LOW-SCALE TECHNICOLOR AT THE LHC

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1. LOW-SCALE TECHNICOLOR BASICS

- Walking technicolor strongly suggests # technfermion doublets $N_D \gg 1$.
  Assume $N_D \simeq 10 \Longrightarrow \pi_T$ decay constant

$$\underline{\boldsymbol{F_{TC} = F_\pi/\sqrt{N_D} \lesssim 100\,\mathrm{GeV} \sim \Lambda_{TC}}}$$

- Expect $M_{\pi_T} \simeq 100 - 300\,\mathrm{GeV}$

- WTC **enhances** M_{π_T} relative to $M_{\rho_T}, \ldots$
  Expect $\underline{\boldsymbol{M_{\rho_T} \lesssim 2M_{\pi_T}}}$

- S-parameter suggests $I^G J^P = 1^- 1^+$ a_T is close to $1^+ 1^-$ ρ_T, w/ similar couplings.

- Focus on *lowest-lying* ρ_T, ω_T and a_T, with $M_{\rho_T} \simeq M_{\omega_T} \lesssim M_{a_T} < 2M_{\pi_T} \simeq 200 - 600\,\text{GeV}$

- All decay rates are electroweak or suppressed by powers of $1/N_D$.
  $\Longrightarrow$ ρ_T, ω_T, a_T are **VERY NARROW**,
  $\Gamma \lesssim$ few GeV !!

2. <u>What we've done:</u>

- **<u>Processes put into</u>** <u>Pythia</u> (S. Mrenna) $\rho_T \to \pi_T\pi_T$, $W_L\pi_T$, W_LW_L; $\rho_T, \omega_T, a_T \to \bar{f}f^{(\prime)}$ **plus**

Process	$V_{V_TG\pi_T}$	$A_{V_TG\pi_T}$
$\omega_T \to \gamma\pi_T^0$	$\cos\chi$	0
$\to \gamma Z_L^0$	$\sin\chi$	0
$\to Z_\perp^0\pi_T^0$	$\cos\chi\cot 2\theta_W$	0
$\to Z_\perp^0 Z_L^0$	$\sin\chi\cot 2\theta_W$	0
$\to W_\perp^\pm\pi_T^\mp$	$\cos\chi/2\sin\theta_W$	0
$\to W_\perp^\pm W_L^\mp$	$\sin\chi/2\sin\theta_W$	0
$\to \gamma\pi_T^{0\prime}$	$(Q_U+Q_D)\cos\chi'$	0
$\to Z_\perp^0\pi_T^{0\prime}$	$-(Q_U+Q_D)\cos\chi'\tan\theta_W$	0
$\rho_T^0 \to \gamma\pi_T^0$	$(Q_U+Q_D)\cos\chi$	0
$\to \gamma Z_L^0$	$(Q_U+Q_D)\sin\chi$	0
$\to Z_\perp^0\pi_T^0$	$-(Q_U+Q_D)\cos\chi\tan\theta_W$	0
$\to Z_\perp^0 Z_L^0$	$-(Q_U+Q_D)\sin\chi\tan\theta_W$	0
$\to W_\perp^\pm\pi_T^\mp$	0	$\pm\cos\chi/2\sin\theta_W$
$\to W_\perp^\pm W_L^\mp$	0	$\pm\sin\chi/2\sin\theta_W$
$\to \gamma\pi_T^{0\prime}$	$\cos\chi'$	0
$\to Z_\perp^0\pi_T^{0\prime}$	$\cos\chi'\cot 2\theta_W$	0
$\rho_T^\pm \to \gamma\pi_T^\pm$	$(Q_U+Q_D)\cos\chi$	0
$\to \gamma W_L^\pm$	$(Q_U+Q_D)\sin\chi$	0
$\to Z_\perp^0\pi_T^\pm$	$-(Q_U+Q_D)\cos\chi\tan\theta_W$	$\pm\cos\chi/\sin 2\theta_W$
$\to W_L^\pm Z_\perp^0$	$-(Q_U+Q_D)\sin\chi\tan\theta_W$	$\pm\sin\chi/\sin 2\theta_W$
$\to W_\perp^\pm\pi_T^0$	0	$\mp\cos\chi/2\sin\theta_W$
$\to W_\perp^\pm Z_L^0$	0	$\mp\sin\chi/2\sin\theta_W$
$\to W_\perp^\pm\pi_T^{0\prime}$	$\cos\chi'/2\sin\theta_W$	0

