Finnish Underground Lab

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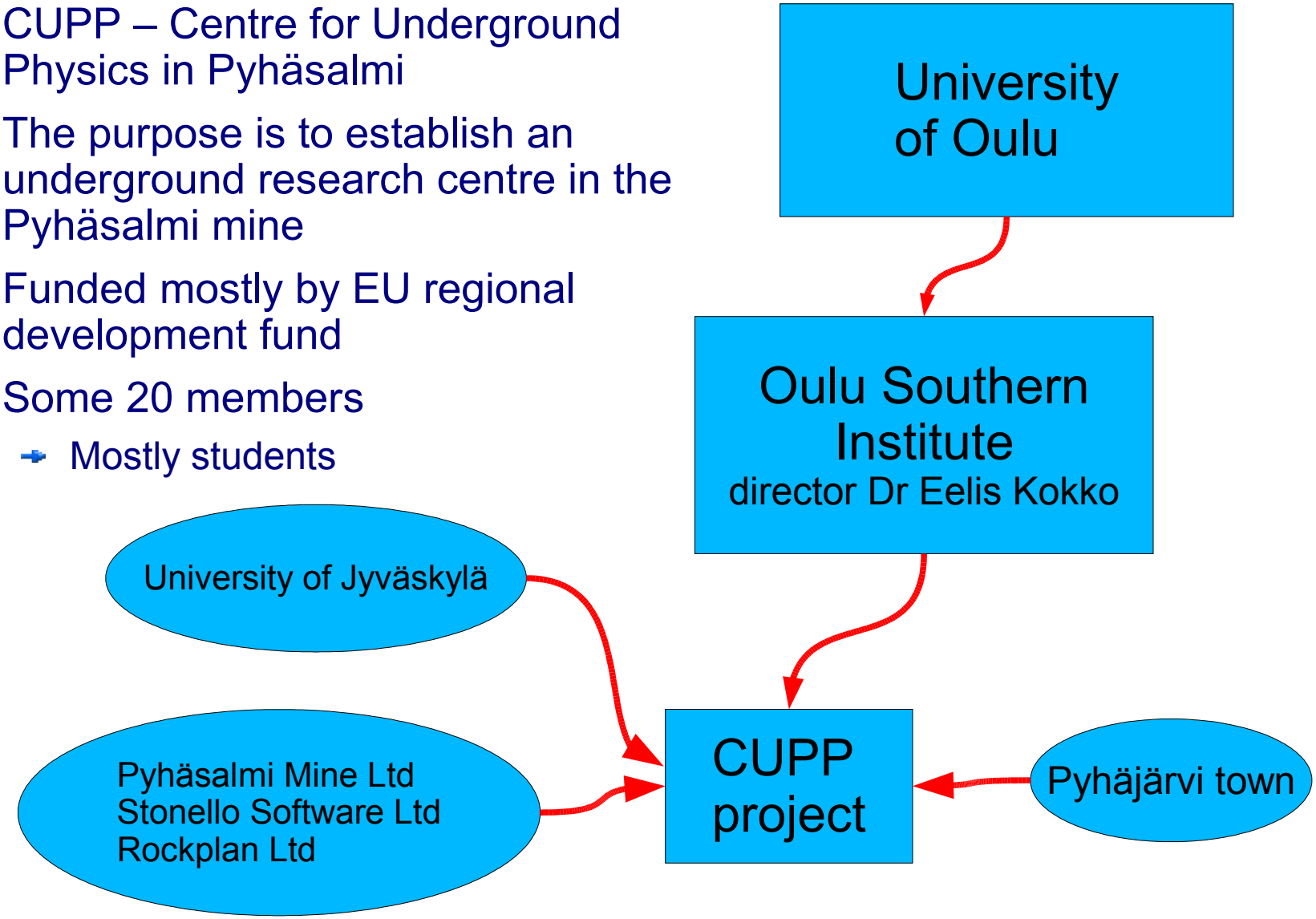
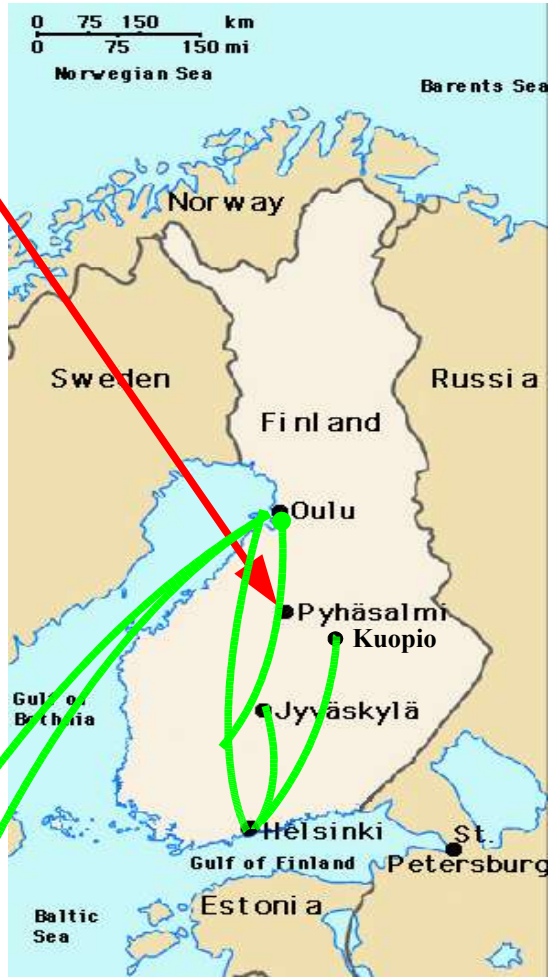
The CUPP project

