Coherent Beam-beam Effects in the LHC

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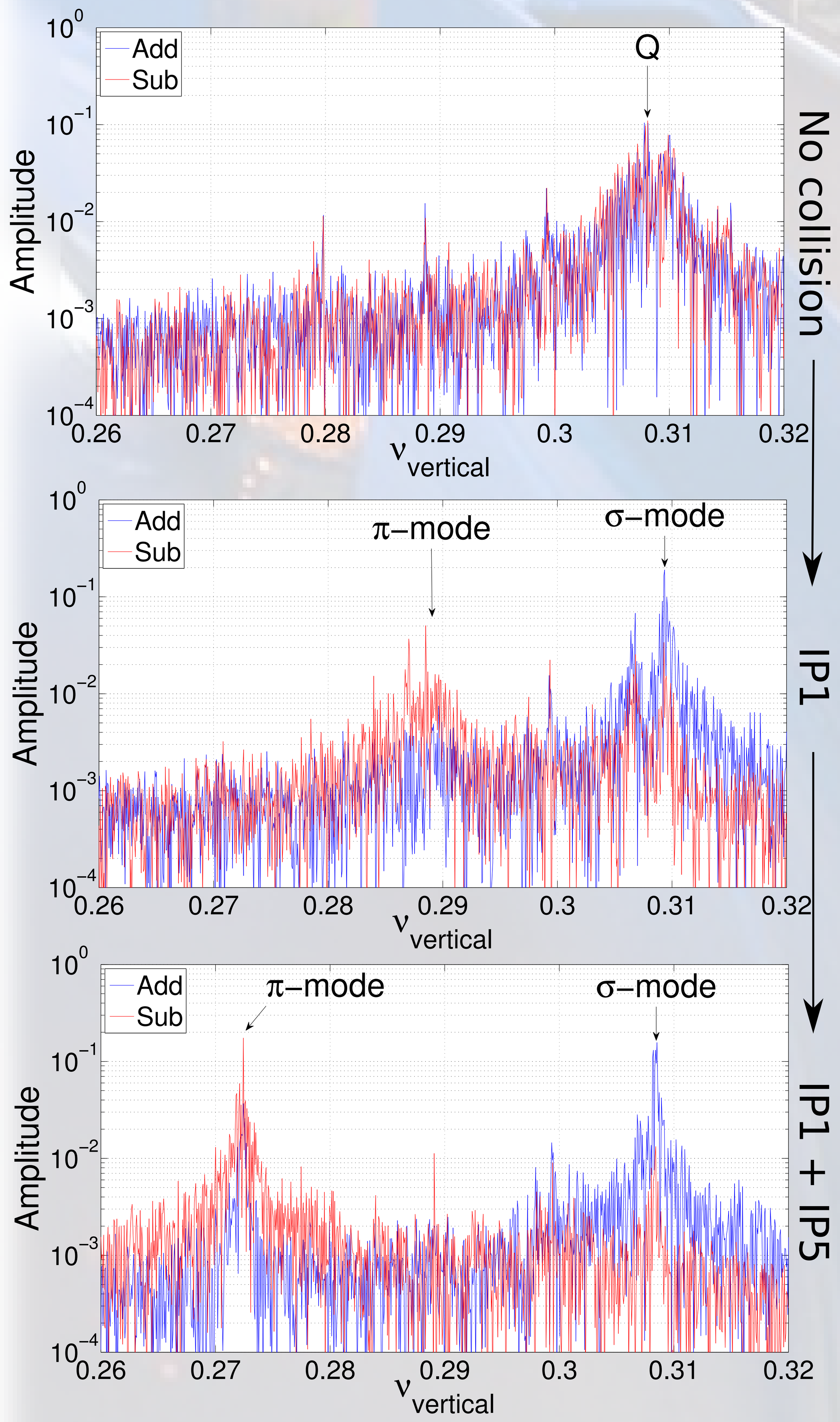
Introduction

- When brought into collision, the two individual beams become a coupled system with different eigenmodes.
- Due to loss of Landau damping, the coherent modes may become unstable.
- Indications of beam-beam driven instability at LHC motivated dedicated experiments with high brightness beams and few bunches.

