POLARIZATION IN W->τν DECAYS AT ATLAS

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on behalf of the ATLAS Collaboration

tau polarization

longitudinal tau polarization: relative production of positive (right-handed) and negative (left-handed) chiral (helicity) states (in relativistic limit) for τ^-

$$P_\tau = \frac{\sigma_R - \sigma_L}{\sigma_R + \sigma_L}$$

motivations

- tests of Standard Model
- searches for new physics
- reject irreducible backgrounds

LHC measurements

- W->τν at ATLAS

Process	P_τ
W->τν	-1
H->ττ	0
$H^\pm$->τν	+1
Z->ττ	≅-0.15

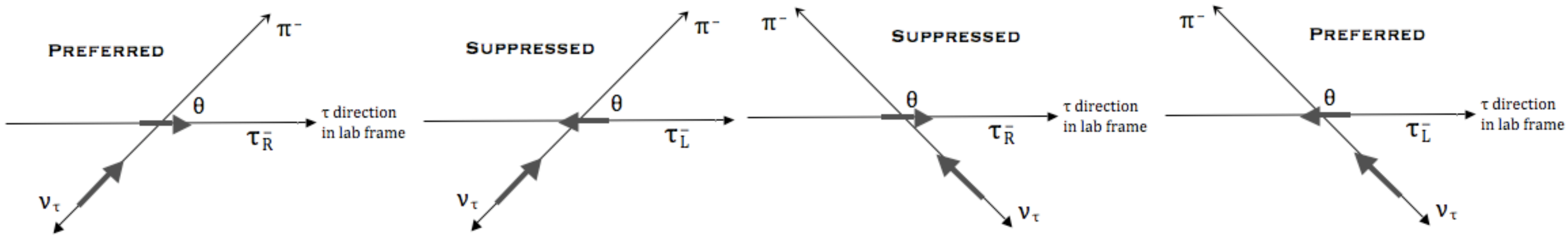
tau decays

- taus are only leptons on which spin analyses can be performed

Channel	Dominant Decay Mode	BR [%]
$e^-\bar{\nu}\nu$	$e^-\bar{\nu}_e\nu_\tau$	$17.82 \pm .04$
$\mu^-\bar{\nu}\nu$	$\mu^-\bar{\nu}_\mu\nu_\tau$	$17.39 \pm .04$
$h^-\nu$	$\pi^-\nu_\tau$	$11.61 \pm .06$
$h^-\pi^0\nu$	$\rho^-\nu_\tau \to \pi^-\pi^0\nu_\tau$	$25.94 \pm .09$
$h^-\pi^0\pi^0(\pi^0)\nu$	$a_1^-\nu_\tau \to \pi^-\pi^0\pi^0\nu_\tau$	$10.85 \pm .11$
$h^-h^-h^+(\pi^0)\nu$	$a_1^-\nu_\tau \to \pi^-\pi^-\pi^+\nu_\tau$	$14.56 \pm .07$

- measurement restricted to hadronic tau decay channels with a single charged hadron

- maximal parity violation in tau decay: spin orientation strongly correlated with angular decay distributions



polarization observables

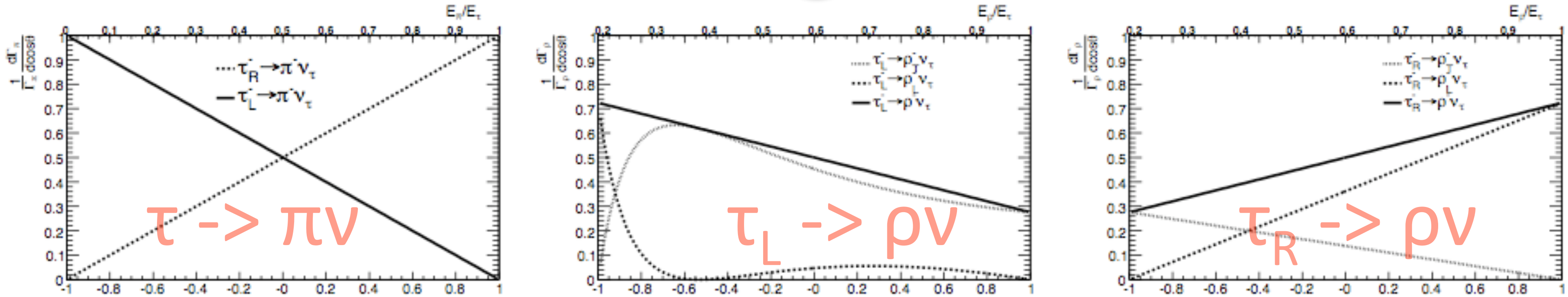
- cos Θ – angle between tau line of flight and charged hadron (π,ρ,a_1) direction in tau rest frame

