A → tautau → lh at 14 TeV (a new taskforce)

Will Davey and Donatella Cavalli

Milano, Melbourne, Freiburg, Dresden, Washington

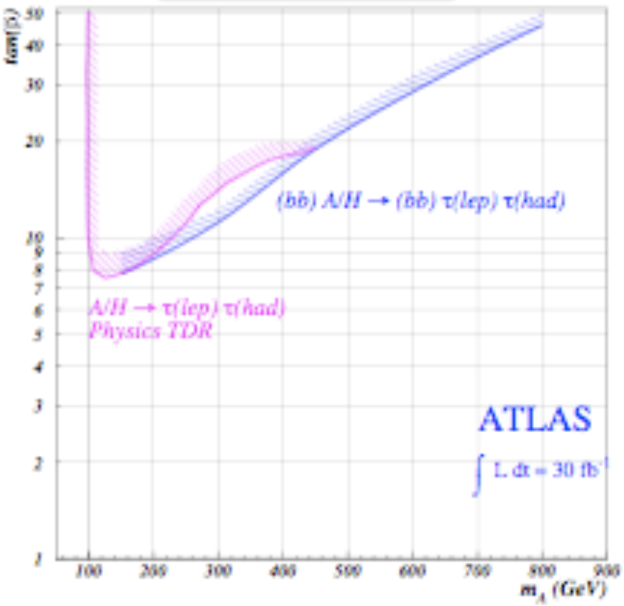
Outline

- Atautau lh at 14TeV Taskforce
  - Outline of project
  - Timeline
  - Production
- Description Of Analysis for 14TeV:
  - Selection Criteria
  - Cut Flow
- Preparing Analysis using available 10 TeV data
  - Performance of Particle Reco + Identification
  - Mass Reconstruction
  - Cut Flow

Project Outline

- Background:
  - The A → tautau → lh channel, is one of the most promising channels for a MSSM higgs discovery in ATLAS.
  - Unfortunately this channel could not be published in the CSC Notes due to lack of simulated background statistics
  - The project is an integral part of the Higgs workprogram in particular HSG4
  - Note: This is NOT a high priority project for the ATLAS Collaboration, and the project must not subtract from the manpower required for the 10 TeV efforts.
- Goals:
  - Complete the analysis of the A→tautau→lh channel at 14TeV
  - Integrate with A→tautau→ll results from CSC Note
  - Publish as PUB Note, giving most up-to-date discovery potential for ATLAS
- TaskForce:
  - **Coordinator**: Wolfgang Mader
  - **Consultants**: J. Tanaka, M. Schumacher, A. Nisati, K. Assamagan, K. Jakobs
  - **Milano**: D. Cavalli, W. Davey,
  - **Freiburg**: C. Anders, J. Dingfelder, J. Glatzer, S. Lai
  - **Melbourne**: E. Barberio, U. Felzmann
  - **Dresden**: M. Kobel, K. Leonhardt, J. Schaarschmidt
  - **Washington**: S. Pashapour, A. Goussiou

5σ Discovery



Project Details

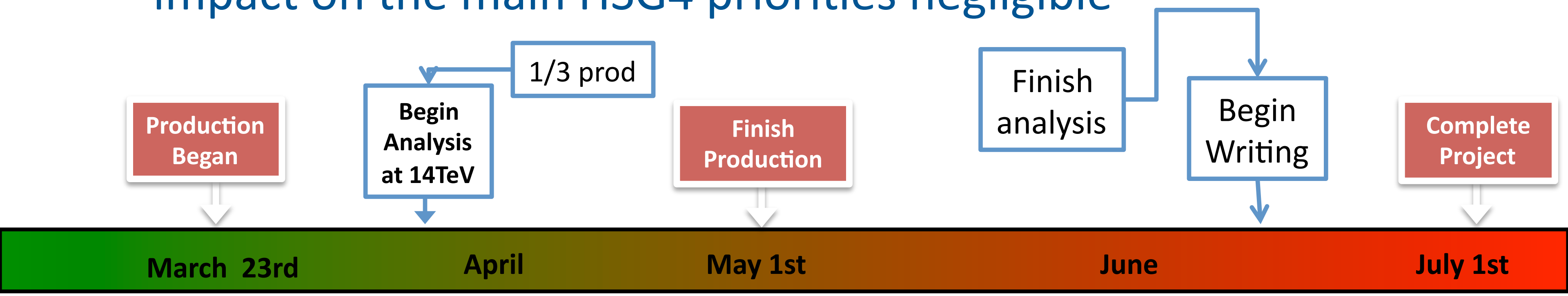
- Analysis Parameters:
  - $\sqrt{s}$ = 14TeV
  - L = 30 fb^{-1}

- Montecarlo Samples:
  - All samples are simulated using AtlfastII
  - All monte carlo production is performed locally at participating institutes
  - Close contact is maintained with ATLAS production/validation experts
  - All datasets are stored locally at institutes
  - Production / Storage of samples will not use official ATLAS resources
  - Samples will be validated with 5k events from central production

- Advantages over CSC anlaysis:
  - 1 order of magnitude larger statistics (possible due to AtlfastII)
  - Lepton filtered QCD samples give effective samples sizes ~10^3 larger
  - Dedicated teams working on data driven background estimation
  - These methods will also be applicable to 10TeV anlaysis!

Timeline and Production

- The project has an aggressive schedule as we aim to keep its impact on the main HSG4 priorities negligible



Signal

	Prod.	m_A / GeV	Generator	Filter	σ / pb	Responsible
ℓh	b	150	SHERPA	NONE	209.34	Dresden
		200	SHERPA	NONE	80.70	
		300	SHERPA	NONE	19.00	
		450	SHERPA	NONE	4.25	
		600	SHERPA	NONE	1.60	
		800	SHERPA	NONE	0.80	
	g	150	PYTHIA	NONE	136.46	Freiburg
		200	PYTHIA	NONE	67.18	
		300	PYTHIA	NONE	49.39	
		450	PYTHIA	NONE	48.10	

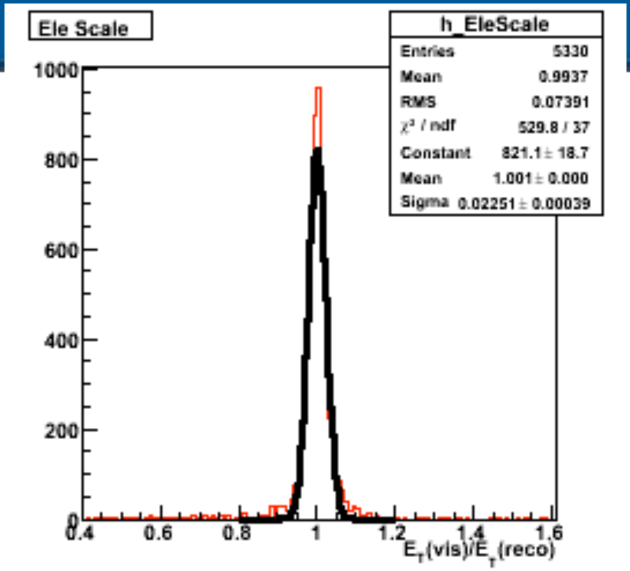
MLF: MultLeptonFilter @ $p_T > 15\,\mathrm{GeV}$

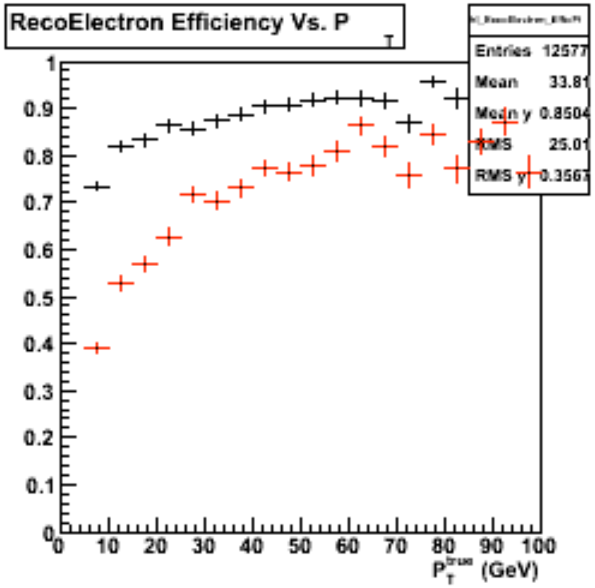
Background

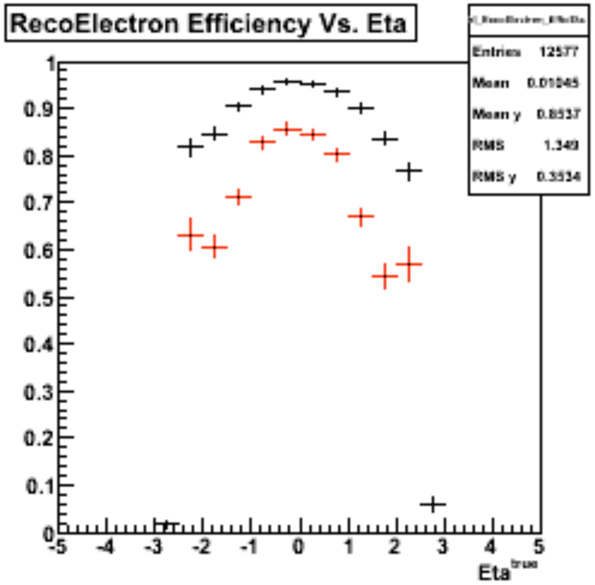
Process	Generator	Filter	Nr.o.Event	Remark	Responsible
$Z \to ee$	SHERPA	MLF	2.0M	$m_{\ell\ell} > 60$ GeV	Freiburg
$Z \to \mu\mu$	SHERPA	MLF	2.0M	$m_{\ell\ell} > 60$ GeV	
$Z \to \tau\tau$	SHERPA	MLF	2.0M	$m_{\ell\ell} > 60$ GeV	
$Z \to \tau\tau \to \ell h$	SHERPA	MLF	0.2M	$150 < m_{\ell\ell} < 250$ GeV	
$Z \to \tau\tau \to \ell h$	SHERPA	MLF	0.2M	$m_{\ell\ell} > 250$ GeV	
$W \to e\nu$	SHERPA	MLF	6.0M		Dresden
$W \to \mu\nu$	SHERPA	MLF	6.0M		
$W \to \tau\nu$	SHERPA	MLF	6.0M		
$t\bar{t}$	MC@NLO	MLF	6.0M	Extend existing DS	Melbourne
QCD	PYTHIA	MLF	1.2M	J1-J6 (200k each)	
QCD	PYTHIA	NONE	2.0M	J3-J7 (400k each)	
QCD $b\bar{b}$	PYTHIA	NONE	1.0M		

