Forward Physics Facility @ LHC: The Facility, FASER2, FASERv2

Jamie Boyd (CERN)

25 November 2024

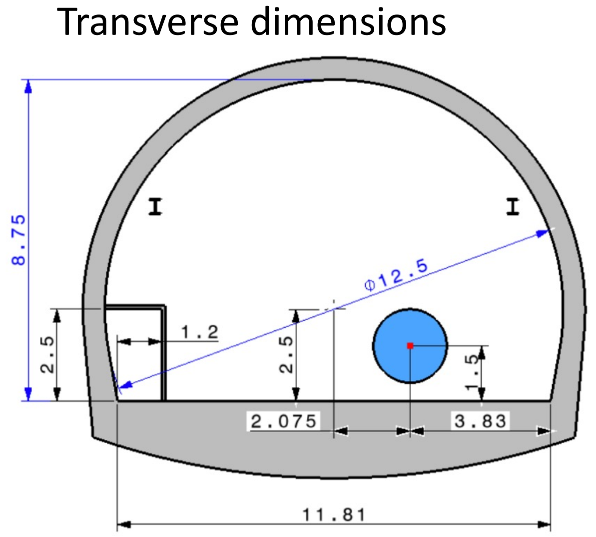
The Facility: Site Selection

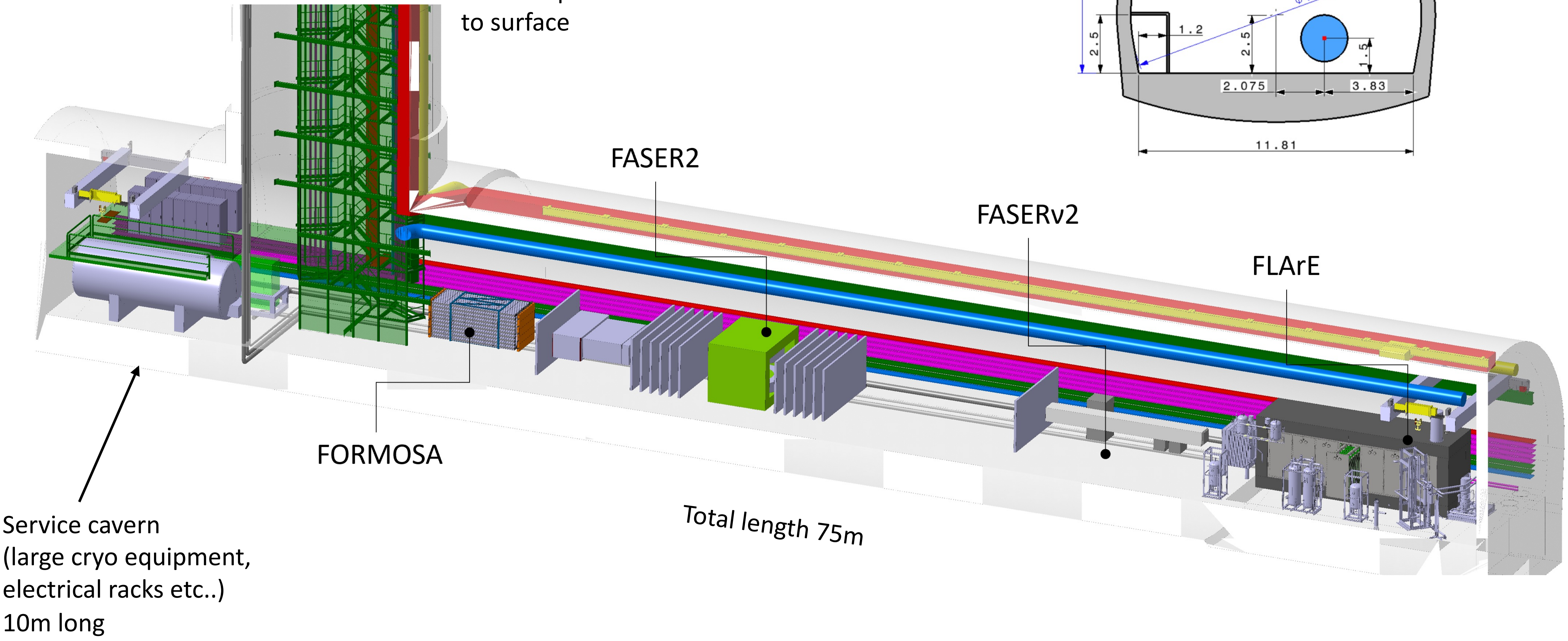
ATLAS IP

Proposed FPF location

After several studies by CERN civil engineering team, looking at options around both the ATLAS and CMS interaction points.
We quickly settled on the location shown. This is ~600m from the ATLAS IP (to the west), and is situated on CERN land in France.

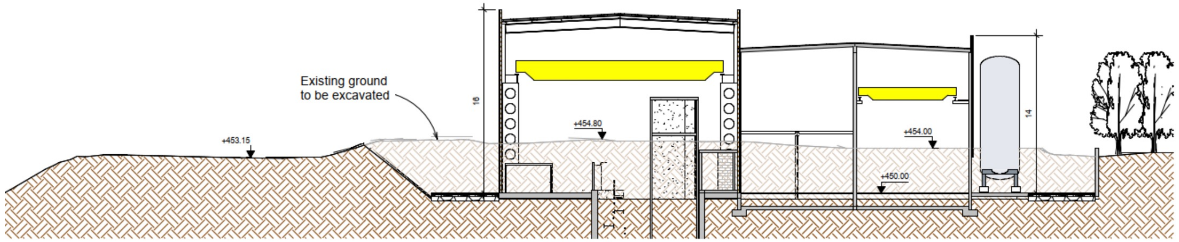
Baseline Layout



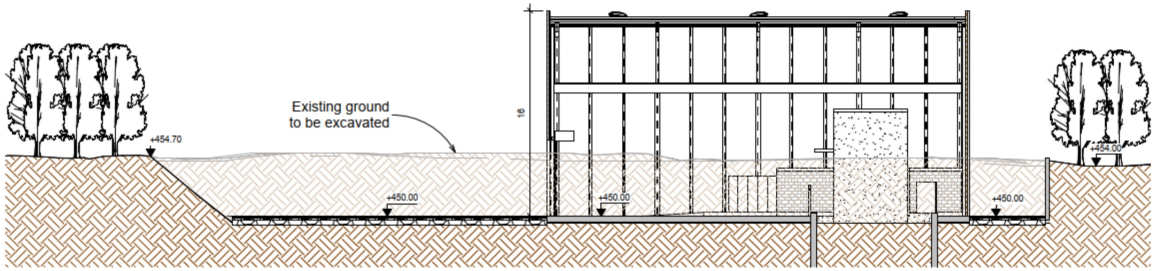


Surface Works Design

The CE design, includes road access, car parking and two surface building for access and services. These are based on the latest standard CERN solutions which have been implemented several times for recent projects.



SECTION 1-1



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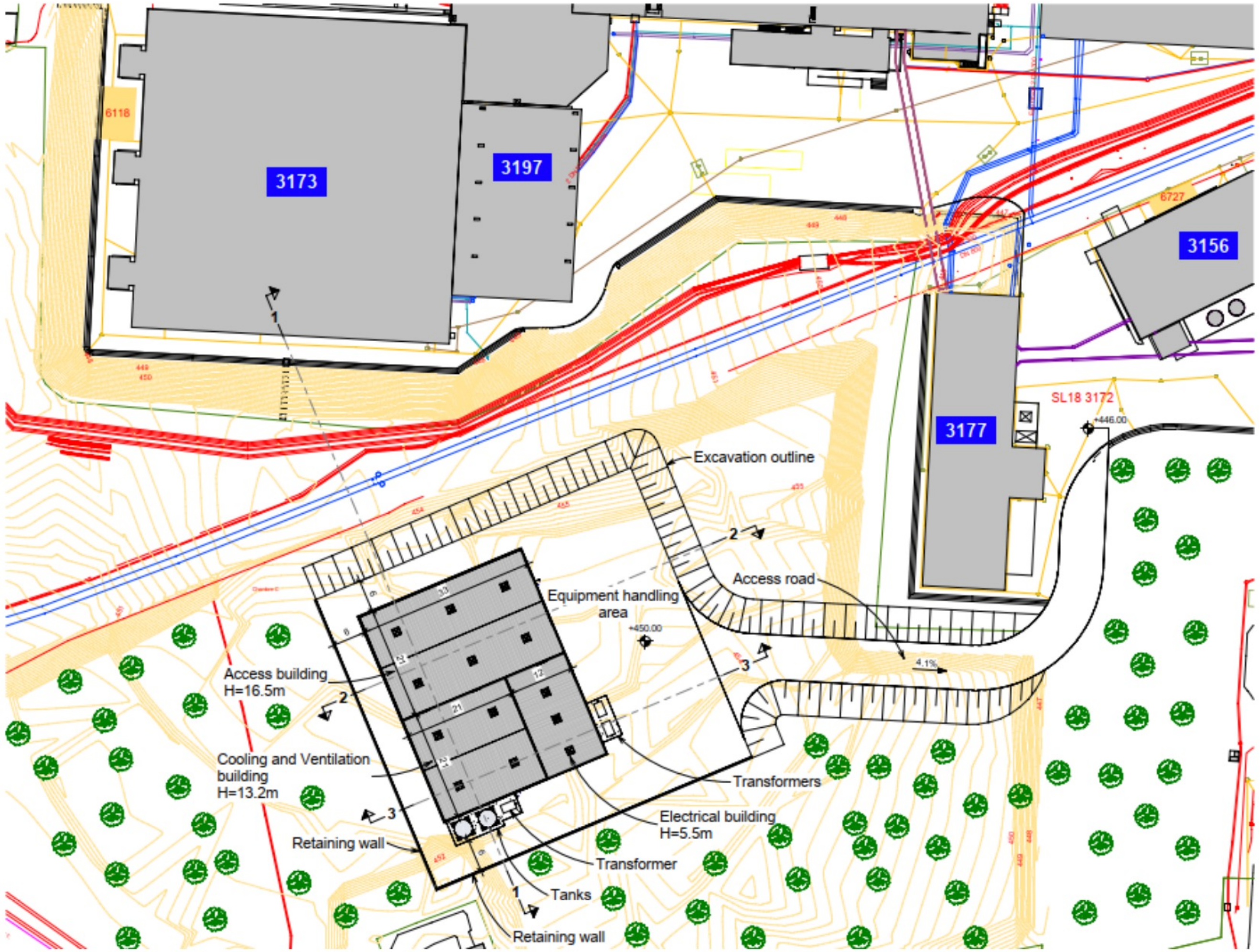

Technical Progress During 2023/4

Study	Status	Conclusion
Excavation works during beam operation?	Sudy by CERN beam physics group. **Complete**	Vibrations / tunnel-movement not expected to be an issue [1]
Access to cavern during beam operation?	Study by CERN Radioprotection group. **Complete**	Can access cavern for people classified as radiation workers. [2]
Muons background flux	Simulation study by CERN FLUKA team. **Complete**	Expected muon flux O(1Hz/cm^2) within 1m or LOS. Generally OK for experiments. [2]
Geological conditions	Site investigation works carried out by CERN civil engineering group (with contractor GADZ SA). **Complete**.	Geological conditions look good for proposed works. [3]
Is one access point to facility OK for safety?	Study by CERN safety team. **Complete**.	Addition of over pressure safety corridor along the facility length allows only 1 access point. [2]
Can we fit in (& transport to) technical infrastructure into cavern?	Study by CERN integration team for main large pieces. **Complete.**	Make cavern slightly longer/wider to allow everything to fit [4]
Preliminary facility costing	First CE works costing updated based on site investigation and checked by external conractor (ARUP). Very preliminary costing of services by CERN groups. **Complete**.	CE costs for baseline facility 35.3 MCHF. (Class 4 costing) [4]. Very preliminary costing of technical services: 8.4MCHF [2] **Total: 44MCHF**

[1] – "Impact of vibration to HL-LHC performance during FPF facility construction", https://cds.cern.ch/record/2901520

[2] – "Update on the FPF Facility technical studies", https://cds.cern.ch/record/2851822/

[3] – "Forward Physics Facility: Geotechnical Report", GADZ SA, https://edms.cern.ch/document/2910442/1

[4] - "Update on facility technical studies for FPF", https://cds.cern.ch/record/2904086/

Documentation of technical studies

CERN-PBC-NOTE 2023-002

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Jamie.Boyd@cern.ch

Update on the FPF Facility technical studies

FPF PBC Working Group:
M. Andreini, G. Arduini, K. Balazs, J. Boyd, R. Bozzi, F. Cerutti, F. Corsanego, J-P. Corso, L. Elie, A. Infantino, A. Navascues Cornago, J. Osborne, G. Peon, M. Sabaté Gilarte
CERN, CH-1211 Geneva, Switzerland

Keywords: FPF

Summary

The Forward Physics Facility (FPF) is a proposed new facility to house several new experiments at the CERN High Luminosity LHC (HL-LHC). The FPF is located such that the experiments can be aligned with the collision axis line of sight (LOS), a location which allows many interesting physics measurements and searches for new physics to be carried out. The status of technical studies related to the FPF, as well as the physics potential were documented in Ref. [1] which was released in March 2022. This note documents updates to the FPF technical studies completed since that time.

1

https://cds.cern.ch/record/2851822

CERN-PBC-NOTE 2024-003

19 July 2024

davide.gamba@cern.ch

Impact of Vibration to HL-LHC Performance During the FPF Facility Construction

D. Gamba, H. Bartosik, M. Guinchard, J. A. Osborne, K. Pál, C. Vendeuvre, J. Wenninger, K. Widuch
CERN, CH-1211 Geneva, Switzerland

Keywords: excavation, forward physics facility, ground motion, tunnel deformation, vibration, FPF, LHC, HL–LHC, SPS

Summary

The Forward Physics Facility (FPF) is a proposed experimental site intended to be positioned approximately 630 meters from the ATLAS interaction point. It aims to capture long-lived particles and neutrinos that travel along the beam collision axis and fall outside the ATLAS detector's acceptance. The construction of this facility, particularly the excavation of the necessary shaft and cavern, could occur concurrently with beam operations at the CERN accelerator complex. Therefore, it is crucial to ensure that the ground motion resulting from these construction activities does not disrupt the normal functioning of the SPS and LHC. This study details how sensitive the SPS and LHC rings are to vibrations and misalignments close to the FPF construction site. It also examines the expected effects on beam operations, incorporating lessons learned from the HL-LHC infrastructure development near the ATLAS experiment, previous civil engineering projects, and established knowledge of slow ground movements in the vicinity.

1

https://cds.cern.ch/record/2901520

CERN-PBC-NOTE 2024-004

12 July 2024

Jamie.Boyd@cern.ch

Update of Facility Technical Studies for the FPF

FPF PBC Working Group
K. Balazs, J. Boyd, T. Bud, J.-P. Corso, D. Gamba, A. Magazinik, A. Navascues Cornago, J. Osborne (CERN, CH-1211 Geneva, Switzerland)

Contributors from the FPF Experiments
FLArE: L. Bartoszek (Bartoszek Engineering), Y. Li (BNL), S. Linden (BNL), C. Miraval (BNL), S. Trabocchi (BNL)
FASERν2: S. Bosco (Bern)
FASER2: N. Sumi (KEK), J. Carroll (Liverpool), A. Lowe (Oxford)
FORMOSA: R. Loos (CERN)

Keywords: FPF

Executive Summary

The Forward Physics Facility (FPF) has been proposed to house a set of detectors to study collider neutrinos and search for new particles in the High-Luminosity LHC era. This report provides an update to the space and infrastructure requirements of the Facility, a result of integration studies carried out by CERN technical teams in conjunction with the FPF experimental community.

