

Review of site options for VLBAI experiments

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2nd TVLBAI Workshop, Imperial College, London, 3rd of April 2024

Outline

Requirements for TVLBAI experiments

CERN

Porta Alpina

Sanford Underground Research Facility (SURF)

Laboratoire Souterrain à Bas Bruit (LSBB)

Callio Lab

Requirements for TVLBAI experiments

Site requirements are classified in two categories:

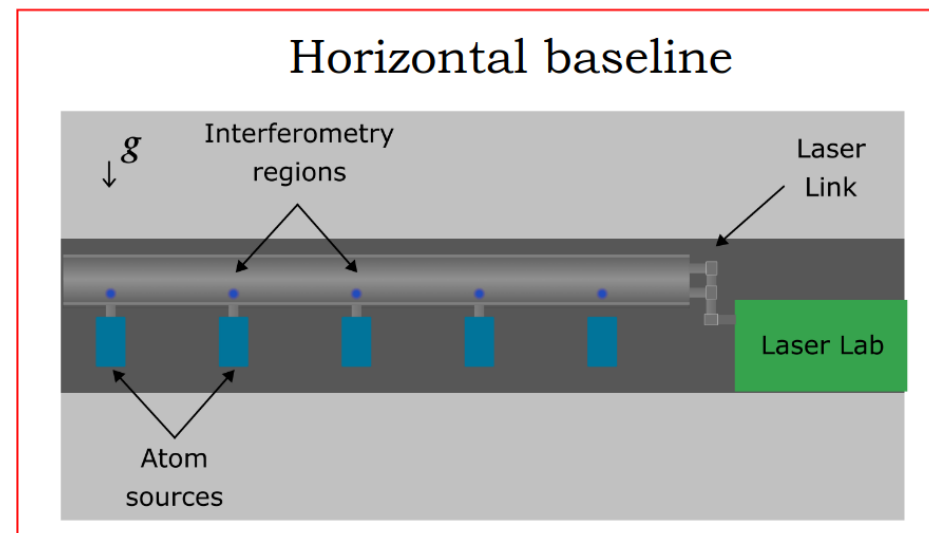
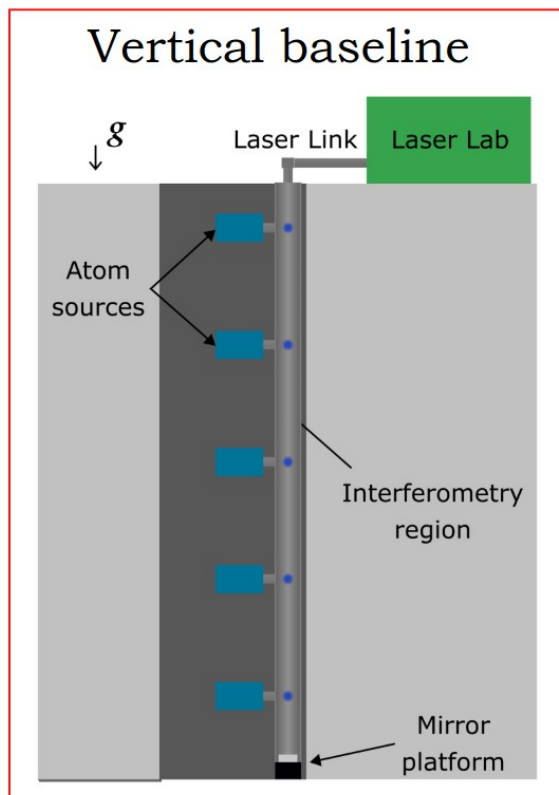
- Infrastructure requirements: ability to accommodate a fully operating experiment
- Environment requirements: sources of noise that could degrade the sensitivity of such experiment

Note: these definitions are similar, but not identical, to those of 1st TVLBAI Workshop summary paper

Requirements for TVLBAI experiments

Summary of infrastructure requirements:

- Interferometry region: ultra-high vacuum over entire baseline, diameter ≥ 15 cm
- Laser laboratory: 50 m², 35 kW, temperature fluctuations < 1 °C
- Atom sources: 2 m³, 200 kg, 10 kW (each unit)



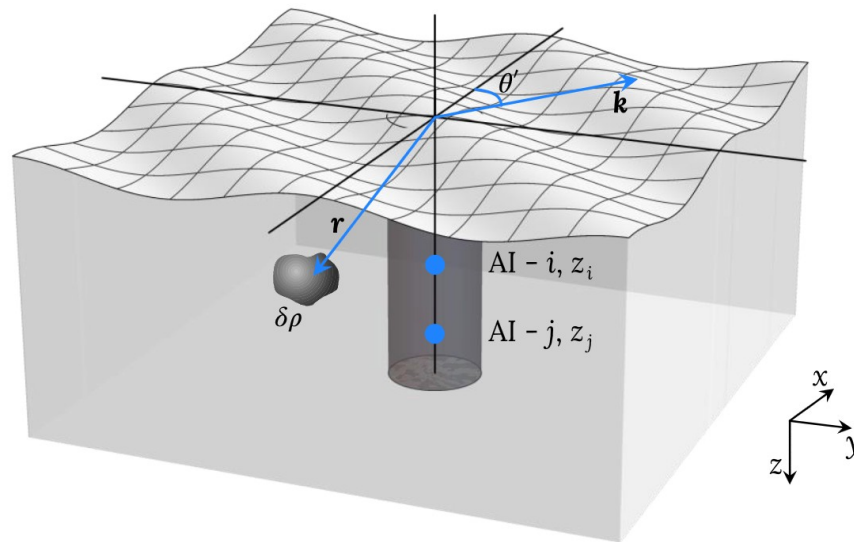
Credit: [Richard Hobson](#)

Requirements for TVLBAI experiments

Gravity gradient noise (GGN): stochastic matter perturbations in the environment that propagate to atom beam through gravitational coupling