  -- cannot reconstruct tau rest frame

  -- cos Θ related to hadronic energy fraction in the lab frame ($E>>m_\tau$)

$$\cos\theta = \frac{2E_{vis}/E_\tau - 1 - m_{vis}^2/m_\tau^2}{1 - m_{vis}^2/m_\tau^2}$$

Not directly observable in W->τν decays at hadron collider



- Spin analysis on intermediate vector meson (ρ,a_1) yields a second observable:

  cos Ψ – angle between vector meson line of flight and charged pion direction in meson rest frame

  -- related to energy sharing between charged and neutral pions in lab frame

$$\cos\psi = \frac{m_v}{\sqrt{m_v^2 - 4m_\pi^2}} \frac{E_{\pi^-} - E_{\pi^0}}{|\mathbf{p}_{\pi^-} + \mathbf{p}_{\pi^0}|}$$

** increased sensitivity in τ -> ρν channel + experimentally accessible observables

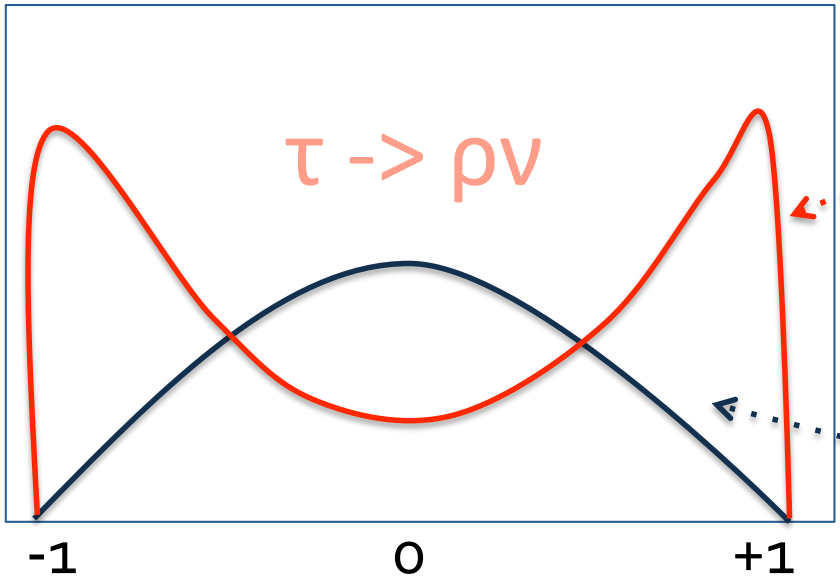
polarization observables

Charged Asymmetry

$$\frac{E_T^{\pi^-} - E_T^{\pi^0}}{p_T} \approx 2\frac{p_T^{trk}}{p_T} - 1 = \Upsilon$$

- $E_T^{\pi^-}$: tau TRACK p_T
- $E_T^{\pi^0}$: difference between TAU p_T and TRACK p_T
- p_T: visible TAU p_T

* optimized for τ->ρν decay mode

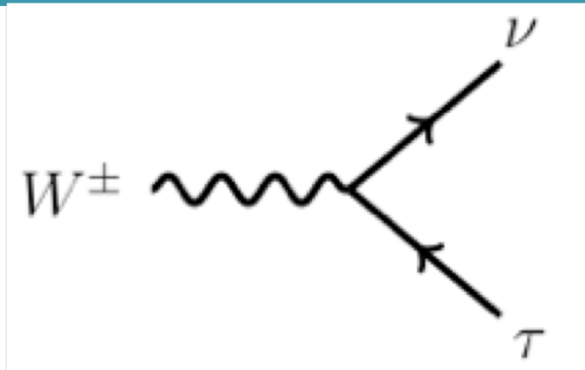


Right-Handed distribution: asymmetric energy sharing (longitudinal ρ)

