Status of halo excitation studies at CERN

R. Bruce, O. Bruning, X. Buffat, R. de Maria, M. Fitterer, M. Giovannozzi, W. Höfle , S. Redaelli, H. Thiesen, CERN

G. Stancari, A. Valishev, Fermilab

Halo removal

- Possible methods under study for halo removal:
  - electron lens (studied by G. Stancari et al.)
  - tune modulation
  - ADT narrow-band excitation
- Brief introduction to the alternative methods
- Ongoing and planned studies

Halo removal

- When do we need it in the operational cycle?
  - Most important during the squeeze and collision preparation, before beams are brought into collision (Run 1). Application to stable beams for increased protection during crab cavity failure
- Timeline:
  - Nothing available for 2015 startup as operational tool. Immediate goal is to define what needs to be studied in MDs. Hollow e-lens: not before LS2. What can we do before?

Tune modulation

- Idea: By modulating the tunes at a fixed frequency, resonance sidebands are introduced around the existing resonance lines (Bruning, Willeke PRL 76:3719)

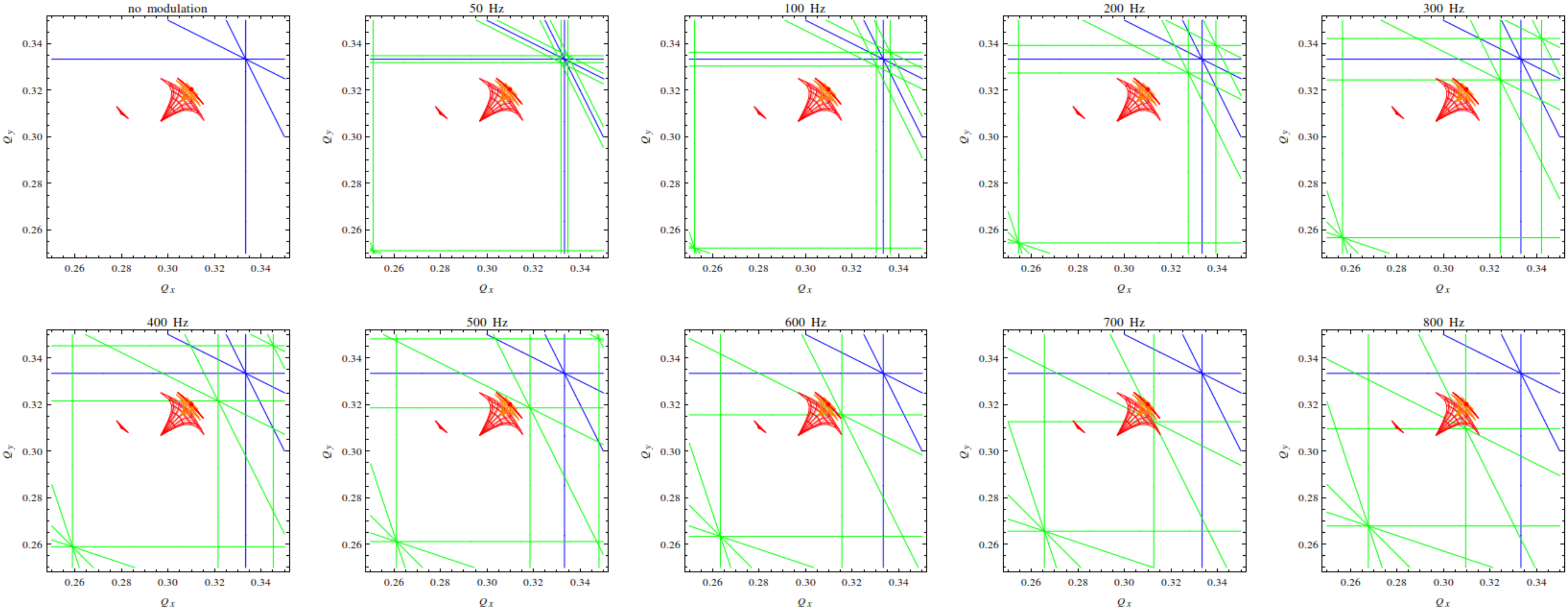
$$l Q_x + m Q_y + n \frac{f_{\mathrm{mod}}}{f_{\mathrm{rev}}} = r, \quad \text{with } l, m, n, r \text{ integers} \tag{1}$$

