Measurement of Tau Polarization in W → τν events at ATLAS

ICHEP 2012

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on behalf of the ATLAS Collaboration

Tau Polarization

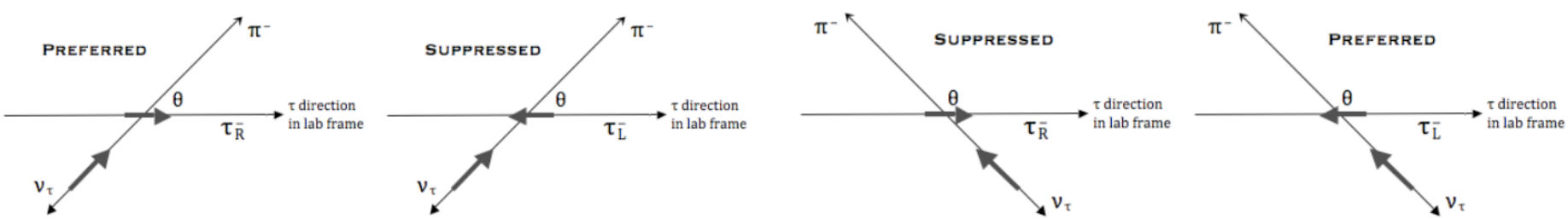
$$P_\tau = \frac{\sigma_R - \sigma_L}{\sigma_R + \sigma_L}$$

relative cross-section of left- and right-handed taus

Access to P_τ allows for

- tests of the SM
- searches for new physics
- discrimination between processes

Process	P_τ Prediction
$W^\pm \to \tau\nu$	-1
$H^\pm \to \tau\nu$	+1
$Z \to \tau\tau$	≈ -0.15
$H \to \tau\tau$	0



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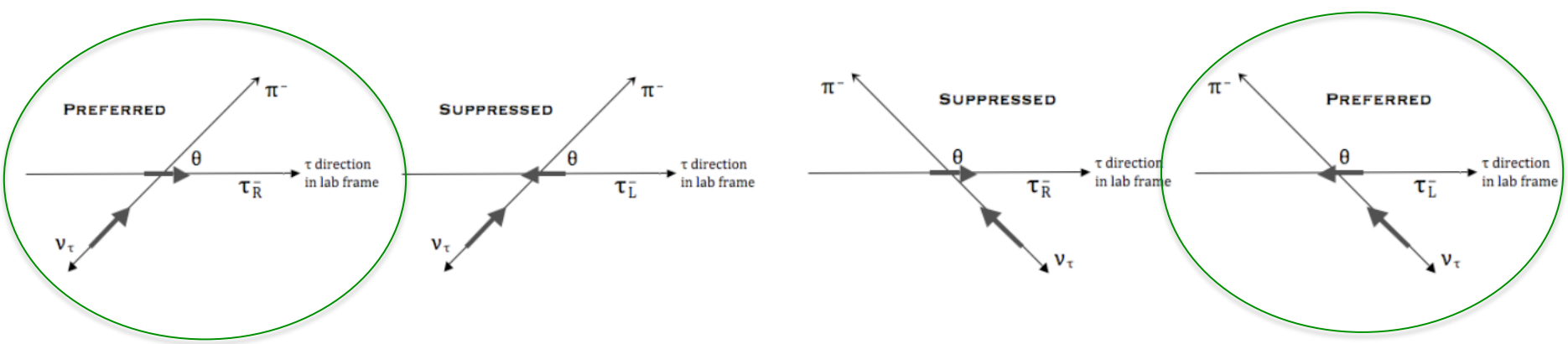


Tau Decays

tau decay channels and their branching ratios

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

Unlike former experiments with electrons and positrons where the initial beam energy gave important constraints to the kinematics,
at a hadron collider, we do not know the initial energy of the interaction.
(not a one-to-one mapping of optimal observables!)

