LAGUNA – LBNO Strategy Update

as defined at the kickoff meeting at
CERN 17 – 19 October 2011

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LAGUNA-LBNO kickoff meeting
CERN 17-19 Oct. 2011

3-fold growth from DS to LBNO

LAGUNA DS: 2008 – 2011 **~100 members**, 10 countries, **1.7 M€**

LAGUNA-LBNO: 2011 – 2014 **~300 members**, 13 countries, **4.9 M€**

What is new in LAGUNA-LBNO vs. DS?

- Input from LAGUNA DS
- Prioritization
- Incremental approach
- Magnetization (bimagic baseline)
- Clear timetable
  - 2013 – European Strategy Update for Particle Physics
  - 2014 – end of LAGUNA-LBNO
  - 2018 – closing of the Pyhäsalmi mine
- Need for stronger consolidation

Outcome of LAGUNA DS

- Required caverns are technologically feasible
  - The required caverns can be constructed at a reasonable cost and in relatively short time
  - Safety requirements can be fulfilled at all stages of the project (excavation, instrumentations, operation)
  - There were no show-stoppers encountered
- Cavern construction is not the dominant cost (10 – 20 %) → so why not 2?
- Physics factors should determine site selection

Astroparticle Physics for Europe

The main physics factors:

Distance from CERN (or other accelerator)

Topic of **LAGUNA – LBNO**

Overburden , in general – the more the better

Must meet the criteria required by the detector

GLACIER ≥ 2500 m.w.e (900 m of rock)

LENA ≥ 4000 m.w.e (1400 m of rock)

MEMPHYS ≥ 3000 m.w.e (1100 m of rock)

Reactor neutrino background & geo-ν flux

Relevant only to LENA (geo-neutrinos, diffuse SN)

Detector requirements:

GLACIER ≥ 2500 m.w.e (900 m of rock)
LENA ≥ 4000 m.w.e (1400 m of rock)
MEMPHYS ≥ 3000 m.w.e (1100 m of rock)

Deep:

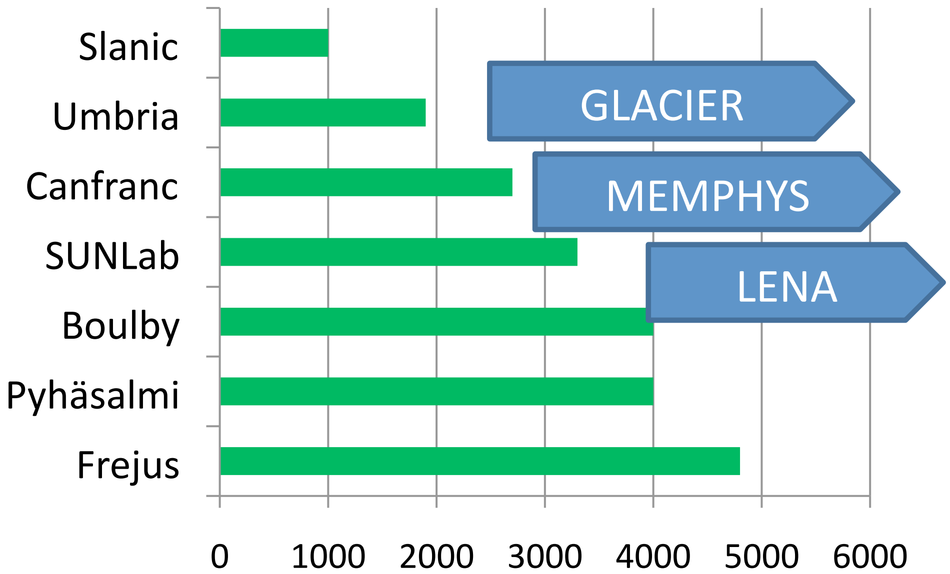
- **Fréjus** – 4800 mwe
- **Pyhäsalmi** – 4000 mwe
- **Boulby** – 4000 mwe

Moderate:

- **SUNLab** – 3300 mwe
- **Canfranc** – 2700 mwe

Shallow:

- **Umbria** – 1900 mwe
- **Slanic** – 1000 mwe



Status before prioritization:

LAGUNA-LBNO (2011- 2014)

Focus on the feasibility and physics potential of utilizing neutrino beams from CERN

Three main options:

- WC @ Frejus (+ LS option)
- LAr @ Pyhäsalmi
- LS @ Pyhäsalmi

Two main sites

One reserve option:

- LAr @ Umbria

Astroparticle Physics for Europe

The EU design study "menu"

2008 — time — 2011 — 2014

LAGUNA

- far detector "RI" for astroparticle and beam physics
- three detector options
- seven potential sites
- excavation costs
- industrial links

LAGUNA-LBNO

- international consortium including EU, Japan and Russia
- two main far sites
- new conventional beam from SPS
- high energy MW-superbeam (HP-PS)
- near detector infrastructure
- detector magnetization
- detector construction and costs

EuroNu

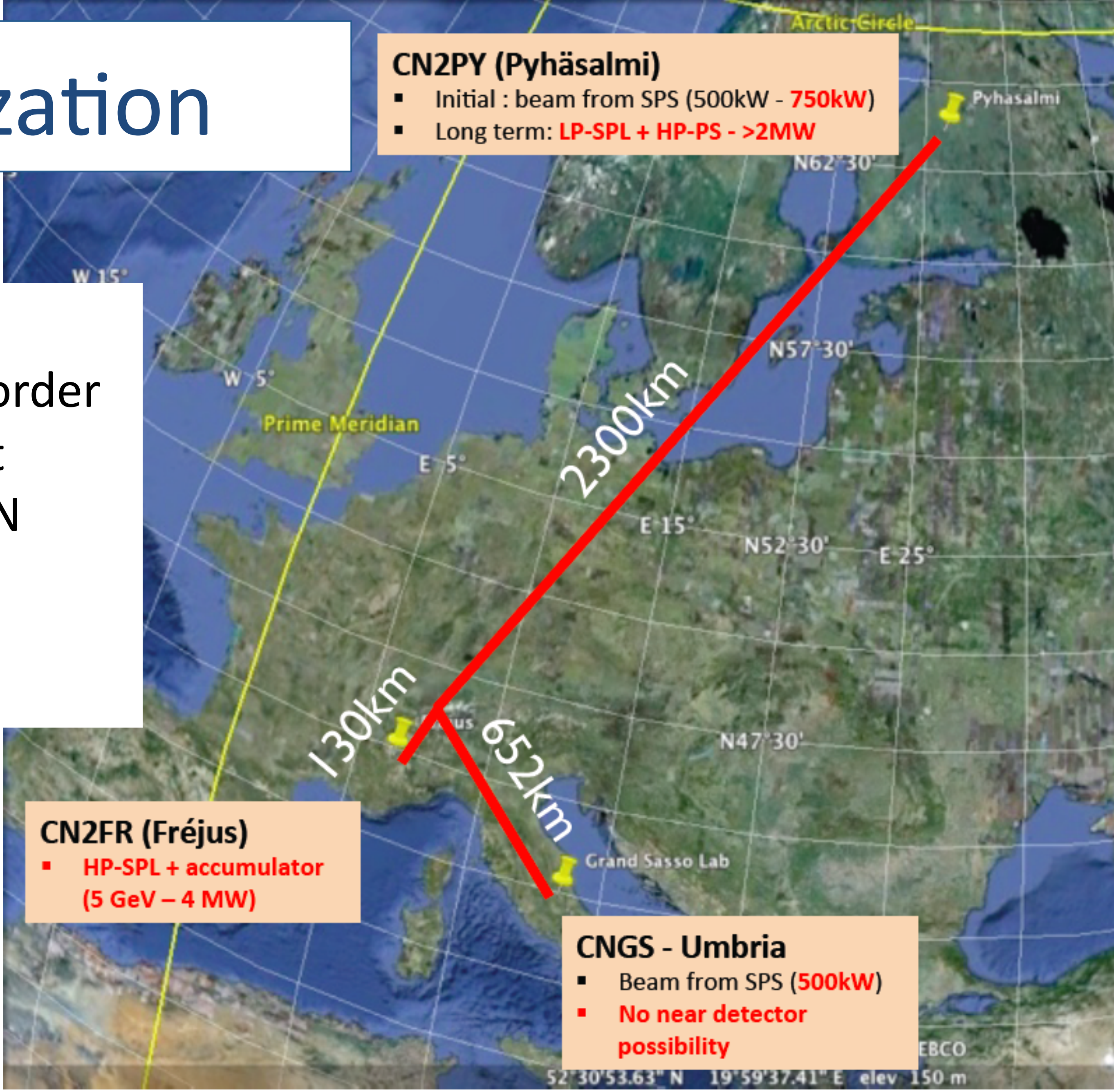
- international consortium
- low energy MW-superbeam (HP-SPL)
- beta beam
- neutrino factory
- costs
- comparison of facilities

-Update European Strategy for Particle Physics

next step(s) ?

