Il bosone di Higgs, LHC ad alta luminosità e le nuove tecnologie per illuminare i segreti della materia

LICEO STATALE VINCENZO MONTI

Cesena,
21 Dic 2015

INTERNATIONAL YEAR OF LIGHT 2015

EuCARD²

EuCARD-2 is co-funded by the partners and the European Commission under Capacities 7th Framework Programme, Grant Agreement 312453

HiLumi LARGE HADRON COLLIDER

Lucio Rossi - CERN
High Luminosity LHC
Project Leader

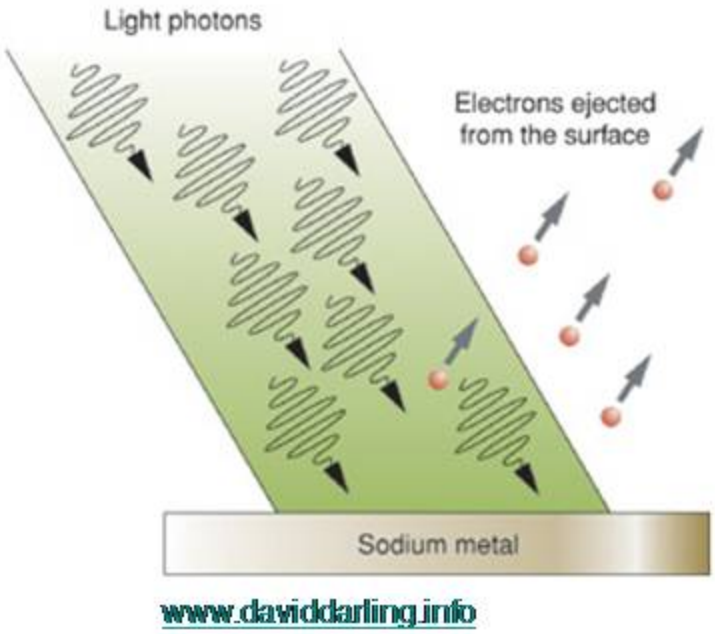
LUCE E STRUMENTI: PADOVA 1600, «…COSE MAI VISTE PRIMA»

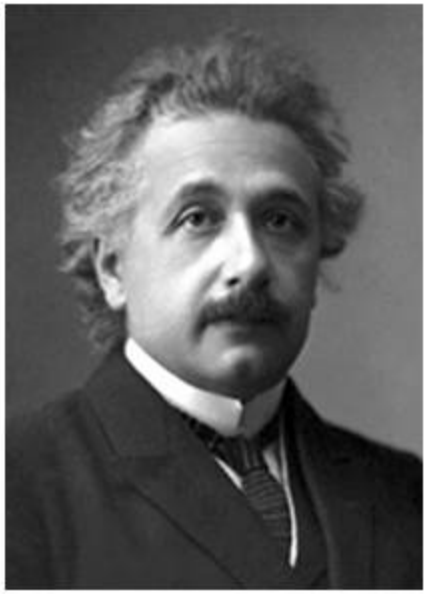
SIDEREVS
NVNCIVS
MAGNA, LONGEQVE ADMIRABILIA
Spectacula pandens, suspiciendaque proponens
vnicuique, præsertim verò
PHILOSOPHIS, nec ASTRONOMIS, quæ à
GALILEO GALILEO
PATRITIO FLORENTINO
Patauini Gymnasij Publico Mathematico
PERSPICILLI
Nuper à se reperti beneficio sunt obseruata in FACIE, FIXIS IN-
NVMERIS, LACTEO CIRCVLO, STELLIS NEBVLOSIS,
Apprimè verò in
QVATVOR PLANETIS
Circa IOVIS Stellam diuersis interuallis, atque periodis, celeri-
tate mirabili circumvolutis; quos, nemini hactenus
data cognitos, nouissimè Author deprehendit primus, atque
MEDICEA SIDERA
NVNCVPANDOS DECREVIT.

VENETIIS, Apud Thomam Baglionum. M DC X.
Superiorum Permissu, & Priuilegio.

LHC project

EINSTEIN, «ANNUS MIRABILIS» 1905: LA LUCE E' ANCHE UNA PARTICELLA

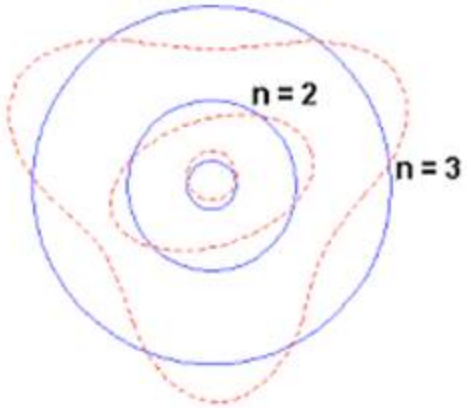




Premio Nobel per la fisica del 1921 attribuito a Albert Einstein "for his services to Theoretical Physics, and especially for his discovery of the law of the photoelectric effect".
Il fotone, il quanto di luce (ovvero di onda e.m.), fu «canonizzato»

LOUIS DE BROGLIE, 1925: LE PARTICELLE SONO ANCHE ONDE…

$$\lambda = h/p = h/mv$$

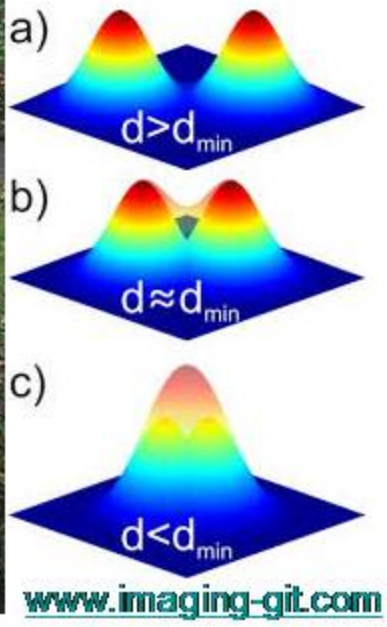


The standing de Broglie waves set up in the first three Bohr orbits.

Louis de Broglie rivette il Nobel per la fisica nel 1929 "for his discovery of the wave nature of electrons".

LA VISTA E I SUOI LIMITI: DIFFRAZIONE

LHC project

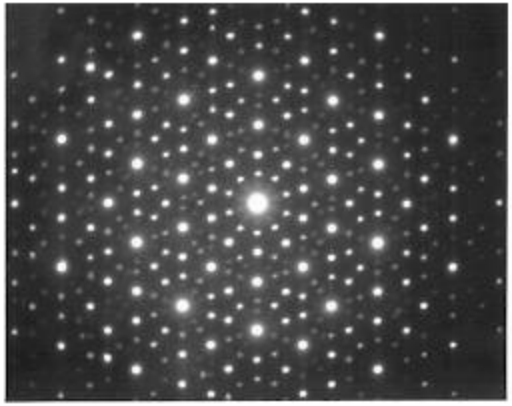


www.imaging-git.com

LHC project

PARTICELLE PER VEDERE E GENRARE NANO-TECNOLOGIE

CERN

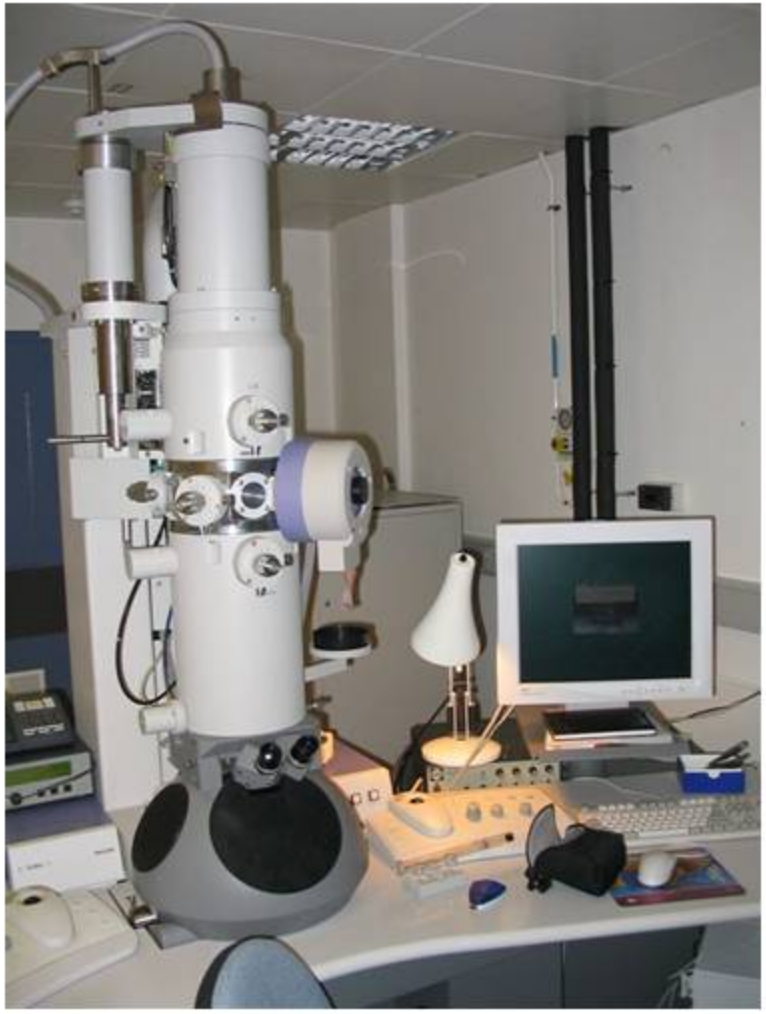


The periodic structure of a crystalline solid acts as a diffraction grating

Electron microscopes use electrons to illuminate a sample. In Transmission Electron Microscopy (TEM), electrons pass through the sample and illuminate film or a digital camera.

100 keV $\rightarrow \lambda = 2.7$ pm !

100 pm is actual resolution limit



LHC project

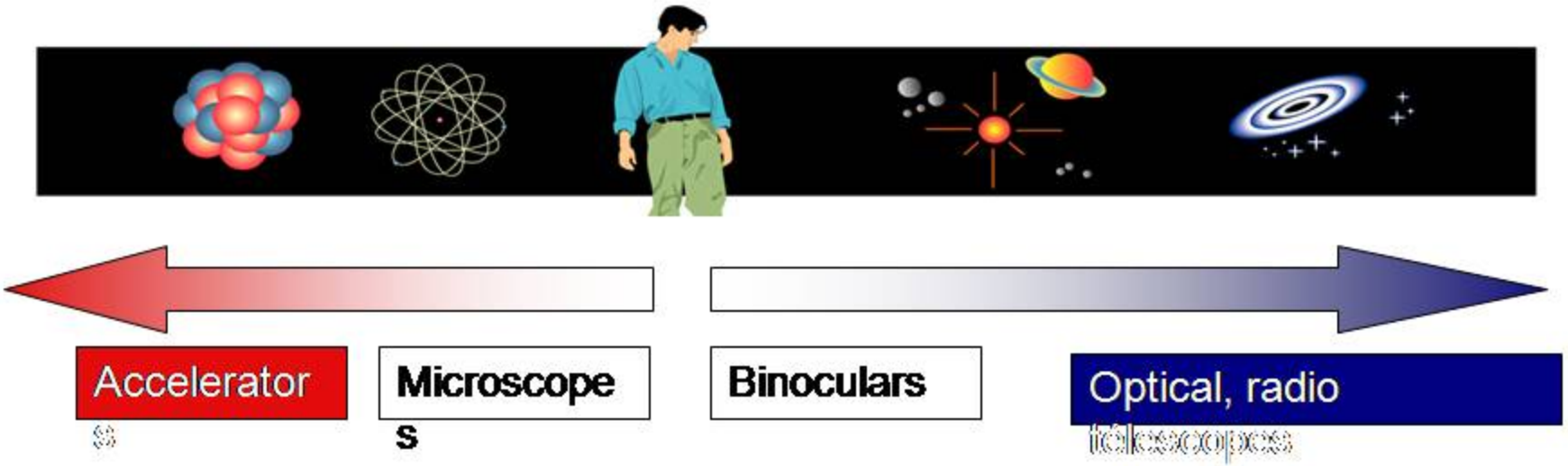
LA VISTA PIU' FINE

Cosa è la fisica delle particelle elementari?

Perchè abbiamo bisogno di tecnologie di frontiera?

LHC project

FISICA DELLE PARTICELLE: VERSO L'INFINITAMENTE PICCOLO …



La Fisica dele Particelle osserva la materia nella sua più piccola dimensione. Gli acceleratori sono finissimi microscopi: ***atto-scopi!***

