



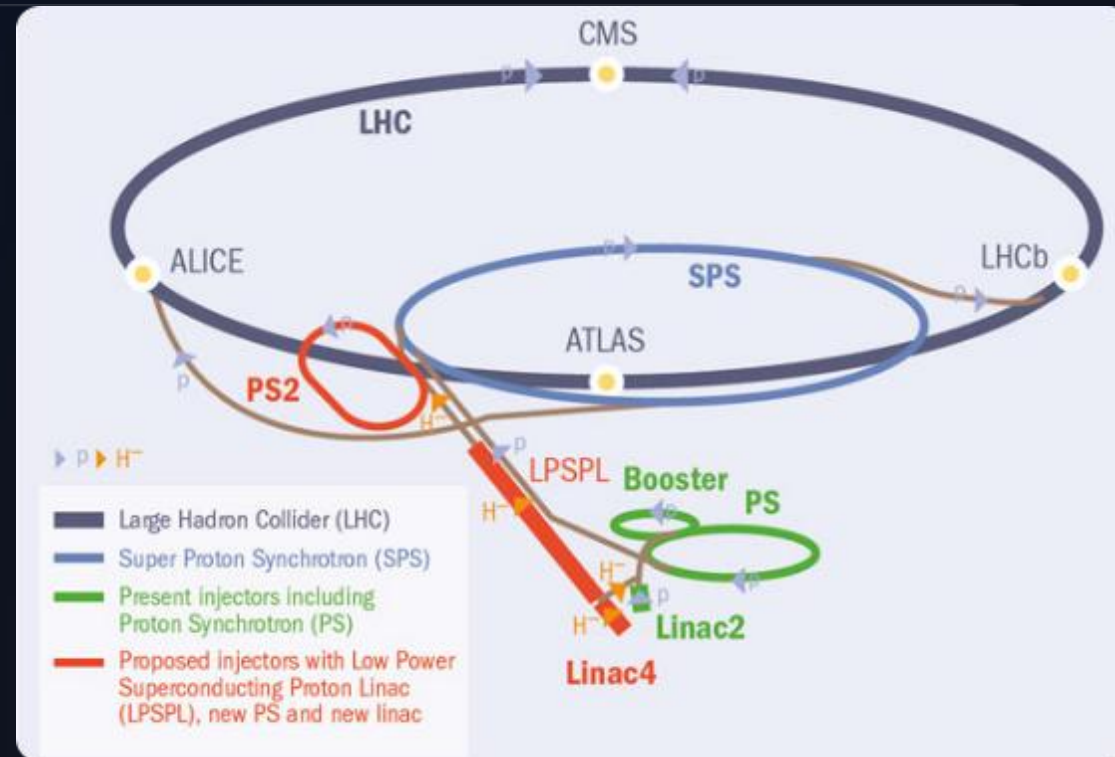
The CERN Accelerator Complex & The LHC

*An Overview of the World's Most Powerful Proton Injection Chain and
Detailed Beam Crossing Parameters*

