Institute of Physics
University of Freiburg

Investigation of Z → ττ (lh) for first data:

Tau Workshop Copenhagen

16.4.09

Susanne Kühn[1], Donatella Cavalli[2], Will Davey[2,3], Karl Jakobs[1], Stan Lai[1], Caterina Pizio[2], Ulrik Sverdrup[1,4]

[1] Albert-Ludwigs University Freiburg

[2] INFN Milano, [3]University of Melbourne,

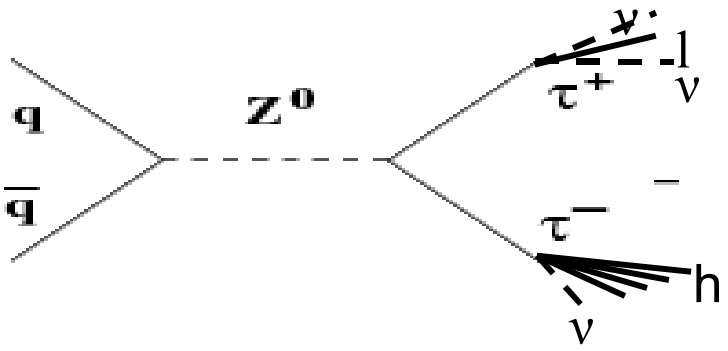
[4]University of Lund

Outline

- Investigation of $Z \rightarrow \tau\tau$ (lh) analysis at $\sqrt{s}$ = 10TeV
  - Estimation of QCD background
  - First look into the optimisation of lepton isolation against QCD
- Analysis with Safe Tau Variables
- Comparison of different simulations (ATLFAST II and full simulation)

Z → ττ (lh)

- NLO Cross-section σ * BR (Z → ττ) = 1368 pb (@ √s = 10TeV)
  → in ∫L = 100 pb^{-1} several hundred selected events (efficiency of cut selection ~ 0.3%)



- Determine scale of E_T^{Miss} → invariant mass analysis
- Determine scale of τ-jet energy → visible mass analysis
- Measure cross-section → invariant mass analysis

- Important to understand for Higgs search H → ττ (lh)

Z → ττ Analysis: Cuts

Cuts for visible mass analysis and invariant mass analysis:

1) Selection of high p_T isolated lepton (e, μ), p_T > 10 GeV (15 GeV)
2) E_T^{Miss} > 20 GeV
3) $M_T(l, E_T^{Miss})$ < 30 (50) GeV
4) $\sum E_T$ < 400 GeV
5) τ-Identification
   Invariant / Visible mass reconstruction (use lepton and highest. p_T τ)
6) | Δφ(τ,lepton)| < 3.1 (2.8)
7) Invariant mass > 0
8) | Δφ(τ,lepton)| > 1
9) Separate opposite sign from same sign events
10) Select mass window for visible mass / invariant mass

Analysis cross checked and cuts agreed upon Milano and Freiburg

Trigger and lepton selection

- Use single trigger EF_e10medium and EF_mu10

Zττ	Ele eff	Muon eff	Tot eff
Lepton pT>10 EF_e10_medium/EF_mu10	86%	82%	84%
Lepton pT>15 EF_e10_medium/EF_mu10	88%	89%	89%
Lepton pT>15 EF_e15_medium/EF_mu15	86%	84%	85%

- Selection of electrons:
  - p_T > 10 GeV (15 GeV), $|\eta|$ < 2.5
  - EgammaAuthor==true, IsEMMedium
  - EtCone20 < 5 GeV

- Selection of muons:
  - p_T > 10 GeV (15 GeV), $|\eta|$ < 2.5
  - IsCombinedMuon, IsHighPtMuon, Matchchi 2 overDoF < 100
  - EtCone20 < 5 GeV

Cross section and statistics

Sample	Simulation	Cross Sec [pb]	Filter	Cross Sec [pb]	Events	Corresp. Lumi [pb-1]
		10 TeV LO	eff.	10 TeV NLO		to NLO cross sec
Z ->ττ	Full	1128	1	1368	199184	145.6
Z -> ττ	AF2	1128	1	1368	199286	145.68
W -> μν	Full	11764.6	0.88		982499	95.27
W -> eν	Full	11764.6	0.88		805222	78.11
W -> τν (lep)	Full	11784.1*BR(τ->l)	0.87		217615	60.3
W -> τν (had)	Full	11.86*BR(τ->had)			179322	23.32
Z -> ee	Full	1144	0.96	1370	172332	131.03
Z -> μμ	Full	1144	0.96	1370	247508	188.19
tt	Full	373.6	0.55	373.6	430890	2097
QCD J1	AF2	8.67E+008	1		39556954	0.05
QCD J2	AF2	5.60E+007	1		39594785	0.71
QCD J3	AF2	3.28E+006	1		9753575	2.97
WW	Full	0.83	1		39935	48207
Gamma+jets	Full	21144.14	1		492287	23.28

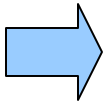
Visible Mass analysis Lepton p_T > 10 GeV

Cuts	$Z \to \tau\tau$	$W \to e\nu$	$W \to \mu\nu$	$W \to \tau\nu$	tt	Zee	$Z\mu\mu$	QCD	WW
Isol lepton (e,μ)	19313	550969	634563	106530	8360	78480	88262	15067210	39
$E_T^{miss} > 20$	5691	462312	593926	55317	7674	2207	24230	1961772	32
$m_T^{lep,E_T^{miss}} < 50$	3269	6517	6180	7769	1186	489	1026	1580875	2
$\Sigma E_T < 400$	3161	6157	6002	7571	517	443	1003	1490003	2
Good τ-cand	789±21	86±10	49±8	125±18	40±1	8±2	25±3	1849±1307	0±0
$\Delta\phi < 2.8$	692±20	84±9	46±8	119±17	39±1	8±2	22±3	1849±1307	0±0
$1 < \Delta\phi$	660±19	81±9	45±8	114±17	33±1	8±2	20±3	0±0	0±0
OS events	638±19	62±8	40±7	90±14	26±1	8±2	18±3	0±0	0±0
$m^{lep,\tau_{had}}$ 0-200	638±19	61±8	40±7	90±14	26±1	8±2	18±3	0±0	0±0
$m^{lep,\tau_{had}}$ 66-116	556±18	24±5	19±5	49±10	11±1	0±0	12±2	0±0	0±0
SS events	22±3	19±4	5±3	25±8	7±1	0±0	2±1		0±0
$m^{lep,\tau_{had}}$ 0-200	22±3	19±4	4±2	25±8	6±1	0±0	2±1		0±0
$m^{lep,\tau_{had}}$ 66-116	11±3	14±4	0±0	17±7	3±0	0±0	0±0		0±0

Fullsim with low statistics

Number of events in 100 pb^{-1} with LO (only for MC @NLO NLO) cross-sections

Trigger EF_e10_medium and EF_mu10 included
Gamma+jets can be neglected
S/B = 5 (without QCD)
$W \to \tau\nu$ dominated by taus decaying to leptons

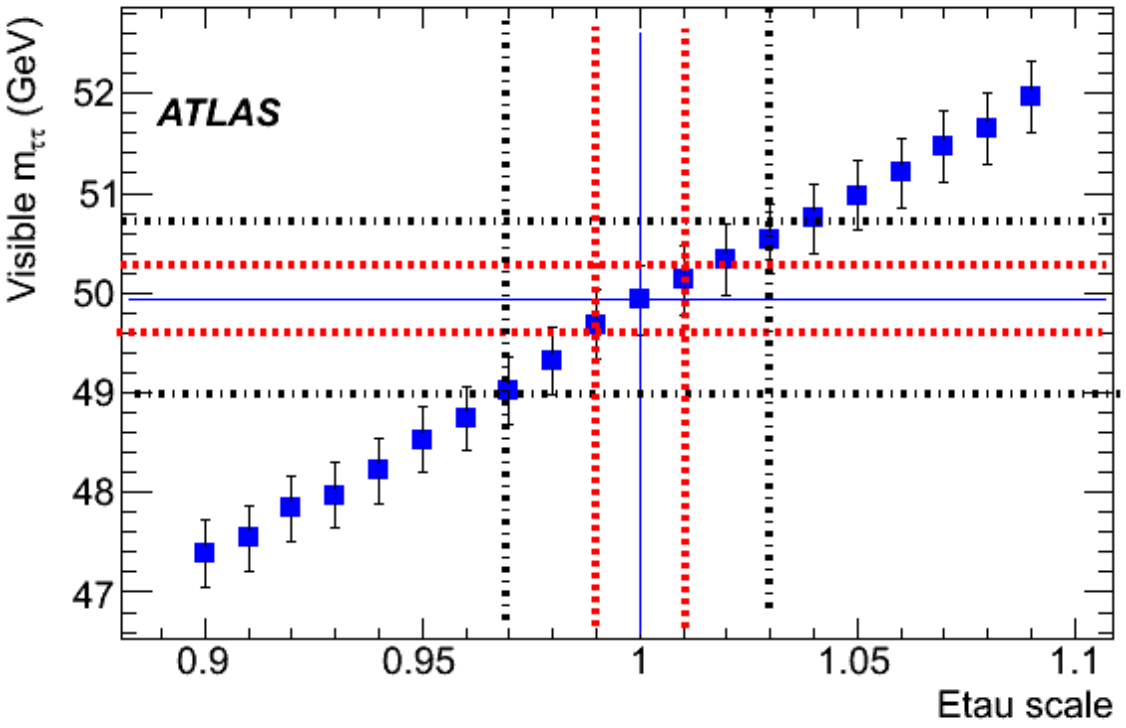


All backgrounds under control
→ Check QCD

Tauscale

Determination of Tauscale with visible mass analysis (lepton p_T > 10 GeV) with 100 pb^{-1} (without QCD background).

