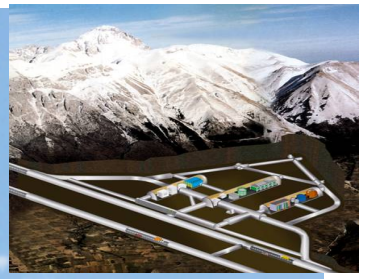
INFN
Istituto Nazionale
di Fisica Nucleare
Laboratori Nazionali del Gran Sasso



Neutrino Physics Searches: Future Perspectives for LNGS

Lucia Votano - LNGS

Gran Sasso Laboratory

3 main halls A B C ~100 x 20 m² (h 20 m)

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

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 (**3800 m w.e.**)

Surface: 17800 m²

Volume: **180000** m³

Rn in air: 20-80 Bq/m³

ISO 14001

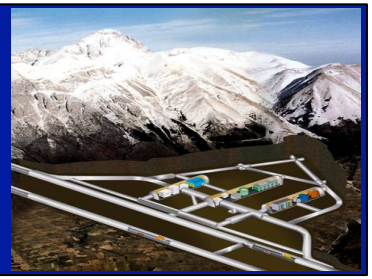
Ventilation: 1 Lab volume/3 h

Electrical power: 1300 kW

Access: horizontal

INFN
Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali del Gran Sasso

Gran Sasso Laboratory

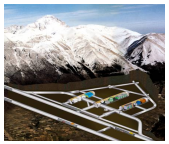


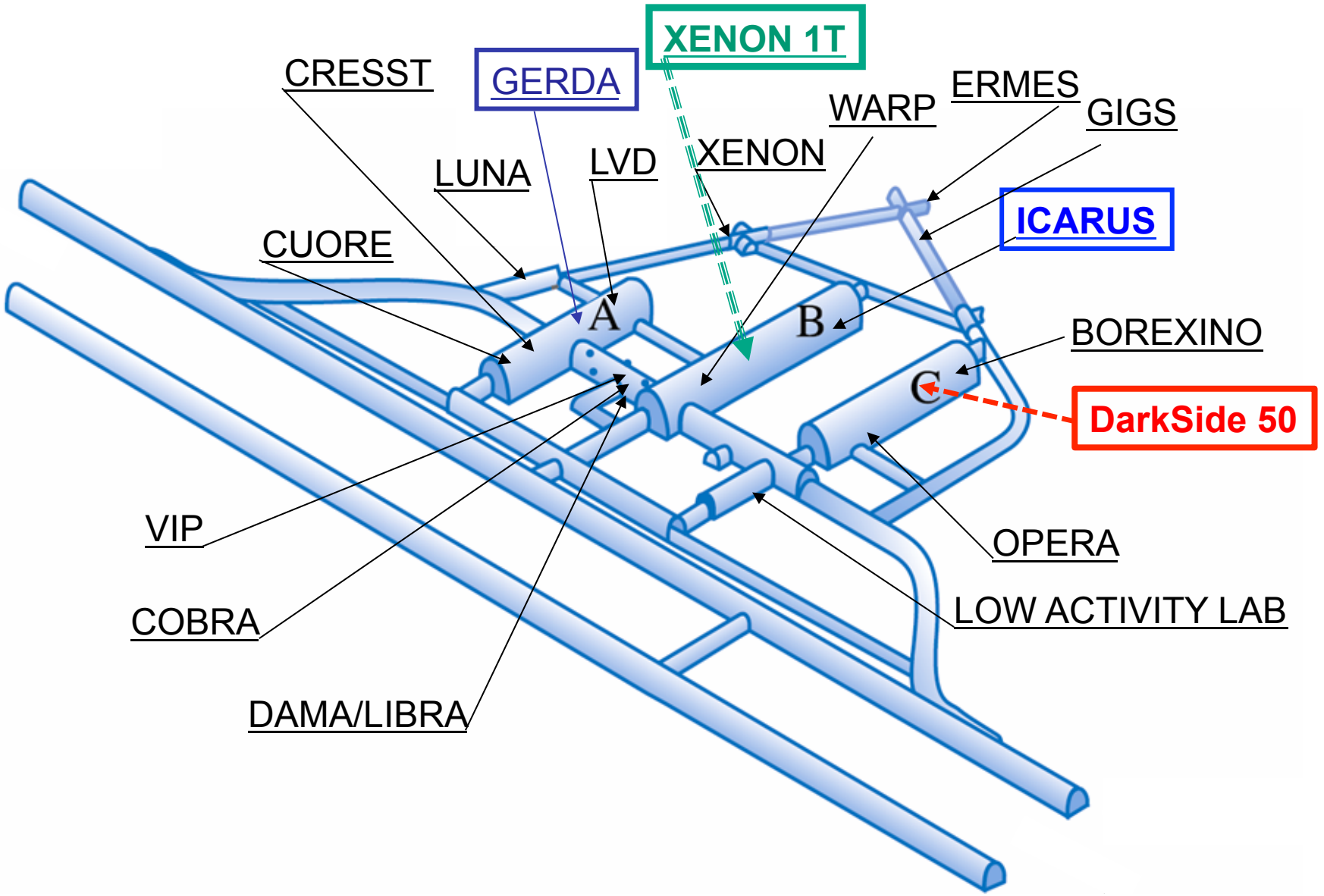
Research activities:

- Dark matter searches
- Neutrino physics
- Nuclear Astrophysics
- Associate Sciences:

  Environmental Radioactivity for Earth Sciences, Geophysics, Fundamental Physics, Biology

OCCUPANCY




XENON 1T
CRESST
GERDA
WARP
ERMES
GIGS
LUNA
LVD
XENON
ICARUS
CUORE
A
B
BOREXINO
C
DarkSide 50
VIP
OPERA
COBRA
LOW ACTIVITY LAB
DAMA/LIBRA

Neutrino physics @ LNGS

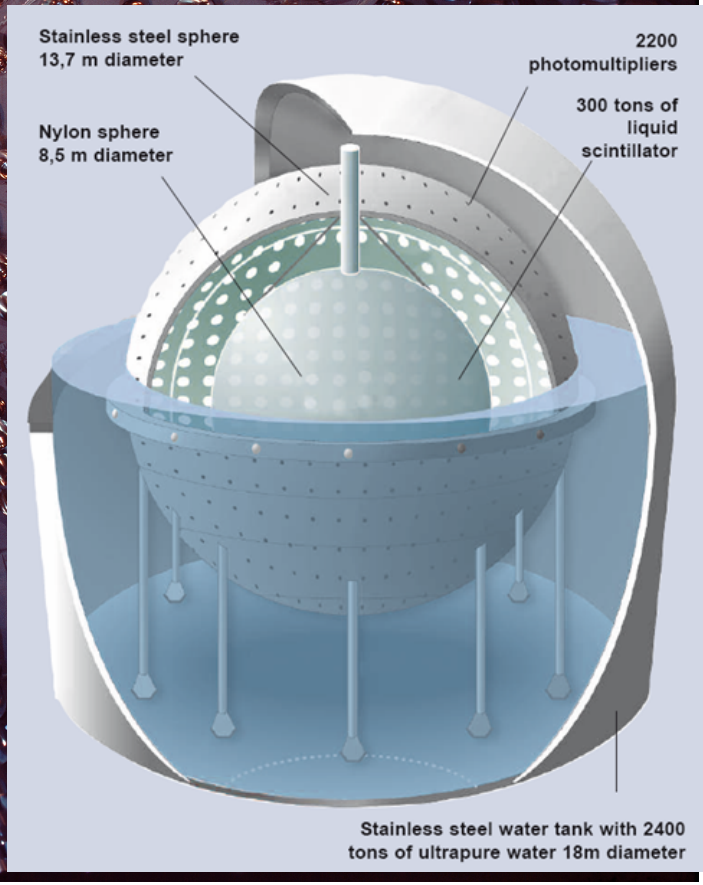
- **Solar neutrinos** (Borexino)
  - ^{7}Be the main target
  - ^{8}B, pep first evidence, CNO limit, and possibly pp
- **Geo anti-neutrinos** (Borexino)
- **CNGS neutrinos**
  - OPERA and ICARUS
- **SuperNova neutrinos**
  - LVD, Borexino and ICARUS
  - LVD and Borexino are in the SNEWS network
- **Basic neutrino properties**
  - **0νDBD**


BOREXINO:
a real time liquide scintillator detector for solar neutrinos

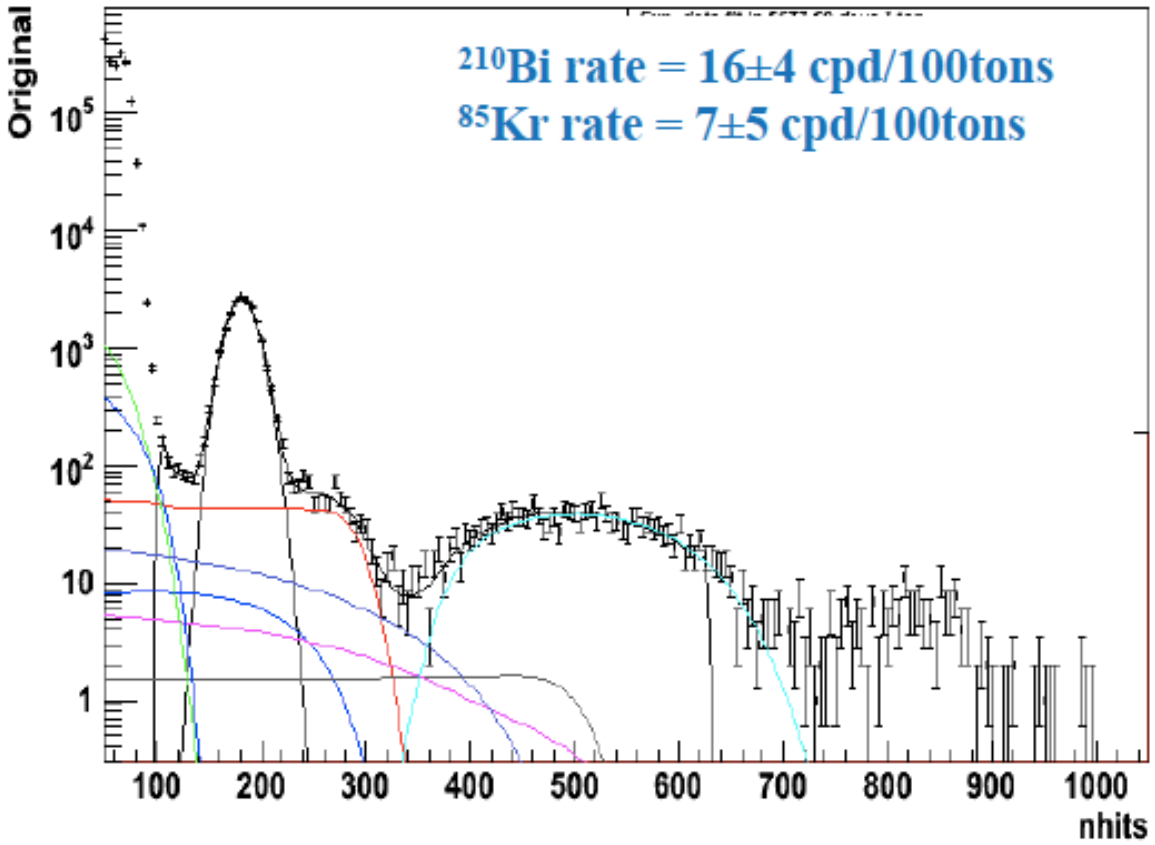
BOREXINO:

a real time liquid scintillator detector for solar neutrinos

- 278 tons of PC+PPO in a nylon bag
- 2200 photomultipliers
- 2500 tons ultrapure water



BOREXINO
Low-level background record



From delayed coincidence analysis (95% C.L.)

- ^{238}U < 9.7 x 10^{-19} g/g;
- ^{232}Th<4.3x10^{-18} g/g;
- The BX scintillator has never been so clean!

