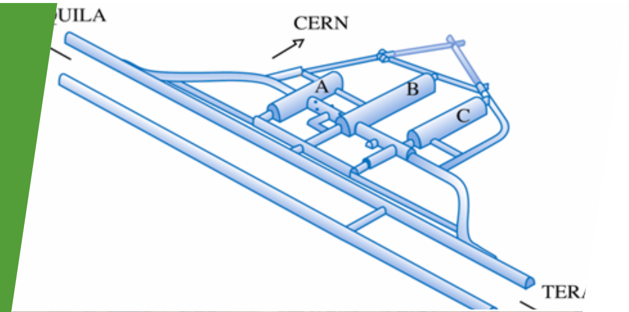
Laboratori Nazionali del Gran Sasso

Natalia Di Marco



A brief history of Gran Sasso National Laboratory

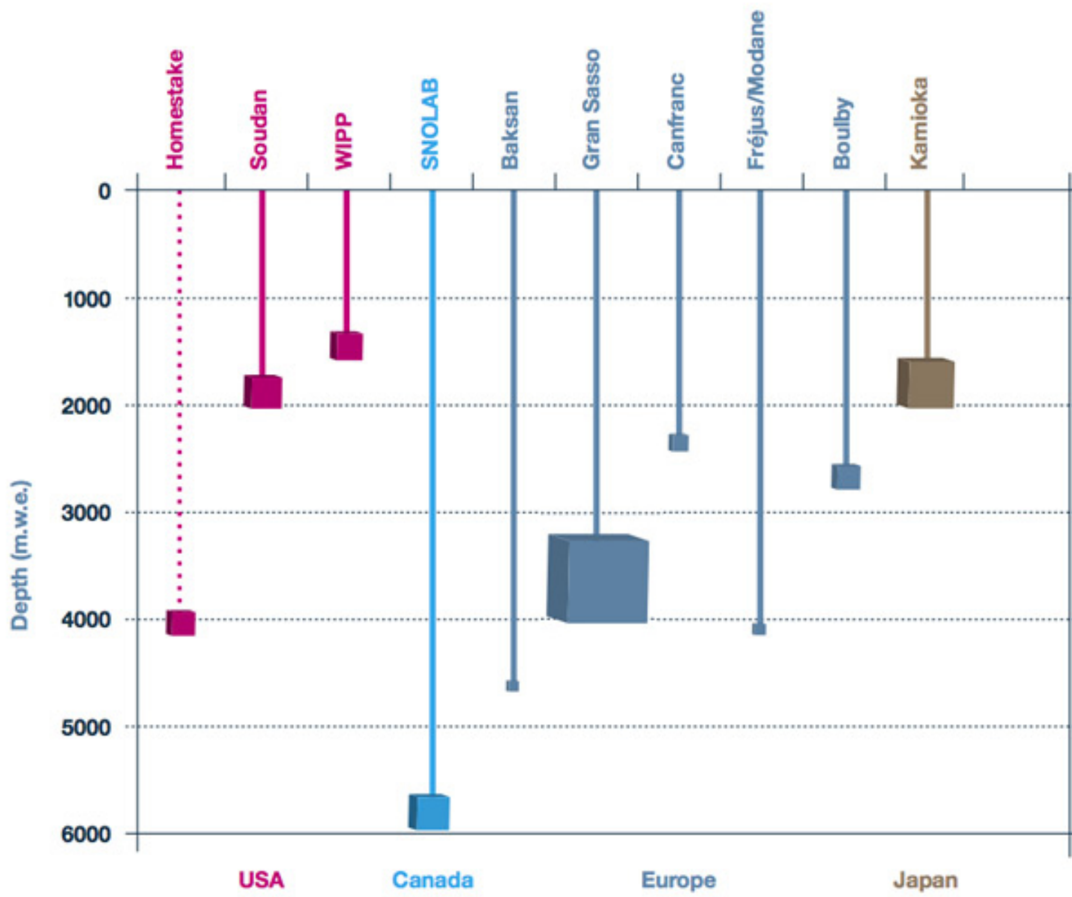
1979
Submission to the Italian Parliament of the proposal about the realization of the Underground Laboratory

1982
Approval of the Parliament

1987
The Underground Laboratory is completed

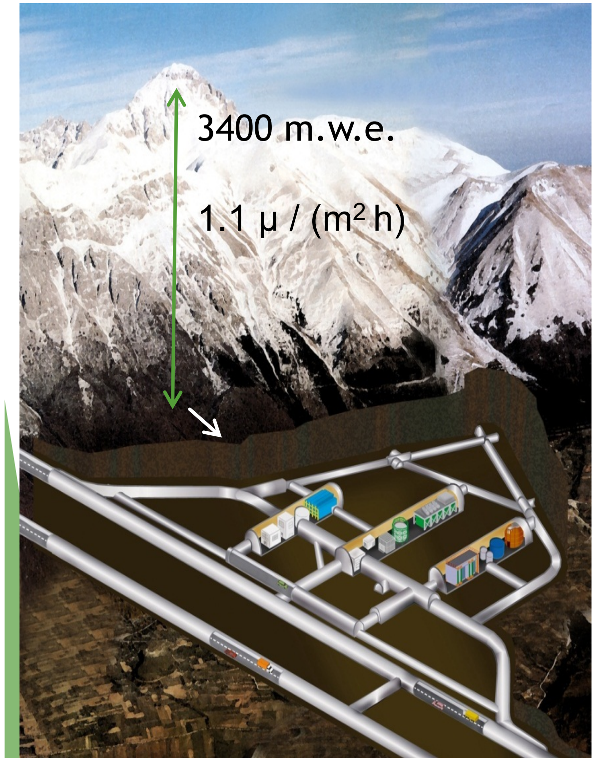
1989
The first experimental apparatus, MACRO, begins the data taking.

‘’Underground’’ Physics

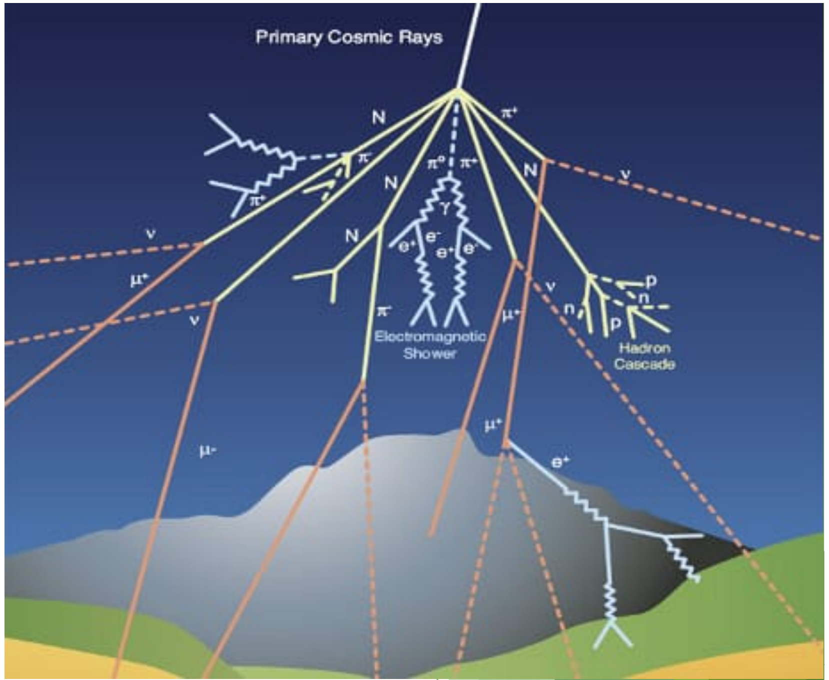


Fifteen experiments in which are working about 800 researchers coming from 25 countries.

Why underground?



Underground laboratories are shielded by layers of rock and offer the unique possibility of studying rare physics phenomena in an environment which is almost free from cosmic ray background



Shield of rock 1400 m thick
Factor of muon flux reduction : 10^6 (~ 1 μ m^{-2} h^{-1})

Underground Volume: 180000 m^3
Underground Surface: 17800 m^3

Research activities

- **Neutrino physics:**

BOREXINO, LVD, GERDA, CUORE, CUPID, COBRA

- **Dark matter:**

DAMA/LIBRA, DARKSIDE-50, XENON, CRESST, SABRE, COSINUS

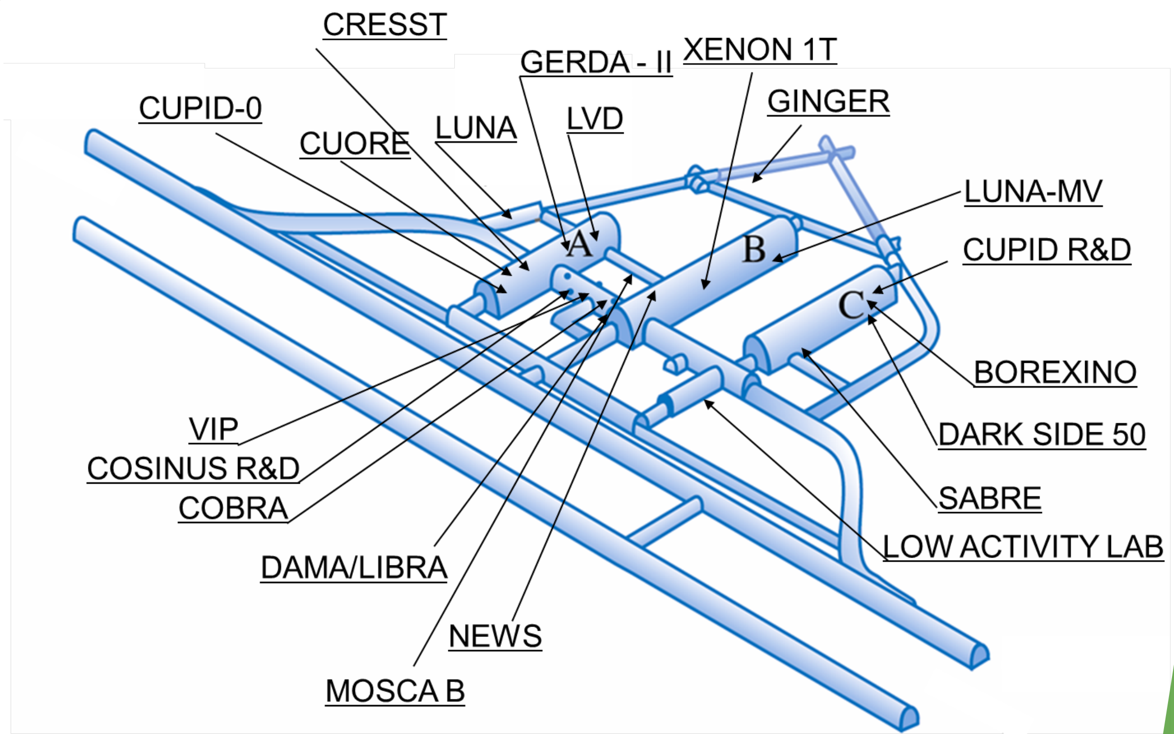
- **Nuclear reactions of astrophysics interest:**

LUNA

- **Fundamental Physics:** VIP

- **Multidisciplinary activities:**

GINGER, Cosmic Silence, ERMES-W



Astroparticle Physics

"Vi chiedo di guardare in entrambe le direzioni. Perché la strada per la conoscenza delle stelle conduce all'atomo; e l'importante conoscenza dell'atomo è stata raggiunta attraverso le stelle."

