
Progress and goals in EPOL

Jacqueline Keintzel and Guy Wilkinson, with many
thanks to colleagues in EPOL Working Group !

FCC Physics Week, Annecy, 29/1/24

Outline

- Remit of EPOL group, and reminder of baseline E_{CM} calibration strategy
- Achievements up to Midterm Review, and remaining tasks for Final Report
- Updates since FCC Week in selected areas
- Conclusions

Remit of EPOL group

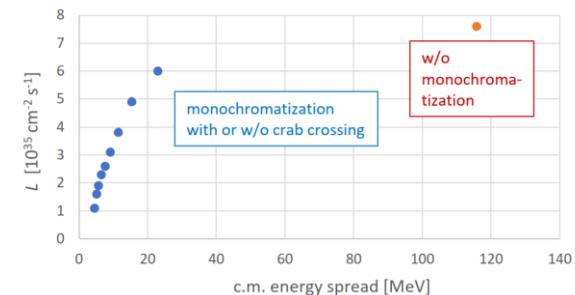
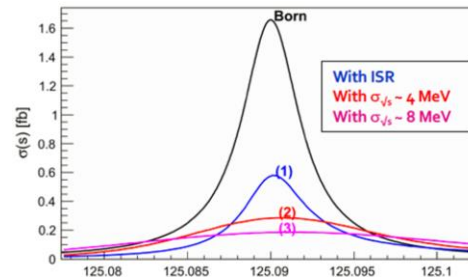
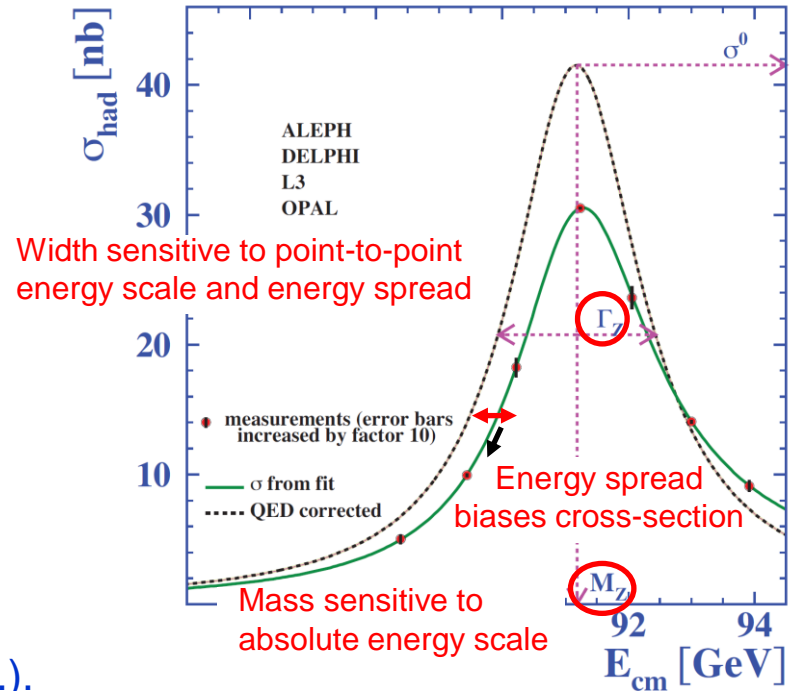
Calibration of E_{CM} , a critical systematic for Z lineshape parameters and W mass. (and needed at higher energies also).

Also needed: measurement of $\sigma_{E_{CM}}$.

Primary tools:

- E_b calibration from resonant depolarisation (RDP), (at least up to WW threshold);
- Measurements from e.g. $e^+e^- \rightarrow f\bar{f}(\gamma)$;
- Measurements needed for IP-specific corrections to go from E_b to E_{CM} (RF sawtooth, dispersion, crossing angle *etc.*).

Investigation of a viable monochromatisation scheme for possible Higgs-pole run (not discussed further today).