- Use detuning with amplitude of the beam
- By choosing wisely the modulation frequency, we could put a resonance line on the halo, while leaving the beam core unaffected

Tune footprints

- Pre-study of tune footprints and resonance lines can give a first hint on which frequencies could be suitable
  - To know the needed modulation amplitude, we need to know the strength of each resonance in the machine. More advanced simulations needed (frequency map, dynamic aperture)
- Look at tune footprints at
  - injection – for MDs
  - flat top, end of squeeze, collision

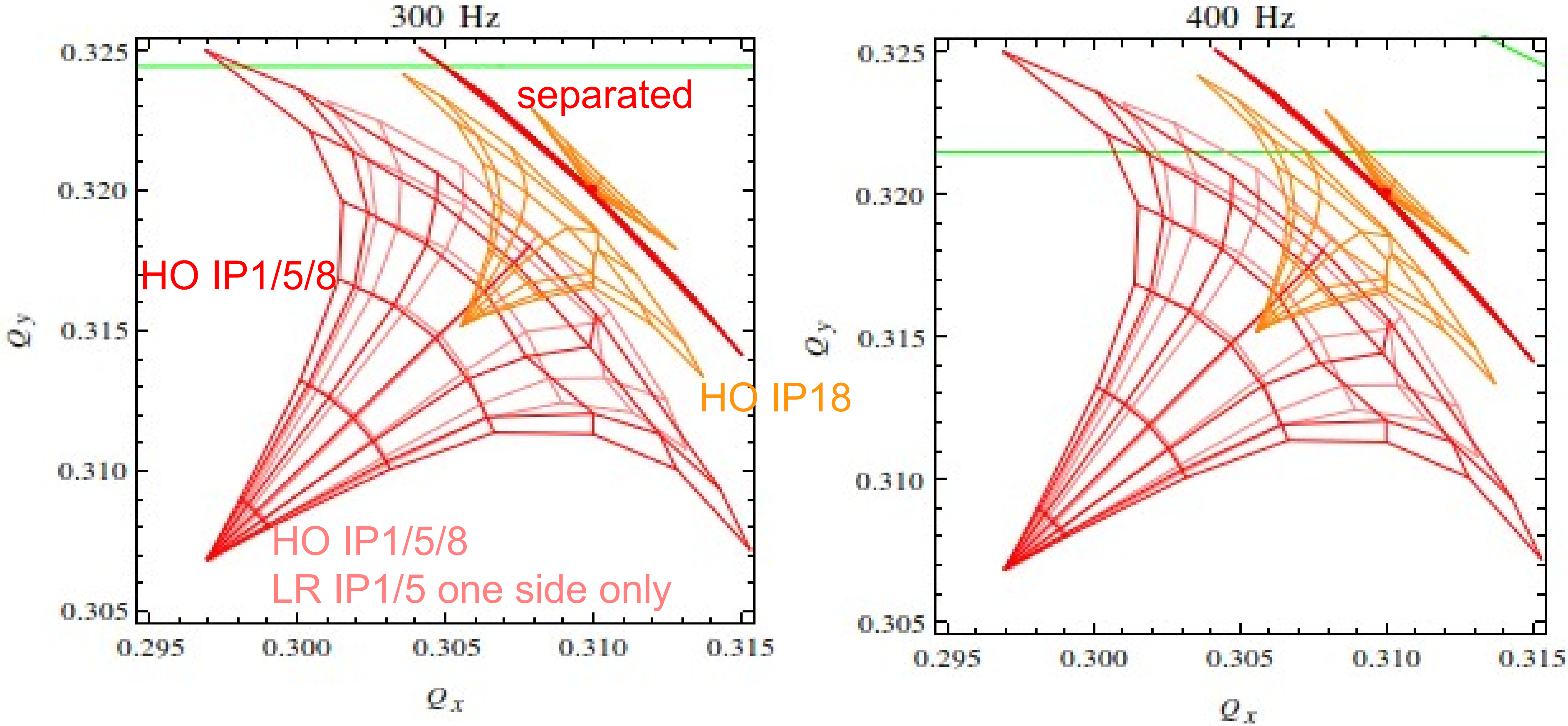
Tune footprints and resonance lines – all footprints, 5th order



Thanks to X. Buffat and beam-beam team for help and input!

