Higgs Self-Coupling Study in Future Muon Collider at $\sqrt{S} = 3TeV$:
preliminary study of DiHiggs Signal Significance

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Overview

Preliminary study to set up a significance estimation of the **μμ->νν*HH*** signal process against main background processes **μμ->νν*bbbb***, **μμ->νν*bbH***, **μμ->νν*bbZ*** in a future muon collider.

Workflow:

- Monte Carlo sample generation
- Detector simulation
- Reconstruction
- Analysis

Study performed using version **V02-05-MC** of the Muon Collider Software (based on ILCSoft), with detector geometry **MuColl_v1**.

Monte Carlo Sample Generation

Samples generated externally at $\sqrt{S} = 3TeV$ in **.hepmc** format using **MadGraph5**.

- diHiggs signal processes generated:

μμ->ννHH	**μμ->μμHH**	**μμ->ZHH**	**μμ->H->HH**
xsec: 0.0007983 ± 5.8e-06	xsec: 3.566e-06 ± 3.1e-08	xsec: 3.241e-05 ± 3.6e-07	xsec: 1.596e-10 ± 3e-19

- Background processes generated:

μμ->ννbbbb	**μμ->ννbbH**	**μμ->ννbbZ**
xsec: 0.0006448 ± 6.8e-06	xsec: 0.002886 ± 2.2e-05	xsec: 0.02573 ± 0.00021

- pT, phi, and eta generation-level validation plots plotted for each process.

Detector Simulation and Reconstruction

Simulation:

- Detector simulation carried out for each of the generated processes.
- Tracker hit pT, phi, and eta simulation-level validation plots plotted for each process.

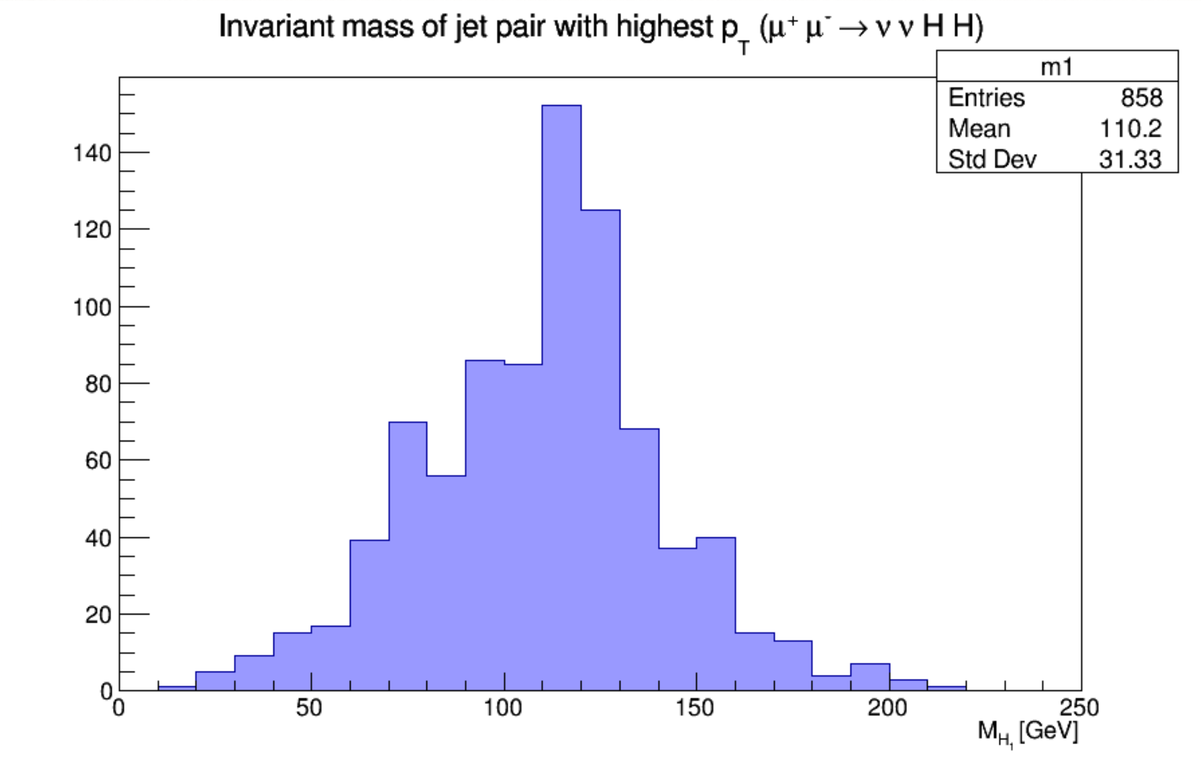
Reconstruction:

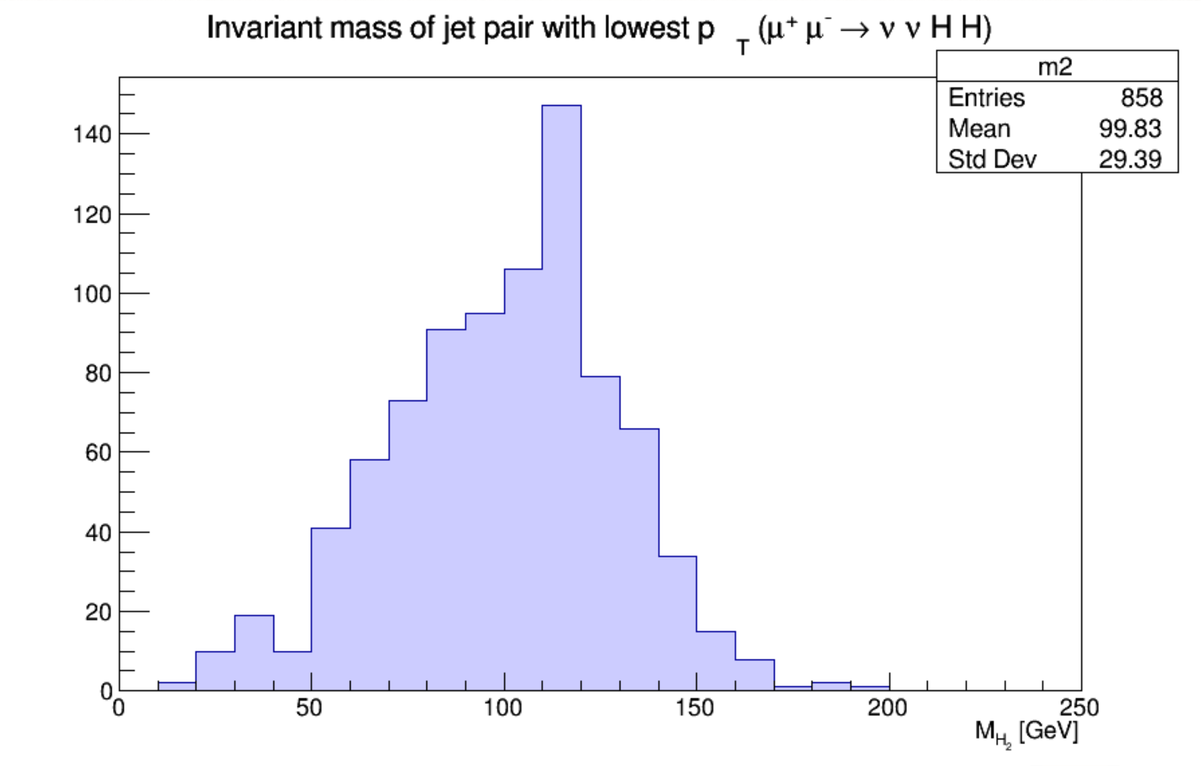
- Reconstruction carried out for each of the processes.
- Jet pT, phi, and eta reconstruction-level validation plots plotted for each process.

Analysis: Invariant Mass - signal process

- Invariant mass of the **jet pair with lowest pT** and **jet pair with highest pT** plotted for the signal process (μμ->ννHH).