- CUPP – Centre for Underground Physics in Pyhäsalmi
- The purpose is to establish an underground research centre in the Pyhäsalmi mine
- Funded mostly by EU regional development fund
- Some 20 members
  - Mostly students



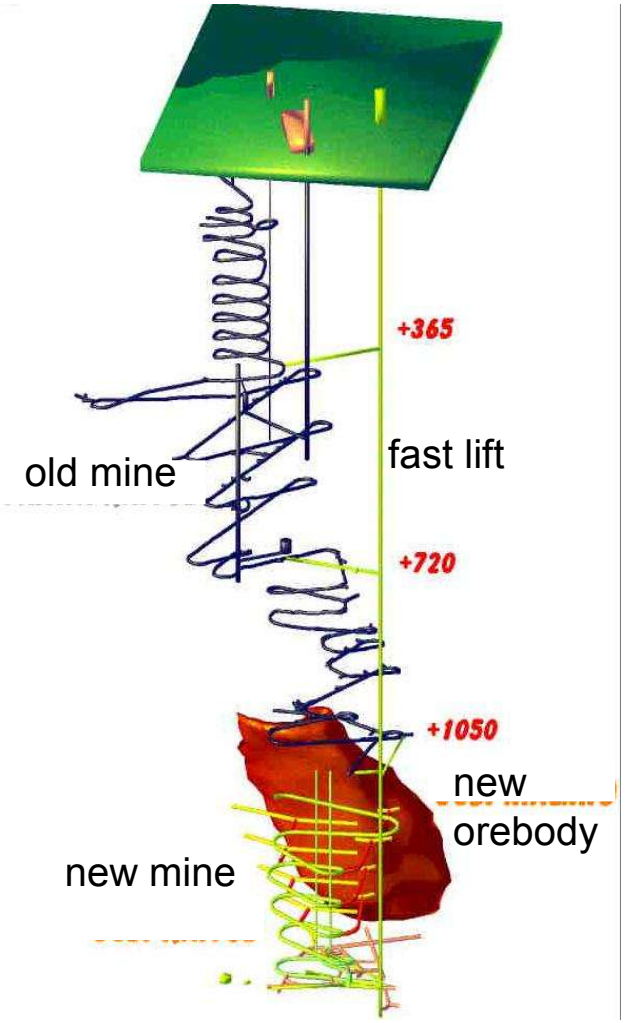
Location of the Pyhäsalmi site

- Pyhäsalmi mine in Pyhäjärvi town
- Connections
  - Roads open all year round
    - Pyhäjärvi-Oulu: 2 h car drive
    - Pyhäjärvi-Jyväskylä: 2 h car drive
  - Pyhäjärvi-Helsinki: bus & train connections
  - 4 airports within 2 hours drive, connections
    - Oulu-Helsinki: ca 20 flights a day
    - Oulu-Stockholm: 1–2 flights a day
  - Railway to the mine
- Distance to accelerators
  - CERN 2300 km
    - Density profile well known
  - JPARC 7100 km



Pyhäsalmi Mine

- Pyhäsalmi Mine Ltd
  - Inmet Mining Corporation, Canada
  - Produces zinc, copper and pyrite (FeS_2)
- The old mine
  - about 1050 m deep
  - Operated 1962–2001
  - Many free caverns available now
- The new mine
  - active since July 2001
  - known ore reserves until ca 2016
    - Depends on future metal prices
  - greatest depth 1444 m
    - the deepest metal mine in Europe
  - access by lift (2 min) or via decline by car (40 min) or by running (1 h 4 min)

