CUPP

# The Pyhäsalmi Underground Laboratory

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LAGUNA

Leverage from the EU 2007–2013 | POHJOIS-POHJANMAAN LIITTO Council of Oulu Region | INMET MINING | ROCKPLAN | NIHAK | UNIVERSITY OF HELSINKI | UNIVERSITY of OULU OULUN YLIOPISTO OULU SOUTHERN INSTITUTE | UNIVERSITY OF JYVÄSKYLÄ

# The Pyhäsalmi underground laboratory

## Content

# The Pyhäsalmi underground laboratory

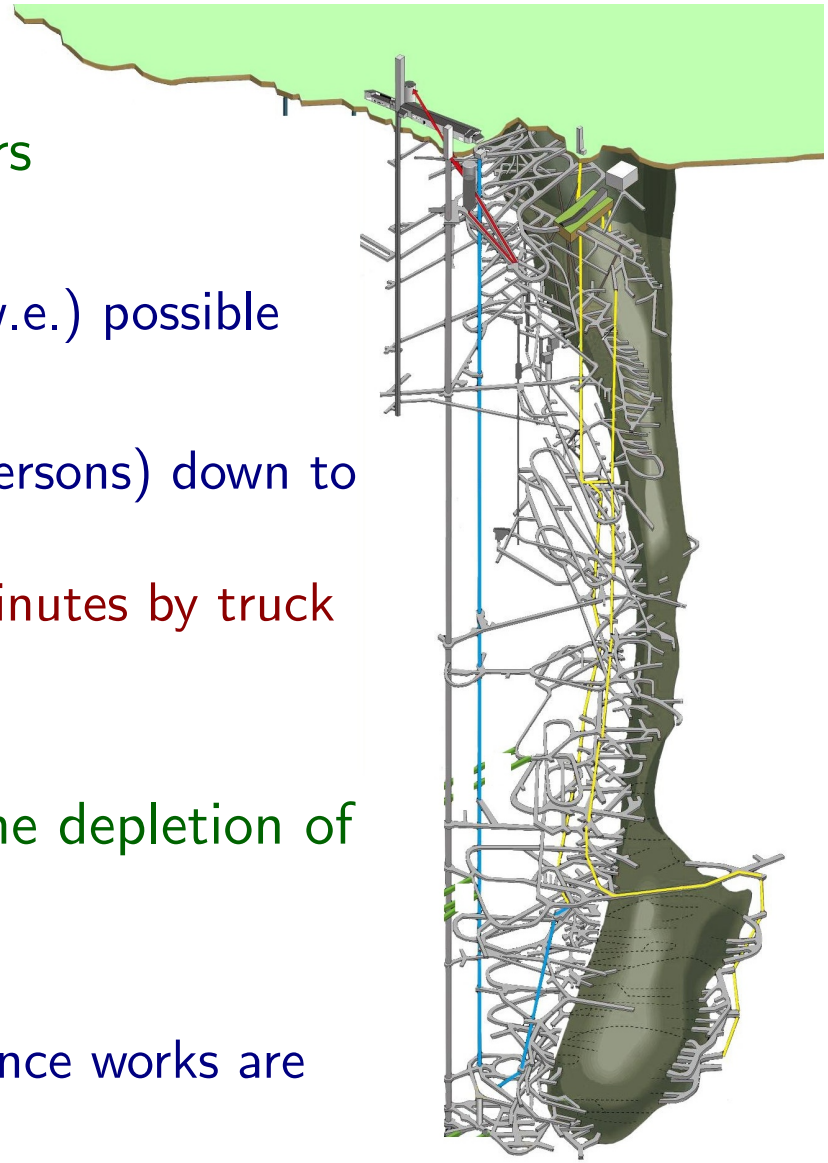
## Site location


- CUPP : Centre for Underground Physics in Pyhäsalmi (www.cupp.fi)
- Location: 63° 39' 31"N – 26° 02' 48"E
- Distances (by roads)
  - Oulu – 165 km
  - Jyväskylä – 180 km
  - Helsinki – 450 km
- Distance to CERN 2300 km
- Good traffic connections
  - the main highway: Helsinki – Jyväskylä – Oulu – ...
  - the second busiest airport in Oulu
  - rail yard at the mine
- Inhabitants: ∼6000

# The Pyhäsalmi underground laboratory

## The Pyhäsalmi mine (Inmet Mining Ltd., Canada)

- Procudes Cu, Zn, and $FeS_2$
- $\sim$220 employee + $\sim$50 subcontractors
- The deepest mine in Europe
  - Depths down to 1400 m (4000 m.w.e.) possible
- Very modern infrastructure
  - a hoist (of 21.5 tons of ore or 20 persons) down to 1400 metres; takes $\sim$3 minutes
  - a 11-km long decline; takes $\sim$40 minutes by truck
  - three ventilation shafts
  - good communication systems
- End of excavations by 2018 due to the depletion of the ore
- Compact mine, small 'foot print'
  - water pumping and other maintenance works are not major issues



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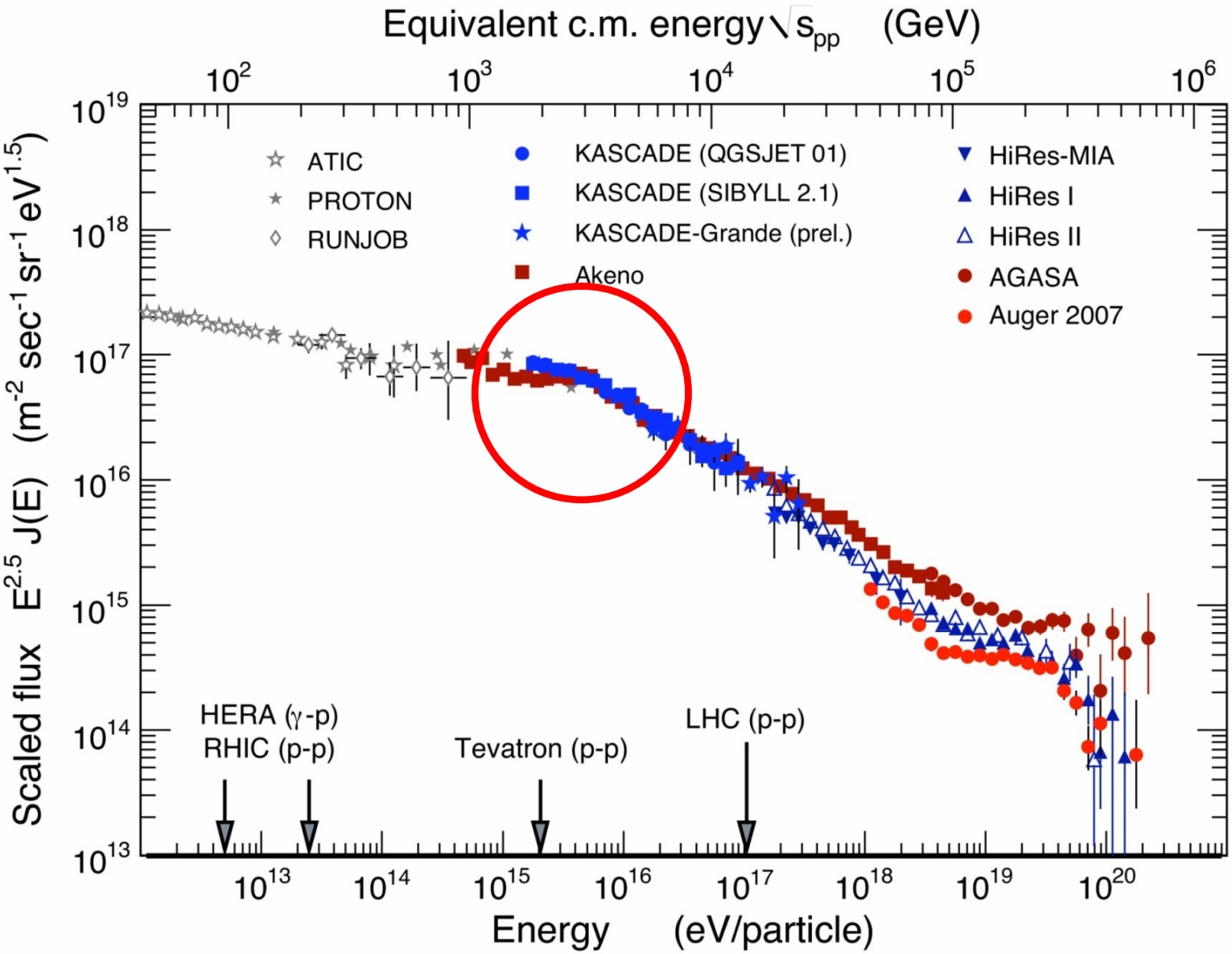
## Cosmic-ray experiment EMMA – Composition at the knee



