Status of the FCC-ee interaction region design

R. Martin[1] R. Tomás[2] L. Medina[3]

[1]CERN, Geneva, Switzerland and Humboldt University Berlin, Germany

[2]CERN, Geneva, Switzerland

[3]Universidad de Guanajuato, Mexico

HF2014 Workshop, Beijing, China
9-12 October, 2014

Acknowledgments: Thanks to A. Bogomyagkov, B. Holzer, B. Haerer and H. Garcia

This work is supported by the Wolfgang-Gentner-Programme of the Federal Ministry of Education and Research, Germany (BMBF).

Outline

FCC-ee

General information

- FCC-ee project:
  - high-luminosity circular e^+e^--collider
  - center-of-mass energies:
    - 90 GeV (Z-Pole)
    - 160 GeV (W pair production threshold)
    - 240 GeV (Higgs resonance)
    - 350 GeV ($t\bar{t}$ threshold)
  - predecessor of a new 100 TeV pp-collider in same tunnel (80-100 km) in Geneva area
- Interaction region:
  - constraints by use of one tunnel for FCC-ee and FCC-hh (tunnel size $\rightarrow$ cost)
  - most challenging setups: Z (high luminosity) and $t\bar{t}$ (beamstrahlung)

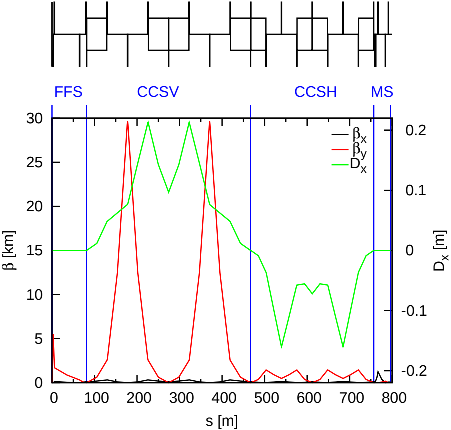
Baseline parameters:

	Z	$t\bar{t}$
Beam energy [GeV]	45.5	175
Crossing angle [mrad]	11	
Bunches / beam	16700	98
Bunch population [10^{11}]	1.8	1.4
Beta function at IP β^*		
- horizontal [m]	0.5	1
- vertical [mm]	1	1
Transverse emittance ϵ		
- horizontal [nm]	29.2	2
- vertical [pm]	60	2
Beam size at IP σ^*		
- horizontal [μm]	121	45
- vertical [μm]	0.25	0.045
Luminosity / IP [10^{34}cm^{-2}s^{-1}]	28.0	1.8

100 km option. Bunches / beam and bunch population determined by the design limit of 50 MW synchrotron radiation per beam.

CERN IR design

- based on generic lattice for LINACs
- local chromaticity correction necessary due to high luminosity goals
- spacial separation of functions $\rightarrow$ modular



CERN IR design. Currently only $t\bar{t}$ setup exists.

Final Focus System

- L^* as small as possible (chromaticity) but large enough for detector
  $\rightarrow L^* = 2m$ considered reasonable
- crossing angle:
  - small crossing angle preferred to keep tunnel diameter small and dipole fields small
  - shared FFS quadrupoles (6 σ_{p_x} separation):

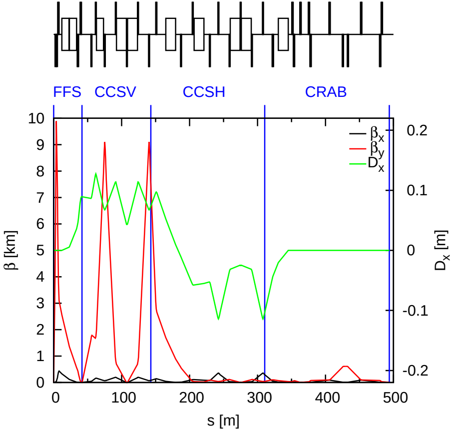
	Z	$t\bar{t}$
average Power from Q1 [kW]	96.8	3.5
average Power from Q2 [kW]	423.0	15.1

Values are per beam and per Quadrupole.

  $\rightarrow$ separate quadrupoles for each beam
  - magnet studies for SuperB and BINP suggest separation of ≈ 22 mm
    $\rightarrow$ minimum crossing angle $= 11$ mrad

BINP IR design

- Different approach: crab waist scheme increases luminosity at lower energies (Z,W)
- no considerable advantage over head-on collision scheme at high energies (H, $t\bar{t}$)
- crossing angle $= 30mrad$
- Parameters chosen to take advantage of crab waist scheme, but also allow running at all energies with one lattice



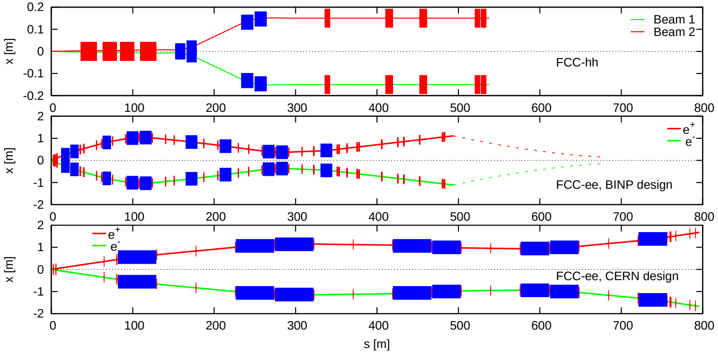
BINP IR design.

