Polarisation monitoring ?

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Outline

Polarization measurement /monitoring near the sources :

FAQ in discussions about polarimetry:

Why not measuring polarization in the DR?

→ Need method sensitive to transverse polarisation

Possibilities:

- **Touschek effect**
- **synchrotron radiation**

Touschek effect

- particles in circulating bunch execute transverse betatron oscillations
- transverse velocities statistically distributed
- Coulomb scattering of charged particles
  - → **transfer transverse momenta to longitudinal momenta (factor ~γ in lab frame)**
  - – **particles lost**
- First observation by Touschek (1963) by observation of beam lifetime in ADA ring
- can also happen with intense beams of low emittance

Touschek effect and polarization

Intra-beam scattering ⇔ Moller cross section

$$\frac{d\sigma}{d\Omega} \sim \frac{1}{\gamma^2}\left(\frac{4}{\sin^4\theta} - \frac{3}{\sin^2\theta} - \frac{\vec{P}_1\vec{P}_2}{\sin^2\theta}\right)$$

→ Touschek effect ~ P^2

→ Polarized beams: less Touschek-radiation

Effect is used to measure polarization differences

Best sensitivity between polarized and unpolarized beam

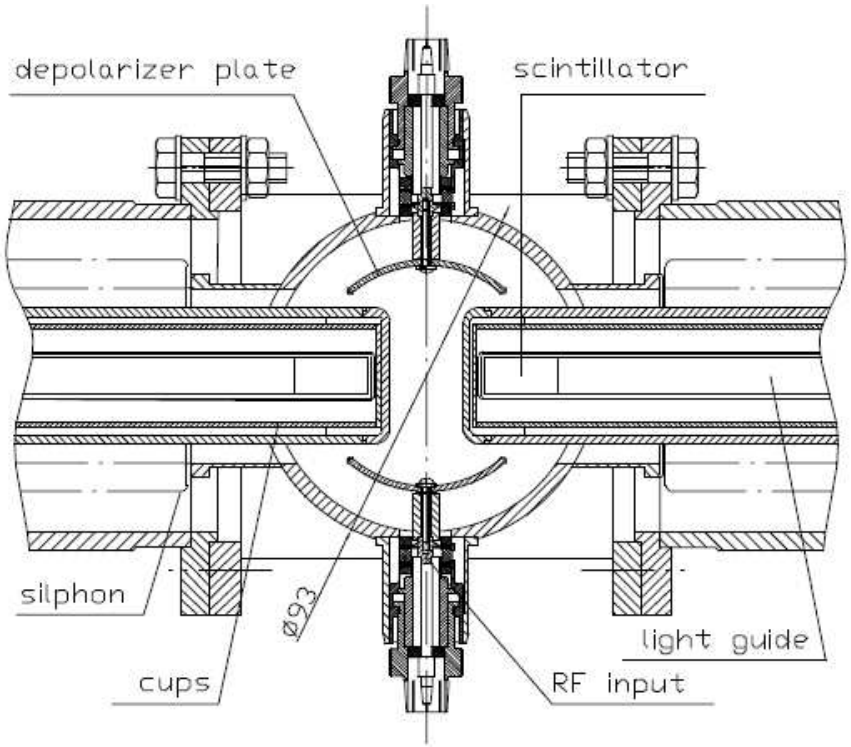
→ Observation of depolarization

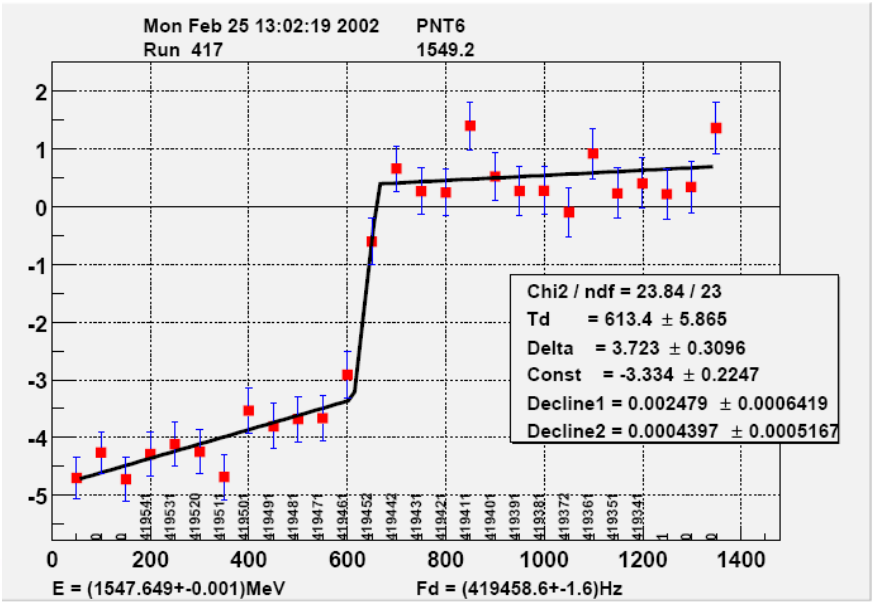
$$\Delta P^2 \propto \frac{N_{unpol} - N_{pol}}{N_{unpol}}$$

