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SHiP
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Acceptance studies & plans for muon shield optimisation

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Acceptance studies

Muon shield optimisation

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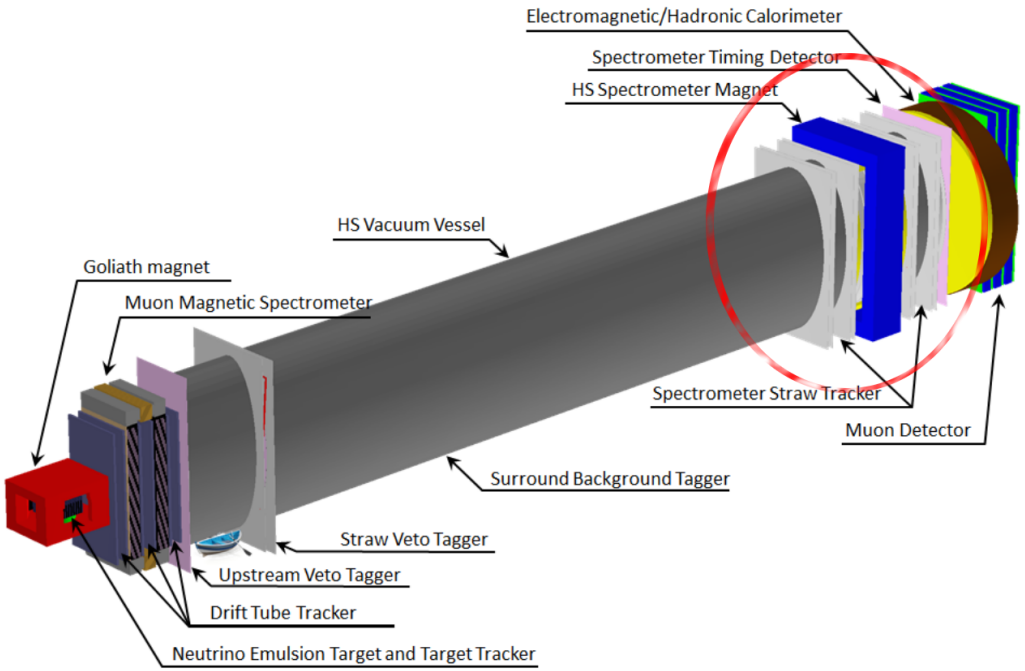
Muon shield optimisation

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

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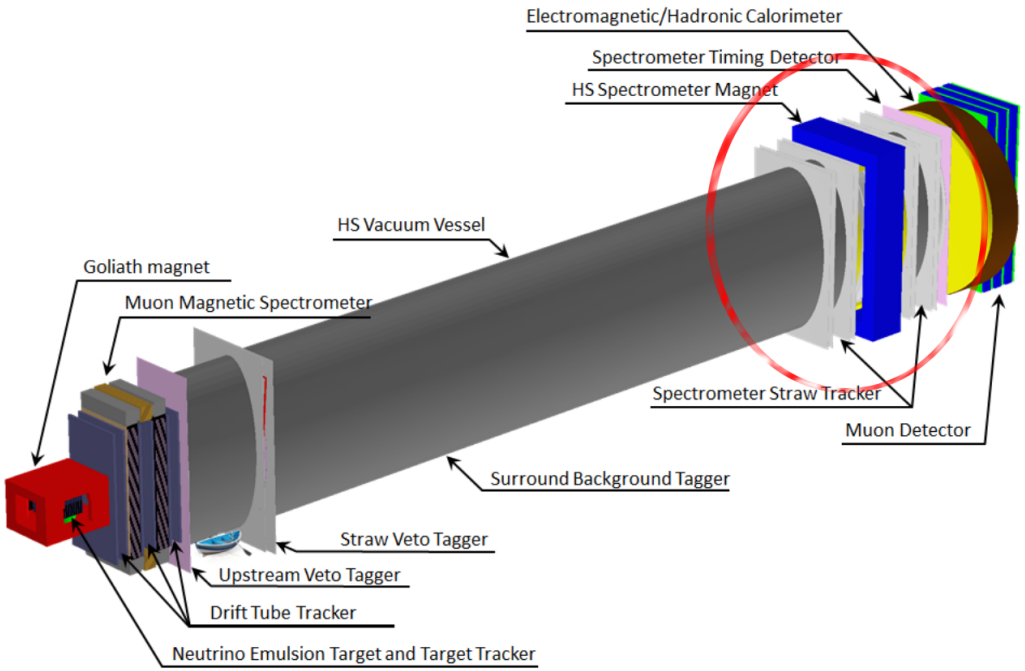

