FUTURE CIRCULAR COLLIDER

CERN

Optics Tuning and Corrections for Future Colliders Workshop - Closing Remarks

Jacqueline Keintzel, Yukiyoshi Ohnishi, Rogelio Tomas

On behalf of the OC and the SPC

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.

Overview

Monday, 26 June 2023	
09:00	**Chair** - Rogelio Tomas Garcia (CERN)
09:05	**Welcome** - Michael Benedikt (CERN)
09:20	**FCC-ee lattice** - Katsunobu Oide (Universite de Geneve (CH))
09:50	**FCC-ee new optics proposal**
10:20	Coffee
10:45	**Chair** - Rogelio Tomas Garcia (CERN)
10:46	**Optics tuning challenges in the SuperKEKB**
11:10	**FCC-ee optics tuning simulations** - Simone Liuzzo (ESRF)
11:35	**FCC-ee field quality tolerances** - Esmaeil Ahmadi (IPM- ILSF)
12:00	**Beam-based alignment in the FCC-ee**
12:25	Lunch
13:45	**Chair** - Jacqueline Keintzel (CERN)
13:46	**PBBA alignment at SPEAR and LCLS**
14:10	**Status of optics tuning simulations in the EIC** - Daniel Marx
14:35	**Injection tuning of SuperKEKB towards its luminosity goal**
15:00	**FCC-ee booster optics tuning**
15:25	Coffee
15:50	**Chair** - Yukisoshi Onishi (KEK)
15:51	**Mitigation of synchro-betatron resonances for the FCC-ee bo…**
16:15	**Optics optimization in the EIC interaction region (remote)**
16:40	**ML application at the Argonne APS**

Tuesday, 27 June 2023	
09:00	**Chair** - Xiaobiao Huang (SLAC National Accelerator Laboratory)
09:01	**Lattice correction studies and commissioning simulations fo…**
09:25	**High bandwidth and high precision orbit feedback design for…**
09:50	**Status of optics tuning simulations in the CEPC (remote)**
10:15	Coffee
10:39	**Chair** - Ilya Agapov (Deutsches Elektronen-Synchrotron (DE))
10:40	**Orbit-response based optics correction studies for FCC-ee (re…**
11:05	**IP tuning**
11:30	**Local Coupling Correction in the LHC IRs (remote)**
11:55	**Non-linear correction in the LHC IR**
12:20	Lunch
13:44	**Chair** - Yannis Papaphilippou (CERN)
13:45	**LOCOM2, an idela method for global optics corrections**
14:10	**Online tuning of storage ring non-linear dynamics at SIRIUS…**
14:35	**Automated commissioning for the APS-U** - Vadim Sajaev (ANL)
15:00	Coffee
15:24	**Chair** - Jacqueline Keintzel (CERN)
15:25	**Polarization in electron storage rings (remote)** - Eliana Gianfelice
15:50	**Polarization and optics tuning needs**
16:15	**Preservation of electron polarization ramping in the EIC rapid…**
16:40	**Polarization preservation issues at the CEPC** - zhe duan

Wednesday, 28 June 2023	
09:00	**Chair** - Tatiana Pieloni (EPFL)
09:01	**Alignment plans for the FCC-ee** - Helene Mainaud Durand (CERN)
09:25	**FCC-ee beam instrumentation** - Thibaut Lefevre (CERN)
09:50	**Field corrections for FCC-ee magnets**
10:15	**Beam stability in modern synchrotron light sources**
10:40	Coffee
11:04	**Chair** - Frank Zimmermann (CERN)
11:05	**Optics correction strategy for KOREA-4GSR** - Gyeongsu Jang
11:30	**Beam-based optimization at PAL-XFEL** - Chi Hyun Shim
11:55	**Beam optics tuning with 6dsim** - Aleksandr Romanov
12:20	Lunch
13:40	**Chair** - Yukiyoshi Ohnishi (KEK)
13:45	**Action and phase jump analysis for local error corrections**
14:10	**Towards fully analytical response matrices** - Andrea Franchi
14:35	**Closing remarks**

