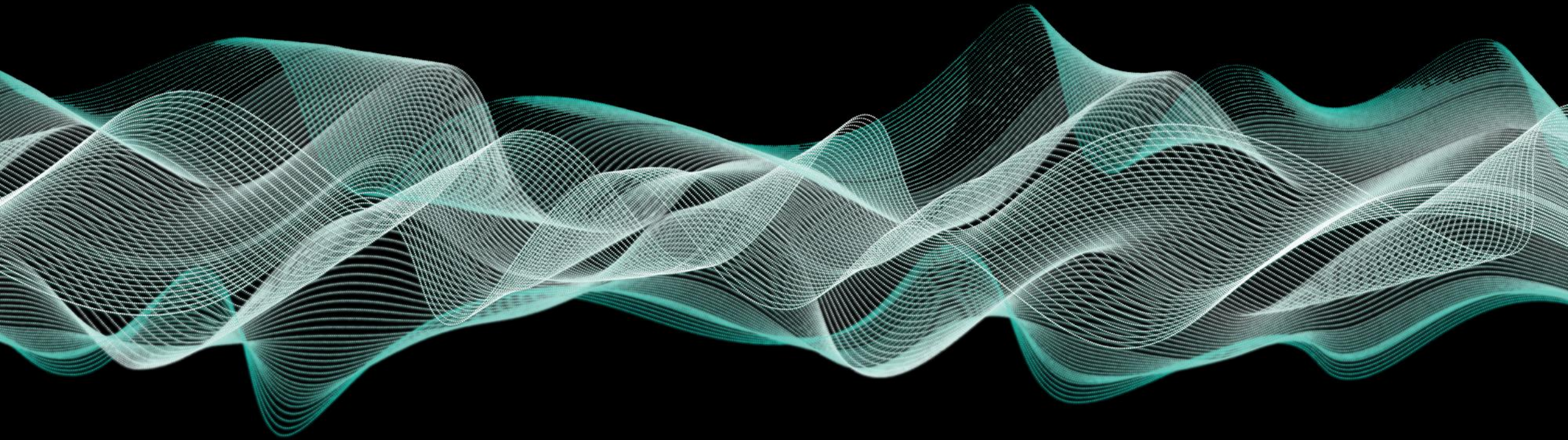


Implementation study for an O(100m) AI at CERN

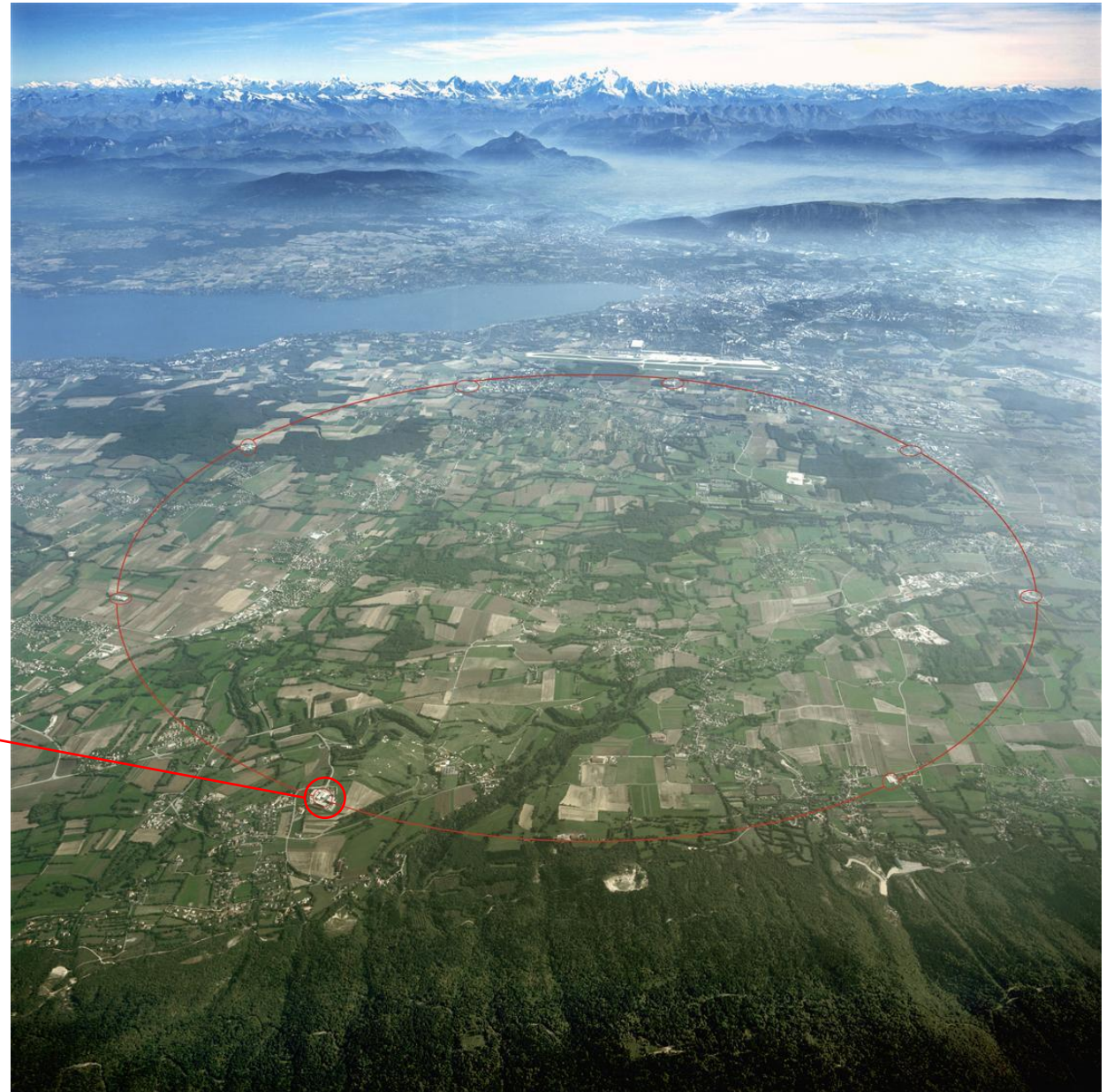


Sergio Calatroni on behalf of the CERN PBC team

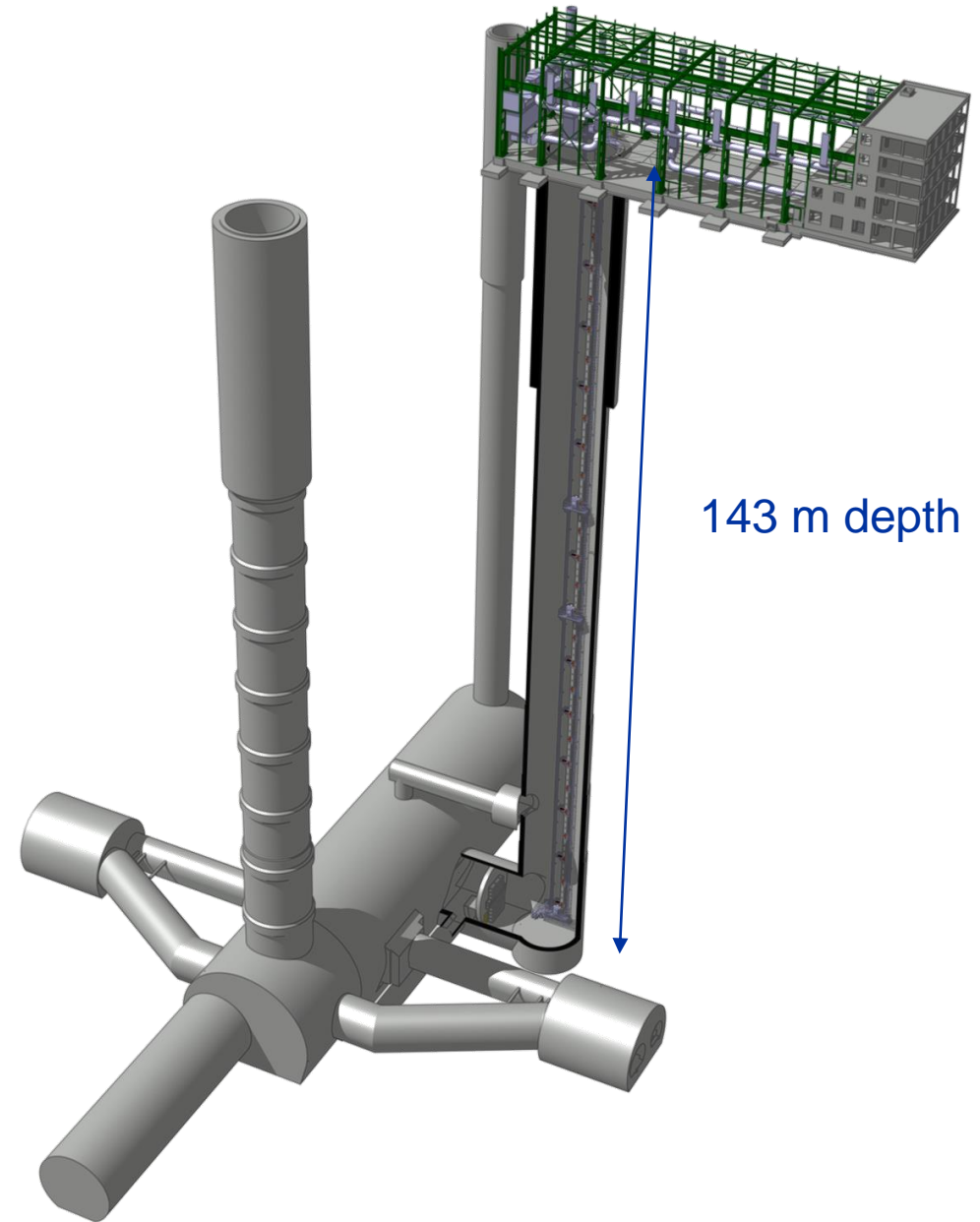
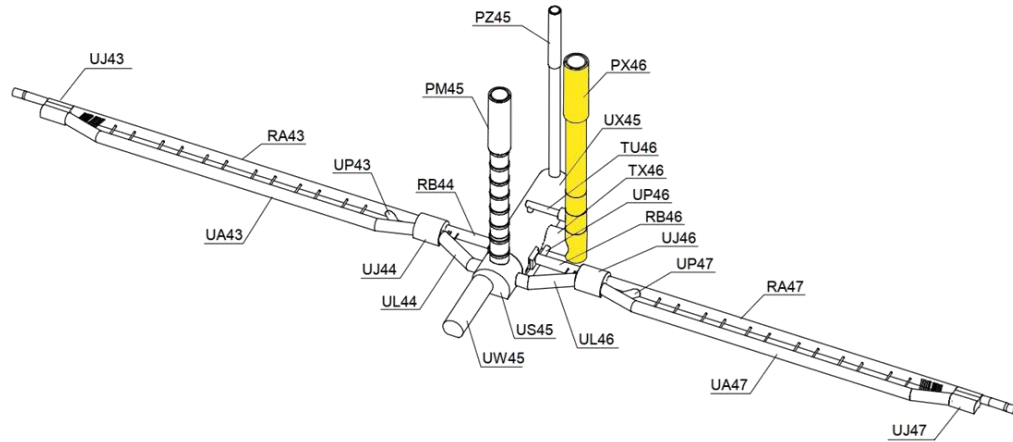