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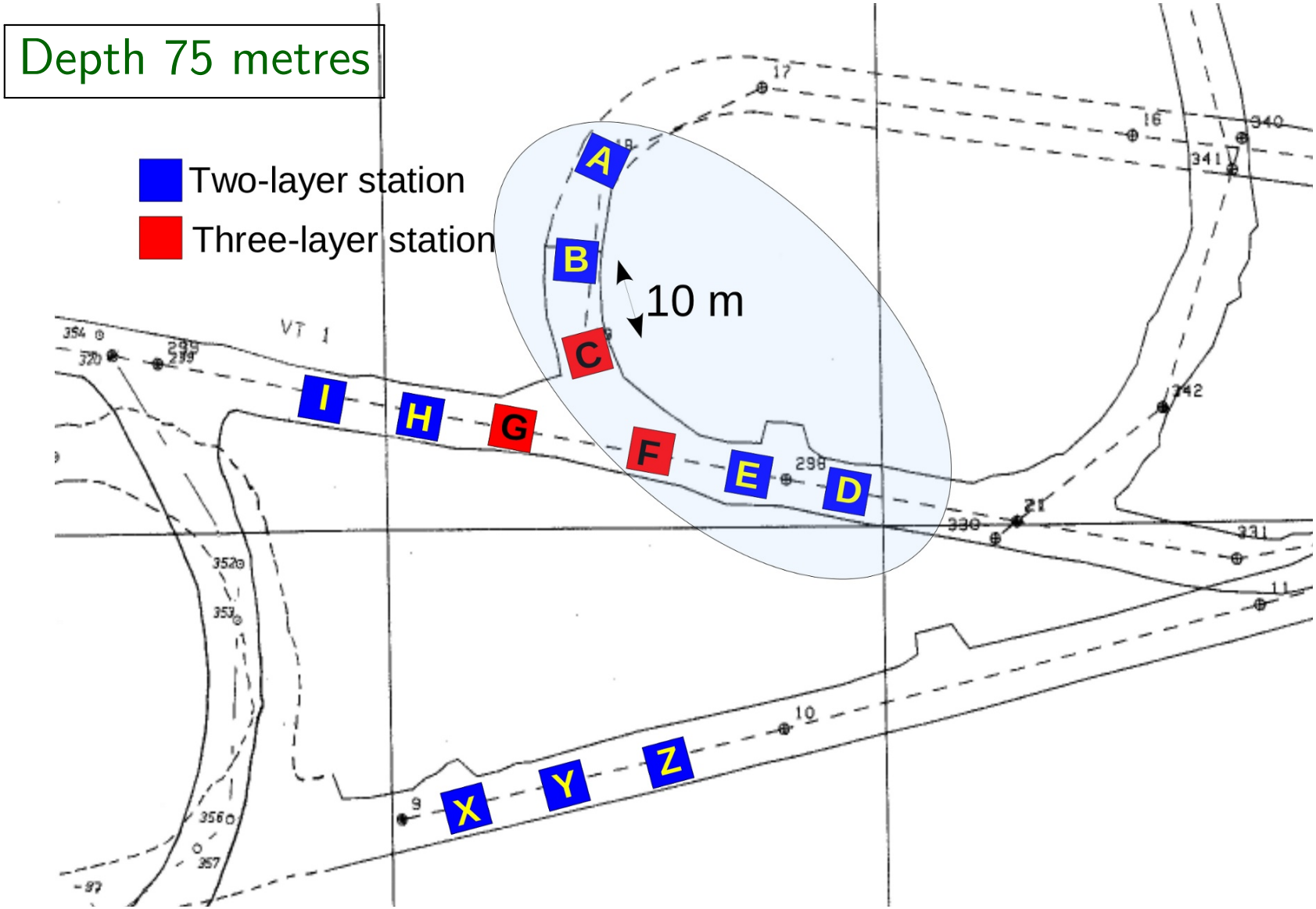
## Cosmic-ray experiment EMMA – Experiment with MultiMuon Array



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## EMMA – Underground detector stations

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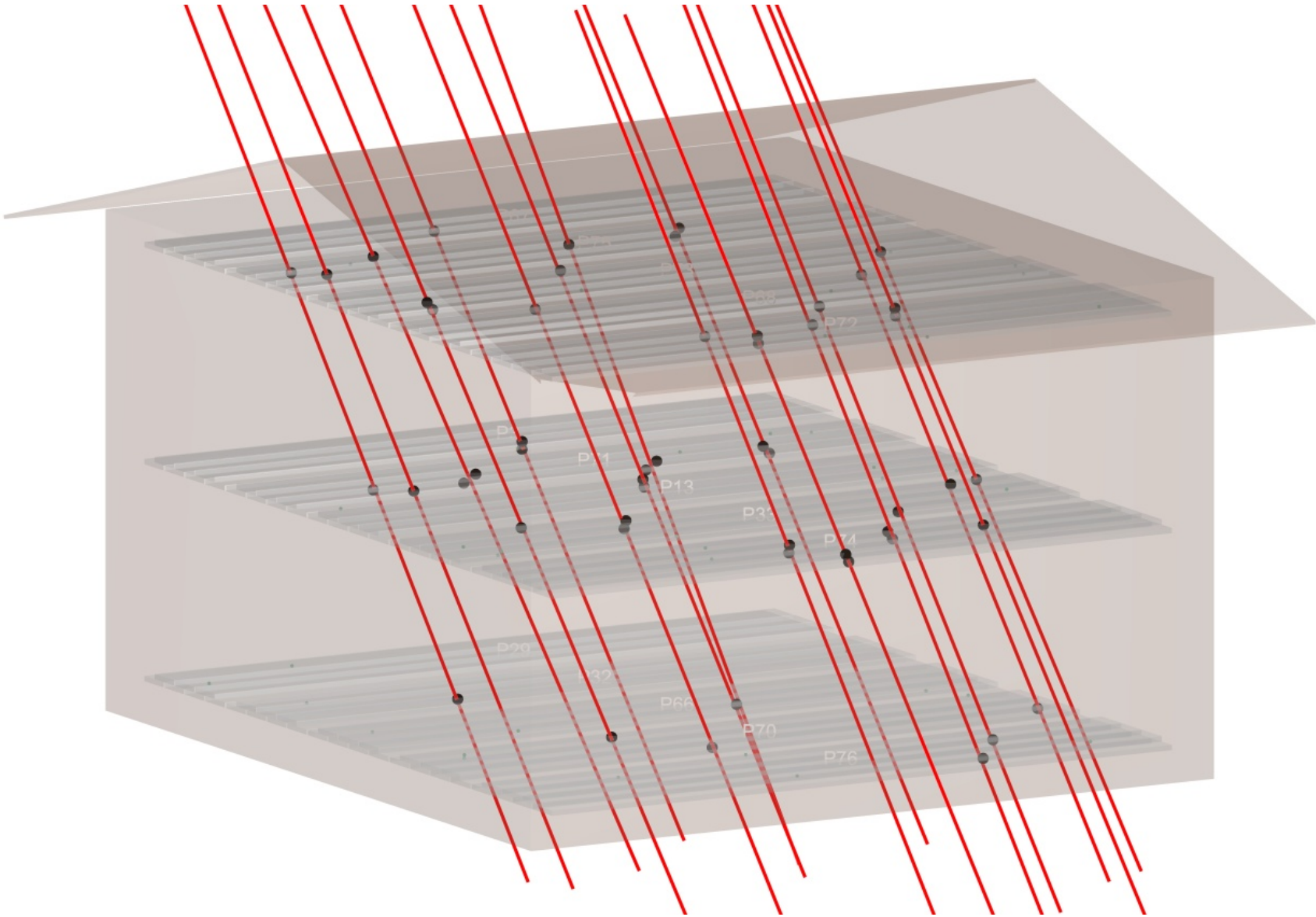
## EMMA – Test measurements – Muon tracking



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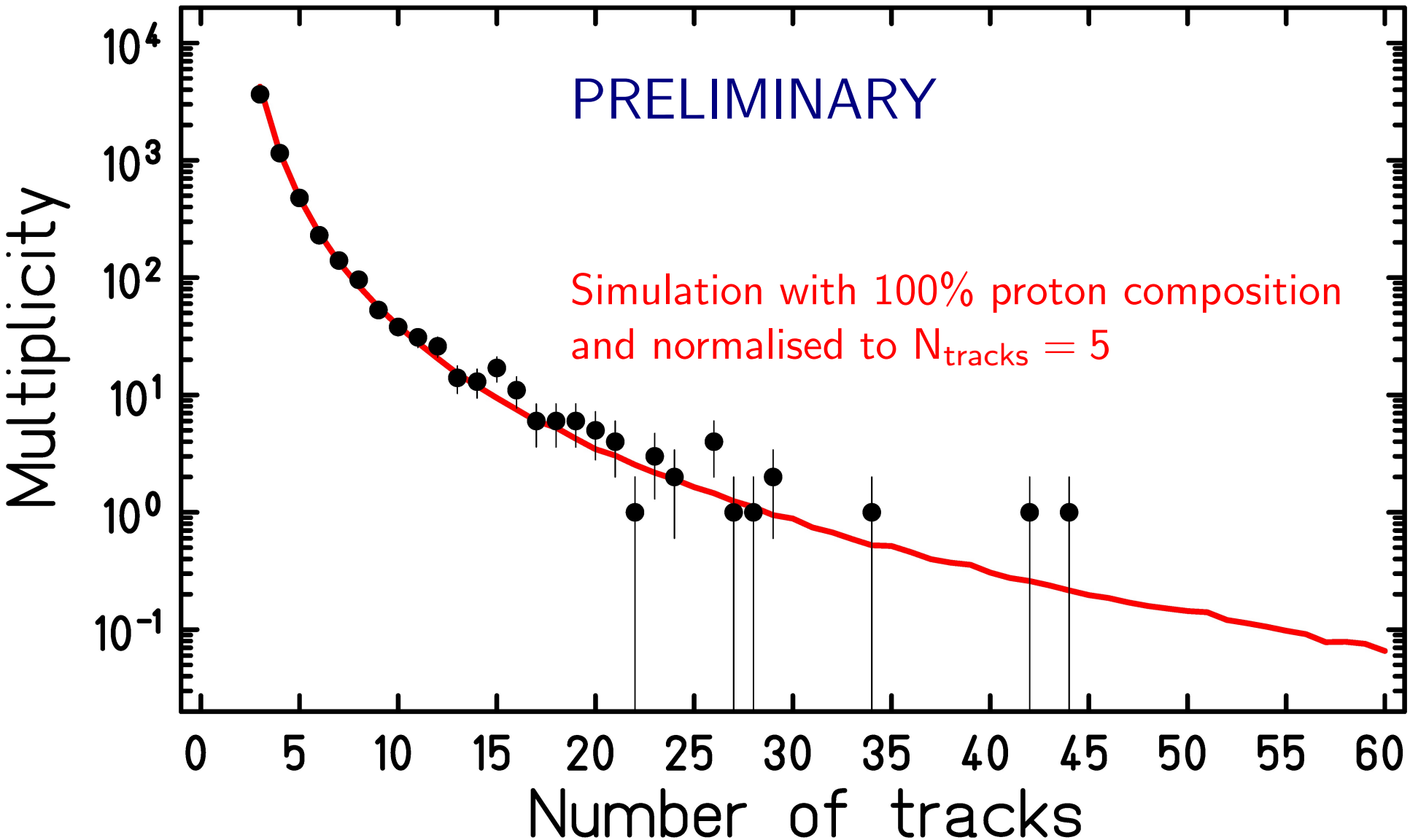
## EMMA – Test measurements – 44 days with Station C



