# VBF Higgs to Invisible cross check analysis

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were produced by two different and independent code frameworks. This a

## 2012 prompt results and publication

- Produced by two different and independent code frameworks
- Allowed debugging via synchronization
- Extra confidence on the final results

## 2012 parked results and publication

Due to lack of man power and time only one full framework. Later decided some level cross check would be beneficial for the analysis. What is being done:

- Cross check analysis starts from the same ntuples produced by the main analysis.
  - All the relevant datasets with not filtering (except golden JSON), just data reduction and parking.
  - Production of ntuples uses same framework on other validated analysis: SM and MSSM Higgs $\tau\bar{\tau}$, the Higgs to $\tau\bar{\tau}b\bar{b}$ and also the prompt invisible result.

# Software

I have created a git software repository for analysis independent software and tools about a year ago this will be the base for the analysis code:

## Base

https://github.com/joaopela/HEPFW

This software package was already forked and was the base for the recent Run II trigger studies and now is being used for the cross check analysis.

## Fork

https://github.com/ICHiggsInv/HEPFW

The target is to have a framework capable of replicating all the relevant pltos and numbers of the main analysis.

# Code structure

Framework development was inspired on CMSSW and ROOT structures and features.

## Structure features

- Configuration files via JSON files
  - Similar function to python in CMSSW
  - Allows complex structures to be passed to program out of the box (vector, map, nested arguments, etc)
  - (Under development) Ability to load other JSON files from initial configuration file
- Working with sequences of modules that access the event (like CMSSW):
  - Analysis modules: Produce plots and tables
  - Filter plots: Pass/fail for an event on a sequence of modules (analysis cuts)
  - Producer plots: Add content to the event (filtered or modified collections)
- (Underdevelopment) Saving events passing a given sequence (like CMSSW)
  - Allows for skimming of both events and events content
  - This feature has been envisaged since the beginning of the development so some of the code hooks are already present.

All this code has been development in the last 2 weeks.

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## Capabilities

- Access IC Dataformats
- Run over all datasets automatically
- Multiple sequence capability
- EDM filter filtering
- Event list filtering
- Collection cuts based filtering
- Collection overlap filtering

## Analysis specific

- Vertex selection
- HLT and L1T filtering
- Electron selection (and veto)
- Muon selection (and veto)
- MET cuts
- Jet cuts (NEW: finished!)
- Multiple object cuts ($Min(\Delta\phi(MET, jets))$)

### Problems

- L1T ETM Cut values $> 40$ vs $>= 40$
- Primary vertex conditions
  - Data: !isFake, $ndof > 4$, $abs(z) <= 24$, $position.rho < 2$
  - MC: minNdof = cms.double(4.0), maxZ = cms.double(24.0)

### Documentation

- Electron additional cuts: Some of the cuts said to be additional are actually default POG cuts.

# Problems Found: Primary vertex conditions

# Problems Found: PFJet ID AN-to-Code disagreement

I found that in the Analysis Note the definition of selected jets is:

- The jet requirements are:
  - Neutral Hadron Fraction $< 0.99$
  - Neutral EM Fraction $< 0.99$
  - Number of Constituents $> 1$
  - Additionally for $|\eta| < 2.4$ we require:

  - Charged Hadron Fraction $> 0$
  - Charged Multiplicity $> 0$
  - Charged EM Fraction 0.99

## In the code

int n_pu = jet-¿charged_multiplicity() + jet-¿neutral_multiplicity() + jet-¿HF_had_multiplicity() + jet-¿HF_em_multiplicity(); n_pu ¿ 0;

It is written that this cuts come from AN 2010/003 but this analysis not is on 'Study of Various Photomultiplier Tubes with Muon Beams And Cerenkov Light Produced in Electron Showers' and has no cuts defined.

# First results - event quality filters

We apply a set of event quality filters to exclude events with clear problems. This filters cover several issue like bad experimental conditions (like too much beam halo), detector noise and problems with reconstruction. The inclusion of the filter is recommended for analysis using MET. The following table has the percentage of rejected events by each filter individually before any other cuts are applied to data. At the end the total percentage event rejection (using an or of all filters) is provided.