GGN correlates with vibrational noise \Rightarrow sites with low vibrational noise are required

Besides, sites with low electromagnetic (EM) noise are also preferred



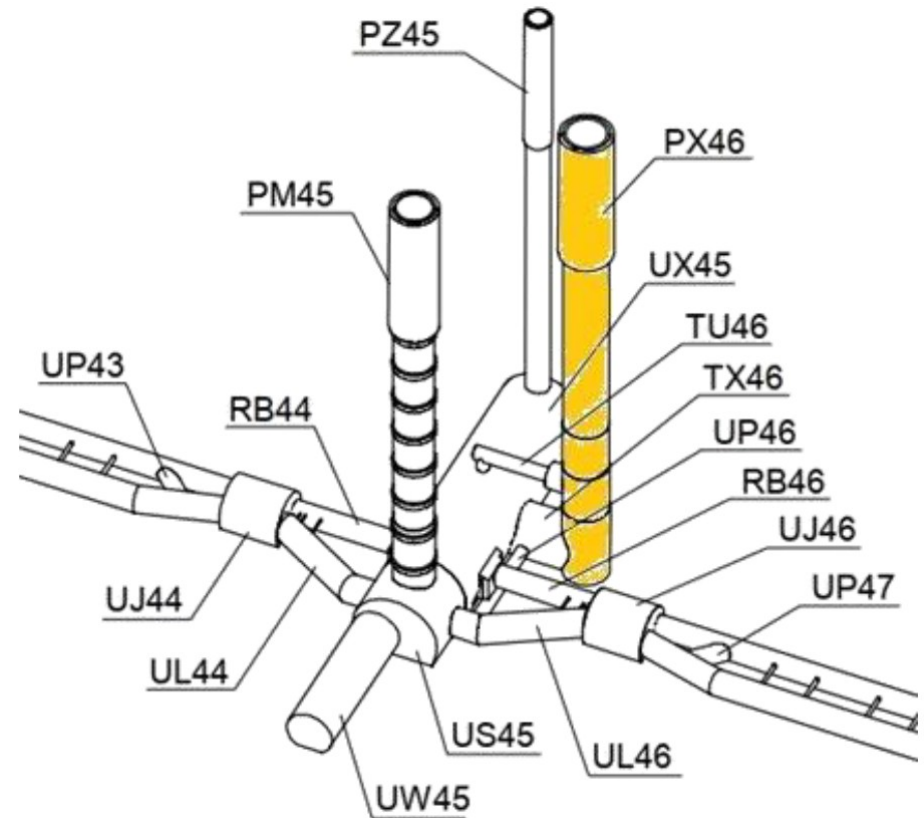
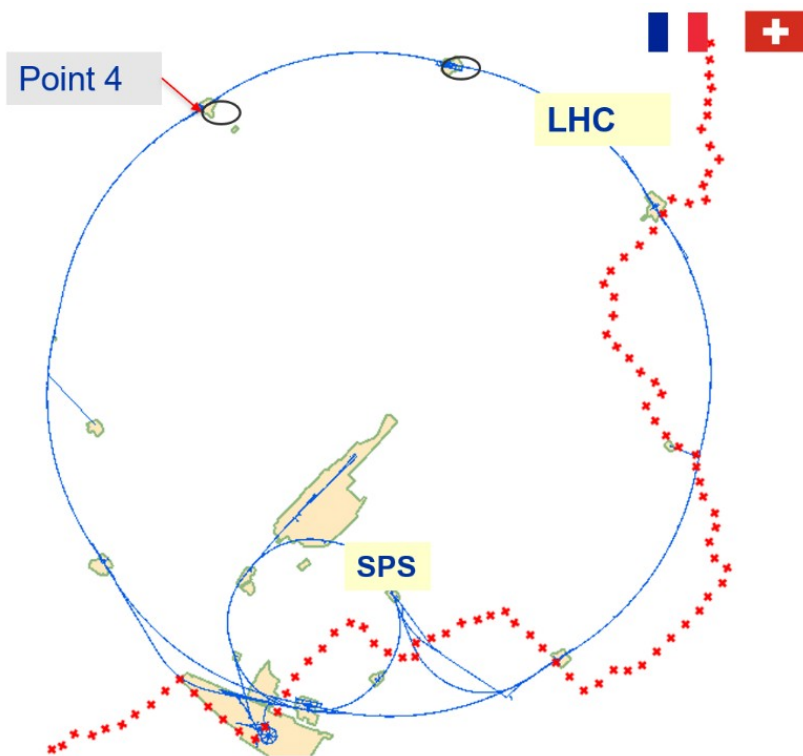
Credit: [Jeremiah Mitchell](#)

CERN

Feasibility study for vertical VLBAI already exists: [CERN-PBC-REPORT-2023-002](#)

