$Z \rightarrow \tau\tau \rightarrow l\tau_h$ in ATLAS 2011

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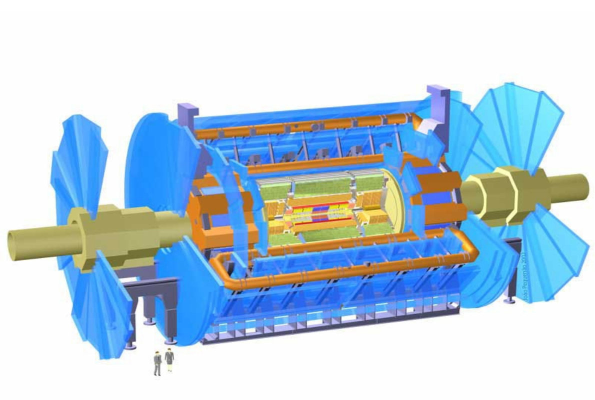
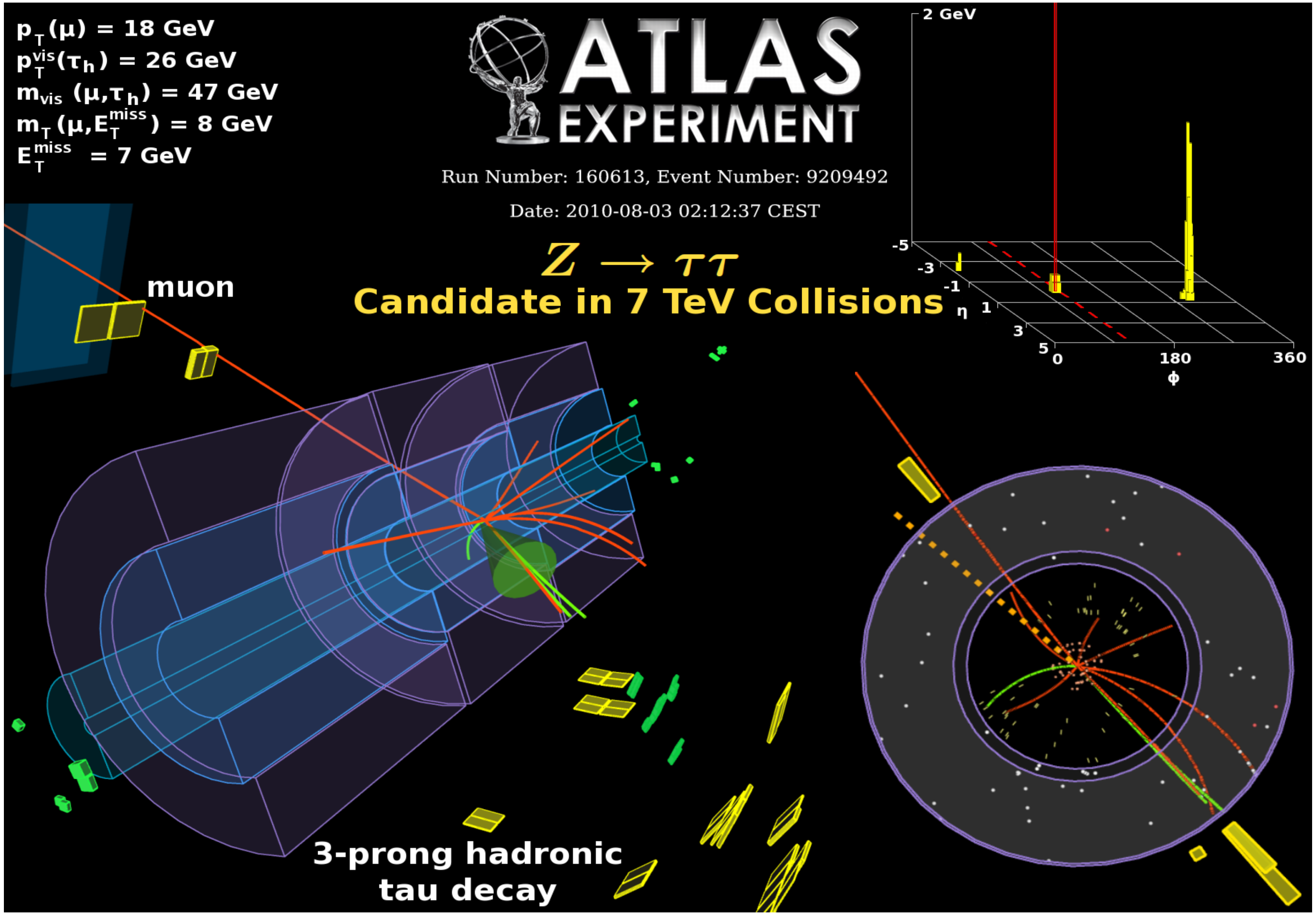
On behalf of the ATLAS $Z \rightarrow \tau\tau$ analysis working group.

Introduction

For Z → $l\tau_h$ reconstruction, all parts of the detector are used:

- Inner detector
- E.m. calorimeter
- Hadronic calorimeter
- Muon spectrometer

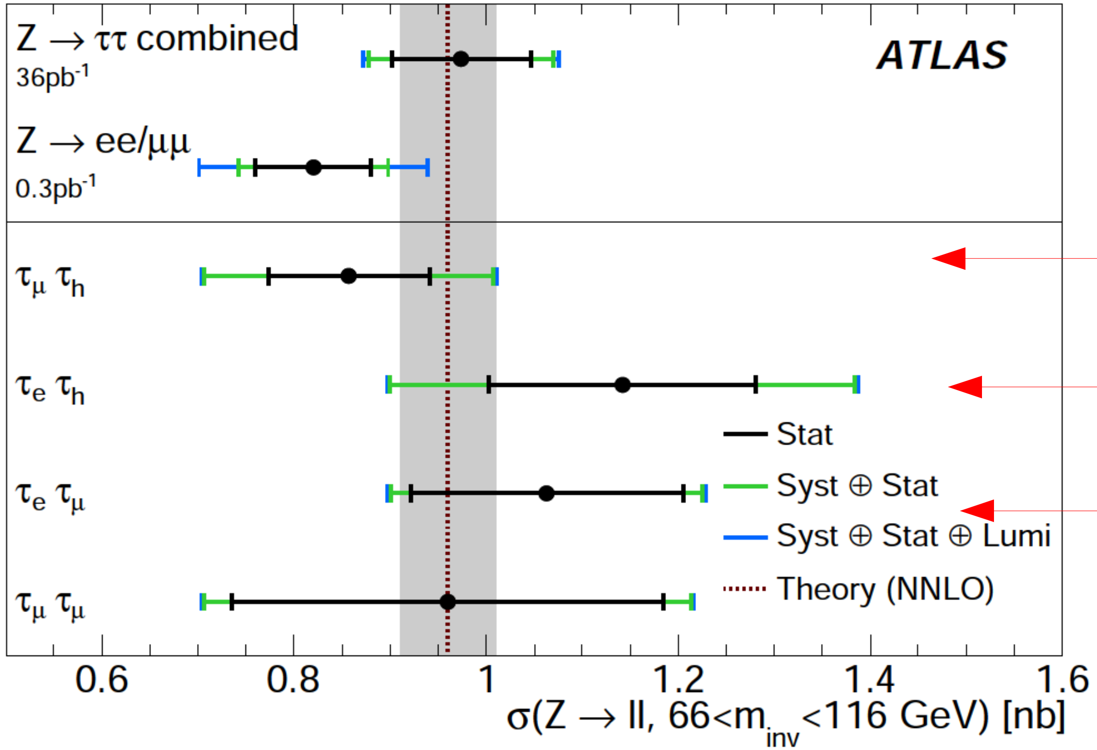




$Z \rightarrow \tau\tau \rightarrow \mu\tau_h + 3\nu$ event candidate in ATLAS from 2010 data taking.

Introduction

- $Z \rightarrow \tau\tau$ cross-section with 36pb^{-1} 2010 data was published by ATLAS.
- This measurement was statistically limited.

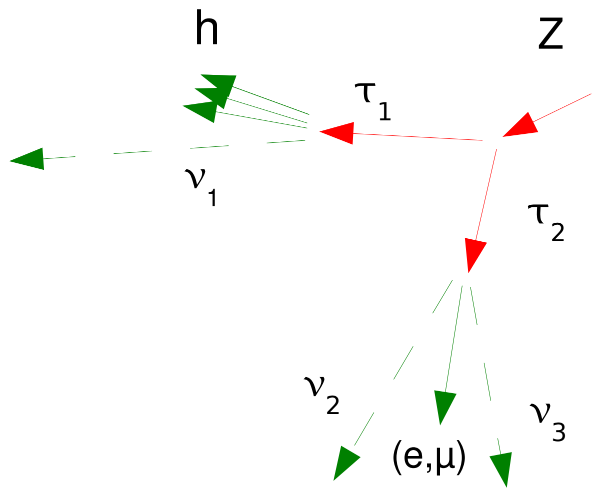


Three channels studied in the 2011 analysis:

mu-had

el-had

el-mu



- 1. Main goal for 2011 measurement: Updated measurement with increased Luminosity to get rid of the statistical limitation.
- 2. Use the well known Z peak to study various $\tau\tau$ mass reconstruction techniques.

- $\rightarrow$ 1.34fb^{-1} to 1.55fb^{-1} of 2011 data for high statistics and still low trigger thresholds for $Z \rightarrow \tau\tau$ studies!