Prioritization

- We start with the Pyhäsalmi site in order to have the report ready for the CERN review in 2013



7 European sites

"reduced" to 3 and "prioritized" to 1:

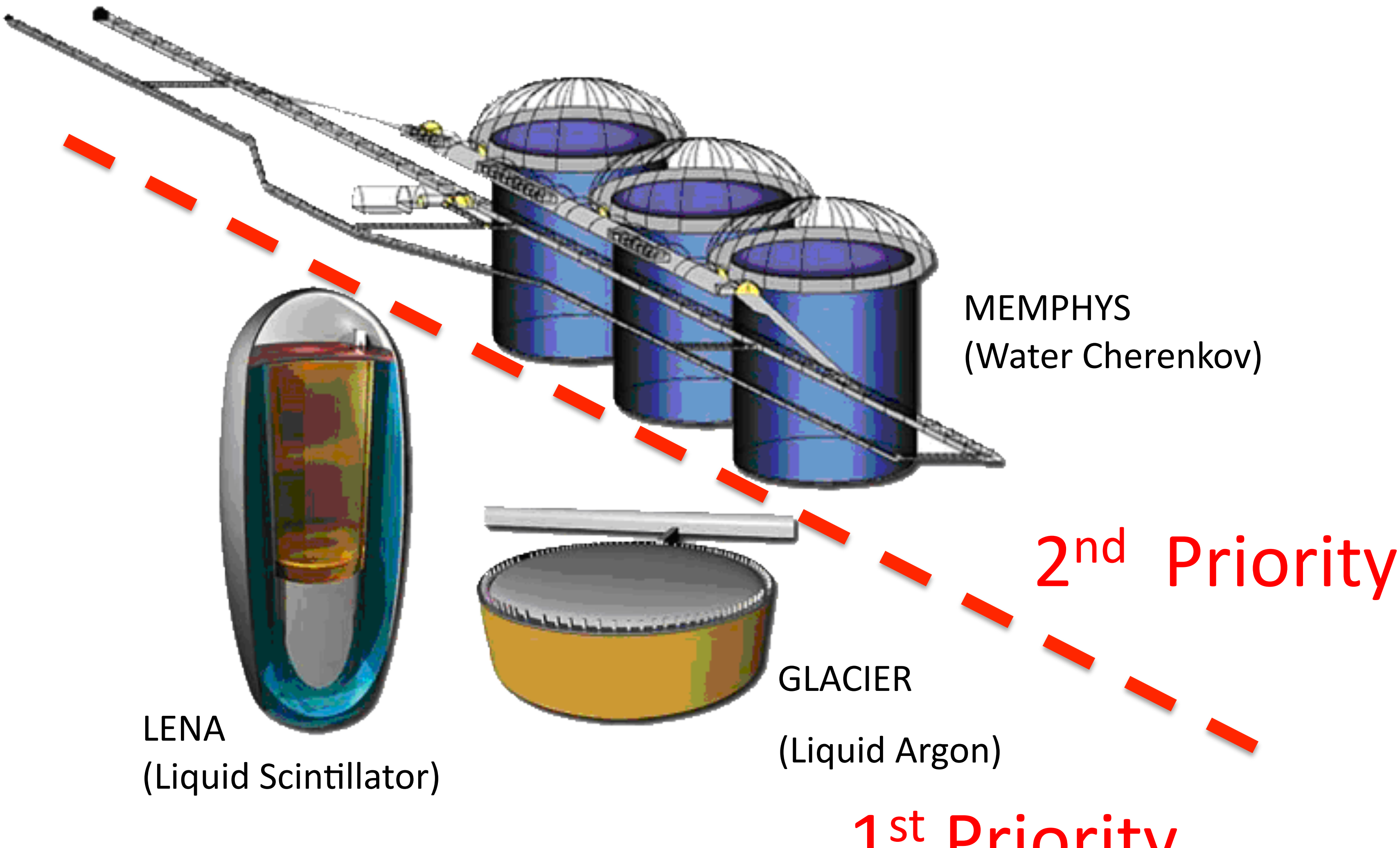
- Pyhäsalmi Finland (mine), ← **Highest priority!**
- Sieroszowice Poland (mine),
- Boulby UK (mine),
- Slanic Romania (mine),

- Fréjus France (road tunnel), ← 2nd priority
- Canfranc Spain (road tunnel),

- Umbria Italy (a virgin site). ← 3rd priority

Astroparticle Physics for Europe

Three detector options



Example of incremental approach

- **A possible way to realize the full LAGUNA facility at Pyhäsalmi:**
  - Phase 0 : full excavation (two+two caverns @900m+1400m) and preparation of underground space
  - Phase 1: LAr 20kt @ 900m + LSc 25kt @ 1400m + Fe detector
  - Phase 2: add LAr 50kt @ 900m + add 2nd LSc 25kt + add Fe
  - Phase 3: replace LAr 20kt by LAr 50kt + add Fe

Produce significant physics results at each phase
Reduce overall risks
Alleviate some funding challenges w/ acceptable total cost
Leave possibility to alter the direction after each phase

LAGUNA-LBNO, GA – 284518
KICK OFF MEETING CERN:
OCT. 17th – 19th, 2011

INFLUENCE OF INCREMENTAL APPROACH ON EXCAVATION COSTS (PRELIMINARY)

ROCKPLAN

1 FULL SIZE MAIN DETECTOR CAVERN

508.002	LAGUNA -LBNO	**FULL SIZE DETECTORS**								
	INCREMENTAL APPROACH FOR LSc and LAr @ PYHÄSALMI & COMBINED REALIZATION									
	INFLUENCE ON EXCAVATION COSTS									
FULL SIZE EXPERIMENT		volume	**LAr @ Pyhäsalmi**		volume	**LSc @ Pyhäsalmi**		volume	**LAr & LSc @ Pyhäsalmi**	
		100 kton			**50 kton**			100 kton + 50 kton		
Preparation costs (M€)				7,00			9,00			14,00
	- General & rock mechanical design		2,50			3,50			5,00	
	- Development & consulting service		2,00			2,50			4,00	
	- Site investigations		2,50			3,00			5,00	
Excavation costs (M€)		277'000 m^3		21,10	427'000 m^3		33,50	691'000 m^3		45,40
	- Main Detector Cavern, MDC	156'000 m^3	5,60		234'000 m^3	8,50		390'000 m^3	14,10	
	- other caverns, tunnels and shafts	121'000 m^3	10,70		193'000 m^3	18,00		301'000 m^3	22,80	
	- additional excavation costs		4,80			7,00			8,50	
Reinforcement costs (M€)				17,80			32,10			42,40
	- bolting of MDC		1,20			3,50			4,70	
	- bolting of other spaces		5,80			10,10			12,90	
	- shotcreting of MDC		2,70			5,20			7,90	
	- shotcreting of other spaces		7,90			12,60			16,00	
	- other related costs		0,20			0,70			0,90	
TOTAL COSTS OF EXCAVATION (M€)				**45,90**			**74,60**			**101,80**
								synergy in combining shafts		
NOTE	**The change in excavation costs, if one decides to construct two half size caverns similarily**							synergy in decline maintenance		
	instead of one big cavern, is minimal (about 2...3% increase)							savings up to		**18,70**

LIQUID ARGON DETECTOR CAVERN

508.002	LAGUNA -LBNO		LIQUID ARGON			
	INCREMENTAL APPROACH FOR LSc and LAr @ PYHÄSALMI					
	EXPERIMENT SIZE vs. MAIN DETECTOR CAVERN					
EXPERIMENT		1 kton	10 kton	50 kton	100 kton	
volume	m3	770	7 700	38 500	77 000	
height	m	10,0	20,0	20,0	20,0	
diameter	m	9,9	22,1	49,5	70,0	
TANK - DETECTOR						
volume	m3	1 575	12 534	56 078	109 139	
height	m	13,3	26,5	26,5	26,5	
diameter	m	12,3	24,5	51,9	72,4	
MAIN DETECTOR CAVERN						
volume	m3	2 891	17 756	78 113	156 009	
height-wall	m	14,8	28,0	28,0	28,0	
height-dome	m	2,2	4,0	7,5	10,0	
height-total	m	17,0	32,0	35,5	38,0	
diameter	m	15,0	27,0	54,5	75,0	
rel.volume		2 %	11 %	50 %	100 %	

LIQUID SCINTILLATOR DETECTOR CAVERN

508.002	LAGUNA -LBNO		LIQUID SCINTILLATOR			
	INCREMENTAL APPROACH FOR LSc and LAr @ PYHÄSALMI					
	EXPERIMENT SIZE vs. MAIN DETECTOR CAVERN					
EXPERIMENT		10 kton	25 kton	50 kton		
volume, LSc	m3	13 804	29 436	50 969		
volume, total	m3	21 206	41 371	70 686		
height	m	30,0	43,0	100,0		
diameter	m	30,0	35,0	30,0		
fiducial mass	kton	12	25	44	*density 0,86 * water*	
TANK - DETECTOR						
volume	m3	24 907	47 840	79 251		
height	m	33,0	47,0	105,0	*incl. concrete slab on bott*	
diameter	m	31,0	36,0	31,0		
MAIN DETECTOR CAVERN						
volume	m3	68 766	122 537	234 143		
height-wall	m	33,0	47,0	105,0		
height-dome	m	13,0	14,0	15,0		
height-total	m	46,0	61,0	120,0		
length, min	m	57,2	62,6	54,4		
length, max	m	62,8	71,2	71,2		
length, top	m	60,7	69,1	65,0		
width, min	m	34,0	39,3	34,0		
width, max	m	39,3	44,6	44,6		
width, top	m	35,3	42,0	40,6		
rel.volume		29 %	52 %	100 %		

