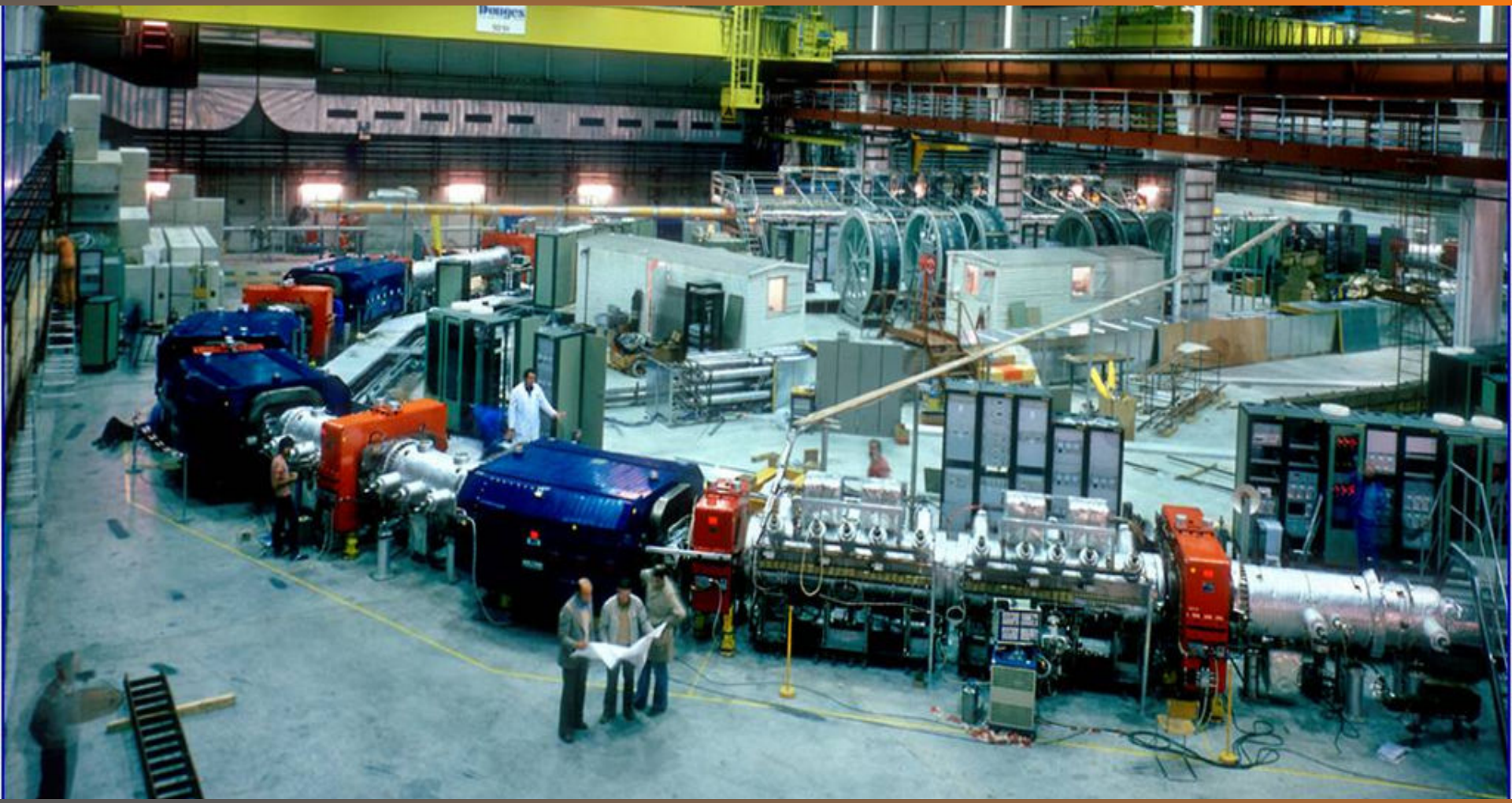
Ppbar experience

Lyn Evans



LHC Beam Commissioning Workshop

CERN, on 19th January 2010

Beam-beam interaction

- When the beams are brought into collision, a much stronger nonlinearity than the magnet imperfections comes into play. It is called the beam-beam interaction and is caused by the force due to the electromagnetic field of one beam on the particles in the other beam. It produces two main effects.
- The first is to cause a variation of the tune with amplitude. This means that the beam does not occupy a point on the Qh, Qv tune diagram but produces an extended "footprint" The second effect is that because of the periodic nature of the force (particles experience a delta function kick on each revolution) it excites nonlinear resonances which can strongly limit the beam lifetime.

