Low Background Laboratories

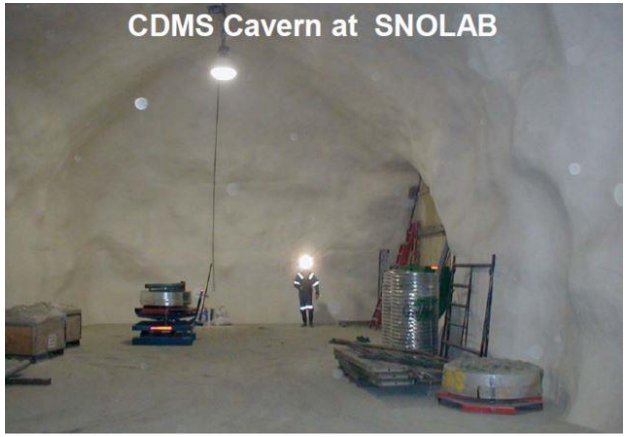
Per Provencher

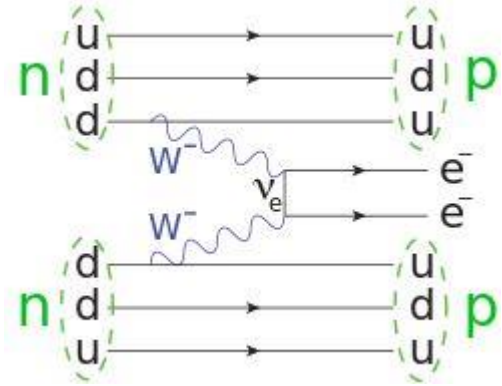
PHYS 575 Fall 2015

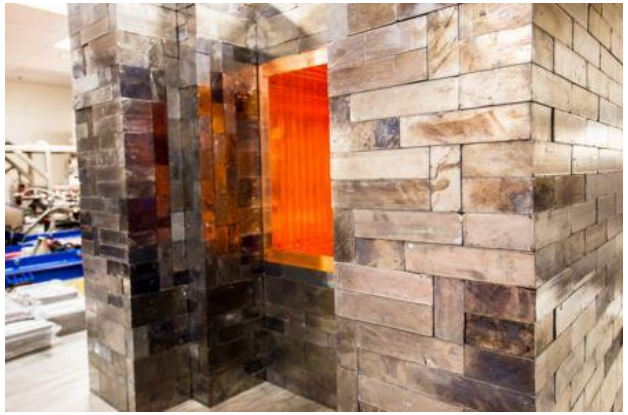
12/1/2015

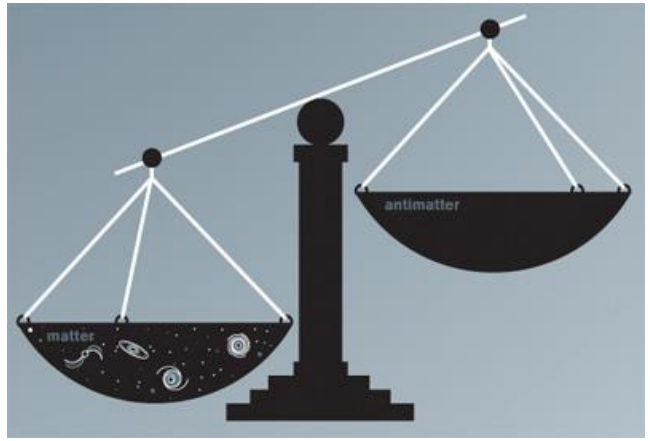
Why Low Background Laboratories?

- For the Science!
  - Dark matter search
  - Matter-antimatter symmetry
    - non-zero positive baryon density aka universe is made of matter!
  - 0νββ search – Majorana particles?
  - Proton decay









[Tykva 1995, Theodórsson 1996, Knoll 2010, Jiao 2013, Wilkes 2015]

