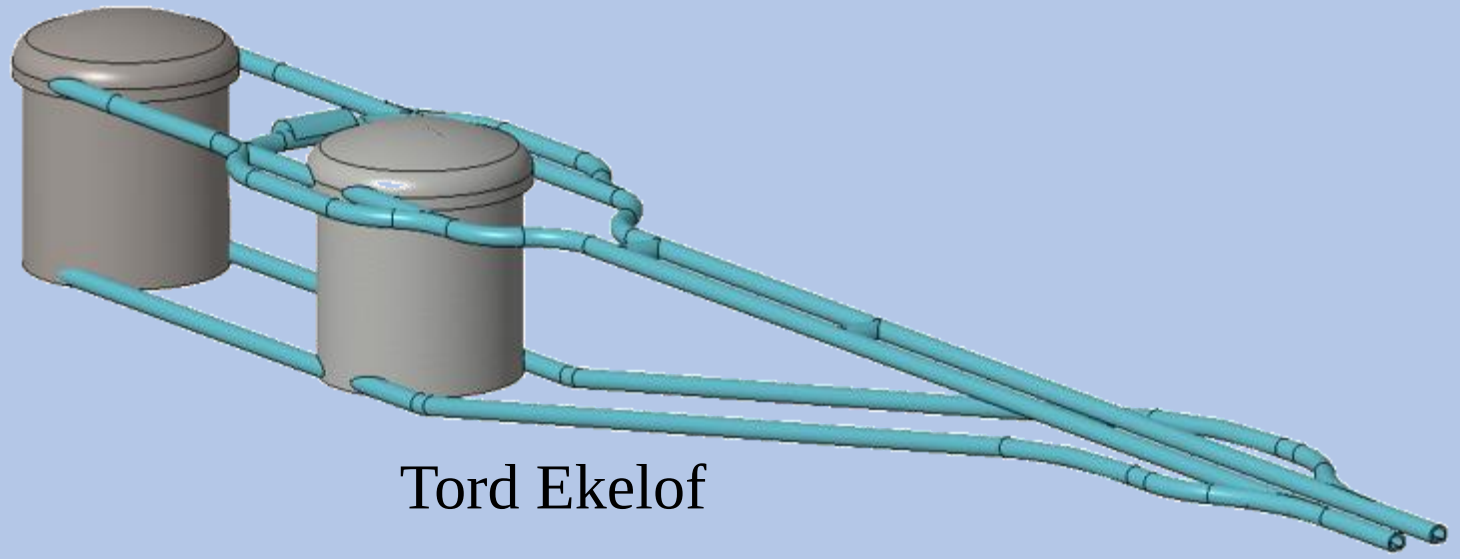
EUROPEAN SPALLATION SOURCE

ESS Neutrino Super Beam Plus

Co-funded by the European Union

ESSnuSB and its large neutrino detector in Zinkgruvan



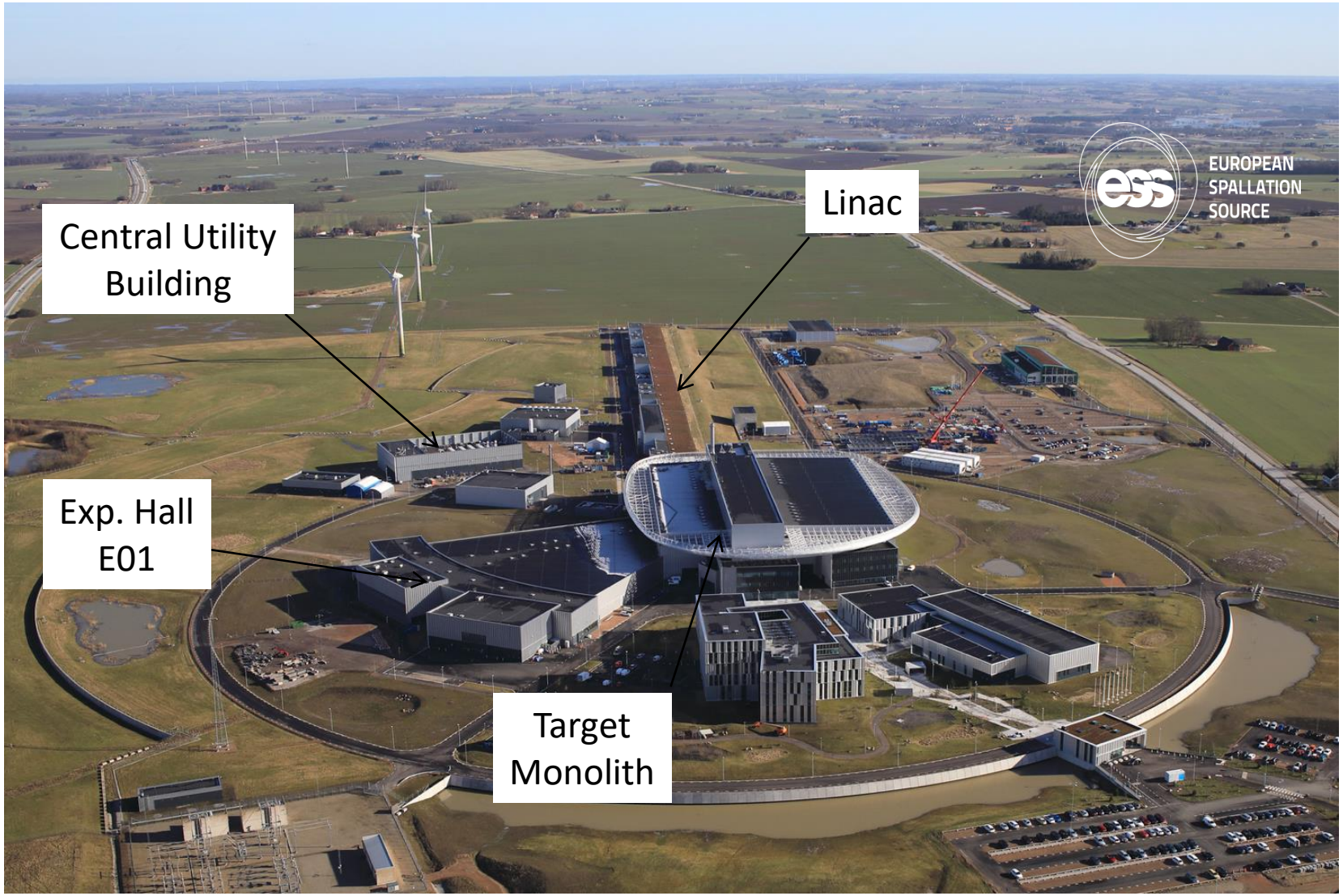
Tord Ekelof

Uppsala University

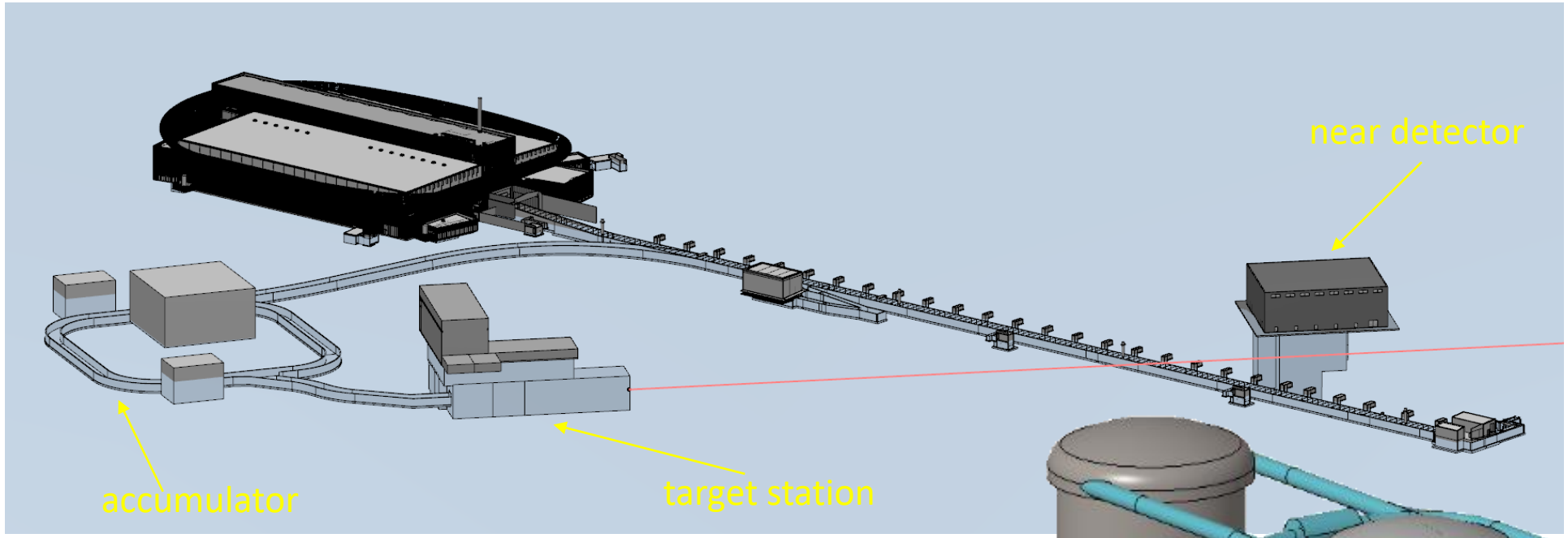
How exlain that there is there a Baryon Asymmetry of the Universe BAU?

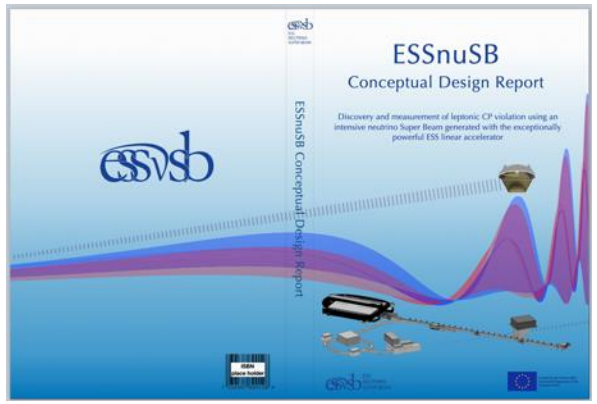
- During the Big Bang the same quantity of matter and antimatter was produced from the initial enormous release of radiation energy
- Within a small fraction of a second matter and antimatter annihilated back into radiation
