Acceptance studies & plans for muon shield optimisation

Oliver Lantwin
8th SHiP Collaboration Meeting

[oliver.lantwin@cern.ch] 13th June 2016
Acceptance studies

Muon shield optimisation
Acceptance studies

Muon shield optimisation
Aim of these studies

- How much do we gain by…
  - … improving the muon shield?
  - … using a conical vessel?
  - … using a longer vessel?

- Acceptance studies for HNL (other channels to be added once in FAIRSHIP)
- Automate this where possible and add to FAIRSHIP once ready
Experimental Configuration

- Stripped down to the bare minimum: straw tracker, production point

To generate all configurations studied:
- Move production point to set distance of tracker from target
- Move/redefine front of vessel to adjust length of vessel
Experimental Configuration

- Stripped down to the bare minimum: straw tracker, production point

- To generate all configurations studied:
  - Move production point to set distance of tracker from target
  - Move/redefine front of vessel to adjust length of vessel
Signal production

- Produce 100 000 HNL per tracker position from charm+cascade and beauty+cascade using standard FAIRSHIP code → other signal models + decay channels simple to check once implemented in FAIRSHIP

- Productions used to generate HNL events:
  - beauty: /eos/ship/data/Beauty/Cascade1M-Beauty.root
  - charm: /eos/ship/data/Charm/Cascade-parp16-MSTP82-1-MSEL4-ntuple_prod_18M.root

- Default FAIRSHIP HNL couplings: $U^2_e : U^2_\mu : U^2_\tau = 1 : 16 : 4.2$, normal hierarchy
- $N_2 \rightarrow \mu \pi$ only considered here
- Studied HNL masses 1, 1.6, 2, 3 GeV, results for 1.6 GeV unless specified otherwise
- PYTHIA simulates HNL in range 0–300m from production point
Signal production

- Produce 100,000 HNL per tracker position from charm+cascade and beauty+cascade using standard FAIRSHIP code
  → other signal models + decay channels simple to check once implemented in FAIRSHIP
- Productions used to generate HNL events:
  - beauty: /eos/ship/data/Beauty/Cascade1M-Beauty.root
  - charm: /eos/ship/data/Charm/Cascade-parp16-MSTP82-1-MSEL4-ntuple_prod_18M.root
- Default FAIRSHIP HNL couplings: $U_e^2 : U_\mu^2 : U_\tau^2 = 1 : 16 : 4.2$, normal hierarchy
- $N_2 \rightarrow \mu\pi$ only considered here
- Studied HNL masses 1,1.6,2,3 GeV, results for 1.6 GeV unless specified otherwise
- PYTHIA simulates HNL in range 0–300m from production point
Reconstruction/Selection

- Use `ShipReco.py` minus PID code (use mc truth)
- Select any reconstructed\(^1\) vertex in the defined vessel volume
- Vessel volume is an elliptic cylinder defined by the tracker dimensions and a set length
- \(O(\text{few } 1000)\) reconstructed events per tracker position
- Weight events by lifetime decay probability, normalise by number of generated events

\(^1\text{reconstructed = both decay products of } N_2 \rightarrow \mu \pi \text{ in tracker}\)
Elliptic-cylindrical vessel dictated by **selection**, but effectively all **reconstructed** events lie in a cone within the cylinder

- Vessel length here: ~40m, distance from target: ~40m
Results: Behaviour for vessel distance from target

- Moving vessel closer for fixed vessel length always better (as expected)
- Different slope for beauty and charm production
- Note: Arbitrary relative normalisation of beauty and charm production
Magnet configurations used for comparison

Technical Proposal (TP) design

Vessel ~60m from target
Magnet configurations used for comparison

New benchmark muon shield? (See Hans’s talk)

Vessel ~35m from target\(^2\)
Note: Tracker dimensions the same for all configurations
→ not the same as in Hans’s 2d simulation

\(^2\)While fulfilling stricter requirements than TP muon shield: no \(\mu\) with \(p > 1\)GeV in T4
Results: Hans’s new benchmark vs. TP

Comparing length at fixed vessel distance from target:\(^3\):

- Gain of \(~20–40\%\), depending on production
- Optimal length in both cases \(~45m\)

\(^3\)Uncertainties are scaled Poisson sampling uncertainty. Lifetime weights taken to be exact.
Results: Heavier/lighter HNL

- Little difference for masses 1,2,3 GeV
- Similar gain, slightly different optimal lengths between ~40–50m
Results: Heavier/lighter HNL

- Little difference for masses 1, 2, 3 GeV
- Similar gain, slightly different optimal lengths between ~40–50m
Little difference for masses 1,2,3 GeV
Similar gain, slightly different optimal lengths between ~40–50m
Conclusions

- Moving from 60 → 35m gives us roughly +30% HNL
- Consistent with Hans’s rule of thumb of 1% more HNL/m
- Optimal vessel length ~45m, approximately independent of distance → savings from muon shield also affect overall length
- Conclusion true for both production mechanisms
Remaining work

- Hope this tool is useful for discussion at this meeting
- Integration into FAIRSHIP will follow\(^4\), implementation details at a SHiP Software meeting soon.
- Implementation problems to solve:
  - Storage (eos?)
  - Computing target (lxbatch? SKYGRID?)
- Make this standard tool to study vessel shapes for different signals
- Other optimal layouts for different channels?

---

\(^4\)If you have opinions on how it should be done, talk to me
Acceptance studies

Muon shield optimisation
Status

- 2d optimisation has given us feasible benchmark to aim for (see Hans’s talk)
- Need full 3d optimisation to be sure, maybe even improvement over 2d
- RAL and CERN engineers investigating possibility of $B$-fields in target area/hadron stoppers: looks like it’s not impossible, need to wait for details (see Mitesh’s and Victoria’s talks)
- In contact with Yandex, will need to/can use their computing clusters for 3d optimisation
Plans

- Aiming to run on Yandex SKYGRID starting end July
  → get conventional 3d optimisation ready by then
- Build on Iaroslava’s magnet design code
- Magnet configurations studied will focus on conventional magnets + different parts of target area magnetised (target itself, hadron stoppers)
- $\nu_\tau$-magnet integration? Could investigate as an option, if there is interest. Will need to think about whether idea feasible, how to implement
- I will be moving to CERN beginning of July, so expect progress to accelerate then.
[Backup Slides]
Comparison of magnets: tracker position instead of length
Move vessel front for fixed tracker position

Weighted total of selected $N_2 \rightarrow \mu \pi$ tracker distance = 120m