Proposing PX46 shaft @ Point 4: 143 m depth, 10.1 m diameter

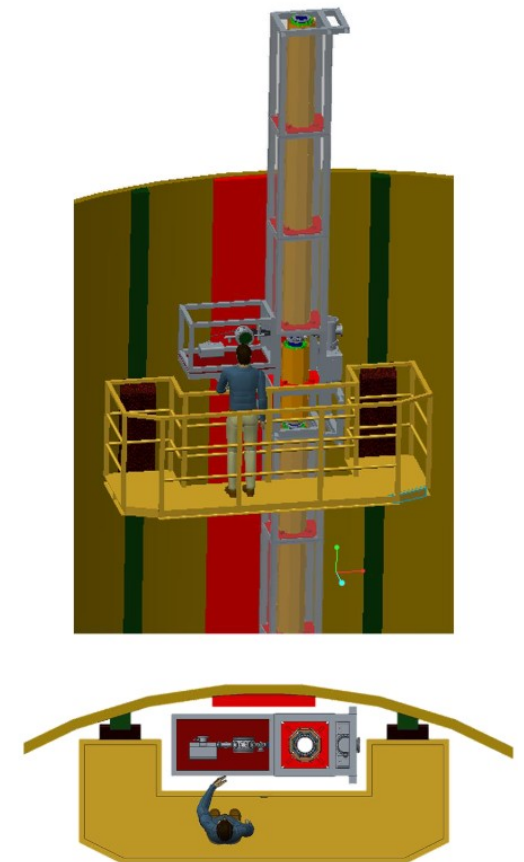
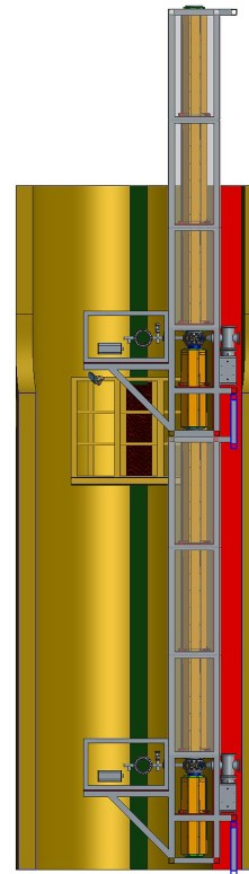
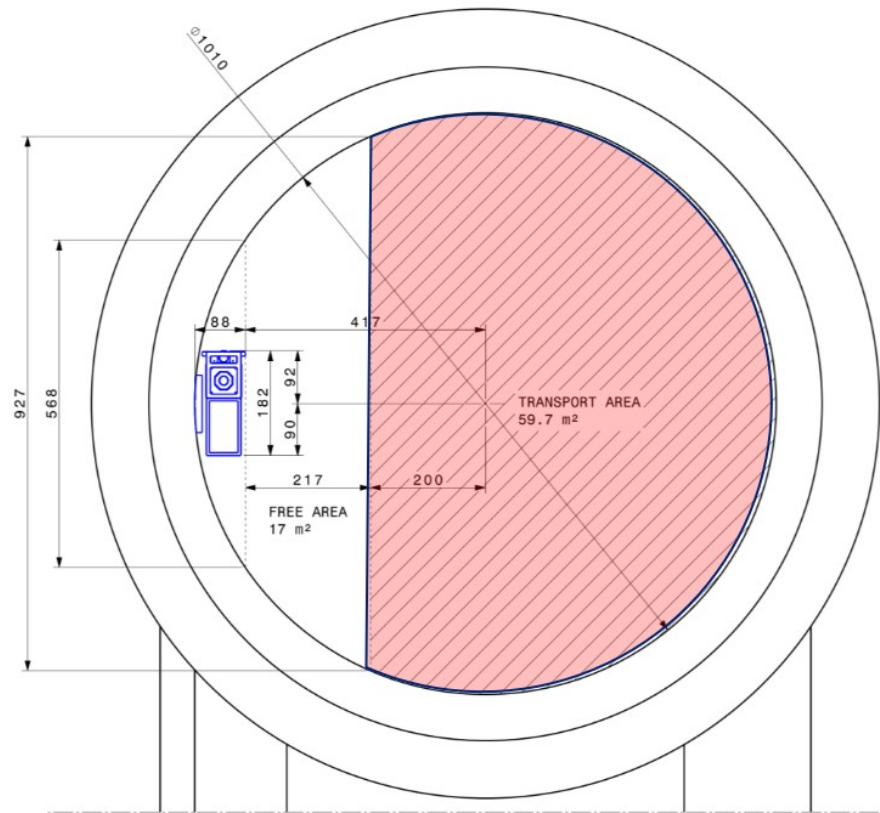
Large building at the top of the shaft



CERN

Proposal includes tentative layout of:

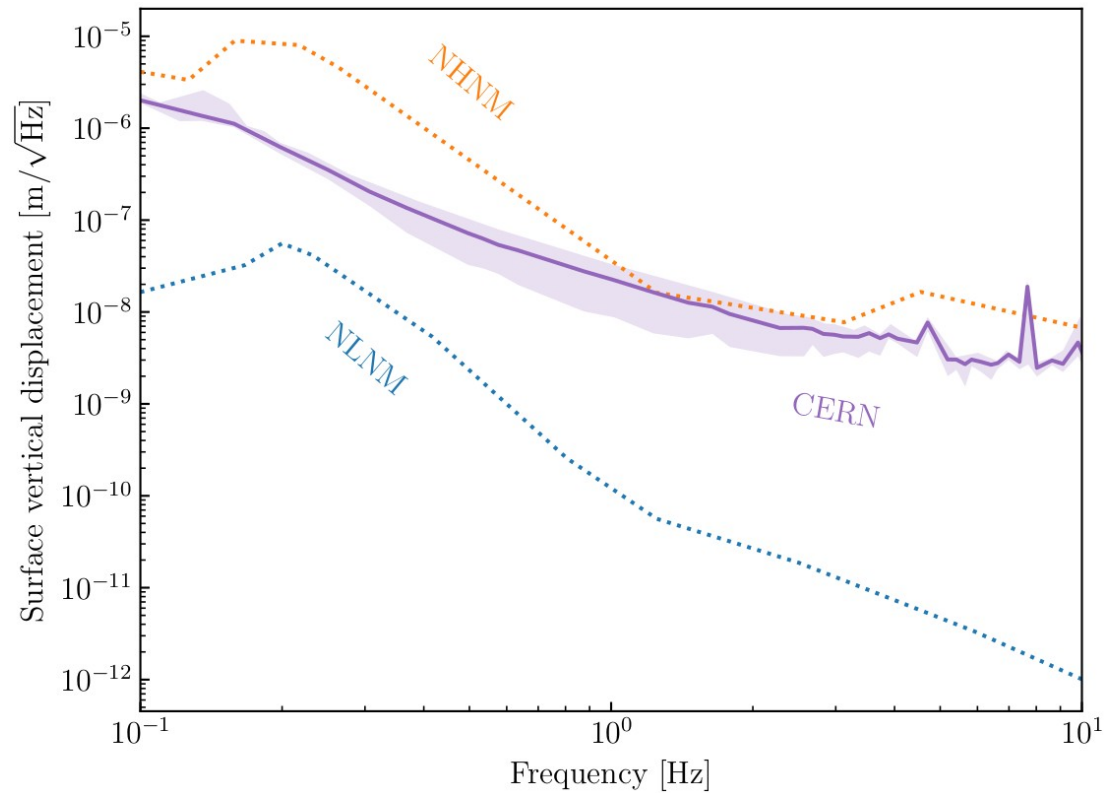
- AI and elevator within the available shaft area
- Radiation shield at the bottom of the shaft



