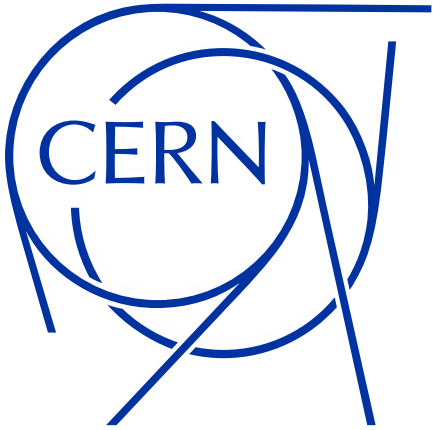


The Lifecycle of the CNGS Target Area:

From Installation to Nuclear Dismantling

Ans Pardons,
A. Devienne, L .Quain, N. Quinquis.

5th Workshop on Particle Accelerator Upgrade Removal and Installation
4–7 May 2026 Bad Zurzach Switzerland

Outline

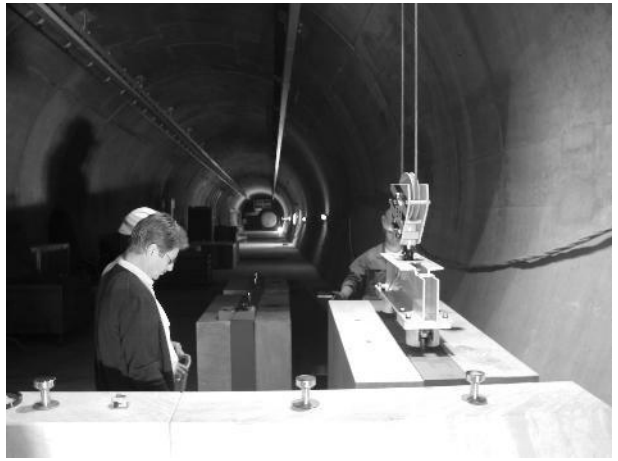
CERN Neutrinos to Gran Sasso (CNGS)

- Introduction
- Smart Design Choices
- From CNGS to AWAKE

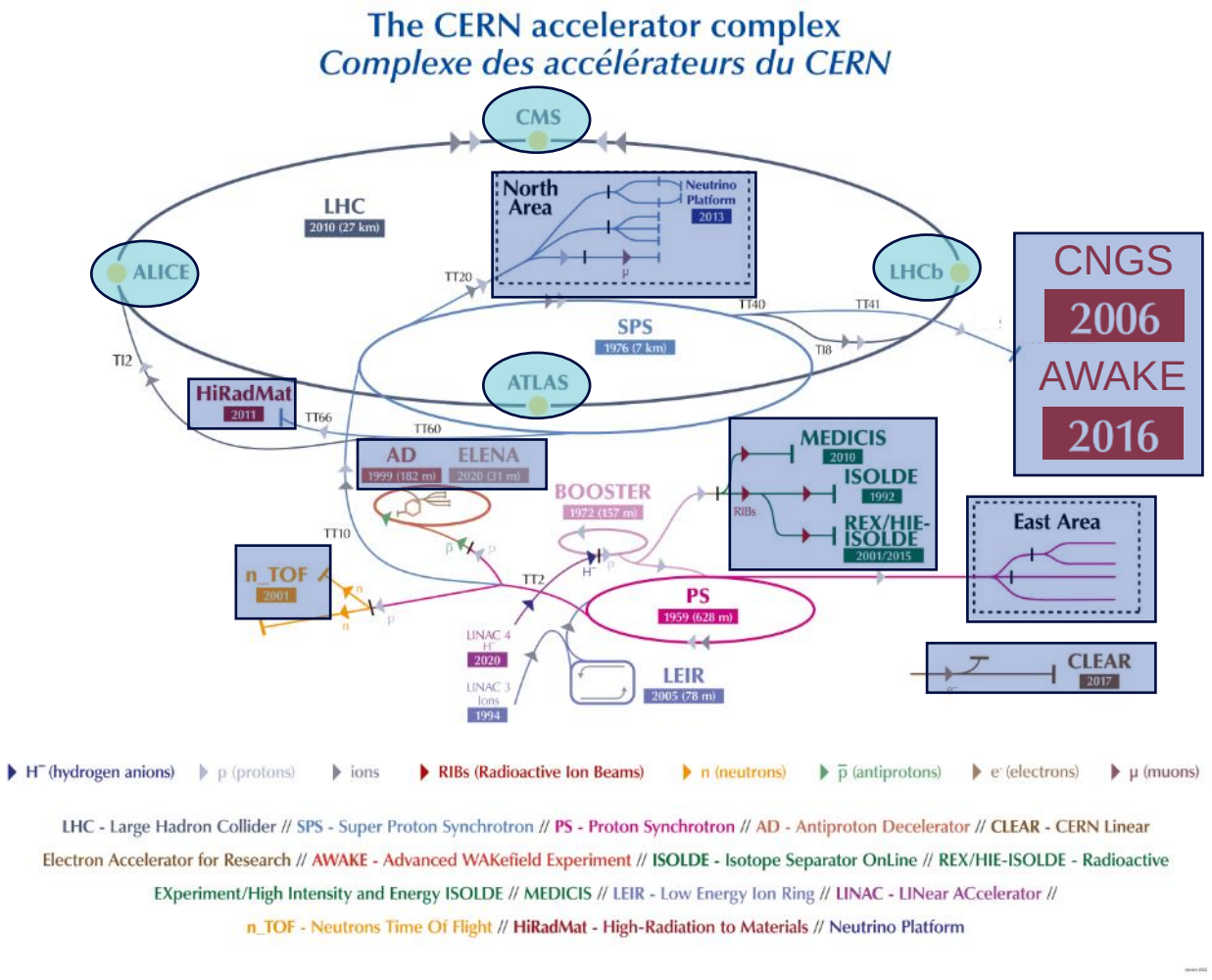
CNGS Target Area Dismantling (CTD)

- From AWAKE to CNGS Dismantling
- Target Area Specifics
- Dismantling Strategy and Execution
- First Observations

