GIOVANI CHE RACCONTANO IL FUTURO

Università degli Studi di Padova

Istituto Nazionale di Fisica Nucleare

Progettare gli acceleratori del futuro

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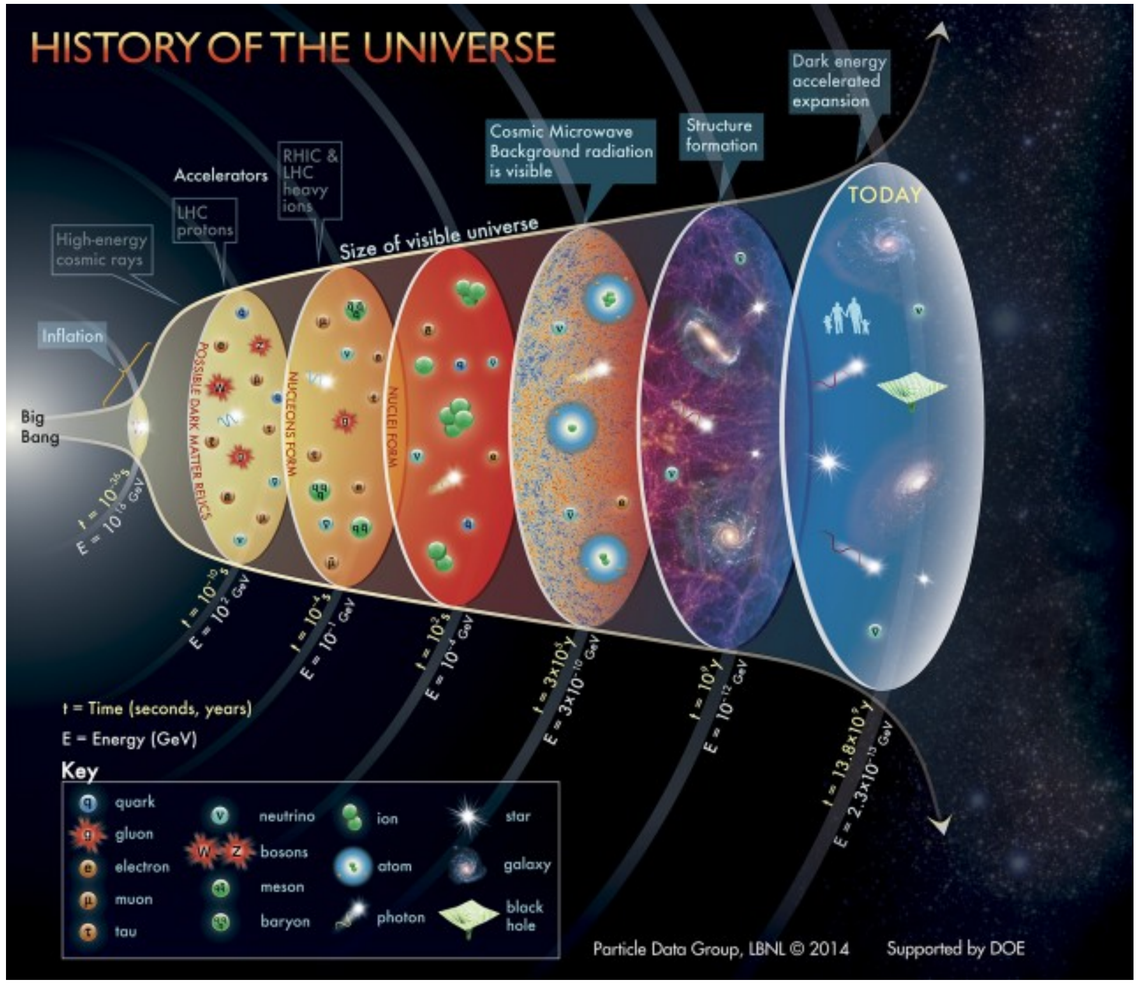
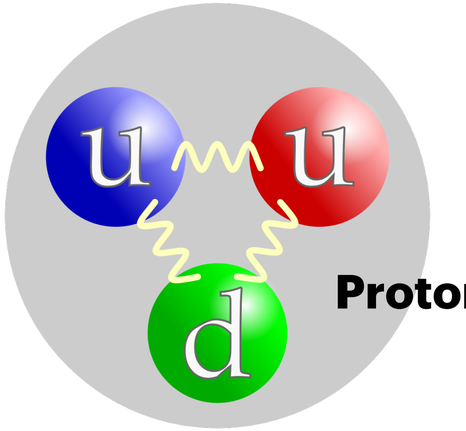
Dipartimento di Fisica G. Galilei - Padova - 9/10/2021

Perché accelerare (e collidere) particelle?



Struttura delle particelle



Protone

Produzione di particelle sconosciute

$$E=mc^2$$

E tante applicazioni mediche e tecnologiche!

Scala di energie

Scala di unità naturali

1 elettronvolt (eV) = 1.6 x 10^{-19} Joule

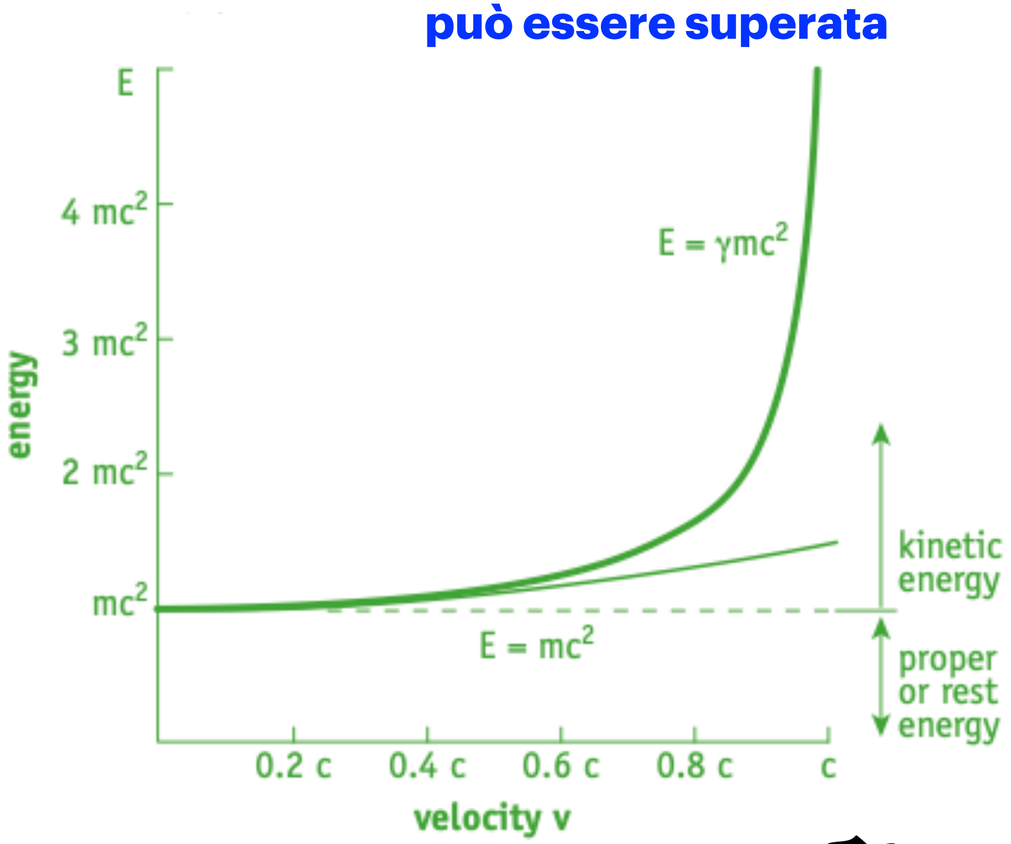
1 TeV = 1000 GeV = 100000 MeV = 10^{12} eV

Kinetic energy of a proton (K)	Speed (%c)	Accelerator
50 MeV	31.4	Linac 2
1.4 GeV	91.6	PS Booster
25 GeV	99.93	PS
450 GeV	99.9998	SPS
7 TeV	99.9999991	LHC

Relationship between kinetic energy and speed of a proton in the CERN machines. The rest mass of the proton is 0.938 GeV/c^2

