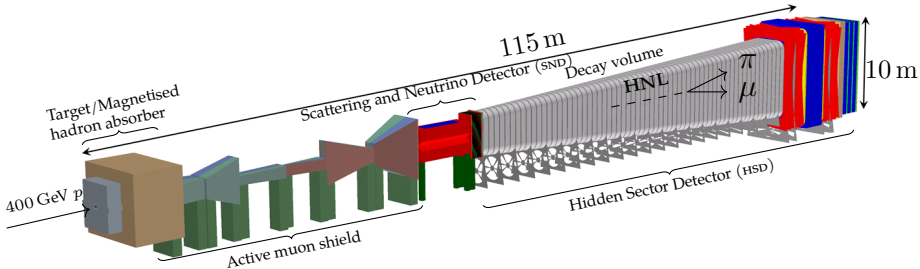
Universität Zürich[UZH]

SHiP
Search for Hidden Particles



SHiP — Status and plans

Oliver Lantwin *on behalf of the SHiP collaboration.*

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PBC working group meeting 2019

November 5, 2019

Outline

- Preparation of CDS report
- Muon flux measurement
- Charm cross-section measurement
- Latest updates on physics performance
- Conclusion & outlook

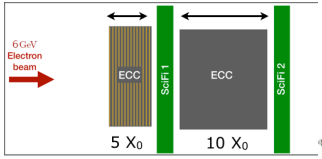
See e.g. the SHiP 2019 progress report [SPSC-SR-248] for more details!

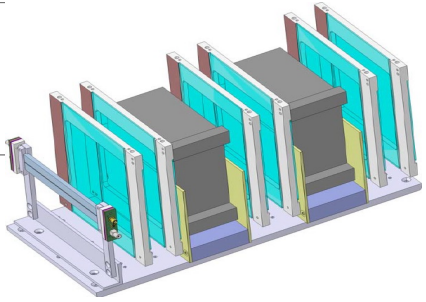
Comprehensive Design Study (CDS) report

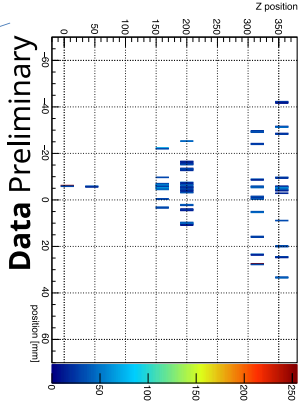
- If approved, TDR phase will involve another full iteration of detector optimisation
- **All subsystems reviewed** (with exception of common electronics, online and computing)
  - Objective: review current status, challenges, design and prototyping plans for the TDR phase, and costs and resources.
  - External reviews of magnetisation of hadron stopper, muon shield, vacuum chamber, spectrometer magnets and spectrometer straw tracker
  - **No showstoppers identified, but many recommendations and identification of challenges and alternatives!**
- CDS report in preparation for submission in December

Thanks to our external experts!
Marco Andreini (safety engineering, CERN),
Vincent Baglin (vacuum, CERN),
Jeremie Bauche (magnets, CERN),
Hans Danielsson (NA62 straw tracker, CERN),
Corrado Gargiulo (structural engineering, CERN),
Marco Garlasche (mechanical engineering, CERN),
Jean-Christophe Gayde (survey, CERN),
Jean-Louid Grenard (transport&handling, CERN),
Dirk Mergelkuhl (survey, CERN),
Antonio Pellegrino (LHCb outer tracker, NIKHEF),
Diego Perini (mechanical engineering, CERN),
Pablo Santos Diaz (Integration, CERN),
Davide Tommasini (magnets, CERN)

Test beam **last week** to test the **electromagnetic shower identification** and **energy measurement** with **emulsion cloud chambers** and **SciFi** → **SND prototype!**







