IS THE SPACE-CHARGE TUNE SPREAD EFFECTIVE FOR LANDAU DAMPING OF THE HEAD-TAIL MODES ?

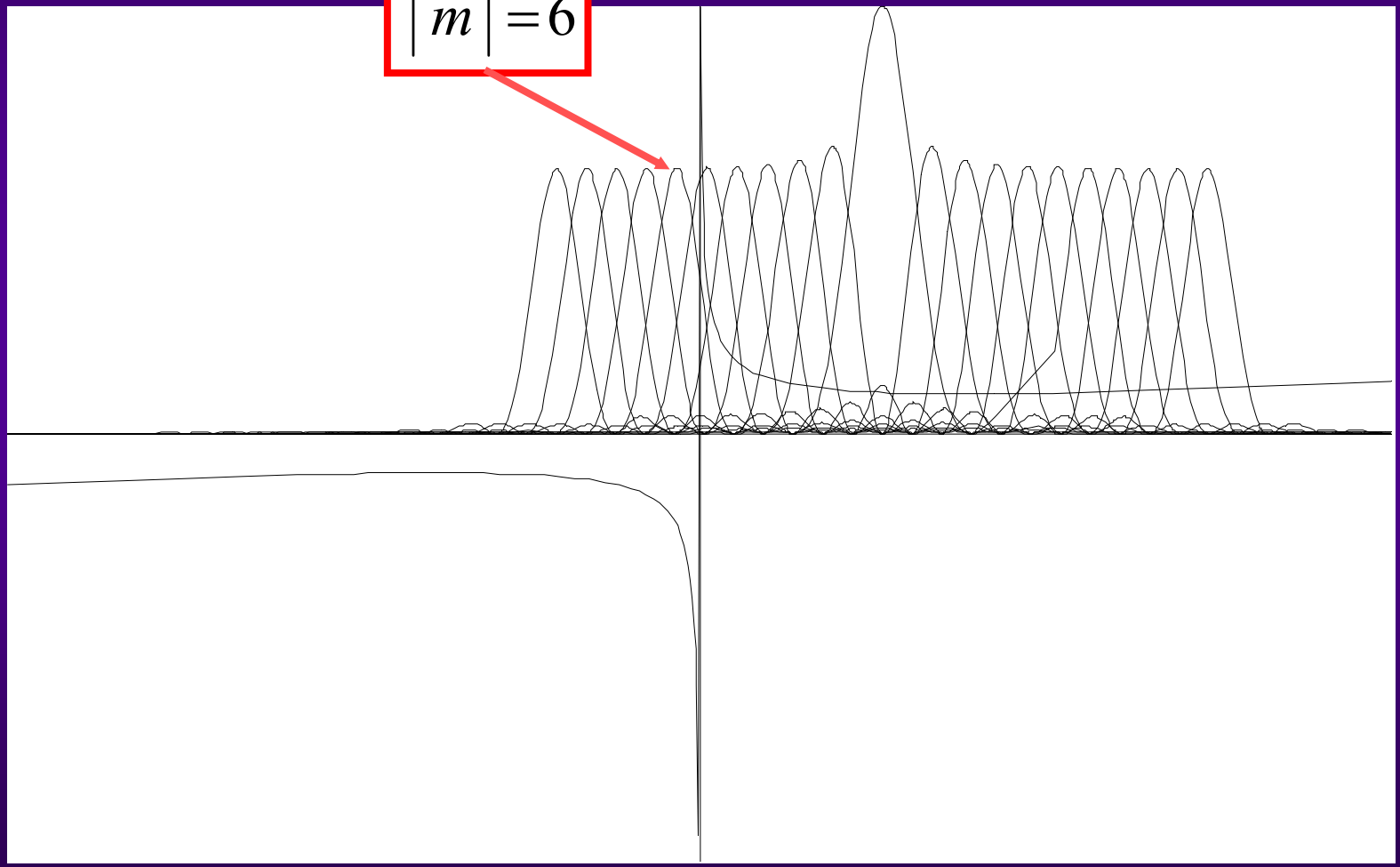
E. Metral

THEORY

- For coasting-beam modes and for rigid-bunch modes
  - See paper "Landau damping by non-linear space-charge forces and octupoles", by Mohl and Schonauer, 1974
- For head-tail modes
  - See paper "On Landau damping of dipole modes by non-linear space charge and octupoles", by Mohl, 1995
- Conclusion
  - The incoherent space-charge tune spread alone (i.e. without external non-linearities) has no stabilizing effect
  - The incoherent space-charge tune spread becomes effective if at least a similar tune spread is introduced by external non-linearities (octupoles) $\Rightarrow$ A factor ~2 in the octupole strength can be gained