38 Talks

Experience of 14 machines

Day One - Start

77 registrations

Dinner

42 joined dinner

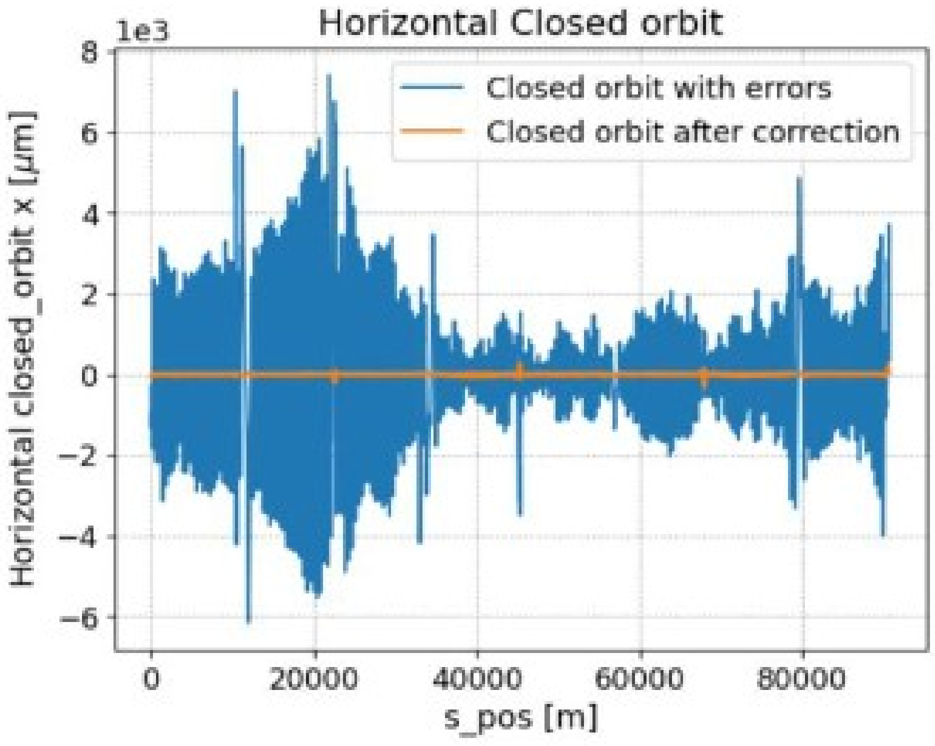
Day Two – After Workshop Dinner

Day Three - Group Picture

Optics Tuning

- Huge effort for various machines ongoing
- Many available codes: MAD-X, pyAT, ELEGANT, 6DSim, ...
- Benchmarking of different lattices for FCC-ee

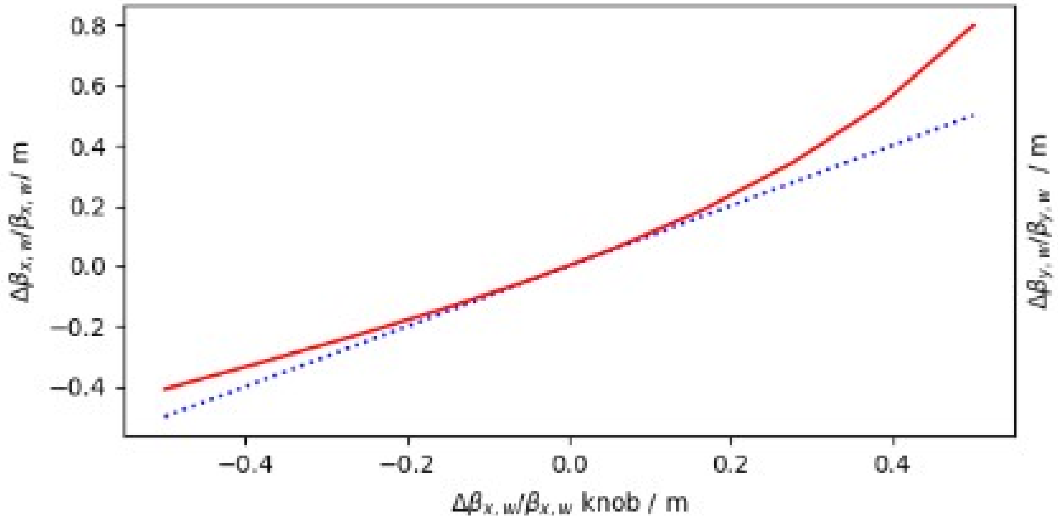
criteria	E_0	#	orbit H 100 µm	orbit V 100 µm	$\Delta\beta/\beta$ H 1 %	$\Delta\beta/\beta$ V 1 %	$\Delta\eta$ H 1 mm	$\Delta\eta$ V 1 mm	$\Delta\epsilon$ H 1%ϵ_h	$\Delta\epsilon$ V 1‰ϵ_h
			arc quadrupoles sensitivity [µm]							
V22	Z	1420	1.9	1.9	2.9	0.7	0.1	0.1	3.0	1.0
HFD61	Z	2408	8.4	7.5	>10	3.0	5.0	1.6	>10	2.7
V22	$t\bar{t}$	2836	1.3	1.5	1.5	0.5	0.12	0.2	0.5	0.17
HFD61	$t\bar{t}$	2408	2.8	3.1	4.2	1.5	1.9	1.0	>10	0.8
			arc sextupoles sensitivity [µm]							
V22	Z	600	>100	>100	17	8.5	3.1	2.6	90	39
HFD61	Z	912	>100	>100	60	26	10	16	>100	>100
V22	$t\bar{t}$	2336	>100	>100	10	7.0	7.5	10	27	26
HFD61	$t\bar{t}$	912	>100	>100	19	8	10	11	78	48