Sir Arthur Eddington
(1882-1944)

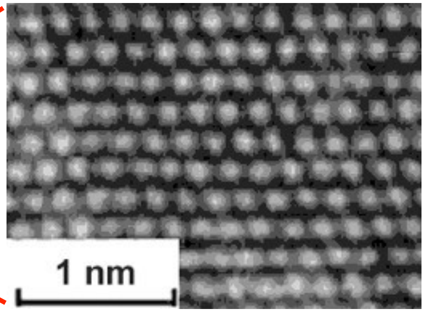
Courtesy of Dott. Massimo Mannarelli

ferro

Courtesy of Dott. Massimo Mannarelli

ferro

reticolo molecolare

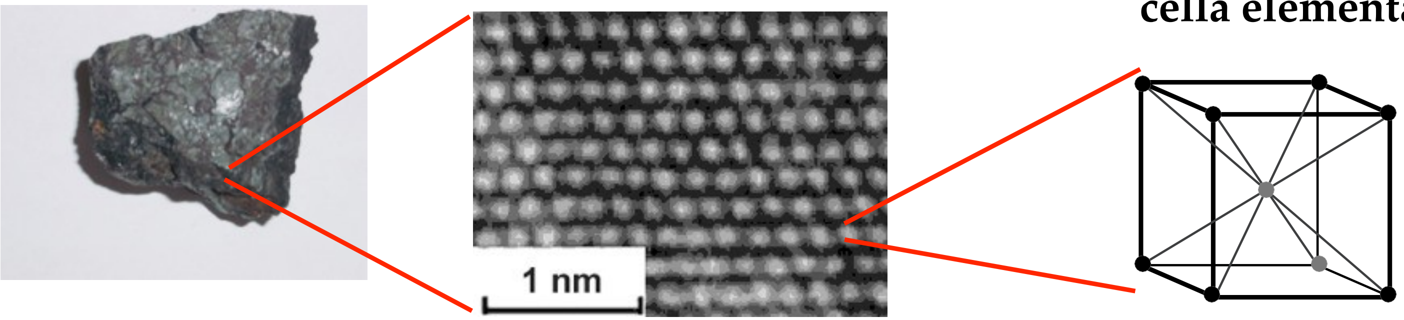


10^{-9}m = nm

Scala di ingrandimento

Courtesy of Dott. Massimo Mannarelli

ferro reticolo molecolare **cella elementare**



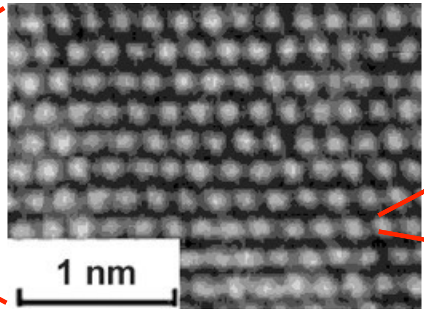
$10^{-9}m = nm$

Scala di ingrandimento

Courtesy of Dott. Massimo Mannarelli

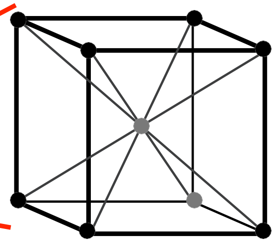
ferro

reticolo molecolare



$10^{-9}m =$ nm

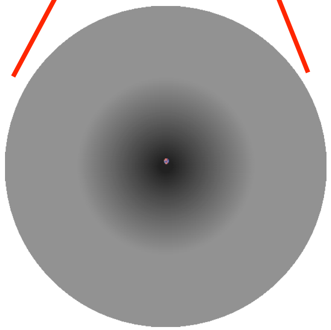
cella elementare



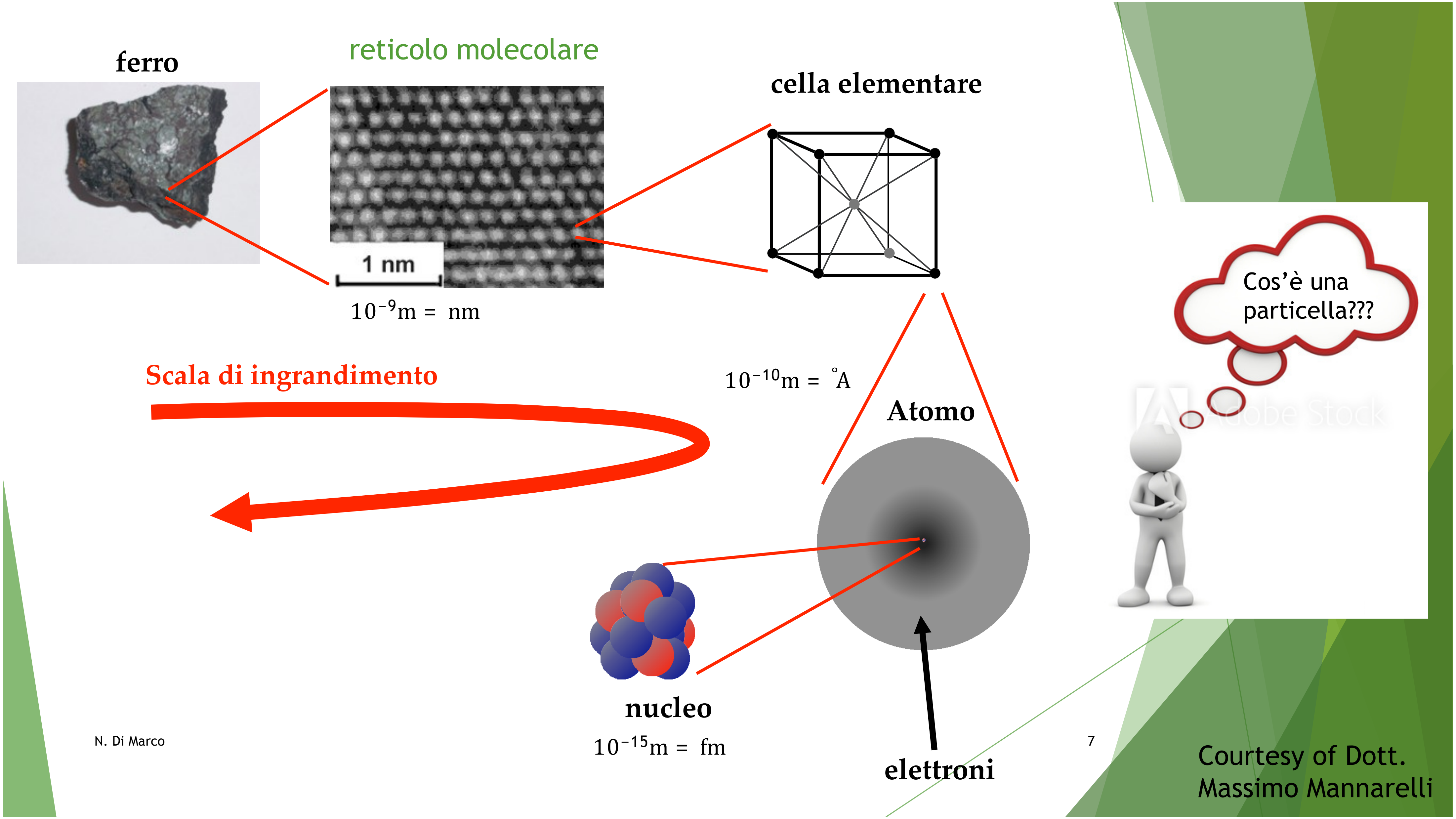
Scala di ingrandimento

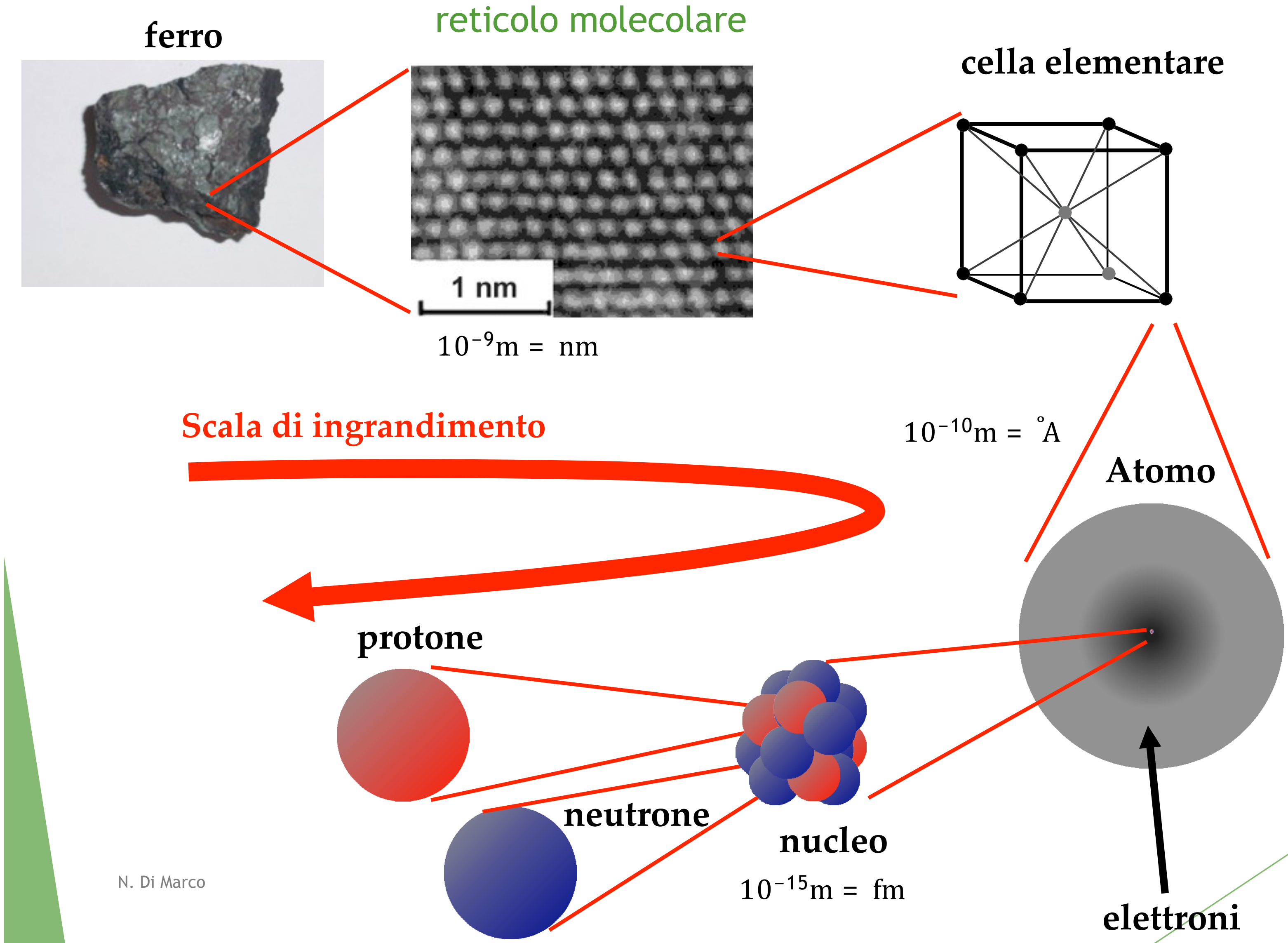
$10^{-10}m = \mathring{A}$