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Signal production

- 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
- $N_2 \to \mu\pi$ 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

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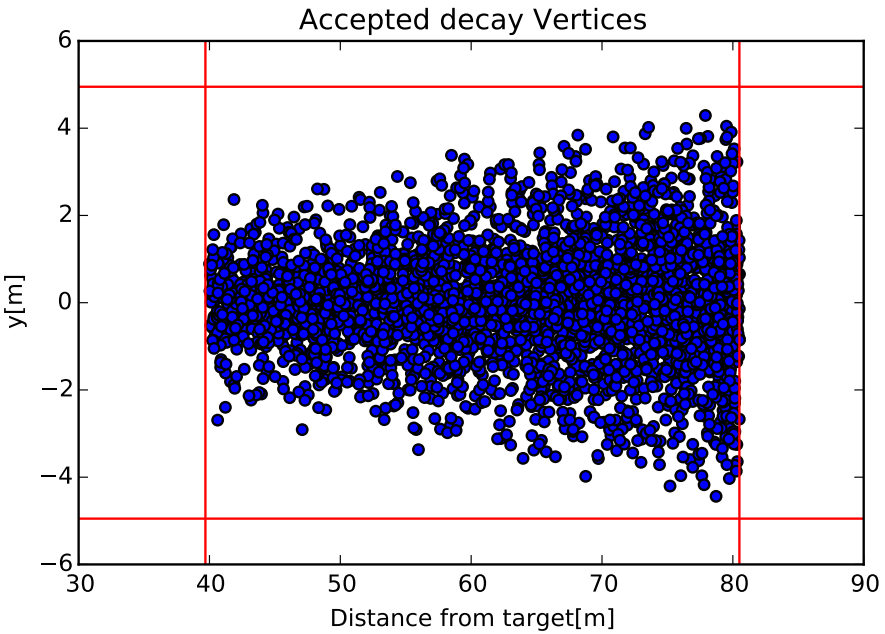
Reconstruction/Selection

- 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
- $\mathcal{O}$(few 1000) reconstructed events per tracker position
- Weight events by lifetime decay probability, normalise by number of generated events