- The possibility to perform further purification steps is being evaluated;
- Collect few more months of data (good data!) to precisely evaluate ^{210}Bi level

CNGS beam:
CERN Neutrino to Gran Sasso

Energy:
optimized for ν_τ appearance mode
Goal:
prove definitely the neutrino oscillations

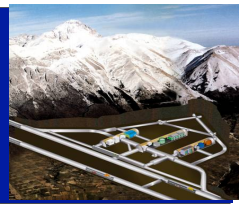
Project INFN-CERN: approved in 1999, started in 2006

ν_μ beam produced at CERN and detected at LNGS

Experimental halls designed in the CERN direction

OPERA running since 2006
ICARUS running since 2010

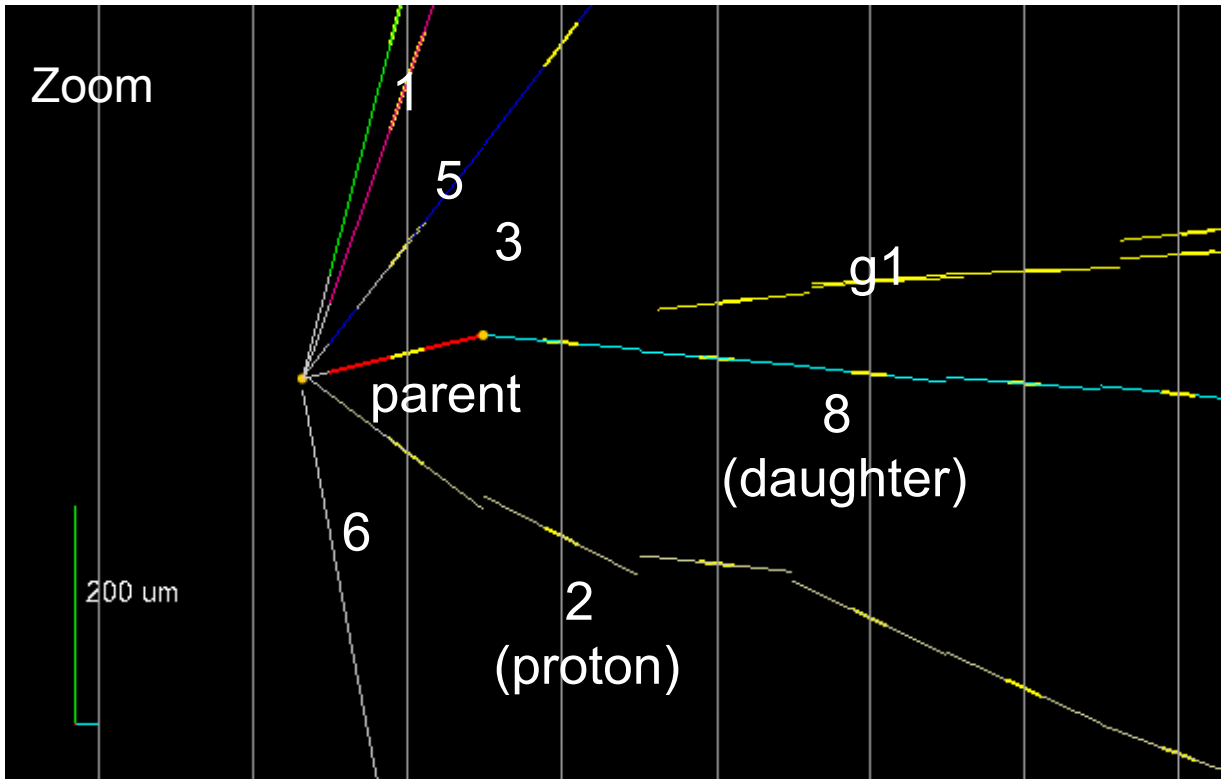
Neutrino Oscillations: OPERA



- In 2010 at LNGS

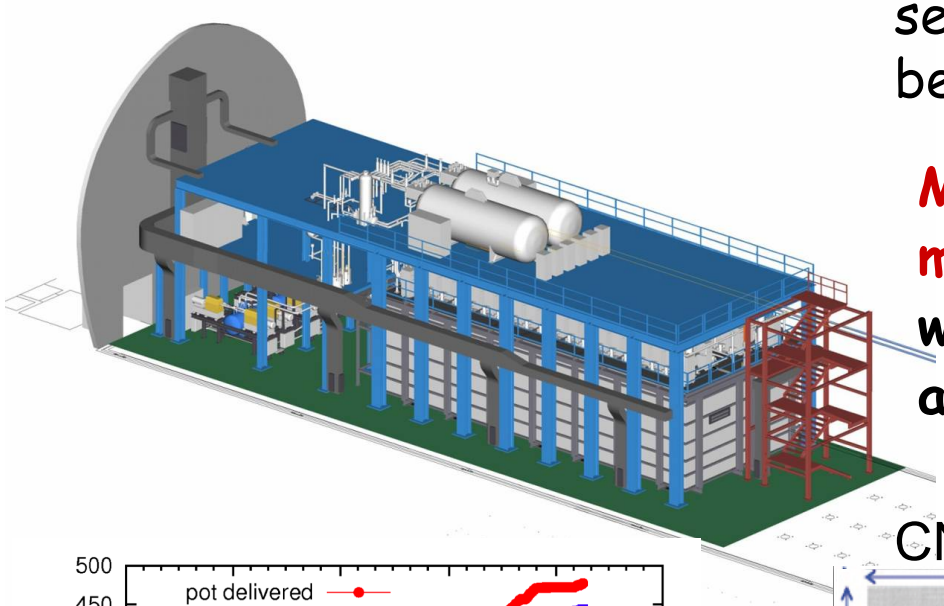
  the first evidence of direct detection of $\nu_\mu \rightarrow \nu_\tau$ oscillation in appearance mode

- Waiting for more events



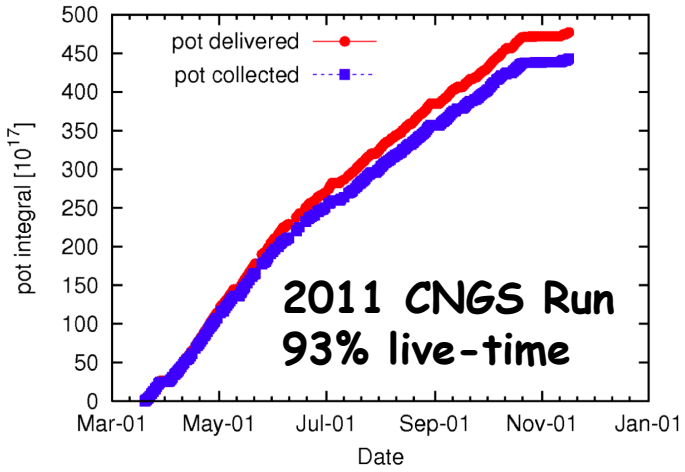
ICARUS T600 in LNGS Hall B

Two identical modules
3.6 x 3.9 x 19.6 ≈ 275 m³ each
Liquid Ar active mass: ≈ 476 t

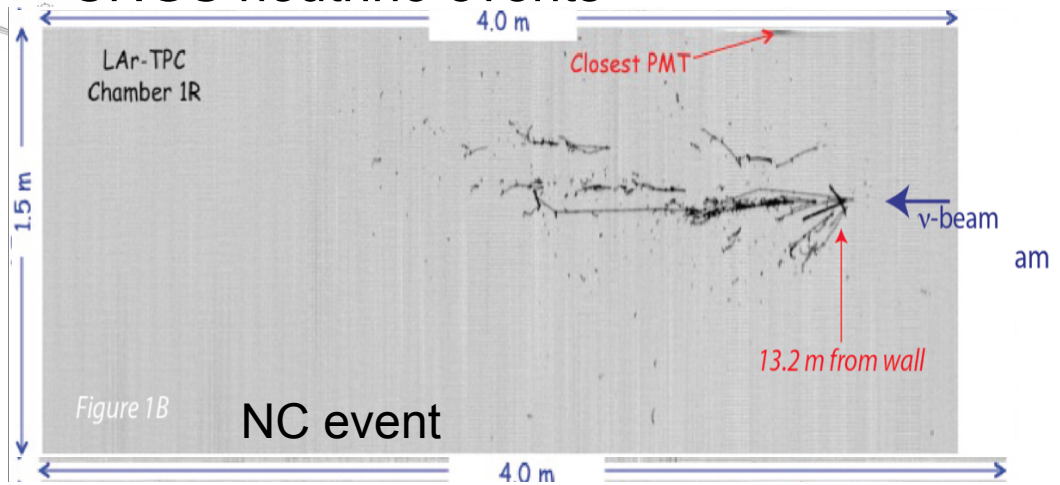


Conceived as a Multi-purpose detector: atmospheric, solar (>8 Mev), supernovae neutrinos, nucleon decay searches in "exotic" channels, CNGS beam

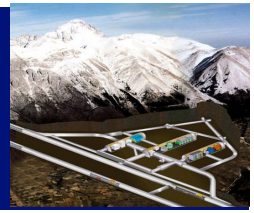
Milestone towards a multi-kton LAr detector with unique imaging capability, and spatial/calorimetric resolutions



CNGS neutrino events



$0\nu\beta\beta$ experiments



Oscillation experiments
have clearly demonstrated that:

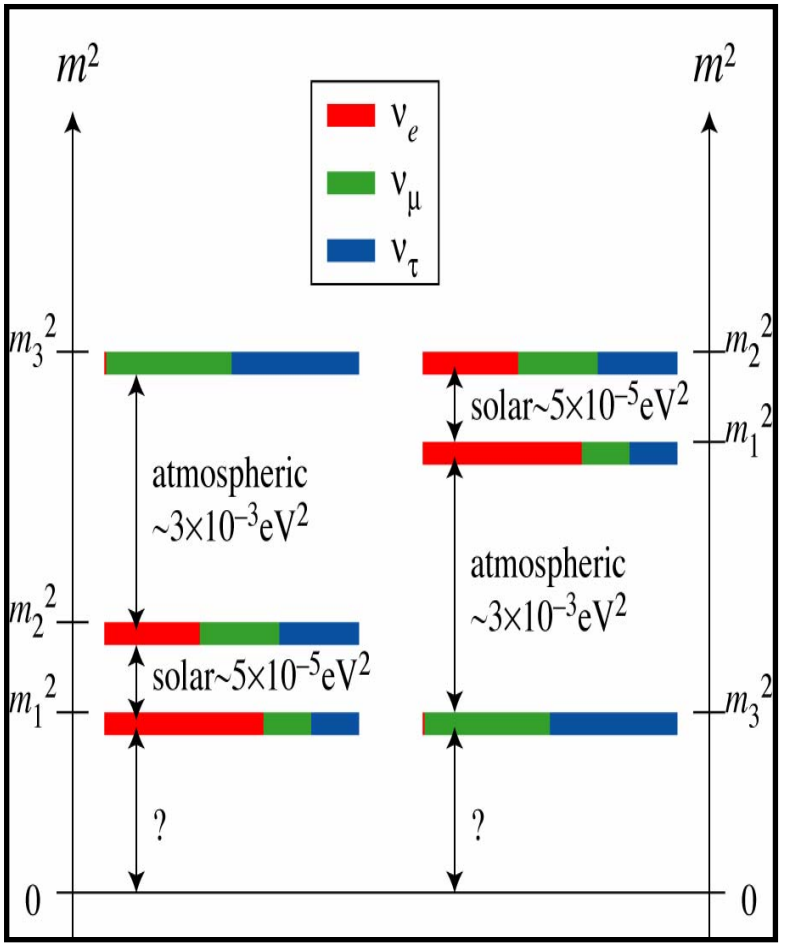
✓neutrinos (ν_e, ν_μ, ν_τ) do oscillate

✓neutrinos (ν_1, ν_2, ν_3) are massive

New Physics beyond SM must exist

Oscillation experiment cannot answer to:

1. are neutrinos Dirac or Majorana particles?
2. what is the absolute mass scale



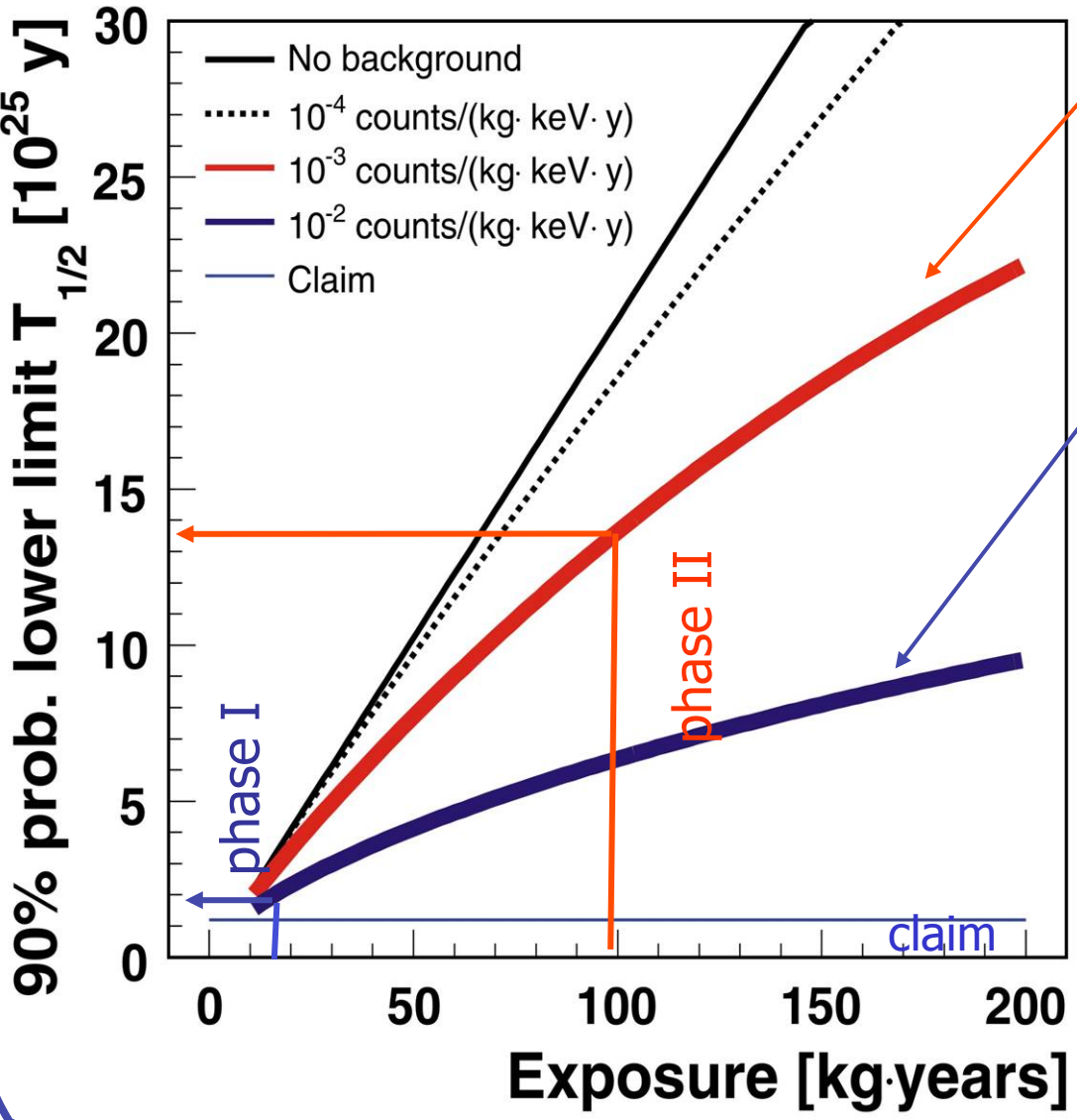
$0\nu\beta\beta$ experiments can answer to 1. and fix constraints on 2.

Neutrinoless Double Beta Decay

LNGS program: complementary approaches concerning isotopes and techniques

- **GERDA**: HPGe detectors enriched in ^{76}Ge
  - **running**
- **CUORE**: TeO_2 bolometers (^{130}Te)
  - **construction phase**.
- **Lucifer R&D** to further suppress background: scintillating bolometers
- **COBRA R&D**: CdZnTe room temperature detectors

GERDA goals and sensitivity



GERDA goal: 10^{-3} counts/(keV kg y)

improvement of a **factor 100** with respect of H-M

Phase I: **test claim**

crystals from HM and IGEX

exposure: 15 kg·y

bck: **10^{-2}** counts/(keV kg y)

Phase II: **measure** $T_{1/2}$ or **improve** limit

new better ^{enr}Ge detectors (bought 40 kg of raw material)

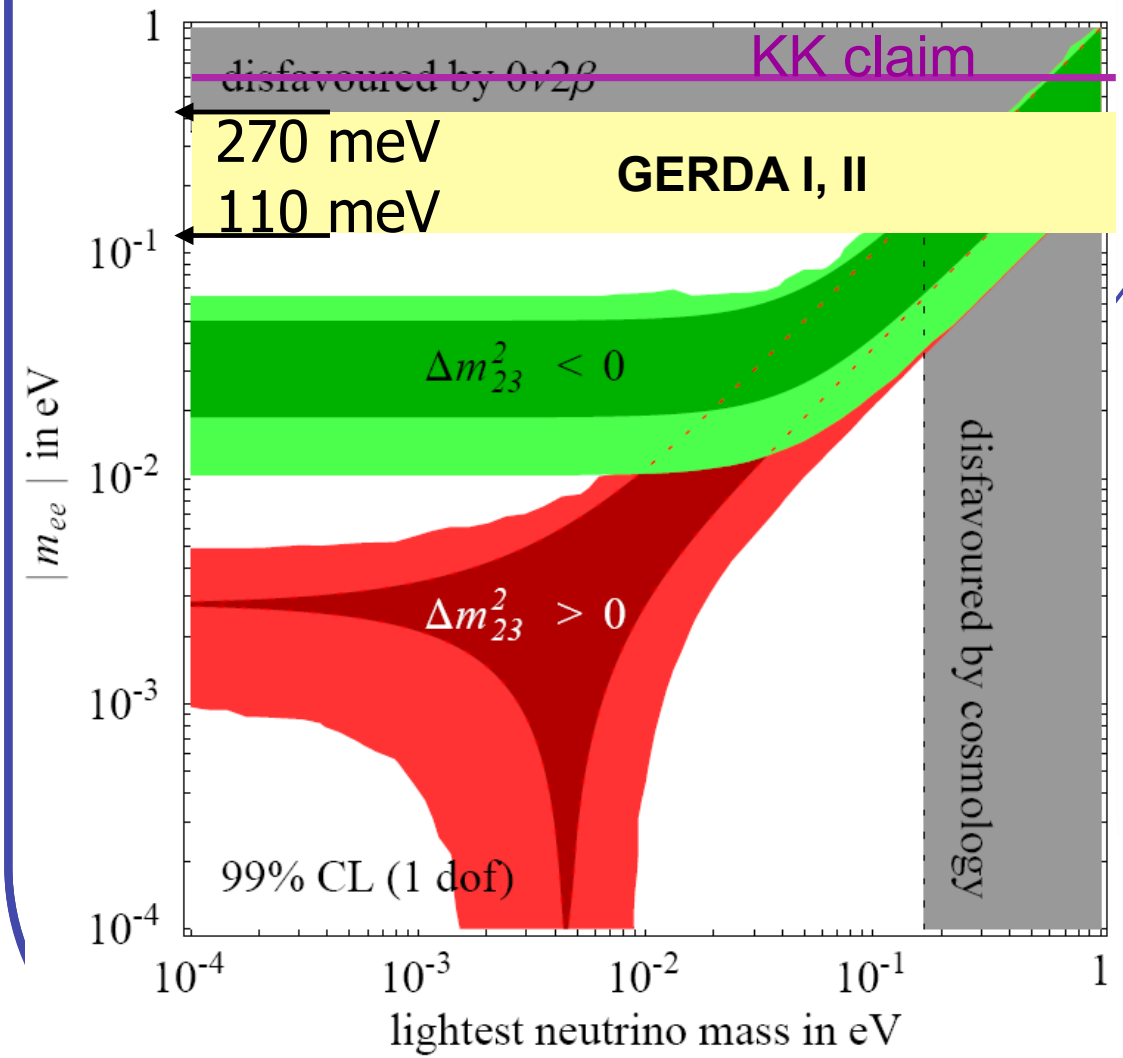
exposure: 100 kg·y

bck: 10^{-3} counts/(keV kg y)

GERDA goals and sensitivity

From Vissani, Strumia

hep-ph/0606054v2



GERDA goal: 10^{-3} counts/(keV kg y)

improvement of a **factor 100** with respect of H-M

Phase I: **test claim**

crystals from HM and IGEX

exposure: 15 kg·y

bck: **10^{-2}** counts/(keV kg y)

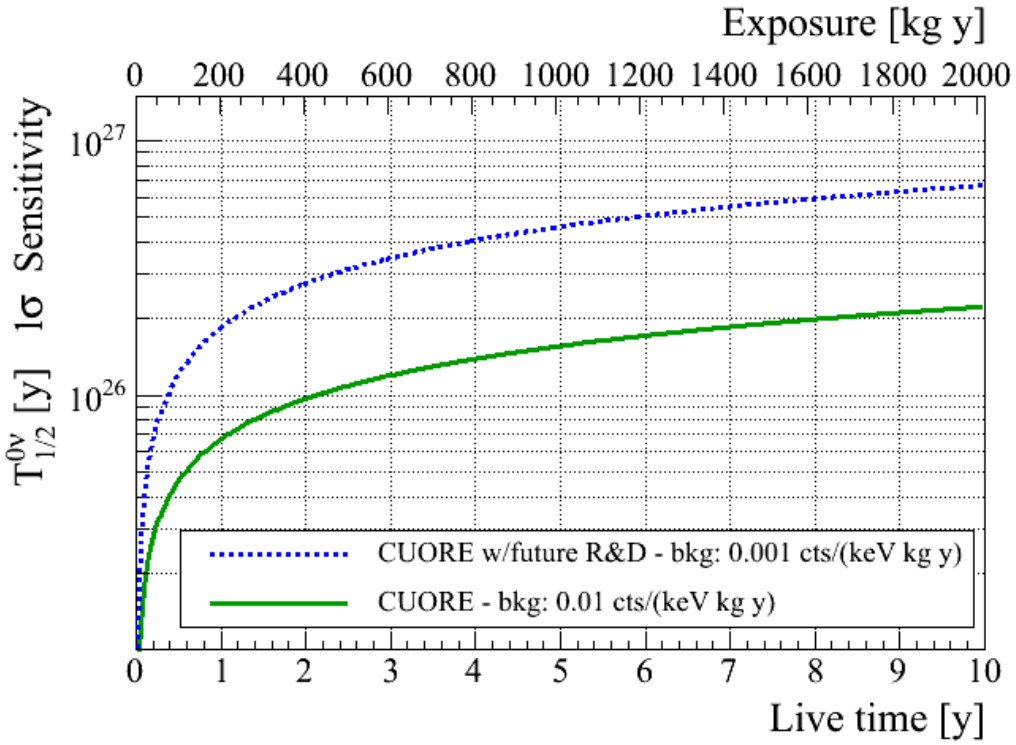
Phase II: **measure** $T_{1/2}$ or **improve** limit

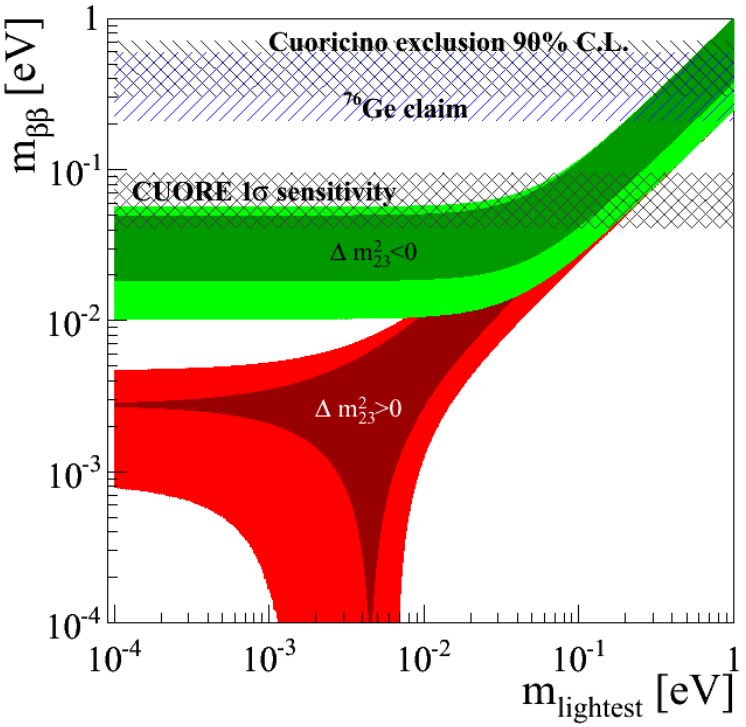
new better ^{enr}Ge detectors (bought 40 kg of raw material)

exposure: 100 kg·y

bck: 10^{-3} counts/(keV kg y)

CUORE goal





Background goal: 0.01 c/keV/kg/y $T_{1/2} = 1.6 \times 10^{26}$ y $m_{\beta\beta} = 41\text{-}95$ meV

Cuoricino result and CUORE 1σ background-fluctuation sensitivity overlaid on plots that show the bands preferred by neutrino oscillation data (inner region: best-fit data; outer region: at 3σ). Both normal (red) and inverted (green) hierarchies are shown.