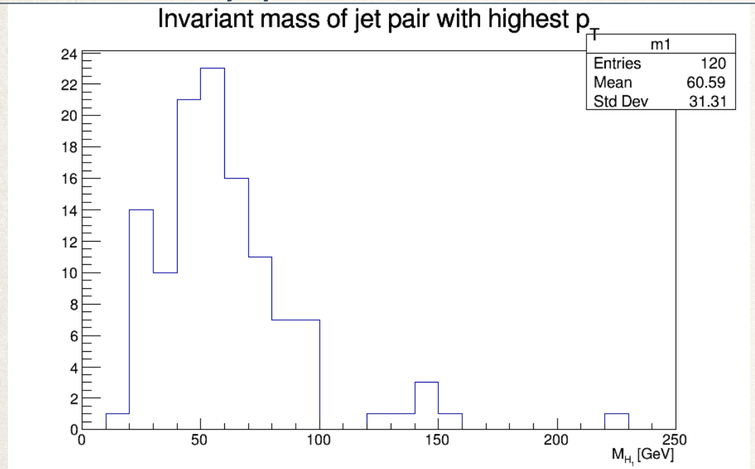
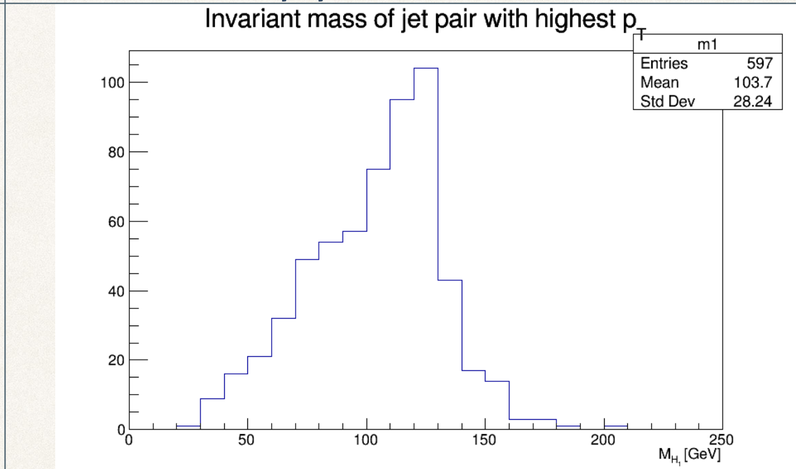
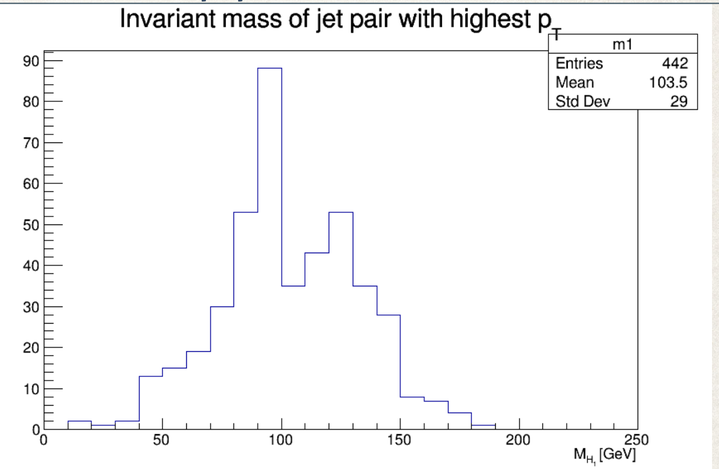
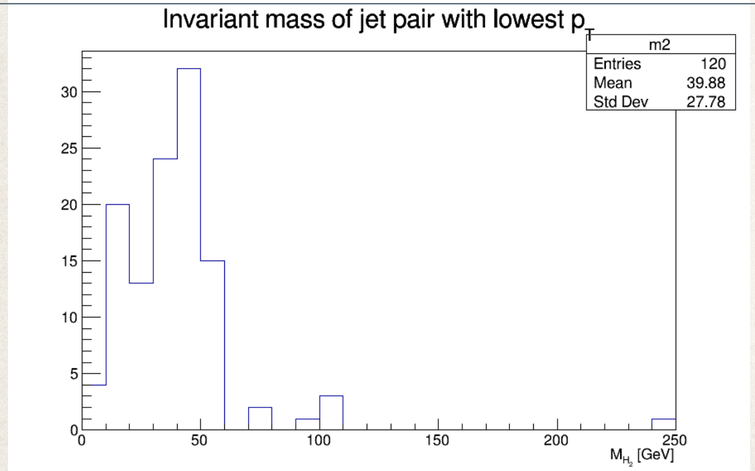