**G. Arduini, O. Buchmueller, T.A. Bud, O. Crespo-Lopez, A. Devienne, J. Ellis,
T. Hakulinen, A. Infantino, D. Lafarge, A.P. Marion**



CERN: the LHC Point 4

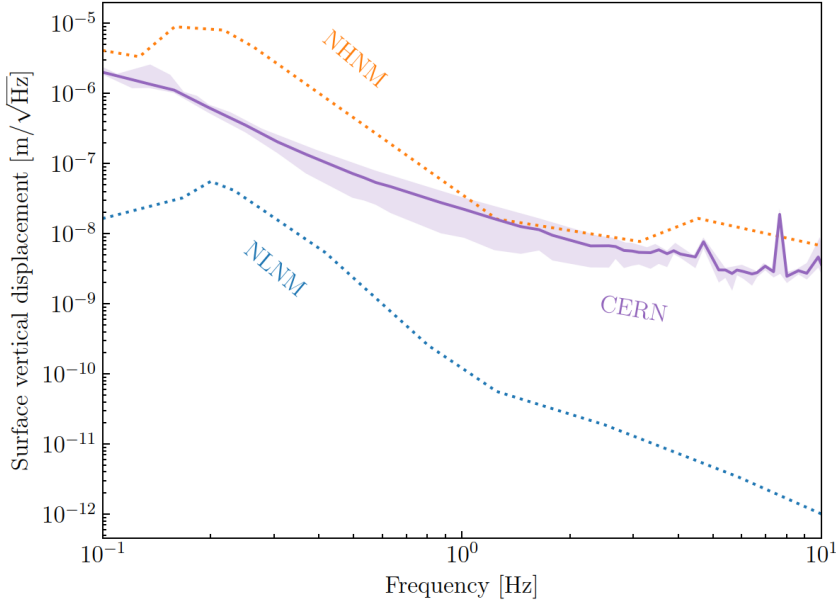
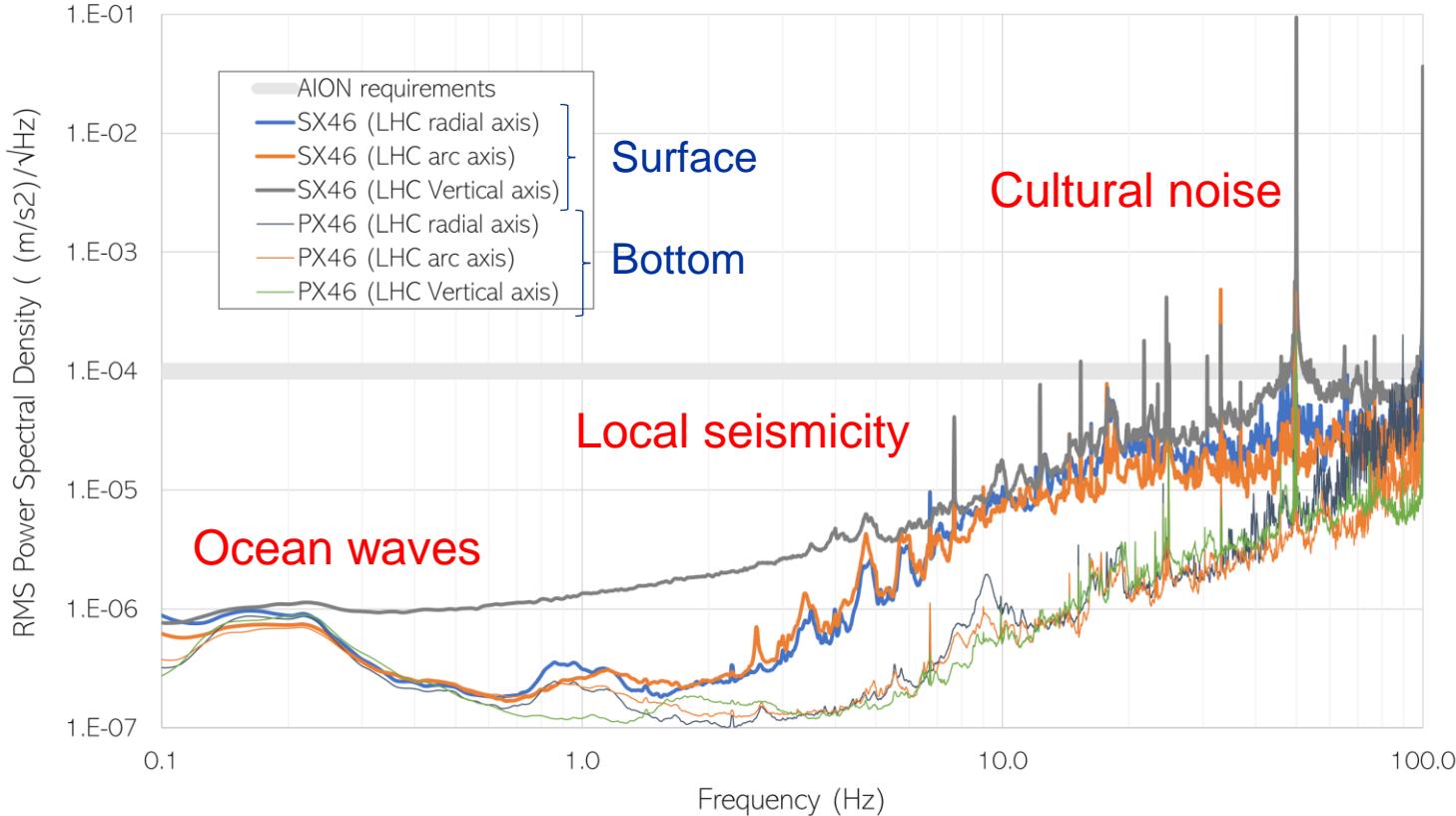


