INFN: present and future

Fernando Ferroni

INFN & Sapienza University-Roma

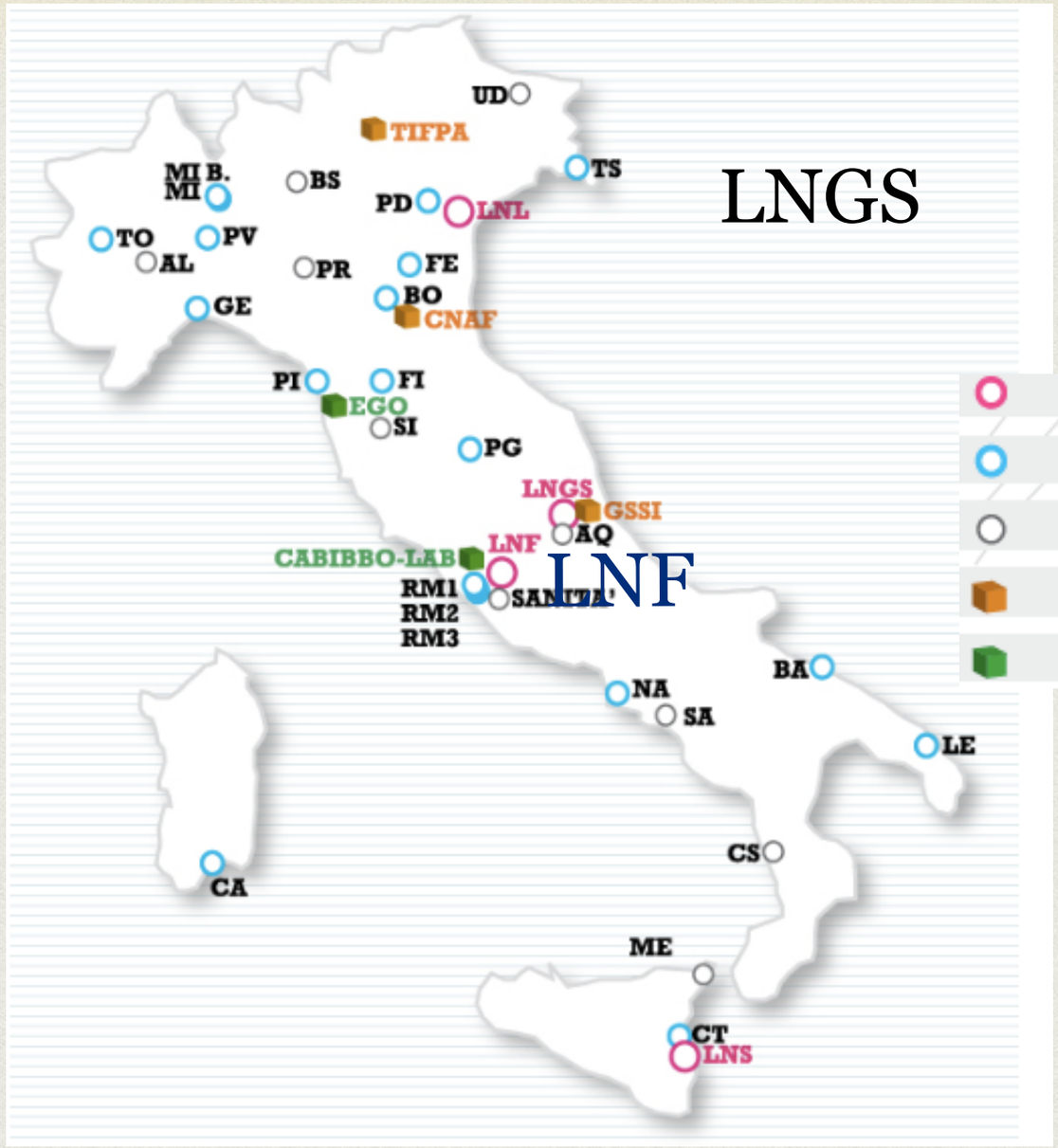
ALBA January 26, 2015

Fabiola Gianotti to lead Cern particle physics research centre

Italian physicist won worldwide attention in 2012 for her leading role in Cern's discovery of Higgs boson particle

INFN GEOGRAPHICALLY

LNL



LNGS

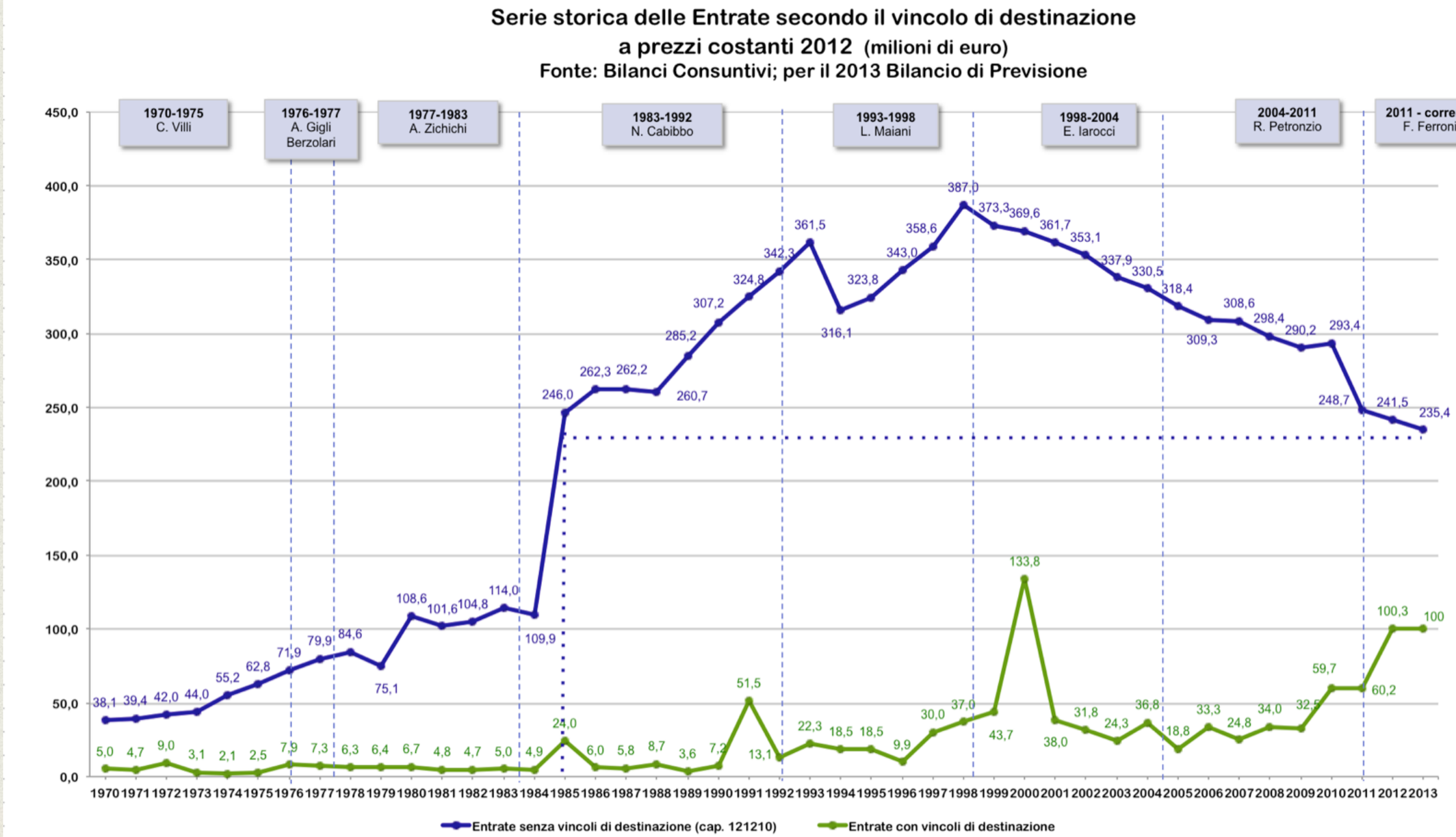
LNGS

laboratories	4
divisions	20
associated groups	10
national centres	3
consortia	2

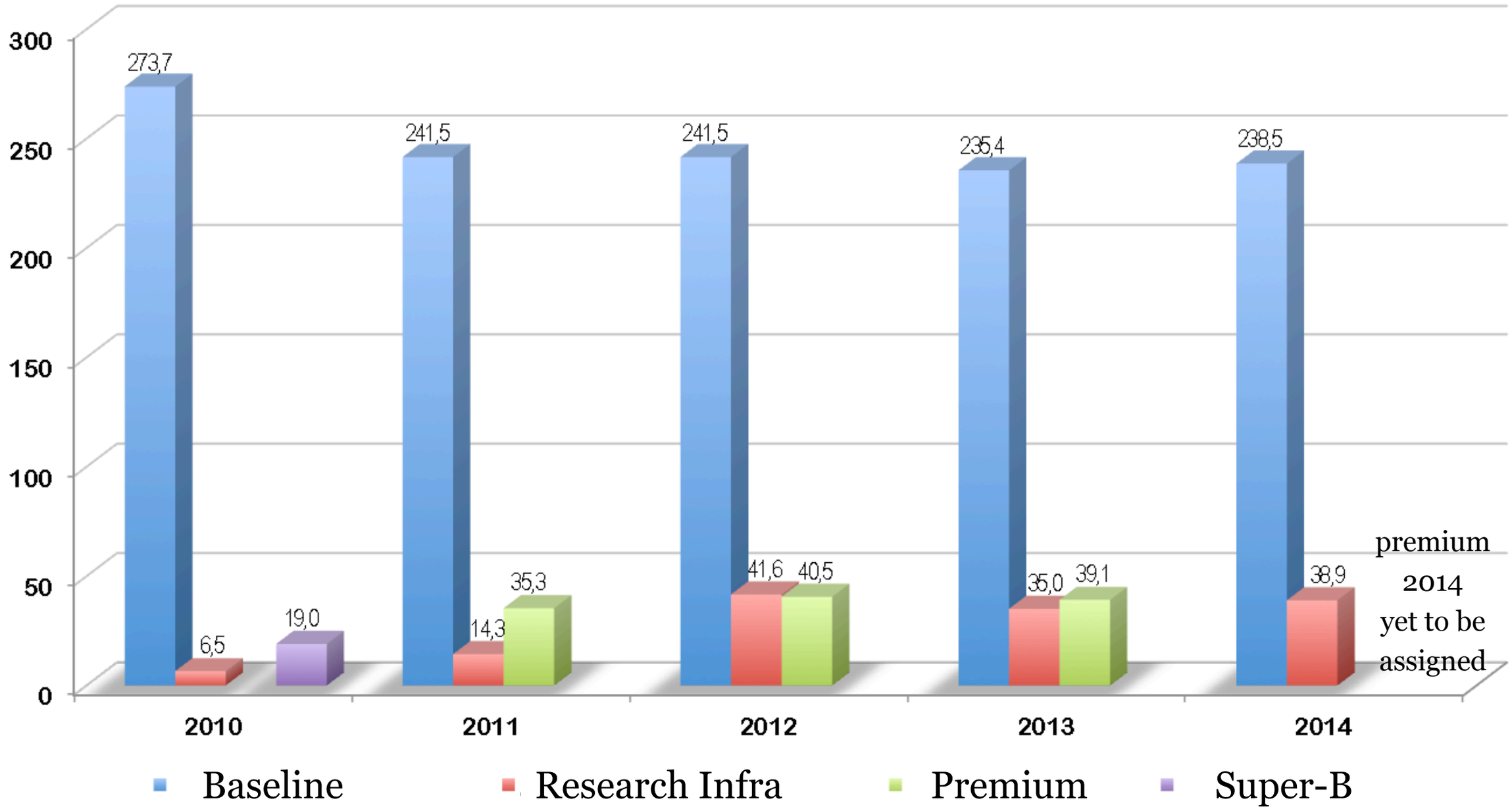
LNS

LNF

INFN FINANCIALLY



BUDGET EVOLUTION



INFN-HUMANLY

DG

Researcher

Engineers

Tech

Administration

Post-Doc

Researcher (full time)

Engineers

Researcher (part time)

Ph. D. students, Post-Doc

Researcher (part time) from other Research Institutions

Retired (still active)

Senior (emeritus)

Foreigner Instituions

Others (unexplicable !)

INFN

1 Dirigente
610 Ricercatori
230 Tecnologi
692 Tecnici
301 Amministrativi
197 Associati Borsisti, Assegnisti

UNIVERSITÀ

843 Associazioni con incarico di ricerca
109 Associazioni con incarico di collaborazione tecnica
651 Associazioni scientifiche/tecnologiche/tecniche
1280 Laureandi, Dottorandi, Borsisti, Assegnisti

ALTRI ENTI

158 Associazioni scientifiche/tecnologiche/tecniche

SENIOR

217 Associazioni scientifiche/tecnologiche/tecniche

ATTRIBUITI DAL PRESIDENTE

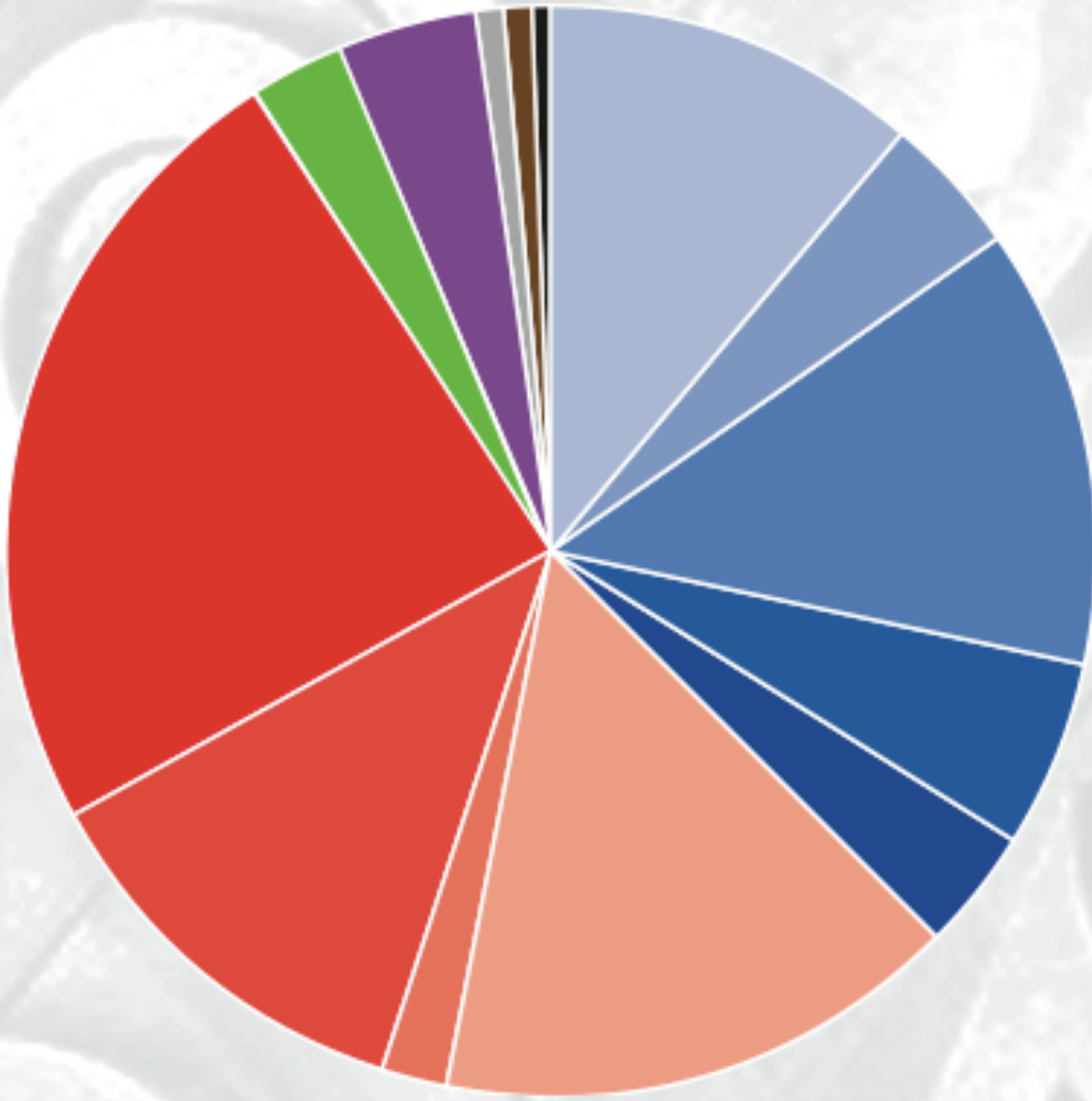
56 Incarichi di ricerca e associazioni scientifiche