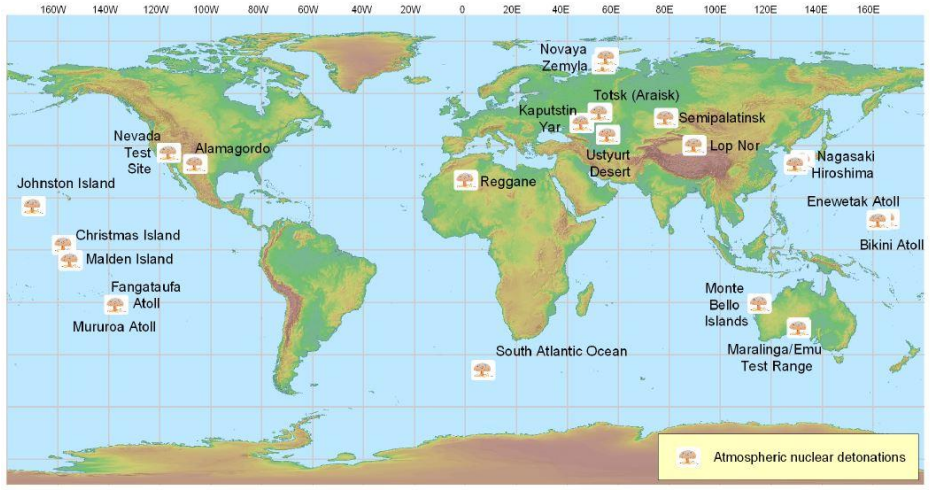
Challenges

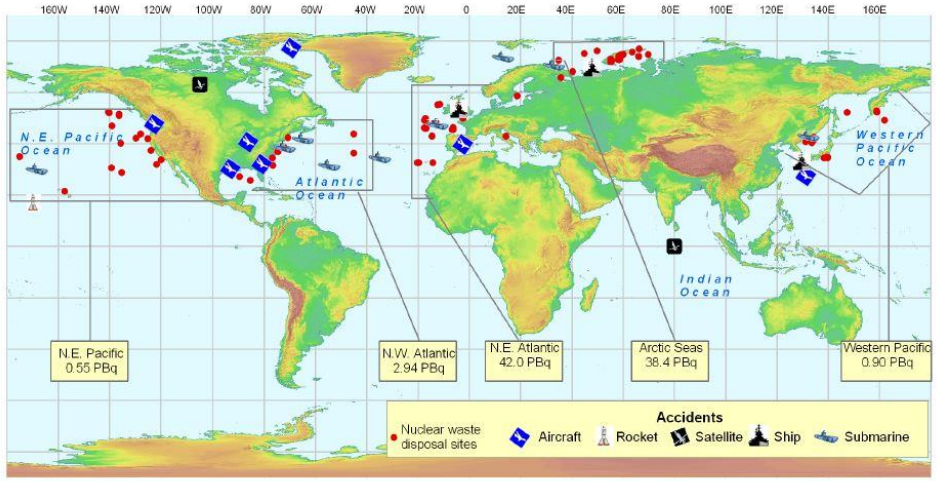
- Activity is everywhere:
  - NORM – Naturally Occurring Radioactive Materials – (Diana 12/8)
  - Cosmic sources – (Erin 12/8)
  - Anthromorphic – it's our fault!
- Show and tell…

[Theodórsson 1996, Livingston 2004, Knoll 2010, Wilkes 2015]

Anthromorphic sources

- Atmospheric testing
- Accidents
- Waste
- Non-nuclear power
- Commercial uses
- Ourselves!





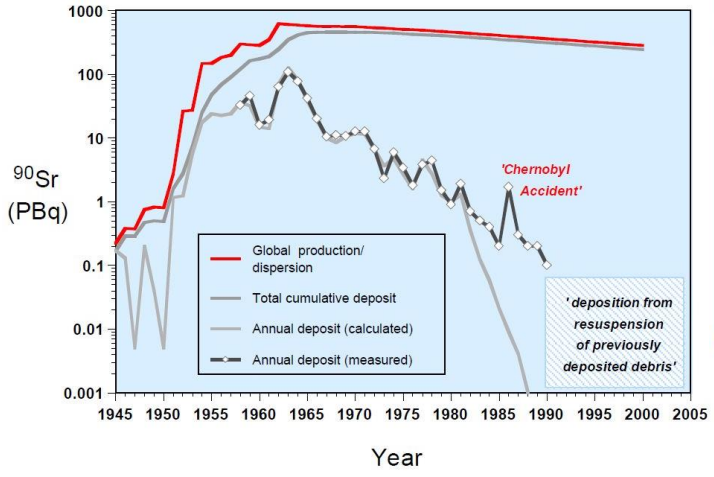


TABLE 1.23. Typical Concentrations in Diet and Intakes of ^{90}Sr in Two American Cities.

