Laboratori Nazionali del Gran Sasso

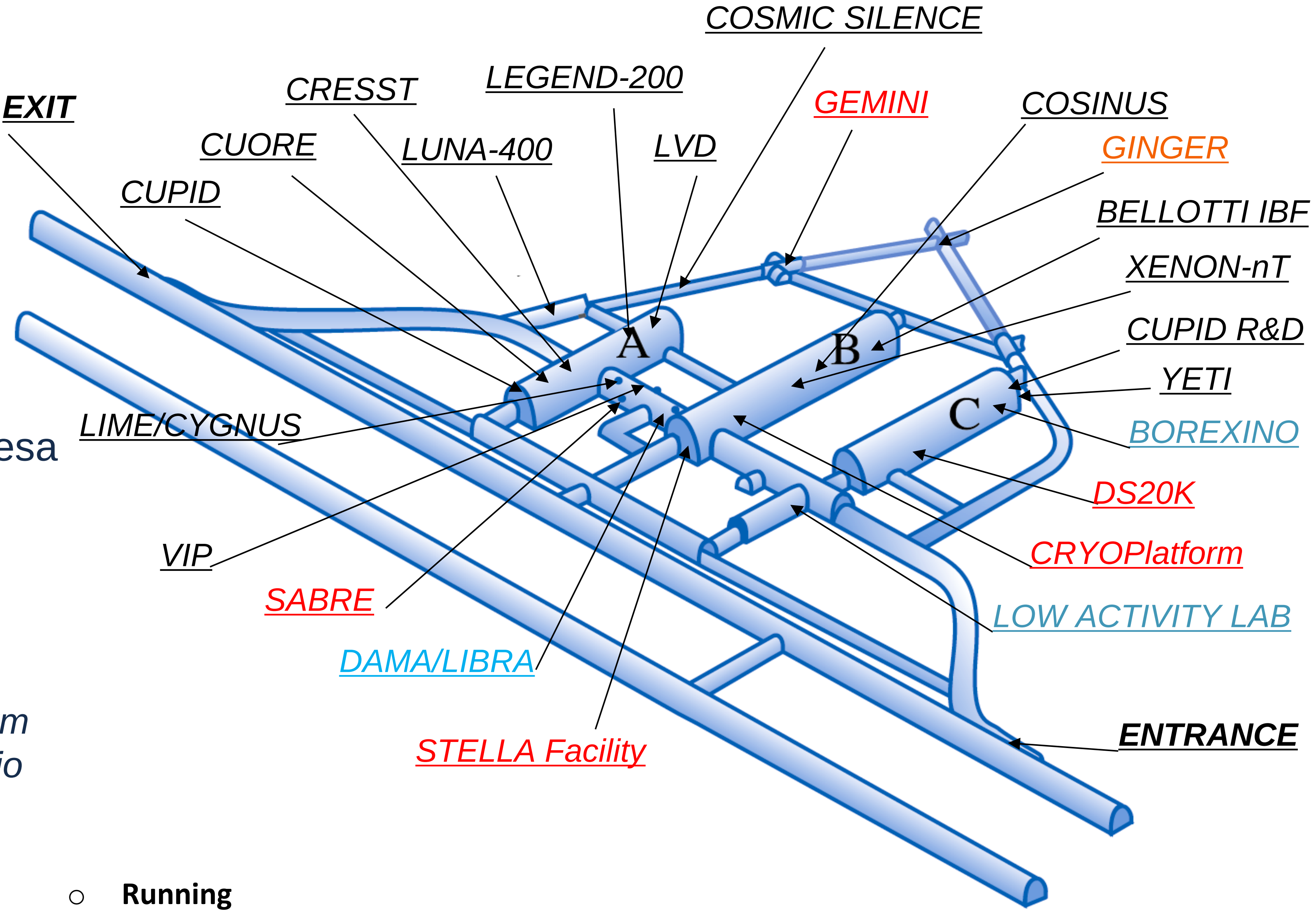
INFN per la Strategia della Fisica delle Particelle 2025-26

Ezio Previtali

LNGS - oggi

Circa **20 esperimenti** in presa dati o in costruzione

Altri progetti
SQMS → YETI
RESNOVA → CRYOPlatform
BULLKID-DM → CRYOPlatform
PTOLEMY → Hall di montaggio



- **Running**
- **Construction/Commissioning**
- **Decommissioning**

LNGS - community

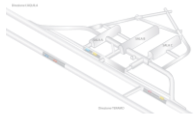
Utenti registrati ai LNGS

Total:	650	(~1334*)
Italian:	359	(~482*)
Foreign:	291	(~852*)

