Laguna-LBNO: Large Apparatus for Grand Unification and Neutrino Astrophysics

&

Long Baseline Neutrino Oscillations

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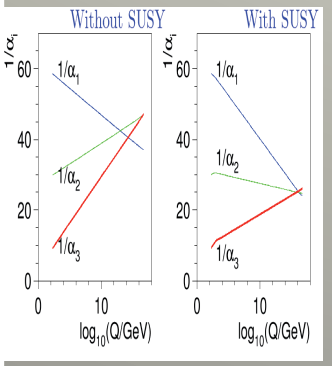
On behalf of the LAGUNA-LBNO Collaboration

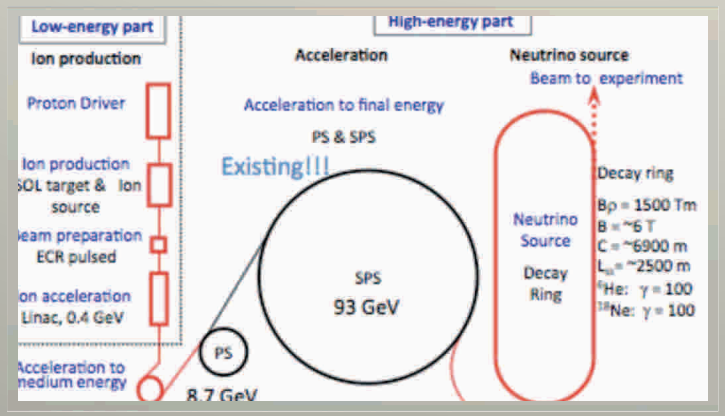
Laguna: **L**arge **A**pparatus for **G**rand **U**nification and **N**eutrino **A**strophysics

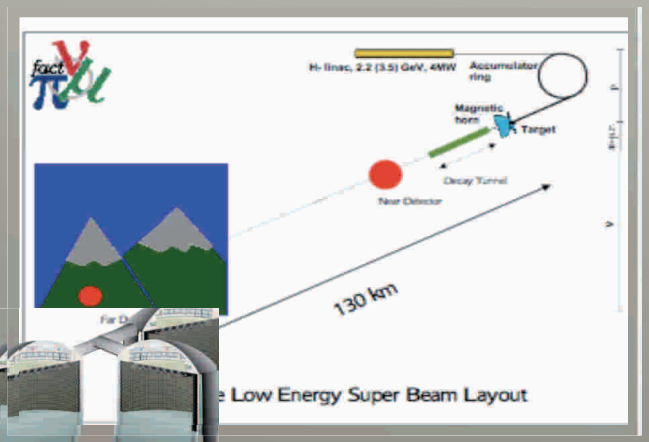
New megaton class, multipurpose detectors will allow to study these fundamental questions

Particle physics

Proton decay
θ13
CP-violation

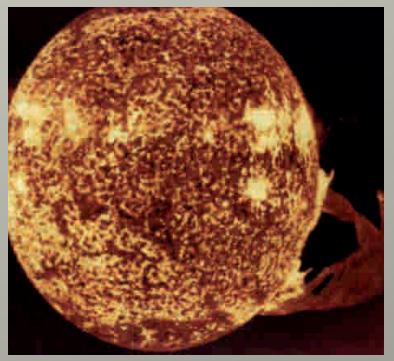


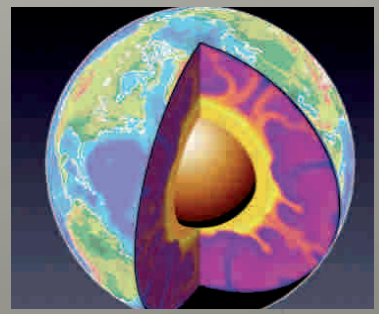




Neutrino astronomy

Supernova neutrinos
Diffuse SN neutrinos
Atmospheric Neutrinos
Solar neutrinos
Dark matter annihilation
Geo-neutrinos...





LAGUNA

Large Apparatus for Grand Unification and Neutrino Astrophysics

... In a

See talk by W. Trzaska

2300 Km, Pyhhäsalmi

2008 - 2011

1,7 M€ from EU

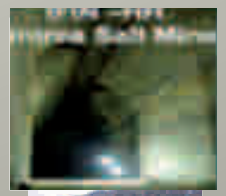
7 canditate sites:

- Boulby
- Fréjus
- Caso
- LSC
- Pyhäsalmi
- Sunlab
- IFIN-HH

Boulby mine
1050 Km

SUNLAB
950 Km

Unirea Salt Mine



CASO, 659 Km

130 Km

630 Km

LENA

MEMPHYS

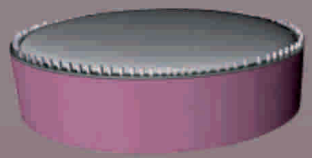
~ 440 ktons fiducial mass

Water Čerenkov

GLACIER

Liquid Argon

~ 100 ktons fiducial mass



Liquid Scintillator

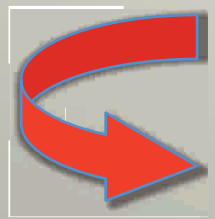
~ 50 ktons fiducial mass

✓Laguna => very comprehensive evaluation of all sites, construction and costs

✓Laguna => baselines from 130 km to 2300 km available in Europe = advantage

✓Laguna => allowed to form a strong community in Europe (> 100 physicists and Ing.)

✓Laguna => showed the need to evaluate constraints and costs for the detector options



New program: Laguna-LBNO (one of the two fully financed by EC, 5M€)
Start September 2011 – End September 2014

