MD 382: BTF and diffusion mechanisms

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Why BTF measurements?

Beam Transfer Function:
beam amplitude response per driving excitation frequency

- Tune measurements
- Spread measurements etc…
- Direct measurements of the Landau Stability Diagrams
- Sensitive to particle distribution changes
- Coherent mode observations in Landau damping region

BTF measurement is the only way to test the model of the Landau stability diagrams

BTF status

- BTFs measurements have been performed parasitically to several MDs of Block 1&2
- The BTF measurements have been set-up, resulted to be completely transparent for not-colliding beams with ADT OFF
- BTF measurements have been successfully performed during different machine configurations (with single bunch per beam):

  - At injection energy on pilot and nominal bunches

  - An octupole scan has been performed to evaluate the tune spread from BTF response
  - At 6.5 TeV on pilot and nominal bunches
  - With beams in collision at injection and at flat top

Motivations of the MD

- Several instabilities occur in the LHC which are not yet understood
- Predictions of stability based on Stability diagrams → no experimental validation done so far
- Understand what happens to the SD in the presence of strong resonances (BB)
- How does particle distributions change in the presence of resonances and/or noise

Possibly find a set-up for the BTF measurements at top energy transparent to the beams and with good signal for possible use during operations in the LHC

Beam and optics parameters

Number of MD's	1
Time required per MD [h]	8
Beams required [1, 2, 1&2]	1&2
Beam energy [GeV]	6.5 TeV
Optics (injection, squeezed, special)	Collision optics, squeezed, 80 cm beta*, colliding
Bunch intensity [#p, #ions]	Nominal (1.15E11)
Number of bunches	1-2 trains of nominal bunches in Beam 2 against single bunch in Beam 1 (tbc)
Transv. emittance [m rad]	2-3 μm
Bunch length [ns @ 4σ]	Nominal
Optics change [yes/no]	No
Orbit change [yes/no]	Reduced crossing angles in IP1&5
Collimation change [yes/no]	TCTs moved with the crossing angle at colliding IP1 & IP5
RF system change [yes/no]	No
Feedback changes [yes/no]	Yes on single bunch ADT off and/or at reduced gain
Tune changes	Tune scan maximum deviation 0.01
What else will be changed?	Chromaticity, Octupole currents
Are parallel studies possible?	No

MD procedure

1. Inject beams: 1-2 trains of bunches in Beam 2 and single bunch in Beam 1.
2. Turn off the ADT on single bunch and measure the BTF for different octupole currents
3. At flat-top reduce the ADT gain and perform BTF measurements on the single bunch changing the octupoles currents (above 450 A)
4. ADT off and measure BTF with full octupole current 550 A.
5. Turn on the feedback gain back to operational conditions and proceed through the betatron squeeze.
6. At the end of the squeeze reduce octupole currents (above 350 A) to measure LR contribution.
7. Back to nominal configuration of octupoles measure BTF for different tunes
8. Reduce chromaticity in steps from 15 to 10.
9. Proceed for collisions.
10. With IP1 and IP5 optimized switch off the ADT on single bunch and perform BTF as a function of separation offset.
11. Reduce crossing angles in IP1 and IP5 corresponding to a reduction of beam separation of STEP (e.g. 1 sigma) and take a BTF measurement at each step switching off the ADT (collimator settings and interlocks as done during the LR MD)
12. Tune scan with BTF measurements at each tune change.

Collimator settings

1. Consider the crossing angle changes from the previous Long-Range MD to reduce progressively the separation of the long range encounters.
2. Consider already calculated TCT & interlock settings from the previous Long-Range MD which were found successful.

