Strong-strong and coherent beam-beam effects

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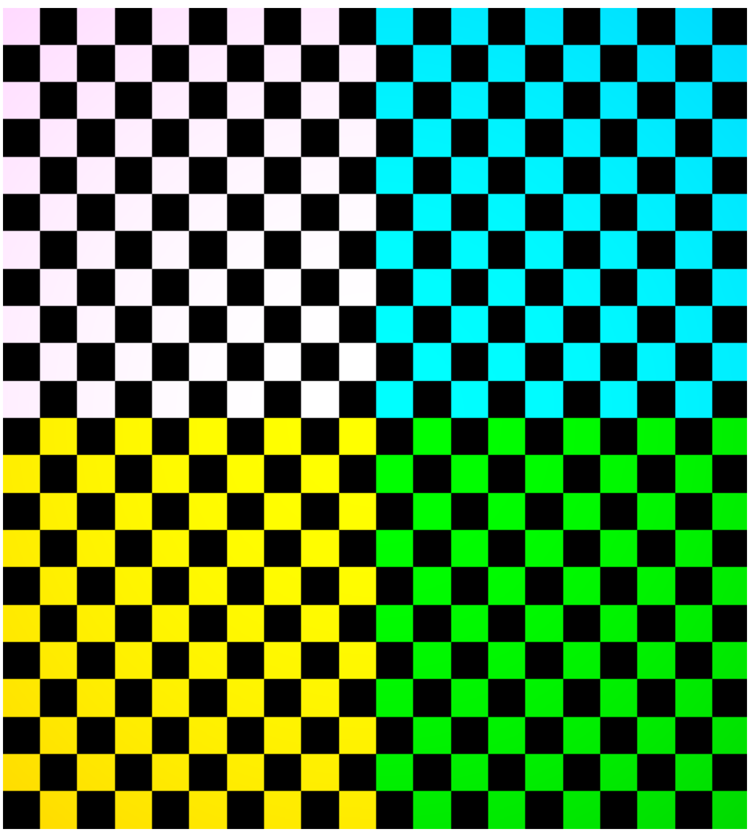
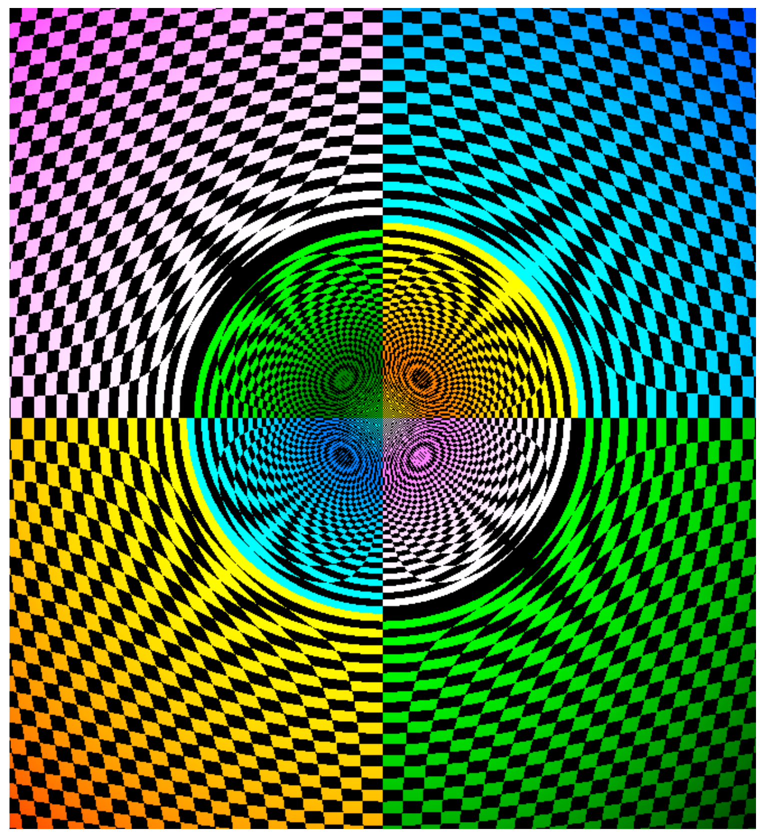
Nicolas Mounet & Lenny Rivkin





Paul A. Goergen
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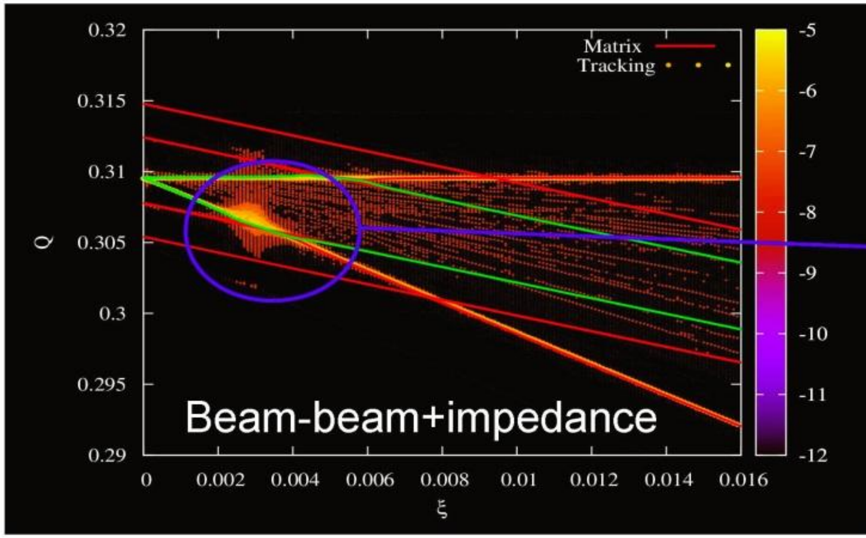
Coherent beam-beam and Impedance

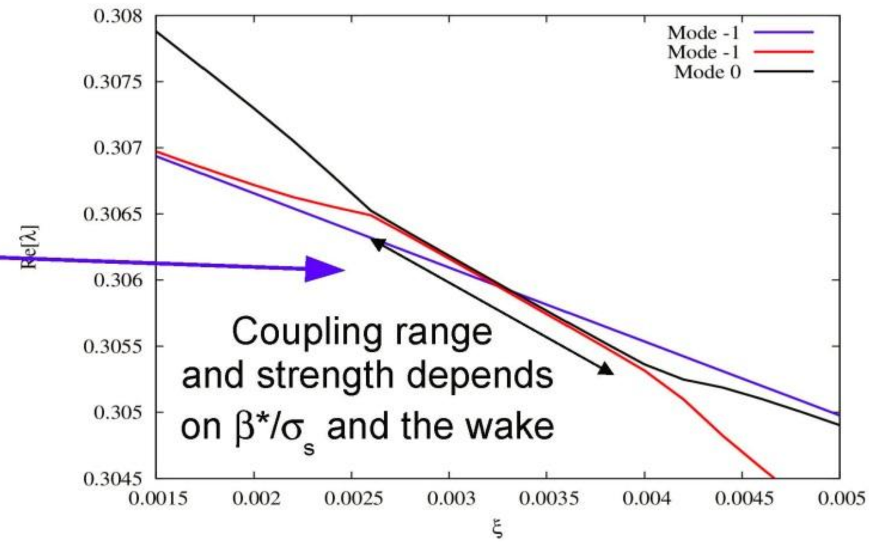
- Beam-beam and Impedance by Simon White
- Coherent modes in LHC by Xavier Buffat
- Coherent modes in Tevatron by Giulio Stancari

