Work Summary

Liverpool FASER Meeting

May 2, 2025

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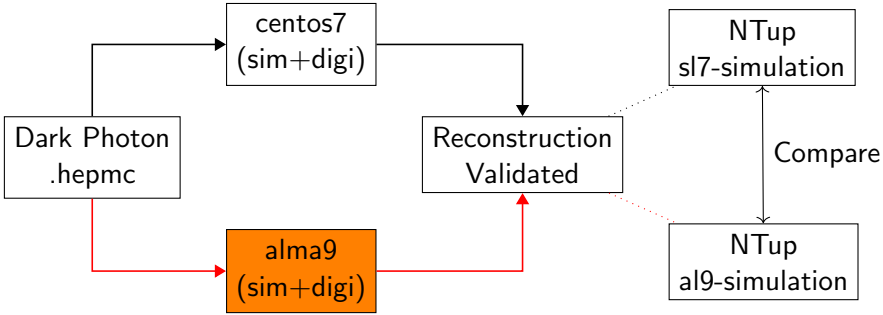
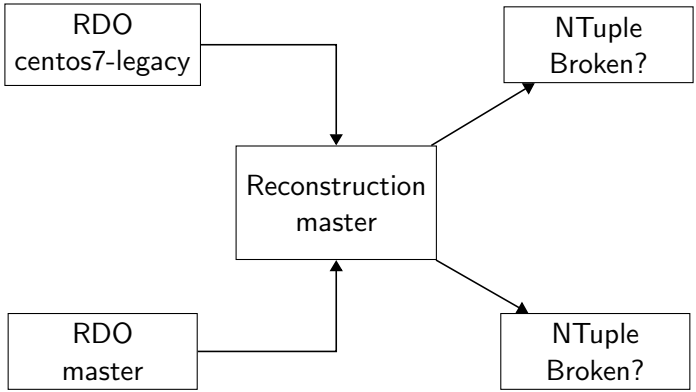
Updates this Month

- Validating New MC Simulation in Alma9
  - Pipeline to Test Simu+Digi
  - Results from Reconstruction with master
  - Results from Reconstruction with centos7-legacy
- Second Look at Dark Higgs
  - Updates on possible reach
  - Issues with background
  - Possible directions forward
- Working on First Year Report
  - One chapter done

MC Simulation Recap/Pipeline



Which Reconstruction to Use?



Reconstruction with master

- NTuples are generated but missing truth branches
  - HepMC not being read/propagated properly
- Furthermore, tracks are not being reconstructed properly
- Conclusion: Likely broken in pipeline.

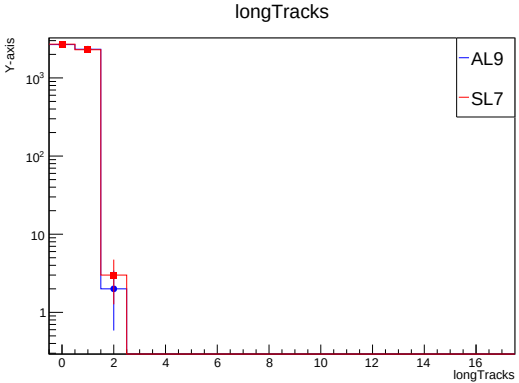
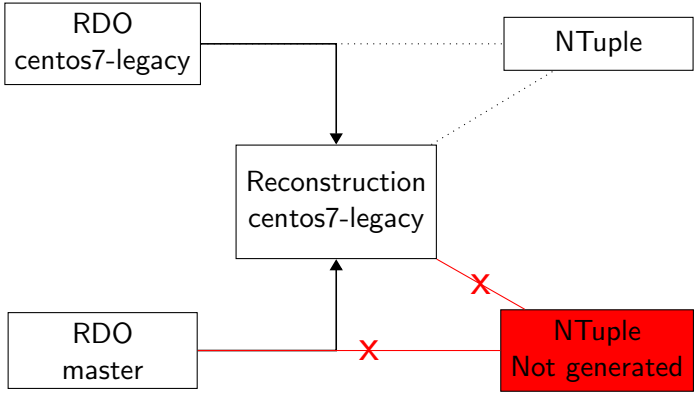


