SHiP backgrounds and simulation

Oliver Lantwin [oliver.lantwin@cern.ch]

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Similarities and differences

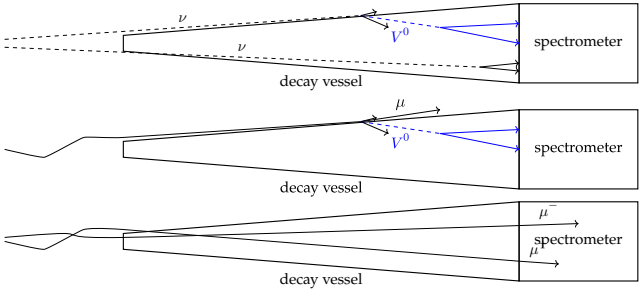
Some numbers to keep in mind

	SHiP
PoT/spill	4×10^{13}
E/GeV	400
spill length/s	1 s
Target material	TZM/W
Distance to Target/m	35
Target Length/λ	12
Beam power during spill/MW	2.3

Some very similar for ProtoDUNE, but not all

Background overview

- Very minimal selection common to all signal channels
- Background tagging being optimised right now to improve signal efficiency while mainting background rejection



	ν DIS	μ DIS	μ Comb
Expected events	< 0.3	$< 10^{-2}$	2.1×10^{-3}

How backgrounds are simulated

1. Target simulation (performed in 2015 and 2018, takes several months)
   - Save neutrinos, and muons passing the hadron absorber with their history
   - Pythia8 for initial collisions, Pythia6 for charm and beauty cascade [SHiP-NOTE-2015-009]
   - Transported by Geant4 (cross-check performed with with FLUKA [CERN-SHiP-ANA-2019-005])
   - Validated in dedicated experiment in H4 in 2018 [CERN-SHiP-NOTE-2019-003; Eur.Phys.J.C 80 (2020) 3, 284]
   - 10^{11} PoT simulated, comparable to collected PoT in 2018
2. Specialised simulations (every significant change, takes a few weeks)
   - 2.1 Muon background (Geant4)
     - Muon DIS (Geant4 -> Pythia6 -> Geant4)
     - Muon combinatorial (Geant4, optionally generate more muons via GAN)
   - 2.2 Neutrino background (Genie -> Geant4)

Cascade simulation [SHiP-NOTE-2015-009]

- In the $12\ \lambda$ SHiP target, reinteractions of particles are non-negligible
  - Increases signal yield ($\times 2.3$ for D, $\times 1.7$ for B)
  - Reduces neutrino interactions due to reinteractions of pions and kaons before leptonic decay
- To simulate the cascade, use Pythia 6 in a recursive fashion *
- Good agreement with muon flux measurement, dedicated measurement for charm cascade-production planned

*Pythia 8 recently added cascade, will check whether we can use it this summer

Cascade pseudo-code/algorithm

1. Start with primary proton and add it to the beam-particle stack
2. While there is a particle on the stack:
   - 2.1 If $\chi_{\mathrm{Norm}} < \mathrm{Uniform}(0,1)$ [†]
     - › Configure Pythia for charm(beauty) production and produce an event
     - › Save stable charm(beauty) hadrons
   - 2.2 Configure Pythia with all processes and produce an event
   - 2.3 Select p, n, $\pi^{\pm}$, $K^{\pm}$ and $K_{\mathrm{S,L}}$ and add them to the stack
   - 2.4 Remove the current beam particle from the stack
3. Return to 1., if stack is empty and more events are needed.

[†] where χ_{Norm} is obtained from xN collisions simulated in Pythia

Conclusion

- Target simulation for high-intensity beam-dumps is very time consuming!
- Muon backgrounds probably mostly negligible in your case
- Cascade likely important for you signal?
- Happy to discuss further, our code is open source and available for use and reference