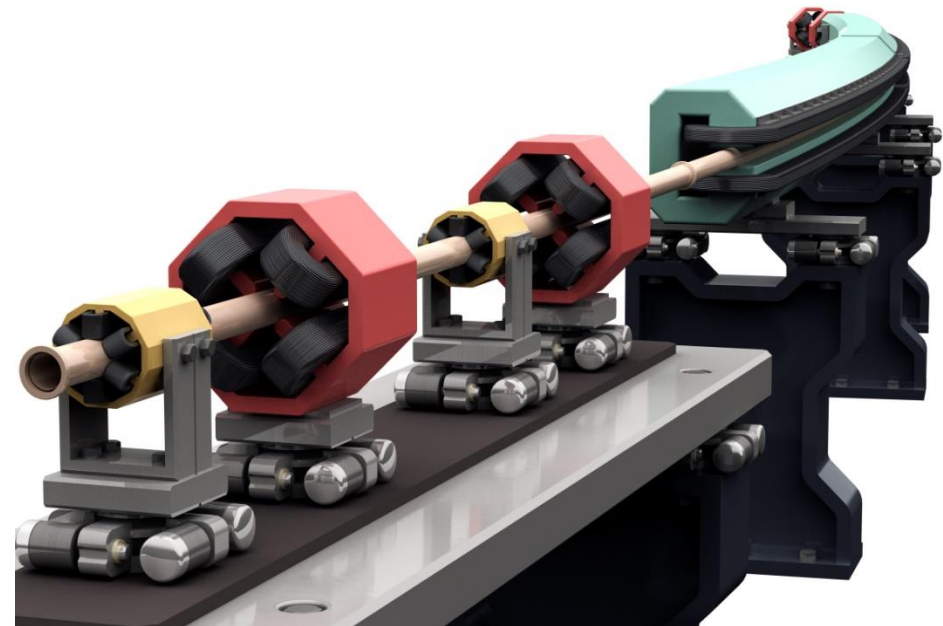




Greek students 2021

Introduction to Power at CERN

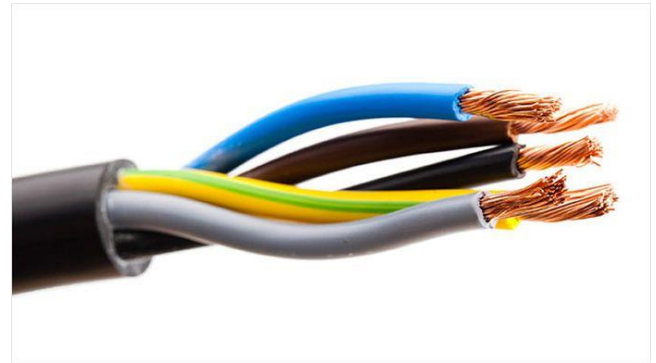
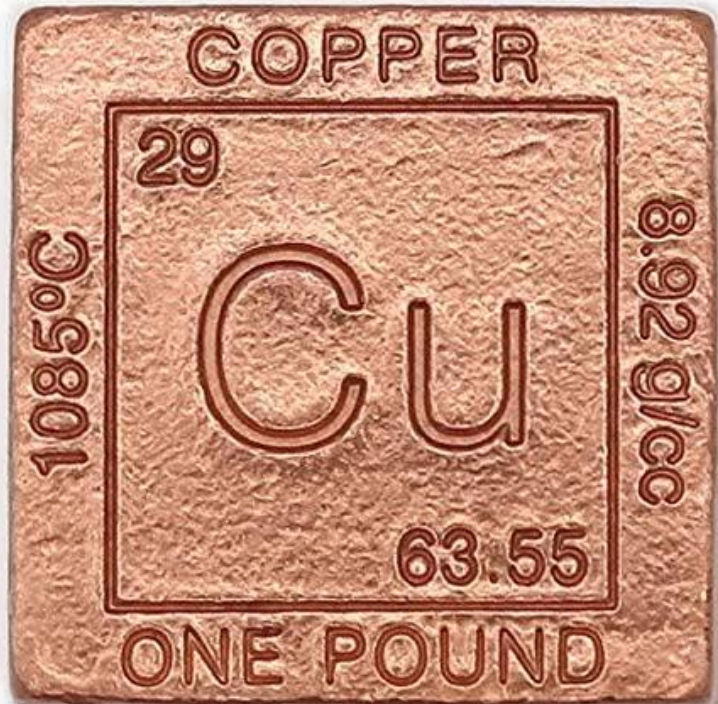
Konstantinos Papastergiou, Accelerator Systems Department
CERN – European Organisation for Nuclear Research



Quiz

- ➔ Gold contains some of it.
- ➔ A household contains 180 kg of this
- ➔ The average car contains about 20kg
- ➔ It is naturally antibacterial
- ➔ 100% recyclable used since ancient times
- ➔ It is located in the middle of the periodic table of elements
- ➔ Price increased about 30% this year alone
- ➔ More than 80kg will be needed for each electric car
- ➔ The demand is expected to increase from 40 to 600m tones in 15 years.

