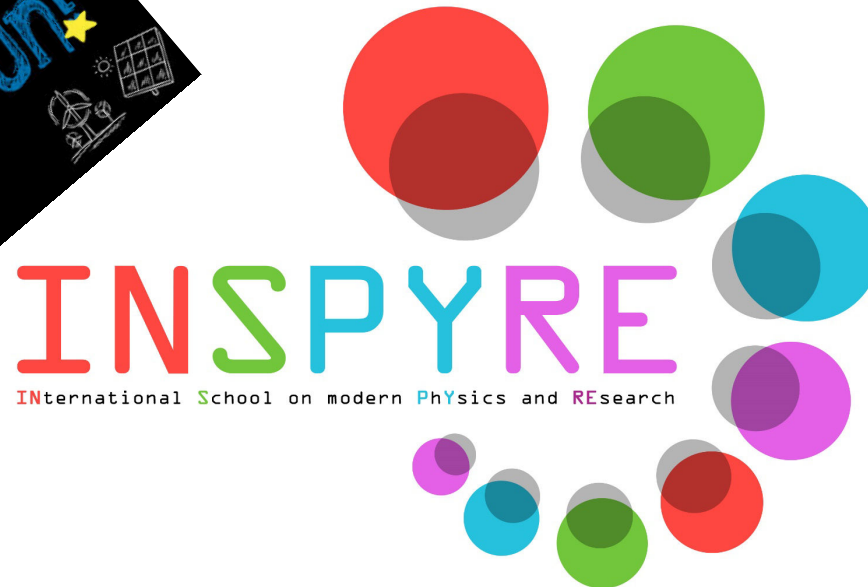


Get **INSPYRED**

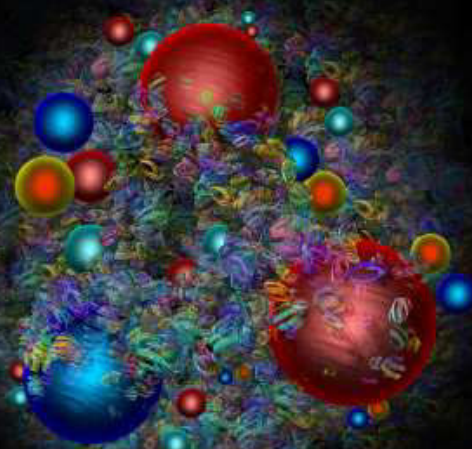


**“From Quarks to Black Holes:  
let’s get INSPYRED!”**

***27-31 March 2023***

**Catalina Curceanu  
LNF-INFN**

# FROM QUARKS TO BLACK HOLES: LET'S GET INSPYRED!



## **Directors**

Catalina Curceanu  
Susanna Bertelli

## **Local organizing committee**

Sara Arnone  
Debora Bifaretti  
Elena Patrignanelli  
Adriana Postiglione  
Sara Reda

**MARCH 27 – 31, 2023**

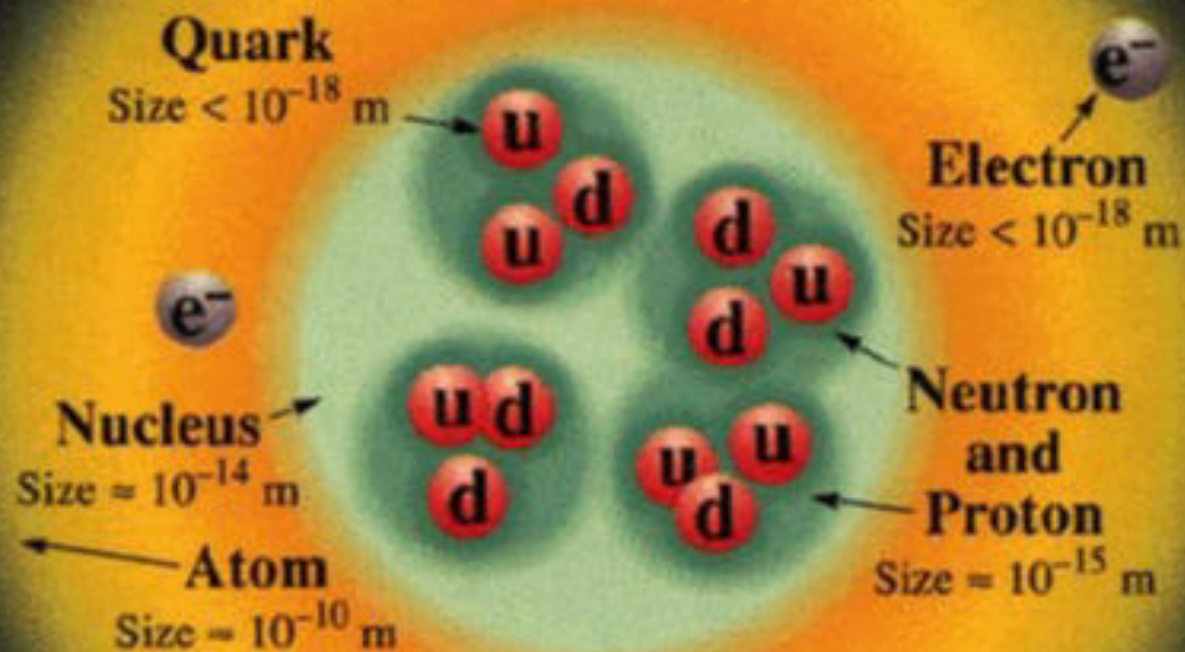
**INFN - LNF**

**AUDITORIUM B. TOUSCHEK**



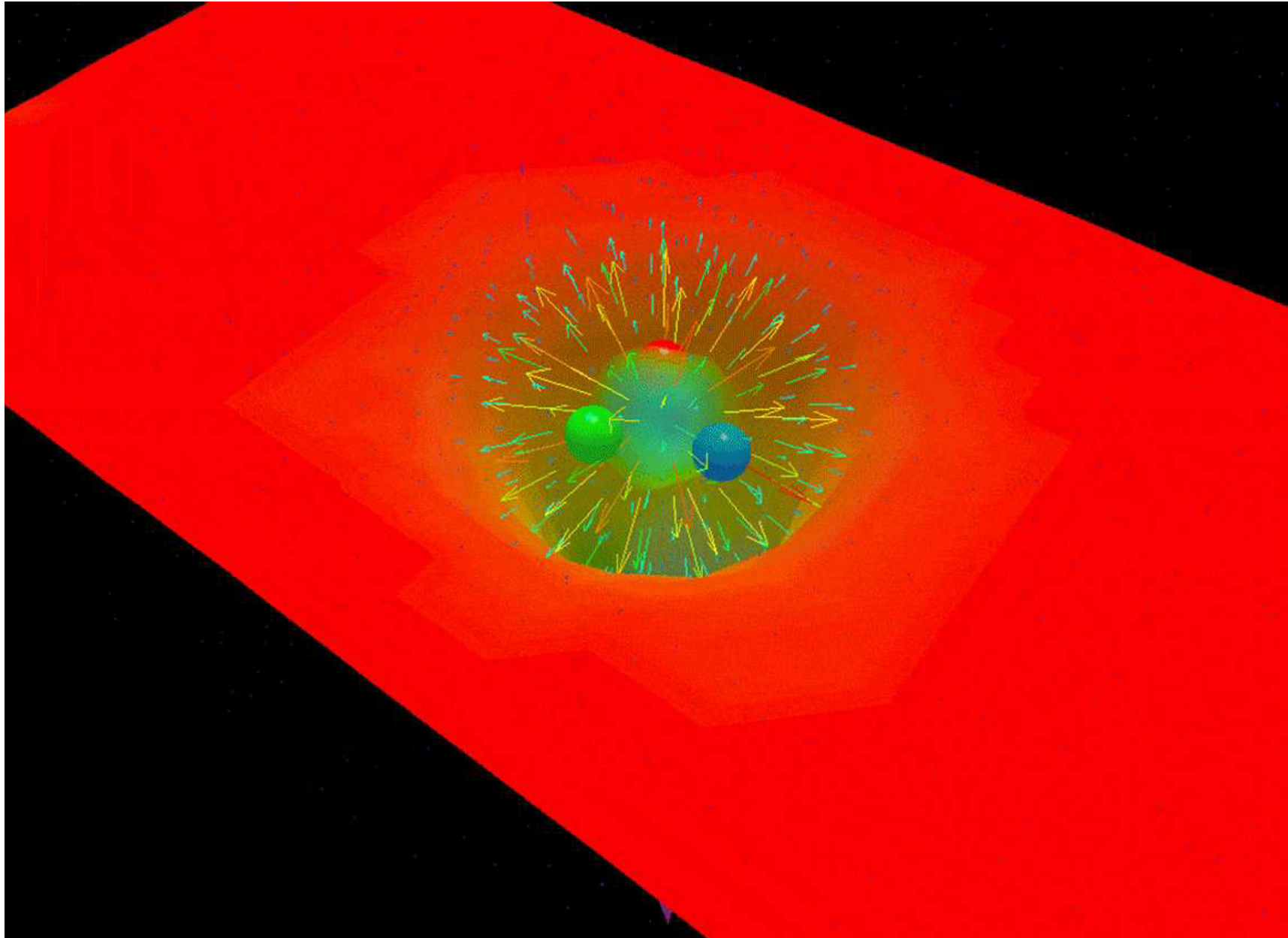


## Structure within the Atom

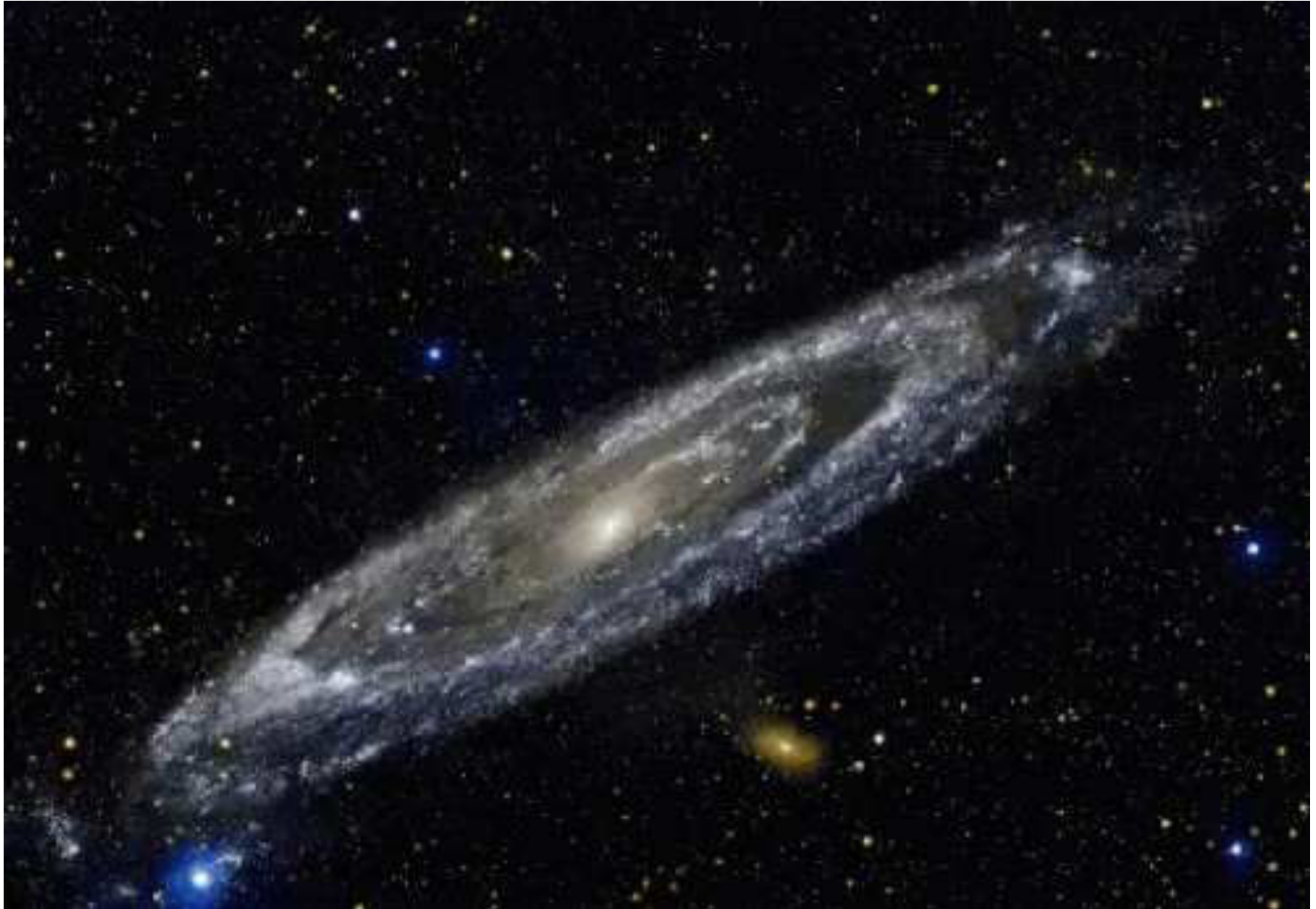


If this picture were drawn to the scale given by the protons and neutrons, then the quarks and electrons would be less than 0.1 mm in size and the entire atom would be about 10 km across.

# Quarks



# Stars









# INSPYRE 2019

International School on modern PhYsics and REsearch

“Challenges in Modern Physics and Quantum Technologies”



Laboratori Nazionali di Frascati  
Auditorium B. Touschek

**9<sup>th</sup> Edition, April 1<sup>st</sup> - 5<sup>th</sup> 2019**

## Directors

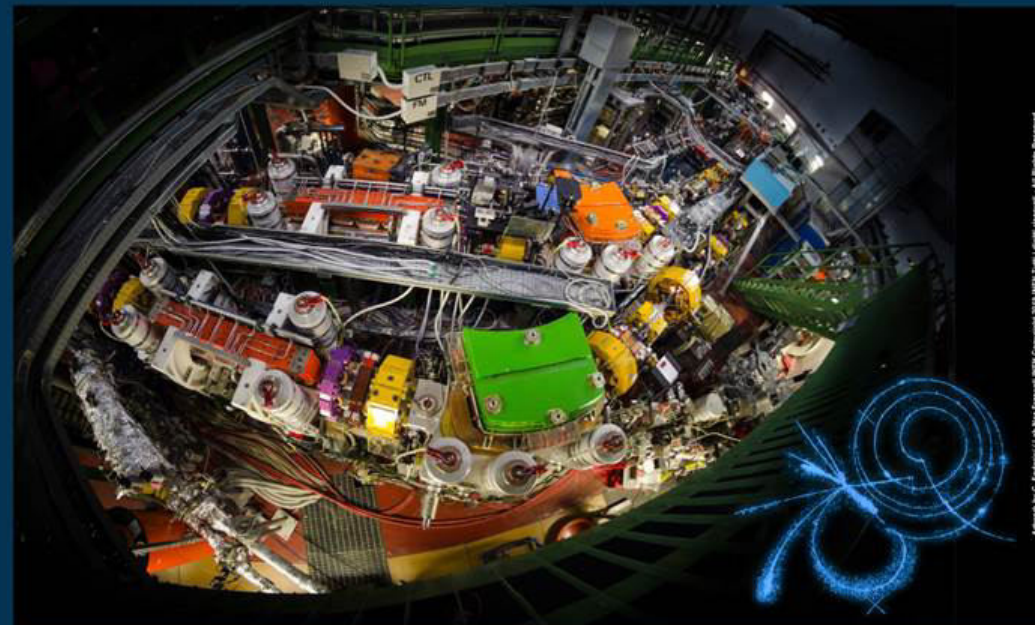
Catalina Curceanu, Rossana Centoni

<http://edu.lnf.infn.it/inspyre-2019/>

## Organization

Camilla Paola Maglione, Debora Bifaretti

The INSPYRE 2019 School is dedicated to the hottest topics of Modern Physics and to the powerful Quantum Technologies. About 100 students in last years of high school, coming from all around the world, will take part to lectures given by experts, hands-on experiments and will visit the main experiments and accelerating facilities of LNF-INFN. INSPYRE 2019 will host a two-days dedicated event organized in the framework of the European COST Action CA15220 Quantum Technologies in Space.



Approved by C. Farnese / LNF-INFN Frascati 2019 INFN Logo / INFN-INFN - All Rights Reserved.



SIDS-Ufficio Educazione e Divulgazione Scientifica

Last time in presence: 2019!  
2020 – 2022 - online  
We missed you!

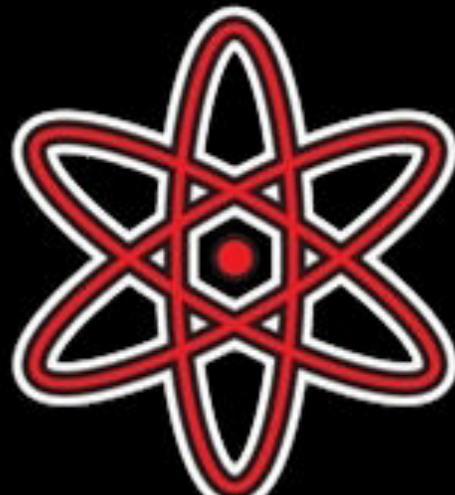
2019: About 90 students  
of 15 nationalities  
from 46 schools  
all around the world!  
2023: 81 students

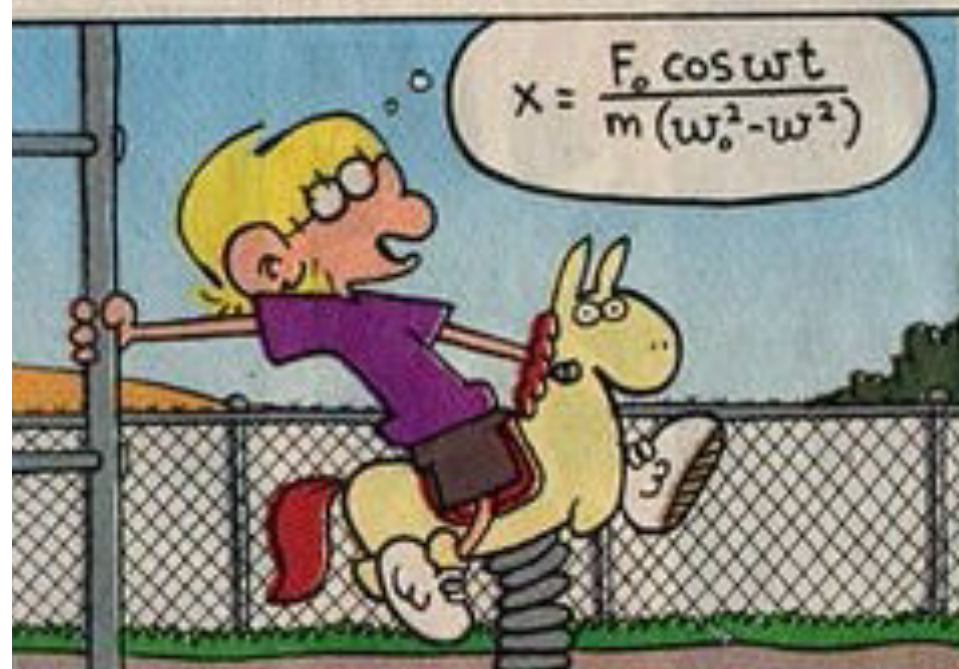
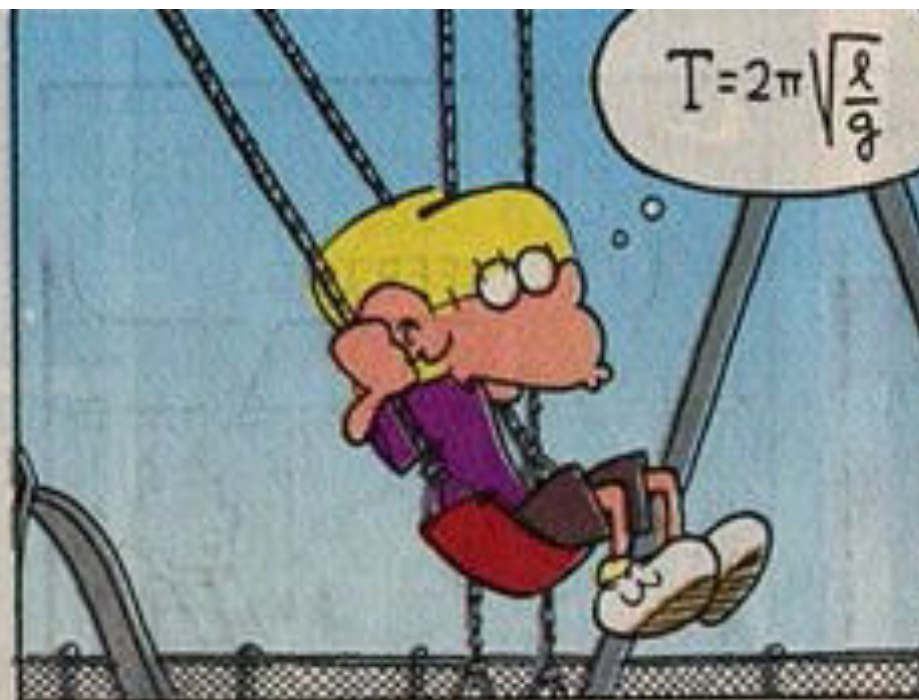