Stable motion

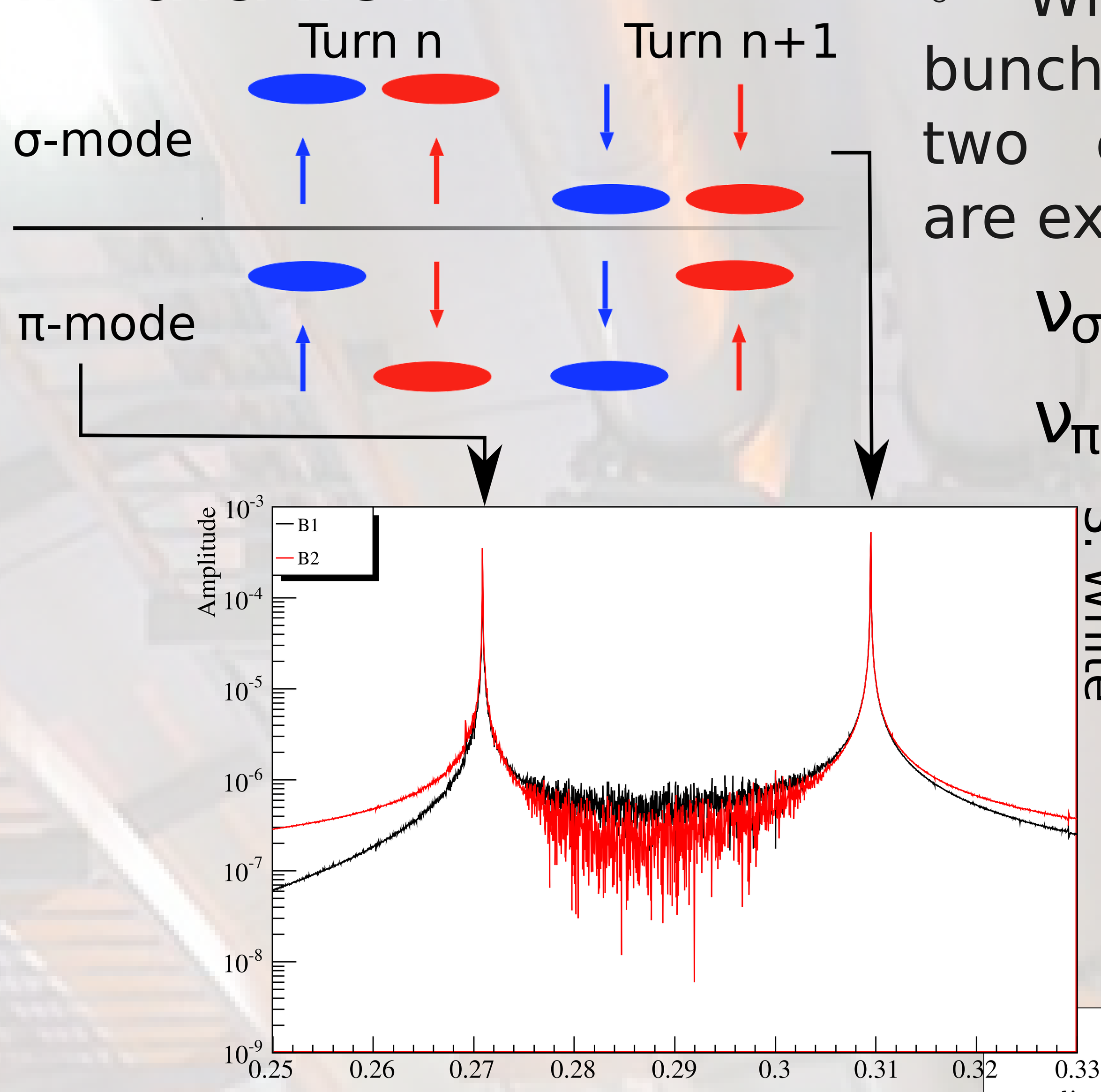


- No optimization of the orbit was performed.
- The beams have remained stable.
- The peaks corresponding to the two modes are enhanced or suppressed in the FFT of the addition or subtraction of the measured position of the two beams (BBQ).
- The observed frequencies are consistent with the simulation
- The theoretical Yokoya factor for equal beams is Y=1.21.