Sensitivity:



→ Tau-energy scale could be determined to 3% uncertainty (only statistical errors, but systematics have to be taken into account)

Investigation of QCD background

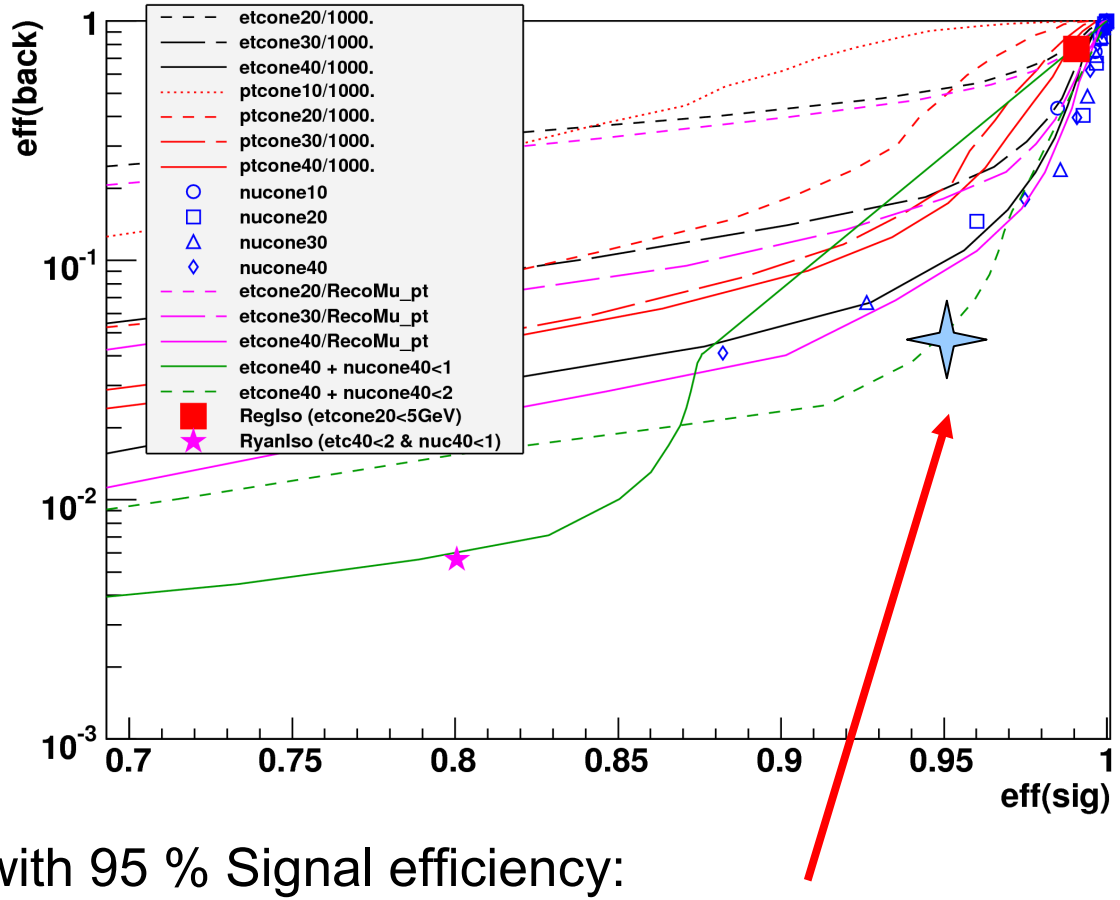
→ QCD background estimated by Ulrik (last TauWG meeting) to be ~ 1700 events in cut OS events (with large Atlfast2 J1+J2+J3 sample)
→ Better rejection of QCD necessary
→ Improve lepton isolation

1) Optimise muon isolation
2) Optimise electron isolation
    A) Use Atlfast2 sample with EtCone variables (large statistics but duplicated events)
    B) Re-run Isolation Tool for Electrons on Atlfast2 QCD sample (small statistics, no dublipated events)

Optimisation of Muon Isolation

Investigation of Isolation of muons (by Will Davey):

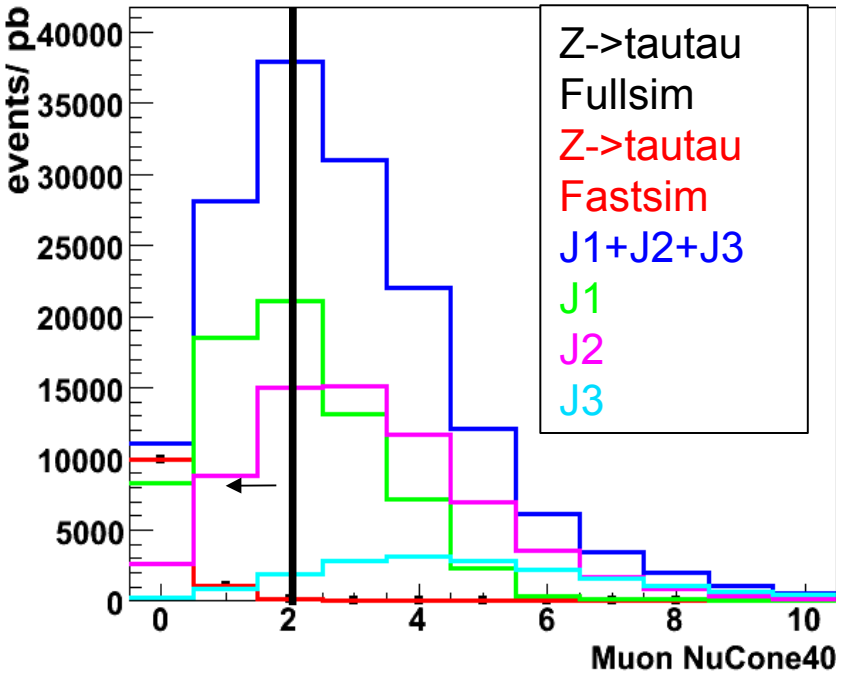
- Use J2 Atlfast2 sample

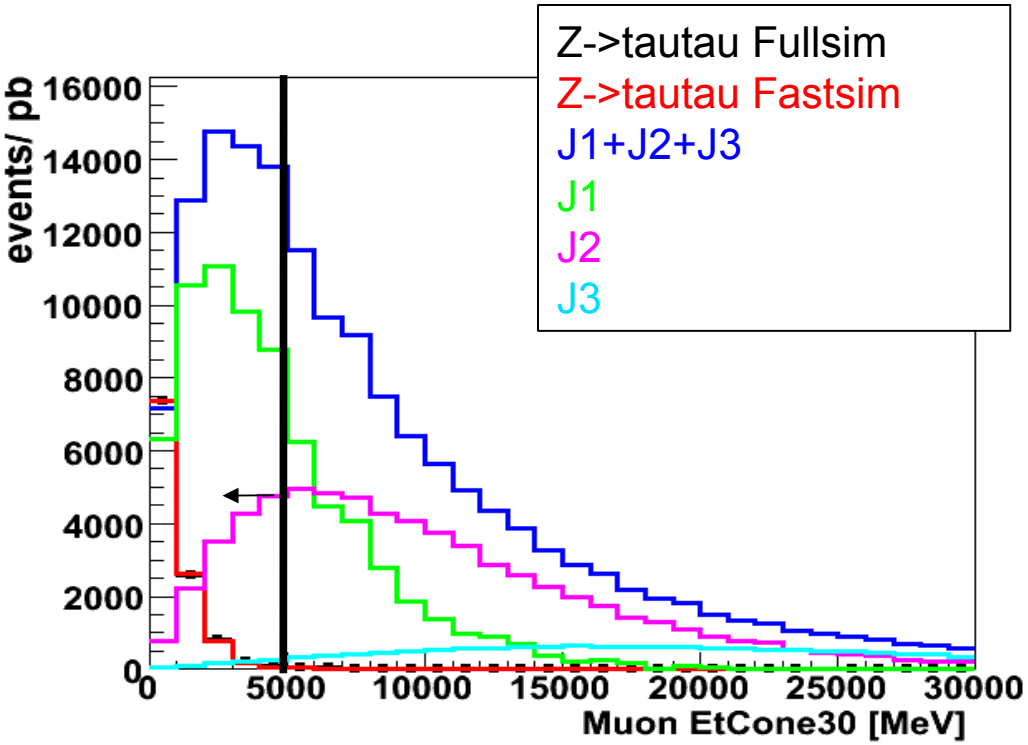


→ Point with 95 % Signal efficiency:
EtCone 40 (muon bug is real EtCone30) < 3.2 GeV && NuCone40 < 2