Left-Handed distribution: symmetric energy sharing (transverse ρ)

event selection

- 24 pb^{-1} collected (2010) with combined tau (p_T>16 GeV) and missing transverse energy (E_T^{miss} >22 GeV) trigger



1. one identified jet-seeded tau with transverse momentum in range [20 GeV,60 GeV] with a single reconstructed track
2. missing transverse energy E_T^{miss}>30 GeV
3. reject events with jet activity in the barrel – end-cap transition region
4. reject events with an identified electron or muon with p_T>15 GeV
5. reject events with jet activity along the direction of reconstructed E_T^{miss}
6. missing transverse energy significance: $S_{E_T^{miss}} = \frac{E_T^{miss}}{\sigma(E_T^{miss})} = \frac{E_T^{miss}}{0.5\sqrt{\Sigma E_T}} \geq 6$

based on "Measurement of the W->τν cross section.." PLB 706 (2012) 276-294.

sample composition

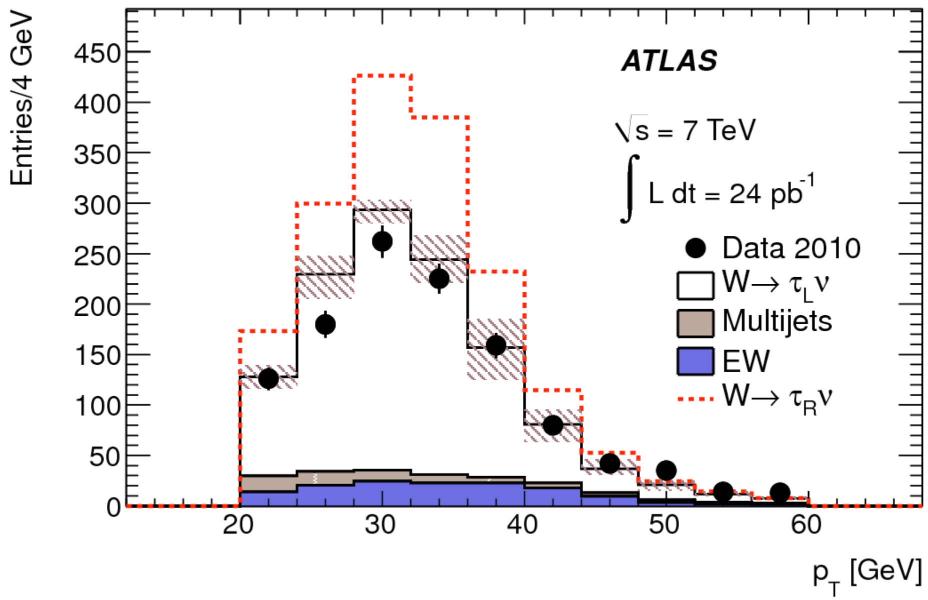
Sample	Number of Events
Data	1136
Electroweak Background	138 ± 4
Left-Handed Signal	
$W \to \tau_L \nu$	1002 ± 16
Multijet Background	69 ± 6
Right-Handed Signal	
$W \to \tau_R \nu$	1523 ± 22
Multijet Background	79 ± 4

EW background estimated from simulation

Multijet background estimated from control sample in data and corrected for EW contamination – results in polarization-dependent normalization

Kinematics in left- and right-handed tau decays yield greater acceptance for right-handed taus which tend to be harder than left-handed taus

