INTEGRATION OF WIGGLER AND POLARIMETER

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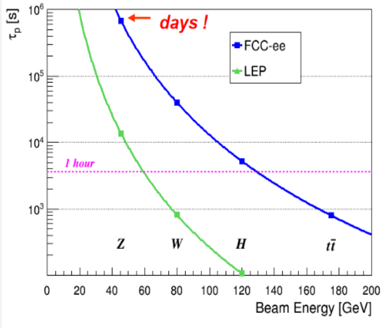
and gratefully acknowledging contributions from many colleagues in the FCC collaboration

FCCIS – The Future Circular Collider Innovation Study. This INFRADEV Research and Innovation Action project receives funding from the European Union's H2020 Framework Programme under grant agreement no. 951754

EPOL operation scenario and Hardware

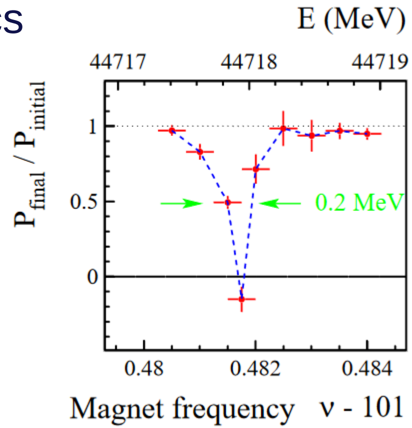
- "Natural" polarization rise time τ_p in FCC-ee at Z above 250h ($\frac{1}{\tau_p} \propto \frac{E^5}{\rho^3}$)
  - Operation scenario foreseen:
    1. Inject ~200 pilot bunches
    2. Use **wigglers (ρ ↓)** to achieve desired level of polarization (> ~5%) in reasonable amount of time
    3. Turn wiggler off and fill up machine for physics
    4. Use **polarimeter** to measure polarization of pilot bunches while frequency sweep of **RF-magnet**

See arXiv:1909.12245 for more detail



Polarization risetimes for LEP and FCC-ee

J. Wenninger, "Polarised Electron Beams/Energy Calibration", CAS 2018



Example RDP measurement at LEP, see https://doi.org/10.1007/BF01496579

Wiggler design

- Length, field, and number of wigglers free parameters, but $\left(\frac{\sigma_E}{E}\right)^2 \propto \frac{E^4}{\gamma^3 \tau_p \Delta E_{loss}}$, (see **PRAB** 19, 101005, 2016)
  - Wiggler design for FCC-ee follows 3 three block LEP design
    J. Jowett and T. Taylor, "Wigglers for control of beam characteristics in LEP"

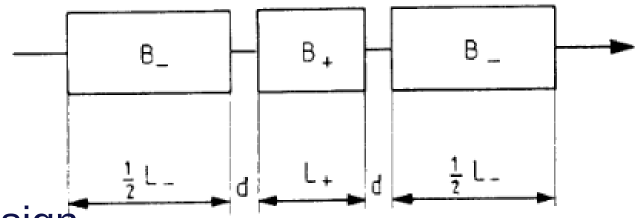


Fig. 1 Model used for calculations.

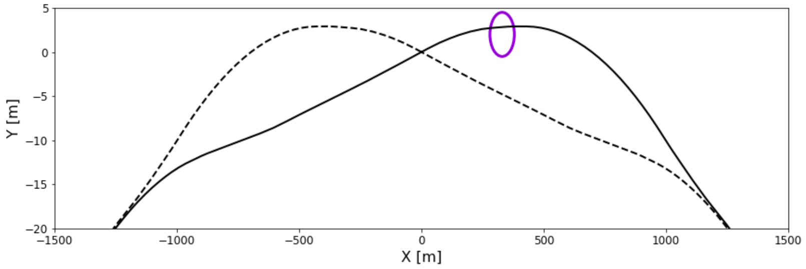
  - Asymmetry parameter $r = \frac{B_+}{B_-} = \frac{L_-}{L_+}$
  - Length of one unit $(L_- + L_+)$ = 3.5m , put together in packages of 3 units with L = 12 m (including extra 0.5m on each side to adjacent element)

