# Challenges for FCC-ee Machine Detector Interface Studies

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# Overview

- The FCC-ee collider is a very challenging machine, with unprecedented high $e^+e^-$ c.m. energy, luminosity…and circumference.

- The Machine Detector Interface group aims at designing the Interaction Region in all its aspects.
- We need a flexible design: a single IR for all the different energy ranges, from 45 to 175 GeV, is the first solution being considered.
- The crab-waist collision scheme is chosen to achieve the highest possible luminosity.
- The large crossing angle (30 mrad) together with the high beam energy may induce in principle high Synchrotron Radiation into the detector, driving the IR layout.
- The MDI group aims at a feasible IR design.

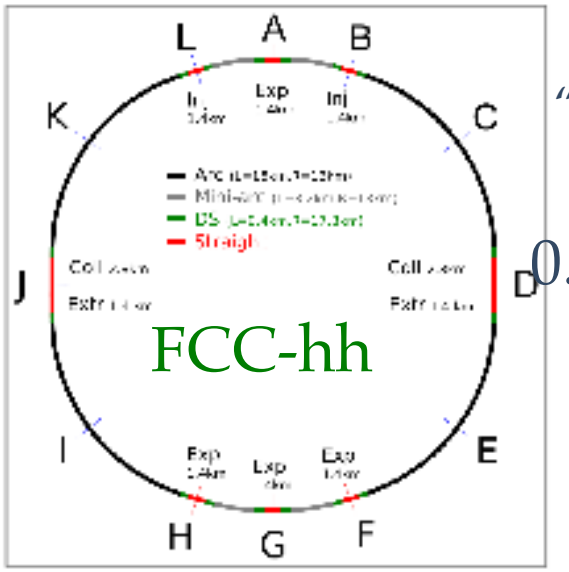
# FCC-ee baseline parameters

| | Z | | WW | ZH | $tt_{bar}$ |
|---|---|---|---|---|---|
| energy/beam [GeV] | 45.6 | | 80 | 120 | 175 |
| bunches/beam | 30180 | 91500 | 5260 | 780 | 81 |
| bunch spacing [ns] | 7.5 | 2.5 | 50 | 400 | 4000 |
| bunch population [$10^{11}$] | 1.0 | 0.33 | 0.6 | 0.8 | 1.7 |
| beam current [mA] | 1450 | 1450 | 152 | 30 | 6.6 |
| H/V emittance [nm] | 0.2 | 0.09 | 0.26 | 0.61 | 1.3 |
| Vertical emittance [pm] | 1 | 1 | 1 | 1.2 | 2.5 |
| luminosity/IP x $10^{34}cm^{-2}s^{-1}$ | 210 | 90 | 19 | 5.1 | 1.3 |
| energy loss/turn [GeV] | 0.03 | 0.03 | 0.33 | 1.67 | 7.55 |
| SR power /beam [MW] | 50 | 50 | 50 | 50 | 50 |
| RF voltage [GV] | 0.4 | 0.2 | 0.8 | 3.0 | 10 |
| Energy acceptance RF [%] | 7.2 | 4.7 | 5.5 | 7.0 | 6.7 |
| Luminosity lifetime [min] | 94 | 185 | 90 | 67 | 57 |

# Some of the main Challenges

- Synchrotron Radiation is the main constraint for IR design and it drives the IR optics and layout.
- Feasibility of magnetic system -main detector magnet, final focus elements, compensation magnets- has to be investigated, also with R&D.
- Luminosity measurement, as well as other particle detectors, are part of the IR design, challenge: very close to IP.
- Accelerator and IP Backgrounds: full simulation to check detector sustainability and design proper masking.
- Underground infrastructure is a challenge it itself, of course, together with MDI group compatibility with FCC-hh option has to be assured.

# Layout of FCC-ee




11.9 m IP

30 mrad

FCC-hh/ Booster

9.4 m

"Middle straight" ~1570 m

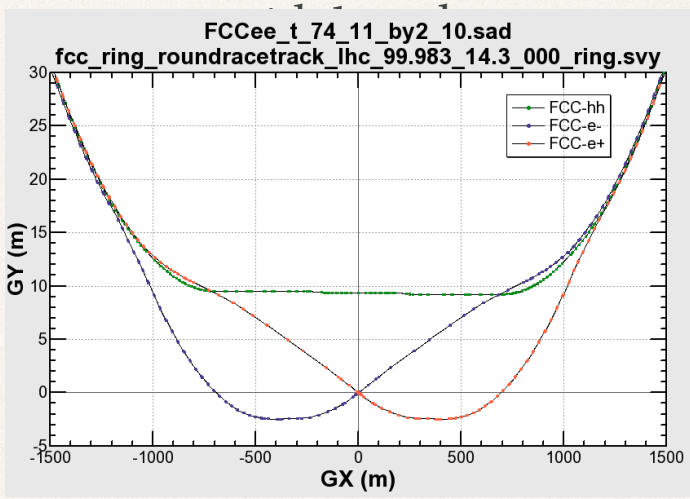
0.6 m

Beams must cross over through the common RF (@ tt) to enter the IP from inside.
Only a half of each ring is filled