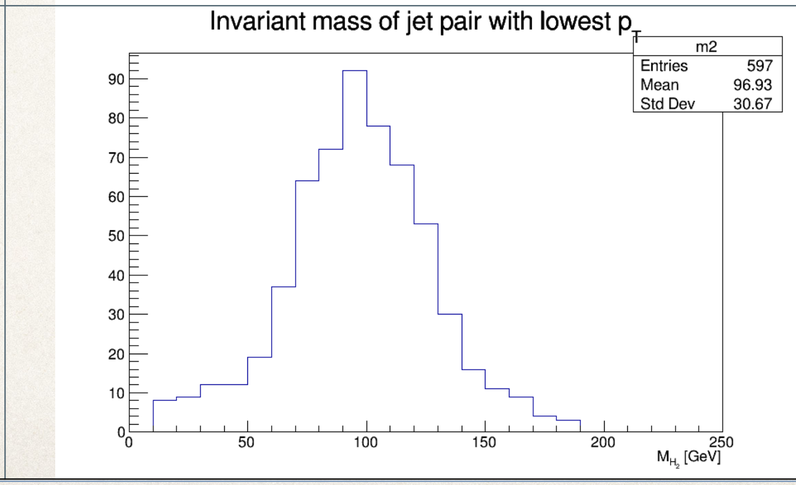
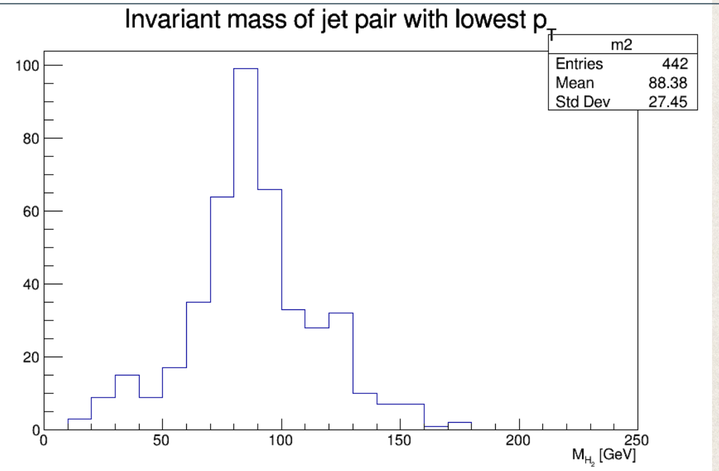
- Expecting to see a peaks at 125 GeV corresponding to each of the Higgs bosons:



