Future Circular Collider simulation status and needs

by Helmut Burkhardt (CERN)

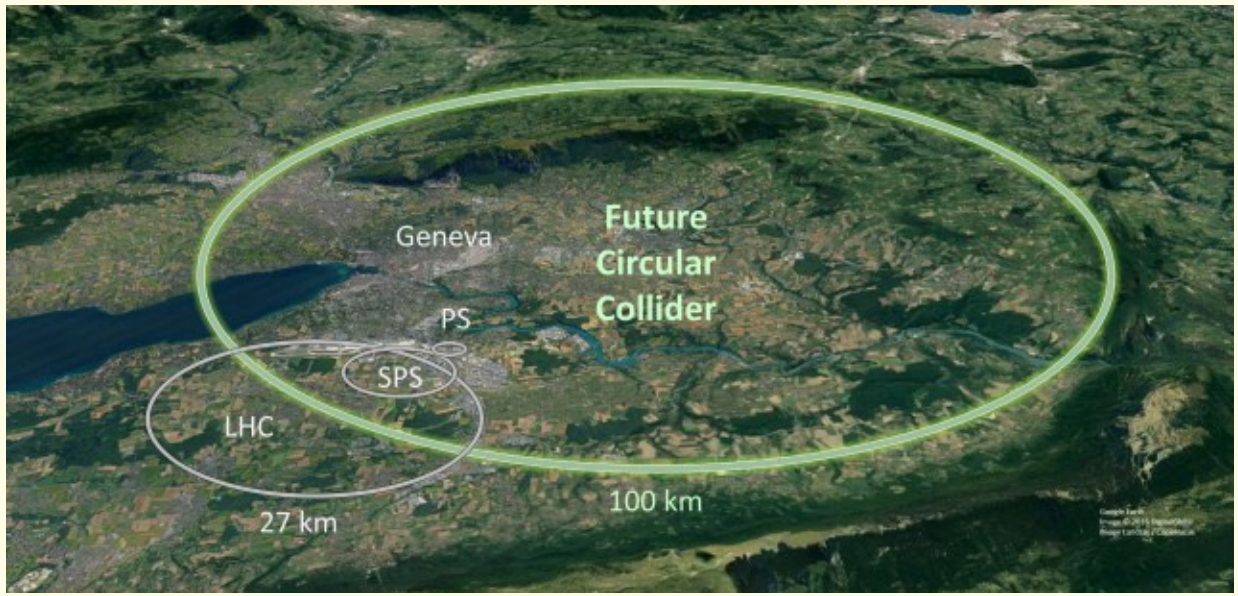
- **Status** as of

Conceptual Design Reports

just published and

recent 24-28 June FCC-week with

examples where Geant4 was used

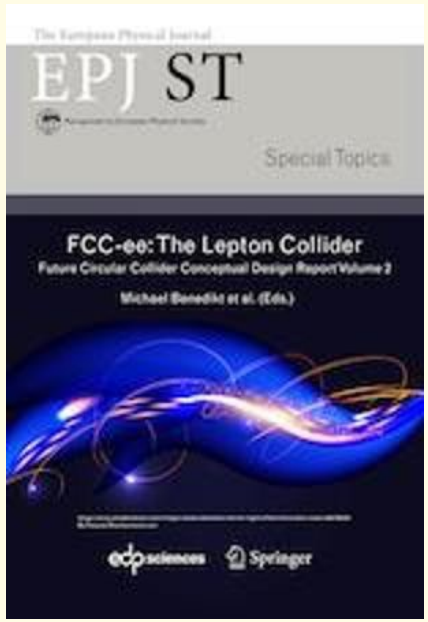


- **Needs**

Strategy meeting Granada :

likely that FCC-ee comes first

EM particularly important



Main links, ref : **FCC**

FCC-ee: The Lepton Collider doi:10.1140/epjst/e2019-900045-4

FCC-hh: The Hadron Collider doi:10.1140/epjst/e2019-900087-0

Improvements done, triggered by FCC

Strategy : avoid "reinventing the wheel"

use existing tools like in particular Geant4, improve and interface where needed

with potentially wide application

Synchrotron radiation, generalisation to all long lived charged particles in G4SynchrotronRadiation.cc and TestEm16 update with example for protons, run01_prot.mac 7/2014

