Experience with the

LHC BPMs for Real time orbit measurement

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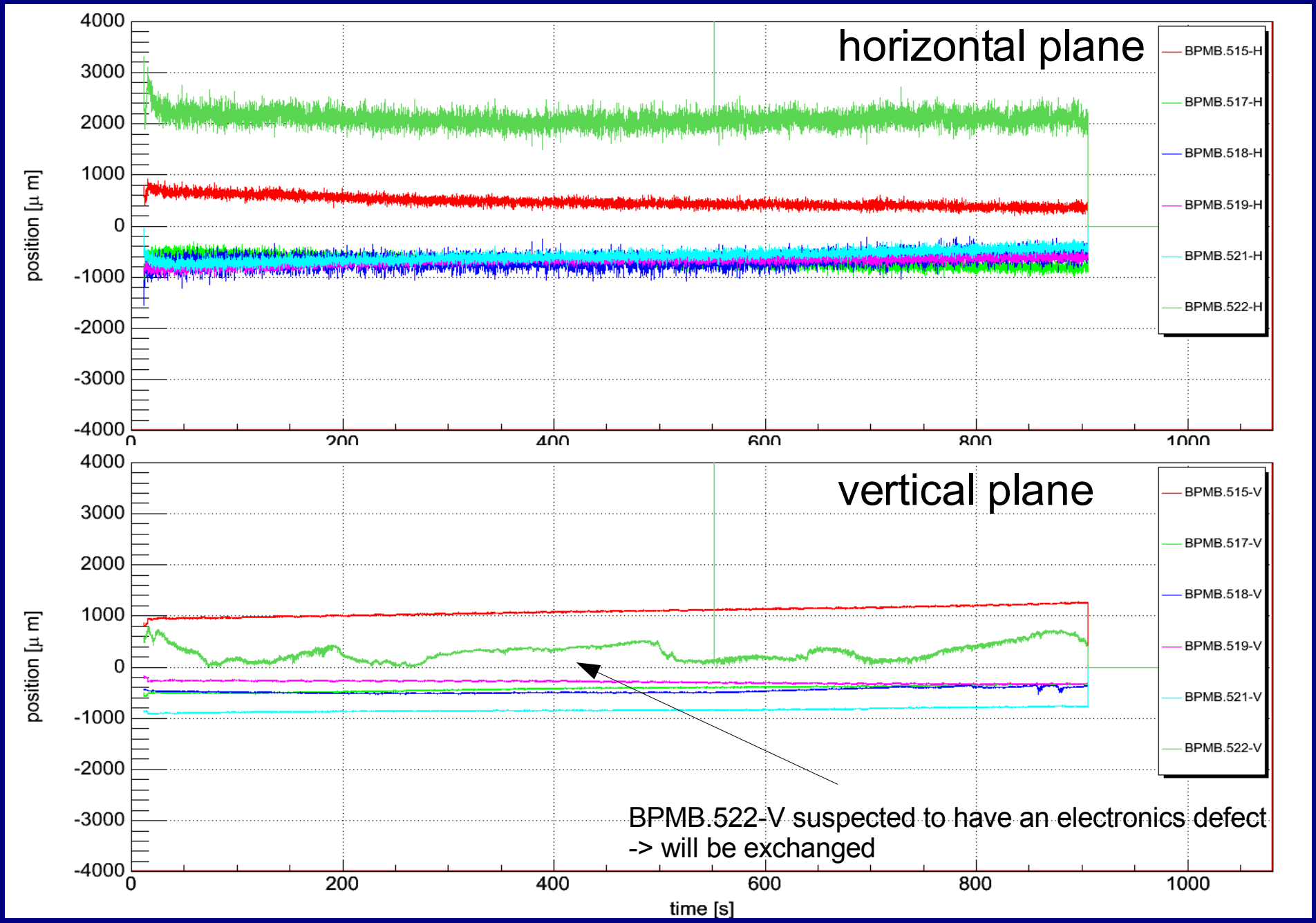
LHC BPMs for Real time orbit measurement outline

- orbit stability
  - Coasting beam
- systematic errors due to:
  - bunch length
  - Intensity
  - Injection pattern
- Control issues
  - 100k turn and orbit acquisition