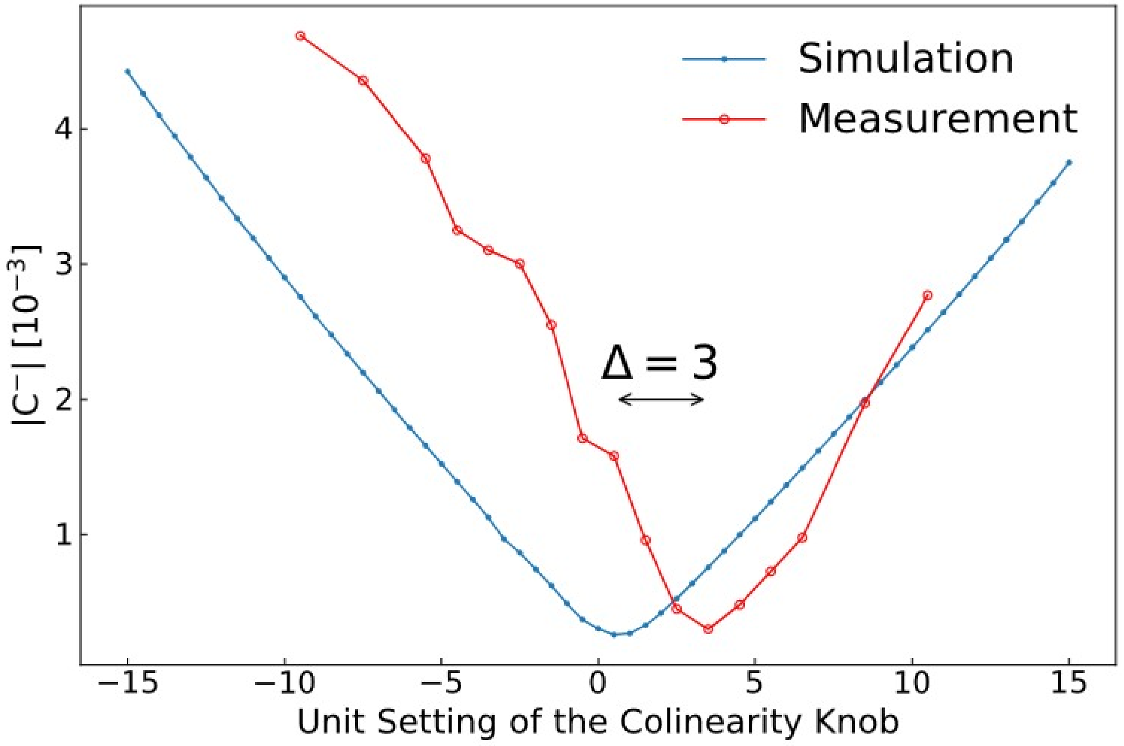


- Essential to define tolerances for future machines

Correction Knobs

- Knobs generated for local corrections
- Knobs allow for easy correction of beta-function, waist, dispersion,etc. at e.g. interaction point

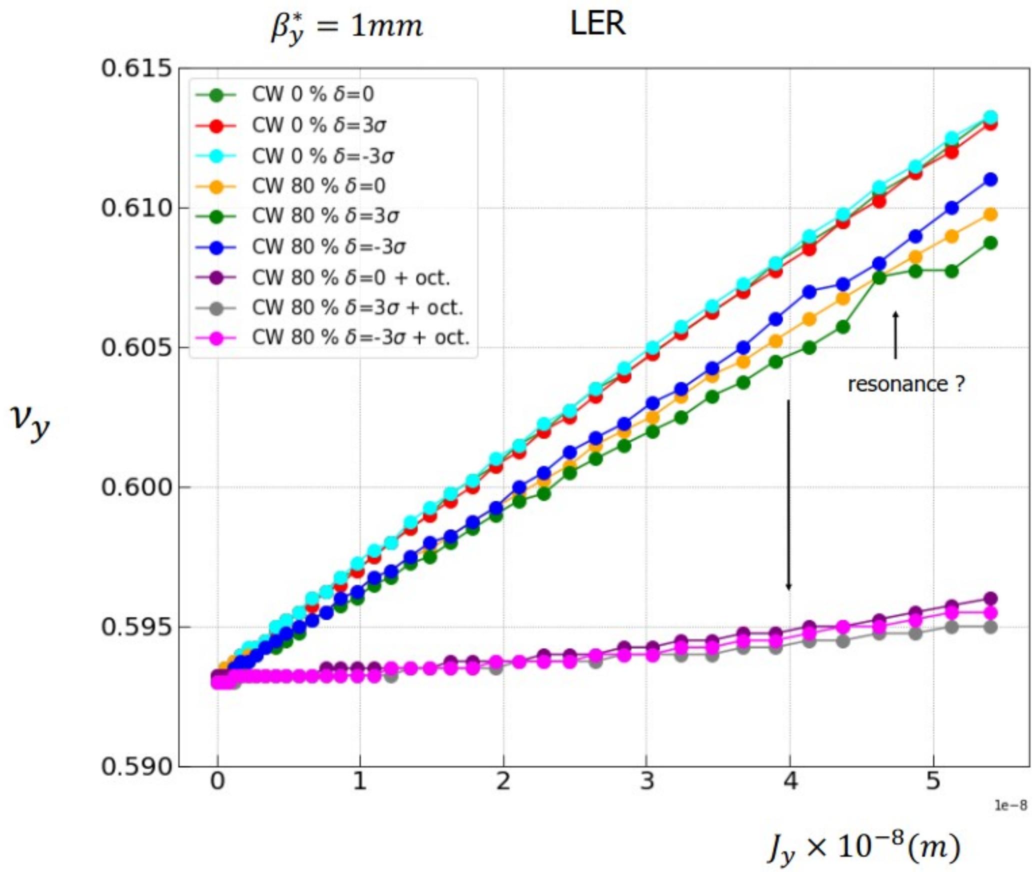




- Rigid waist-shift knob for linear coupling ath the interaction point for LHC
- Up to almost 10 % instantaneous luminosity increase