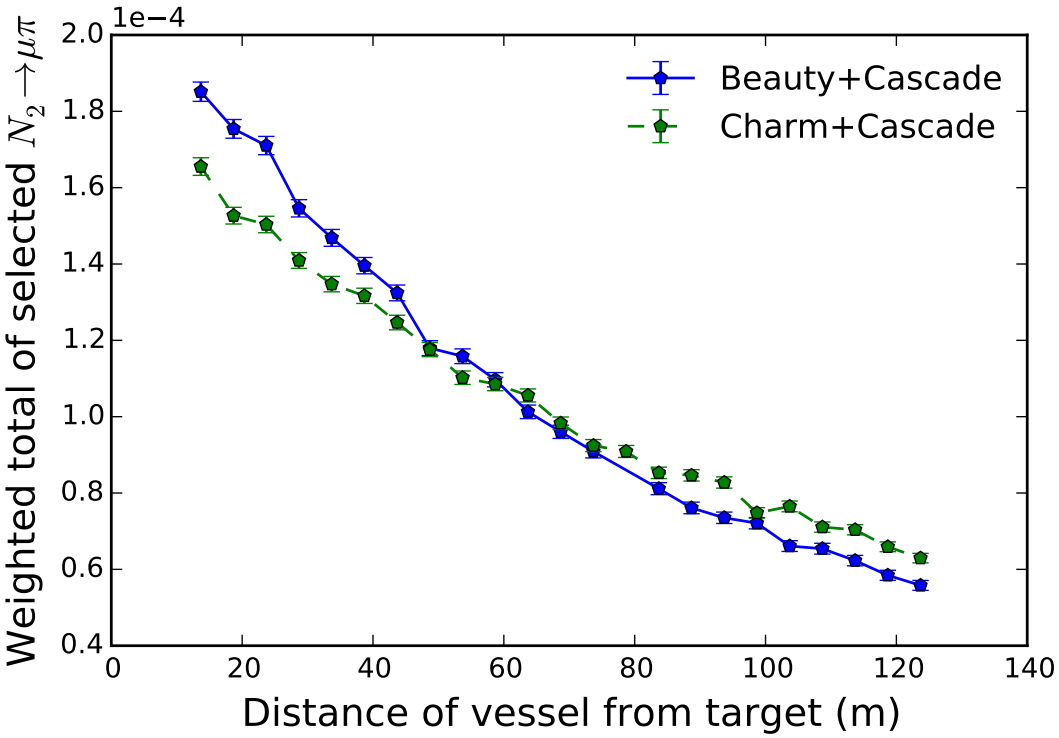
[1] reconstructed = both decay products of $N_2 \to \mu\pi$ in tracker

Selection & vessel geometry



- 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

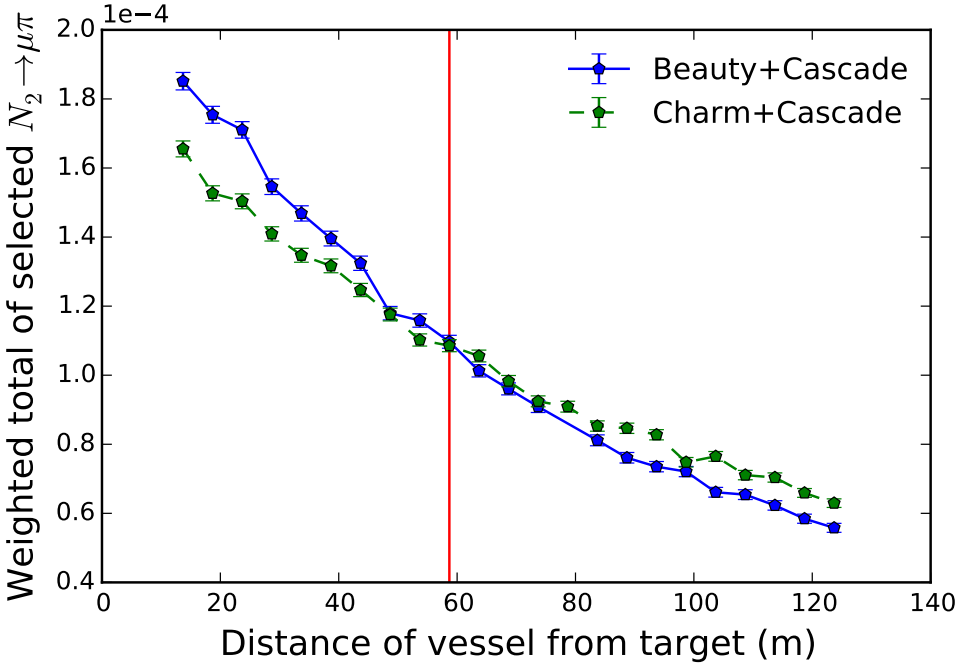
Results: Behaviour for vessel distance from target

