Messages Parallel Wednesday 21, WP1

Ivan Koop

EPOL-2022, September 22, 2022

4 session talks presented +1 by Guy:

- **EIC e-Injector Polarization,** Speaker: Vahid Ranjbar (BNL)
- **EIC esr Polarization,** Speaker: Eliana Gianfelice (Fermilab)
- **EIC ESR Tracking Studies,** Speaker: Matthew Signorelli (Cornell)
- **LEP Polarization,** Speaker: Jorg Wenninger (CERN)

- **Requirements for polarization measurements,**

Speaker: Guy Wilkinson (University of Oxford (GB))

Concept Overview: Spin Resonance Free Lattice – by Vahid Ranjbar

- Both the strong intrinsic and imperfection resonances occur at:
  - K = nP +/- Qy
  - K = nP +/- [Qy] (integer part of tune)
- To accelerate from 400 MeV to 18 GeV requires the spin tune ramping from
  - **$0.907 < G\Upsilon < 41.$**
- If we use a periodicity of P=96 and a tune with an integer value of 50 then our first two intrinsic resonances will occur outside of the range of our spin tunes
  - $K1 = 50+\nu_y$ (ν_y is the fractional part of the tune)
  - $K2 = 96 – (50+\nu_y) = 46-\nu_y$
  - Also our imperfection will follow suit with the first major one occurring at K2 = 96 – 50 = 46

Summary of Vahid Ranjbar

- Resonances in RCS lattice are driven by imperfections
- Intrinsic resonances are so weak that even large field distortions don't hurt.
- Resilient to misalignments, dipole rolls and orbit distortions:

  - Up to 0.4 mm quadrupole misalignments and 2.5 mrad dipole rolls are tolerable provided the orbit is corrected to 0.5 mm RMS level.

  - Assume orbit correction using SVD algorithm with a corrector and a BPM next to each quadrupole.

  - within state-of-the art orbit control hard-and software

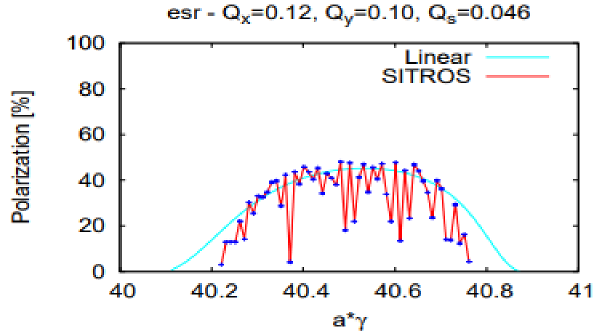
- This will result in > 95% polarization transmission.
- To provide additional margin we show that fixed orthogonal imperfection bumps are capable of removing any residual polarization losses.
- Using intrinsic resonance canceling arc cells one can build up a whole ring with all sorts of broken symmetry and still avoid strong intrinsic depolarization. One of the challenges is to build these cells in such a way that the beta functions and dispersion are controlled. Additionally, their natural dynamic aperture and chromatic features should be studied to better understand the optimal configuration.

Eliana – EIC - polarization simulation in esr:

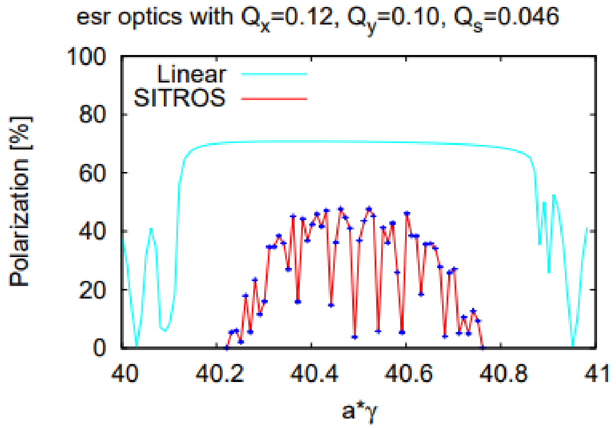
SITROS tracking after coupling correction.

