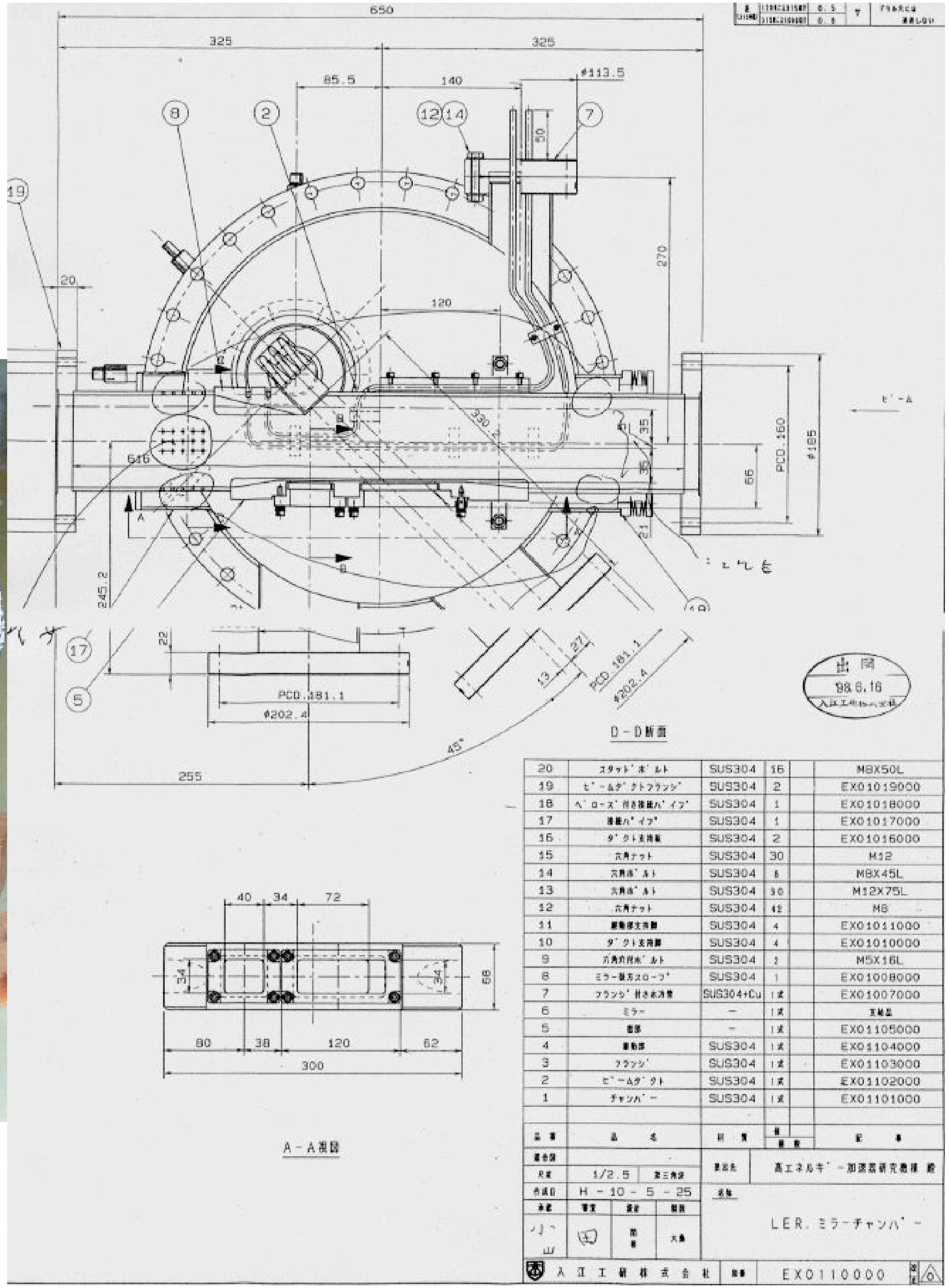
- Goal: Try to see details of proposed blow-up mechanisms
  - Bunch shape distortions
  - Spectrum (quadrupole peak)
- Methods:
  - Streak Camera: October 2002
  - PMT + BPM data: January 2003

Hardware Improvements

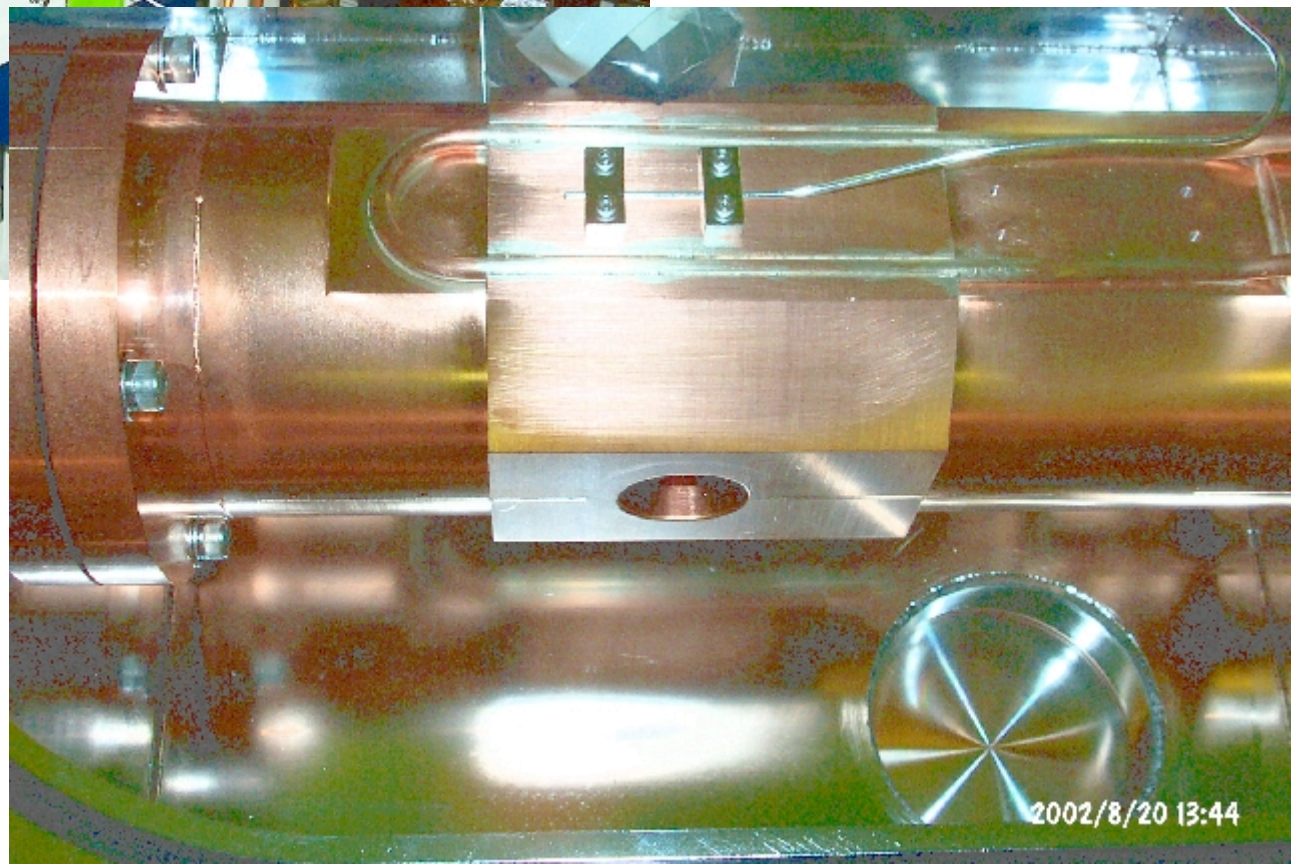
- New SR extraction chamber in LER
  - Beam-pipe section changed from stainless steel to copper, reducing resistive wall heating and improving stability of extraction mirror mount, and eliminating the need for optical axis feedback compensation with changing beam currents. Also makes study measurements much easier.
  - Similar replacement planned for HER in summer 2003.

Old LER SR Extraction Chamber
1998 - 7/2002





New LER SR
Extraction
Chamber
8/2002 -

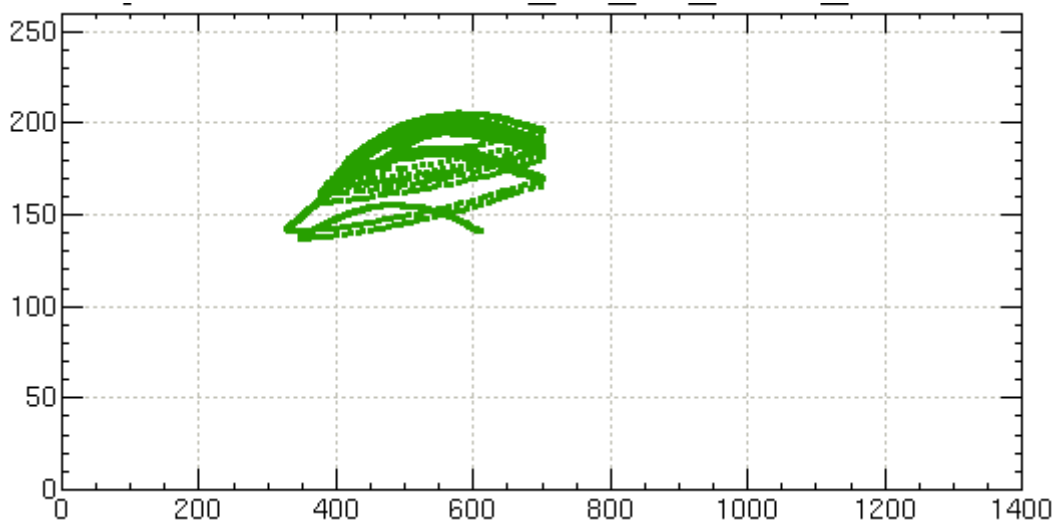


Beam-Pipe Temperature

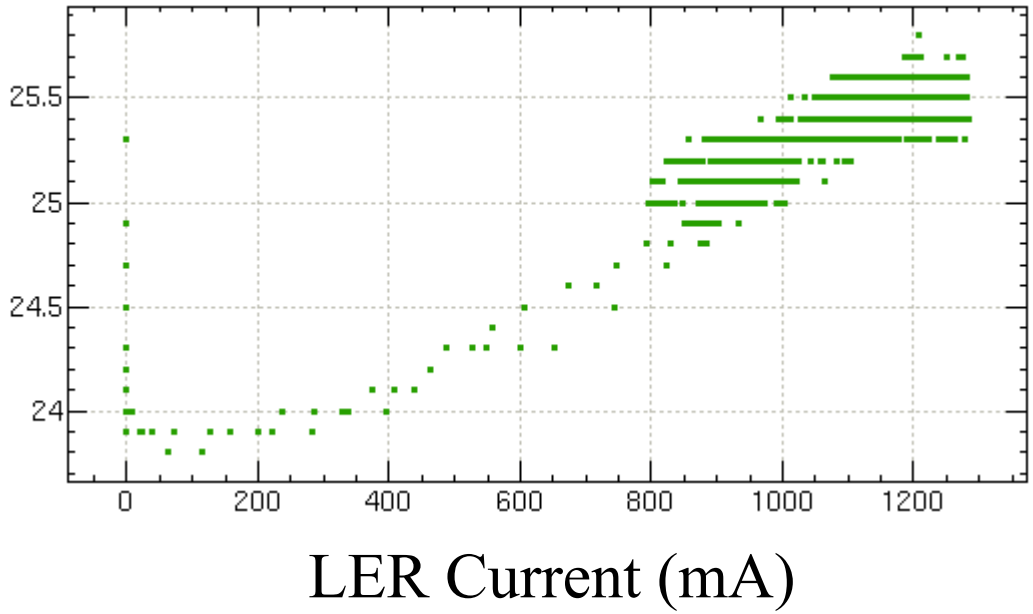
SUS: Resistive losses at
1 A → ~20 W → 100°/10cm