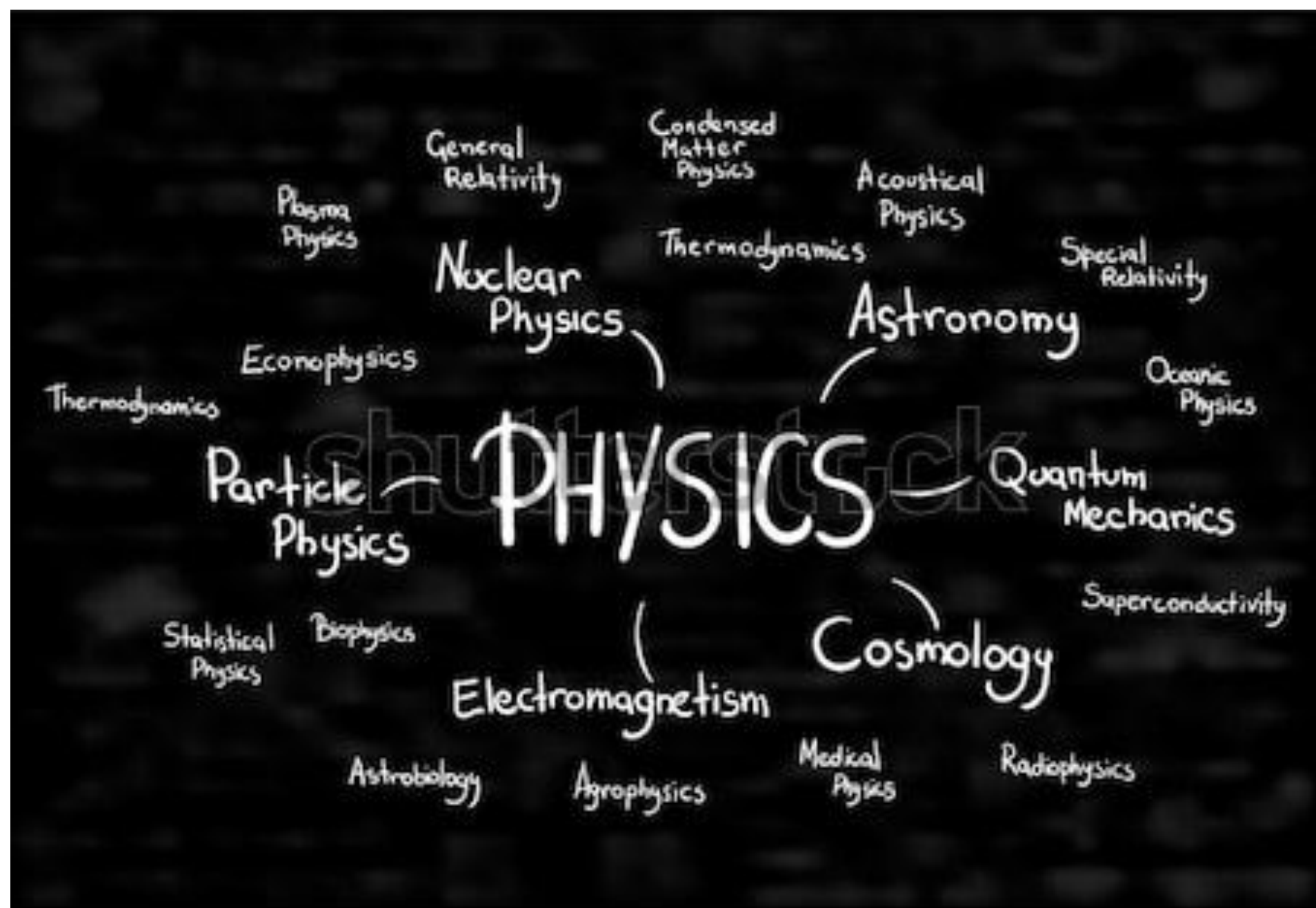
**EVERYTHING HAPPENS  
FOR A REASON  
AND THAT REASON  
IS**

**EVERYTHING HAPPENS  
FOR A REASON  
AND THAT REASON  
IS USUALLY**

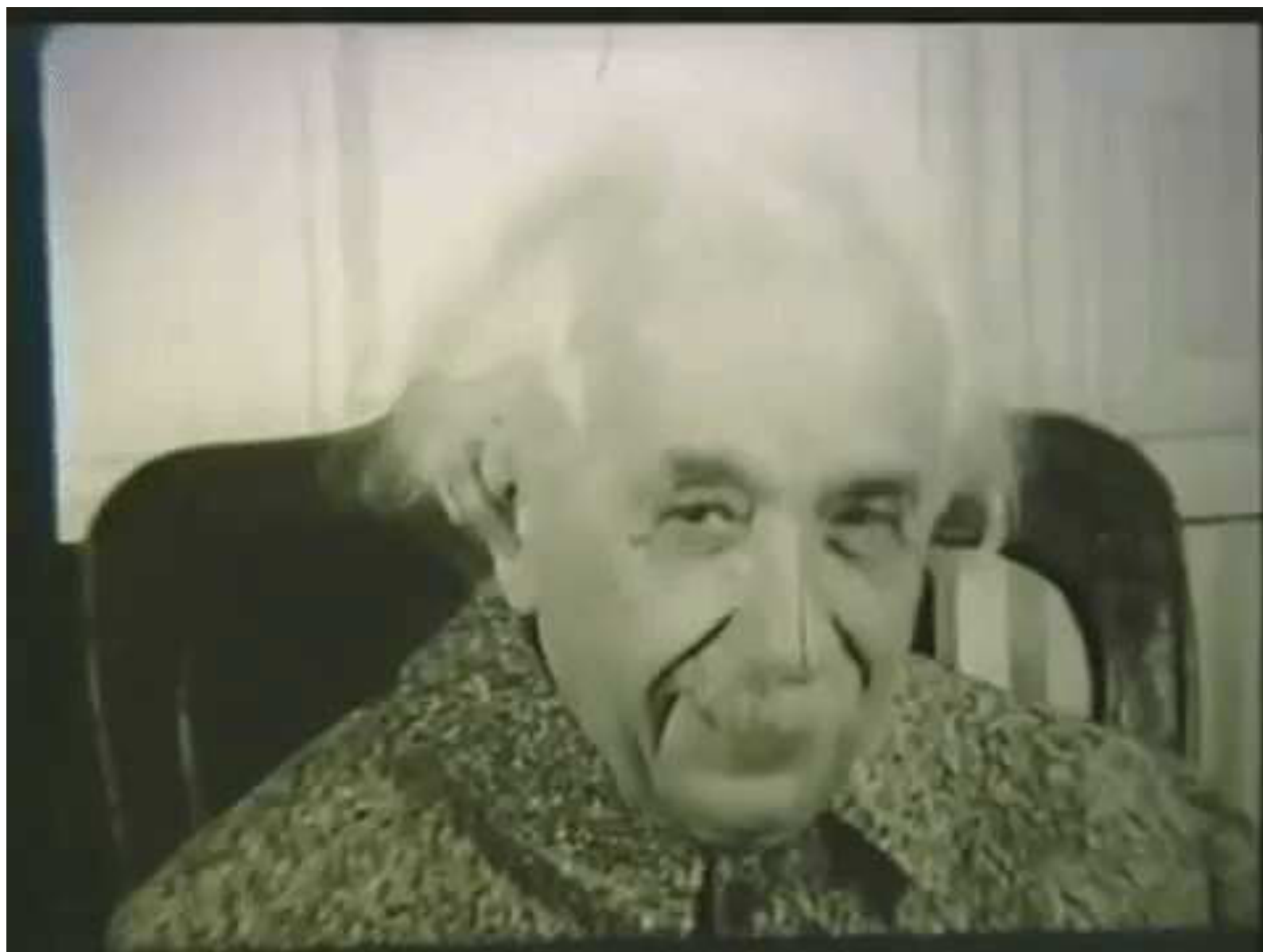
**PHYSICS**













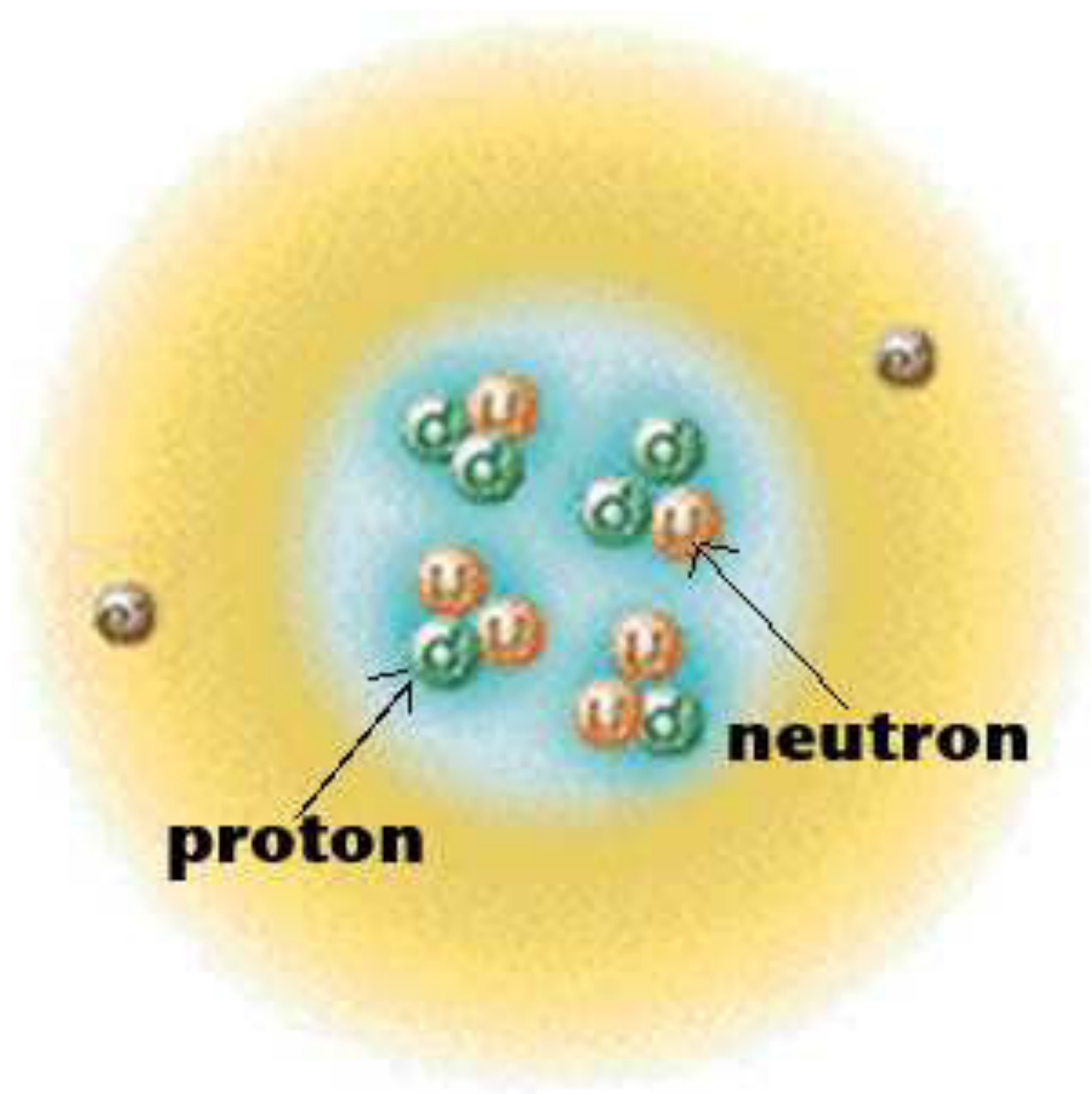


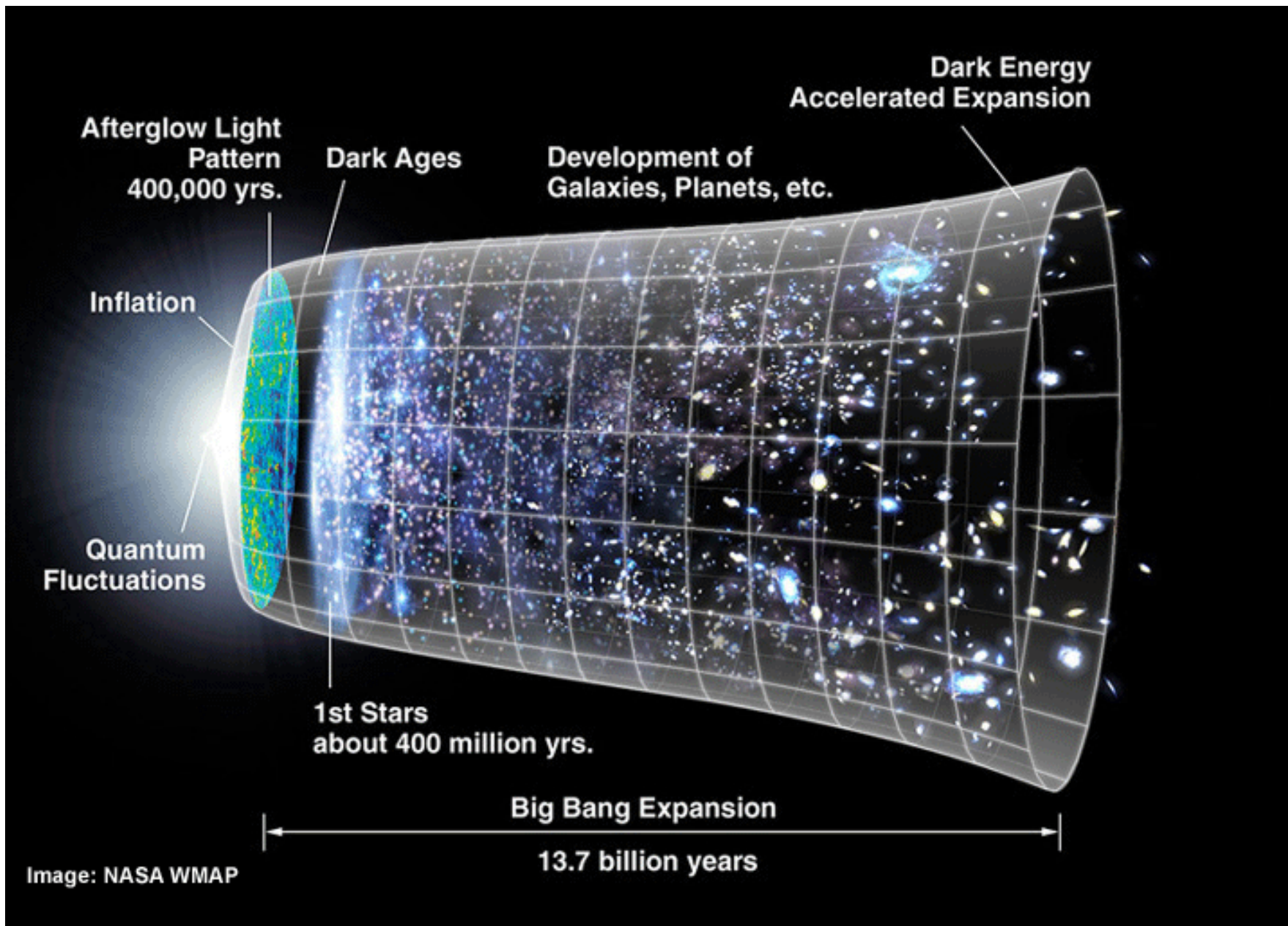




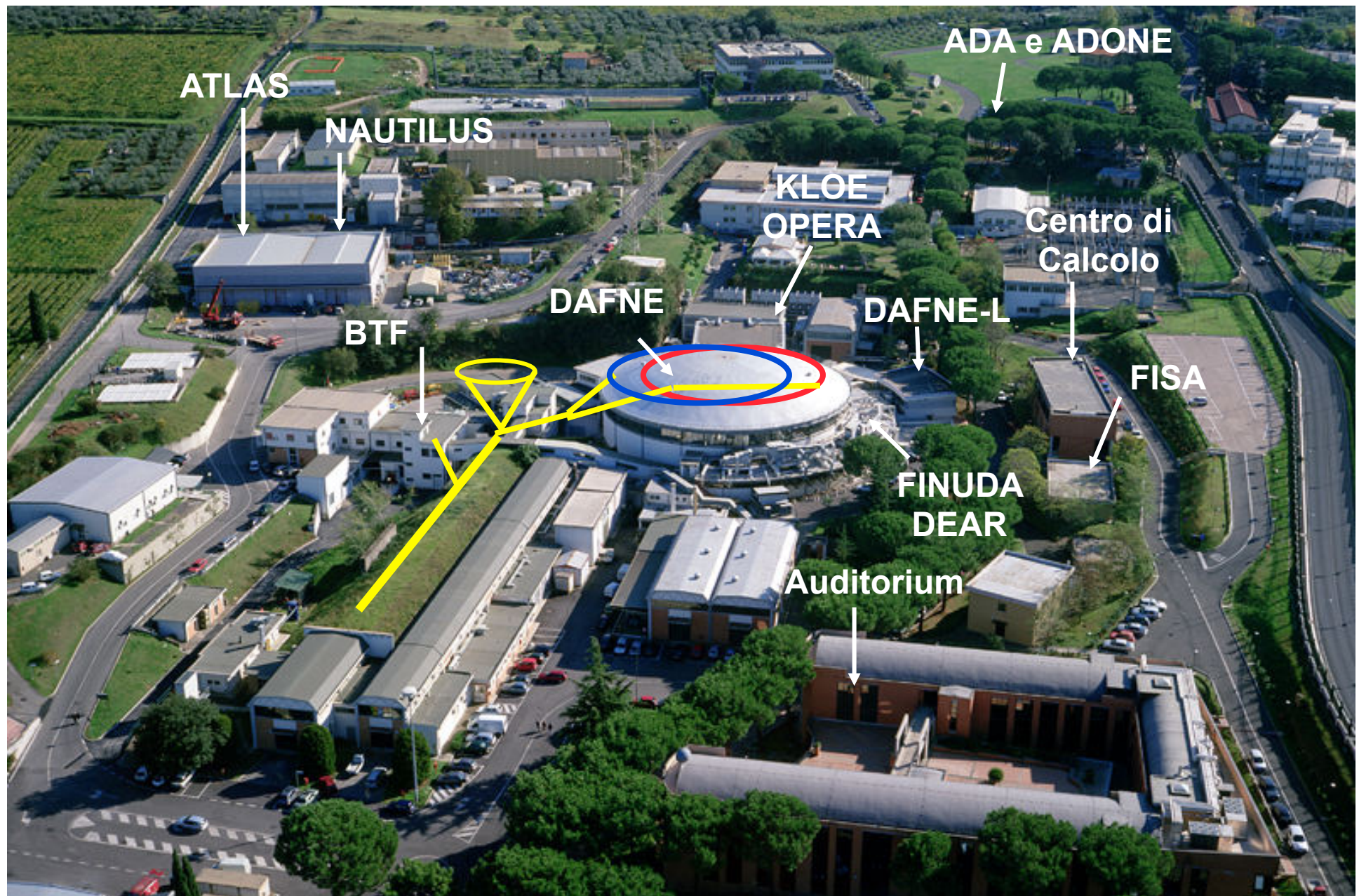
# Inside LNF-INFN







## ***Laboratori Nazionali di Frascati***





# ***Istituto Nazionale di Fisica Nucleare***

The INFN promotes, coordinates and performs  
scientific research in the sub-nuclear,  
nuclear and astroparticle physics, as well as  
the research and technological development  
necessaries to the activities in these sectors,  
in strong connection with the University and  
in the framework of international cooperation  
and confrontation



