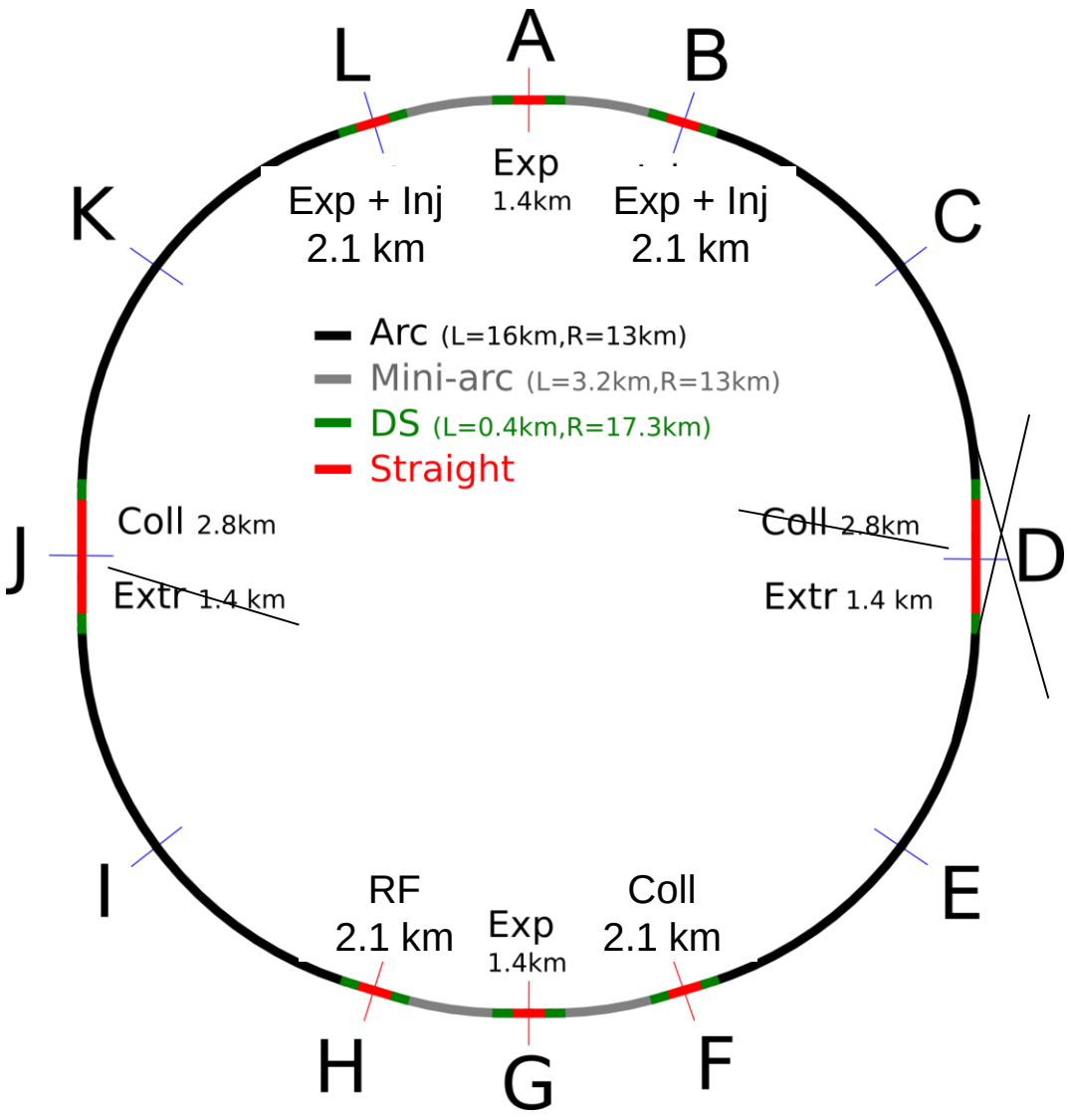
FCC-hh beam instruments

FCC-hh new baseline

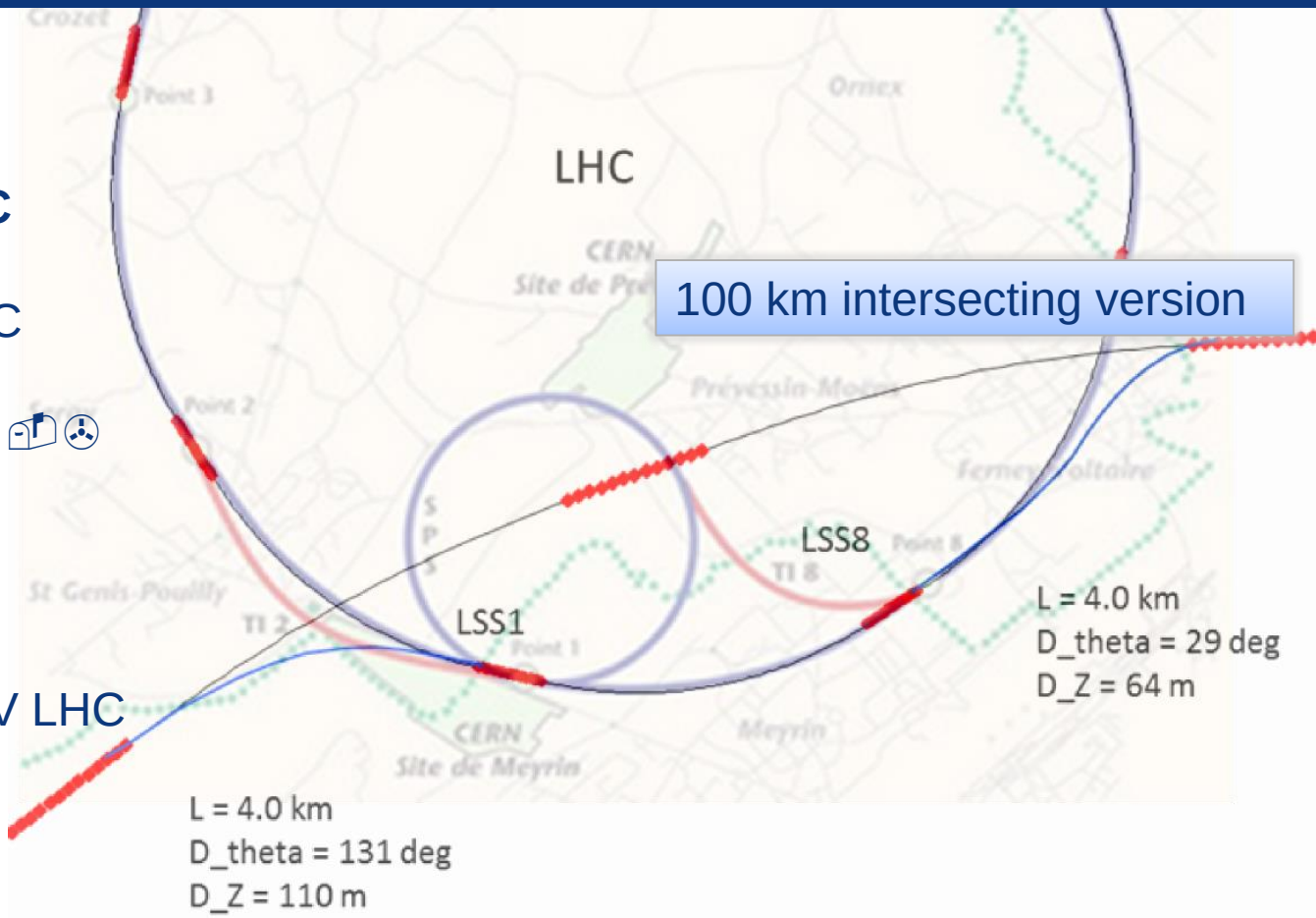
- Two high-luminosity experiments (A and G)
- Two other experiments (B and L):
  - Injection through experiments!
- One collimation insertions in J
- Extraction insertion in D
-
- One insertions with RF
- One insertion with energy collimation
- Circumference 100km
-
- Can use LHC or SPS as injector



FCC-hh injector studies

Injector options:

- **SPS =>LHC FCC**
- SPS/SPS$_{upgrade}$ FCC
  - SPS -> FCC booster FCC



Current baseline:

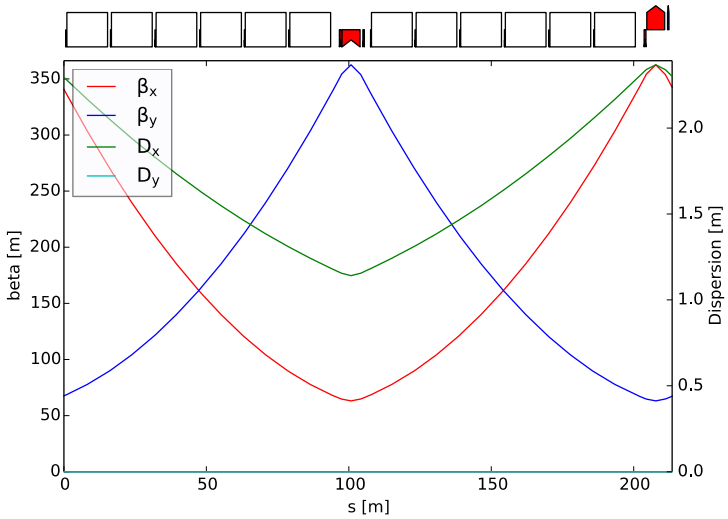
- injection energy 3.3 TeV LHC
- confirmed by review

Alternative options:

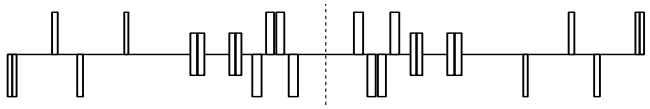
- Injection around 1.5 TeV
- compatible with: SPS$_{upgrade}$, LHC, FCC booster

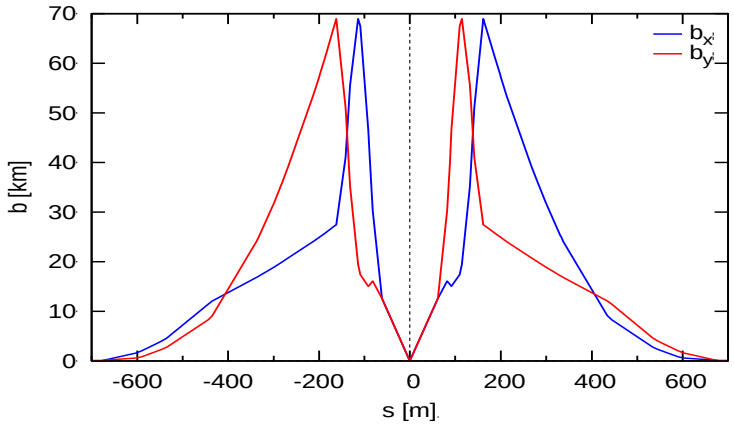
Machine parameters

Regular arc cell



Interaction region





Parameters

Parameter		Value
Energy	TeV	50
Circumference	km	100.171
β^*	m	0.3
L^*	m	45
α	10^{-4}	1.008
γ_{tr}	-	99.580
Q_x	-	111.31
Q_y	-	108.32
Q'_x	-	2
Q'_y	-	2
# dipoles MB	-	4616
MB field	T	15.93
# quadrupoles MQ	-	846
Max grad MQ	T/m	370 [a]
# sextupoles MS	-	710
Max grad MS	T/m^2	18670

a. in the arcs

Beam parameters

	(HL)-LHC	FCC-hh baseline	FCC-hh ultimate
Collision energy [TeV]	14	100	100
Dipole field [T]	8.3	16	
Luminosity L [10^34 $cm^{-2}s^{-1}$]	(5) 1	5	20-30
Normalized emittance [um]	(2.5) 3.5	2.2 (0.44)	
Bunch intensity [10^11]	(2.2) 1.15	1 (0.2)	
Bunch spacing [ns] (option)	25	25 (5)	
Beta* [m]	(0.15) 0.55	1.1	0.3
Number of bunch	2808	10600 (53000)	
IP beam size [um]	16.7	6.8 (3)	3.5 (1.6)
Rms bunch length [cm]		8	
Stored energy/beam [GJ]	(0.7) 0.36	8.4	
Synchrotron rad. [W/m/beam]	(0.35) 0.18	30	
Dipole coil aperture [mm]	56	40	

