# The polarized electron beam at ELSA

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**Abstract.**
The future medium energy physics program at the electron stretcher accelerator ELSA of Bonn University mainly relies on experiments using polarized electrons in the energy range from 1 to 3.2 GeV.

To provide a polarized beam with high polarization and sufficient intensity a dedicated source has been developed and set into operation. To prevent depolarization during acceleration in the circular accelerators several depolarizing resonances have to be corrected for. Intrinsic resonances are compensated using two pulsed betatron tune jump quadrupoles. The influence of imperfection resonances is successfully reduced applying a dynamic closed orbit correction in combination with an empirical harmonic correction on the energy ramp.

In order to minimize beam depolarization, both types of resonances and the correction techniques have been studied in detail. It turned out that the polarization in ELSA can be conserved up to 2.5 GeV and partially up to 3.2 GeV which is demonstrated by measurements using a Møller polarimeter installed in the external GDH[1]-beamline.

## I INTRODUCTION

At ELSA [1] external fixed target experiments with longitudinally polarized electrons or circularly polarized photons (produced by Bremsstrahlung) are carried out. The first one is the GDH experiment, which just has started with data acquisition. Because self polarization of the beam by Sokolov-Ternov effect can not be used due to the operation mode of ELSA, a polarized electron source is used. The polarized electron beam is preaccelerated in a linac and a fast cycling booster (50 Hz). After injection into the main ring further acceleration up to 3.5 GeV is possible (Fig. 1).

[1]) The GDH collaboration is named after the authors of the so-called Drell-Hearn-Gerasimov sum rule.