- How come that a small fraction (10^{-9}) of the initial matter survived that is now forming the present Universe?
- Or, how come we exist?
- Matter and antimatter obey to the same physics laws
- How could the matter-antimatter symmetry be broken?
- Can a Leptogenesis theory that explains this be verified by experiment?

We propose to use the European Spallation Source linac - that will start up next year - to look for an answer to this question



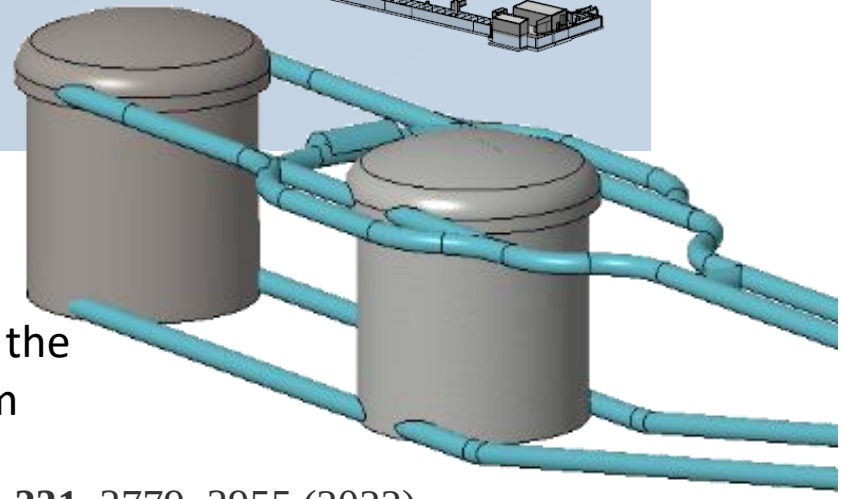
ESSnuSB facility configuration at ESS





Conceptual Design Report

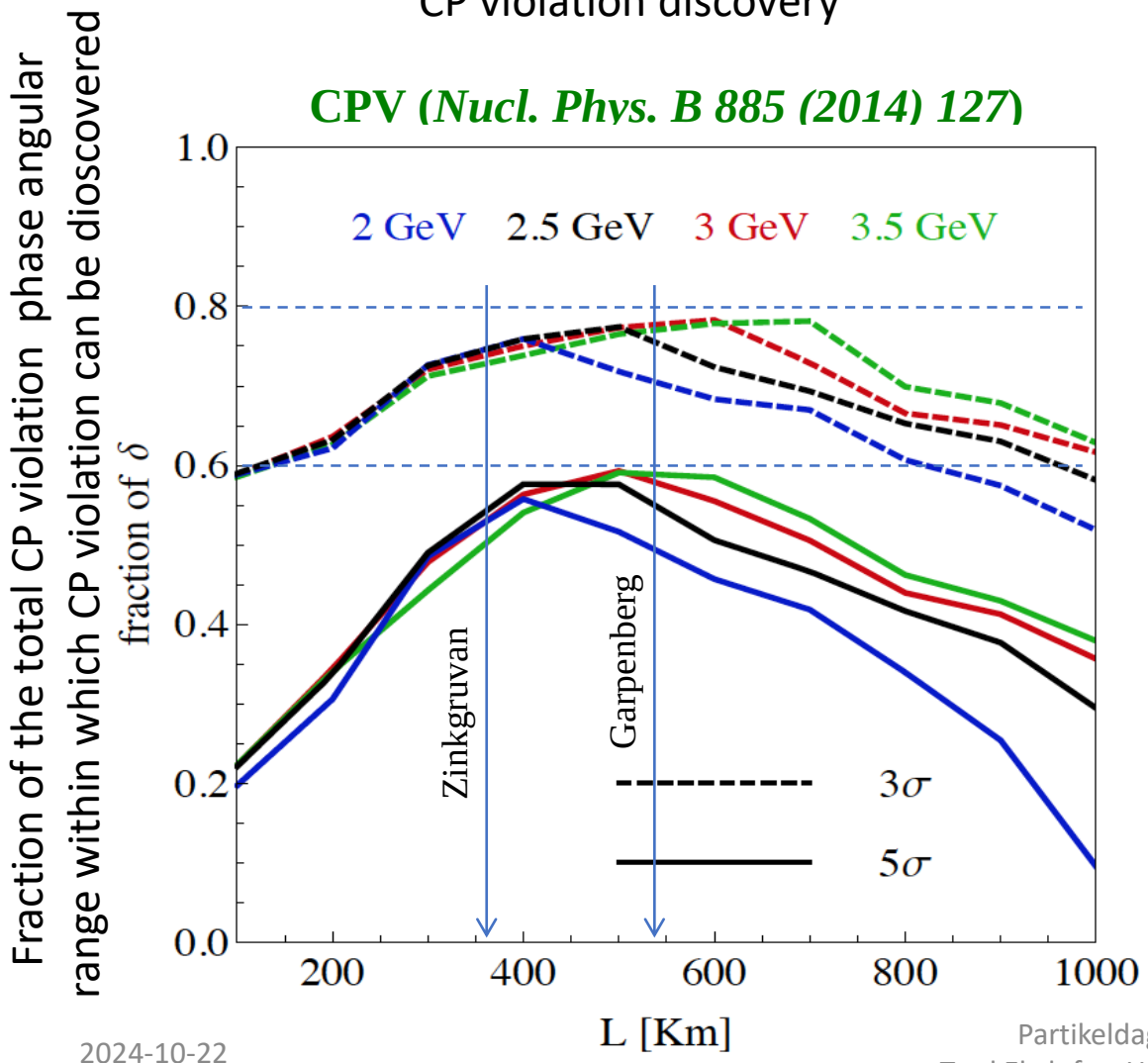
The Far Detector located at the **second** oscillation maximum