Perspectives @ LNGS

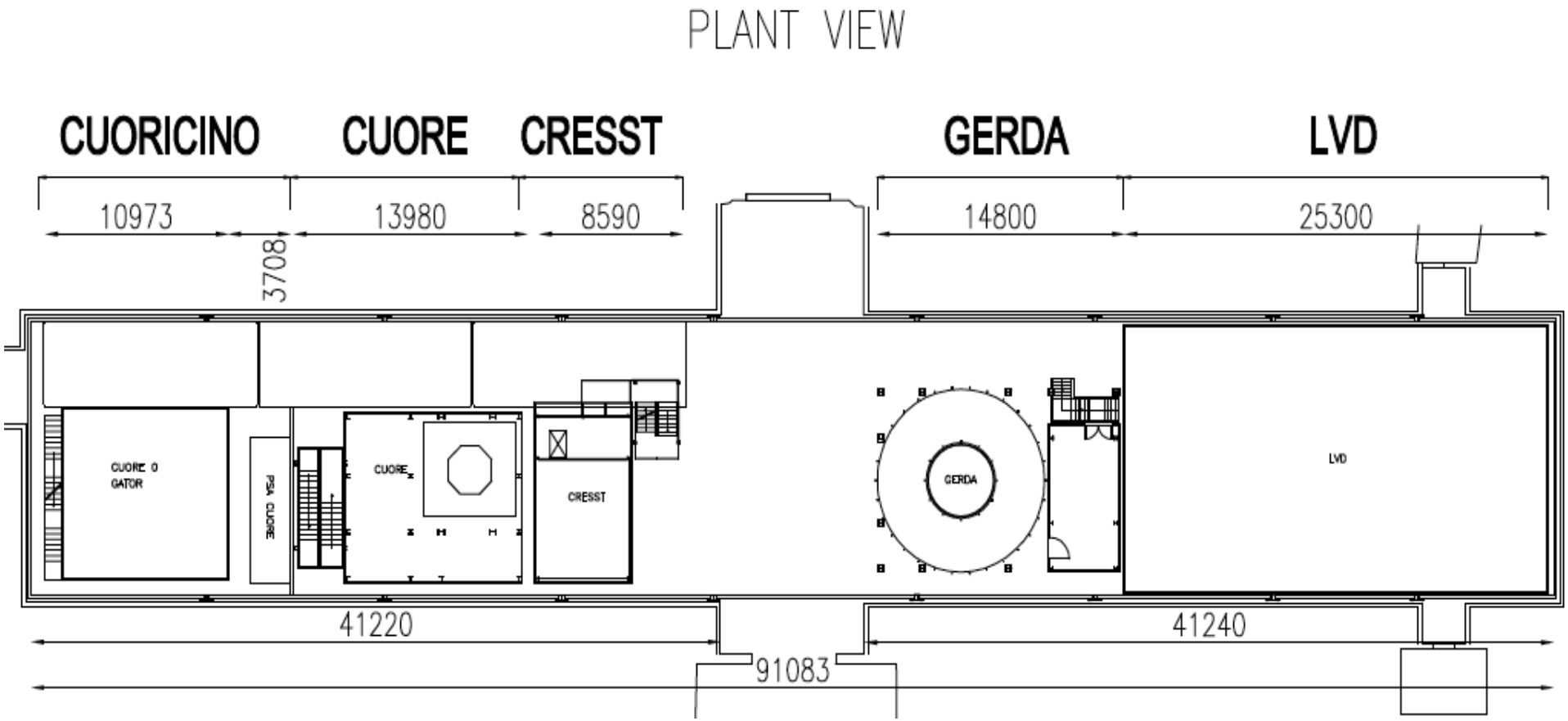
- LNGS can host in future new detectors for neutrino physics searches
- νturn workshop: a step towards an assessment of a physics program

1. **Present underground Laboratory:**

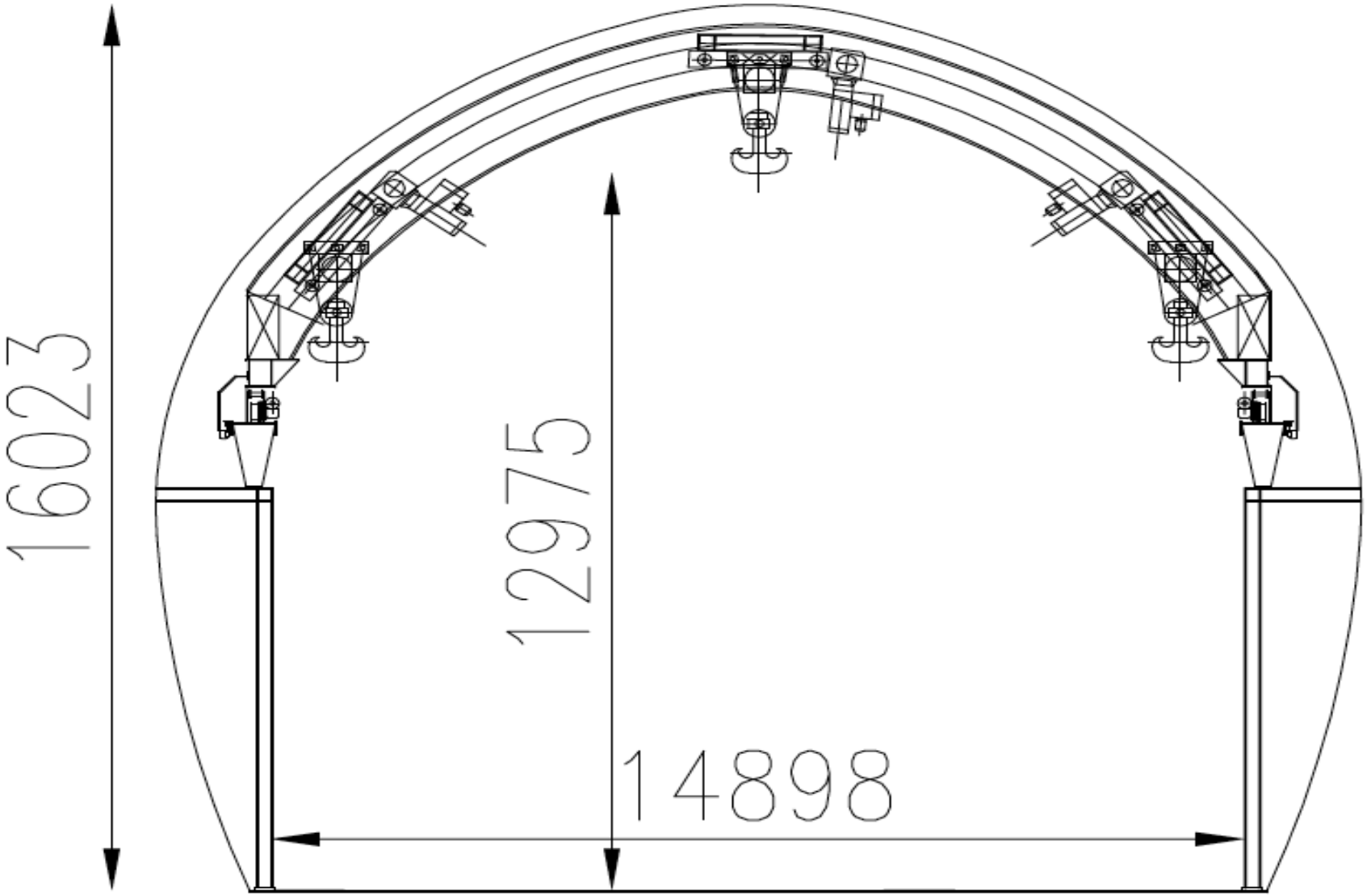
   After the end of the CNGS program (2013-2015),
   large underground space could be made available

HALL A @ LNGS

Present situation



HALL A @ LNGS



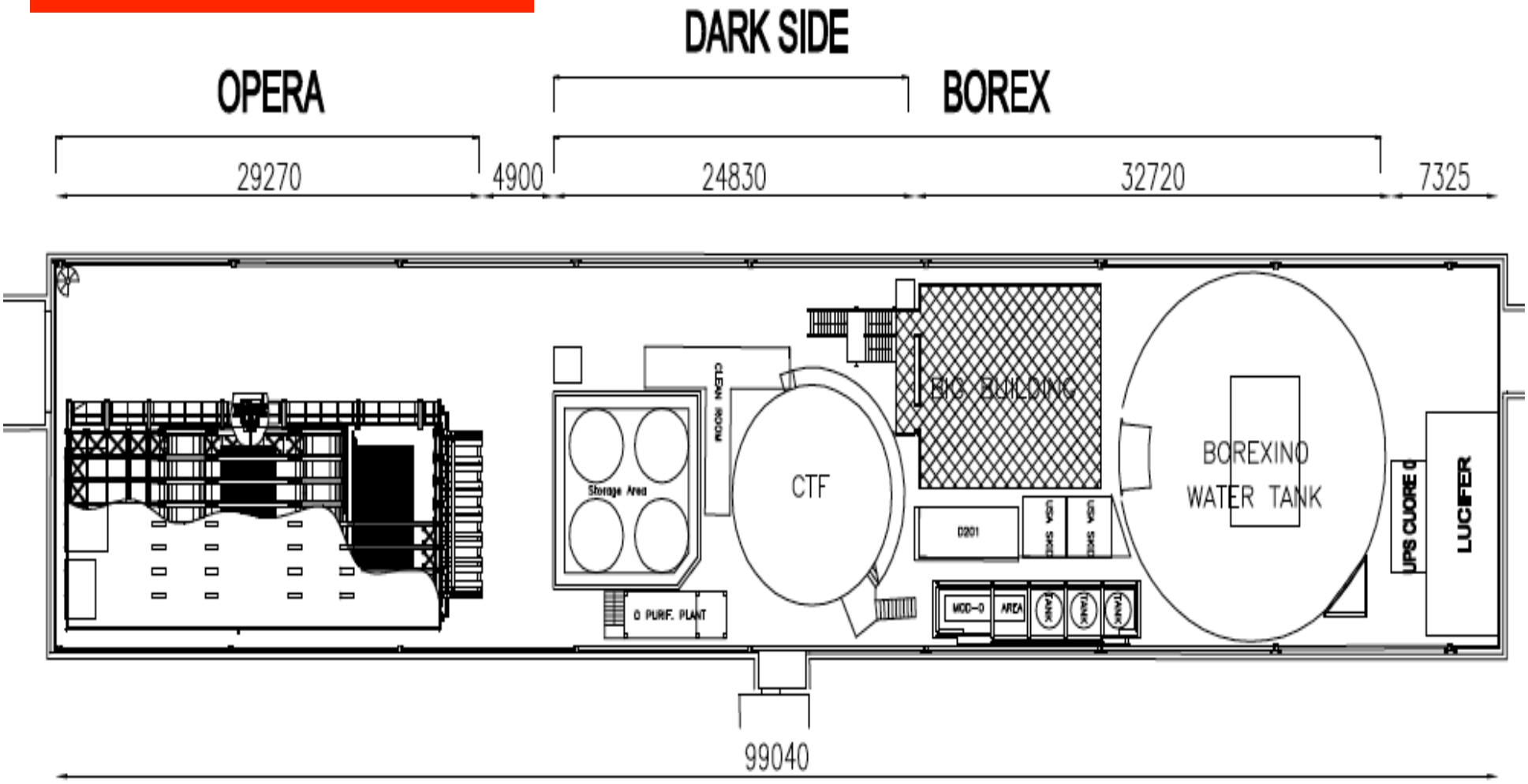
HALL A @ LNGS

- LVD: observatory for ν from stellar collapses
- GERDA
  - Completion of Phase I and start of PHASE II data taking in spring 2013
  - After Phase II completion (100kgyear)
    decision on Phase III based on physics results,
    in close contact with Majorana collaboration
- CUORE
  - In construction phase, start data taking in 2014
  - the program will extend up to the end of this decade
- CRESST (DM)
  - Results shown last September, resume Data Taking with low bkg
  - precursor of the next-generation dark matter project EURECA