Reminder of baseline strategy (Z^0 example)

- Start of fill: inject ~ 200 non-colliding pilot bunches with wigglers on.
- Wait 60-100 mins for polarisation to grow (exact time requirement under study).
- Turn off wigglers and inject physics bunches.
- Perform (essentially) continuous Resonant Depolarisation (RDP) measurements of E_b for both e^+ and e^- pilot bunches (Free Precession Frequency (FSP) measurements a complementary option).
Rely on Sokolov-Ternov effect to replenish polarisation in used bunches.
- Monitor longitudinal polarisation levels in physics bunches (must be \sim zero!); depolarise if necessary.
- Continually adjust f_{RF} to keep beams centred in quads (minimise tide effects).
- Monitor and log all machine parameters ! Track E_b evolution between measurements with model à la LEP.
- Auxiliary procedures and measurements required to suppress and account for dispersion-related IP-specific effects in going from E_b to E_{CM} . Also necessary: corrections for RF sawtooth, measurements of / corrections for crossing angle and energy spread from $e^+e^- \rightarrow f\bar{f}(\gamma)$ events... *etc.*

EPOL ‘requirements’ document: (still evolving) report prepared to accompany Midterm Review



Preliminary draft 08:32 31 August 2023

31 August 2023

Accelerator and physics requirements for the calibration of the collision energy

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Keywords: EPOL, BI

Abstract

The Future Circular Collider (FCC) technical and financial Feasibility Study (FS) includes a work package on Energy Calibration, Polarisation and Monochromatisation (EPOL), which is concerned with the precision determination of the centre-of-mass energy at the e^+e^- machine, FCC-ee. To achieve this goal it is proposed to use resonant depolarisation and possibly spin precession measurements, in conjunction with precise measurement by the detectors of the energy spread and other parameters with physics events. Beam diagnostics, provided by polarimeters and beam-position monitors, play an essential role in monitoring the polarisation level and controlling numerous beam parameters at the interaction point. Specific items of accelerator equipment include polarisation wigglers and depolarising RF-kickers. The target is to achieve a precision commensurate to the remarkable statistical precision achievable in the physics experiments. The possible monochromatisation of colliding beams in view of a measurement of the $e^+e^- \rightarrow H(125)$ process is also being studied, with the specific requirements of this procedure under investigation.

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Builds on work presented in [\[arXiv:1909.12245\]](https://arxiv.org/abs/1909.12245), which was prepared for the CDR.

Tasks for remainder of Feasibility Study

- Ensure sufficient polarisation in optics, including HSM studies at Z & WW
- Procedure, systematics and ultimate precision on RDP & FSP measurements
- Inform studies through series of measurements at KARA (and other accelerators)
- Arrive at full conceptual design of polarimeter, including infrastructure
- Full costing of EPOL related items
- Wigglers vs polarisation ring (probably not essential for Feasibility Study, but an interesting question)
- Requirements on depolariser and agreement on depolarisation procedure for pilot and physics bunches
- Deepen understanding of IP-specific corrections, in particular dispersion and offset effects
- Improve understanding of input from experiments, e.g. effect of higher-order corrections and detector resolutions *etc.* in $e^+e^- \rightarrow f\bar{f}(\gamma)$ studies
- Establish feasibility and expected performance of monochromatisation scheme for electron Yukawa run

Tasks for remainder of Feasibility Study

A few remarks on these topics in the remainder of this talk

- Ensure sufficient polarisation in optics, including HSM studies at Z & WW
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Tasks for remainder of Feasibility Study

These topics to be covered in parallel sessions on Thursday

- Ensure sufficient polarisation in optics, including HSM studies at Z & WW

Y. Wu + S. Liuzzo (plenary)

- Procedure, systematics and ultimate precision on RDP & FSP measurements

I. Koop

- Inform studies through series of measurements at KARA (and other accelerators)

J. Keintzel

- Arrive at full conceptual design of polarimeter, including infrastructure

A. Martens

- Full costing of EPOL related items
- Wigglers vs polarisation ring (probably not essential for Feasibility Study, but an interesting question)

Plus discussion on CEPC EPOL

Z. Duan

- Requirements on depolariser and agreement on depolarisation procedure for pilot and physics bunches

- Deepen understanding of IP-specific corrections, in particular dispersion and offset effects

A. Blondel

Improve understanding of input from experiments, e.g. effect of higher-order corrections and detector resolutions *etc.* in $e^+e^- \rightarrow f\bar{f}(\gamma)$ studies

