Recent observations of Instabilities

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Thanks to:

OP crews for many measurements and observations

S. Fartoukh for discussions and LCU team for optics files

Summary of Fills Analyzed

Fill	Time	Beam	Plane
2857	Adjust (IP 1&5 collapse Sep lumi)	2 - 1	H
2859	Squeeze (IP1&5 approx 1 m)	2 – 1	H
2860	Adjust (during IP8 rotation)	2 - 1	H
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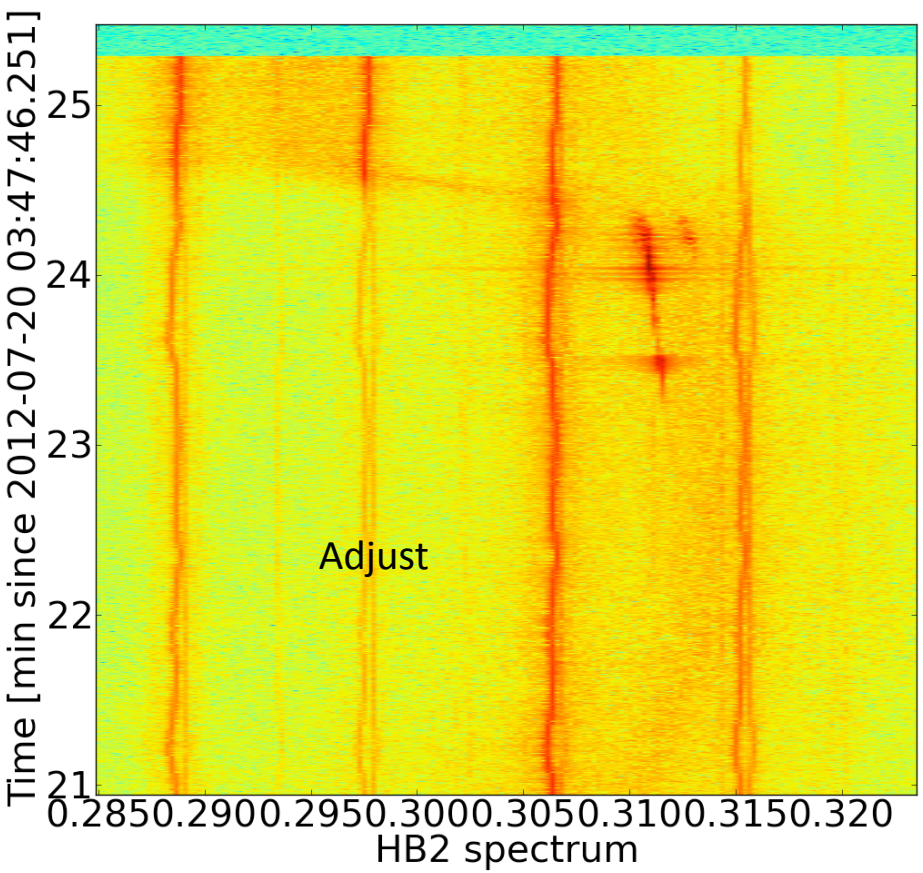
2883	Squeeze (IP1&5 approx 1 m)	1 -2	H
2886	Adjust (IP 1&5 collapse Sep lumi)	1	H

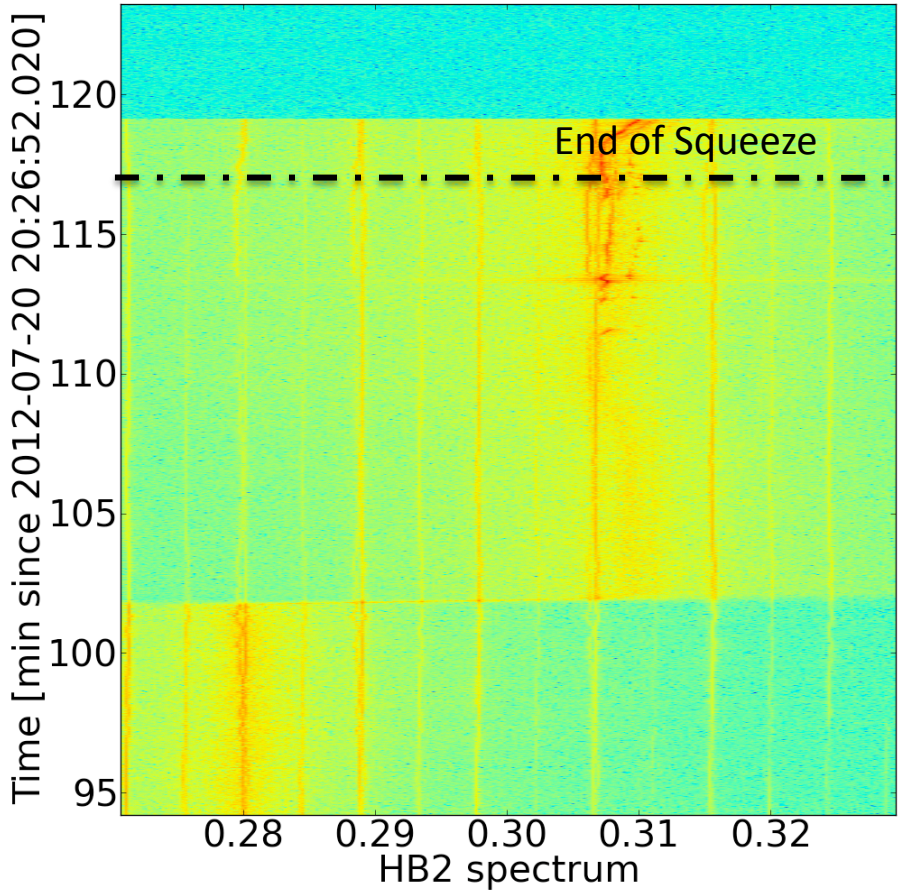
3 Main cases:

- Instability during end squeeze (after IP2 & 8 at 3 m)
- Instability during first minutes of Adjust
- Instability during Adjust lumi part

Common ingredient **always H plane** now preference for B2 but not obvious looking at past

