LNGS strategy for Double Beta Decay

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Gran Sasso Laboratory

External Buildings

Underground Site

Gran Sasso DUL

Shielded by 1400 m (3800 m.w.e.) of rock (Gran Sasso Mountains)

Total Muon flux 3 10^{-8} cm^{-2} s^{-1}

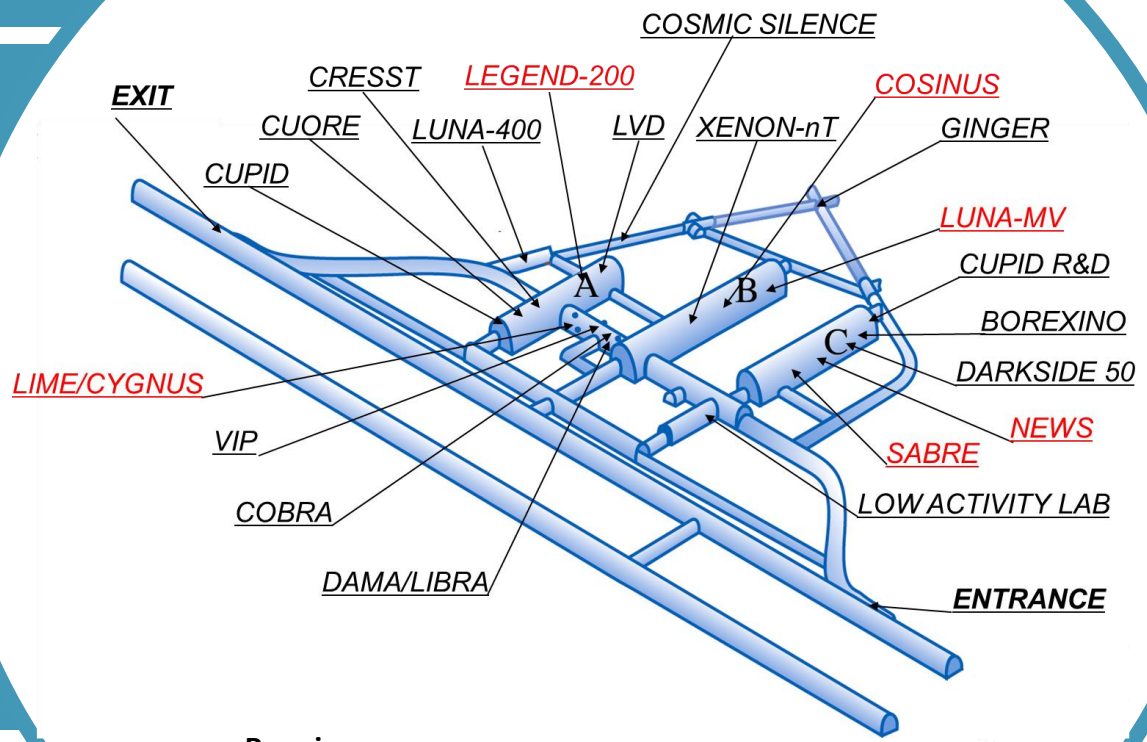
Easy access directly from the A24 highway

