FUTURE CIRCULAR COLLIDER

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EPOL Summary

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On behalf of the
FCC-ee EPOL working group

7th FCC Physics Workshop
LAPP, Annecy, France
02 February 2024

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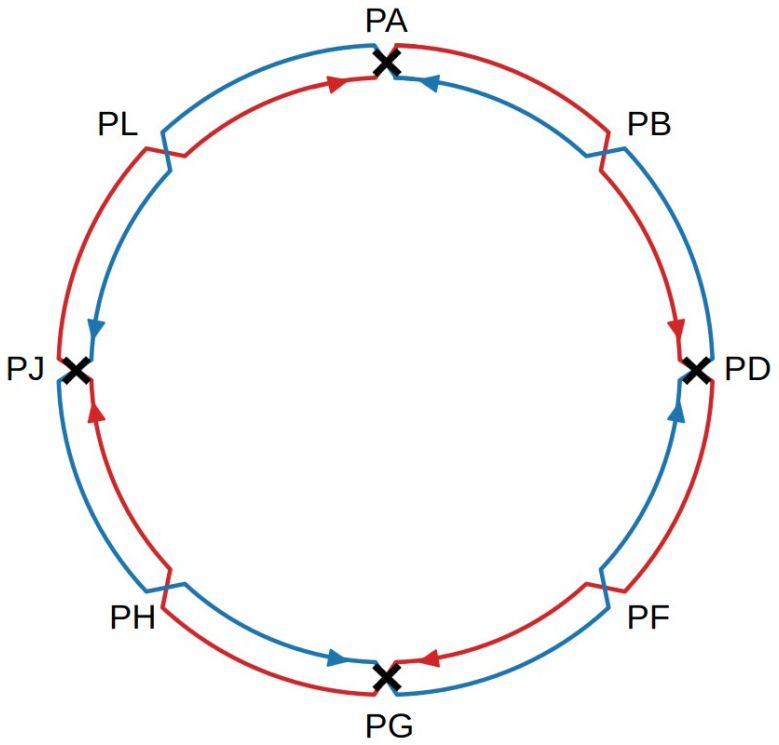
FCCIS – The Future Circular Collider Innovation Study. This INFRADEV Research and Innovation Action project receives funding from the European Union's H2020 Framework Programme under grant agreement no. 951754.

FCC-ee Overview

Particle Physics:

- Higgs and electro-weak factory
- 4 baseline beam energies and diverse particle physics program
  - 45.6 GeV: Z-pole
  - 80 GeV: W-pair-threshold
  - 120 GeV: ZH-production
  - 182.5 GeV: top-pair-threshold
- High number of statistics



Accelerator Physics:

- 4-fold super-symmetric layout
  - Up to 4 Interaction Points (IPs)
  - 1 RF-section per beam
  - 1 collimation section
  - 1 section for injection and dump
- Nanometer beam size at IPs
- Strong synchrotron radiation

Precision particle physics experiments ⟺ Center-of-mass energy determination

Expected Precision

	Quantity	statistics	ΔE_{CMabs} 100 keV	$\Delta E_{CMSyst-ptp}$ **40 keV**	calib. stats. 200 keV/$\sqrt{(N^i)}$	σE_{CM} (84) $\pm$ **0.05** MeV
Z	m_Z (keV)	**4**	100	**28**	1	–
	Γ_Z (keV)	**4**	2.5	**22**	1	**10**
	$sin^2\theta_W^{eff} \times 10^6$ from $A_{FB}^{\mu\mu}$	**2**	–	**2.4**	0.1	–
	$\frac{\Delta\alpha_{QED}(M_Z)}{\alpha_{QED}(M_Z)} \times 10^5$	**3**	0.1	**0.9**	–	**0.05**
WW	Further clarification ongoing			300 keV	150 keV	
	m_w(MeV)	**0.200**	**(?)**	75 keV?		
	Γ_w (MeV)			(75?)	small	OK