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## EMMA – Collaboration

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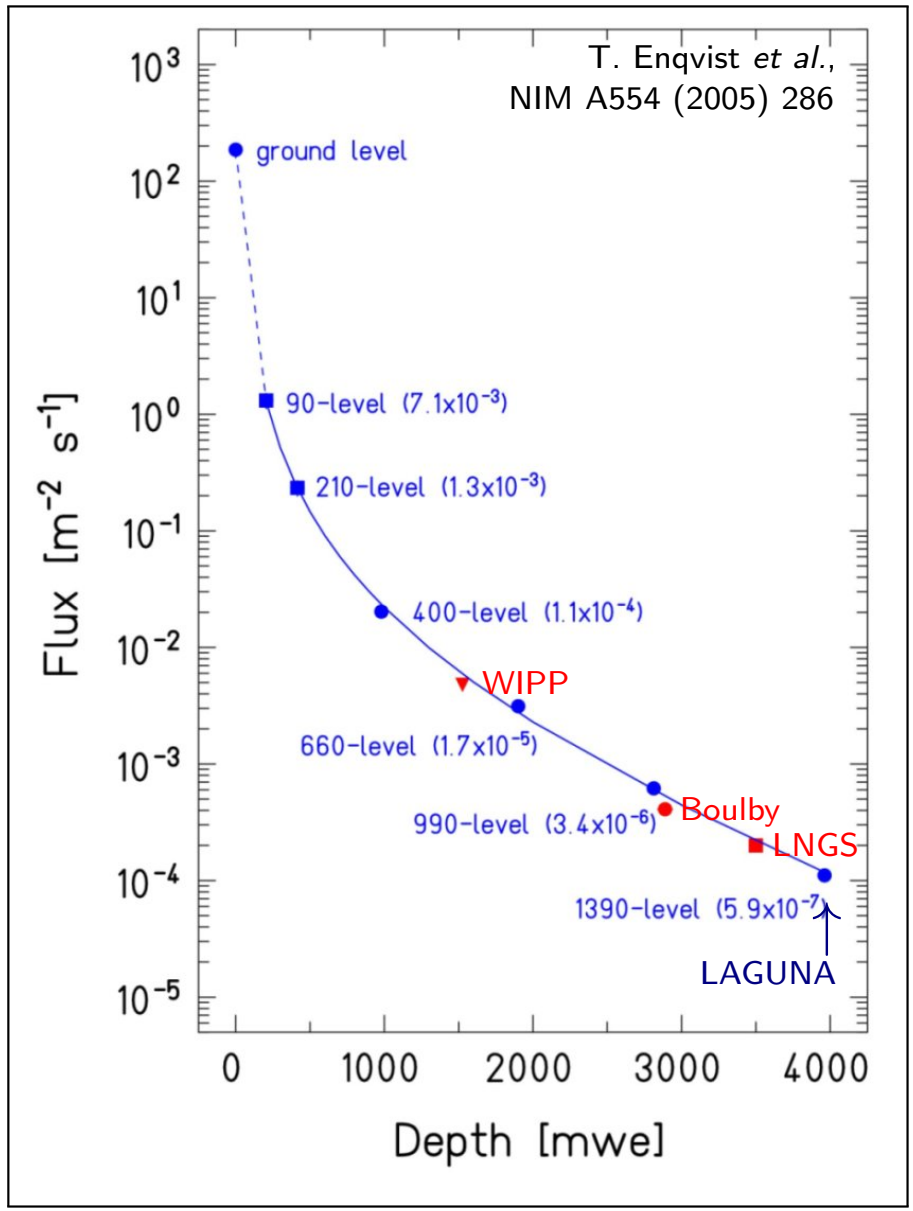
## Muon flux and neutron background measurements

- The muon flux was measured in 2004–2005 at different levels of the mine $\Longrightarrow$

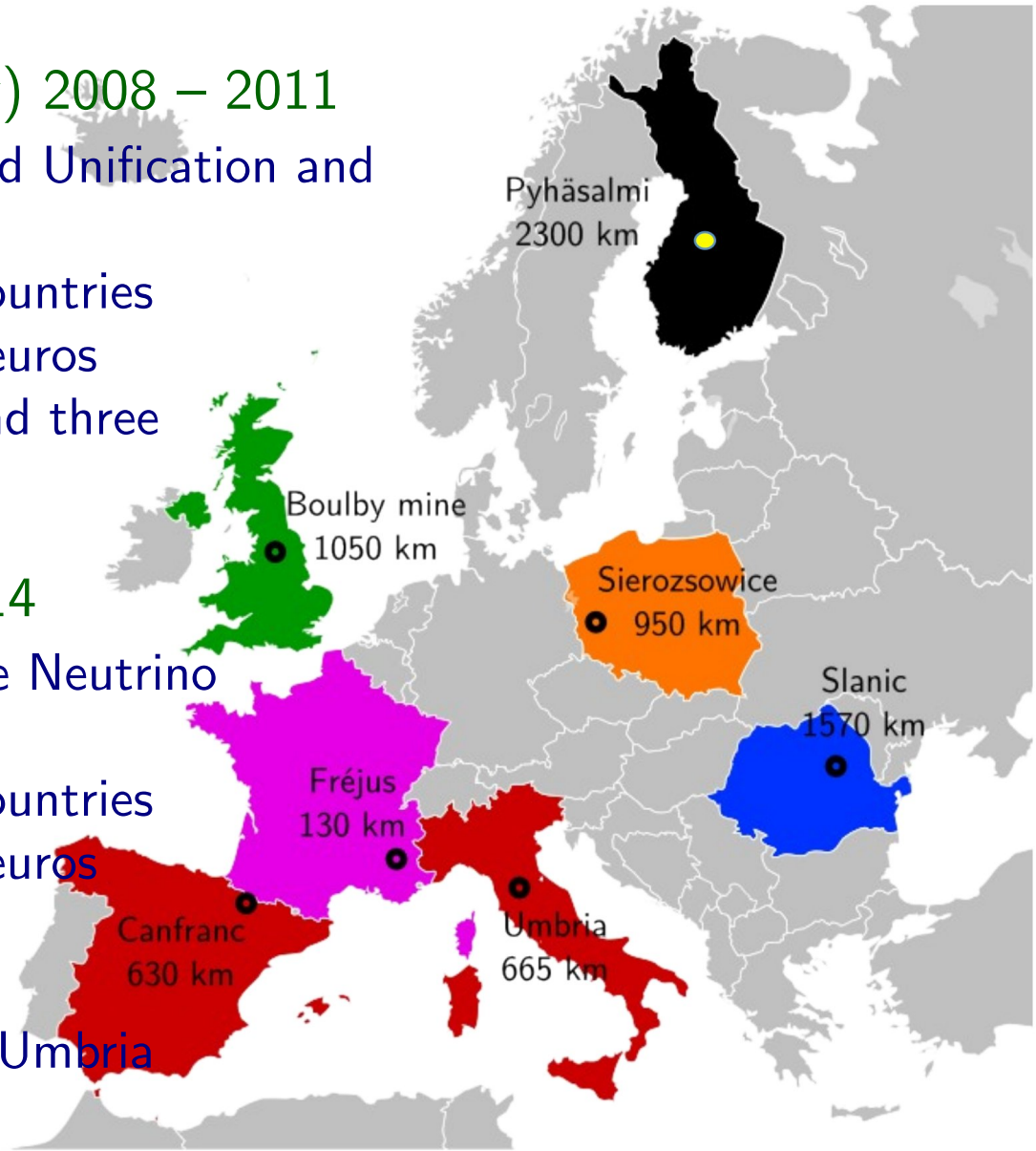



- The neutron flux measurement is going to be started in Sept. 2012 in co-operation with Jacek Szabelski (Lodz, Poland)

# The Pyhäsalmi underground laboratory

## LAGUNA Consortiums

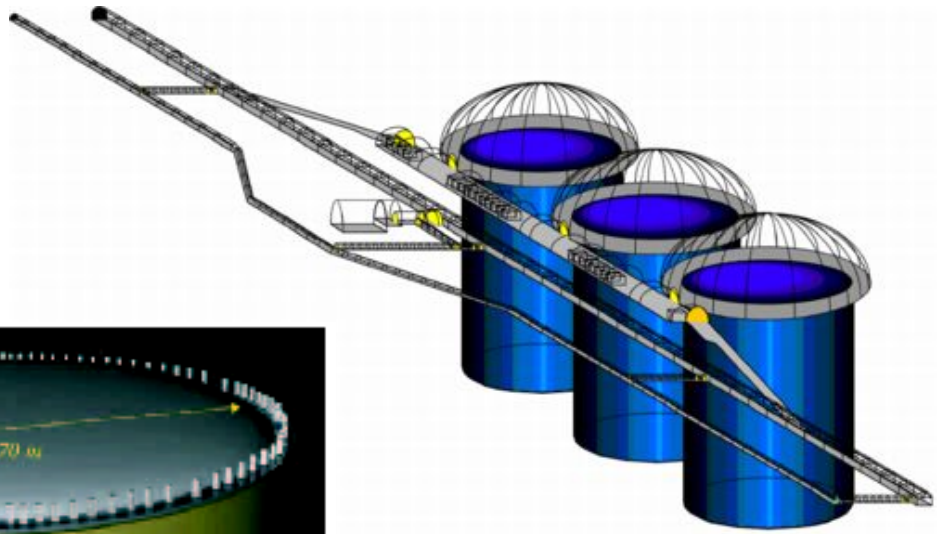
- LAGUNA DS (Design Study) 2008 – 2011
  - Large Apparatus for Grand Unification and Neutrino Astrophysics
  - ∼100 members and 10 countries
  - EU funding (FP7) 1.7 Meuros
  - Seven preselected sites and three detector options
- LAGUNA-LBNO 2011 – 2014
  - LAGUNA – Long Baseline Neutrino Oscillations
  - ∼300 members and 13 countries
  - EU funding (FP7) 4.9 Meuros
  - Prioritization (LBNO): CERN – Pyhäsalmi, CERN – Fréjus, CERN – Umbria

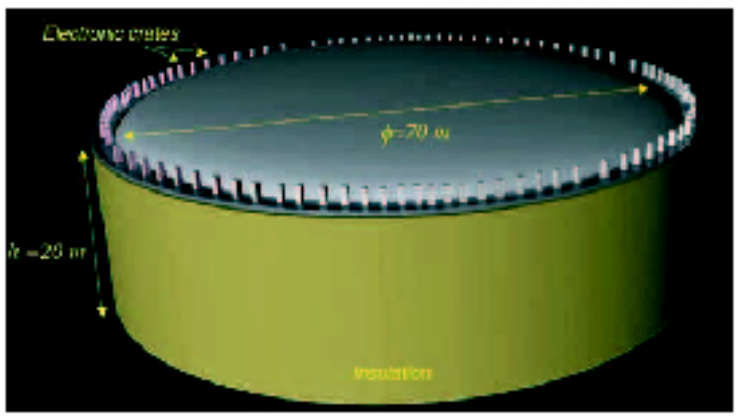


# The Pyhäsalmi underground laboratory

## LAGUNA DS (2008 – 2011)

- Main results of LAGUNA DS (2008 – 2011) for Pyhäsalmi
  - all three detector options possible (simultaneously) in their optimum sizes and depths
  - cavern construction not the dominant cost



