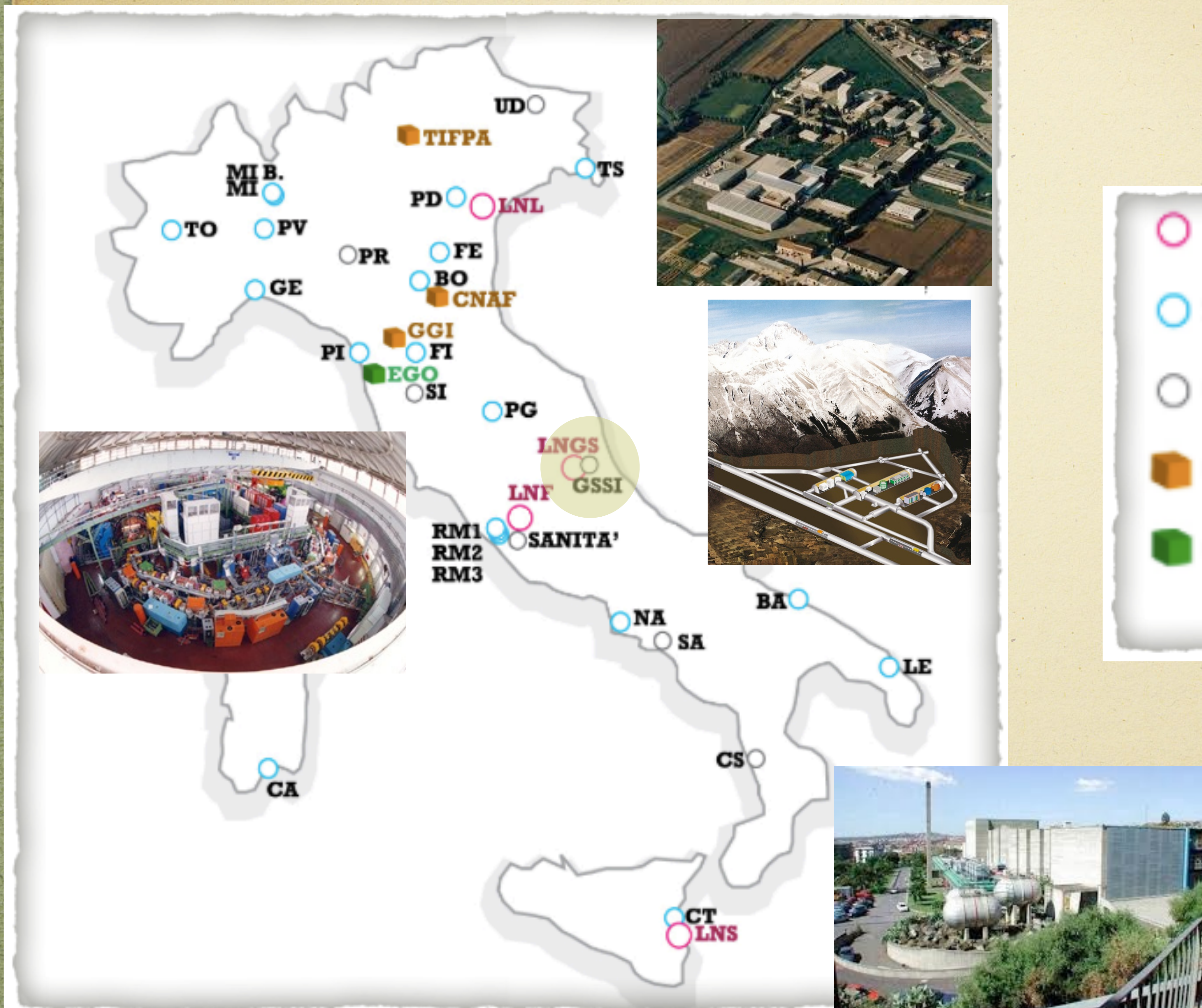
INFN
looking at the future

Fernando Ferroni

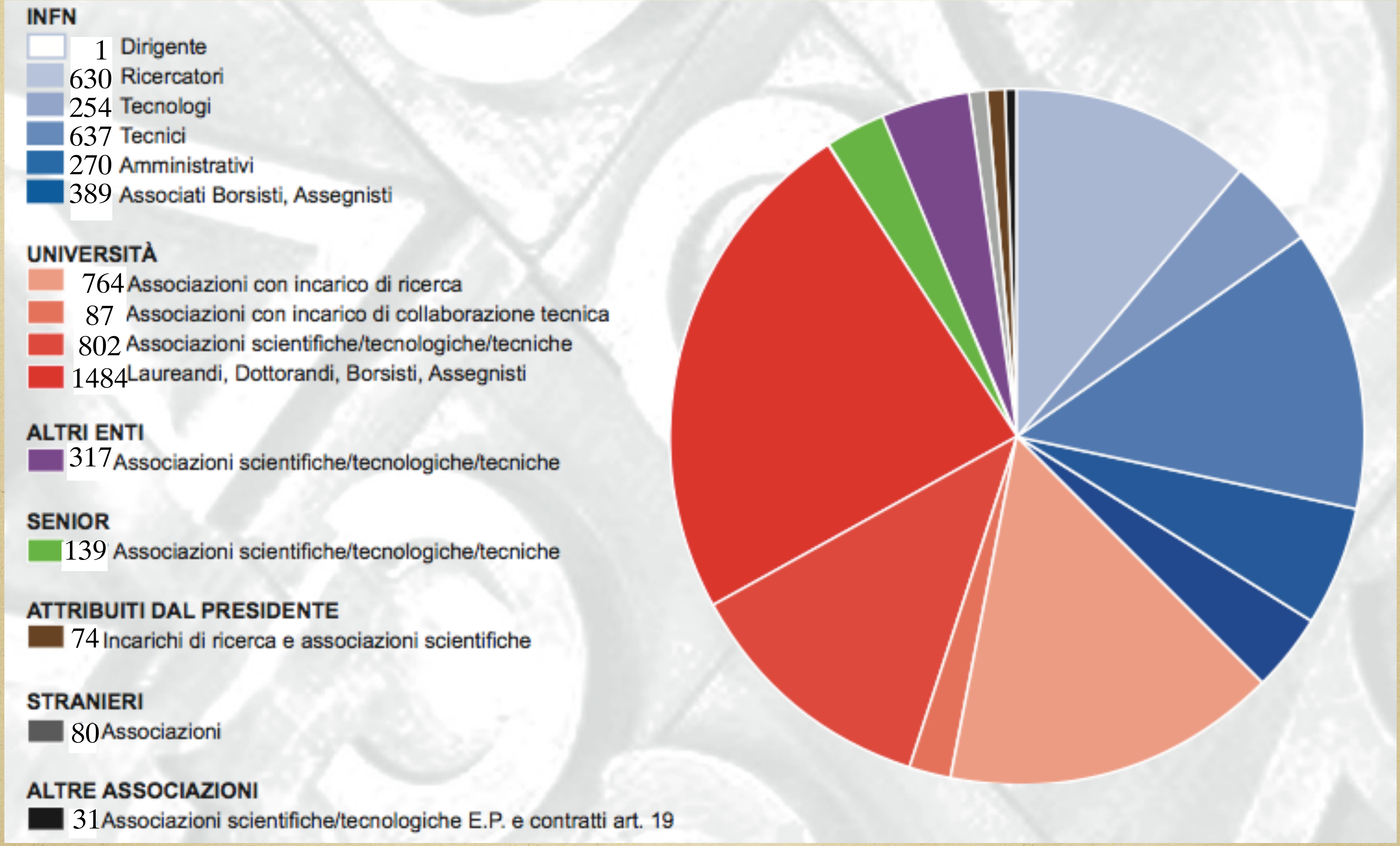
INFN & Sapienza Universita', Roma

A federal institute

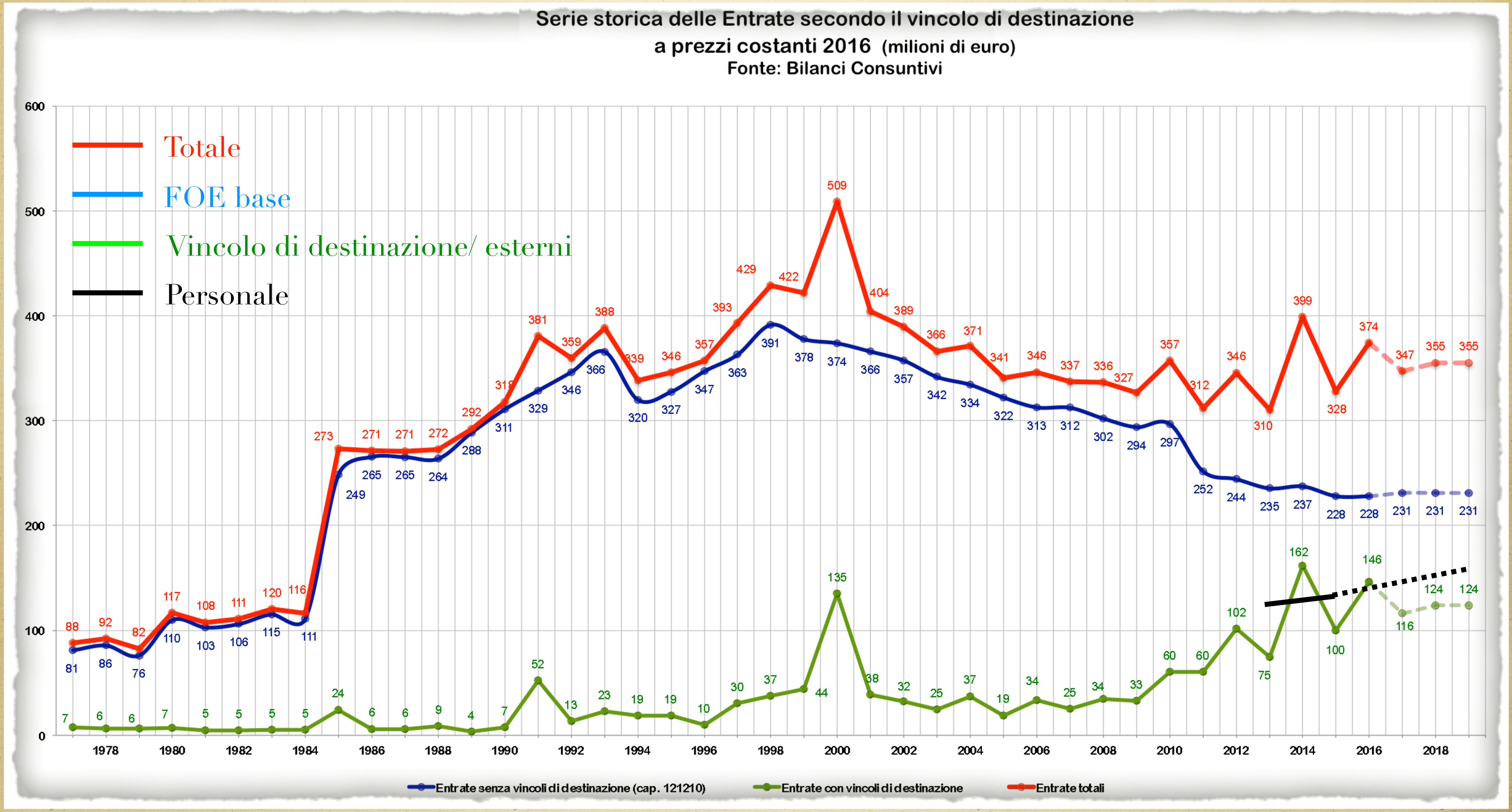


- Laboratori Nazionali (4)
- Sezioni (20)
- Gruppi collegati (11)
- Centri Nazionali e Scuole (3)
- Consorzi (1)

deeply integrated with University



with an evolving budget



importante notare che le spese di personale sono contenute al 60% del FOE base

Research is mostly bottom-up

- at CERN where l'INFN provides innovative technologies and has a clear leadership in the experiments
- at LNGS , the largest underground lab un the world
- at EGO-Virgo where Gravitational Waves are studied
- with KM3Net in the depth of Mediterranean Sea, offshore of Capo Passero where the neutrinos of the highest energies produced from the violent Universe will be intercepted
- and in many other labs   (in USA, in Japan, in China, in Argentina……)

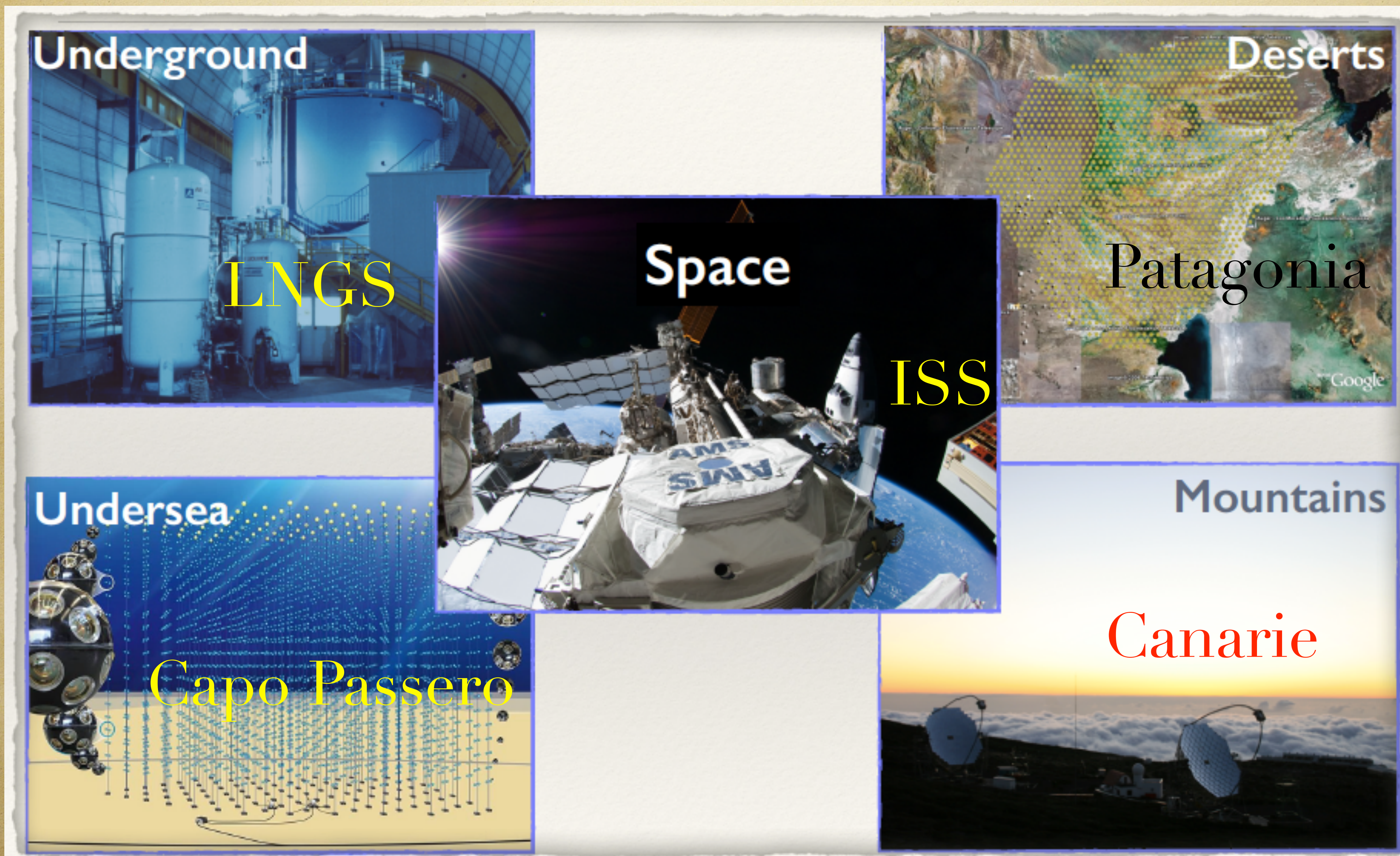
we have a power of attraction

- In a recent competition for 73 positions of staff researchers (divided by MIUR with an algorithm performance-based that has given 35% of the pot wrt. to 15% unweighted share)
- 35% of the winners are post-docs coming back to Italy
- 10% have a foreign passport

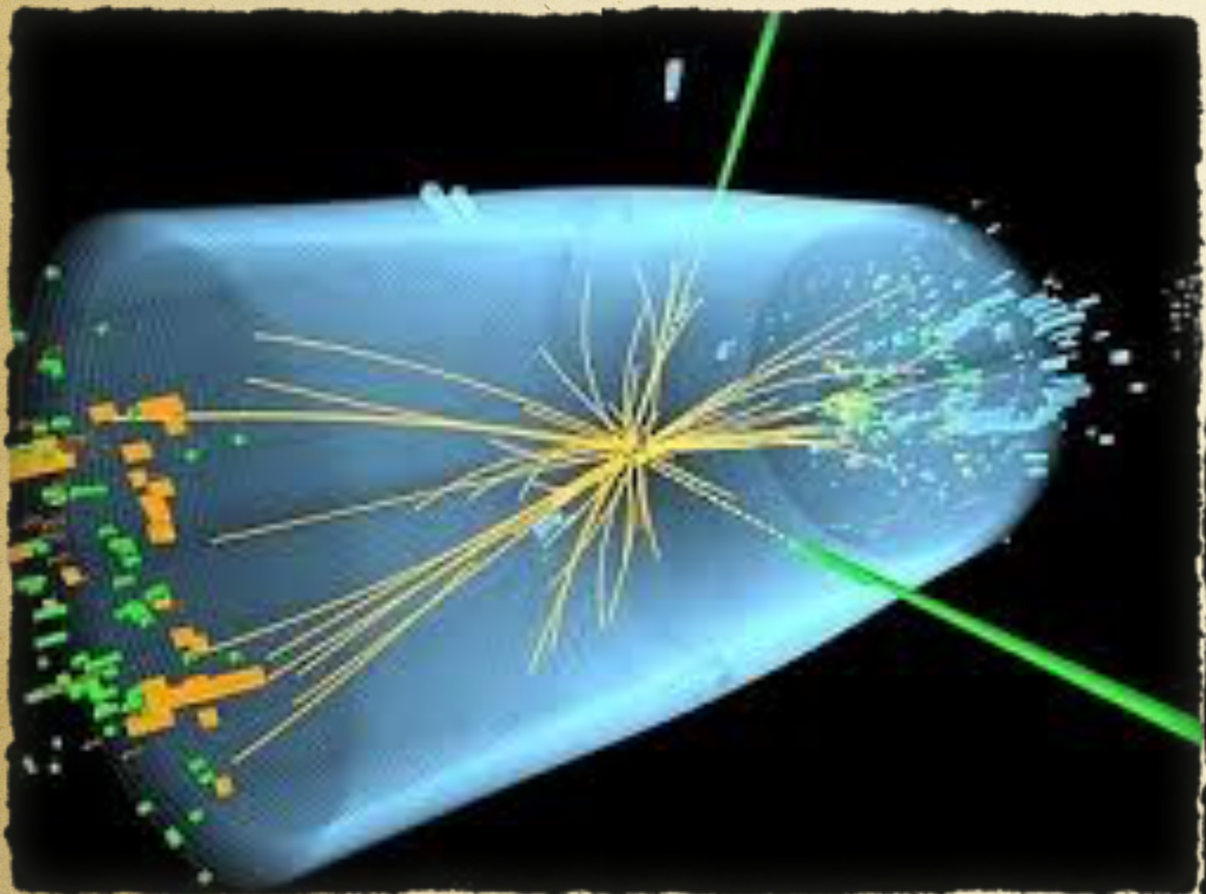
priorities

- Higgs boson properties
- Searching for what we do not know what it is although we know (?!) that exists
- Using GW both for studying the Cosmo and for Nuclear Physics
- Multi Messenger Astronomy

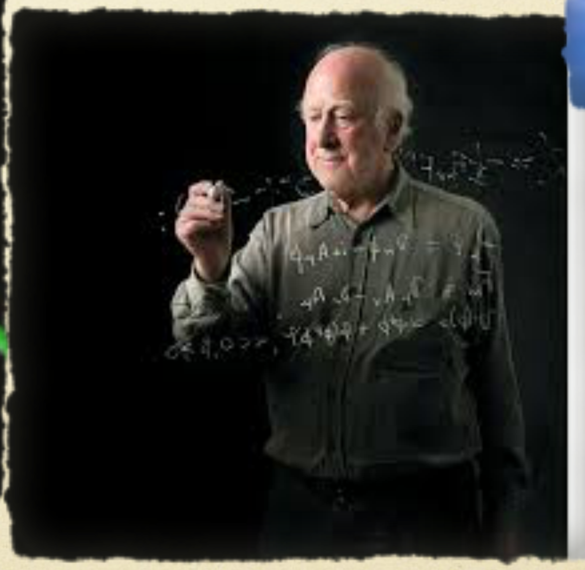
up in the sky, down in the earth, in the depth of the sea, in the most remote area of the planet

