The LAGUNA project (Large Apparatus studying Grand Unification and Neutrino Astrophysics)

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(on behalf of Andre Rubbia, ETH Zürich)

ASPERA workshop „Linking of existing infrastructures”
Berlin, 25.10.2007

Characterization of the LAGUNA project

Answering the asked questions

What is LAGUNA?

The European project „Large Apparatus studying Grand Unification and Neutrino Astrophysics" aiming at defining and realizing this research programme in Europe.

It includes the majority of European groups interested in the construction of the very massive detector (10^5 – 10^6 tons) realized in one of the three technologies using liquids: water, liquid argon and liquid scintillator.

No one of the existing European underground laboratories is able to host such a huge detector → a new large underground infrastructure is needed.

The group applied for the RI Design Study in the framework of FP7 (2.05.2007) with the main goal to study possible localizations of the future laboratory together with further R&D for the proposed detector technologies.

The AppEC roadmap, January 2007

Field/ Experiments	Cost scale (M€)	Desirable start of construction	Remarks
Dark Matter Search: Low background experiments with 1-ton mass	60-100 M€	2011-2013	2 experiments (different nuclei, different techniques), e.g. 1 bolometric, 1 noble liquid; more than 2 worldwide.
Proton decay and low energy neutrino astronomy: Large infrastructure for p-decay and ν astronomy on the 100kt-1Mton scale	400-800 M€	2011-2013	- multi-purpose - 3 different techniques; large synergy between them. - needs huge new excavation - expenditures likely also after 2015 • worldwide sharing • possibly also accelerator neutrinos in long baseline experiments
The high energy universe: *Gamma rays:* Cherenkov Telescope Array CTA	100 M€ (South) 50 M€ (North)	first site in 2010	Physics potential well defined by rich physics from present gamma experiments
Charged Cosmic Rays: Auger North	85 M€	2009	Confirmation of physics potential from Auger South results expected in 2007
Neutrinos: KM3NeT	300 M€	2011	FP6 design study. Confirmation of physics potential from IceCube and gamma ray telescopes expected in 2008-2010
Gravitational Waves: Third generation interferometer	250-300 M€	Civil engineering 2012	Conceived as underground laboratory

The ApPEC roadmap, January 2007

"We recommend that a new large European infrastructure is put forward, as a future international multi-purpose facility on the 100'000-1'000'000 tons scale for improved studies of proton decay and of low-energy neutrinos from astrophysical origin. The three detection techniques being studied for such large detectors in Europe, Water-Cherenkov, Liquid Scintillator and Liquid Argon, should be evaluated in the context of a common design study, which should also address the underground infrastructure, and the possibility of an eventual detection of future accelerator neutrino beams. This design study should take into account worldwide efforts and converge, on a time scale of 2010, to a common proposal."

Research programme

1. Search for the proton decay

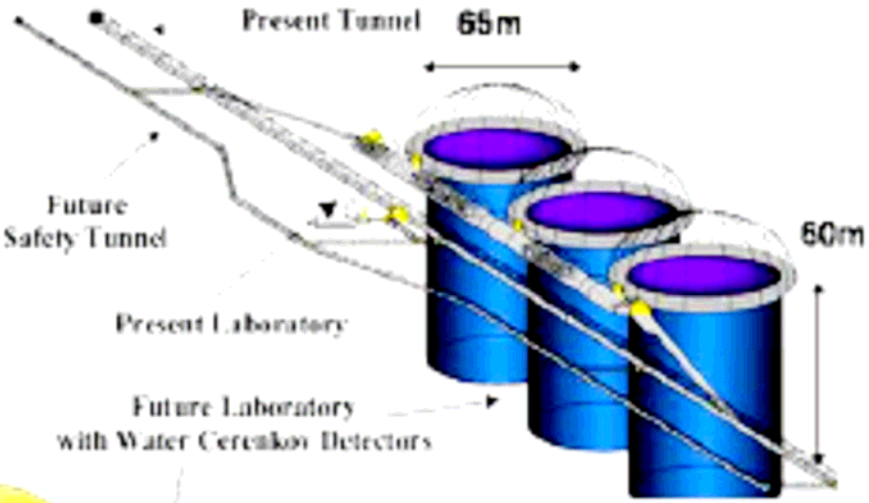
2. Studies of the low energy neutrinos from astrophysical sources (SN explosion, Sun, atmosheric neutrinos, relic SN neutrinos in our galaxy) and of the geo-neutrinos