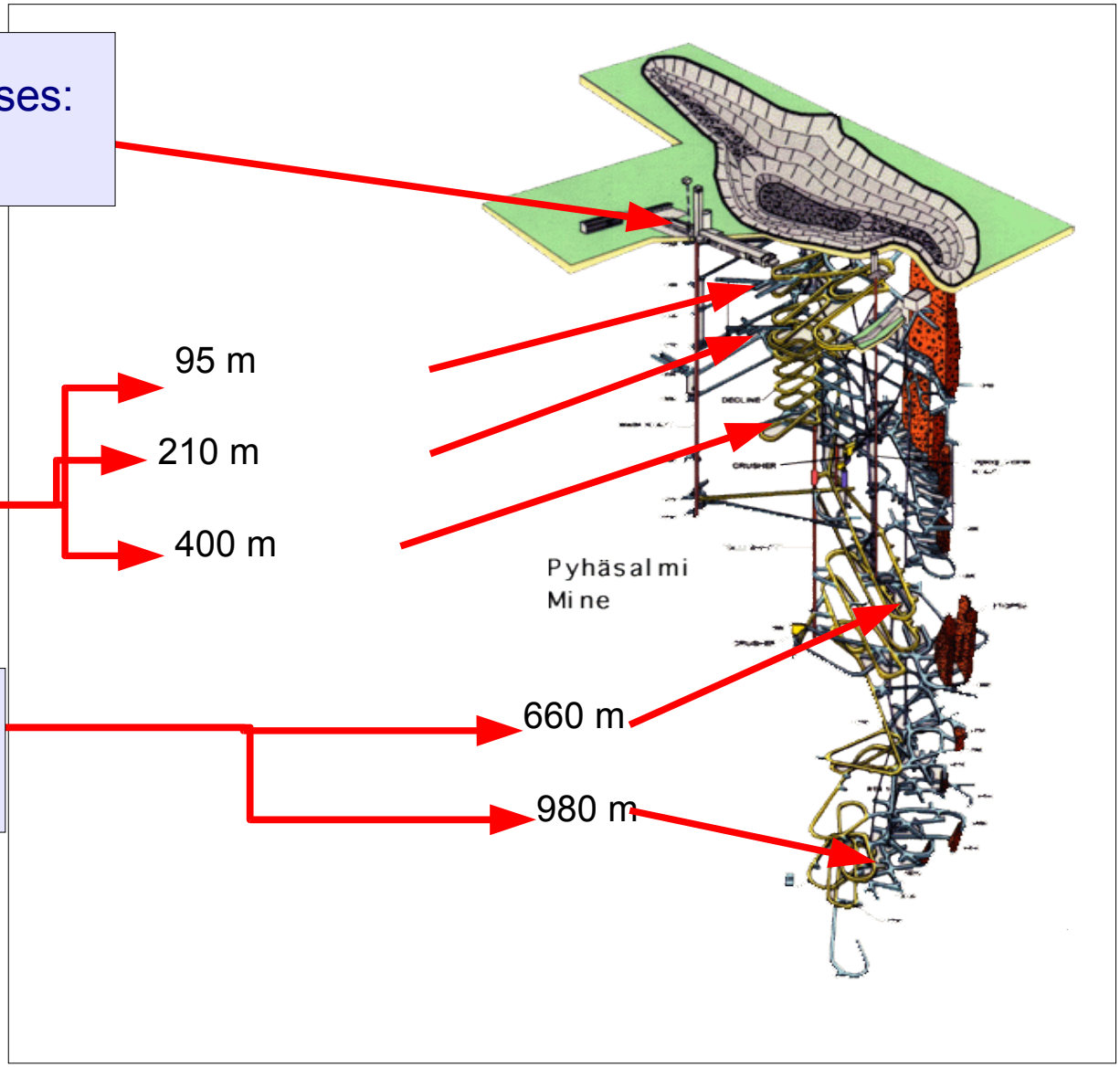


Present and available premises

Surface premises: old mining hut

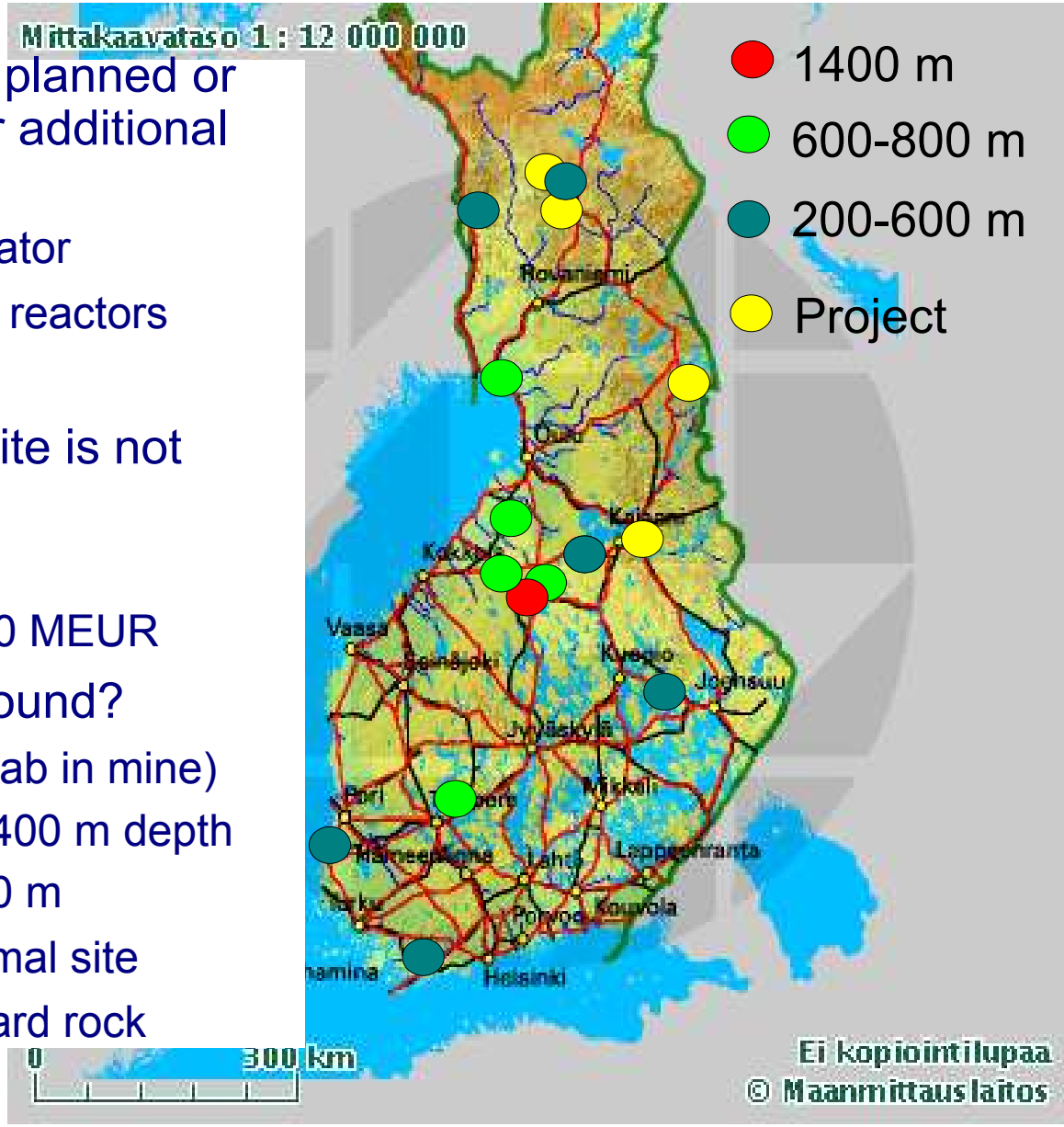
Underground facilities in use

Other existing halls



Other possible sites in Finland

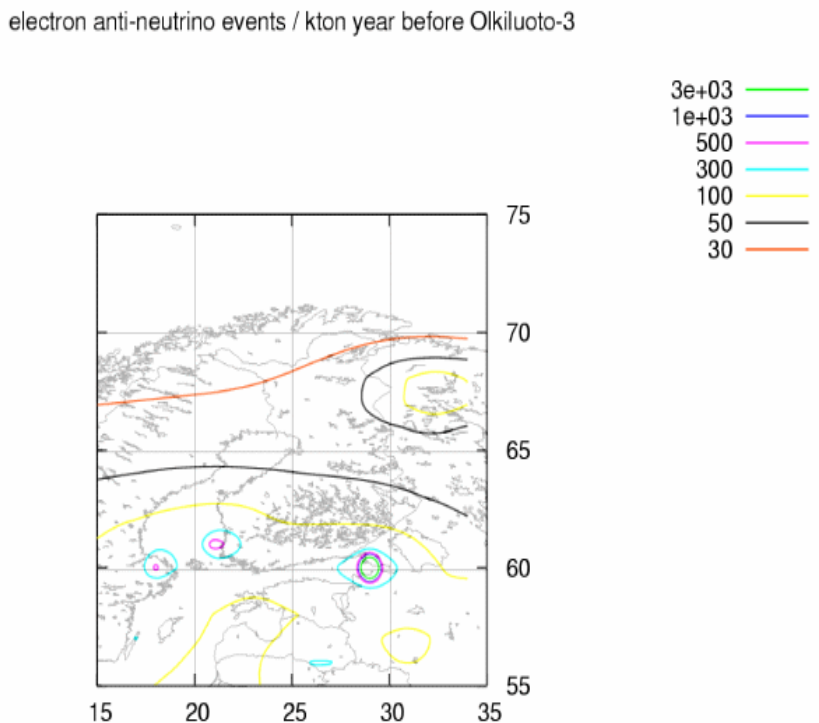
- Several other active, planned or abandoned mines for additional or alternative sites
  - Distance to accelerator
  - Distance to nuclear reactors
  - Logistics
- Deepening another site is not completely infeasible
  - Ca 20 000 EUR/m.
  - e.g. 800->1400 = 10 MEUR
- New hole in virgin ground?
  - Additional cost (vs lab in mine)
    - 20 MEUR for 1400 m depth
    - 5 MEUR for 600 m
  - May select the optimal site
  - Need well known hard rock
    - Most of Finland