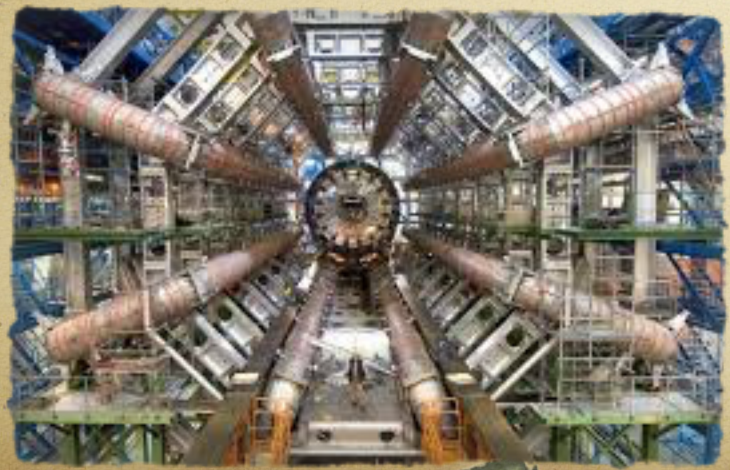


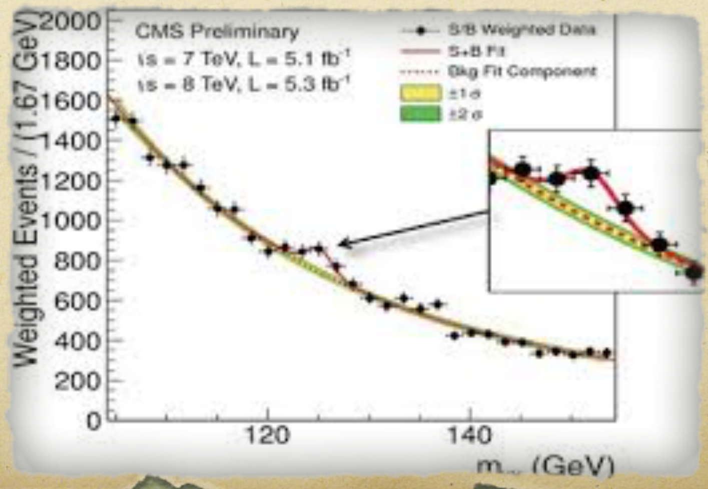
following the success of 2012



Higgs





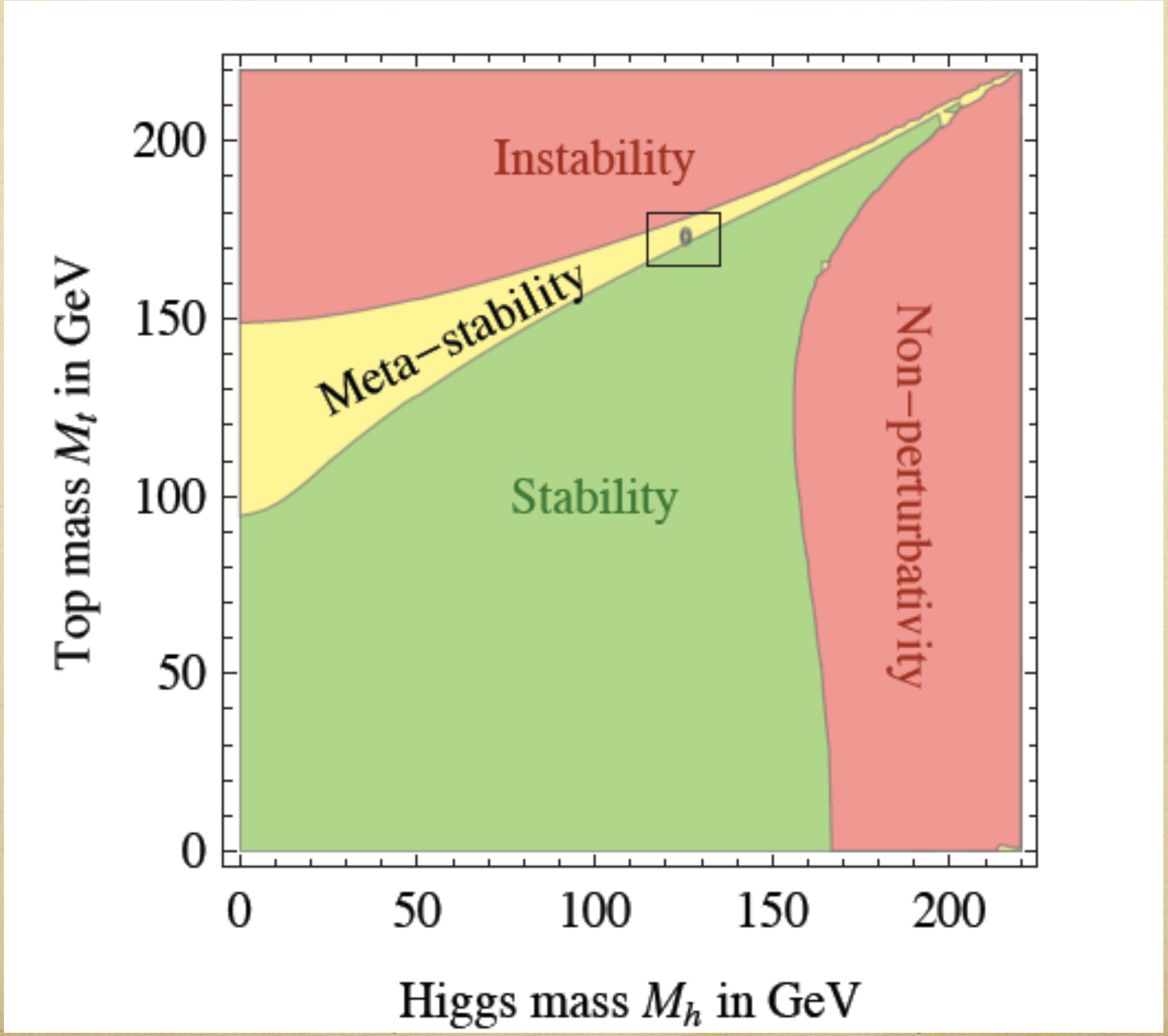


Fabiola Gianotti
CERN DG

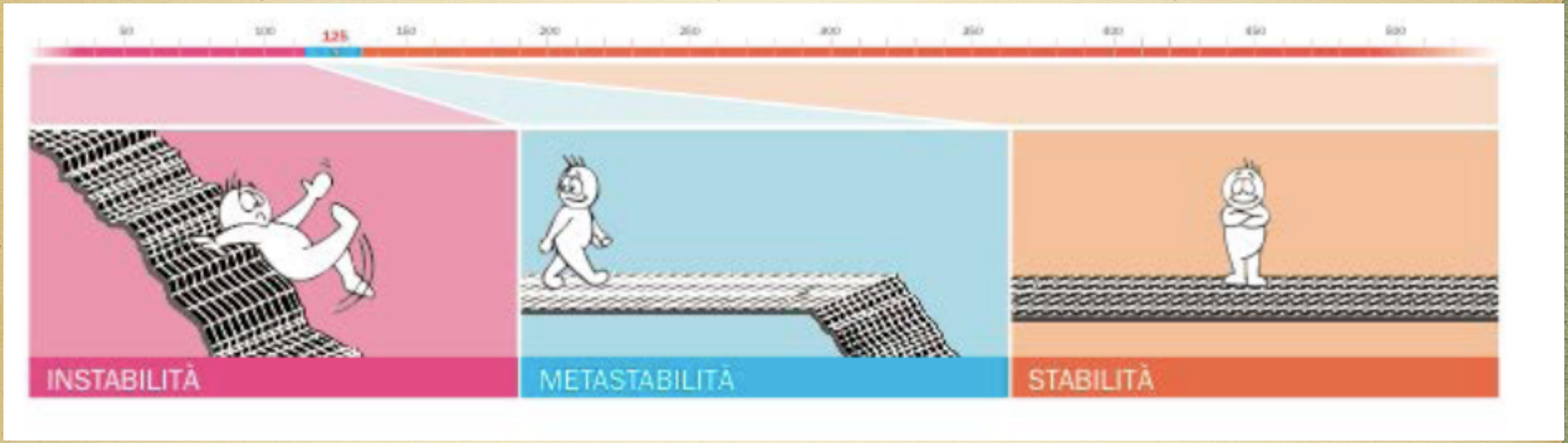
is that the end of history ?

- (fortunately) NOT
- why Higgs boson has such a border line mass ?
- what is the reason for the our very existence (how antimatter has disappeared ?)
- what is the Dark Matter ? And how can we (eventually) observe it

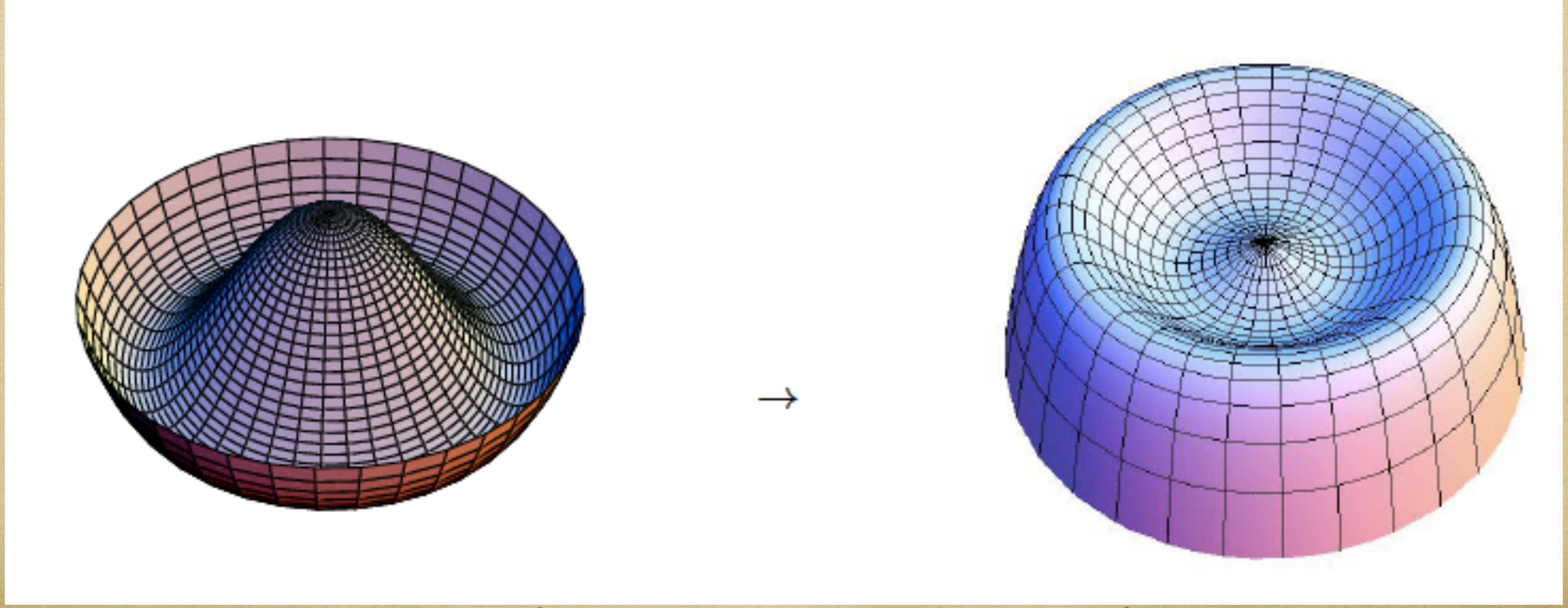
stable-metastable-unstable



not irrelevant (?!)



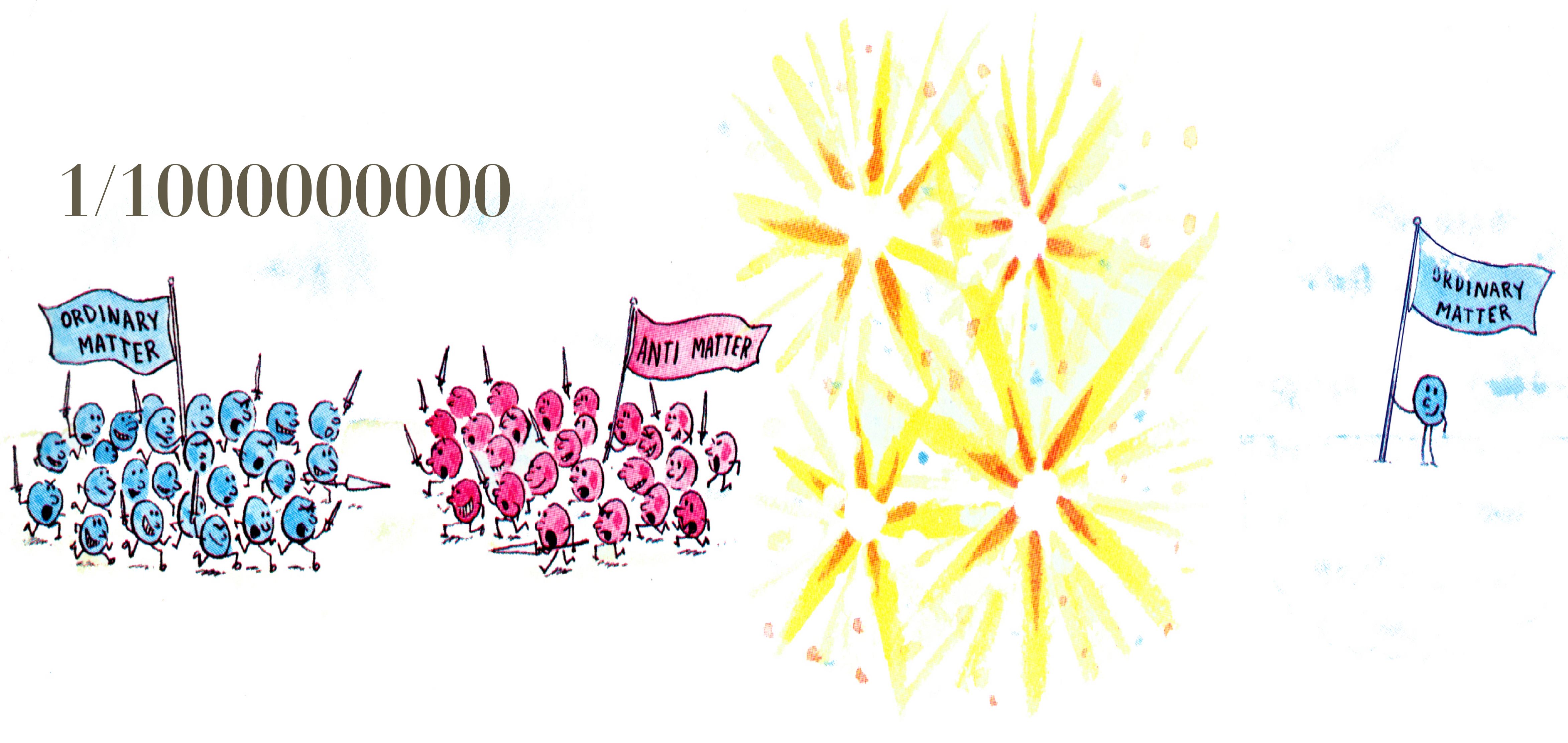
sooner or (much) later in the vacuum will fall



ATLAS and CMS at LHC

Decay channel	Branching ratio	Rel. uncertainty
$H \to \gamma\gamma$	2.27×10^{-3}	$+5.0\%$ -4.9%
$H \to ZZ$	2.62×10^{-2}	$+4.3\%$ -4.1%
$H \to W^+W^-$	2.14×10^{-1}	$+4.3\%$ -4.2%
$H \to \tau^+\tau^-$	6.27×10^{-2}	$+5.7\%$ -5.7%
$H \to b\bar{b}$	5.84×10^{-1}	$+3.2\%$ -3.3%
$H \to Z\gamma$	1.53×10^{-3}	$+9.0\%$ -8.9%
$H \to \mu^+\mu^-$	2.18×10^{-4}	$+6.0\%$ -5.9%

nice picture, inspired by the most perverse game of the human kind but …..?



For every billion ordinary particles annihilating with antimatter in the early Universe, one extra was left "standing."

need an answer !

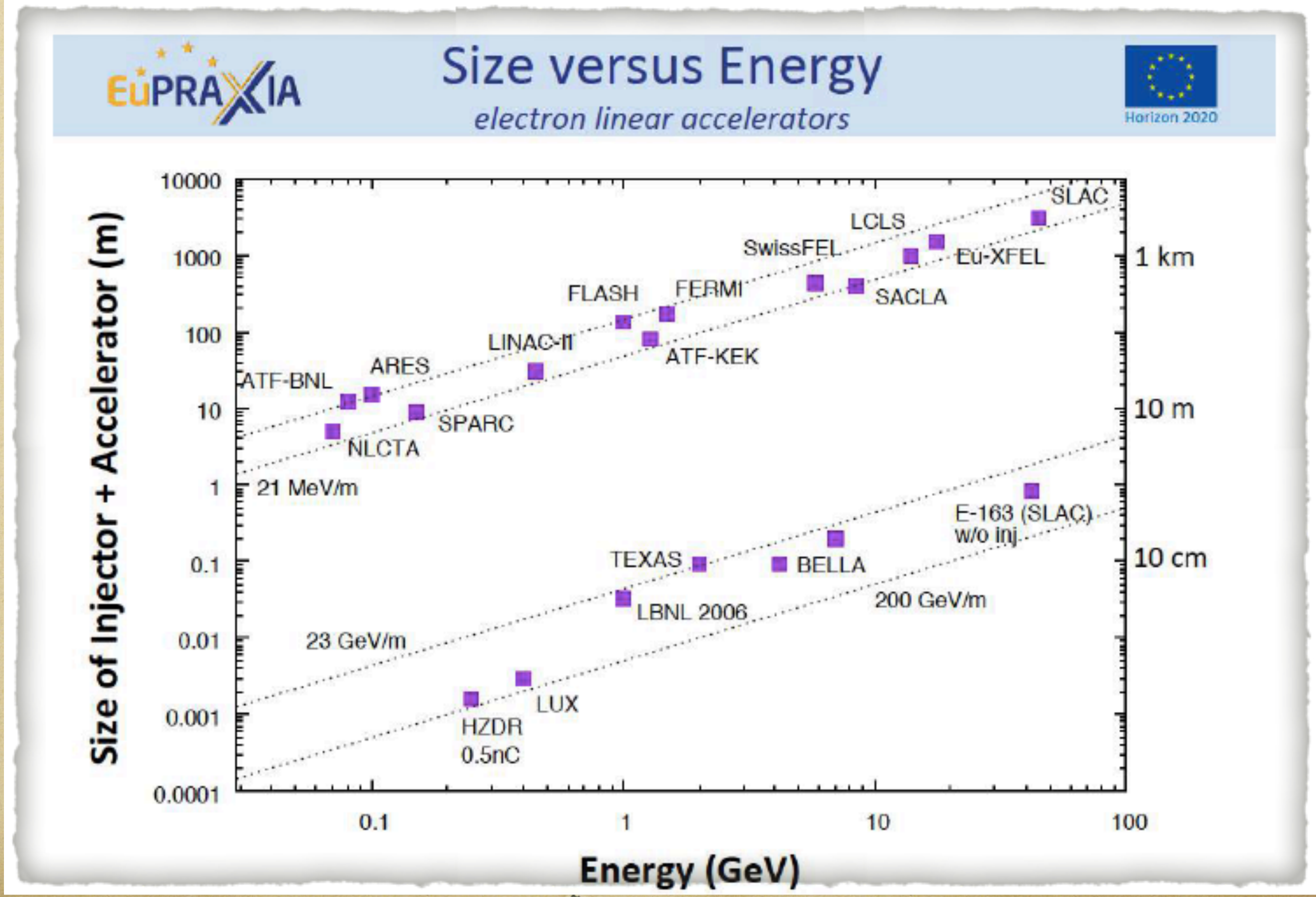
LHCb at LHC
and
BelleII at KEK-B

Flavour Physics is still an amazing mistery

New accelerators ? Yes indeed

- look for innovative solutions, new technologies, new concepts
- brute force is not intellectually challenging

shorter is better (if it works !)



