Generic Analysis and Optimal Observables

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Generic Analysis Structure
Method of Optimal Observables
High Level Analysis Methods
D0 Single Top Search as an Example

Generic Structure of Analysis

- Create MC Model
- Apply some preselection cuts
- Find some observables which help to sepa-rate signal from background
- Apply some method of High Level Analysis to get final numbers of the predicted Signal/Background and Data

Method of Optimal Observables

- Provides general receipt how to choose most effective variables to separate Signal/Background
- Based on the analysis of Feynman diagrams which contribute to signal and Background
- Described in different examples
  - Higgs search hep-ph/0406152 p.69-71 (E.Boos and L.D.)
  - Single Top search AIHENP'99 (E.B. and L.D.),

    hep-ph/9903215 and D0 publications on Single Top Search
  - Ttbar in progress (E.B., L.D., H. Frisch, S. Levy)

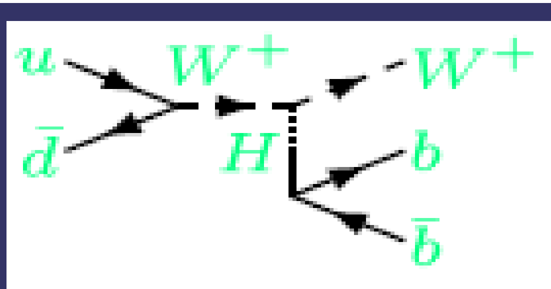
Three Classes of Variables

- “Singular” Sensitive Variables (denominator of Feynman diagrams)

Most of the rates of signal and background processes come from the integration over the phase space region close to the singularities. If some of the singular variables are different or the positions of the singularities are different the corresponding distributions will differ most strongly

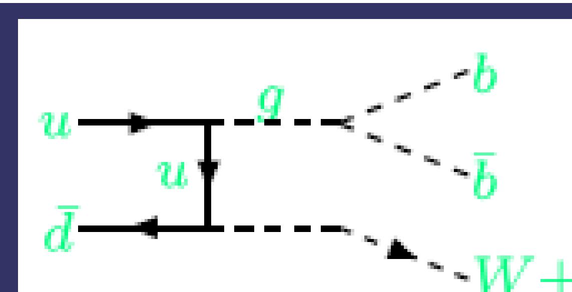
s-channel singularities

$$M^2_{f1,f2} = (p_{f1} + p_{f2})^2$$



t-channel singularities

$$\hat{t}_{i,f} = (p_f - p_i)^2 = -\sqrt{\hat{s}}e^{Y} p_T^f e^{-|y_f|}$$



Three Classes of Variables

- "Angular" variables, Spin effects (numerator of Feynman diagrams)

$$\frac{1}{\Gamma_T}\frac{d\Gamma}{d(\cos\chi_\ell^W)} = \frac{3}{4}\,\frac{m_t^2\sin^2\chi_\ell^W + 2m_W^2\,\frac{1}{2}(1-\cos\chi_\ell^W)^2}{m_t^2+2m_W^2}$$

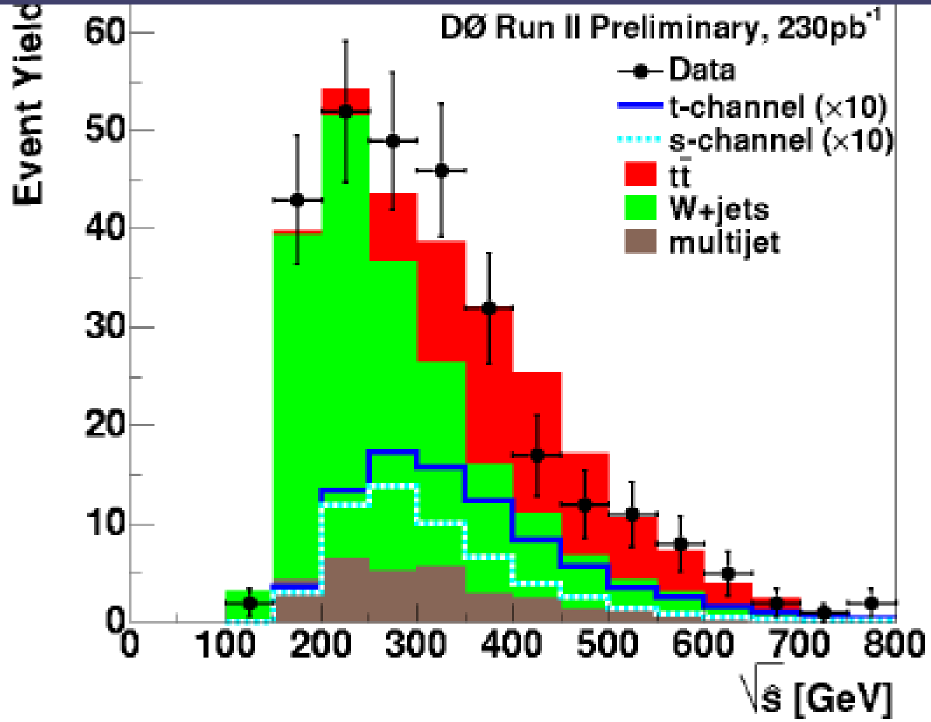
G. Mahlon, S. Parke Phys.Rev. D55 (1997) 7249-7254

