WG7
Low energy neutrinos
and
proton decay

André Rubbia (ETHZ)

ASPERA/ApPEC preparatory meeting,
Paris, July 19th-20th

Community in WG7

Community in WG7

- LVD
- BOREXINO / CTF
- DOUBLE-CHOOZ
- ICARUS T600
- MEMPHYS R&D
- LENA R&D
- GLACIER R&D
- (Eventually possibly also OPERA and T2K-EU ?)

→ *Convergence*

“Almost” all questionnaires have been filled out

Meeting in Chambery, March 2nd

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- Status of several on-going projects
- Mostly discussions
    - Input to the roadmap, how to proceed, definition milestones
    - How to prepare input for ASPERA Amsterdam meeting
    - Focus on large underground infrastructures for next generation proton decay, low energy neutrinos, long baseline neutrino beams
- Discussion on LAGUNA DS proposal

Attendance in Chambery

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Comment: First Workshop 2 march 2007 - Chambery

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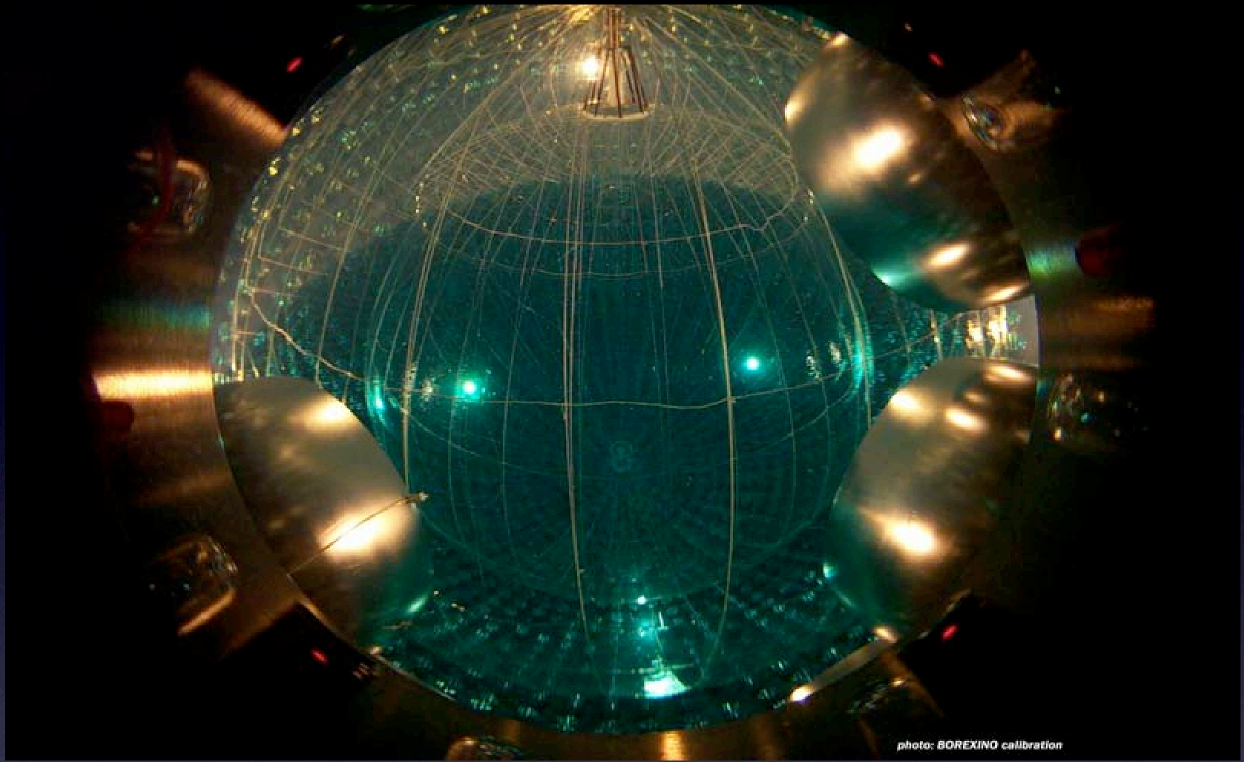
LVD-Gd

- LVD foresees an upgrade of the detector.
- Filling 1 out of 3 towers (about 300 tons) with Gd-doped liquid scintillator.
- Increase of detection efficiency for supernova events.

BOREXINO / CTF



- BOREXINO: 100% filled & taking data !
- First results soon
- CTF : continue operation as a general facility for scintillator development

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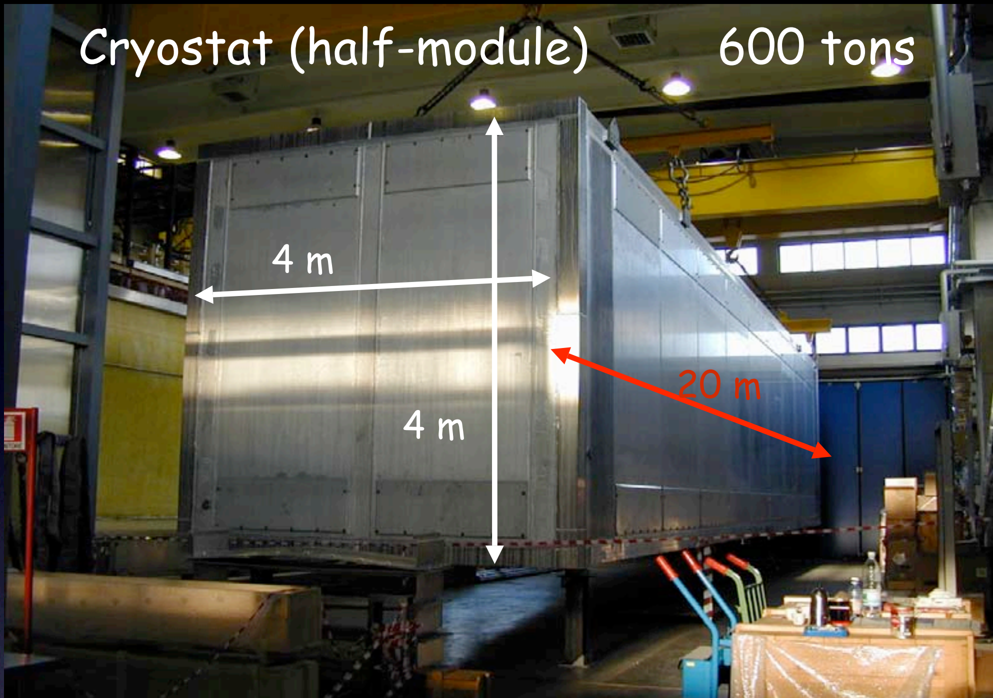
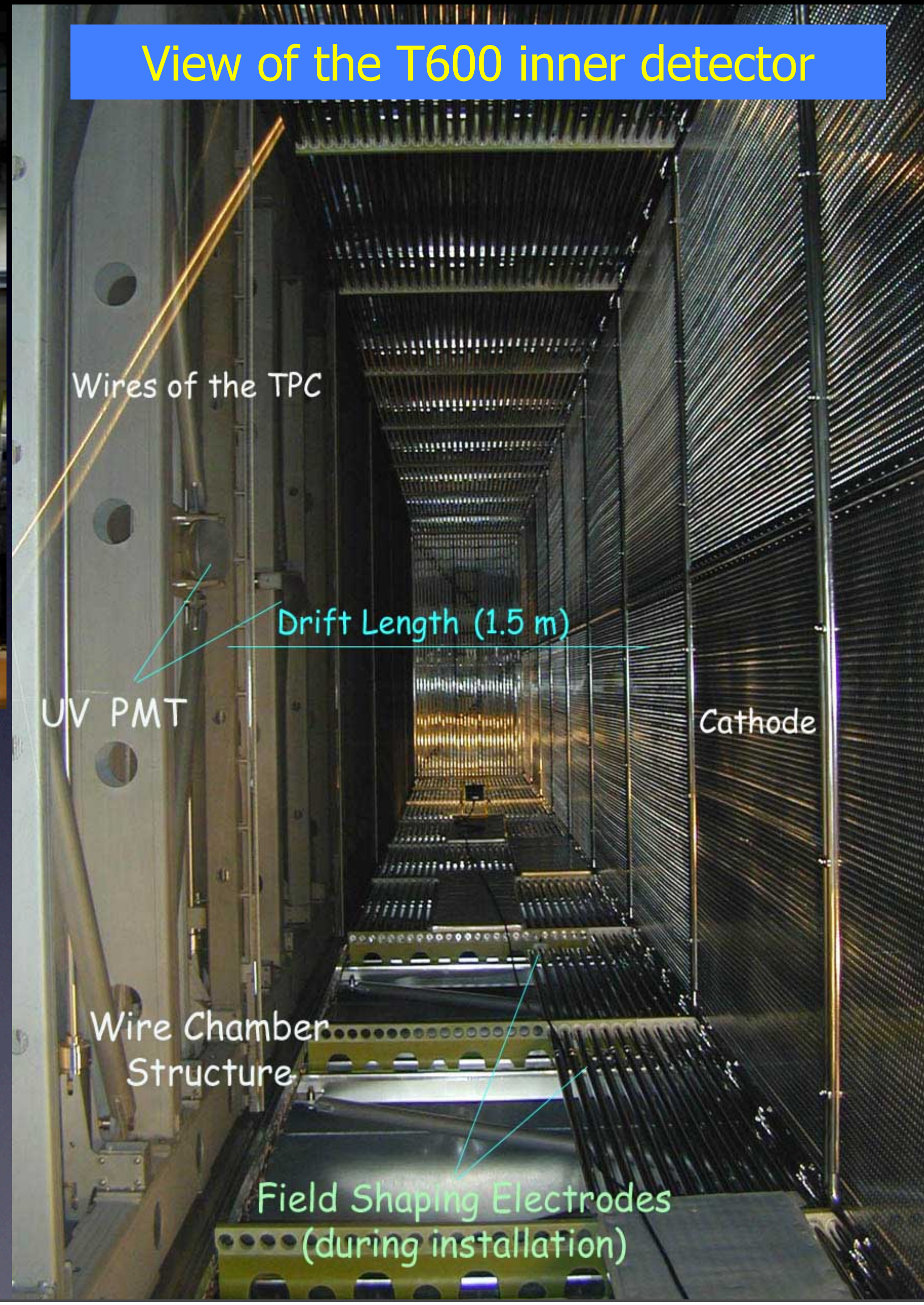
Double CHOOZ

- Under construction
- Installation of the far detector, to take data starting in 2008
- Installation of the near detector planned for 2009
- Data taking with both detectors until ≈2011

The ICARUS T600 detector

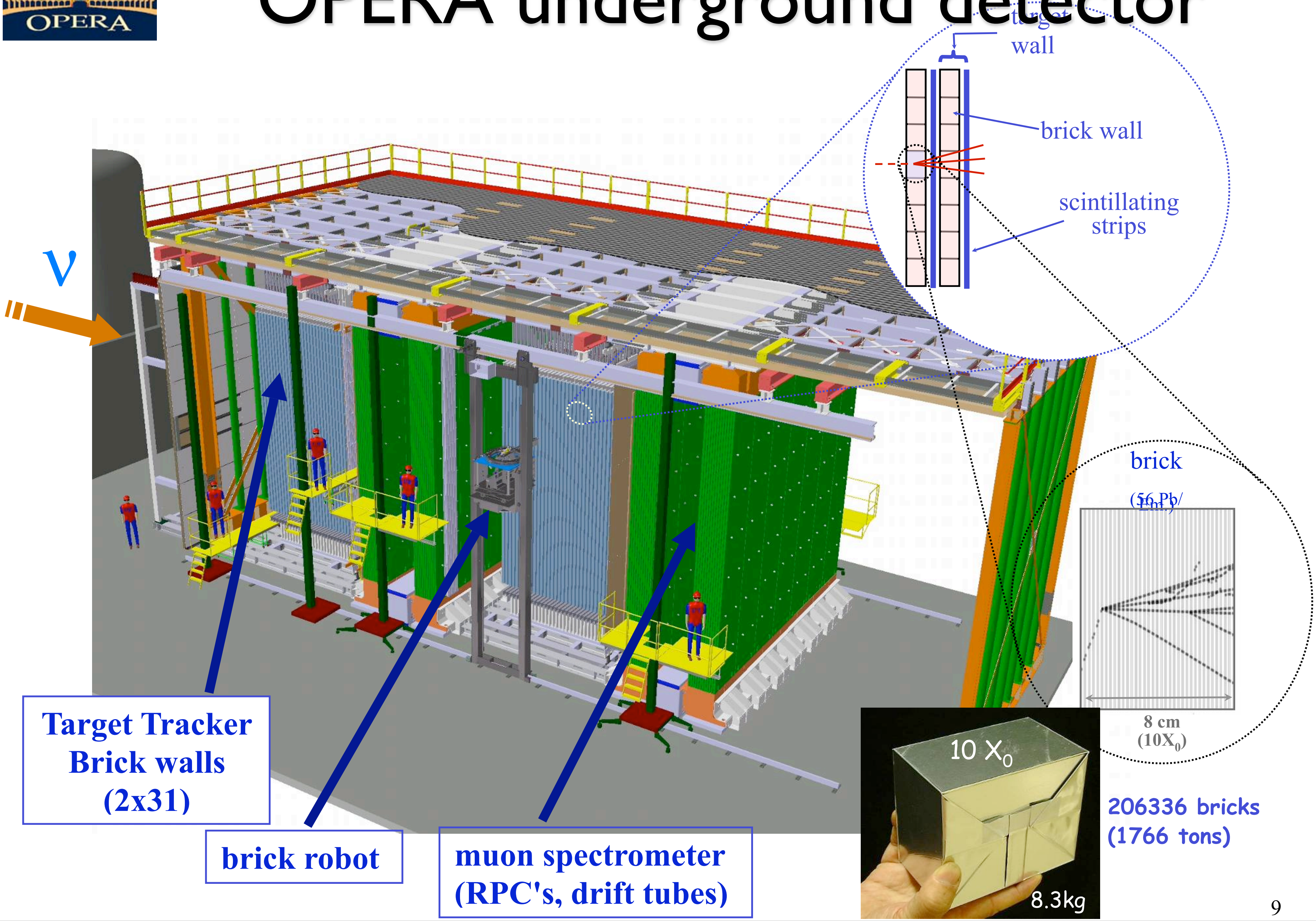




- Built between years 1997 and 2001
- Completely assembled on surface
- Full scale demonstration test run on surface conditions of one half-module in summer 2001
- Full unit assembly terminated in 2002
- Results published
- Transportation to LNGS in 12/2004
- **Planned T600 commissioning in 2007 ?**
- INFN contemplates construction of bigger modules in new nearby LNGS site (off-axis CNGS)

See arXiv:0704.1422 (April 2007)