STRANIERI

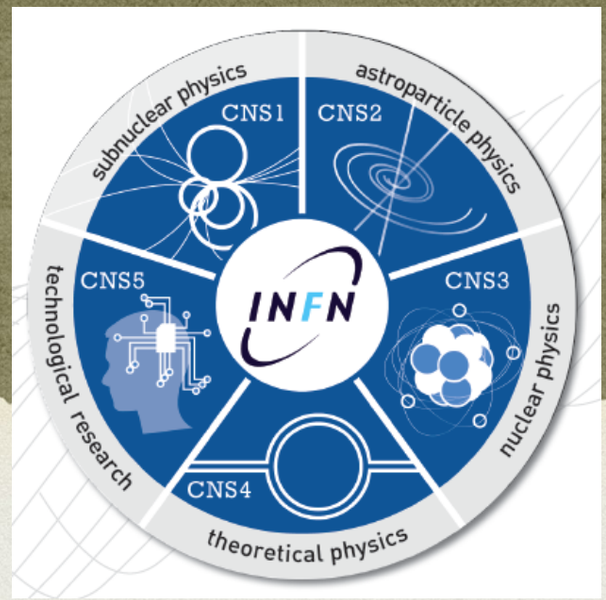
41 Associazioni

ALTRE ASSOCIAZIONI

23 Associazioni scientifiche/tecnologiche E.P. e contratti art. 19



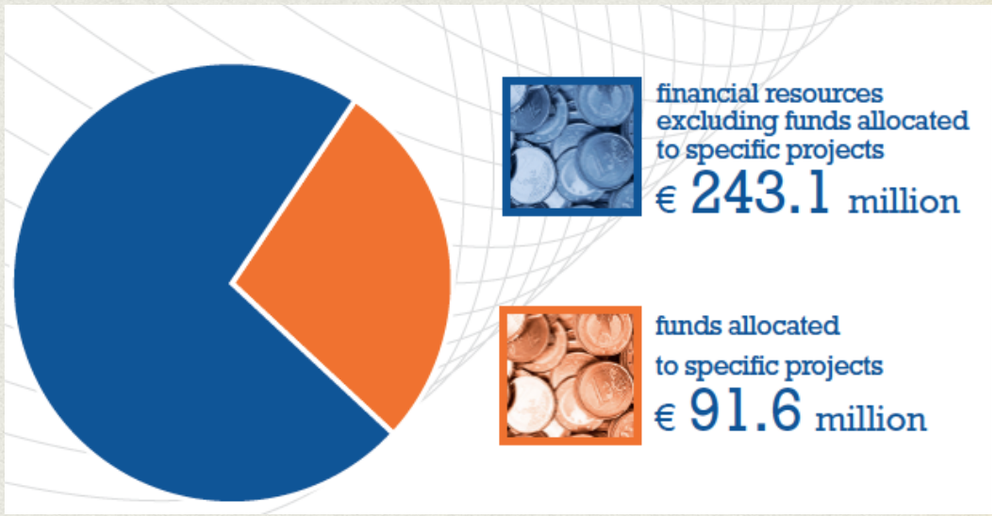
THE LINES OF RESEARCH



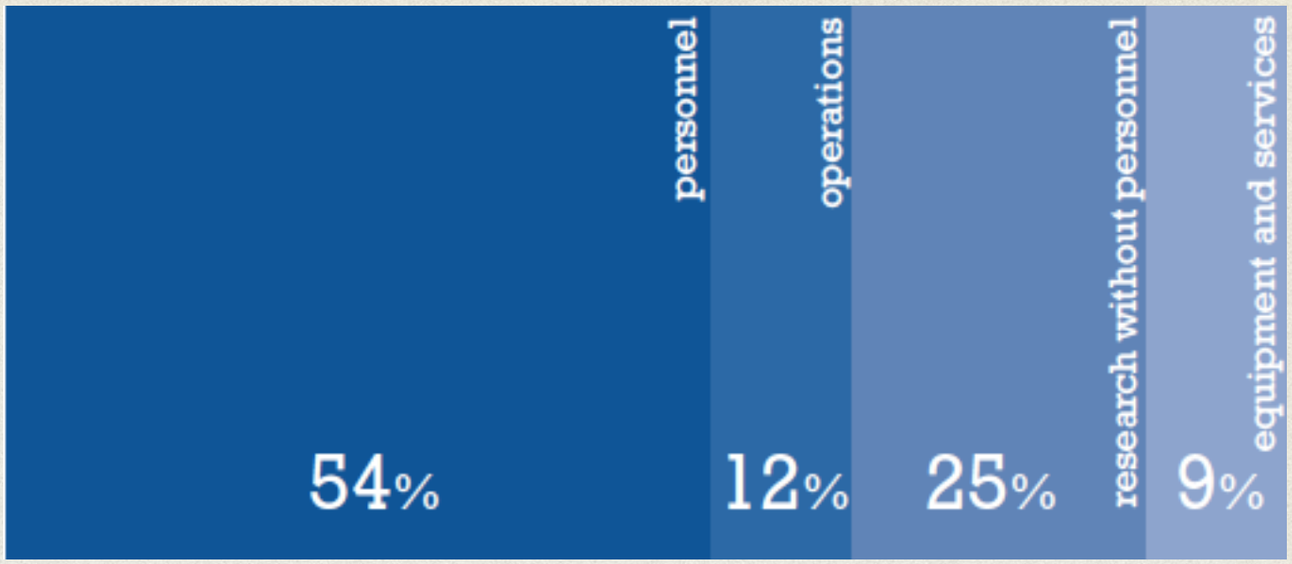
- Particle Physics (with accelerators)
- Astroparticle Physics (includes all ν)
- Nuclear Physics (includes ALICE)
- Theoretical Physics
- Research & Development (+Accelerators)

INFN BUDGET (2012)

- It is composed by few different pieces
- Its total is above 300 MEuro
- The ‘unlabeled’ part is about 240 MEuro
- Then there are ‘premium projects’, special projects, external funds……in variable proportions



4 LINES OF BUDGET



- Salaries : 135 ME
- Research direct costs : 50 ME
- Infrastructures & operations: 60 ME
- ‘Other’ projects (this money does not commute with anything else)

BUDGET:DIRECT COSTS OF RESEARCH

- CSN1 20 MEuro
- CSN2 14 MEuro
- CSN3 10 MEuro
- CSN4 1.5 MEuro
- CSN5 5 MEuro

-this is our core business: travels, consumables, investment
-does not include electric power, lab services, personnel

THE SPECIAL PROJECTS

- IFMIF for ITER
- XFEL (Germany)
- Extreme Light Infrastructure (Magurele and Prague)
- European Spallation Source (Sweden)
- Gran Sasso Science Institute

A CULTURAL CHANGE

- Projects sometime require somebody doing something that he/she would not have done being in the old good times

- Projects require collaboration with other research institutions in Italy that was not seen as an opportunity in the past

- Chasing european/regional funds need a dedicated structure

Moving from a feeling of self-sufficiency to a complex environment

IMPROVING WRT. EU FUNDS

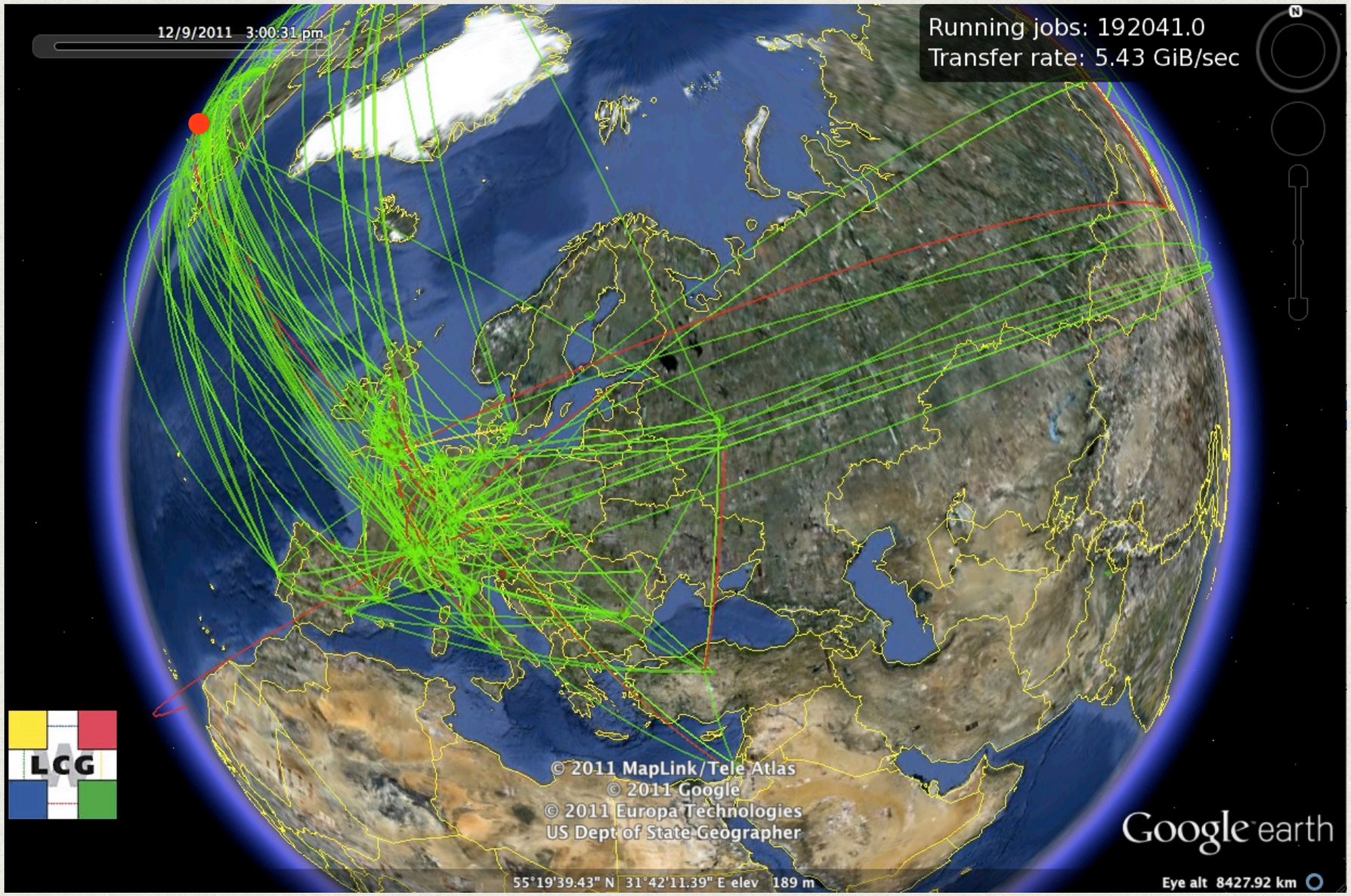
Top 10 beneficiaries, EC financial contribution granted in FP7

Name	Number of Participants	EC financial contribution € million
CONSIGLIO NAZIONALE DELLE RICERCHE (CNR)	692	230,70
POLITECNICO DI MILANO (POLIMI)	246	84,57
ALMA MATER STUDIORUM-UNIVERSITA DI BOLOGNA (UNIBO)	243	80,75
UNIVERSITA DEGLI STUDI DI ROMA LA SAPIENZA	202	78,67
CENTRO RICERCHE FIAT SCPA (CENTRO RICERCHE FIAT)	196	73,03
UNIVERSITA DEGLI STUDI DI PADOVA (UNIPD)	186	60,22
POLITECNICO DI TORINO (POLITO)	209	52,58
FONDAZIONE ISTITUTO ITALIANO DI TECNOLOGIA (IIT)	96	49,23
ISTITUTO NAZIONALE DI FISICA NUCLEARE (INFN)	85	48,99
UNIVERSITA DEGLI STUDI DI MILANO (UMIL)	141	48,98

LHC

We participate in all LHC experiments, about 800 FTE’s. Very important responsibilities.

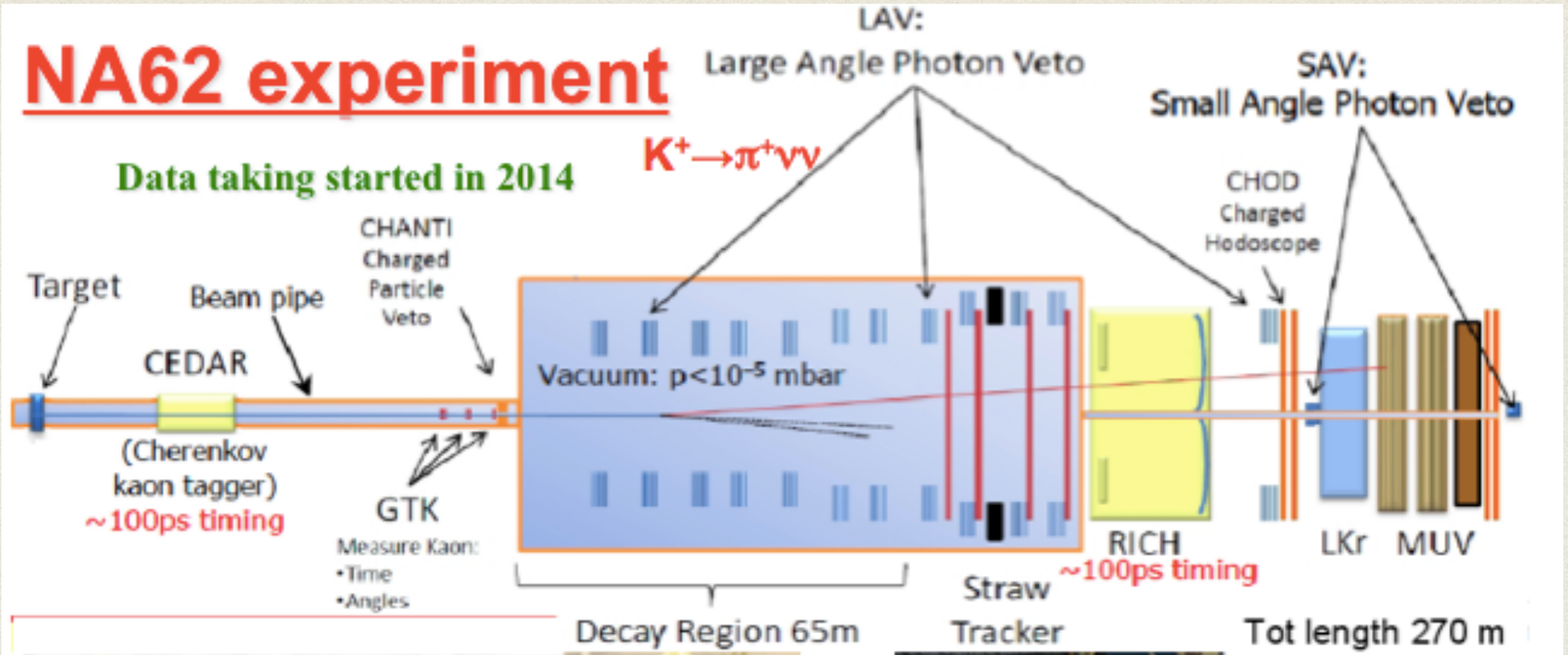
the INFN Tier1 Computing Center

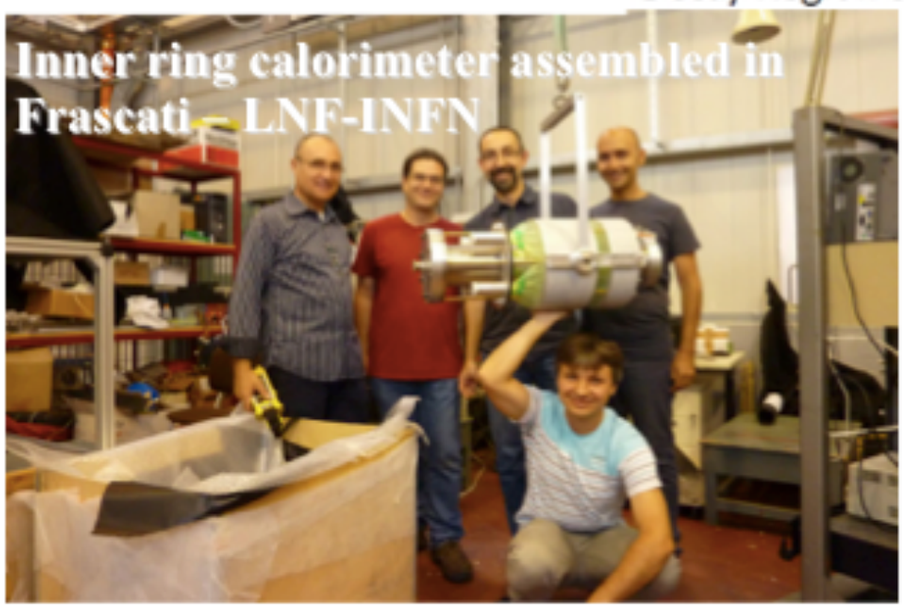


LHC FUTURE

- Phase I upgrades in execution now for large experiments
- LHCb special case. Single step upgrade. Costly but worth….
- R&D for phase II in negotiation
- Phase II upgrade….depends on a few things……..

MORE THAN LHC





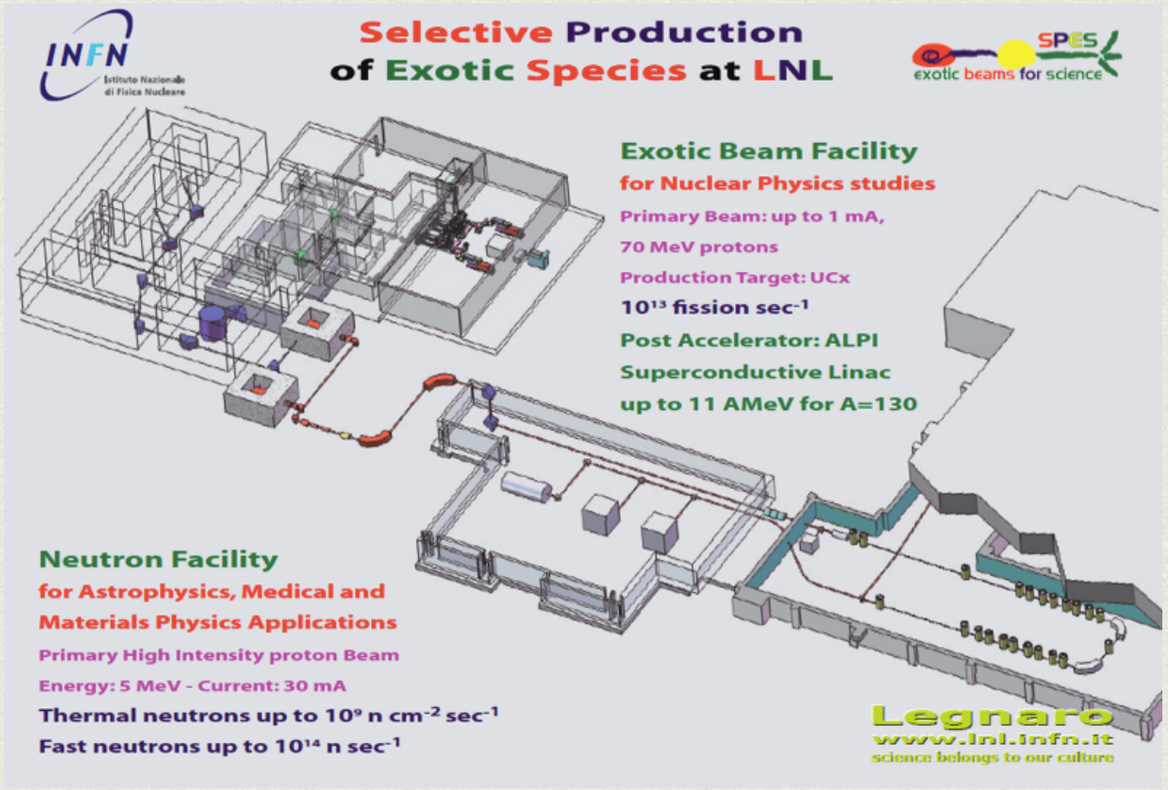
- IRC design and mechanics produced by University of Sofia and LTDP - BAS-BG
- Design review and assembly at LNF
- SAC upgrade and PMT test at LNF BTF

LNL

LNL

1. Radioactive Ion Beams are produced by proton induced fission on a UCx direct target at a rate of 10^{13} fission/s.
2. Neutron rich re-accelerated beams will be available at energies up to 13 MeV/u in the mass region A=130.
3. Re-acceleration will be performed by the superconducting linear accelerator complex (PIAVE-ALPI) of the Laboratori Nazionali di Legnaro.
4. The facility for applied physics is based on proton and neutron beams from a two exit port cyclotron (70 MeV, 500 microA) and the high intensity RFQ TRASCO (5 MeV, 30 mA).

