

Lecture 2 - Overview of Accelerators II

ACCELERATOR PHYSICS

MT 2014

E. J. N. Wilson

Summary Lecture 1 - Overview of Accelerators I

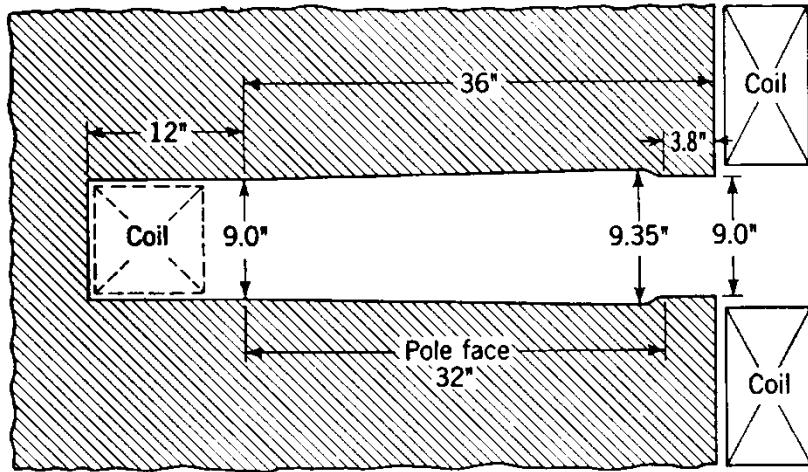
- ◆ The history of accelerators
- ◆ Need for Accelerators
- ◆ The race to high energies
- ◆ Cockcroft and Walton - Electrostatic
- ◆ Van der Graaf
- ◆ Linear accelerator
- ◆ Wideroe's Linac
- ◆ Fermilab linac (400MeV)
- ◆ Inside the Fermilab linac
- ◆ The Stanford Linear Accelerator
- ◆ The International Linear Collider (ILC)
- ◆ Cyclotrons –an inspired discovery
- ◆ Magnetic Rigidity
- ◆ Vertical Focusing
- ◆ Discovery of the Synchrotron
- ◆ Components of a synchrotron
- ◆ Phase stability
- ◆ Cosmotron
- ◆ Weak focusing in a synchrotron

Lecture 2 – Overview II - Contents

- ◆ The “n-value”
- ◆ Weak focusing in a synchrotron
- ◆ Cosmotron people
- ◆ Strong focussing
- ◆ CERN at BNL
- ◆ CERN 25 GeV PS
- ◆ CERNS RINGS
- ◆ SPS
- ◆ Center of mass *v.* Fixed target
- ◆ AdA - The first collider e-plus-minus
- ◆ ISR AND PS
- ◆ Luminosity
- ◆ SPS
- ◆ Physics of the electron *v.* protons
- ◆ LEP
- ◆ Inside LEP
- ◆ The Tevatron at FNAL
- ◆ The Large Hadron Collider (LHC)
- ◆ Superconducting magnets



Weak focusing in a synchrotron

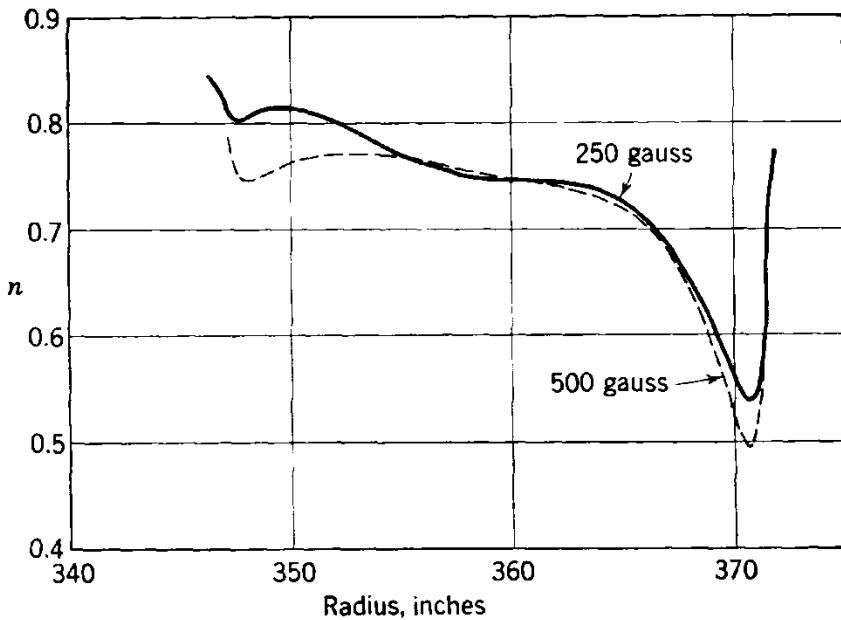


The Cosmotron magnet



- ◆ Vertical focussing comes from the curvature of the field lines when the field falls off with radius (positive n-value)
- ◆ Horizontal focussing from the curvature of the path
- ◆ The negative field gradient defocuses horizontally and must not be so strong as to cancel the path curvature effect

