STRONG FOCUSING SYNCHROTRON

A BRIEF INTRODUCTION

- ORIGINS, PRINCIPLE
- COMBINED/SEPARATED FUNCTION
- SF-SYNCHROTRON TODAY

Bibliography

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[] JACoW http://www.jacow.org/
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[] USPAS archives
[] National Lab sites, US, EU
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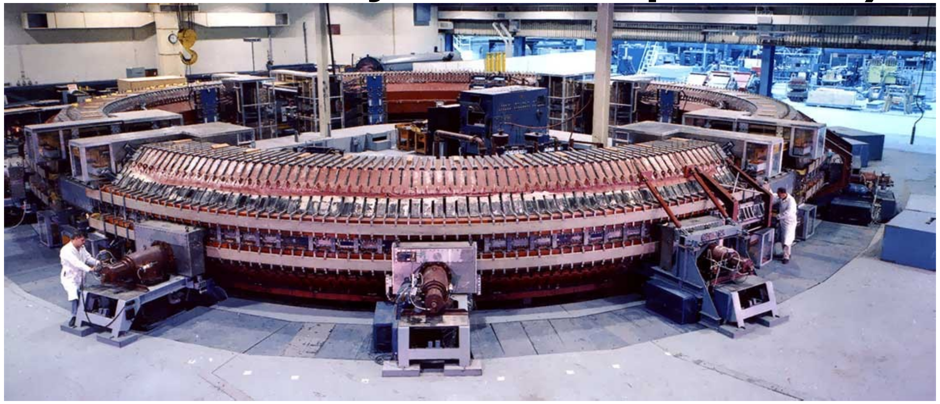
Synchrotron landscape, when strong focusing was invented, 1950

Cosmotron at BNL, 1952-1968, 3.3 GeV, the first GeV+ accelerator (beam to target, cosmic rays' mesons, heavy unstable particles),



occupied the front of the scene.

and Bevatron at Berkley, 1954-1993, 6 GeV, 10,000 tons of iron (discovery of antiproton, of antineutron),

Even more ! In spite of that invention:

Synchrophasatron in Dubna (10GeV, 1957-2003!), Saturne in France (3GeV, 1958), ZGS at Argonne (12GeV, 1963!-1979), Nimrod in the UK (8 GeV, 1964!-1978) would be built.

Genesis

- Strong focusing was patented in the early 1950s, in Greece and in the USA

- At BNL it was desired to alternate the COSMOTRON C-shaped yokes opening (all were outward), looking alternately outward and inward ... It was realized that nothing precluded strongly increasing the gradient, from its weak $0<n<1$ to a strong $|n|>>1$ with alternate sign. That's how it was discovered there in 1953

- Visitors from CERN brought BNL’s idea back home, this led to the
  CERN PS, 25 GeV. PS start-up: 1959.

gamma-transition was an issue... it was solved on the fly by the PS group

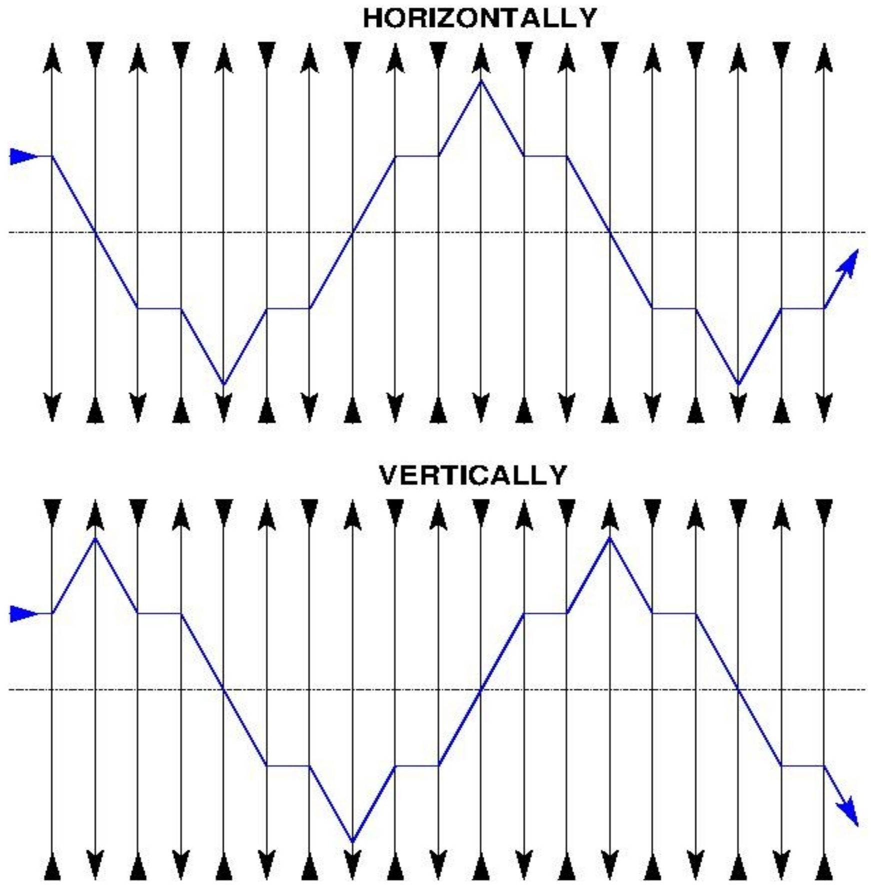
Today CERN PS role still paramount, part of the injector chain to LHC