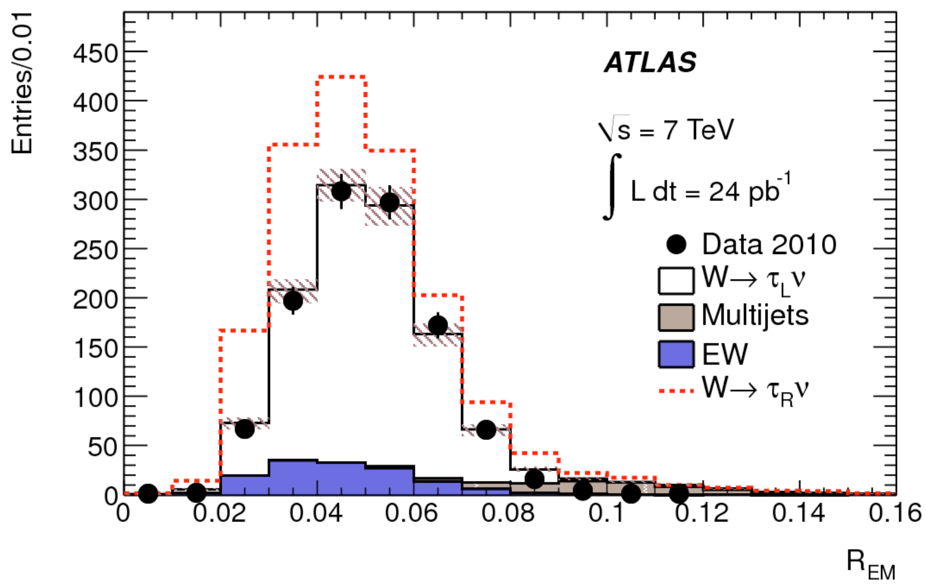
kinematic distributions



TAU TRANSVERSE MOMENTUM

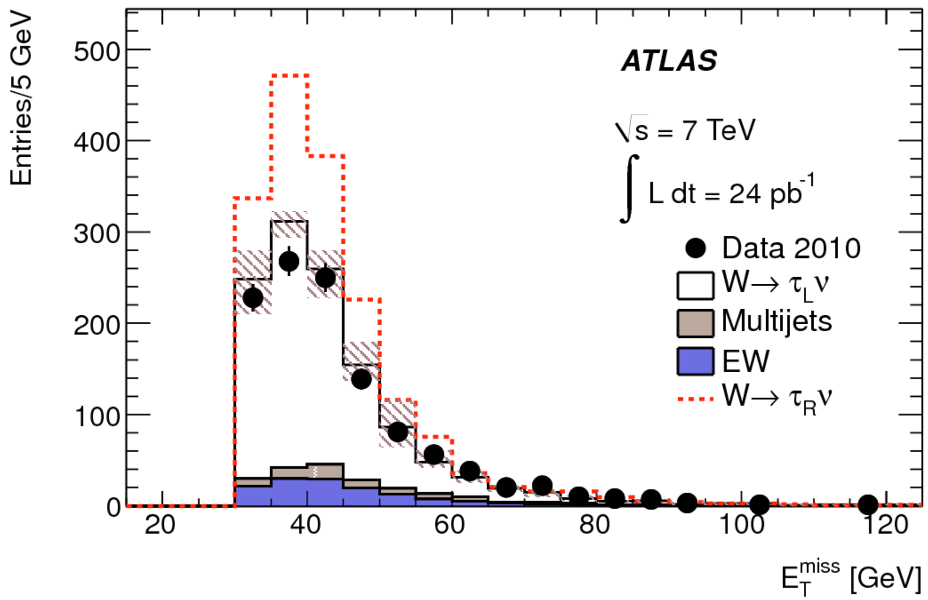
RED: simulated right-handed tau decay distributions
BLACK: simulated left-handed tau decays

ELECTROMAGNETIC RADIUS



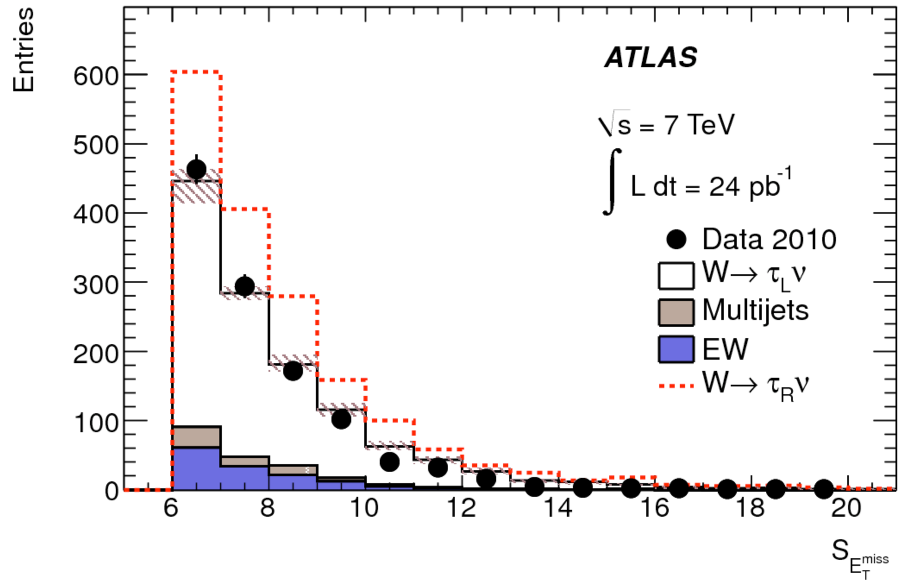
* normalized to integrated luminosity; decay kinematics affect the shape and acceptance in left-handed and right-handed simulated distributions