3. Studies of the neutrino properties based on accelarator neutrino beams

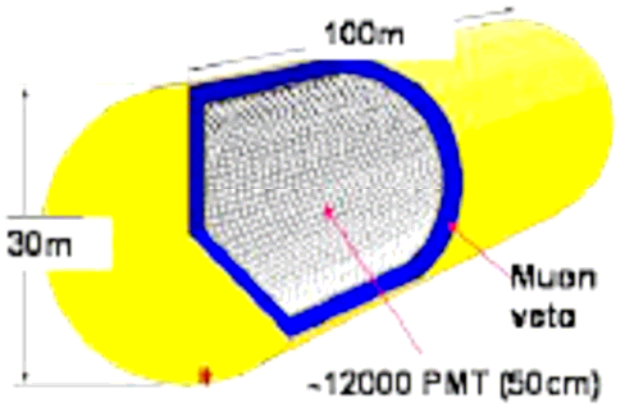
Detector concepts

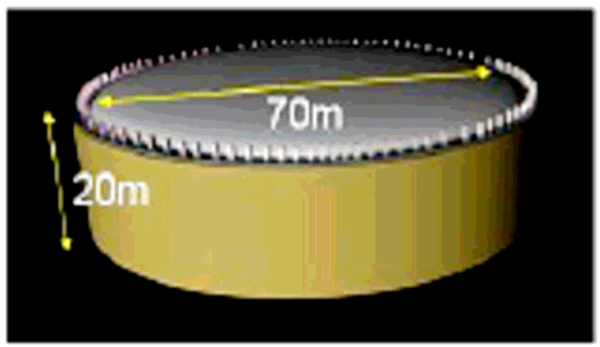
Three liquids: water (MEMPHYS), scintillator (LENA), liquid argon (GLACIER)

MEMPHYS:
Water Cherenkov,
(420 kton -1 Mton)



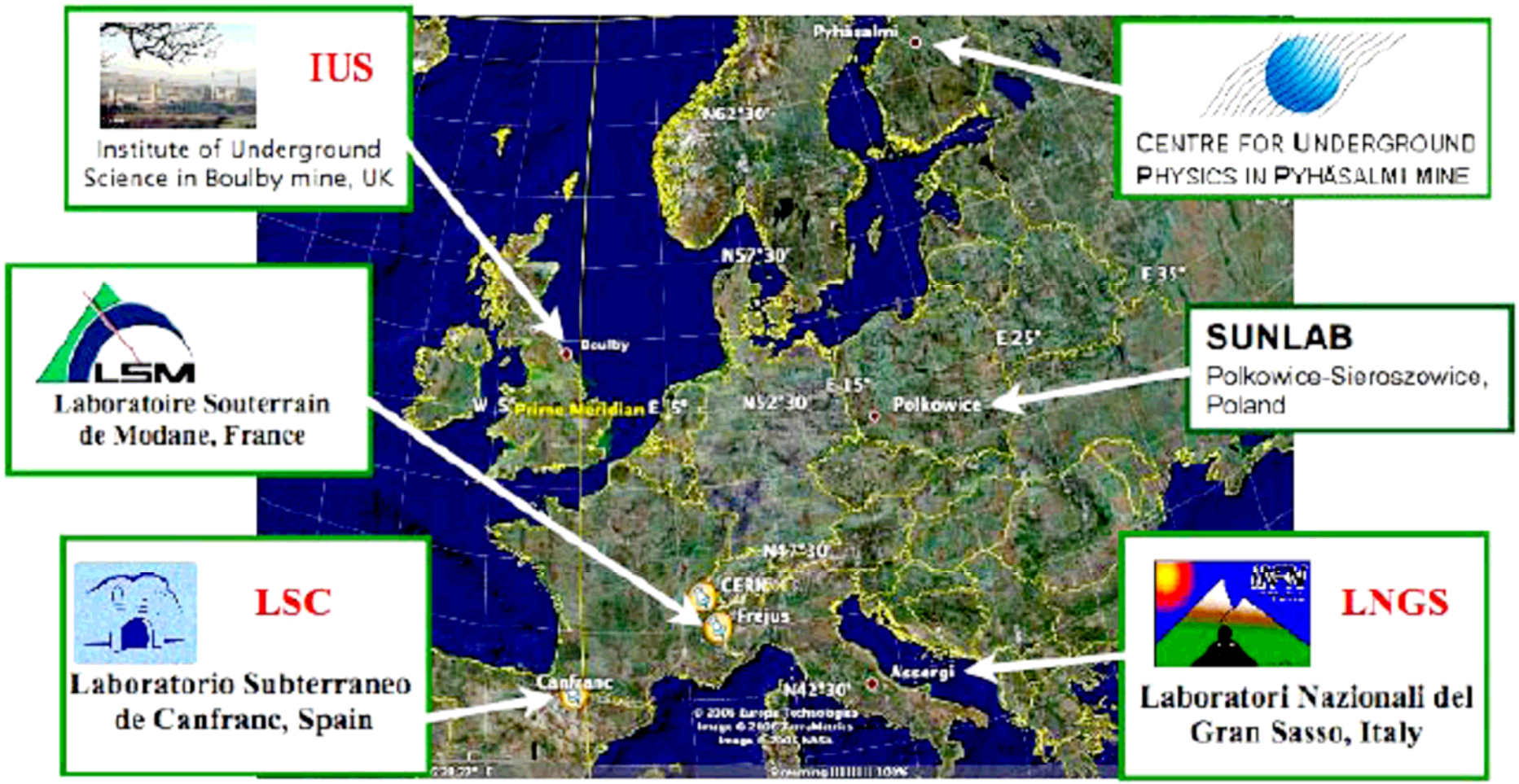
LENA:
Liquid Scintillator
(30-70 kton)