- Experimental setup VEPP-4M

  (Blinov et al., EPAC 2002)

  Method used to detect forced depolarization





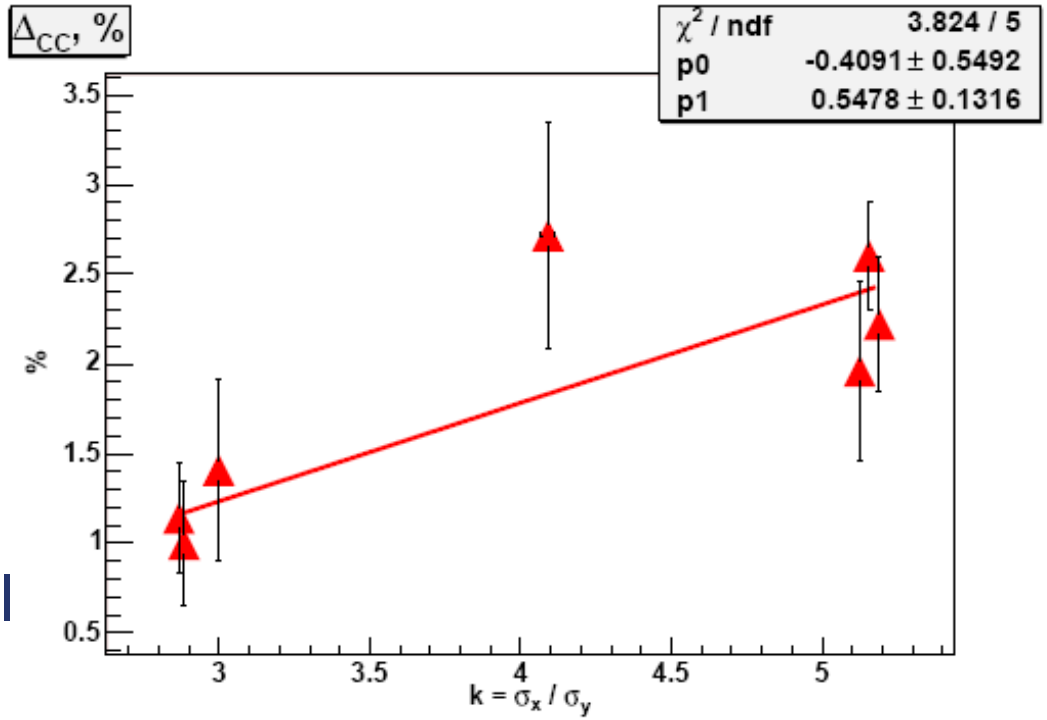
Depolarization →
Jump in counting rate of Touschek electrons

Size of the polarization dependent effect:

few percent-level

VEPP-4M: Nikitin, Nikolaev, BINP, EPAC 2006 Proceedings

Jump of counting rate
for Touschek electrons
vs ratio horizontal /vertical
beam size



Touschek effect to monitor polarization

Relative polarization measurement:

- **Method is non-destructive, simple**
- **variation from P=0.8 to P=0.6 → ΔP^2 changed by factor 1.8**
- **Observe large polarization differences for ↓ and ↑ orientation**

But:

- **rates depend on beam sizes, #particles/bunch,…**
  → Need **very** stable beams
- **we do not expect serious depolarization or large ↓ ↑ differences**
  →Method not sensitive enough
- **Effect for positrons (P^2=0.09) smaller than for electrons (P^2=0.64)**

- One should check whether BPMs can be used to detect asymmetries between $\downarrow$ and $\uparrow$ or depolarization effects

- But most likely the statistical fluctuations in a linear machine are larger than effect to be measured

Synchrotron radiation

Bondar, Saldin: NIM 195(1982)577, Belomestnykh et al., NIM 227(1984)173

- Measure the tiny spin dependent component of SR
- Small differences in spectra of high energy photons emitted from polarized or unpolarized beams

$$W_0 = \frac{2}{3} e^2 \gamma^4 \left| \dot{\vec{v}} \right|^2$$

$$\dot{\vec{v}} = e\left(\vec{v} \times \vec{H}\right) / m\gamma$$

$$W_S = 2\frac{e^2}{m}\gamma^6 \left| \dot{\vec{v}} \right|^2 \left(\vec{\omega} \cdot \vec{S}\right)$$