**1951**

4 University Sections  
Milano, Torino, Padova, e Roma

**1957**

Laboratori Nazionali di  
Frascati



**Frascati**



**Legnaro**

**Gran Sasso**



**19 Sections**  
**11 Related Groups**  
**4 National Laboratories**



**VIRGO-EGO**  
**European**  
**Gravitational**  
**Observatory**



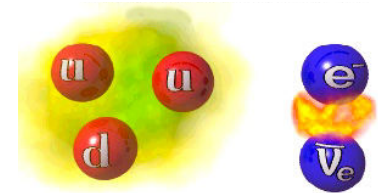
**Laboratori del Sud**  
**(Catania)**



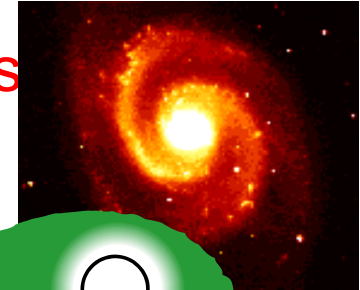
# What are the activities performed at Laboratori Nazionali di Frascati?



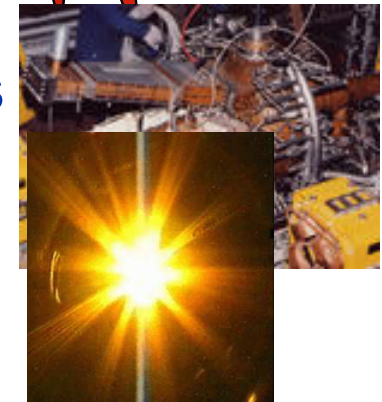
Fundamental research



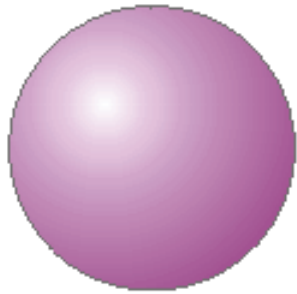
- Studies of the **ultimate matter structure**
- Search for **gravitational waves**
- Developments of **theoretical models**



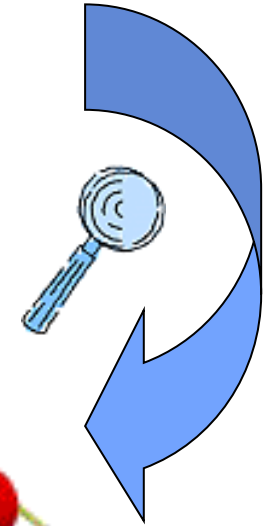
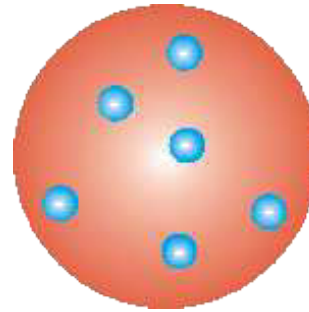
- Development and construction of **particle detectors**
- Studies and development of **accelerating techniques**
- Material studies and **bio-medical research** with the synchrotron light
- Development and support for **computing systems and nets**



L'atomo all'inizio del '900



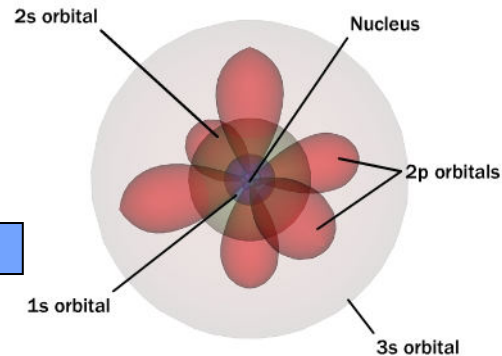
L'atomo di Thompson



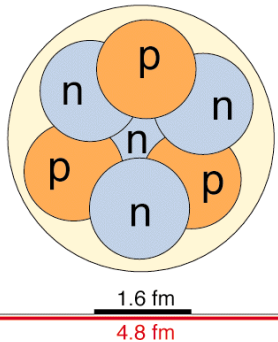
L'atomo di Rutherford e Bohr



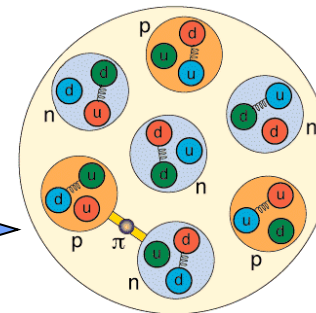
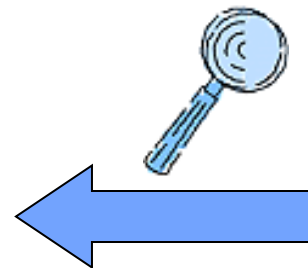
L'atomo quantistico



©2001 How Stuff Works



La struttura del nucleo

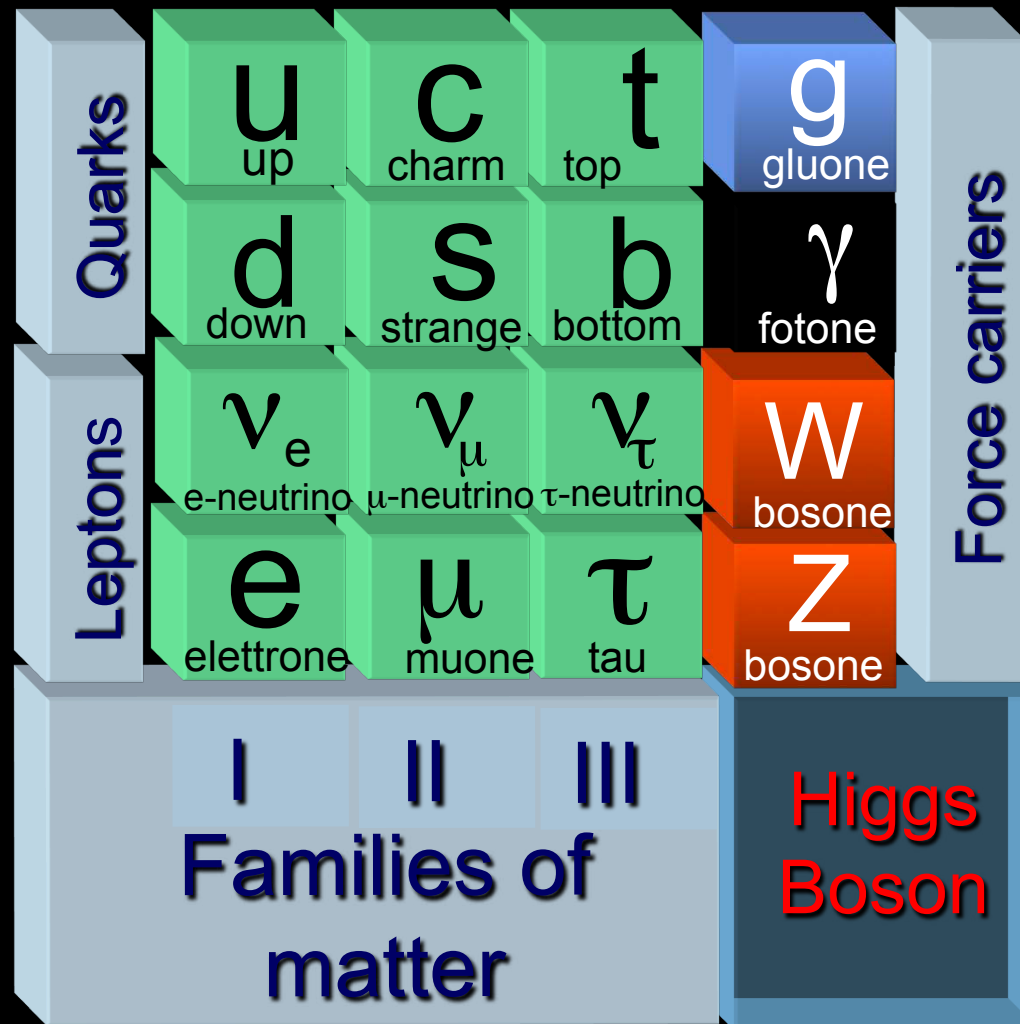


Il nucleo oggi

# The Standard Model

# Fermions

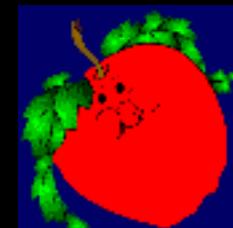
# Bosons



# Gravity



# The... “opera Ghost”



# ***Frascati National Labs (LNF)***

<b>Total Staff</b> of which: <b>364</b>	<b>Researchers</b>  <b>98</b>	<b>Technologist/ Engineers</b>  <b>57</b>	<b>Technicians</b>  <b>170</b>	<b>Administration/ Services</b>  <b>39</b>
<b>External Users</b> <b>546</b>	<i>Italian</i> <b>346</b>		<i>Foreign</i> <b>200</b>	
<b>Visitors</b> <b>3960</b>	<b>Stages</b> <b>310</b>	<b>Conference Workshops</b>  <b>17</b>	<b>Participants to Conf. / Work.</b>  <b>776</b>	<b>Master Courses</b> <b>1 (27 positions)</b>



**LNF**

**DAFNE-light**

**LINAC**

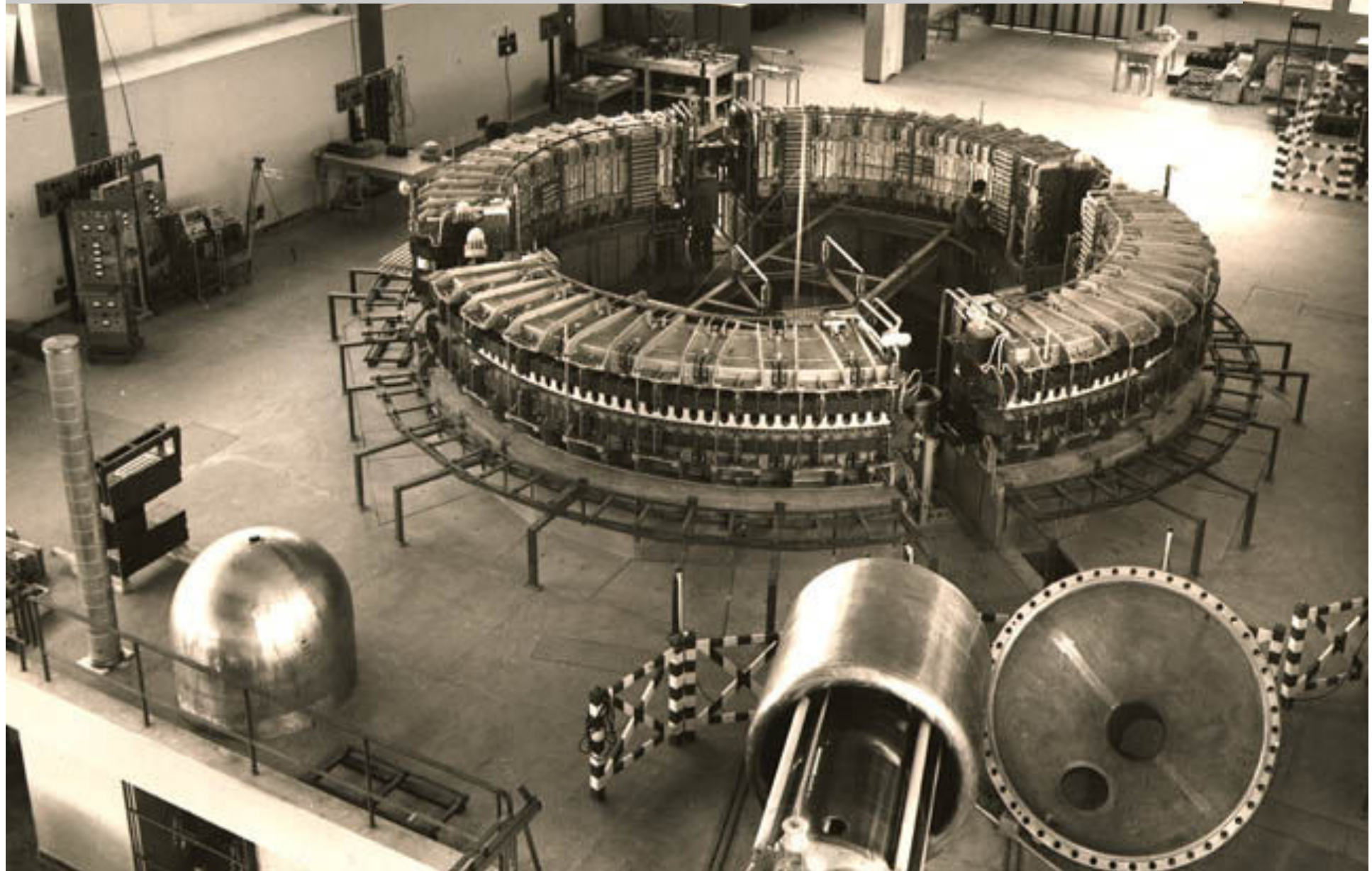
**DAFNE**

**BTF**

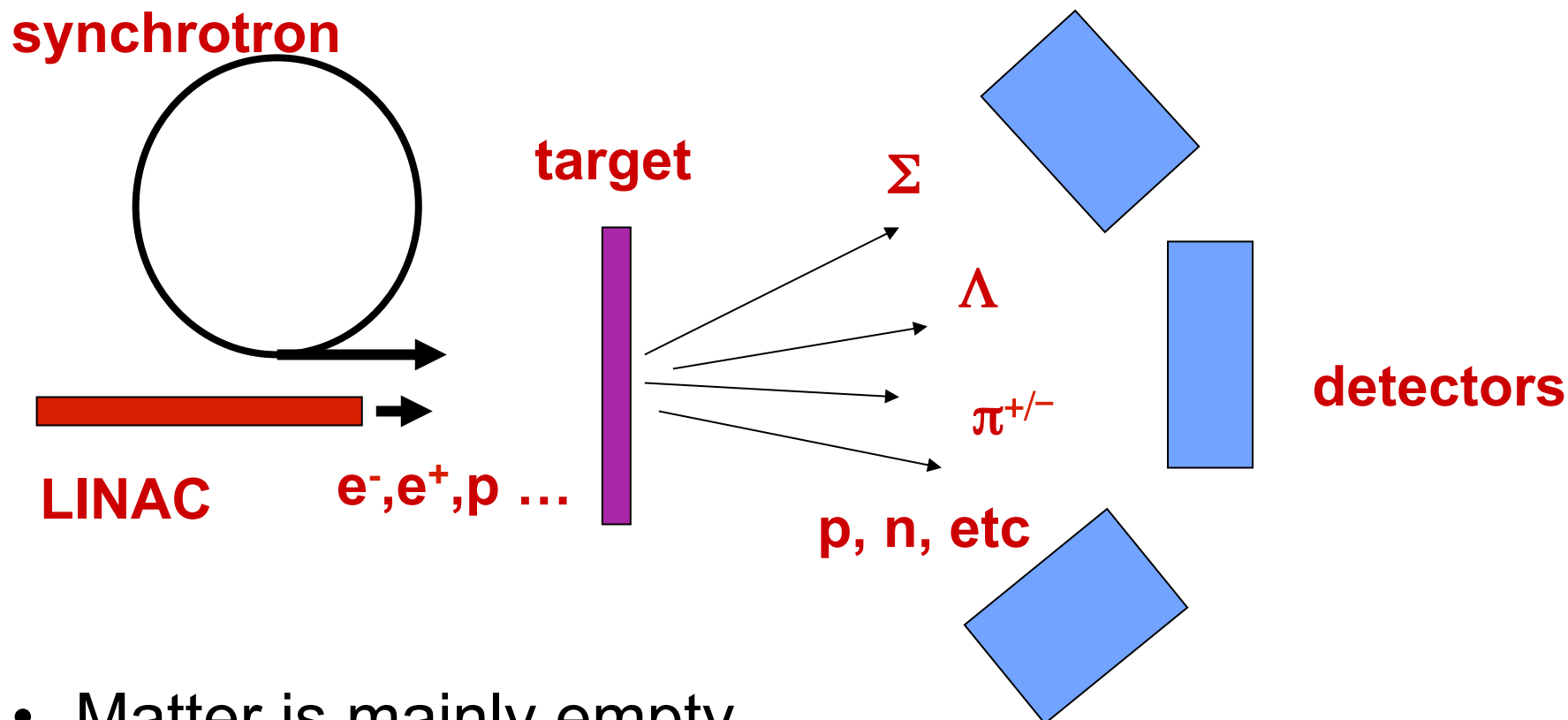
**SPARC**

**FLAME**

## Frascati electrosynchrotron 1959-1975

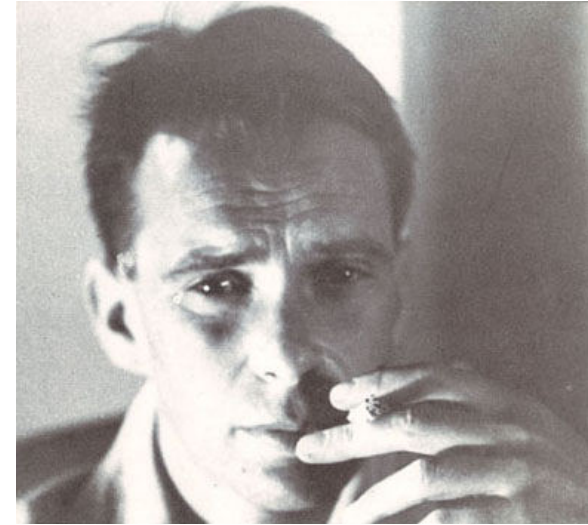
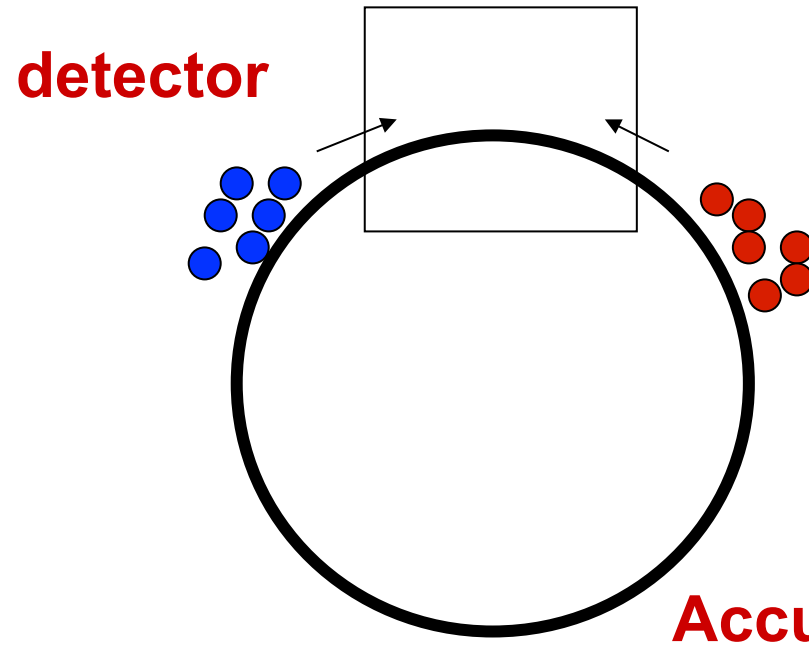


