LAGUNA – Large Apparatus for Grand Unification and Neutrino Astrophysics

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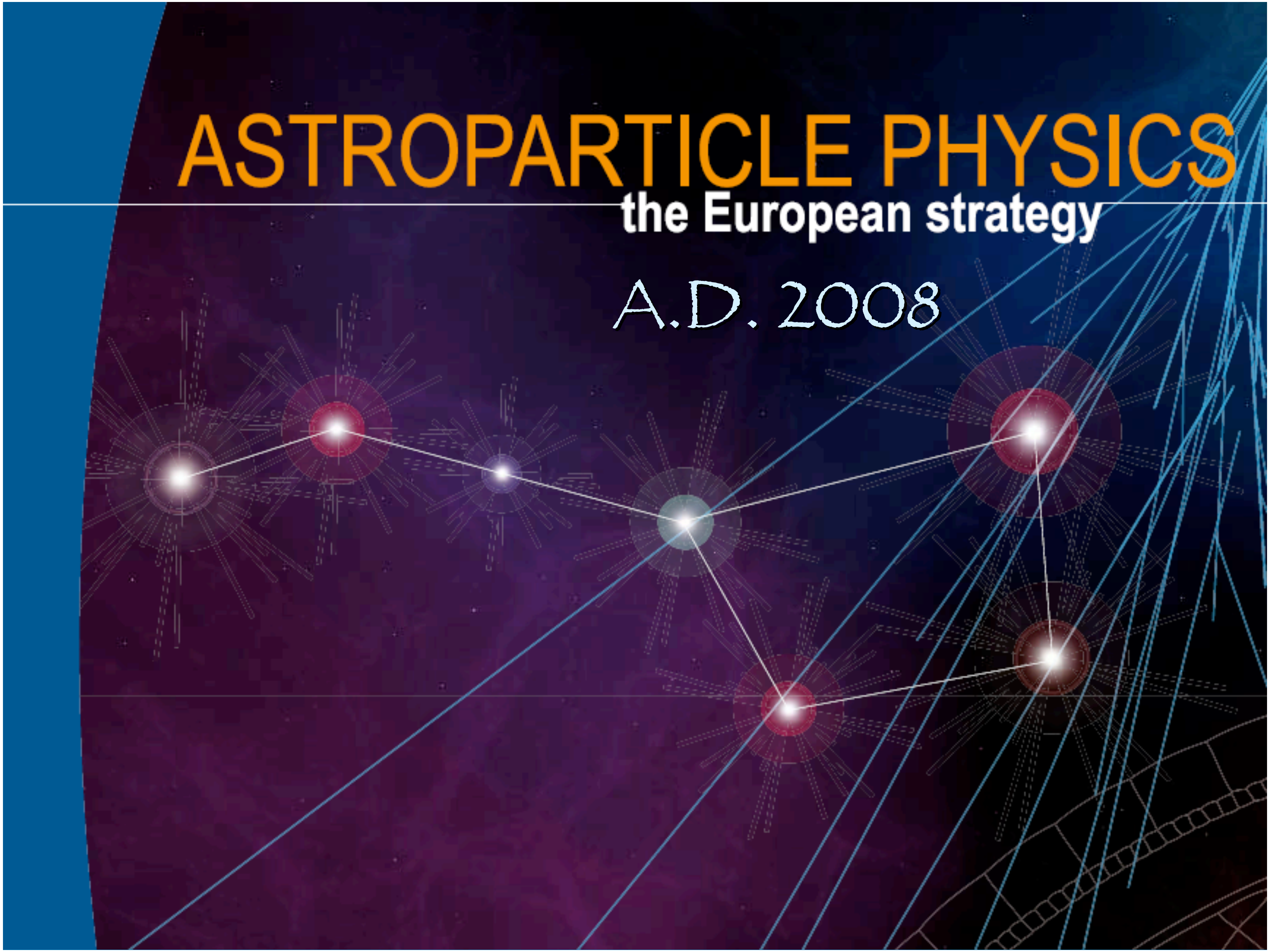
on behalf of LAGUNA collaboration


ASTROPARTICLE PHYSICS
the European strategy
A.D. 2008

Roadmap recommends

projects that have strong potential for taking the experimental science above the threshold of new, exciting discoveries addressing questions like the nature of dark matter and dark energy; the stability of protons and the physics of the Big Bang; the properties of neutrinos and their role in cosmic evolution; the interior of the Sun or supernovae as seen with neutrinos; the origin of cosmic rays and the view of the sky at extreme energies; and violent cosmic processes as seen with gravitational waves.

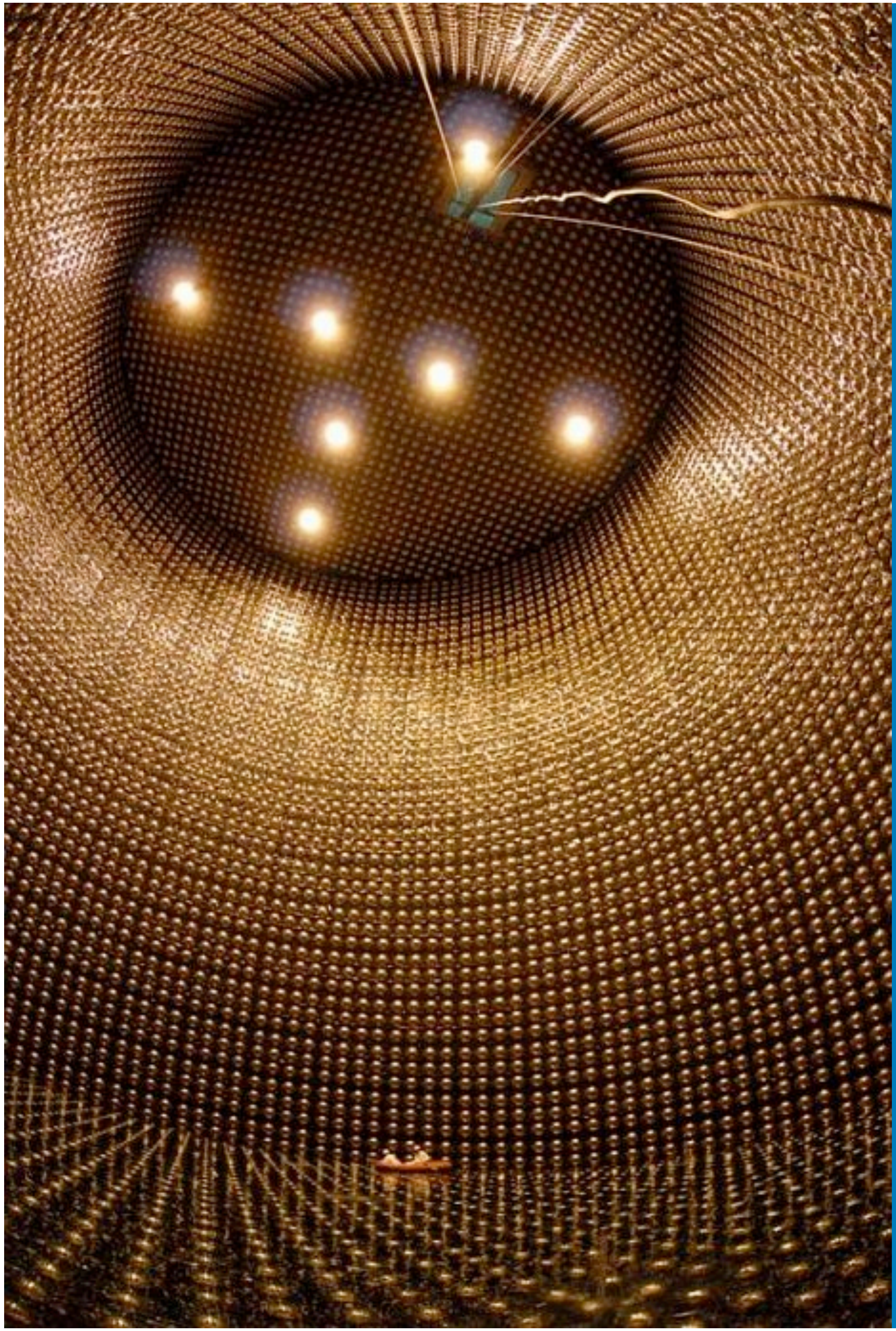
ASPERA

SIXTH FRAMEWORK PROGRAMME

On the top of the recommendation list

- Next-generation underground Megaton-scale detector for the search for
  - proton decay,
  - neutrino astrophysics
  - investigation of neutrino properties.