Motivations

EuPRAXIA

Horizon2020

PRESENT EXPERIMENTS

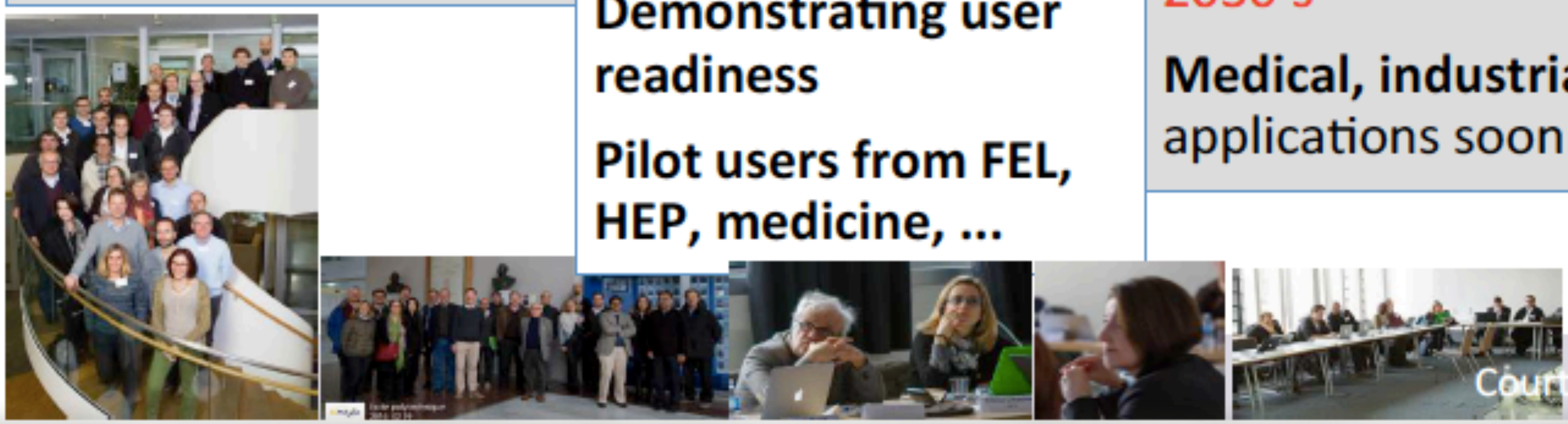
- Demonstrating **100 GV/m** routinely
- Demonstrating **GeV** electron beams
- Demonstrating basic **quality**

EuPRAXIA INFRASTRUCTURE

- **Engineering a high quality, compact plasma accelerator**
- **5 GeV electron beam for the 2020's**
- **Demonstrating user readiness**
- **Pilot users from FEL, HEP, medicine, ...**

PRODUCTION FACILITIES

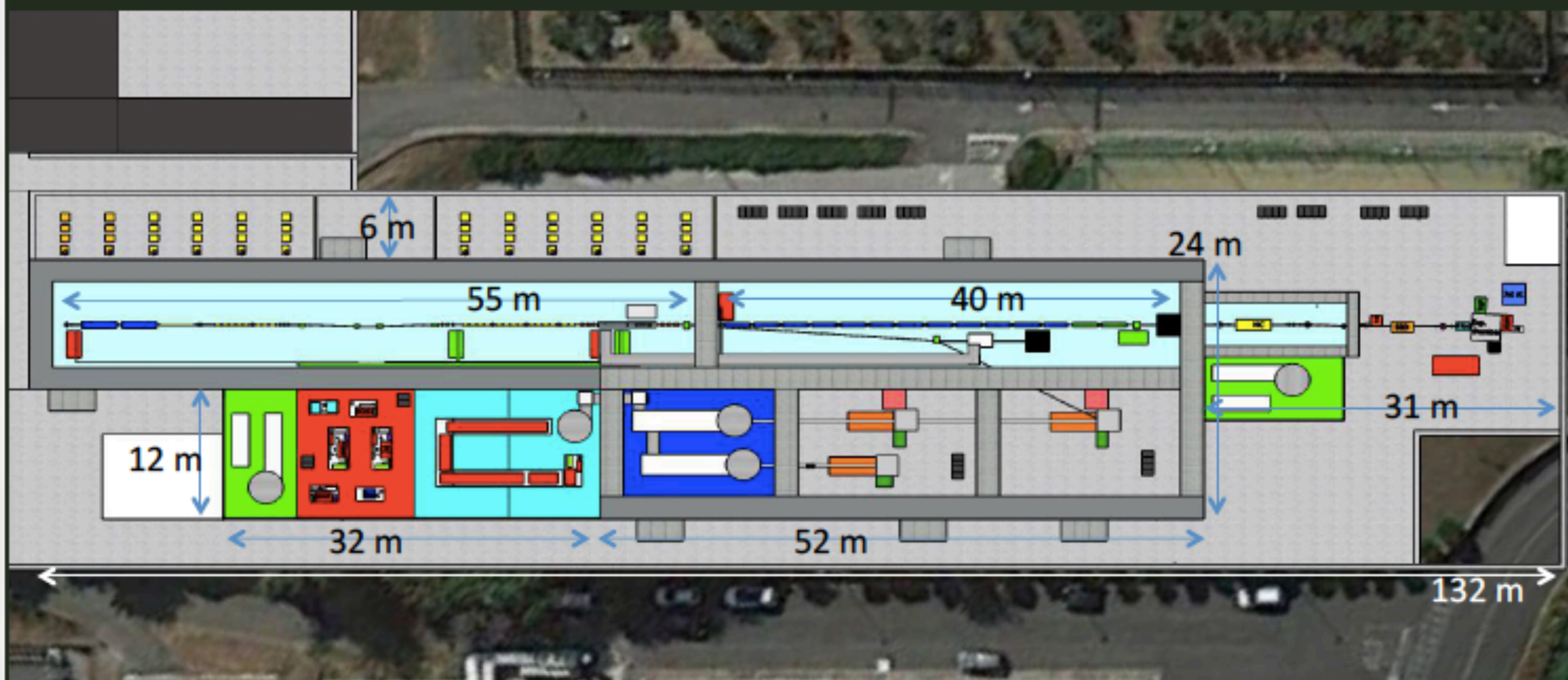
- Plasma-based **linear collider** in 2040's
- Plasma-based **FEL** in 2030's
- **Medical, industrial** applications soon



Courtesy R. Assmann

EuPRAXIA@SPARC_LAB

- Candidate LNF to host EuPRAXIA (1-5 GeV)
- FEL user facility (1 GeV – 3nm)
- Advanced Accelerator Test facility (LC) + CERN



- 500 MeV by RF Linac + 500 MeV by Plasma (LWFA or PWFA)
- 1 GeV by X-band RF Linac only
- Final goal compact 5 GeV accelerator

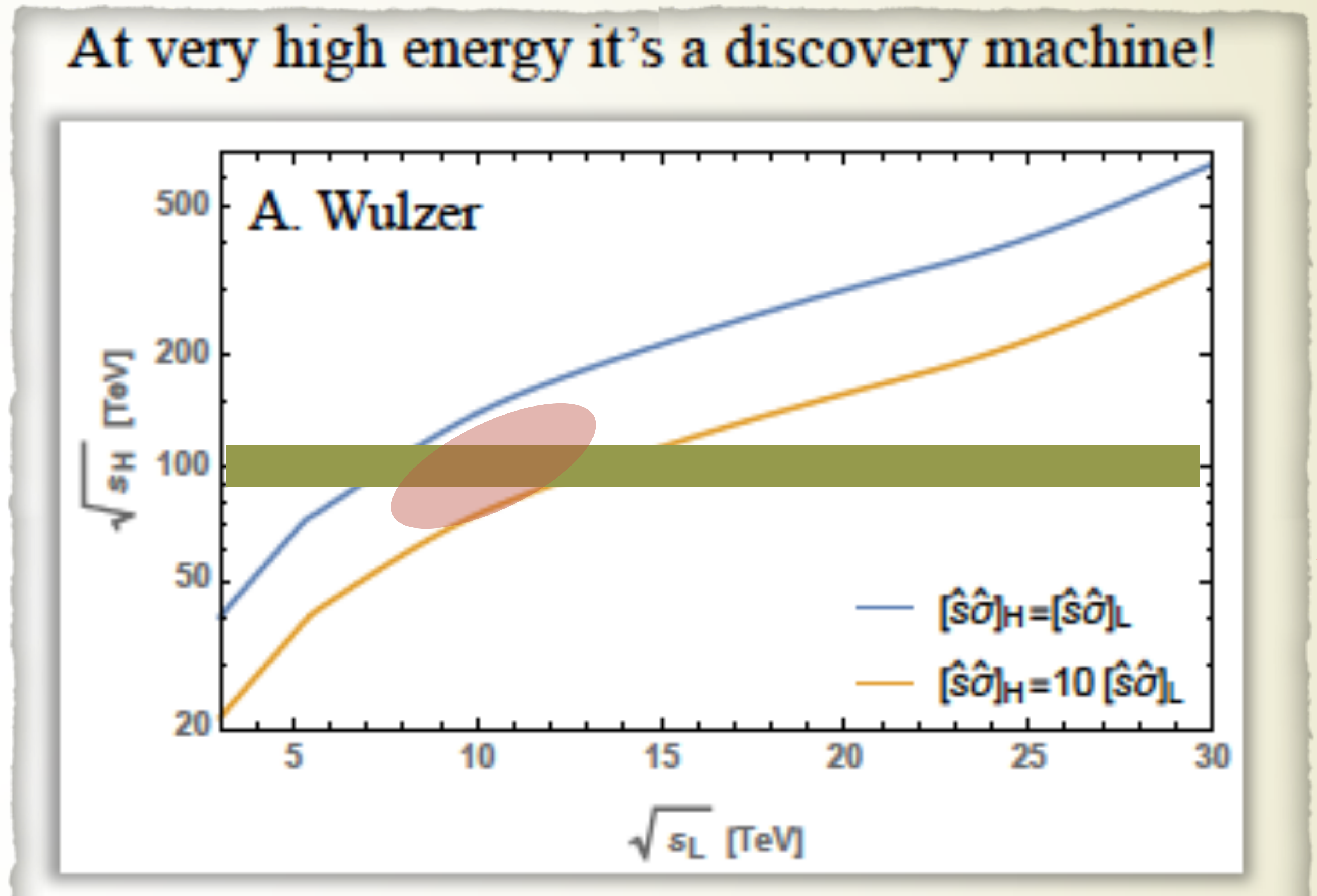
and the idea of a muon collider without the muon cooling

- we need another collider in the future
- a) to study the Higgs coupling (solid argument)
- b) to explore the multi-TeV region (never know !)
- try not to use brute force, make experimentalists happy (no background) and accelerator community excited (something new)

Higgs coupling

- no space for new idea, need it soon
- CEPC is the perfect machine for this scope. ILC is second and HL-LHC third. However HL-LHC we (will) have it, the others who knows !
- Producing Higgs in s-channel would be great but you cannot be competitive in terms of yield.

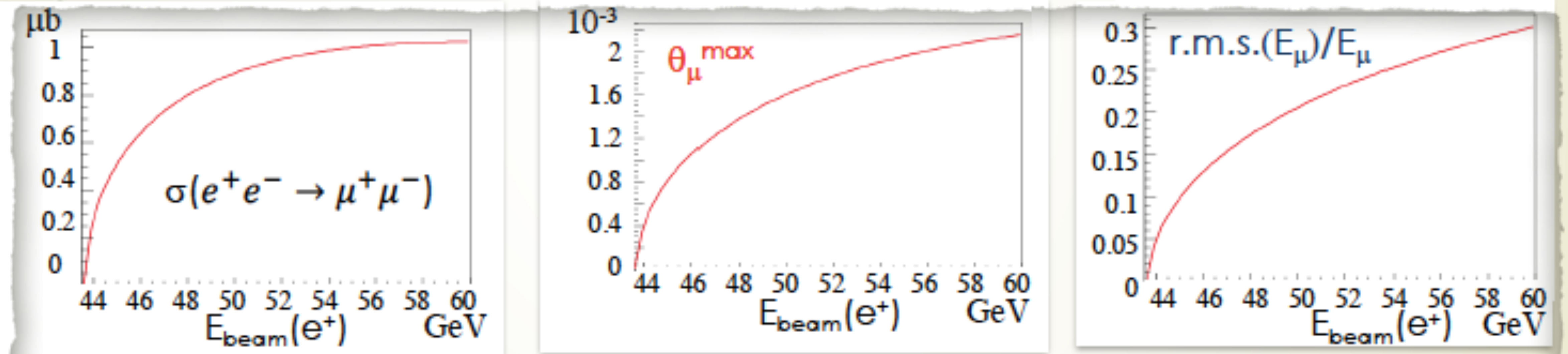
but…at high energy…



$$\sigma_L(s_L) = \frac{1}{s_L}[\hat{s}\hat{\sigma}]_L \qquad \sigma_H(E, s_H) = \frac{1}{s_H}\int_{E^2/s_H}^{1}\frac{d\tau}{\tau}\frac{dL}{d\tau}[\hat{s}\hat{\sigma}]_H$$

the tunnel
would already
exist !

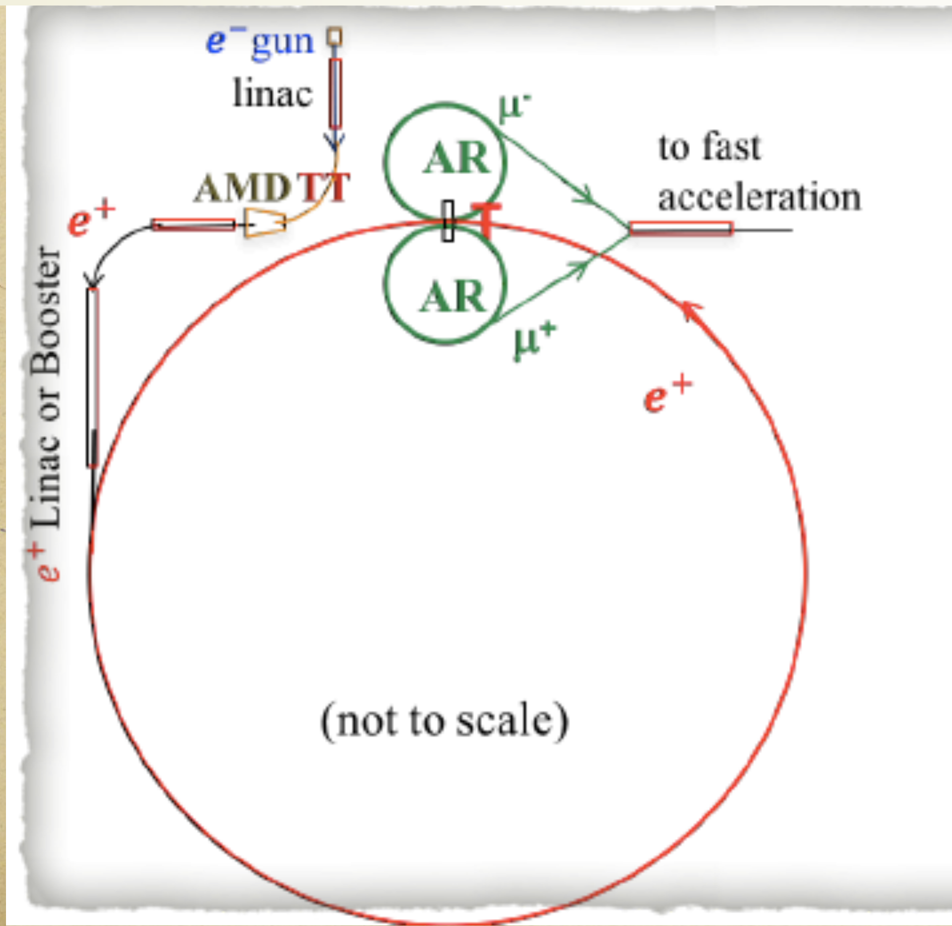
LEMS



$E_{beam}(e^+) = 45$ GeV is assumed

$\gamma(\mu) \approx 200 \Rightarrow$ laboratory lifetime of about 500 μs

"Natural" Beam Energy Spread 0.05



Positron Source

- e^- on conventional Heavy Thick Target (TT) for e^+e^- pairs production.
- Adiabatic Matching Device (AMD) for e^+ collection

Positron Ring

- Acceleration and injection (Linac/Booster)
- 6.3 km 45 GeV storage ring with target T for muon production

Muon Beams

- $\mu^\pm$ produced by e^+ beam on target T with E≈ 22GeV, $\gamma(\mu) \approx 200 \rightarrow \tau_{lab}(\mu) \approx 500\mu s$
- AR: 60 m isochronous and high momentum acceptance rings to recombine $\mu^\pm$ bunches in~1 τ_μ^{lab} ≈2500 turns
- $\mu^\pm$ fast acceleration

if….

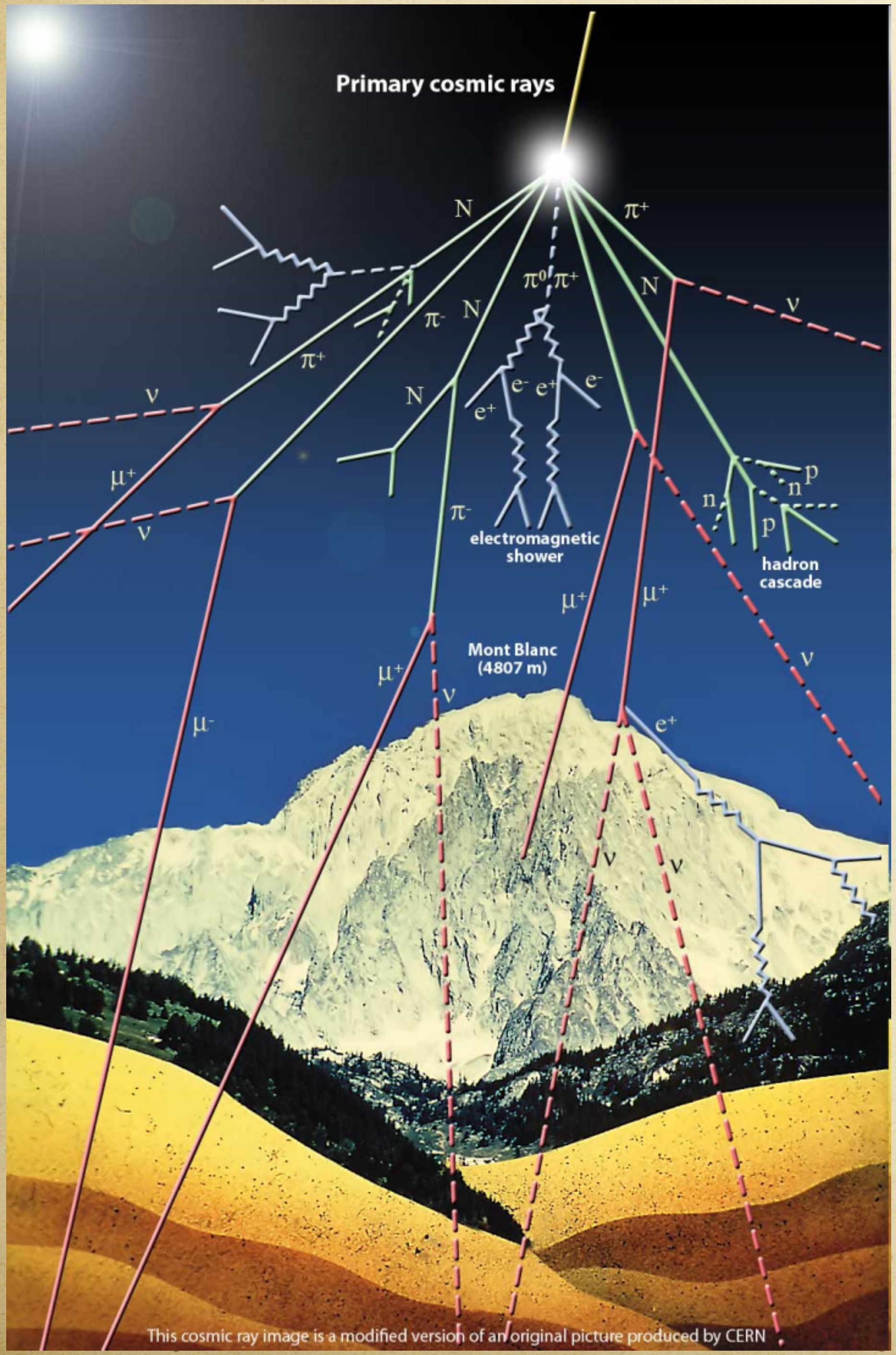
- if could be done
- it would be a great machine
- saving space and money
- producing clean physics
- and a great intellectual challenge to demonstrate

Looking for Dark Matter

LNGS

- The lab where we study (surprisingly for many) the life of the stars from birth to death
- A leading lab for Dark Matter searches
- A leading lab for testing Majorana neutrino hypothesis

A lab in a National Park



3 exp halls ~100 x 20 m2 (h 20 m)

Muon Flux
$3.0\ 10^{-4}\ \mu\ m^{-2}\ s^{-1}$

with a 10^8 reduction wrt. surface

Neutron Flux	
$2.92\ 10^{-6}$ n $cm^{-2}\ s^{-1}$	(0-1 keV)
$0.86\ 10^{-6}$ n $cm^{-2}\ s^{-1}$	(> 1 keV)

