Review of definitions: n_1 vs σ_n

- During LHC design, normalized apertures calculated in terms of n_1:
  - n_1 defines as the "maximum acceptable primary collimator opening, in units of beam σ, that still provides a protection of the mechanical aperture against losses from secondary beam halo."
  - accounts for closed orbit excursion, mechanical and alignment tolerances and an off-momentum component

Parameter	Value	Unit
Primary halo extension	6	σ
Secondary halo extension, hor./ver.	7.3	σ
Secondary halo extension, radial	8.4	σ
Normalised emittance ϵ_n	3.75	μm
Radial closed orbit excursion x_{co}	3	mm
Momentum offset δ_p	8.6×10^{-4}	–
Fractional beam size change from β-beating k_β	1.1	–
Relative parasitic dispersion f_{arc}	0.27	–

From CERN-ACC-2014-0044

LHC target design value: n_1 >7

Review of definitions: n_1 vs σ_n

- n1 notation very good in design phase, however is not always adequate
- Recent aperture calculation for HL-LHC done directly in units of σ_n instead of n_1 (see CERN-ACC-2014-0044), with revised parameters based on operational experience.
  - n_1 model relies on assumption of secondary halo shape and does not account for tertiary halo or off-momentum halo
  - n_1 model not adequate for real cleaning bottleneck: at LHC limiting losses in DS caused by off-momentum particles from single diffractive scattering in TCPs
  - σ_n notation easier to grasp: collimator settings in σ_n (need the real aperture!)

Parameters used for HL-LHC aperture calculations in units of σ_n

Parameter set	LHC design	**HL-LHC design**
Primary halo extension	6 σ	**6 σ**
Secondary halo, hor./ver.	6 σ	**6 σ**
Secondary halo, radial	6 σ	**6 σ**
Normalised emittance ϵ_n	3.75 μm	**3.5 μm**
Radial closed orbit excursion x_{co}	3 mm	**2 mm**
Momentum offset δ_p	8.6×10^{-4}	**2×10^{-4}**
β-beating fractional beam size change k_β	1.1	**1.1**
Relative parasitic dispersion f_{arc}	0.27	**0.1**

From CERN-ACC-2014-0044

Collimator settings

- For FCC we are trying to have a consistent notation using real emittance.
- Plan to repeat aperture calculation done for HL-LHC also for FCC
- For the moment, extrapolating from HL-LHC: collimator settings from HL-LHC baseline in σ_n (from CERN-ACC-2014-0044) and equivalent scaled settings for FCC:

HL-LHC (ε = 3.5 μm)

TCP	5.7
TCS	7.7
TCDQ	9.0
TCT	10.9
aperture	12.3

FCC-hh (ε = 2.2 μm)

TCP	7.2
TCS	9.7
TCDQ	11.4
TCT	13.7
aperture	15.5

Same settings as HL-LHC in σ units (for ε = 3.5 μm), re-expressed in σ units for ε = 2.2 μm