CERN: the LHC Point 4. The PX46 access shaft



Vibrations and seismic noise

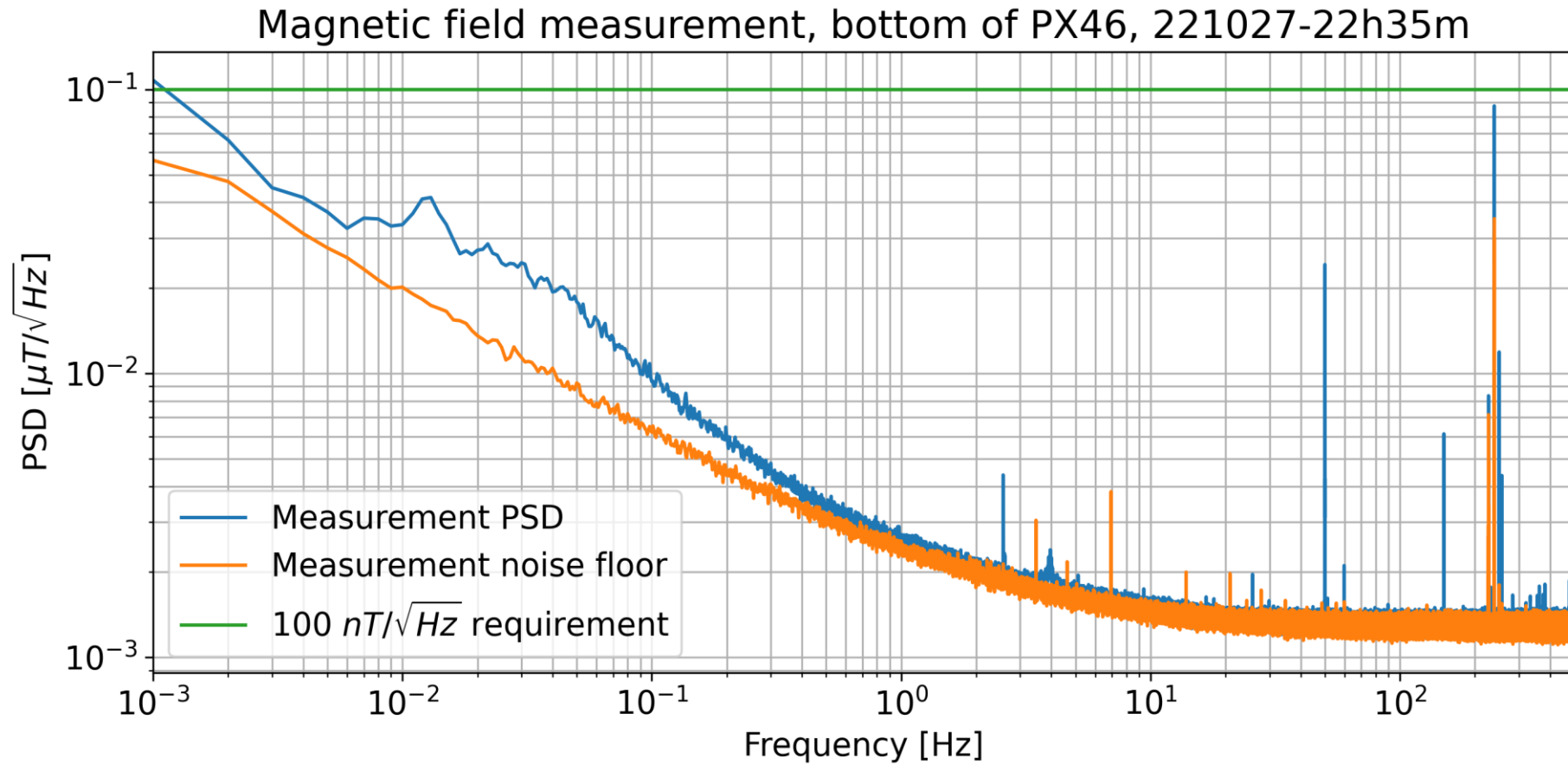
PX46 / SX46 Ground motion overview



RMS power spectral density (time block 64s, averaged over the worst day)

✓ Measured values within acceptable limits

EM noise



Power spectral density low-frequency magnetic field measurement

✓ Measured values within acceptable limits

From feasibility study to implementation study



CERN-PBC Report-2023-002

A Long-Baseline Atom Interferometer at CERN: Conceptual Feasibility Study

G. Arduini^{1,}, L. Badurina², K. Balazs¹, C. Baynham³, O. Buchmueller^{3,4,*}, M. Buzio¹, S. Calatroni^{1,*}, J.-P. Corso¹, J. Ellis^{1,2,*}, Ch. Gaignant¹, M. Guinchard¹, T. Hakulinen¹, R. Hobson³, A. Infantino¹, D. Lafarge¹, R. Langlois¹, C. Marcel¹, J. Mitchell⁵, M. Parodi¹, M. Pentella¹, D. Valuch¹, H. Vincke¹*

¹ CERN, ² King's College London, ³ Imperial College London, ⁴ University of Oxford,
⁵ University of Cambridge
* Editors

Abstract

We present results from exploratory studies, supported by the Physics Beyond Colliders (PBC) Study Group, of the suitability of a CERN site and its infrastructure for hosting a vertical atom interferometer (AI) with a baseline of about 100 m. We first review the scientific motivations for such an experiment to search for ultralight dark matter and measure gravitational waves, and then outline the general technical requirements for such an atom interferometer, using the AION-100 project as an example. We present a possible CERN site in the PX46 access shaft to the Large Hadron Collider (LHC), including the motivations for this choice and a description of its infrastructure. We then assess its compliance with the technical requirements of such an experiment and what upgrades may be needed. We analyse issues related to the proximity of the LHC machine and its ancillary hardware and present a preliminary safety analysis and the required mitigation measures and infrastructure modifications. In conclusion, we identify primary cost drivers and describe constraints on the experimental installation and operation schedules arising from LHC operation. We find no technical obstacles: the CERN site is a very promising location for an AI experiment with a vertical baseline of about 100 m.