- This device is LAGUNA detector – Large Apparatus for Grand Unification and Neutrino Astrophysics.

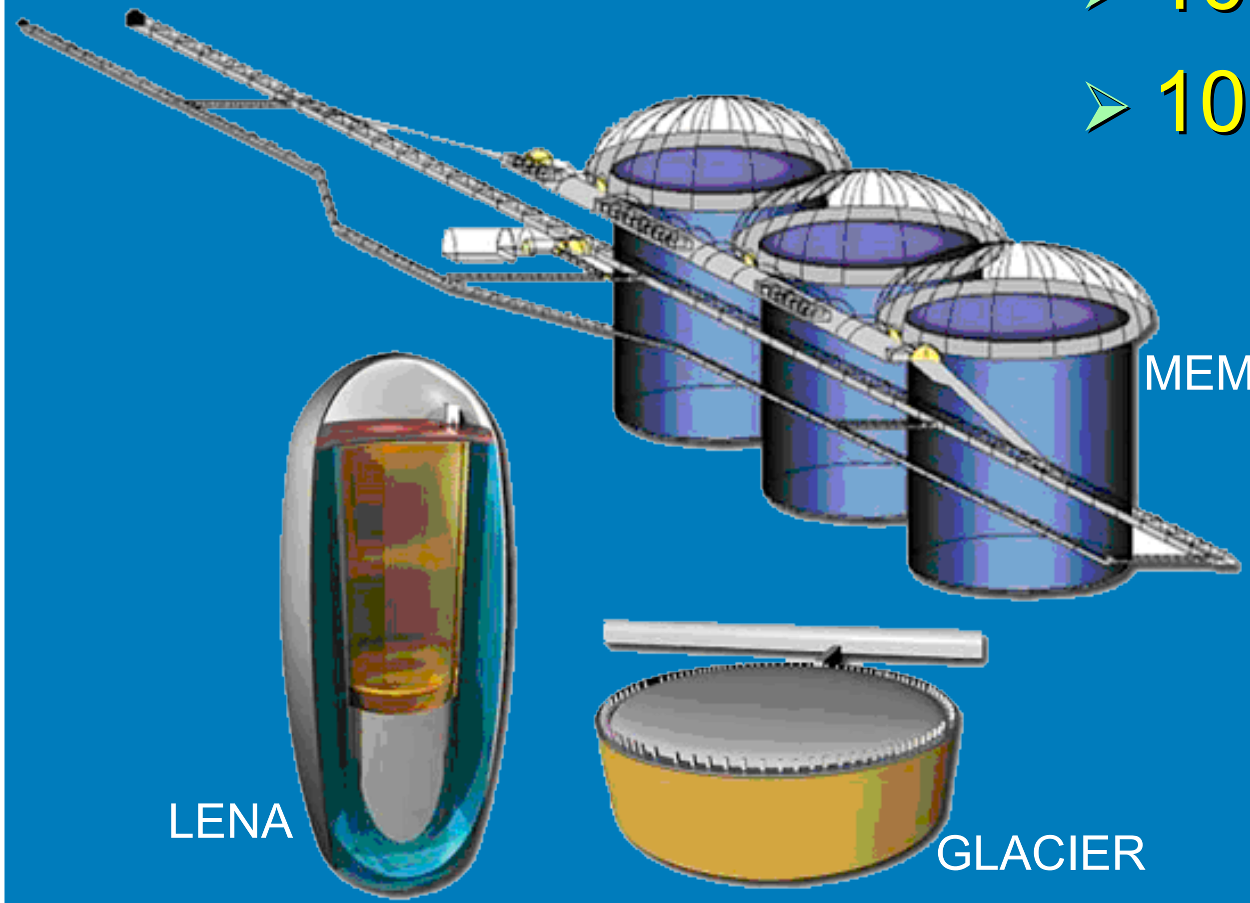


Super-K

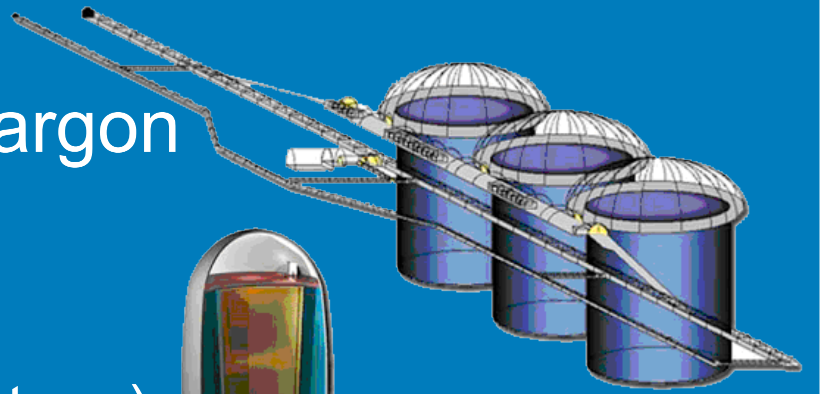
- One of the most successful devices in modern physics
  - Discovery of neutrino oscillations
  - Solar neutrino measurements
  - Best upper limits on proton lifetime
- The largest running underground experiment
  - 50 000 ton H_2O
  - 1 km underground

To be a worthy successor, LAGUNA has to be:

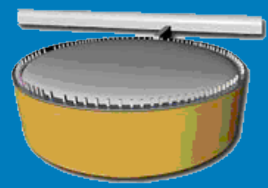
- **10 x bigger** or / and
- **10 x better**



Considered technologies



- GLACIER – 100 kton of liquid argon
  - Excellent tracking (TPC)
  - Rapidly developing technology
  - Needs more R&D (a 1 kton prototype)
  - Requires 2500 m.w.e (900 m of rock)



- LENA – 50 kton liquid scintillator
  - Big astrophysics potential (Super Borexino)
  - Robust and proven technology
  - Requires 4000 m.w.e (1400 m of rock)
- MEMPHYS – 500 kton water Cherenkov
  - Competitor for Hyper - K
  - Requires 3000 m.w.e (1100 m of rock)

7 European sites are being considered

- **Pyhäsalmi** in Finland (mine),
- **Fréjus** in France (road tunnel),
- **Boulby** in the UK (mine),
- **Umbria** region in Italy (a virgin site),
- **Sieroszowice** in Poland (mine),
- **Canfranc** in Spain (road tunnel) and
- **Slanic** in Romania (mine).