Problem 1921, Bugzilla from 7 digits to full double : /control/useDoublePrecision 11/2016

Problem 1931, Bugzilla Torus geometry fix 1/2017

ROOT-8844 Loss of precision in GDML Export 5/2018

field-V10-05-01 correcting transformation to local system in G4QuadrupoleMagField.cc 4/2019

On accelerator side :

Main tool : machine description in MAD-X

Enhanced by (MDISim interface) generating automatically input files for GEANT4

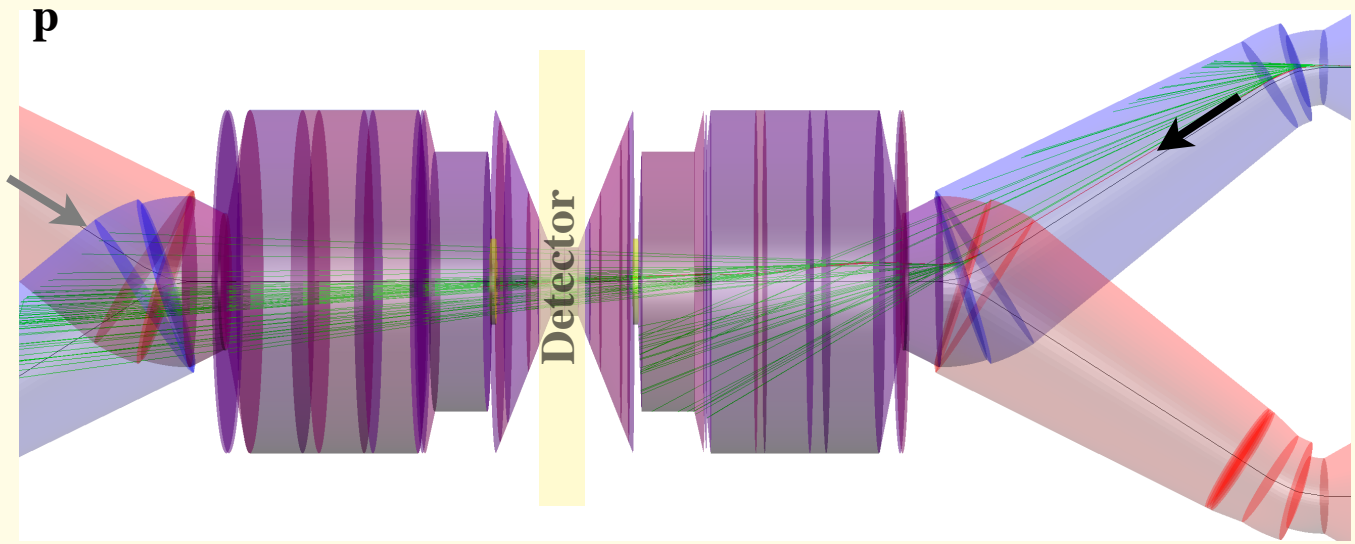
- machine lattice - geometry export in gdml or root format
- beam interface gun particle / position / direction generator at selected start element
- magnetic field description using ascii input files read at "detector construction"

Examples, FCC-hh

Simulations done within EU supported EuroCirCol study by CERN + INFN Frascati

1) Synchrotron radiation backgrounds for the FCC-hh experiments

J.Phys.Conf.Ser. 874 (2017) no.1, 012004



2) Beam-gas Background Characterization in the FCC-ee IR

J.Phys.Conf.Ser. 1067 (2018) no.2, 022012

Team : Francesco Collamati, Manuela Boscolo, Oscar Blanco / INFN Frascati
Marian Lückhof, Roberto Kersevan, Helmut Burkhardt / CERN

