A Novel Technique to reconstruct Z mass in WZ/ZZ events with lepton(s), MET and three jets at CDF II

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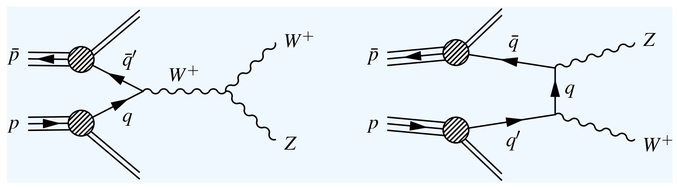
ON BEHALF OF THE CDF COLLABORATION

Motivations

Measurements of diboson associated production are **fundamental tests of the EWK sector of SM**

1. SM $\sigma^{NLO}_{WZ/ZZ} \sim$ pb for $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV
2. $W^{\pm}$, Z coupling (TGC) is sensitive to new physics



3. $WZ \to \ell\nu q\bar{q}$ is a preliminar step for $WH \to \ell\nu q\bar{q}$
   $\Rightarrow WZ \to l\nu q\bar{q}$ is a standard candle for the optimization of many techniques used in Higgs searches

Observing $WZ \to \ell\nu b\bar{b}$ is extremely difficult for two main reasons:

1^{st} The event rate is extremely low

It would be very important to be able to search for the signal also in events with more than two high energy jets.

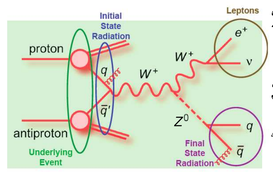
2^{nd} Signal to Background ratio is very poor.

A preferred discriminant used at CDF to separate the background from the diboson signal is the invariant mass of the two E_T-leading jets.

Optimal dijet mass resolution is of utmost importance for discriminating this BG.

So we look at the sample with 3 jets where about **33%** of the signal events lie.

1. Radiation from interacting partons (**ISR**)
2. Radiation from Z-decay products (**FSR**)
3. lepton mis-identified as a jet
4. Extra-activity produced by spectator partons or by pile-up of events (negligible)



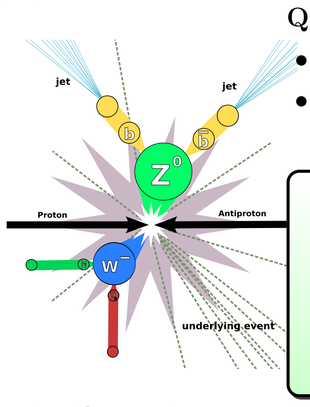
3 jets Region

Event Selection

- **3 jets** $E_T > 25, 15, 15$ GeV
- $\not\!\!E_T > 20$ GeV

QCD veto

- Cut on M_T^W
- Cut on $\not\!\!E_T$ along the jets



2 different regions:

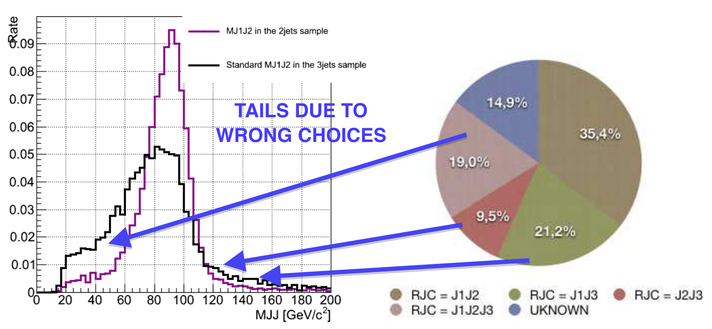
- **T A G : two jets are b-tagged**
- **N O T A G : no jet is b-tagged**

Isolated lepton triggering the event:

- Central Electron : $E_T > 20$ GeV
- Central muon : $p_T > 20$ GeV

State of the art

- The extra jet due to initial (ISR) or final state radiation (FSR) confuses the choice of the jet system to be attributed to Z decay.
- Which jet combination should be used to build the mass?
  → a wrong choice spoils the resolution



Procedure: Studies on WZ MC

- Jets are ordered in decreasing "b-likeness" (Tag) or E_T (NoTag)
  – Jets are matched in direction to quarks from Z decay
  – Events with a number of matches $\neq 2$ are not considered.
  – Investigate at generator level the origin of the not-matched jet (**NMJ**) in order to find the Right Jet Combination (**RJC**)

1. **NMJ = J3 is from ISR $\mapsto$ RJC = J1J2**
2. **NMJ = J2 is from ISR $\mapsto$ RJC = J1J3**
3. **NMJ = J1 is from ISR $\mapsto$ RJC = J2J3**
4. **NMJ = J1 or J2 or J3 is from FSR $\mapsto$ RJC = J1J2J3**
5. **About 15% of events do not belong to these classes and require further studies**

- We decide to use 4 different NNs for selecting the 4 different combinations: MJJ_{COMB} is an appropriate mixture of them.

The Novel Technique

A list of the variables used as input for the NNs.