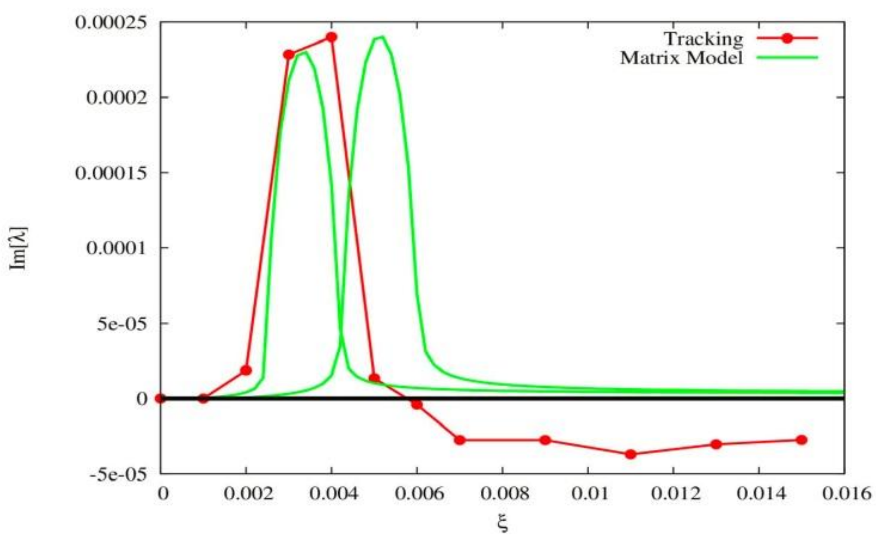
Instrumentation and observations

- Digitized BPM signals by Giulio Stancari
- Orbit effects in LHC by Michaela Schaumann
- Ultrafast orbit effects by Tobias Baer
- BTF measurements by Paul Görgen

Impedance and beam-beam





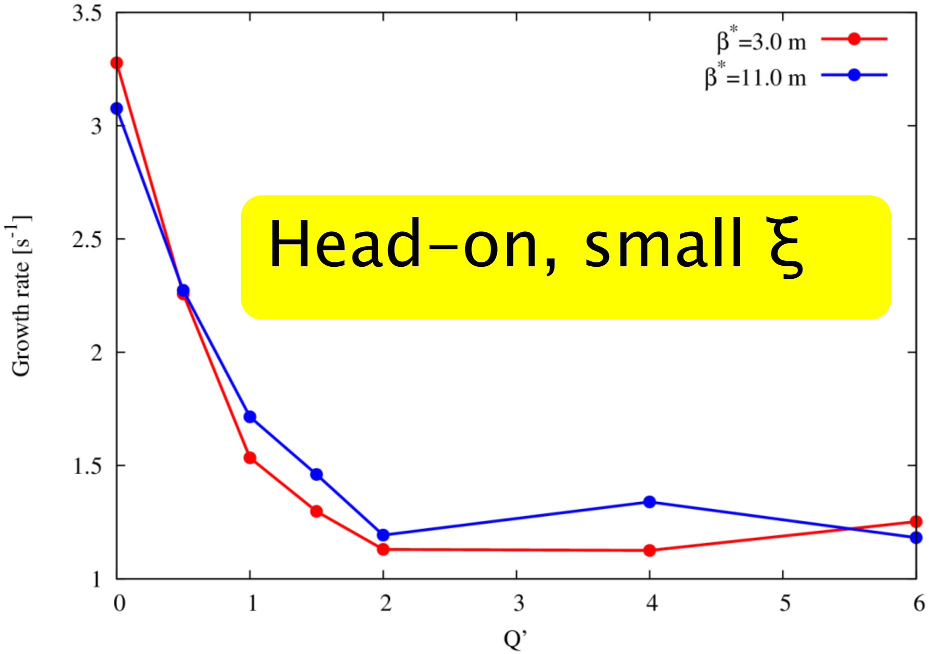


→ Scan the head-on beam-beam parameters at Q'=0.0 and constant wake

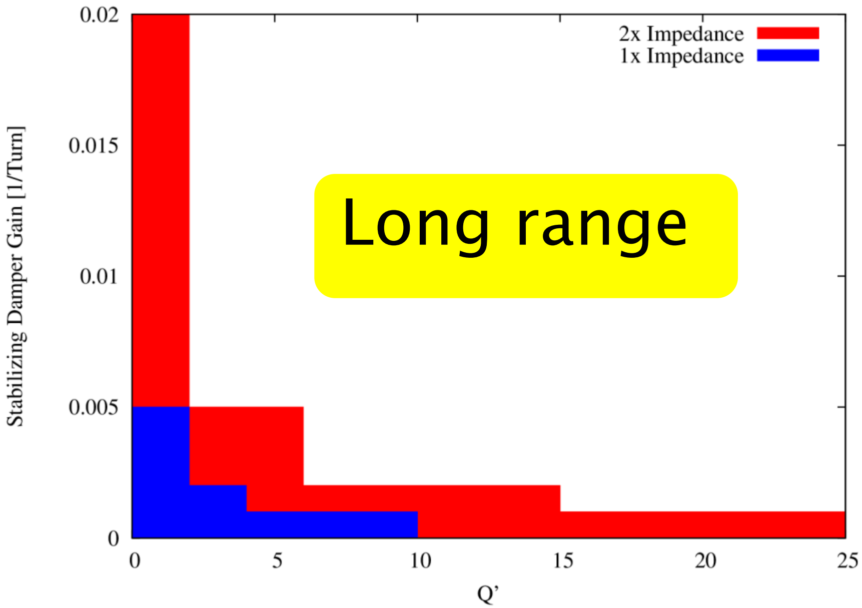
→ The beam-beam interaction shifts the π-mode down faster: coupling between modes 0 and -1 could occur at lower intensity

→ Although the analytical model predicts also coupling between σ-mode and mode +1 it is not observed in tracking simulations

Single bunch: Head-on & long range



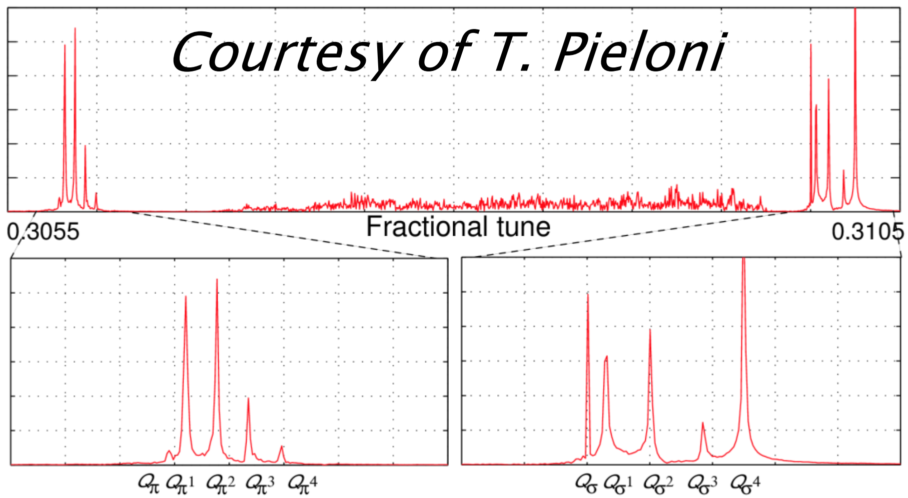
Chromaticity

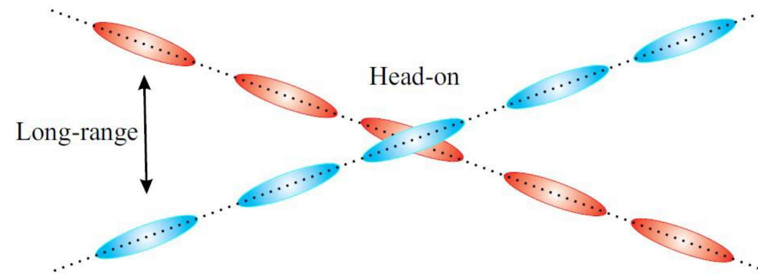


Chromaticity

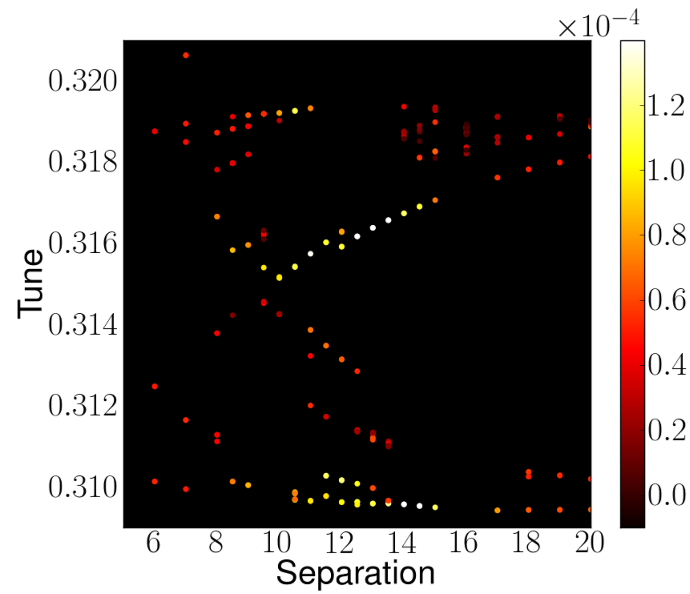
Full head-on has a clear stabilizing effect even without chromaticity, octupoles or damper