Depth: 1400 m

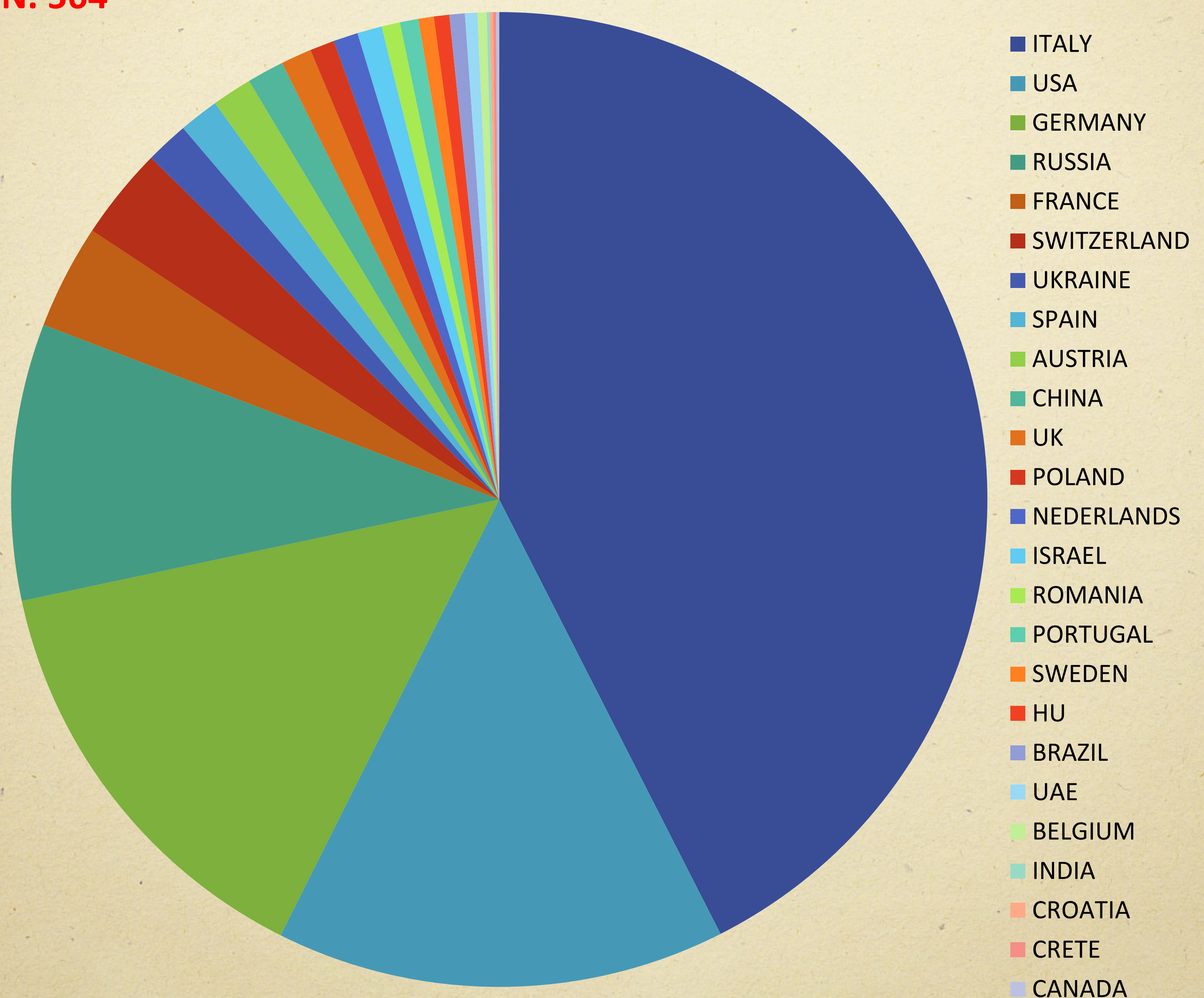
Surface: 17800 m2

Volume: 180000 m3

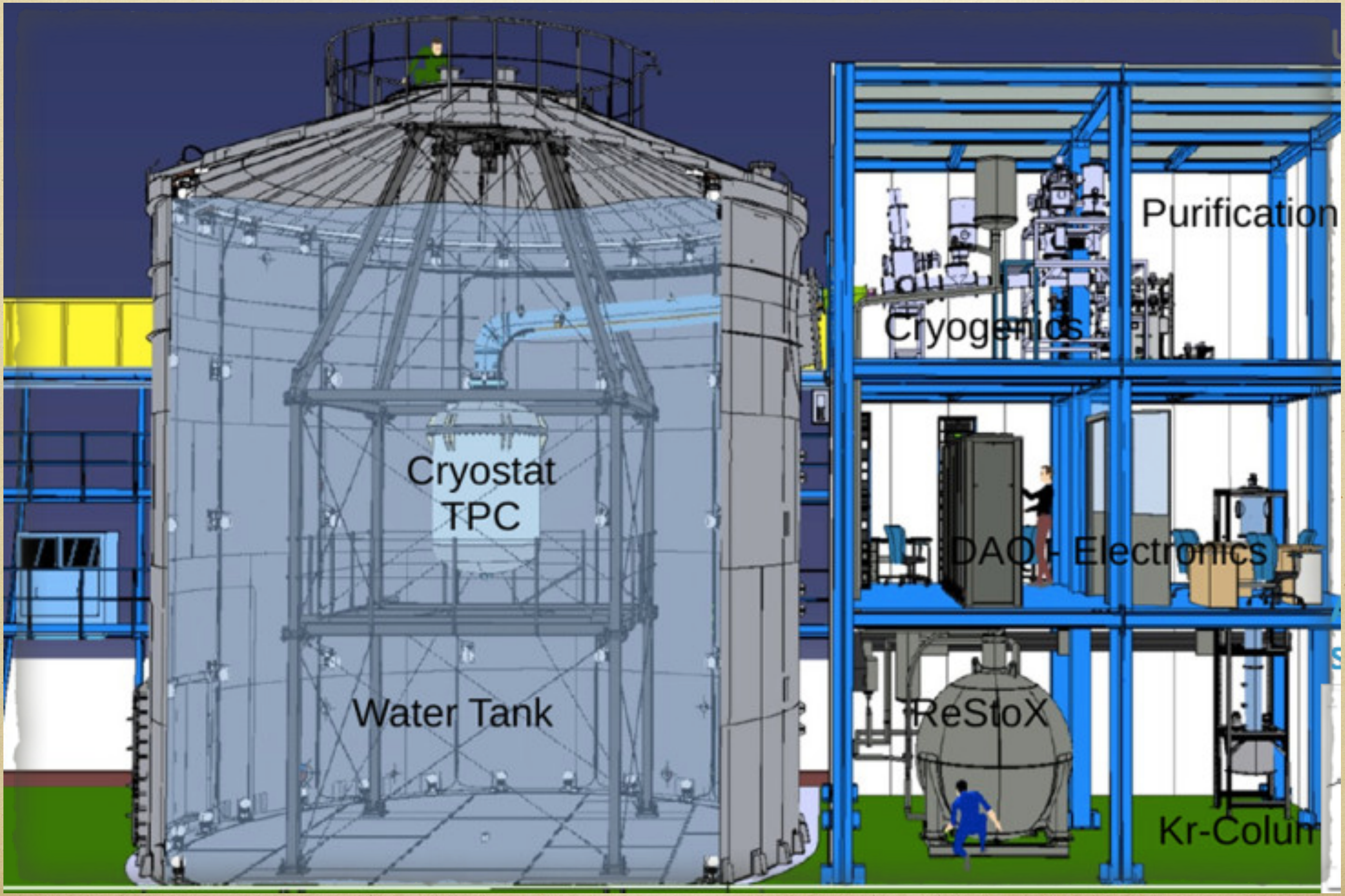
Access: horizontal

An international lab

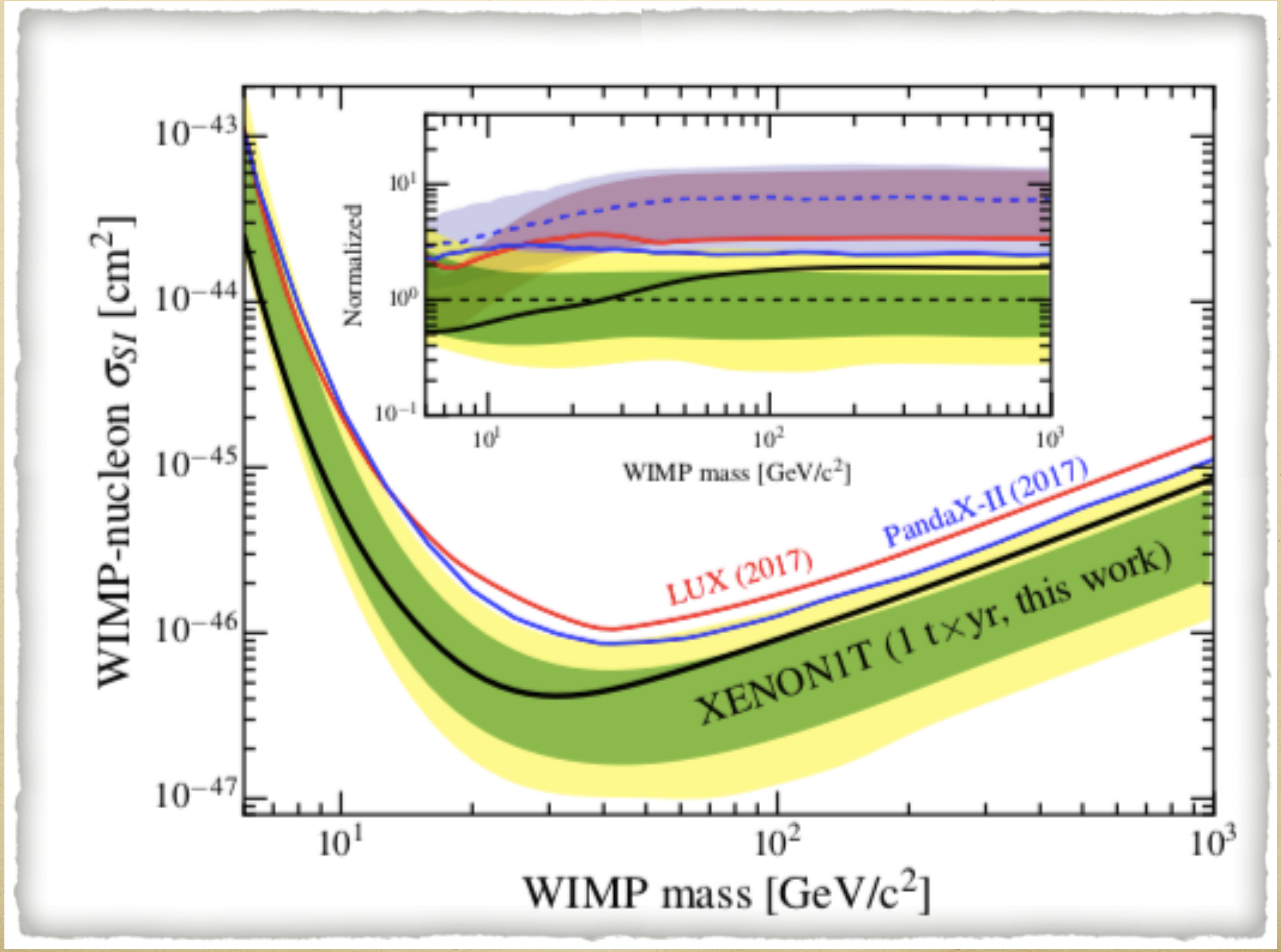
TOTAL USERS: N. 981
ITALIAN USERS: N. 417
FOREIGN USERS: N. 564