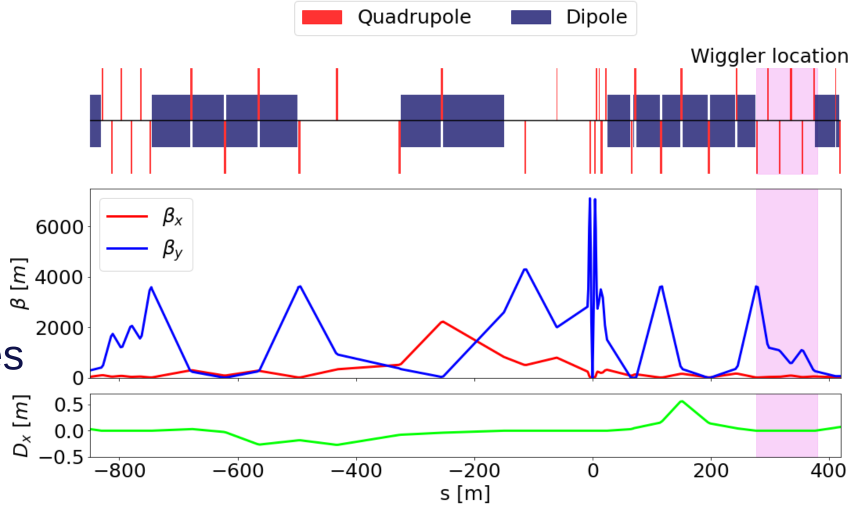
Parameter	w/ wiggler	w/o wiggler
Energy spread [MeV]	64	17
τ_∞ [h]	12	248
ΔE_{loss} [MeV]	51.4	35.8
ΔL [mm]	0.0135	

Parameter	FCC-ee	LEP
Number of units per beam	24	8
B_+ [T]	0.7	1.0
L_+ [mm]	430	760
r	6	2.5
d [mm]	250	200
Crit. Energy of SR photons [keV]	968	1350

Wiggler Location

- Should be installed in dispersion free section and ideally small β_x to limit impact on aperture
- Wigglers foreseen to be installed in 16m long drift space downstream of the interaction point
- Sufficient physical aperture for orbit excursion of $\Delta x = 0.8\ mm$ created by wigglers
- Tracking studies show impact of wigglers on beam lifetime (see K.Oide, FCC-Week 2022)
  - Partially mitigated by turning off crab sextupoles

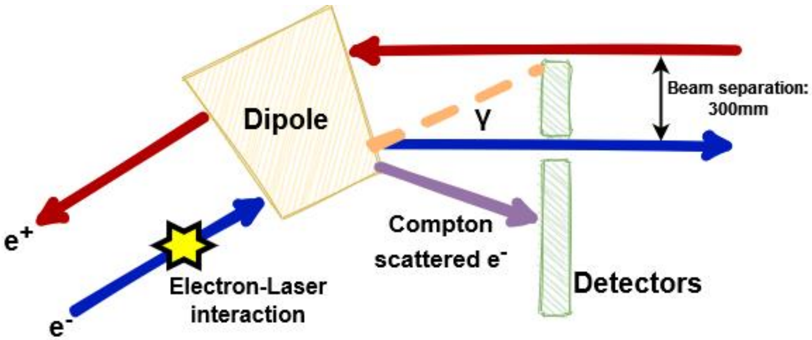




Polarimeter working principle

- Measure polarization based on spin-dependent Compton scattering of circularly polarized laser with $e^{\pm}$-beam
  - Detection not only of photons but also scattered electron