Summary



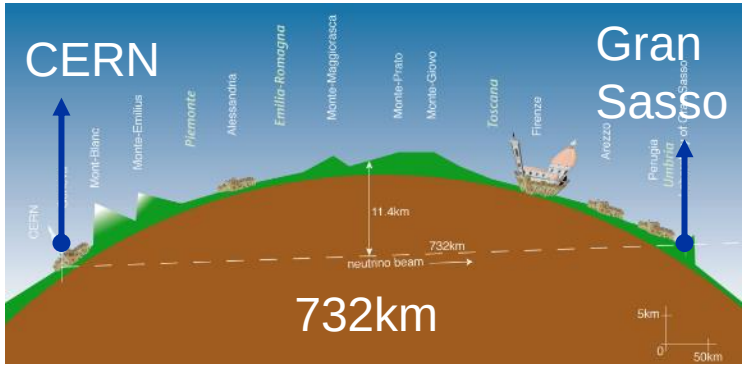
CERN Accelerator Complex

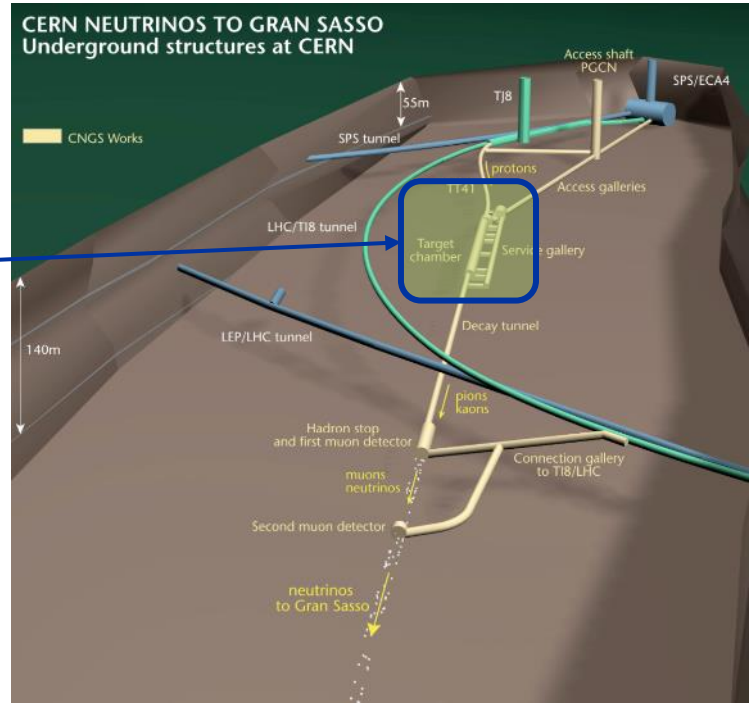


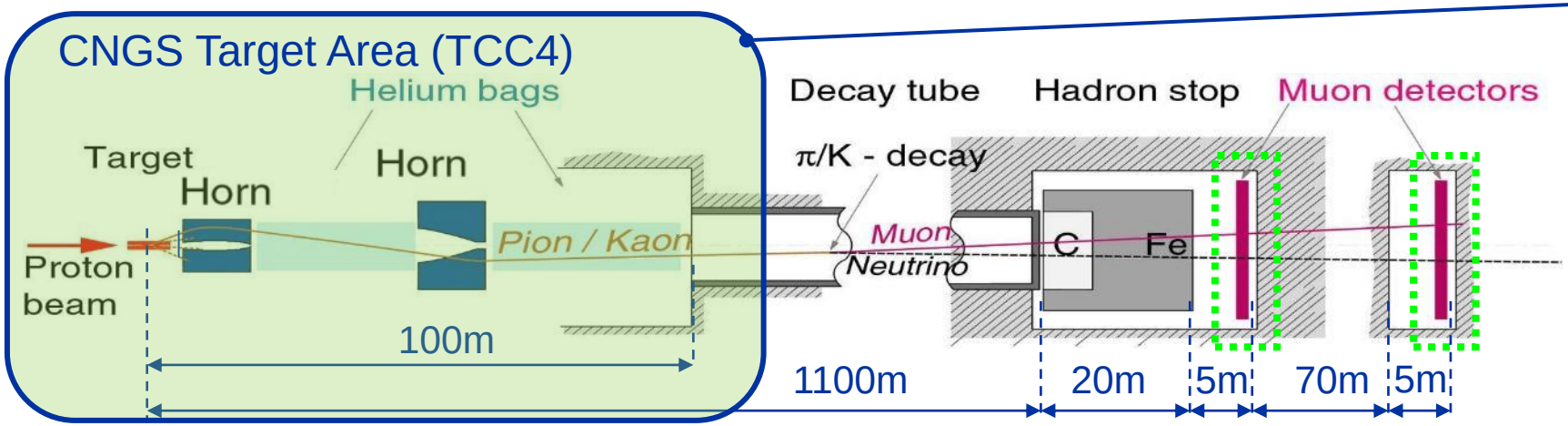
- **Runs with protons and ions**
- **Consists of**
  - LHC collider with large detectors in each of the four interaction points
  - Multi-stage injector chain (LINAC, Booster, PS and SPS) with several experimental facilities for physics and R&D
- **Provides**
  - Very diverse program for the physics community
  - Technological innovation opportunities in a large range of fields, e.g. cryogenics, vacuum, and power distribution.
- **Includes CNGS and AWAKE facilities,** where CNGS target area dismantling (CTD) is a prerequisite for the next phase of AWAKE

CNGS: CERN Neutrinos to Gran Sasso

- The CNGS facility (2006-2012) sent muon neutrinos from CERN to INFN's Gran Sasso lab, to better understand neutrino oscillation.
- **SPS protons** interact with a **target** to create pions and kaons. **Magnetic horns** focus the resulting beam, while **helium tanks** and a 1-km-long **decay tube** allow the decay into muons and muon neutrinos. A **beam dump** stops all hadrons, while muons are absorbed further on. Neutrinos travel to the detectors in Gran Sasso.
- New tunnels were excavated at CERN to house the facility, including a 1-km-long access gallery leading to a 100-m-long **target area**.





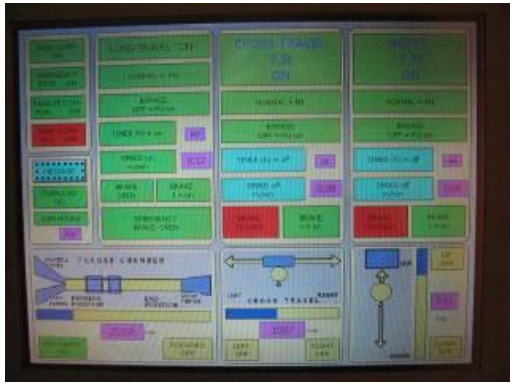


Smart Design Choices

Radiation-smart (ALARA) dismantling of CNGS was integrated from the design phase on.

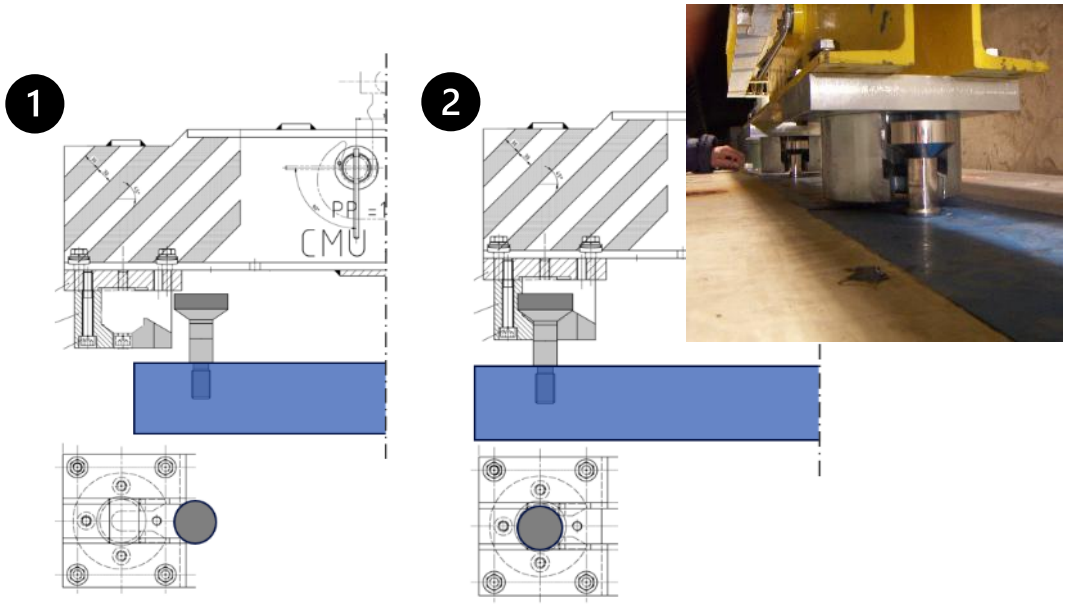
How?

- Foresee infrastructure, e.g. **remote overhead crane** with cameras and a coordinate system
- Make smart material/shielding/paint choices
- **Design for remote actions**
- **Test** removal procedure **on clean equipment**
- **Document** it all (and more):
  - Complete CAD models, technical drawings and layouts
  - Complete removal procedures (incl. crane coordinates, videos of tests, list of tools, time and position for each step, and more)
  - Photos of different installation steps



Also: invest where you gain the most
→ concentrate on the target and horn areas

Design for Remote Actions



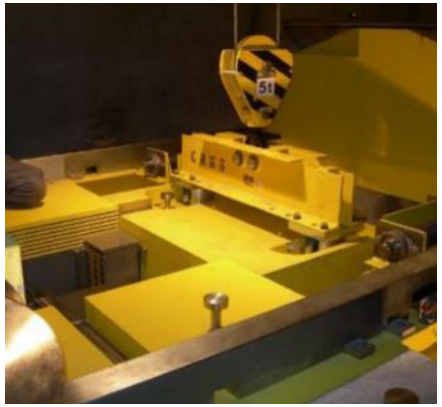
Shielding blocks:

Self aligning “mushroom” lifting pins on shielding and elements, with adapted “hooves” on lifting beam.

