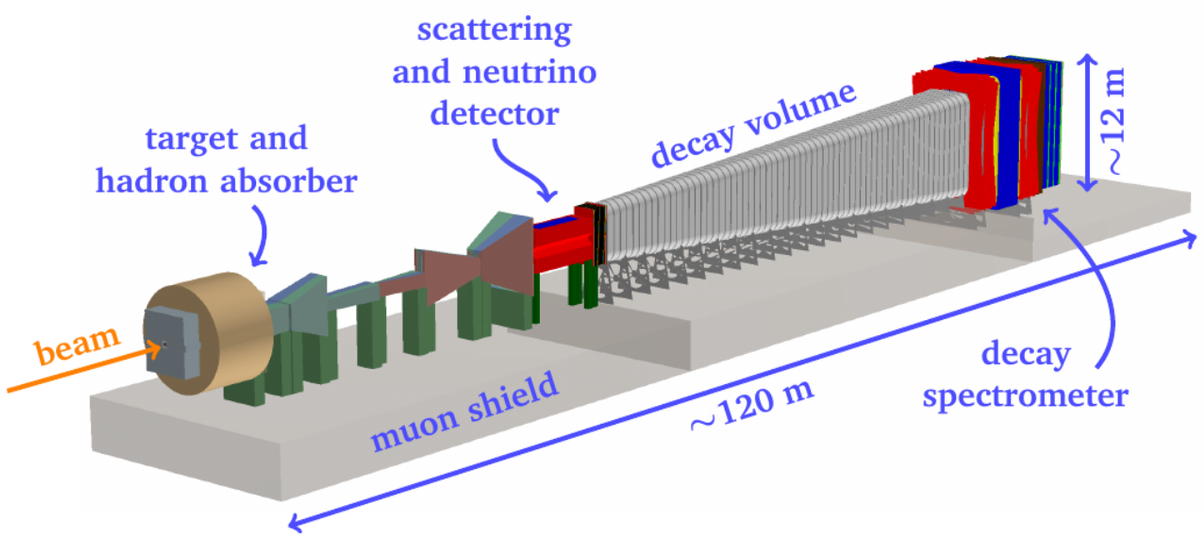
Status of the SHiP proposal

Mario Campanelli (UCL)

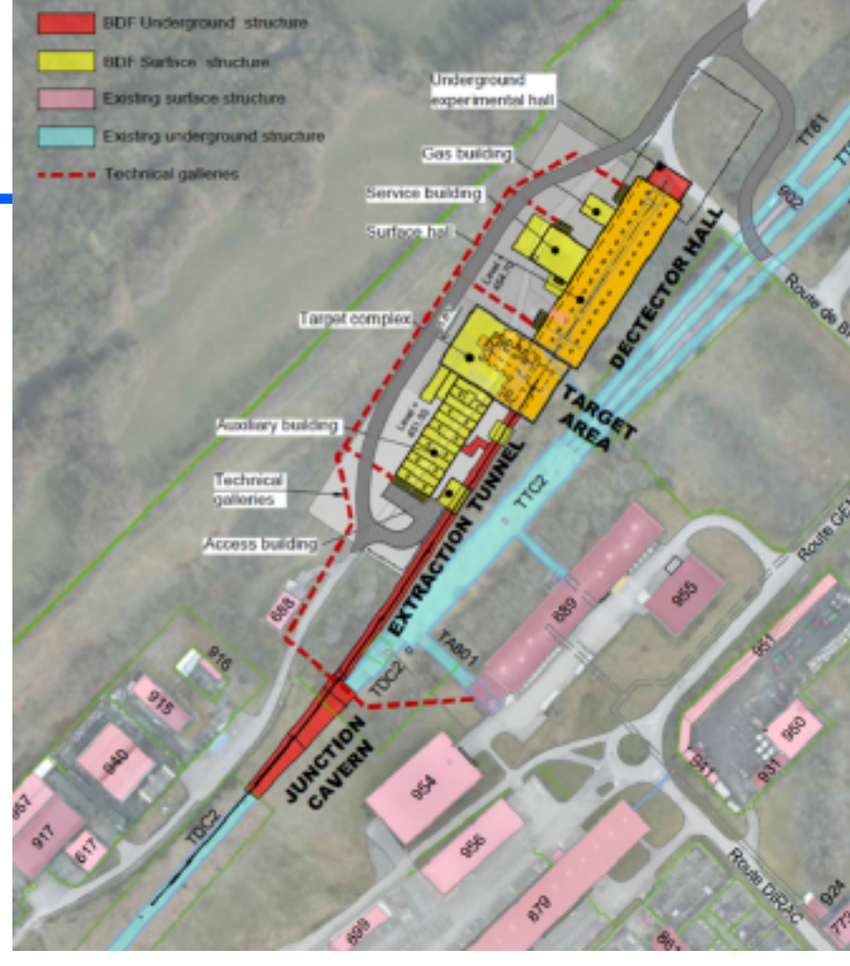
on behalf of SHiP UK

A.Golutvin, M.Patel (ICL)
K. Petridis (Bristol)
G.Barker (Warwick)
S.Ricciardi (RAL)