Figure: Distribution of Reconstructed tracks

Reconstruction with centos7-legacy

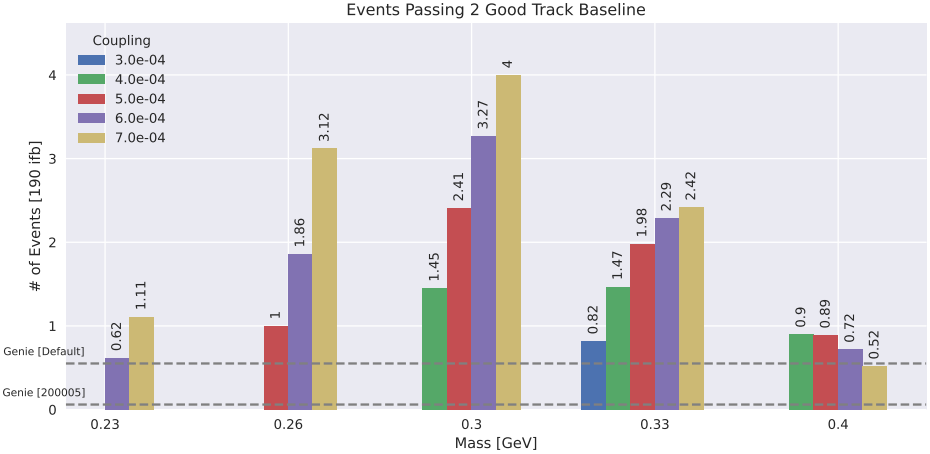


- Master based simulation cannot be reconstructed by centos7
- Unsupported McEventCollection

Steps Forward

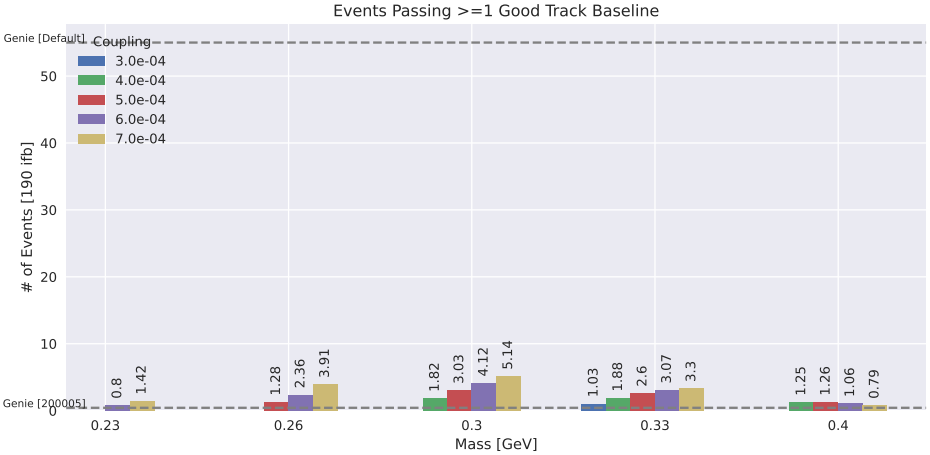
- Check the master pipeline with recent DarkHiggs
  - Should work given the minor changes
  - Re-validates the master reconstruction
- Need fixes for HepMC reading in master branches
  - NTuples missing the truth branches/particles
- If everything works, we can start comparing NTuples
- If not, might need to compare at RDO Level

Dark Higgs Recap – Reach with 2-Track Selection



- Basically, we didn't have much reach with a two-track selection

Reach with 1-Track Selection



- At 1 track, no reach but Neutrino background is much higher
- The background disagreement is really high ($\frac{673}{300} = 2.24$ Event/ab vs $\frac{125+1116+1654}{10} = 289.5$)