Distributions of Muon Isolation

NuCone = # tracks in Cone dR
Default track selection

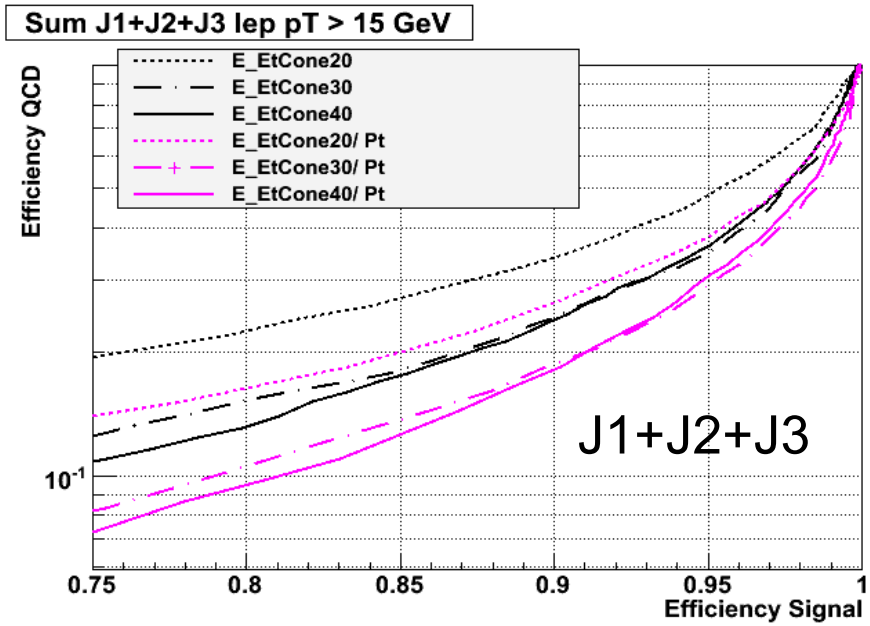


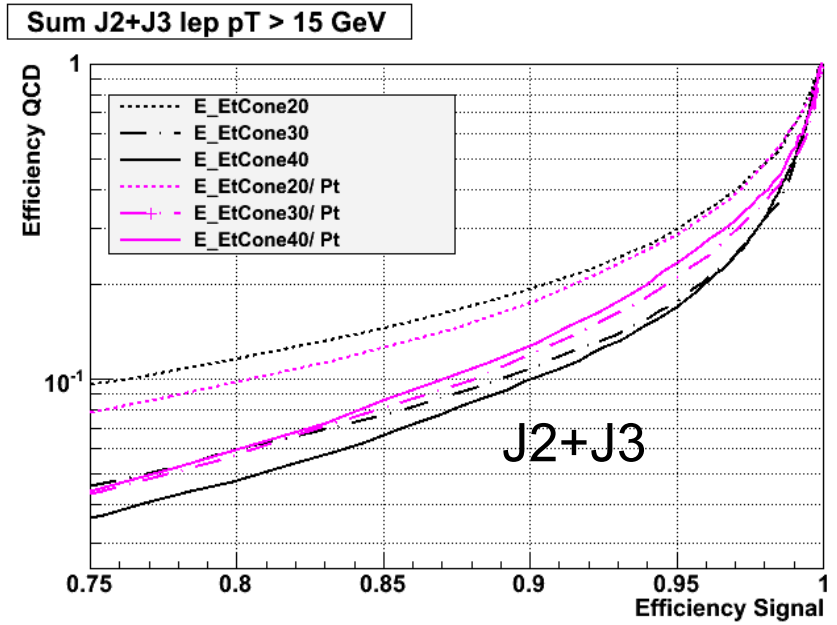


Distributions for lepton p_T > 15 GeV

Optimisation of Electron Isolation

Investigation of Isolation of electrons:
A) Use J1, J2, J3 Atlfast2 samples with duplicated events, full statistics, electron p_T > 15 GeV, IsEMMedium, EgammaAuthor and $|\eta|$ < 2.5





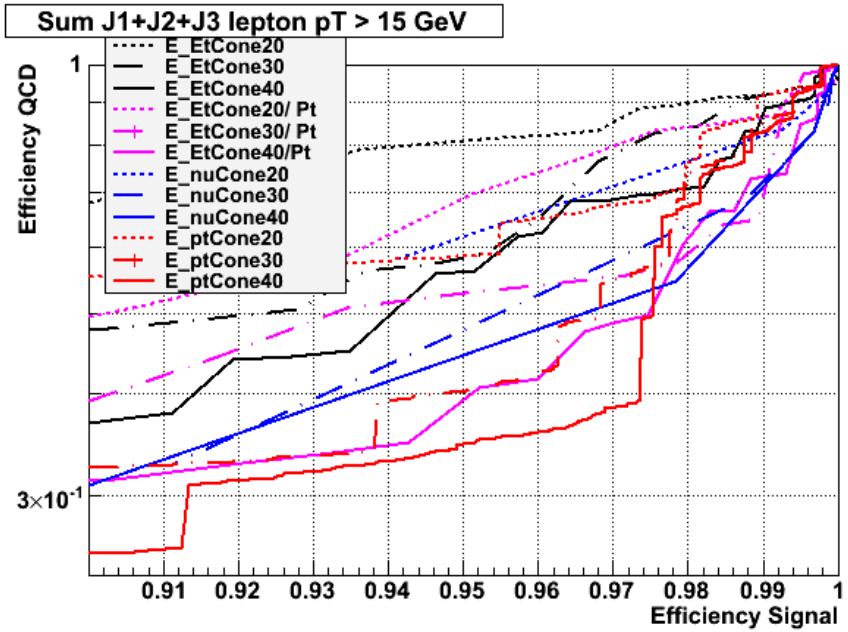
→ Optimise against J2 and J3 with EtCone30 < 4.1 GeV
Background efficiency similar for lepton p_T > 10 GeV and p_T > 15 GeV

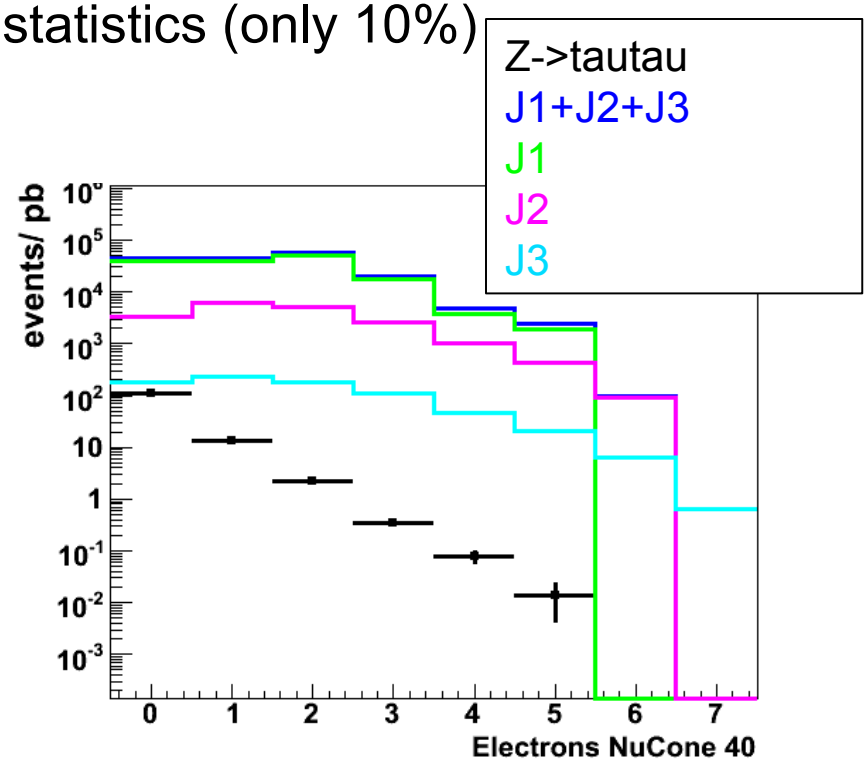
Signal efficiency	95.00%
J1+J2+J3 eff.	35.90%
J2+J3	18.20%

Optimisation of Electron Isolation

B) Rerun Isolation Tool for Electrons on remaining J1, J2, J3 Atlfast2 samples without duplicated events, low statistics (only 10%)

Apply cut on EtCone30 < 4.1 GeV





→ NuCone30 or NuCone40 variable look promising for further reduction of QCD (NuCone is number of tracks (with p_T > 1 GeV) in cone dR around electron (not available in Jx large statistics samples)

→ use for now EtCone30 < 4.1 GeV

Use of the isolation

Use for lepton isolation:

Electrons: EtCone30 < 4.1 GeV

Muons: EtCone 30 < 3.2 GeV && NuCone40 < 2

Statistics of Jx not sufficient for full cutflow → Factorization of Jx:
Loose Tau ID (pT > 15 GeV && |eta| < 2.5 && |charge| = 1) instead full TauID

For J1 factor obtained before MET, for J2+J3 after SumET

Errors for Jx scaled due to duplicated events

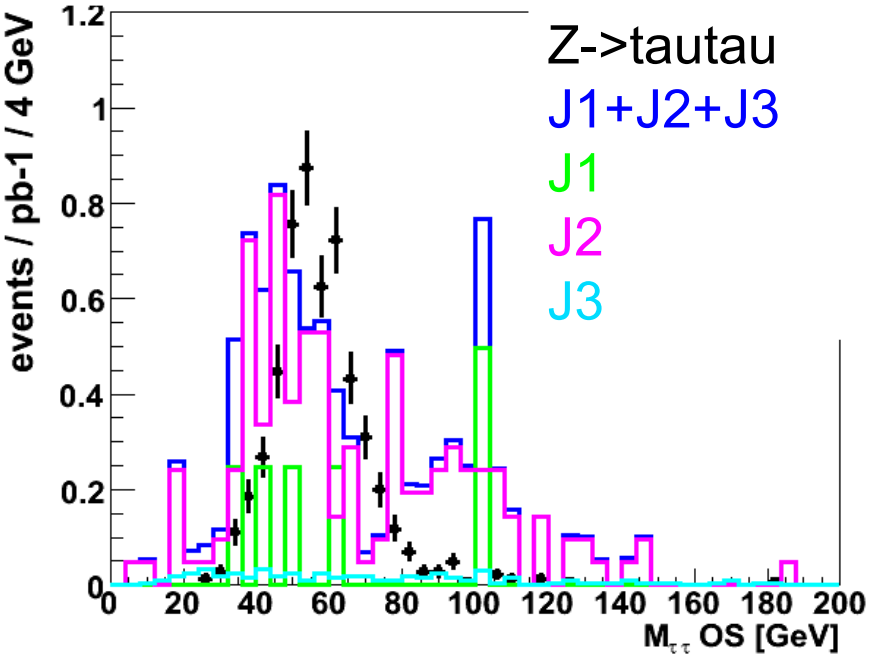
Optimised visible Mass analysis Lepton p_T > 15 GeV

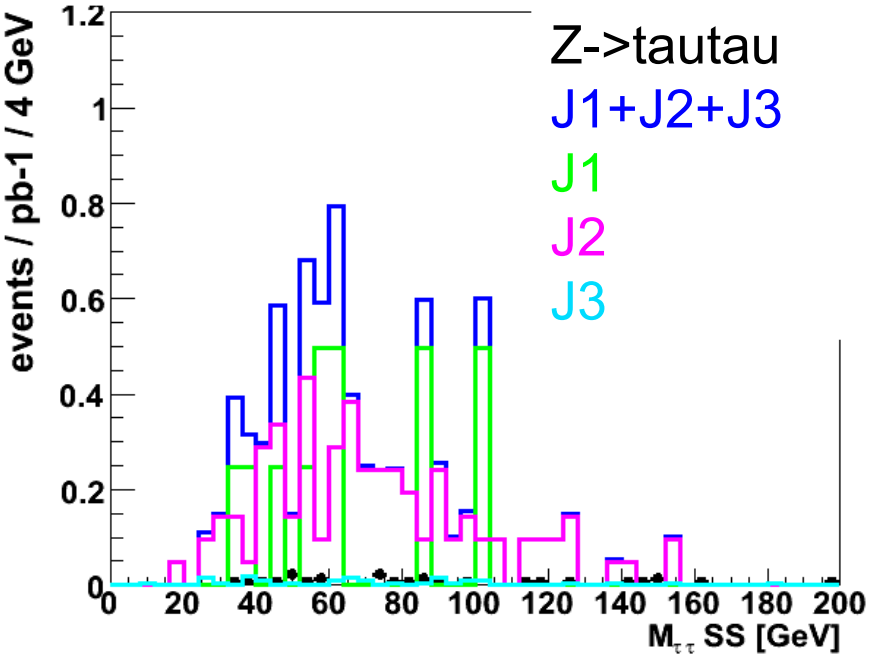
Optimised visible mass analysis	Z->tautau	J1+J2+J3	J1+J2+J3 Electrons	J1+J2+J3 Muons
lepton pT > 15 GeV				
Good muon/ele + Isolation	18198 +- 111	77034+-1134	50864+-906	26170+-683
PtMiss > 20 GeV	5435 +- 61	5498+-263	3081+-182	2418+-190
Mtlepmet < 30 GeV	2733+- 43	3479+-184	2217+-144	1262+-115
SumEt < 400 GeV	2635 +- 43	3433+-184	2183+-143	1251+-115.
A selected tau	657.35 +- 21.25	1629.23+-124.01	1032.61+-95.84	596.62+-78.70
Delta Phi < 3.1	588.66 +- 20.11	1565.65+-122.79	984.45+-94.63	581.20+-78.25
Visible Mass reconstruction	588.66+- 20.11	1565.65+-122.79	984.45+-94.63	581.20+-78.25
DeltaPhi > 1	556.38 +- 19.55	1409.50 +-119.95	873.58+-92.07	535.92+-76.89
Tau charge* lep charge = -1	534.40 +- 19.16	725.37+-75.82	421.35+-58.17	304.02+-48.63
0 GeV < Mass < 200 GeV	532.33 +- 19.12	720.55+-75.67	421.35+-58.17	299.20+-48.39
37 GeV < Mass < 75 GeV	473.26 +- 18.03	435.76+-58.92	223.31+-38.87	212.45+-44.28
Tau charge* lep charge = -1	21.98 +- 3.89	684.13+-92.95	452.23+-71.36	231.90+-59.56
0 GeV < Mass < 200 GeV	19.23 +- 3.63	683.16+-92.95	451.26+-71.35	231.90+-59.56
37 GeV < Mass < 75 GeV	8.24 +- 2.38	417.29+-73.67	271.62+-57.05	145.67+-46.60

Errors for Jx scaled due to dublicated events

Optimised visible Mass analysis Lepton p_T > 15 GeV

Visible mass distributions for factorized QCD





Opposite Sign	Z->tautau	J1+J2+J3	J1+J2+J3 Electrons	J1+J2+J3 Muons
37 GeV < Mass < 75 GeV	473.26 +- 18.03	435.76+-58.92	223.31+-38.87	212.45+-44.28
Same Sign				
37 GeV < Mass < 75 GeV	8.24 +- 2.38	417.29+-73.67	271.62+-57.05	145.67+-46.60

Test of Ryan's optimisation for muons

Estimate how much we can gain with better isolation:
With Ryan's cut for muons: EtCone30 <= 2 && NuCone40 < 1

Visble Mass analysis lepton pT>15	Z->tautau (electrons and muons)	J1+J2+J3 Muons
Muons Ryan isolation	Events in 100 pb-1	Events in 100 pb-1
Good muon/ele + Isolation	167256 +- 107	6095+-384
PtMiss > 20 GeV	4930 +- 58	587+-112
Mtlepmet < 30 GeV	2508 +- 42	191+-52
SumEt < 400 GeV	2421 +- 41	191+-52
A selected tau	589+- 20	94.99+-41.55
Delta Phi < 3.1	527 +- 19	93.55+-41.53
Visible Mass reconstruction	527 +- 19	93.55+-41.53
DeltaPhi > 1	496 +- 18	93.55+-41.53
Tau charge* lep charge = -1	476.70 +- 18.10	50.51+-29.63
0 GeV < Mass < 200 GeV	475.32 +- 18.07	50.51+-29.63
37 GeV < Mass < 75 GeV	421.75 +- 17.02	45.62+-29.40
Tau charge* lep charge = -1	19.23 +- 3.63	43.04+-29.10
0 GeV < Mass < 200 GeV	17.17 +- 3.43	43.04+-29.10
37 GeV < Mass < 75 GeV	7.56 +- 2.28	41.60+-29.06

→ With Ryan's muon isolation only 20% muon events left, but signal 12 % less
→ Promising for Electrons

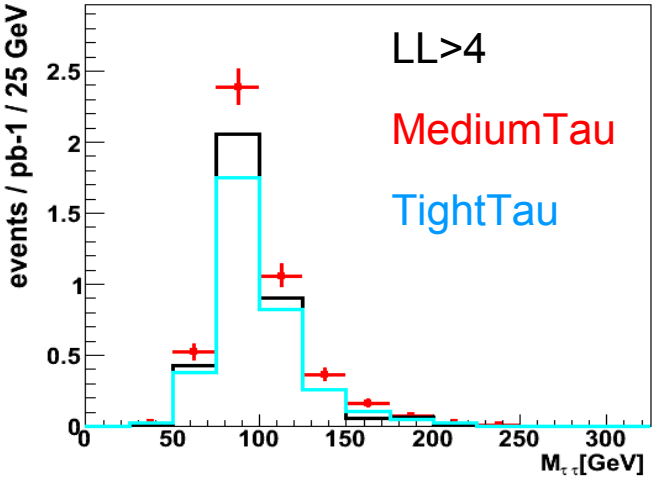
Analysis with Safe Tau variables

Rerun IsTau on Z → ττ sample

Comparison of TauId with Likelihood > 4, TauCutMedium=true or TauCutTight=true for Invariant Mass analysis, lepton p_T > 10 GeV

