Imperial College London

Higgs to Invisible MC Comparison

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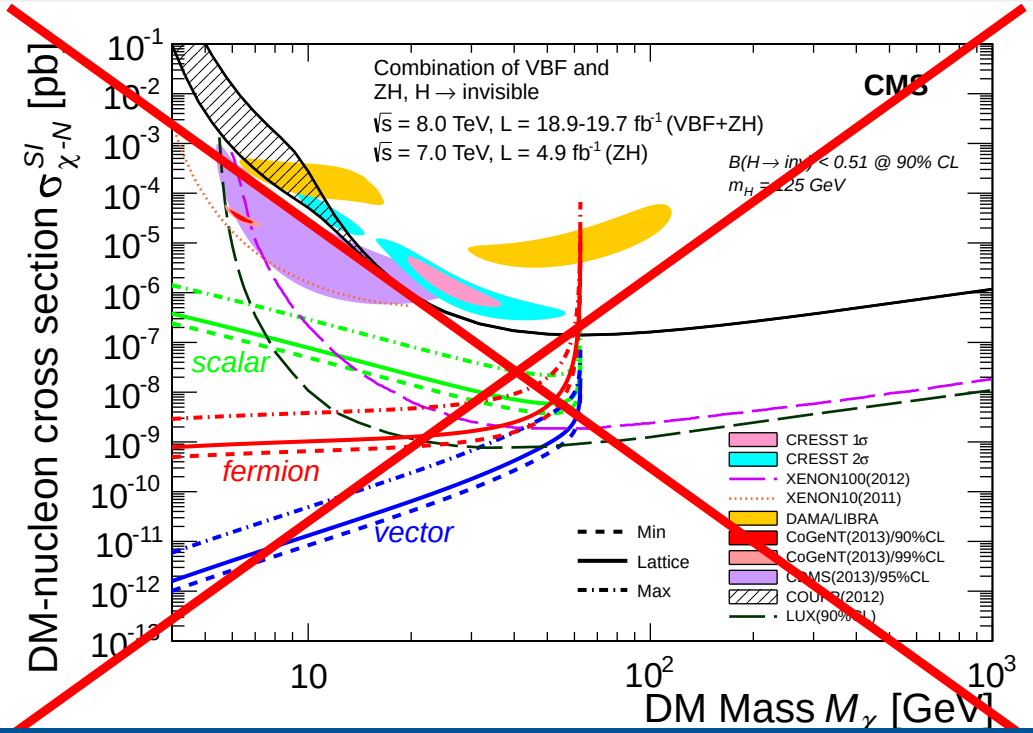
Introduction

- For HIG-13-030 we used a higgs-portal model to set limits on dark matter
- This is wrong due to cross-section going to infinity as mass goes to zero
- Working with theorists at Rutgers to interpret VBF H→inv search in several robust BSM dark matter models



Plan for Sample Production

- The theorists have generated Madgraph samples for several models (SM, EFT, 2HDM, Higgs portal without problems from before) hadronised with pythia
- We process them through delphes detector simulation
- We then use the scorpion framework to get yields for the models

Validation

- We have SM Higgs to invisible samples generated at 8 TeV with madgraph processed through delphes
  - Delphes was modified to include met significance
- These were compared to CMS samples generated with Powheg and CMS fullsim
- Compare yields through cutflow starting at met significance>3, $\Delta\eta_{jj} > 3.6$

Cut added	Powheg + CMS yield	Madgraph + Delphes yield
$j_1 p_T > 50$, $j_2 p_T > 45$	1351	1834
min$\Delta\phi(j, met) > 2.3$	649	812
met> 90	624	802
$M_{jj} > 1200$	300	194
met significance> 4	273	167

- Not very compatible
- Mjj cut seems to be the cause of the largest difference

Delphes Validation

- We wanted to check if the differences seen between Madgraph+delphes and Powheg+CMS were from generator or reconstruction
- Powheg samples generated with the same config as the CMS samples were processed with delphes
- Default pileup in delphes found to be 50
  - After correcting to 21 Powheg+CMS and Powheg+Delphes yields now match to 10%

Madgraph vs Powheg: Cut Flow

- Next check is Madgraph vs Powheg
- Compare yields cut by cut
- Start with $\eta_{j1} \cdot \eta_{j2} < 0$, MET significance$>$ 3, $\Delta\eta_{jj} > 3.6$, jet 1 $p_T > 35$ GeV, jet 2 $p_T > 35$ GeV, $M_{jj} > 700$ GeV, trigger MET$>$ 40 GeV
  - All variables at trigger threshold plus MET significance$>$ 3 for technical reasons