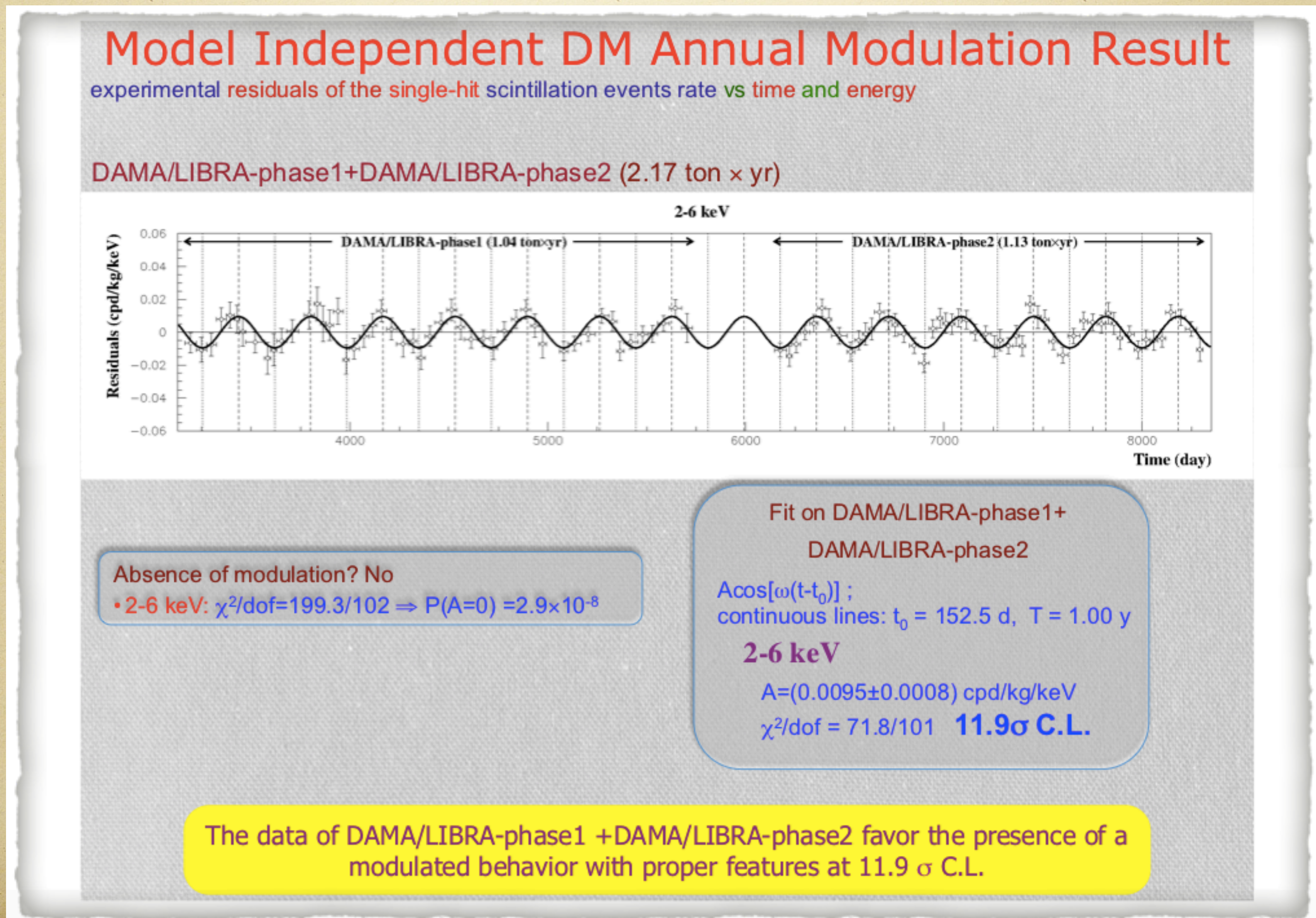
A leader experiment Xenon1Ton



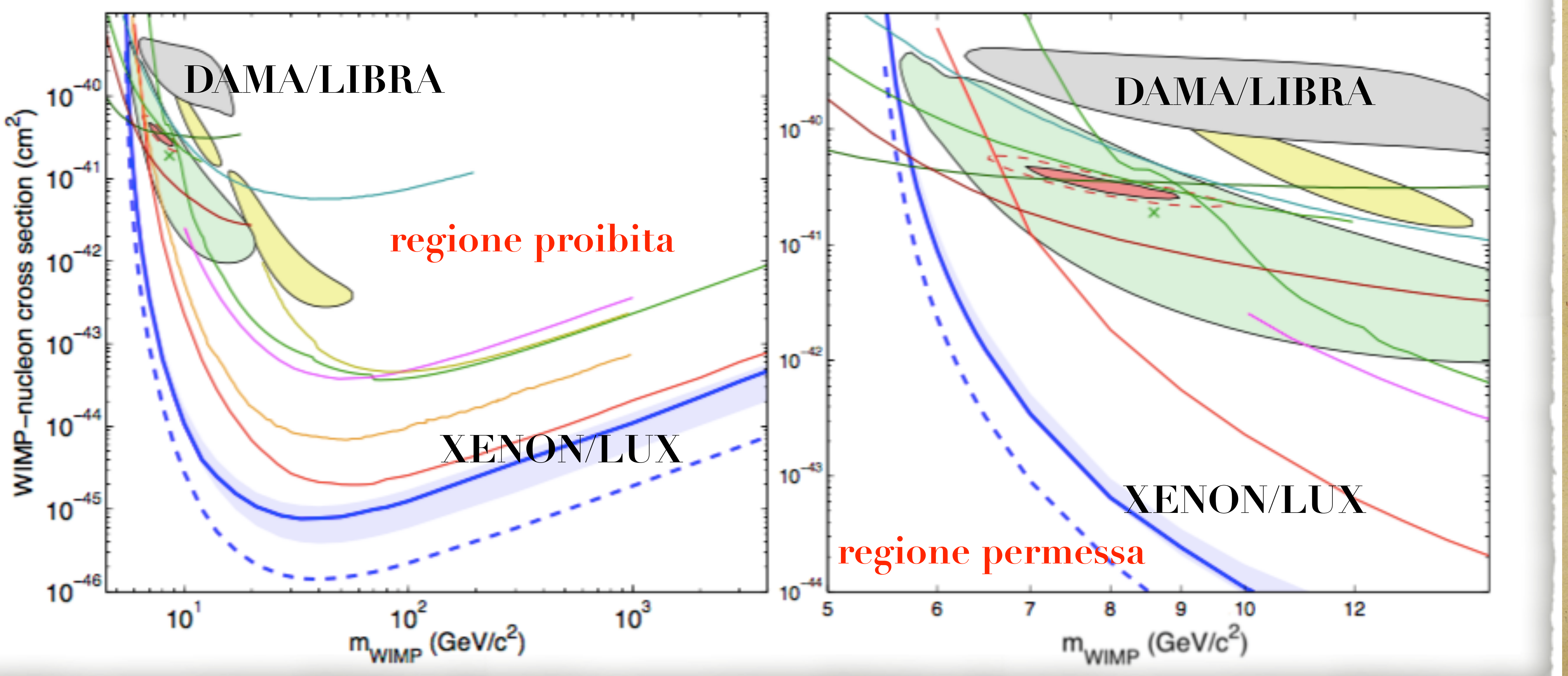
The XENON world record



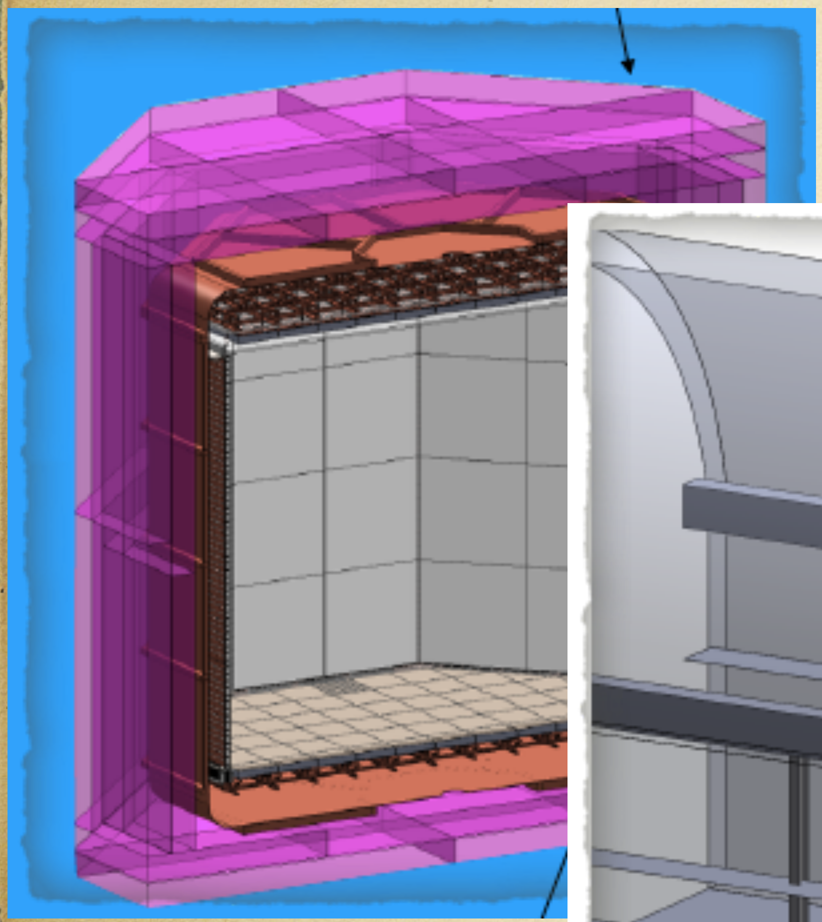
with the mistery of DAMA/LIBRA

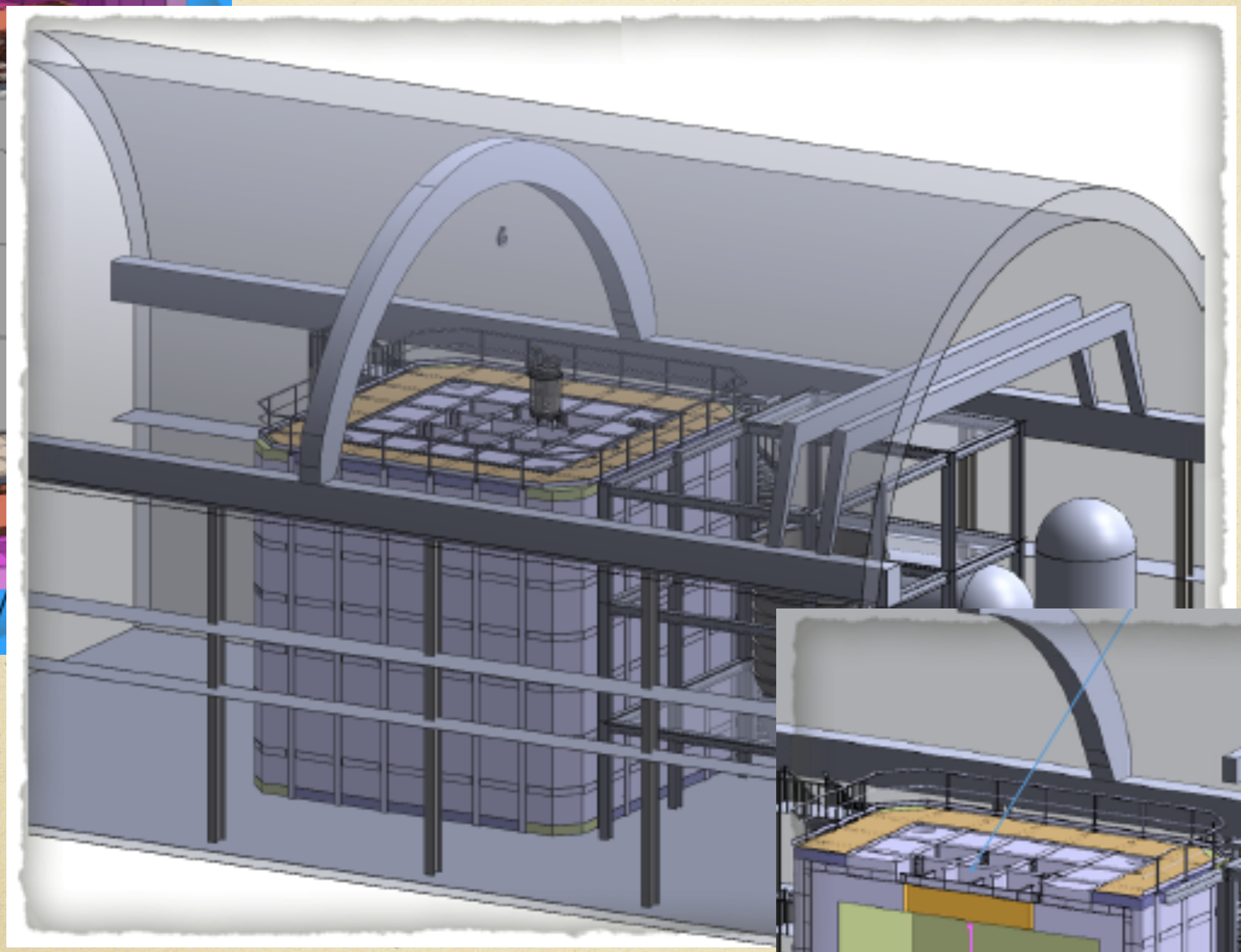


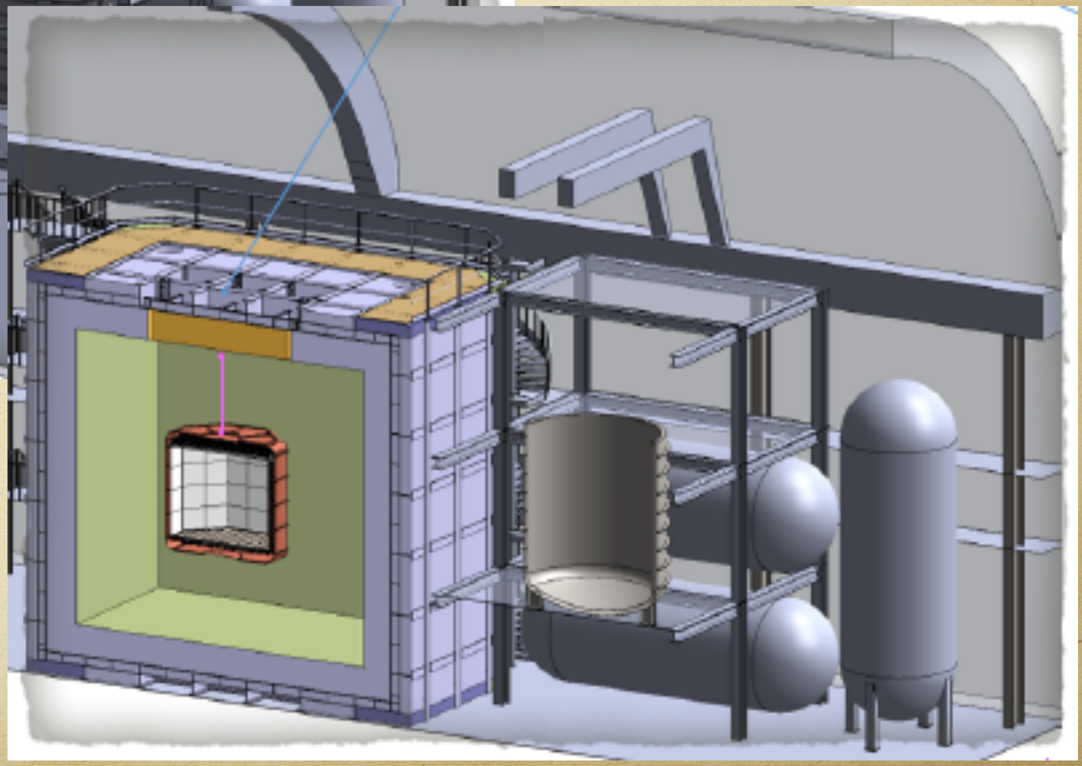
well, I can’t understand



Dark Side@LNGS







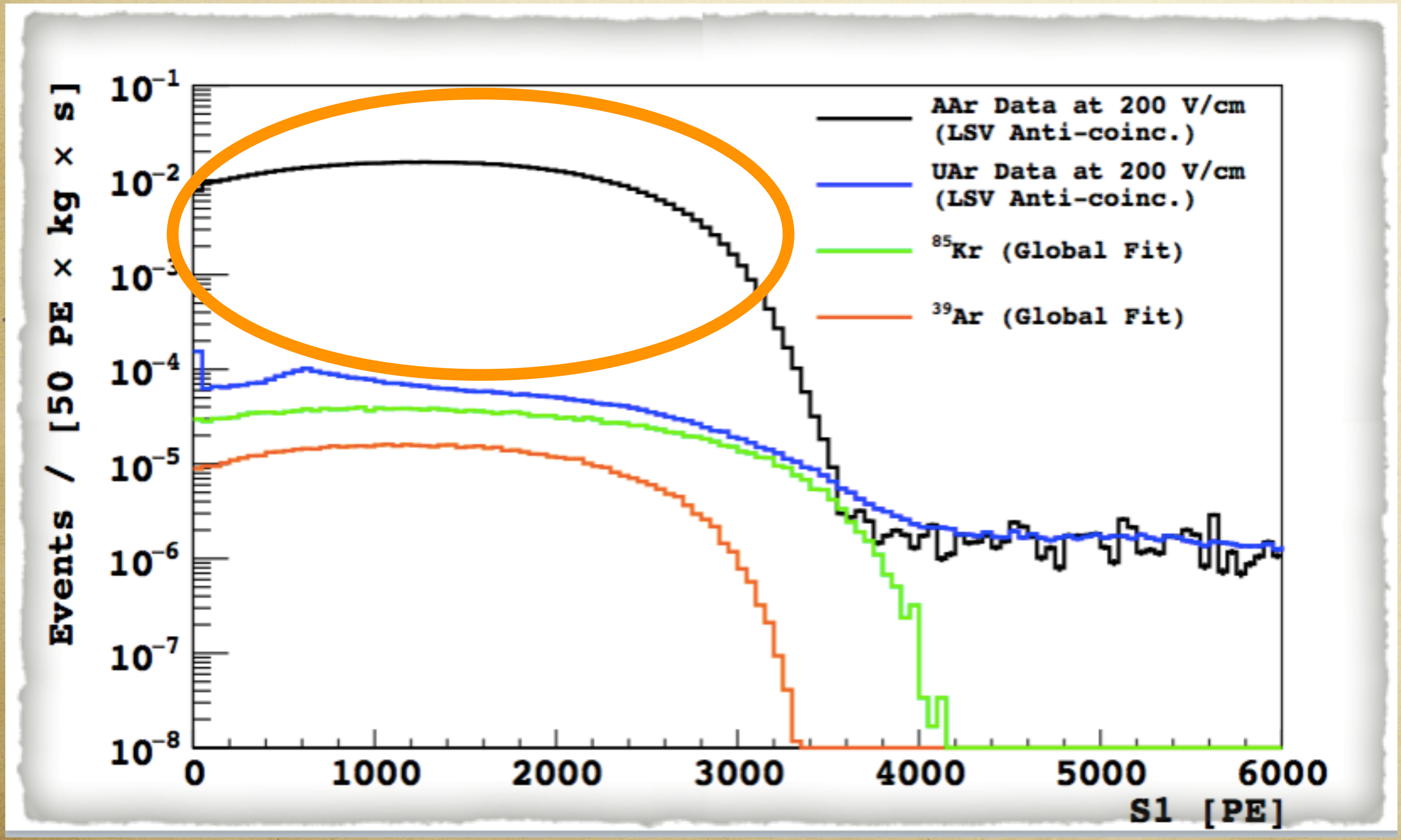
The Argon Way

a daring enterprise

^{39}Ar is radioactive, it has to be eliminated

It is created in the atmosphere by cosmic rays interactions

First remedy is to extract the Ar from a mine



Second step is distillation

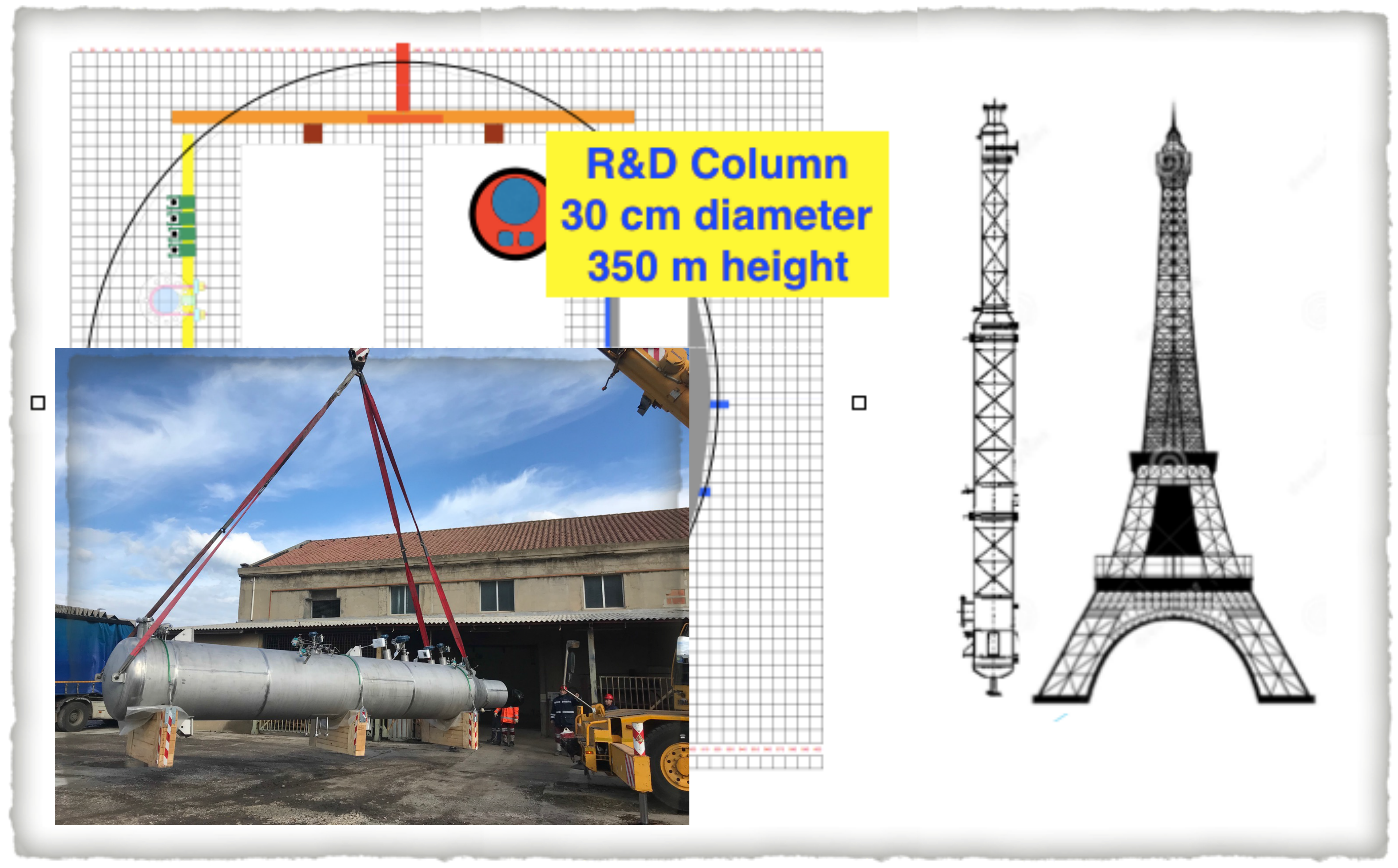
How ? Where ?

Aria@Sulcis

The shaft of a coal mine that is being shut down and needs reconversion of activity

In Sardinia.

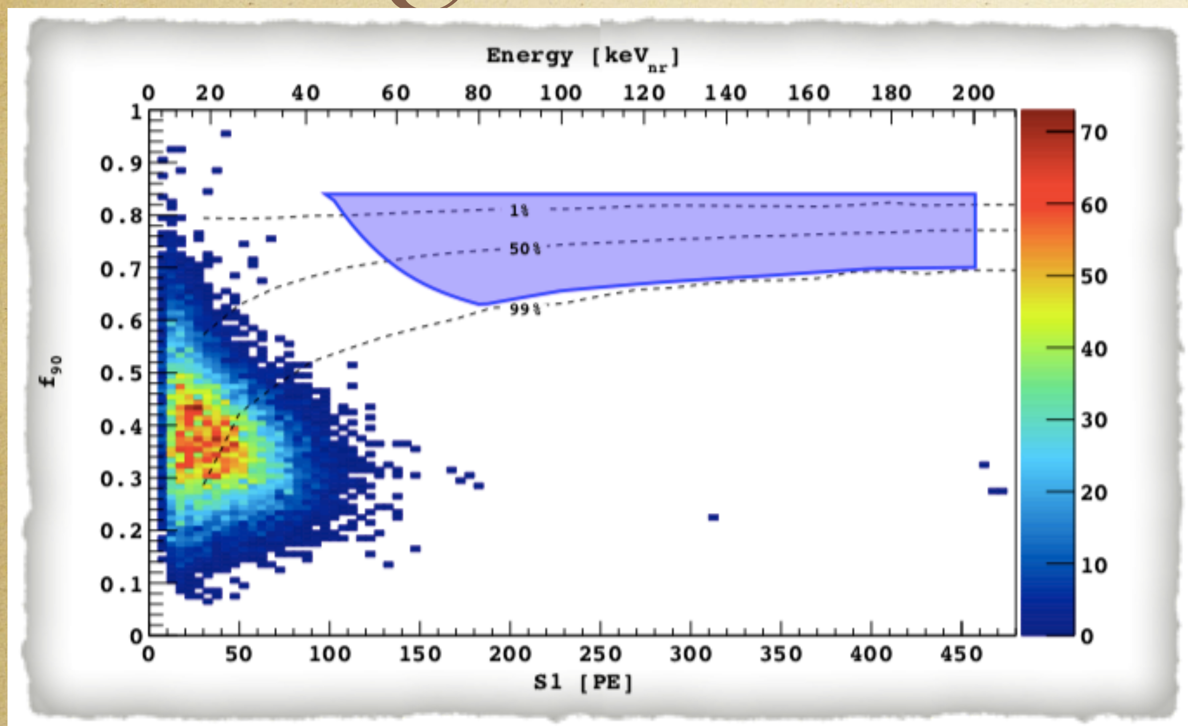
Separation by cryo-distillation



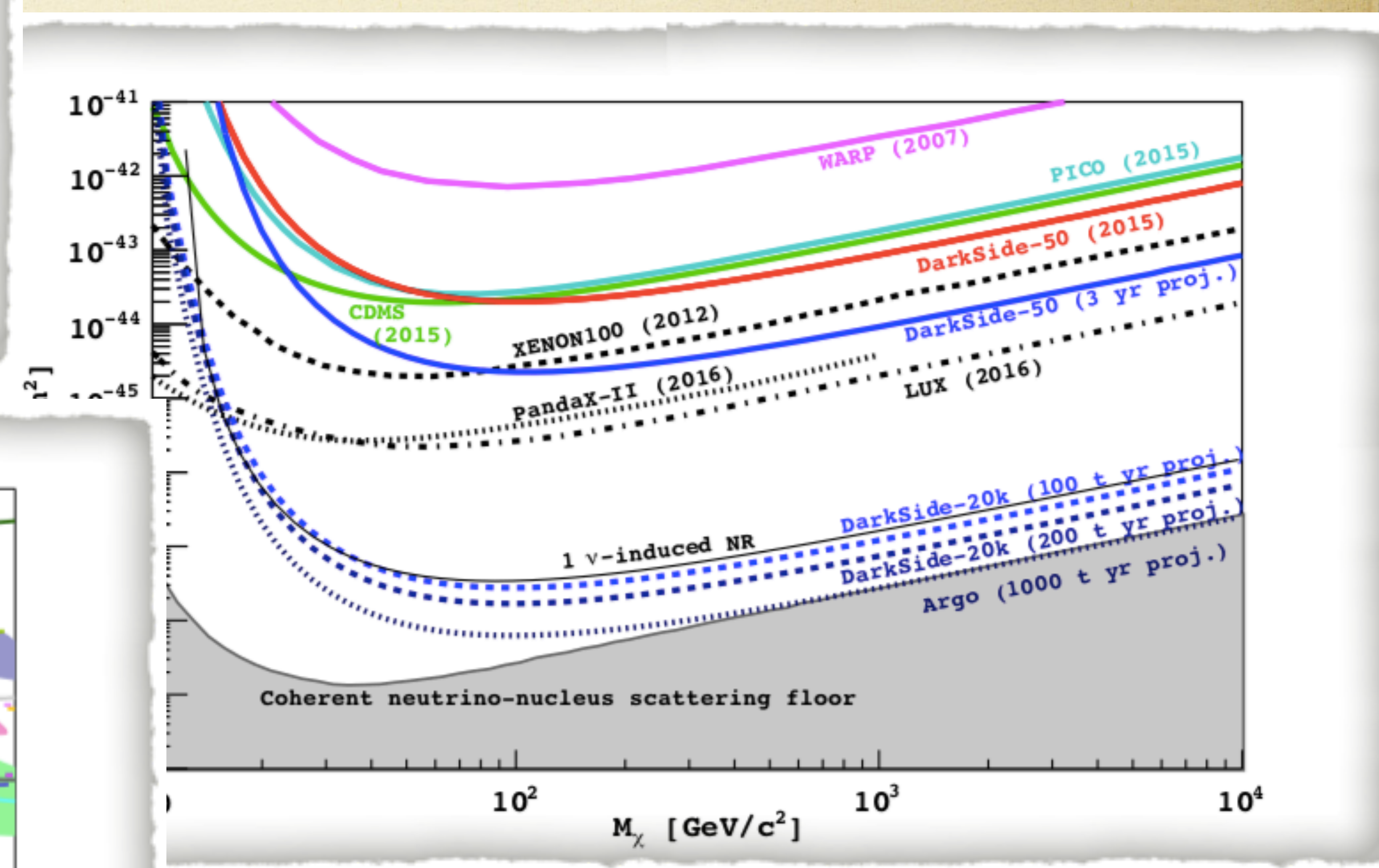
It has even interesting by-products !

