2d FCC Polarization Workshop -- week 2

FUTURE CIRCULAR COLLIDER

Sep 19 – 30, 2022
CERN
Europe/Zurich timezone

113 registered participants from many participating institutes from different continents (> success)

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Contact

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Welcome to the 2d FCC Energy Calibration, Polarization and Mono-chromatisation workshop which will be held at CERN from September 19 to 30 2022. The first week of this workshop (September 19 to 23) is

Considerable amount of information was exchanged on first week already – and its only a start!

A few particular points that we learned

-- We have three high energy physics projects involving electron (e- and/or e+) polarization in storage rings

-- different physics motivations

-- center-of-mass calibration for ~on-shell EW physics at FCC

-- chirality control for off shell physics at SuperKEKb

-- chirality control for understanding spin distribution among proton constituants at EIC

-- different emphasis on transverse vs longitudinal, high precision vs high polarization etc...

We will think and propose a follow-up organization to build on synergies

-- polarization of electron beams in a storage ring is a complex matter, and not so easy to understand

-- many thanks to Georg for the luminous introduction to te topic.

-- and yes, it is worth investigating kinetic polarization of colliding beams arising from beam beam forces!

-- Nevertheless considerable know-how is being developed and tuned into codes

-- exchange between projects emphasizes **synergies – different goals but similar issues**

-- controling spin resonances to increase polarization or eliminate interference with spin precession

FCC-ee overall goal

target: match systematic precision on centre-of-mass determination with the statistical capability of the machine

A big question: what is the motivation for measuring things so precisely? ➔ **Grojean**

with the discovery of the Higgs boson, the matrix of particles and their interactions, called 'Standard Model' , is complete.

This theory reproduces remarkably well the experimental results with a few notable exceptions

-- the neutrino masses

-- the Baryon Asymmetry of the Universe

-- the existence and nature of Dark Matter

-- and many other questions of theoretical nature.

and in the present situation **'SM has nowhere to go'. -- any deviation = discovery**

The main question that precision measurements address is: can we detect any evidence of the new phenomena that can explain the above questions. Or put more simply

'are there any more particles that couple to, or mix with, the particles that we already know'.

this is not a forgone conclusion

precision = discovery potential

First set of results obtained in the FCC Design Study:

Polarization and Centre-of-mass Energy Calibration at FCC-ee, arXiv:1909.12245

Table 15: Calculated uncertainties on the quantities most affected by the center-of-mass energy uncertainties, under the final systematic assumptions.

Quantity	statistics	ΔE_{CMabs} 100 keV	$\Delta E_{CMSyst-ptp}$ **40 keV**	calib. stats. 200 keV/$\sqrt{(N^i)}$	σE_{CM} (84) ± **0.05** MeV	stat/present
m_Z (keV)	**4**	100	**28**	1	–	500
Γ_Z (keV)	**4**	2.5	**22**	1	**10**	400
$sin^2\theta_W^{eff} \times 10^6$ from $A_{FB}^{\mu\mu}$	**2**	–	**2.4**	0.1	–	75
$\frac{\Delta\alpha_{QED}(M_Z)}{\alpha_{QED}(M_Z)} \times 10^5$	**3**	0.1	**0.9**	–	**0.05**	15 (qualitiative!)
m_W(MeV)	**0.200**	-- **0.300** --				40

matching these statistical errors implies the following uncertainties (or better) **(luminosity integrated averages)**

absolute energy scale error at Z — **6 keV** — **can be relaxed some since Z mass is input**

point to point E_{cm} uncertainty in Z scan — **4 keV** — **🡐 this is most significant, highest priority**

E_{cm} spread — **15 keV** — **NB highly variable quantity (factor 3-5 between low lumi and highest lumi running)**

Absolute energy scale at H — **<1-2 MeV** — **requirement at all times in running**

Energy spread at H — **joint requirement on energy spread and luminosity performance development of scheme should be possible already during Z running**

absolute E_{cm} energy scale error at W — **100 keV** — **seems « easier » because of faster polarization**

Workpackages

A- Simulations of polarization and spin-tune to beam energy relationship

-- simulations of spin polarization in realistic machine (also able to calculate emittances, luminosity)

-- res. depolarization at Z and WW threshold

-- design and integration of wigglers, RF kickers, in FCC-ee

B. Simulation of the relationship between beam energies and centre-of-mass energy

-- studies of operation scenarios

-- control of offsets and vertical dispersion

-- Impact and control of energy losses: Synchrotron rad., Beamstrahlung, impedance, etc.

