Energy from Q_s in 2000

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- Synchrotron oscillation revisited
  - linear $\rightarrow$ nonlinear regime
- Impact on Y2K data
  - In 2000 the longitudinal oscillation was excited for the Q_s MDs (no excitation in 1998 and 1999!)
  - A frequency shift $\propto -Q_s$ changes the the voltage calibration factor g in the calibration datasets (40 - 60 GeV) if not taken into account

Longitudinal Oscillations

- RF voltage: $V_{RF}(\psi) = V_0 \sin\psi$

- Stable phase: $\sin\psi_s = U_0/e$

- Small amplitude oscillation around ψ_s:

$$\ddot{\psi} + \Omega^2 \psi = 0$$

with

$$\Omega^2 = \omega_{rev}^2 \left(\frac{\alpha_c h}{2\pi E_0}\right) e \frac{dV}{d\psi}(\psi_s)$$

- Synchrotron tune Q_s:

$$Q_s^2 = \left(\frac{\Omega}{\omega_{rev}}\right)^2 = \left(\frac{\alpha_c h}{2\pi E_0}\right) e V_0 \cos\psi_s$$
$$= \left(\frac{\alpha_c h}{2\pi E_0}\right) \sqrt{e^2 V_0^2 - U_0^2}$$

Q_s

Q_s at Large Amplitudes

- Driving force: $Q_s^2 \propto \cos\psi_s = F$ (tangent!)

  → for large amplitudes a better approximation of the driving force is needed....

- Change in driving force $\Delta F \propto F'' = -\cos\psi_s$

- Example:

$$\langle F \rangle = \frac{1}{2}\left[\cos(\psi_s - \Delta\psi) + \cos(\psi_s + \Delta\psi)\right]$$

and

$$\Delta F = \frac{1}{2}\left[\cos(\psi_s + \Delta\psi) - 2\cos\psi_s + \cos(\psi_s - \Delta\psi)\right]$$
$$\propto \cos''\psi_s = -\cos\psi_s$$

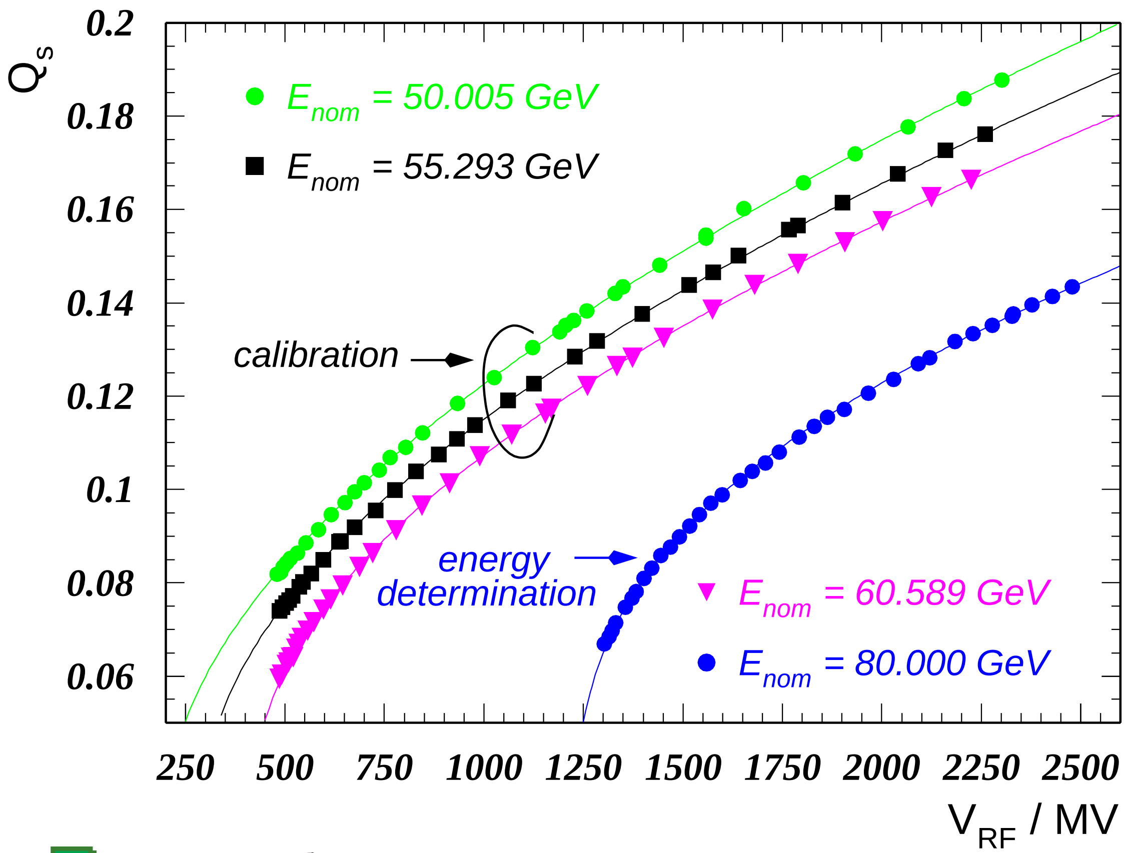
$$\triangleright \quad \Delta Q_s^2 \propto -Q_s^2$$