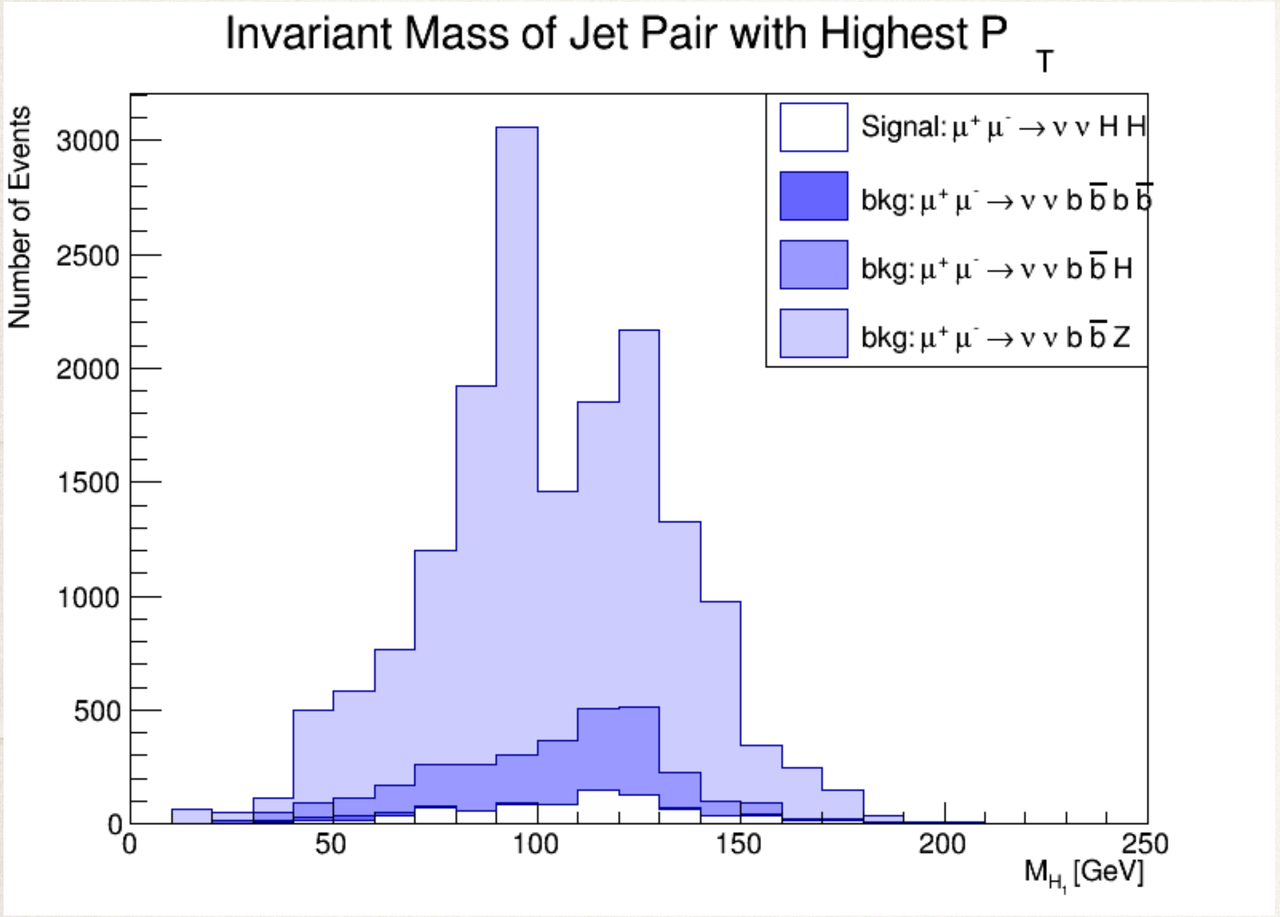


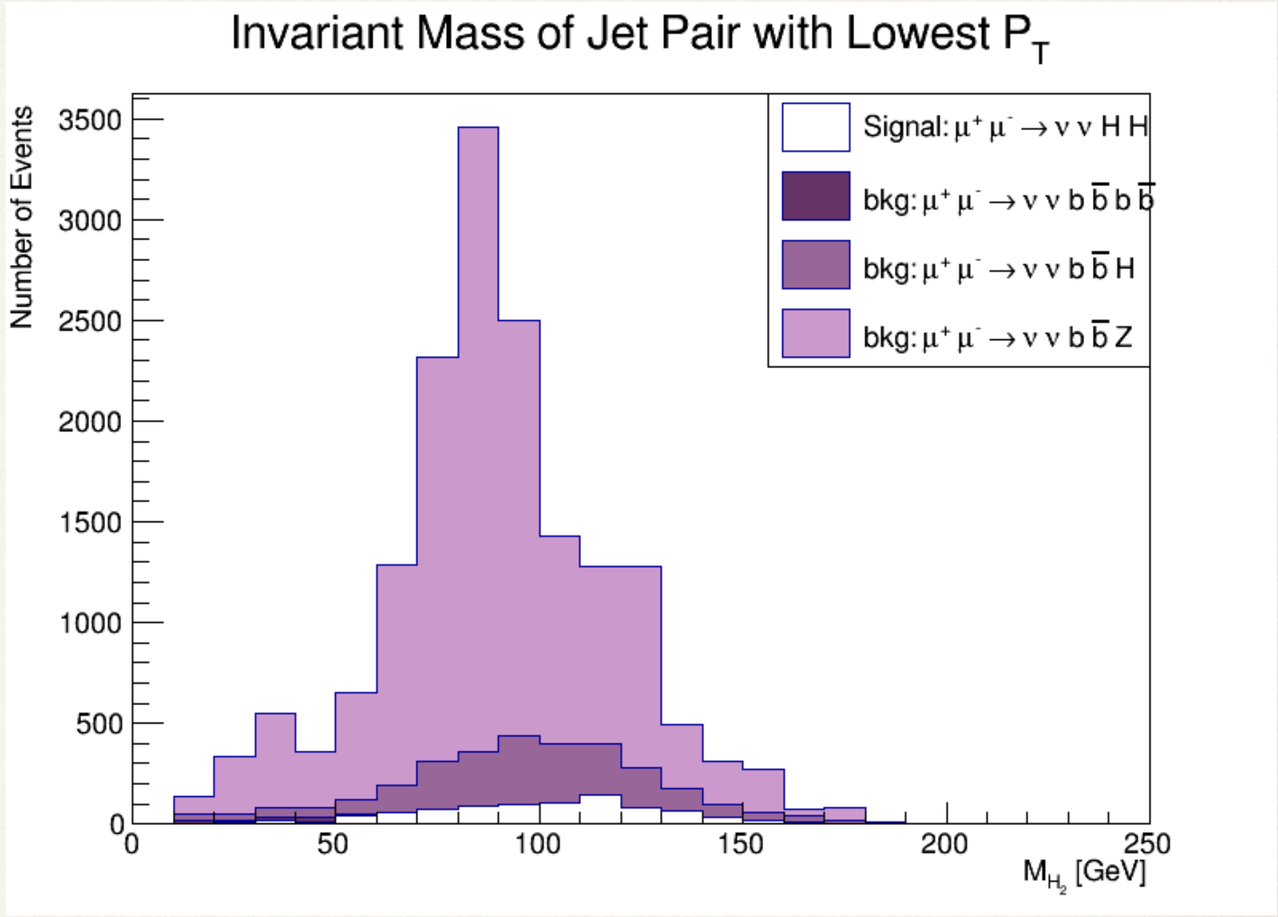
Analysis: Invariant Mass - background

- Invariant mass of the **jet pair with lowest pT** and **jet pair with highest pT** plotted for each of the background processes:

μμ->νννbbbb	μμ->νννbbH	μμ->νννbbZ
		
		

Analysis: signal to background ratio





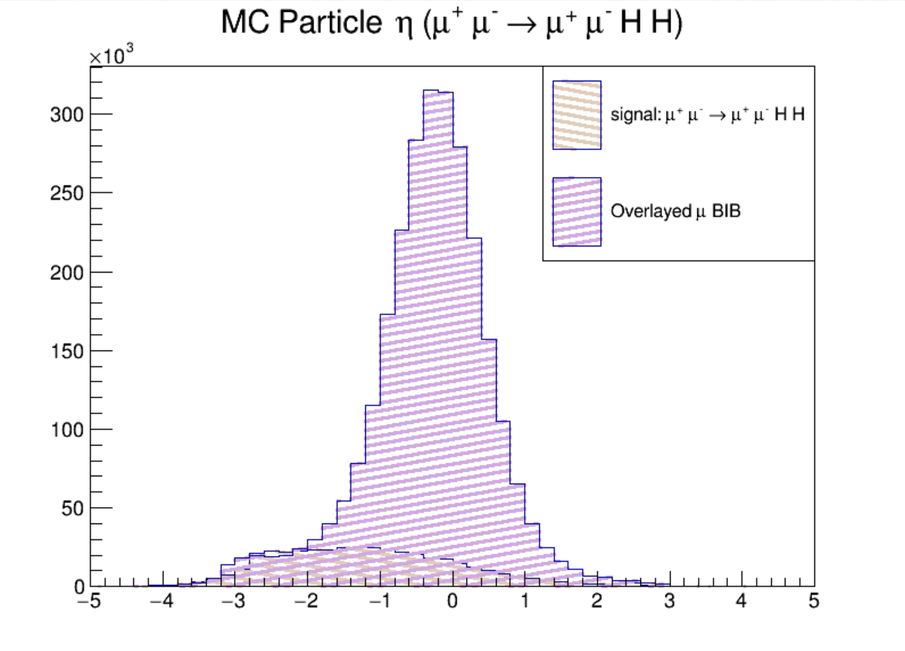
* Background processes scaled relative to signal process according to cross-section ratios.