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Vibrational and EM noise within acceptable ranges

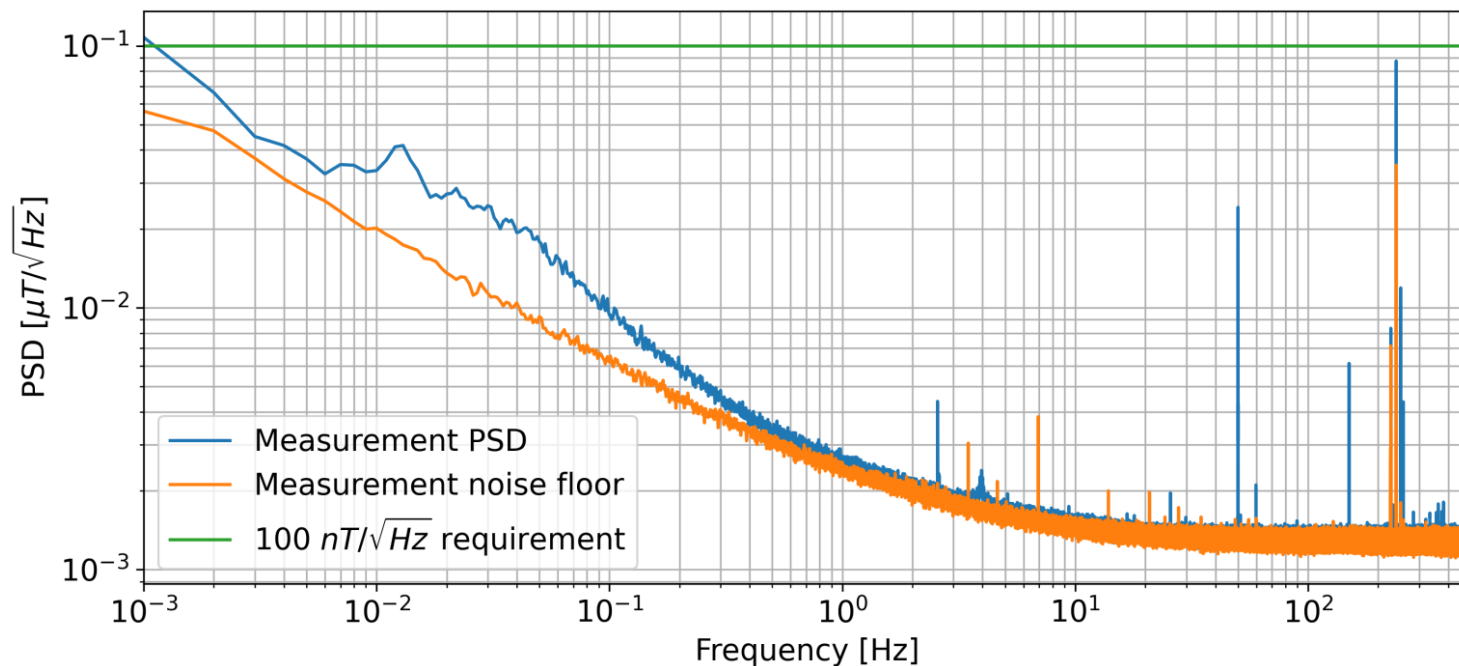
Magnetic field variations due to LHC operations (~ 50 nT) follow a predictable pattern, and therefore could be subtracted



CERN

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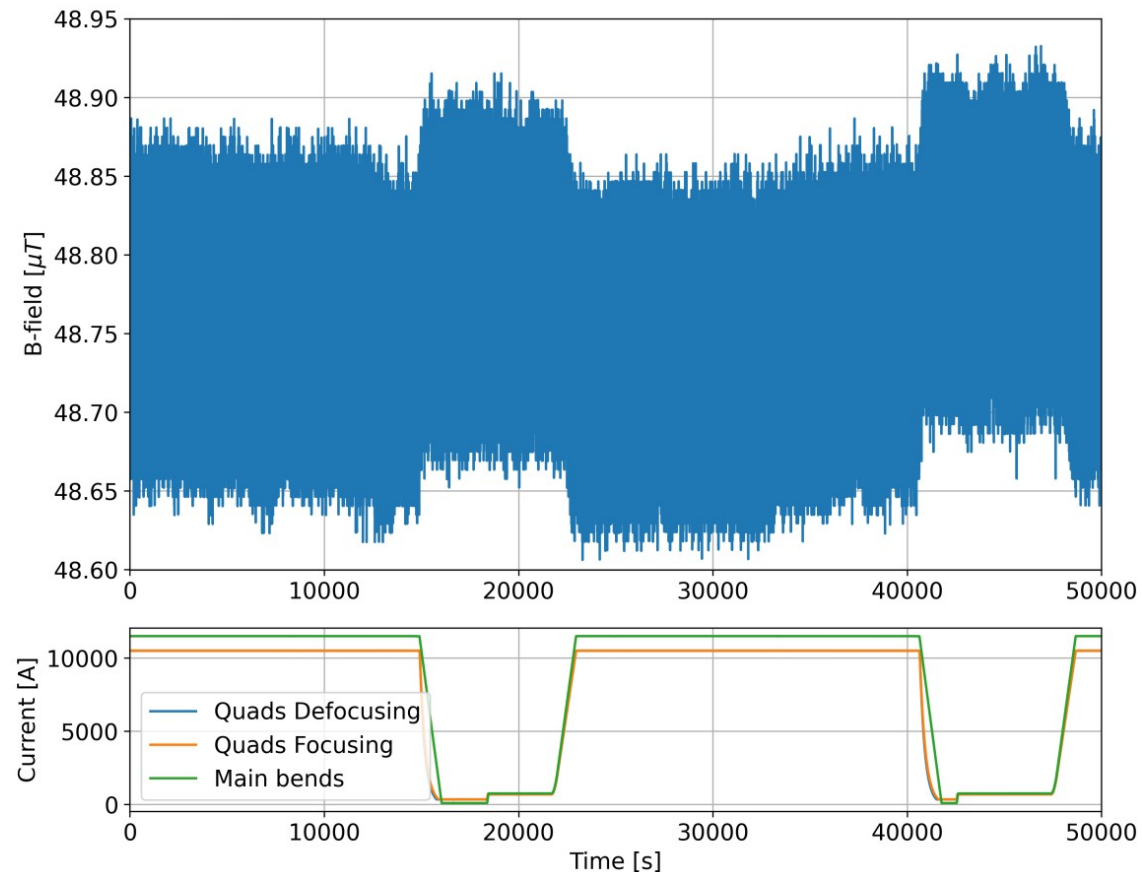
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CERN