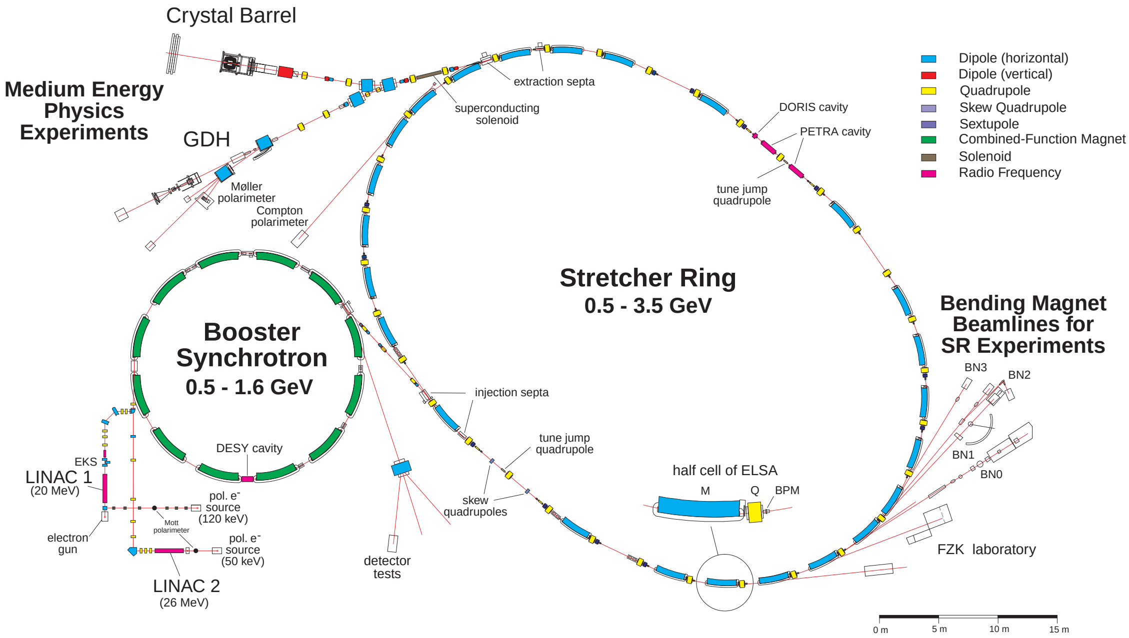


**FIGURE 1.** The ELSA facility at Bonn University.

# II THE POLARIZED ELECTRON SOURCE

A pulsed low energy beam of polarized electrons is produced in a newly developed polarized electron gun [2]. In order to enhance the overall efficiency it operates with a new pulsed injector linac which requires an injection energy of 50 keV, a pulse length of 1 $\mu$s and a repetition rate of 50 Hz [3]. The inverted high voltage structure of the gun permits to vary the distance between cathode and anode and allows to adjust the perveance of the gun. For medium energy experiments, the gun is operated in space charge limitation, emitting a peak current of 100 mA in rectangular 1 $\mu$s long electron pulses. Using a Be-InGaAs/Be-AlGaAs superlattice photocathode [4] a polarization of 80 % and a corresponding quantum efficiency of 0.4 % was obtained. The photocathode lifetime during operation is higher than 3000 hours [5].

# III DEPOLARIZING RESONANCES

In ELSA depolarization is caused mainly by intrinsic and imperfection resonances [6]. The spin originally oriented nearly perpendicular to the accelerator plane precesses around the direction of the magnetic field in the bending magnets. During circulation of the particles in the synchrotron only the polarization component parallel to the guiding field is conserved while the other components are lost. Horizontal magnetic fields cause polarization loss in the case of a resonance with the spin precession frequency. Imperfection resonances are caused by closed orbit displacements in the focusing quadrupoles. Intrinsic resonances are driven by the vertical betatron motion of the electrons, characterized by the vertical betatron tune $Q_z$.

The depolarization caused by linear crossing of an isolated resonance is quantified by the Froissart-Stora-Formula [7]

$$\frac{P_f}{P_i} = 2e^{-\frac{\pi|\epsilon|^2}{2\alpha}} - 1 \quad , \tag{1}$$

where $\epsilon$ is the resonance strength and $\alpha$ the crossing speed. Small polarization losses can be obtained for a small resonance strength $\epsilon$ or a high crossing speed ($\alpha = \frac{\dot{\gamma}a \mp \dot{Q}_z}{\omega_0}$ for intrinsic resonances). In this formula the influence of synchrotron oscillations and radiation is neglected. To take these effects into account we use a modified Froissart-Stora-Formula which essentially describes the depolarization after independently crossing of a depolarizing resonance and the two first order synchrotron satellites:

$$\frac{P_f}{P_i} = \left(2e^{-\frac{\pi|\epsilon|^2}{2\alpha}} - 1\right)\left(2e^{-\frac{\pi|\epsilon_s|^2}{2\alpha}} - 1\right)^2 \quad , \tag{2}$$

where $\epsilon_s$ is the resonance strength of the first order synchrotron satellites.

Spin tracking studies show that this description is sufficient to explain the behavior of depolarization at resonances at higher energies in ELSA. Especially a total spin flip ($\frac{P_f}{P_i} = -1$) can not be observed in ELSA at energies higher than 1.6 GeV.

Three techniques are used to avoid depolarization: Intrinsic resonances are crossed fast with help of two **pulsed betatron tune jump quadrupoles** which shift the vertical betatron tune. The strengths of imperfection resonances must be reduced to avoid depolarization. This is done with a **dynamic correction of the closed orbit** during the energy ramp. For further reduction of the remaining resonance strengths **harmonic corrections** are applied.

## A Tune jumps

For intrinsic resonances a high resonance crossing speed can be achieved by fast shifting the vertical betatron tune $Q_z$ using pulsed quadrupoles. Before crossing the resonance, the vertical betatron tune is shifted fast by the tune jump quadrupoles. The tune jump system at ELSA consists of two quadrupoles which can be pulsed up to 500 A in 4–14 $\mu$s [11–13]. This corresponds to a tune shift of $\Delta Q_z = 0.1$. The vertical betatron tune is shifted back to its original value within 4 to 20 ms before the next resonance is crossed.