Tune footprints and resonance lines – all footprints, 5th order

Zoom on collision tunes – separated and colliding beams, 6.5 TeV, b*=55cm



Preliminary considerations on frequency

- Different frequencies might be needed depending on where in the operational cycle we want to act
- Depending on tune, which tune footprint we want to hit, and which resonance we want to use: big spread of possible frequencies... 50-800Hz
  – different bunches have different footprints depending on where they collide. Need to be careful... when hitting the halo in some bunches, we risk to hit the core in others!

Modulation depth

- Previous guess (Oliver, Hermann in 2013 collimation review): dQ of 1e-4 needed => with MQWB.5R7.B1, we would need about 0.6A
    - If we run out of strength: consider either using all MQWA, or using cold quadrupoles in arc. QPS to be verified
- We should do some more detailed simulation studies (SixTrack) to understand what modulation depth is needed (as well as the relative strengths of different resonance lines)
    - Frequency map analysis including realistic magnetic errors

Hardware constraints

- Using warm IR7 trim quad: power converter can do modulation on top of existing current without any hardware modifications
- Max. frequency = 500 Hz, with 1A peak-to-peak. Higher frequencies might be possible but requires modifications. Measurements planned in week 21
- Need to verify transfer function power converter → magnetic field inside the beam screen. High frequencies usually heavily damped by the magnet inductance and beam screen
- Stefano in contact with Marco Buzio – hoping to do measurements on surface using spare magnet during the year.
- With all ingredients (hardware capabilities and expected behaviour from theoretical studies) our goal is to plan MDs to be carried out in the LHC in 2015

ADT excitation

- Instead of modulating the tune with a quadrupole, we could use the transverse damper (electrostatic kicker) to make a narrow-band excitation
- Again, rely on detuning with amplitude.
- Simplest approach: Knowing the fractional tune of the halo Q_h, apply kick in resonance at frequency $f_{rev}(n \pm Q_h)$
- More advanced ideas: colored noise
- Hardware-wise, no modifications needed
- Should do a theoretical feasibility study with SixTrack
  - Frequency map analysis
- During 2014: plan MDs

Pros and cons (1)

- Tune modulation affects both beams simultaneously
- ADT can on a single beam and plane, and even on single bunch
  - Could imagine having different excitations for different positions in the filling pattern, e.g. hit only bunches with head-on in IR1/5
  - Could allow for “witness bunches” which are not affected. Advantage for early detection of e.g. UFOs

Pros and cons (2)

- Both ADT and tune modulation rely on a good knowledge of the tune and detuning with amplitude. Risk to hit the core if parameters are not carefully optimized
  - How well do we know the tune in the squeeze, and how well reproducible is it fill-to-fill?
  - Need convincing validation with beam at the LHC (in particular if these methods are needed continuously in Stable Beams)

Comparing with hollow e-lens

- Hollow e-lens has the advantage of being completely independent on the tune. It extracts particles based only on amplitude
  - Robust against any changes in machine configuration, optics, filling pattern etc
- The e-lens can not resolve single bunches, but it can act differently on different trains. Can have “witness trains”
- Tune modulation and ADT rely on existing hardware – no major system changes needed.
- Hollow e-lens cannot be available until after LS2
  - If we need halo excitation in the LHC before then, we have to rely on alternative methods