The “n-value”



$$B_z = B_0 \left(1 - n \frac{\Delta r}{r_0} \right) \quad n = -\frac{r}{B} \frac{\partial B}{\partial r}$$

$$f_r = f_0 (1 - n)^{1/2} \quad f_z = f_0 n^{1/2}$$

Stable if : $0 < n < 1$

- ◆ As the C magnet saturates the n value – which is the rate of droop – increases

Cosmotron people



E.Courant -Lattice Designer



Stan Livingston - Boss

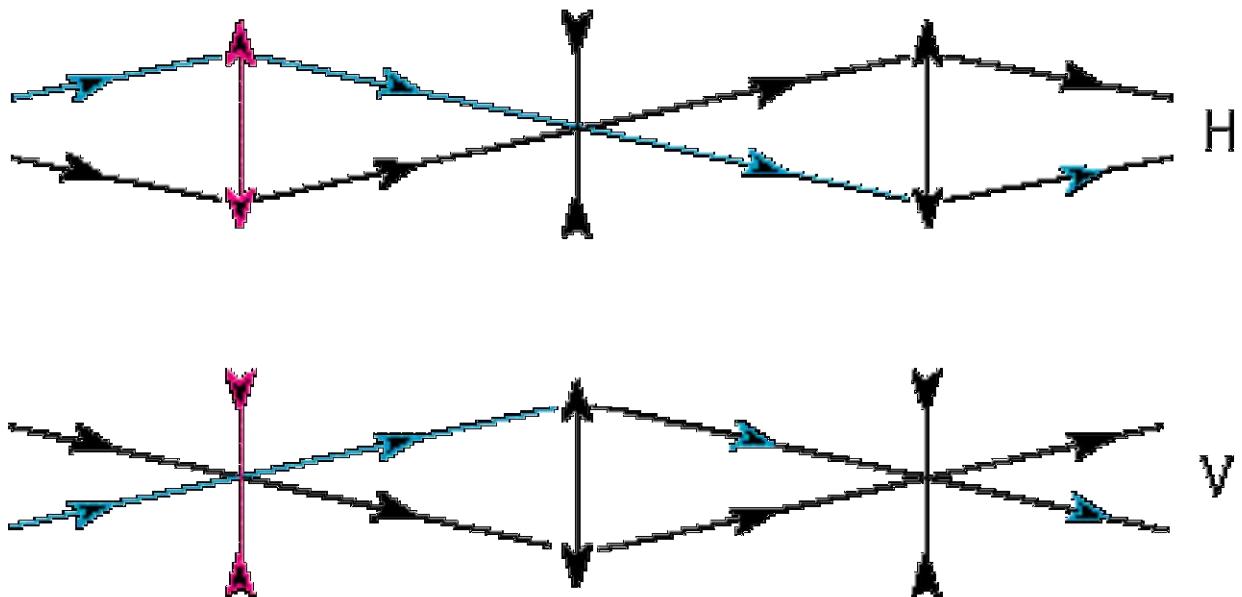
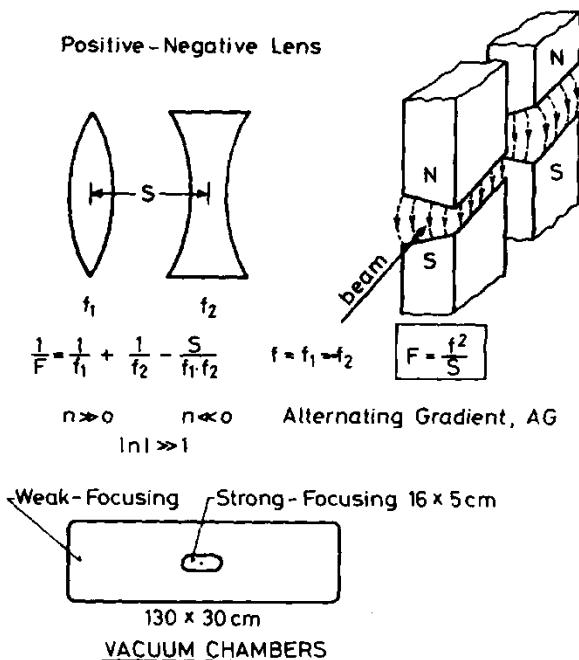


Snyder -theorist



Christofilos - inventor
Lecture 2 - E. Wilson 16 Oct 2014 -- Slide 6
FOURGUYS.pct