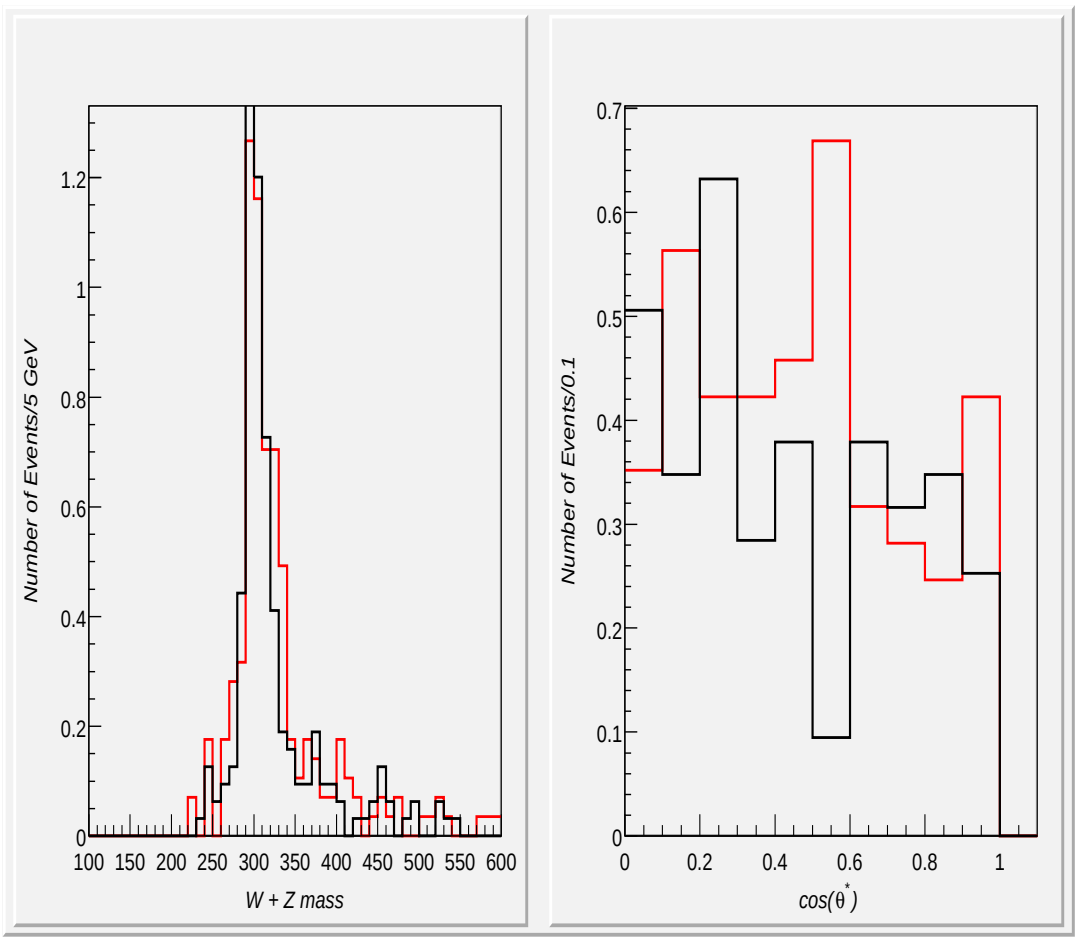
Process	$V_{a_T G\, \pi_T/V_T}$	$A_{a_T G\, \pi_T/V_T}$
$a_T^0 \to W_\perp^\pm \pi_T^\mp$	0	$\mp \cos\chi/2\sin\theta_W$
$\to W_\perp^\pm W_L^\mp$	0	$\mp \sin\chi/2\sin\theta_W$
$\to Z_\perp^0 \pi_T^{0\prime}$	$-\cos\chi'/\sin 2\theta_W$	0
$\to \gamma\rho_T^0$	$Q_U + Q_D$	0
$\to \gamma\omega_T$	1	0
$\to W_\perp^\pm \rho_T^\mp$	0	$\pm 1/2\sin\theta_W$
$\to Z_\perp^0 \rho_T^0$	$-(Q_U + Q_D)\ \tan\theta_W$	0
$\to Z_\perp^0 \omega_T$	$\cot 2\theta_W$	0
$a_T^\pm \to \gamma\pi_T^\pm$	0	$\mp\cos\chi$
$\to \gamma W_L^\pm$	0	$\mp\sin\chi$
$\to W_\perp^\pm \pi_T^0$	0	$\pm\cos\chi/2\sin\theta_W$
$\to W_\perp^\pm Z_L^0$	0	$\pm\sin\chi/2\sin\theta_W$
$\to Z_\perp^0 \pi_T^\pm$	0	$\mp\cos\chi\cot 2\theta_W$
$\to W_L^\pm Z_\perp^0$	0	$\mp\sin\chi\cot 2\theta_W$
$\to W_\perp^\pm \pi_T^{0\prime}$	$-\cos\chi'/2\sin\theta_W$	0
$\to \gamma\rho_T^\pm$	$Q_U + Q_D$	0
$\to W_\perp^\pm \rho_T^0$	0	$\mp 1/2\sin\theta_W$
$\to W_\perp^\pm \omega_T$	$1/2\sin\theta_W$	0
$\to Z_\perp^0 \rho_T^\pm$	$-(Q_U + Q_D)\tan\theta_W$	$\pm 1/\sin 2\theta_W$