*** Collaborazioni scientifiche**

Dati relative all'anno 2024

LNGS – linee di ricerca



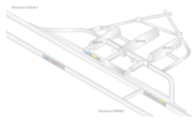
Principali linee di ricerca:

- Doppio decadimento beta senza emissione di neutrino
- Ricerca di materia oscura, misure dirette
- Astrofisica nucleare

Attività di R&D e sviluppo di nuove tecnologie:

- Onde gravitazionali
- Misure di relatività generale
- Test di meccanica quantistica
- Processi quantistici (sensoristica, computer,…)
- Biologia
- Geologia e geofisica
- …………

Astro-Particles Physics strategy - Europe



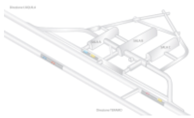
Double Beta Decay APPEC Committee Report - February 11, 2020

A. Giuliani, J.J. Gomez Cadenas, S. Pascoli (Chair), E. Previtali, R. Saakyan, K. Schaffner and S. Schonert

Recommendation 1. ***The search for neutrinoless double beta decay is a top priority in particle and astroparticle physics,*** *as this process provides the most sensitive test of lepton number violation.*

The discovery of neutrino masses and mixing, implied by neutrino oscillations, is so far the only particle physics evidence of physics beyond the Standard Model (SM). It has opened new key questions, among which establishing the nature of neutrinos is arguably the most important. The latter is intrinsically related to the conservation of lepton number, which is related to the fundamental symmetries of nature, the origin of neutrino masses in theories beyond the Standard Model and the generation of the observed matter-antimatter asymmetry in the Universe via the leptogenesis mechanism. **Generically, neutrinoless double beta decay (DBD0v) is the most sensitive probe of lepton number violation.** The 3 light massive neutrinos, if they are of Majorana type, induce this process with half-lives which may be at reach in current and future experiments. The theoretical predictions depend on the values of neutrino masses, whether they are with normal (m1 < m2 < m3) or inverted (m3 < m1 < m2) ordering, and on the CP violating phases. Other lepton number violating processes, e.g. sterile neutrinos, in extensions of the SM give also a contribution to neutrinoless double beta decay at a level which, in specific models, may be relevant for current and future experiments.

Astro-Particles Physics strategy - Europe



Double Beta Decay APPEC Committee Report - February 11, 2020

A. Giuliani, J.J. Gomez Cadenas, S. Pascoli (Chair), E. Previtali, R. Saakyan, K. Schaffner and S. Schonert

Recommendation 5. ***The European underground laboratories should provide the required space and infrastructure for next generation double beta decay experiments.*** *A strong level of coordination is required among European laboratories for radiopurity material assays and low background instrumentation development in order to ensure that the challenging sensitivities of the next generation experiments can be achieved on competitive timescales.*

In order to establish a multi-technology and multi-isotope DBD0v physics program, extensive underground space to host the DBD0v-experiments and related R&Ds activities is necessary. **In Europe the Gran Sasso underground laboratory has the required depth and could host all currently proposed next generation DBD0v European experiments. At the same time all other underground laboratories must be strongly involved in the present DBD0v strategy to support various R&D phases for detector development and to guarantee sufficient resources for material selection and detector design.** Pilot experiments will be needed to implement complex and costly experimental apparatus and onsite expertise in low-background techniques is necessary for an effective and timely implementation of the experimental programs. In order to pursue the next generation of neutrinoless double beta decay experiments, a close coordination between the European underground laboratories in the areas of low-background instrumentation development, detector prototyping and radiopurity screening is therefore mandatory.

Double Beta Decay strategy – EU + US + Ca

Anche in Nord America si sono discusse possibili strategie per il DBD.
E' stata condotta una valutazione congiunta su:

- Sensibilità degli esperimenti
- Budget richiesto per ogni esperimento
- Definizione delle collaborazioni internazionali
- Selezione del possible laboratorio sotterrabeo

  *SNOLab/SURF – **North America***

  *LNGS – **Europe** (with other European labs)*

2021 Workshop @ LNGS
2023 Workshop @ SNOLab
2025 Workshop @ Heidelberg

	$T_{1/2}(10^{28}$ years)		$m_{\beta\beta}$(meV) 3σ Discovery		
	Excl. Sens.	3σ Discovery	Median	Range	
CUPID	0.14	0.10	15	12 to 20	← ^{100}Mo
LEGEND-1k	1.60	1.30	12	9 to 21	← ^{76}Ge
nEXO	1.35	0.74	11	7 to 32	← ^{136}Xe

DBD strategy on next generation experiments

Closed session statement

North American – Europe Strategical meeting

- Neutrino-less double beta decay search is recognised as very compelling science capable of reshaping current understanding of nature

→ Three experiment will be supported

- The international stakeholders in neutrino-less double beta decay research do agree in principle that the best chance for success is an international campaign with more than one large ton-scale experiment implemented in the next decade, with one ton scale experiment in Europe and the other in North America.