$\lambda = h/p$; @LHC: $T = 1\ TeV \Rightarrow \lambda \cong 10^{-18}\ m$

Gli acceleratori sono dei nano-nanoscopi

LA SCALA SPAZIALE DEL MONDO

LHC project

Big Bang

10^{-32} 10^{-28} 10^{-24} 10^{-20} 10^{-16} 10^{-12} 10^{-8} 10^{-4} 10^{4}

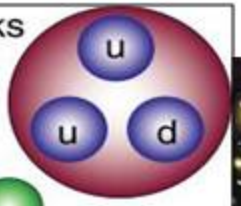
Protone

Atomo

LHC

Attoscopio

Quarks



Proton

Neutron

Nucleus

Electron

Atom

Molecule

Matter

aggio delle galassie

Universo

10^{28}

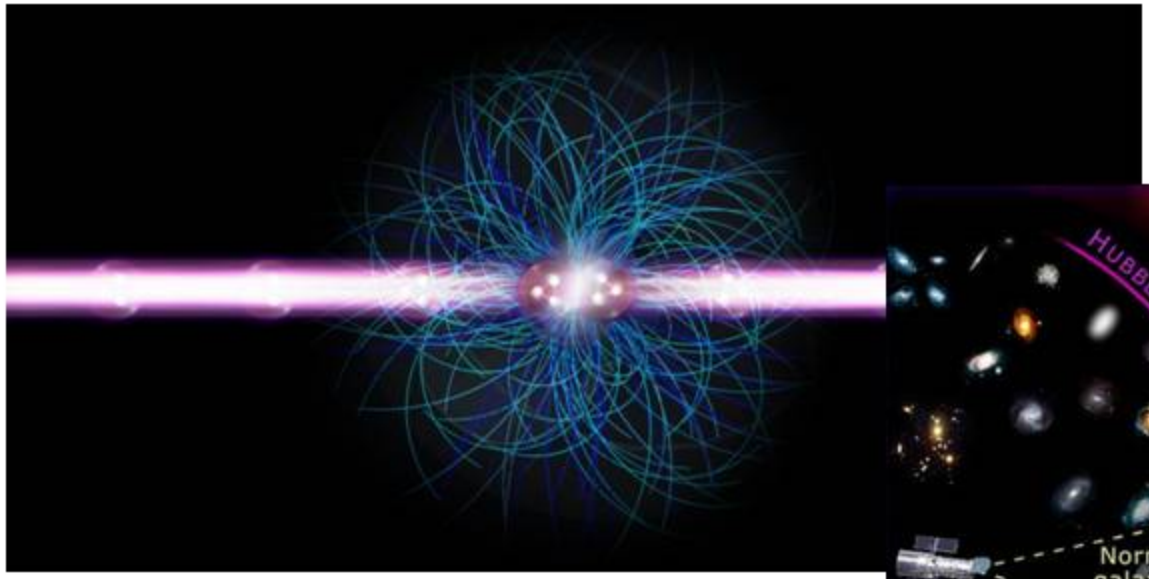
cm

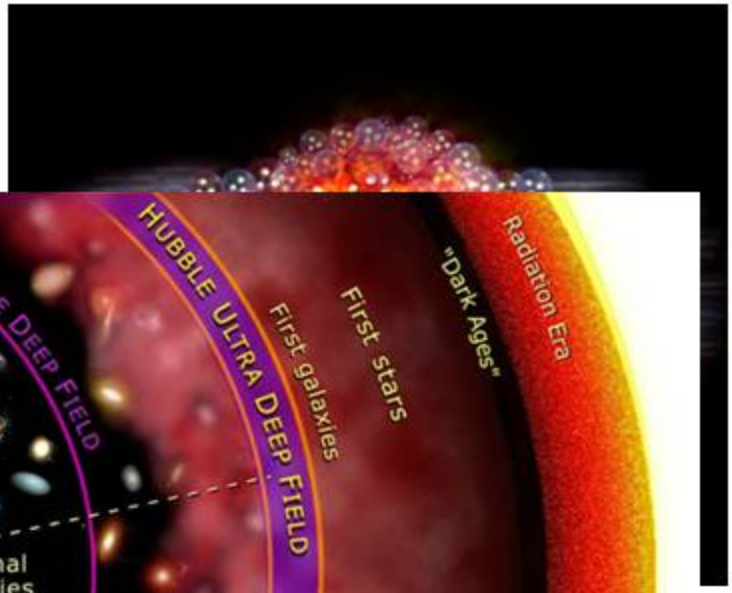
LHC project

MACCHINE DEL TEMPO
ACCELERATORI E TELESCOPI

CERN

- Viaggio indietro nel tempo $t_{\mu s} \cong 1/E^2_{Gev}$
- $T \cong 1$ ps per creazione di particelle singole
- $T \cong 1$ μs per fenomeni collettivi QGS (Quark-Gluon Soup)





Come astrofisica!

LA "SUMMA" DI 40 ANNI DI RICERCHE : IL MODELLO STANDARD

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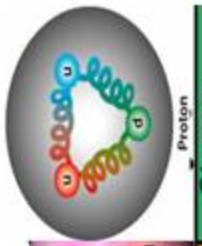
CERN

The Standard Model



Carried By

Strong	Electromagnetic (Electroweak)	Weak (Electroweak)	Gravity
Gluon	Photon	W^+ W^- Z^0	Graviton (not yet observed)

Quarks			Force Carriers
u up	c charm	t top	g gluon
d down	s strange	b bottom	γ photon
Leptons			
e electron	μ muon	τ tau	W W boson
ν_e e-neutrino	ν_μ μ-neutrino	ν_τ τ-neutrino	Z Z boson
I	II	III	Higgs Boson?

Generations of matter

© Brian Foster

Particelle

e

Forze

Ciascuna con la sua antiparticella

COSA RIMANE QUINDI ?

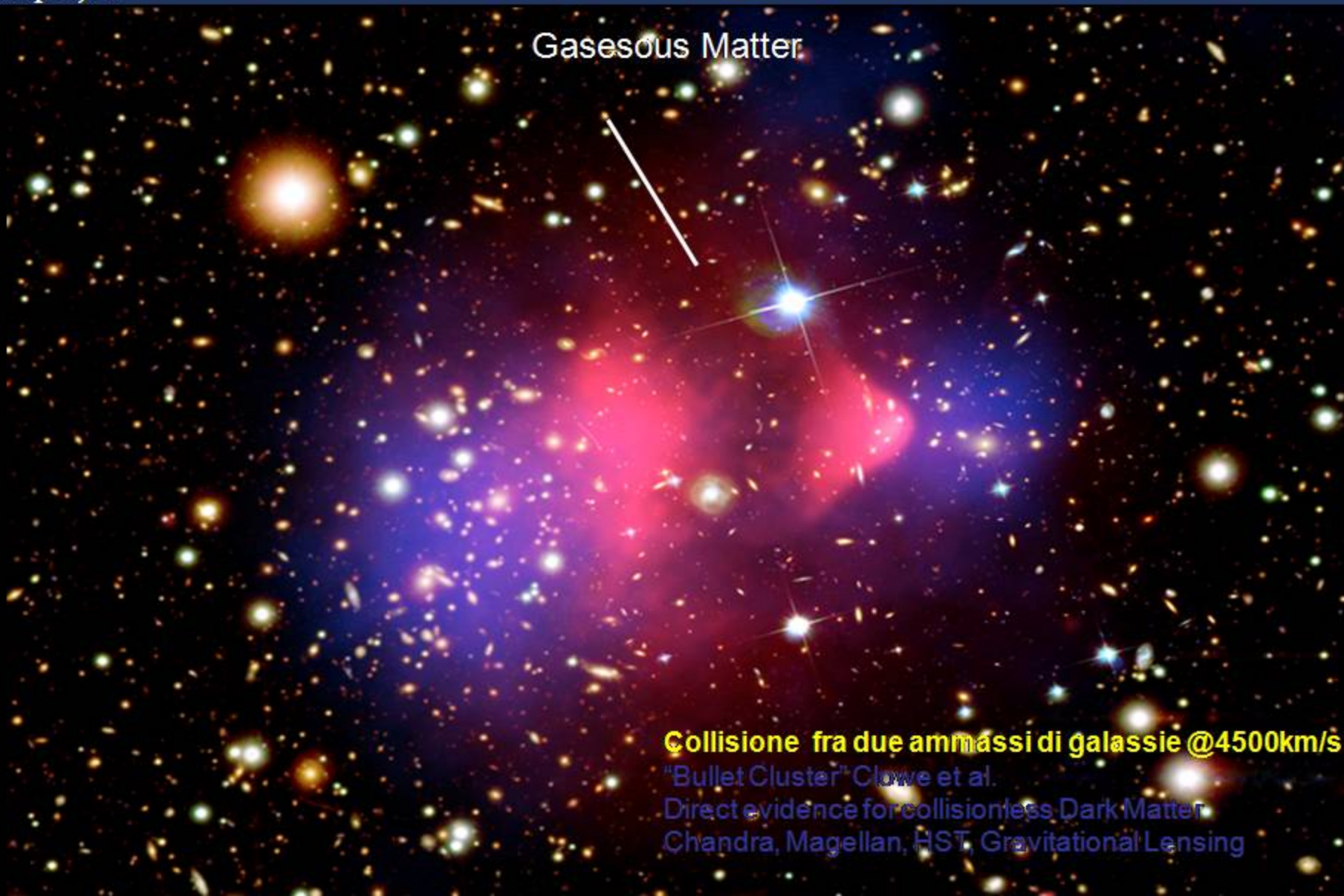
- Il modello standard è una buonissima *descrizione* dell'Universo alla scala delle particelle che conosciamo
  - Ma *non risponde* a molte domande
    - Perchè tante particelle?
    - Perchè diversi tipi di forza?
    - Cosa è la massa?
      - Perchè le particelle hanno la massa che hanno?

LHC !

i neutrini soo leggerissimi < 1 meV
elettrone: 511 eV
protone 1 GeV (1 miliardo di eV
quark top : 170 GeV !!!!
alcune particelle-forza (fotone) non hanno massa
altre particelle-forza (Z, W) sono massicci: 80-90 GeV

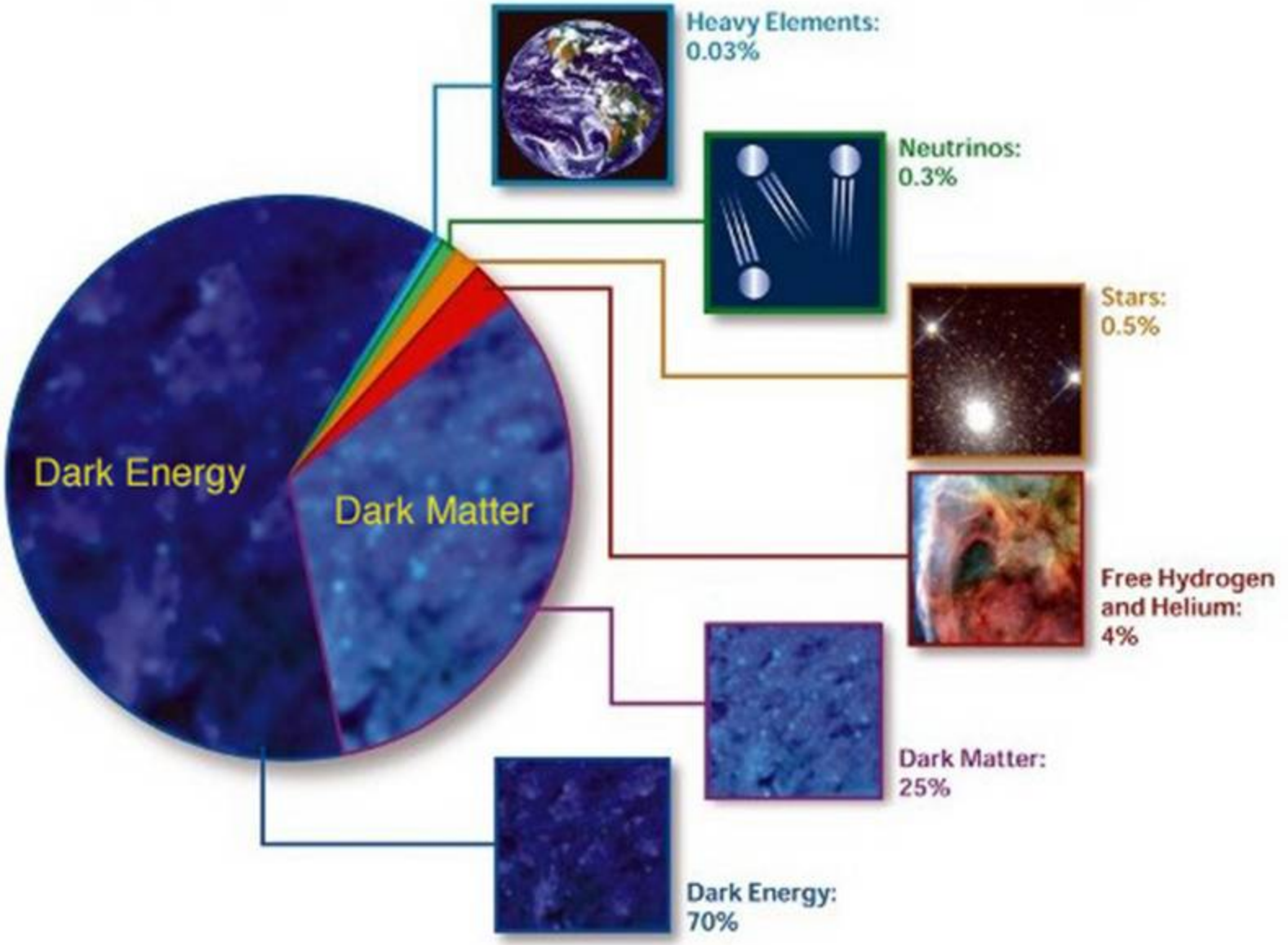
PROVE DELLA METERIA OSCURA

LHC project

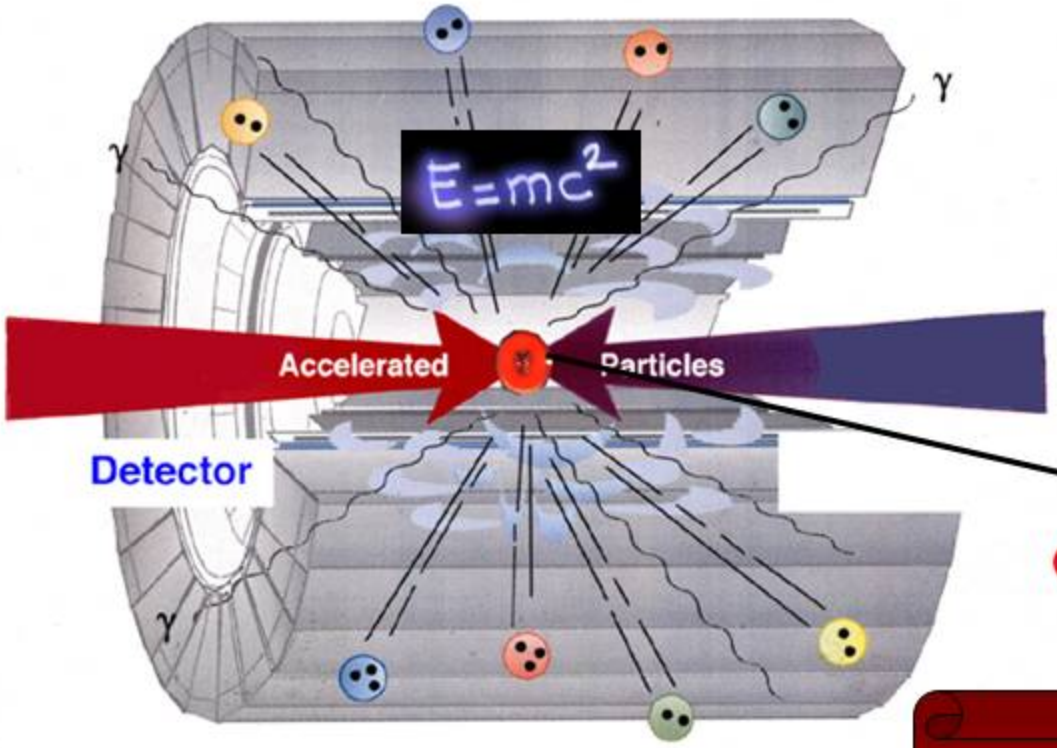


LHC project

IL CONTENUTO MASSA –ENERGIA DELL'UNIVERSO



GLI STRUMENTI DELLA HEP



1) Concentrate energy on particles (**accelerator**)

2) **Collide** particles (recreate conditions after Big Bang)

3) **Identify created particles in Detector (search for new clues)**

Entrambi richiedono tecnologie di punta (superconduttività, e molte altre)