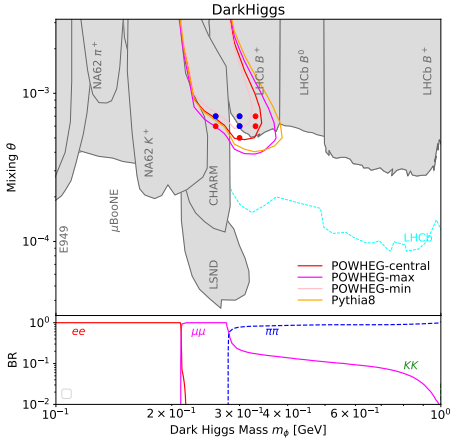
Deeper Look at the Background

Cut	Genie 200035				Genie 200026				Genie 200025				Genie 200005			
	Input	Pass	Eff	CumEff	Input	Pass	Eff	CumEff	Input	Pass	Eff	CumEff	Input	Pass	Eff	CumEff
No timing saturation	394774	346562	87.787%	87.787%	1380095	1222328	88.568%	88.568%	1010000	944973	93.562%	93.562%	30653	29734	97.002%	97.002%
No Raw VetoNu Signal	346562	211896	61.142%	53.675%	1222328	805547	65.903%	58.369%	944973	701429	74.227%	69.448%	29734	29728	99.980%	96.982%
No Raw Veto Signal	211896	151578	71.534%	38.396%	805547	549745	68.245%	39.834%	701429	485742	69.250%	48.093%	29728	29584	99.516%	96.513%
Timing Raw Signal	151578	24837	16.386%	6.291%	549745	84510	15.373%	6.123%	485742	66306	13.650%	6.565%	29584	7841	26.504%	25.580%
Preshower Raw Signal	24837	10010	40.303%	2.536%	84510	35115	41.551%	2.544%	66306	23213	35.009%	2.298%	7841	7508	95.753%	24.494%
≥ 1 good track	10010	125	1.249%	0.032%	35115	1116	3.178%	0.081%	23213	1654	7.125%	0.164%	7508	673	8.964%	2.196%
== 2 good tracks	125	0	0.000%	0.000%	1116	20	1.792%	0.001%	1654	9	0.544%	0.001%	673	95	14.116%	0.310%
Track_R $<$ 95 mm	0	0	nan%	0.000%	20	1	5.000%	0.000%	9	0	0.000%	0.000%	95	48	50.526%	0.157%
Calo E $>$ 470 GeV	0	0	nan%	0.000%	1	0	0.000%	0.000%	0	0	nan%	0.000%	48	11	22.917%	0.036%
Calo E $>$ 500 GeV	0	0	nan%	0.000%	0	0	nan%	0.000%	0	0	nan%	0.000%	11	11	100.000%	0.036%
Calo E $>$ 530 GeV	0	0	nan%	0.000%	0	0	nan%	0.000%	0	0	nan%	0.000%	11	10	90.909%	0.033%
Calo E $>$ 1000 GeV	0	0	nan%	0.000%	0	0	nan%	0.000%	0	0	nan%	0.000%	10	6	60.000%	0.020%

Table: Cutflow comparison for Various Genie Samples

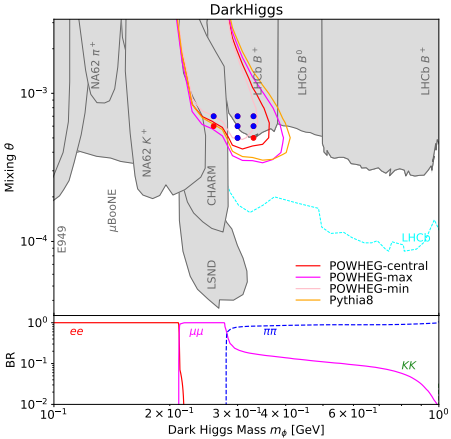
- Genie 200005 [300 iab]
  - Used in the old analysis, also has mis-modelling errors (needs upscaling by 17/11)
  - Interactions starting downstream of the decay volume
- New Default Genie Samples
  - Genie 200035 [10 iab] : P8-MONASH-Charm
  - Genie 200026 [10 iab] : EPOSLHC-Kaon
  - Genie 200025 [10 iab] : EPOSLHC-Pion

What does the Reach Look Like at 190 ifb?



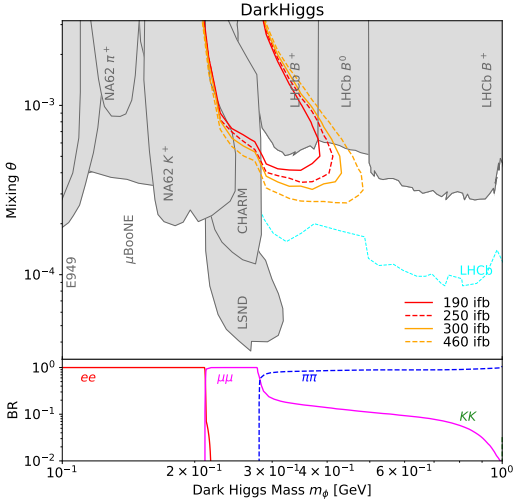
- No novelty in the reach with two-track selection
- Maybe one new point with one-track selection

What does the Reach Look Like at 250 ifb?