FCC-ee parameters

Frank Zimmermann, FCC-ee design overview at FCC-ee week 2019

parameter	Z	WW	H (ZH)	ttbar
beam energy [GeV]	45	80	120	182.5
beam current [mA]	1390	147	29	5.4
no. bunches/beam	16640	2000	393	48
bunch intensity [10^{11}]	1.7	1.5	1.5	2.3
SR energy loss / turn [GeV]	0.036	0.34	1.72	9.21
total RF voltage [GV]	0.1	0.44	2.0	10.9
long. damping time [turns]	1281	235	70	20
horizontal beta* [m]	0.15	0.2	0.3	1
vertical beta* [mm]	0.8	1	1	1.6
horiz. geometric emittance [nm]	0.27	0.28	0.63	1.46
vert. geom. emittance [pm]	1.0	1.7	1.3	2.9
bunch length with SR / BS [mm]	3.5 / 12.1	3.0 / 6.0	3.3 / 5.3	2.0 / 2.5
luminosity per IP [10^{34} $cm^{-2}s^{-1}$]	230	28	8.5	1.55
beam lifetime rad Bhabha / BS [min]	68 / >200	49 / >1000	38 / 18	40 / 18

Example FCC-ee (1/2)

From CDR that just got published

online in open access as of 4/6/2019

Simulated with GEANT4 displayed with ROOT

Subject of PhD thesis by Marian Lückhof CERN + Hamburg Univ.