Cu: 1/40-1/50 of SUS

Old Chamber



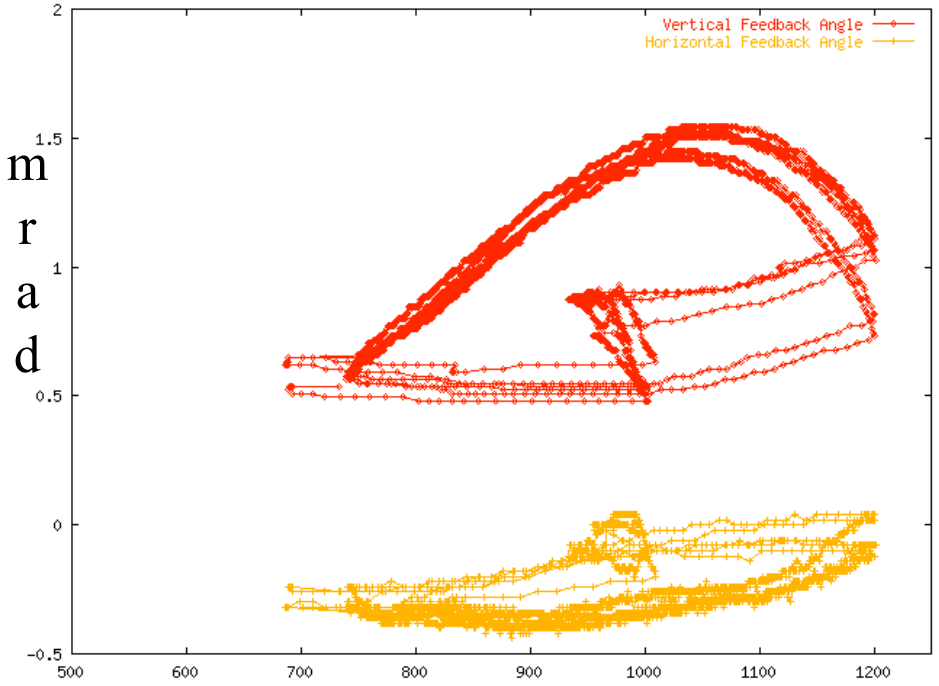
New Chamber



Extraction Mirror Orientation

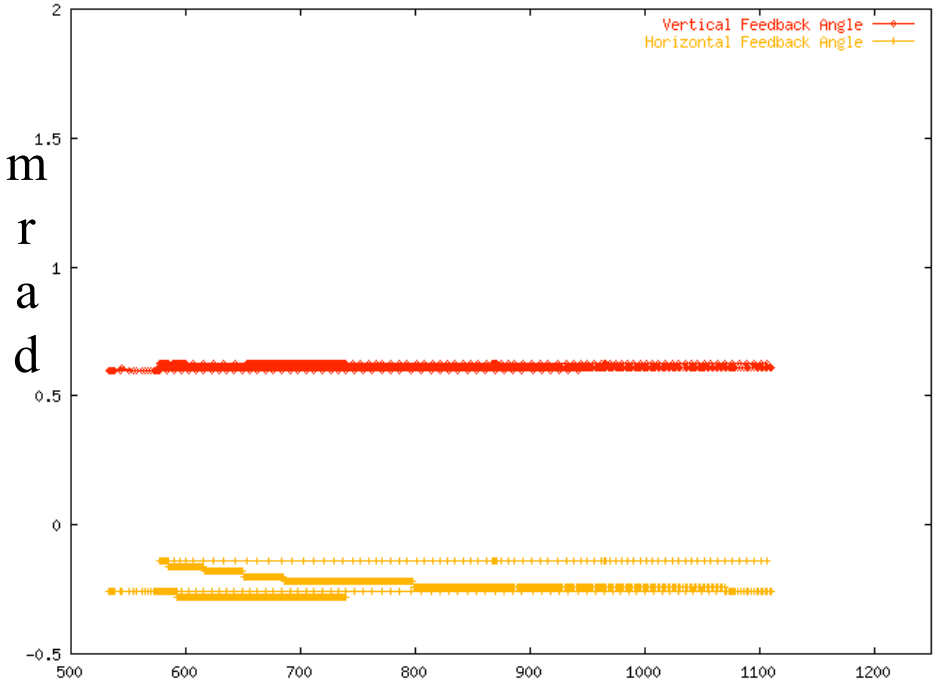
Optical-axis feedback compensation angles

Old Chamber



LER Current (mA)

New Chamber



LER Current (mA)

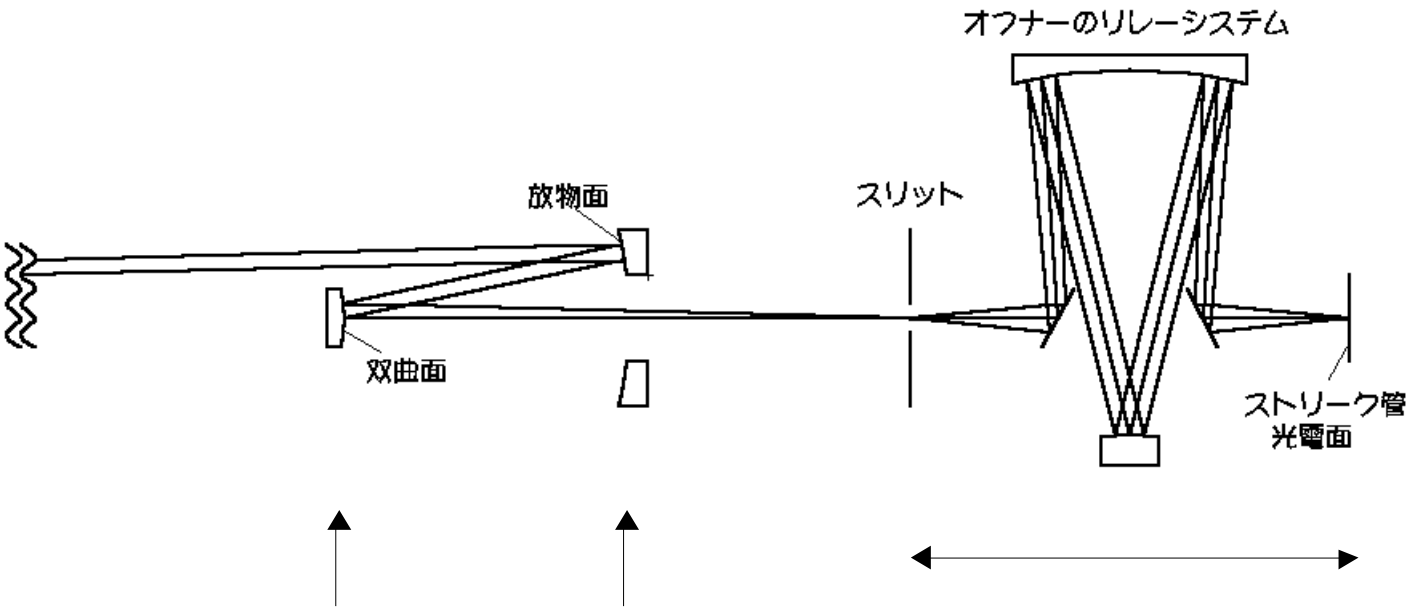
•Optical-axis feedback is now unnecessary, turned off in LER

Hardware Improvements (cont.)

- Reflective optics system for streak camera
  - Use of focusing mirrors instead of lenses eliminates chromatic aberration, making bandpass filtering unnecessary and greatly increasing light intensity of beam image.
  - Single bunch/single turn images now easily obtained with streak camera.

Reflective Optics for Streak Camera

Designed by T. Mitsuhashi



Hyperbolic mirror

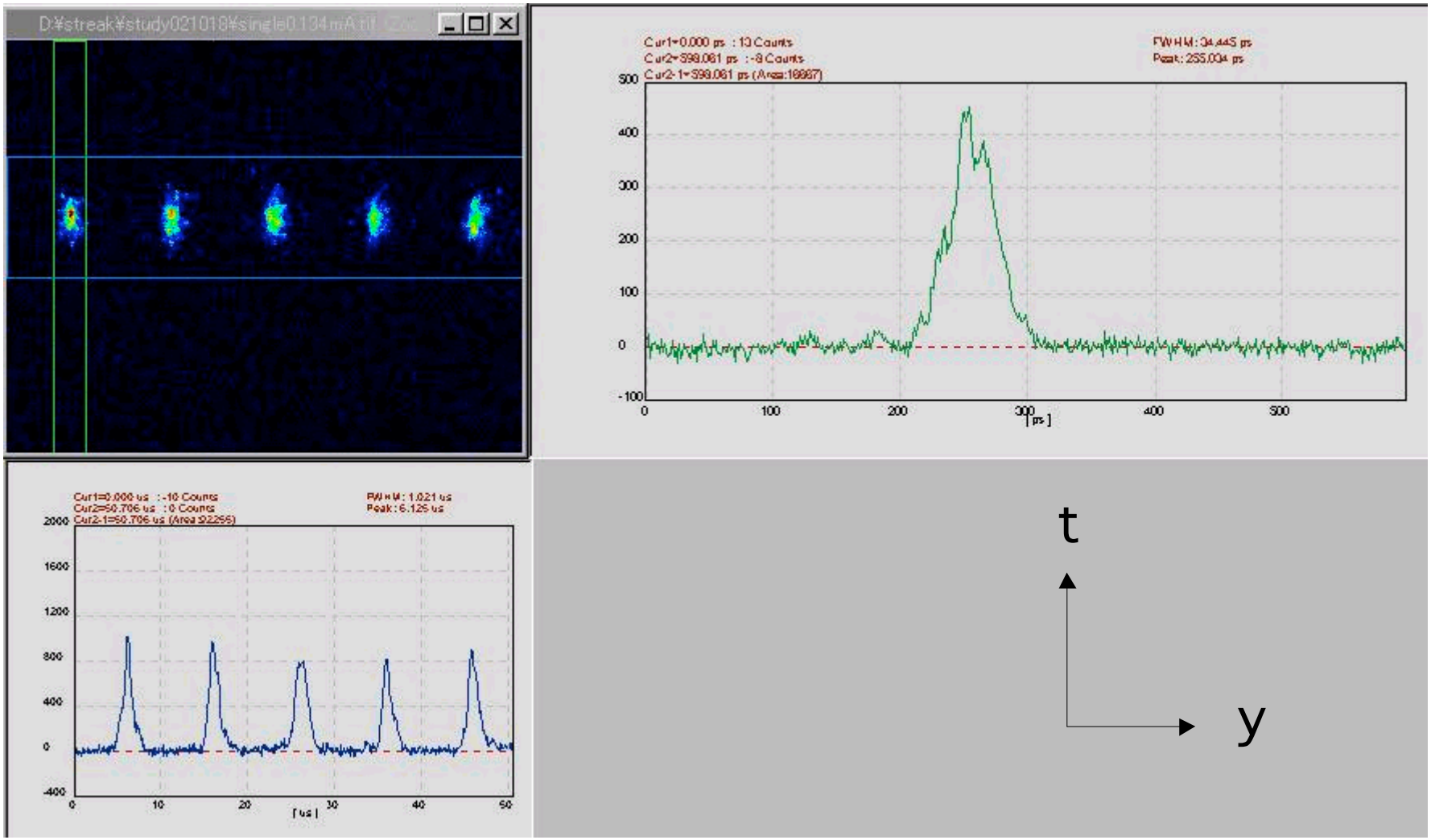
Parabolic mirror

Streak camera internal relay optics (custom-made)

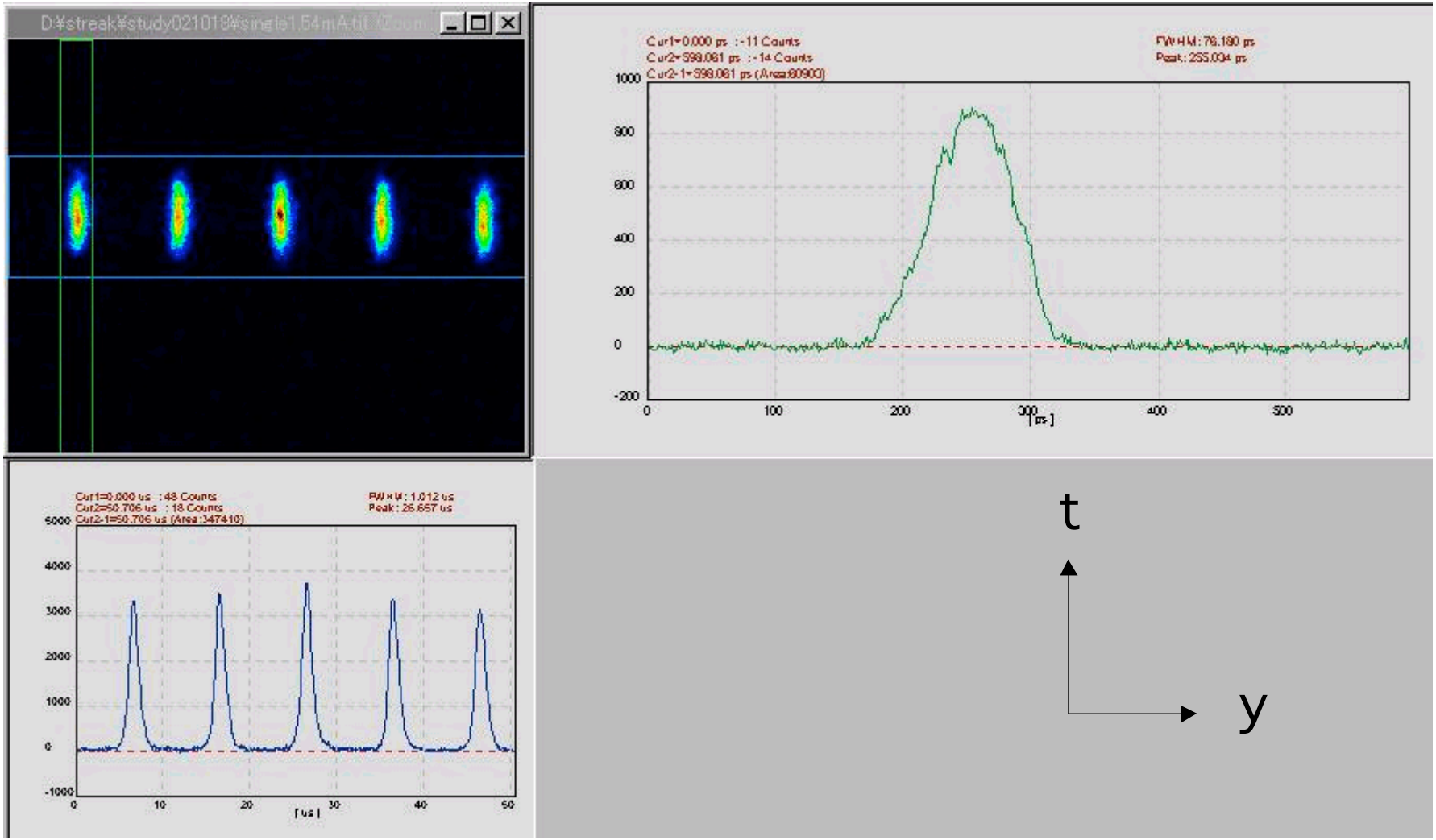
Streak Camera Observations

- Observation date: 2003.10.18
- Beam conditions:
  - LER single-beam
  - Single bunch
    - Bunch length measurement
  - 2 trains, 140 bunches/train
    - Bunch length measurement
    - Bunch shape observation
    - 4 bucket spacing (8 ns) between bunches