Atomo

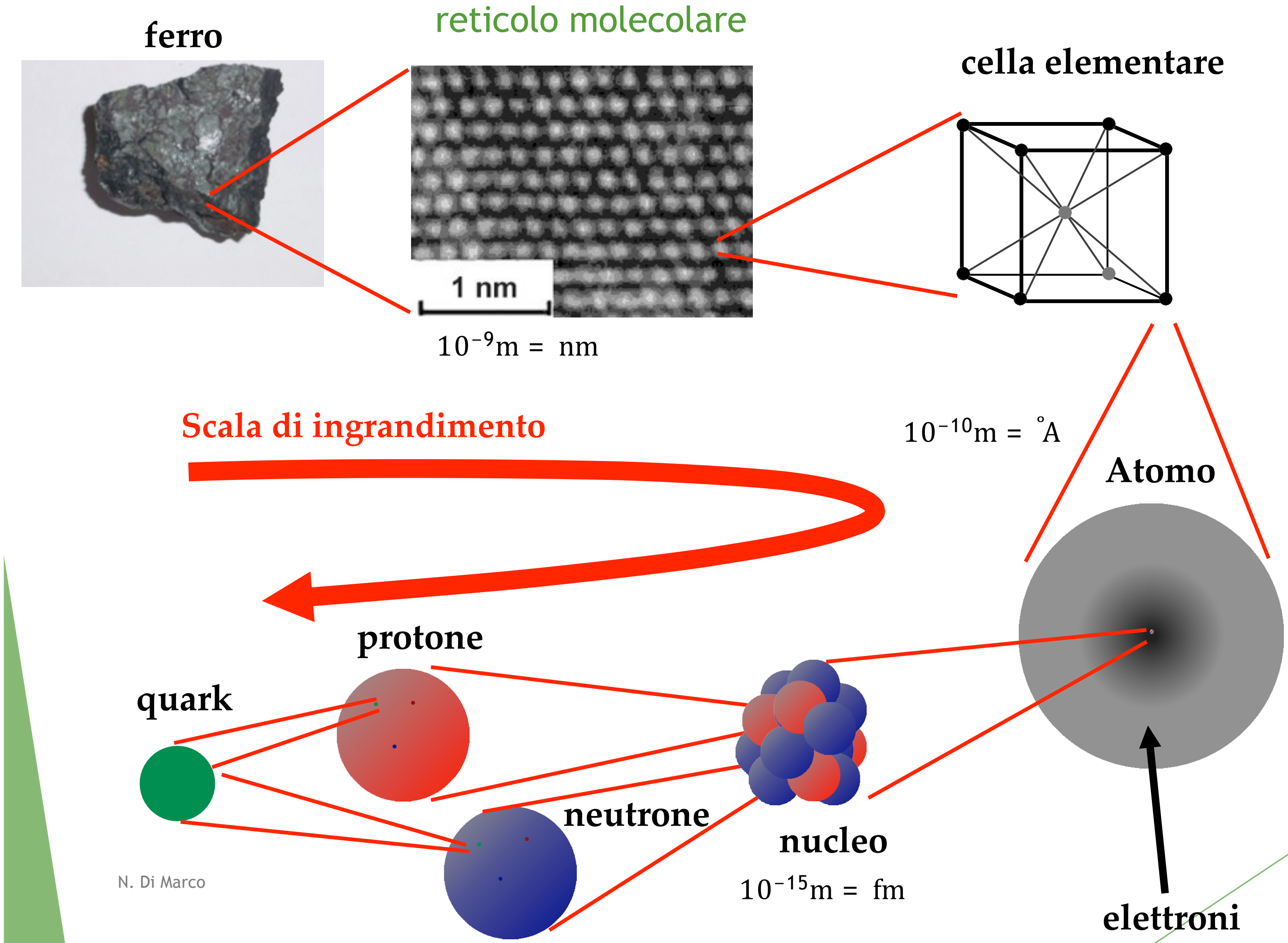


Courtesy of Dott.
Massimo Mannarelli

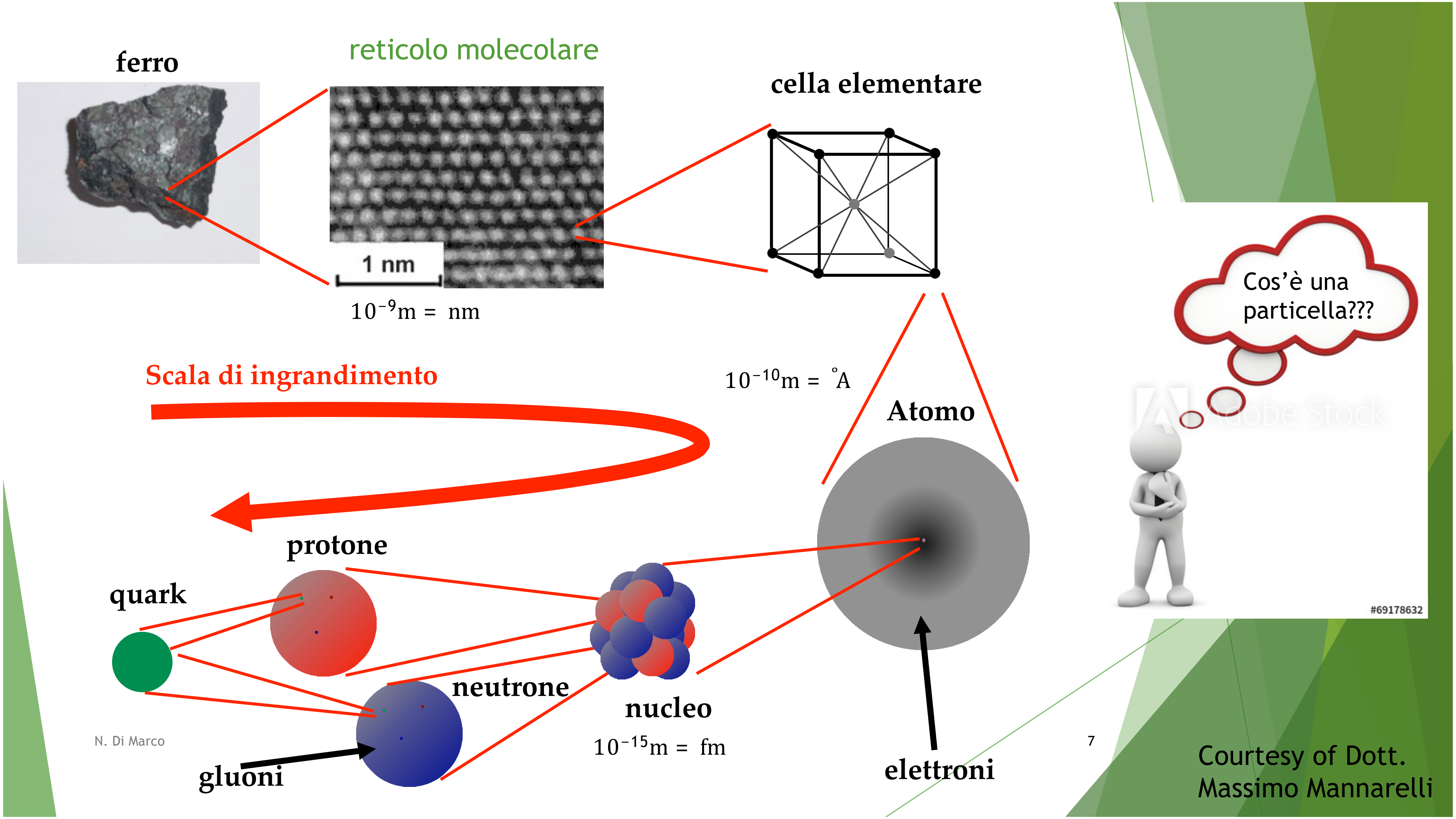

ferro
reticolo molecolare
1 nm
10^{-9}m = nm
cella elementare
Scala di ingrandimento
10^{-10}m = Å
Atomo
nucleo
10^{-15}m = fm
elettroni
Cos'è una particella???
Courtesy of Dott. Massimo Mannarelli

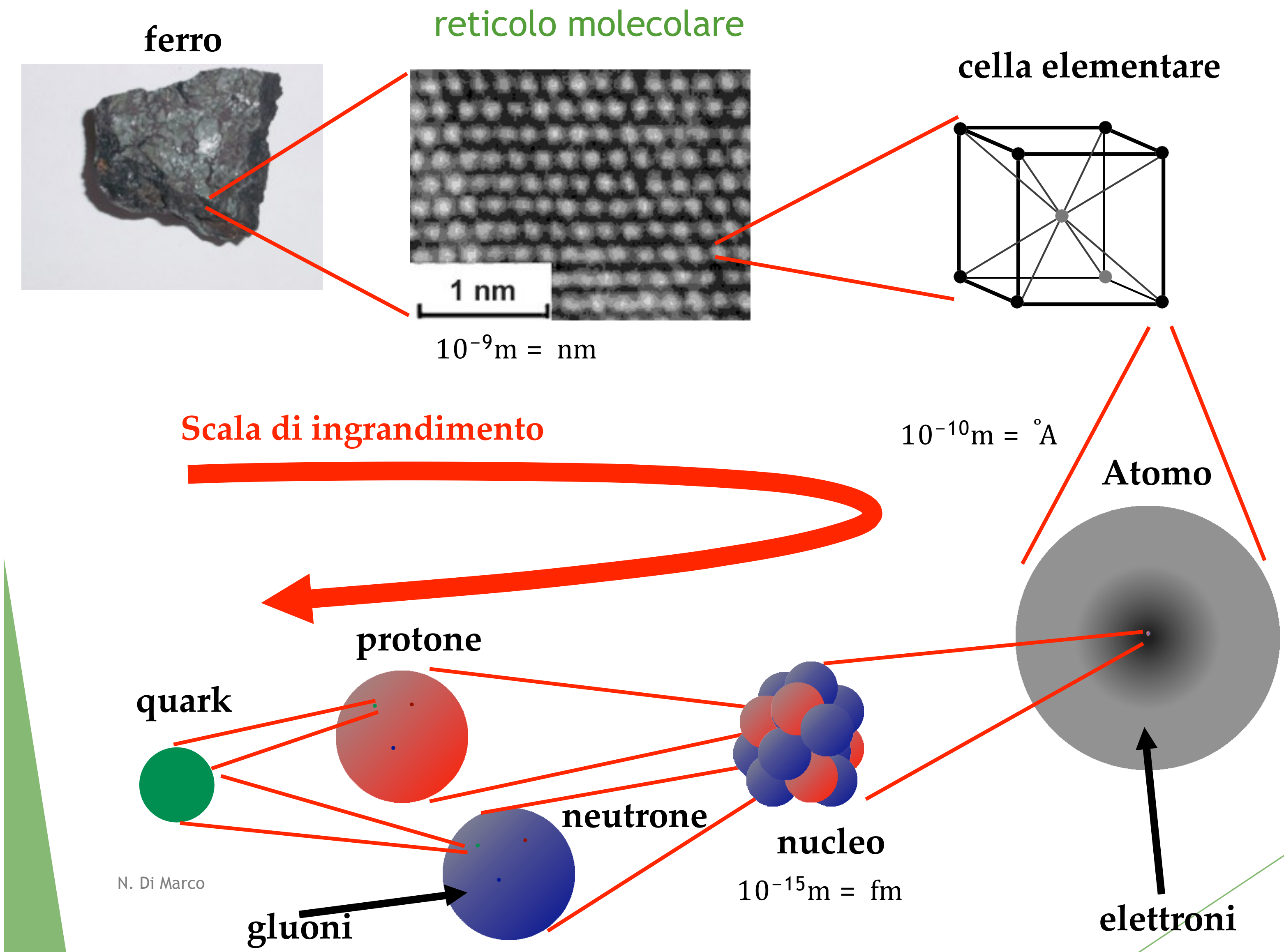


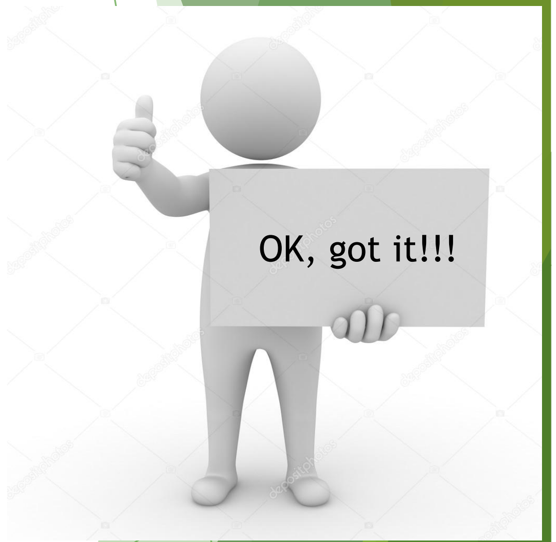
Courtesy of Dott.
Massimo Mannarelli



Courtesy of Dott. Massimo Mannarelli


ferro
reticolo molecolare
1 nm
10^{-9}m = nm
cella elementare
Scala di ingrandimento
10^{-10}m = Å
Atomo
protone
quark
neutrone
nucleo
10^{-15}m = fm
gluoni
elettroni
Cos'è una particella???
#69178632
Courtesy of Dott. Massimo Mannarelli