- BNL AGS start up: 1960.

AGS role still paramount today: RHIC injector, and part of the future EIC

A simple principle:

A strong index, and alternating sign

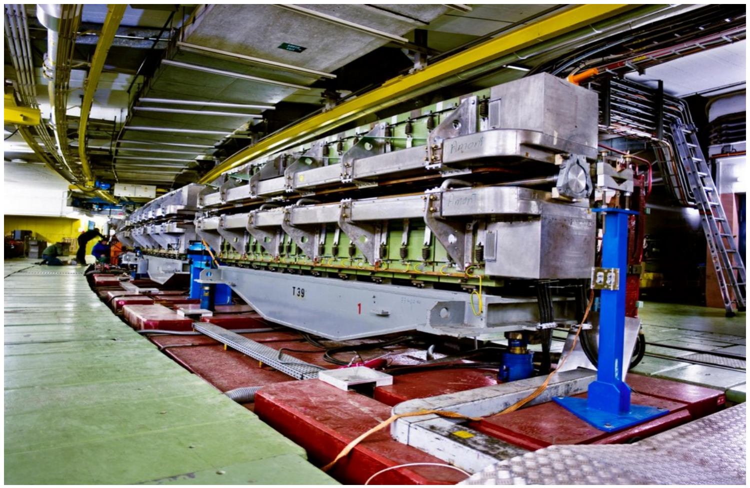


Just like in geometrical optics:

a doublet satisfies 1/f = 1/f1 + 1/f2, designed converging, here

Strong index dipole n=ρ/B dB/dx + alternating gradient

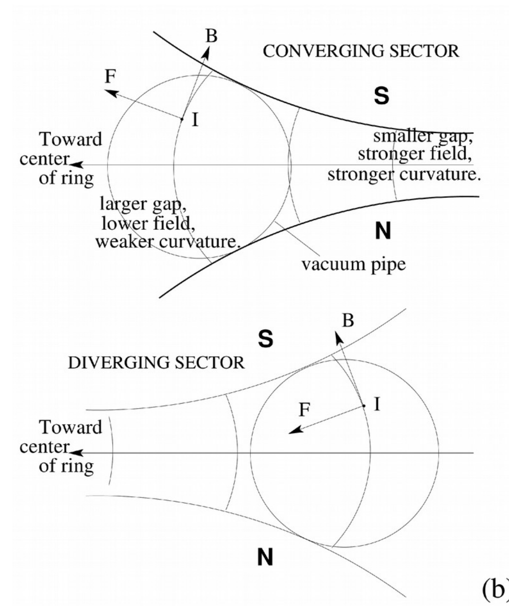
Hyperbolic gap, V=a xy



PS or AGS, 30 GeV: few cm diameter vacuum chamber

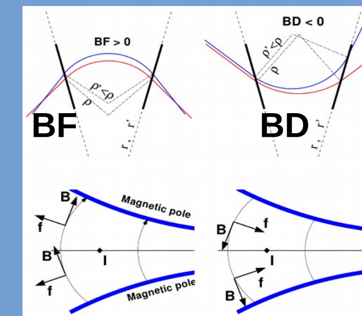
Compare dipole size:

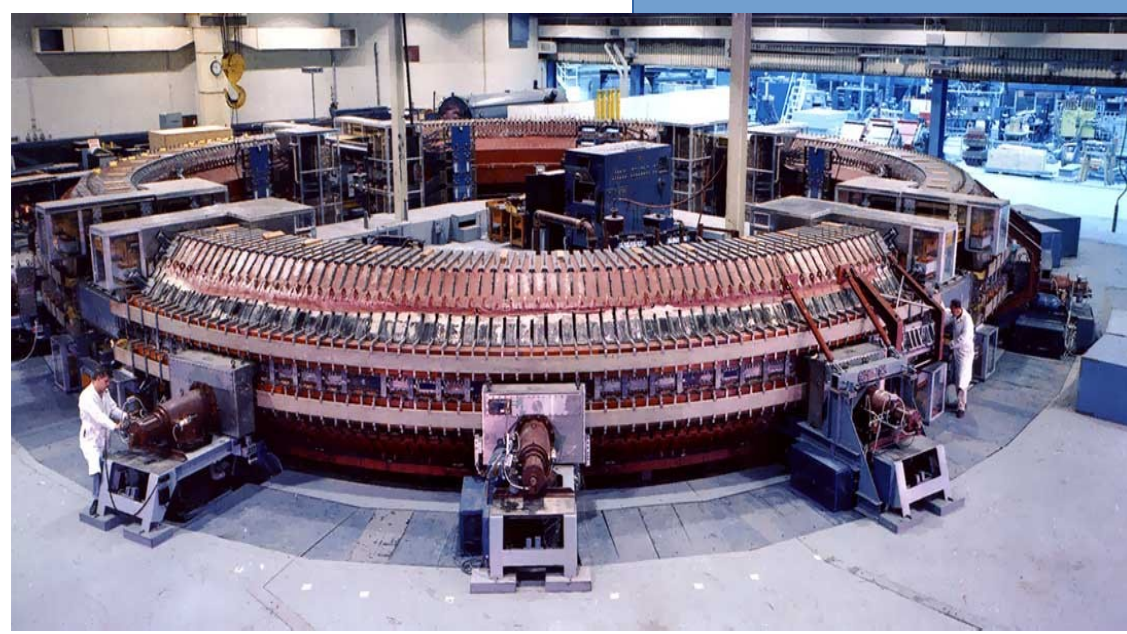
Cosmotron, 3 GeV: 1.22mx0.22m vacuum chamber



FFAG SF Optics:

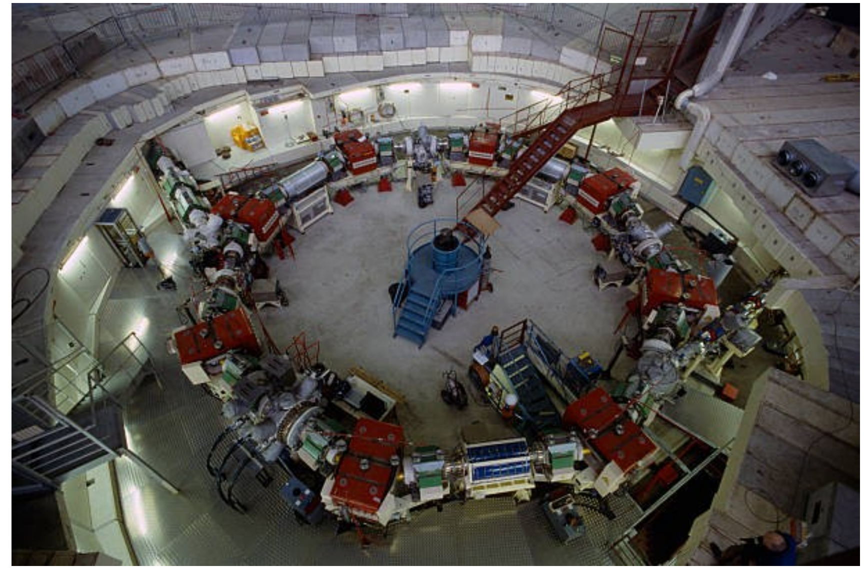
Sign of B alternates





Compare SATURNE 1, weak focusing and SATURNE 2, strong focusing

Mimas injector of polarized particles, of the Saturn Synchrotron at the Atomic Energy Center (CEA) in Saclay. First beam March 02, 1988 License