Previous radiation protection (RP) studies showed that access to the FPF cavern during LHC beam operation was expected to be possible. This update includes vibration studies, which indicate that no major disruptions to HL-LHC and SPS performance are expected during FPF excavation works. FPF construction, then, is not expected to interfere with the LHC and can proceed largely independent of the LHC schedule.

Since the last study, a site investigation, where a core was drilled to the depth of the FPF cavern, yielded broadly positive results, confirming the reliability of the Facility design. More detailed considerations of services have been incorporated, leading to a slight increase in size of the proposed cavern. The FPF facility could be constructed within a few years of approval, with no special R&D needed for the design.

1

https://cds.cern.ch/record/2904086

FPF Site Investigation Works

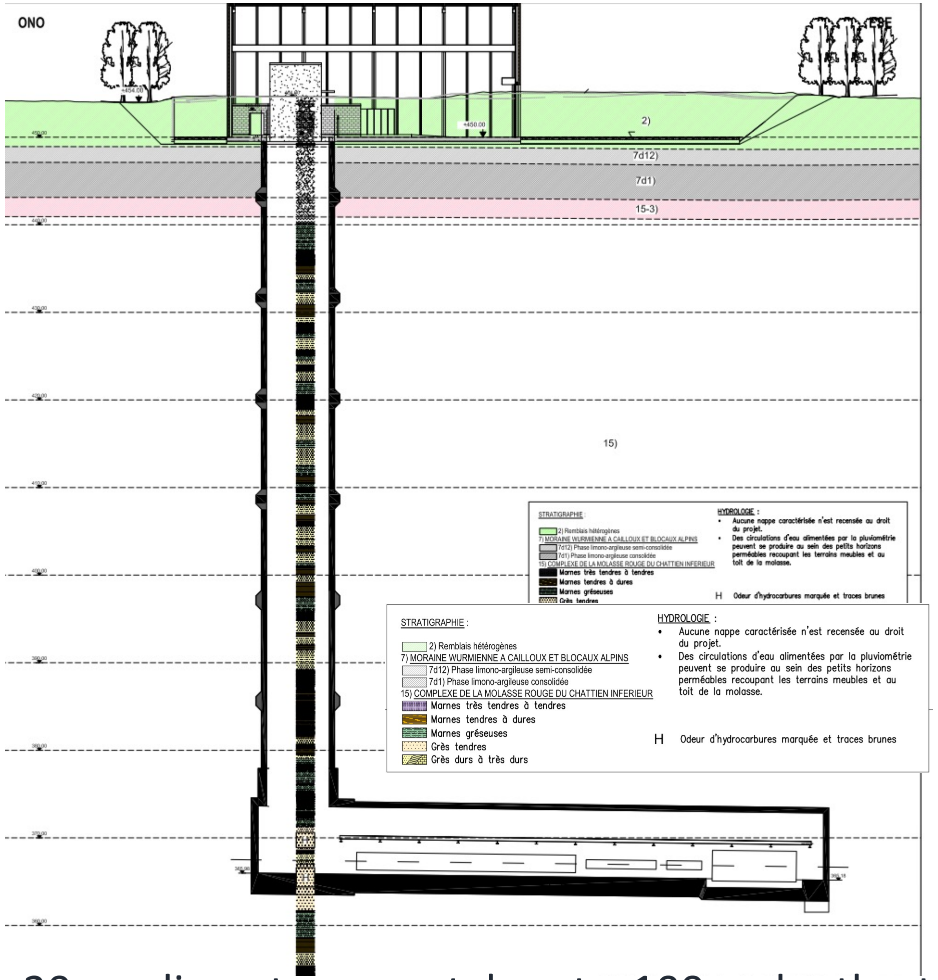
➢ Drilling machine in place

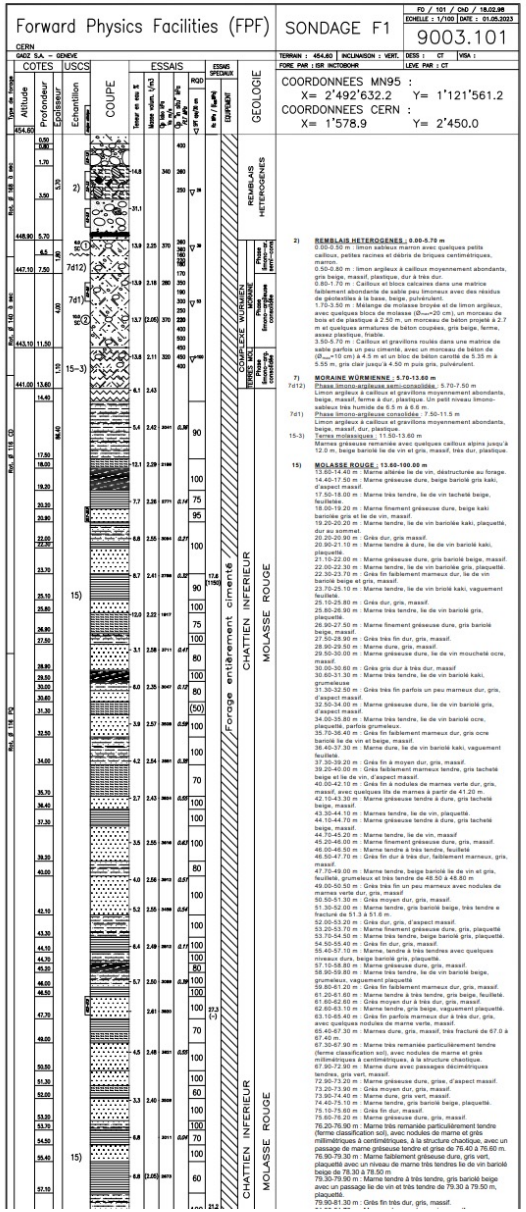
➢ Works started

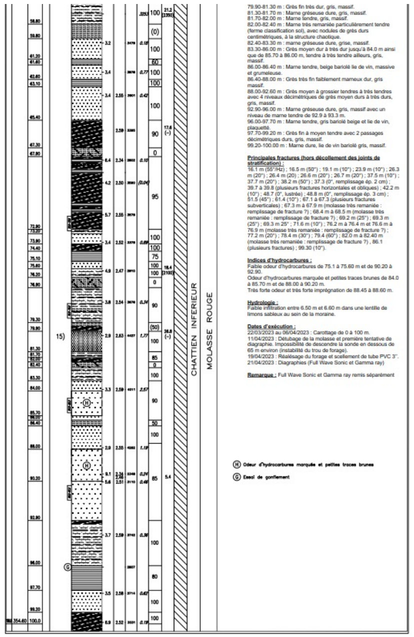
➢ Core samples

Site investigation (single core sample drilled, down 100m at location of FPF shaft): March/April 2023

FPF Site Investigation Works







- 20cm diameter core taken to 100m depth at proposed FPF location
- Detailed Geological study of core carried out
  - No showstoppers identified
  - Area looks good for excavation

Site Investigation Works

Results and Recommendations

Results

- Ground found mostly competent for tunnelling purposes
- Signs of hydrocarbons were found in the soft sandstone at depths between 84m and 90m
- Foundations of the surface buildings will sit within competent moraine
- No water table has been identified. Overall the ground is not very permeable.
- Vertical swelling test carried out showed a high swelling potential.
- Slight exceedance shown of fluoride levels in the existing backfill material.

Recommendations

- Excavation material contaminated with liquid hydrocarbons will require specific spoil management
- Underground tunnels and works in contact with soils contaminated with hydrocarbons will require specialised waterproofing membrane
- Swelling pressures to be considered during the design of the final lining
- Existing backfill material will need to be disposed of at appropriate facilities

Summary: Ground conditions are favourable, with some attention needed to hydrocarbons, fluoride and swelling

Based on site investigation findings, and other factors (inflation), and a modest increase in the cavern size (following detailed integartion studies) an updated cost estimate for the facility was produced, and validated by an external experts. This led to the current class 4 cost estimate of 35MCHF for the CE works.

Costing

Civil Engineering Cost Estimate FPF // September 2024

Ref.	Work Package	Cost [CHF]	Percentage of the CE Works
1.	Underground Works	12,392,344.00	35%
1.1	Preliminary activities	1,845,000.00	5.2%
1.2	Access shaft	4,424,143.00	12.5%
1.3	Experimental Cavern	6,123,201.00	17.3%
2.	Surface Works	6,727,231.00	19%
2.1	General items	720,776.00	2.0%
2.2	Topsoil and earthworks	702,227.00	2.0%
2.3	Roads and network	796,122.00	2.3%
2.4	Buildings	4,508,106.00	12.8%
2.4.1	Access building	2,224,786.00	6.3%
2.4.2	Cooling and ventilation building	1,497,350.00	4.2%
2.4.3	Electrical Building	563,689.00	1.6%
2.4.5	External platforms	222,281.00	0.6%
3.	General items	11,815,899.00	33.4%
4.	Miscellaneous	4,397,504.00	12.4%
	TOTAL CE WORKS	35,332,978.00	100.0%

Item	Details	Cost (MCHF)
Electrical Installation	2MVA electrical power	1.5
Ventillation	Fresh air supply Presurization Ar / Smoke extraction	2.5
Access / Safety Systems	Access system Oxygen deficiency Hazard Fire safety Evacuation	2.5
Transport/Handling Infrastructure	Shaft crane (25t) Cavern crane (25t) Lift	1.9
Total		**8.4**

Assumptions

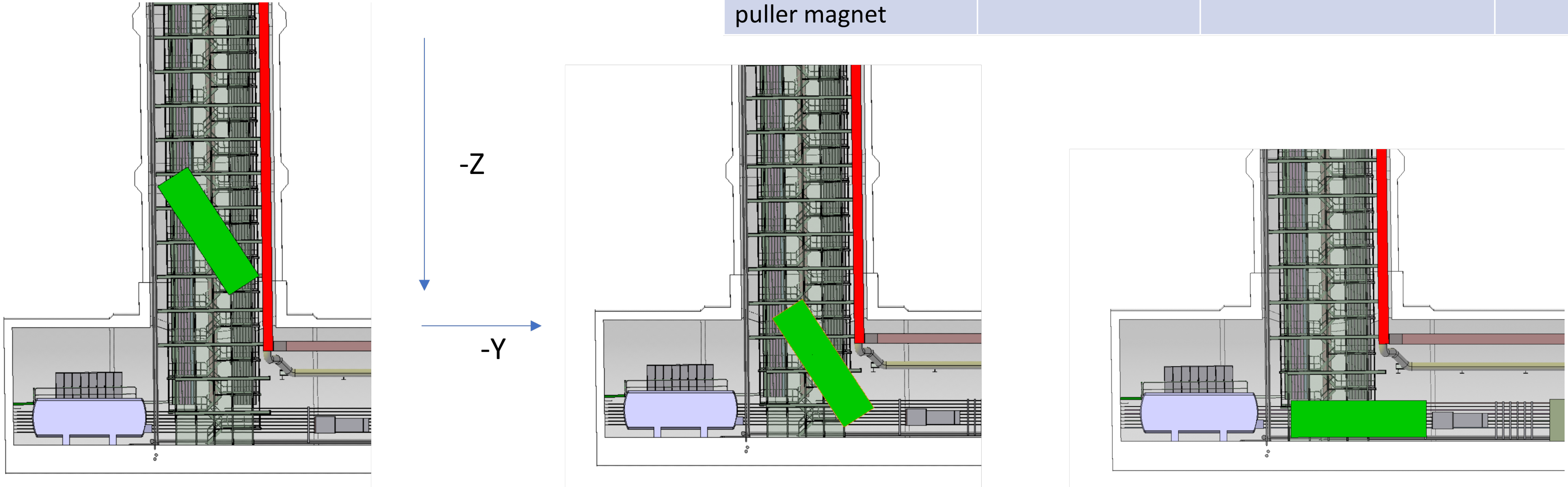
1. Services not included
2. Technical galleries not included
3. Cranes not included
4. Access building as a conventional steel portal frame structure with cladding, only one floor
5. CV Building as a reinforced concrete building, only one floor
6. Finished floor level at 450m ASL
7. Sectional doors not included
8. Unit costs are based on a combination of Hi-Lumi (2018), Faser (2018), SPS Tunnel eye enlargement
9. Inflation figures have been taken dating from 2017-T4, with 2021 as the benchmark year

Simplified Transport studies

Simplified transport study carried out to demonstrate that largest pieces that need to be transported as a single piece can be transported into the cavern, and to their final location.
Everything considered works, except LAr storage tank that is too big. Could be transported before stairs are installed in shaft, or smaller options could be considered.

Name	Weight estimation	Dimensions	System
Turbo-Brayton	Full 15 t	9.5 m x 2.6 m x 1.7 m	Cryogenics
Ar Storage tank	Empty – 13.9 t Full Ar – 57.8 t	Diam. 2.8 m, L = 7.7 m	Cryogenics
FLArE module	1 t	1.2 m x 2.3 m x 2.2 m	Detector
FASER2 Samurai magnet coil	1.8 t	Diam. 3 m, h = 0.5 m	Detector
FASER2 Crystall puller magnet	9 t	Diam. 2.4 m, h = 1.25 m	Detector

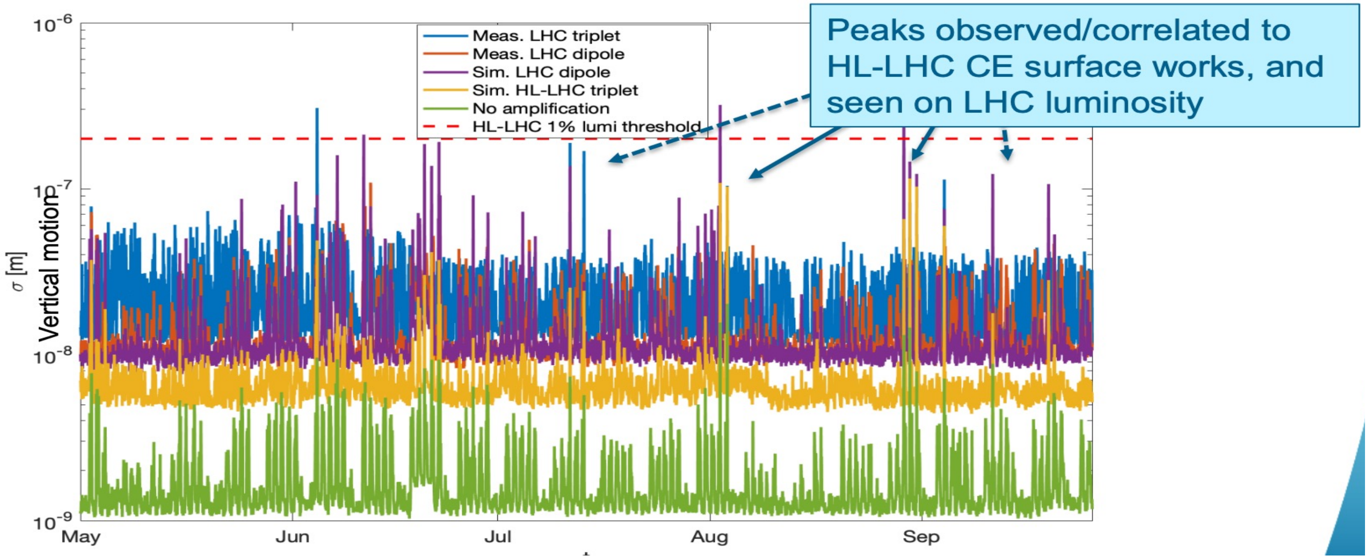
Example: transporting TB-unit down shaft into cavern