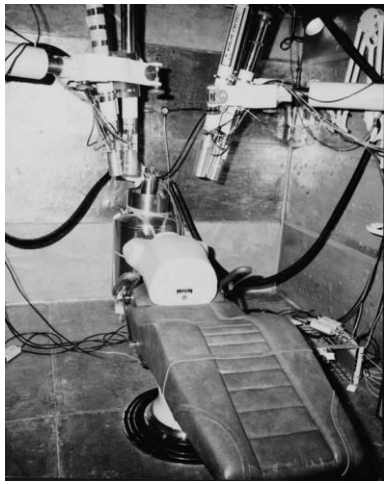
Diet Category	Consumption (kg/y)	New York City Concentration (mBq/kg)	New York City Intake (Bq/y)	San Francisco Concentration (mBq/kg)	San Francisco Intake (Bq/y)
Dairy products	200	118	23.7	37	7.4
Fresh vegetables	48	326	15.6	89	4.3
Canned vegetables	22	200	4.4	107	2.4
Root vegetables	10	125	1.3	111	1.4
Potatoes	38	85	3.3	78	2.9
Dry beans	3	588	1.8	292	2.0
Fresh fruit	59	96	5.6	48	2.8
Canned fruit	11	41	0.4	30	0.3
Fruit juice	28	63	1.8	52	1.5
Bakery products	44	111	4.8	70	3.1
Flour	34	167	5.7	130	4.4
Grain products	11	222	2.6	107	1.2
Macaroni	3	89	0.3	85	0.3
Rice	3	22	0.1	30	0.1
Meat	79	15	1.3	15	1.1
Poultry	20	11	0.2	11	0.2
Eggs	15	22	0.4	22	0.3
Fresh fish	8	7	0.04	4	0.04
Shell fish	1	7	<0.04	26	0.04
Yearly intake			73.2 Bq		35.8 Bq

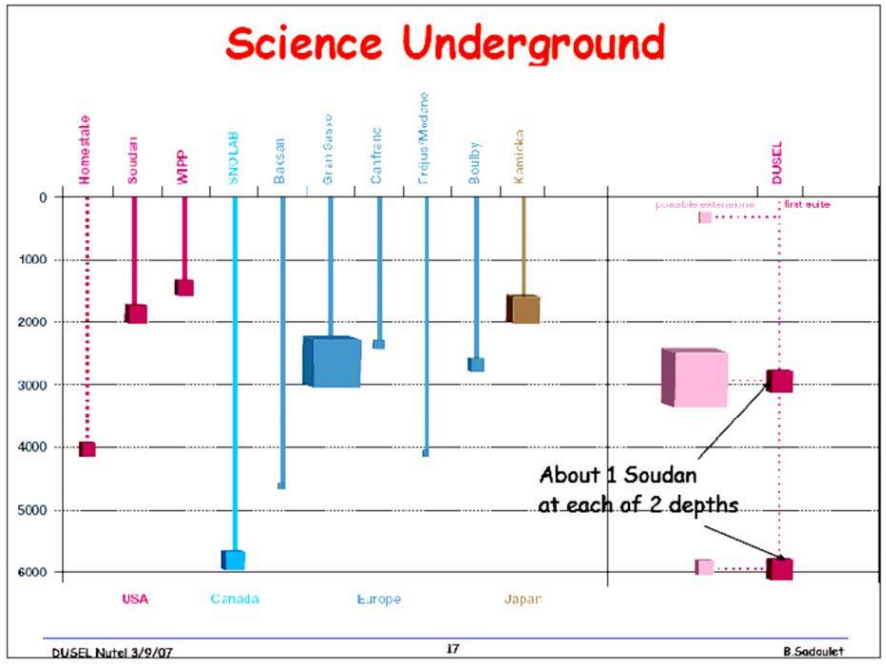
Adapted from Eisenbud (1987).