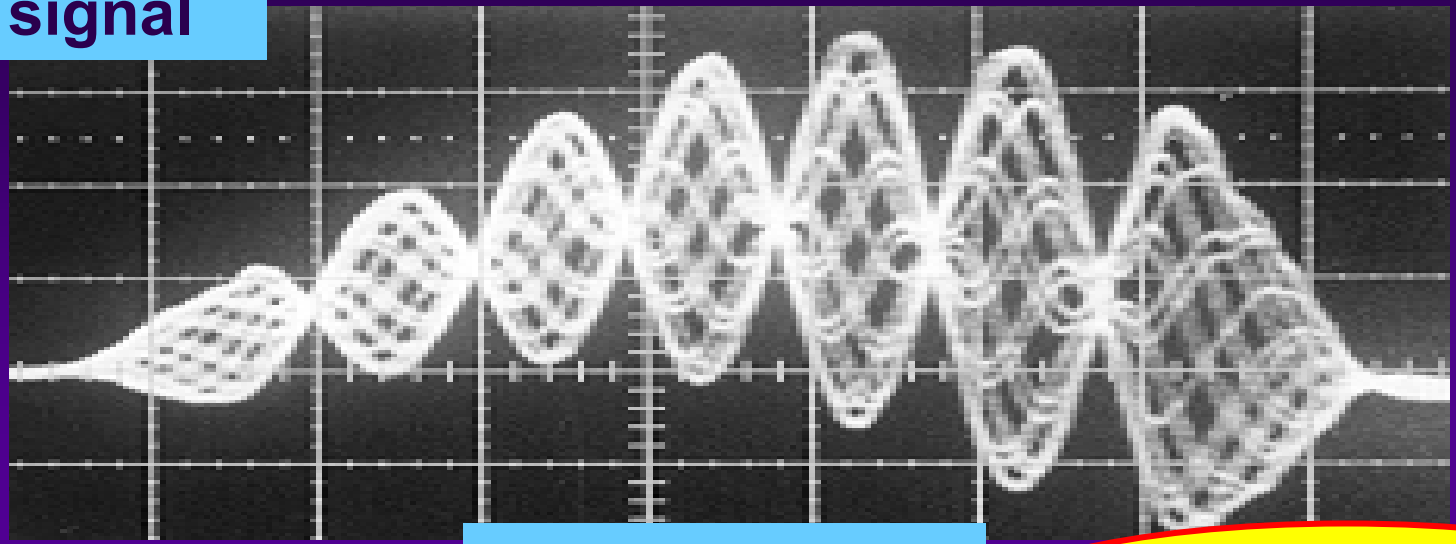
EXPERIMENTS IN THE CERN PS (1/4)

- **Horizontal single-bunch head-tail instability with the LHC beam (m=6) predicted by Sacherer theory due to the resistive-wall impedance**



EXPERIMENTS IN THE CERN PS (2/4)