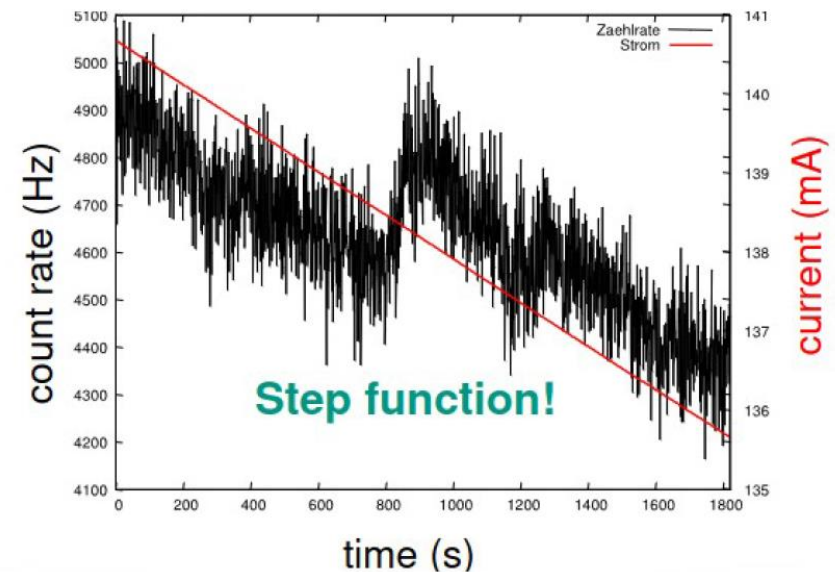
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A. Faus-Golfe

RDP studies at KARA

Karsruhe Research Accelerator (KARA) at KIT has electron beam energy up to 2.5 GeV and offers a valuable opportunity for polarisation studies.

No Compton polarimeter, but RDP observable through change in Touschek lifetime.



Very short polarisation times (~10 minutes), so many measurements possible.

RDP studies at KARA

First set of measurements performed on 30-31 October last year (many thanks to KIT colleagues, especially Bastian Härer).

Many interesting studies possible, e.g.:

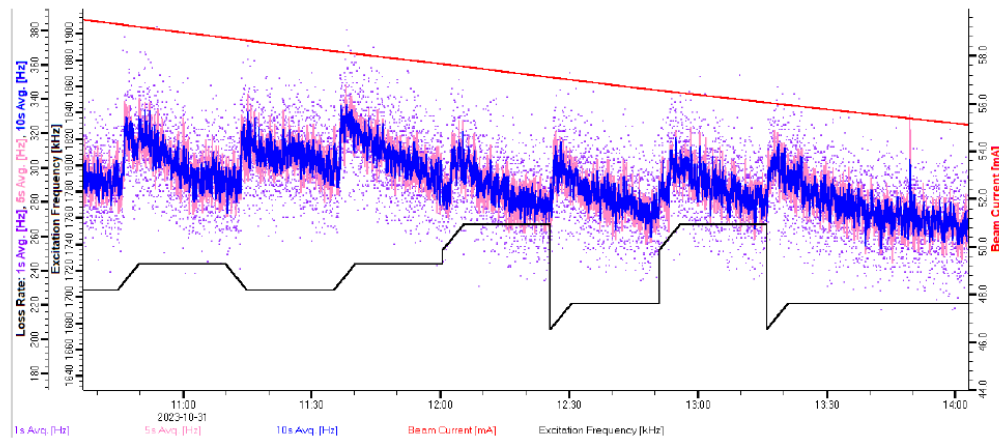
- Ways to optimise polarisation level (although absolute value of polarisation difficult to extract from measurements)
- Possible biases in relationship between RDP frequency and E_b arising from spin resonances in lattice, scan direction, scan frequency speed *etc.*

Analysis ongoing (see Jacqueline's talk on Thursday). More measurements foreseen.

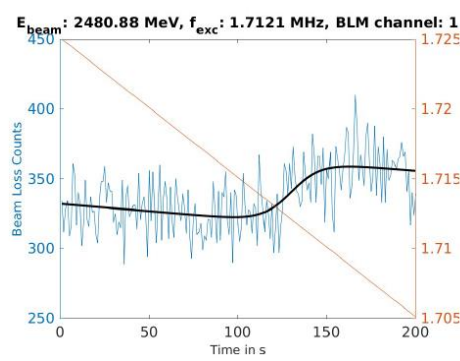
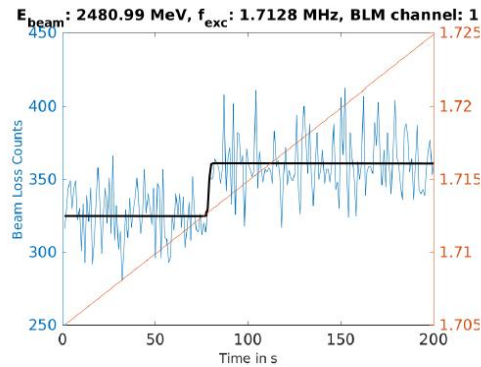


RDP studies at KARA

Repeated, automated RDP measurements.