[Tykva 1995, Theodórsson 1996, Livingston 2004, Knoll 2010, Peltoniemi 2014, Piquemal 2012, Patzak 2011]

Mitigation Strategies

- Active
  - Coincidence and Anti-coincidence
  - Data analysis
- Passive:
  - Careful material selection
  - Shielding (Roman lead, pre-1945 armor)
  - Go underwater or underground



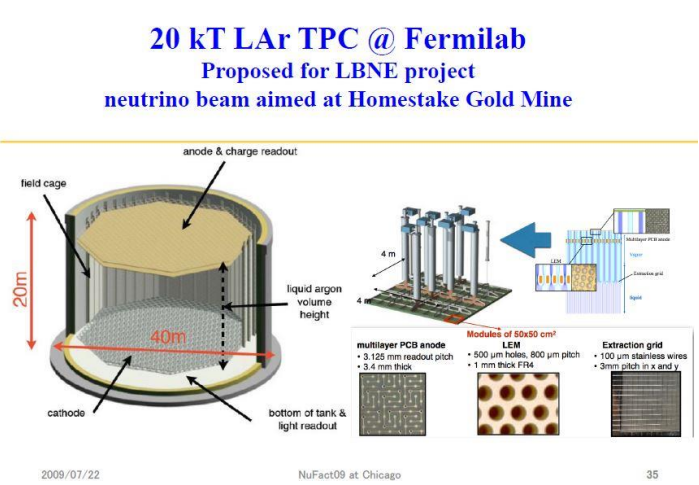


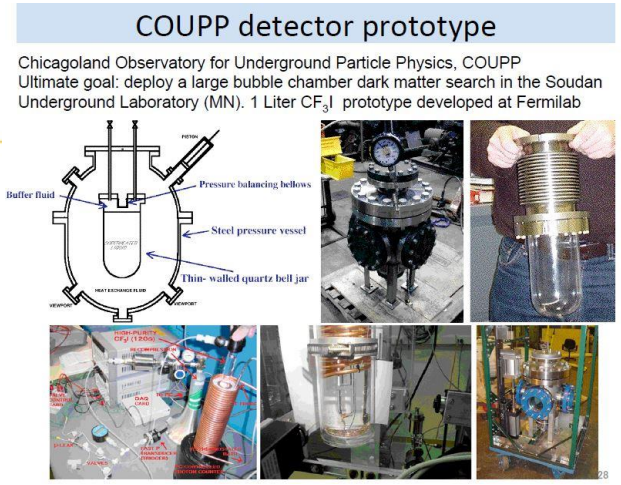
[Tykva 1995, Theodórsson 1996, Livingston 2004, Knoll 2010, Peltoniemi 2014, Piquemal 2012, Patzak 2011, Wilkes 2015]

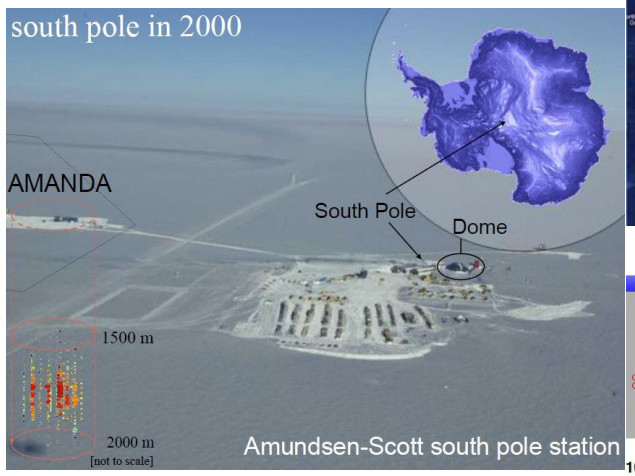

PYHÄSALMI
BOULBY
SNO
SOUDAN
LSM
SUL
KAMIOKA
BNO
LSC
Y2L
HOMESTAKE
UNIREA
LNGS
OTO-Cosmo

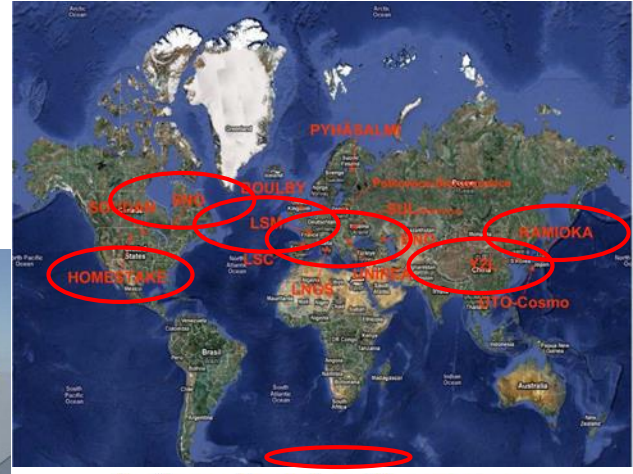
[Votano 2010]