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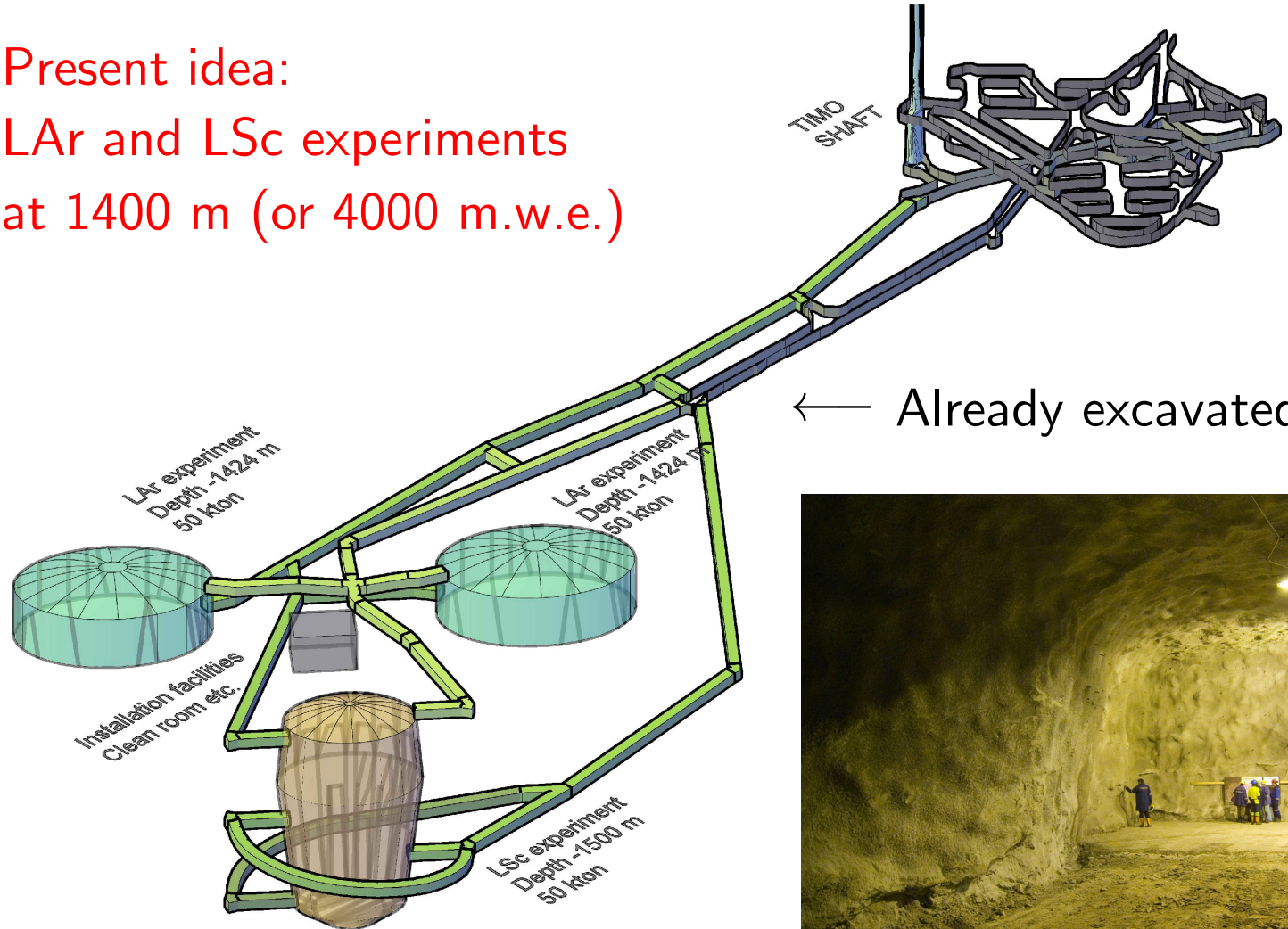
## LAGUNA–LBNO (2011 – 2014) – Improved desing

Present idea:
LAr and LSc experiments
at 1400 m (or 4000 m.w.e.)




by RockPlan

⟵ Already excavated

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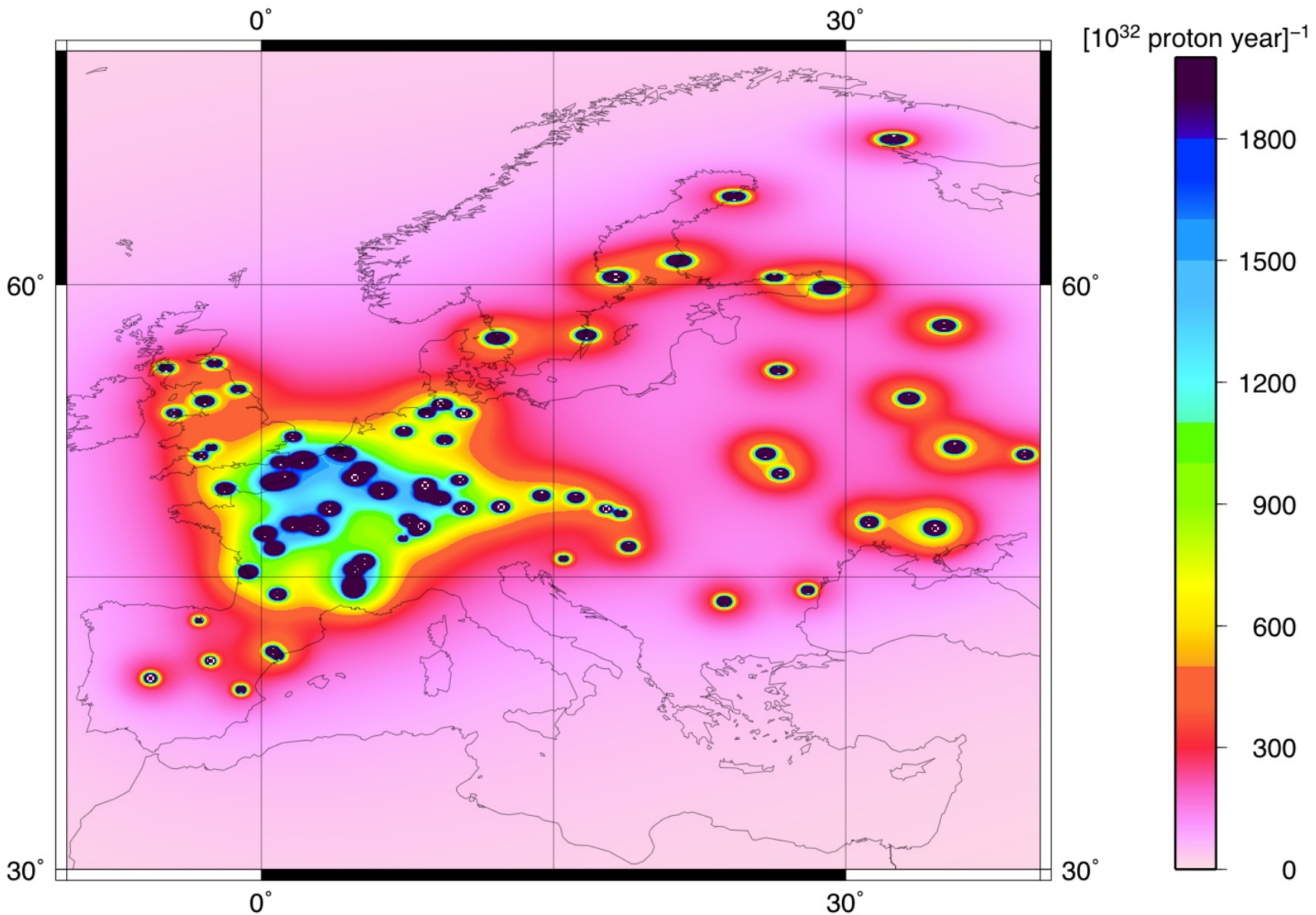
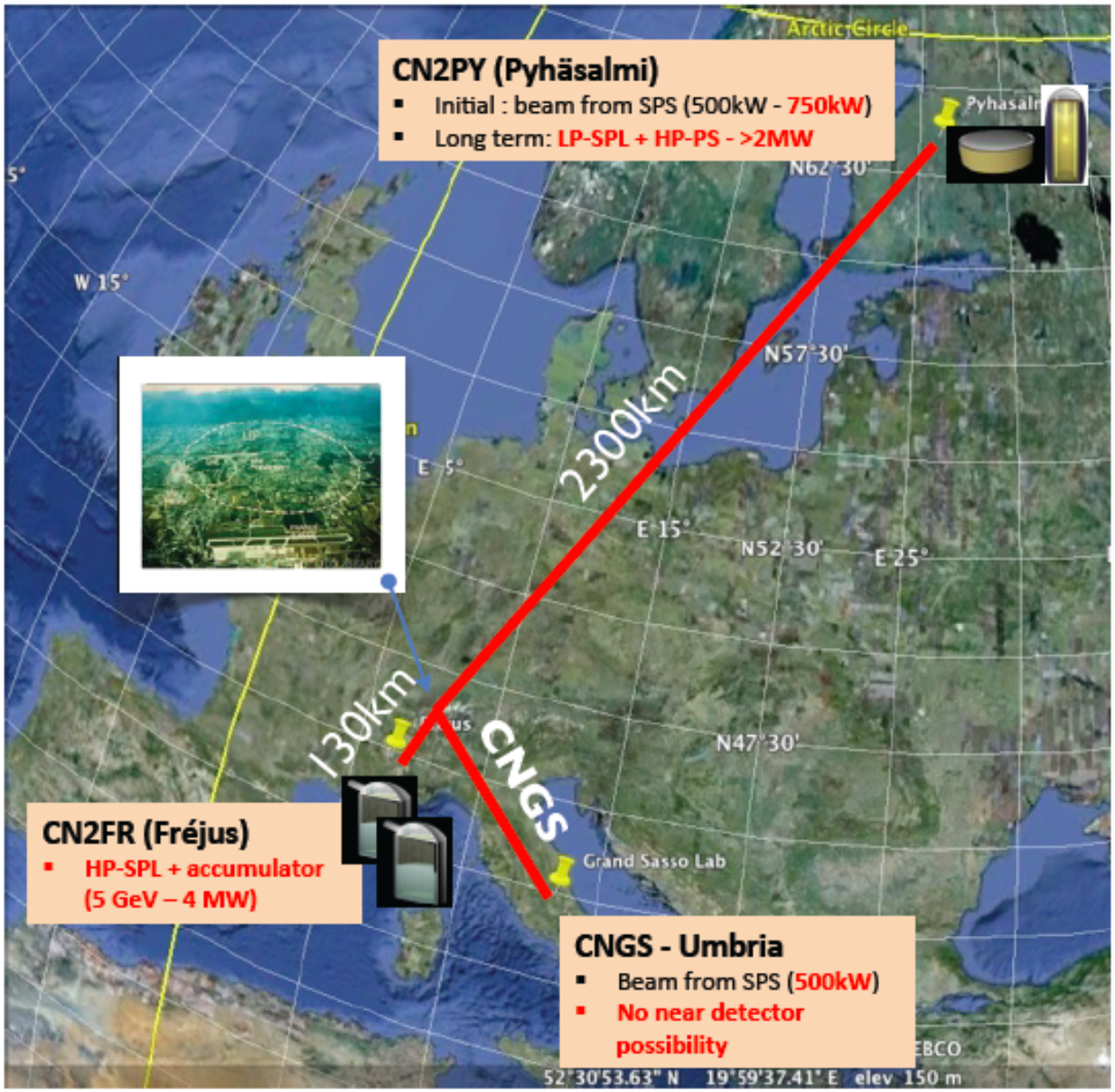
## Site advantages – reactor neutrino background




