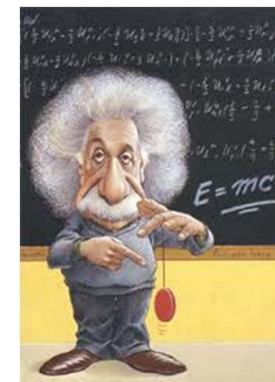




**Fisica:  
un passaporto  
per nuove frontiere**

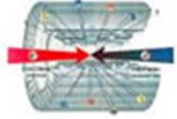


*Alessandro Feliciello*  
**I.N.F.N. - Sezione di Torino**

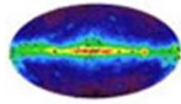
# Sommario

- Introduzione
  - fisica delle **particelle**
  - fisica **nucleare**
- Come nasce un esperimento
  - l'esperimento **OBELIX**
  - l'esperimento **FINUDA**
- Le ricadute tecnologiche
  - strumenti di calcolo
  - **web** e **GRID**
  - applicazioni **mediche**
  - studio e salvaguardia di **beni culturali**

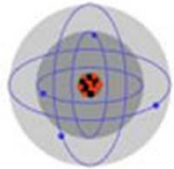
# L'Istituto Nazionale di Fisica Nucleare



I. fisica delle particelle



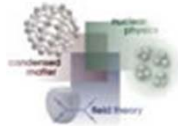
II. astrofisica particellare



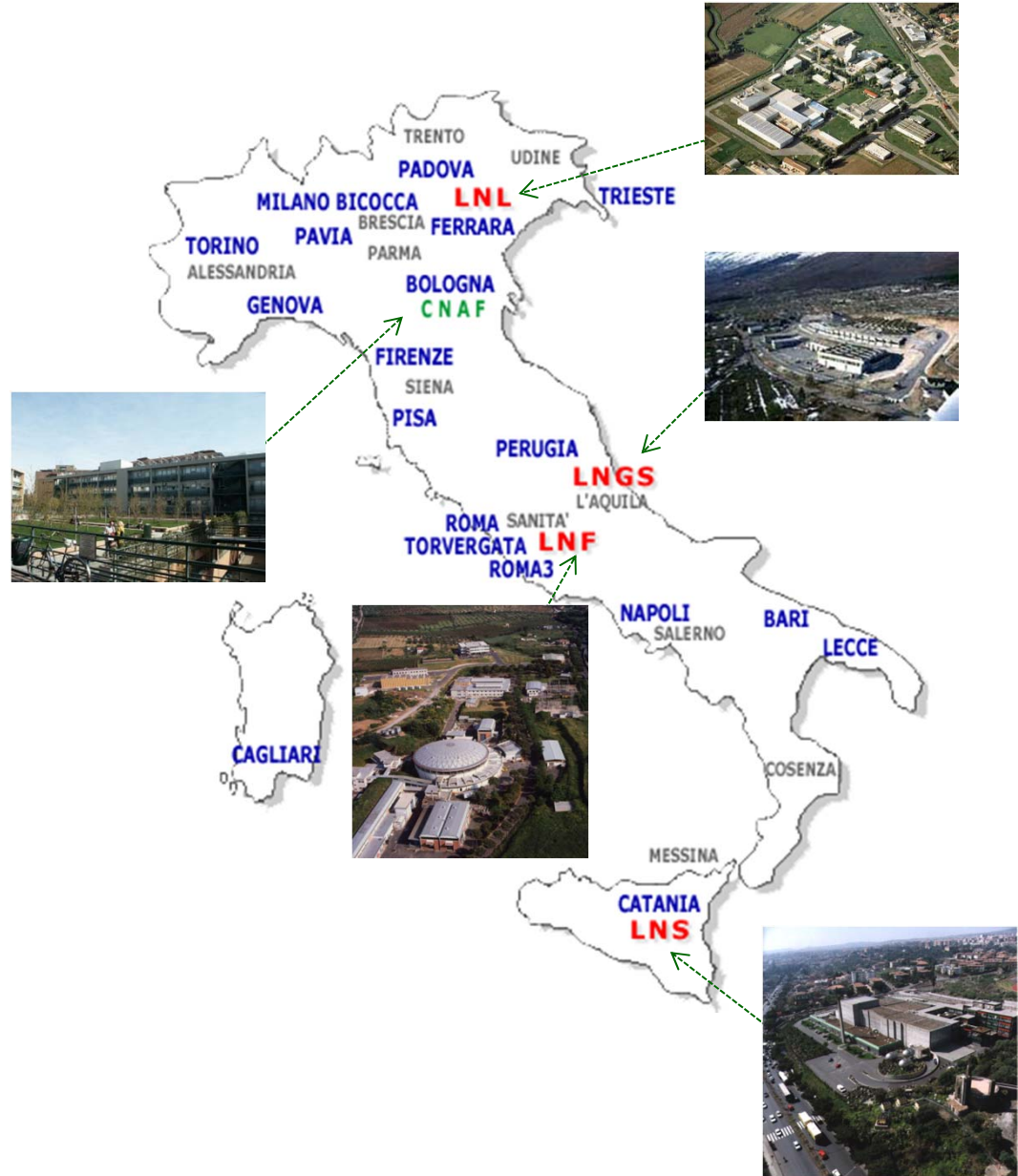
III. fisica nucleare



V. ricerca tecnologica



IV. fisica teorica



# Le domande fondamentali

L'uomo da sempre si chiede:

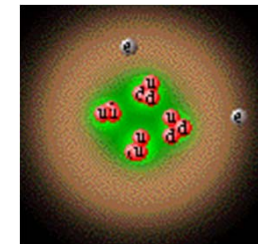
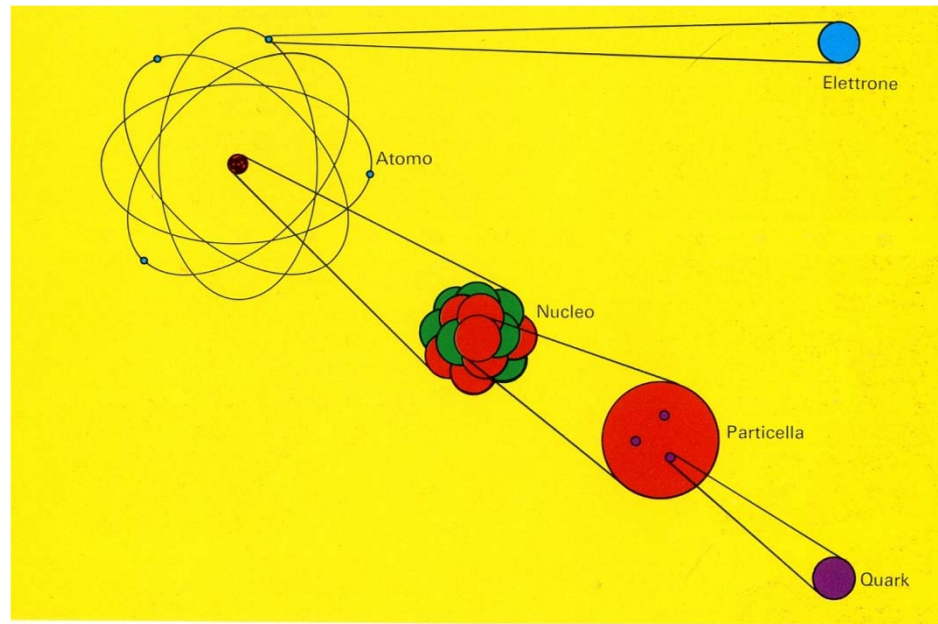
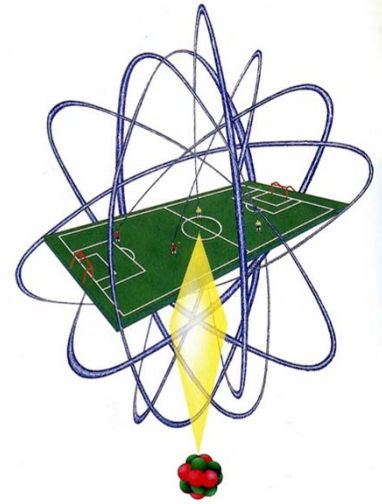
di che cosa è composta la materia?

cosa la tiene insieme?

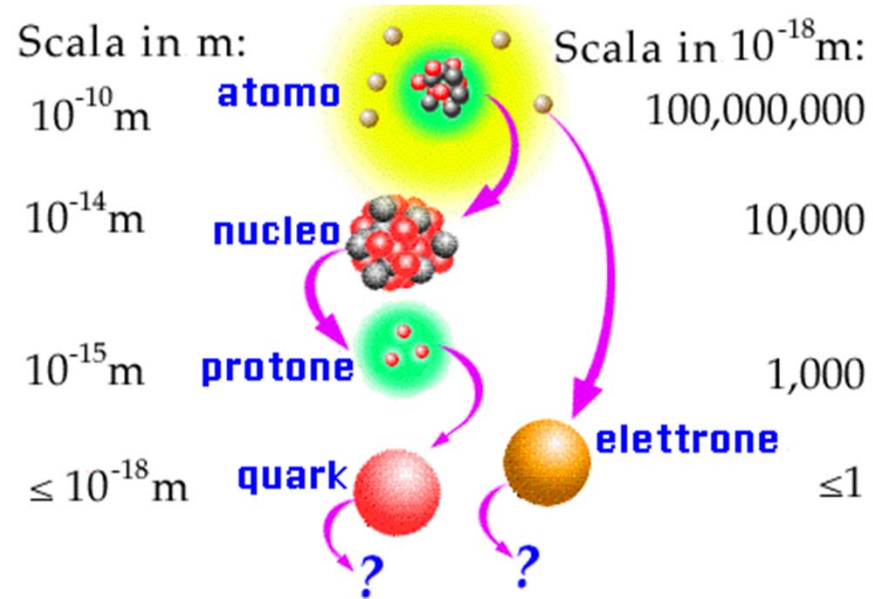
cosa genera la massa?



# Di che cosa è costituita la materia?

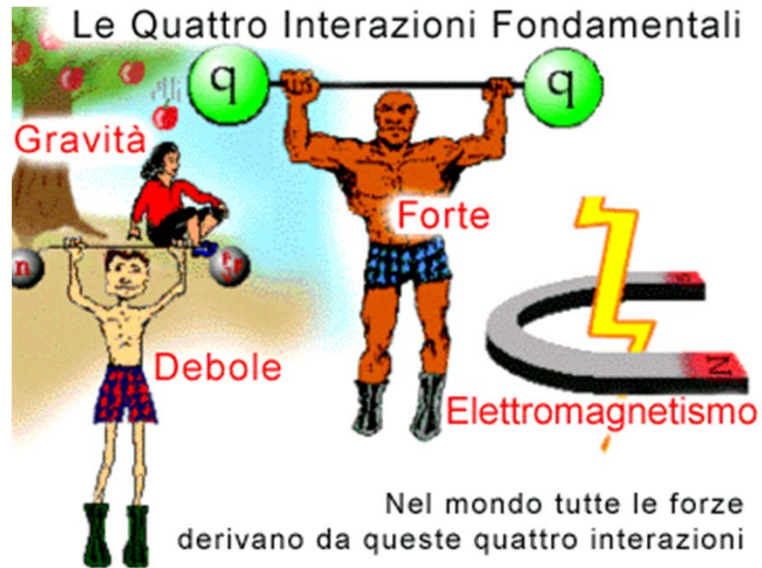


# Le dimensioni del problema



Valore	Potenza di 10	Prefisso	Simbolo
1.000.000.000.000.000.000	$10^{18}$	<u>Exa</u>	<u>E</u>
1.000.000.000.000.000	$10^{15}$	<u>Peta</u>	<u>P</u>
1.000.000.000.000	$10^{12}$	<u>Tera</u>	<u>T</u>
1.000.000.000	$10^9$	<u>Giga</u>	<u>G</u>
1.000.000	$10^6$	<u>Mega</u>	<u>M</u>
1.000	$10^3$	<u>Chilo</u>	<u>k</u>
100	$10^2$	<u>Etto</u>	<u>h</u>
10	$10^1$	<u>Deca</u>	<u>da</u>
0,1	$10^{-1}$	<u>Deci</u>	<u>d</u>
0,01	$10^{-2}$	<u>Centi</u>	<u>c</u>
0,001	$10^{-3}$	<u>Milli</u>	<u>m</u>
0,000001	$10^{-6}$	<u>Micro</u>	<u>μ</u>
0,000000001	$10^{-9}$	<u>Nano</u>	<u>n</u>
0,0000000000001	$10^{-12}$	<u>Pico</u>	<u>p</u>
0,0000000000000001	$10^{-15}$	<u>Femto</u>	<u>f</u>
0,0000000000000000001	$10^{-18}$	<u>Atto</u>	<u>a</u>

# Che cosa tiene insieme la materia?



- forte
- elettromagnetica
- debole
- gravitazionale

intensità

raggio d'azione

$10^{38}$

$\approx 10^{-15}$  m

$10^{36}$

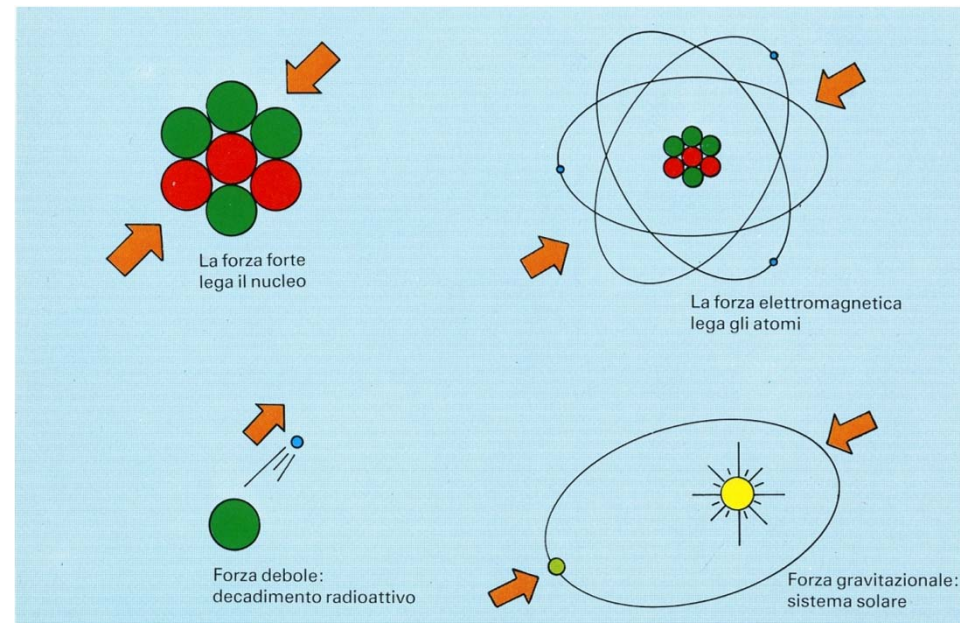
$\infty$

$10^{25}$

$\approx 10^{-18}$  m

1

$\infty$



# Tavola del modello standard

## Standard Model of FUNDAMENTAL PARTICLES AND INTERACTIONS

The Standard Model summarizes the current knowledge in Particle Physics. It is the quantum theory that includes the theory of strong interactions (quantum chromodynamics or QCD) and the unified theory of weak and electromagnetic interactions (electroweak). Gravity is included on this chart because it is one of the fundamental interactions even though not part of the "Standard Model."