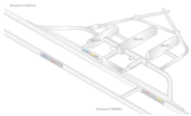
→ Two experiments in Europe CUPID + ***LEGEND1000***

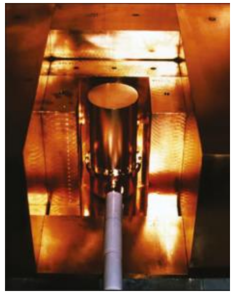
Two experiment @ LNGS

- The international stakeholders in neutrino-less double beta decay are interested in exploring whether a more formal structure for international coordination on this research would be beneficial, not only for experiments of the next decade but also for future multi-ton and/or multi-site experiments.

→ Define international coordination between international stakeholders

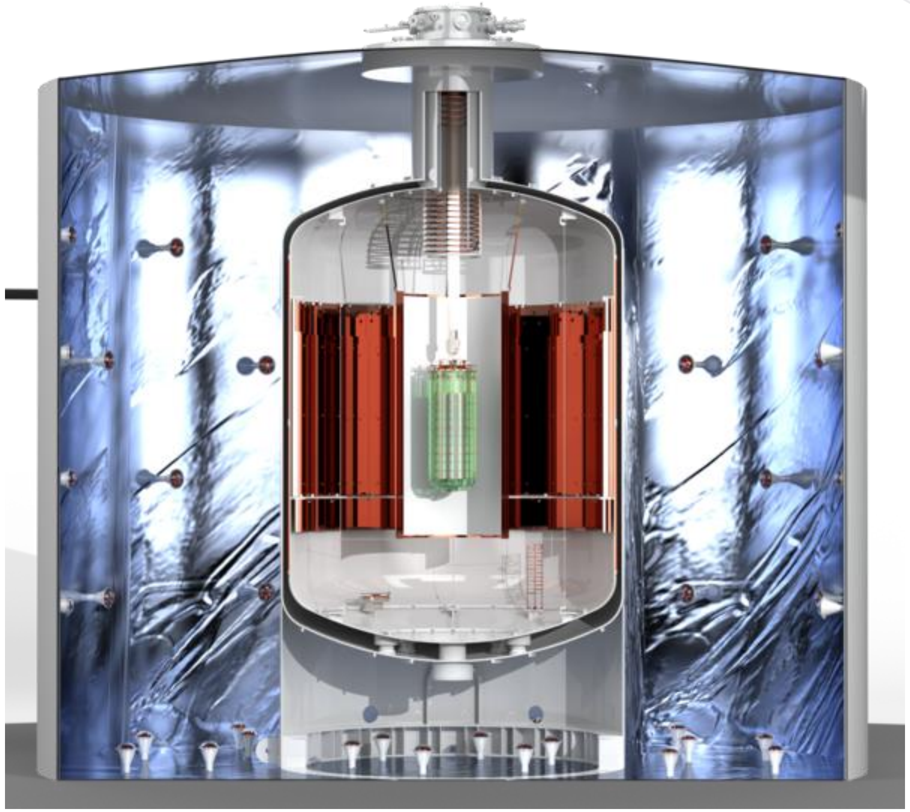
Germanium Detector





Heidelberg – Moscow ßß