Strong focussing

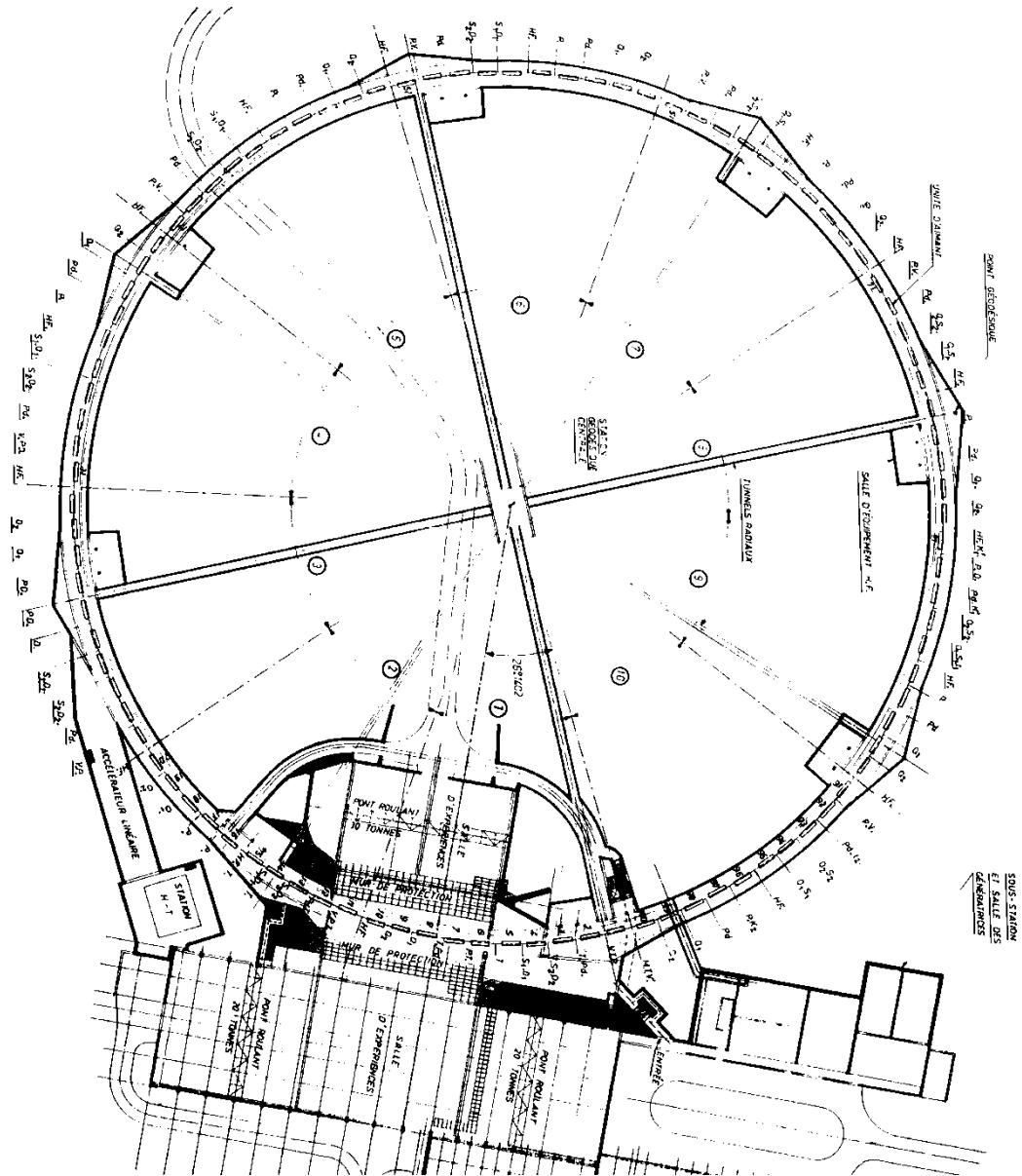


CERN at BNL



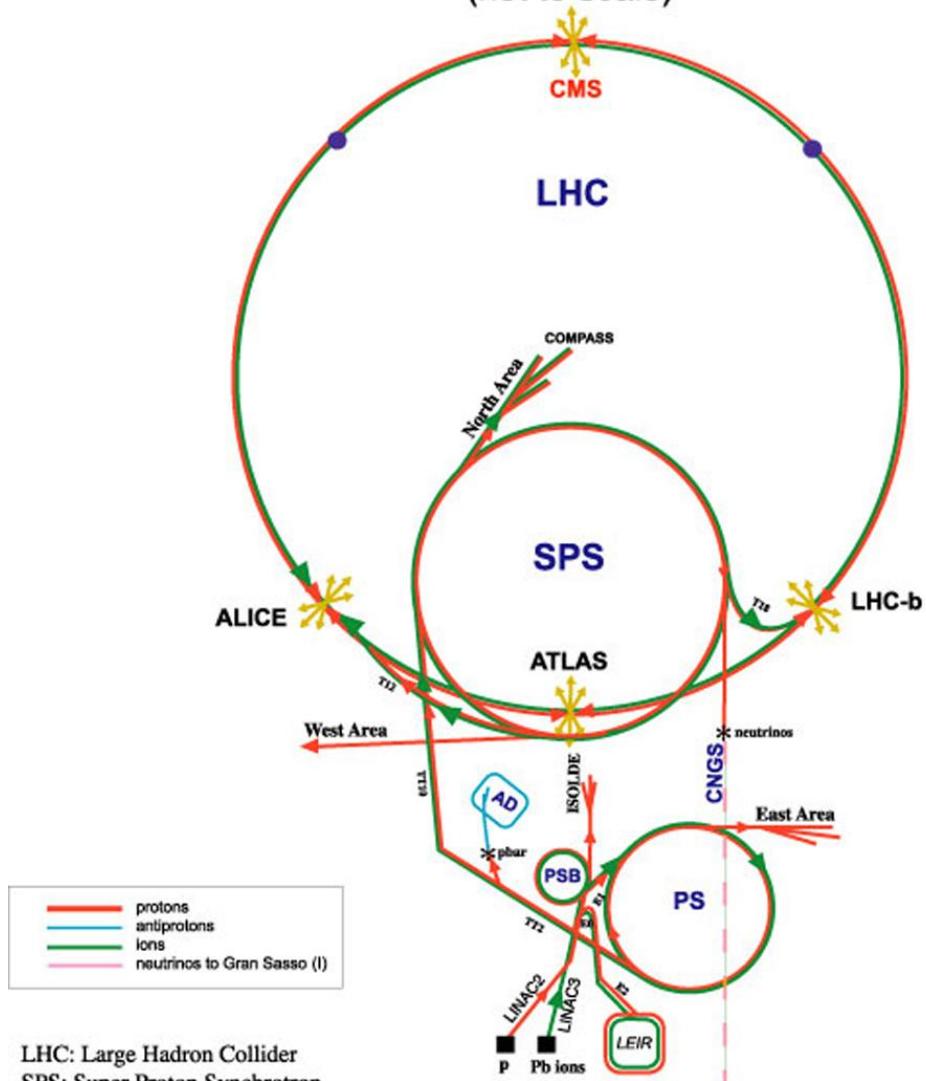
- ◆ **Odd Dahl, Frank Goward, and Rolf Wideröe**
- ◆ **(right hand trio)**

CERN 25 GeV PS



CERNS RINGS

CERN Accelerators
(not to scale)



LHC: Large Hadron Collider

SPS: Super Proton Synchrotron

AD: Antiproton Decelerator

ISOLDE: Isotope Separator OnLine DEvice

PSB: Proton Synchrotron Booster

PS: Proton Synchrotron

LINAC: LINear ACcelerator

LEIR: Low Energy Ion Ring

CNGS: Cern Neutrinos to Gran Sasso