Some Familiar Laboratories…

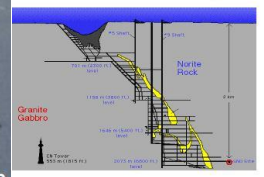


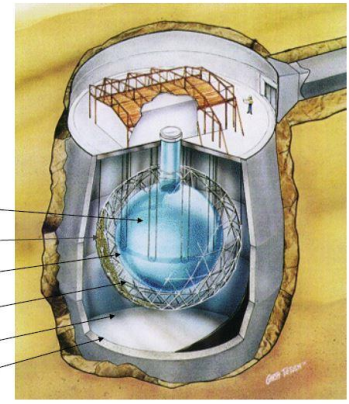






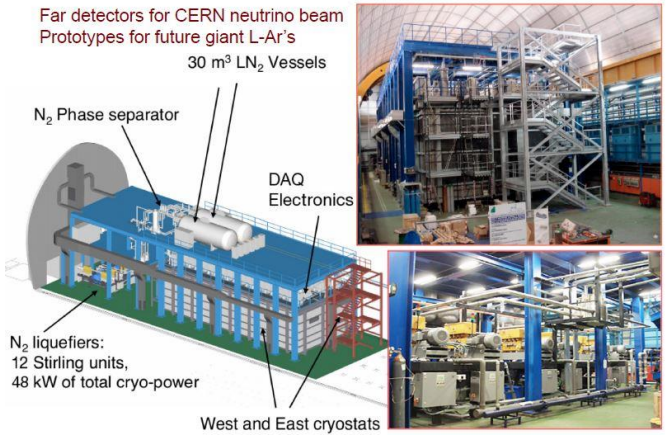
Sudbury Neutrino Observatory





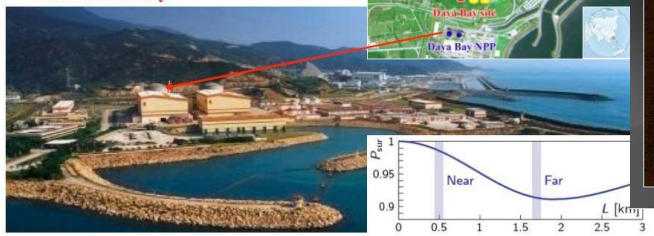
Liquid Argon TPCs in Gran Sasso Tunnel Lab

Far detectors for CERN neutrino beam
Prototypes for future giant L-Ar's



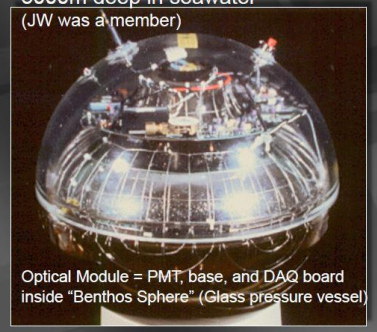
The Daya Bay Experiment

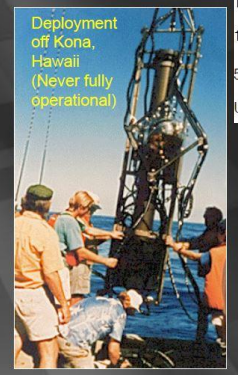
- 6 reactor cores, 17.4 GW_{th}
- Relative measurement
  - 2 near sites, 1 far site
- Multiple detector modules
- Good cosmic shielding
  - 250 m.w.e @ near sites
  - 860 m.w.e @ far site
- Redundancy



Water Cherenkov arrays for neutrinos

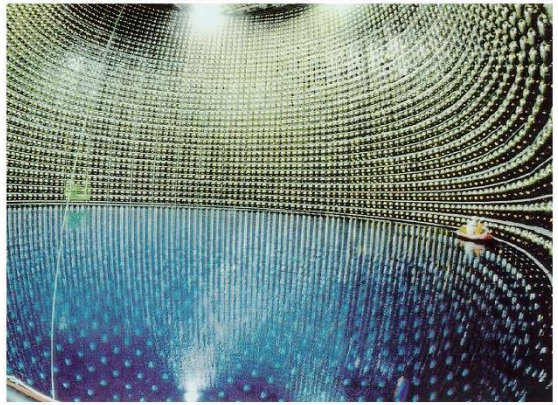
1987: DUMAND Deep Undersea Muon and Neutrino Detector
5000m deep in seawater
(JW was a member)





Just how big is Super-K?