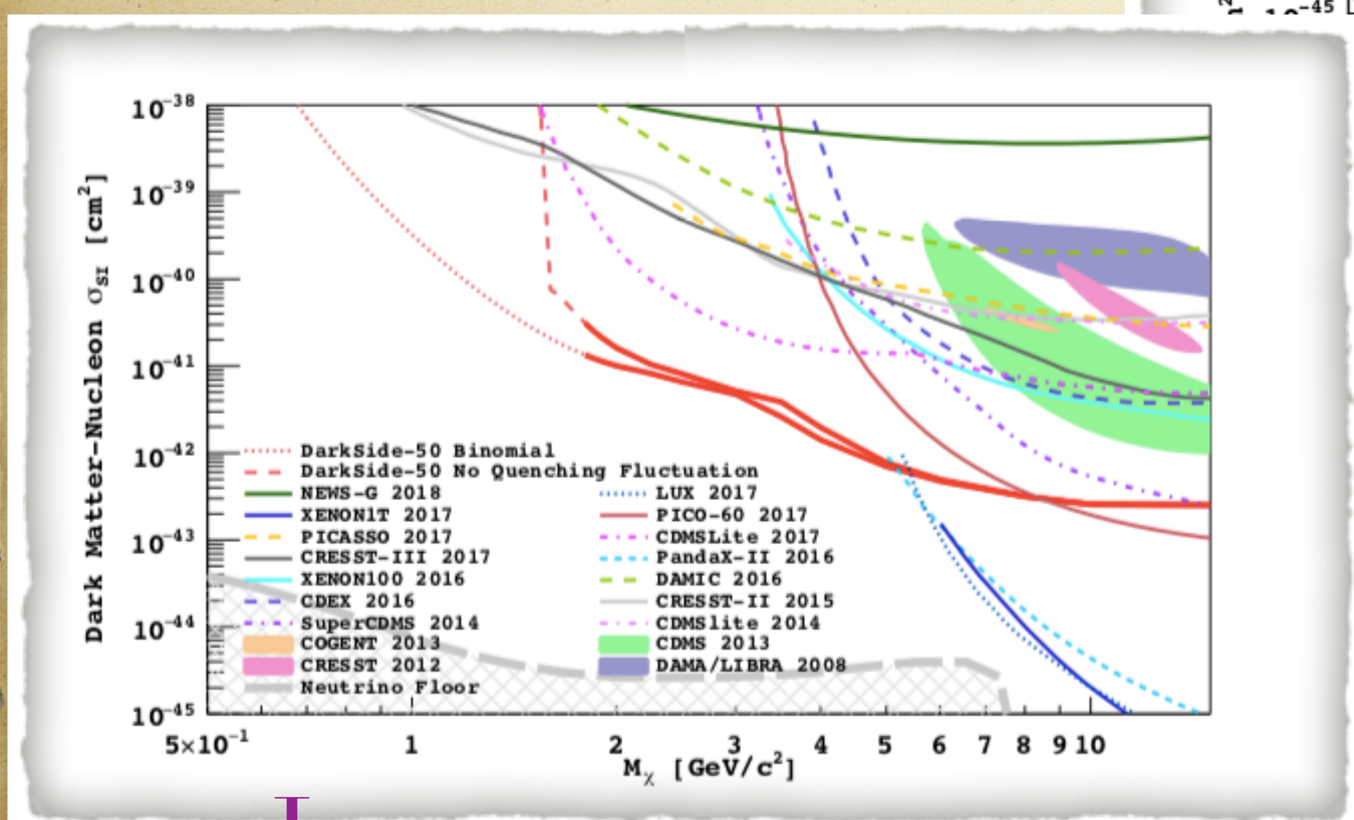
- it works better for lighter elements
- ^{18}O ($H_2{}^{18}O$ for the production of ^{18}F for PET)
- ^{13}C (breath test, NMR)
- ^{15}N (several possibilities)

Argon is worth to pursue



Zero bckg !





ν floor

Low masses

Gravitational Waves

the gift in 2017

NEWS FEATURE

MERGER MAKER

An astronomer helped scientists make the most of a historic gravitational-wave event.

BY DAVIDE CASTELVECCHI

For a few weeks starting on 17 August, it seemed as if every telescope on Earth and in space was looking in the same direction. Prompted by the latest detection of gravitational waves by facilities in Italy and the United States, some 70 teams of astronomers rushed to capture the first direct observations of the collision between two inspiralling neutron stars. What they saw solved several astrophysical mysteries at once, including the nature of certain γ-ray bursts and the origin of the Universe's heavier elements.

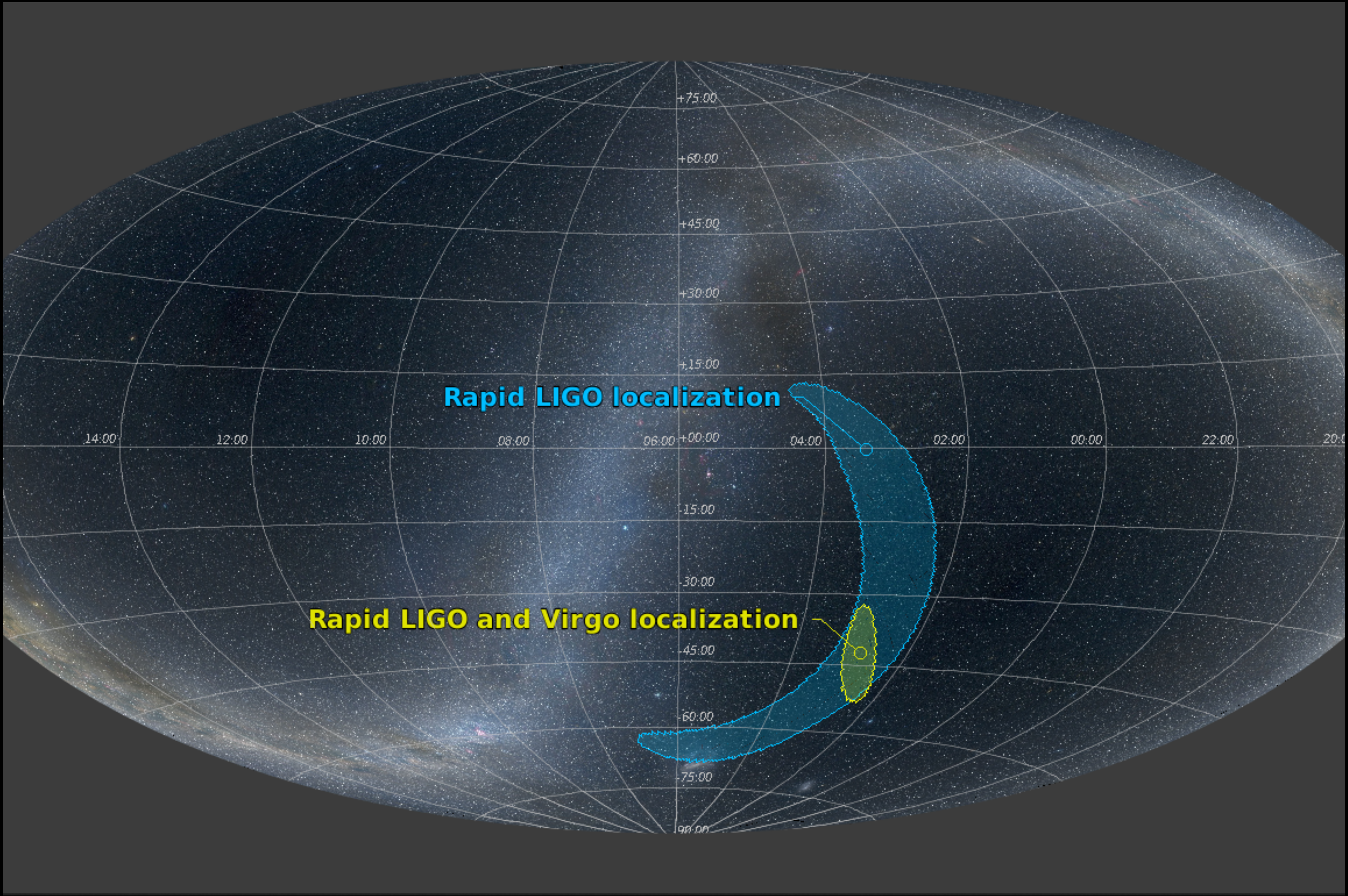
This effort was the result of years of preparation spearheaded by Marica Branchesi, a member of the Virgo collaboration, which operates the gravitational-wave detector near Pisa, Italy. Branchesi bridged the divide between observational astronomy and the physics-heavy realm of gravitational-wave research — fields that, until recently, had little reason to work together. "Marica has been the key communicator between astronomers and physicists," says Gabriela González, a physicist at Louisiana State University in Baton Rouge and the former spokesperson for Virgo's partner, the collaboration that runs the US-based Laser Interferometer Gravitational-Wave Observatory (LIGO).

Branchesi, an astronomer herself, joined Virgo in 2009 when she got a job at the University of Urbino, located in her Italian hometown. At the time, Virgo and LIGO were beginning to operate as one group, and it had become clear that they needed someone to act as an ambassador to the astronomy community. Gravitational waves, which are ripples in the fabric of space-time, reveal a side of the cosmos that ordinary telescopes cannot see. But in the case of a neutron-star merger, LIGO and Virgo would be able to detect only the final minutes leading up to it; much of the information about such collisions — and the elements produced in the process — would be accessible only by conventional telescopes.

When Branchesi began, she found that she had to encourage physicists to send out alerts about potential events, even when they were not completely sure they were genuine. She also had to persuade astronomers that it would be worth listening. Many were sceptical that LIGO and Virgo, which had already run for years without a single detection, would find anything. "It was my job to convince astronomers that it was a promising field," says Branchesi, who moved to Italy's Gran Sasso Science Institute

in memory of
Adalberto Giazotto

VIRGO@Cascina


Rapid LIGO localization
Rapid LIGO and Virgo localization
+75:00
+60:00
+45:00
+30:00
+15:00
+00:00
-15:00
-30:00
-45:00
-60:00
-75:00
-90:00
14:00
12:00
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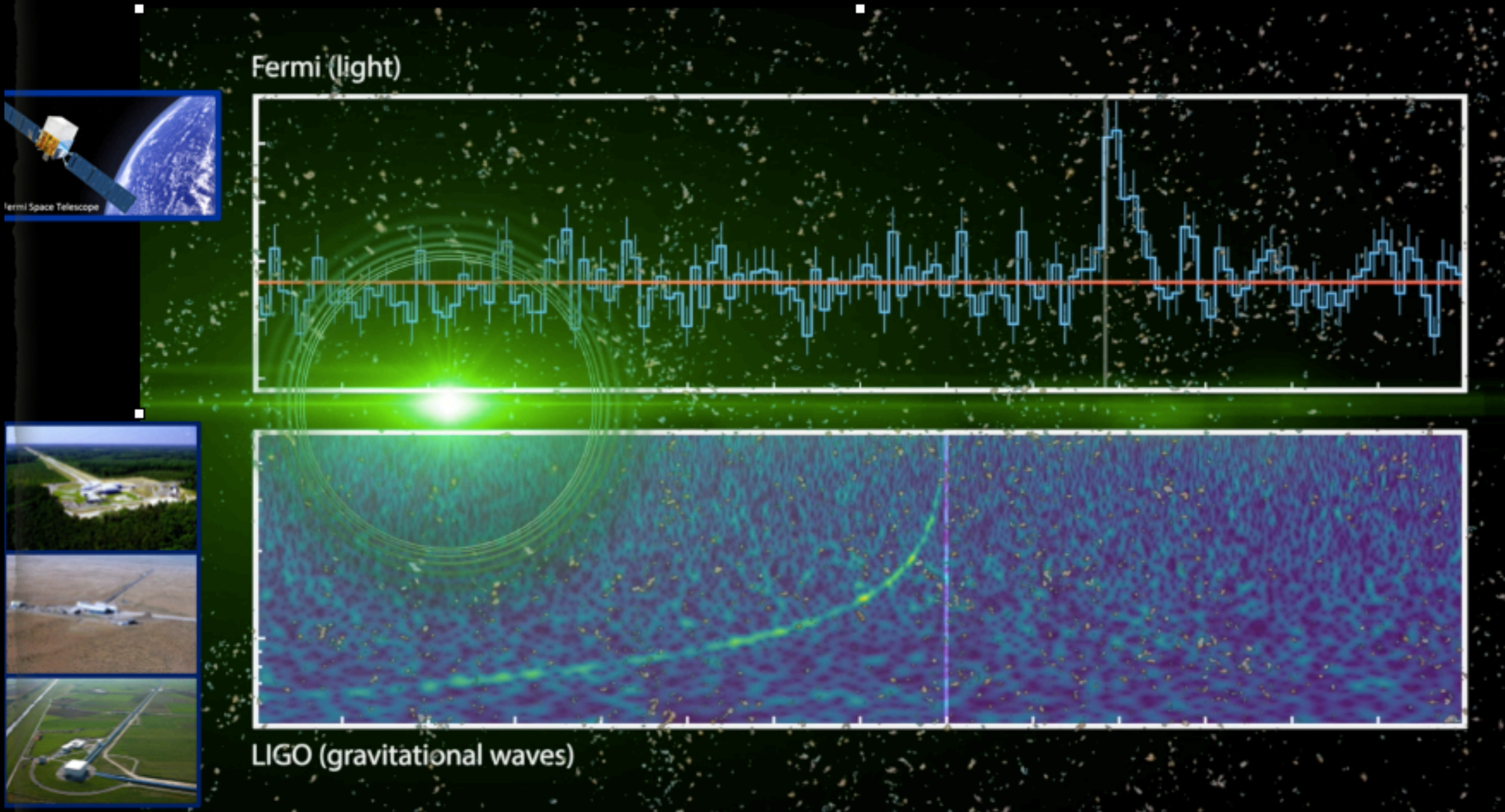
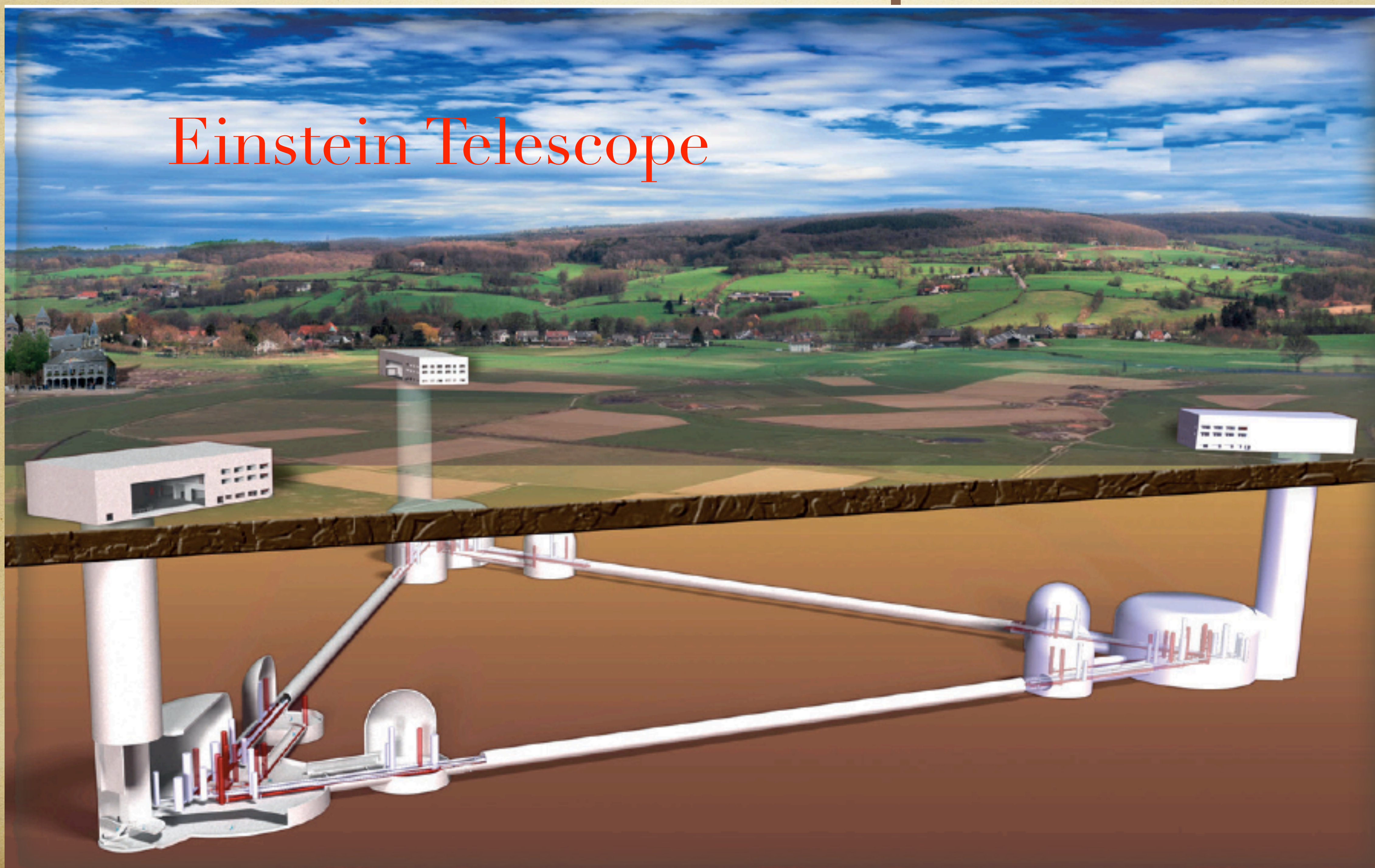
02:00
00:00
22:00

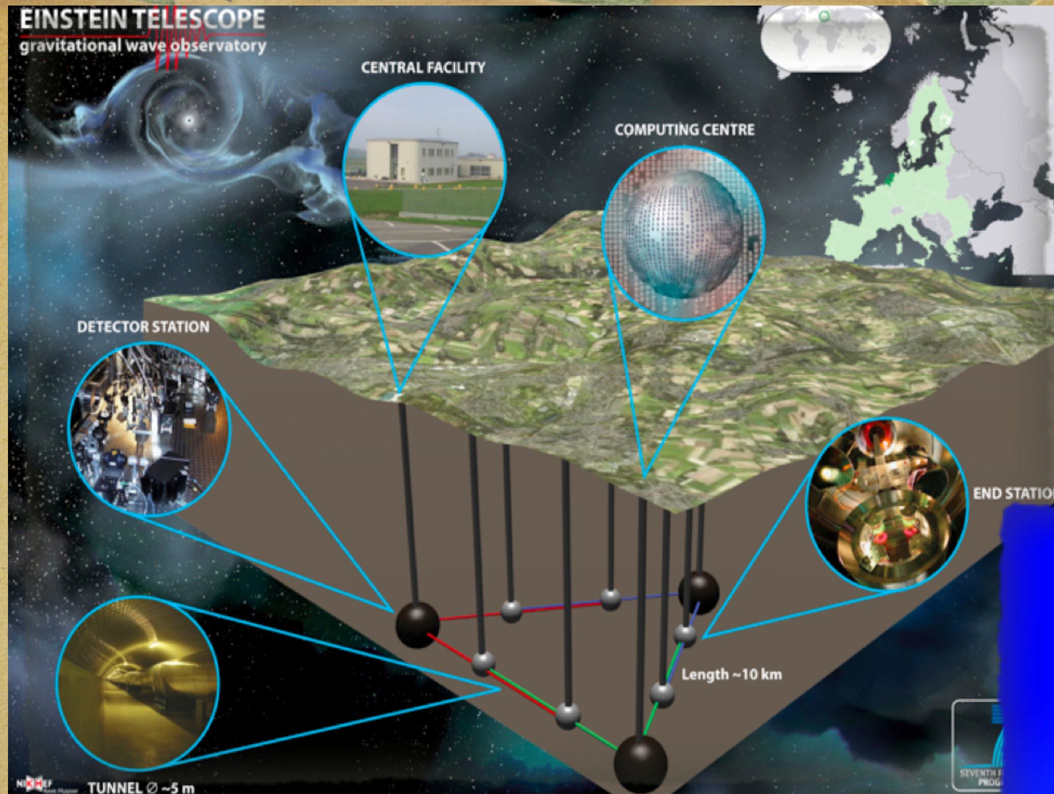


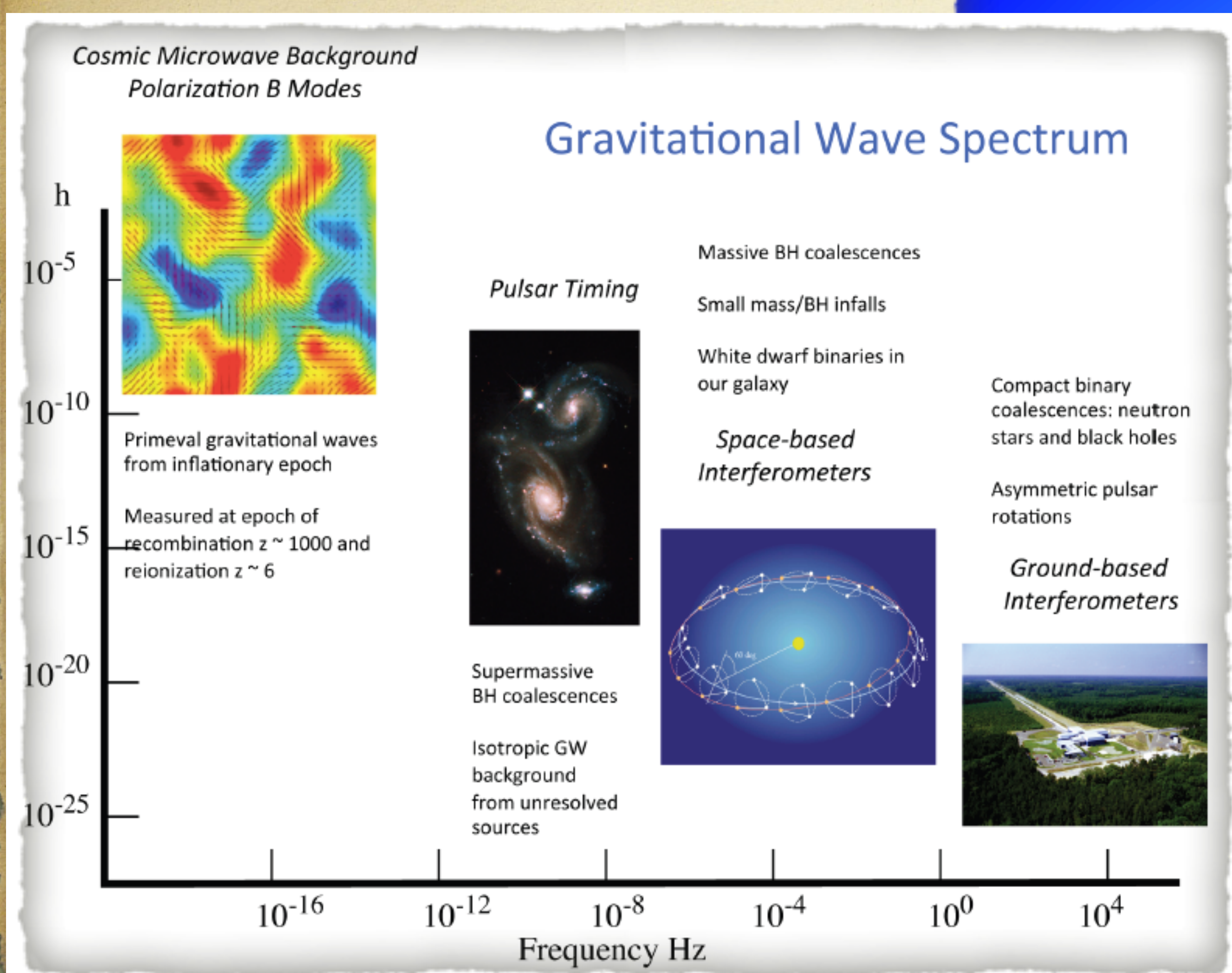
Credit: NASA's Goddard Space Flight Center/