For each item, record two crane positions (x,y,z) during installation → **remove or install remotely**

Target cylinder:

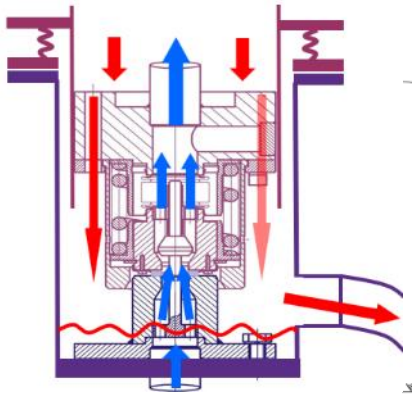
Revolver that contains 5 target cylinders. Rotating mechanism with remote-controlled motors outside of shielding → **change to new target cylinder remotely**

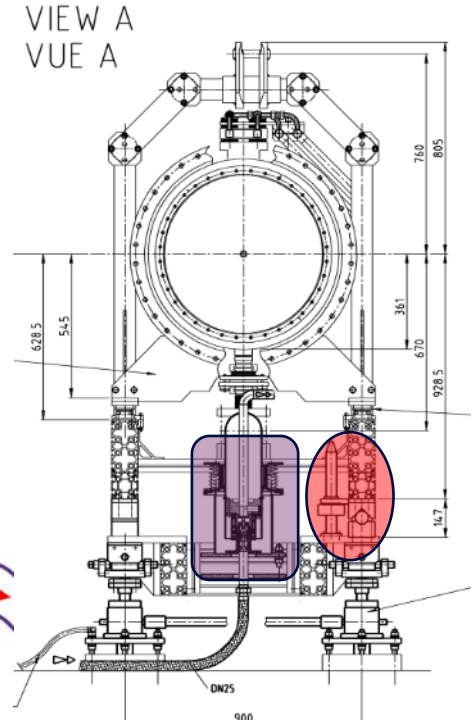


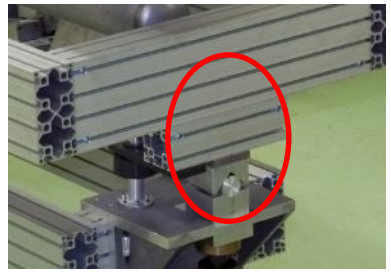
Design for Remote Actions

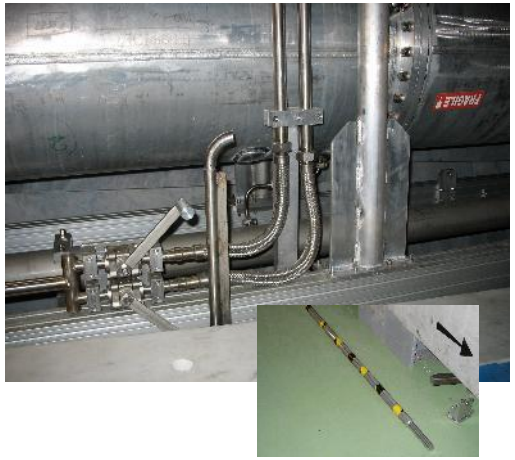
Horn & Reflector

- Mechanical self-aligning plugs and supports
- Spare water circuit, switch to spare
  from outside of shielding
- Electrical striplines with remotely moved
  sliding connection







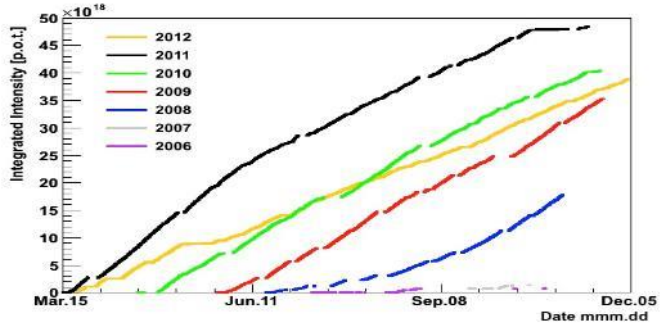


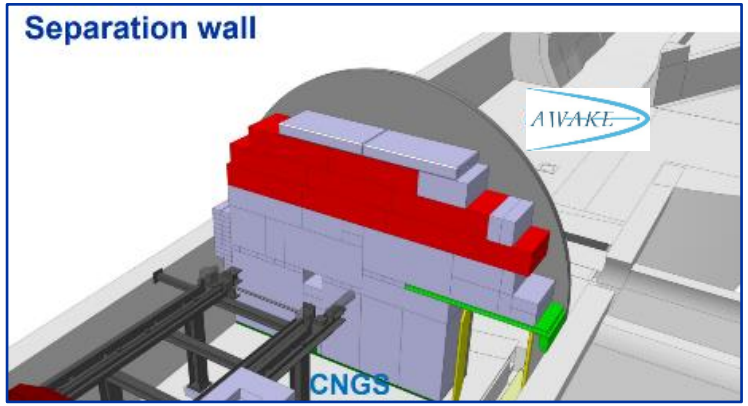
From CNGS to AWAKE

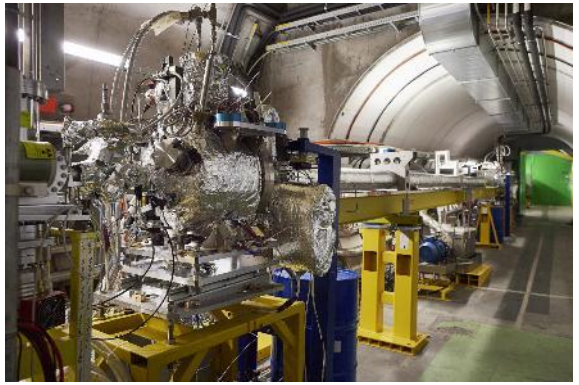
- CNGS operated with beam from 2006 until 2012, sending **$1.8 \cdot 10^{20}$ protons on target**.
- Afterwards, all **equipment** in the target chamber was **left in place**.
- Cooling circuits were drained, and ventilation (**humidity control**) and **access** system (**restriction**) remained operational.
- Controlled Radiation Area - **Limited Stay (max 2mSv/h)** with **contamination risk.**
- In 2014, a shielded and airtight **separation wall** was installed upstream of the target.
- The **AWAKE** facility (Proton-driven advanced wakefield experiment) was installed upstream of the wall and ran from 2016-2025 with SPS protons. (see extra slides)

CNGS Beam Parameters

- SPS protons of 400GeV/c
- Beam size on target σ~0.5mm
- $5 \cdot 10^{13}$ protons per cycle (6s)