### FERMIONS

Leptons spin = 1/2			Quarks spin = 1/2		
Flavor	Mass GeV/c <sup>2</sup>	Electric charge	Flavor	Approx. Mass GeV/c <sup>2</sup>	Electric charge
$\nu_e$ electron neutrino	$<1 \times 10^{-8}$	0	<b>u</b> up	0.003	2/3
<b>e</b> electron	0.000511	-1	<b>d</b> down	0.006	-1/3
$\nu_\mu$ muon neutrino	$<0.0002$	0	<b>c</b> charm	1.3	2/3
<b><math>\mu</math></b> muon	0.106	-1	<b>s</b> strange	0.1	-1/3
$\nu_\tau$ tau neutrino	$<0.02$	0	<b>t</b> top	175	2/3
<b><math>\tau</math></b> tau	1.7771	-1	<b>b</b> bottom	4.3	-1/3

**Spin** is the intrinsic angular momentum of particles. Spin is given in units of  $\hbar$ , which is the quantum unit of angular momentum, where  $\hbar = h/2\pi = 6.58 \times 10^{-25}$  GeV s =  $1.05 \times 10^{-34}$  J s.

**Electric charges** are given in units of the proton's charge. In SI units the electric charge of the proton is  $1.60 \times 10^{-19}$  coulombs.

The **energy** unit of particle physics is the electronvolt (eV), the energy gained by one electron in crossing a potential difference of one volt. **Masses** are given in GeV/c<sup>2</sup> (remember  $E = mc^2$ ), where  $1 \text{ GeV} = 10^9 \text{ eV} = 1.60 \times 10^{-10}$  joule. The mass of the proton is  $0.938 \text{ GeV}/c^2 = 1.67 \times 10^{-27}$  kg.

**matter constituents**  
spin = 1/2, 3/2, 5/2, ...

### BOSONS

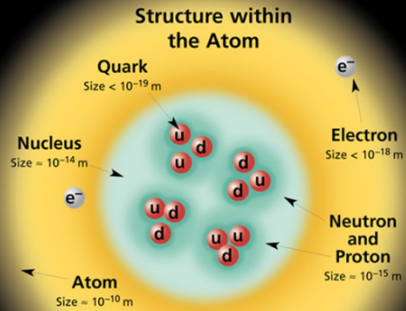
Unified Electroweak spin = 1			Strong (color) spin = 1		
Name	Mass GeV/c <sup>2</sup>	Electric charge	Name	Mass GeV/c <sup>2</sup>	Electric charge
$\gamma$ photon	0	0	<b>g</b> gluon	0	0
<b>W<sup>-</sup></b>	80.4	-1			
<b>W<sup>+</sup></b>	80.4	+1			
<b>Z<sup>0</sup></b>	91.187	0			

**force carriers**  
spin = 0, 1, 2, ...

**Color Charge**  
Each quark carries one of three types of "strong charge," also called "color charge." These charges have nothing to do with the colors of visible light. There are eight possible types of color charge for gluons. Just as electrically-charged particles interact by exchanging photons, in strong interactions color-charged particles interact by exchanging gluons. Leptons, photons, and **W** and **Z** bosons have no strong interactions and hence no color charge.

**Quarks Confined in Mesons and Baryons**  
One cannot isolate quarks and gluons; they are confined in color-neutral particles called **hadrons**. This confinement (binding) results from multiple exchanges of gluons among the color-charged constituents. As color-charged particles (quarks and gluons) move apart, the energy in the color-force field between them increases. This energy eventually is converted into additional quark-antiquark pairs (see figure below). The quarks and antiquarks then combine into hadrons; these are the particles seen to emerge. Two types of hadrons have been observed in nature: **mesons**  $q\bar{q}$  and **baryons**  $qqq$ .

**Residual Strong Interaction**  
The strong binding of color-neutral protons and neutrons to form nuclei is due to residual strong interactions between their color-charged constituents. It is similar to the residual electrical interaction that binds electrically neutral atoms to form molecules. It can also be viewed as the exchange of mesons between the hadrons.



If the protons and neutrons in this picture were 10 cm across, then the quarks and electrons would be less than 0.1 mm in size and the entire atom would be about 10 km across.

### PROPERTIES OF THE INTERACTIONS

Baryons $qqq$ and Antibaryons $\bar{q}\bar{q}\bar{q}$					
Baryons are fermionic hadrons. There are about 120 types of baryons.					
Symbol	Name	Quark content	Electric charge	Mass GeV/c <sup>2</sup>	Spin
<b>p</b>	proton	<b>uud</b>	1	0.938	1/2
$\bar{p}$	anti-proton	$\bar{u}\bar{u}\bar{d}$	-1	0.938	1/2
<b>n</b>	neutron	<b>udd</b>	0	0.940	1/2
$\bar{n}$	anti-neutron	$\bar{u}\bar{d}\bar{d}$	0	0.940	1/2
$\Lambda$	lambda	<b>uds</b>	0	1.116	1/2
$\bar{\Lambda}$	anti-lambda	$\bar{u}\bar{d}\bar{s}$	0	1.116	1/2
$\Omega^-$	omega	<b>sss</b>	-1	1.672	3/2

Property	Interaction	Weak (Electroweak)		Strong	
		Gravitational	Electromagnetic	Fundamental	Residual
<b>Acts on:</b>		Mass - Energy	Flavor	Electric Charge	Color Charge
<b>Particles experiencing:</b>		All	Quarks, Leptons	Electrically charged	Quarks, Gluons
<b>Particles mediating:</b>		Graviton (not yet observed)	<b>W<sup>+</sup> W<sup>-</sup> Z<sup>0</sup></b>	$\gamma$	Gluons
<b>Strength relative to electromag for two u quarks at:</b>	$10^{-18}$ m $3 \times 10^{-17}$ m	$10^{-41}$ $10^{-41}$ $10^{-36}$	0.8 $10^{-4}$ $10^{-7}$	1 1 1	25 60 Not applicable to hadrons
<b>for two protons in nucleus</b>					20

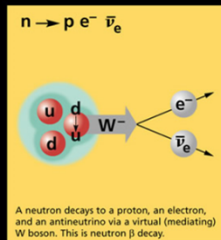
Mesons $q\bar{q}$					
Mesons are bosonic hadrons. There are about 140 types of mesons.					
Symbol	Name	Quark content	Electric charge	Mass GeV/c <sup>2</sup>	Spin
$\pi^+$	pion	<b>u<math>\bar{d}</math></b>	+1	0.140	0
$\pi^-$	anti-pion	$\bar{u}d$	-1	0.140	0
$K^+$	kaon	<b>u<math>\bar{s}</math></b>	+1	0.494	0
$K^-$	anti-kaon	$\bar{u}s$	-1	0.494	0
$\rho^+$	rho	<b>u<math>\bar{d}</math></b>	+1	0.770	1
$\rho^-$	anti-rho	$\bar{u}d$	-1	0.770	1
$B^0$	B-zero	<b>d<math>\bar{b}</math></b>	0	5.279	0
$\bar{B}^0$	anti-B-zero	$\bar{d}b$	0	5.279	0
$\eta_c$	eta-c	<b>c<math>\bar{c}</math></b>	0	2.980	0

#### Matter and Antimatter

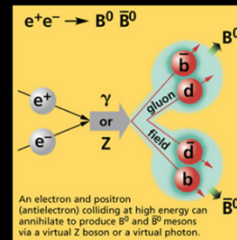
For every particle type there is a corresponding antiparticle type, denoted by a bar over the particle symbol (unless + or - charge is shown). Particle and antiparticle have identical mass and spin but opposite charges. Some electrically neutral bosons (e.g.,  $Z^0$ ,  $\gamma$ , and  $\eta_c = c\bar{c}$ , but not  $K^0 = d\bar{s}$ ) are their own antiparticles.

#### Figures

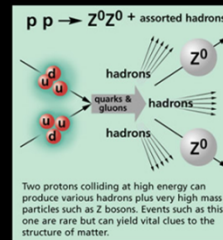
These diagrams are an artist's conception of physical processes. They are not exact and have no meaningful scale. Green shaded areas represent the cloud of gluons or the gluon field, and red lines the quark paths.



A neutron decays to a proton, an electron, and an antineutrino via a virtual (mediating)  $W^-$  boson. This is neutron  $\beta$  decay.



An electron and positron (antielectron) colliding at high energy can annihilate to produce  $B^0$  and  $\bar{B}^0$  mesons via a virtual  $Z$  boson or a virtual photon.



Two protons colliding at high energy can produce various hadrons plus very high mass particles such as  $Z$  bosons. Events such as this one are rare but can yield vital clues to the structure of matter.

#### The Particle Adventure

Visit the award-winning web feature *The Particle Adventure* at <http://ParticleAdventure.org>

This chart has been made possible by the generous support of:

- U.S. Department of Energy
- U.S. National Science Foundation
- Lawrence Berkeley National Laboratory
- Stanford Linear Accelerator Center
- American Physical Society, Division of Particles and Fields
- BURLE** INDUSTRIES, INC.

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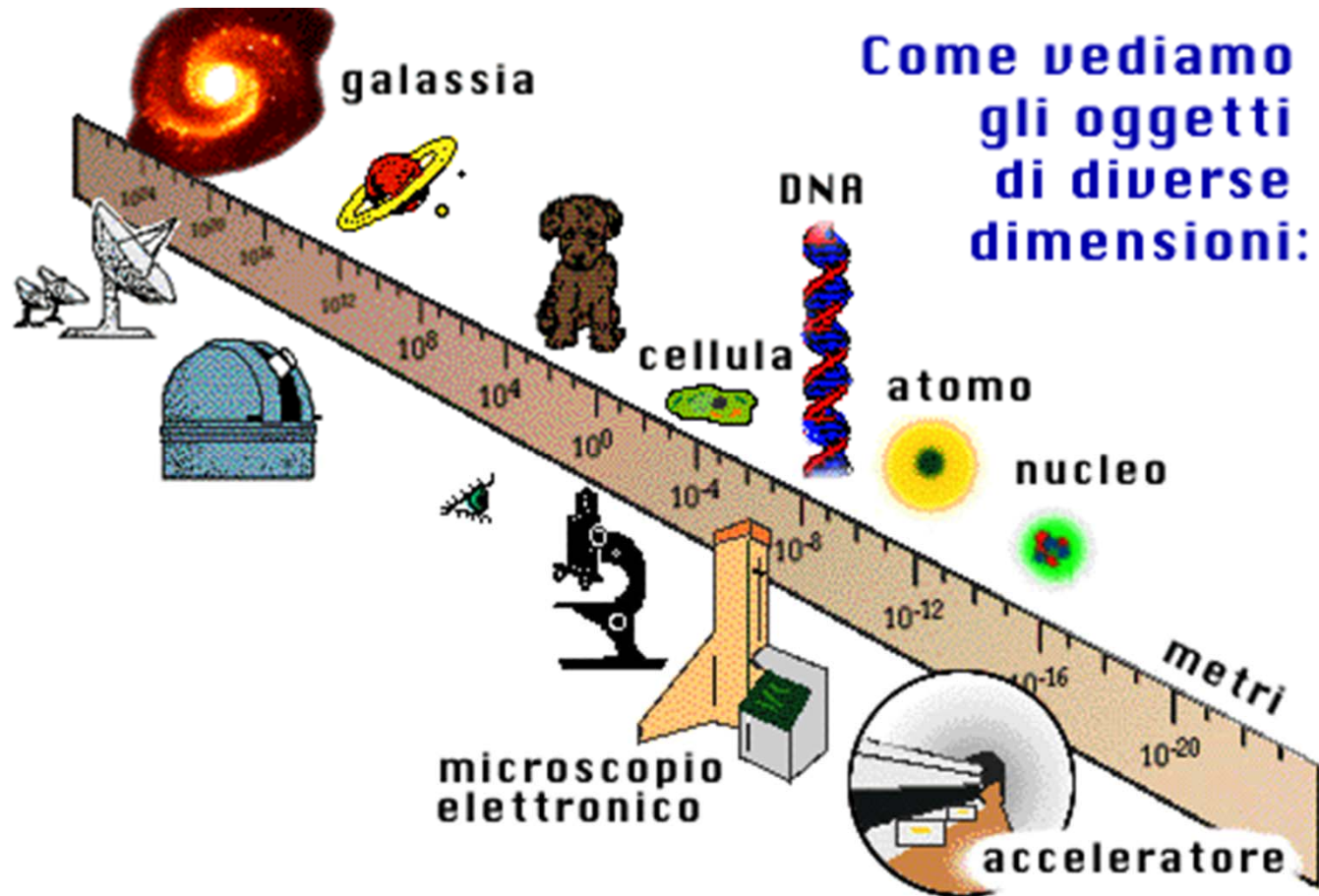




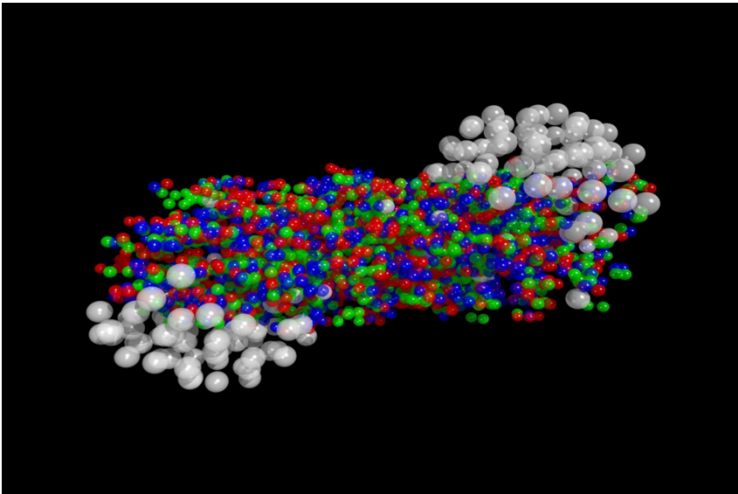
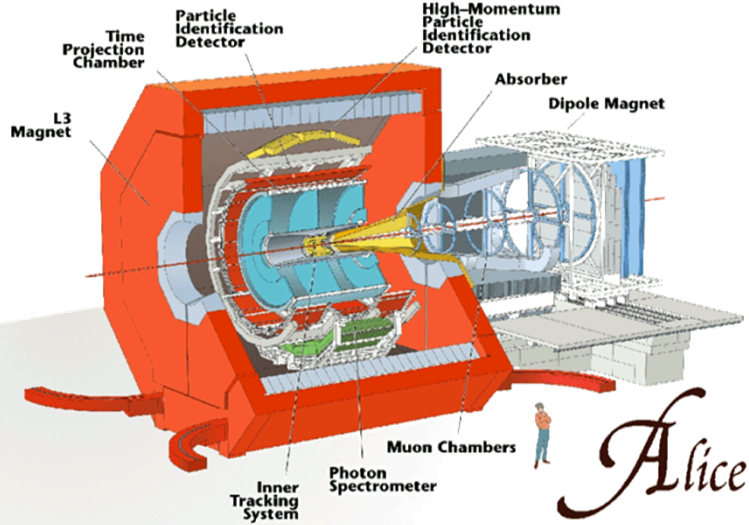
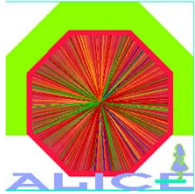
# Un martello sempre più grande!