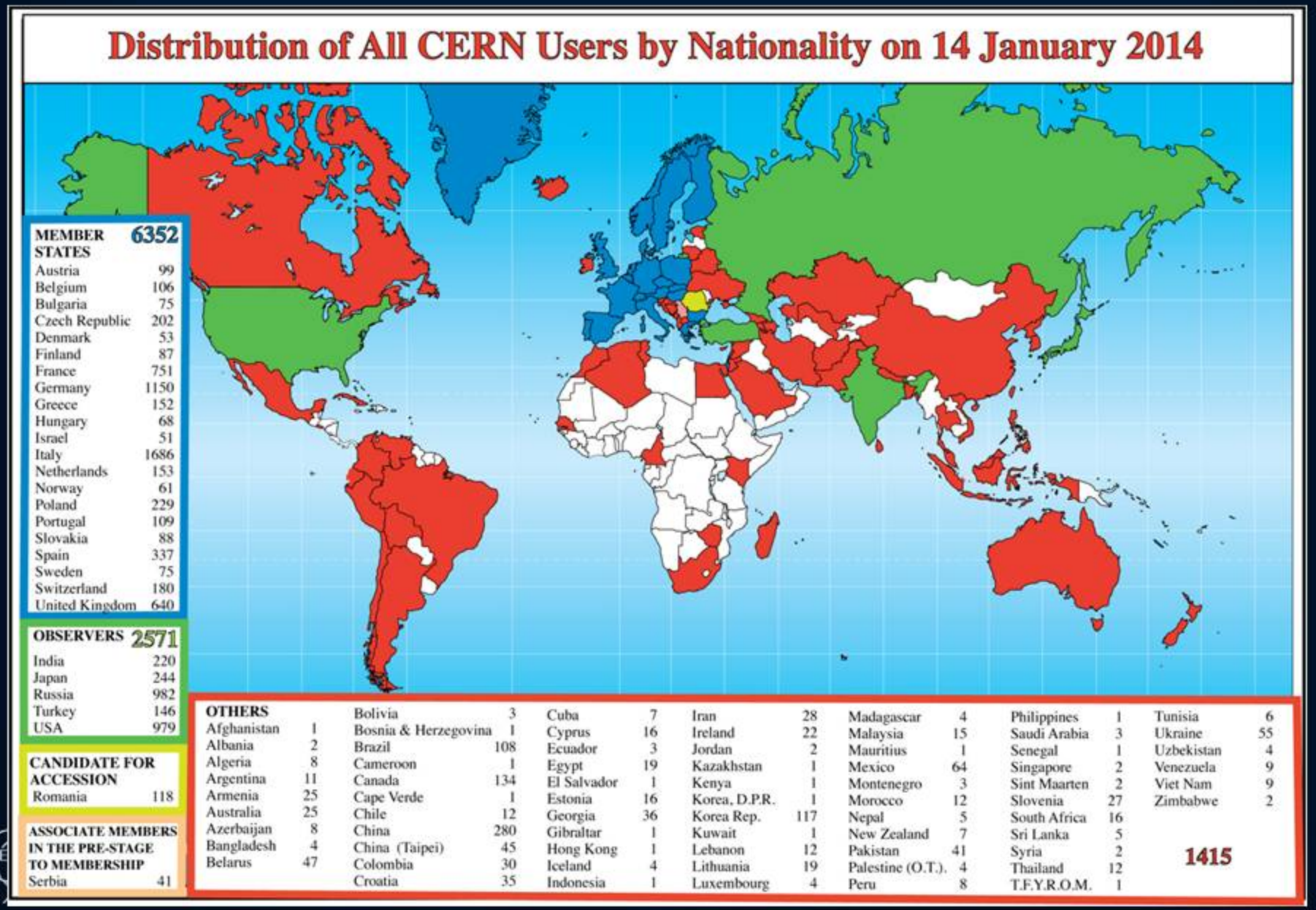
LHC project

CERN

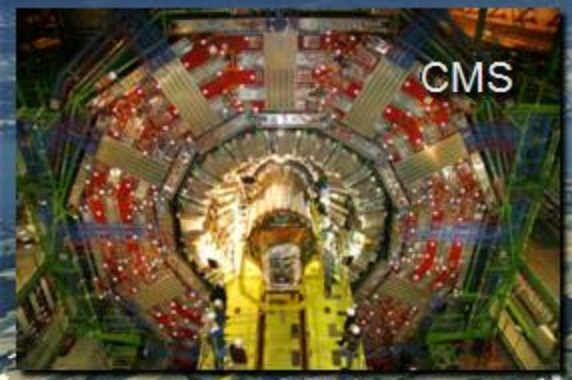
European Organization for Nuclear Research

- Fondato nel 1954, oggi 21 stati membri
- Circa 11'000 utilizzatori da tutto il mondo
- ~900 M€ di budget annuale
- 2250 staff permanente + 1000 associati

Science is getting more and more global



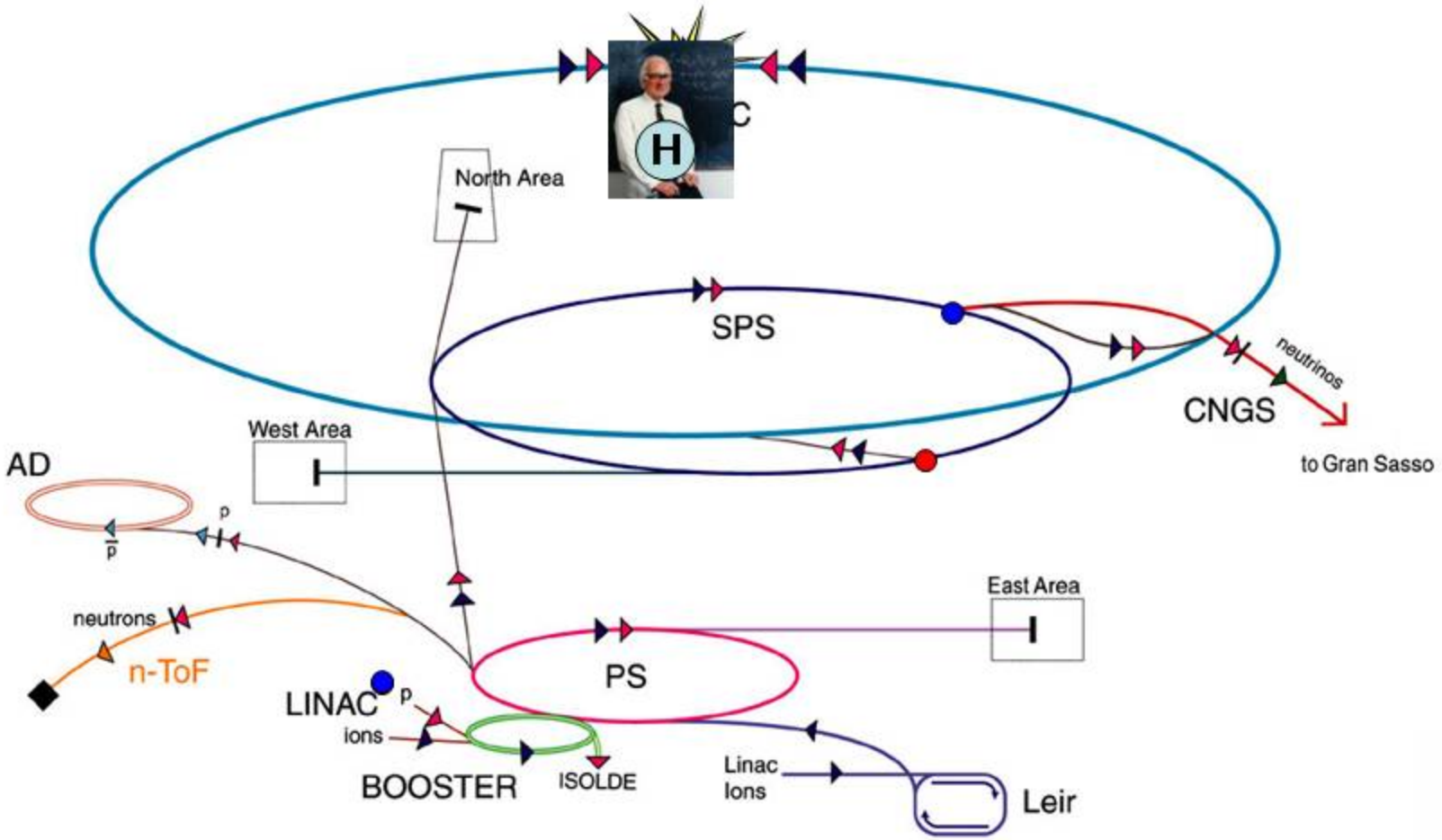
LHC: il gigante $E_{beam} \cong 0.3BR$ con 4 [illegible]ch



Esplorazione della nuova frontiera con collisioni adroniche

CERN: LA CATENA DI ACCELRATORI

LHC project



p (proton)
ion
neutron

p̄ (antiproton)
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

LHC: UN PROGETTO DI 30 ANNI…

LHC project

First ideas
Twin Dipoles
Hell cooling

R&D for 8-10 T: 13 kA cables, short models, 10 m long prototypes, 1st string test

Final design, industrialization start pre-series

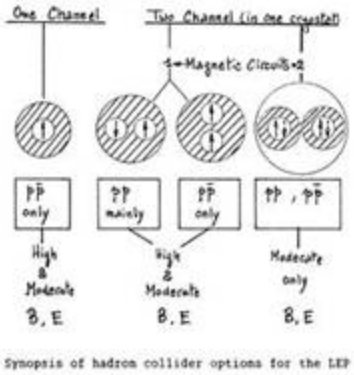
Magnet construction, performance test, tunnel preparation

Installation, LHC start Incident

Re-start 4.2 T

1985 1990 1995 2000 2005 2010 8 T

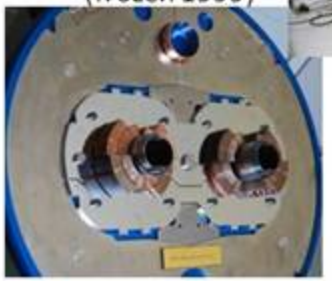
Magnet designs at first LHC workshop, 1984



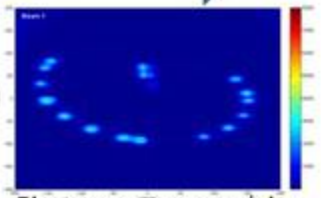
Synopsis of hadron collider options for the LEP tu


First LHC dipole prototype on the test bench (June1994)

Final dipole cross section (frozen 1999)




Assembly of 15 m long coils in industry, 2003


First energy record in the proton beam, December 2009


Continuous magnet line installed in the 27 km LHC tunnel, 2006

LHC project

SUPERCONDUTTIVITA': UN FENOMENO DI ORDINE

CERN

Elettroni in metallo normale (resisitivo)

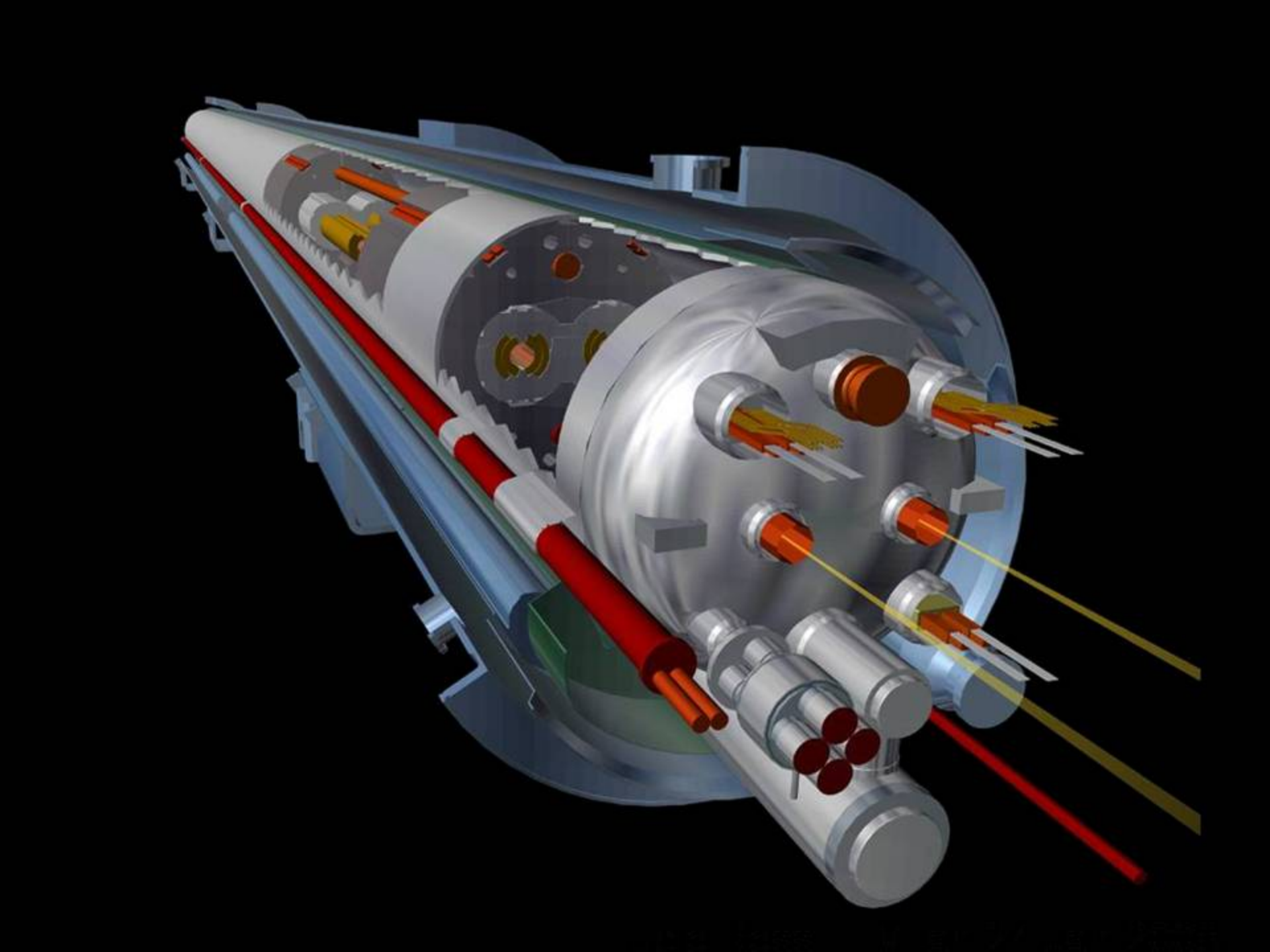
Coppie di elettroni: metallo superconduttore (fermions ⇒ bosons)

LHC project

LHC: 24 KM DI MAGNETI SUPERCONDUTTORI

1232 grandi magneti dipoli (15 m)

Altri 400 quadrupoli (7 m)