Geneva, Switzerland
March 30, 2023

<https://cds.cern.ch/record/2851946>



CERN-PBC Report-2025-004

A Long-Baseline Atom Interferometer at CERN LHC Point 4: Implementation Study

G. Arduini¹, O. Buchmueller^{2,3}, T.A. Bud¹, S. Calatroni^{1,}, O. Crespo-Lopez¹, A. Devienne¹, J. Ellis^{1,4}, T. Hakulinen¹, A. Infantino¹, D. Lafarge¹, A.P. Marion¹*

¹ CERN, ² Imperial College London, ³ University of Oxford, ⁴ King's College London
* Editor

Abstract

Building on the feasibility study in [1], this report supported by the Physics Beyond Colliders (PBC) Study Group describes the technical implementation of modifications to the PX46 shaft at LHC Point 4 during LS3 (June 2026 – June 2030) that would enable it to accommodate the installation and operation of a vertical long-baseline Atom Interferometer during Run 4 without affecting LHC operations. We specify in detail the necessary civil-engineering work, installation of bespoke radiation shielding, deployment of access-control systems and safety alarms, and design of a mobile elevator platform. Our comprehensive technical assessment identifies no fundamental obstacles or showstoppers to implementation. Refined cost estimates and a critical-path schedule confirm that, from formal approval, all interventions can be completed within a 1.5-year window. These preparations would ensure seamless, concurrent operation of the Atom Interferometer experiment and the HL-LHC, with all technical challenges successfully addressed through established engineering solutions.

Geneva, Switzerland
August 12, 2025

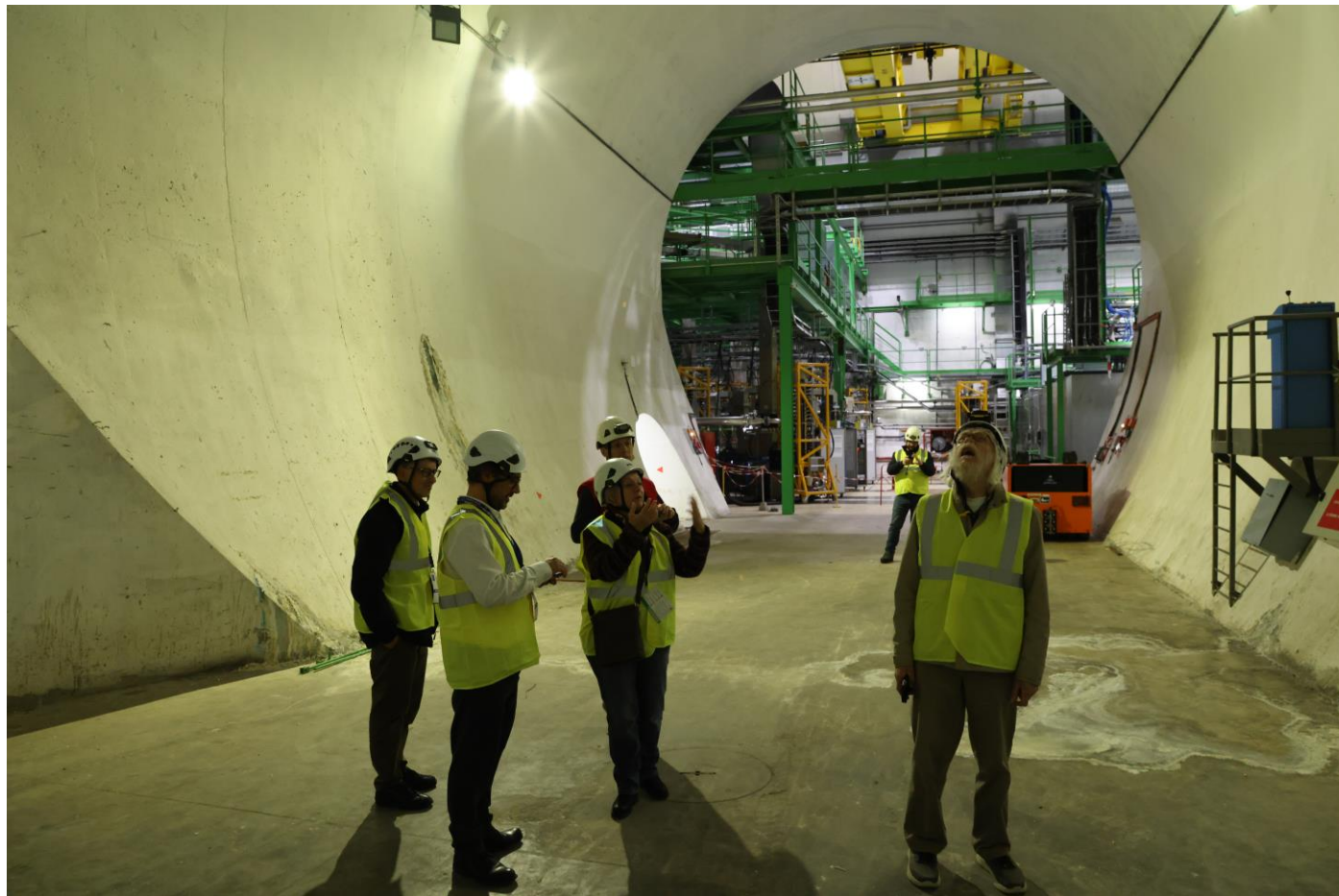
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Motivation

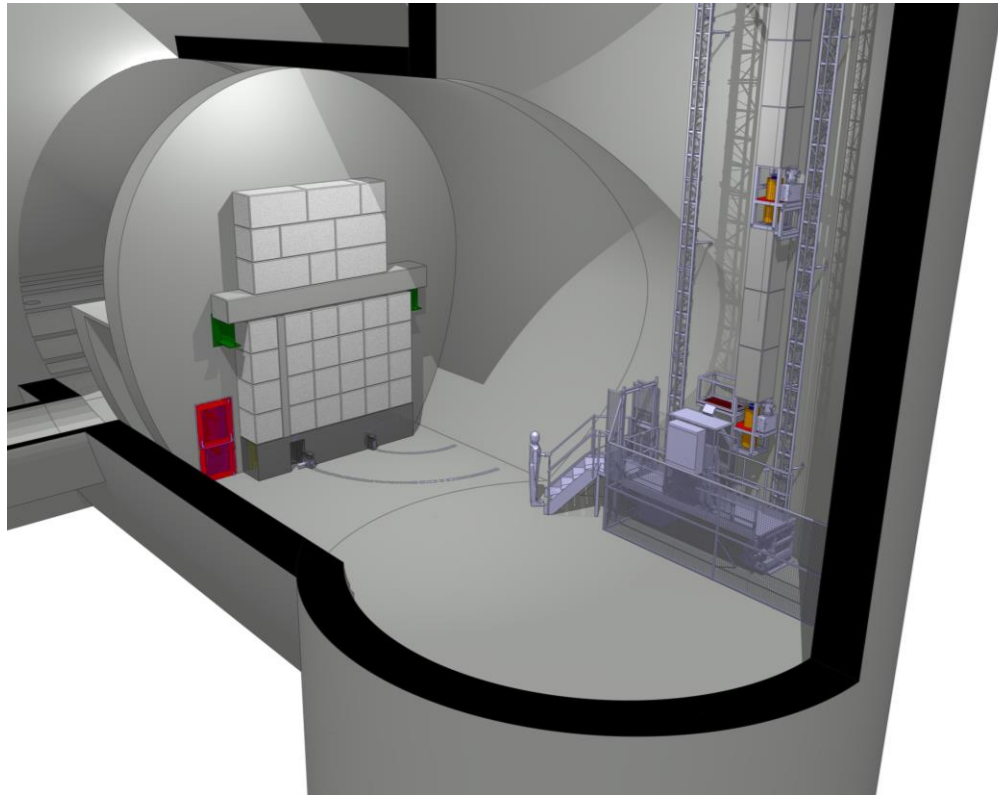
- We had identified the **PX46 LHC access shaft** as potential location for an **O(100m) AI**
 - Environmental conditions well adapted for an AI, all needed utilities already available on-site
- A physical separation of PX46 from the LHC would allow access 24h/25 - 365d/year to an AI experiment even during LHC operations
 - LHC environment **does not have a significant impact on safety**, provided some measures are taken: radiation shielding wall, appropriate escape routes, access control system.
- We have refined the study to **precisely define the engineering details, cost and technical schedule** for performing the necessary works
- Most important, we wanted to **verify whether the works fit in the planned schedule of the coming Long Shutdown #3 (LS3) of the LHC**, foreseen from mid-2026 to mid-2030