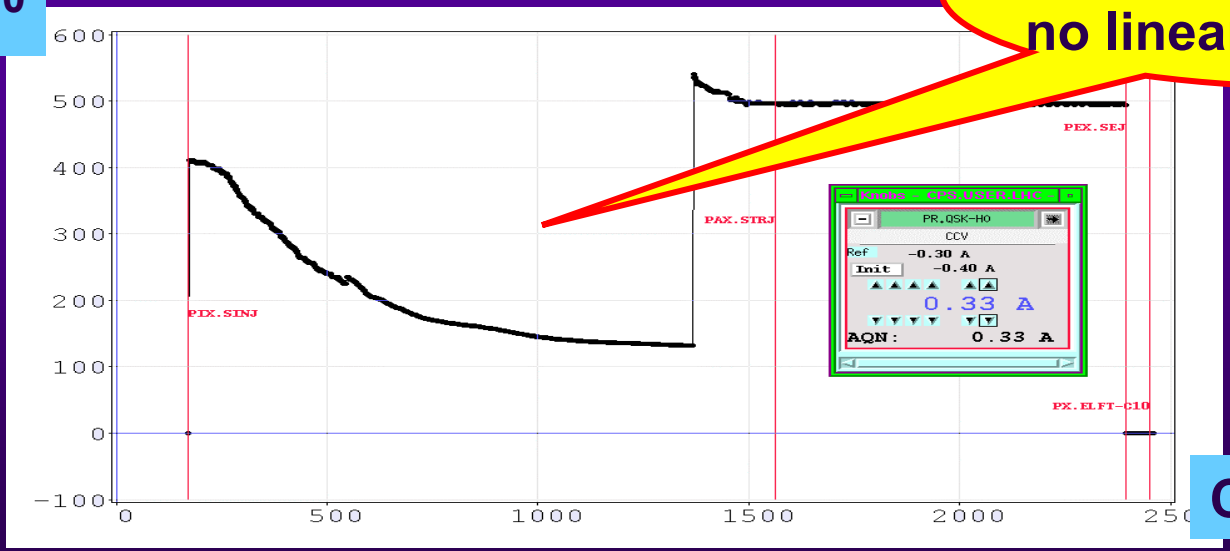
ΔR signal



$$|m| = 6$$

Time (20 ns/div)

×10¹⁰

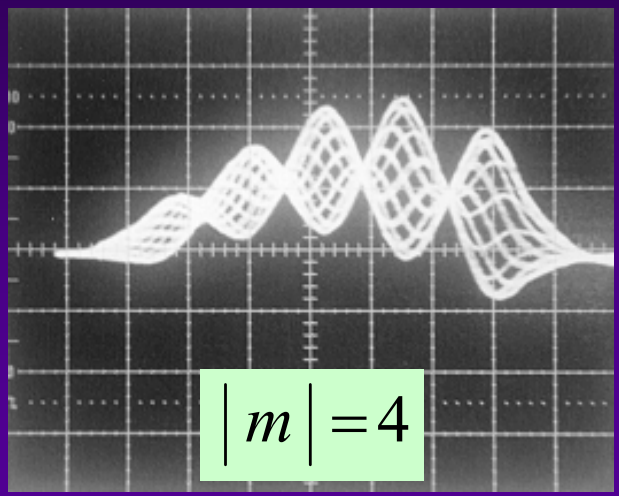


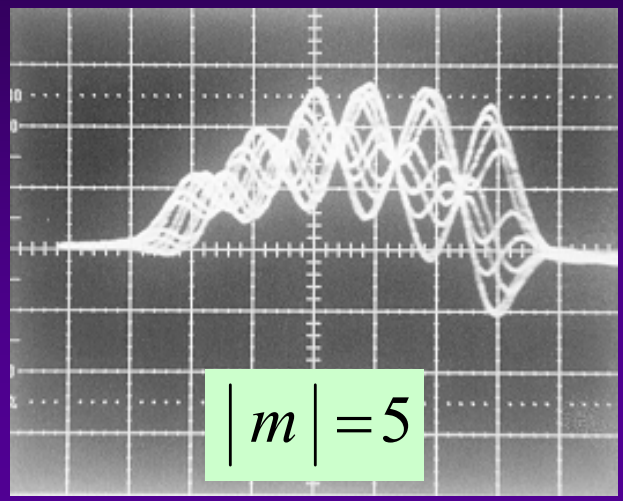
No octupole, no feedback, no linear coupling

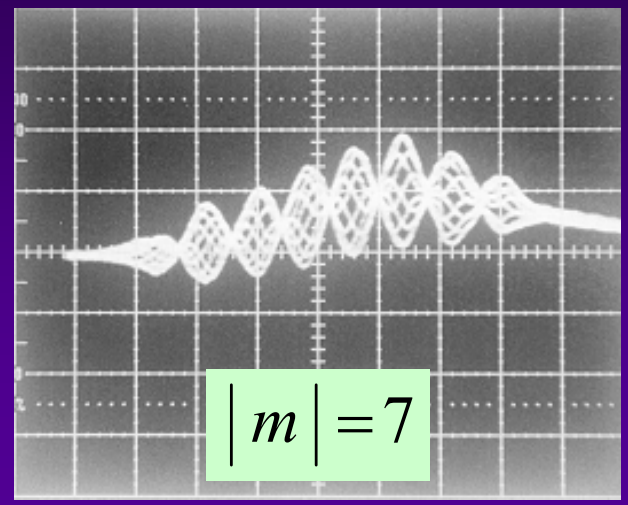
C Time [ms]