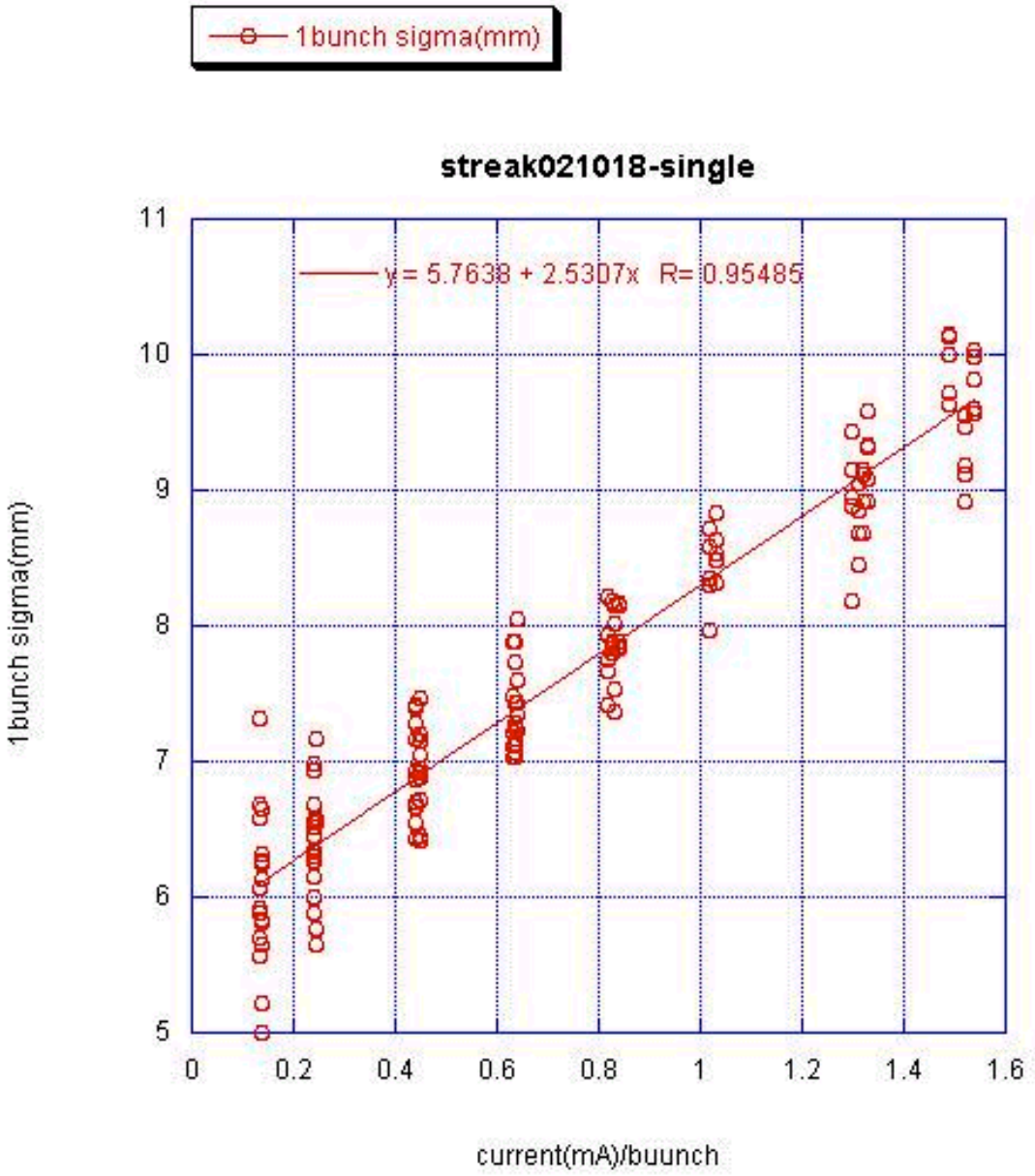
Single Bunch, 0.134 mA



Single Bunch, 1.54 mA



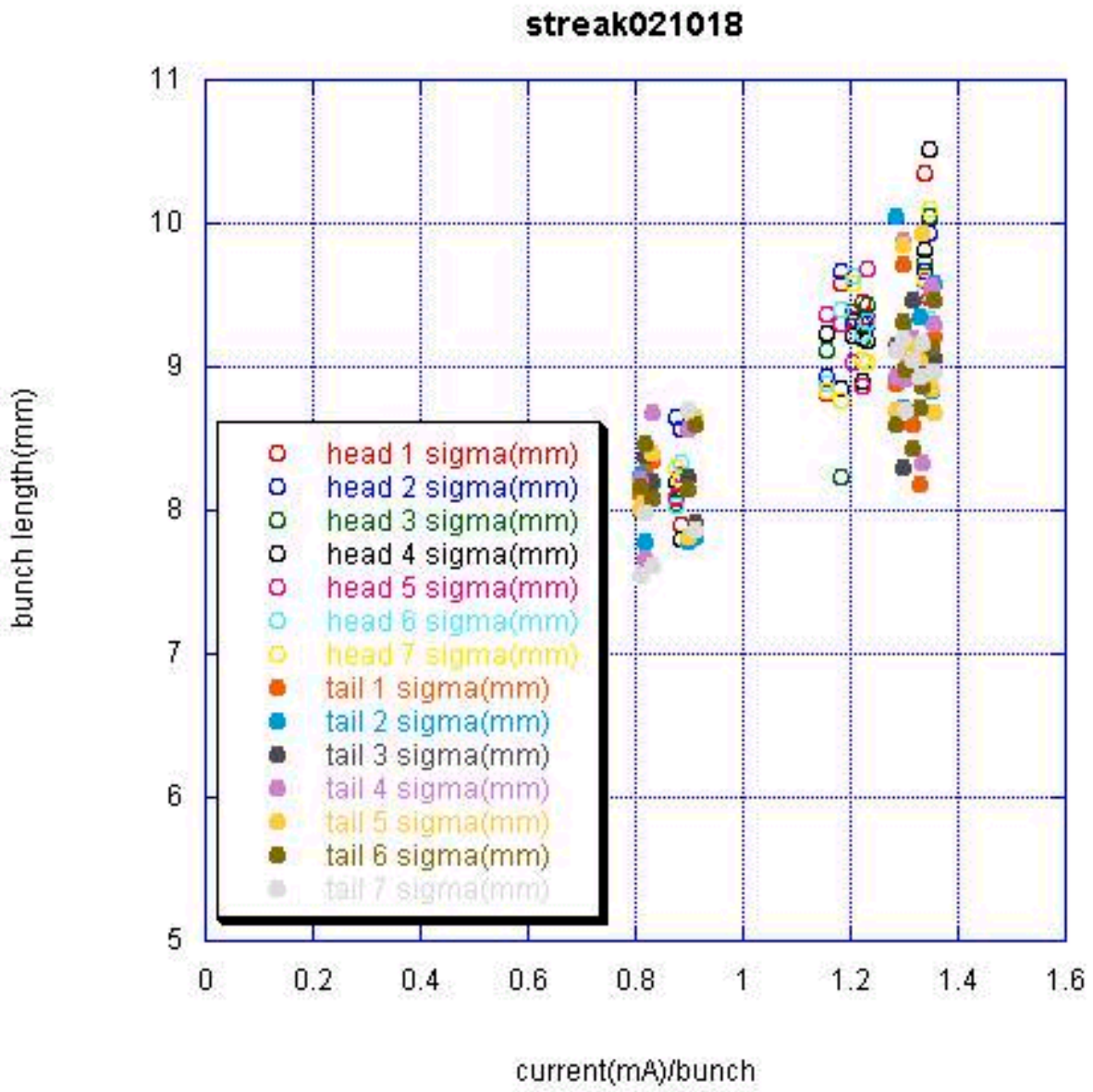
Single-bunch dependence of length on bunch current



H. Ikeda

•Natural bunch length = 5.8 mm.

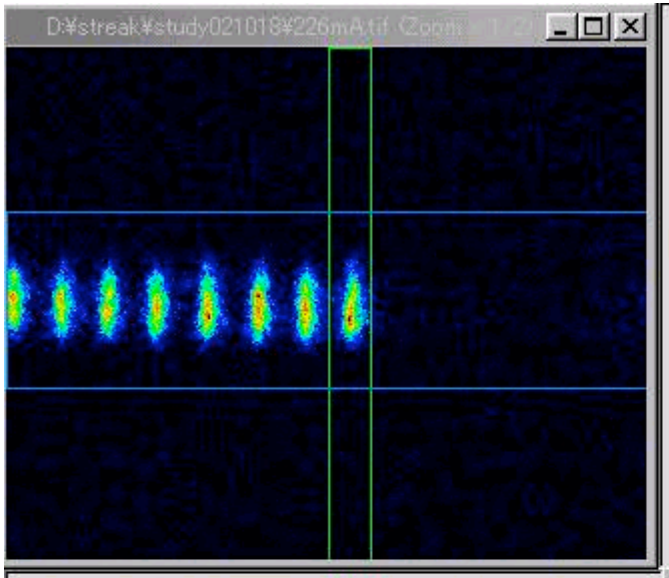
Bunch length at head and tail of train

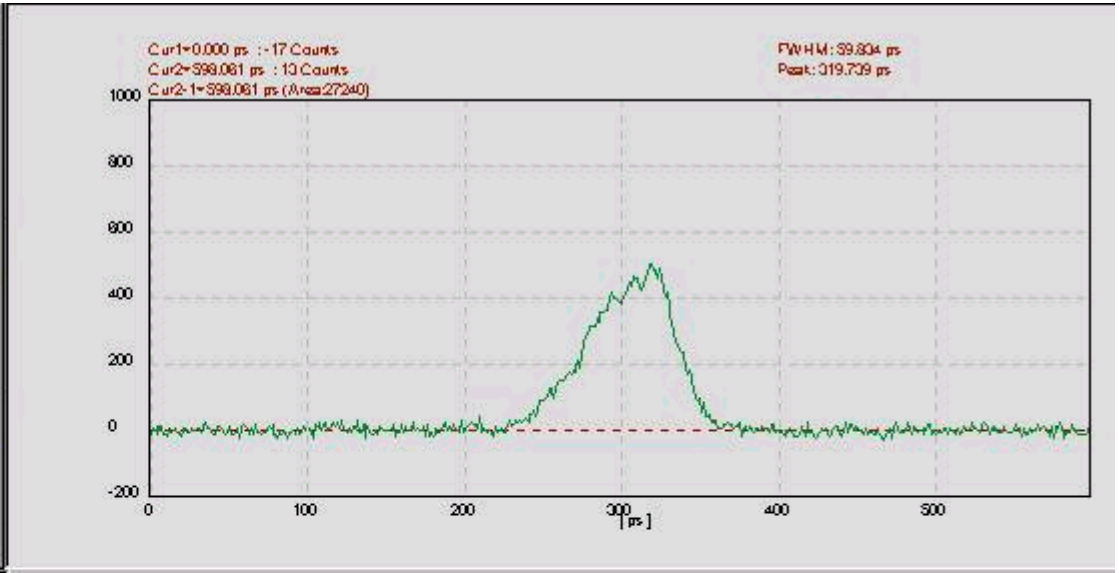


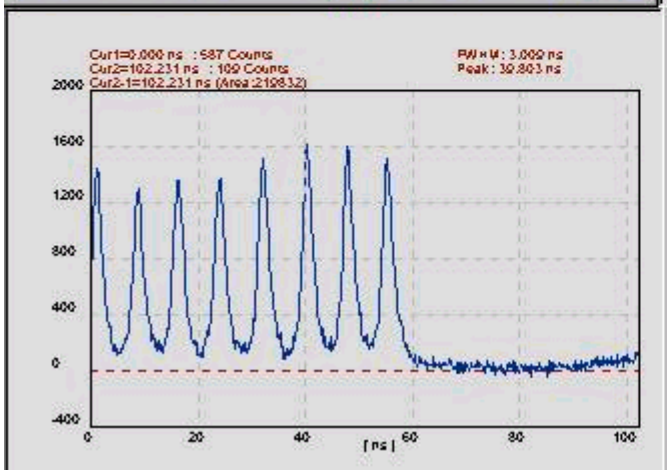
H. Ikeda

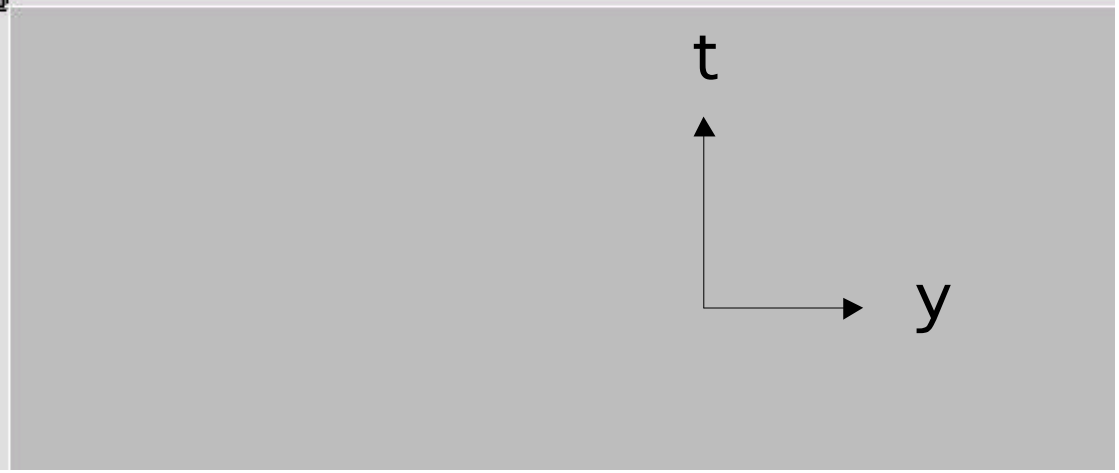
•At high current bunch length longer at head than at tail of train.