View of PX46

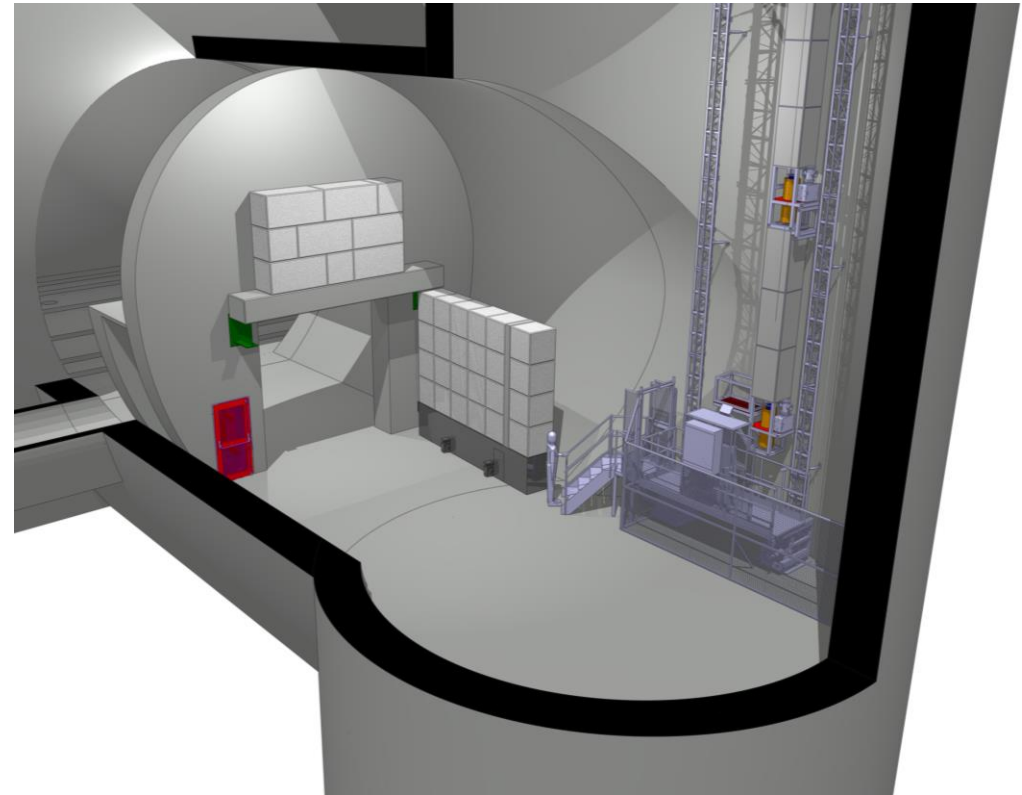


Detailed shielding wall layout - I

Closed door – experiment accessible to operators from top (elevator)

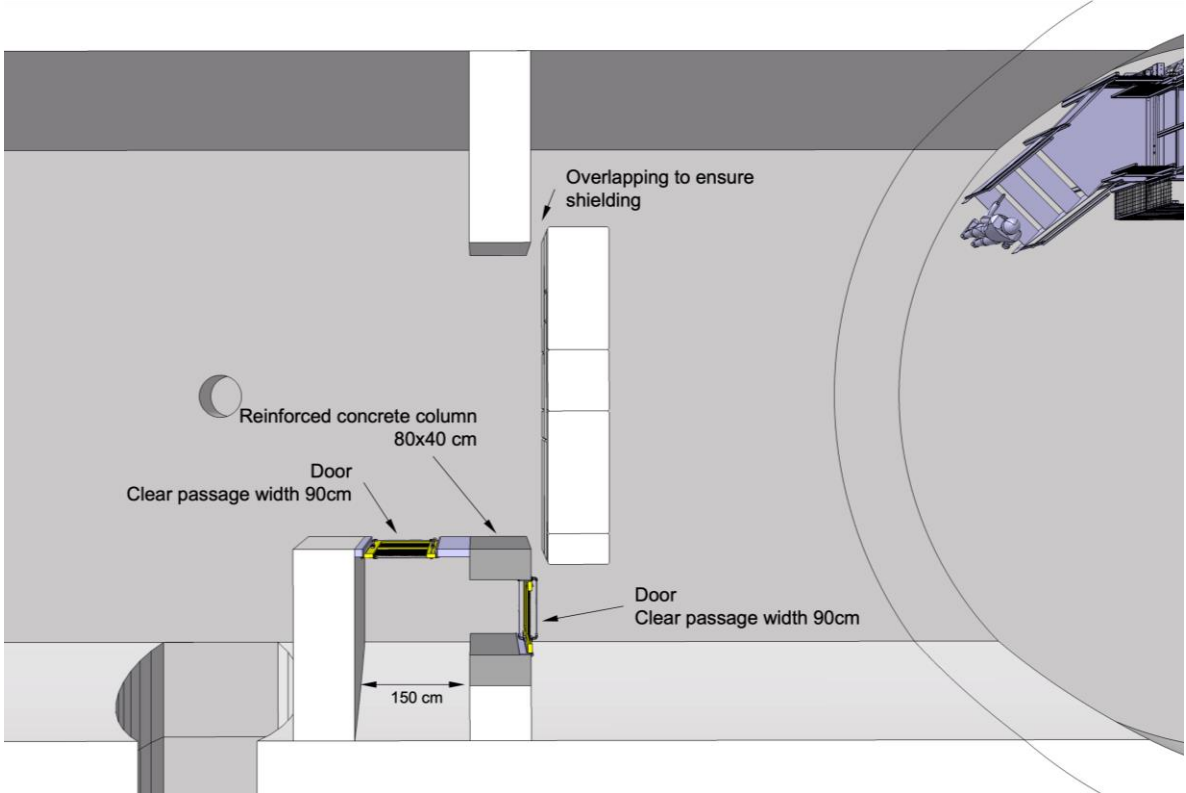
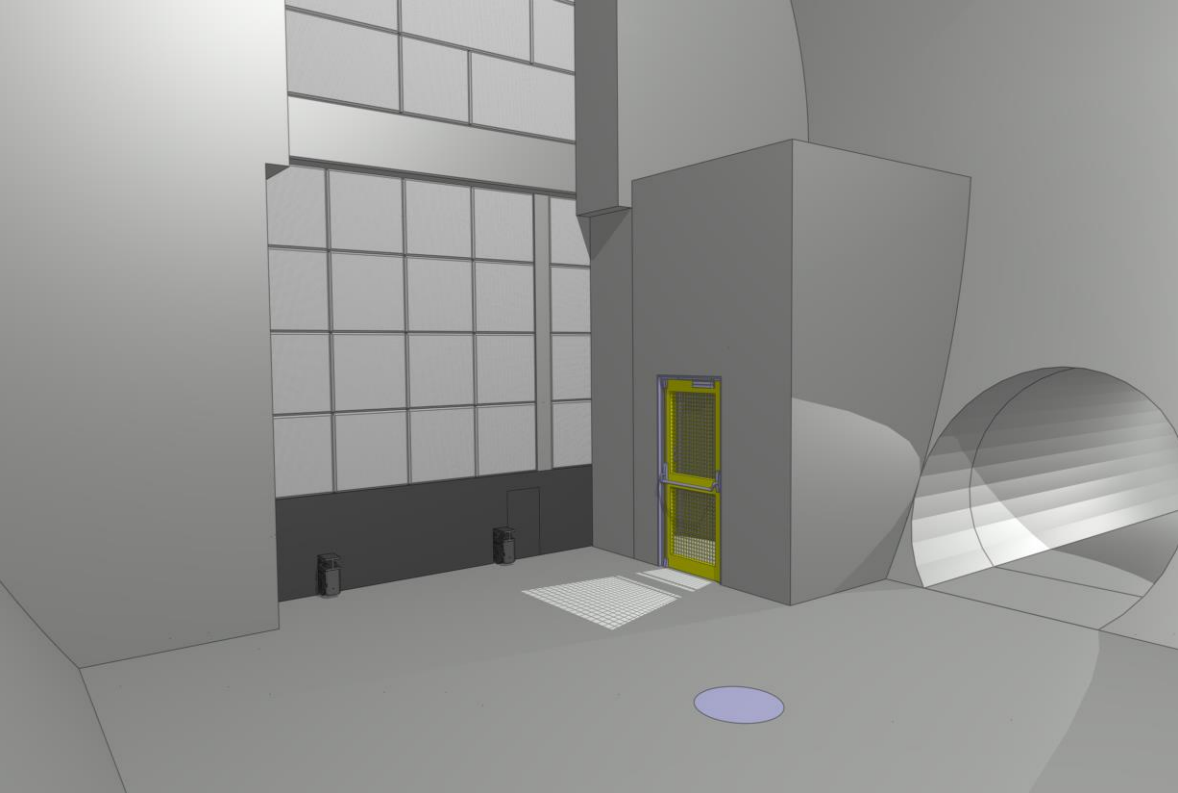


