Plans for studies of a collimation system for FCC-ee

R. Bruce, A. Abramov, M. Moudgalya, S. Redaelli

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Status of FCC-ee collimation

• Collimation for background control previously studied by M. Luckhof, H. Burkhardt, M. Boscolo and others

• Around 20 collimators inserted for minimizing synchrotron radiation background at experiments, and off-momentum collimators in IRs for thermal scattering

• Do we need further collimators?
  – For comparison: LEP had ~100 collimators
Damage from beam losses

- Other lepton colliders suffered from damage to collimators
- SuperKEKB example:

> "In high-current operations at 500 mA or above, the jaws were occasionally damaged by hitting abnormal beams, as shown in Fig. 16."

FIG. 16. Photograph of a damaged jaw in (a) a top side and (b) a bottom side of the D06V2 collimator. The traveling direction of the beam is from left to right in this photograph.
Stored energy in lepton colliders

The total beam energy in various lepton colliders.

- LEP 2
- SuperKEKB (e-)
- SuperKEKB (e+)
- HERA (leptons)
- PEP II (e-)
- PEP II (e+)
- FCC-ee: 182.5 GeV
- FCC-ee: 175 GeV
- FCC-ee: 120 GeV
- FCC-ee: 80 GeV
- FCC-ee: 45.6 GeV

M. Moudgalya
Control of beam losses in FCC-ee

- FCC-ee will have a stored beam energy of up to 20.6 MJ (at 45.6 GeV for Z measurements)
  - This is the same stored beam energy as foreseen in HL-LHC heavy-ion runs!
  - Even though most magnets are normal-conducting, control of beam losses is important
    - Need to avoid damage to components from beam losses
    - Need to avoid quenches of the super-conducting elements (final focus doublets – potential aperture bottleneck, RF cavities...)

- Several known processes will cause regular beam losses
  - Continuous losses from radiative Bhabha-scattering, beamstrahlung, thermal photon, Touschek effect, beam-gas...
    - Combined beam lifetime down to 18 minutes

- Irregular losses from instabilities, failures ...

- In addition: Beamstrahlung photons with up to >400 kW total power, lost downstream of IP
Different types of collimators

• Where do these losses end up?
  – Risk for losses on collimators and aperture bottlenecks in front of experiments?

• Collimators should help protecting the machine and ensure smooth operation

• Roles of collimation in FCC-ee
  – Background control
  – Cleaning of betatron and off-momentum halo - Localize losses to area far away from experiments
  – Protection from damage
  – Protection from quenches (superconducting doublets in final focus, superconducting RF – rest of machine normal conducting)
  – Local protection of hotspots and in front of sensitive elements
    • Intercept collision products
    – All this while keeping impedance under control

• Not looking at protection of arc magnets from continuous synchrotron radiation – need local, distributed solutions. Work ongoing in vacuum/FLUKA teams
Work plan

• **First step: halo collimation system** – not previously studied
  – Localize regular and irregular losses far away from experiments
  – Protect from damage and quenches

• Later: could continue studies of collimation in experimental insertions, in collaboration with MDI colleagues

• People to work on FCC-ee collimation
  – EPFL master student (M. Moudgalya)
  – Fellow just started in ABP collimation team (A. Abramov)
  – Hope to collaborate with many of you (e.g. optics, MDI, impedance, energy deposition)
General workflow (1)

• Define requirements for collimators
  – Get an overview of the aperture to protect, “beam stay clear”, betatron and off-momentum
    • Need model of mechanical aperture – under study
    • Need to define expected errors and tolerances (emittance, optics correction, orbit correction, alignment…)
    • Allows to define first guess on needed collimator cuts, assuming that they should be the aperture bottlenecks of the ring
    • Also cannot have too tight collimators – could influence lifetime
      – E.g. certain momentum acceptance needed to re-capture particles after beamstrahlung

• Loss scenarios to protect against. What happens without collimators?
  • Define reference beam loss cases, study locations and magnitude of beam losses
  • Look at regular and accidental losses
General workflow (2)

• Make preliminary proposal for new collimators
  – Define placement in ring
  – First proposal for optics (collaboration with optics team)
    • Initial proposal discussed to scale LHC insertion
    • Considering constraints on minimum gap - probably not a hard constraint
  – Study whether a multi-stage system is needed (LEP had one!)
    • First “zero-order” guess: scale LHC system
  – Study if we need separate systems for betatron and off-momentum cleaning
  – Simulate cleaning process and residual losses
    • Study specific loss processes and “generic” beam halo
    • Study risk of collimator damage
  – Study of materials: compromise between robustness, impedance, absorption
  – Potential need of energy deposition studies (in collaboration with FLUKA team)
  – Provide inputs for impedance calculations to impedance colleagues

• At a (much) later stage: think about mechanical design of collimators
Placement of collimation system?

• Which IRs are still “free” to be used for halo collimation?
  – 2 or 4 experiments?

• In FCC-hh, using IRJ for betatron cleaning and IRF for momentum cleaning
  – In FCC-ee, IRJ taken by RF
  – Is IRF still free?
    • Polarimeter installation still gives some space
Simulation codes for collimation

• Requirements:
  – Magnetic tracking, ideally including tapering and synchrotron radiation
  – Beamstrahlung? Beam-beam?
  – Particle-matter interactions inside collimators
  – Satisfactory speed for multi-turn tracking in 100 km lattice

• Some candidate codes to be examined, but no 1-to-1 match (yet)
  – SixTrack + scattering routine (e.g. FLUKA), BDSIM, MDISIM, Merlin++, ....
Meetings

• Work to be reported to meetings where useful
• Plan to restart FCC collimation meeting (previously focused on FCC-hh, and to a minor extent HE-LHC collimation)
  – Can be used for detailed technical follow-up
  – Anyone interested to join this meetings can sign up to the e-group *fcc-collimation-design* or email Roderik
• Where useful, we can report results of more general interest to the FCC-ee optics design meeting and/or the MDI meeting
Conclusions

• Up to 20.5 MJ beam energy foreseen – about two orders of magnitude higher than SuperKEKB

• Losses could be critical
  – A number of regular loss processes are well known
  – Irregular losses due to instabilities, failures etc possible
  – Need to localize regular and irregular losses away from experiments
  – Need to protect the machine from damage (and quenches of superconducting magnets)

• Very likely we need a collimation system in FCC-ee to ensure safe and smooth operation

• In addition to existing collimators for background control, will likely need
  – Halo collimators
  – Local protection of hotspots

• Work starting on a collimation system for FCC-ee to fulfill these needs

• Collaboration and inputs are very welcome!