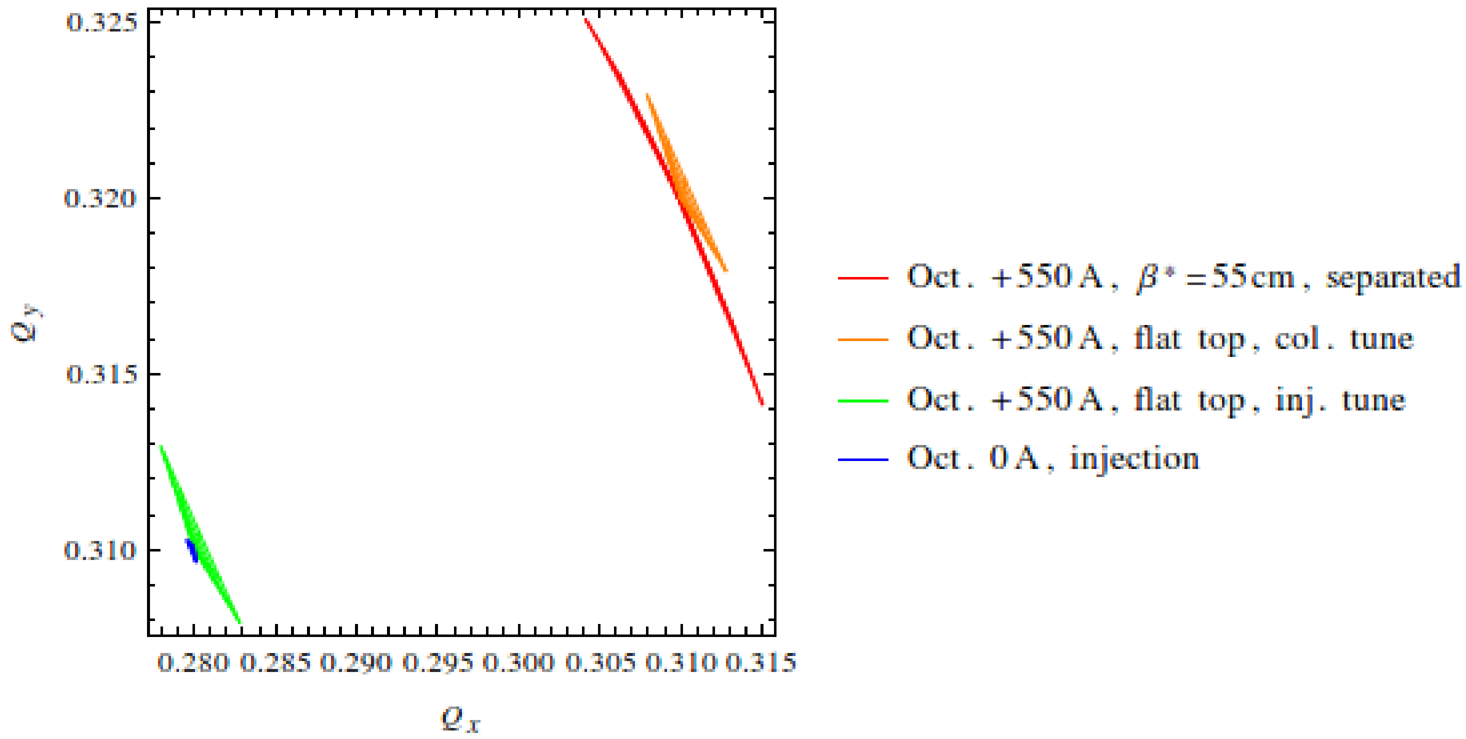
Proposed strategy

- All options should be studied
- Immediate goal: Discuss a consistent parameter set at the LARP/HiLumi Collaboration Meeting with Fermilab colleagues
  - Coordinate effort and compare results
- Based on theoretical studies and hardware capabilities, we should plan MDs on tune modulation and ADT excitation that can be carried out in 2015
- A collimation fellow or PhD student in ABP, expected at next selection, could work a fraction of his time on a comparative assessment of all methods
- In parallel, continue work on development of hollow electron lens