Open door – for transport of heavy LHC equipment

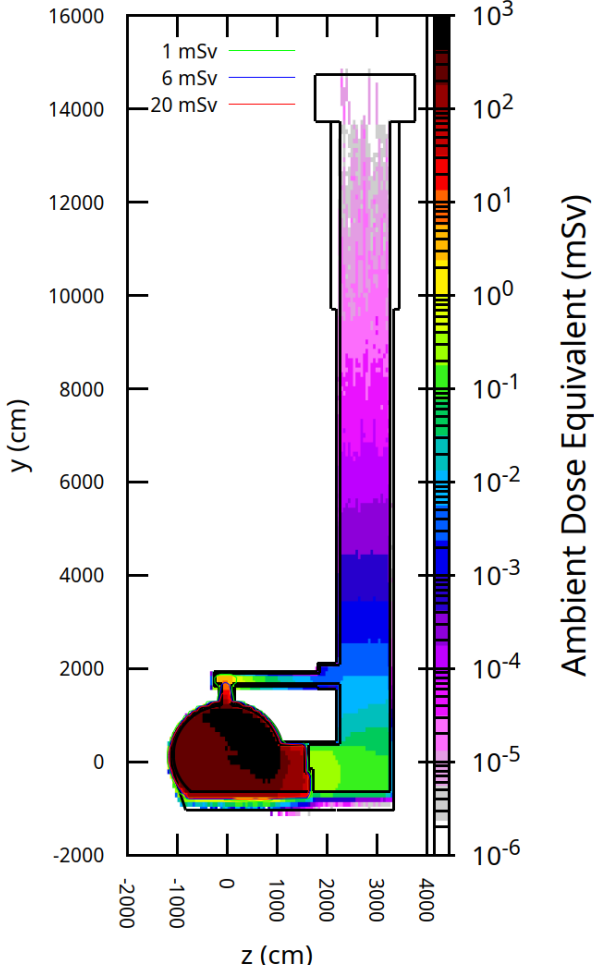
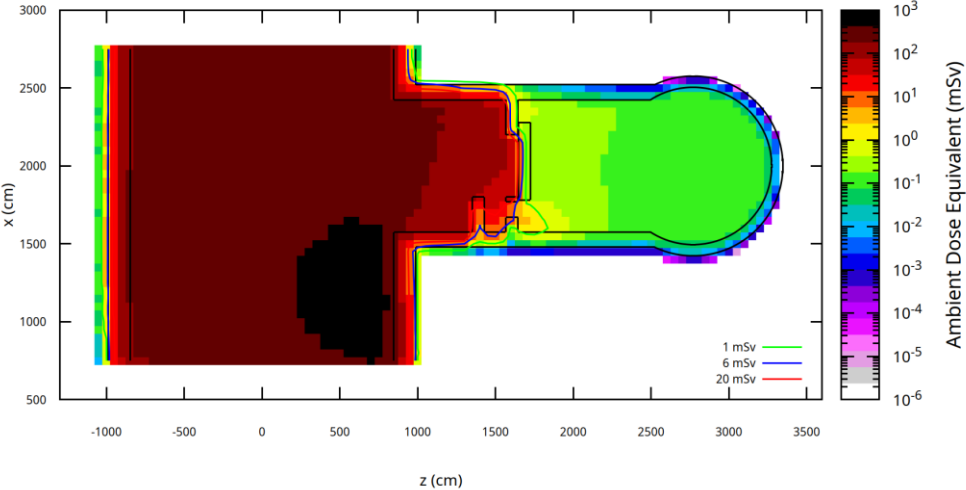


Detailed shielding wall layout - II

Chicane and door to the UX45 cavern 2D schematic view



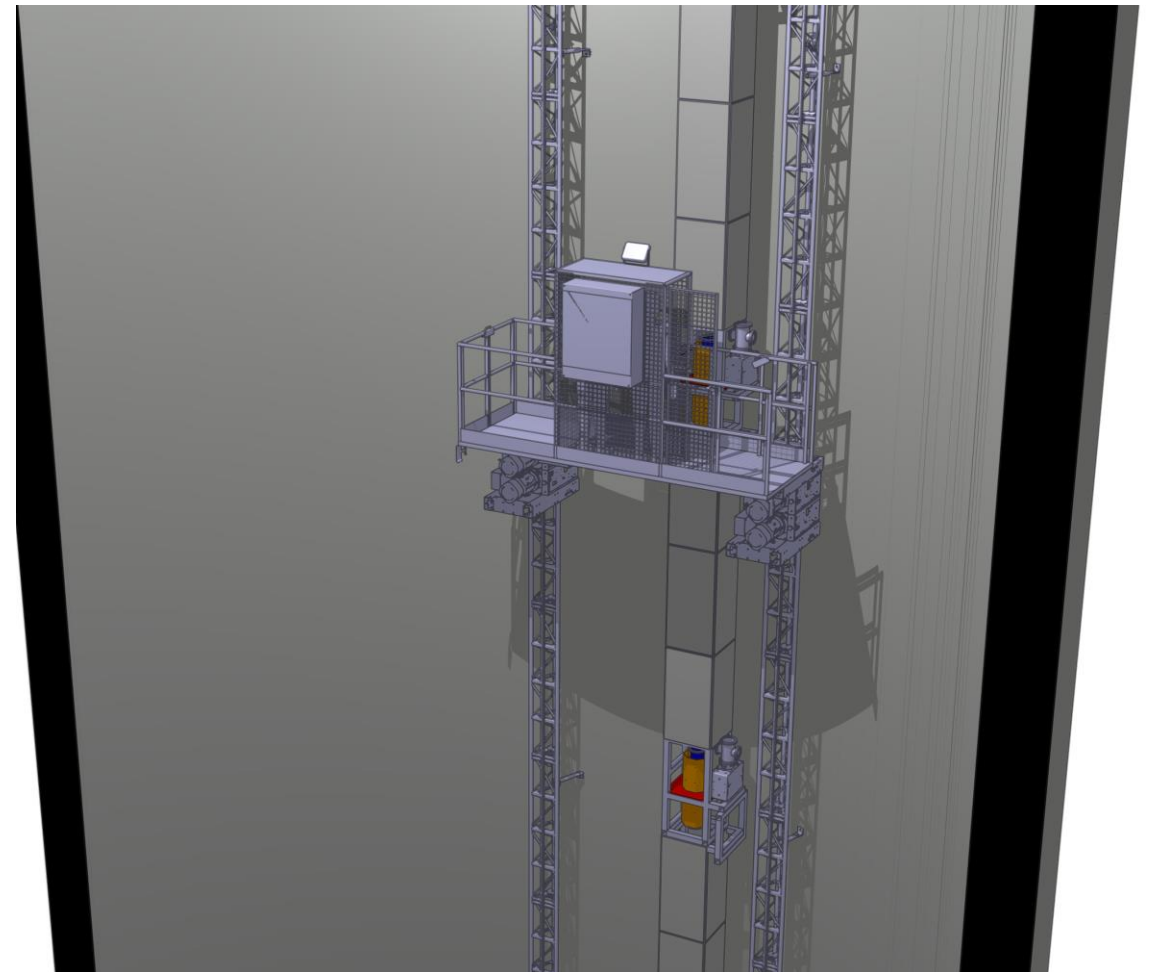
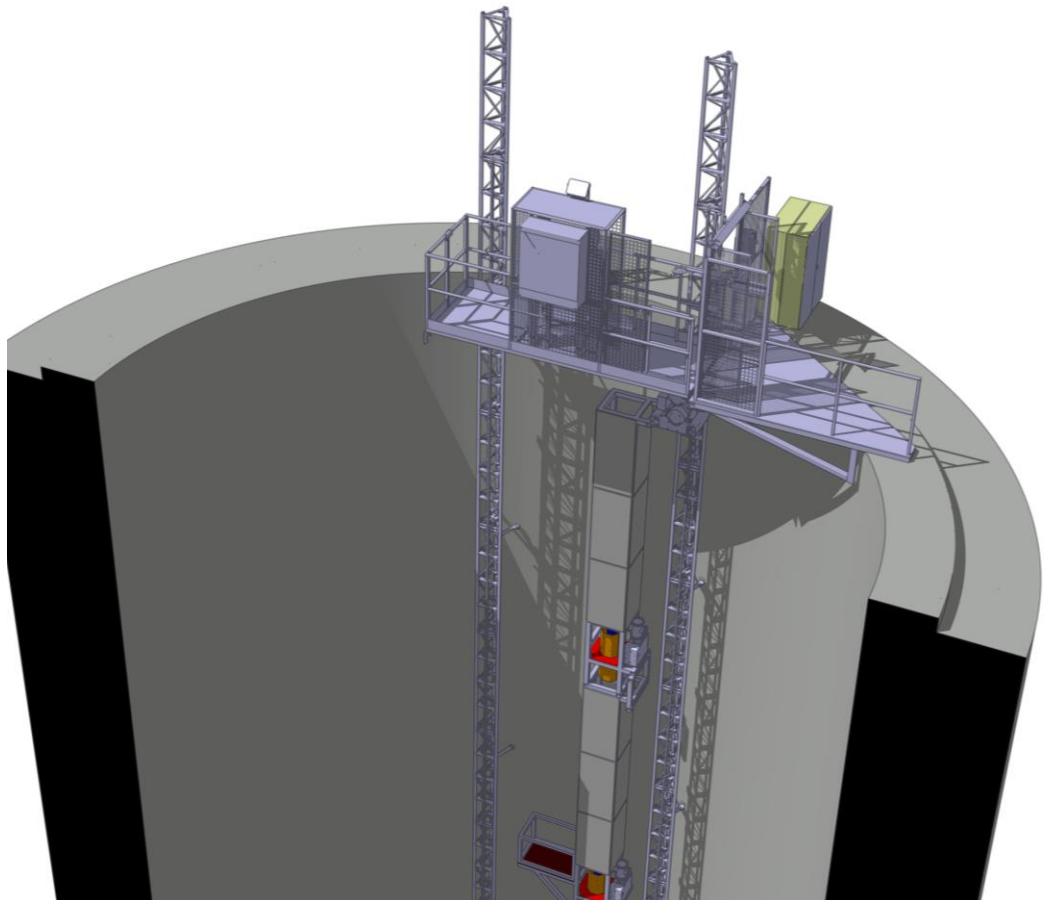
Radiation levels in case of beam loss