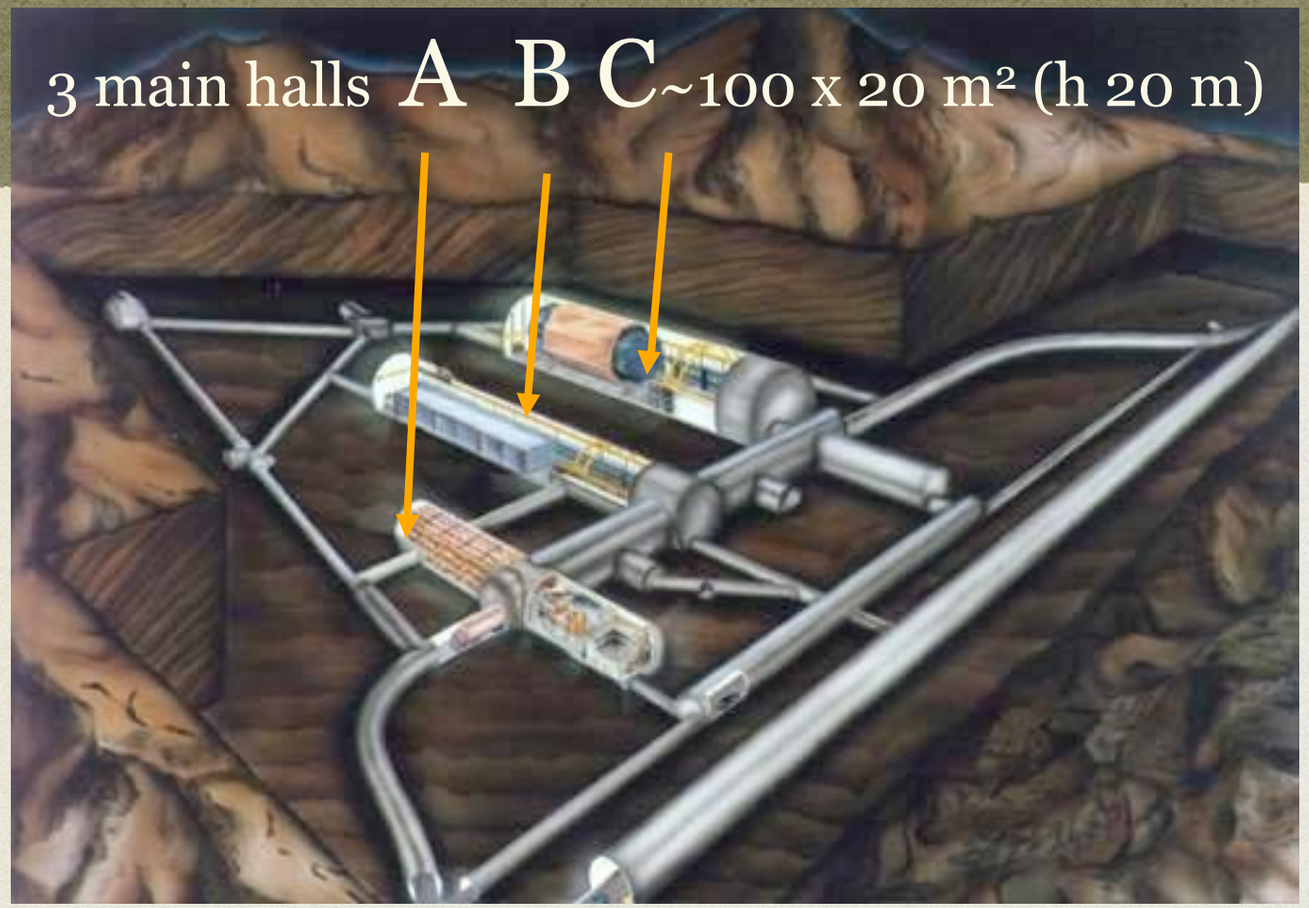
Working out an agreement with a private company for radioisotopes production



INFN
Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali del Gran Sasso

INFN-GRAN SASSO NATIONAL LABORATORY

GRAN SASSO LABORATORY



Muon Flux

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

Depth: 1400 m (**3800 m w.e.**)

Surface: 17800 m²

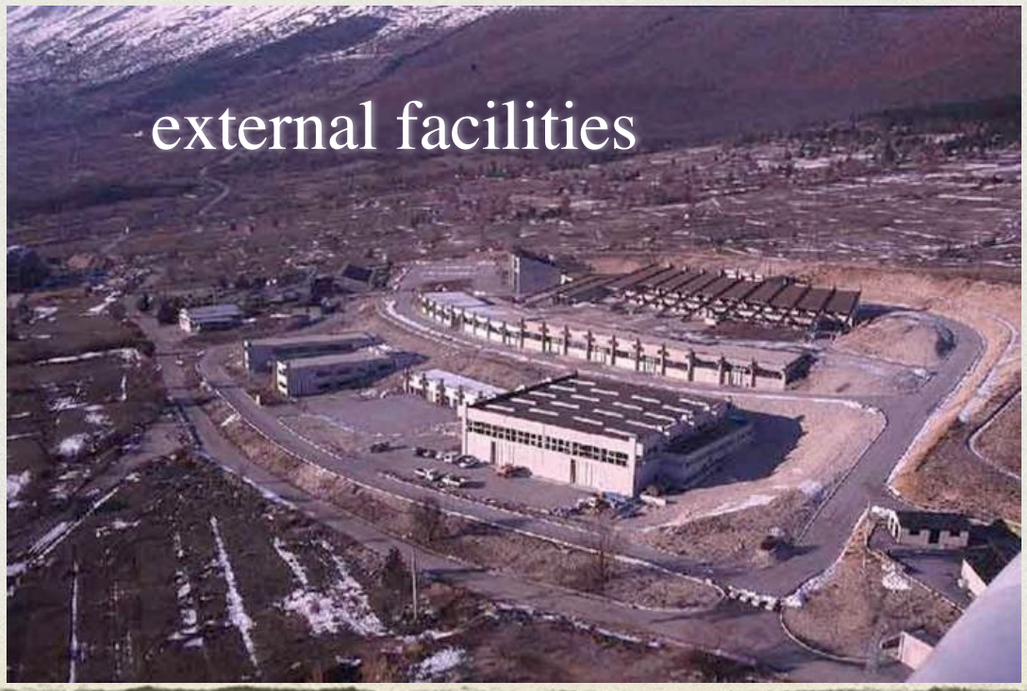
Volume: **180000** m³

Rn in air: 20-80 Bq/m³

ISO 14001

Ventilation: 1 Lab volume/3 h

Electrical power: 1300 kW



Physics at LNGS

The inventory of Universe and the dark matter

DAMA/LIBRA
CRESST
XENON 1T
Dark Side

LBL - CNGS
OPERA
Icarus T600

Properties of neutrinos and their role in cosmic evolution

$2\beta0\nu$
CUORE
GERDA
COBRA
Lucifer R&D

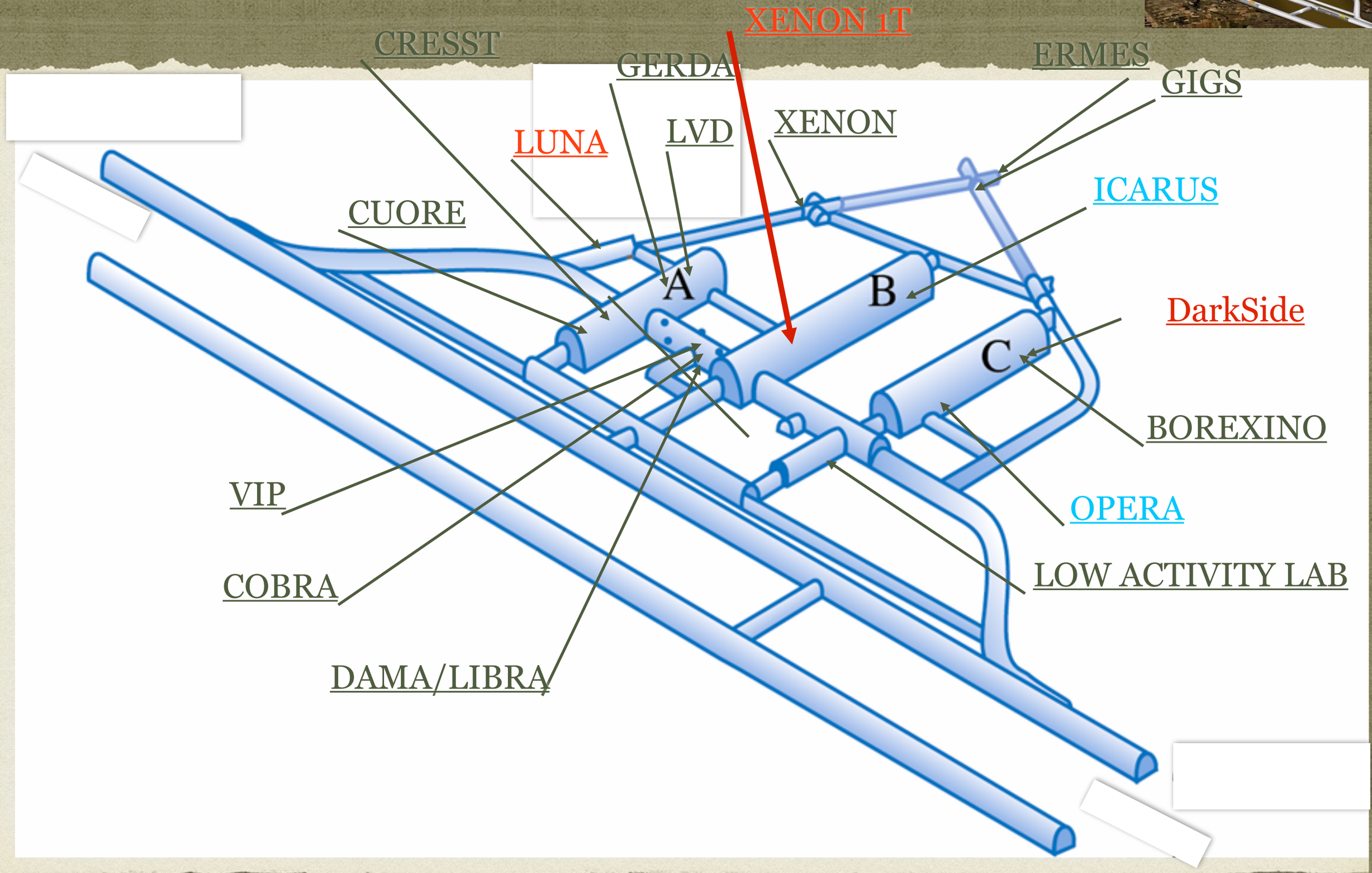
What about the interior of the Sun and the Earth

BOREXINO
SOX
LUNA

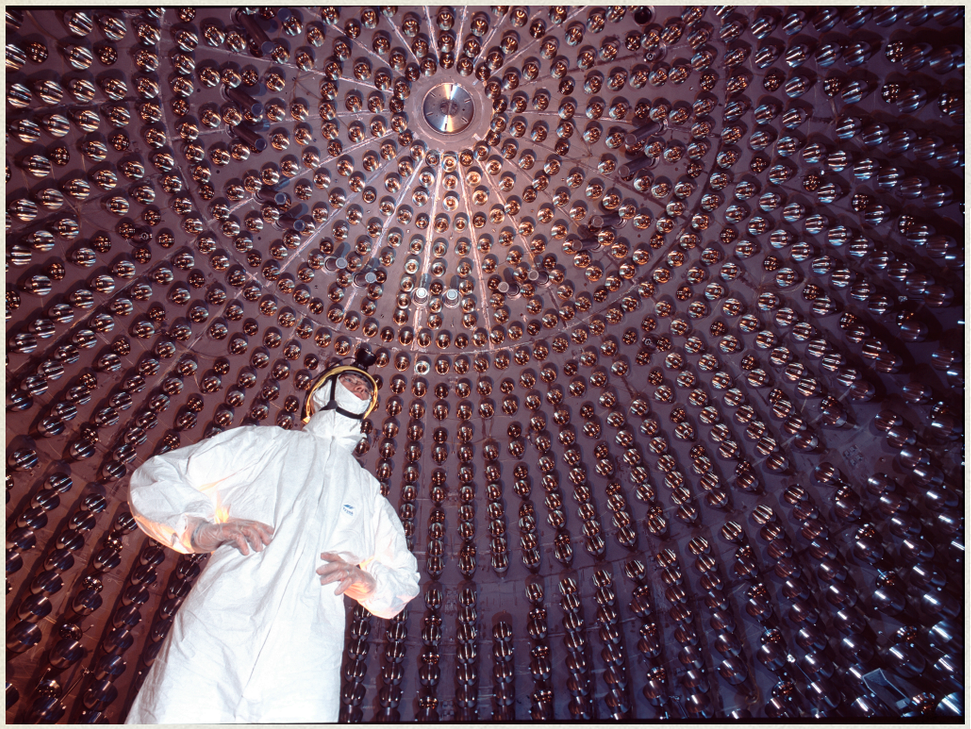
LVD

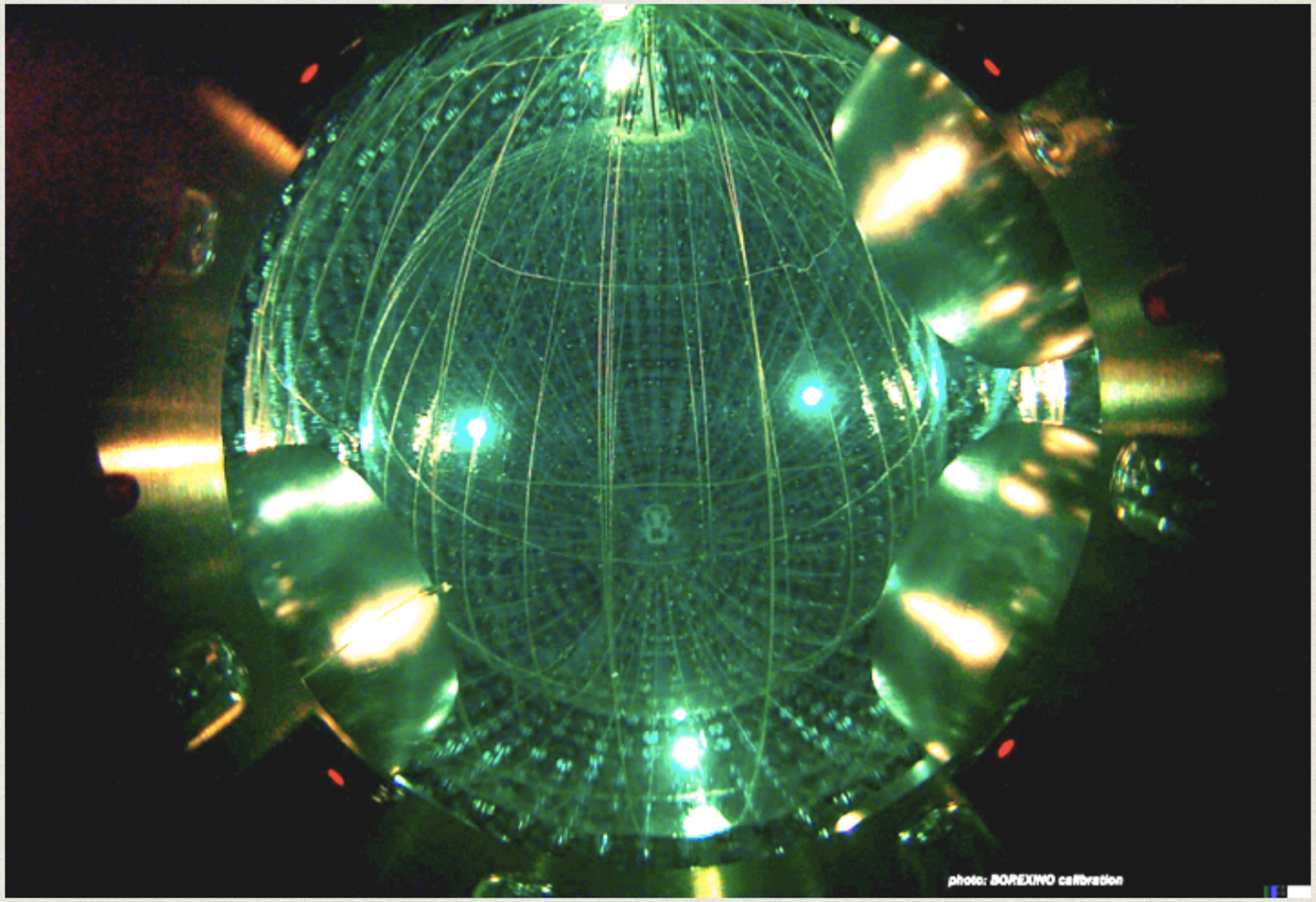
What about the supernova explosions

A BUSY LAB

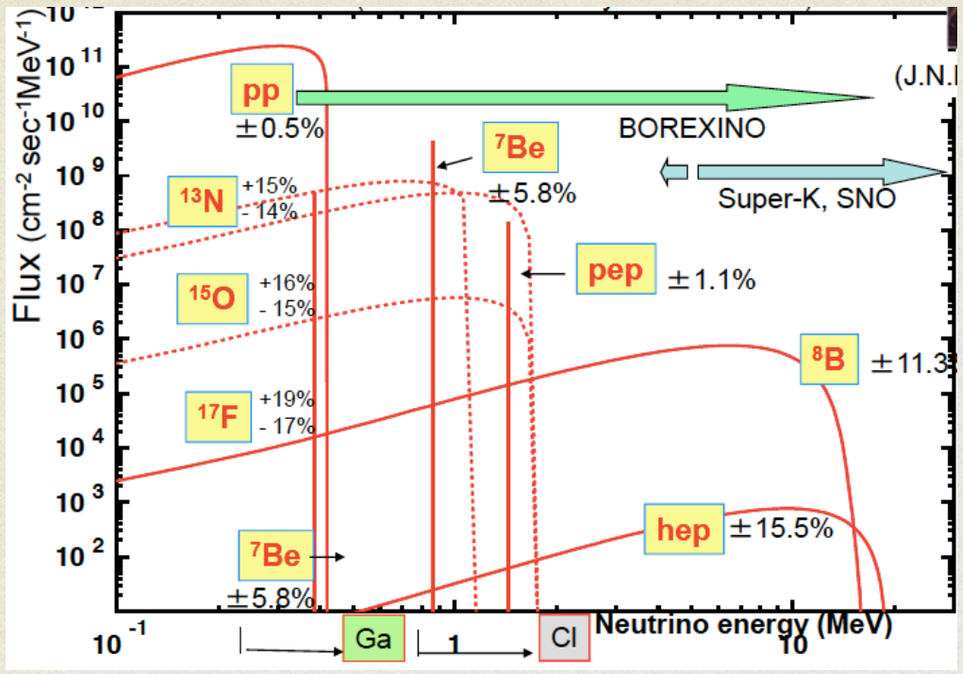

CRESST
XENON 1T
GERDA
ERMES
GIGS
LUNA
LVD
XENON
CUORE
ICARUS
A
B
DarkSide
C
BOREXINO
VIP
OPERA
COBRA
LOW ACTIVITY LAB
DAMA/LIBRA