Non-Linear Optics

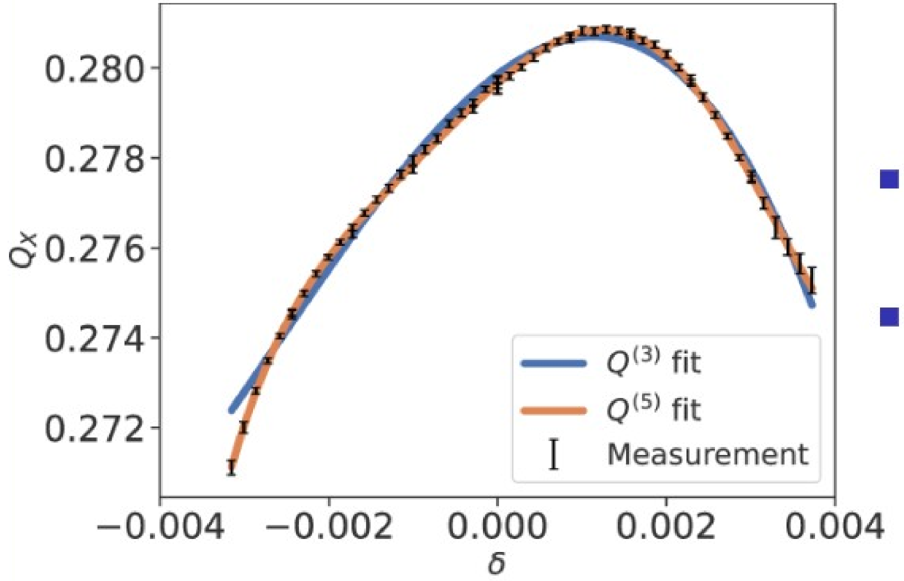
- More machines with large amplitude detuning



nonlinear vs nonlinear

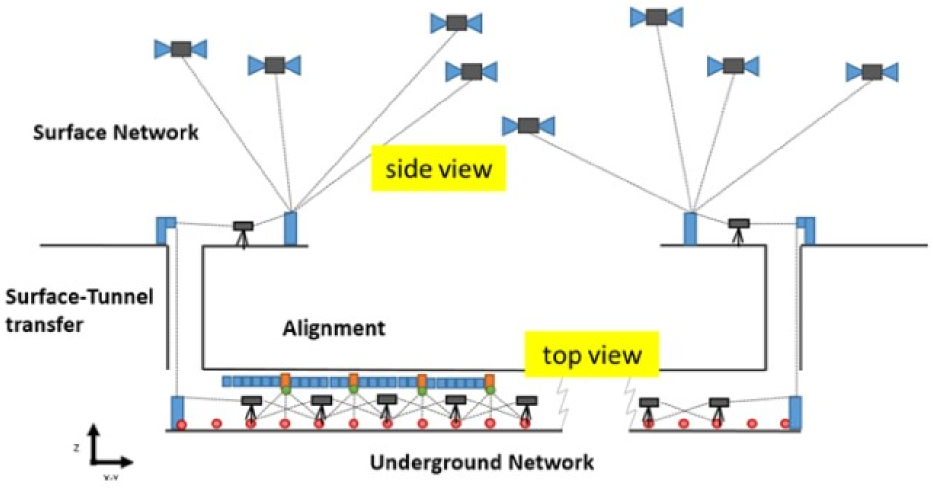
- Crab-waist balance
- Abberations
- Multipole errors

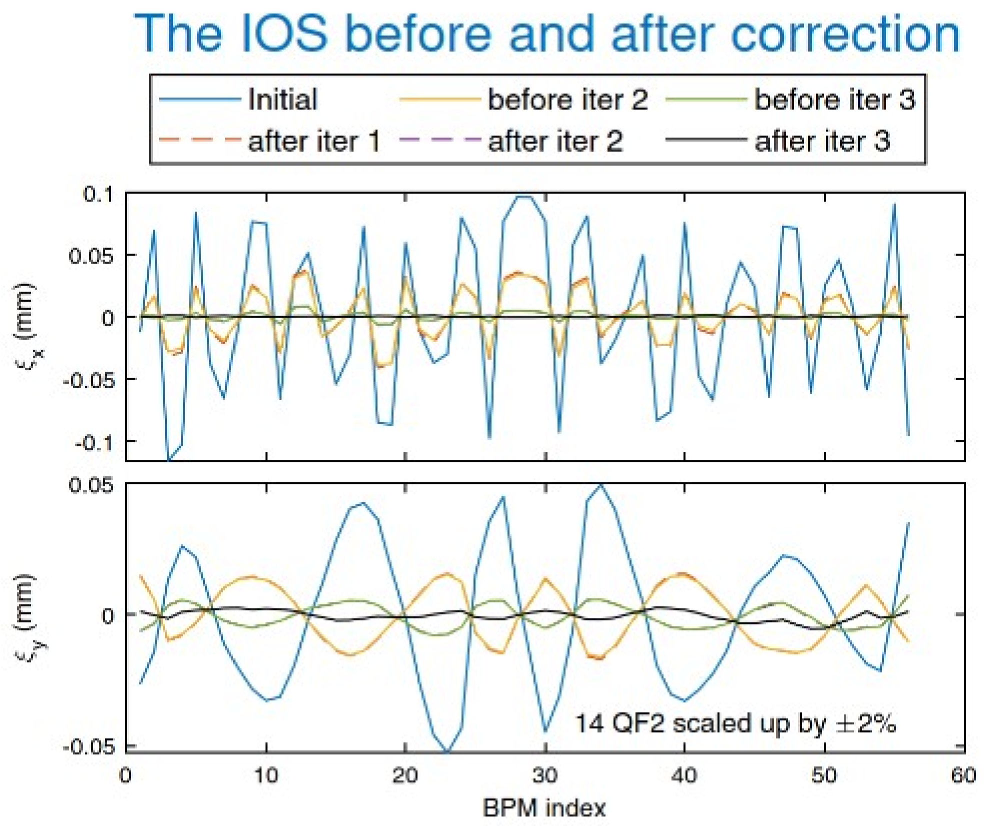
- 5^{th} order chromaticity measured in the LHC