Events in 100pb-1	TauID LL>4	TauCutMedium	TauCutTight
SumEt < 400 GeV	6253.38 +- 65.54	6253.66 +- 65.58	6253.66 +- 65.58
A selected tau	1329.12 +- 30.22	1717.99 +- 34.37	1211.12 +- 28.86
Invariant Mass reconstruction	378.47 +- 16.12	465.60 +- 17.89	343.18 +- 15.36
DeltaPhi > 1	355.12 +- 15.62	438.09 +- 17.36	323.24 +- 14.91
Tau charge* lep charge = -1	349.62 +- 15.50	414.02 +- 16.87	310.17 +- 14.61
0 GeV < Mass < 200 GeV	348.94 +- 15.48	409.21 +- 16.78	306.73 +- 14.52

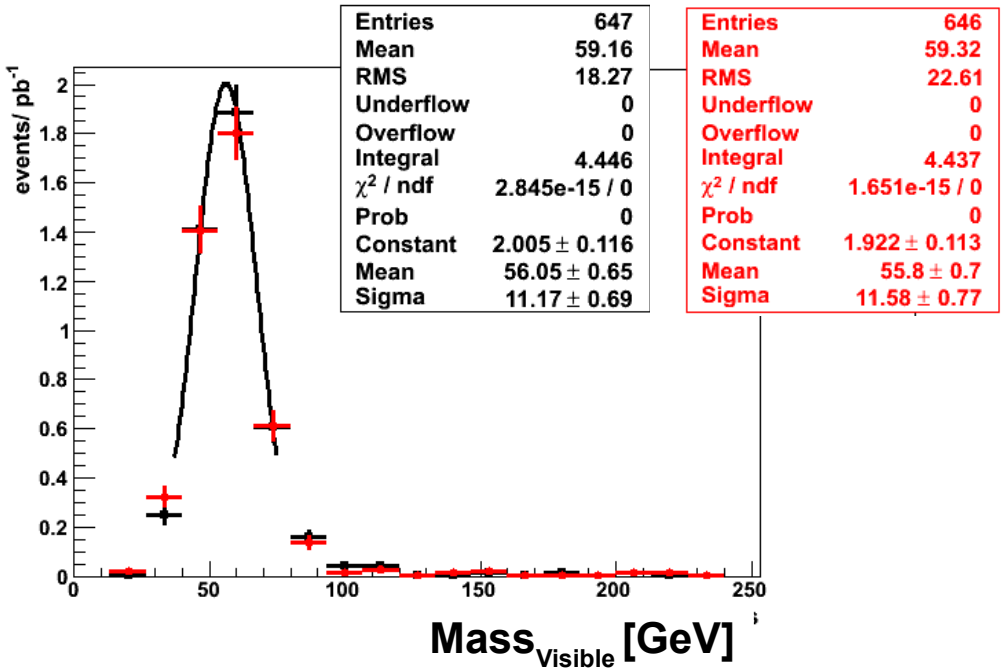
To be checked for backgrounds

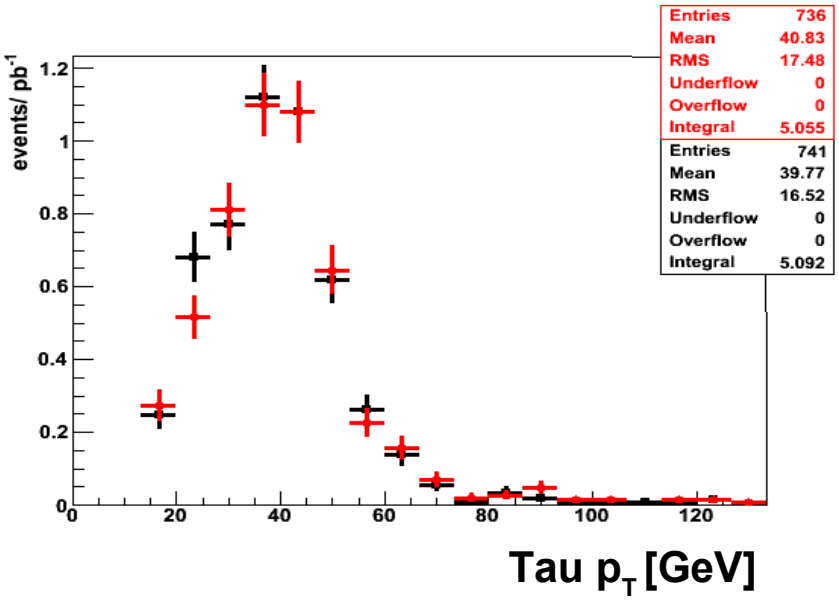


ATLFAST II vs. Fullsimulation

Comparison of PYTHIA Full simulation ATLFAST II Fast simulation without AOD-AOD corrections (visible mass analysis, p_T>15GeV)

HEC sector in Full simulation off ($-3.5 < \eta < -1.5$ and $-\pi/2 < \varphi < 0$)
→ Events with truth Jet, Electron or Tau in this region excluded





Cross-sec. After cut	Fullsim Pythia	Fastsim Pythia
37 GeV < visible mass < 75 GeV	292 ± 14	284 ± 14

→ Ratio Fullsim. / Fast sim.: 1.03 ± 0.07

Good agreement between ATLFAST II and full simulation

Conclusion

- Z → ττ analysis set up for first data
- Tools set up to optimise further against QCD with new large statistics samples (especially for electrons)
- Agreement of Atlfast2 and Fullsim better than 5% without corrections

Outlook:

- Optimise further against QCD with large statistics sample, p_T dependent
- Prepare estimation of backgrounds and efficiencies from data
- Large statistics needed to estimate OS to SS ratio

- Include analysis in WZ performance package

- Redo analysis with Sherpa Z → ττ + 3 Jets
- Check Safe Tau Variables on Backgrounds

Backup

Samples

Samples used release 14.2.20 data:
Bug on MET Muon term: run Wμν with bug fix and re-reconstruct Zμμ with 14.2.25 (where bug is fixed)

Ztautau mc08.106052.PythiaZtautau.recon.AOD.e347_s462_r541
Ztautau mc08.106052.PythiaZtautau.recon.e347_a68
Wenu mc08.106020.PythiaWenu_1Lepton.recon.AOD.e352_s462_r541
Wmunu mc08.106021.PythiaWmunu_1Lepton.recon.AOD.e352_s462_r541
Wtaunu mc08.106023.PythiaWhadtaunu.recon.e347_s462_r541 and mc08.106022.PythiaWtaunu_1Lepton.recon.e352_s462_r541
tt mc08.105200.T1_McAtNlo_Jimmy.recon.AOD.e357_s462_r541
Zee mc08.106050.PythiaZee_1Lepton.recon.AOD.e347_s462_r541
Zee mc08.106050.PythiaZee_1Lepton.recon.AOD.e347_s462_r541
J1 mc08.105010.J1_pythia_jetjet.recon.e344_a68 (10 Mio but dublicated events)
J2 mc08.105011.J2_pythia_jetjet.recon.e344_a68 (40 Mio but dublicated events)
J3 mc08.105012.J3_pythia_jetjet.recon.e344_a68 (40 Mio but dublicated events)

Cutflow Z→ ττ visible mass pT,l > 15 GeV

Normalized to NLO 1368 pb	Fullsim Pythia [pb]	Cut i+1 /Cut i	Fullsim Alpgen [pb]	Cut i+1 /Cut i	Fullsim MC@NLO [pb]	Cut i+1 /Cut i
Good muon/ele + Isolation	112.02 +- 0.88	0.08	111.23 +- 0.87	0.08	114.46 +- 1.09	0.08
PtMiss > 20 GeV	31.88 +- 0.47	0.28	32.14 +- 0.42	0.29	31.97 +- 0.57	0.28
Mtlepmet < 30 GeV	15.85 +- 0.33	0.5	15.58 +- 0.25	0.48	16.01 +- 0.41	0.50
SumEt < 400 GeV	15.33 +- 0.32	0.97	14.77 +- 0.25	0.95	15.80 +- 0.40	0.98
A selected tau	3.99 +- 0.17	0.260	3.94 +- 0.15	0.267	4.51 +- 0.21	0.285
Delta Phi < 3.1	3.56 +- 0.16	0.89	3.41 +- 0.13	0.87	3.92 +- 0.20	0.86
DeltaPhi > 1	3.38 +- 0.15	0.95	3.23 +- 0.13	0.95	3.73 +- 0.19	0.95
Tau charge* lep charge = -1	3.28 +- 0.15	0.97	3.10 +- 0.13	0.96	3.64 +- 0.19	0.97
0 GeV < Mass < 200 GeV	3.28 +- 0.15	1	3.10 +- 0.13	1	3.64 +- 0.19	1.00
37 GeV < Mass < 75 GeV	2.92 +- 0.14	0.89	2.72 +- 0.12	0.88	3.25 +- 0.18	0.91
Ratio Cut(0 GeV < Mass < 200 GeV) to without cut		0.0024		0.0023		0.0027
For invariant mass analysis						
0 GeV < Mass < 200 GeV	1.14 +- 0.09		1.29 +- 0.06		1.23 +- 0.11	
Ratio Mass cut / without cut		0.0008		0.0009		0.0009