GLACIER: Liquid Argon (50 -100 kton)

Possible localizations of the future large underground laboratory



COLLABORATIVE PROJECT 2.05.2007

Design Study

FP7-INFRASTRUCTURES-2007-1

Proposal title (max 200 characters)	**Design of a pan-European Infrastructure for Large Apparatus studying Grand Unification and Neutrino Astrophysics**
Proposal acronym	**LAGUNA**
Type of funding scheme	RI design study implemented as Collaborative Project
Work programme topics addressed	Deep underground science, particle physics, astroparticle physics
Name of the coordinating person	**Prof. André Rubbia**

List of participants:

Participant no.	Participant organisation name	Country
1. ETH Zurich	Swiss Federal Institute of Technology Zurich	Switzerland
2. U-Bern	University of Bern	Switzerland
3. U-Jyväskylä	University of Jyväskylä	Finland
4. U-Oulu	University of Oulu	Finland
5. Rockplan	Kalliosuunnittelu Oy Rockplan Ltd	Finland
6. CEA/ DSM/ DAPNIA	Commissariat à l'Energie Atomique /Direction des Sciences de la Matière	France
7. IN2P3	Institut National de Physique Nucléaire et de Physique des Particules (CNRS/IN2P3)	France
8. MPG	Max-Planck-Gesellschaft zur Förderung der Wissenschaften e.V.	Germany
9. TUM	Technische Universität München	Germany
10. U-Hamburg	Universität Hamburg	Germany
11. IFJ PAN	H.Niewodniczanski Institute of Nuclear Physics of the Polish Academy of Sciences, Krakow	Poland
12. IPJ	A.Sołtan Institute for Nuclear Studies	Poland
13. US	University of Silesia	Poland
14. UWr	Wroclaw University	Poland
15. KGHM CUPRUM	KGHM CUPRUM Ltd Research and Development Centre	Poland
16. IGSMiE PAN	Mineral and Energy Economy Research Institute of the Polish Academy of Sciences	Poland
17. LSC	Laboratorio Subterraneo de Canfranc	Spain
18. UGR	University of Granada	Spain
19. UDUR	University of Durham	United Kingdom
20. U-Sheffield	The University of Sheffield	United Kingdom
21. Technodyne	Technodyne International Ltd	United Kingdom
22. ETL	Electron Tubes	United Kingdom
23. U-Aarhus	University of Aarhus	Denmark
24. AGT	AGT Ingegneria Srl, Perugia	Italy

Berlin, 25.

Work package no.	Work package title	Type of activity	Lead participant no.	Person-months	Start month	End month
WP1	Management, coordination and assessment	MGT	ETHZ	52	1	36
WP2	Underground Infrastructures and Engineering	RTD	U-Oulu	221	1	35
WP3	Tank Infrastructure and Liquid Handling	RTD	TUM	249	1	35
WP4	Tank Instrumentation and Data Handling	RTD	IN2P3	439	1	35
WP5	Safety and environmental issues	RTD	U-Sheffield	65	1	35
WP6	Science Impact and Outreach	RTD	IFJ PAN	454	1	35
	TOTAL			**1480**		