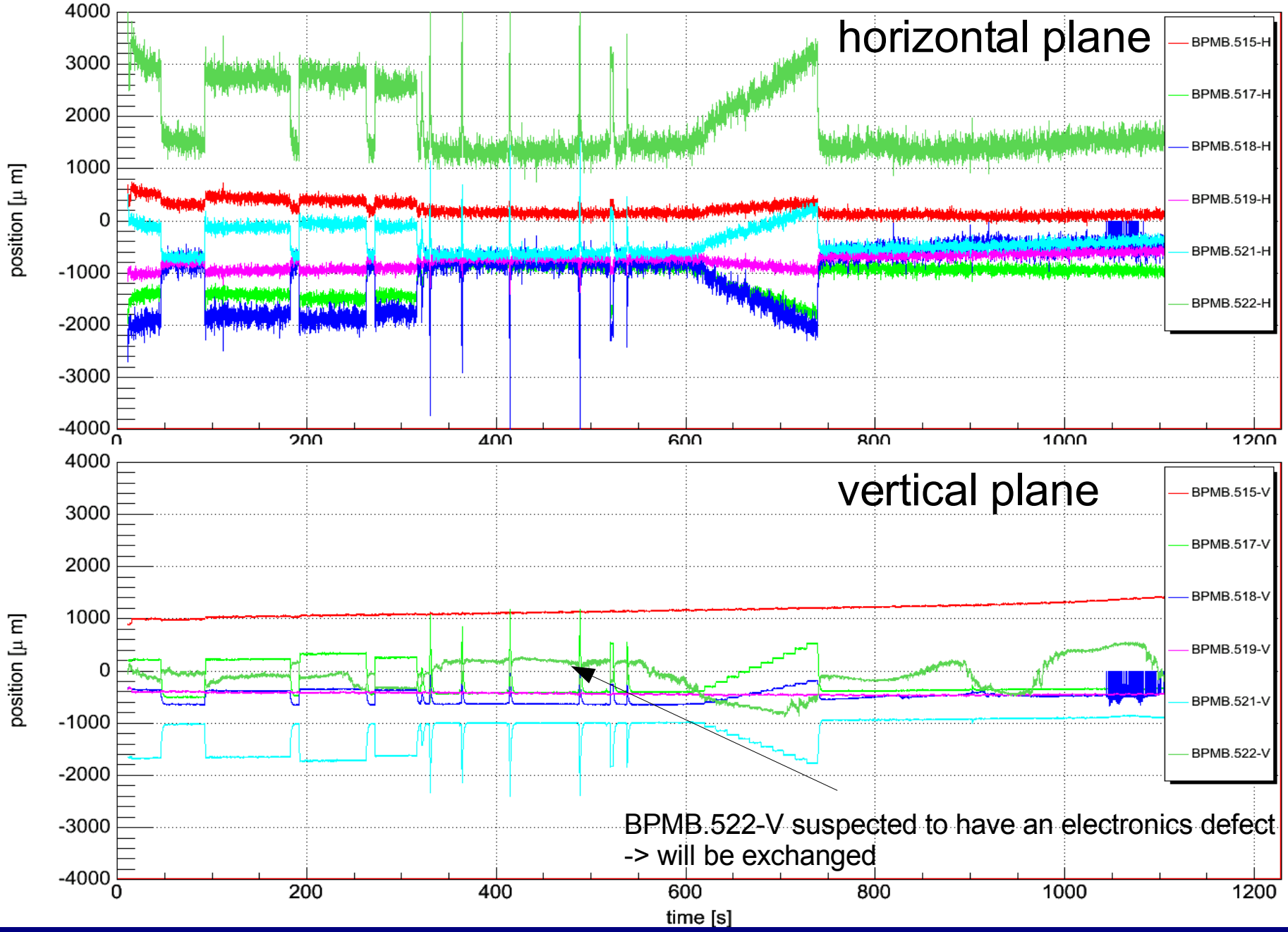
coasting beam – MD 20040825

"good" example: SSC #0136716 (start at 11:45:49)



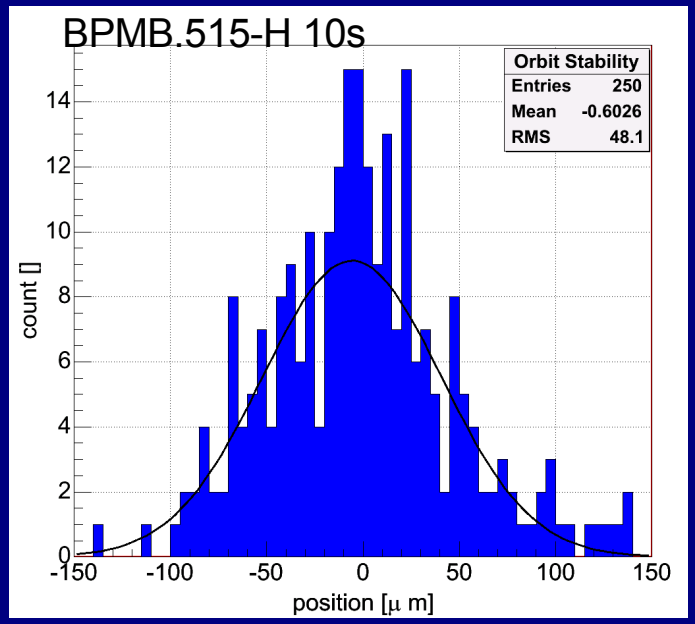
coasting beam – MD 20040825

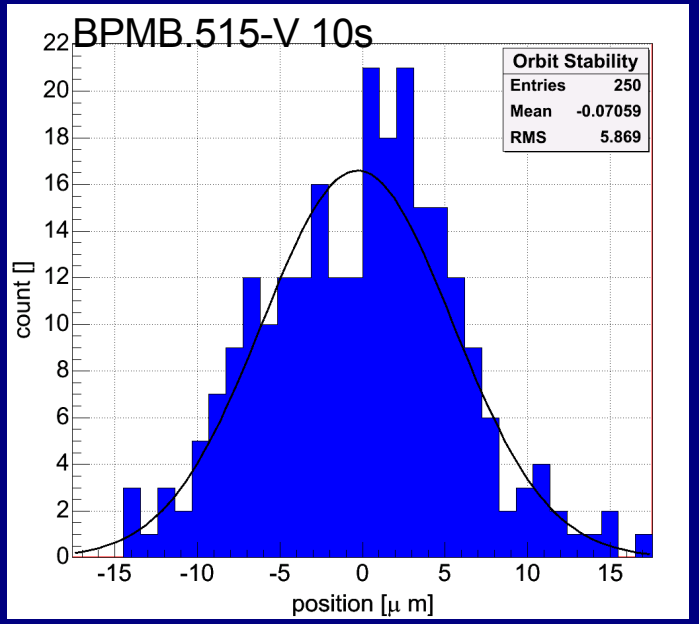
"bad" example (5/12 total): SSC #0137538 (start at 15:37:01)



coasting beam – MD 20040825
orbit stability: SSC #0136716 ("normal" case)

