Search for rare Standard Model processes in the $\not\!\!E_T$+b-jets signature

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Why $\not\!\!E_T$+b-jets ?

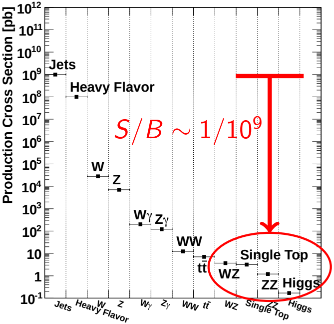
Interesting signature in searching for **both SM and BSM physics**

- $ZH \to \nu\nu b\bar{b}$ is one of the most sensitive decay modes for a low mass Higgs;
- $ZZ \to \nu\nu b\bar{b}$ is on the road to the Higgs;
- Sensitive to single top, mainly through hadronic τ decays;
- SUSY: $\tilde{b}\bar{\tilde{b}} \to b\tilde{\chi}^0\bar{b}\tilde{\chi}^0$;
- Technicolor: $\rho_T^{\pm} \to Z\pi_T^{\pm} \to \nu\nu b\bar{q}$;

Extra acceptance from W decays

- Hadronic τ decays (τ ID not very efficient);
- Also, the e/μ acceptance is not very high;
- Thus, this signature collects 50% of the leptonic W decays at CDF;
- So, we are sensitive to $WH \to \not\ell\nu b\bar{b}$, $WZ \to \not\ell\nu b\bar{b}$, and $\rho_T^{\pm} \to W^{\pm}\pi_T^0 \to \ell\nu b\bar{b}$;

The Challenges



Final state limitations

- Many SM processes mimic the $\not\!\!E_T$+b-jets final state;
  - Requires modeling for many backgrounds;

Different cause for $\not\!\!E_T$ in backgrounds

- EW backgrounds yield **intrinsic** $\not\!\!E_T$;
- QCD multi-jet yields **instrumental** $\not\!\!E_T$;

Pre-selection cuts are not enough for sensitive analysis

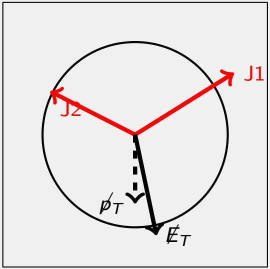
- We reject mis-measured events (with $\not\!\!E_T$ collinear to a jet), and require b-jets,
- Yet, we have **low S/B** : 1/50 (Single Top), 1/150 (WZ/ZZ), 1/500 (SM Higgs);
- We have to do something more to further reject the backgrounds;

Intrinsic $\not{E}_T$ vs. instrumental $\not{E}_T$

How we measure $\not{E}_T$

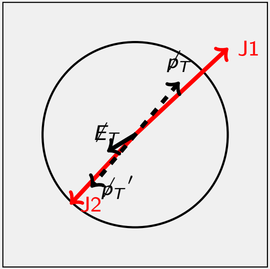
- Typically provided by the transverse energy imbalance ($\not{E}_T$) in the **calorimeter**;
- We also use the **transverse momentum flow imbalance** ($\not{p}_T$) from the **spectrometer**;
  - $\not{p}_T$ largely correlated with $\not{E}_T$ in presence of neutrinos (or $\tilde{\chi}^0$, etc.);
  - Very different for instrumental $\not{E}_T$: $\not{p}_T$ and $\not{E}_T$ <u>either correlated or anti-correlated</u>;

Exemple: $ZZ \to \nu\nu b\bar{b}$



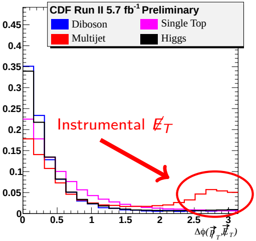
[$\not{E}_T$ aligned to $\not{p}_T$]

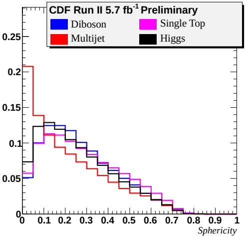
Example: QCD $b\bar{b}$



[$\not{p}_T$ is not aligned to $\not{E}_T$]