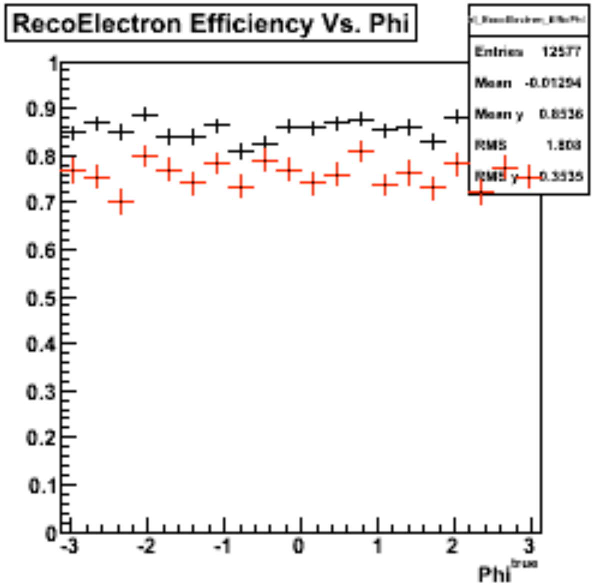
Electrons

- Container: ElectronAODCollection
- Selection:
  - p_T > 24 GeV, |eta| < 2.5
  - Author: Electron (Don't use low pt algos)
  - IsEM: Medium (Bitwise discriminator)
  - EtCone20 < 5GeV (need to optimise)
    - Plan to use TrackIsolationTool



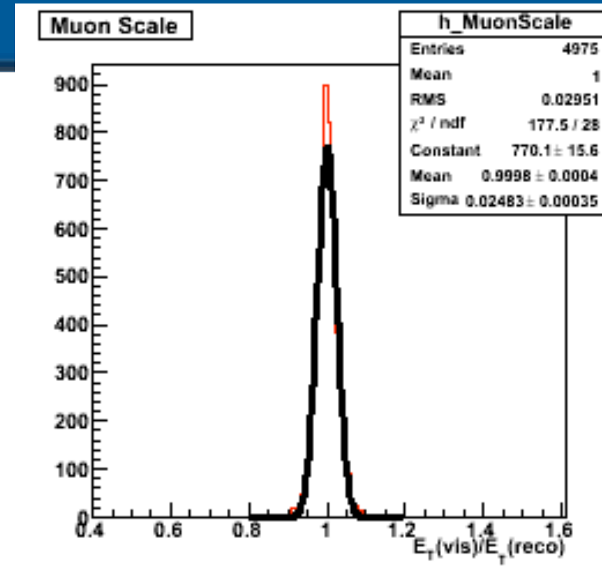


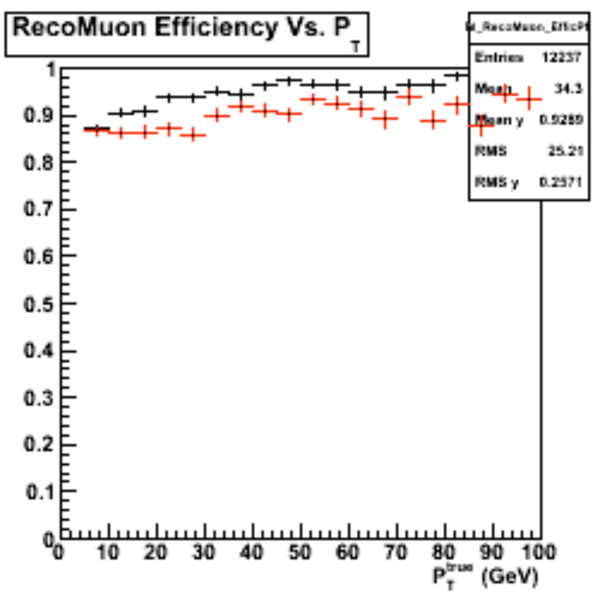


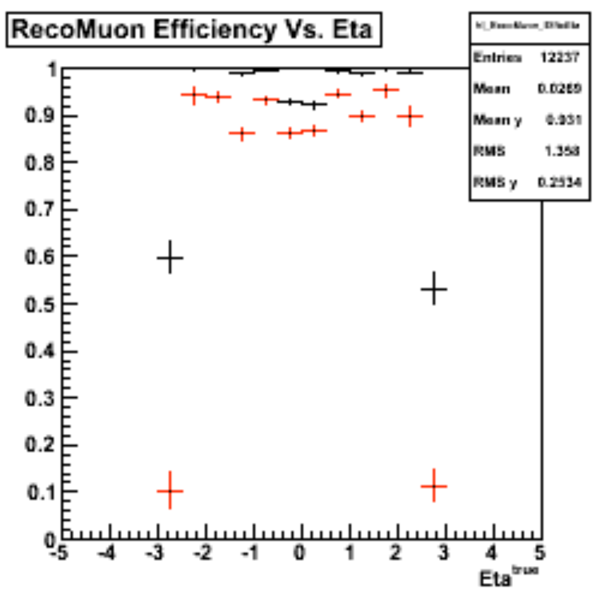


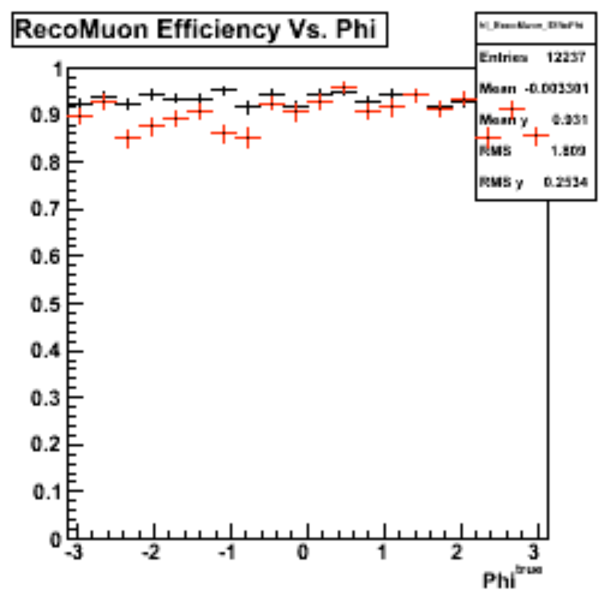
Muons

- Container: StacoMuonCollection
- Selection:
  - p_T > 24GeV, |eta| < 2.5
  - isHighPt (track in Muon Spec)
  - isCombined (track in ID)
  - MatchChi2OverDof < 100
  - EtCone20 < 5GeV (need to optimise) (EtCone10 here)
    - Plan to TrackIsolationTool