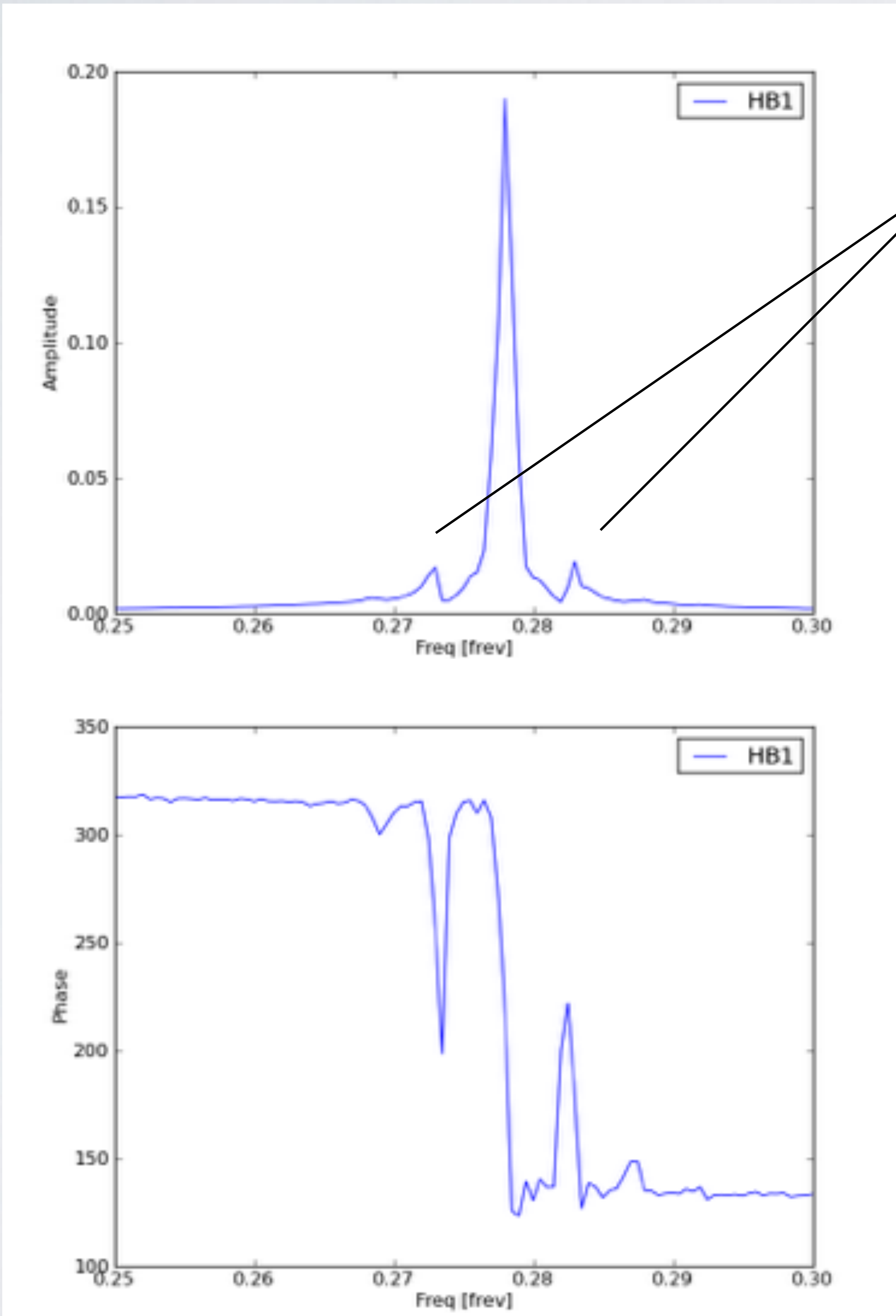
Half crossing angle (μrad)	Beam-Beam sep (units of 3.75 μm)	B1 Δy at TCTVA.4L1 (μm)	B2 Δy at TCTVA.4R1 (μm)	Δy relative to previous step (μm)
-145	11.2	0	0	0
-130	10	-106	-106	-106
-117	9	-198	-198	-92
-106	8.2	-276	-276	-78
-96	7.4	-347	-347	-71
-87	6.7	-411	-411	-64
-79	6	-467	-467	-57
-72	5.5	-517	-517	-50
-65	5	-567	-567	-50
-58.5	4.5	-613	-613	-46
-52.65	4	-654	-654	-41
-47.4	3.6	-691	-691	-37
-42.65	3.3	-725	-725	-34

Table 2: IP1 crossing angle changes and the corresponding relative steps in collimator positions and interlocks. Intermediate steps can be linearly interpolated from the ones reported

Half crossing angle (μrad)	Beam-Beam sep (units of 3.75 μm)	B1 Δx at TCTH.4L5 (μm)	B2 Δx at TCTH.4R5 (μm)	Δx relative to previous step (μm)
145	11.2	0	0	
130	10	140	-140	140
117	9	261	-261	121
106	8.2	363	-363	102
96	7.4	456	-456	93
87	6.7	540	-540	84
79	6	614	-614	74
72	5.5	680	-680	65
65	5	745	-745	65
58.5	4.5	805	-805	61
52.65	4	860	-860	54
47.4	3.6	909	-909	49
42.65	3.3	953	-953	44

Table 3: IP5 crossing angle changes and corresponding relative steps in collimator positions and interlocks. Intermediate steps can be linearly interpolated from the ones reported.

Measured BTF amplitude response



Synchrotron sidebands visible in the BTF signal

Phase jump clearly visible in correspondence of the synchrotron sidebands

BTF signal when beams in collisions in IP1&5: pi and sigma-mode visible