Status of the FCC-ee interaction region design

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Outline

- 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)

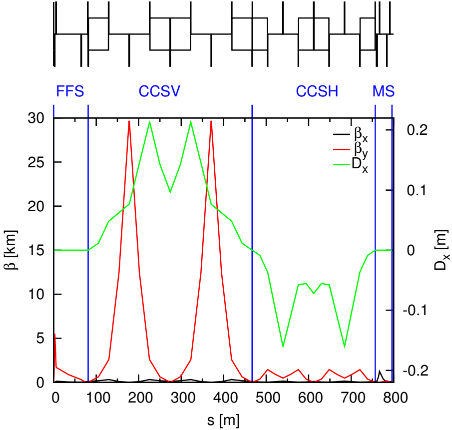
Baseline parameters:

	Z	$t\bar{t}$
Beam energy [GeV]	45.5	175
Bunches / beam	16700	98
Bunch population [10^{11}]	1.8	1.4
Energy loss / turn [GeV]	0.03	7.55
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
Energy spread [%]	0.06	0.19
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):

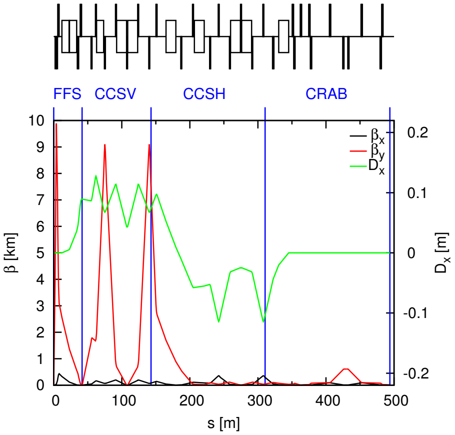
	Z	$t\bar{t}$
average Power from Q1 [kW]	96.8	3.5
average Power from Q2 [kW]	423.0	15.1

Values are per beam and per Quadrupole.

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

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 $= 30 mrad$
- Parameters chosen according to crab waist scheme, but also allow running at all energies with one lattice



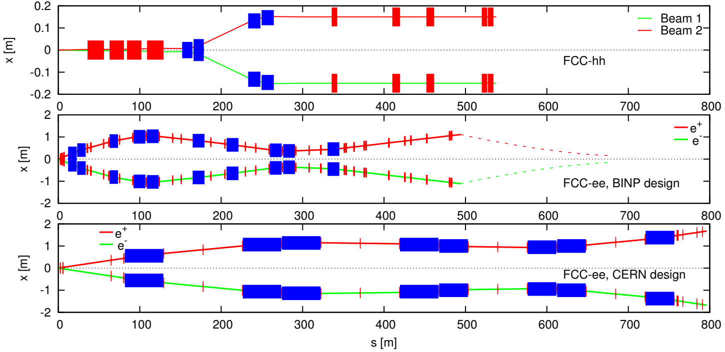
BINP IR design.

Parameters for crab waist scheme

	Z	$t\bar{t}$
Beam energy [GeV]	45.5	175
Bunches / beam	29791	33
Bunch population [10^{11}]	1	4
Energy loss / turn [GeV]	0.03	7.7
Beta function at IP β^*		
- horizontal [m]	0.5	0.5
- vertical [mm]	1	1
Transverse emittance ϵ		
- horizontal [nm]	0.14	2.1
- vertical [pm]	1	4.3
Energy spread [%]	0.11	0.26
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
- CERN design far too long, even for longer FCC-hh, BINP design might work out

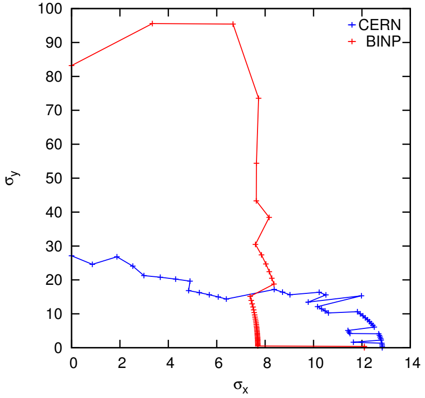
Synchrotron radiation load

- 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)
- last dipoles in BINP design close to IP and high critical energy $\rightarrow$ shielding difficult

	Z	$t\bar{t}$
Average total power per side per IP [kW]		
- CERN	69	69
- BINP	730	710
Energy loss per particle [MeV]		
- CERN	0.4	84
- BINP	1.0	220
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

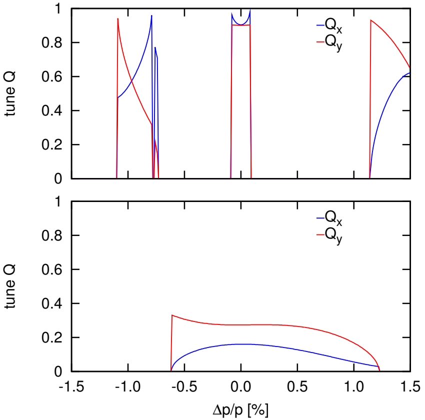
Dynamic aperture

- first tracking calculations with full 100 km arc lattice were conducted
- all simulations for on-momentum particles, 500 turns, without radiation
- CERN: up to 12 σ_x and 25 σ_y
- BINP: only 8 σ_x but 100 σ_y which is important because vertical beamsize is very small $\rightarrow$ imperfactions have large relative impact



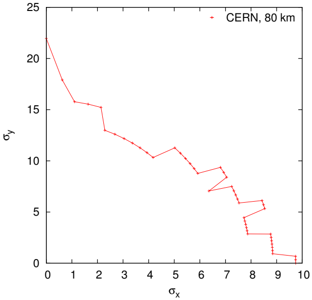
Momentum acceptance

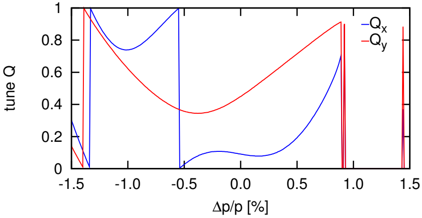
- recent beam-beam studies: minimum momentum acceptance at $t\bar{t}$ energy between $\frac{\Delta p}{p} = 1.5\%$ and 2.0% $\rightarrow$ beamstrahlung lifetime between $0.4 min$ and $6 min$
- relaxed requirements for lower energies
- both design far from goal yet (CERN $\pm 0.1\%$, BINP from -0.6% to $+1.2\%$)



top: CERN 100 km, bottom: BINP 100 km. For empty sections no stable orbit was found.

CERN, 80 km option





CERN 80 km option.

Outlook

- rematching of both designs to lower energy arc lattice
  - Dynamic aperture
  - momentum acceptance
- CERN design still at very early stage, a lot of potential for optimization (dynamic aperture, momentum acceptance)
- Studies of dynamic aperture vs. momentum deviation

Any comments welcome