Future Circular Collider Technical and Financial Feasibility Study
2d FCC Energy Calibration, Polarization and Mono-chromatisation workshop

# The LEP polarimeter

## FCC EPOL WORKSHOP

J. Wenninger

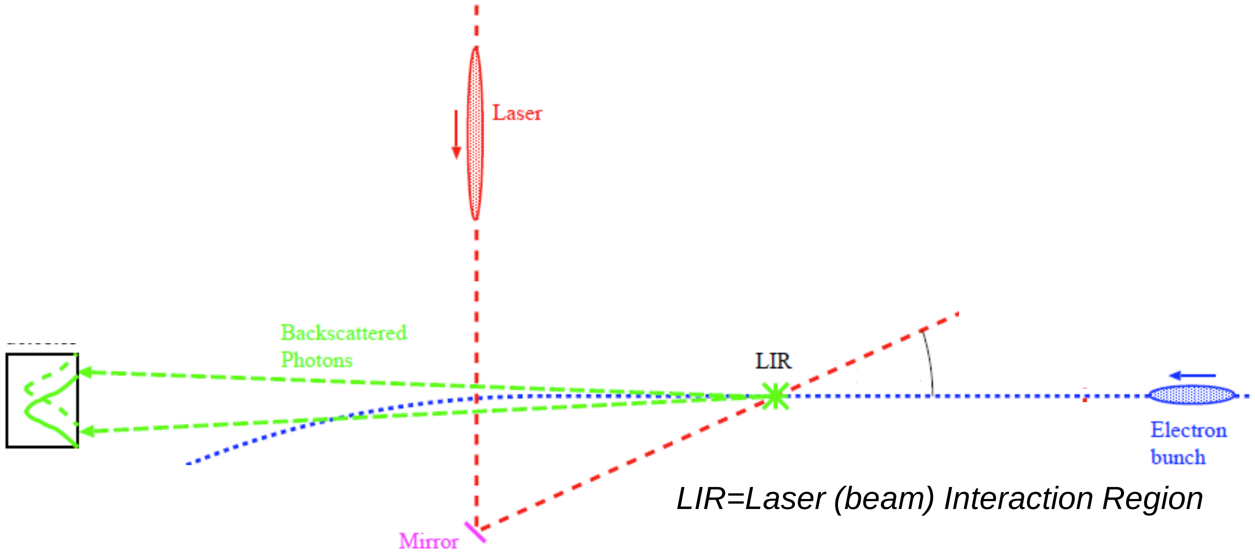
**19-30 September 2022 at CERN**

*remote participation possible*

**https://indico.cern.ch/e/EPOL2022**

# LEP polarimeter principle

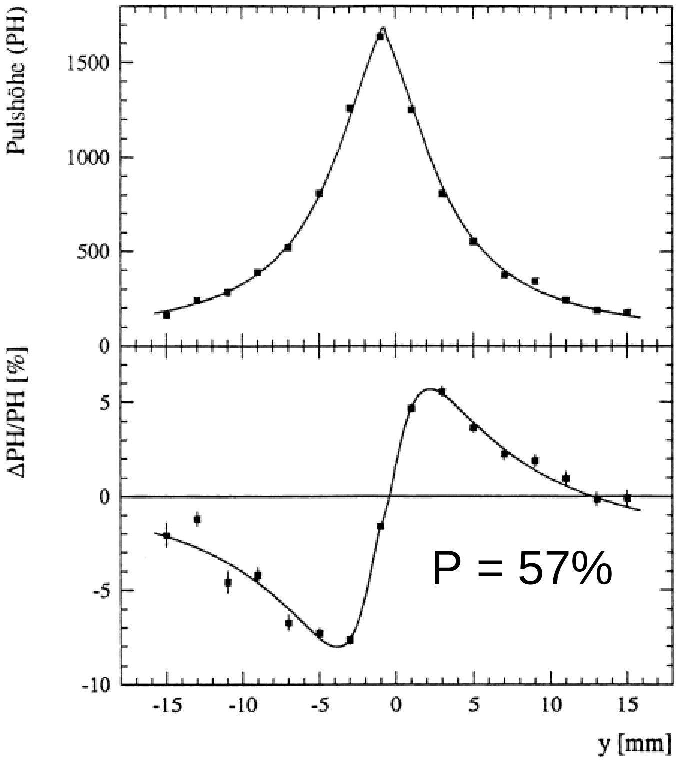
- The LEP polarimeter operated with Compton photons obtained by scattering polarized Nd-YAG laser photons on the e-/e+ beams.
  - The beam polarization was encoded in the **vertical shift** of the scattered photon distribution for the two laser helicities.
  - The LEP polarimeter operated in **multi-photon mode**: for every laser shot thousands of Compton photons were collected in the detector.
- Typical sensitivities at the LEP photon detector: $\Delta y = S \times P_T$
  - ***S ~ 5 $\mu$m / %*** *(depends on lever arm LIR – detector).*
  - *By flipping the laser helicity one only has to measure a relative shift.*