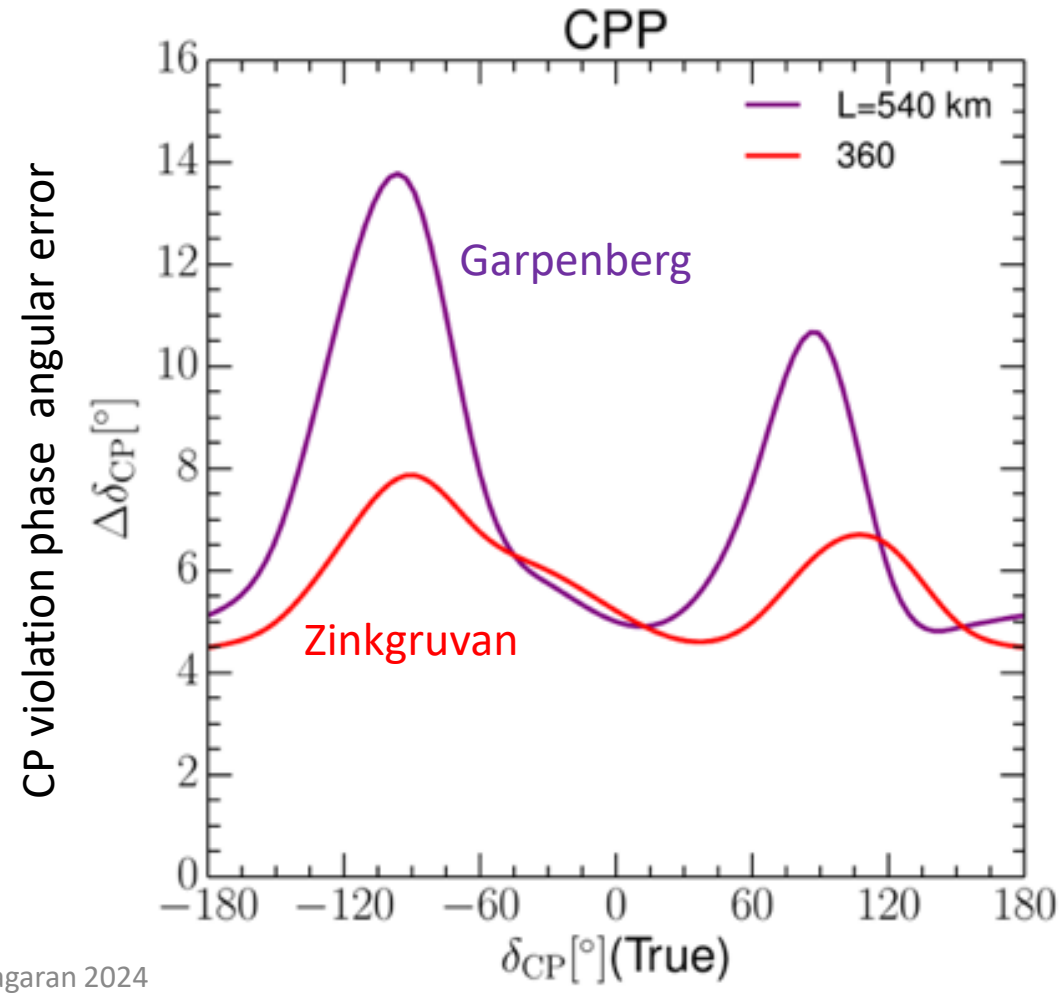
European Physical Journal Spec. Top. **231**, 3779–3955 (2022).
https://doi.org/10.1140/epjs/s11734-022-00664-w https://arxiv.org/abs/2206.01208

Which is the optimal distance from ESS to the neutrino detector?

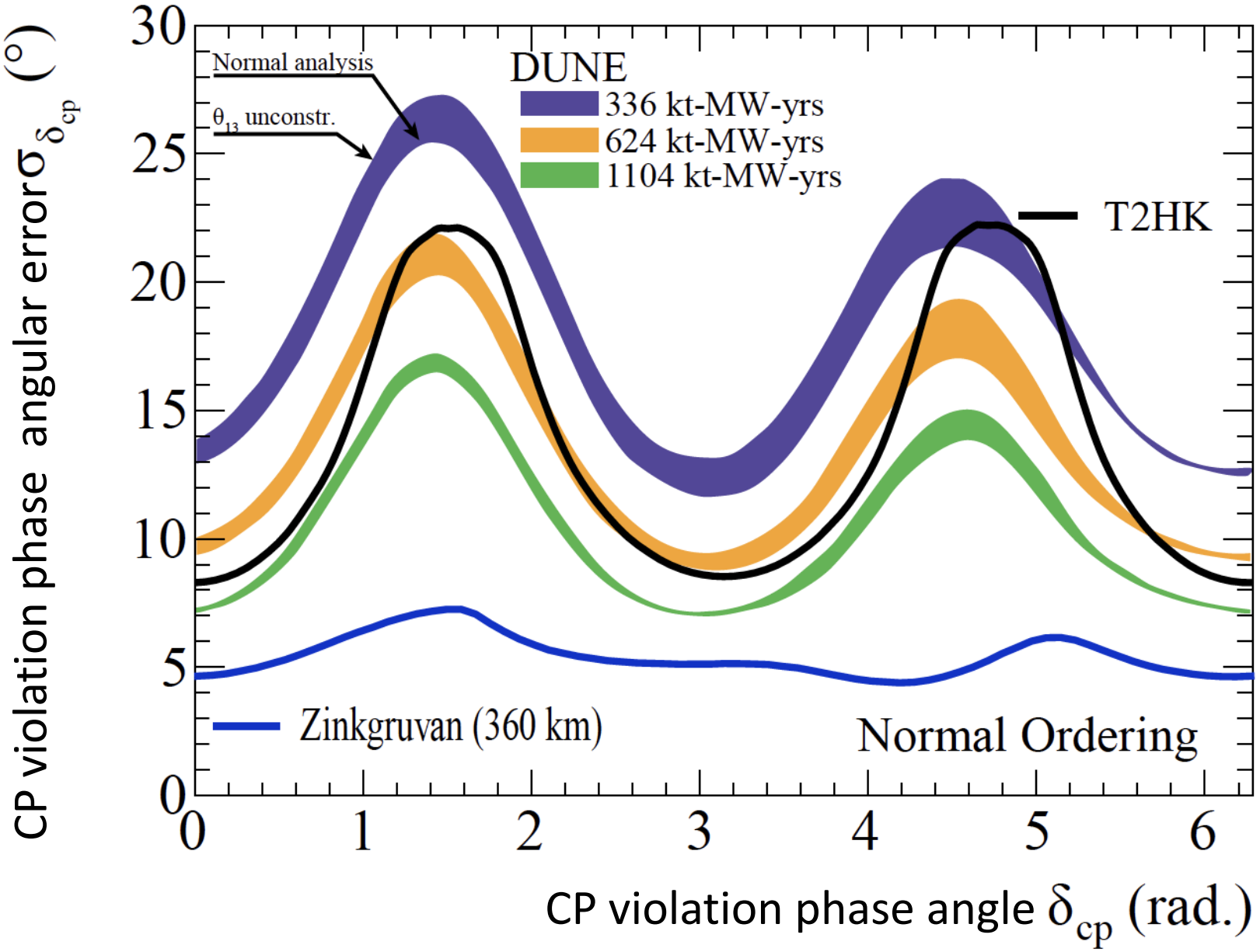
CP violation discovery



Measurement of the CP violation phase angle



Comparison with DUNE and Hyper-K of the CP violation angular precision



Memorandum of Understanding

The Department of Physics and Astronomy of Uppsala University (UU), represented by Richard Brenner, Head of the Department of Physics and Astronomy of Uppsala University (UU)