Fill 2857 - 2859



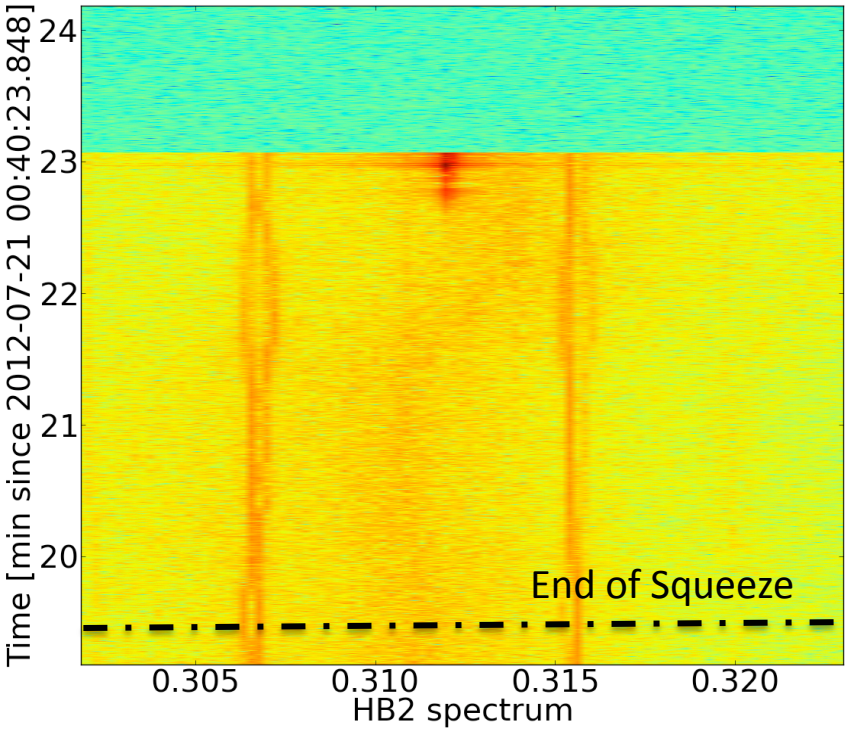


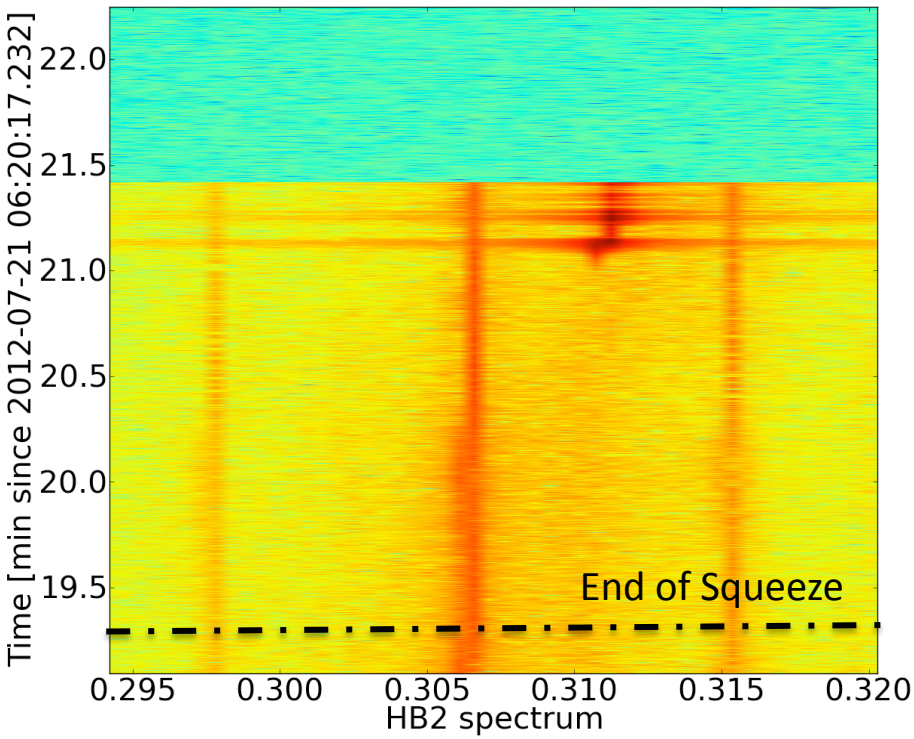
Typical instability **2-3 frequencies** develops before adjust and/or during adjust and propagates for several minutes

Losses start as soon as instability occurs and some time beams are dumped or make it through the collision beam process

There is a source of excitation (not understood yet) finds **bunches with weak damping properties** during the different moments of the beam process

Fill 2860 - 2862



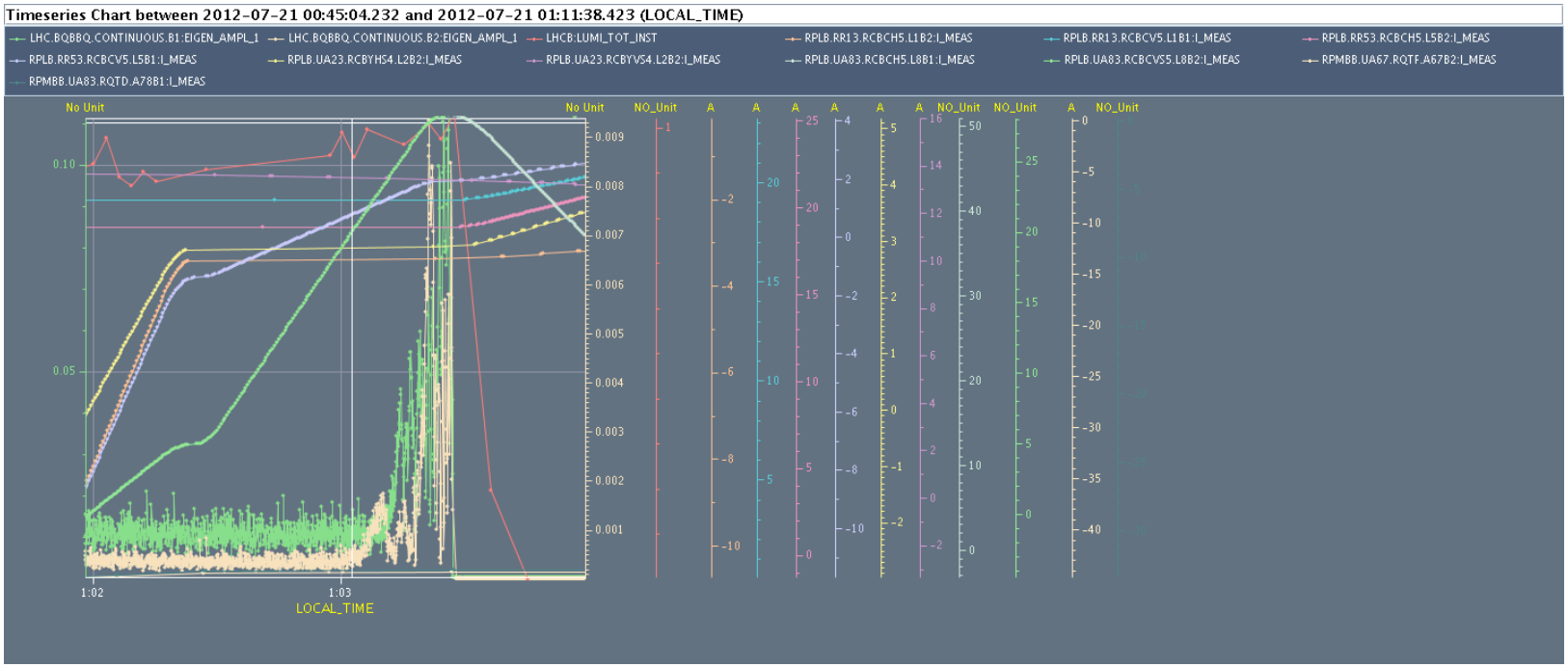


Very fast instability

Both fills instabilities develop after few minutes in adjust after first separation is collapsed while LHCb rotation occurs

Spectra are different **no sidebands** and very fast losses start on B2 after B1 follows