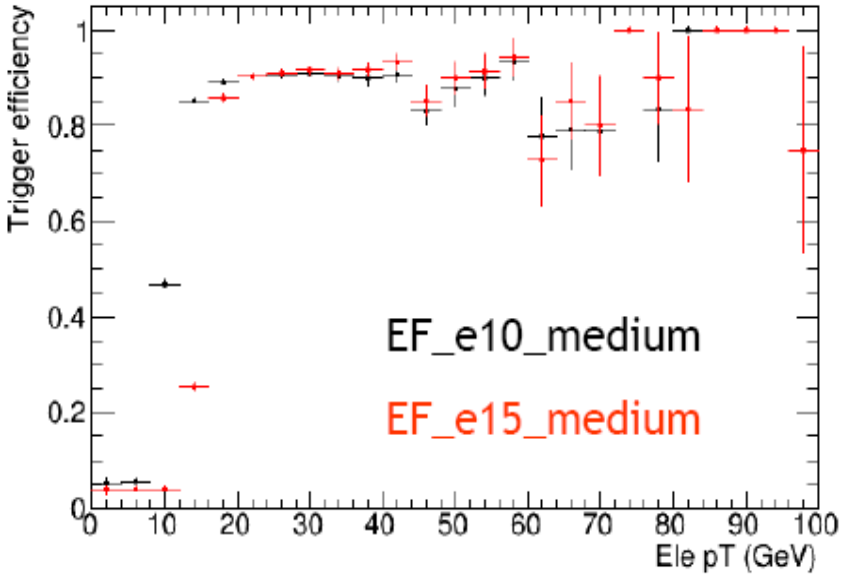
Events in HEC (hadronic endcap calorimeter) sector (-3.5 < η < -1.5 and - π/2 < φ < 0) rejected

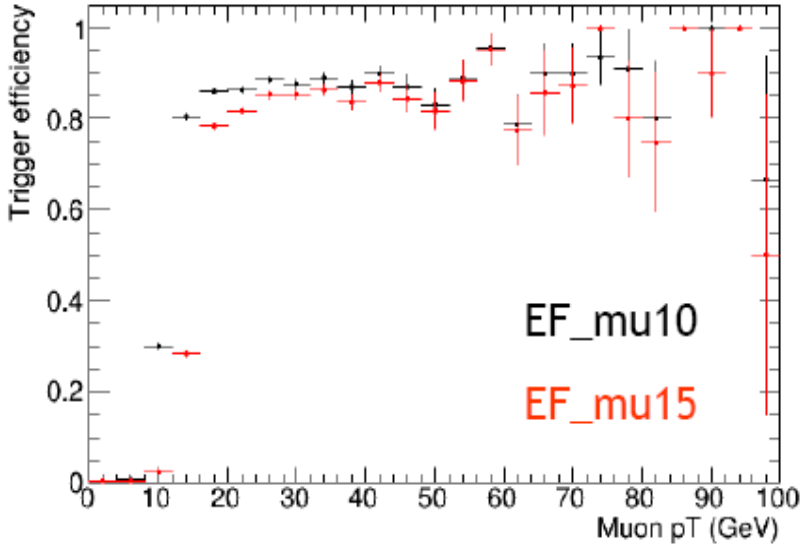
Cutflow Z→ ττ invariant mass

Normalized to NLO 1368 pb	Fullsim Pythia [pb]		Fullsim Alpgen [pb]		Fullsim MC@NLO [pb]	
Good muon/ele + Isolation	112.02 +- 0.88	0.08	111.23 +- 0.87	0.08	114.46 +- 1.09	0.08
PtMiss > 20 GeV	31.88 +- 0.47	0.28	32.14 +- 0.42	0.29	31.97 +- 0.57	0.28
Mtlepmet < 50 GeV	23.24 +- 0.40	0.73	23.80 +- 0.32	0.74	23.44 +- 0.49	0.73
SumEt < 400 GeV	22.65 +- 0.39	0.97	22.81 +- 0.26	0.96	23.15 +- 0.49	0.99
A selected tau	4.48 +- 0.18	0.2	4.50 +- 0.12	0.2	4.98 +- 0.23	0.22
Delta Phi < 2.8	2.06 +- 0.12	0.46	2.26 +- 0.08	0.5	2.40 +- 0.15	0.48
Invariant mass > 0 GeV	1.29 +- 0.09	0.63	1.46 +- 0.06	0.65	1.36+-0.12	0.51
DeltaPhi > 1	1.16 +- 0.09	0.9	1.32 +- 0.06	0.9	1.23+-0.11	0.90
Tau charge* lep charge = -1	1.14 +- 0.09	0.98	1.29 +- 0.06	0.98	1.23+-0.11	1.00
0 GeV < Mass < 200 GeV	1.14 +- 0.09	1	1.29 +- 0.06	1	1.23+-0.11	1.00
37 GeV < Mass < 75 GeV	1.02 +- 0.08	0.89	1.15 +- 0.06	0.89	1.09 +- 0.11	0.89
Cut 0 / Cut 11		0.0007		0.0008		0.0008

Events in HEC (hadronic endcap calorimeter) sector ($-3.5 < \eta < -1.5$ and $-\pi/2 < \varphi < 0$) rejected

Trigger (from Caterina)





Zττ	Ele eff	Muon eff	Tot eff
Lepton pT>10 EF_e10_medium/EF_mu10	86%	82%	84%
Lepton pT>15 EF_e10_medium/EF_mu10	88%	89%	89%
Lepton pT>15 EF_e15_medium/EF_mu15	86%	84%	85%

Samples for Generator comparison

Samples used:

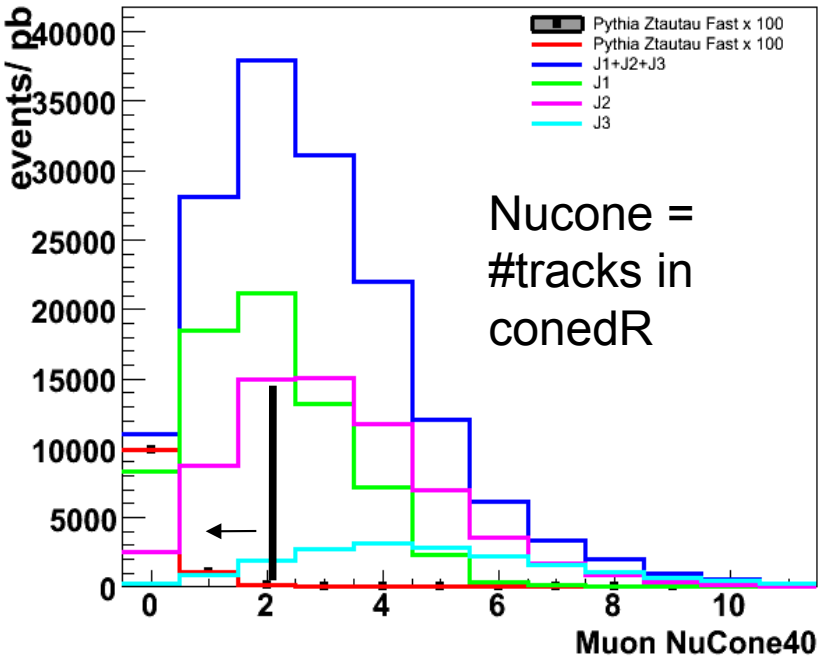
mc08.106052.PythiaZtautau.recon.e347_a68/
mc08.106052.PythiaZtautau.recon.e347_s462_r541/
mc08.106062.McAtNloZtautau.recon.e352_s462_r541/
mc08.107670.AlpgenJimmyZtautauNp0_pt20.recon.e376_s462_r563/
mc08.107671.AlpgenJimmyZtautauNp1_pt20.recon.e376_s462_r563/
mc08.107672.AlpgenJimmyZtautauNp2_pt20.recon.e376_s462_r563/
mc08.107673.AlpgenJimmyZtautauNp3_pt20.recon.e376_s462_r563/
mc08.107674.AlpgenJimmyZtautauNp4_pt20.recon.e376_s462_r563/
mc08.107675.AlpgenJimmyZtautauNp5_pt20.recon.e376_s462_r563/