Courtesy of Dott. Massimo Mannarelli

Standard Model of Elementary Particles

Leptoni

e elettrone		

Quark

u up	c charm	t top
d down	s strange	b bottom

γ tone
Z ne Z
W osone W
g gluone

Standard Model of Elementary Particles

Leptoni			
	e elettrone	μ muone	
Quark	u up	c charm	t top
	d down	s strange	b bottom

γ tone
Z ne Z
W osone W
g gluone

Standard Model of Elementary Particles

Leptoni			
	e elettrone	μ muone	τ tau
Quark	u up	c charm	t top
	d down	s strange	b bottom

γ tone
Z ne Z
W osone W
g gluone

Standard Model of Elementary Particles

Leptoni	ν_e neutrino e	ν_μ neutrino mu	ν_τ neutrino tau
	e elettrone	μ muone	τ tau
Quark	u up	c charm	t top
	d down	s strange	b bottom

γ tone
Z ne Z
W osone W
g gluone

Standard Model of Elementary Particles

Leptoni	ν_e neutrino e	ν_μ neutrino mu	ν_τ neutrino tau
	e elettrone	μ muone	τ tau
Quark	u up	c charm	t top
	d down	s strange	b bottom

H bosone di Higgs

γ fotone
Z bosone Z
W bosone W
g gluone

Neutrino History in brief

1930: Pauli proposes the existence of a new neutral particle to explain the apparent energy non conservation in radioactive decay

1933:
Enrico **Fermi** proposes "neutrino" as the name for Pauli's postulated particle

1956:
First neutrino detection by Reines and Cowan

1957:
An Italian physicist, **Bruno Pontecorvo**, living in the USSR, formulates a theory of neutrino "oscillations"

1962:
Steinberger, Lederman, and Schwartz demonstrate the existence of two species of neutrinos

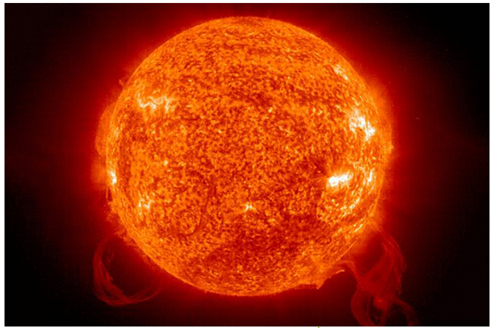
1968: Davis, at Homestake mine in South Dakota makes the first observation of neutrinos from the sun. But experimenters see far fewer neutrinos than solar models had predict

2015:
Nobel Prize to Takaaki Kajita and B. McDonald for the discovery of neutrino oscillation

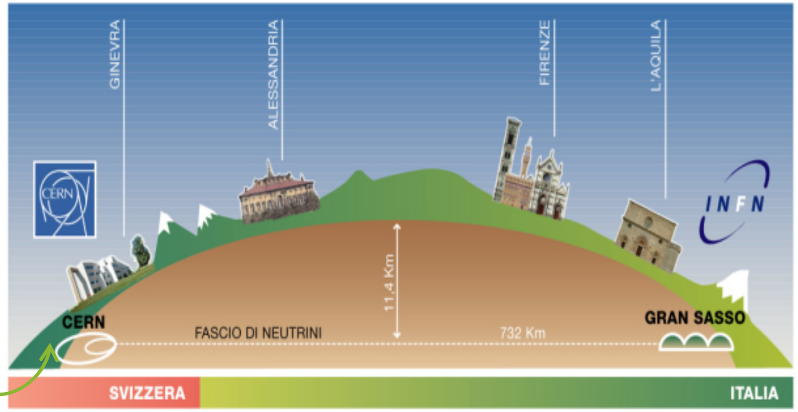
What's next?

Neutrino sources

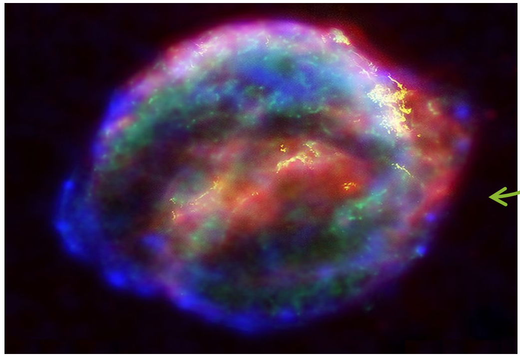
Solar



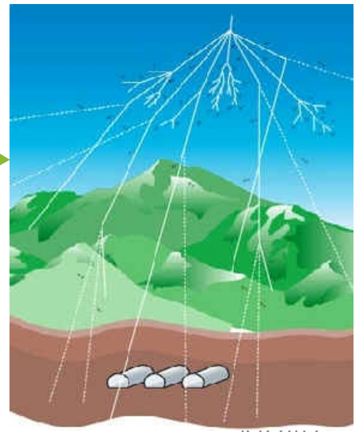
Accelerator



SuperNovae

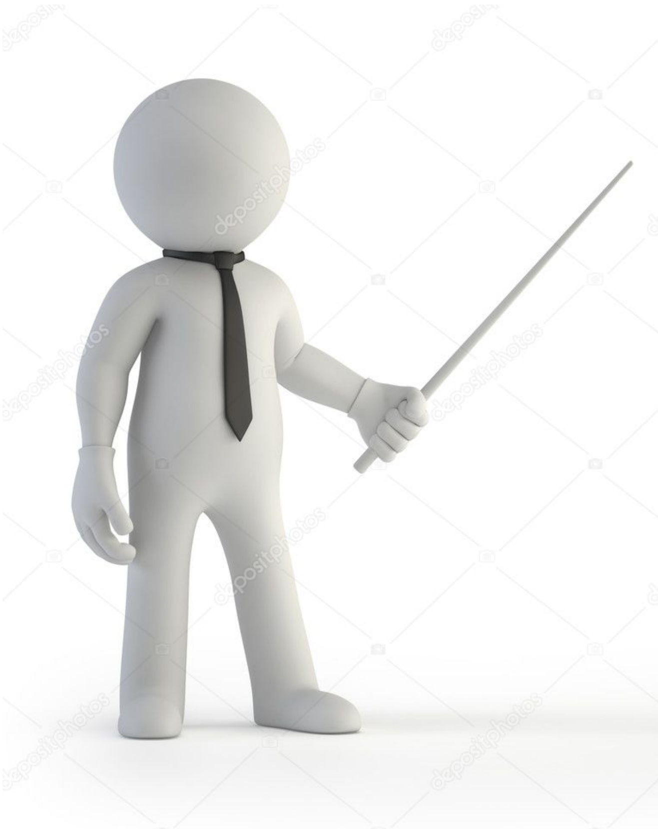


ν



Atmospheric

What's so special about neutrino?



- Elementary particle
- No electrical charge
- (incredibly) small mass (…not yet measured)
- Neutrino oscillation
  (Nobel Prize to Kajita and McDonald in 2015)
- Huge flux on earth: $O(10x10^9\ \nu/cm^2/s)$
- Very weakly with matter →
  $O(10^{21}$ cm H_2O to stop a solar $\nu)$

But…

Why the mass is so small?

Neutrino is a Dirac or a Majorana particle?

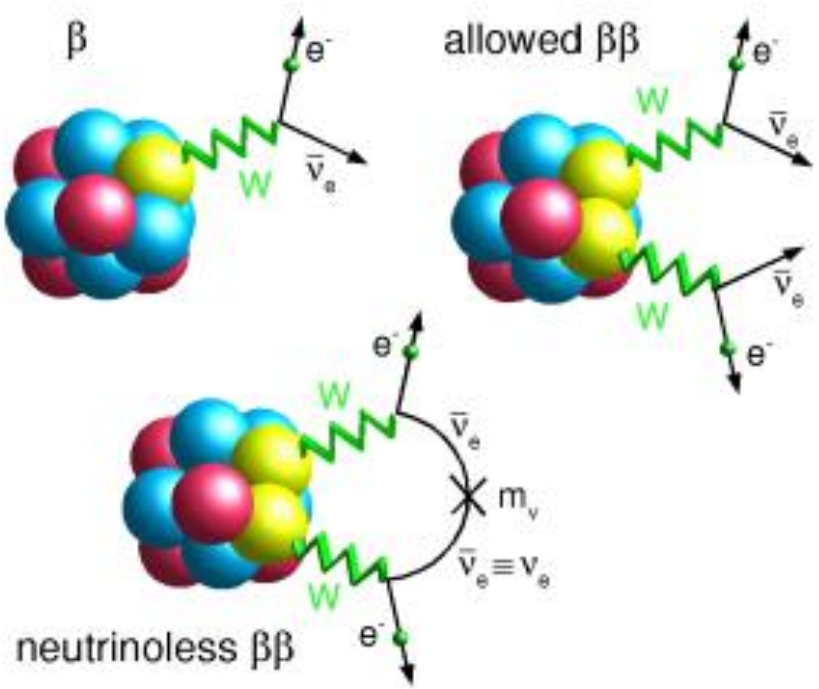
(i.e. is $\nu = \bar{\nu}$?)

Mass hierarchy?

CP violation?

1 or more **sterile** neutrinos?