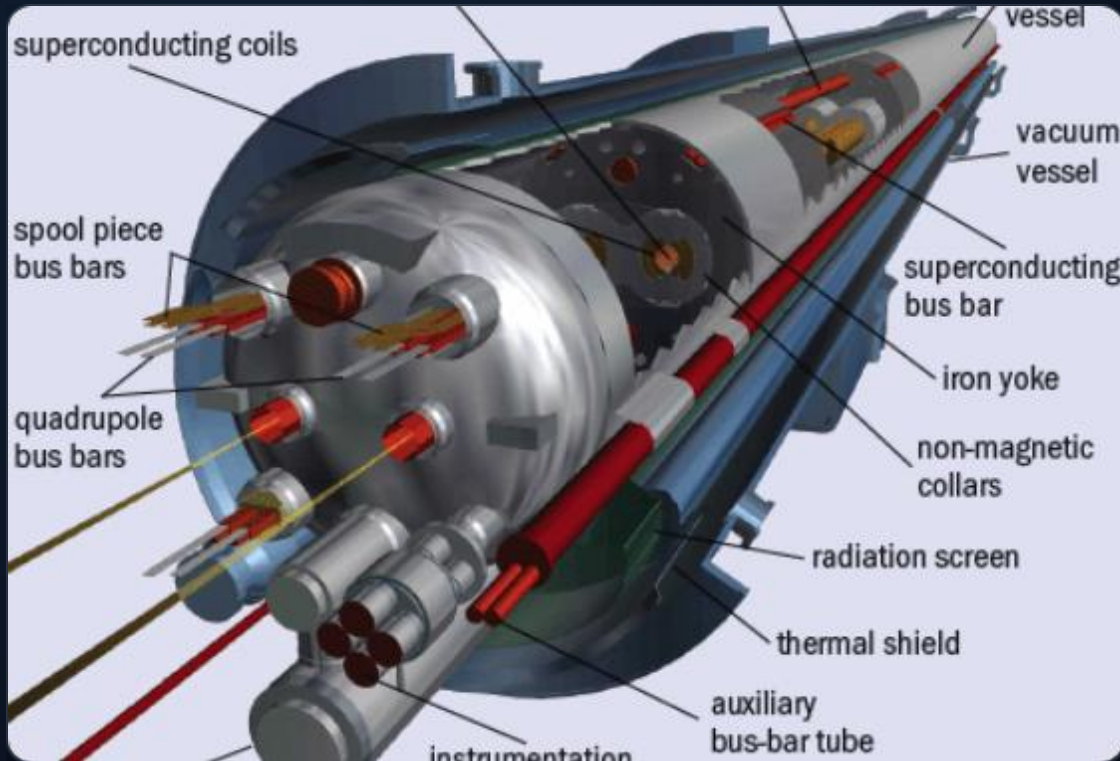
The CERN Accelerator System

- **Sequential Acceleration Chain:** Protons start in **Linac4** (160 MeV) and pass through successive synchrotrons.
- **PS Booster (PSB):** Accelerates protons up to 2 GeV.
- **Proton Synchrotron (PS):** Boosts energy to 26 GeV and structures the beam into 25 ns bunch spacing.
- **Super Proton Synchrotron (SPS):** Final injector ring accelerating protons to 450 GeV before LHC injection.

the proton journey



LHC Machine Infrastructure



- **26.7 km Circumference Ring:** Situated 100 meters underground near Geneva, Switzerland.
- **1,232 Main Dipoles:** Twin-aperture superconducting magnets generating an 8.33 Tesla bending field.
- **Superfluid Cryogenics:** Operates at 1.9 K (-271.3°C) using liquid Helium to maintain superconductivity.
- **Collision Energy:** Nominal 13 TeV - 14 TeV center-of-mass energy (6.5 to 7 TeV per beam).

🎯 LHC Bunch & Crossing Parameters

2,808

Number of Bunches per Beam
Separated by 25 ns (7.5 meters apart)

1.15×10^{11}

Particles per Bunch
Protons concentrated per RF bucket

⚡ Bunch Size at Interaction Point (IP Crossing)

