$Z^0 \rightarrow \tau^+\tau^-$
Prospects for hadronic τ efficiency determination in first data and the Charge Asymmetry problem

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Schedule

Motivation for $\mathrm{Z}^0 \to \tau^+\tau^- \to had\,\ell$

Selection Strategy

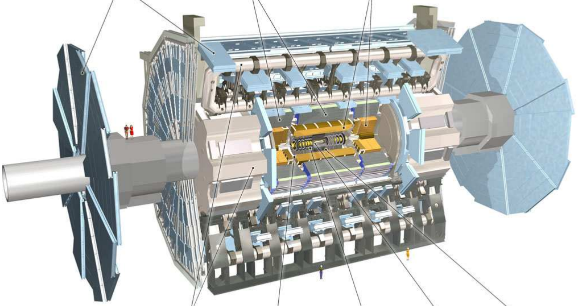
Efficiency determination

Summary and Outlook

$Z^0 \to \tau^+\tau^- \to had\,\ell$

- τ leptons are an important final state for different SUSY scenarios
- most important control channel (together with $W \to \tau\nu$ and $t \to \tau\nu b$) to control the tau reconstruction
- Challenge to suppress the backgrounds due mainly to QCD and $W \to \tau\nu$, $W \to \mu\nu$ and $W \to e\nu$ channels
- Comparison with $Z^0 \to \mu^+\mu^-$ or $Z^0 \to e^+e^-$ allows efficiency determination using Z-Resonance

ATLAS Detector at LHC



- BR for $\tau \to$ hadron of about 68 $\%$ but difficult do identify due to the QCD background
- fortunately different behaviour of hadronic decaying Tau (Tau-Jet) and QCD dijets $\Longrightarrow$ important to have a good tracking and (high granularity) calorimeter system

Used data sets

- event weight corrosponds to luminosity $\mathcal{L}$ = 100 pb^{-1}
- cross section σ for LO $\longrightarrow N_{expect.events}$ = $\mathcal{L} \cdot \sigma$

Signal	Number events	event weight
Ztautau	109917	1.3

BG	events	weight	**BG**	events	weight
DiJet(8-17)GeV	1,68 Mio	696167	**Zee**	169099	0.67
DiJet(17-35)GeV	338777	253687	**Zmumu**	148029	0.7
DiJet(35-70)GeV	247796	23030	**Wenu**	340457	3.5
DiJet(70-140)GeV	134073	245	**Wmunu**	290073	4.1
DiJet(140-280)GeV	15031	123	**Wtaunu**	563719	2
DiJet(280-560)GeV	19678	25	**ttbar**	14685	3.4

- all muons in (Tau-Jet, Tau-Muon) combinations are truth matched muons $\Rightarrow$ Jet samples including truth lepton filter needed $\Rightarrow$ could decrease the effective event weight to $\mathcal{O}(1)$
- in general more statistic is needed!

Selection cuts

Trigger:

Electron: e10_medium
Muon: mu10i

Event Cuts:

Missing $E_T > 12$ GeV (QCD BG reduction)
Sum $P_T < 400$ GeV (QCD BG reduction)

general cuts for single particle:

$P_T > 12$ GeV (for Tau-Jet or Lepton candidate)
$|Charge|$=1
$|\eta|$ <2.5
m_T <30 GeV (supresses semileptonic events from W decay)

general cuts for Tau-Jet,Tau-Lepton combinations:

$1 < |\Delta\Phi_{TauJet,Lepton}|$ <2.9 (rejects back to back jets)
opposite and same sign charge
37 GeV<invariant Mass<75 GeV

Selection cuts for particle identification

tau identification:

track multiplicity: 1 or 3
TauLikelihood $>$ 2 (τ-Jet/QCD-Jet separation)
TauElTauLikelihood $>$ -4 (τ/e separation)
Δ R(Jet,Tau-Jet) $>$0.4

electron identification:

IsEM=0
El_EtCone20 $<$ 5 GeV
Δ R(Electron,Tau-Jet) $>$0.4

muon identification:

Mu_EtCone20 $<$ 5 GeV
Δ R(Muon,Tau-Jet) $>$0.4

Number of combinations for signal and background ($\mathcal{L}$ = 100 pb^{-1})