Localization of the future laboratory

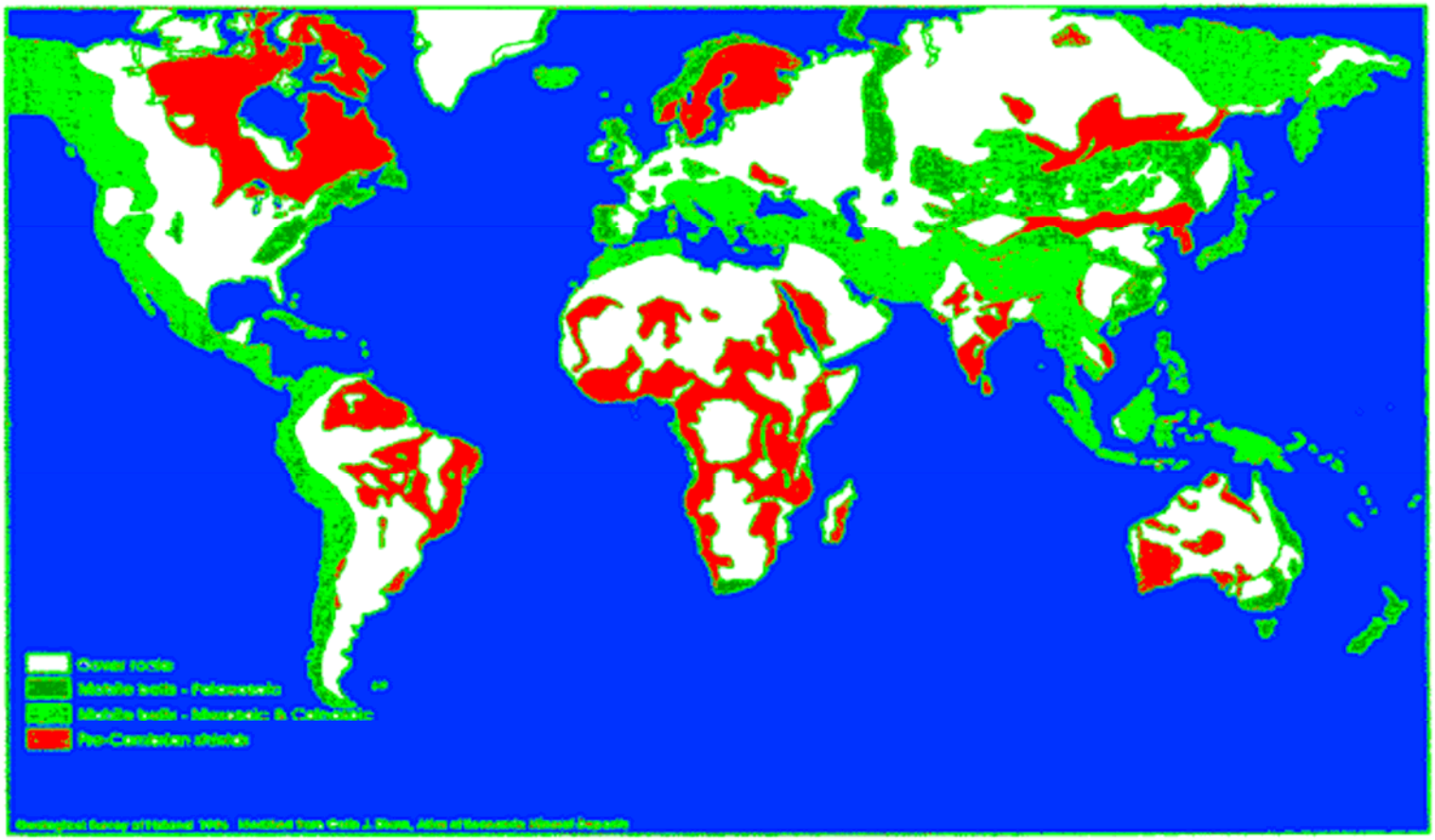
Very preliminary sites vs experiments

		Mt Water Cerenkov	50 kt Liquid Scintillator	100 kt Liquid Argon
Fréjus	Tunnel / hard rock	√√√	√√	√√
Gran Sasso	Tunnel / soft rock	√	√√	√
Canfranc	Tunnel	?	?	?
Pyhäsalmi	Mine / hard rock	√	√√√	√√
Boulby	Mine / salt (potash)	?	?	?
Polkowice - Sieroszowice	Mine / salt & rock	√	√√	√√√
Green fields	Own shaft / Hard rock	√	√	√√√

√√√ primary interest; √√ probably; √ unlikely; ? unknown

Bedrock zones in the Earth

- Red: very old bedrock, hard crystalline rock: usually very good
- Green: mobile belts (mountains etc), hard rock: fair/variable
- White: sedimentary covers (soft rock): often bad
- Local variations within each zone



Nuclear reactor background

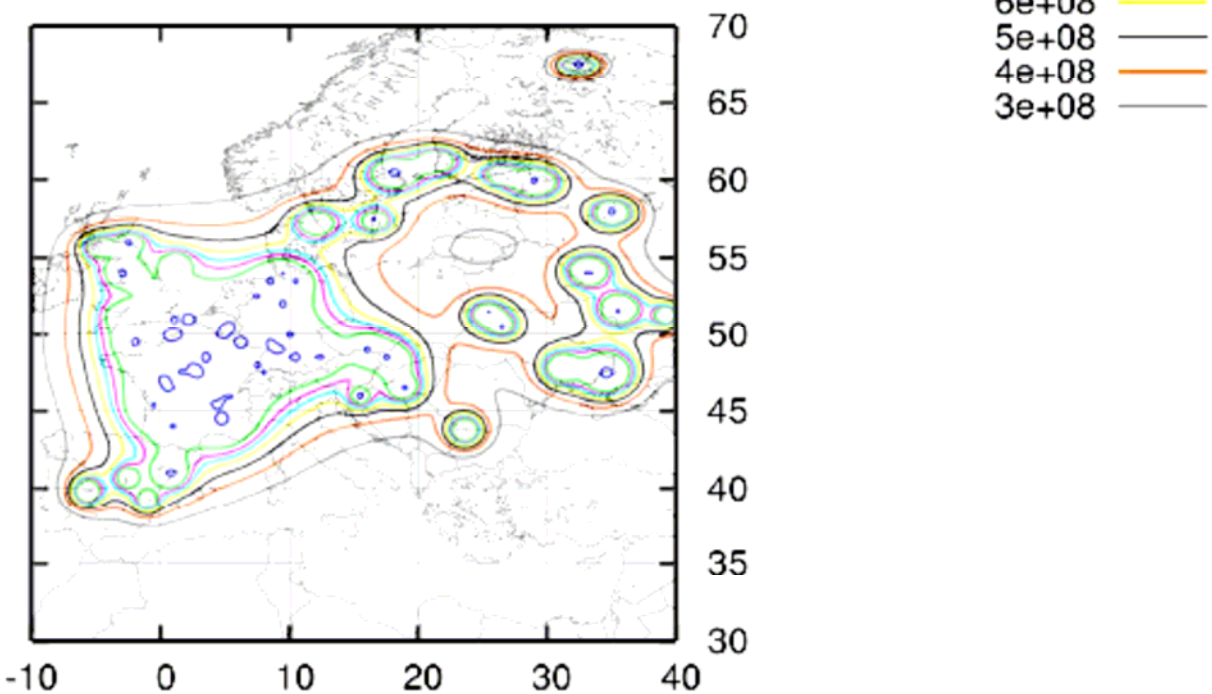
- Relevant mostly for LENA
- Reactor fluxes estimated globally
- Marine reactors irrelevant?