	Area classification	Dose limit	Ambient dose equivalent rate		Specific airborne radioactivity	Specific surface contamination	Access, Personnel categories	Monitoring, Personal dosimetry
			At permanent workplaces	In low-occupancy areas				
	Non-designated Area	1 mSv / y	< 0.5 $\mu\text{Sv h}^{-1}$	< 2.5 $\mu\text{Sv h}^{-1}$	0.05 CA	-	no restriction, all	passive or active, not required
	Supervised Radiation Area	6 mSv / y	< 3 $\mu\text{Sv h}^{-1}$	< 15 $\mu\text{Sv h}^{-1}$	< 0.1 CA		supervised, radiation workers and VCT	passive or active, personal dosimeter
Controlled Radiation Area	Simple Controlled Radiation Area	20 mSv / y	< 10 $\mu\text{Sv h}^{-1}$	< 50 $\mu\text{Sv h}^{-1}$	< 0.1 CA			active, personal dosimeter
	Limited Stay Area			< 2 mSv h ⁻¹	< 100 CA	< 4000 CS	controlled, radiation workers	active, personal dosimeter and operational dosimeter
	High Radiation Area			< 100 mSv h ⁻¹	< 1000 CA	< 40000 CS		
	Prohibited Area			> 100 mSv h ⁻¹	> 1000 CA	> 40000 CS		