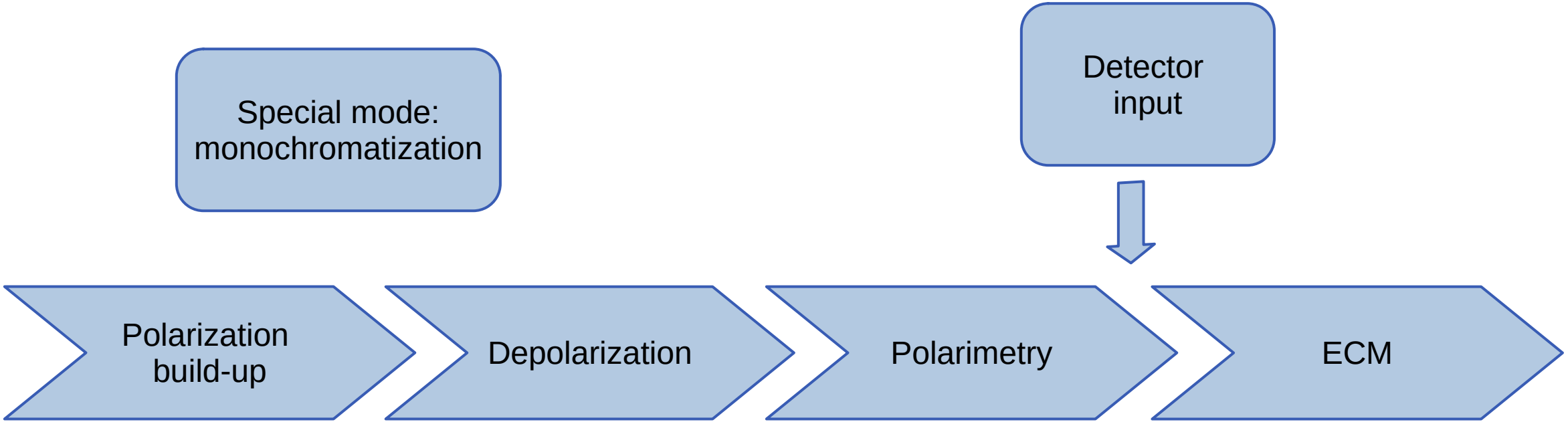
Large expected luminosity → huge statistics → small statistical error: **4 / 100 keV per Z / W - boson**

Aim to achieve same order of magnitude for systematic errors → Scope of the **EPOL working group**

EPOL: Energy calibration, polarization and monochromatization

arXiv:1909.12245

How to?



- Resonances
- Wigglers
- Beam tests

- Resonant depolarization
- Free spin precession

- Polarimeter incl. laser, Si-detectors
- e.g. EIC experience

- Systematic errrors
- Statistical errors
- Accurate models

Sessions Overview

Thursday 11:00 – 12:30

Prospects for polarization and energy measurements at CEPC; Speaker: Zhe Duan

Progress with polarimeter studies and design
Speaker: Aurélien Martens

Polarization studies at KARA
Speaker: Jacqueline Keintzel

Orbit correction and polarization studies
Speaker: Yi Wu

Thursday 17:45 – 18:45

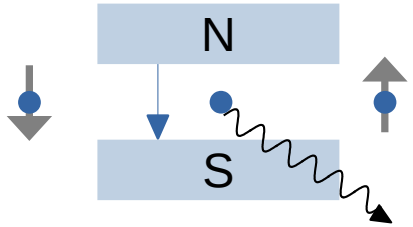
Progress on energy measurements
Speaker: Ivan Koop

Progress on opposite sign dispersion and offset studies; Speaker: Alain Blondel

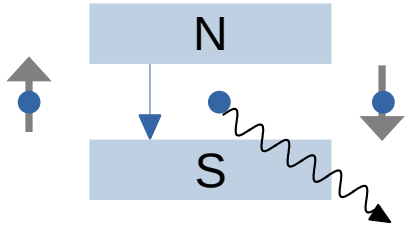
Progress on monochromatization studies
Speaker: Angeles Faus-Golfe

Polarization Build-Up

More likely
(by factor ~25)



Less likely



- Statistically every 10^{10th} emitted synchrotron photon flips the spin
- Probability depends on the initial spin orientation

- Leads to a natural **polarization build-up** over time
- Orientation is **anti-parallel** to the guiding magnetic field

- Maximum theoretical polarization of **92.4 %**
- Spin precesses through the lattice → Spin tune