3 main experimental halls
100 m long, 20 m width and 18 m hight

Many small tunnels for lab facilities and small experiments

Actually there are 14 (20) experiments in data taking or under construction

Very sensitive laboratory for very low radioactivity measurements



- Running
- Construction/Commissioning

Area: 17.800 m^2

Volume: 180.000 m^3

Gran Sasso Community

110 staff personnel

- Researchers - 14
- Engineers - 35
- Technicians - 38

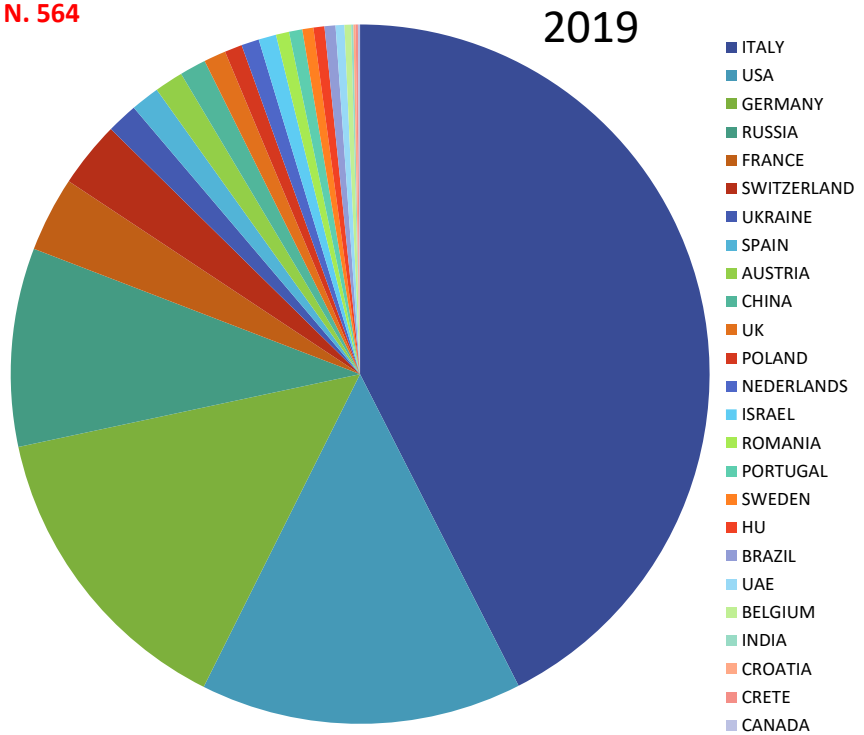
Direct connection with LNGS for associated members:

Gran Sasso Science Institutes (doctorate school)

University of L'Aquila

LNGS involved people 215 (110 staff + 95 associated)

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



Double Beta Decay APPEC Committee Report

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 DBD0 physics program, extensive underground space to host the DBD0-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 DBD0 European experiments****.* ***At the same time all other underground laboratories must be strongly involved in the present DBD0 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.*

Coordination activities between the European underground labs are under discussion to support the new generation double beta decay experiments

Workshop on future of Double Beta Decay Experiments

Meeting between North American and European funding agencies

- Selection of **future DBD experiments**
  - Experimental **sensitivities**
  - **Budget requested** for each experiment
  - International **collaborations**
- Selection of possible undegroud laboratories
  - SNOLab/SURF – North America
  - **LNGS - Europe**

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

← Prosecutor of CUORE

Closed session statement

- 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 + ……..