Study on CE works during HL-LHC operation

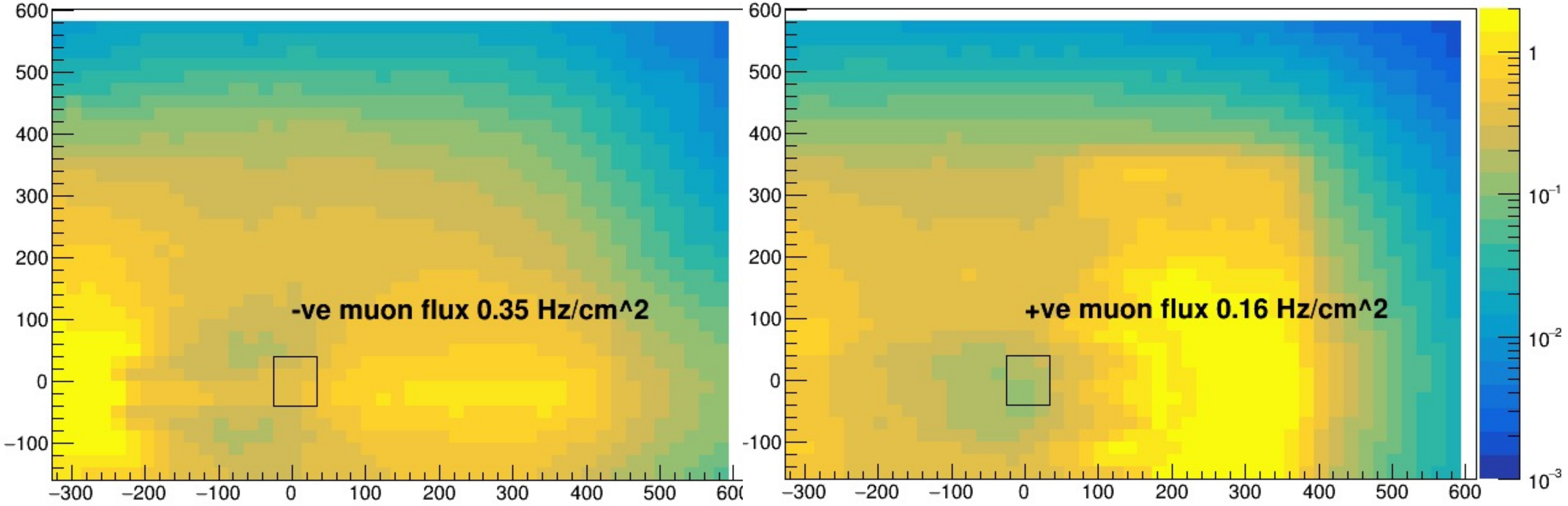
- Detailed study carried out, on the possible effect of FPF CE works on HL-LHC operations
- Benefit from significant work done on this for HL-LHC underground works at IP1/5
  - FPF is much further from interaction point
    - About 4x more attenuation compared to HL-LHC works
  - FPF is closer to LHC tunnel
    - Up to 4x less attenuation compared to HL-LHC works
  - Net impact expected to be similar or smaller effect on beam operations from vibrations
    - a few punctual drops in luminosity at the 1% level
    - very low risk of beam dump from ground motion
- Previous studies show that compatification of spoil on surface is one of the most problematic operations
  - For FPF spoil will be taken off site before compatification
  - Compacting for road building / surface-works can try to be scheduled when LHC is not running
- Effect og static tunnel movements due to nearby excavation also considered using historical CERN data
  - Possible movement at level of <1mm possible, which could be mitigated by beam corrector magnets or accelerator components local re-alignment

Example simulated and observed movements from 2018 when point-1 HL-LHC works ongoing.



Muon background fluence

- A key consideration for the FPF experiments is the rate of background particles
- With 200m shielding of rock from the IP, the only interacting particles that get to the FPF are high energy muons
- Detailed FLUKA simulations carried out to assess the muon flux at the FPF for the HL-LHC scenario
  - Estimated rate O(1 Hz/cm^2) close to the LOS for a luminosity of 5e34cm^{-2}s^{-1}
- FLUKA estimate of Run 3 LHC muon flux on LOS, validated by FASER data within 25%
  - Many parts of the LHC will change for HL-LHC, so not a direct validation of the FPF setup
- Expected muon rate OK for the proposed FPF experiments. However, would be beneficial to reduce this (e.g. to reduce emulsion cost for FASERv2
  - Studies ongoing on possible sweeper magnet in LHC tunnel, or use of LHC corrector magnets to reduce the muon rate



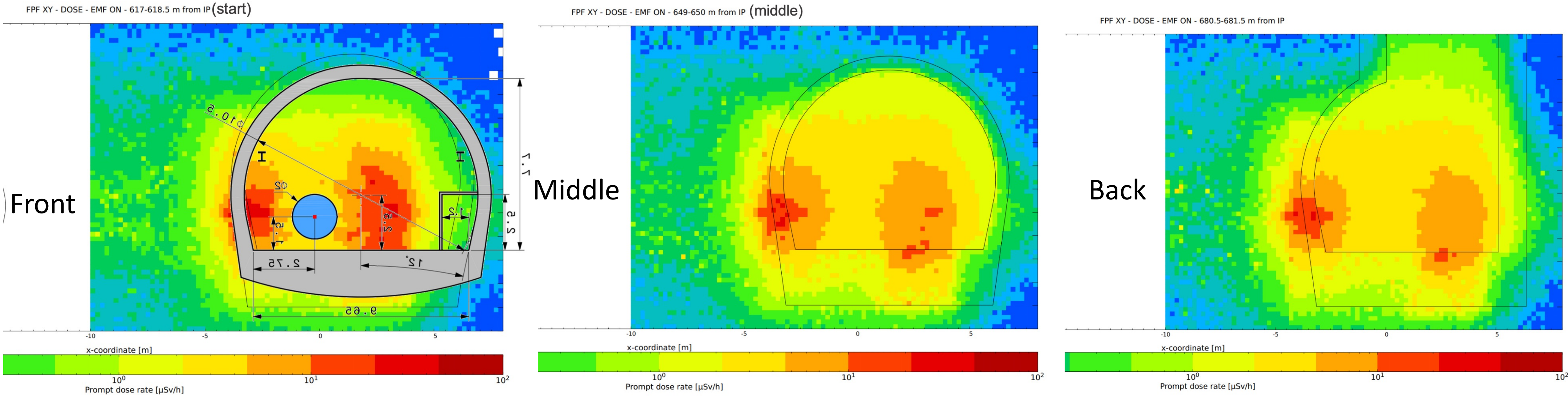
FLUKA muon flux at start of FPF (617m from IP1). Baseline HL-LHC crossing angle of 250urad would push the LOS ~16cm to +ve x in these plots. (LHC tunnel would be at at -1300cm on these plots scale)

Access to the FPF during HL-LHC operations

The CERN Radiation-Protection group has completed a detailed FLUKA study to see if people can access the FPF cavern during HL-LHC operations. They have studied radiation from:

- Accidental beam loss close in the LHC or SPS close to the FPF,
- Radiation from beam-gas interactions in the LHC,
- Radiation dose from the prompt muons passing through the FPF

For the ultimate HL-LHC performance ($L=7.5e34cm^{-2}s^{-1}$) only the last of these is seen to be close to the limit.
Assuming people spend <20% of their time there, and with possible restrictions for local hotspots in the cavern, access will be possible during operations (dosimeter will be required).



Instantaneous dose rate (assuming $7.5e34cm^{-2}s^{-1}$ lumi for full year).

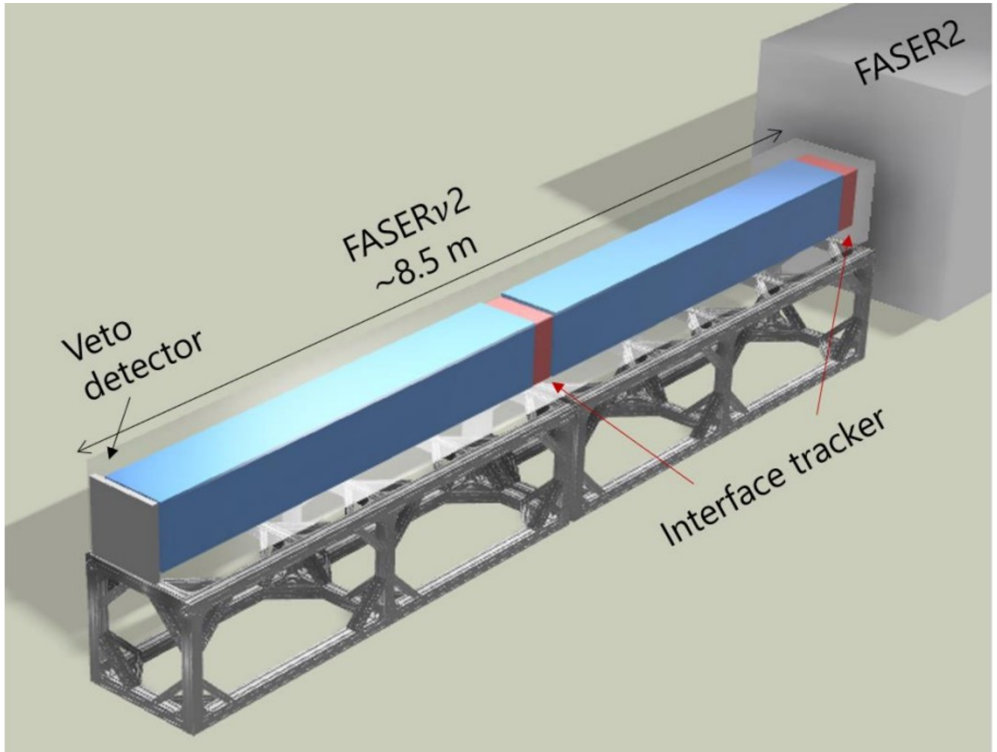
Important result for feasibility of FPF implementation as will allow experiments to be installed/commissioned/upgraded during beam operations.

Summary on Facility

- Several technical studies carried out on design and feasibility of implementing the FPF Facility
  - Lots of progress
  - No showstoppers identified
- CERN has lots of experience of realizing similar projects, and FPF studies greatly benefit from previous work and can often use standard solutions
- Site investigation showed the geographic conditions are good for the proposed excavation works
- Additional important positive results related to:
  - Construction of facility during beam operation
  - Expected muon background rate
  - Access to cavern during beam operations (in terms of RP)
- Have gone through an iteration on the facility design, to allow sufficient space for the needed technical infrastructure(including transport requirements)
- Preliminary costing (class 4 estimate for CE works, more preliminary for technical infrastructure/services)
  - 35.3MCHF for CE works, 8.4MCHF for services

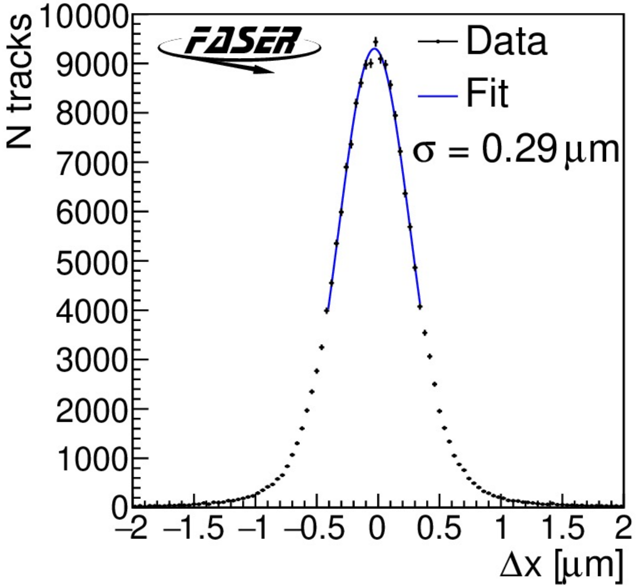
FASERν2

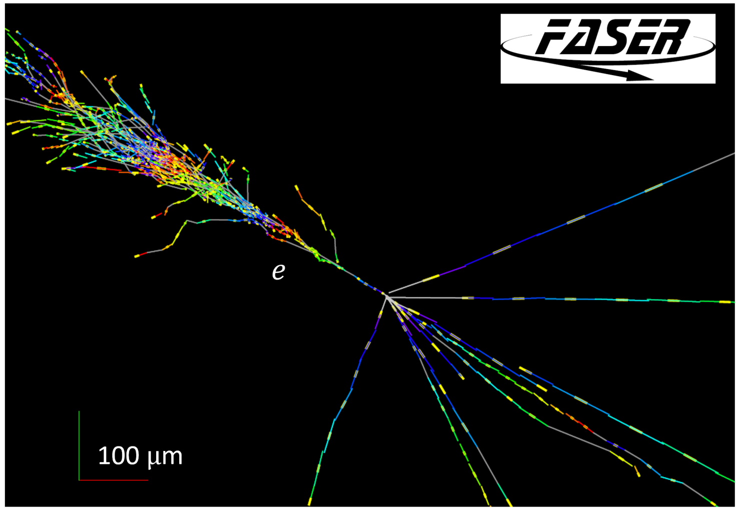
- FASERν2 is a tungsten/emulsion detector
  - 20 tonne target mass
  - 40cm x 40cm x 8.5m long
  - Detector cooled to prolong emulsion performance
  - Muons from neutrino interactions in tungsten can be reconstructed (charge / momentum) in FASER2 spectrometer
    - Requires scintillator veto system and interface trackers
- Dealing with high detector occupancy from muon background (~1Hz/cm^2) is the main challenge
  - Investigating sweeper magnet to reduce muon flux
  - Investigating improved emulsion reconstruction to cope with higher occupancy
- FASERν2 effort drivin by Japanese community with strong expertise in emulsion detectors (Nagoya, Kyushu, Chiba)
- Core cost of experiment for 10 years (assuming 1 emulsion set/year) is 16MCHF



