Measurement of Tau Polarization in $W \rightarrow \tau \nu$ events at ATLAS

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on behalf of the ATLAS Collaboration
**Tau Polarization**

The relative cross-section of left- and right-handed taus is given by:

\[ P_\tau = \frac{\sigma_R - \sigma_L}{\sigma_R + \sigma_L} \]

Access to \( P_\tau \) allows for:
- tests of the SM
- searches for new physics
- discrimination between processes

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<th>( P_\tau ) Prediction</th>
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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 $\rho$ decays is a way to regain sensitivity at the LHC.
**Polarization Observable**

**Charged Asymmetry:**

\[
\Upsilon = \frac{2(\text{track}_{p_T})}{\text{tau}_{p_T}} - 1
\]

When the energy is shared **evenly** between charged and neutral pions, \( \Upsilon \) will peak at zero.

When the energy is shared **unevenly** between charged and neutral pions, \( \Upsilon \) will have peaks at +1 and -1.

- Transversely polarized \( \rho \) favored by \( \tau_L \)
- Longitudinally polarized \( \rho \) favored by \( \tau_R \)
Identifying Taus at ATLAS

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

Hadronic tile calorimeter

Fine granularity LAr electromagnetic calorimeter

Silicon technology in pixels and microstrips surrounded by 2 T magnetic field
Event Selection

First measurement of tau polarization at a hadron collider

Understand Sensitivity

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 $W \rightarrow \tau\nu$ 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)

<table>
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<th>Sample</th>
<th>Number of Events</th>
</tr>
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<tbody>
<tr>
<td>Data</td>
<td>1136</td>
</tr>
<tr>
<td>Electroweak Background</td>
<td>138 ± 4</td>
</tr>
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</table>

Left-Handed Signal

- $W \rightarrow \tau_L \nu$: 1002 ± 16
- Multijet Background: 69 ± 6

Right-Handed Signal

- $W \rightarrow \tau_R \nu$: 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
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## Sources of Systematic Uncertainty

<table>
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<tr>
<th>Source</th>
<th>$+\Delta P_\tau$</th>
<th>$-\Delta P_\tau$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy scale central</td>
<td>0.042</td>
<td>0.063</td>
</tr>
<tr>
<td>Energy scale forward</td>
<td>0.007</td>
<td>0.002</td>
</tr>
<tr>
<td>$E_{T}^{\text{miss}}$ resolution</td>
<td>0.014</td>
<td>-</td>
</tr>
<tr>
<td>No FCal</td>
<td>0.003</td>
<td>-</td>
</tr>
<tr>
<td>$\tau$ identification</td>
<td>0.005</td>
<td>0.006</td>
</tr>
<tr>
<td>Trigger</td>
<td>0.007</td>
<td>0.006</td>
</tr>
<tr>
<td>MC model</td>
<td>0.020</td>
<td>0.020</td>
</tr>
<tr>
<td>$W$ cross-section</td>
<td>0.005</td>
<td>0.005</td>
</tr>
<tr>
<td>$Z$ cross-section</td>
<td>0.006</td>
<td>0.006</td>
</tr>
<tr>
<td>Combined</td>
<td>0.05</td>
<td>0.07</td>
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MC (+ multijet data) right-handed and left-handed taus as $\Upsilon$ templates

Fit distribution of $\Upsilon$ 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± and SM Higgs

Thanks very much for your time and attention!