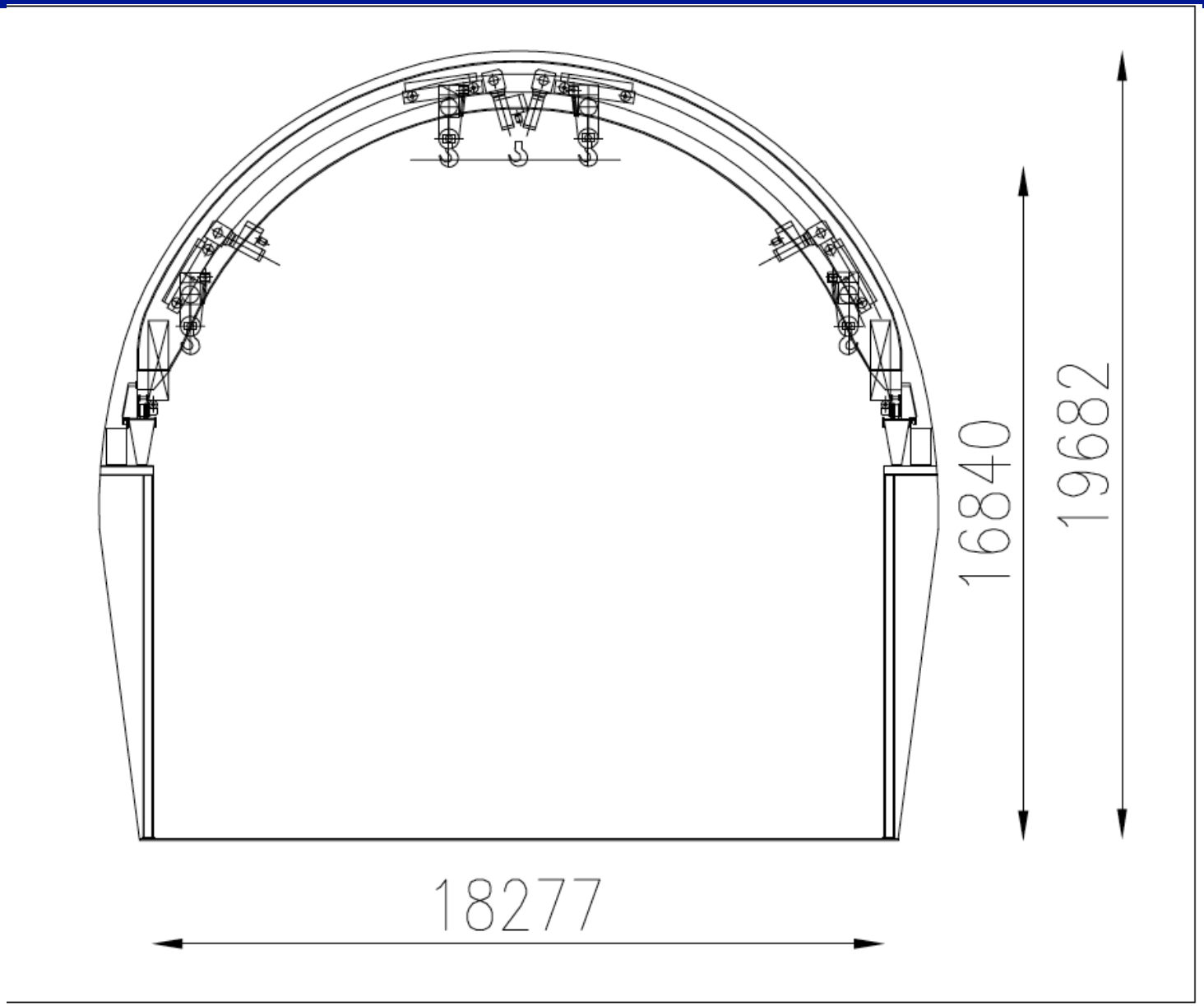
HALL C @ LNGS

Present situation

Volume under the crane ≈ 25×10^3 m^3



HALL C @ LNGS



HALL C @ LNGS

- Borexino Phase II (3-4 years) Physics goal
  - Improve significance of pep signal
  - Improve limit (or observation?) of CNO
  - Search for pp neutrinos
  - Improve precision on ^{7}Be neutrinos
  - Improve significance of geo-antineutrinos
- Proposal for a short baseline sterile neutrino search experiment submitted to LNGS SC
  - ν ^{51}Cr Source under the detector
  - Antiν ^{144}Ce-^{144}Pr inside the detector
- Convert Borexino to $0\nu\beta\beta$ experiment?

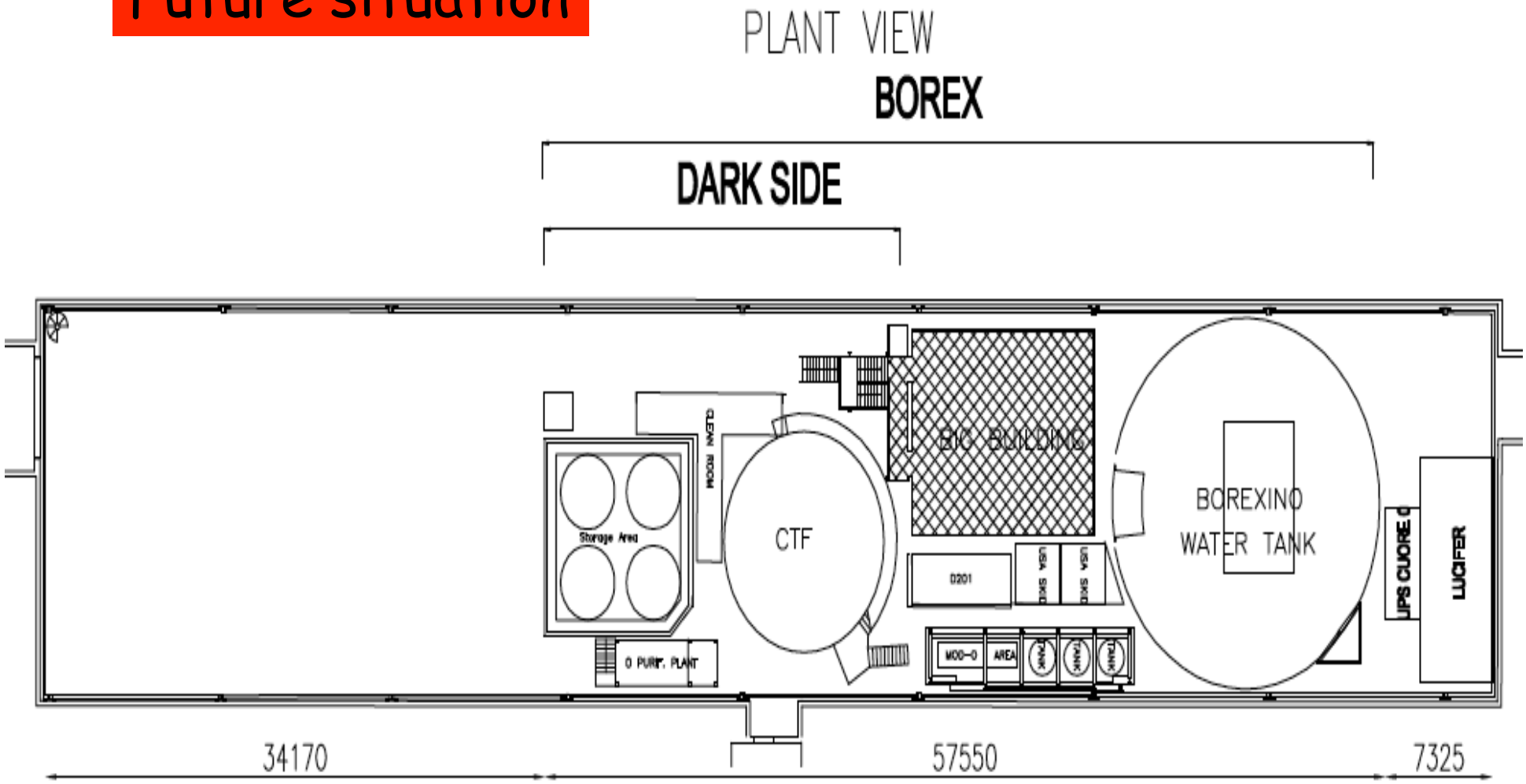
HALL C @ LNGS

- **DarkSide WIMP-Dark-Matter Program**
  - DS-50 approved, inside CTF, commissioning by 2013
  - Multi ton detector (Goal: ~10^{-11} pb)
    could be accommodated inside the CTF in the future

- **OPERA**
  - Run in 2012, if 4.7×10^{19} pot, 82% of the proposed value
  - Decision on possible extension of data taking, after CERN shutdown, related to physics results
  - 2-3 years for emulsion scanning analysis needed after the end of data taking

HALL C @ LNGS

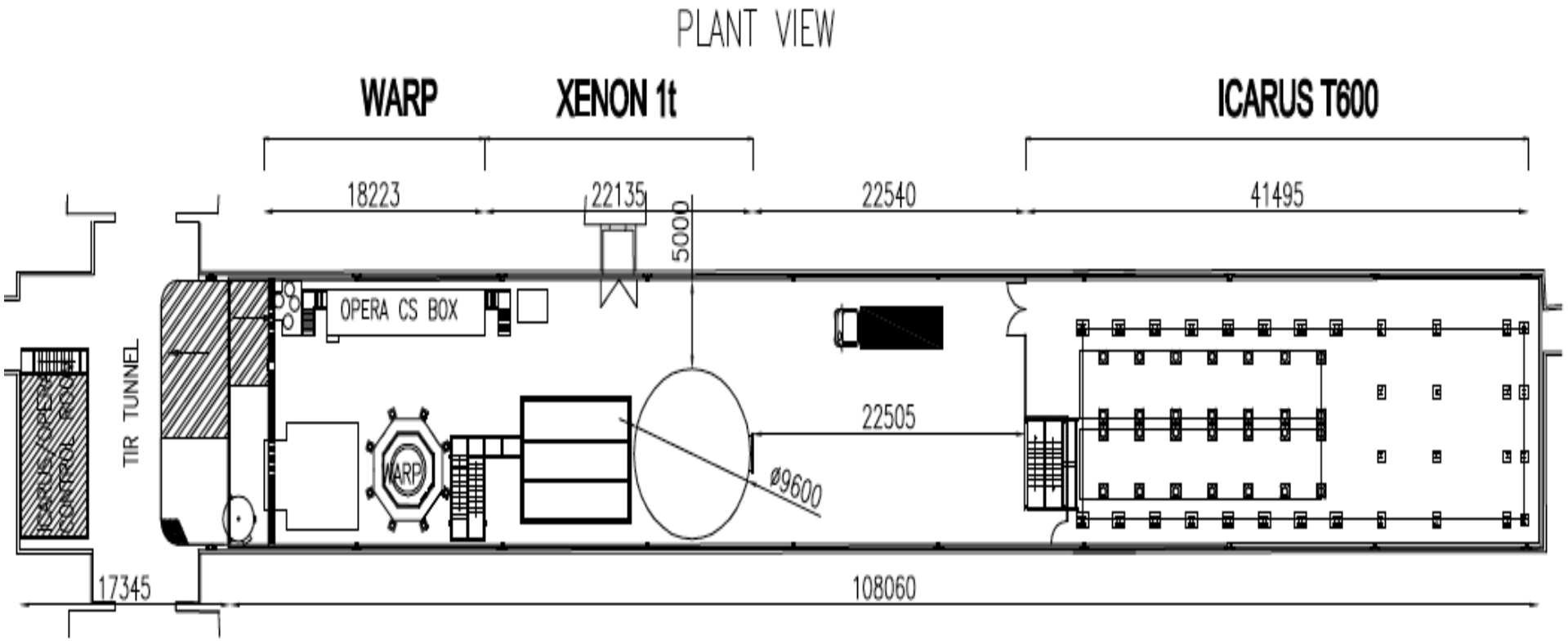
Future situation



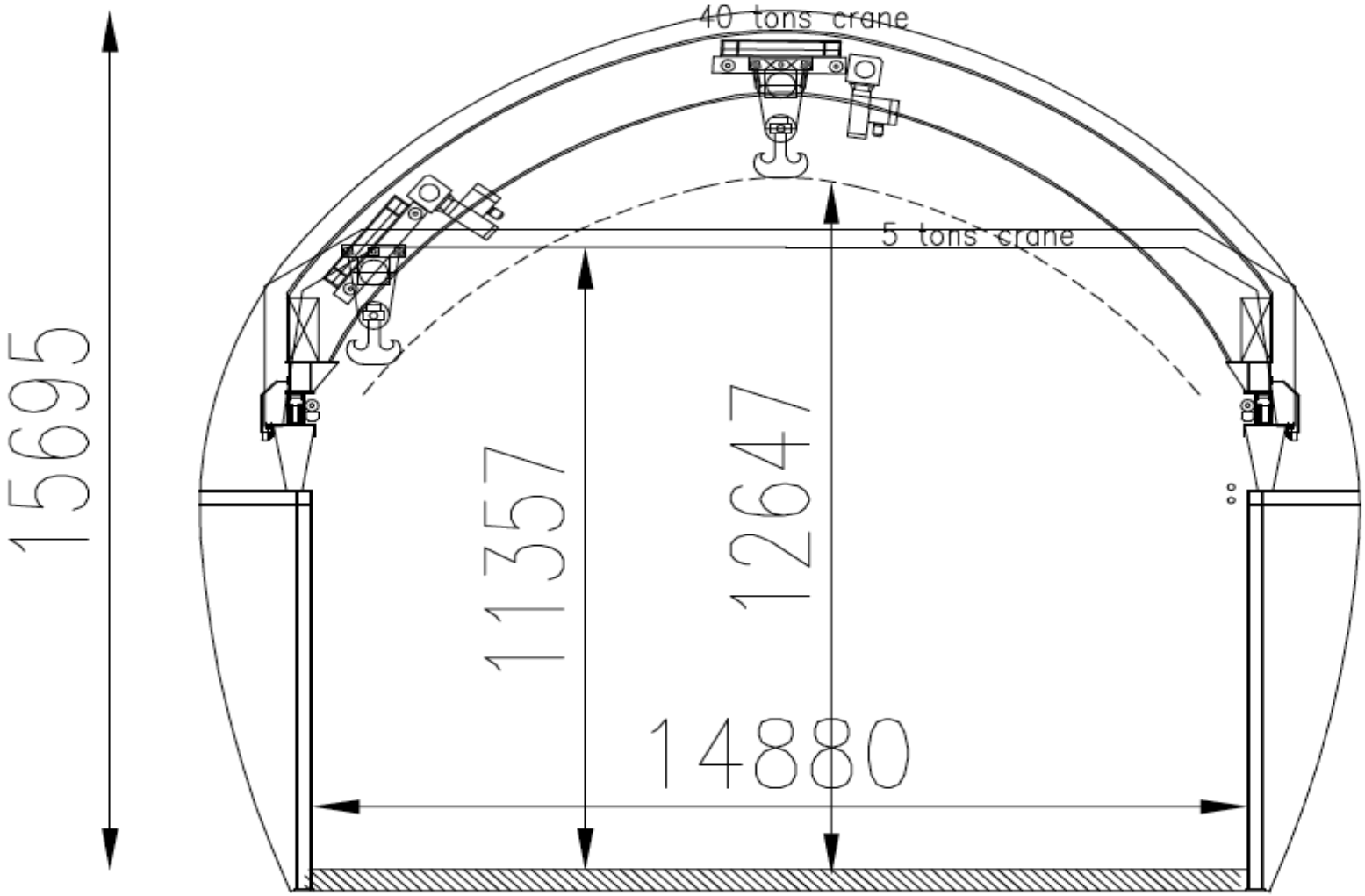
HALL B @ LNGS

Present situation + Xenon 1t

Volume under the crane ≈ 17×10^3 m^3



HALL B @ LNGS



HALL B @ LNGS

- **ICARUS**
  - Run up to 2013
  - Afterwards could be moved to CERN if the Proposal

    "Search for "anomalies" from neutrino and anti-neutrino oscillations at $\Delta m^2 \approx 1 eV^2$ with muon spectrometers and large LAr-TPC imaging detectors."