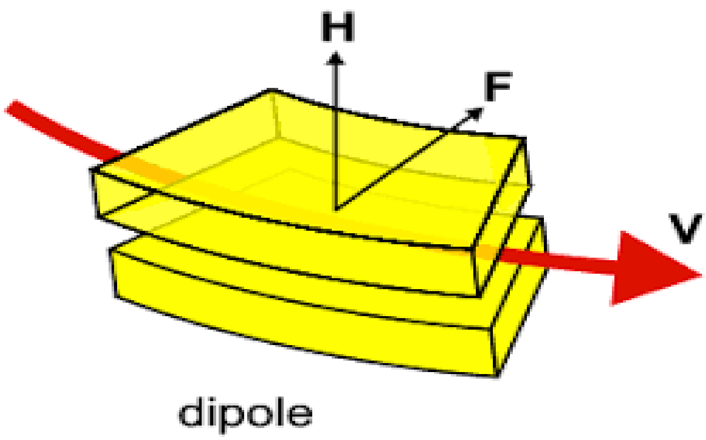
SATURNE 2, second (after ZGS) polarized ion synnchrotron. Same energy as SAT1: 3GeV.

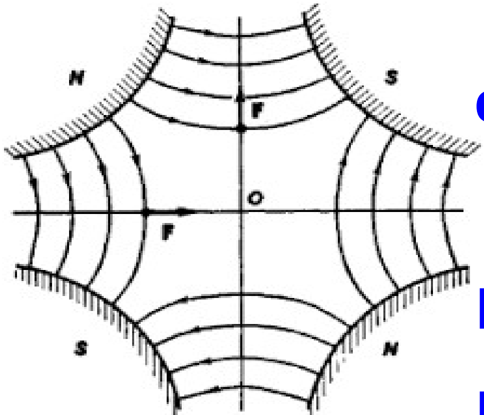
Same location,
same circumference (109 vs 105 m),
same energy (3 GeV)

The concept evolved, from "combined function" to "separated function" optics

Dipole: steering

Quadrupole: strong focusing





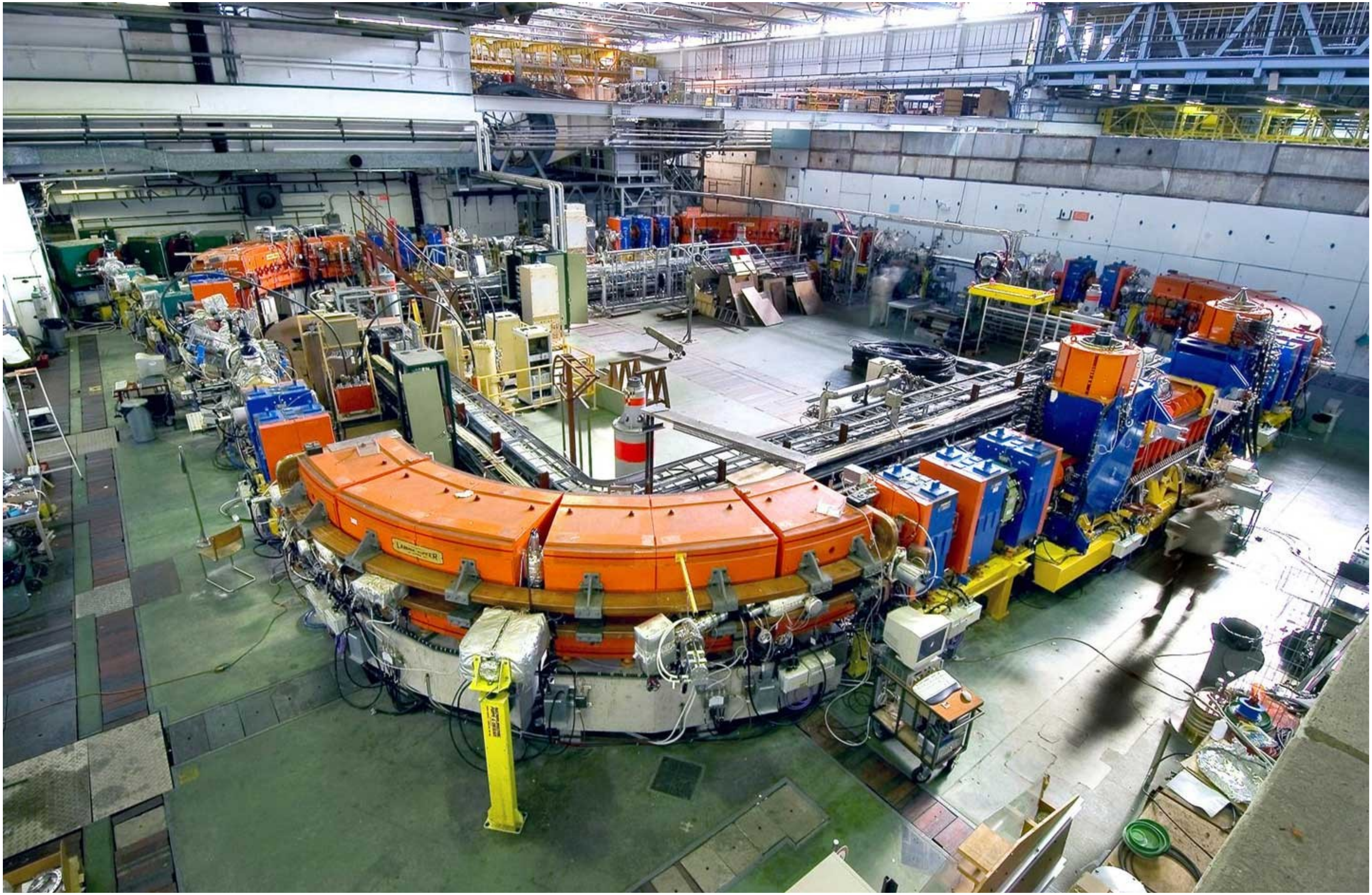
Parabolic equipotential:

$V = Gxy$

$B_x = dV/dx = Gy$

$B_y = dV/dy = Gx$

Separated function optics at LEIR

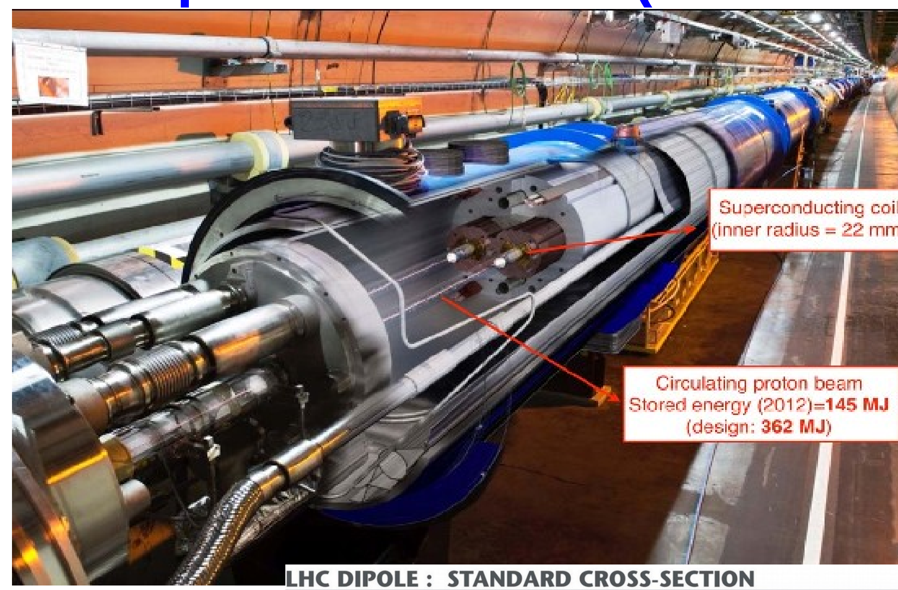


Cryo-magnetism allows high field B (~8 T at LHC, 4 T at RHIC)

And high field gradient dB/dx (~250 T/m)