"90/270 straight" ~4.7 km

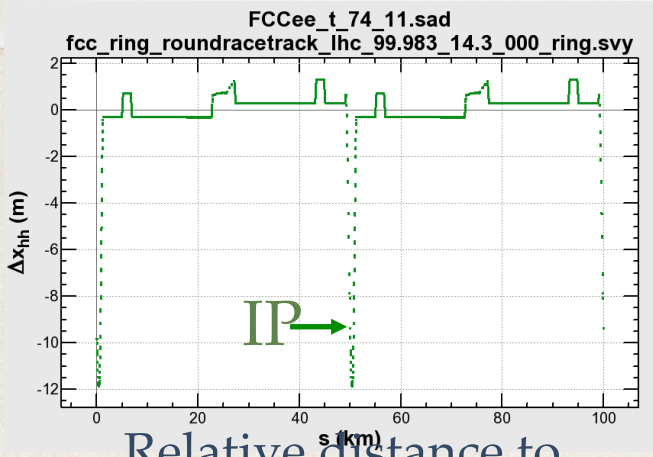
Common RF (tt)

Common RF (tt)




The separation of 3(4) rings is about 12 m: wide tunnel and two tunnels are necessary around the IR, for ±1.2 km.
A more compact layout/optics around the IP is also possible(A. Bogomyagkov).

IP




Relative distance to FCC-hh

K. Oide

# MDI Work Plan

**Step 1:**

- Design a IR Layout, main constraint is from SR
- Develop a detector model, starting from CLIC model

**Step 2:**

- effects of SR in the detector to determine its constraints
- lumi background simulation (bhabha, e+e- e+e-,e+e-μ+μ-)
- design of SR shieldings, masks
- IR magnetic system design with detector geometrical constraints
- beam backgrounds simulations

**In parallel also**

- Integration of magnetic system with solenoid field compensation
- Luminosity measurement
- Technical Infrastructures with constraint from FCC-hh option
- Any other low angle particle detector

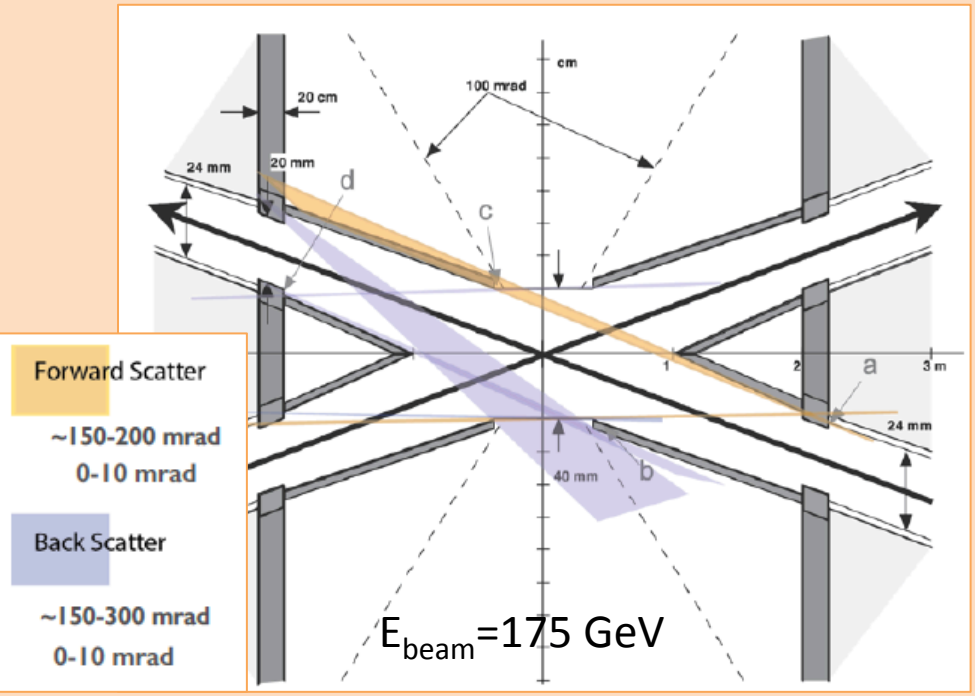
**Iterative procedure following the optics changes**