# *Observing on fixed target*



- Matter is mainly empty
- All those particles which did not interact get lost
- Energy loss by moving the center of mass
- Target is complex

# *First Frascati's idea*



*Bruno Touschek*

- The non-interacting particles can be re-used in the successive rounds
- Collisions are performed in the center of mass frame
- The circulating particles can be either elementary or complex (nuclei or atoms)

# *Second Frascati's idea*

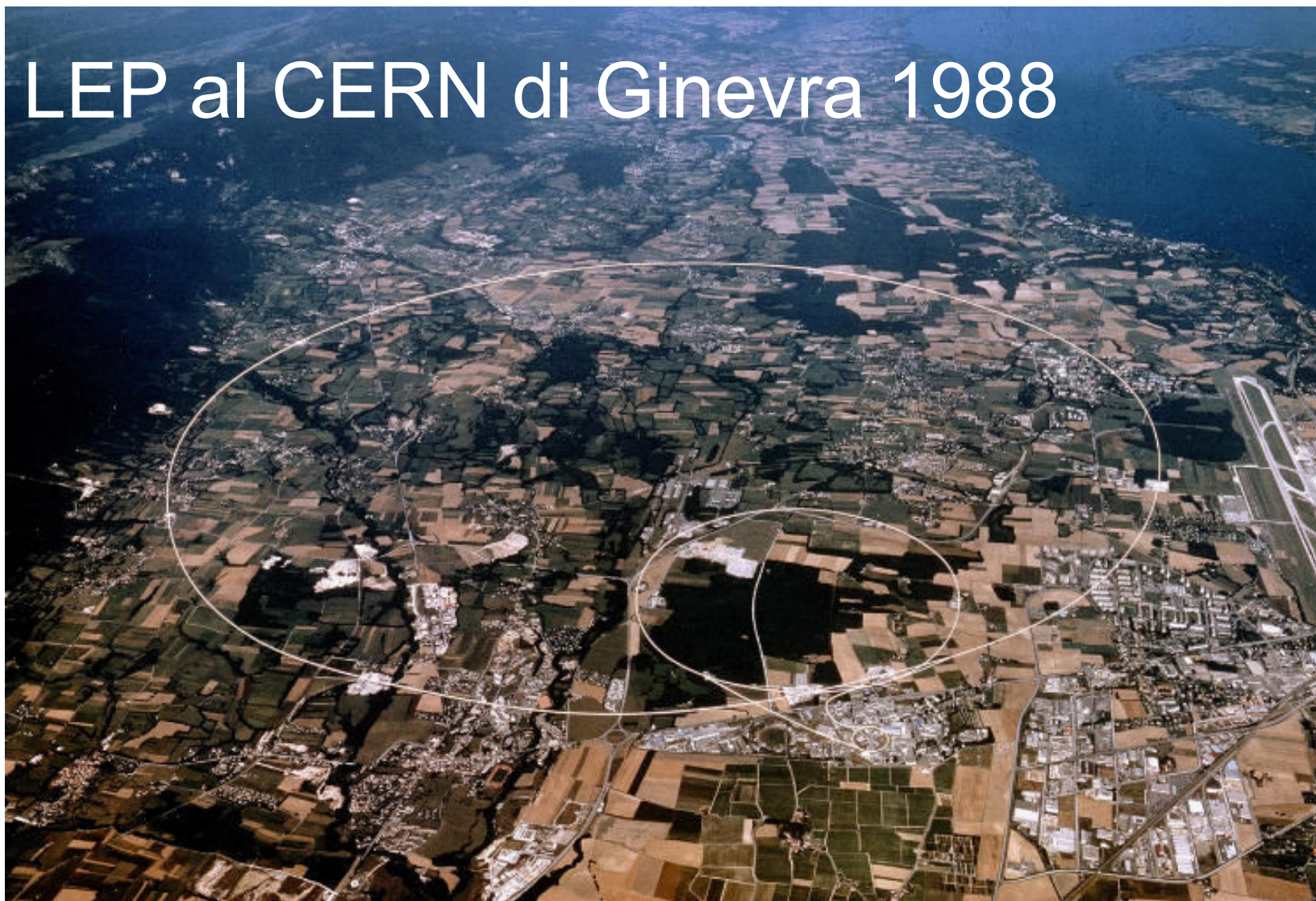


$$E = m c^2$$

Bigger the energy is, more and more particles can be studied

# ***Matter-antimatter colliders***

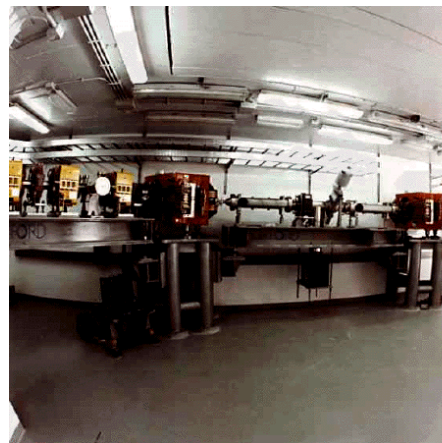
LEP al CERN di Ginevra 1988



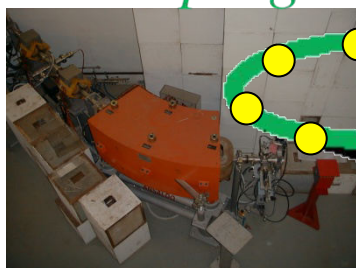
LHC at Cern (pp)



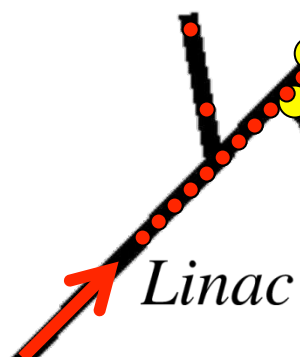
# DAΦNE



*Damping ring*



*Test beam*

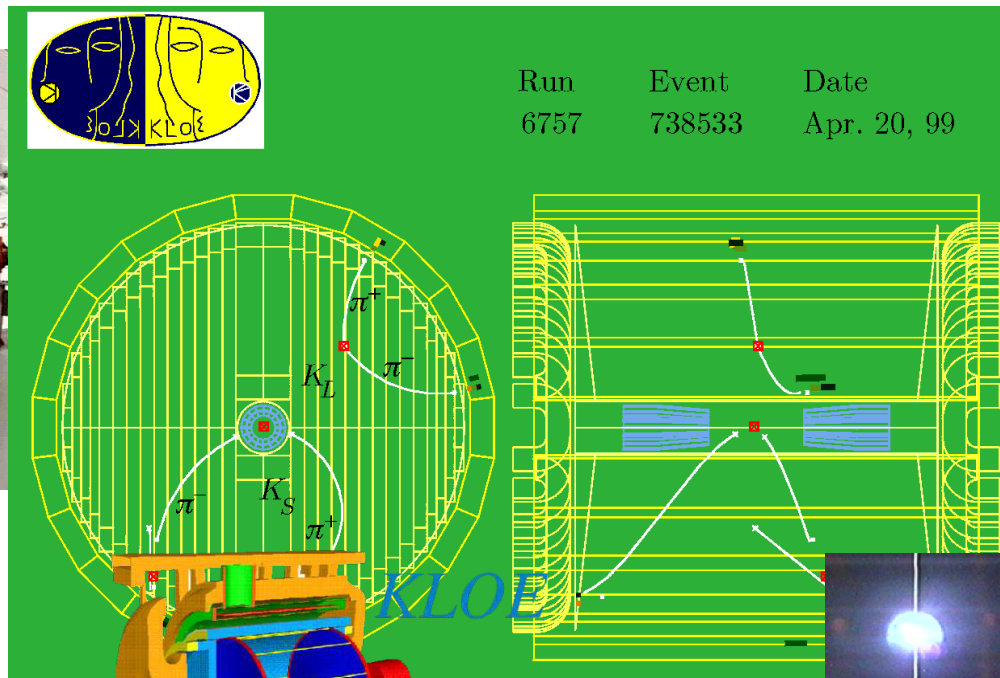


*Linac*

*Main rings*



*DEAR  
FINUDA*



Run  
6757

Event  
738533

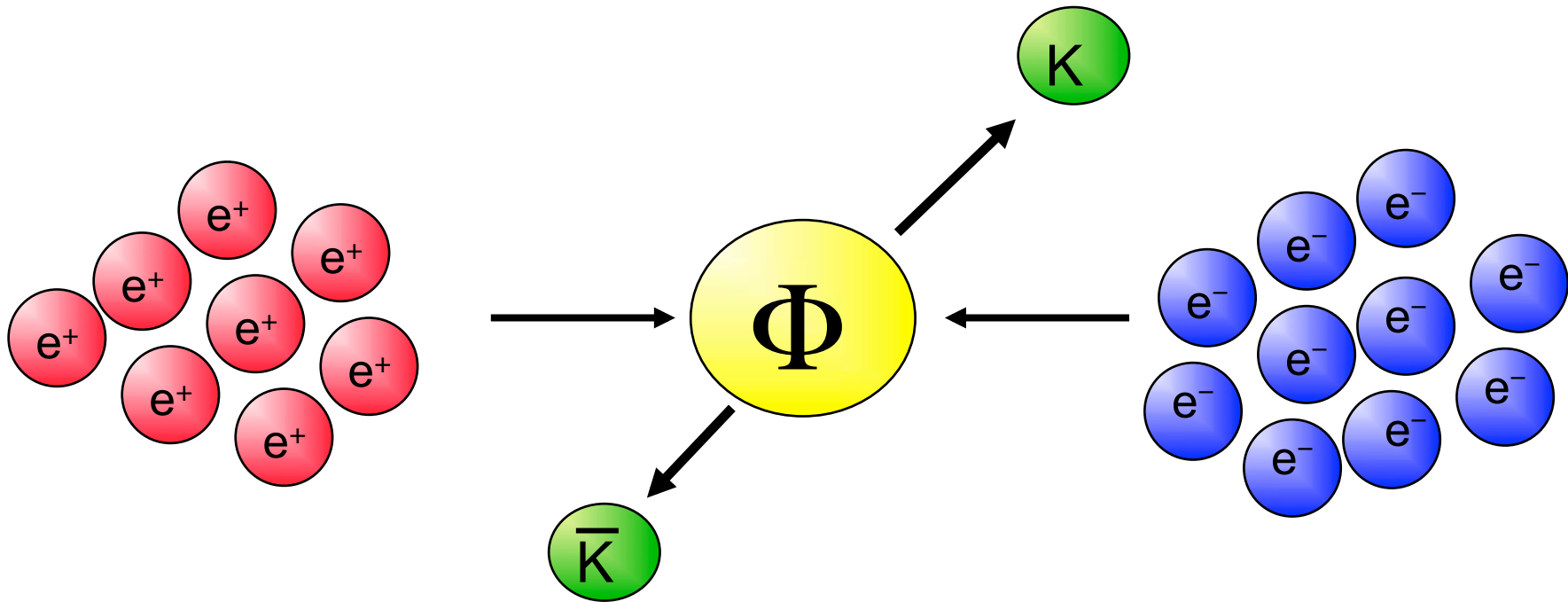
Date  
Apr. 20, 99

*DAFNE-Light*



# *Physics at DAΦNE*

Out of the electron – positron collisions the  $\Phi$  meson can be produced; it decays immediately in other two particles, the  $K$ -mesons (kaons). The kaons can be both neutrals or charged.



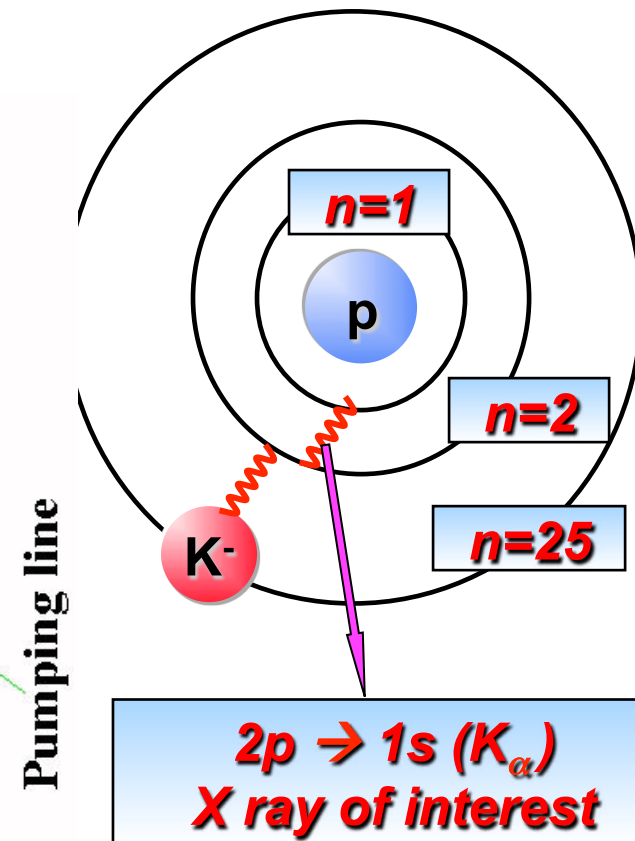
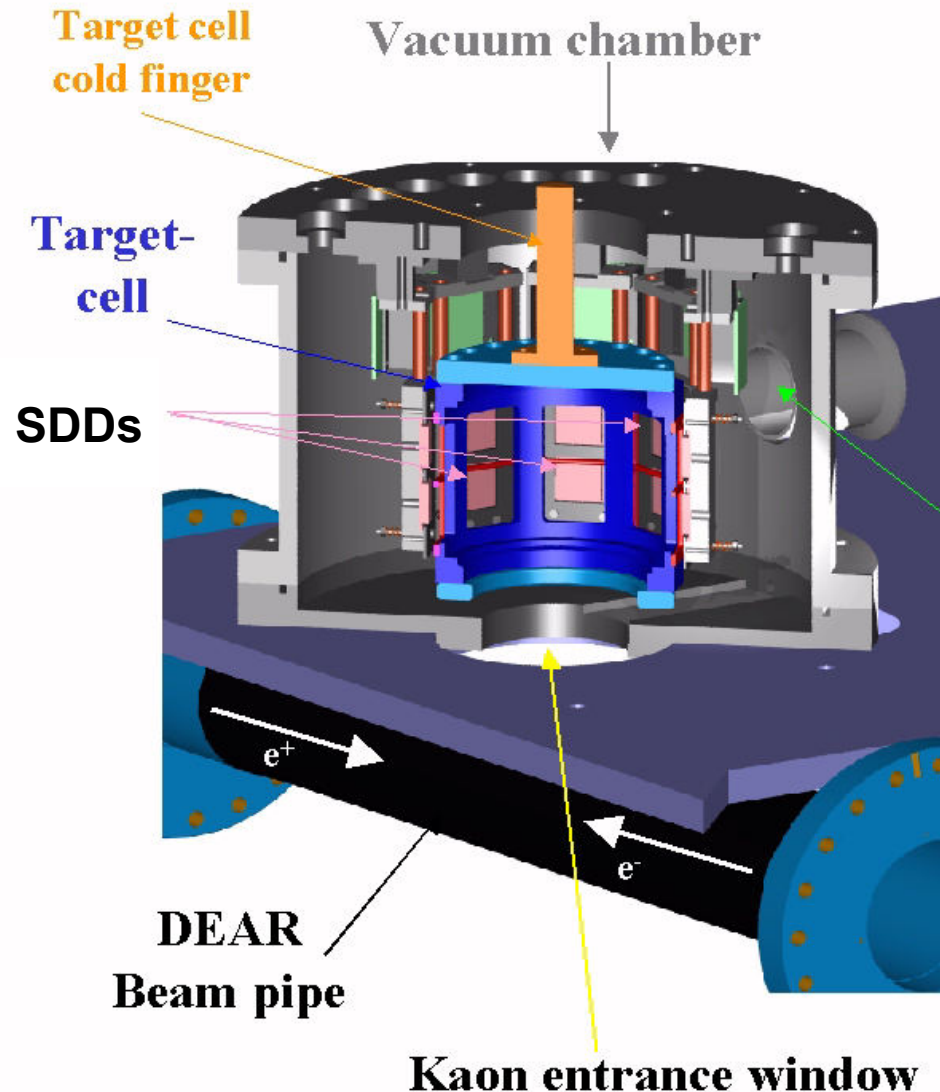
The  $K$  are the particles used by the three experiments, DEAR, FINUDA and KLOE, to reach their scientific goals.