Event Selection

- 2011 data with 1.34fb^{-1} to 1.55fb^{-1} is used.
- Usual ATLAS cleaning cuts and "good runs list" is used.

Trigger

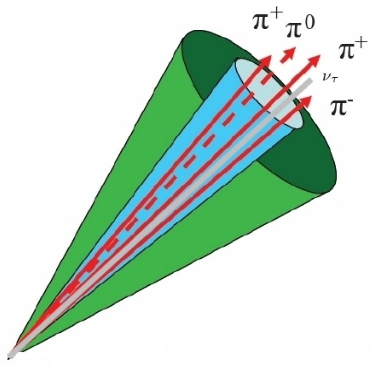
	tau-el channel	tau-mu channel + el-mu channel
• Trigger Stream:	JetTauEtmiss stream	Muons stream
• Lvl. 3 Trigger:	EF_tau16_loose_e15_medium	EF_mu15i, EF_mu15i_medium

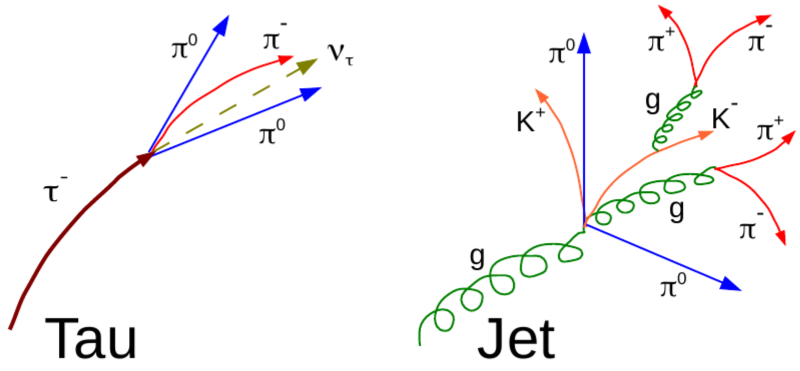
- Use of "exotic" triggers with the aim:
  - Have as low as possible p_T threshold of trigger → low offline p_T cut of the objects
  - To maximise signal efficiency of rel. low mass $Z \rightarrow \tau\tau$ signal, compared to Higgs searches.

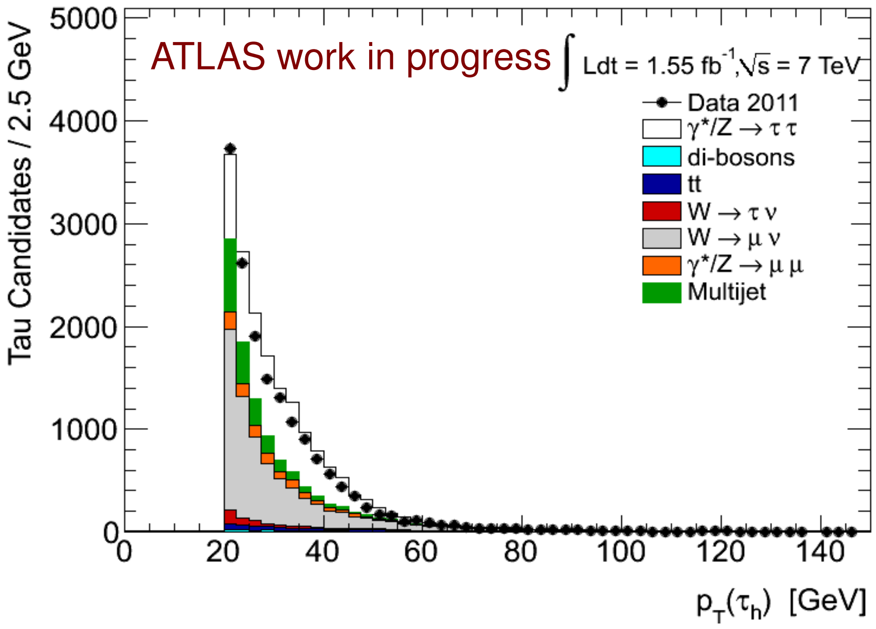
Object Selection - Tau

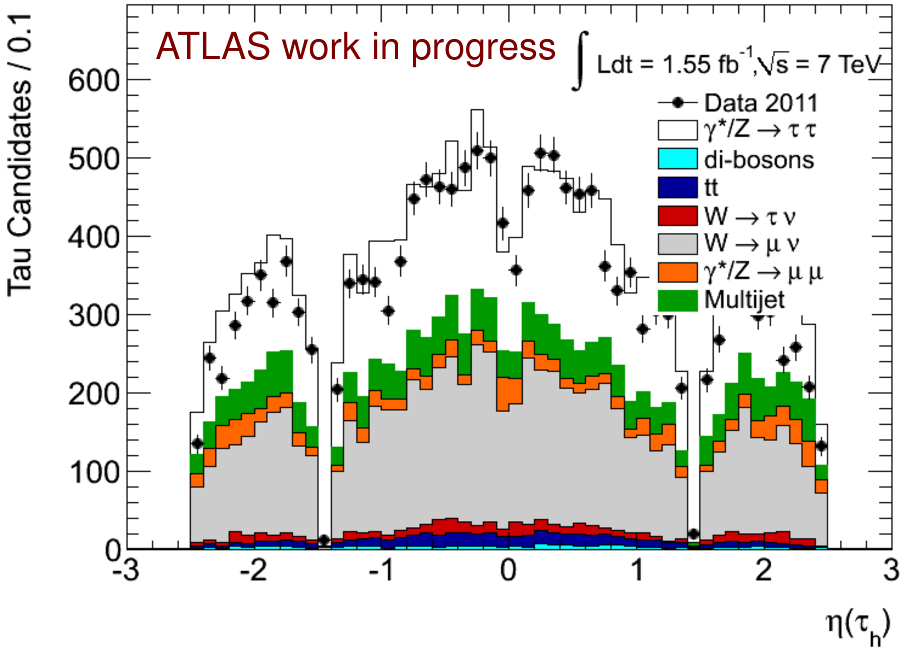
- E_T > 20.0 GeV (mu-τ_h)
- E_T > 25.0 GeV (el-τ_h)
- Eta < 2.47 / [1.37, 1.52]
- ID BDT medium
- Electron Veto Tight

Distinguish hadronic taus from multijets and electrons.









Object Selection - Leptons

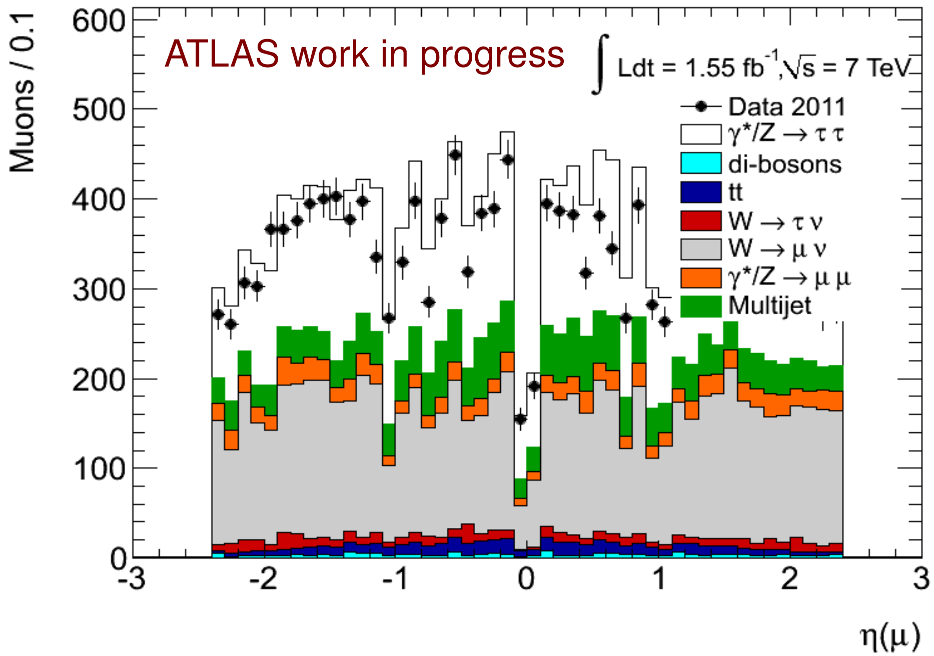
Muon

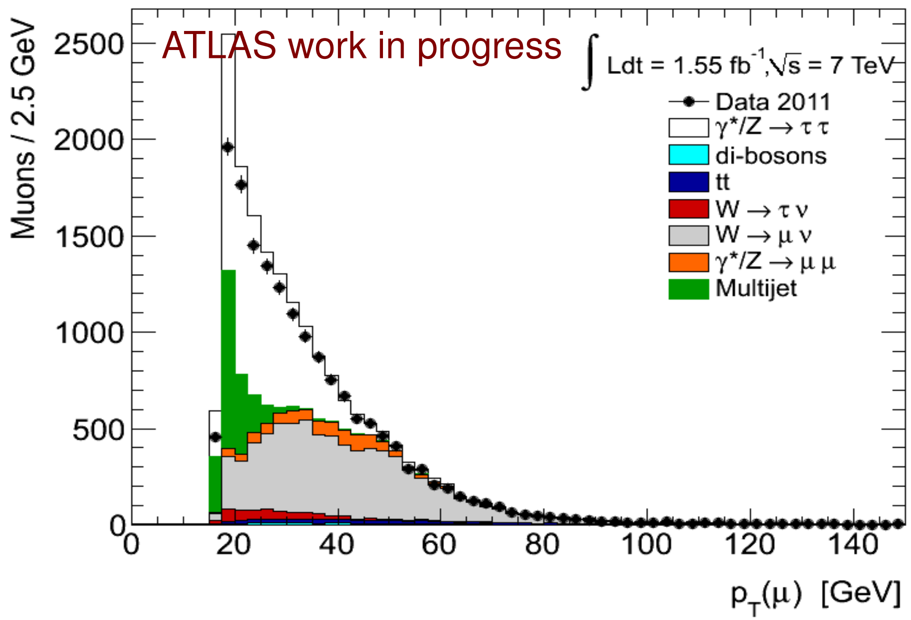
- P_T > 17.0 GeV
- Eta < 2.4
- "Staco Loose" identification
- E_TConeRel30 < 0.04
- P_TConeRel40 < 0.03

Electron

- P_T > 17.0 GeV
- Eta < 2.47 / [1.37, 1.52]
- Tight identification
- E_TConeRel40 < 0.10
- P_TConeRel40 < 0.06

Isolation cuts to supress Multijet background (more on next slide).