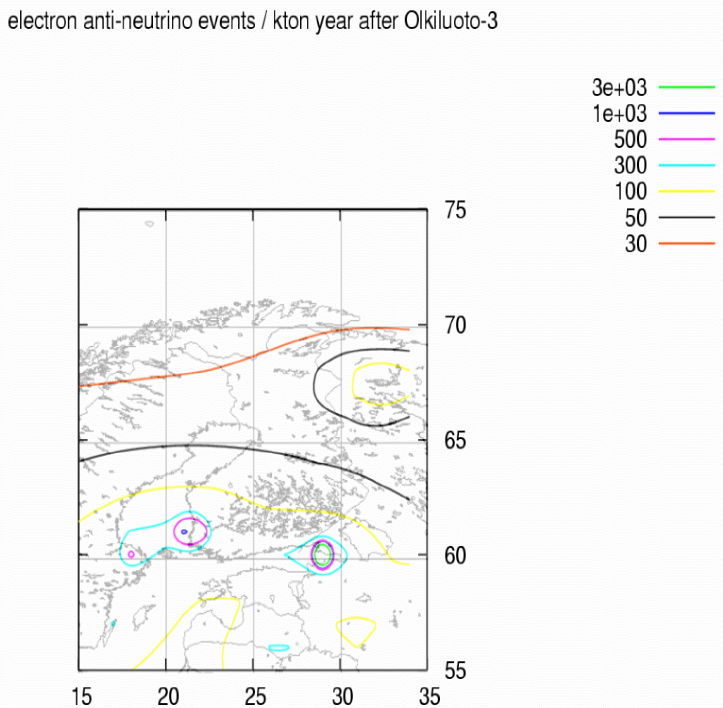


Nuclear reactor background

- Relevant for LENA
- A new reactor under construction in Finland
  - World's largest single reactor
    - Electric power 1.6 GW
  - 10 % increase of flux
  - Probably compensated by the shutdown of Sosnovy Bor

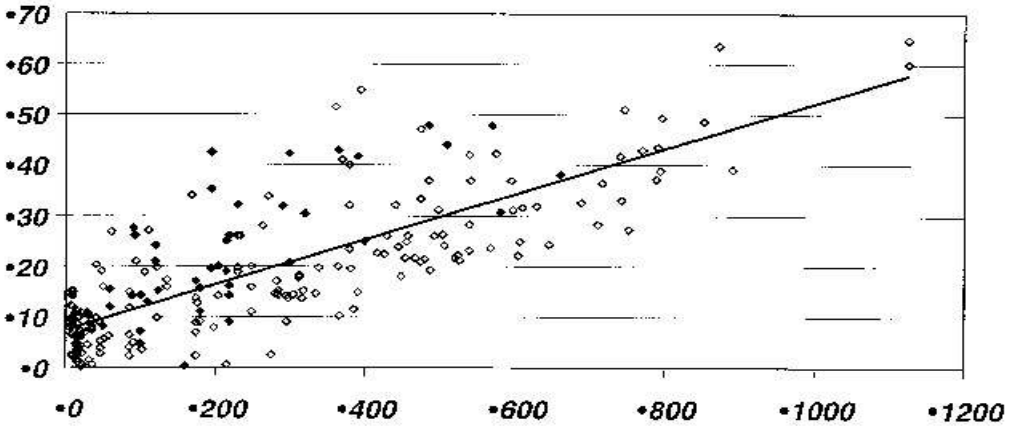
Location	Neutrinos (10^8 1/m^2 s)
Pyhäsalmi	40
Gran Sasso	54
Frejus	175
Canfranc	196
Boulby	190
Kamioka	408
Sudbury	100
Soudan	33
Crete (sea)	13