The DAΦNE luminosity allows to produce about  
10000  $K$  in a second

# SIDDHARTA

(DAΦNE Exotic Atom Research)

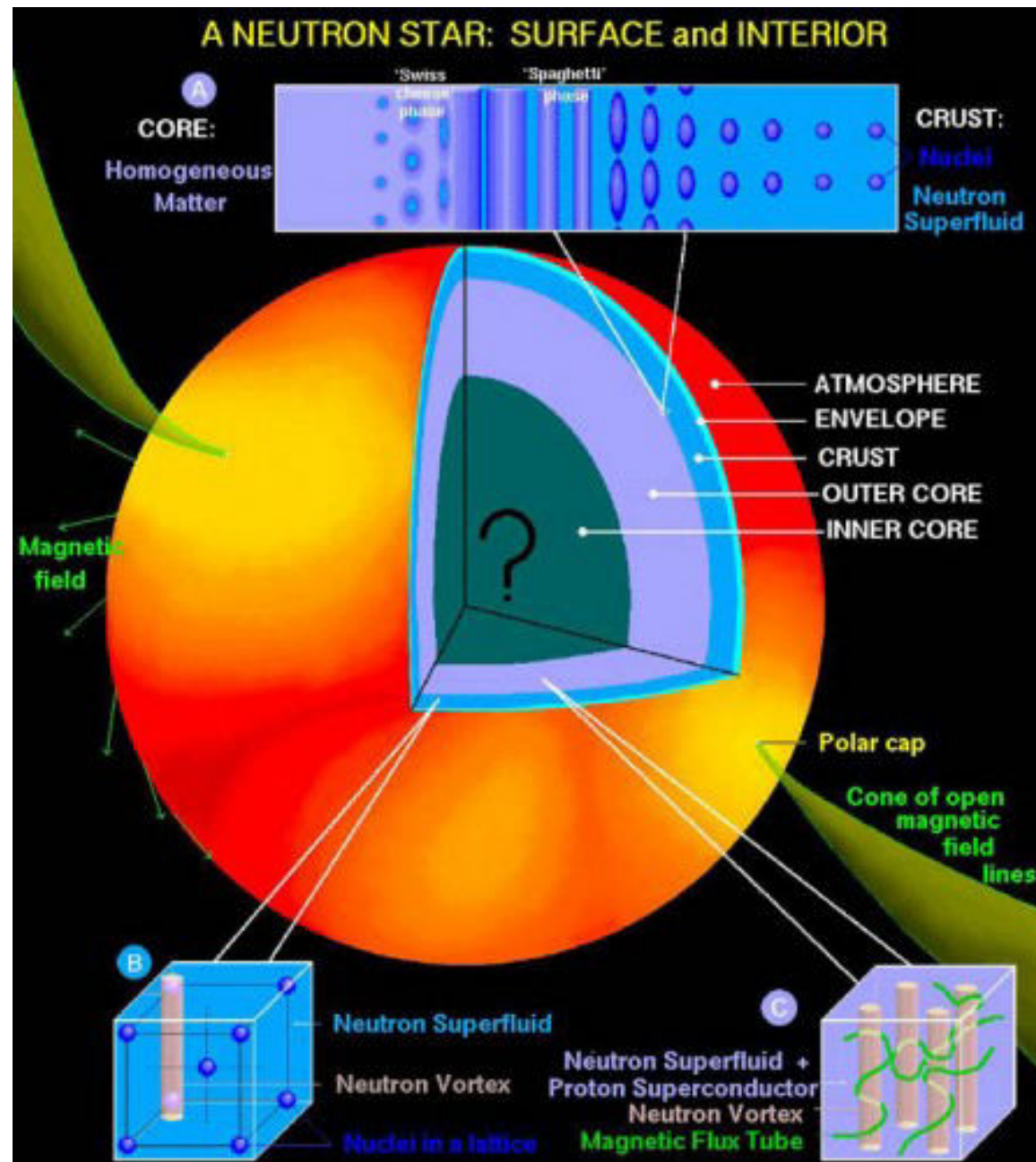
## *Kaonic hydrogen*



The DEAR experiment investigates the strong force by studying the kaonic atoms (in which a K<sup>-</sup> is substituting an atomic electron).

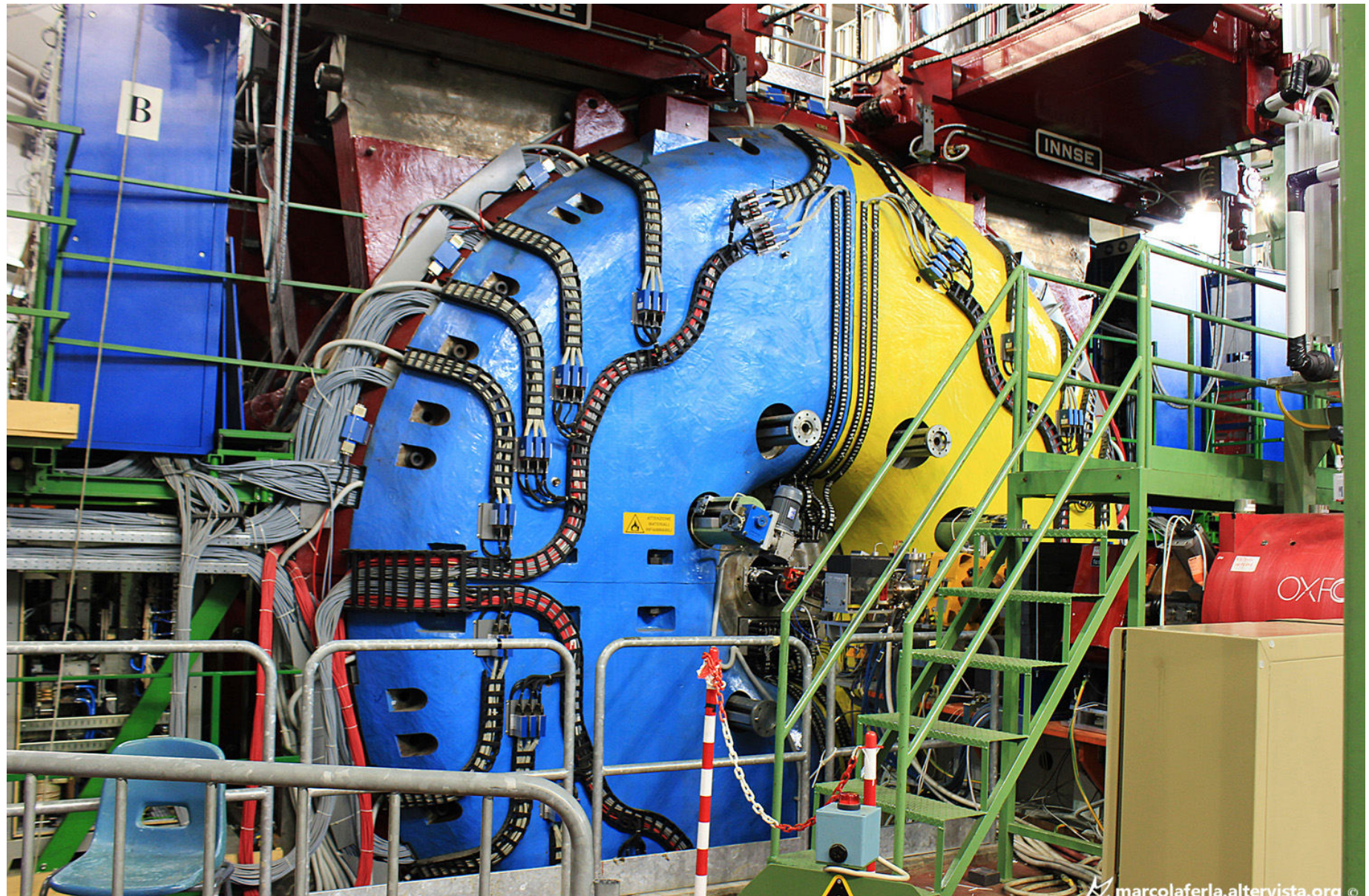


# Could strangeness play a role in neutron stars?

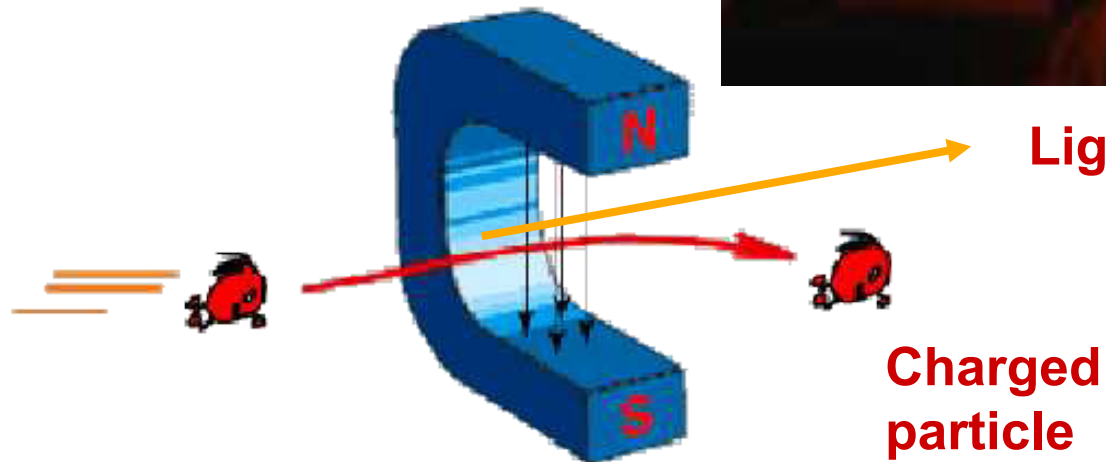
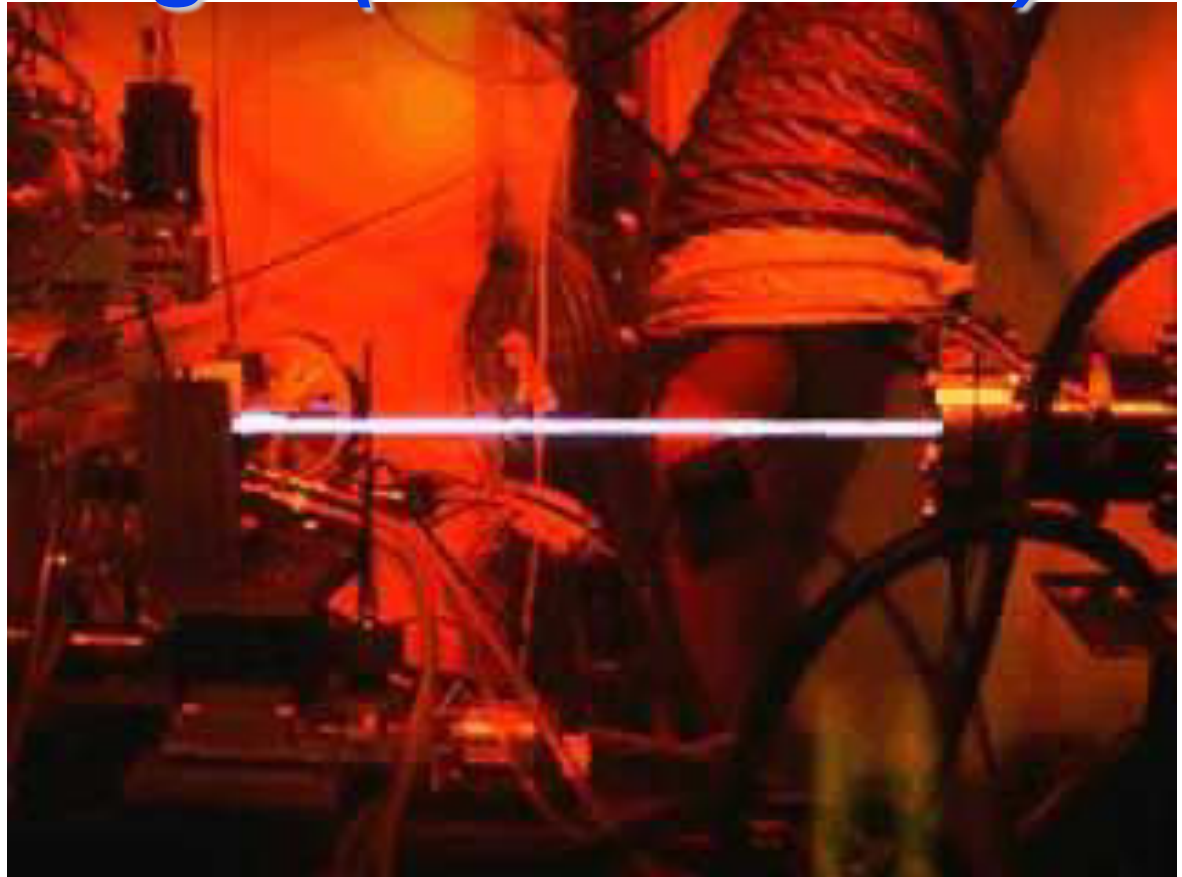


# KLOE2

(K Long Experiment)



# *Synchrotron light (DAΦNE-luce)*



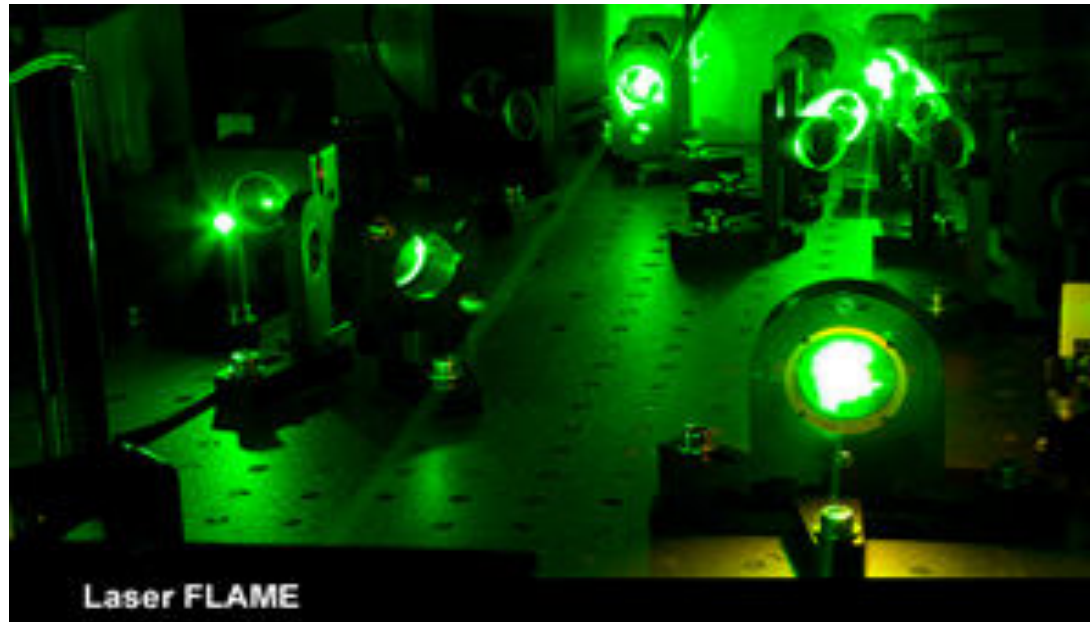
**Light (photons)**

European Synchrotron  
Radiation Facility

**Charged  
particle**

## ***FLAME: Frascati Laser for Acceleration and Multidisciplinary Experiments***

Laser of high power ( $> 100$  TW), able to produce pulses of 6 J in 20 fs at 10 Hz

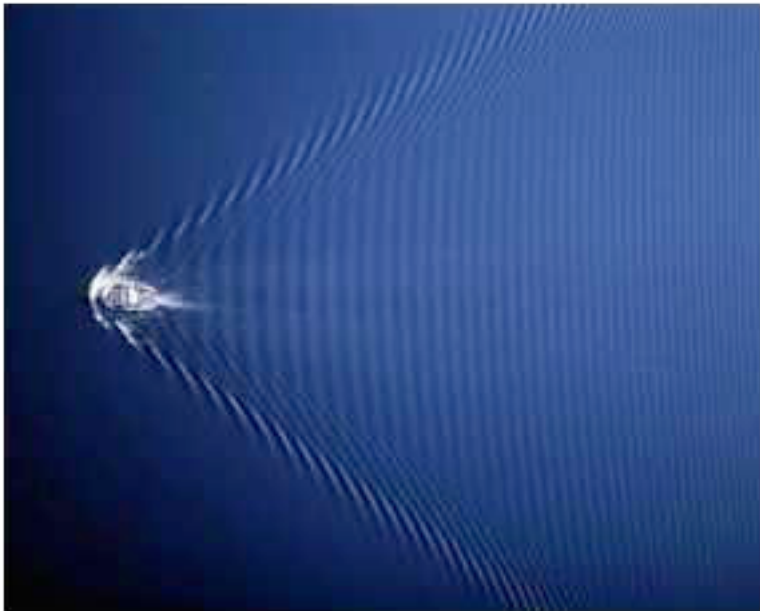


1) If FLAME beam is injected into a gas the electrons inside get highly accelerated (new acceleration technique)

2) If FLAME beam is colliding head-on with an electron beam (SPARC) an intense source of X rays is produced

