FCC-ee Polarization and Centre-of-mass Energy Calibration

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Abstract
A significant part of the FCC-ee physics program lays in the precise (ppm) measurements of the W and Z masses and widths, as well as forward backward asymmetries. To this effect the centre-of-mass energy and its distribution should be provided with high precision. This can be done by using the transverse polarization of the beams that builds up naturally, resonant depolarization providing a means to measure the energy of the beams with a relative precision of around 10^{-6}. Further corrections are needed to derive the centre-of-mass energy with little loss of precision. This document
i) describes the possibilities offered by FCC-ee;
ii) proposes a running scheme that can meet the goals;
ii) describes the additional hardware suitable to achieve it;
iii) discusses the program of further design and R& D required before undertaking the actual construction of the accelerator.

Contents

To do (for discussion)

Further studies and simulations

-- **polarimeter**

-- detail design of photon and electron detector as polarimeter

-- detail design of polarimeter light box (light polarization measurement and flip)

-- design of laser insertion in the ring

-- detailed study of operation as spectrometer, electron detector and BPMs
(effect of orbit motions, use at higher energies, cross-calibration with RDP)

-- **depolarization process**

-- full study with spin tracking in various conditions to study systematics

-- **spin correction bumps**

-- design dispersion-free algorithms + V.dispersion correction + HSM
using existing orbit bumps or perhaps a few dedicated ones?

-- online orbit correction scripts

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-- **polarization wigglers**

-- SR absorbers,

-- magnet design and alignment so that they can be turned off and on easily

-- use as SR light source for beam diagnotics (bunch length, etc)

-- beamstrahlung monitor

-- detection of BS photons (other?)

-- others?

-- further design of longitudinal polarization option?