- "Threshold" variables
  s_hat and Ht variables relate to the fact that various signal and background processes may have very different energy thresholds

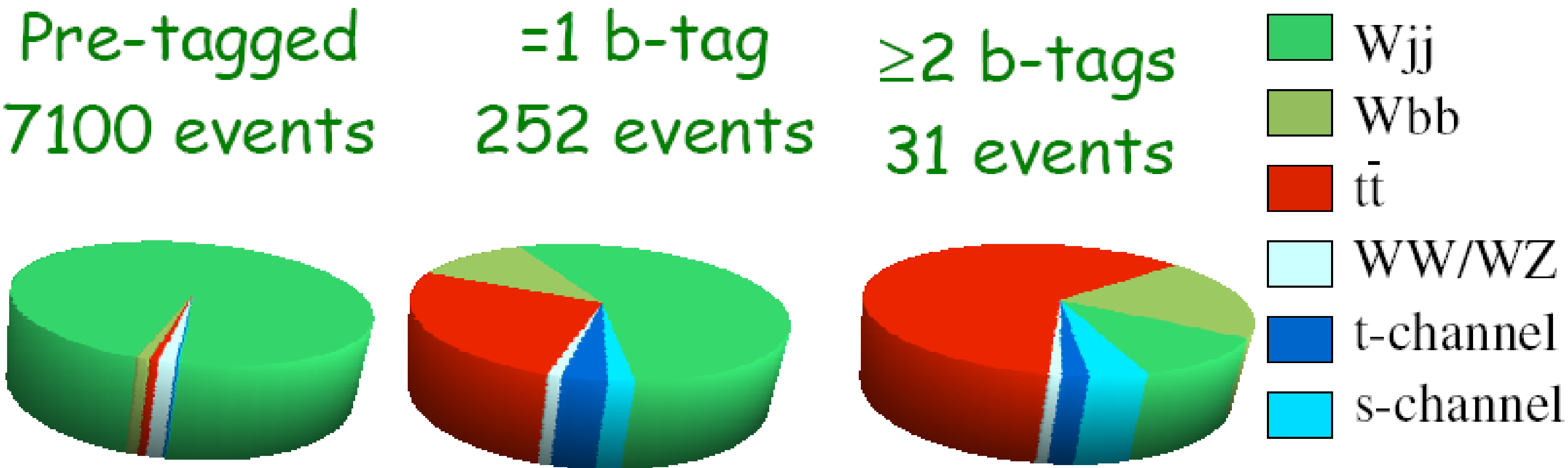
D0 Analysis

PHENO 03/05/05 talk by R. Schwienhorst

	s-channel	t-channel
Cut acceptance	23%	22%
b-tag efficiency	54%	38%
Signal yield	5.5	8.5
BKgnd yield	287	276
Signal/bkgnd	1:52	1:32