- Maybe one new point with two-track selection
- Probably should move our focus to the Uphilic Analysis

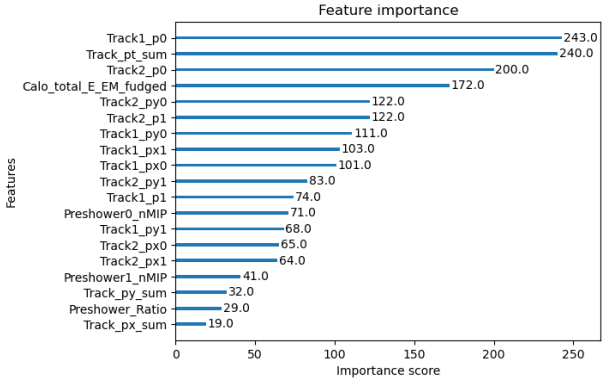
Maybe Higher Luminosity Helps?



- This is ideal reach – assuming zero background and perfect selection
- The two-track selection on average has an efficiency of 50%
- Underlying problem remains – neutrino background
- Might be time to look at Uphilic analysis

Back to Lowering the Background

- How to Lower the Background?
  - We looked at Preshower and Calo variables – inconclusive
  - Maybe a BDT could find something we missed – higher dimensional cut?
- BDT seemed to prefer the track variables



What did the BDT Find? – Track pT

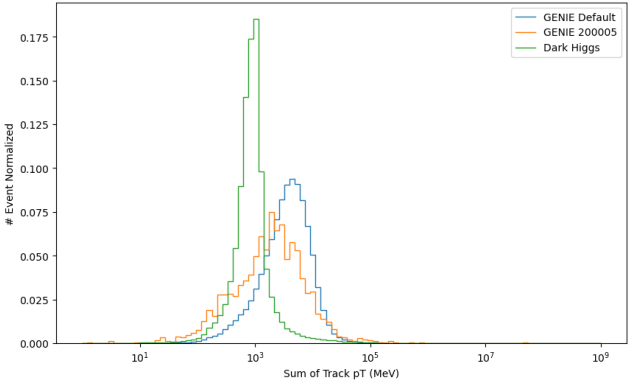
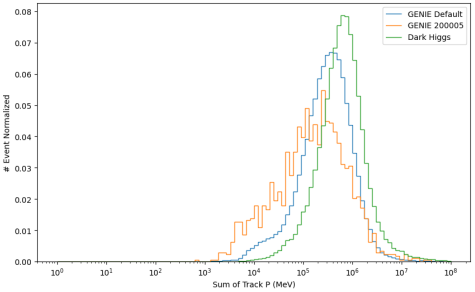


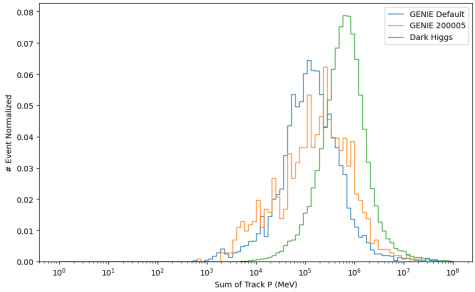
Figure: Sum Track pT Distribution without cuts

- Track pT could be a good variable to separate the background
- But difference is backgrounds is concerning

What did the BDT Find? – Track P



(a) Sum Track P Distribution without any cuts



(b) Sum Track P Distribution after 1-track selection

- Track P is not a good variable in general
- But seems to gets better after baseline selection
- Post two track selection, background is quite low for a plot
  - The BDT most likely picked up on this.
- Understand the kinematics better

