Physics with WZ production at LPC

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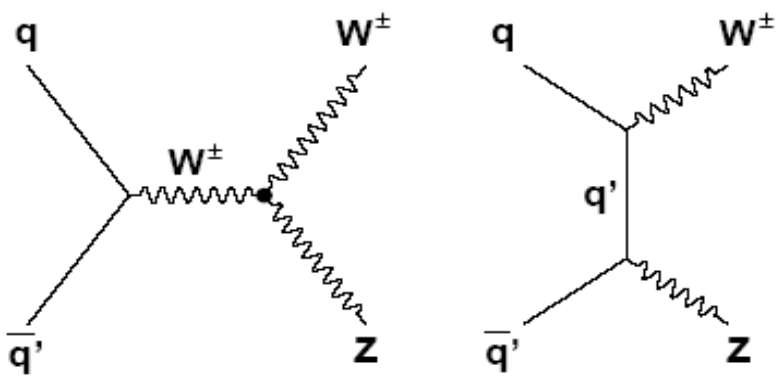
Motivation

- Production of two bosons and their interactions provide tests of the electroweak sector of the standard model (SM);
- Any deviation of TGCs of gauge bosons from their SM values would be an indication for new physics;
- Di-boson pair production is one of the ways to understand the mechanism of electroweak symmetry breaking (EWSB).

Theory

- The non-Abelian nature of electroweak standard model allows for *WWZ* and *WWγ* vertices;

- We are interested in s-channel WZ production.



Theory

- According to the most general Lorentz invariant Lagrangian there can be seven independent couplings describing each of the *WWγ* and *WWZ* vertices;

- Number of parameters can be reduced by requiring the Lagrangian to satisfy electromagnetic gauge invariance and charge conjugation as well as parity invariance.

$$\mathcal{L}_{\mathrm{eff}}^{WWV} = \mathrm{i} g_{WWV} \left[g_1^V \left(W_{\mu\nu}^+ W^{-\mu} - W^{+\mu} W_{\mu\nu}^- \right) V^\nu + \kappa_V W_\mu^+ W_\nu^- V^{\mu\nu} + \frac{\lambda_V}{m_W^2} W_\mu^{+\nu} W_\nu^{-\rho} V_\rho^\mu \right]$$

$$- \frac{e z_Z}{m_W^2} \partial_\alpha \hat{Z}_{\rho\sigma} \left(W^{+\alpha} \overleftrightarrow{\partial^\rho} W^{-\sigma} - W^{+\sigma} \overleftrightarrow{\partial^\rho} W^{-\alpha} \right)$$

$$\kappa_\gamma = \kappa_Z = g_1^Z = 1 \text{ and } \lambda_\gamma = \lambda_Z = z_Z = 0$$

Extraction of WZ Signal

- Study has been made considering leptonic final states;

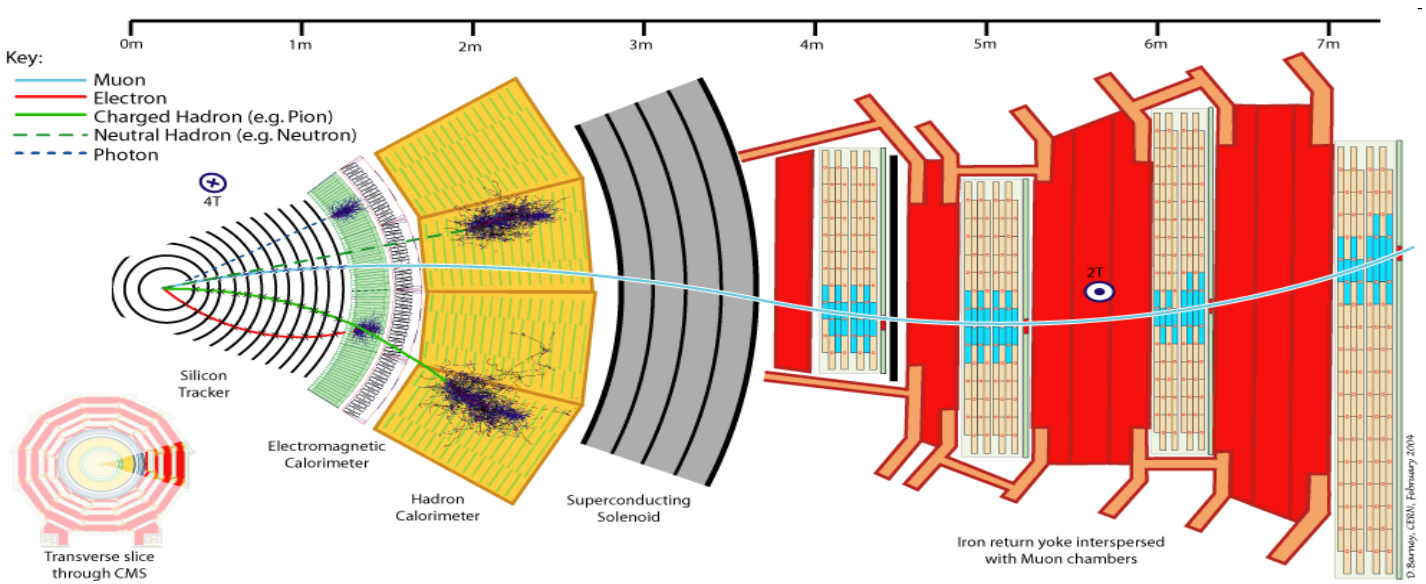
  - $3e$: for WZ^0 events with $W \longrightarrow e\nu$ and $Z^0 \longrightarrow e^+e^-$
  - $2e1\mu$: for WZ^0 events with $W \longrightarrow \mu\nu$ and $Z^0 \longrightarrow e^+e^-$
  - $2\mu1e$: for WZ^0 events with $W \longrightarrow e\nu$ and $Z^0 \longrightarrow \mu^+\mu^-$
  - 3μ: for WZ^0 events with $W \longrightarrow \mu\nu$ and $Z^0 \longrightarrow \mu^+\mu^-$