Multi bunch: complexity



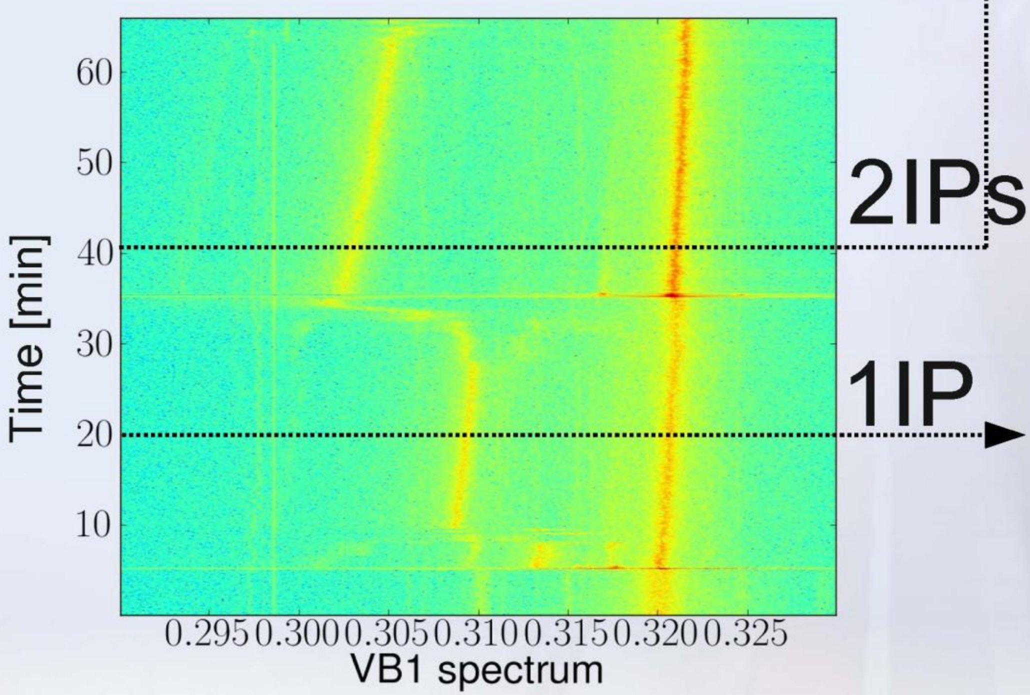


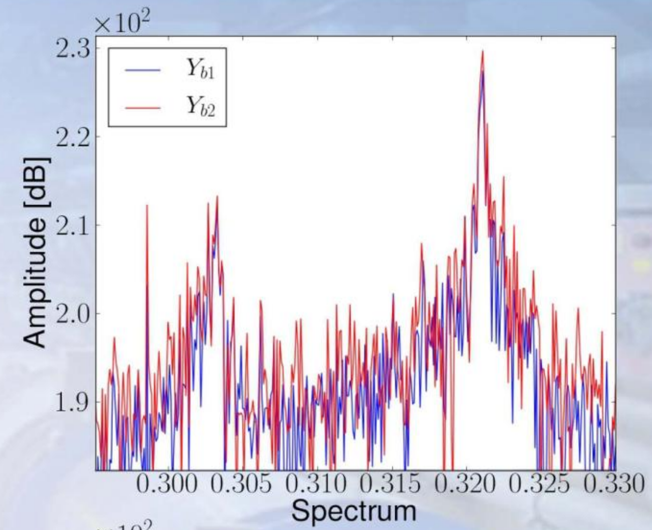
COMBI code for 36x36 bunches colliding in one IP

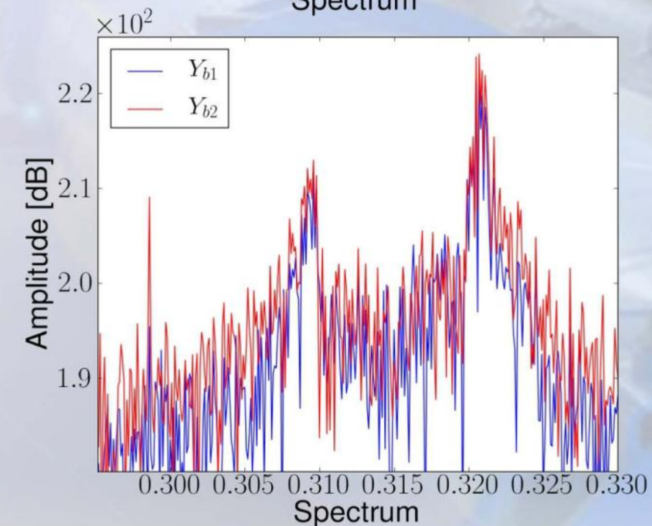


Stable single bunch mode in dedicated experiment

- Single bunch, 450 GeV
  - ξ~0.01 per IP
  - Modes are visible but usually stable
  - Transverse feedback is off