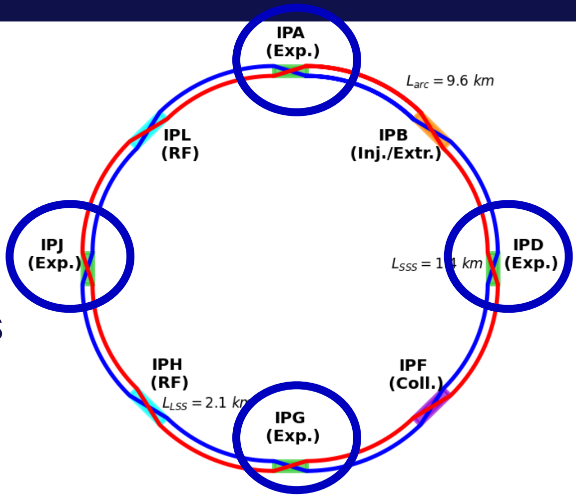
- Baseline: One polarimeter per beam
- Requirements:
  - Dipole magnet with high precision field map ($\theta_{dipole} = 2\ mrad$)
  - Field free region ($L_{drift} = 100m$) after dipole to separate scattered $e^{\pm}$ and γ from main beam
  - Si-Detector for scattered e^{+}/e^{-}, roughly 400mm wide [ref] (cf. to beam separation of 300mm)

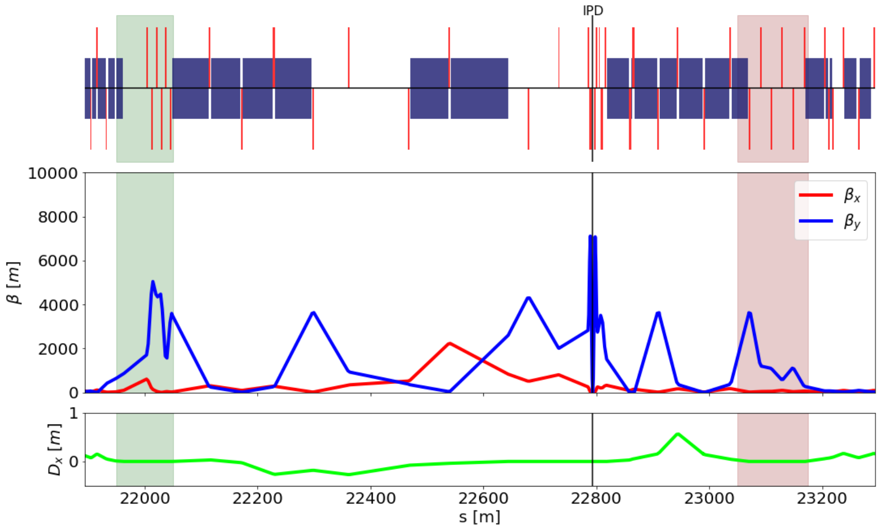


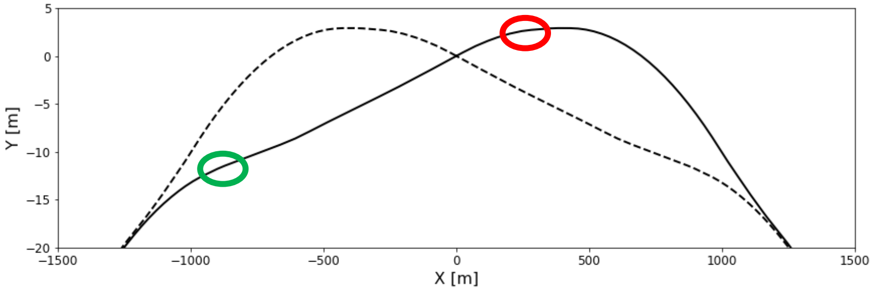
- Two options under study, either upstream of IP, or in RF-section

Polarimeter upstream of IP

- Preferred option to install polarimeter on inside beam to provide space for e^+/e^- detector
  - In current 4-IP layout, only the case upstream of experiments
  - Option downstream discarded due to interference with crab sextupole