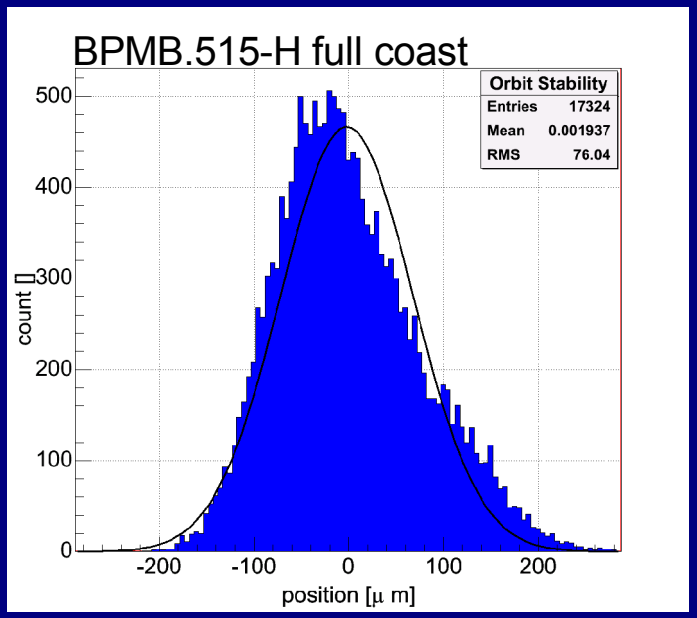
- Short term stability (over 10 s):
  - H: 48 μm
  - V: 6 μm

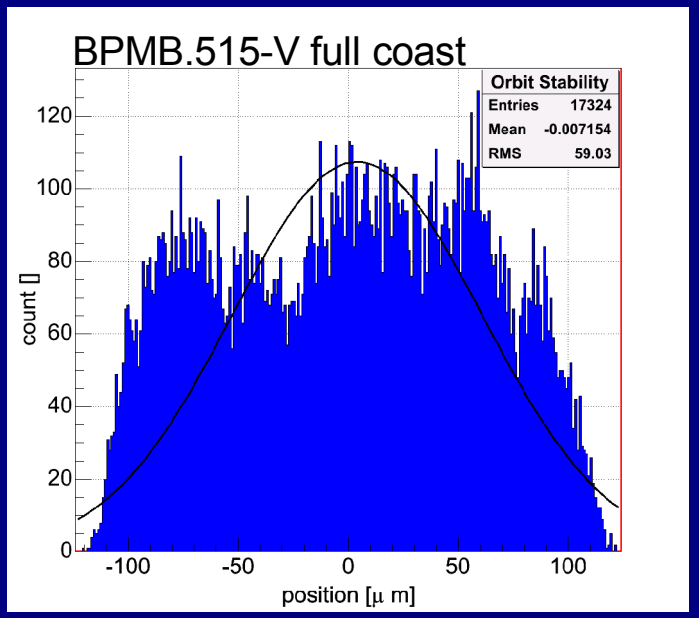




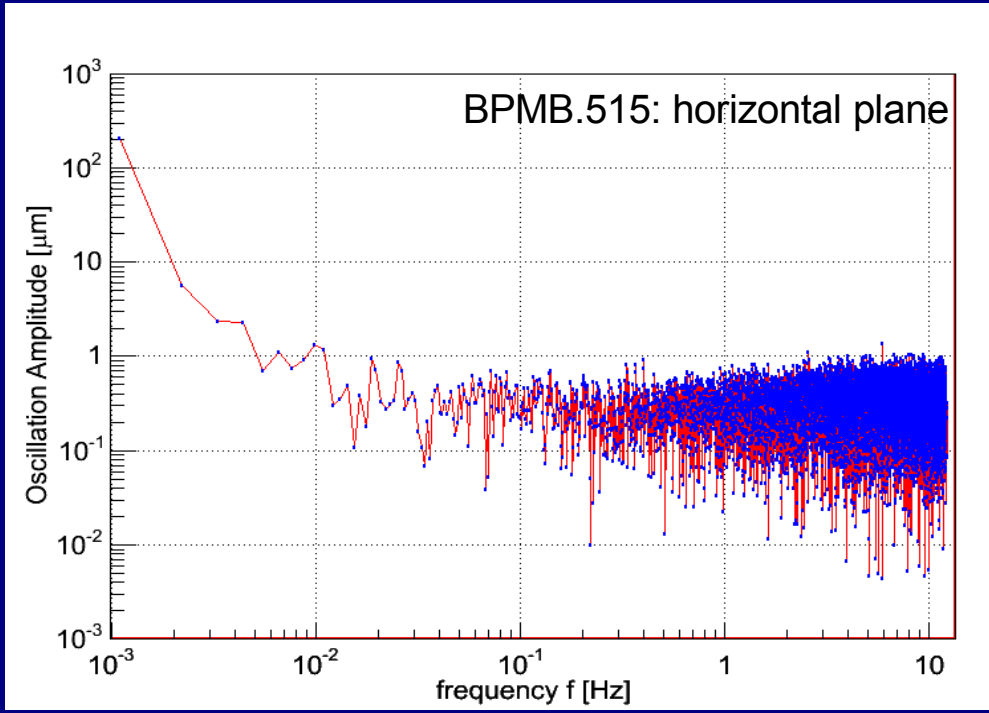
- long term stability (over full coast):
  - H: 76 μm
  - V: 59 μm
  - dominated by slow drifts