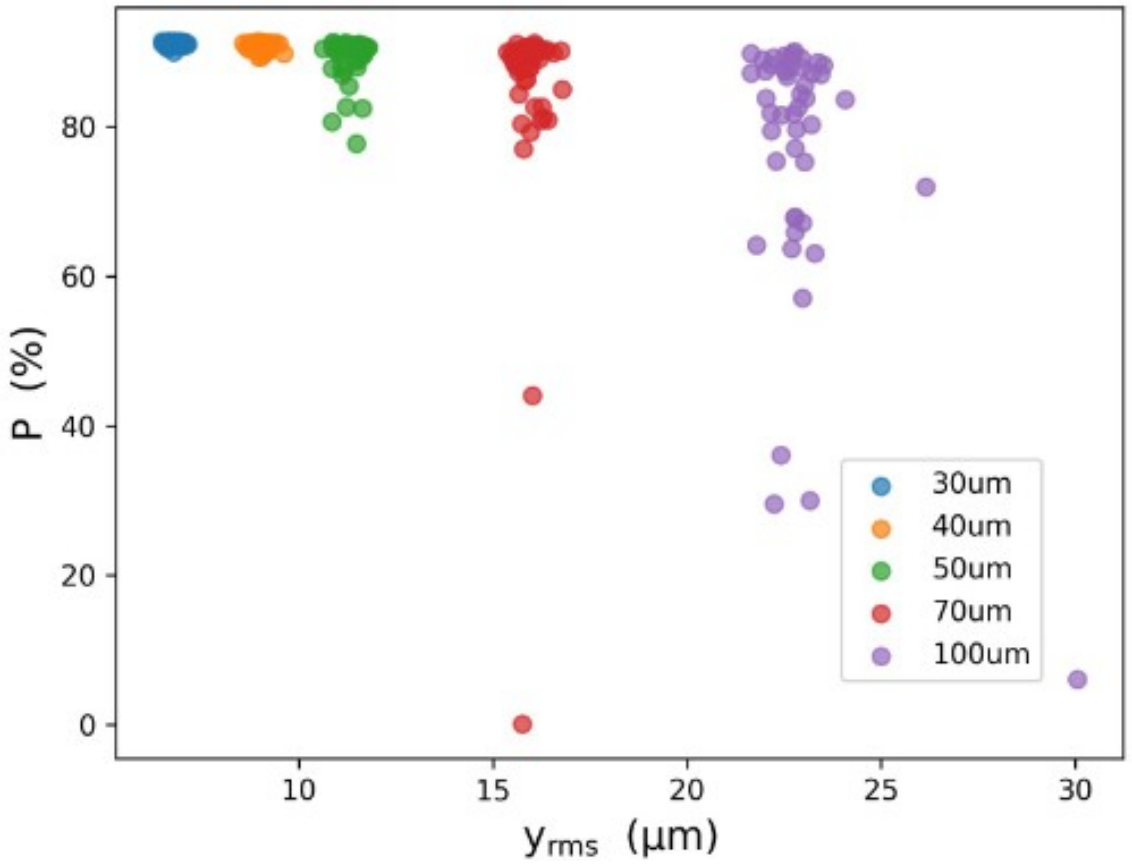
$$\nu = a * \gamma_{Rel}$$

a … gyro-magnetic anomaly
γ_{Rel} … Lorentz-factor

What are the advantages of wigglers or a dedicated polarization ring?

Polarization and Misalignments

Orbit correction and polarization studies
Speaker: Yi Wu



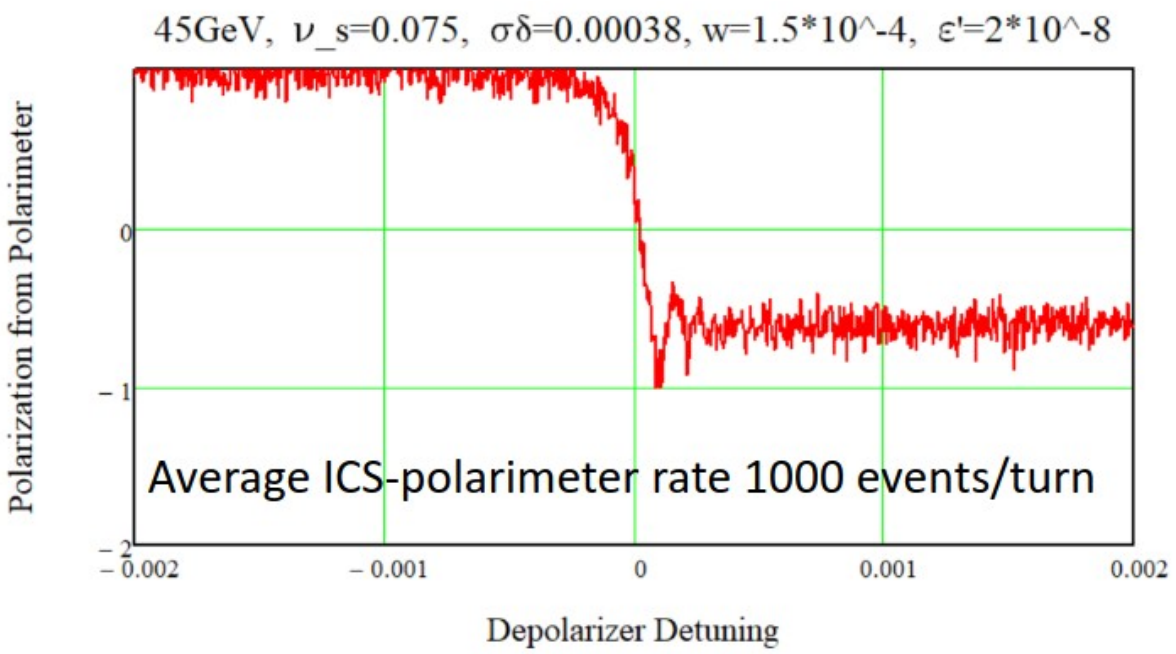
- Misalingment errors applied in the arcs and corrected
- Maximum polarization calculated
- Spread of max polarization significantly increased

