Use of rapidity and event shape variables in single top quark analysis

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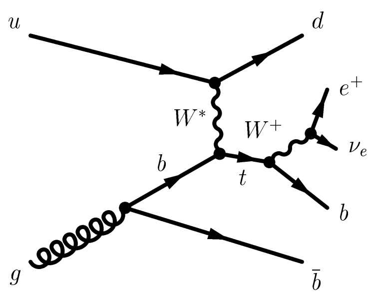
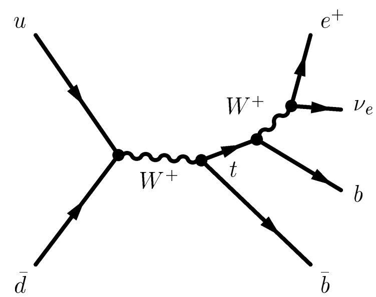
This talk summarizes the results of CDF-note 5976

9/19/2002 top-meeting

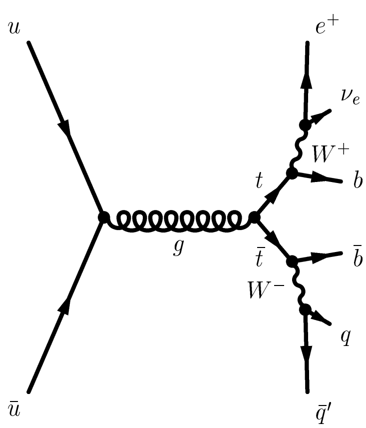
The production channels and their backgrounds



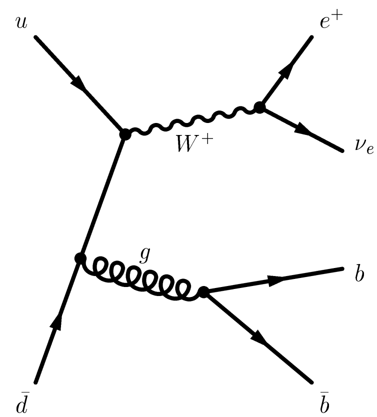
top W + Gluon Fusion



single top s-channel

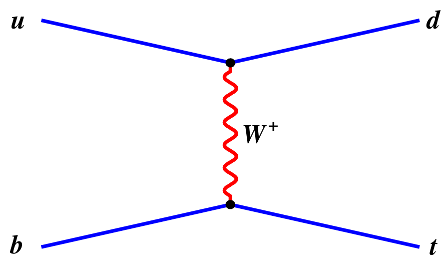


$t\bar{t}$ (semi-leptonic)



$Wb\bar{b}$

Kinematics of the hard process: Δy

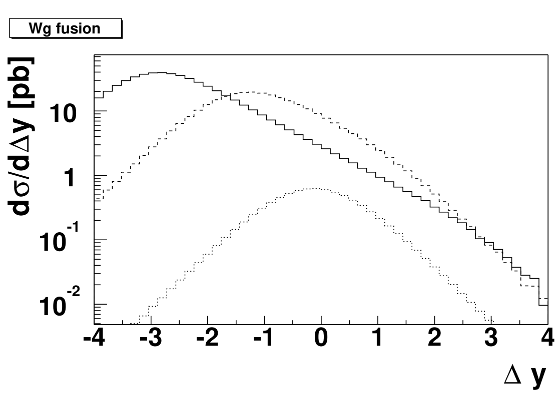


$\Rightarrow$ "Rutherford scattering"
$\Rightarrow$ forward scattering dominates

Rapidity: $y = \frac{1}{2} \ln \frac{E+P_z}{E-P_z}$ for d- and t-quark

$$\begin{aligned}\Delta y &= y_{\text{top}} - y_{\text{d}} \\ &= \ldots \\ &= \tanh^{-1}\left[\frac{\cos\hat{\theta}}{\sqrt{1+\frac{4m_t^2}{\hat{s}}}}\right] + \tanh^{-1}\left[\cos\hat{\theta}\right]\end{aligned}$$