Neutrino experiments@LNGS



2νββ →

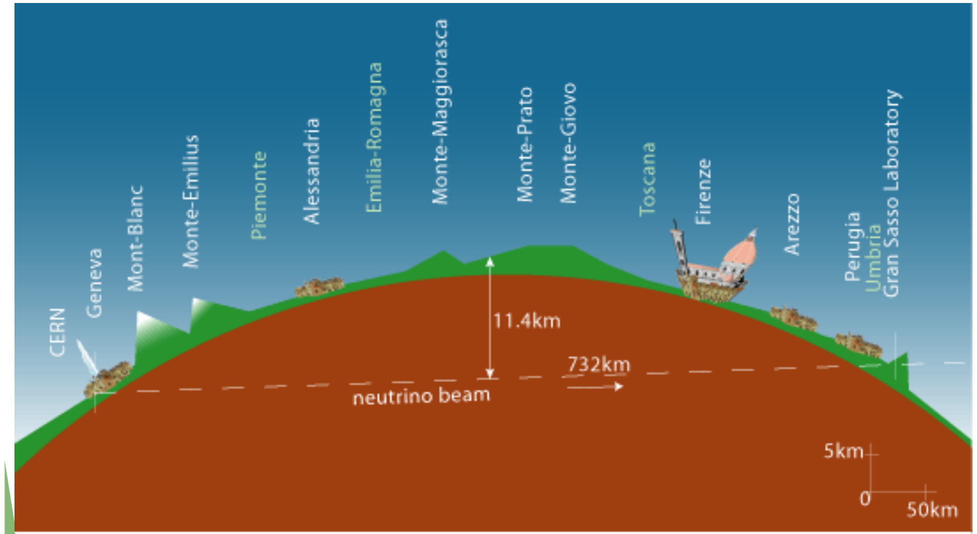
$T_{1/2}$ **~ 10^{21} yr (observed)**

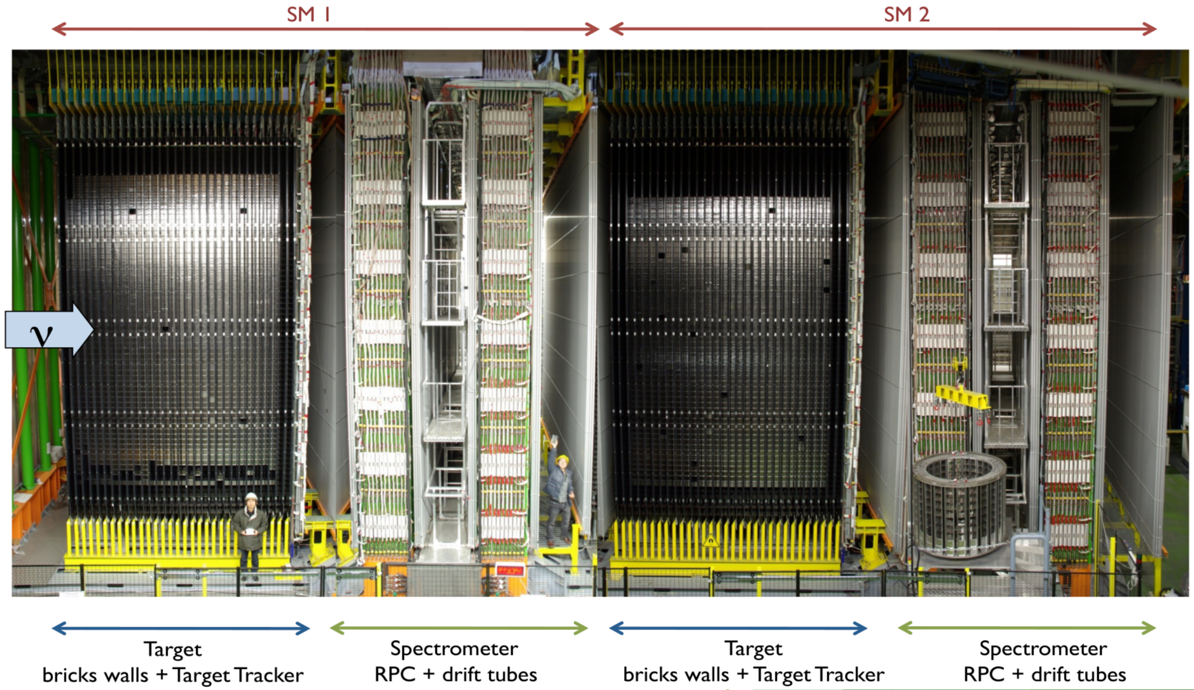
0νββ →

$T_{1/2}$ **> 10^{26} yr**

Neutrino experiments@LNGS

OPERA

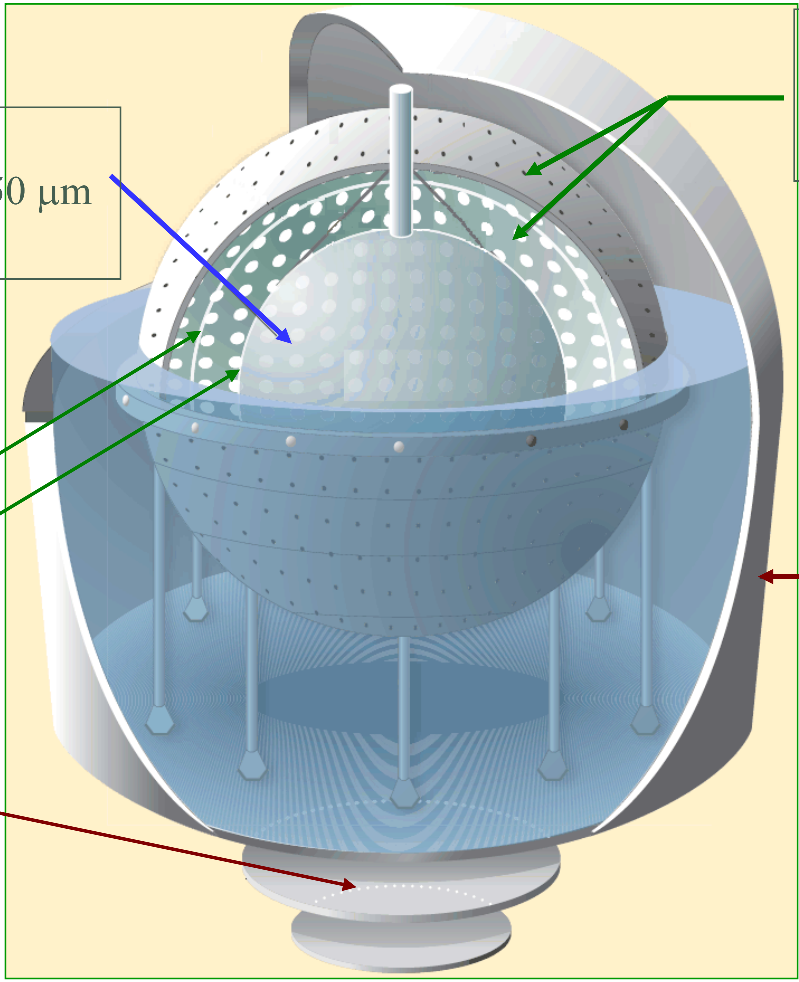




Discovery of neutrino oscillation in the $\nu_\mu \rightarrow \nu_\tau$ channel

Neutrino experiments@LNGS

Scintillator:
270 t PC+PPO in a 150 μm thick nylon vessel



Stainless Steel Sphere:
2212 PMTs
1350 m³

Nylon vessels:
Inner: 4.25 m
Outer: 5.50 m

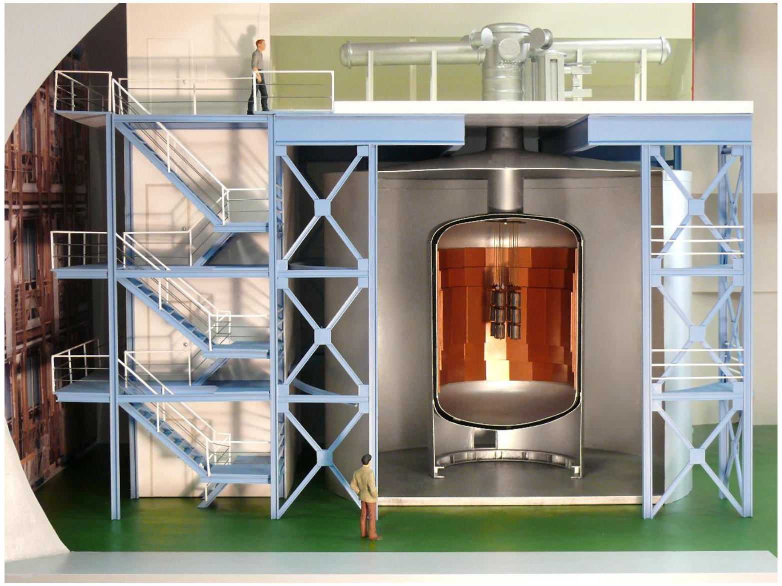
Water Tank:
γ and n shield
μ water Č detector
208 PMTs in water
2100 m³

Carbon steel plates

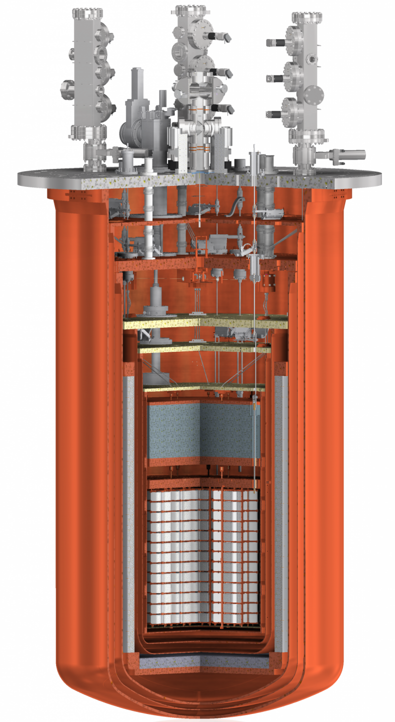
$\nu x + e^- \rightarrow \nu x + e^-$ (ES)