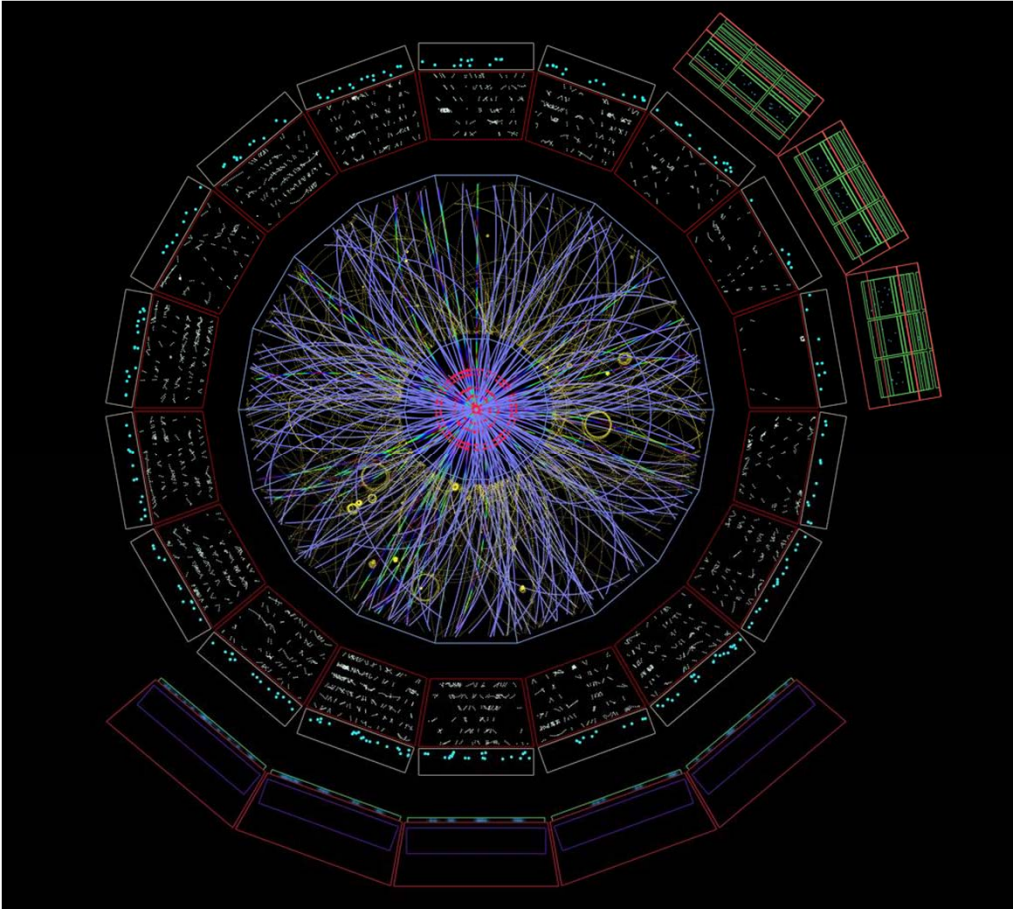
# Lo strumento adatto



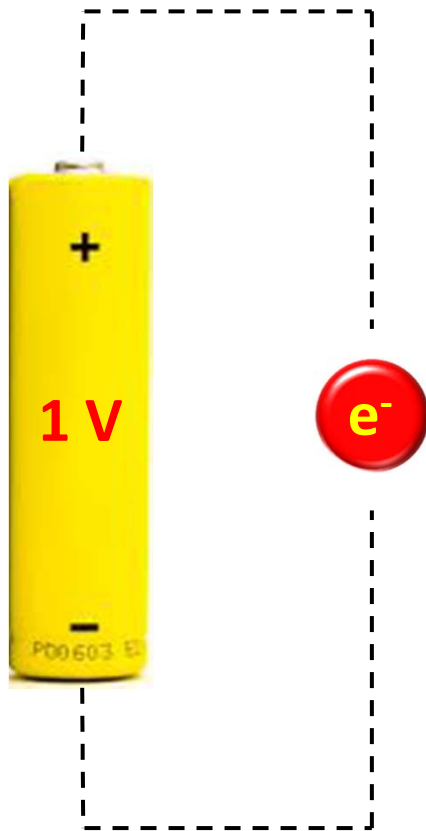
# L'esperimento ALICE



Pb + Pb @ 7 TeV



# Le energie in gioco



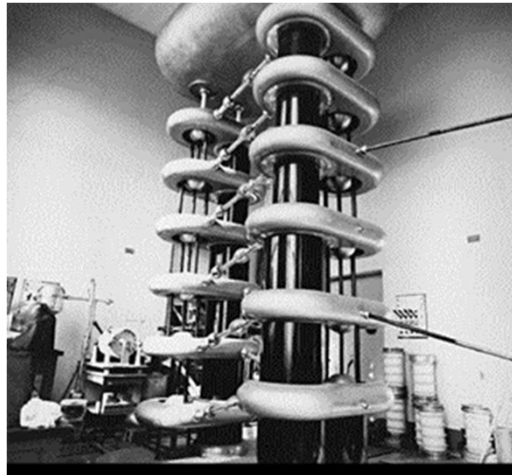
1 eV corrisponde all'aumento di energia di un elettrone sottoposto ad una differenza di potenziale di 1 V.

- 1 eV =  $1,6 \times 10^{-19}$  Joule
- 1 MeV =  $10^6$  eV
- 1 GeV =  $10^9$  eV
- 1 TeV =  $10^{12}$  eV

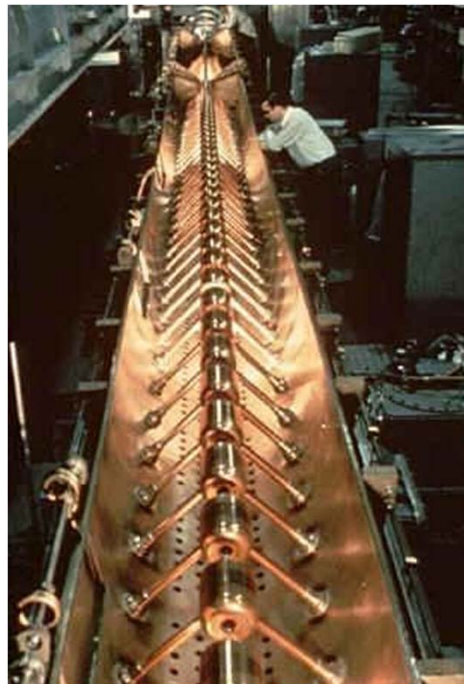


1 TeV è circa l'energia cinetica di una zanzara!

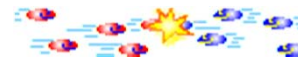
# Gli acceleratori lineari



Il primo acceleratore di particelle realizzato a Cambridge da Cockroft e Walton nel 1932

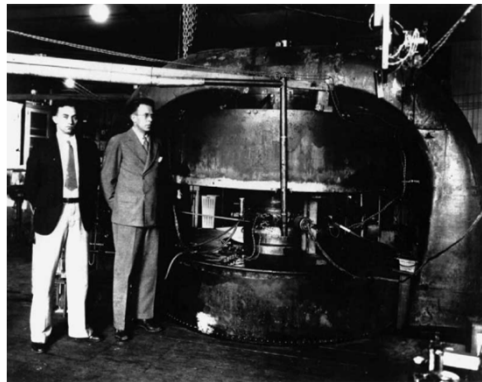
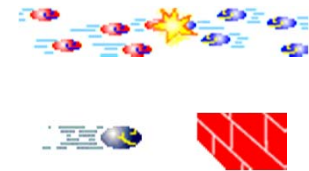


esperimenti a bersaglio fisso

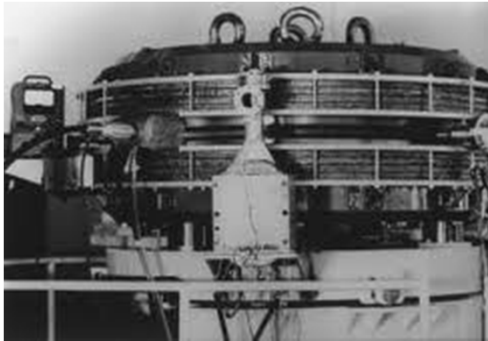


esperimenti con fasci collidenti

# Gli acceleratori circolari



ciclotrone  
(1929)



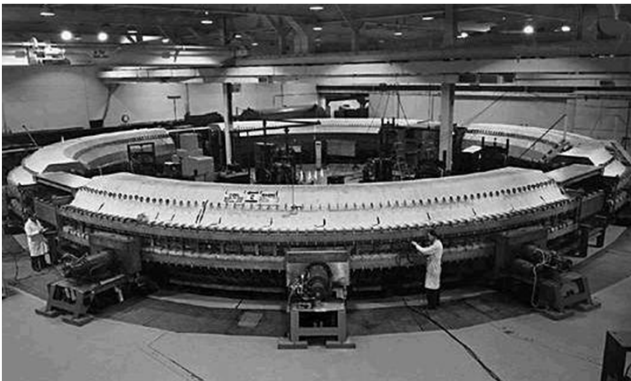
A.d.A.  
(1961-1964)



betatrone  
(6 MeV, 1942)



Adone  
(1969-1993)



sincrotrone  
(1952)



DA ΦNE  
(2000- ...)

# Gestire la complessità del sistema



LHC  
(2008- ...)



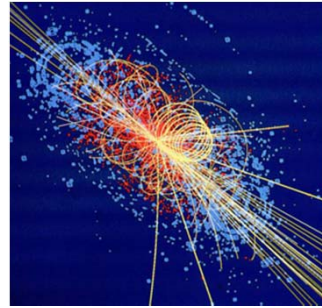
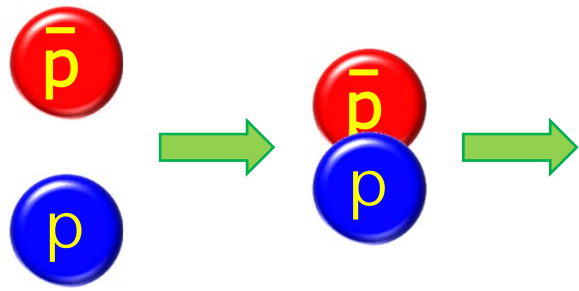
Sala controllo missioni spaziali Apollo  
(1969)



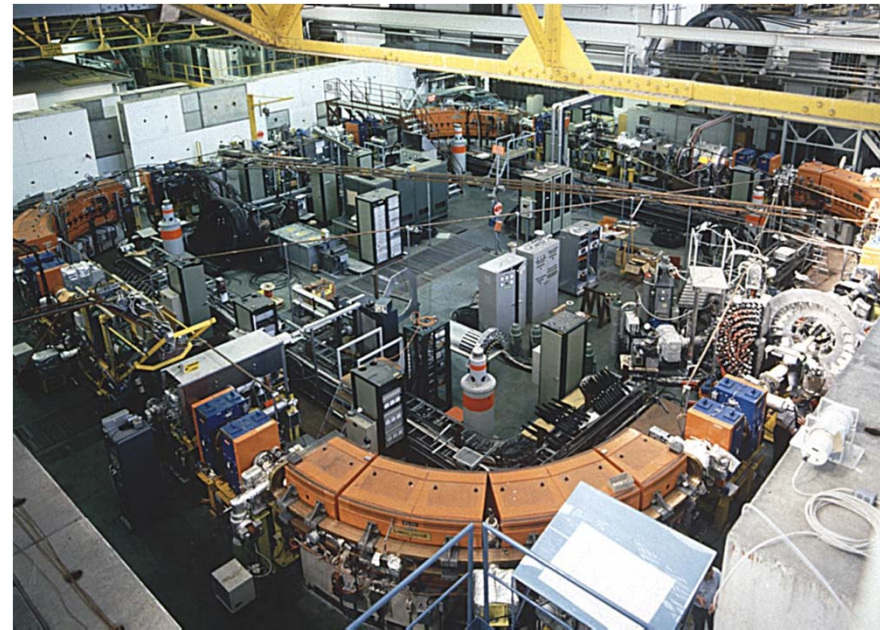
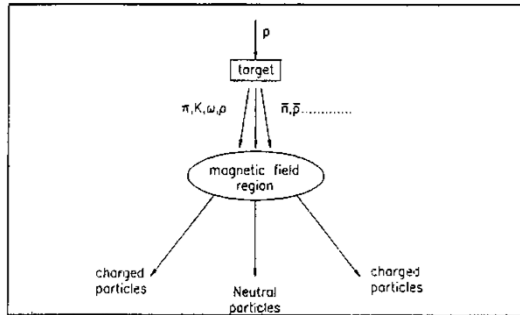
Sala di controllo principale  
acceleratore LHC  
(2008)