## *1) New acceleration technique*

Laser pulse creates a wave

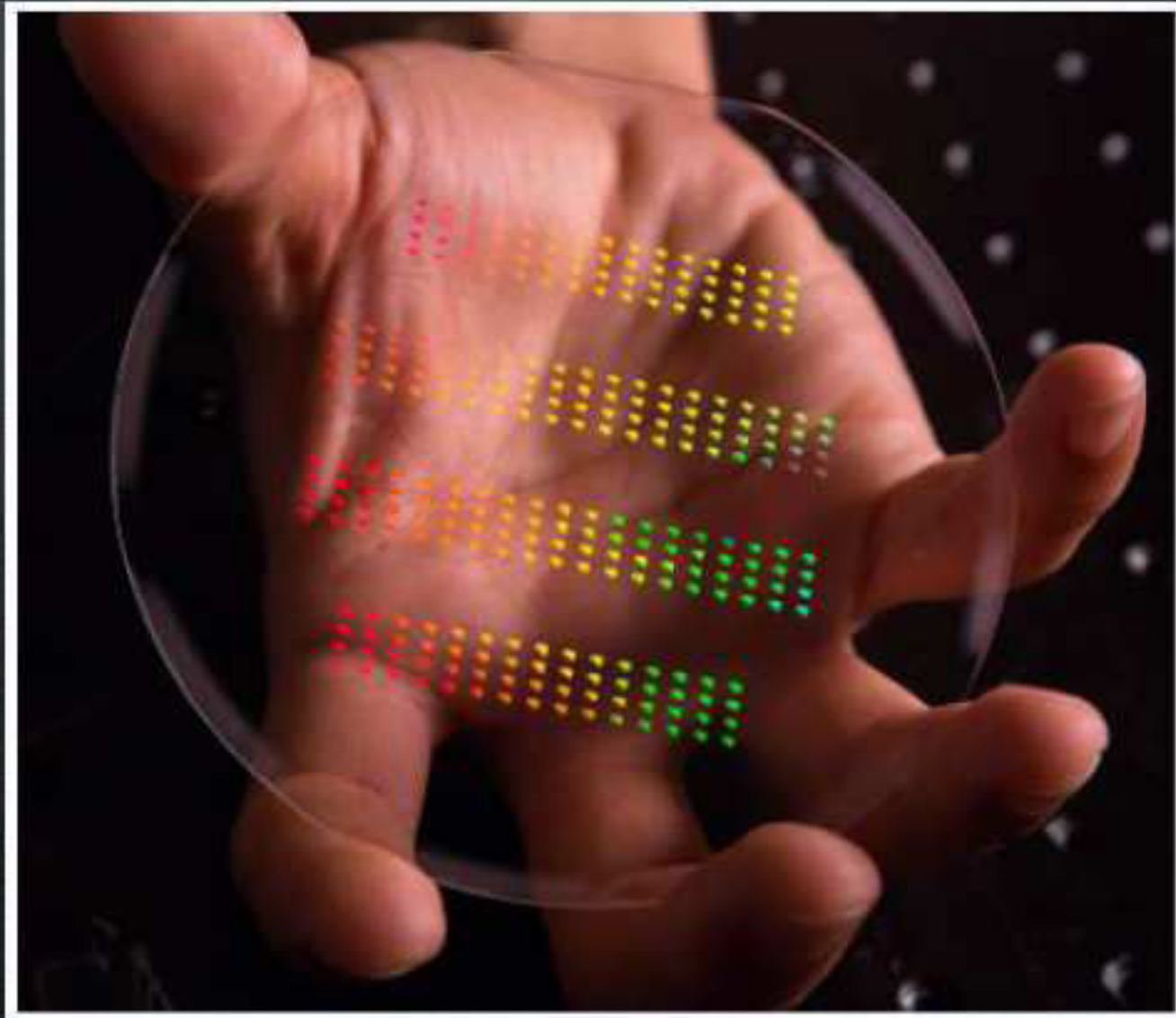


Particles get accelerated

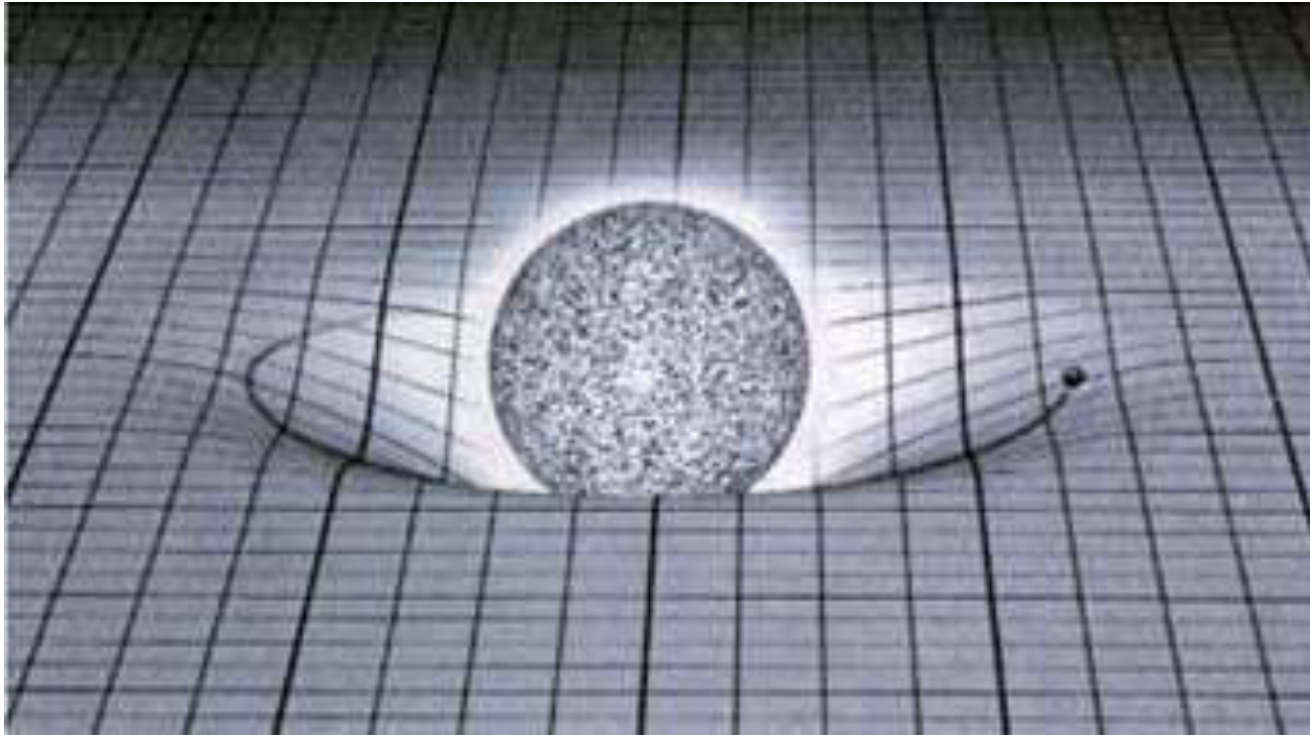


**In few cm electrons get accelerations as in present accelerators of hundred meters**

# Accelerator on a Chip?

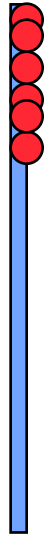


# ***Gravity force`***



***Distortion of space-time***

Antenna

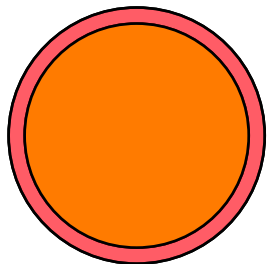


The electromagnetic waves are produced by an electric charge in movement

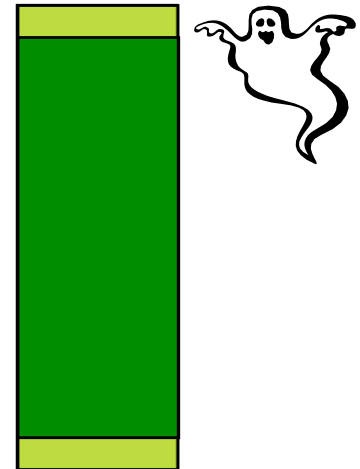
Butta la pasta!



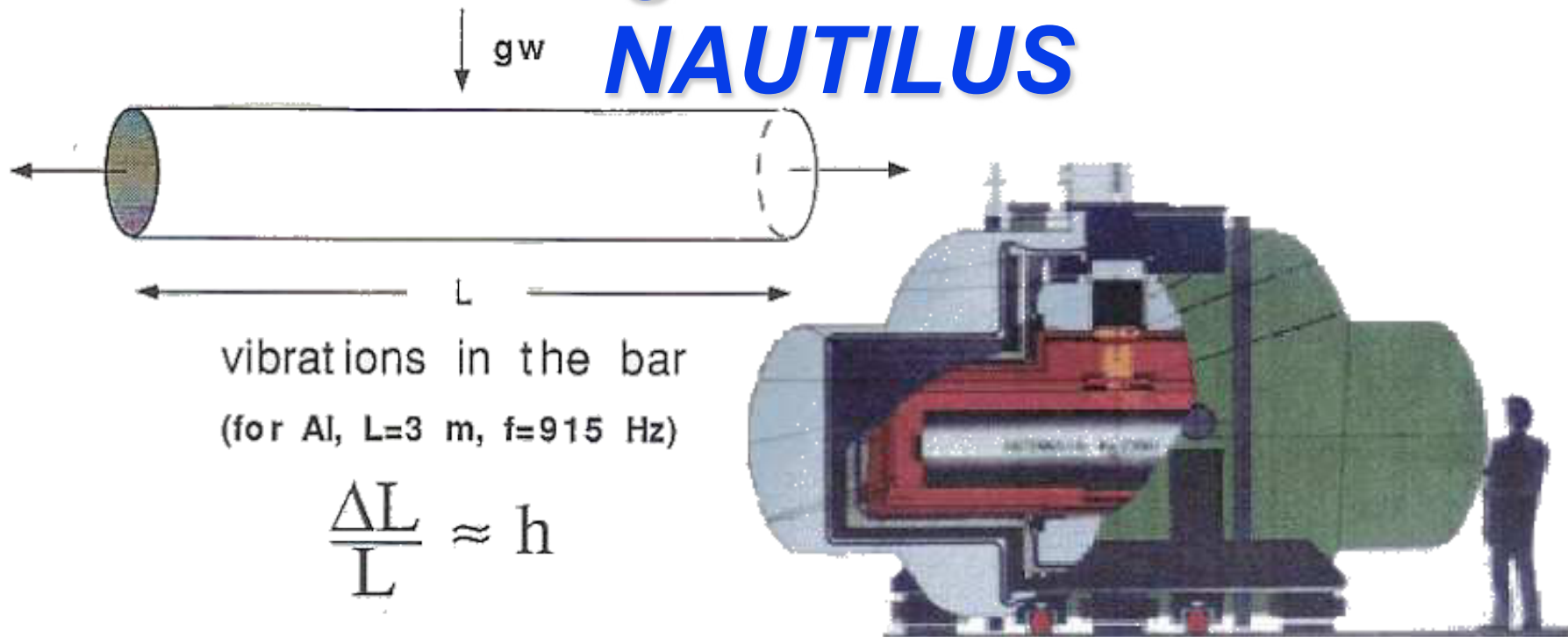
## ***Gravitational waves: an analogy***



Gravitational waves are produced by masses in movement....



# ***Search for gravitational waves:*** **NAUTILUS**



- Supernova in our Galassia  $h=10^{-18}$
- Supernova in Virgo  $h=10^{-21}$
- Thermal noise @  $T=300$  K,  $\Delta L=10^{-16}$  m
- Thermal noise @  $T=3$  K,  $\Delta L=10^{-17}$  m
- Thermal noise @  $T=300$  mK  $\rightarrow \Delta L=10^{-18}$  m

# After 100 years of General Relativity...

*Imagine travelling through space on a beam of light at the speed of light.*



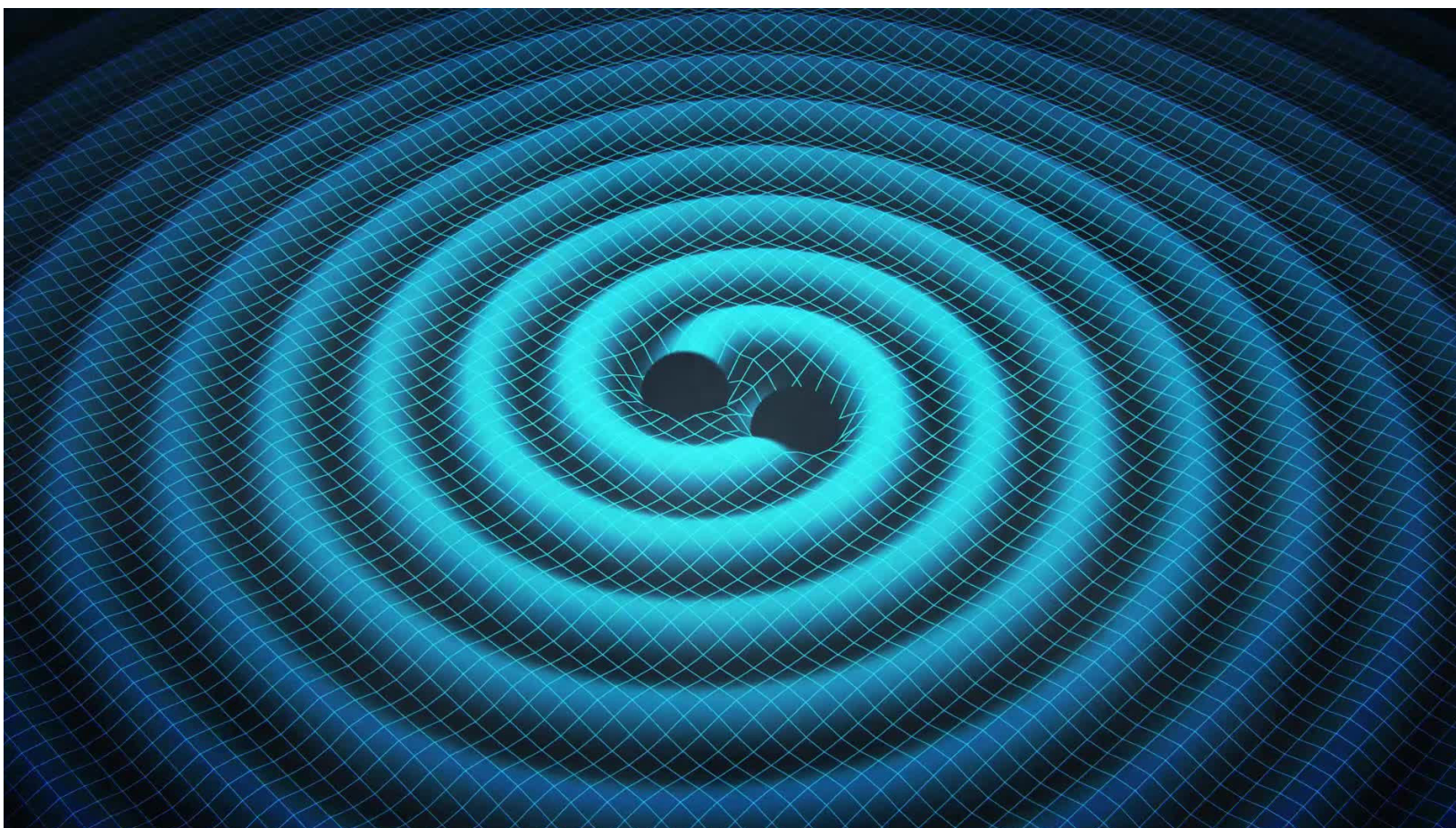
*Albert Einstein, theory of relativity, gravity, velocity, energy, mass, speed, time,  $E=mc^2$  Albert Ein*

*Bobonart*

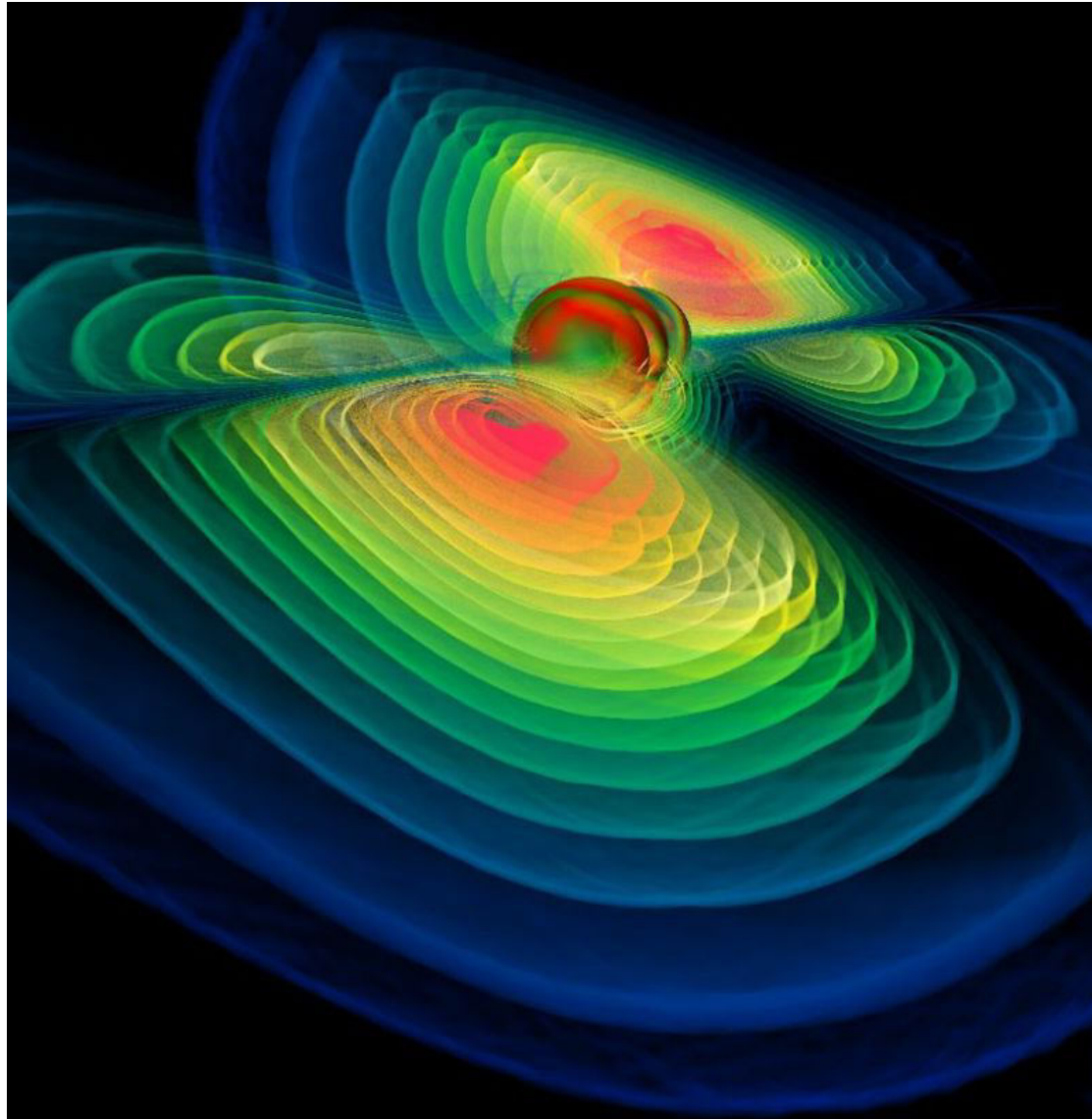
***Discovery of the gravitational waves (14 Sept.  
2015 -> 11 Feb 2016)***