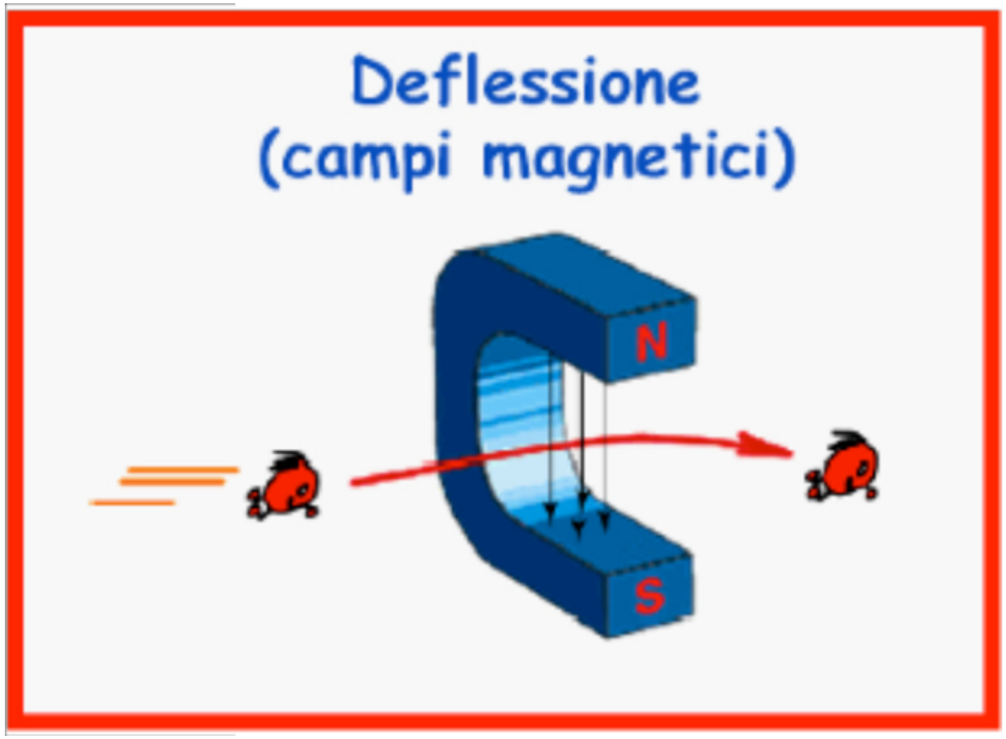
https://home.cern

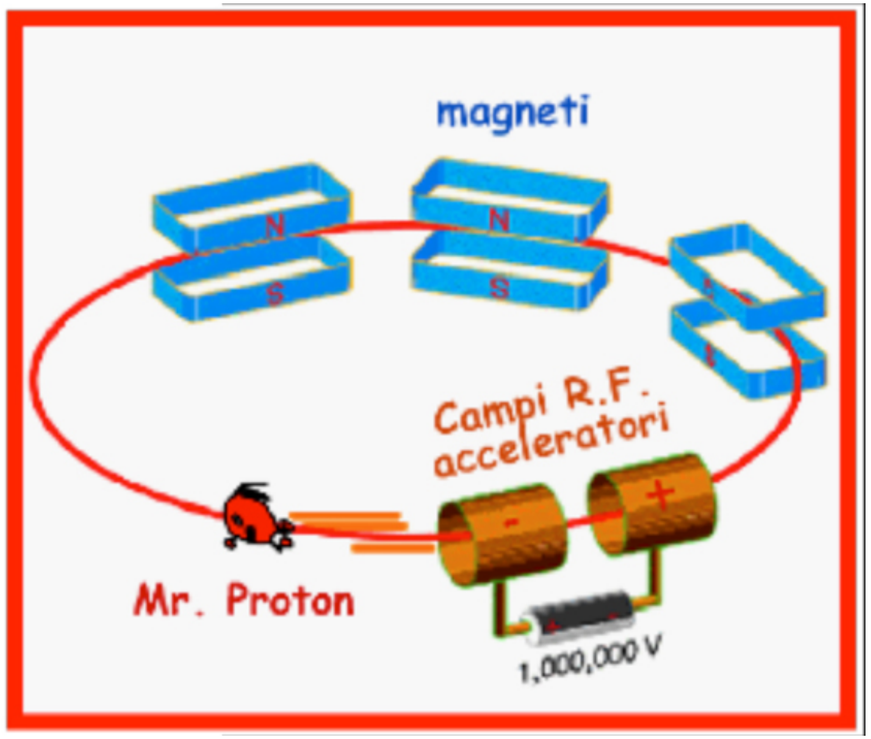
Relatività: la velocità della luce non può essere superata



energia protone a 7 TeV = energia motocicletta di 150 Kg a 150 Km/h

Come si costruisce un acceleratore?





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

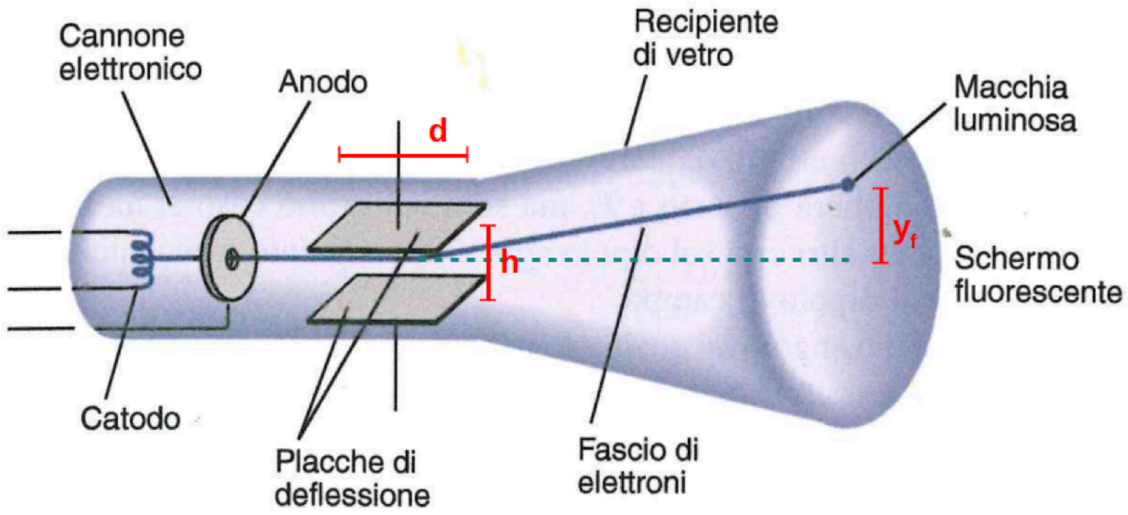
Forza magnetica

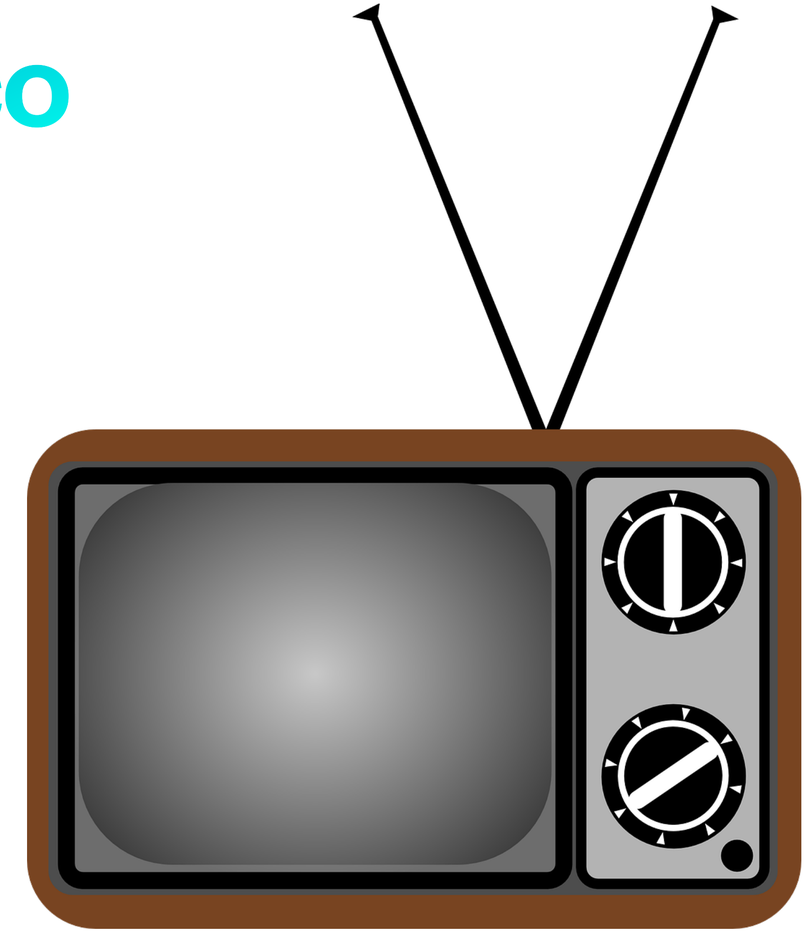
$$\vec{F} = q \cdot \vec{E}$$

Forza elettrica

Tubo catodico

Un acceleratore molto comune qualche anno fa



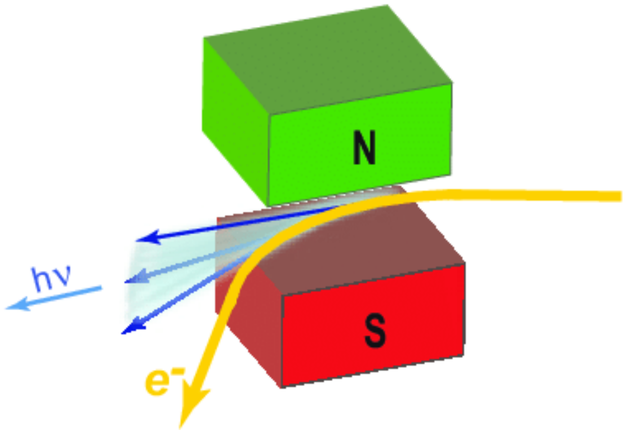


Accelerazione e deflessione tramite campi elettrici (elettrodi a tensione)

Magneti

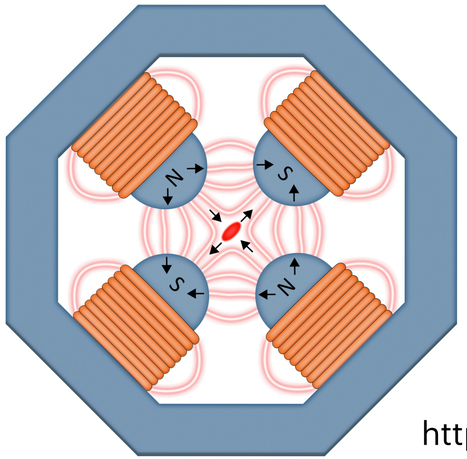
Dipolo magnetico: deflessione

Solo per le particelle leggere (elettroni): emissione di fotoni durante la deflessione

