Hunting Ghost Particles: Testing a Detector for CERN's Next Big Experiment

How well does the SHiP Upstream Background Tagger perform in a real beam environment?

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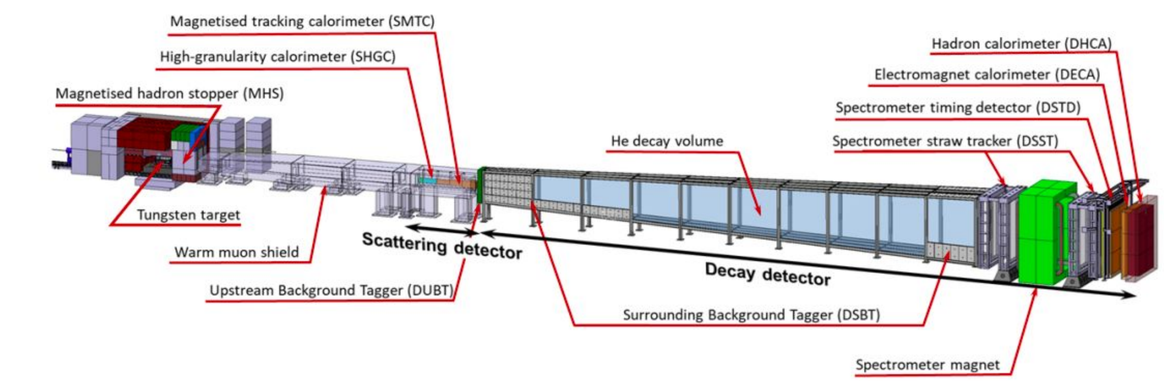
MOTIVATION / RESEARCH QUESTION

- SHiP: detect extremely rare Feebly Interacting Particles (FIPs). [1]
  Problem: rare FIP signals can be easily mimicked by background events.
- SHiP detector: not yet build, background veto detectors must be validated before construction to guarantee reliable FIP discrimination. [2]
- Characterisation of UBT performance using a SciFi telescope prototype.

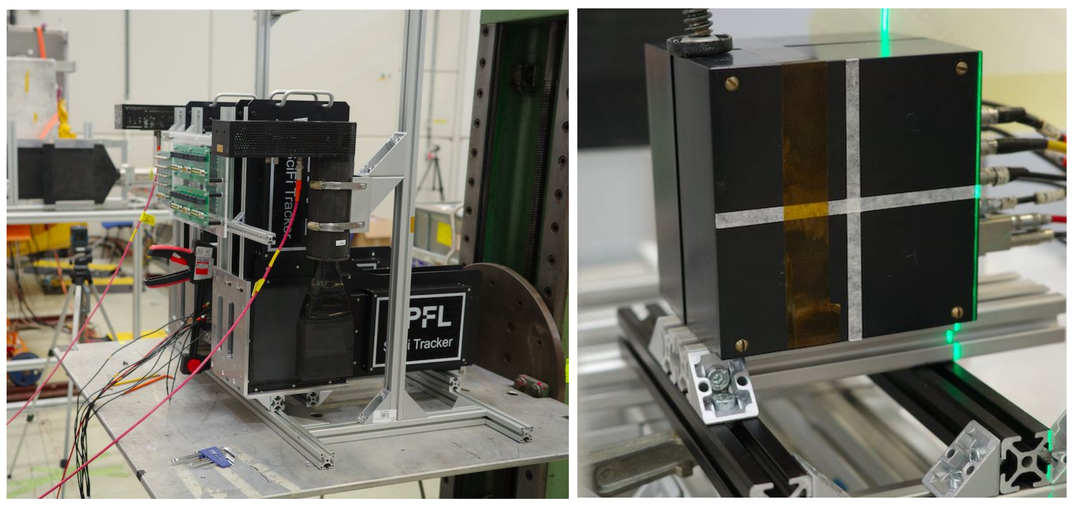
BACKGROUND

- SHiP : Beyond Standard Model (BSM) physics. Looking for FIPs (dark photons, Heavy Neutral Leptons), could explain dark matter and neutrino physics. [2]
- Detection of such faint signals, background particles (e.g. from upstream interactions) must be vetoed before reaching the decay volume. [1][2]
- Upstream Background Tagger (UBT) : monitors the upstream region of the decay volume, tags residual background muons. [3]



Representation of the SHiP detector.