OPERA underground detector



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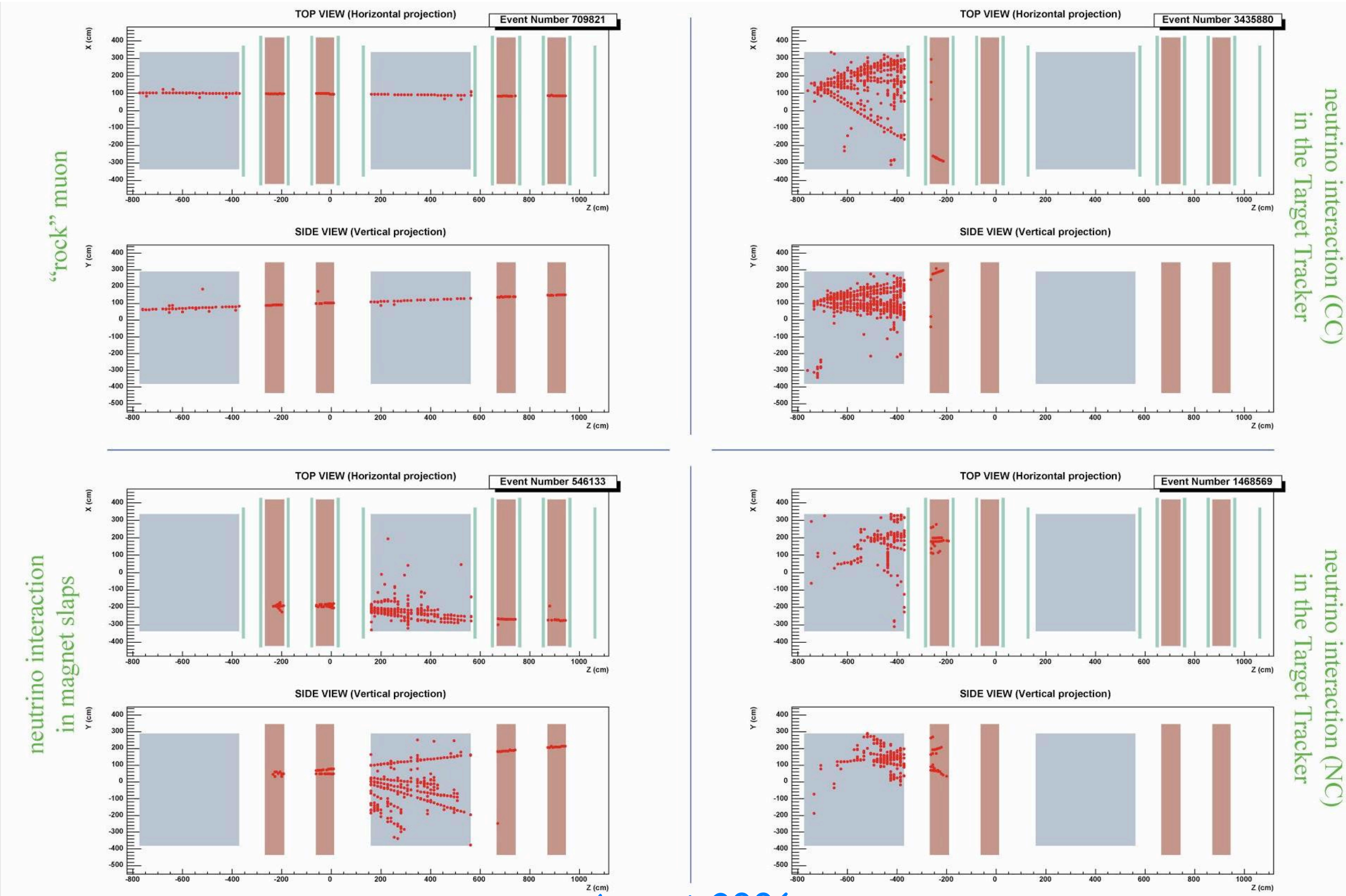
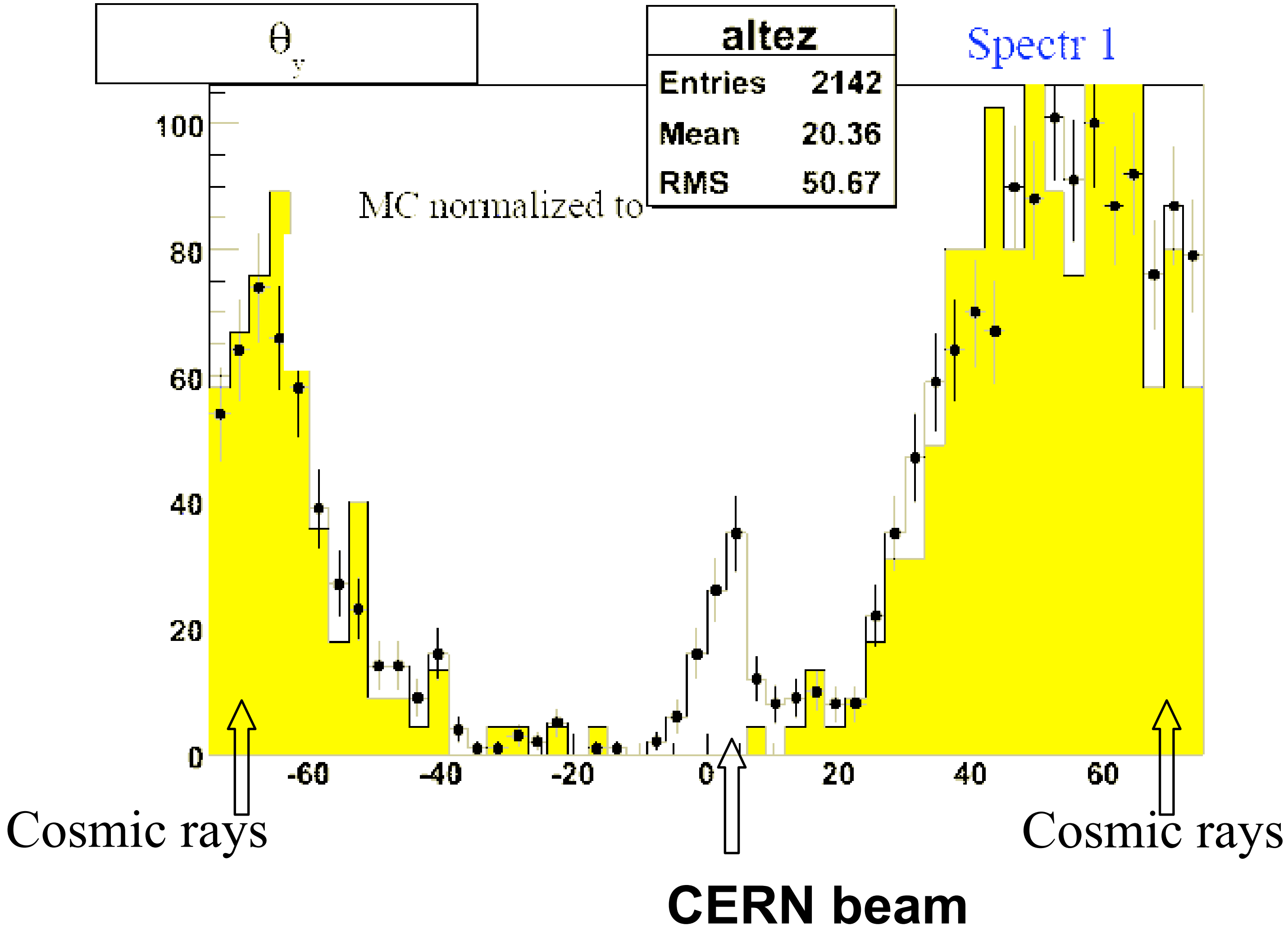
CNGS events

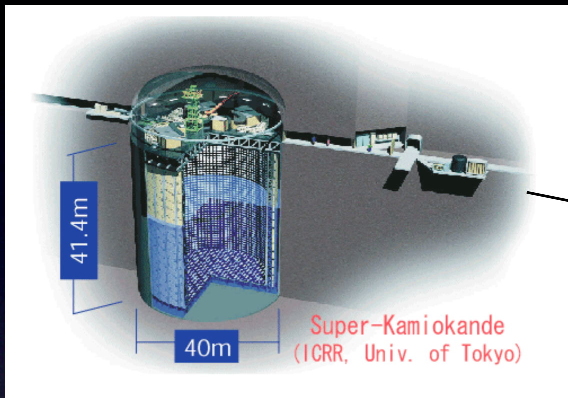


August 2006

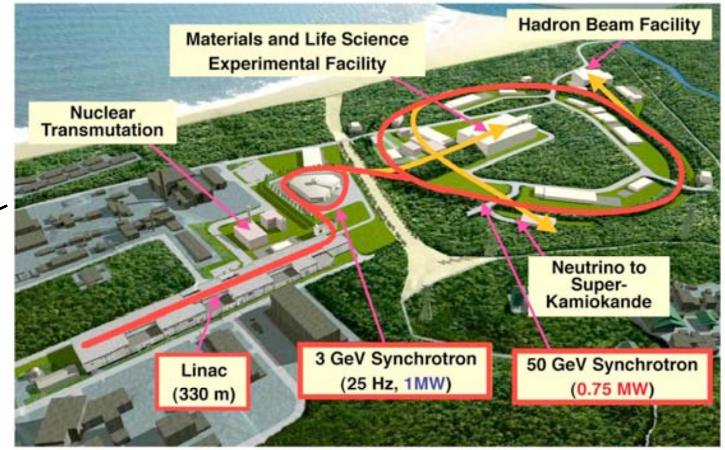
OPERA as a cosmic ray detector !



Tokai to Kamioka (T2K)

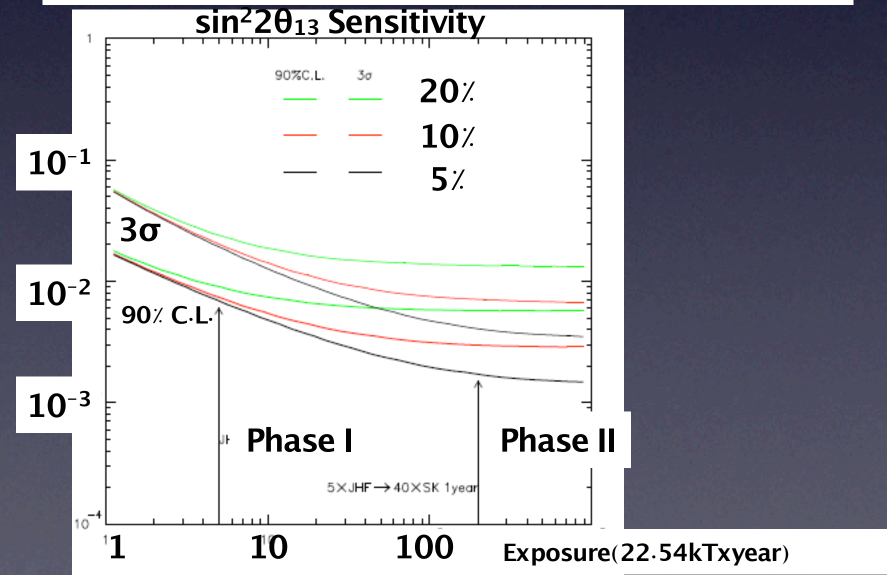


Far detector : Super Kamiokande



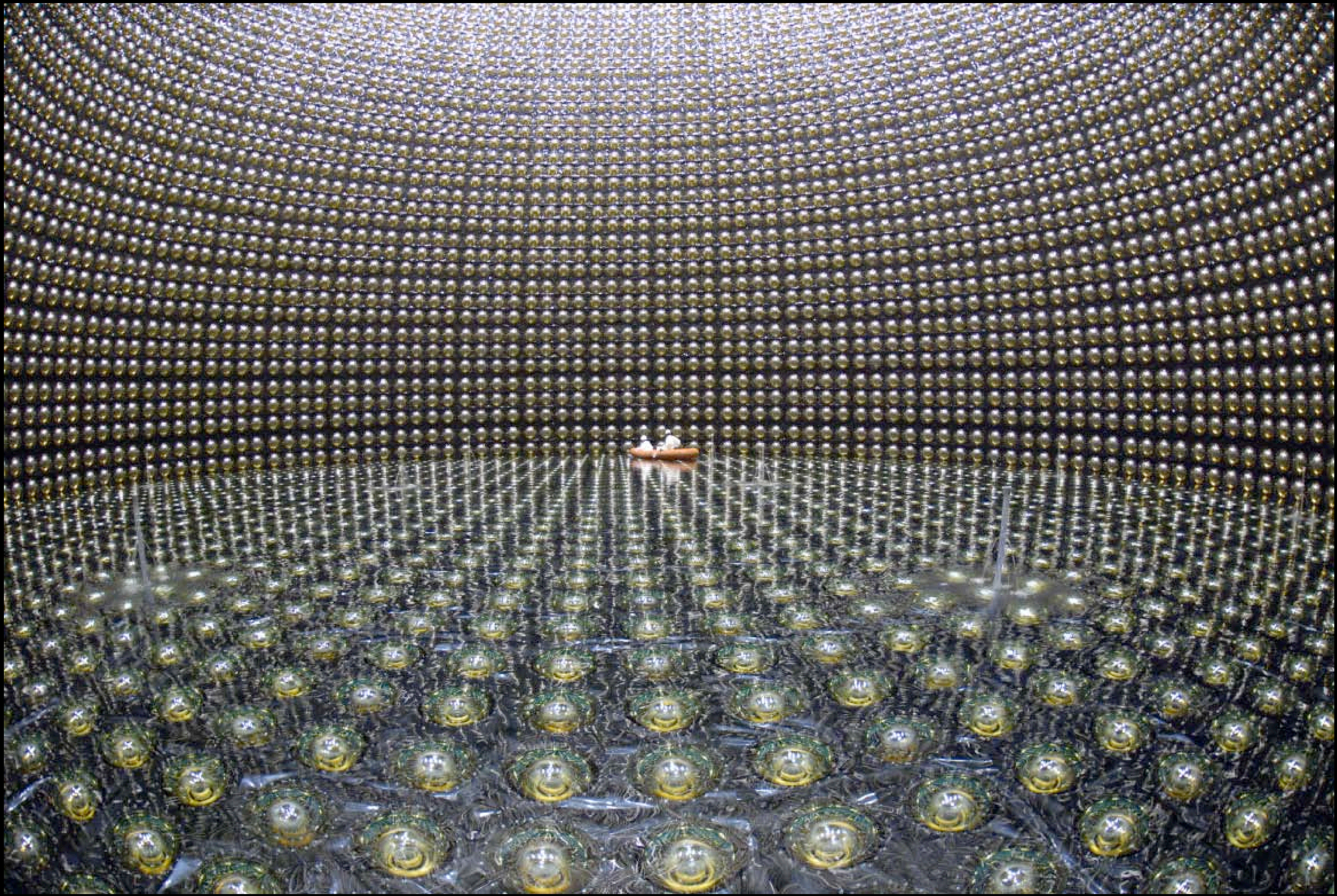
ν beam : J-PARC facility

- ➡ **2009 Phase I : θ_{13}, θ_{23}, Δm^2_{23}**
  - J-PARC : 0.75 MW @ 30 GeV
  - SK-III : 22.5 kT FV, full PMT coverage
- ➡ **2015 Phase II : θ_{13}, δ_{CP} ?**
  - J-PARC : 4MW @ 50 GeV (?)
  - HyperK : 1 MT scale



Currently 28/62 European institutes, ~170/370 European names

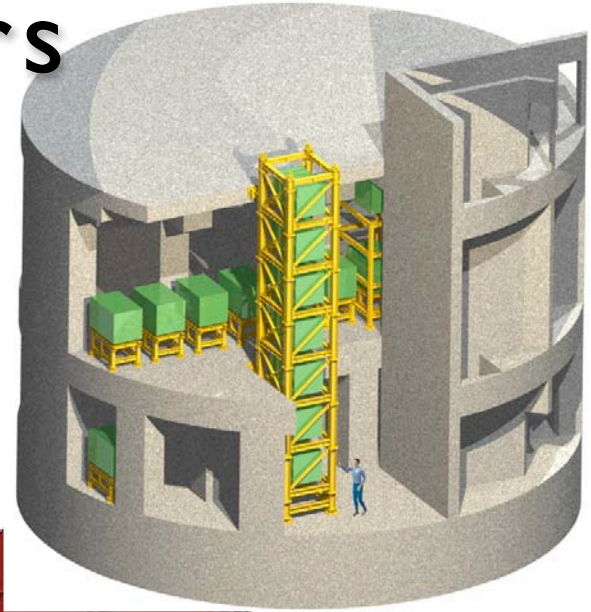
T2K Far detector: SK-III



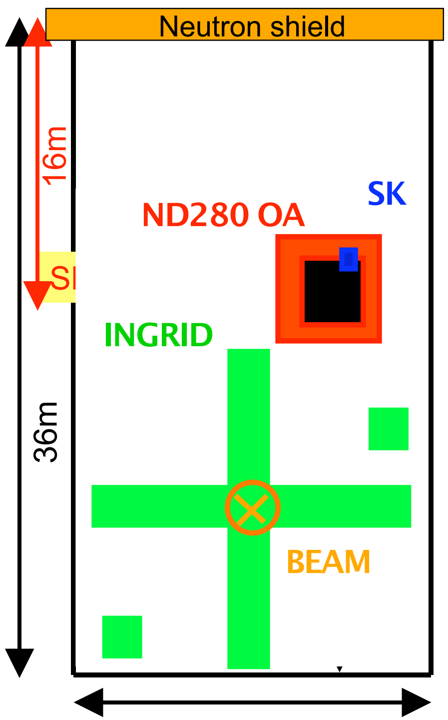
- *Rebuilt and operational*

ND280 Near Detectors

- To be measured before oscillation: Beam flux, Beam νe contamination, non-QE background
- Near detector tasks :
  - SuperK νe background < 10%
  - νμ event normalisation < 5%
  - Energy scale <2%
  - Beam linear distortion < 20%
  - Width < 10%
  - non-QE/CCQE at 5-10%



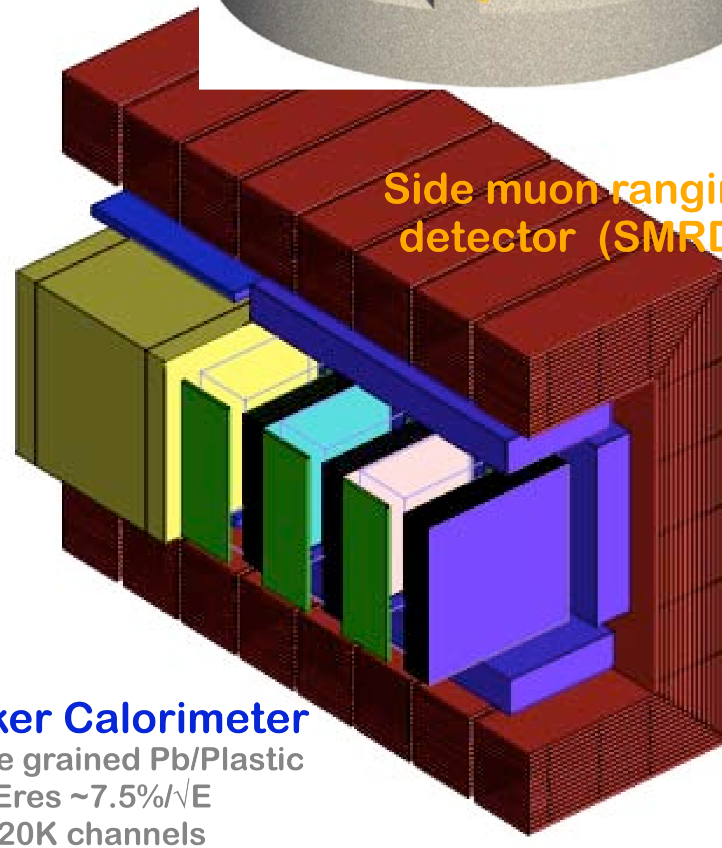
ND280 Pit



UA1/NOMAD magnet
B=0.2 T

3 TPC modules
MicroMegas pads
Position resolution < 0.8 mm
Mom resolution to 1GeV <7-8%

2 Fine Grained 2x1.3t target detectors (FGD)
FGD1(C): X-Y plastic
FGD2(H20): X-Y plastic+passive water target
8k channels



Tracker Calorimeter
X-Y fine grained Pb/Plastic
Eres ~7.5%/√E
20K channels

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Large underground infrastructures

Large underground infrastructures

- Advances in low energy neutrino astronomy and direct investigation of Grand Unification require the construction of very large volume underground observatories.
- There is currently no such infrastructure in Europe able to host underground instruments of this size, although many national underground laboratories with high technical expertise are currently operated with leading-edge smaller-scale underground experiments.
- A pan-European infrastructure able to host underground instruments with volumes up to 1’000’000 m^3 will provide new and unique scientific opportunities in low energy neutrino astronomy and Grand Unification physics.
- This field of research is at the forefront of particle and astro-particle physics and is the subject of intense investigation also in North America and Asia. Such an infrastructure in Europe would attract scientists from all over the world and ensure that Europe will continue to play a leading and innovative role in the field.