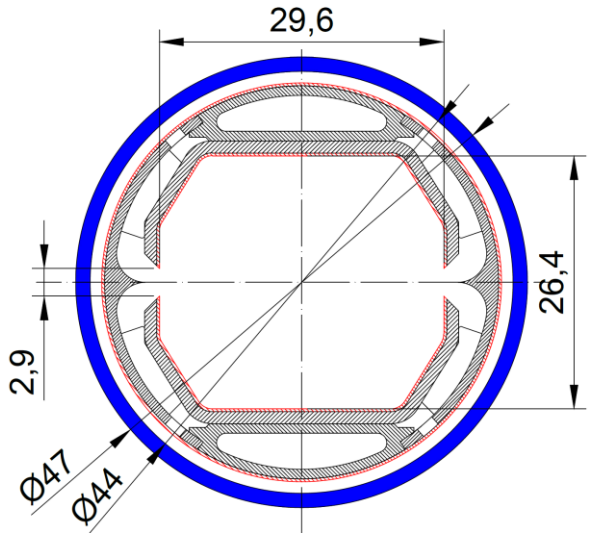
Synchrotron radiation/beam screen

High synchrotron radiation load of protons @ 50 TeV:

- **~30 W/m/beam (@16 T)** (LHC <0.2W/m)
- **5 MW total in arcs**

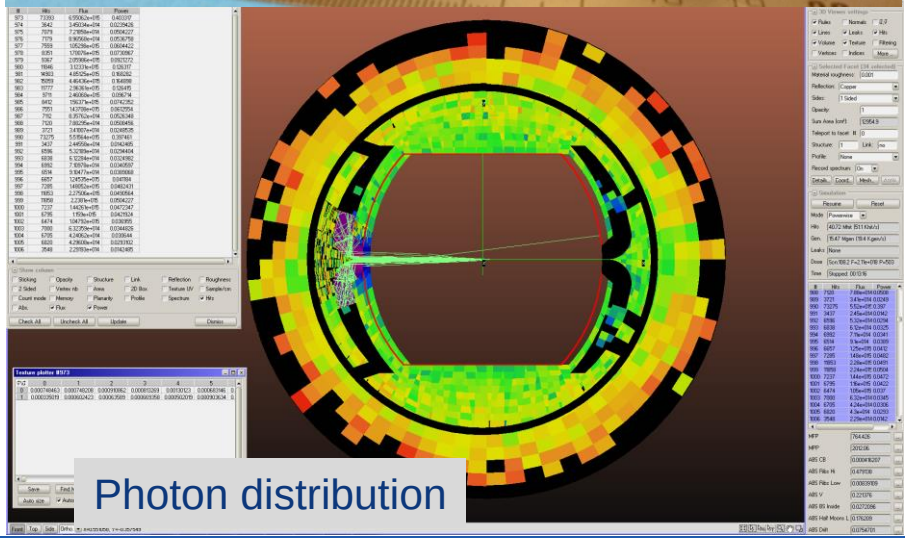
New Beam screen with ante-chamber

- absorption of synchrotron radiation at 50 K to reduce cryogenic power
- avoids photo-electrons, helps vacuum



First FCC-hh beam screen prototype

Testing 2017 in ANKA within EuroCirCol



Photon distribution

Instruments

List of instruments:

- beam position + AC-dipole + k-modulation+ coupling
- tune, chromaticity
- beam intensity (DC, bunch to bunch), lifetime
- beam losses
- transverse profiles
- abort gap population
- longitudinal profiles
- specific instrumentation for machine protection:

(aka interlocked BPMs, beam presence flags…)

Beam Position Monitor

- In LHC, used to measure:
  - ✓ *Injection trajectories, closed orbits, dispersion, coupling, optics (via phase advance), resonance driving terms etc*

Functionality:

- Measurement of the **closed orbit**
- provide **turn-by-turn data** for injection oscillations, optics measurements…
- Closed orbit used for Orbit and radial position real-time feedback
-
- Machine protection, Interlocked BPM?
- A few special BPMs should provide high resolution (μm) **bunch-by-bunch** and **turn-by-turn data** for special purposes (instability observations etc).

- Alignment tolerance comparable to LHC:
  - 100 um in the arc
  - 50 um in IR

- => LHC-like BPM system but Synchrotron Radiation!

Beam Loss Monitor

- Based on LHC BLM system:
  - Quench protection → beam loss scenarios needed
  - UFO detection
  - Vacuum spike detection?
- Continuous/discrete measurements?
- Simulation needed

Other instruments

Functionality:

- Tune measurement
  - Cohabitation with transverse feedback
- Transverse profiles:
  - SR in the arc: critical photon energy 0.575 keV (0.044 keV in LHC)
- Beam intensity : DC, bunch by bunch, lifetime
  - Same dynamic range as LHC: from 5x10^9 to 1 10^11
- Abort gap population
- Longitudinal profiles
- Obs Box