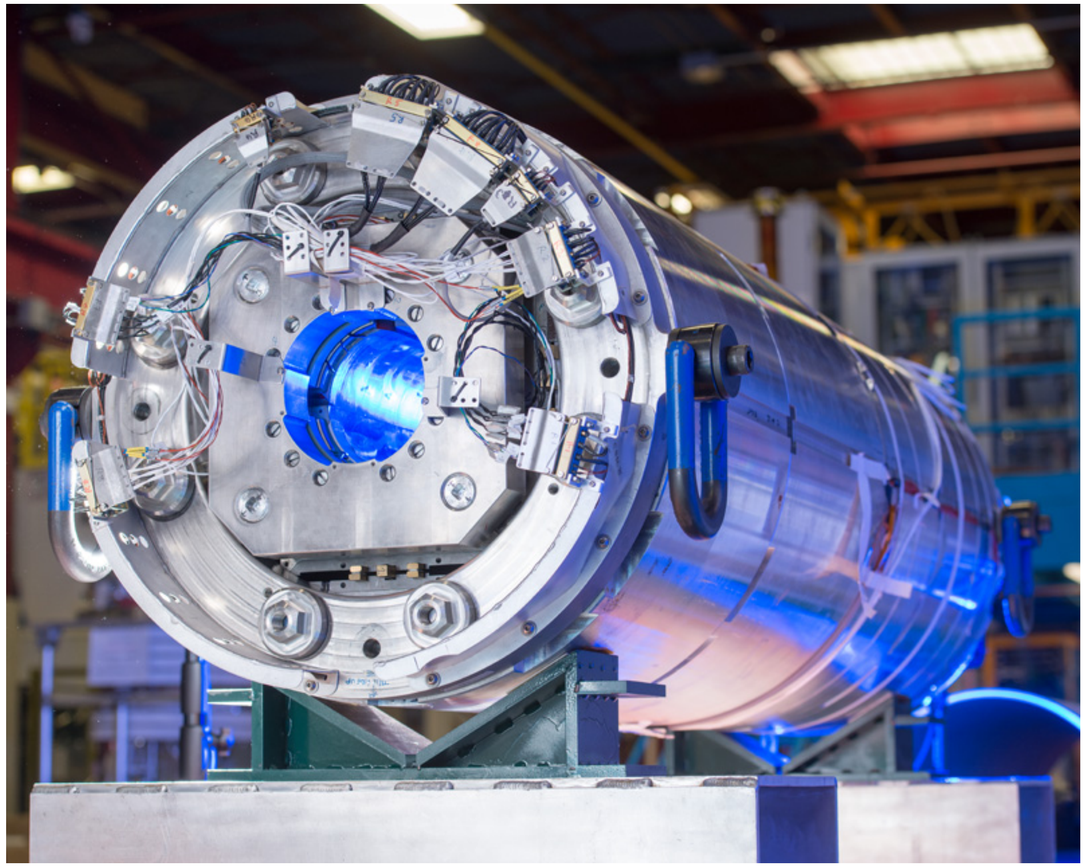


O. Travnikova: **Structure and Dynamics of Core-Excited Species, 2008**

Quadrupolo magnetico: focalizzazione



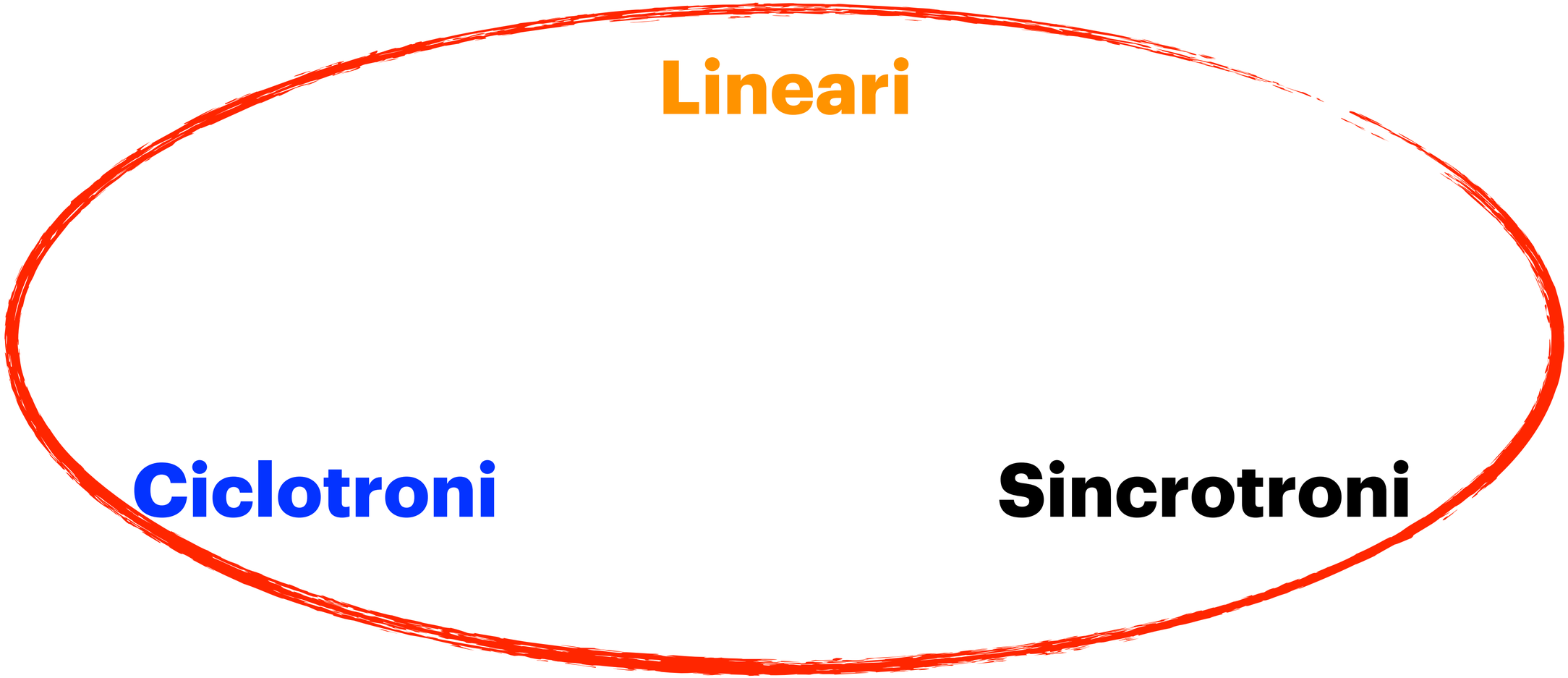
Magnete per l'aggiornamento del Large Hadron Collider



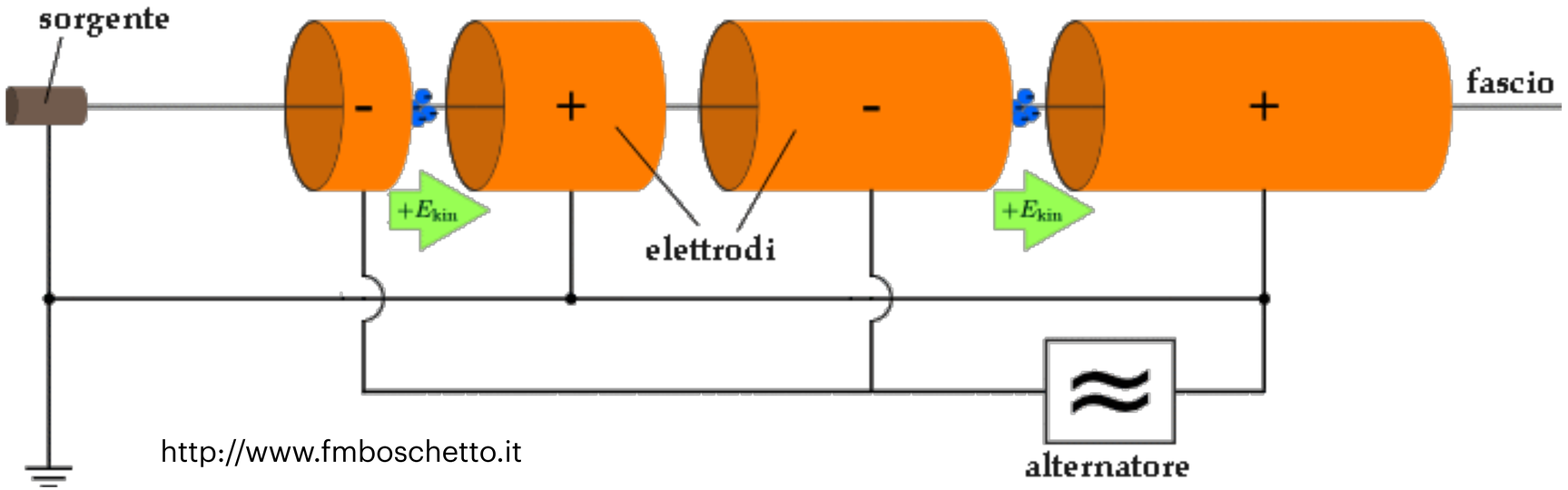
B = 8.3 Tesla -> più di 100'000 volte il campo magnetico terrestre