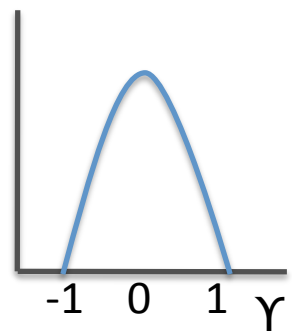
The ability to access the final state particles from the ρ decays is a way to regain sensitivity at the LHC.

Polarization Observable

Charged Asymmetry:

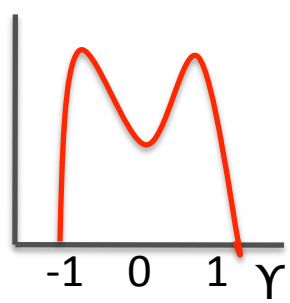
$$\Upsilon = \frac{2(track_{p_T})}{tau_{p_T}} - 1$$

When the energy is shared **evenly** between charged and neutral pions
ϒ will peak at zero



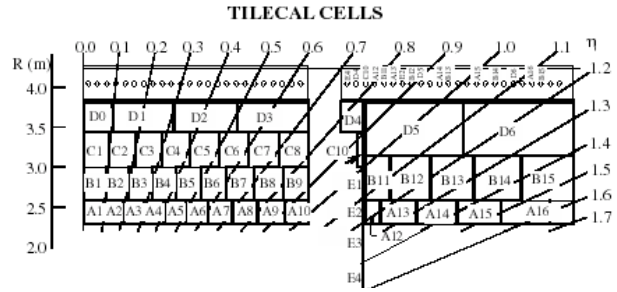
transversely polarized
ρ favored by τ_L

When the energy is shared **unevenly** between charged and neutral pions
ϒ will have peaks at +1 and -1