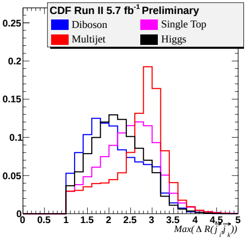
A Neural Network to reject QCD

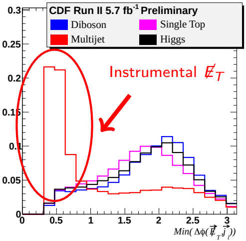


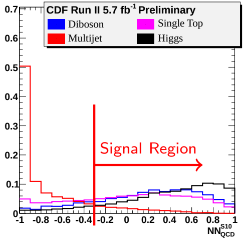


We combine novel variables to identify instrumental $\not\!\!E_T$ and distinguish it from "real" $\not\!\!E_T$.

Adding more variables



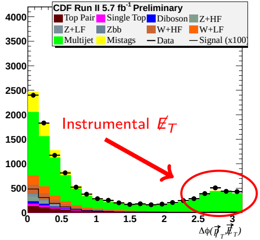


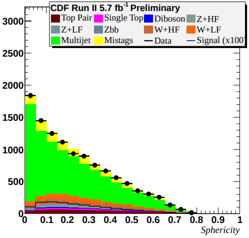


Performance

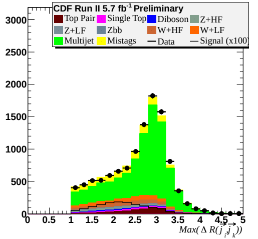
Signal acceptance	90-95%
Multi-jet rejection	$\sim$ 90%

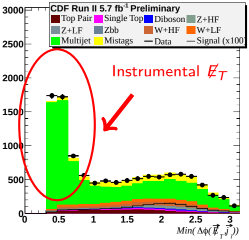
A Neural Network to reject QCD





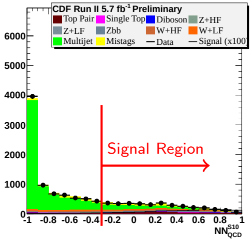
Every input variable is validated in several control regions.
The neural network output is also checked for mis-modeling.





S/B

Single Top	1/20	($\times$2.5)
WZ/ZZ	1/50	($\times$3.0)
SM Higgs	1/200	($\times$2.5)



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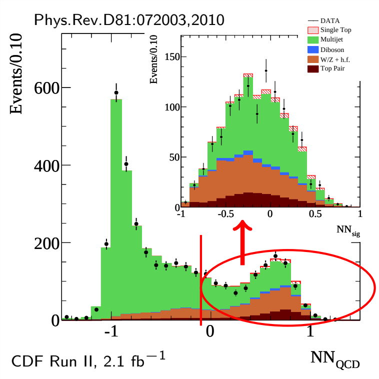
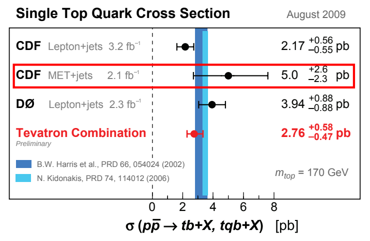
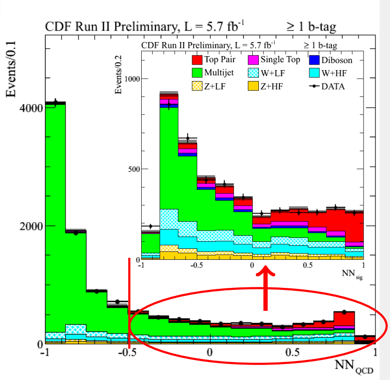
Single top production: part of observation

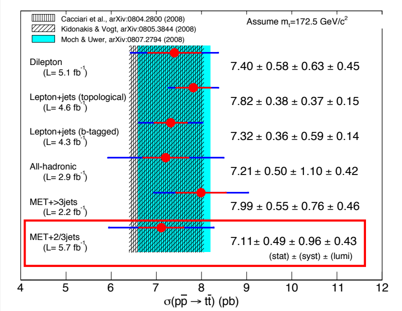




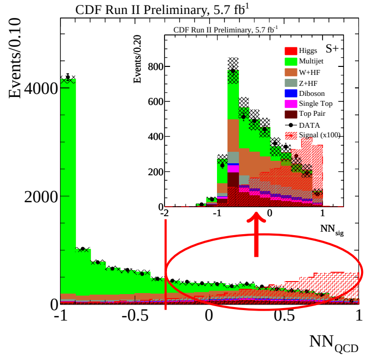
CDF Analyses in the $\not{E}_T$+b-jets signature