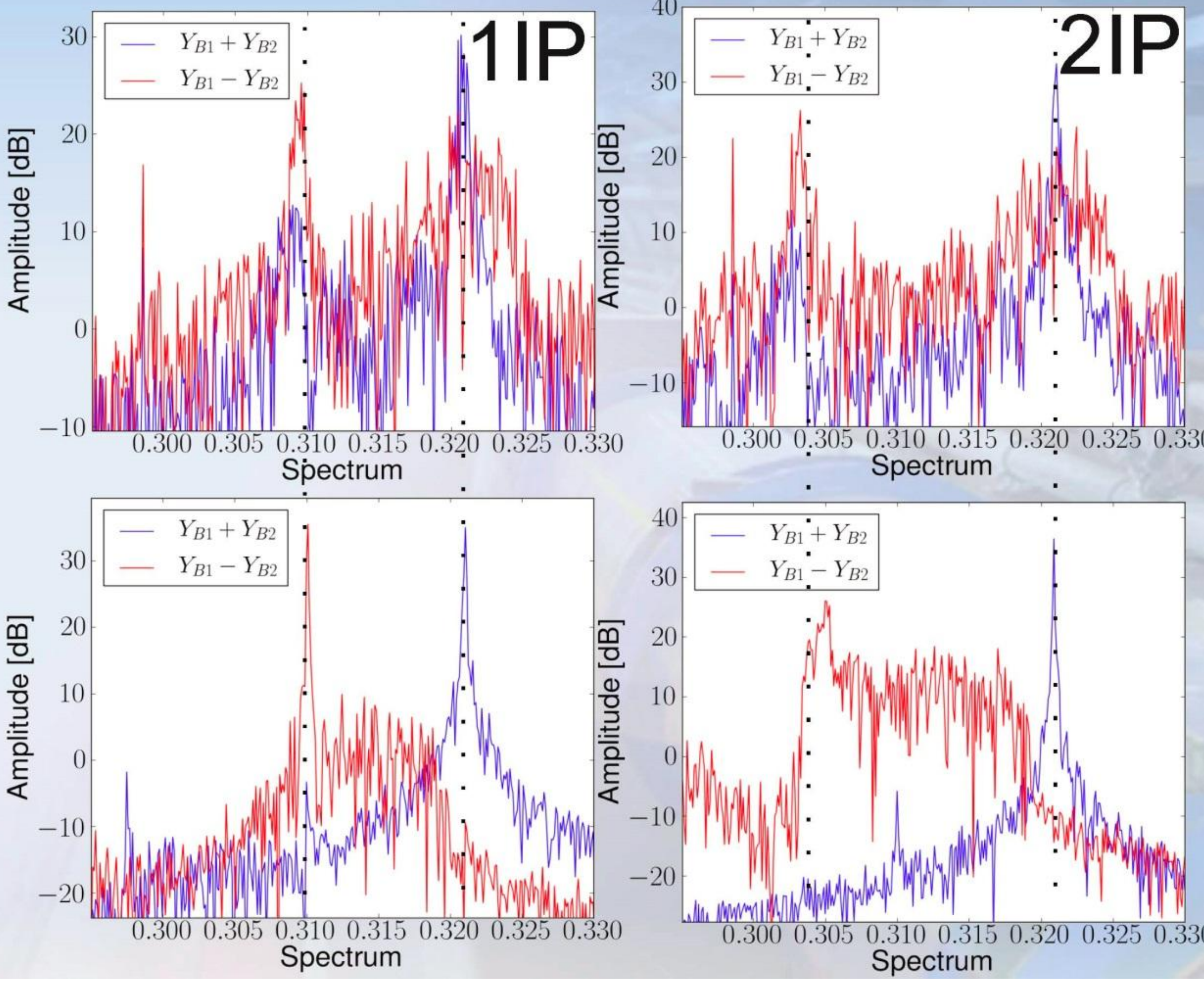




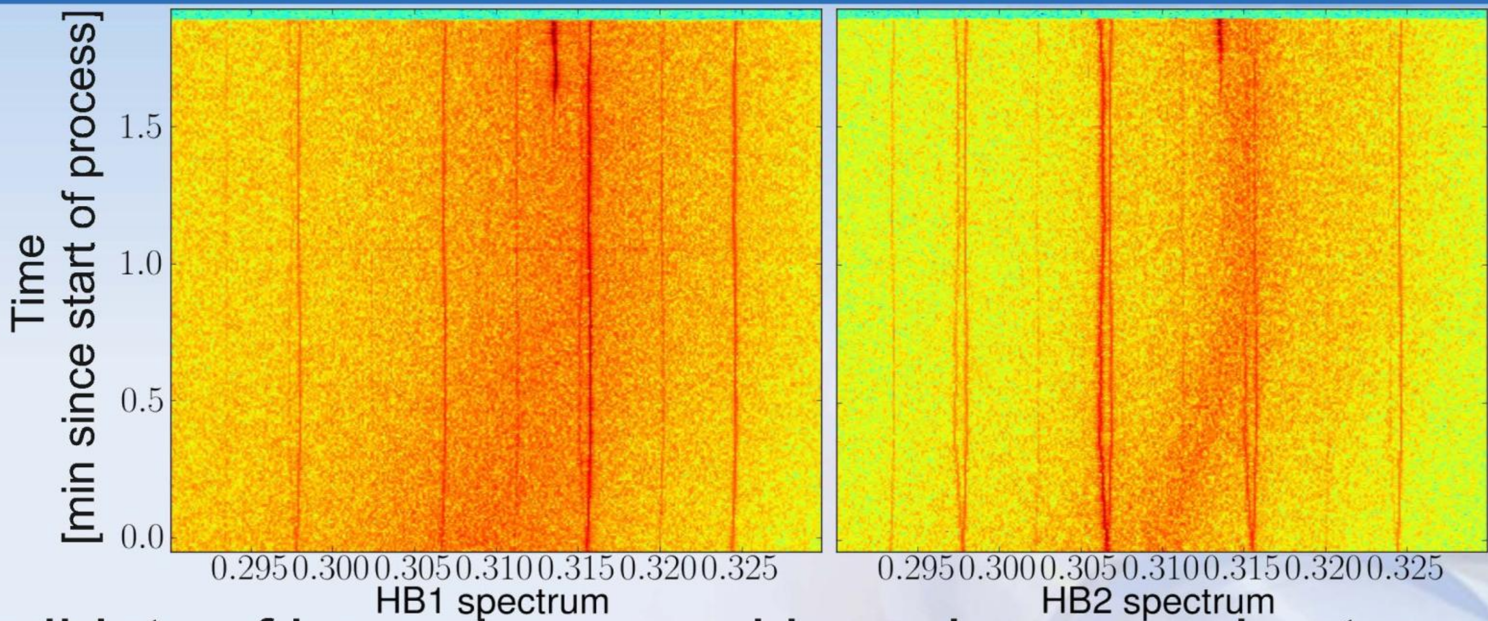


Comparison with simulation

- Bunch parameters are too different to measure the Yokoya factor
- Good agreement with self-consistent multiparticle tracking (COMBI)
  - Measured tunes, intensities and emittances used as input

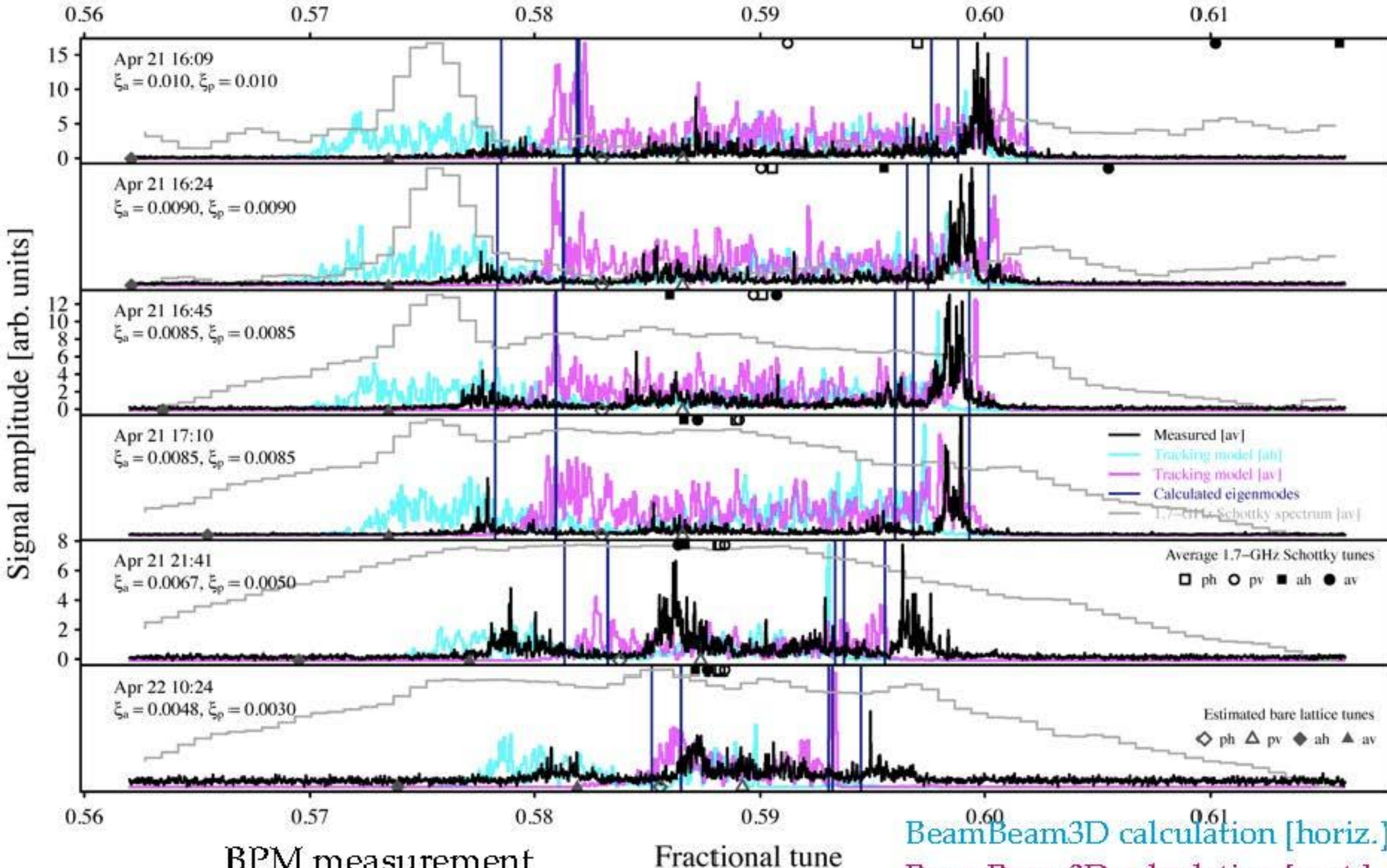


Coherent instabilities in standard operation



- Candidate of beam-beam and impedance mode at small separation while bringing the beams into collision (Fill 2808, July 2012)
- Not distinguishable from a single beam instability, with incoherent transimition of the signal to the other beam, via the beam-beam force (Using instrumentation available at the time)

Evolution of frequency spectra during collider store (narrow span)



