RF WP2: Cavity Design and Beam Interaction

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WP2 Scope

For the moment concentrated on FCC-ee

Cavity design for FCC-ee

- Study and optimization of RF cavities for high energy operation
- Study and optimization of RF cavities and Higher Order Mode damping scheme for high intensity operation

Cavity design for FCC-hh

- Study and optimization of RF cavities for high intensity operation

Beam dynamics

- Beam dynamics and impedance studies for FCC-ee and FCC-hh

Low-Level RF

- Definition of LLRF requirements for FCC-ee and FCC-hh
- LLRF requirements for FCC-hh

Cavity design summary (FCC-ee)

Design of cavity for high energy operation (S. Gorgi, Uni. Rostock):

- 4-cell 800MHz for H and tt machines
- Optimized for peak fields, losses, field flatness, HOMs placement & propagation...
- fixed input coupler Q_{ext}=2.2x10^6 good for H and tt
- HOMs, coupled bunch growth rates vs SR damping
- LHC-style HOM damping (2xBB + 2xNB couplers)

Parameters	Value
Frequency [MHz]	801.58
Number of Cells	4
R/Q [Ω]	417
Geometry Factor [Ω]	273
H_{pk}/E_{acc} $[mT/(MV/m)]$	4.3
E_{pk}/E_{acc}	2.05
Cavity Active Length [mm]	733.8
Cell to cell coupling of mid cells [%]	2.25
Field Flatness [%]	99
$k_{\|\|}(\sigma_z = 2mm)$ [V/pC]	2.7
$k_{\perp}(\sigma_z = 2mm)$ [V/pC/m]	3.1
HOM Power for H beam [kW]	0.84
E_{acc} [MV/m]	20
No. of cavities needed for H machine	200
Q_{ext} of input coupler [10^6]	2.2

Beam dynamics summary (FCC-ee)

- Simulation code for lepton machines:
  - SR effects added to longitudinal simulation code BLonD
- Single bunch stability:
  - estimations of microwave instability thresholds using BLonD in agreement with previous results
  - strong SR damping keeps bunch stable even for Z machine
- Coupled bunch stability for HOMs:
  - analytical estimation of threshold wrt SR damping
  - some modifications to BLonD to facilitate coupled-bunch simulations
- HOM power
  - Estimation for bare cavity (JE Mueller): 0.8 to 1.5kW for Z machine single cell 400MHz
  - Calculations with different layouts (with tapers + beam pipes) ongoing (Ivan)

LLRF summary (FCC-ee)

- Most challenging: Z machine (I_b = 1.45 A)
- Some input & simulations from D. Teytelman (DimTel Inc.)
  - “Extremely challenging, similar to high current SuperPEP2 ideas, RF system design must be driven by beam loading considerations”
  - Choice of filling pattern to minimize transients
  - Need aggressive RF feedback to manage longitudinal instabilities driven by large detuning at 1.45 A
    - without feedback longitudinal growth time is 1.6 ms (cf SR damping time of 440 ms)
    - minimum number of cavities/maximum cavity voltage to minimize detuning