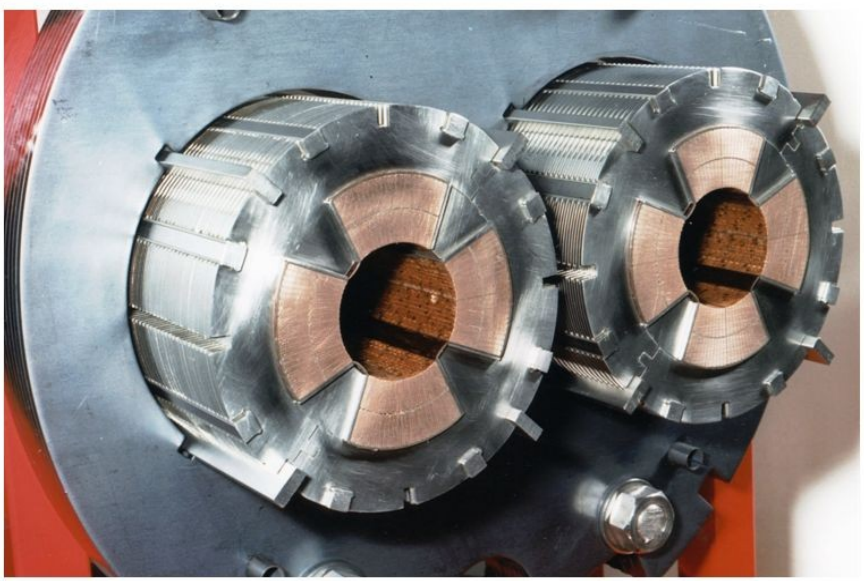
LHC, circumference 27km, E=7TeV:

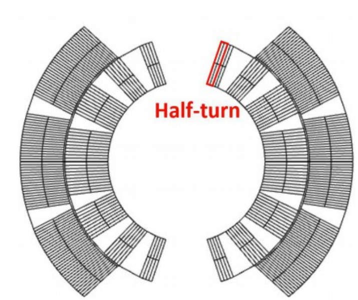
2-in-1 dipole field 8.32 T (1232 units)



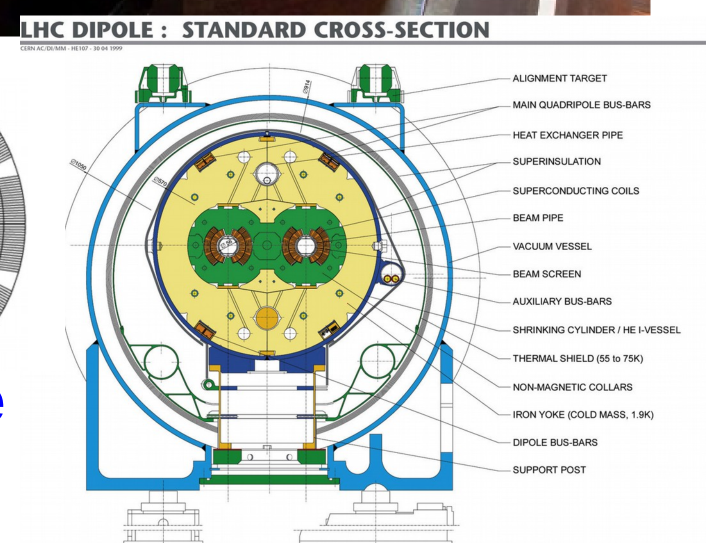
Quadrupole gradient 225 T/m (392 units)