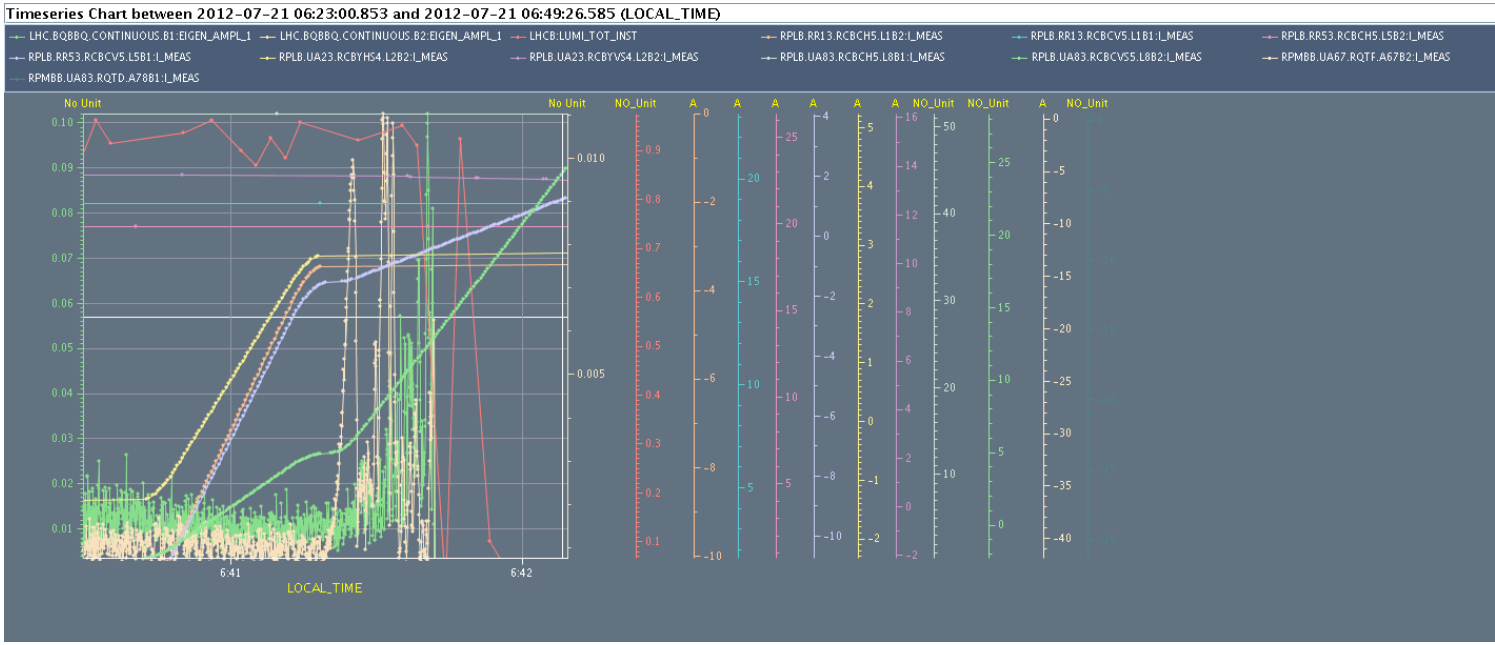
Fill 2860 & 2862



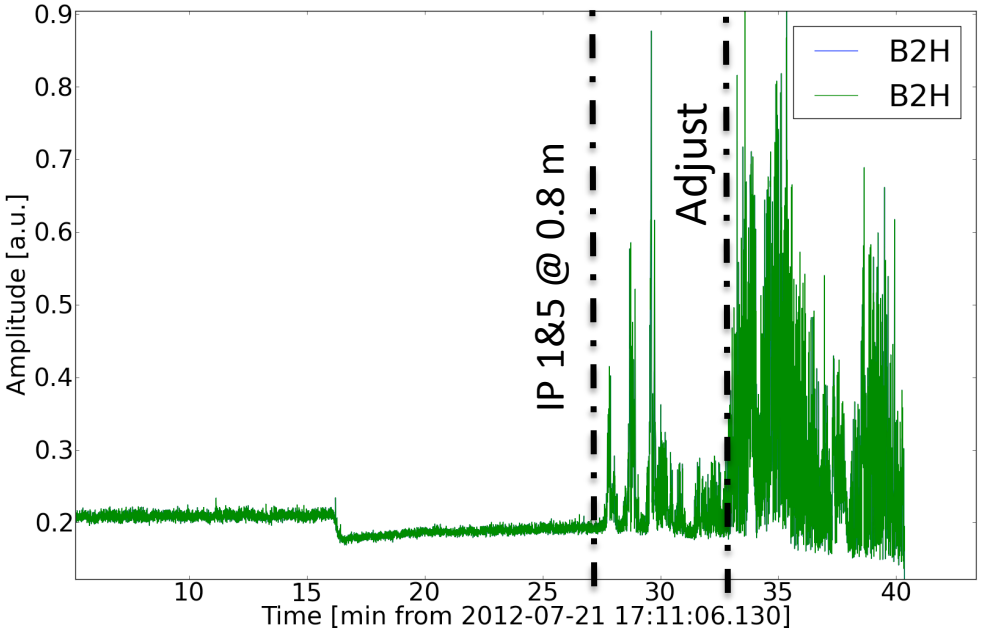
Instabilities occurs after first separation collapsed

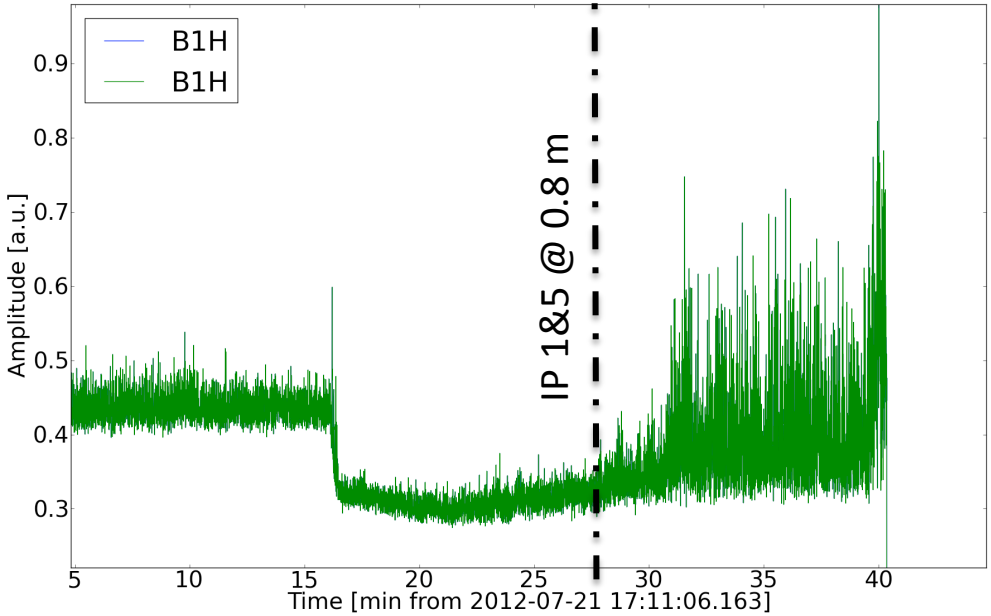
But not at same time

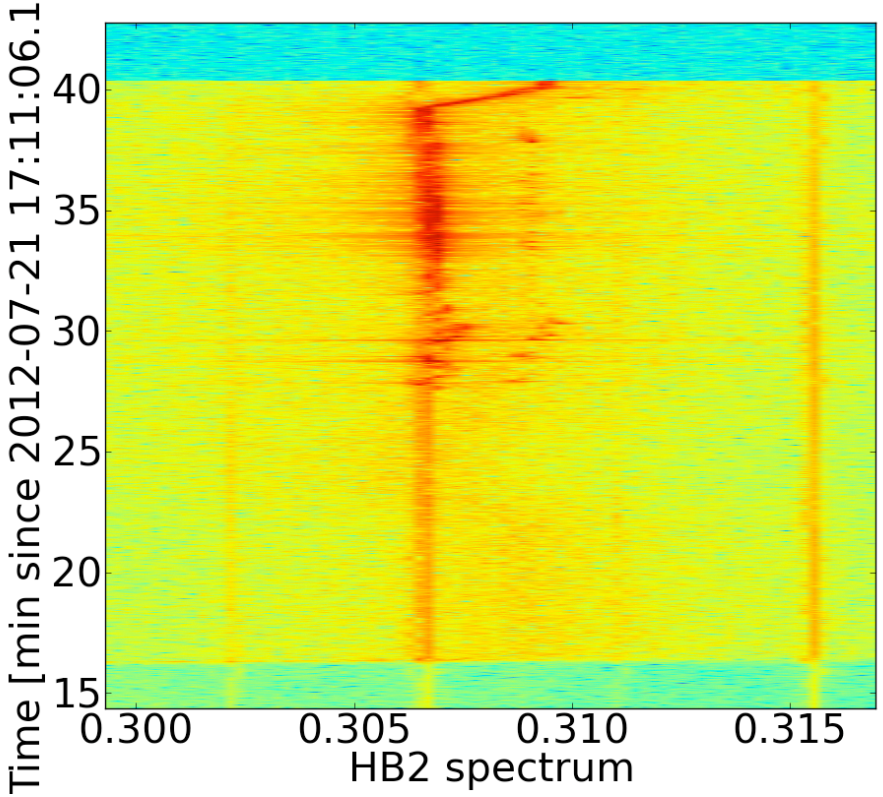
Very fast losses and dump



Fill2866

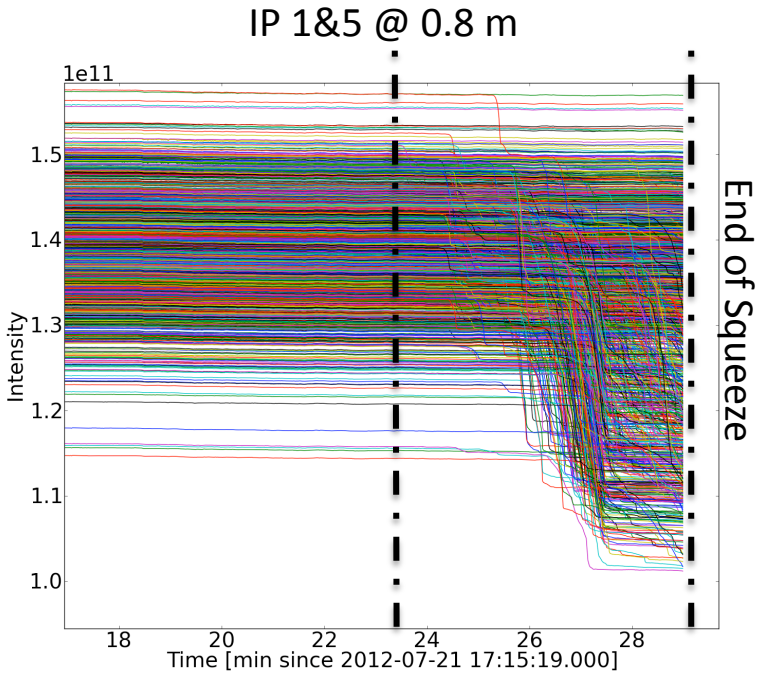


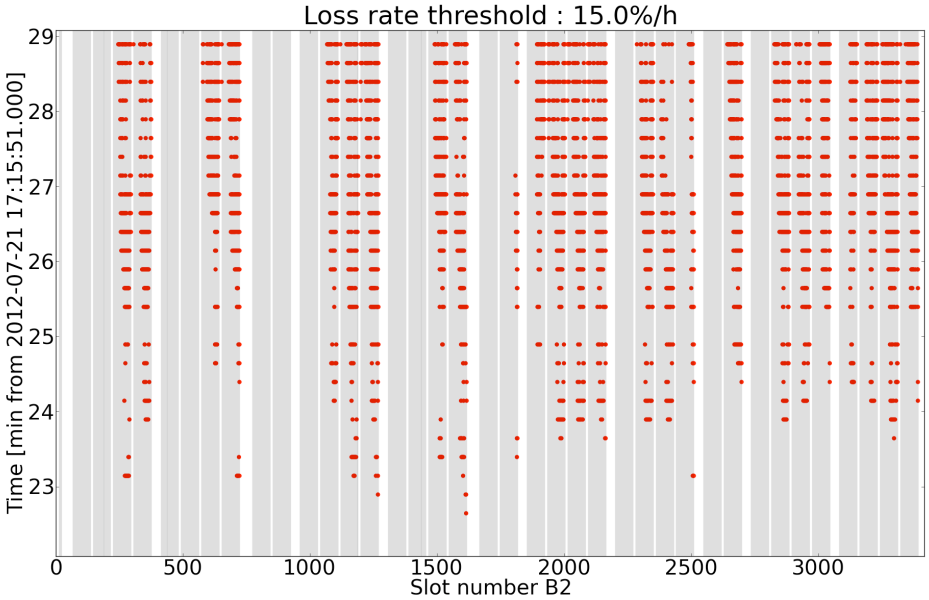




Typical instability **2 frequencies** develop during squeeze and propagates for several minutes