Alignment and BBA

- No existing solutions directly applicable for FCC-ee
- A lot to be learned from LHC, CLIC, etc.



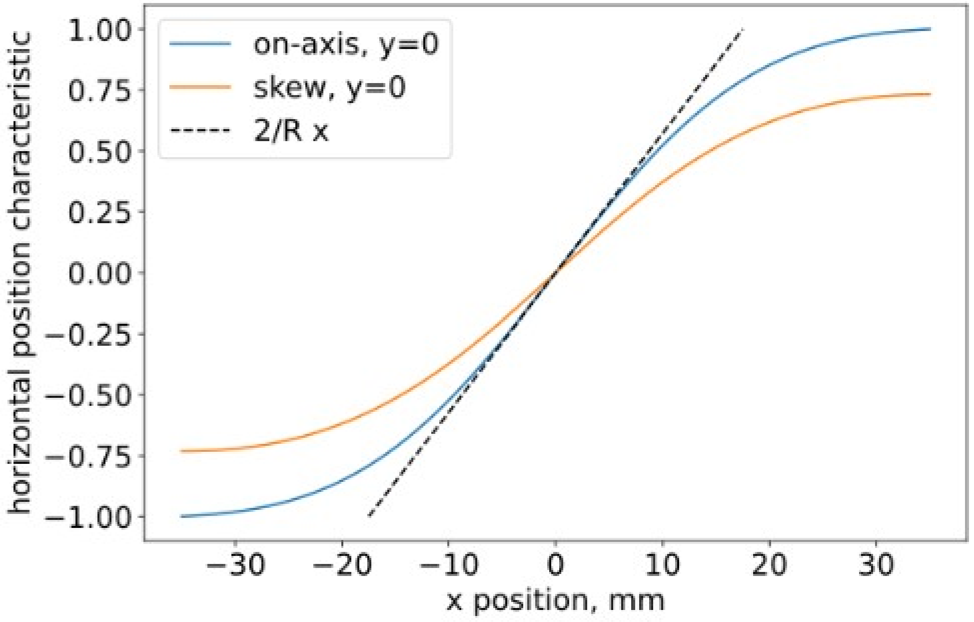


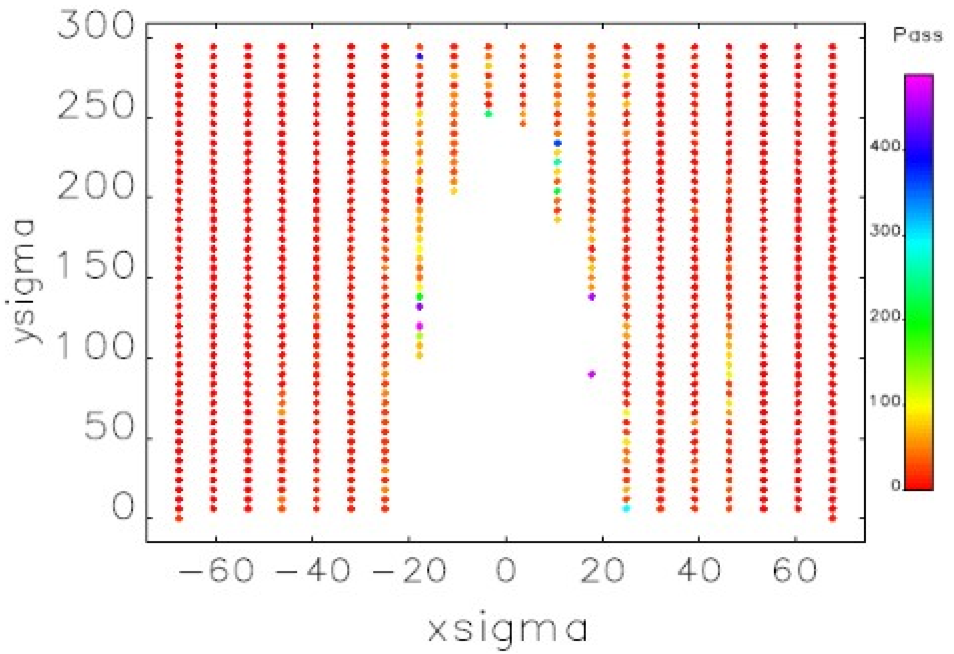
- In ALS-U 35 µm alignment achieved
- 13 µm (H) and 20 µm (V) achieved with BBA