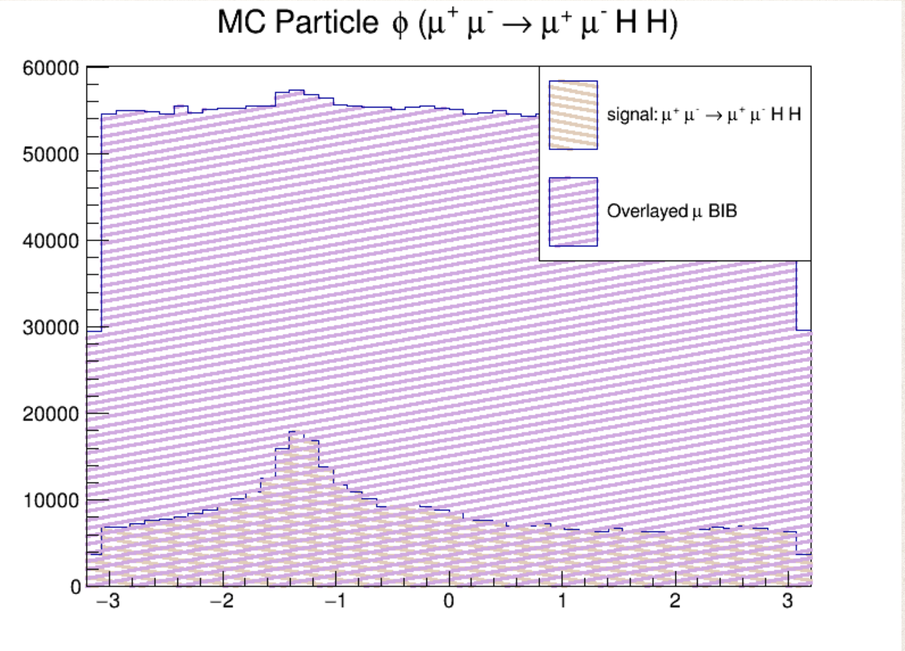
Muon Beam-Induced-Background (BIB) Challenge

- Physically significant due to the large amount of detector hits it would produce

=> needs to be taken into account in a comprehensive detector simulation for muon collider study/analysis.

Just 0.3% of $\sqrt{S} = 1.5TeV$ BIB overlayed for 10 events of a diHiggs signal process :





- Simulated BIB samples at relevant $\sqrt{S}$ would need to be overlayed with the studies processes during reconstruction. However this is a computing challenge that is yet to be overcome.

Conclusion and Outlook

- In conclusion, preliminary analysis has been performed for the estimate of a signal significance estimation, as part of the study on the Higgs self-coupling for diHiggs processes as $\sqrt{S} = 3TeV$ in a future muon collider.

- Next steps before setting up estimation of signal significance:

1. This pre-analysis has been performed on 1,000 events -> step this up to at least 10,000 events for better validation and statistics.
2. Examine accuracy of the cross-sections of the signal and background processes to ensure correct ratio.
3. Optimize analysis utilizing kinematic selections.

- Start looking at effect of the muon beam-induces background at $\sqrt{S} = 3TeV$.

Backup Slides - **Technical Notes**

Monte Carlo Sample Generation

Samples generated externally (not on lxplus) and then scp'd to lxplus as .hepmc files.

- Generated using MadGraph5_aMC@NLO
- Installed from http://madgraph.phys.ucl.ac.be/
- Setup and instructions for sample generation: https://twiki.cern.ch/twiki/bin/view/CMSPublic/MadgraphTutorial#Installing_ROOT

Muon Collider Software

- **Muon Collider Tutorial**: overview of work stages, use of software and steering files for each stage (https://indico.cern.ch/event/938616/contributions/3943417/attachments/2075780/3485569/casarsa-MuC_tutorial.pdf)

- **Accessing software on lxplus:**

  git clone https://github.com/MuonColliderSoft/MuonCutil
  cd confile

- **Using software on lxplus:** no need to install, singularity available, but only works in home directory (doesn't work in work directory)

  singularity run /cvmfs/unpacked.cern.ch/registry.hub.docker.com/infnpd/mucoll-ilc-framework:1.4-centos8

- 10 events run through the stages quickly, good for testing things. ~100 events can take a few hours and is the maximum on lxplus. For more events can run in batches of 100 and merge the root files.
- The biggest files are the reconstruction .slcio files (reconstructed .slcio file of 100 events of a diHiggs signal process ~ 6 GB)