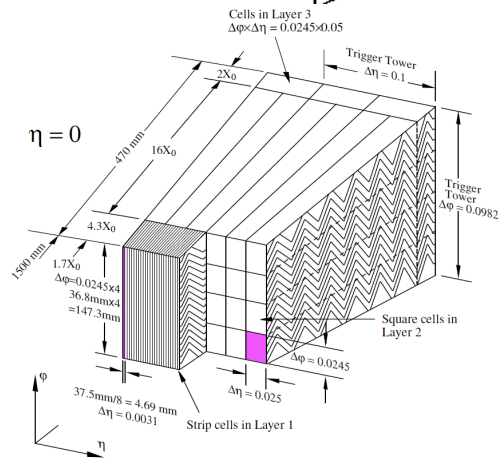


longitudinally polarized
ρ favored by τ_R

Identifying Taus at ATLAS

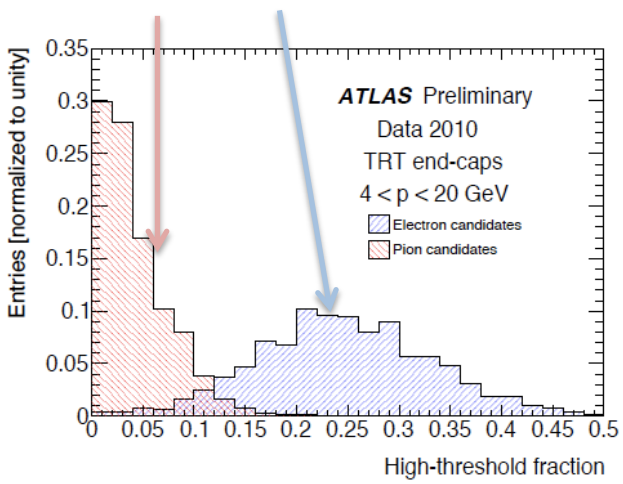


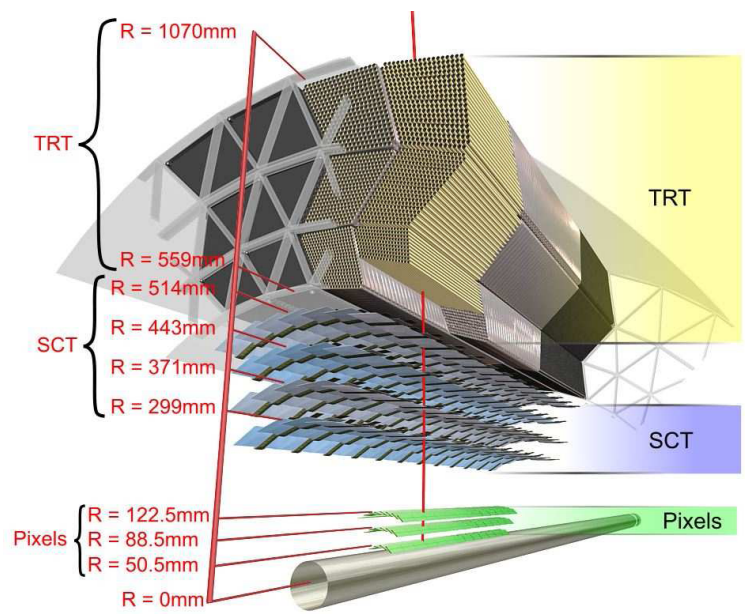
hadronic tile calorimeter



Fine granularity LAr electromagnetic calorimeter

The ATLAS transition-radiation tracker (TRT):
pion /electron separation



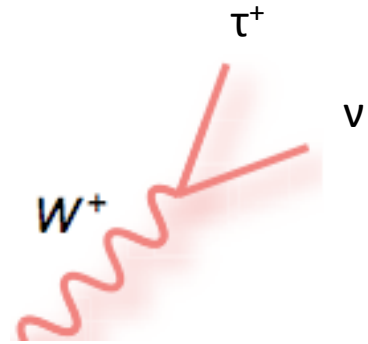


silicon technology in pixels and microstrips surrounded by 2 T magnetic field

Event Selection

First measurement of tau polarization at a hadron collider

<u>Understand Sensitivity</u>
W decays:
the measurement
has not been made at high Q^2



- 24 pb-1 from 2010 data with tau (16 GeV) + Missing E_T (22 GeV) trigger
- Offline: single-track tau with p_T > 20 GeV and Missing ET greater than 30 GeV
- Reject events with jet activity in region between the central and endcap detectors
- Reject events with electron or muon greater than 15 GeV E_T
- Reject events with jet activity along direction of event Missing E_T
- Require Missing ET significance > 6

$$S_{E_T^{miss}} = \frac{E_T^{miss}}{\sigma(E_T^{miss})}$$

Based on ATLAS W-> τν cross section measurement: Phys. Lett. B 706, 276 (2012)

Sample Composition

EW background from simulation, not dependent on tau Polarization

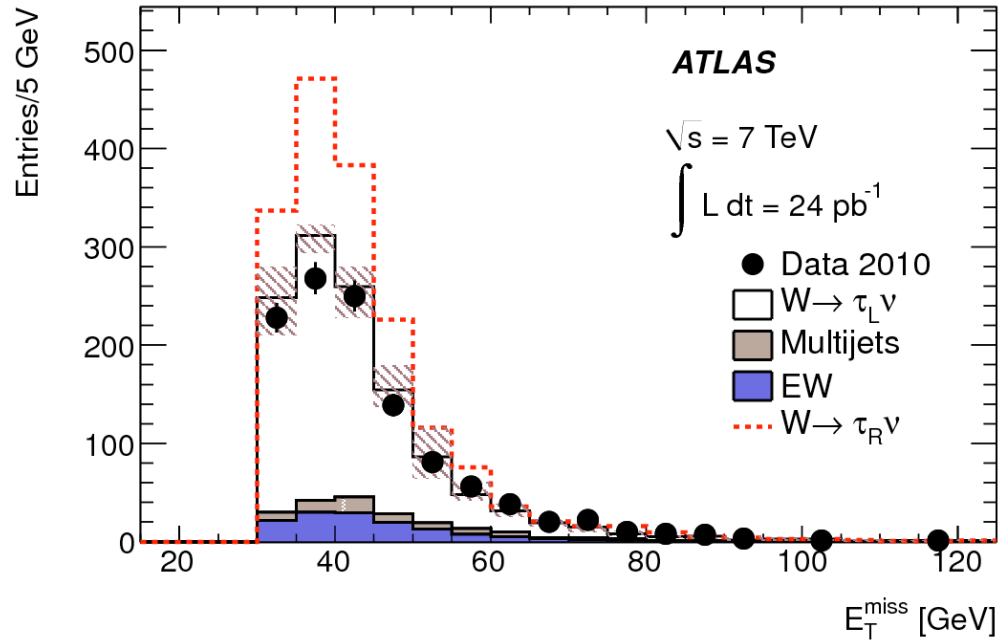
Multijet background from data, corrected for signal contribution (and therefore dependent on tau Polarization)