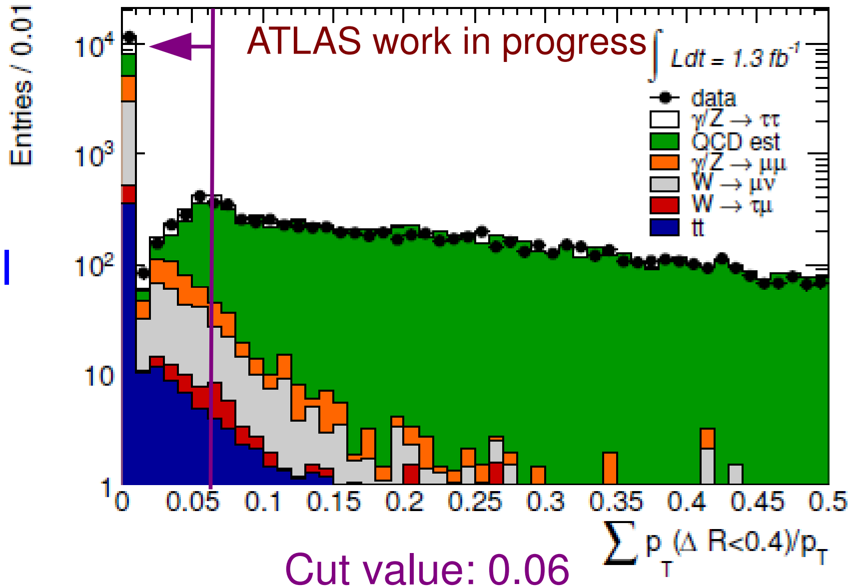




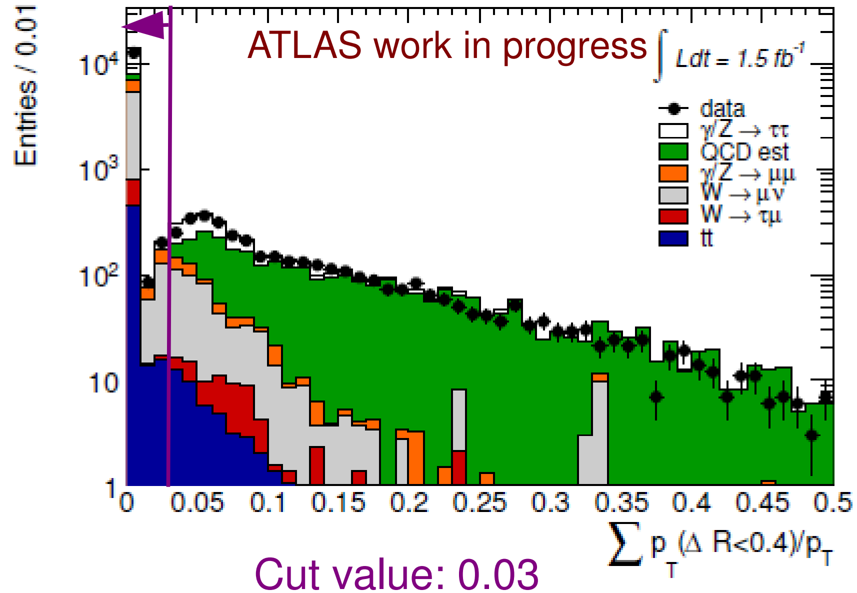
Lepton isolation

electron | muon

P_T cone rel

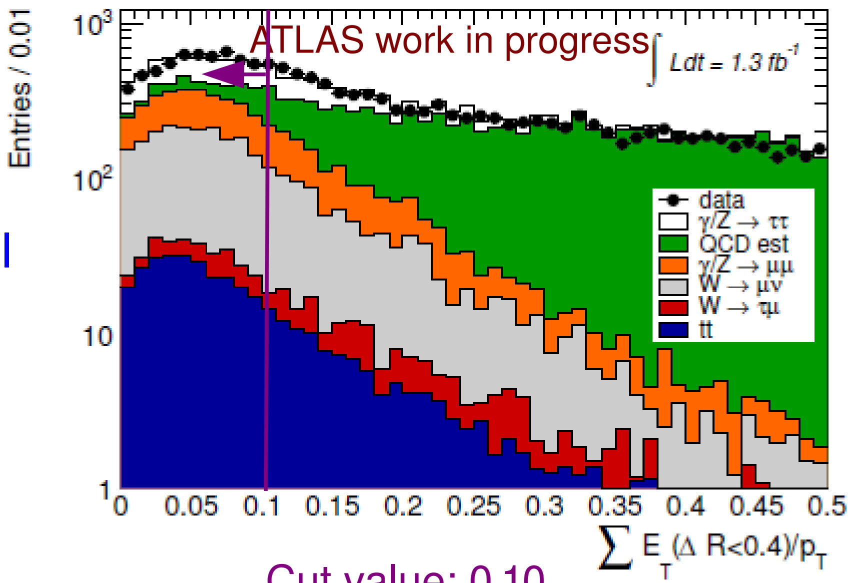


Cut value: 0.06

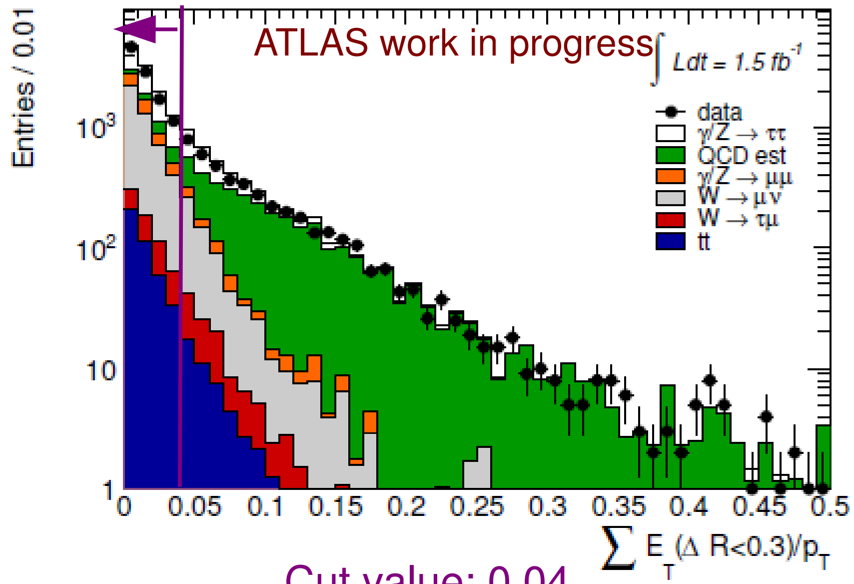


Cut value: 0.03

E_T cone rel



Cut value: 0.10



Cut value: 0.04

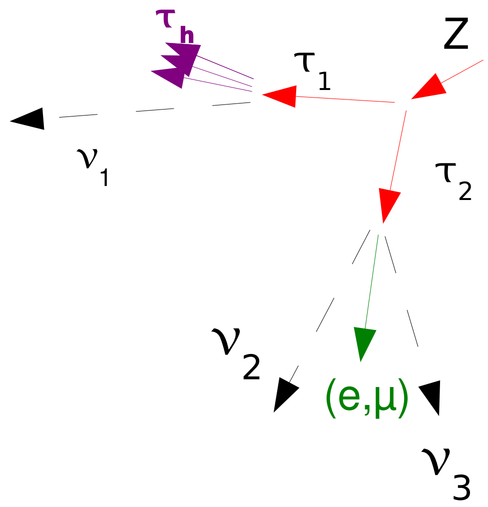
Further event selection

Requirements considered for the selection:

- **Dilepton veto** → Against $Z \rightarrow ll$ background
- **Opposite charge of lep and τ_h**
- **$\cos[\varphi(\text{lep}) - \varphi(E_T^{miss})] + \cos[\varphi(\tau_h) - \varphi(E_T^{miss})] > -0.15$**
- **Transverse mass $M_T(\text{lep}, E_T^{miss}) < 50$ GeV**