1 HALF SIZE MAIN DETECTOR CAVERN

508.002	LAGUNA -LBNO	**HALF SIZE DETECTORS**								
	INCREMENTAL APPROACH FOR LSc and LAr @ PYHÄSALMI & COMBINED REALIZATION									
	INFLUENCE ON EXCAVATION COSTS									
HALF SIZE EXPERIMENT		volume	**LAr @ Pyhäsalmi**		volume	**LSc @ Pyhäsalmi**		volume	**LAr & LSc @ Pyhäsalmi**	
		50 kton			**25 kton**			50 kton + 25 kton		
Preparation costs (M€)				6,50			8,50			13,00
	- General & rock mechanical design		2,25			3,25			4,50	
	- Development & consulting service		1,75			2,25			3,50	
	- Site investigations		2,50			3,00			5,00	
Excavation costs (M€)		153'000 m^3		14,05	239'000 m^3		22,80	392'000 m^3		29,35
	- Main Detector Cavern, MDC	78'000 m^3	2,80		123'000 m^3	4,40		201'000 m^3	7,20	
	- other caverns, tunnels and shafts	75'000 m^3	8,60		116'000 m^3	14,50		191'000 m^3	17,20	
	- additional excavation costs	55 %	2,65		56 %	3,90		57 %	4,95	
Reinforcement costs (M€)				12,75			22,20			27,45
	- bolting of MDC		0,60			1,75			2,35	
	- bolting of other spaces		4,40			7,70			9,10	
	- shotcreting of MDC		1,35			2,60			3,95	
	- shotcreting of other spaces		6,20			9,70			11,40	
	- other related costs		0,20			0,45			0,65	
TOTAL COSTS OF EXCAVATION (M€)				**33,30**			**53,50**			**69,80**
	amount of new tunnels decrease at same rate as MDC decrease							synergy in combining shafts		
	amount of shafts and auxiliary rooms does not change							synergy in decline maintenance		
								savings up to		**17,00**
SAVING COSTS vs. FULL SIZE EXCAVATION (M€)				**12,60**			**21,10**			**32,00**
	relative savings			27 %			28 %			31 %

ANOTHER HALF SIZE MAIN DETECTOR CAVERN, EXCAVATED ON A LATER STAGE

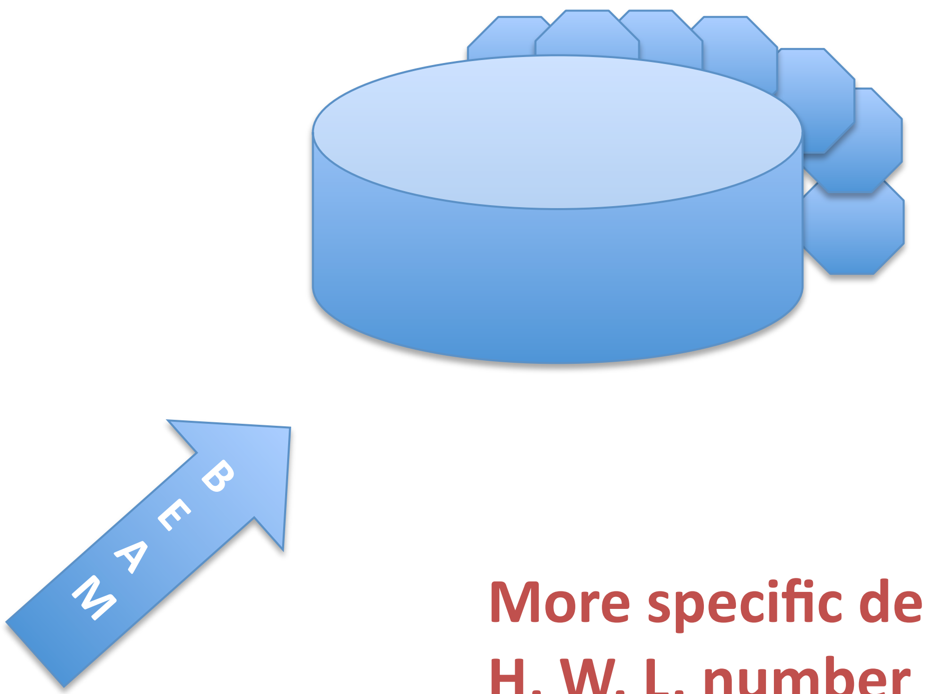
508.002	LAGUNA -LBNO	ANOTHER HALF SIZE DETECTOR (CONSTRUCTED ON A LATER DATE)						Note: no inflation taken into		
	INCREMENTAL APPROACH FOR LSc and LAr @ PYHÄSALMI & COMBINED REALIZATION							account		
	INFLUENCE ON EXCAVATION COSTS									
ANOTHER HALF SIZE EXPERIMENT		volume	**LAr @ Pyhäsalmi**		volume	**LSc @ Pyhäsalmi**		volume	**LAr & LSc @ Pyhäsalmi**	
		50 kton			**25 kton**			50 kton + 25 kton		
Preparation costs (M€)				3,00			3,50			6,50
	- General & rock mechanical design		1,50			1,75			3,25	
	- Development & consulting service		1,00			1,25			2,25	
	- Site investigations		0,50			0,50			1,00	
Excavation costs (M€)		144'000 m^3		11,70	200'000 m^3		18,20	344'000 m^3		29,90
	- Main Detector Cavern, MDC	78'000 m^3	2,80		123'000 m^3	4,40		201'000 m^3	7,20	
	- other caverns, tunnels	66'000 m^3	2,10		77'000 m^3	4,50		143'000 m^3	6,60	
	- additional excavation costs		6,80			9,30			16,10	
Reinforcement costs (M€)				5,25			10,10			7,85
	- bolting of MDC		0,60			1,75			2,35	
	- bolting of other spaces		1,40			2,40			0,80	
	- shotcreting of MDC		1,35			2,60			3,95	
	- shotcreting of other spaces		1,70			2,90			0,10	
	- other related costs		0,20			0,45			0,65	
TOTAL COSTS OF EXCAVATION (M€)				**19,95**			**31,80**			**44,25**
	additional excavations costs include low vibration excavation + transport to surface, safety procurement in existing spaces									
	not including cost estimate for disturbing of existing scientific programm (may be significant risks, t.b.d.)									
TOTAL COSTS OF EXCAVATION (M€) incl. COSTS OF STAGE 1				**53,25**			**85,30**			**114,05**
	additional excavations costs include low vibration excavation + transport to surface									
	increase of costs compared to 1 staged approach			16 %			14 %			12 %

SUMMARY

508.002	LAGUNA -LBNO	SUMMARY AND COMPARISON						Note: no inflation taken into		
	INCREMENTAL APPROACH FOR LSc and LAr @ PYHÄSALMI & COMBINED REALIZATION							account		
	INFLUENCE ON EXCAVATION COSTS									
EXPERIMENT		volume	**LAr @ Pyhäsalmi**		volume	**LSc @ Pyhäsalmi**		volume	**LAr & LSc @ Pyhäsalmi**	
		50 kton			**25 kton**			50 kton + 25 kton		
FULL SIZE EXPERIMENT, 1 BIG MDC				45,90			74,60			101,80
								synergy in combining shafts		
								synergy in decline maintenance		
								savings up to		18,70
FULL SIZE EXPERIMENT, 2 SMALL MDC				47,00			76,00			104,00
	cost increase compared to 1 full size MDC			*1,10*			*1,40*			*2,20*
HALF SIZE EXPERIMENT, 1 SMALL MDC				33,30			53,50			69,80
	amount of new tunnels decrease at same rate as MDC decrease									
	amount of shafts and auxiliary rooms does not change									
	relative savings compared to full size MDC			*12,60*			*21,10*			*32,00*
FULL SIZE EXPERIMENT, 1 SMALL MDC NOW AND 1 MDC LATER				53,25			85,30			114,05
	additional excavations costs include low vibration excavation + transport to surface, safety procurement in existing spaces									
	not including cost estimate for disturbing of existing scientific programm (may be significant risks, t.b.d.)									
	cost increase compared to 1 direct full size MDC			*7,35*			*10,70*			*12,25*

Magnetization

“folding screen” MIND behind LAr



More specific description needed: H, W, L, number of segments, etc.

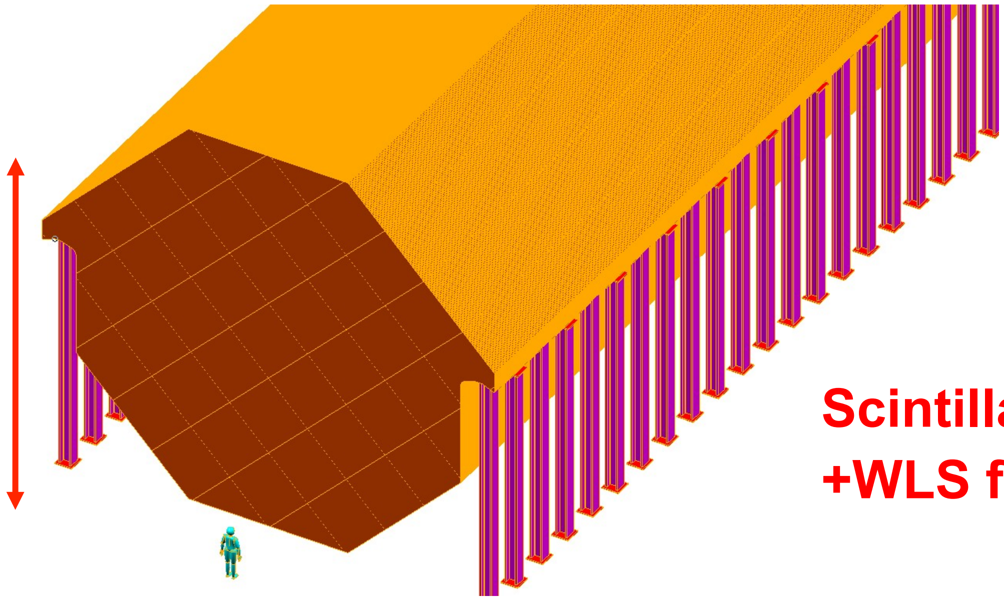
MIND for Neutrino Factories

talk by Alfons Weber (University of Oxford)