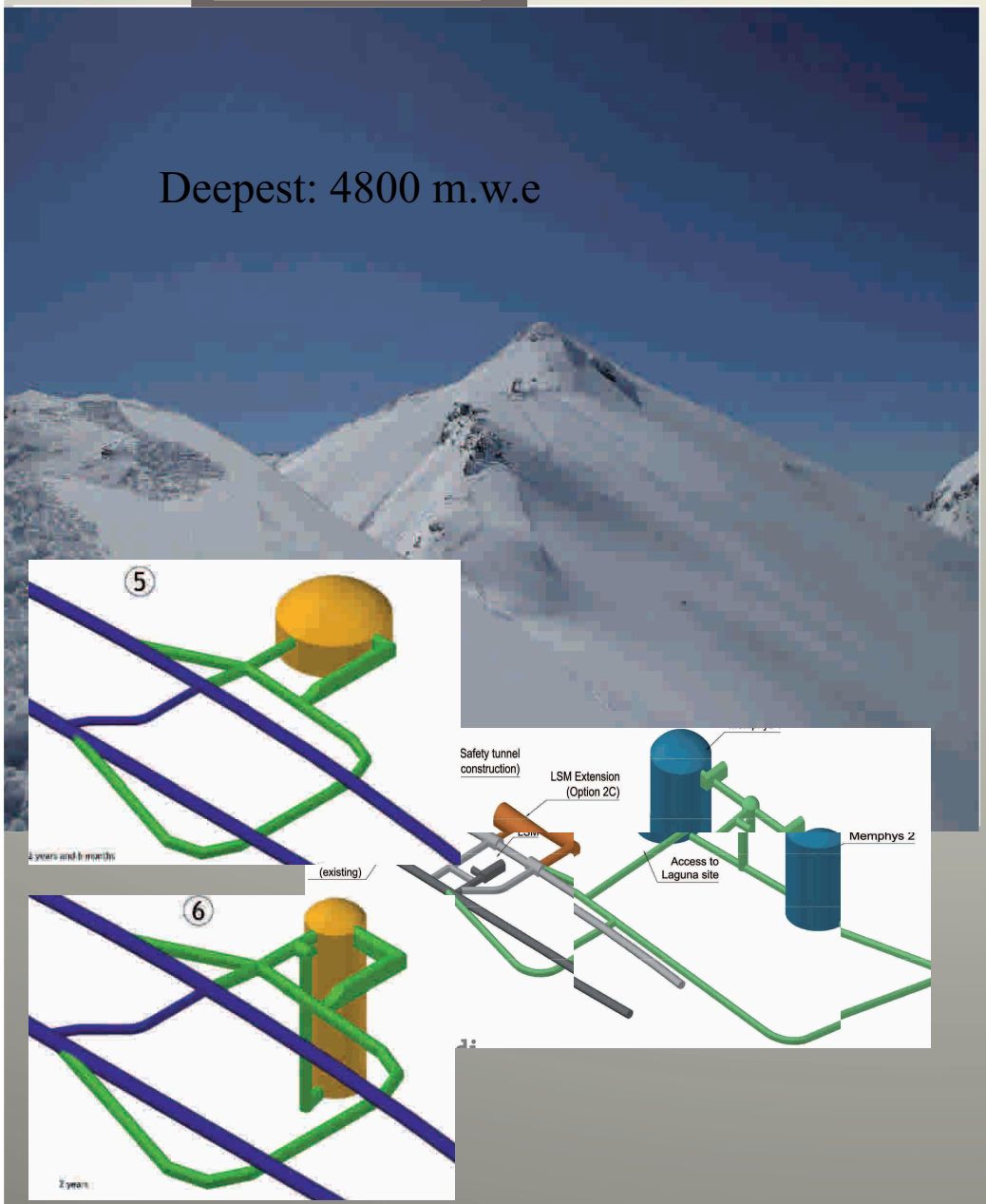
- Laguna-LBNO: evaluate costs for detector construction and long term running (> 30y)
- Laguna-LBNO: investigates complementary beam options from CERN
- Laguna-LBNO: deep study of physics potential for the combination detector/site
- Laguna-LBNO: strengthens the community even more:

> 250 physicists, 13 countries, 39 beneficiaries

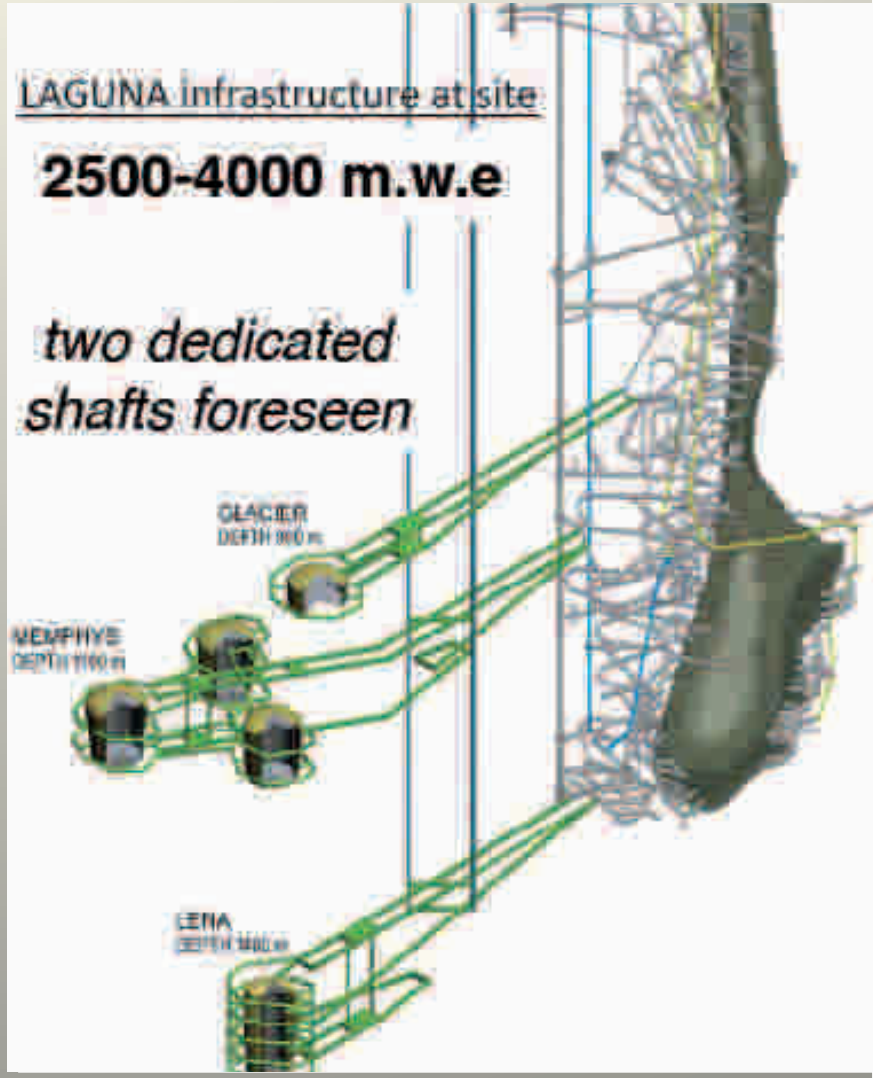
<u>Focus on 3 options:</u>

1. Shortest baseline (130 km), CERN -> Fréjus: no matter effects; clean measurement of LCPV
2. Longest baseline (2300 km), CERN -> Pyhhäsalmi: matter effect; mass hirarchy, LCPV
3. (Existing CNGS beam (650 km), CERN -> Umbria)