kinematic distributions



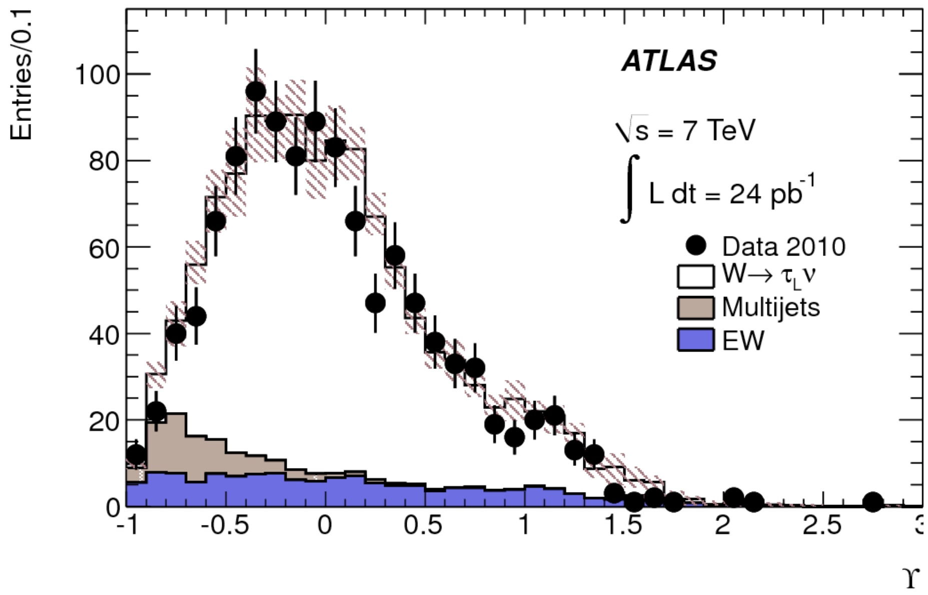
MISSING TRANSVERSE ENERGY

MISSING E_T SIGNIFICANCE

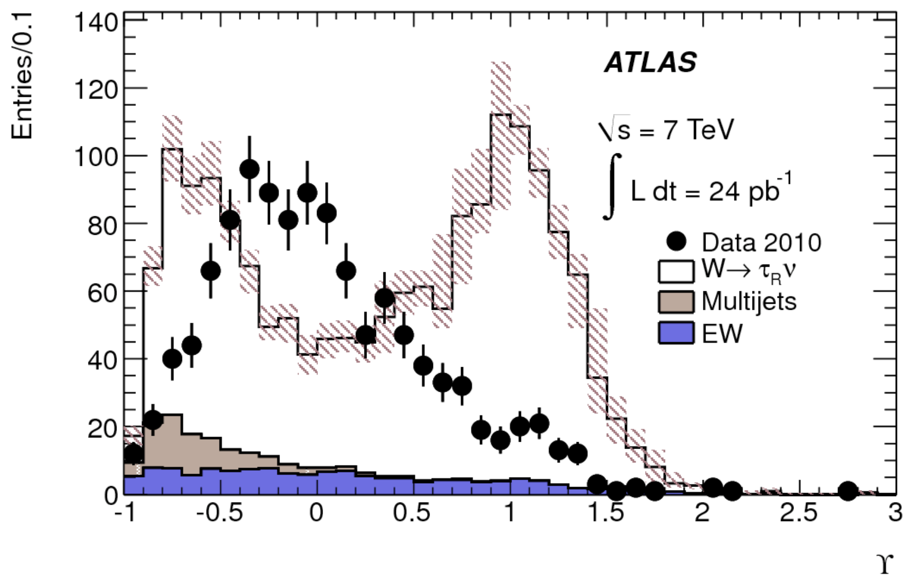


* tau p_T and missing E_T cuts increase sensitivity to tau polarization measurement in W->τν decays by rejecting τ->πν decay modes for which Y is not optimized; more pronounced in left-handed signal