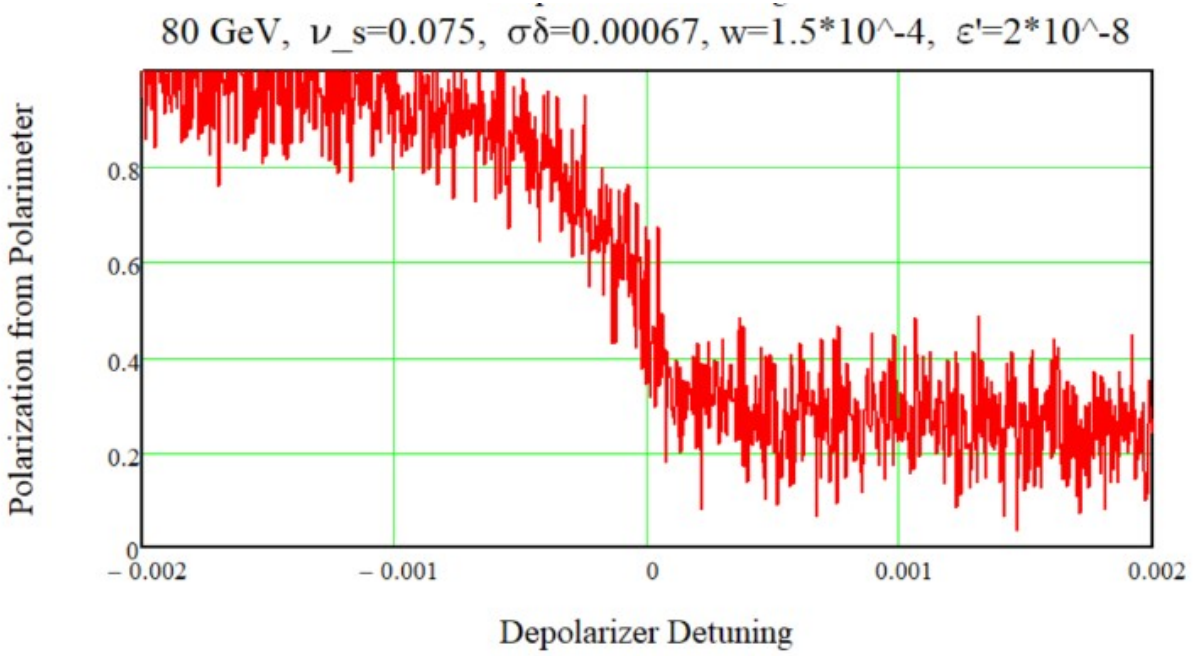
- Polarization possibly improved by harmonic spin matching
- Shift of spin tune with misalignments to be evaluated

Energy Measurement Simulation

- Independent depolarizers per beam
- Transverse resonant depolarization time 5 - 10 min
- To control longitudinal polarization: continous operation on all colliding bunches → increased power