# IR layout

K. Oide, Monday plenary
A. Bogomyagkov, Optics session

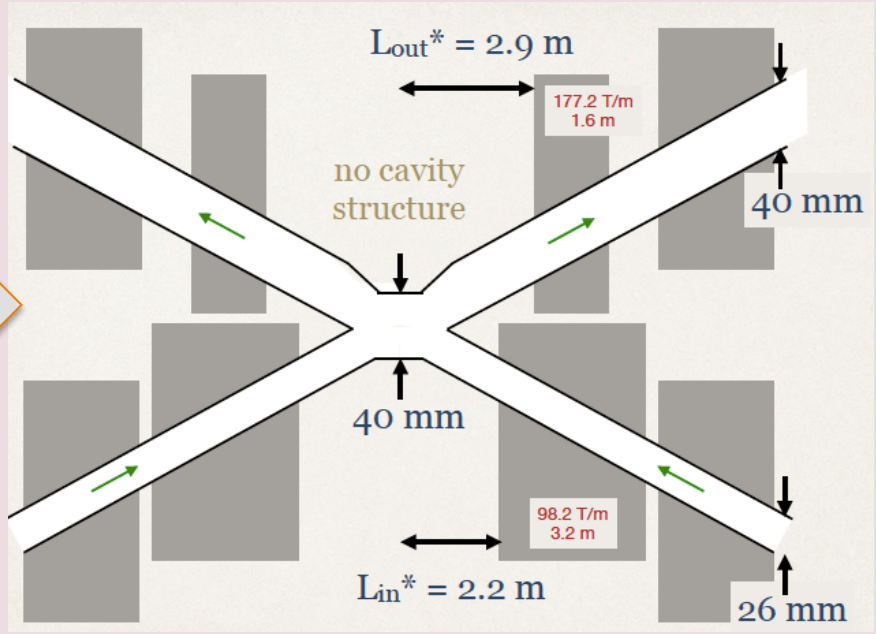
- Different IR options under study, pros & cons considered
- Crab-waist collision scheme adopted
- Synchrotron radiation is the main constraint (next talk H. Burkhardt)

IR Layout from baseline KO optics (M. Sullivan's talk)




Corresponding SR photon angles estimation for studies of detector SR tolerances (A. Kolano)

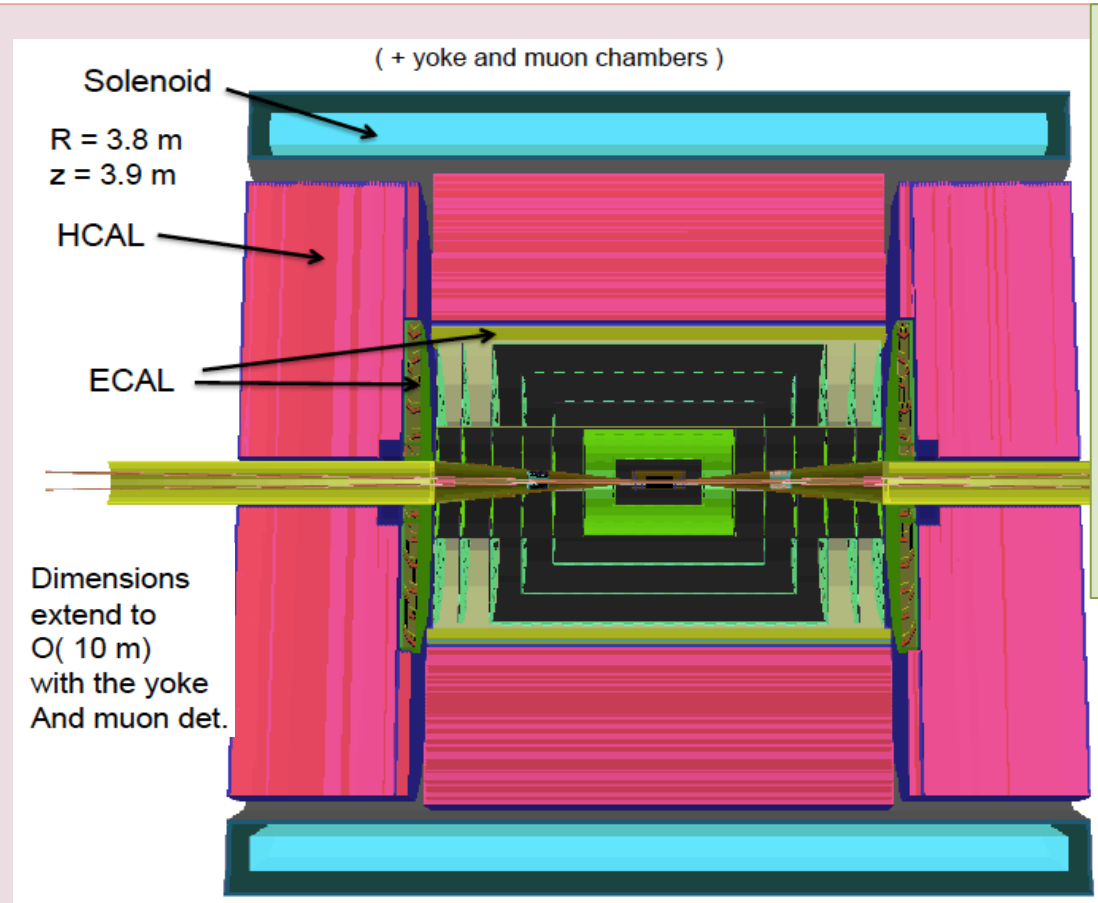
KO Asymmetric IR layout: proposed solution to overcome RF cavity structure and HOM at IR.