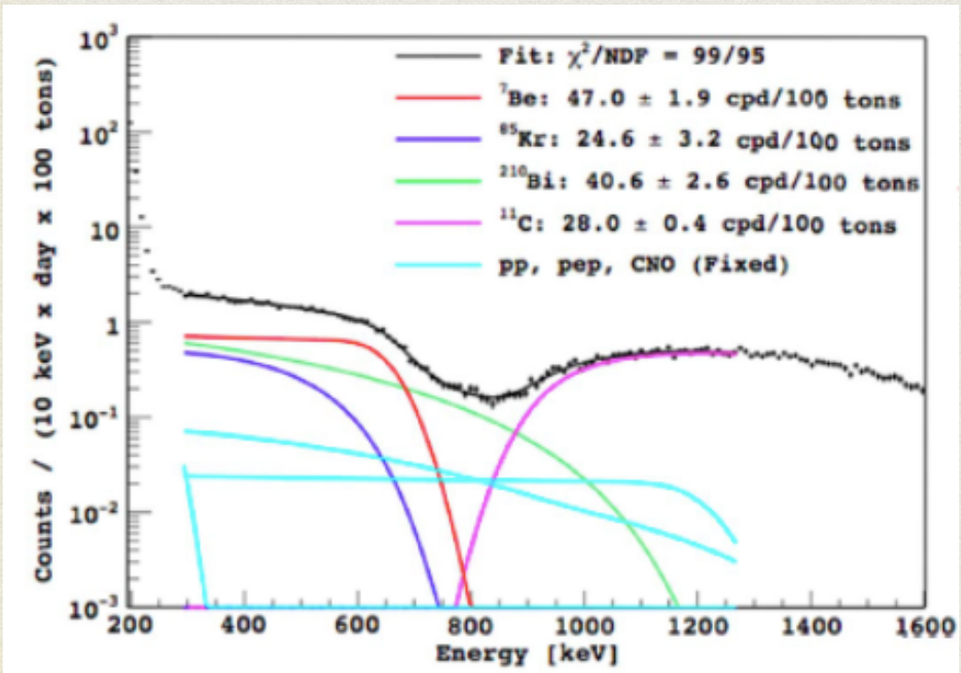
BOREXINO @ LNGS

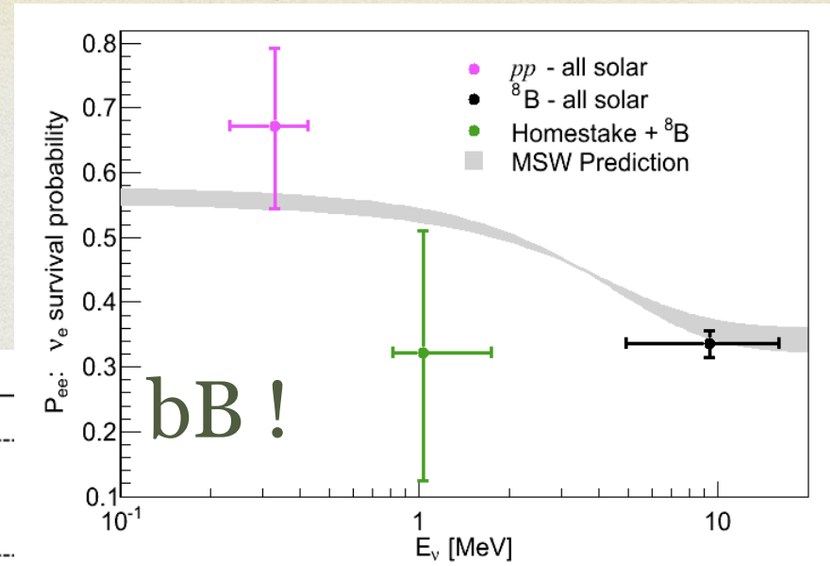


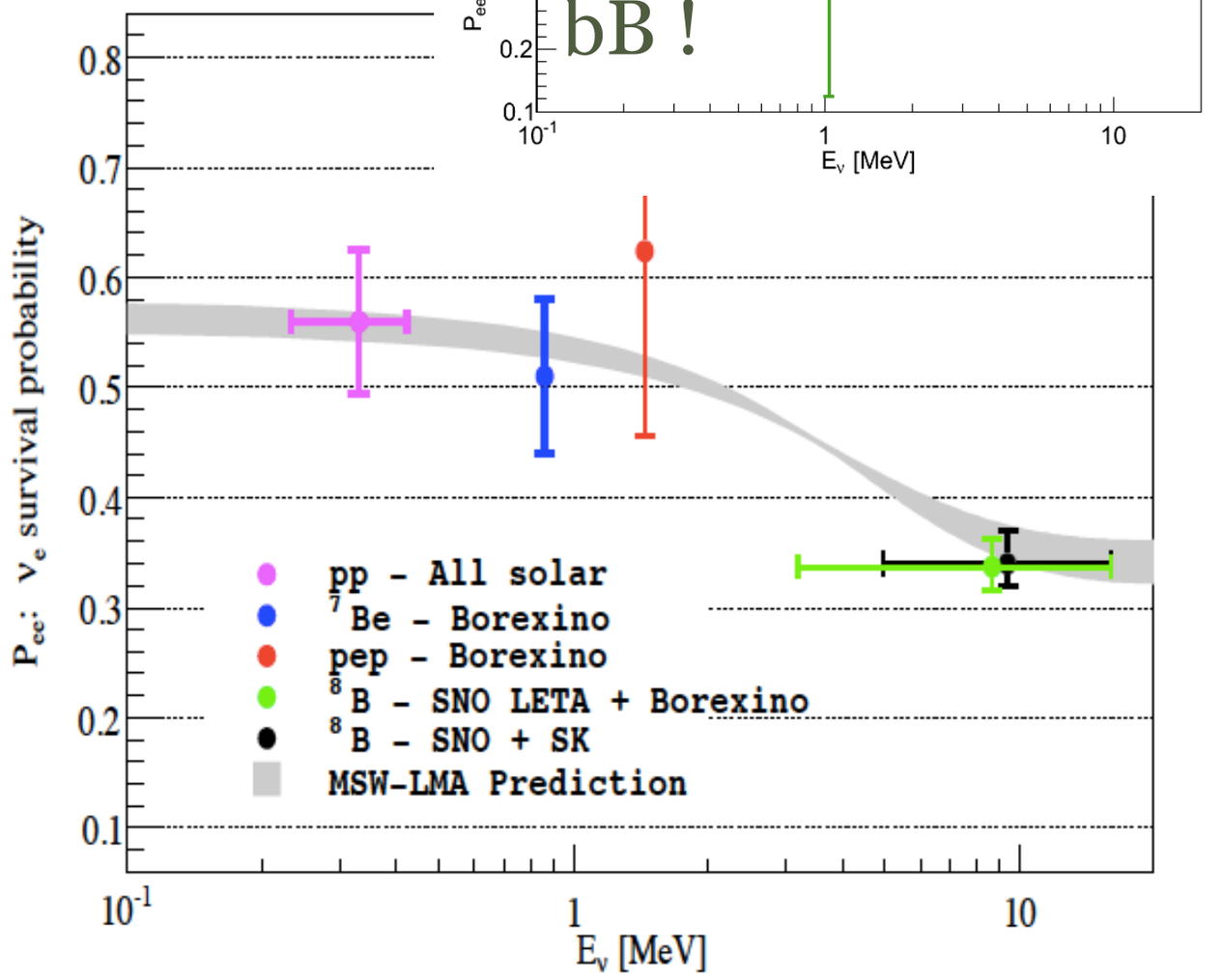


BOREXINO : ALL IN ONE !









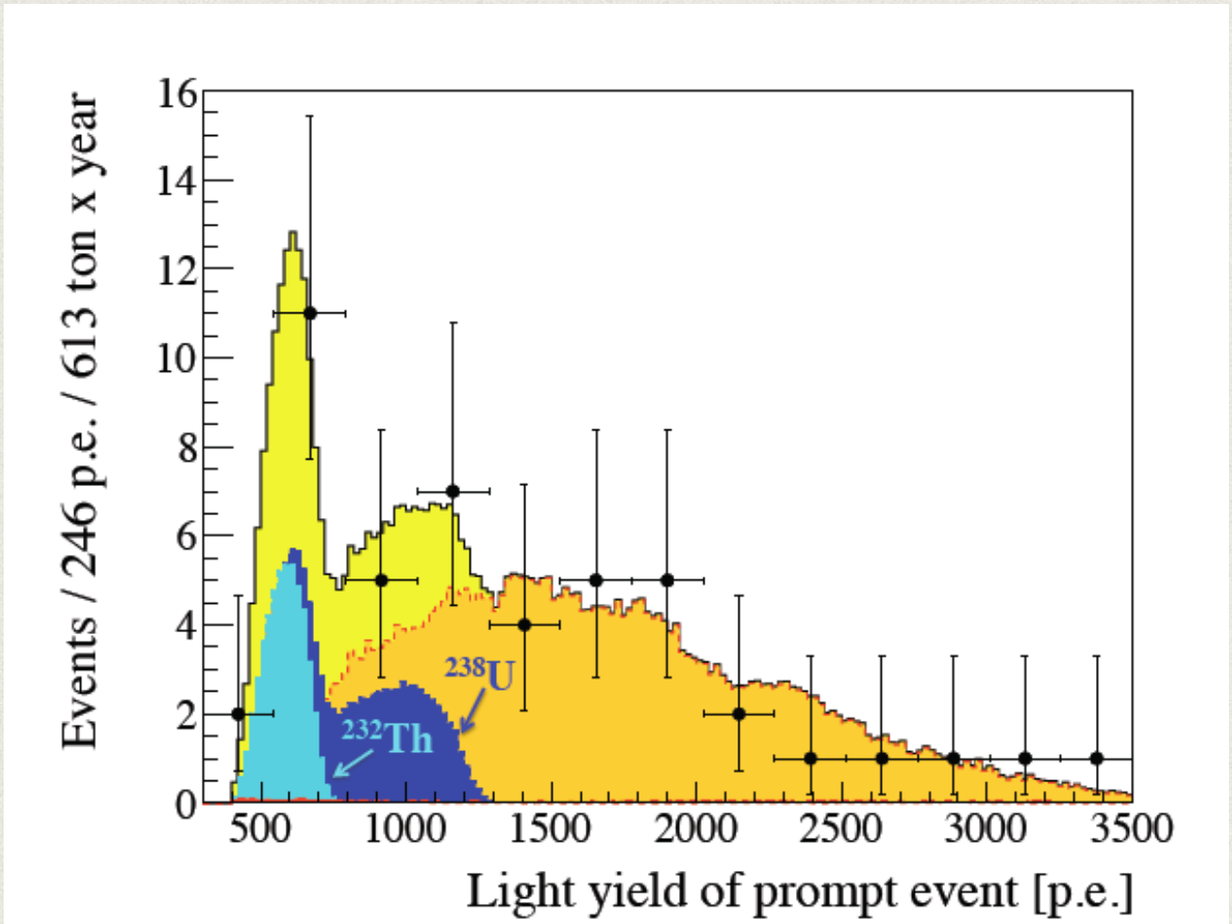
BOREXINO LOOKING DOWN TO EARTH

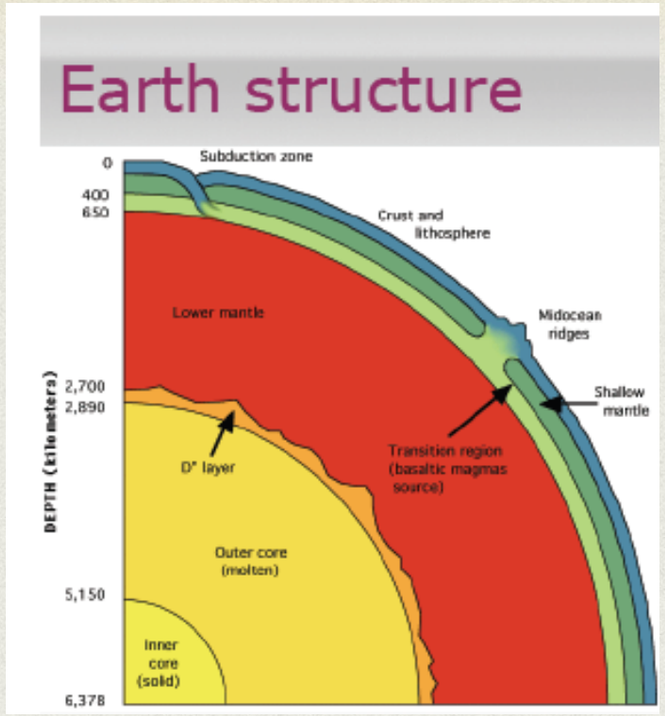
The Earth shines in anti-ν

$^{238}U \quad ^{206}Pb + 8\,\alpha + 8\,e^- + 6\,\bar{\nu}_e + 51.7\ MeV$

$^{232}Th \quad ^{208}Pb + 6\,\alpha + 4\,e^- + 4\,\bar{\nu}_e + 42.8\ MeV$

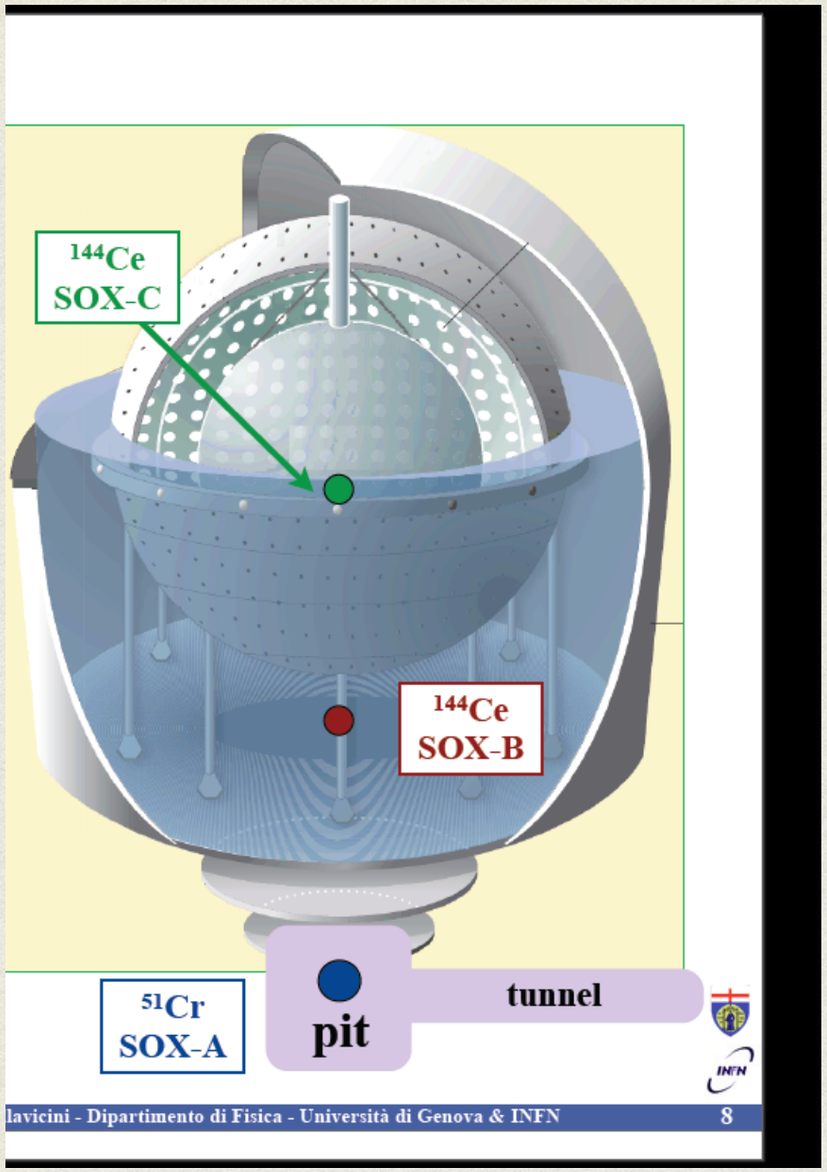
$^{40}K \quad ^{40}Ca + e^- + 1\,\bar{\nu}_e + 1.32\ MeV$





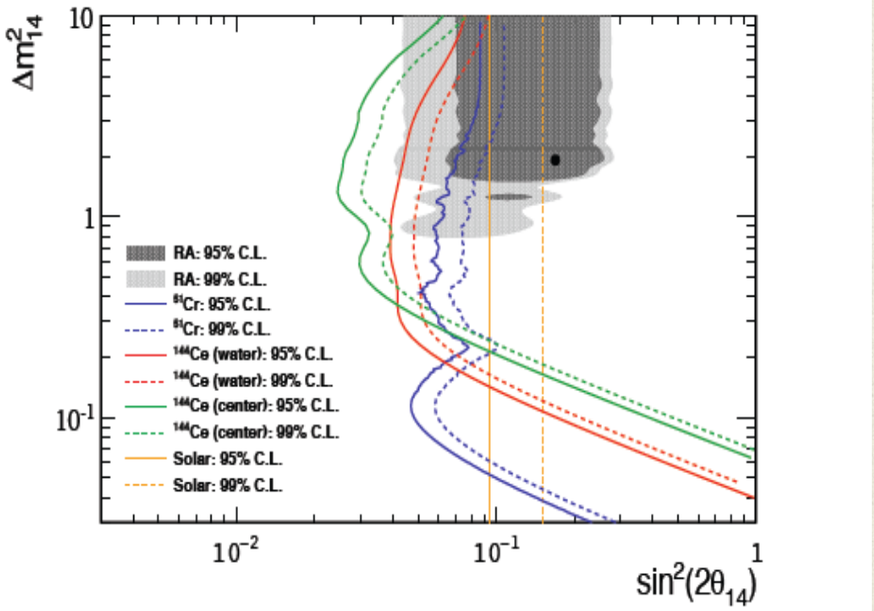
Uranium & Thorium contribution disentangled

BOREXINO REINCARNATE IN SOX

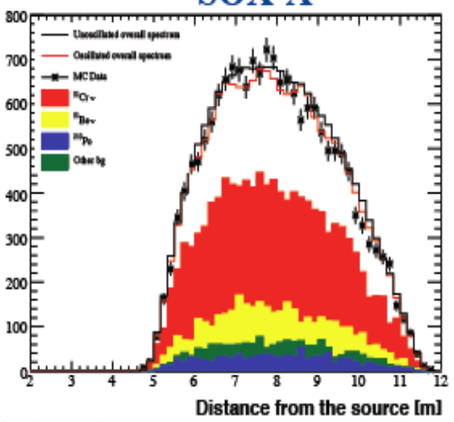


anti-neutrino sources

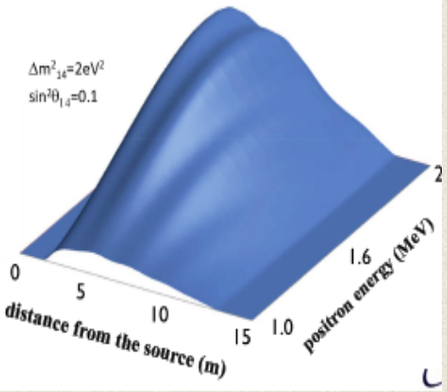
- **SOX-A**
  - ^{51}Cr neutrino source (external)
  - Tentative schedule: 2015/2016
- **SOX-B**
  - ^{144}Ce anti-neutrino source (external)
  - Tentative schedule: 2015-2016 (TBD)
- **SOX-C**
  - ^{144}Ce anti-neutrino source (internal)
  - No schedule (>2016)



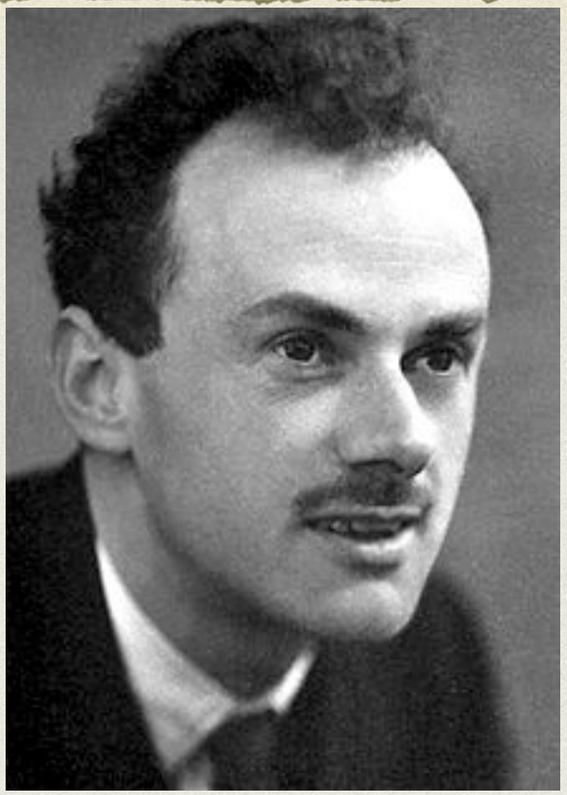
SOX-A



SOX-C



WHAT IS A NEUTRINO ?