## Topics

| Filter | Prompt A | Prompt B | Prompt C | Prompt D | Parked B | Parked C | Parked D |
|---|---|---|---|---|---|---|---|
| HBHENoiseFilter | 22.900905 | 22.527028 | 24.197981 | 21.830762 | 0.190670 | 0.187739 | 0.170753 |
| EcalDeadCellTriggerPrimitiveFilter | 0.375381 | 2.106058 | 2.122628 | 0.838167 | 0.009300 | 0.010206 | 0.012526 |
| eeBadScFilter | 0.007852 | 0.002690 | 0.000087 | 0.001883 | 0.000001 | 0.000000 | 0.000009 |
| trackingFailureFilter | 3.073876 | 1.147820 | 1.638249 | 1.723157 | 0.000328 | 0.007464 | 0.000290 |
| manystripclus53X | 0.001829 | 0.004350 | 0.007730 | 0.005510 | 0.001319 | 0.002335 | 0.001327 |
| toomanystripclus53X | 0.000484 | 0.001765 | 0.003141 | 0.001732 | 0.001149 | 0.002006 | 0.001173 |
| logErrorTooManyClusters | 0.000027 | 0.000190 | 0.000379 | 0.000102 | 0.000009 | 0.000021 | 0.000016 |
| CSCTightHaloFilter | 10.263068 | 7.792489 | 6.133730 | 8.346904 | 0.398497 | 0.402936 | 0.508025 |
| Total | 28.501208 | 28.317395 | 28.978159 | 26.047078 | 0.598417 | 0.601999 | 0.689380 |

## Comparison with main analysis:

This values can be found on the first part of table 3 on the AN2014_243_v4. While total filter efficiency matched exactly the values presented on the note, there are small discrepancies on individual filters with very low event exclusion. This discrepancies may be due to rounding problems or double vs float conversions where precision is lot.

There are events that should be not be considered due to have been recorded while the ECAL and/or HCAL laser calibration sequence was happening. The identification of this events is provided through a file list which is used by the code framework to remove those events. The following table shows the individual and total percentage of events vetoed out of the the ones already passing the event quality filters of the previous section.

## Topics

| Filter | Prompt A | Prompt B | Prompt C | Prompt D | Parked B | Parked C | Parked D |
|---|---|---|---|---|---|---|---|
| ECAL Laser Filter | 0.928521 | 1.195528 | 0.000000 | 0.000000 | 0.008659 | 0.000000 | 0.000000 |
| HCAL Laser Filter | 0.007258 | 0.000027 | 0.004963 | 0.000000 | 0.000000 | 0.000270 | 0.000000 |
| ECAL+HCAL Laser Filter | 0.935704 | 1.195556 | 0.004963 | 0.000000 | 0.008659 | 0.000270 | 0.000000 |

## Comparison with main analysis:

The "ECAL+HCAL Laser Filter" line of values can be compared with the one on table 3 on the AN2014_243_v4. Values match exactly the ones of the main analysis.

# First results - Preselection data yield

## Yield

- DATA_MET_2012A: 388
- DATA_MET_2012B: 1541
- DATA_MET_2012C: 2941
- DATA_MET_2012D: 2905
- DATA_VBF_Parked_2012B: 1737
- DATA_VBF_Parked_2012C: 3282
- DATA_VBF_Parked_2012D: 3184

Total events 8591 while the main analysis has 8971 (so I have less 4.2%). Caveats main analysis number does not have the L1T ETM fix and the $n_{Constituents}$ fix. Code needs to be reviewed to find where is the problem.