and

The Department of Civil, Environmental and Natural Resources Engineering, represented by Charlotta Johansson, Head of the Department Luleå University of Technology (LTU)

and

Zinkgruvan Mining AB (ZM) , represented by Craig Griffiths, General Manager of the Zinkgruvan Mining AB

hereby wish to enter into a non-binding agreement ("Memorandum of Understanding" or "MoU") the purpose of which is to serve as basis for the parties contemplated future arrangements to facilitate a design-study by UU and LTU in cooperation with ZM of the feasibility of locating and operating a large neutrino detector below ground at the site of the ZM in Zinkgruvan (the "ZM Site"). The detector would measure the neutrinos generated by the accelerator of the European Spallation Source in Lund, which started its construction phase in September 2014 and is now planned to deliver first beams in 2025. The international ESS neutrino Super Beam (ESSnuSB) consortium, currently comprising some 80 scientists at 20 European universities and laboratories, has after 4 years of design study published in November 2022 "The European Spallation Source neutrino super-beam conceptual design report" in the European Physical Journal (available at https://doi.org/10.1140/epjs/s11734-022-00664-w) in which the neutrino beam and the neutrino detector are described.

Within the framework of this MoU it is the intention of the parties that ZM will allow UU and LTU agents to access the ZM site and consult and cooperate with ZM personnel for specific design study activities regarding the installation and operation of the underground neutrino detector. For the avoidance of doubt, the parties acknowledge that ZM does not intend to provide funds to the project. While it is the intention of the parties that ZM will provide access to the underground site free of charge, ZM shall be entitled to compensation for providing personnel, and other direct or indirect costs. The specific activities will be defined in separately authorized Annexes to this MoU, from time to time as appropriate and subject to the agreement of the parties. Separate confidentiality agreements may be signed between the parties.

The signing of this Memorandum of Understanding does not imply the commitment of resources on either party.

This Memorandum of Understanding becomes valid on the date of signature and it is the intention of the parties, but not a binding obligation, that it remains valid till one year after the day on which one of the parties has expressed the wish to terminate the MoU.

Except the below term regarding Swedish law, nothing in this MoU shall in any manner impose any binding obligations on the parties.

This Memorandum of Understanding is governed by Swedish law.

Signed on behalf of UU	Signed on behalf of LTU	Signed on behalf of ZM
Richard Brenner	Charlotta Johansson	Staffan Sandström
Date 20230904	Date 1 sept. 202[illegible]	Date 2023-10-02
Place Uppsala	Place Luleå	Place Zinkgruvan

The original signatures above, here combined, appear on two separate but identical versions of this MoU

The current ESSnuSB Collaboration – ca 80 physicists from 20 different institutions in 11 European countries

Supported by Horizon Europe 2019-2022 and by Horizon Europe 2023-2026 with grants of in total 6 M€

Participant no.	Participant organisation name	Part. short name	Country
1 (Coordinator)	Centre National de la Recherche Scientifique	CNRS	France
2	Université de Strasbourg	UNISTRA[1]	France
3	Rudjer Boskovic Institute	RBI	Croatia
4	Tokai National Higher Education and Research System, National University Corporation	NU[2]	Japan
5	Uppsala Universitet	UU	Sweden
6	Lunds Universitet	ULUND	Sweden
7	European Spallation Source ERIC	ESS	Sweden
8	Kungliga Tekniska Hoegskolan	KTH	Sweden
9	Universitaet Hamburg	UHH	Germany
10	University of Cukurova	CU	Turkey
11	National Center for Scientific Research "Demokritos"	NCSRD	Greece
12	Aristotelio Panepistimio Thessalonikis	AUTH[1]	Greece
13	Sofia University St. Kliment Ohridski	UniSofia	Bulgaria
14	Lulea Tekniska Universitet	LTU	Sweden
15	European Organisation for Nuclear Research	CERN	IEIO[3]
16	Universita degli Studi Roma Tre	UNIROMA3	Italy
17	Universita degli Istudi di Milano-Bicocca	UNIMIB	Italy
18	Istituto Nazionale di Fisica Nucleare	INFN	Italy
19	Universita degli Istudi di Padova	UNIPD[1]	Italy
20	Consorcio para la construccion, equipamiento y explotacion de la sede espanola de la fuente Europea de neutrones por espalacion	ESSB	Spain

[1] Affiliated Partner
[2] Associated Institute
[3] International European Interest Organisation

Members of the ESSnuSB Executive Committee visiting Zinkgruvan last week

In the underground service workshop at -900 m

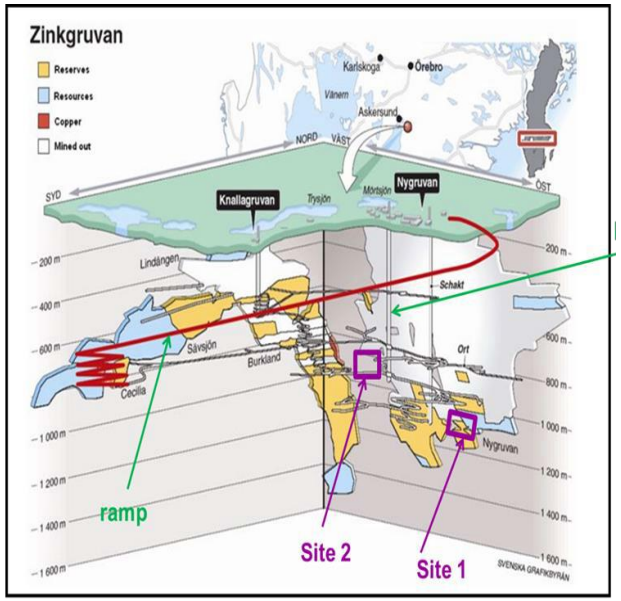
AT the deepest drift at -1300 m

THE PLAN OF THE ZINKGGRUVAN DETECTOR DESIGN WORK PROGRAMME

1. Site investigation, core drilling and evaluation of rock pressure and strength at the neutrino detector underground site 1.0 M€
Luleå Technical University, Zinkgruvan Mining AB

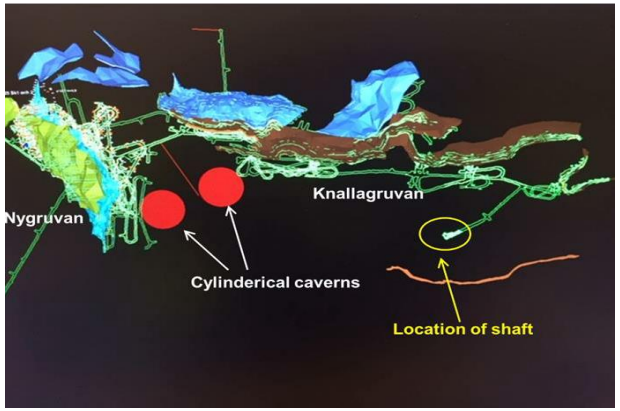
Visist to Zinkgruvan March 2019

Underground map of Zinkgruvan



Two potential sites identified are marked Site 1 and Site 2. Site 2 is considered as best considering access to main transport infrastructure and located in an area less disturbed by mining activities