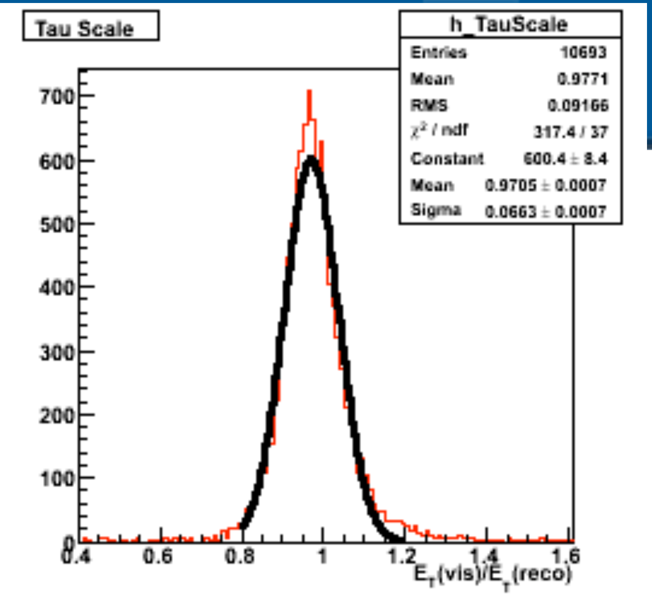


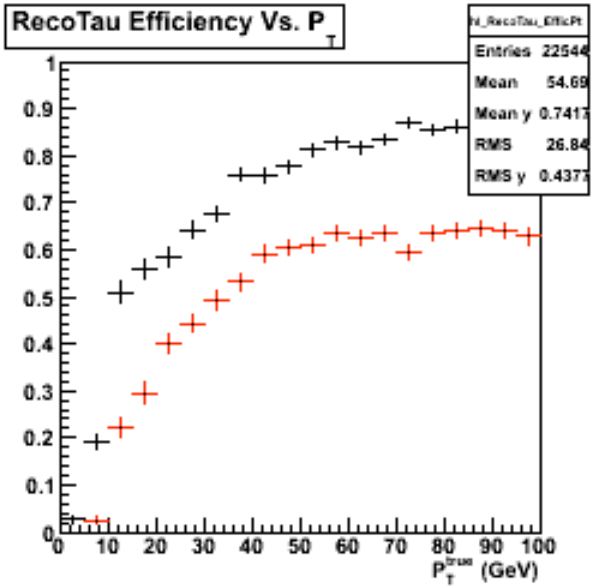


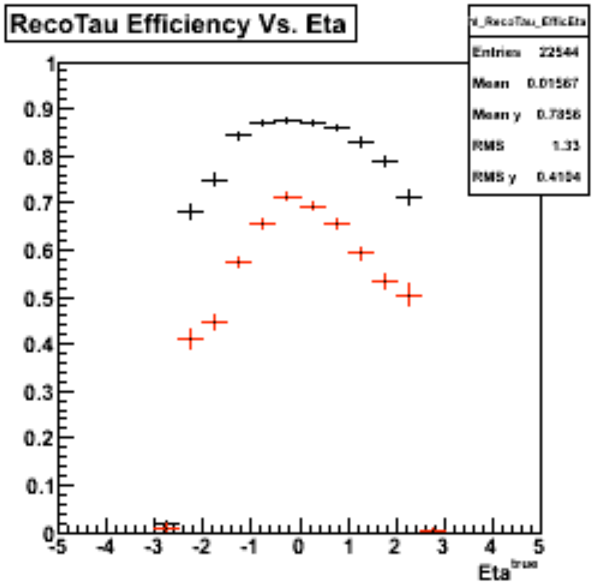


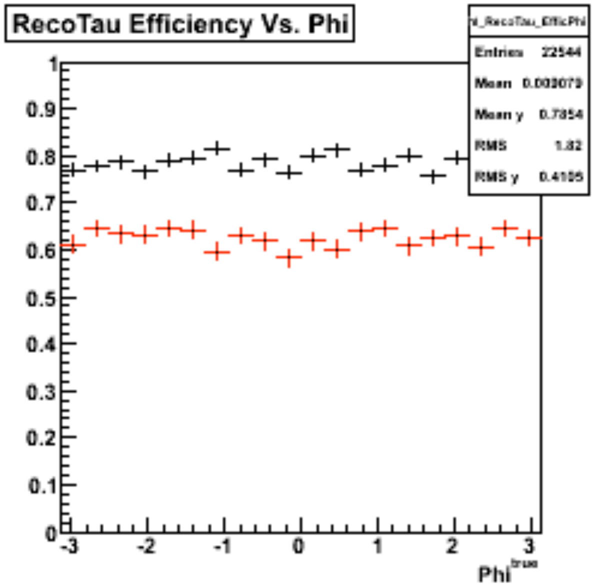
Taus

- Container: TauRecContainer
- Selection:
  - pT > 40 GeV, |eta| < 2.5
  - Seeded by TauRec && Tau1p3p **(ie overlap only!)**
  - nTrack == 1 || 3
  - |q| == 1
  - Likelihood > 4 (QCD)
  - ElectronVeto && MuonVeto









BTagging

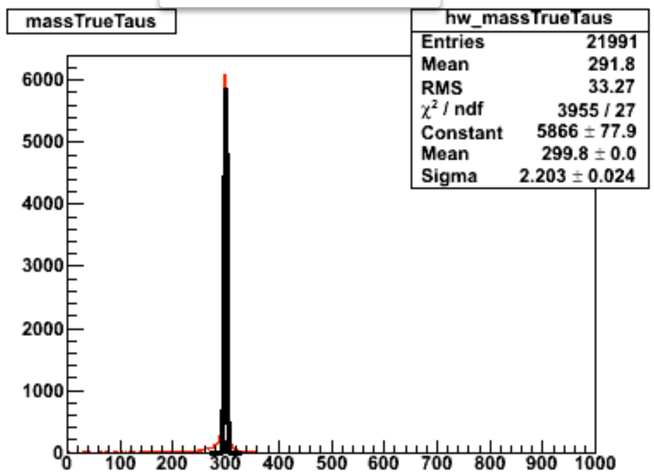
- Collection: Cone4H1TopoJets
  - Run btagger on the fly
- Selection:
  - pT > 15 GeV, |eta| < 2.5
- Tagger:
  - (*jetItr)->getFlavourTagWeight();
  - combination of IP3D and SV (recommended tagger)
  - Weight > 4

Mass Reconstruction

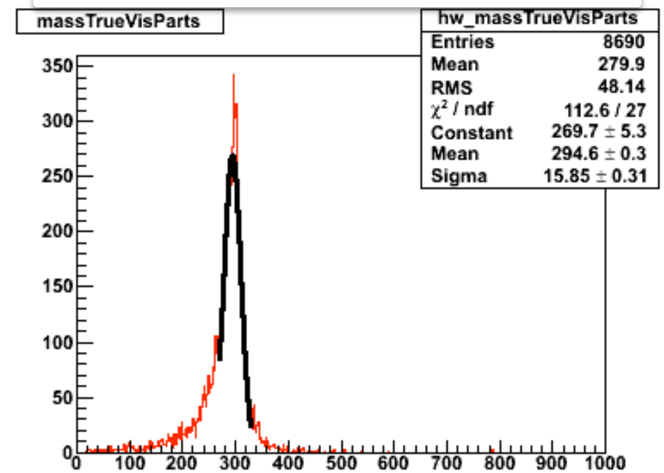
- Mass Resolution Depends on:
  - **Collinear Approx.**
  - **EtMiss Resolution**
  - Particle Resolution (Almost negligible)

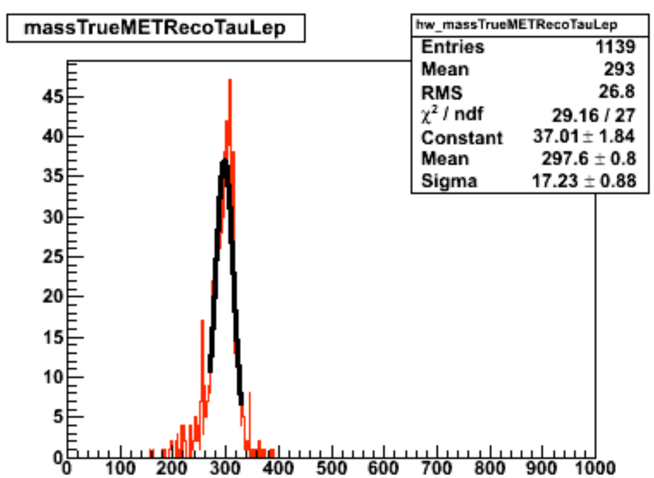
- MassBins: 1.5σ
  - m_A150 (30)
  - m_A300 (55)
  - m_A450 (75)
  - m_A600 (120)
  - m_A800 (165)
  - May need to change for biased mean