charged asymmetry



LEFT-HANDED



RIGHT-HANDED

Extraction of Tau Polarization

- Fit observed charged asymmetry in data to linear combination of right-handed and left-handed templates w. simulated samples and EW backgrounds plus multijet data
- Maximize binned log-likelihood (constructed as product of poisson terms w. fit parameters for overall Monte Carlo samples normalization and multijet normalization)

Fit Result: P_τ = -1.06 ± 0.04(stat)

systematic uncertainty

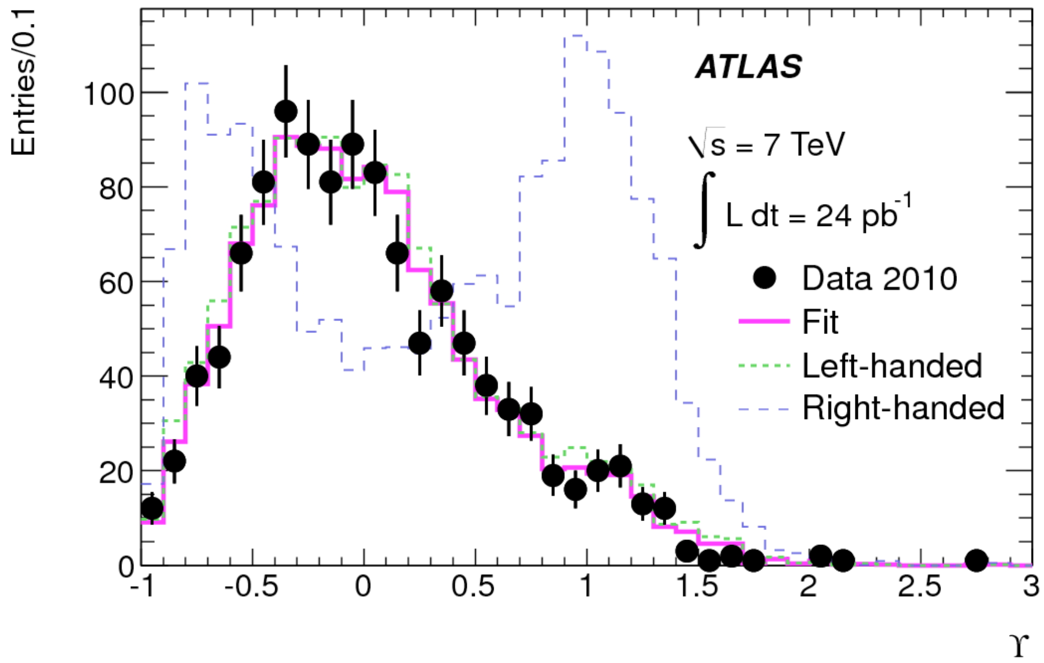
- 'shifted' templates produced for each source of systematic uncertainty and new fit value – nominal fit value gives ΔP_τ

scale factors applied to jet energy calibration and tau energy scales for all clusters in central region

nominal templates produced with HERWIG++ generated signal samples; comparison to PYTHIA6

Source	$+\Delta P_\tau$	$-\Delta P_\tau$
Energy scale central	0.042	0.063
Energy scale forward	0.007	0.002
E_T^{miss} resolution	0.014	–
No FCal	0.003	–
τ identification	0.005	0.006
Trigger	0.007	0.006
MC model	0.020	0.020
W cross-section	0.005	0.005
Z cross-section	0.006	0.006
Combined	0.05	0.07

results



$$P_\tau = -1.06 \pm 0.04\ (\text{stat})^{+0.05}_{-0.07}\ (\text{syst})$$

Bayesian 95% credibility interval restricted to physically allowed range [-1,-0.91]

summary

"Measurement of τ polarization in W->τν decays with the ATLAS detector in pp collisions at √s=7 TeV" EPJC 72 (2012) 2062

http://www.springerlink.com/content/3h24r0j573181876/

**generic method for measuring tau polarization*

& systematic uncertainties are relatively small

& first measurement of tau polarization at a hadron collider

& first probe of helicity structure in Wτν coupling at high Q^2

& results consistent with Standard Model

** measure tau polarization in any tau production mechanism*

& characterize coupling to taus in event of discovery

& use as discriminating variable in searches

BACK-UP

FITTING METHOD

Tau Polarization parameter of interest – weights the relative contributions of left- and right-handed signals