Tau-Jet,Lepton	**Signal**	**Background**
$1 < |\Delta\Phi| <$2.9	300	257
opposite sign	278	182
37 GeV $<$invMass-OS$<$75 GeV	208	96
same sign	22	75
37 GeV $<$invMass-SS$<$75 GeV	15	42
Tau-Jet,Electron	**Signal**	**Background**
$1 < |\Delta\Phi| <$2.9	133	60
opposite sign	120	38
37 GeV $<$invMass-OS$<$75 GeV	86	20
same sign	13	22
37 GeV $<$invMass-SS$<$75 GeV	4	15
Tau-Jet,Muon	**Signal**	**Background**
$1 < |\Delta\Phi| <$2.9	167	197
opposite sign	158	144
37 GeV $<$invMass-OS$<$75 GeV	122	76
same sign	9	53
37 GeV $<$invMass-SS$<$75 GeV	11	27

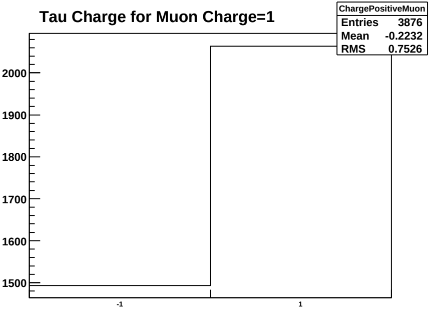
BREAK Statistic (for $\mathcal{L}$ = 100 pb^{-1})

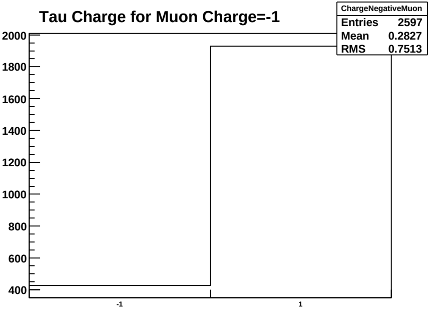
- Problem with old $\mathrm{W} \rightarrow \mu\nu$ sample $\Longrightarrow$ choose another sample (splitted in 0 partons to 5 partons)
- that means, different number of final state partons

Sample	exp. events	mc events	event weight
Np0	1012500	272560	3.71
Np1	215500	60580	3.55
Np3	20200	42740	0.47
Np4	5500	11900	0.46
Np5	1650	3500	0.47

Charge Asymmetry

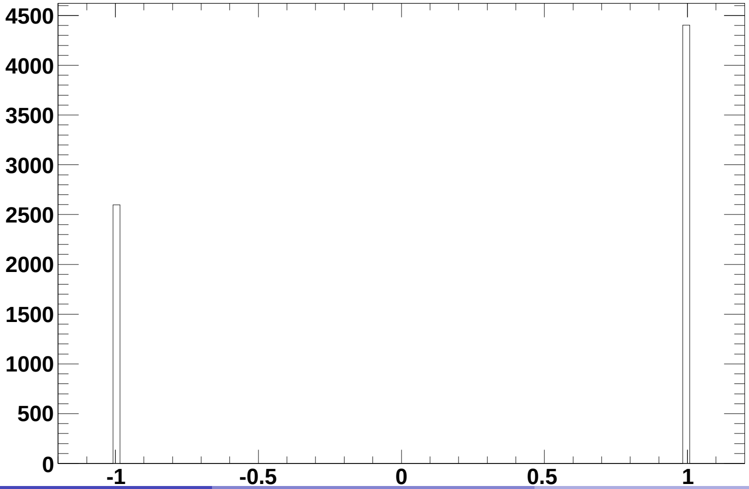
- test with $W \to \mu\nu$ (all final states, not normalized, no cuts!)
- Slightly different charge distribution





Charge distribution for W decay (truth information)

- (all final states, not normalized, no cuts!)
  WDecay_charge {WDecay_charge != 0}



Cut Flow (again for $\mathcal{L}$ = 100 pb^{-1})

- Cut flow for $\mathrm{W} \rightarrow \mu\nu$
- OS-SS asymmetry dominated by production with less final state partons
-

	m_T<30 GeV		m_T>30 GeV	
sample	os	ss	os	ss
0 partons	14,8	11,1	240,1	102,3
1 parton	10,7	3.6	510,7	100,4
2 partons	bug	bug	bug	bug
3 partons	2,4	3,3	70,0	31,7
4 partons	0	0	18,4	17,0
5 partons	0	0	2,8	2,8
All	**28,3**	**18,3**	**642**	**241**

