Greek students 2021

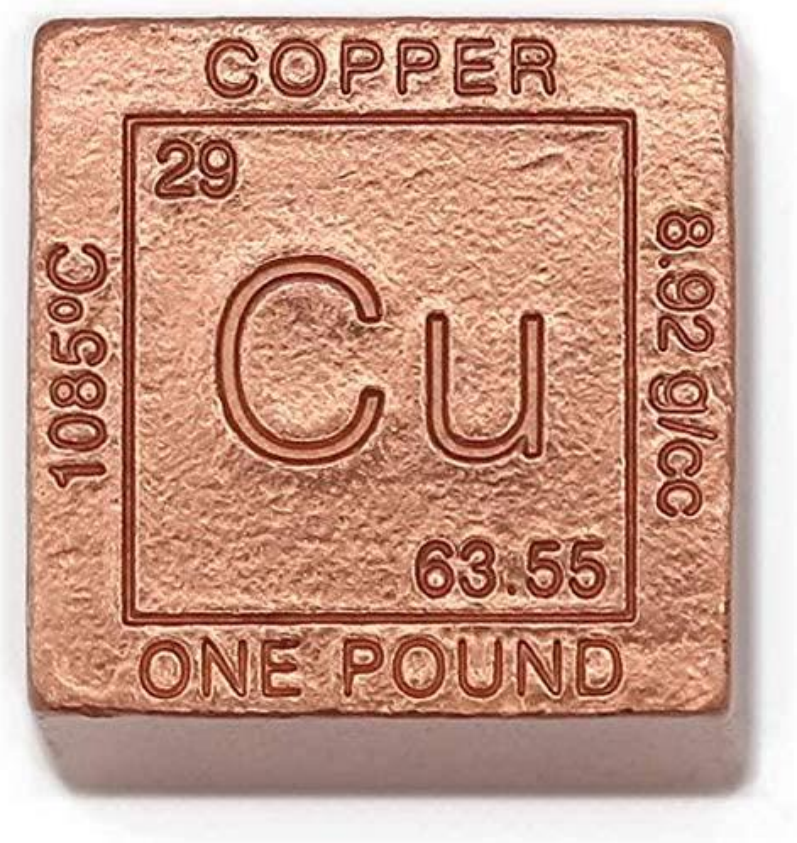
Introduction to Power at CERN

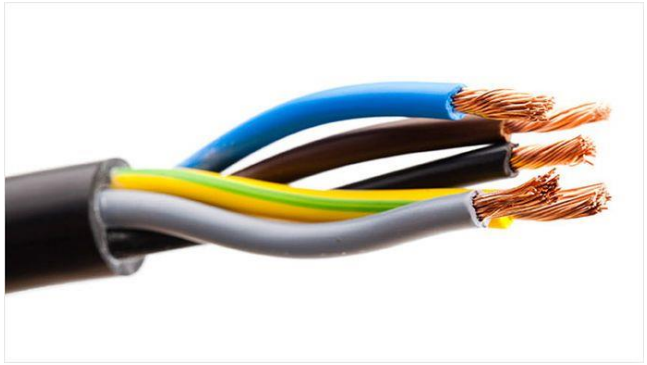
Konstantinos Papastergiou, Accelerator Systems Department
CERN – European Organisation for Nuclear Research

Quizz

- 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

Industrial Robots

10kW

Source: Le monde (Kawada Robot)