Progress on energy measurements
Speaker: Ivan Koop

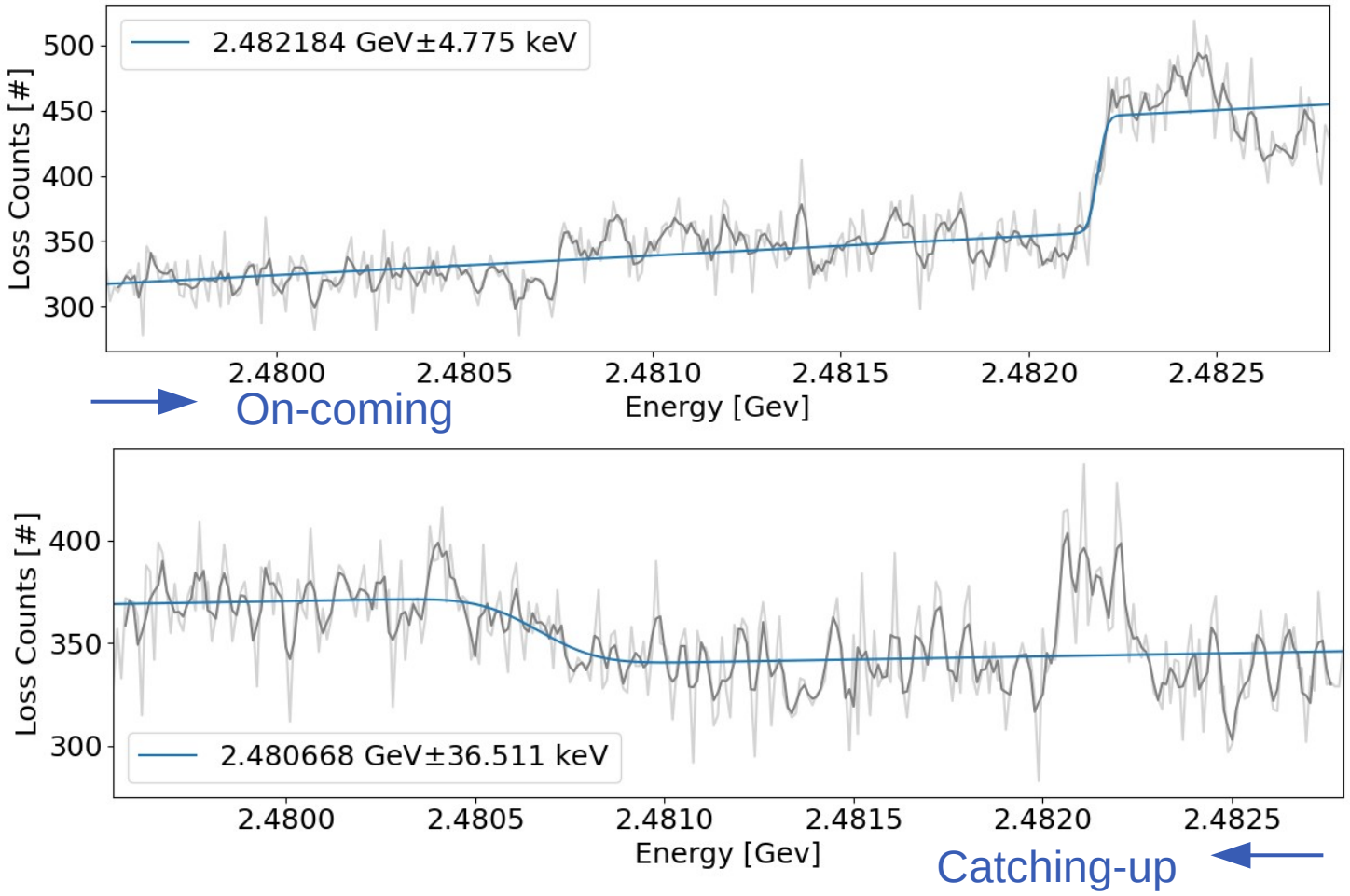




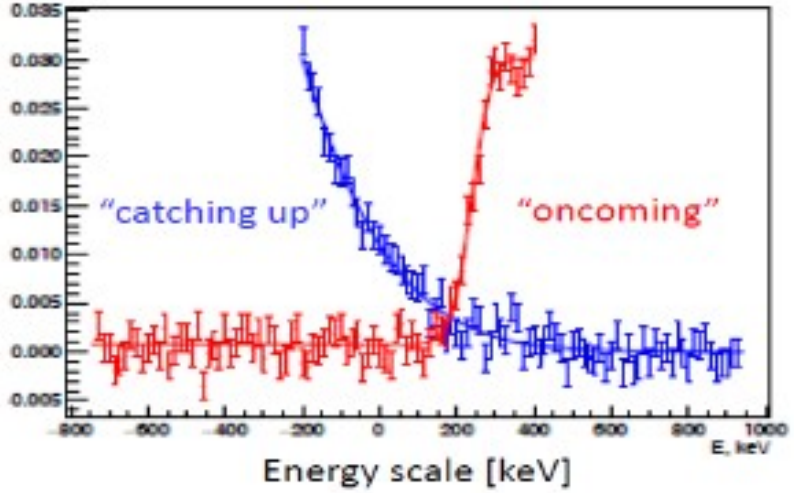
Measuring Polarization at KARA

Excitation frequency ↔ Beam energy

Polarization studies at KARA
Speaker: Jacqueline Keintzel



- Findings consistent with FCC simulations
- Suggests negative engergy drift

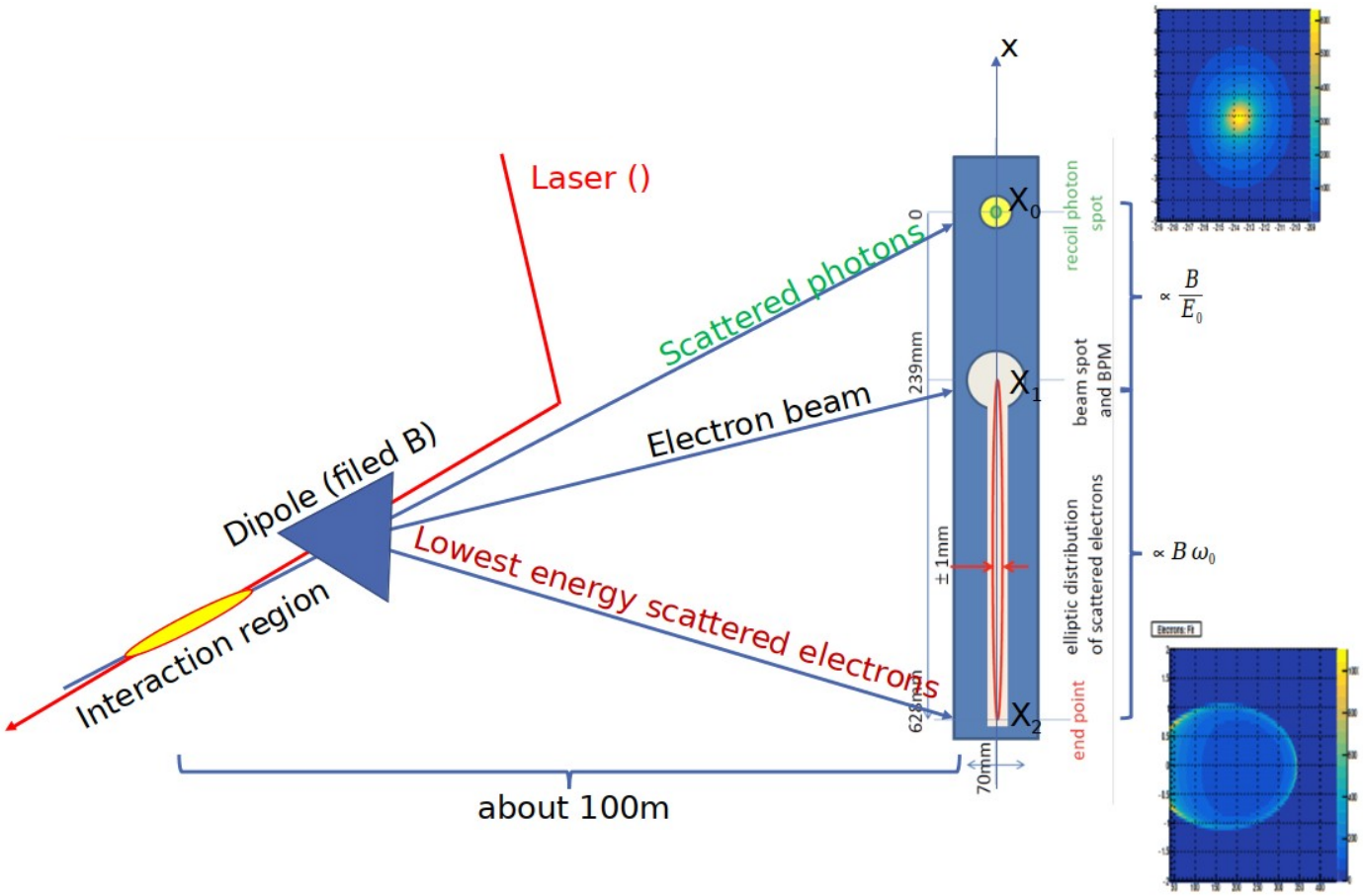


Courtesy: S. Nikitin, I. Koop

Polarimeter

- 3D polarimetry to measure transverse and longitudinal polarization

Progress with polarimeter studies and design
Speaker: Aurélien Martens



$$\int B_x dl \ll \frac{\sigma_y \gamma}{L_2}\frac{mc}{q} \approx 1.1 \times 10^{-4}\ \text{T.m and}$$