- Parallel BBA reduces significantly time
- Yields comparable results than conventional BBA

Instrumentation and Magnets

- Radiation hard instrumentation required
- BPM specifications being defined (resolution, number)
  - 50 nm for closed orbit, 2 µm for turn-by-turn?
  - At least 1 BPM per quadrupole

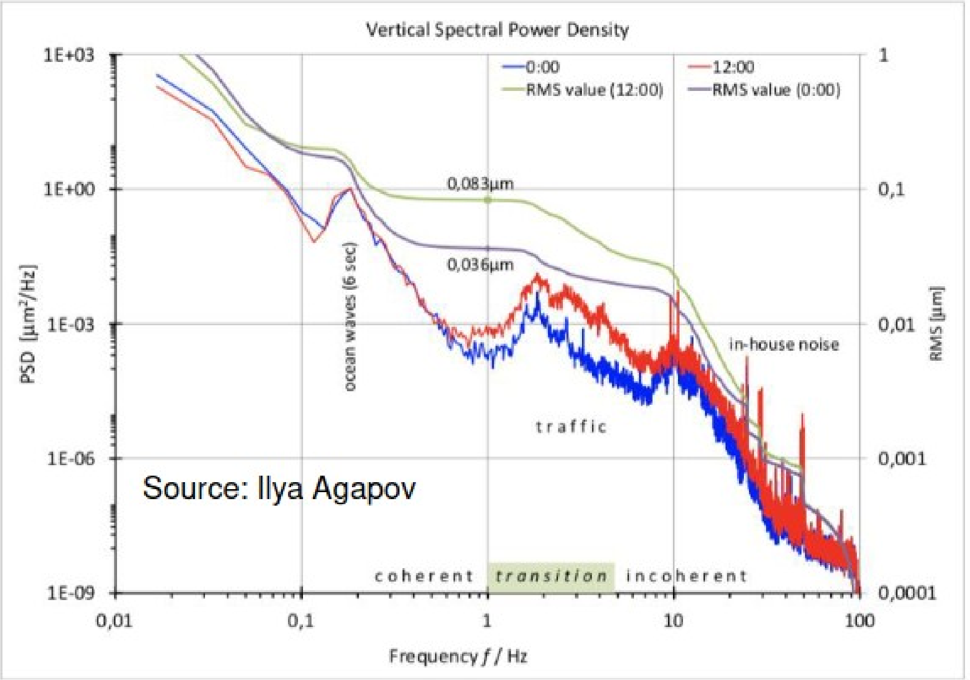




- 0.01 units field error on FCC quadrupoles between local chromaticity correction sextupoles
- New design: 30 units b3/a3 introduced by orbit trim coils
- Longitudinal variation of magnet errors to be studied

Stability and Feedback

- Possible nm stability of final focus required for FCC
- Careful design of feedback systems required



Sources of perturbation: natural + cultural noise

- Long term (weeks - years)
  - Ground settlement
  - Seasonal ground motion
- Medium term (minutes - days)
  - Daily thermal cycle
  - Earth's tides (~12 hrs)
  - Beam intensity/fill pattern
- Short term (milliseconds - seconds)
  - Ocean waves (0.13 Hz), wind
  - Ground vibration due to traffic/trains
  - Rotating machinery (cooling water/AC)
  - Power supply (PS) noise
  - ID gap variation
- High frequency (sub-milliseconds)
  - Synchrotron oscillation
  - Injection transients
  - Beam instabilities