Cut added	Madgraph + Delphes	Powheg + Delphes
Start point	1552	2311
jet 1 $p_T > 50$ GeV, jet 2 $p_T > 45$ GeV	1203	1834
MET$>$ 90 GeV	1170	1793
$M_{jj} > 1200$ GeV	412	689
MET significance$>$ 4	315	519
min$\Delta\phi(j, MET) > 2.3$	143	248

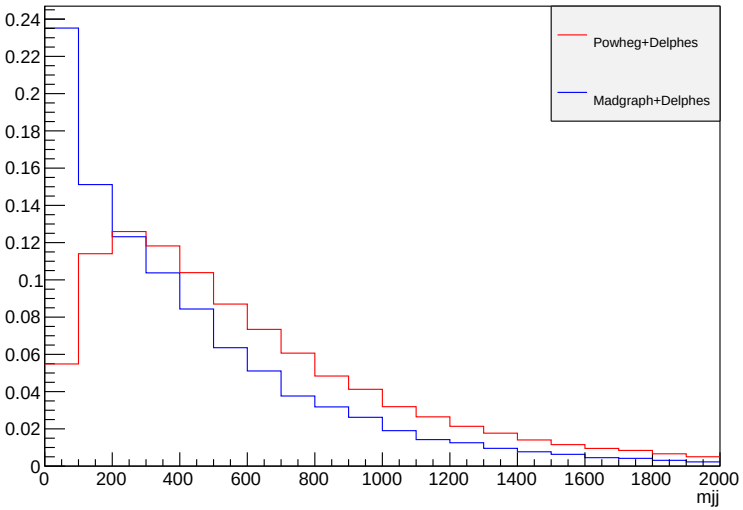
Madgraph vs Powheg: Efficiencies

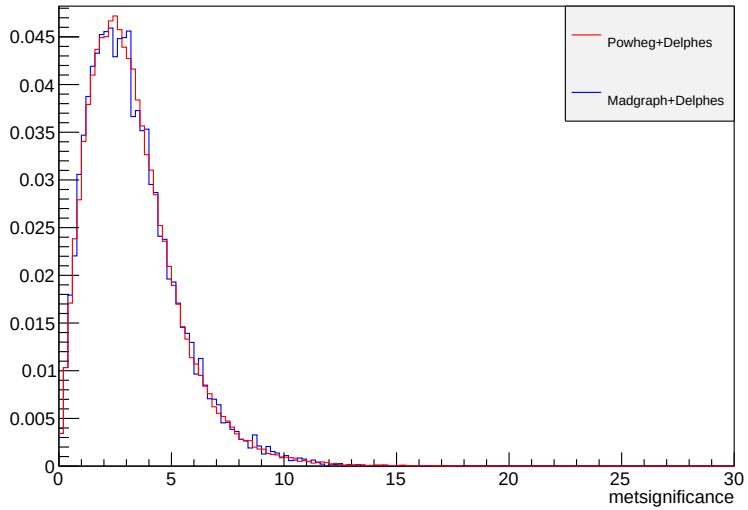
- Compare efficiencies of last cut cut by cut (numbers shown are efficiencies)
- Start with $\eta_{j1} \cdot \eta_{j2} < 0$, MET significance$>$ 3, $\Delta\eta_{jj} > 3.6$, jet 1 $p_T > 35$ GeV, jet 2 $p_T > 35$ GeV, $M_{jj} > 700$ GeV, trigger MET$>$ 40 GeV
  - All variables at trigger threshold plus MET significance$>$ 3 for technical reasons
- Efficiencies are very similar
- Events that make it to the first step are behaving like they should

Cut added	Madgraph + Delphes	Powheg + Delphes
jet 1 $p_T > 50$ GeV, jet 2 $p_T > 45$ GeV	0.78	0.79
MET$>$ 90 GeV	0.97	0.98
$M_{jj} > 1200$ GeV	0.35	0.38
MET significance$>$ 4	0.76	0.75
min$\Delta\phi(j, MET) > 2.3$	0.45	0.48

Compare Distributions

- Use looser selection to look for differences in distributions between Powheg and Madgraph
- All plots are normalised to same number of events
- Selection: 2 pf jets $p_T > 30$ GeV
- Very different Mjj shape