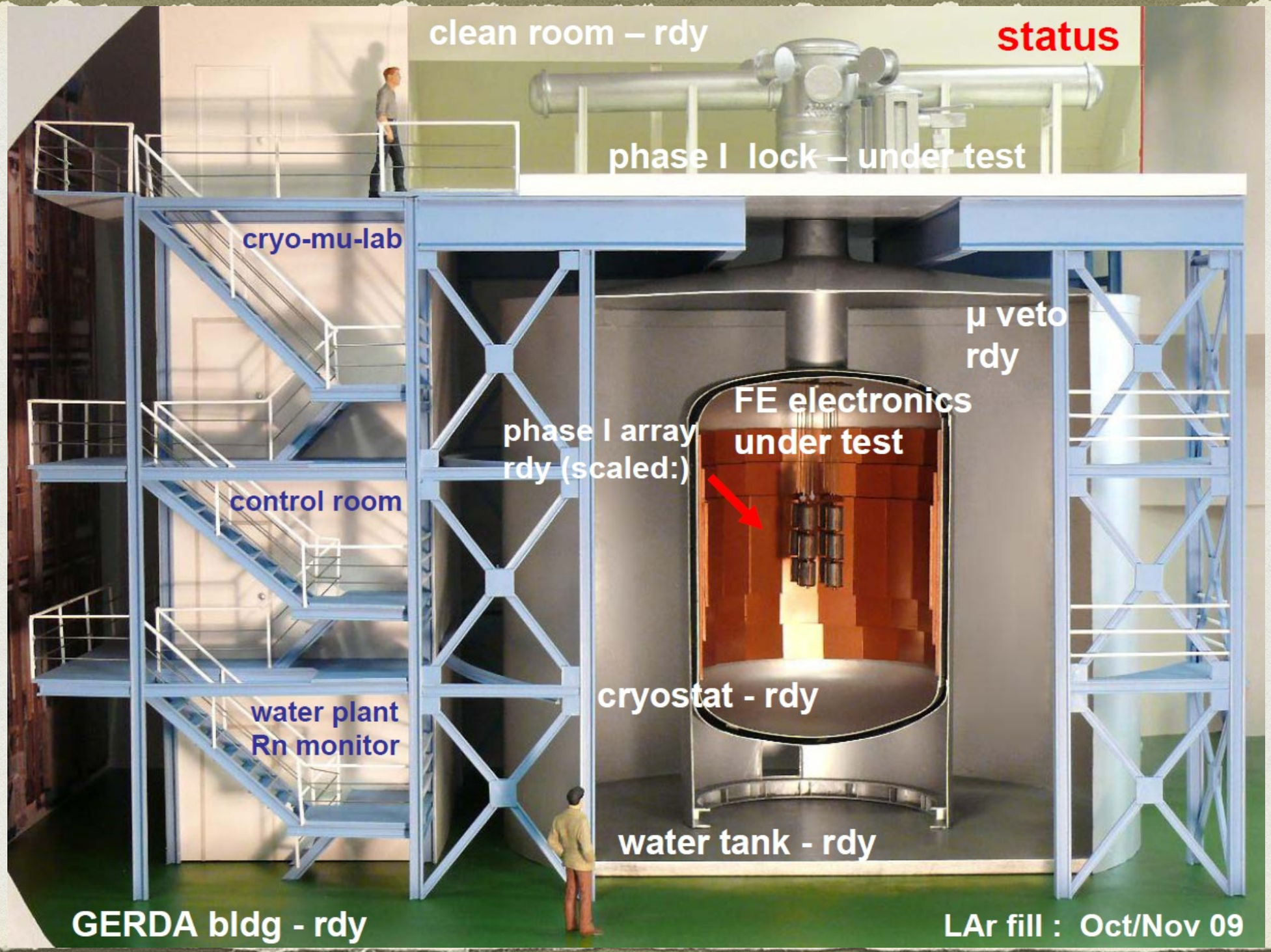
$$\nu_L^M \xleftrightarrow[\text{Lorentz}]{\text{CPT}} \nu_R^M$$

Majorana

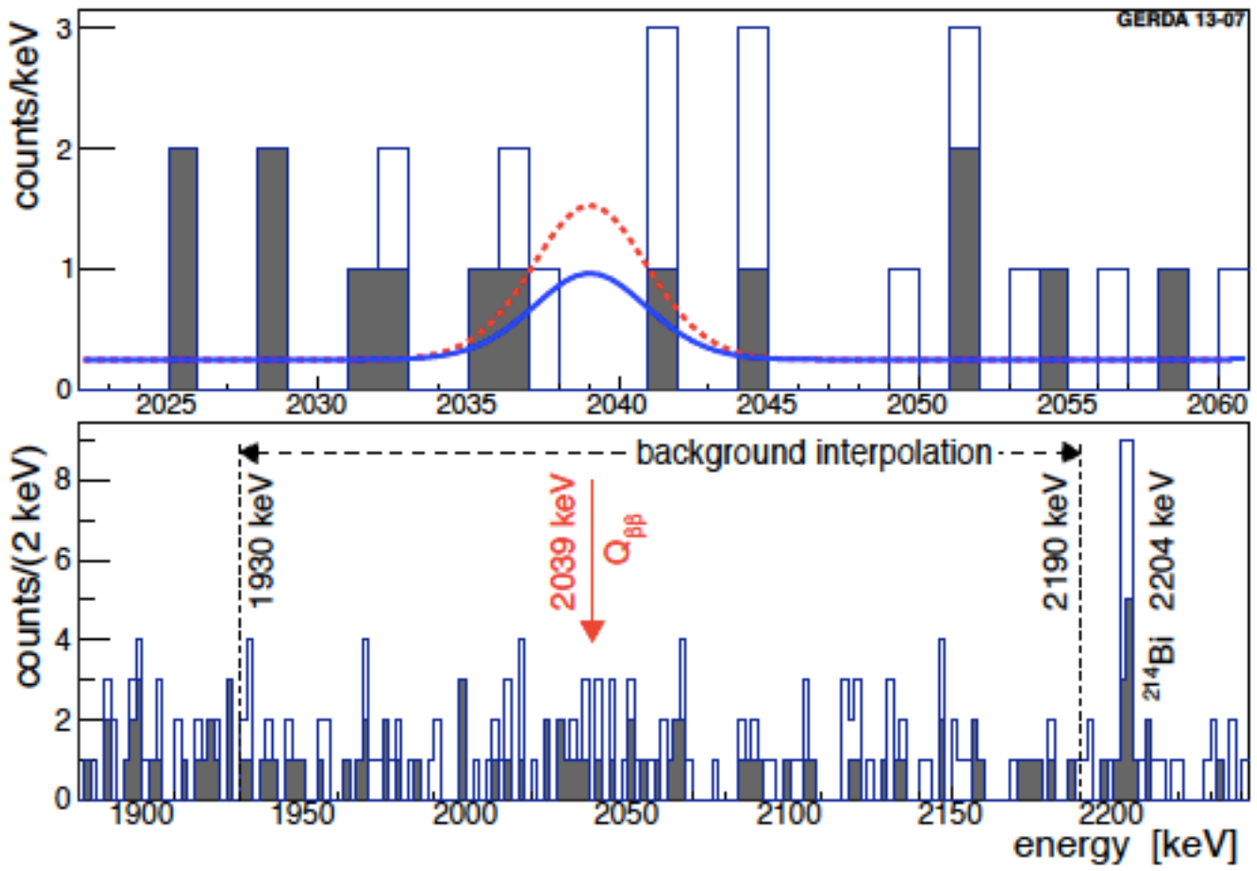
$$\begin{array}{ccc} \nu_L^D & \xleftrightarrow{\text{Lorentz}} & \nu_R^D \\ \Big\updownarrow \text{CPT} & & \Big\updownarrow \text{CPT} \\ \overline{\nu}_R^D & \xleftrightarrow{\text{Lorentz}} & \overline{\nu}_L^D \end{array}$$

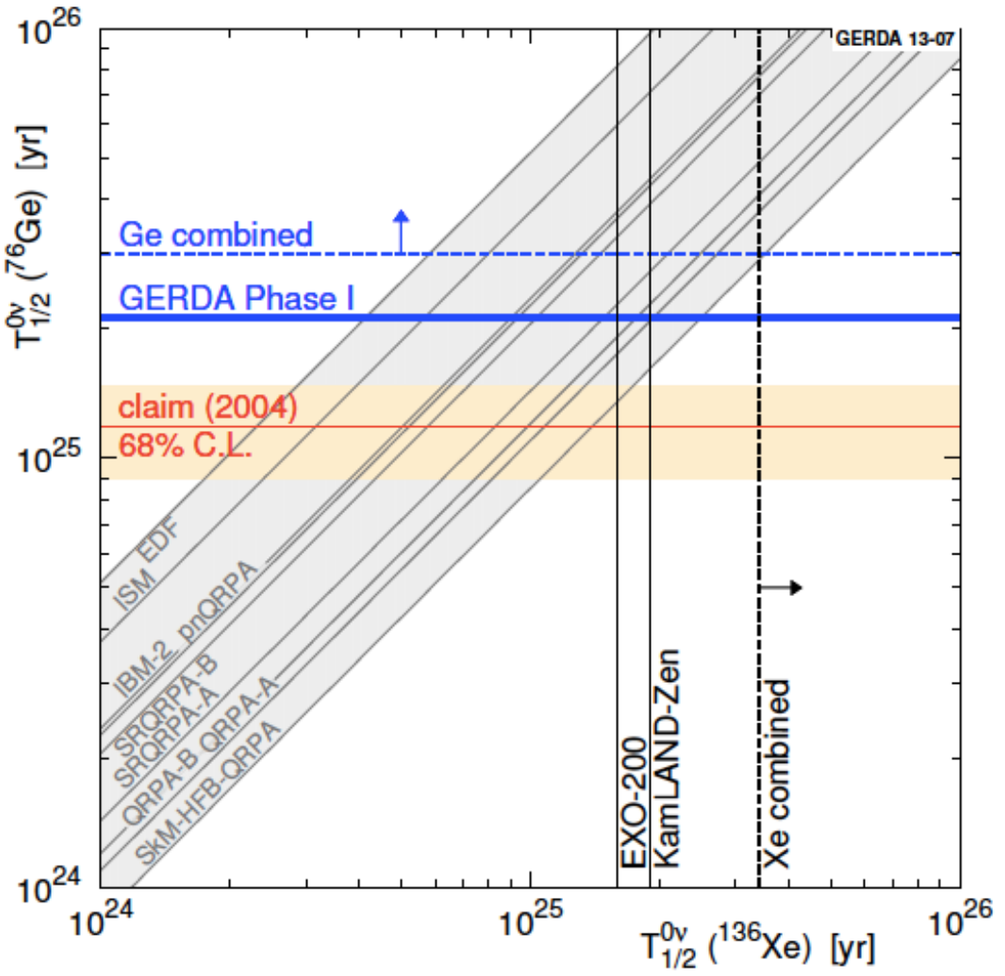
Dirac

GERDA


clean room – rdy
status
phase I lock – under test
cryo-mu-lab
μ veto
rdy
FE electronics
under test
phase I array
rdy (scaled:)
control room
cryostat - rdy
water plant
Rn monitor
water tank - rdy
GERDA bldg - rdy
LAr fill : Oct/Nov 09

GERDA DBD SPECTRUM



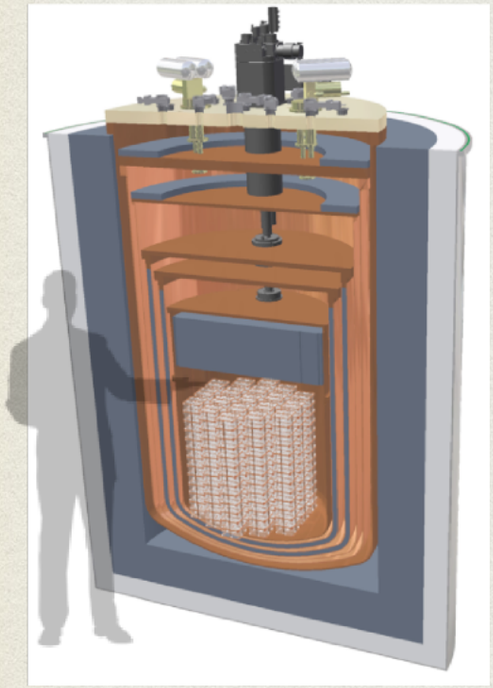


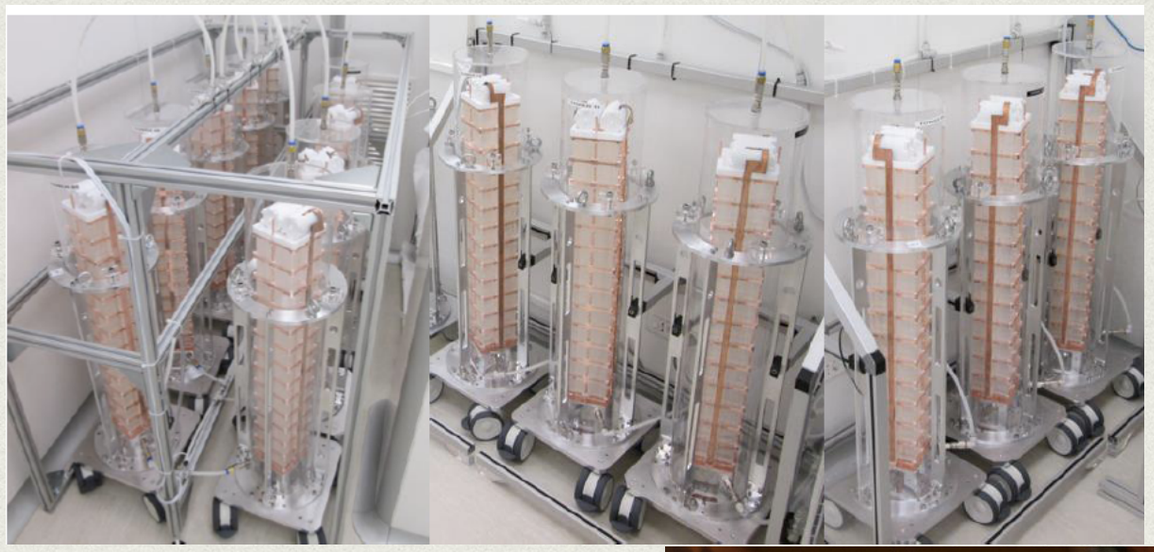
CUORE

Cryogenic Underground Observatory for Rare Events

CUORE: The Coldest Heart in the Known Universe

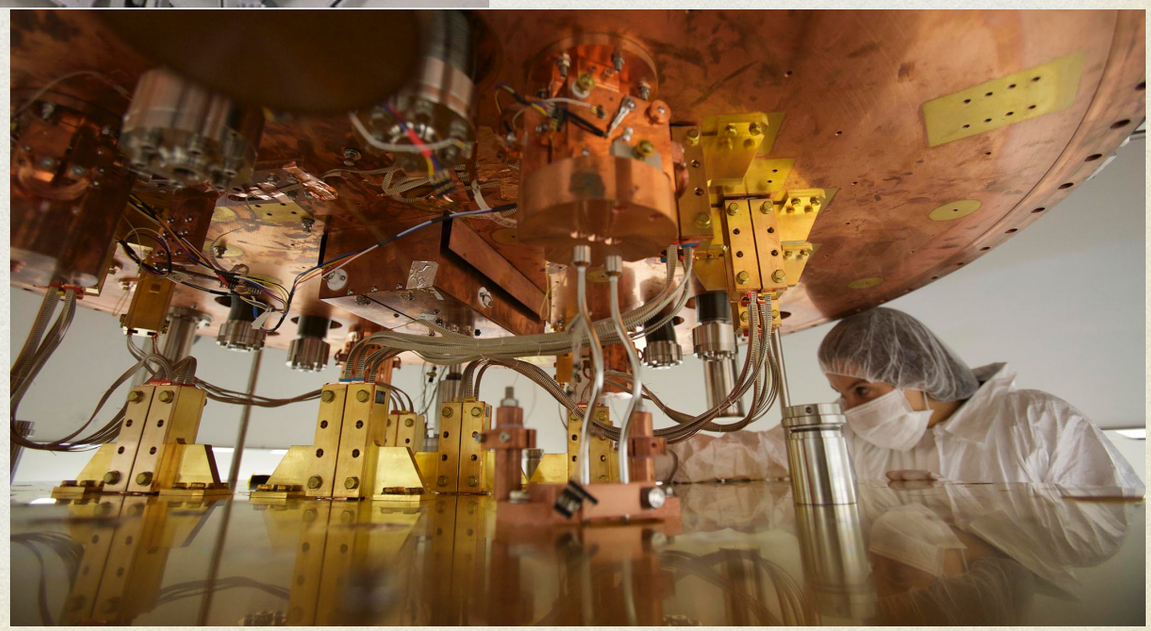
1 m^3 at 8mK



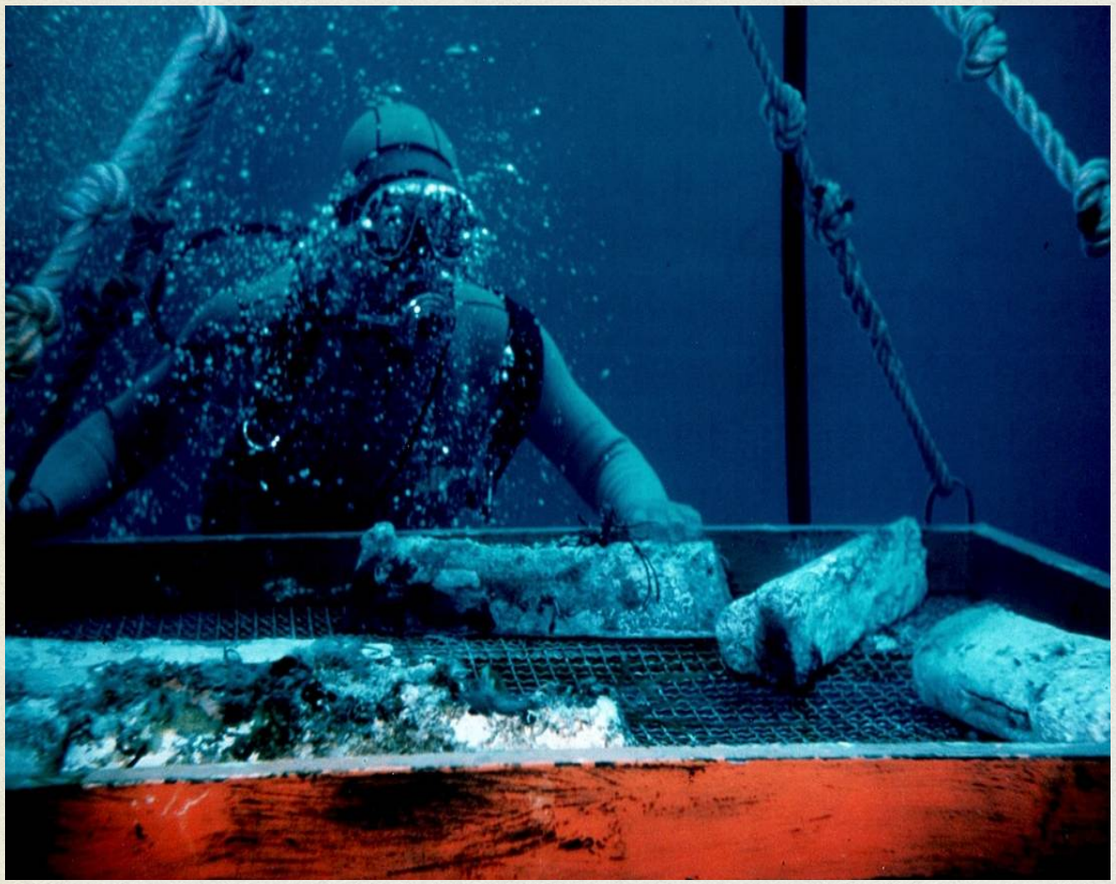


200 Kg
^{130}Te

5 Years sensitivity:
$T_{1/2} = 2.1 \times 10^{26}$ y,
$m_{\beta\beta}$=41–95 meV
background counting rate
10^{-2} c/keV/kg/y