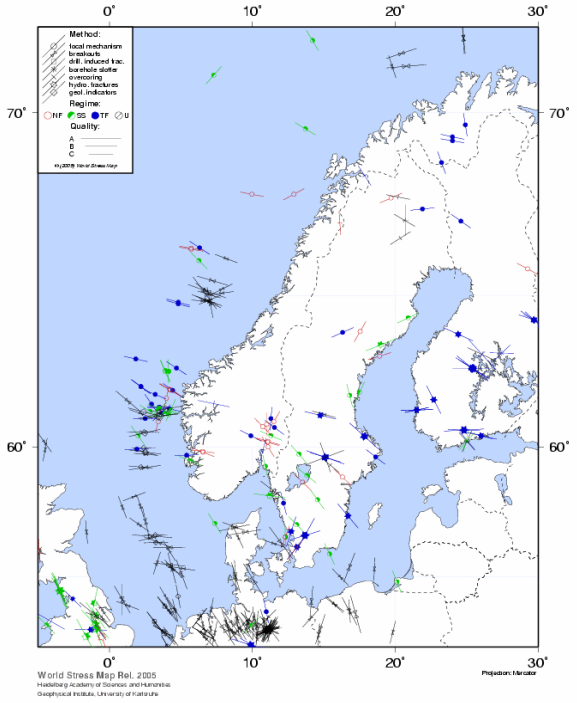




Special features of Finnish rock

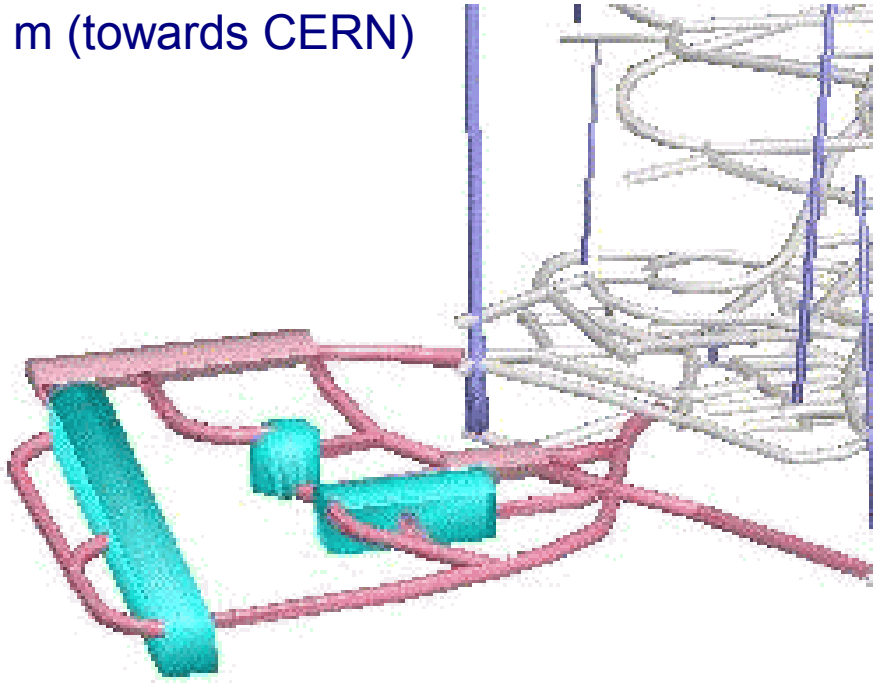
- Typically very hard rock
  - Rockbed very old (1-2 Ga) and thick
  - Similar zones in Scandinavia, in north-eastern Canada and in several separated areas in Asia, Africa and South America
- Advantages
  - Rock construction easy
  - Rock is very stable
  - Deep rock is water tight
  - Comfortable temperatures (23 C at 1500 m)
- Challenges
  - Rock stress