GERDA



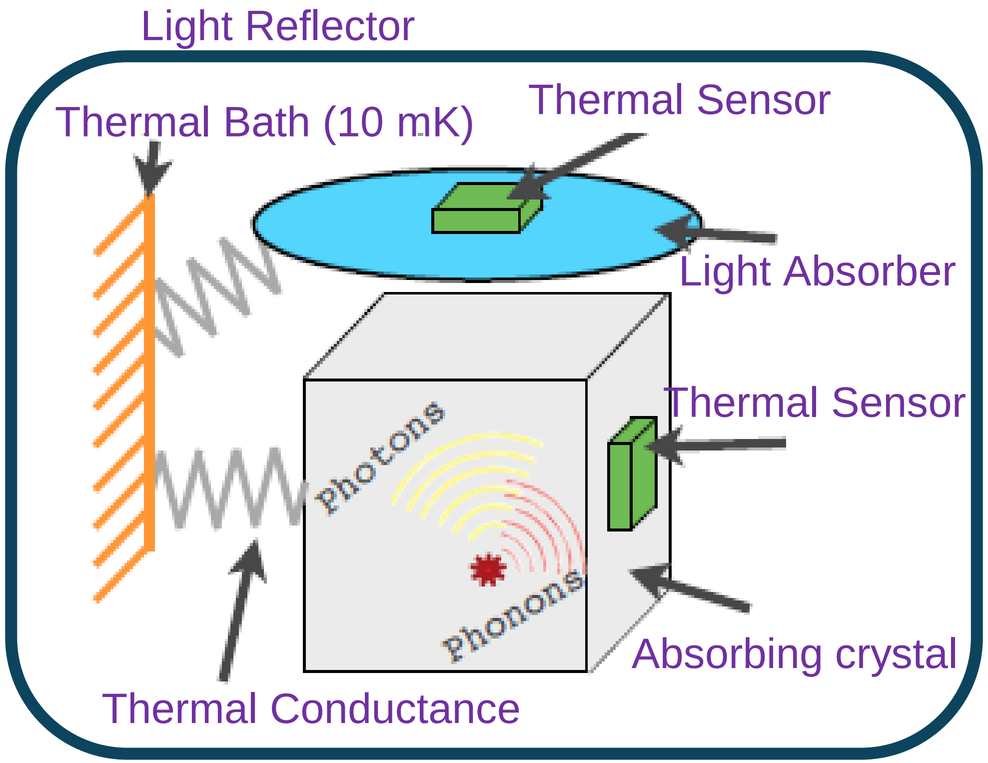
LEGEND-200

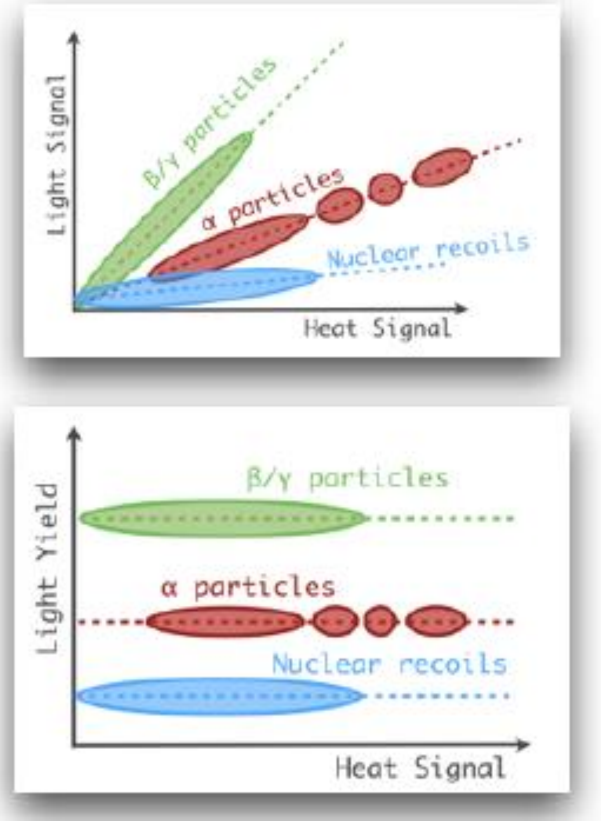
1990

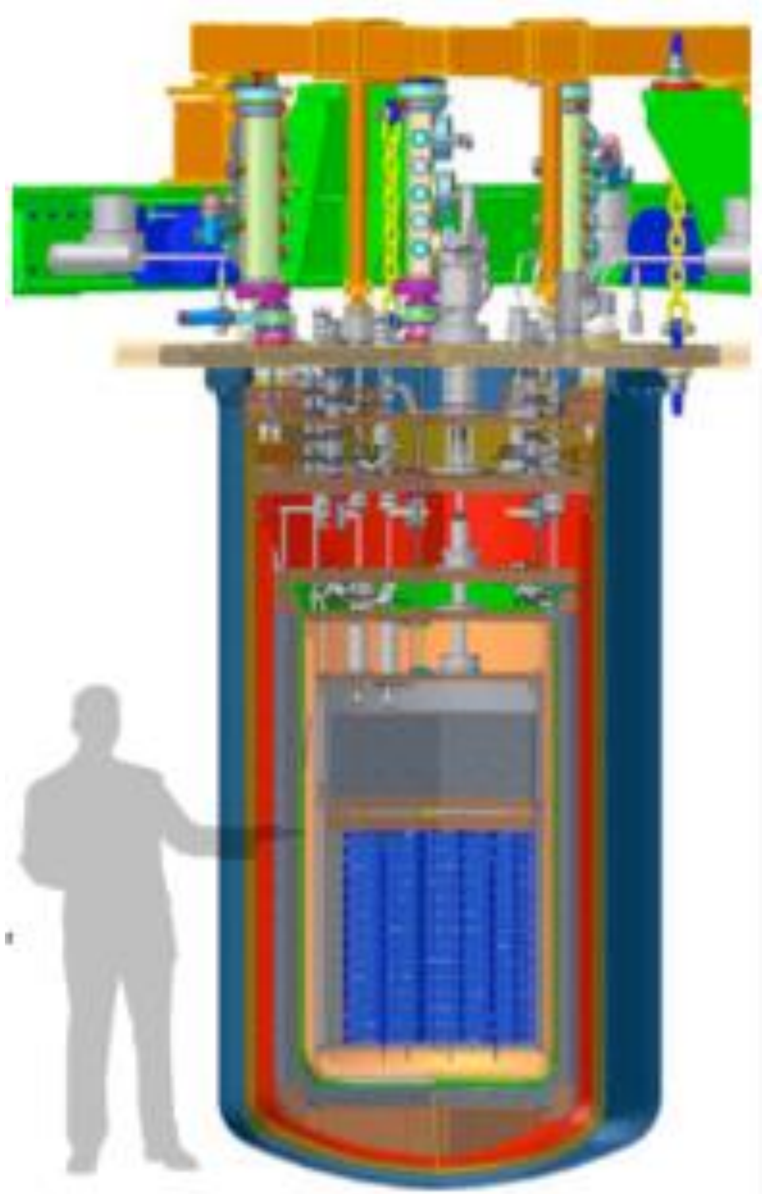
2011

2021

CUPID: CUORE Upgrade with Particles ID







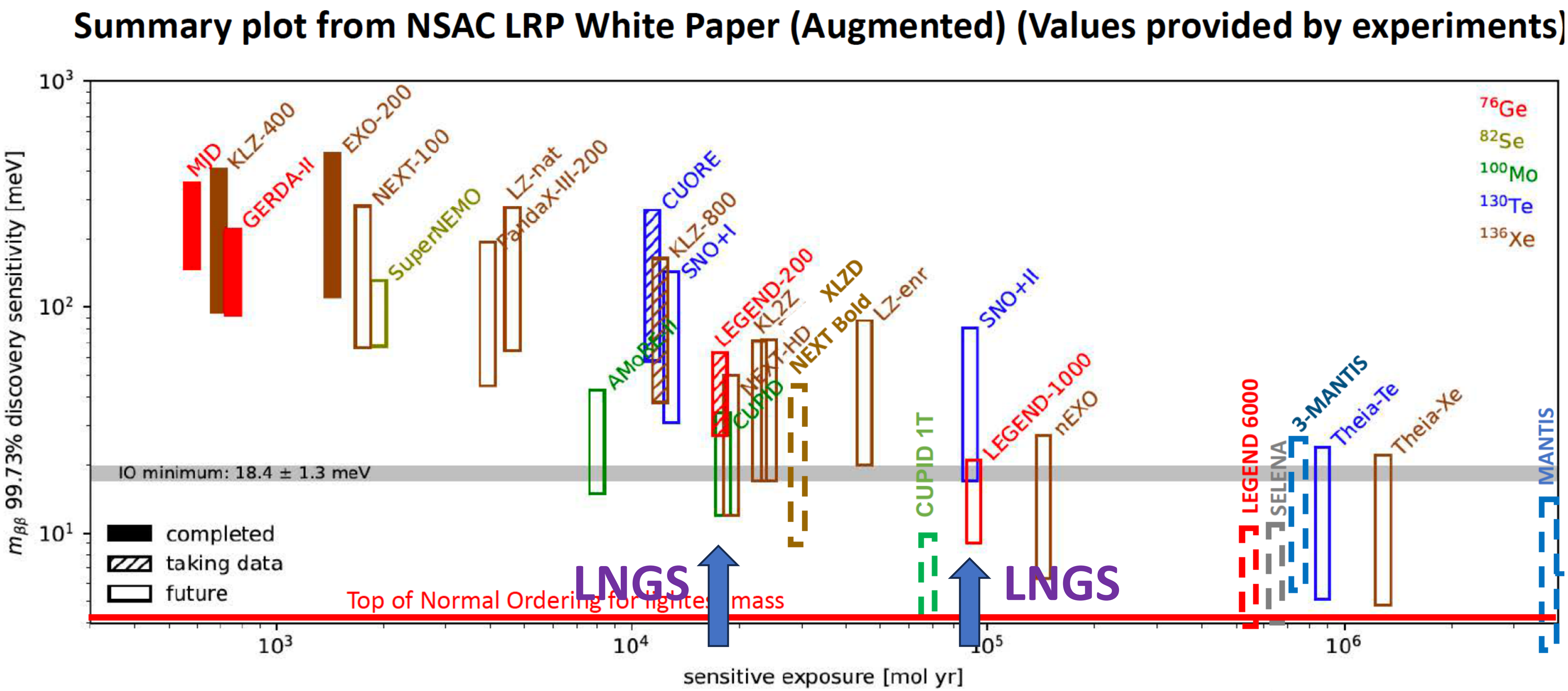
Simultaneous read-out of **Photons and Phonons**