226 mA (0.81 mA/bunch)
Tail of Train

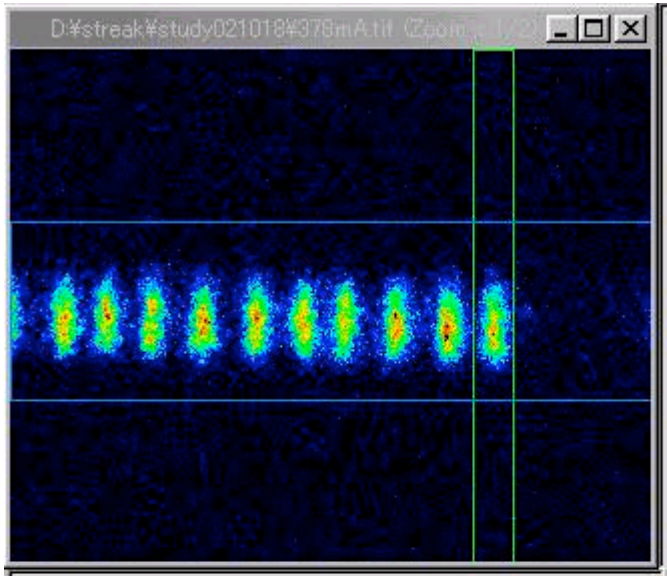


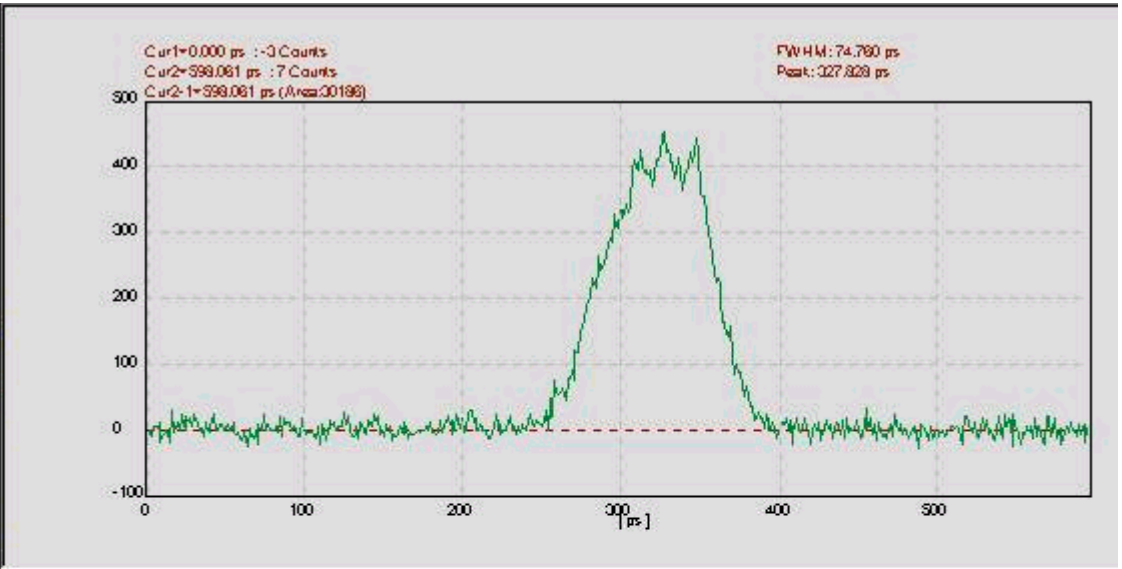


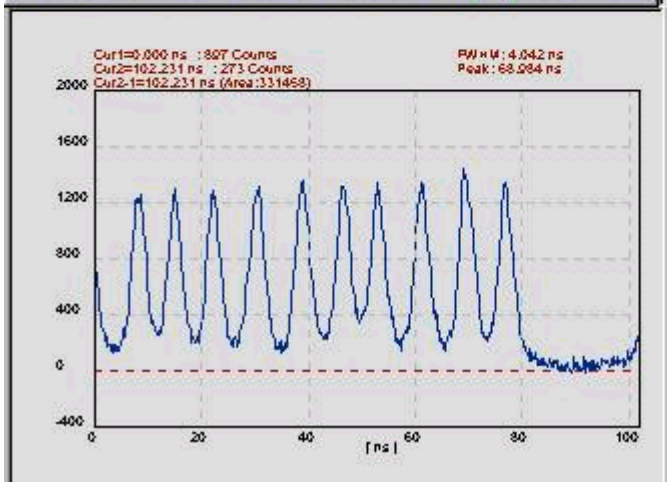


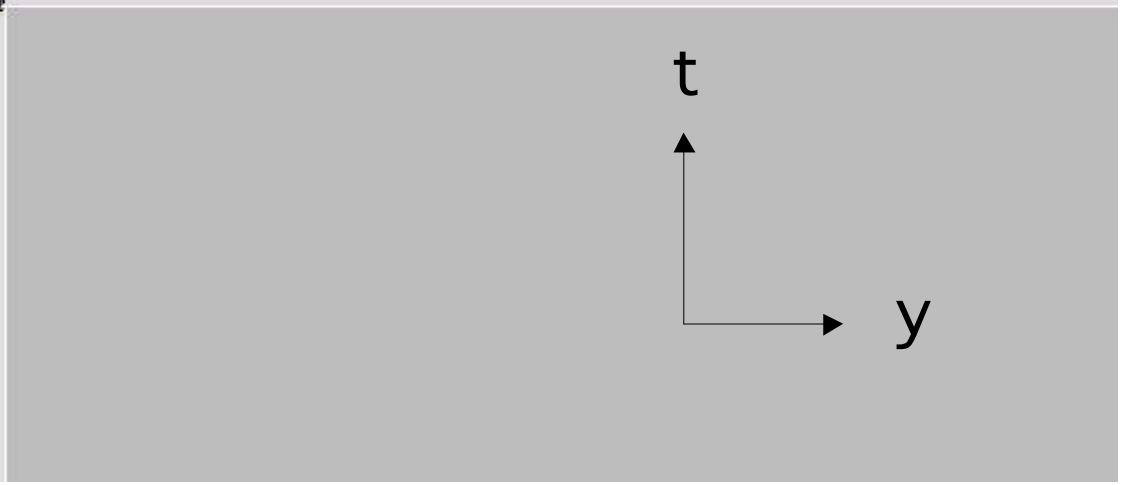


379 mA (1.35 mA/bunch)
Tail of Train









Streak Camera Summary

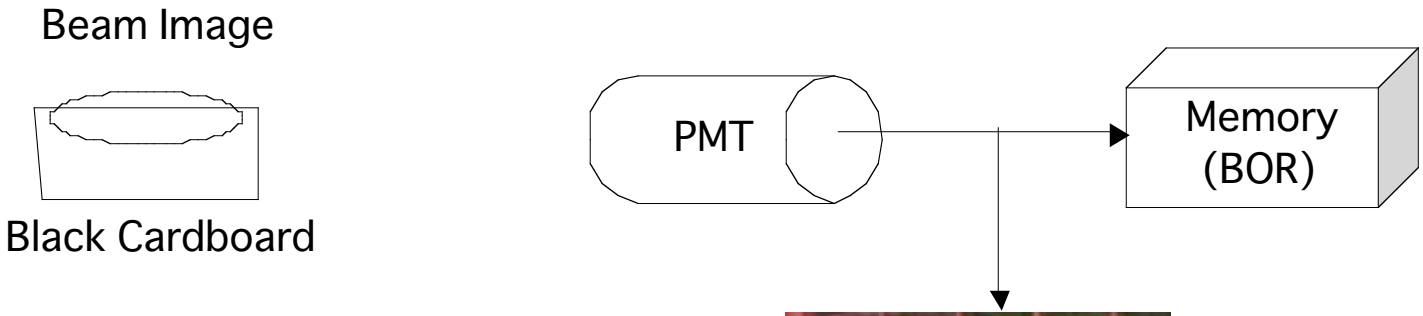
- First observations very preliminary
- Bunch length measurements:
  - Natural bunch length = 5.8 mm.
  - At high current bunch length longer at head than at tail of train.
- Dipole oscillations (vertical offset) visible
- Synchrotron motion also observed
- Hints of head-tail tilt perhaps seen in some bunches, especially accompanying longitudinally shifted ones.

SRM+FB BOR Data

2003.1.29

- Beam: LER, single beam, solenoids OFF
  - Fill pattern: 4/200/4 (4 trains, 100 bunches/train, 4 RF bucket spacing) => 800 bunches
  - Beam current: 900 mA => 1.125 mA/bunch
  - $\nu_y = 0.5858$, $\nu_x = 0.5319$, $\xi_y = 4.94$ (set), $\xi_x = 1.89$ (set)
  - $\nu_s = 2.25$ kHz
  - $\beta_y^* = 5$ mm (normally 2 mm)
- Detector:
  - PMT + partially blocked SR beam image (Perevedentsev method)
  - FB Bunch Oscillation Recorder (BPM)
    - Both read out using FB memory system: 5120 bunches x 4096 turns worth taken at once.

PMT setup (proposed by Perevedentsev)

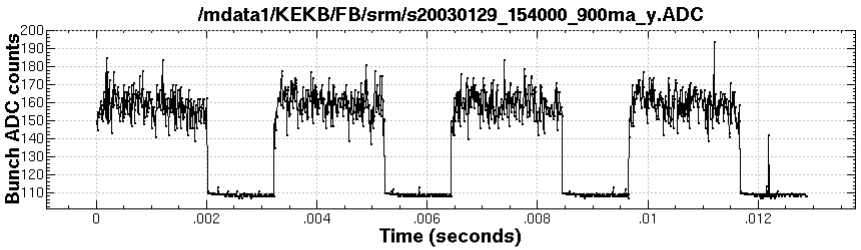


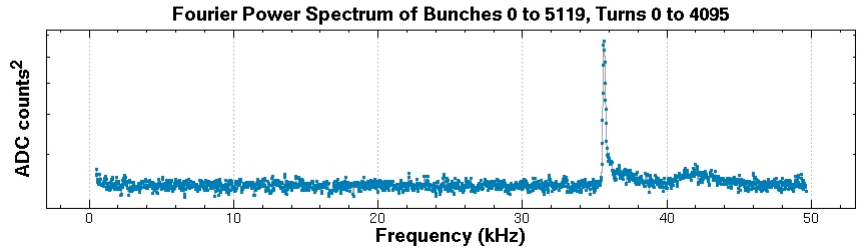
Partially block beam image with black cardboard, and measure light intensity of the visible part with a PMT. The PMT signal is buffered and then recorded using a feedback BOR digitizer/memory board.