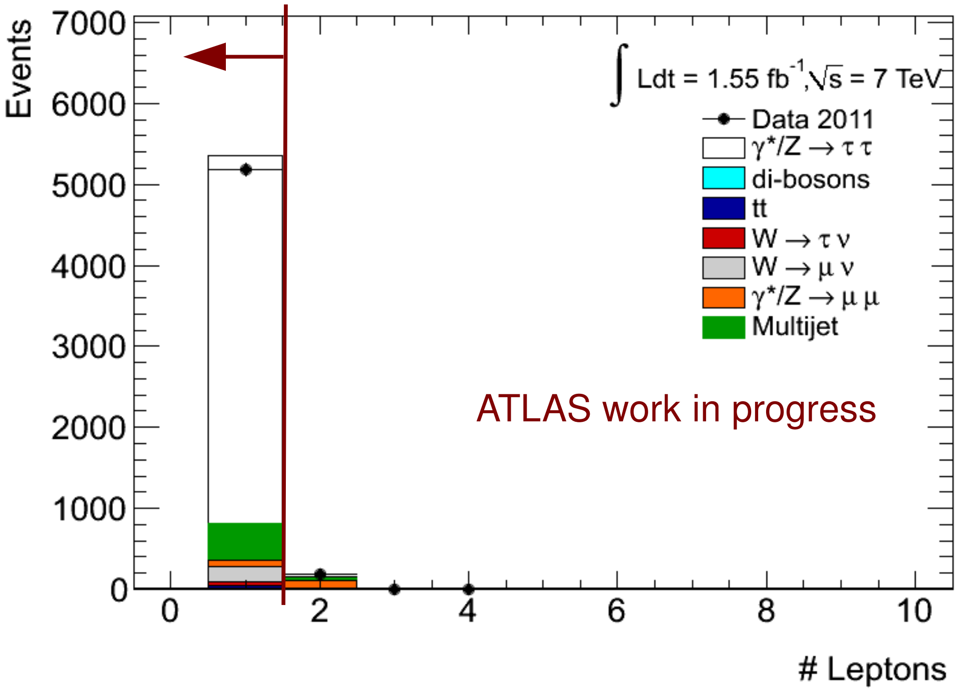
→ Against W+jets background

- **τ_h : N_{prong} = 1 or 3, |charge| = 1**
- **35 GeV < $M_{vis}(\text{lep}, \tau_h)$ < 75 GeV**



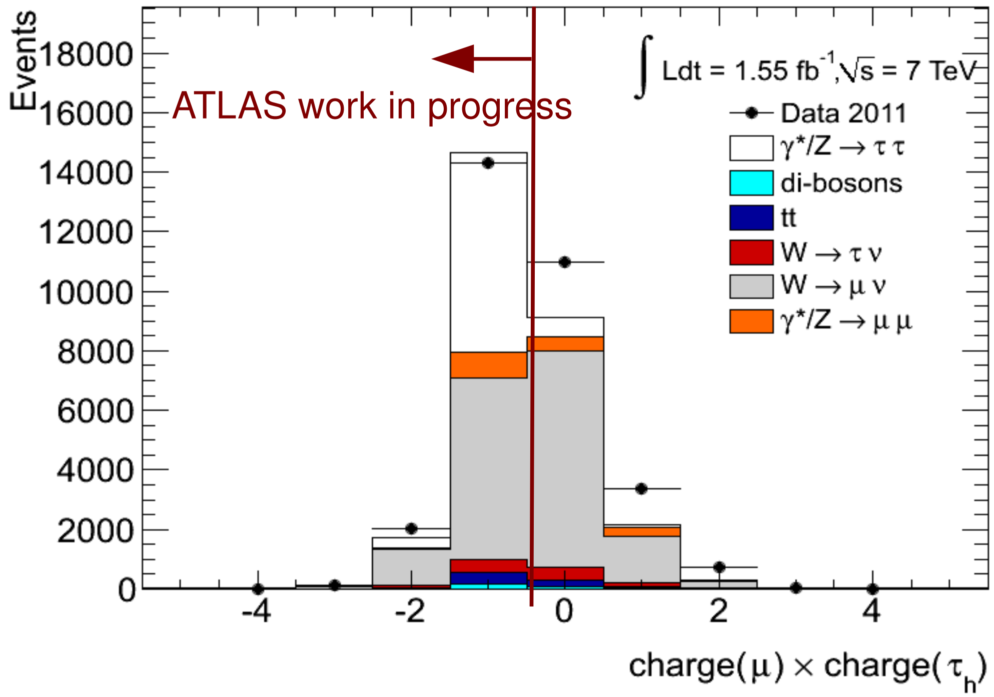
Kinematic distributions and cuts

Dilepton veto cut (muon channel):



Number of the selected leptons in the event.

Opposite sign cut (muon channel):

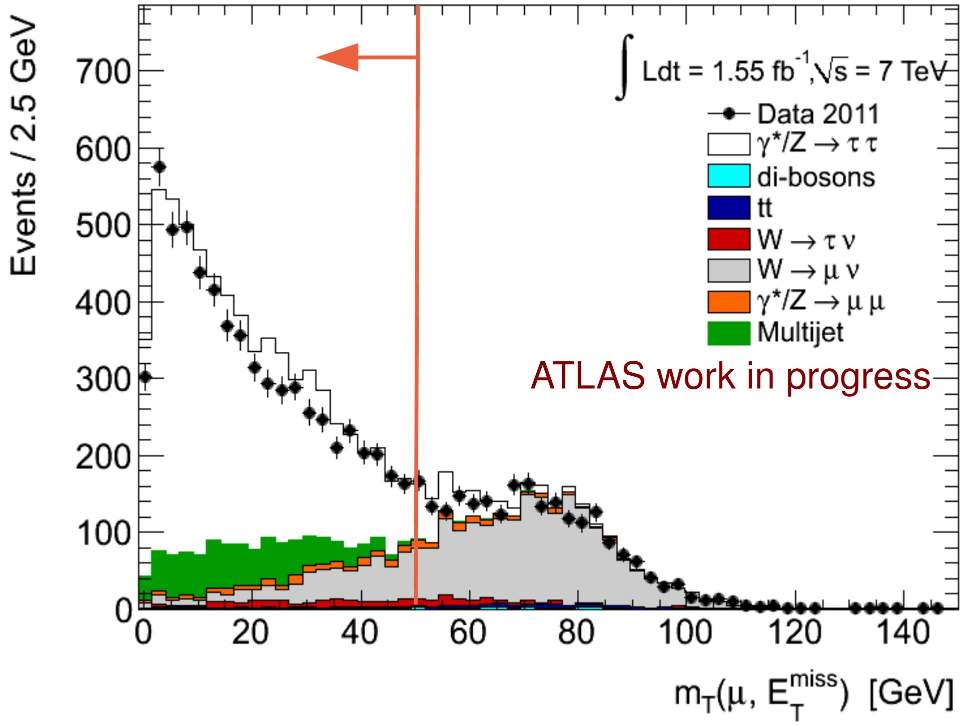


Product of the reconstructed charge of the tau and the lepton (No multijet estimation applied here).

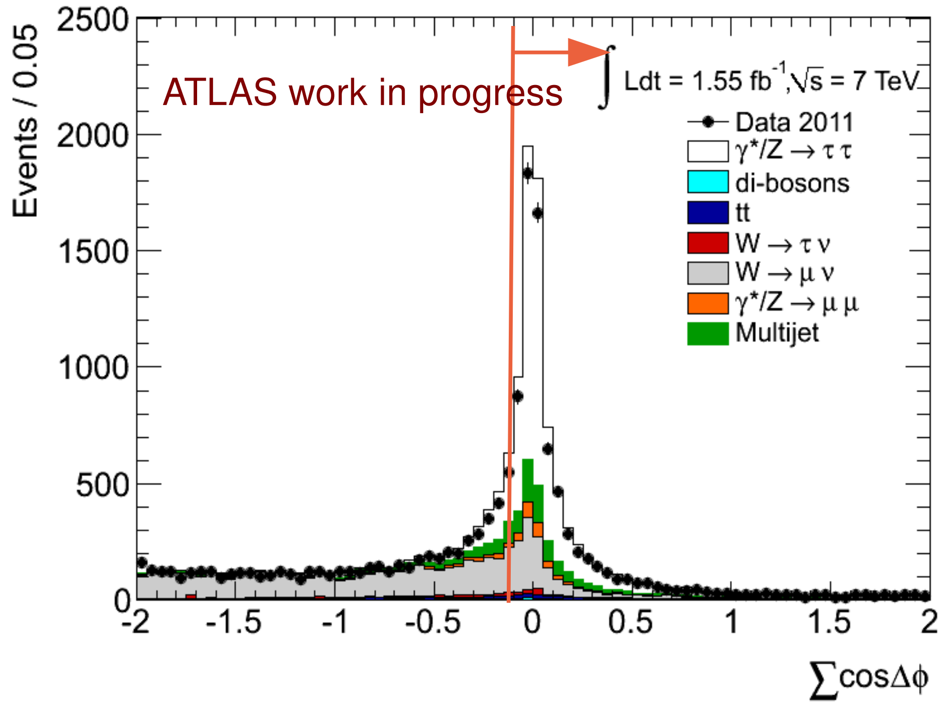
Kinematic distributions and cuts

Cuts against $W \rightarrow l\nu$ + jets background (muon channel):

Transverse Mass



cos[Δφ(lep, MET)] + cos[Δφ(tau, MET)]