Vibrational and EM noise within acceptable ranges

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CERN

Proposal addresses safety requirements: fire, He release (+radiation protection)

Estimated cost to prepare the site for a VLBAI experiment: ~1.5 MCHF

Major opportunities for installation works: LHC Long Shutdowns (2026-28, 2033-34)

Item	Cost [kCHF]
Shielding	400
Lifting platform	400
Access, safety systems and monitoring	200
General services and utilities	500
Total	1500

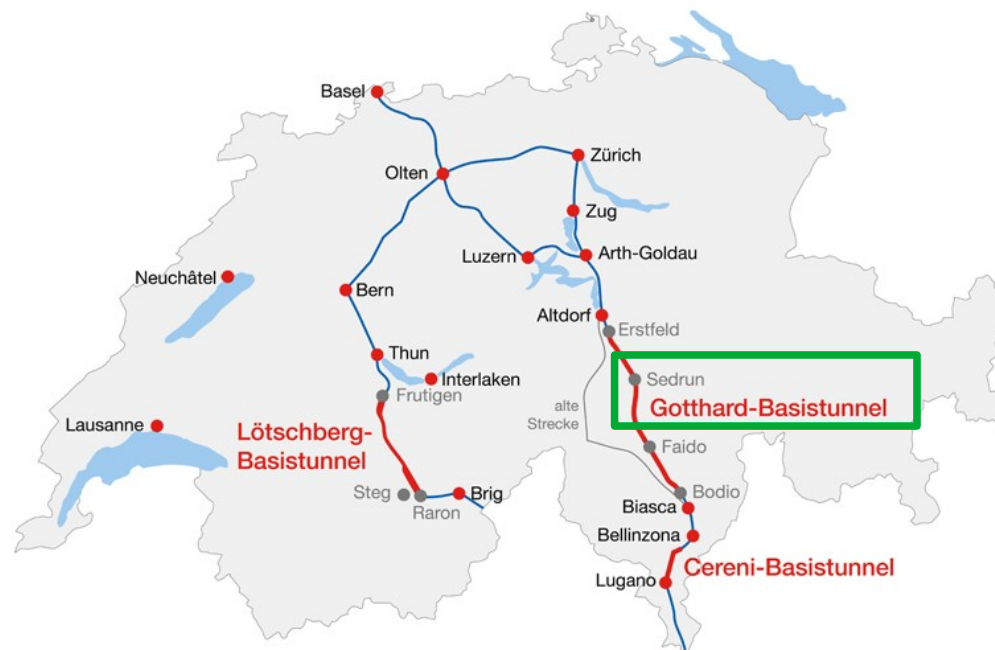
Porta Alpina

Thanks to [Lucas Lombriser](#)

Concept: use infrastructures of Gotthard Base Tunnel (Switzerland) to deploy a vertical VLBAI

Gotthard Base Tunnel:

- Railroad tunnel, 57 km long
- Opened in 2016, longest railroad tunnel & deepest traffic tunnel in the world
- Built from 5 sites to reduce construction time: Erstfeld, Amsteg, Sedrun, Faido, Bodio