Fill2866

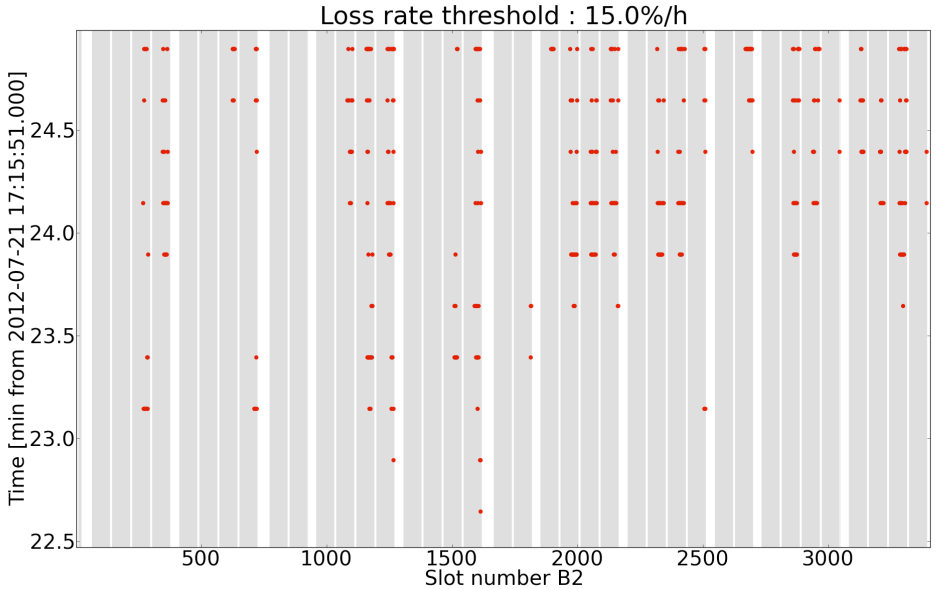




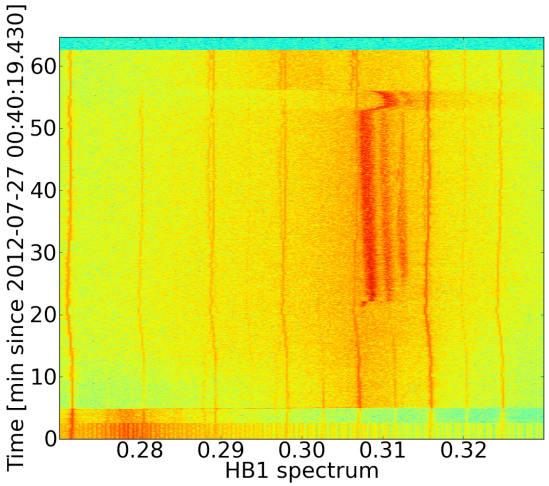
Losses start as soon as instability occurs

Only B2 few bunches end of trains (less LR) middle of trains (full LR)