PHYSICS & ARCHEOLOGY



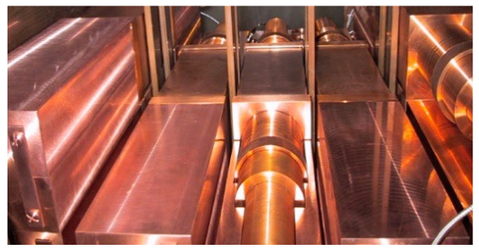
A couple of hundred ingots
for the CUORE shielding

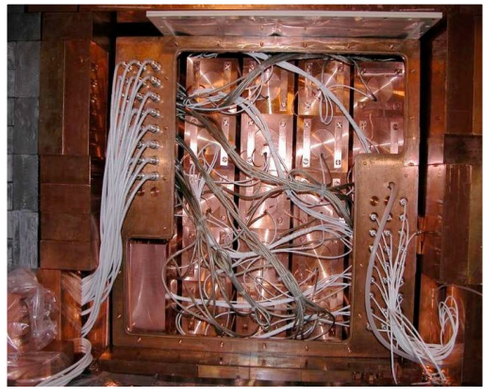
^{210}Pb free (22.3 y half-life)
2000 y shielded by sea water

DARK MATTER SEARCHES

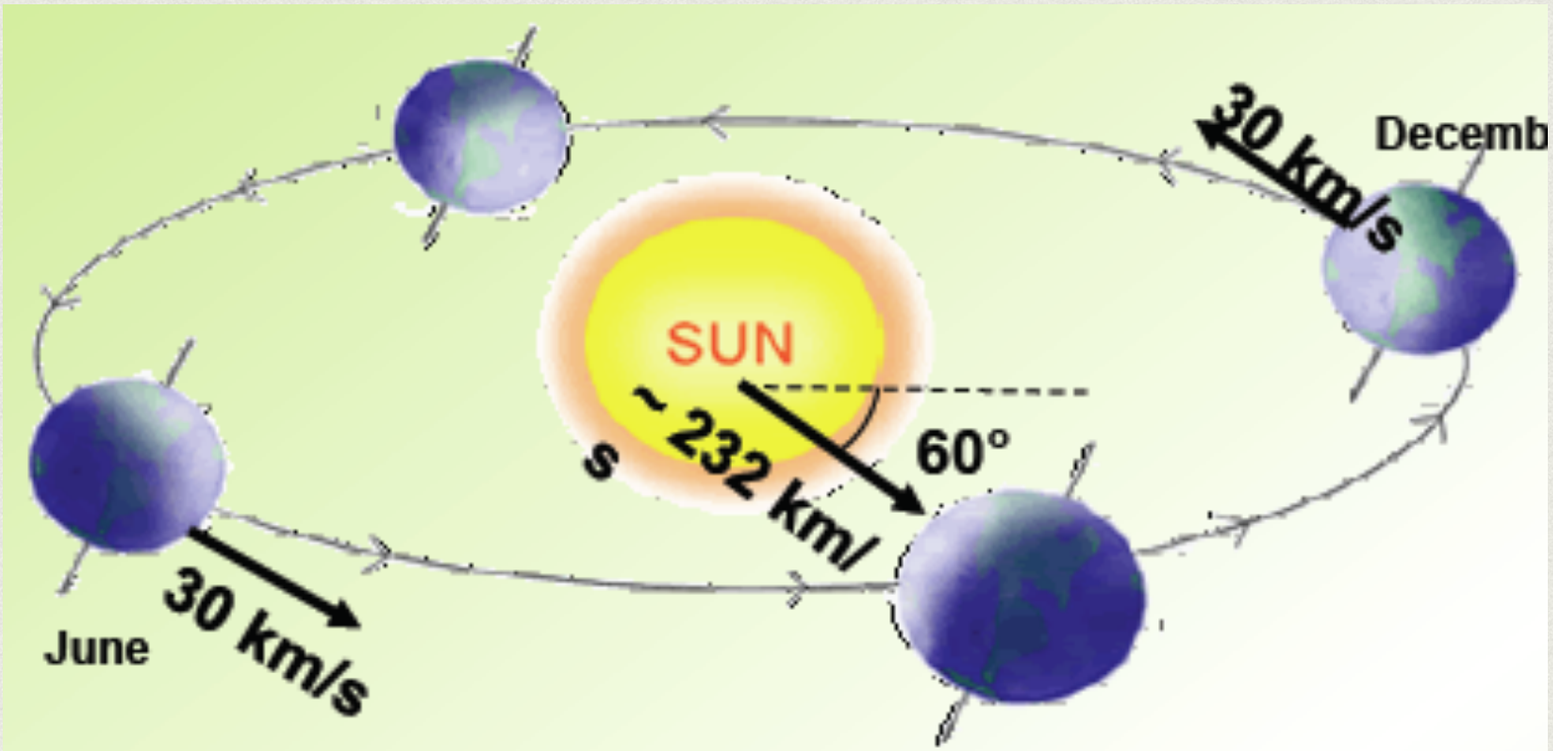
DAMA/LIBRA

- Ultrapure Na(Tl)
  - Residual contamination
    - ^{232}Th, ^{238}U and ^{40}K at level of 10^{-12} g/g



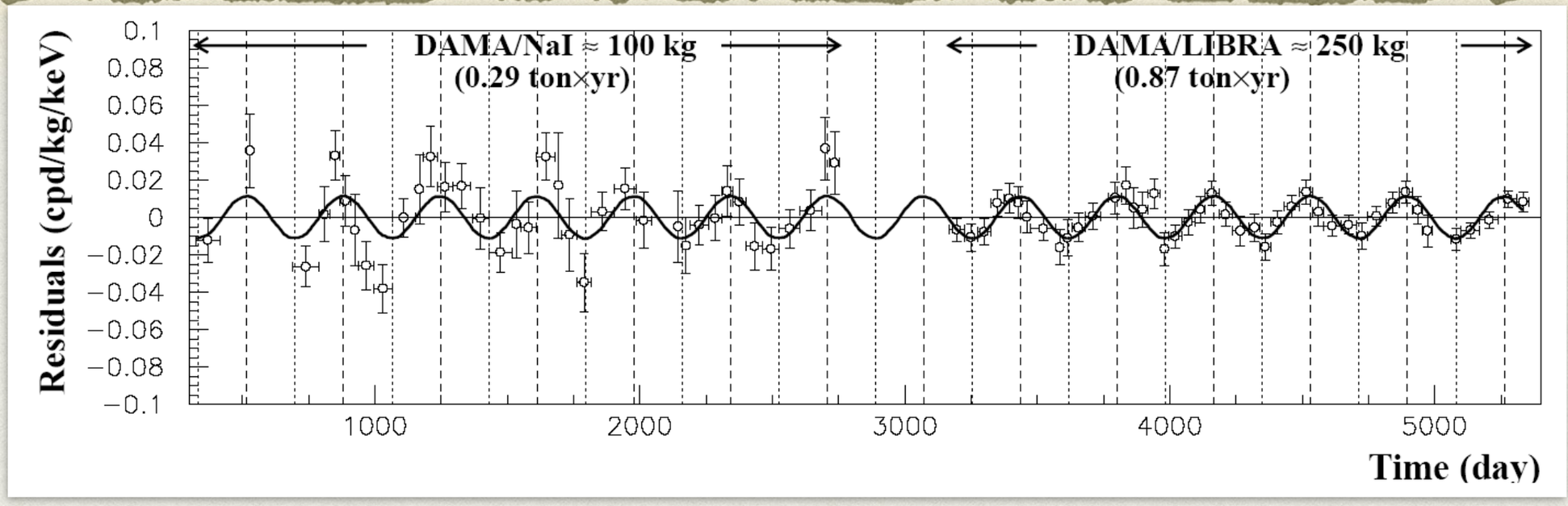


HITTING FRONTALLY OR FROM BEHIND !

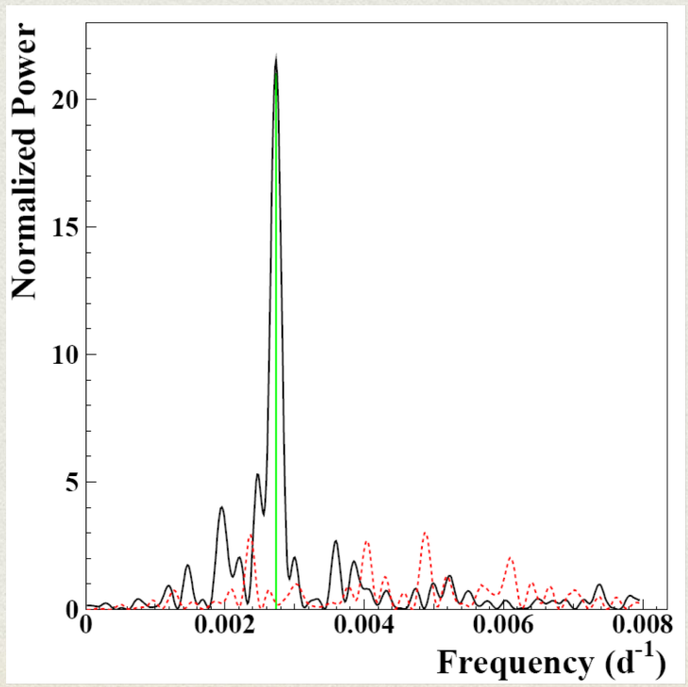


- v_{sun} ~ 232 km/s (Sun velocity in the halo)
- v_{orb} = 30 km/s (Earth velocity around the Sun)
- $\gamma = \pi/3$, $\omega = 2\pi/T$, T = 1 year
- t_0 = 2nd June (when $v_\oplus$ is maximum)

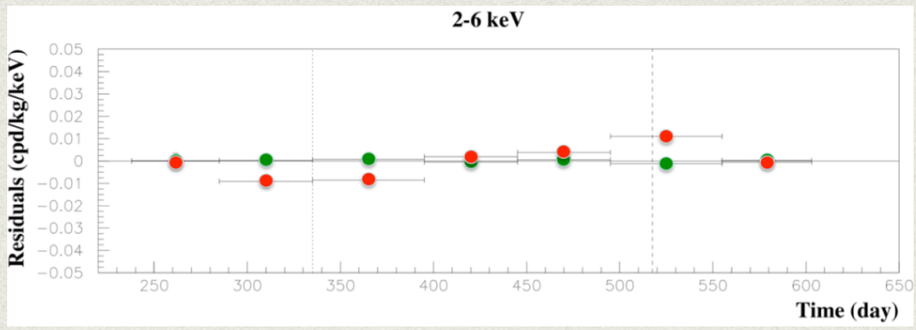
DAMA/LIBRA ANNUAL MODULATION



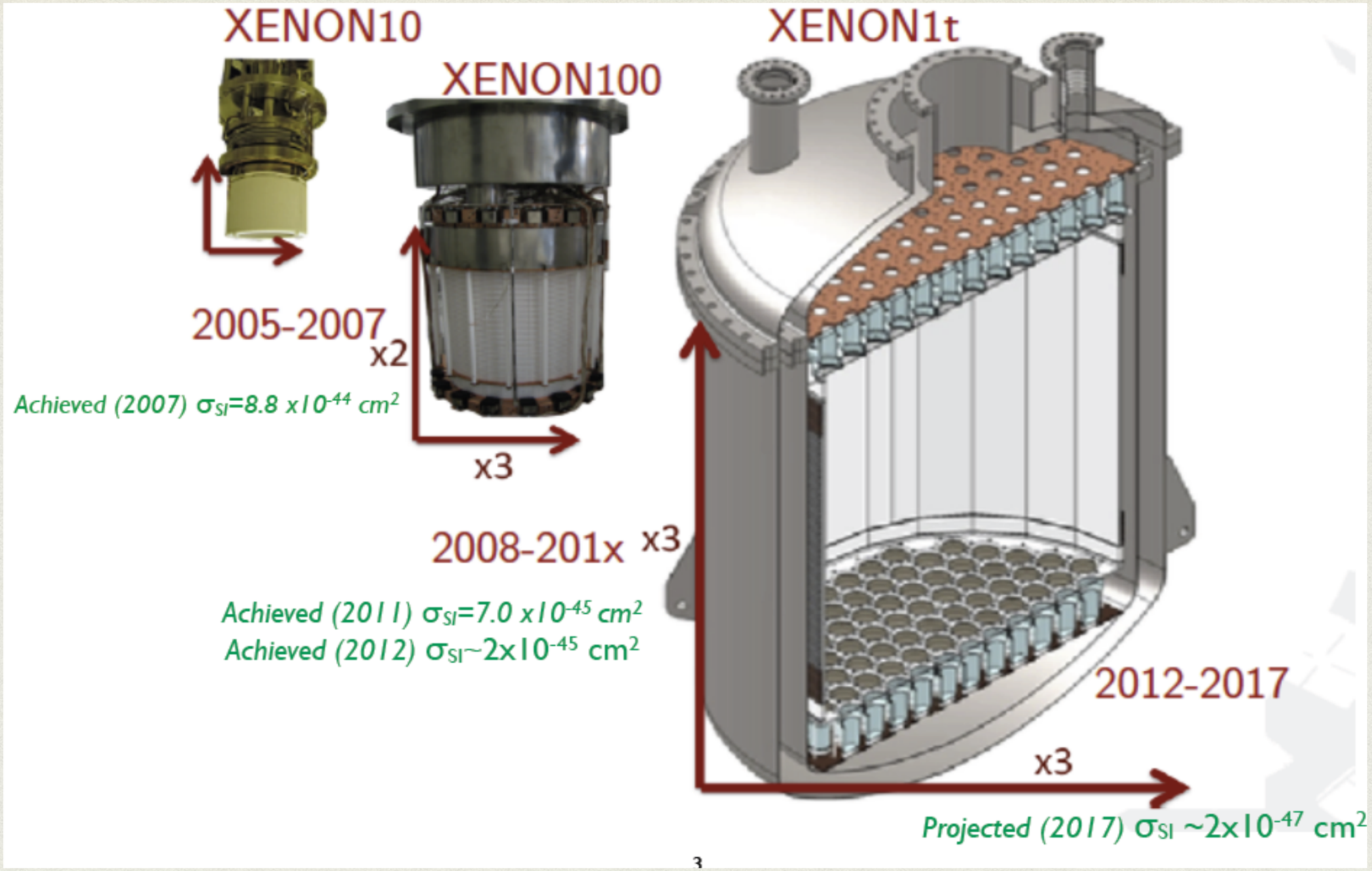
Power spectrum



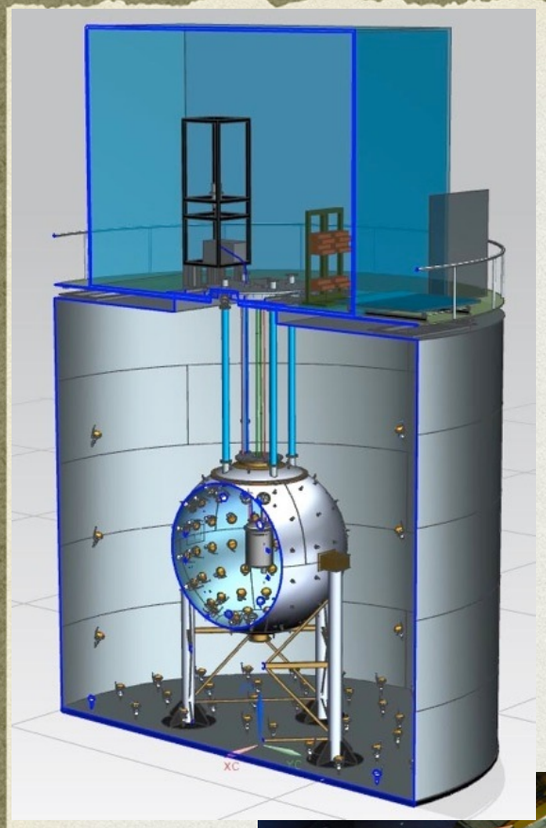
Comparison between single hit residual rate (red points) and multiple hit residual rate (green points).