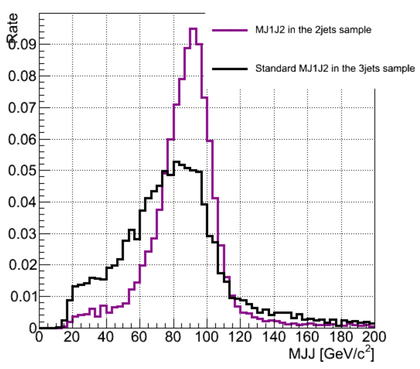
1 Kinematical Variables

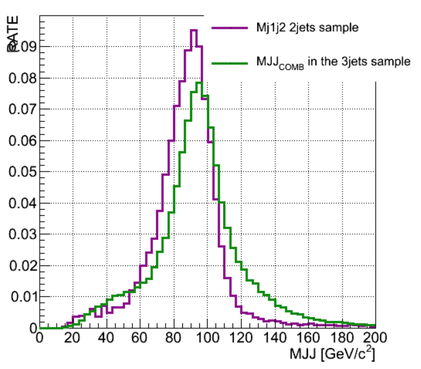
- $\mathbf{d}\eta_{j_ij_k}$, $\mathbf{dR}_{j_ij_k}$, $dR_{j_i\ell}$
- $dR_{j_kj_l,j_p}$, $dR_{j_1j_2j_3,j_k}$
- **i, k, p** $= 1, 2, 3$
- $\ell =$ **highest** $\mathbf{E}_T$ **lepton**

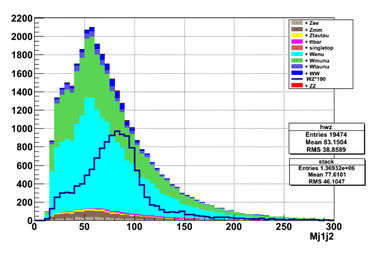
2 Variables related with the jet systems.

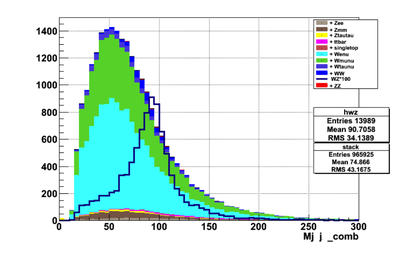
- $m_{j_ij_k}/m_{j_1j_2j_3}$
- $\gamma_{j_ij_k} = (E_{j_i} + E_{j_k})/m_{j_ij_k}$
- $\gamma_{jjj} = (E_{j_1} + E_{j_2} + E_{j_3})/m_{j_1j_2j_3}$
- **'pt-imbalance':** $P_{TJ1} + P_{TJ2} - P_{T\ell}$**+ MET**
- $\eta(j_i + j_k)/\eta(j_p)$, $p_T(j_i + j_k)/p_T(j_p)$

3 CDF tools for discriminating b and gluon jets from light jets.









- MJJ_{COMB} **has a resolution comparable with the one of MJ1J2 in the 2-jets sample**
- MJJ_{COMB} **allows a better separation of the WZ/ZZ signal from background**

Results

Studied two samples to test the method: MJ1J2 VS MJJ_{COMB}

- We analysed a simulated *pretag* sample of WW/WZ/ZZ events.
- We estimate the probability at three standard deviations level to extract an inclusive diboson signal (P3σ).
- P3σ is $\sim$ 4 times greater when fitting MJJ_{COMB} rather than the standard MJ1J2.

Fit Method	**P2σ**	**P3σ**
$WZ/ZZ/WW$ pretag		
- MJ1J2	51.2%	6.4%
- MJJ_{COMB}	66.7%	25.9%

- In order to discriminate against the WW contribution we apply our technique considering only WZ/ZZ as the signal. Information of the *notag* and *tag* channels is exploited.
- The expected p-value is about 30% greater when MJJ_{COMB} is used rather than the standard MJ1J2.

Fit Method	**p-value**
WZ/ZZ notag+tag	
- MJ1J2	0.35 σ
- MJJ_{COMB}	0.45 σ

Conclusions

- We show a procedure to reconstruct Z in diboson production with large $\not\!\!E_T$, lepton and 3 jets final state.
- **When WZ/ZZ/WW are considered as signal, the 3σ evidence (P3σ) increases by a factor 4**
- By fitting on MJJ_{COMB} rather than MJ1J2 enhances the sensitivity of extracting the WZ/ZZ signal.
- Adding the 3-jets to 2-jets sample in the WZ/ZZ analyses increases the expected p-value by about 40%
- Improvements to this technique and other possible applications are being investigated.

References:

[1] G. Bellettini, G. Latino,V. Rusu, M. Trovato, G. Velev, C. Vernieri *Search for WZ/ZZ production in events with lepton(s) plus jets plus missing transverse energy* CDF Note **10630** (2011)

[2] J. Freeman, W. Ketchum, S. Poprocki, S. Pronko, V. Rusu, and P. Wittich *Search for Diboson Production in MET+$b\bar{b}$ channel* CDF Note **10204** [arXiv:1108:2060].