*LIR=Laser (beam) Interaction Region*

**The LEP polarimeter was designed by M. Placidi & R. Rossmanith**

*$\gamma$ profile and asymmetry (R/L laser helicity) at LEP*

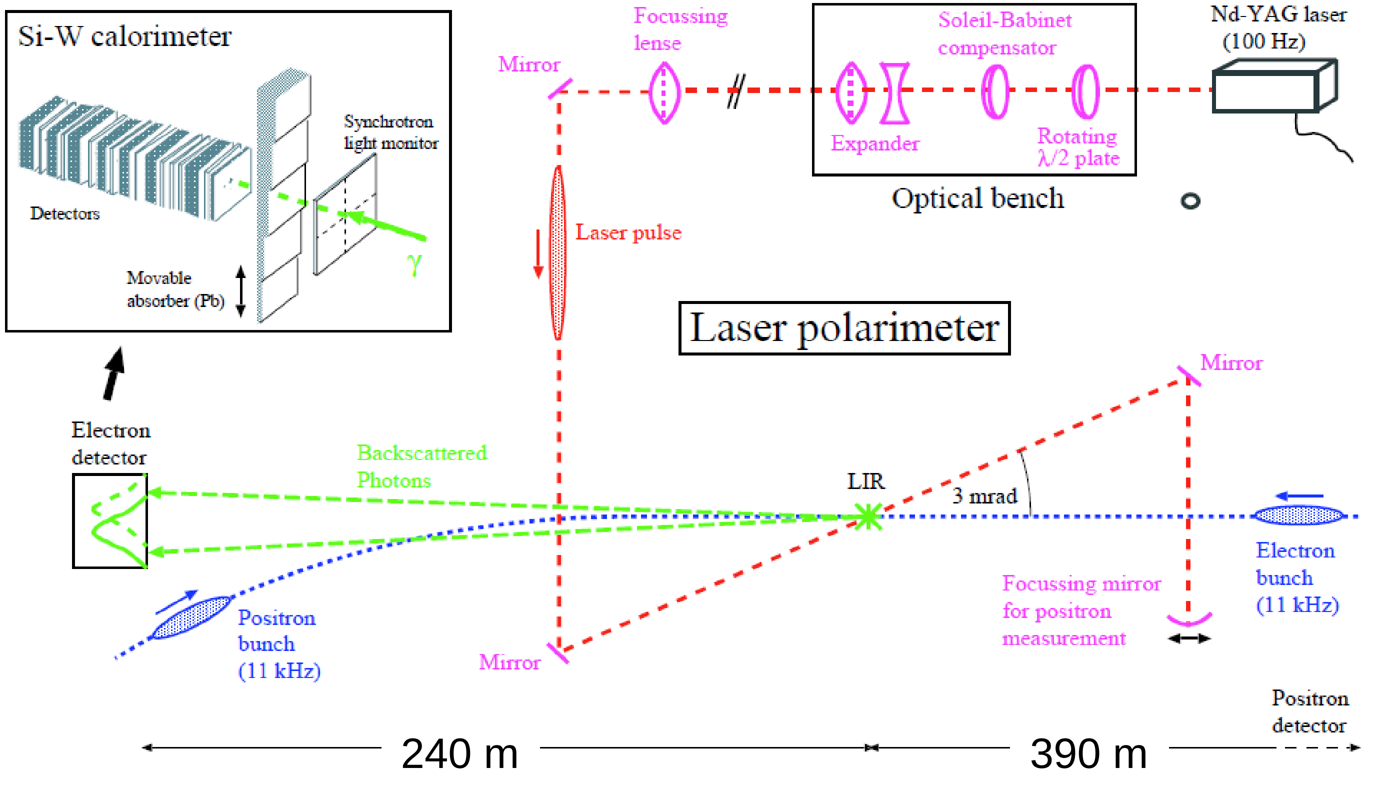



*R. Assman (PHD)*

# The LEP polarimeter – second generation (1993+)

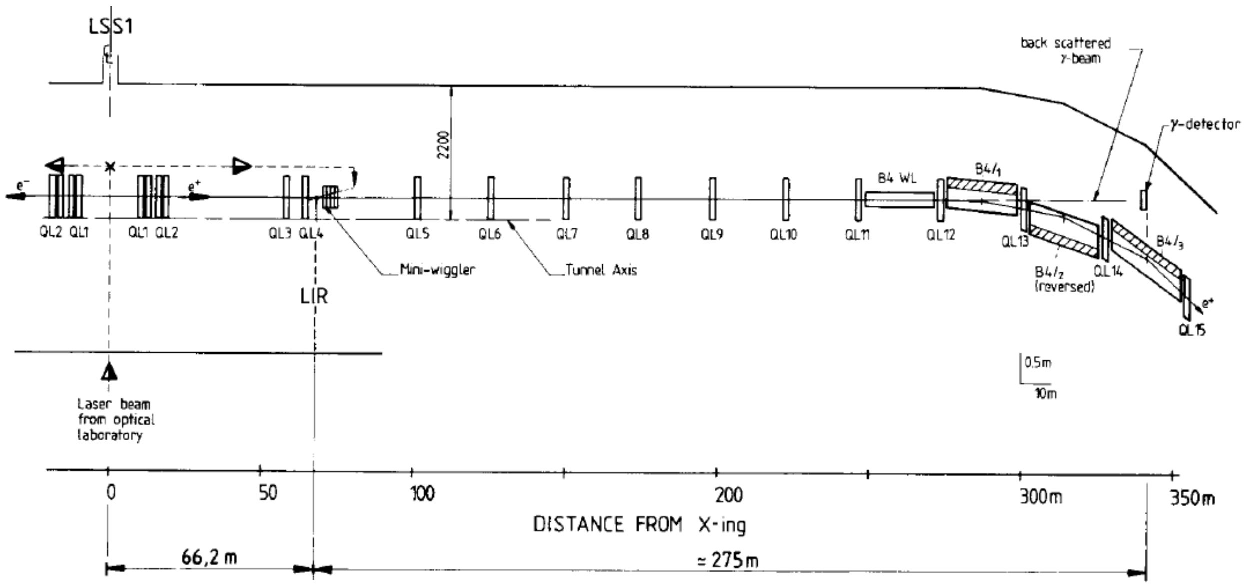
- The LEP polarimeter was installed in LEP point 1 (now the middle of the ATLAS detector).
  - ND-YAG laser @ 100 Hz, interleaved right / left circularly polarized laser light (optical bench),
  - Laser light path into the LEP vacuum chamber, in vacuum mirrors,
  - **Si strip detector** (2 mm strips) for **gamma profile measurement**, interleaved detector and absorber planes.

- Both e- and e+ polarizations could be measured.
  - e+ measurement difficult due to mirror vibration issues, performed only 2-3 times during the entire LEP area.
- Distances to photon detectors of 240m (e-) and 390m (e+).