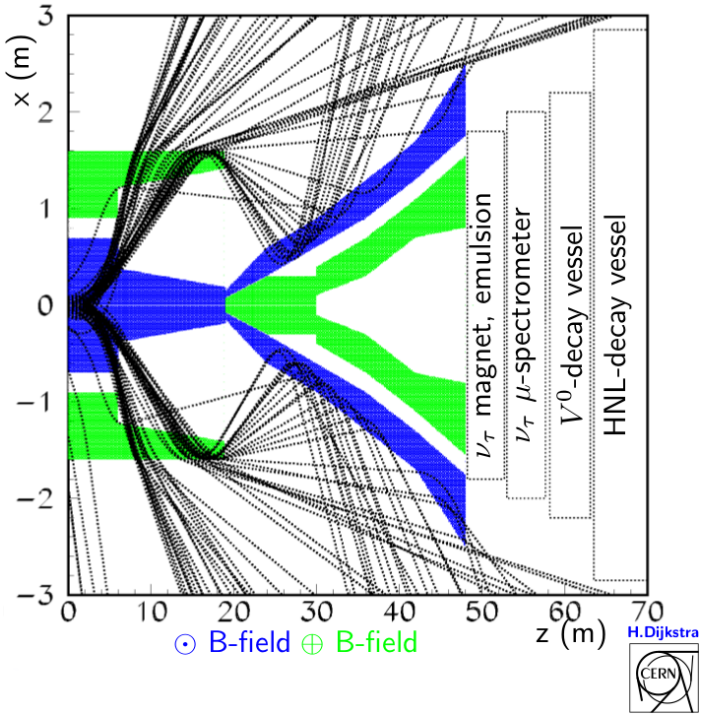


- Moving vessel closer for fixed vessel length always better (as expected)
- Different slope for beauty and charm production
- Note: Arbitrary relative normalisation of beauty and charm production