$$\int B_z dl \ll \frac{\sigma_y \gamma}{L_2 \kappa \theta_0}\frac{mc}{q} \approx 3.2 \times 10^{-2}\ \text{T.m.}$$

- Transition from conceptual design to definition of hardware specifications
  - Dipole field quality and alignment
  - Pixel size for photon and electron detector
  - Detector design started

Additional person power is joining project

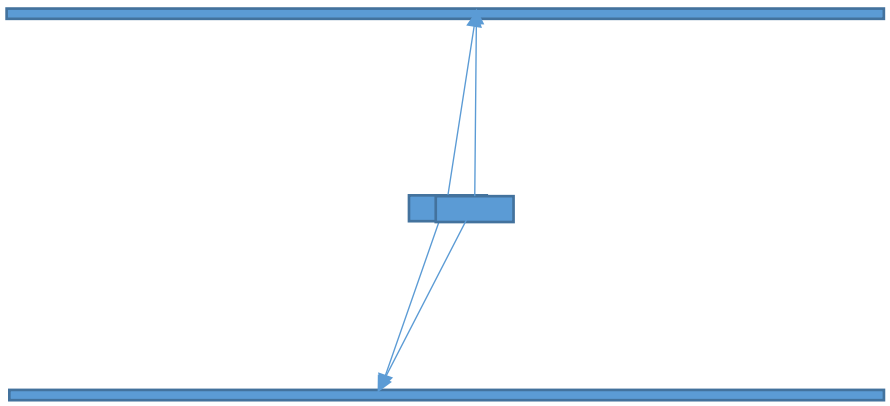
ECM Energy Shifts

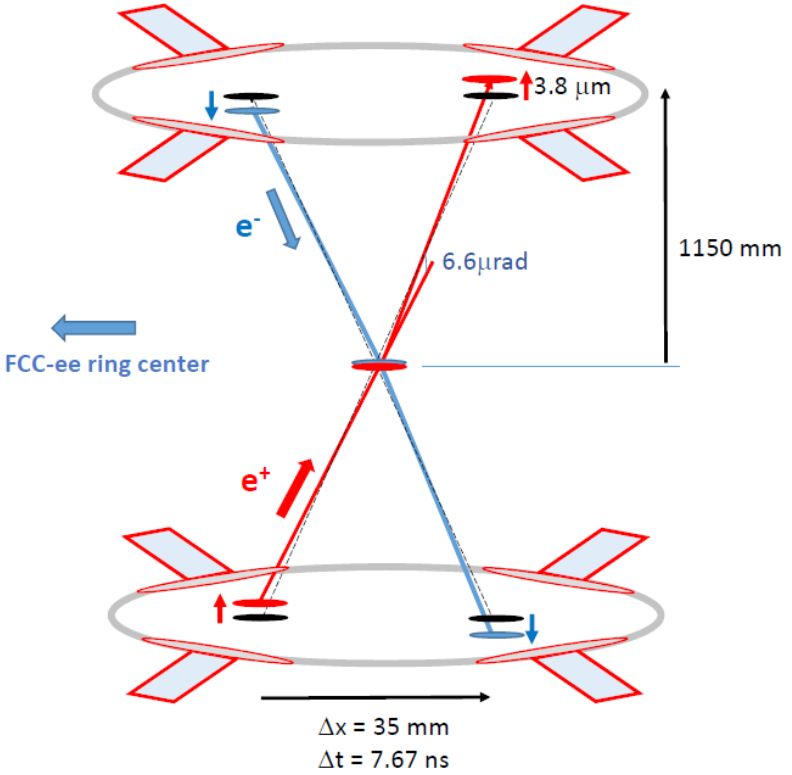
- Opposite sign dispersion and collision offsets modify $\sqrt{s}$
- Collision offset could be measured with lumical BPM