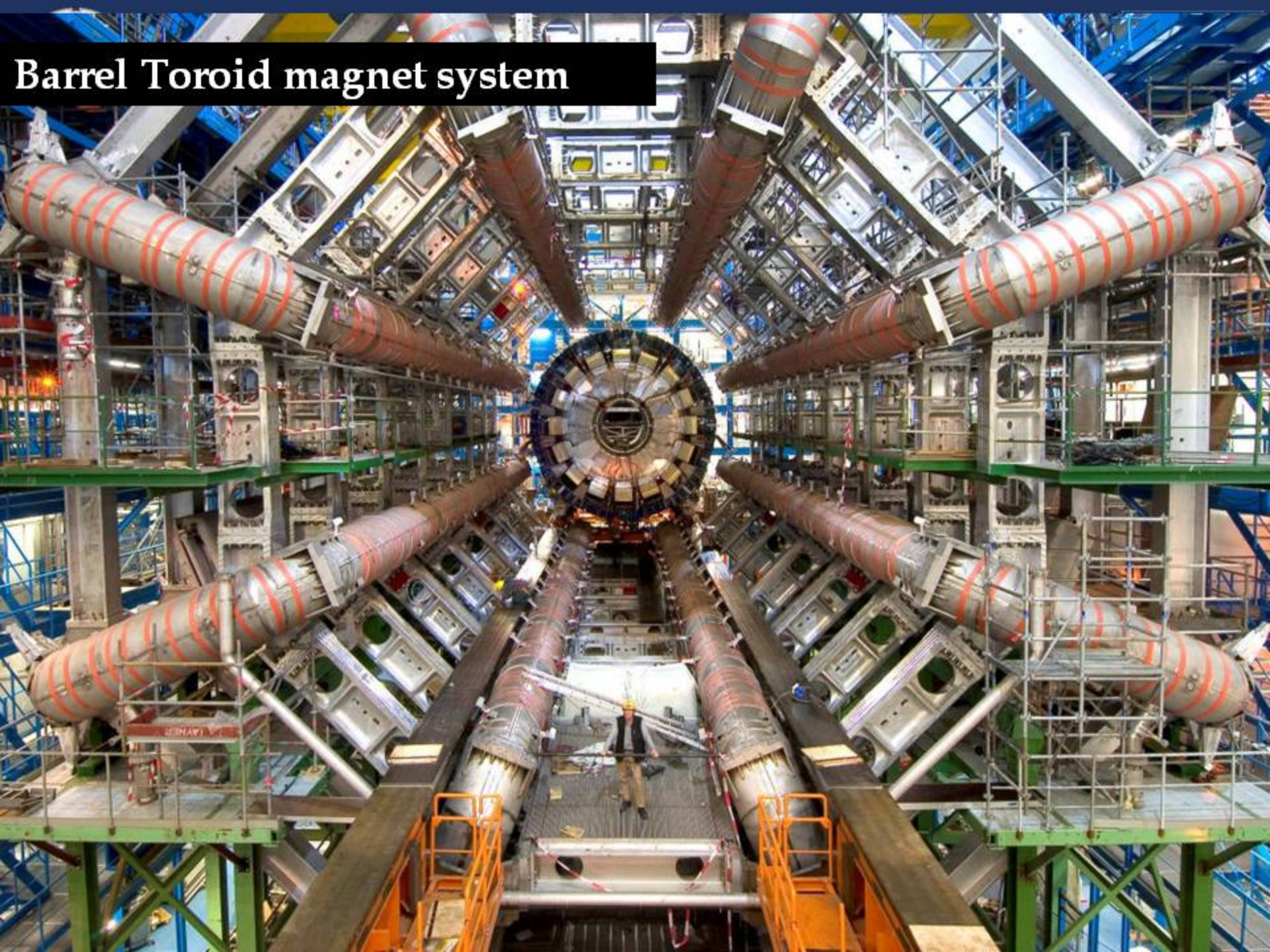
LHC project

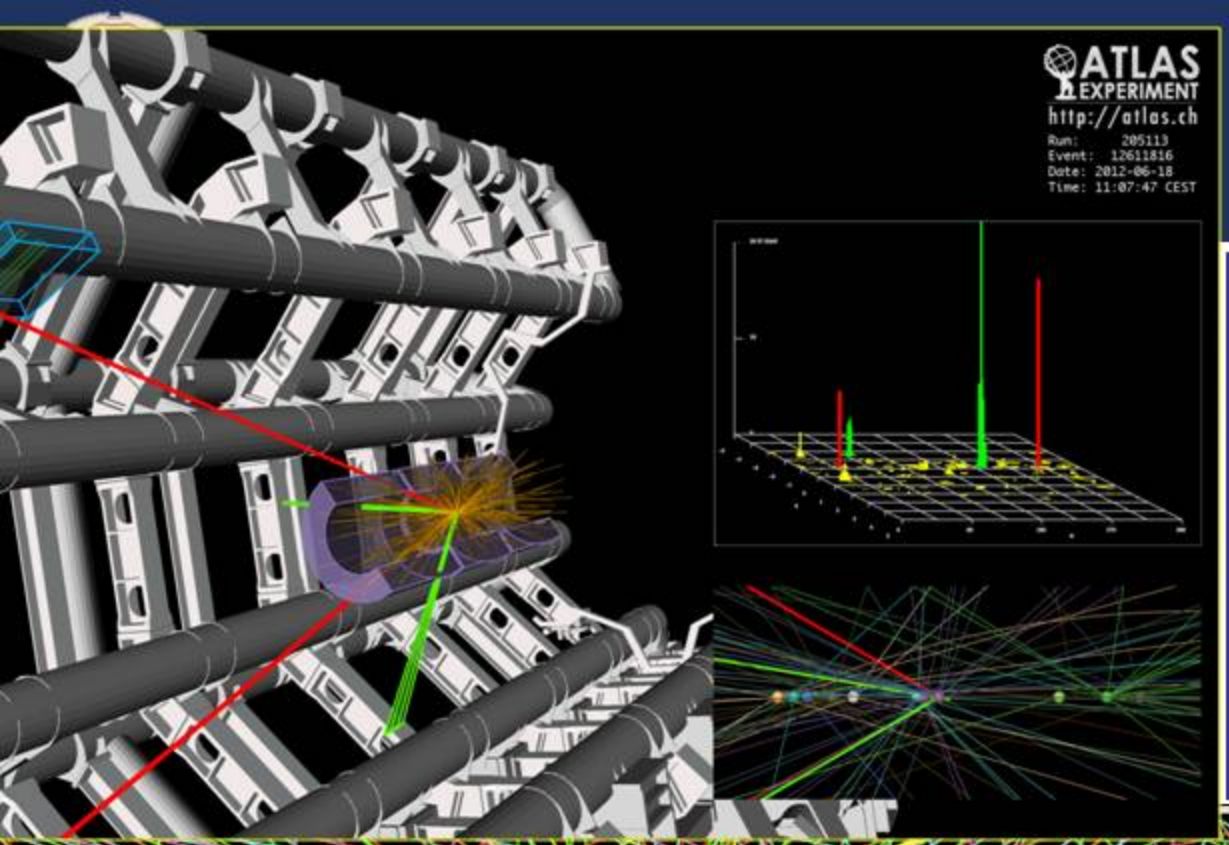
LHC: ORIGINI SONO MOLTO ITALIANE

LHC project

CAVITÀ RF PER ACCELERARE IN LHC SEMPRE SUPERCONDUTTIVE

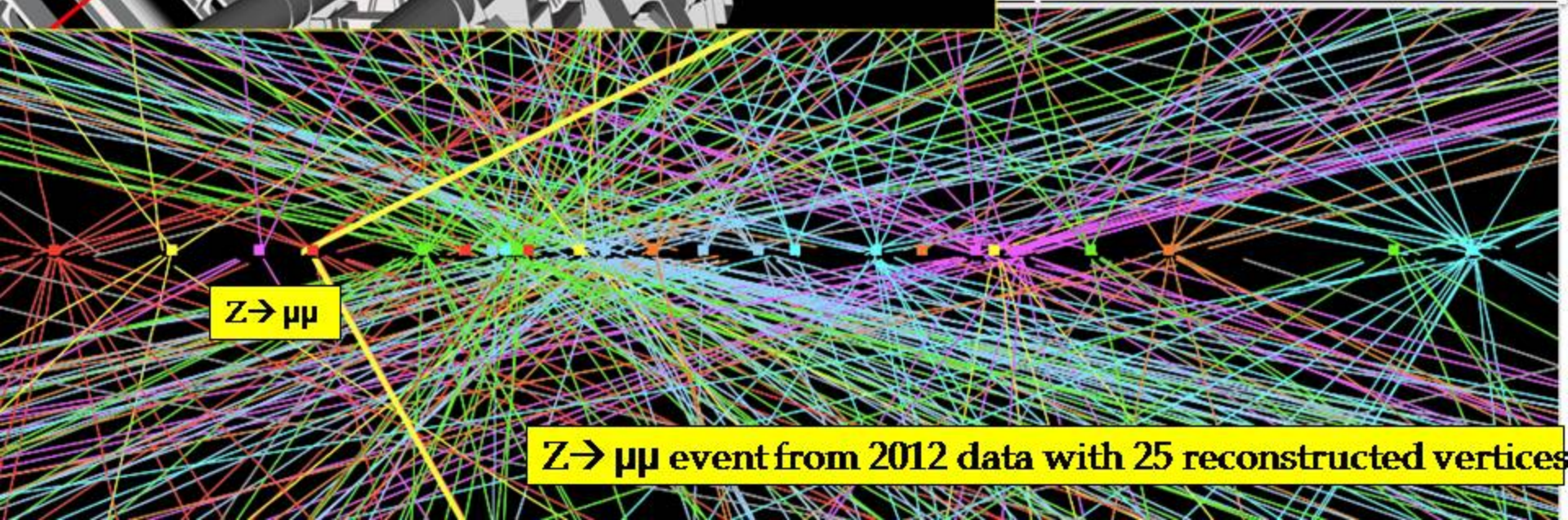
Barrel Toroid magnet system





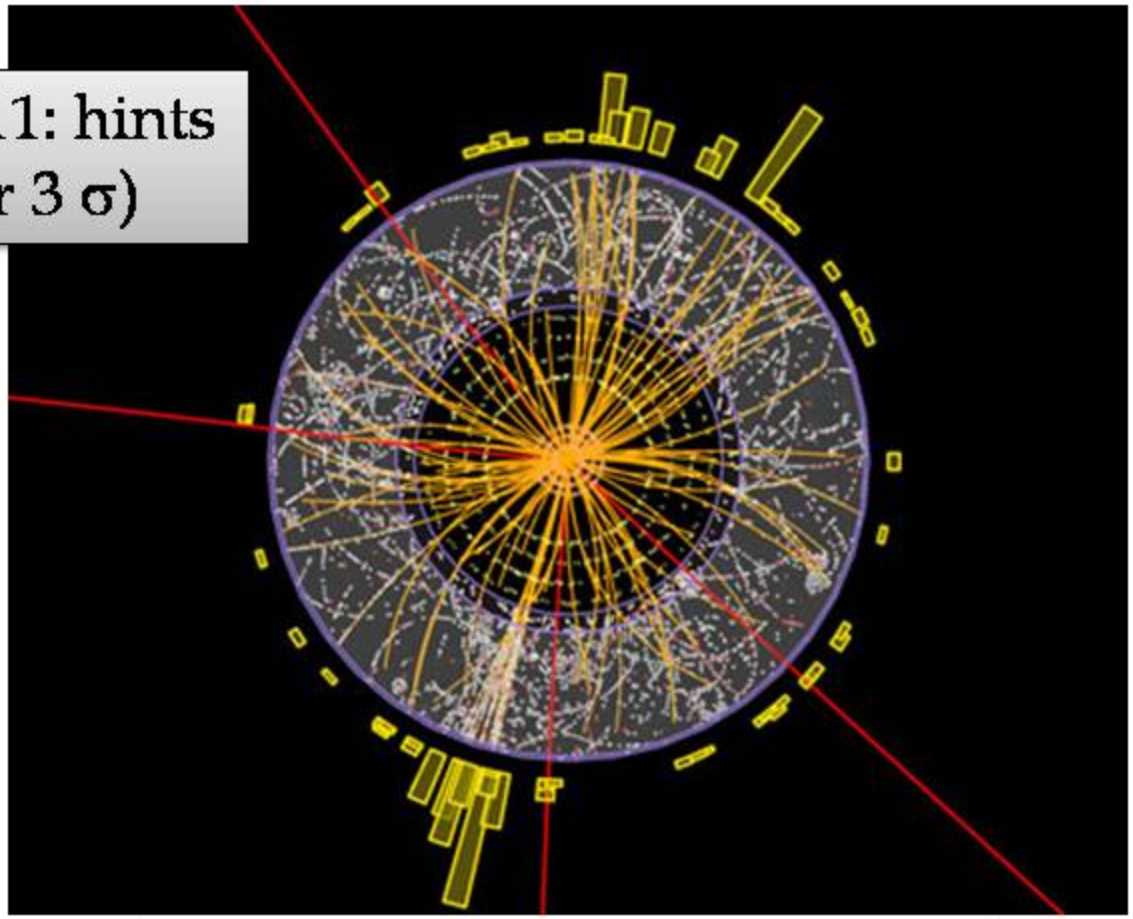
Higgs: l'ago nel pagliaio

Foto ripetuta 40 Milioni di volte al secondo



ECCO L'HIGGS (PROBABILMENTE…)

December 2011: hints of Higgs (near 3 σ)