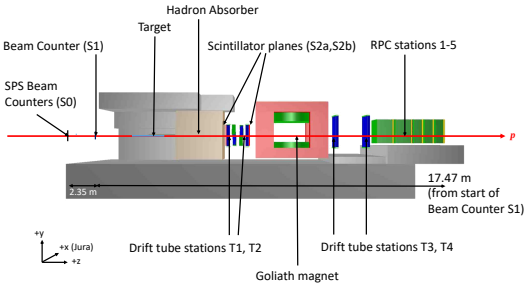
Institutes involved:

EPFL, Lebedev, MISiS, Moscow State University, Napoli, Zurich

SHiP muon flux validation

- SHiP uses a thick target to reduce π and K decays
- Absolute flux and momentum spectrum of muons leaving the target main uncertainty on background estimates
- Validation of target simulation (including cascade) important

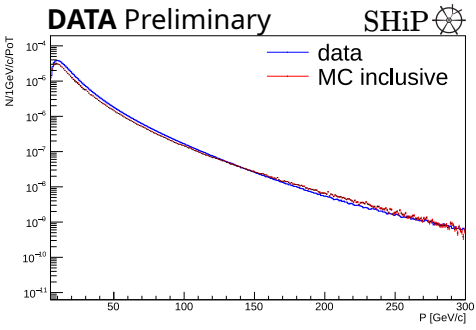
[SPSC-EOI-016]

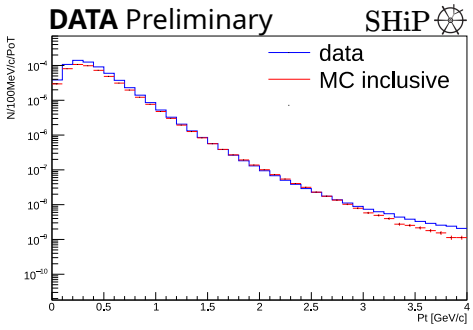


→ Dedicated experiment to measure the muon momentum spectrum at the SPS in 2018

Muon flux measurement

- Used H4 beamline and Goliath magnet at SPS north area
- SHiP replica target (tungsten/molybdenum) purpose-built
- OPERA drift tubes (test modules)
- New RPCs for muon stations
- Set-up in 1 week for 3 weeks of data taking
- Accumulated 3×10^{11} protons on target at 400 GeV

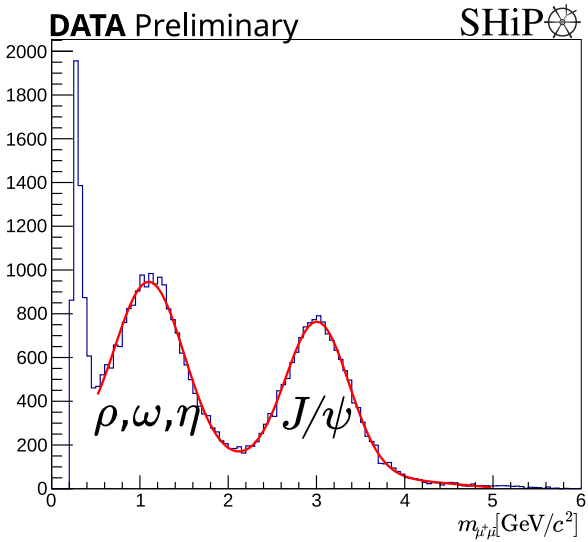




- Analysis complete, paper under internal review
- Overall good agreement between data and MC for our purpose
- Well within margins of background estimations
- MC can be used for further validation of muon shield technical design

Interval	data	MC
$5-10$ GeV/c	$(1.14 \pm 0.02) \times 10^5$	$(1.12 \pm 0.03) \times 10^5$
$10-50$ GeV/c	$(1.19 \pm 0.03) \times 10^4$	$(0.91 \pm 0.3) \times 10^4$
$50-100$ GeV/c	642 ± 14	515 ± 16
$100-150$ GeV/c	73.9 ± 1.6	66 ± 2
$150-200$ GeV/c	12.9 ± 0.3	13.3 ± 0.6
$200-250$ GeV/c	3.1 ± 0.1	3.3 ± 0.2
$250-300$ GeV/c	1.04 ± 0.02	1.01 ± 0.11