https://news.fnal.gov

Tre principali tipi di acceleratori

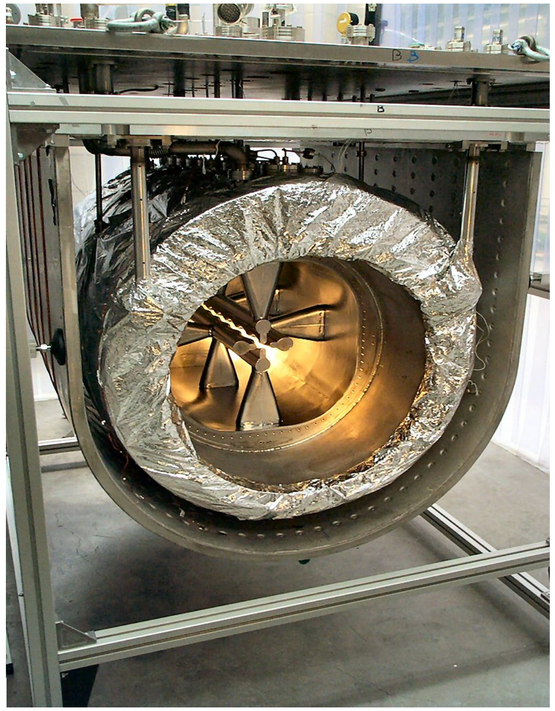


Acceleratori lineari

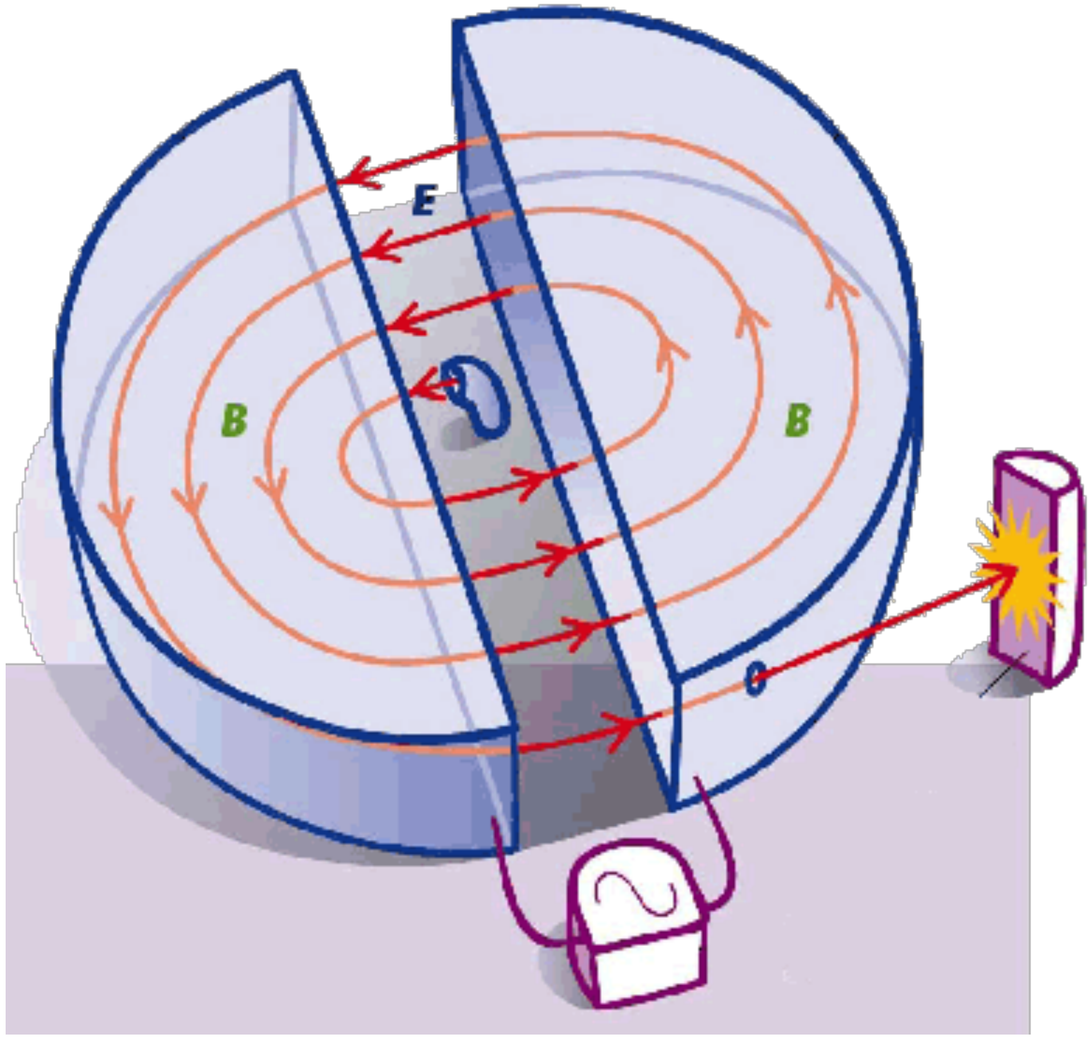


http://www.fmboschetto.it

Cavità risonante dell'acceleratore lineare ALPI ai Laboratori di Legnaro



Ciclotroni

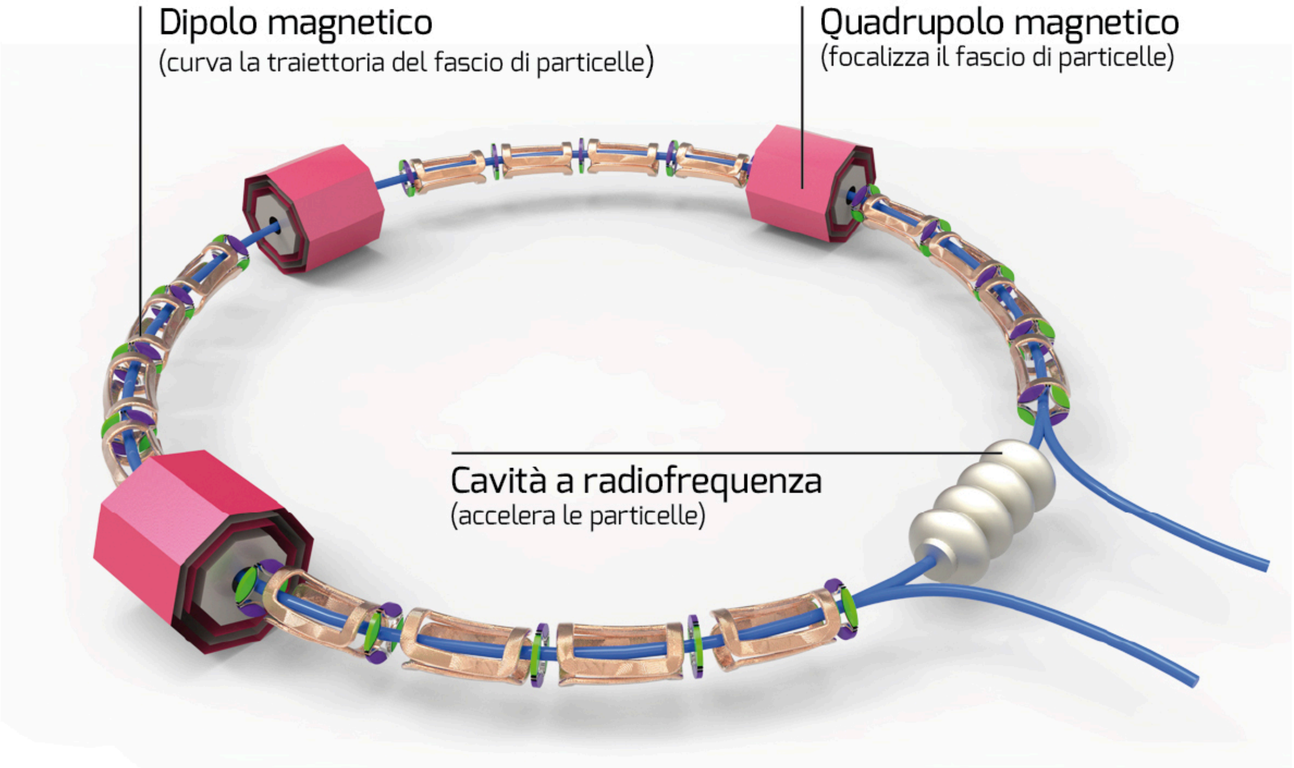


http://www.fmboschetto.it

Ciclotrone SPES ai Laboratori di Legnaro

Sincrotroni

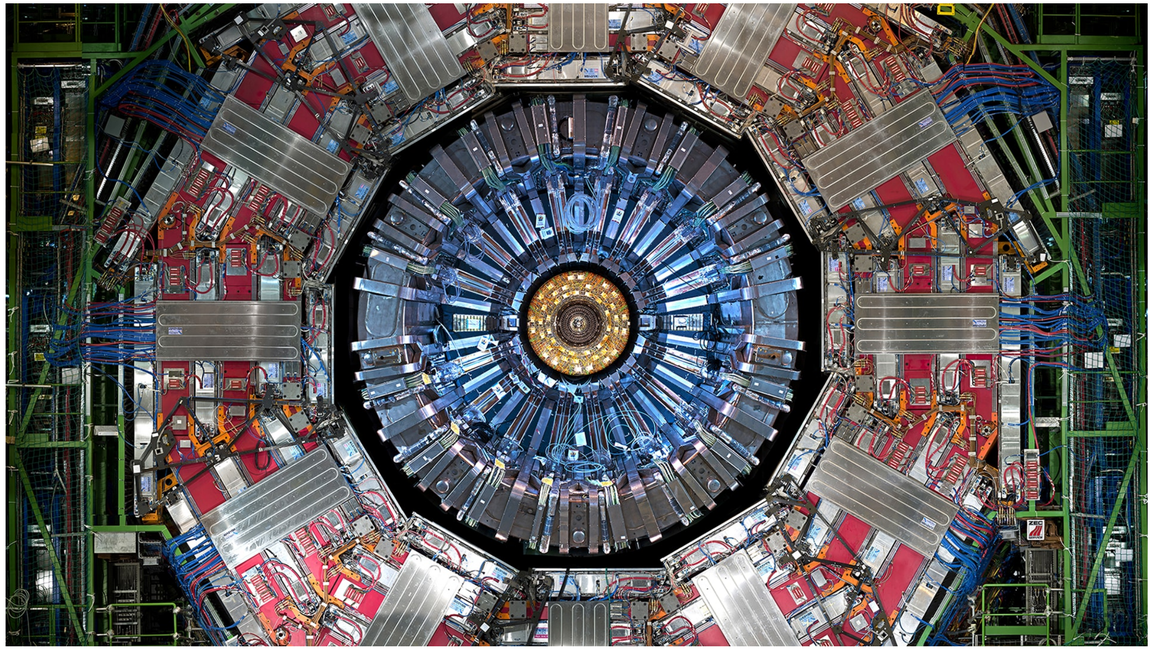
$$R = \frac{m(t)v(t)}{qB(t)}$$