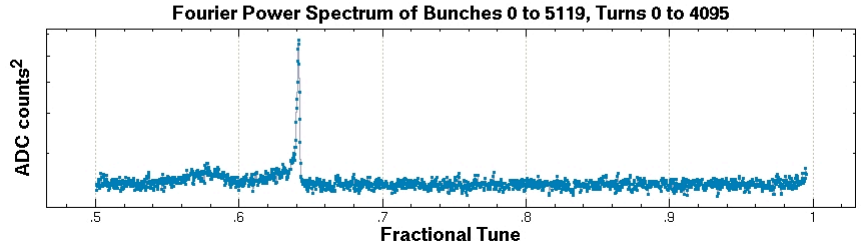
y: 100 mV/division
x: 10 ns/division

Averaged Power Spectra of All Bunches

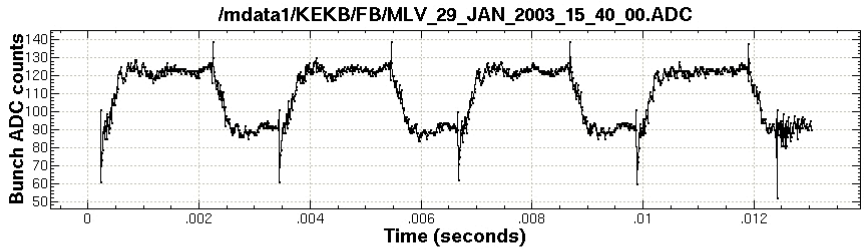
PMT Data

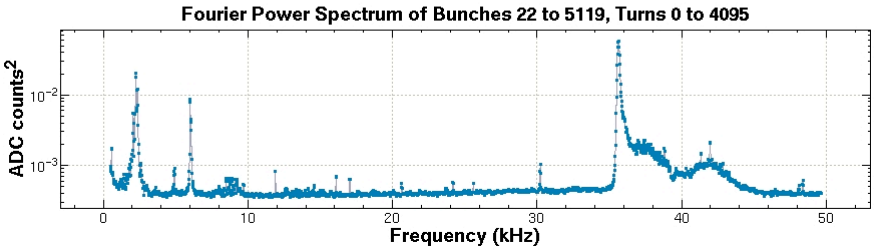


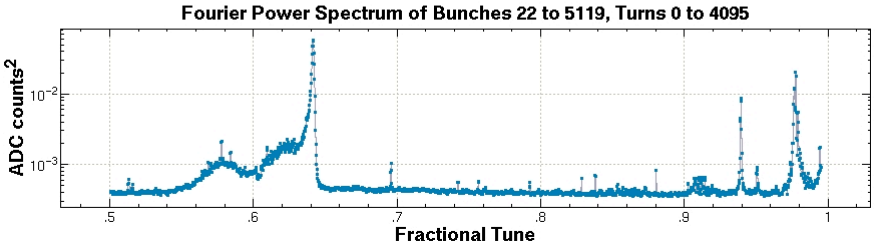




BPM Data



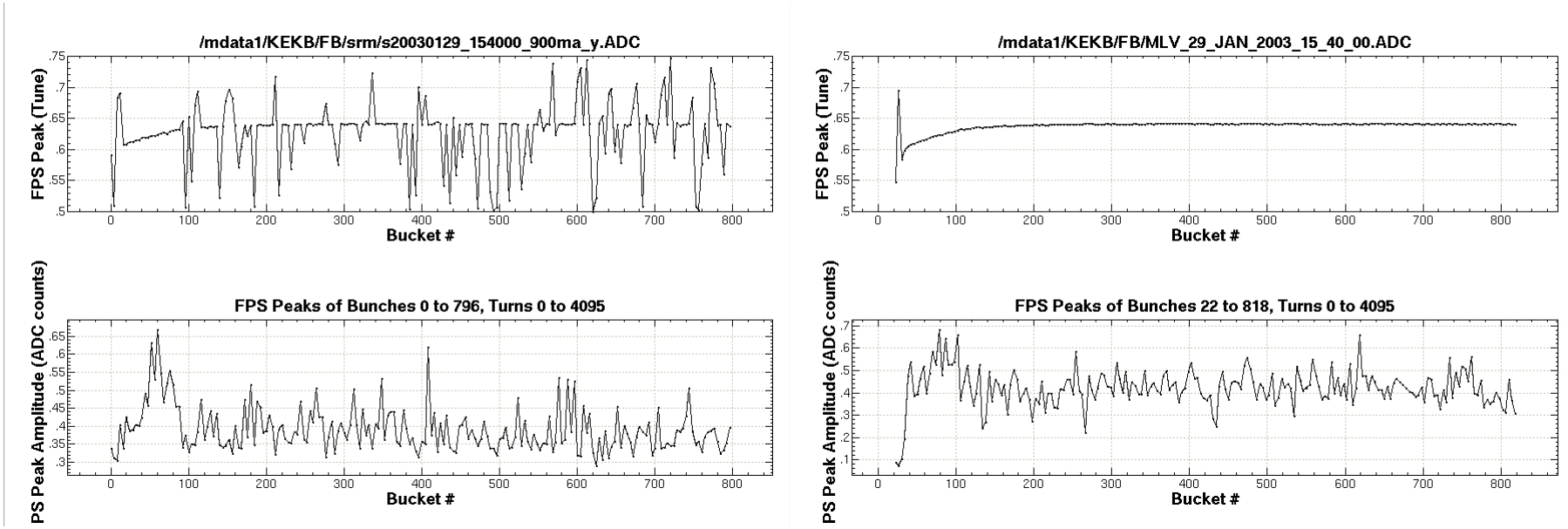




Characteristics of Spectral Peak along Train

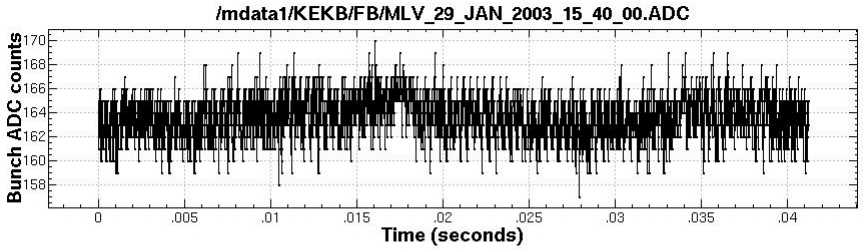
PMT

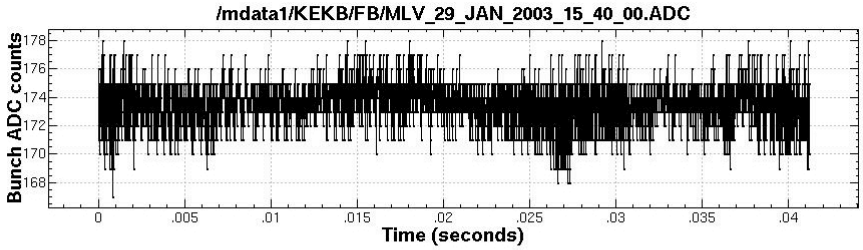
BPM

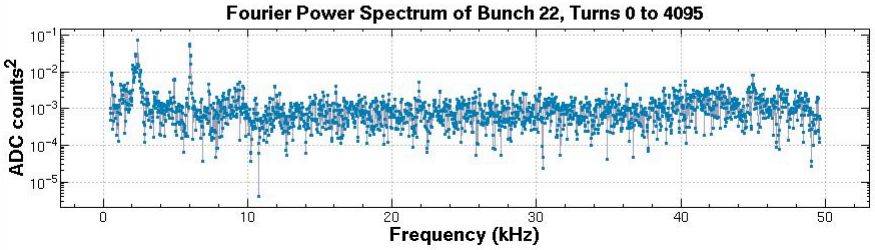


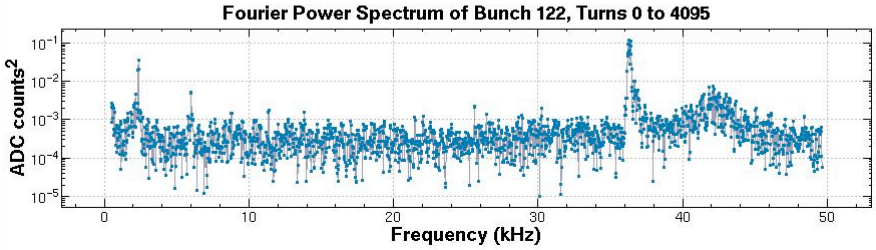
- Peak shifts along train, saturates at $\Delta\Delta y = +0.055$
- Maximum oscillation amplitude near 15th bunch (60th bucket)

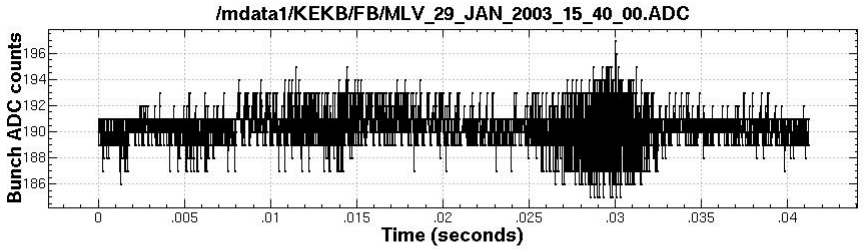
BPM Example Bunch Time Series and Single-Bunch Spectra

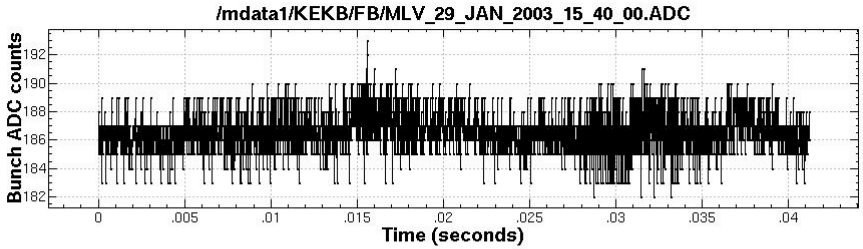


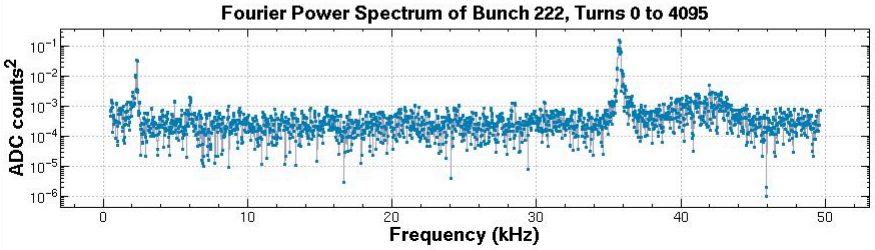


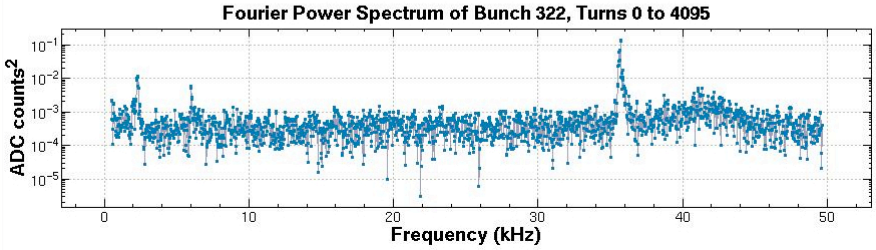




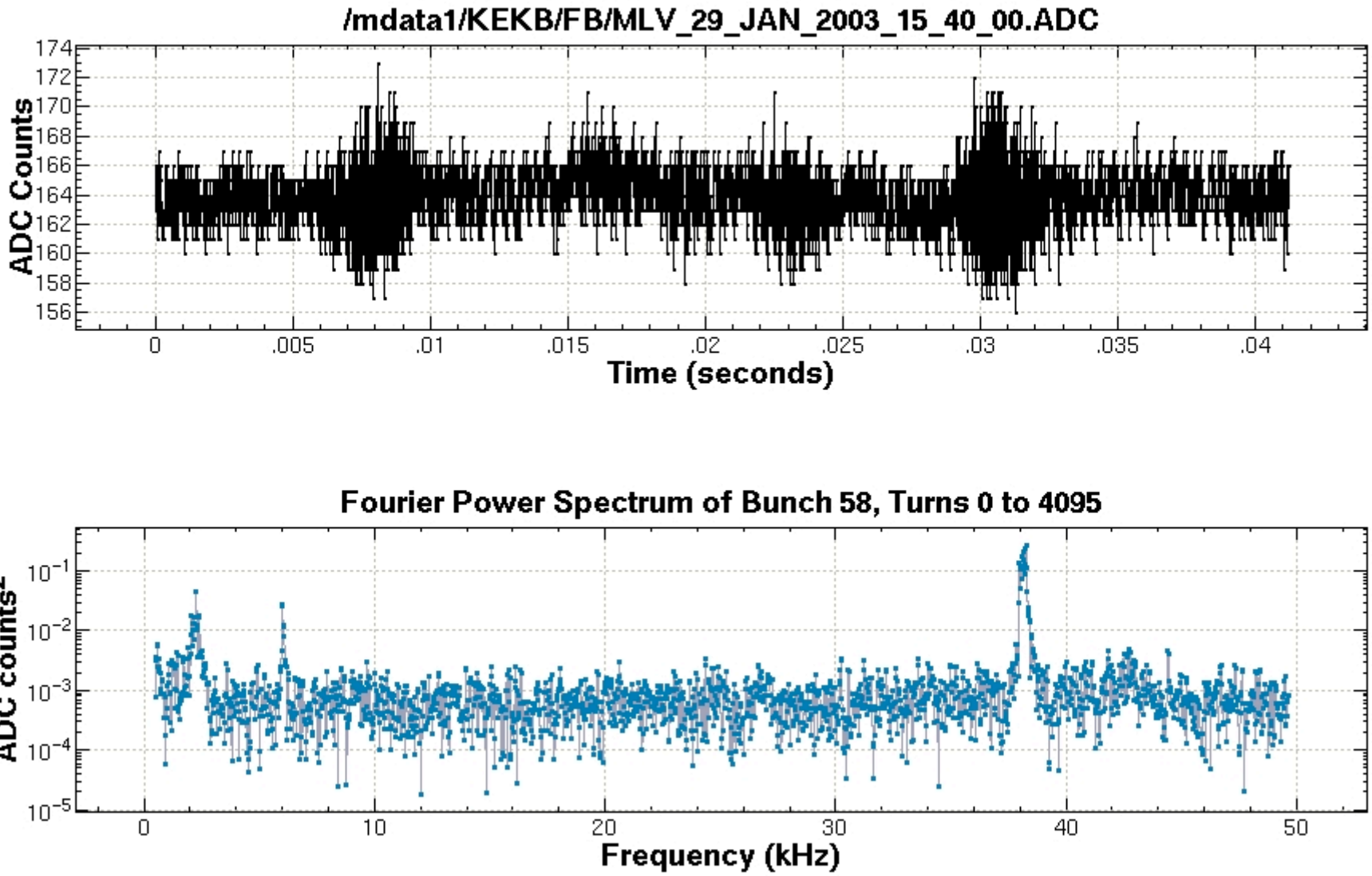






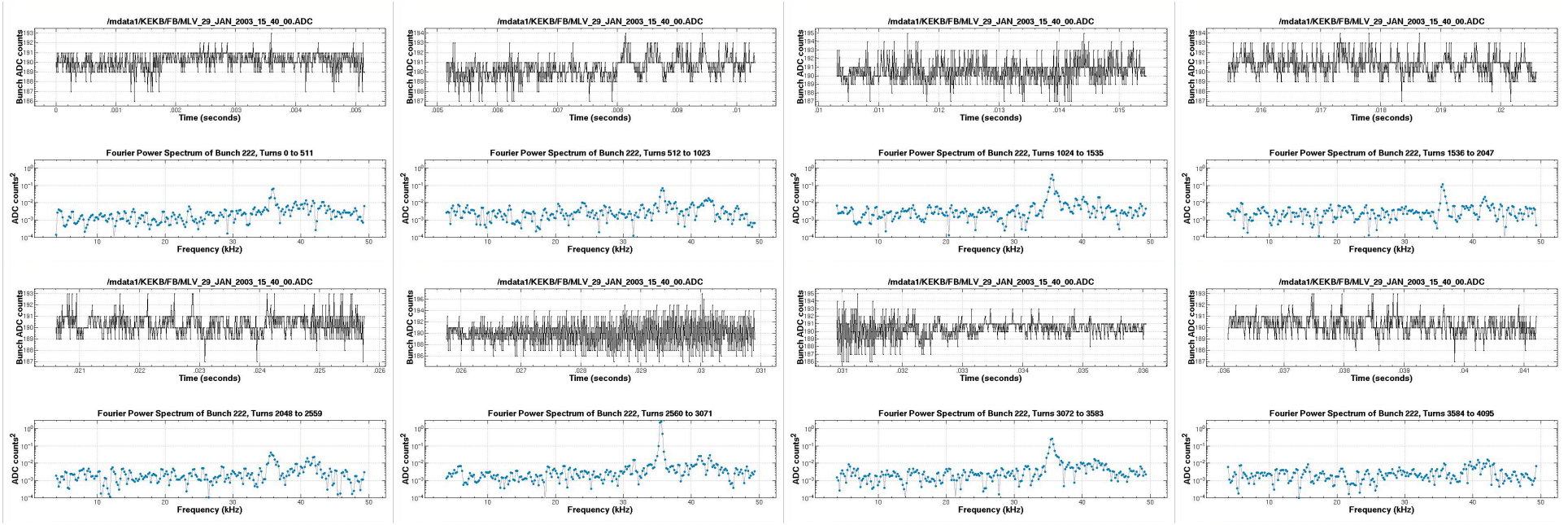


Example of double-burst (10th bunch)