Copper



Quizz



- ➔ Has 14 protons in the nucleus
- ➔ It is called a metalloid
- ➔ It is extracted from the sand
- ➔ Dangerous if inhaled – can cause xxx-cosis
- ➔ Combined with carbon it makes xxx-carbide the hardest substance after diomond
- ➔ Plants use it to strengthen their cell walls
- ➔ California xxx-valey is a famous user of the element

Silicon



Semiconductors

Applications of power electronics

Power supply/chargers

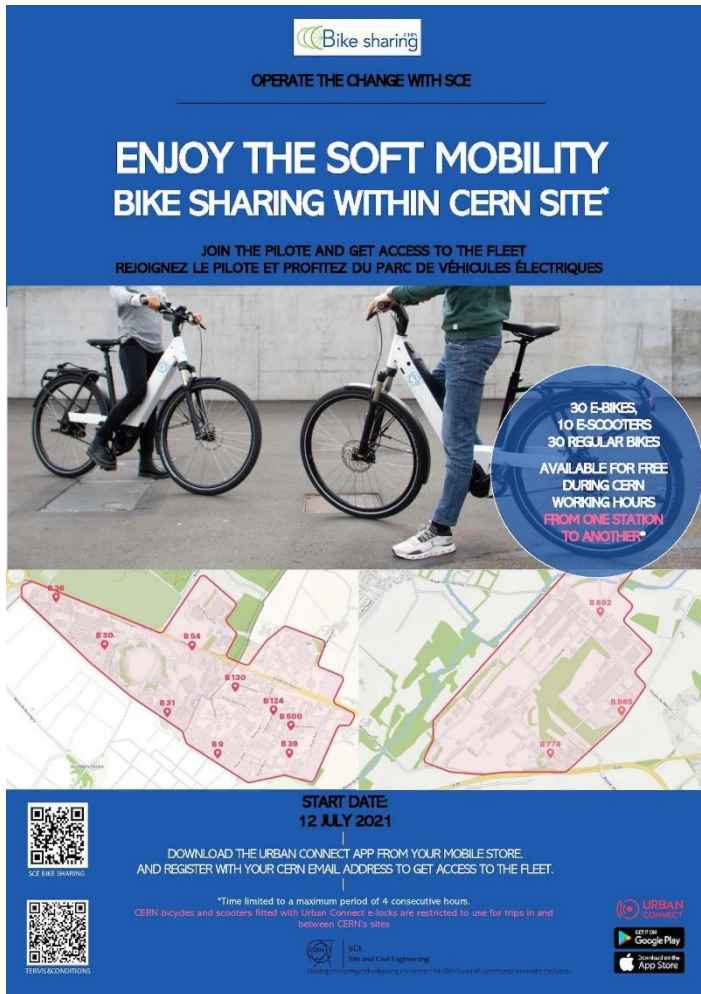
15W



Source: yootech Chargeur

Electric scooter/bike

400W



Bike sharing
OPERATE THE CHANGE WITH SCE

ENJOY THE SOFT MOBILITY BIKE SHARING WITHIN CERN SITE*

JOIN THE PILOTE AND GET ACCESS TO THE FLEET
REJOIGNEZ LE PILOTE ET PROFITEZ DU PARC DE VÉHICULES ÉLECTRIQUES

30 E-BIKES,
10 E-SCOOTERS
30 REGULAR BIKES

AVAILABLE FOR FREE
DURING CERN
WORKING HOURS
FROM ONE STATION
TO ANOTHER*

START DATE:
12 JULY 2021

DOWNLOAD THE URBAN CONNECT APP FROM YOUR MOBILE STORE
AND REGISTER WITH YOUR CERN EMAIL ADDRESS TO GET ACCESS TO THE FLEET.

*Time limited to a maximum period of 4 consecutive hours.
CERN bicycles and scooters fitted with Urban Connect e-locks are restricted to use for trips in and between CERN's sites.