1. True Taus

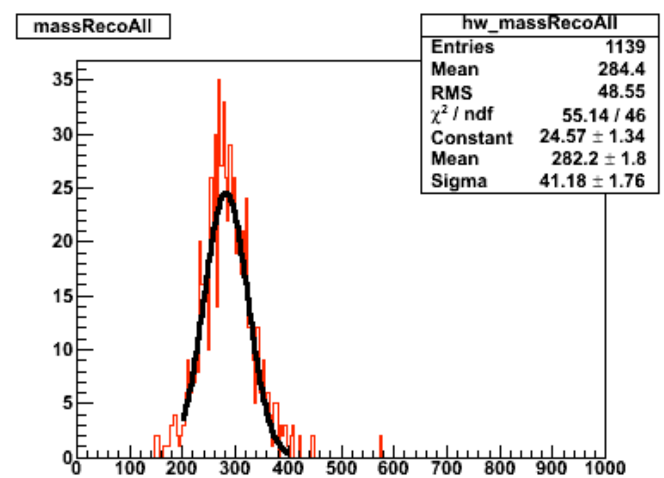


2. Collinear on True Vis Parts





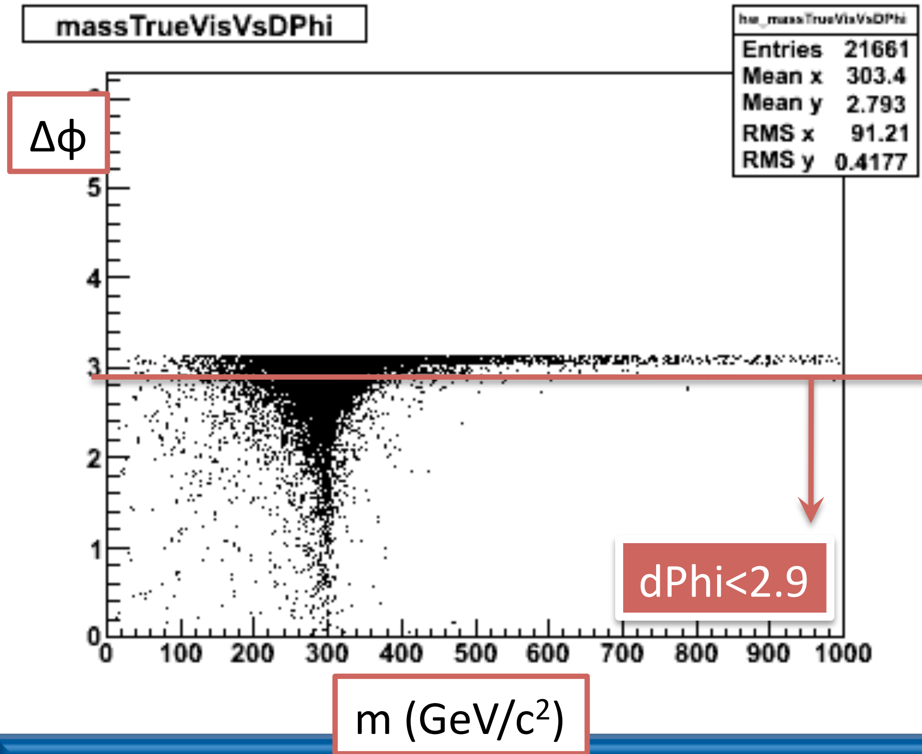
3. Add Reco Tau and Lep

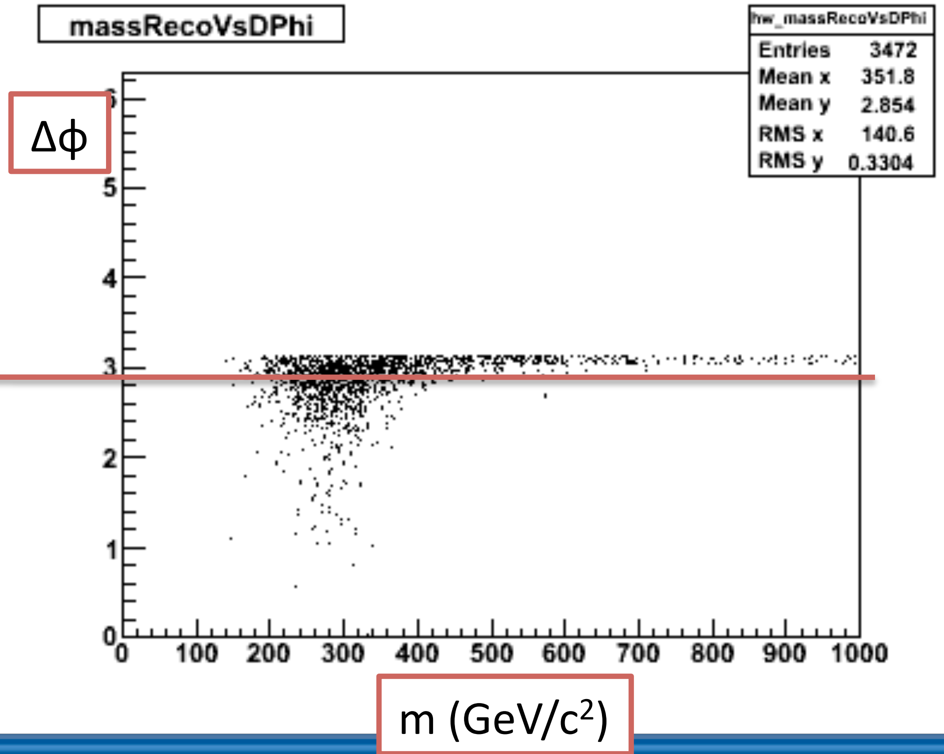


4. Add Reco EtMiss

Mass Scatter

- Reconstructed mass Vs. Dphi(lep, tau)
  – Large tail in back to back region!

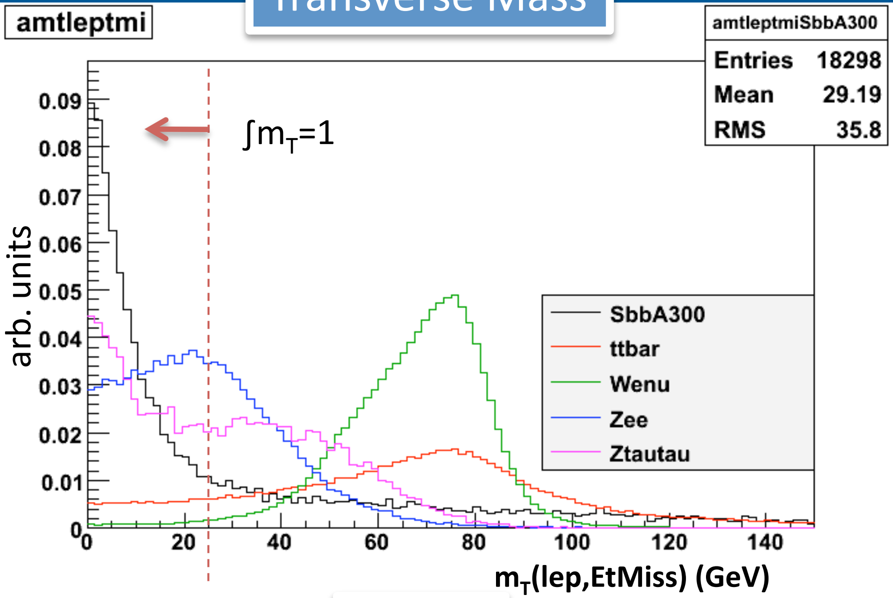




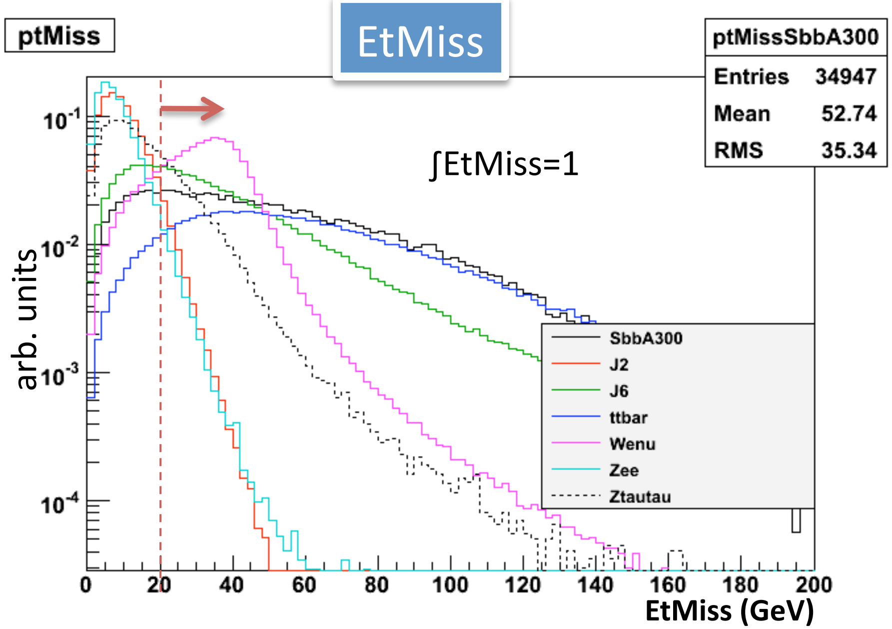
Cut Flow

- Good Lepton
- EtMiss (RefFinal) > 20 GeV
  - Disc. against QCD, Zll
  - EtMiss becomes nonlinear under 20 GeV.
- m_T(lept,EtMiss) < 25 GeV
  - Disc. against real Ws
- Good Tau
- |Δϕ(tau,lept)| < 2.9
  - Needed for good mass reconstruction
- invMass(tau,lept,EtMiss) > 0
  - Physical solution to collinear approx.
- |Δϕ(tau,lept)| > 0.28
  - Disc. against collinear lepton-jet from b's in ttbar
- Opposite Sign (tau,lep)
- MassBin(invMass)
- nbtag >= 1 (analysis 1)
  - ttbar is main background (room for optimisation)
- nbtag = 0 (analysis 2)
  - (ttbar, W+jets,QCD, Ztautau)