Worldwide roadmaps...

Worldwide roadmaps...

A neutrino detector optimized for neutrino energies of the order of ~1 GeV and to search for proton decay

★ Asia: Super-K (50 kton WC) ➠ Hyper-K (1 Mton WC) (T2K phase II / T2KK)

★ US: Report of the US long baseline neutrino experiment study "*A well instrumented very large detector, in addition to its accelerator based neutrino program, could be sensitive to proton decay which is one of the top priorities in fundamental science... Indeed, there is such a natural marriage between the requirements to discover leptonic CP violation and see proton decay that it could be hard to imagine undertaking either effort without being able to do the other*"

★ EU: ApPEC recommendation "*We recommend that a new large European infrastructure is put forward as a future international multi-purpose facility on the 100 – 1000 ktons scale for improved studies of proton decay and of low-energy neutrinos from astrophysical origin. The detection techniques ... 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*"

ApPEC Phase I 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

Proton decay and low energy neutrino astrophysics

A. Rubbia

Worldwide context: very large volumes

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Worldwide context: very large volumes

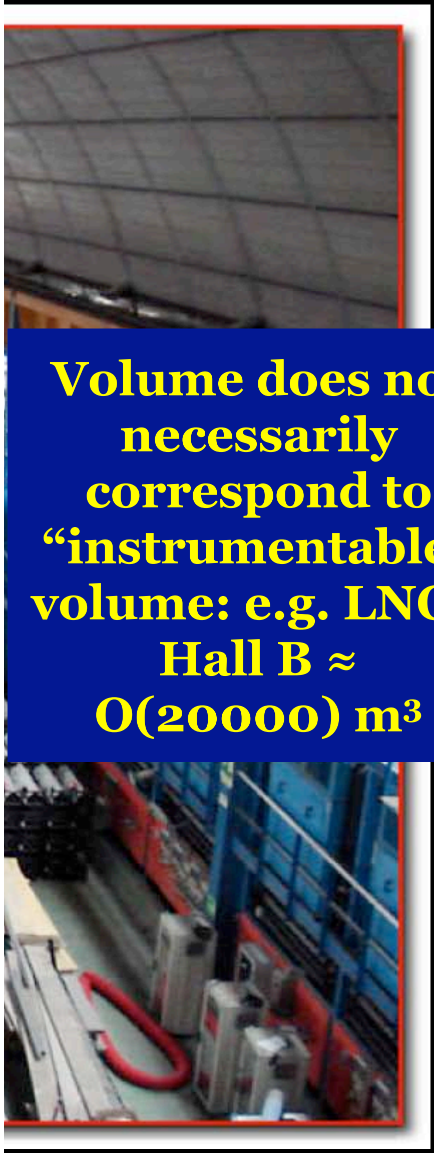
Europe enjoys today the most experience in underground science and sites, but lacks a coordinated plan for a possible future infrastructure of very large size

A. Rubbia

Instrumenting underground cavities

Instrumenting underground cavities

Infrastructure ▸	LNGS Gran Sasso	LSM Fréjus	LSC Canfranc	IUS Boulby	BNO Baksan	CUPP Pyhäsalmi
Year of completion	1987	1982	1986, 2005	1989	1977, 1987	1993 (2001)
Area (m^2)	13000	500	150+600	500+1000	550, 600	500-1000
Volume (m^3)	180000	3500	8000	3000	6400, 6500	100-10000
Access	Horizontal	Horizontal	Horizontal	Vertical	Horizontal	Slanted truck road
Depth (m.w.e.)	3700	4800	2450	2800	850, 4800	1050, 1444 up to 4060
Surface profile	Mountain	Mountain	Mountain	Flat	Mountain	Flat
Muon flux (m^{-2} day^{-1})	24	4	406	34	4320, 2.6	8.6 @ 4060m
Neutron flux (>1 MeV) (10^{-6} cm^{-2} s^{-1})	*O* (1)	*O* (1)	*O* (1)	*O* (1)	- , *O* (1)	?
Radon content (Bq/m^3)	*O* (100)	*O* (10)	*O* (100)	*O* (10)	*O* (100)	*O* (100)
Main past and present scientific activities	- DM - ββ - solar ν - SN ν - atmos. ν - monopole - nuclear astrophysics - CRs (μ) - LBL ν's	Eighties: - Proton decay - atmos.ν Now: - DM (Edelweiss) - ββ (NEMO, TGV)	- DM (IGEX-DM, ROSEBUD, ANAIS) - ββ (IGEX)	- DM (Zeplin I,II, III, DRIFT)	*BUST:* - solar ν - SN ν - atmos. ν - CRs (μ) - monopo-les *SAGE:* - solar ν	- CRs (test set-up)
Number of visiting scientists	700	100	50	30	55	15



Volume does not necessarily correspond to "instrumentable" volume: e.g. LNGS Hall B ≈ O(20000) m³

Broad and rich physics programme

- Direct evidence for Grand Unification (Proton decay)
- Low energy neutrino astronomy (SN, solar, geo, atm)
- Long baseline neutrino beam ($\not{C}P$)

Combine accelerator & non-accelerator physics

Broad and rich physics programme

- Direct evidence for Grand Unification (Proton decay)
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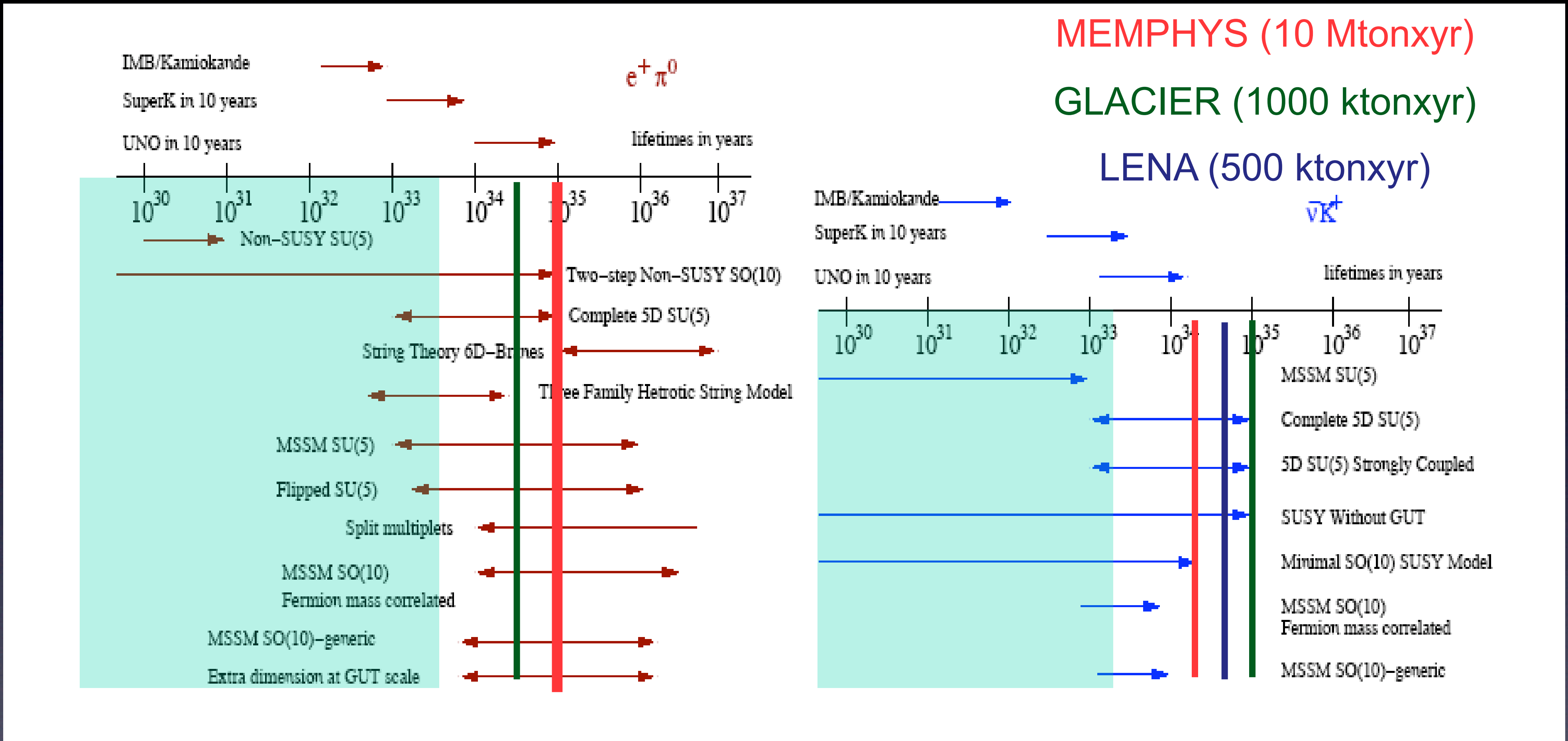
Combine accelerator & non-accelerator physics

Sensitivity to proton decay



Higher dimension models (eg. 6D SO(10)) not included

Definitively not exhaustive.

A. Rubbia

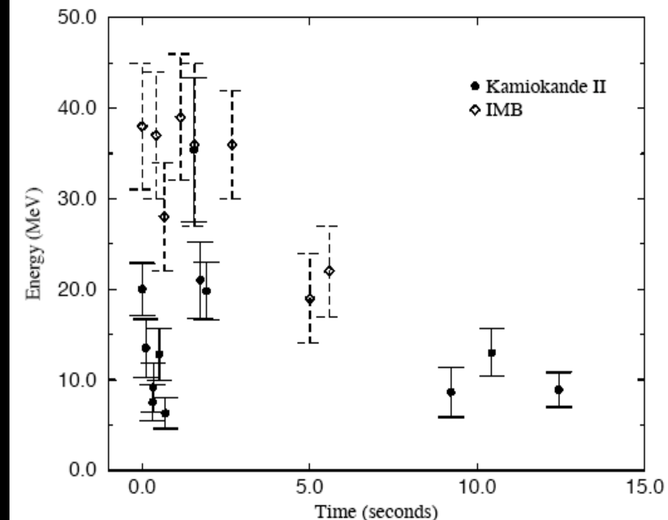
Supernova type-II neutrinos

⇒Access supernova and neutrino physics simultaneously

⇒Decouple supernova & neutrino properties via different detection channels

SN1987A Type II in LMC (~55 kpc)

Water Cherenkov:	IMB	E_{th} ~ 29 MeV, 6 kton		8 events
	Kam II	E_{th} ~ 8.5 MeV, 2.4 kton		11 events
Liquid Scintillator:	Baksan	E_{th} ~ 10 MeV, 130 ton		3-5 events
	Mont Blanc	E_{th} ~ 7 MeV, 90 ton		5 events??



Confirmed baseline model... but still many questions

1. Supernova physics:

- Gravitational collapse mechanism
- Supernova evolution in time
- Burst detection
- Cooling of the proto-neutron star
- Shock wave propagation
- Black hole formation?

2. Neutrino properties

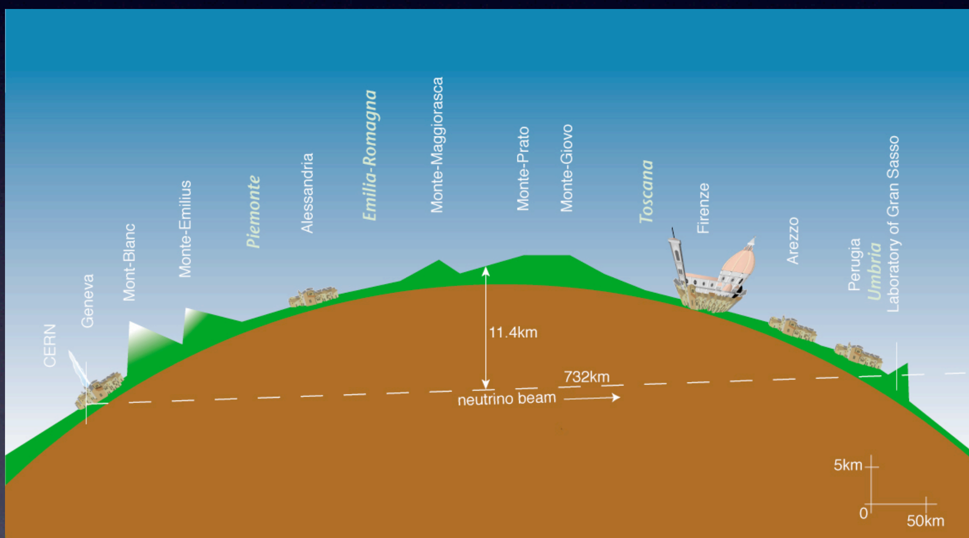
- Neutrino mass (time of flight delay)
- Oscillation parameters (flavor transformation in SN core and/or in Earth): Type of mass hierarchy and θ_{13} mixing angle

3. Early alert for astronomers

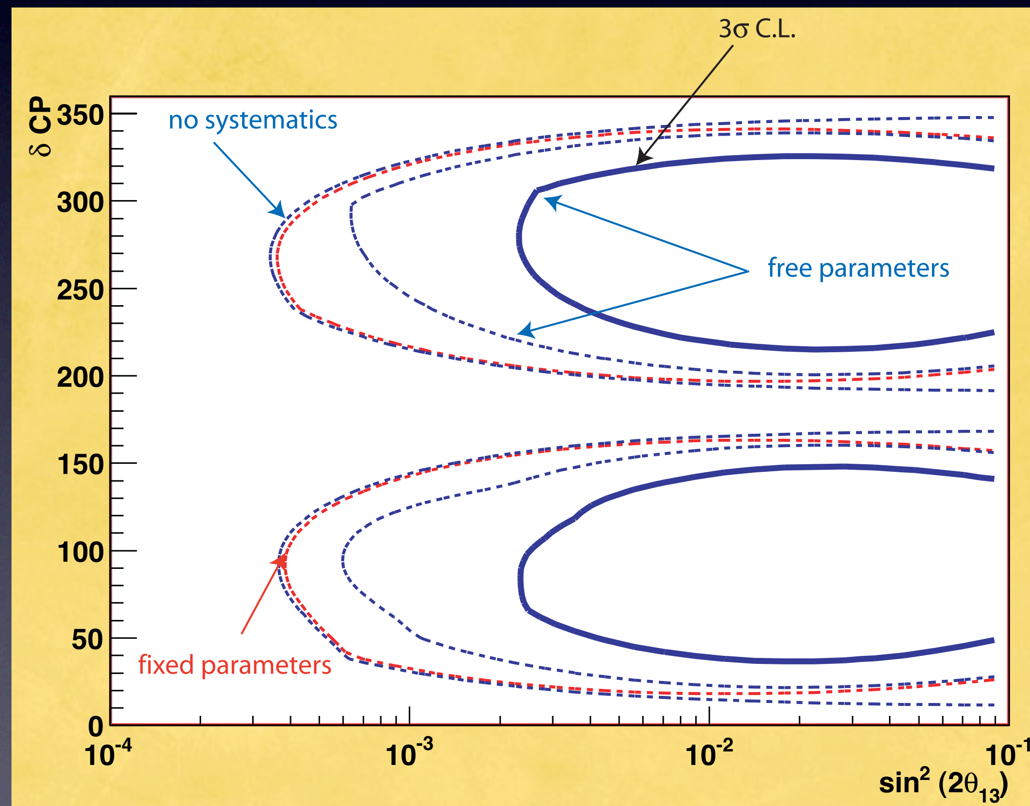
- Pointing to the supernova

Long baseline beams : CP-violation & matter effects

- Precision measurement of neutrino oscillations to determine missing elements in neutrino mixing matrix and possibly discover CP-violation in the leptonic sector



CERN-SPS 400 GeV protons
New LHC injection chain ➠
MW-class neutrino beam (>2016)