Neutrino experiments@LNGS

GERDA



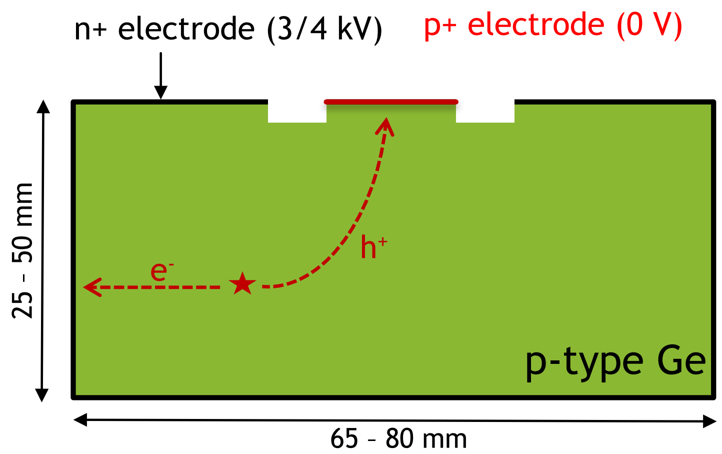
CUORE

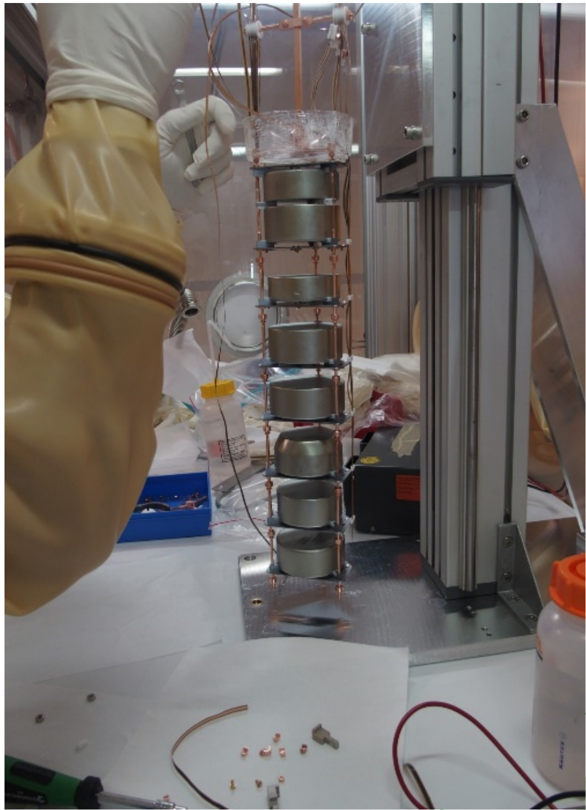


Neutrino experiments@LNGS

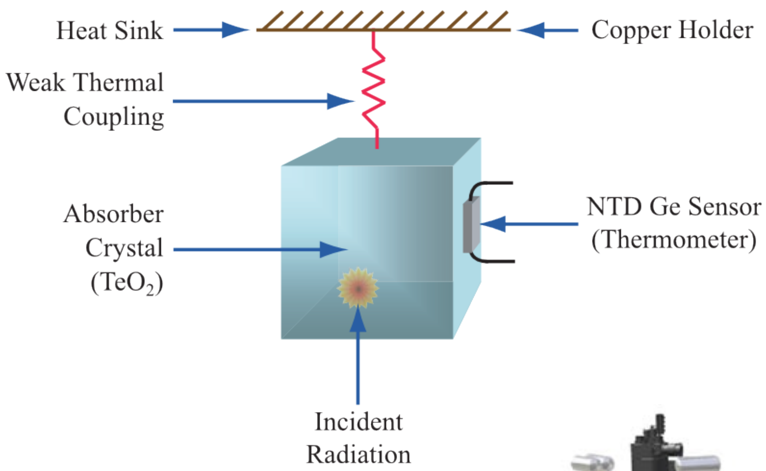
0νββ

GERDA/LEGEND

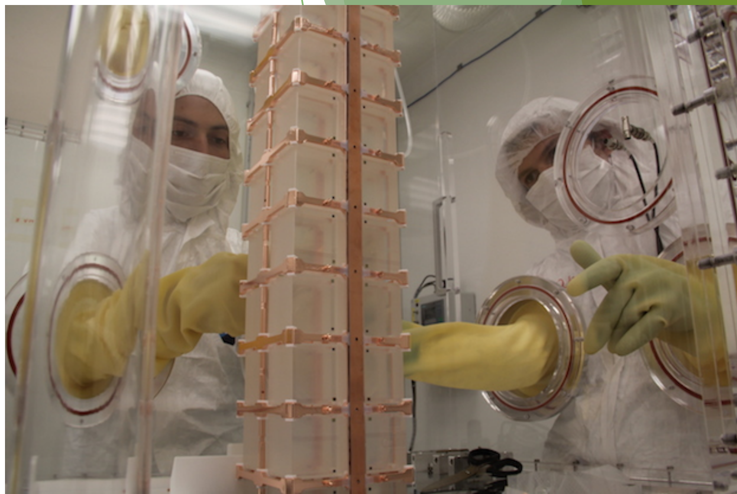


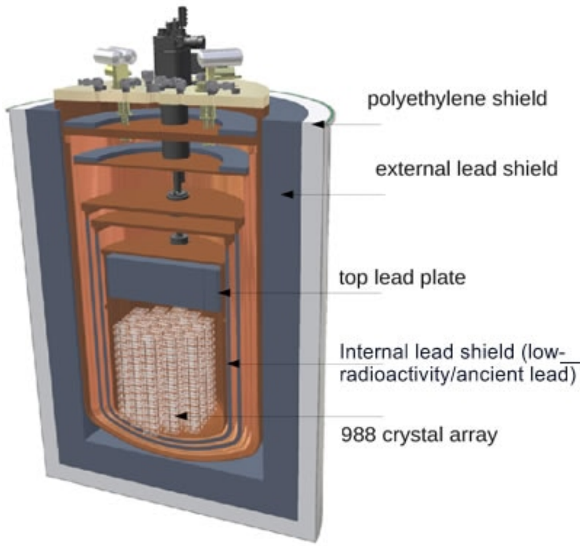


Neutrino experiments@LNGS



CUORE

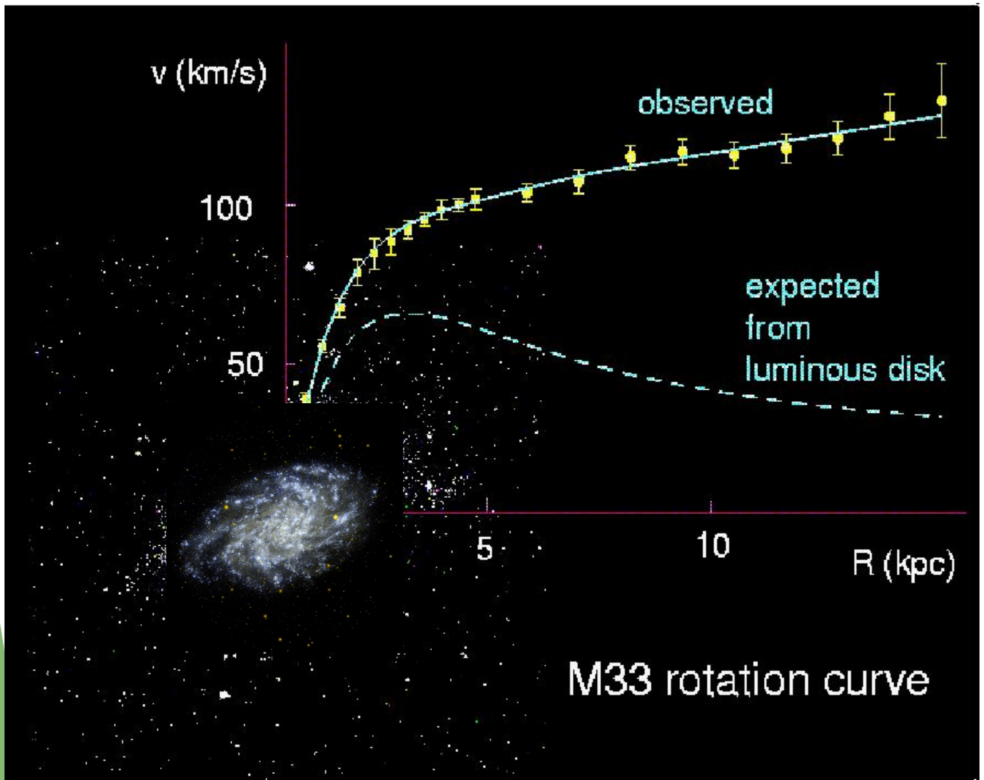


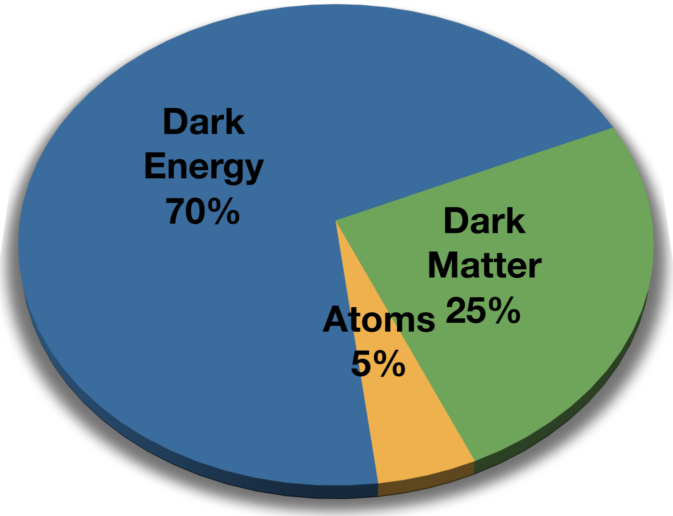


The coldest cubic meter in the known universe!!!

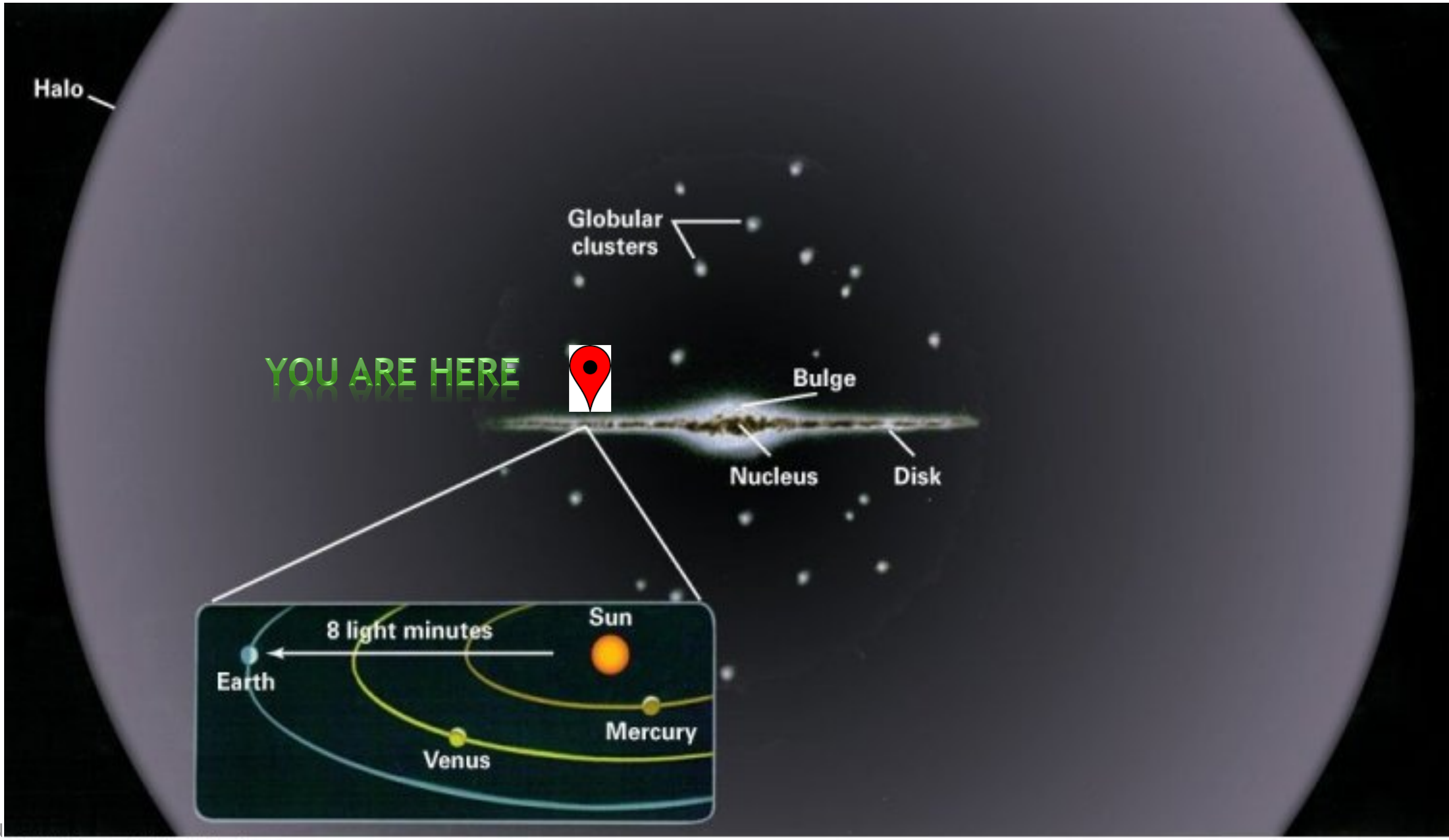
The Dark Side of the Universe

Dark Matter

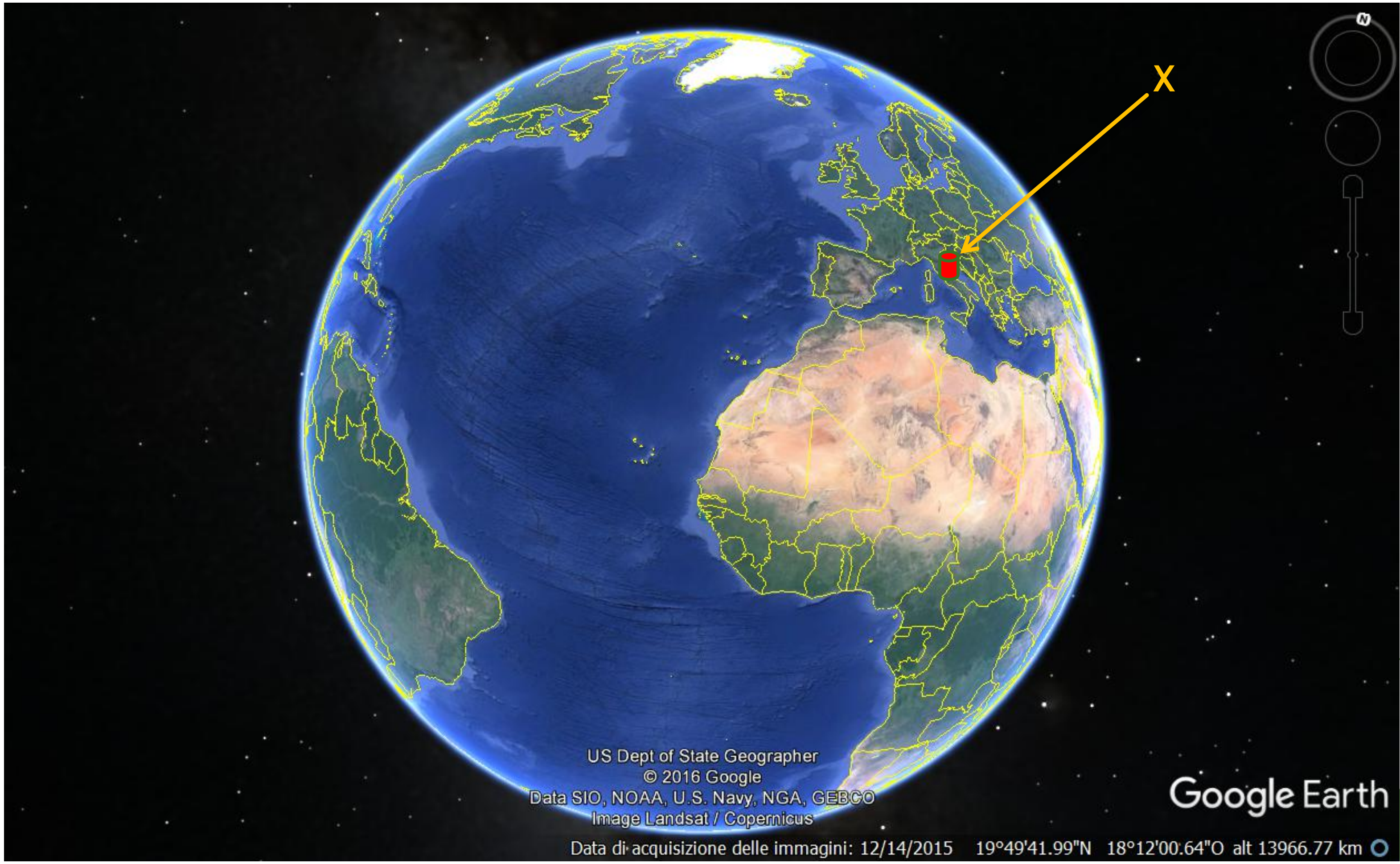

v (km/s)
observed
100
expected
from
luminous disk
50
5
10
R (kpc)
M33 rotation curve