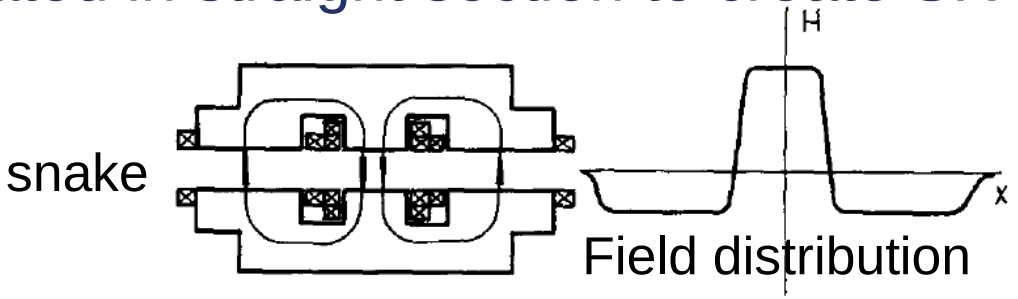
- SR from polarized beam more intense than from unpolarized, relative difference is

$$\delta = y \cdot \gamma \cdot P \qquad y = \frac{\omega}{\omega_C} \qquad \omega_C = \frac{3eH\gamma^2}{2mc}$$

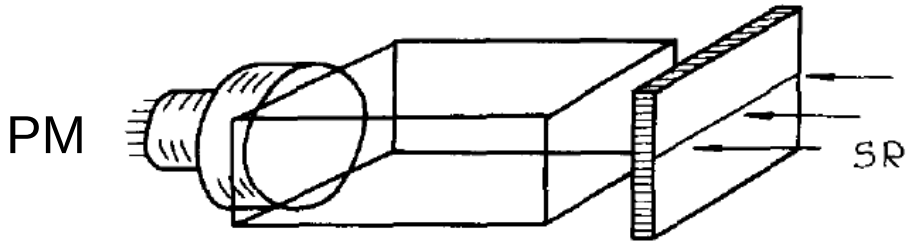
- Better sensitivity for $\omega >> \omega_C$, $\delta \sim H\gamma$ effect is small, ~10e-4… 10e-3
- spin effect depends on sign → reversal of H to reduce syst. effects

Measurement of spin dependence at VEPP

- Smallness of effect → stability of
  - Beam position
  - Beam energy
  - Beam intensity
- 2 bunches chosen to observe relative variations when one is depolarized
- Use snake located in straight section to create SR