URBAN CONNECT
GET IT ON Google Play
GET IT ON the App Store

SCE
Site and Civil Engineering
Contact: scen@cern.ch | www.sce.cern.ch



Industrial Robots

10kW



Source: Le monde (Kawada Robot)

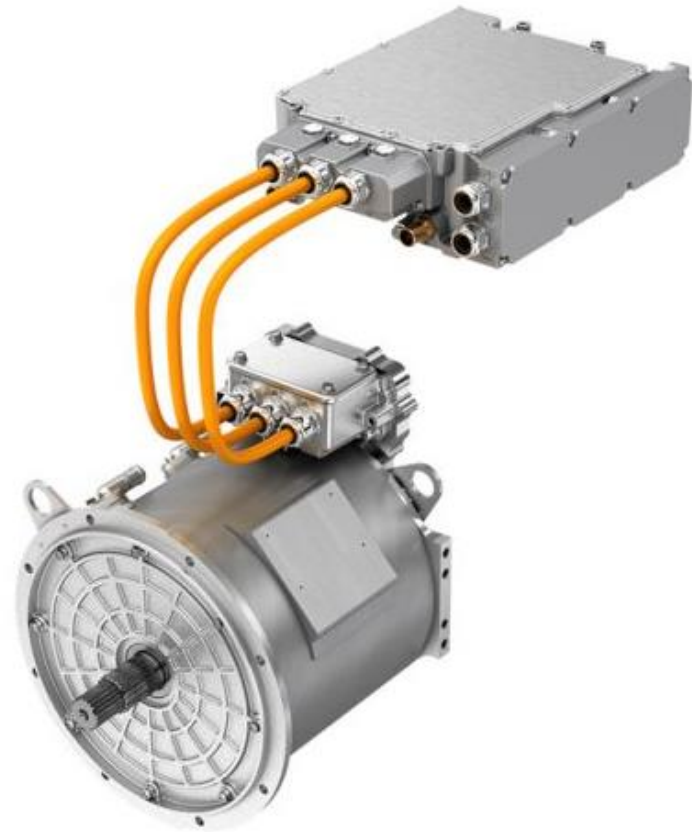
Terrestrial/satellite

10kW



Electric car/truck/plane

50kW



Industrial drives

500kW



Renewable generation

3MW

3MW Onshore Wind Turbine Platform

GE Renewable Energy

Pitch System

Aerodynamic brake:
Full feathering of
blade pitch.
Speed regulation;
Electric drive
pitch control with
battery backup.

Rotor

Rotor diameter ranging
from 130 to 137 meters.

Tower

Hub height ranging from
85 to 164.5 meters.
Tower made of tubular steel,
or hybrid pre-cast concrete &
tubular steel with logistic
friendly tower options.

App Suite & Predix* Platform

GE's software applications generate smooth, predictable power, thanks to big data and the Industrial Internet. Our apps enhance annual energy production and improve wind farm predictability.

Generator

Nameplate ranging
from 3.2 to 3.8 MW
at 50 or 60 Hz.



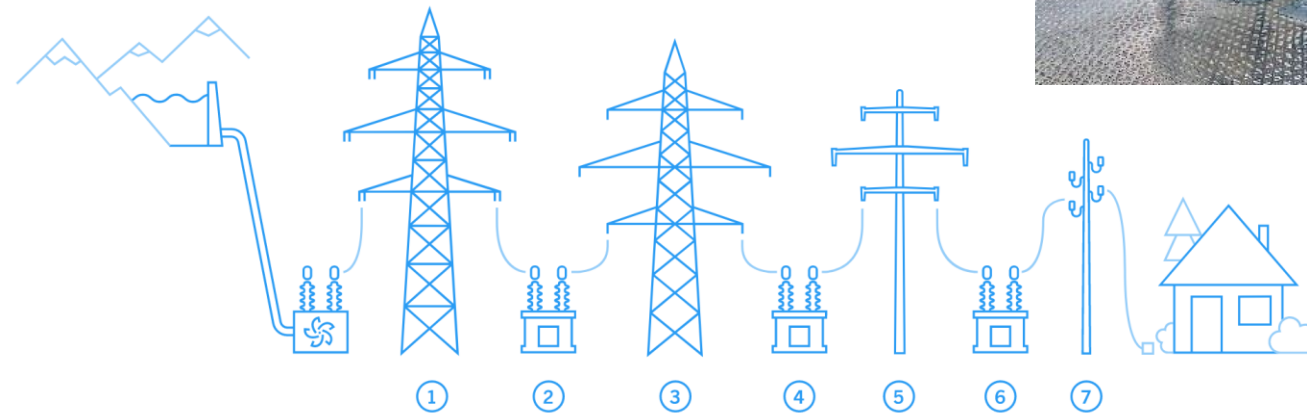
Powerful and efficient

- GE's 3MW platform can be customized based on nameplate, rotor diameter and hub height
- The 3.6-137 is our highest performing turbine for Class III winds