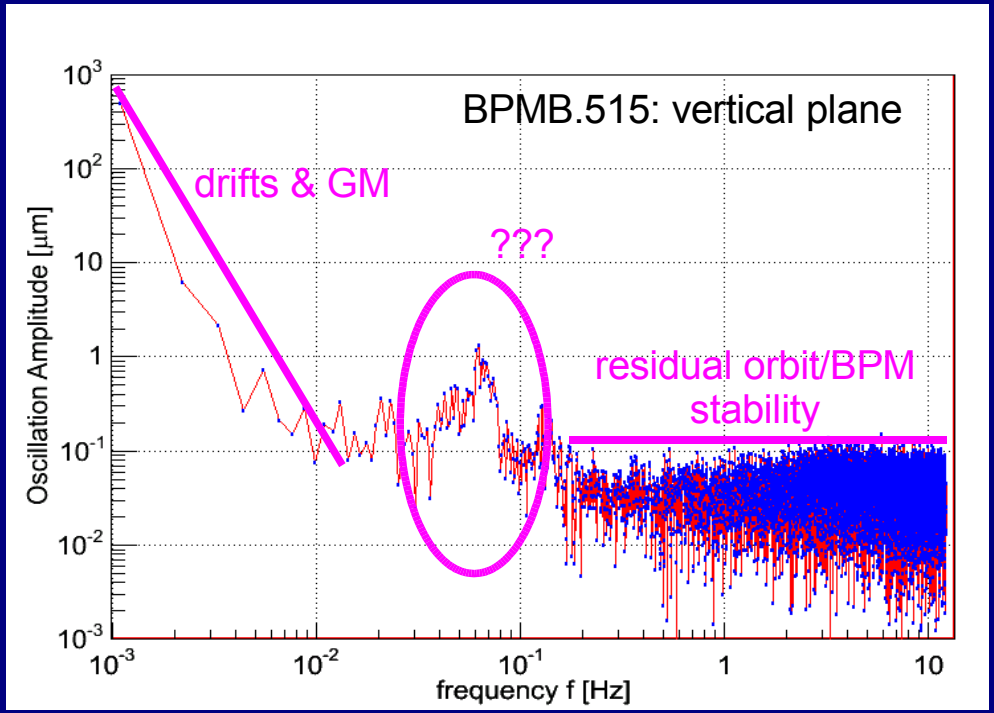
- not a Gaussian process (fits are approximations)





coasting beam – MD 20040825
FFT of orbit position: SSC #0136716 ("normal" case)



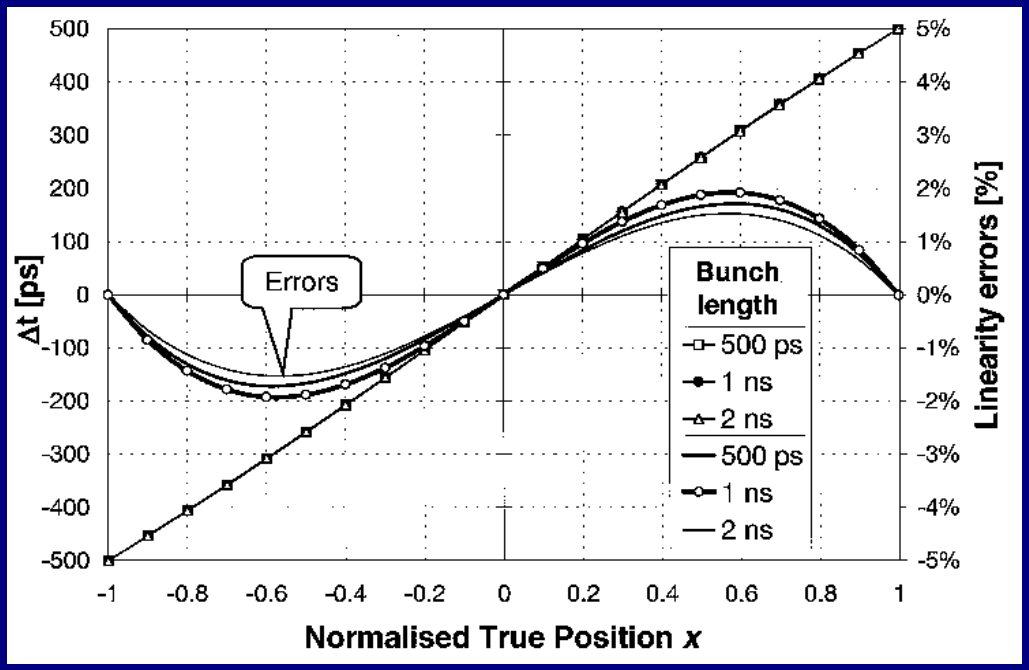


- Low frequency (power) spectrum increases with $1/f^2$
  - Typical for drifts of magnets and random ground motion
- For high frequency no signal structure visible ('white noise')
  - horizontal and vertical residual noise (power) is one (two) magnitude larger (beam or BPM effect?)
- Vertical plane (all BPMs):
  - beam noise ±15 µm @ ~ 0.1 Hz
    (source not yet identified, unlikely an aliasing effect)