The SHiP experiment

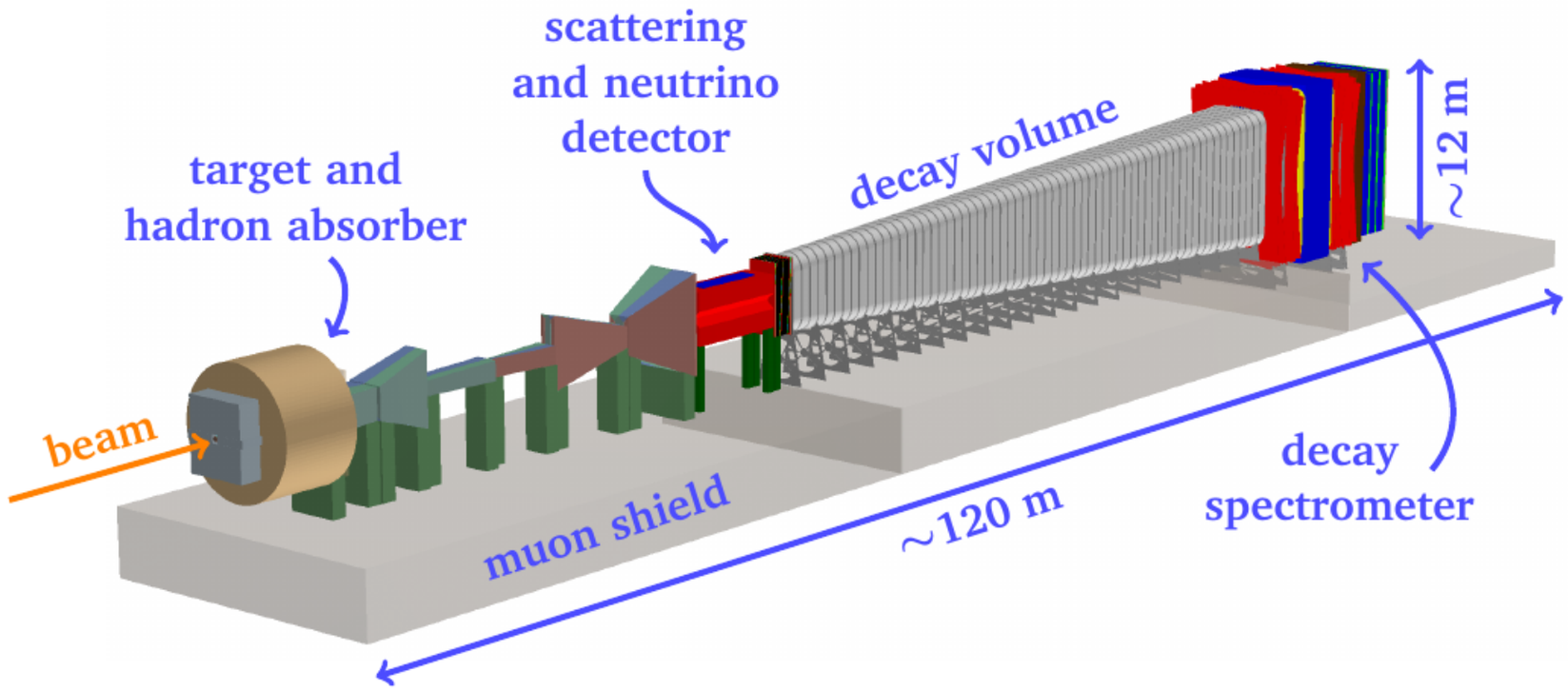
Dedicated detector for weakly coupled long-lived particles, plus tau neutrino and LDM scattering, to be run at future beam-dump facility at CERN.



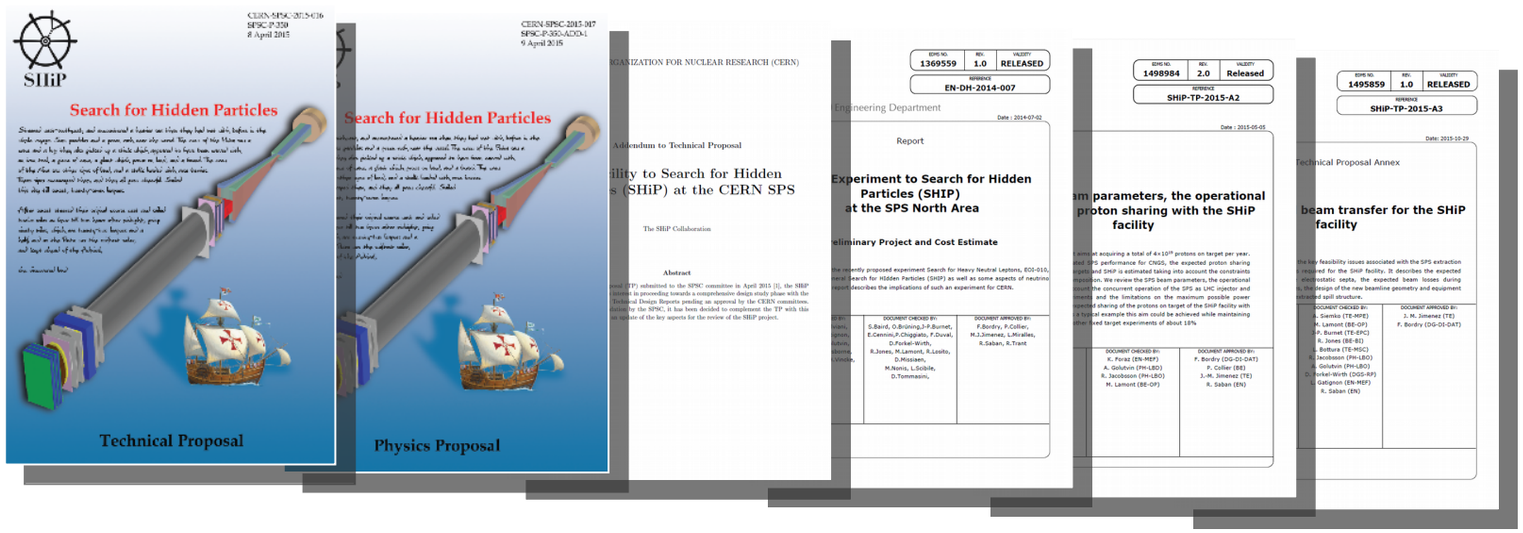
The spectrometer is located ~100m

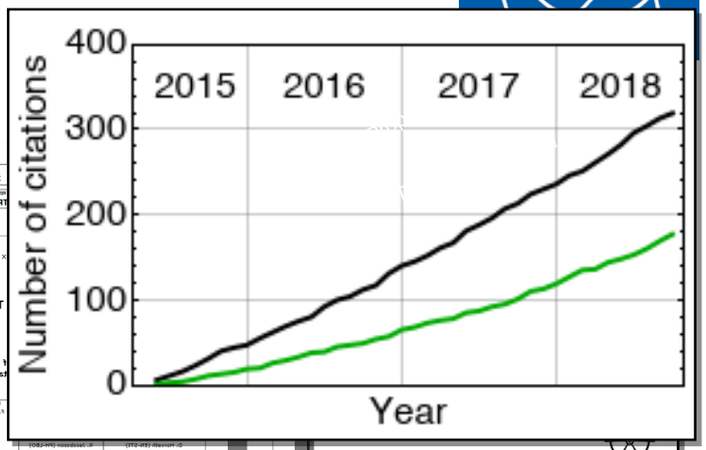
downstream of the target, after a magnetised muon shield, the scattering and neutrino detector and a long decay volume

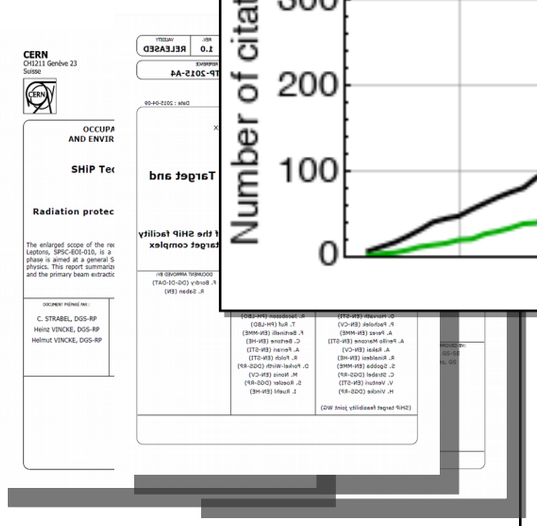
Aim for a 0-BG experiment (2 events → discovery)