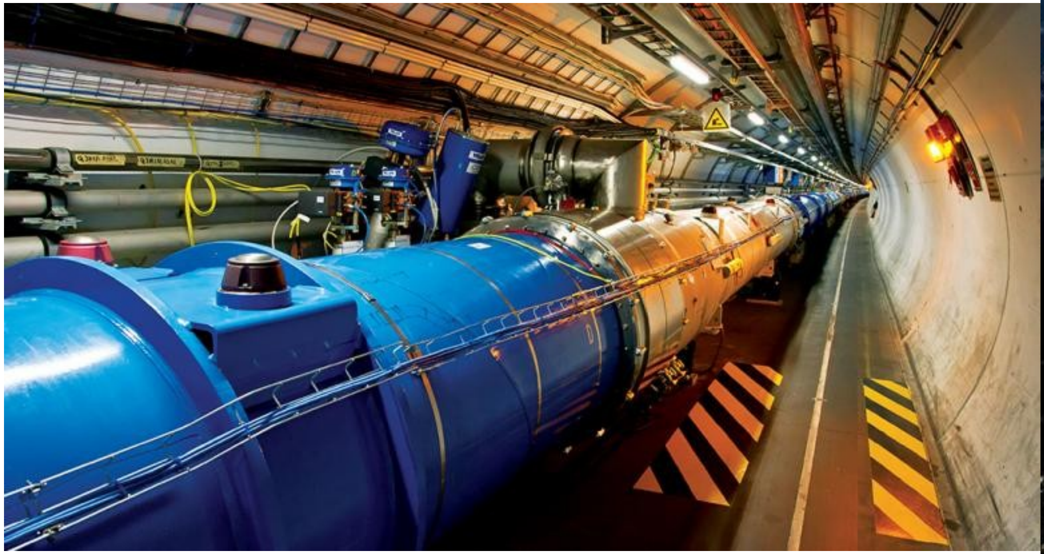
This is a cross section of a main quadrupole of the LHC at CERN: 223 T/m × 3.2 m

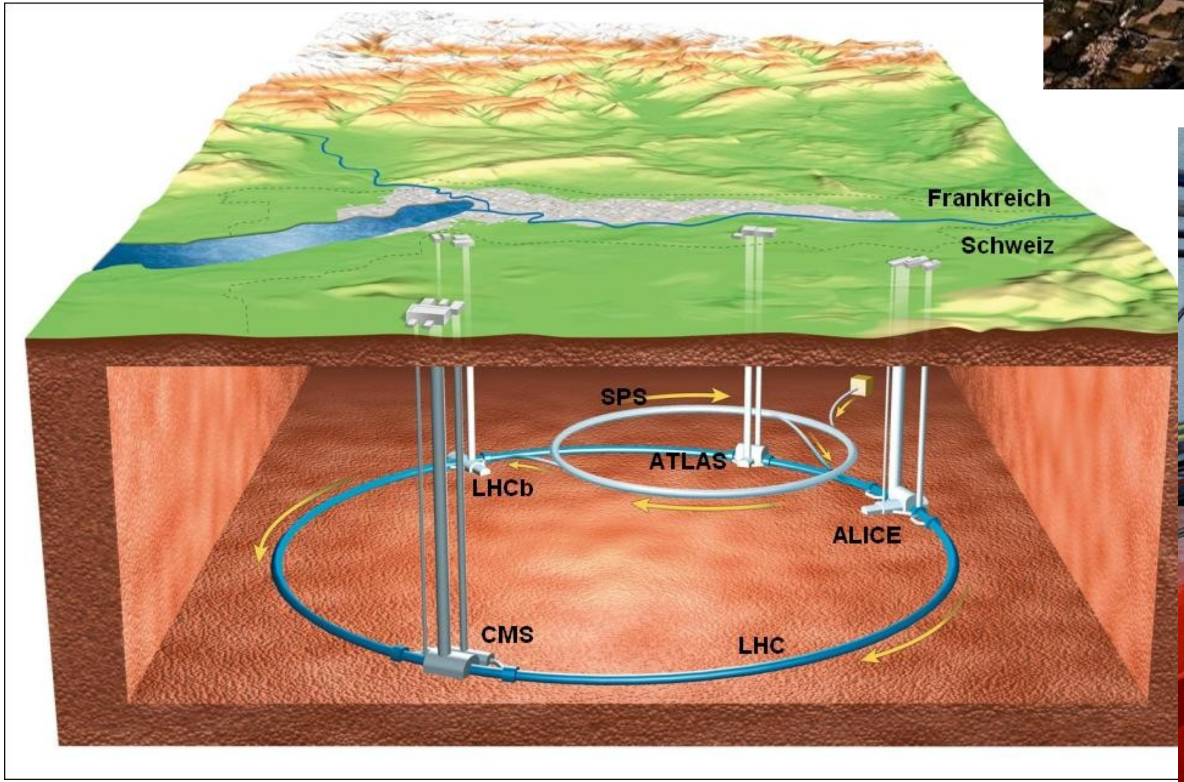




Aperture
Φ56mm






Frankreich
Schweiz
SPS
ATLAS
LHCb
ALICE
CMS
LHC

The future of HEP:
still strong-focusing optics,
still similar size magnet aperture (cms) and beam (mm)

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