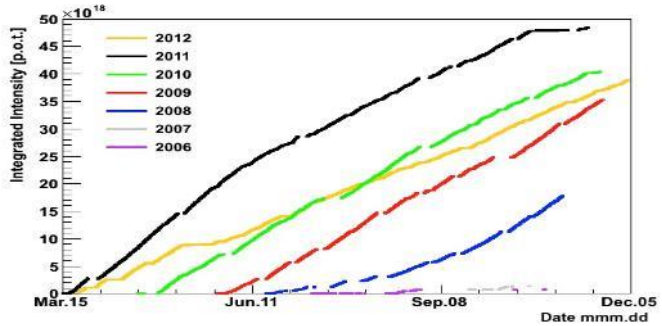


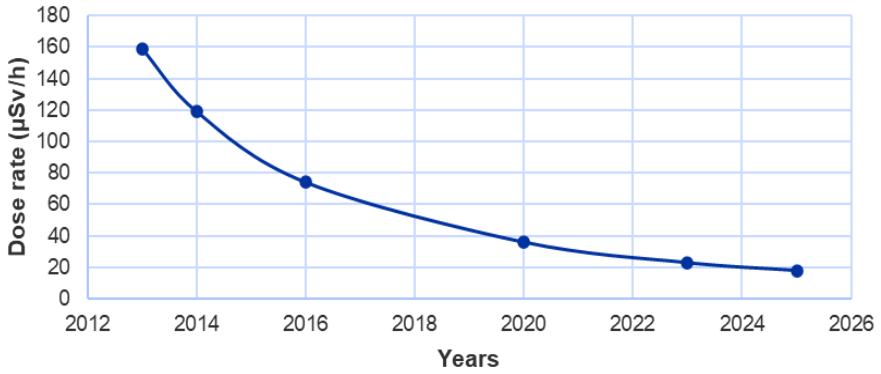
From AWAKE to CNGS Dismantling

- CNGS operated with beam from 2006 until 2012, sending **$1.8 \cdot 10^{20}$ protons on target**.
- Afterwards, all **equipment** in the target chamber was **left in place**.
- Cooling circuits were drained, and ventilation (**humidity control**) and **access** system (**restriction**) remained operational.
- Controlled Radiation Area - **Limited Stay (max 2mSv/h)** with **contamination risk.**
- In 2014, a shielded and airtight **separation wall** was installed upstream of the target.
- The **AWAKE** facility (Proton-driven advanced wakefield experiment) was installed upstream of the wall and ran from 2016-2025 with SPS protons. (see extra slides)
- In 2020, **AWAKE requests the dismantling** and decontamination of the CNGS target area **to install its next phase** in 2027 → CTD project is approved in 2022

CNGS Beam Parameters

- SPS protons of 400GeV/c
- Beam size on target σ~0.5mm
- $5 \cdot 10^{13}$ protons per cycle (6s)





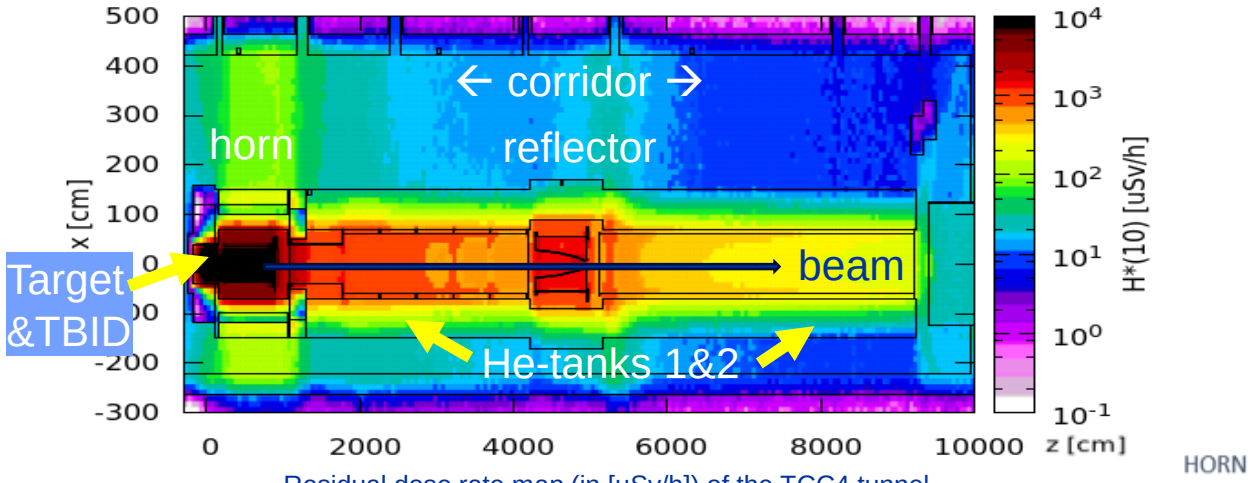
Average residual dose rate in TCC4 corridor over the years (FLUKA)

Key CNGS Target area Dismantling project info

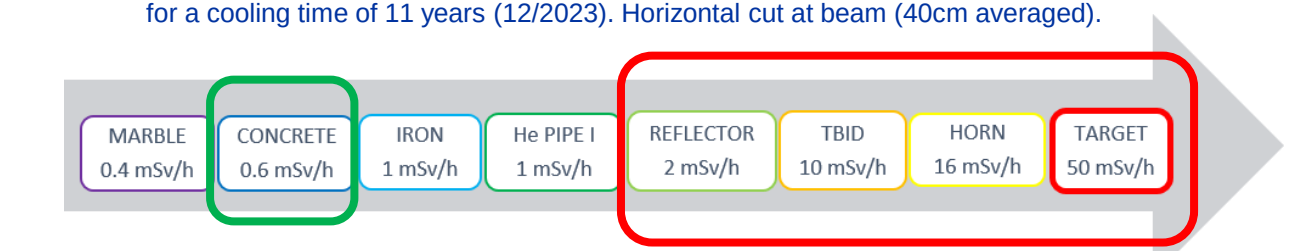
- 9 months dismantling, 2 months cleaning empty tunnel (from Dec 2025 until Nov 2026)
- Dose estimate: ~20p.mSv collective (~1.5mSv max.ind.)
- External company GDES for nuclear dismantling
- Transport and handling by CERN team
- Radiation Protection and waste treatment by CERN team

Target Area Specifics

Dose rate simulations highlight the area's **four high dose rate elements** (designed for remote removal, 2-50mSv/h), and its medium-to-low dose rate shielding blocks and Helium tanks (up to 1mSv/h), including 400m3 of **concrete blocks** (two-thirds of total).

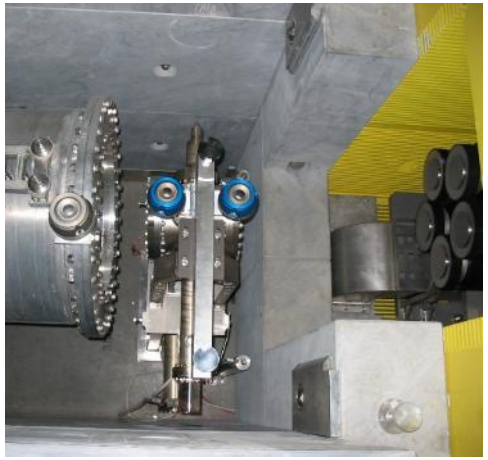


Residual dose rate map (in [µSv/h]) of the TCC4 tunnel
for a cooling time of 11 years (12/2023). Horizontal cut at beam (40cm averaged).



Maximum residual dose rate at contact for the most activated equipment and shielding in 12/2023
(for most irradiated item per equipment type)

Spare target and shielding set up in lab

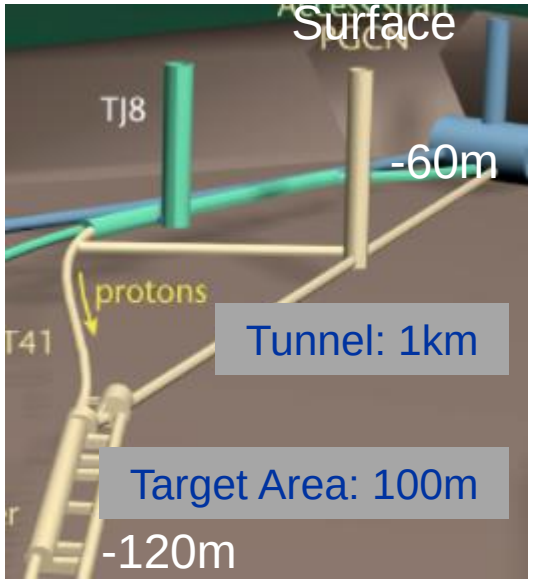


Horn, TBID and target (left to right)