e-be

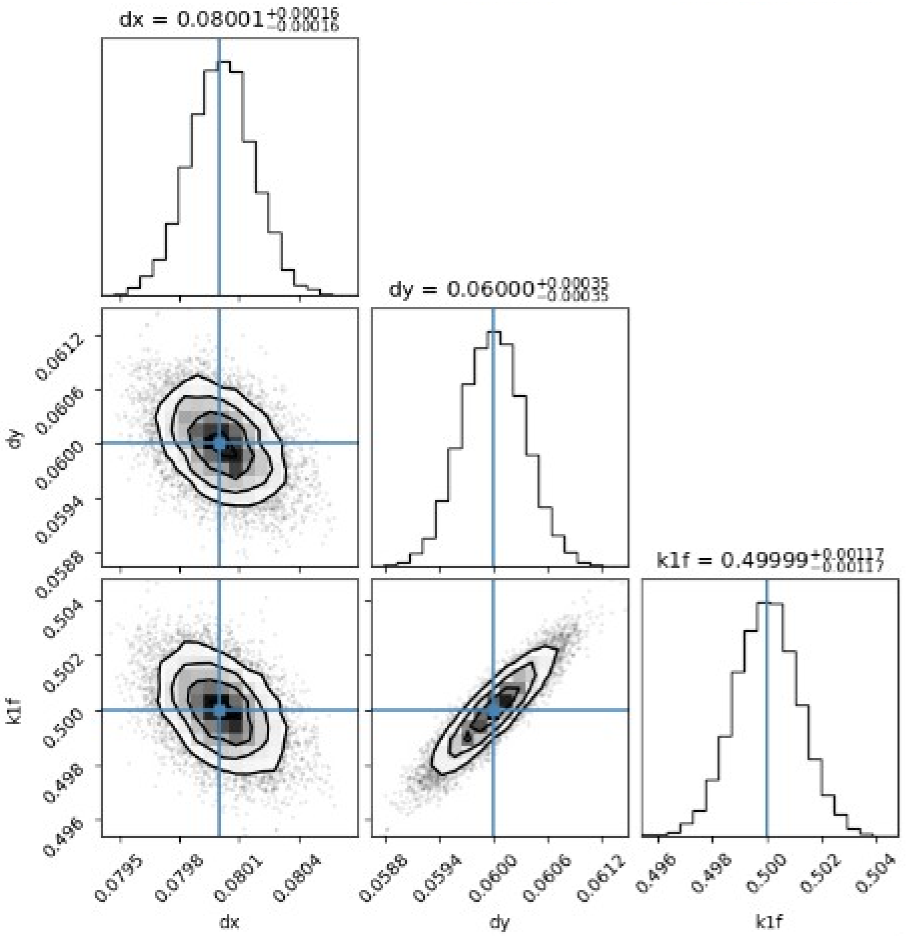
Orbit

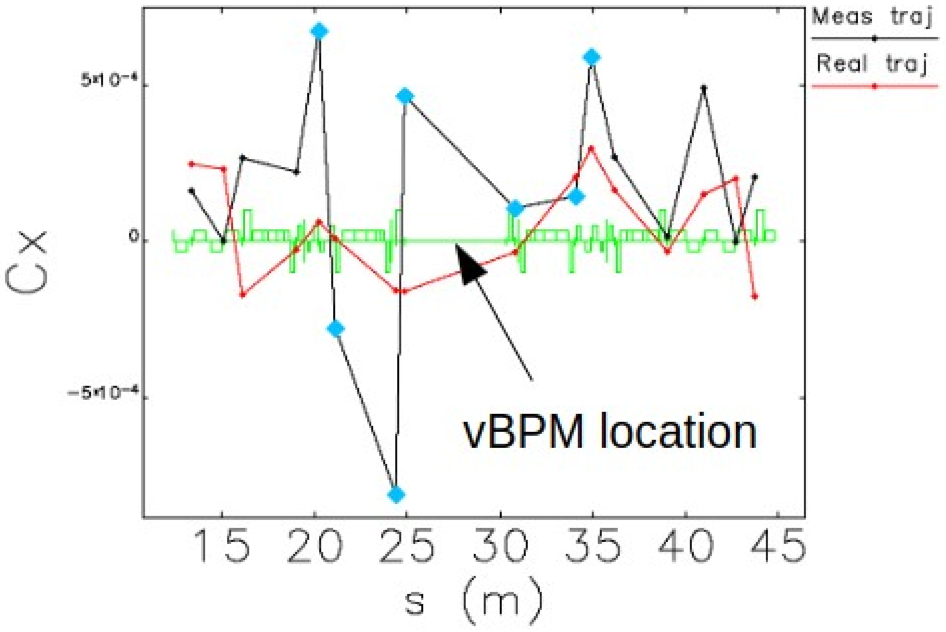
Beam Size

- Measures to improve beam stability
  - Building design
  - Girder – mechanical design
  - Advances in PS stability
  - Advances in BPM and feedback systems