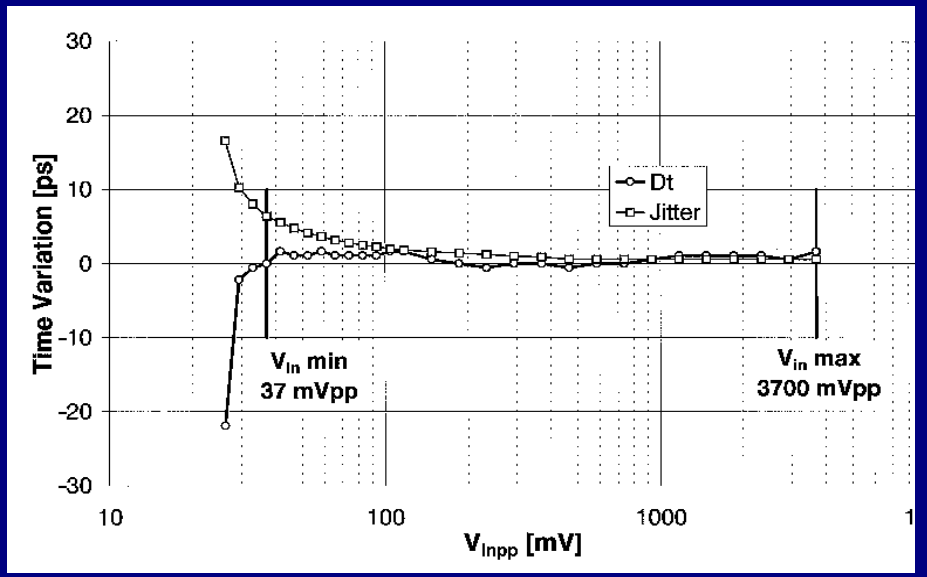
Systematic LHC BPM errors

- From the electronics design one expects systematic errors on the level of 1-2% of the half aperture as described in:
  D. Cocq*: *"The wide band time normaliser – a new circuit to measure transverse bunch positions in accelerators and colliders"*, NIM A416, 1998

dependence on the bunch length:



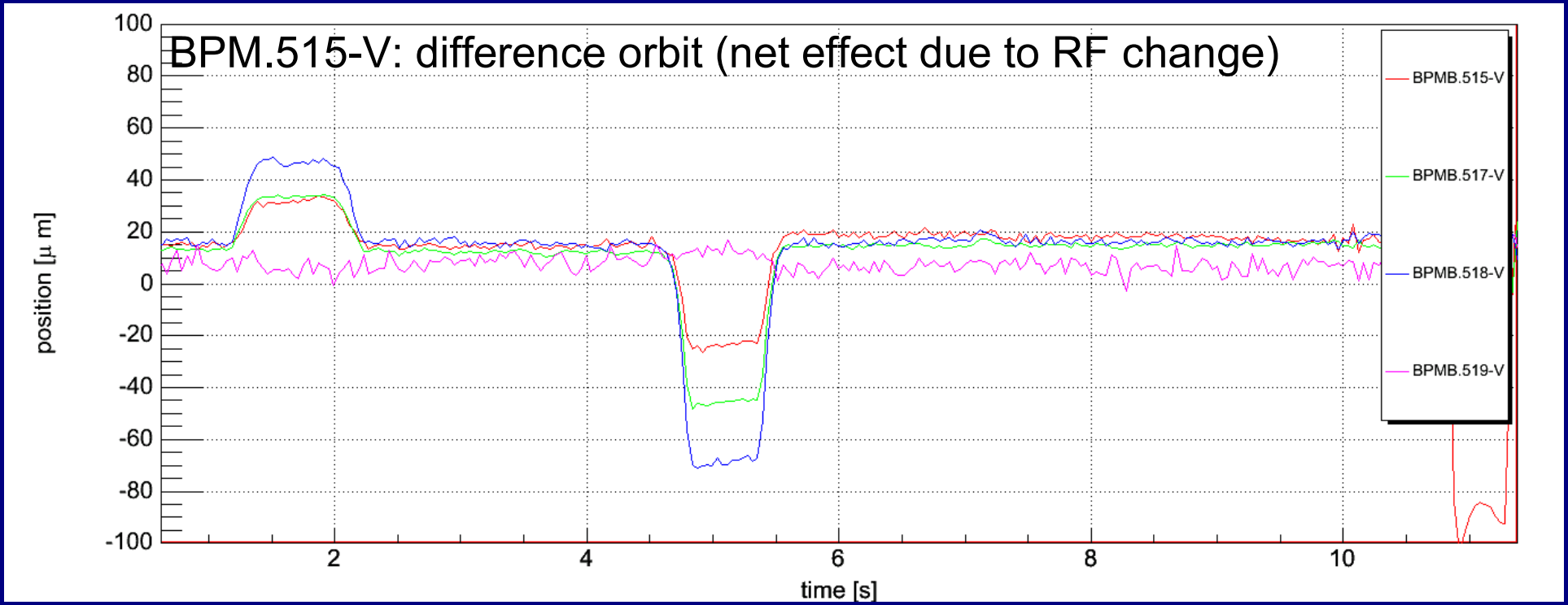
dependence on the intensity:

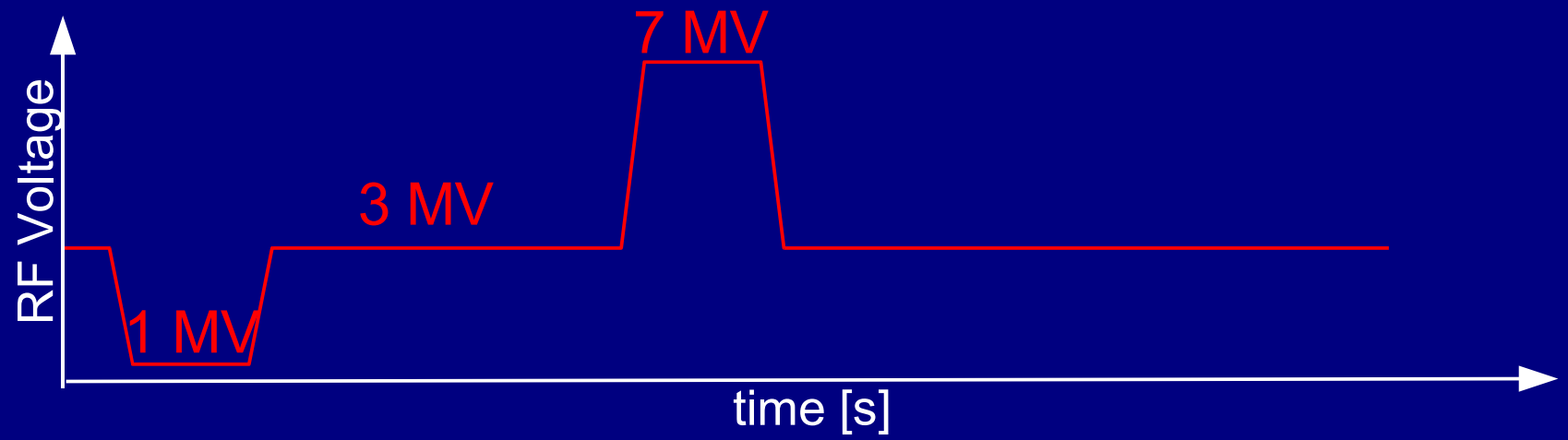


- *Daniel Cocq, formerly SL/BDI, retired

Systematic LHC BPM errors position dependency on bunch length

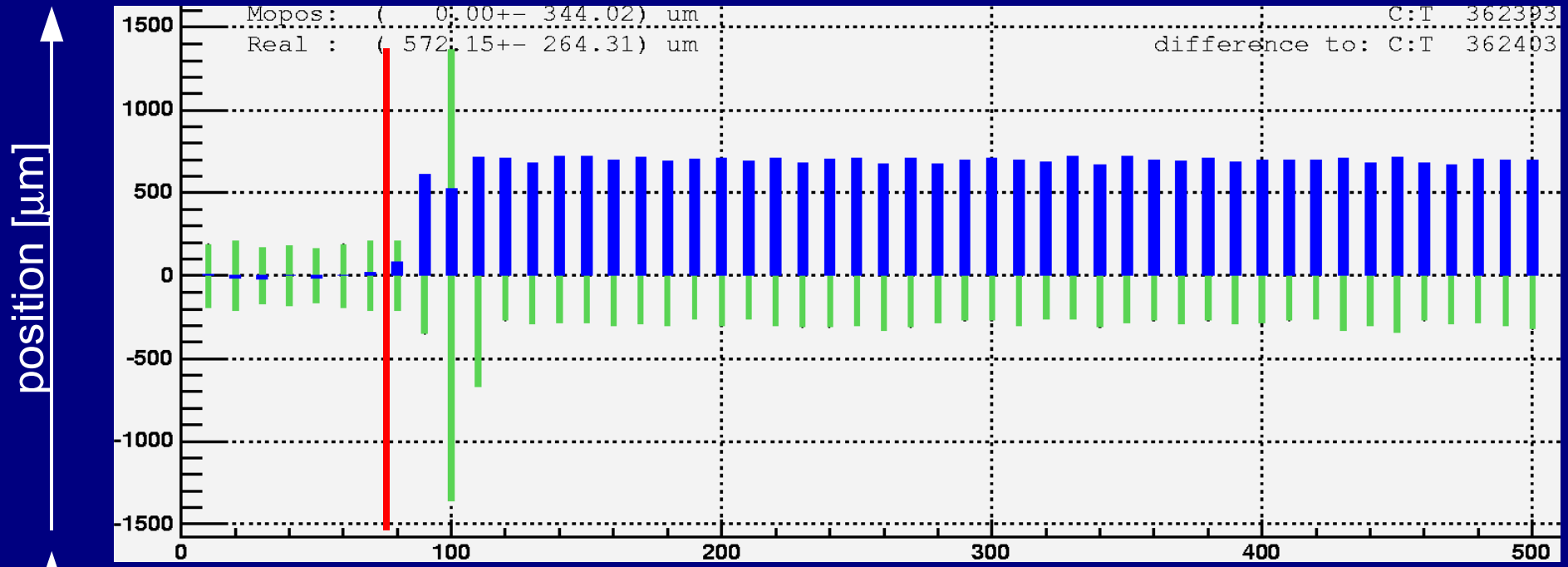
- Change of the bunch length at 26 GeV by changing the RF voltage