Transverse Mass



EtMiss



Cut Flow for 30fb^{-1}

PRELIMINARY

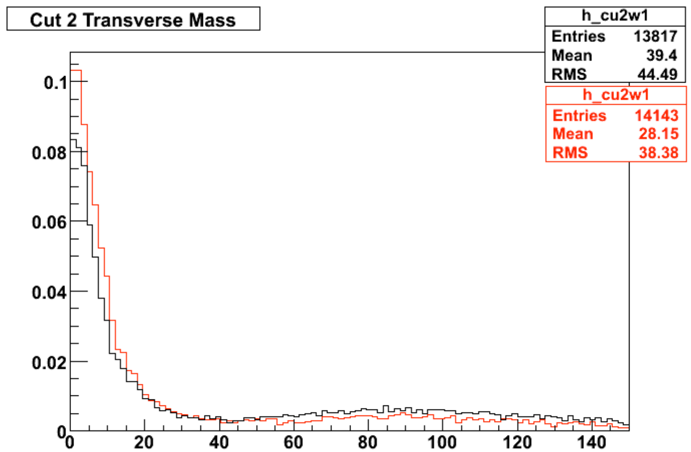
	SbbA300	PAbbA300	Wenu	Ztautau	ttbar	J6
X-Sec(pb)*filter	0.208	0.2957	1.031e+04	1128	205.5	111.9
Simulated Events	35k	50k	982k	199k	318k	348k
Total	6240	8871	3.094e+08	3.384e+07	6.165e+06	3.358e+06
Good Lepton	3289+-24.21	3271+-24.09	1.314e+08+-2.034e+05	2.087e+06+-1.883e+04	4.05e+06+-8866	2039+-140.4
ptMiss > 20 GeV	2509+-21.15	2451+-20.85	1.207e+08+-1.95e+05	6.984e+05+-1.089e+04	3.675e+06+-8445	1614+-124.9
m_T(lep,EtMiss) < 25 GeV	1726+-17.54	1346+-15.45	7.542e+05+-1.541e+04	2.528e+05+-6554	3.908e+05+-2754	753.6+-85.33
Good Tau	1055+-13.72	773.9+-11.72	7558+-1543	2.463e+04+-2046	1.26e+04+-494.5	0+-0
$\|\Delta\phi\| < 2.9$	282.6+-7.098	192.1+-5.839	3779+-1091	1.376e+04+-1529	1.035e+04+-448.1	0+-0
$m_{\tau\tau} > 0$	165.1+-5.425	115+-4.516	2204+-833.2	6456+-1047	4561+-297.5	0+-0
$0.28 < \|\Delta\phi\|$	164.6+-5.416	114.3+-4.502	2204+-833.2	6116+-1019	4484+-295	0+-0
OS	161.5+-5.366	112+-4.457	1889+-771.3	5776+-990.6	3668+-266.8	0+-0
massbin A300	120.7+-4.639	79.31+-3.751	944.7+-545.4	0+-0	776.4+-122.8	0+-0
numbtag >= 1 (analysis 1)	53.66+-3.093	42.23+-2.737	0+-0	0+-0	562.9+-104.5	0+-0
btagmax < 60 GeV	26.21+-2.162	19.87+-1.878	0+-0	0+-0	232.9+-67.24	0+-0
numbtag < 1 (analysis 2)	67.04+-3.457	37.08+-2.565	944.7+-545.4	0+-0	213.5+-64.37	0+-0
SS	3.031+-0.7351	2.306+-0.6397	314.9+-314.9	339.8+-240.3	815.2+-125.8	0+-0
massbin A300	1.783+-0.5638	1.597+-0.5323	314.9+-314.9	169.9+-169.9	213.5+-64.37	0+-0
numbtag >= 1 (analysis 1)	1.426+-0.5043	0.7097+-0.3548	0+-0	0+-0	135.9+-51.35	0+-0
btagmax < 60 GeV	0.7131+-0.3566	0.5323+-0.3073	0+-0	0+-0	77.64+-38.82	0+-0
numbtag < 1 (analysis 2)	0.3566+-0.2521	0.8871+-0.3967	314.9+-314.9	169.9+-169.9	77.64+-38.82	0+-0

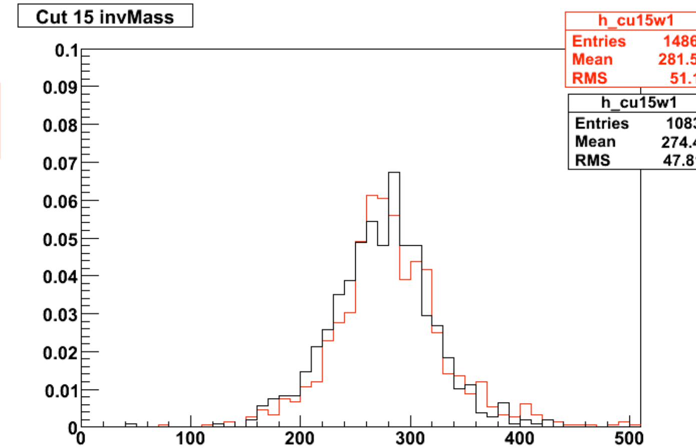
- Statistics too low to determine background contributions
- Need to factorise cut(s), esp. for QCD
- Large difference in Kinematics for Pythia Vs Sherpa signal samples (pt(A) higher in Sherpa!).

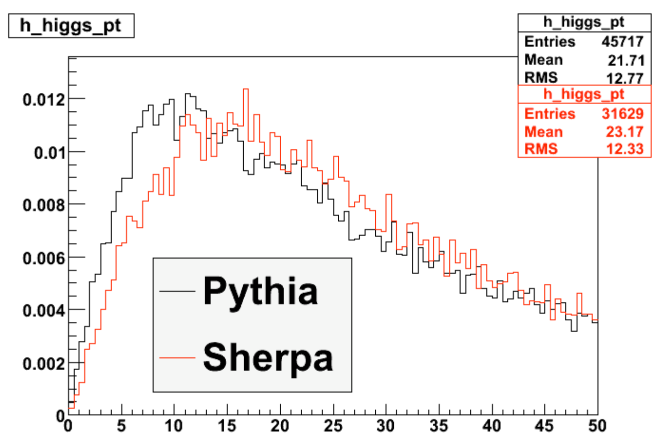
Sherpa Vs Pythia

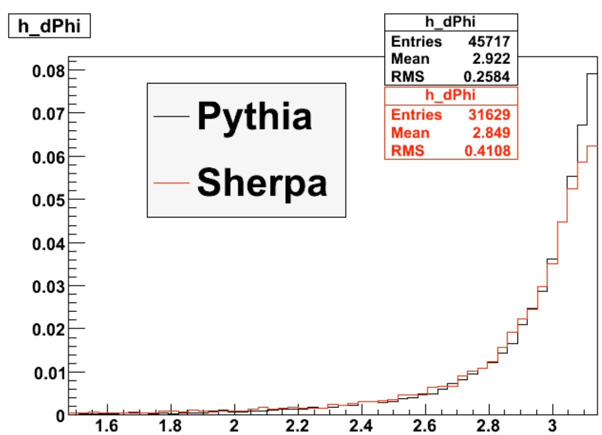
- Pythia: 2-2
  - gg→bbA
- Sherpa: up to 2-5
  - gg->bbA
  - gb->bA
  - bb->A
  - No double counting
- Expect some differences in kinematics

- **General consensus in HSG4 to use Sherpa**
- **Sherpa was used for the ll channel for the CSC Note**
- **Sherpa should be used**









Factorise TauID

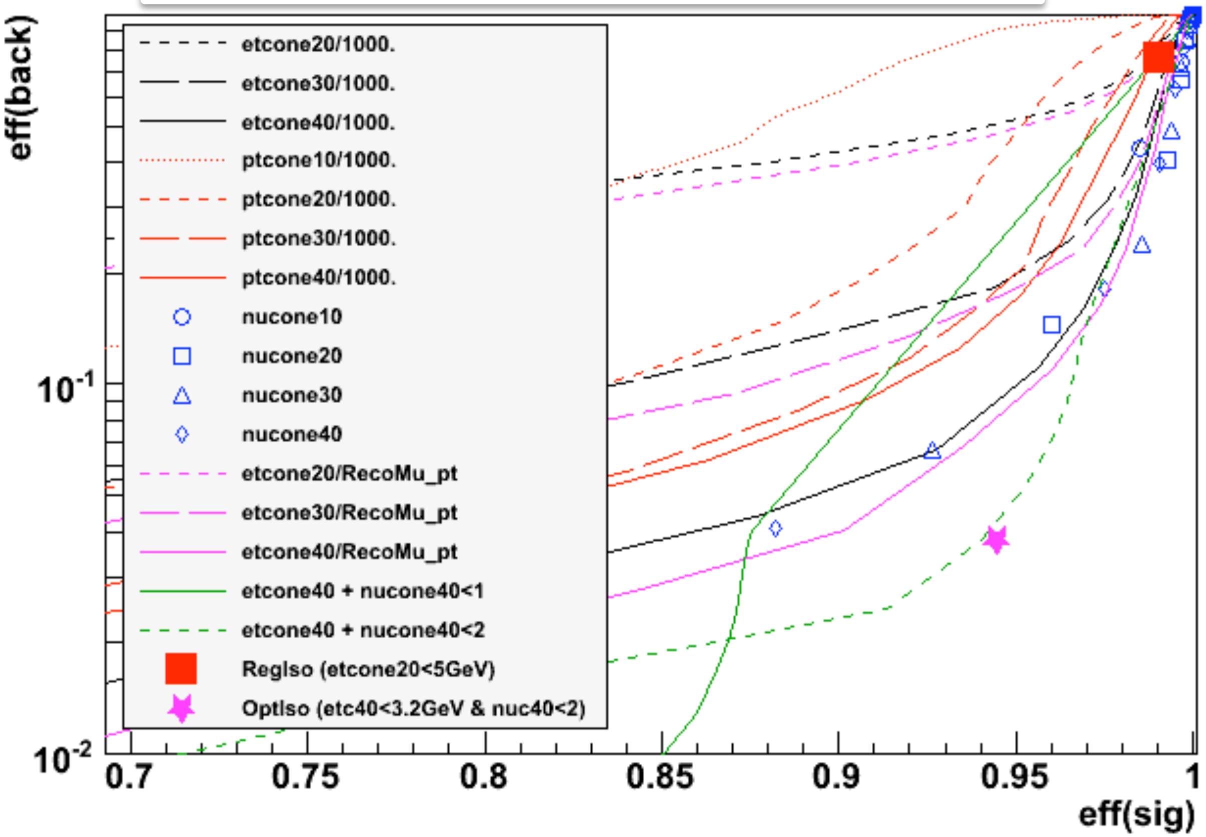
	SbbA300	J3-tauID	J6-tauID	Wenu-tauID
X-Sec(pb)*filter	0.208	3.287e+06	111.9	1.031e+04
Simulated Events	35k	3045k	99k	592k
Total	6240	9.86e+10	3.358e+06	3.094e+08
Good Lepton	3289+-24.21	2.733e+07+-9.407e+05	576.2+-139.7	1.316e+08+-2.623e+05
ptMiss > 20 GeV	2509+-21.15	7.933e+06+-5.069e+05	474.5+-126.8	1.21e+08+-2.514e+05
m_T(lep,EtMiss) < 25 GeV	1726+-17.54	6.412e+06+-4.556e+05	169.5+-75.79	7.697e+05+-2.006e+04
Good Tau	1055+-13.72	4.182e+04+-2826	0.7467+-0.176	1.252e+04+-349.5
$\|\Delta\phi\| < 2.9$	282.6+-7.098	2.444e+04+-2160	0.6638+-0.1659	6372+-249.4
$m_{\tau\tau} > 0$	165.1+-5.425	8402+-1267	0.2489+-0.1016	2049+-141.4
$0.28 < \|\Delta\phi\|$	164.6+-5.416	8020+-1238	0.2074+-0.09276	2040+-141.1
OS	161.5+-5.366	1528+-540.1	0.04148+-0.04148	517.2+-71.04
massbin A300	120.7+-4.639	190.9+-190.9	0+-0	146.4+-37.79
numbtag >= 1 (analysis 1)	53.66+-3.093	0+-0	0+-0	9.759+-9.759
btagmax < 60 GeV	26.21+-2.162	0+-0	0+-0	0+-0
numbtag < 1 (analysis 2)	67.04+-3.457	190.9+-190.9	0+-0	136.6+-36.51
SS	3.031+-0.7351	763.8+-381.9	0.04148+-0.04148	400.1+-62.49
massbin A300	1.783+-0.5638	0+-0	0+-0	126.9+-35.19
numbtag >= 1 (analysis 1)	1.426+-0.5043	0+-0	0+-0	0+-0
btagmax < 60 GeV	0.7131+-0.3566	0+-0	0+-0	0+-0
numbtag < 1 (analysis 2)	0.3566+-0.2521	0+-0	0+-0	126.9+-35.19