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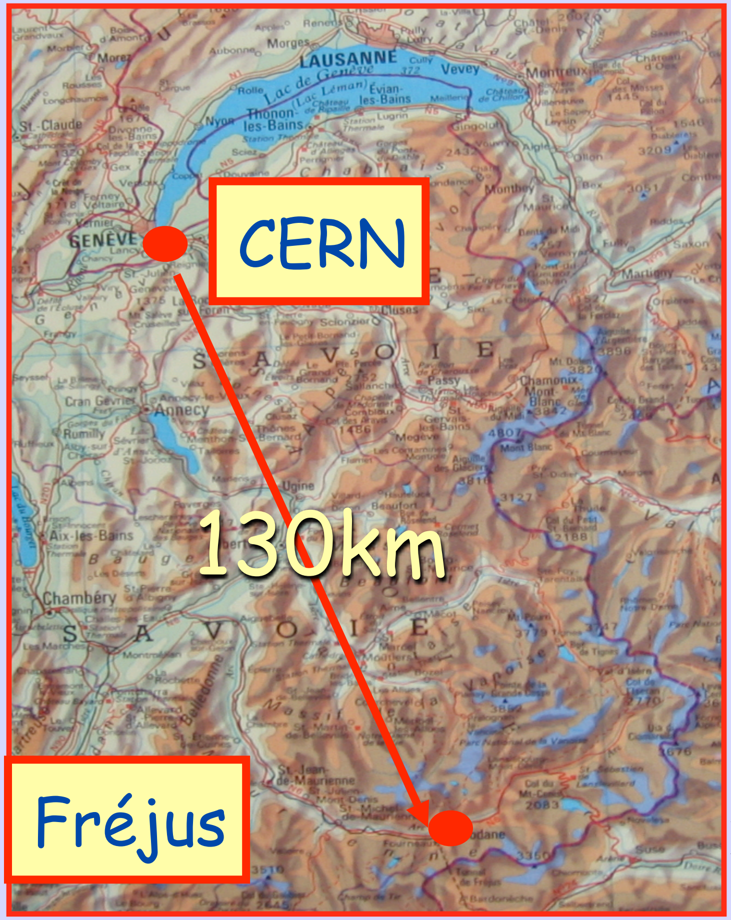
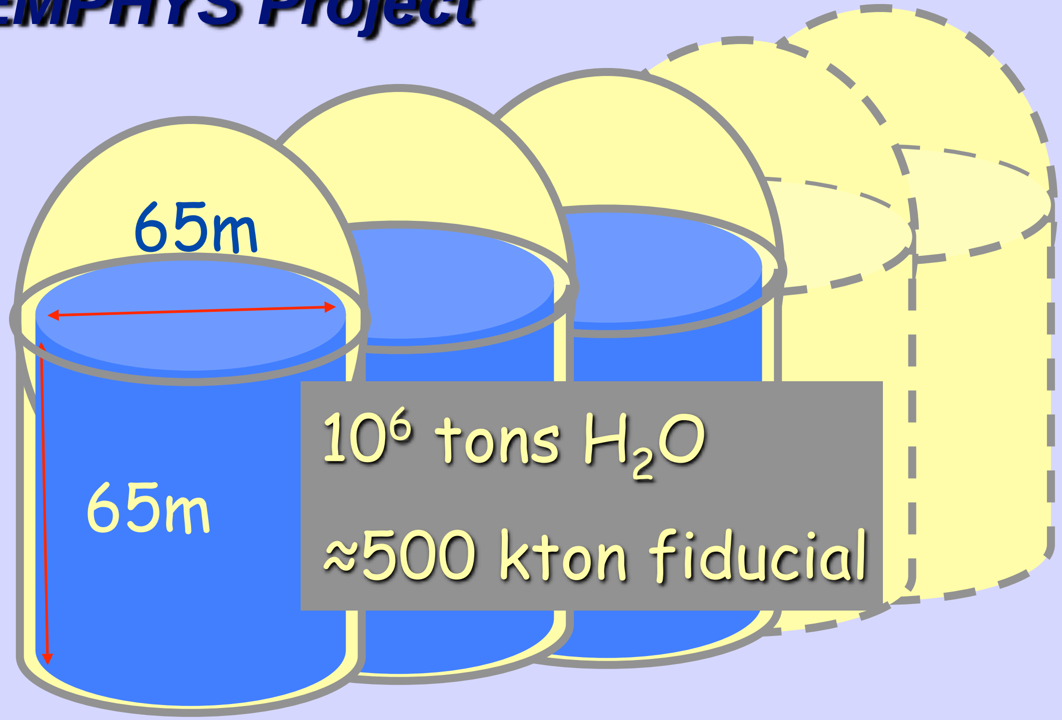
The MEMPHYS Project





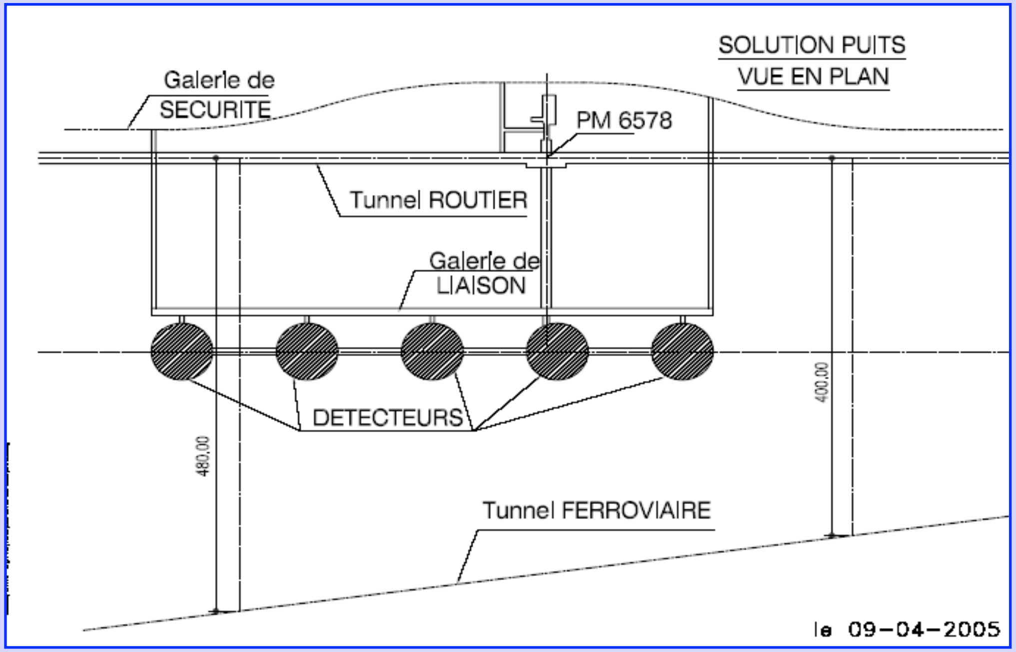
Water Cerenkov modules at Fréjus

CERN-Fréjus distance ⇔ unique opportunity for very intense, low energy (≈300 MeV) beam (Super-beam and Beta-beam)

- ★ Concept emerged considering new potential neutrino sources at CERN (low energy super Beam, Beta Beam). This requires construction of the new high-intensity proton driver SPL and the EURISOL facility at CERN.
- ★ In addition, Nucleon Decay, Super Novae Neutrinos (burst & relic), Solar & Atmospheric Neutrinos like in the Japanese study

A new very large laboratory in Fréjus

Excavation engineering pre-study
has been done for 5 shafts



1) the best site (rock quality) is found in the middle of the mountain, at a depth of 4800 mwe : a really good chance !

2) of the two considered shapes : “tunnel” and “shaft”, the “shaft (= well) shape” is strongly preferred

3) Cylindrical shafts are feasible up to :

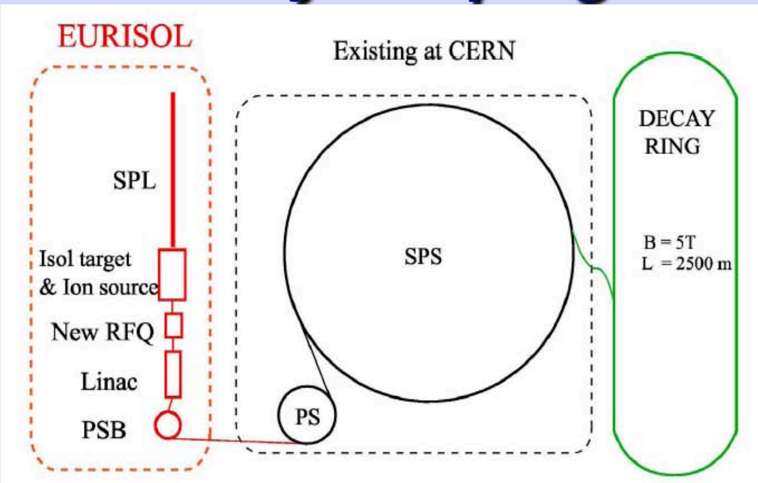
a diameter Φ = 65 m and a full height h = 80 m (≈ 250 000 m^3)

4) with “egg shape” or “intermediate shape” the volume of the shafts could be still increased

5) The estimated cost is ≈ 80 M€ X Nb of shafts

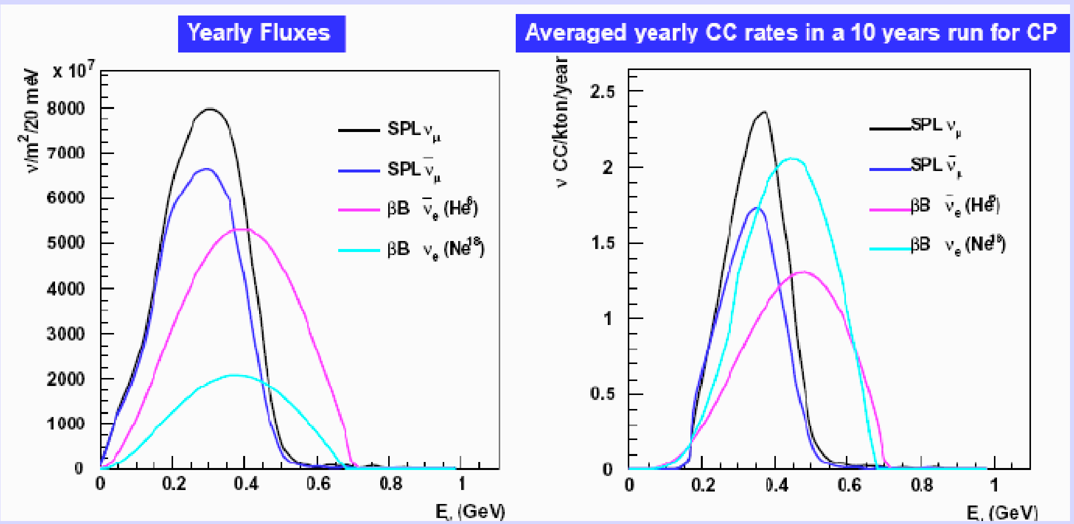
1 module ≈ 4 x SK
≈ 100kT fiducial mass)
equipped with a large number of Photodetectors
(eg. 50,000 PMTs 12”)

Physics program with new CERN low energy beams

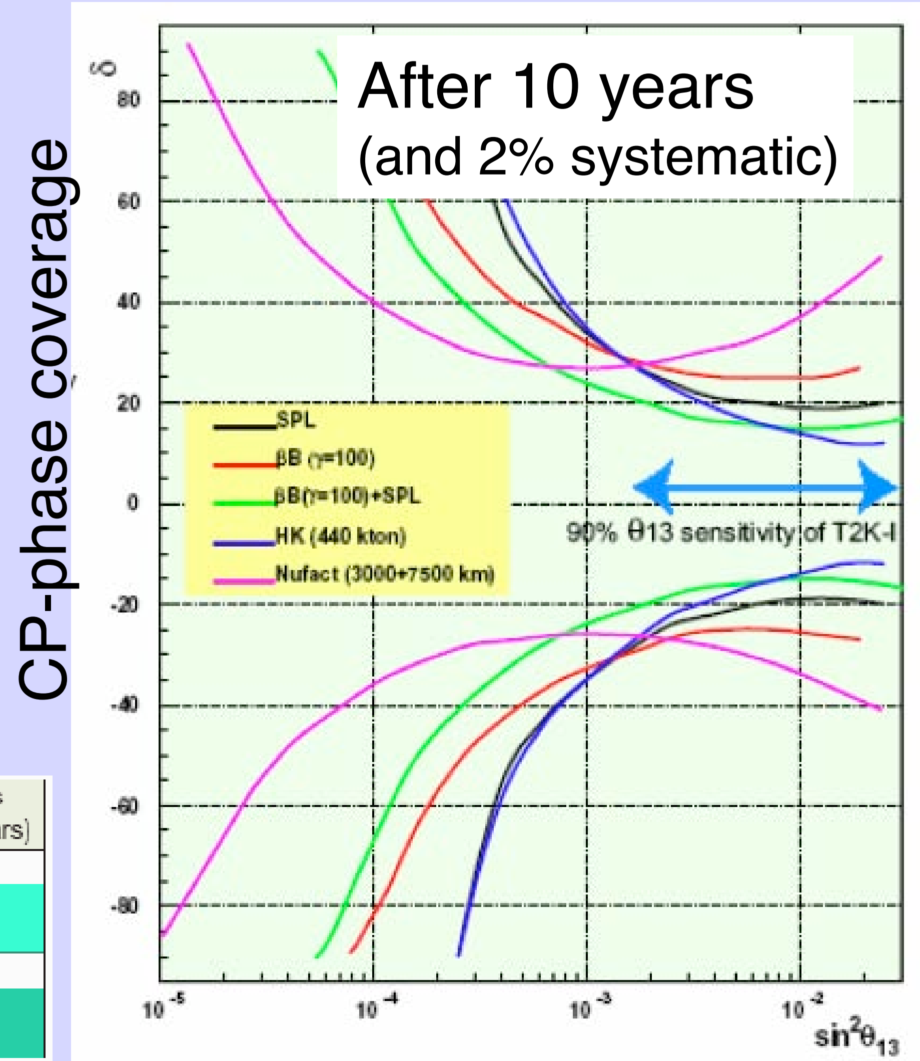


Search for $\nu_e \rightarrow \nu_\mu$ oscillations with beta-beams:

- easier detector task (μ detection)
- however, need good event reconstruction: pions in NC can fake muons
- low energy makes pion production below Cerenkov threshold



	Fluxes @ 130 km $\nu/m^2/yr$	$\langle E_\nu \rangle$ (GeV)	CC rate (no osc) events/kton/yr	$\langle E_\nu \rangle$ (GeV)	Years	Integrated events (440 kton × 10 years)
			SPL Super Beam			
ν_μ	$11.80 \cdot 10^{11}$	0.29	121.7	0.36	2	107127
$\overline{\nu}_\mu$	$9.66 \cdot 10^{11}$	0.28	23.1	0.35	8	81164
			Beta Beam			
$\overline{\nu}_e(\gamma = 100)$	$10.92 \cdot 10^{11}$	0.40	46.0	0.46	5	101262
$\nu_e(\gamma = 100)$	$4.06 \cdot 10^{11}$	0.38	65.4	0.44	5	143887



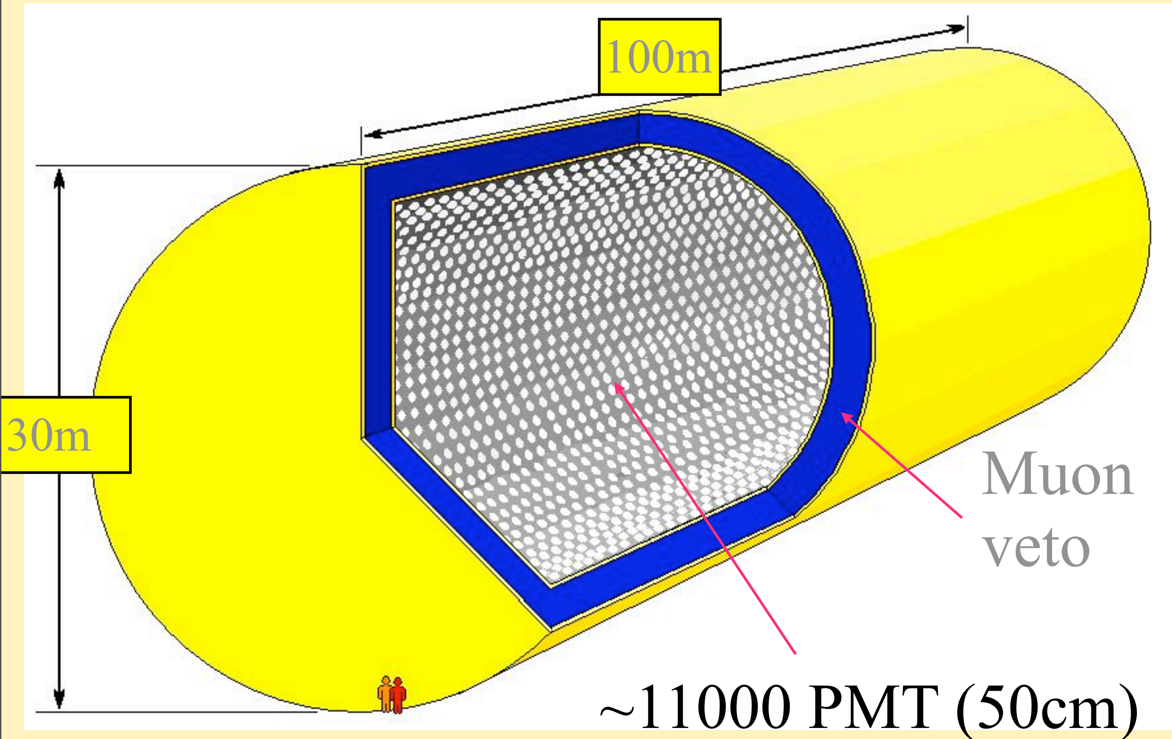
MEMPHYS R&D

- R & D on large area photomultiplier production
- R&D on integrated photomultiplier electronics production
- Smaller scale prototypes (e. g. MEMPHYNO)

