SHiP news

Konstantinos A. Petridis
for the SHiP collaboration

University of Bristol

June 14, 2018
In the past year huge endeavour to re-optimise the muon magnetic shield configuration and as a consequence the detector layout.

Yields for $2 \times 10^{20}$ pot (5 years):

$D \sim 1.6 \times 10^{18}$, $B \sim 1 \times 10^{14}$

Cascade enhancement factors:
x2.3 for D, x1.7 for B

Enormous simulation samples produced to both optimise the muon shield as well as precisely determine level of various backgrounds using GEANT4 and including floor, ceiling, walls and detector supports.
Background types

Due to time constraints focus on Neutrino, Combinatorial and DIS
Background studies

Redundancy is key:

1. Combination of momentum and vertex information to reject candidates not originating from collision point

2. Combine with veto subsystems
   - Surrounding the decay vessel
   - At the entrance of the decay vessel
   - Backgrounds leave multiple hits in veto systems $\rightarrow$ very effective vetos

3. Add timing information between candidate tracks ($\sigma = 100$ ps)
   $\rightarrow$ Aim for zero background experiment
   $\rightarrow$ Well defined control regions to measure backgrounds
Combinatorial muons

- Muon shield reduces rate from $10^{11}$ Hz to $10^4$ Hz of muons reaching spectrometer
  - Additional selections needed to reduce this
- Simulate $10^{11}$ pot with enhanced $\mu$ production from $J^{PC} = 1^{--}$ states and increased $\gamma$-conversion to $\mu$

HNL, Combinatorial

- Loose set of selections highly efficient on signal:
  - Momentum, IP and DOCA
  - Veto systems
  - Timing information
  \[ \rightarrow 10^{-4} \text{ combinatorial background events in SHiP lifetime} \]
Deep Inelastic Scattering

- Muons scatter on walls producing $V^0$s decaying in volume
- Muons with deep inelastic scatter in material of the decay volume producing $V^0$s

- Produced a large sample corresponding to 1/40 of full SHiP statistics to study this effect
- Loose selections on Momentum, IP, DOCA and including information from veto detectors
  $\rightarrow < 10^{-3}$ DIS events in SHiP lifetime
Neutrino interactions

- Neutrinos produced primary interaction can interact inelastically with decay volume producing $V^0$s

- Produced a sample corresponding to the full 5 years of SHiP operation, simulating neutrino interactions with vessel, walls, floor and ceiling through GENIE

- Interplay of particle-id, vertex position and veto systems
  → No $\nu$-interactions events left in SHiP lifetime equivalent sample

- Simulating 50 years of SHiP to make sure
Signal sensitivities

- Zero background in SHiP lifetime
  - Selection loose enough to maintain high efficiency for partially reconstructed final states

- 2 candidates isolated in the vacuum vessel pointing back to the target is a discovery

- Can measure mass of candidate and identify final they state
  - Provide information on physics model
Signal sensitivities

- HNL
- SHiP Preliminary
- CMS 13TeV
- BBN
- Seesaw

- $U_{\mu}^2$
- Mass [GeV]

- $A' \rightarrow \ell\ell$

- ALP → $\gamma\gamma$

- Dark Scalar

- $S$ parameter

- $m_{S} (\text{GeV/c}^2)$

- SHiP Preliminary

- SHiP (PBC Input)

- SHiP news

- PBC meeting June 2018

- + others

- B → $\pi^+ + X$
- $B \rightarrow K + \text{invisible}$
- $K^+ \rightarrow \pi^+ + X$
- BaBar
- $B \rightarrow K \mu^+ \mu^-$
- $K \rightarrow \pi^+ + X$
- ALP → $\ell\ell$
- $S$ parameter
- $m_{S} (\text{GeV/c}^2)$
A note of indirect detection of HS

- Can use emulsion spectrometer to detect HS particles
- Light Dark Matter is such an example
- Will also be able to search for other models e.g. with leptophobic couplings
- Major ongoing effort to optimise emulsion and reconstruction algorithms in time for SHiP CDS
Muon spectrum measurement SHiP-EOI-016

- Validate simulations in difficult corners of muon phase space
  - Measure momentum and charge of muons produced from replica of SHiP’s target using $4 \times 10^{11}$ pot
- Detector geometry finalised
- Assembly schedule in place, with data taking starting second week of July

---

**Target Ø 10 cm, 157.6 cm long**

- **Hadron absorber**
  - $240 \times 240 \times 240$ cm$^3$
  - $50 \times 100 \times 54$ cm$^3$
  - 60° stereo angle
  - 270μ μ resolution

- **Distance hadron absorber-Goliath** 121 cm
- **Distance T1-T2 (center)** 63 cm

- **Distance Goliath-muon tagger (RPCs)** 199.5 cm
- **Distance T3-T4 (center)** 160 cm

---

**Distance**
- Goliath-muon tagger (RPCs) 199.5 cm
- Hadron absorber-Goliath 121 cm
- T1-T2 (center) 63 cm
- T3-T4 (center) 160 cm

---

**T3, T4 and RPCs centered with respect to Goliath center to maximise acceptance**
Inclusive cross-section measurement

- Charm production in **proton interactions** and in **hadron cascades** in the SHiP target important for Hidden Sector searches normalization and $\nu_\tau$ cross-section measurement
- Charm yield from cascade expected 2.3 times larger than prompt contribution

- **Lead target**, 12×10 cm$^2$ Pb blocks (few cm) interleaved with emulsion to identify charm topology. **Measurement will be later repeated with SHiP target replica**

- Instrumentation of $\sim 1.6 \ \lambda$ to study charm production in **primary interactions** and **hadron cascades**
- **July 2018**: $\sim 150$ fully reconstructed charm-pairs
- Data taking after LS2: $\sim 1000$ fully reconstructed charm-pairs
Other news

- All sub-detectors with at least a first level of prototyping + electronics
- Prototyping of the shield also well underway
Other news

- Engineering designs progressing well including CAD and FEA
  - Detector is becoming increasingly real

- Muon shield
- Emulsion spectrometer
- Decay volume
- Main spectrometer magnet
- Straw tracker tandem box
- Timing detector
- Downstream muon system
Conclusions

- Major effort to reoptimise shield and redesign detector
- Redundant set of detector systems to reduce background to zero over experiment lifetime
  - Demonstrated so far that this is the case through a large simulation campaign
  - More studies are being performed and larger samples are being generated
- Test beams imminent to measure muon flux and charm cross-section
- SHiP is taking shape through major prototyping and engineering design effort