Fréjus Tunnel

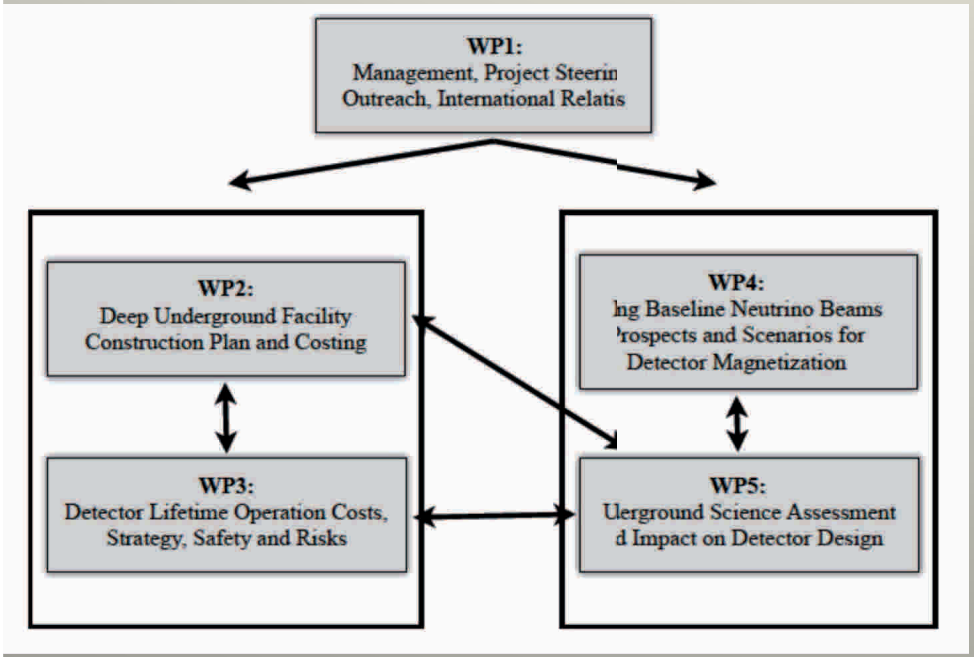


Pyhäsalmi Mine



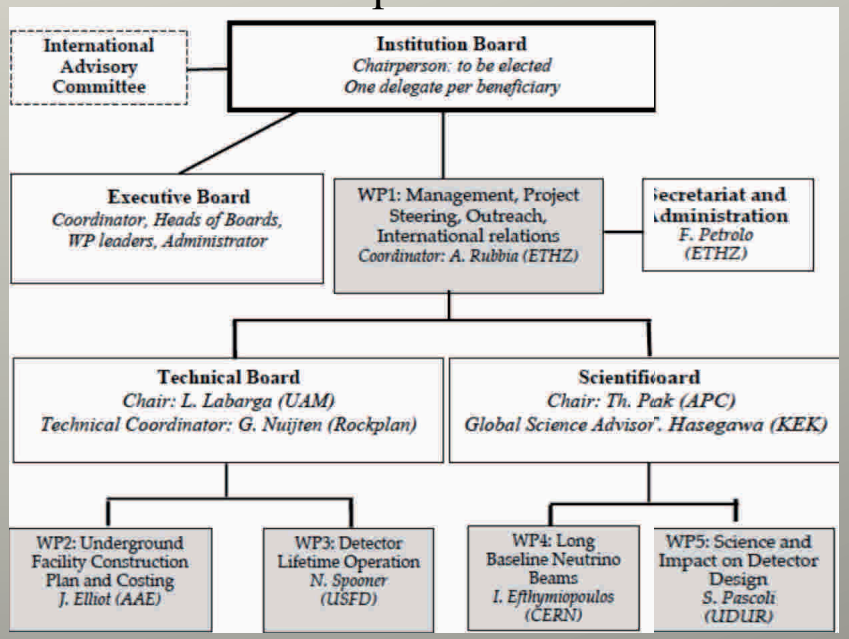
Laguna-LBNO: Pan European Infrastructure for Large Apparatus Studying Grand Unification, Neutrino Astrophysics and Long Baseline Neutrino Oscillations

New FP7 2010 DS starting September 1st 2011



250 participants:

- Universities & nat. labs
- CERN
- Industrial partners



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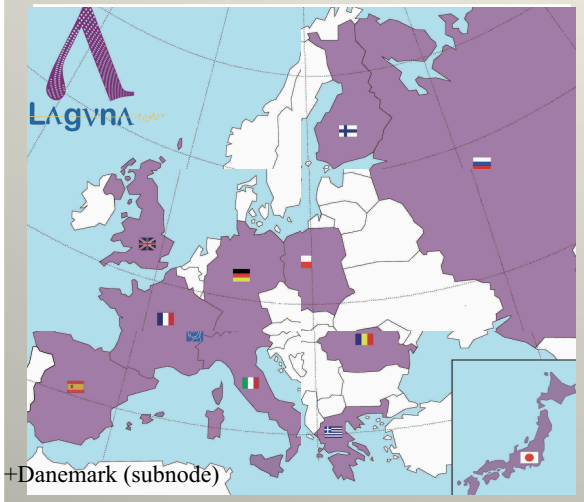
LAGUNA-LBNO consortium



13 countries, 45 institutions, ~300 members

Switzerland

University Bern
University Geneva
ETH Zürich
Lombardi Engineering*

Finland

University Jyväskylä
University Helsinki
University Oulu
Rockplan Oy Ltd*

CERN

France

CEA
CNRS-IN2P3
Sofregaz*

Germany

TU Munich
University Hamburg
Max-Planck-Gesellschaft
Aachen(**)
University Tübingen(**)