$$\xi \sim 2 \cdot 0.016 \rightarrow Y \sim 1.13$$

- The difference with the measured one is explained by the asymettry (Intensity, emittance)between the two beams.

Simulation

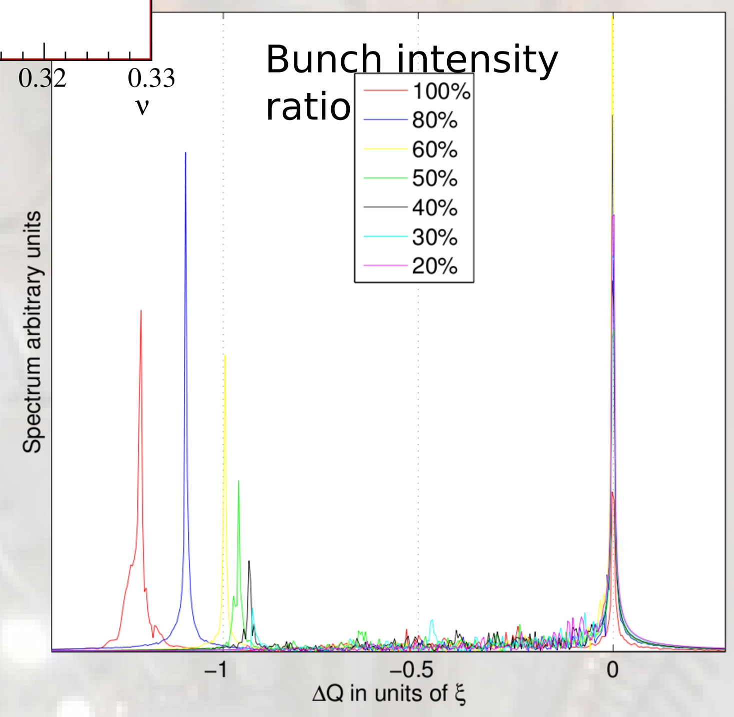


- When colliding one bunch against another, two coherent modes are expected.

$$\nu_\sigma = Q$$
$$\nu_\pi = Q - Y\xi$$

- Coherents mode can be well predicated by self consistent simulation, i.e. multiparticle tracking.