***Discovery of the gravitational waves (14 Sept.  
2015 -> 11 Feb 2016)***

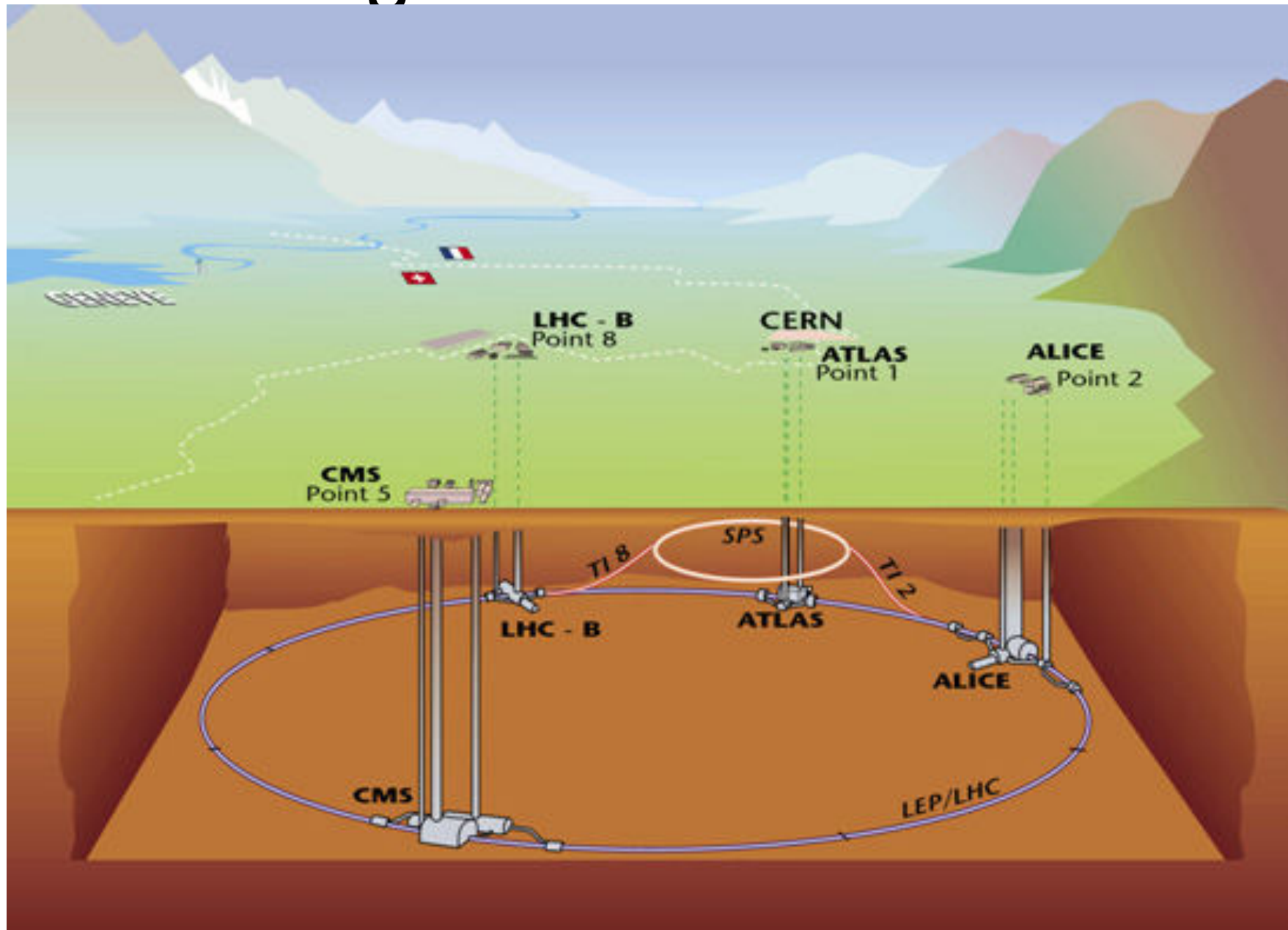


***Discovery of the gravitational waves (14 Sept. 2015 -  
> 11 Feb 2016) – talk Viviana Fafone***



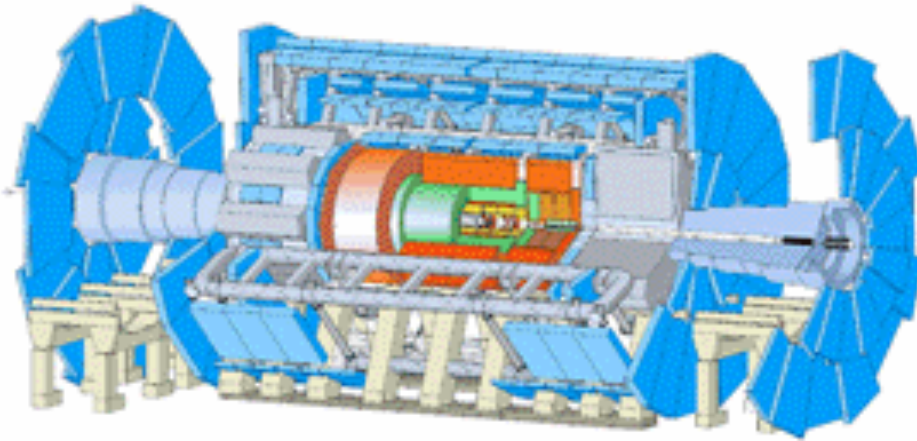


# Large Hadron Collider

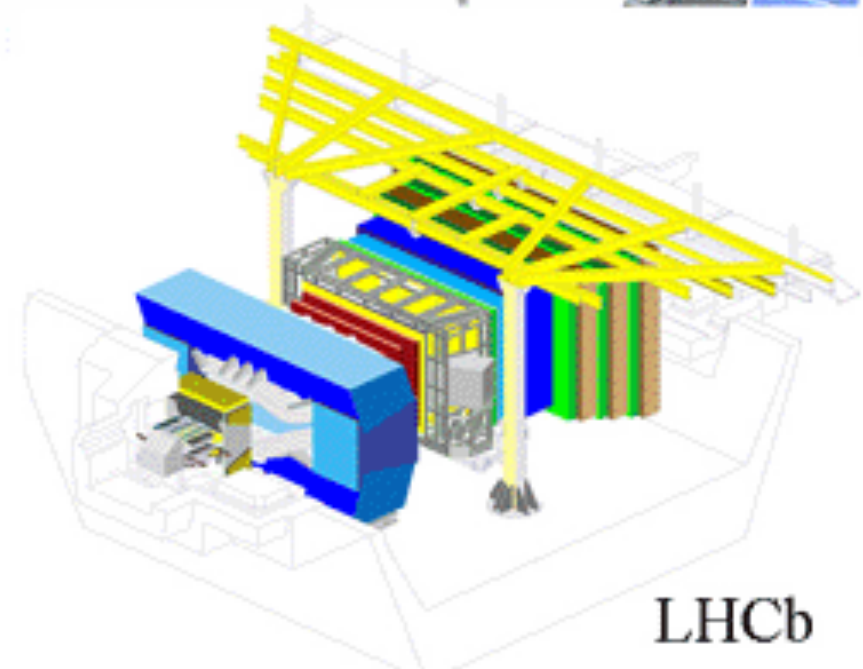
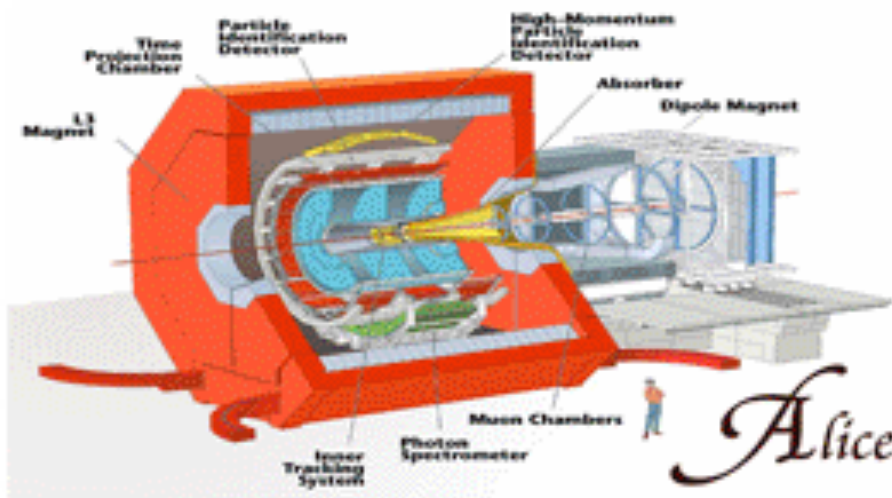
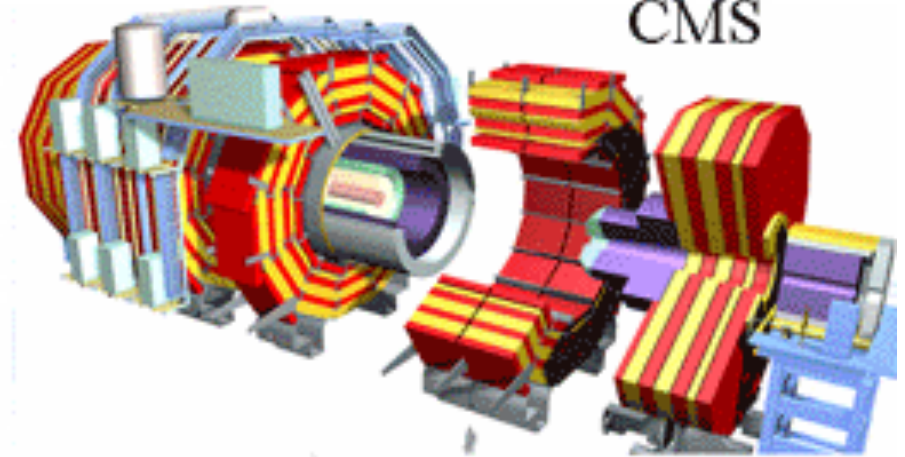