⬇

High energy resolution: **as bolometer**

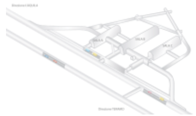
High discrimination capability: **as scintillator**

Next generation DBD



From: Fundamental Symmetries, Neutrons, and Neutrinos (FSNN): Whitepaper for the 2023 Nuclear Science Advisory Committee Long Range Plan: arXiv:2304.03451iv:2304.03451

Astro-Particles Physics strategy - Europe



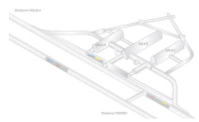
Direct Detection of Dark Matter, APPEC Committee Report - April 15, 2021

J.Billard, M.Boulay, S.Cebrián, L.Covi, G.Fiorillo, A.Green, J.Kopp, B.Majorovits, K.Palladino, F.Petricca, L.Roszkowski (chair), M.Schumann

Recommendation 1. ***The search for dark matter with the aim of detecting a direct signal of DM particle interactions with a detector*** *should be given top priority in astroparticle physics, and in all particle physics, and beyond, as a positive measurement will provide the most unambiguous confirmation of the particle nature of dark matter in the Universe.*

The nature of invisible dark matter (DM) that constitutes some 26% of the mass-energy balance of the Universe remains one of the most fundamental puzzles in physics today. The most compelling solution to the DM enigma is provided by postulating some new elementary particle that must be outside of the spectrum of the Standard Model (SM) – which in fact provides one of the strongest arguments in support of “new physics” beyond the SM (BSM). The hypothetical relic particle is probably cold, i.e., non-relativistic, but otherwise in principle not much is known about its basic properties, with the allowed mass range spanning nearly fifty decades, while non-particle DM, for instance in the form of (primordial) black holes, can be even much heavier. Likewise, so far only gravitational effects of DM have been observed. Nevertheless, there are good reasons to expect that a particle DM relic exhibits also much less feeble interactions, up to the (electro)weak ones of the SM, as is the case of weakly interacting massive particles (WIMPs) in a large variety of BSM models, or intermediate ones, in the case of axions and, more generally, pseudoscalar axion-like particles (ALPs). A decades-long, intense, trans-national and increasingly global worldwide experimental WIMP search is conducted following three main strategies: direct detection (DD) of the scattering of a DM particle off a target in deep underground detectors, indirect detection (ID) of exotic products of DM pair annihilation (or possibly decay) in the Galactic halo and beyond, and their production in accelerators or fixed-target experiments. ………

Astro-Particles Physics strategy - Europe



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Recommendation 5. The long-term future of underground science in Europe would strongly benefit from creating a distributed but integrated structure of underground laboratories for the needs of the forthcoming generation of new experiments, and beyond. This strategic initiative would be most efficiently implemented by forming the European Laboratory of Underground Science.