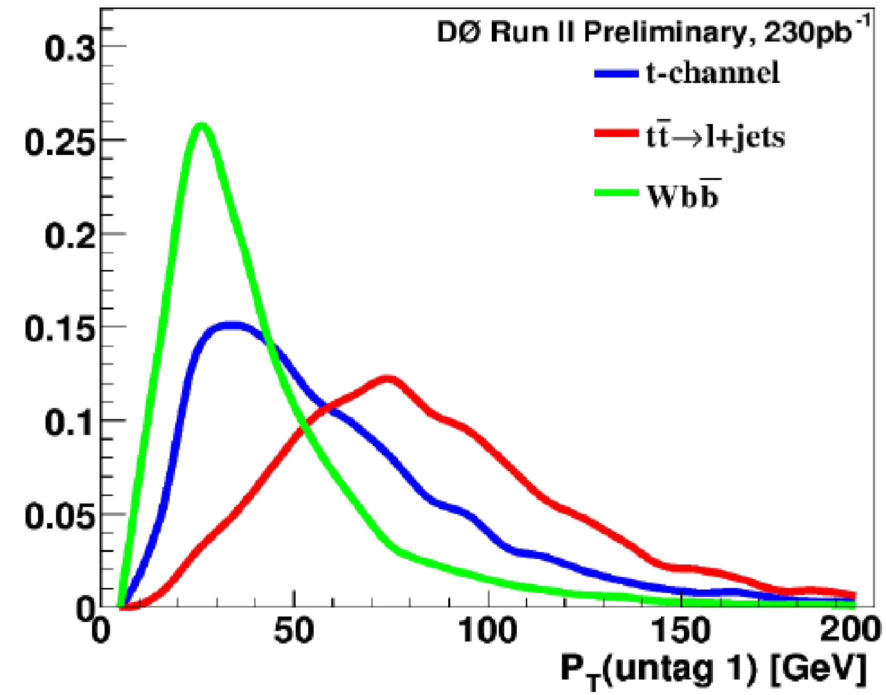


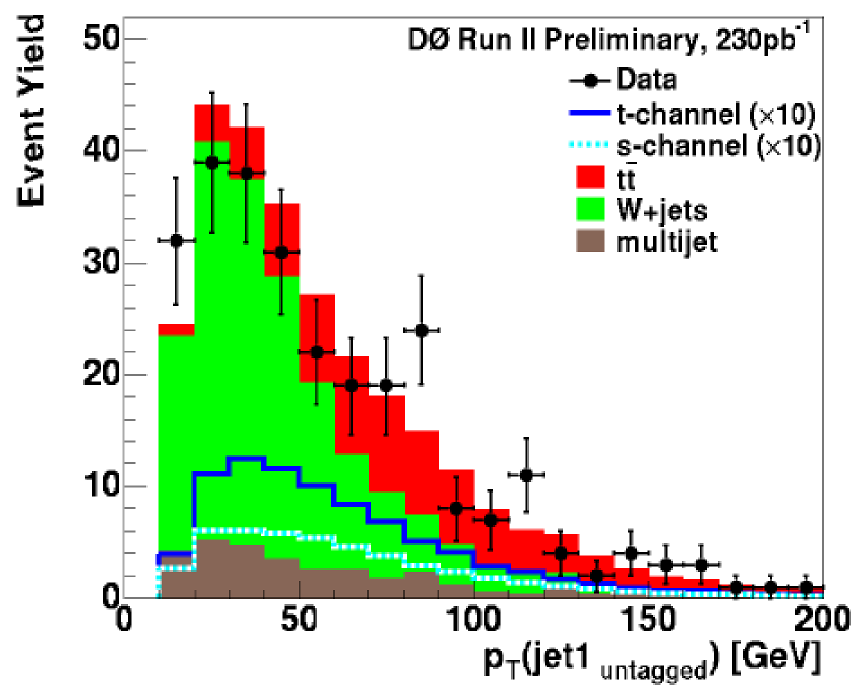
Pre-tagged	=1 b-tag	≥2 b-tags
7100 events	252 events	31 events