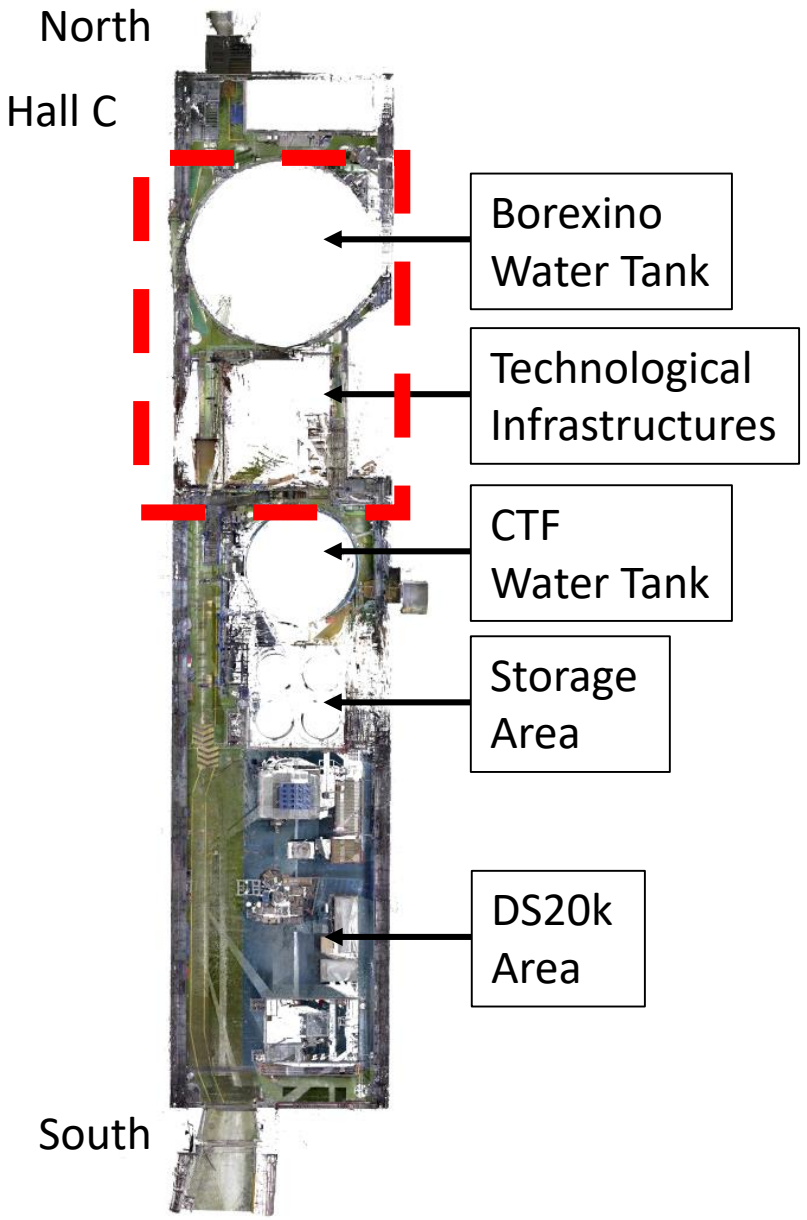
↓

Two experiment in 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

Hall C @ LNGS



Borexino decommissioning is ongoing
An underground area will be available for new experiment

It will be possible also to recover the Borexino infrastructures

- Water tank is equipped with photomultipliers
- Ultra pure water production is operative
- Water pipes and recirculation systems are installed
- Clean rooms could be refurbished and partially available
- Electronics, DAQ and other instrumentation could be useful
- ……

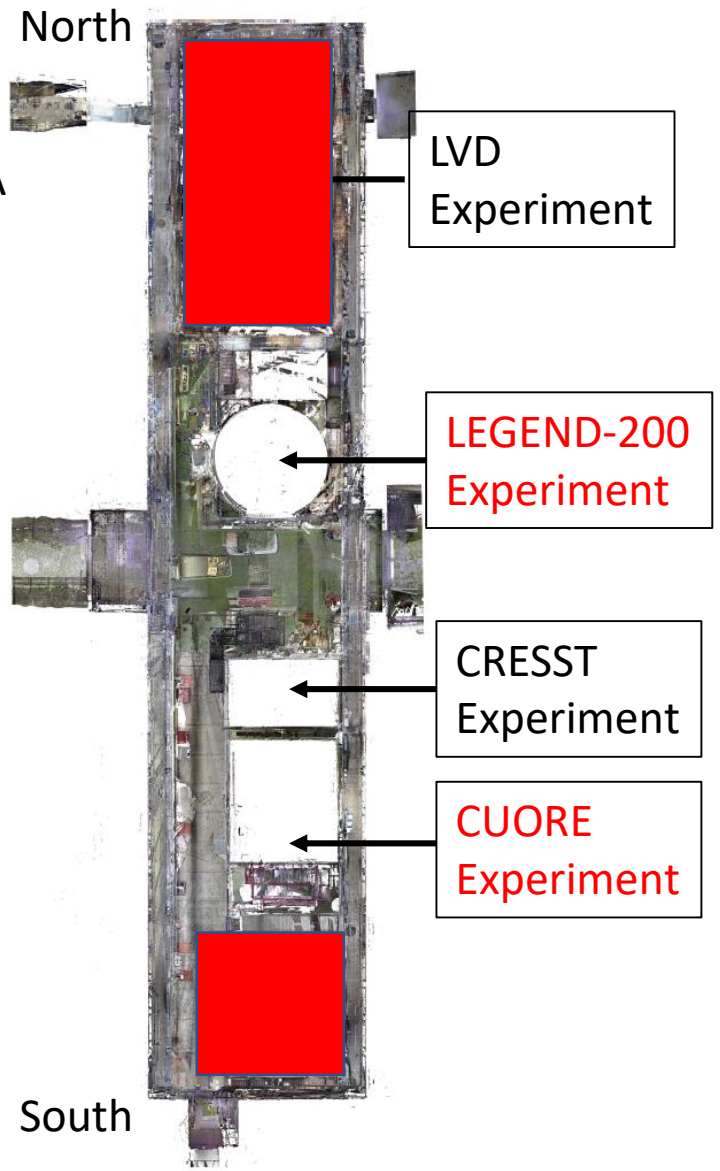
The Borexino infrastructure will be refurbished for LEGEND-1000