C. Polarimeter design and performance

-- now working to build a global collaboration

-- Aim to provide integration of polarimeters,

-- conceptual design and cost estimate of polarimeter for FCC FS

D. Measurements in Particle Physics Experiments

-- use of dimuons and other processes to determine centre-of-mass energy spread, boost, at and within IP

E. Monochromatization

-- new ideas for monochromatization in other dimensions than horizontal (x) axis. (time, z)

-- what its the limit?

Detailed descriptions from October 2021 recalled, including additions and corrections resulting from work that has already been done

Full lists to be completed by participants during this workshop and aimed to be summarized in one document

WP1 simulations of polarization and spin-tune vs beam energy relation

-- we now have three proposals for beam energy measurements

-- resonant depolarization → simulation of possible deviations of spin-tune vs beam energy relation

-- spin precession measurement → ibid.

-- polarimeter beam energy {from electron end point to backscattered photon distance}

-- to which one can add

-- the calculation of energy losses in the ring or in the beam-beam interaction (beamstrahlung)

-- the boost and E_{cm} measurements in IPs

-- the control of beam-beam collision offsets and opposite sign dispersion @ IPs

QUESTIONS

- How to speed up spin tracking simulations? Maps vs element by element?
- Do we need a special optics or only tunes to measure the spin tune as in LEP?
- Harmonic spin matching to increase polarization level?
- Pi-bumps to avoid losing polarization level over IPs?
- Can we inject already polarized electron beams? At which cost? (what is the cost of a 500Tm solenoid?)
- How can we avoid polarization for colliding bunches?
- Can one design experiments testing the concepts somewhere, e.g. KARA?
- Can one design operation and Ecm points to identify/correct/eliminate non-linear ν_{spin} to E_{cm} relation?

WP2 from beam energy to center-of-mass energy

considerable proress but a lot of work in sight.

- Is there sufficient aperture to inject in Pilot Bunches with the booster/main-rings configurations?

- (How) Can we assure that the colliding bunches are +/- 5 % of the nominal intensity?

- Which dispersion can we except at the IP? → link to tuning studies

- How can we control and correct dispersion and offsets at the IP?
  - -- Vernier scans
  - -- beam-beam deflection scans
  - -- each time: compare colliding with pilot bunches in given + other IPs ?

- Can we have non-colliding bunches with the same intensity as colliding ones?
  is it important? (see Manfred Wendt)

- What is the best scheme of low-intensity, nominal intensity, (non-) colliding bunches?

WG3 Polarimeter and polarization measurement

Polarimetry

-- several designs for polarimeters in different projects, some with very different aims

resonant depolarization,
precise measurement of high polarization
precise measurement of zero polarization
fast measurement of spin precession