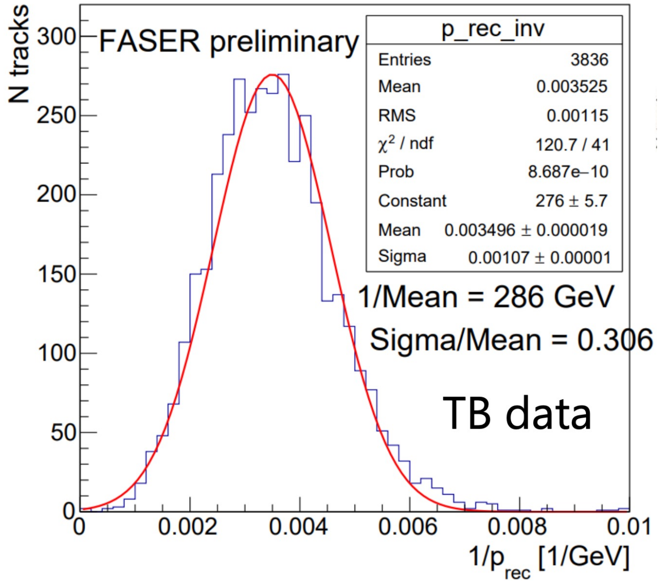
FASERv2: Benefits of emulsion

- Emulsion has incredible position resolution
  - Only detector technology proven to be able to directly detect tau neutrinos
  - Can identify muons as long tracks, and measure their momentum using multiple coloumb scattering
    - ~30% resolution at 200GeV validated in testbeam
  - Can identify EM showers from electrons, and measure their energy from the profile at the shower maximum
    - ~30% resolution at 200GeV validated in testbeam





300GeV Muons testbeam



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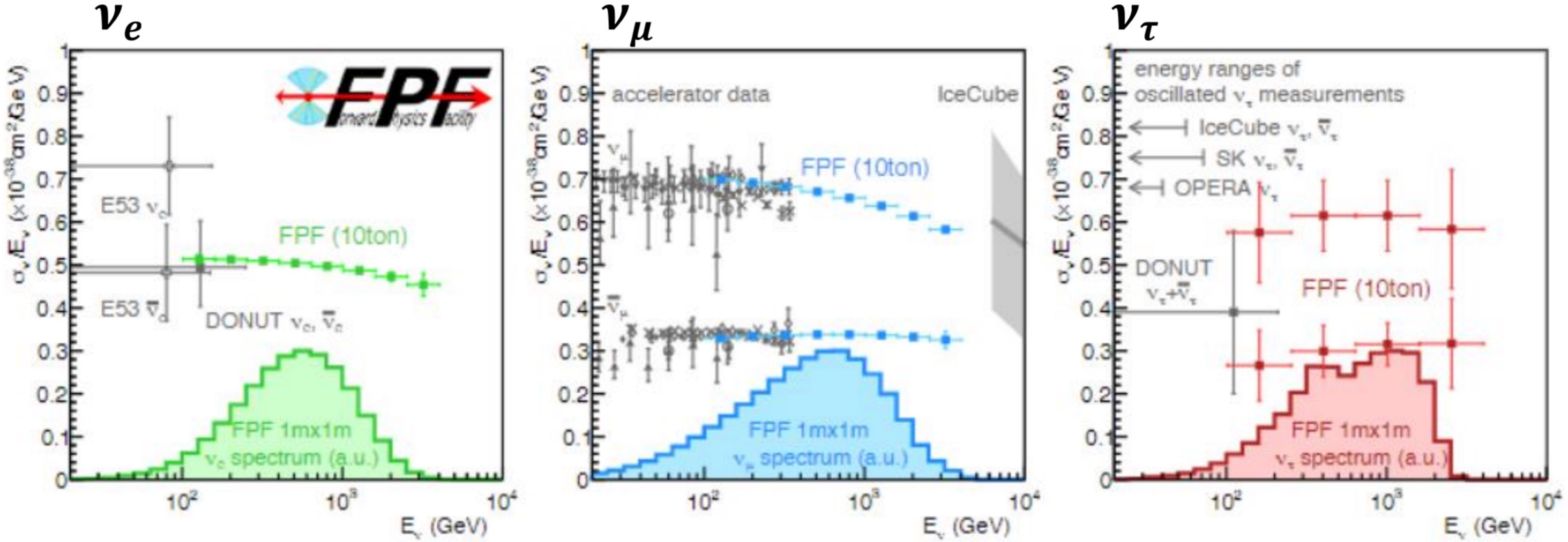
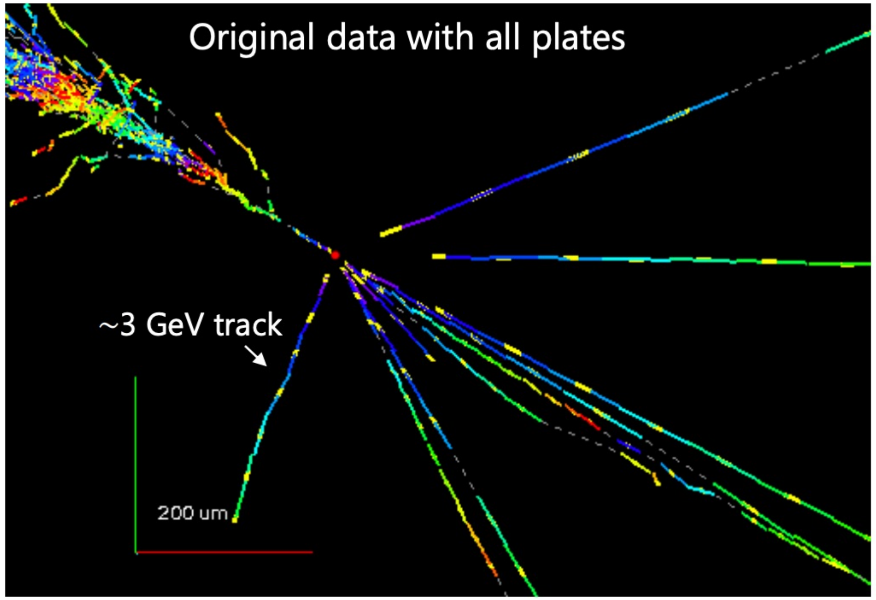
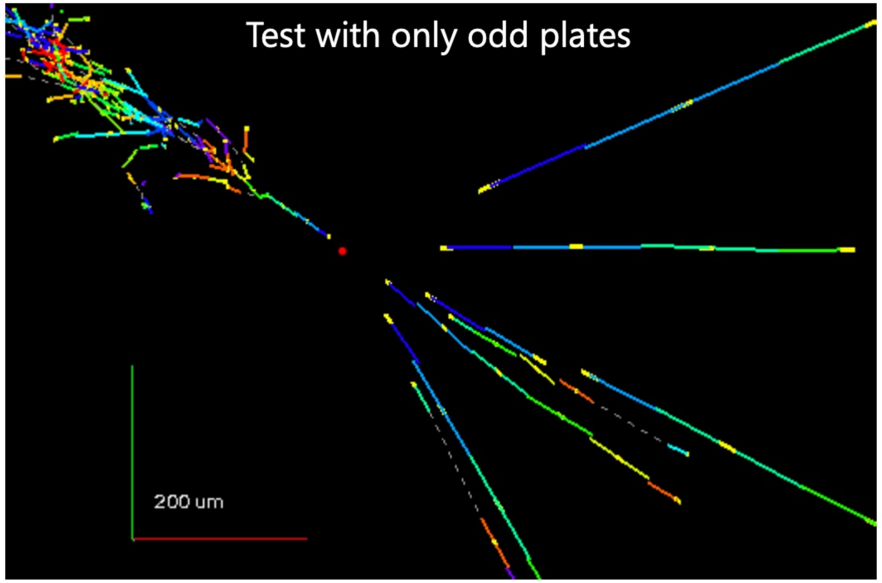


FASERν2 – recent studies

- Long term stability test of emulsion film ongoing
  - Test noise-hit (fog) rate and track efficiency after long exposure (as would be the case in the FASERν2)
  - Test using films exposed to test beam in Aug 2023
  - Films kept in different temperatures and for different lengths of time, and then developed to study performance
- Test of using 2mm thick tungsten plates between films (cf 1mm plates in FASERν)
  - Reconstruct FASERν data skipping every other emulsion film
  - Compare neutrino candidates with default and modified reconstruction
  - Results looks encouraging

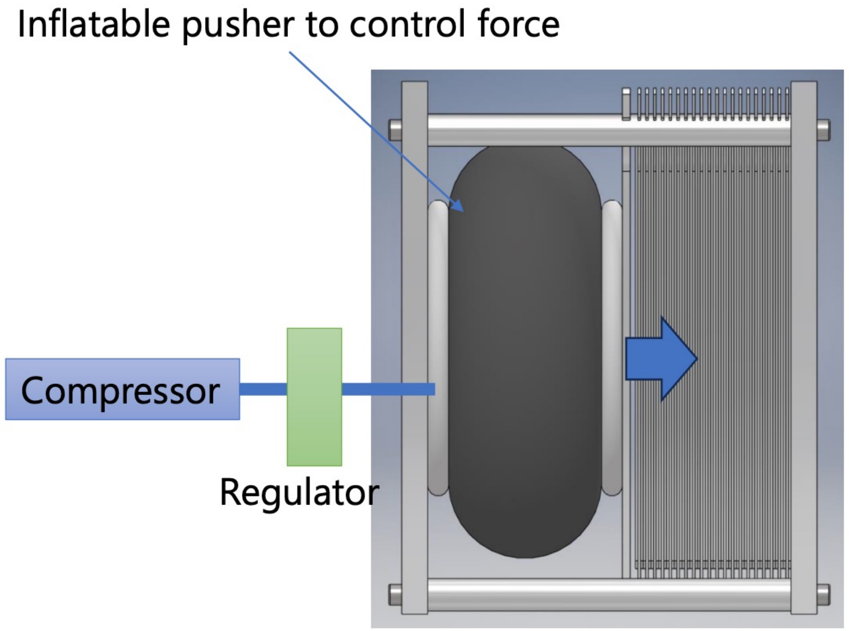




FASERν2 – recent studies

- Detector structure development
  - Design structure to allow assembly of emulsion detector (after exchange of emulsion) on site
  - Need system to apply sufficient pressure (1atm) on tungsten/emulsion to ensure good alignment
  - Small prototype developed to test proof of concept for FASERν2 structure:
    - 20 single-film packs with 20 iron plates, assembled under light and pressurized by compressed air
  - Sucesfully tested in 2024 testbeam

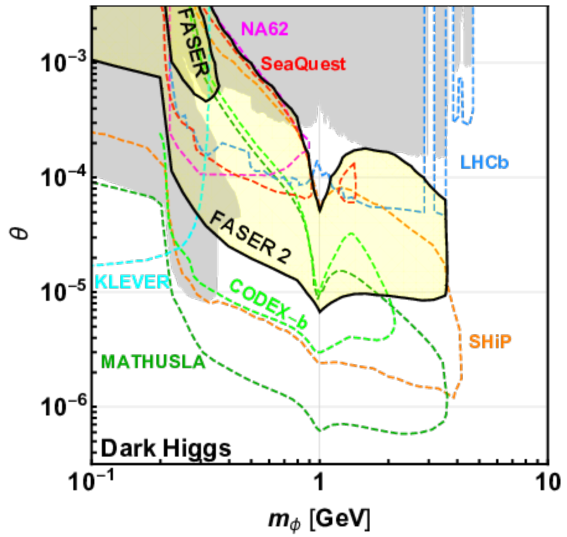
FASERν2 test module



FASER2

FASER2 is a scaled-up version of FASER:

- Transverse area $300cm^2$ => $3m^2$
- Decay volume: 1.5m => 10m
- Luminosity at HL-LHC 10x LHC



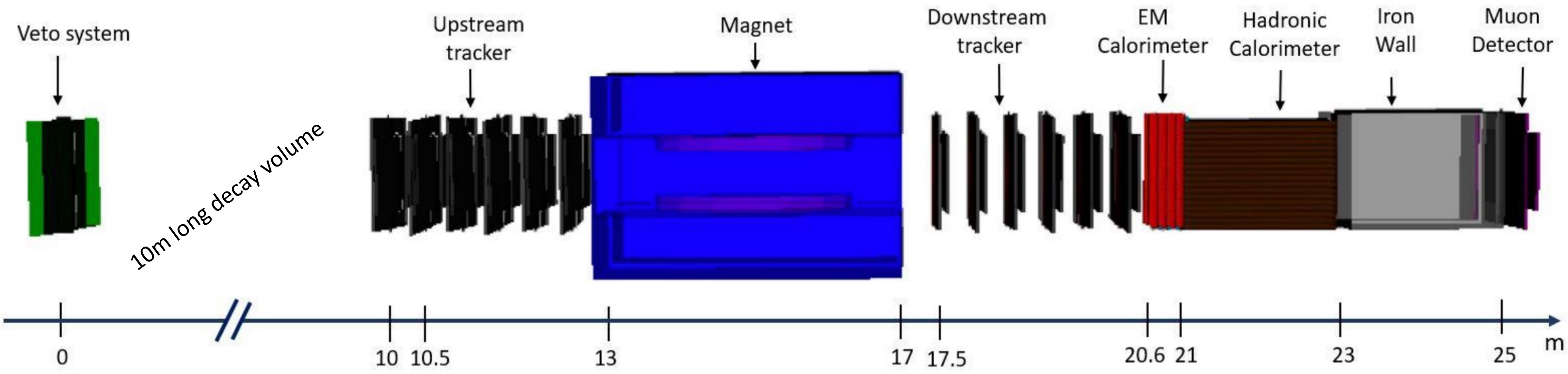
=> **Big** increase in physics potential.

Especially for new particles from heavy flavour decay which are more spread out around the LOS (like Dark Higgs).

FASER2 spectrometer also used to measure momentum and charge of muons from neutrino interactions in upstream detectors.

- Due to big scaling-up in size, can not use same technology as FASER, especially for the magnet.
  - Needs large apperture super conducting magnet. Since this drives the cost and the dimensions, studying different magnet options has been a focus of the FASER2 efforts.
- In addition, many simulation studies to define spectrometer requirements for example:
  - transverse size, magnet bending power, tracker hit resolution, alignment tolerances, material budget, number of tracking layers…

FASER2: Baseline layout



Tracker:

- Based on LHCb's SciFi tracker
- SiPM and scintillating fiber design
- Detector resolution: ~ 100 μm

Magnet:

- Large aperture
- 3m wide X 1m gap
- Superconducting technology
- Magnetic Field : 2-4 Tm
- Based on the SAMURAI magnet

Calorimeter:

- Based on dual-readout calorimetery
- Spatial resolution: 1-10 mm

FASER2 effort led by UK insitutes, but with also Japanese, Swiss, US, and Serbian participation.
Core cost of the baseline detector: 13MCHF

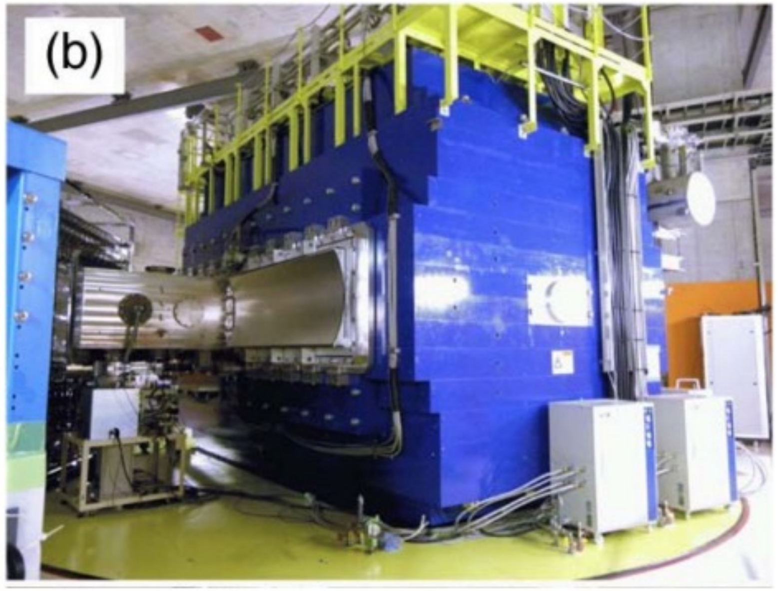
FASER2 magnet - baseline

FASER2 spectrometer has a large apperture magnet. Options discussed with Toshiba, Japan and TESLA, UK.
Baseline design is a superconducting dipole magnet based on the SAMURAI magnet (manufactured by Toshiba).