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

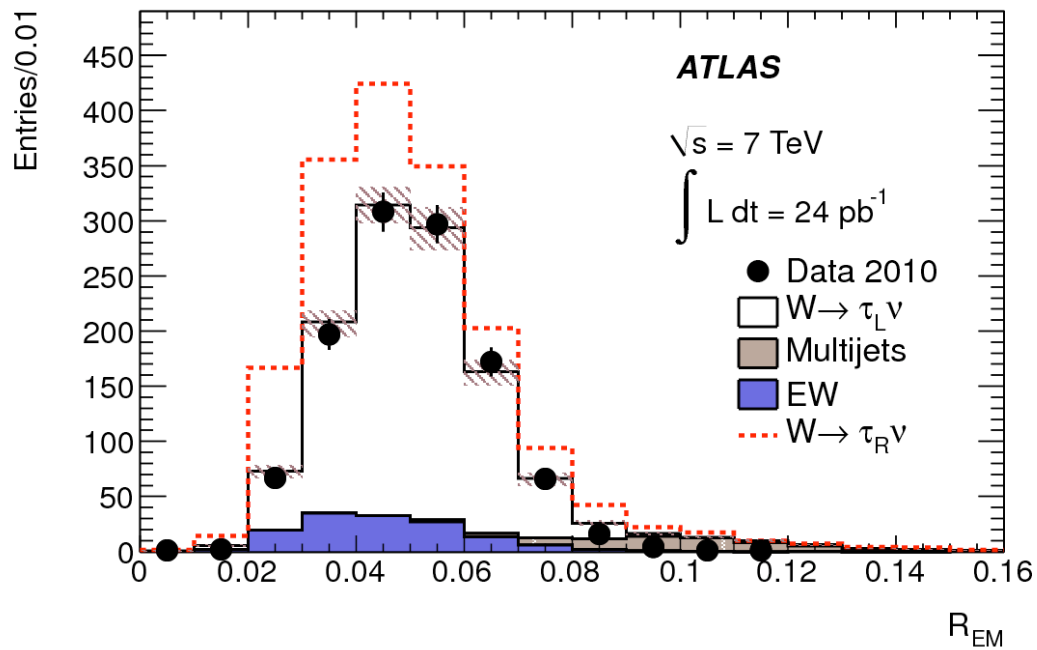
Signal to background ratio better than 5:1