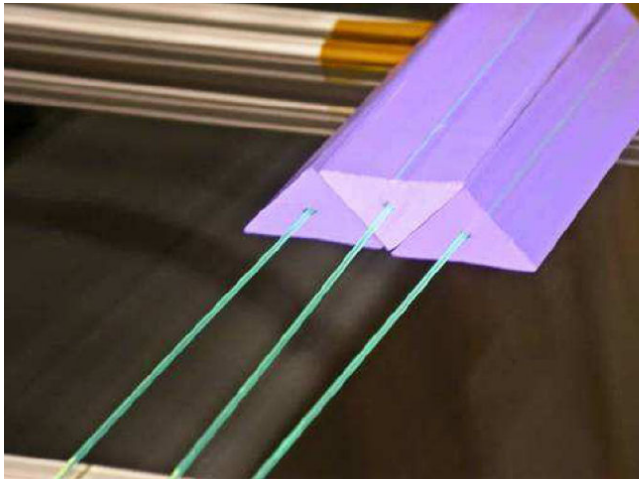
Status of the MIND analysis

talk by Anselmo Cervera Villanueva (IFIC)

14 m

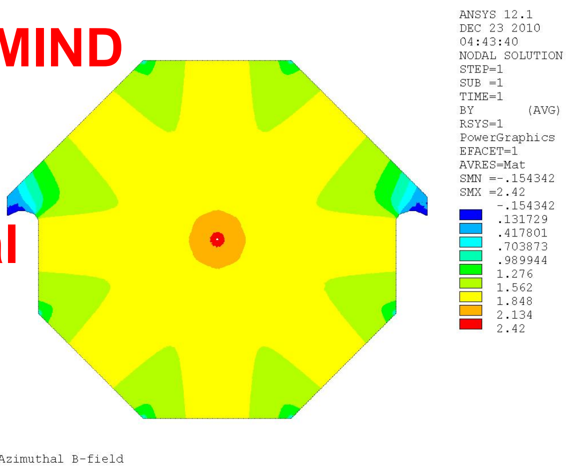


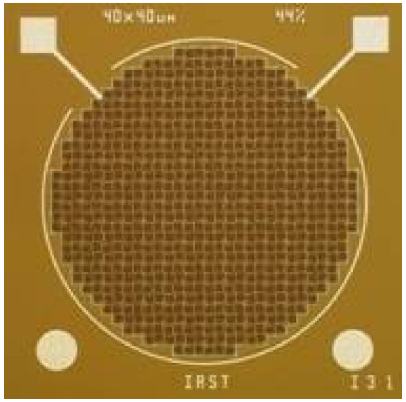
Scintillator +WLS fibre



50-100 kt MIND

Toroidal B-field: 1-2.2 T





Multi Pixel Photon Counter (MPPC)

*) Phys.Rev. D 68, 037301, 2003
**)arXiv:0908.3741
**)Phys.Rev.Lett.105:261802,2010

Magic* (7250 km) and Bimagic** (2540 km) baseline

- Lack of any information on the CP violating phase δ_{CP} weakens the ability to determine neutrino mass hierarchy. This problem is overcome at magic and bimagic baseline.
- Bimagic distance of 2540 km offers multiple advantages with a detector that can identify muon charge. **(LAr + MIND)**
- At this baseline, for any neutrino hierarchy, the wrong-sign muon signal is almost independent of CP violation and θ_{13} in certain energy ranges.
- This allows the identification of the hierarchy in a clean way. In addition, part of the muon spectrum is also sensitive to the CP violating phase and θ_{13}, so that the same setup can be used to probe these parameters as well.

Comparison of the proposed sites and detectors in Europe, USA and Japan

Europe

Frejus	– 4800 m.w.e.	(2 x 330 kt WCh + LS?)	130 km
Pyhäsalmi	– 4000 m.w.e.	(50 kt LS)	2300 km
	– 2500 m.w.e.	(100 kt LAr)	
Umbria	– 1900 m.w.e.	(100 kt LAr)	670 km

USA

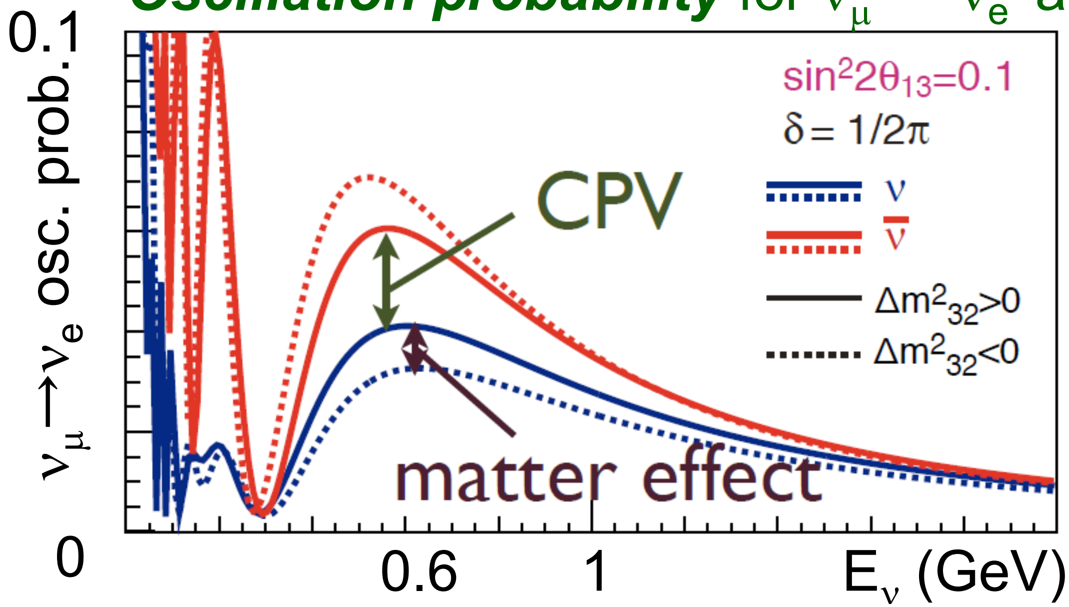
Homestake	– 4290 m.w.e.	(200 kt WCh or 34 kt LAr)	1300 km

Japan

Kamioka	– 1300 m.w.e.	(1 000 kt WCh)	295 km
Okinoshima	– 600 m.w.e.	(100 kt LAr)	658 km

Pyhäsalmi is at the bimagic or magic distance from all 3 labs delivering neutrino beams!

Oscillation probability for $\nu_\mu \rightarrow \nu_e$ at 295km



$\Delta m^2_{21}=7.6\times10^{-5}eV^2$

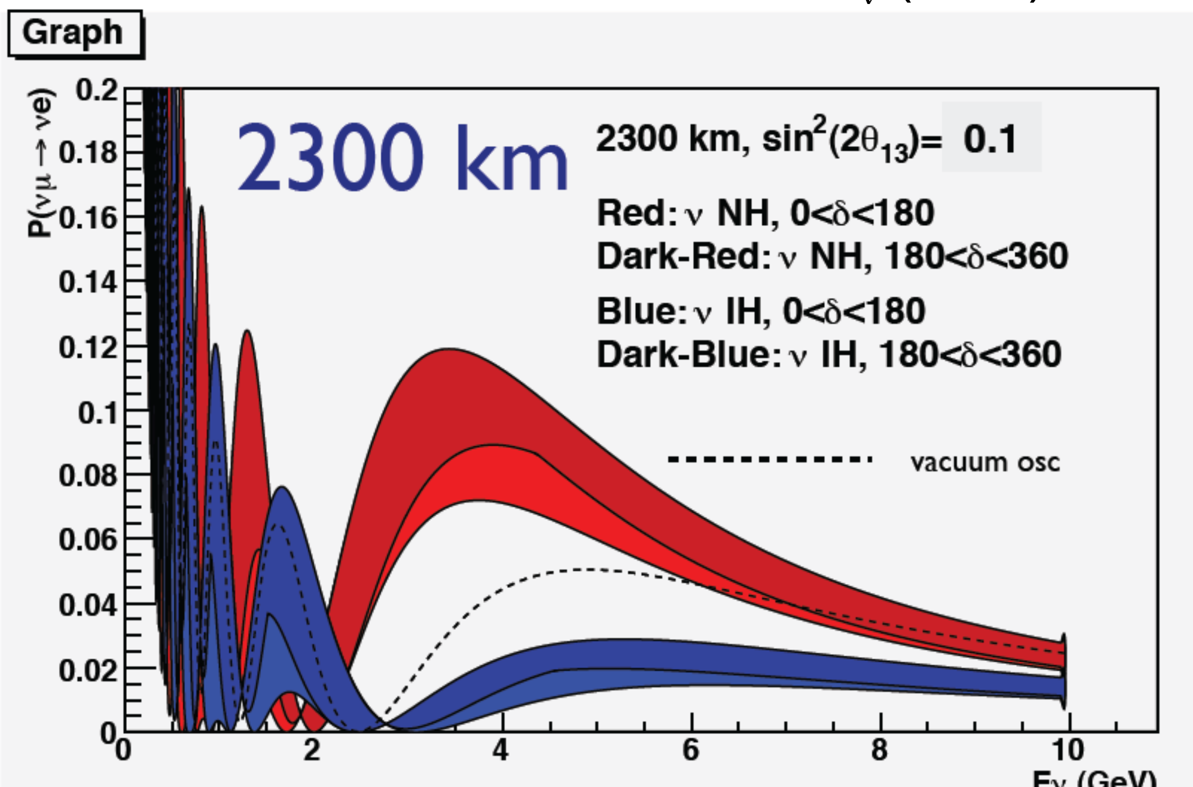
$|\Delta m^2_{32}|=2.4\times10^{-3}eV^2$