Potential location in Site 2

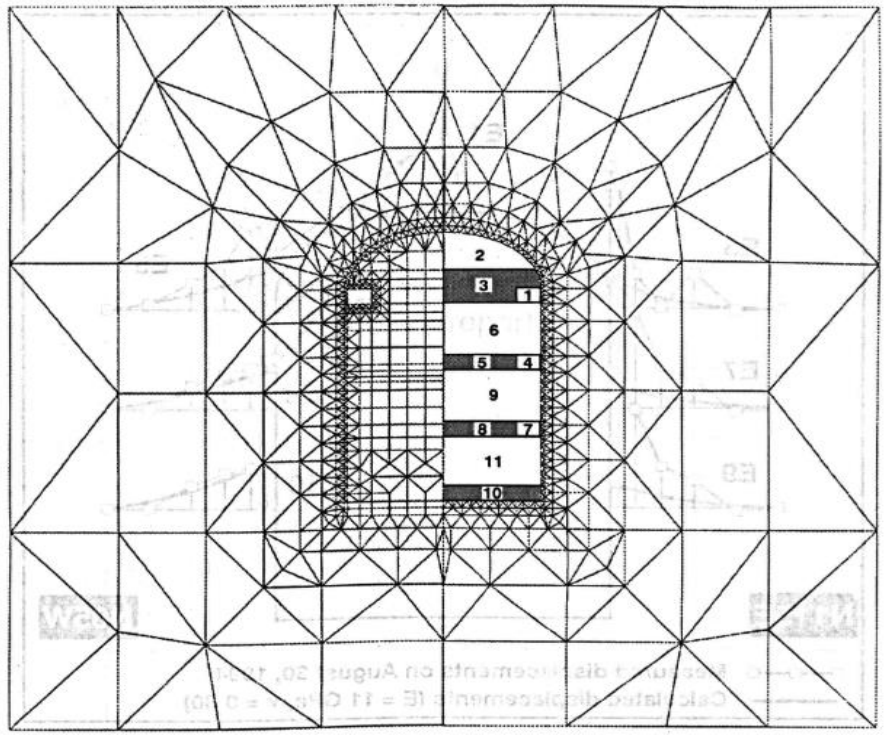


Core drilling samples

2. Engineering Design of the two 270’000 m^3 caverns and service galleries 1000 m underground and the access shaft 1.0 M€

Luleå and Wroclaw Technical Universities, Zinkgruvan Mining

Finite element analysis, excavation sequence, extensometers and displacements of the Super-Kamoikande cavern



The axisymmetric finite element divisions used for the stress and displacement analysis of the Super-KAMIOKAI

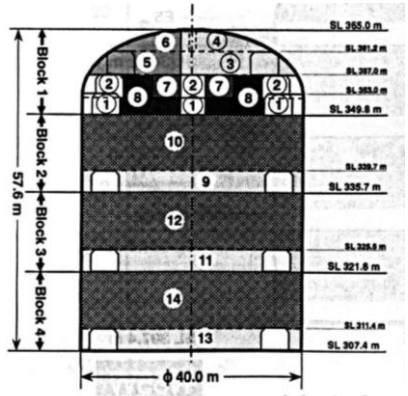
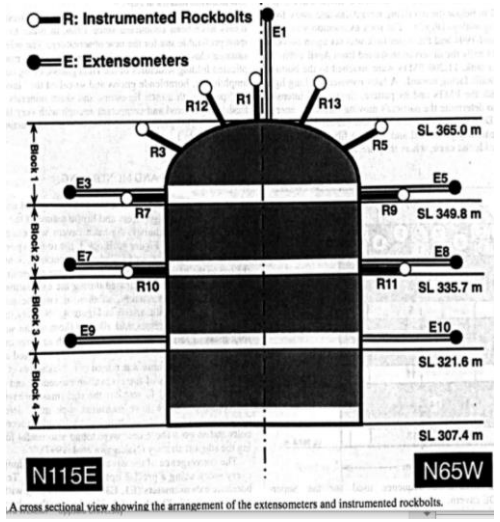


Figure 4 The excavation sequence used for the Super-KAMIOKANDE cavern.



A cross sectional view showing the arrangement of the extensometers and instrumented rockbolts.

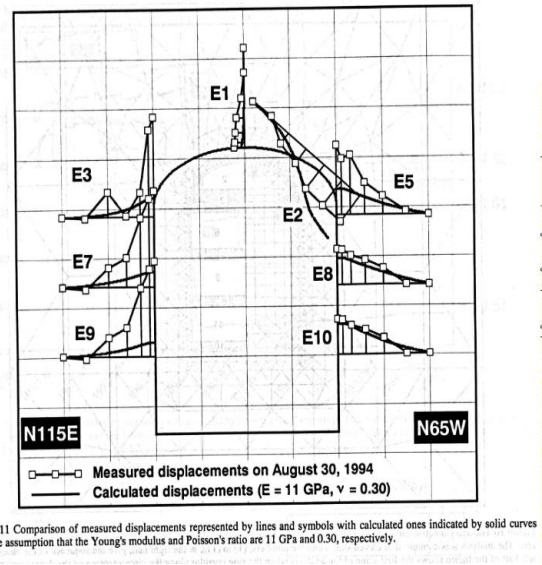
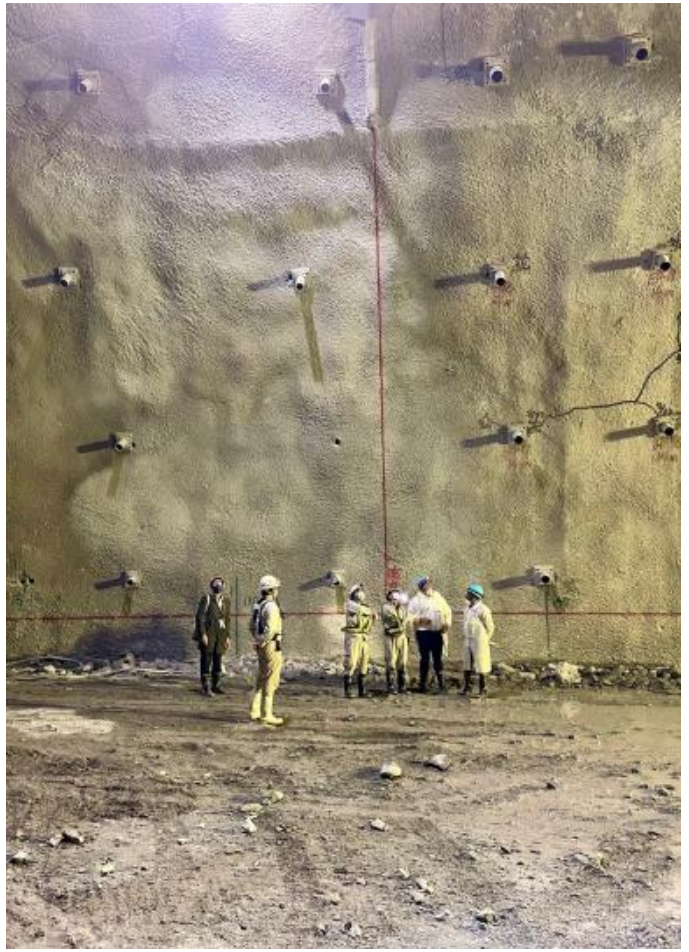