Backup

Tune footprints with separated beams

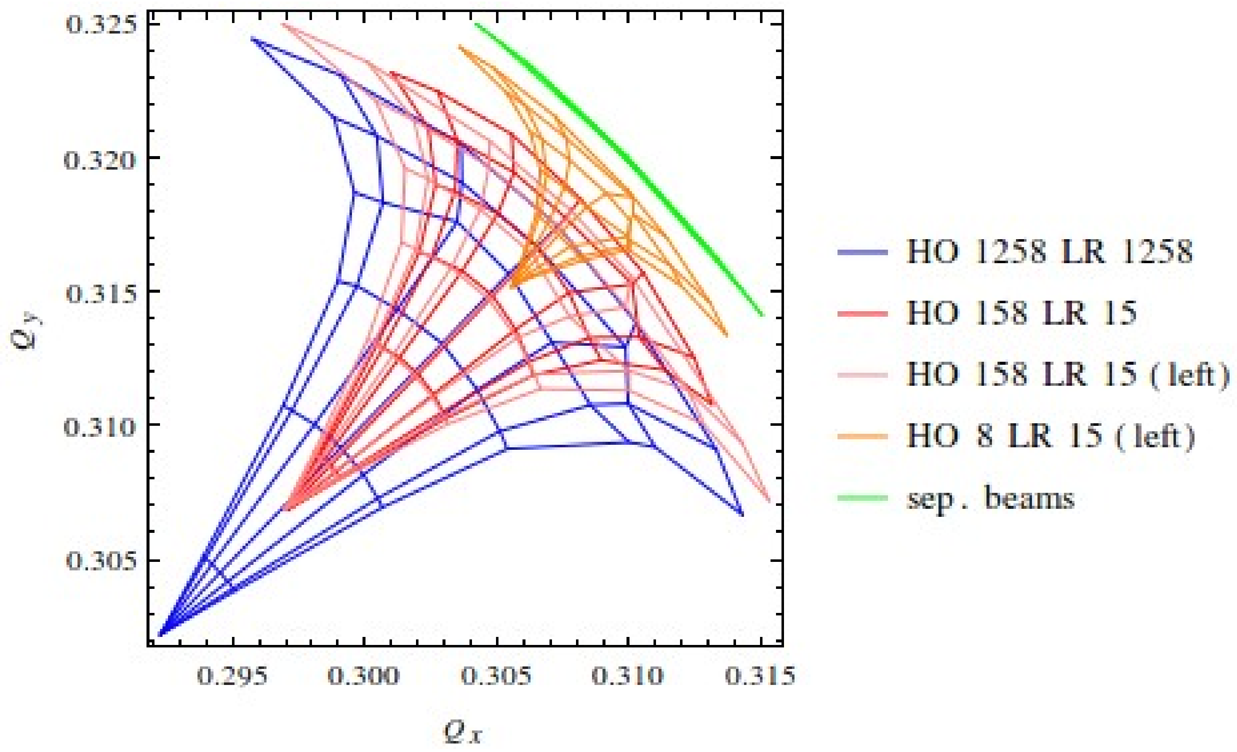
separated beams, 0.45-6.5 TeV, 25 ns, exn=3.75um



Thanks to X. Buffat and beam-beam team for help and input!