Infrastructure Design Study

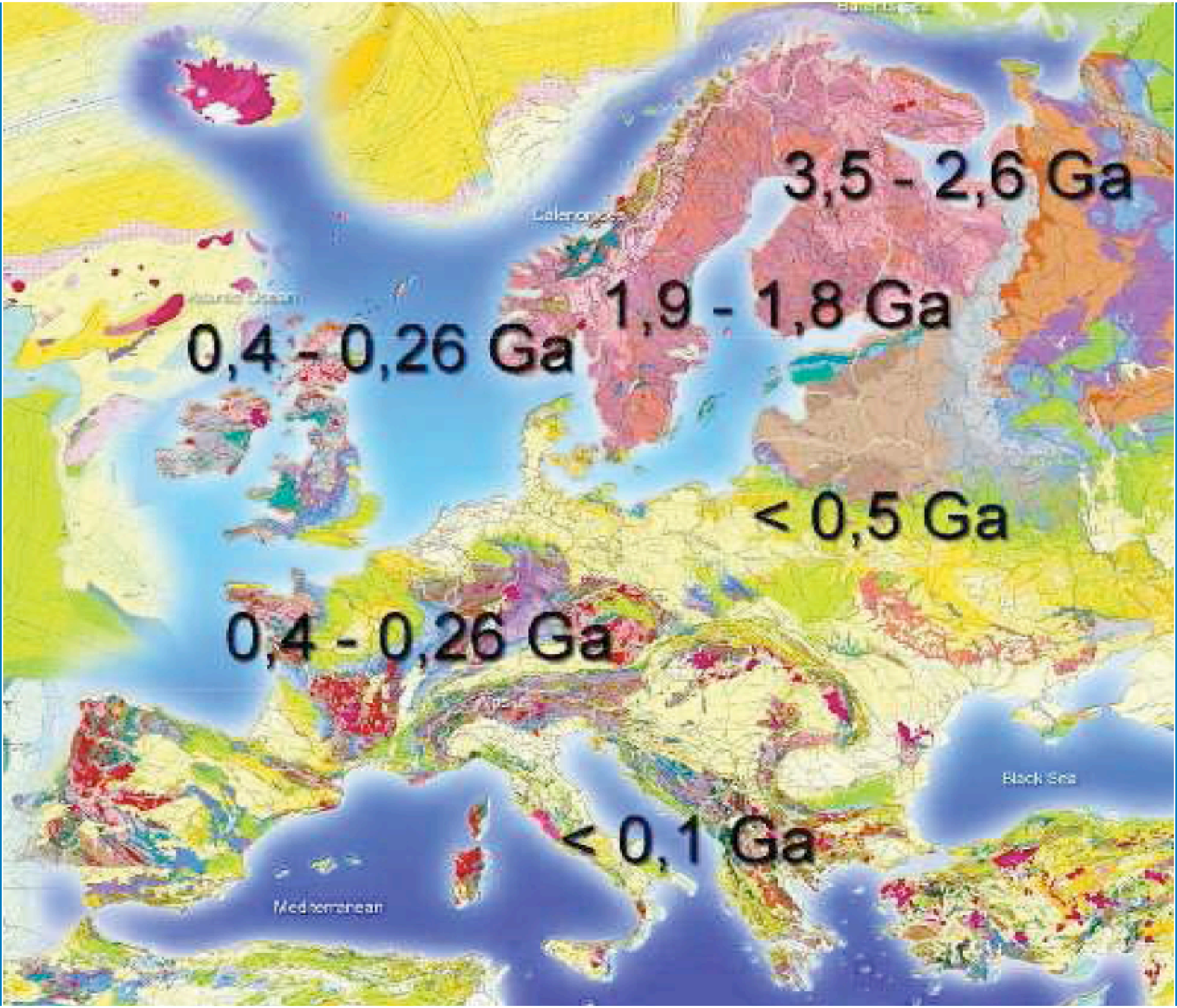
- The purpose: evaluate the proposed sites and to give realistic estimates of the cost and the time needed to prepare large-scale underground laboratories for LAGUNA detectors
- Supported with 1.7 M€ by the Framework Programme 7 of the EC (2008 – 2010)
- Involves over 100 physicists and engineers from 10 countries.

What is required of a LAGUNA site?

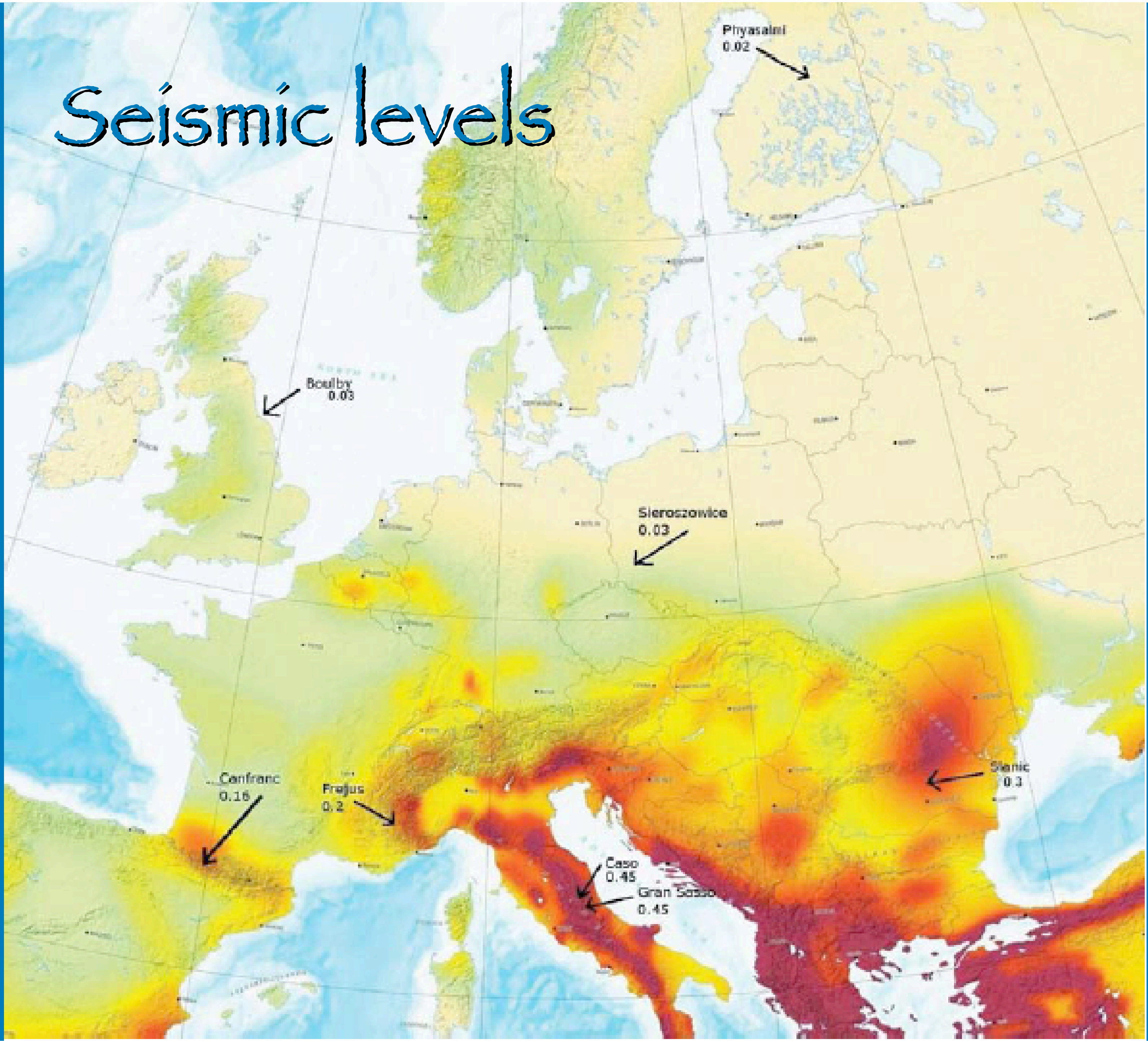
- Quality of the rock
- Seismic stability

Safety & construction cost

- Ready infrastructure & clear legal status
- Presence of scientific activity on site
- Experienced industrial partner
- Low background from nuclear power plants


3,5 - 2,6 Ga
1,9 - 1,8 Ga
0,4 - 0,26 Ga
< 0,5 Ga
0,4 - 0,26 Ga
Black Sea
< 0,1 Ga
Mediterranean

Seismic levels



What is required of a LAGUNA site?

- Quality of the rock
- Seismic stability
- Ready infrastructure & clear legal status
- Presence of scientific activity on site
- Experienced industrial partner
- Low background from nuclear power plants

Reduces construction time & cost

What is required of a LAGUNA site?

Cooperation between science & industry can not be taken for granted

- Quality of the rock
- Seismic stability
- Ready infrastructure & clear legal status
- Presence of scientific activity on site
- Experienced industrial partner
- Low background from nuclear power plants

What is required of a LAGUNA site?

Engineering & construction challenge!

- Quality of the rock
- Seismic stability
- Ready infrastructure & clear legal status
- Presence of scientific activity on site
- Experienced industrial partner
- Low background from nuclear power plants

What is required of a LAGUNA site?