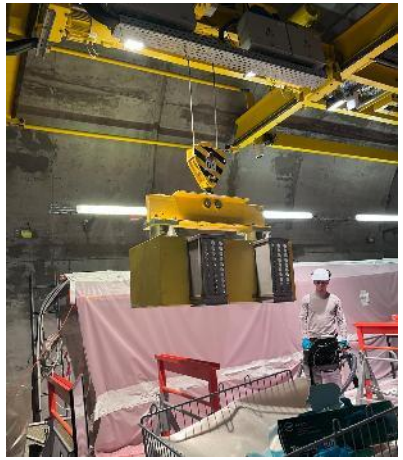
Horn in shielding castle before and after shielding's completion

Target Area Specifics

- 100m-long target area has a **6% slope** → dedicated rack-and-pinion remote-controlled crane (7.5t) with lifting beams
- From the target area, a narrow **1-km long**, 6%-sloped **tunnel** (TAG41) and 60m-deep pit (BB4) lead to the surface
- Large, heavy shielding blocks make up the majority of items to be transported. A shielding block will travel 1.5 hours from its beam position to the surface, with one hour to prepare for the next block → **transport defines schedule**



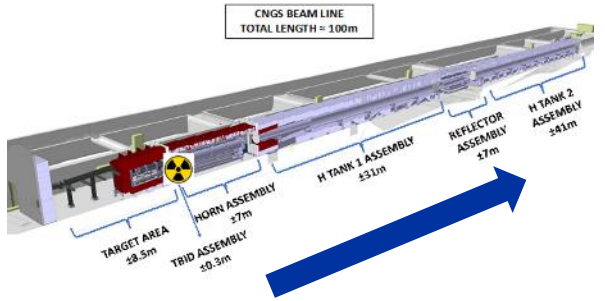
Installation photos 2004

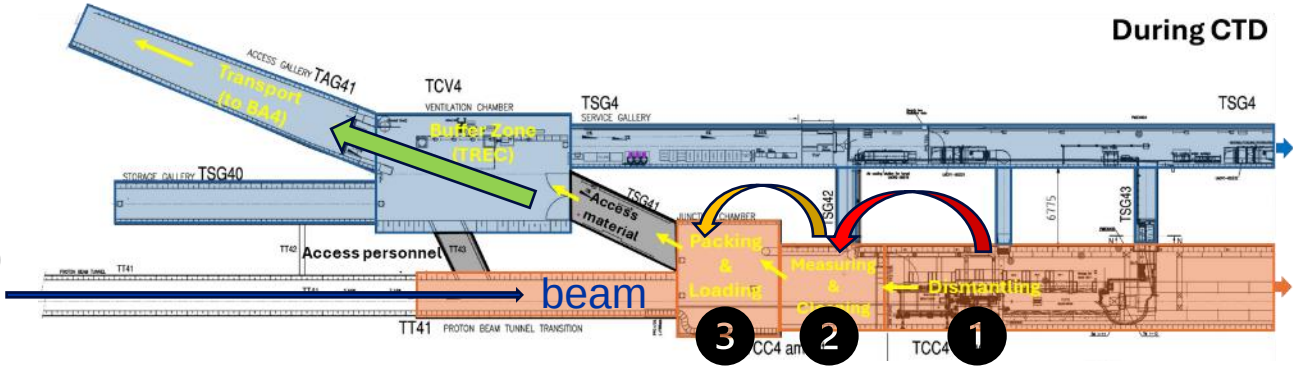


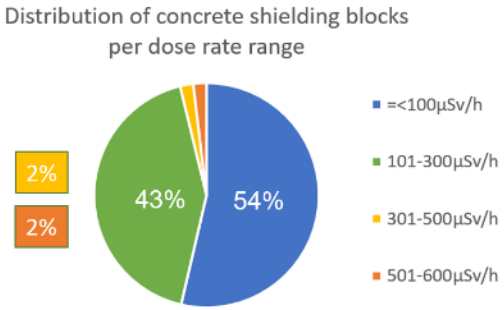
Dismantling photos 2026

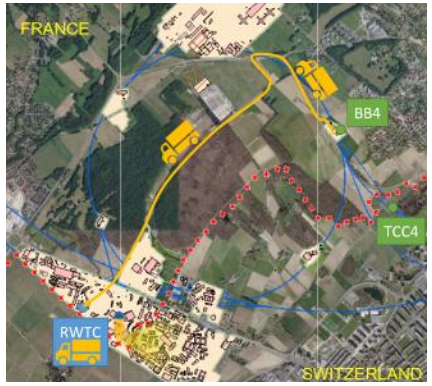
Dismantling Strategy

- (Get approval to start from CERN ALARA committee)
- (Remove AWAKE and separation wall)
- Dismantle from **upstream to downstream** (remove hot spots)
- **Remove** each item from the beamline to TCC4 work area, then **measure, decontaminate, identify and transport** to surface
  - Zone 1: area to be dismantled: high dose rate, high contamination risk
  - Zone 2: measuring & decontamination area: lower dose rate, high contamination risk (wrap if not reasonably decontaminatable)
  - Zone 3: packaging and loading: low dose rate, low contamination risk
  - Rest of path to surface: low dose rate, no contamination risk
- Transport 200m^3 radioactive **waste** (target, horns, He-tanks, blocks, etc.) **on public roads** to CERN Radioactive Waste Treatment Centre for processing, packaging, storage before being sent to final repository
- Keep 400m^3 radioactive **standard concrete blocks** at CERN (**upcycle**)
  - Decontaminate underground, bring to **new surface building**
  - Create inventory to share, store until used elsewhere







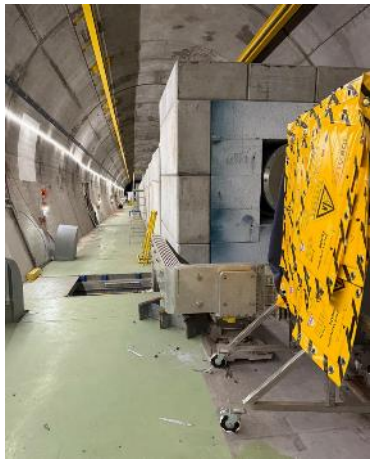


Part 1: Wall Removal & Logistics Set-up (<0.2mSv)

COMPLETED

COMPLETED

- **Separation wall removed** = Start of nuclear dismantling
- Area is currently a Controlled Radiation Area - **High Radiation** (max 100mSv/h) with contamination risk.
- Vinyl on floor in zones 2 & 3 for easy & regular decontamination of floor
- Airlock for material passage & separate personnel passage (overshoes, gloves)
- Remote is handling system is tested and dismantling equipment is ready.
- Local shielding is ready (mobile structures with lead curtains).

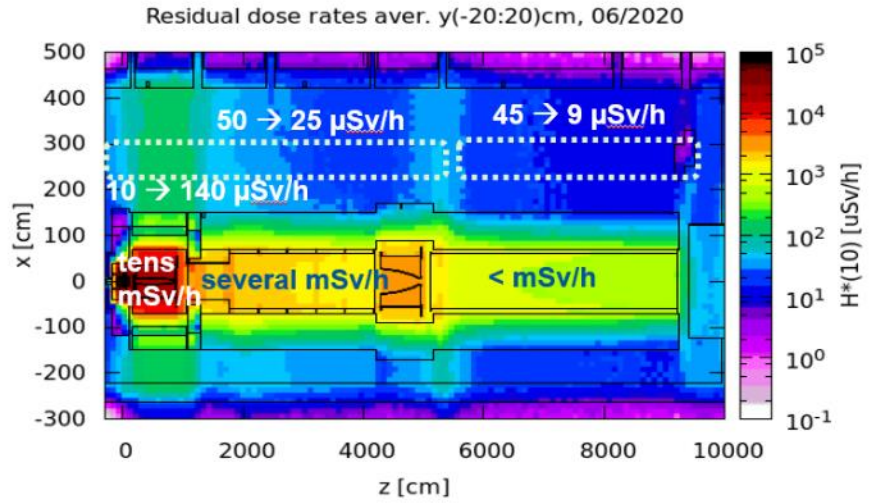


Part 2: Target Removal (up to 50mSv/h)

COMPLETED

Went well and (mostly) as planned. Also:

- Discovery 2 months prior: old picture shows small cable tray sticking out – was not on any drawing!
  The target would not fit in container without removing it.
- Tests with CERN robot Teodor on clean mock-up to confirm feasibility of cutting with robot.
- **Opportunity**: tested whether robot can also measure dose rate and swab for contamination check → useful for other dismantling projects



Part 3: TBID and Horn Removal (~20mSv/h)

COMPLETED

Ongoing

TBID removal went very well.