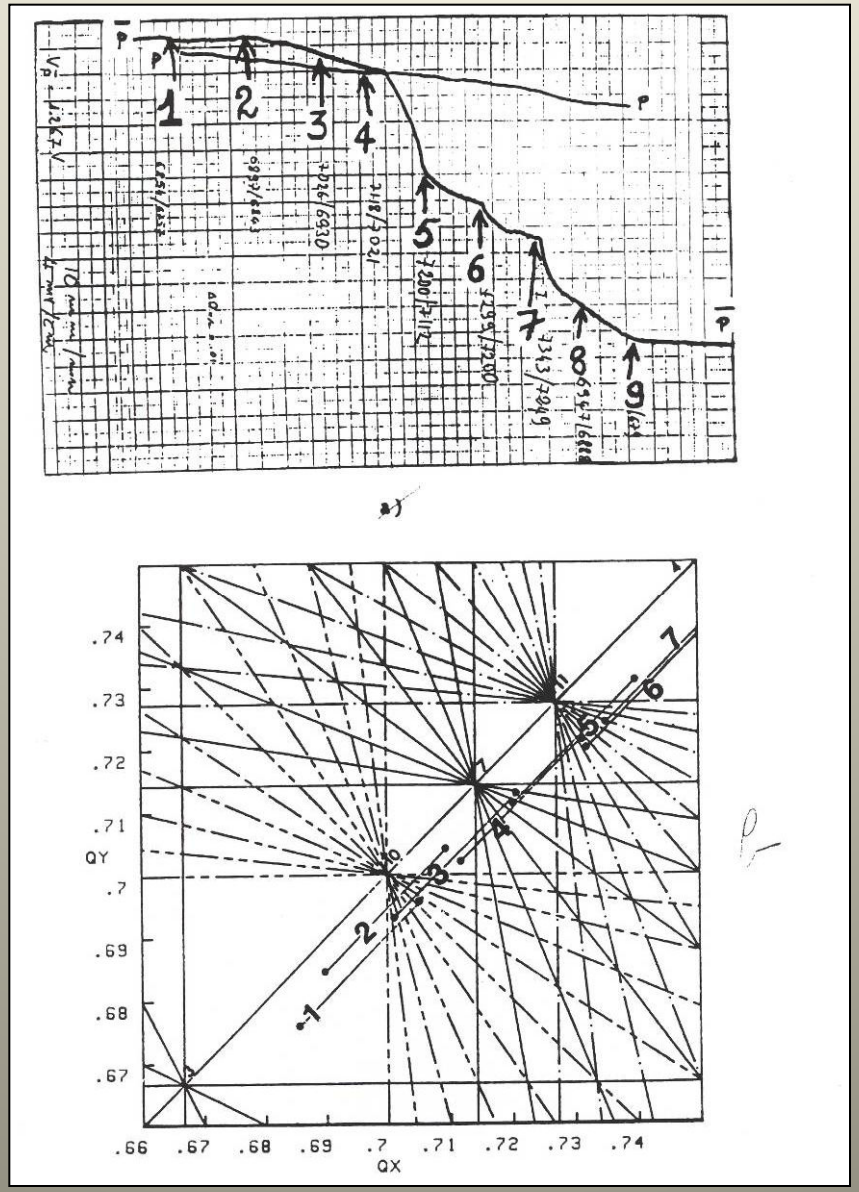
Beam-beam tune shift

$$\Delta Q = \frac{N_b r_p}{4\pi\varepsilon_n}$$

Independent of

Energy
Beta

A beam-beam resonance scan at the SPS collider



Phase space trajectories in the vicinity of the half-integer and 4th order beam-beam resonances