Figure 11 Comparison of measured displacements represented by lines and symbols with calculated ones indicated by solid curves with the assumption that the Young's modulus and Poisson's ratio are 11 GPa and 0.30, respectively.

https://admin.onepetro.org/isrmcongress/proceedings/CONGRESS99/All-CONGRESS99/ISRM-9CONGRESS-1999-305/168876

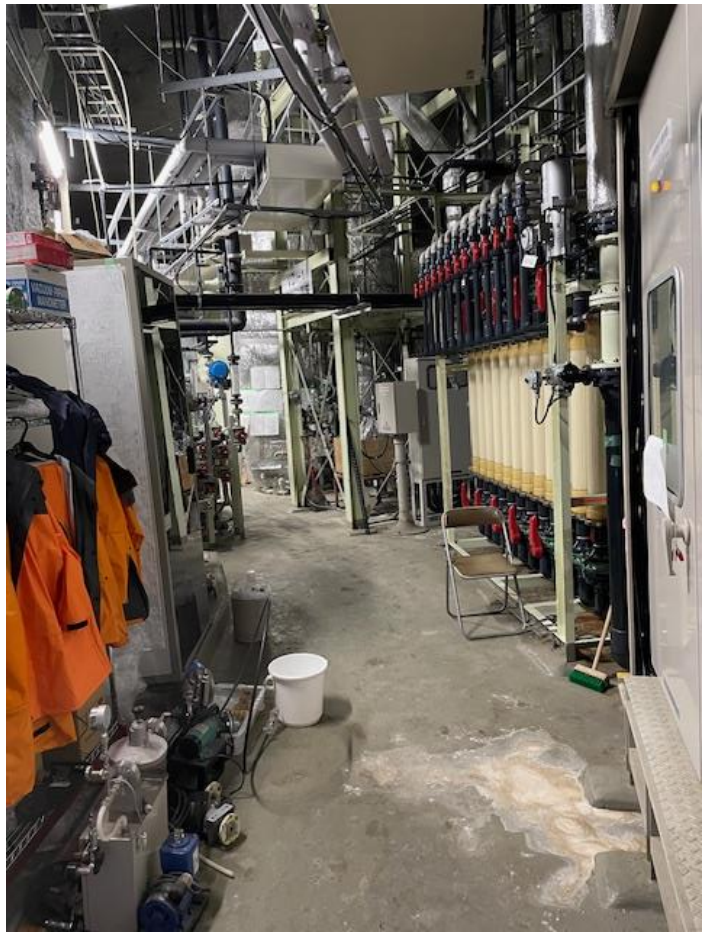
Visit to th Hyper-Kamikande detector construction site in Japan
September 2023

The HK main cavity top dome



Water purification gallery

….and to the Super-Kamiokande service galleries



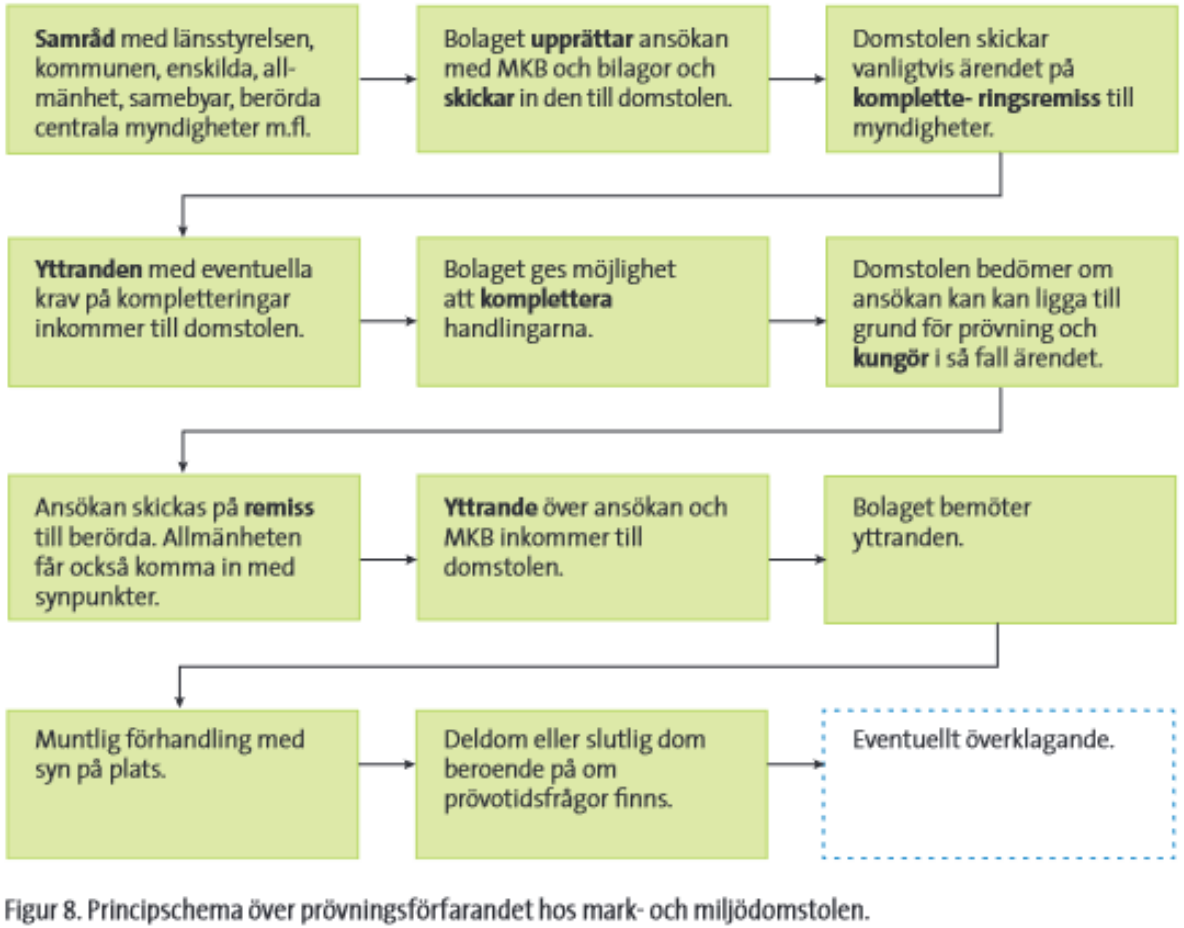
Super-K water cleaning plant

Super-K Gadolinium mixing plant

Hypr-K Gadolinium sulphate storage (top) and dissolution plant (bottom)

3. Studies of the licencing required for the construction of the underground caverns 0.3 M€

ESS European Spallation Source, Zinkgruvan Mining AB

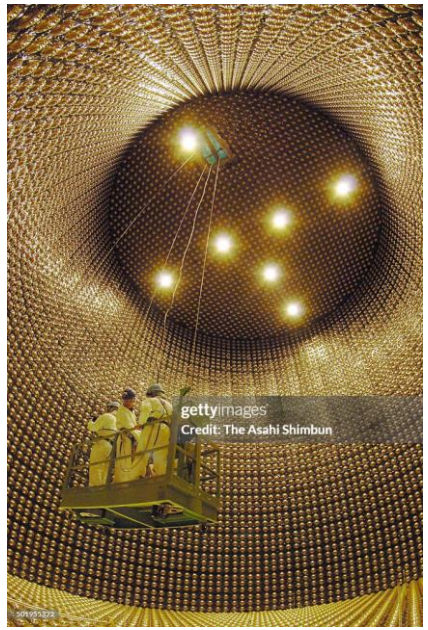


Figur 8. Principschema över prövningsförfarandet hos mark- och miljödomstolen.

http://resource.sgu.se/produkter/sgurapp/s1623-rapport.pdf

4. Design of the installation and operation in the two large caverns of the Cherenkov detector, including all operative systems 1.0 M€

