Single Top s-channel Production in $\slashed{E}_T$+jets at CDF

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The top quark can be produced:
- in $t\bar{t}$ pairs through strong interaction;
- as single top via EW interaction.

Observed by CDF and DØ in 2009:

Two dominant processes:
- t-channel;
- s-channel.
  - Wt-channel has a small cross section at the Tevatron.

<table>
<thead>
<tr>
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<th>$\sigma$(pb)</th>
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<tbody>
<tr>
<td>s-ch</td>
<td>1.05 ± 0.05</td>
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<tr>
<td>t-ch</td>
<td>2.08 ± 0.08</td>
</tr>
<tr>
<td>Wt-ch</td>
<td>0.25 ± 0.03</td>
</tr>
<tr>
<td>$t\bar{t}$</td>
<td>7.08 ± 0.49</td>
</tr>
</tbody>
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Cross sections at Tevatron considering $m_t = 173\text{GeV}/c^2$
arXiv:1205.3453 (May 2012)
It has not been observed yet;
  - DØ recently claimed a 3.7 \( \sigma \) evidence\(^1\).

Difficult at LHC;
  - \( \sigma_{s-ch}^{SM} \approx 5 \text{ pb}, \sigma_{t-ch}^{SM} \approx 65 \text{ pb} \) at LHC 7 TeV.

Deviations from SM prediction may indicate new physics, like the existence of a W’ or of a charged Higgs boson\(^2\).

At CDF, two statistically independent samples are analyzed:

- the **lepton+jets** sample;
  - one isolated lepton, missing transverse energy and jets are required.

- the **\( \not{E}_T + \text{jets} \)** sample.

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\(^1\)http://theory.fnal.gov/jetp/talks/WineAndCheese_20130621_v6.pdf

We analyze the full CDF Run II dataset (9.5 fb$^{-1}$) looking for single top s-channel events when $t \rightarrow Wb$ and $W$ decays leptonically, but:

- there are no identified leptons.
- there are $\tau$s decay hadronically.

Events are accepted on line by the trigger if they contain large missing transverse energy ($\slashed{E}_T$) and at least two jets. Off line we require:

- Large $\slashed{E}_T$;
- **No isolated leptons**;
  - We use loose identification cuts to reject events with isolated leptons.
- 2 or 3 jets, one or two identified as $b$-jets;
- $\Delta \phi(\slashed{E}_T, j_2) > 0.4$. 

![Diagram of parton level events](image.png)
**s-channel in $\not{E}_T + \text{jets}/2$**

**Signal and Background Composition and Model**

**Composition:**
- QCD multijet production is by far the largest background contribution;
- $t$-channel and WH/ZH are included as backgrounds.

**Model:**
- **Signal:** POWHEG
- **$t$-channel:** POWHEG
- **$W/Z+\text{jets}$:** ALPGEN, normalization left unconstrained in the final fit
- **$t\bar{t}$, $WW/WZ/ZZ$, WH/ZH:** PYTHIA
  - $t\bar{t}$ is normalized to the measured cross section.

The parton showering is performed by PYTHIA.

QCD multijet is data-derived, validated in several control regions:
- **QCD region**: QCD enriched region, $\Delta\phi(\not{E}_T, j_2) < 0.4$;
- **EWK region**: defined requiring a reconstructed lepton.
Since we are looking for a small signal in a very large background, we need to use **Multivariate Techniques**. In this analysis we employ:

- a Neural Network (NN) **QCD veto**, to reject the QCD multijet production as much as possible. It reduces this background by an order of magnitude;
- two other dedicated NNs:
  - to distinguish signal from **$W/Z$-jets** production;
  - to distinguish signal from **$t\bar{t}$** background.

combined together in a **Final Discriminant** used to fit for signal.
After applying the QCD veto, we derive the QCD multijet normalization in the rejected region.
We fit the data distribution of the final discriminant to extract the single top s-channel cross section.
Results

Cross Section Measurement

- Bayesian approach: binned likelihood;
- Uniform, non-negative prior for signal cross section;
- All the uncertainties and their correlations taken into account
- Expected result:
  \[ \sigma_{\text{exp}}^{s-ch} = 1.00^{+0.56}_{-0.60} \times SM \text{ (stat+syst)} \]
- Measured single top s-channel cross section:
  \[ \sigma_{\text{obs}}^{s-ch} = 1.10^{+0.65}_{-0.66} \text{ (stat+syst) pb} \]

This result is consistent with the standard model cross section
\[ \sigma_{\text{SM}}^{s-ch} = 1.05 \pm 0.05 \text{ pb} \]
Summary

- Measured the single top s-channel cross section in $\not{E}_T+$jets with the full CDF dataset, 9.5 fb$^{-1}$;
- First time that a single top s-channel measurement is performed in the $\not{E}_T+$jets final state;
- A legacy measurement from CDF/Tevatron;
- The CDF s-channel measurement is lepton+jets is on-going, will combine the results soon;
- Combination with DØ measurement is planned.