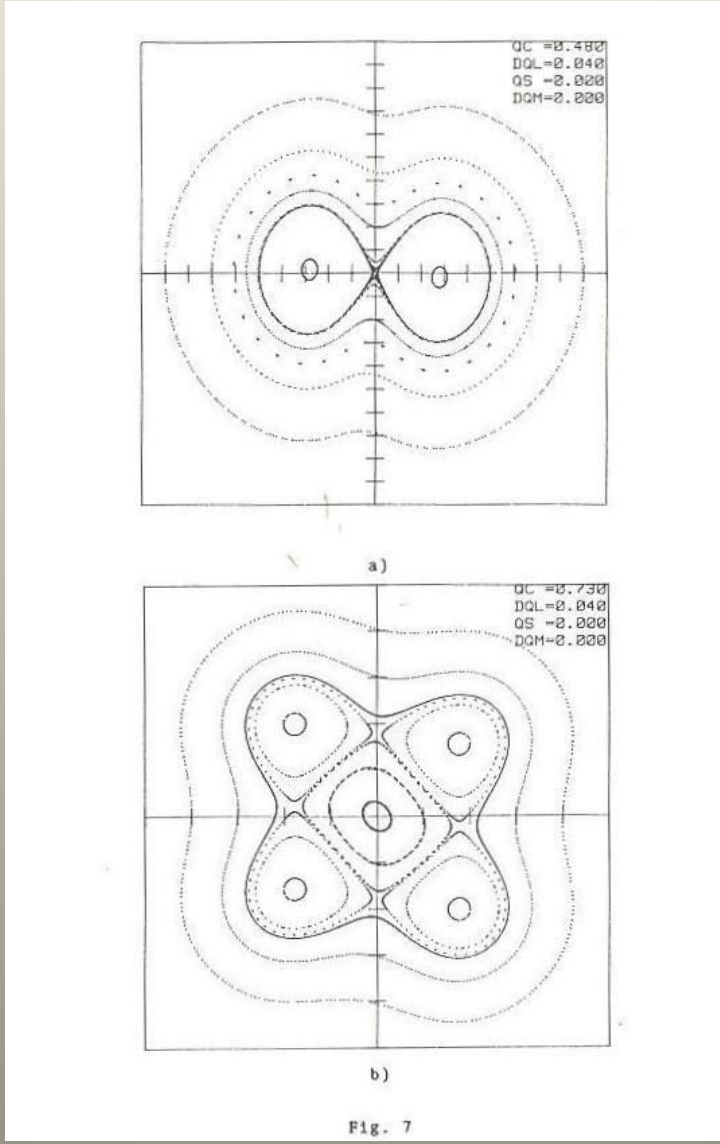


Fig. 7

Plate 2

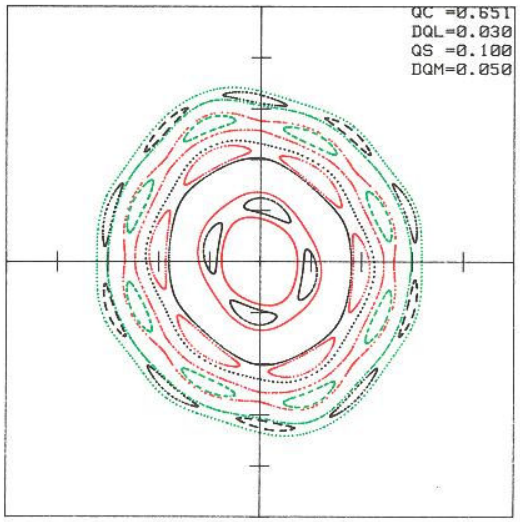


Plate 2a

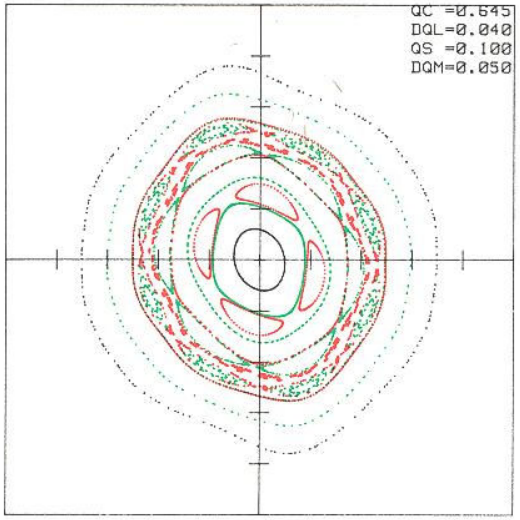