by
Kai Loo

# The Pyhäsalmi underground laboratory

## Site advantages – bi-magic distance from CERN



# The Pyhäsalmi underground laboratory

## Mine infrastructures – restaurant at 1410 level: LAGUNA meeting 2009

# The Pyhäsalmi underground laboratory

## Mine infrastructures – restaurant at 1410 level: LAGUNA meeting 2012

# The Pyhäsalmi underground laboratory

## Mine infrastructures – communication at 1410 level

# The Pyhäsalmi underground laboratory

## Mine infrastructures – a maintenance hall at 1410 level

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## Mine infrastructures – a maintenance hall at 1410 level – repairing a dumper

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## Mine infrastructures – ample storage room

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## Mine infrastructures – ample storage room: the material truck

# The Pyhäsalmi underground laboratory

## Mine infrastructures – fuel input: surface $\longrightarrow$ underground

# Fuel lines

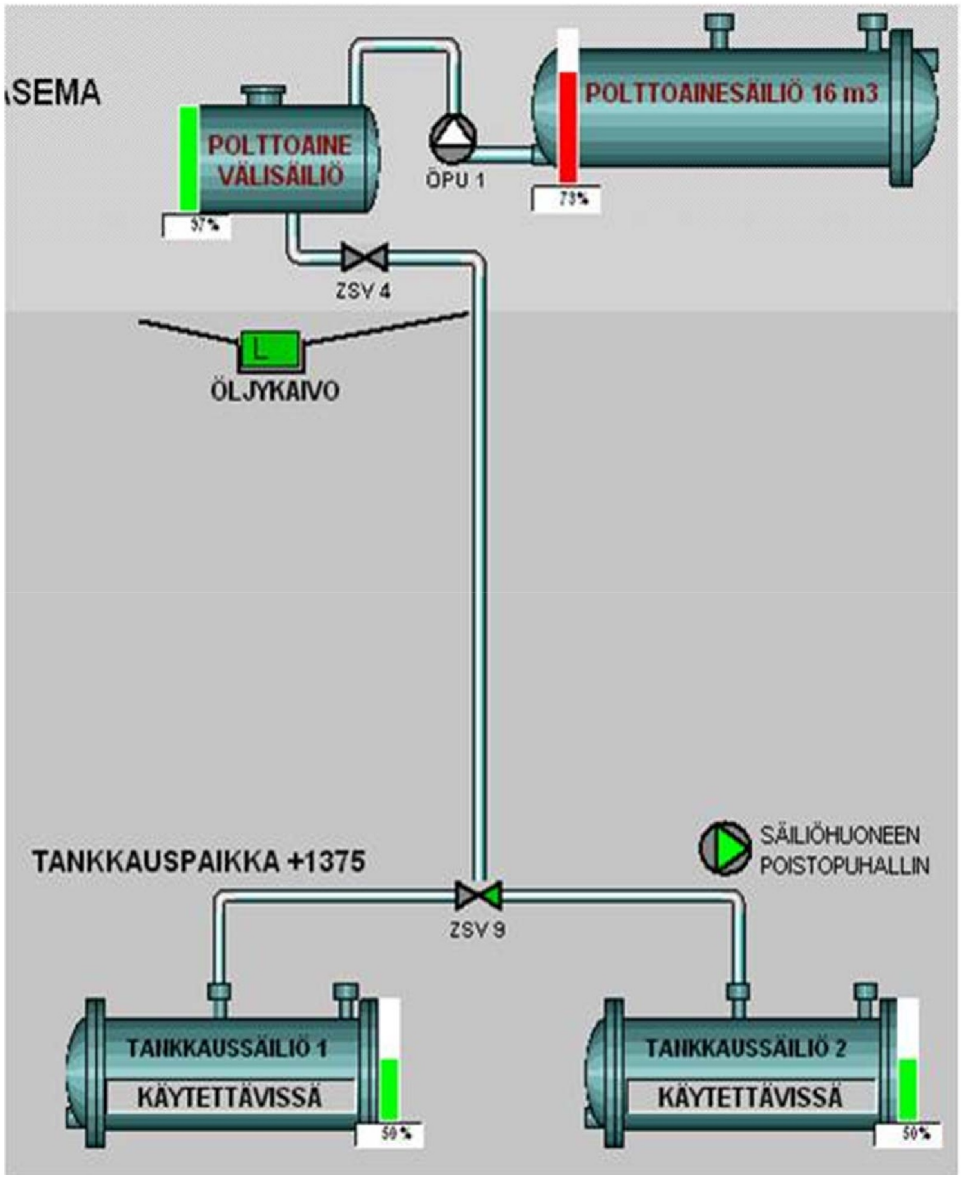
*asema = station*

*polttoaine= fuel*
*polttoainesäiliö = fuel reservoir*
*polttoainevälisäiliö = fuel buffer reservoir*

*öljykaivo + oil pit (for collection)*

*tankkauspaikka = fuel fill up location*
*tankkaussäiliö = tank reservoir*
*käytettävissä = in function*

*säiliöhuoneen poistopuhallin = reservoir room ventilation fan*



# The Pyhäsalmi underground laboratory

## Mine infrastructures – fuel input: surface $\longrightarrow$ underground

# The Pyhäsalmi underground laboratory

## Mine infrastructures – water pumping

Dewatering system

Rock conditions: leaking from surface to 650m, below 650m dry to completely dry

Capacity 130m3/h, average 100m3/h

Pumping levels

| | |
|---|---|
| 1444m | submersible pump |
| 1430m | pump svedala, blade wheel, engine 45kW, 2960rpm, 2+2 pcs |
| 1300m | pump svedala, blade wheel, engine 45kW, 2960rpm, 4+4 pcs |
| 970m | pump svedala, blade wheel, engine 45kW, 2960rpm, 4+4 pcs |
| 640m | settling pond, pump Ahlström, engine 355kW, 2 pcs |
| 000m | groundlevel |

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## Mine infrastructures – water pumping: a pump at 640 level

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## Mine infrastructures – the main transformer at 1400 level

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## Mine infrastructures – looking for new ore

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## Mine infrastructures – the decline (11 km)

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## Mine infrastructures – surface area from the air

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## Mine infrastructures – on-surface production area

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## Mine infrastructures – transportation of the excavated products by train

# The Pyhäsalmi underground laboratory

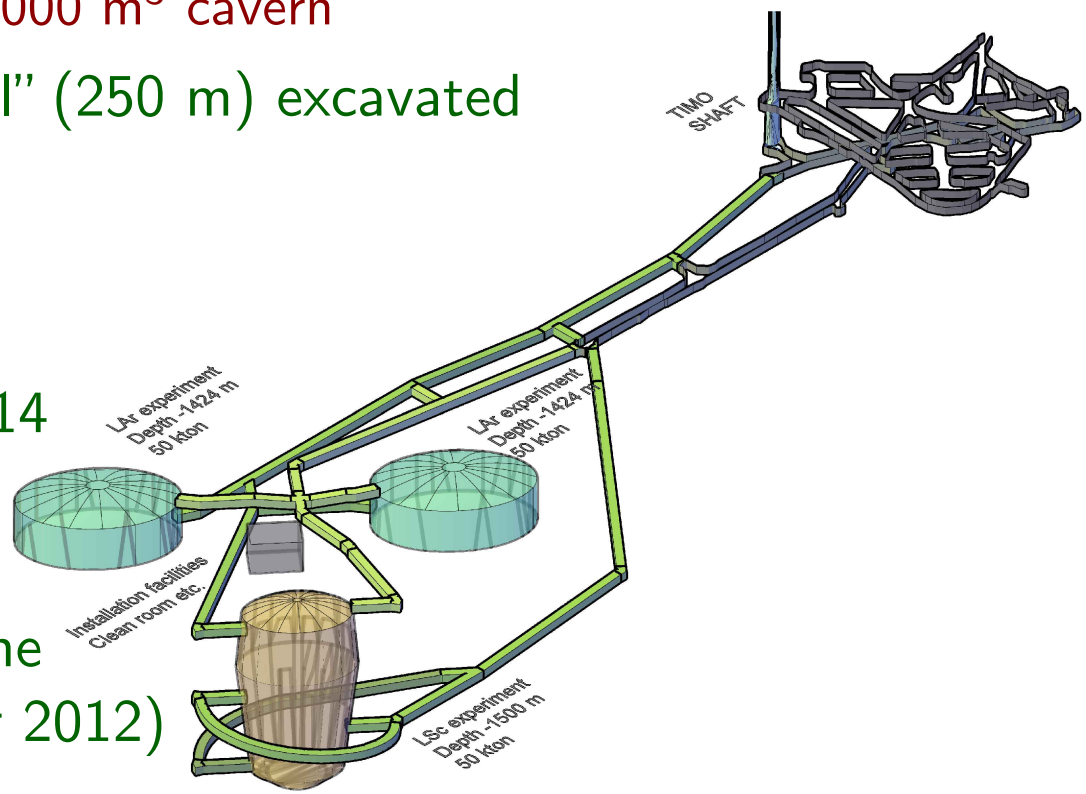
Unique features – many optimal conditions satisfied **simultaneously**