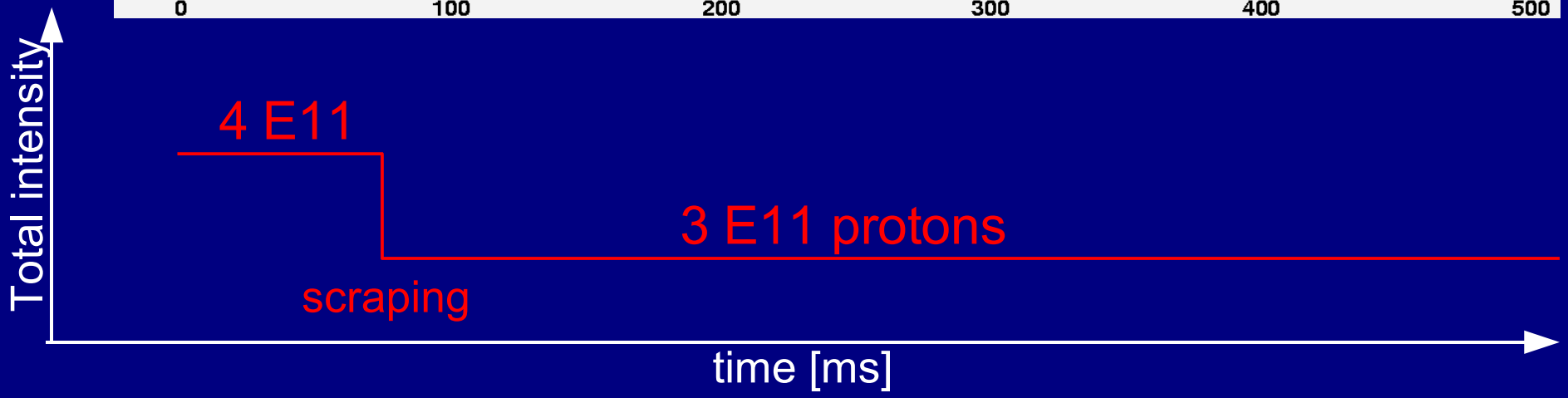




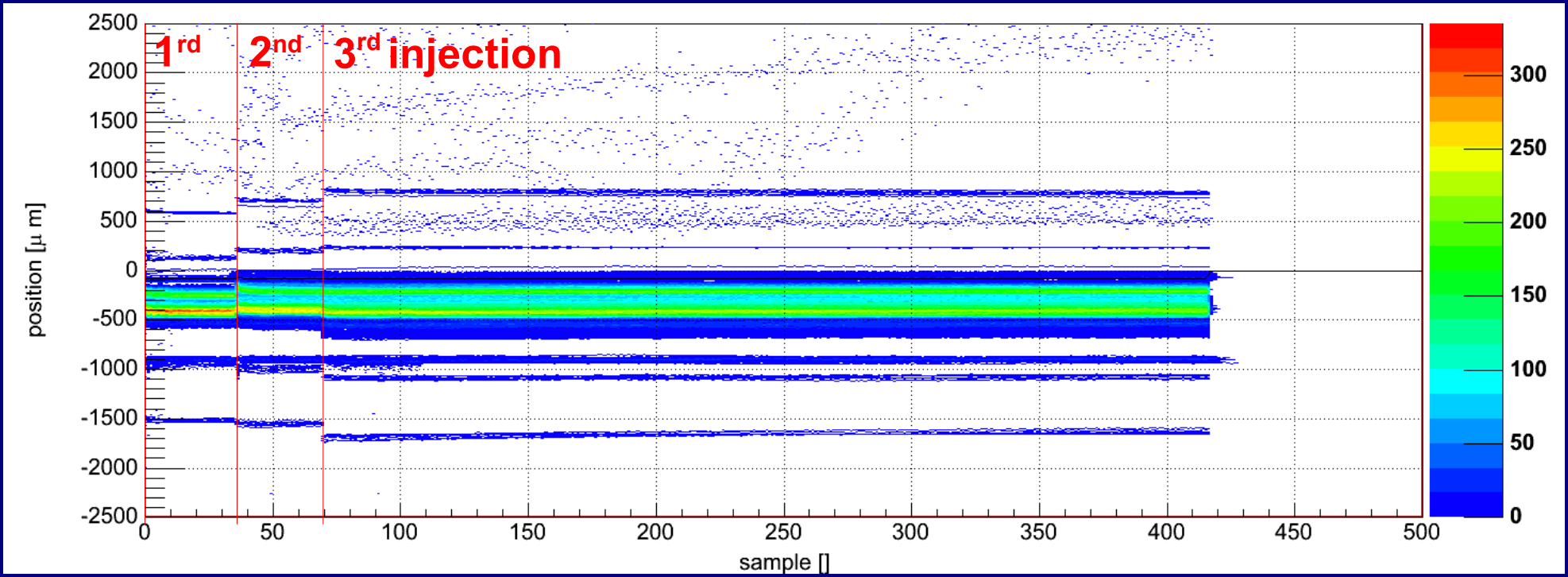
Systematic LHC BPM errors position dependency on intensity

- BPM.515-V: difference orbit (net effect due to intensity change)