- Checking photomultiplier tubes by boat as the tank fills (1996)

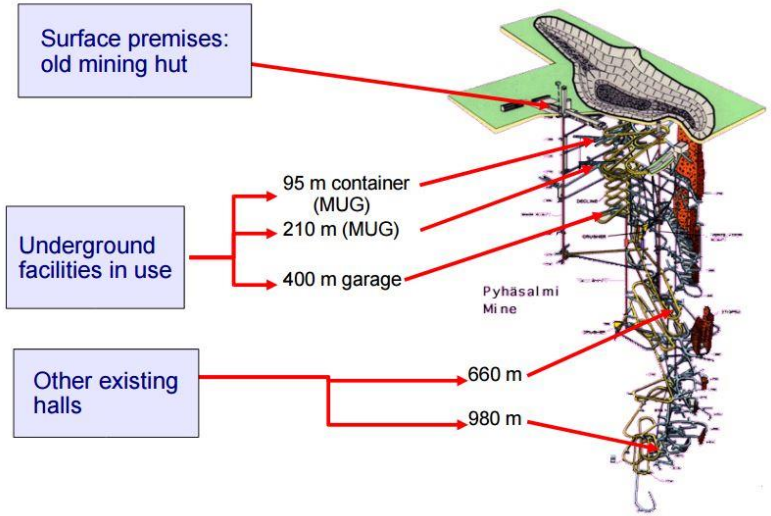


[Wilkes 2015]

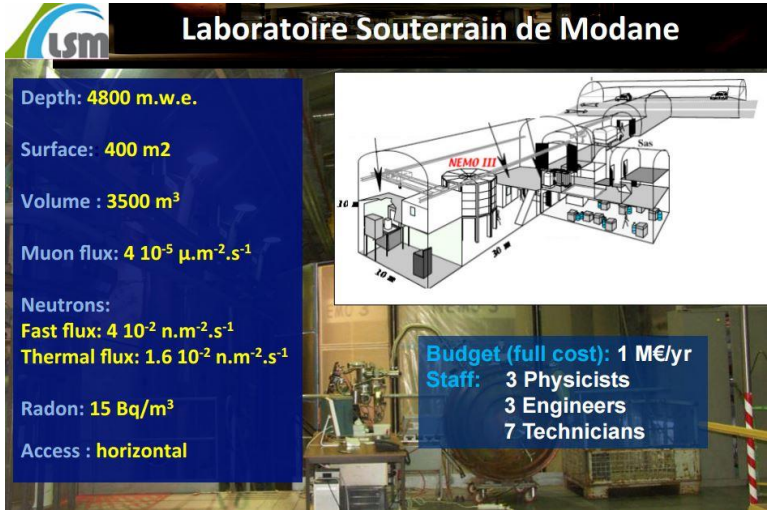
More Low Background Labs…

- Pyhäsalmi

  Finland



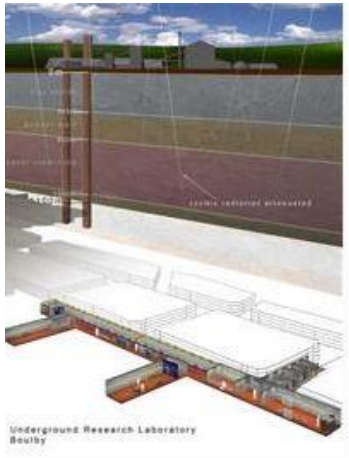
- LSM France



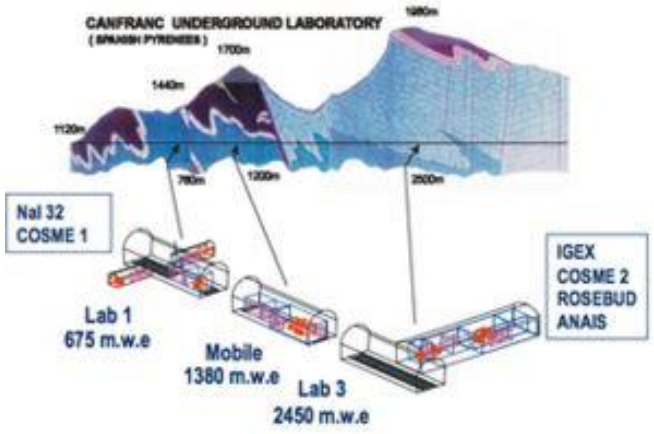
[Peltoniemi 2014, Piquemal 2012, Patzak 2011, Zalewska 2007]