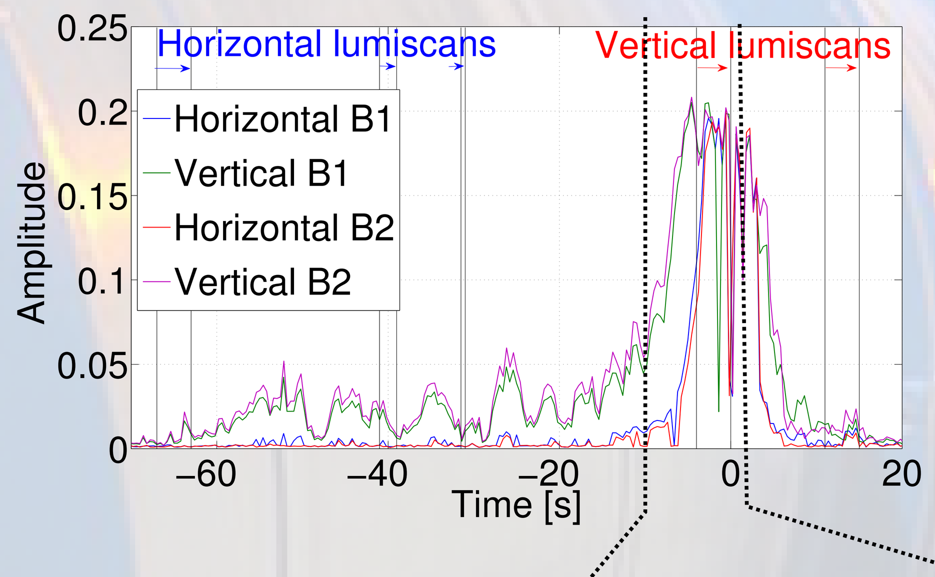
S. White



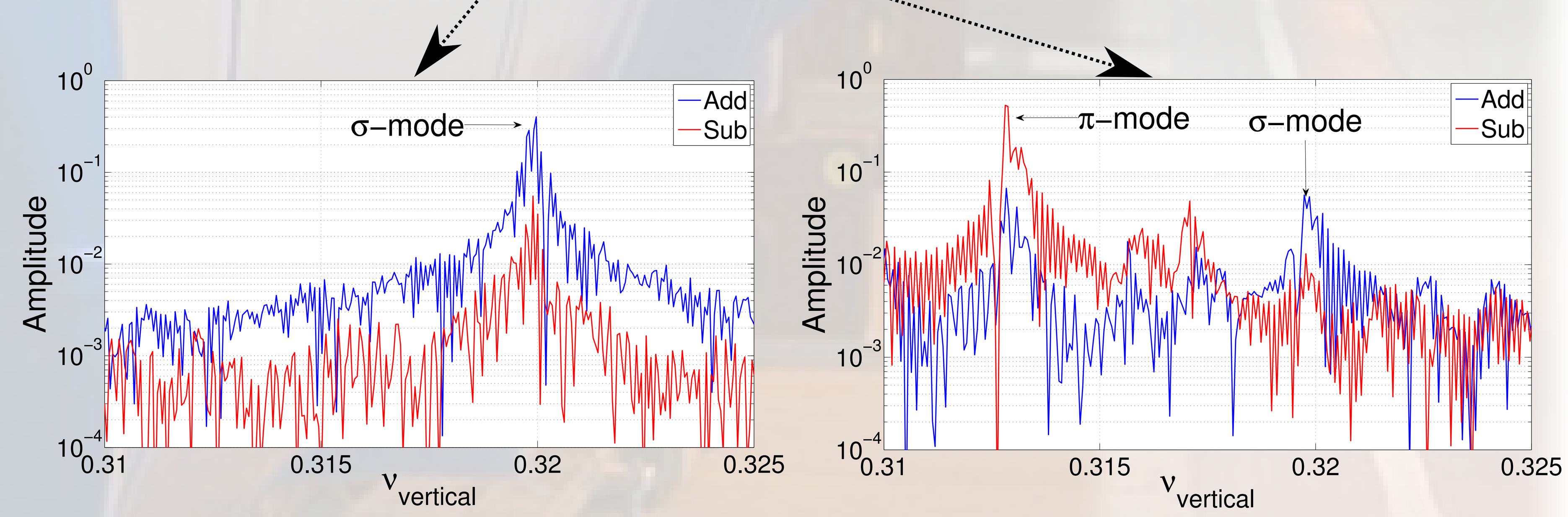
T. Pieloni

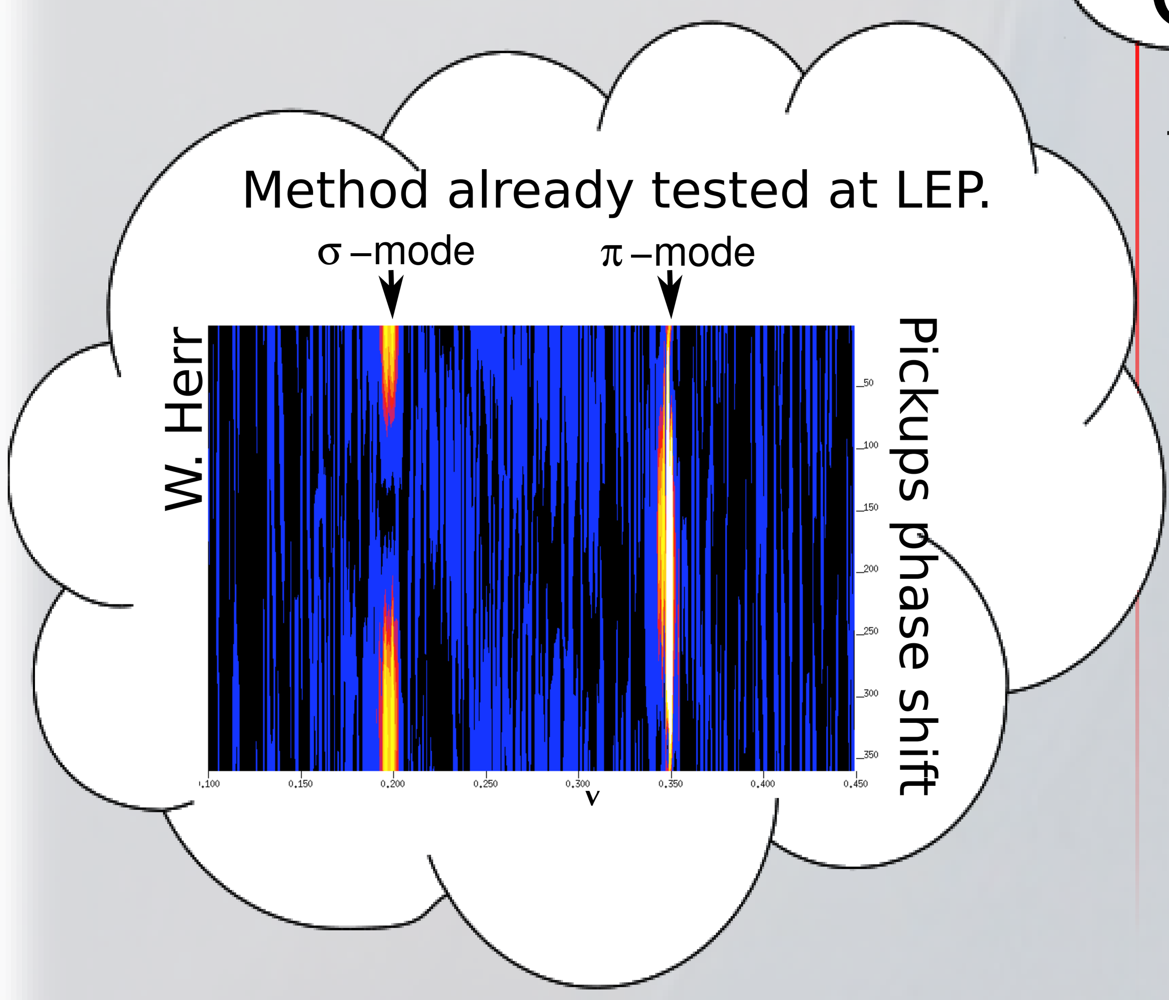
- When symetries are broken, coherent modes tends to be suppressed, e.g. different bunch intensities brings the π-mode to the Landau damped region.
- Different collision scheme (e.g. PACMAN effects), unequal emittances or different phase advance between the IPs also lower the symetry.

Unstable motion



- An instability was observed during optimization of the orbit for luminosity, which involved both modes.
- The transverse damper was off. It is on during operation for physics





Conclusion

- Coherent motion is observed in dedicated experiment in which the most favourable conditions for the appearence of coherent motion are setup.
- The beams have mostly remained stable, in particular when kept in a steady state.
- Some instabilities were observed when moving the beam against each other during optimisation of the orbit for luminosity.
- No such instability is observed during standard operation, as the transverse damper is systematically kept on during production of luminosity.
- Theory predicts the supression of coherent modes for non symmetric machine and beam parameters. This will be tested in future experiment. It is believed that the numerous symmetry breaking parameters of the LHC, such as different phase advance between the IPs and bunch by bunch differences will allow a suppression of the cohrent modes.