# Sperimentare con l'antimateria



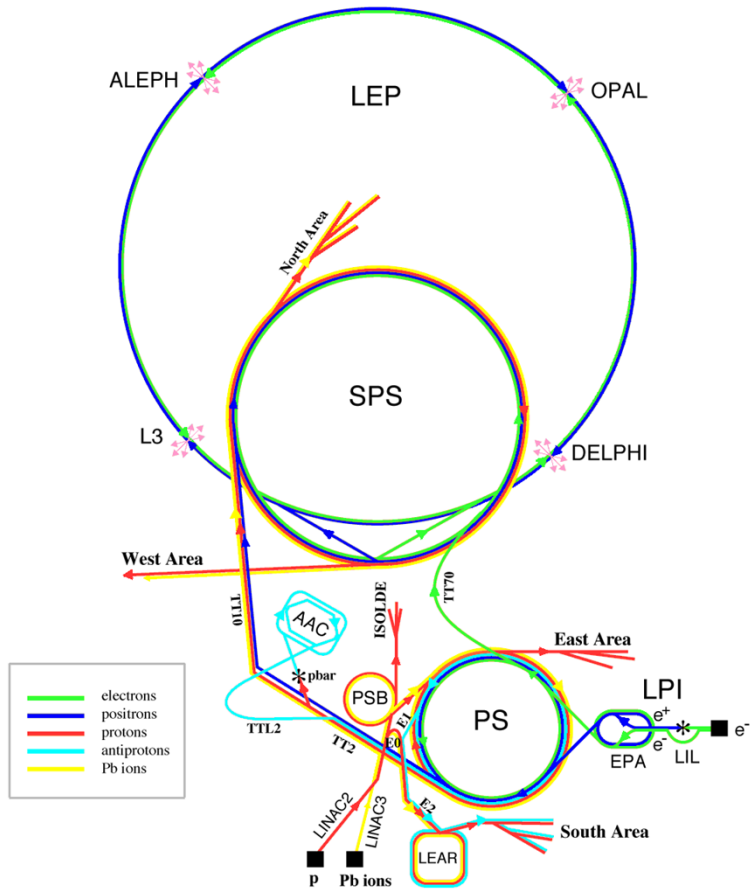
$$E = mc^2$$



LEAR 1983 - 1996



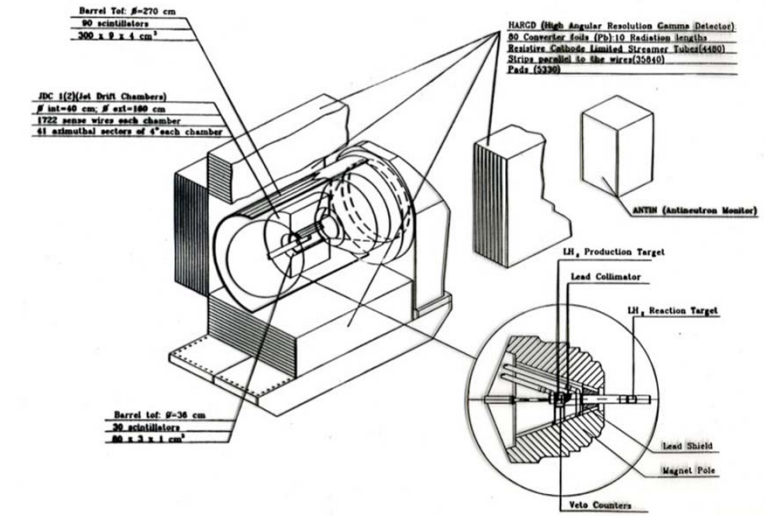
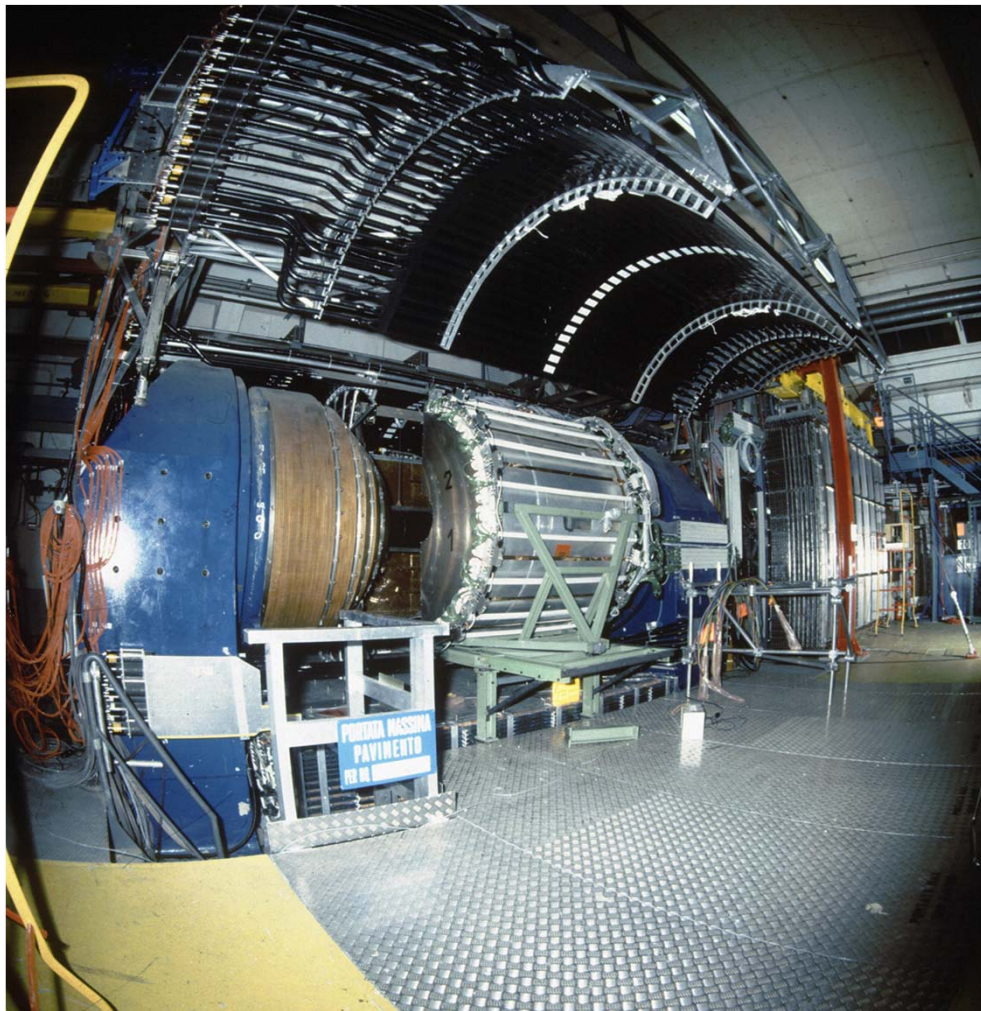
# Il laboratorio



A. Felcicello / Liceo M. Mazzarello, Torino, 3 febbraio 2011



# L'esperimento OBELIX

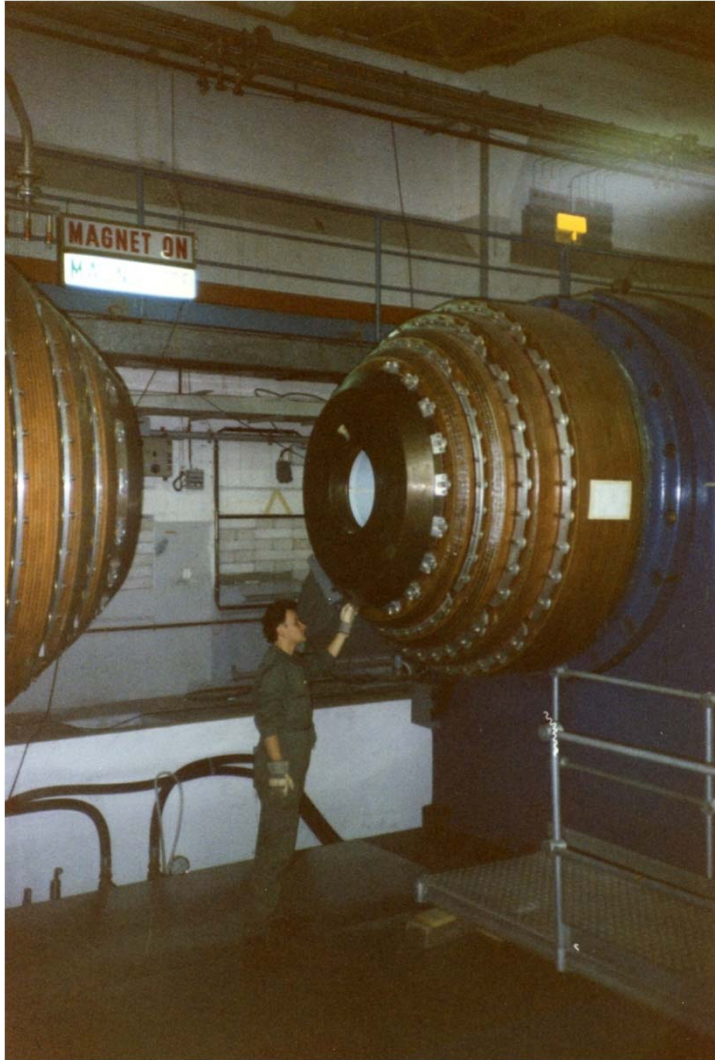


1990 - 1996

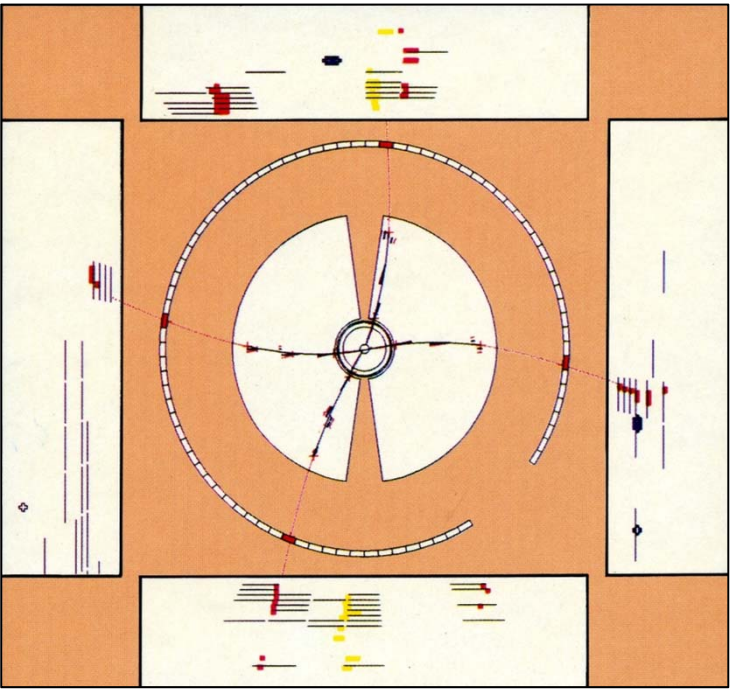
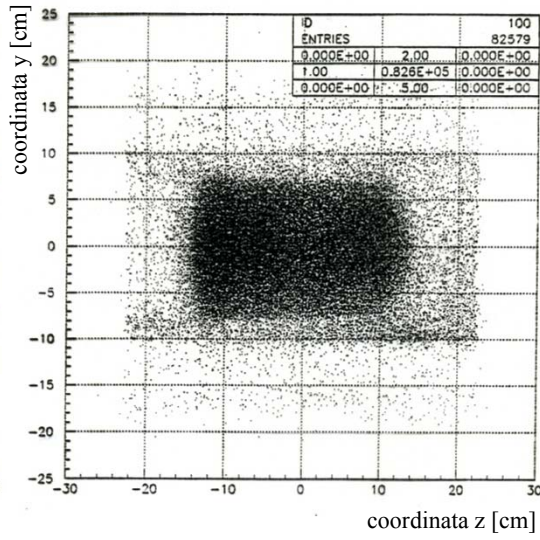
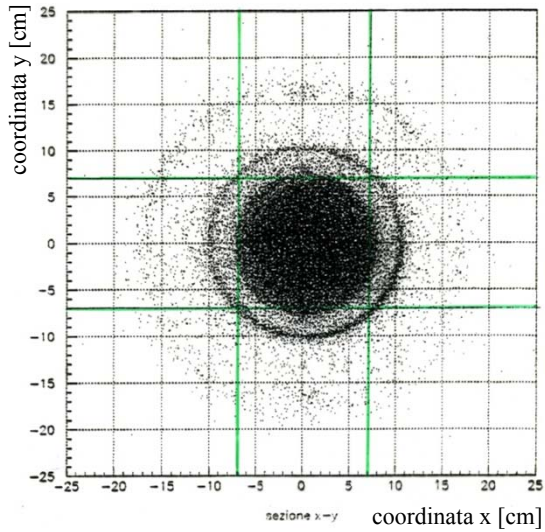
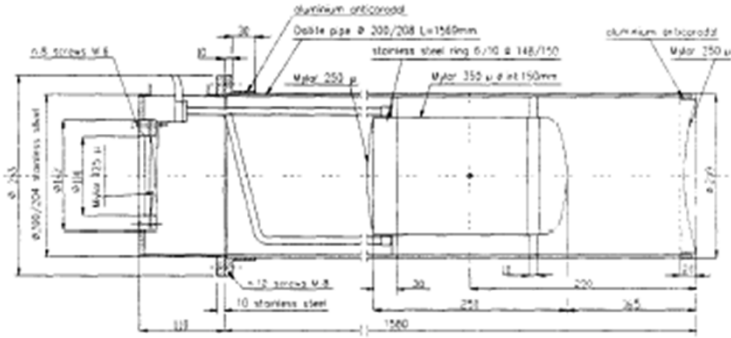
A. Felcicello / Liceo M. Mazzarello, Torino, 3 febbraio 2011



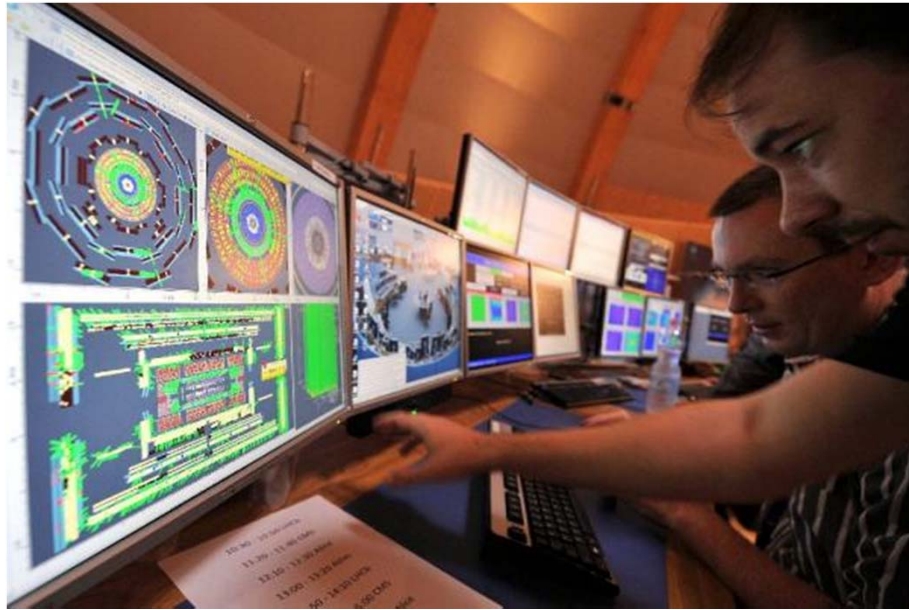
# La fase realizzativa



# Una costosa radiografia!

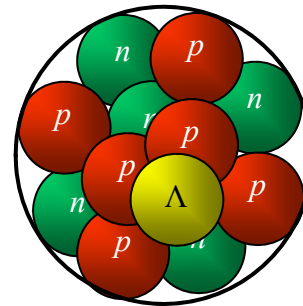
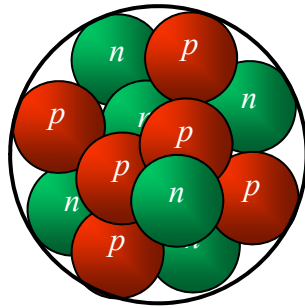


# Il ruolo dell'informatica



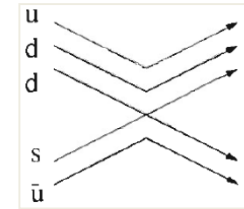
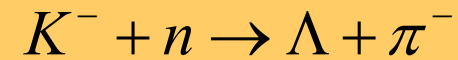
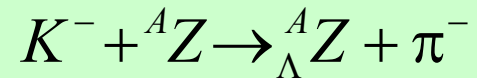
# Cosa è un iper-nucleo?