Distributions

Missing Transverse Energy for Events Passing Selection



Shower width of tau candidate in electromagnetic calorimeter

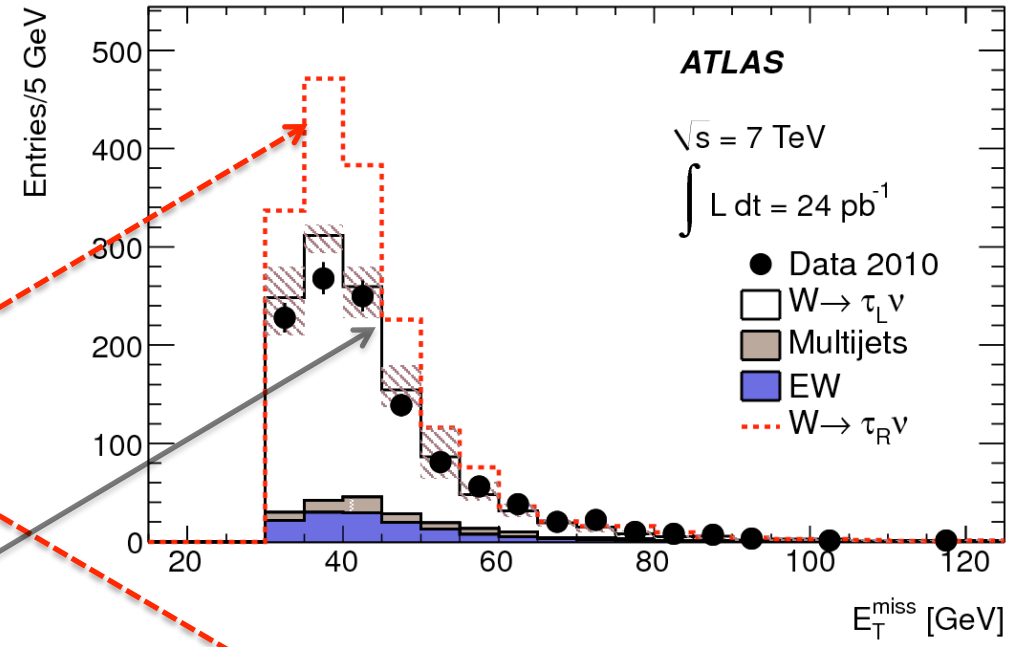


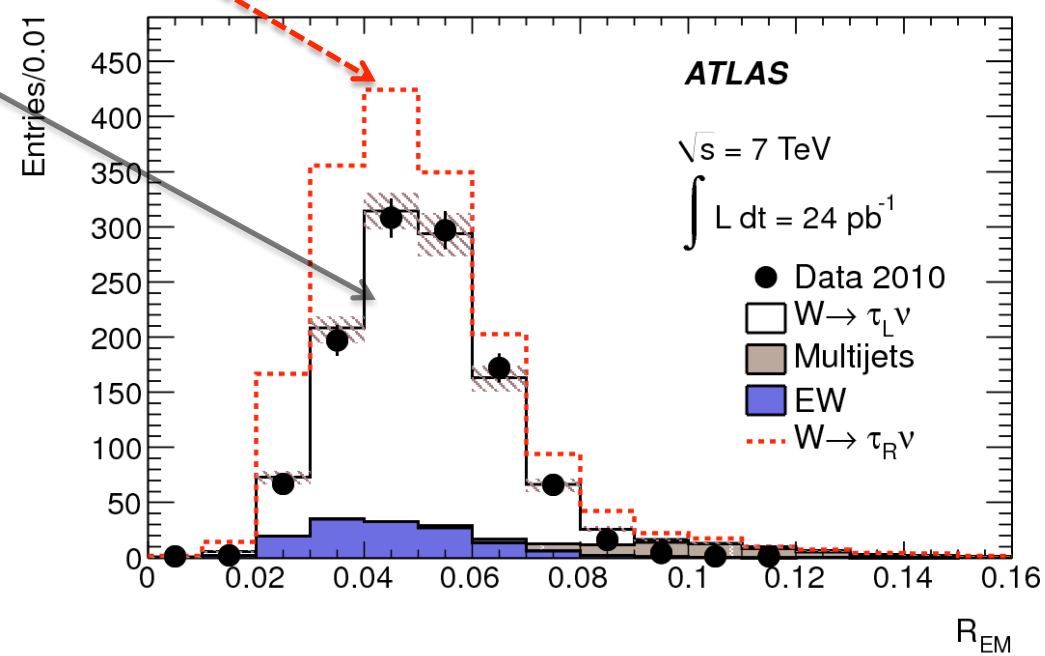
The handedness, given its impact on momentum, affects both the acceptance and the shape of distributions