Beam size at IP

	σ_x (mm)	σ_y (μm)	σ_ℓ (mm)
Analytic	0.111	1.758	8.543
Tracking	0.107	2.044	8.357



SITROS tracking for unperturbed v5.2 optics for comparison.



- Aggressive closed orbit and betatron coupling correction restored the 40% polarization level, but σ_y^* is about 6 times too small for matching p-beam.

Eliana – EIC - polarization simulation in esr:

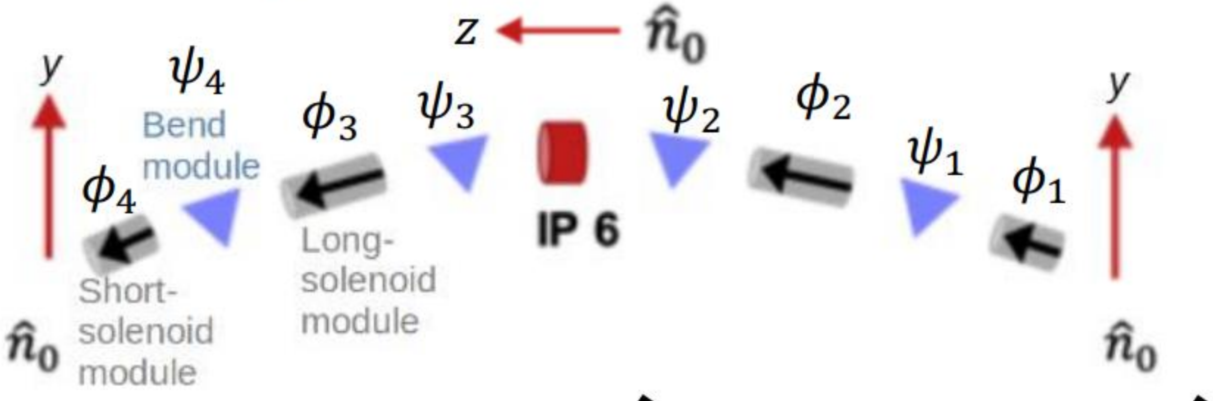
Summary

- Differences of the sensitivity to errors for different optics. It can be explained by the different $\gamma \frac{\partial \hat{n}}{\partial \gamma}$.
- With the current rotator scheme the unperturbed polarization is much lower but the machine being less sensitive to errors it does not need a pushed correction procedure.
  - Closed orbit of $\approx 100\ \mu$m is fine.
  - Coupling correction may be not crucial to reach 35% polarization.
  - Currently a less generous correction scheme (as in HERAe) considered for the machine arcs
    - one BPM (dual plane reading) close to each vertical focusing quadrupole;
    - one vertical corrector close to each vertically focusing quadrupole;
    - one horizontal corrector close to each horizontally focusing quadrupole;

    $\longrightarrow$ All together: 271 CHs, 242 CVs and 242 BPMs. It seems sufficient!
  - σ_y^* knobs may be not needed.

Matt – EIC - polarization simulation in esr:

EIC-ESR Spin Matching Conditions



$$\begin{pmatrix}\alpha\\ \beta\end{pmatrix}_f = \boldsymbol{G_x}\begin{pmatrix}x\\ p_x\end{pmatrix}_i + \underbrace{\cancel{\boldsymbol{G_y}\begin{pmatrix}y\\ p_y\end{pmatrix}_i}}_{0} + \boldsymbol{G_z}\begin{pmatrix}z\\ p_z\end{pmatrix}_i + \underbrace{\cancel{\boldsymbol{D}\begin{pmatrix}\alpha\\ \beta\end{pmatrix}_i}}_{0}$$

$\boldsymbol{G_x} = \boldsymbol{0}$ by conditions on quads between solenoids

$\boldsymbol{G_z} = \boldsymbol{0}$ by conditions on periodic dispersion η, η'

Images from [10], ESR spin matching conditions in [11] or [9].