Un **iper-nucleo** è il risultato di una **manipolazione genetica** effettuata su un nucleo

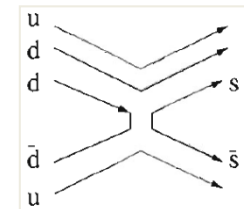
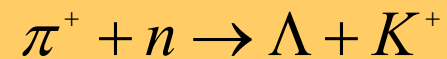
 $^{12}\text{C}$ 

 $^{12}_{\Lambda}\text{C}$

# Produzione di iper-nuclei

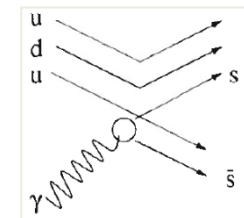
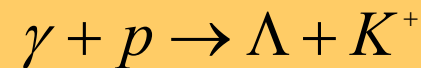
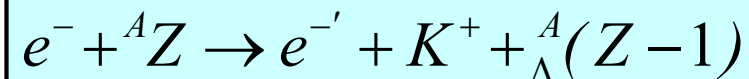
- 1) scambio di **stranezza** (in volo e a riposo):



- 2) produzione associata di **stranezza**:



- 3) "elettro produzione":

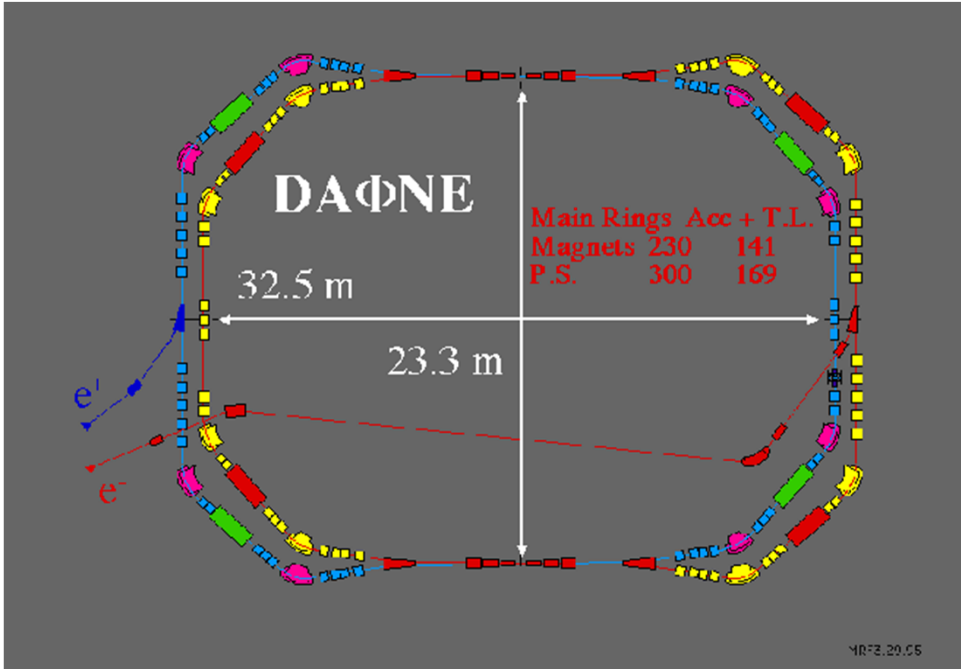
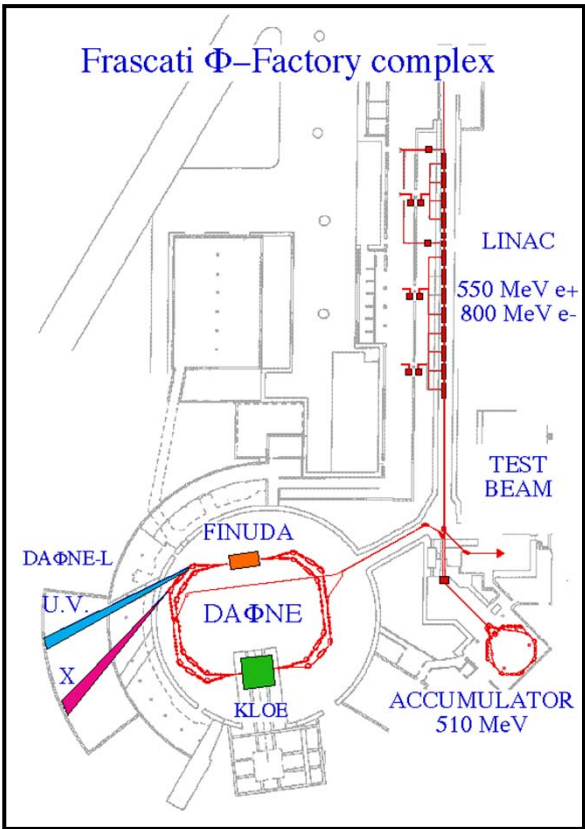


# Il laboratorio

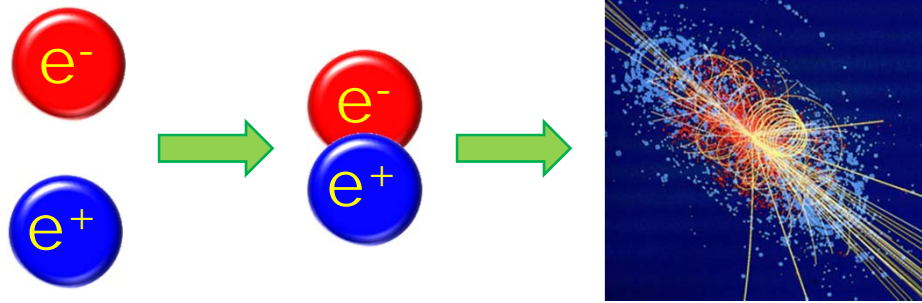




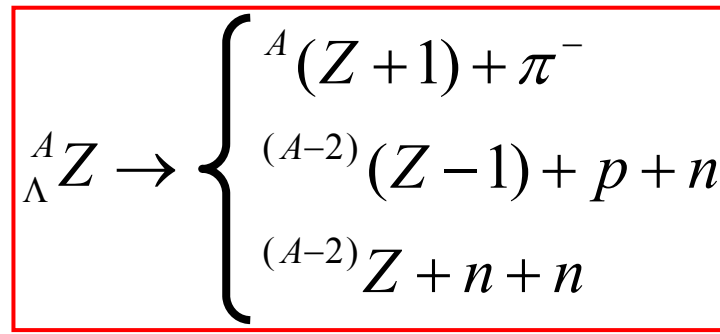
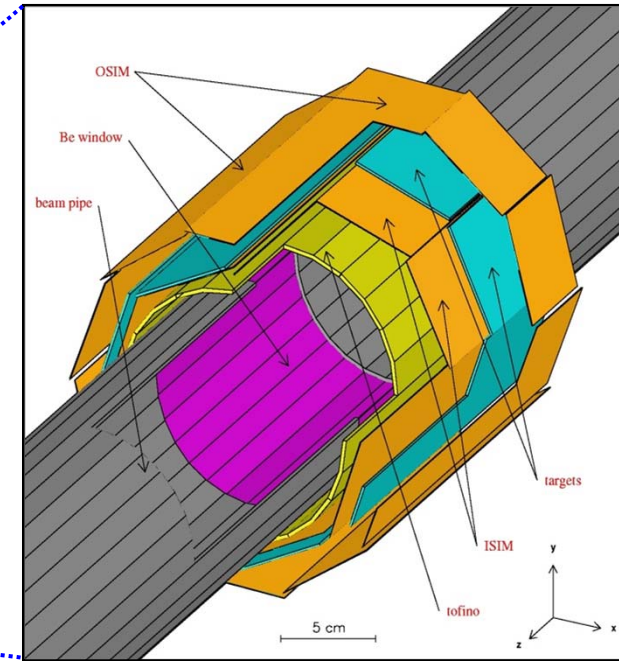
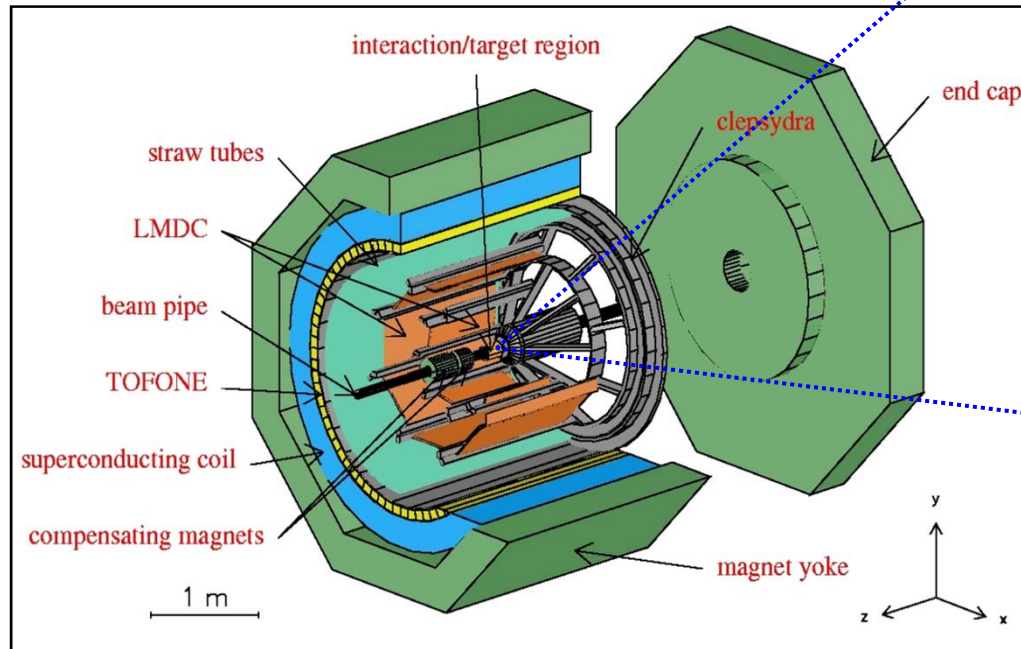
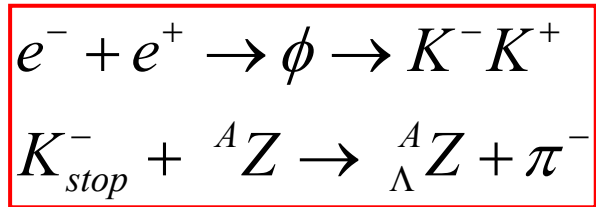
# Il laboratorio



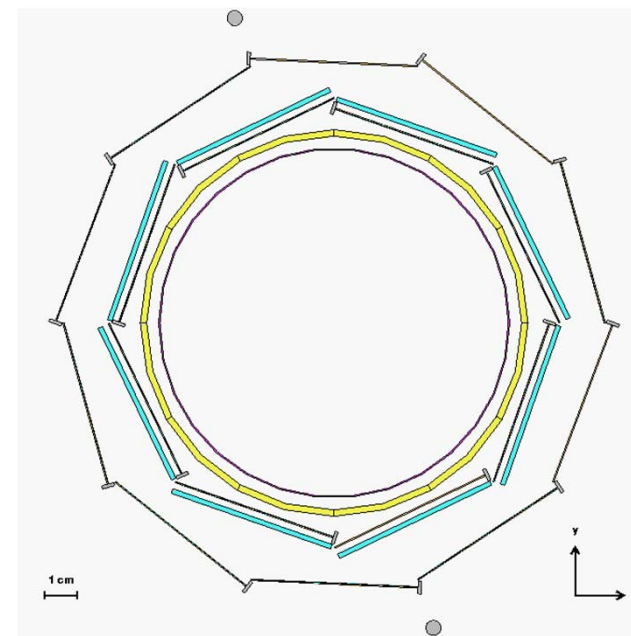
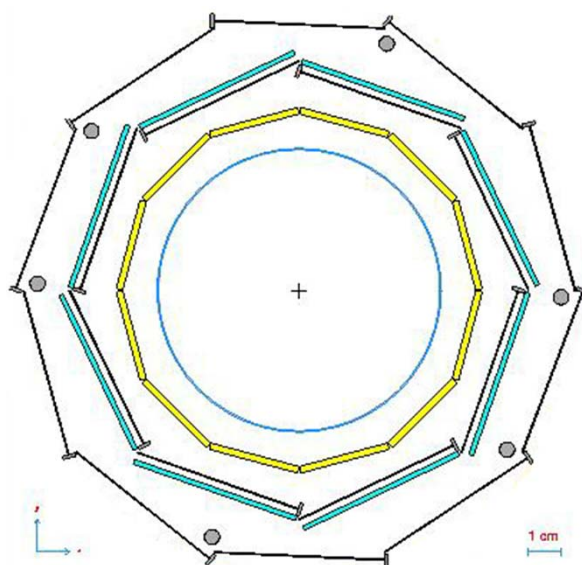
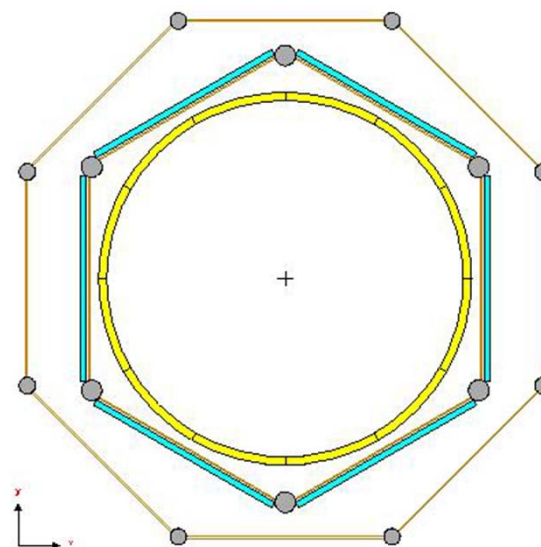
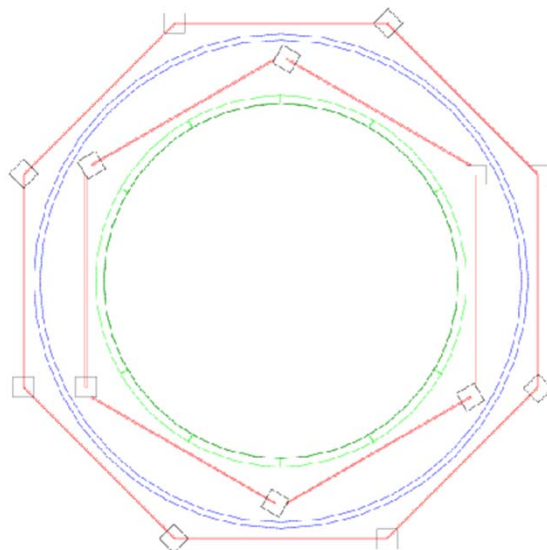
# L'esperimento FINUDA