Rudolf LEY, PS Division, CERN, 02.09.96
Revised and adapted by Antonella Del Rosso, EIT Div.,
in collaboration with B. Desforges, SL Div., and
D. Manglik, PS Div. CERN, 23.05.01

SPS

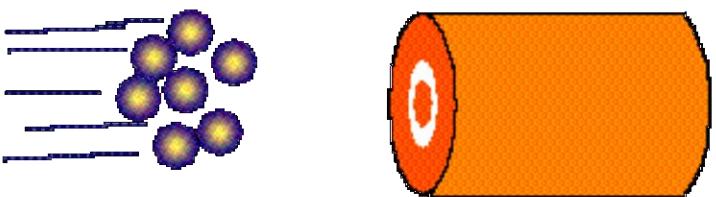


Center of mass v. Fixed target

W = Energy available in center-of-mass for making new particles

For **fixed target** :

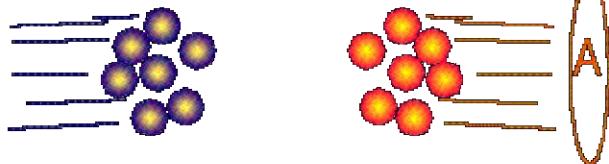
$$E_{c.m.} \approx \sqrt{2m_T E_B}$$



... and we rapidly run out of money trying to gain a factor 10 in c.m. energy

But a **storage ring** , **colliding** two beams, gives:

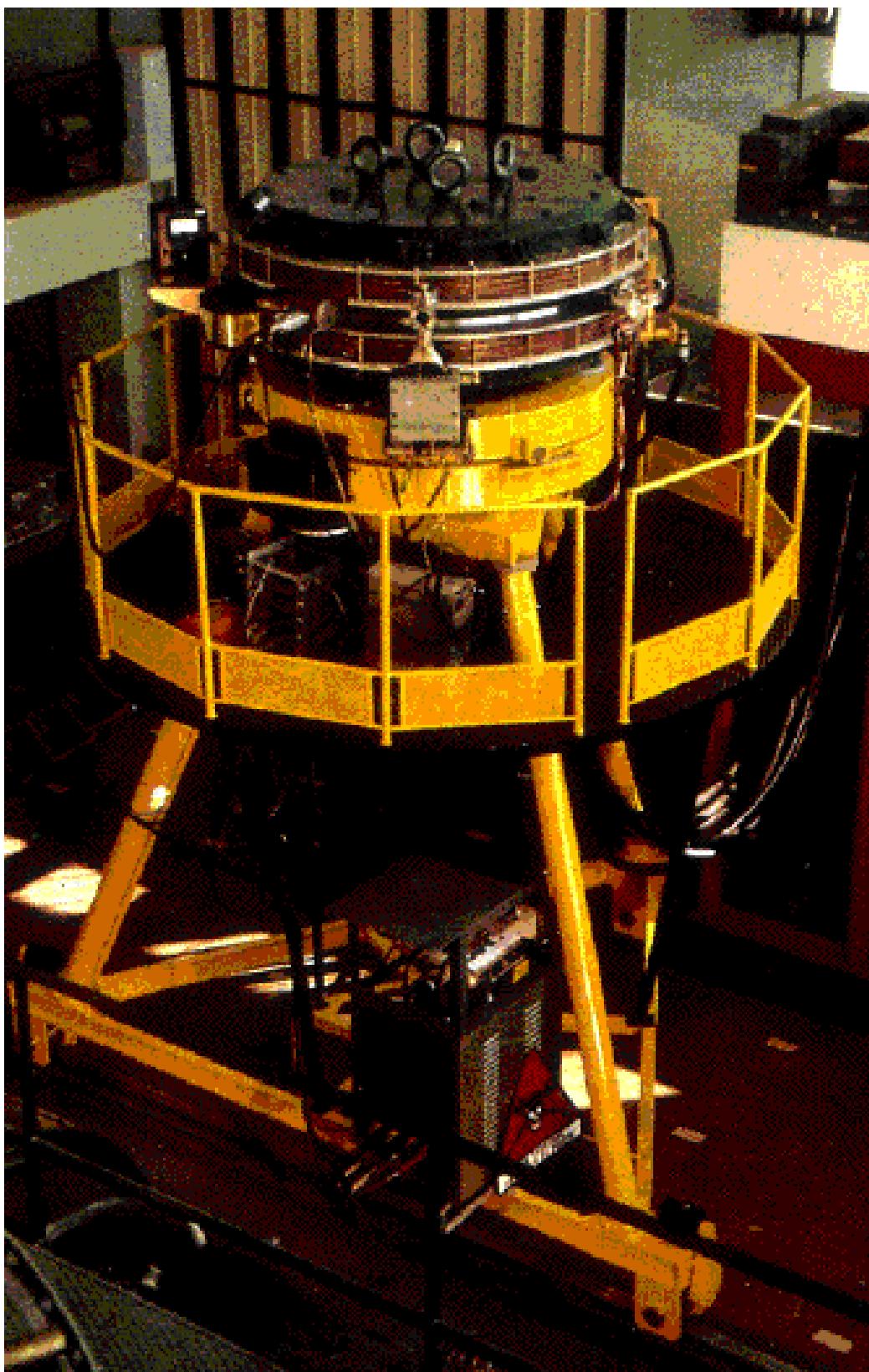
$$E_{c.m.} \approx 2 E_B$$



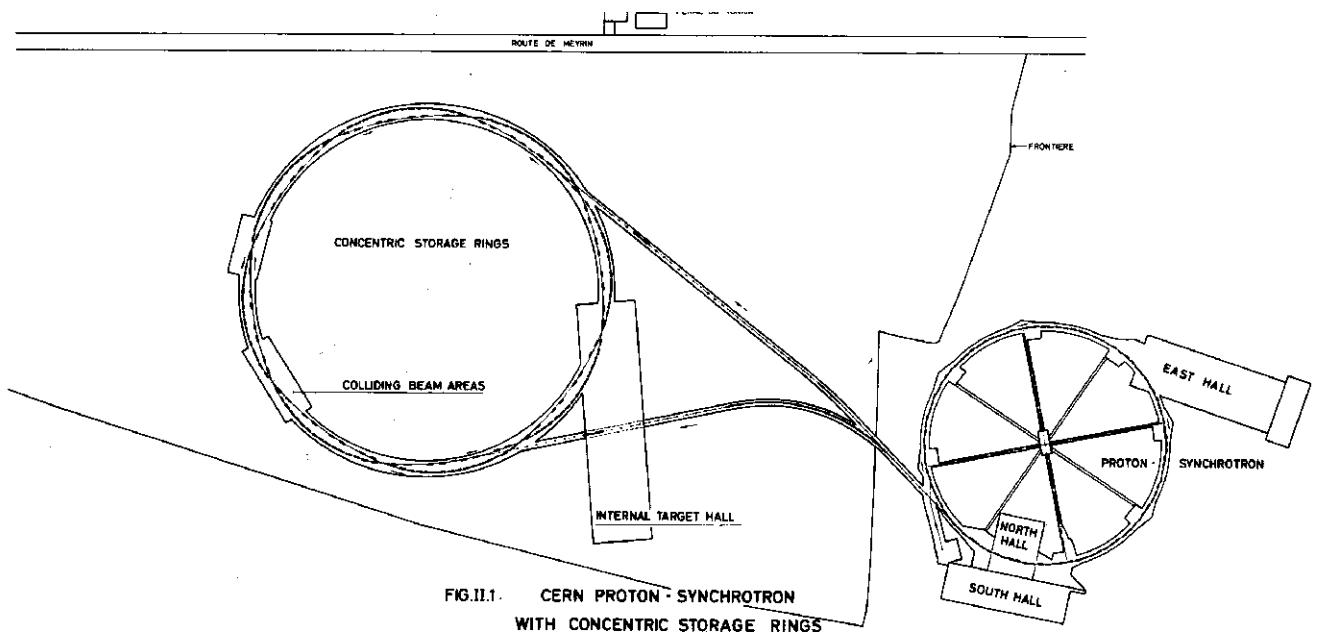
Problem: Smaller probability that accelerated particles collide "Luminosity" of a collider