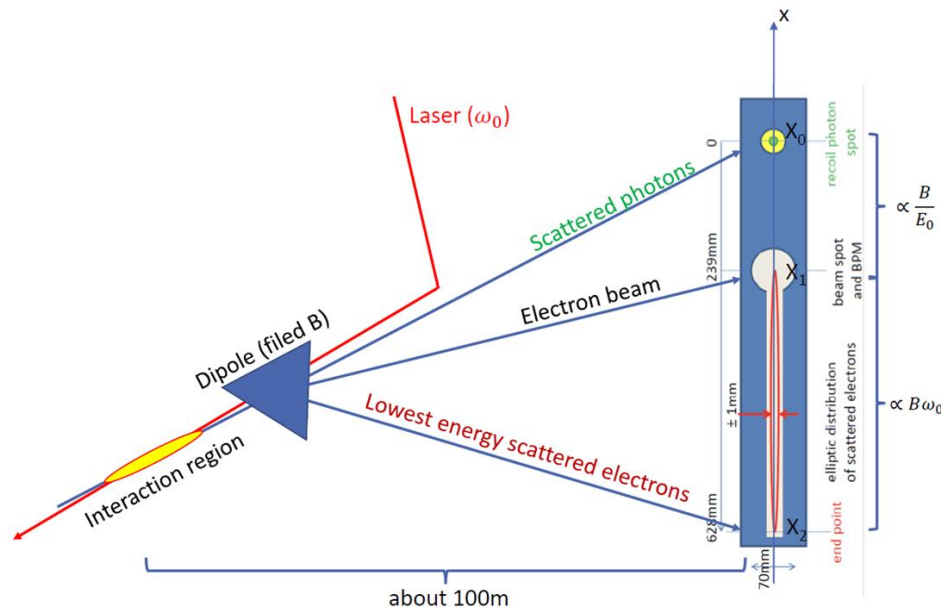
RDP measurements scanning frequency in different directions.



Polarimeter studies

Compton polarimeter a vital tool in beam-energy calibration with multiple tasks:


- Measure transverse polarisation level for RDP measurement;
- Measure precession of longitudinal polarisation in FSP measurement;
- Measure residual longitudinal (and transverse) polarisation in physics bunches;
- Transverse and longitudinal measurements requires detection of *both* scattered γ and e.
- Provide real-time energy measurement of E_b through scattered electron distribution.



Excellent initial conceptual work of N. Muchnoi and A. Martens now being augmented with more refined studies and considerations of practical implementation and tolerances.

Polarization measurements: ongoing work

Several potential sources of bias investigated, plus requirements defined:

- Impact of higher-order (α^3) QED corrections [[Martens et al. JINST 18 \(2023\) P10001](#)].
Conclusion: can be per mille level effect if neglected.
- Studies of tolerances on field uniformity, fringe fields, dipole alignment *etc.* So far, do not look excessive. 
- Studies of required pixel size in detector.

Magnetic field tolerances for FCC-ee polarimeters

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Abstract

The FCC-ee Compton polarimeter consist of a laser beam that interacts with an electron (or positron) beam and a dipolar magnetic field that deflects the main electron beam and the scattered electrons. The transverse distribution of scattered photons and scattered electrons are then measured with pixel detectors [1]. Both detectors provide information that allows to infer the electron and laser beam polarizations. This note summarizes some tentative studies to examine the sensitivity of the polarization measurement with the electron detector to various defects in the dipolar magnetic field.

Keywords

Compton scattering; Magnetic field.