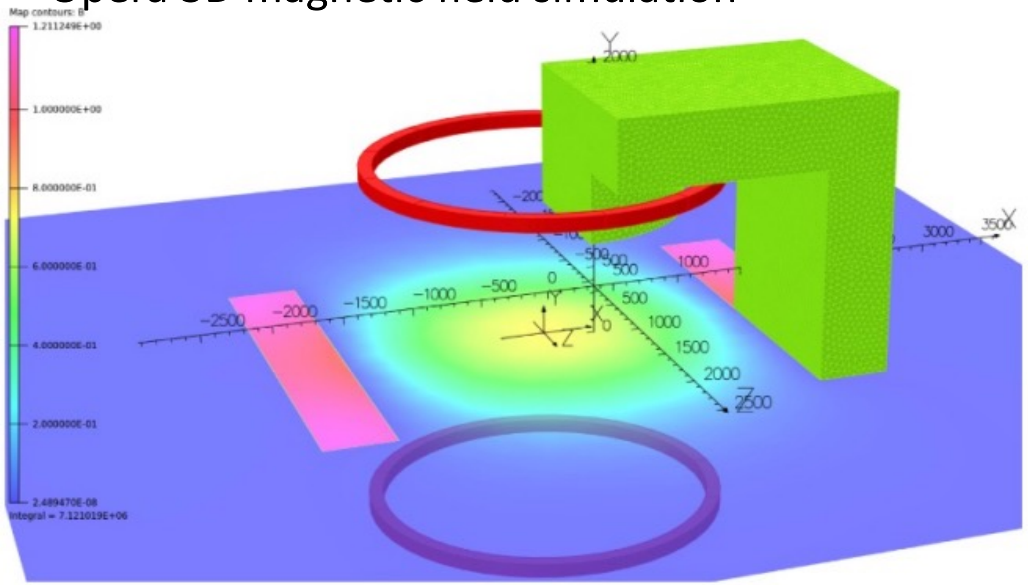
- 2Tm bending power
- 3m x 1m (gap) apperture (also studying a square apperture 1.7m x 1.7m)
- 4m wide x 3m high outer dimensions
- Peripheral equipment:
    - Cryogenics based on 4 cryo coolers
    - Other equipment (Vacuum pump unit, Water cooled compressor, Power source)
    - 36kW maximum power usage

Rough costing from Toshiba of 4.3MCHF (without transportation), and 3-4 year lead time.
Study of transporting super conducting coils into cavern carried out.

SAMURAI magnet at Riken in Japan



Opera 3D magnetic field simulation

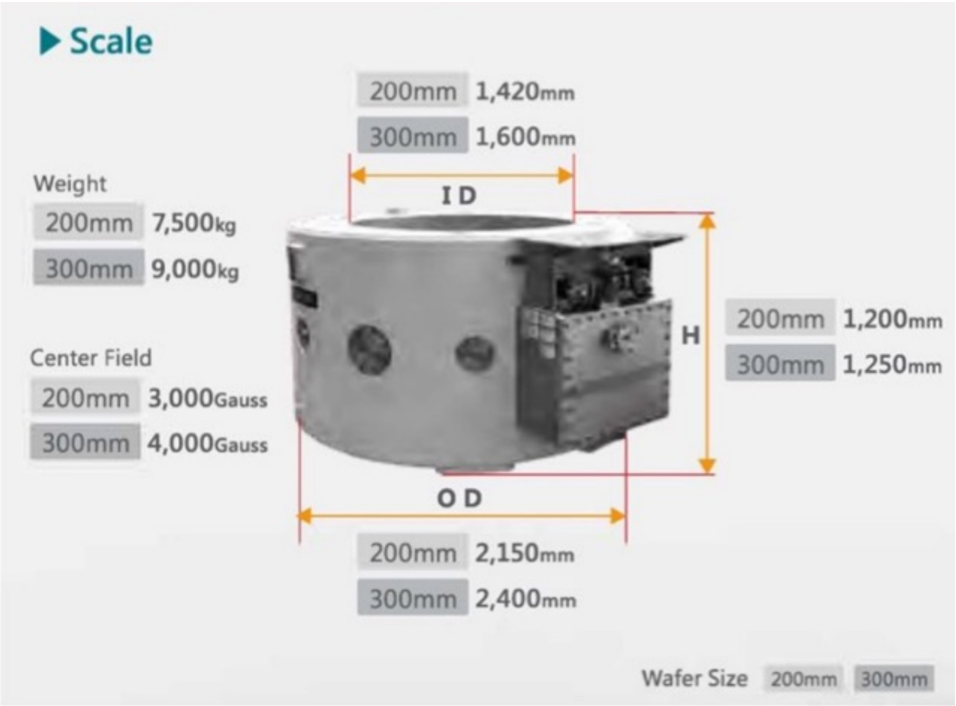


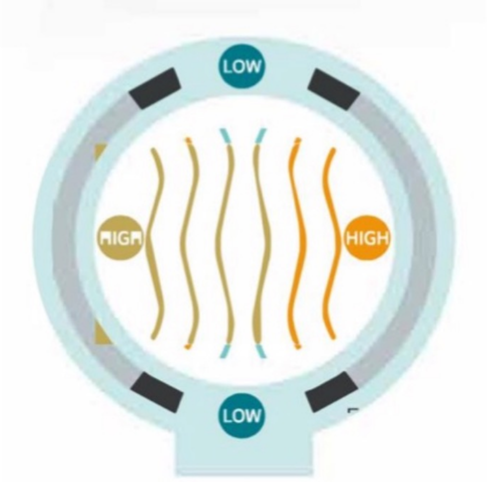
FASER2 magnet - alternative

FASER2 spectrometer has a large apperture magnet. Options discussed with Toshiba, Japan and TESLA, UK.
A possibility is to use an off-the-shelf 'crystal-puller' magnet available from both companies.
Specifications:

- Central field 0.4 – 0.5T
  - Can be chained together to provide more bending power e.g. 3 magnets can give 1.8 Tm
- Aperture 1.6m diameter (possibly up to 2m diameter)
- Advantages: Off the shelf, no R&D needed (shorter lead time, less risk), cryo system integrated into unit, cheaper
- Units would need to be rotated, seems doable

Transport into cavern checked.

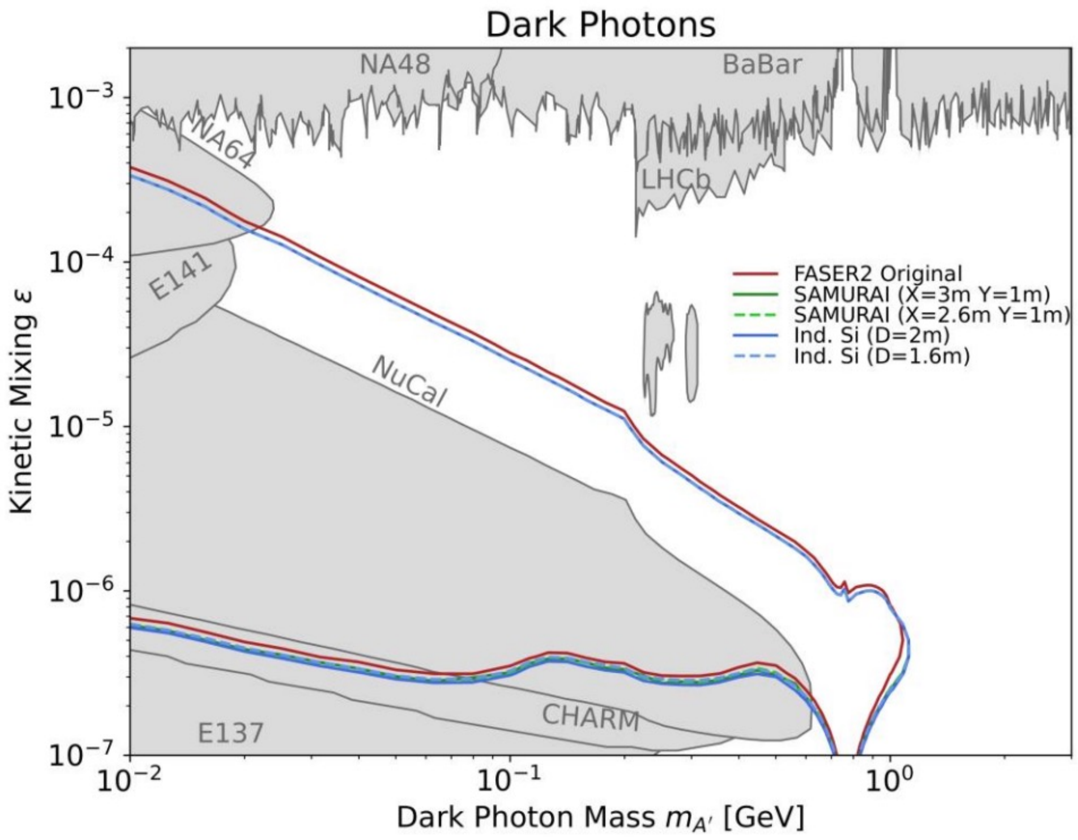


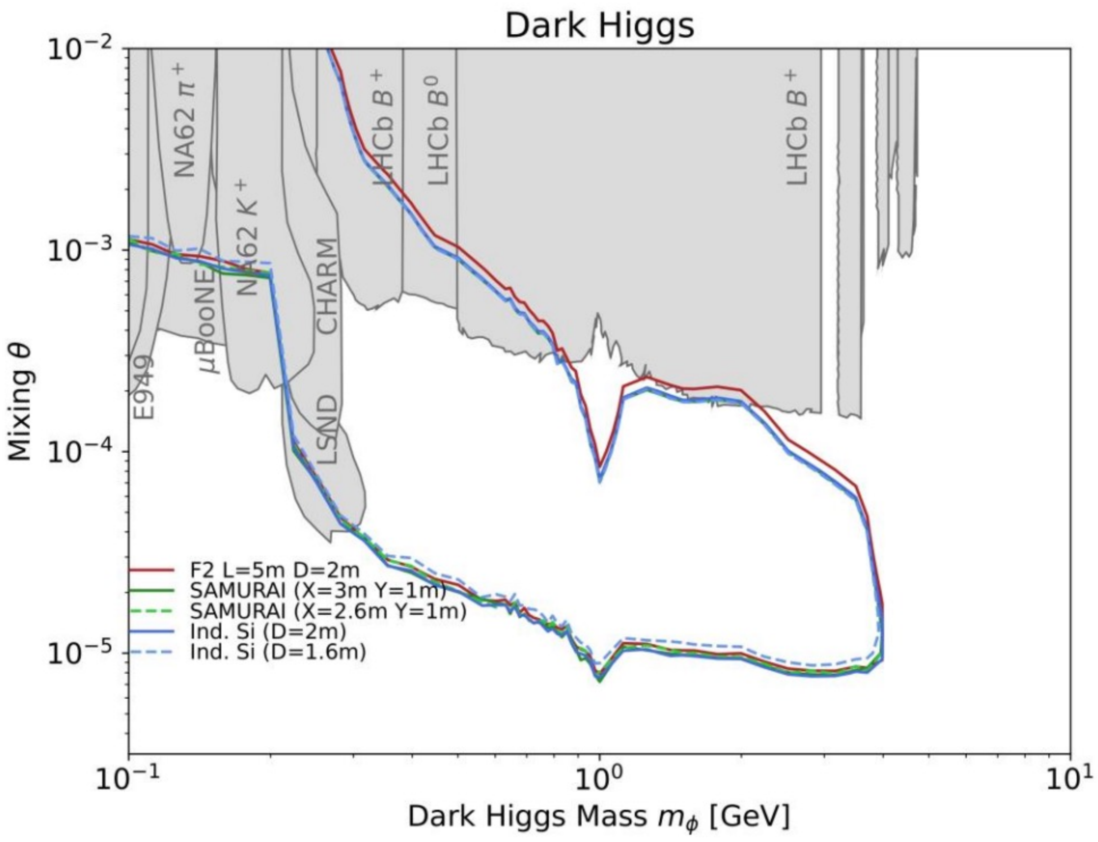


Large uniform field area.

FASER2 studies

Studying physics reach with different magnet and detector setups:





Ongoing studies related to:

- Segmentation of scintillator veto system
- If decay volume should be under vacum or light gas to reduce background from nerutrino interactions in air
- Trigger strategy: inclusive trigger like FASER would have a rate of O(250kHz)

BACKUP…

https://cerncourier.com/a/looking-forward-at-the-lhc/

CERNCOURIER | Reporting on international high-energy physics

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SEARCHES FOR NEW PHYSICS | MEETING REPORT

Looking forward at the LHC

1 September 2023

New territory 3D rendering of the proposed Forward Physics Facility and its experiments. Credit: A Navascues Cornago

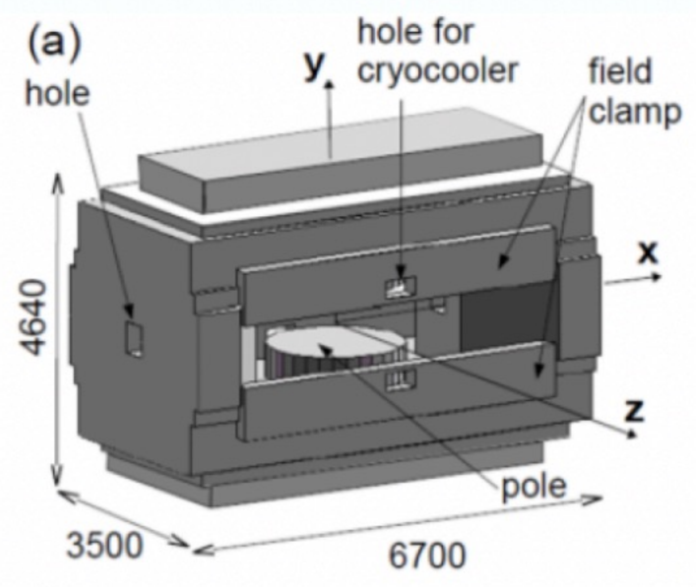
The Forward Physics Facility (FPF) is a proposed new facility to operate concurrently with the High-Luminosity LHC, housing several new experiments on the ATLAS collision axis. The FPF offers a broad, far-reaching physics programme ranging from neutrino, QCD and hadron-structure studies to beyond-the-Standard Model (BSM) searches. The project, which is being studied within the Physics Beyond Colliders initiative, would exploit the pre-existing HL-LHC beams and thus have minimal energy-consumption requirements.

On 8 and 9 June, the 6th workshop on the Forward Physics Facility was held at CERN and online. Attracting about 160 participants, the workshop was organised in sessions focusing on the facility design, the proposed experiments and physics studies, leaving plenty of time for discussion about the next steps.

FASER2 Magnet: Custom SC Dipole

Samurai

The Samurai magnet was also made by Toshiba for RIKEN.