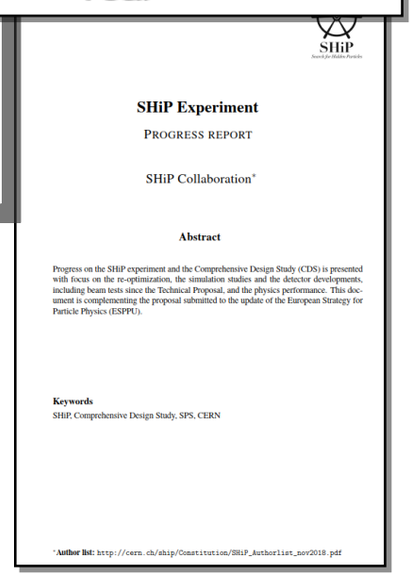


SHiP history








SHiP Experiment

PROGRESS REPORT

SHiP Collaboration*

Abstract

Progress on the SHiP experiment and the Comprehensive Design Study (CDS) is presented with focus on the re-optimization, the simulation studies and the detector developments, including beam tests since the Technical Proposal, and the physics performance. This document is complementing the proposal submitted to the update of the European Strategy for Particle Physics (ESPPU).

Keywords
SHiP, Comprehensive Design Study, SPS, CERN

*Author list: http://cern.ch/ship/Constitution/SHiP_Authorlist_nov2018.pdf

2013 Oct: EOI with SHiP@SPS NA

...following brainstorming SHiP@IP8, SHiP@LBD, SHiP@CNGS, SHiP@WANF

2014 Jan: Encouraged to produce TP and inter-departmental task force setup to study feasibility of proposed facility

2015 Apr: TP with ~700 pages by SHiP theorists, experimentalists, and CERN accelerator, engineering, and safety departments

2016 Jan: Recommendation by CERN SPSC to proceed to 3-year Comprehensive Design Study

2016 Apr: CERN management launch of Beyond Collider Physics study group

SHiP experimental facility included under PBC as Beam Dump Facility

2018: EPPSU contribution submitted by SHiP and BDF, and submission of SHiP Progress Report

SHiP Collaboration: ***290 authors, 52 Institutes, 17 countries***

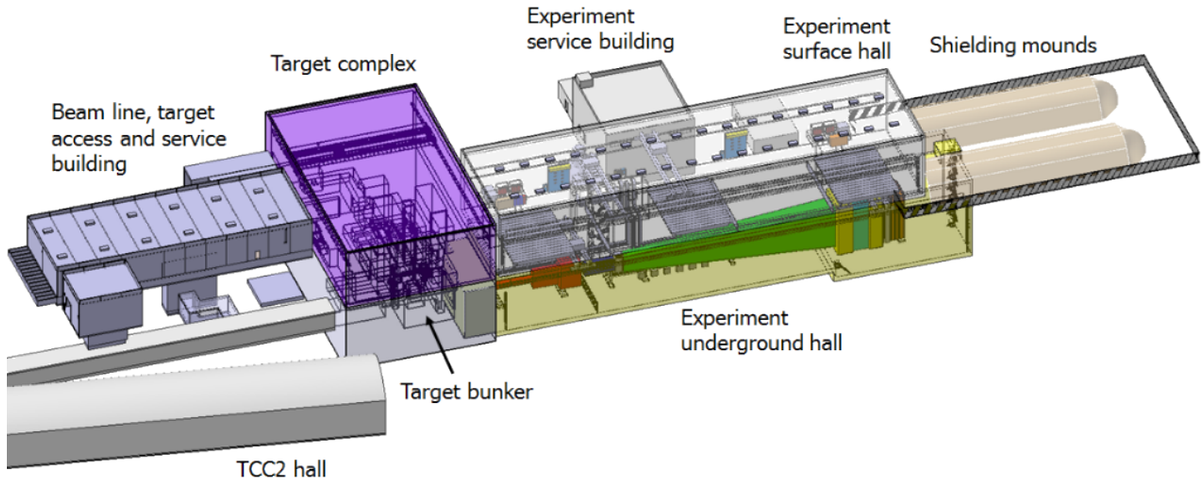
Status of Beam Dump Facility

3-year Comprehensive Design Study completed by BDF team

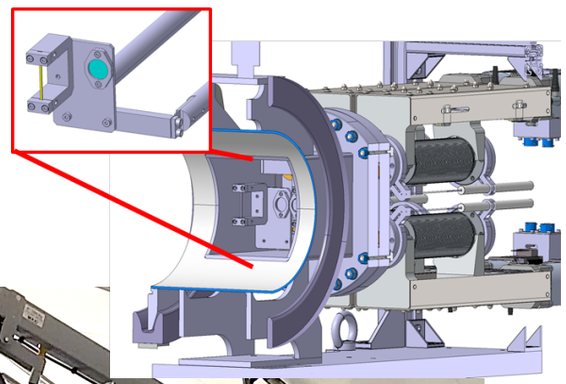
- In-depth feasibility study with prototypes of key elements
  - SPS extraction and proton delivery
  - Target system and target complex, including remote handling
  - Underground experimental area, layout of surface buildings for construction/installation and operation
  - Evaluations of the radiological aspects and safety
  - First iteration of detailed integration and civil engineering studies
  - Updated realistic schedule and cost, detailed project plan and resources for TDR phase

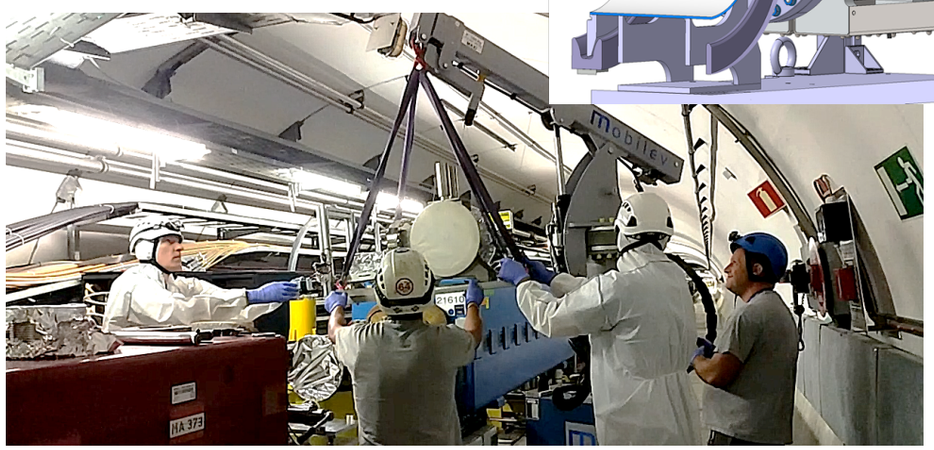
➔Documented in 580-page Yellow Report (being submitted)