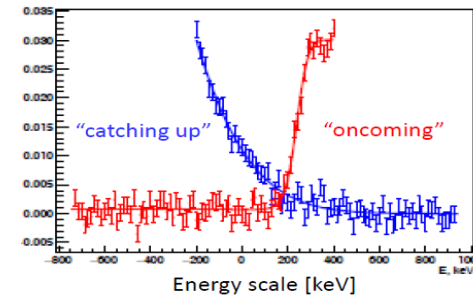
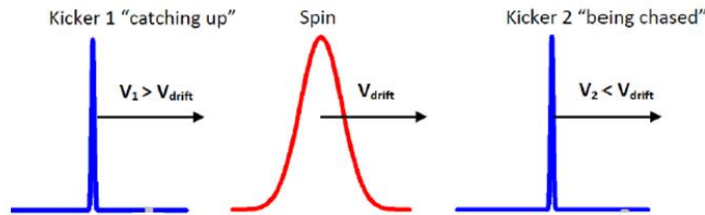
For more information, see Aurelien's talk on Thursday.

Recent positive news: additional person-power from CERN assigned to investigate detector requirements, as well as laser transport, integration aspects *etc.*, plus PhD student position to begin in the autumn. Good prospects of a realistic system design + cost estimate for end of Feasibility Study.

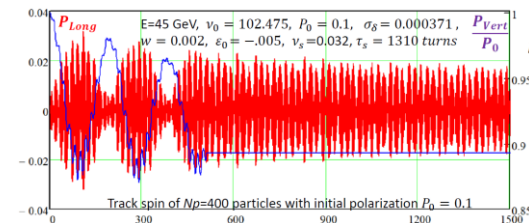
Depolariser studies

Depolariser system has three tasks, with differing requirements:

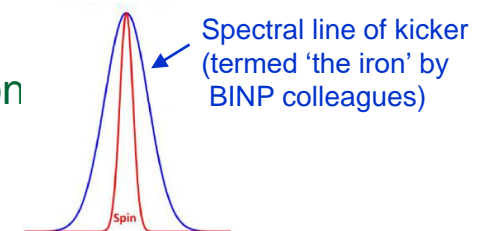
- RDP of pilot bunches – Resolution is key ! Thin spectral line & likely need to depolarise two bunches simultaneously, below & above spin tune, to minimise E_b drift systematics.



- FSP of pilot bunches – Here need to flip polarisation vector into horizontal plane, which is a different manipulation to simple depolarisation.



- Depolarisation of physics bunches – Must keep longitudinal polarisation below 10^{-5} . Could require ~ constant depolarisation of all bunches. Thicker spectral line needed. Different power requirements to RDP. Implications for beam stability *etc.*



[S. Nikitin, I. Koop et al.]

Depolariser studies

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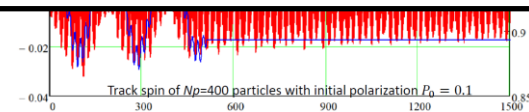
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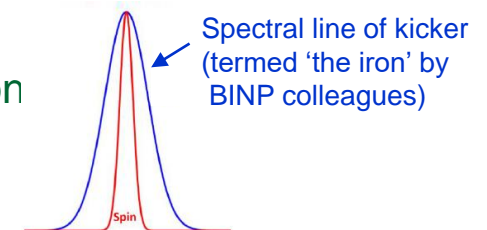
Not obvious these needs can all be met by the same technology (e.g. travelling-wave strip-line depolariser can generate the short pulses RDP requires, whereas AC solenoid may be more suited for physics bunches).

If possible, it would be desirable to satisfy some of these tasks through the transverse feedback system. An important question to resolve !

- F
v
manipulation to simple depolarisation.



- Depolarisation of physics bunches – Must keep longitudinal polarisation below 10^{-5} . Could require ~ constant depolarisation of all bunches. Thicker spectral line needed. Different power requirements to RDP. Implications for beam stability etc.



Conclusions and outlook

A baseline plan for meeting EPOL-related requirements was established in CDR, and refined for Midterm Report of FS. Key issues are now being investigated in more detail, with aim to have realisable solutions in place for Final Report.

Help very much welcome ! EPOL issues may be limiting systematics of many of the flagship measurements of the FCC-ee precision programme.

Sign up to e-group fcc-ee-PolarizationAndEnergyCalibration@cern.ch
Meetings can be found under <https://indico.cern.ch/category/8678/>

See parallel session talks on Thursday, and Jacqueline's summary on Friday.

Backups