- J6 negligible, and probably J5
- Need to control J2-J4 with lepton isolation
- Wenu seems under control for analysis 1, must study methods of suppression for analysis 2

Lepton Isolation

- QCD background can quite easily be controlled using a combination of track and calo lepton isolation
- Although NOT using pileup for this study, we should not disregard its affect on isolation.
- Plan to use TrackIsolationTool with specific parameters as in Kostas Talk
  http://indico.cern.ch/conferenceDisplay.py?confId=54927

Muon Isolation efficiency for Ztautau Vs J2

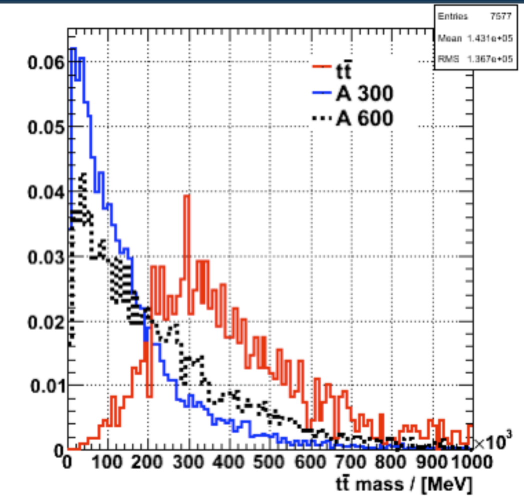


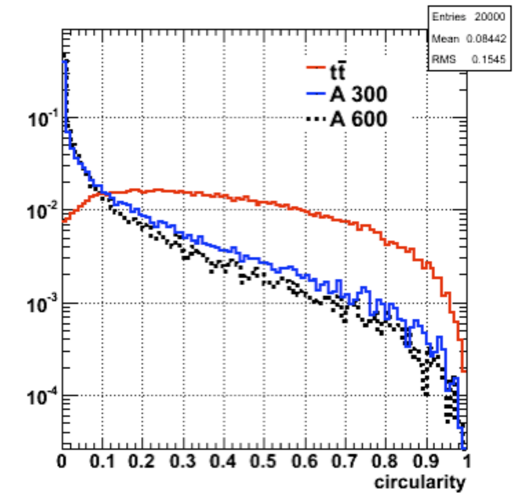
ttbar

- tt bar background is most complicated bkg process showing both reducible and irreducible contributions
  - s x BR(tt → leptonic modes) = 840 pb x 56% = 470 pb
- From tt bar MC@NLO dataset (s x filter = 200 pb)
  - 2% of the events show reconstructed hadronic tau together with at least one lepton (after pre-selection)
  - Composition (fake taus in more than 50%!)

tt bar bkg composition	contribution	type	idea for suppression
di-leptonic	17.5%	reducible	di-lepton veto
semi-leptonic	33.6%	reducible	inv. tt bar mass cut?
hadronic tau + lepton(s)	40.4%	irreducible	jet kinematics, event shape?
hadronic tau + leptonic tau	3.0%	irreducible	jet kinematics, event shape?
leptonic tau + X	5.0%	reducible	jet kinematics, event shape?
2 lep taus	<0.5%	reducible	di-lepton veto

- Biggest contributions:
  - Semi-leptonic tt bar mode
    - reconstruct inv. tt bar mass (only one neutrino)
    - can be done even w/o b-tagging (robust!)
  - Hadronic tau modes: study of event shapes on-going
    - One option: Circularity (takes small values for linear and high values for circular events)





Slide from Uli Felzmann

Other Important Points

- Trigger – Not directly included in the analysis (AtlfastII), but study on FullSim signal will be used to determine its affect.
- Systematics – will be taken from the description at the beginning of the CSC note along with consultation with experts.
- Cut Factorisation – We aim to perform a cut correlation study to aid in cut factorisation for backgrounds
- Pileup – Although pileup will not be used directly for this study (due to the timescale), a number of independent studies will be made to investigate its impact on the analysis. This is necessary for elements of the analysis that are particularly susceptible to changes in the event enviroment such as EtMiss and Lepton Isolation

Summary

- About to begin running analysis on the new 14 TeV data
- A dedicated task-force has been put together to complete the analysis in the allowed time-frame
- Production is well underway, and nearing completion
- Analysis is up and running on latest AOD data
- Preliminary Results seem reasonable
- The project is on-track for a timely completion