Time Development of Instability: 512-turn slices

BPM signal, 51st Bunch



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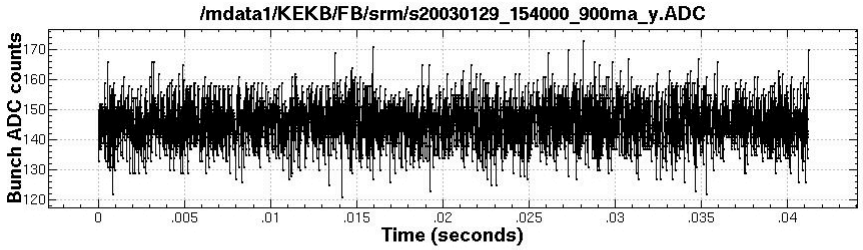
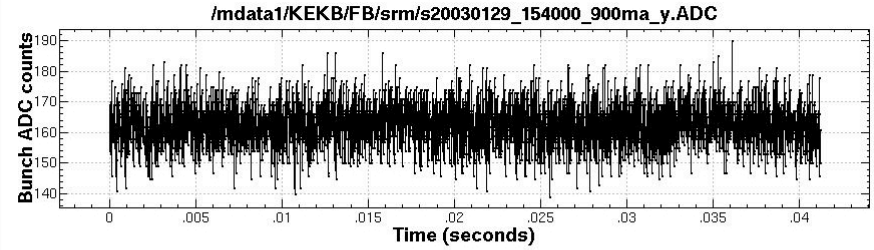
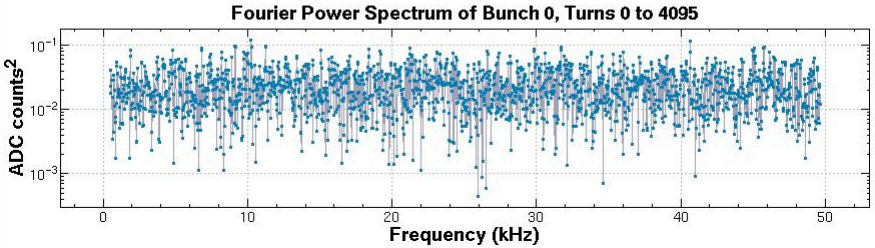
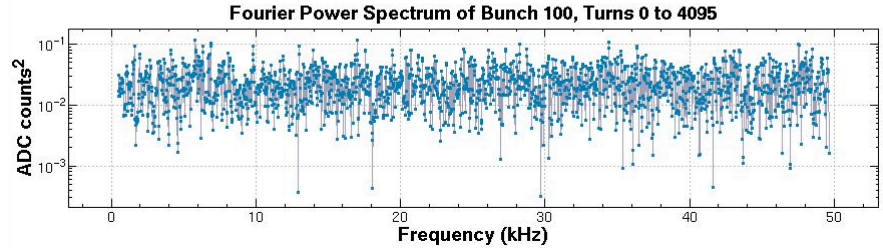
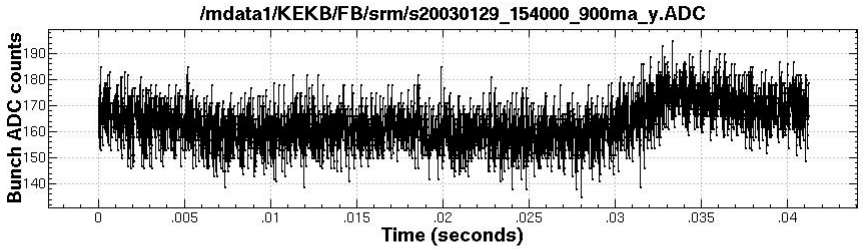
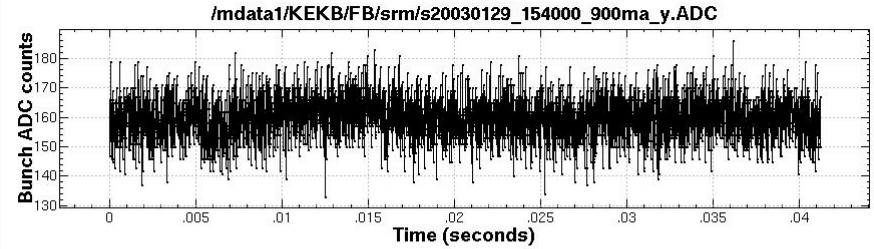


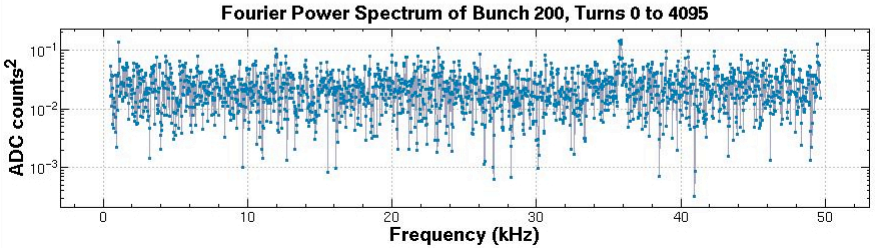


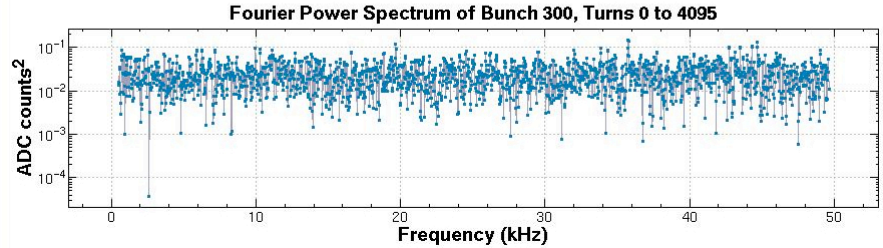




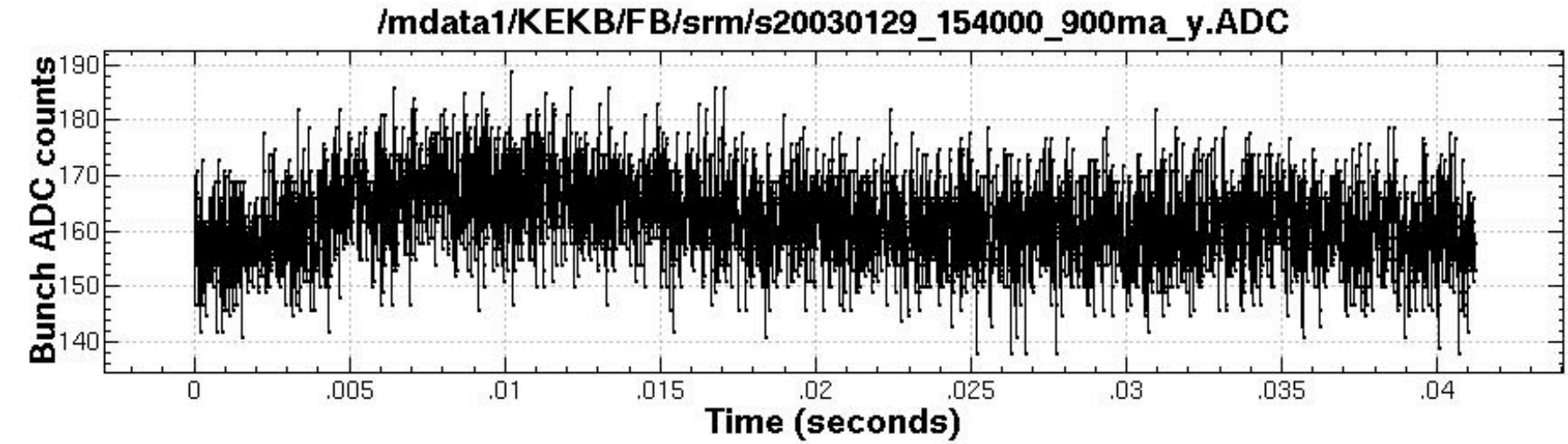


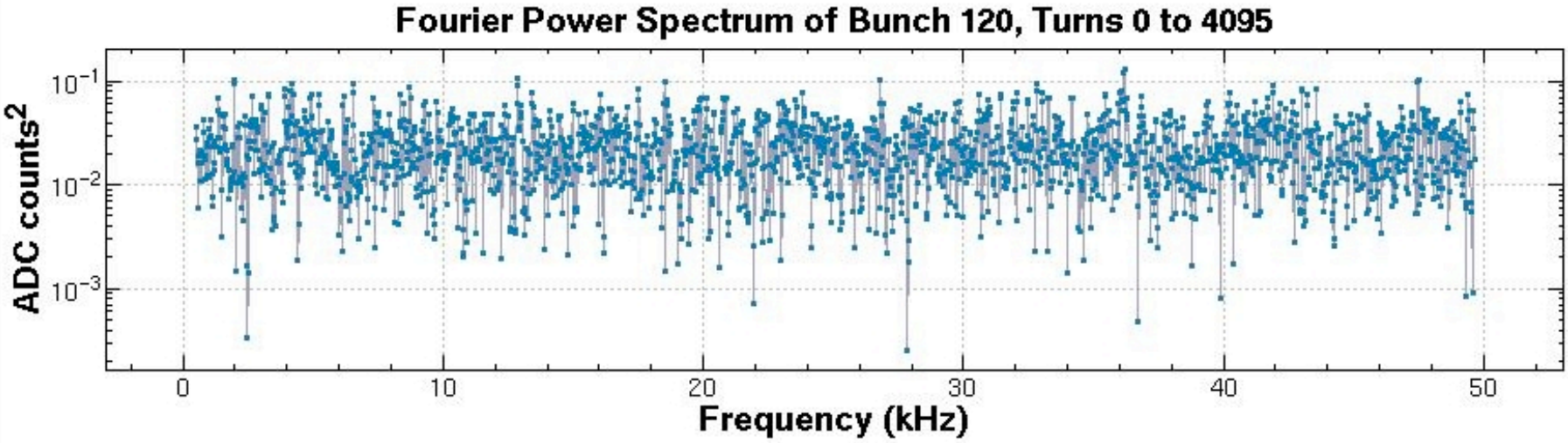






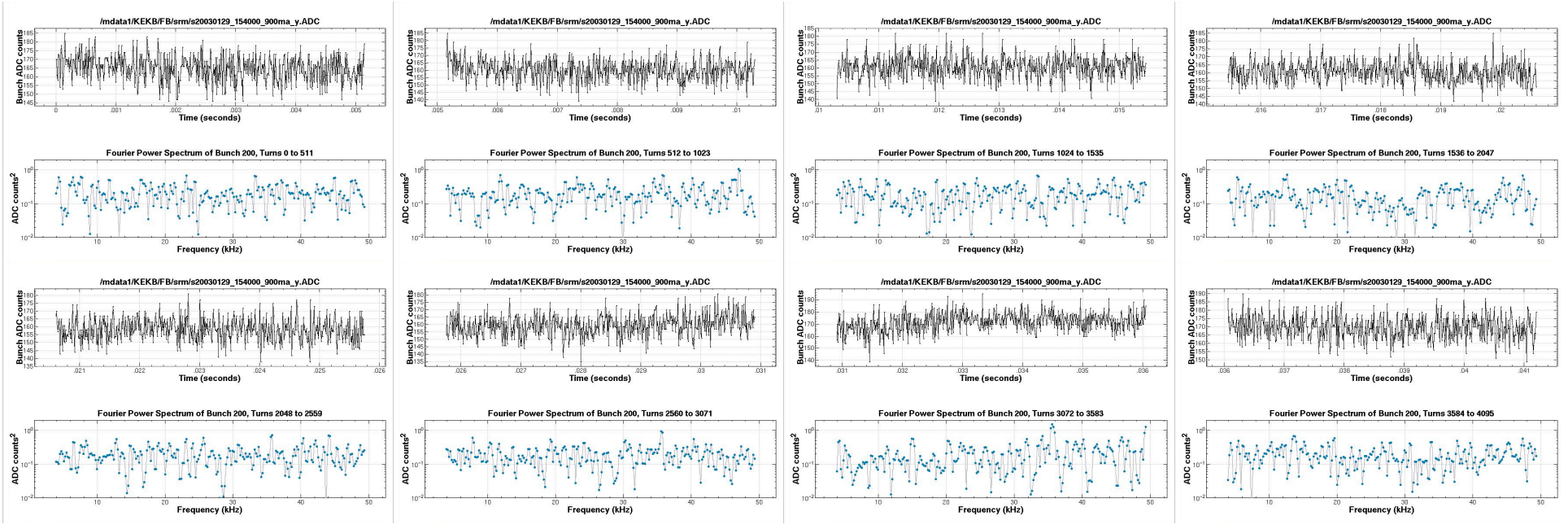
Example showing blow-up decay time ~1500 turns