The bedrock of European experimental leadership has been the role played by large world-class laboratories and support facilities, as over the years has been prominently demonstrated by the example of CERN in leading the world's collider physics program. In underground science, in contrast, the effort is somewhat divided and scattered among several deep underground laboratories, **primarily LNGS in Italy that over the years has become a European hub for many leading neutrino physics and DM search experiments.** ….. Recent attempts to form **a network of Deep Underground Laboratories in Europe need to be re-invigorated and opened to cooperation with facilities on other continents**. There is emerging need to combine the current national underground laboratories into a single legal entity, a European Laboratory of Underground Science that, while geographically distributed across different countries, could have the status of an international organisation. The most efficient way to implement this strategic initiative would be to use the platform of a European Research Infrastructure Consortium (ERIC). …… We recommend that a working group is formed to investigate this possibility further. The creation of the European Laboratory of Underground Science would help foster in Europe closer and much more efficient cooperation between **the European astroparticle physics community, national laboratories across Europe and CERN in order to more effectively exploit the numerous cross-disciplinary synergies and address common technological challenges facing particle and astroparticle physics for the next decade and beyond. We recommend a closer collaboration between these communities to further the progress of both particle and astroparticle physics that cannot be treated as separate anymore and in fact are increasingly interdependent**

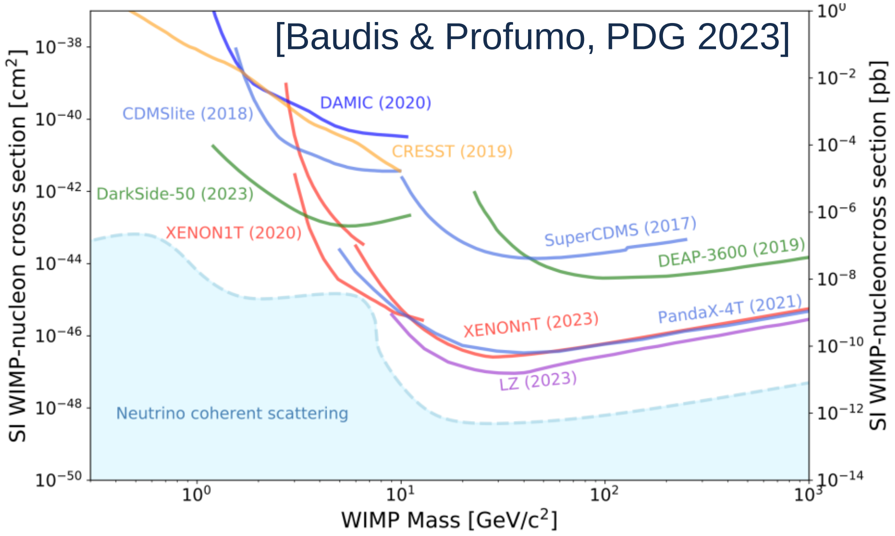
Direct Dark Matter searches @ LNGS

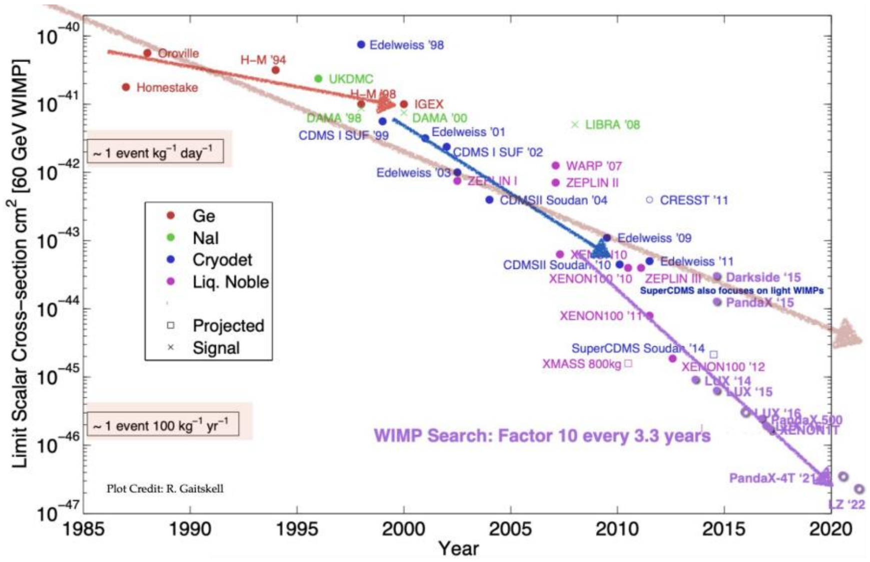
Ai LNGS si stanno conducendo diversi esperimenti con diverse tipologie di rivelatori

- **XENONnT**
- **DAMA**
- **CRESST**
- **COSINUS**
- **CYGNO**
- SABRE
- DarkSide20k
- BULLKID-DM
- ……..

Considerando gli aspetti strategici **per raggiungere sensibilità al cosidetto limite del neutrino floor** diversi di questi esperimenti potranno avere ulteriori sviluppi in futuro andando a definire la strategia dei LNGS.

