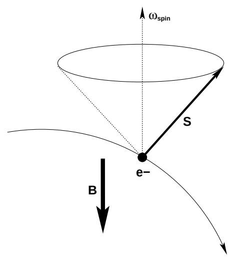
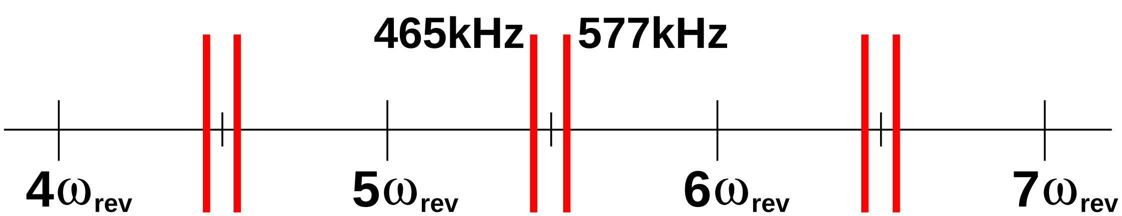
Energy Calibration With High Precision

- Bending magnet field measurements (Hall Probes): $\rightarrow \frac{\Delta E}{E} = (1-2)\cdot 10^{-3}$
- For higher precision $\rightarrow$ Resonant Spin Depolarization
- In a flat machine the ideal electron sees $\vec{B}_{\perp}$ $\rightarrow$ spin vector precesses according to Thomas-BMT equation:



$$\omega_{spin} = \omega_{rev}\nu_{ST} = \omega_{rev}\cdot a\gamma$$
$$a = \frac{g-2}{2} = 0.00115965(2)$$

- SLS: $E = 2.4$ GeV, $\omega_{rev} = 1042$ kHz
  $\rightarrow \nu_{ST} = 5.4465$ corresponding to $\omega_{res-depol} \approx 465/577$ kHz



Polarization

- Spin-flip synchrotron radiation (only $\approx 10^{-11}$ of total radiation power) $\rightarrow$ polarization build-up anti-parallel to main bending field:

  $$P(t) = P_0(1 - e^{-\frac{t}{\tau}}) \qquad \frac{1}{\tau} = \frac{1}{\tau_p} + \frac{1}{\tau_d} \qquad P_0 = P_{ST}\frac{\tau_d}{\tau_p + \tau_d}$$

  $P_{ST} = 92.4\%$ theoretical maximum for a flat ring

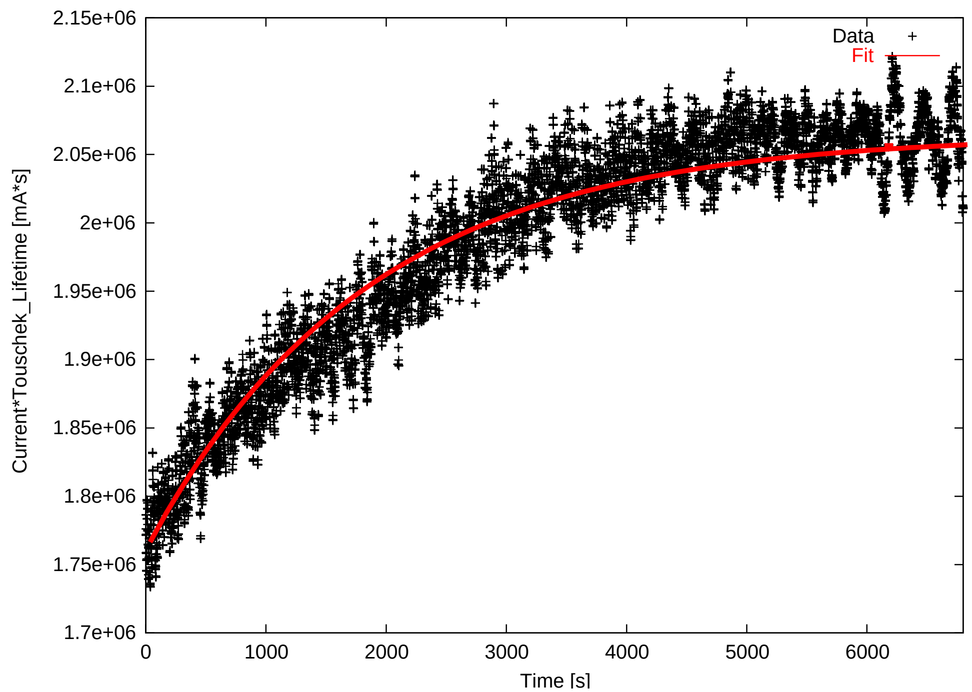
  $$\tau_p = \left(\frac{5\sqrt{3}}{8} \cdot \frac{e^2\hbar}{{m_e}^2c^2}\right)^{-1} \cdot \frac{\rho^3}{\gamma^5}$$