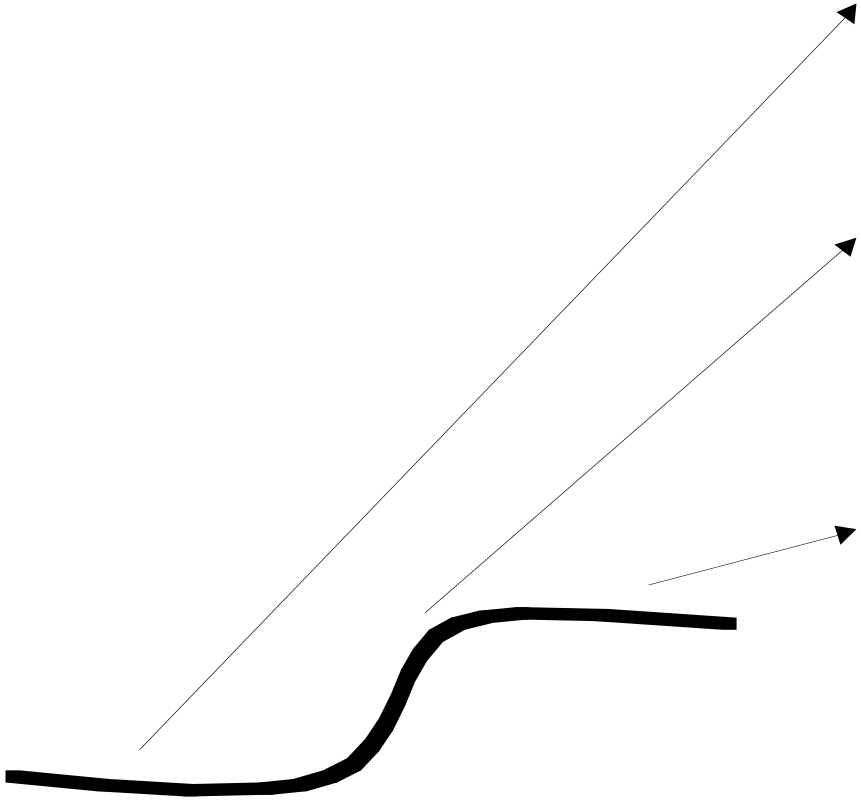
Time Development of Instability: 512-turn slices

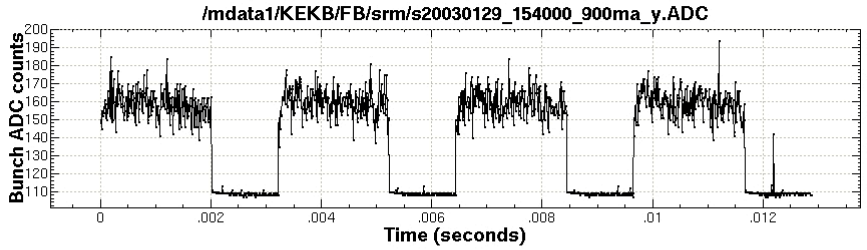
PMT signal, 51st Bunch

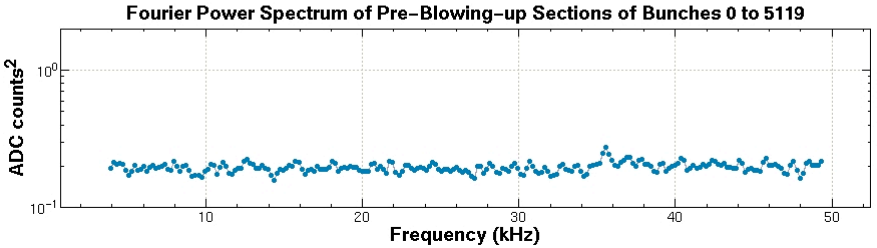


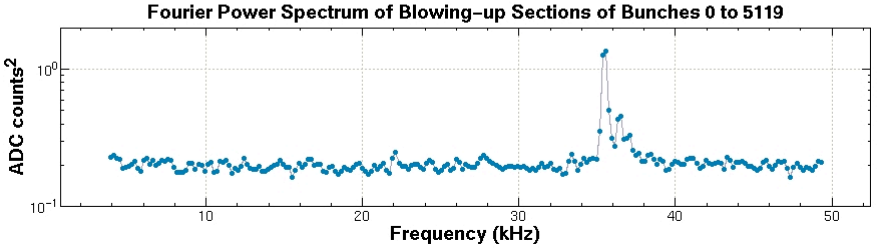
Blow-up Pattern Analysis

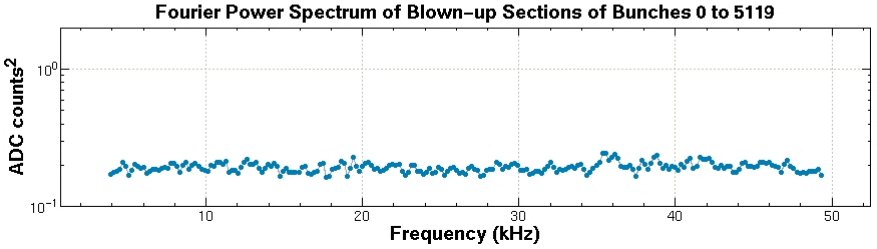
Find a bunch with characteristic blow-up pattern, and take spectra of 3 stages separately. Then average the 3 spectra over all bunches that have this pattern.





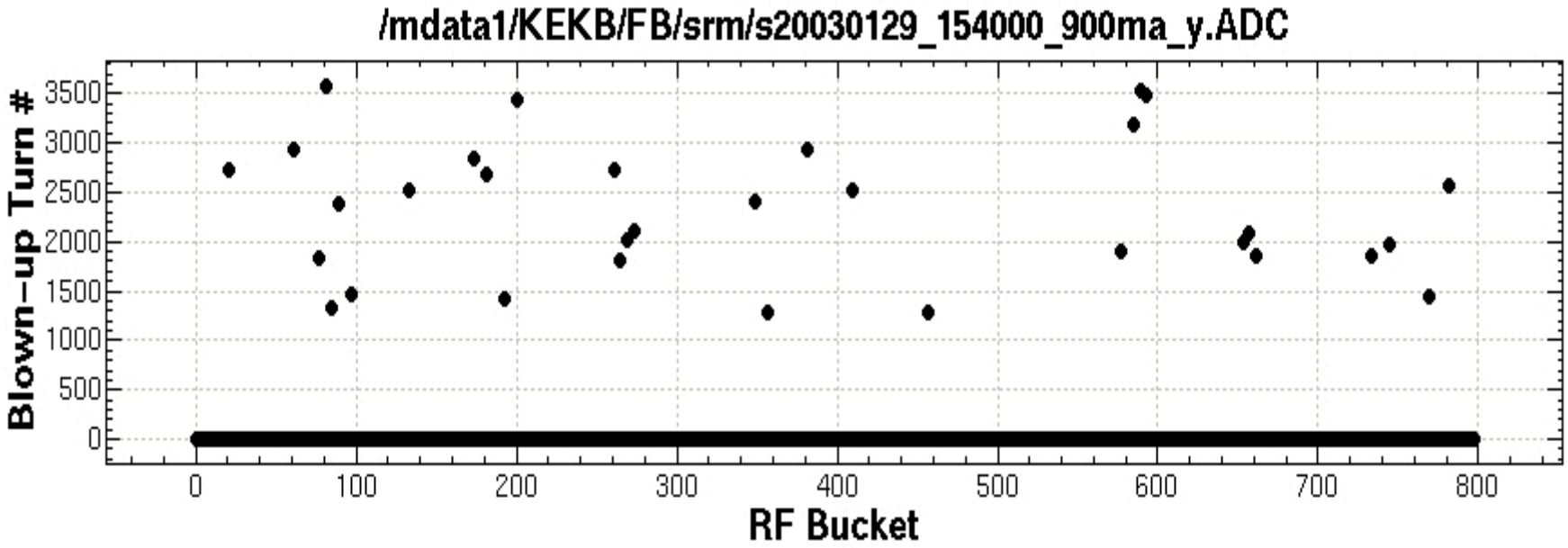






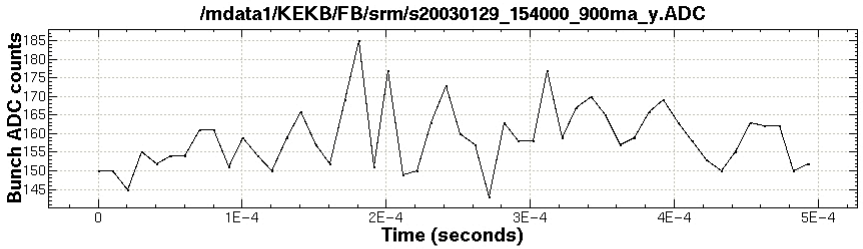
Distribution of blow-up events along train

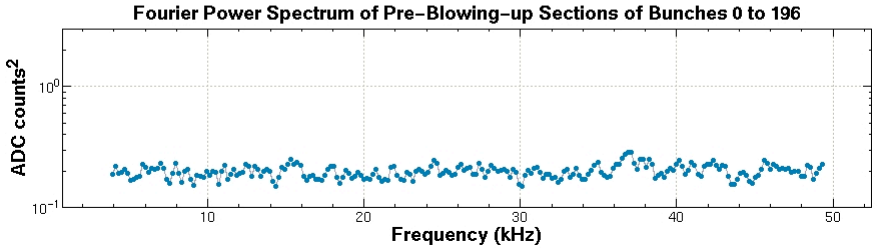
Turn # of peak PMT signal after blow-up ramp

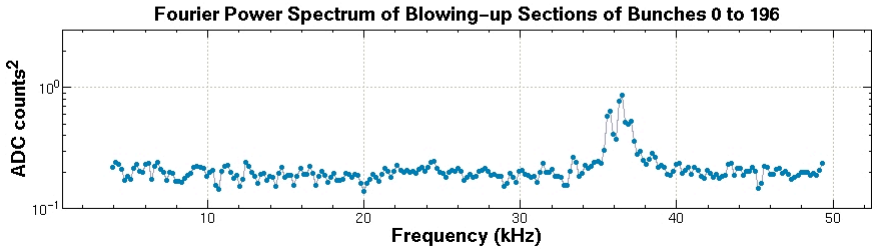


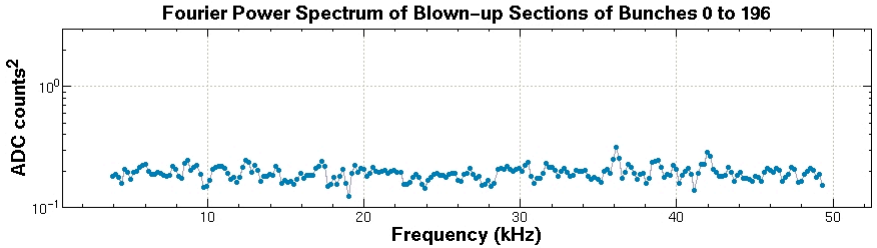
- 32 events found in 1st train (200 bunches)
- 3 clusters of adjacent bunches with similar timing, but otherwise events are independent.