➔ **can one set-up realize all of these goals in FCC?**

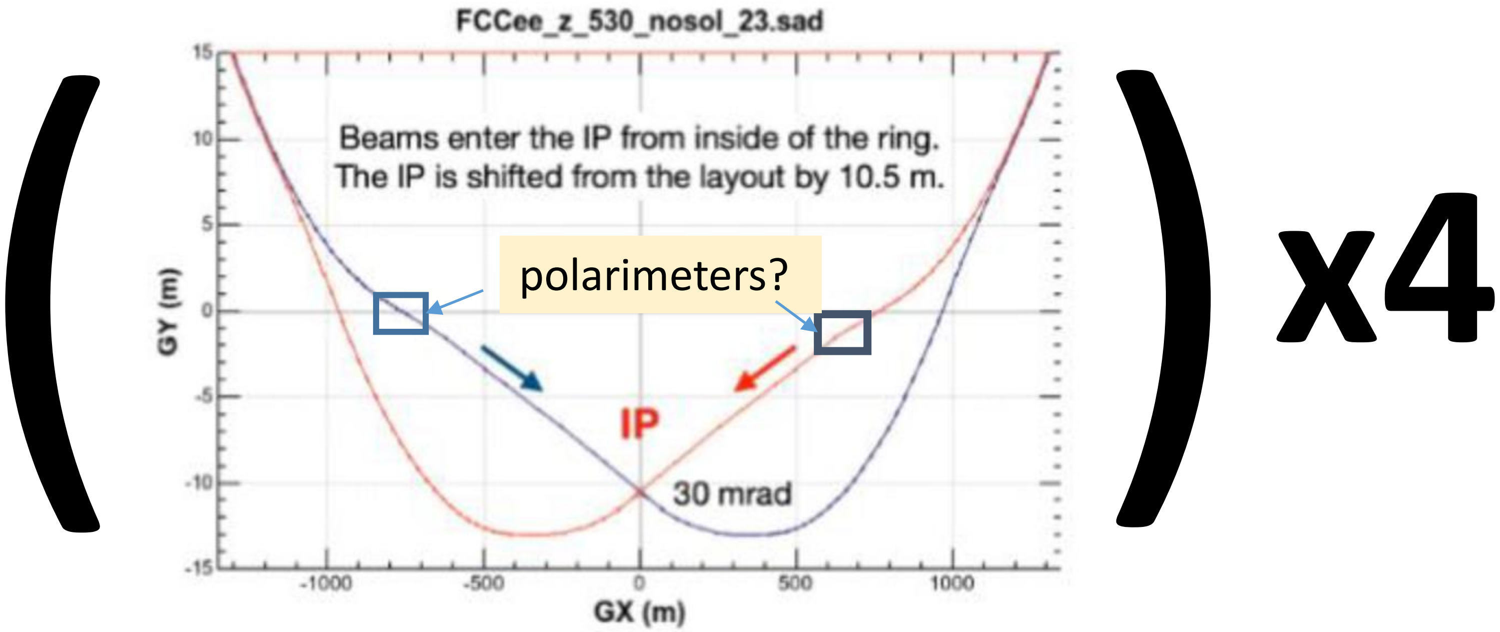
-- things that seem impossible (10^{-5} measurement!!) may not be so impossible after all ☺

more burning questions for FCC (I)

1. How many polarimeters for FCC-ee?

-- baseline: at least two, one e+ and one e-

-- if more are really needed, consider last strong magnet before the experiments on incoming lines.



++ this might make it easier to propagate the 3D polarization measurement to the IPs.

-- lets evaluate cost and operational issues and understand the possible gains before changing the baseline of 2 (e+ and e-) polarimeters!

