

# ***STRONG FOCUSING SYNCHROTRON***

## ***A BRIEF INTRODUCTION***

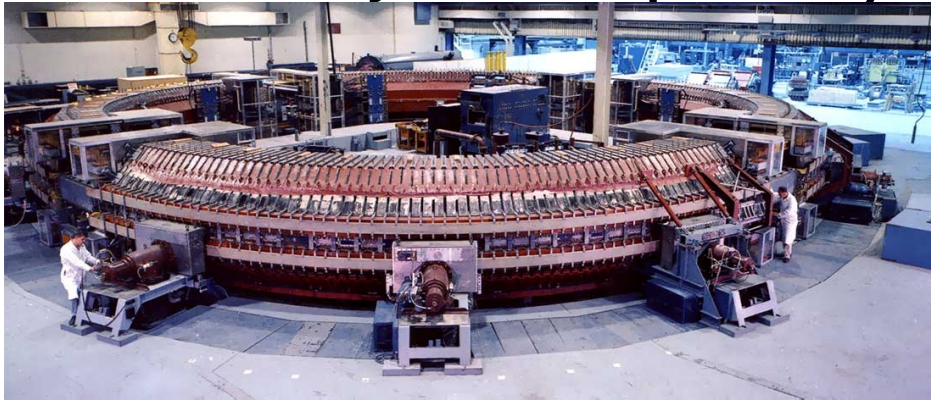
- ORIGINS, PRINCIPLE
- COMBINED/SEPARATED FUNCTION
- SF-SYNCHROTRON TODAY

# Bibliography

- A. Sessler, E. Wilson, Engines of Discovery, World Scientific (2007)
- M.S.~Livingston, The Development of High-Energy Accelerators, Dover Pub. Inc., NY (1966).
- CERN Accelerator School archives
- JACoW <http://www.jacow.org/>
- Joint Universities Accelerator School lectures  
<http://www.esi-archamps.eu/Thematic-Schools/Discover-JUAS>
- USPAS archives
- National Lab sites, US, EU
- CERN documentation web sites
- BNL's Flickr photo gallery
- Wikipedia
- G.~Leleux, Circular accelerators, INSTN lectures, SATURNE Laboratory, CEA Saclay (Juin 1978).