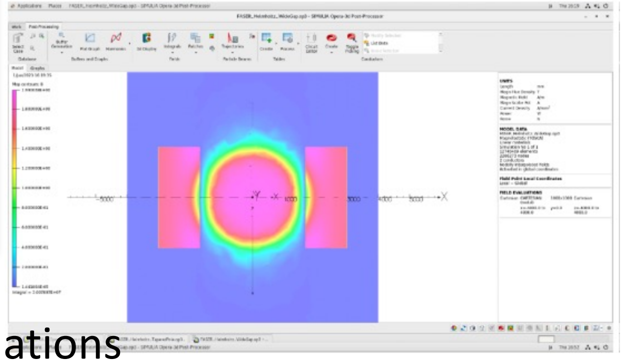


Apperture 3.4m wide and 88cm gap (2m diameter coil).
3T in centre.
Integrated field 7Tm.
Stored energy 27MJ.

- This is an H typer SC dipole. https://ribf.riken.jp/SAMURAI/index.php?Magnet
- The magnet construction took 2.5 years after the delivery of final specifications and contract.
- Special support structure needed to be designed because coils were very heavy.

Dimensions/field scaled down for FASER2 usecase:
Apperture 3m wide and 1m gap (2.6m diameter coil).
0.75T in centre.
Integrated field 2Tm.
Stored energy 7MJ.
(current density <70 A/mm^2)

With above parameters thickness of iron yoke can be reduced to 66cm on each side.



KEK experts have made rough conceptual design and checked several points with OPERA calculations (field, current density, iron return yoke etc..)

Site Visits

Toshinobu Ito, Shohei Takami, Tomofumi Orisaka (senior scientist), Kiyokaku Sato (Senior Engineer), MVD, Yasuhiro Makida, Naoyuki Sumi

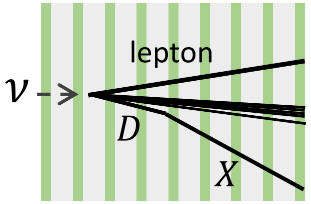
Site visit of Alan Barr to TESLA in Sept. (no photos allowed!)

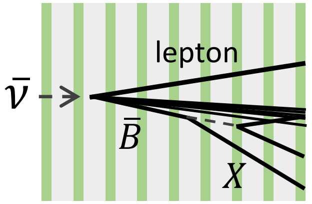
FASERν and FASERν2: expected number of events

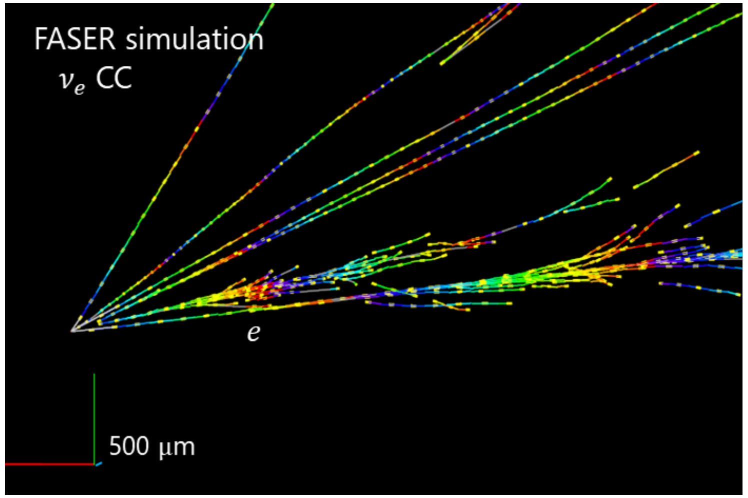
Based on "F. Kling and L.J. Nevay, Forward Neutrino Fluxes at the LHC, Phys. Rev. D 104, 113008"
and "J.L. Feng et al., The Forward Physics Facility at the High-Luminosity LHC, arxiv:2203.05090"

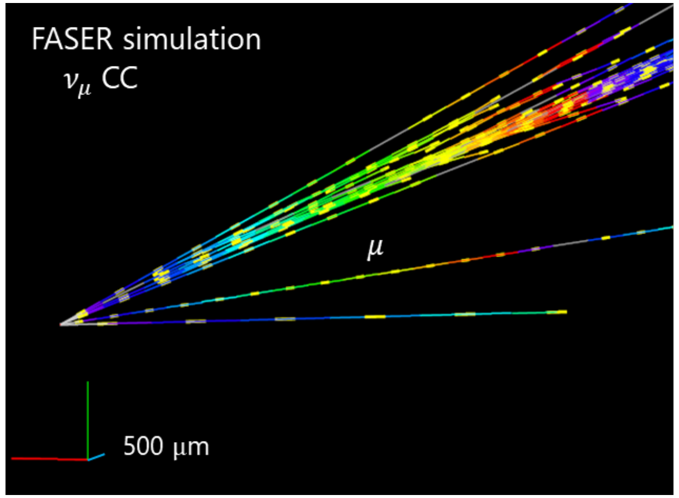
(ν int. rate estimated using **Sibyll 2.3d**) (**DPMJET 3.2017**)

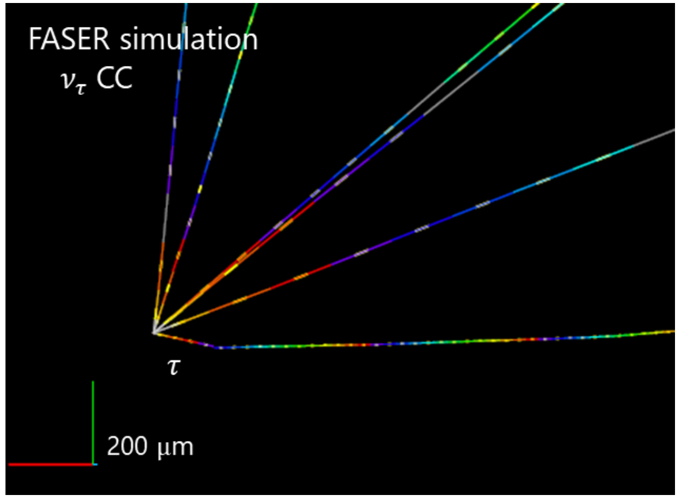
			$\nu_e+\overline{\nu_e}$ CC	$\nu_\mu+\overline{\nu_\mu}$ CC	$\nu_\tau+\overline{\nu_\tau}$ CC		$\nu_e+\overline{\nu_e}$ CC	$\nu_\mu+\overline{\nu_\mu}$ CC	$\nu_\tau+\overline{\nu_\tau}$ CC
FASERν (1.1 tons, 150 fb^{-1})	**ν int.**		**0.9k**	**4.8k**	**15**		**3.5k**	**7.1k**	**97**
	ν int. with charm		~0.1k	~0.5k	~2		~0.4k	~0.7k	~10
	ν int. with beauty		-	~0.05	-		-	~0.1	-
FASERν2 (20 tons, 3 ab^{-1})	**ν int.**		**178k**	**943k**	**2.3k**		**668k**	**1400k**	**20k**
	ν int. with charm		~20k	~90k	~0.2k		~70k	~100k	~2k
	ν int. with beauty		~2	~10	~0.02		~7	~10	~0.2











Emulsion film

[“Nuclear Emulsions”, https://link.springer.com/chapter/10.1007/978-3-030-35318-6_9](https://link.springer.com/chapter/10.1007/978-3-030-35318-6_9)

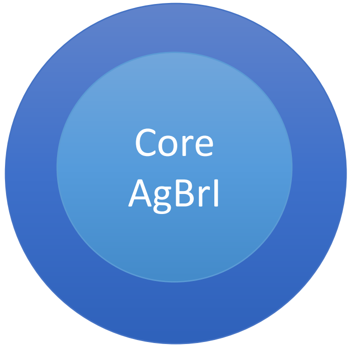
A minimal detector:

Silver bromide (AgBr) Cristal

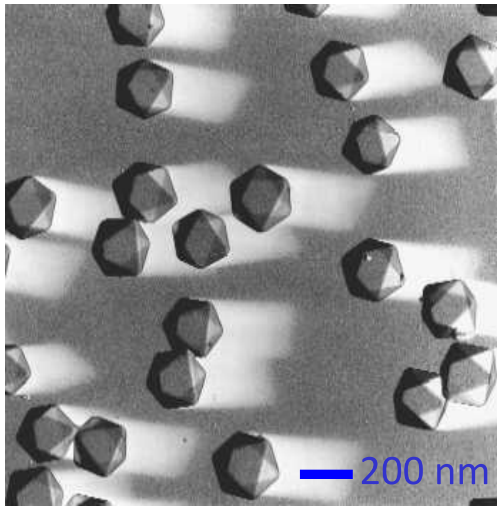
- diameter = 200 nm
- detection eff. = 0.16/crystal
- noise rate = 0.5×10^{-4}/crystal
- volume occupancy = 30%

10^{14} detection channels per cm^3

Core-shell structure



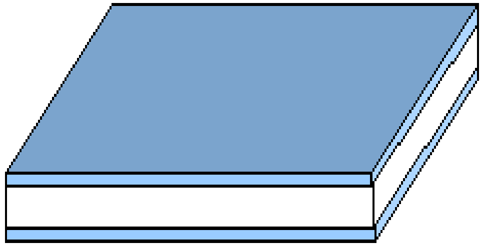
Shell AgBr (+Fe)

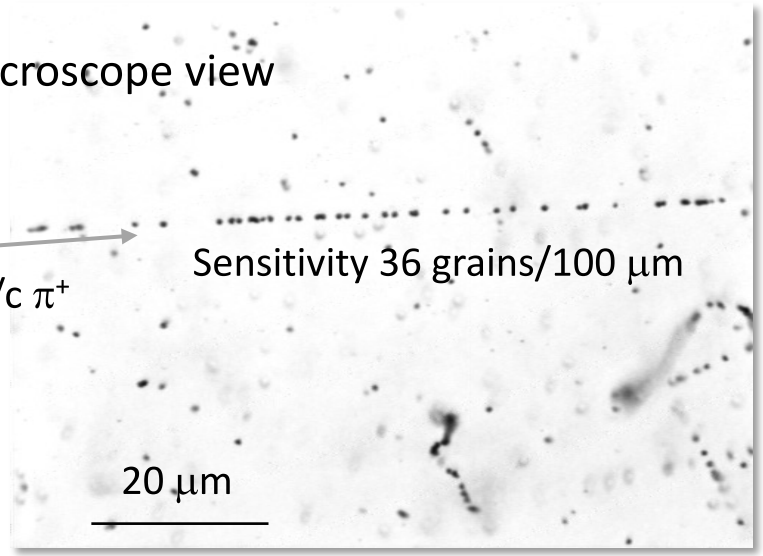


AgBr crystals of 200 nm diameter

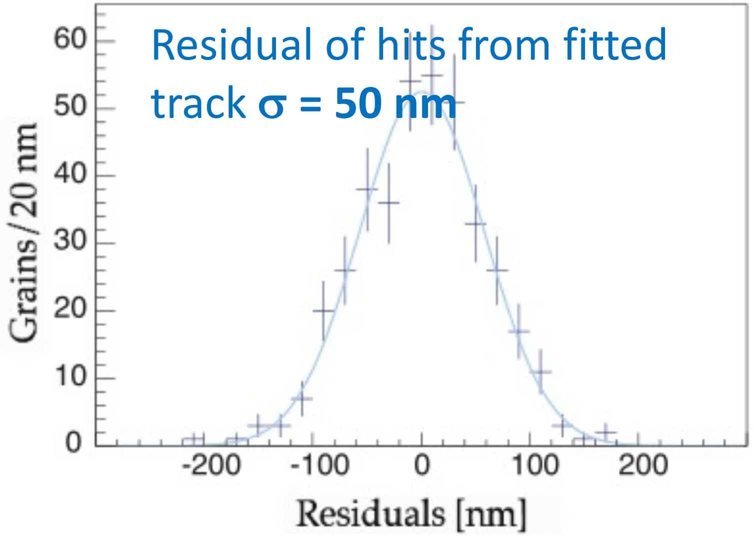
Emulsion gel = composite of AgBr crystals and gelatin

Emulsion film has two layers of 65-μm-thick emulsion layer on both sides of 210-μm plastic base





10 GeV/c π^+

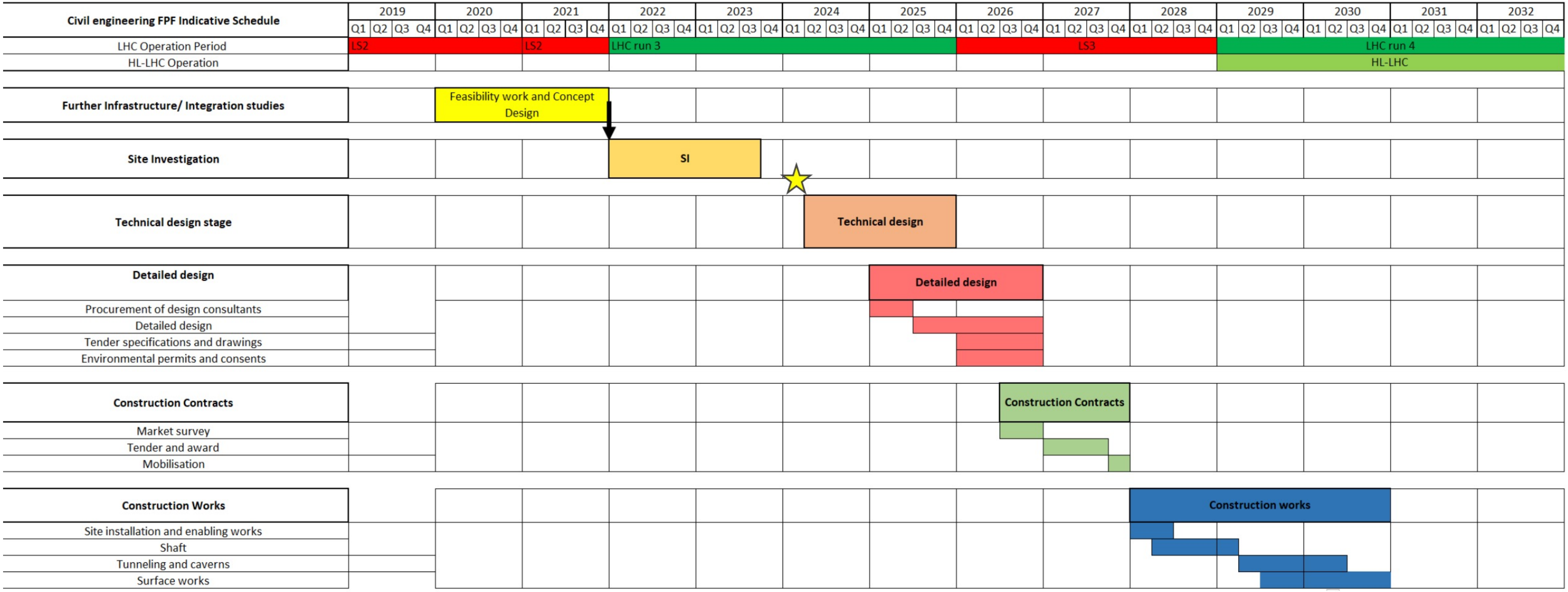


FASERv2
Cost estimate

Item	Cost (kCHF)	How many years	Sub-total	Comments
Fixed costs				
Tungsten	2000		2000	2-mm-thick 40x40 cm^2, 3300 plates +10%
Emulsion readout	1700		1700	
Expert of the readout system	500		500	
Veto / interface detectors	200		200	
Support structure	400		400	
Cooling system	100		100	
Annual cost				
Emulsion	1000	10	10000	40x40 cm^2, 3300 films
Chemicals for development	50	10	500	
Personnel for scanning	50	10	500	
Total			15900	