BPM measurement

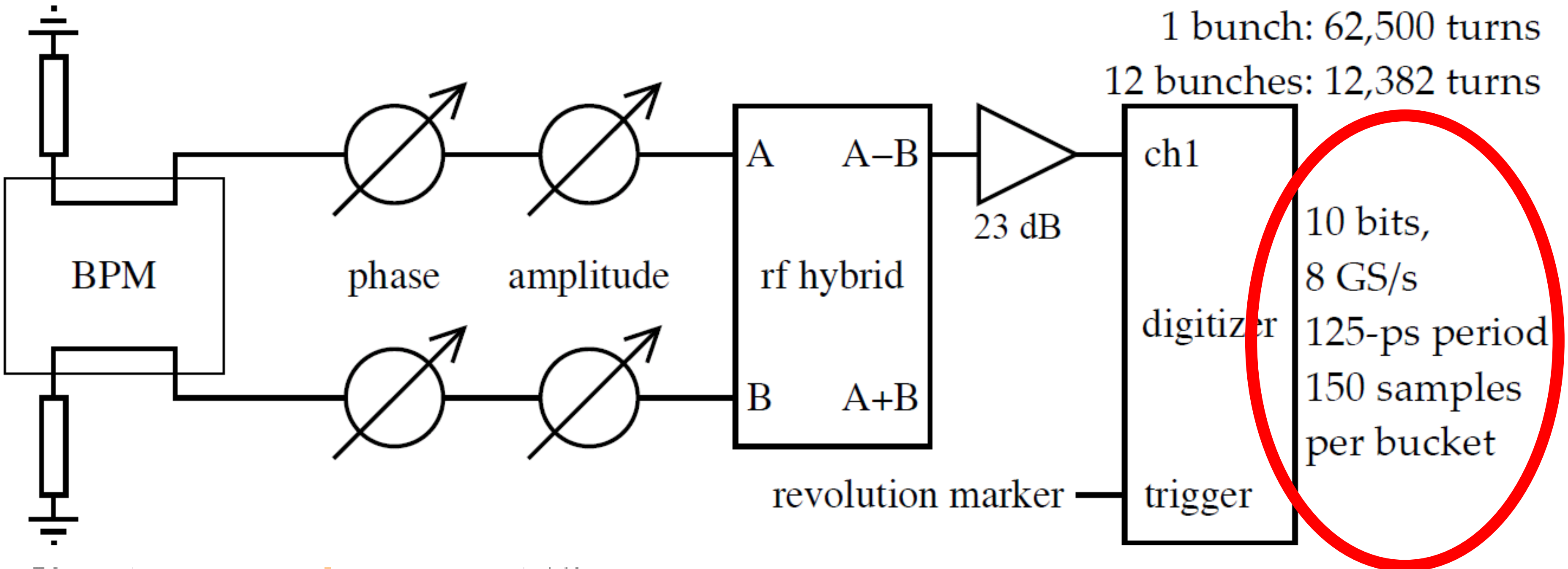
1.7-GHz Schottky

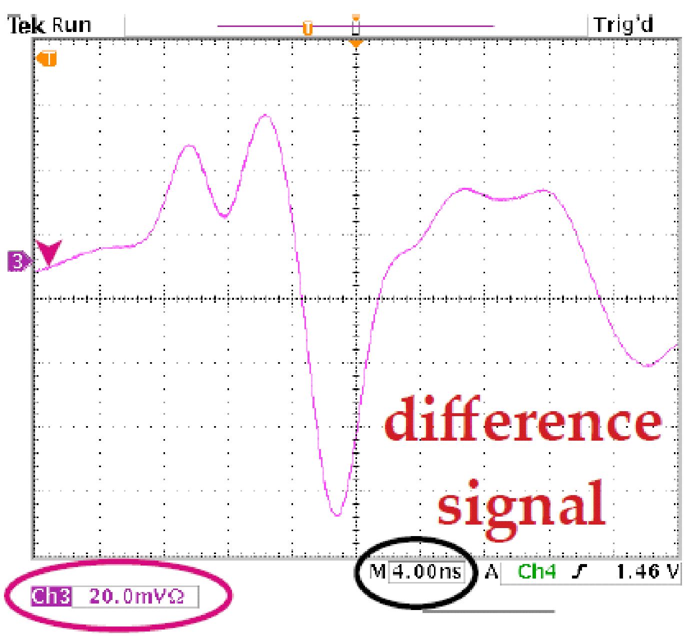
BeamBeam3D calculation [horiz.]

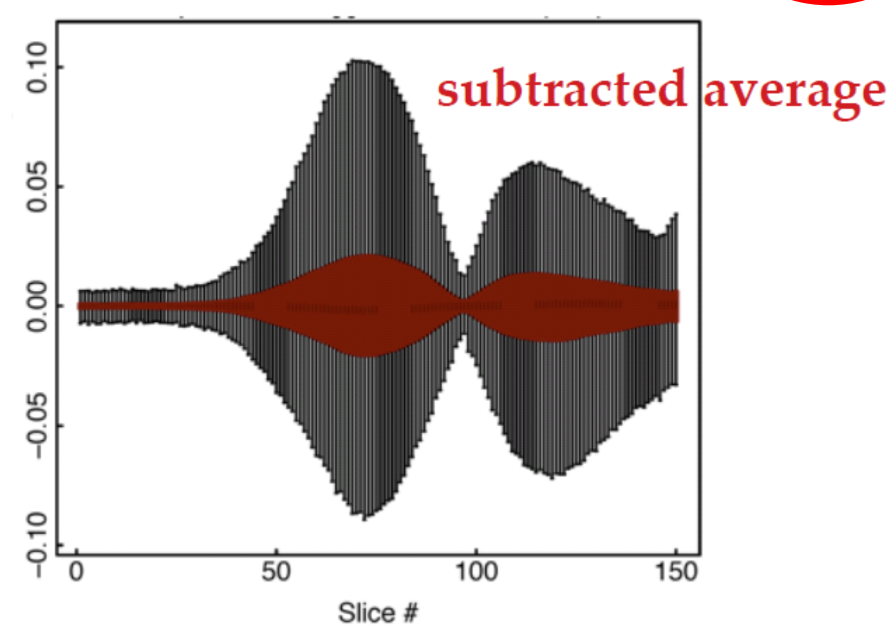
BeamBeam3D calculation [vert.]