Low Energy Neutrino Astrophysics (LENA)

Design for a large (~50 kton) liquid scintillator underground detector

Use technology developed for BOREXINO



Scintillator solvent: PXE ($C_{16}H_{18}$), ultrapure.
Assumed attenuation length ≈ 12 m @430 nm

Estimated light yield ~ 110 pe / MeV
Total number of photomultiplier ~ 11000 (30% coverage)

- **non hazardous, flashpoint 145° C ➠ easy handling**
- **density 0.99 ➠ high self shielding**
- **high light yield ➠ low energy events**
- **low background level U, Th ➠ solar ν, geo ν, srn ν**

Supernova neutrino detection

Electron Antineutrino spectroscopy

- $\overline{\nu}_e + p \rightarrow n + e^+$ (Q=1.8 MeV)
  $n + p \rightarrow d + \gamma$; $E_\gamma = 2.2$ MeV ~8700 events
- $\overline{\nu}_e + {}^{12}\mathrm{C} \rightarrow {}^{12}\mathrm{B} + e^- +$ (Q=17.3 MeV)
  ${}^{12}\mathrm{B} \rightarrow {}^{12}\mathrm{C} + e^+ + \overline{\nu}_e$; $\tau_{1/2} = 20.20$ ms ~494 events

Electron neutrino spectroscopy

- $\nu_e + {}^{12}\mathrm{C} \rightarrow e^- + {}^{12}\mathrm{N}$ (Q=13.4 MeV)
  ${}^{12}\mathrm{N} \rightarrow {}^{12}\mathrm{C} + e^+ + \nu_e$; $\tau_{1/2} = 11.00$ ms ~85 events

Neutral current interactions; info on all flavours

- $\nu_x + {}^{12}\mathrm{C} \rightarrow {}^{12}\mathrm{C}^* + \nu_x$
  with ${}^{12}\mathrm{C}^* \rightarrow {}^{12}\mathrm{C} + \gamma$; $E_\gamma = 15.11$ MeV ~2925 events
- $\nu_x + e^- \rightarrow \nu_x + e^-$ (elastic scattering) ~610 events
- $\nu_x + p \rightarrow \nu_x + p$ (elastic scattering)
  Detector energy threshold: $E_{th} = 0.2$ MeV ~7370 events

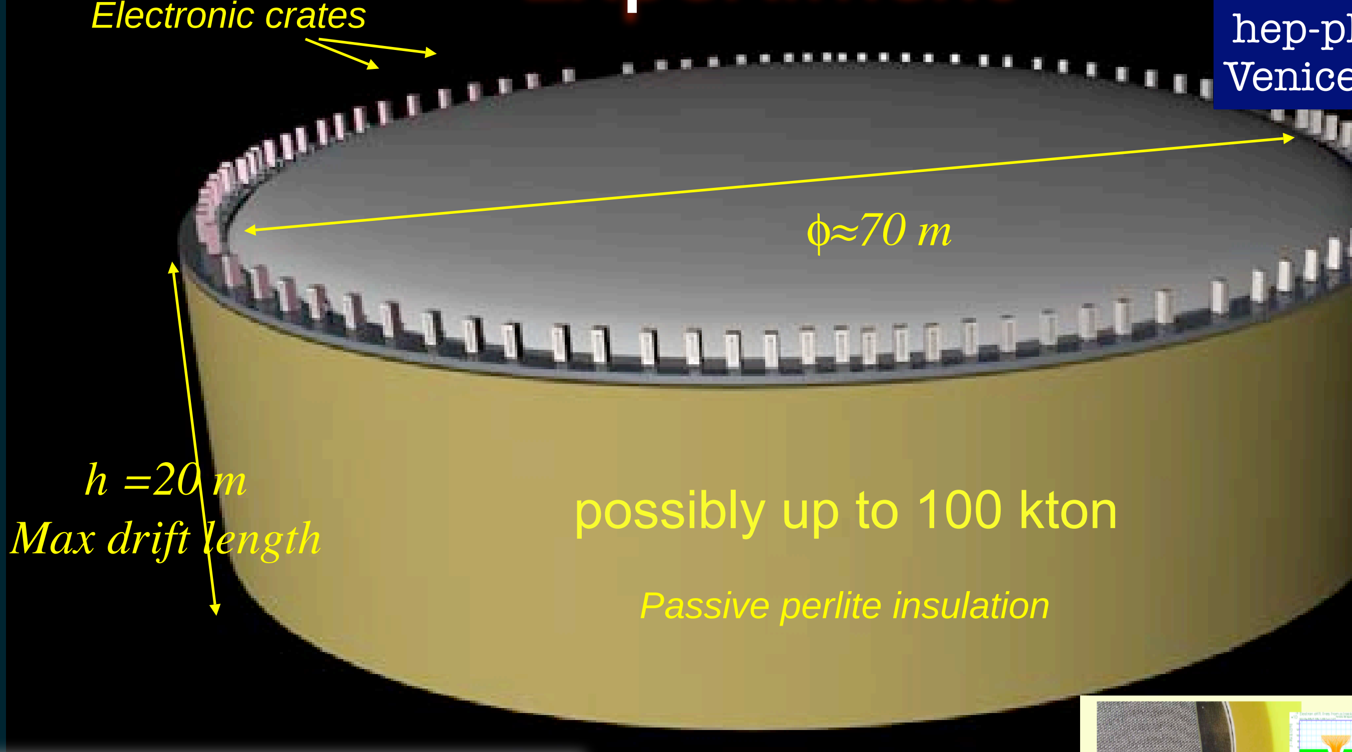
Total ≈ 20000 events

Event rates for a SN type IIa in the galactic center (10 kpc)

LENA R&D

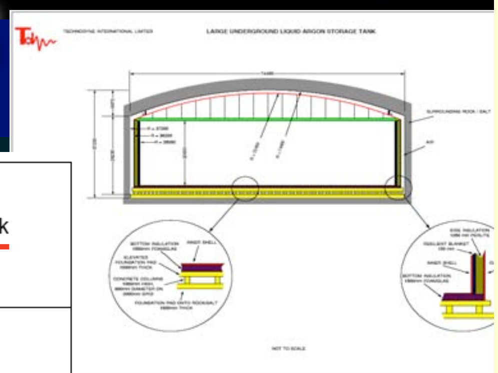
- Funded on a national scale in the " Center for excellence : origin and structure of the universe" and the "Sonderforschungsbereich- Transregio TR27: neutrinos and beyond" both at the Technische Universität München.
- The funding covers local expenses for the preparation of a full European design study.

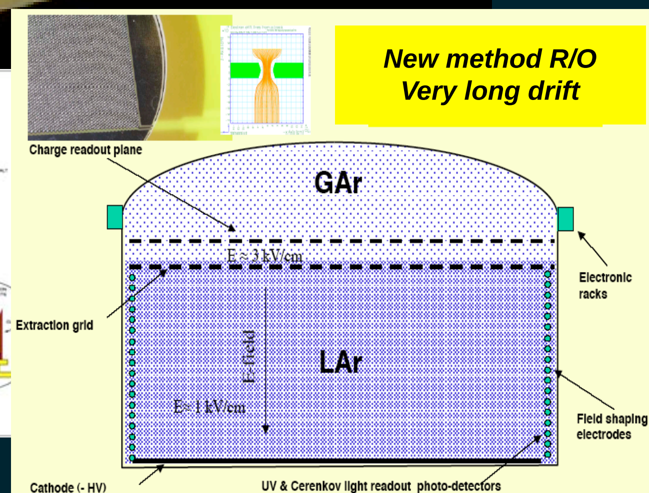
GLACIER: Giant Liquid Ar Charge Imaging ExpeRiment



hep-ph/0402110
Venice, Nov 2003

Single module cryo-tanker based on industrial LNG technology





	Project: Large Underground Argon Storage Tank
Issued By: JMH	Document Title: Study report

A feasibility study mandated to Technodyne Ltd (UK): Feb-Dec 2004

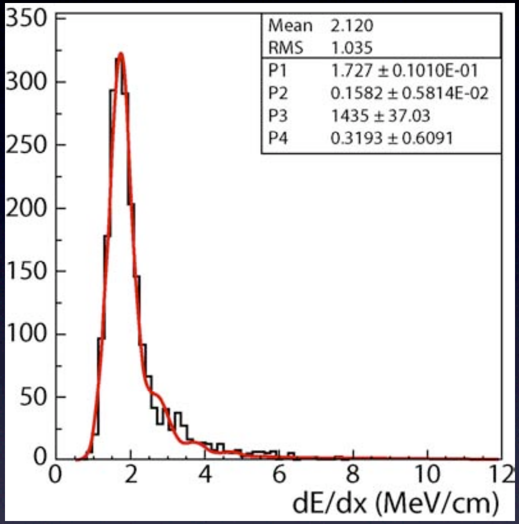
A. Rubbia

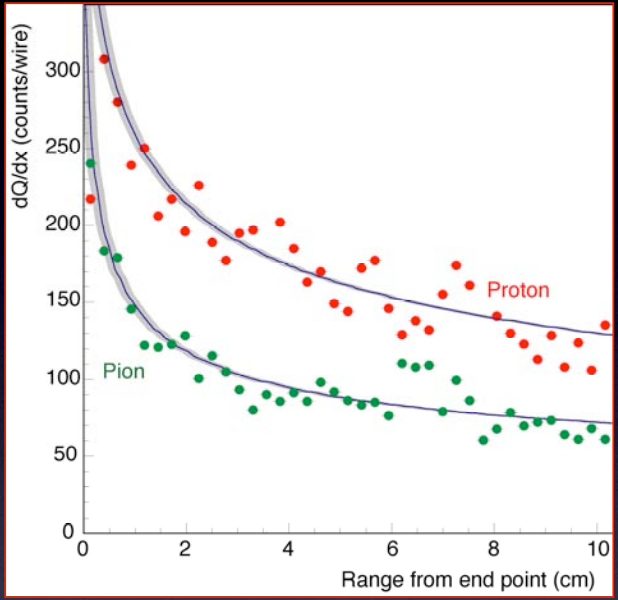
A tracking calorimeter

- High granularity: readout pitch ≈3 mm, local energy deposition measurement, particle type identification

$$T_{kin} = \int \frac{dE}{dx} dx$$

$$\frac{\sigma_{T_{kin}}}{T_{kin}} \approx 4\%$$





- Fully homogenous, full sampling calorimeter
  - ✦ Low energy electrons: $$\frac{\sigma(E_e)}{E_e} = \frac{11\%}{\sqrt{E_e(MeV)}} \oplus 2.5\%$$
  - ✦ Electromagnetic shower: $$\frac{\sigma(E_{em})}{E_{em}} = \frac{3\%}{\sqrt{E_{em}(GeV)}} \oplus 1.5\%$$
  - ✦ Hadronic shower: $$\frac{\sigma(E_{had})}{E_{had}} \simeq \frac{30\%}{\sqrt{E_{had}(GeV)}} \oplus 10\%$$

A. Rubbia

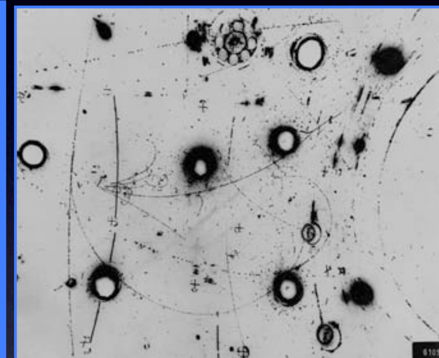
Full imaging of interactions

- Fully active, homogeneous, high-resolution device: **high statistics neutrino interaction studies with bubble chamber accuracy.**
- Reconstruction of low momentum hadrons (below Cerenkov threshold), especially recoiling protons: a proton of 1070 MeV/c (Cerenkov threshold in Water) travels 1 metre in LAr.
- Exclusive measurement of νNC events with clean π^0 identification and a very good e/π^0 discrimination.

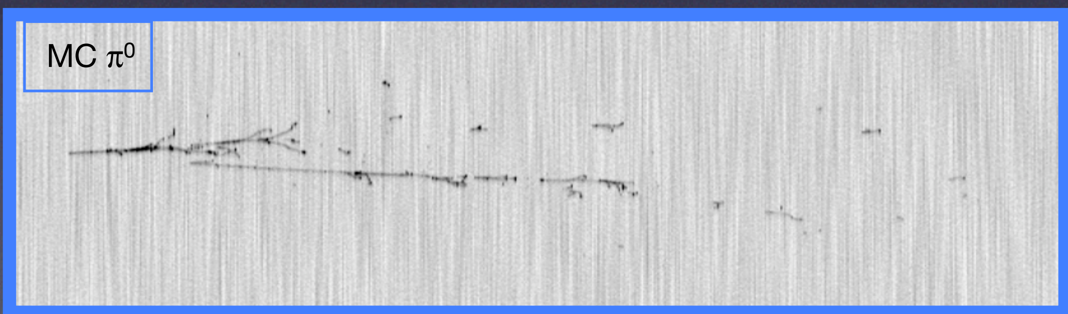
Real event in ICARUS

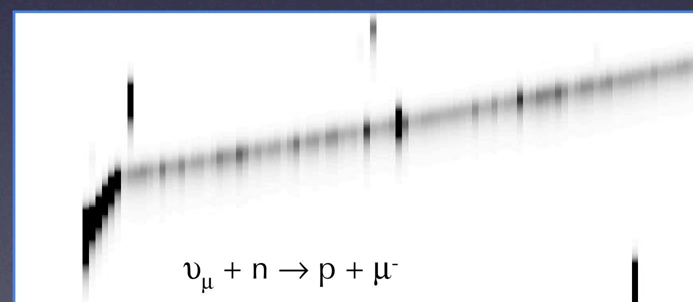
High granularity: Sampling = 0.02 X_0
"bubble" size $\approx 3 \times 3 \times 0.4$ mm^3

Gargamelle bubble chamber



bubble diameter $\approx$3mm





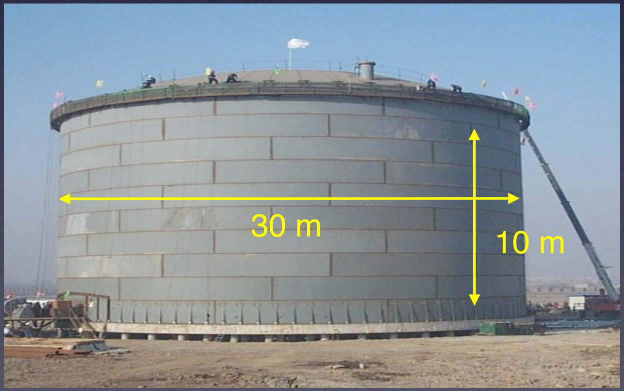
MC QE event, p momentum = 490 MeV/c

Scaling parameters for GLACIER

100 kton:

Dewar	$\phi \approx$ 70 m, height $\approx$ 20 m, perlite insulated, heat input $\approx$ 5 W/m^2
Argon storage	Boiling Argon, low pressure (<100 mbar overpressure)
Argon total volume	73000 m^3, ratio area/volume $\approx$ 15%
Argon total mass	102000 tons
Hydrostatic pressure at bottom	3 atmospheres
Inner detector dimensions	Disc $\phi \approx$70 m located in gas phase above liquid phase
Charge readout electronics	100000 channels, 100 racks on top of the dewar
Scintillation light readout	Yes (also for triggering), 1000 immersed 8" PMTs with WLS
Visible light readout	Yes (Cerenkov light), 27000 immersed 8" PMTs of 20% coverage, single γ counting capability

10 kton:



Dewar	$\phi \approx$ 30 m, height $\approx$10 m, perlite insulated, heat input $\approx$ 5 W/m^2
Argon storage	Boiling Argon, low pressure (<100 mbar overpressure)
Argon total volume	7000 m^3, ratio area/volume $\approx$ 33%
Argon total mass	9900 tons
Hydrostatic pressure at bottom	1.5 atmospheres
Inner detector dimensions	Disc $\phi \approx$30 m located in gas phase above liquid phase
Charge readout electronics	30000 channels, 30 racks on top of the dewar
Scintillation light readout	Yes (also for triggering), 300 immersed 8" PMTs with WLS

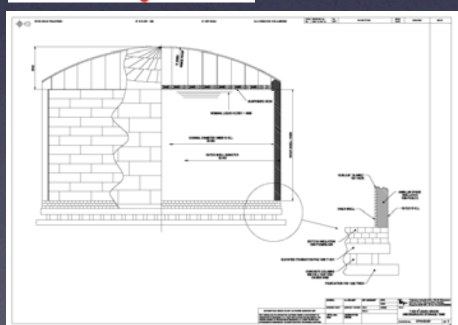
1 kton:

1% prototype: engineering detector, $\phi \approx$ 10m, h $\approx$ 10m, shallow depth?