➔BDF ready for 3-year TDR phase



A few high-lights:



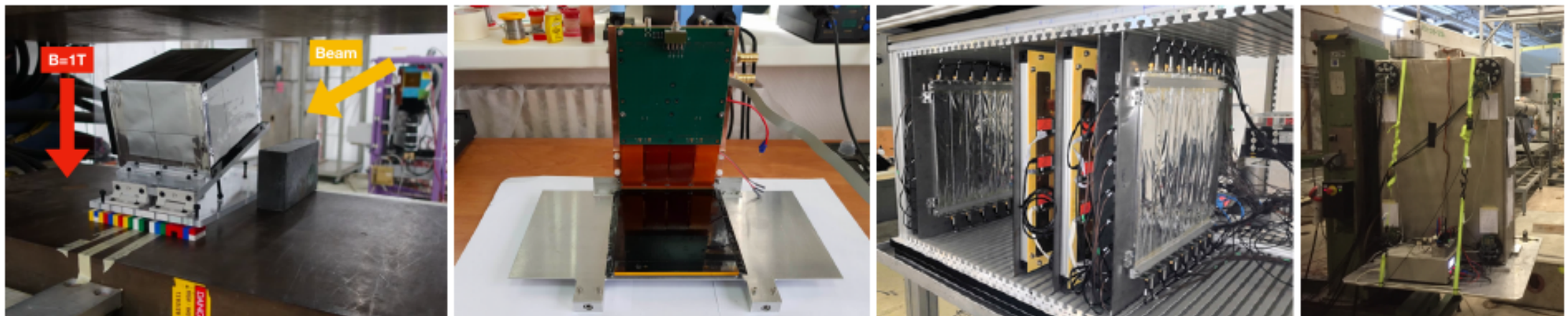


Crystal shadowing of extraction septum wires combined with improvements of beam dynamics and automated alignment achieved factor 3-4 less losses in SPS extraction, validating the SHiP requirements

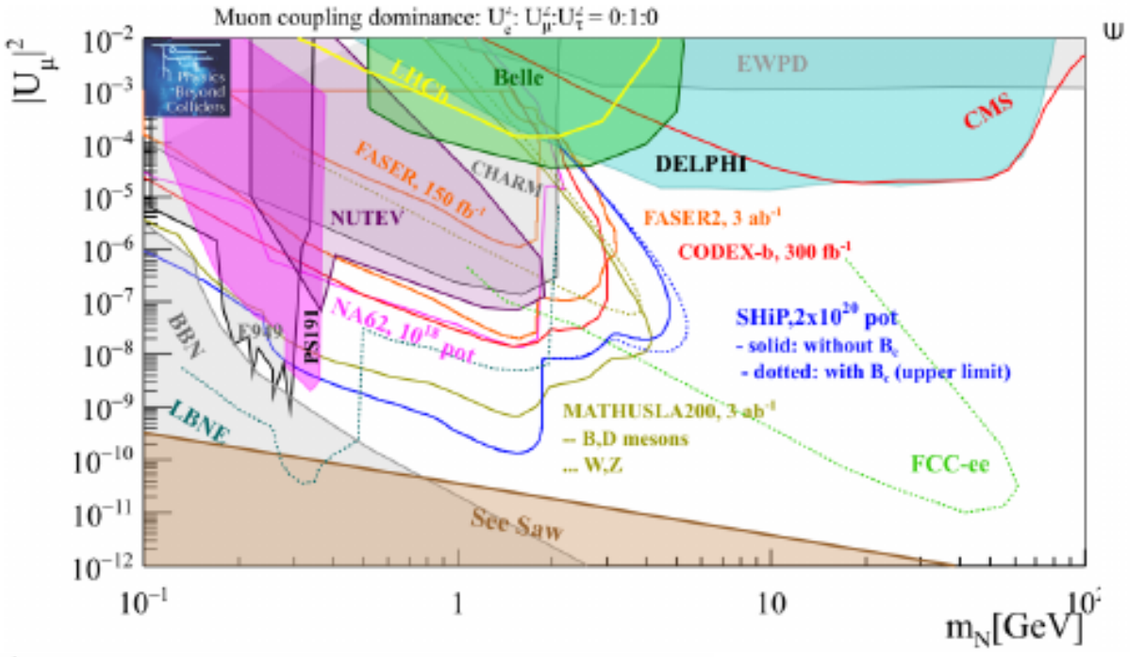
Target prototype, operated successfully in beam