- We're test-driving the new Pythia – not sure it's going in the right direction yet.

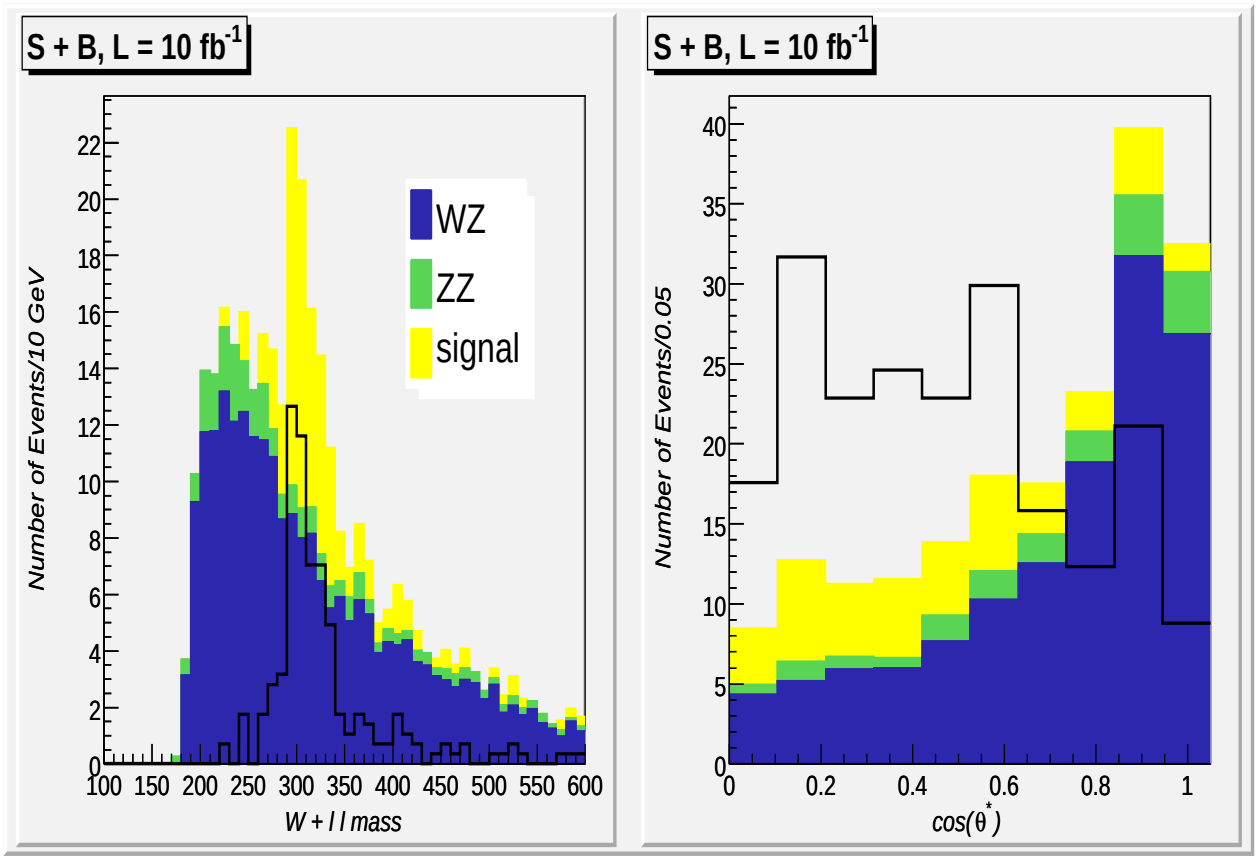
- At the LHC, $\rho_T \to W^\pm \pi_T$ is swamped by $\bar{t}t$ and $W +$ HF. Go to $\rho_T^\pm \to W^\pm Z$. ($a_T^\pm \to W^\pm Z$ *seems* too small to see at LHC!)