- Lepton identification is the crucial part of WZ signal extraction

Extraction of WZ Signal

- Electron selection: track reconstructed in central tracker matched to energy deposition in ECAL

- Muon selection: track reconstructed in central tracker matched to track from muon detector

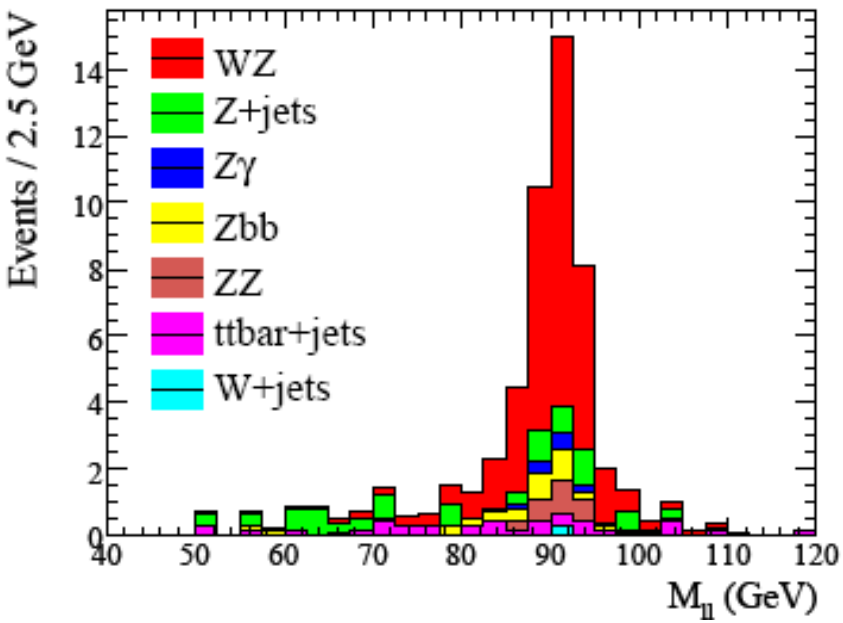


Extraction of WZ Signal

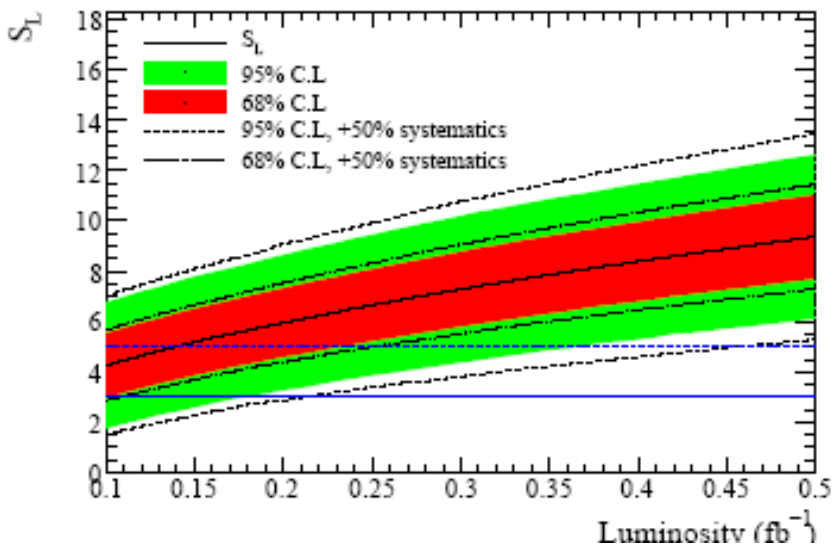
- Backgrounds to WZ production:
  - physics background from Zγ and ZZ production;
  - processes without a genuine Z boson from ttbar + jets and W + jets production which are 6% of the WZ signal;
  - processes with a genuine Z boson from Z + jets production which is the major background due to jet being misidentified as a lepton from the W boson decay.