Terrestrial/satellite

10kW

Electric car/truck/plane

50kW

Industrial drives

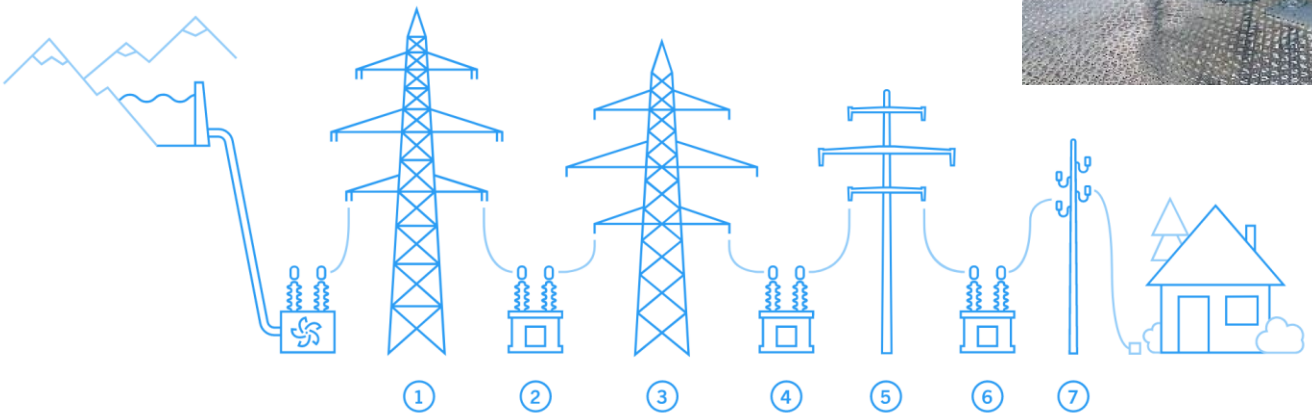
500kW

Renewable generation

3MW

Energy Transmission

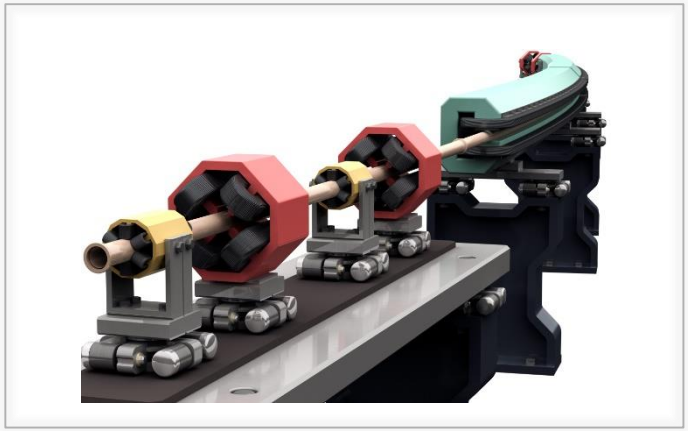
2GW



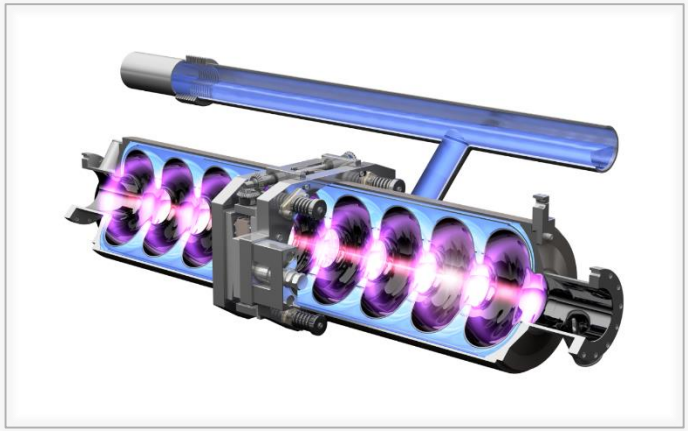
Source: Swissgrid.ch

Power at CERN

CERN power electronics



Electromagnets



Microwave cavities

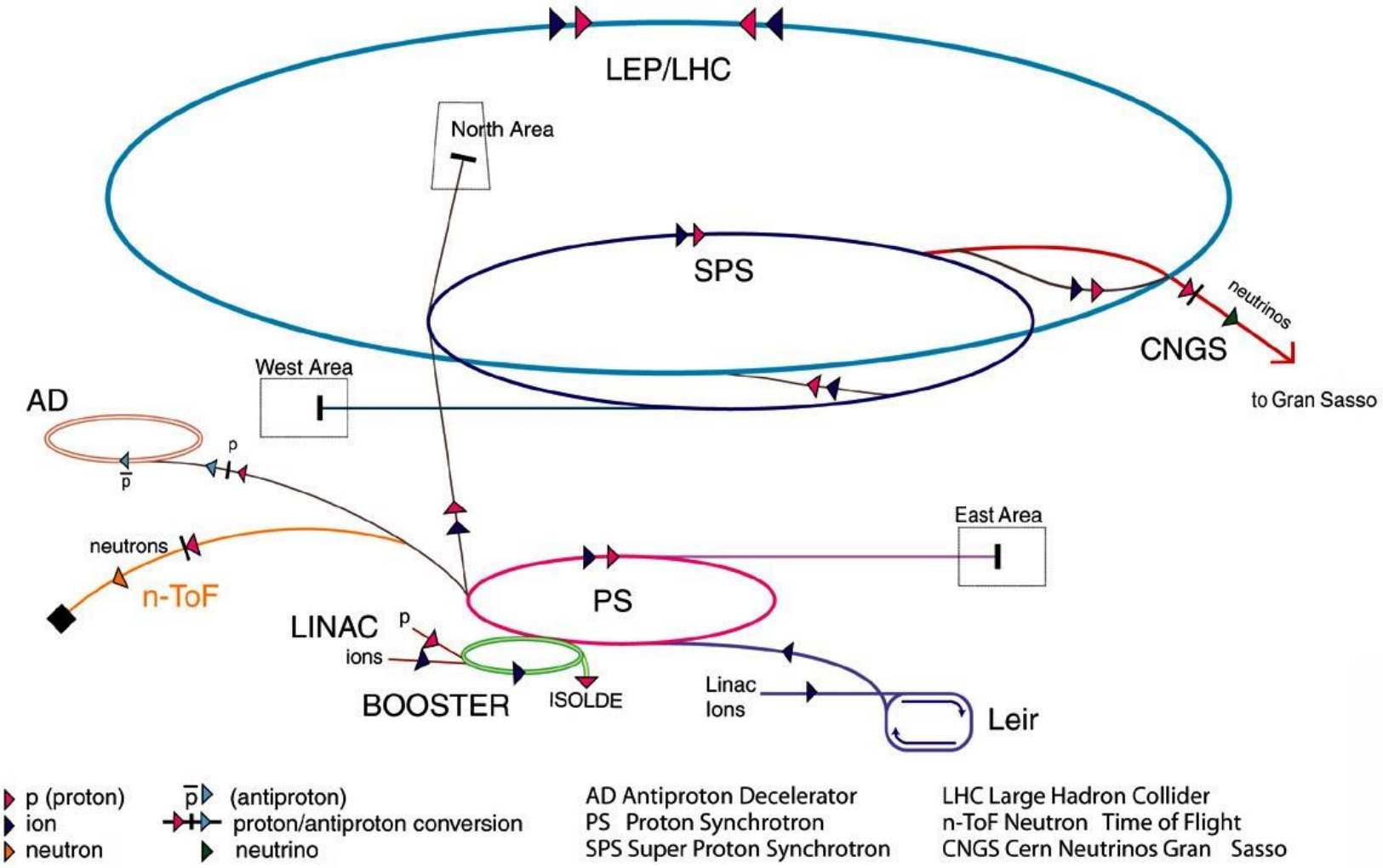
Cryogenics/Cooling/ventillation

Courtesy: ABB

Power quality

Graphics by Rey.Hori / KEK, Japan

Accelerators at CERN