Rigid-bunch model

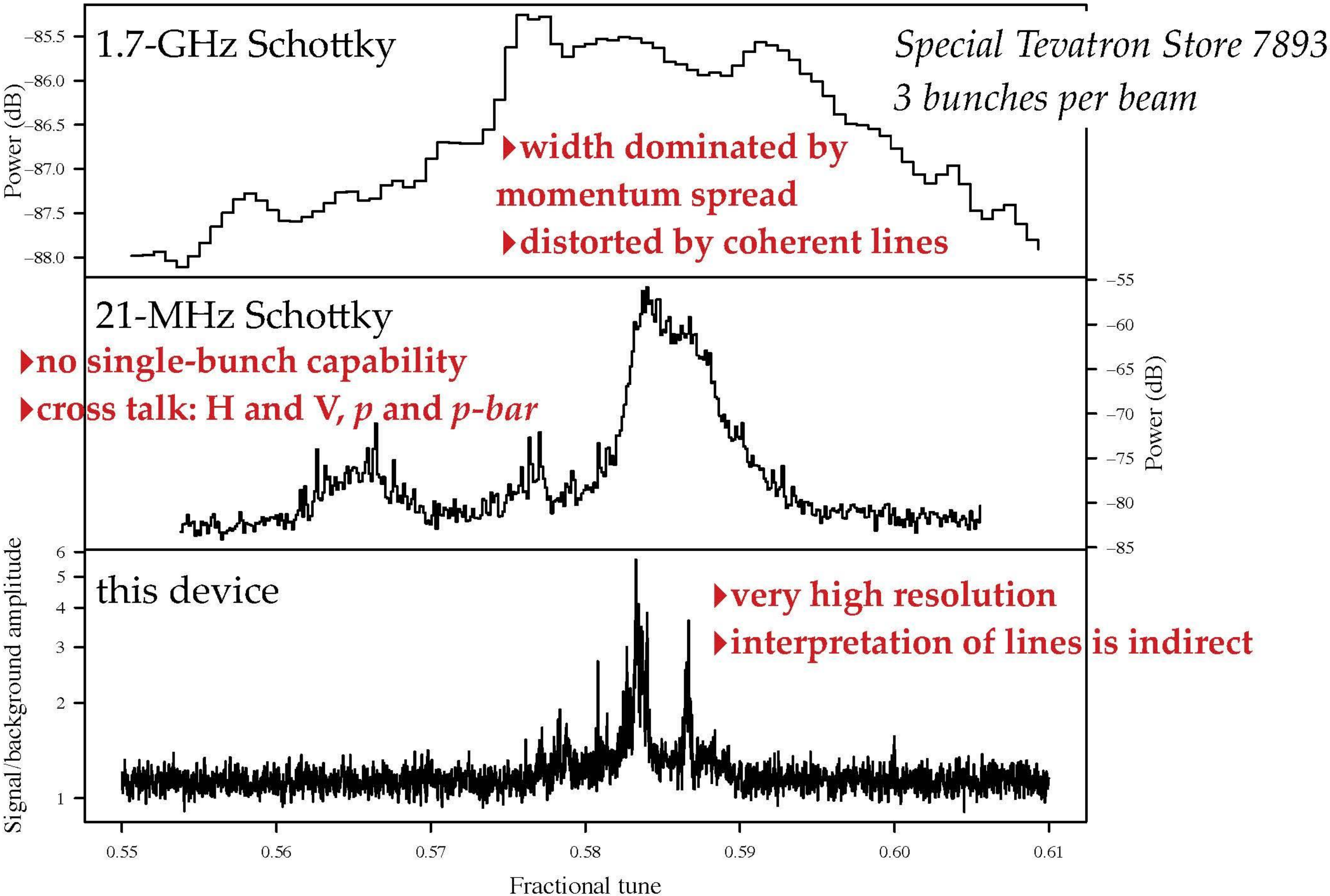
Apparatus


1 bunch: 62,500 turns
12 bunches: 12,382 turns
BPM
phase
amplitude
A
A–B
B
A+B
rf hybrid
23 dB
ch1
digitizer
trigger
revolution marker
10 bits,
8 GS/s
125-ps period
150 samples
per bucket