MDI-team meetings on indico

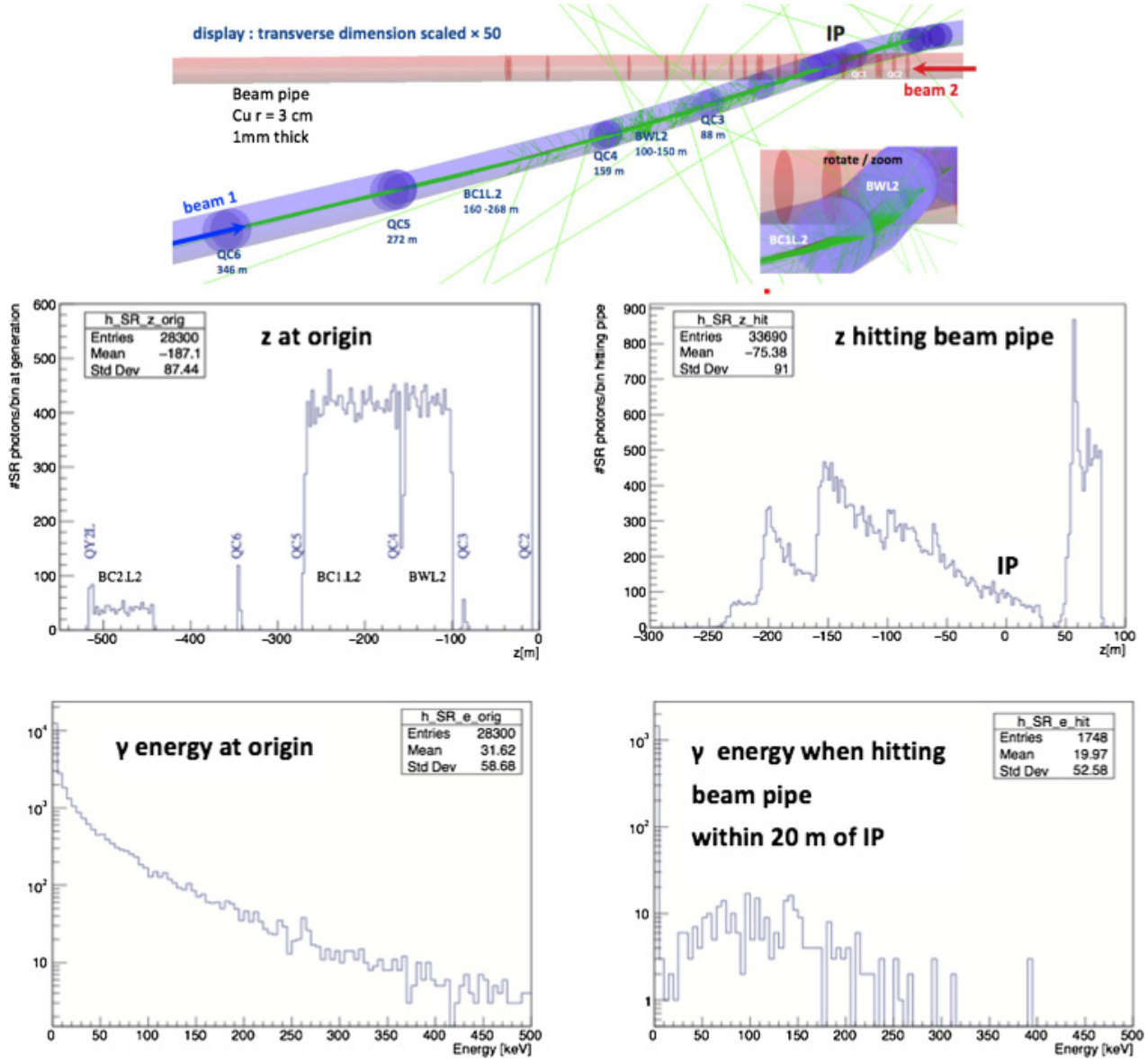


Fig. 2.21. Top: 3D representation of a positron beam track at 175 GeV beam. Bottom: simulation of the distribution of the photons generated in the interaction region for that beam.

The main sources of the SR background in the IR regions are the photons from the last bending magnets and photons emitted by higher amplitude particles in

Example FCC-ee, (2/2) IR-design

From CDR that just got published

Collaboration with Mike Sullivan / SLAC, collective effects & impedance experts, Vacuum group CERN R. Kersevan et al. Detector - Interface : Nicola Bacchetta et al. and connection to Linear collider / CLIC IR / CLD - detector simulations