More Low Background Labs…

- Boulby UK



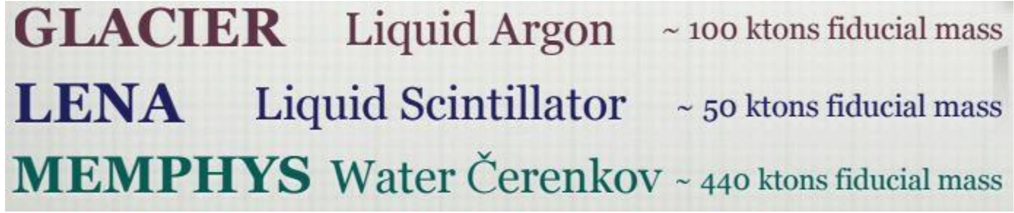
- LSC Spain



[Peltoniemi 2014, Piquemal 2012, Patzak 2011, Zalewska 2007]

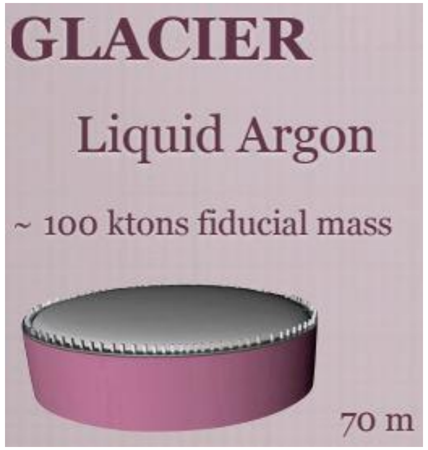
Future >Kiloton Detectors: LAGUNA

- **Large Apparatus studying Grand Unification and Neutrino Astrophysics**
- 3 components:
  - GLACIER – liquid argon
  - LENA – liquid scintillator
  - MEMPHYS – water Cherenkov

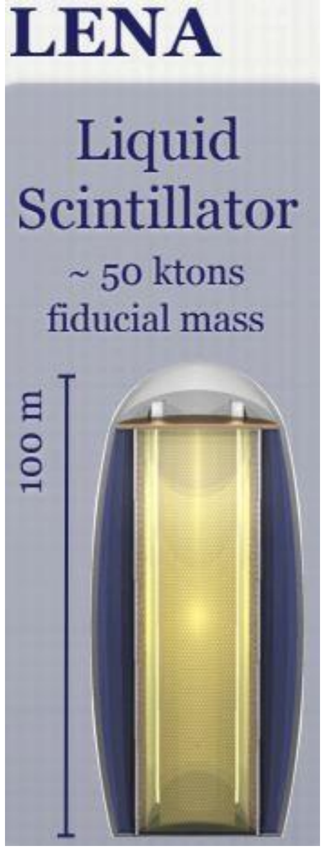


GLACIER	Liquid Argon	~ 100 ktons fiducial mass
LENA	Liquid Scintillator	~ 50 ktons fiducial mass
MEMPHYS	Water Čerenkov	~ 440 ktons fiducial mass

- 7 potential locations:
  - Boulby, Canfranc, Modane; Caso Umbria, Pyhäsalmi, Sierozsowice, Slanic



(sic)



[Votano 2010, O'Keeffe 2011, Peltoniemi 2014, Piquemal 2012, Patzak 2011, Zalewska 2007, Rubbia 2012]

Future >Kiloton Detectors

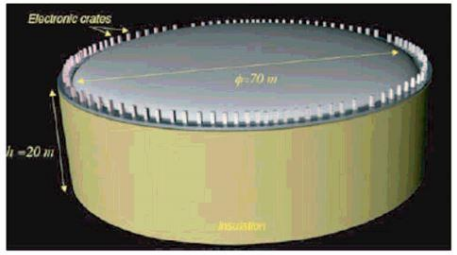
GLACIER – the Liquid Argon detector

Concept: initialy developed for Sieroszowice and Gran Sasso, prototype – the ICARUS detector, rescaling by a factor 150