Location	ν (10^8 1/m² s)
Pyhäsalmi	40
Gran Sasso	54
Frejus	175
Canfranc	196
Boulby	190
Kamioka	408
Sudbury	100
Soudan	33
Pylos	12

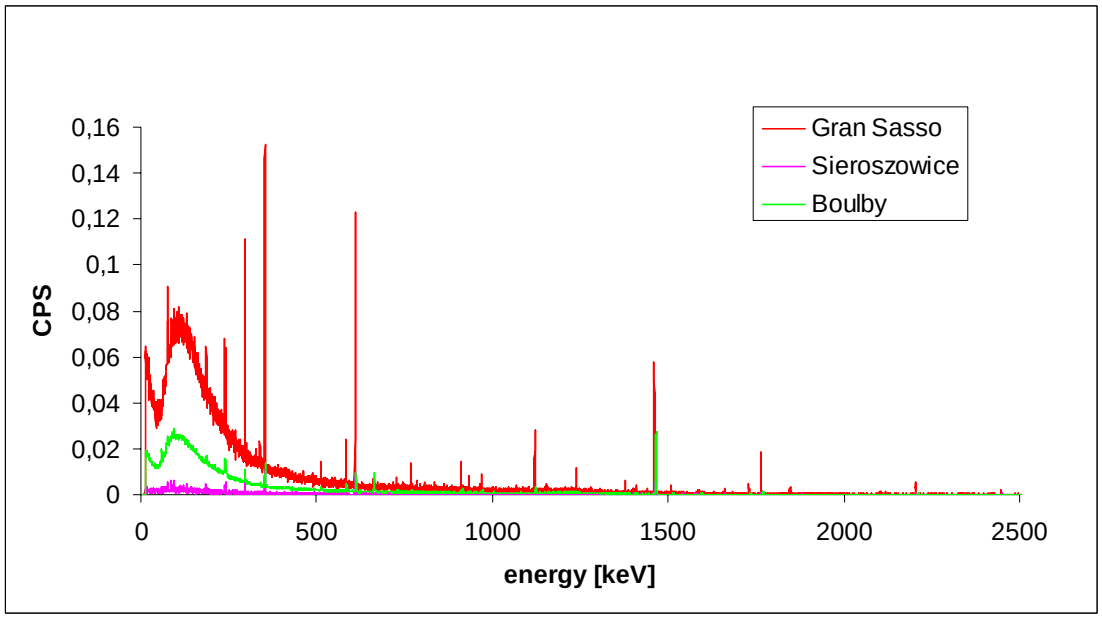
2005

Reactor electron anti-neutrino flux density

Prediction for 2015



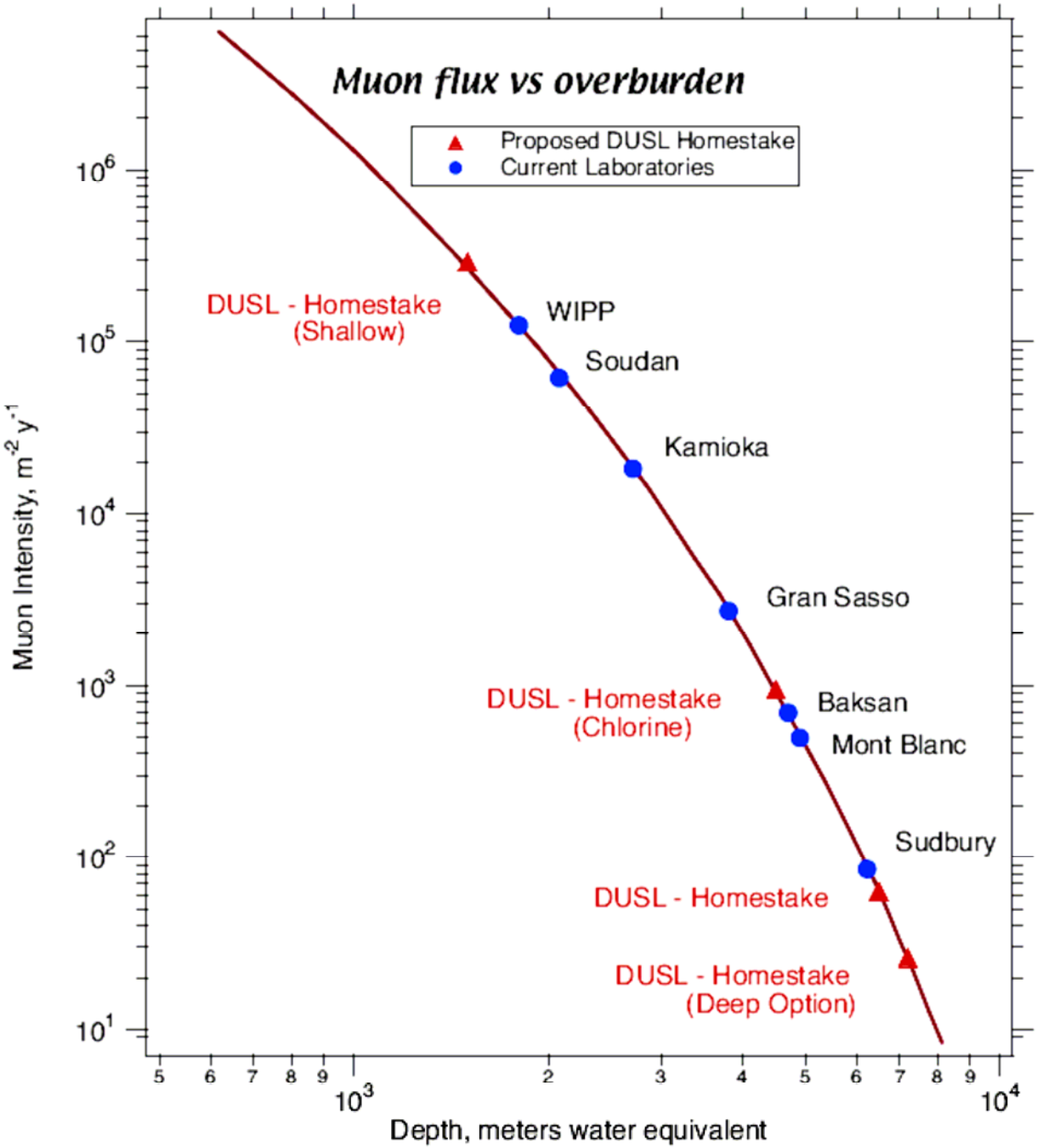
Background due to natural radioactivity

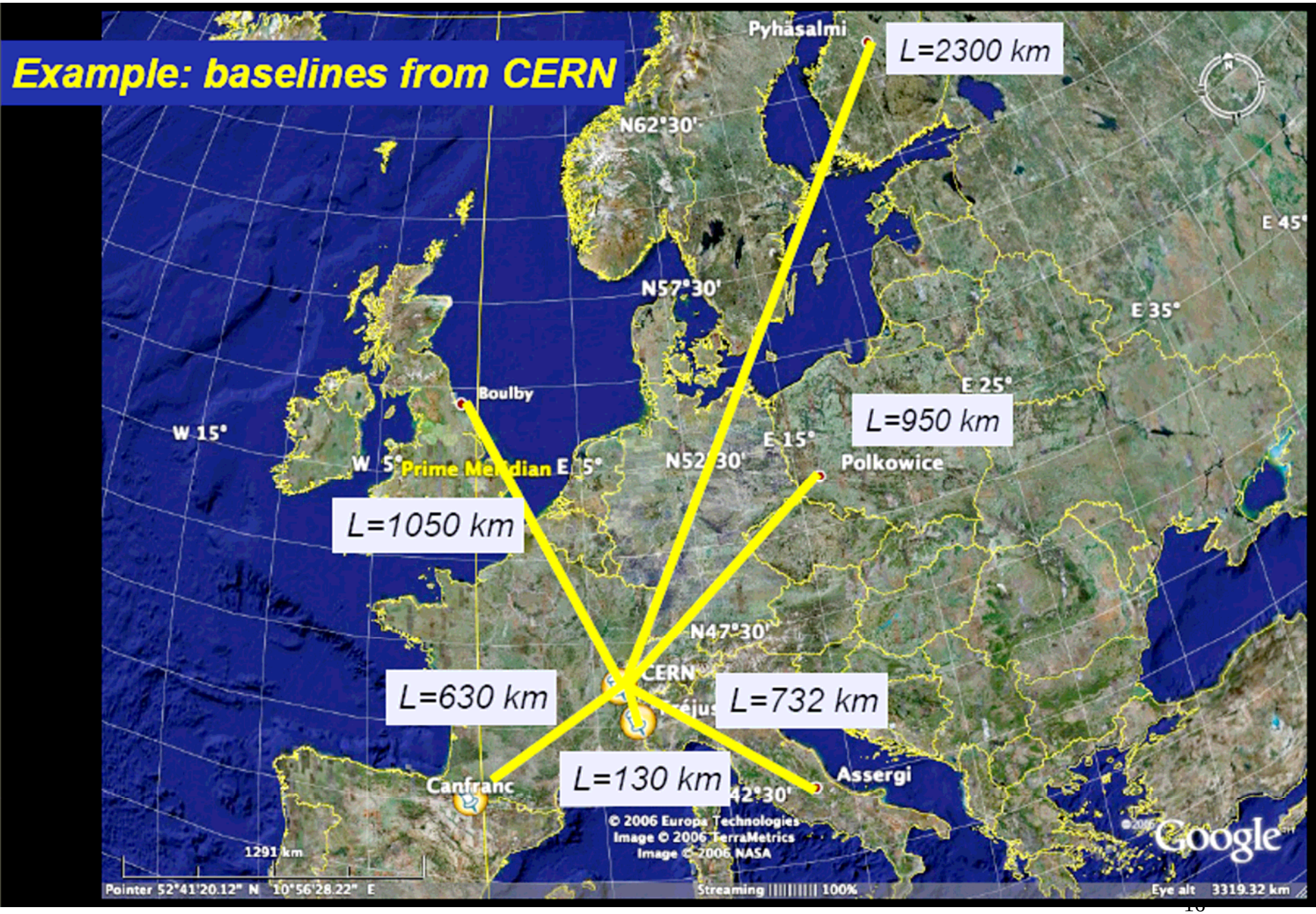


J.Kisiel et al..

In situ measurements: GS, Boulby, Sieroszowice