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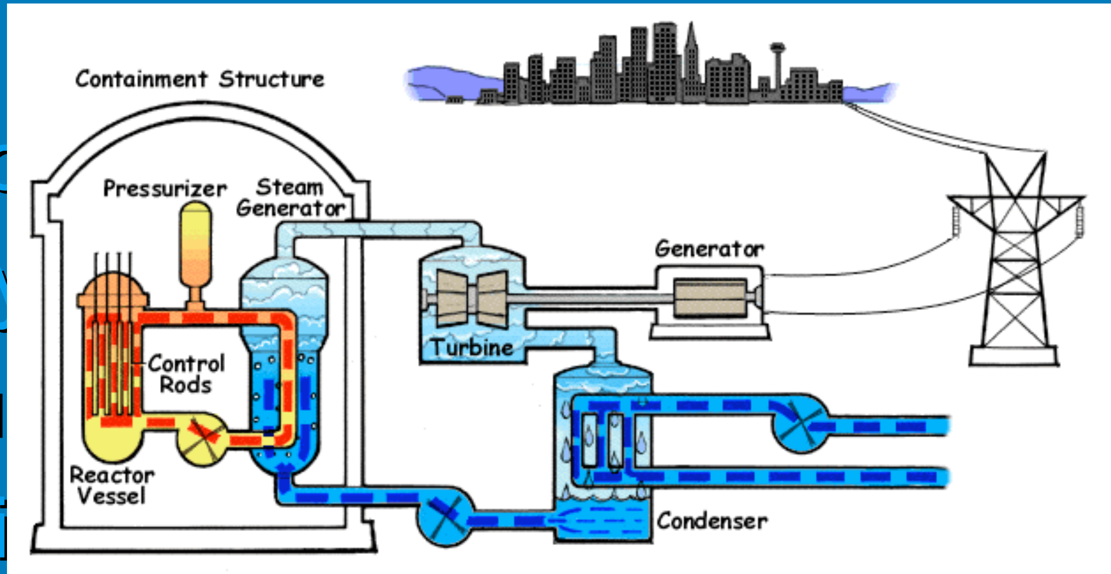


Essential for geo- and diffuse supernova neutrinos

Nuclear power plants in Europe (2009)

Reactor neutrinos

Reactor:

Fuel composition:

^{235}U, ^{238}U, ^{239}Pu, ^{241}Pu

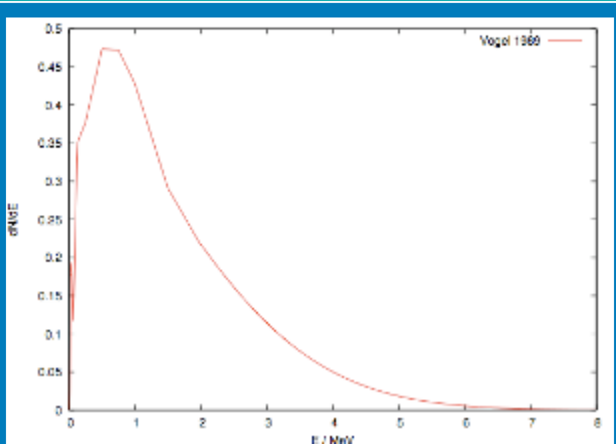
-Produces electron antineutrinos
-Production rate: ~2e20 $GW^{-1}s^{-1}$
-prop. to thermal power

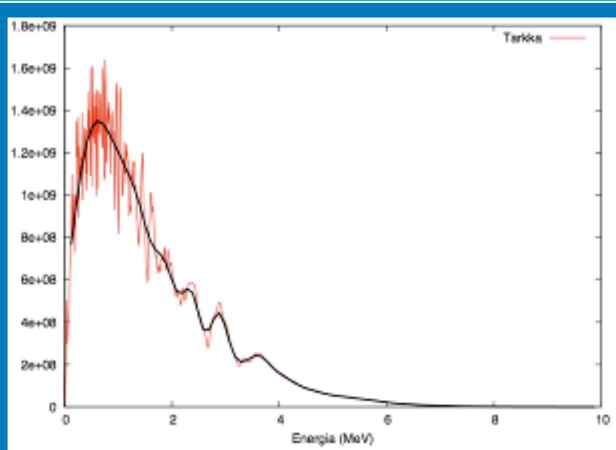
Propagation through the Earth

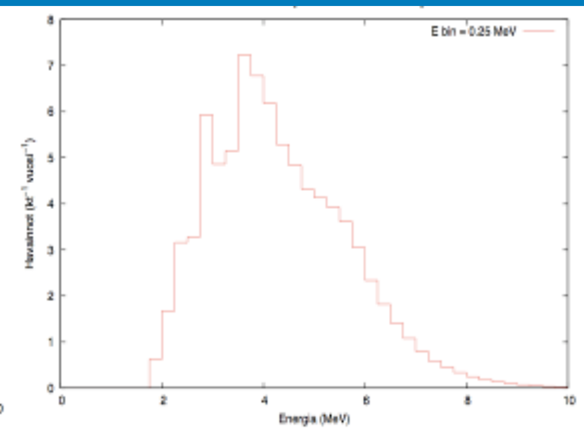
-Neutrino oscillation
-Matter effects negligible

Detection:

-via inverse β-decay
($E_{thr} \approx 1.8$ MeV)