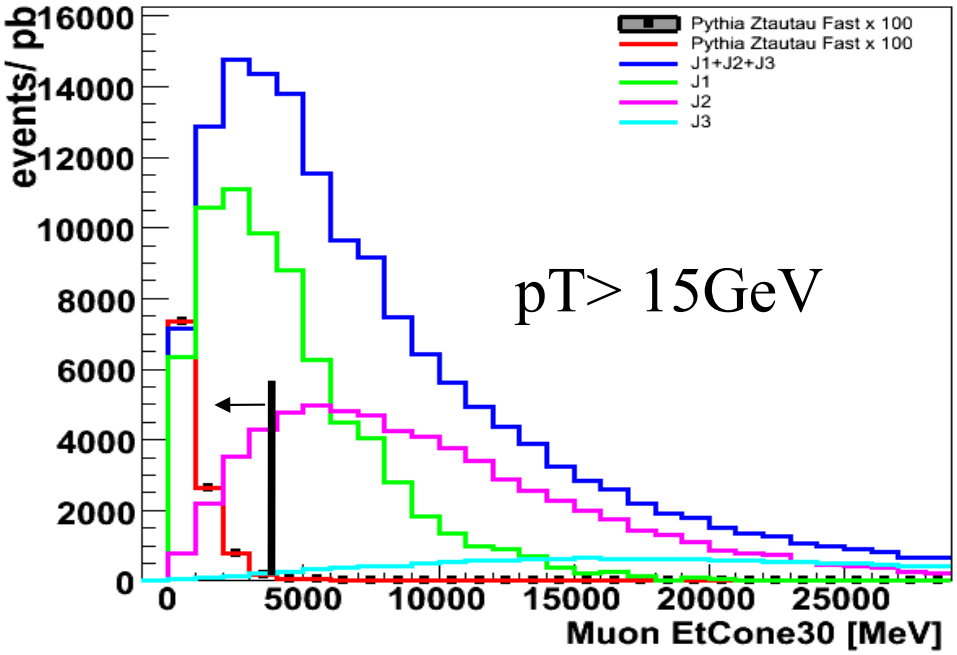
Cutflow Z→ ττ: visMass pT>15GeV

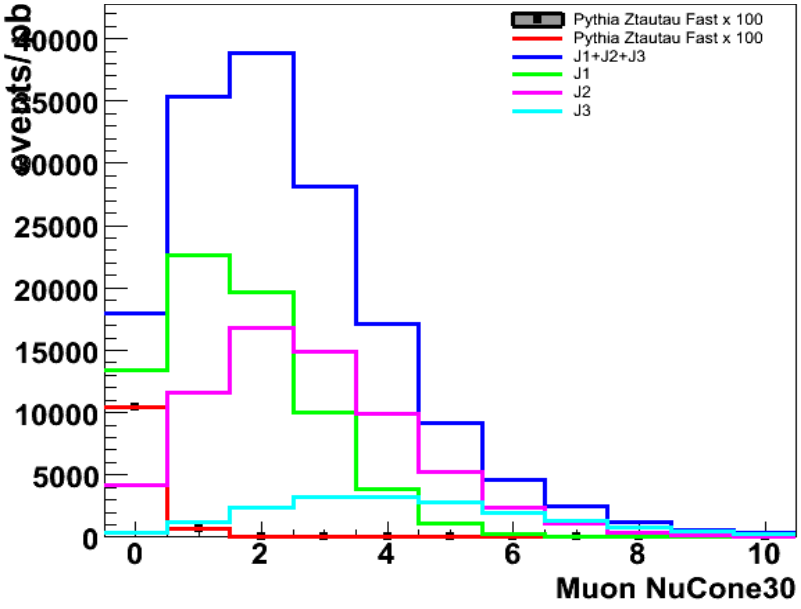
Normalized to NLO 1368 pb	Fullsim Pythia [pb]	Cut i+1 /Cut i	Fastsim Pythia [pb]	Cut i+1 /Cut i
Good muon/ele + Isolation	112.02 +- 0.88	0.08	111.82 +- 0.88	0.08
PtMiss > 20 GeV	31.88 +- 0.47	0.28	31.16 +- 0.46	0.28
Mtlepmet < 30 GeV	15.85 +- 0.33	0.5	14.86 +- 0.32	0.48
SumEt < 400 GeV	15.33 +- 0.32	0.97	14.43 +- 0.31	0.97
A selected tau	3.99 +- 0.17	0.26	3.87 +- 0.16	0.27
Delta Phi < 3.1	3.56 +- 0.16	0.89	3.47 +- 0.15	0.9
DeltaPhi > 1	3.38 +- 0.15	0.95	3.33 +- 0.15	0.96
Tau charge* lep charge = -1	3.28 +- 0.15	0.97	3.20 +- 0.15	0.96
0 GeV < Mass < 200 GeV	3.28 +- 0.15	1	3.17 +- 0.15	0.99
37 GeV < Mass < 75 GeV	2.92 +- 0.14	0.89	2.84 +- 0.14	0.9
Ratio Cut(0 GeV < Mass < 200 GeV) to without cut		0.0024		0.0023

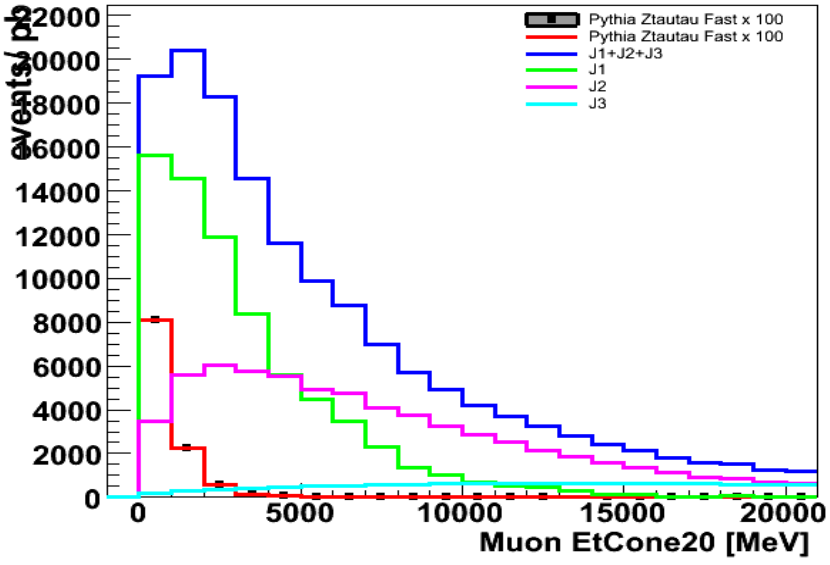
Events in HEC (hadronic endcap calorimeter) sector ($-3.5 < \eta < -1.5$ and $-\pi/2 < \varphi < 0$) rejected