# Summary and next steps

## Summary:

- Now able to replicate some number of the analys note.
- Some bugs already found (minimal influce in main analysis):
  - Good vertex requirement not being requested on main analysis code (effect unknow but should be small)
  - L1T met cut was $> 40$ and not $>= 40$
- Analysis contribution
  - Checking all definitions against POG recommendation

## Next Steps:

- Replicate pre-selection results.

https://twiki.cern.ch/twiki/bin/viewauth/CMS/VBFHInvParkedDataCrossCheck

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# dcd

| | Vertex Filter | Event Quality Filters | HCAL Laser Filter | ECAL Laser Filter | L1T ETM Filter | HLT Trigger | Loose Electrons Producer | Electron veto | Loose Muon Producer |
|---|---|---|---|---|---|---|---|---|---|
| DATA MET 2012A | 3606391 | 2658960 | 2658767 | 2634080 | 2461217 | 97522 | 97522 | 96600 | 96600 |
| DATA MET 2012B | 15076553 | 10926634 | 10926631 | 10796000 | 9316076 | 633305 | 633305 | 627254 | 627254 |
| DATA MET 2012C | 21570165 | 15555671 | 15554899 | 15554899 | 13668424 | 1154795 | 1154795 | 1143298 | 1143298 |
| DATA MET 2012D | 59027309 | 44411435 | 44411435 | 44411435 | 37528140 | 2222706 | 2222706 | 2203960 | 2203960 |
| DATA VBF Parked 2012B | 132346320 | 131554431 | 131554431 | 131543040 | 88174347 | 75100422 | 75100422 | 74947192 | 74947192 |
| DATA VBF Parked 2012C | 228049748 | 226680352 | 226679741 | 226679741 | 160560859 | 137527238 | 137527238 | 137241812 | 137241812 |
| DATA VBF Parked 2012D | 308041846 | 305918529 | 305918529 | 305918529 | 227801622 | 152041761 | 152041761 | 151725585 | 151725585 |

| | Muon veto | Selected Jet Producer | PFJets-Loose Electron cleaning | PFJets-Loose Muon cleaning | MET Cut | MET Significance | Dijet | MET Jets DPhi |
|---|---|---|---|---|---|---|---|---|
| DATA MET 2012A | 94961 | 94961 | 94961 | 94961 | 19574 | 10079 | 3831 | 388 |
| DATA MET 2012B | 620327 | 620327 | 620327 | 620327 | 107139 | 53054 | 16505 | 1541 |
| DATA MET 2012C | 1130114 | 1130114 | 1130114 | 1130114 | 189540 | 94349 | 29268 | 2941 |
| DATA MET 2012D | 2188438 | 2188438 | 2188438 | 2188438 | 250910 | 105014 | 30007 | 2905 |
| DATA VBF Parked 2012B | 74917473 | 74917473 | 74917473 | 74917473 | 203555 | 85225 | 24211 | 1737 |
| DATA VBF Parked 2012C | 137187462 | 137187462 | 137187462 | 137187462 | 345103 | 138386 | 42730 | 3282 |
| DATA VBF Parked 2012D | 151662101 | 151662101 | 151662101 | 151662101 | 436510 | 145761 | 41667 | 3184 |

| Jet $p_\perp$ | Jet $\|\eta\|$ | $BDT_{score}$ |
|---|---|---|
| $20 < p_\perp \leq 30$ | $\|\eta\| < 2.5$ | $BDT_{score} > -0.80$ |
| $20 < p_\perp \leq 30$ | $2.50 \leq \|\eta\| < 2.75$ | $BDT_{score} > -0.85$ |
| $20 < p_\perp \leq 30$ | $2.75 \leq \|\eta\| < 3.00$ | $BDT_{score} > -0.84$ |
| $20 < p_\perp \leq 30$ | $3.00 \leq \|\eta\| < 5.00$ | $BDT_{score} > -0.85$ |
| $30 < p_\perp$ | $\|\eta\| < 2.5$ | $BDT_{score} > -0.80$ |
| $30 < p_\perp$ | $2.50 \leq \|\eta\| < 2.75$ | $BDT_{score} > -0.74$ |
| $30 < p_\perp$ | $2.75 \leq \|\eta\| < 3.00$ | $BDT_{score} > -0.68$ |
| $30 < p_\perp$ | $3.00 \leq \|\eta\| < 5.00$ | $BDT_{score} > -0.77$ |