- ✓ Dedicated project for the refurbishment of the infrastructures
- ✓ Time profile for the complete reconfiguration around 30 months
- ✓ New cryogenic infrastructure to support experiments

LNGS is acquiring dedicated funds for:

- New electrical distribution in the underground labs
- Specific improvement on underground ventilation
- New safety infrastructures in the underground halls

Hall A @ LNGS



LVD decommissioning phase will start during 2022
All the area will be completely free for new experiments during 2023

LEGEND-200 will start the data taking soon
It will be an important test also for the future DBD experiments

CUORE experiment is in stable data taking
The cryogenic infrastructure is will be available for CUPID experiment

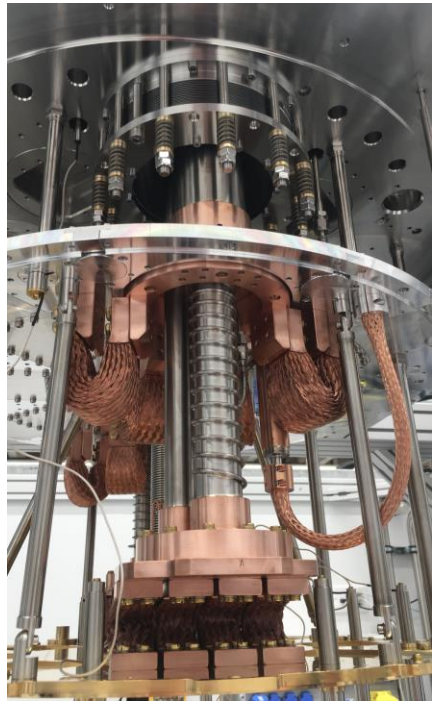
For CUPID some dedicated improvements are ongoing:

- New cryogenic infrastructure for low temperature
  - New LN liquefier and distribution pipes
  - New LHe liquefier
- A new cryogenic platform facility for tests (next slide)

New CryPlatform Facility for Cryogenic Detectors

New cryogenic setup to perform measurements of detectors and devices @ very low temperatures

- dry ^{3}He/^{4}He dilution refrigerator
- Large experimental space: Ø 50 cm, h 75 cm
- Base temperature < 10 mK
- Low radioactivity & low vibration environment
- *Funded by INFN, BMBF and SQMS*



Useful for low-background tests of

- Cryogenic detectors equipped with TES, NTD, …
- Qubits

The Cryo-Platform facility will be available in 2023

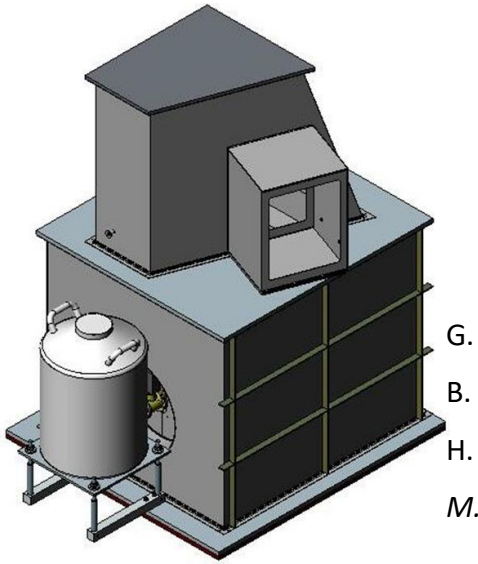
Access procedures approved by a PAC

A new LN liquefier with a total power of around 50 kW@77 K will be installed underground
Dedicated cryogenic distribution lines will be designed for each experiment