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:

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

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

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

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

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

by differentiating:

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

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.

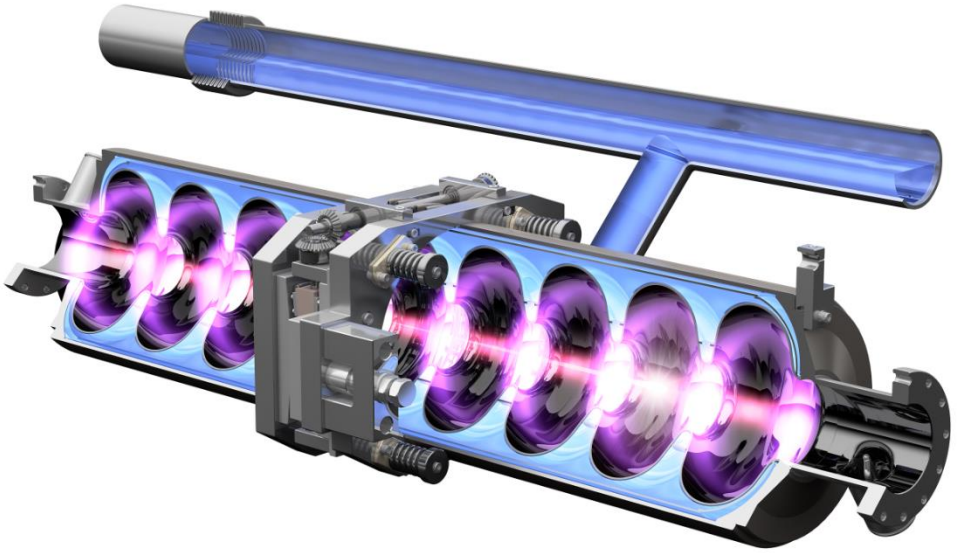
RF Cavities - Klystron

Functions:

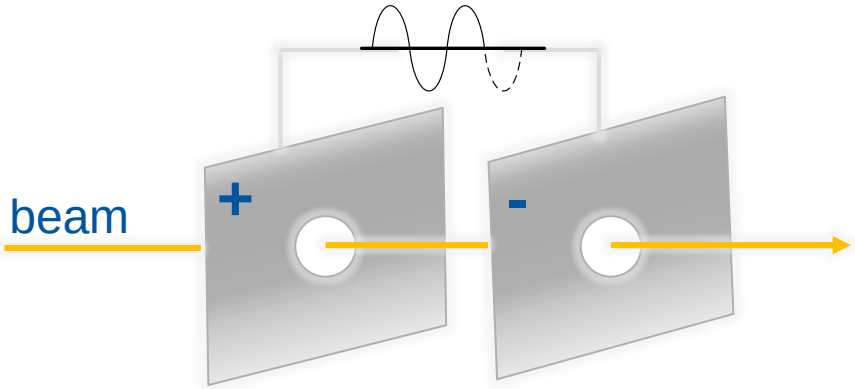
- Particle acceleration

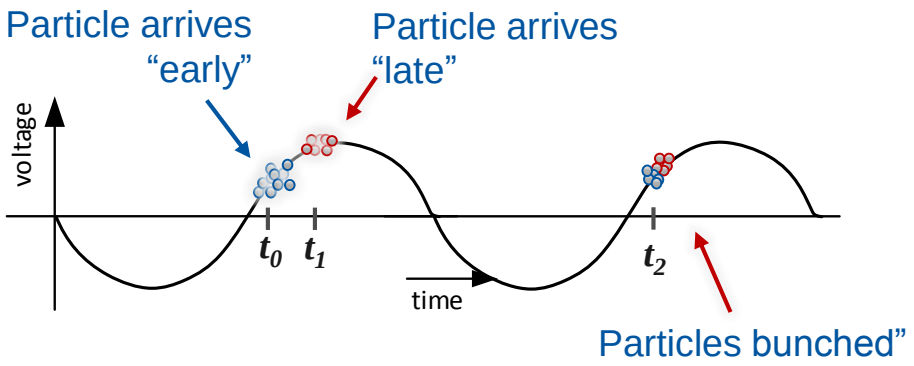
$$\Delta E = \int_{s1}^{s2} \vec{F} \cdot d\vec{s} = q \cdot \int_{s1}^{s2} \vec{E} \cdot d\vec{s} = q \cdot U$$

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



(c) Rey Hori / KEK



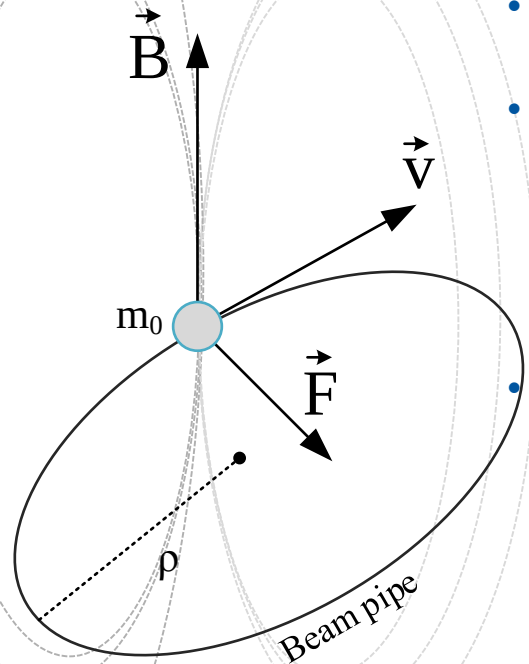


Electro-magnets

Functions:

- Beam steering

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



- At first sight F is not dependent on mass
- Since v on a circle of radius ρ-> F = centripetal force