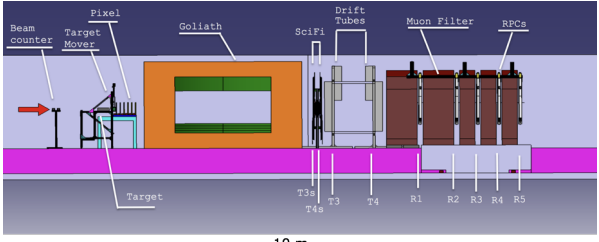
Preliminary data/MC comparison

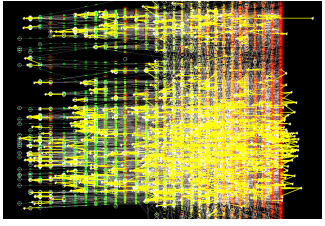


- Look at opposite sign muons leaving the hadron absorber
- Rediscovery of the J/ψ by SHiP

- Important to measure open charm production in a thick target to constrain theoretical uncertainties at SHiP!
  - Signal production
  - Tau neutrino flux
- Instrumented target of emulsion films + lead
- Feasibility study for full measurement

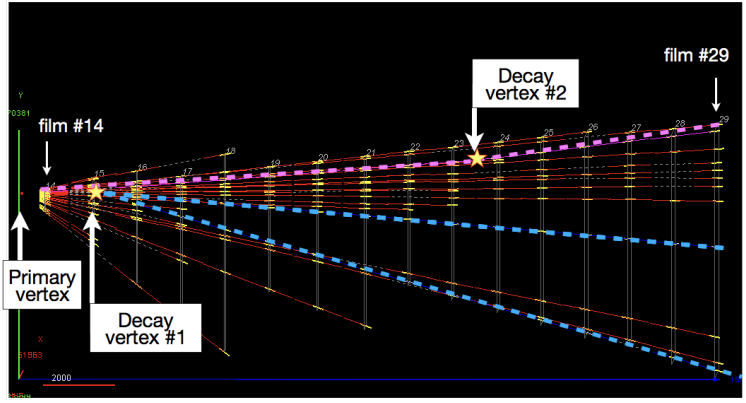
SciFi + drift tubes





Instrumented target

Double-charm decay topology



Event topology:

Primary vertex multiplicity: 31

Secondary vertices: 2

Decay vertex #1:

V^0-like topology

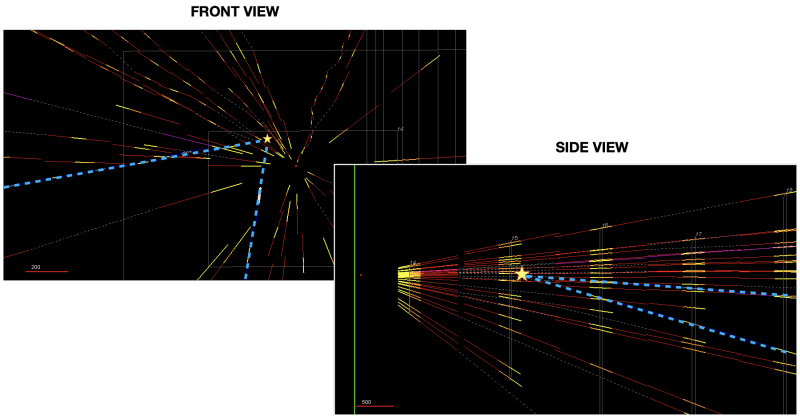
→ D^0 candidate

Decay vertex #2:

Kink-like topology

→ Charged D candidate

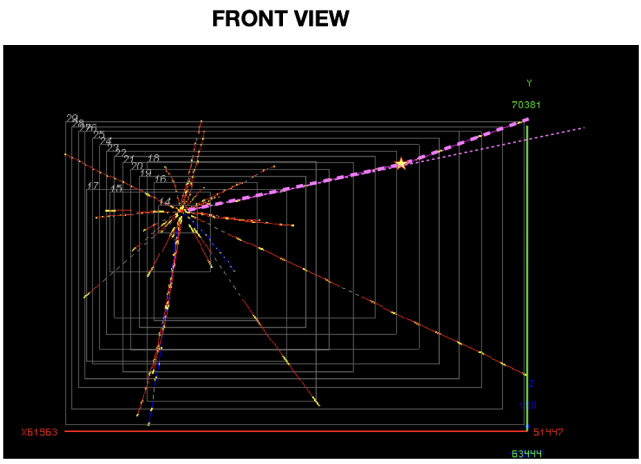
Double-charm decay topology



Decay vertex #1

- 2 prongs
- Impact parameters to primary vertex: 594 µm, 253 µm
- Flight length: 2.1 mm

Double-charm decay topology

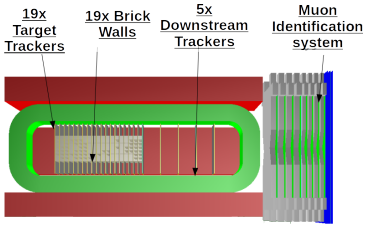


Decay vertex #2

- 1 prong
- Kink angle: 31 mrad
- Flight length: 12.7 mm
- Impact parameter to primary vertex: 393 µm

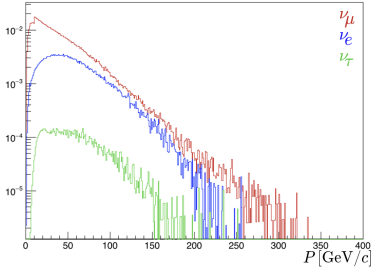
Updates on SHiP physics performance

- Latest hidden sector performance in progress report
- Scattering and Neutrino Detector (SND):
  - Tau neutrino measurements
  - Neutrino induced charm production
  - Neutrino anomalous magnetic moment
  - Neutrino Lepton Flavour Universality
  - Search for light dark matter



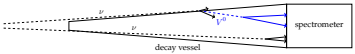
	<E>[GeV]	CC DIS interactions	<E>[GeV]	CC DIS charm prod.
N_{ν_e}	59	1.1×10^6	66	6.0×10^4
N_{ν_μ}	42	2.7×10^6	55	1.3×10^5
N_{ν_τ}	52	3.2×10^4		
$N_{\overline{\nu}_e}$	46	2.6×10^5	57	1.3×10^4
$N_{\overline{\nu}_\mu}$	36	6.0×10^5	49	2.5×10^4
$N_{\overline{\nu}_\tau}$	70	2.1×10^4		

Decay channel	ν_τ	$\overline{\nu}_\tau$
$\tau \to \mu$	1200	1000
$\tau \to h$	4000	3000
$\tau \to 3h$	1000	700
total	6200	4700



Reminder: SHiP hidden sector background studies

Neutrino background

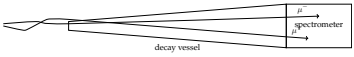


Selection cut	Expected Bkg
Basic selection	135
PID	12
Background tagger	0.05

Muon DIS

Selection cut	Expected Bkg
Reconstructed events	1.5×10^6
Selection cuts	566
Background tagger	$< 6 \times 10^{-4}$

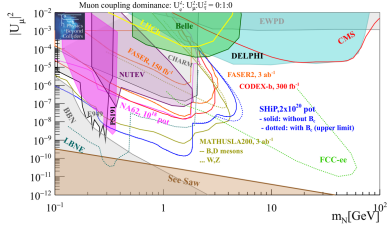
Muon combinatorial

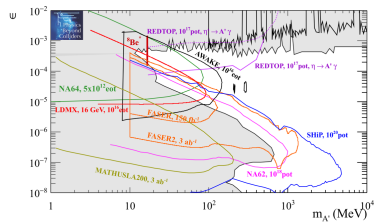


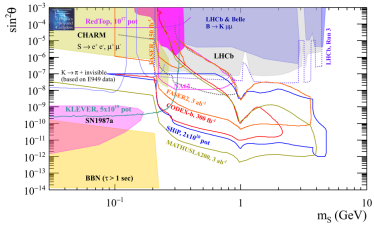
Selection cut	Expected Bkg
Acceptance	8.5×10^{15}
Selection cuts	10^9
Timing	10^{-2}