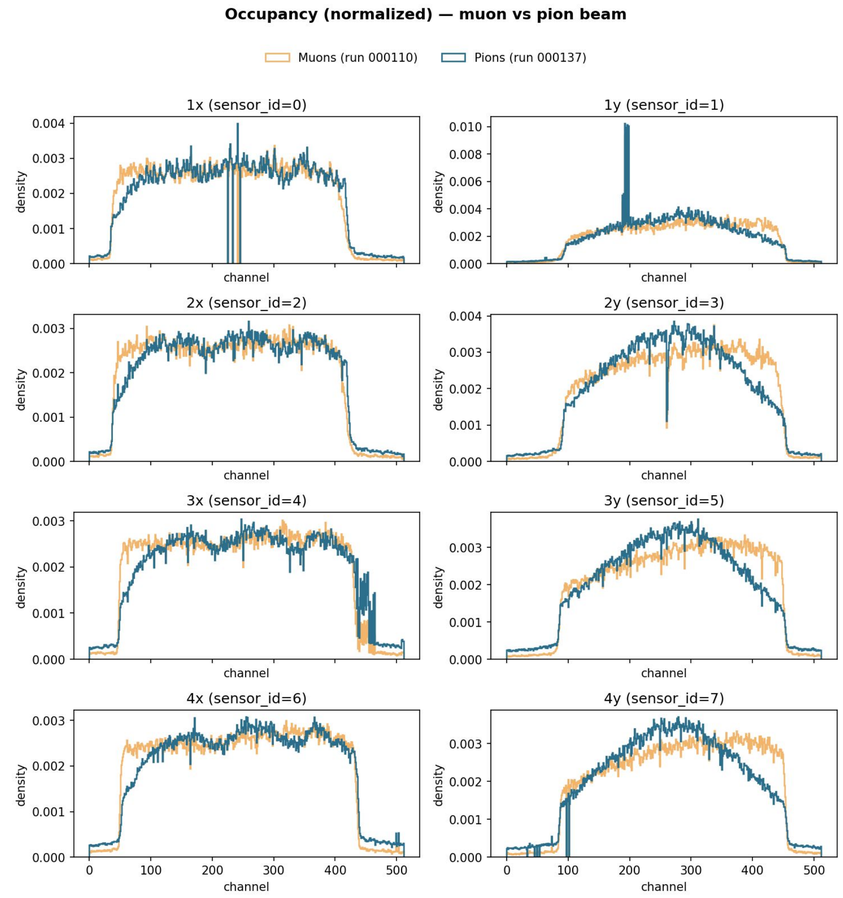
METHODS / SETUP



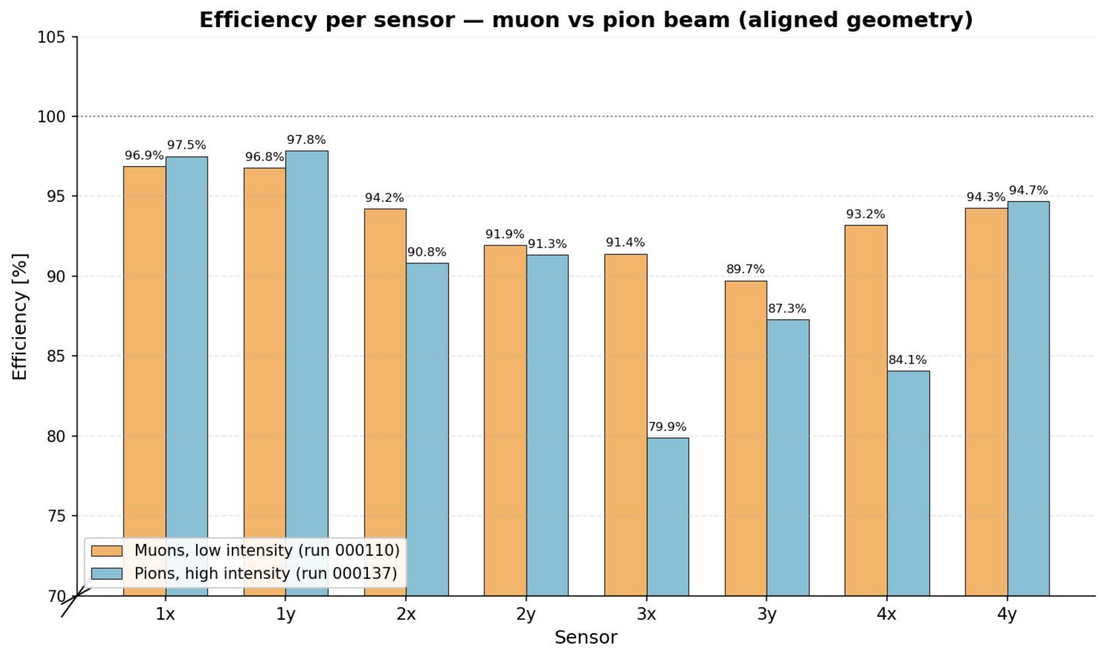
Experimental setup of the testbeam: we used the EPFL SciFi (Scintillating Fiber) tracker telescope, and a SiPM (Silicon PhotoMultiplier) as a timing detector.

- SciFi tracking telescope: 4 stations, X/Y fibre mats, 512 ch/mat, ~13×13 cm² acceptance.
- External SiPM (Silicon PhotoMultiplier) used as timing reference detector.
- Low-intensity (5 GeV) muon beam and High-intensity (15 GeV) pion beam.
- CuboDAQ acquisition & reconstruction software (developed by LPHE). [4]
- Offline chain: clustering → straight-line track fit → per-run x/y/t alignment → tag-and-probe efficiency.
- Analysis: Occupancy plot, efficiency measurement.

MAIN RESULTS



Normalized channel occupancy, muon (run 110) vs pion (run 137) beams.
Profiles largely overlap, confirming the 1x/1y hot channel as beam-independent, except on Y mats and plane 3x, consistent with its efficiency drop.



Efficiency plot comparison for 5 GeV muon beam (run 110, 440k events) and 15 GeV pion beam (run 137, 2.6M events).
87.3–97.8% for all sensors under the low-intensity muon beam, versus a marked drop on plane 3x (79.9%) under the high-intensity pion beam: explanation not clear yet, further investigation needed.

DISCUSSION

- Efficiency stays high and uniform for muons, showing the telescope is a reliable tracking reference in normal beam conditions.