Number of tau candidates

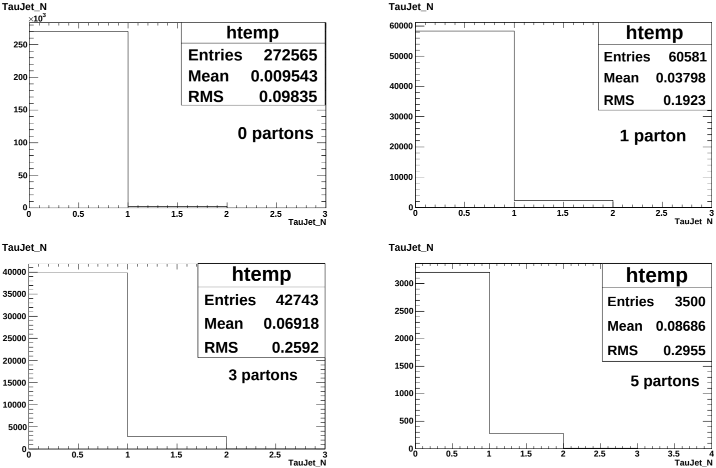


Figure: For Number of partons = 0 and 1 (top) and 3 and 5 (bottom)

Charge distribution for tracks

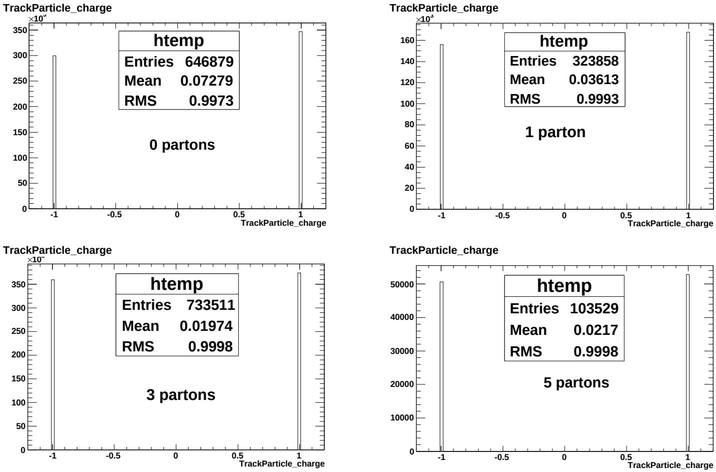


Figure: For Number of partons = 0 and 1 (top) and 3 and 5 (bottom)

CONTINUE! Final Number of Tau-Jet,Lepton Comb. for signal & bg ($\mathcal{L}$ = 100 pb^{-1})

- after all cuts within "invariant mass window" 37 GeV $< M_{inv} <$ 75 GeV

Sample	# OS (Tau-Jet,Lepton)	# SS (Tau-Jet,Lepton)	σ_{OS-SS}
$\mathrm{Z}^0 \rightarrow \tau\tau$	208	15	
DiJet (8-560)GeV [1]	0	0	-
$\mathrm{Z}^0 \rightarrow ee$	2	2	0
$\mathrm{Z}^0 \rightarrow \mu\mu$	6	4	1.2
$\mathrm{W} \rightarrow \tau\nu$	29	10	2
$\mathrm{W} \rightarrow \mu\nu$	36	12	2.7
$\mathrm{W} \rightarrow e\nu$	14	10	1.5
ttbar [2]	7	3	0.6

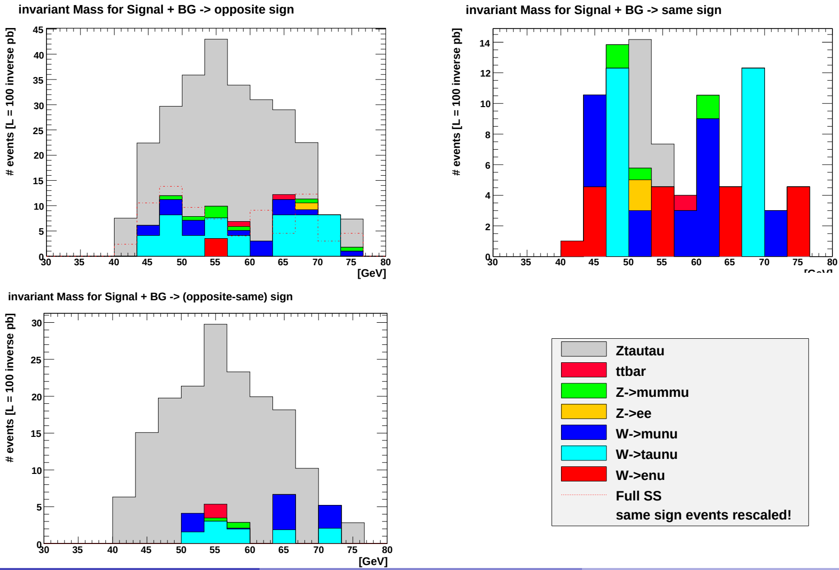
- intrinsic charge asymetry in $\mathrm{W} \rightarrow \ell\nu$ because of initial $pp \rightarrow W$ production which is slightly dominated by W^+