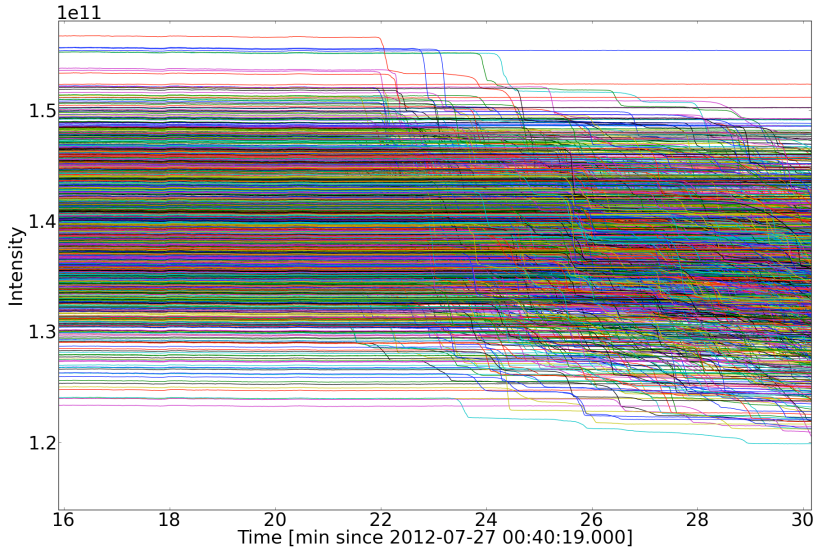
Propagates to neighbors not via BB

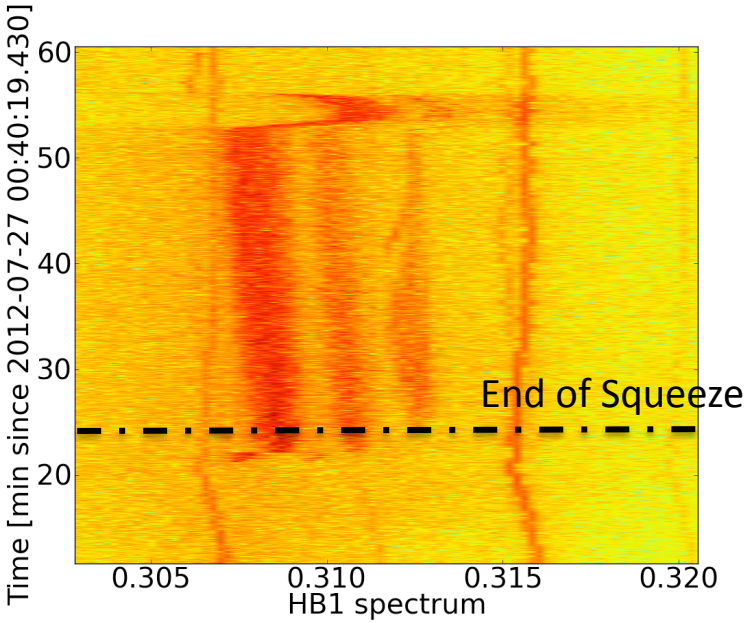


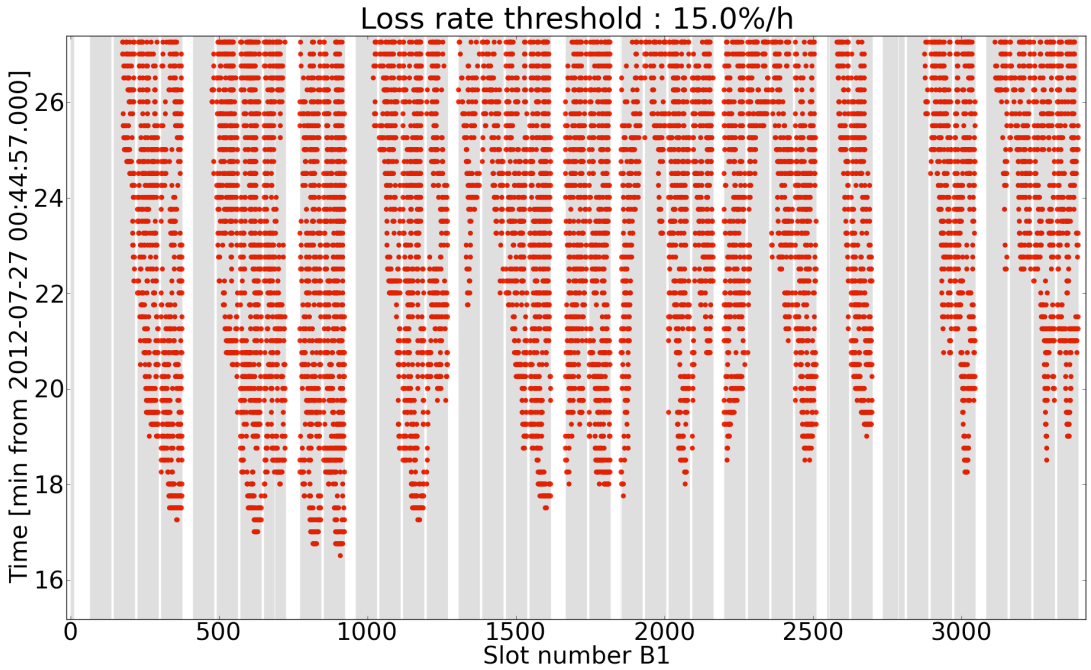
Fill 2883



B1 looses first





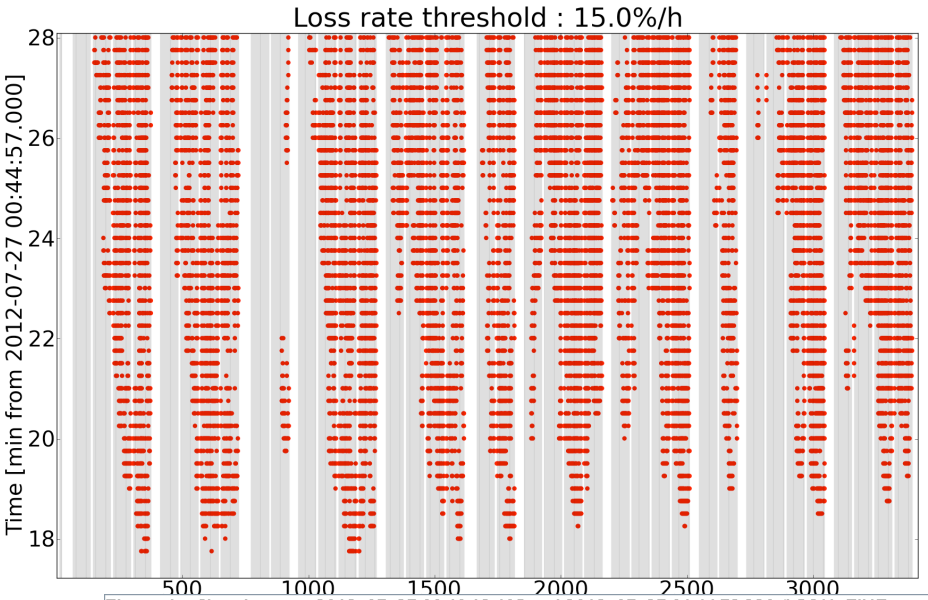


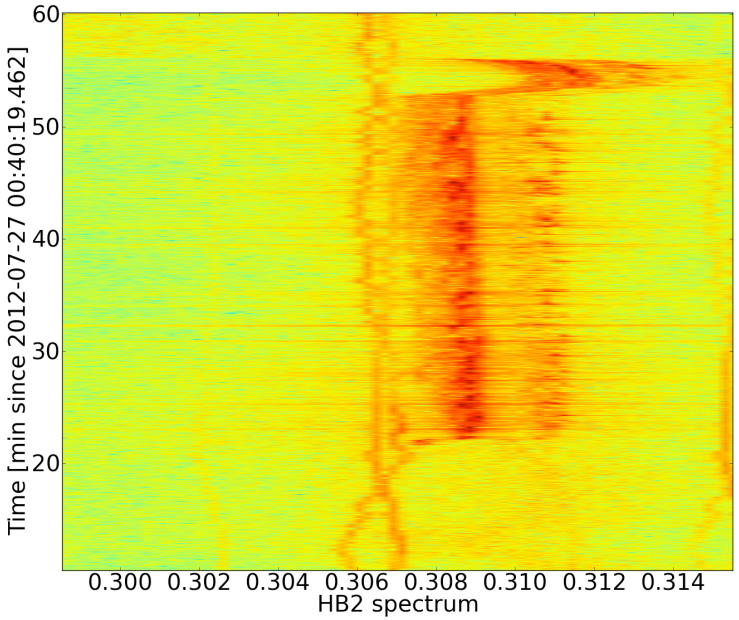
Losses starts on very **few bunches** B1

Propagates to neighbors not evident it is via BB (beams separated! Damper?)

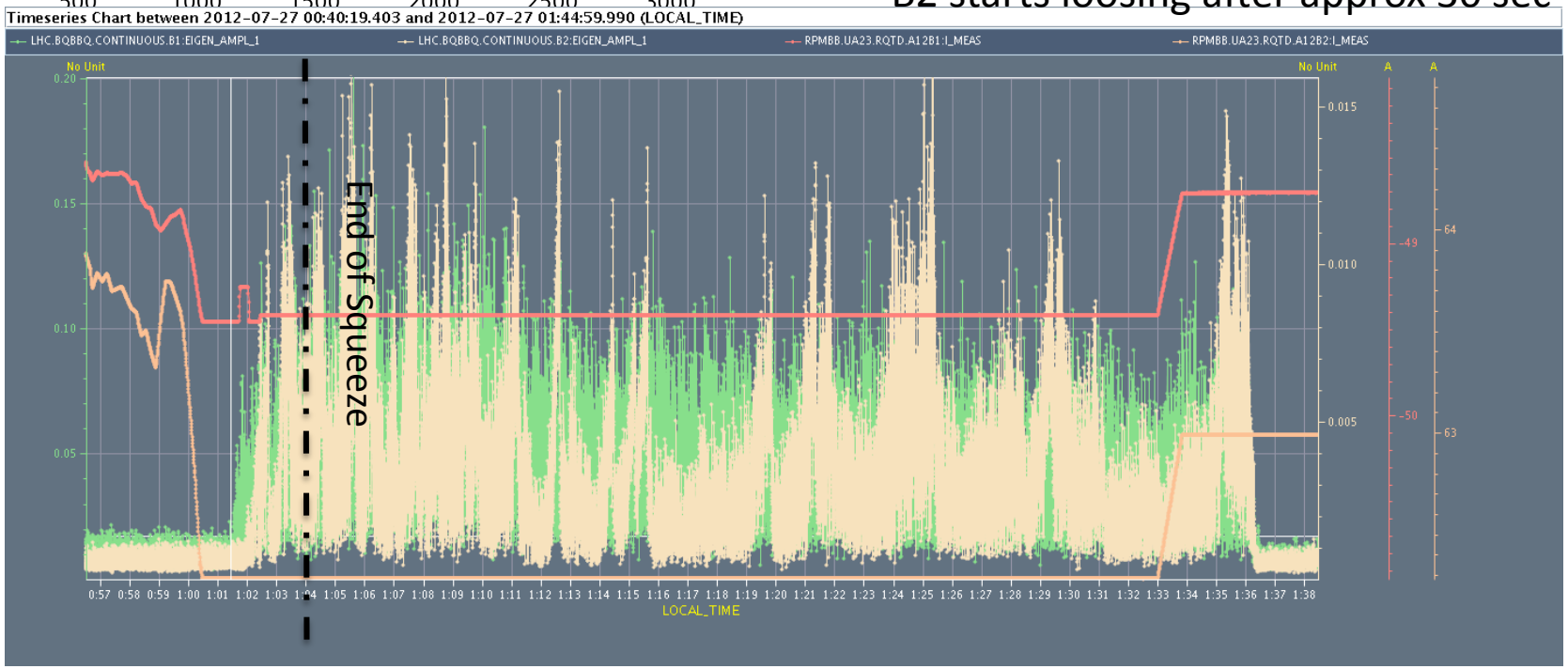
Losses are higher for bunches at **end of trains** (coupled bunch?)