Horn: several challenges and lessons learnt:

- 7-m long, 2-m wide, radioactive **horn** needs **shielded container** for dose reduction and contamination containment (as does target), but this does not easily (ALARA) pass through **narrowest part of tunnel**.

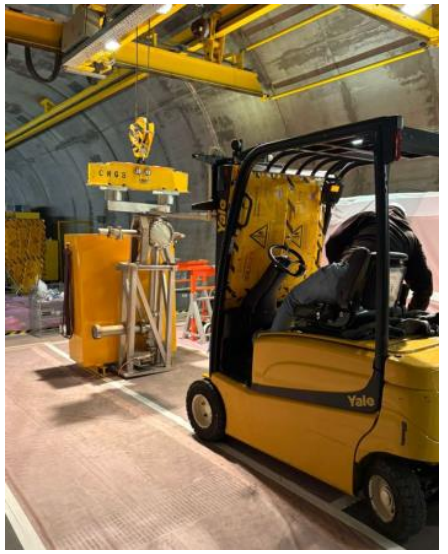
  → **Perform empty container transport tests** to find a quick (minimal dose) transport through. **Remove container lid** in tunnel, add light cover. **Test first with lower-dose** element (reflector, same size).

Lesson: Ensure (design+later) enough space for removal in large container

- **Marble** shielding blocks were ordered with “unpolished surface”, which is **difficult to decontaminate** by vacuum cleaner or wipes (porous). All **concrete** blocks have a porous surface. → **wrap blocks**

  → **Develop and use a new** decontamination procedure for the **concrete** blocks (**fix contamination),** marble blocks stay wrapped.

Lesson: Polish or paint shielding blocks for easier future decontamination; foresee different decontamination methods



Other Observations

Ongoing

Transport on public roads for radioactive waste items

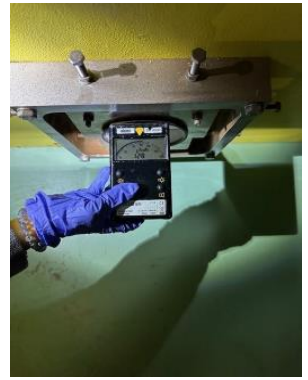
- The surface building is also a very short-term buffer zone for waste items before transport to the waste
- We planned for high-dose rate items to immediately be placed in the truck when arriving at the surface
- **Preparation before transport** (documentation, measurements) **takes longer** than anticipated
  - takes more space/time in surface building → we will increase external shielding to allow higher pile-up
  - more handling of radioactive items → more dose to personnel → dose estimate update

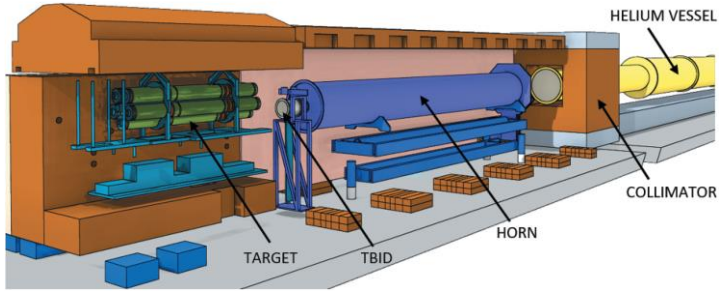
Other Observations

Ongoing

Simulations and measurements versus real values

- Most high-dose-rate and contamination-prone locations (inside shielding, target and horns) were unreachable before dismantling started.
- **Simulation results were validated with measurements** where possible, e.g. by removing the target roof shielding remotely and measuring inside the target shielding castle → **a good agreement** (dose rate) simulation/measurement.
- Still, **dose rates and contamination levels** of many (medium-dose-rate) items are **higher than expected**, → more dose to personnel → dose estimate update

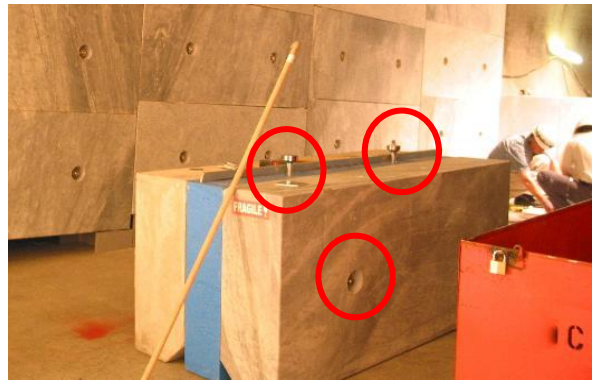




However,

Granularity of Monte Carlo **simulations** is limited & exact **chemical material composition** is not always known. Effect is larger for “more ALARA” design.

- For example, the clamping rods (and lifting points) of shielding blocks were not modelled, while their isotopes dominate the block’s dose rate. A more detailed simulation model (but this may not be feasible!) would have helped.
- Even if the rods, lifting points, flanges, bolts, etc. had been modelled, the exact content of additives (% Si, Mn, P, S, Co) can vary within the standard. Samples taken at the installation phase would have helped.



Other Observations

Ongoing

Preparation and coordination of on-site works

- Nuclear dismantling is not CERN's expertise
  → Having a **specialised nuclear dismantling contractor** is necessary.
- The contractor was included early on in the CERN environment and RP practises
  → Excellent collaboration with other teams and large adaptability
- On-site, three teams work together (nuclear dismantling, CERN handling and transport and CERN RP). Coordination by CERN staff hired for CTD.
  → Works very well.
- Twice a week on-site meetings, Weekly reports, **Daily dose follow-up.**
  → Works very well

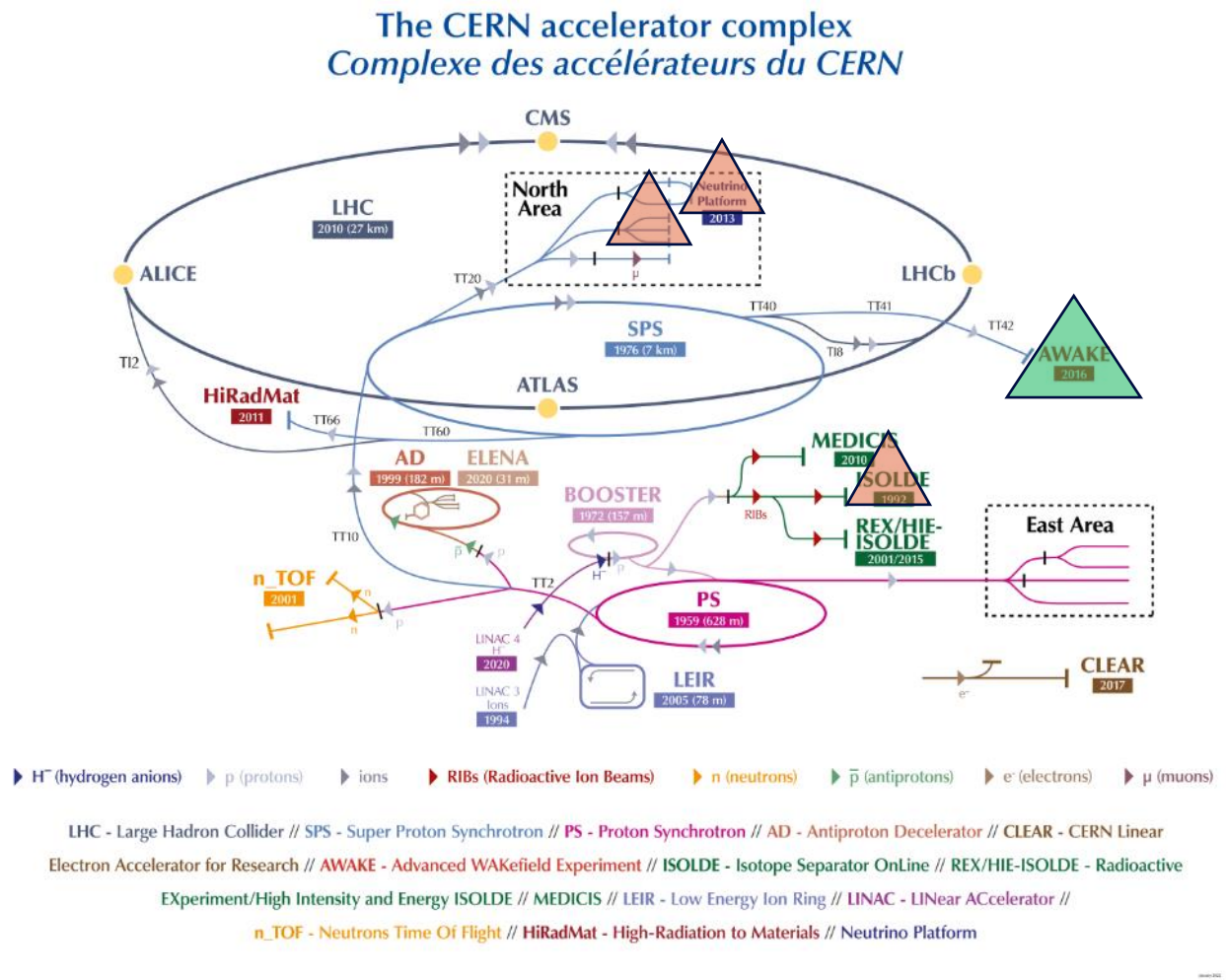
Continuous optimisation, flexibility and awareness