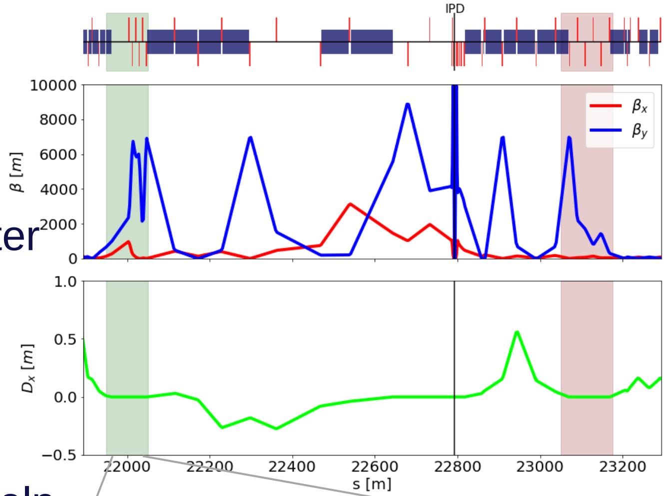


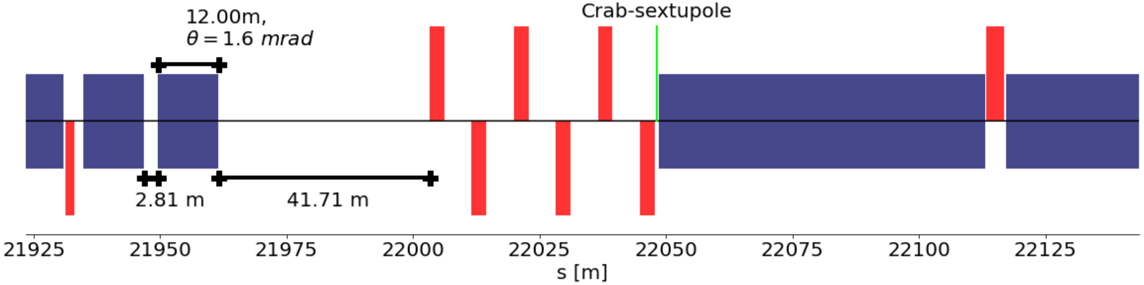


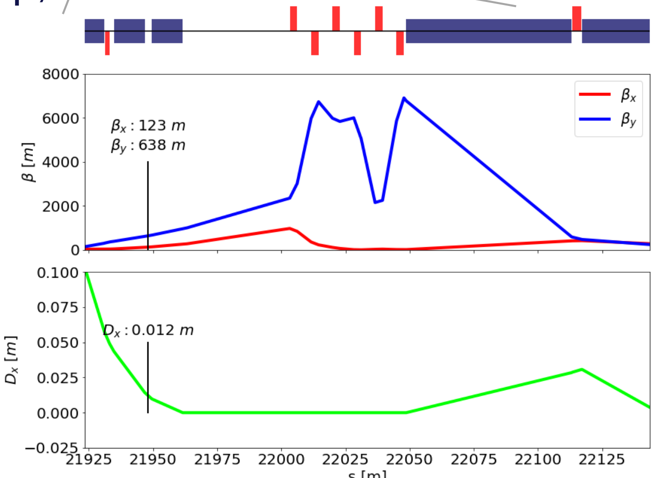
Polarimeter upstream of IP

- Modified layout provides sufficient space for detectors, compatible with all operation modes and multiple polarimeter

  - Drift space to detector less than half of targeted length
  - Could be compensated by change of laser wavelength or detector [ref]
  - Moving dipoles and crab sextupoles closer to IP may help, but could have implication on DA, SR background, ..