Local background dose ~0.5 mSv/y

Elevator platform



Opening on the top

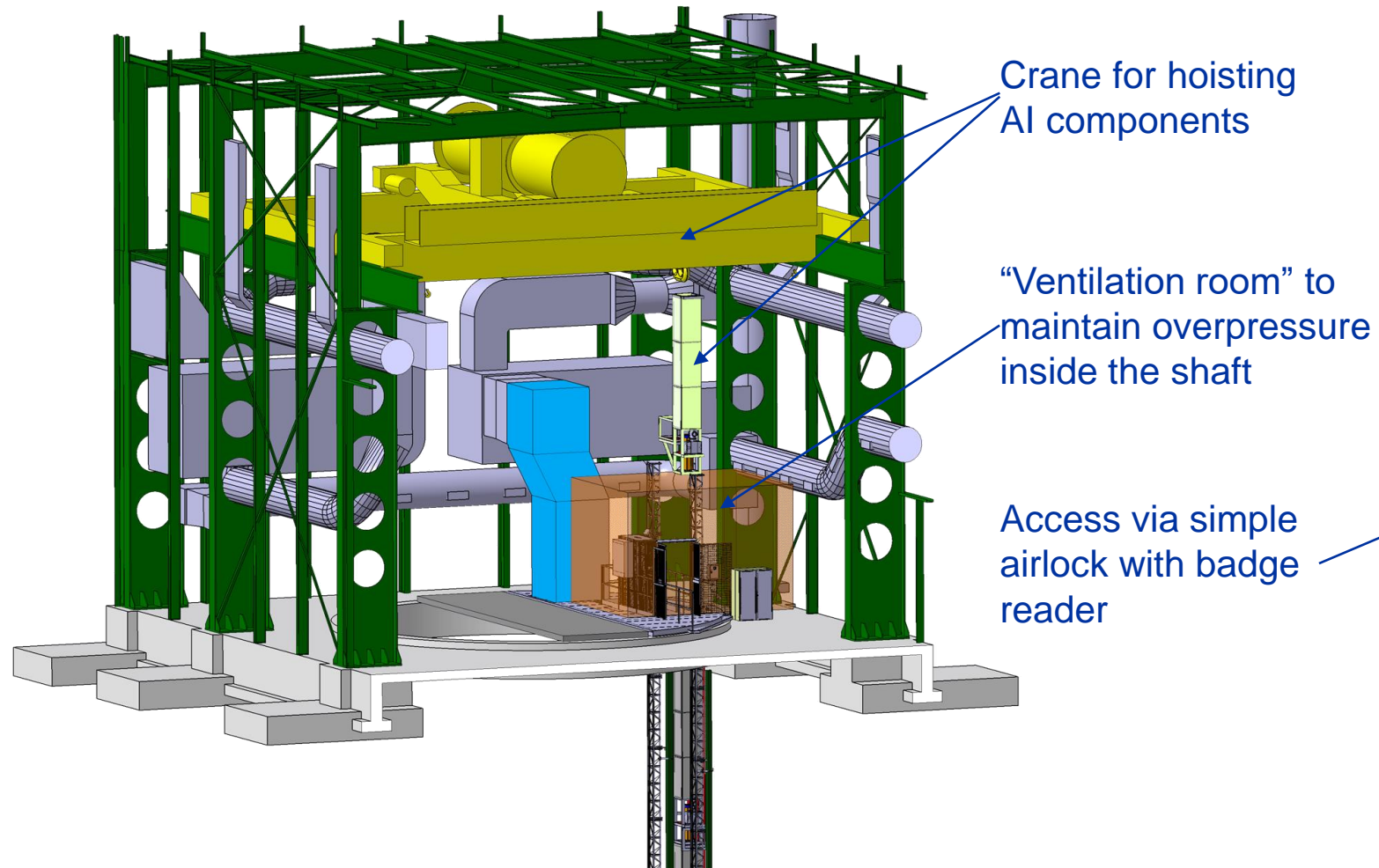
Open top lid and crane



View inside the shaft



Access from top



Revised “Class 4” cost estimates

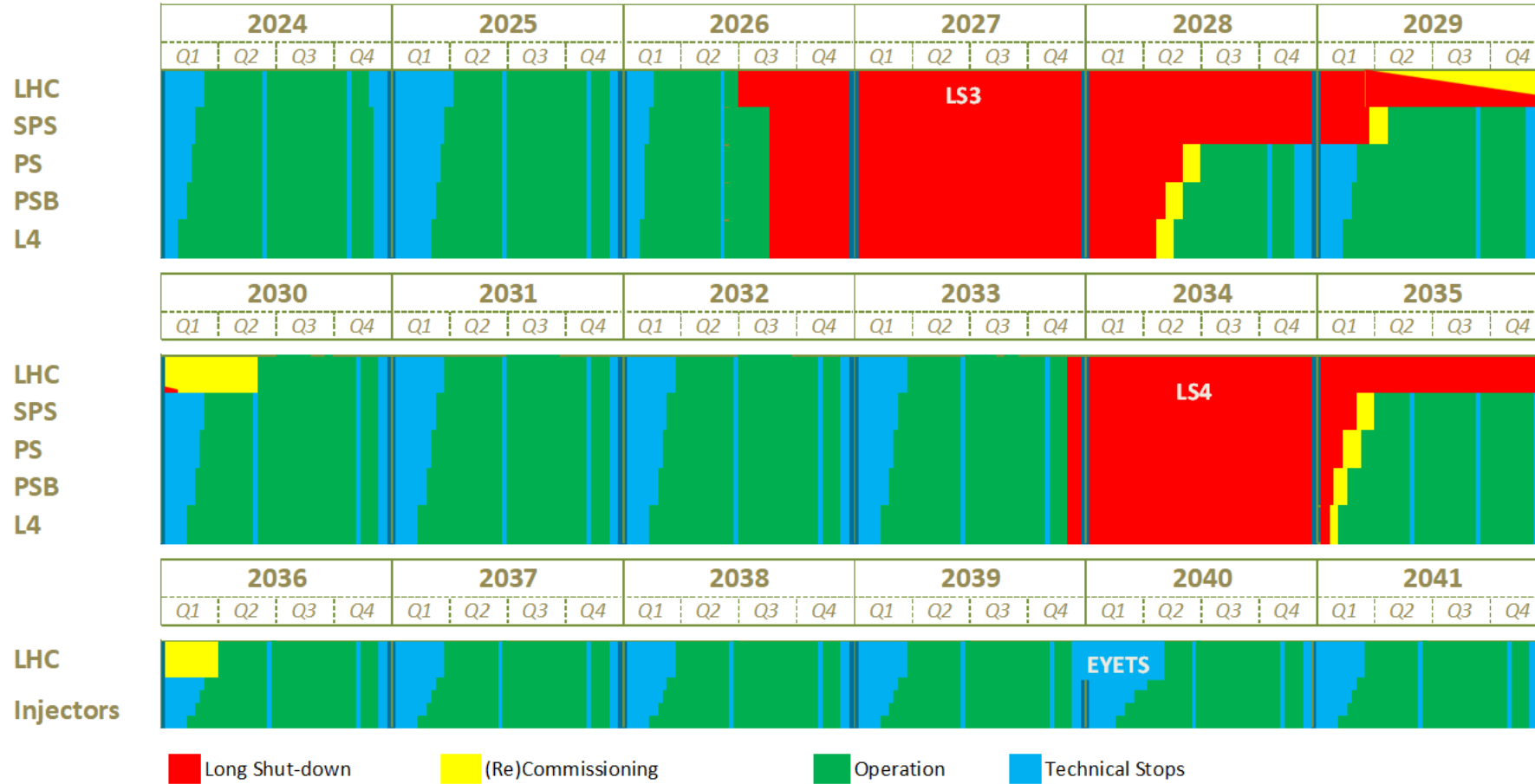
- **Class 4: low margin from -15% to -30%; high margin from +20% to +50% (from [DOE G 413.3-21A, Cost Estimating Guide](#))**

Description	Cost (CHF)
Civil engineering design services	130'000
Civil engineering works (including concrete blocks and door rails)	260'000
LHC Access Safety System (LASS)	65'000
Fire detection, alarms, emergency communications	30'000
RP monitor	20'000
Lifting platform	400'000
Movable shielding door (structure)	100'000
Modifications of shaft top plug (including ventilation room)	75'000
Additional hoist in SX4	130'000
Grand total	1'210'000

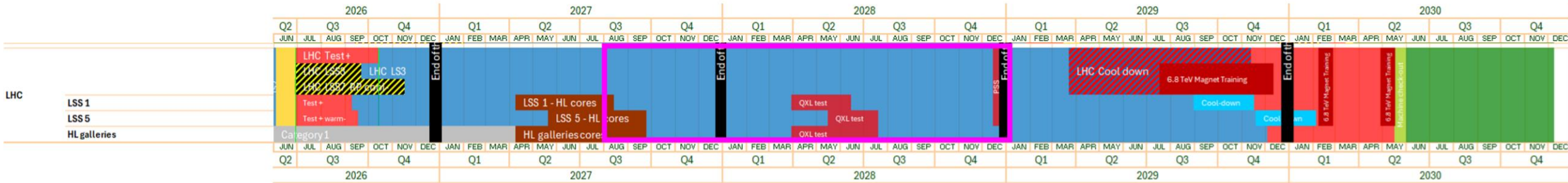
- **Lower than for initial Class 5 estimate (1.5 MCHF), however non-essential ancillaries (chilling water production and distribution system and electrical and service cabling for the experiment) no longer included**

The LS3: works to improve x10 the LHC luminosity

Long Term Schedule for CERN Accelerator complex



Planning: fitting into the LS3 schedule



Description of the task	2025				2026				2027				2028				2029			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Milestone: project approval and budget allocation					★															
Civil engineering activities:																				
Integration and design studies																				
Component assessment and site Investigation works																				
Procurement for construction contracts																				
Civil works for shielding wall																				
Lifting platform:																				
Integration and design studies																				
Call for tender																				
Installation (8 weeks) and commissioning																				
Mobile shielding and additional lifting equipment:																				
Call for tender																				
Installation (3+4 weeks) and commissioning																				
Access control and alarms:																				
LASS system																				
Fire detection and alarms																				

Conclusions and perspectives

- **No showstoppers for the separation of PX46 shaft from the LHC environment**
 - All constraints stemming from the LHC environment duly considered in the engineering design
 - Budget revised (Class4) ready for project proposal to relevant CERN bodies
 - Construction planning fits into LS3 schedule
- **New technical report published: CERN-PBC Report-2025-004**
- **Next step: Letter of Intent (LoI) to the LHC experiments Committee (LHCC)**
- **The LHCC sends recommendations to the CERN Research Board, who takes decisions on them. Once approved, the proposals become part of the CERN official programme.**
- **This activity will then exit the scope of our Physics Beyond Colliders programme**

A personal note

- CERN is known for the “big science” and very large-scale experiments
- However, **many small experiments exist** (talk on Alpha at the Antimatter Factory yesterday – many more like that)
- Many experiments have **rather small communities**
- CERN is organized to cater the needs of both the large experiments and of the small ones
- In fact, it strives to preserve the **diversity of its experimental programme** that the smaller communities bring in
- Scope of the experiment must fit CERN mission: **physics goals of the AI certainly do!**



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