Matt – EIC - polarization simulation in esr:

Cornell Laboratory for Accelerator-based Sciences and Education (CLASSE)

Conclusions

Brookhaven National Laboratory

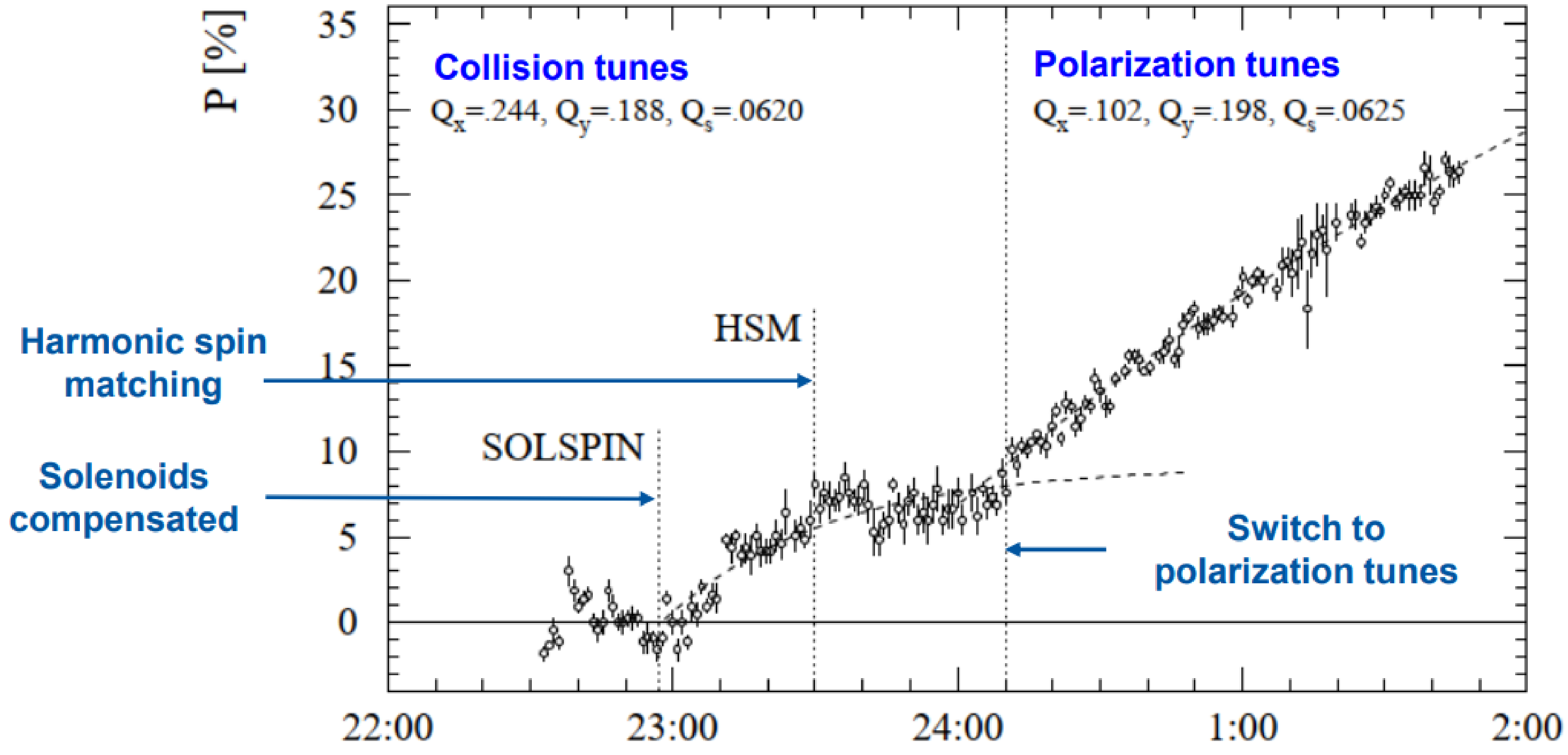
- **Zero dispersion in the solenoid modules is necessary**
  - Else, coupling is not fully corrected for off-energy particles
  - However, the longitudinal spin match is unachievable with $\eta, \eta' = 0$
- **v5.6 1IP ($\boldsymbol{G_z \neq 0}$) maintains sufficient polarization in fully nonlinear case**
- **More work to be done on $\boldsymbol{\epsilon_y}$-creation: determine most feasible method with least significant effect on polarization**
  - Closed η_y-bump would require spin matching, which proved difficult
- **v5.6 2IP polarizations lower than 1IP**