15.9MCHF including 10 sets of emulsion film

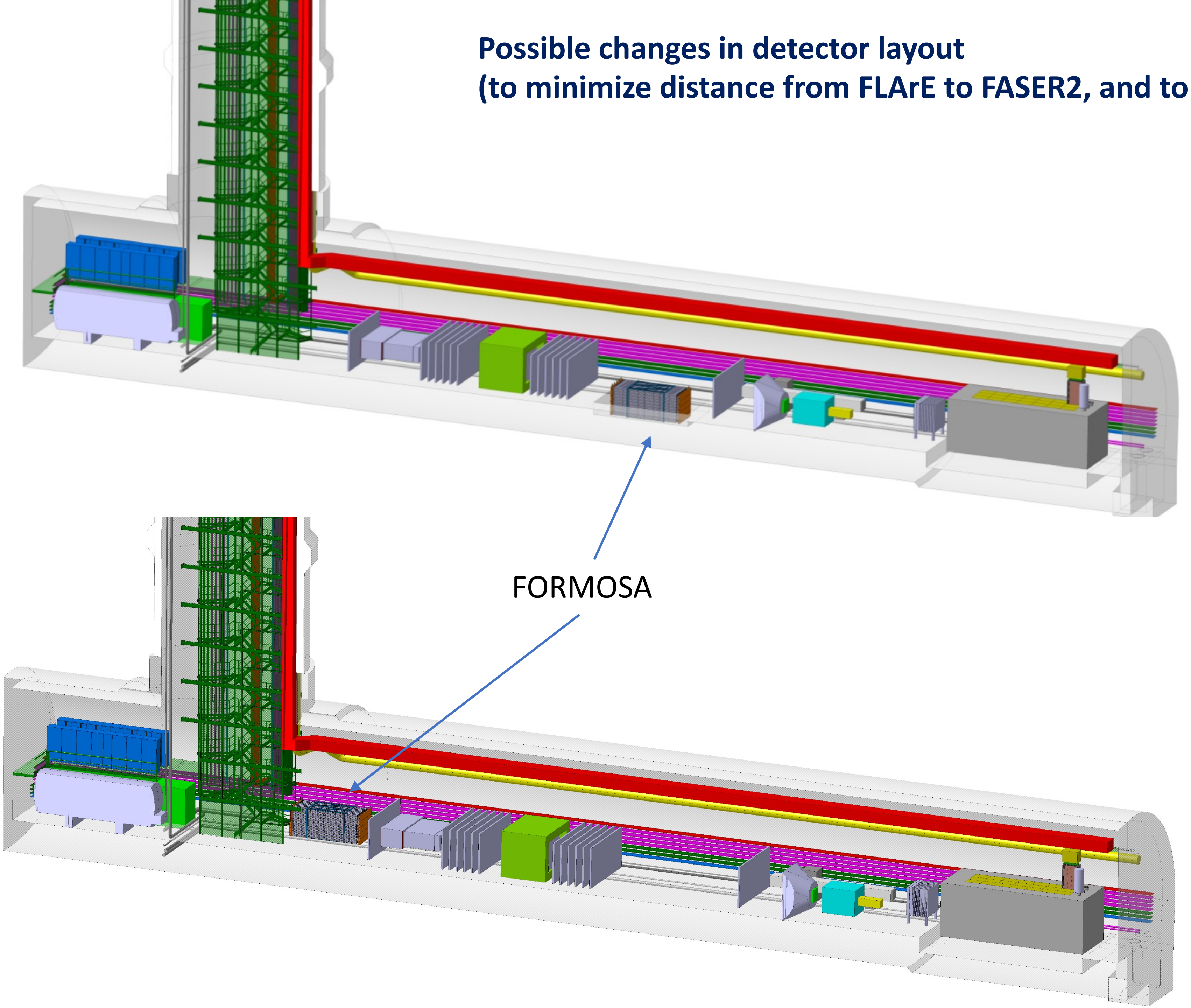
Proposed Civil Engineering Schedule



NB Very early stage estimate for schedule

☆ **Design must be frozen before technical design can begin**

Possible changes in detector layout
(to minimize distance from FLArE to FASER2, and to save space)



Cost and Timeline

Work	Months	Comments
Designing	9	
Procurement	12	could be started before designing
Winding wire	6	could be done while designing
Assembly	12	
Test	3	
Dismantlement, Delivery	2	
	44 (3.6 years)	could be 35 (2.9 years)

3-4 years expected before commissioing

	JPY [MJPY]	CHF [MCHF]
Material	**384**	**2.2**
Superconducting wire	6.3	0.04
Yoke material	88	0.51
Yoke manufacturing	106	0.62
Vacuum chamber, shield, etc	130	0.76
Coil winding jig, assembly jig	51	0.30
Testing instruments	2.7	0.02
Commercial product (cryogenics, power supply, etc)	**73**	**0.43**
Manufacturing and assembly	**102**	**0.60**
Others (Designing, testing, etc)	**174**	**1.02**
	733	**4.29**

Transportation fee is not included

Magnet parameters

In addition, 3 m x 2 m aperture (wider gap) with 2 Tm is also tried

- 50 cm thick return yoke still work; total width is kept at 4 m, while total height increases to 4 m
- Stored energy still below 10 MJ, no need to use Liquid He bath cooling

	SAMURAI	2 Tm gap 1 m	2 Tm gap 2 m
Coil diameter [m]	2.6	2.6	2.6
Coil cross section [mm^2]	180×160	100×100	100×100
Current density [A/mm^2]	66.74	37	86
Coil current for Φ1.2 mm cable [A]	563	48	112
Total width [m]	6.7	4	4
Total height [m]	4.64	3	4
Iron yoke thickness [m]	1.65	0.5	0.5
Iron weight [t]	566	167	190
Gap [m]	0.88	1	2
Coil center field [T]	3.08	0.89	0.75
Max field in coil [T]	5.4	1.5	2.9
Integral magnetic field at center [Tm]	7.05	2.20	1.92
Stored energy [MJ]	27.4	2.2	8.2

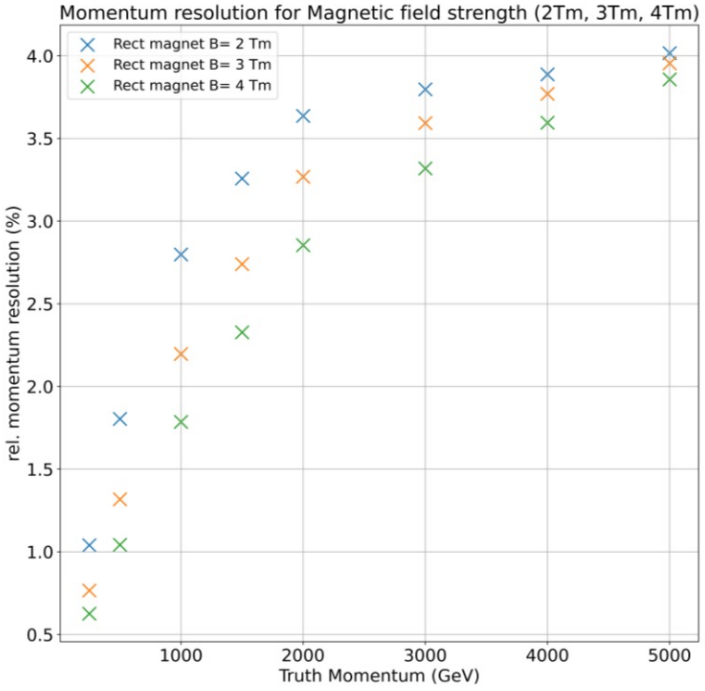
4.3 MCHF + ~1 MCHF [TBC]

1.7 m x 1.7 m aperture will be tried in the next iteration

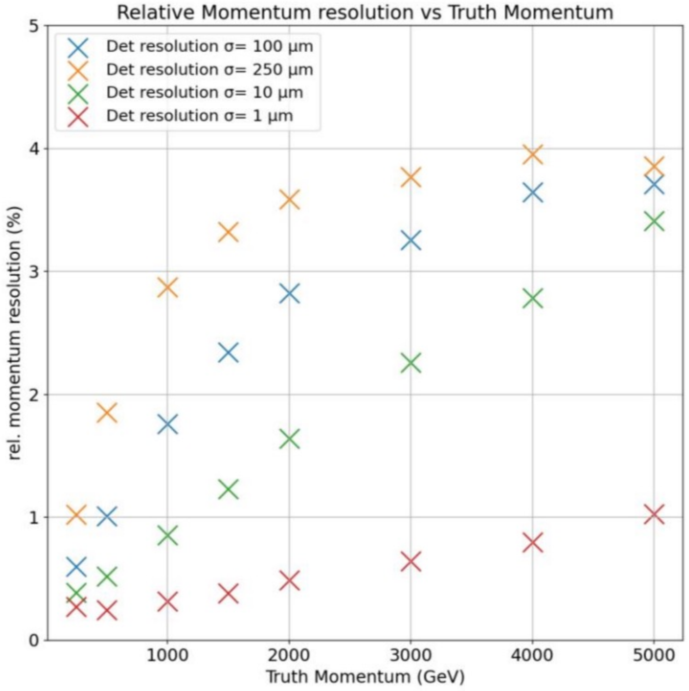
FASER2 Software: Performances

- ACTS performance plots for different FASER2 detector configurations/parameters

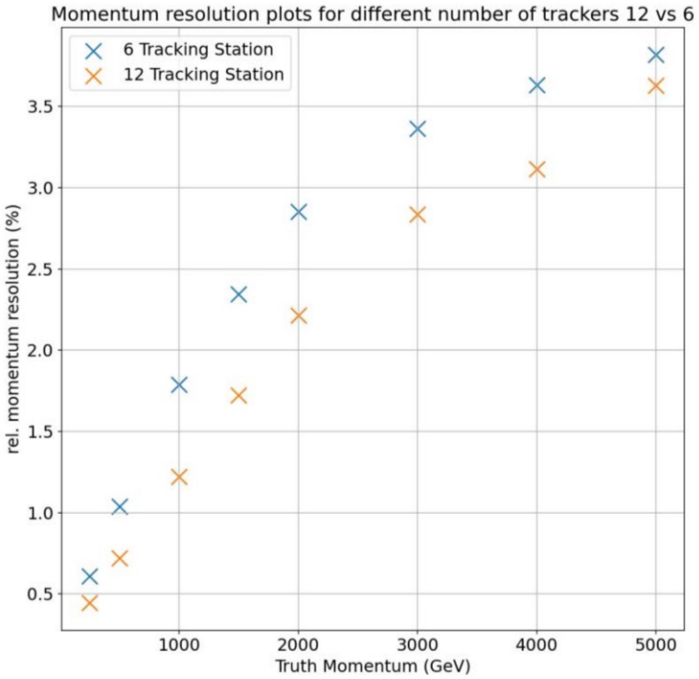
Field strength



Tracker resolution



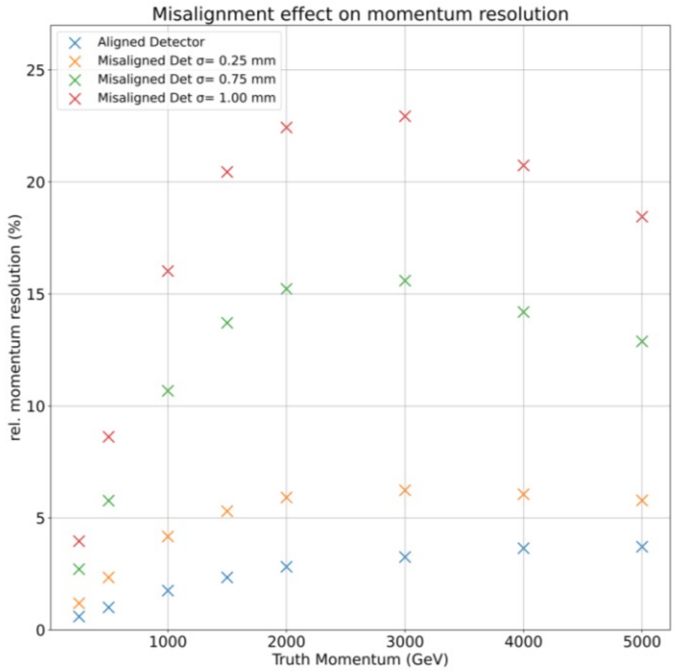
Number of tracking station

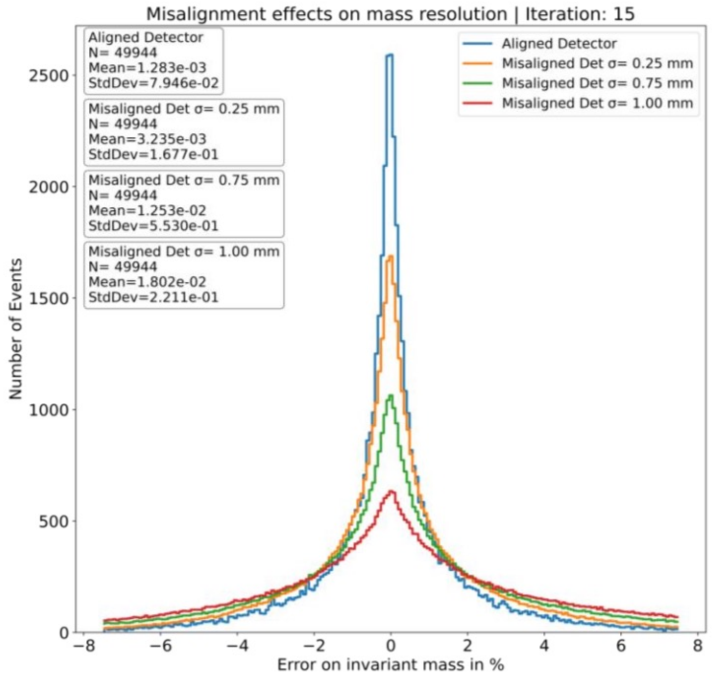


- Momentum resolution remains good while reducing magnetic field to 2 Tm
- Effect of tracker resolution on the momentum resolution
- Good performances with 6 tracking layers configuration