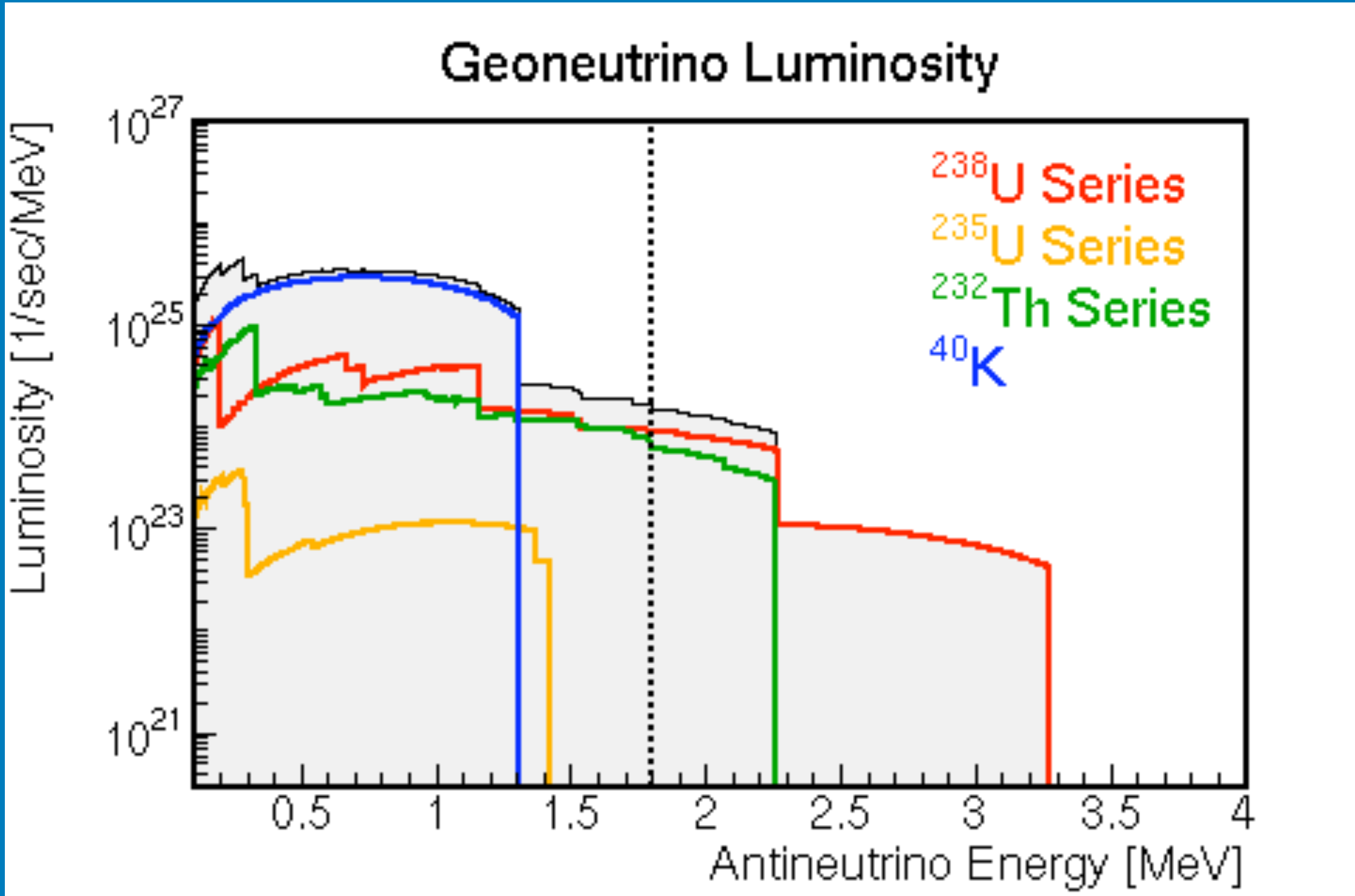






Background for geo- and supernova diffusion neutrinos

Geo-ν luminosity of the Earth



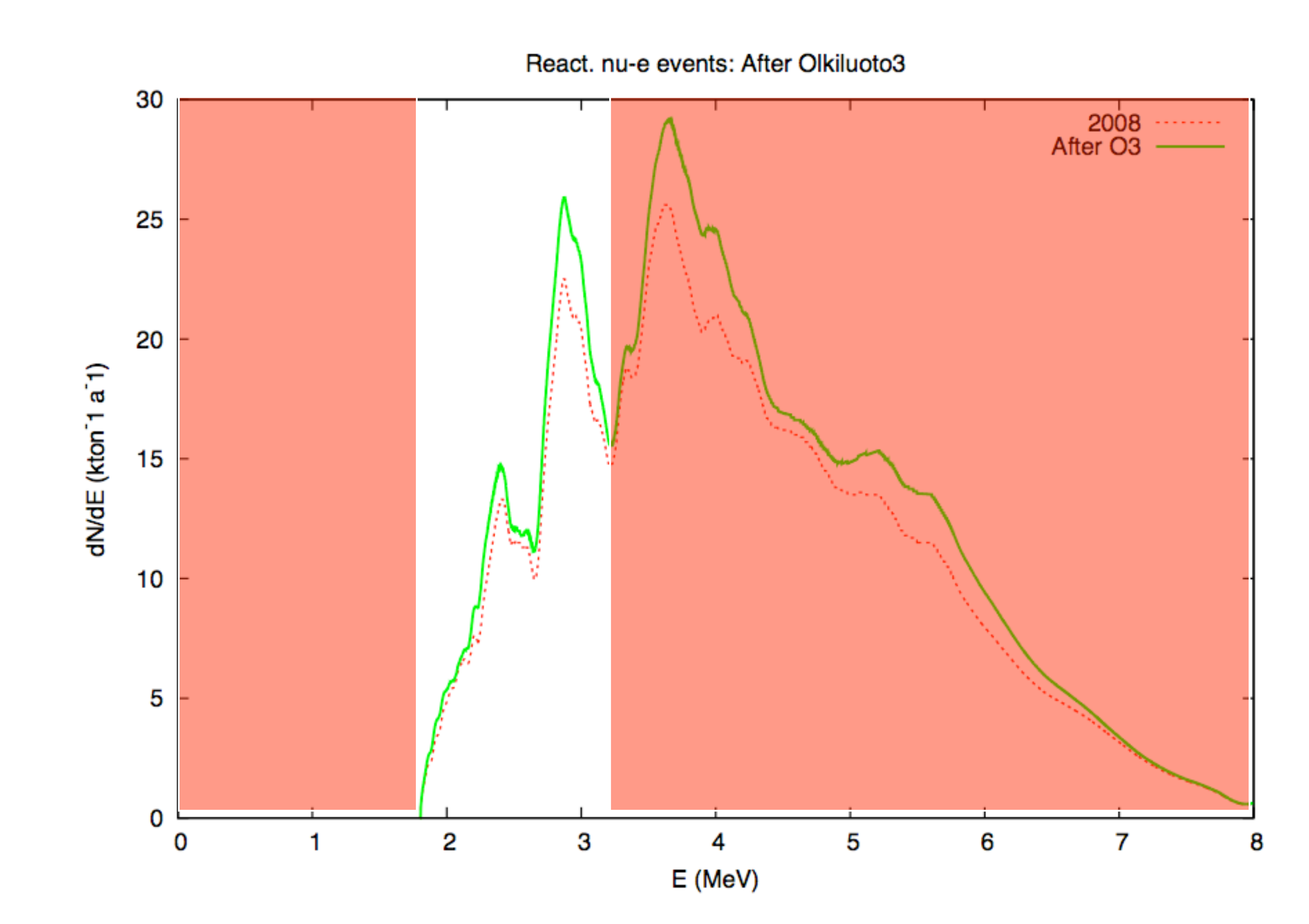
Luminosities [x 10^{24} 1/s]

U-238:
- Total: 6.65
- Above E_{thr}: 0.43

Th-232:
- Total: 5.30
- Above E_{thr}: 0.206

Effect of reactor neutrinos on Geo-neutrino background

- Geo -window
  - U + Th: 1.806 – 2.254 MeV
  - U only: 2.254 – 3.27 MeV

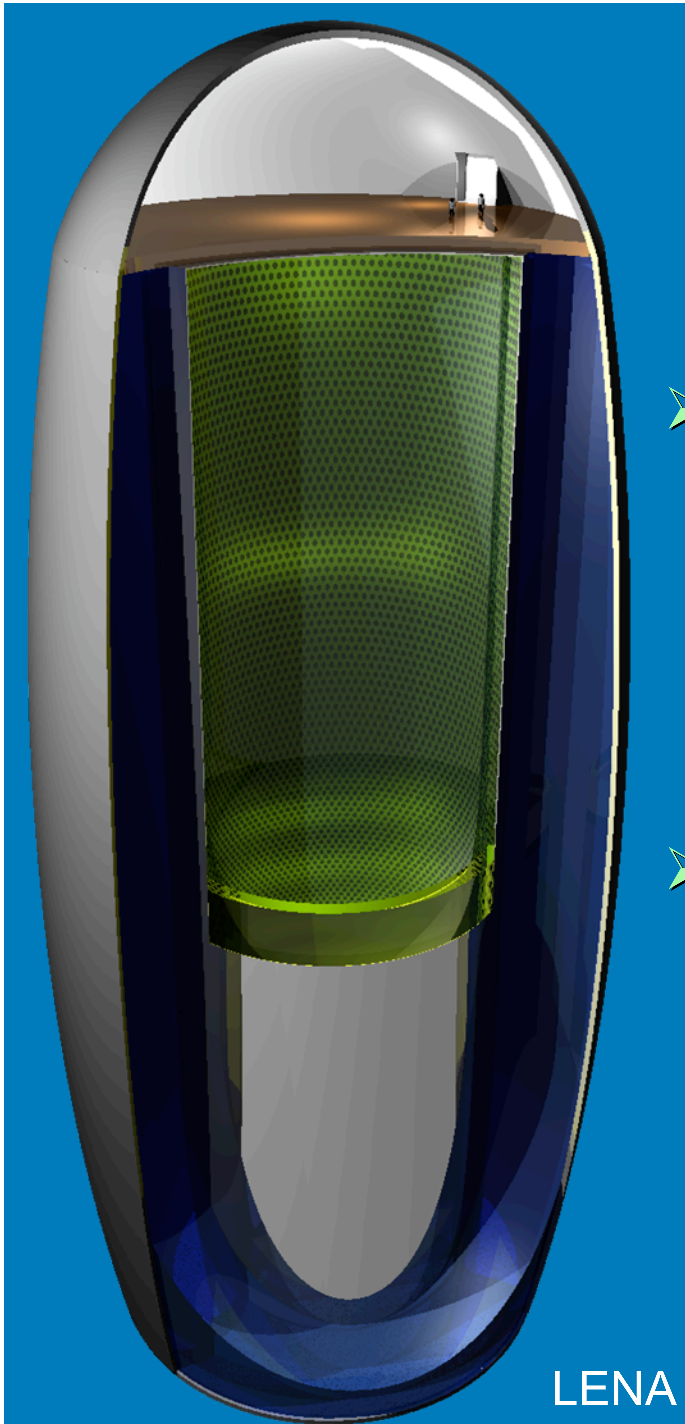


Neutrino Background from Power Plants based on 2009 data (Kai Loo)

Location	Flux [$x10^9$ $m^{-2}s^{-1}$]		Events (Inv. β.) [10^{32} proton year]
	Total	Anti-nu_e	
Pyhäsalmi (FIN)	1.44	0.74	73
Caso (ITA)	2.10	1.07	106
Slanic (ROM)	2.41	1.25	122
Sieroszowice (POI	3.63	1.86	182
Canfranc (ESP)	5.42	2.8	275
Frejus (FRA)	11.9	6.21	645
Boulby (GBR)	25.1	10.5	1470

Measured spectra of reactor neutrinos for U-235,Pu-239 and Pu-241 were used. For U-238 calculated spectra were used.

Event rates were calculated for a KamLand-type scintillator det.