Fill 2883

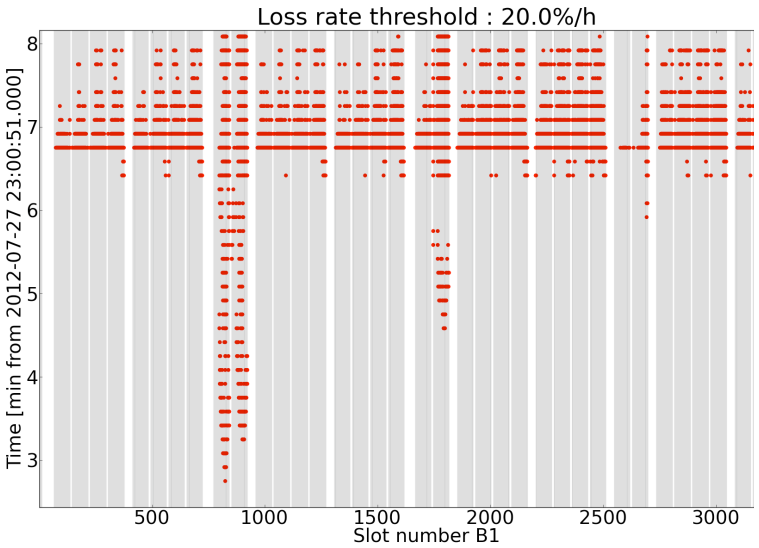


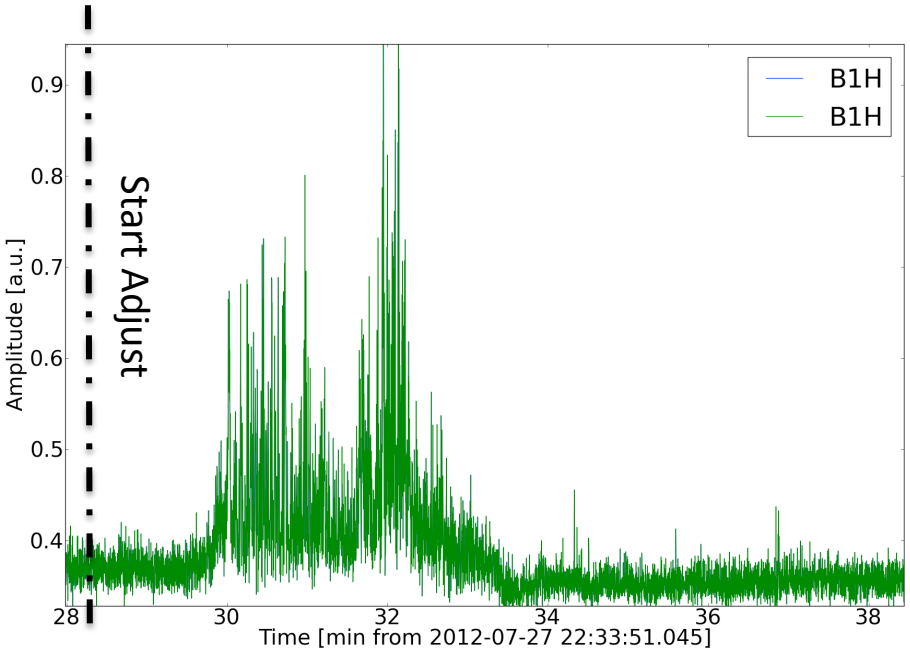


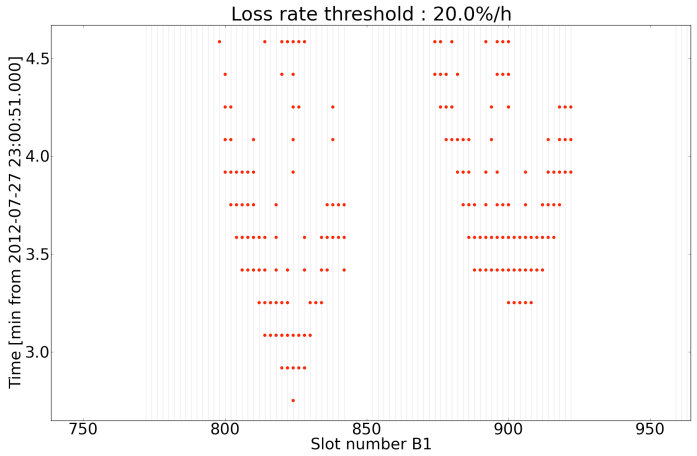
B2 starts loosing after approx 30 sec

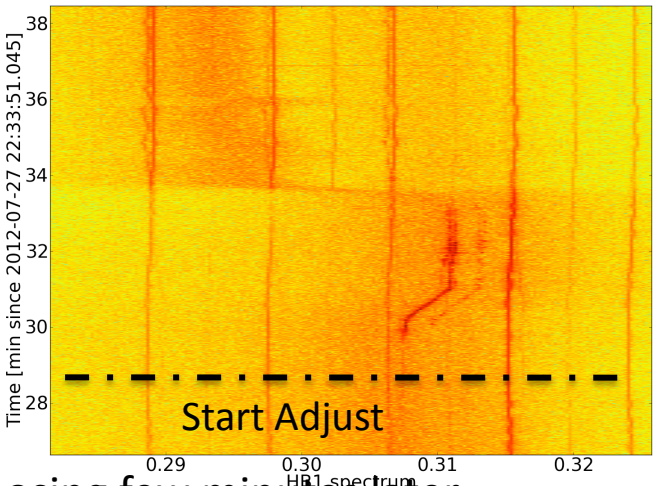


Fill2886







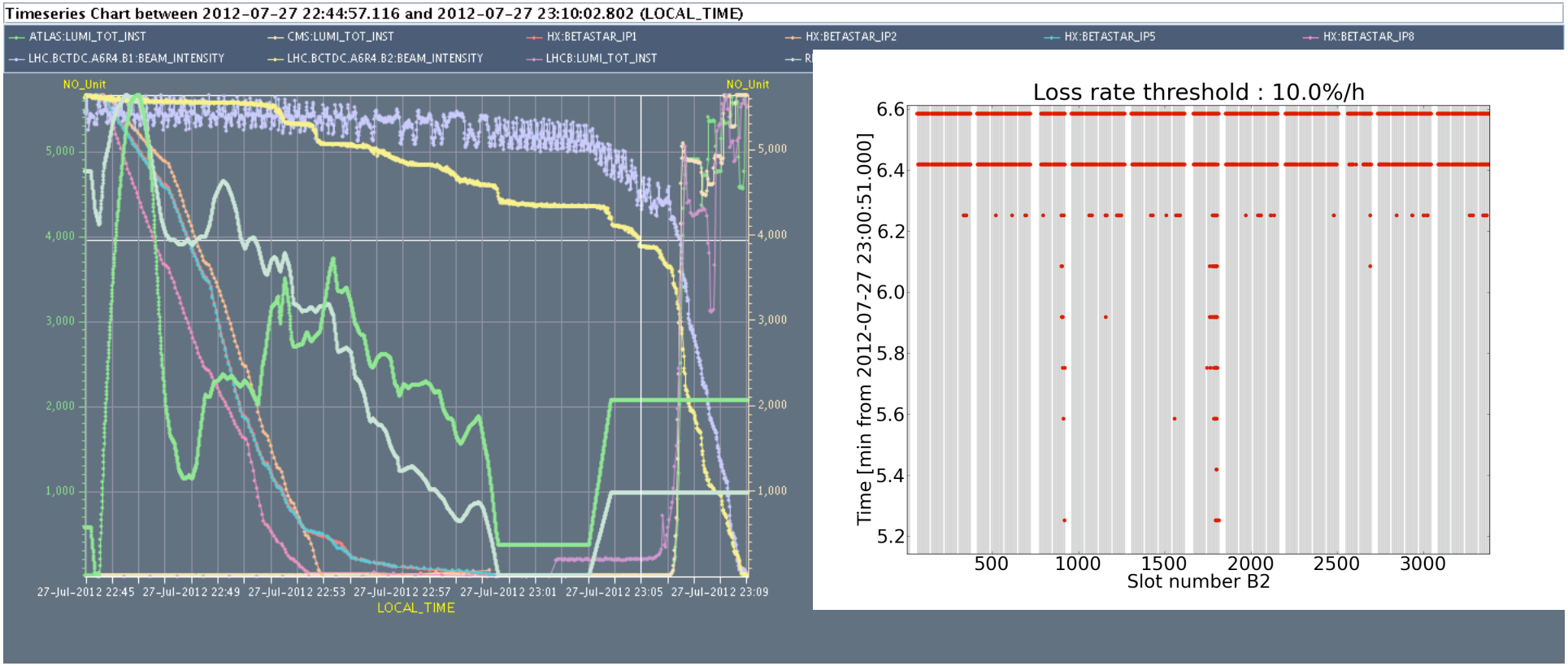


Losses starts on very few bunches B1 (**single**), B2 starts loosing few minutes later

Propagation over B1 not coming from BB

Losses are in second part of train (tails)

Fill2886



Beam 2 starts losing after 1-2 minutes

Instability propagates to B2 via BB

Losses during luminosity increase affects all bunches (maybe more due to HO collisions "compensating")

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3 Main cases:

- Instability during end squeeze (after IP2 & 8 at 3 m)
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- Instability during Adjust lumi part

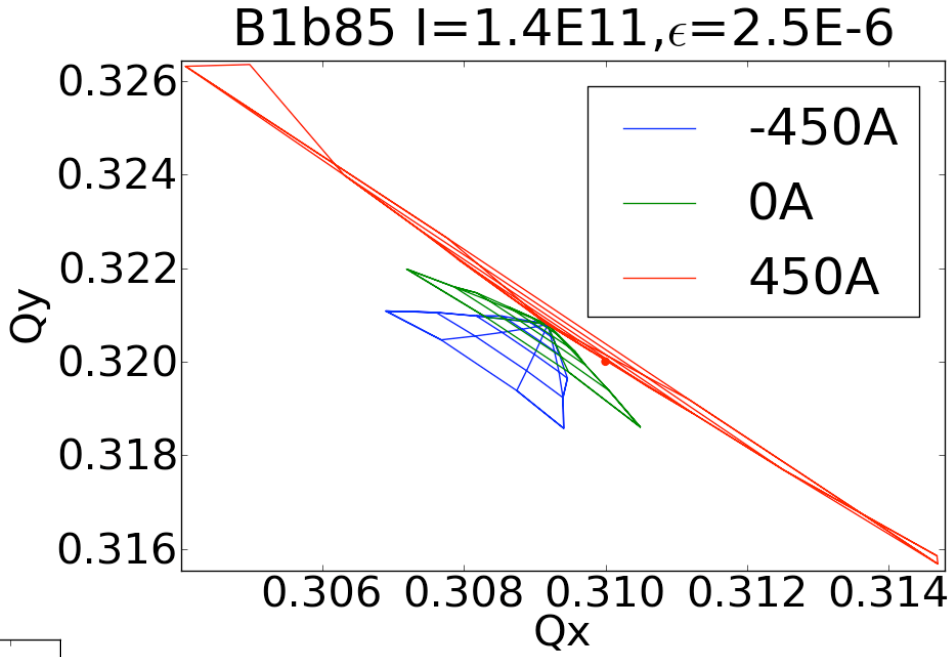
Common ingredient **always H plane** now preference for B2 but not obvious looking at past