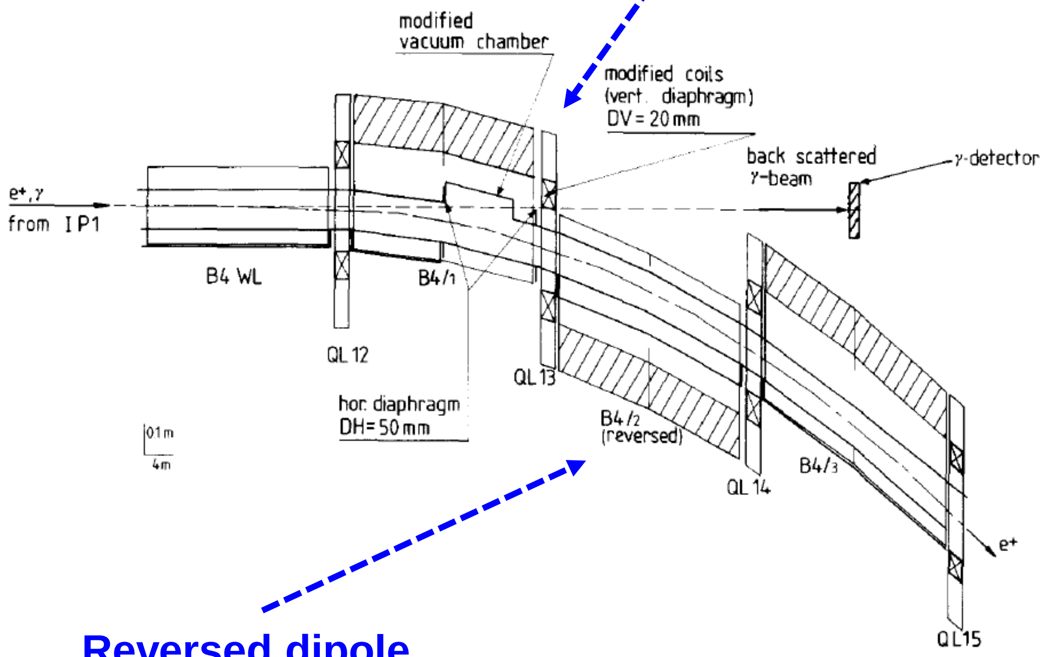


# Photon extraction

- The backscattered Compton photons were extracted at the entrance of the arc (Al window in the vacuum chamber ~ 50 x 25 mm$^2$).
  - One **dipole was "reversed"** to allow extraction of the Compton photons (C-shape dipoles).
  - One **quadrupole** had a hole in the iron yoke & modified coild to allow extraction of photons.
  - The layout show here is for e+.
  - $\beta$ functions at LIR (Laser-beam IR) ~40-120 m, beam sizes ~0.4 -1 mm.




**Quadrupole with modified coils**




**Reversed dipole**

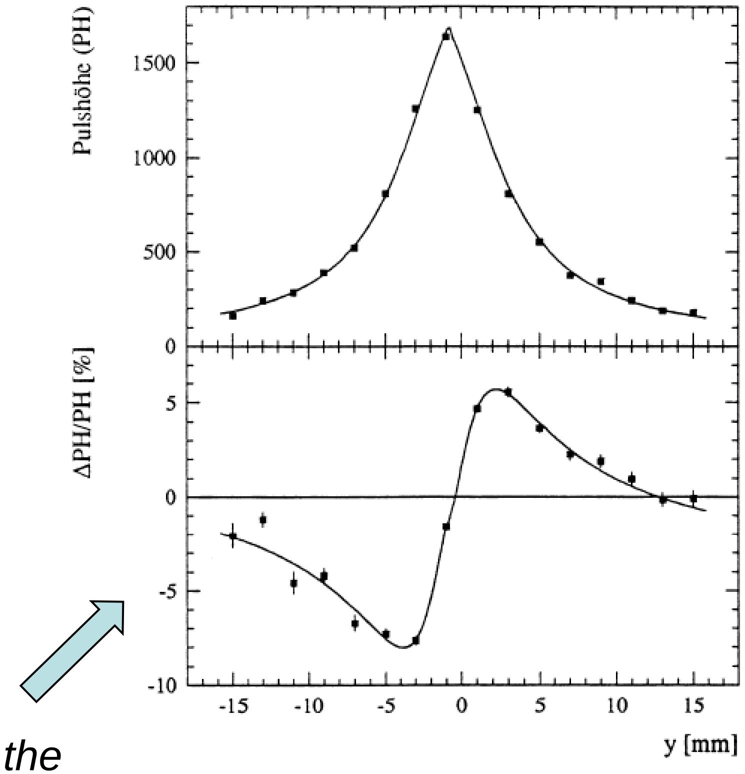
# LEP polarimeter laser

In 1993 the LEP polarimeter laser was upgraded for higher power and 100 Hz operation:

- Nd-Yag laser operated at **100 Hz**.
  - In reality two 50 Hz lasers with a single cavity. A pair of lamps+rods were pulsed alternatively (each at 50 Hz).
  - Trigger locked to LEP RF clock.
- Pulse energy 125 mJ → ~4000 Compton photons per pulse (45 GeV).
- Pulse length ~5 ns for a bunch length of ~1-2 cm (~30-60 ps).
  - Angle of 3 mrad between laser and beam – luminosity loss of ~10 due to the crossing and laser+beam parameters.
- Circular polarization flipped every other pulse.
- With optimal overlap of laser & beam**, the target bunch lifetime was lowered from > 20 hours to ~4-6 hours**.
  - The laser was **synchronized to one bunch at a time**, switching from one bunch to another in a fraction of a second.

# Detector

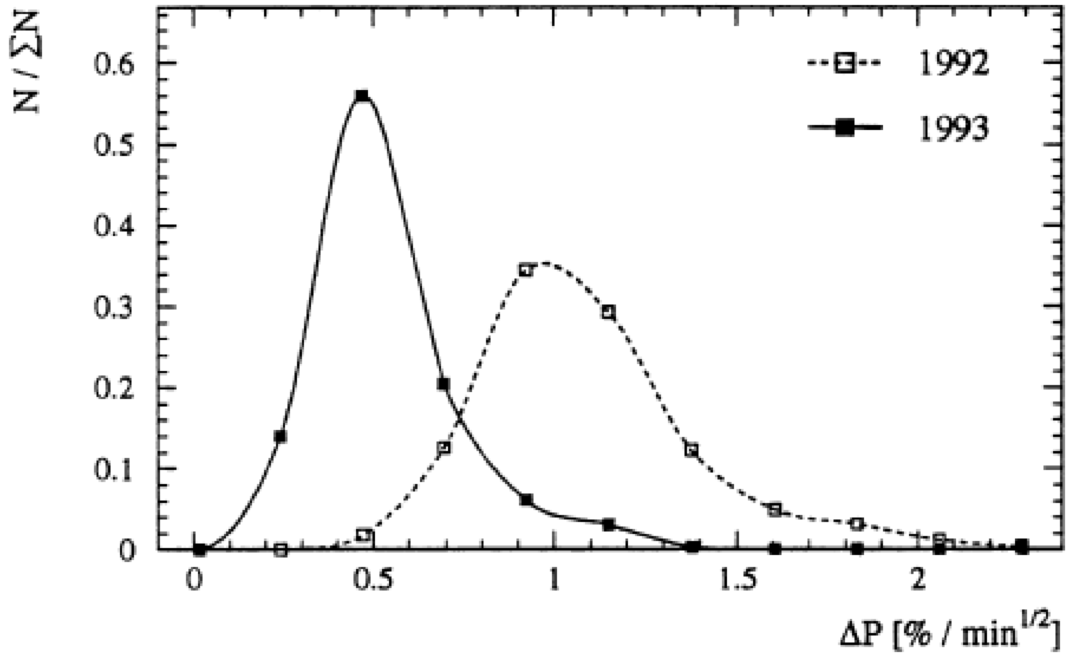
- Operated in multi-photon mode, read out of every pulse.
  - Electronics accumulated + and – helicity distributions separately.
- Si-strip detectors with 2 mm wide strips, 32 mm total detector width.
- Typically ~2 RL of Tungsten in front of detectors.
- Horizontal & vertical profiles available, ~ 5 mm rms wide.
- Position of photon beam in the detector stabilized with a **FB on the beam angle at the laser IR**.
  - Manual re-steering of beam position if pulse height dropped (too much).
- Sensitivity @ detector: $\Delta y = S \times P$
  - *Simulation : $S = 5.4 \pm 1 \mu m / \%$*
  - *Measured : $S = 4.4 \pm 0.2\ \mu m / \%$*
  - → *$\Delta y = 440\ \mu m$ for 100% polarization*




*Profile asymmetry for the 2 helicities of the laser*

# Polarization measurement

- Data acquisition provided ~ one measurement / 8 seconds.
- Typical LEP polarization accuracy was ~0.5% / min (1993+). This corresponds to $\Delta y$ of ~ 2 $\mu$m.