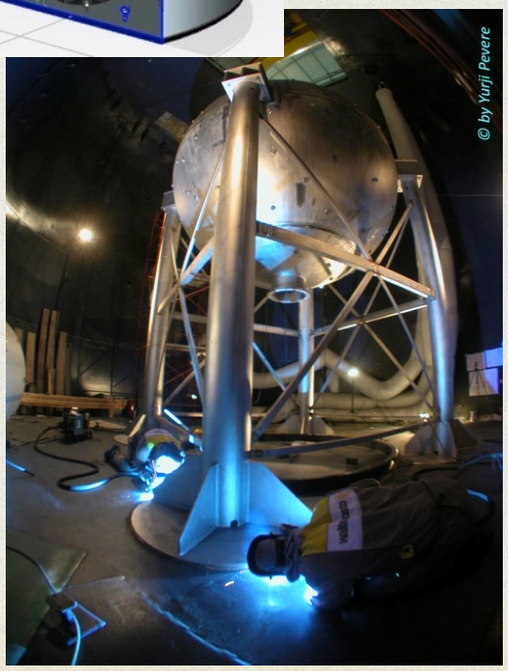


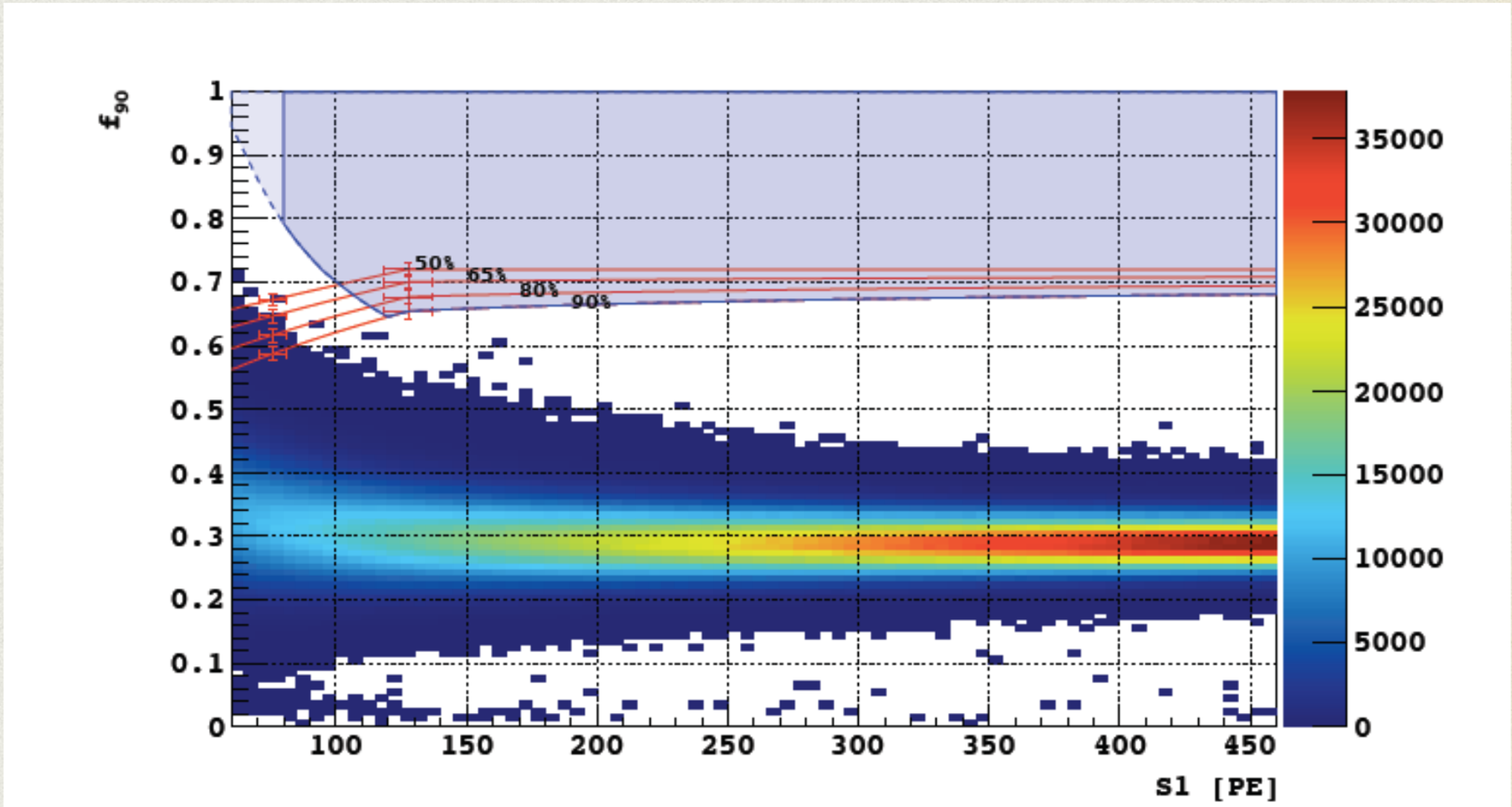
THE XENON FAMILY



DARKSIDE (LAR DARK MATTER SEARCH)







SEVERAL TECHNOLOGIES AT WORK IN LNGS

- Liquid Argon cryostat for hundreds of Tons
- Large Area counter detectors (RPC's)
- Liquid scintillators at highest purity
- Double phase liquid Xenon detectors
- Radiopure NaI scintillators
- Large volume Germanium detectors
- Large volume bolometers at few mK operation

GRAN SASSO SCIENCE INSTITUTE

- Role of INFN in preparing excellent researcher fully recognized by Ministry of University and Research

- Funding (12ME/year) for starting a Ph.D. school (Physics, Mathematics and Computing Sciences, Social Sciences*)

  - in L'Aquila for contributing to revive the local economy after the earthquake

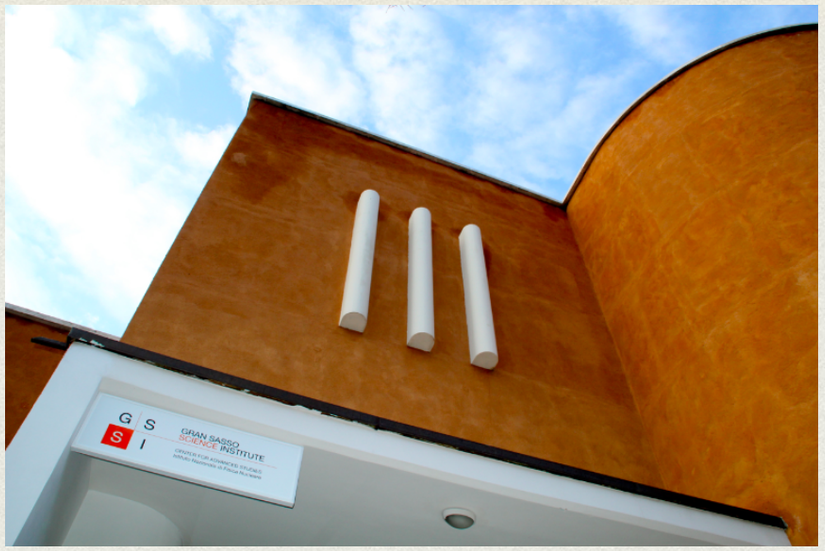
  - A great proof of confidence, a big challenge and an enormous responsibility

*Smart Cities, Cultural Heritage, Risk assessment and Disaster Recovery

GSSI

GRAN SASSO SCIENCE INSTITUTE

CENTER FOR ADVANCED STUDIES
Istituto Nazionale di Fisica Nucleare



The INFN center for advanced study and international PhD school *Gran Sasso Science Institute* has started its educational and scientific activities in October 2013, and is now entering his second year of life.

36 PhD students selected, divided into 4 courses:

- *Astroparticle Physics (10)*
- *Mathematics in Natural, Social and Life Science (6)*
- *Computer Science (8)*
- *Urban Studies (12)*

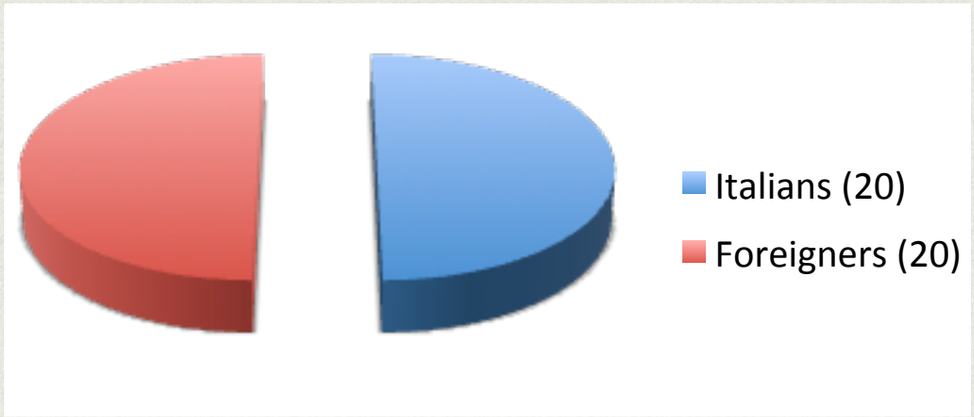
Also appointed: 16 Post-docs with two-years research grants

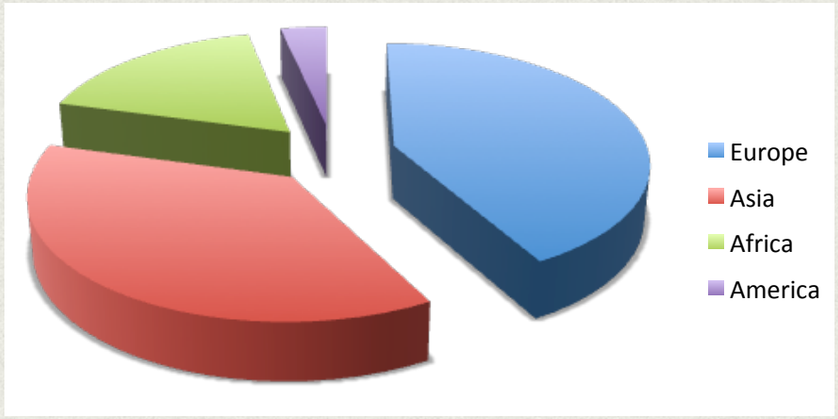
Scientific Committee appointed: F. Barca (MEF, Italy, Chair); R. Barbieri (SNS, Italy); B. Barish (Caltech, USA); S. Iammarino (LSE, UK); A. Quarteroni (Pol. Losanna, CH); A. S. Vincentelli (Berkley, USA). 1° meeting November 25, 2014.

A TRULY INTERNATIONAL SCHOOL

Call 2014

811 applications
40 Students admitted





Italian Universities

University of Roma La Sapienza	4
University of L'Aquila	3
University of Roma Tor Vergata	2
University of Bologna	2
University of Milano	2
University of Torino	2
University of Roma Tre	1
University of Milano Bicocca	1
University of Napoli Federico II	1
University of Salento	1
University of Basilicata	1
Total	**20**

Foreigner Universities

University of Athens (Greece)	2
University of Warsaw (Poland)	2
University of Banja Luca (Bosnia Erzegovina)	1
Bauhaus University Weimer (Germany)	1
University of California Berkley (USA)	1
University of Bogotà (Colombia)	1
University of Hanoi (Vietnam)	1
University of Ho Chi Min City (Vietnam)	1
Isfahan University of Technology (Iran)	1
University of Karachi (India)	1
University of Lyon (France)	1
University of Mumbai (India)	1
University of Munchen (Germany)	1
University of Patras (Greece)	1
University of Rio de Janeiro (Brazil)	1
University of Strasbourg (France)	1
University of Tbilisi (Georgia)	1
University of Varna (Bulgaria)	1
Total	**20**

TIFPA

(TRENTO CENTER FOR PHYSICS AND APPLICATIONS)

INFN

with

- University (physics, biology)
- Health care system (proton therapy cyclotron)
- FBK (applied physics, silicon detectors)
- ECT* (nuclear physics theory)

LINES OF RESEARCH

- Clinical radiobiology (Marco Durante -hired from GSI)
- Space science (Stefano Vitale -Lisa Pathfinder, eLisa in close collaboration with ASI (Roberto Battiston professor in Trento)
- Innovative detectors (in collaboration with FBK -SiPM on top priority)
- Cold Atoms (Sandro Stringari- a What Next line of research)

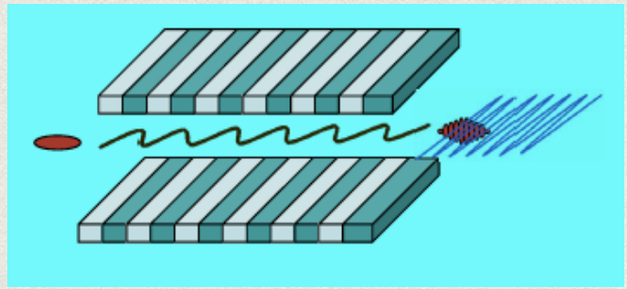
LNF Rascati

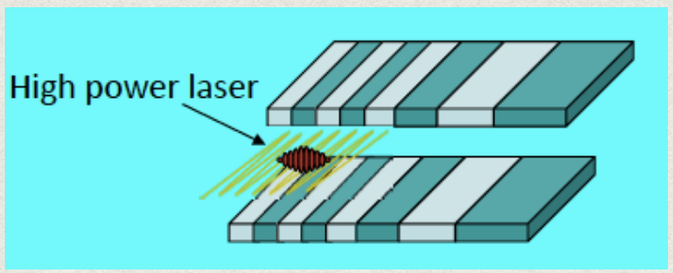
LNF

- the bigger laboratory in INFN, need to design a solid future
- Big machines cannot be done in this economic conditions
- Fully exploit the Beam Test Facility also connecting it to a more general Space Program Facility
- SPARC and Plasma Wakefield Acceleration the main future
- run Dafne with KLOE a bit longer, find a future in the study of accelerators
- a center for detector R&D and big construction

A NEW FRONTIER :MARRYING LASERS AND PARTICLE BEAMS

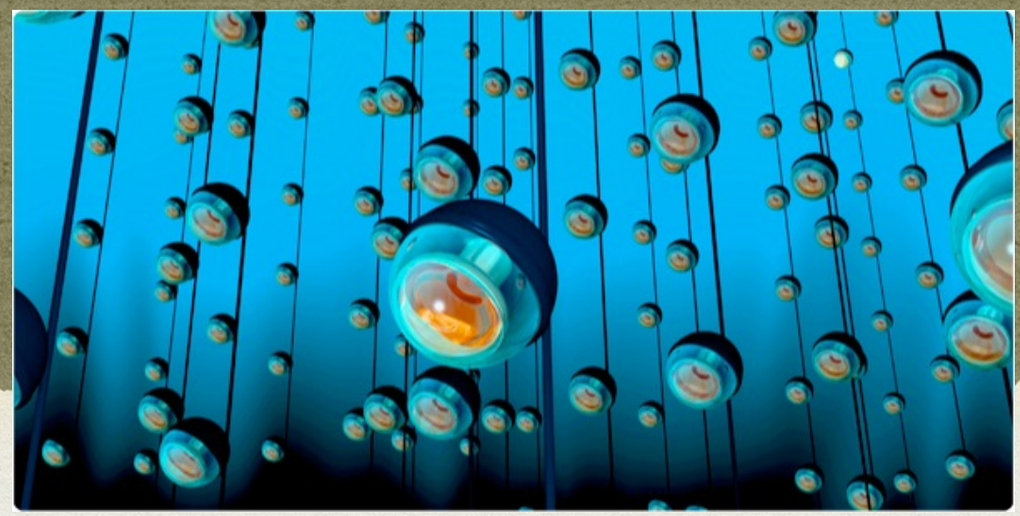
Seeding a High Gain Free Electron Laser: transfer coherence from the Laser to the FEL radiation through the Electron Beam



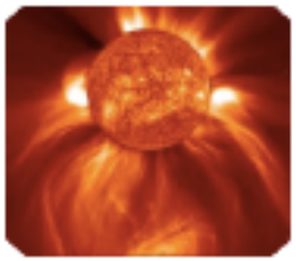


Inverse Free Electron Laser: transfer energy from the Laser to the Electron Beam through the FEL radiation

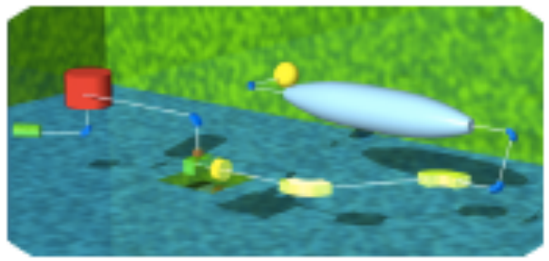
LNS



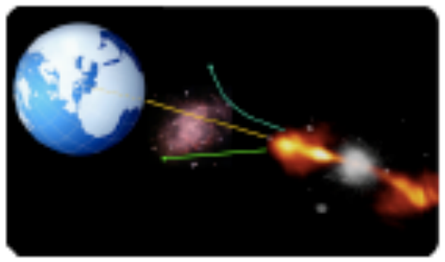
LNS activity overview



Nuclear Physics



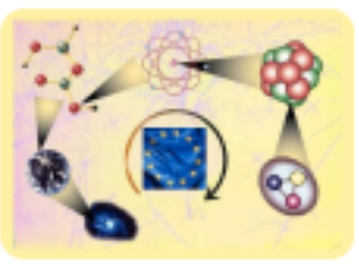
Accelerators



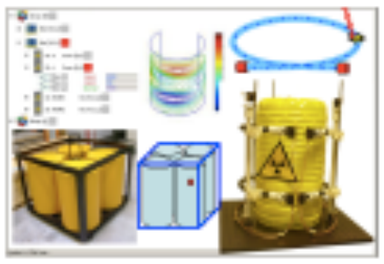
Astroparticle Physics

Detector systems

Ion Sources



Theory



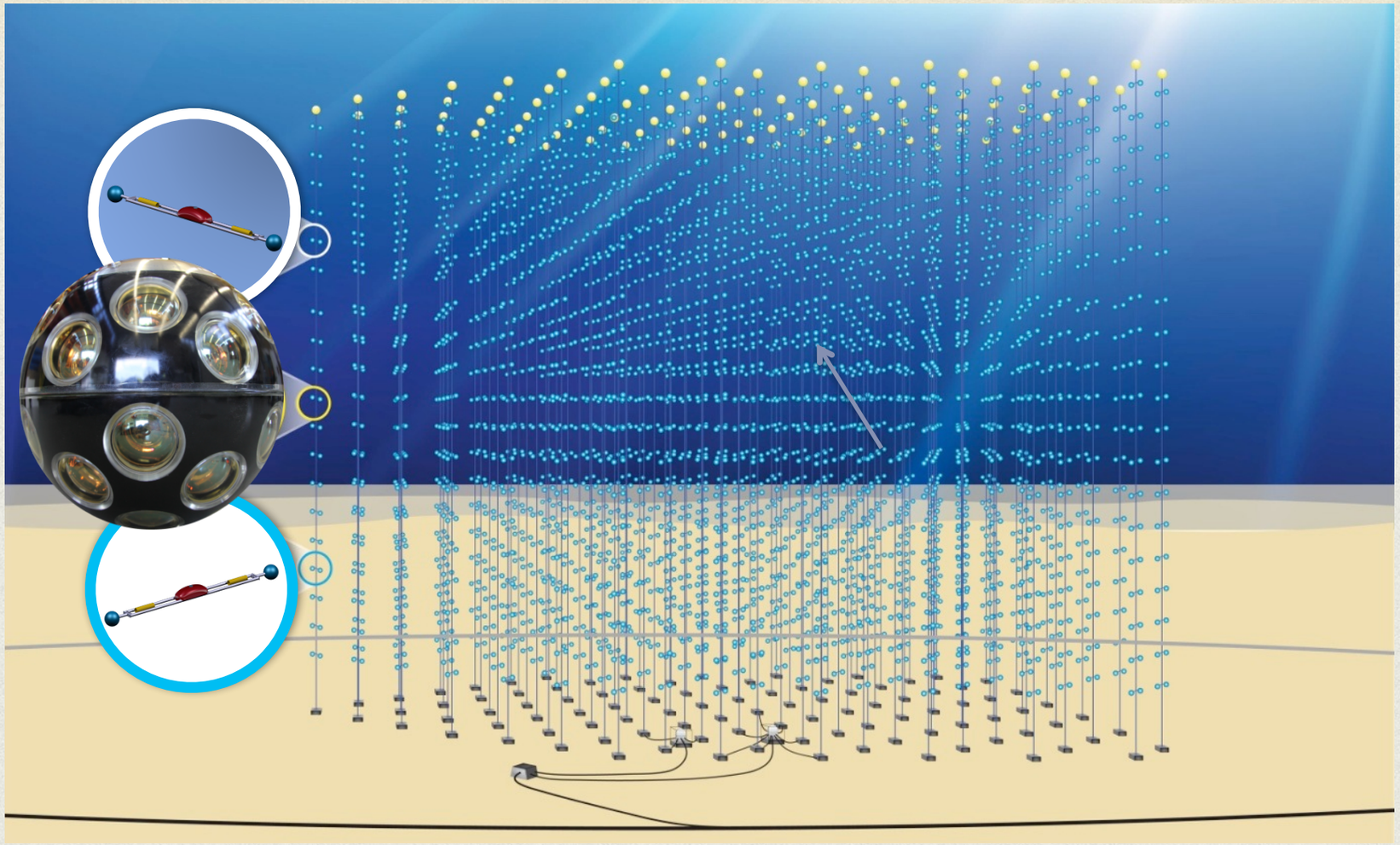
INFN-Energy

PTANA

Protontherapy

Multidisciplinary facilities

BEING DEPLOYED



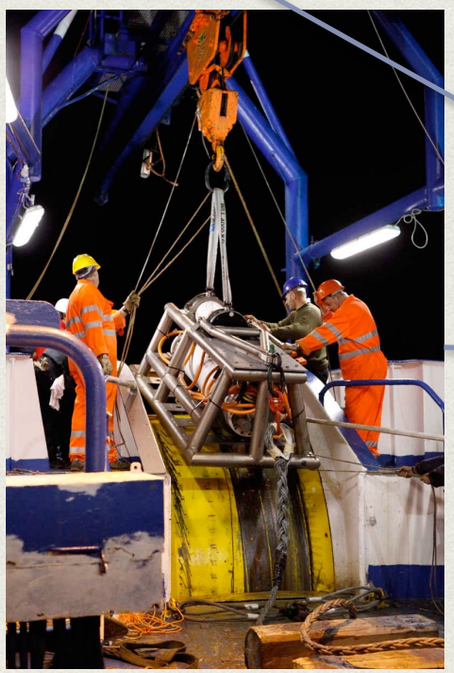
Very high energy neutrinos from sources in cosmo.