Poland

IFJ PAN
IPJ
University Silesia
Wroklaw UT
KGHM CUPRUM*

Greece

Demokritos

Spain

LSC
UA Madrid
CSIC/IFIC
ACCIONA*

United Kingdom

Imperial College London
Durham
Oxford
QMUL
Liverpool
Sheffield
RAL
Warwick
Technodyne Ltd*
Alan Auld Ltd*
Ryhal Engineering*

Romania

IFIN-HH
University Bucharest

Denmark

Aahrus(**)

Italy

AGT*

Russia

INR
PNPI

Japan

KEK

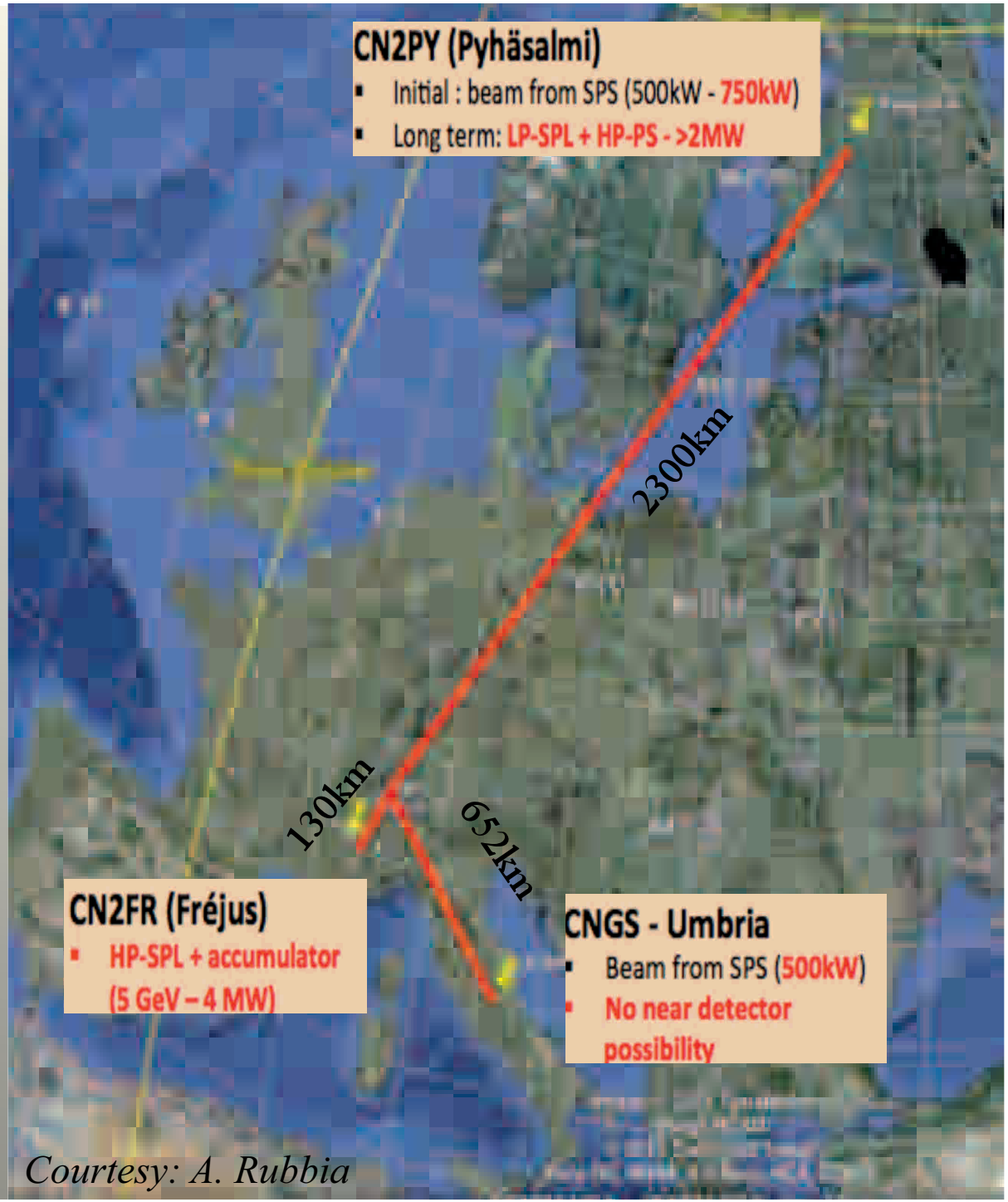
(=industrial partners*
***=associated)*

Courtesy: A. Rubbia

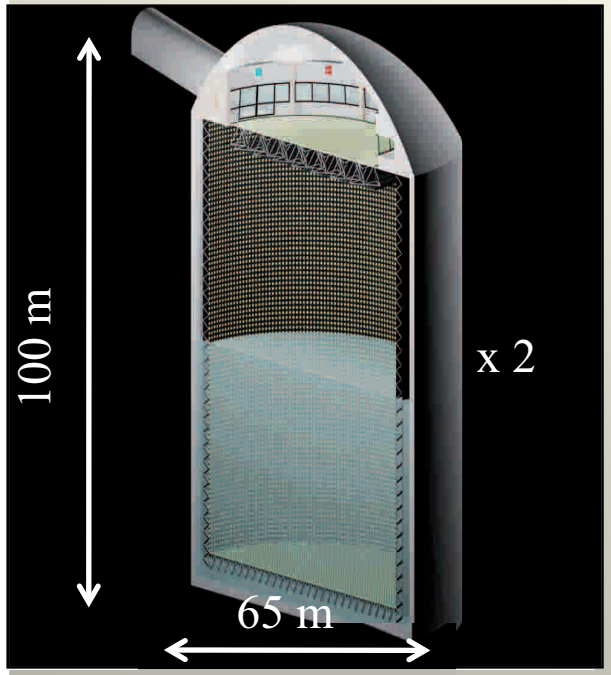
LAGUNA-LBNO sites

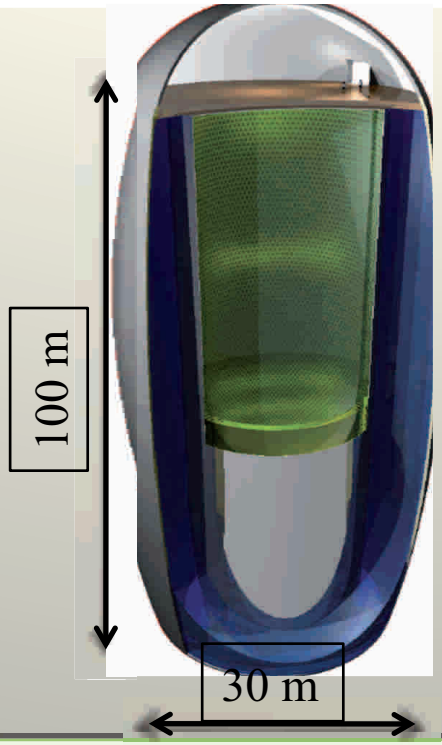
New conventional beams to be considered based on CNGS experience