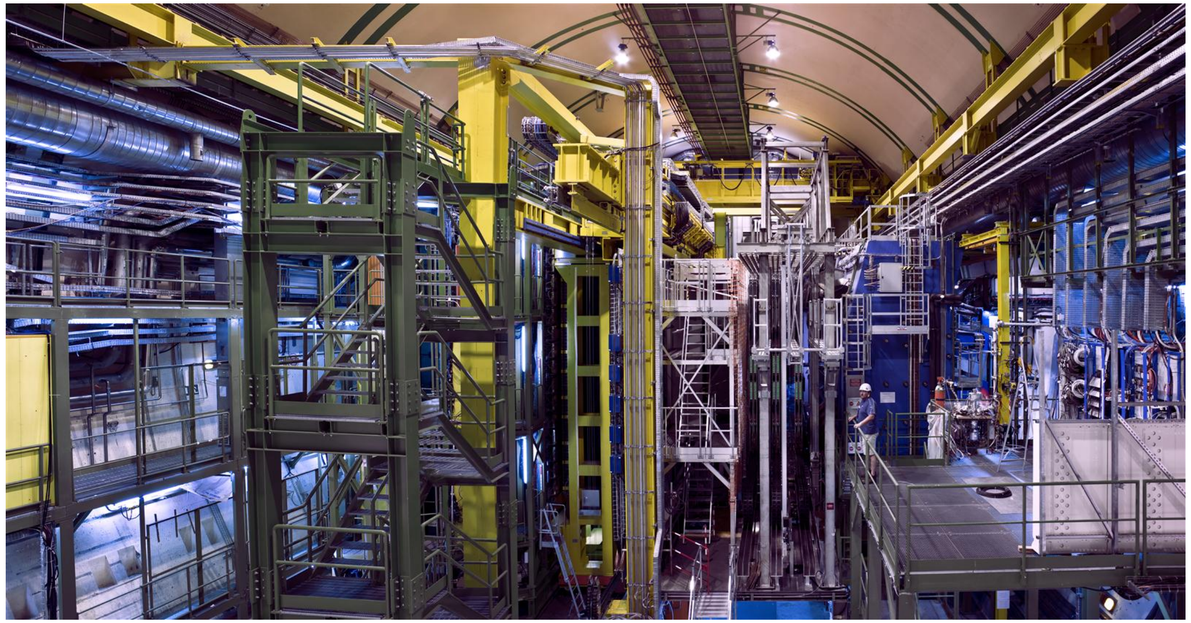
Sincrotrone Elettra a Trieste

I nostri “occhi” nelle collisioni

Rivelatore CMS ad LHC

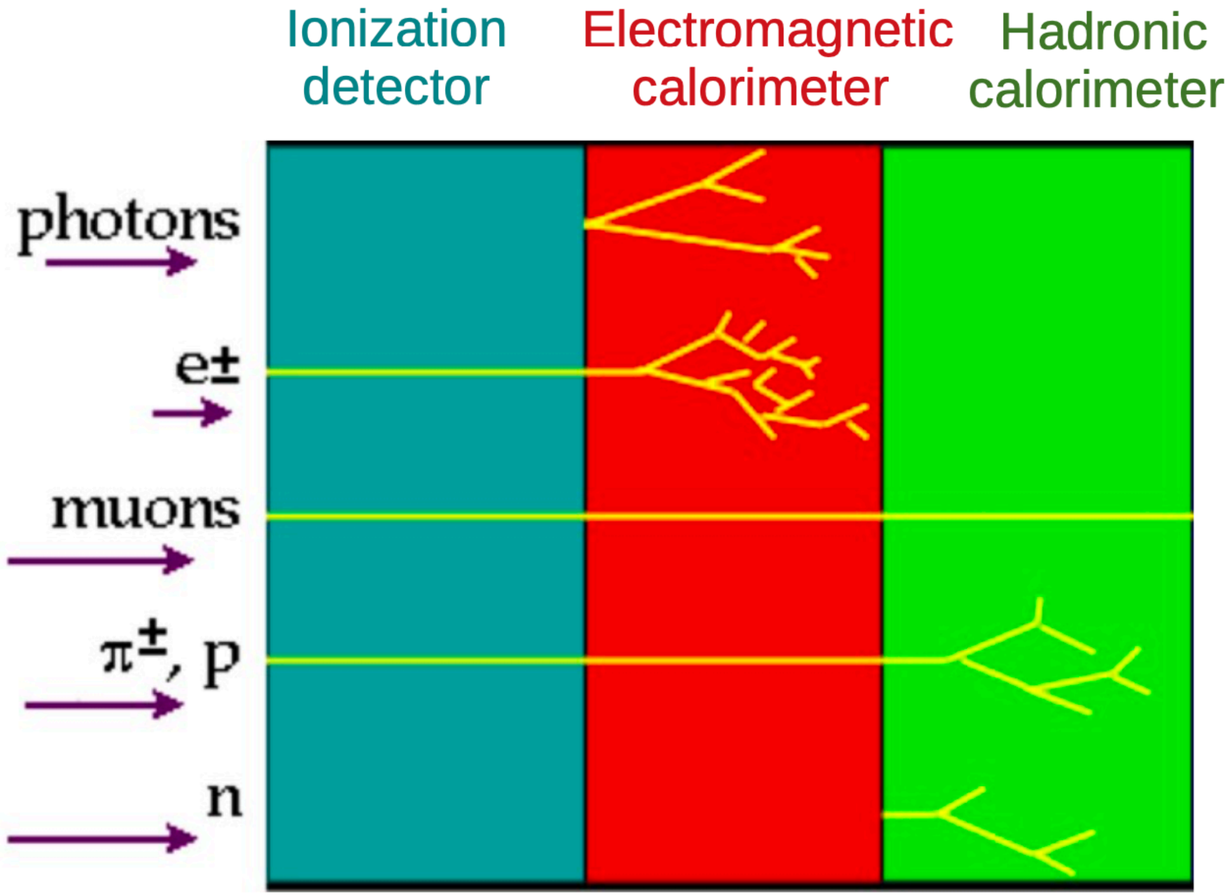


Rivelatore LHCb ad LHC

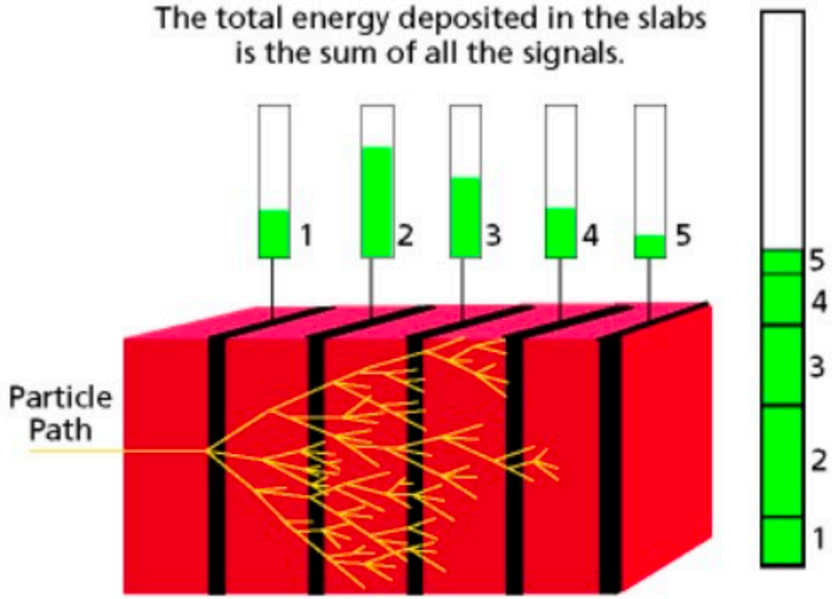


I nostri “occhi” nelle collisioni

Identificare le particelle prodotte nella collisione



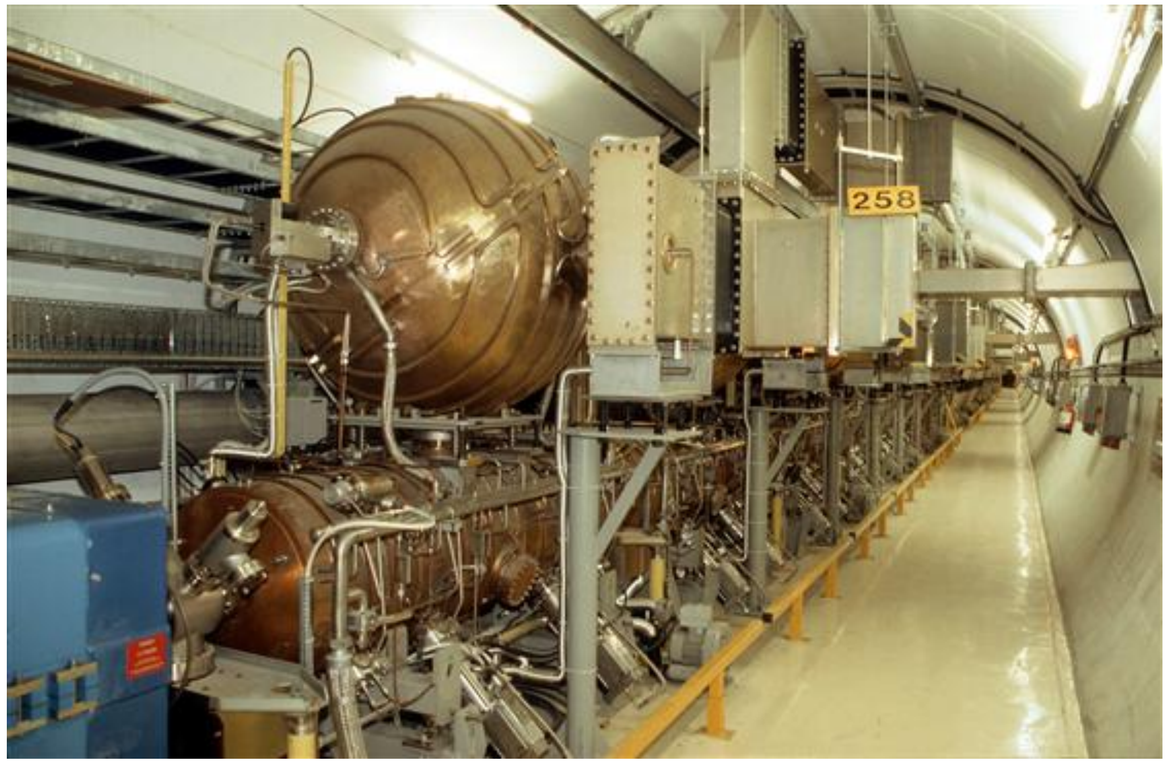
Misurare la loro energia

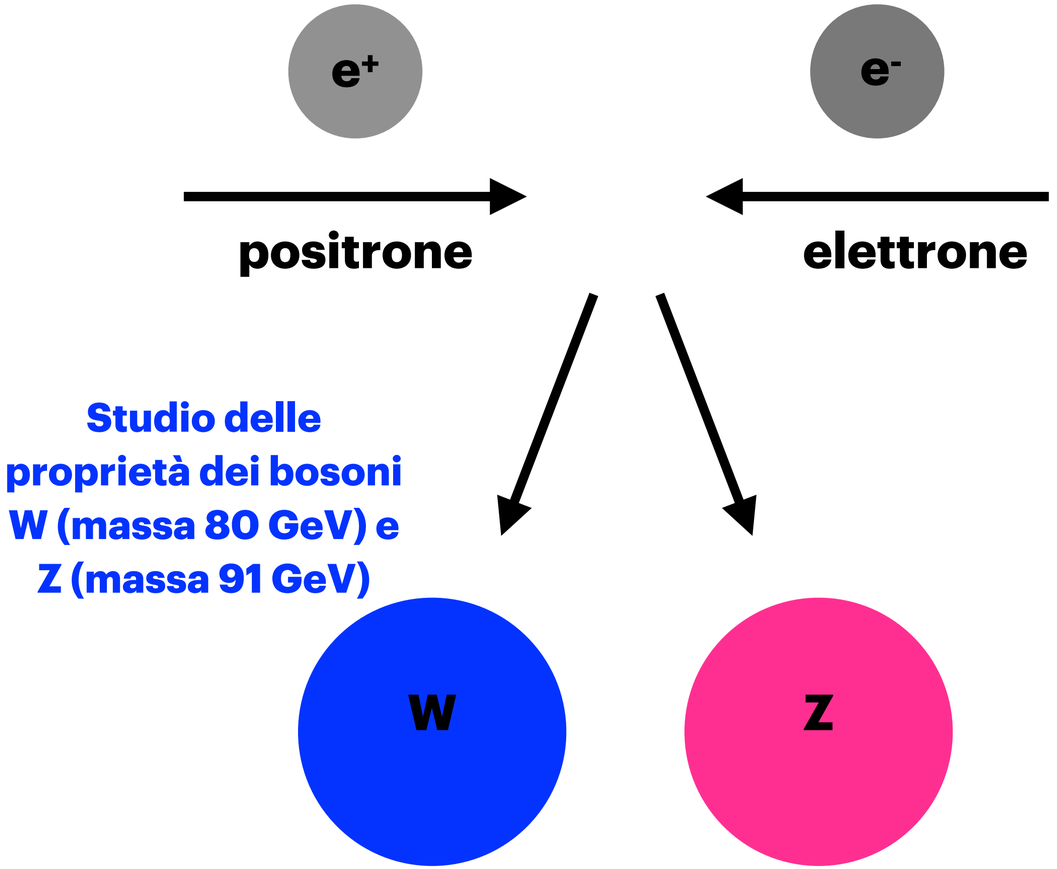


Quali particelle sappiamo accelerare?