New STELLA Facility for Material Screening

STELLA (SubTErranean Low Level Assay)

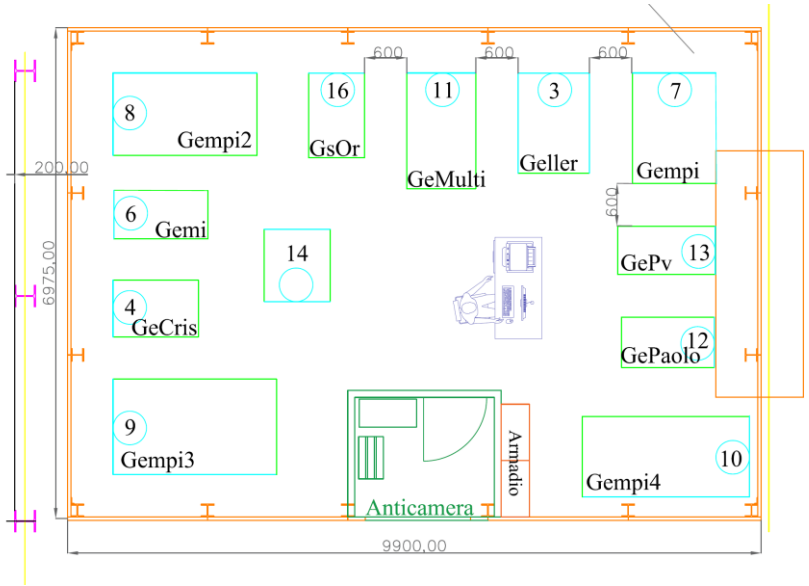
GeMPI type configuration
Custom made, Ultra Sensitive



G. Heusser
B. Prokosch
H. Neder
M. Laubenstein

New facility for radio assay

- 16 HPGe detectors
  - Sensitivity few tens of µBq/kg
  - Possibility for large mass sample
- High sensitive alpha spectrometry
- Liquid scintillator counters

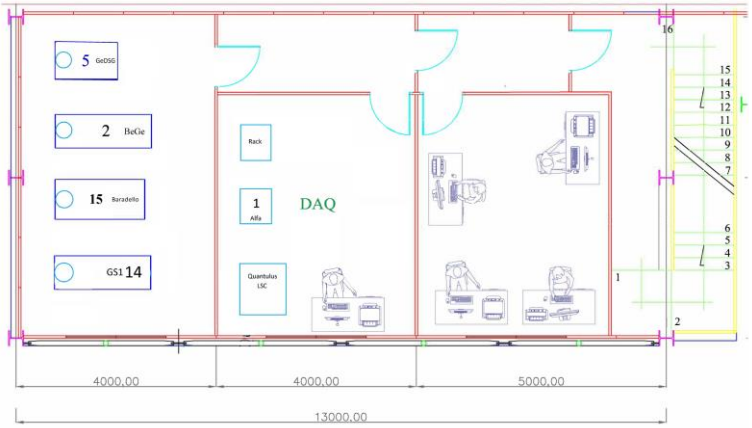


Stella design completed
Construction will start soon

New HPGe detectors will be designed:

- Improving sensitivities
- Increase sample rates

(Agreement between LNGS-INFN and BMBF)



Other European underground labs could be involved in material screening

ICP-MS Facility for Material Selection

High sensitive ICP-MS laboratories.