[1] not realistic because of event weight

[2] OS-SS asymmetry because of small statistic

visible invariant Z mass for signal + BG

ATLAS unofficial



τ-efficiency

hadronic τ Efficiency is defined as:

$$\epsilon_{\tau\rightarrow had} = \frac{N^{sel}_{Z^0\rightarrow\tau^+\tau^-}}{N^{ini}_{Z^0\rightarrow\tau^+\tau^-} \cdot BR_{\tau\rightarrow had} \cdot BR_{\tau\rightarrow lep} \cdot \epsilon^{kin}_{Z^0\rightarrow\tau^+\tau^-} \cdot \epsilon_{\tau\rightarrow lep}} \quad (1)$$

possible to substitute $N^{ini}_{Z^0\rightarrow\tau^+\tau^-}$

with

$$\frac{N^{sel}_{Z^0\rightarrow\mu^+\mu^-} \cdot \frac{BR_{Z^0\rightarrow\mu^+\mu^-}}{BR_{Z^0\rightarrow\tau^+\tau^-}}}{\epsilon^{kin}_{Z^0\rightarrow\mu^+\mu^-} \cdot \epsilon^2_{\mu}} \quad (2)$$

Finally for efficiency calculation:

$$\epsilon_{\tau\rightarrow had} = \frac{\epsilon^{kin}_{Z^0\rightarrow\mu^+\mu^-}}{\epsilon^{kin}_{Z^0\rightarrow\tau^+\tau^-}} \cdot \frac{N^{sel}_{Z^0\rightarrow\tau^+\tau^-} \cdot BR_{Z^0\rightarrow\mu^+\mu^-} \cdot \epsilon_{\mu}}{N^{sel}_{Z^0\rightarrow\mu^+\mu^-} \cdot BR_{\tau\rightarrow lep} \cdot BR_{\tau\rightarrow had} \cdot BR_{Z^0\rightarrow\tau^+\tau^-}} \quad (3)$$

Parameter

- all BR available from PDG
- kinematic efficiencies (systematic studies for uncertainties of kin. efficiencies upcoming! Assume error $\mathcal{O}(10\ \%)$ just in order to check whether this would lead to acceptable order of magnitude of overall error)

  $\epsilon^{kin}_{Z^0\rightarrow\mu^+\mu^-}$ = 0.26 $\pm$ 0.026

  $\epsilon^{kin}_{Z^0\rightarrow\tau^+\tau^-}$ = 0.0230 $\pm$ 0.002
- selected number of events

  $N^{sel}_{Z^0\rightarrow\tau^+\tau^-}$ = 208 $\pm$ 14

  $N^{sel}_{Z^0\rightarrow\mu^+\mu^-}$ = 21517 $\pm$ 147
- Muon efficiency (uncertainty from ATLAS Note)

$$\epsilon_\mu = \sqrt{\frac{\frac{N^{sel}_{Z^0\rightarrow\mu^+\mu^-}}{\sigma_{Z^0\rightarrow\mu^+\mu^-}\cdot 100pb^{-1}}}{\epsilon^{kin}_{Z^0\rightarrow\mu^+\mu^-}}} = 0.85 \pm 0.05$$

Current values for hadronic efficiency

- Tau-Jet,Tau-Lepton combinations for $\mathcal{L}$ = 100 pb^{-1}
- SS events for background rescaled! (from MC events)

Signal	**OS**	**SS**
selected taus	208	11
selected taus truthmatched	201	2
Background	**OS**	**SS**
selected taus	96	91

- **hadronic efficiency** ϵ_{had} **for (OS-SS)** (uncertainty with error propagation)

  ϵ_{had} (Signal) = 0.537 $\pm$ 0.0642

  ϵ_{had} (Signal (truth)) = 0.542 $\pm$ 0.0654

  ϵ_{had} (Signal + BG) = 0.550 $\pm$ 0.073
- effects from selection uncertainties have to be studied in detail

Conclusion and Outlook

Summary:

- efficiency determination works in principle (with uncertainty of about 14 $\%$ if systematic in kinematic efficiency is at level of 10 $\%$)
- need to control systematics of $\frac{\epsilon^{kin}_{Z^0 \to \mu^+\mu^-}}{\epsilon^{kin}_{Z^0 \to \tau^+\tau^-}}$ at 10 $\%$ level
- current hadronic τ efficiency is 0.550 $\pm$ 0.073
- asymmetry in OS-SS for $W \to \ell\nu$
- much more statistic for better description of W and Jet BG needed

Outlook:

- start with detailed systematic studies
- use and check specific cut optimization to improve the selection (purity...)
- higher statistic of QCD background $\longrightarrow$ truth filter for lepton
- can be used for first data