Large Electron-Positron collider (LEP), CERN 1989-2000

Energia dei fasci fino a 104.5 GeV





Studio delle proprietà dei bosoni W (massa 80 GeV) e Z (massa 91 GeV)

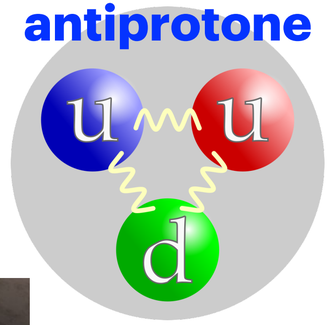
Quali particelle sappiamo accelerare?

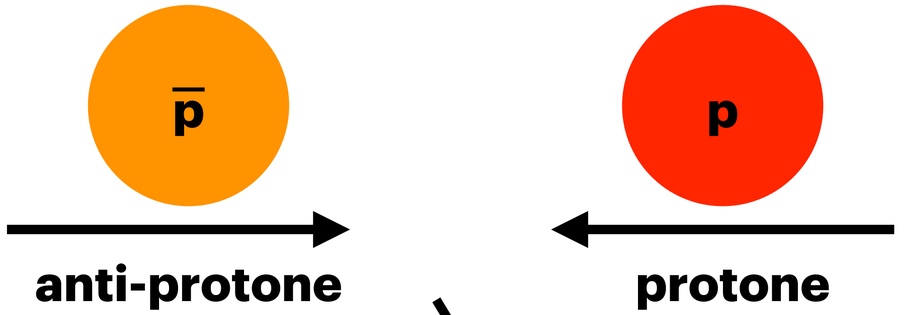
Tevatron, Fermilab-Chicago 1983-2011

Energia delle collisioni fino a 1.96 TeV

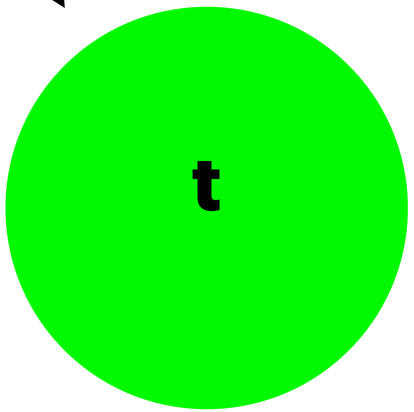
https://www.fnal.gov

Energia divisa tra i costituenti del protone/ antiprotone





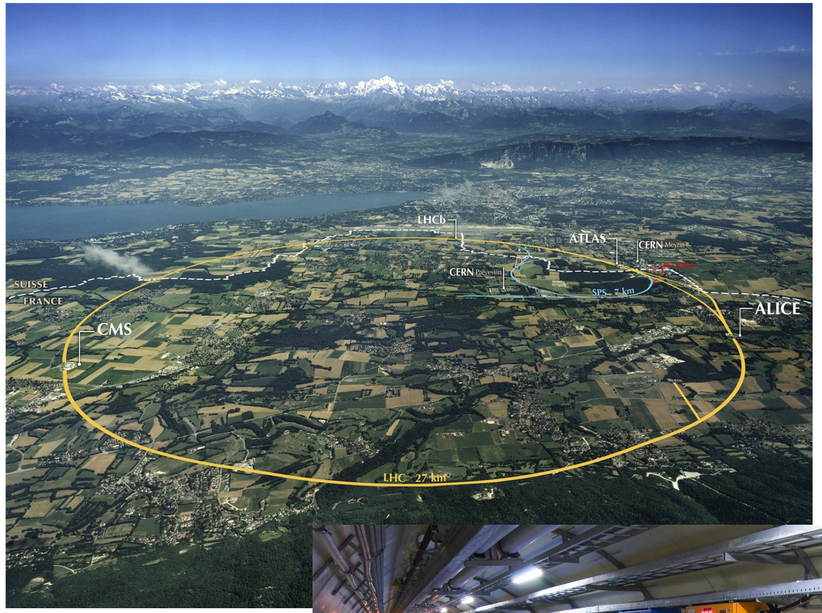
Scoperta del quark Top (massa 173 GeV)

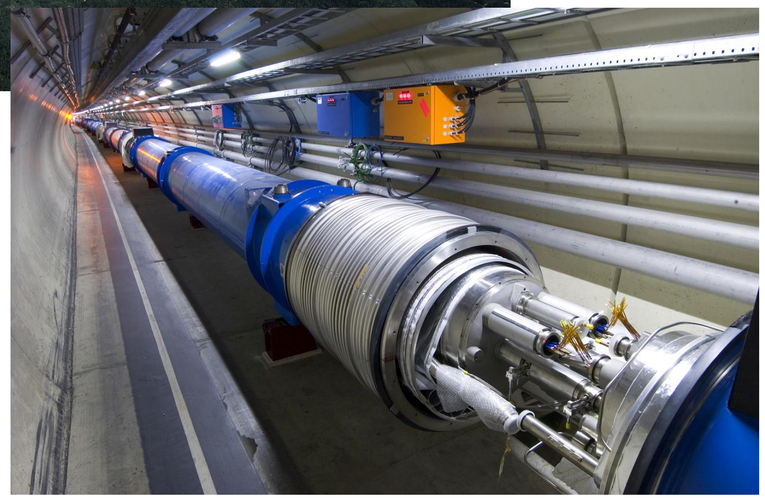


Quali particelle sappiamo accelerare?