- Excellent infrastructure of the mine
  - infrastructure in perfect state because of the current operation
  - two modes of access (shaft and decline)
  - other assets available (ventilation, water pumping, pipes for liquids, underground workshops, ...)
  - little environmental water (dry below 700 m)
  - could be dedicated to science after the mine explotation ends (around 2018)
- One of the deepest location considered in Europe (overburden 1400 m or 4000 m.w.e., T = 22 $^o$C)
- Unusually small footprint of the ore
- The distance from CERN (2300 km) offers unique LBL opportunities, not found elsewhere in Europe or in the World
- The site has one of the lowest reactor neutrino background in Europe, important for the LSc option

# The Pyhäsalmi underground laboratory

## Time line for LAGUNA in Pyhäsalmi – performed or going on

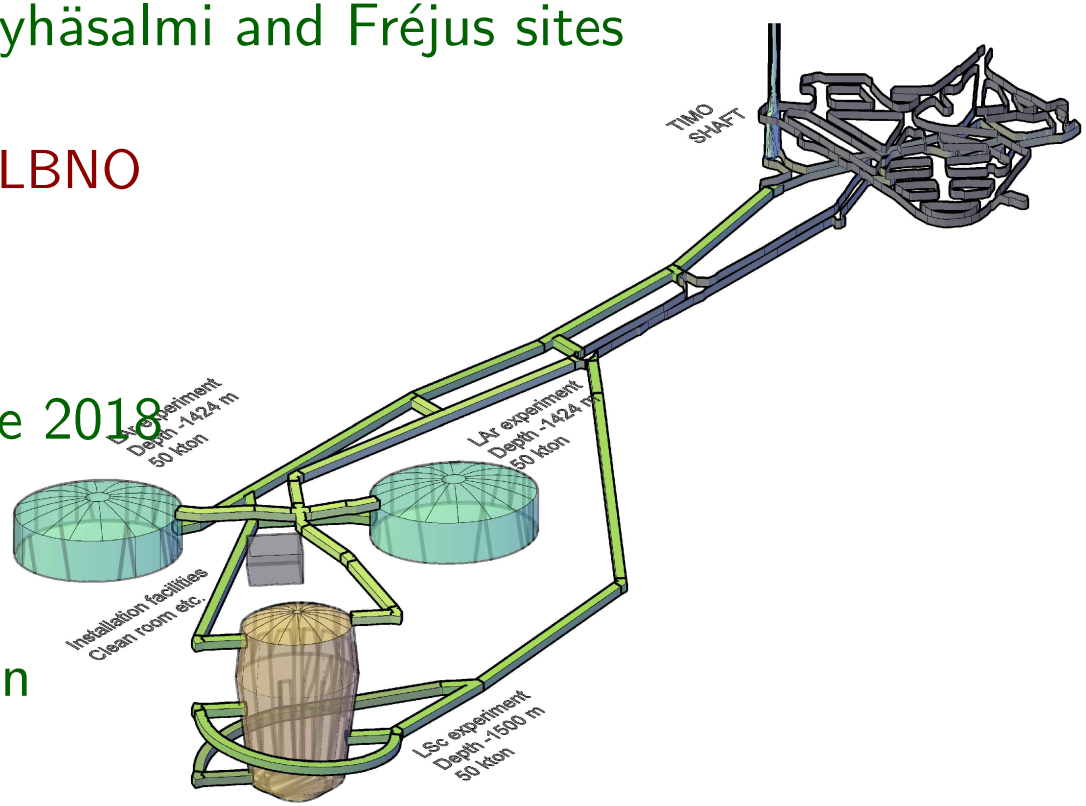
- Muon flux measured 2004 – 2005
- Pre-suitability study of LSc option by RockPlan Ltd. 2007 – 2008
  - preparatory site investigation to locate a 50 kton detector at the depth of 1400 m in a 220000 $m^3$ cavern
- Half of the "LAGUNA tunnel" (250 m) excavated 2008 – 2009
- LAGUNA DS 2008 – 2011
  - Site visit in Sep 2009
- LAGUNA–LBNO 2011 – 2014
  - Site investigation in Jan 2012
- EoI to SPSC and input to the strategy update (by summer 2012)



# The Pyhäsalmi underground laboratory

## Time line for LAGUNA in Pyhäsalmi – near future

- Extensive site investigations 2012 – 2014
  - sample drillings of 2–3 km in total
  - funding from Finland (not approved yet)
- A complete evaluation for Pyhäsalmi and Fréjus sites by the end of 2014
  - deliverables of LAGUNA–LBNO
- Start of excavations 2016
  - three large caverns
- End of operation of the mine 2018
- Start of detector (tank) construction 2018
- Start of tank instrumentation 2022



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## Conclusion

- Cosmic-ray experiment EMMA under construction and running at shallow depth (75 m)
  - composition at the knee region
  - muon bundle studies together with ALICE
  - measurements can be started around the middle of 2013
- LAGUNA DS 2008 – 2011
  - Pyhäsalmi site can host all three detector options:
  - good rock conditions and excellent infrastructure
  - low background of reactor neutrinos
- LAGUNA–LBNO 2011 – 2014
  - Pyhäsalmi offers a site for the baseline of 2300 km from CERN
  - detector techniques: liquid argon and liquid scintillator
- LAGUNA and LAGUNA in Pyhäsalmi are well on track
  - prioritization and clear time line
- Pyhäsalmi site satisfies many optimal conditions simultaneously

# The Pyhäsalmi underground laboratory

## Acknowledgments


- FP7 Research Infrastructure "Design Studies"
  - LAGUNA
    (Grant Agreement No. 212343 FP7-INFRA-2007-1)
  - LAGUNA-LBNO
    (Grant Agreement No. 284518 FP7-INFRA-2011-1)

# The Pyhäsalmi underground laboratory

- Backup slides

# The Pyhäsalmi underground laboratory

## LAGUNA Location

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## LENA – Low Energy Neutrino Astronomy

**Liquid scintillator**
50 kt LAB/PPO+ bisMSB

**Inner vessel (nylon)**
Radius r = 13m

**Buffer**
15kt LAB, Δr =2m

**Cylindrical steel tank, e.g.**
**55000 PMTs (8“) with**
**Winston Cones (2x area)**
r = 15m, height = 100m,
optical coverage: 30%

**Water cherenkov muon veto**
5,000 PMTs, Δr > 2m to shield fast neutrons

**Cavern egg-shaped for increased stability**

**Rock overburden:** 4000 mwe

Pyhäsalmi design

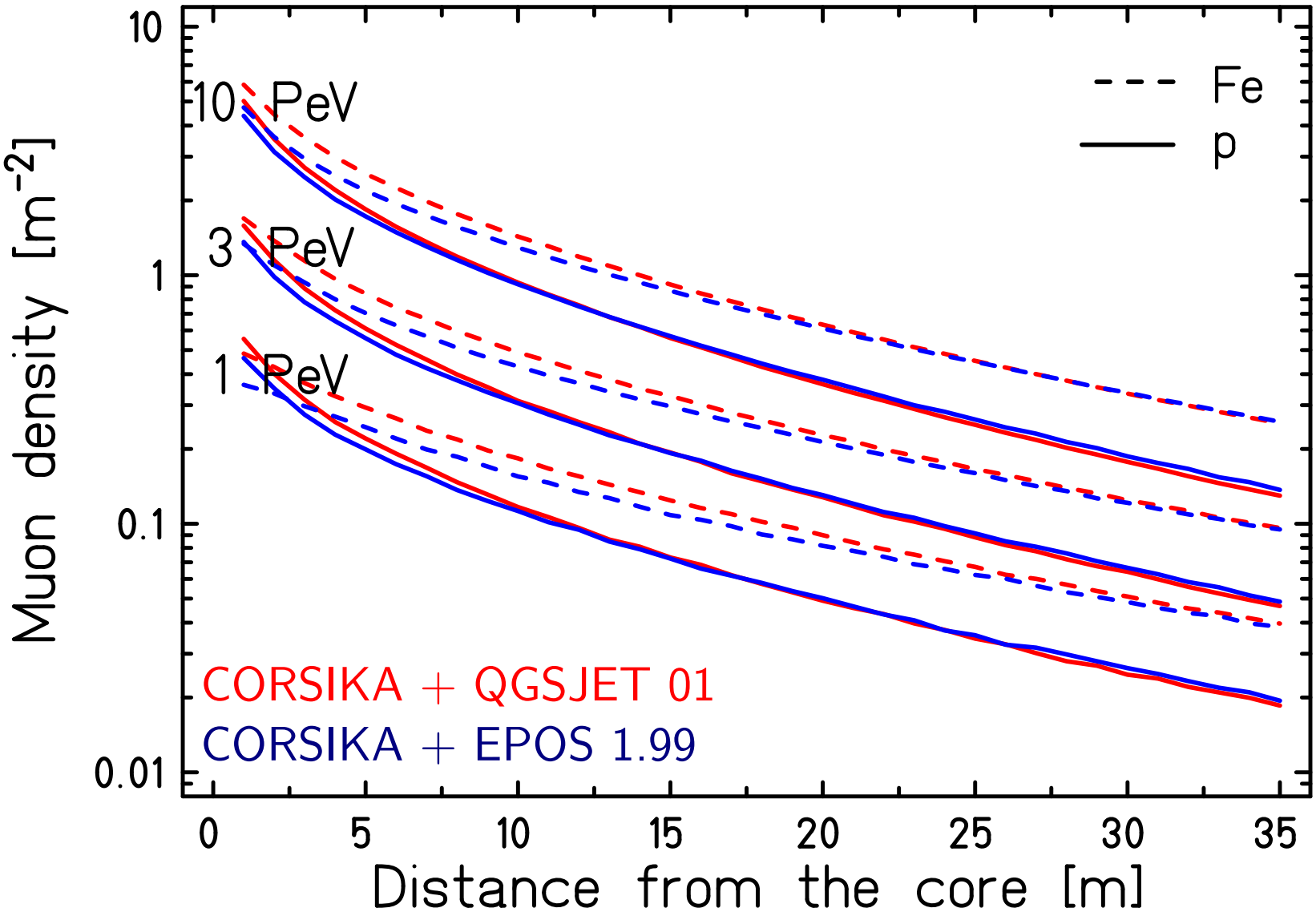
Desired **energy resolution**
→ 30% optical coverage
→ 3000m² effective photo-sensitive area