Trademark of General Electric Company

Energy Transmission

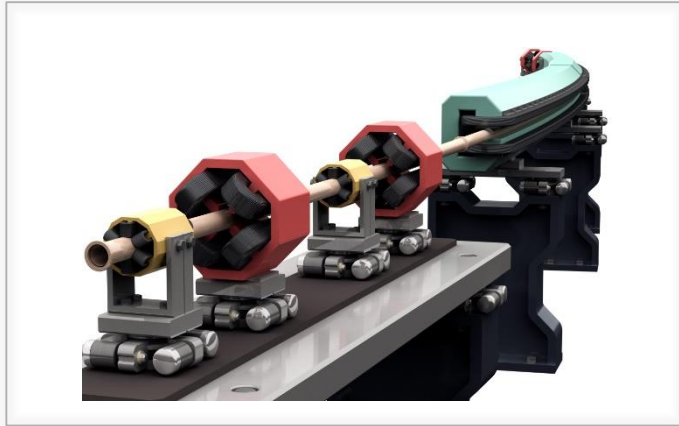
2GW



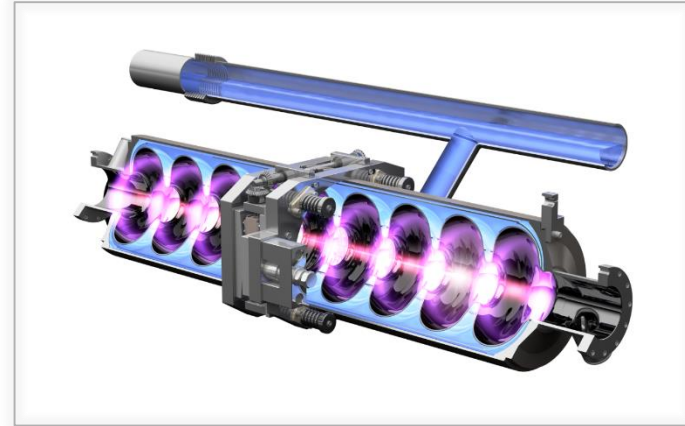
Source: Swissgrid.ch

Power at CERN

CERN power electronics



Electromagnets



Microwave cavities



Cryogenics/Cooling/ventillation

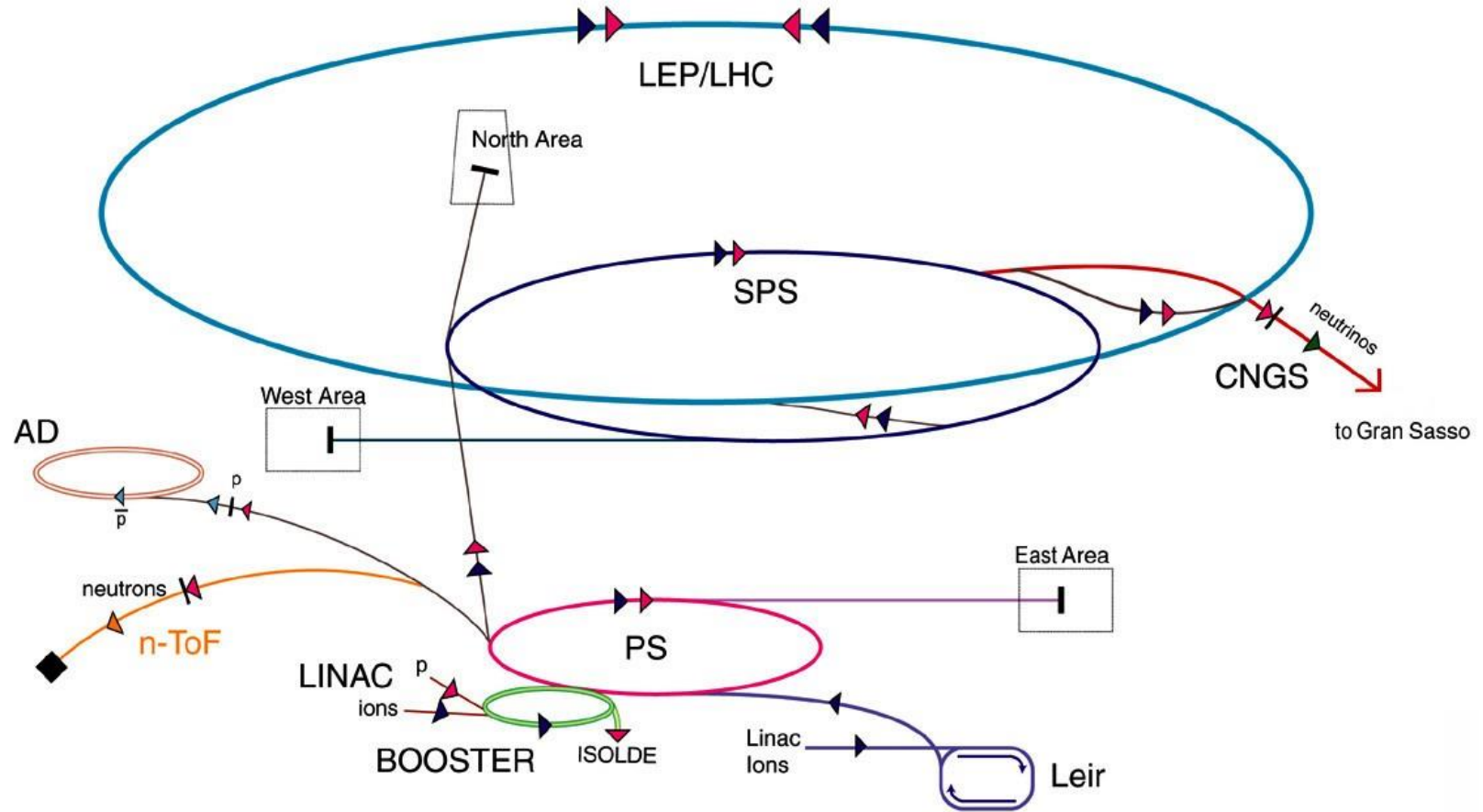


Courtesy: ABB

Power quality

Graphics by Rey.Hori / KEK, Japan

Accelerators at CERN



- ▶ p (proton)
- ▶ ion
- ▶ neutron
- ▶ \bar{p} (antiproton)
- ▶ \leftrightarrow proton/antiproton conversion
- ▶ neutrino

- AD Antiproton Decelerator
- PS Proton Synchrotron
- SPS Super Proton Synchrotron

- LHC Large Hadron Collider
- n-ToF Neutron Time of Flight
- CNGS CERN Neutrinos Gran Sasso

Force on Charged Particle

The force on a charged particle is proportional to the charge, the electric field, and the cross product of the velocity vector and magnetic field:

Lorenz force:

$$\vec{F} = q \cdot (\vec{E} + \vec{v} \times \vec{B})$$

Where q is the electrons' (positrons', protons'...) elementary charge:

$$q = e_0 = 1.602 \cdot 10^{-19} \text{ [C]}$$

For conservative forces (work done independent of the path) the work done by a force F along the path $s_1 \rightarrow s_2$ transversed by the particle is:

$$\Delta E = \int_{s_1}^{s_2} \vec{F} \cdot d\vec{s}$$

by differentiating:

$$\frac{\Delta E}{dt} = q \cdot (\vec{v} \cdot \vec{E} + \vec{v} \cdot (\vec{v} \times \vec{B})) = q \cdot \vec{v} \cdot \vec{E}$$

Conclusion the magnetic field does not produce any work on the direction of the vector travelled by the charged particle. Energy (acceleration) is only gained under the effect of electric field.



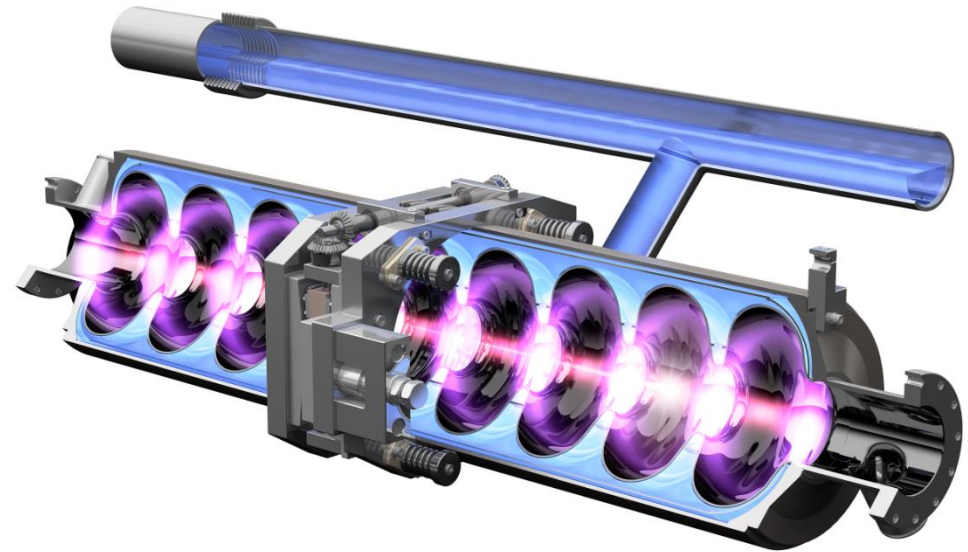
RF Cavities - Klystron

Functions:

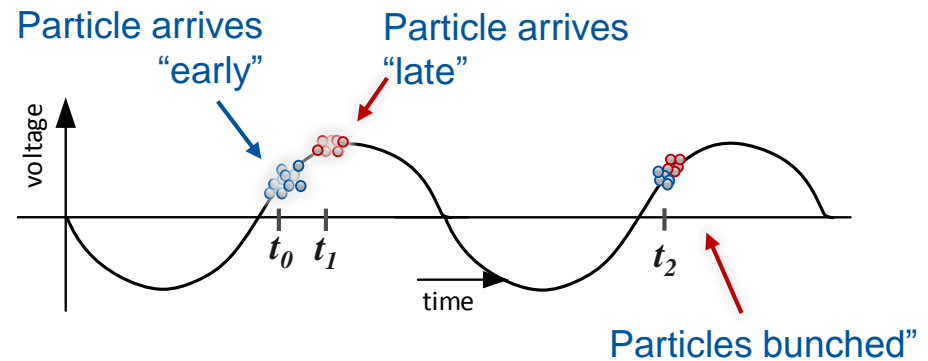
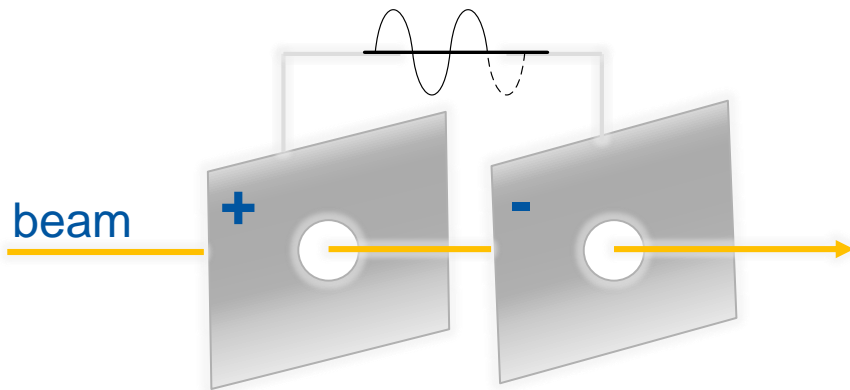
- Particle acceleration

$$\Delta E = \int_{s1}^{s2} \vec{F} \cdot d\vec{s} = q \cdot \int_{s1}^{s2} \vec{E} \cdot d\vec{s} = q \cdot U$$

* The rhythm of energy build up depends on the particles' charge and the electric field voltage



(c) Rey Hori / KEK



Electro-magnets

Functions:

- Beam steering

$$\vec{F} = q \cdot (\vec{v} \times \vec{B})$$

- At first sight F is not dependent on mass
- Since v on a circle of radius $\rho \rightarrow F = \text{centripetal force}$

$$\vec{F} = q \cdot (\vec{v} \times \vec{B}) = m_r \cdot \vec{a}_C = \frac{m_r \cdot v^2}{\rho}$$

$$m_r = \gamma \cdot m_0$$

* γ : lorenz factor ($\gamma = 1/(1-v^2/c^2)$)

- Rearranging yields the beam rigidity i.e. a measure of the force needed to bend the charge direction
- And the bending angle inside a magnet field

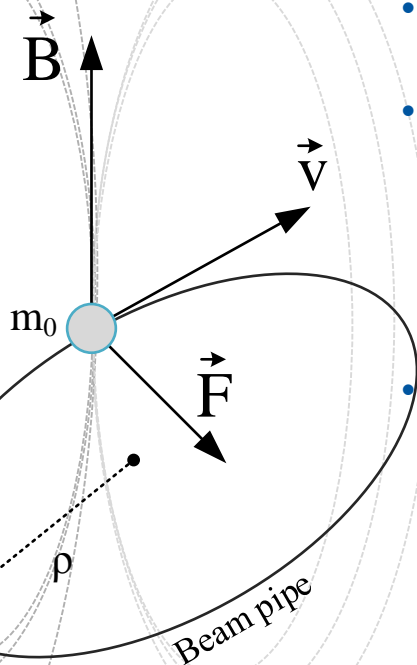
$$\vec{B} \cdot \rho = \frac{m \cdot v}{q} = \frac{p}{e}$$

$$a = \frac{\int \vec{B} \cdot ds}{B \cdot \rho}$$

- The integrated field is a magnet property also given by Amperes law:

$$\oint_C \vec{B} \cdot ds = \mu_0 \cdot \iint_A \vec{J} \cdot dA = \mu_0 \cdot I_C$$