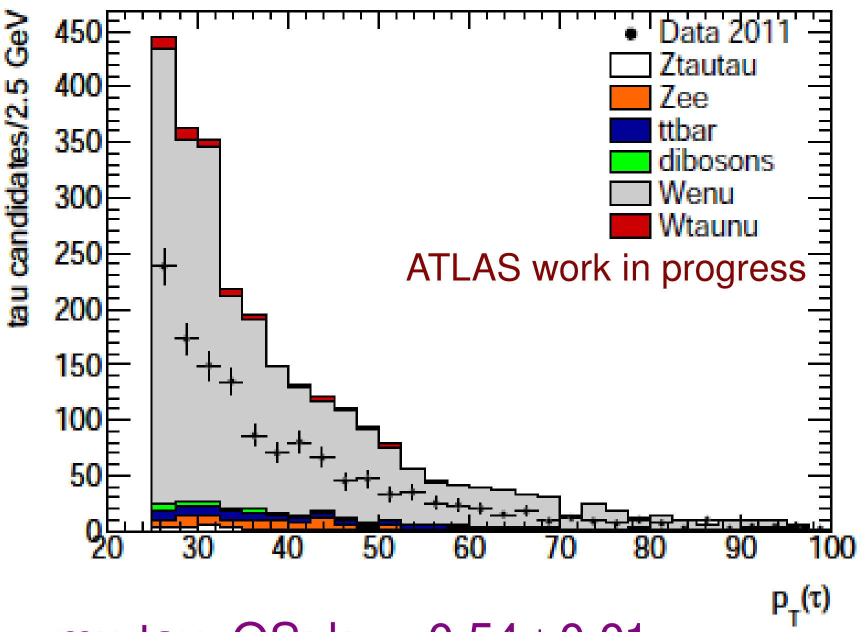


W+jets background normalisation

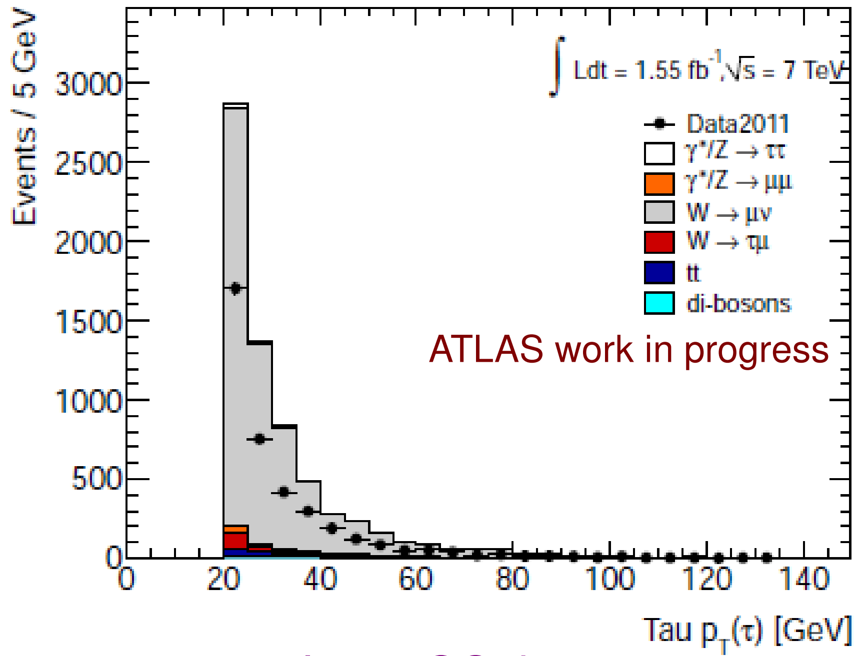
In W+jets and Z+jets MC samples, the tau fake rate is overestimated (Tau Id: BDT medium). This leads to a too high yield of MC events compared to data. Correction factors were obtained from control regions and applied to W+jets and Z+jets MC.

W+jets control region (inversion of W-cuts from previous slide):

electron-tau channel



muon-tau channel



mu-tau, OS: $k_W = 0.54 \pm 0.01$

mu-tau, SS: $k_W = 0.74 \pm 0.03$

el-tau, OS: $k_W = 0.46 \pm 0.02$

el-tau, SS: $k_W = 0.56 \pm 0.04$

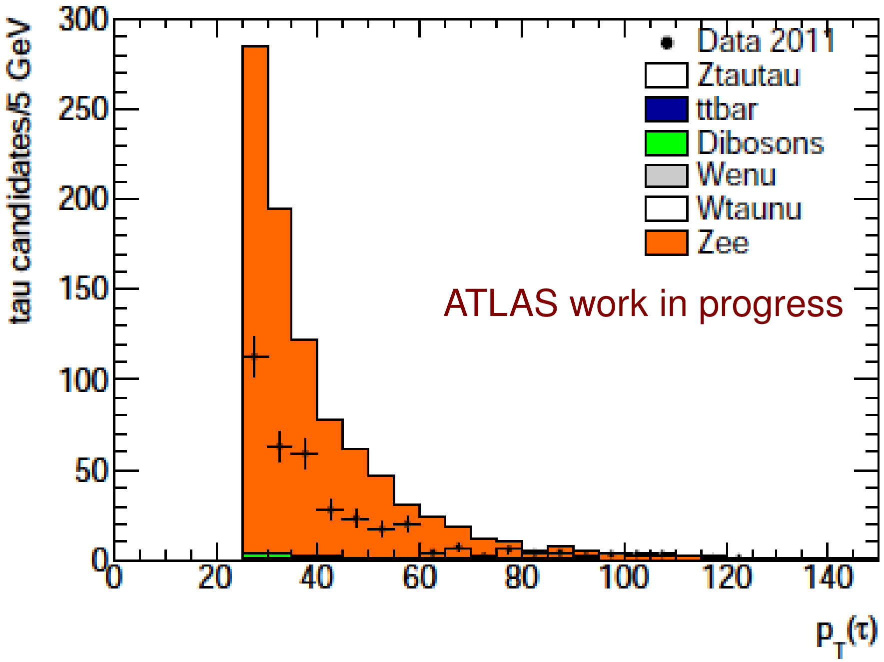
Plots are before applying the k_W factors.

Z+jets background normalisation

Z+jets control region, where a jet fakes the tau is chosen by requiring a second preselected lepton and the invariant mass of both leptons to be: 66GeV < M_{ll} < 116GeV.

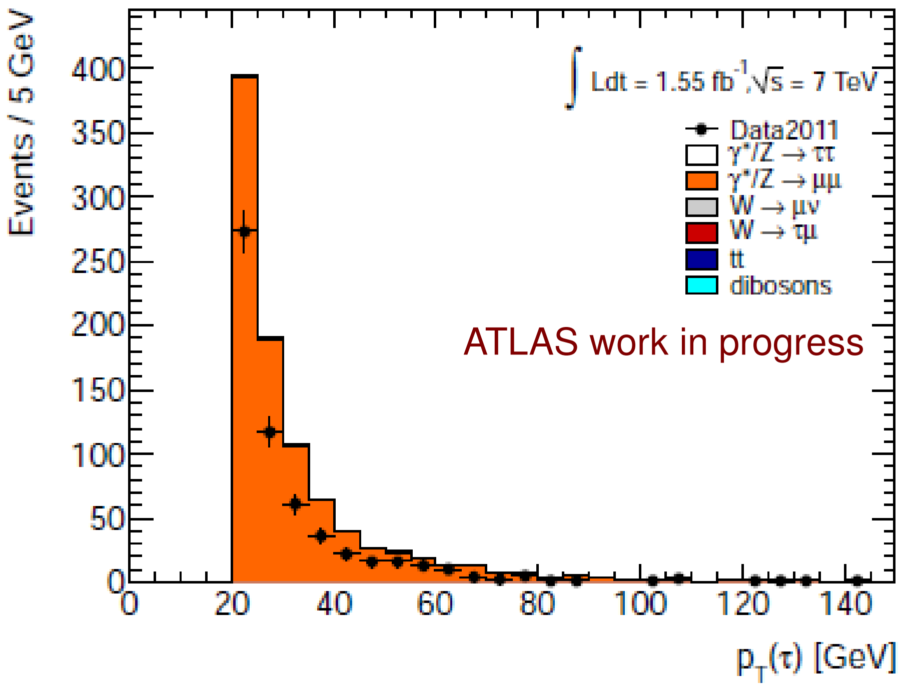
Z+jets control region:

muon-tau channel



mu-tau, OS: $k_W = 0.57 \pm 0.04$

electron-tau channel

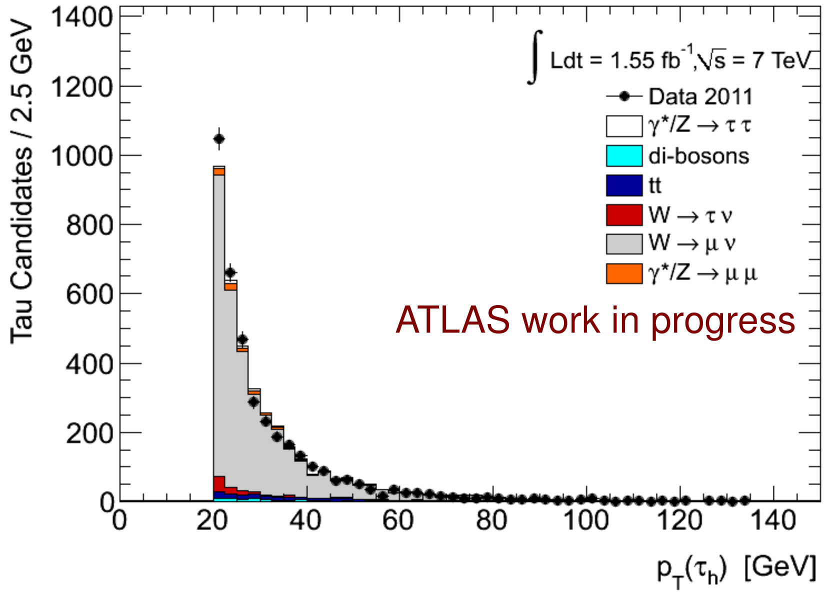


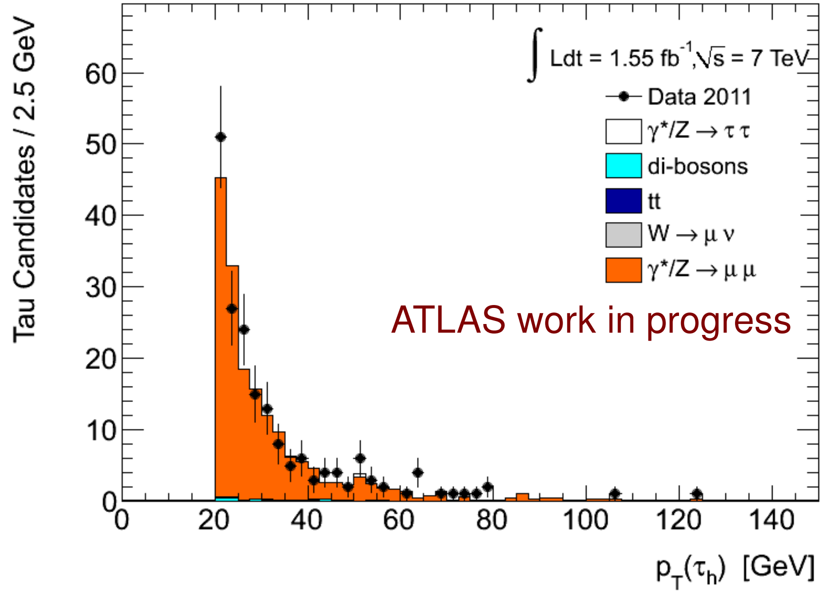
el-tau, OS: $k_W = 0.39 \pm 0.05$

Plots are before applying the k_W factors.

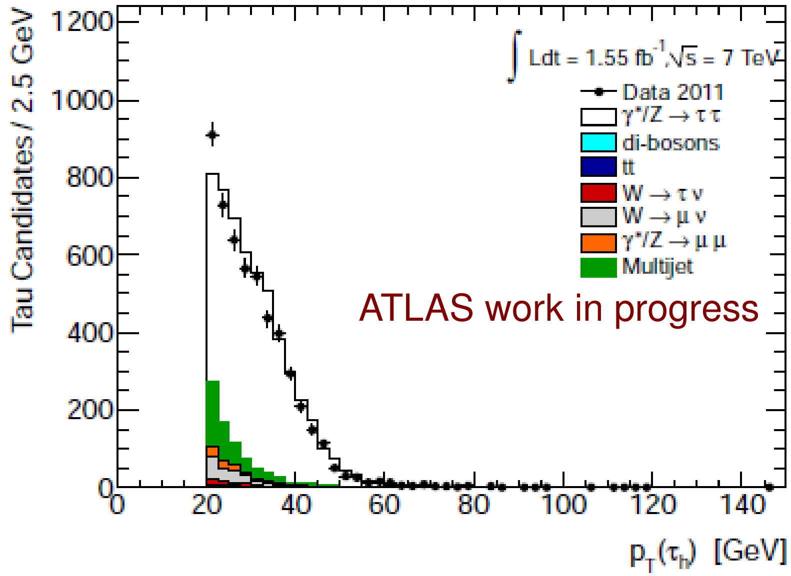
Distributions after correction

W- and Z control regions for muon-tau channel:



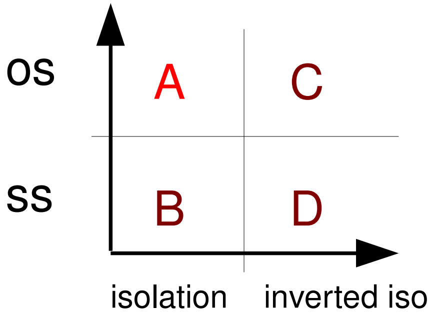


Tau pT distribution in signal region after final selection:



QCD Background estimation

- ABCD method with isolation/antiisolation and OS/SS ratio is used.
- OS: the charge-product of tau and lepton is negative (signal signature).
- SS: the charge-product of tau and lepton is positive (background signature).



$QCD^A = QCD^B * R_{OS/SS}$, with $R_{OS/SS} = QCD^C / QCD^D$

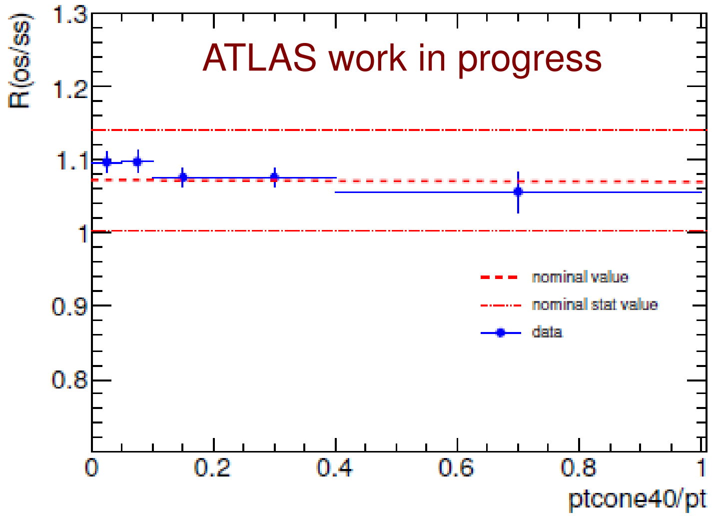
Measured:

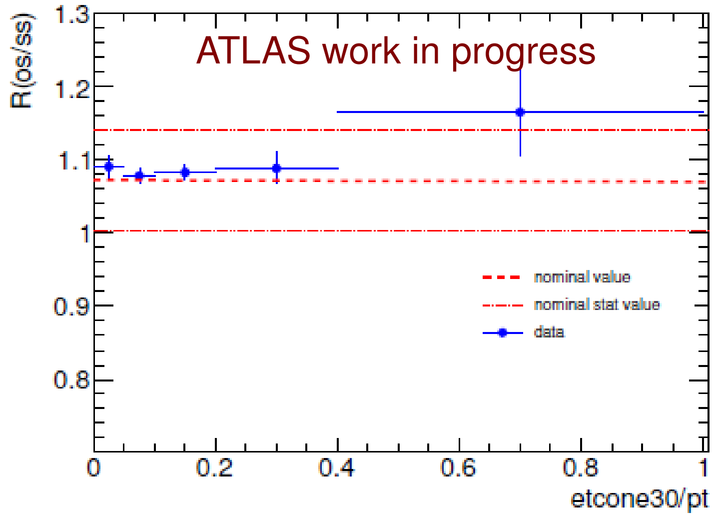
$R_{OS/SS}$(el-tau) $= 1.06 \pm 0.03$

$R_{OS/SS}$(mu-tau) $= 1.13 \pm 0.04$

$R_{OS/SS}$(el-mu) $= 2.20 \pm 0.22$

- $R_{OS/SS}$ is independent of the isolation within the statistical uncertainties (muon channel):