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

$$m_r = \gamma \cdot m_0$$

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

- Rearanging 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

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

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

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

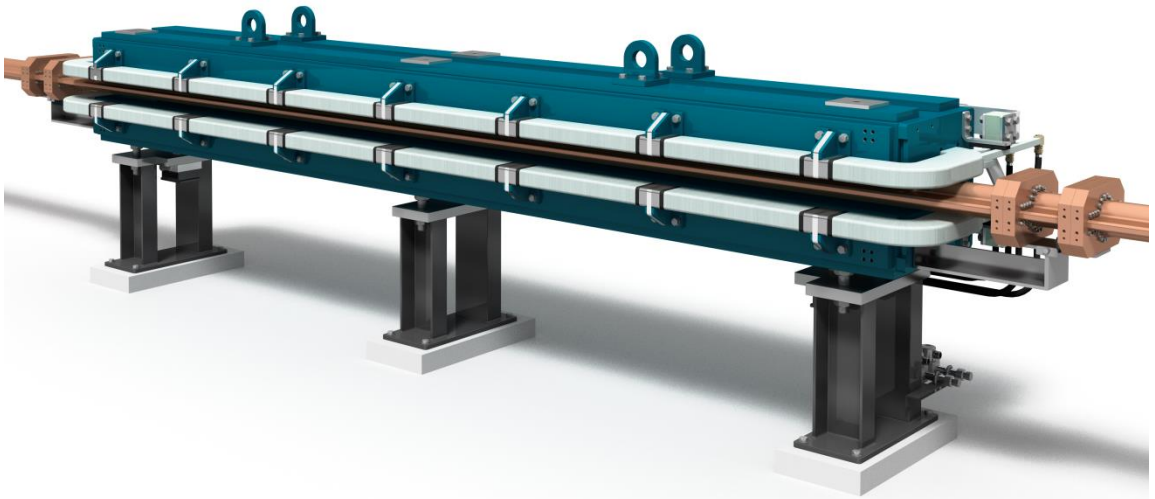
$$\oint_C \vec{B} \cdot ds = \mu_0 \cdot \iint_A \vec{J} \cdot dA = \mu_0 \cdot I_C$$

*μ_0: magnetic permeability of the air

Dipole magnet

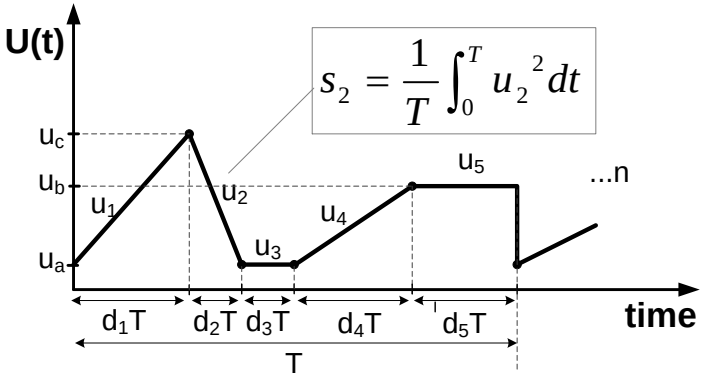
Functions:

- Beam steering



(c) Rey Hori / KEK

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

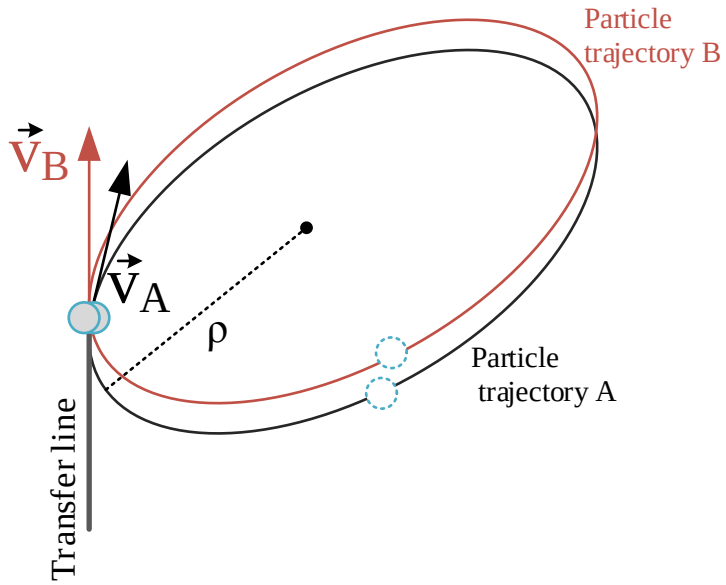


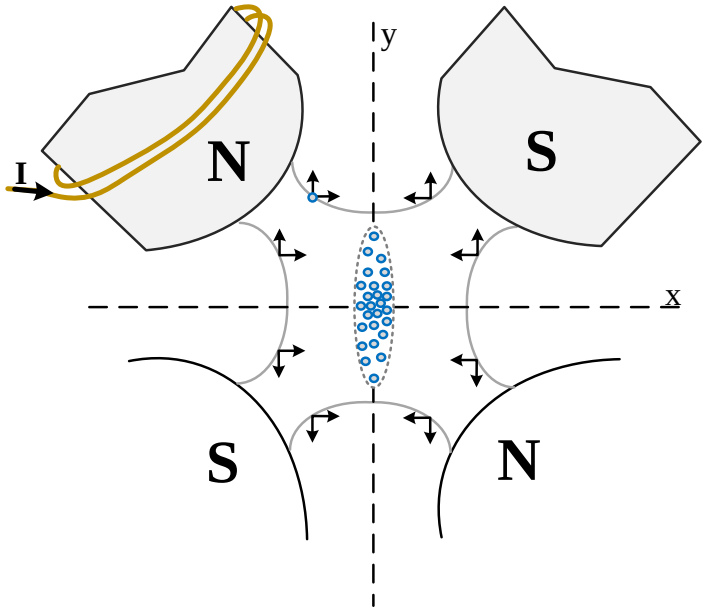
Quadrupole magnets

Functions:

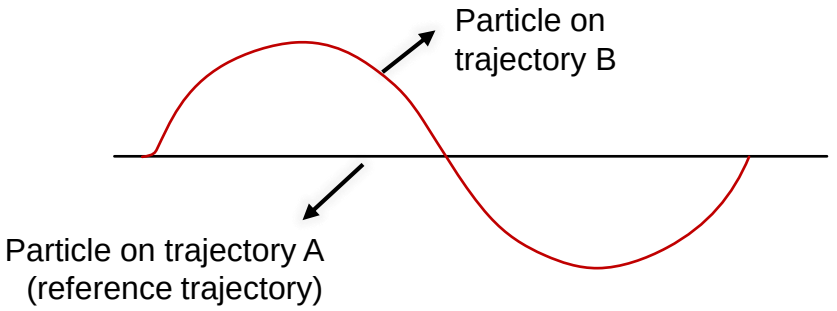
- Focussing-defocusing

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 μετατροπέων
- 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

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

Άλλες δραστηριότητες

- Συμμετοχή σε συνέδρια
- Επισκέψεις σχολείων

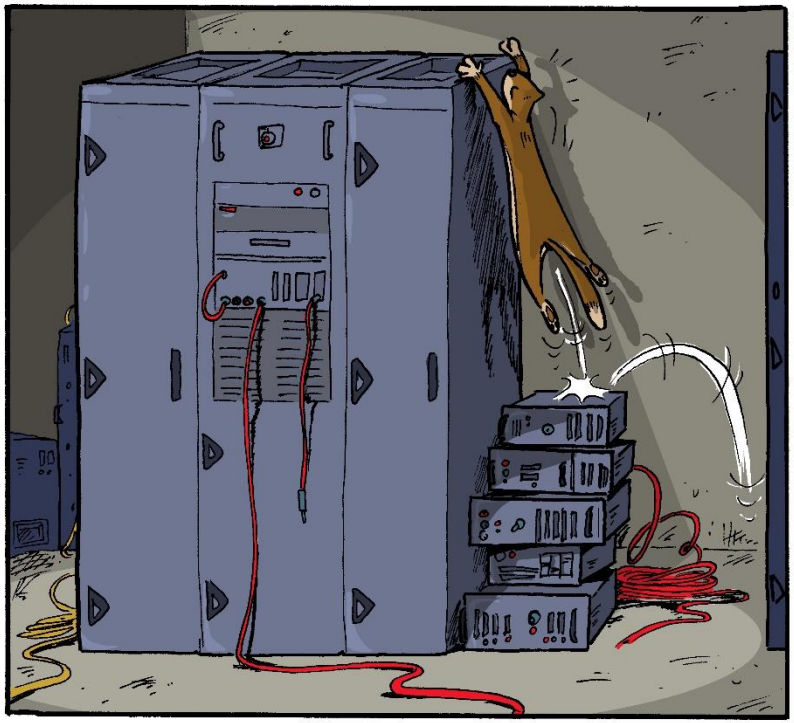


Illustration of power converter by Klimis Keramitsopoulos


SIRIUS
power brick
energy storage
2P
SIRIUS

- Ερωτήσεις;

http://www.cern.ch/aftervisit

Life at CERN

www.cern.ch