* μ_0 : magnetic permeability of the air



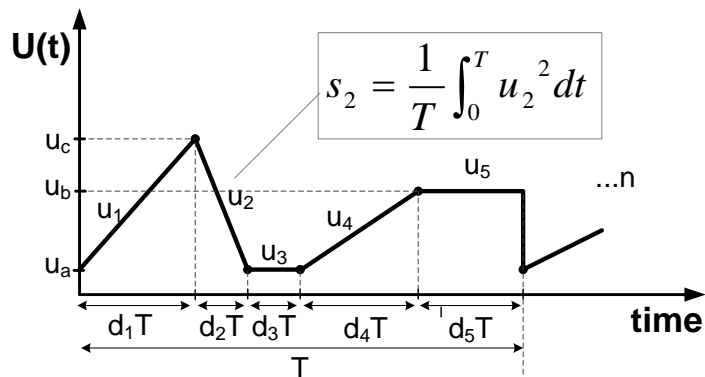
Dipole magnet

Functions:

- Beam steering
- Stores energy $E=0.5 L I^2$
- Consumes power $P=I^2 R$



(c) Rey Hori / KEK

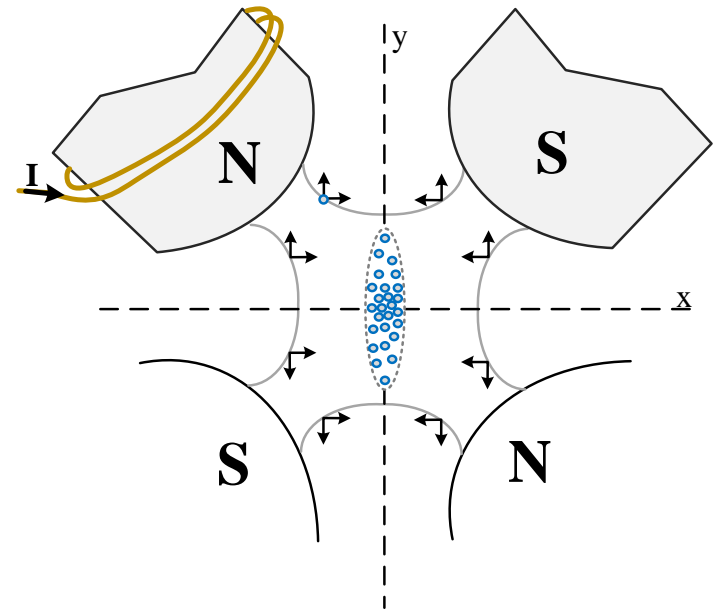
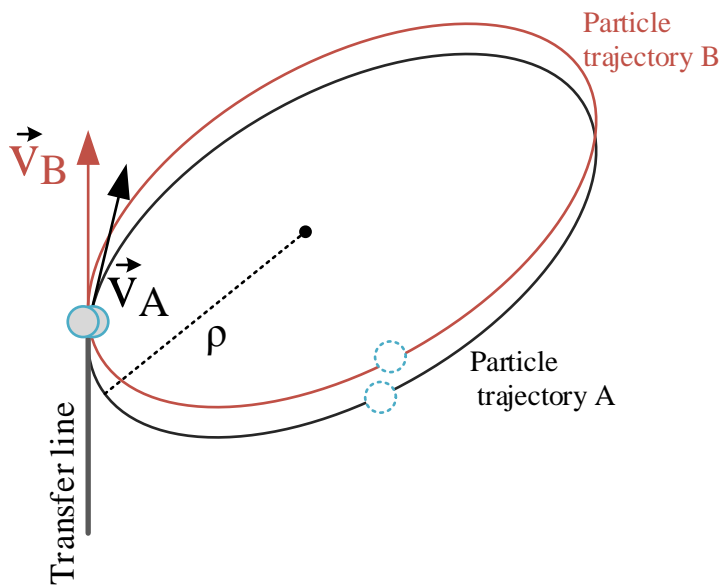