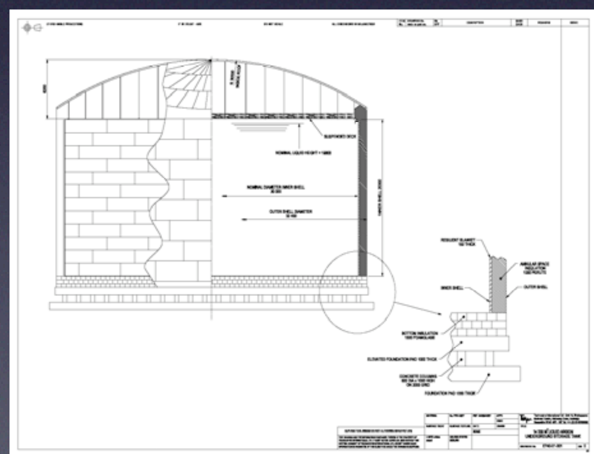
A. Rubbia

Scaling: three options to reach 40 kton

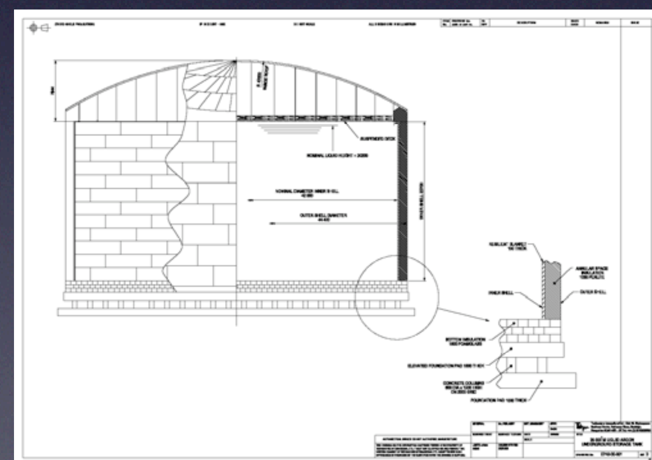
	1 unit of	2 units of	4 units of
Liquid Argon mass (per unit)	39.2 kton	19.6 kton	9.8 kton
Fiducial volume m^3 (per unit)	28000	14000	7000
Total liquid Argon mass	39.2 kton	39.2 kton	39.2 kton



Φ=30 m, h=10 m →



Φ=30 m, h=20 m →



Φ=40 m, h=20 m

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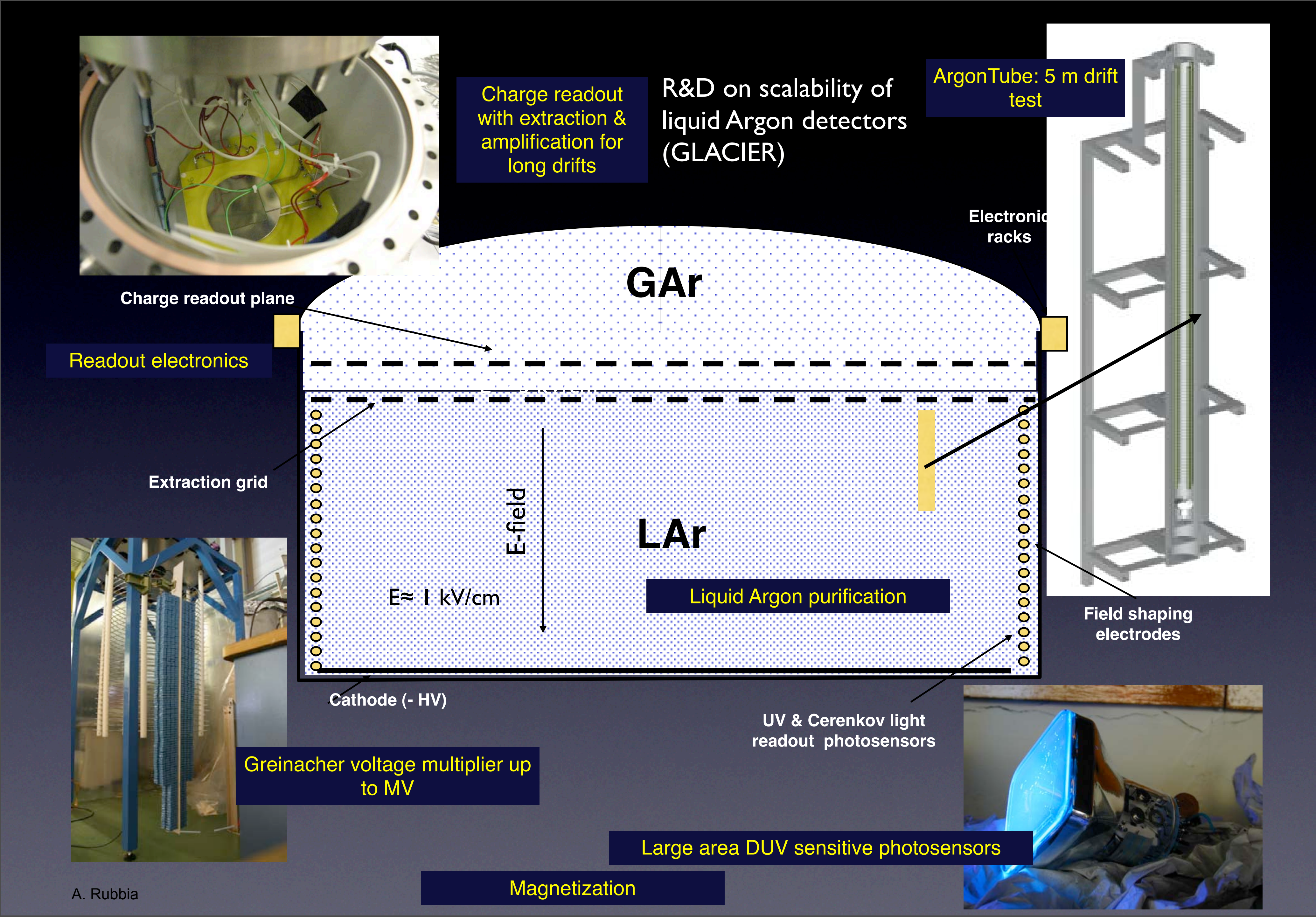
Charge readout with extraction & amplification for long drifts
R&D on scalability of liquid Argon detectors (GLACIER)
ArgonTube: 5 m drift test
Electronic racks
GAr
Charge readout plane
Readout electronics
Extraction grid
E-field
LAr
E≈ 1 kV/cm
Liquid Argon purification
Field shaping electrodes
Cathode (- HV)
UV & Cerenkov light readout photosensors
Greinacher voltage multiplier up to MV
Large area DUV sensitive photosensors
Magnetization
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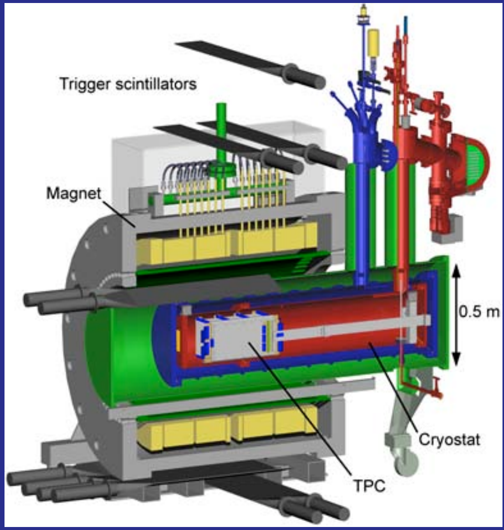
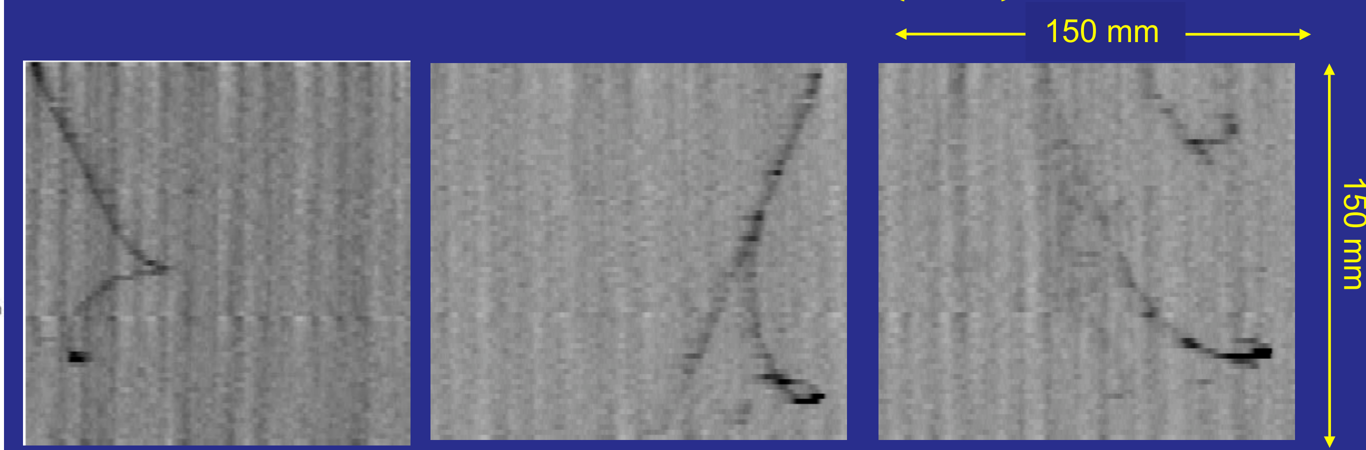
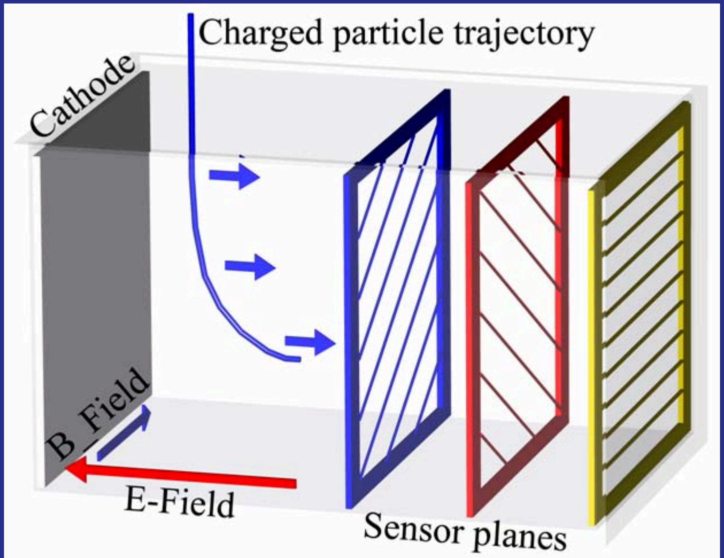
First operation of a LAr TPC embedded in a B-field

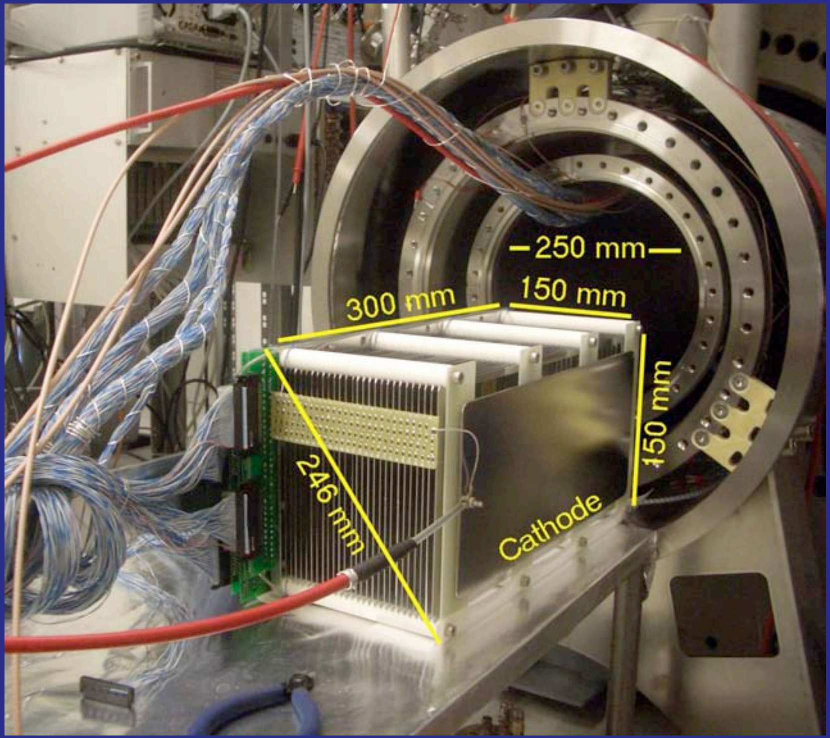
First real events in B-field (B=0.55T):

New J. Phys. 7 (2005) 63
NIM A 555 (2005) 294









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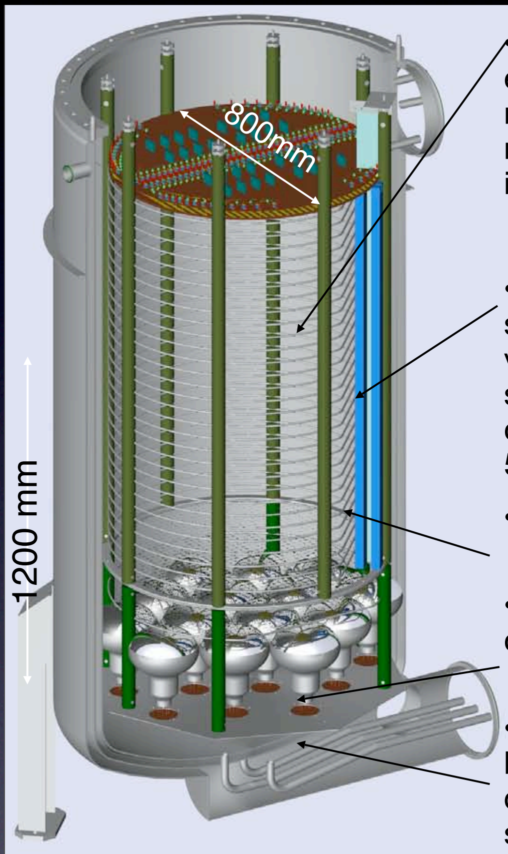
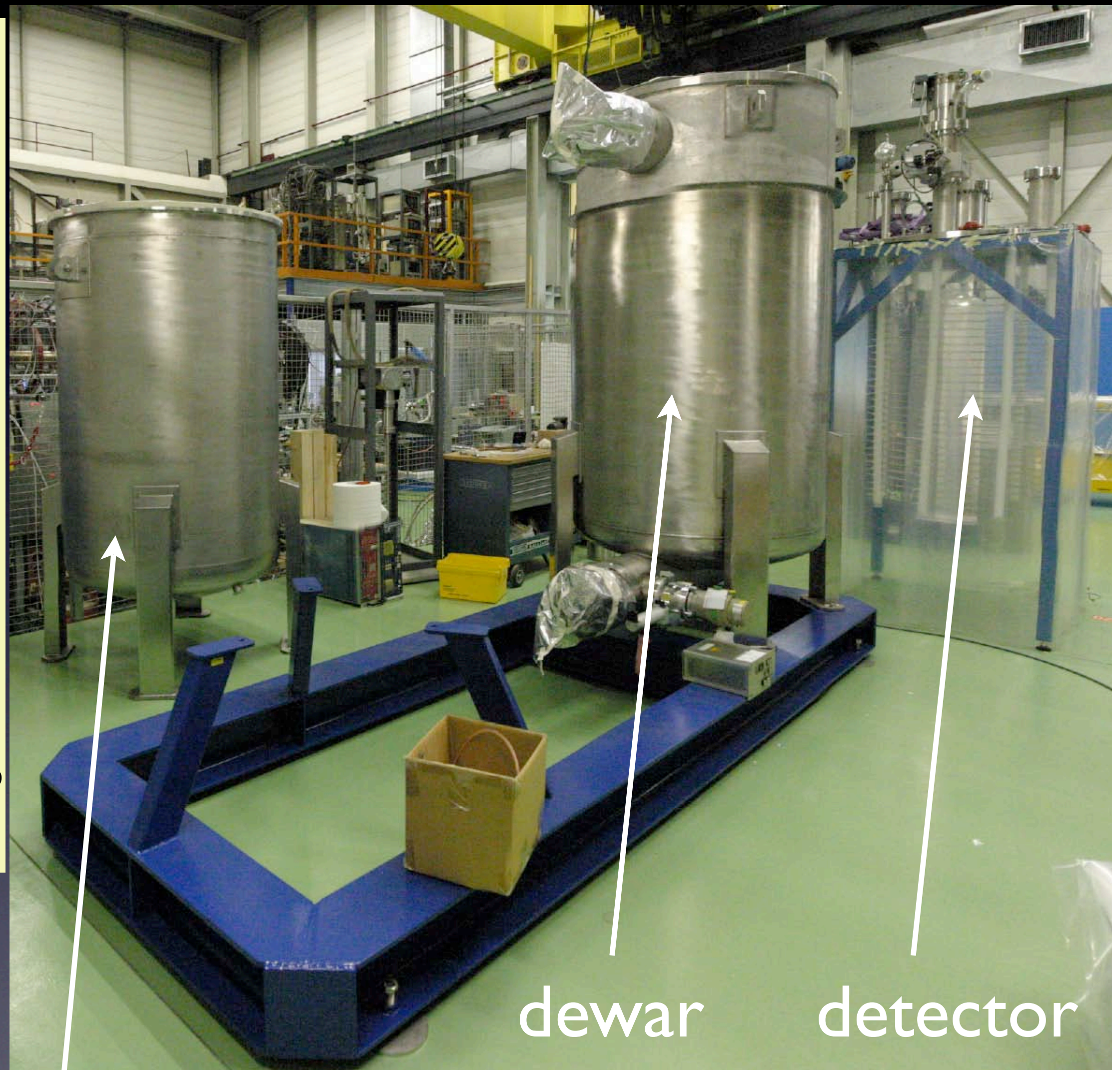
ArDM assembly @ CERN