$$L = N_1 N_2 \frac{1}{A} \frac{\beta c}{2\pi R} \approx 10^{29} \dots 10^{34} \text{ cm}^{-2} \text{s}^{-1}$$

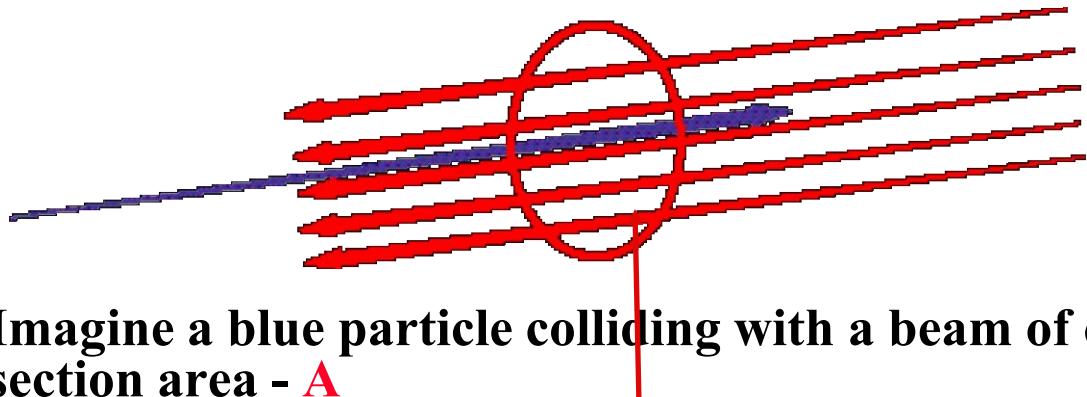
AdA - The first collider e-plus-minus



ISR AND PS



Luminosity



- ◆ Imagine a blue particle colliding with a beam of cross section area - A
- ◆ Probability of collision is $\frac{\sigma}{A} \cdot N$
- ◆ For N particles in both beams $\frac{\sigma}{A} \cdot N^2$
- ◆ Suppose they meet f times per second at the revolution frequency