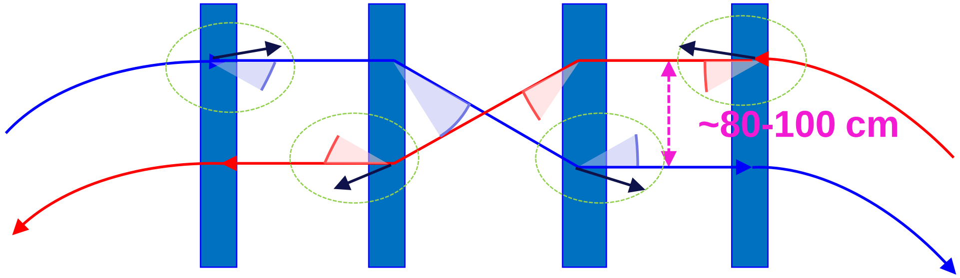


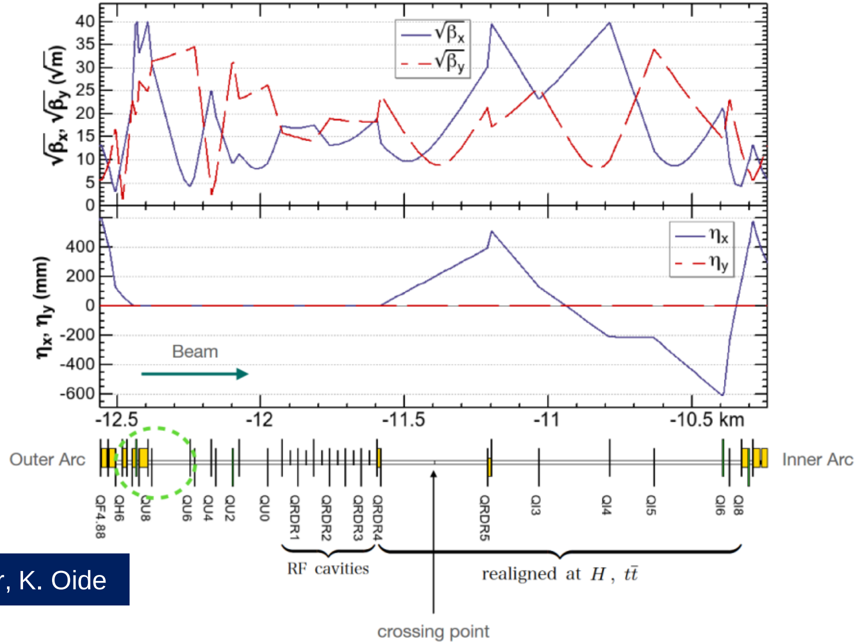




Polarimeter upstream of RF

- Alternative proposal to increase beam separation of non-IP straight to accommodate detector between beams
  - During Z operation, cavities installed only in one RF section, polarimeter used in “empty” insertion





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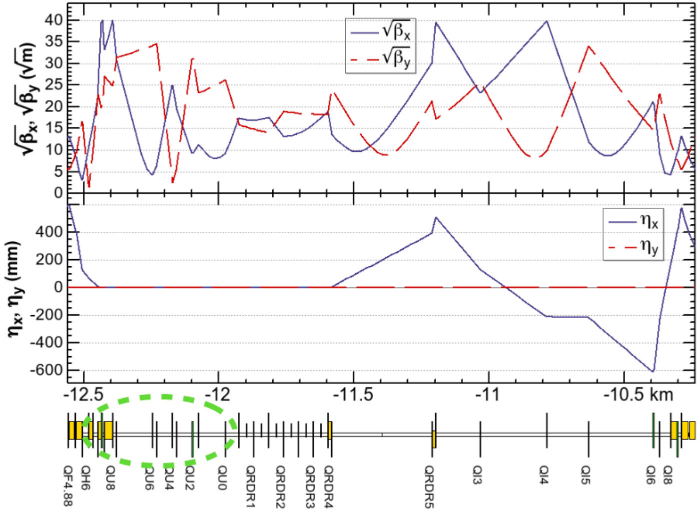
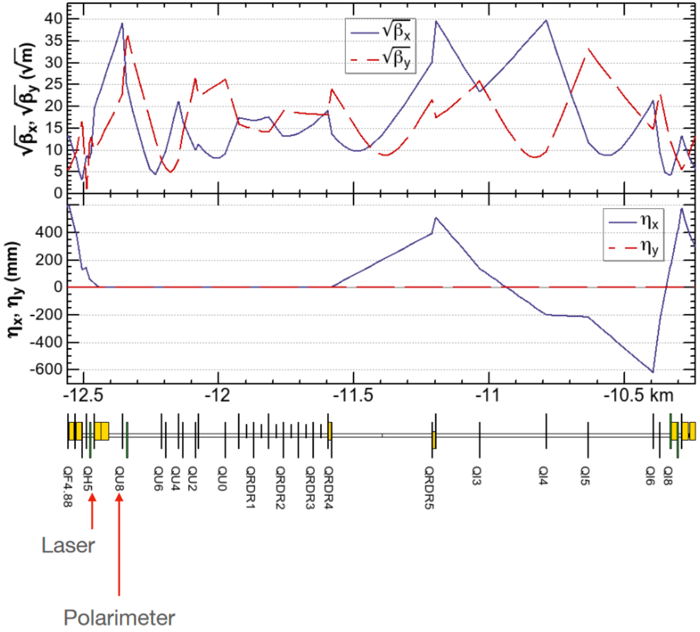
Polarimeter upstream of RF