- Two-stage LEM for electron multiplication and readout to measure ionization charge
- Greinacher chain: supplies the right voltages to the field shaper rings and the cathode up to 500 kV
- Field shapers
- Transparent cathode
- Photodetectors below the cathode to detect the scintillation light



(backup dewar)

First tests foreseen in 2007

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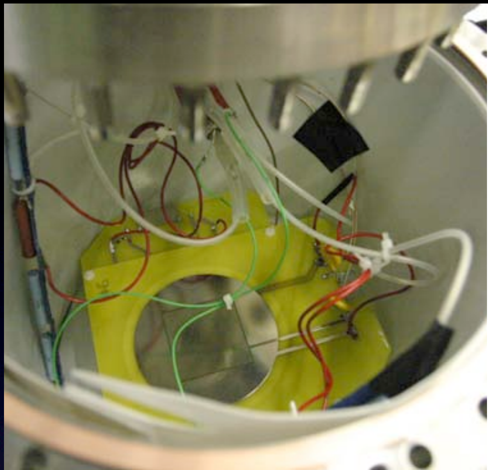
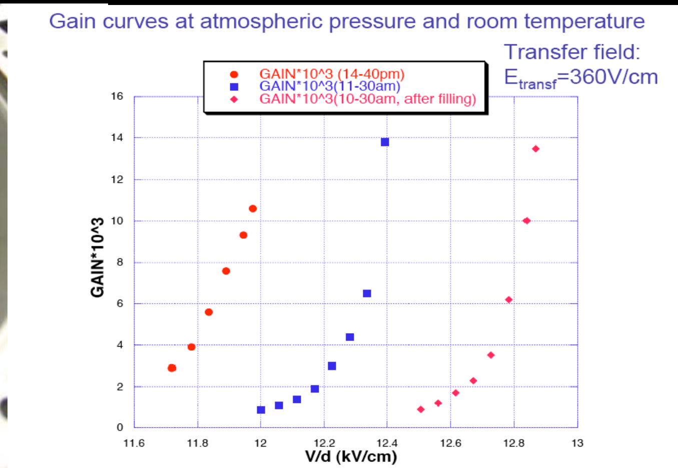
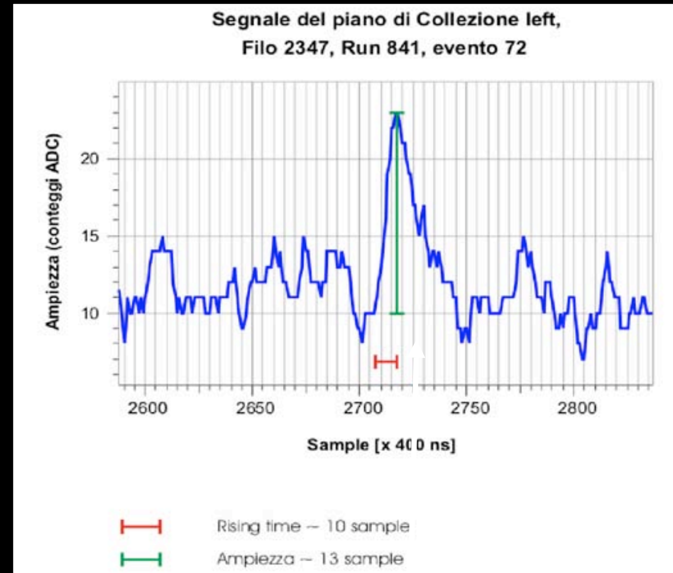
Charge readout: Thick Large Electron Multiplier (LEM)

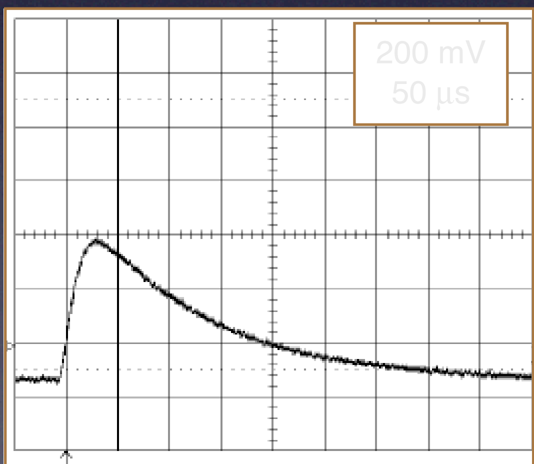


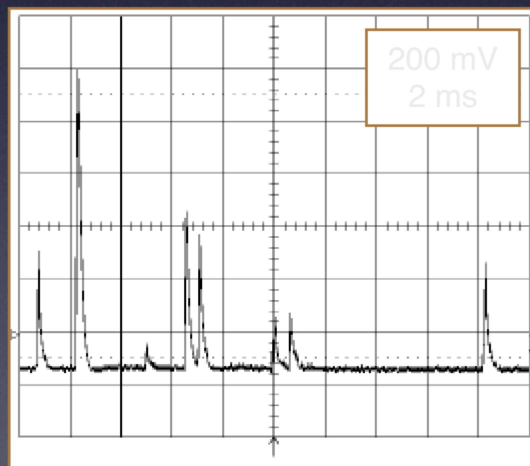


MIP signal in ICARUS T300



Shapes from Fe^{55} radioactive source (5.8 keV, event rate about 1kHz) of the signals from double-stage LEM system have a very clean S/N ratio.





This technique solves the non-scalability of the traditional wire readout used in ICARUS
E.g. MIP signal @ ≈2 MeV/cm has poor S/N !

Full imaging TPC with LEM to be tested in ArDM experiment

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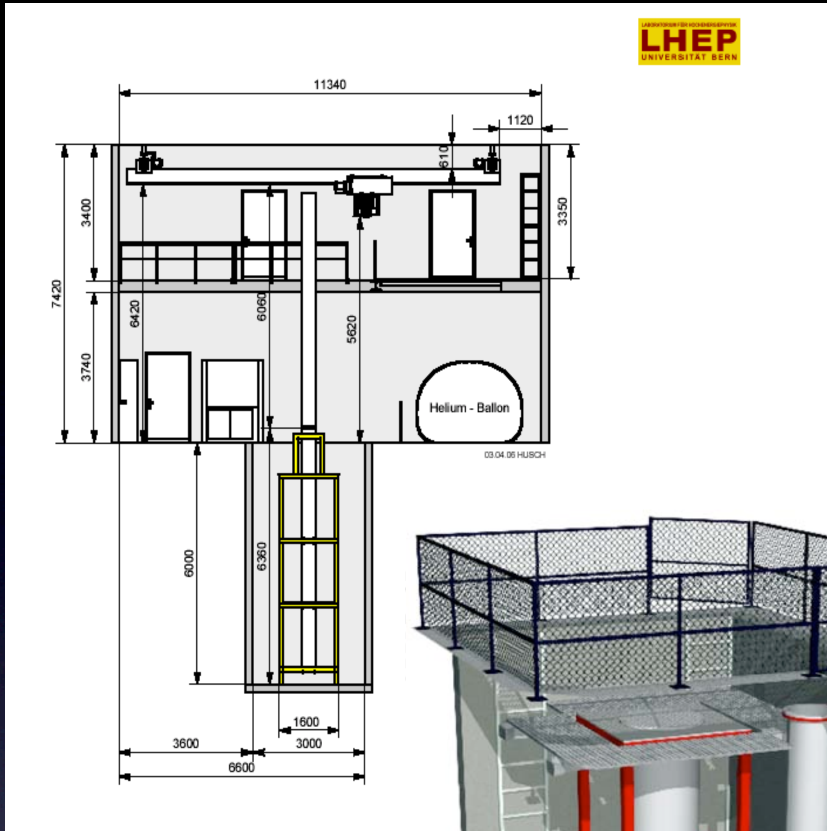
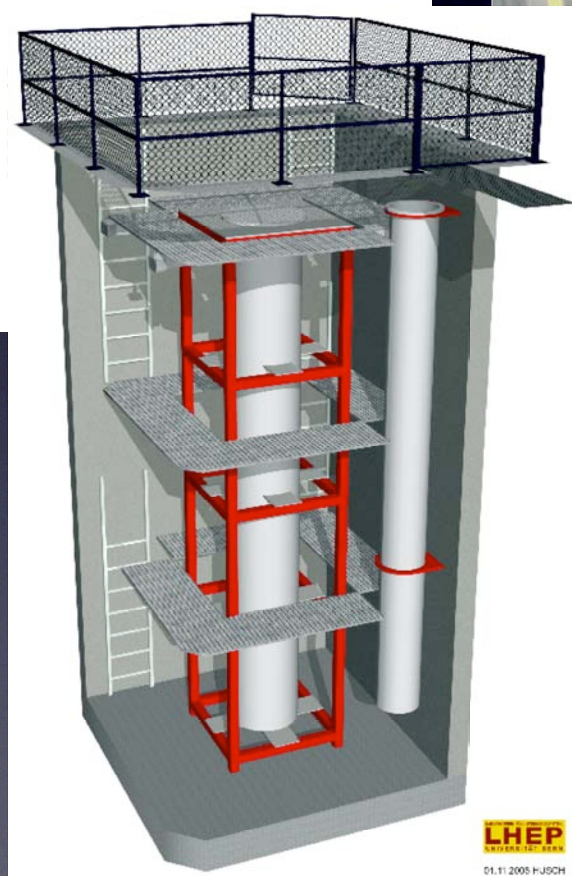




5 m drift with new readout: First tests foreseen in 2008

A. Rubbia

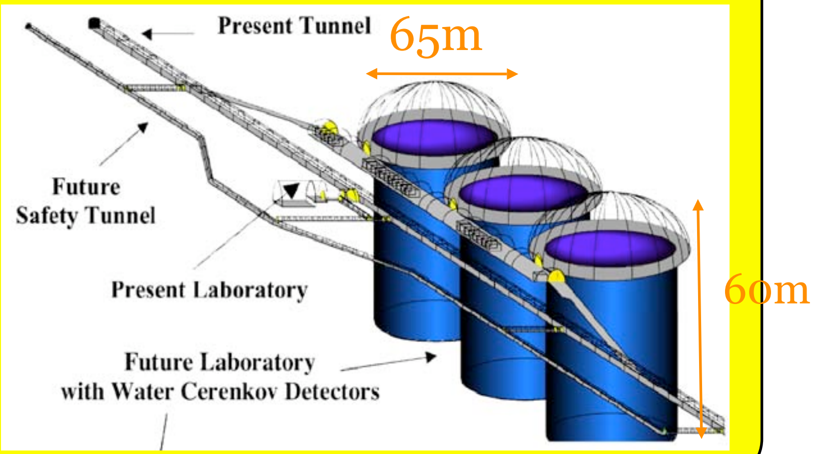
GLACIER R&D

- Funding in place for R&D
- 1 ton ArDM experiment under construction (2007)
- Cold readout electronics ASIC (2007)
- 5 m drift ArgonTube under construction (2008)
- 150 ton in neutrino beam (T2K LOI submitted to JPARC PAC)

LAGUNA: a proposal for a "Design of a pan-european infrastructure for large apparatus studying Grand Unification and Neutrino Astrophysics"

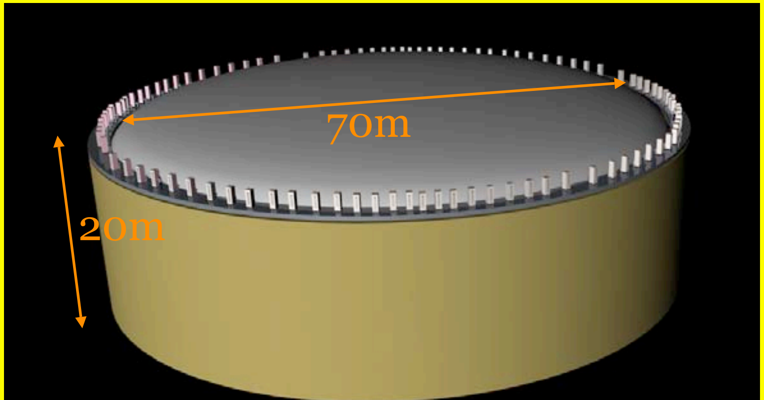
3 detection techniques under considerations

MEMPHYS



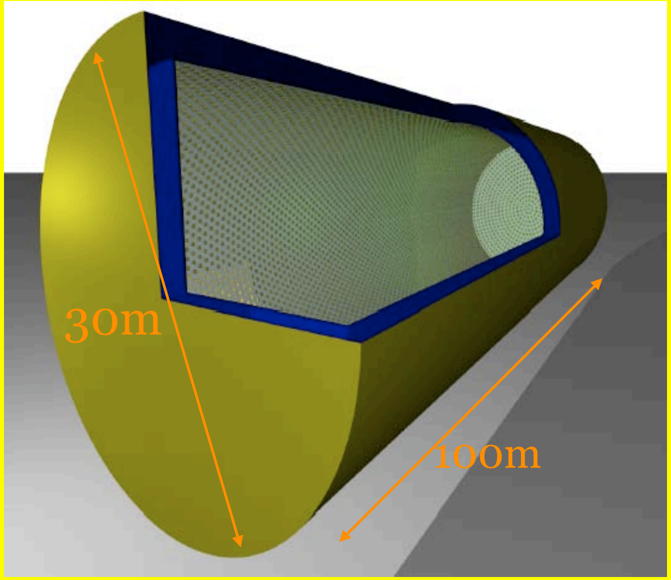
Water Cherenkov (≈0.5 → 1 Mton)

GLACIER



Liquid Argon (≈10→100 kton)

LENA



Liquid Scintillator (→ 50 kton)

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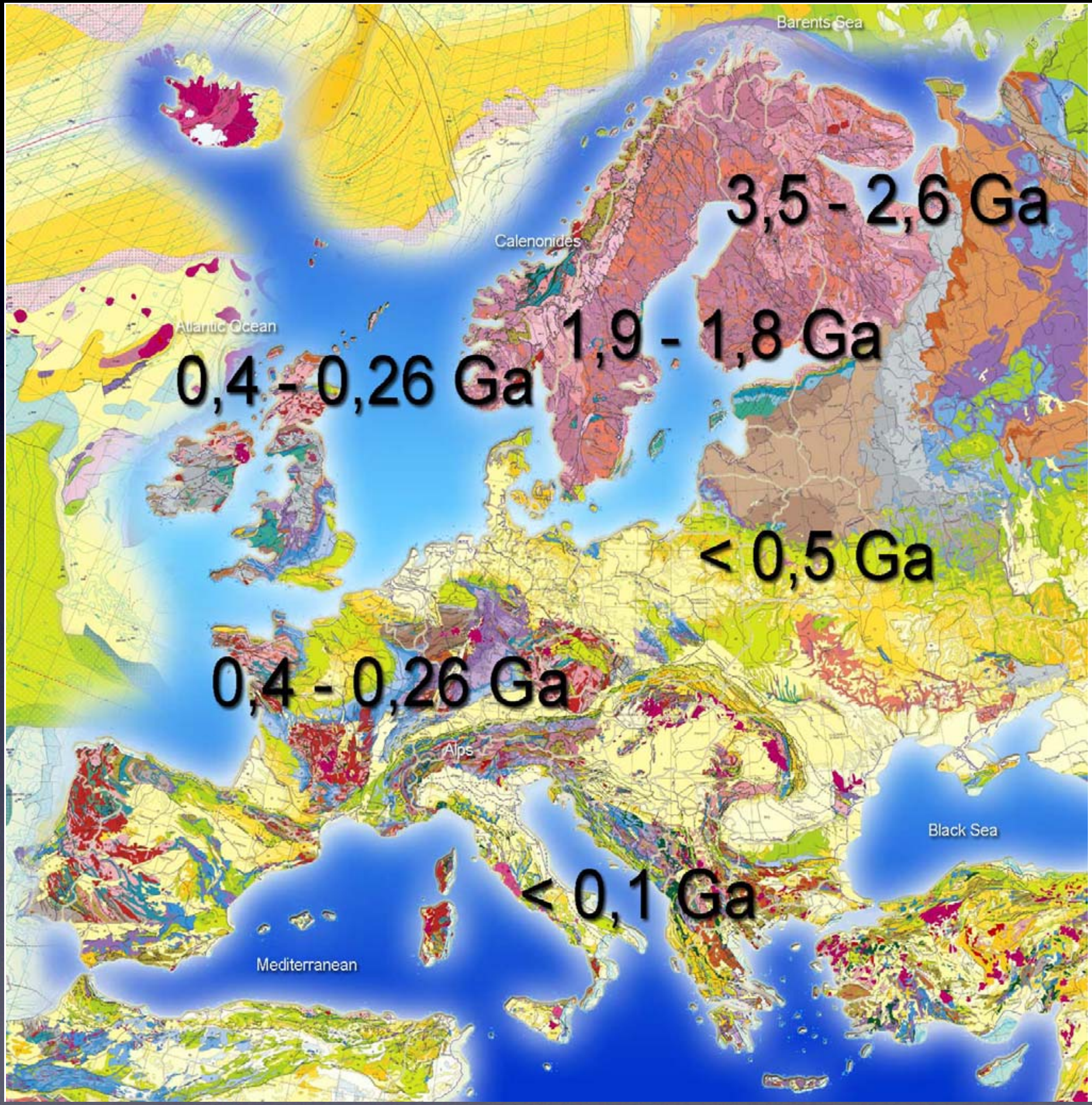
Towards a CDR around 2010

- The construction and operation of next generation large underground detectors clearly represents a difficult technological challenge and a significant investment on the scale of several hundred millions of Euros.
- It is intimately connected to the question of large underground infrastructures.
- The choice of the most appropriate technology, of the site and of the designs of such super-massive detectors should be carefully optimized taking into account the technical feasibility and predicted costs, the multiple physics goals, and also the possible existence of accelerator neutrino beams.
- The technical and economical feasibility of an underground observatory of this magnitude, perhaps ultimate in size, requires a strong coordinate and coherent European strategy and will be heavily reliant on the possibility to contain costs compared to today's state-of-the-art by a careful optimization of all elements involved in the project:
  - ★ (1) the excavation and preparation of the underground space,
  - ★ (2) the design and construction of the tank,
  - ★ (3) the instrumentation and
  - ★ (4) the safety aspects.