$\sin^2\theta_{12}=0.31$

$\sin^2\theta_{23}=0.5$

$\rho=2.6g/cm^3$

Yoshinari Hayato ANT11



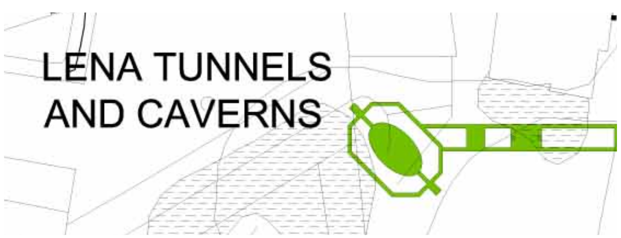
CERN → Pyhäsalmi

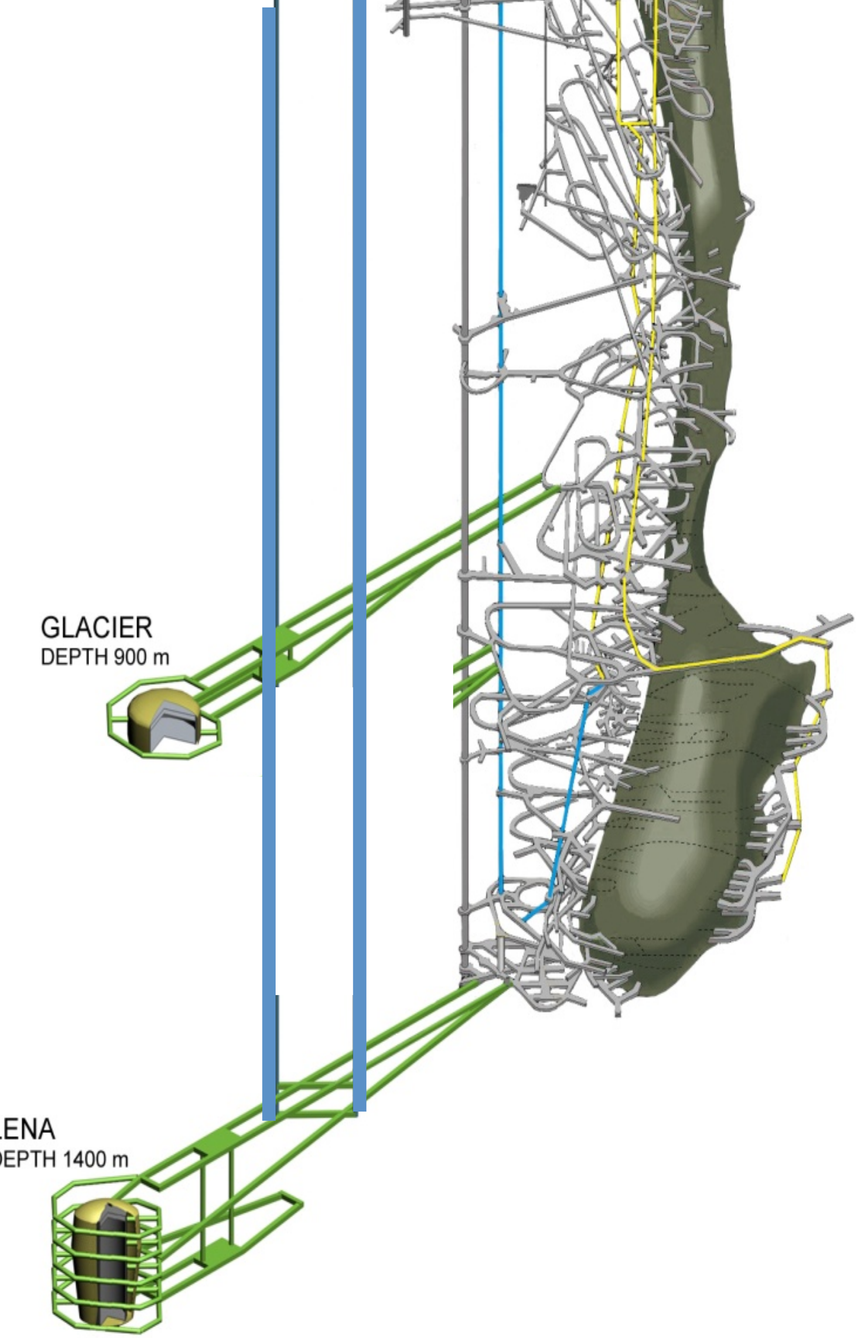
A.Rubbia GLA2011

Above the threshold for τ production!

Excavations

- All excavations should be done during Phase 0 and desirably before the mine closure in 2018
- Common infrastructure for both detectors

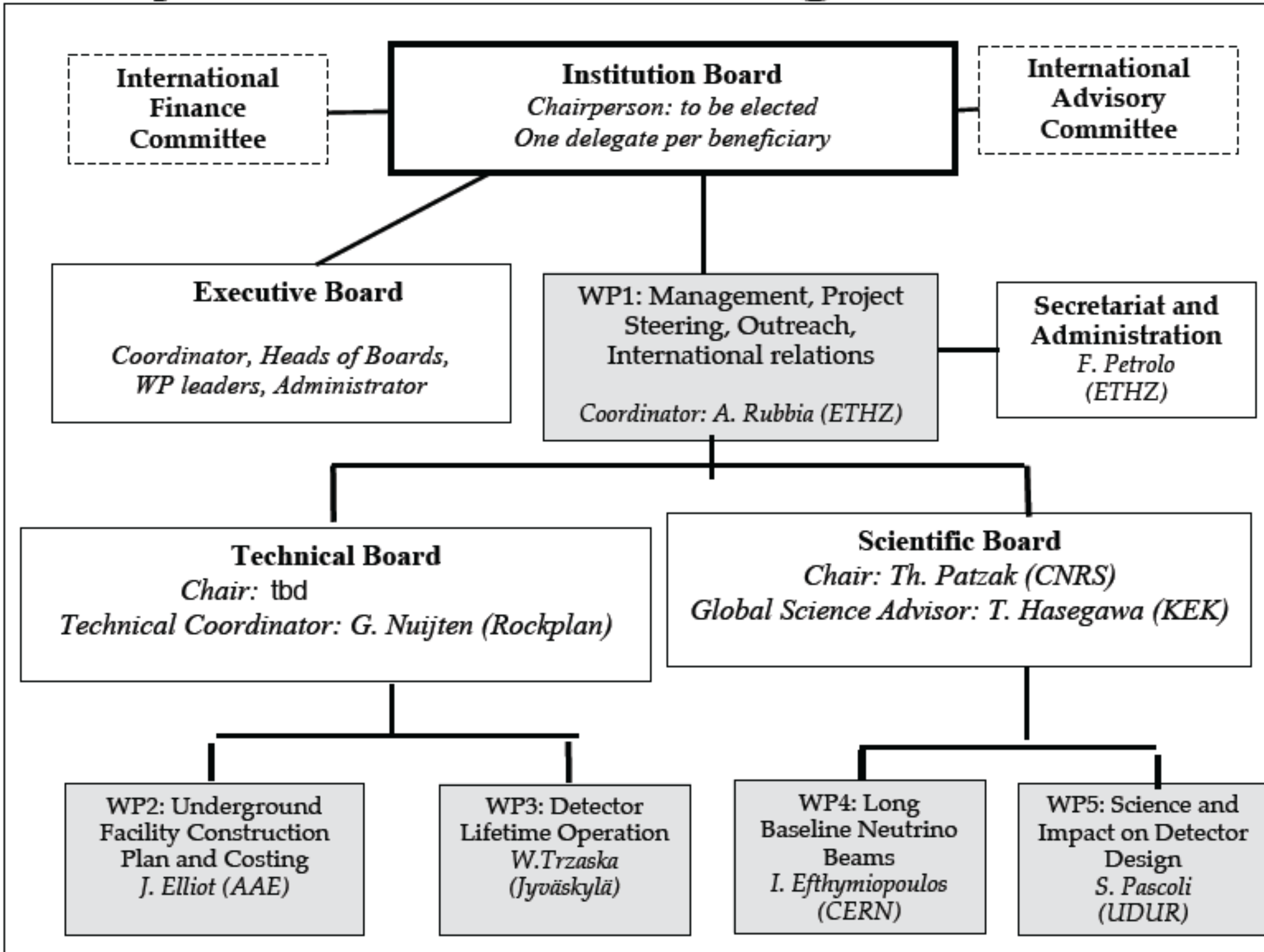




Consolidation

- Importance of unity within LAGUNA
  - GLACIER → LAr
  - MEMPHIS → WC or LWater
  - LENA → LSc
- Strong presence of LSc in LAGUNA