Ad esempio XENONnT → DARWIN/XLZD





Strategia DBD e DM @LNGS

CUPID

LEGEND1000

LEGEND200

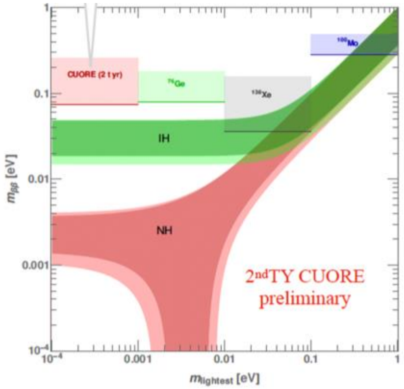
CUORE

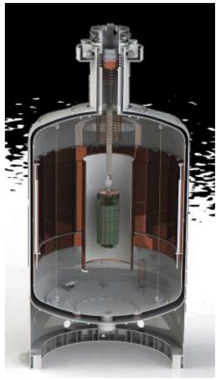
2025 2027 2029 2031 2033 2035 2037 2039 2041 2043 2045 2047

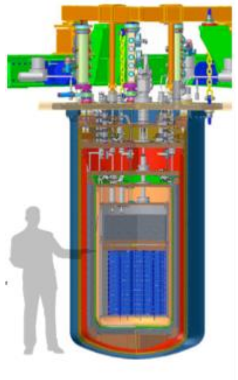
XENONnT

DS20k

Darwin/XLZD???



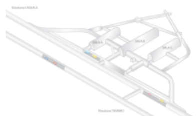




Considerando **3/4 grandi esperimenti sulla ricerca del DBD e della DM** a cui sommare le attività di R&D su altri esperimenti i LNGS possono considerarsi praticamente full committed fino a quasi il 2040.

Questa strategia è complementare e sinergica con lo sviluppo degli esperimenti agli acceleratori

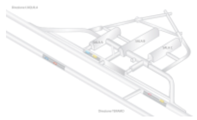
Attività di ricercar a LNGS



Sulle attività di ricerca LNGS è in definizione un programma che prevede:

- DDB e Dark Matter come linee principali di sviluppo
    - Le collaborazioni internazionali sono sostanzialmente identificate
    - Ci sono incertezze sui costi e sulle tempistiche
    - Il programma si spalmerà indicativamente su circa 15 anni
- Il programma di astrofisica nucleare continuerà nei prossimi anni
    - Verrà riconfigurato lo schema dei due acceleratori in galleria
    - Molte richieste stanno arrivando dalla comunità internazionale
    - Programma pressoché definito per i prossimi 4/5 anni
- Alcune nuove linee di ricerca sono in evoluzione
    - La linea quantum potrebbe pesare di più in futuro
    - Supporto a esperimenti su onde gravitazionali e relatività generale
    - Ulteriori richieste per sviluppo di nuovi esperimenti possono comportare ulteriori impegni

Strategie condivise su tecnologie



NOA – Nuova Officina Assergi:

- Sviluppo comune sulla componentistica per fotorivelatori al silicio
- Produzione su larga scala di strumentazione per esperimenti

Sviluppo di rivelatori criogenici (Bolometri, Lar, Lxe):

- Dimensionamento e realizzazione di infrastrutture criogeniche
- Strumentazione e apparecchiature per misure criogeniche

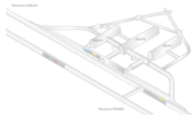
Additive manufacturing:

- Sviluppo di nuovi materiali per meccanica additiva, caratterizzazione e analisi
- Progettazione e realizzazione di componenti meccanici in stampa 3D

Altre possibilità di supporto:

- Chimica analitica avanzata e misure di elementi in ultra tracce
- *Possibile utilizzo di fasci di protoni ad alta intensità per test su componentistica*

Conclusioni



- Si è individuato un programma per la fisica underground condivisa a livello globale
- Le ricerche su fisica del neutrino e sulla dark matter hanno forti motivazioni scientifiche
- L’istaurarsi di una comunità all’interno dei DULs è in fase di consolidamento
- E’ importante consolidare e rafforzare le sinergie tra le varie *anime* del mondo particellare
- La complementarietà tra la strategia agli acceleratori e ai DULs è evidente e cruciale
- Diverse linee di sviluppo tecnologico sono comuni e le sinergie vanno rafforzate
- La EPPS dovrebbe declinare le varie linee di ricerca in maniera organica

Laboratori Nazionali del Gran Sasso