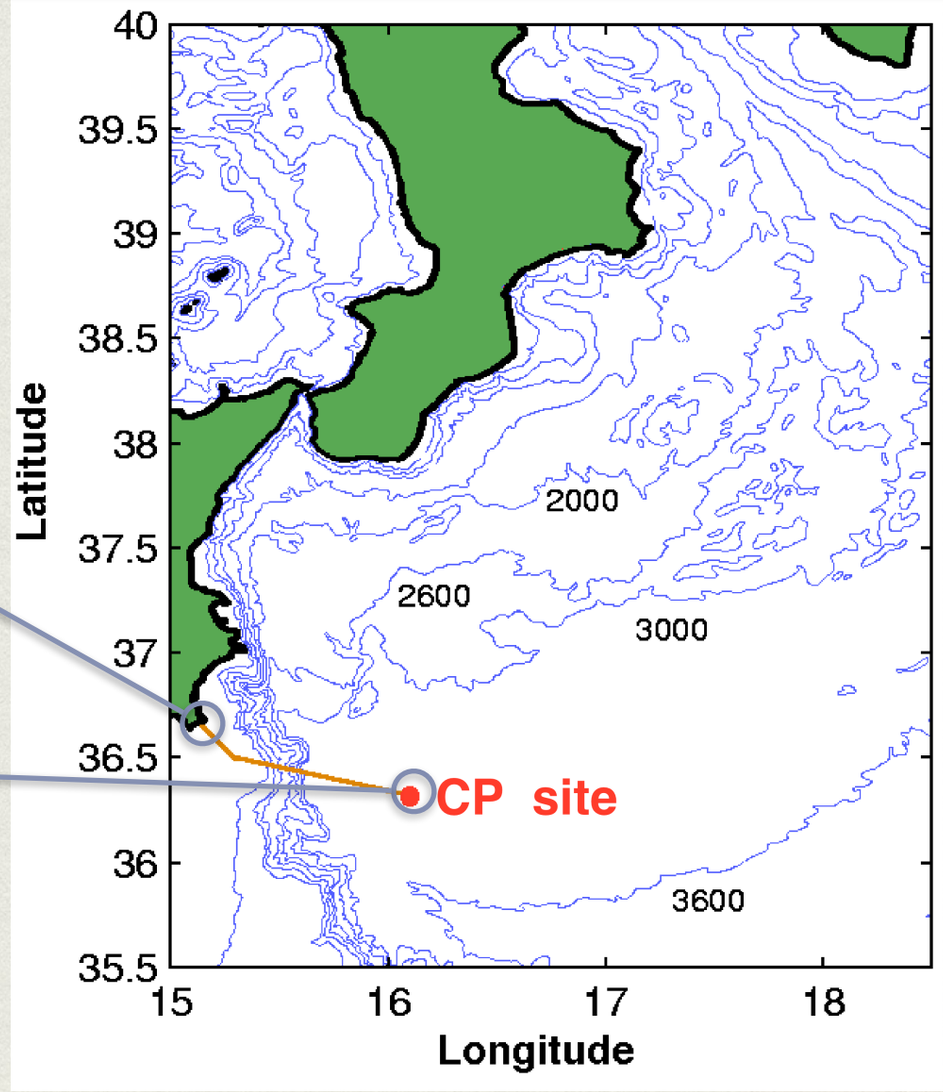
THE CAPO PASSERO SITE

Capo Passero is one of the candidate sites for the installation of KM3NeT
Deep sea site studied and fully characterized in the past 12 years
Already existing infrastructure with to be upgraded for KM3NeT-Italia

Present infrastrucures

- Deep-sea 10 kW DC/DC converter
- Main 100 km electro-optical cable
- Power feeding system
- Shore station
- High bandwidth (1 Gbps) connection to LNS





VIRGO

EGO-VIRGO

Consortium of

cnrs

INFN

dépasser les frontières

The

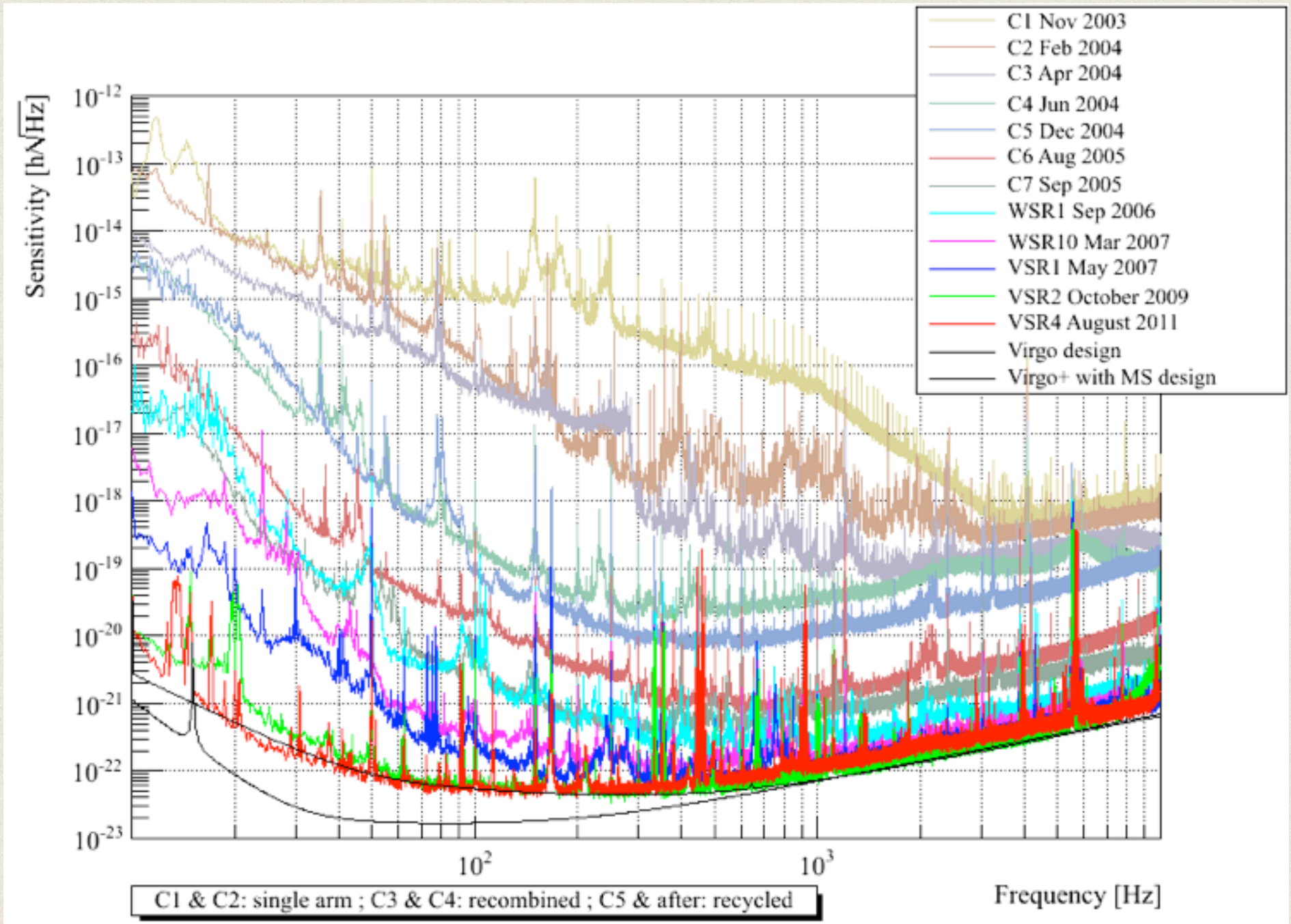
Gravitation

al

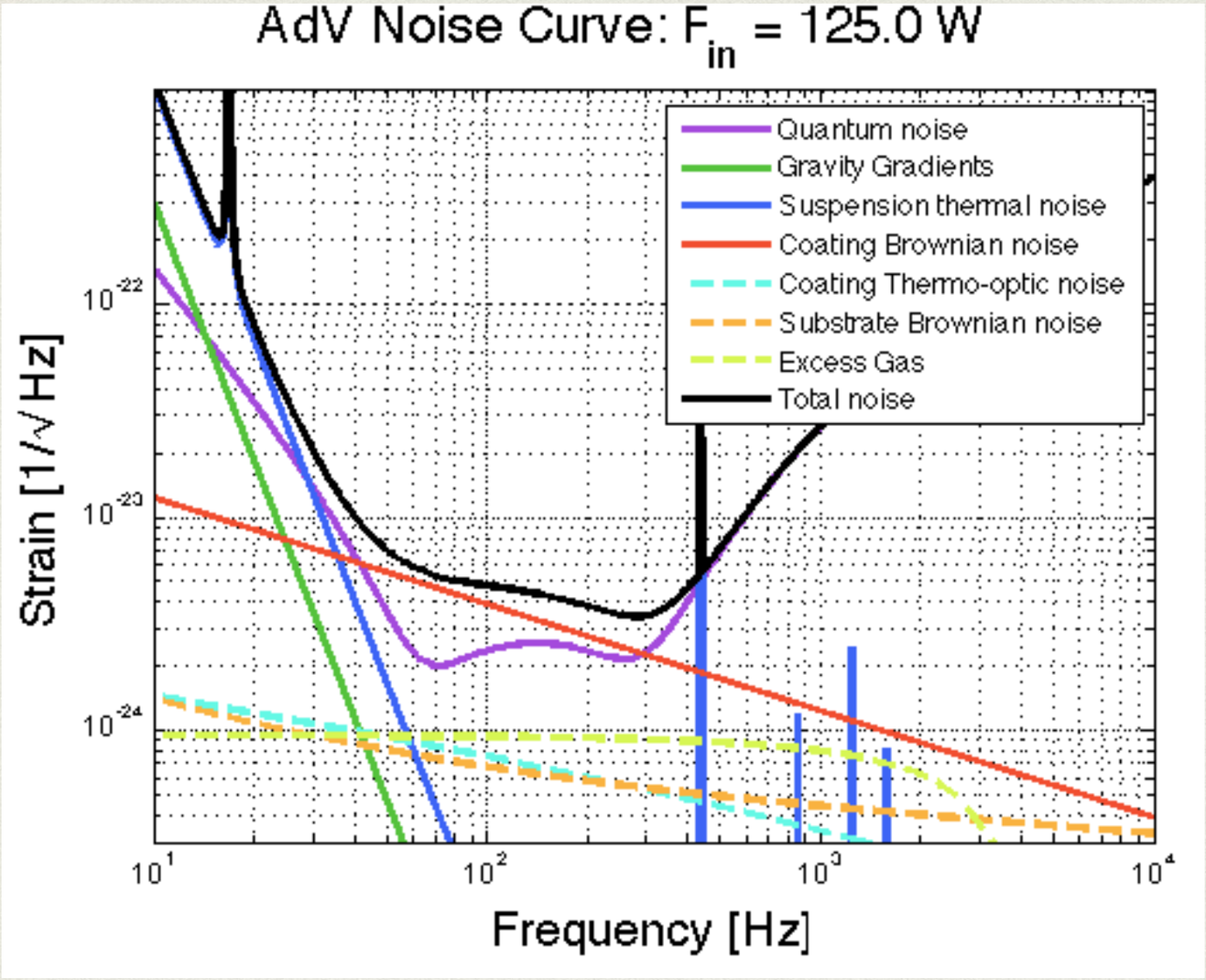
Waves

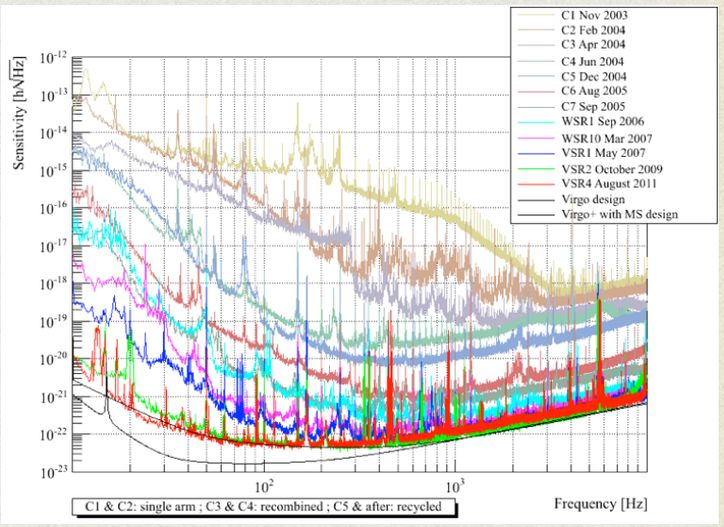
quest

Sensitivity achieved



ADVANCED VIRGO: 2016



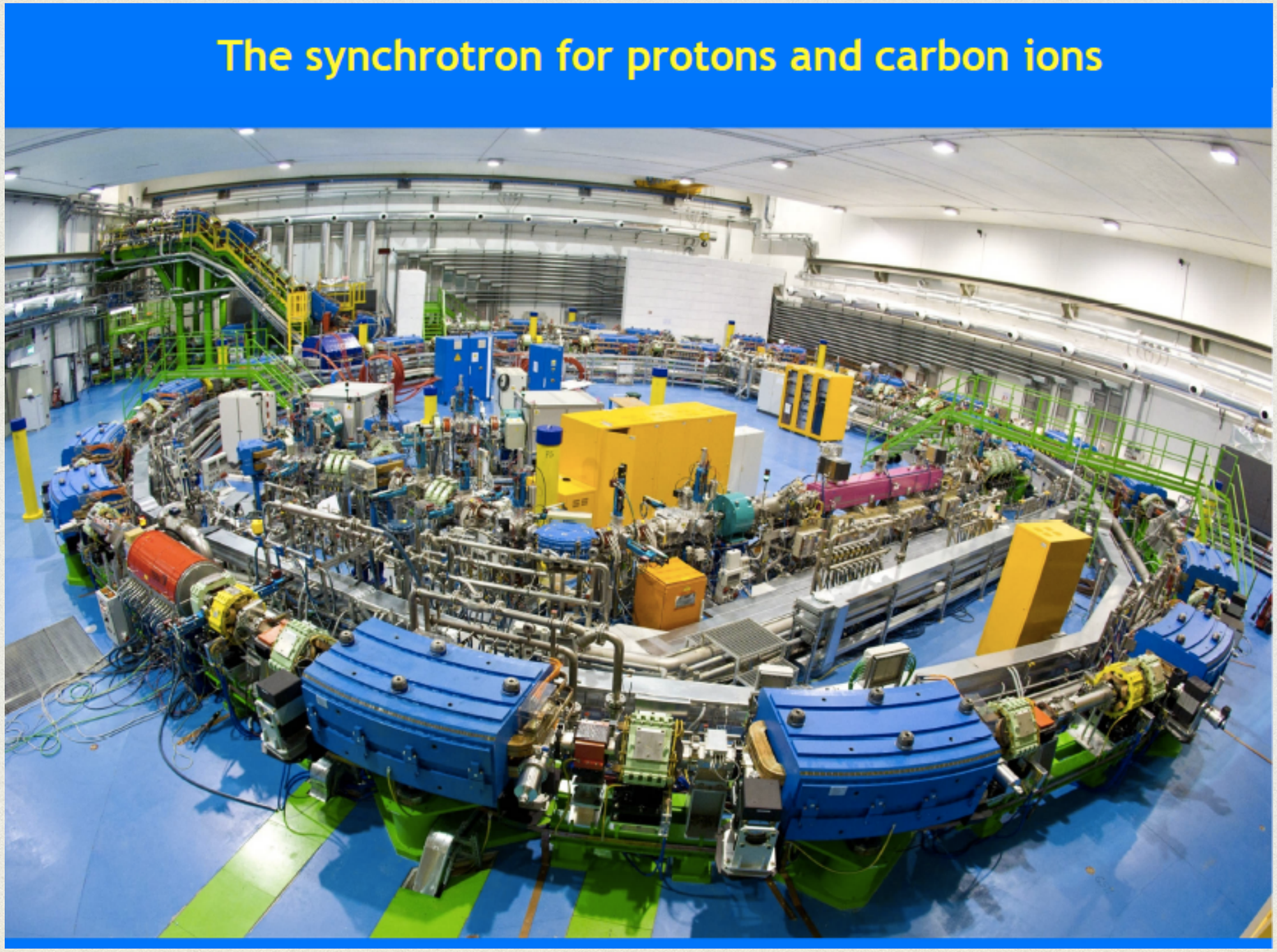


SPACE

- AGILE, FERMI, PAMELA (past)
- AMS (present)
- DAMPE, GAMMA400…….HERD (future)

A BRAND NEW CENTER FOR ION THERAPY

CNAO IN PAVIA



ITALIAN POSTS

AND EVEN GOOGLE

DISCUSSING THE FUTURE

700+ people

No WiFi

A MINE OF OPPORTUNITIES

- CMB (a test balloon for validating the technology for a possible ESA mission on polarisation)

- Dark Energy (EUCLID science and some technology)

- Axions (an idea that might compete with ADMX together with INRIM)

- Cold atoms quantum simulator (in collaboration with the best of condensate matter in Italy- Florence LENS and Trento)

STRATEGIC PARTNERSHIP: CHINA

fostered by ARGO, perhaps not much physics but a seed that has generated a robust plant

- BES experiment upgrade (cylindrical GEM from LNF)
- DAMPE satellite (silicon tracker on chinese money)
- CSES satellite (premium project)
- JUNO experiment (Borexino technology for purification)
- others development in discussion including an experiment at LNGS on DM

LAST BUT NOT LEAST

THE MUST DO

- LHC physics at 13 TeV connected to LHC Phase 2 Upgrade
- stay at the frontier with DM and ν-lessDBD at LNGS
- discover GW (a must)
- open up mind and field of investigations (What Next ?)

CONCLUSIONS

- The ‘ballistic’ science is robust and giving fruits
- Need to prepare for a future more diversified and yet as robust as the present