## B Closed orbit correction

The closed orbit is measured with a BPM system consisting of 28 monitor stations. After correction with 19 vertical and 21 horizontal corrector magnets the

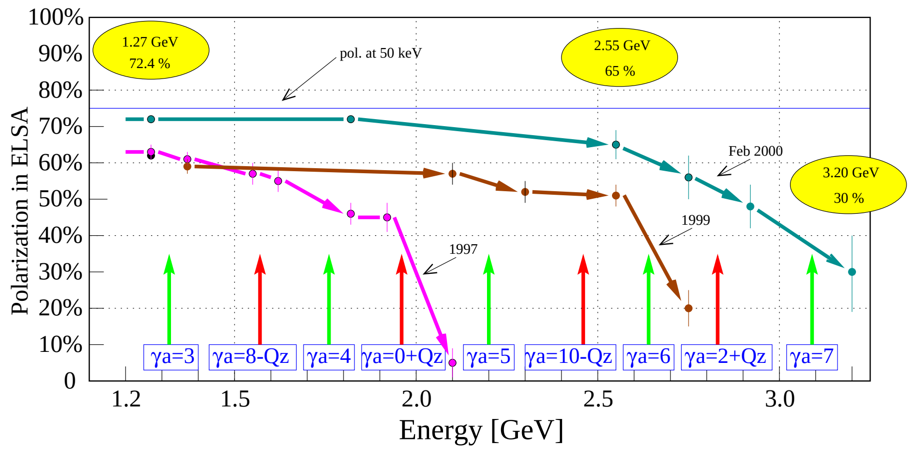


**FIGURE 2.** Achieved polarization in ELSA. The black arrows indicate the energies of intrinsic resonances ($Q_z = 4.431$), the gray ones the position of the imperfection resonances.

remaining horizontal and vertical distortions (determining the depolarization) are smaller than 0.2 mm (rms) [8–10].

The closed orbit is measured and corrected at the energies of the imperfection resonances. Between these energies a linear interpolation of all corrector kick angles is done. With this interpolation a dynamic closed orbit correction during the energy ramp is achieved. After this correction most of the imperfection resonances become so weak that no significant depolarization is observed.

## C Harmonic correction

A further reduction of the strength of each imperfection resonance can be achieved by harmonic correction. The closed orbit harmonics relevant for a single resonance are corrected by modifying the vertical closed orbit. For each resonance two modulation parameters have to be found empirically by measurements of the polarization of the extracted beam.

# IV THE GDH-MØLLER POLARIMETER

All polarization measurements were performed with the GDH-Møller polarimeter in the external beamline [14]. This two-arm polarimeter consists of a target system, a spectrometer dipole magnet and a detector system. The target system is composed of several changeable polarized foils with different orientations of the magnetization relative to the electron beam which enable the measurement of all three vector components of the electron beam polarization. Both Møller scattered electrons are energy separated in the dipole magnet and are identified in coincidence in the detector system.

# V POLARIZATION OF THE EXTRACTED BEAM

Polarized electrons could be successfully accelerated to higher energies by means of the corrections for depolarizing resonances. We observe a polarization of $P \approx 72\%$ up to energies of 2 GeV, which decreases to $P \approx 65\%$ at 2.55 GeV and drops to $P \approx 30\%$ at 3.2 GeV (see Fig.2). An external current of max. 3 nA could be delivered to the GDH-Tagger target. Optimization of the polarization levels at higher energies is subject to future studies at ELSA.

# VI SUMMARY

At ELSA a new polarized electron source has been developed and set into operation. A polarization of $P = 80\%$, $QE = 0.4\%$ and a current of 100 mA were obtained. Polarized electrons have been successfully accelerated to higher energies. Several techniques for correction of depolarizing resonances have been implemented. The longitudinal and transversal polarization components were measured with a Møller polarimeter installed in the extraction beamline. We now can provide a polarized electron beam over the full energy range of ELSA.

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