Jorg – LEP Polarization setup:

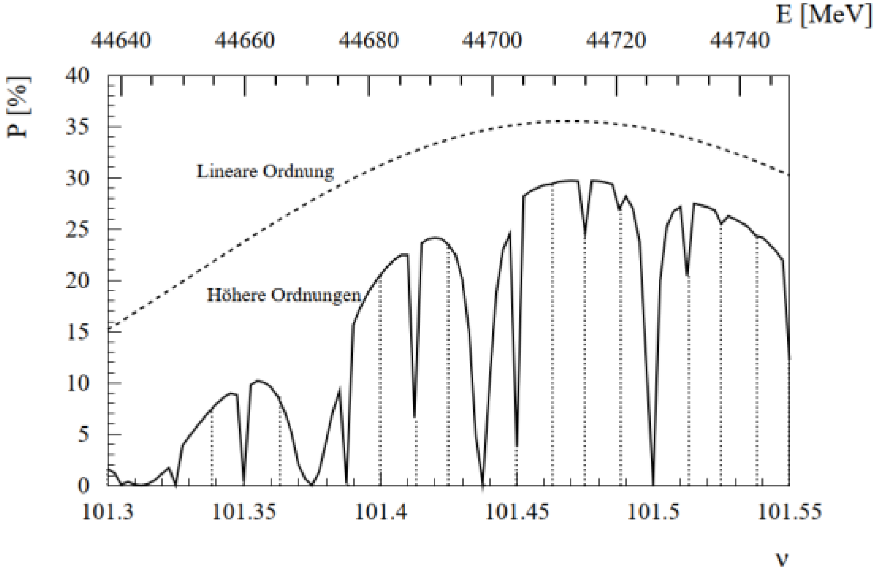
Tunes

Around the Z resonance, optimized fractional tunes for polarization : **Q_x = 0.1, Q_y = 0.2, Q_s = 0.0625**

Collision tunes were not favorable for transverse polarization



Simulation (SODOM) for polarization tunes



PhD R. Assmann (1994)

Jorg – LEP – Spin Flip:

Polarization for day-to-day energy calibration

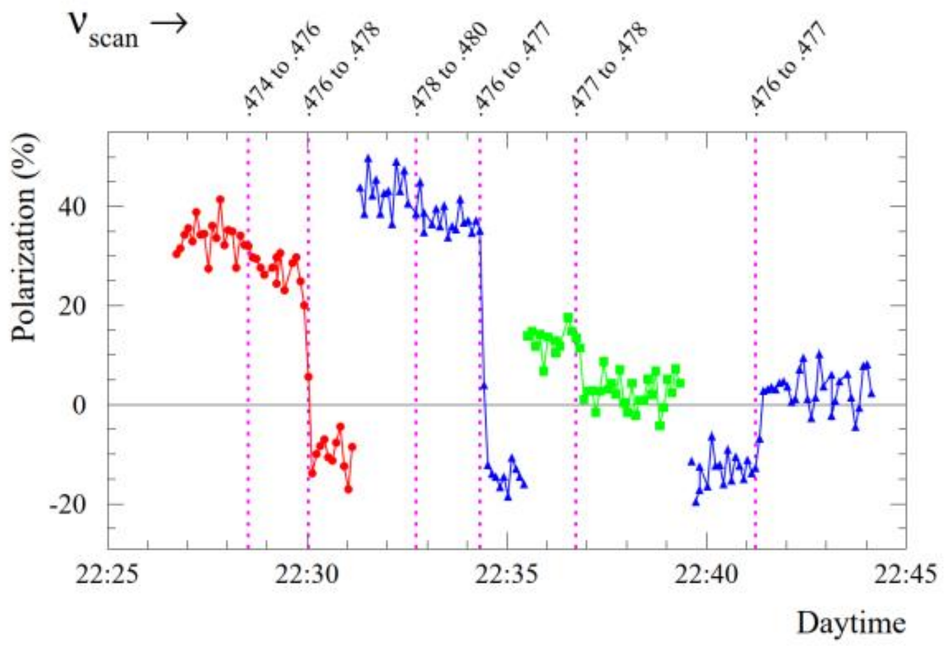
The regular end-of-fill (EoF) energy calibrations followed the recipe:

- **Re-separation of the beams at the 4 IPs.**
- **Switch tunes to optimum polarization tunes.**
- **Correct the orbit.**
- **Apply solenoid compensation bumps.**
- **Apply deterministic HSM.**

Observe polarization build-up and start the RDP scans to determine the beam energy.

As far as I can remember, we always observed polarization with **asymptotic values of ~4% to ~20%.**

- **Large scatter of polarization values, deterministic HSM not always successful / efficient.**
- 3-4% of polarization were sufficient for an energy calibration.



*The colors refers to different bunches, in one case (**blue**) the polarization is flipped, and flipped polarization is used to re-depolarize a second time .*

1 point every ~ 8 seconds.

Jorg – LEP - Collisions:

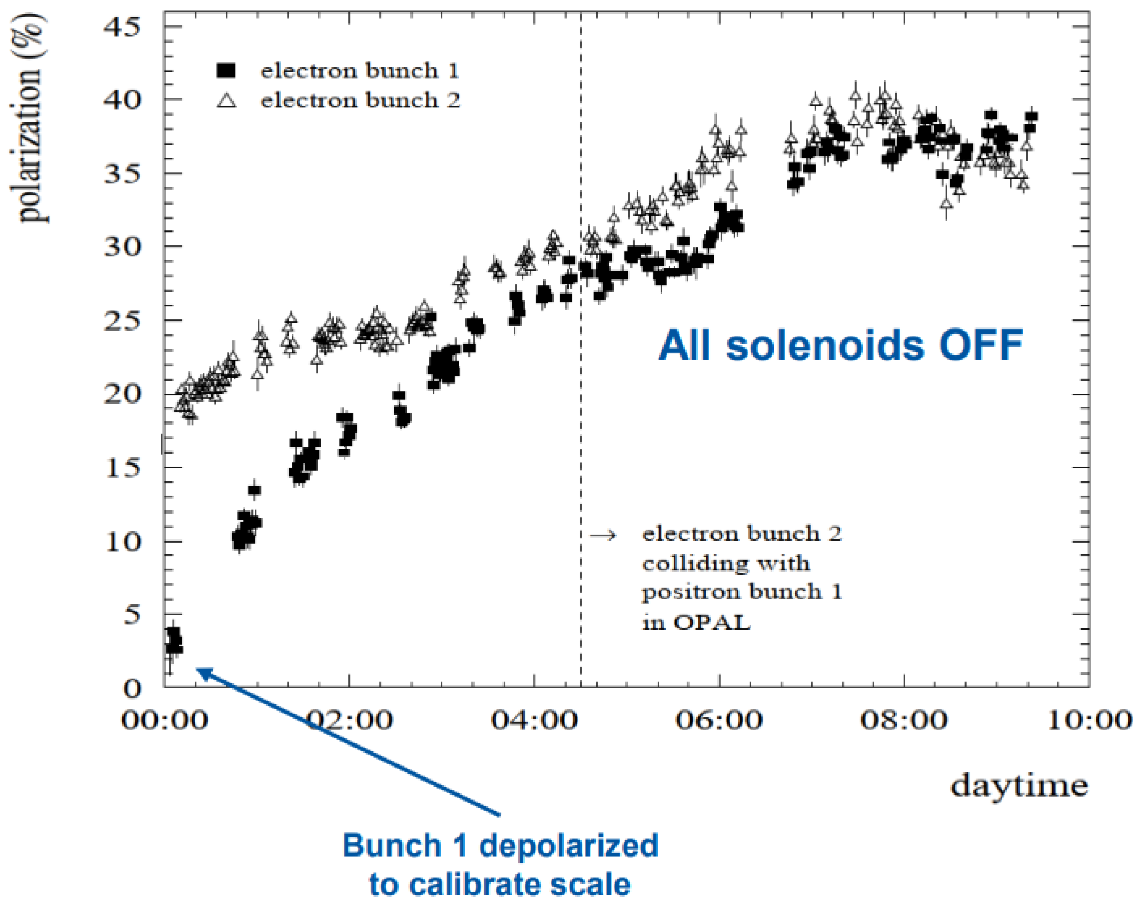
Polarization and collisions

In 1994 two experiments were performed to study **polarization with colliding beams**.