Magnet configurations used for comparison

Technical proposal (TP) design

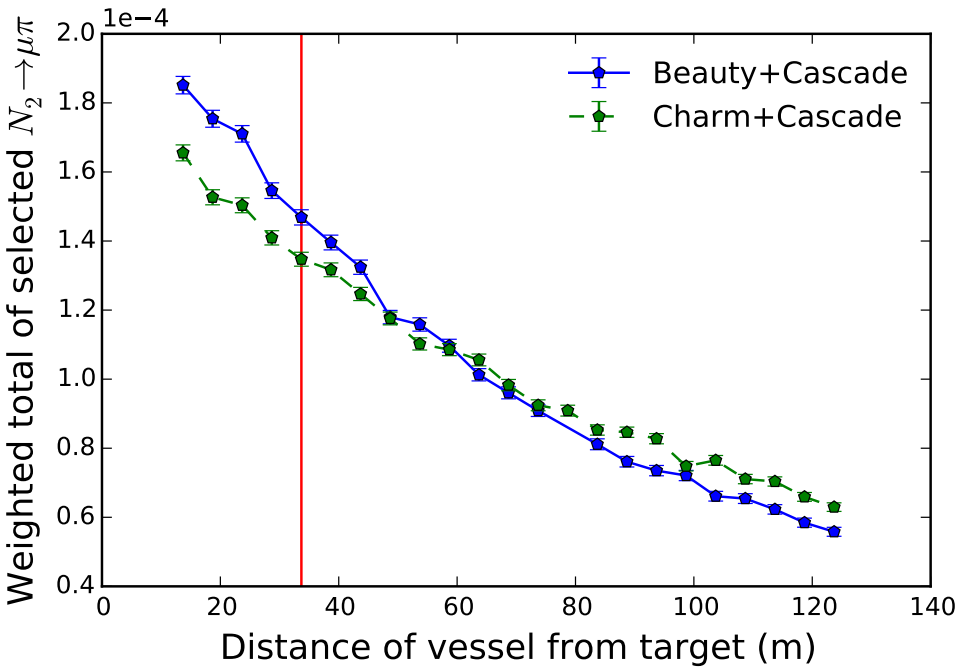


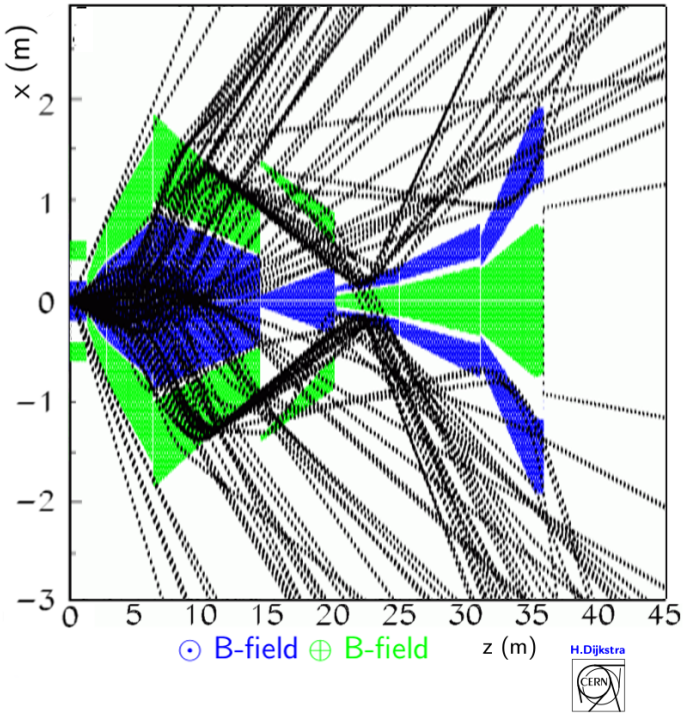


Vessel ~60m from target

Magnet configurations used for comparison

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



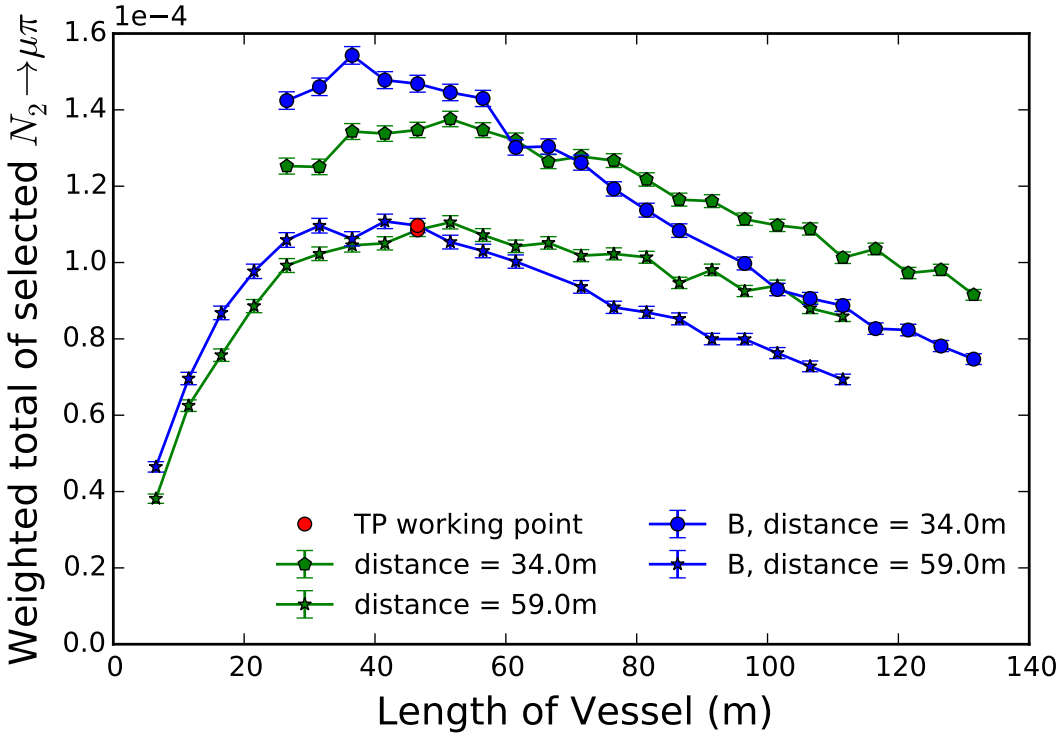


Vessel ~35m from target[2]