Light yield ≥ 200 pe/MeV

The **tracking option** adds to the requirements of the PMT array and electronics:
→ more, but smaller, faster PMTs
→ full waveform digitizing

# The Pyhäsalmi underground laboratory

## EMMA – muon lateral density distribution – 50 GeV cut-off



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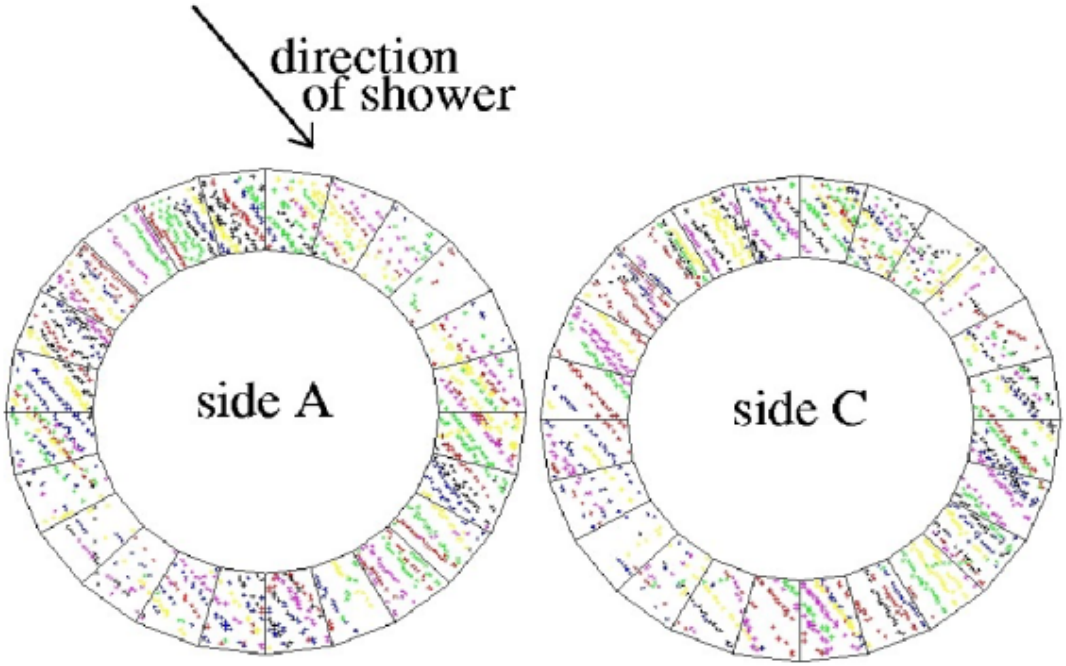
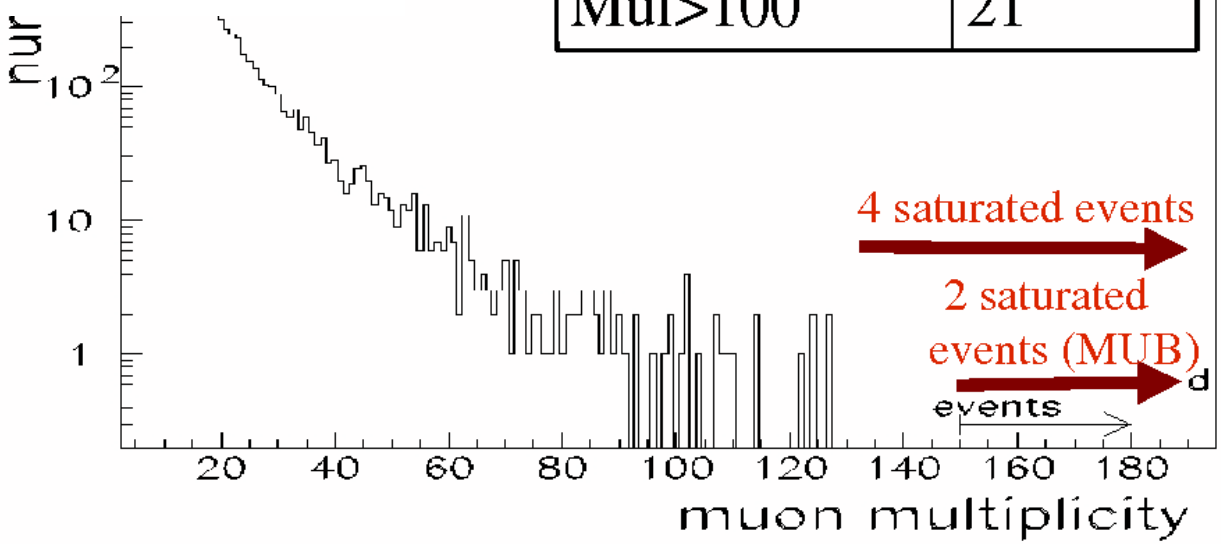
## EMMA – Muon bundles at LEP




| | |
|---|---|
| Mul> 3 | 54201 |
| Mul>30 | 1065 |
| Mul>70 | 78 |
| Mul>100 | 21 |



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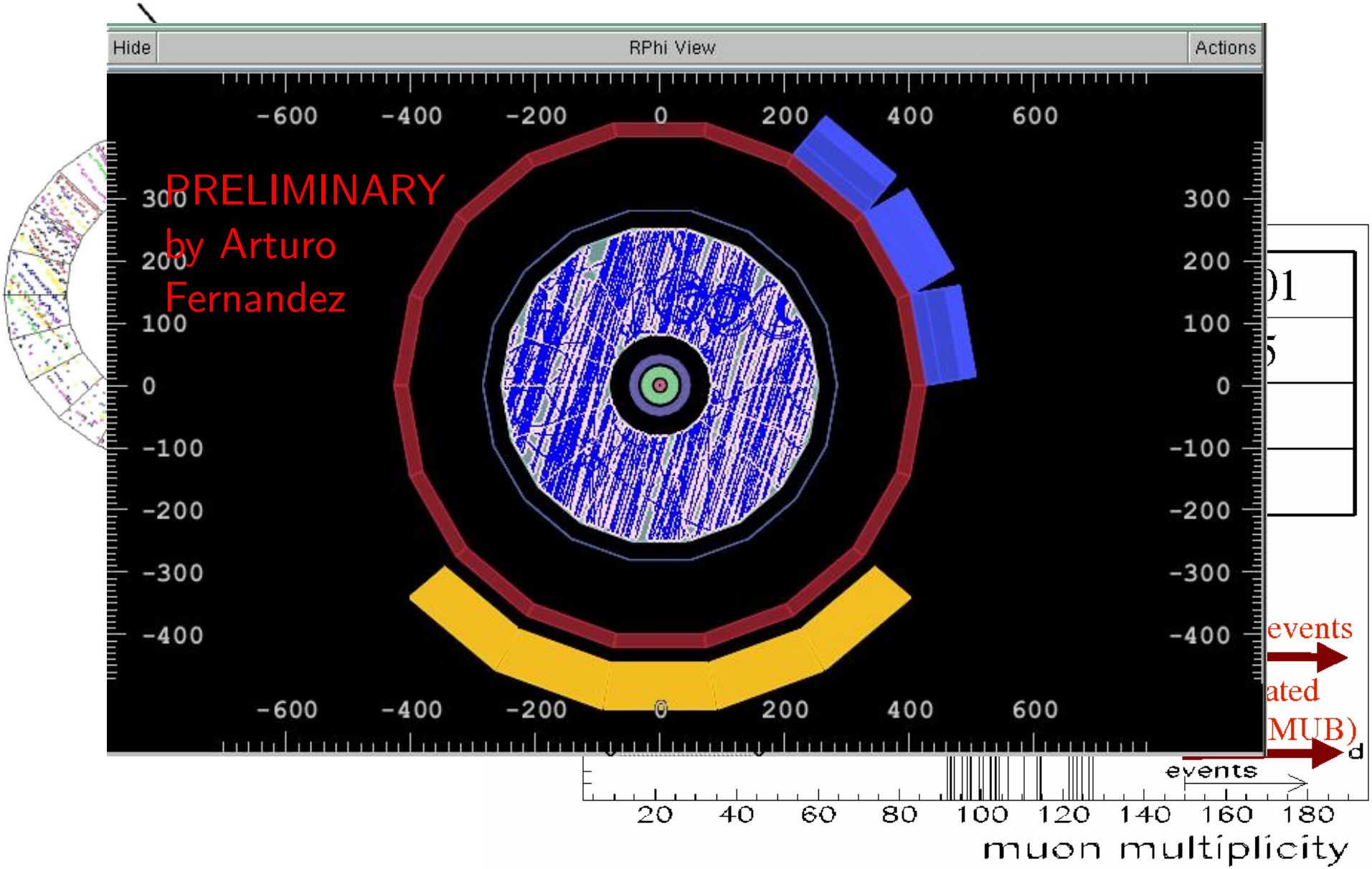
## EMMA – Muon bundles at LEP and ALICE