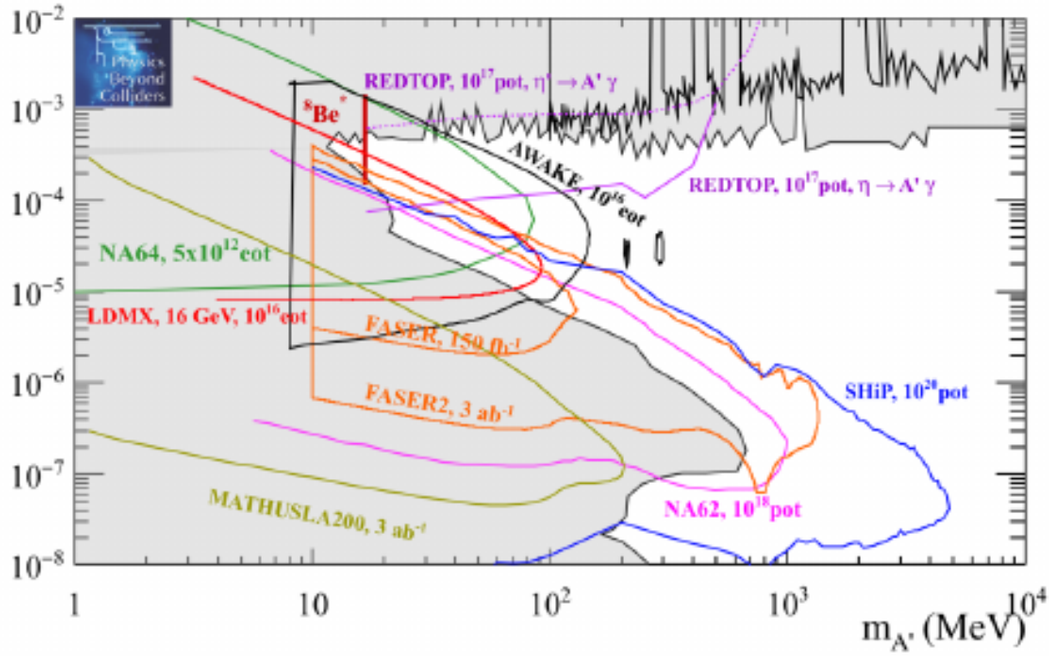
Current status of the experiment

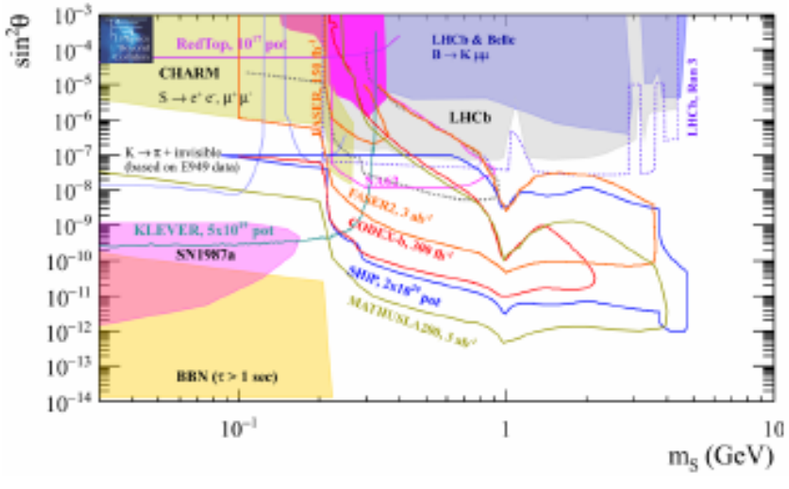
- Collaboration is preparing a Comprehensive Design Study for November 2019, then we expect to be requested a TDR
- Phase-1 prototypes for all sub-detectors built and tested on a beam in summer 2018
- From the summer 2019 ECFA newsletter:
  - Among them, the SPS Beam Dump Facility with the SHiP and (possibly) the TauFV experiment has been identified as having unique potential in the worldwide landscape for dark photon and heavy neutral lepton searches, as well as for third flavour physics ($\nu\tau$ interactions and τ rare decays). It is now mature and ready for an implementation decision pending the Strategy guidelines.
- Phase-2 prototypes under construction, to be tested on beam in 2019-21.

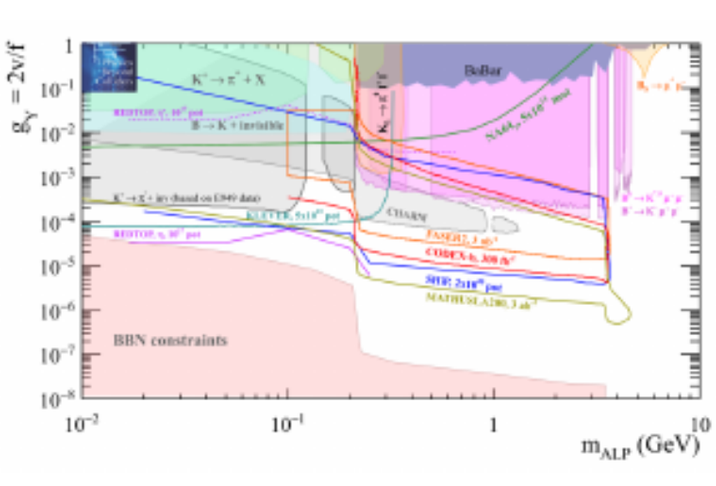


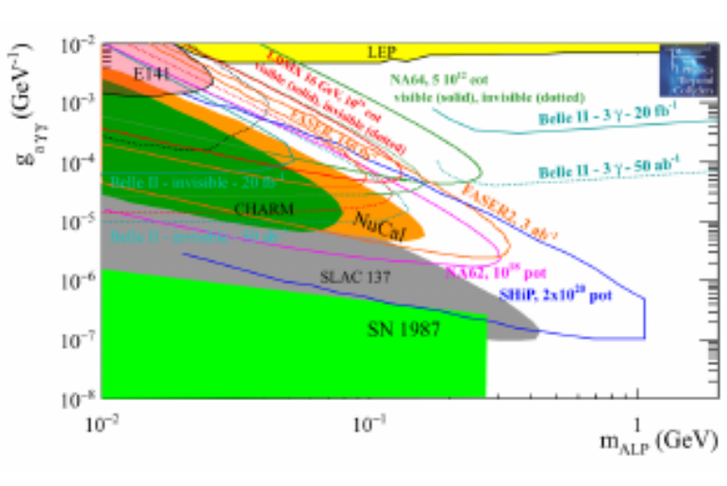
Updated physics reach











[1504.04956, 1504.04855, 1811.00930, 1901.09966]

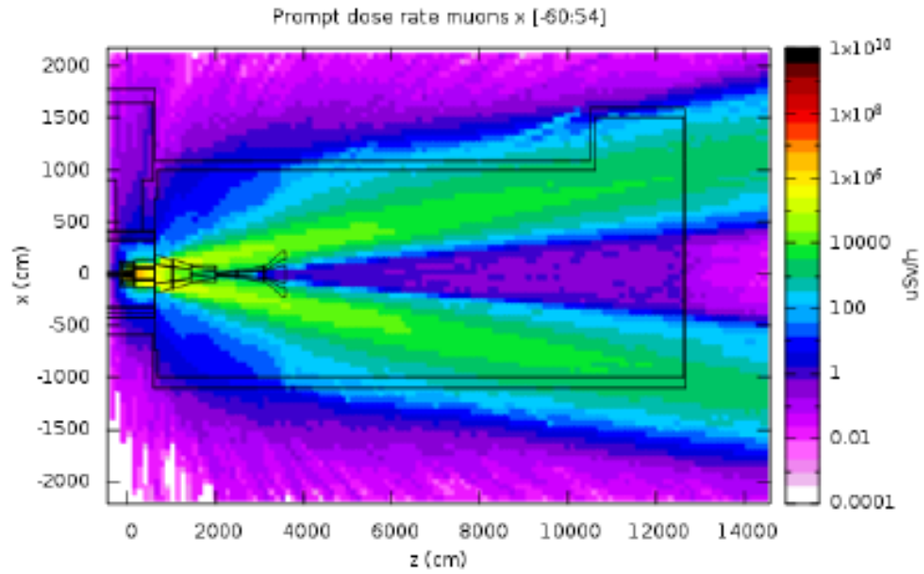
- from top left: HNL (heavy meson decays), dark photon (decays + bremsstrahlung + QCD), scalar (K and B decays), ALPs coupled to fermions, ALPs coupled to photons