  @SLS: $\tau_p = 1873$ s ($\gamma = 4700$)
  @LEP: $\tau_p = 360$ min ($\gamma = 86000$)

  $\tau_d \propto (a\gamma)^{-2}$ $\qquad$ $\tau_d \gg \tau_p$ for low-energy machines

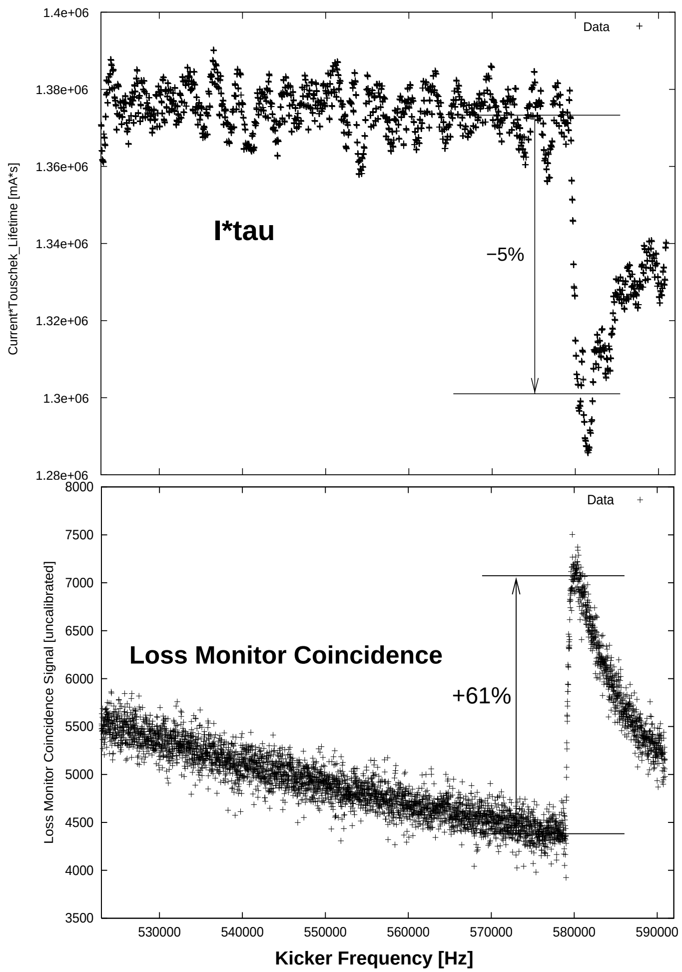
- How to measure polarization without a polarimeter?
  - Touschek lifetime is polarization dependent: $\sigma_{ts} = f_1 - P^2 f_2$
  - Choose filling with high bunch current $\rightarrow \tau$ is dominated by τ_{ts}
  - Identify changes in $I \cdot \tau_{ts}$ with changes in P

Polarization Measurements



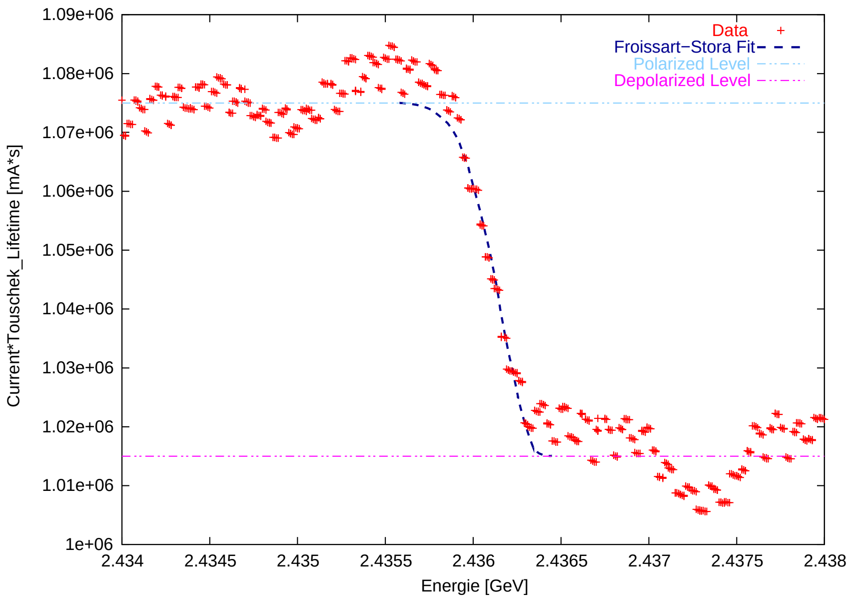
- For SLS storage ring: $\tau_p = 1873$ s
- From fit: $\tau = (1837 \pm 1)$ s $\longrightarrow$ $\tau_d = 95.6 \cdot 10^3$ s
  $\rightarrow P_0 = P_{ST} \cdot \frac{\tau_d}{\tau_p + \tau_d} = 91\%$