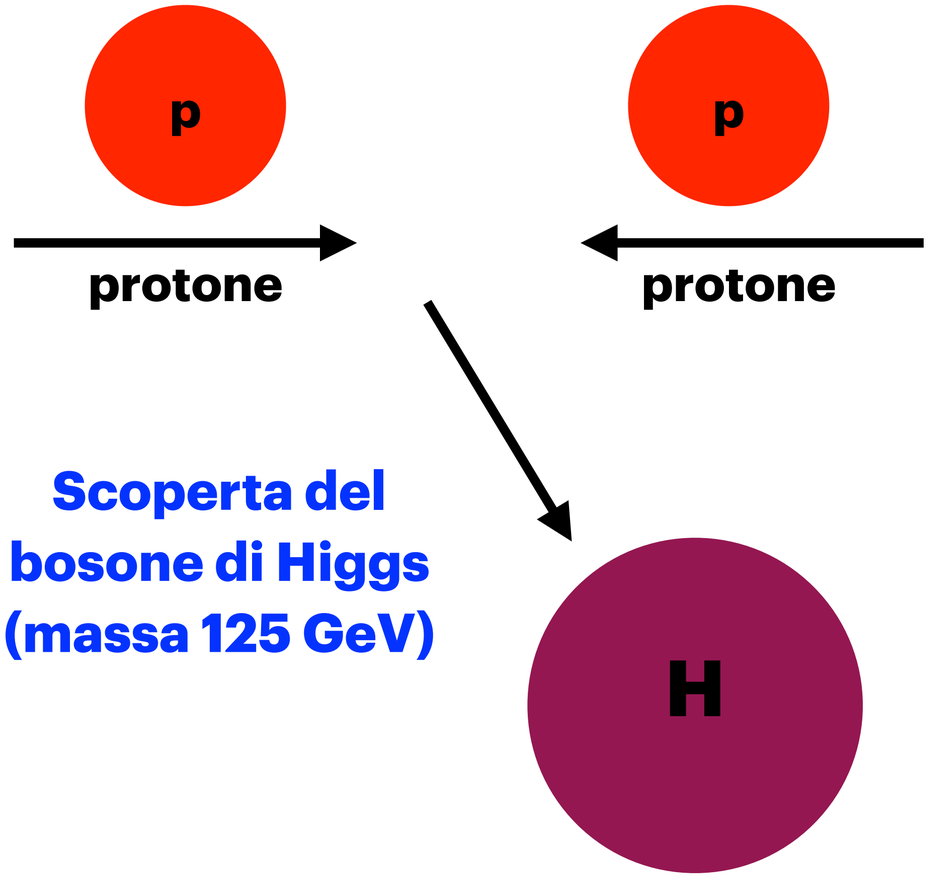
LHC, CERN 2010-oggi

Energia delle collisioni fino a 14 TeV





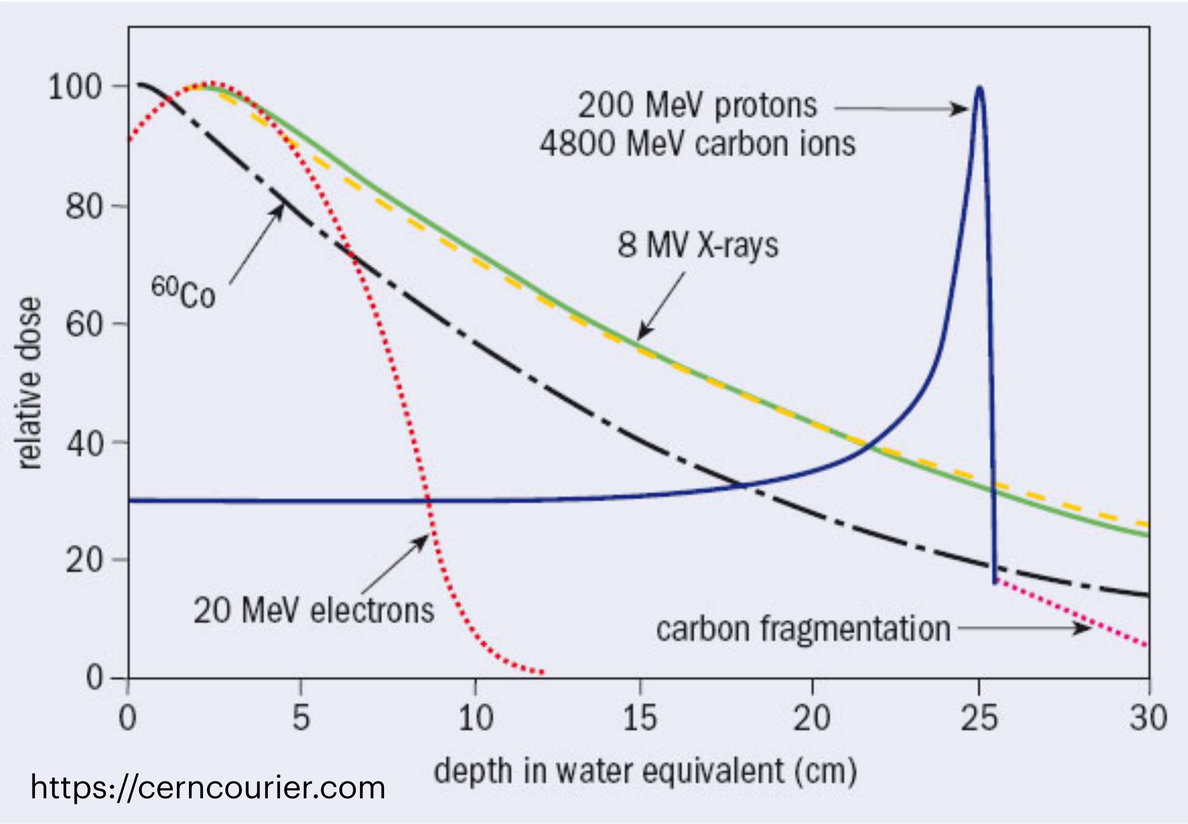
Possibilità di accelerare gli ioni!



Scoperta del bosone di Higgs (massa 125 GeV)

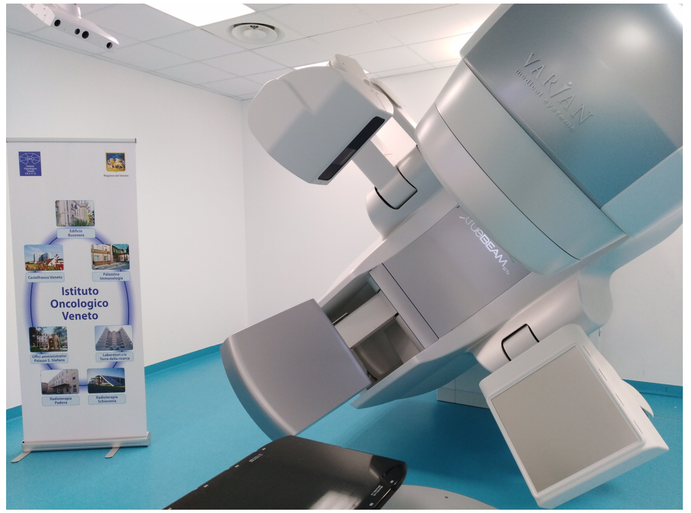
Applicazioni nella Fisica Medica

Dose: $D = \frac{E_d}{m}$ E_d: energia assorbita da una massa m. 1Gy=1 J/Kg

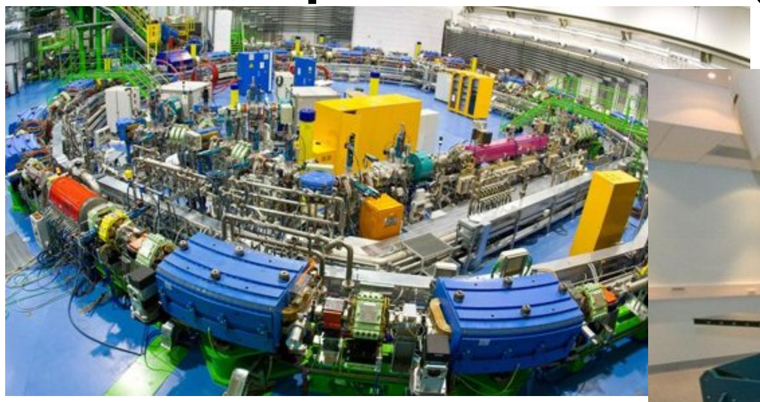


https://cerncourier.com

Radioterapia convenzionale (elettroni, fotoni)

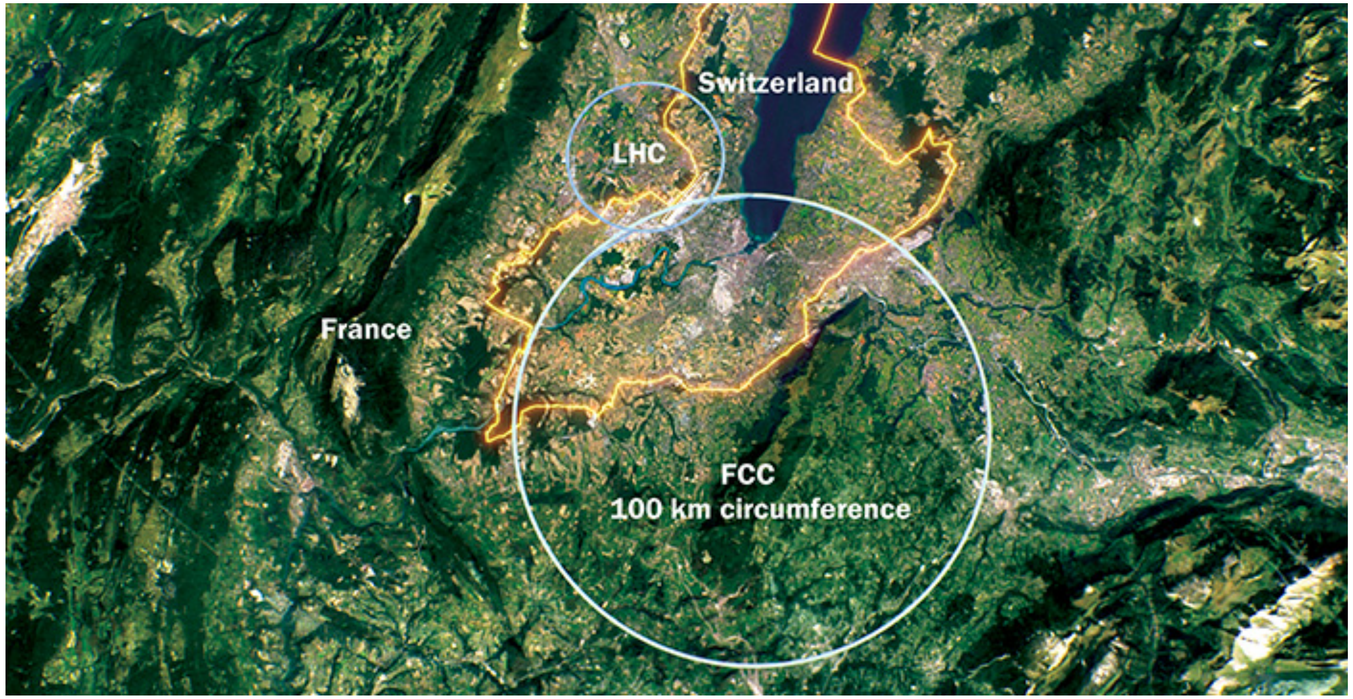


Adroterapia al CNAO di Pavia (protoni, ioni)

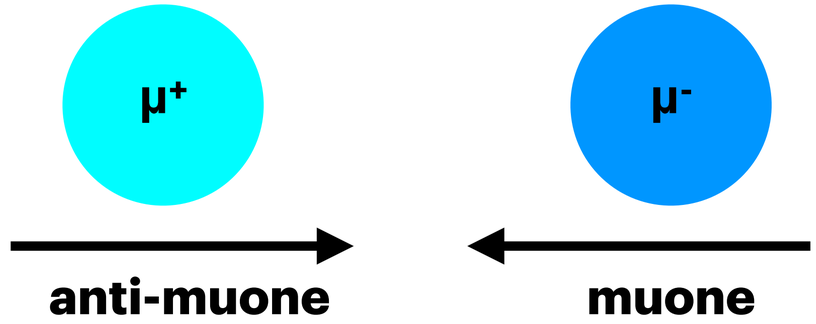


What next?

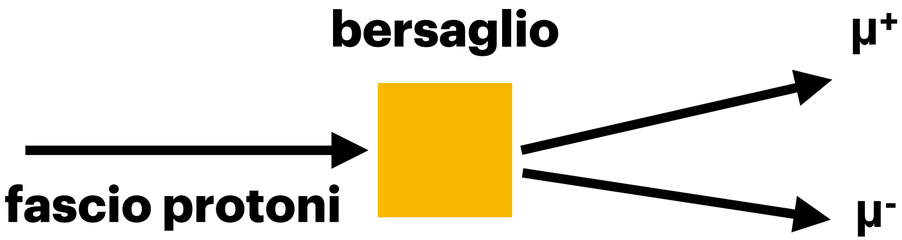
Future Circular Collider: collisioni (elettrone-positrone o protone-protone) fino a energie di 100 TeV



Particelle mai accelerate prima

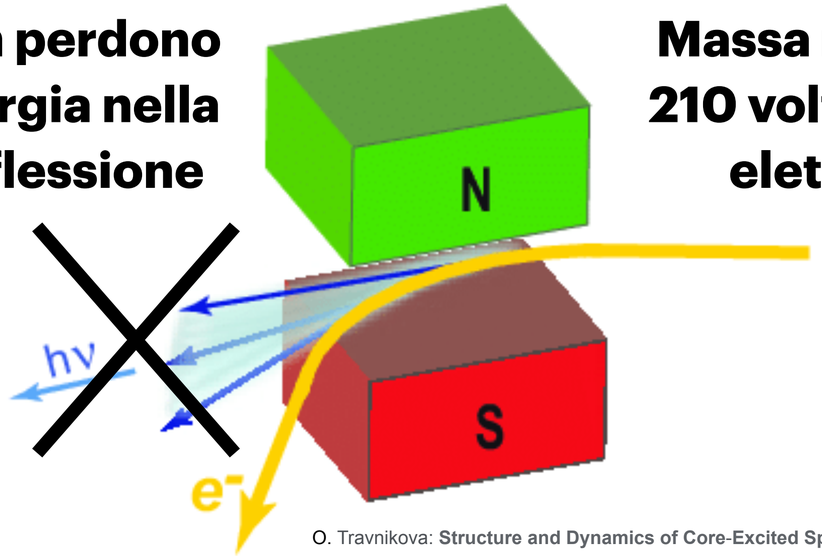


I muoni sono estremamente rari sulla Terra!