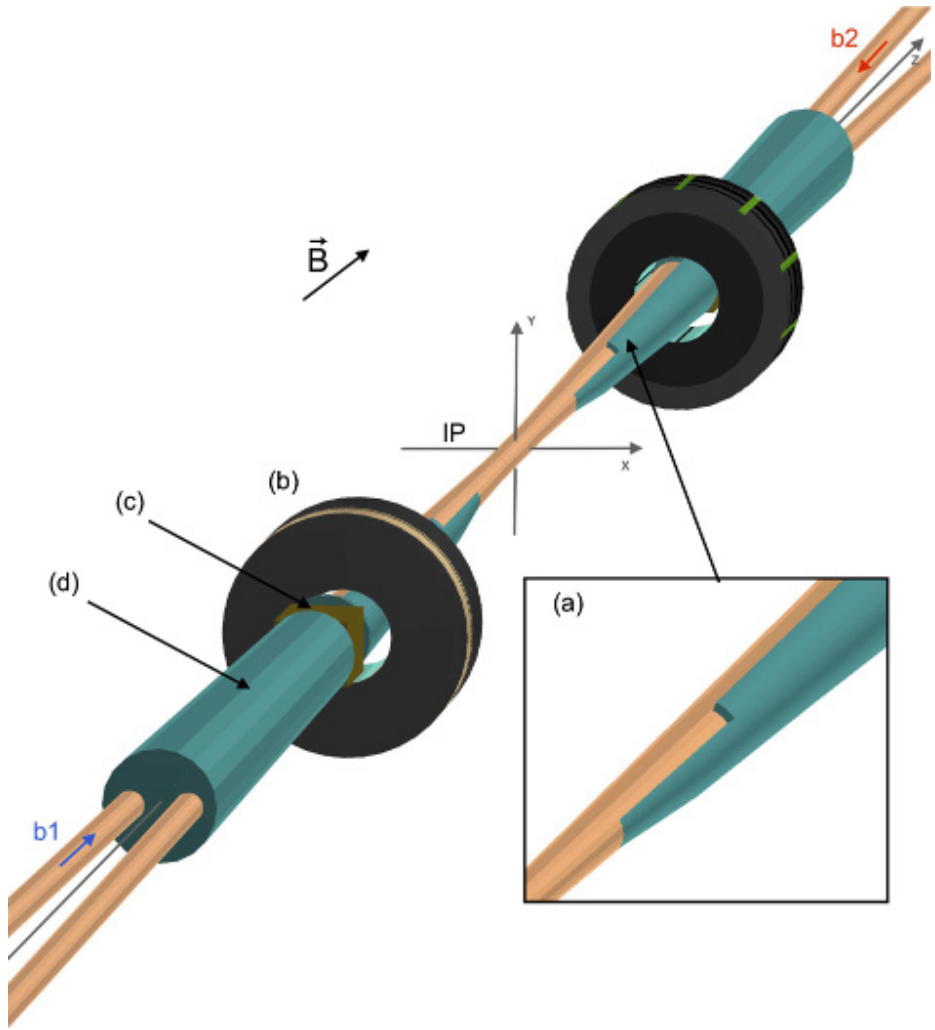


Fig. 7.1. Sketch of the implementation of the interaction region in GEANT4. The tungsten shielding of the beam pipe appears in turquoise blue. The shielding from 330 mm (a) to the rear of the luminometer at 1191.4 mm (b) is 0.1 mm thick and covers only a 68° azimuthal wedge on the positive-x side of the beam pipe. Further back at the rear of the HOM absorber (c), a full 15 mm thick tungsten cone (d) covers both beam pipes to protect the tracking detectors from synchrotron radiation.

Needs, Plans (1/2) EM

to my knowledge, for discussion — maybe some done or in progress, please let me know ?

Our recent work focused mainly one using the current tools to deliver the CDR in time

Needs still mostly as already presented in 1/2018 important to improve for next phase

EM

- **X-ray mirror, specular reflection for keV photons, depends on surface, roughness.**
  if not stopped by collimators (to be designed) could significantly increase backgrounds into detectors for FCC-ee

  got G4XrayGrazingAngleScattering.cc from Buis, Vacanti via Alexander Howard, not straightforward to use,
  surface defined only for Silicon (and Vacuum)
  will have to see with PhD student M.Lückhof that we get at least upper limits soon (like 100% reflection if below grazing angle); goal as for LEP that photons have to scatter at least twice to reach the detector ; using collimators + masks
- benchmarking with light source studies for FCC and comparison with SynRad by R. Kersevan
- **γ (MeV) - nuclear, giant-dipole/quadruple resonance (started ?)**
- e+e- --> τ+τ- production AnnihiToTauPair, relevant for Ee+ > 12.4 TeV (FCC-hh)
- update TestEm.., new example(s) with beamline(s) as generated for FCC, documentation ..

Needs, Plans (2/2) more general

Persistency :

these days all design work computer based

- Mechanical designs (CAD programs, EDMS documents)
- RF - behaviour, impedance studies (Microwave Studio, HFFS ..)
- Magnet lattice and field definition (MAD, SAD)
- Particle scattering toolkits GEANT, FLUKA

need to connect with proper interfaces and / or exchange formats

Hadrons :

Check / update processes to 100 TeV, (update cross sections, improve diffractive…)

Field :

We created a dedicated IP_Field.cc class to handle

Solenoid/anti-solenoid for the moment based on analytic formulas in absence of measured field maps

+ summing up with Quadrupole fields around IR, probably of little general interest ?

FCC-ee has **strong** "crab waist" **sextupoles** (4 L/R each IP, between 118 to 727 m for IP)

New **G4SextupoleMagField.cc** ~ ready to commit if of general interest, rather short and similar to G4QuadrupoleMagField.cc