- Even though CNGS-era documentation was available and several CNGS experts were still at CERN, we still had **many unknowns and surprises**.
  → need **flexibility**
- Even though processes were defined in detail, **several adaptations** and more optimisation were needed, e.g. horn transport or decontamination methods.
  → need **continuous optimisation**
- Occasionally, complacency led to more dose taken than needed
  → need **continuous awareness**

Sharing of "what we did, what worked and what didn't" is key

Complete feedback documents will be compiled and shared at a more advanced stage → to be continued

CERN 2026-2030 Long Shutdown (LS3)



1. Machine consolidation and upgrade (C&U)

- Upgrade High Luminosity LHC, see also Simon's presentation:

Engineering developments for the dismantling of the LHC cryogenic distribution line *Simon Barrière*

- Consolidation of injector complex

2. Experimental facilities C&U, including for

- ISOLDE: nuclear dismantling of 50-year-old beam dumps and installation of new beam dumps.
- NACONS – TCC2: nuclear dismantling, followed by installation of new elements and infrastructure
- HI-ECN3 – TCC8: nuclear dismantling followed by installation of new facility, see also Fernando's poster flash talk:

HI-ECN3 dismantling and installation strategy *Fernando Pedrosa*

Importance of synergy and transparency to reduce dose

- The **company** hired for CTD (GDES) and the CERN experts are **also** involved in the **dismantling of the other areas**
- All CTD **procedures, tools, and lessons** learnt are **shared** regularly with other project teams
- Other teams visit the CTD site to better plan their own
- CTD will have an **extensive feedback document**, to be **shared and presented** in different committees and meetings

Summary

- CNGS was **designed** with nuclear dismantling in mind, and was well documented.
- The CTD **preparation** combined CERN and external expert knowledge.
- CTD built a new shielded **surface building** to be used as a buffer zone and storage area.
- CTD **started Dec 2025**, to remove 600m^3 of radioactive items, where one third becomes waste, and the rest is stored for CERN-wide reuse
- **Status** May 2026: Most high-dose-rate elements and many shielding blocks were successfully removed.
- **First lessons** learnt are shown and shared, also for CERN's many upcoming nuclear dismantling activities

Extra slides: AWAKE

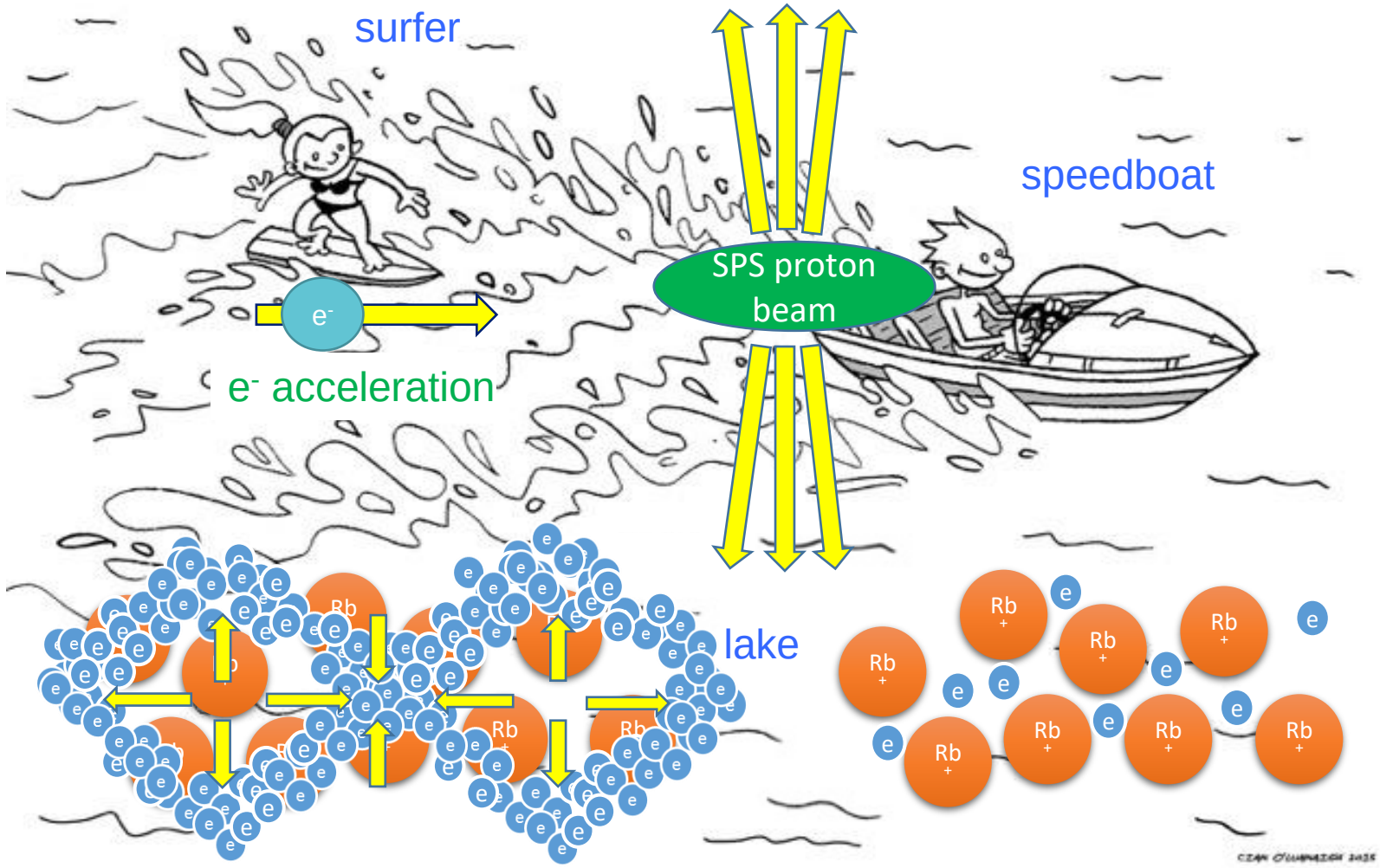
Why dismantle now? AWAKE

Wakefield acceleration is a novel, **more compact** and **fully scalable** way to **accelerate particles.**

In AWAKE (cern.ch/awake):