Progress on opposite sign dispersion and offset studies; Speaker: Alain Blondel

- Cosmic muons necessary to resolve weak modes –

  time needed to accumulate sufficiently large sample under evaluation



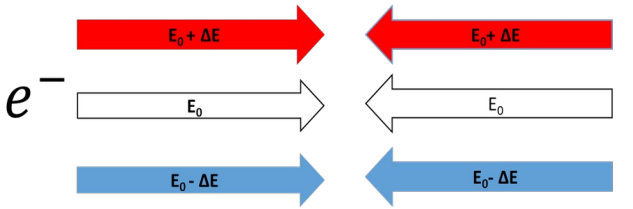


Monochromatization

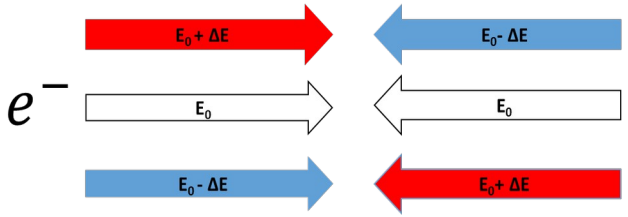
Progress on monochromatization studies
Speaker: Angeles Faus-Golfe

- 62.5 GeV beam energy → peak of Higgs-production
- For minimization of collision energy spread –> monochromatization
- Trade-off between collision energy spread and luminosity production