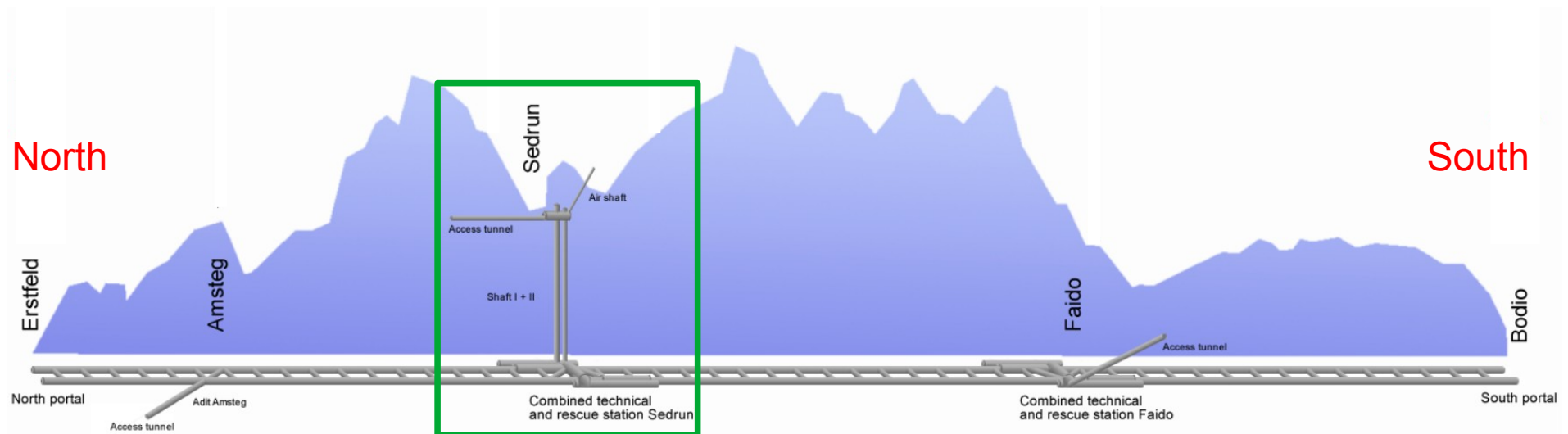
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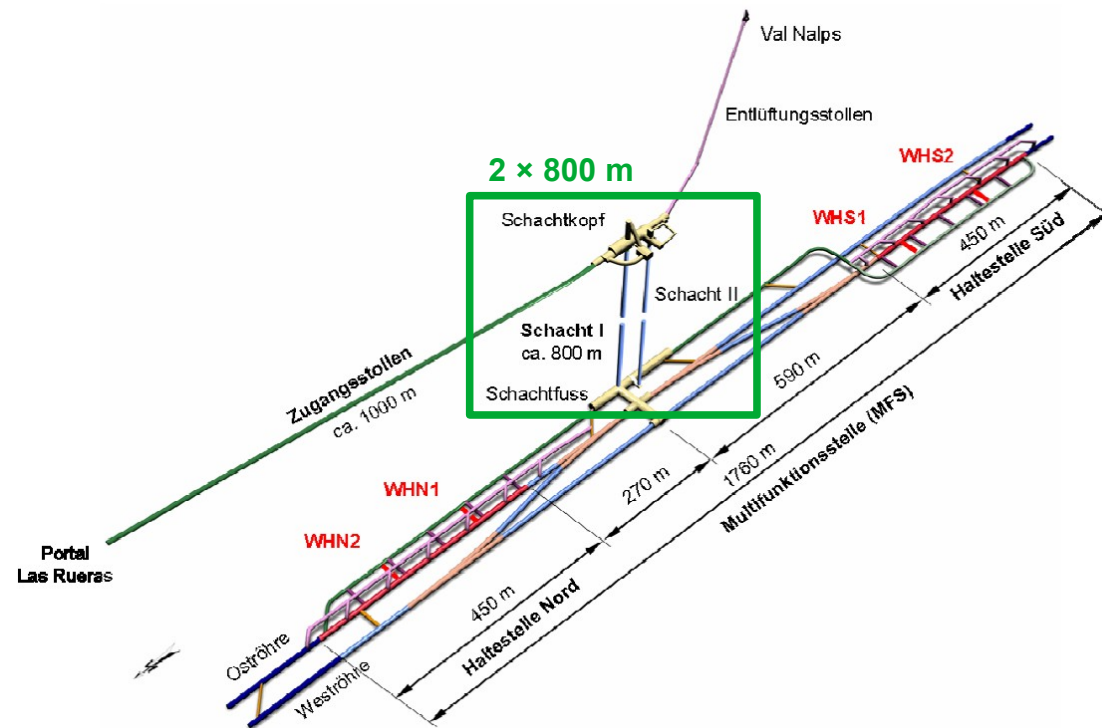


Porta Alpina

Thanks to [Lucas Lombriser](#)

In particular, considering Sedrun access site:

- 2 shafts for maintenance & ventilation: 800 m depth, 8.6 m & 7 m diameter
- Access from Sedrun through horizontal tunnel (1 km)
- 4 caverns built for Porta Alpina underground station (on hold since 2007): WHN1+2, WHS1+2 ($38 \times 10 \times 5.5 \text{ m}^3$ each)



Porta Alpina

Thanks to [Lucas Lombriser](#)

Proposal to host a vertical VLBAI at Sedrun access site is supported by influential political figures, and several Swiss offices

Site inspection scheduled for November 2024 (postponed twice from October 2023 due to freight train accident)

Contact: Lucas Lombriser, Oliver Buchmüller, John Ellis



Swiss Federal Railways



National and States Councillors



Governing Councilor & Department
of Infrastructure, Energy & Mobility



Mayor of Tujetsch



Office of Higher Education

Sanford Underground Research Facility (SURF)

Major underground laboratory in South Dakota (US), opened in 2007

Home of leading experiments in dark matter (LZ) and neutrino physics (Majorana Demonstrator, LBNF/DUNE)