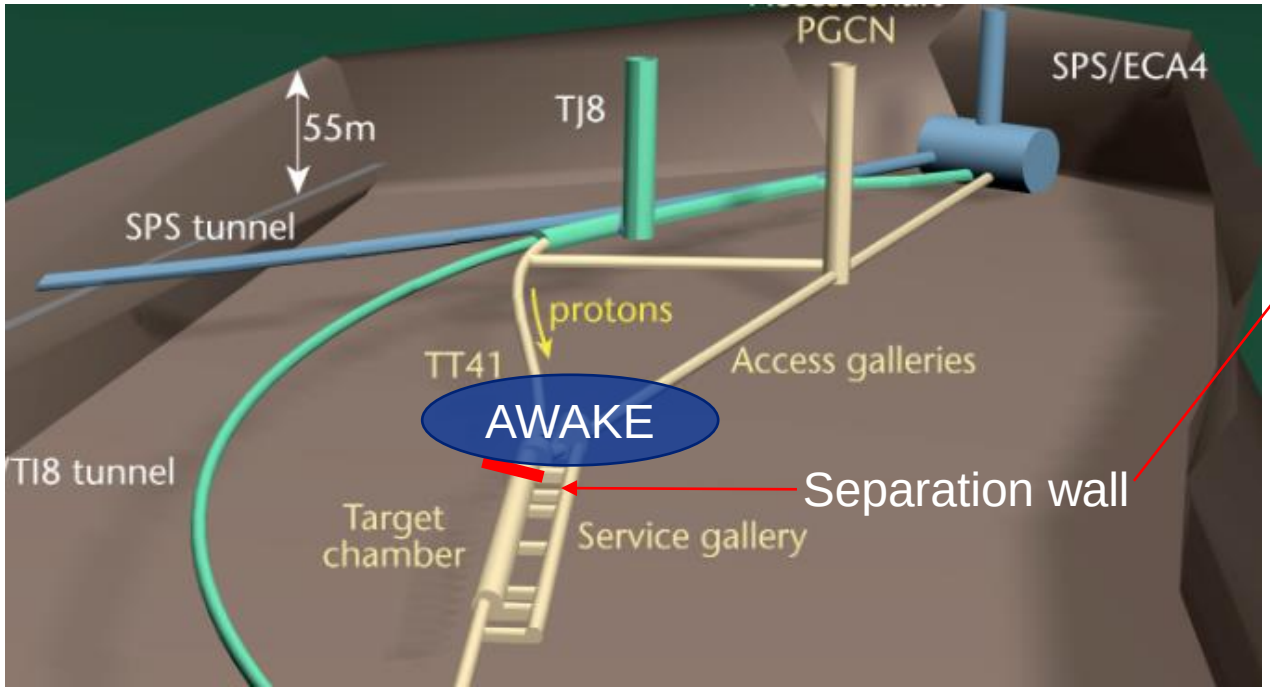
A **speedboat** (SPS protons) creates (electrostatic) waves in a **lake** (ionised gas/plasma). **Surfers** (electrons) are injected and accelerate on the waves.

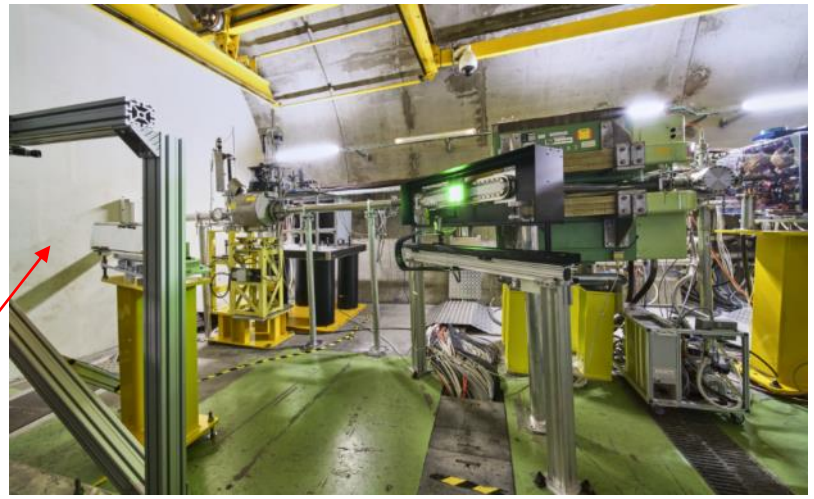
AWAKE is the only proton-driven plasma wakefield experiment worldwide, **starting with a 10-m plasma cell**, but **continuing with longer** plasma cells of various types.



AWAKE: Advanced Wakefield Experiment

In 2013, a separation wall was built just upstream of the CNGS target. **AWAKE** was **installed upstream** of the wall.





AWAKE facility, with separation wall to CNGS target area on the left

AWAKE: Advanced Wakefield Experiment

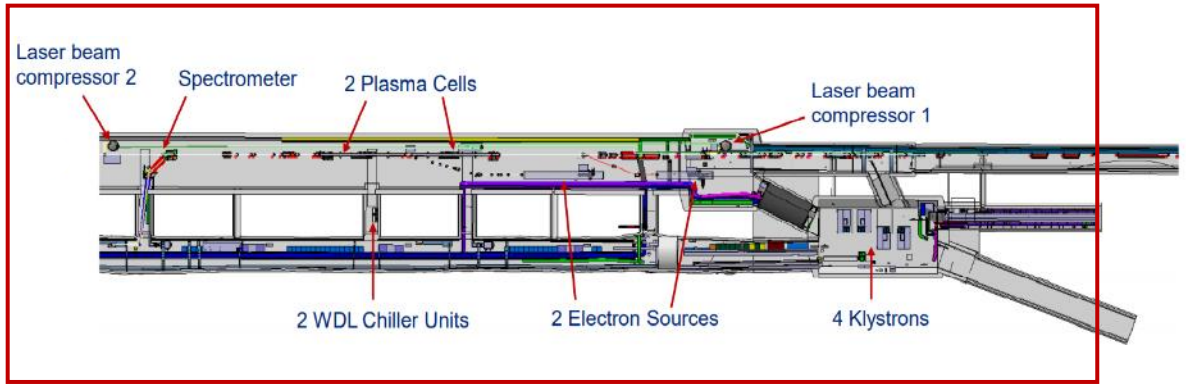
In 2013, a separation wall was built just upstream of the CNGS target. **AWAKE** was **installed upstream** of the wall.

From 2016 on, the AWAKE facility has been operational, **showing electron acceleration** in a 10-m plasma cell.

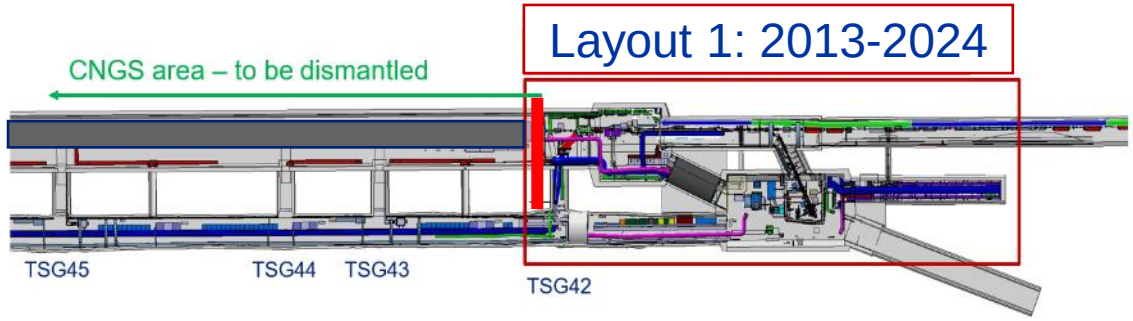
To increase the quality of the accelerated electron beam and to prove scalability of the concept, **AWAKE must expand**, requiring the **full dismantling of the 100m-long CNGS target area.**

AWAKE facility, with separation wall to CNGS target area on the left

Layout 2: from 2028



Layout 1: 2013-2024



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