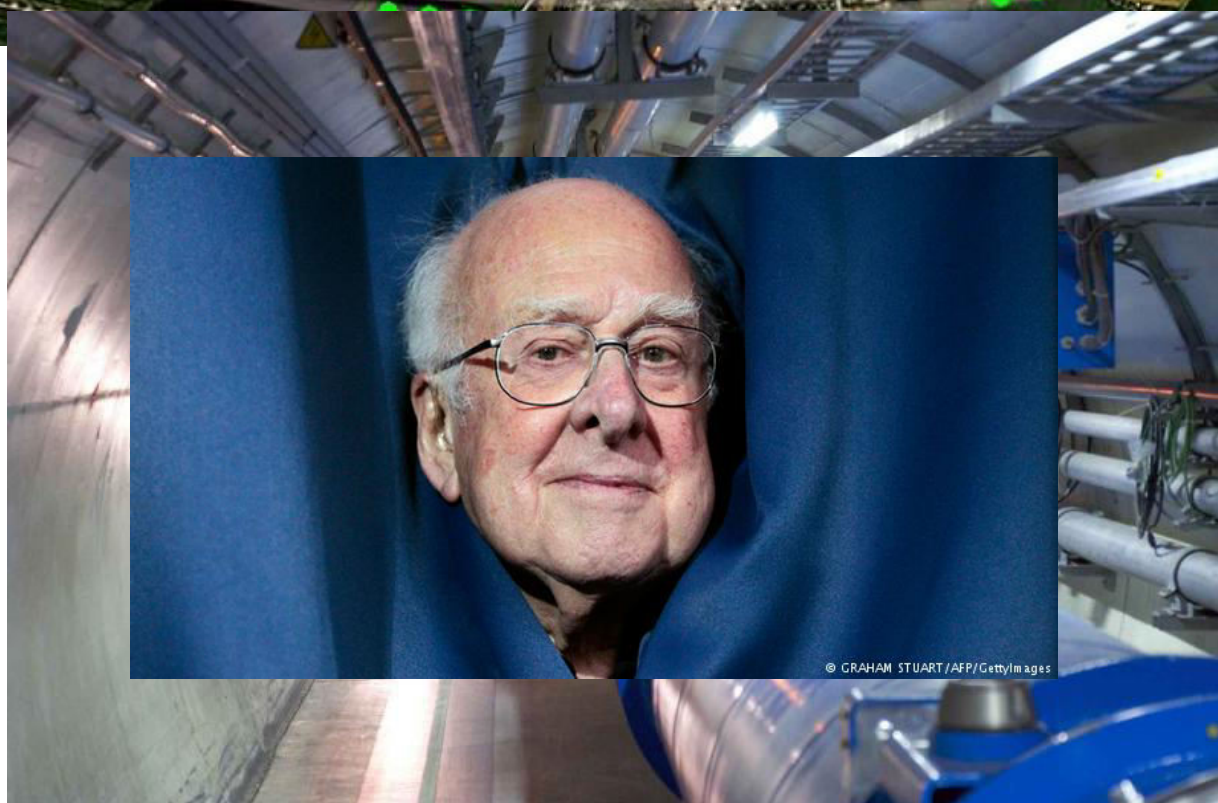
# Large Hadron Collider

ATLAS

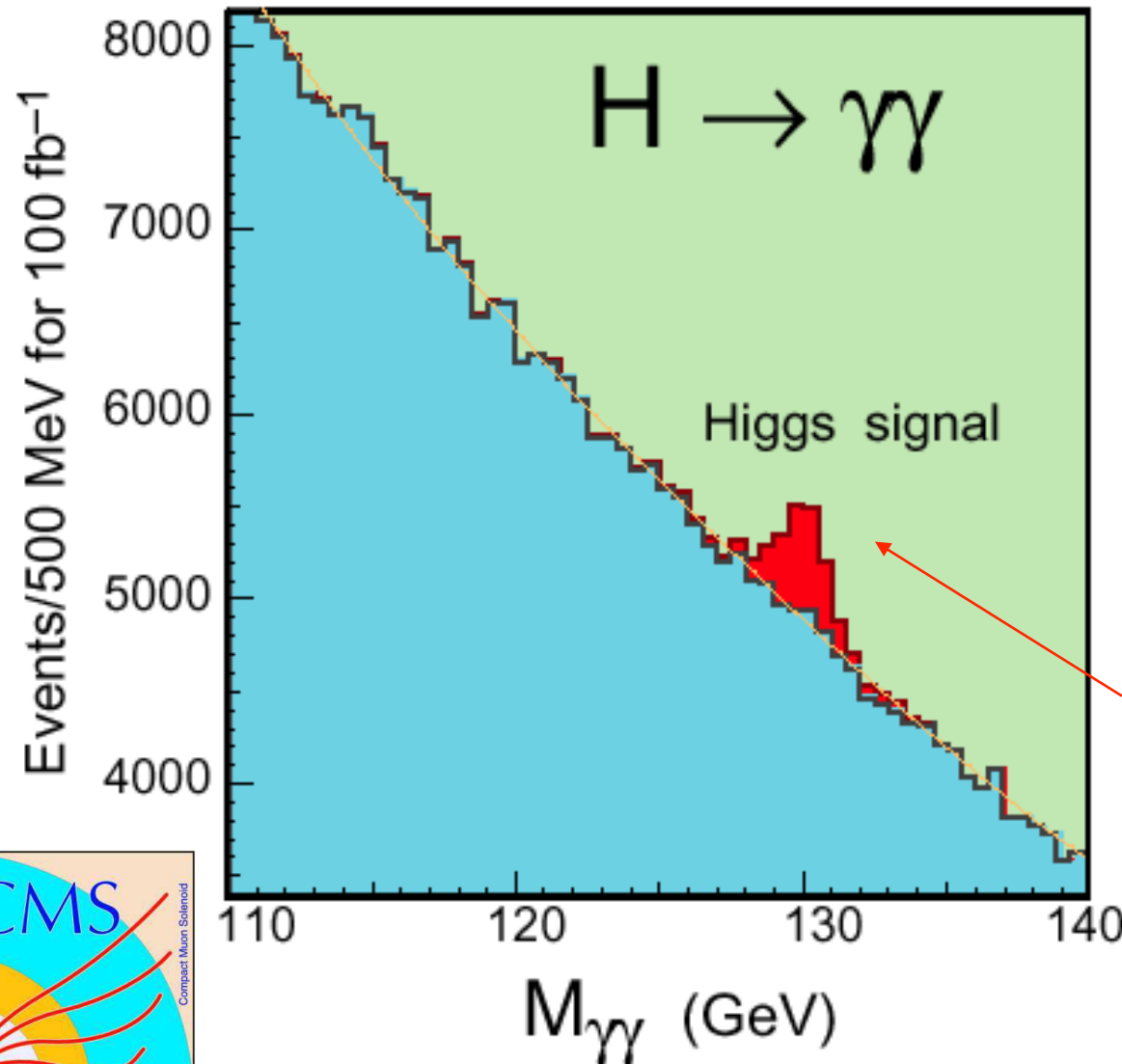


CMS

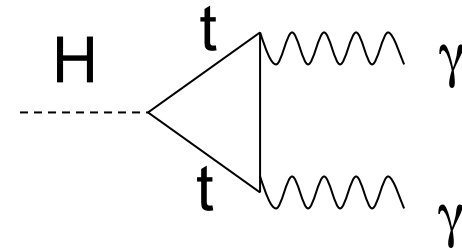




# Higgs Decay to Photons



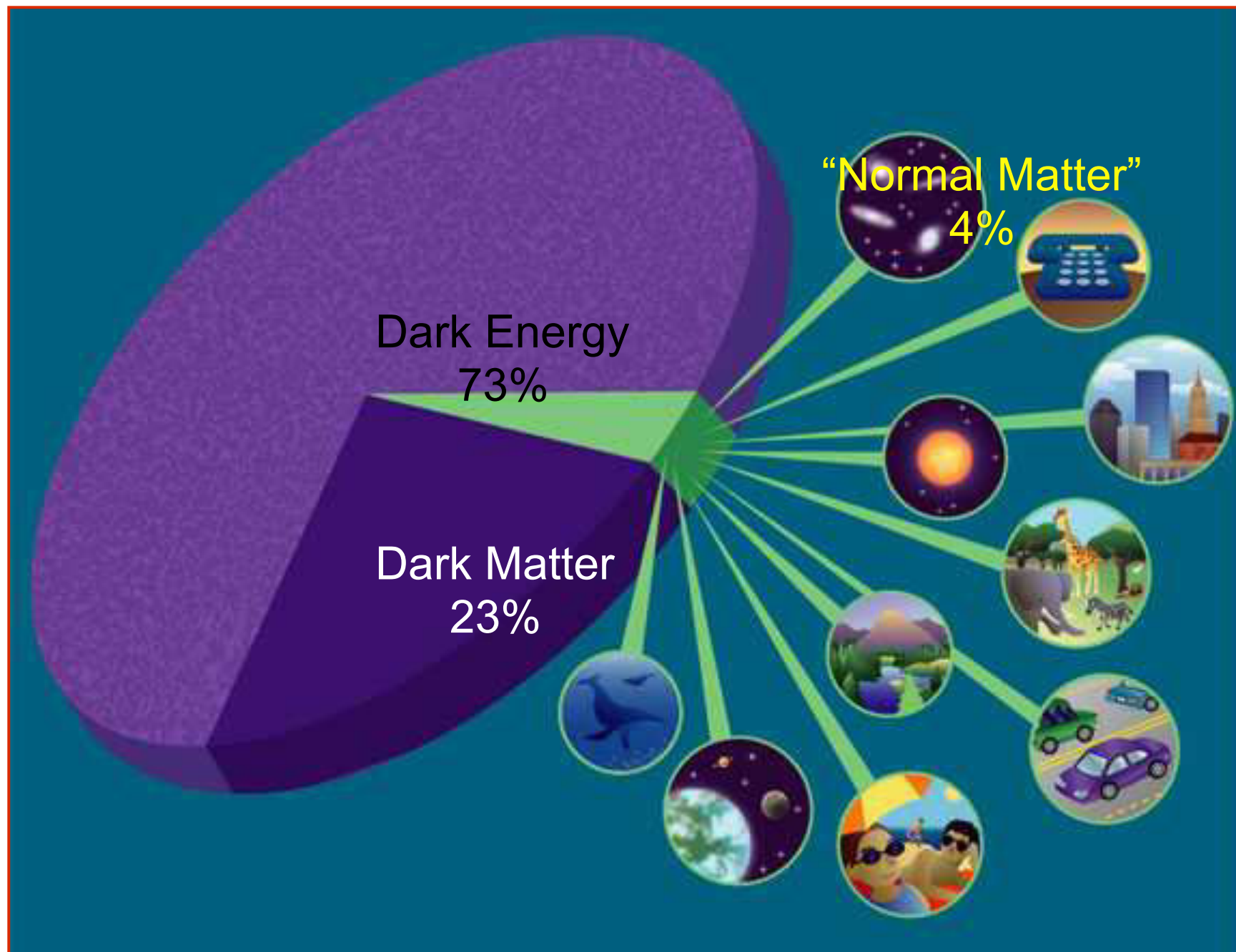
Rare decay in SM



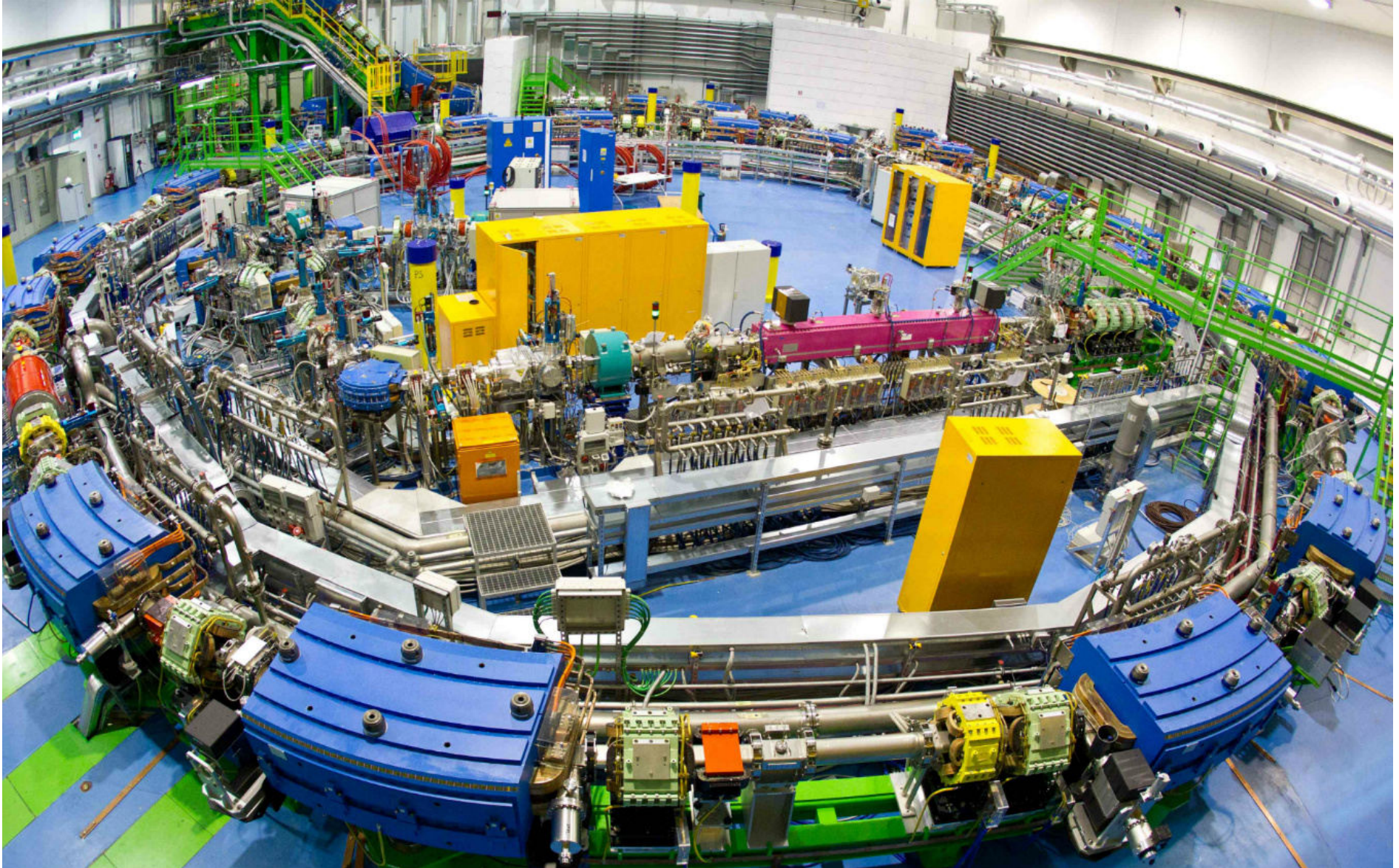
LHC detectors have been optimized to find **this peak!**

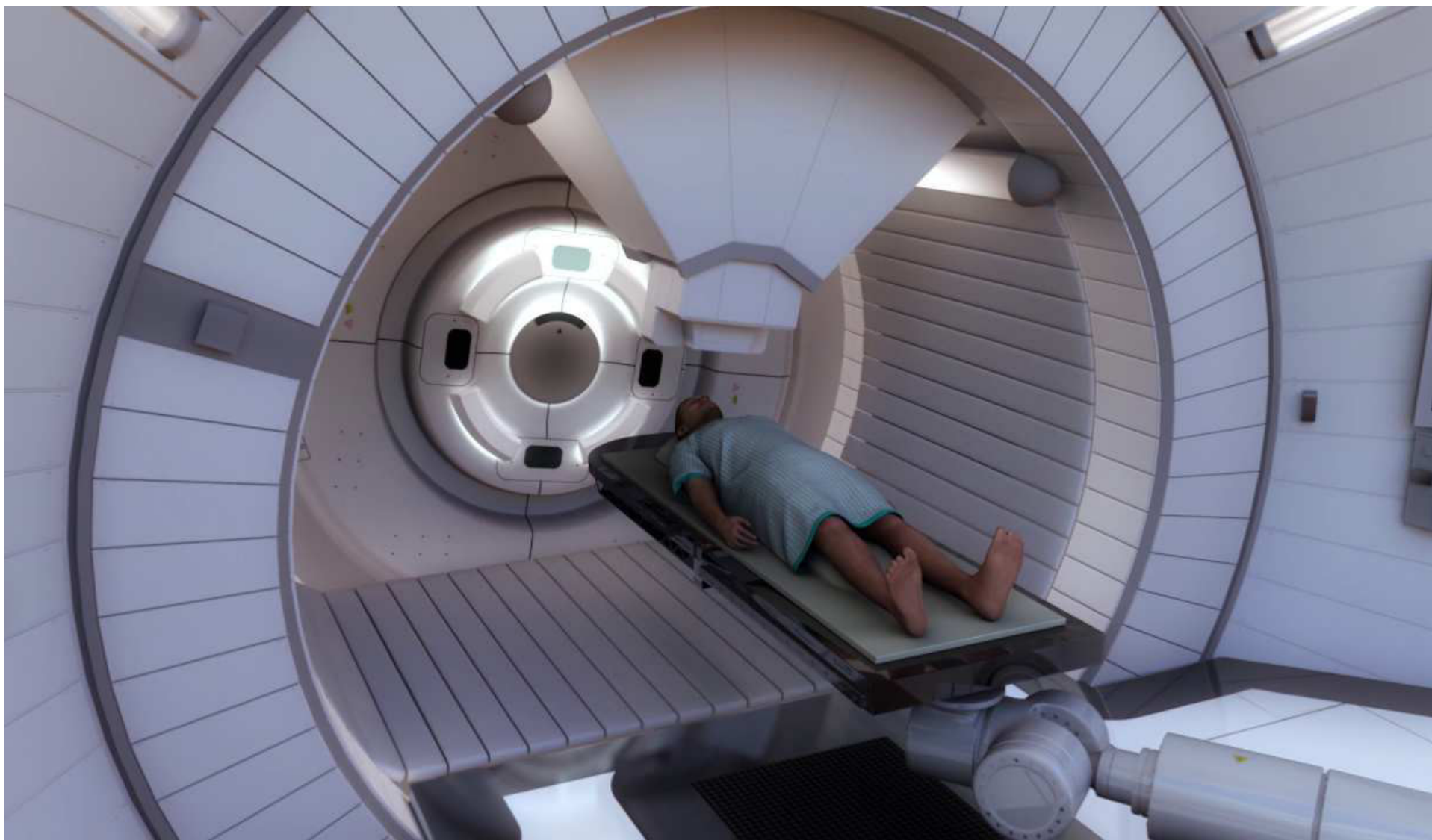


U. NIJSEN



# CNAO





# PROGRAM

Monday 27 March – Auditorium B. Touschek

*Chairwoman: Susanna Bertelli*

09:00 – 10:00 Registration

10:00 – 10:15 Welcome

10:15 – 11:00 Get INSPYRED – Introduction and Presentation of LNF-INFN activities (INSPYRE Directors: C. Curceanu)

*11:00 – 11:30 Coffee Break*

11:30 – 12:30 **Students' introduction – Speed date INSPYRE 2023**

12:30 – 13:30 **Symmetries in Physics** – A. D. Polosa (Univ. Sapienza, Rome)

13:30 – 14:30 Lunch

14:45 – 16:00 **Quantum cryptography: an introduction** – A. Bassi (Univ. of Trieste)

## Tuesday 28 March – Auditorium B. Touschek

Chairwoman: Adriana Postiglione

09:15 – 10:15 **The physics of habitable worlds** – A. Balbi (Univ. Tor Vergata, Rome)

10:30 – 11:30 **Accelerating the future** – M. Ferrario (INFN-LNF)

11:30 – 12:00 *Coffee Break*

12:00 – 13:15 **Exploring the Universe with gravitational radiation: where we come from and where we're going** – V. Fafone (Univ. Tor Vergata, Rome)

13:30 – 14:30 *Lunch*

Chairwoman: Catalina Curceanu

14:45 – 16:00 **JWST, the Universe in a sand grain** – F. Vitali (INAF)

16:00 – 17:00 **Nuclear Physics in everyday life** – S. Pirrone (INFN-Catania)

17:00 – 17:30 **Visit to Bruno Touschek Visitor Center**

17:30 **Social Event**



Wednesday 29 March – Auditorium B. Touschek

09:20 – 13:30 Dedicated to experiments: hands-on!

13:30 – 14:30 *Lunch*

Chairwoman: Adriana Postiglione

14:45 – 15:10 **Stranger things – the muons** – E. Diociaiuti (INFN-LNF)

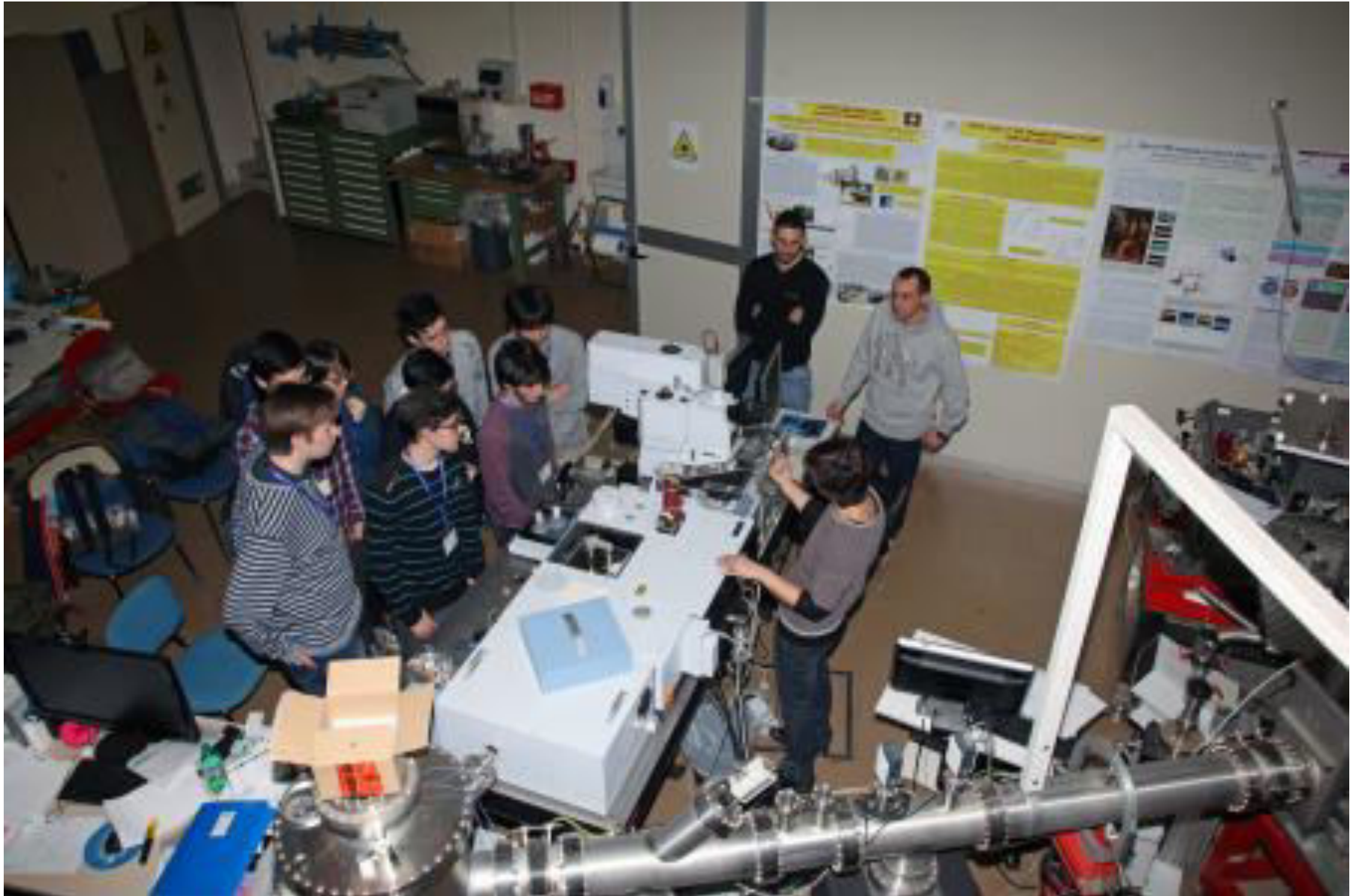
15:10 – 15:35 **Unravelling the Secrets of the Strong Force: The SIDDHARTA-2 Experiment at the DAFNE Collider** – F. Sgaramella (INFN-LNF)

15:35 – 16:00 **Rogue Electron: A Physics Wars Story.** – L. De Paolis (INFN-LNF)

16:00 – 17:00 **Superconductors to jump in the future** – A. Bersani (INFN-Genova)

17:00 – 18:00 **Visit to Bruno Touschek Visitor Center**

# Hands-on



Thursday 30 March– Auditorium B. Touschek

09:20 – 13:30          Dedicated to experiments:

13:30 – 14:30          *Lunch*

Chairwoman: Catalina Curceanu

14:45 – 16:00 **That's life** – S. Pisano (CREF, INFN-LNF)

16:00 – 17:00 **Nuclear Physics at the extremes: exotic nuclei for research and applications. A glimpse of the SPES project.** – T. Marchi (INFN-LNL)

Friday 31 March

Chairwoman: Adriana Postiglione

09:00 – 10:15 **Dark Matter: Modern quintessence of the universe**

– P. Gianotti (INFN-LNF)

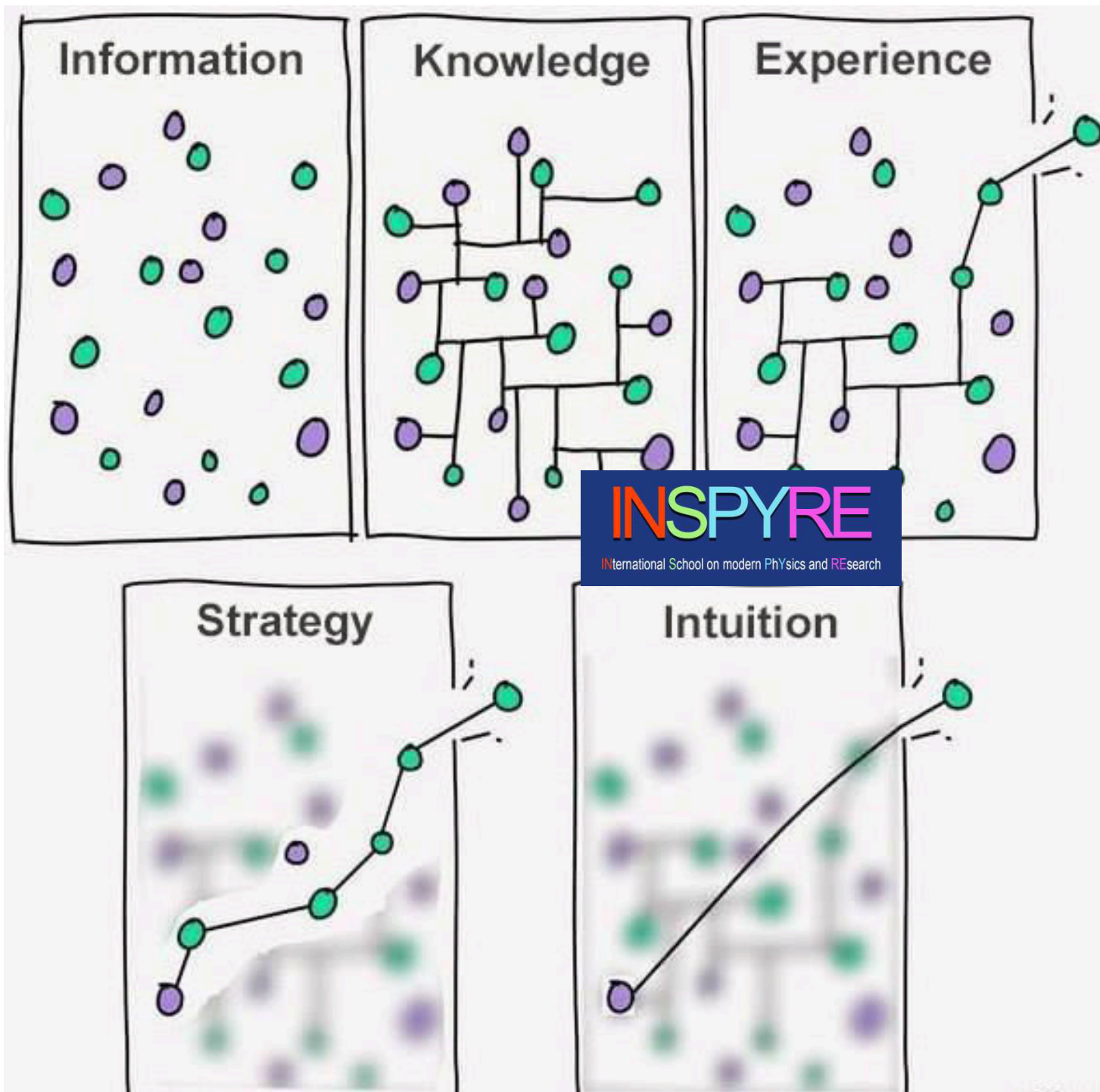
10:15 – 11:15 **7 Open problems of Modern Physics: the new Einstein could be you!** – C. Curceanu (INFN-LNF)

*11:15 – 11:45 Coffee Break*

11:45 – 12:45 **Nuclear energy from fission and fusion: an overview** – M. Ripani (INFN-Genova)

12:45 – 13:30 Discussions, participation certificates awarding and farewell

*13:30 – 14:45 Lunch*



# Science has no borders!



from Russia



from India



from Korea



from England



from Nippon

© 2000  
BY PIONEER



**Science for Peace**



National project of INFN Third Mission Committee

INSPYRE 2023 is organized with the participation and support of:



Foundational Questions



STRONG 2020



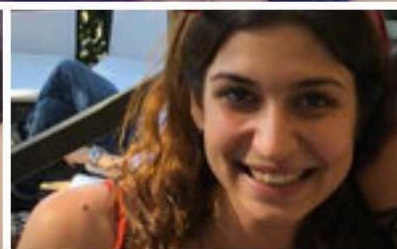
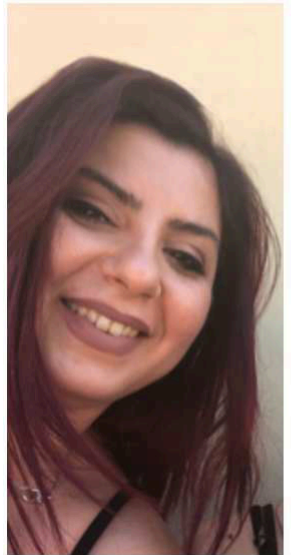
John Templeton Foundation

## INSPYRE 2022 TEAM

Sara Reda

Elisa Santinelli

Susanna Bertelli



Sara Arnone

Debora Bifaretti

Elena Patrignanelli

INFN – LNF Education and Public Outreach Group

# Lise Meitner