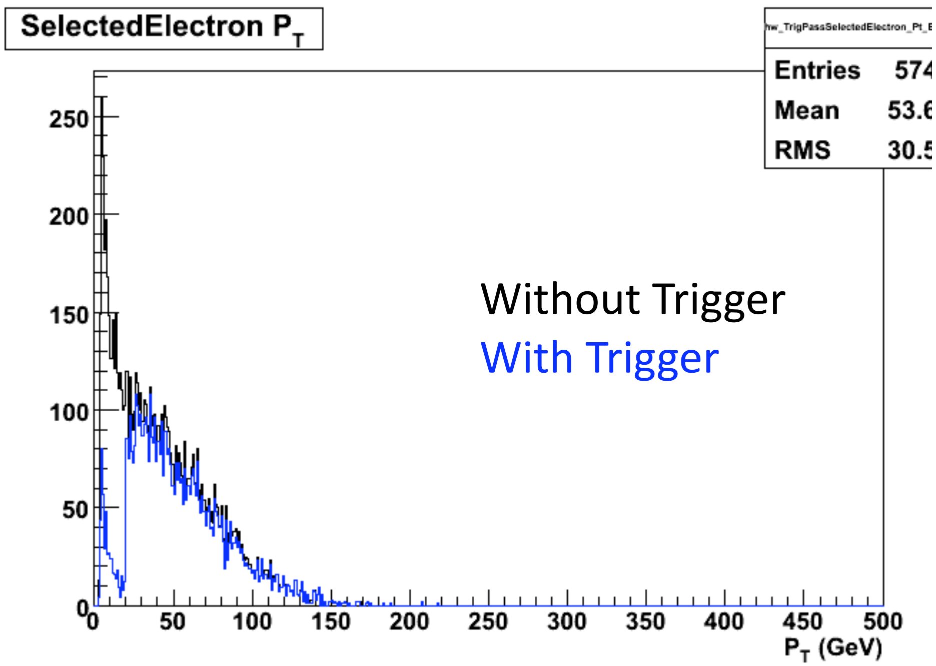
BACKUP SLIDES

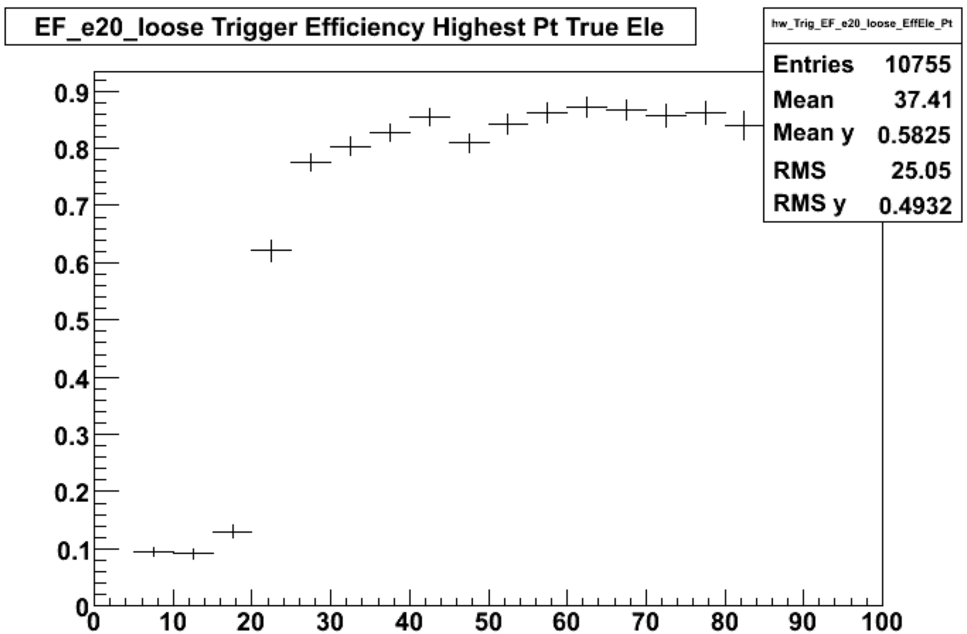
Trigger

- Aim:
  - Check Impact of trigger on Efficiency of Analysis
  - Check Impact of trigger on Higgs Mass Reconstruction
- Use Triggers:
  - EF_e20_loose (20 GeV Electron Trigger)
    - May need EF_e25i when running at 10^{33}
  - EF_mu20 (20 GeV Muon Trigger)

EF_e20_loose

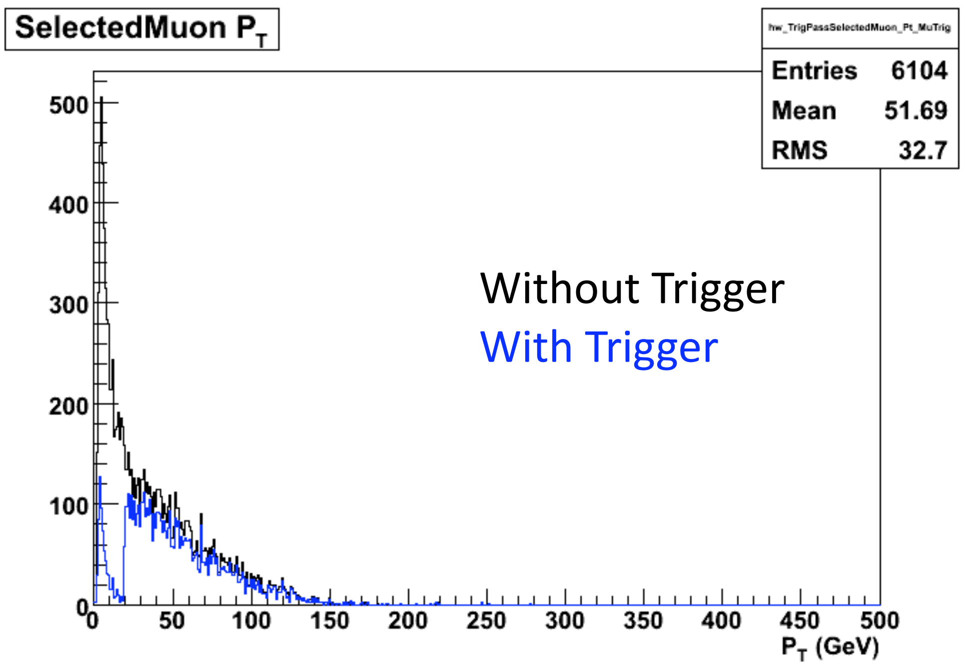
- Trigger Efficiency:
  - Take leading pt TRUE electron.
  - Check if Trigger Passed

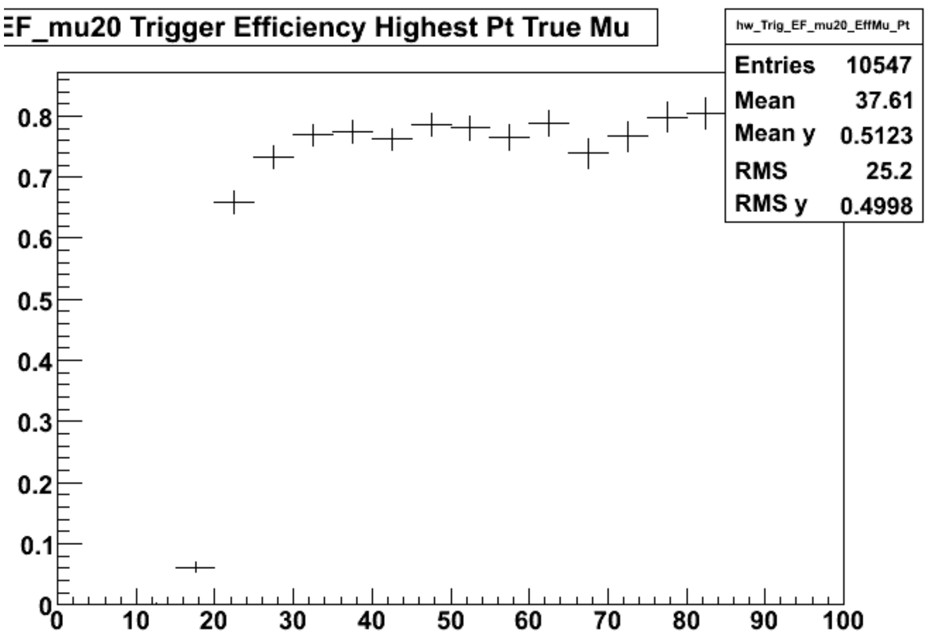




EF_mu20

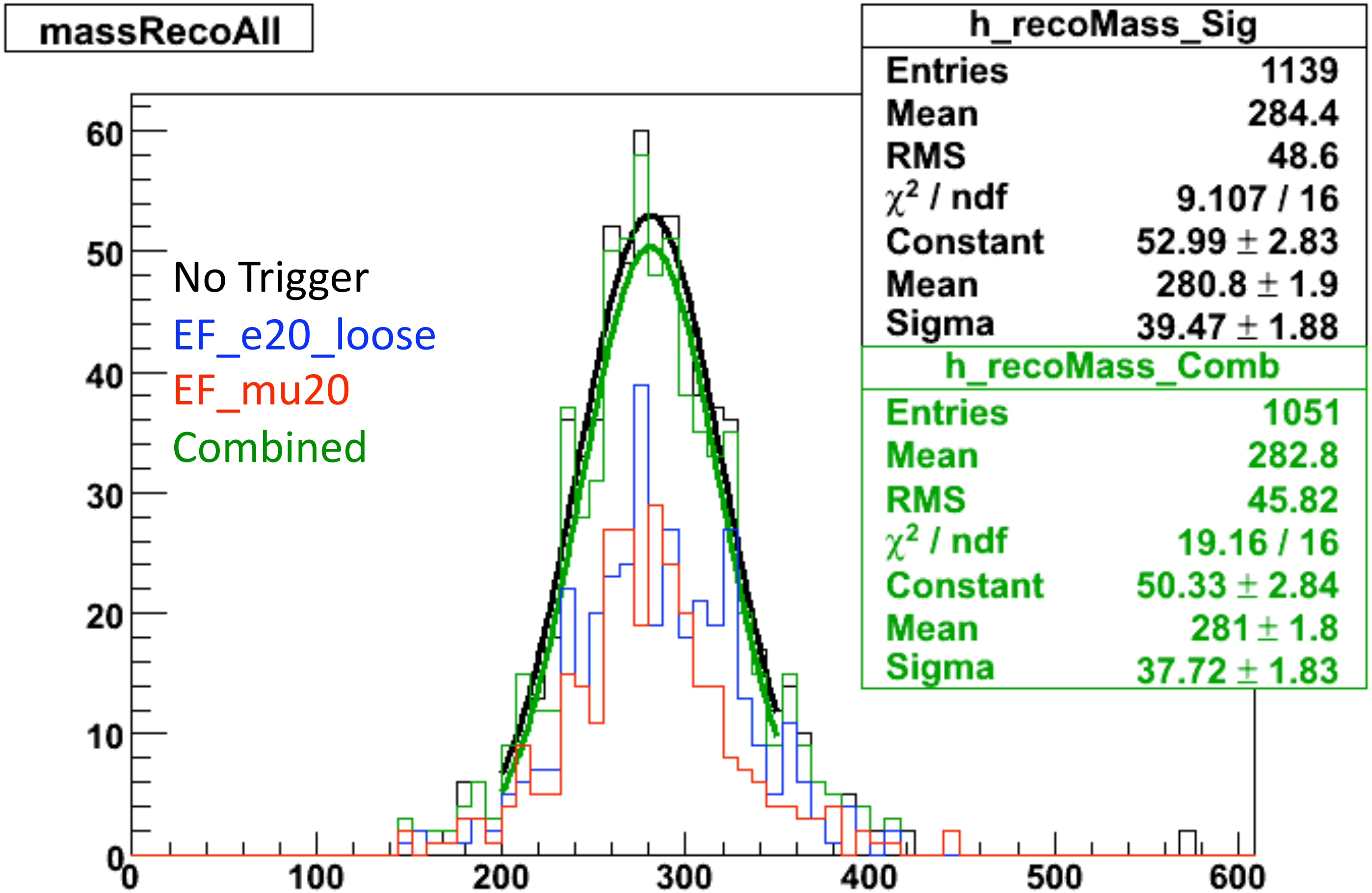
- Trigger Efficiency:
  - Take leading pt TRUE muon.
  - Check if Trigger Passed