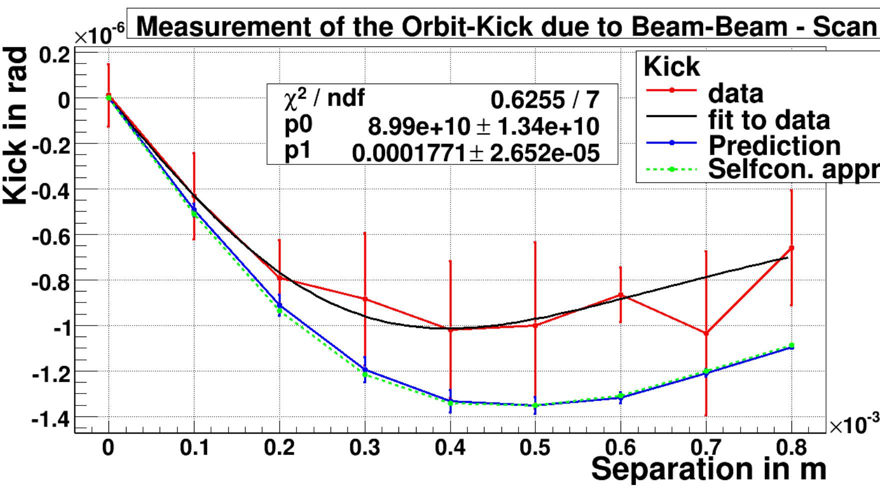

Tek Run
Trig'd
difference
signal
Ch3 20.0mVΩ
M 4.00ns
A Ch4 1.46 V

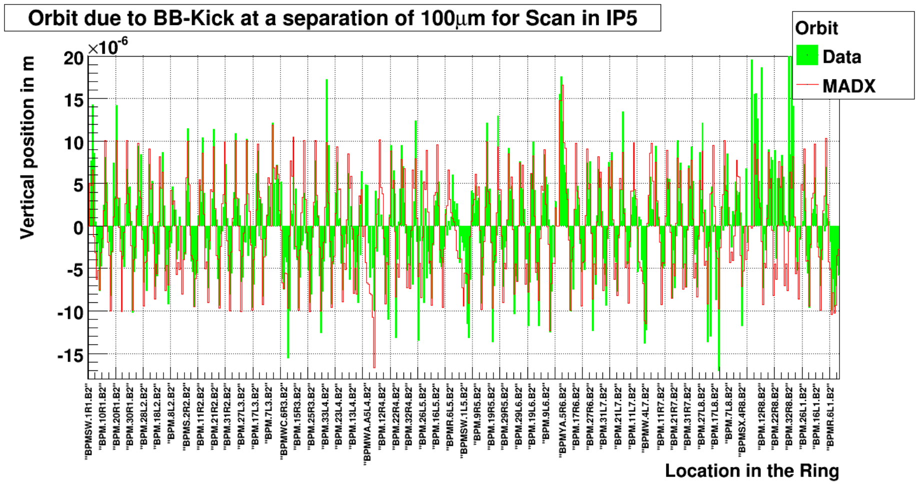

subtracted average
0.10
0.05
0.00
−0.05
−0.10
0
50
100
150
Slice #

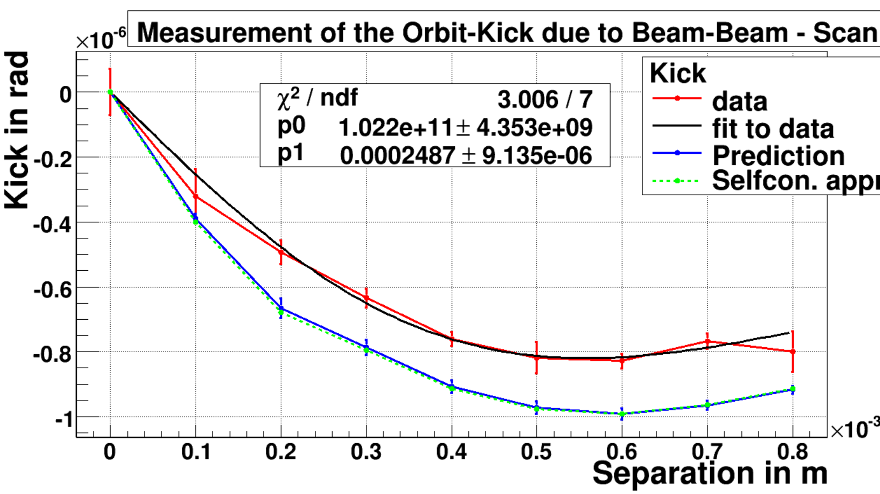
Comparison with Schottky detectors

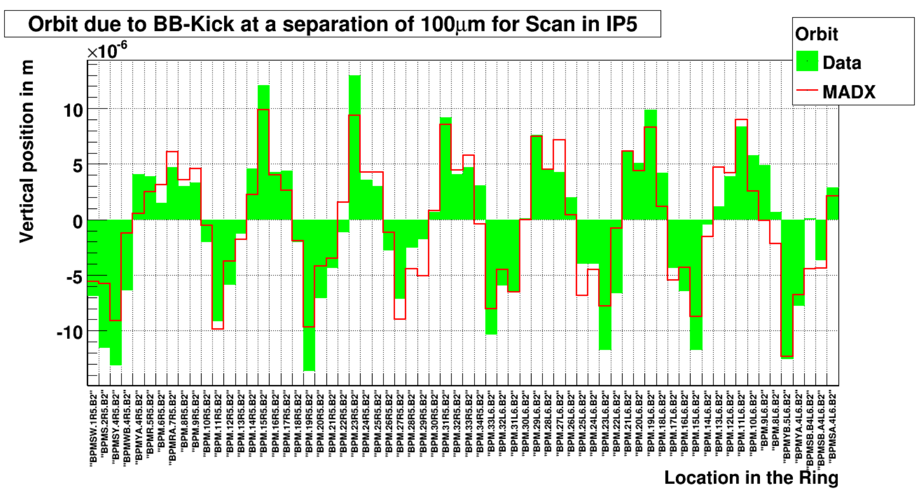


Michaela Shaumann – Observed Beam-Beam Induced Orbit Effects at LHC

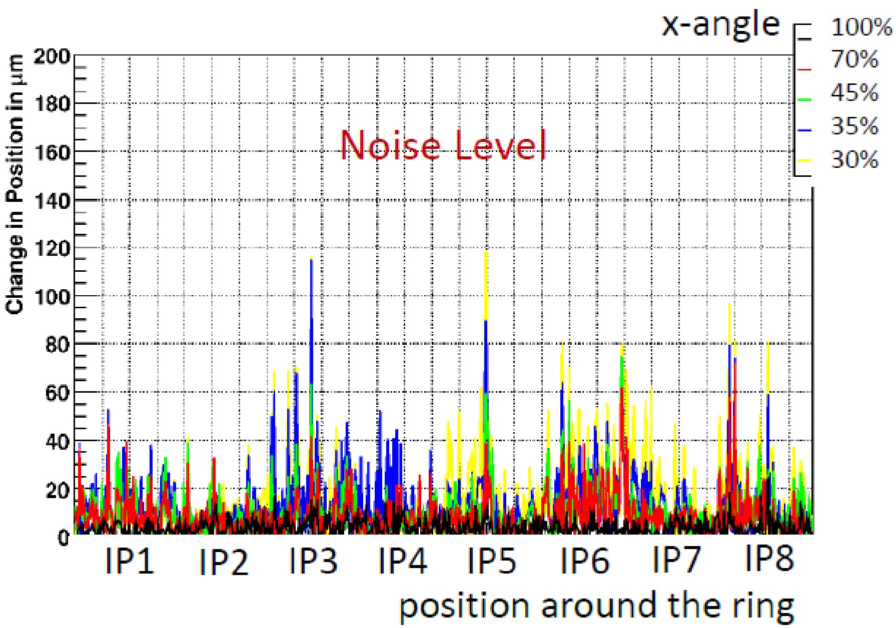




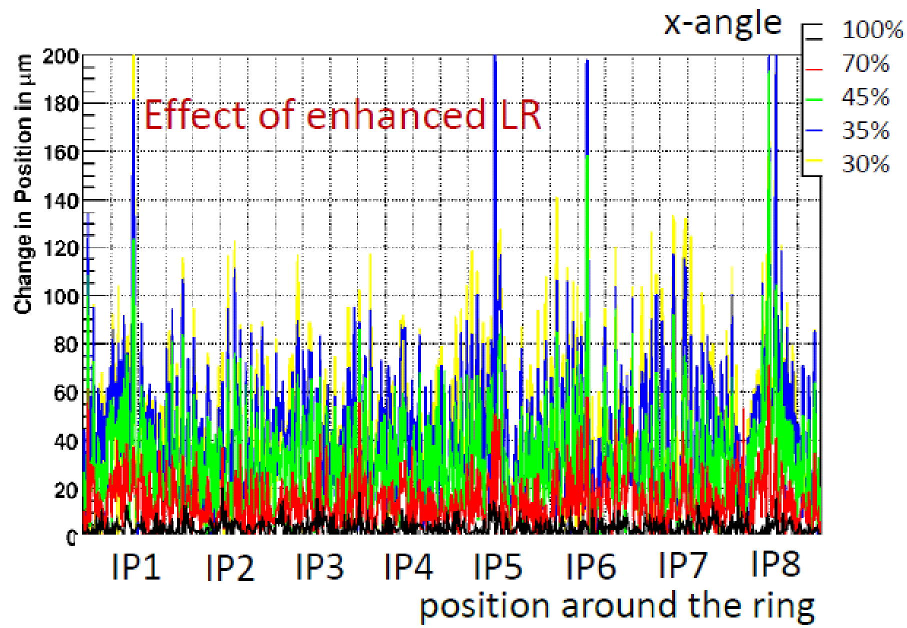




- In operation the BPM resolution is not enough to resolve beam-beam effects,
  → only during a dedicated experiment it was possible to observe relative orbit changes bunch-by-bunch and around the ring while reducing the crossing angle.



Bunch with no HO or LR collisions w.r.t. reference bunch of same conditions.

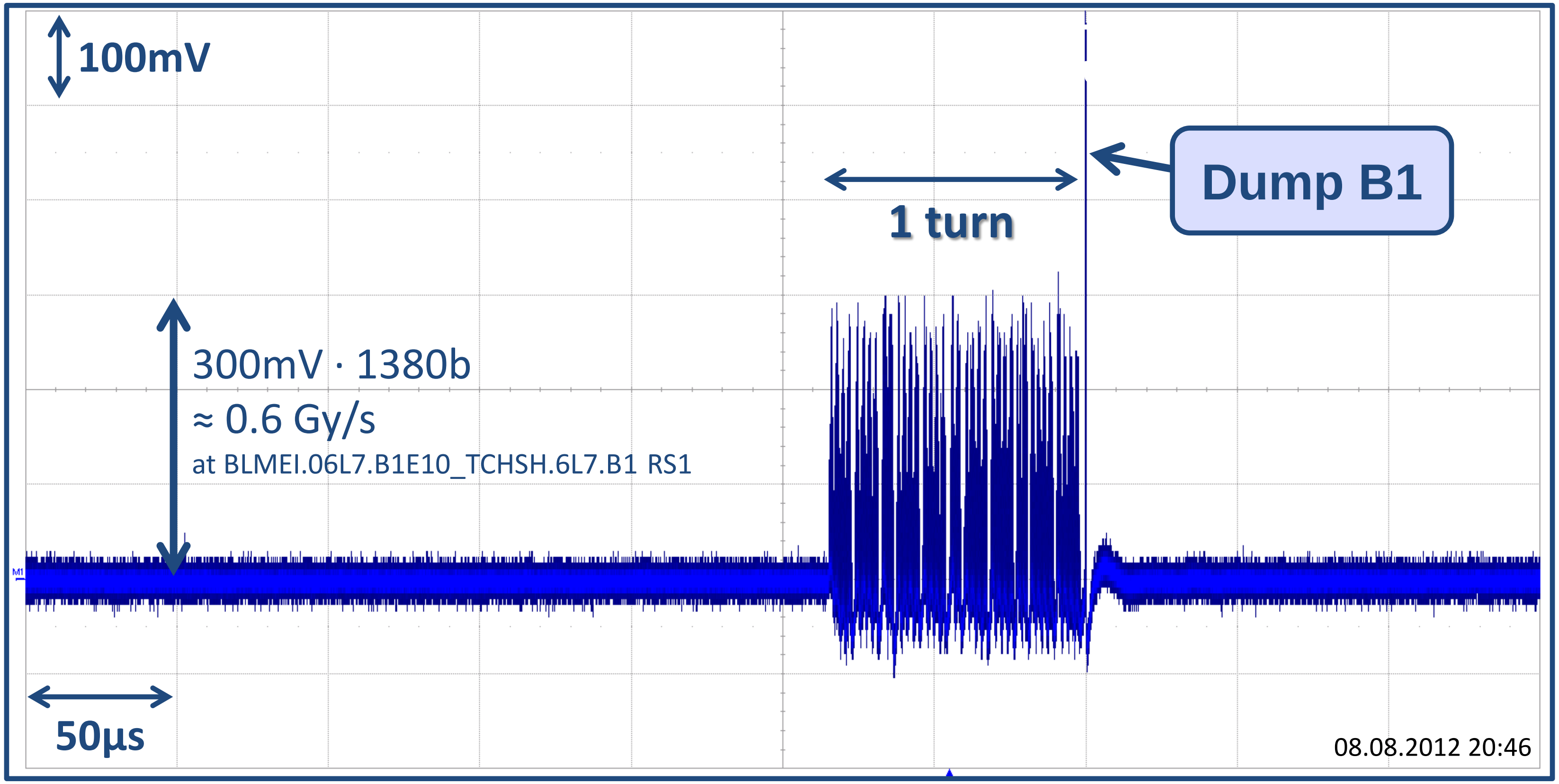


Bunch with 3 HO (in IP 1,2,5) and 16 LR w.r.t. reference bunch with no HO or LR.

Beam Dump on 8.7.2012

Beam dump trigger by B2 LL-RF (cryo problem).

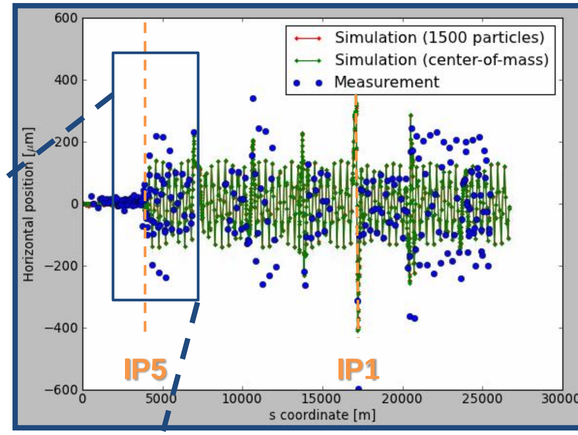
Unusual single-turn losses on B1 in before beam dump.