Plate 2b

Plate 3

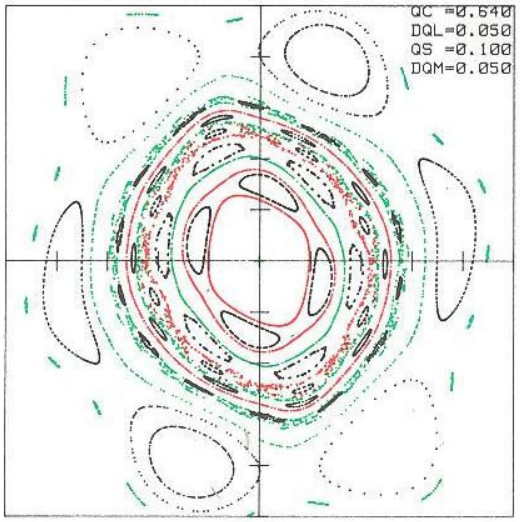


Plate 3a

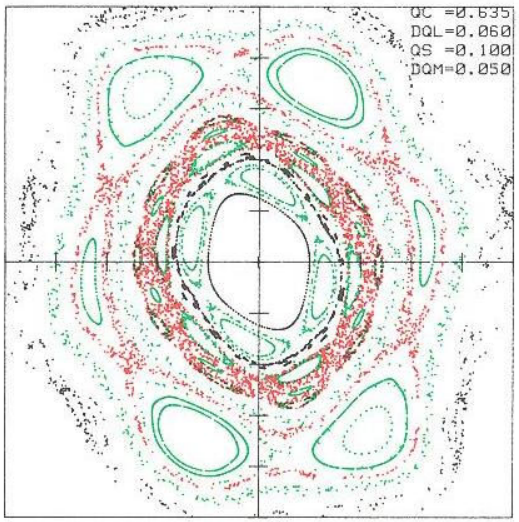
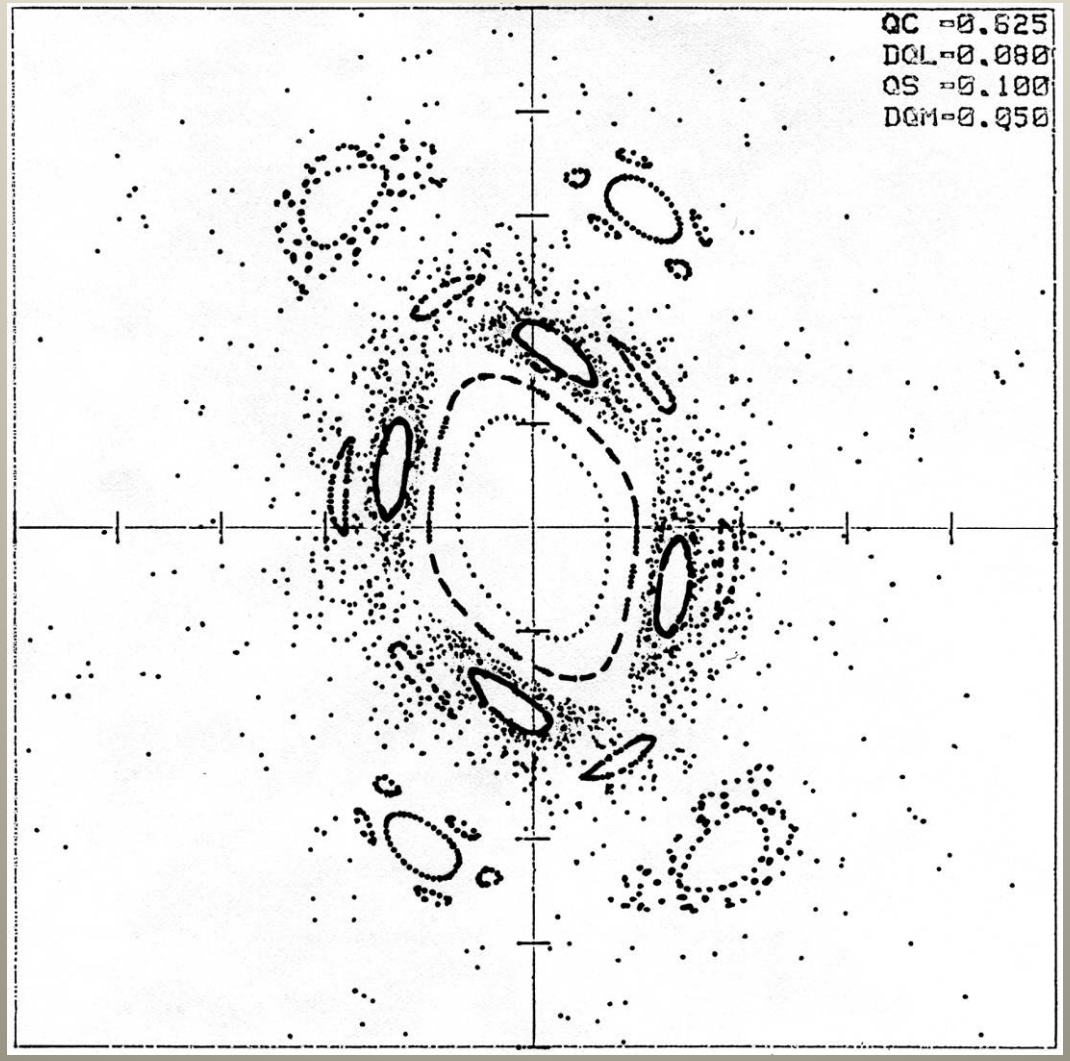