Target and shielding

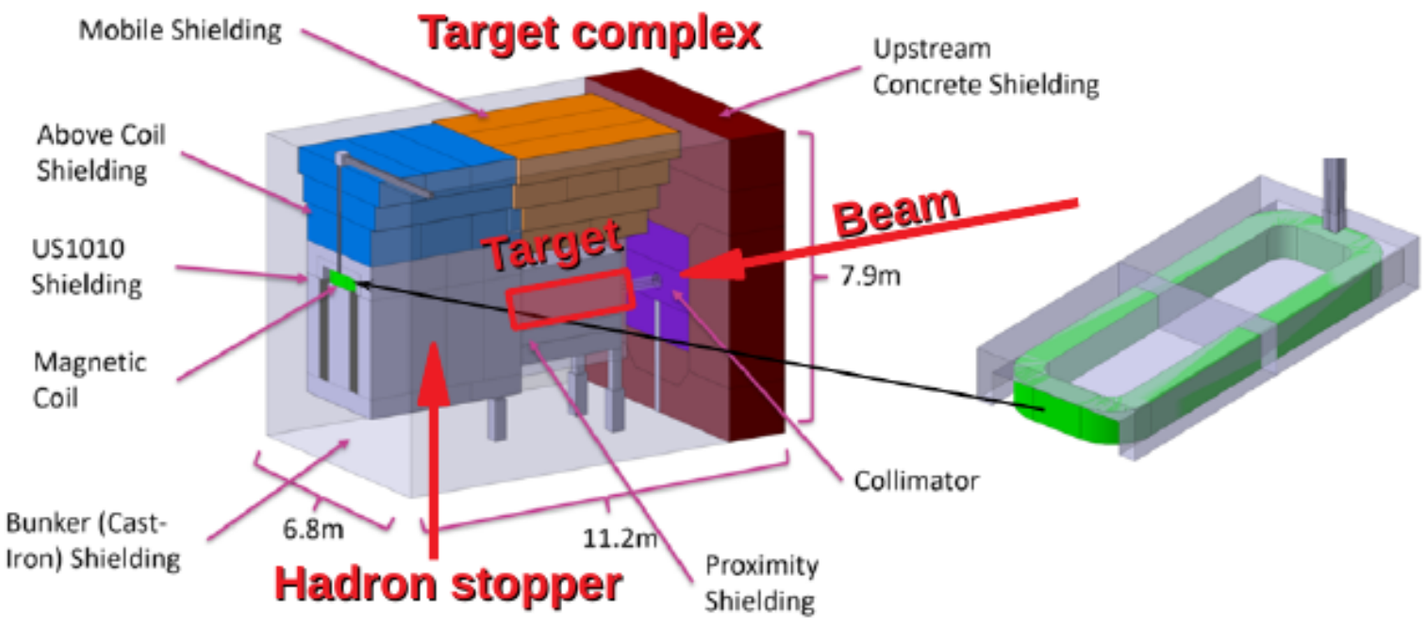
[JINST 12(2017)05 P05011]

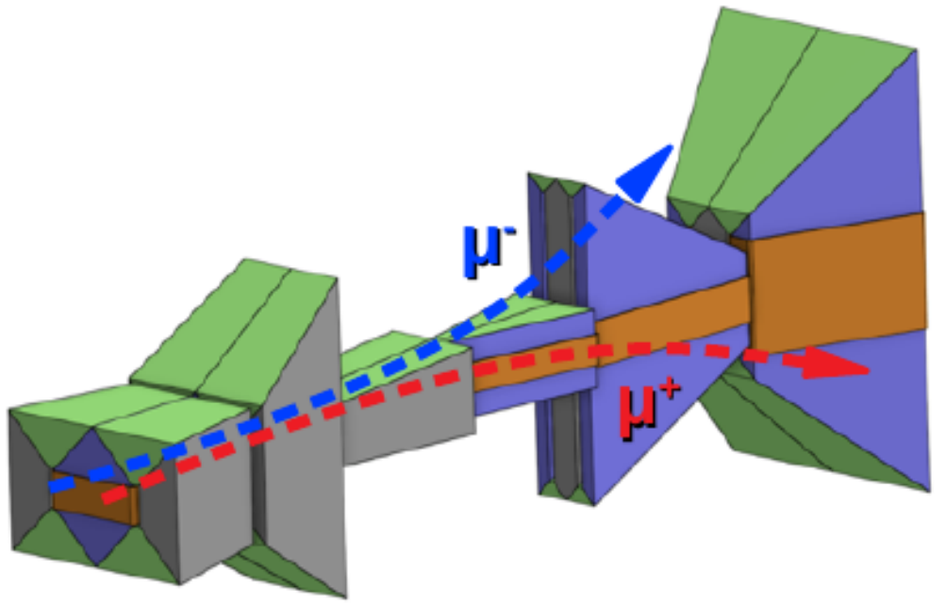
- heavy target to absorbe πs before decay
- magnetized hadron stopper: immediately separate $\mu^{\pm}$
- ideal muon shield configuration optimised with machine learning