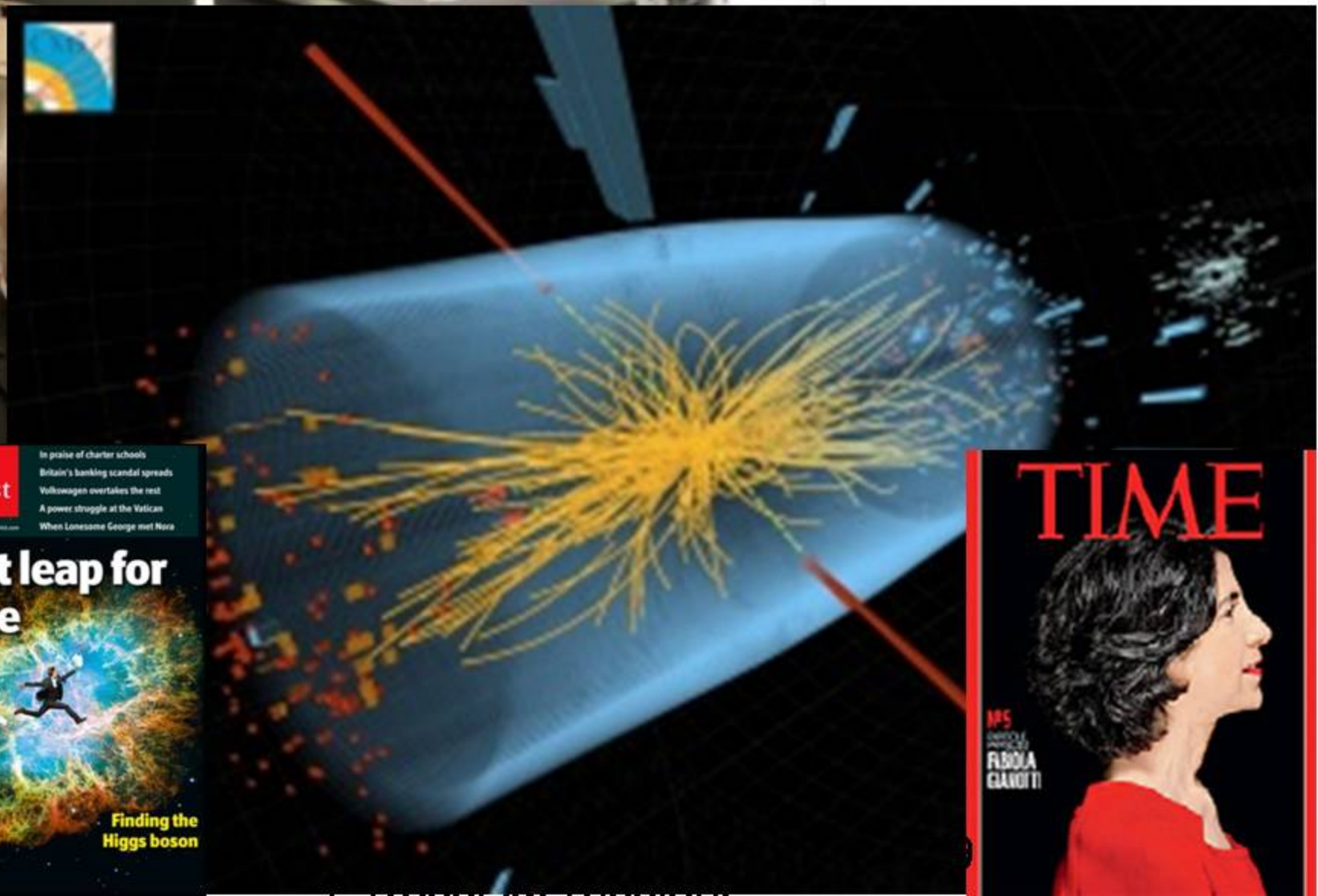


Higgs →2 Z→ 4 μ

LHC project

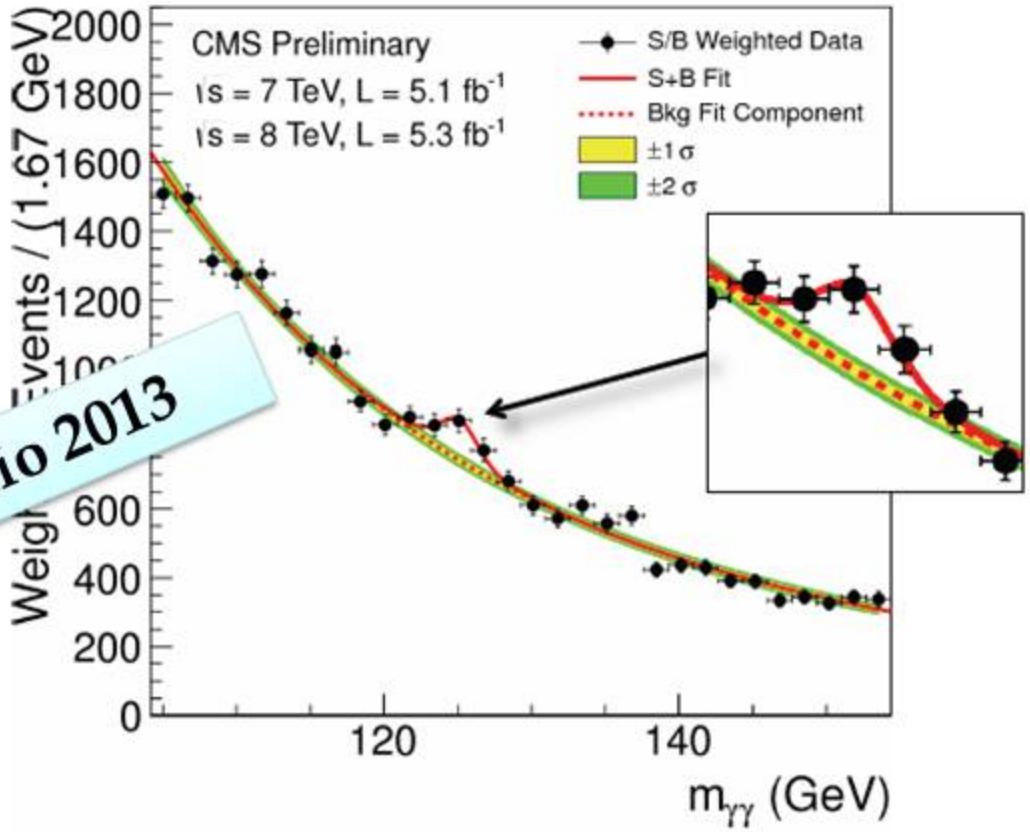
4 LUGLIO 2012 : BOSONE CATTURATO!

CERN



S/B Weighted Mass Distribution

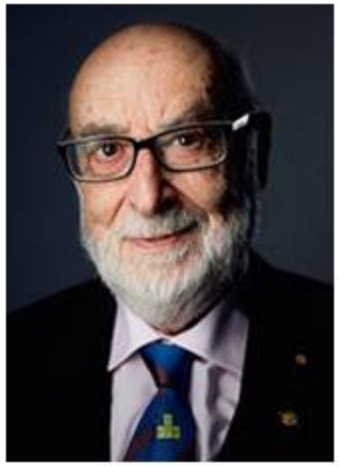
- Sum of mass distributions for each event class, weighted by S/B
  - B is integral of background model over a constant signal fraction interval

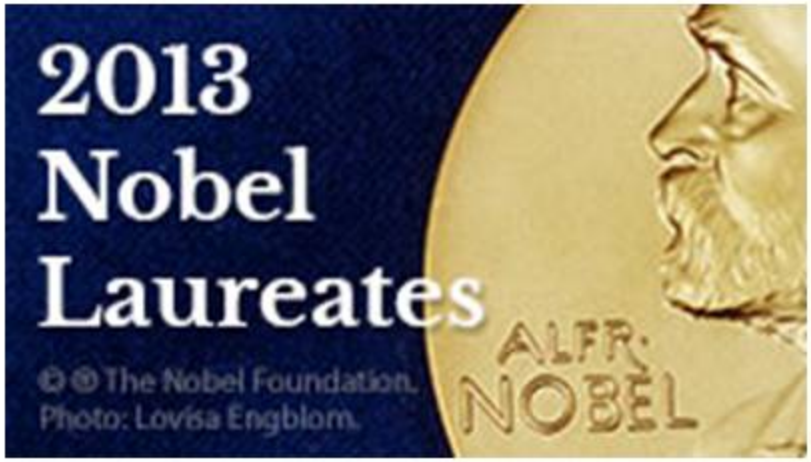


Pesaro Gennaio 2013

BROUT – ENGLERT – HIGGS MECHANISM NOBEL 2013 PE RLA FISICA

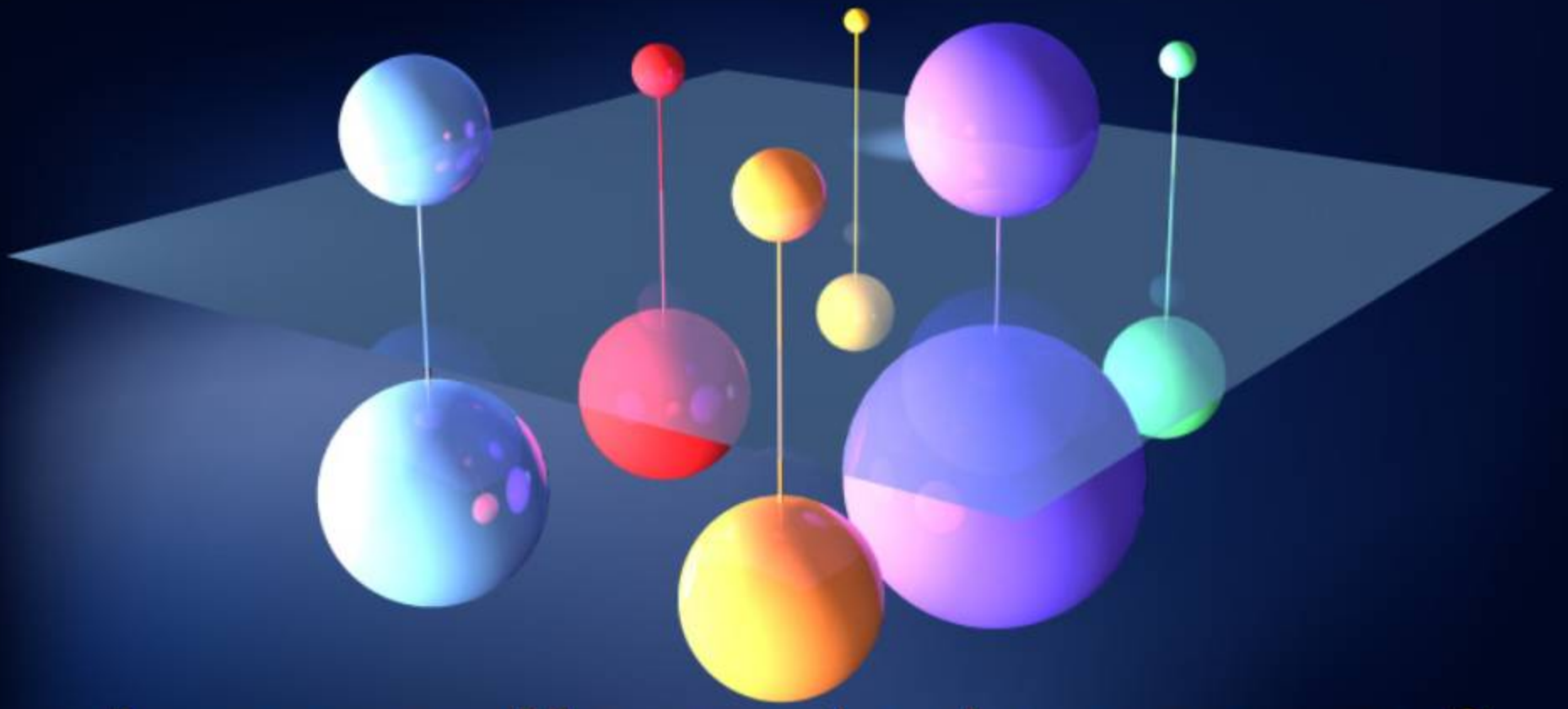
LHC project





…for the theoretical discovery of a mechanism that contributes to our understanding of the origin of mass of subatomic particles, and which recently was confirmed through the discovery of the predicted fundamental particle, by the ATLAS and CMS experiments at CERN's Large Hadron Collider

Un supermondo davanti a noi?

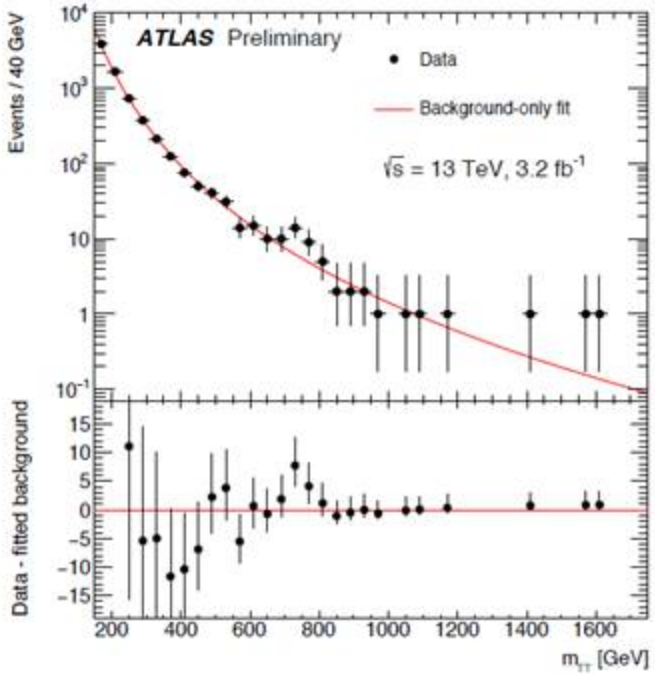


Luce sulla materia oscura?

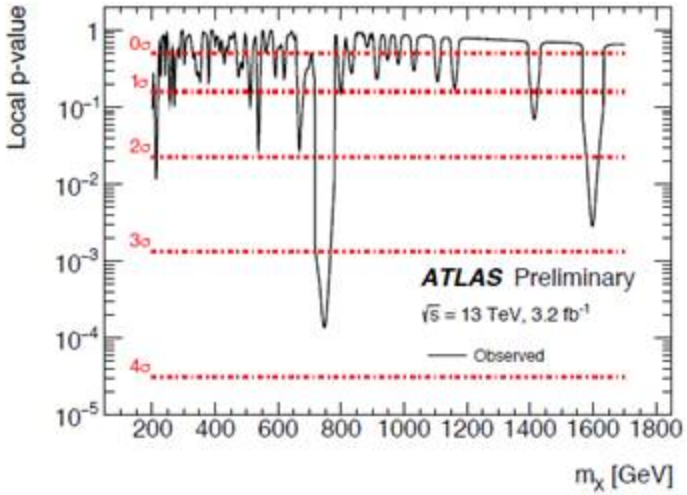
PRIMI RISULTATI 2015 ! SEMINARIO ATLAS 16.12.2015

Search for a **Two Photons Resonance** (II)

Results: Events with mass in excess of 200 GeV are included in **unbinned fit**



- **In the NWA search**, an excess of **3.6σ** (local) is observed at a mass hypothesis of minimal p_0 of 750 GeV



In the NWA fit the resolution uncertainty is profiled in the NWA fit and is pulled by 1.5σ

The data was then fit under a **LW hypothesis** yielding a width of approximately 45 GeV
(Approx. 6% of the best fit mass of approximately 750 GeV)