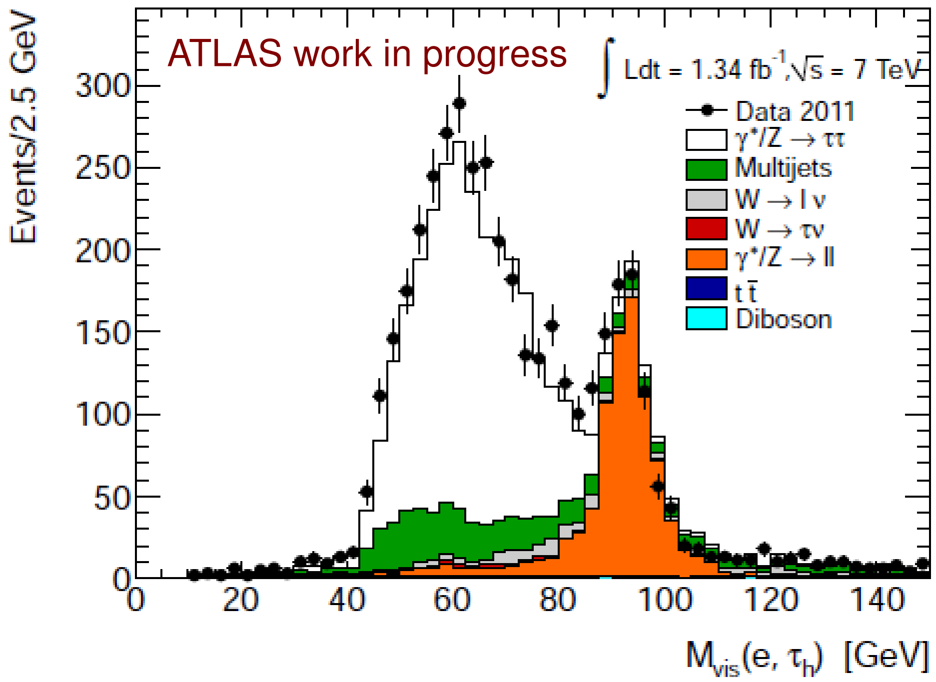




Kinematic distributions and cuts

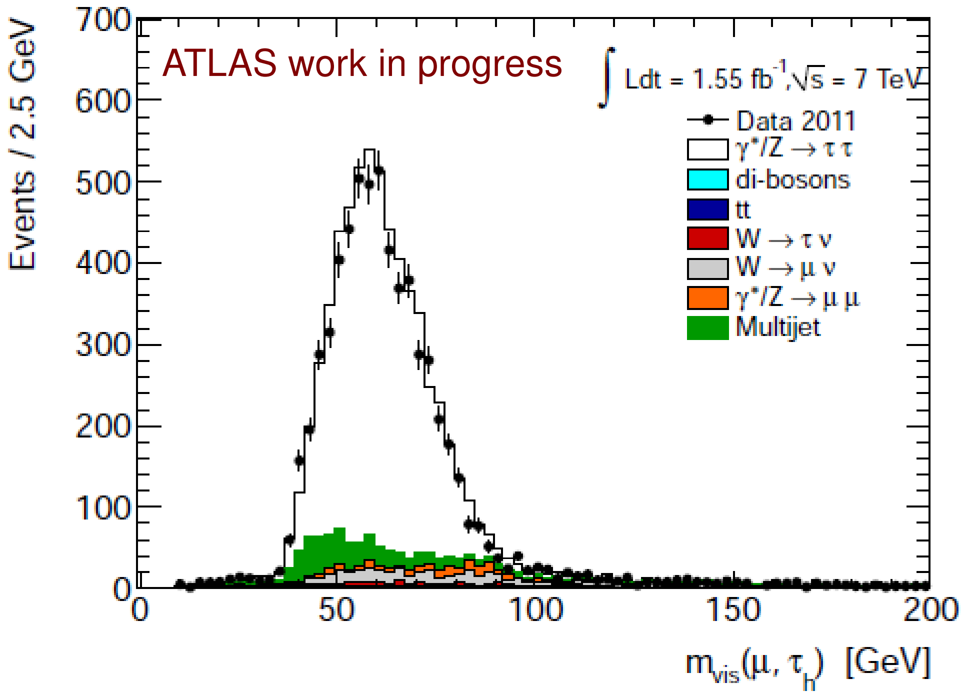
After applying some further tau-cleaning cuts (Charge = 1, NumTrack = 1 || 3), we obtain our final VisMass distributions:

el-had channel



(a) electron channel

mu-had channel



(b) muon channel

As can be seen: the electron-tau fake rate is much higher than the muon-tau fake rate!

For the final measurement, the events within the Mass window of 35GeV < Mvis < 75GeV are taken to further reduce Z→ee or Z→mumu background.

Systematic uncertainties

Systematic uncertainty	$\delta\sigma/\sigma$ (%) $\tau_\mu\tau_h$	$\delta\sigma/\sigma$ (%) $\tau_e\tau_h$	$\delta\sigma/\sigma$ (%) $\tau_e\tau_\mu$
lepton SF	1.7	+5.2/-4.7	6.2
muon resolution	< 0.01	-	< 0.01
electron resolution	-	0.1	0.2
jet resolution	-	-	1.7
LAr hole	-	0.02	< 0.01
τ id efficiency	+5.4/-4.9	+5.4/-4.9	-
electron-tau jet rate	-	0.2	-
e, τ, jet and E_T^{miss} energy scale	+8.9/-7.2	work in progress	4.1
tau trigger	-	+5.2/-4.1	-
k_W	0.03	0.05	-
k_Z	0.03	0.03	-
QCD estimation	0.74	0.5	0.7
MC cross sections	0.10	0.2	0.2
A_Z uncertainties	X	X	X
Total systematic unc.	+10.6/-8.9	+9.1/-8.0	7.7
Statistical uncertainty	2.1	2.7	5.3

ATLAS work in progress

Table 21: Systematic and statistical uncertainties on the total cross section measurement.

Most dominant systematics contributions. (red ellipse)

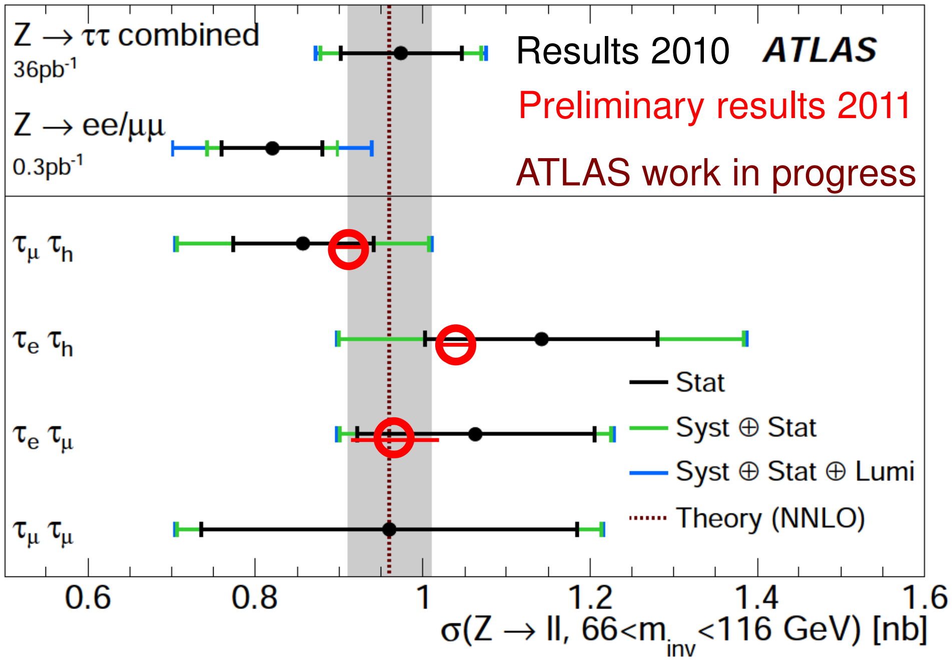
Preliminary calculated without Energy scale systematics. (blue ellipse)

Calculation of the cross-section

The Z $\rightarrow \tau\tau$ cross-section is calculated as:

$$\sigma(Z \rightarrow \tau\tau) \times BR = \frac{N_{data} - N_{background}}{A_Z \times C_Z \times \text{Luminosity}}$$

Comparison of preliminary obtained results with 2010 measurement and theory prediction ($960 \pm 50\ pb^{-1}$):



No systematic uncertainties included here!

Conclusions

- An updated measurement of the Z $\rightarrow \tau\tau$ cross-section is presented with increased statistics compared to the measurement with the 2010 data set in ATLAS.
- The result is in agreement with results obtained in 2010 and with the predictions from theory.
- Interesting: Isolated muon trigger and combined electron-tau trigger were used in this study.
- In addition various different mass reconstruction techniques were studied and compared within this analysis (not discussed further in this presentation).

Backup

- Monte Carlo samples used in this study -

Z + jets

Process	Dataset Number	AMI Tag	tauD3PD Tag	LO Cross Section * NNLO-factor [pb^{-1}]	Events
$Z \to \tau\tau$ ($m_{\ell\ell} > 60$ GeV) + Np0	107670	e844_s933_s946_r2302_r2300	01-01-06	6.6956E-01 * 1.25	6608784
$Z \to \tau\tau$ ($m_{\ell\ell} > 60$ GeV) + Np1	107671	e844_s933_s946_r2302_r2300	01-01-06	1.3465E-01 * 1.25	1327672
$Z \to \tau\tau$ ($m_{\ell\ell} > 60$ GeV) + Np2	107672	e844_s933_s946_r2302_r2300	01-01-06	4.0762E-02 * 1.25	403864
$Z \to \tau\tau$ ($m_{\ell\ell} > 60$ GeV) + Np3	107673	e844_s933_s946_r2302_r2300	01-01-06	1.1274E-02 * 1.25	109947
$Z \to \tau\tau$ ($m_{\ell\ell} > 60$ GeV) + Np4	107674	e844_s933_s946_r2302_r2300	01-01-06	2.8390E-03 * 1.25	29977
$Z \to \tau\tau$ ($m_{\ell\ell} > 60$ GeV) + Np5	107675	e844_s933_s946_r2302_r2300	01-01-06	7.6125E-04 * 1.25	9990
$Z \to ee$ ($m_{\ell\ell} > 60$ GeV) + Np0	107650	e737_s933_s946_r2302_r2300	01-01-06	6.6967E-01 * 1.25	6612265
$Z \to ee$ ($m_{\ell\ell} > 60$ GeV) + Np1	107651	e737_s933_s946_r2302_r2300	01-01-06	1.3441E-01 * 1.25	1333745
$Z \to ee$ ($m_{\ell\ell} > 60$ GeV) + Np2	107652	e737_s933_s946_r2302_r2300	01-01-06	4.0724E-02 * 1.25	404873
$Z \to ee$ ($m_{\ell\ell} > 60$ GeV) + Np3	107653	e737_s933_s946_r2302_r2300	01-01-06	1.1298E-02 * 1.25	109942
$Z \to ee$ ($m_{\ell\ell} > 60$ GeV) + Np4	107654	e737_s933_s946_r2302_r2300	01-01-06	2.8570E-03 * 1.25	29992
$Z \to ee$ ($m_{\ell\ell} > 60$ GeV) + Np5	107655	e737_s933_s946_r2302_r2300	01-01-06	7.5883E-04 * 1.25	8992
$Z \to \mu\mu$ ($m_{\ell\ell} > 60$ GeV) + Np0	107660	e737_s933_s946_r2302_r2300	01-01-06	6.6968E-01 * 1.25	6619010
$Z \to \mu\mu$ ($m_{\ell\ell} > 60$ GeV) + Np1	107661	e737_s933_s946_r2302_r2300	01-01-06	1.3464E-01 * 1.25	1334723
$Z \to \mu\mu$ ($m_{\ell\ell} > 60$ GeV) + Np2	107662	e737_s933_s946_r2302_r2300	01-01-06	4.0749E-02 * 1.25	403886
$Z \to \mu\mu$ ($m_{\ell\ell} > 60$ GeV) + Np3	107663	e737_s933_s946_r2302_r2300	01-01-06	1.1246E-02 * 1.25	109954
$Z \to \mu\mu$ ($m_{\ell\ell} > 60$ GeV) + Np4	107664	e737_s933_s946_r2302_r2300	01-01-06	2.8462E-03 * 1.25	29978
$Z \to \mu\mu$ ($m_{\ell\ell} > 60$ GeV) + Np5	107665	e737_s933_s946_r2302_r2300	01-01-06	7.6319E-04 * 1.25	9993

Table 1: List of Monte Carlo samples for Z+jets production. The samples are generated with AlpGen. The samples are split per number of initial partons (NpX, X=0, ..., 5) and they have been created with a minimum parton p_T cut at 20 GeV.