Chemical labs for Ultra-Trace Analysis will be equipped with:

- New ICP MS quadrupole instrument
- Magnetic Sector ICP MS instrument
- TIMS for isotopic measurements
- New Laser Ablation ICP MS (LNGS-INFN and BMBF agreement)
- Pre-concentration chemical lines with dedicated resins

Infrastructure is organized with:

- Clean Room of ISO6 Class
- Instrumentation for chemical treatments

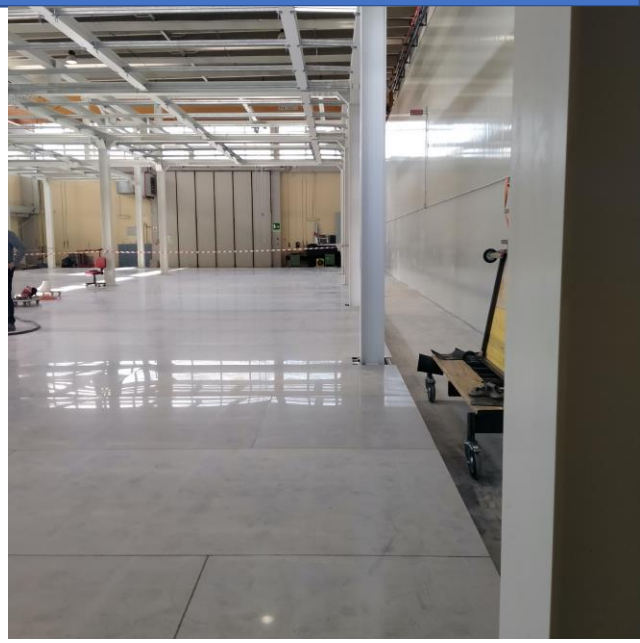
Achieved sensitivities on U and Th <1 µBq/kg (on primodials)

Chemical treatments and purifications could be possible

Nuova Officina Assergi (NOA) Clean Room

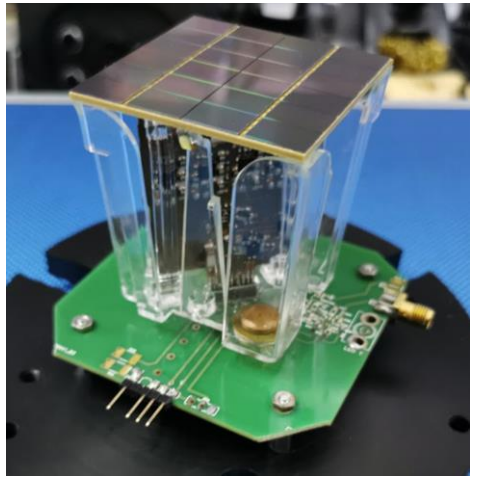
NOA will be an advanced clean room Radon free facility

- 450 m^2 Clean Room suitable for Radon Free operation
- Detector instrumentation for
  - Bonding
  - Dicing
  - Thermo-compression/epoxy bonding
  - Wire bonding
- PCB preparation
  - Advanced and radio-clean reflow system
- Testing capabilities
  - Performances characterization at cryogenic temperature
- Production
  - 1st production for DS20k: ~ 20 m^2 SiPM



The facility will be available for semiconductor

- Production
- Testing
- Packging



Ready to start April 2022

Other dedicated facilities for new experiments

Advanced Workshops

- Engineering design of custom components
- CAD/CAM advanced software support
- Advanced Additive Manufacturing (Copper 3D printing)
  - e-formed copper produced at LSC
  - copper atomized and 3D printing at LNGS
  - screening to assay radio-purity level both LNGS and LSC
- New cutting machines for faster productions
- New workshop will be installed underground (LNGS-INFN and BMBF agreement)

Laboratories for electronics

- Direct support for electronics design
- CAD/CAE advanced software support
- Instrumentation for PCB testing

New HPC Data Center installed in the esternal labs (HPC, storage, ….)

LNGS technical division could also support engineering for experiments

LNGS will support the requested authorization for new experiments

Conclusions

- LNGS is working to support the next generation DBD experiments
- LNGS could host new DBD experiments, also of big sizes, after the decommissioning of LVD and Borexino
- Specific project for the refurbishing of the Borexino infrastructures was successfully prepared
- The cryogenic infrastructure of the CUORE experiment could be easily reconfigured for CUPID
- Material screening facilities are under construction for high sensitivities and high throughputs
- Dedicated facilities (clean rooms, workshops, electronic and chemical labs) are now in construction
- Established and future collaborations between all the underground labs could help in develop optimized strategies
- LNGS will specific resources for a successfully construction of next generation DBD experiments

Thank you