Object p_T

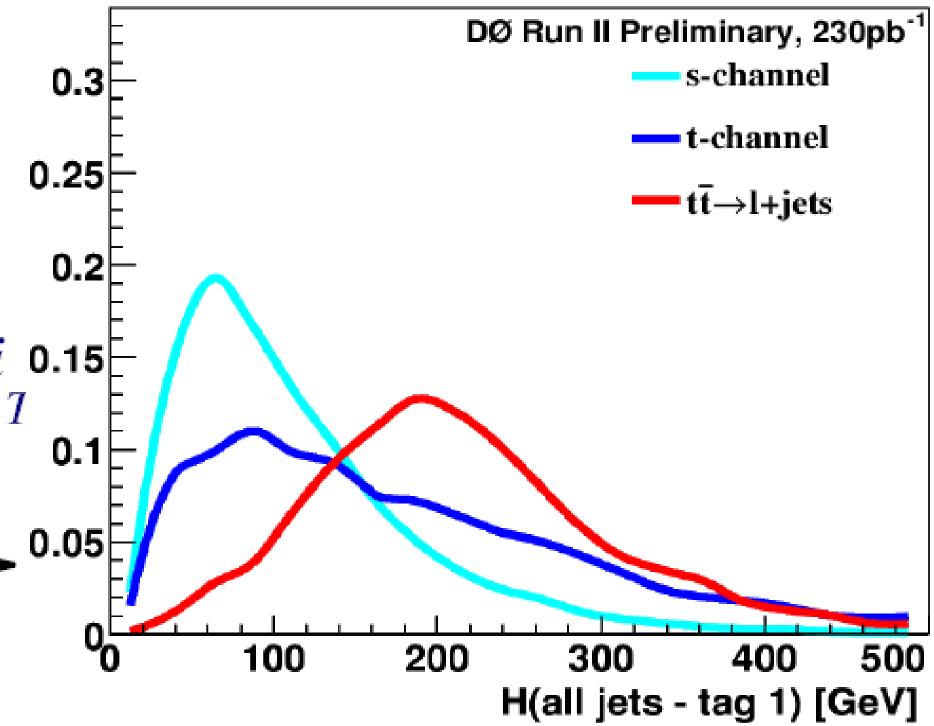
- p_T of jets:
  - Both s-channel and t-channel:
    - $\text{Jet1}_{\text{tagged}}$
  - Only t-channel:
    - $\text{Jet 1}_{\text{untagged}}$
    - $\text{Jet 2}_{\text{untagged}}$
  - Only s-channel:
    - $\text{Jet 1}_{\text{non-best}}$
    - $\text{Jet 2}_{\text{non-best}}$