Parameters for crab waist scheme

	Z	$\mathbf{t\bar{t}}$
Beam energy [GeV]	45.5	175
Crossing angle [mrad]	30	
Bunches / beam	29791	33
Bunch population [10^{11}]	1	4
Beta function at IP β^*		
- horizontal [m]	0.5	
- vertical [mm]	1	
Transverse emittance ϵ		
- horizontal [nm]	0.14	2.1
- vertical [pm]	1	4.3
Beam size at IP σ^*		
- horizontal [µm]	8.4	0.3
- vertical [µm]	0.03	0.07
Luminosity / IP [10^{34}cm^{-2}s^{-1}]	212	1.3

100 km option, crab waist scheme.

Geometry



- tunnel diameter of both FCC-ee designs $\approx 2m \rightarrow$ reasonable
- still need for matching section bending beams back together, place for RF
- CERN design far too long, even for longer FCC-hh, BINP design might work out

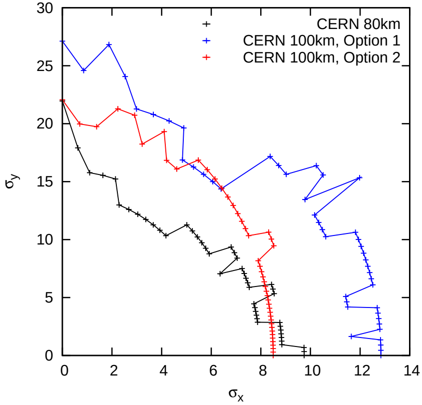
Synchrotron radiation load

- larger luminosity in crab waist scheme (8x at Z, 2x at W, 1.6x at H) but has stronger dipole fields
- overall synchrotron radiation in 4 IPs for BINP design: 5.6MW ($\approx$ 10% of overall synchrotron radiation budget)
- Studies needed to determine if radiation hits detector and shielding is required

	Z	$t\bar{t}$
Average total power per IP [kW]		
- CERN	138	138
- BINP	1460	1410
Energy loss per particle per IP [MeV]		
- CERN	0.8	168
- BINP	2.0	440
Average power in last dipole [kW]		
- CERN	7.3	7.3
- BINP	8.2	8.0
Critical Energy in last dipoles $\hbar\omega_c$ [keV]		
- CERN	8.8	503
- BINP	20	1100

Dynamic aperture

- first tracking calculations with full 100 km arc lattice were conducted
- preliminary matching to arcs
- all simulations for on-momentum particles, 500 turns, without radiation
- CERN: calculations for different working points
- Aim is to find working lattice with acceptable dynamic aperture and momentum acceptance, refinement later
- DA for CERN: up to 12 σ_x and 25 σ_y

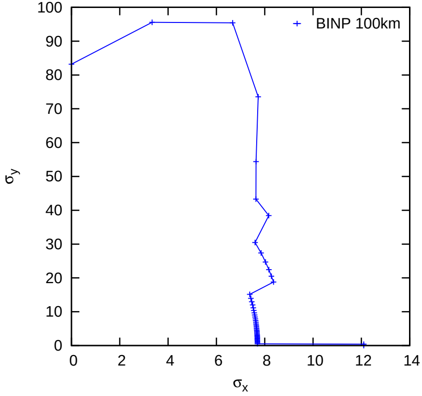


Dynamic aperture

- BINP: 8 σ_x but 100 σ_y (important because vertical beamsize is very small $\rightarrow$ imperfactions have large relative impact)

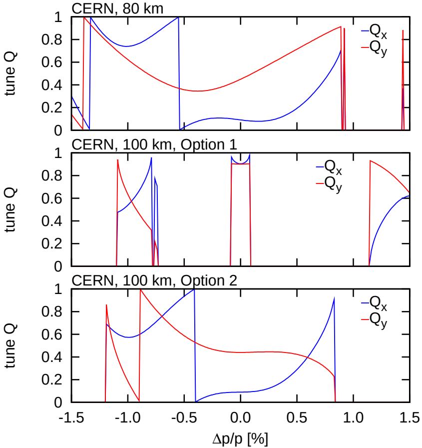
	ψ_x	ψ_y
CERN, 80 km	0.77	0.61
CERN, 100 km, Option 1	0.48	0.23
CERN, 100 km, Option 2	0.77	0.11
BINP, 100 km	0.54	0.57

Non-integer part of phase advance between the IPs



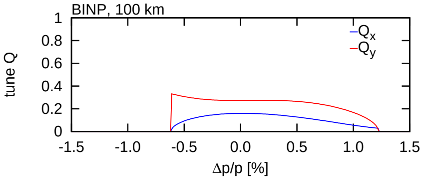
Momentum acceptance

- recent beam-beam studies: minimum momentum acceptance at $t\bar{t}$ energy between $\frac{\Delta p}{p} = 1.5\%$ and 2.0% $\rightarrow$ beamstrahlung lifetime between $0.4min$ and $6min$
- relaxed requirements for lower energies
- Montague W functions not yet matched



Momentum acceptance

- CERN: highest Momentum acceptance from $-0.6\,\%$ to $0.9\,\%$
- BINP: from $-0.6\,\%$ to $1.2\,\%$
- Considering preliminary matching, results give hope that required momentum acceptance is achievable



Outlook

- refinement of matching sections to properly match Montague W functions $\rightarrow$ optimization momentum acceptance
- CERN design still at very early stage, a lot of potential for optimization (dynamic aperture, momentum acceptance)
- further tune scans of CERN design to find better relation of dynamic aperture and momentum acceptance
- rematching of both designs to lower energy arc lattice
    - Dynamic aperture
    - momentum acceptance
- Studies of dynamic aperture vs. momentum deviation

Thank you for your attention