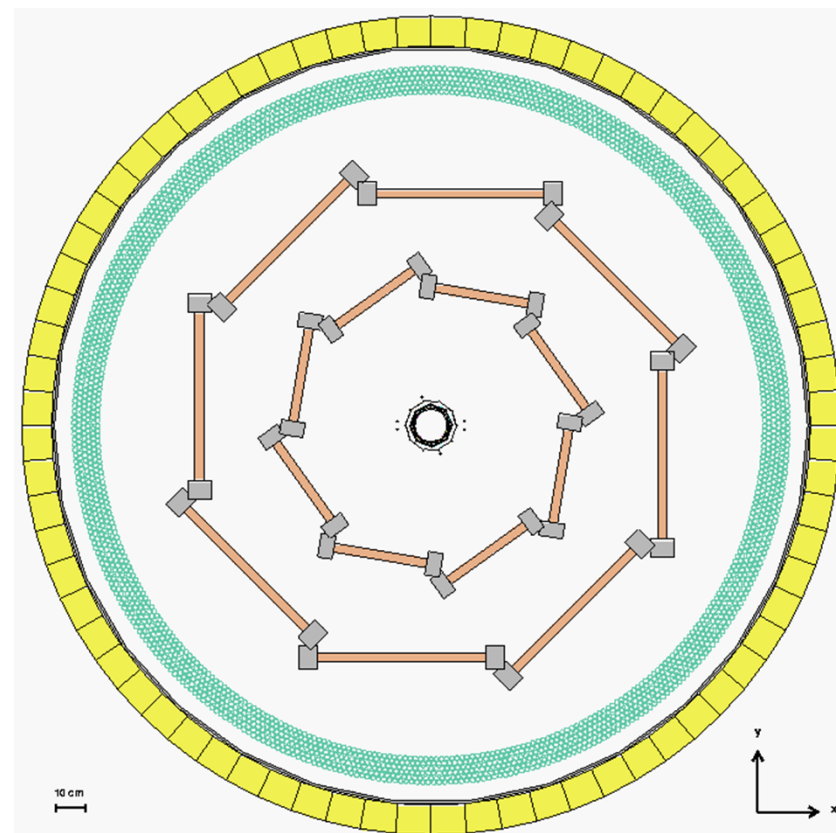
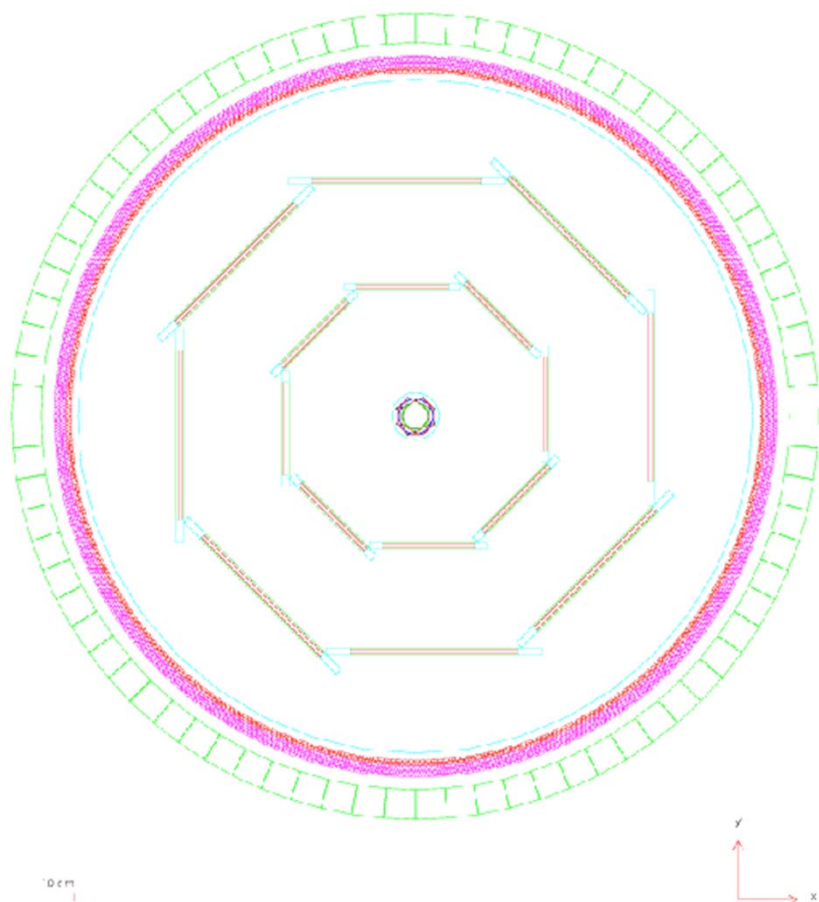
$E = mc^2$



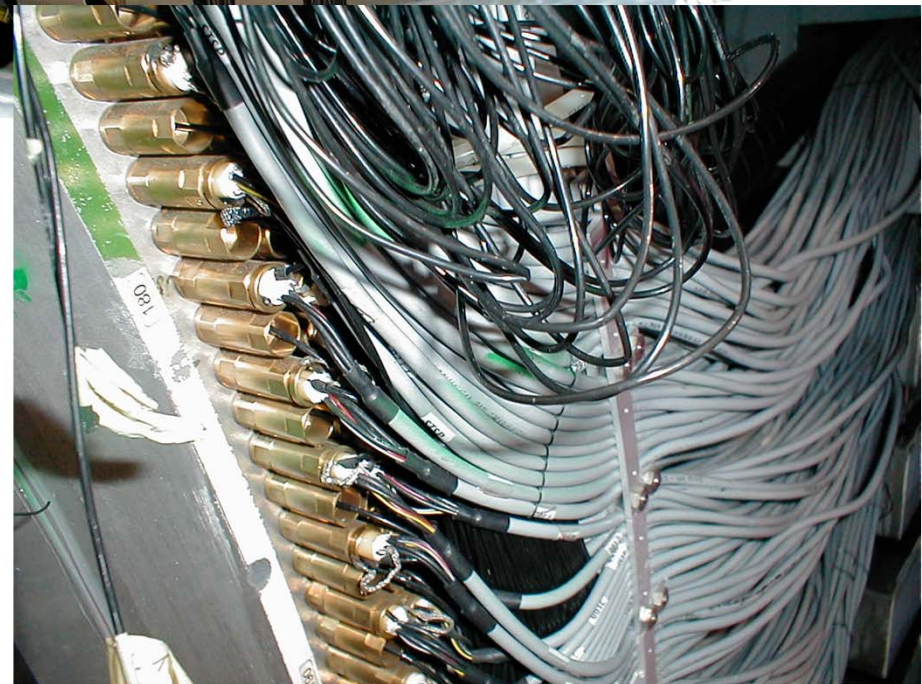
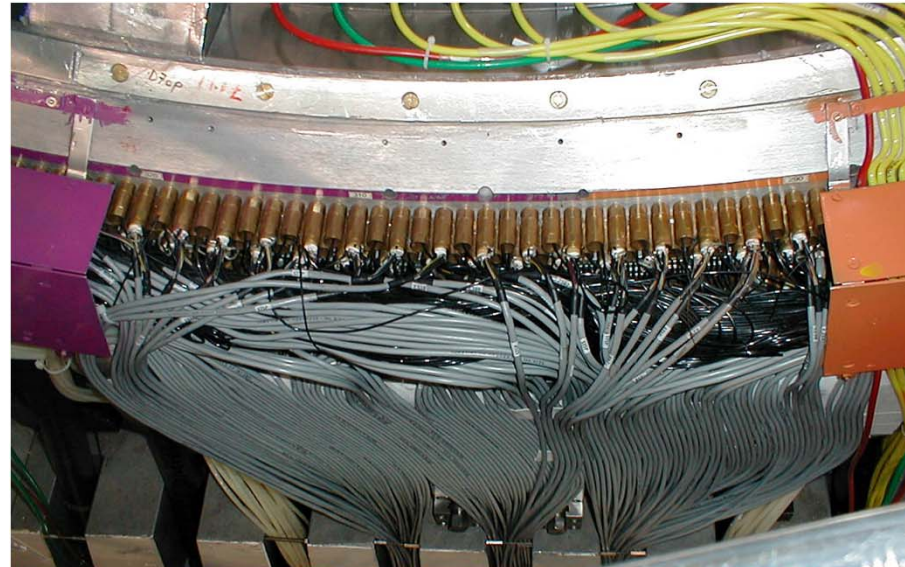
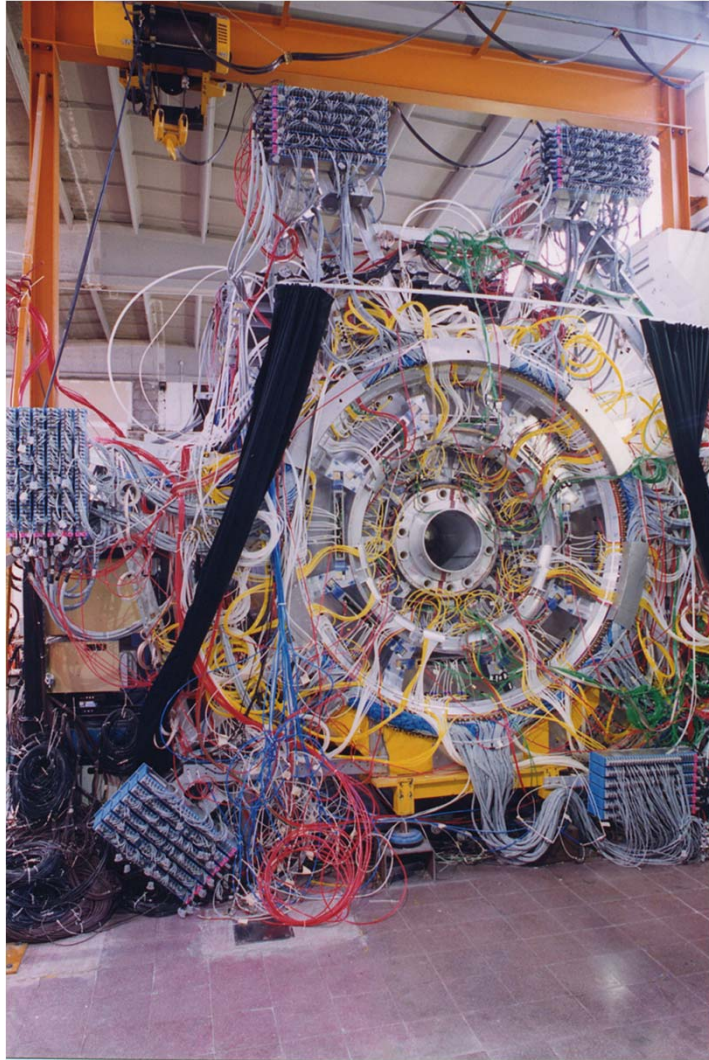
# L'evoluzione del rivelatore