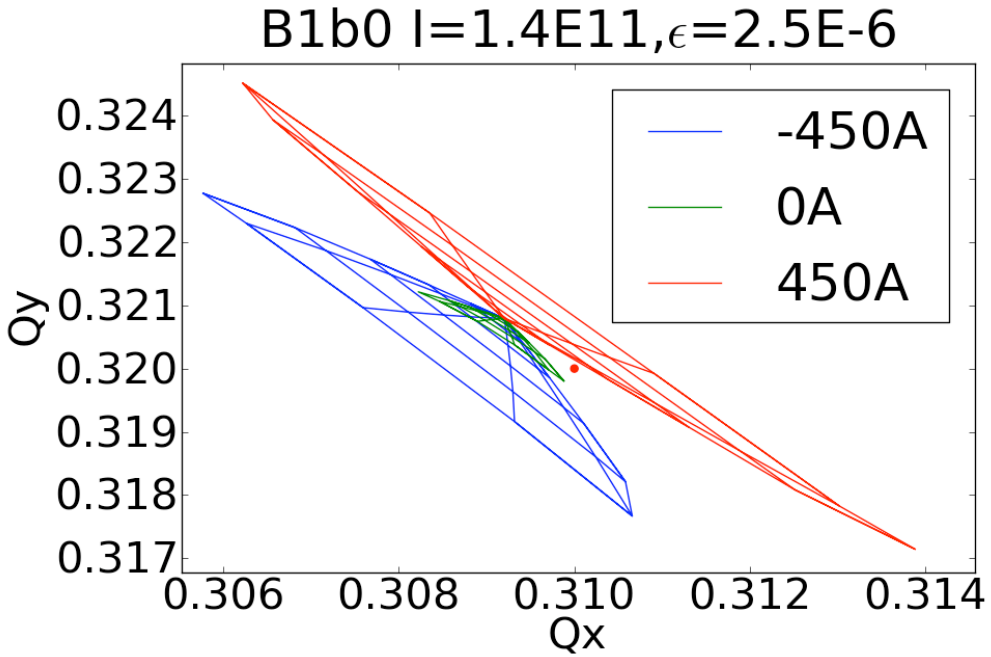
All this is very similar to what observed before TS

Beam-beam Footprints End of Squeeze

End of the squeeze bunches are fully separated but long range interactions already in place

Beam-beam gives detuning with amplitude

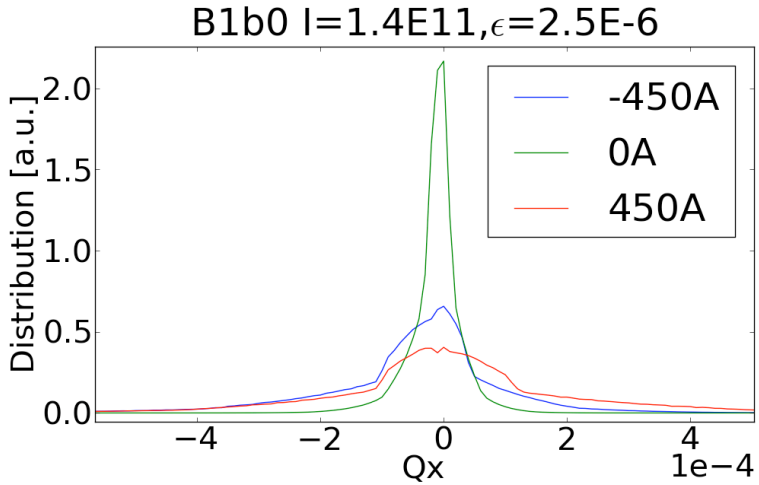


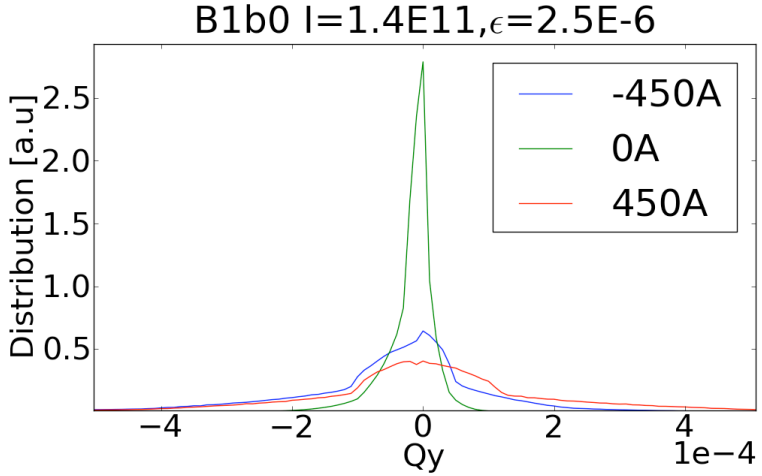


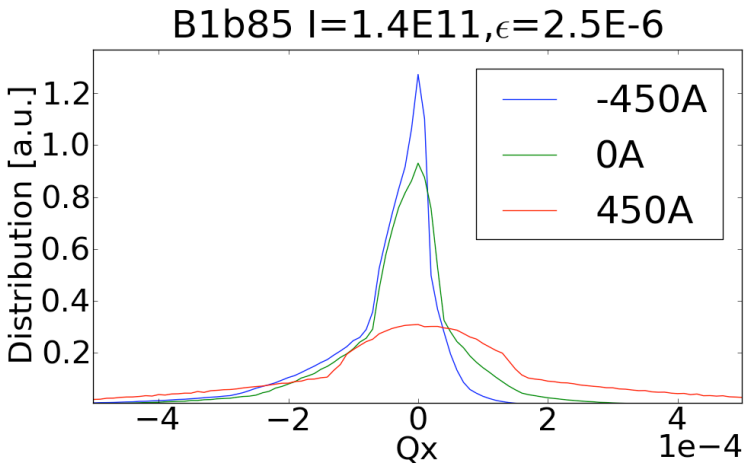
To provide **Landau damping** one need tune spread (BB + Octupoles) and particles at those frequency (assuming Gaussian distribution one has to look at 3 σ amplitude footprints)

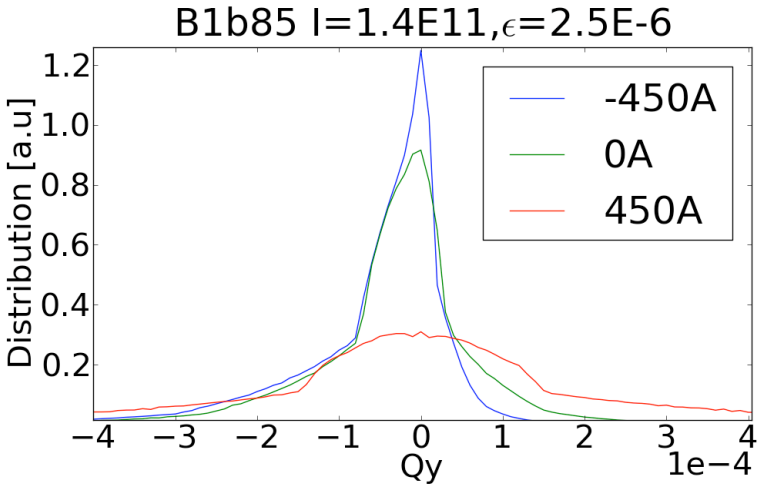
Landau Damping

For Landau Damping one needs **tune spread** and **particles with given frequency**