Compare Distributions

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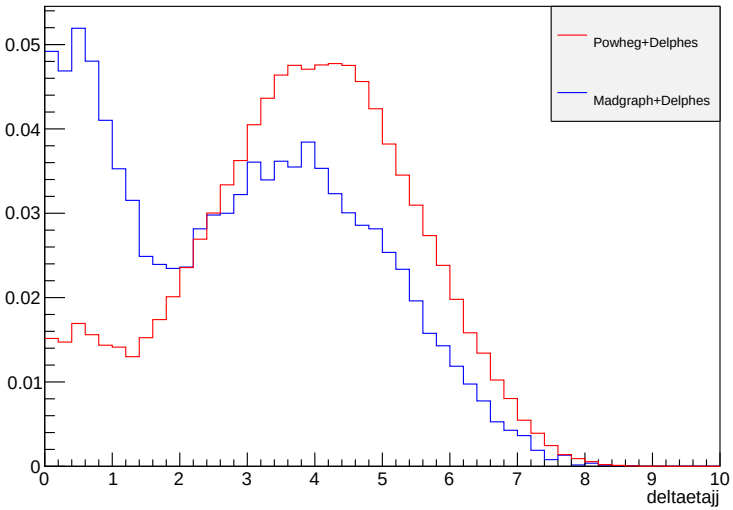
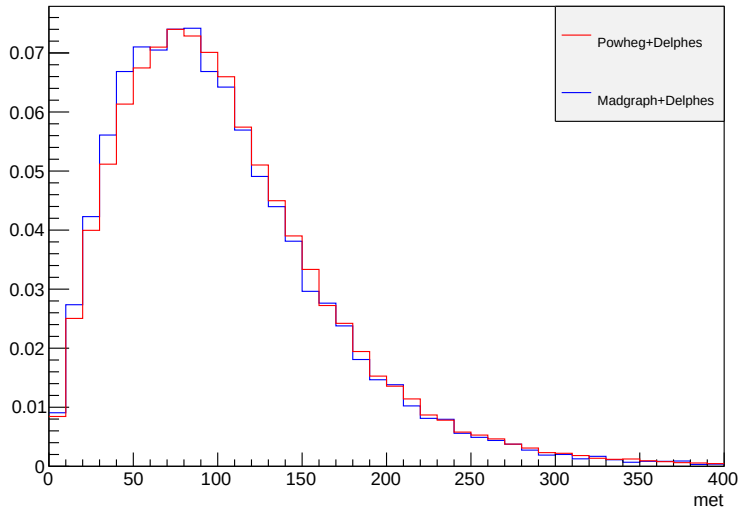
- Very non-VBF like events evident in $\Delta\eta_{jj}$





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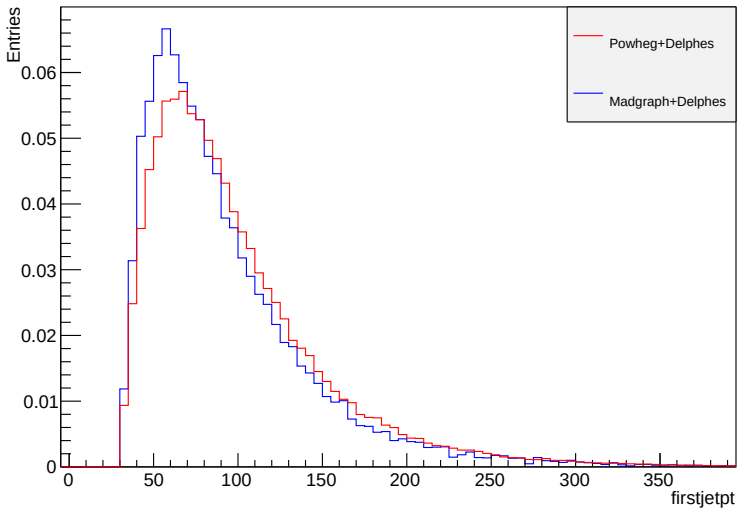