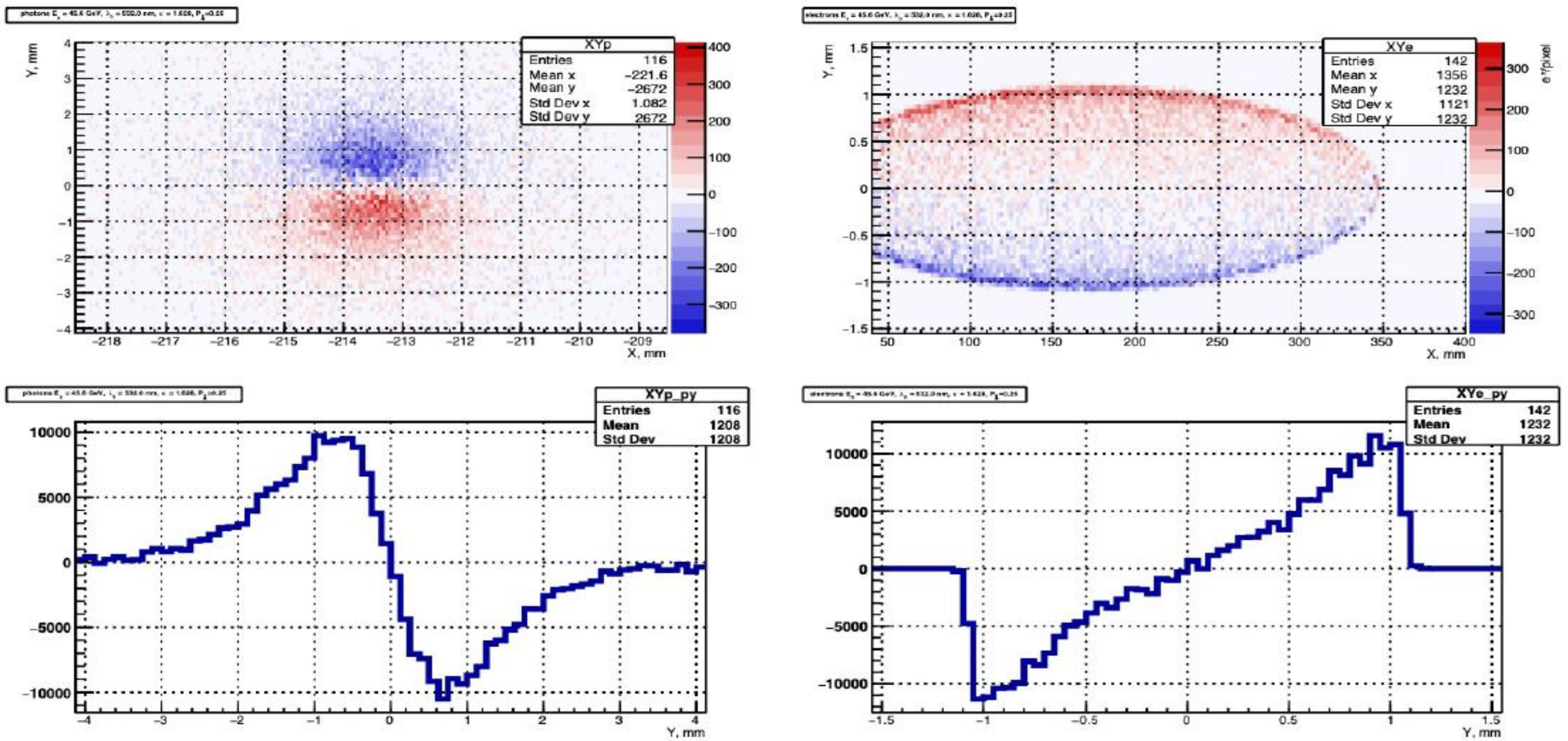
-- a nice place anyway. Investigate with M. Hofer, K. Hanke if this is a feasible location.

Polarimeter detectors

to be considered:
-- backgrounds
-- space resolution
-- photon vs electron detector
-- multi vs single event mode?

Blondel et al., arXiv:1909.12245

Laser helicity asymmetries



this is only ±1mm at 100 m distance

Reproductible and well known laser helicity flip is required

Some possible laser systems

nice table by Aurélien (from FCC week)

do we really want
-- multi-photon for pilot bunch
and
-- single photon for colliding bunches
???

would we not prefer similar conditions (# scatterings per shot) for pilot and colliding bunches <u>given that they will be using the same detector?</u>

Nikolai's baseline

Laser param.	1 pilot	1 pilot v2	All colliding bunches (at Z)
Repetition rate	3 kHz	3 kHz	50 MHz
Pulse energy	1 mJ	1 mJ	100 nJ
Pulse duration	5 ns	5 ps (**)	5 ps (**)
Average power	3 W	3 W (***)	5 W (***)
Scattering rate	4×10^5/s (*)	2×10^6/s (****)	2×10^6/s (****)
Scattering rate per bunch	4×10^5/s (*)	2×10^6/s	1.7×10^2/s

Same oscillator may be used but two different amplification schemes

(*) Large piwinski contribution, nearly scales as crossing angle, very dependent on laser beam size (was 2×10^6/s in ref. paper)
(**) Short pulse duration → broader laser spectrum, energy measurement from threshold more difficult
(***) Can be increased to typically ~100W (nowadays) but requires operational validation, management of thermal effects…
(****) not limited by Piwinski contribution → significantly increases when decreasing laser beam size

more burning questions for FCC (II)