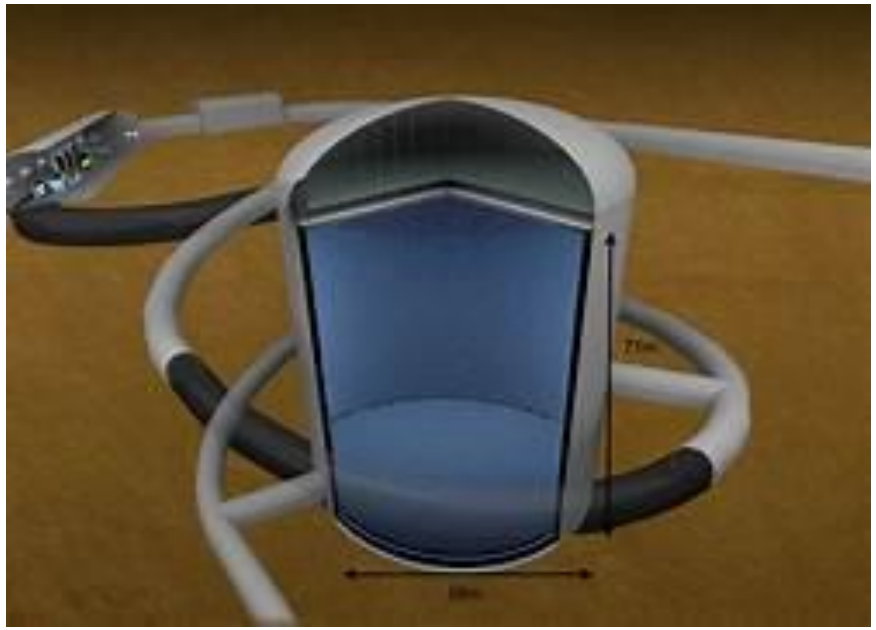
Uppsala, Hamburg and Demokritos Universities



Super-K

50 cm

Super-K Light detector



Hyper-K

ESSnuSB

Water Cherenkov Test Experiments in the Proton Synchrotron East Hall at CERN in Geneva that will start operation in a weeks time

Support cage (in front) for the light detectors and the outer water container (in the back)

View inside with the light detectors on the cylinder wall

A new type of light detector consisting of several smaller units

Water Cherenkov Test Experiment at CERN

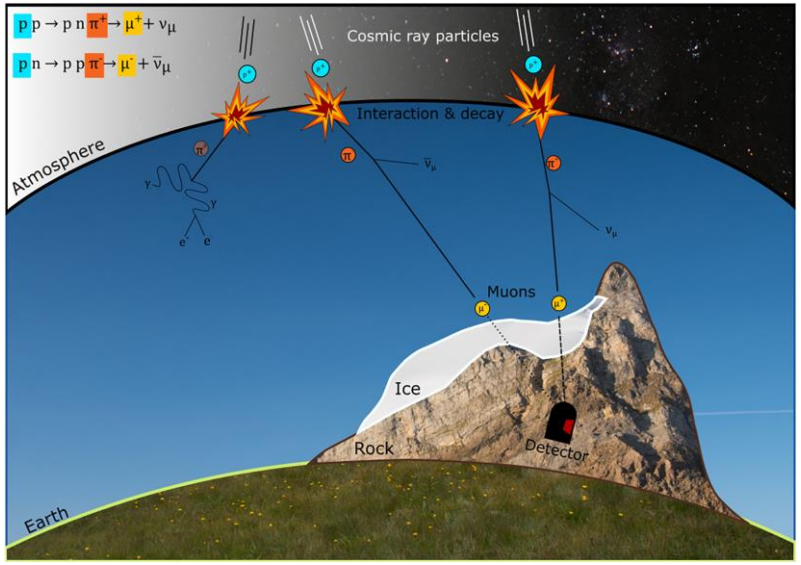
Water filtering and cleaning system built up and tested by Uppsala Master Thesis student Titouan Gressier

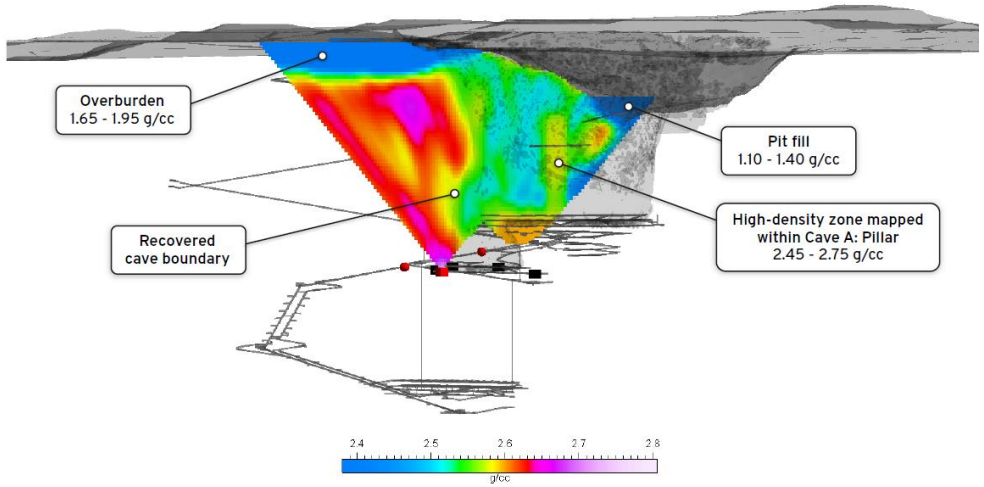
Tanks for the mixing in and extraction of Gadolinium provided by Uppsala University

Support cage with mPMTs being inserted **last week** in the outer water container in the East Hall t9 beam

5. Concurrent use of the Cherenkov detector for muon tomography 0.5 M€

Thessaloniki, Demokritos, Strasbourg and Oulo Technical University





Using muon tomography, the Ideon Technologies company remotely mapped the full cave back at the New Afton Mine in Canada to 25 m or less spatial resolution at a depth of approximately 800 m, using no additional drilling to image 830 million m3 of earth. Presented at International Mass Mining Conference and Exhibition **(MassMin) in Kiruna, Sweden September 18 2024**.

JUNO Top Muon Tracker Prototype at Strasbourg

The Muon Telescope (JUNO Top Tracker Prototype) consists of 4 XY planes and each XY plane has two crossed modules.

Each modules is made of 64 plastic scintillators strip equipped each with one Wave Length Shifting fibers.

The size of a plastic scintillator bar has a cross section of 10mmx25,6mm and about 1.68m long.

All the 64 fibers are read by a 64 channels multianodes photomultipliers from Hamamatsu.