Normalization parameter for the multijet background

$$T_i(N_{MC},P_\tau,N_{MJ}) = N_{MC}\cdot\left[\left(\frac{1-P_\tau}{2}\right)s_i^L\mu_{s^L} + \left(\frac{1+P_\tau}{2}\right)s_i^R\mu_{s^R}\right] + N_{MC}\cdot\left[\sum_j b_i^j\mu_{b^j}\right] + N_{MJ}\cdot q_i'$$

Normalization parameter for the Monte Carlo (signals and EW backgrounds)

Parameters for the left-handed and right-handed signal contributions scaled to cross section x integrated luminosity

Parameters for the EW background process contributions scaled to cross section x integrated luminosity

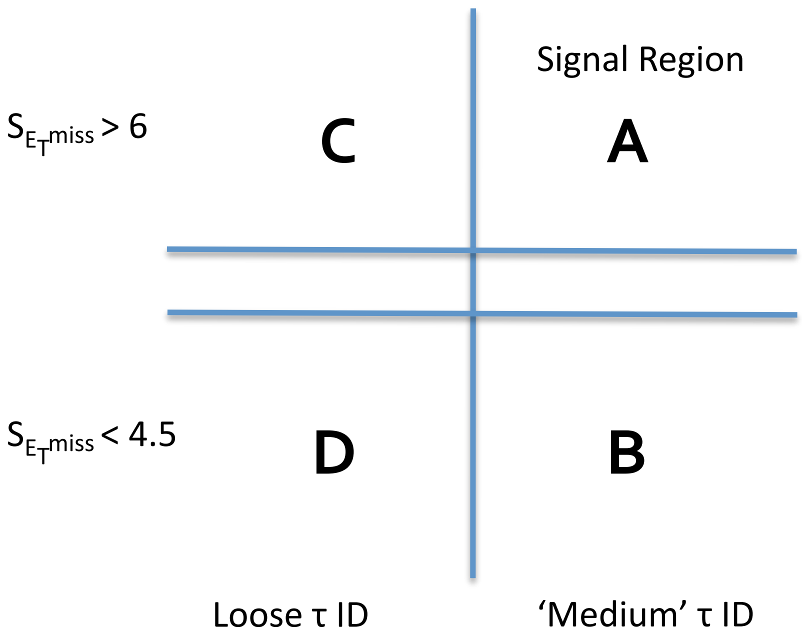
Mulitjet background parameter corrected for EW contamination

Maximize binned log-likelihood for likelihood constructed per bin i:

$$\mathcal{L}[i] = \frac{e^{-T_i}(T_i)^{N_i}}{N_i!}\cdot\prod_{k=L,R}\frac{e^{-s_i^k}(s_i^k)^{S_i^k}}{S_i^k!}\cdot\prod_j\frac{e^{-b_i^j}(b_i^j)^{B_i^j}}{B_i^j!}\cdot\frac{e^{-q_i}(q_i)^{Q_i}}{Q_i!}$$

N_i, S_i^L (S_i^R), B_i^j, Q_i: number of events* per bin in data, left-handed (right-handed) signal, j^{th} EW background, and multijets (*prior to scaling for MC samples)

MultiJet Background



EW Corrections:

$$N^i_{corrected} = N^i - c_i(N^A - N^A_{QCD})$$

$$c_i = \frac{N^i_{sig} + N^i_{EW}}{N^A_{sig} + N^A_{EW}}$$

$$N^A_{QCD} = N^B \times N^C / N^D$$

-Shape of multijet contribution to charged asymmetry distributions taken from region D
-correction factors applied for EW contamination per bin
-overall multijet background normalization included as fit parameter