*P measurement accuracy for a 1 minute measurement time*

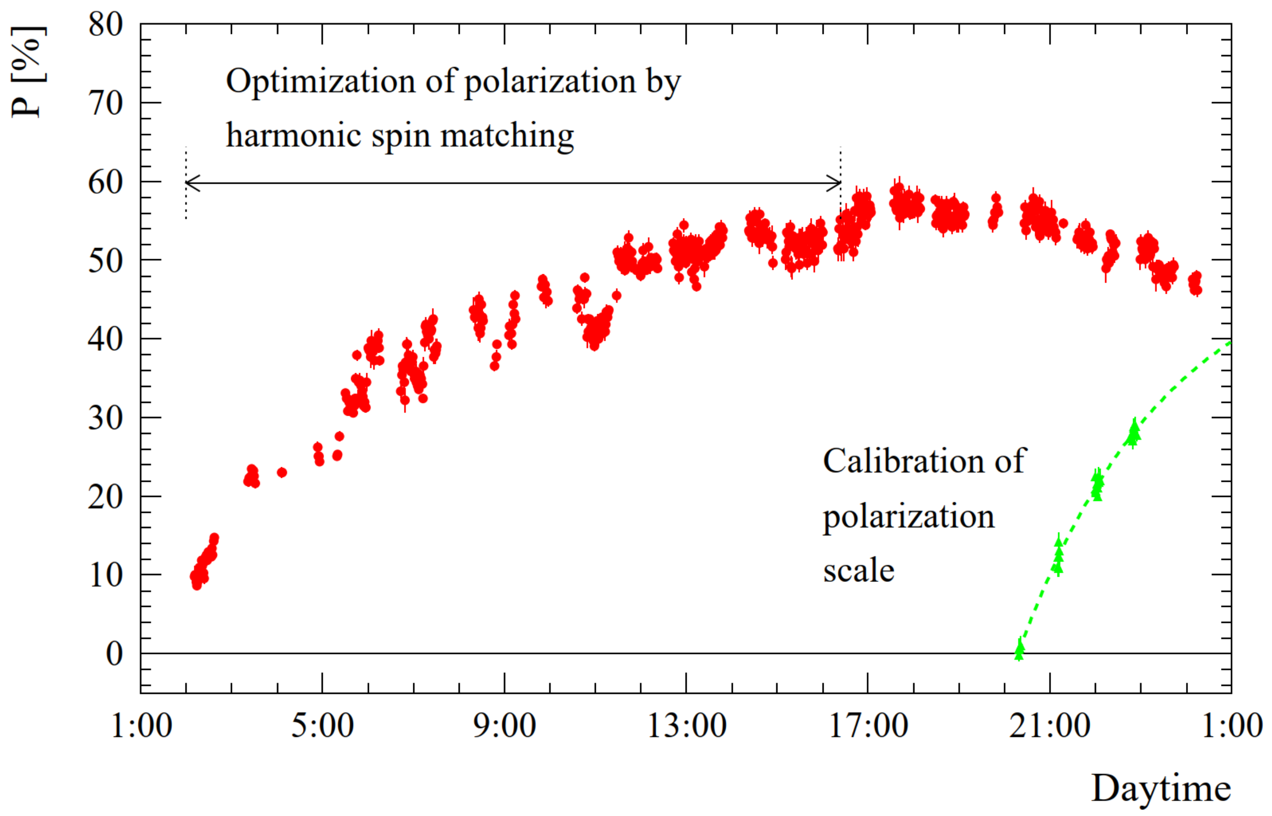
*for the first generation laser (1992) and for the upgraded laser (1993)*