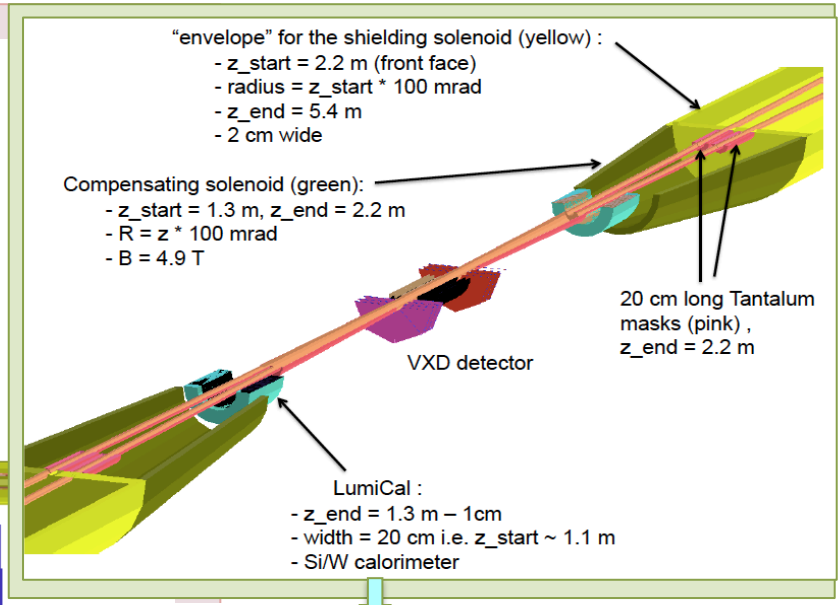



HOMs are being evaluated.
Best solution will be defined.

# Detector model

- CLIC detector model and software was the starting point, FCC-ee IR layout implemented
- Main topics in progress: SR into detectors and IP backgrounds




(talk by M. Dams on Luminosity Measurement, FCC-ee Exp. I session Thurs.)

(more details in last talk in this MDI session by E. Perez)

# Beam Induced Backgrounds

- **Luminosity sources**
  - Beamstrahlung
  - Bhabha (Radiative)
  - 2-photon pair production
    $e^+e^- \rightarrow e^+e^-\ e^+e^-$
    $e^+e^- \rightarrow e^+e^-\ \mu^+\mu^-$
  - Beam-beam (Halo)
- **Linear with Currents**
  - Synchrotron radiation
  - Beam-gas Coulomb/ Bremsstrahlung
- **Other sources**
  - thermal outgassing due to HOM losses
  - top-up injection background
  - High order modes
  - Compton thermal photons
  - ion or electron cloud
  - single / multiple Touschek scattering

Some cause backgrounds due to direct beam losses: particle tracking needed.

The impact of these effects is of course dependent on machine parameters (like beam energy, energy acceptance)

# Conclusions

- FCC-ee MDI working group is investigating challenging aspects of the IR design.
- Final goal: develop a feasible and complete IR design with sustainable backgrounds.
- Masking design also with impedance evaluation.
- Luminosity monitor with detailed simulation.
- Different options for the IR layout are being considered and analysed.
- IR design will be optimized for all energy ranges, even if we are now focusing on 175 GeV.