Loss of Landau damping in the SPS.
Undamped quadrupole oscillations

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- Measurements at 26 GeV/c
- Model for parabolic bunch
- Effect of synchrotron frequency distribution
Quadrupole frequency shift - measurements

- Measurements of quadrupole frequency shift with intensity are used to monitor impedance changes in the SPS (slope was reduced by a factor 2.5).

- After impedance reduction (2001) the quadrupole oscillations are not damped anymore starting already from some moderate intensities ($\sim 2 \times 10^{10}$) → studies.
Quadrupole frequency shift - measurements

Experimental set-up

- 26 GeV/c (14 GeV/c - less clear data)
- Constant mismatched voltage 700 kV (500 kV, 900 kV) → quadrupole oscillations after injection
- Change of intensity in PSB
- Bunch: $\tau = 2.5$ ns, $\epsilon = 0.14$ eVs
- Methods of bunch observation:
  - Mountain range display of bunch profiles
  - Peak detected (PD) signal
  - Schottky spectrum of PD signal
Quadrupole frequency shift - measurements

Coherent oscillation frequency

Bunch profiles

PD signal
PD Schottky spectrum - measurements

coherent frequency

incoherent band
Quadrupole frequency shift - calculations

Coherent and incoherent oscillation frequencies

\[ \omega_{coh}, \omega_{inc} \]

\[ \frac{(\omega_{coh} - \omega_{inc})}{\omega_{s0}} \]

- Exact solution for parabolic bunch in mismatched linear voltage
  \( \left( \frac{\omega_{s0}^2}{\Omega^2} = 1.27 \right) \), synchrotron frequency spread = 0.13

\[ \frac{\epsilon}{\Omega^2} \approx 4.0 \cdot 10^{-3} \frac{N_b}{10^{10}} \frac{\text{Im}Z}{n} \tau_0 \]

\( 0 < \frac{\epsilon}{\Omega^2} < 0.45 \) for \( 0 < N_b < 10^{11} \) and \( \text{Im}Z/n = 5 \text{ Ohm} \)
PD Schottky spectrum - measurements

 calculated

 measured
Synchrotron frequency distribution

Binomial line density distribution with $\mu = 2.5$, $x_b = 1.5$.
Potential well of the form:

$$W(x) = 1 - \cos x + \lambda(1 - x^2 / x_b^2)\mu$$

Example: $\lambda = 0, 0.1, 0.2$
PD Schottky spectrum - measurements

dipole

sextupole
PD Schottky spectrum - measurements

dipole + sextupole scaled

+ quadrupole