- ◆ Event rate

$$f_{rev} = \frac{\beta c}{2\pi R}$$

$$\frac{f_{rev} N^2}{A} \cdot \sigma$$

Make big
e.g. 10^{-25}
Make small

LUMINOSITY $\approx 10^{30}$ to 10^{34} $[\text{cm}^{-2} \text{ s}^{-1}]$

SPS



Physics of the electron v. protons

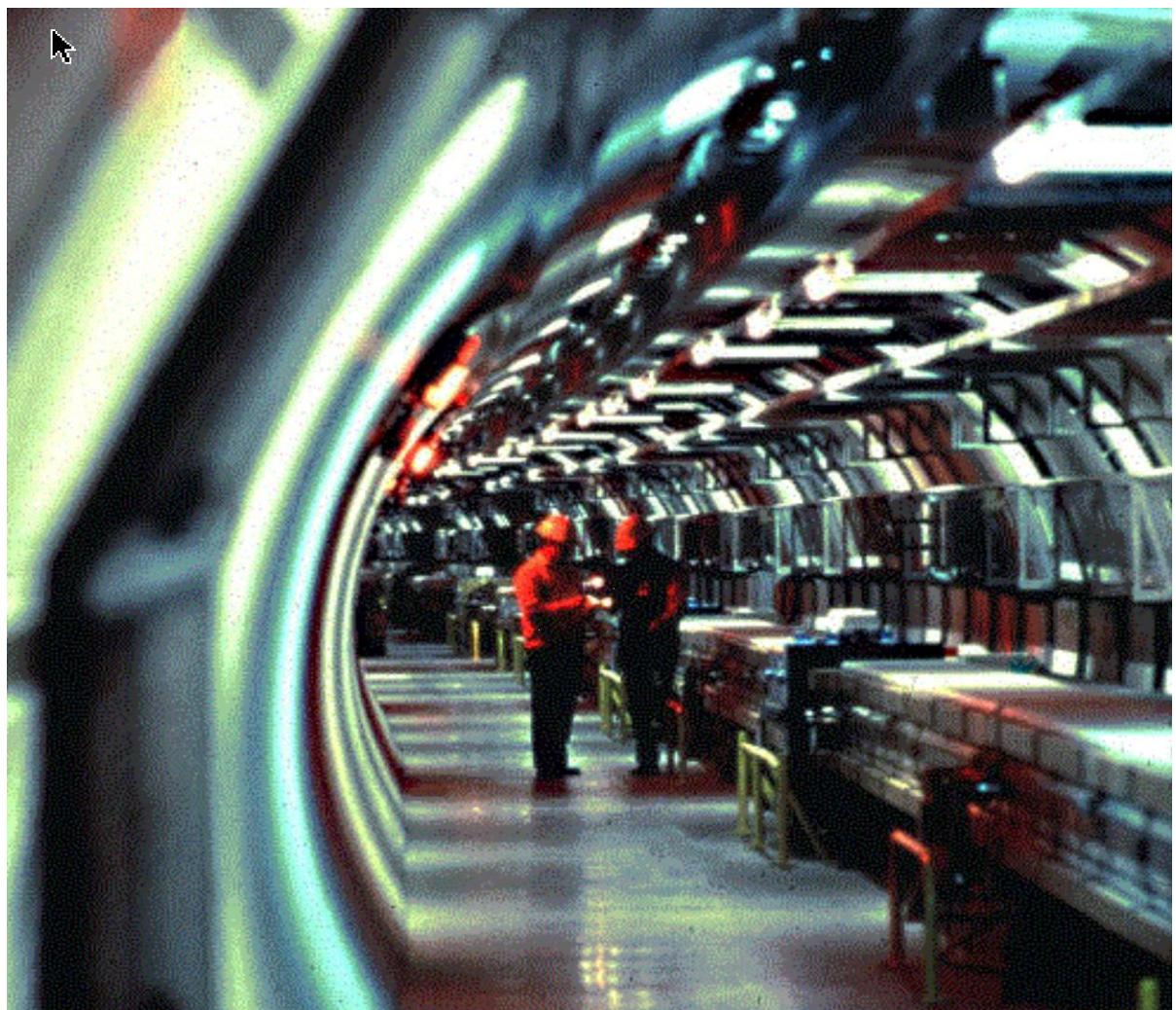
- ◆ When we collide Protons we collide complex assemblies of three quarks
- ◆ Only two quarks interact
- ◆ Their available energy is on average only 10% of the total centre of mass energy
- ◆ We do not know which quarks they are
- ◆ Hence in some ways 100 GeV LEP is as good as 1000 GeV TEVATRON