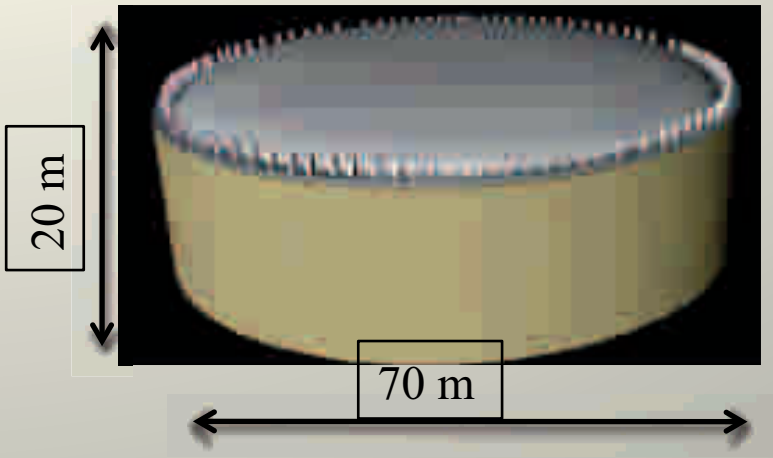
- CERN-Fréjus is a short baseline. It offers good synergy for enhanced physics reach with β-beam at γ=100
- CERN-Pyhäsalmi is the longest baseline. It offers good synergy for enhanced physics reach with a NF
- [CERN-Umbria has an existing beam but is considered at lower priority (missing near detector, limited power upgrade scenarios)]



Courtesy: A. Rubbia







Memphys
2 x 330 kt
220'000 8" or 10" PMT's

QE > 25%
DR 1 to 300 p.e.
Time resolution 1 ns
Low after pulsing
Pressure 10 bars
Lifetime > 30 y

LENA
50 kt
55'000 8" PMT's

QE > 25%
DR 0.2 MeV to 10 GeV
Time resolution < ns
Low after pulsing
Pressure 15 bars
Lifetime > 30 y

See talk by J. Winter

Glacier
100 kt
1'000 8" WLS-coated cryo PMT's
27'000 cryogenic PMT's

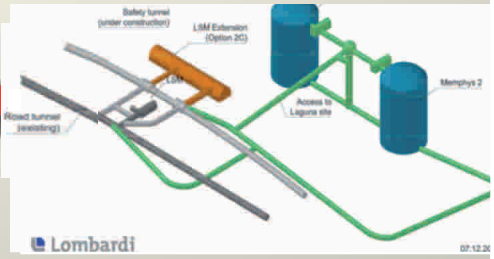
QE > 25%
Time resolution O ns
Lifetime > 30 y cryogenic!