Plate 3b

The beam-beam interaction



Phase space topology near a 6th order beam-beam resonance

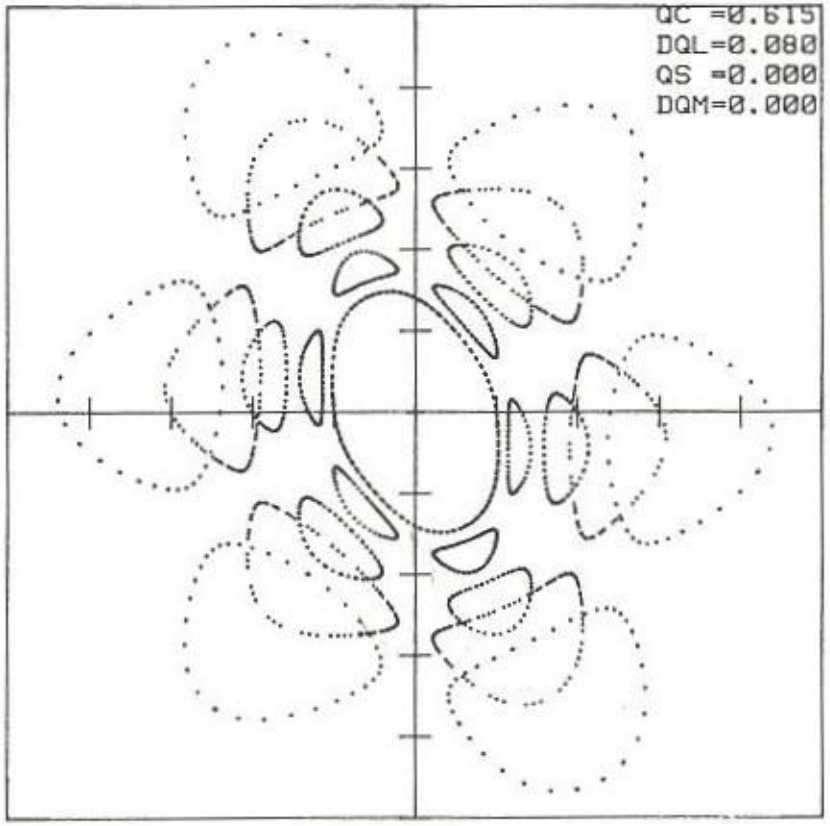


Fig. 9

Instantaneous 'snapshots' of the phase space topology near a 6th order beam-beam resonance as the tune is changed from 0.615 (inner islands) to 0.645 in steps of 0.01.