Integral background counting rates

Energy [keV]	Gran Sasso	Boulby	Sieroszowice
50-2700	57.68 (0.05)	17.00 (0.01)	2.30 (0.02)

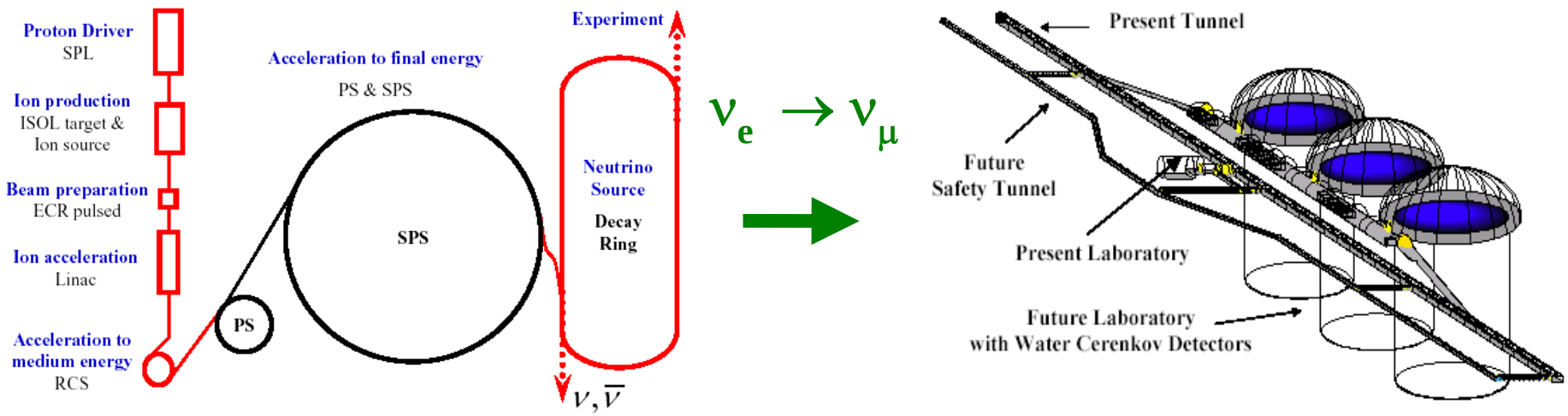

Muon flux vs overburden
Proposed DUSL Homestake
Current Laboratories
DUSL - Homestake
(Shallow)
WIPP
Soudan
Kamioka
Gran Sasso
DUSL - Homestake
(Chlorine)
Baksan
Mont Blanc
Sudbury
DUSL - Homestake
DUSL - Homestake
(Deep Option)
Muon Intensity, m-2 y-1
Depth, meters water equivalent


Example: baselines from CERN
Pyhäsalmi
L=2300 km
N62°30'
N57°30'
E 45°
E 35°
E 25°
Boulby
L=950 km
W 15°
E 15°
W 5°
Prime Meridian
E 5°
N52°30'
Polkowice
L=1050 km
N47°30'
CERN
L=630 km
L=732 km
L=130 km
Canfranc
Assergi
42°30'
© 2006 Europa Technologies
Image © 2006 TerraMetrics
Image © 2006 NASA
1291 km
Google
Pointer 52°41'20.12" N 10°56'28.22" E
Streaming 100%
Eye alt 3319.32 km