- Frequency shift due to nonlinearity:

$$\boxed{\Delta Q_s \propto -Q_s}$$

Impact on Energy Determination

- Input data:



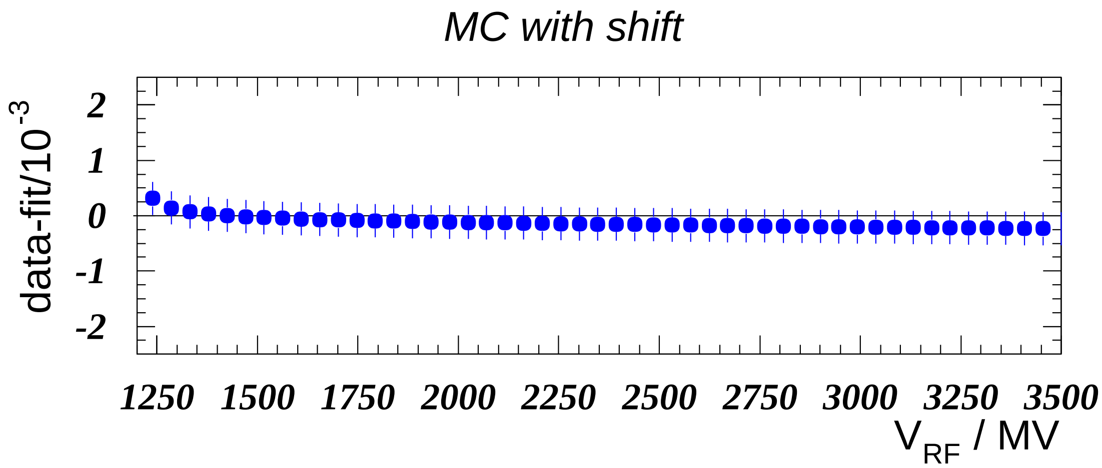
- Procedure:
  - get voltage calibration factor “g” from low energy datasets
  - assume constant g and extract E with fit
- New in 2000:
  - apparent “slope” in $g = f(E)$
    ($\chi^2/N = 3$ for assumption of zero slope)
  - introduce $Q_s = Q_s + f_x Q_s$
    ($\chi^2/N = 1$ for assumption of zero slope)

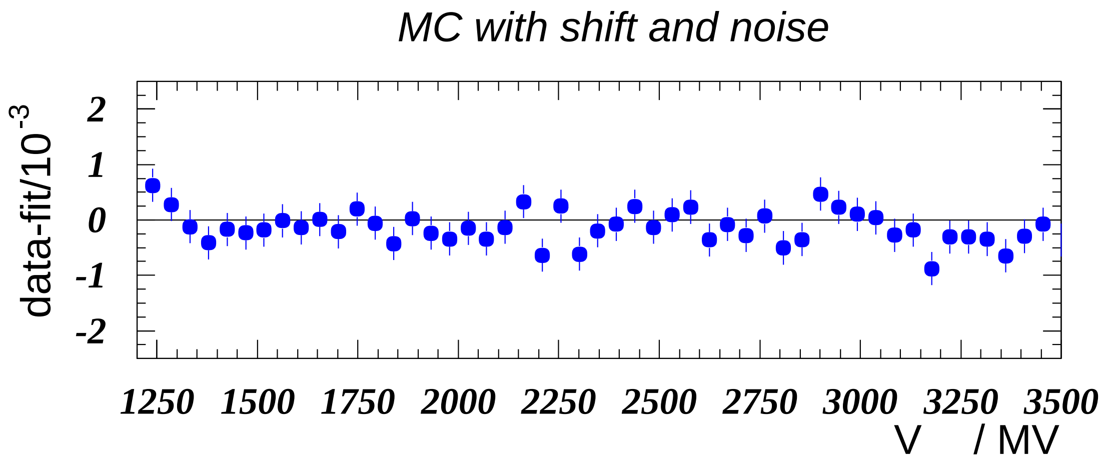
Q_s

Monte Carlo Example

With $Q_s = Q_s + f_x Q_S$ and $f_x = -\,5\;10^{-3}$

- Difference between "data" and fit:

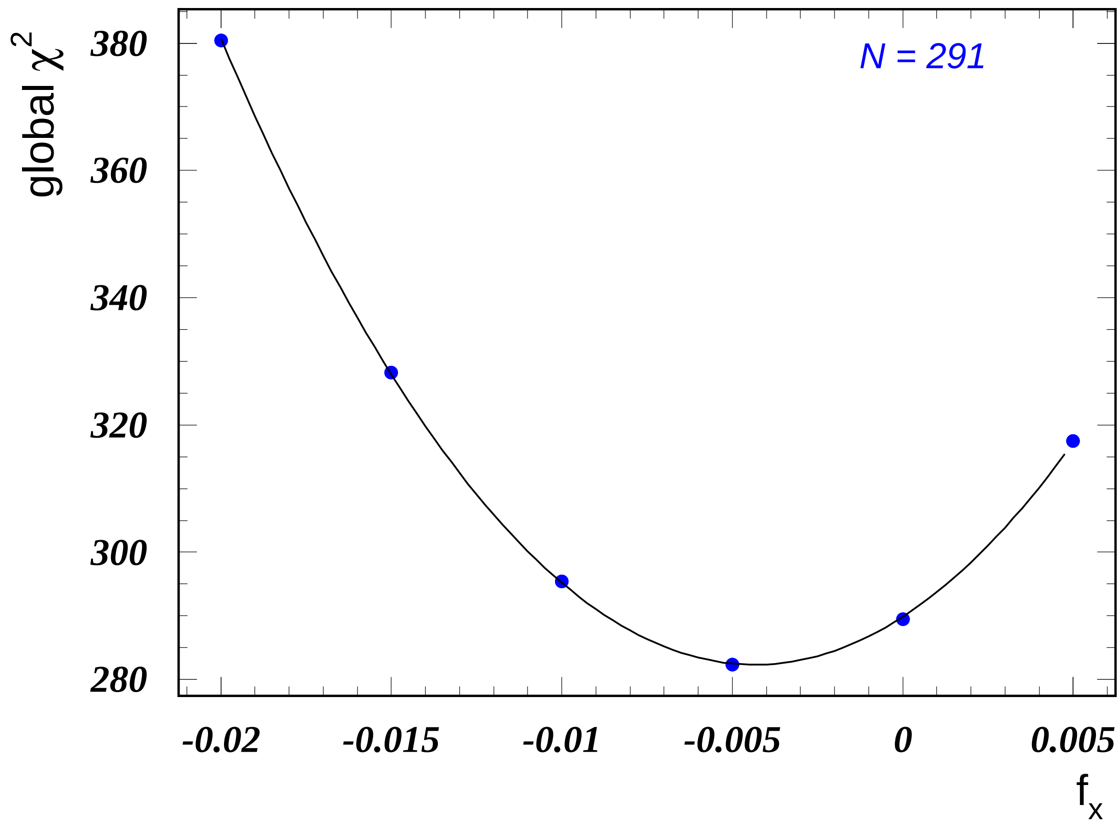




- g seems to have slope of 10^{-4} / GeV

Extracting f_x

- Determine the global χ^2 for all LE datasets as a function of f_x
- f_x given by global minimum
- Global χ^2 for all LE datasets:



$\gtrdot$ $f_x = -(0.0043 \pm 0.0016)$

Results

- Energies from 2000 HE datasets:

MD35: $E_{Q_s} = (79.962 \pm 0.037 \pm 0.045)$ GeV

$\Delta E = -11$ MeV

MD36: $E_{Q_s} = (79.942 \pm 0.027 \pm 0.026)$ GeV

$\Delta E = -48$ MeV

MD42: $E_{Q_s} = (79.905 \pm 0.017 \pm 0.049)$ GeV

$\Delta E = -58$ MeV

- Resulting energy shift at 80 GeV:

⩾ $\Delta E = -(43 \pm 27)$ MeV