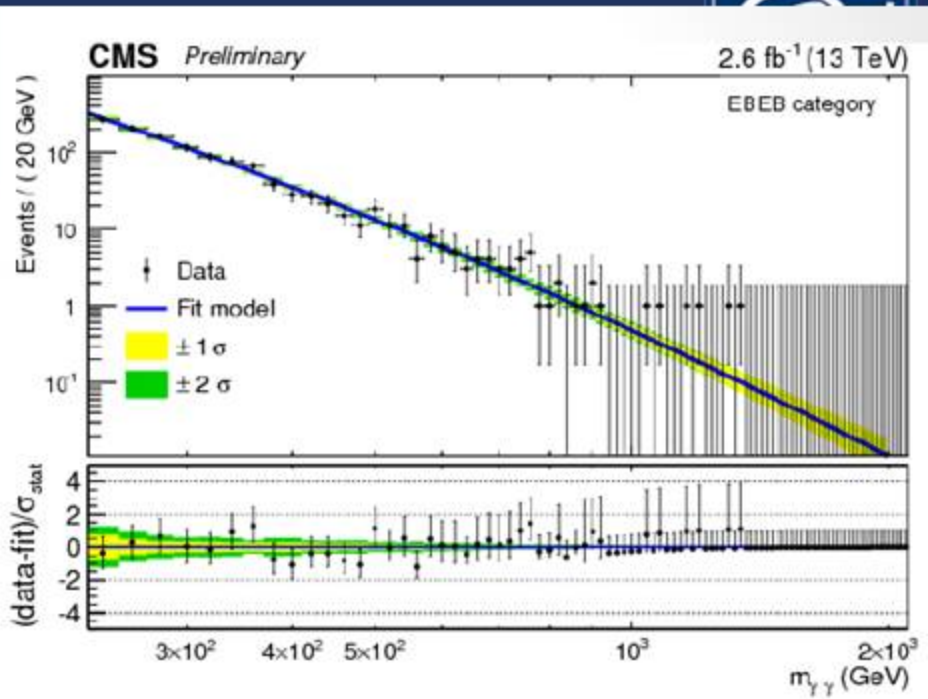
- As expected the local significance increases to **3.9σ**

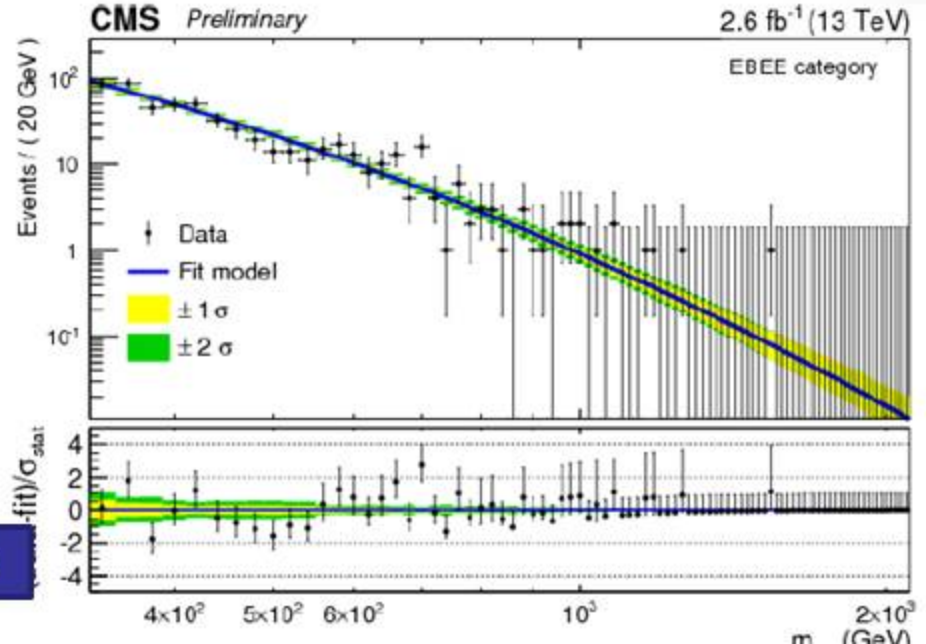
Cortesia Marumi Kado & ATLAS collaboration

SEMINARIO CMS

LHC project

- Il segnale è un po debole ma…
- Siamo al 5-%0.1% di incertezza (o errore)…
- Allora cosa fare?
- Piu la conoscenza è indiretta e piu si richiede impegno
  ⇒ piu' misure… cioè piu' luce!



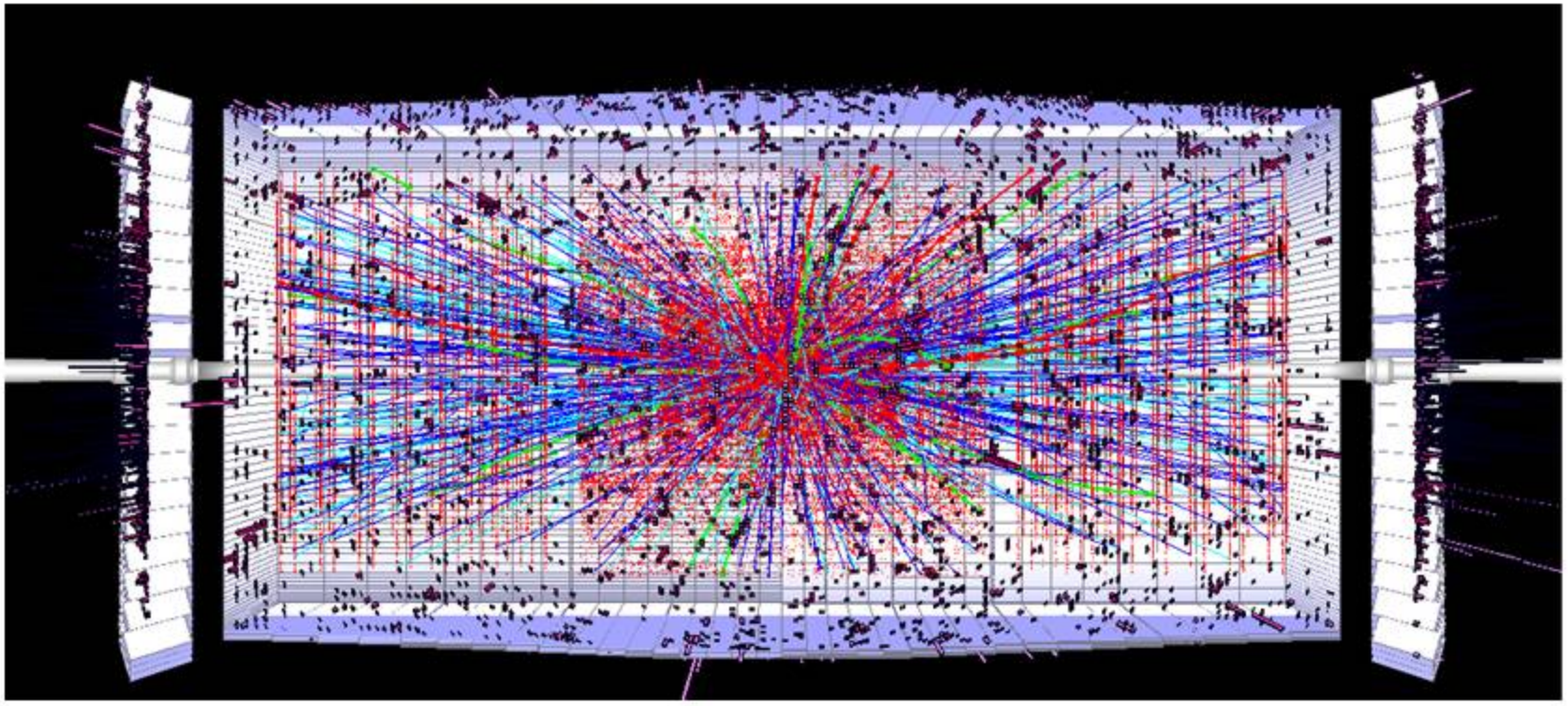


cortesia Jim Olsen & CMS collaboration

LHC project

High Luminosity LHC

The HiLumi LHC Design Study (a sub-system of HL-LHC) is cofunded by the European Commission within the Framework Programme 7 Capacities Specific Programme, Grant Agreement 284404



HILUMI: 1.2 KM DI NUOVA TECNOLOGIA

LHC project

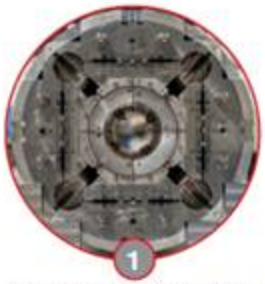
CERN

CIVIL ENGINEERING
2 new 300-metre service tunnels and 2 shafts near to ATLAS and CMS.

"CRAB" CAVITIES
16 superconducting „crab" cavities for each of the ATLAS and CMS experiments to tilt the beams before collisions.

Cryo@P1-P5

Cryo@P4



LHC TUNNEL

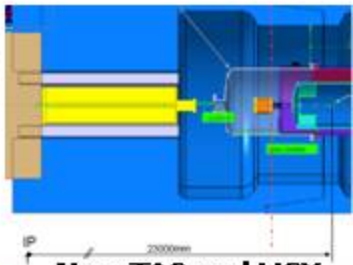
CMS

ALICE

ATLAS

LHCb

FOCUSING MAGNETS
12 more powerful quadrupole magnets for each of the ATLAS and CMS experiments, designed to increase the concentration of the beams before collisions.



New TAS and VCX

Beam diagnostics
BGV

SUPERCONDUCTING LINKS
Electrical transmission lines based on a high-temperature superconductor to carry current to the magnets from the new service tunnels near ATLAS and CMS.

COLLIMATORS
15 to 20 new collimators and 60 replacement collimators to reinforce machine protection.

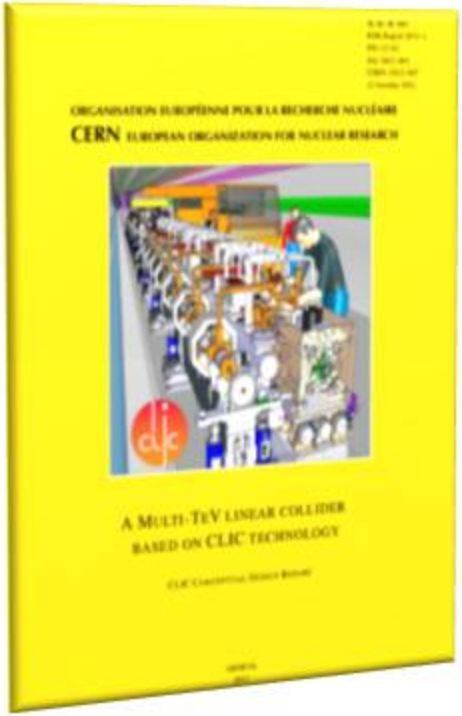
BENDING MAGNETS
4 pairs of shorter and more powerful dipole bending magnets to free up space for the new collimators.

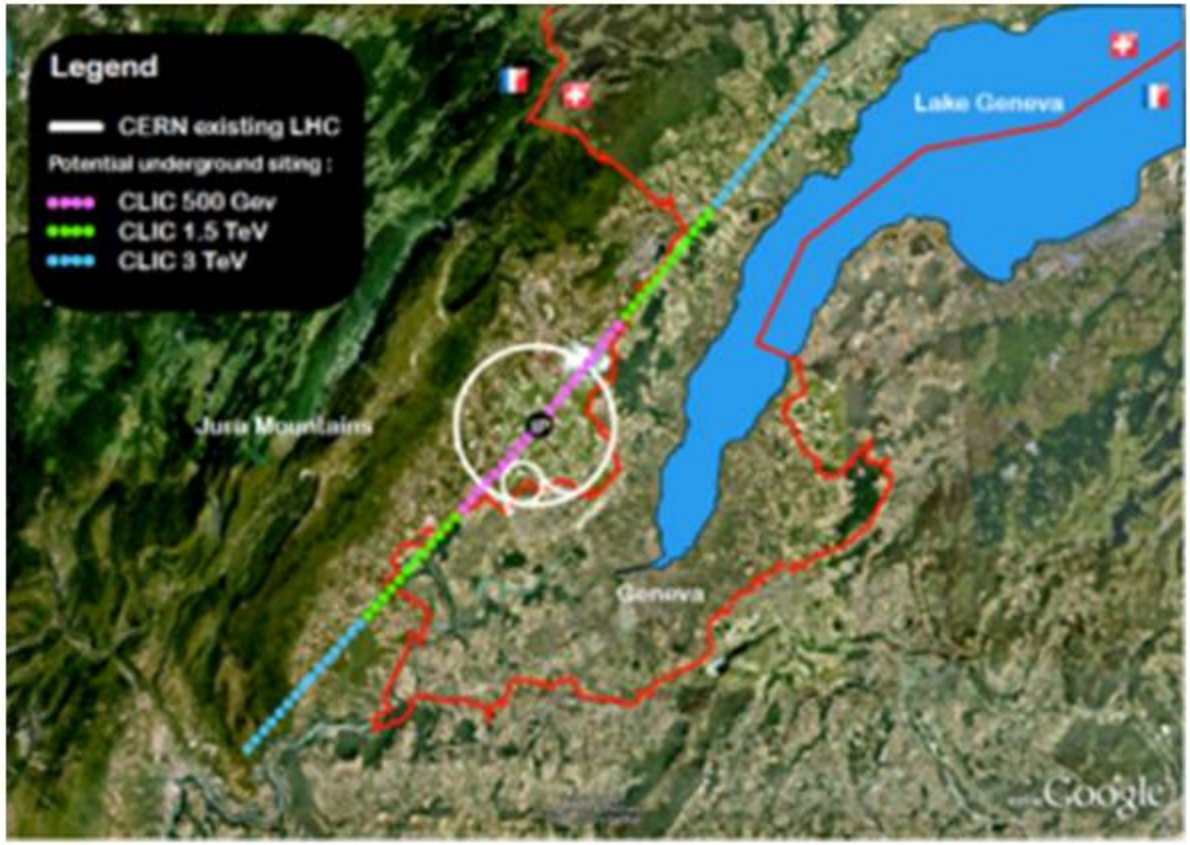
CERN-November 2015

L.Rossi @ Riccione

LHC project

CLIC: UN ACCELRATORE LINEARE DA 50 KM PERIL CERN?