- Rearranging some quadrupoles and splitting last dipole of the dispersion suppressor allows to meet requirements





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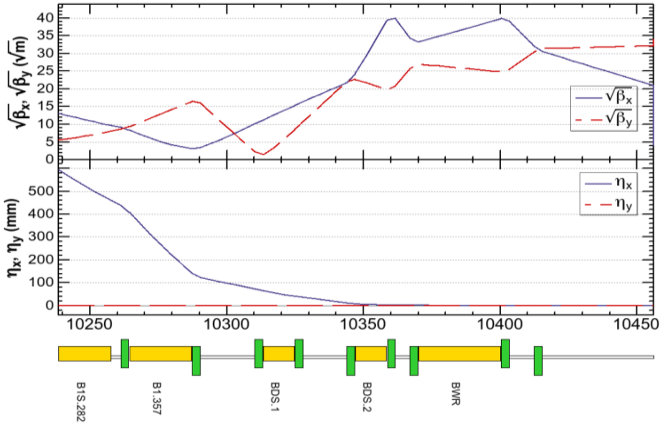
Polarimeter upstream of RF

- Rearranging some quadrupoles and splitting last dipole of the dispersion suppressor allows to meet requirements
  - Design consistent with RF layout for $H/t\bar{t}$ operation
  - Common design for both RF straight, with weak bending dipole (BWR) to avoid SR on cavities



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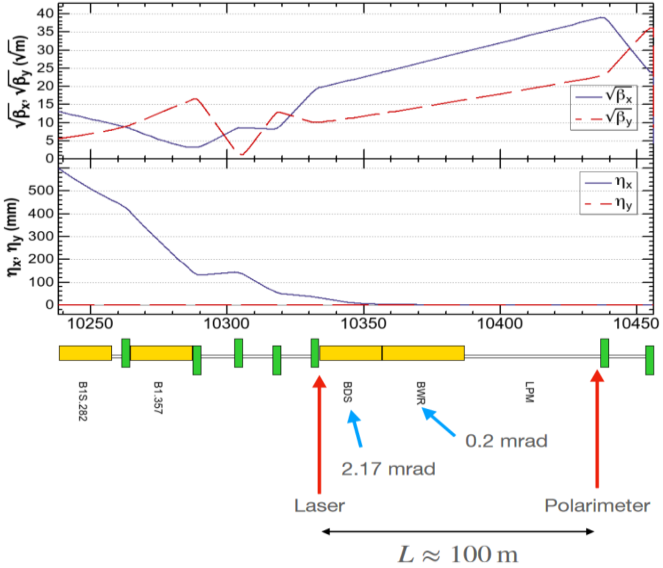

Conclusions and next steps

- FCC-ee aims at e^+e^- collision with unprecedented energies and record luminosity
  - Sheer size and ambitious parameter set to provide interesting (optics-)challenges

- Baseline optics design for collider ring established,
  continuous development to provide consistent design for Feasibility Study Report in 2025

- Despite enormous size of FCC-ee, some challenge to find optimal location for hardware for polarization measurements
  - Wigglers located downstream of each IP
  - Two options for Polarimeter under study
    - Location in an RF straight with larger beam separation
    - Upstream of IP compatible with multiple polarimeters in the ring,
      but may require changes in laser or detector
  - RF-kickers not discussed yet
    - Working assumption: system similar to LHC TFB sufficient ($L_{total} \approx 6\,m$),
      potential to install in RF-straight

Thanks for your attention!