Project internal organization



LAGUNA-LBNO

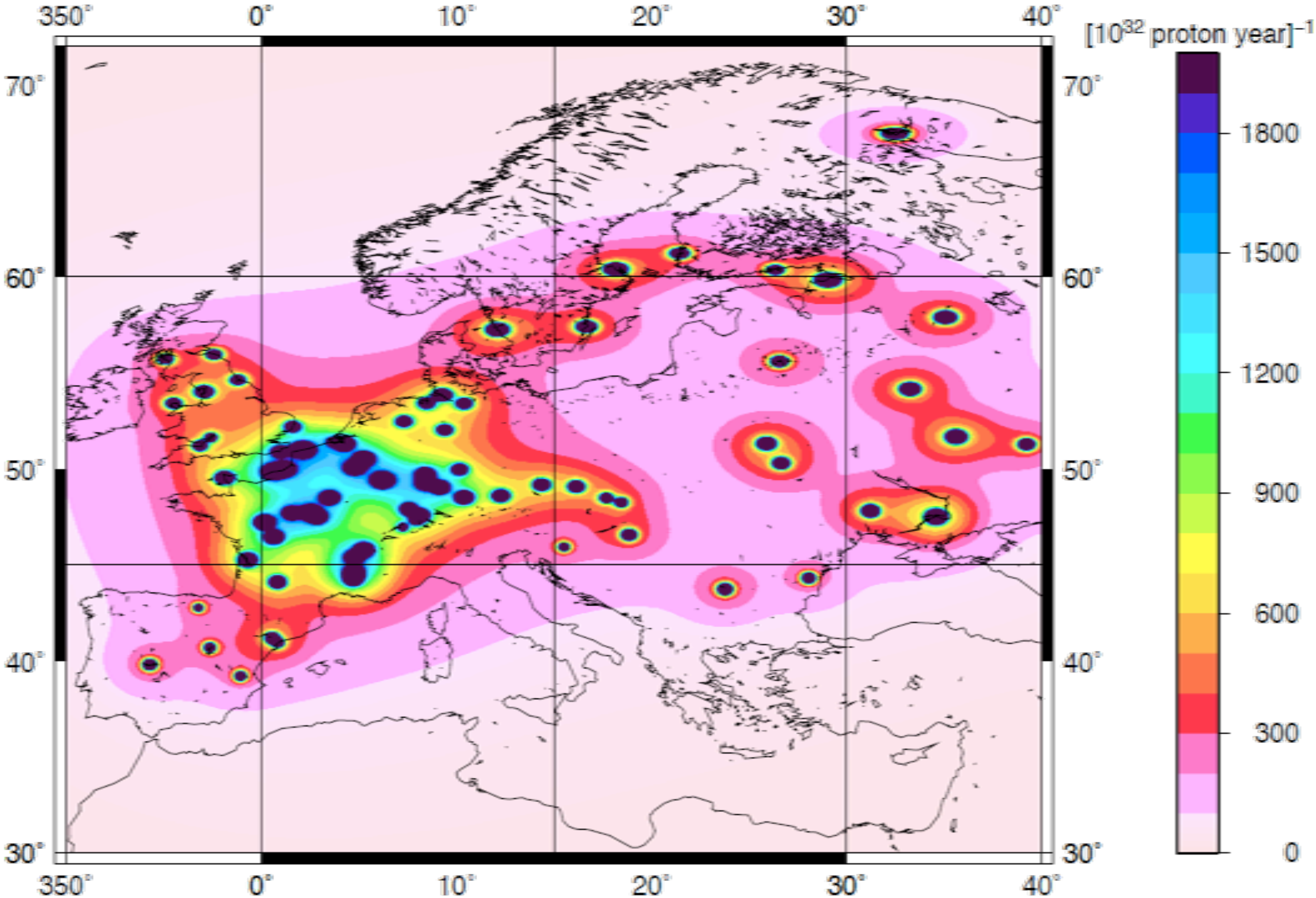
Low energy neutrinos -
Reactor and geoneutrinos