- $d\Gamma(q\bar{q}' \to \rho_T^\pm \to W^\pm Z)/d(\cos\theta^*) \propto \sin^2\theta^*$ is an *important test of the underlying TC dynamics!*

- Results (so far) with $M_{\rho_T,\omega_T} = 300$, $M_{a_T} = 330$, $M_{\pi_T} = 200\,\text{GeV}$. For $\rho_T^\pm + a_T^\pm \to W^\pm Z^0$ via Drell-Yan: $\sigma \cdot B(W^\pm Z^0 \to \ell^\pm \nu \ell^+ \ell^-) \simeq 75\,\text{fb}$



Comparison of $\rho_T^\pm$ (black) and $\rho_T^\pm + a_T^\pm \to W^\pm Z$ mass (left) and $\cos\theta^*$ (right) distributions.



Signal and backgrounds for $\rho_T^{\pm}$, $a_T^{\pm} \to W^{\pm}Z$ mass and angular distributions. $M_{\rho_T} = 300\,\text{GeV}$, $M_{a_T} = 330\,\text{GeV}$, $M_{\pi_T} = 200\,\text{GeV}$.

3. <u>What we'll do:</u>

- $\rho_T^\pm \to W^\pm Z$ analysis so far based on CMS study by P. Kreuzer. Critically examine Kreuzer's cuts. Re-optimize for $\cos\theta^*$ study — enhance signal purity.

- Study $\not{E}_T$ resolution.

- Study $p_{\nu,z}$ solution; e.g., maximize $\hat{\boldsymbol{p}}_\nu \cdot \hat{\boldsymbol{p}}_\ell$?

- Repeat for other mass points up to $M_{\rho_T} \simeq 600\,\text{GeV}$; etc., etc.

- P.S. WZ fusion of ρ_T, a_T is hopelessly small.

- Study discovery and angular distribution of $a_T^\pm \to \gamma W^\pm$, $\omega_T \to \gamma Z$ and $\omega_T \to \gamma \pi_T^0 \to \gamma \bar{b} b$.

  $\sigma \cdot B(a_T^\pm \to \gamma \ell^\pm \nu) \simeq 150\,\text{fb}$; $\sigma \cdot B(\omega_T \to \gamma \ell^+ \ell^-) \simeq 20\,\text{fb}$
  $S/B \sim 1 \Longrightarrow$ **very exciting possibilities here!**

  $\sigma \cdot B(\omega_T \to \gamma \bar{b} b) \simeq 400\,\text{fb}$ — but backgrounds??