Note: Tracker dimensions the same for all configurations
→ not the same as in Hans's 2d simulation

[2] While fulfilling stricter requirements than TP muon shield: no μ with $p > 1$GeV in T4

Results: Hans's new benchmark vs. TP

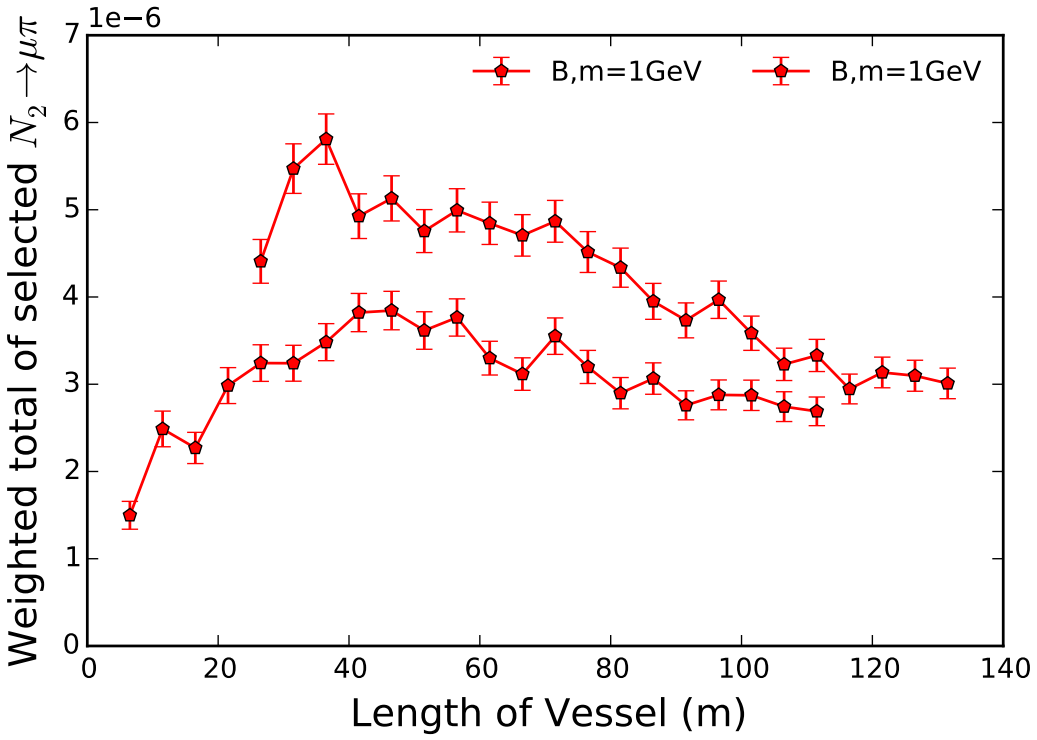
Comparing length at fixed vessel distance from target[3]:



- 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

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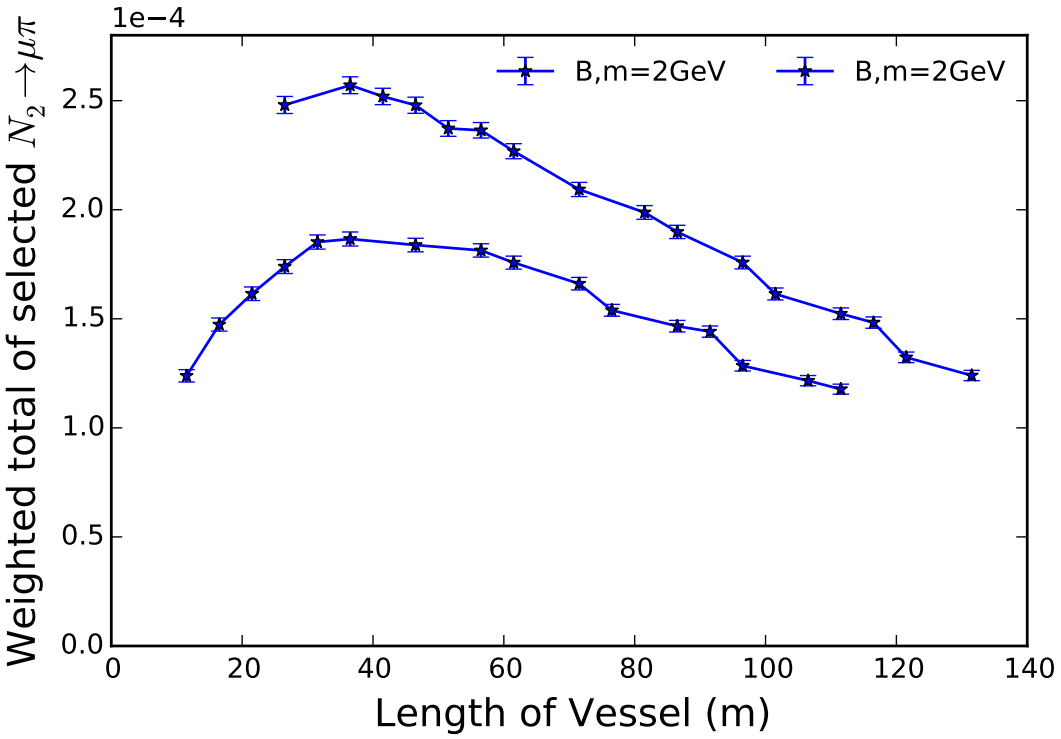

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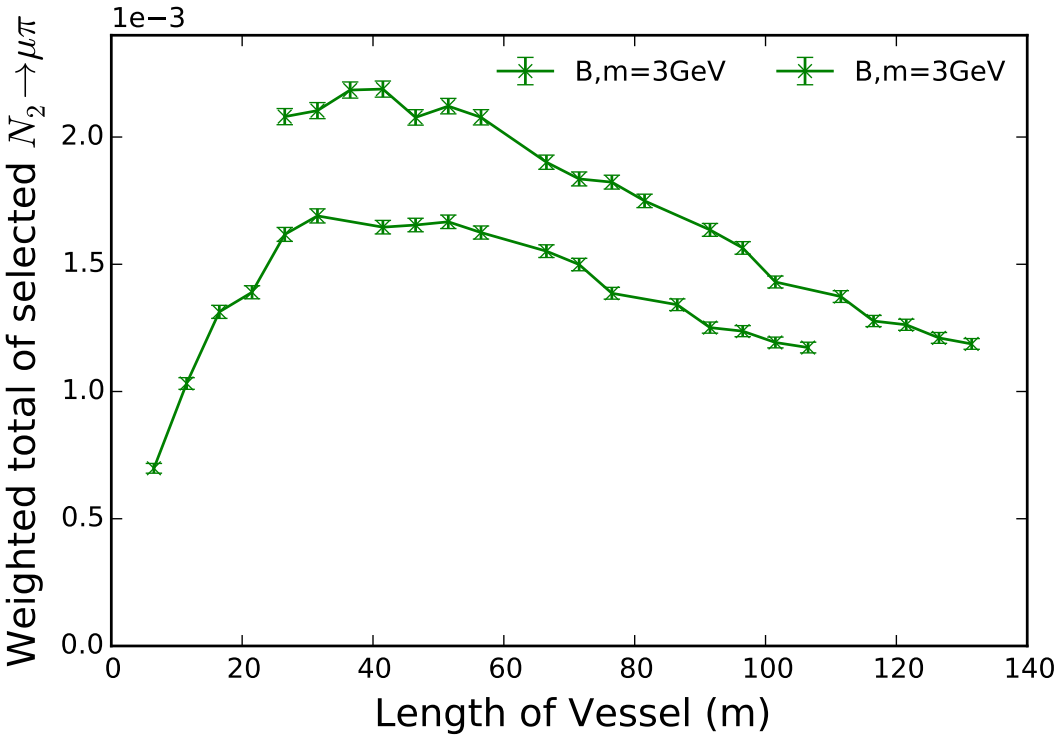