2. How feasible is it to depolarize the colliding bunches continuously?

The need to control the longitudinal polarization of the colliding bunches to better than 10^{-5} was stressed by G. Wilkinson
Beam polarization grows by 10^{-6} every second [second=10^{-6} x (250 hours= 0.9 10^{6} s)]

➔ < 10^{-5} requires depolarizing every 10 seconds

Beam polarization grows by 10^{-6} every [second=10^{-6} x (250 hours= 0.9 10^{6} s)]

➔ 10^{-5} requires depolarizing every 10 seconds !!

Can the RF kicker actually take this additional charge?

3. How feasible is it to manipulate the polarization vector in the horizontal plane to measure precession frequency?

what are the specs for the depolarizaer and are they feasible with the envisaged (LHC transverse feedback) kickers

WG4 measurements in particle physics experiments

principle well established with dimuons in the design study paper

-- need to verify that one can match the requirements set by the statistical precision
-- can one use e+e- final state (low angle scattering) to improve the precision esp at high energies (and 125 point)
-- experiments can measure

    -- x, z and t and boost event by event better than beam sizes.
        Ecm spread, E+-E- monitor depolarization
    -- explore more dimensions (x', y', E_{cm}) ?

-- develop idea of energy model and quantify Ecm determination requirements esp at WW.

WP5 monochromatization

still very much uncharted territory.

- **Can we have a sufficient monochromatization optics at the Higgs? (development started!)**
- How much can we reduce the background for the experiments using more info from the beam parameters?
- Can we test monochromatization scheme for Higgs-mode already at the Z-pole?
- Do we need crab-cavities for monochromatization?

etc. etc.

-- **this is all pressing hard/stimulating** on the machine physics, alignments, diagnostics, correction procedures and optimization methods. **(WG2)** Huge progress since LEP times!

A considerable amount of very reliable information comes from the **HEP experiments themselves**. Examples:

- -- measurement of beam polarization from final state tau helicity measurements (SuperKEKb)
- -- measurement of energy spread (and other beam parameters) from $\mu\mu$/ee pairs (even within beam phase space)

Lots of subtle questions were discussed about monochromatization

-- only possible when we are face to face!

Let us continue our investigations this coming week!

Mon 26	Tue 27	Wed 28	Thu 29	Fri 30
Discussions and Work 4/S-020 37/R-022	**Discussions and Work** 4/S-020 37/R-022	**Discussions and Work** 4/S-020 37/R-022	**Discussions and Work** 4/S-020	**Discussions and Work** 4/S-020
Lunch				
Plenary 3162/1-K01 **Extra Rooms** 3150/R-002 37/R-022	**Plenary** 3162/1-K01 **Extra Rooms** 3150/R-002 37/R-022	**Plenary** 3162/1-K01 **Extra Rooms** 3150/R-002 37/R-022	**Plenary** 3162/1-K01 **Extra Rooms** 3150/R-002	**Summary** 13/2-005 **Extra Room** 3150/R-002
Coffee				
empty 37/R-022; **WG3** 3150/R-002; **WG2 WG4** 3162/1-K01	maybe **WG4** 37/R-022; **WG3** 3150/R-002; **WG1** 3162/1-K01	empty 37/R-022; **WG3** 3150/R-002; **WG2** 3162/1-K01	**WG4 WG5** 93/R-031; **WG3** 3150/R-002; **WG1 WG2** 3162/1-K01 **Discussions all WGs** 93/R-031 3150/R-002 3162/1-K01	**Summary** 13/2-005 **Extra Room** 3150/R-002
Break ?				
Discussions, Work or Parallel 37/R-022 3150/R-002 3162/1-K01	**Discussions, Work or Parallel** 37/R-022 3150/R-002 3162/1-K01	**Discussions, Work or Parallel** 37/R-022 3150/R-002 3162/1-K01	**Discussions all WGs** 93/R-031 3150/R-002 3162/1-K01	
			Dinner	