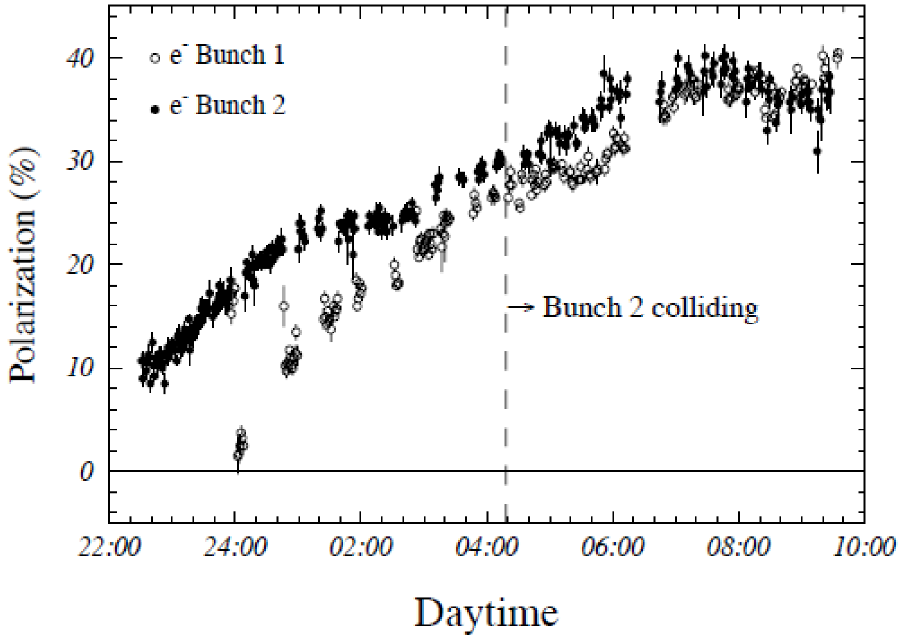


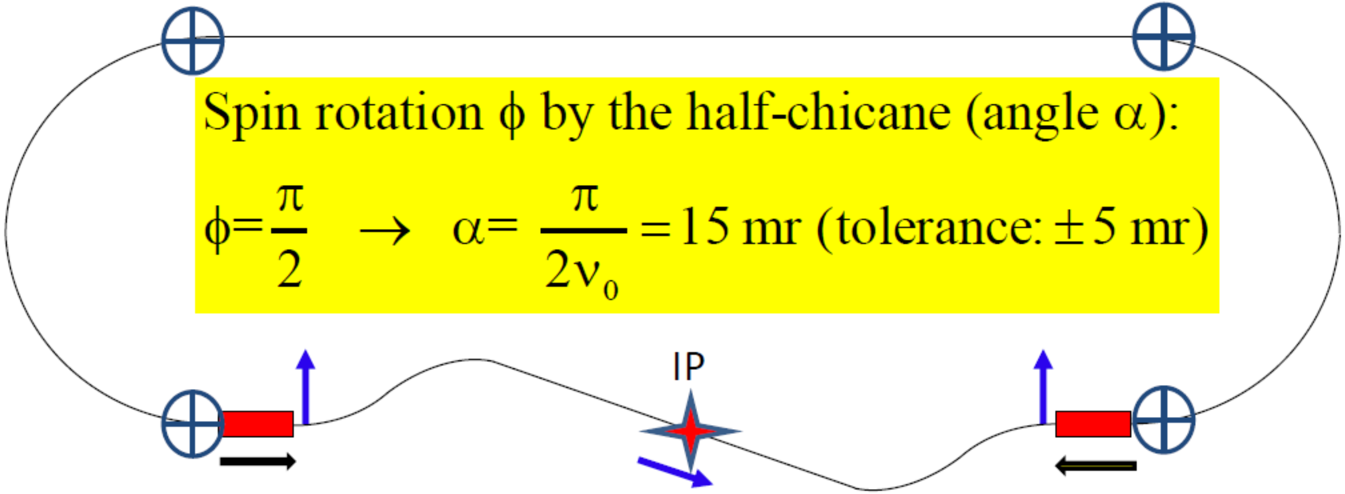
Fig. 5: Proof of principle for polarization in collisions around the Z pole energy at LEP ($E_{\mathrm{beam}} = 44.71$ GeV). The measured transverse polarization of the two electron bunches is plotted as function of time. One of the two electron bunches was brought into collisions with a positron bunch at 4:10 am, and remained polarized at the same level as the non-colliding bunch for more than five hours afterwards.

Longitudinal polarization at Z peak

Anti-symmetric layout of the Interaction Region Chicane provides the longest depolarization time!

Spin rotation ϕ by the half-chicane (angle α):

$$\phi=\frac{\pi}{2} \quad \rightarrow \quad \alpha=\frac{\pi}{2\nu_0}=15\ \mathrm{mr}\ (\mathrm{tolerance}: \pm 5\ \mathrm{mr})$$



Advantage: Spin direction in arcs is vertical and achromatic: $|d|_{arcs}=0$.
Chicane magnets only contributed to the radiative depolarization, therefore the spin relaxation time exceeds 24 hours!

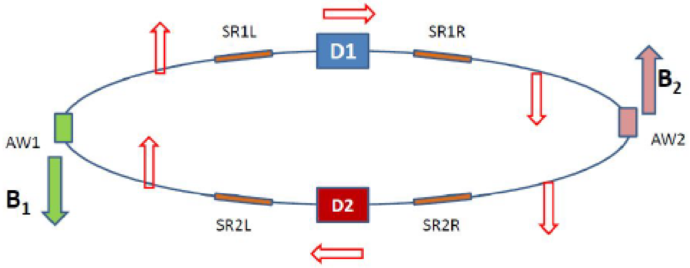


Fig. 6: A possible scheme to obtain longitudinal beam polarization at high energies ($E_{\mathrm{beam}} \gg m_Z/2$) with TLEP. Taking advantage of the low magnetic field in the arcs, the polarization is generated dominantly by strong asymmetric wigglers of opposite polarities (AW1 and AW2) in two halves of the ring. The transverse polarization obtained this way is rotated to longitudinal in the experimental straight sections in detector D1, by 90 degrees spin rotators (SR1L, etc.), and brought back to vertical (but reversed) in the following arc, and similarly for the next experimental straight section, D2. The scheme easily generalizes to the situation with four IPs. This scheme generates a spin transport with an integer part of the spin tune equal to zero. The spin polarization of the electrons is shown. Given separated beam pipes for the e^+ and e^- beams, they can be exposed to wigglers of opposite polarity, enabling positron polarization parallel to that of the electrons. In this way highly polarized e^+e^- systems at the collision point can be obtained. Polarization can be reversed by reversing the wiggler polarity. The possibility of depolarizing a fraction of the bunches in this scheme, to provide a normalization of polarimetry from the measured cross-sections, is being investigated.

note: because e+ and e- are stored in separate channels the polarization of the beams need not be opposite (improvement of polarization level)
the following combinations of
➔➔ , ➔O, O➔, OO, for one expt
🡐🡐 , O🡐, 🡐O, OO for the other.
or the more classic
➔🡐 , ➔O, O🡐, OO, and
🡐➔ , 🡐O, O➔, OO,
can be obtained.

The wiggler configurations can be reversed on a fill-by-fill basis and for each beam independently.

Next steps

Much progress during workshop, lets keep the momentum

-- complete long version of document
-- please be gentle with editors who will be trying to harmonize contributions. ☺
-- Aim to finish distributable draft version for Christmas

-- further remaining studies to be completed for Amsterdam meeting

-- section on further needed studies and R&D open to contributions until the end.

We will resume with every-two-week VIDYO meeting to share status of things

Thank you!