Bedrock conditions in Europe



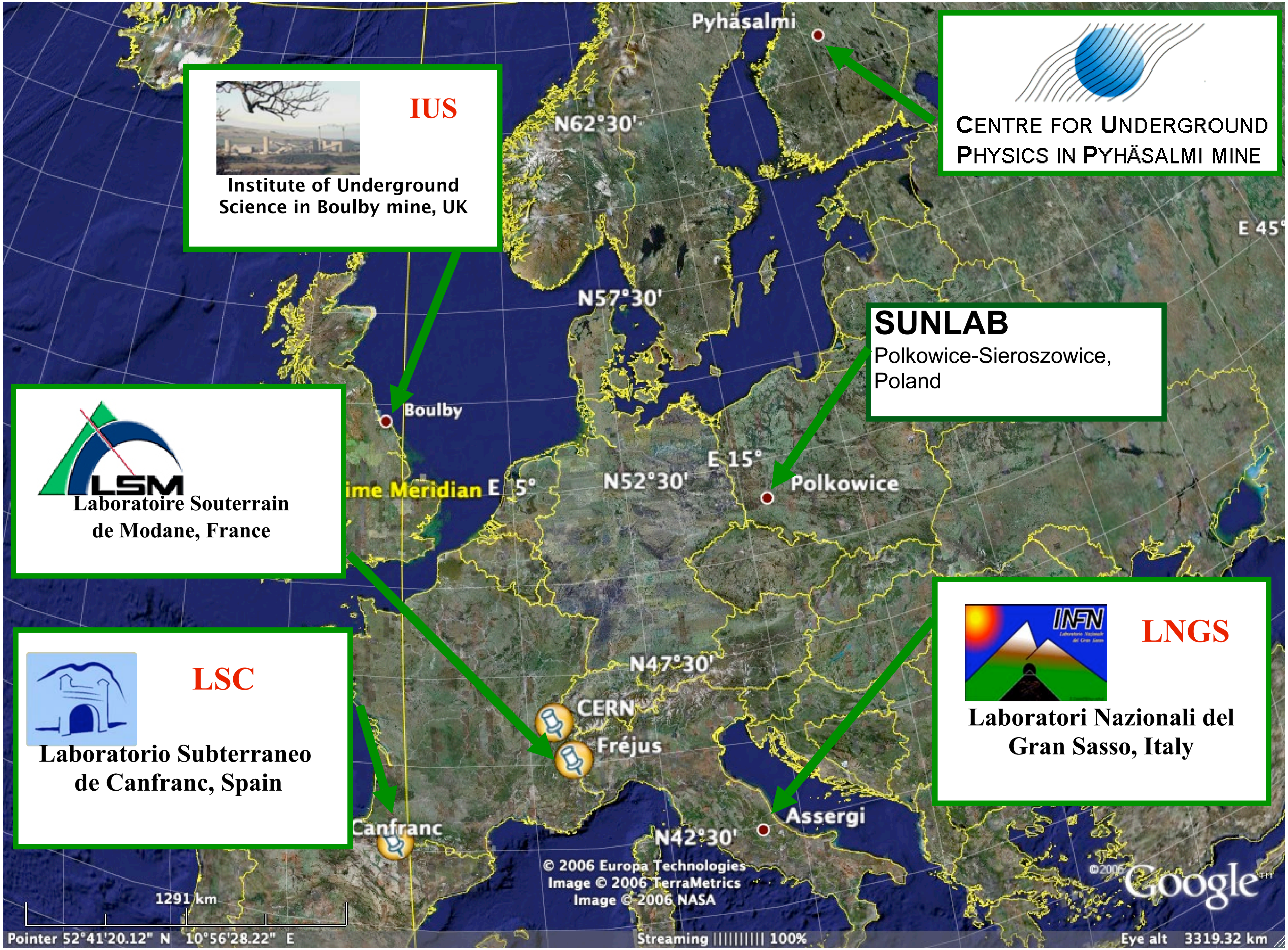
The age of the bedrock in Finland varies between 2 – 3,5 billion years

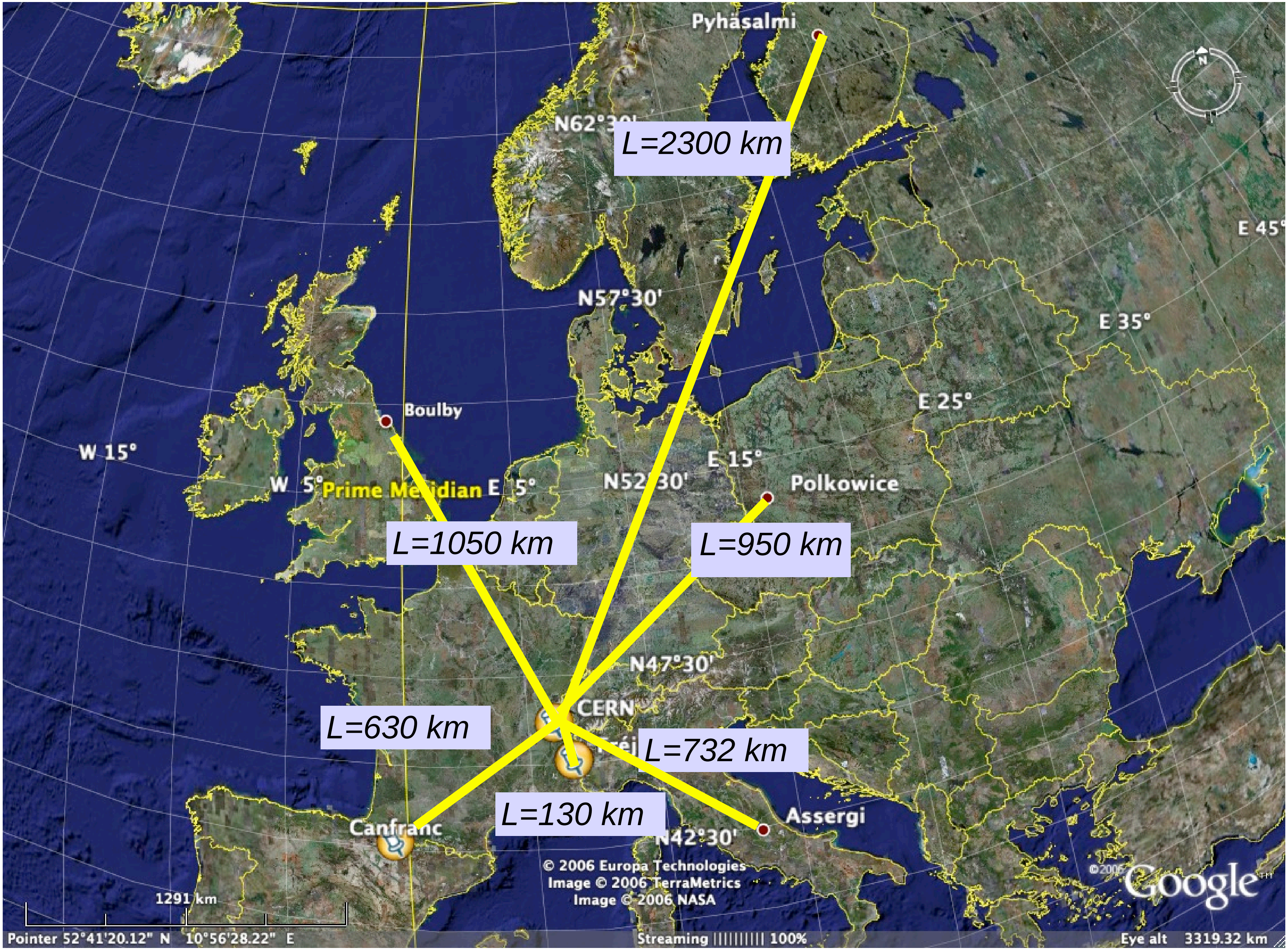
KALLIOSUUNNITTELU OY
ROCKPLAN LTD

University of Helsinki

GTK

A. Rubbia


IUS
Institute of Underground Science in Boulby mine, UK
Centre for Underground Physics in Pyhäsalmi mine
SUNLAB
Polkowice-Sieroszowice, Poland
LSM
Laboratoire Souterrain de Modane, France
LSC
Laboratorio Subterraneo de Canfranc, Spain
INFN
LNGS
Laboratori Nazionali del Gran Sasso, Italy
Pyhäsalmi
N62°30'
N57°30'
E 45°
Boulby
Prime Meridian E 5°
N52°30'
E 15°
Polkowice
N47°30'
CERN
Fréjus
Canfranc
Assergi
N42°30'
© 2006 Europa Technologies
Image © 2006 TerraMetrics
Image © 2006 NASA
© 2006 Google
1291 km
Pointer 52°41'20.12" N 10°56'28.22" E
Streaming |||||||||| 100%
Eye alt 3319.32 km


Pyhäsalmi
L=2300 km
N62°30'
N57°30'
E 45°
E 35°
E 25°
Boulby
W 15°
W 5°
Prime Meridian
E 5°
E 15°
N52°30'
Polkowice
L=1050 km
L=950 km
N47°30'
CERN
L=630 km
L=732 km
L=130 km
Canfranc
Assergi
N42°30'
© 2006 Europa Technologies
Image © 2006 TerraMetrics
Image © 2006 NASA
1291 km
Pointer 52°41'20.12" N 10°56'28.22" E
Streaming |||||||||| 100%
Eye alt 3319.32 km

CERN Proton economics (>2016)

CERN-AB-2007-013 PAF

	SPS cycle length	6 s		4.8 s	
	Injection momentum	14 GeV/c		26 GeV/c	
	Beam sharing / Max SPS intensity @ 400GeV [x10^{13}]	0.45	0.85	0.45	0.85
Present injectors + machines' improvement	4.8 – "Nominal CNGS"	5	9.4		
	5.7- "Max. SPS"	5.9	11.1		
Future injectors + SPS RF upgrade	7 – "Ultimate CNGS"			9	17.1
Future injectors + new SPS RF system + CNGS new equipment design	10 – "Max. PS2"			12.9	24.5

x10^{19}

CERN LHC new injection chain can open new opportunities
In JHEP 0611:032,2006 we assumed 3.3 x 10^{20} pot/yr ➠ rescale by factor 1.3 number of years (5 yrs ➠ 6.7 yrs)

A. Rubbia

From LAGUNA WG to DS

- The WG was proposed & accepted in November 2005 at the ApPEC "Munich meeting"
- During 2006-2007, an effort has been made to consolidate LAGUNA ideas into a format compatible with a potential "design study".
- A series of working meeting were held
  - ☑ Munich, April 24th, 2006
  - ☑ Munich, June 2nd, 2006
  - ☑ Paris, July 21st ,2006
  - ☑ Zurich, October 12th, 2006
  - ☑ Paris, December 18th, 2006
  - ☑ Chambery, March 2nd, 2007
  - ☑ Paris, March 29th, 2007
- Design study ("Collaborative Project FP7-Infrastructures-2007-1") has been submitted on May 2nd 2007.
- ≈ 60 members
- 24 participants: ETH Zürich, Bern, Jyväskylä, Oulu, Rockplan, CEA/DSM/DAPNIA, IN2P3, MPG, TUM, Hamburg, IFJ PAN, IPJ, US, UWr, KGHM CUPRUM, IGSMiE PAN, LSC, Granada, Durham, Sheffield, Technodyne, ETL, Aarhus, AGT
- 9 countries

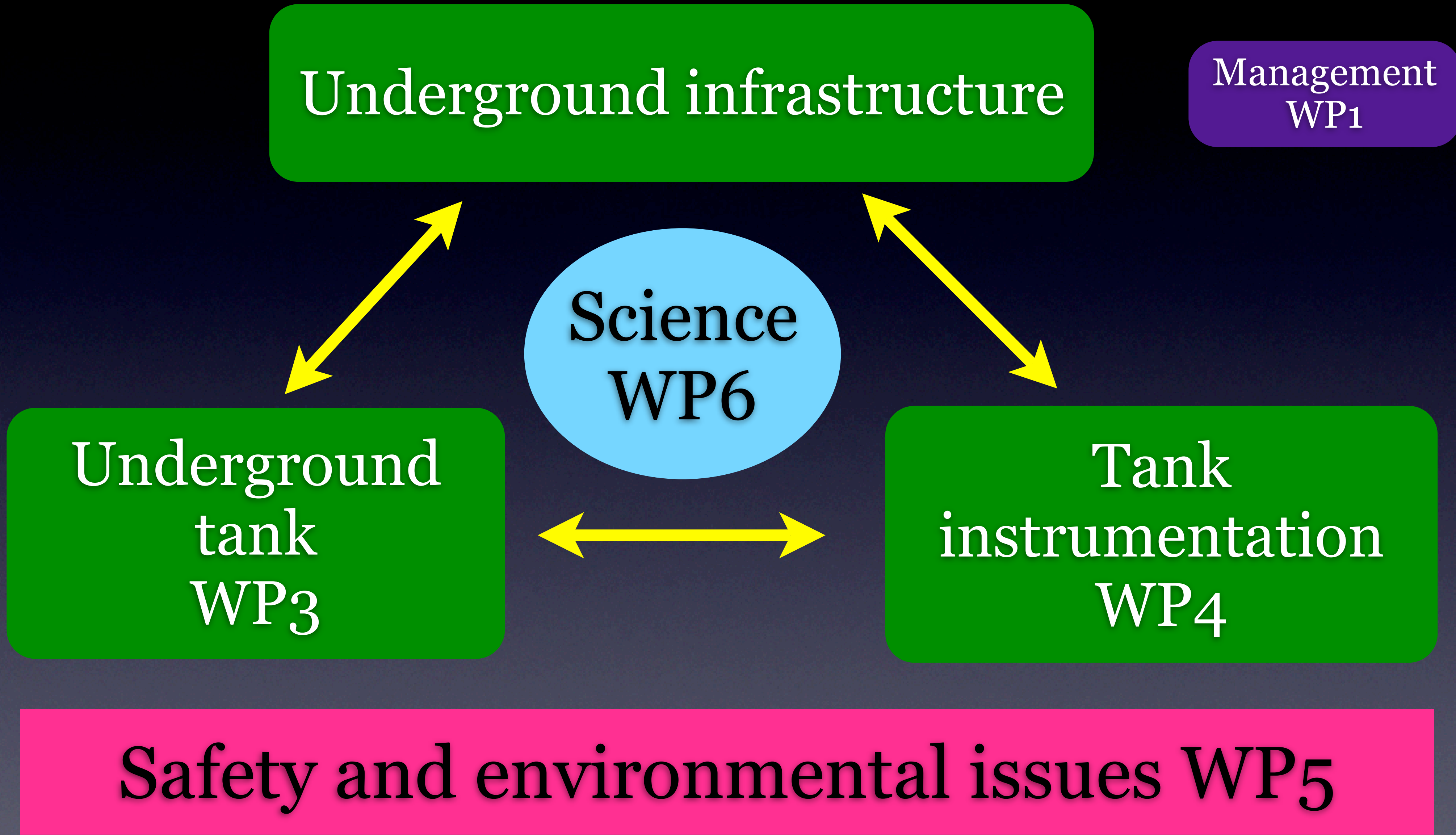
Work package list

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**		

≈120 man x years

A. Rubbia

WP interconnection



The main “deliverable”

The main "deliverable"

- The DS will lead to a "conceptual design report" for a new infrastructure, to allow policy makers and their advisors to prepare the relevant strategic decisions for the development of a new research infrastructure in Europe.
- The deliverables contain the elaboration of "decision factors" like

(i) technical feasibility (cavern, access, safety, liquid procurement, ...)
(ii) cost optimization of infrastructure (digging, safety, ...)
(iii) physics performance (e.g. depth, baseline, ...)
(iv) ...

A. Rubbia

Outlook

Outlook

- Several on-going projects. WG7 focus is towards very large volume underground infrastructures.
  - ✦The direct evidence for Grand Unification would be one of the most fundamental discoveries in particle physics.
  - ✦An extensive neutrino physics and astronomy programme will be accessible detecting supernova, atmospheric, possibly solar and geo-neutrinos, as well as artificial neutrinos from accelerators. These latter measurements could lead to the discovery of CP-violation in the leptonic sector.
- The LAGUNA design study will provide the means to perform site feasibility studies and to develop mature conceptual design for large volume underground instruments including their infrastructures, with a credible cost estimate. The DS will provide the means to elaborate the scientific and objective information needed to make an optimized choice for site(s) for the pan-European Underground Infrastructure.
- Not (yet) 100% overlap between WG7 & LAGUNA WG/DS