Mass Reco With Trigger

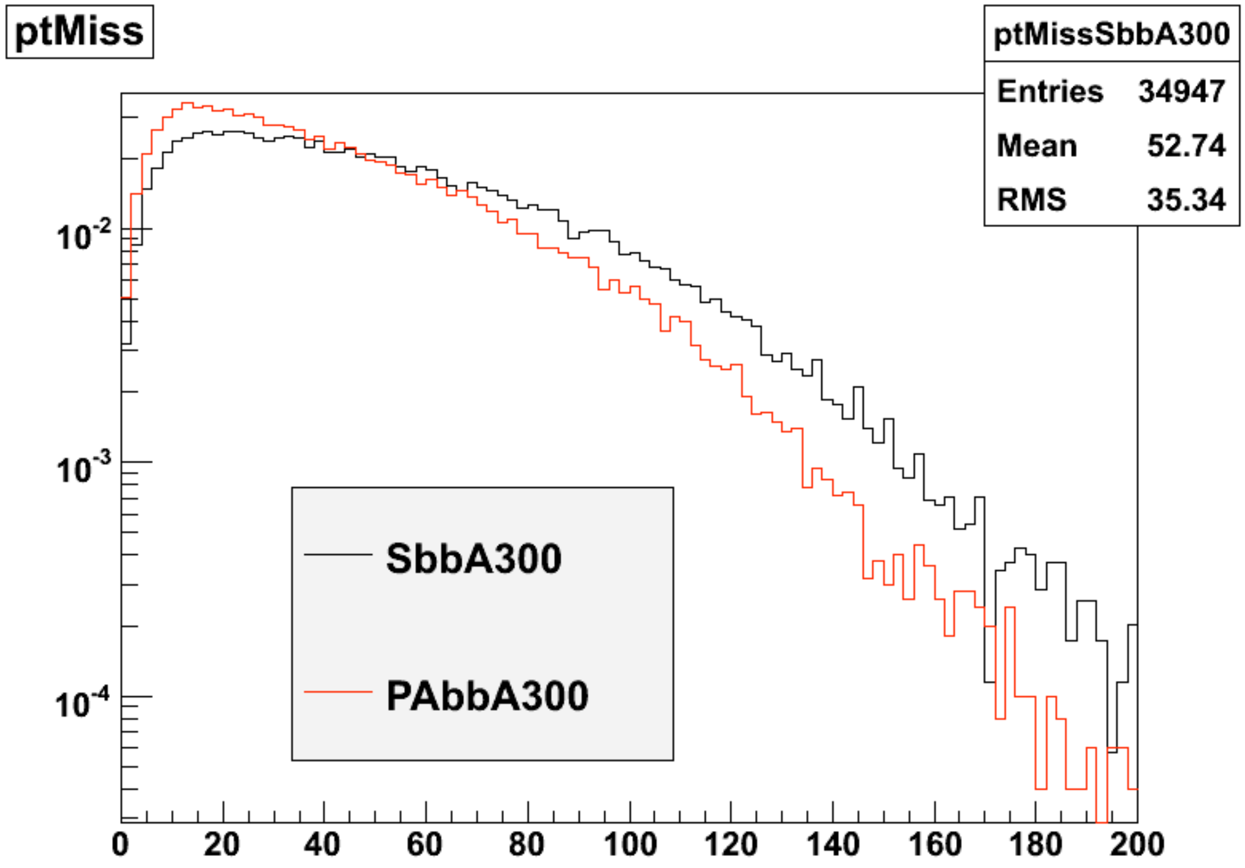
- Check to see Triggers aren't biasing Mass Reconstruction
- Combined results from both triggers seem quite good!



Backup

	SbbA300	PAbbA300	Wenu	Wmunu	Zee	Ztautau	ttbar	J2	J3	J6	J3-1elec
X-Sec(pb)*filter	0.208	0.2957	10313	10310	1098	1128	205.5	5.60133e+07	3.28672e+06	111.947	52258.8
Int Lum(pb^{-1})	168014	169090	95.268	23.9963	156.951	176.582	1545.66	0.00731557	0.108034	3104.92	1.25255
Total	34947	50000	982499	247402	172332	199184	317634	409769	355076	347587	65457
Good Lepton	18298	18438	417183	134406	106617	12284	208649	113	385	211	259
ptMiss > 20 GeV	14338	13817	383338	125779	3040	4111	189327	12	135	167	70
m_T(lep,EtMiss) < 25 GeV	9567	7587	2395	664	494	1488	20134	8	98	78	54
Good Tau	5479	4362	24	2	9	145	649	0	0	0	1
$\|\Delta\phi\| < 2.9$	1824	1083	12	0	5	81	533	0	0	0	0
$m_{\tau\tau} > 0$	1131	648	7	0	2	38	235	0	0	0	0
$0.28 < \|\Delta\phi\|$	1129	644	7	0	2	36	231	0	0	0	0
OS	1113	631	6	0	2	34	189	0	0	0	0
massbin A300	818	447	3	0	0	0	40	0	0	0	0
numbtag >= 1 (Associated)	85	238	0	0	0	0	29	0	0	0	0
btagmax < 60 GeV	49	112	0	0	0	0	12	0	0	0	0
numbtag < 1 (Direct)	733	209	3	0	0	0	11	0	0	0	0
SS	16	13	1	0	0	2	42	0	0	0	0
massbin A300	9	9	1	0	0	1	11	0	0	0	0
numbtag >= 1 (Associated)	0	4	0	0	0	0	7	0	0	0	0
btagmax < 60 GeV	0	3	0	0	0	0	4	0	0	0	0
numbtag < 1 (Direct)	9	5	1	0	0	1	4	0	0	0	0

Backup



ptMiss
ptMissSbbA300
Entries 34947
Mean 52.74
RMS 35.34
10^{-2}
10^{-3}
10^{-4}
SbbA300
PAbbA300
0
20
40
60
80
100
120
140
160
180
200

Samples

- mc08.105011.J2_pythia_jetjet.recon.AOD.e344_s479_r541
- mc08.105012.J3_pythia_jetjet.recon.AOD.e344_s479_r541
- mc08.105015.J6_pythia_jetjet.recon.AOD.e344_s479_r541
- mc08.105200.T1_McAtNlo_Jimmy.recon.AOD.e357_s462_r541
- mc08.106020.PythiaWenu_1Lepton.recon.AOD.e352_s462_r541
- user08.CaterinaPizio.ganga.mc08.106021.PythiaWmunu_1Lepton.recon.ESD.e352_s462_r541_tid028736_v1.20090205190132._00099.AOD.pool.root
- mc08.106050.PythiaZee_1Lepton.recon.AOD.e347_s462_r541
- mc08.106052.PythiaZtautau.recon.AOD.e347_s462_r541
- mc08.106573.PythiabbAtautauMA800TB35.recon.AOD.e347_s462_r541
- mc08.109123.SherpabbAtautaulhMA300TB20.recon.AOD.e361_s462_r563
- mc08.109226.PythiabbAtautauMA300TB20.recon.AOD.e384_a82
- mc08.109273.J3_pythia_jetjet_1elec.recon.AOD.e384_s462_r617

Production

Samples

Process	Generator	Filter	Nr.o.Event	Remark	Responsible
$Z \to ee$	SHERPA	MLF	2.0M	$m_{\ell\ell} > 60$ GeV	
$Z \to \mu\mu$	SHERPA	MLF	2.0M	$m_{\ell\ell} > 60$ GeV	
$Z \to \tau\tau$	SHERPA	MLF	2.0M	$m_{\ell\ell} > 60$ GeV	Freiburg
$Z \to \tau\tau \to \ell h$	SHERPA	MLF	0.2M	$150 < m_{\ell\ell} < 250$ GeV	
$Z \to \tau\tau \to \ell h$	SHERPA	MLF	0.2M	$m_{\ell\ell} > 250$ GeV	
$W \to e\nu$	SHERPA	MLF	6.0M		
$W \to \mu\nu$	SHERPA	MLF	6.0M		Dresden
$W \to \tau\nu$	SHERPA	MLF	6.0M		
$t\bar{t}$	MC@NLO	MLF	6.0M	Extend existing DS	
QCD	PYTHIA	MLF	1.2M	J1-J6 (200k each)	Melbourne
QCD	PYTHIA	NONE	2.0M	J3-J7 (400k each)	
QCD $b\bar{b}$	PYTHIA	NONE	1.0M		

	Prod.	m_A / GeV	Generator	Filter	σ / pb	$\sigma \times \mathcal{B}(H \to \tau\tau)$ / pb	Responsible
ℓh	b	150	SHERPA	NONE	209.34	19.49	Dresden
		200	SHERPA	NONE	80.70	7.74	
		300	SHERPA	NONE	19.00	1.66	
		450	SHERPA	NONE	4.25	0.26	
		600	SHERPA	NONE	1.60	0.08	
		800	SHERPA	NONE	0.80	0.04	
	g	150	PYTHIA	NONE	136.46	12.45	Freiburg
		200	PYTHIA	NONE	67.18	5.49	
		300	PYTHIA	NONE	49.39	3.16	
		450	PYTHIA	NONE	48.10	2.73	

MLF: MultLeptonFilter @ $p_T > 15$ GeV