Site examples

- **Slanic** salt mine in Romania
  - The most beautiful site
  - Suitable only for GLACIER
  - 1570 km from CERN
- **Pyhäsalmi** mine in Finland
  - The deepest mine in Europe
  - Suitable for all: LENA, MEMPHYS and GLACIER
  - 2288 km from CERN

Slanic site (Romania)

Skip Slanic


208 m below the ground level


~55 m high, 70 000 m²


DIN TOATE TARILE
CLASA MUNCITOARE


old mining equipment
WC
TOILET
TOILETTE
WC


water ponds


cafeteria
buffet

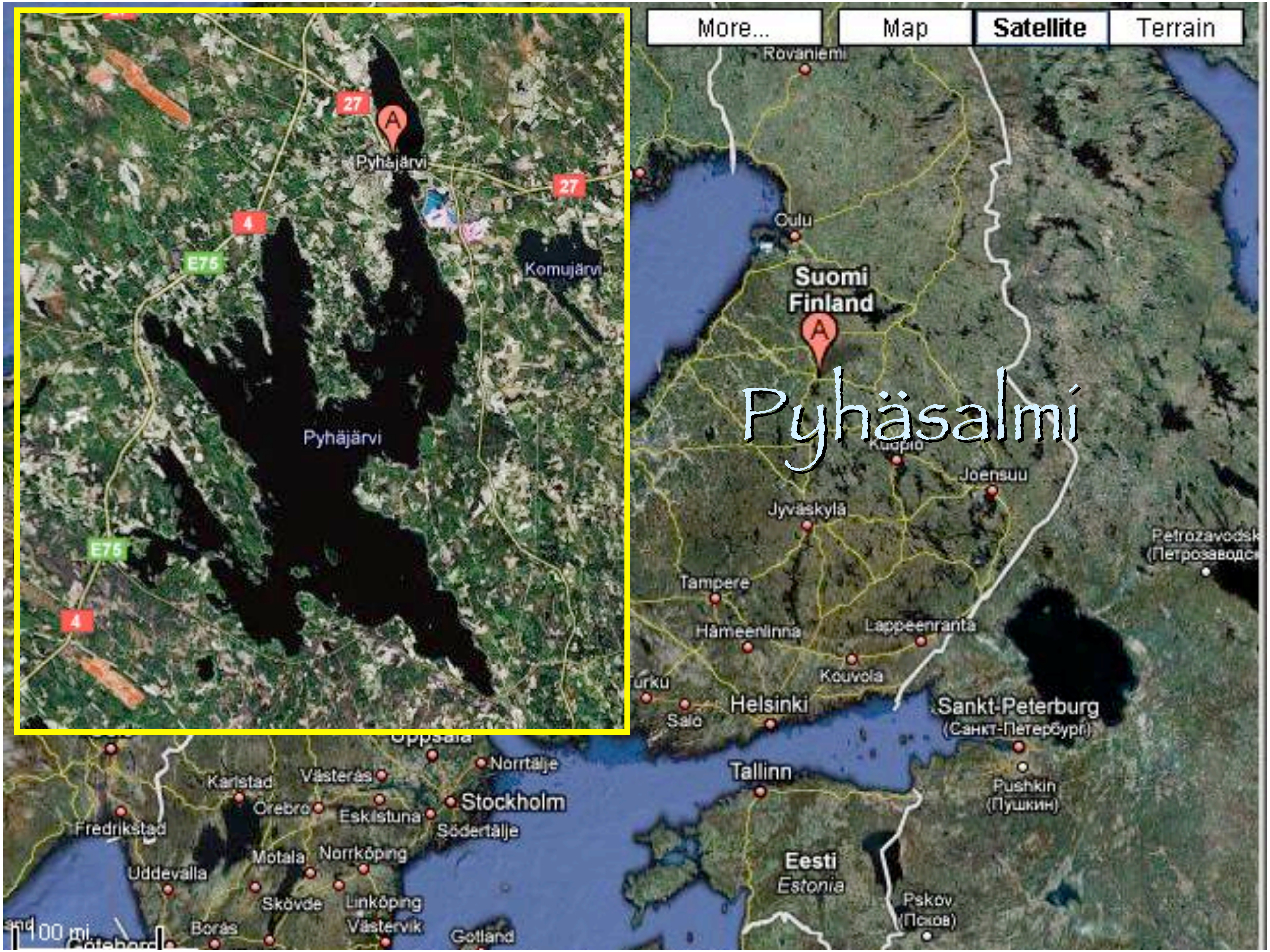

sanatorium


art museum

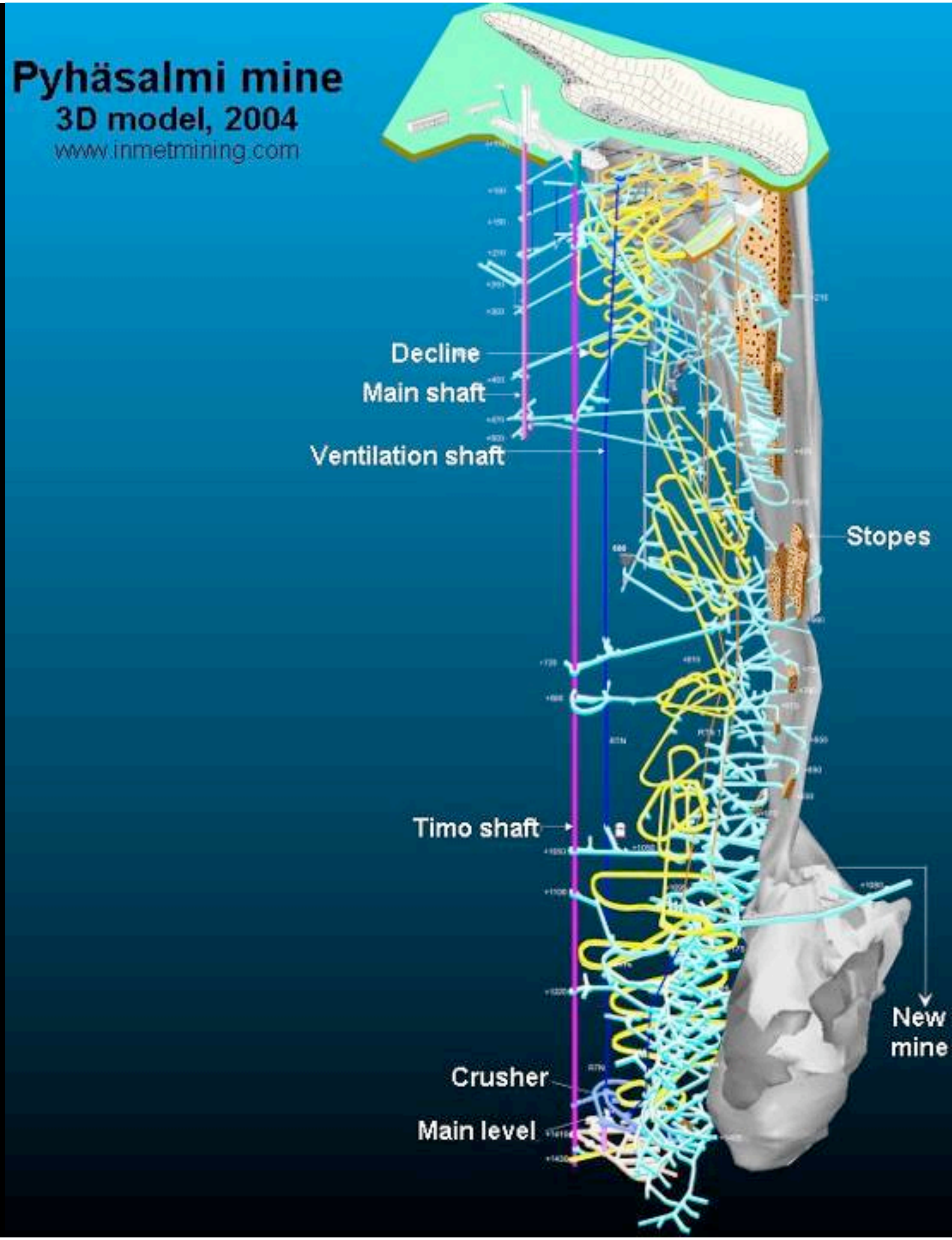

low-background lab
IFIN-HH

Pyhäsalmi site (Finland)

Skip to Conclusions



More...
Map
Satellite
Terrain
Pyhäjärvi
Komujärvi
Pyhäjärvi
27
4
E75
Rovaniemi
Oulu
Suomi
Finland
Pyhäsalmi
Kuopio
Joensuu
Jyväskylä
Tampere
Hämeenlinna
Lappeenranta
Kouvola
Helsinki
Salo
Sankt-Peterburg
(Санкт-Петербург)
Petrozavodsk
Tallinn
Pushkin
(Пушкин)
Eesti
Estonia
Pskov
(Псков)
Karlstad
Västerås
Norrtälje
Örebro
Eskilstuna
Stockholm
Södertälje
Fredrikstad
Motala
Norrköping
Uddevalla
Skövde
Linköping
Västervik
Borås
Gotland
100 mi