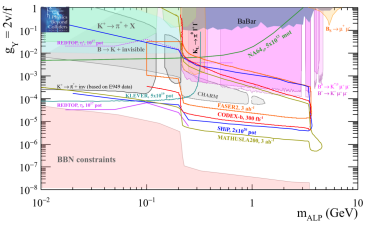
Less than 0.1 background events over 5 years — studied with full simulation

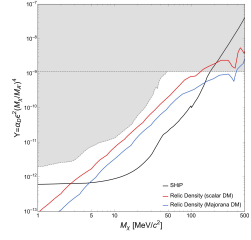
Reminder: BSM sensitivities



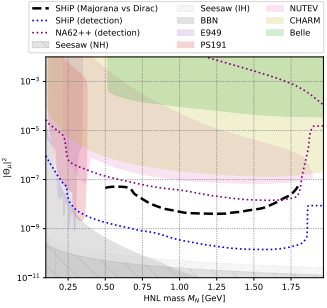


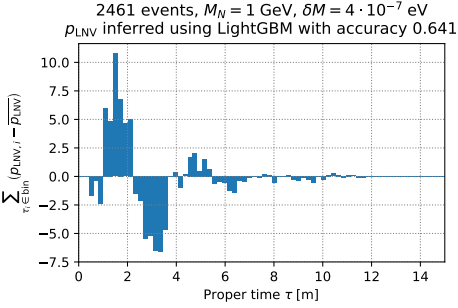






- SHiP could do more than just discover HNL:
  - Are neutrinos Majorana or Dirac?
  - What is their mass splitting? → HNL oscillations!





Details to be published soon: Tastet & Timiryasov [1911.XXXXX]!

Recent and forthcoming publications

Published:

[JHEP 1904 (2019) 077]

Published for SISSA by Springer

Received: *November 19, 2018*
Revised: *March 15, 2019*
Accepted: *April 1, 2019*
Published: *April 9, 2019*

Sensitivity of the SHiP experiment to Heavy Neutral Leptons

[JINST 14 (2019) no.03, P03025]

Published by IOP Publishing for Sissa Medialab

Received: *November 2, 2018*
Accepted: *February 25, 2019*
Published: *March 25, 2019*

The experimental facility for the Search for Hidden Particles at the CERN SPS

In journal review:

[arXiv:1909.04451]

Prepared for submission to JINST

Fast simulation of muons produced at the SHiP experiment using Generative Adversarial Networks

[arXiv:1910.02952]

Prepared for submission to JINST

The Magnet of the Scattering and Neutrino Detector for the SHiP experiment at CERN

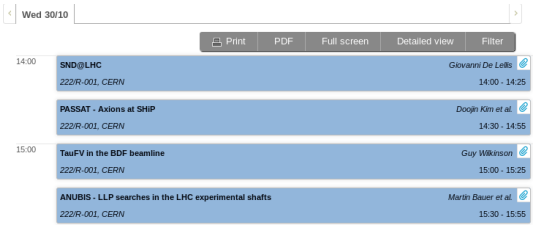
In internal review or preparation:

- “Sensitivity of the SHiP experiment to Dark Photons”
- “Search for light dark matter at SHiP”
- “Measurement of the muon flux for the SHiP experiment”
- “Neutrino Physics with the SHiP experiment”
- “The SHiP detector at the CERN SPS”

Conclusion

- Very successful measurements
  - Prototyping of SHiP target, DAQ, Data format, Software, **Collaboration**
  - First analysis concluding, more to follow!

- Continuing optimisation of physics studies and extending physics case
  → Thanks to the PBC forum!
- Next stage of prototyping started
- CDS concluding
  → the plan for 3-year TDR phase clear!



Open session at SHiP week

Looking forward to start preparing the TDR in 2020!