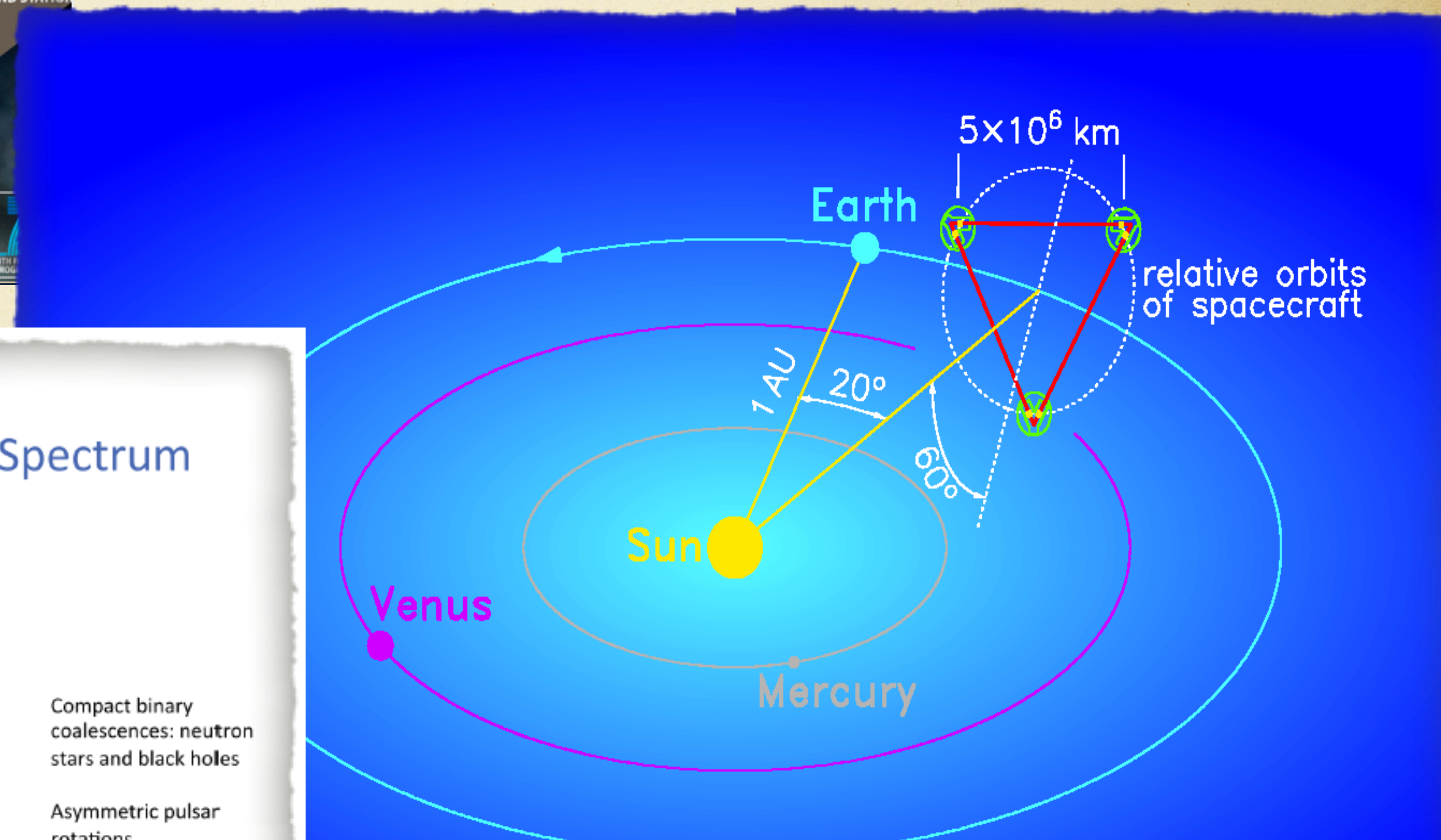
A two-fold future
Land and Space



and LISA


EINSTEIN TELESCOPE
gravitational wave observatory
CENTRAL FACILITY
COMPUTING CENTRE
DETECTOR STATION
END STATION
Length ~10 km
TUNNEL ⌀ ~5 m

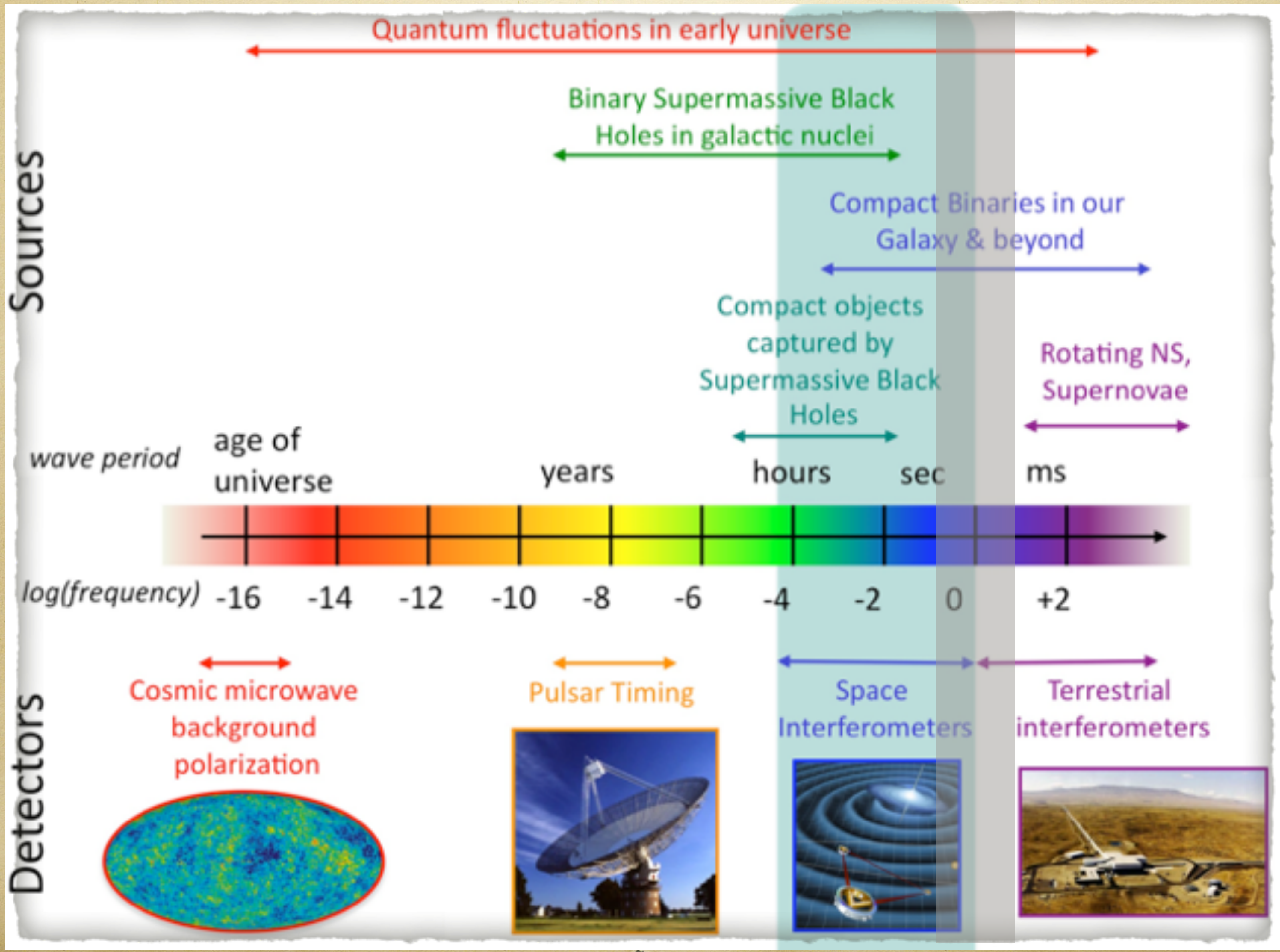

Cosmic Microwave Background
Polarization B Modes
Gravitational Wave Spectrum
h
10-5
10-10
10-15
10-20
10-25
Primeval gravitational waves from inflationary epoch
Measured at epoch of recombination z ~ 1000 and reionization z ~ 6
Pulsar Timing
Supermassive BH coalescences
Isotropic GW background from unresolved sources
Massive BH coalescences
Small mass/BH infalls
White dwarf binaries in our galaxy
Space-based Interferometers
Compact binary coalescences: neutron stars and black holes
Asymmetric pulsar rotations
Ground-based Interferometers
10-16
10-12
10-8
10-4
100
104
Frequency Hz


5×106 km
Earth
relative orbits of spacecraft
1AU
20°
60°
Sun
Venus
Mercury

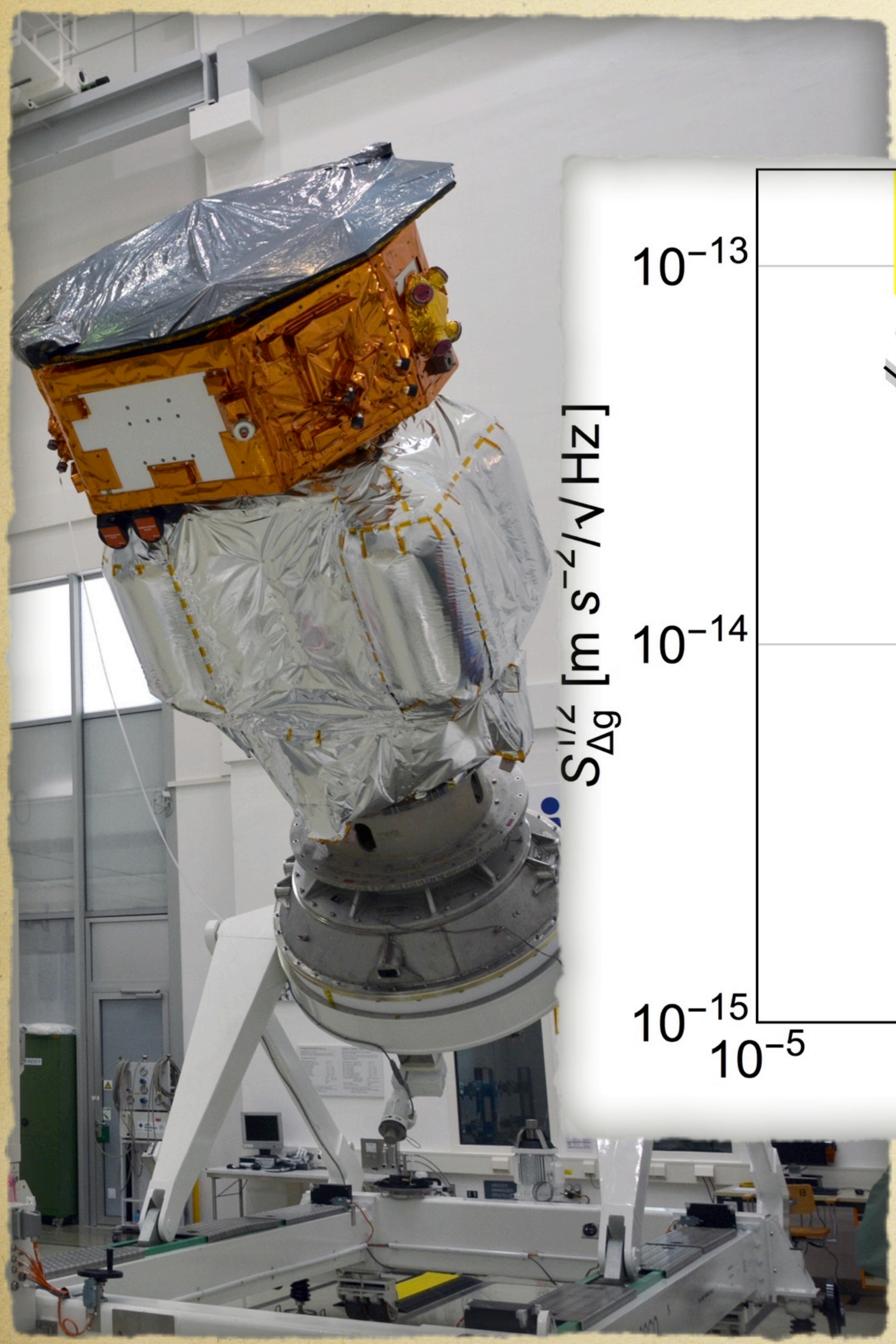
Warning

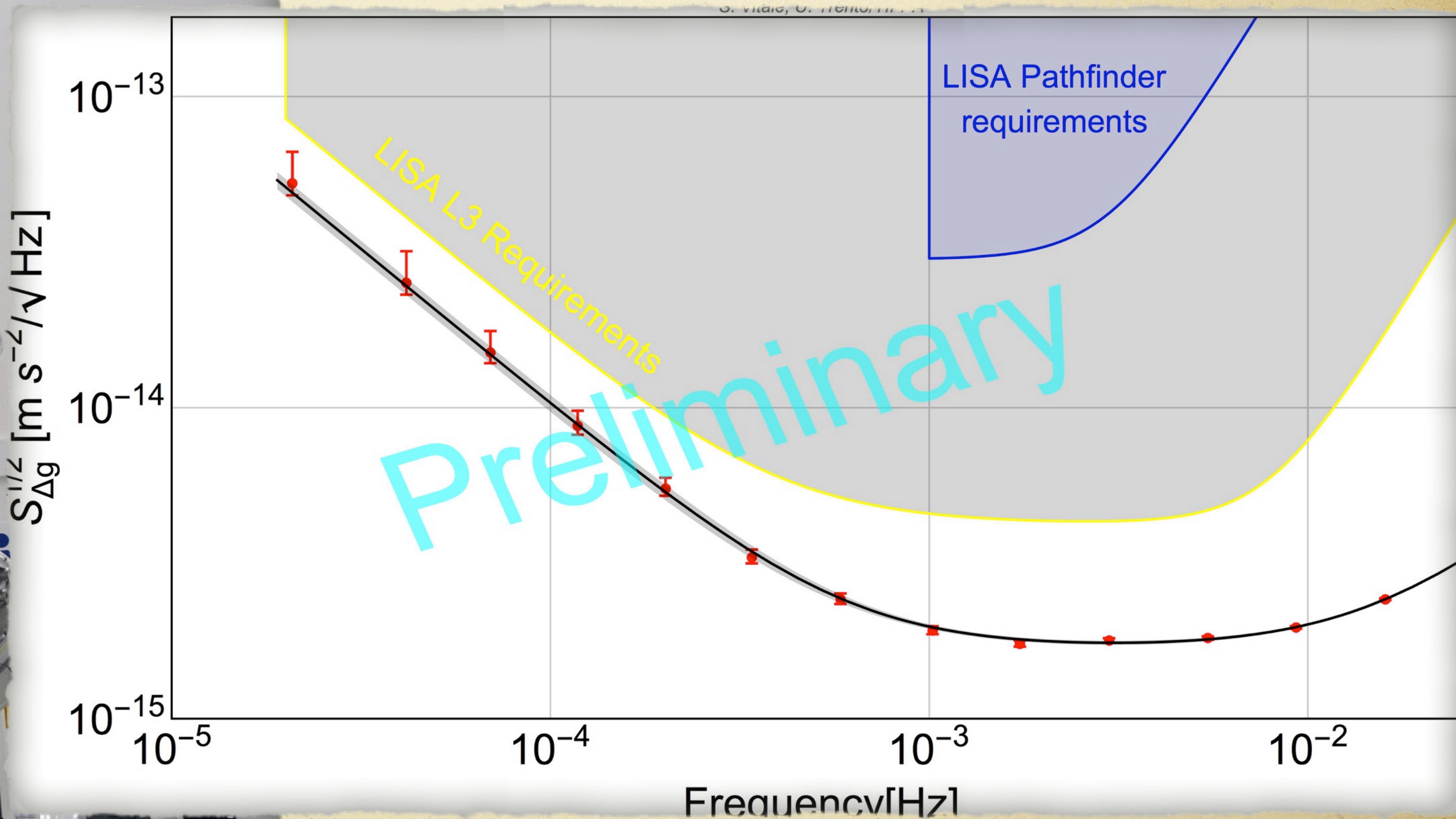
- ET and LISA will do two different things.
- Their sensitivity in frequency will not overlap.
- Both will be required to unravel the Universe hidden beauty.

the frequency spectrum

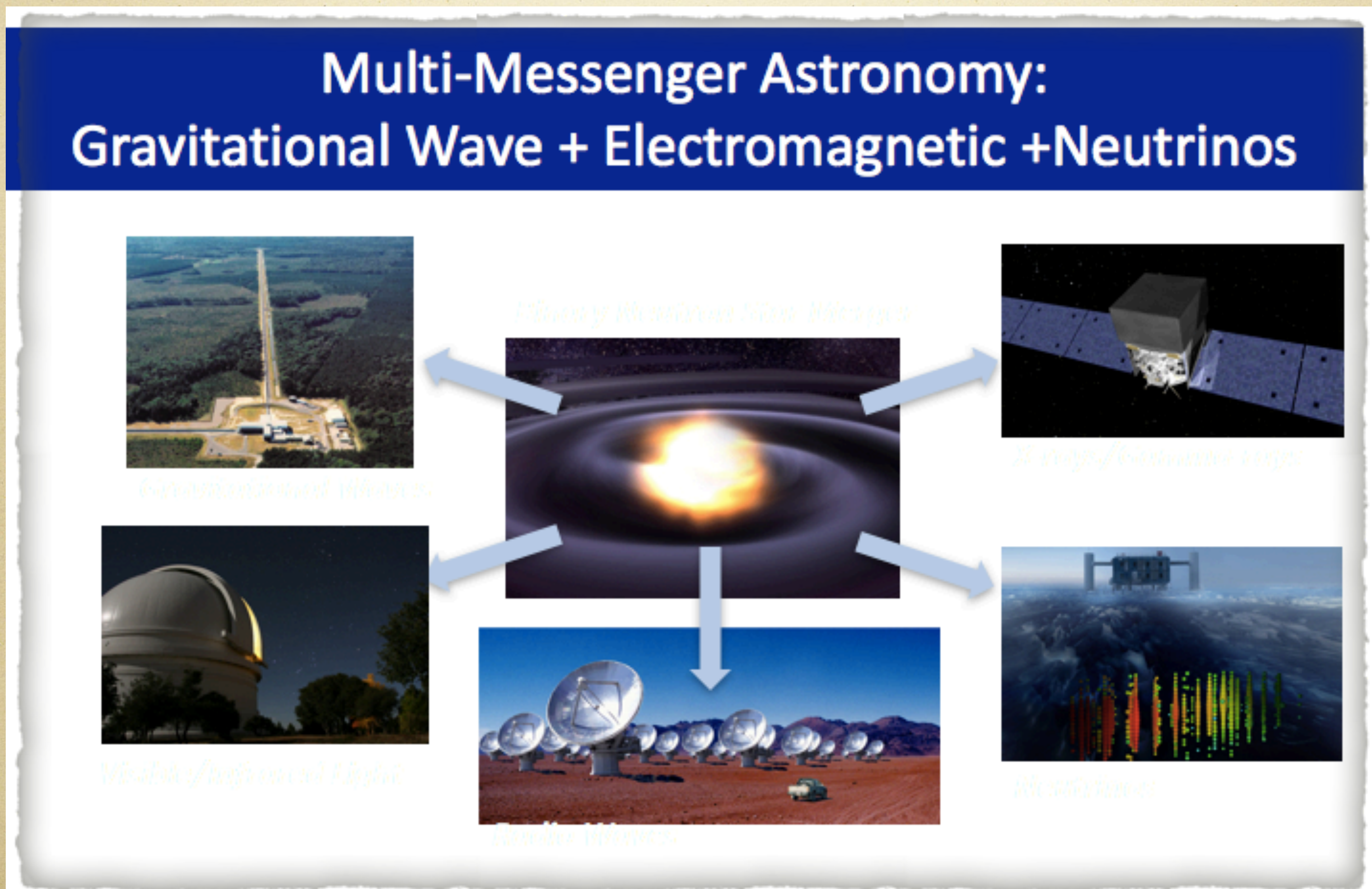


LISA has been demonstrated





Multimessenger Astronomy has become a reality



First-time detection of VHE gamma rays by MAGIC from a direction consistent with the recent EHE neutrino event IceCube-170922A