Advantages: very good positional and energetic resolutions
→ imaging topologies, identification of low energy hadrons

Challanges: 20-m long drift of electrons, huge cryogenic installation, dewar thermal insulation

Construction: cylinder 70m in diameter and 20 m hight, total mass - 100 ktons of Liquid Argon, read out of the electron ionisation and light signals (scintillations – 1000 8" PMT, Cherenkov light – 27000 8" PMT)



Przegorzały.15.10.2007

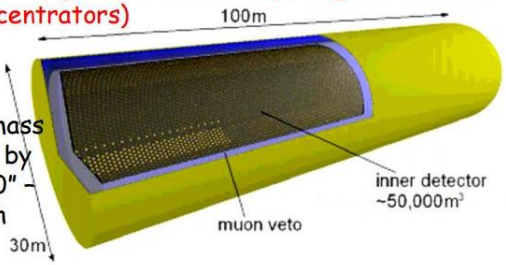
LENA – the liquid scintillator detector

Concept: initial work for the Pyhäsalmi mine in Finland (underwater placement near Pylos was also considered), the Borexino, Chooz and KamLAND detectors as prototypes, rescaling by a factor 40-50

Advantages: very low energy threshold, good energy resolution, known technology

Challenges: scintillator cleaning, better and cheaper light detection (photomultipliers, light concentrators)

Construction: cylindrical tank 100m long and with a diameter of 30m, fiducial mass of about 50 ktons, readout by 12 000 photomultipliers (20" – 30% surface coverage, with added light concentrates - 50% coverage)



Przegorzały.15.10.2007

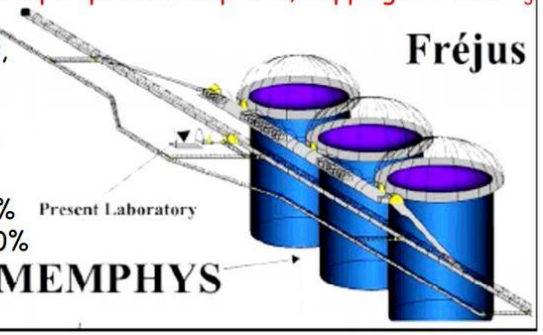
MEMPHYS – water Cherenkov detector

Concept: initial work for the Frejus laboratory, the SuperKamiokande detector as a prototype, rescaling by a factor up to 20

Advantages: the cheapest target material, mature technology, possible extrapolation to the 1 Mton mass

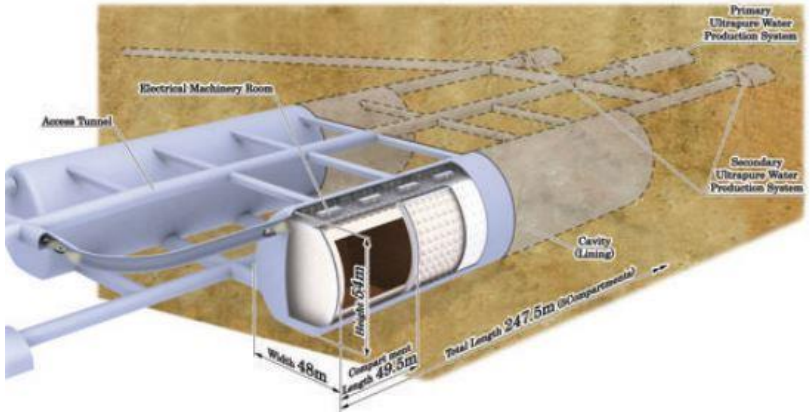
Challenges: better and cheaper photomultipliers, dopping with $GdCl_3$

Construction: 3-5 tanks, each one with a diameter and a height of 65 m, fiducial mass of 147 ktons read out by 81000 photomultipliers (12" – 30% surface coverage, 20" – 40% coverage)



Przegorzały.15.10.2007

And Hyper-K!



Peltoniemi 2014, Piquemal 2012, Patzak 2011, Zalewska 2007, Wilkes 2015, Rubbia 2012]

Questions?

Citations:

as [Tykva 1995, Theodórsson 1996, Livingston 2004, Knoll 2010, Votano 2010, Jiao 2013, O'Keeffe 2011, Peltoniemi 2014, Piquemal 2012, Patzak 2011, Zalewska 2007, Wilkes 2015, Rubbia 2012]

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