Pyhäsalmi mine
3D model, 2004
www.inmetmining.com
Decline
Main shaft
Ventilation shaft
Stopes
Timo shaft
New mine
Crusher
Main level

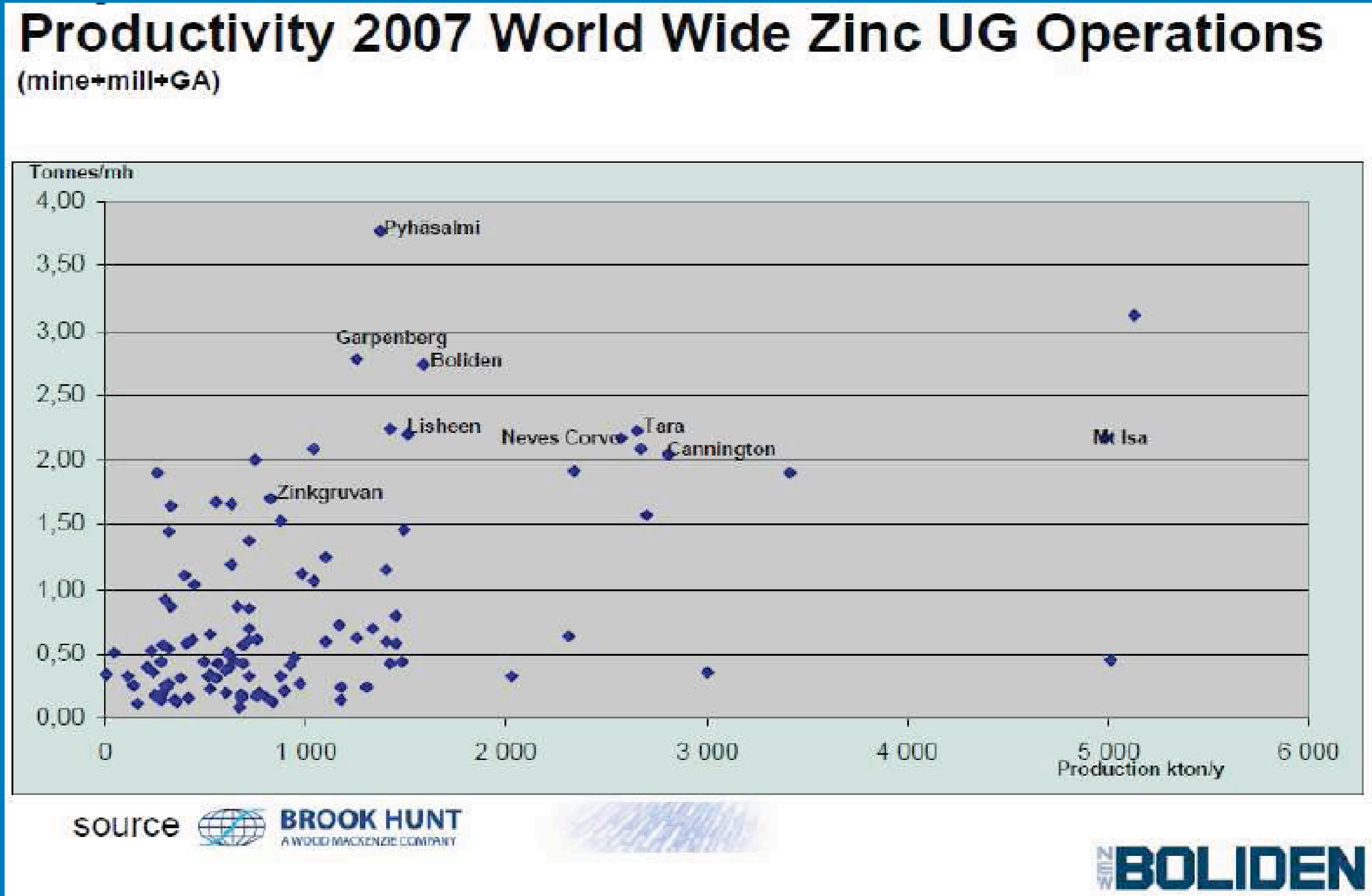

To reach the bottom by car:
11 km serpentine
... or in 3 minutes with the elevator