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Conclusions

- 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

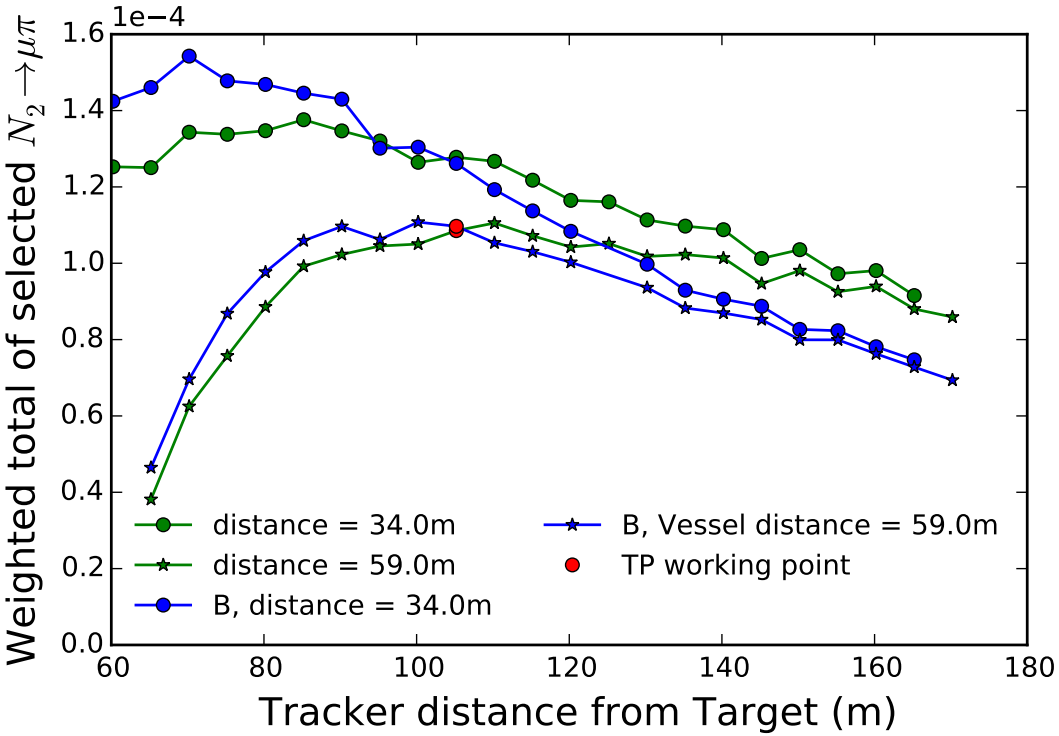
- 2d optimisation has given us feasible benchmark to aim for (see Hans's talk)
- Need full 3d optimisation to be sure, maybe even improvement over 2d
- RAL and CERN engineers investigating possibility of B-fields in target area/hadron stoppers: looks like it's not impossible, need to wait for details (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)
- ν_τ-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