Extraction of WZ Signal

- Z boson candidate invariant mass for all four channels combined, normalized to integrated luminosity of 300 pb^{-1} (arXiv:0905.1877).



- Expected signal significance for WZ production as a function of integrated luminosity. The corresponding 68% and 95% C.L. regions are displayed as red and green bands, respectively.



Technicolor Search

- Technicolor (TC) - A strongly interacting gauge theory, which allows for the dynamical break-down of electroweak symmetry, (along with Extended TC) is arguably more advantages model then Elementary Higgs models (arXiv:hep-ph/0202255v1);

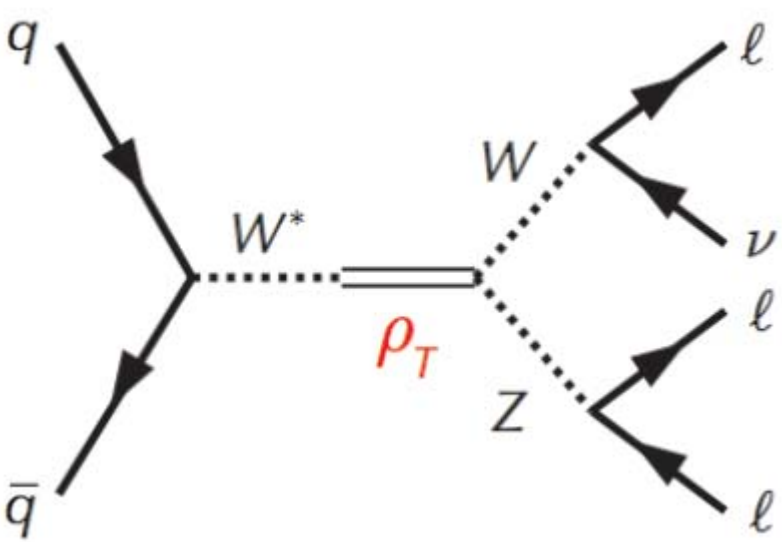
- Its recent version has slowly-running or “walking” couplings which result in reducing the technicolor scale down to 250 GeV. This makes TC more accessible at LHC;

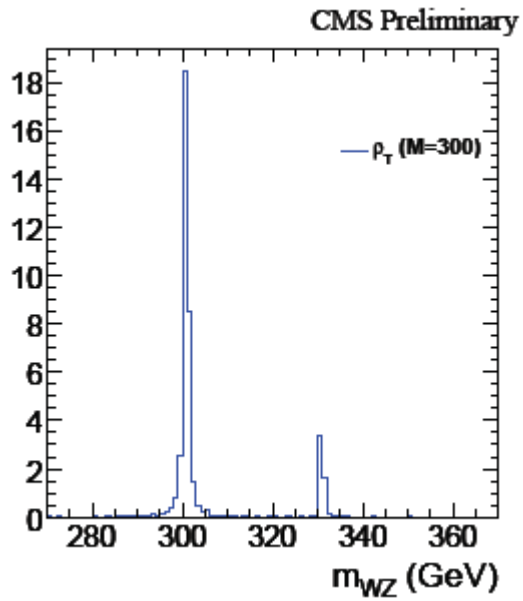
- $\rho T/aT \rightarrow WZ \rightarrow lll\nu$ is one of the signatures in low-scale walking TC models which makes TC strongly bound to WZ Analysis;

Technicolor Search

- The ρ_T (and a_T) production in pp collisions at the LHC occurs primarily through quark annihilation into an intermediate W^* boson;

- Techni-particle decay channels (e.g. $\rho_T \rightarrow WZ$) have distinctive signatures with narrow resonant peaks.