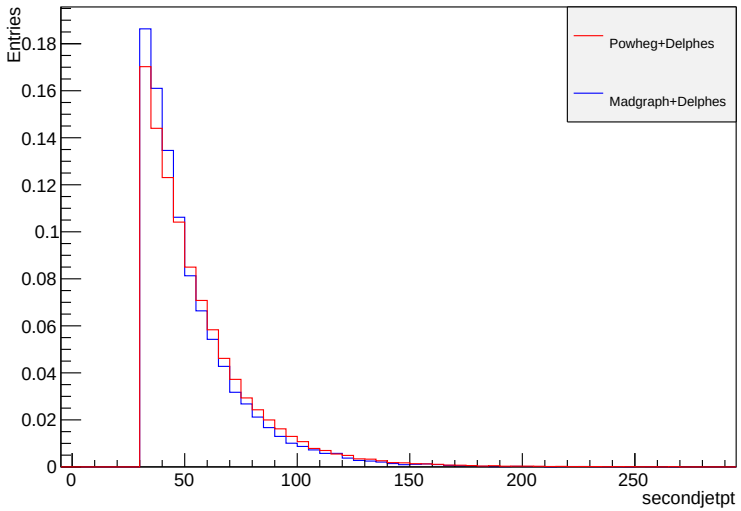

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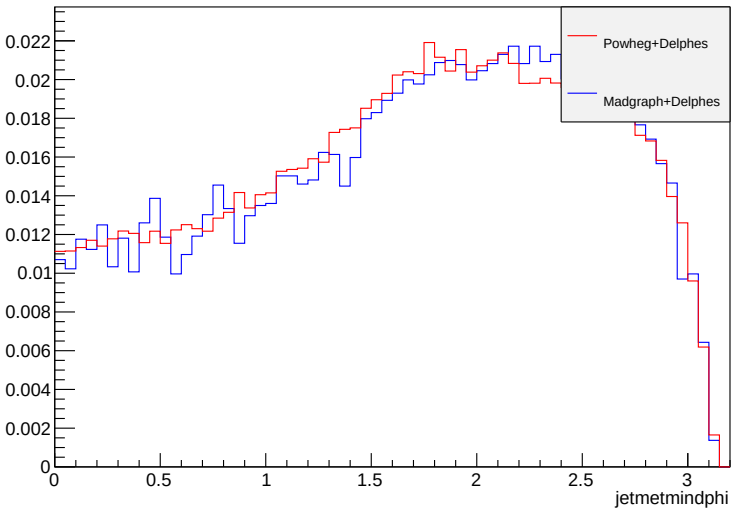

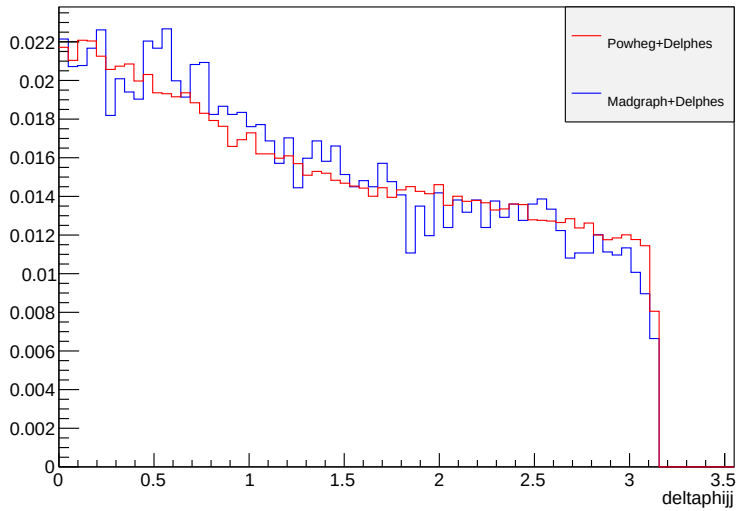

Problem Resolved

- On discussion with theorists VH production is same EWK order as VBF and therefore present in Madgraph samples
- We expect no VH events to pass our full selection so changing normalisation cross-section should resolve differences

Cut added	Madgraph + Delphes	Powheg + Delphes
Start point	2653	2311
jet 1 $p_T > 50$ GeV, jet 2 $p_T > 45$ GeV	2056	1834
MET$>$ 90 GeV	2000	1793
$M_{jj} > 1200$ GeV	704	689
MET significance$>$ 4	539	519
min$\Delta\phi(j, MET) > 2.3$	244	248

- Agreement now very good

Limits

- Non-CMS publication so we cannot use full datacard with internal correlation and uncertainty information
- I have made a datacard using only the information publicly available in the PAS
- Compare limits:

Card	Signal estimate used	Observed (expected) limit
CMS	CMS	57(40)
CMS	CMS	63(45)
Public info	MG+Delphes	58(42)
Public info	MG+Delphes	65(47)

- For MG+Delphes signal estimate I've assumed the same errors and the same proportion of ggH contamination
- Using public info only doesn't change limit much
- Different signal estimate leads to agreement at 10% level

Summary

- We have a well validated software chain to emulate the CMS VBF H→invisible parked analysis
- We will now process the BSM samples generated by the theorists
- We will also extrapolate to 13 TeV to estimate future sensitivity
  - Scale backgrounds by parton luminosity, systematics constant/$\sqrt{\mathcal{L}}$

Backup