Bunches 1-50

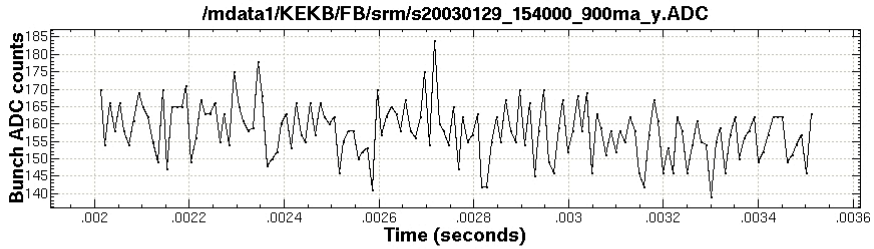


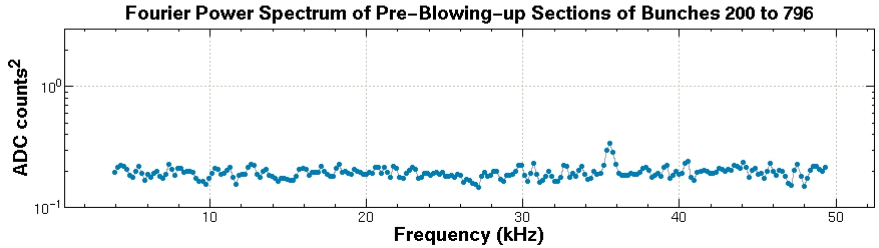


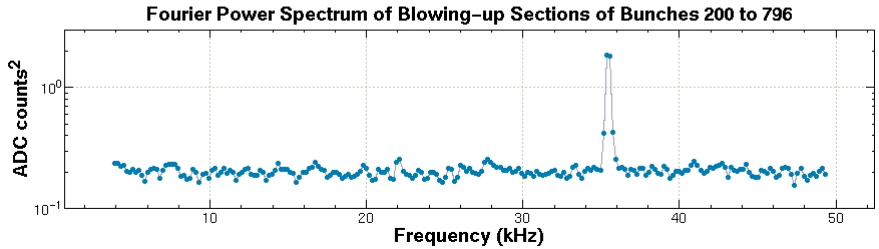


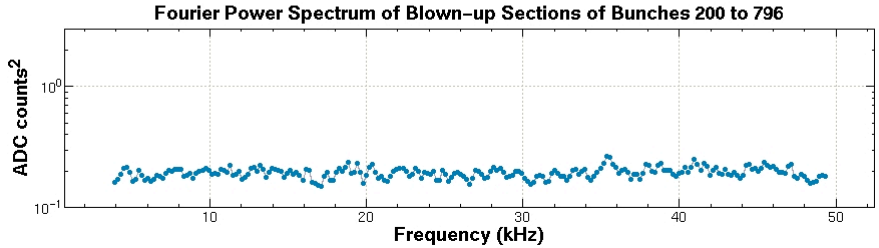


Bunches 51-200

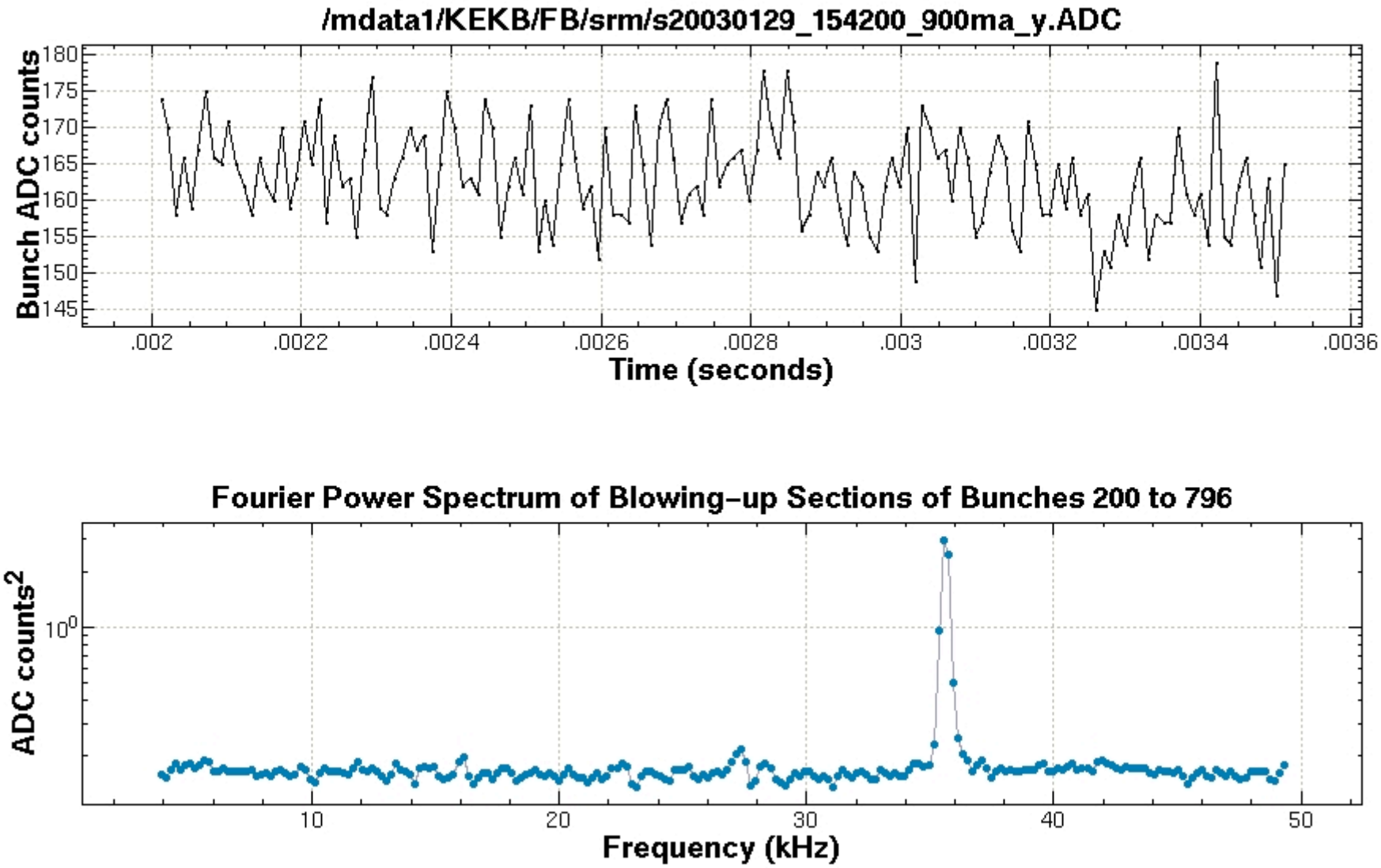




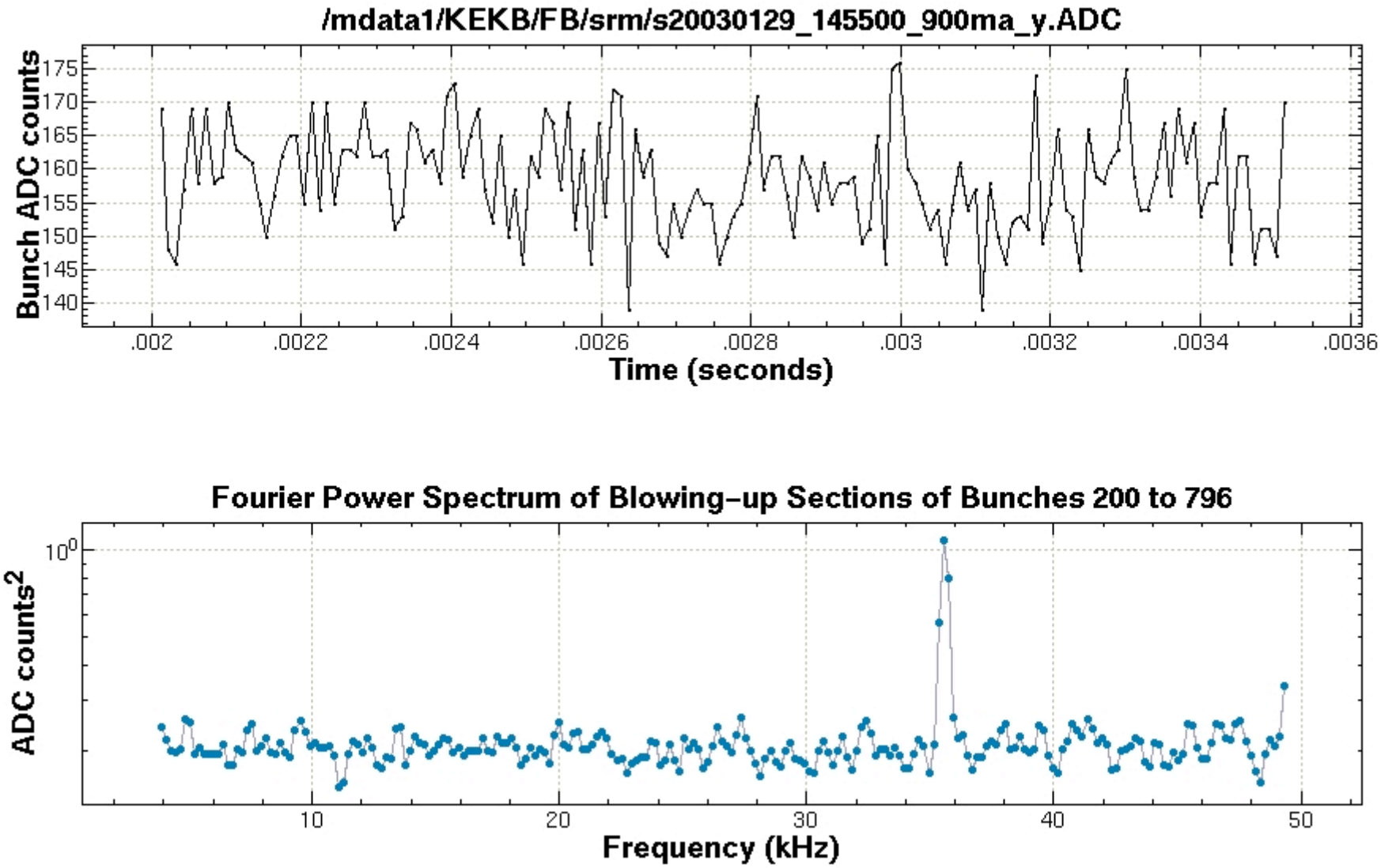




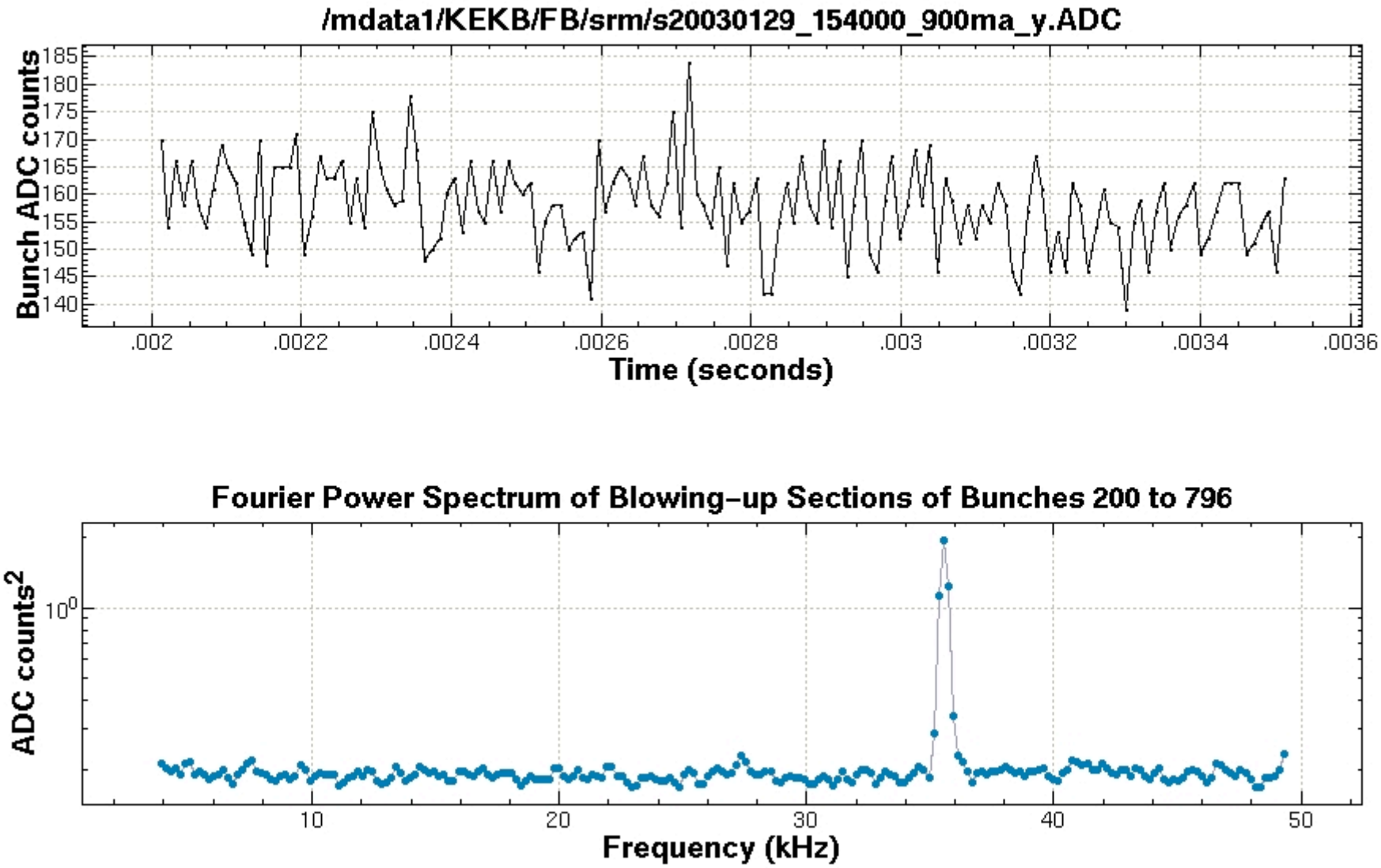
Mid-blow-up averaged spectrum of *2nd* data set at same tune



Mid-blow-up averaged spectrum of *3rd* data set at same tune



Mid-blow-up averaged spectrum of *all 3* data sets at same tune



PMT+BPM Summary

- Dipole Oscillation seen in both PMT and BPM data.
- Amplitude of oscillation in BPM data: 0.1-0.2 □m
- Frequency corresponds to that of a tune shift saturating at +0.055 by ~50th bunch.
- Time Structure seen:
  - Maximum oscillation amplitude occurs in short bursts
    - ~500 turns (5 ms)
  - After burst dies down, beam is enlarged for a period, gradually shrinking again over ~1500 turns (15 ms).
  - Bursts occasionally occur in adjacent bunches at the same time, but most often occur in isolation.
  - No clear quadrupole signature seen yet.
- Plan to take more data with streak camera and PMT in parallel.