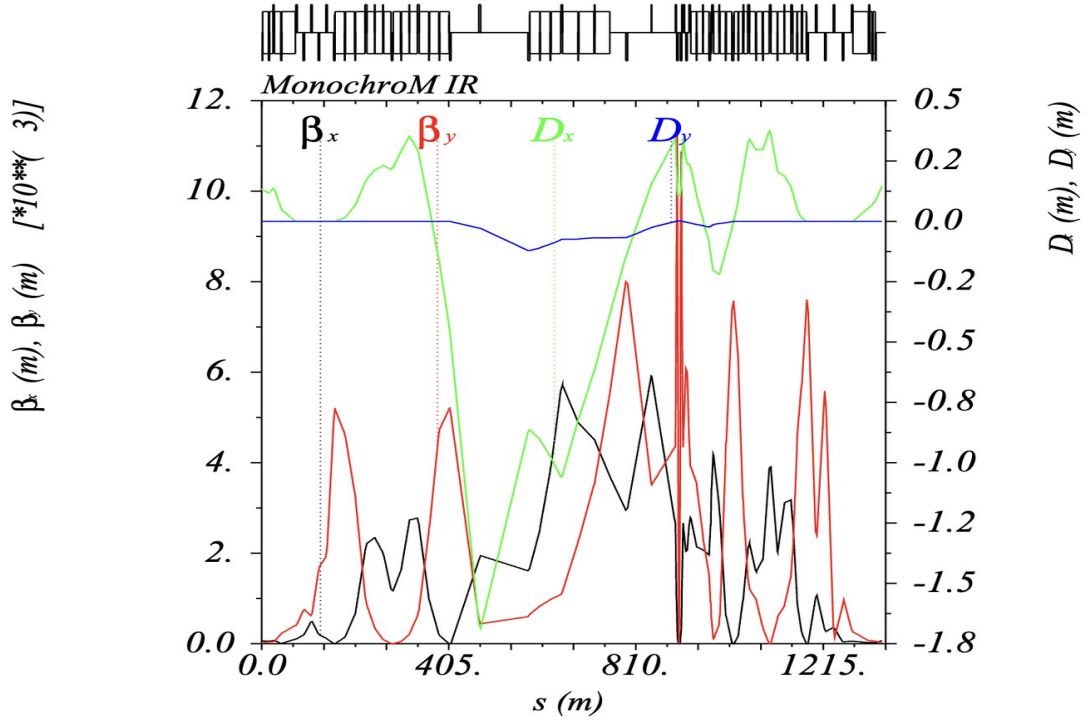
Introducing dispersion



Same sign dispersion at the interaction point leads to change of E_{CM}



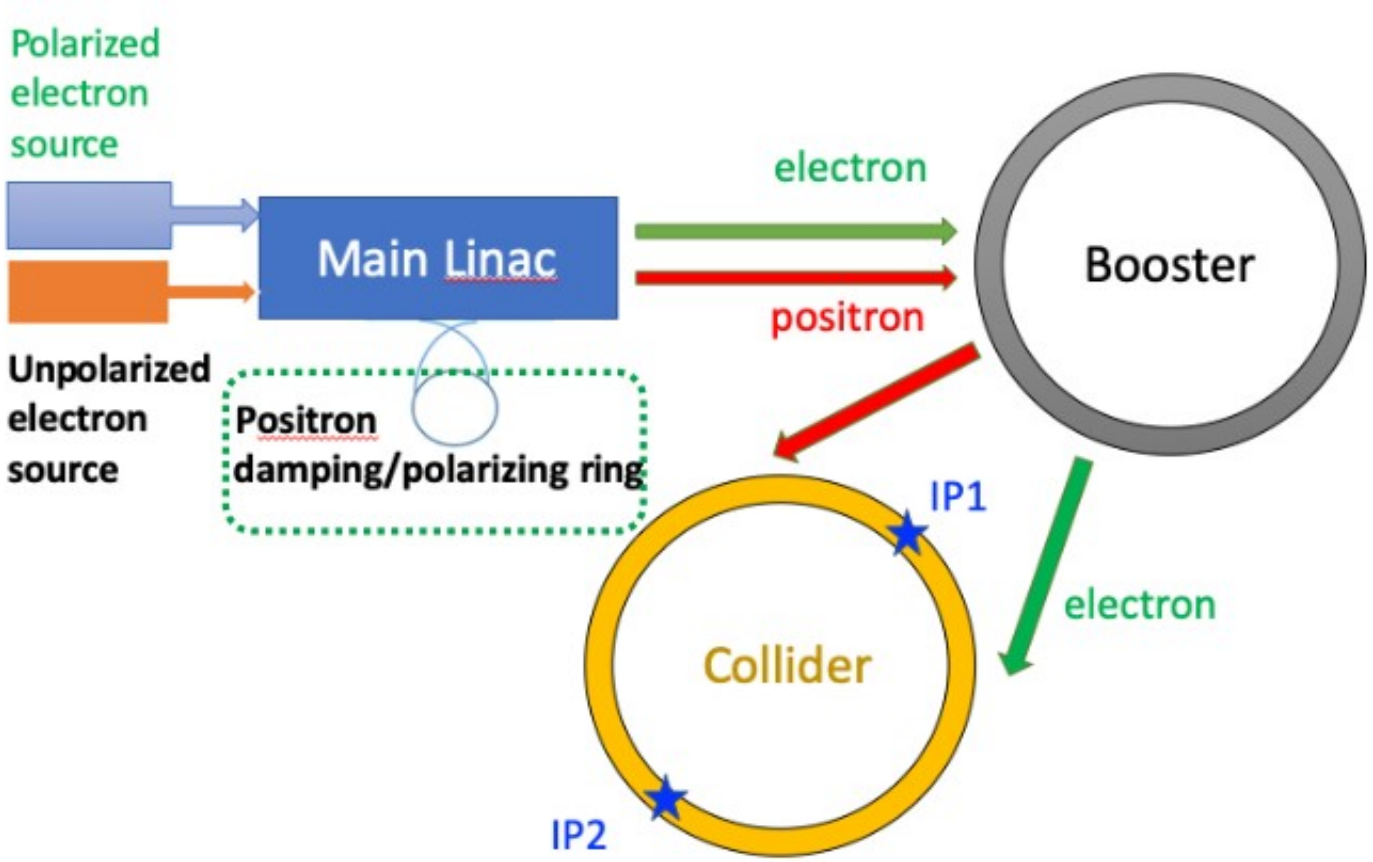
Opposite sign (horizontal) dispersion helps reducing E_{CM} spread



4 MeV spread ↔ 18 x 10^{34} $cm^{-2}s^{-1}$, possible optimization

CEPC Polarization Scheme

Prospects for polarization and energy measurements at CEPC; Speaker: Zhe Duan



- Injection of polarized electrons and positrons in collider rings at Z and W
  - Longitudinal polarization for physics bunches
  - Transverse polarization for pilot bunches
  - More time for physics
- Possibly also polarized beams at H

Outlook

- Presently aimed to achieve *4 / 100 keV* systematic uncertainty at the *Z- / W- modes –> EPOL*
- Important questions aimed to be investigated before the end of the feasibility study, for example:
  - Does the spin tune shift if misalingments and correction schemes are applied?
  - What are the systematics energy shifts between pilot bunches and colliding ones?
  - Could the requirements for the depolarizer be integrated into the feedback system?
  - ...

Regular EPOL meetings:
indico.cern.ch/category/8678/
Typically every third Thursday 16:30-18:30

Any help is welcome!

Mailing list:
fcc-ee-PolarizationAndEnergyCalibration@cern.ch

Self-subscription from:
https://e-groups.cern.ch/e-groups/EgroupsSearch.do

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Thank you!

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