The SHiP experiment at the SPS Beam Dump Facility

ADDENDUM

SHiP Collaboration

Abstract

The SHiP Collaboration has proposed a general purpose experimental facility at the CERN SPS accelerator to search for feebly interacting GeV-scale particles. SHiP complements the world-wide program of New Physics searches by covering a large region of parameter space which cannot be addressed by other experiments. The SHiP detector is sensitive both to decay and scattering signatures of models with heavy neutral leptons, dark photons, dark scalars, light dark matter and other super-weakly interacting particles. In addition, SHiP can perform unprecedented measurements with tau neutrinos and neutrino-induced charm production. *In complement to the comprehensive overview submitted to the EPPSU, this addendum provides information on the schedule and the cost of the detector*.

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Appendix

A. Time-line

The SHiP project time-line has been drawn up to make maximum use of the SPS in parallel to the HL-LHC, while at the same time respecting the technical constraints and the operating schedule of the CERN beam facilities during the construction. The civil engineering required for the Beam Dump Facility is an important driver of the time to completion. The global time-line is shown in Figure 1. It has been elaborated in collaboration with the Beam Dump Facility Working Group. More details on the schedule can be found in Ref. [1, 2].

The schedule foresees three years for the continued detector R&D, prototyping, and the preparation of the Technical Design Reports. With the past three years of Comprehensive Design Study, and first prototypes of all subsystems already constructed and tested, this amount of time is considered sufficient with margins for financial delays. It is estimated that the detector production will require two to three years, and that the detector assembly and installation, including infrastructure, will require another two years. The schedule aims at commissioning and starting data taking early in Run 4.

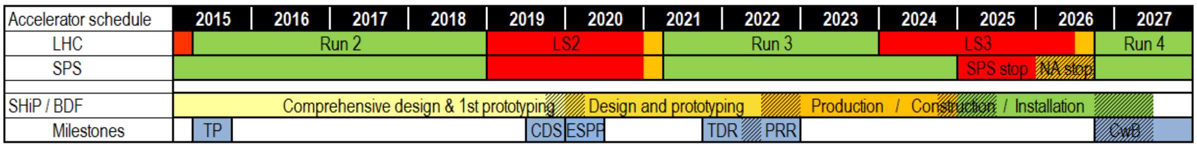

Figure 1: Global project schedule for the Beam Dump Facility and the SHiP detector. CDS, TDR, PRR mark the submission of the Comprehensive Design Study report, submission of Technical Design Reports, and Production Readiness Reviews for the SHiP detector, and CwB marks commissioning with beam.

B. Cost

A Class 3 $\left({}^{+(10-30)\%}_{-(10-20)\%}\right)$ cost estimate based on a detailed breakdown of each item in the conceptual design of the detector, was prepared for the Technical Proposal [4, 5]. The cost estimate for the detector is reproduced in Table 1 including the Muon Shield. A new cost estimate is in preparation for the Comprehensive Design Study report which will be submitted in the second half of 2019. It is expected that the cost will remain within the uncertainty of the TP cost estimate. Below is a summary of the changes since the TP as indicators of the impacts on the cost.

- The magnetisation of the hadron stopper was not included in the TP.
- The Muon Shield optimization has led to a magnet system which is $35\,\mathrm{m}$ in length instead of 48 m, and has 1400 tonnes of magnetic mass instead of 2900 tonnes, required in the TP.
- The magnet around the LDM/neutrino target, instrumented with emulsion and the Target Tracker, was added after the TP. Including the power converter it was estimated to 1.5 MCHF.
- The Muon Magnetic Spectrometer of the Scattering and Neutrino Detector was replaced with a conventional muon identification system without magnetization.
- The Upstream Veto Tagger has been removed. It has been shown that the SND muon system can perform the same function.
- The original Decay Volume, shaped as an elliptical cylinder with inner dimensions $5 \times 10\,\mathrm{m}^2$, has been redesigned as a conical frustum with inner dimensions of $1.7 \times 4.4\,\mathrm{m}^2$ upstream, and $5 \times 10\,\mathrm{m}^2$ downstream. The length is maintained at $50\,\mathrm{m}$. It has been shown that a pressure of 10^{-3} bar is sufficient (TP: 10^{-6} bar).
- The in-vacuum Straw Veto Tagger has been removed.
- The Spectrometer Straw Tracker stations and the vacuum tank through the spectrometer magnet have been designed with transverse dimensions of $5 \times 10\,\mathrm{m}^2$ throughout.

– The Spectrometer Straw Tracker tube diameter has been changed from 10 mm to 20 mm, halving the total number of tubes.
– Further design studies of the spectrometer vacuum tank, the straw tracker mechanics and interfaces with the spectrometer magnet have shown that this section is more complex than initially expected.
– The shashlik-based Electromagnetic Calorimeter has been replaced with a calorimeter based on two different types of active layers, in order to extend its capability to reconstruct two-photon final states. While most sampling layers are based on scintillating bars, resulting in a significant cost reduction compared to the shashlik technology, a few high-precision layers are instrumented with micro-pattern or alternatively scintillating fibre detectors.
– The Hadron Calorimeter has been removed, only the absorber is kept as the first muon filter. The new Electromagnetic Calorimeter is expected to be capable of providing sufficient identification for low momentum particles.
– The original muon system with scintillating bars has been replaced by a system based on scintillating tiles with SiPM readout.

Item		**Cost (MCHF)**
Muon Shield		**11.4**
Scattering and Neutrino Detector		**11.6**
Emulsion Target (no magnet)	6.8	
Target Tracker	2.5	
Muon Magnetic Spectrometer	2.3	
Decay Spectrometer		**46.8**
Decay Volume	11.7	
Surround Background Tagger	2.1	
Upstream Veto Tagger	0.1	
Straw Veto Tagger	0.8	
Spectrometer Straw Tracker	6.4	
Spectrometer Magnet	5.3	
Spectrometer Timing Detector	0.5	
Electromagnetic Calorimeter	10.2	
Hadron Calorimeter	4.8	
Muon Detector	2.5	
Muon iron filter	2.3	
Computing and online system		**0.2**
Total		**70.0**

Table 1: Breakdown of the cost of the SHiP detectors and the Muon Shield, including infrastructure, as estimated for the Technical Proposal.

The production and the construction of the detector is based on the concept of deliverables, which includes the detector components and assembly, the associated electronics and infrastructure systems, as well as the transport to CERN and the specific operations related to the installation.

Bibliography

[1] C. Ahdida et al., *SPS Beam dump facility - Comprehensive overview*, submitted to EPPSU, 2018.

[2] C. Ahdida et al., *SPS Beam Dump Facility Comprehensive Design Study*, CERN-PBC-REPORT-2018-001.

[3] SHiP Collaboration, *Status of the SHiP experiment*, CERN-SHiP-NOTE-2018-001, to be submitted to SPSC, January 2019.

[4] SHiP Collaboration, *A facility to Search for Hidden Particles (SHiP) at the CERN SPS*, Technical Proposal, CERN-SPSC-2015-016, SPSC-P-350, [arXiv:1504.04956], 2015.

[5] SHiP Collaboration, *A Facility to Search for Hidden Particles (SHiP) at the CERN SPS*, Addendum to Technical Proposal, CERN-SPSC-2015-040, SPSC-P-350-ADD-2, 2015.