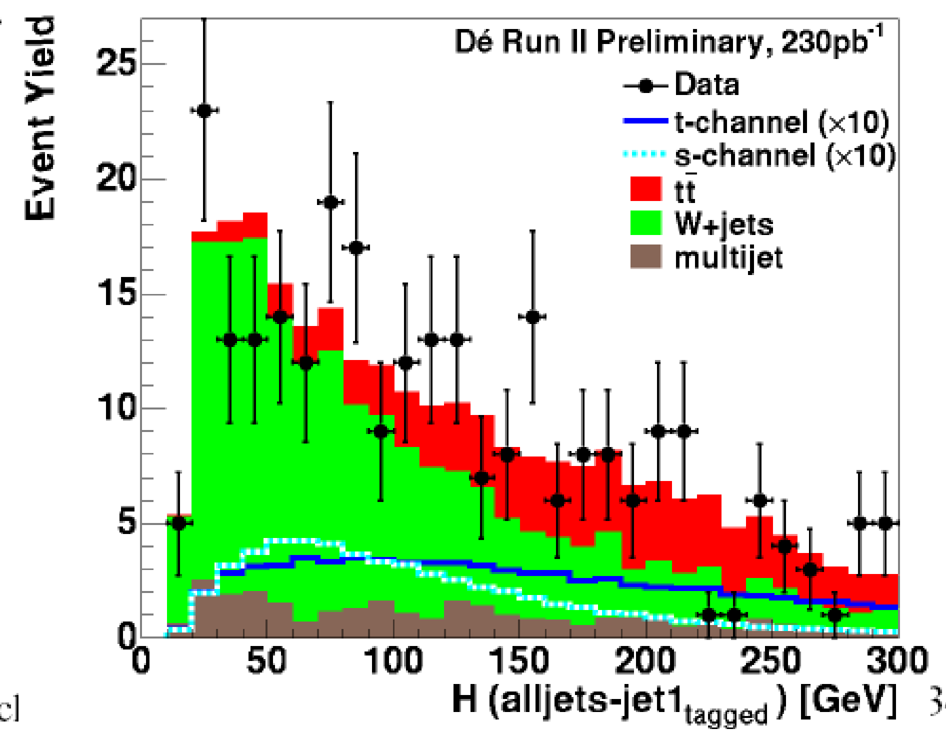




Event Energy

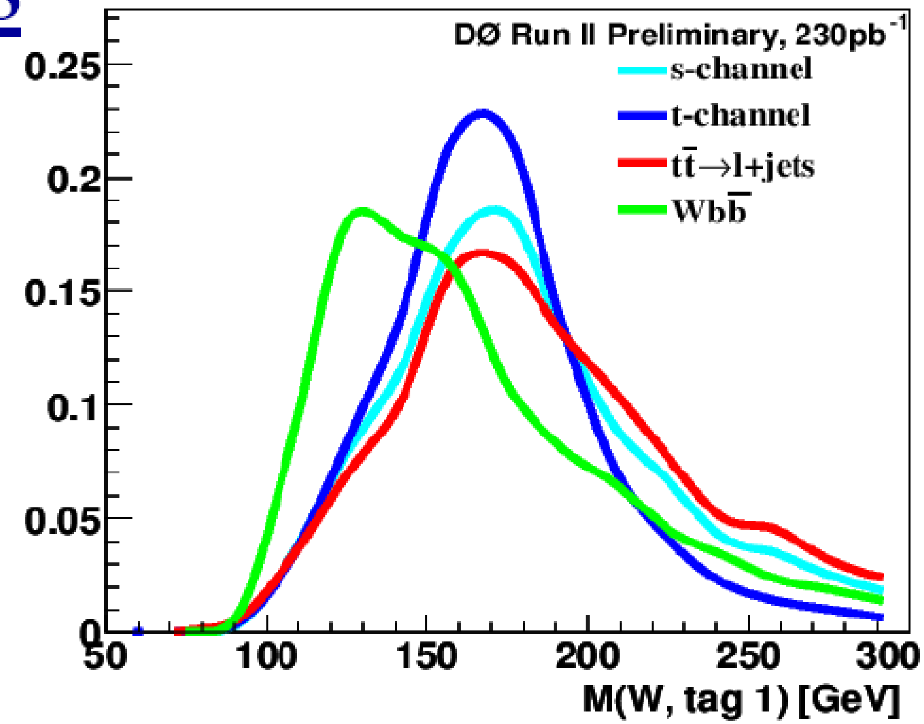
- Total energy $H = \Sigma_i E^i$
  transverse energy $H_T = \Sigma_i E^i_T$
  - Both s-channel and t-channel:
    - H(all jets – Jet1$_{tagged}$)
  - Only t-channel:
    - H_T(all jets)
    - H_T(all jets – Jet1$_{tagged}$)
  - Only s-channel:
    - H(all jets – Jet$_{best}$)
    - H_T(all jets – Jet$_{best}$)