ATel #10817; ***Razmik Mirzoyan for the MAGIC Collaboration***
*on **4 Oct 2017; 17:17 UT***
Credential Certification: Razmik Mirzoyan (Razmik.Mirzoyan@mpp.mpg.de)

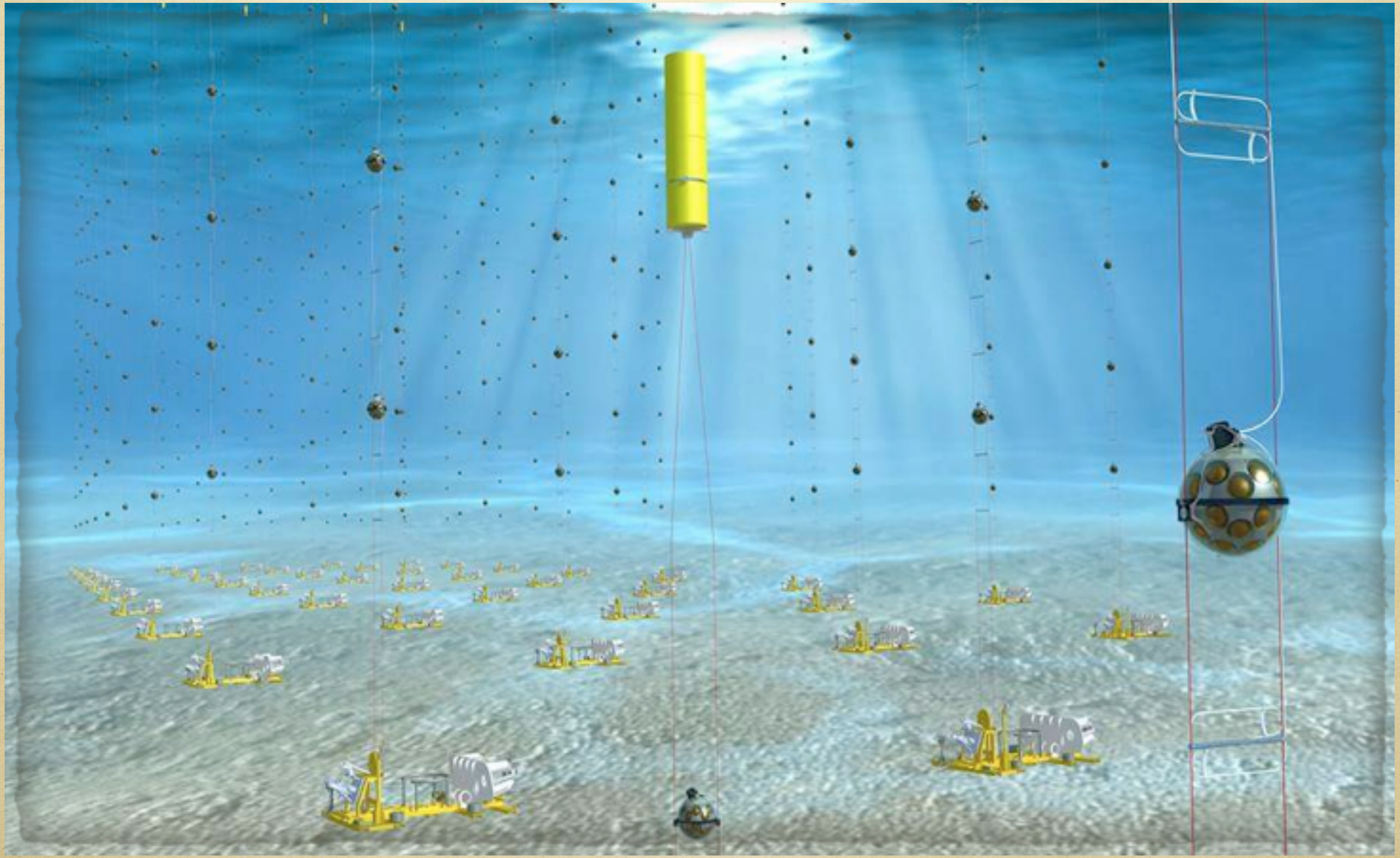
Subjects: Optical, Gamma Ray, >GeV, TeV, VHE, UHE, Neutrinos, AGN, Blazar

Referred to by ATel #: 10830, 10833, 10838, 10840, 10844, 10845, 10942

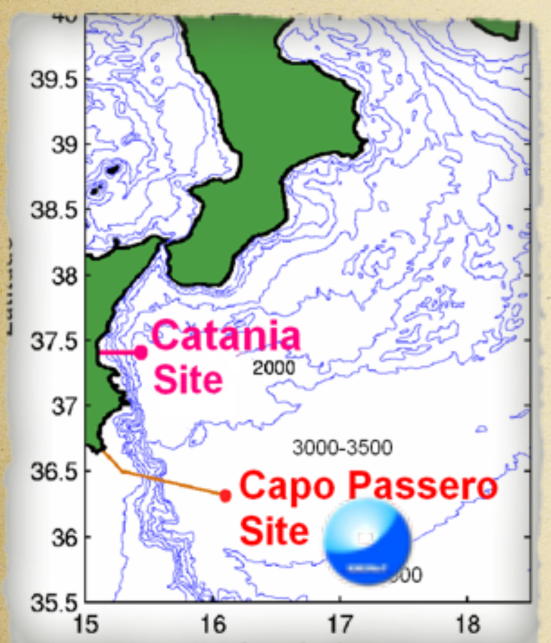
After the IceCube neutrino event EHE 170922A detected on 22/09/2017 (GCN circular #21916), Fermi-LAT measured enhanced gamma-ray emission from the blazar TXS 0506+056 (05 09 25.96370, +05 41 35.3279 (J2000), [Lani et al., Astron. J., 139, 1695-1712 (2010)]), located 6 arcmin from the EHE 170922A estimated direction (ATel #10791). MAGIC observed this source under good weather conditions and a 5 sigma detection above 100 GeV was achieved after 12 h of observations from September 28th till October 3rd. This is the first time that VHE gamma rays are measured from a direction consistent with a detected neutrino event. Several follow up observations from other observatories have been reported in ATels: #10773, #10787, #10791, #10792, #10794, #10799, #10801, GCN: #21941, #21930, #21924, #21923, #21917, #21916. The MAGIC contact persons for these observations are R. Mirzoyan (Razmik.Mirzoyan@mpp.mpg.de) E. Bernardini (elisa.bernardini@desy.de), K.Satalecka (konstancja.satalecka@desy.de). MAGIC is a system of two 17m-diameter Imaging Atmospheric Cherenkov Telescopes located at the Observatory Roque de los Muchachos on the Canary island La Palma, Spain, and designed to perform gamma-ray astronomy in the energy range from 50 GeV to greater than 50 TeV.

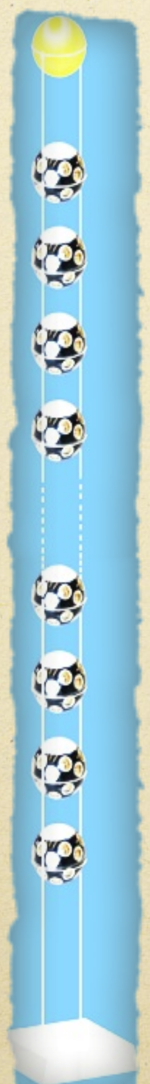
KM3Net

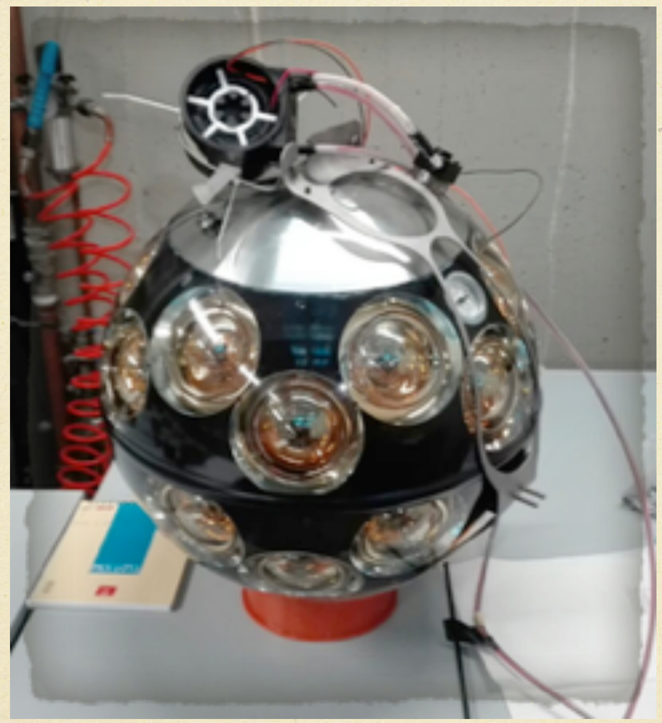
Mediterranean Sea
is a nice complement to South Pole

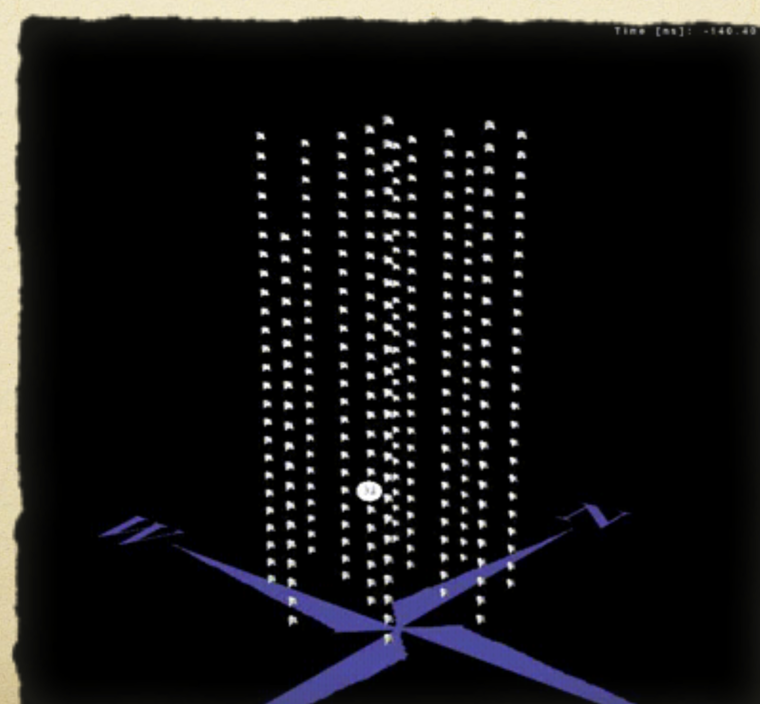


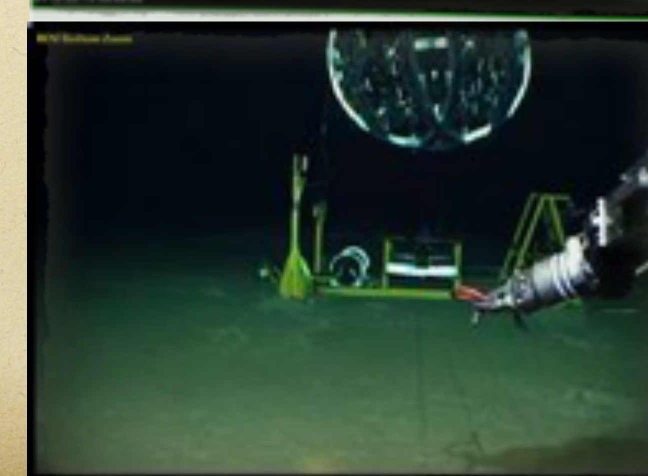
offshore of Capo Passero





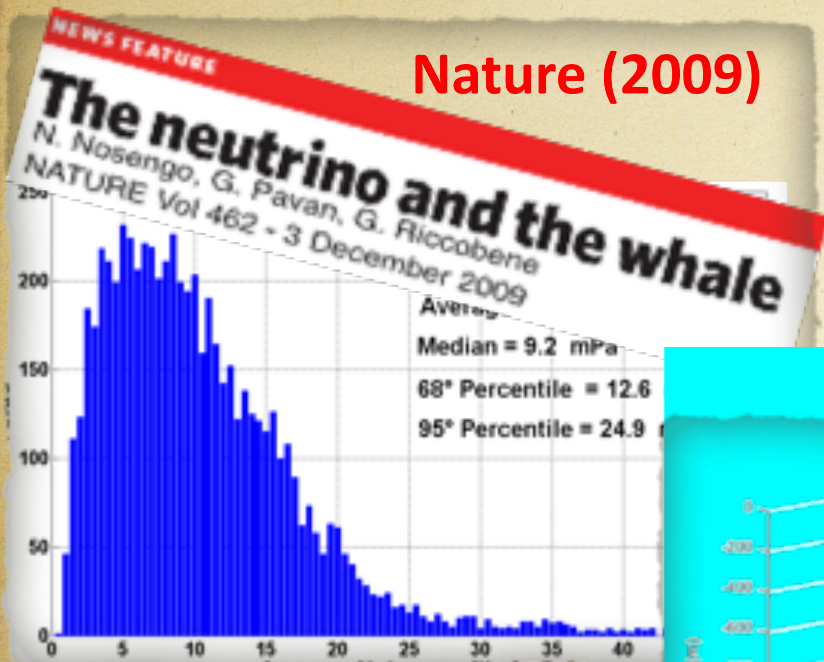


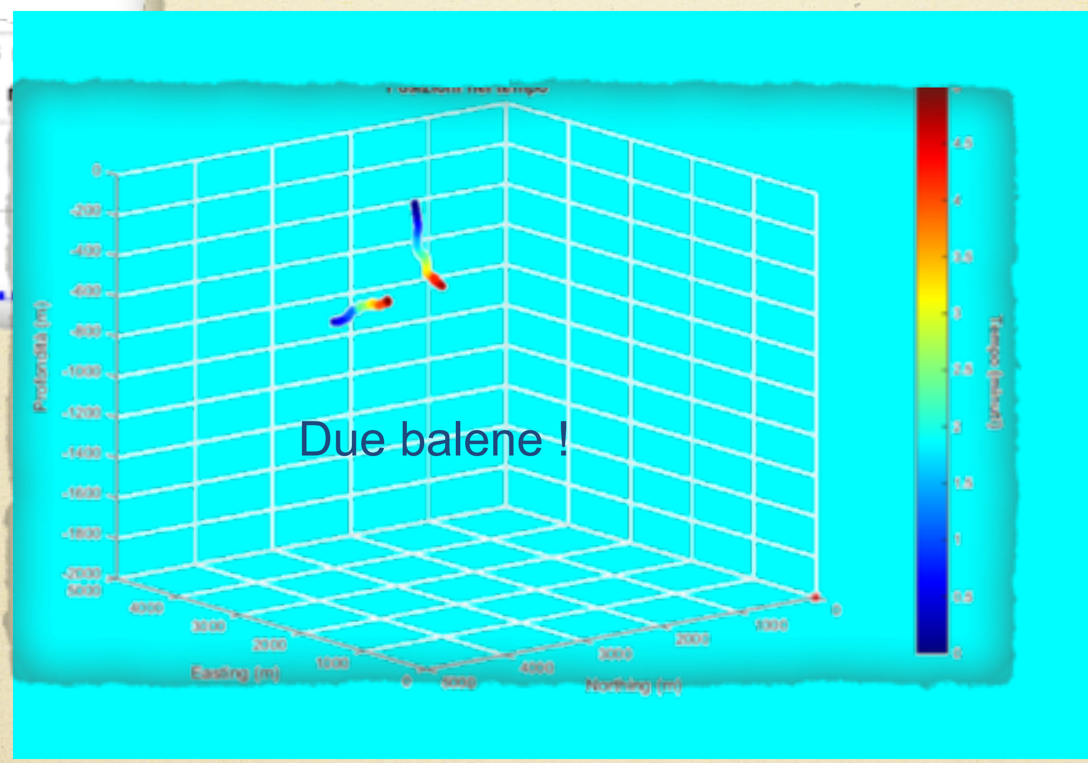


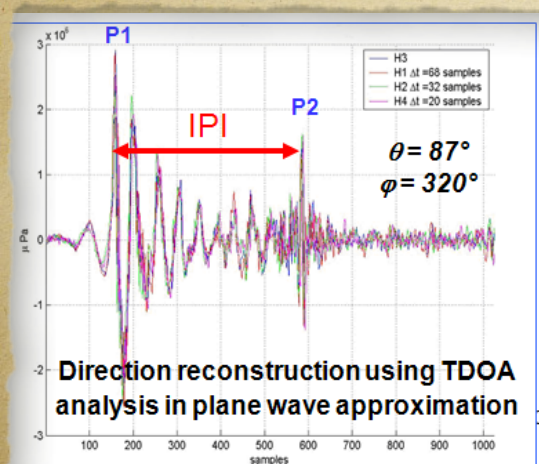


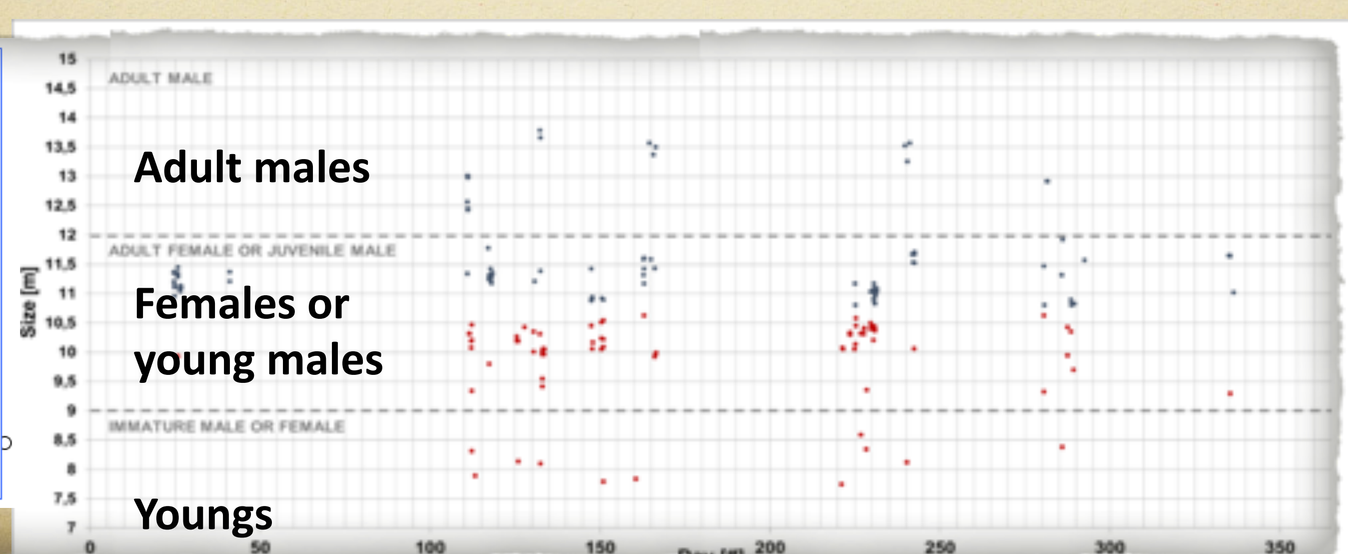
a 3500m

also....


NEWS FEATURE
Nature (2009)
The neutrino and the whale
N. Nosengo, G. Pavan, G. Riccobene
NATURE Vol 462 - 3 December 2009
Median = 9.2 mPa
68° Percentile = 12.6
95° Percentile = 24.9


Due balene !


P1
P2
IPI
θ= 87°
φ= 320°
Direction reconstruction using TDOA analysis in plane wave approximation


ADULT MALE
ADULT FEMALE OR JUVENILE MALE
IMMATURE MALE OR FEMALE
Adult males
Females or young males
Youngs
Size [m]
Day [#]

The cost book

- HL-LHC upgrade (ATLAS-CMS) : ~ 50M€ (special grant from PM)
- Dark Side will cost 75 M€ at least (43 Euro from several regional, ministerial grants + INFN +other funding agencies (NSF and Canada first mostly on Argon extraction in Colorado)
- AdV+ and ET studies will cost to INFN no less than 20 M€, ET is a G€ scale IR (to ESFRI next year)
- KM3Net has costed 25 M€ to Italy so far, the deployment of ARCA initial phase out of Sicily can count on 20 M€ from regional funds, 20 M€ of matching funds from INFN, 17 M€ from ministerial grant and some more from NIKHEF
- EUPRAXIA investment depends on the national/regional scale of the project. No less than 50 M€ for sure.

Conclusions

- We have enough people to do a lot of things
- More money would be welcome
- We have priorities
- We give a lot of attention to applications in several fields