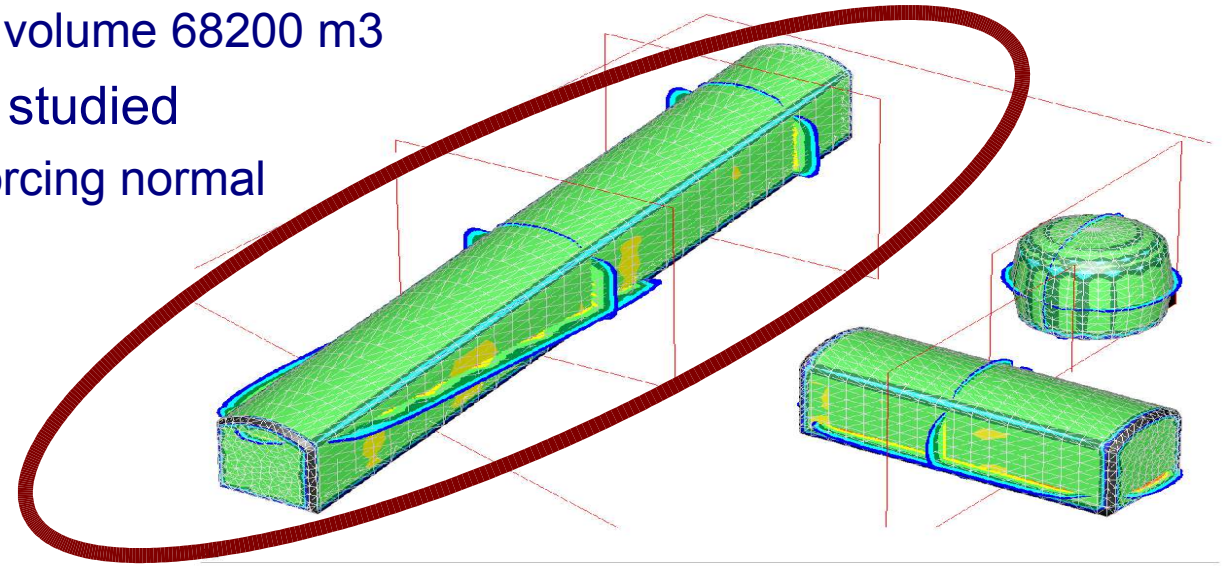
Rock studies

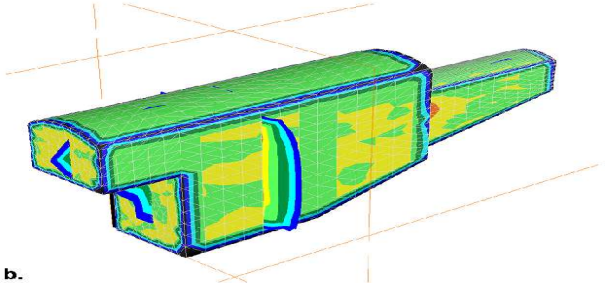
- Properties of rock, rock mechanics and constructibility of the laboratory in Pyhäsalmi mine studied in a pre-feasibility study
  - No show-stoppers
  - Very good rock
  - Rock types vary, sometimes even at O(1m) scale.
  - Natural radioactivity rather low (but varies)
- Studied several caverns in detail, and found feasible
  - Inclined hall 20 m x 20 m x 120 m (towards CERN)
  - Cylinder d=25 m, h=25 m

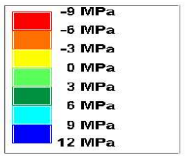


Cavern for a Detector for Neutrino Beam

- Included in the pre-feasibility study 2002
- Studied in detail a cavern of 20 m x 20 m x 120 m
  - Inclined 11 degrees downwards
  - Direction almost orthogonal to main stress component (bad)
  - Area 3000 m2, volume 68200 m3
- Stress behaviour studied
  - Required reinforcing normal
  - No obstacles







Cost estimate for neutrino cavern

- Excludes access and general laboratory structures
- Includes
  - Detailed rock studies & architectural design
  - Excavation, reinforcing, water shielding
  - Electric power line 1 MW
  - Cooling, 1 MW machine in the surface
  - Cranes, internal lifts and staircases
  - All clean room
  - Basic radiation protection
- Ready to install the experiment

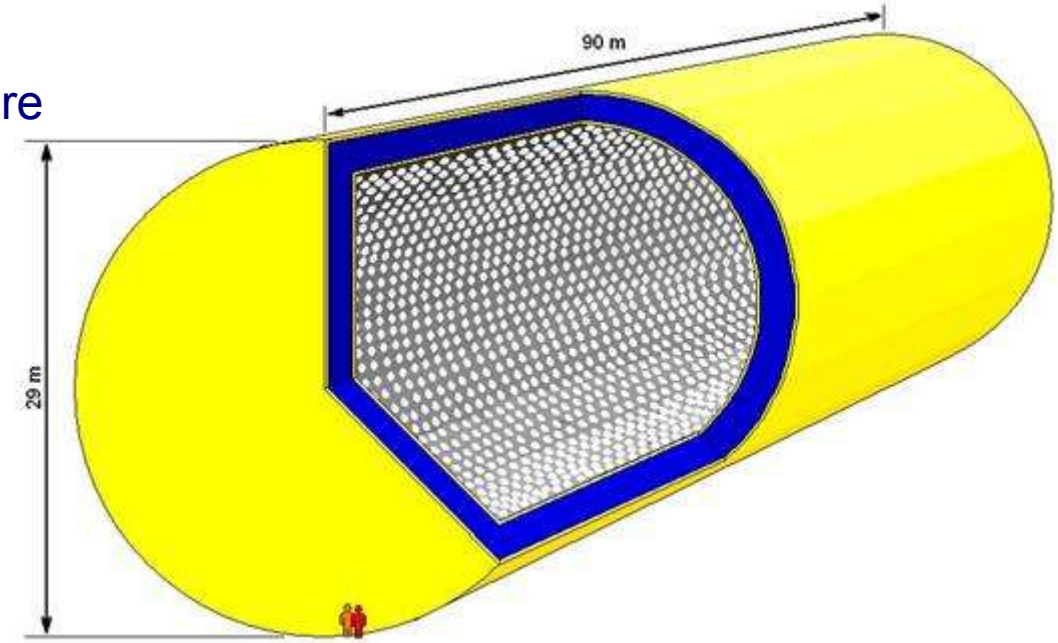
	EUR	EUR/m^2	EUR/m^3
Purchaser's costs 14 %	1 300 000 €		
Rock construction and excavation	5 400 000 €		
Building technical work	3 050 000 €		
HVAC	810 000 €		
Contingency 20 %	2 110 000 €		
TOTAL	12 670 000 €	2300	185