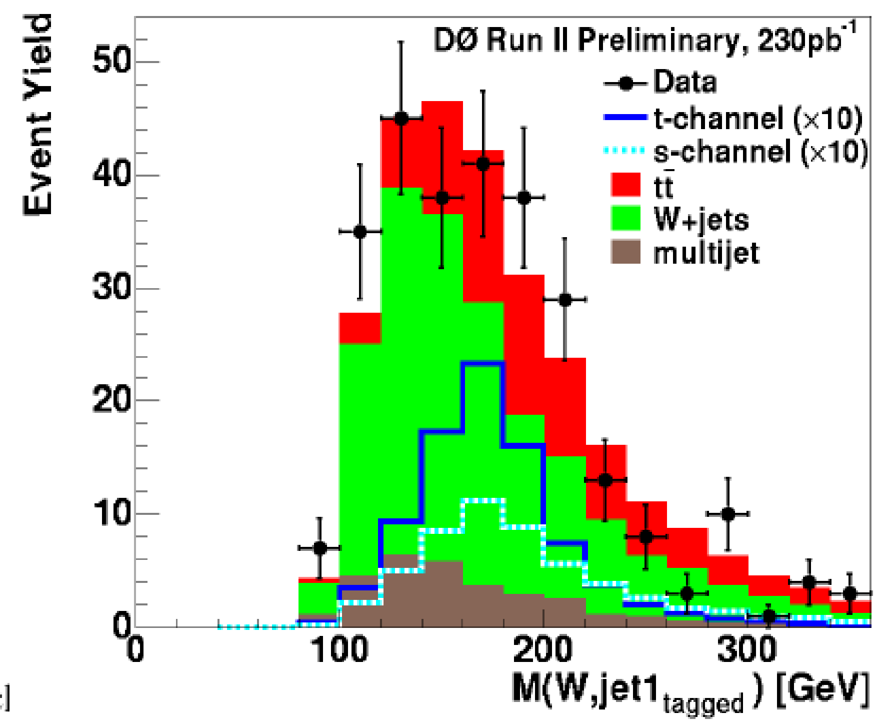




Reconstructed Objects

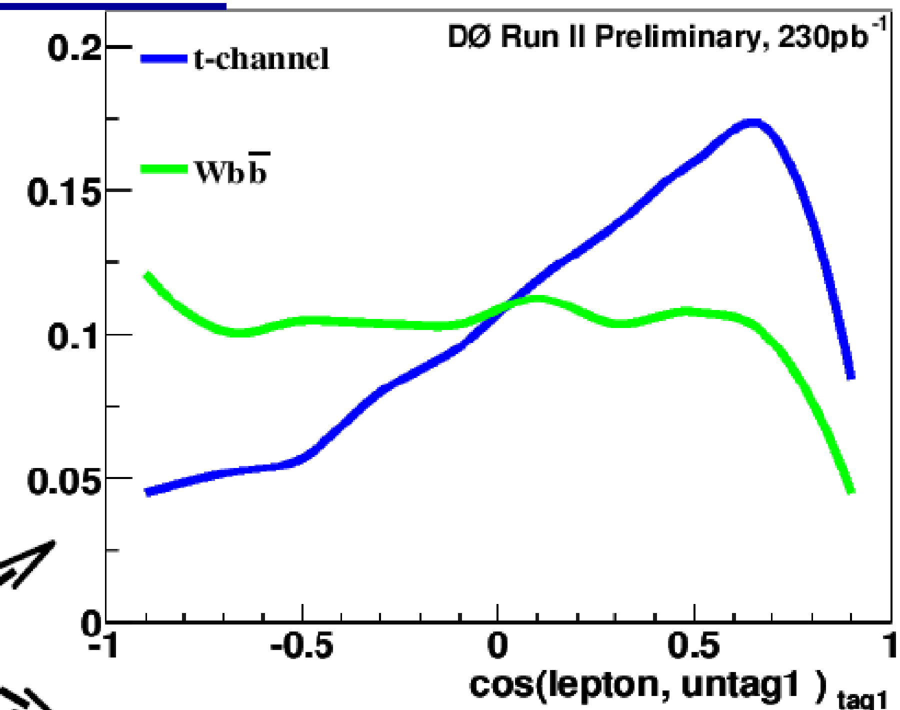
- Both s-channel and t-channel:
  - M(all jets)
  - p_T(all jets – $\text{Jet1}_{\text{tagged}}$)
  - $M(\text{top}_{\text{tagged}})$
  - $\sqrt{\hat{s}}$
- Only t-channel:
  - M(all jets – $\text{Jet1}_{\text{tagged}}$)
- Only s-channel:
  - M_T(Jet1, Jet2)
  - p_T(Jet1, Jet2)
  - M(all jets – $\text{Jet1}_{\text{best}}$)
  - $M(\text{top}_{\text{best}})$