Distributions

Expected Distributions for right-handed taus

Expected Distributions for left-handed taus





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Systematic Uncertainties

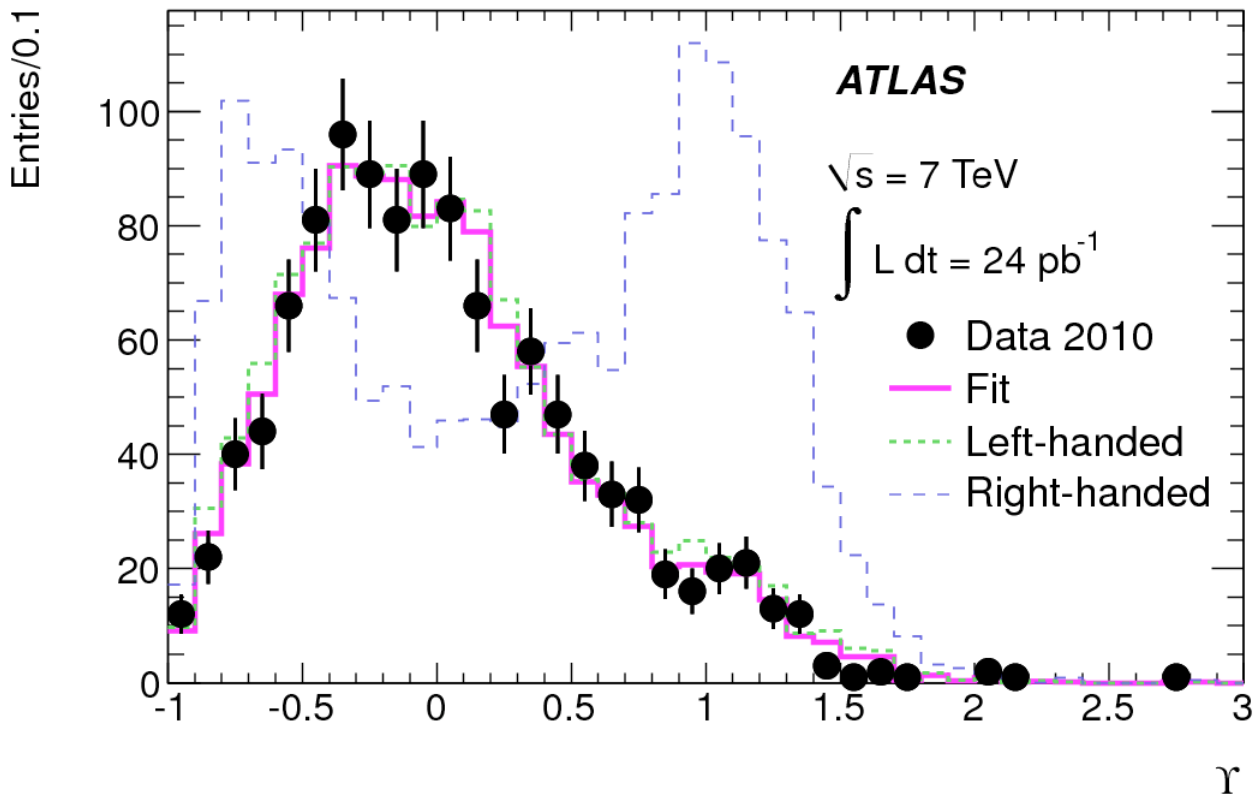
Sources of Systematic Uncertainty

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

MC (+ multijet data) right-handed and left-handed taus as ϒ templates

Fit distribution of ϒ in data
(maximize binned log likelihood function)



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

arXiv:1204.6720v1

Looking Forward

Possible Next Steps?

- Measure tau polarization in Z decays
- Access spin correlations in Z decays
- Use tau polarization as a discriminating variable in searches for $H^{\pm}$ and SM Higgs

Thanks very much for your time and attention!