W + jets

Process	Dataset Number	AMI Tag	tauD3PD Tag	LO Cross Section * NNLO-factor [pb^{-1}]	Events
$W \to \tau\nu$ + Np0	107700	e844_s933_s946_r2302_r2300	01-01-06	6.9322E+00 * 1.20	3259564
$W \to \tau\nu$ + Np1	107701	e844_s933_s946_r2302_r2300	01-01-06	1.3047E+00 * 1.20	2496467
$W \to \tau\nu$ + Np2	107702	e844_s933_s946_r2302_r2300	01-01-06	3.7780E-01 * 1.20	3764804
$W \to \tau\nu$ + Np3	107703	e844_s933_s946_r2302_r2300	01-01-06	1.0190E-01 * 1.20	1008514
$W \to \tau\nu$ + Np4	107704	e844_s933_s946_r2302_r2300	01-01-06	2.5651E-02 * 1.20	248864
$W \to \tau\nu$ + Np5	107705	e844_s933_s946_r2302_r2300	01-01-06	6.9938E-03 * 1.20	64950
$W \to e\nu$ + Np0	107680	e600_s933_s946_r2302_r2300	01-01-06	6.9216E+00 * 1.20	3455037
$W \to e\nu$ + Np1	107681	e798_s933_s946_r2302_r2300	01-01-06	1.3054E+00 * 1.20	2499513
$W \to e\nu$ + Np2	107682	e760_s933_s946_r2302_r2300	01-01-06	3.7801E-01 * 1.20	3768265
$W \to e\nu$ + Np3	107683	e760_s933_s946_r2302_r2300	01-01-06	1.0185E-01 * 1.20	1009641
$W \to e\nu$ + Np4	107684	e760_s933_s946_r2302_r2300	01-01-06	2.5674E-02 * 1.20	249869
$W \to e\nu$ + Np5	107685	e760_s933_s946_r2302_r2300	01-01-06	7.0177E-03 * 1.20	69953
$W \to \mu\nu$ + Np0	107690	e600_s933_s946_r2302_r2300	01-01-06	6.9196E+00 * 1.20	3466523
$W \to \mu\nu$ + Np1	107691	e798_s933_s946_r2302_r2300	01-01-06	1.3055E+00 * 1.20	2499513
$W \to \mu\nu$ + Np2	107692	e760_s933_s946_r2302_r2300	01-01-06	3.7806E-01 * 1.20	3768893
$W \to \mu\nu$ + Np3	107693	e760_s933_s946_r2302_r2300	01-01-06	1.0196E-01 * 1.20	1009589
$W \to \mu\nu$ + Np4	107694	e760_s933_s946_r2302_r2300	01-01-06	2.5642E-02 * 1.20	254879
$W \to \mu\nu$ + Np5	107695	e760_s933_s946_r2302_r2300	01-01-06	6.9862E-03 * 1.20	69958

Table 2: List of Monte Carlo samples for W+jets process generated with AlpGen. The samples are split per number of partons produced (NpX, X=0, ..., 5) and they have been created with a minimum parton p_T cut at 20 GeV.

γ*/Z low mass / ttbar / di-boson

Process	Dataset Number	AMI Tag	tauD3PD Tag	LO Cross Section * NNLO-factor [pb^{-1}]	Even
$\gamma^*/Z \to \tau\tau$ (10 GeV < $m_{\ell\ell}$ < 60 GeV) + Np0	116270	e844_s933_s946_r2302_r2300	01-01-06	3055.1 * 1.25	9598
$\gamma^*/Z \to \tau\tau$ (10 GeV < $m_{\ell\ell}$ < 60 GeV) + Np1	116271	e844_s933_s946_r2302_r2300	01-01-06	84.93 * 1.25	2969
$\gamma^*/Z \to \tau\tau$ (10 GeV < $m_{\ell\ell}$ < 60 GeV) + Np2	116272	e844_s933_s946_r2302_r2300	01-01-06	41.47 * 1.25	4988
$\gamma^*/Z \to \tau\tau$ (10 GeV < $m_{\ell\ell}$ < 60 GeV) + Np3	116273	e844_s933_s946_r2302_r2300	01-01-06	8.36 * 1.25	1499
$\gamma^*/Z \to \tau\tau$ (10 GeV < $m_{\ell\ell}$ < 60 GeV) + Np4	116274	e844_s933_s946_r2302_r2300	01-01-06	1.85 * 1.25	399
$\gamma^*/Z \to \tau\tau$ (10 GeV < $m_{\ell\ell}$ < 60 GeV) + Np5	116275	e844_s933_s946_r2302_r2300	01-01-06	0.46 * 1.25	99
$\gamma^*/Z \to ee$ (15 GeV < $m_{\ell\ell}$ < 60 GeV) + Np0	116250	e660_s933_s946_r2302_r2300	01-01-06	3055.2 * 1.25	9998
$\gamma^*/Z \to ee$ (15 GeV < $m_{\ell\ell}$ < 60 GeV) + Np1	116251	e660_s933_s946_r2302_r2300	01-01-06	84.92 * 1.25	2999
$\gamma^*/Z \to ee$ (15 GeV < $m_{\ell\ell}$ < 60 GeV) + Np2	116252	e660_s933_s946_r2302_r2300	01-01-06	41.41 * 1.25	4998
$\gamma^*/Z \to ee$ (15 GeV < $m_{\ell\ell}$ < 60 GeV) + Np3	116253	e660_s933_s946_r2302_r2300	01-01-06	8.38 * 1.25	1499
$\gamma^*/Z \to ee$ (15 GeV < $m_{\ell\ell}$ < 60 GeV) + Np4	116254	e660_s933_s946_r2302_r2300	01-01-06	1.85 * 1.25	399
$\gamma^*/Z \to ee$ (15 GeV < $m_{\ell\ell}$ < 60 GeV) + Np5	116255	e660_s933_s946_r2302_r2300	01-01-06	0.46 * 1.25	99
$\gamma^*/Z \to \mu\mu$ (15 GeV < $m_{\ell\ell}$ < 60 GeV)+ Np0	116260	e660_s933_s946_r2302_r2300	01-01-06	3054.9 * 1.25	9998
$\gamma^*/Z \to \mu\mu$ (15 GeV < $m_{\ell\ell}$ < 60 GeV)+ Np1	116261	e660_s933_s946_r2302_r2300	01-01-06	84.87 * 1.25	2998
$\gamma^*/Z \to \mu\mu$ (15 GeV < $m_{\ell\ell}$ < 60 GeV)+ Np2	116262	e660_s933_s946_r2302_r2300	01-01-06	41.45 * 1.25	4998
$\gamma^*/Z \to \mu\mu$ (15 GeV < $m_{\ell\ell}$ < 60 GeV)+ Np3	116263	e660_s933_s946_r2302_r2300	01-01-06	8.38 * 1.25	1499
$\gamma^*/Z \to \mu\mu$ (15 GeV < $m_{\ell\ell}$ < 60 GeV)+ Np4	116264	e660_s933_s946_r2302_r2300	01-01-06	1.85 * 1.25	399
$\gamma^*/Z \to \mu\mu$ (15 GeV < $m_{\ell\ell}$ < 60 GeV)+ Np5	116265	e660_s933_s946_r2302_r2300	01-01-06	0.46 * 1.25	99

Table 3: List of Monte Carlo samples for Drell Yan process. The samples are generated with AlpGen. The samples are split per number of partons produced (NpX, X=0, ..., 5) and they have been created with a minimum parton p_T cut at 20 GeV.

Process	Dataset Number	AMI Tag	tauD3PD Tag	Cross Section [pb^{-1}]	Events
$t\bar{t}$ (no fully hadronic decays)	105200	e844_s933_s946_r2302_r2300	01-01-06	90.15	14845714
WW	105985	e598_s933_s946_r2302_r2300	01-01-06	17.02	2495756
ZZ	105986	e598_s933_s946_r2302_r2300	01-01-06	5.54	249906
WZ	105987	e598_s933_s946_r2302_r2300	01-01-06	1.26	249923

Table 4: List of Monte Carlo samples for $t\bar{t}$ process generated with MC@NLO and for diboson production generated with Herwig.