Resonant Depolarization



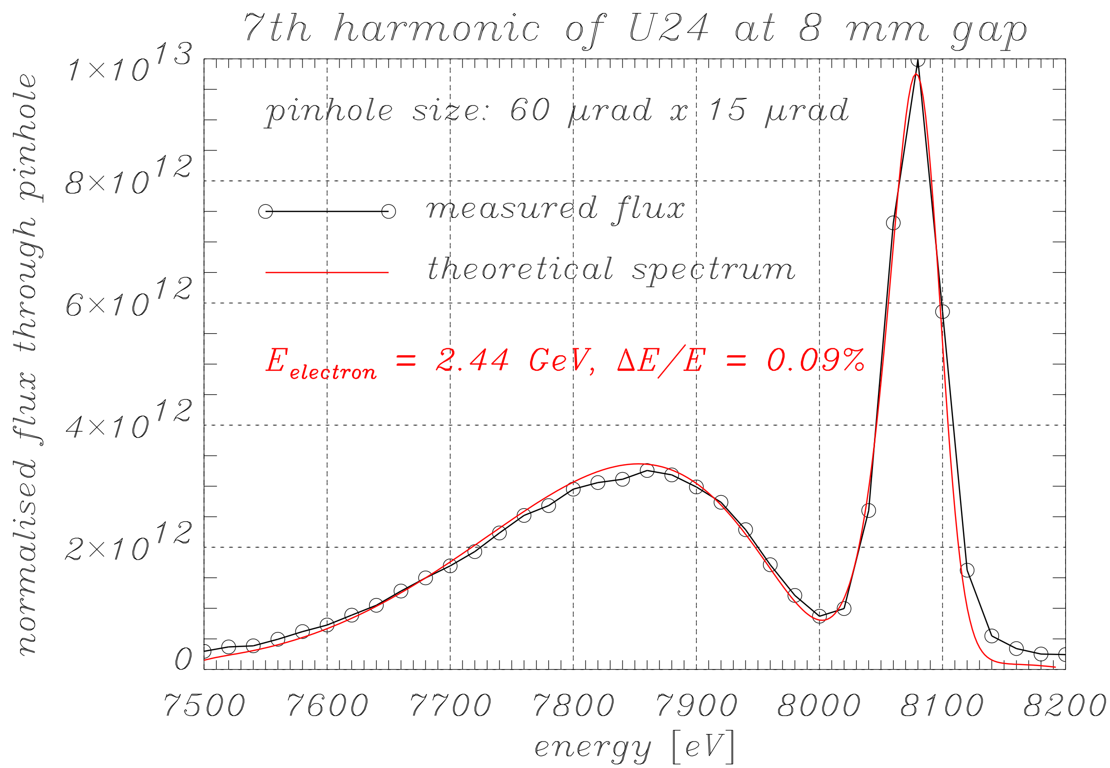
- Feed sinusoidal signal to vertical tune kicker magnet
- Sweep signal frequency over interval around resonant depolarizing frequency
  $\rightarrow$ At $\omega_{res-depol}$ the ensemble's mean spin vector can be tilted into the horizontal plane (together with spin diffusion)
  $\rightarrow$ Reduce polarization
  $\rightarrow$ Reduce $I \cdot \tau_{ts}$
- Verification of the resonance through (uncalibrated) loss monitor coincidence signal from two scintillators installed in the vicinity of in-vacuum undulator U24
  $\rightarrow$ Pairs of Touschek-scattered electrons

Energy Calibration



- Froissart-Stora fit for isolated resonance crossing
  $\rightarrow E = (2.4361 \pm 0.00018)$ GeV
  $\rightarrow \frac{\Delta E}{E} \approx 7 \cdot 10^{-5}$ ($10^2\times$ higher than Hall probe measurements!)
- Energy is 1.5% higher than determined from dipole calibration
  $\rightarrow$ Confirms previous increase of the quadrupole and sextupole magnet strength of $+1.2\%$ with respect to design at 2.4 GeV

Energy Calibration



- E is in excellent agreement with the energy derival from a scan of the 7th harmonic of U24 revealing $E = 2.44(2)$ GeV

Non-Linearity of Momentum Compaction

- High precision of energy calibration $\longrightarrow$ measure non-linearity of Momentum Compaction:
  $-\frac{\Delta f_{RF}}{f_{RF}} = \alpha \cdot \frac{\Delta E}{E} + \alpha_1 \cdot (\frac{\Delta E}{E})^2$
- Results: $\alpha = 5.6 \cdot 10^{-4}$ and $\alpha_1 = 4.4 \cdot 10^{-3}$
  - From dispersion measurements: $\alpha = 6.0 \cdot 10^{-4}, \alpha_1 = 4.2 \cdot 10^{-3}$
  - From machine model and detuning: $\alpha = 6.5 \cdot 10^{-4}, \alpha_1 = 4.5 \cdot 10^{-3}$
- But only three data points (no error bars on measurement!)
  $\longrightarrow$ Need to repeat measurement and acquire more data!