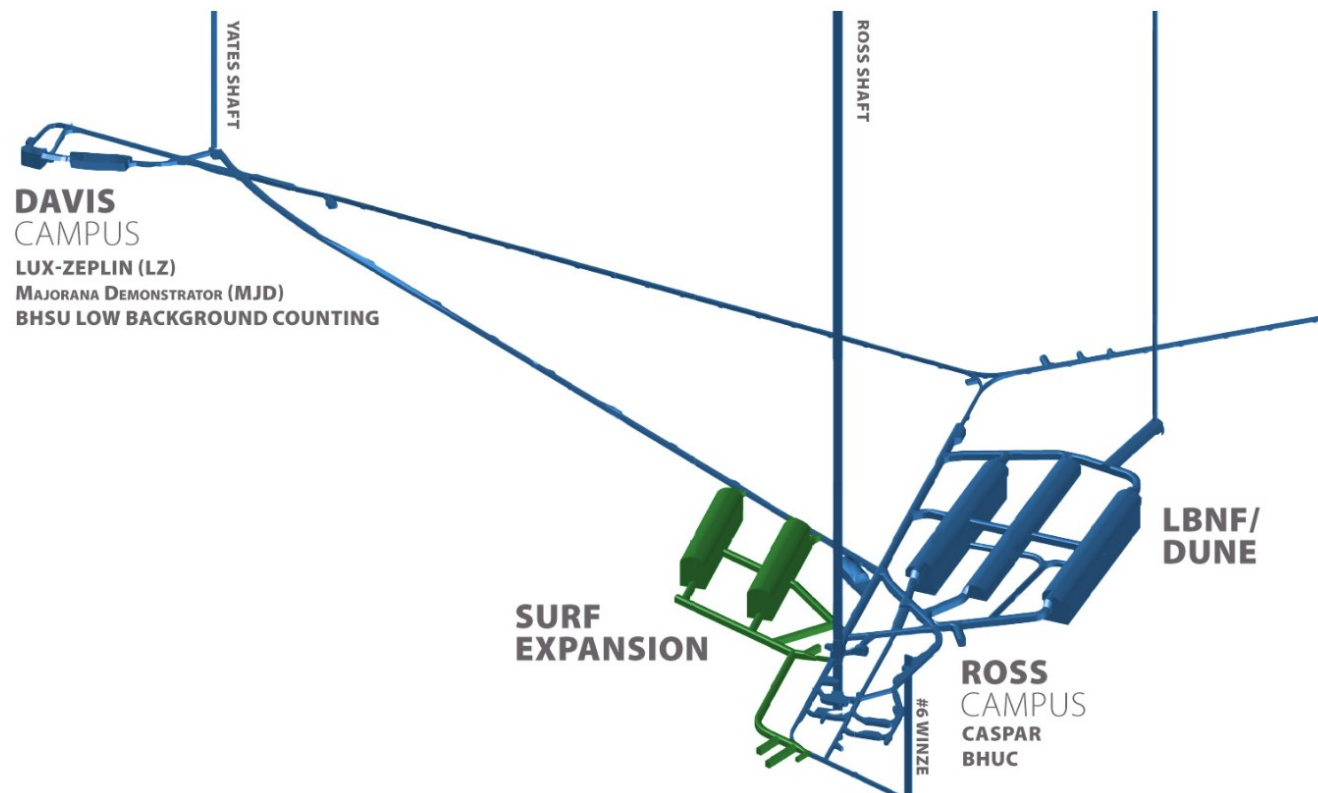


Sanford Underground Research Facility (SURF)

2 experiment areas at 1500 m depth (4850 level): Davis Campus, Ross Campus

Accessed by 2 shafts (Yates, Ross) respectively

Strong community support endorsing more space at SURF ⇒ plans to excavate 2 new caverns ($100 \times 20 \times 24 \text{ m}^3$) on 4850 level, for next-generation experiments (~2030)



Sanford Underground Research Facility (SURF)

Besides, interest in developing a vertical facility at SURF, that could host a VLBAI:

- [SURF Long-Term Vision Workshop 2021](#)
- Initial evaluation study completed in 2022
- Identified 4 options for a medium-sized vertical facility (~100 m), and 2 options for a large-sized vertical facility (~1 km)
- Respective diameters range between 2.4 m and 5 m

Structure – <u>medium size</u>	Available part	Depth of available part	Comments
#6 Winze	4550 to 5000 level	140 m	Extends down to 8000 level
Milliken Winze	2000 to 3500 level	460 m	
Milnarich Shaft	Surface to 800 level	240 m	Need to verify dimensions Need to remove top concrete plug
31 Exhaust Raise	4100 to 4850 level	230 m	Need to verify dimensions

Structure – <u>large size</u>	Available part	Depth of available part	Comments
#5 Shaft	Surface to 4850 level	1500 m	
Ellison Shaft	Surface to 3200 level	1000 m	Need to remove top concrete plug

Sanford Underground Research Facility (SURF)

SURF has recently opened a [request for proposals](#) (Letters of Interest) to develop experiments at this facility

Proposals from the VLBAI community are welcome, for vertical or horizontal experiments

Guidelines are provided [here](#), proposals received by 17th of May 2024 will receive full consideration

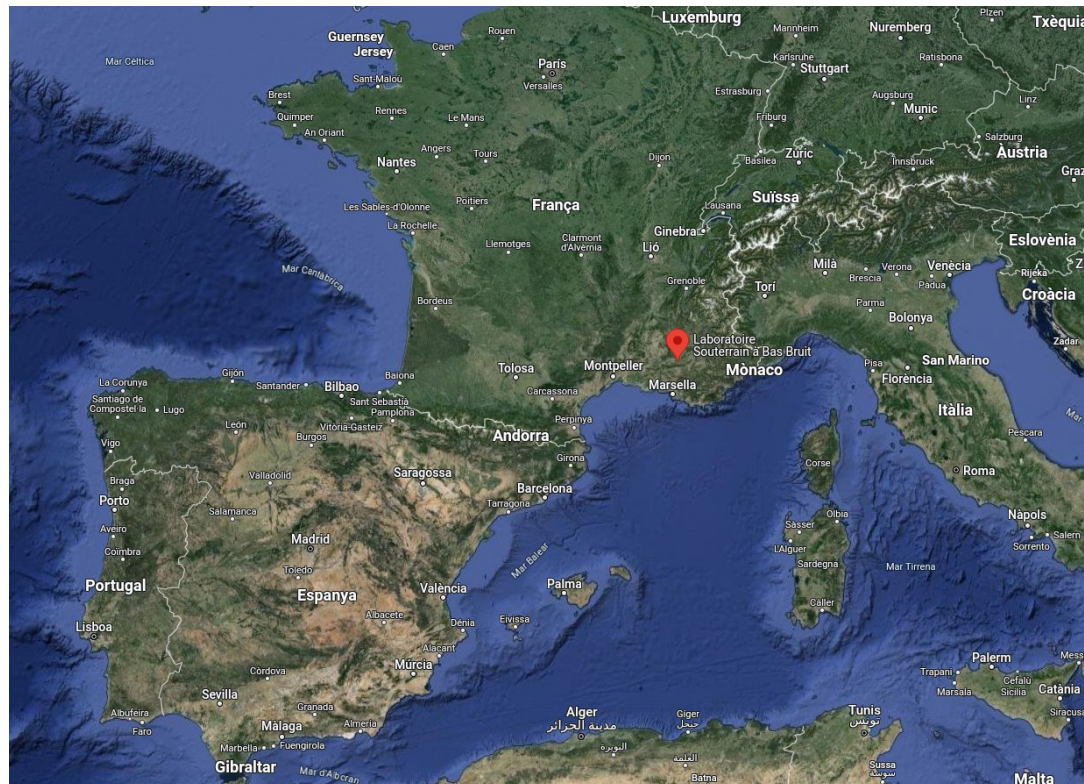
Contact: [Jaret Heise](#)