- The pion-induced drop on plane 3x points to particle-type-dependent effects: relevant for future UBT operation under mixed backgrounds.
- One hot channel (1x/1y) persists across every run and intensity tested: fixed electronics defect.
- Remaining efficiency loss likely from hit-matching ambiguity in dense events, not intrinsic fibre inefficiency.

CONCLUSIONS

- Full offline pipeline validated end-to-end, from raw hits to per-plane occupancy and efficiency.
- SciFi telescope performs reliably: > 88% efficiency on every plane, uniform occupancy.
- Two concrete defects identified (hot channel, weak station) - ready to fix before next campaign.

REFERENCES & ACKNOWLEDGEMENTS

[1] SHiP Collaboration, BDF/SHiP Annual Report 2025, Tech. Rep. CERN-SPSC-2025-039, SPSC-SR-370, CERN, Geneva (2025).

[2] Climescu, M. (2026) *The SHiP/NA67 experiment: the flagship to probe hidden sectors* [PowerPoint slides], CERN Summer Student program 2026. Department of Physics and Astronomy, Ghent University.

[3] Di Crescenzo, A. « The SHiP Experiment at CERN ». *Il Nuovo Cimento C* [IT], vol. 49, nos 1-2, January 2026, p. 1-6. *DOI.org (CSL JSON)*, https://doi.org/10.1393/ncc/i2026-26049-8.

[4] « CuboDAQ / CuboDAQ SW · GitLab ». *GitLab*, https://gitlab.cern.ch/cubodaq/cubodaq-sw.

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