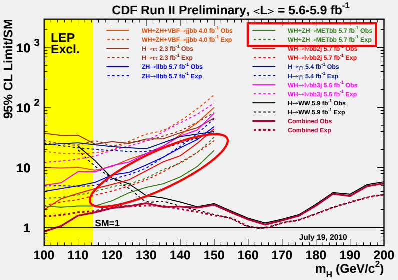
Top pair production: Cross-check using well understood signal.





SM Higgs: among most sensitive low mass (< 135 GeV$/c^2$) channels





Summary

An interesting channel for SM and BSM physics

- Many SM and BSM yield $\not{E}_T$+b-jets;
- This channel has very large acceptance;
- Very sensitive provided we get rid of the large QCD multijet-background;

A powerful tool to reject QCD multi-jet

- Novel combination of kinematic variables (exploits correlations);
- The technique is very **generic**: works with many different signals;
- It is as powerful as a lepton ID, in a channel with much larger acceptance;
- Made three SM analyses possible at CDF (and similarly at DZero);
- We plan to use this technique to measure $\sigma(WZ/ZZ \to \not{E}_T + b\bar{b})$;

Thank You

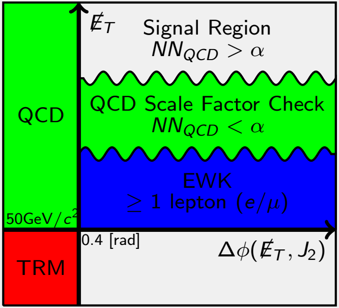
Backup Slides

Data-driven model and control regions

Data-driven model for multi-jet (MJ) production

- **Why?** Efficiency is so low that we would need a very large QCD Monte Carlo sample;
- **Data-driven method**: deriving a (4D) **Tag-Rate-Matrix** from QCD MJ sample ($> 99.9\%$);
- Applying the matrix to the (pre-tag) data to get b-tagging probability for each event;
  - We apply the matrix to the Monte Carlo and subtract to avoid double counting;
- Excellent agreement in the shape. Normalization obtained from control region;

Control regions

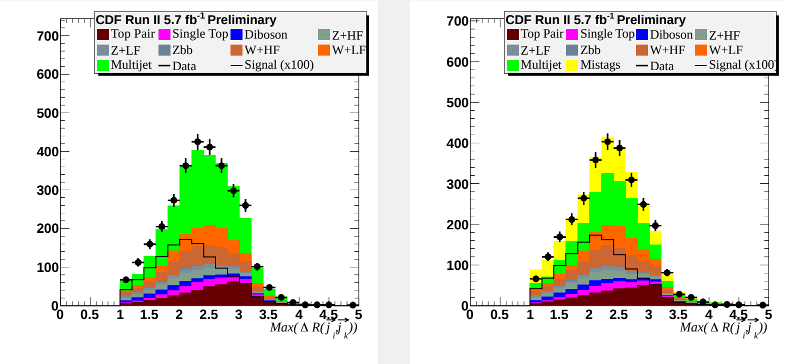


- **TRM**: training sample for Tag-Rate-Matrix;
- **QCD**: cross-check for the data-driven model;
- **EWK**: cross-check for the EWK backgrounds (MC);
- **QCD Scale Factor Check**: derivation of the QCD MJ scale factor (~ 1);
- New: extra regions with high NN output in pre-tag;

More on the QCD multi-jet (MJ) model

Components of multi-jet bakground

- The multi-jet background in the past analyses consisted mainly of QCD + EWK mis-tags;
- We are now using a new modeling in which the EWK mis-tags are modeled separately;



Checking the modeling: Control Regions

- Every input to the NN is checked in more than 5 orthogonal control regions;
- We check both the data-driven and Monte Carlo modeling;
- Excellent agreement throughout;