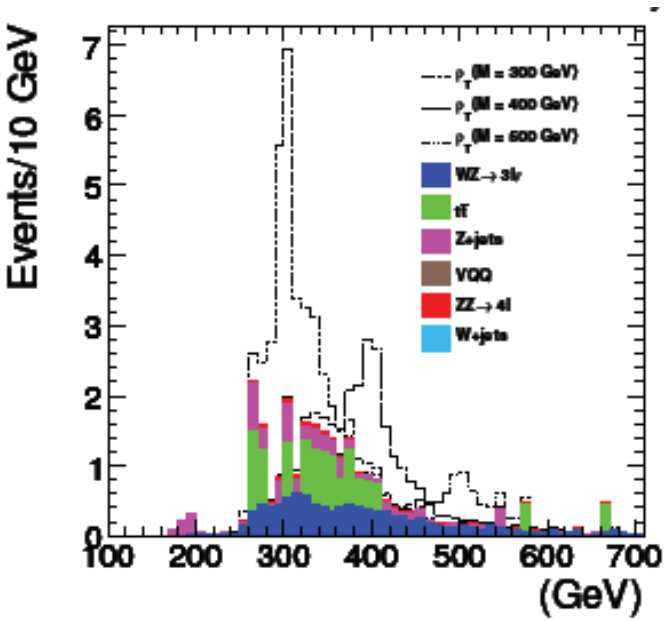


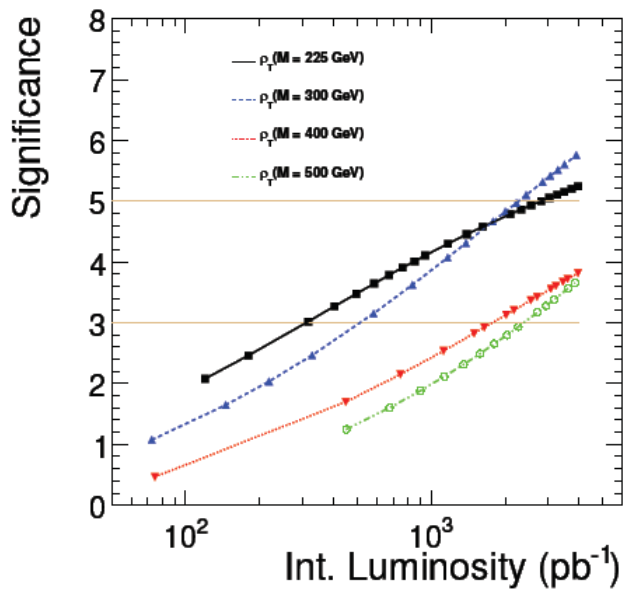


Technicolor Search

- Study has shown that it is possible to exclude at 95% C.L. the $\rho_T \rightarrow WZ$ process for ρ_T masses up to 400 GeV with 366 pb^{-1} of data. A 5σ observation of this process for these masses would need 2.8 fb^{-1} of data.

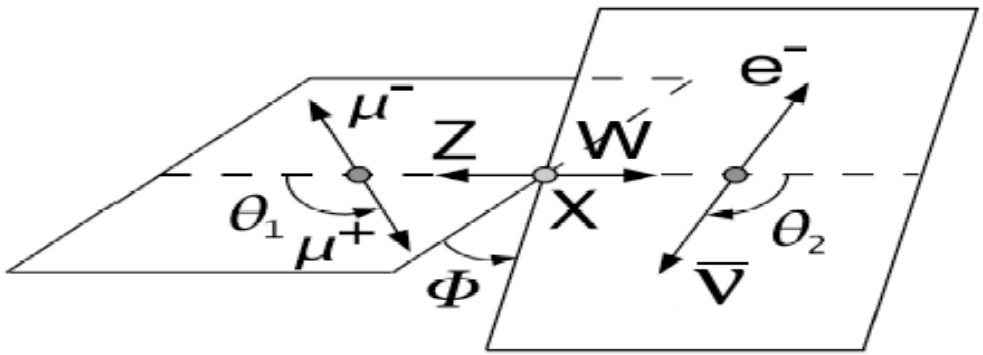
- *WZ* invariant mass distributions for signal (ρ_T [M=300,400, 500 GeV]) and background samples. The distributions are normalized to an integrated luminosity of 1 fb^{-1} (CMS AN-2009/099).





Kinematical (angular) approach to TGCs

- The theoretical description of the four fermions produced in WZ-pair production leads to natural variables
  - invariant masses for W and Z identification
  - Set of angles for TGC determinations



- Using angular variables can help us to:
  - further suppress background
  - distinguish between different spin and CP states
- Work in this direction is in progress

Conclusions

- Tools are developed and ready for data to observe WZ production and search for NP (like TC, etc.);
- Other tools are being developed or tuned for better efficiency and accuracy;
- New ways of di-boson signal extraction are being studied.
- To find out more about these works, see TWiki pages:
  - SM WZ production: https://twiki.cern.ch/twiki/bin/view/CMS/CroatiaZggroup
  - *X*→*WZ* search: https://twiki.cern.ch/twiki/bin/view/CMS/Technicolor
- If you are interested, you can join us on the dilepton+X group meetings. We meet every other Thursday at 1 pm CST in Sunrise room.