## *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

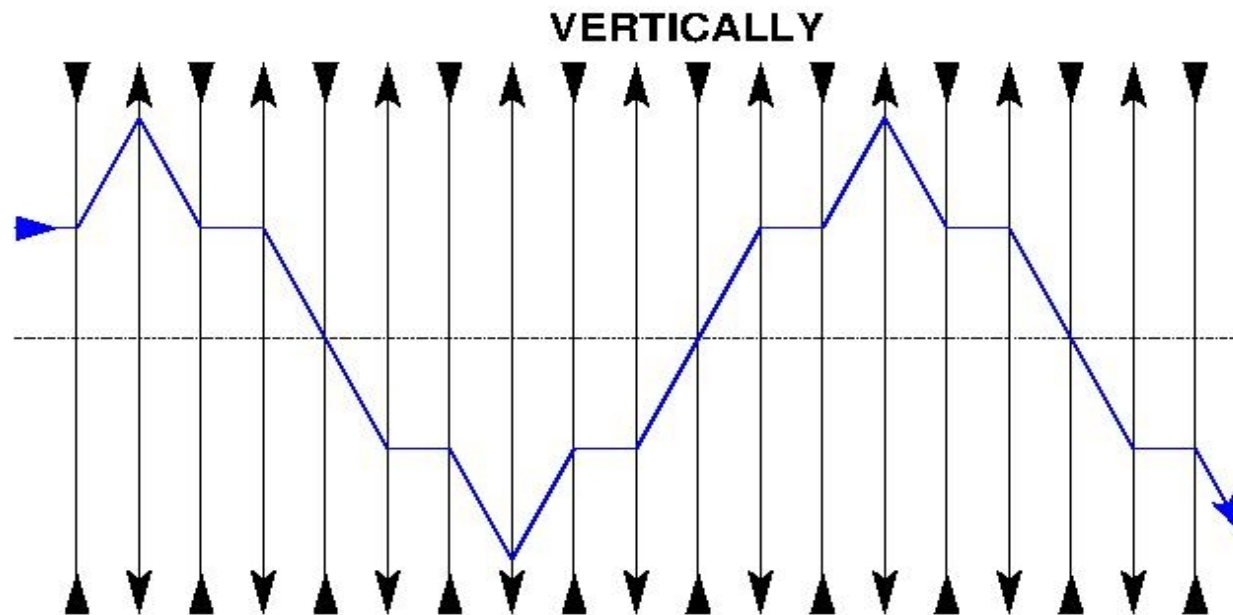
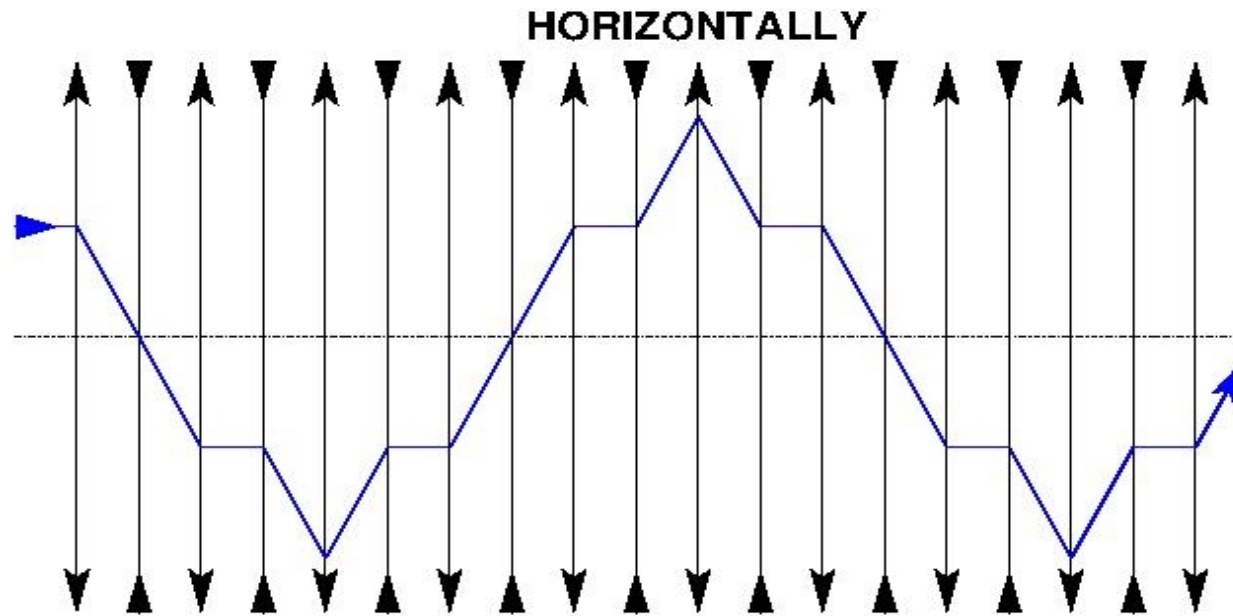
- Strong focusing was patented in 1950, in Greece and USA
- At BNL it was desired to alternate the COSMOTRON C-shaped yokes opening (all were outward), looking alternately outward and inward ... It was realized that nothing precluded strongly increasing the gradient, from its weak  $0 < n < 1$  to a strong  $|n| \gg 1$  with alternate sign. That's how it was discovered there in 1953
- CERN visitors brought the idea back there, this led to the **CERN PS, 25 GeV, started in 1959.**