Kai Loo
University of Jyväskylä

LAGUNA-LBNO
Kick off meeting 17.-19.10.2011, Cern

UNIVERSITY OF JYVÄSKYLÄ

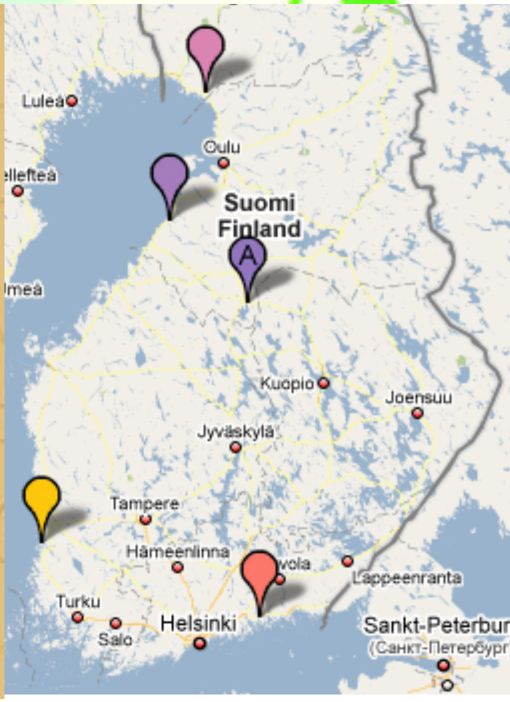
Reactor BG



Calculations by Kai Loo

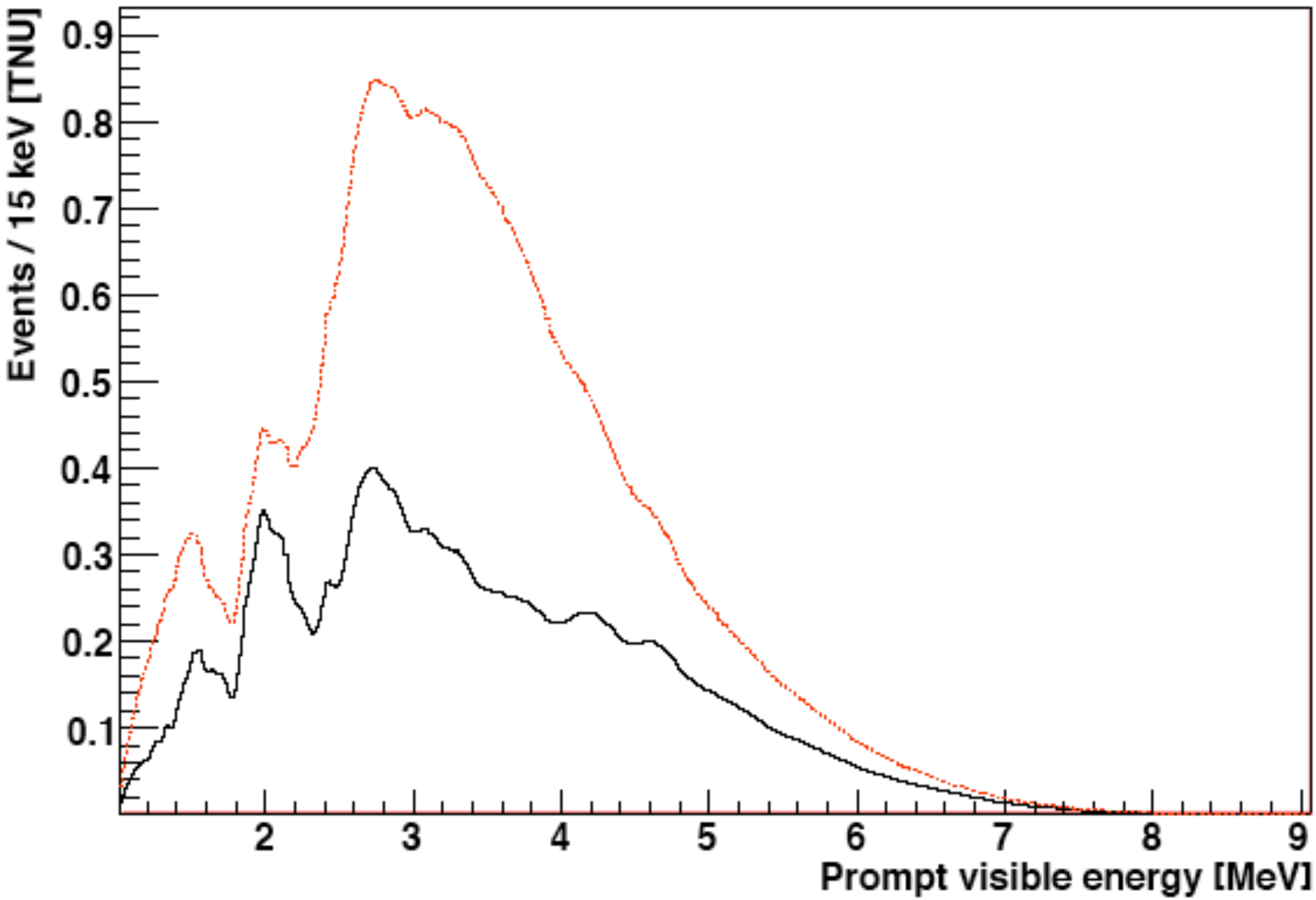

SIMO
PYHÄJOK


Simo
230 km from Pyhäsalmi
Oulu
Pyhäjoki
130 km from Pyhäsalmi

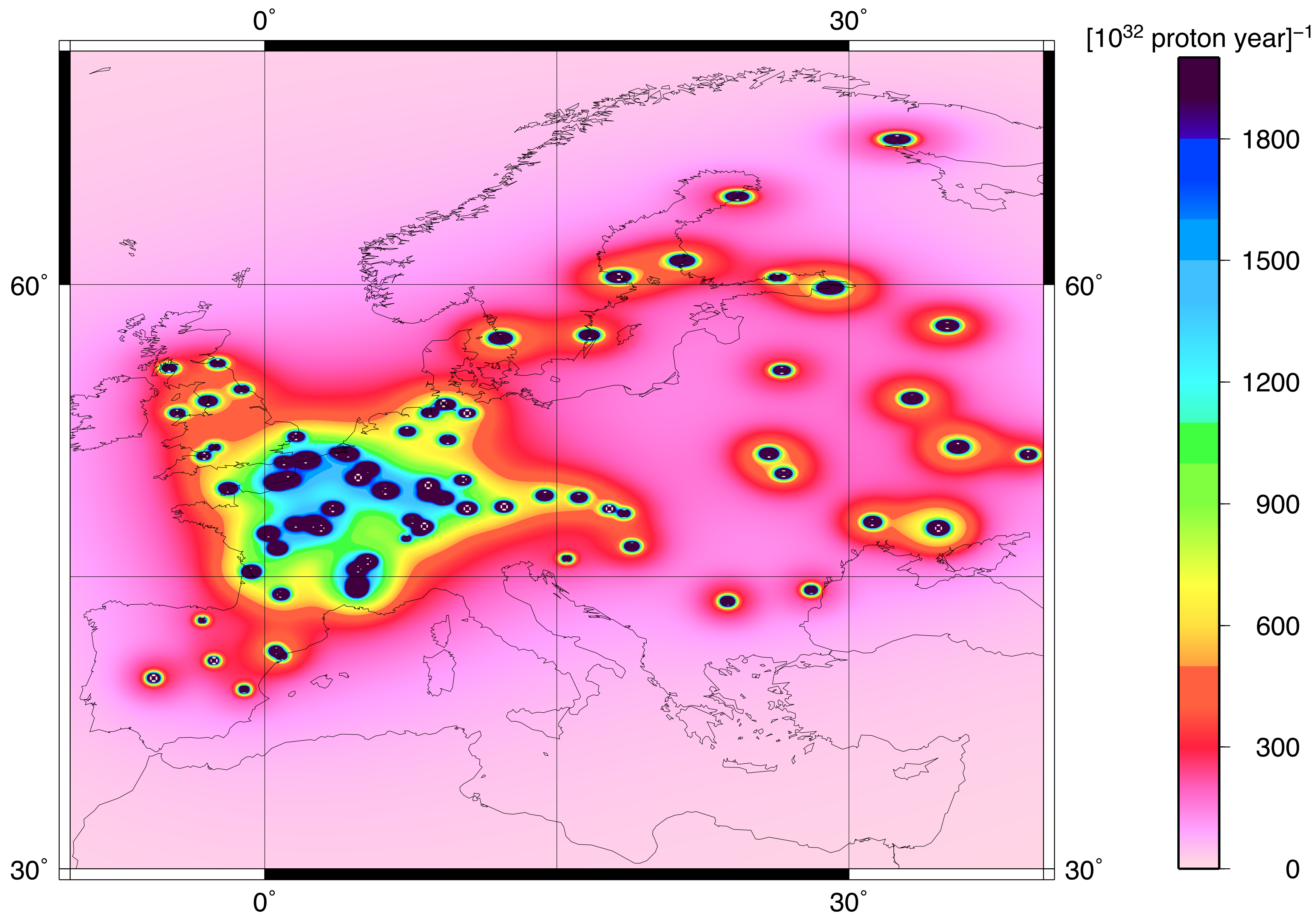

Luleå
Oulu
Suomi
Finland
A
Kuopio
Joensuu
Jyväskylä
Tampere
Hämeenlinna
Lappeenranta
Turku
Salo
Helsinki

Pyhäjoki power plant

- Site selected 05.10.2011
- 1250 – 1600 MW
- Areva / Toshiba



Events / 15 keV [TNU]
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
2
3
4
5
6
7
8
9
Prompt visible energy [MeV]


0°
30°
60°
30°
[10^32 proton year]^-1
1800
1500
1200
900
600
300
0

LENA & LAGUNA White papers

REACTOR NEUTRINO EVENT RATES

Location	Signal 1-10 MeV [TNU]	Signal 1-2.6 MeV [TNU]
Pyhäsalmi	70.9 ± 3.8	20.8 ± 1.1
Pyhäsalmi*	145.9 ± 7.7	37.3 ± 1.9
Fréjus	554 ± 29.4	145 ± 7.7

TABLE V: Expected reactor $\bar{\nu}_e$ signal. (*future Finnish reactors are taken into account)

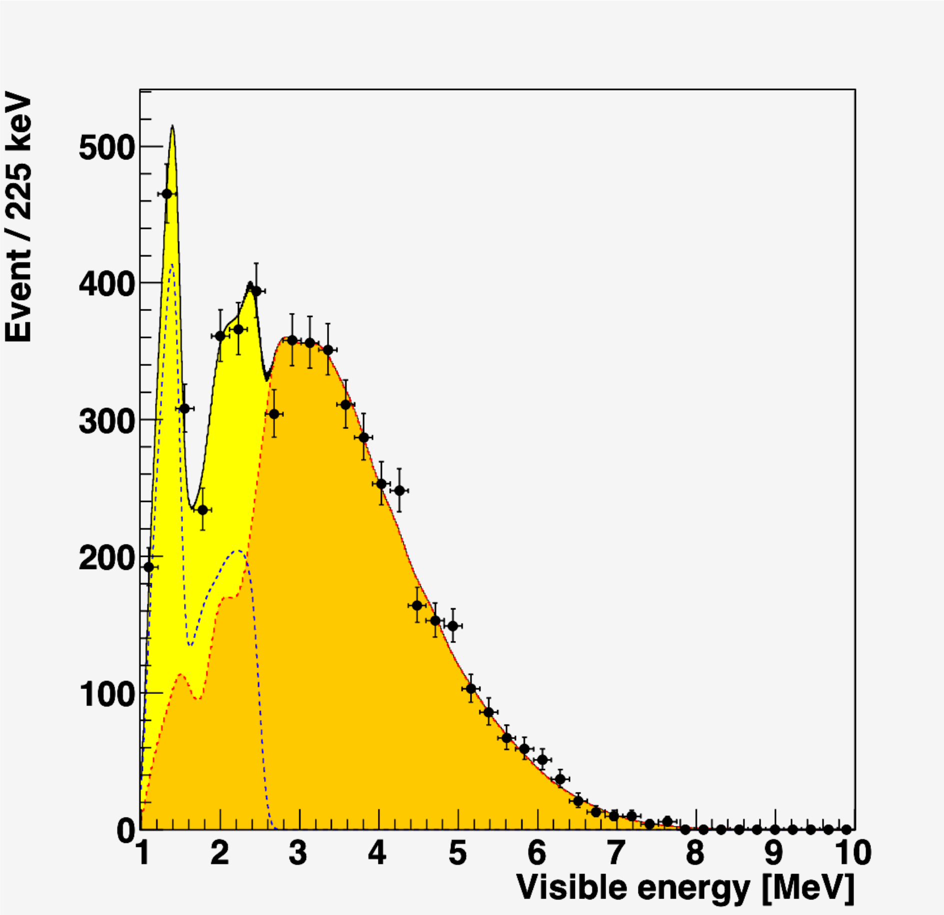
Geoneutrino signals U+Th:

-Pyhäsalmi 51.3±7.1 TNU

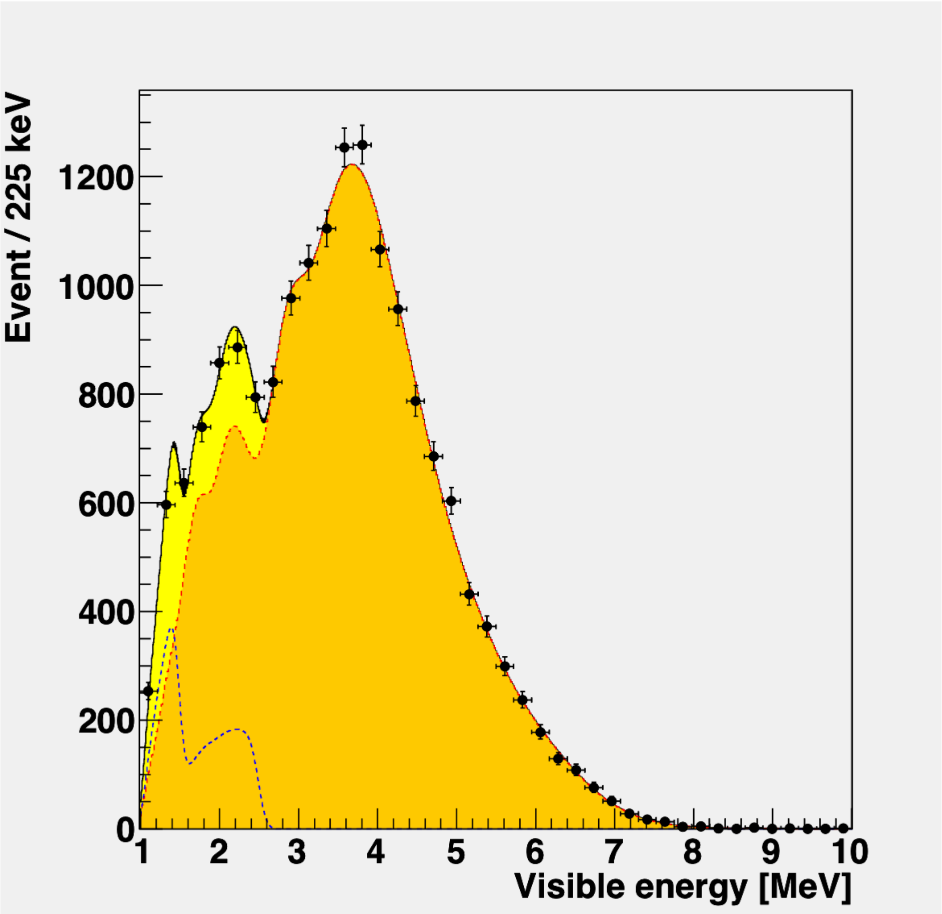
-Fréjus 41.4±5.6 TNU

One year measurement

Pyhäsalmi



Fréjus



LENA & LAGUNA White papers

EFFECT OF PYHÄJOKI POWER PLANT TO GEONEUTRINO MEASUREMENT

TOTAL FLUX

Live time	Pyhäsalmi	Pyhäsalmi*	Fréjus
1 yr	3%	4%	6%
3 yrs	2%	2%	3%
10 yrs	1%	1%	2%

TABLE VI: Expected precision in the measurement of the total geo-ν flux (*future Finnish reactors are taken into account). Details in text.