# Polarization scale



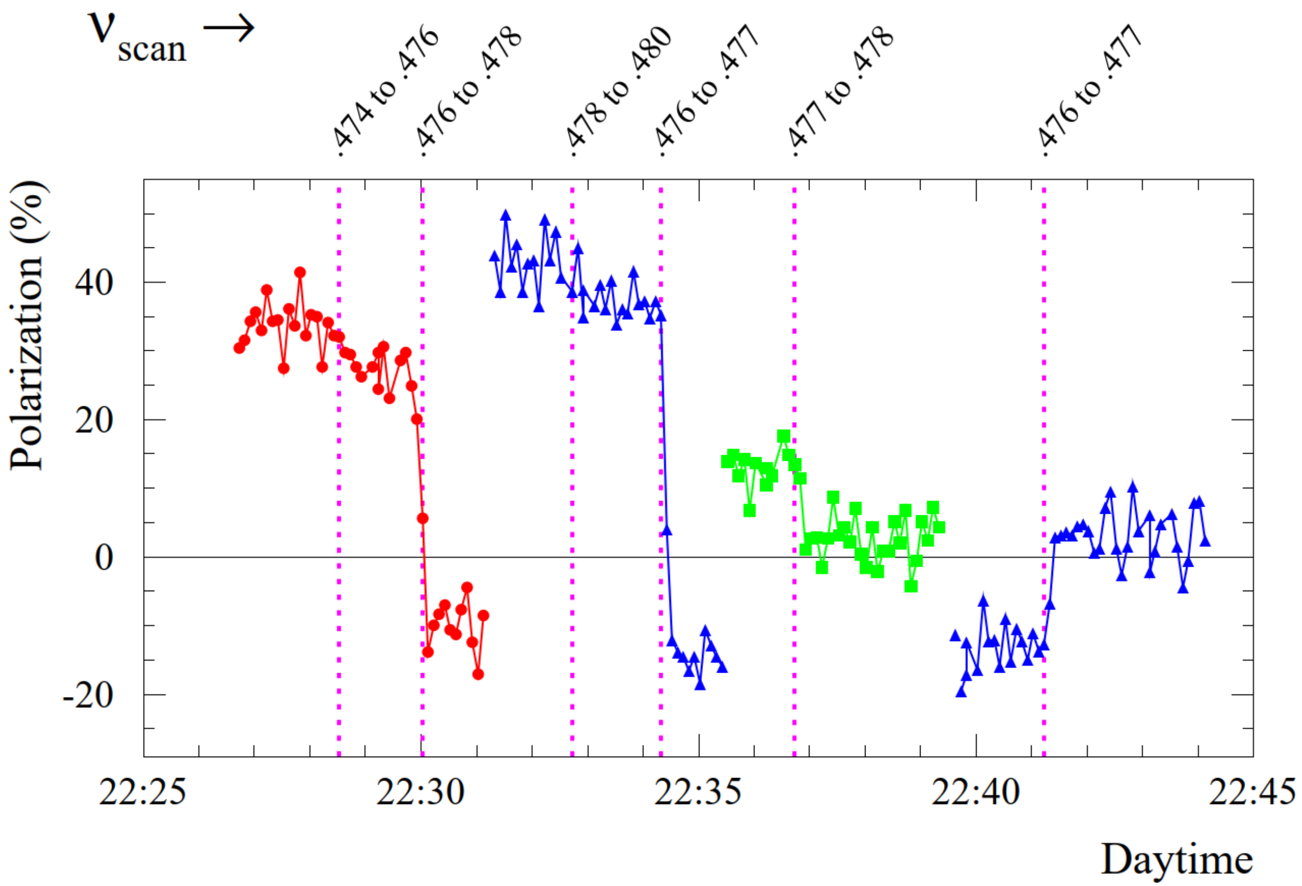
- The polarization scale was calibrated using the relation between polarization time $\tau$ and the equilibrium polarization level.
  - One bunch is depolarized, and the polarization curve is recorded to determine the polarization time.

$P_\infty = 92.4\% \, \tau / \tau_P$ $\qquad$ $\tau_P$ = polarization time of ideal machine ~ 320 mins @ Z



# In action

- Polarization levels of 4-5% were sufficient for energy calibration by depolarization, but a level of 8% or more made the measurements more reliable and much faster.
  - But we have done it with 3%..




*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.*