Distributions of muon isolation



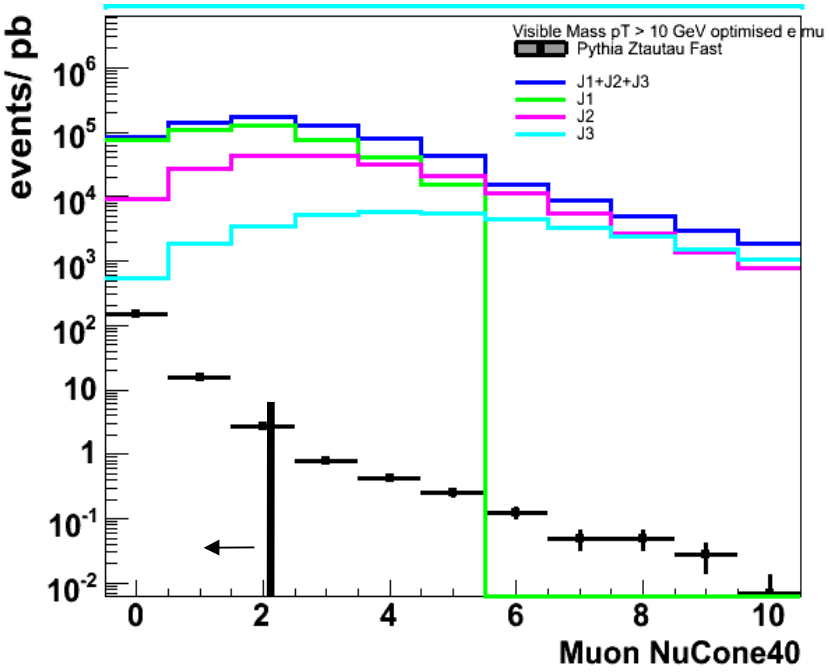


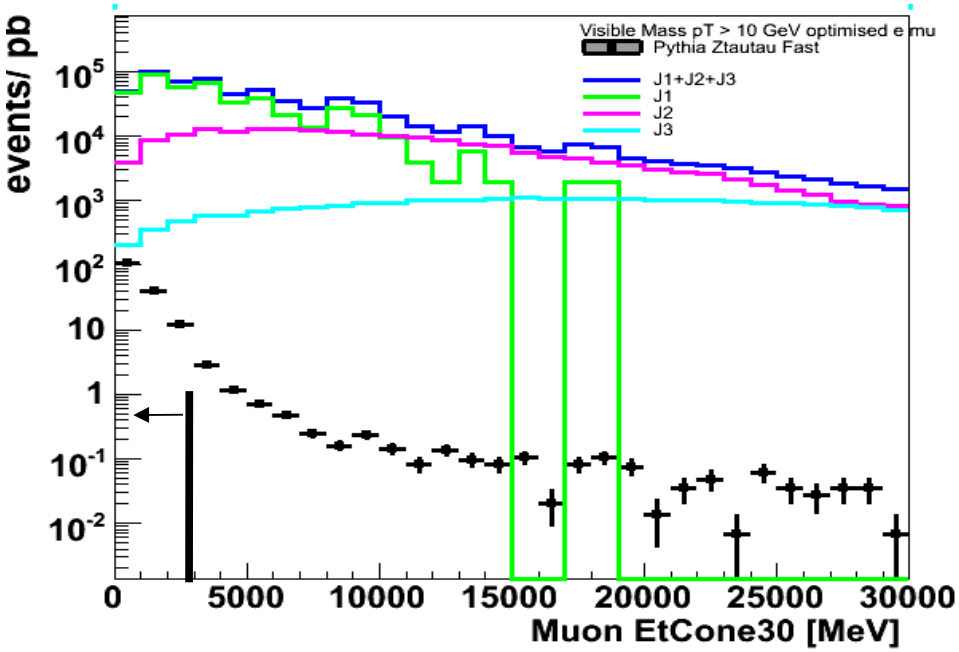




Distributions of muon isolation

NuCone = # tracks in Cone dR
Default track selection



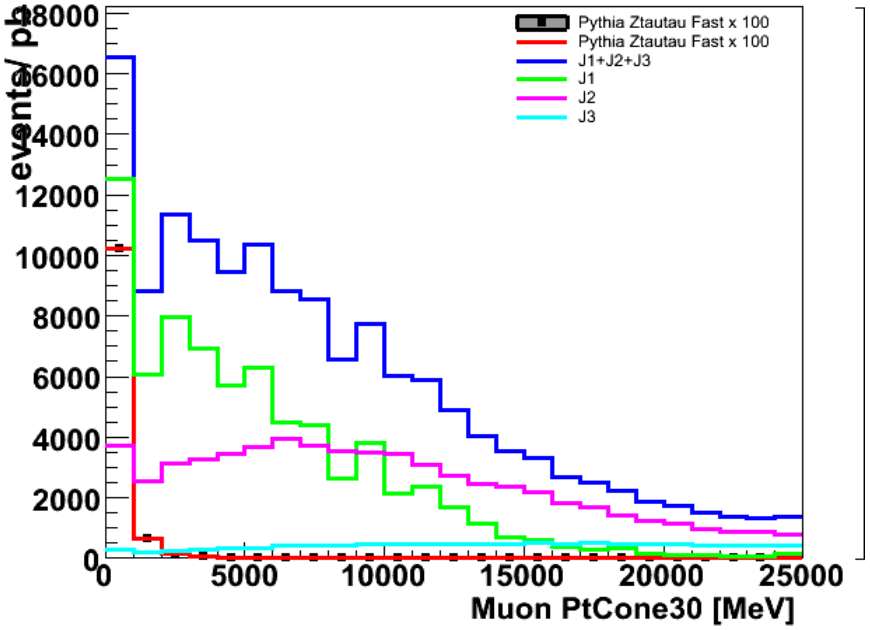


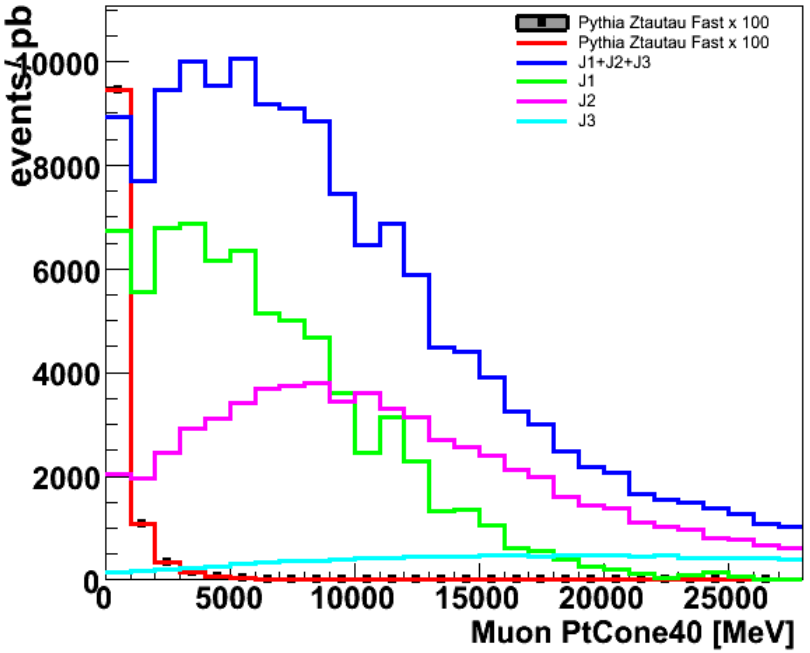
Distributions for lepton pT > 10 GeV

Muon distributions from Ulrik Sample

Ptcone = Sum Pt of tracks in conedR

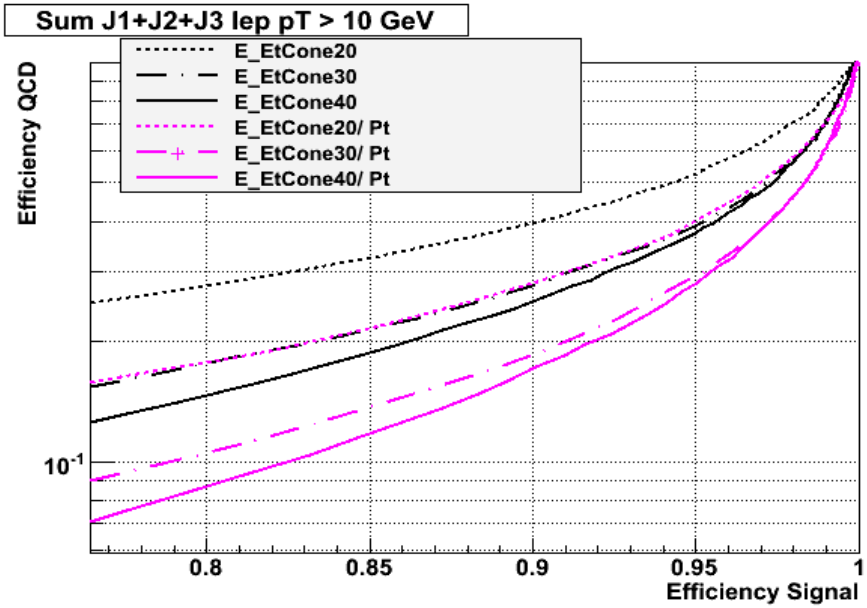
pT> 15GeV

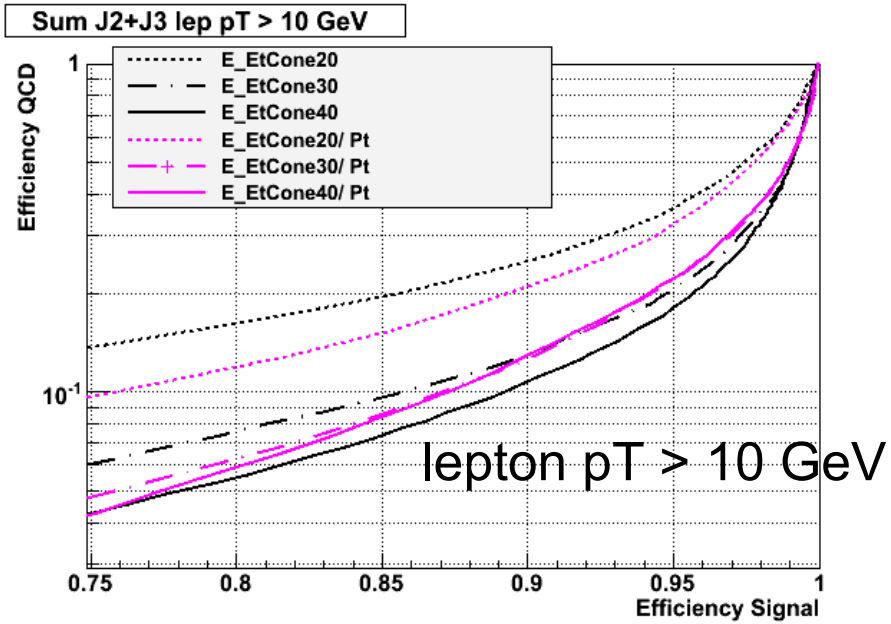




Optimisation of Lepton Isolation

Investigation of Isolation of electrons:
A) Use J1, J2, J3 Atlfast2 samples with dublicated events, full statistics





→ Optimise against J2 and J3 with EtCone30 < 4.1 GeV pT> 10GeV
95% signal eff., background eff J1+J2+J3: 0.404; eff J2+J3: 0.2158
Background eff similar for lepton pT > 10 GeV and pT > 15 GeV

Electron distributions from Stan Sample

Ptcone = Sum Pt of tracks in conedR

pT> 15GeV