**HENCE THE RETURN TO LEP AFTER SPS
AND THEN LHC AFTER LEP**

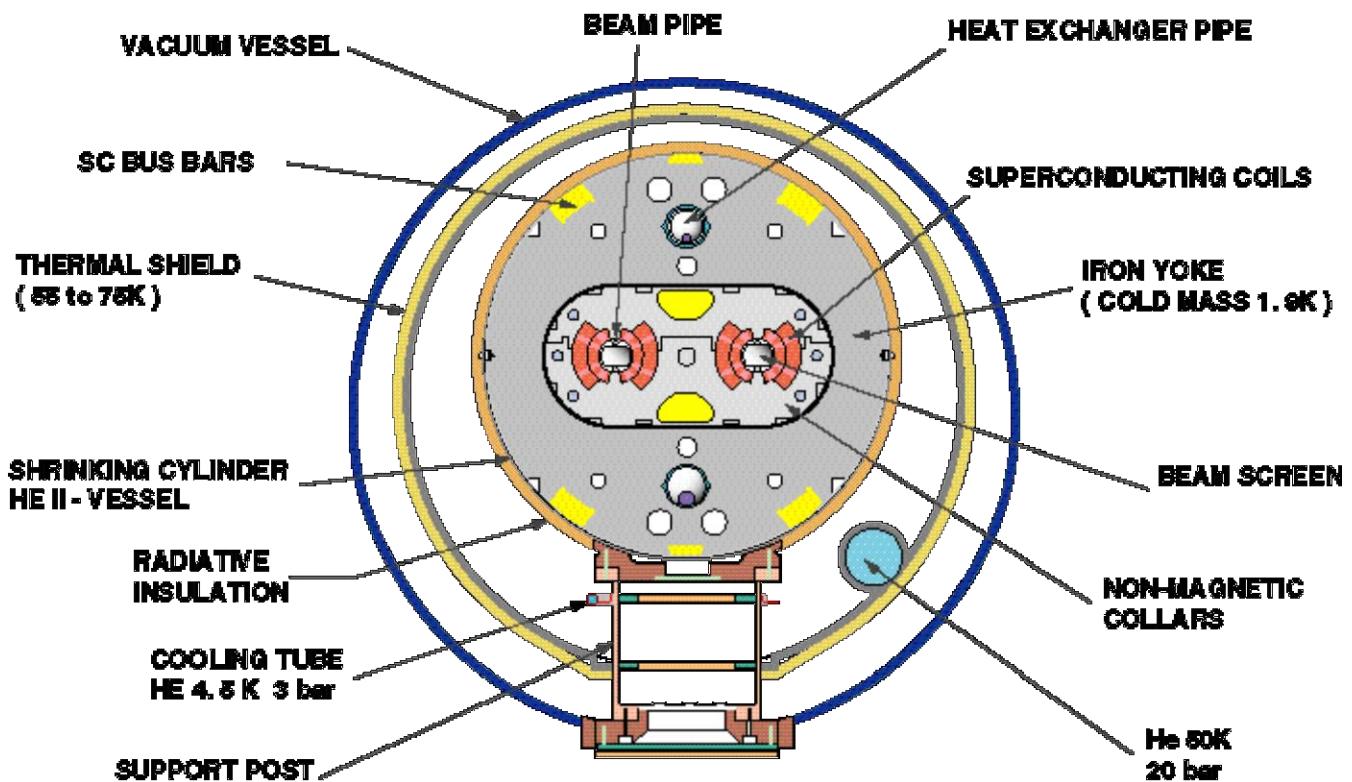
LEP



Inside LEP



Superconducting magnets

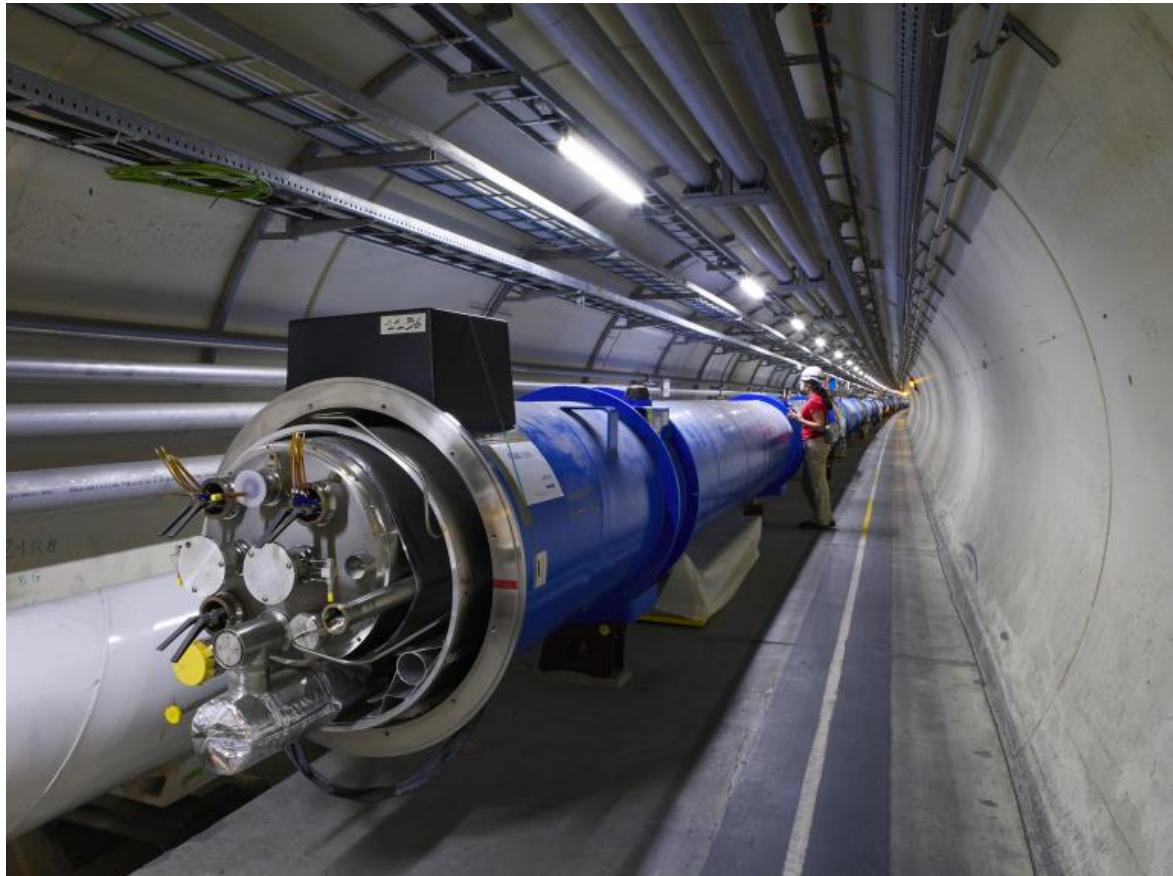


The Tevatron at FNAL



Fermilab's superconducting Tevatron can just be seen below the red and blue room temperature magnets of the 400 GeV main ring.

The Large Hadron Collider (LHC)



CERN Control Centre – LHC Startup



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