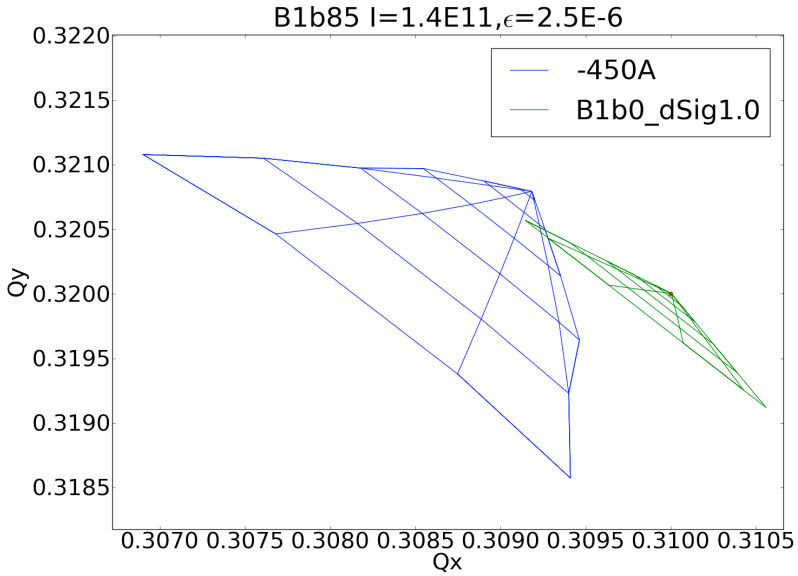




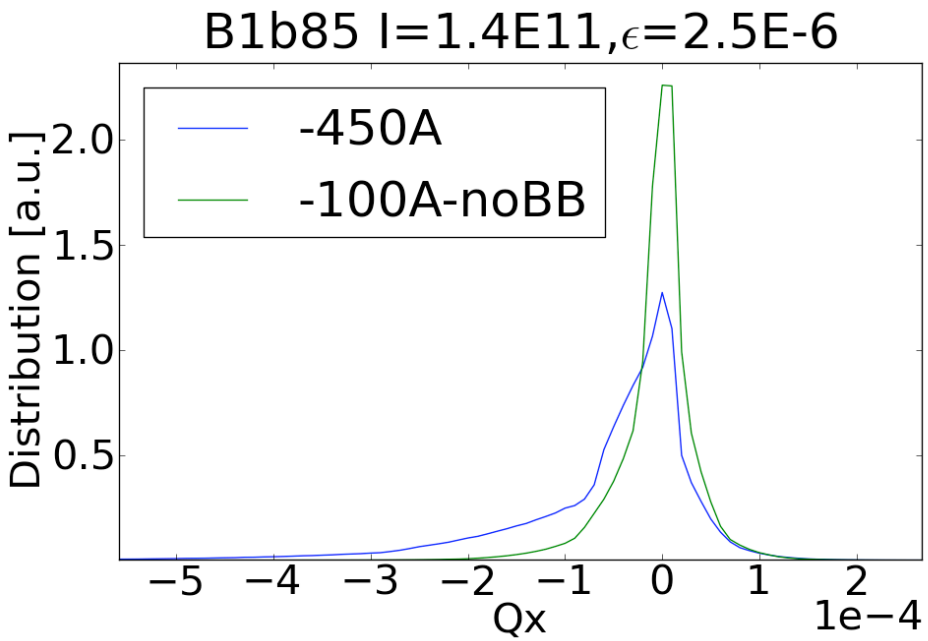
Tune spread (BB+Octupoles) integrated over particle distribution end of squeeze

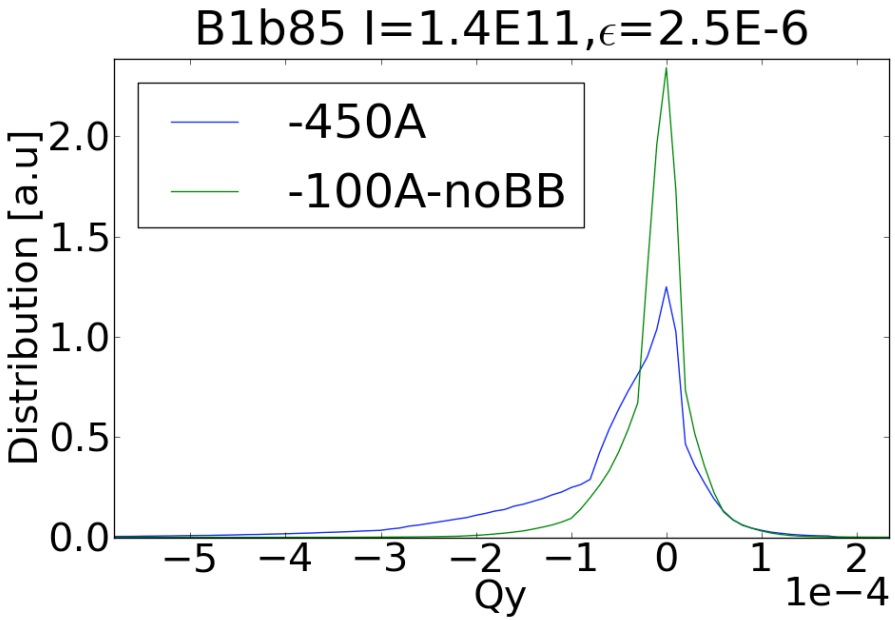
Opposite sign of octupoles gives larger damping area

Landau Damping

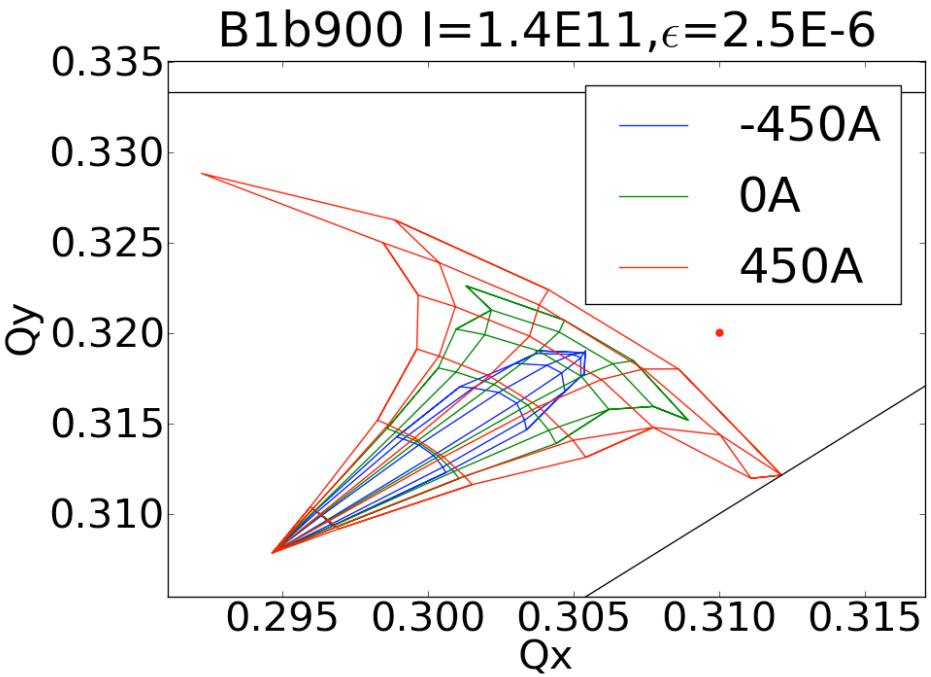


Landau damping provided by -450 A Octupoles + BB compared to what needed on single beam (-100 A)





Landau Damping in collision



One **Head-On collision guarantees the sufficient tune spread and particle distribution for Landau damping**

Opposite sign of octupoles as to be setted properly because **adds up with head-on affecting large amplitude particles (not those useful for Landau damping)**

Possibly **DA** problems so current has to be reduced!

If all bunches collide at least with 1 head-on, **beam-beam provides enough damping** (Octupoles off)

Open questions & conclusions:

A source of excitation develops and most probably finds bunches with weak damping properties during the different beam processes

Open questions to understand the source of instability:

- Why at the end of squeeze? Why LR IP2 & 8 should play a role?
- During end of squeeze starts with few single bunches and propagates (not via BB) → Single bunch instability? **Damper propagates**?
- During first minutes of adjust seems to occur when IP8 gymnastics is on-going → **check with past fills** if it is always during this period
- During Adjust (small sep) propagates via BB beams are coupled

Conclusions& Plans:

- In collision Landau damping is provided by BB head-on collisions, octupoles should be reduced to minimum value needed for non colliding bunches
- Opposite sign of octupoles has positive effect on separated beams shuold be explored to understand if some cases can be cured
- The Octupole with opposite sign should be set to avoid problems on nominal bunches (add up with HO)
- More data and looking backwards to past fills dividing into families (T. Pieloni)
- Reproducing stability diagrams with beam-beam and octupoles during BP (X. Buffat)
- Introduce in the stability diagram also combined effect with ADT (N. Mounet & A. Burov)
- Test Octupoles properties on colliding beams with +/- sign and reducing current with MDs or EoF studies
- Try to develop with beta* leveling strong/robust alternative
- We still need bbb diagnostics to understand the source of instability