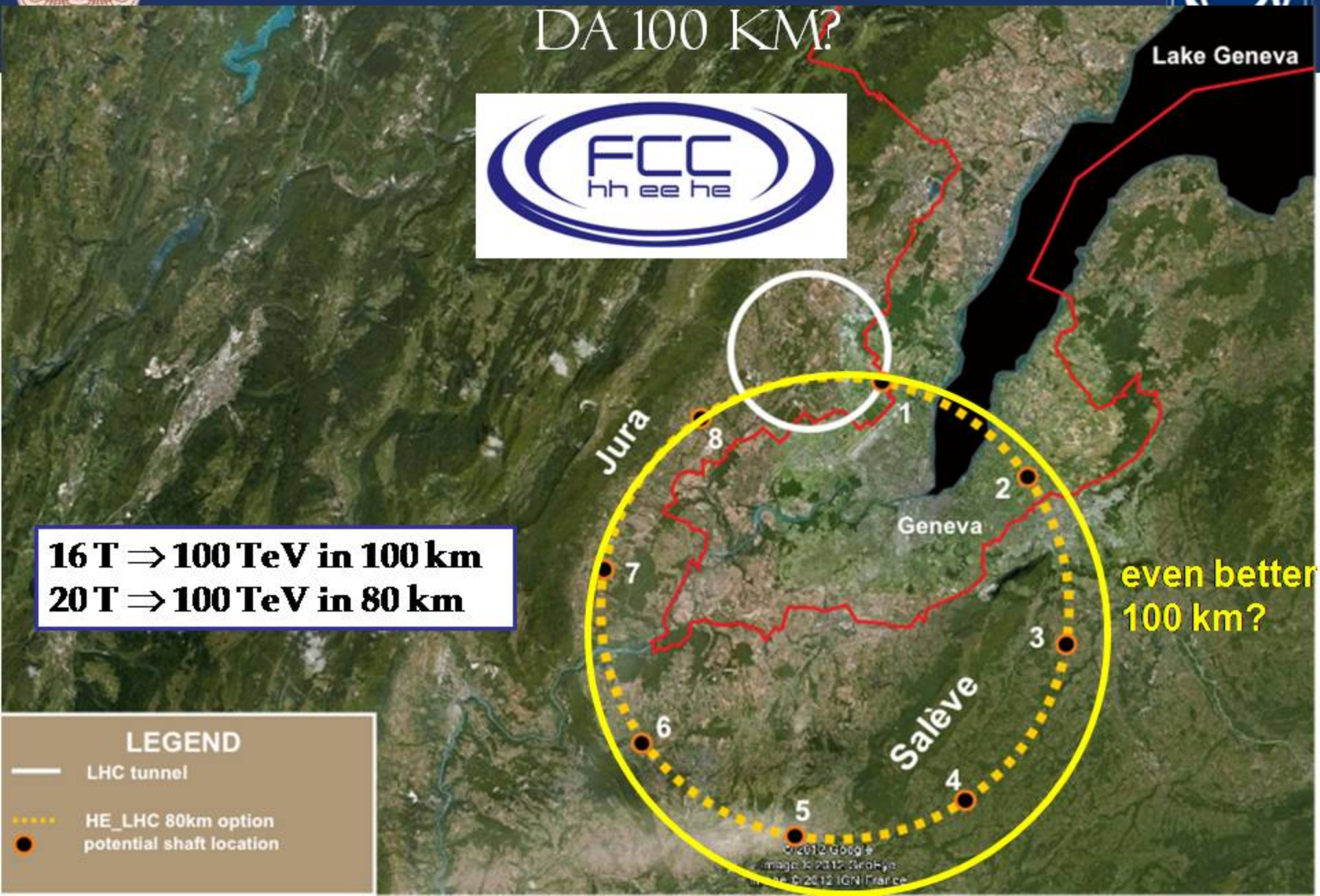


Highest possible energy e^+e^- with CLIC (CDR 2012)

Multi-lateral collaboration

F. Bordry

UN ACCELERATORE CIRCOLARE DA 100 KM?



BASIC INPUT TO FCC INFRASTRUCTURE & OPERATION

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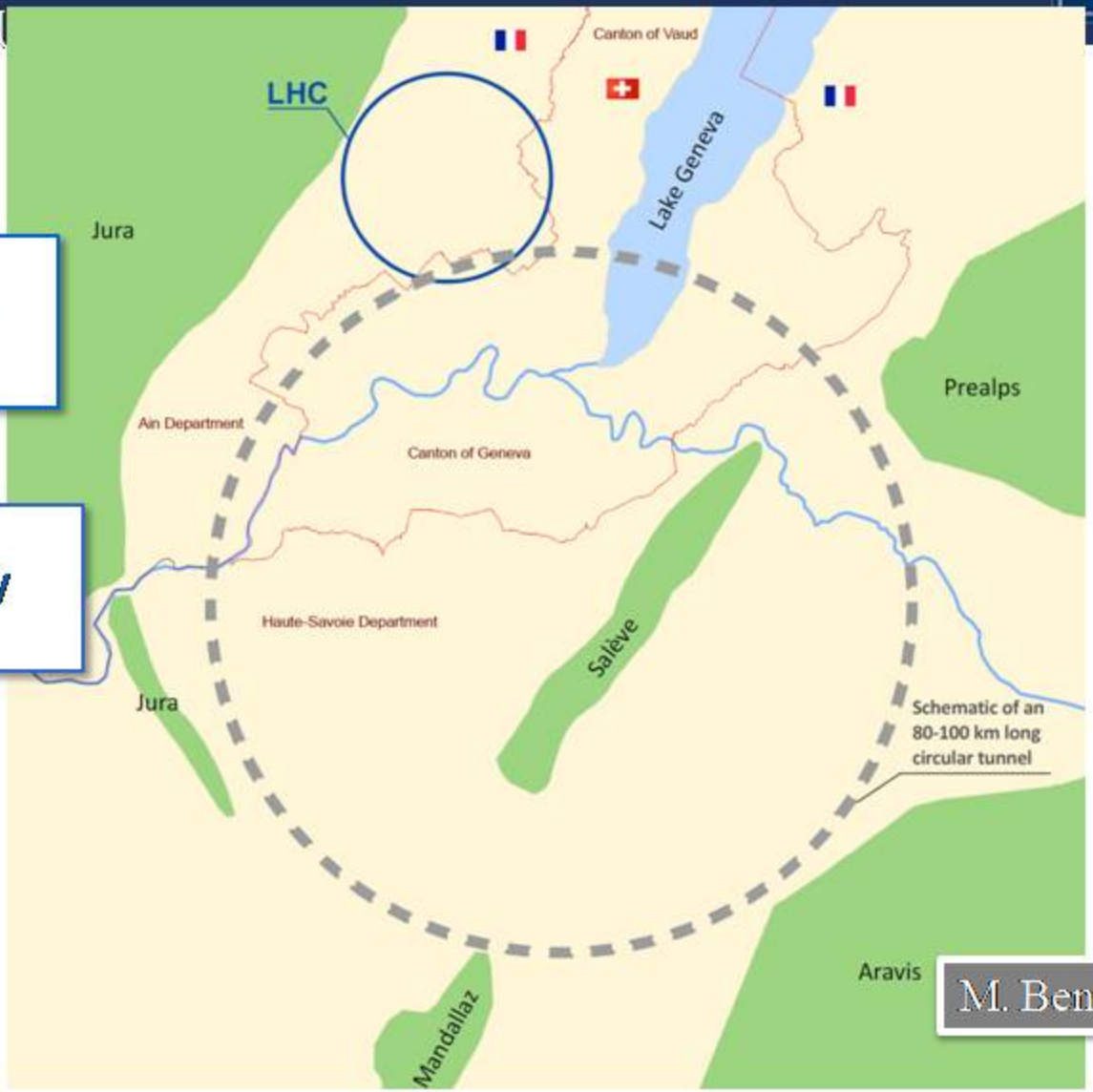
QUASI-CIRCU

Hadron collider
16 T ⇒ 100 TeV for 100 km
20 T ⇒ 100 TeV for 80 km

e+ e– collider
Collision energy 90 to 350 GeV
Very high luminosity



3D DIGITAL MODEL OF LOCAL GEOLOGY

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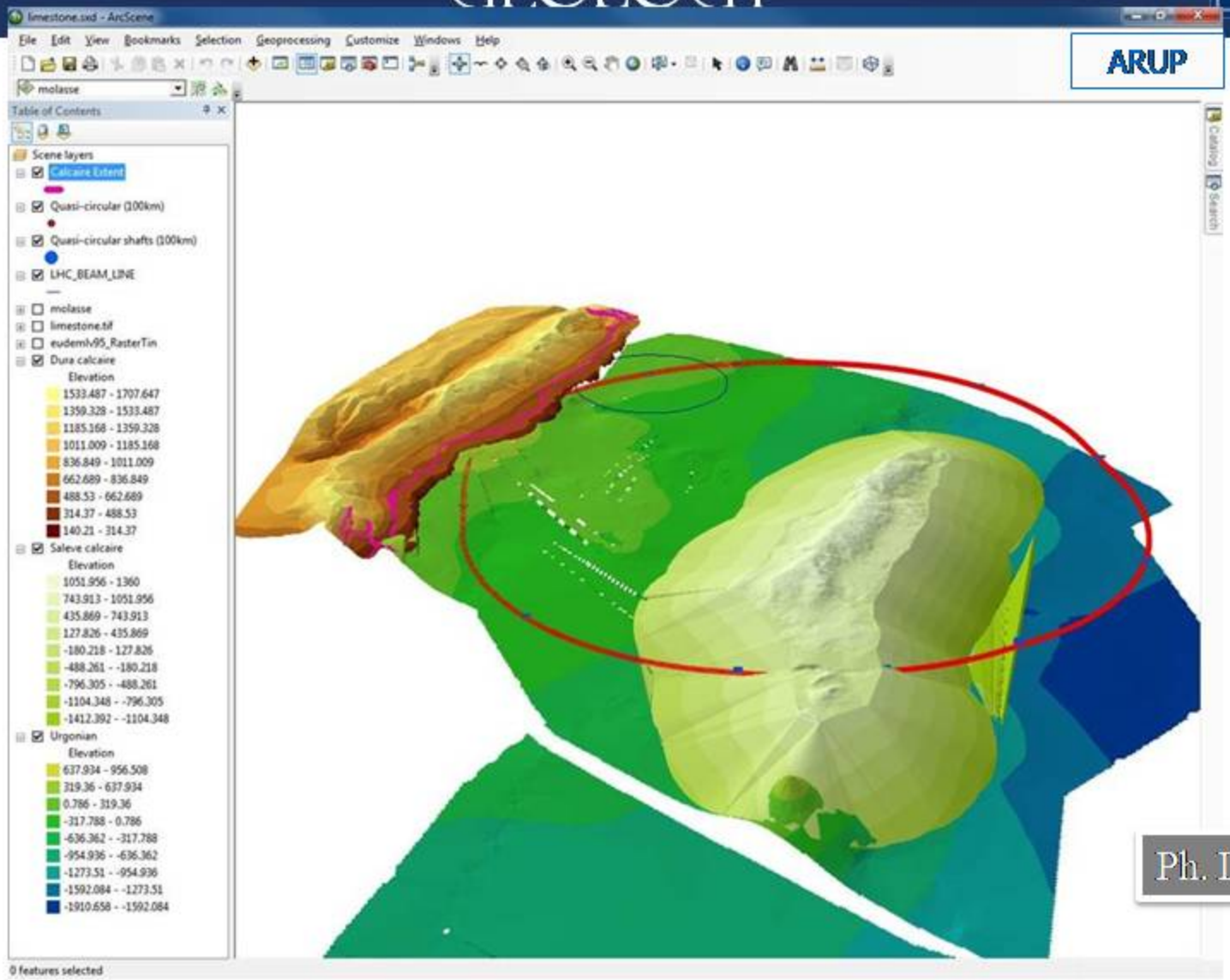
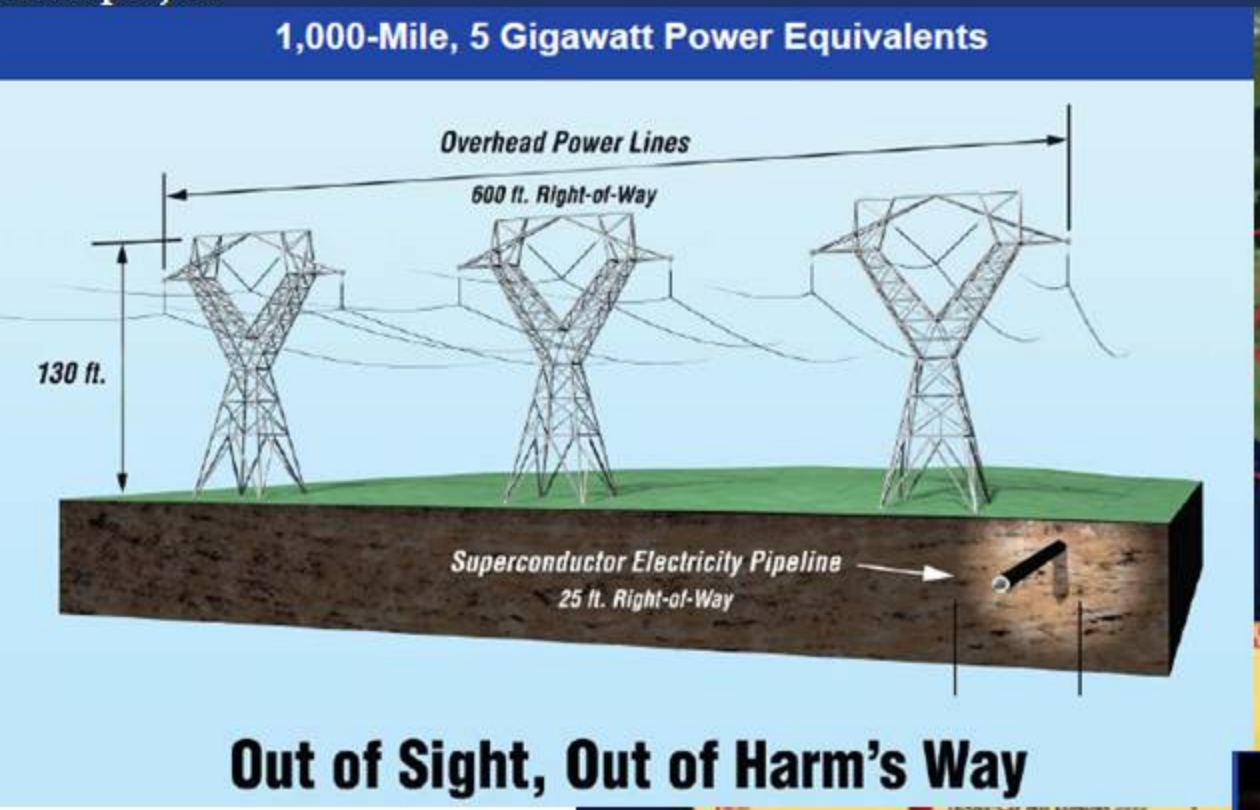