See talk by A. Rubbia

Physics channels@

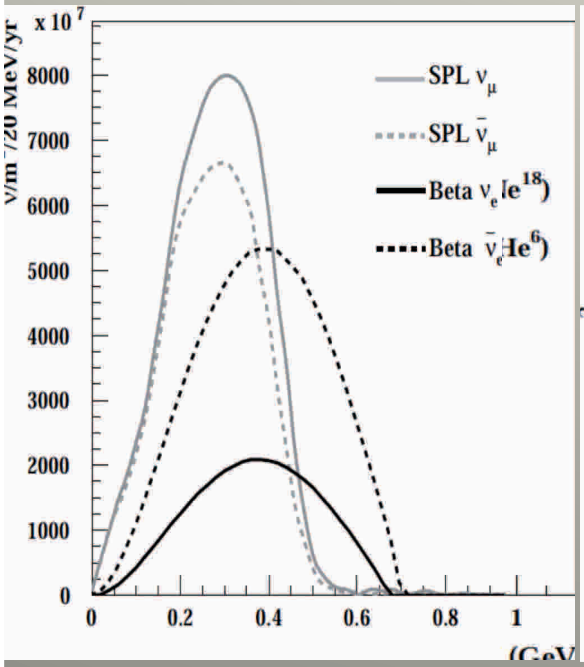
MEMPHYS

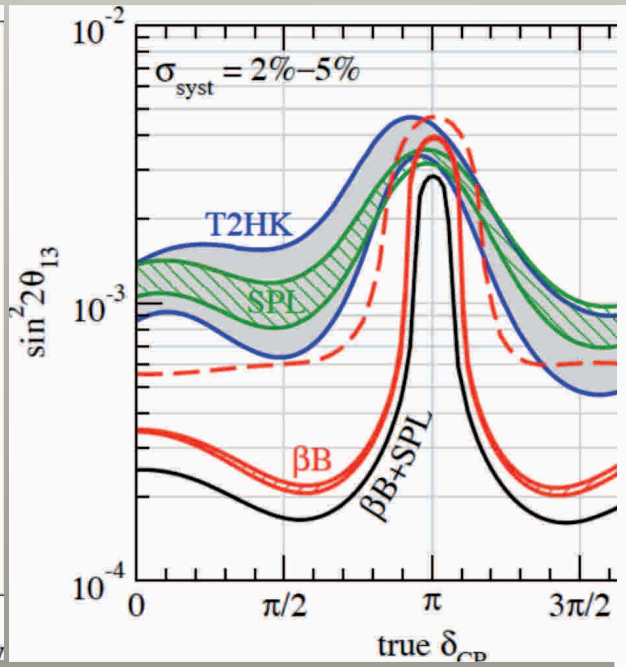
130 Km CERN-LSM

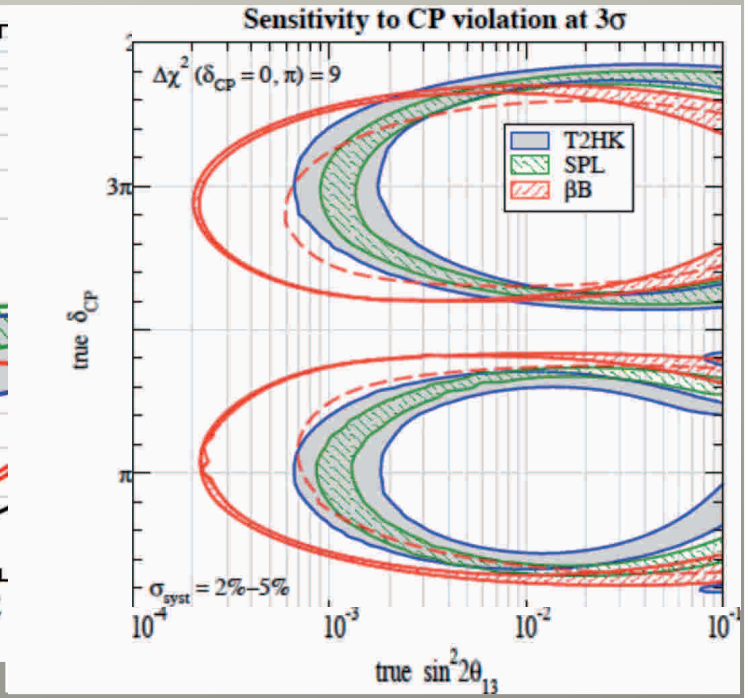


SUPER-BEAMS BETA-BEAMS

The main goals: search of a non-zero θ_{13} angle or its measurement; searching for possible leptonic ***CP violation***; determining the **mass hierarchy** and the θ_{23} ***octant***.

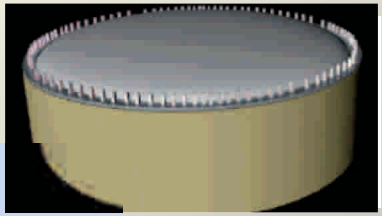






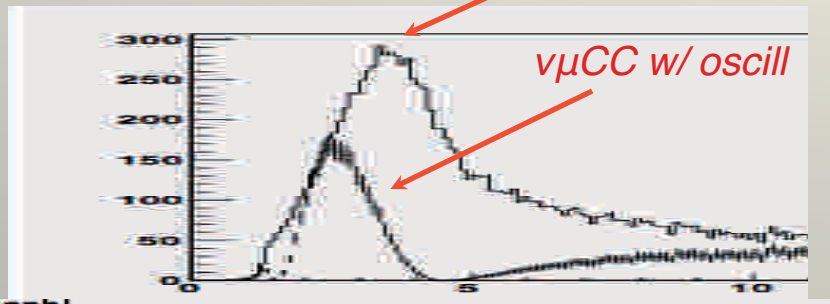
JE Campagne, M. Maltoni, M. Mezzetto, T. Schwetz, arXiv:hep-ph/0603172v3

LAGUNA-LBNO Pyhäsalmi physics prospects and Galcier:



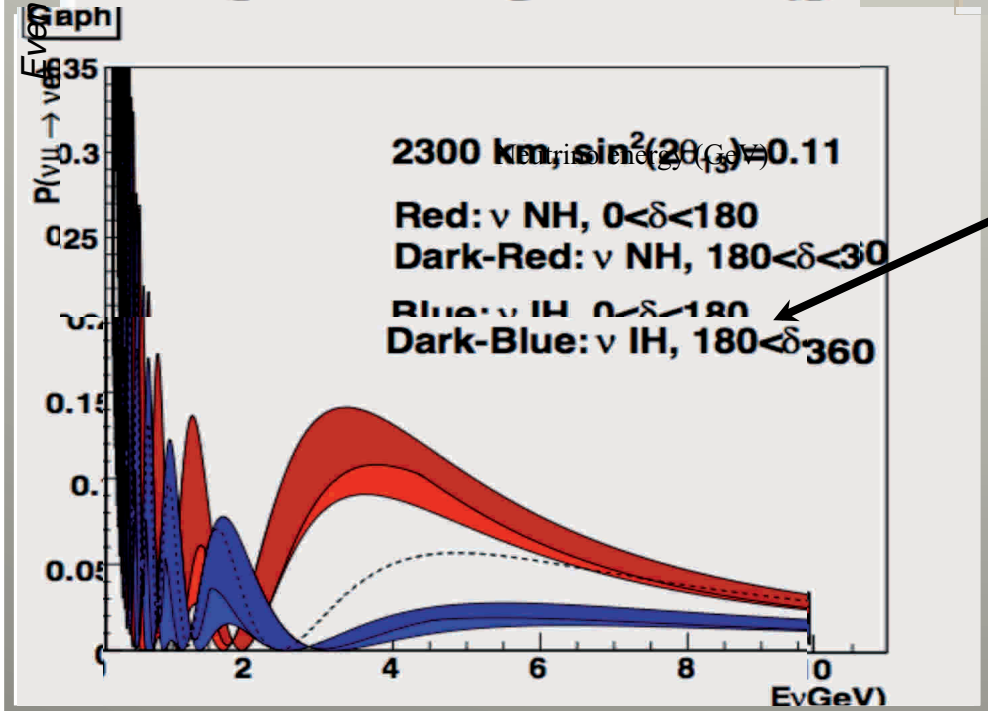
Muon disappearance

Event rates: CERN SPS 400 GeV
5 years @ 9.4x10[19] pots/year

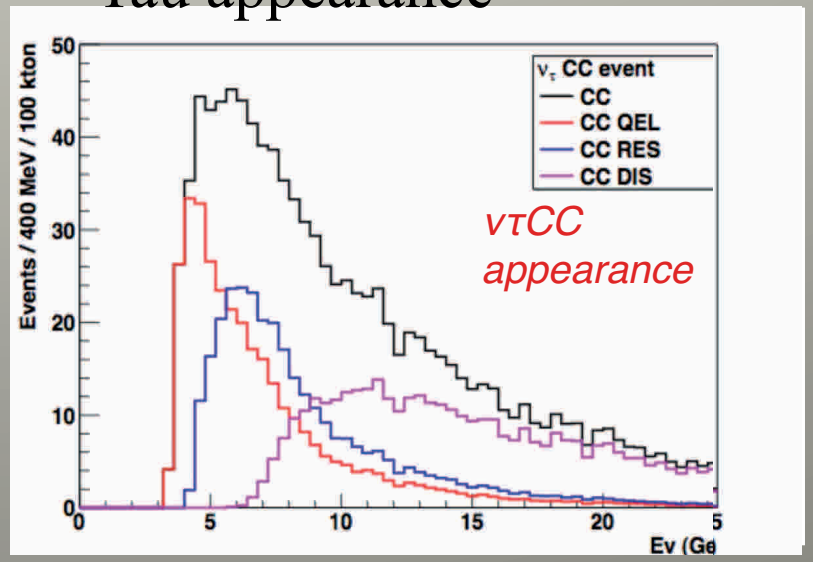


Neutrino beam polarity
$\sin^2 2\theta_{23}=1.0$, $\sin^2 2\theta_{13}=0.1$

Distance/OA	ν_μCC	$\bar{\nu}_\mu$CC	$\nu_e \to \nu_\mu$	$\bar{\nu}_e \to \bar{\nu}_\mu$
Pyhäsalmi 2300 km 0.35 deg	1752	358	880	1018