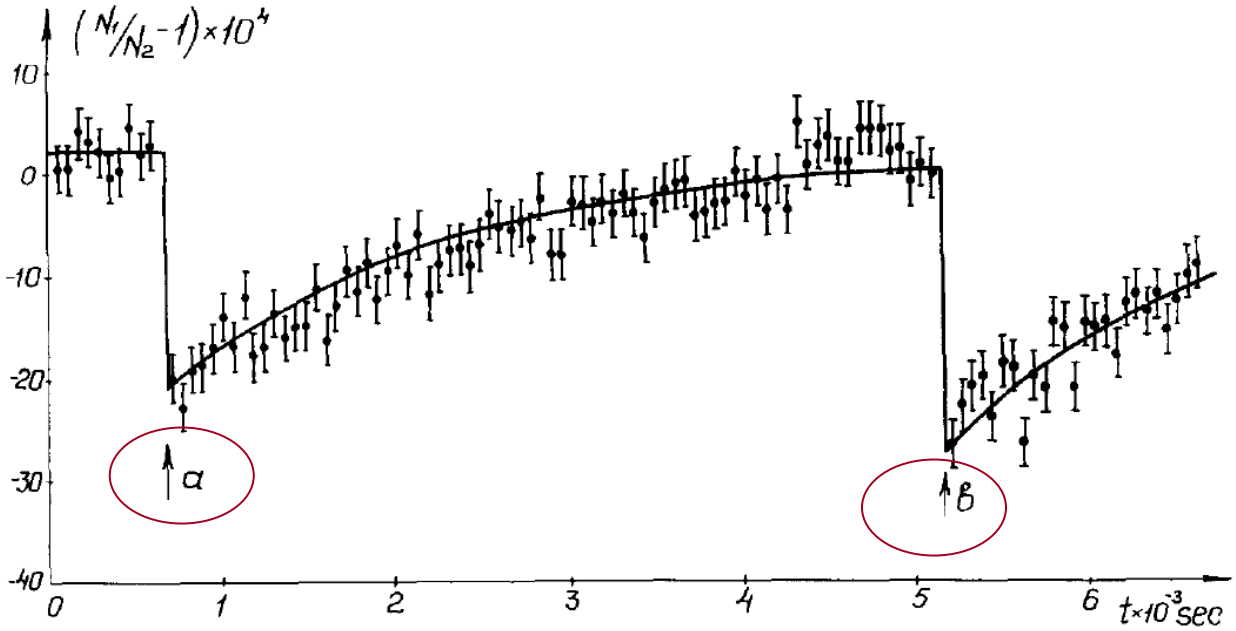


- Detector: scintillator with Pb plate to eliminate photons with low ω



Results

- ‘equalize’ bunches
- Measure counting rates N1 and N2 in the detector for the bunches when they pass the snake
- One bunch is depolarized at time a and b

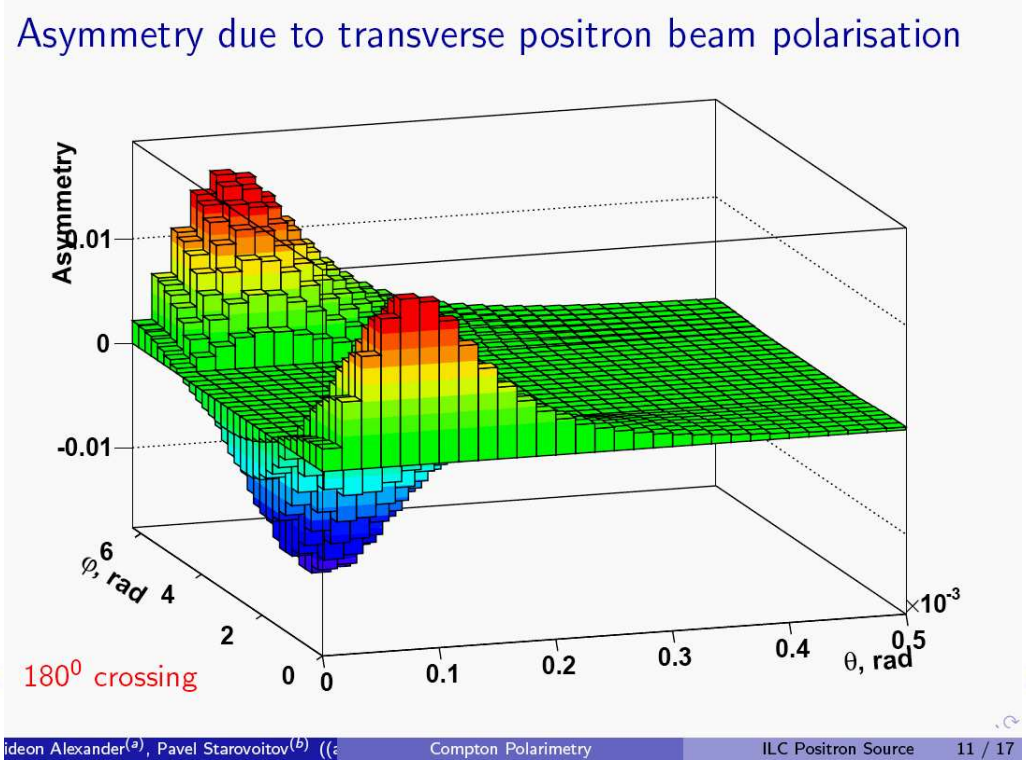


To obtain the effect with ILC beam needs extremely high stability → not suited to monitor or measure the polarization

For comparison: Compton polarimeter

Measurement of transverse polarization:

- Cross section and luminosity are the same as for long. Polarization
- Small asymmetry, 1…2%
- More complicated detector since E deposition and angular distribution position have to be measured