U – Th SEPARATION

Location	Live time [yrs]	U flux [%]	Th flux [%]	U/Th [%]
Pyhäsalmi	1	6	12	17
	3	3	8	10
	10	2	4	5
Pyhäsalmi*	1	7	14	21
	3	4	8	11
	10	2	4	6
Fréjus	1	14	25	35
	3	9	12	20
	10	4	7	11

TABLE VII: Expected precision in the measurement of the U and Th geo-ν flux and in the U/Th ratio. (* future Finnish reactors are taken into account). Details in text.

Tasks overview for WP3

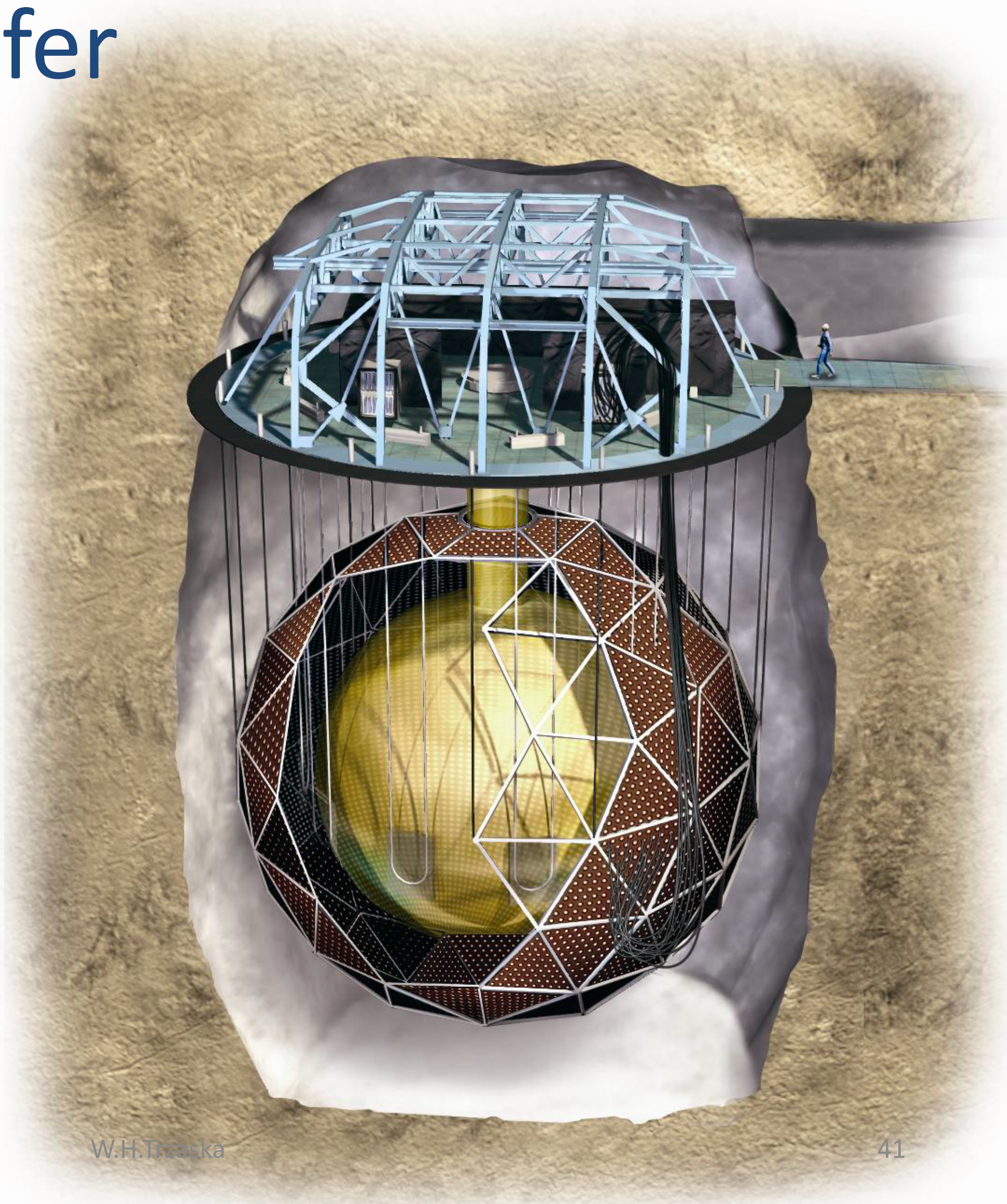
- Instrumentation
  - What is needed
  - How to transport it to the site, take it underground, test, assemble and commission
- Filling
  - How to bring, store, purify, transfer to the tank underground and verify the quality of the liquid
- Operation
  - How to maintain and operate the experiment including the liquid and instrumentation

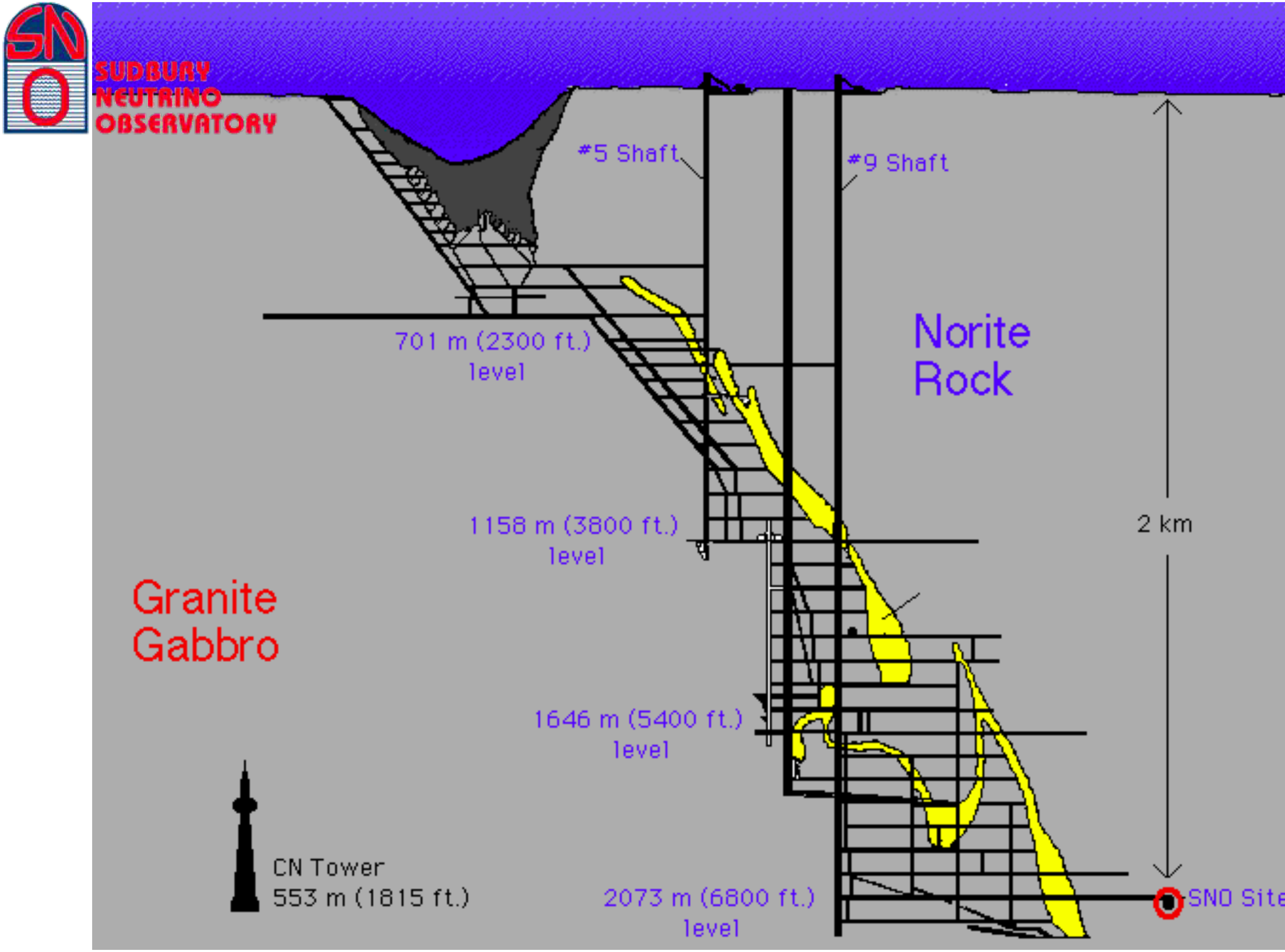
From Guido's slides; based on DoW

- instrumentation WP3
  - clean room preparation
  - ionization- and photo-sensors installation
  - active volumes definition (drift cage or membrane)
  - low and high voltage cabling
  - readout electronics installation
  - membrane between the scintillating and non-scintillating oil
  - Detector magnetization
- liquid handling WP3
  - purification
  - recirculation
  - filling process
  - filling
- operation WP3
  - use of mine infrastructure before and after closing of mine
  - care and maintenance of mine infrastructure
  - care and maintenance of the underground physics laboratory

Knowhow transfer

- For instance, LS:
  - Borexino
  - SNO → SNO+
  - KamLAND
- PMT
- Electronics
- etc.




SUDBURY
NEUTRINO
OBSERVATORY
#5 Shaft
#9 Shaft
Norite
Rock
701 m (2300 ft.)
level
1158 m (3800 ft.)
level
2 km
Granite
Gabbro
1646 m (5400 ft.)
level
CN Tower
553 m (1815 ft.)
2073 m (6800 ft.)
level
SNO Site

Floor anchor seals

SUDBURY NEUTRINO OBSERVATORY

Thank you for your attention!