  $\Longrightarrow$ μ rate reduced to $\sim$ 25 kHz



- μ spectrum validated with dedicated experiment in 2018





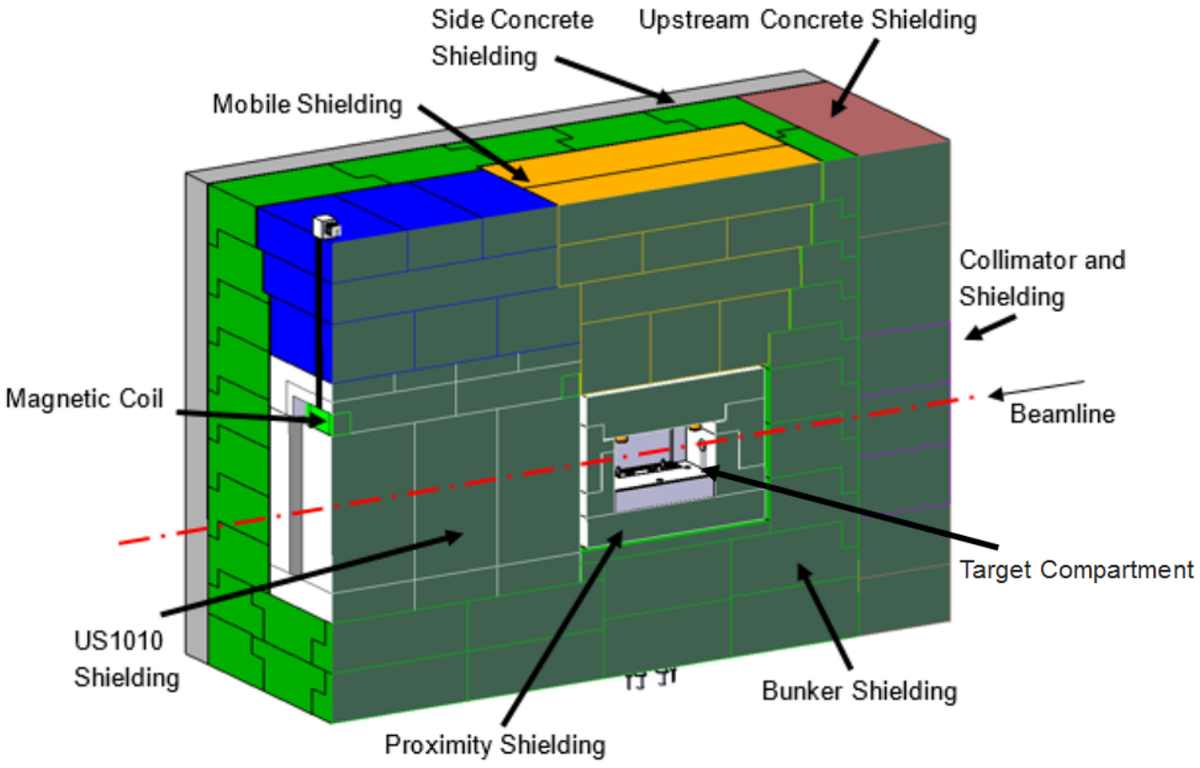
Magnetisation of hadron stopper

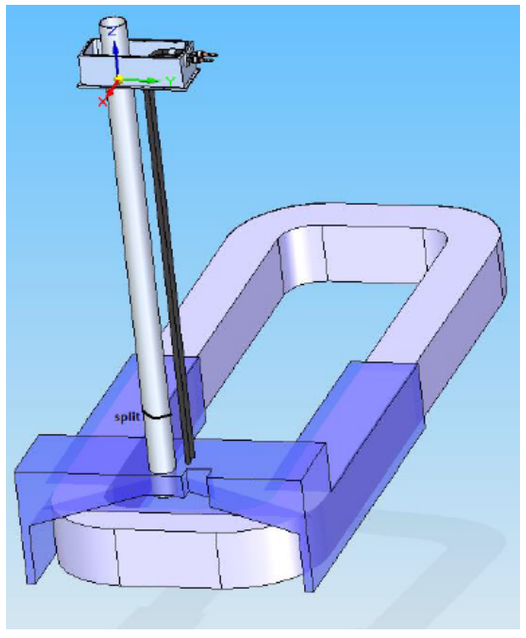
Detailed design study completed by RAL (V. Bayliss, J. Boehm, G. Gilley) through Collaboration Agreement with CERN

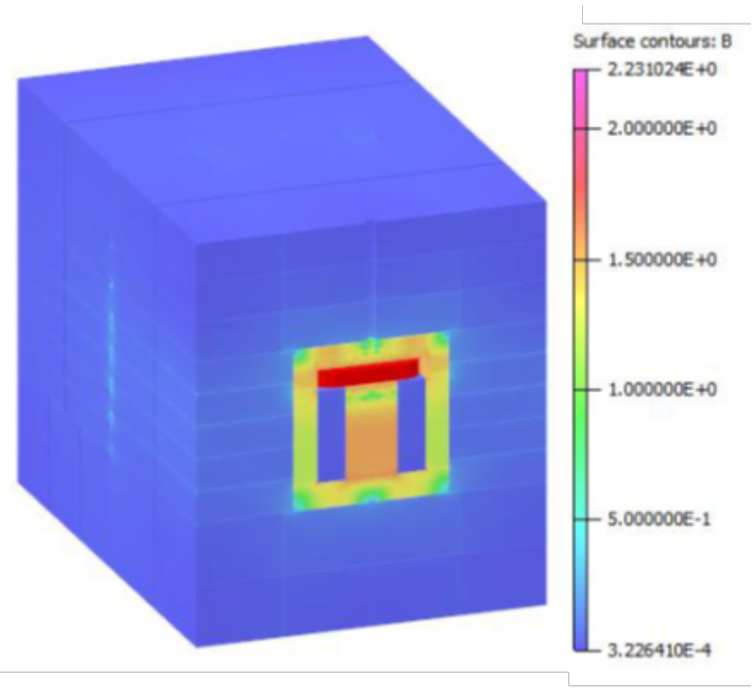
- Optimisation of the magnetic circuit
    - Simulated field maps for use in physics simulations and for optimisation of the subsequent free-standing muon shield
    - Hysteresis effects after multiple powering cycles;
    - Magnetic forces of the entire magnetized assembly and target shielding
    - Stray fields

- Preliminary engineering design compatible with the target complex and radiation environment
    - Power requirements
    - Thermal management (consideration of water and gas cooling)
    - Technical solution for connections of power cables, cooling, sensors etc.
    - Technical solution for the integration of magnetic iron blocks and remote handling of blocks and coils

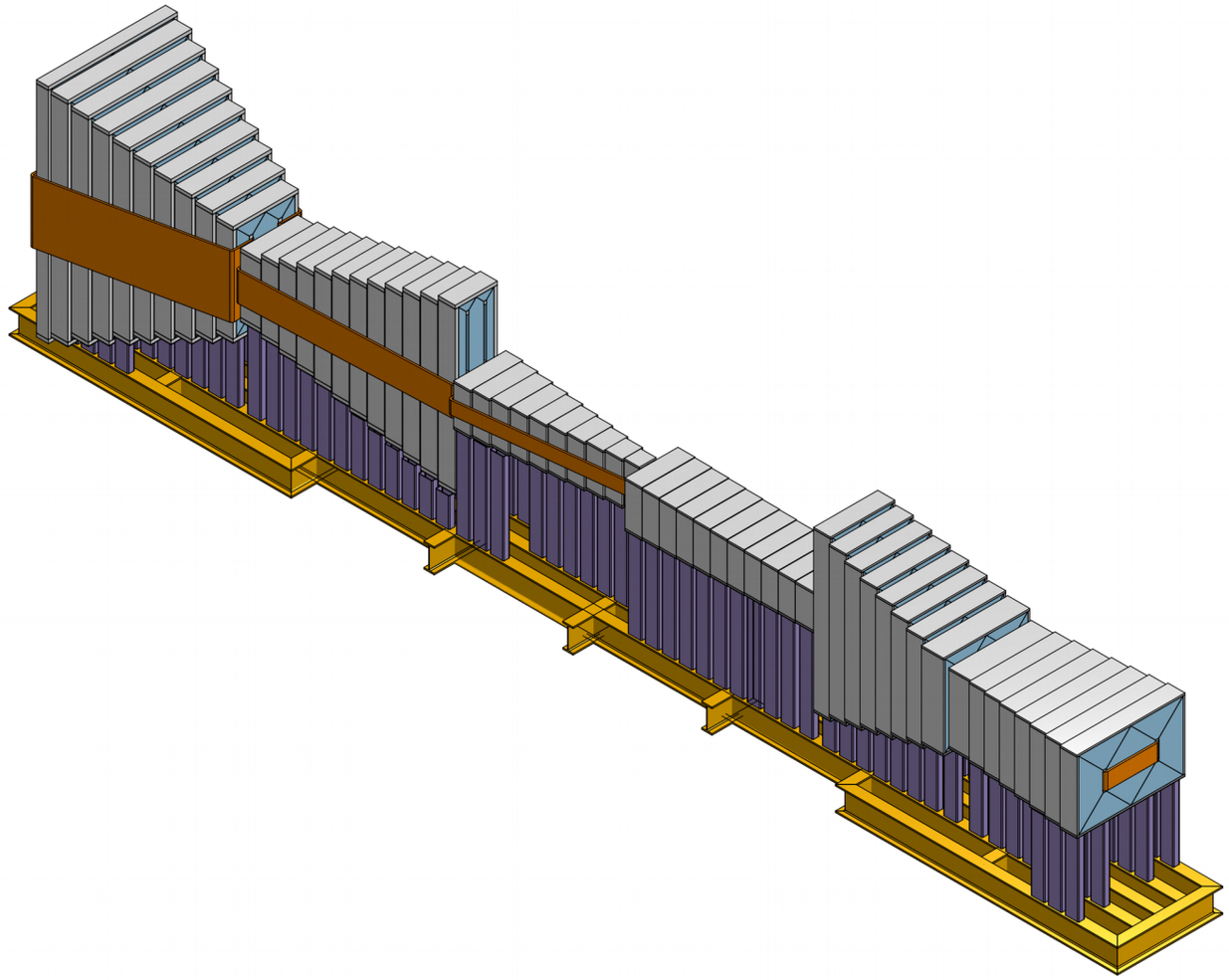
- Project plan towards TDR and outlook to construction, resource needs and preliminary costing