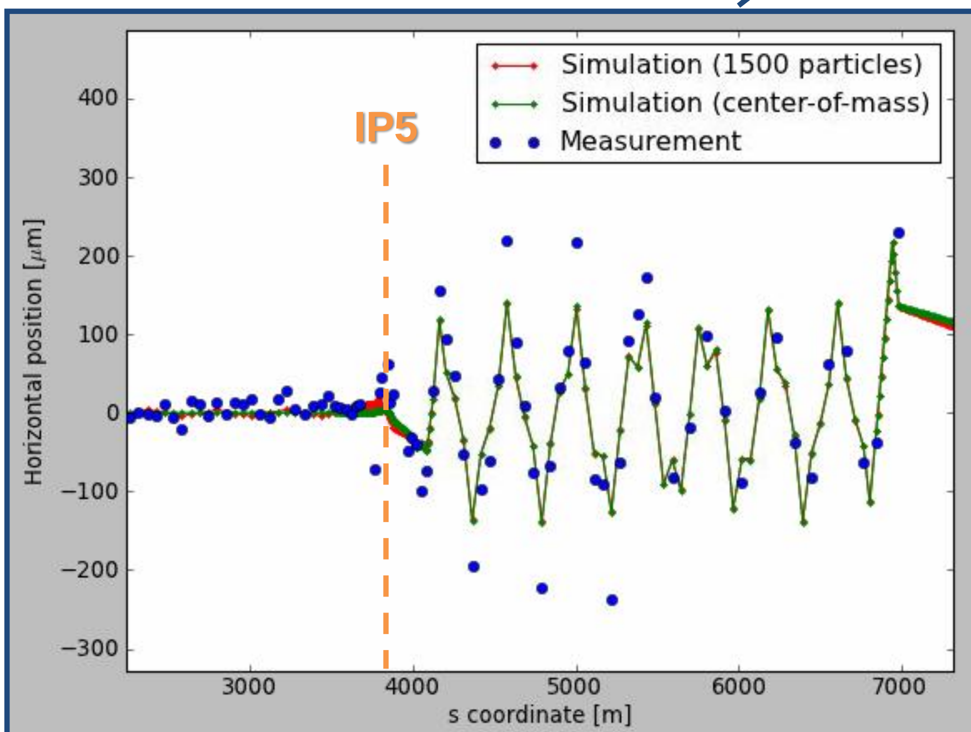


Signal from B1 diamond BLM in IR7.

First Turn Horizontal

- Phase of oscillation very well explained.
- Simulated oscillation amplitude **40% smaller** than measured amplitude.
- Good agreement between simulations of Gaussian beam and particle in bunch centre.

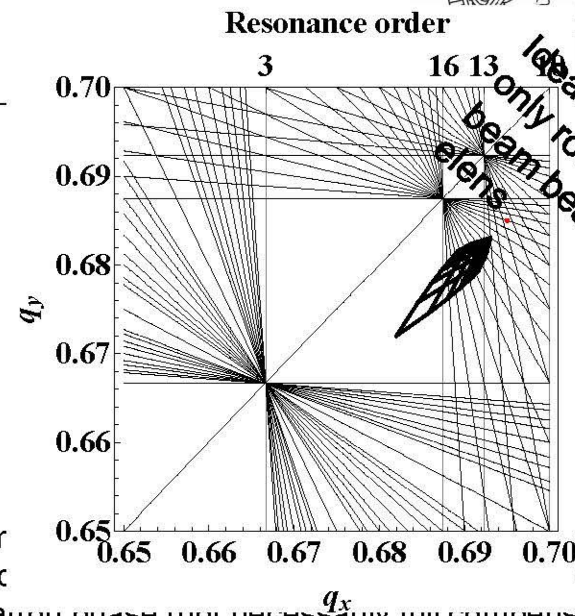




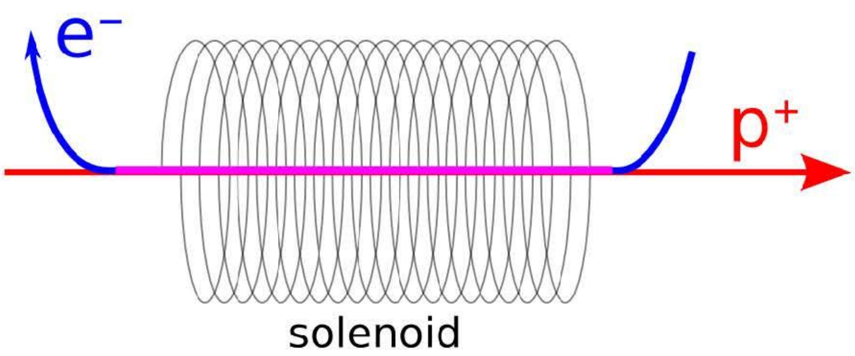
Simulation and measurement for bunches with full long range interactions. Not all BPMs have a valid acquisition, in some areas data is only available for BPMs at low beta function.

Counter-Measure against incoherent spread from beam-beam: electron lens

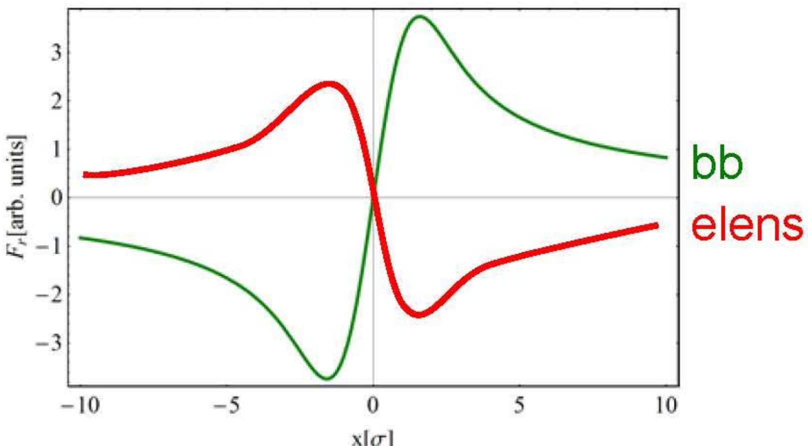
- Reduction of beam-beam tune spread
  - Need lens shaped like beam-beam interaction to compensate
  - Can be done by electron beam of correct profile (not by magnets)
  - Installation 2013



Com… n electron beam of cc… dentical betatron phase (not necessarily full compensation)



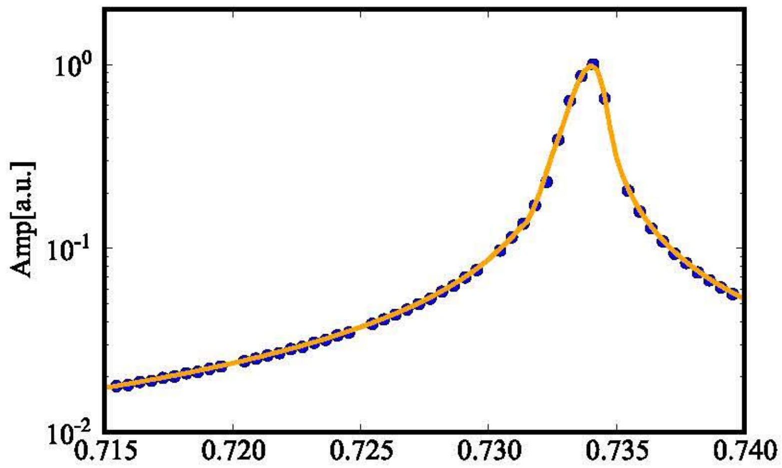
Elens cartoon modified from “RHIC electron lenses” slides by W. Fischer et al.



Elens force (negative beam-beam force)

Conclusion and Outlook

- Working BTF model in code
- Analytic Theory for Elens BTF
- Strenght recovery using fit
- Split tunes under special conditions
- Should be usable as elens diagnostics
  - Now we need to look more at beam-beam
  - And test this against a more suitable measurement



Coherent beam-beam and Impedance

- Good start in treating beam-beam and impedance, lots of work ahead, some very promising results

Instrumentation and observations

LHC needs many observables to help unravel the rich structure of this «universal» machine – on to 25 ns and beyond!

Diagnostics

- does not have to be interesting
- does not have to be 120% right
- IT HAS TO BE USABLE AND BE USED