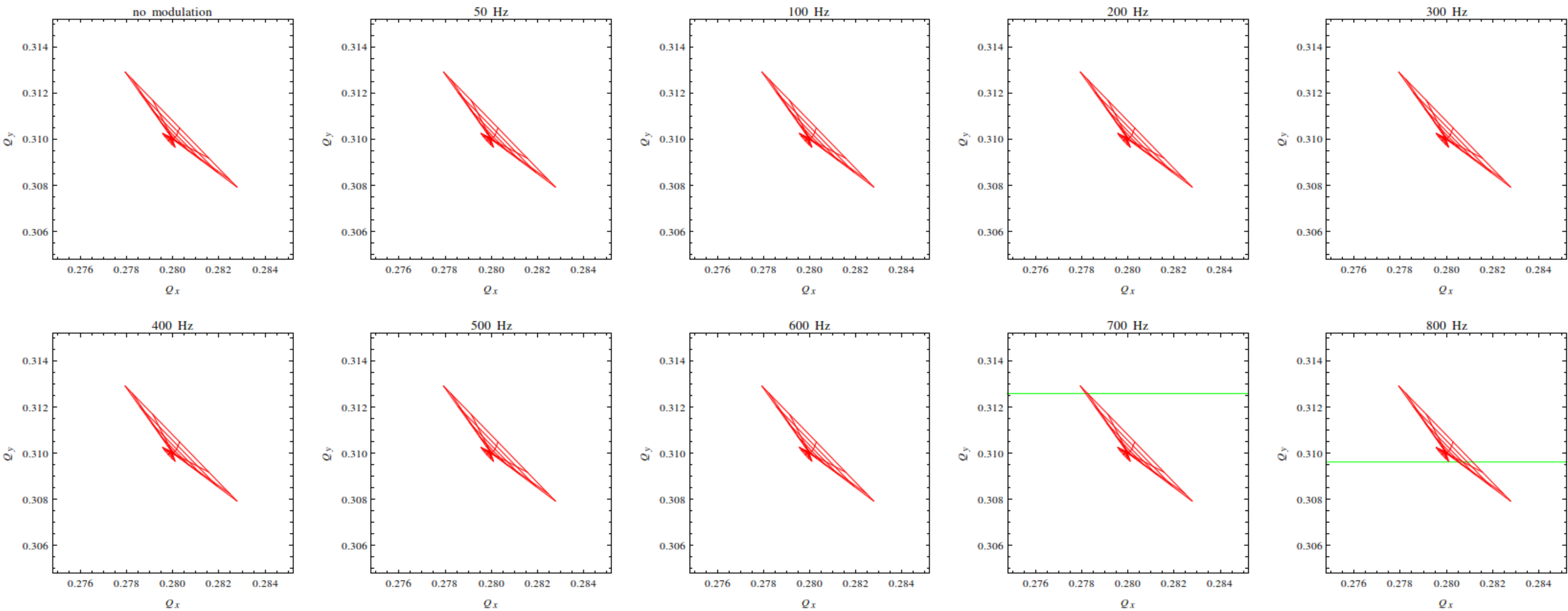
Tune footprints with colliding beams

separated and colliding beams, collision tune, 6.5 TeV, b*=55cm, 142.5 urad, 25 ns, exn=3.75um



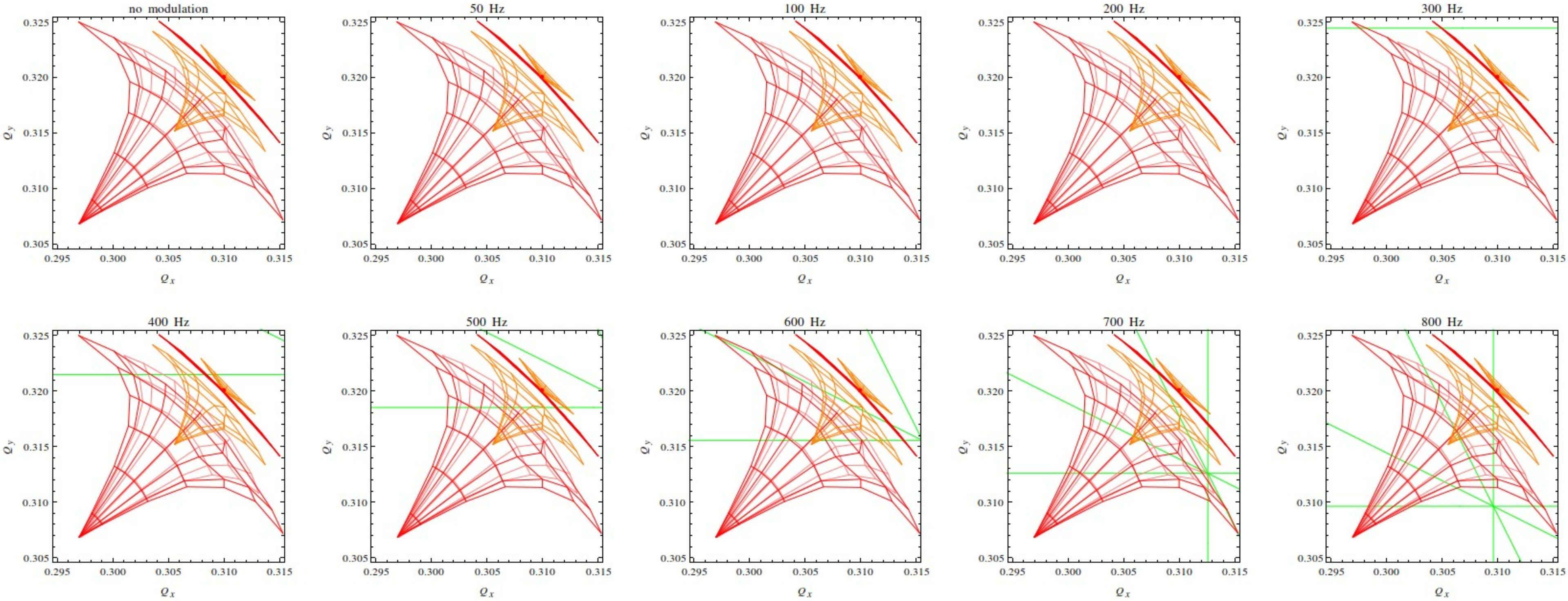
Tune footprints and resonance lines – all footprints, 5th order

Zoom on injection tunes at 450GeV and 6.5 TeV



Tune footprints and resonance lines – all footprints, 5th order

Zoom on collision tunes – separated and colliding beams, 6.5 TeV, b*=55cm



Tune footprints and resonance lines – all footprints, 10th order