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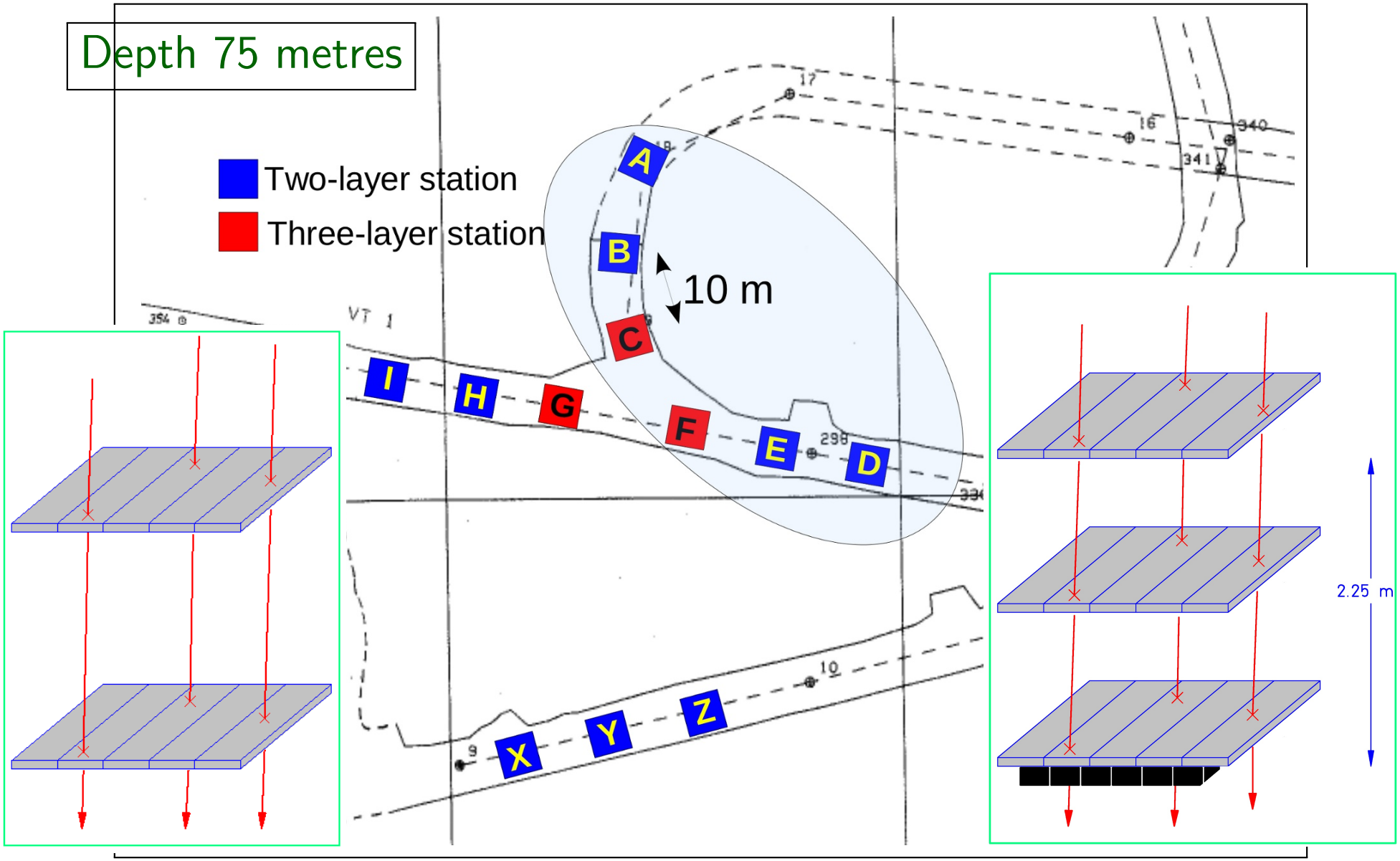
## EMMA – Experiment with MultiMuon Array



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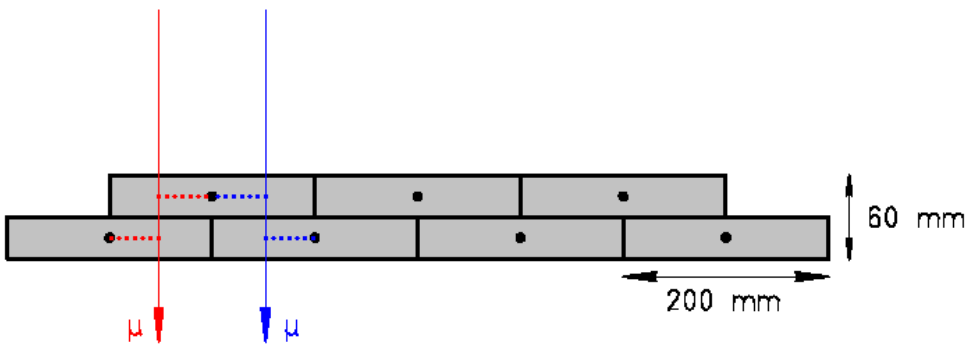
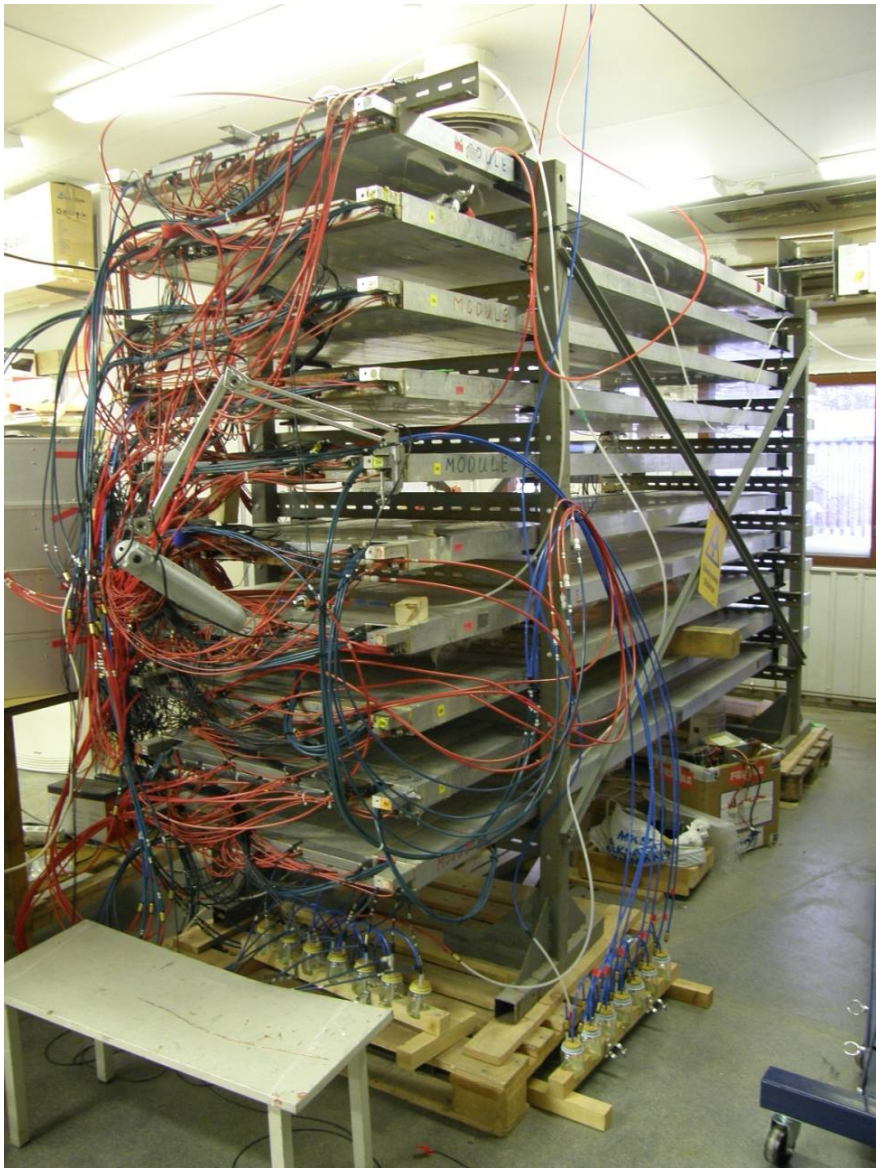
## EMMA – Drift chambers

- Former LEP–DELPHI MUBs (planks)
  - 7 individual chambers per plank
  - mass $\sim$ 120 kg per plank
  - 365 cm $\times$ 20 cm per chamber
  - 3 signals (anode, 2 delays) per chamber
- position resolution $\sim$1 cm$^2$
- Ar (92%) : $CO_2$ (8%) at 1 bar
  - min $\sim$0.25 bar$\cdot\ell$/min (/plank)
- EMMA: 80 + 4 planks ($\sim$230 m$^2$)

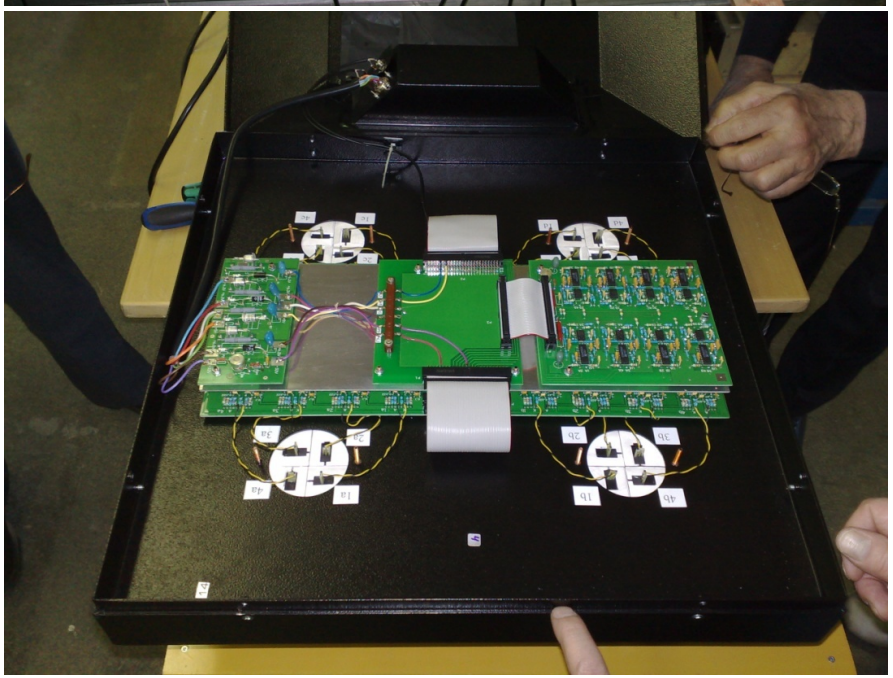


# The Pyhäsalmi underground laboratory

## EMMA – Plastic scintillation detectors

- SC16 detector
  - $50 \times 50$ cm$^2$, H $= 13$ cm
  - mass $\sim 20$ kg per SC16
  - contains 16 individual pixels of 12 cm $\times$ 12 cm and 3 cm thick
  - employ APDs
  - time resolution $\sim$1 ns
- EMMA: 96 SC16 detectors (24 m$^2$), 1536 single pixels
- Designed for
  - large muon multiplicities
  - fast trigger and start time
  - initial guess for arrival angle
- Made by Russian Academy of Sciences



# The Pyhäsalmi underground laboratory

## EMMA – Gas handling – 1

# The Pyhäsalmi underground laboratory

## EMMA – Gas handling – 2

# The Pyhäsalmi underground laboratory

## EMMA – Gas handling – 3