Costs for constructing underground laboratory

- Large underground laboratory hall: typically 200 EUR/m^3
  - Rock construction 40 % (80 EUR/m^3)
    - Drill & blast: cheap, can be automatized
    - rock removal: variable, but typically < 10 EUR/m^3
    - reinforcing (shotcreting, bolting): manual work, expensive
- Raw caverns much cheaper < 50 EUR/m^3
- Access construction:
  - Wide decline (tunnel, ramp) with heavy truck access: 2000 EUR/m
  - Narrow tunnel: 1000 EUR/m
  - Shaft (7 m) 5000 EUR/m, (2 m) 1000 EUR/m.
  - Own hoist (lift) to surface 2-10 MEUR
- Note: In Finland it is typically cheaper to construct large halls (shallow) underground than in the surface.

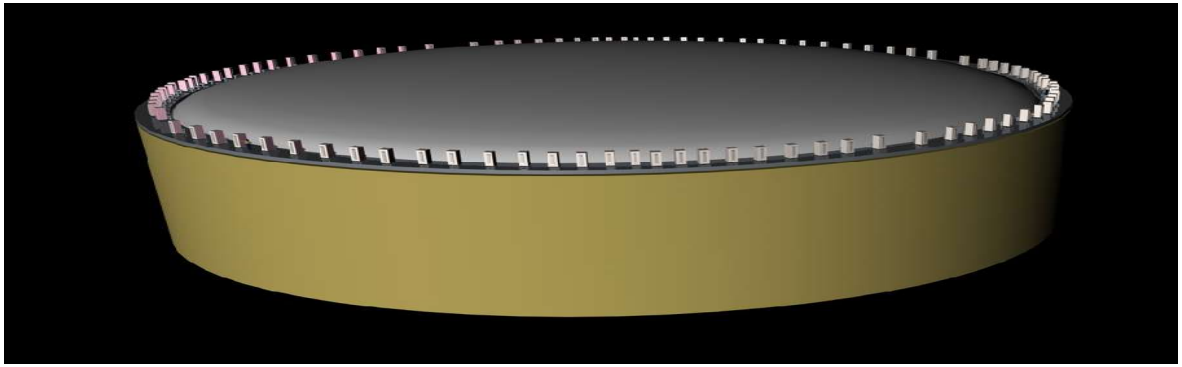
LENA in Finland

- Need ca 30 m wide cavern
  - Rock mechanics not studied in detail
  - Probably not a major problem to construct
  - Slightly smaller cavern (20 x 20 x 120) found feasible
  - Need to study carefully the properties of rock in selected site
- Estimated cost for rock construction: 10 MEUR
  - Compare: An underground oil tank of 45 000 m^3: 7 MEUR
- Environmentally robust
  - Well below the biosphere



Liquid argon experiment in Finland?

- Cavern for 10 kton experiment trivial
- Cavern for 100 kton experiment non-trivial
  - 70 m span requires special (expensive) techniques
  - Need exceptionally good (hard) rock
  - Feasilibility in Pyhäsalmi not studied
  - Depends on the depth (rock stress is important): 200 m ”easy”
  - Excavation cost probably 10-30 MEUR



- Availability of liquid argon
  - Production in Finland >100 kton/a
  - Free capacity in Finland 20-30 kton/a
  - Price < 300 EUR/ton (150 ?)

Huge Water Cherenkov in Finland?

- Construction of 1 000 000 m^3 cavern very non-trivial
  - A spherical cavern with r=70 m virtually impossible everywhere
  - A long tube of 40-60 m diameter may be possible
  - Array of <100 000 m^3 caverns easiest
  - Requires very careful site selection and detailed rock mechanical studies
- Possibilities in Finland unclear
  - So far no specific push from scientific community (ν–beams etc.)
  - No studies for exceptionally large caverns made so far
  - Probably no worse than elsewhere
  - Estimated cost of rock construction: 100-300 MEUR
    - Higher for large-span caverns
  - Rather impossible in an operational mine
    - Wait for closure or do it elsewhere
- Water
  - Water certainly available everywhere

Conclusions

- Large volume detectors can be hosted in Finland
  - Pyhäsalmi mine (1444 m)
    - Mine probably closed at 2016
    - Pay more if lab constructed parallel to mining
  - Other underground sites (0-800 m) may be available now
    - Additional cost of 10 MEUR if deepened to 1400 m
- Advantages
  - Distance to accelerators (depends...)
  - Low nuclear reactor flux
  - Environmentally robust
  - Good rock – low construction cost
  - No excessive temperatures in deep sites
  - ”Optimal site for a supernova detector”
- Experiments:
  - LENA: feasible, 10-15 MEUR
  - GLACIER: probably doable 10-30 MEUR
  - UNO/MEMPHYS: unclear (why here?) 100-300 MEUR