FASER2 Software: Alignment

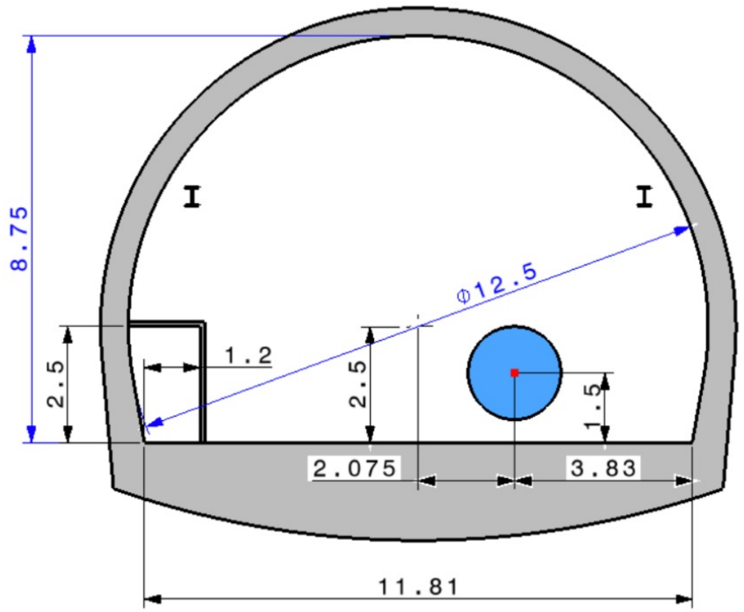
- ACTS performance plots for detector toy misalignment of FASER2
- Study identifies the tracker alignment is a key performance driver



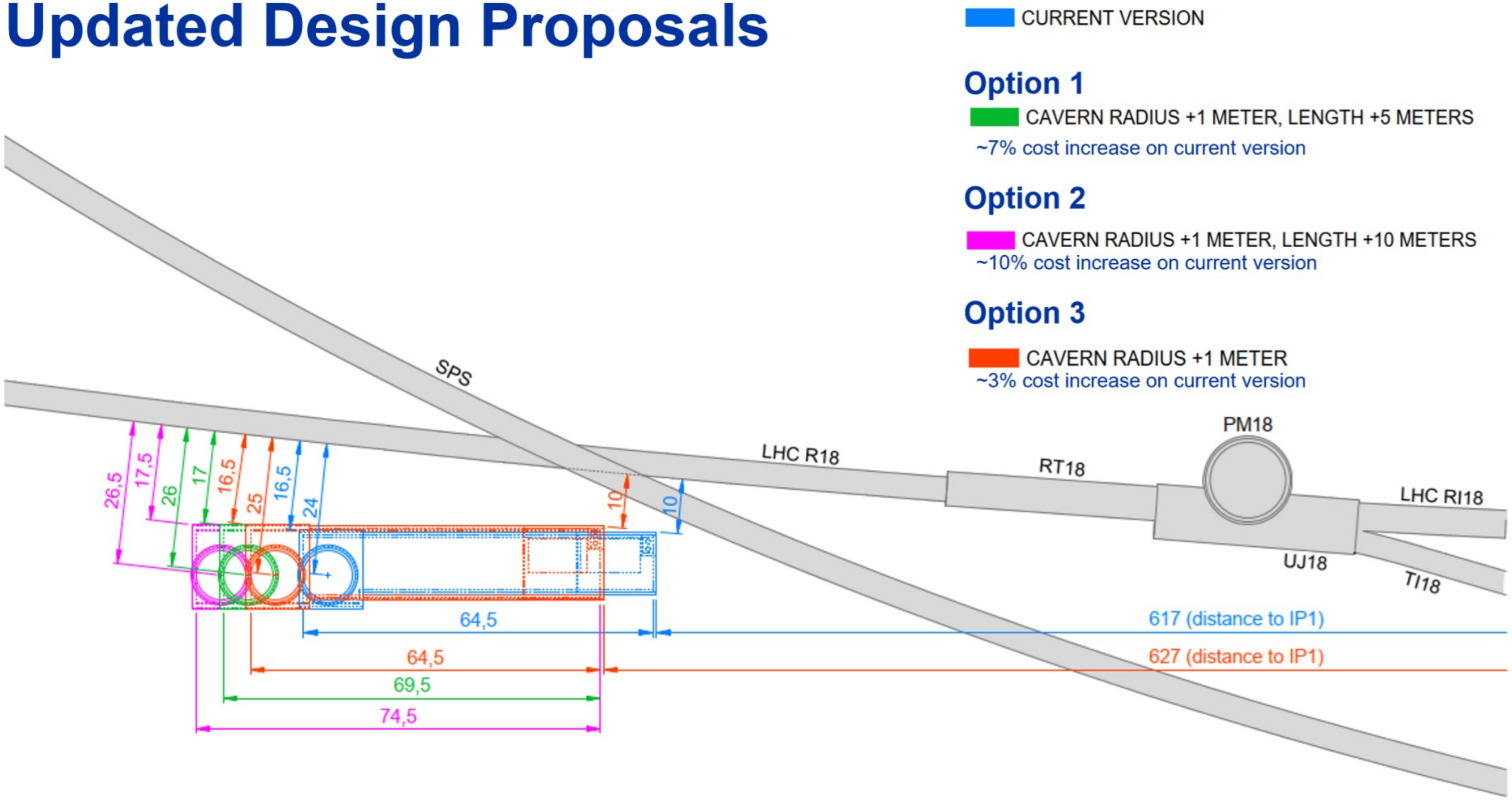


- Misalignment of tracking station > 250 μm starts to have significant impact on momentum resolution
- Expected mechanical precision should have alignment precision of 250 μm
  - ➢ Achieving 250μm alignment precision across large detectors (~10m appart) is challenging
- On-going studies to use the muon background for track alignment (Luke Kennedy)

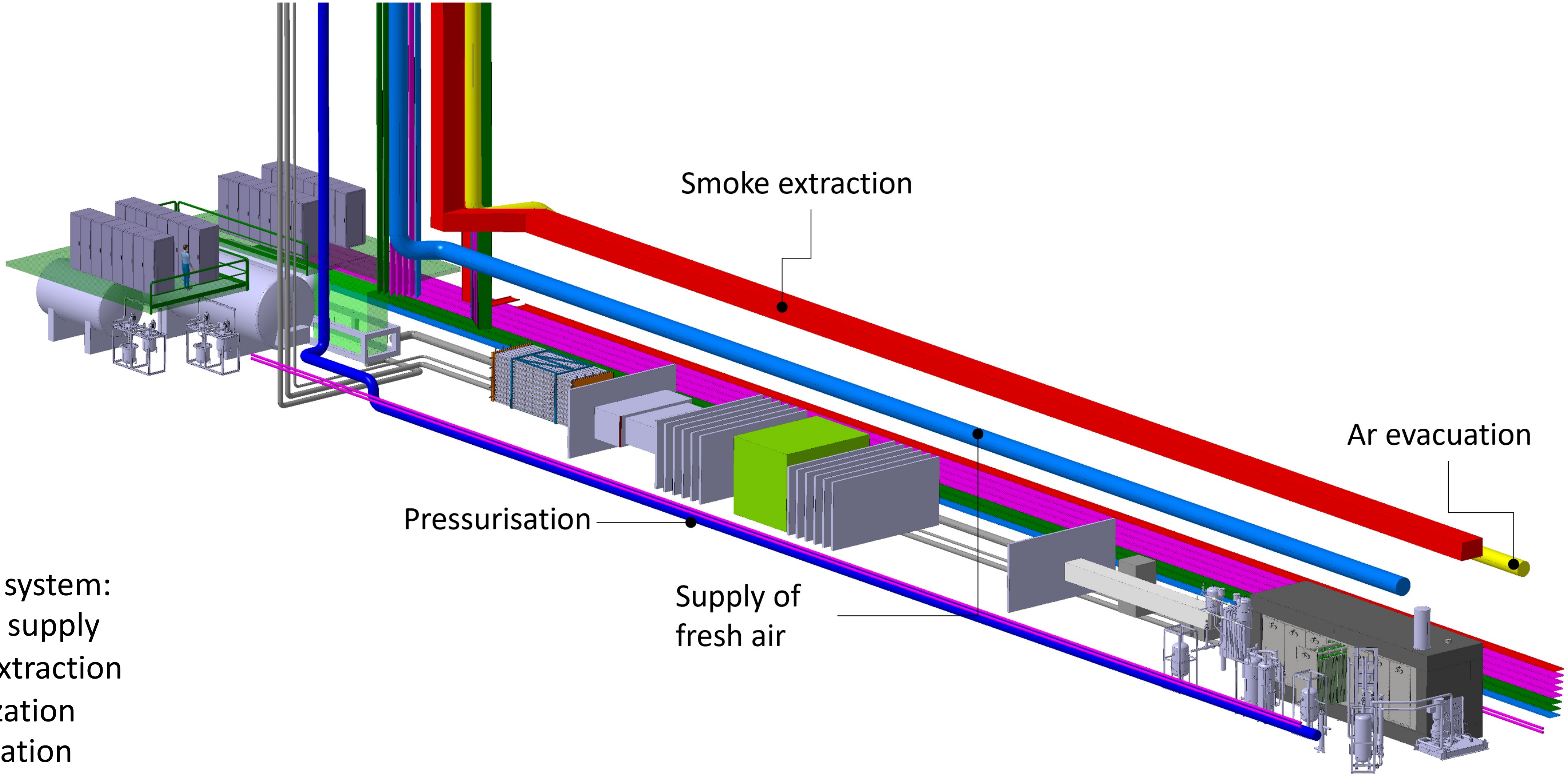
Facility Optimization



Updated Design Proposals



Integration updates: ventillation



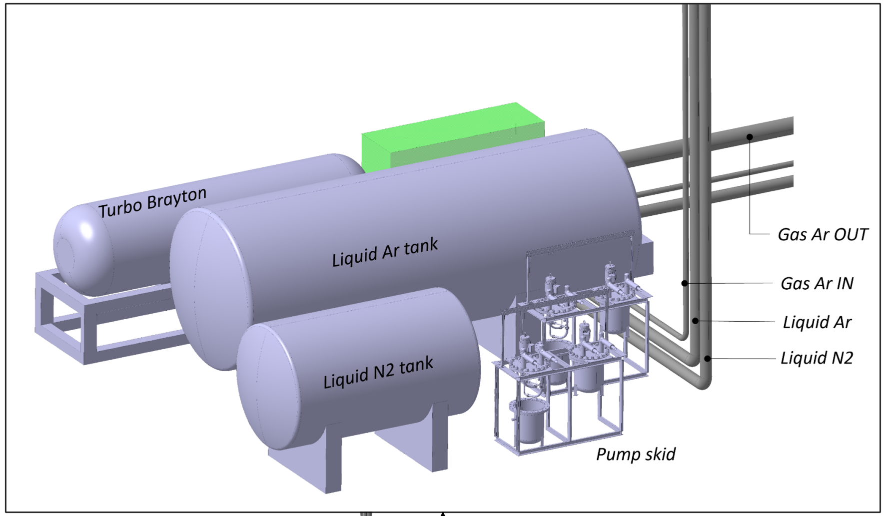
Ventillation system:

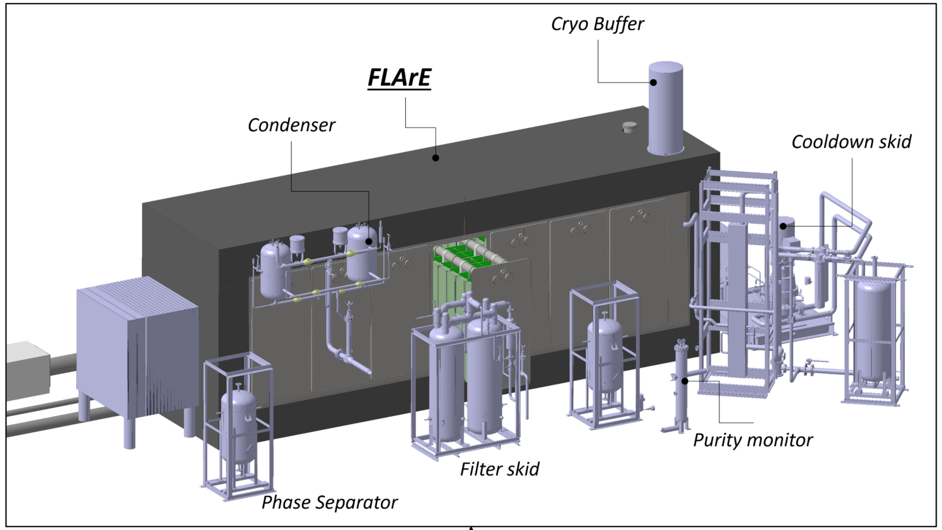
- Fresh air supply
- Smoke extraction
- Pressurization
- Ar evacuation

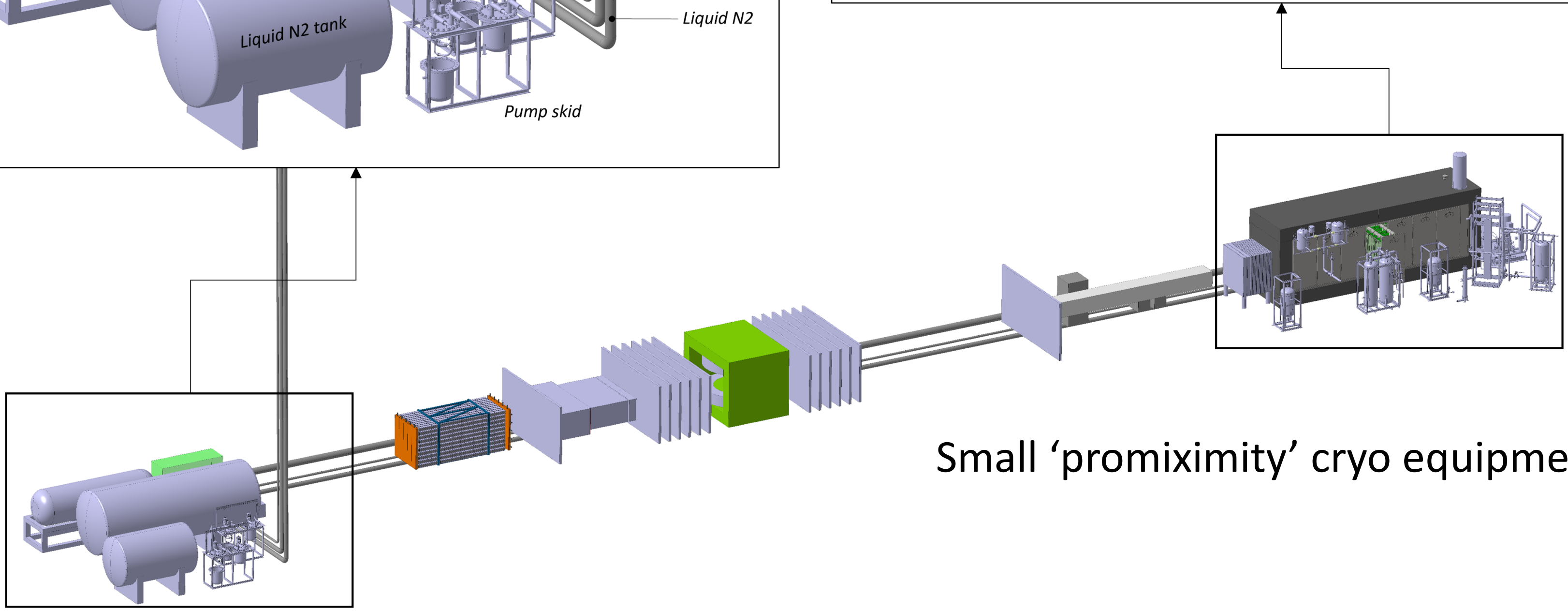
Integration updates: Cryogenics

Large cryo equipment in separate service cavern:

- Turbo-Brayton cooling unit
- Storage tanks (LAr, N_2)







Small 'promiximity' cryo equipment close to FLArE cryostat

Handling Equipment