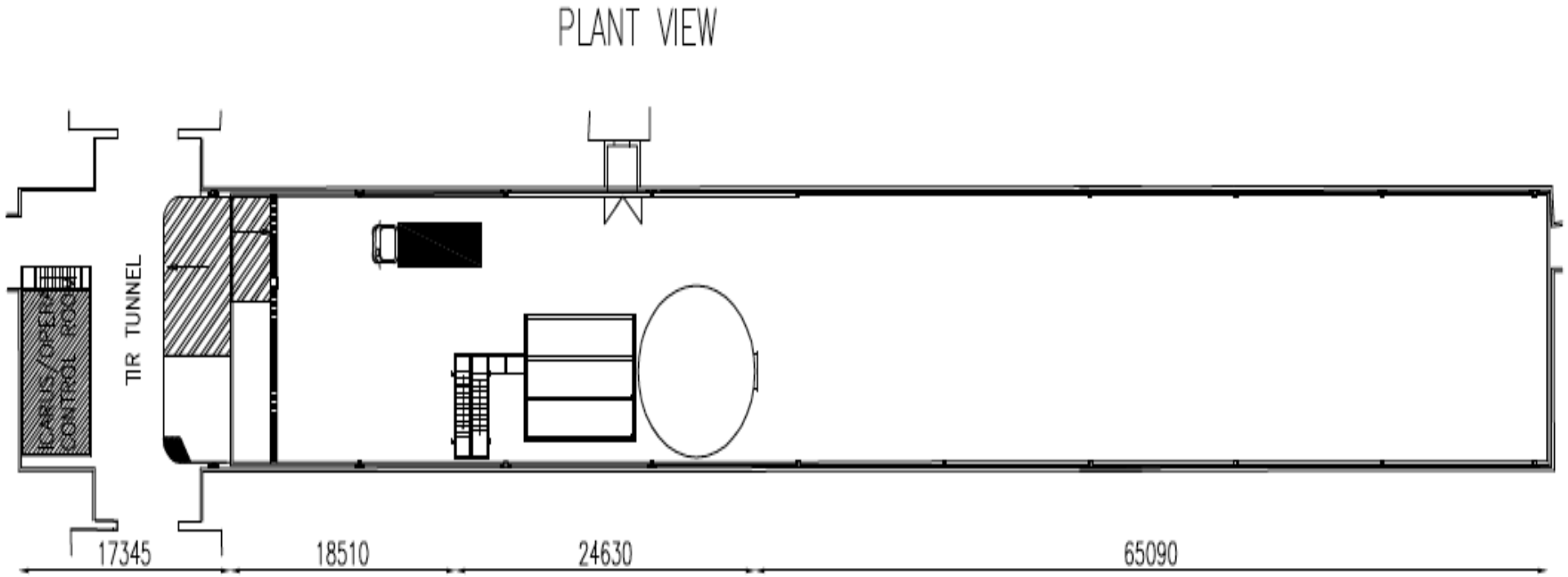
    is approved, or dismounted in any case

- **XENON DM program**
  - XENON 1t: Start installation by fall 2012, data taking in 2015

- **WARP**
  - End data taking, can be decommissioned

HALL B @ LNGS

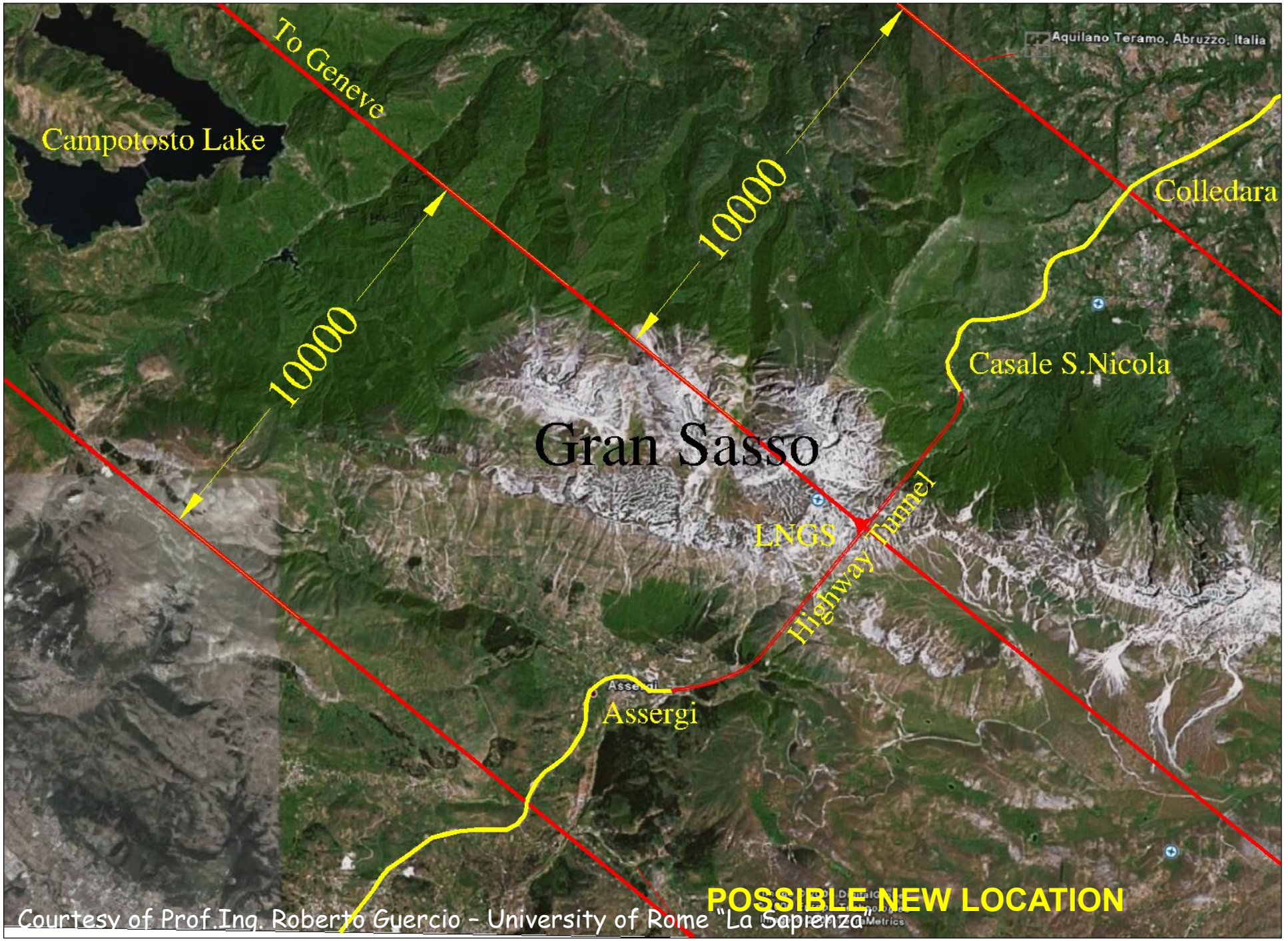
Future situation

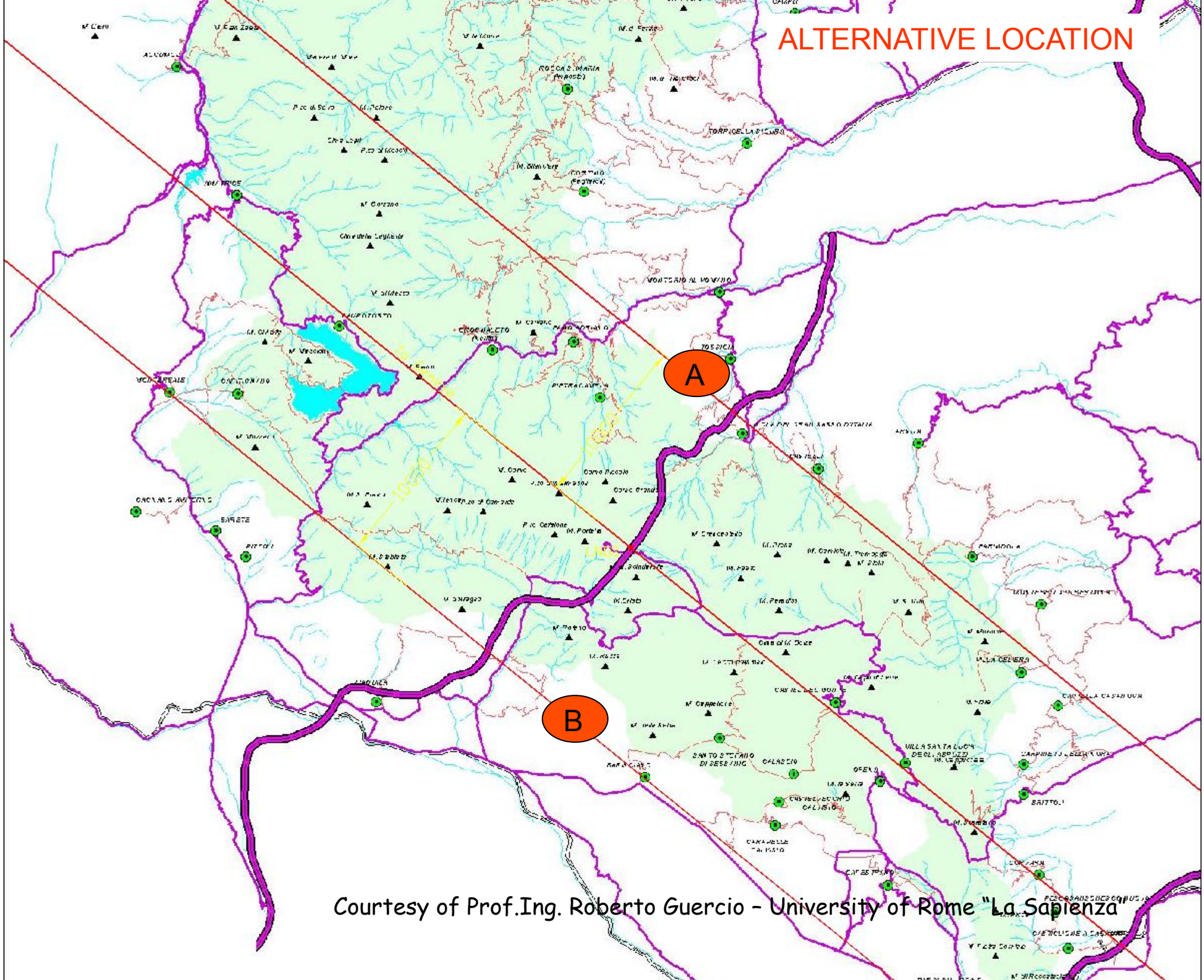


Perspectives @ LNGS

- LNGS can host in future new detectors for neutrino physics searches
- νturn workshop: a step towards an assessment of a physics program