Dark
Energy
70%
Dark
Matter
25%
Atoms
5%

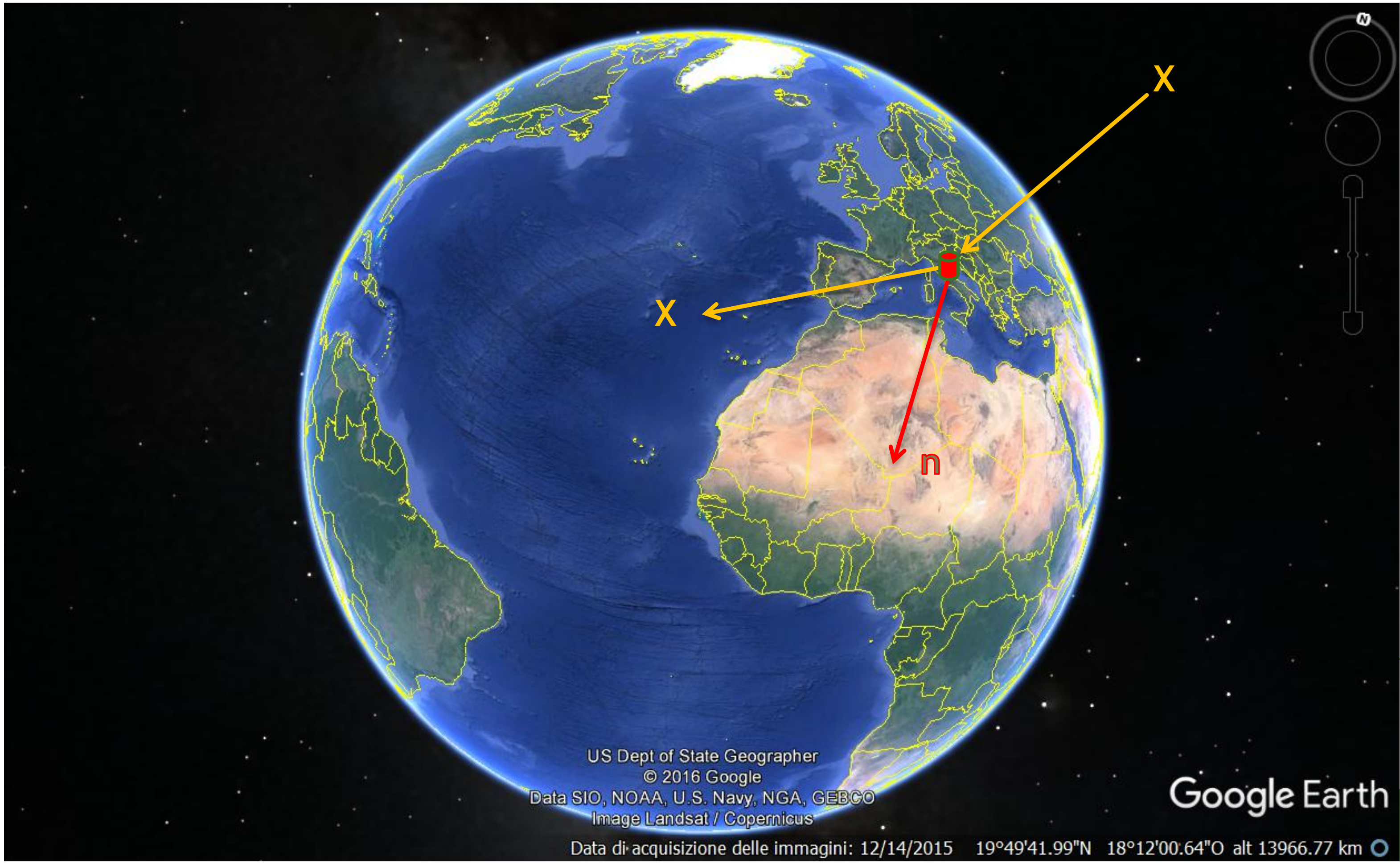
Dark Matter

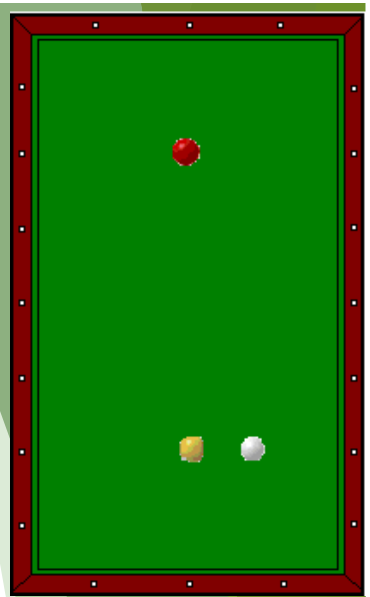

Halo
Globular clusters
YOU ARE HERE
Bulge
Nucleus
Disk
8 light minutes
Sun
Earth
Mercury
Venus

Dark Matter

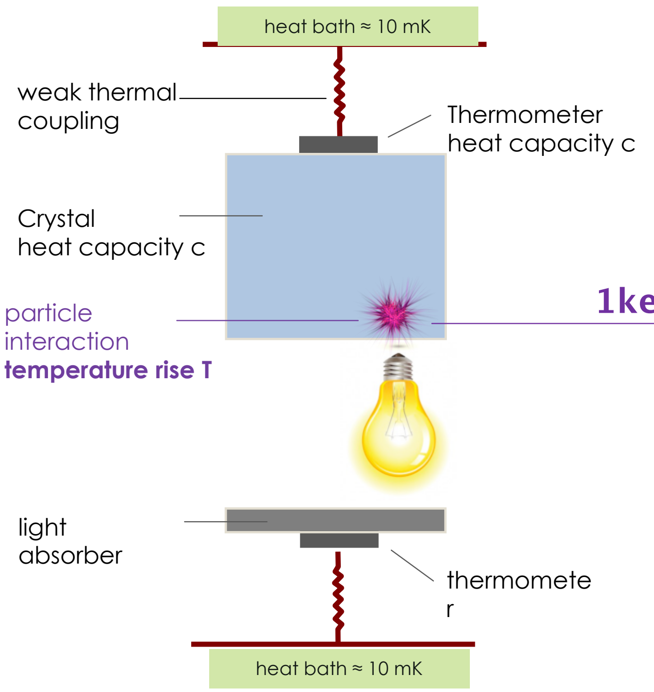

X
US Dept of State Geographer
© 2016 Google
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image Landsat / Copernicus
Google Earth
Data di acquisizione delle immagini: 12/14/2015 19°49'41.99"N 18°12'00.64"O alt 13966.77 km

Dark Matter


X
X
n
US Dept of State Geographer
© 2016 Google
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image Landsat / Copernicus
Google Earth
Data di acquisizione delle immagini: 12/14/2015 19°49'41.99"N 18°12'00.64"O alt 13966.77 km



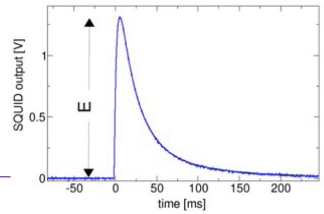
Dark Matter Experiment @LNGS



1keV → µK

Phonon signal (~ 90 %)

- (almost) independent of particle type
- precise measurement of the deposited energy

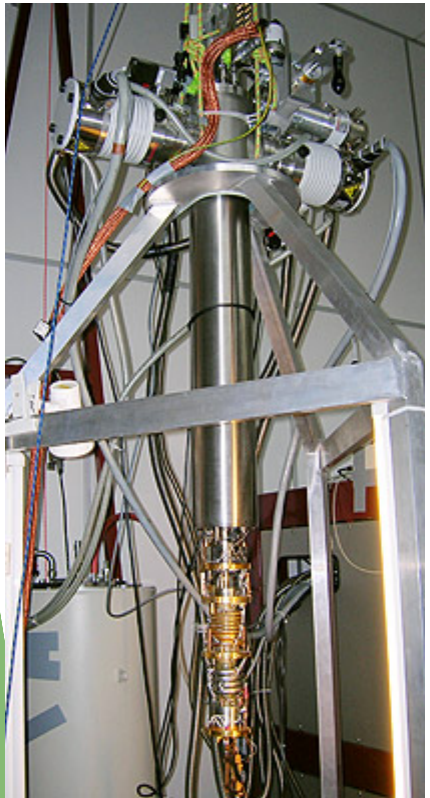


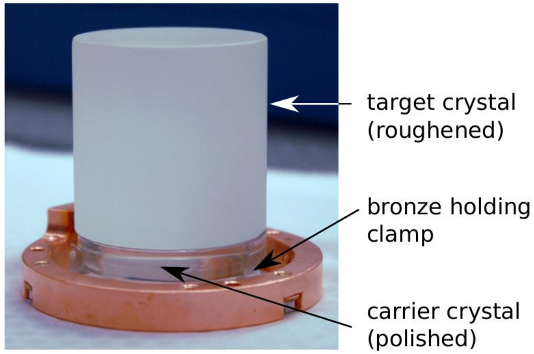
Scintillation light (few %)

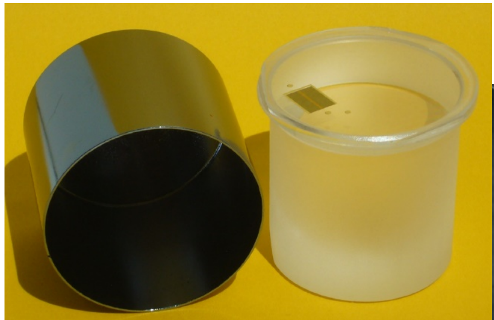
→ **add cryogenic light detector** for scintillation light detection

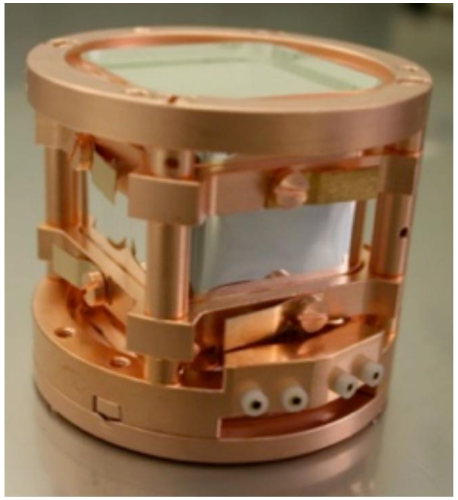
- amount of emitted light depends on particle type → LIGHT QUENCHING
- discrimination of interacting particle via the **ratio light to phonon signal** → ***LIGHT YIELD***