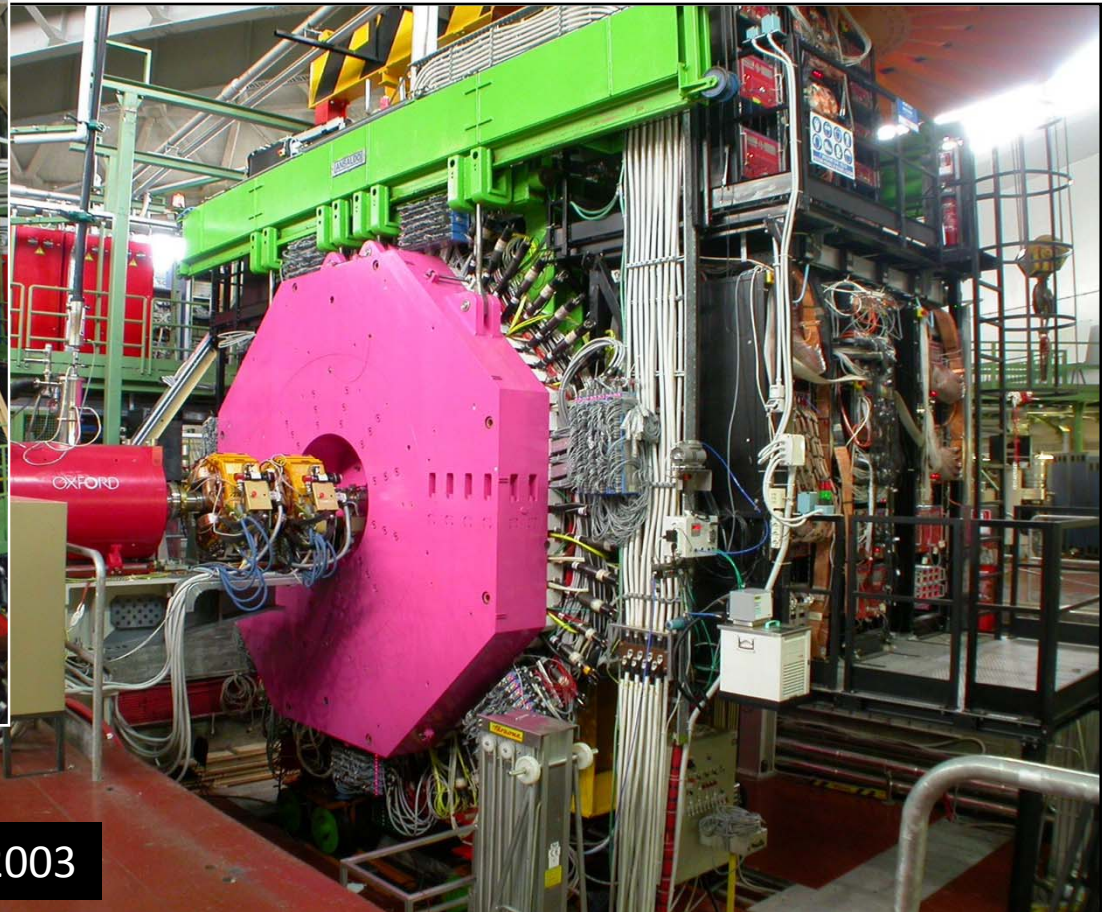
# L'evoluzione del rivelatore



# La fase realizzativa

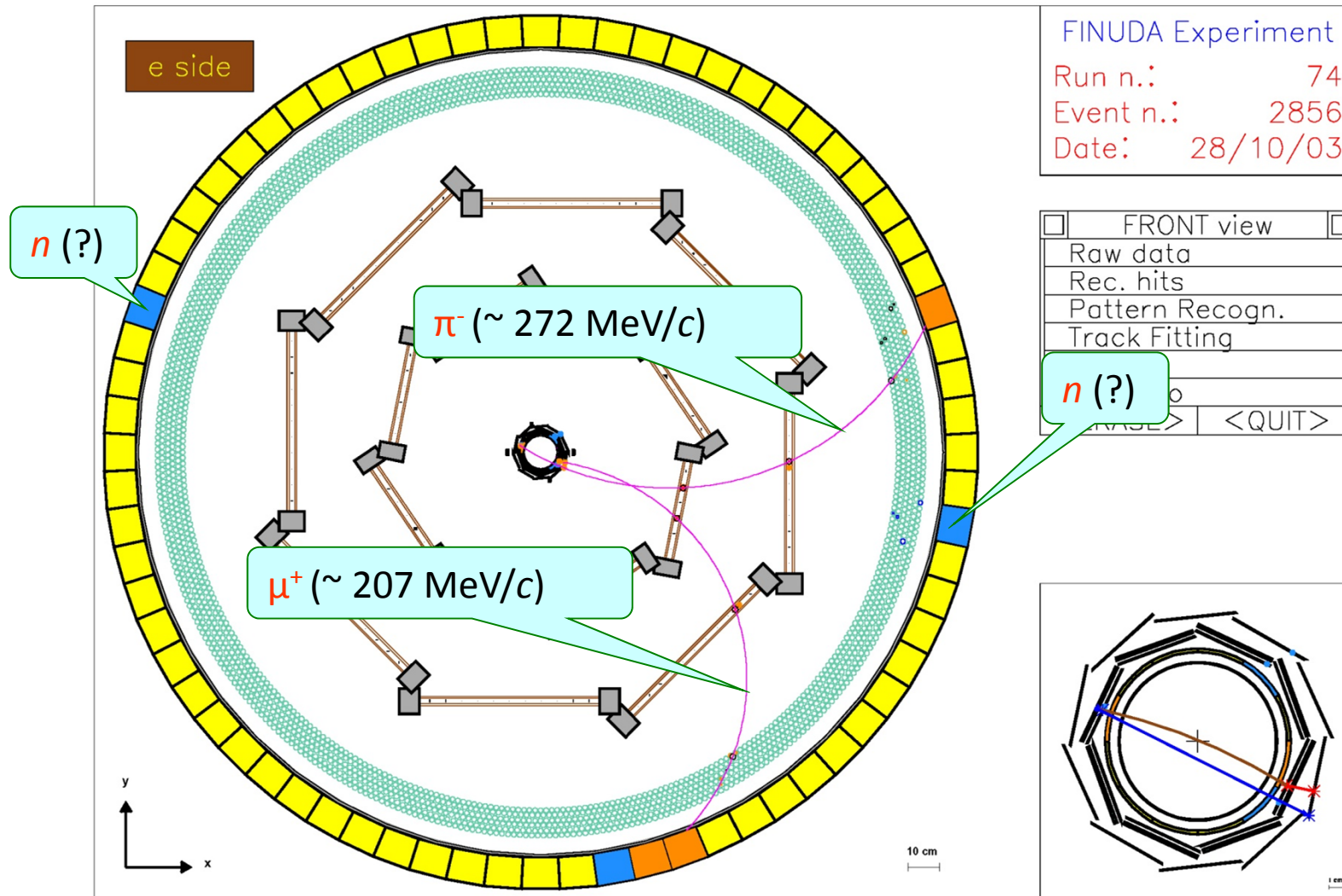


# L'apparato FINUDA

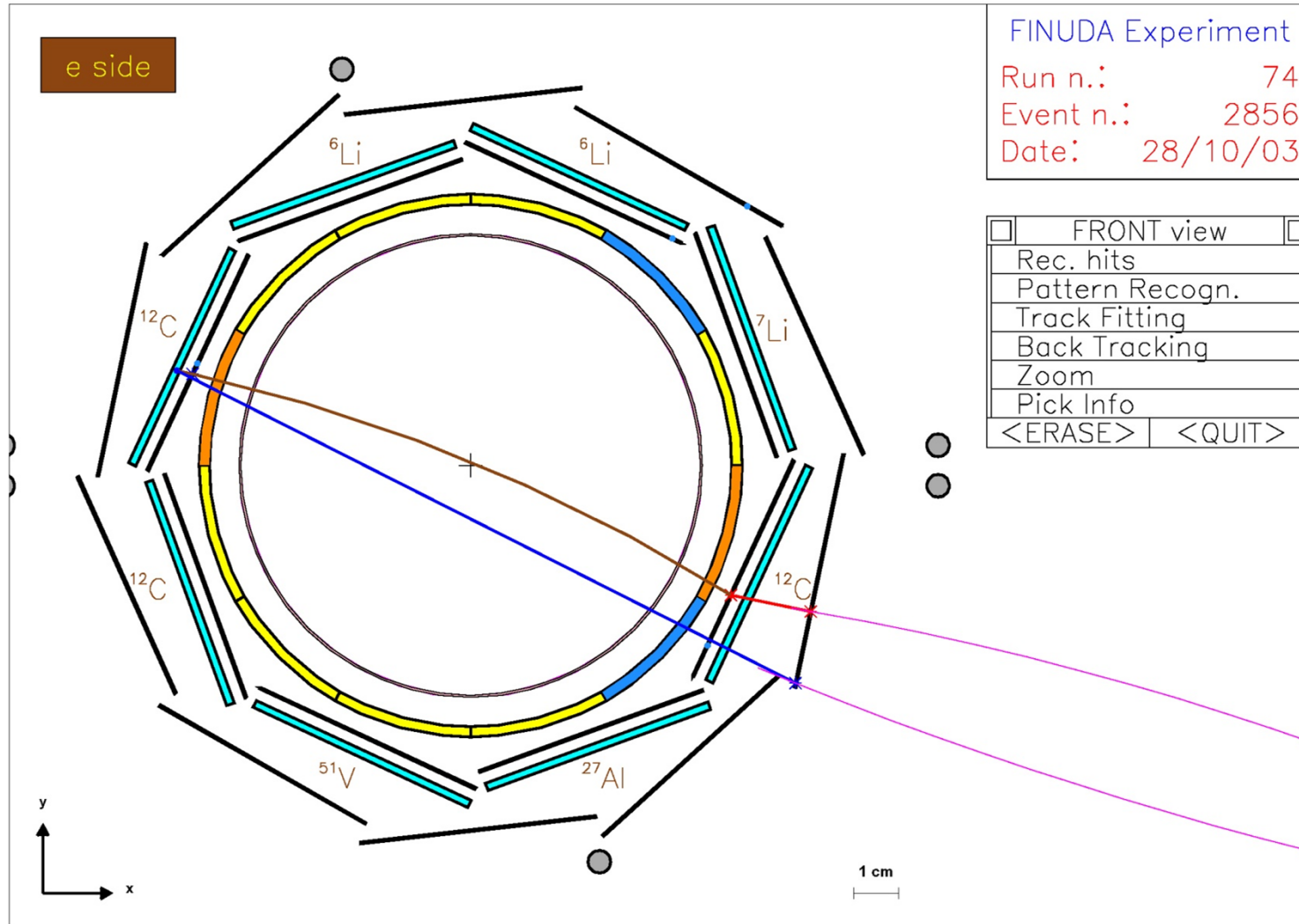


maggio 2003

# Un evento tipico



# Un evento tipico





# *Le ricadute tecnologiche*

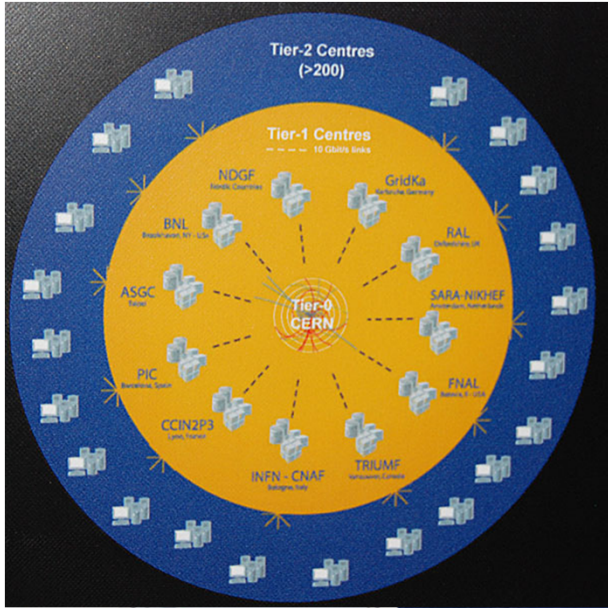
# World Wide Web (WWW)



06 agosto 1991



# GRID computing



## MonALISA Repository for ALICE

★ Catalogue browser ★ Repository Home Administration Section ALICE Reports Events XML Feed Firefox Toolbar Mon

● Running jobs 
 ● Running jobs but no ML info 
 ● Site service problem(s) prevents job execution 
 ● No jobs match the site resources 
 ● ML service down & no runn

Map options  Show xroold transfers

Jump to:

Repository Home - ALICE Web Page - ALICE Clusters - Contact - Links

Dynamic charts  
close all

This page: bookmark, URL

Running jobs trend

9429 jobs

Running jobs trend

→ 24h 
 → 12h 
 → 6h 
 → 1h

(click arrows for detailed view)

A. Felcicello / Liceo M. Mazzarello, Torino, 3 febbraio 2011

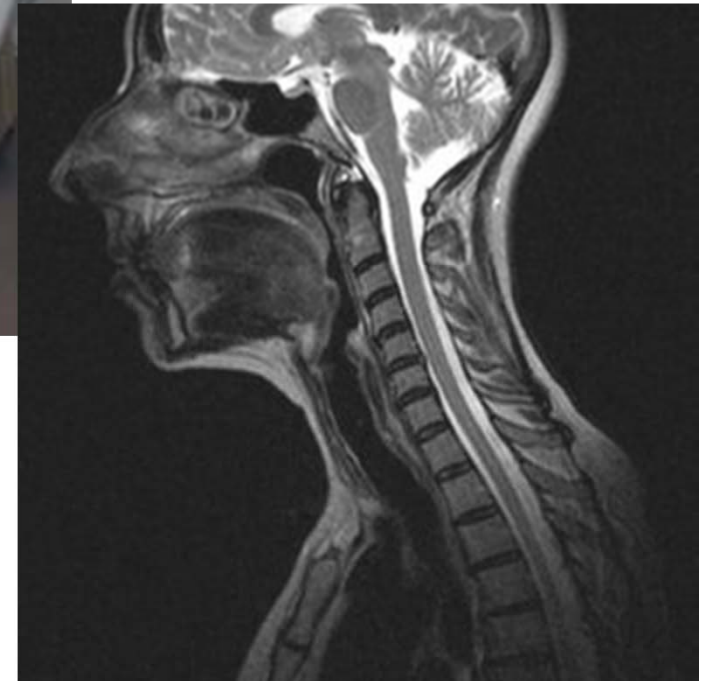


# *Contributi della fisica alla medicina*

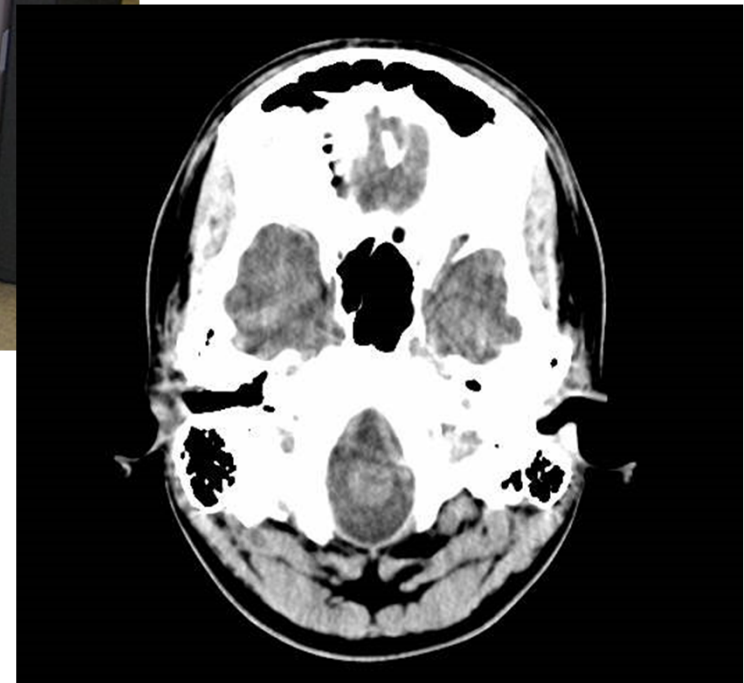
# L'ecografia



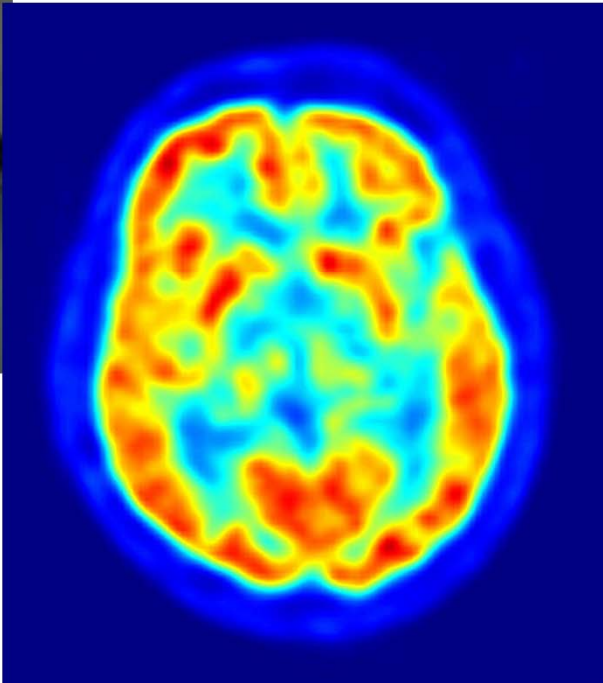
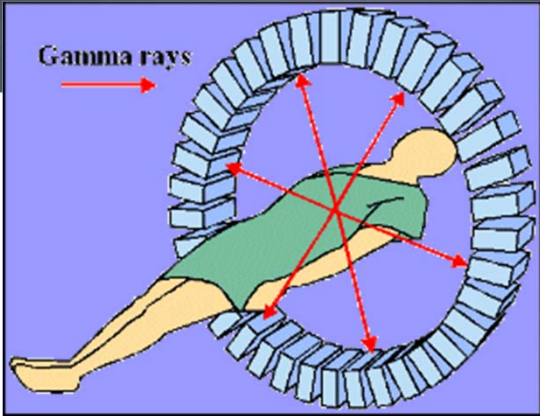
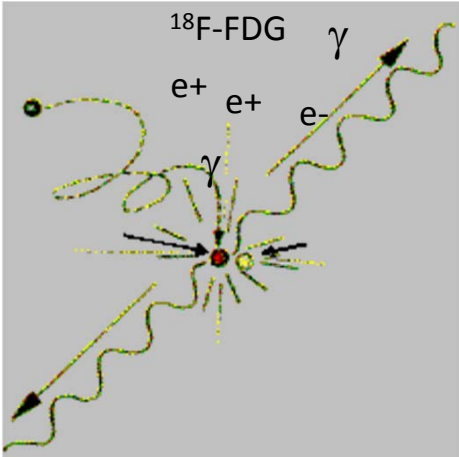
# Risonanza Magnetica Nucleare (R.M.N.)