Tau appearance

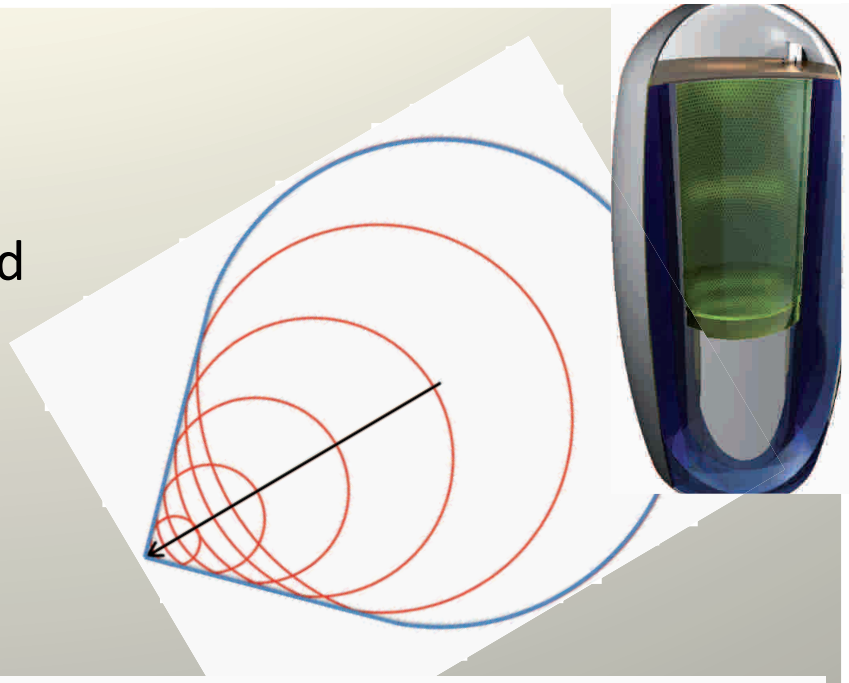


Electron appearance

Courtesy: A. Rubbia

LENA and beams:

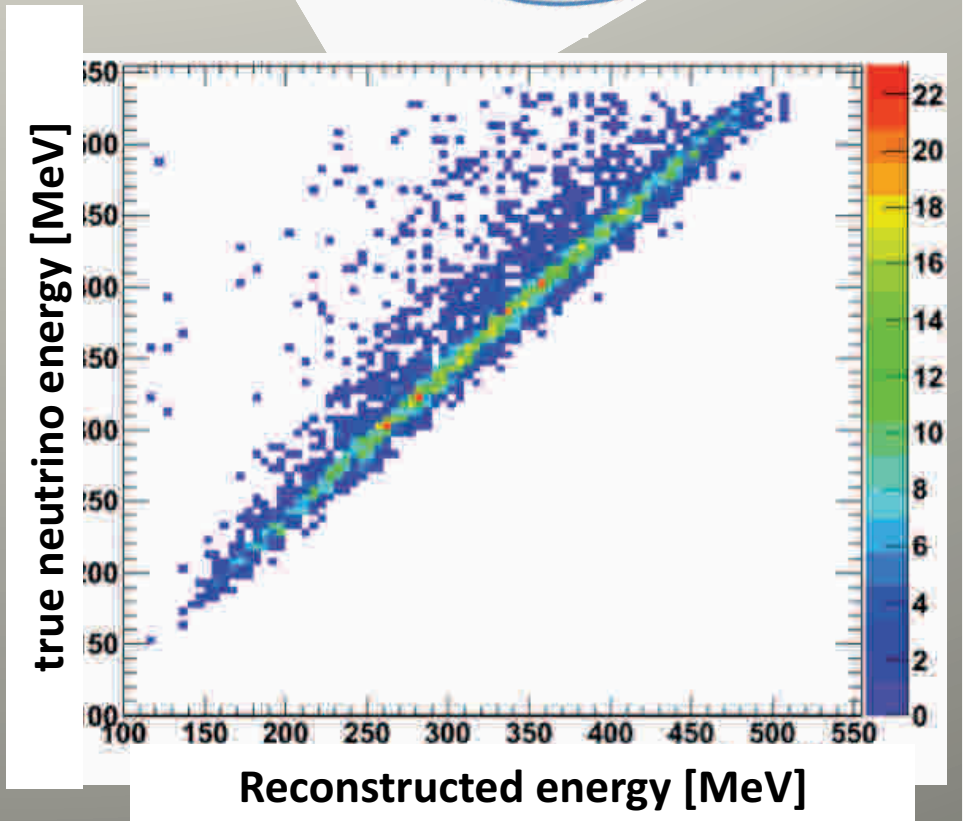
In LENA: High-energy particle tracking based on Cherenkov-like scintillation light fronts.



Expected detector performance:

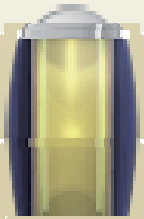
- **$\nu_{\square}$ selection based on delayed $\square$-decay electrons:**
  ν_e rejection > 99.96% (95%CL)
  for 85% $\nu_{\square}$ acceptance
- **calorimetric energy measurement:**
  e.g. ΔE_ν = 22 MeV at 400 MeV
- **rejection of $\pi^{\pm}$ backgrounds:**
  work still in progress ...

→ no sensitivity estimate yet,
but first results look promising!