Quadrupole magnets

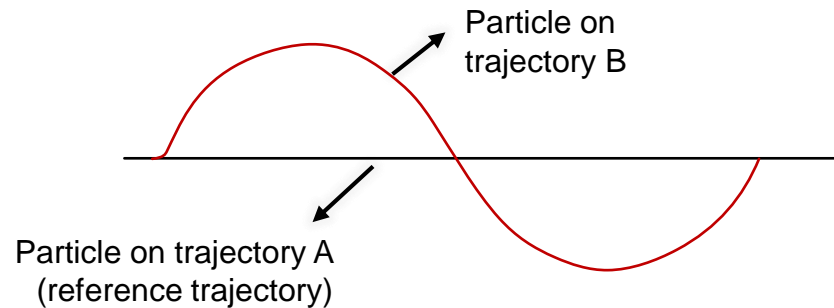
Functions:

- Focussing-defocussing

Two particles enter in the accelerator with different velocity vectors:



Betatron Oscillation



Εμπειρία στο CERN

Τμήμα Συστημάτων Επιταχυντών

Μεταφορά δέσμης

Μικροκυματικές κοιλότητες

Μετατροπείς Ενέργειας

Μετρήσεις Δέσμης

Στόχοι & απόθεση δέσμης

- Συστήματα ελέγχου μετατροπών
- Ηλεκτρονικές διατάξεις ελέγχου
- Συστήματα υψηλής ισχύος
- **Συστήματα μέσης ισχύος**
- Συστήματα χαμηλής ισχύος
- Συστήματα παλμικής τροφοδοσίας
- Μετρήσεις ακριβείας



Ακρίβεια συστημάτων

Σαν να πετυχαίνει κανείς ace (τρύπα με το πρώτο χτύπημα) από απόσταση 20χιλιομέτρων

Electronics & Power Electronics

- ➔ Electronics is the act of manipulating the flow of electrons to perform certain functions
 - ⇒ Receive, transmit and store information
 - ⇒ Generate electromagnetic waves (heat, light)
 - ⇒ Convert electricity to kinetic energy (motors)

Analog & Digital Electronics



Power Electronics



Παράδειγμα ενός μετατροπέα



Ο ρόλος του μηχανικού

Τεχνικά

- Έρευνα και σχεδίαση ηλ.ισχύος
- Προσομοίωση στον υπολογιστή
- Ηλεκτρολογικό & μηχανολογικό σχέδιο
- Μετρήσεις και πιστοποίηση
- Επίλυση βλαβών 24/7

Έργα

- Σχεδίαση και επίβλεψη έργων
- Διενέργεια διαγωνισμών
- Επίβλεψη ομάδων
- Συνεργασία με τη βιομηχανία

Άλλες δραστηριότητες

- Συμμετοχή σε συνέδρια
- Επισκέψεις σχολείων

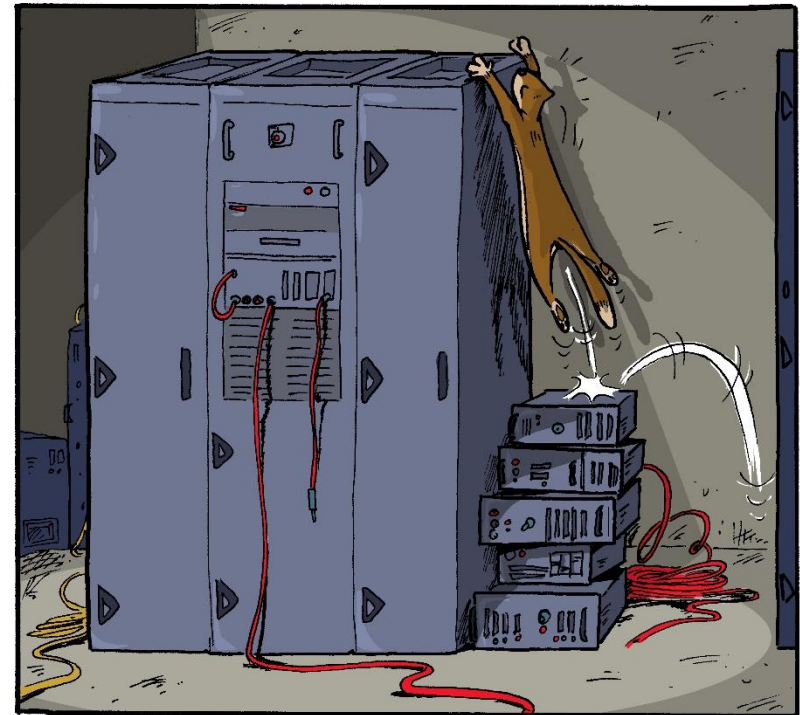


Illustration of power converter by Klimis Keramitsopoulos





- Ερωτήσεις;

<http://www.cern.ch/aftervisit>

Life at CERN





www.cern.ch