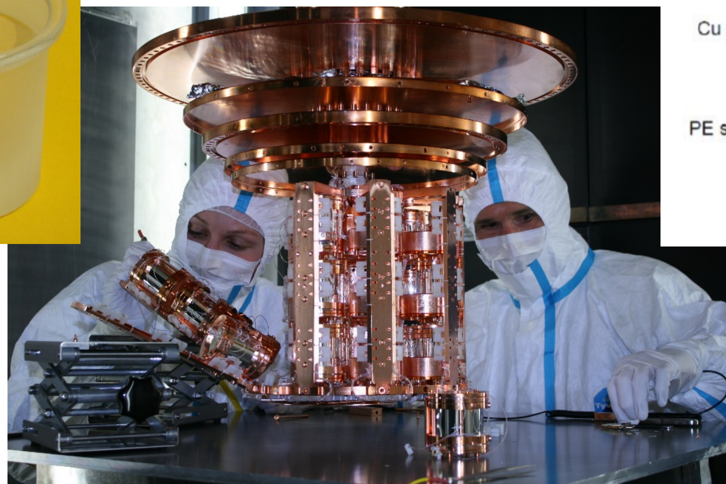
Dark Matter Experiment @LNGS

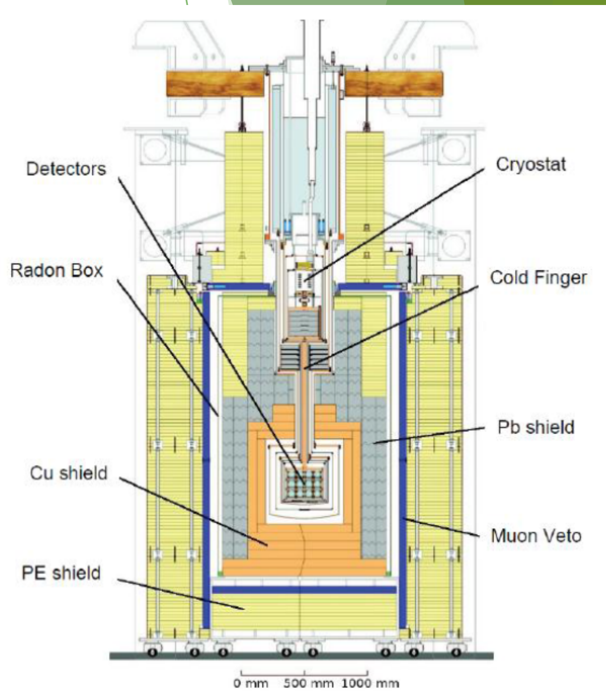










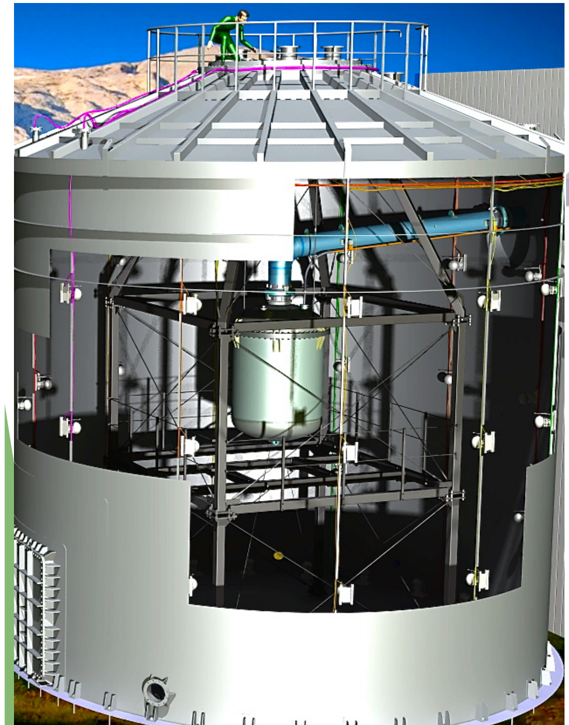


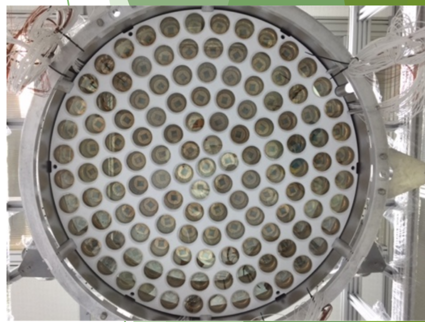
Dark Matter Experiment @LNGS

- **Science goal**: 100 x more sensitive than XENON100
- **Target/Detector**: 3.5 ton of Xe/ dual-phase TPC with 250 high QE - low radioactivity PMTs.
- **Shielding:** water Cherenkov muon veto.
- **Cryogenic Plants:** Xe cooling/purification/ distillation/storage systems designed to handle up to 10 ton of Xe. Upgrade to a larger detector ***(XENONnT)*** planned for 2018
- **Status:** All systems successfully tested. Commissioning of detector ongoing. First science run this Fall.
- **Sensitivity Goal: 2×10^{-47} cm^2 @ 50 GeV in 2ty**

XENON

Dark Matter Experiment @LNGS





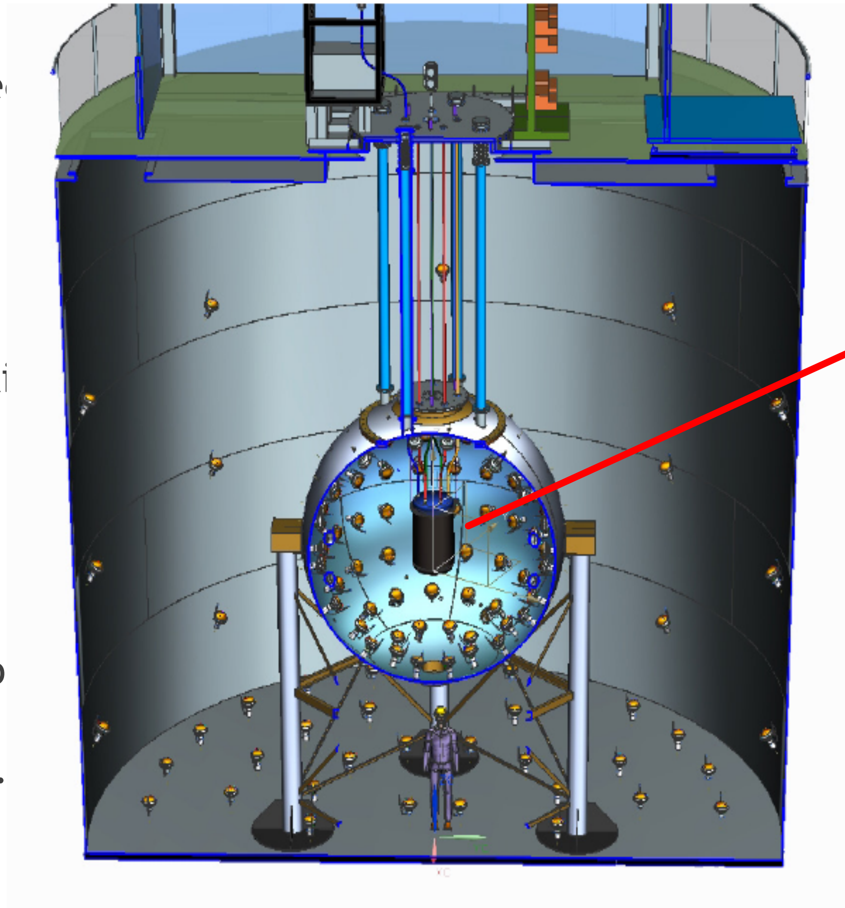
DarkSide50

Dark Matter Experiment @LNGS

- Dual phase TPC with 46 kg 39Ar-deplete
LAr (1400 background reduction factor) inside 30 tons LS neutron veto inside a 1000 tons water Cherenkov muon veto
- 1st result from 2616 kg d with UAr

-> no event in search region . Still taki
data

- Proposed **DS20k.** TDR in preparation. Large R&D effort on SiPMs and other technologies.
- Construction of the very large distillatio facility (350 m column) placed inside a coal mine (Seruci, Sardinia) has started.



N. Di Marco

Dark Matter Experiment @LNGS

The DAMA/LIBRA set-up ~250 kg NaI(Tl) (Large sodium Iodide Bulk for RAre processes)

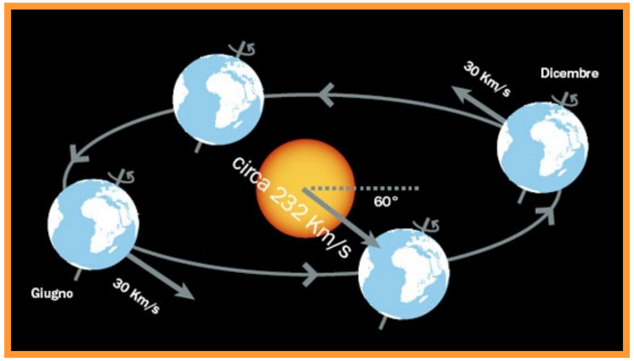
As a result of a 2nd generation R&D for more radiopure NaI(Tl) by exploiting new chemical/physical radiopurification techniques (all operations involving - including photos - in HP Nitrogen atmosphere)

Residual contaminations in the new DAMA/LIBRA NaI(Tl) detectors: ^{232}Th, ^{238}U and ^{40}K at level of 10^{-12} g/g

- Radiopurity, performances, procedures, etc.: NIMA592(2008)297, JINST 7 (2012) 03009
- Results on DM particles, Annual Modulation Signature: EPJC56(2008)333, EPJC67(2010)39, EPJC73(2013)2648. Related results: PRD84(2011)055014, EPJC72(2012)2064, IJMPA28(2013)1330022, EPJC74(2014)2827, EPJC74(2014)3196, EPJC75(2015)239, EPJC75(2015)400
- Results on rare processes: PEPv: EPJC62(2009)327; CNC: EPJC72(2012)1920; IPP in ^{241}Am: EPJA49(2013)64

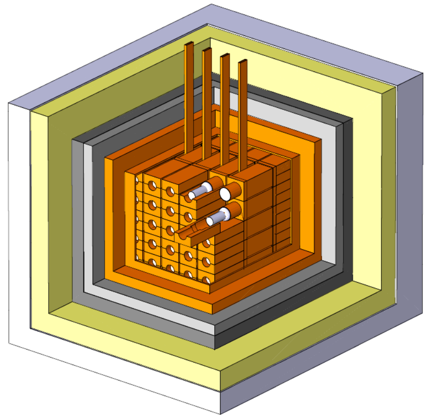
DAMA/LIBRA

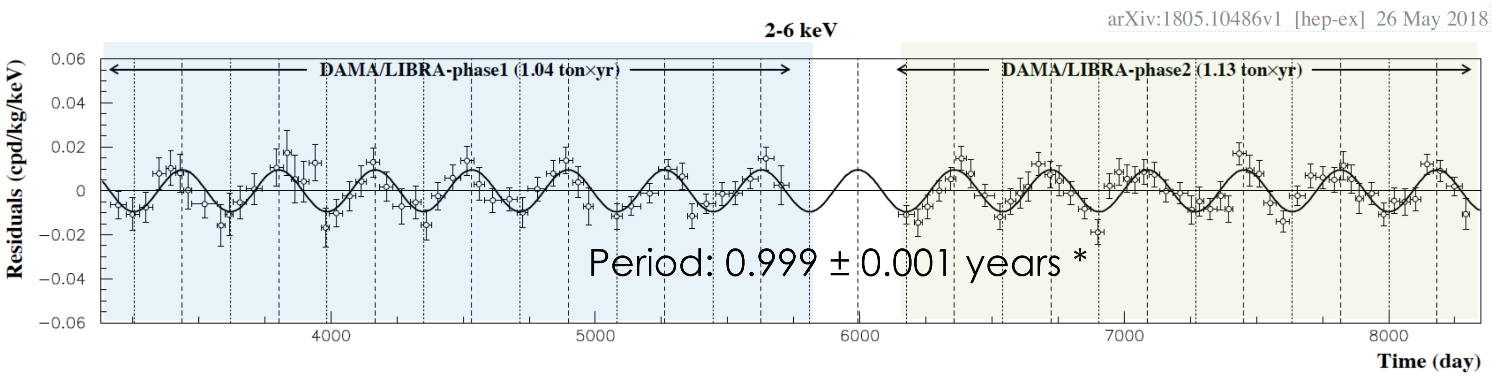
Dark Matter Experiment @LNGS



- 250 Kg NaI(Tl)
- Threshold 1 KeVee
- Running since 1996

Total exposure: 2.17 tonne years (phase 1 + 2)
Statistical significance: >11.9 σ
(combined with DAMA/NaI: 2.46 tonne years and 12.9σ !!!!)
Phase: 25^{th} May +/- 5 days (cosine peaking June 2^{nd})





Period: 0.999 ± 0.001 years *

LNGS Outreach activities

- Sharper: Notte Europea dei Ricercatori
- Open Day
- FameLab
- Pint Of Science
- Gran Sasso Video Game

https://www.gransassovideogame.it/