# Tomografia computerizzata (T.C.)



# Tomografia ad emissione di positroni (P.E.T.)





# La P.E.T. nella diagnosi e nella cura dei tumori

**PET whole body  
eseguita su un malato  
oncologico prima e dopo  
la chemioterapia**



**Prima della  
chemioterapia**



**2 mesi dopo la  
chemioterapia**



**4 mesi dopo la  
chemioterapia**

# Terapia con radiazioni

- radioterapia con **fotoni**: **cobaltoterapia**
  - acceleratore lineare
- radioterapia con **adroni**: **protoni e ioni**
  - Centro di AdroTerapia ed Applicazioni Avanzate (**CATANA**, Catania)
  - Centro Nazionale di Adroterapia Oncologica (**C.N.A.O.**, Pavia)

# CATANA

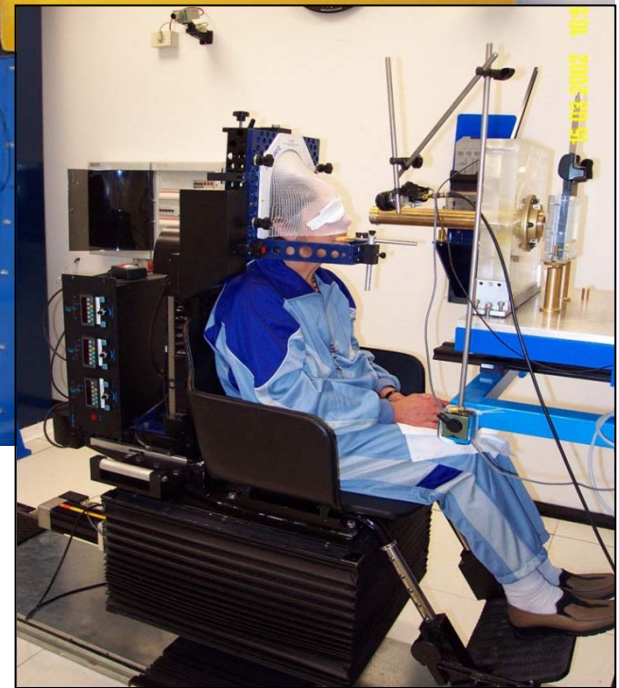
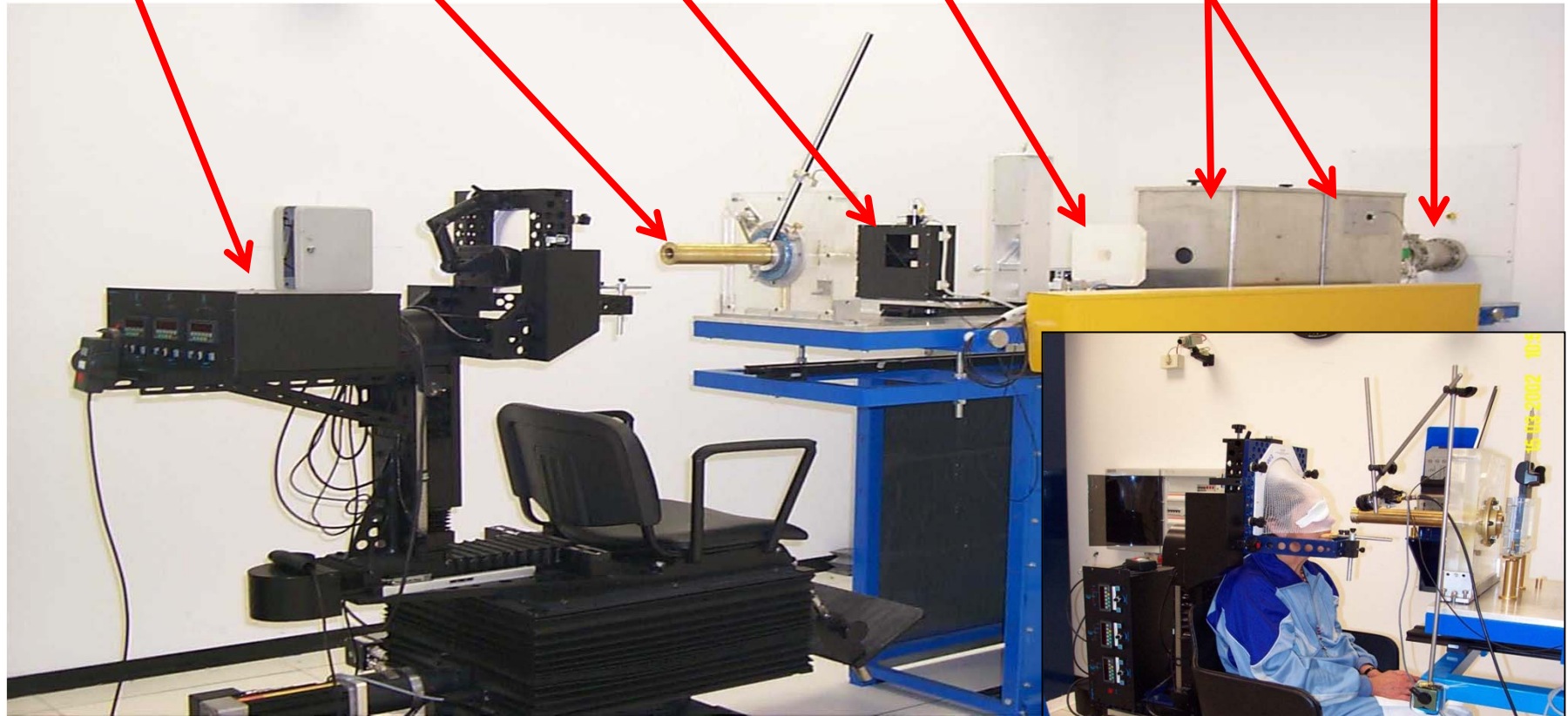
Motorized Chair  
Final Collimator

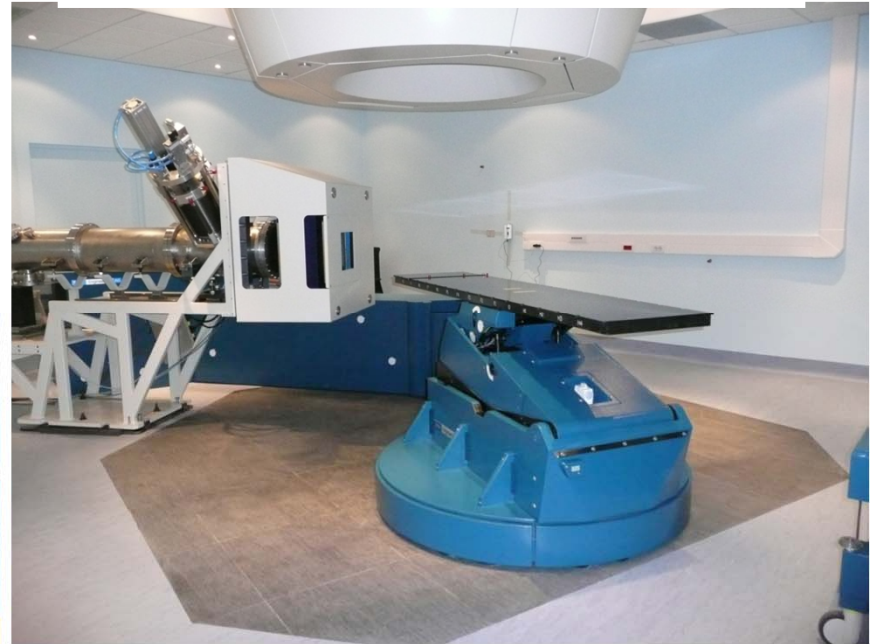
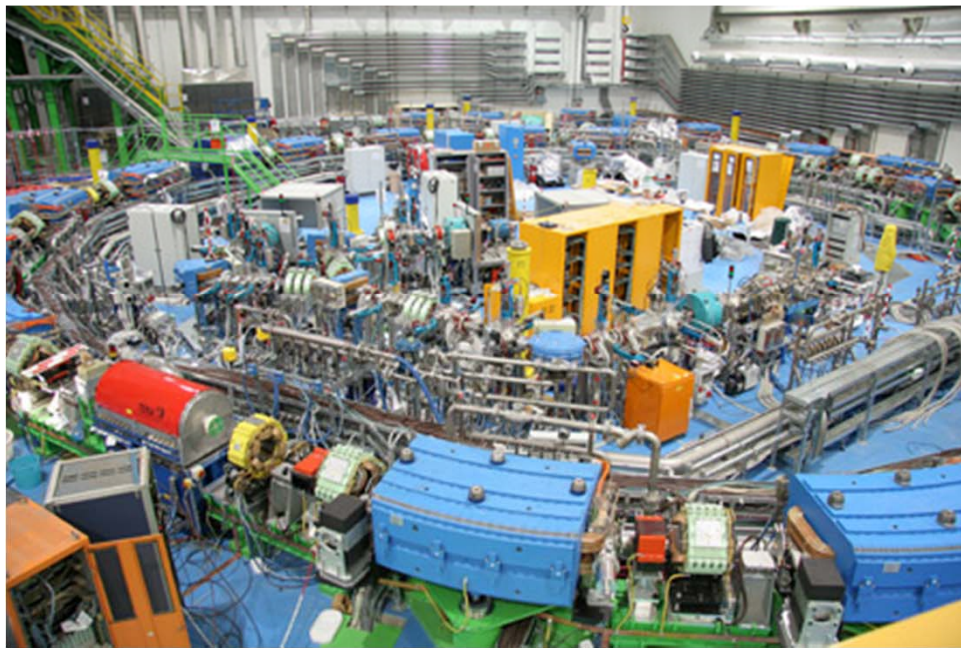
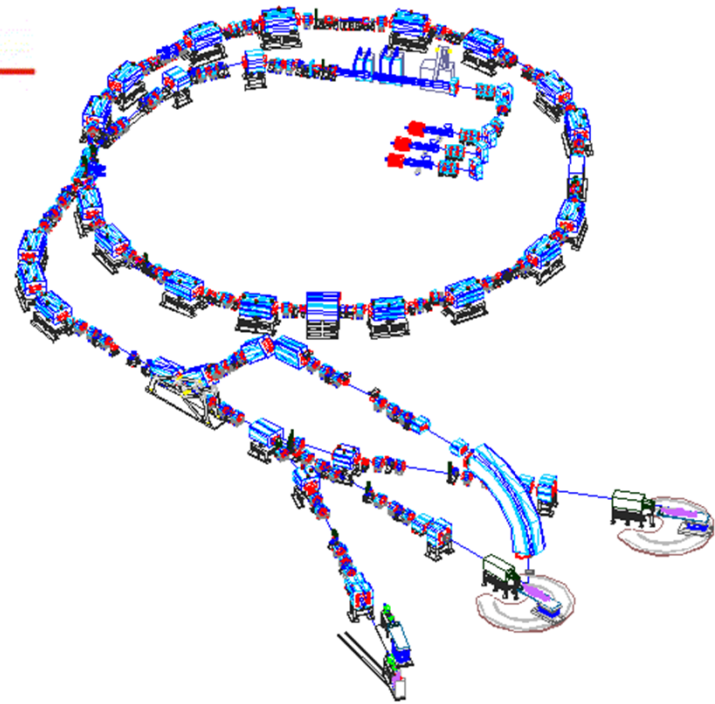
Centering Laser

Collimator

Range Shifter and Modulator

Exit Window

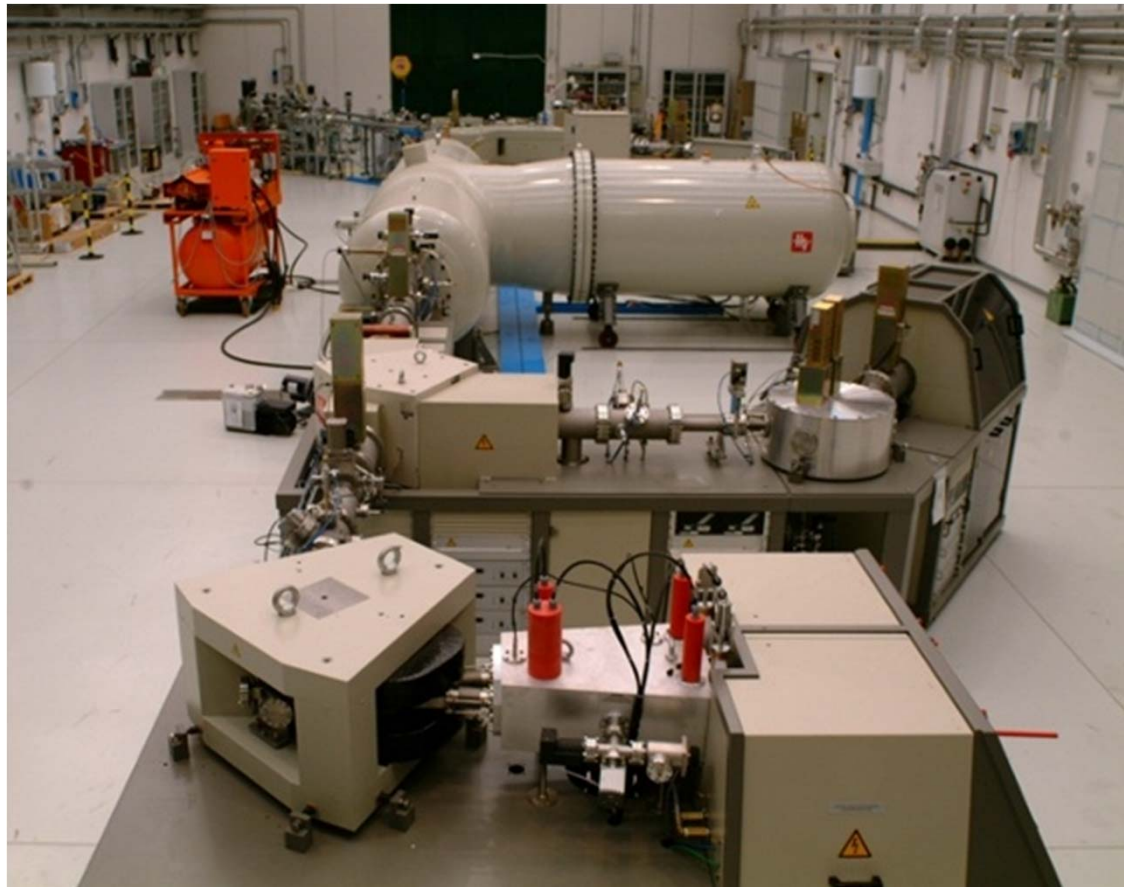




# Laboratorio di Tecniche Nucleari per i Beni Culturali (LABEC, FIRENZE)



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***Arrivederci a fisica!***