UNA POSSIBILE APPLICAZIONE DI HILUMI: TRASPORTO ENERGIA

LHC project

CERN



Courtesy Southwire Company

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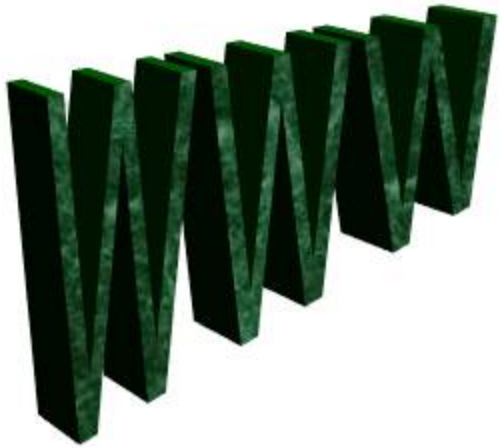
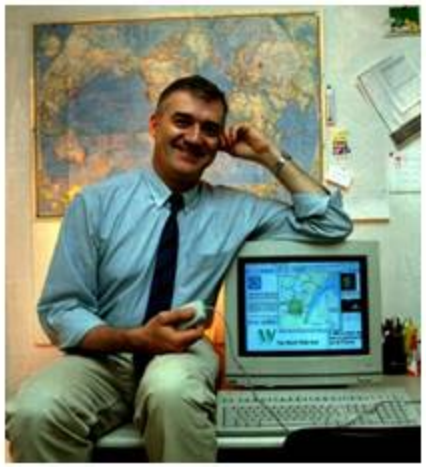
LA VALORIZZAZIONE DELLA COMUNICAZIONE:



1989 il WEB
2009 la celebrazione

Tim Berners-Lee



Robert Cailliau

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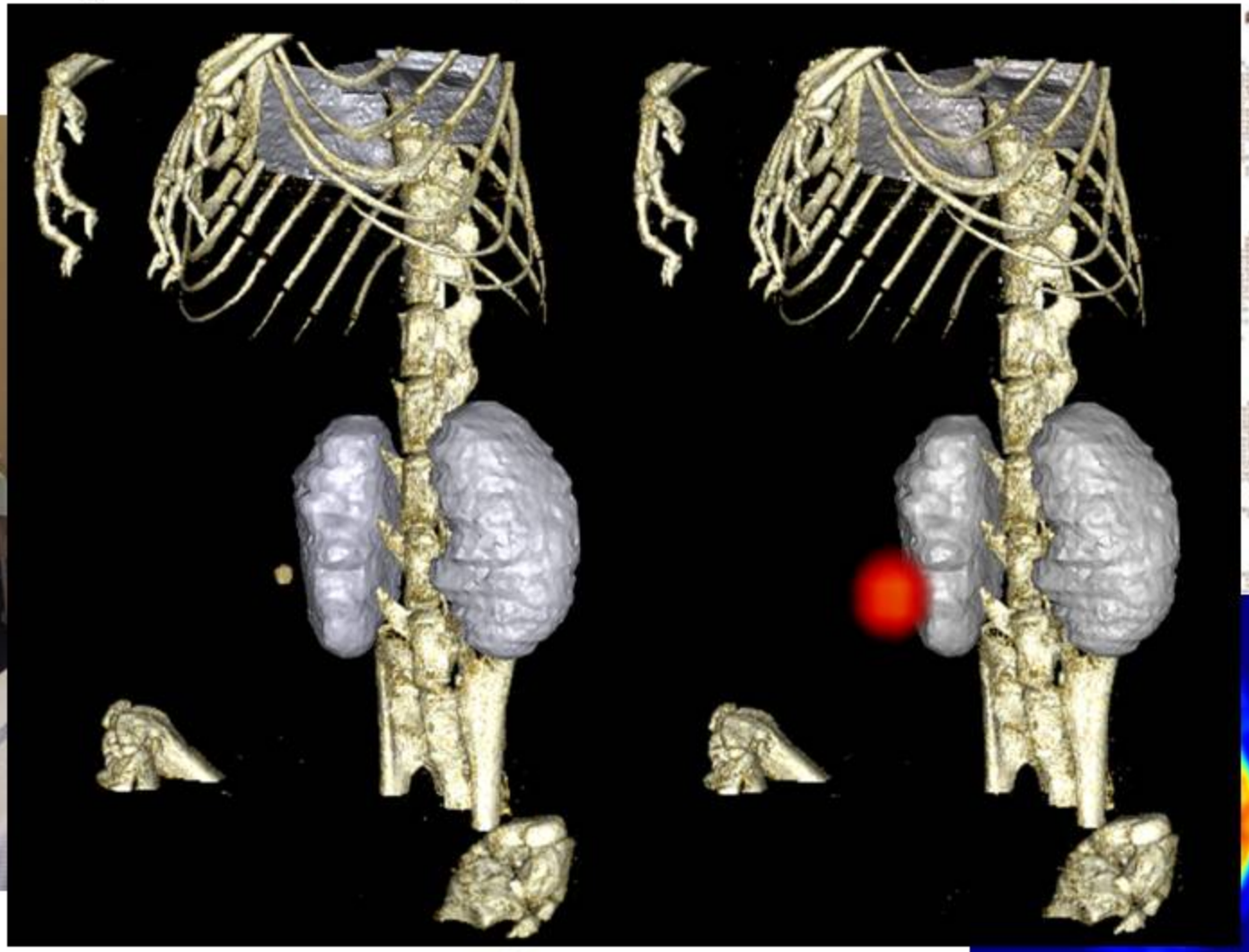
IL SUCCESSORE DEL WEB: GRID

CERN

Il LHC computing GRID è un progetto finanziato dall'UE con l'obiettivo di construire la futura generazione di infrastruttura di calcolo per fornire una capacità di calcolo e analisi mai vista.

LE APPLICAZIONI MEDICHE: PET

Prima immagine PET CERN, circa 1975



ADROTERAPIA ONCOLOGICA
CNAO PAVIA & PSI (CH)

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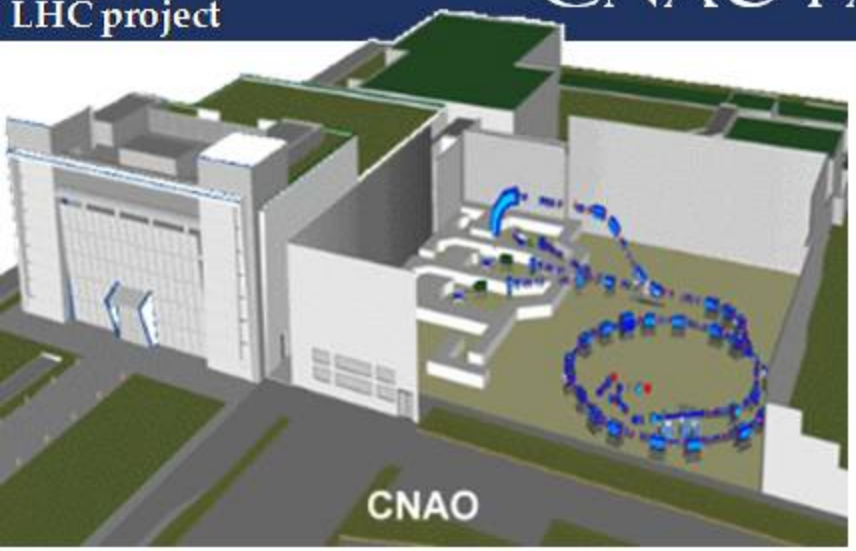
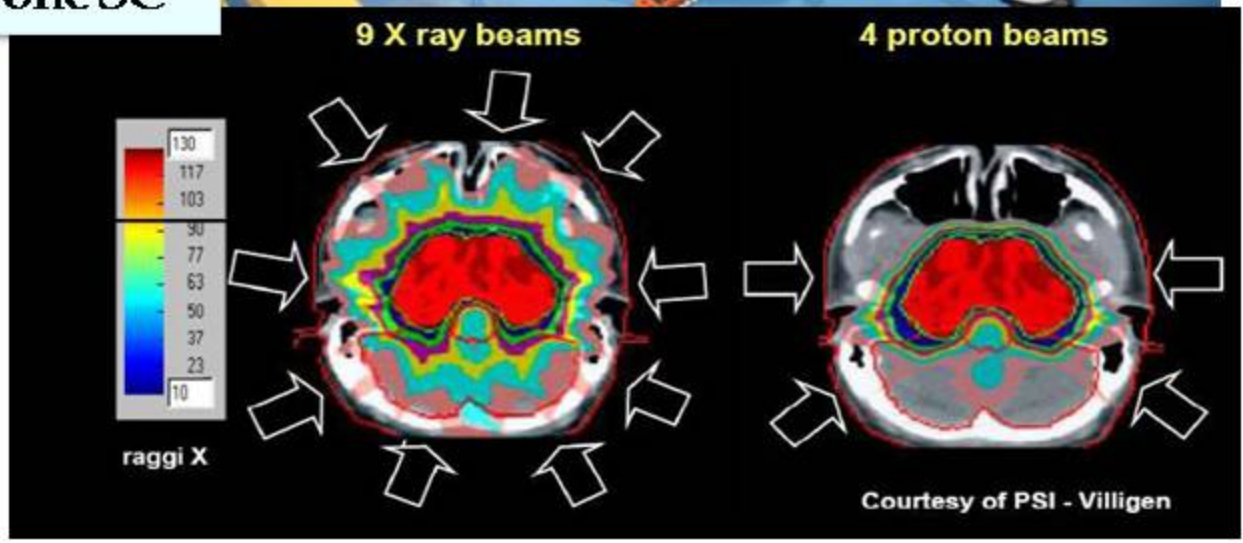


Ciclotrone SC



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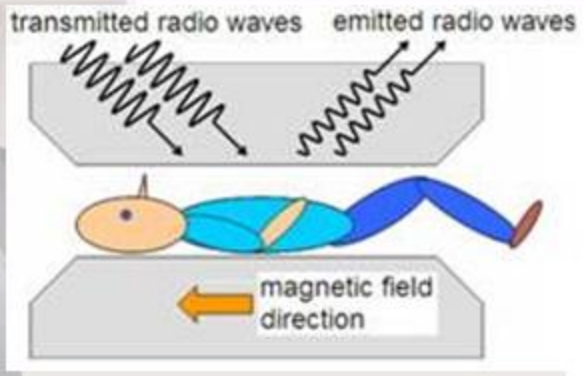
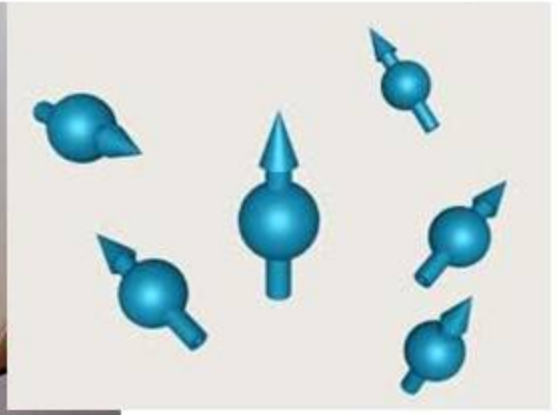
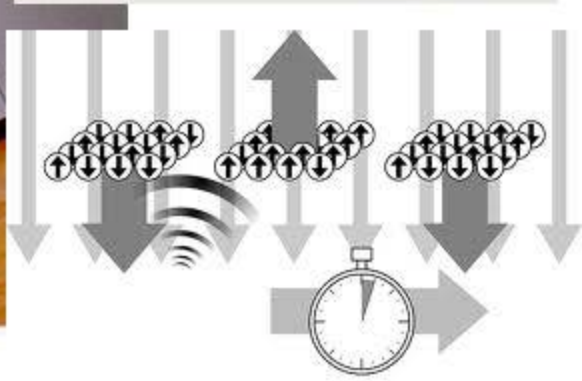
LA "GRANDE" APPLICAZIONI SANITARIA: RISONANZA MAGNETICA







MAGLEV

L'IMPORTANZA DEL MAESTRO

- Il tramandarsi una tradizione tiene viva la domanda ⇒ grandi scuole di fisica
- **Assicura, aiuta, che l'esperienza sia un cammino verso una certezza piu' grande con un metodo che è quello di tutte le realtà umane positive:**
- Verifica onesta: esperienza
- Dedizione, affezione
- Capacità di lavorare insieme
- Confronto tra l'esperienza e l'ipotesi
- Condivisione risultati: da questo la domanda si alimenta

… e speriamo che la luce brilli su LHC ancora per molti anni a venire…

IL MECCANISMO DI HIGGS

- Analogia: la luce viene rallentata quando attraversa un mezzo materiale
- Idea 1: le particelle non hanno massa ma vengono rallentate dall'interazione con qualcosa.
- Idea 2: il vuoto non è il niente. E' permeato da un campo (o sostanza) d Higgs
- 1+2 : la massa delle particelle è l'energia di interazione ($E=mc^2$) con il campo di Higgs

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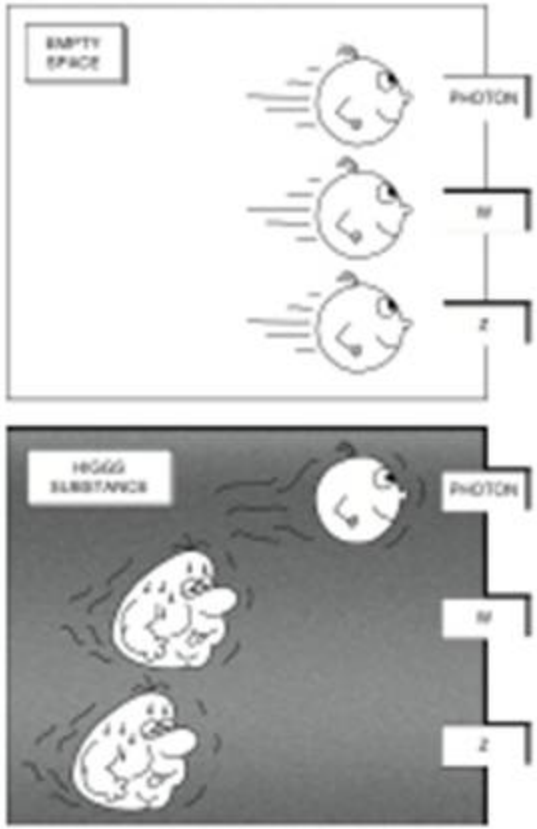
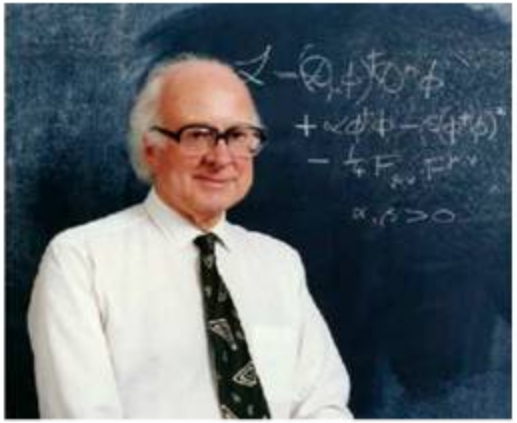
HIGGS : VEDIAMOLO!





Certo la domanda si è solo spostata
Da: come una particella ha una certa massa
A: come una particella si accopia di piu o meno col campo di Higgs!
Come vedere il campo di Higgs?
Percuotendolo!, emetterà delle onde. Ma le onde sono particelle, la particella di Higgs
La particella di Higgs è un bosone (ama la compagnia a differenza dei fermioni)