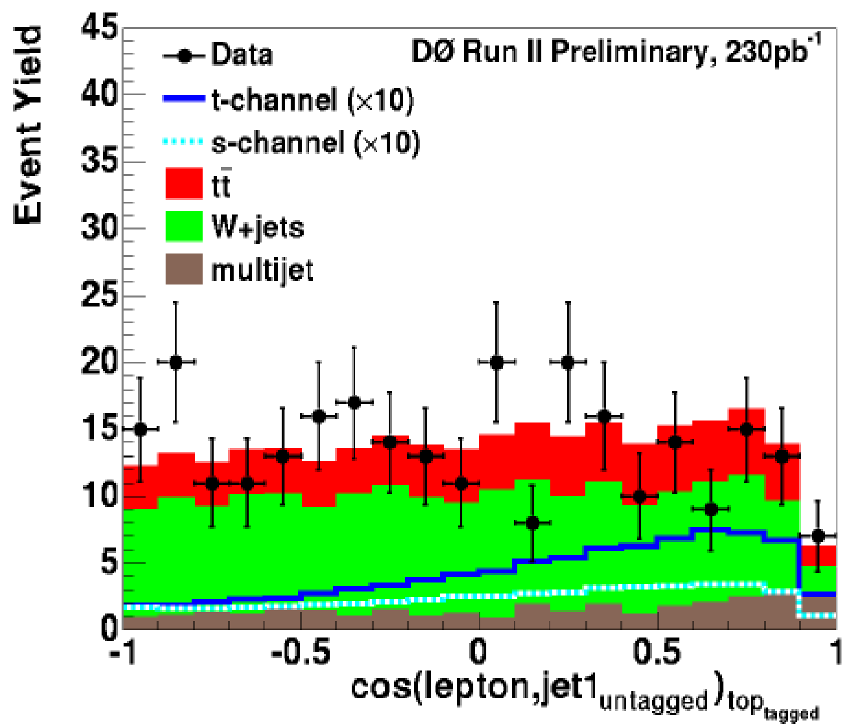




Angular Correlations

- Both s-channel and t-channel:
  - $\Delta R(\text{Jet1}, \text{Jet2})$
- Only t-channel:
  - $\eta(\text{Jet1}_{\text{untagged}}) \times Q(\text{lepton})$
  - $\cos(\text{lepton}, \text{Jet1}_{\text{untagged}})_{\text{top}_{\text{tagged}}}$
    - Spin correlation in optimal basis
  - $\cos(\text{all jets}, \text{Jet1}_{\text{tagged}})_{\text{all jets}}$
- Only s-channel:
  - $\cos(\text{lepton}, Q(\text{lepton}) \times z)_{\text{top}_{\text{best}}}$
    - Spin correlation in optimal basis
  - $\cos(\text{all jets}, \text{Jet1}_{\text{non-best}})_{\text{all jets}}$

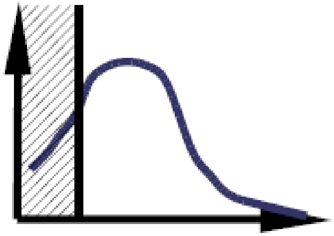




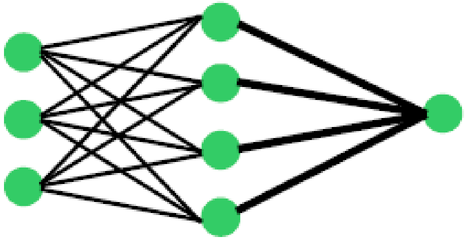
Separating Signal from Backgrounds

- Three analysis methods

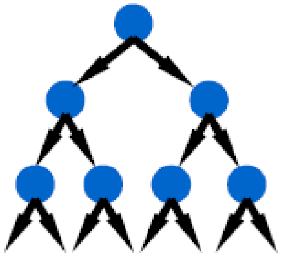
Cut-Based



Neural Networks



Decision Trees



- Each using the same structure:
  - Optimize separately for s-channel and t-channel
    - Optimize separately for electron and muon channel (same variables)
  - Focus on dominant backgrounds: W+jets, tt
    - W+jets – train on tb-Wbb and tqb-Wbb
    - tt – train on tb – $tt \rightarrow l + \text{jets}$ and tqb – $tt \rightarrow l + \text{jets}$
  - Based on same set of discriminating variables

➔ 8 separate sets of cuts/networks/trees

The Latest Tevatron Results

	s-channel	t-channel
NLO cross section	0.88 pb	1.98 pb

95% CL upper cross section limits [pb]

	s-channel	t-channel
DØ Run I	17	22
CDF Run II (160pb^{-1})	13.6	10.1
This analysis (230pb^{-1})		
cut-based	10.6	11.3
DTs & binned likelihood	8.3	8.1
NNs & binned likelihood	6.4	5

Generic High-Level Analysis Strategy

- Distinguish kinematically different backgrounds (ttbar, Wbb, Wjets, QCD fake, diboson)
- Construct set of “optimal observables” for each pair of Signal/Background (e.g. t-channel/Wbb)
- Train different networks for each pair of Signal/Background processes
- Combine NN outputs