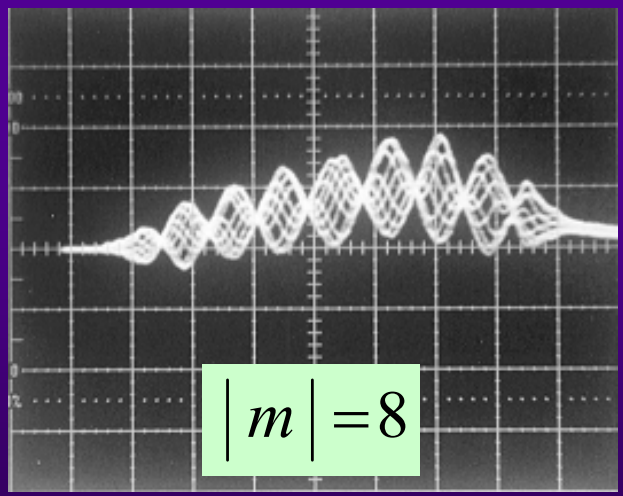
EXPERIMENTS IN THE CERN PS (3/4)

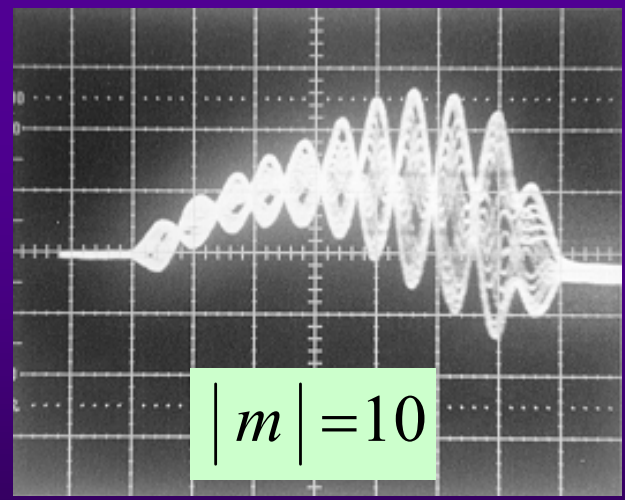
- **Chromaticity tuning**











$\Longrightarrow$ **It is an agreement with theory and confirms the fact that the instability is due to the resistive-wall impedance**

EXPERIMENTS IN THE CERN PS (4/4)

- **Simplified stability criterion, which is drawn from dispersion relation analysis considering "elliptical" betatron frequency distributions**

$$\Delta\omega^{x}_{\mathrm{HWHH}} \geq \sqrt{3}\left|\Delta\omega^{x}_{\mathrm{c,m}}\right| \quad \Rightarrow \quad \Delta Q^{x}_{\mathrm{HWHH}} \geq 1.6\times10^{-4}$$

Measured and theoretical stabilizing octupole currents for the nominal single-bunch beam.

I_{oct}^{exp}[A]	$I_{oct}^{\mathrm{theory}}$[A]	Ratio = $\lvert I_{oct}^{\mathrm{exp}} / I_{oct}^{\mathrm{theory}} \rvert$
8	6.6	1.2
-10	6.6	1.5

$\Longrightarrow$ **Good agreement between theory and experiments for Landau damping by octupoles**

- **Space-charge tune spread** $\Delta Q^{x,spacecharge}_{\mathrm{total}} \approx 0.2$

CONCLUSION

- The space-charge tune spread is not effective for Landau damping of head-tail modes (the dipole mode and all the higher-order modes!!!) in the PS as predicted by Mohl

- The space-charge tune spread may not be effective for Landau damping of head-tail modes in the LHC at injection