$\sigma(x) = 16.6 \mu\text{m}$

Horizontal RMS Size

$\sigma(y) = 16.6 \mu\text{m}$

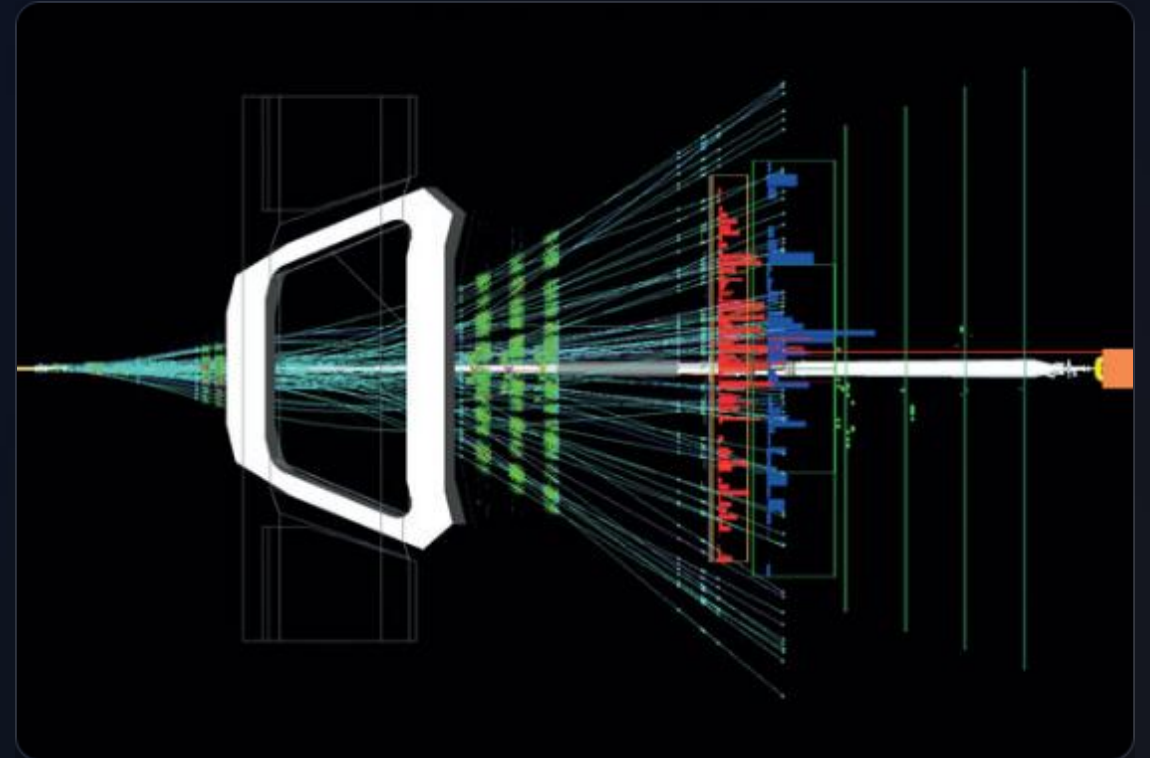
Vertical RMS Size

$\sigma(z) = 7.55 \text{ cm}$

Longitudinal Length (z)

★ Collision Dynamics & Main Experiments

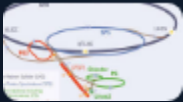
- **40 MHz Crossing Frequency:** Bunches collide every **25 nanoseconds** at 4 interaction points.
- **Crossing Angle:** A small angle ($\sim 300 \mu\text{rad}$) prevents parasitic collisions outside the detector center.
- **Major Detectors:**
 - **ATLAS & CMS:** General-purpose high-luminosity experiments.
 - **ALICE:** Optimized for heavy-ion (Pb-Pb) physics.
 - **LHCb:** Specialized in b-quark physics & CP violation.



Summary of LHC pp Collision Properties

Beam Parameter	Nominal Design Value	Physical Significance
Number of Bunches (Nb)	2,808 per beam	Maximizes luminosity & event statistics
Particles per Bunch (N)	1.15×10^{11} protons	Concentrated bunch charge
Transverse Size (σ_x, σ_y)	16.6 μm at IP	Squeezed beam focal spot at crossing
Longitudinal Size (σ_z)	7.55 cm	RMS bunch length along motion axis
Design Luminosity	$1.0 \times 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$	Instantaneous collision rate density

Image Sources



https://cerncourier.com/wp-content/uploads/2008/07/CCELHC1_07-08.jpg

Source: cerncourier.com



https://cerncourier.com/wp-content/uploads/2006/10/CCEthe1_10-06.gif

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