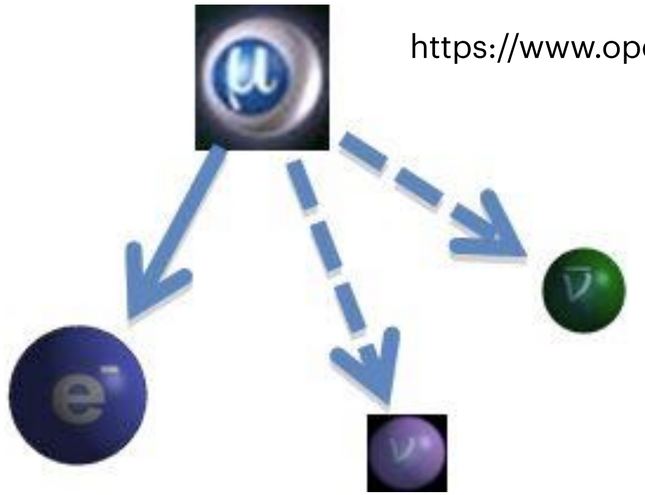
Accelerare i muoni

Non perdono energia nella deflessione

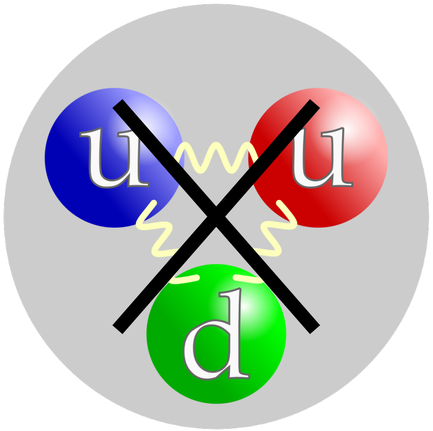


O. Travnikova: **Structure and Dynamics of Core-Excited Species, 2008**

Massa muone = 210 volte massa elettrone



https://www.openfisica.com



<u>Non sono costituiti da altre particelle</u>: tutta l'energia è disponibile per la collisione!

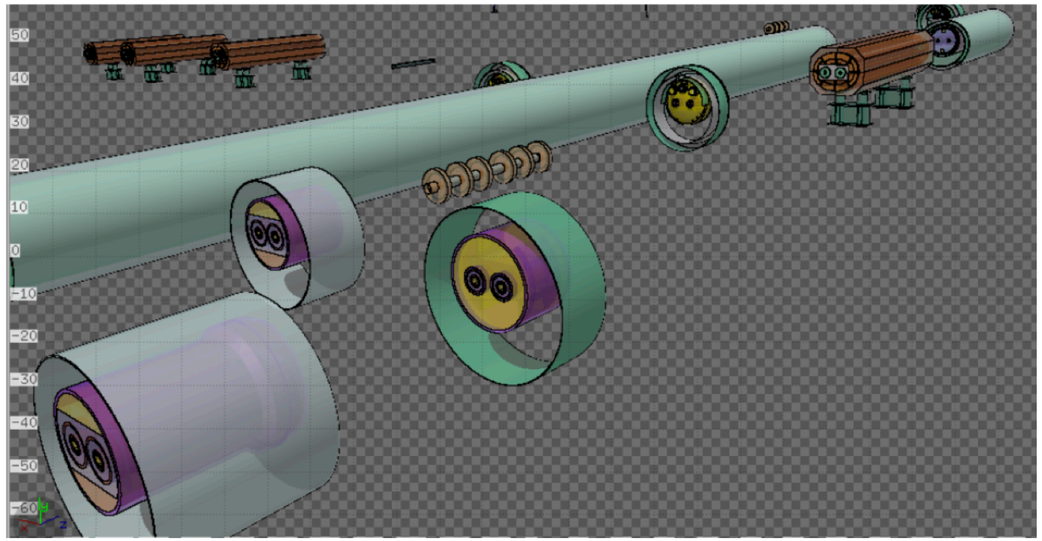
Purtroppo decadono velocemente...

Devono essere accelerati in circa 0.000001 secondi

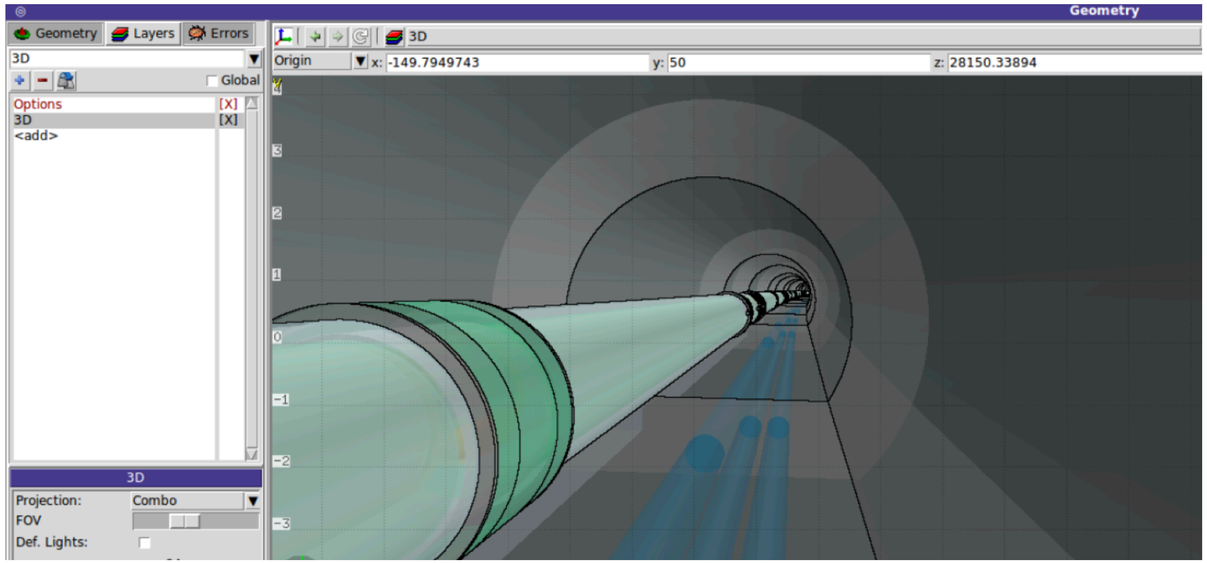
Progettare un Muon Collider

Esistono dei software che permettono di simulare gli acceleratori

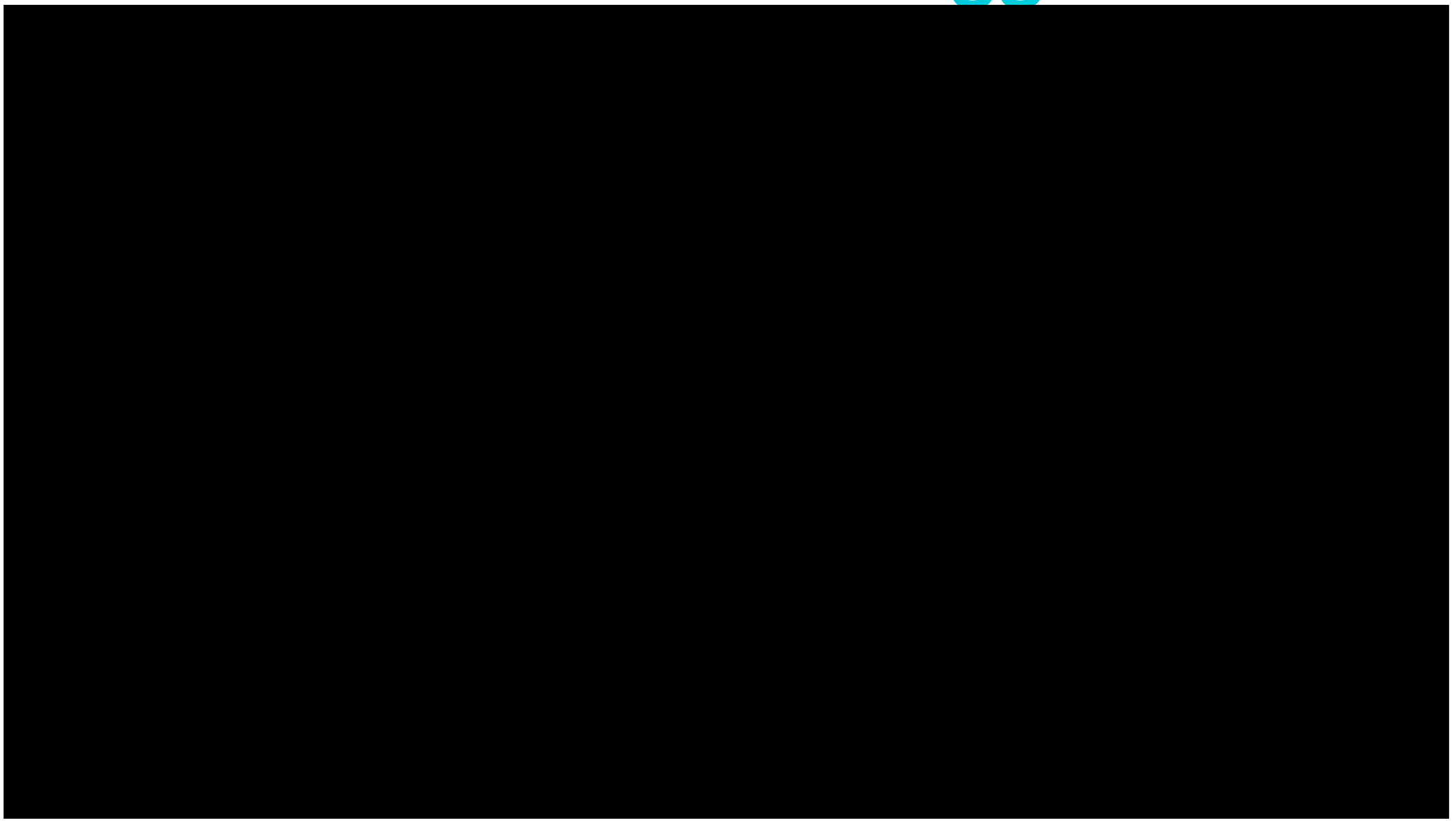
Si scelgono i vari componenti



Si assembla l'acceleratore



Dentro alla simulazione: il viaggio del muone



Grazie per l’attenzione!