Laboratoire Souterrain à Bas Bruit (LSBB)

Located in a decommissioned military facility near Rustrel (France)

4 km of galleries, featuring very low seismic and EM noise

Excavated 2 new perpendicular galleries (150 m each) for MIGA, at ~1 km from the laboratory entrance

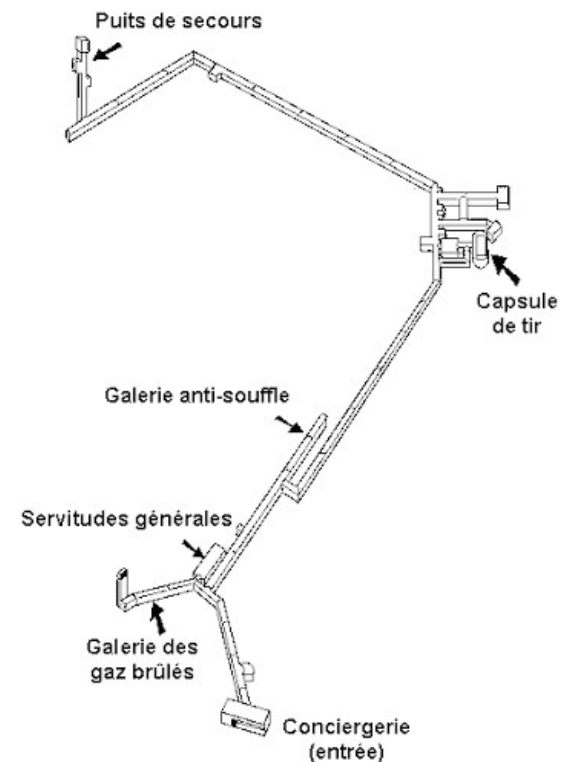


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Callio Lab

Located in Pyhäsalmi mine (Finland)

Started in 2000 as Centre for Underground Physics in Pysähalmi (CUPP), operating as Callio Lab since 2015

Home of experiments in cosmic rays (EMMA) and neutrino physics (LAGUNA)



Callio Lab

4 laboratories at different depths, down to 1430 m

Area of lowest laboratory: 120 m²

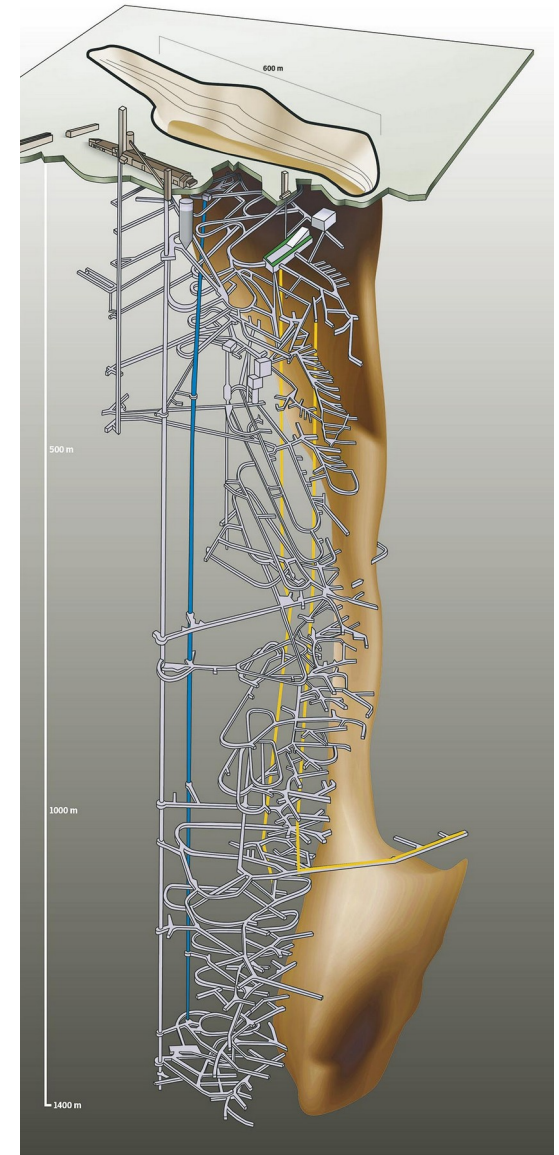
Access:

- Elevator (3 min)
- Inclined tunnel (11 km to lowest laboratory), enabling shipments by truck to underground areas

Estimated tunneling cost, assuming 100 m: ~350k EUR, includes excavation, ventilation, electrical installation and water lines

Among other services, Callio Lab provides microseismic monitoring

More details about Callio Lab [here](#)



Summary

5 potential sites have been reviewed in this talk

CERN: detailed feasibility study published in 2023, proposing PX46 shaft (143 m)

Porta Alpina: two shafts (800 m each) in the Swiss Alps, between surface and Gotthard Base Tunnel

SURF: initial evaluation study completed in 2022, identified 6 shaft & winzes for 100 m and 1 km vertical facility

LSBB: 2 perpendicular galleries (150 m each) have already been excavated for MIGA

Callio Lab: currently 4 laboratories at different depths, down to 1430 m

Don't miss next dedicated talks on Boulby, ZAIGA and Canfranc!