Machine Learning, Automatation

- ML can help in commissioning and to find corrections

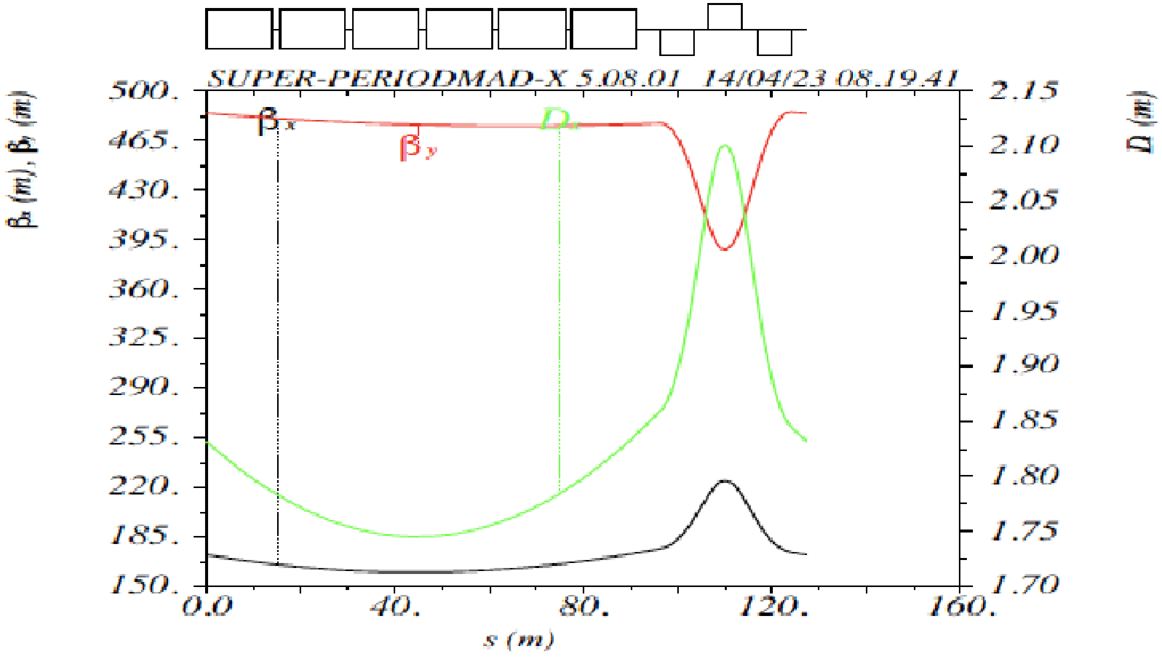


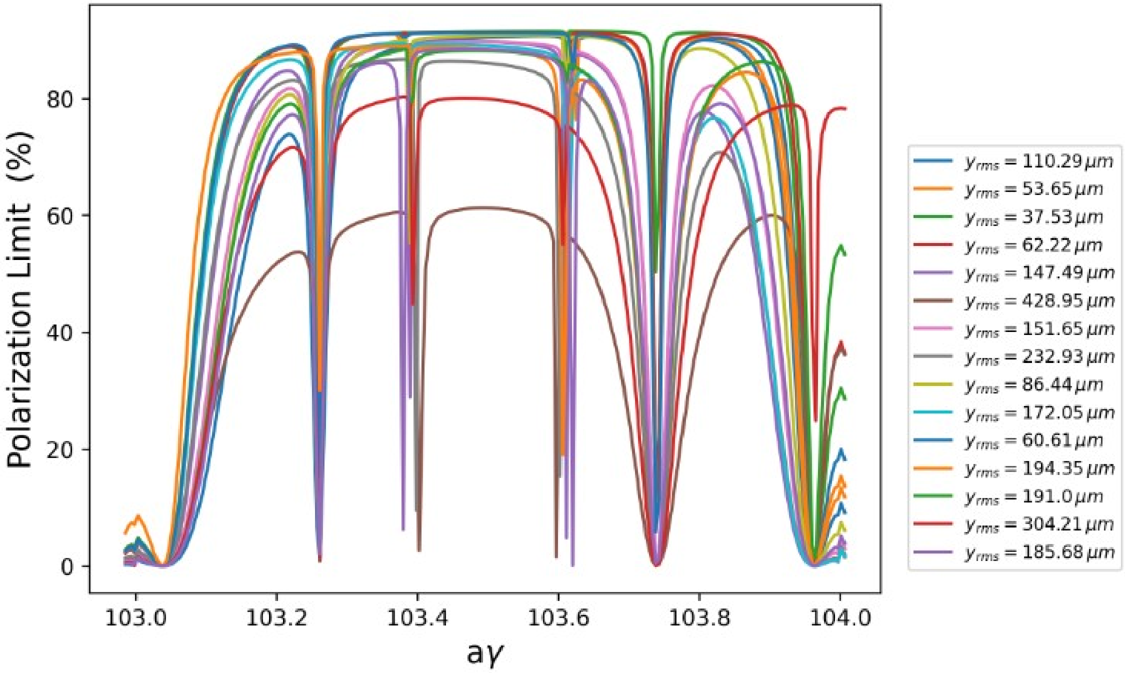


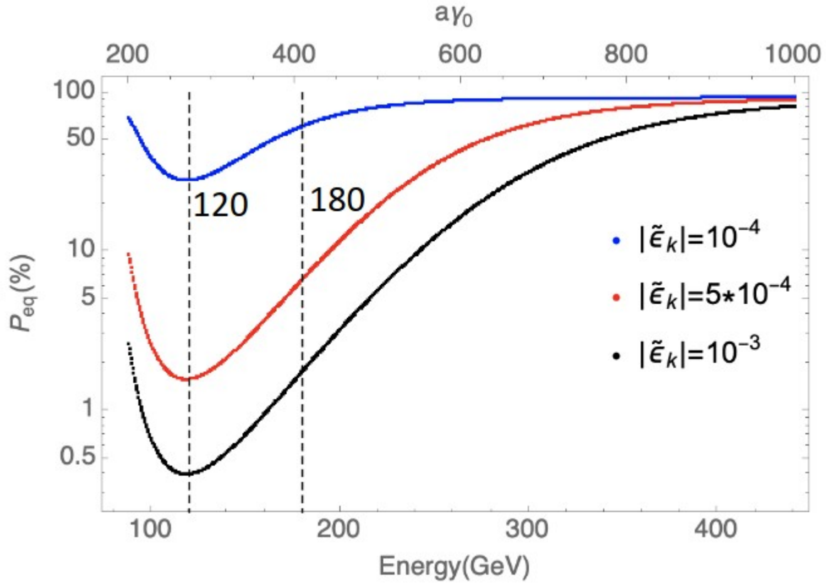
- Automated commissioning is key to fast commissioning
- Additional virtual BMPs introduced to easy correction

Polarization

- Small closed orbit increases polarization level
- Imperfections increase depolarization process
- Resonance cancelling lattice could be designed







Thank you!

Closing Remarks

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Thank you

Thank you

Scientific Program Committee

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