Neutrinos from β beam – MEMPHYS

- Acceleration of ^{6}He nuclei (source of antineutrinos) and of ^{18}Ne nuclei (source of neutrinos), R&D in the framework of EURISOL DS. (FP6)

- ...But a small obstacle (worth ~1 billion CHF) – the programme requires a serious intervention into the CERN accelerator chain, also problems with poor knowledge of low energy neutrino cross-sections



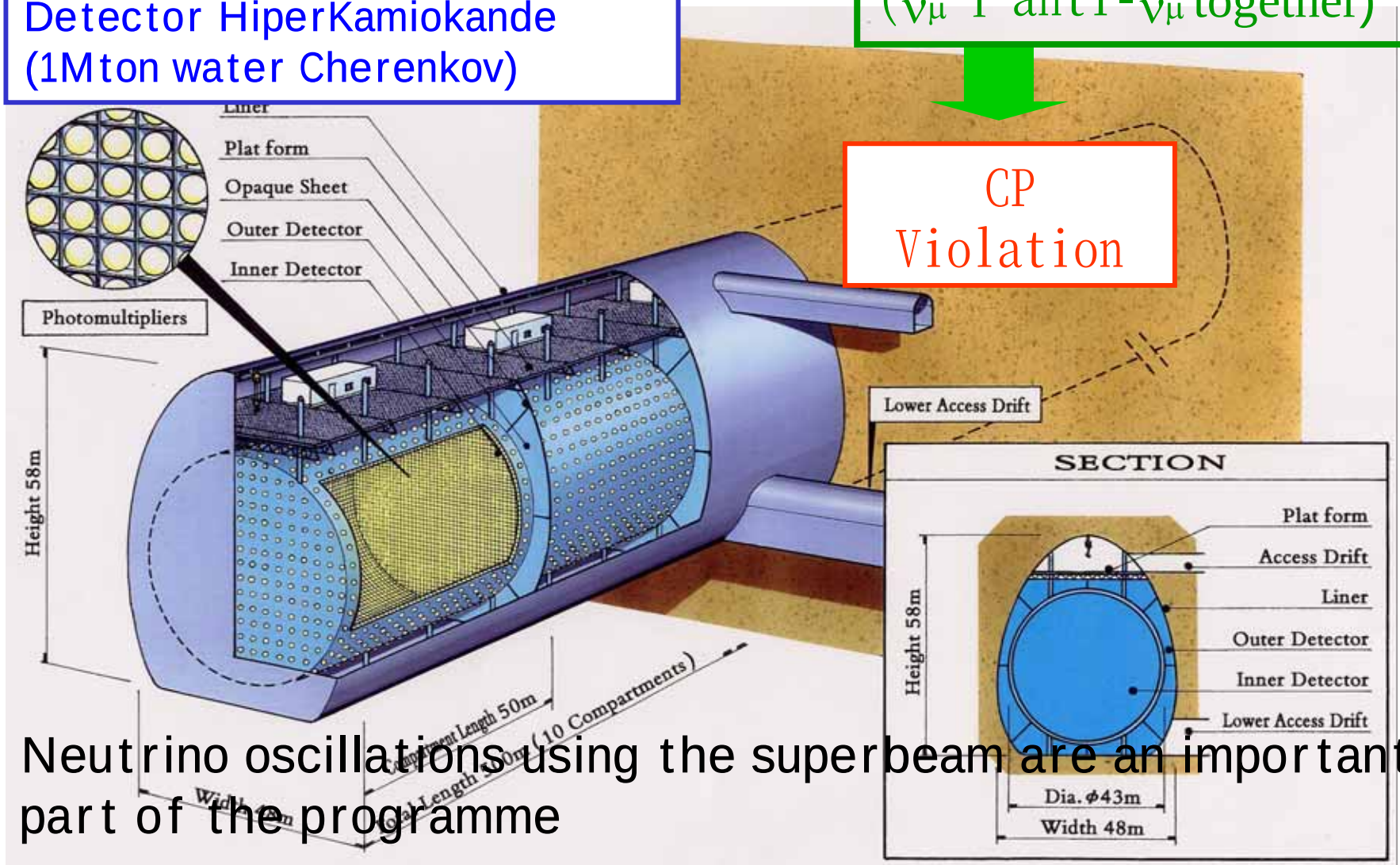
Outside Europe: Japan – T2K phase II (?)

Accelerator: 4 MW

Detector HiperKamiokande
(1Mton water Cherenkov)

10^6 events
(ν_μ i anti-ν_μ together)

CP
Violation



Neutrino oscillations using the superbeam are an important part of the programme

Outside Europe: USA - DUSEL

DUSEL – Deep Underground Science and Engineering Laboratory

Very rich interdisciplinary programme – from fundamental physics, through biology and egineering studies to the education and outreach.