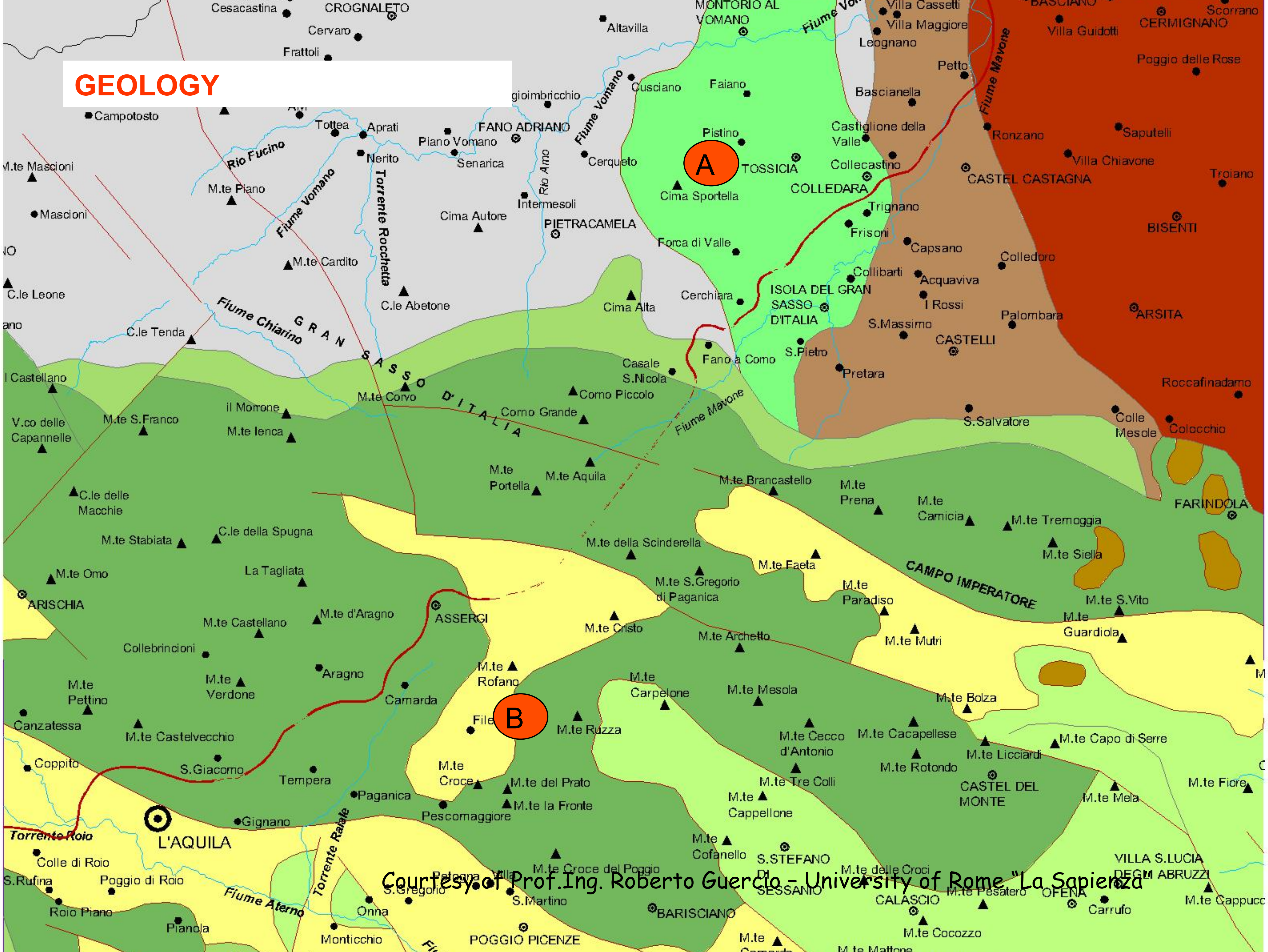
1. Present underground Laboratory:
   After the end of the CNGS program (2013-2015),
   large underground space could be made available
2. New halls in the present site can hardly be excavated
3. LNGS-B proposal
   A shallow depth (1.2 Km w.e.) new laboratory
   2 possible sites, 7-12 Km off axis CNGS
   Out of the protected area of the Gran Sasso Park
   Any presence of significant Uwater
   Partially based on Regional Funds


To Geneve
Campotosto Lake
10000
10000
Aquilano Teramo, Abruzzo, Italia
Colledara
Casale S.Nicola
Gran Sasso
LNGS
Highway Tunnel
Assergi
POSSIBLE NEW LOCATION
Courtesy of Prof.Ing. Roberto Guercio – University of Rome "La Sapienza"



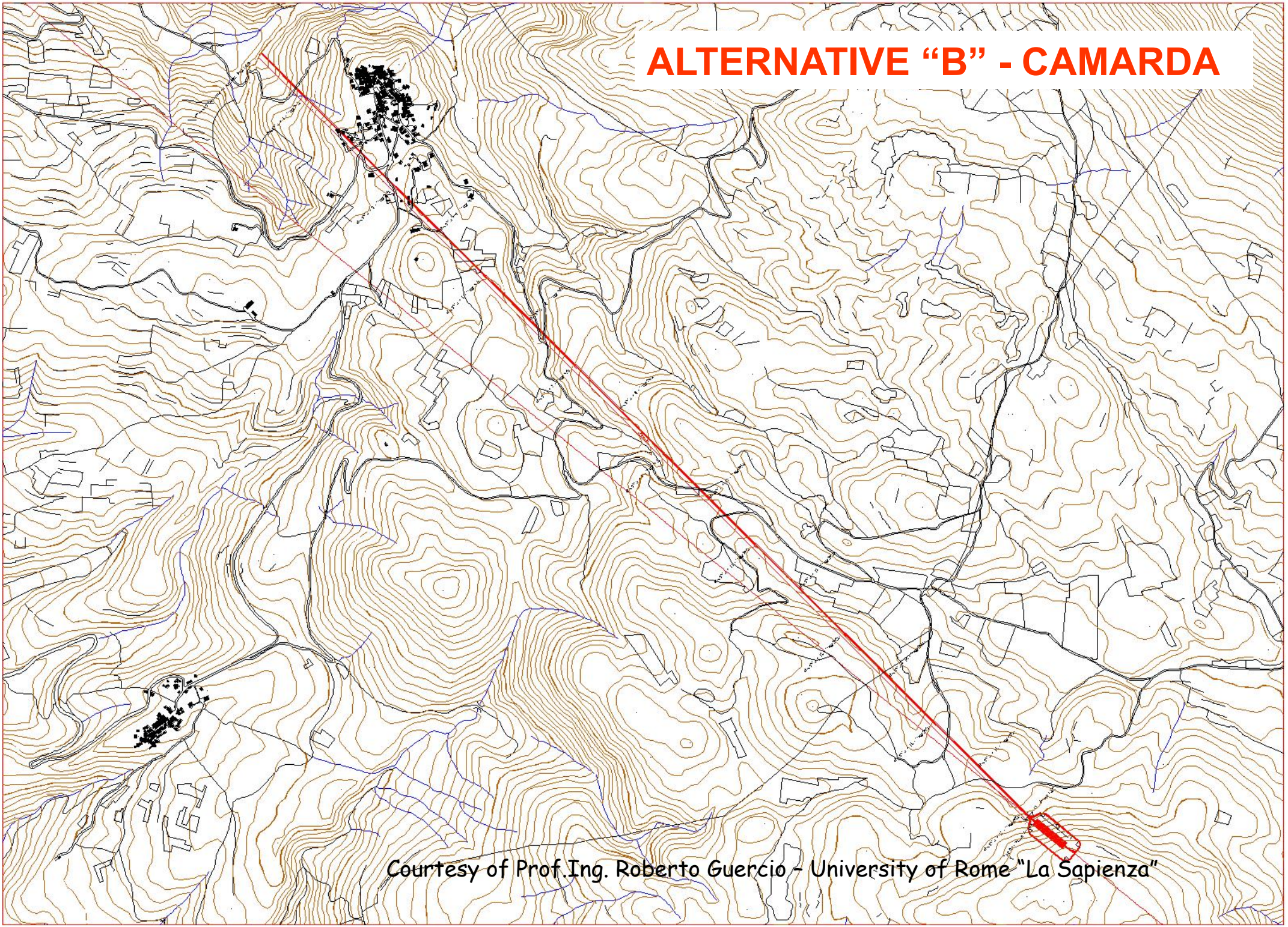
Courtesy of Prof.Ing. Roberto Guercio – University of Rome "La Sapienza"

GEOLOGY



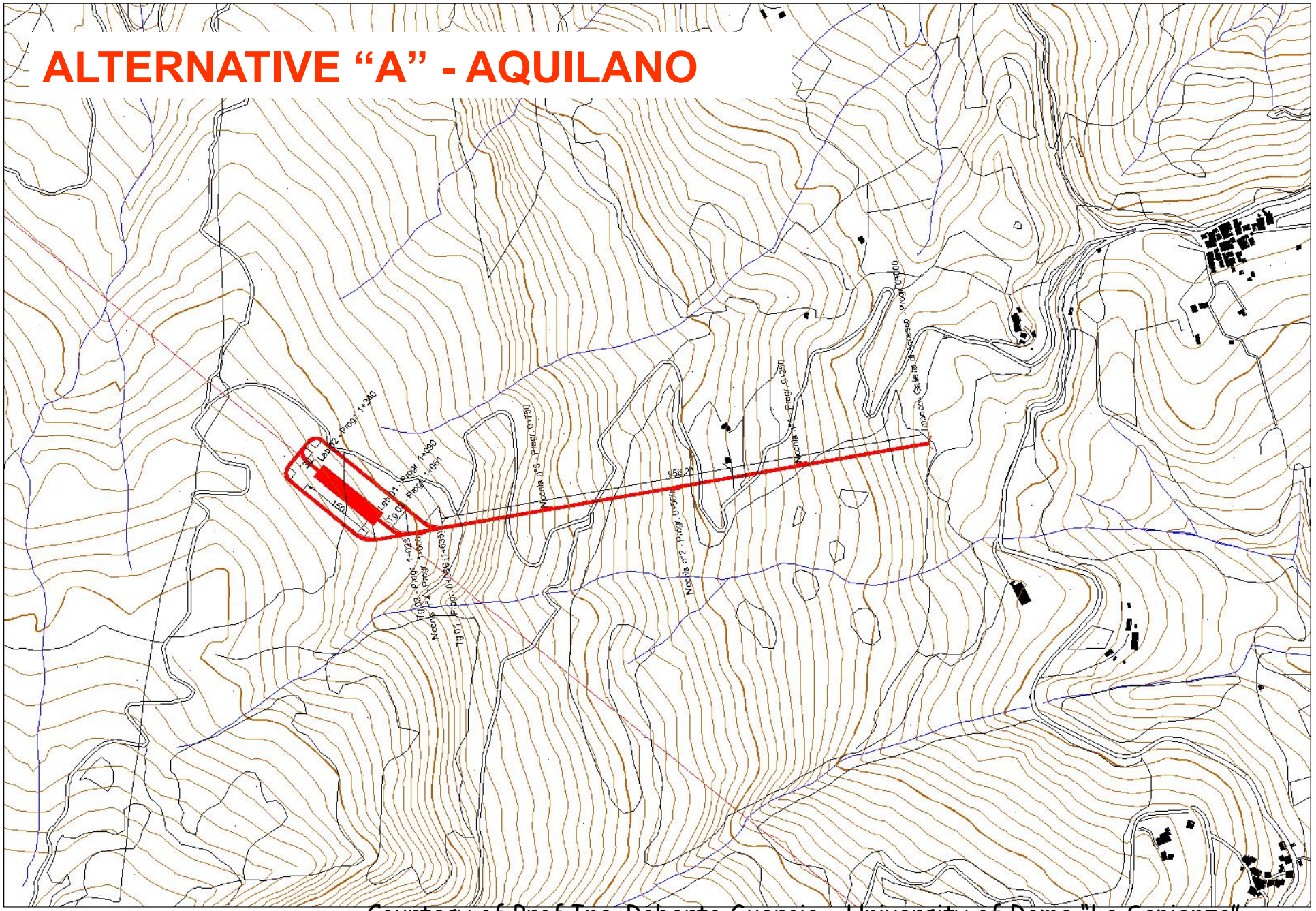
Courtesy of Prof.Ing. Roberto Guercio - University of Rome "La Sapienza"