Courtesy: M. Wurm

Outstanding physics goals

	 GLACIER	 LENA	 MEMPHYS
Total mass	100 Kton	50 kton	500 Kton
p -> $e\pi^0$ in 10 y	0.5 x 10^{35} y ε = 45%, ~1 BG event	?	1.2 x 10^{35} y ε = 17%, ~1 BG event
p -> ν K in 10 y	1.1 x 10^{35} y ε = 97%, ~1 BG event	0.4 x 10^{35} y ε = 65%, <1 BG event	0.15 x 10^{35} y ε = 8.6%, ~30 BG events
SN cool off at 10 Kpc	38·500 (all flavors) (64·000 if NH-L mixing)	20·000 (all flavors)	194·000 (mostly $\nu_e p \rightarrow e^+ n$)
Sn in Andromeda	7 - (12 if NH-L mixing)	4 events	40 events
SN burst at 10 Kpc	380 ν_e CC (flavor sensitive)	~ 30 events	~ 250 ν-e elastic scattering
DSN	50	20-40	250 (2500 with Gd)
Atm. neutirnos	~1·100 events/y	5600/y	56·000 events/y
Solar neutrinos	324·000 events/y	?	91·250·000/y
Geo-neutirnos	0	~ 3·000 events/y	0

The EU design study "menu"

2008

2011

2013

time

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

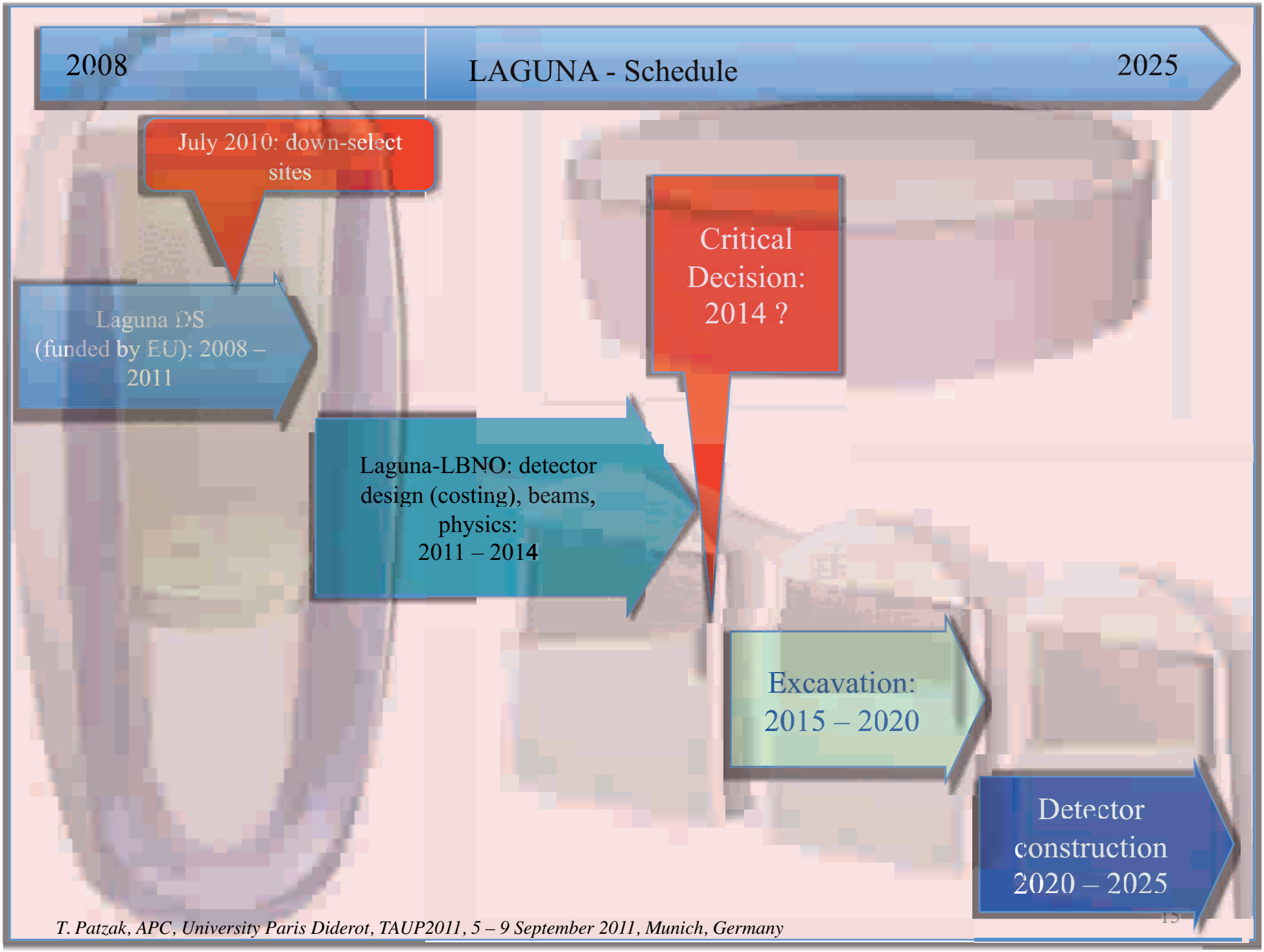
EuroNu

-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) ?

Courtesy: A. Rubbia


2008
LAGUNA - Schedule
2025
July 2010: down-select sites
Laguna DS (funded by EU): 2008 – 2011
Laguna-LBNO: detector design (costing), beams, physics: 2011 – 2014
Critical Decision: 2014 ?
Excavation: 2015 – 2020
Detector construction 2020 – 2025

Summary

- World-wide interest for next generation long-baseline based on the conventional neutrino beam technology, with longer baselines to address CP-violation and mass hierarchy, as the next step beyond T2K/NOvA.
- Next generation Neutrino Physics will come from new, megaton scale underground detectors
- Europe has a unique advantage of big choice of sites, detector technologies and beam options
- β−beam is an European invention and provides unreached sensitivity to LCPV and θ13, intensively studied in Euronu
- Laguna-Pyhäsalmi beam will be studied in Laguna-LBNO by CERN
- A LAGUNA-LBNO staged approach (“pilot project”) will likely be proposed. Open to all interested !

http://www.laguna-science.eu/


Thank YOU !

Acknowledgements

- FP7 Research Infrastructure “Design Studies” LAGUNA (Grant Agreement No. 212343 FP7-INFRA-2007-1)