Coverage 1.68m x 1.68m
Muon track angular resolution 0.85°

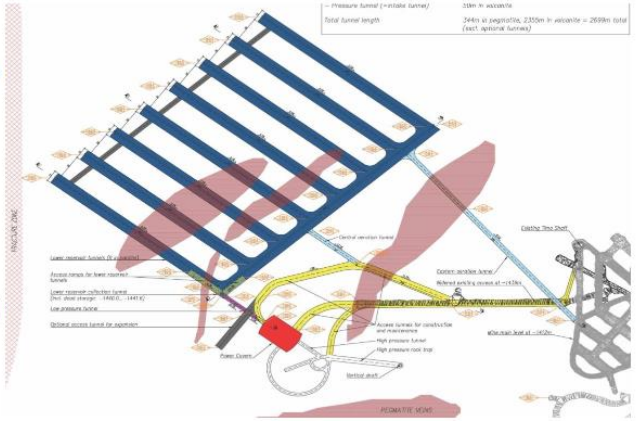
6. Use after the decommissioning of ESSnuSB of the 540’000 m³ cavern volumes for pumped hydro-electricity 0.2 M€

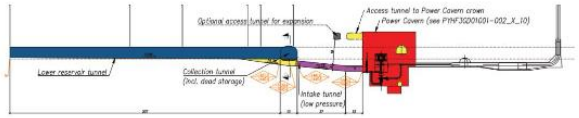
Oulu Technical University

Current project at the Pyhäsalmi Mine in Finland

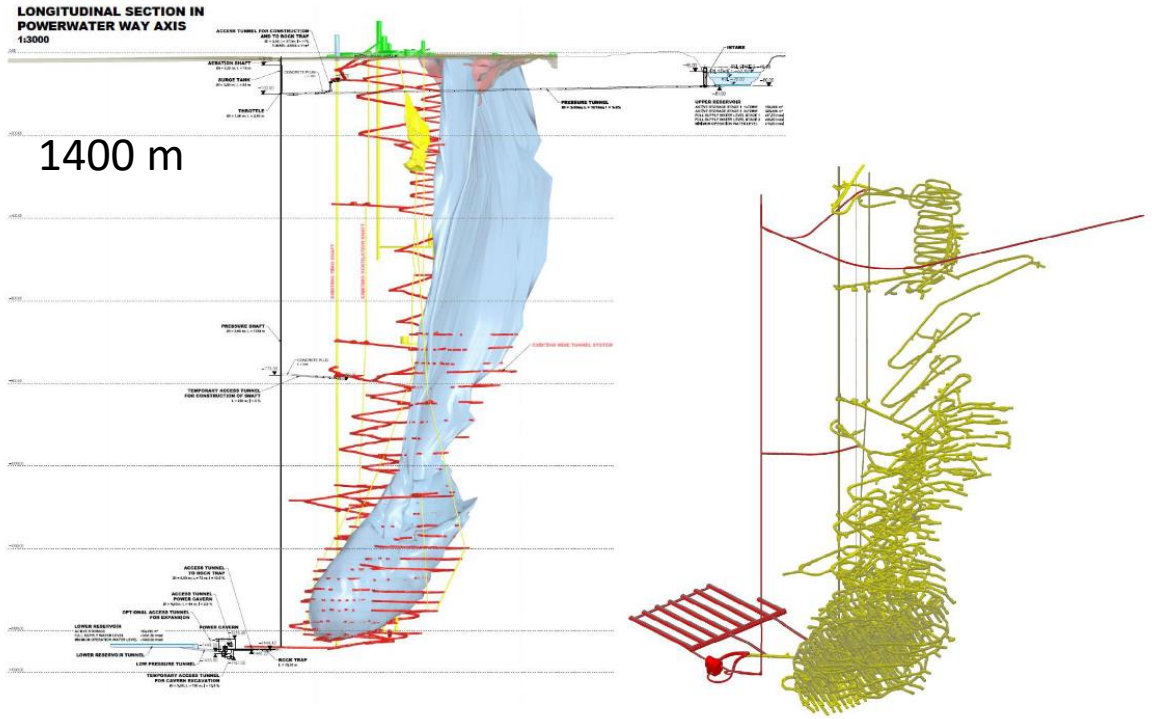
LOWER RESERVOIR

- Layout of final tunnels optimized in respect to geological conditions (joint systems, primary state of stress) and existing tunnel system
- Aeration tunnel can be used for construction, partly as reservoir and for later access in case of maintenance
- Active storage of 162,000 m³ and 21,000 m³ for dewatering of power waterway





MAIN PLANT SECTION – 75MW



Summary and Conclusion

- **The location of the Zingruvan Mine near the second neutrino oscillation maximum of the world-uniquely intense neutrino beam from ESS provides the optimal resolution in the measurement of the CP violation phase angle which is crucial for the formulation and validation of a Leptogensis theory that explains BAU.**
- **A design study is being planned of the realization of the ESSnuSB neutrino detector at Zinkgruvan 1000 m under ground level.**
- **The design study will be carried out by ESSnuSB including groups at the rock engineering departments of the technical universities in Luleå, Wroclaw and Oulo and of the Zinkgruvan Mining AB**

Thank you

Backup Slides

The particular announced EU call that we have found fitting the required design study of the ESSnuSB neutrino detector in the Zinkgruvan Mine is:
HORIZON-INFRA-2023-DEV-01-03: Consolidation of the RI landscape – Individual support for evolution and long-term sustainability of pan-European research Infrastructures

The announcement text is available on pages 14-16 of
https://indico.cern.ch/event/1443347/attachments/2906084/5097846/_HORIZON-INFRA-2025_06_25_2024.pdf
The total EU budget for this EU call in 2025 is 40 M€ and the previewed budget per proposal is 3-4 M€.

The currently proposed working title of our EU fund request/project is:
UnuDET - Exploring the engineering and usage of large underground spaces for fundamental neutrino oscillation research as well as for for ore finding and energy-storage purposes

Preliminary overview of the project for which funding of 4 M€ will be requested – lead institutions in bold letters

Project coordination 0.2 M€
Luleå Technical University

Site investigation, core drilling for evaluation of rock pressure and strength at the detector site 1.0 M€
Luleå Technical University**,** Zinkgruvan Mining AB

Engineering Design of the two 270’000 m^3 caverns and service galleries and the access shaft 1.0 M€
Luleå and Wroclaw Technical Universities, Zinkgruvan Mining

Studies of the licencing required for the construction of the underground caverns 0.2 M€
ESS European Spallation Source**,** Zinkgruvan Mining AB

Design and installation in the two large caverns of the Cherenkov detector, including all operative systems 1.0 M€
Uppsala, Hamburg and Demokritos Universities

Concurrent use of the Cherenkov detector for muon tomography 0.4 M€
Thessaloniki, Demokritos and Strasbourg Universities and Stockholm and Oulo Technical Universities

Use after ESSnuSB decommissioning of the 540’000 m^3 cavern volumes for pumped hydro-electricity 0.2 M€
Oulu Technical University

EU requires that an applying consortium must include at least one of the ESFRI Landmarks or European Research Infrastructures Consortia (ERICs) **We note that in our case the ERIC is ESS.**

EU requires that this call targets the strengthening, long-term sustainability, reorientation or evolution of ESFRI Landmarks or other European Research Infrastructure Consortia (ERICs). **We note that ESS is an ERIC that ESSnuSB will strengthen, sustain, reorient and evolve in a longer perspective.**

EU requires that proposals should explain any synergies and complementarities with previous or current EU grants. **We note that ESSnuSB has previously obtained EU grants in 2016 of 0.3 M€ from COST, in 2018 of 3 M€ from Horizon Europe and of 3M€ from 2022 Horizon Europe.**

EU expects the following outcome of our project :

- **better structured and strengthened European research infrastructure landscape;**
- **reinforced global competitiveness of the European Research Area**

We note that neutrino detectors are being build in USA and Japan but so far none in in Europe.

- **increased long-term sustainability of European research infrastructures;**

We note that our project is long term and will increase the sustainability of ESS

Proposed ESSnuSB strategy for the ESFRI and ESPP processes during the 18 months to come

In order to obtain the support from our national funding authorities for having ESSnuSB included in the ESFRI Roadmap and the European Strategy for Particle Physics, both in 2026, **each national ESSnuSB group needs to make contact with its national representatives in the various committees that will influence and participate in the priority decisions**. These committees are:

The European Strategy Forum on Research Infrastructures ESFRI 2026
ESFRI Strategy Working Group on Physical Sciences and Engineering SWGPSE
The European Strategy Group for Particle Physics ESG for the update 2026
The CERN Scientific Policy Committee SPC
The European Committee for Future Accelerators ECFA
The Laboratory Directors Group LDG