At 1.4 km below the surface

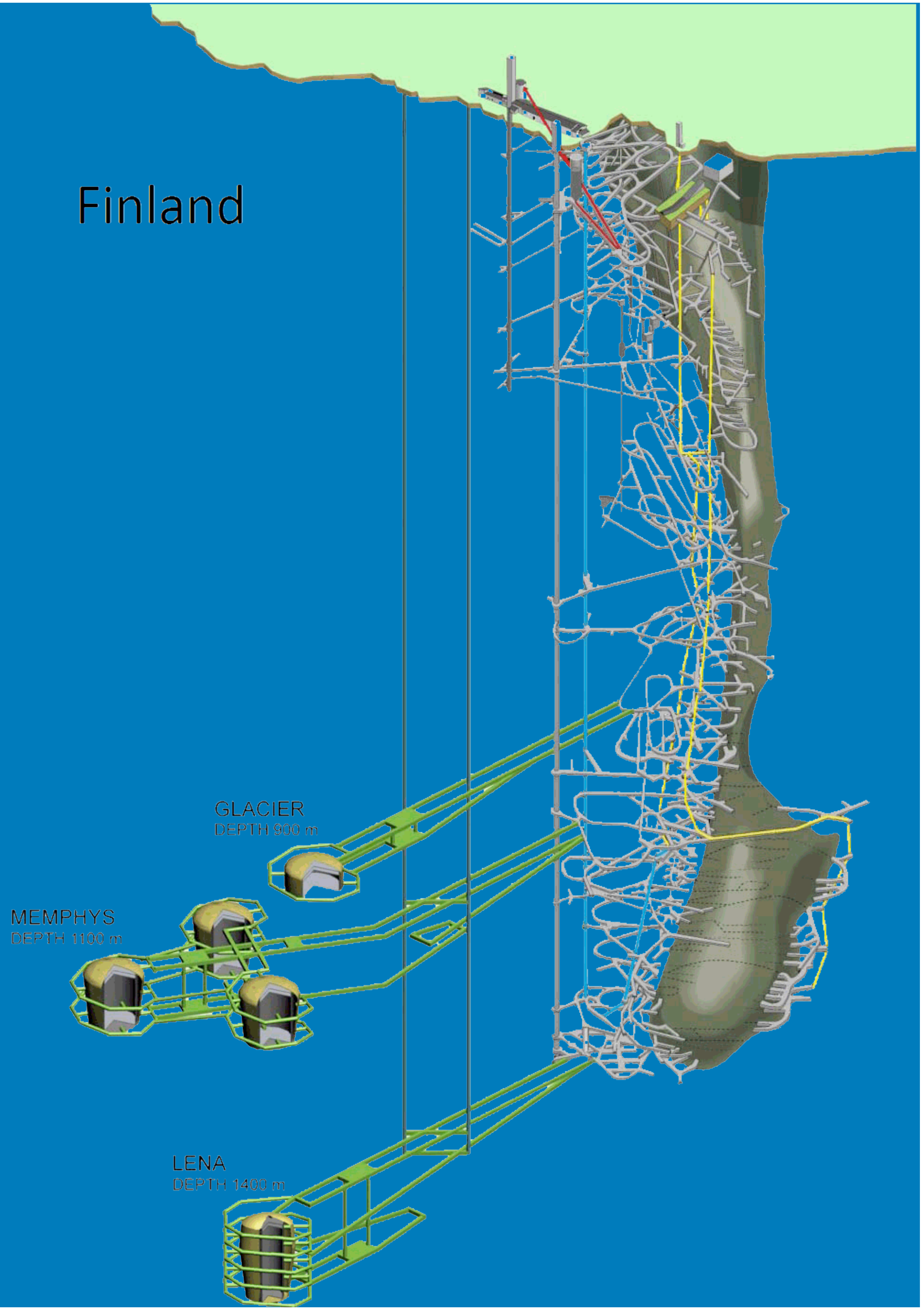
Axera


1
2

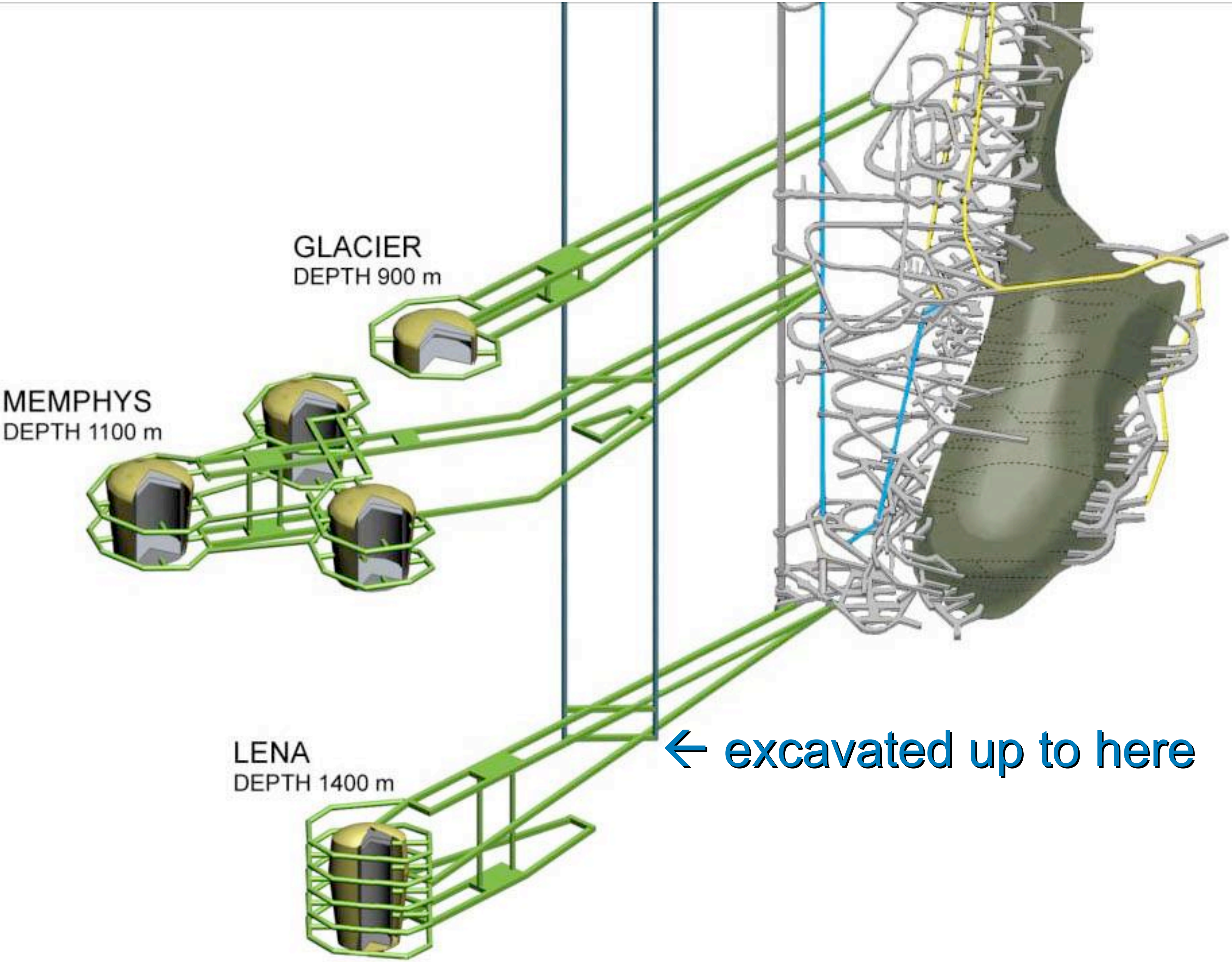
Productivity of the Pyhäsalmi mine



All 3 proposed
LAGUNA detectors
can be safely &
<u>cost-effectively</u>
located in
Pyhäsalmi!



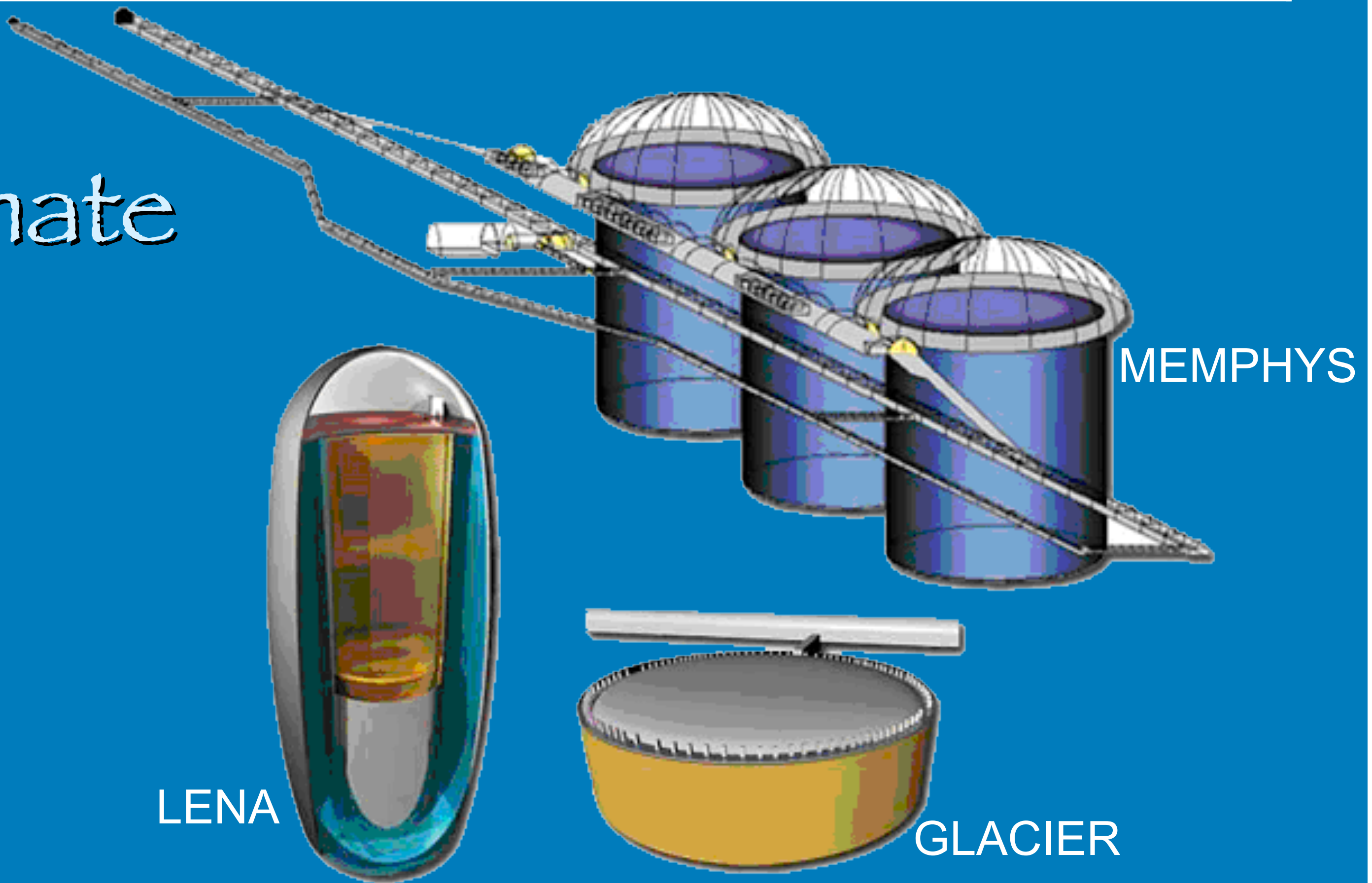

This tunnel was excavated
half way (250 m) towards the
proposed LENA site
HILUX
ZSI·165


GLACIER
DEPTH 900 m
MEMPHYS
DEPTH 1100 m
LENA
DEPTH 1400 m
← excavated up to here

Dry, room temperature conditions at the 1430m level (below the ground)

	GLACIER	LENA	MEMPYS
CAVERN	50 – 75	40 – 85	130 - 200
DETECTOR	380	280	580
TOTAL	455	365	780

Cost estimate (M€)



Summary

- LAGUNA Design Study (FP7 funded) is a very successful project and is well underway
- Feasibility of 3 detector types at 7 sites was evaluated
- We are now finalizing deliverables, adding comparison among sites, and prioritizing the sites:
  - ranking list by Fall 2010 ?
- "LAGUNA NEXT" will be submitted in November 2010
  - long baseline neutrino beam from CERN
- If the project can start in 2013, LAGUNA detectors will come into operation around 2020-2025.