What did the BDT Find? – Calo Energy

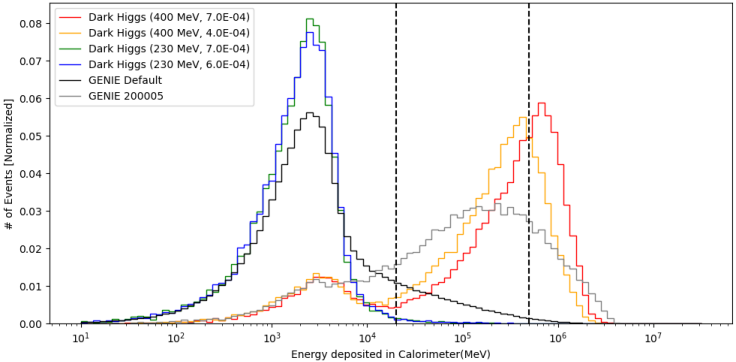


Figure: Calo Energy Distribution without any cuts

- Maybe the high mass points are saved by the Calo requirements
- Although depends on the neutrino sample

Conclusions and Next Steps

- Reach with two track selection
  - Not much reach with existing Luminosity of 190 ifb
  - Not promising with 250 ifb
  - Neutrino Background without energy requirements is still high
- Reach with one track selection
  - Reach still low
  - Large disagreement between the background
- Need new ways to cut down on the background
- Preliminary results from BDT show some promise with track-momenta based variables
  - Look at this through event displays to understand the kinematics

Progress on Event Display

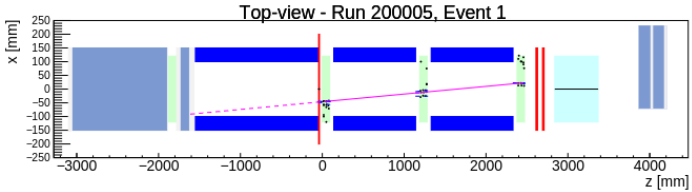


Figure: Event Display of Dark Higgs

- Some great progress on the event display – MuonID added
- Previously, did not work with new geometry (DarkHiggs) or MC Selection
- Thanks Carl and Brian

Progress on Report

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Figure: ToC of report

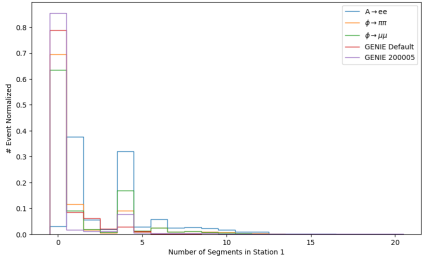
- Finished first draft of Chapter 6
- Chapter 4 is structurally similar
- Waiting for feedback
- Meanwhile, working on Chapter 2,3

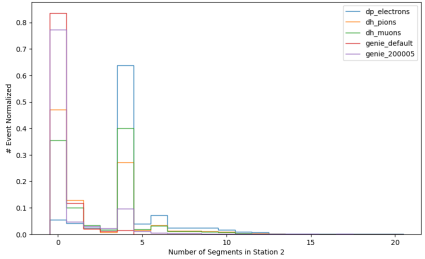
Conclusions and Next Steps

- MC Validation
  - Need to validate new simulation code
  - Pipeline to validate simulation needs some work
- Dark Higgs
  - Background disagreement needs to be resolved
  - Kinematics seem to be the key to selection
- Report
  - Finished first draft of Chapter 6

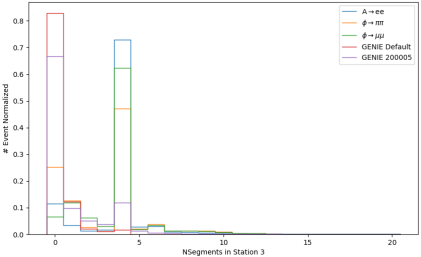
BackUp

Track Segments in Each Station

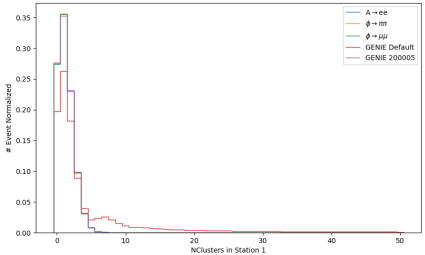


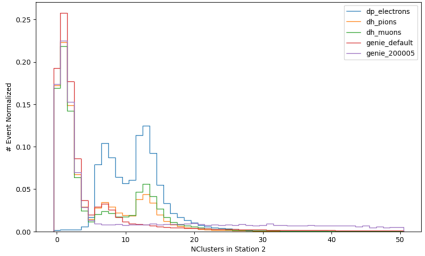


- Number of Segments in Each Station



Track Clusters in Each Station





- Number of Clusters in Each Station