Transition was an issue... it was solved on the fly by the PS group

Today CERN PS is part of the injector chain to LHC

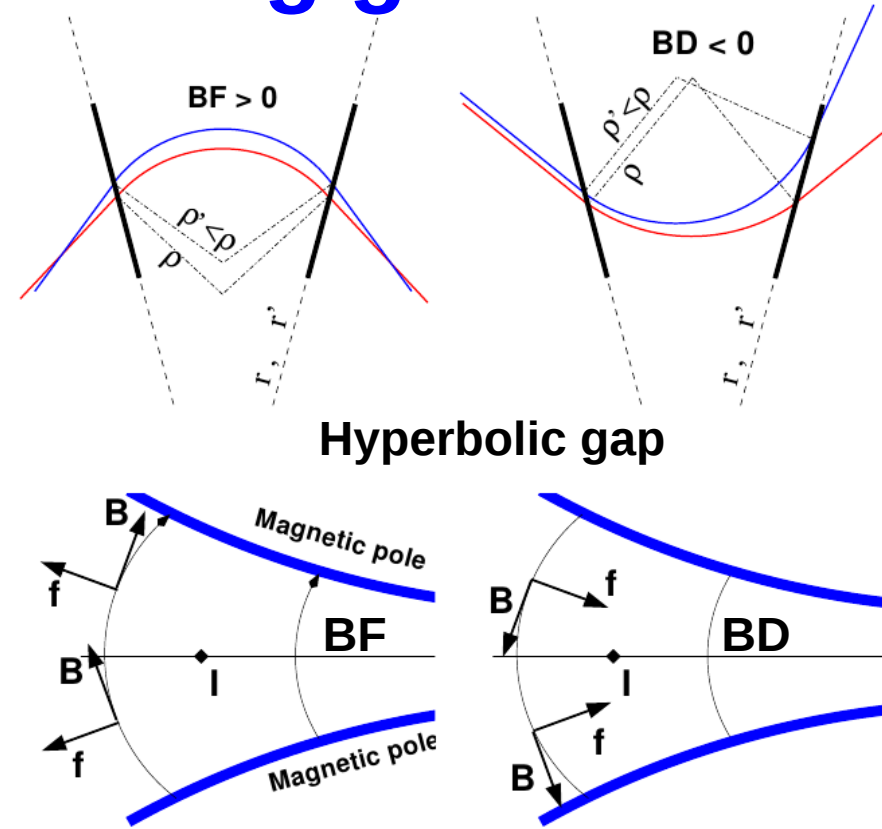
- **BNL AGS was switched on in 1960.**

## Key element: strong index, alternating





# Strong index dipole + alternating gradient



Compare the dipoles:

Cosmotron, 3 GeV  
1.22m x 0.22m vacuum  
chamber

AGS (same combined  
function magnet as PS,  
above), 30 GeV few cm  
diameter vacuum chamber

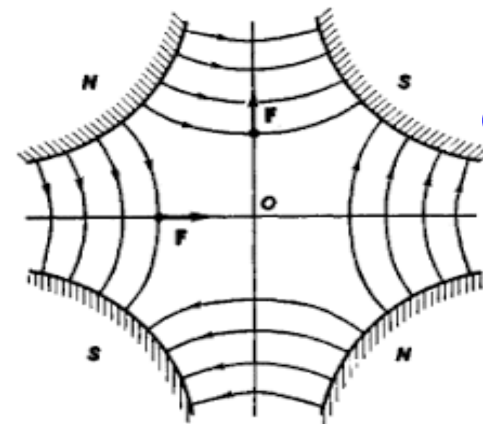
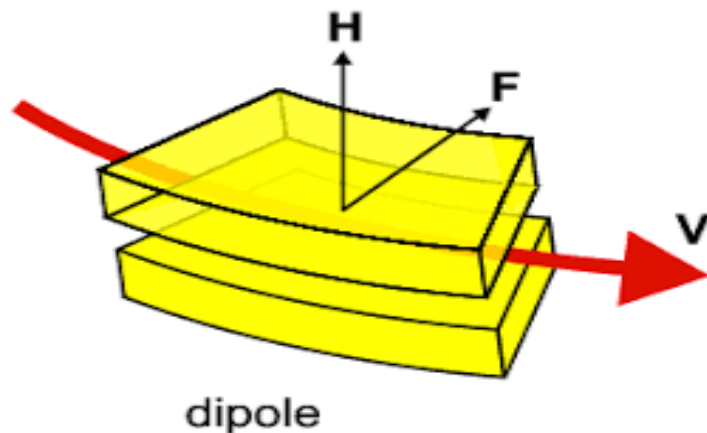


# The concept evolve into separated function optics

Dipole: steering



Quadrupole:



Parabolic  
equipotential:

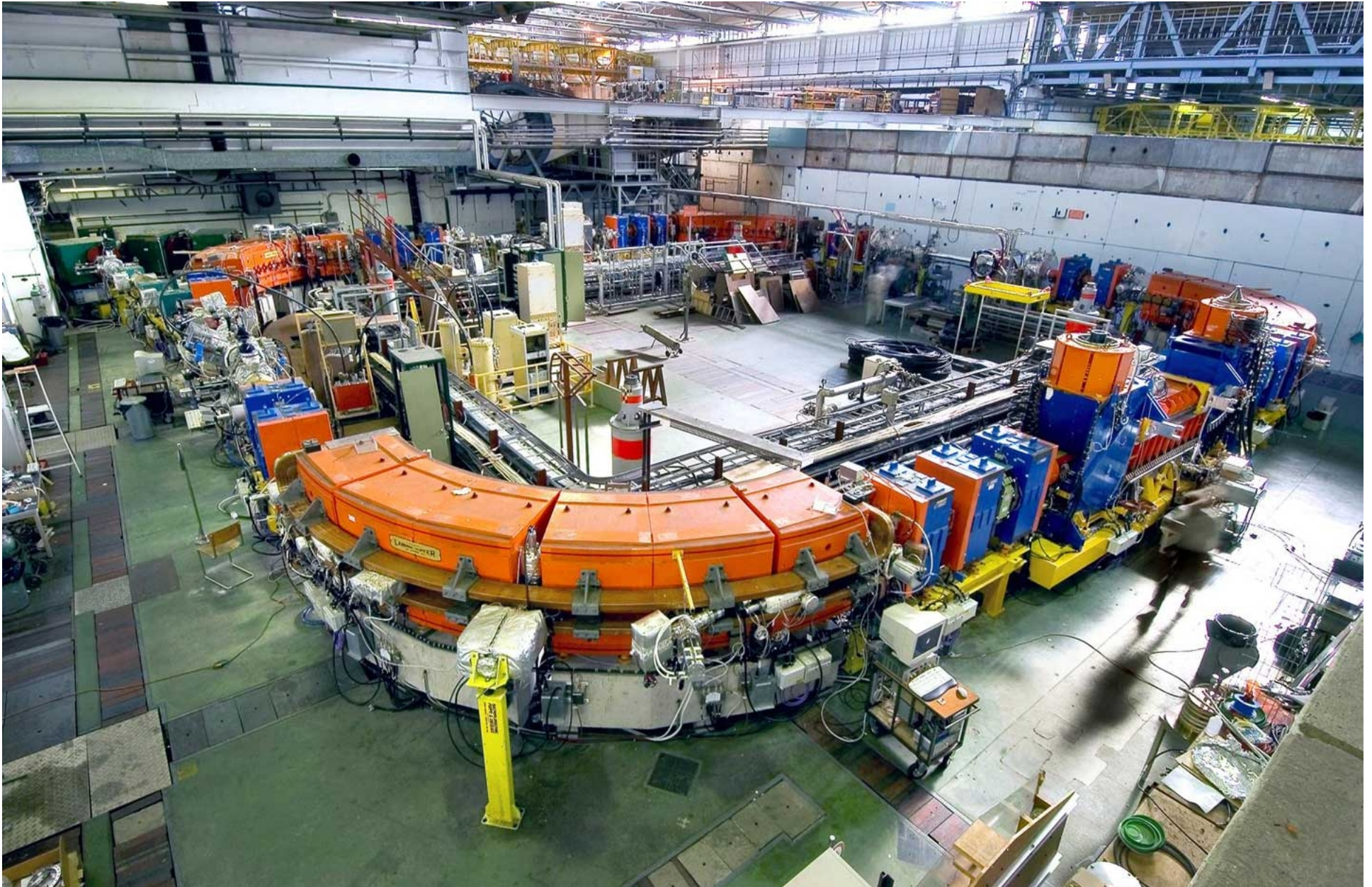
$$V=Gxy$$

$$B_x=dV/dx=Gy$$

$$B_y=dV/dy=Gx$$



# *Separated function optics at LEIR*





# Cryo-magnetism today

LHC, circumference 27km, E=7TeV

LHC dipole, 8.32 T

LHC quadrupoles

Bore ~5 cm

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