ALTERNATIVE “B” - CAMARDA

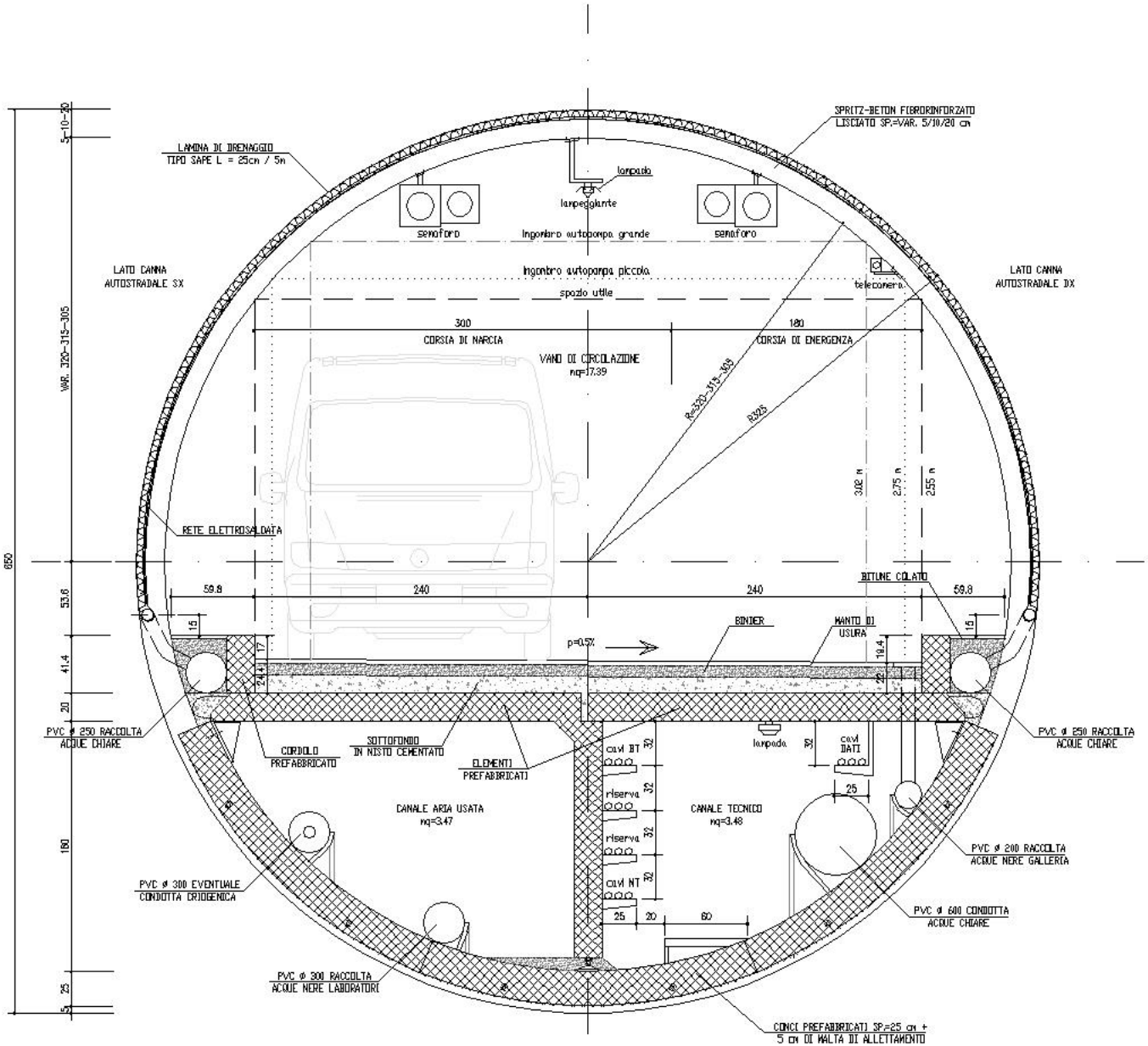


Courtesy of Prof.Ing. Roberto Guercio – University of Rome “La Sapienza”

ALTERNATIVE “A” - AQUILANO



Courtesy of Prof.Ing. Roberto Guercio – University of Rome “La Sapienza”

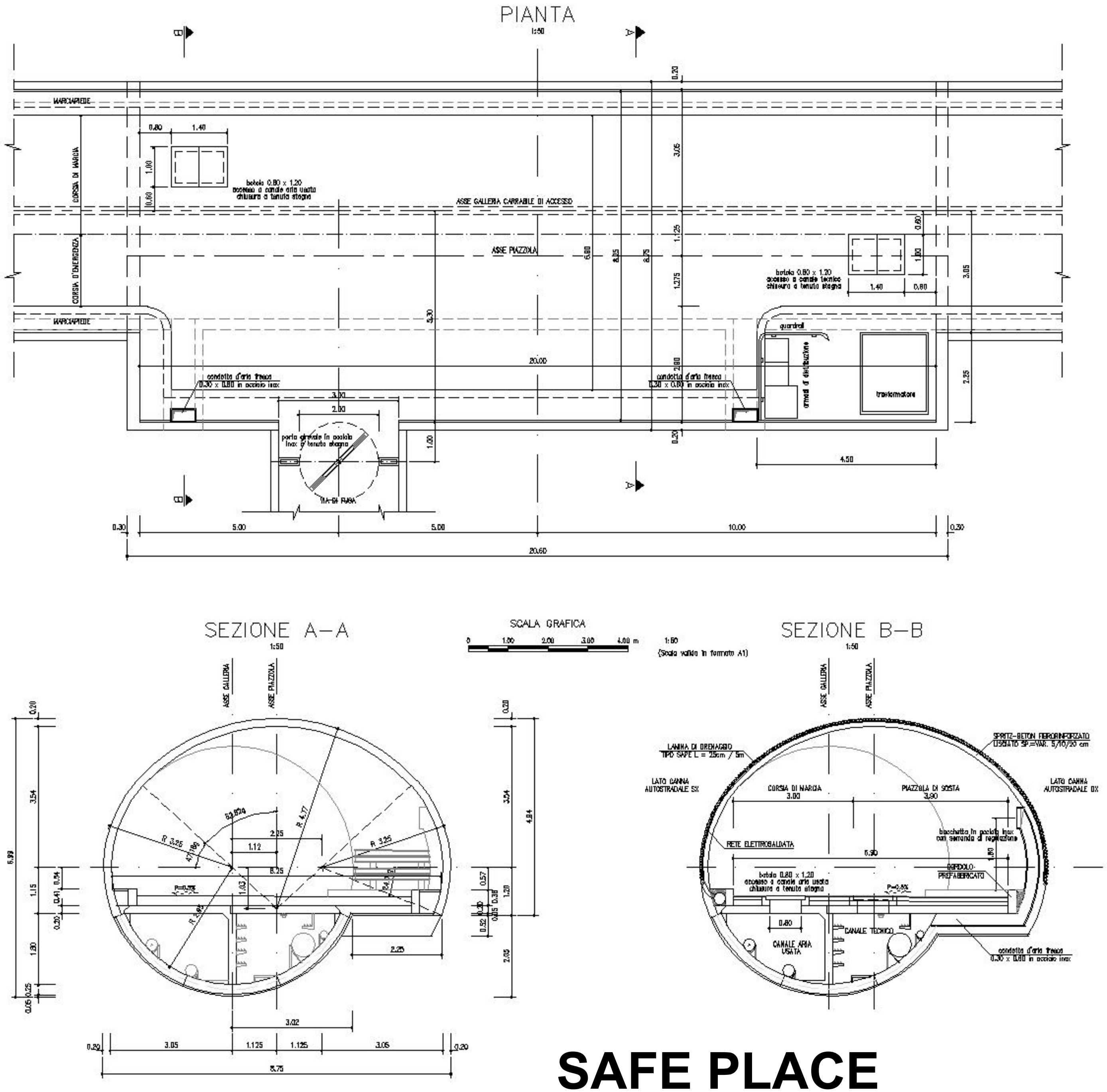


TUNNEL TYPICAL SECTION

SEZIONE TIPICA

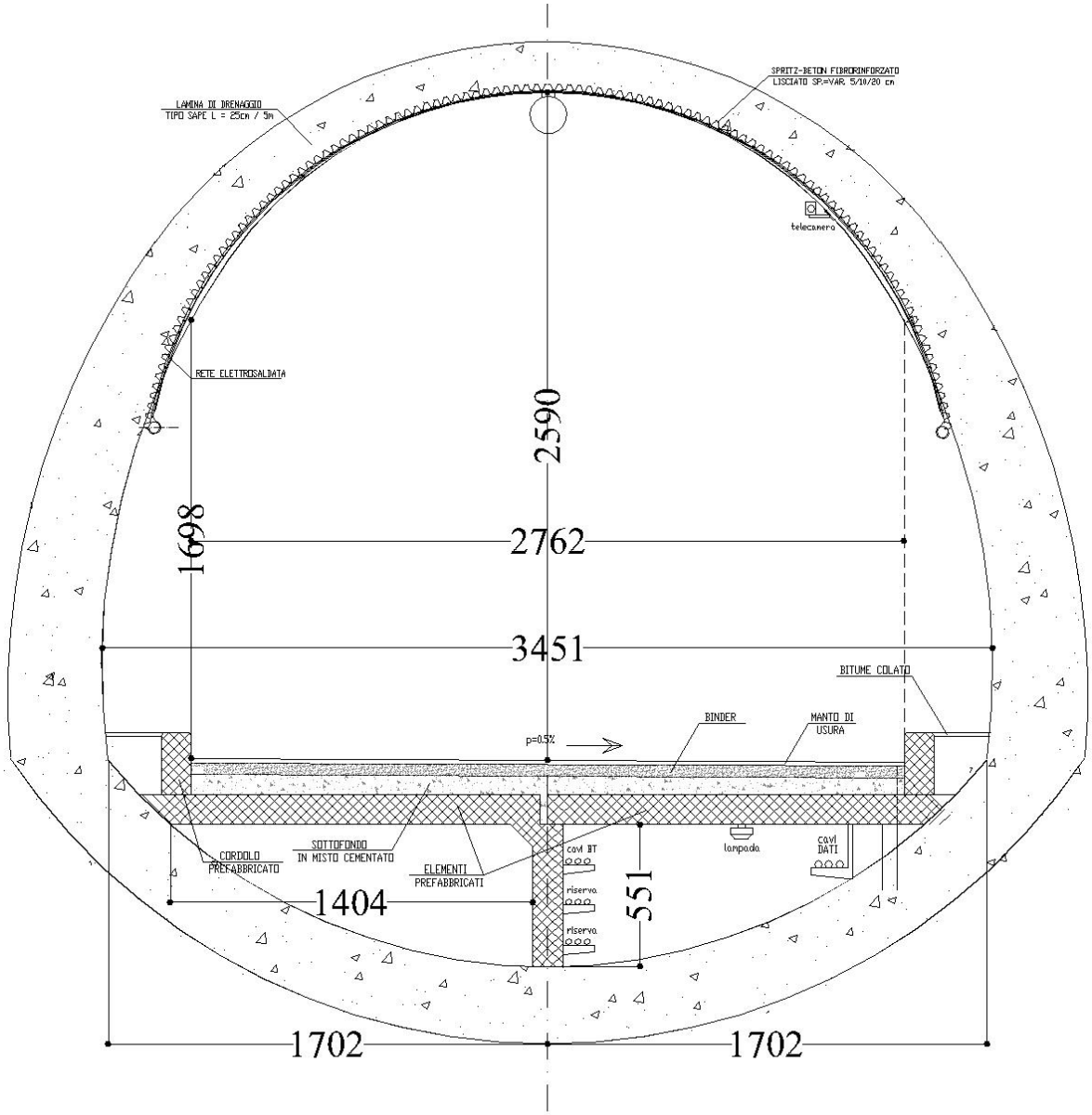
SCALA 1:20

Courtesy of Prof.Ing. Roberto Guercio – University of Rome "La Sapienza"


PIANTA
1:50
MARCIAPIEDE
CORSIA DI MARCIA
CORSIA D'EMERGENZA
botola 0.80 x 1.20
accesso a canale aria usata
chiusura a tenuta stagna
ASSE GALLERIA CARRABILE DI ACCESSO
ASSE PIAZZOLA
botola 0.80 x 1.20
accesso a canale tecnico
chiusura a tenuta stagna
guardrail
armadi di distribuzione
trasformatore
condotta d'aria fresca
0.30 x 0.80 in acciaio inox
porta girevole in acciaio inox a tenuta stagna
VIA DI FUGA
20.00
20.60
SEZIONE A-A
1:50
ASSE GALLERIA
ASSE PIAZZOLA
SCALA GRAFICA
1:50
(Scala valida in formato A1)
SEZIONE B-B
1:50
LAMINA DI DRENAGGIO
TIPO SAFE L = 25cm / 5m
SPRITZ-BETON FIBRORINFORZATO
LISCIATO SP.=VAR. 5/10/20 cm
LATO CANNA AUTOSTRADALE SX
LATO CANNA AUTOSTRADALE DX
CORSIA DI MARCIA
PIAZZOLA DI SOSTA
RETE ELETTROSALDATA
bocchetta in acciaio inox con serranda di regolazione
CORDOLO PREFABBRICATO
CANALE ARIA USATA
CANALE TECNICO
condotta d'aria fresca
0.30 x 0.80 in acciaio inox

SAFE PLACE

NEW LABORATORY SECTION



Courtesy of Prof.Ing. Roberto Guercio – University of Rome "La Sapienza"

Conclusions

- INFN-Gran Sasso Laboratory:
  - 18 experiments + R&D activities, including world-leading in the fields of solar neutrinos, accelerator neutrinos, double beta decay, dark matter and nuclear astrophysics
  - Leadership in massive experiments with record performance and low-level background
- Plan to maintain the scientific excellence in the next years by an extensive physics program (new experiments and upgrades of the present ones)
- After the end of the CNGS program (2013-2015), underground space (OPERA and ICARUS) could be made available
- LNGS-B: a shallow depth new laboratory can be envisaged