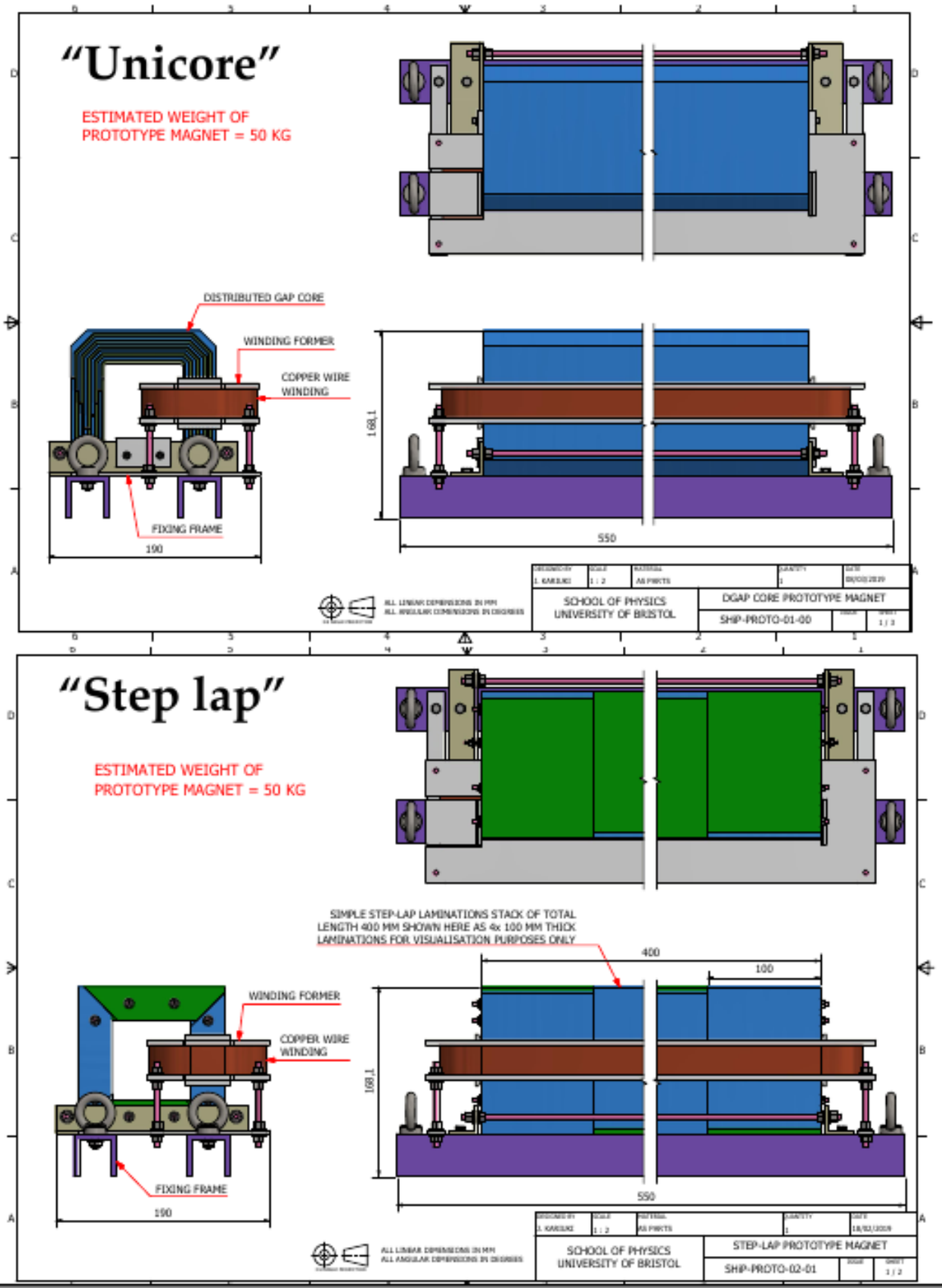
Magnetic Shield for SHiP (UK-Russia responsibility)



- about 600 individual modules (one block in the figure is 10 modules)
- total weight of about 10000 tons
- modules up to 6.5×4 m^2 in size
- about 2000 km of sheet cutting length

Magnet prototypes

- Two 50kg magnet prototypes have been constructed with different assembly techniques by UK companies using UK Grain Oriented Steel
  - Complementary approach to welding of laminations
  - Target field of ~1.8T with stacking factor >0.95
  - Test for loses of magnetic flux around the loop due to the different types of connections between laminations
- Awaiting delivery to CERN for testing



Primary TDR Goals

- Develop technologies for welding batches of thin steel sheets into ≥5 cm depth modules 6.5×4 m² in size
  - with following annealing of produced modules
  - at production rate fast enough to produce 600 modules in time
- Produced modules should satisfy requirements
  - magnetic field better 1.8T at induction 2 kA/m
  - mechanical soundness necessary for shipping, installation, operation
  - geometrical precision better 1 mm
  - packing factor >95%

SHiP Schedule

- Phase-2 prototypes ongoing
- 3 years to prepare TRD
- Construction, installation commissioning 6-7 years after TRD
- Beamline construction 5 years (in parallel with detector)
- Data taking in Run 4 (> 10 years from now)
- Big expenditures after 2026
- Until then, only participation to prototyping and travel

Conclusions

- SHiP has been strongly endorsed during the ES process, and has good support at CERN in the name of program diversification
- The timing is such that no big spending is foreseen before 2026
- The UK has an essential responsibility on the active muon shield, beneficial to UK companies
- We use novel techniques for shield simulation like adversarial networks https://arxiv.org/abs/1909.04451 or evolutionary algorithms
- Support for test-beams and phase-2 prototypes now essential.