Tune diagram in store

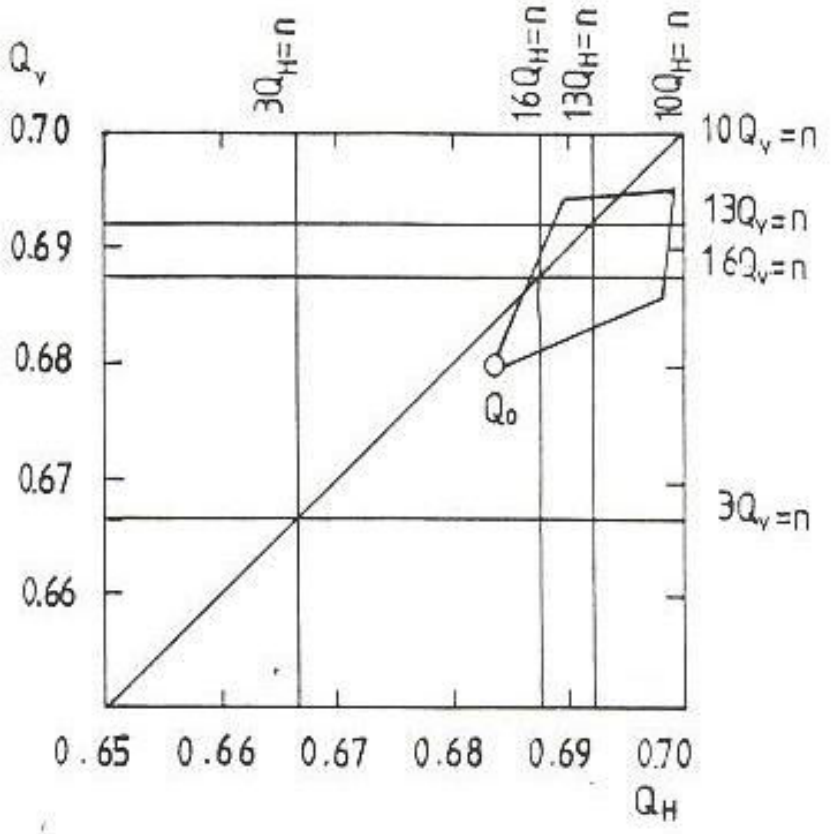
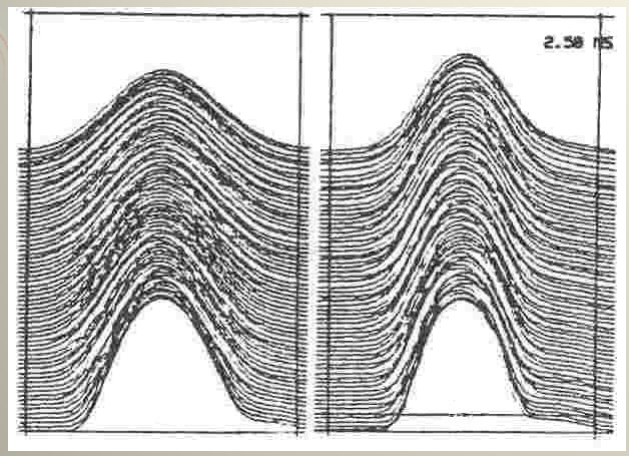


Fig.5: Tune diagram in store. The tunespread for protons and antiprotons in store due to the beam-beam force is similar. At the store energy of 315 GeV the Laslett space charge detuning is negligible.

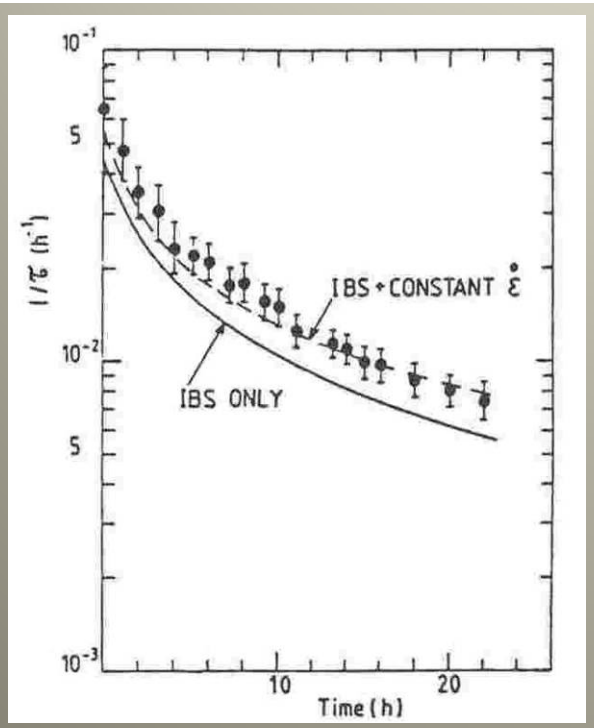
Intrabeam scattering

As particles perform their betatron and synchrotron oscillations, they exchange energy due to multiple Coulomb scattering. The correct frame of reference to understand the phenomenon is the rest frame of the beam. The transverse rms momenta $\sigma'_{x,y}$ are unchanged by this transformation whereas the longitudinal momentum σ_p is transformed into σ_p/γ. In a highly relativistic beam like the LHC, the longitudinal plane is therefore very "cold" compared with the transverse planes and one would expect a damping of the transverse dimensions and an increase in the energy spread, which would be good for luminosity preservation. This indeed does occur in the vertical plane although the damping time is very long. Unfortunately, in the regions where the dispersion is not zero (most of the machine), a particle changes its energy by Coulomb scattering but does not change its position and therefore finds itself on the wrong orbit for its momentum. It can only make a betatron oscillation around its new equilibrium orbit, adding a heating term that completely swamps the slow damping in the radial plane.

Intrabeam scattering in the SPS



Bunch lengthening with time for a strong proton bunch (left) and a weak antiproton bunch (right).



IBS growth rate compared with theory.