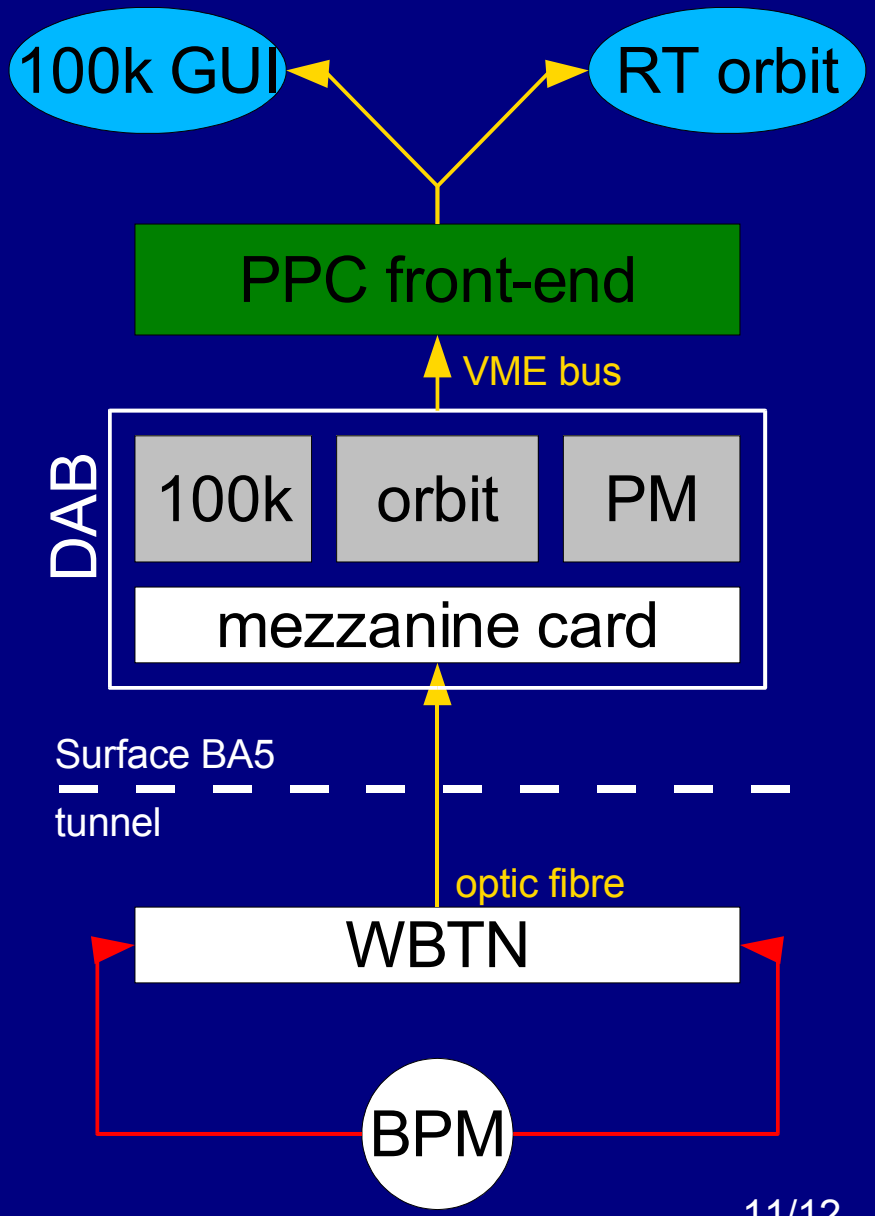
LHC BPM errors
position dependency on injection pattern



- data taken during 'Scrubbing run' (10 Hz sampling)
- Orbit distribution over 5900 cycles at BPMB.515-H
- Injection: change of total intensity, but intensity p. bunch is constant
- The measured position jump (~ 100 µm) at each injection is visible
- source not yet identified

Some control issues
100k turn and orbit acquisition

- 100k turn and orbit acquisition share the same hardware (WBTN, DAB)
  - Similar 100k buffers for post-mortem, 100k and orbit (orbit acquisition does some further pre-processing though)
  - common shared gain intensity settings
  - same triggers retrieval mechanisms
- One front-end computer for both data streams:
  - Presently: interference between 100k turn and orbit acquisition
    - block each other on OS level
    - data delivery of 100k turn data causes gaps (long delays) in RT acquisition (awkward for RT control)
  - 1 BPM 64k turns = ~500kb data
    - cause a ~ 400 ms long blindness of the RT orbit
  - Future: 18 BPM per crate
    - -> 18*400 ms = 7.2 s long unavailability of RT orbit????



Some conclusions

- The horizontal/vertical stability of the orbit during coast (estimates)
  - within 10 s: 48 μm / 6 μm
  - over coast: 76 μm / 59 μm
  - with feedback @ 25 Hz (based on 2003 experiences): ~30 μm (or better)
- The beam based measured non-linearities due to bunch length variation and bunch intensity change are consistent with the predicted 1-2% based on the electronic design
- present BPM front-end shows (at least partial) mutual exclusion between 100k turn and orbit acquisition (100k turn blocks the orbit readout! and vice versa in certain conditions) – must be solved for the LHC

- ToDo's :
  - Future MD's till end of this run:
    - Study of systematics:
      - bunch length vs. orbit position
      - orbit position shift vs. Intensity vs. orbit position
    - separation of BPM from “real” beam effects
  - Improvements of real-time parameters (constant delays, reliability...)