Details see

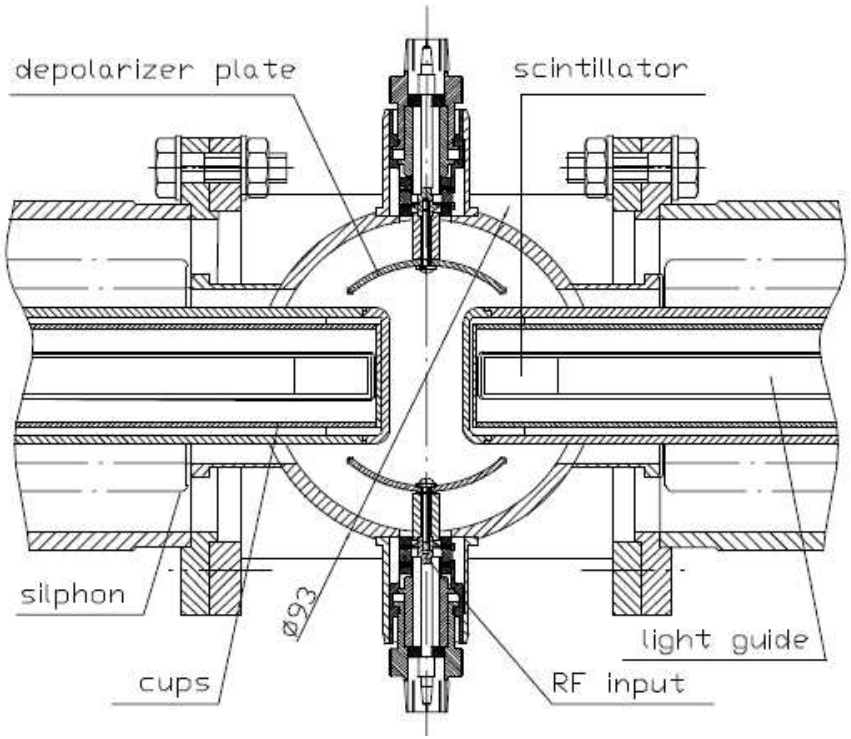
Alexander,Starovoitov, LC-M-2007-014, 2007

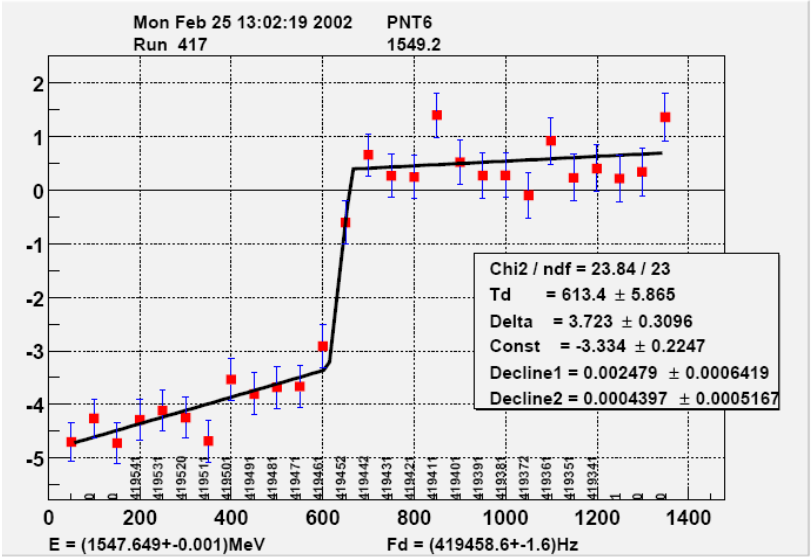
Summary

- Advantage: presented methods work with transverse beam polarisation, not expensive, non-destructive
- Disadvantage: effects are very small
- Use in linear machines would require extreme stability, otherwise statistical fluctuations are larger than effect

These methods cannot replace the polarization measurement at the source

- Experimental setup VEPP-4M (Blinov et al., EPAC 2002)
  - **Method used to detect forced depolarization**





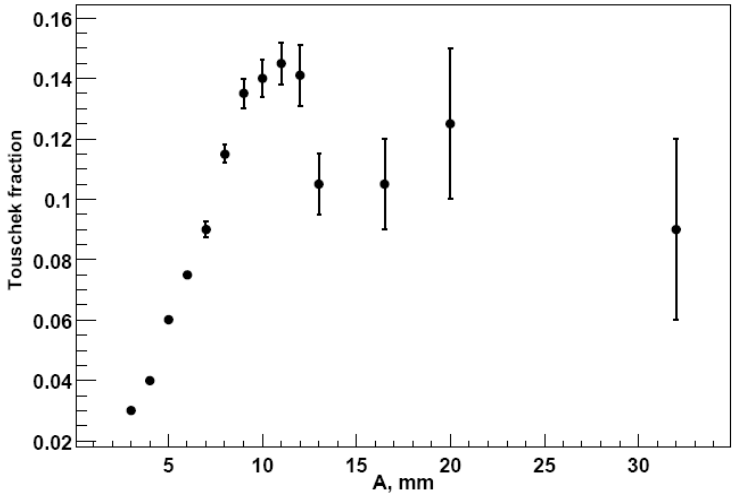


Figure 5: Relative fraction of Touschek electrons in the total counting rate vs. the distance A.