The results were encouraging (after deterministic & empirical HSM) for a **SINGLE collision point**:

- P_T ~**40%** for **vertical BB tune shift ~0.04** with **solenoids OFF,**
- P_T ~**20%** for **vertical BB tune shift ~0.037** with **solenoids ON.**
- Both exp with polarization tunes.

But there was no “follow up”: the 1995 energy calibration campaign was performed with measurements at EoF.



Guy – Polarization Requirements:

Importance of longitudinal polarisation measurement

Any residual longitudinal-polarisation will bias cross sections & forward-backward asymmetries (indeed, high longitudinal polarisation is actually useful, but we assume we are not in that regime – rather longitudinal polarisation is a nuisance).

Consider forward-backward asymmetry of $b\bar{b}$ at Z pole: $A^b_{\mathrm{FB}} = \frac{3}{4}\mathcal{A}_e\mathcal{A}_b$

where in the SM $\mathcal{A}_e \approx 0.15,\quad \mathcal{A}_b \approx 0.95 \Longrightarrow A^b_{\mathrm{FB}} \approx 0.11$

Now, if there is longitudinal polarisation, asymmetry becomes: $(A^b_{\mathrm{FB}})' = \frac{3}{4}\mathcal{A}'_e\mathcal{A}_b$

where $\mathcal{A}'_e = -\left(\frac{\mathcal{A}_e - P}{1 - \mathcal{A}_e P}\right)$ with $P = \frac{(P_z)_{e^-} - (P_z)_{e^+}}{1 - (P_z)_{e^-}(P_z)_{e^+}}$

and $(P_z)_{e^\pm}$ the longitudinal polarisation of the $e^\pm$.

Guy – Longitudinal Polarization measurements:

Importance of longitudinal polarisation measurement

Any residual longitudinal-polarisation will bias cross sections & forward-backward asymmetries (indeed, high longitudinal polarisation is actually useful, but we assume we are not in that regime – rather longitudinal polarisation is a nuisance).

So, if $(P_z)_{e^-} = (P_z)_{e^+}$ (no reason to be so) = 10^{-5} (ballpark guess)

$$P = 2 \times 10^{-5} \quad \Longrightarrow \frac{(A^b_{FB})' - A^b_{FB}}{A^b_{FB}} = 1.3 \times 10^{-4}$$

Statistical uncertainty on A^b_{FB} around 2×10^{-5} (relative), and QCD uncertainty which will probably be larger. Still, to be safe we would want to control P_Z to $< 10^{-5}$.

How is this to be done ? Measurements must be made on colliding bunches, where scattering rates are lower. Can we sample all bunches ? Will it prove necessary to depolarise the physics bunches ? If so, we will still need to monitor residual effects.

Note also, that calculations required to transport the measurement of 3-vector at polarimeter to P_Z value at the interaction points. How can this be cross checked ?

Guy – Open questions:

Summary: open questions for workshop

- Dependence of polarisation & RDP precision on backscatter rate. (maybe straightforward for polarisation, less so for energy measurement itself);
- Ultimate intrinsic precision (correlated between measurements) of RDP at FCC-ee;
- Variation (at Z, H) energies of RDP time with polarisation level & bunch intensity;
- Frequency & duration of measurements under standard conditions;
- Precision attainable on knowledge of longitudinal polarisation at interaction point;
- Systematic uncertainties on direct energy measurement;
- Challenges in the W^+W^- regime: level of polarisation required, time required for measurement, uncertainties on measurement ? Is 0.2 MeV feasible ?
- What are requirements of FSP measurement and its precision, both at Z and in W^+W^- regime ? How often should these measurements be performed ?