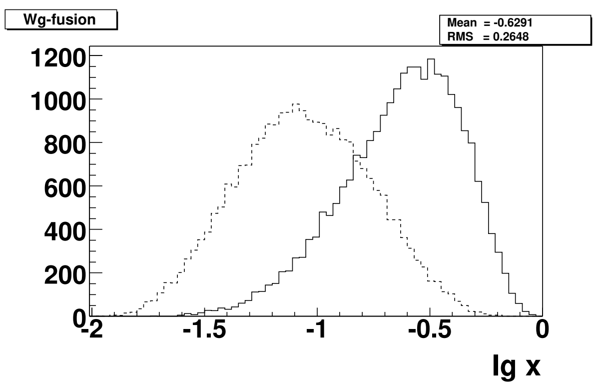
for $\sqrt{\hat{s}} >> m_{\text{top}}$ (or m_{top} small ...) $\rightarrow \tanh\left(\frac{\Delta y}{2}\right) = \cos\hat{\theta}$



dotted line: $\sqrt{\hat{s}} = 180$ GeV
dashed line: $\sqrt{\hat{s}} = 250$ GeV
solid line: $\sqrt{\hat{s}} = 500$ GeV

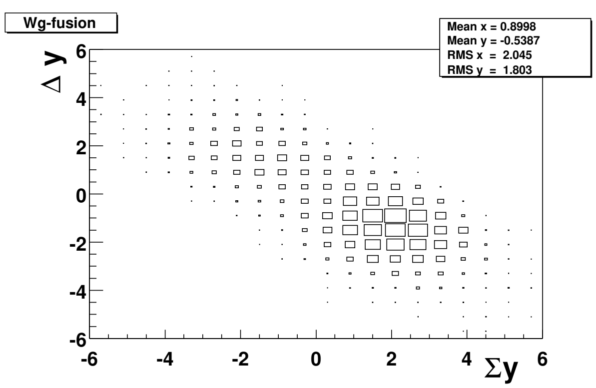
Kinematics of the hard process: Σy (boost)

Fractional momenta: incoming light (solid) and b-quark (dashed)



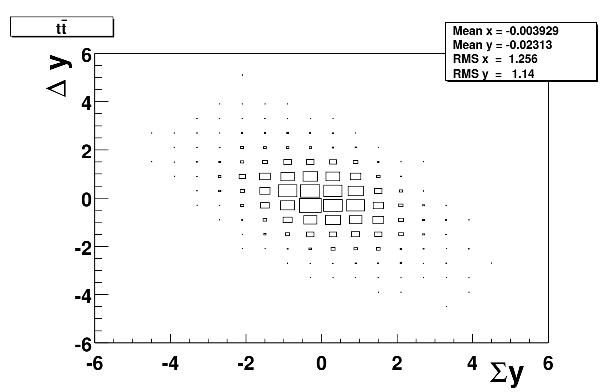
$\rightarrow$ boost of the partonic system vs lab system $y_{\text{boost}} = \frac{\Sigma y}{2} = \frac{y_{\text{top}} + y_{\text{light quark}}}{2}$

combining Σy with Δy:



largest population away from $\hat{\theta} = 90^\circ$ ($\Delta y > 0$)

$t\bar{t}$-Production: largest population: $\hat{\theta} \approx 90^\circ$ ($\Delta y \approx 0$)
Incoming PDF x distributed symmetrically



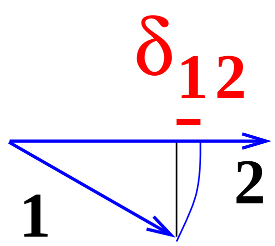
Event shape variable

Jet counting difficult:

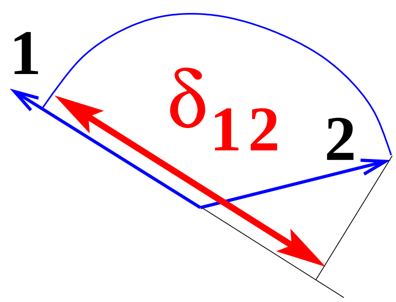
- Gluon radiation: $n_{\text{jets}} \nearrow$
- Fluctuations in the detector energy measurements
- Jet-algorithms, cone-size

$\rightarrow$ continuous variable from the k_T jet algorithm

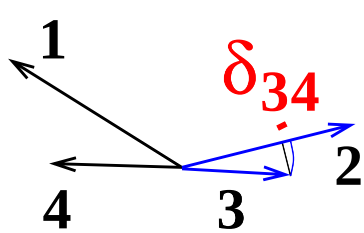
$$\delta_{i,j} = \frac{\min(E_i^2, E_j^2)(1-\cos\alpha_{i,j})}{E^2}; \qquad \delta_{n,n+1} = \min(\delta_{i,j})$$



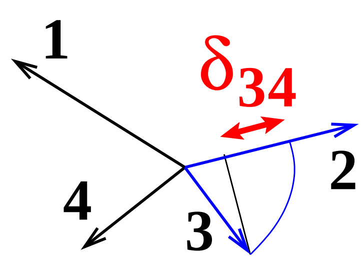
$Wb\bar{b}$ e.g.



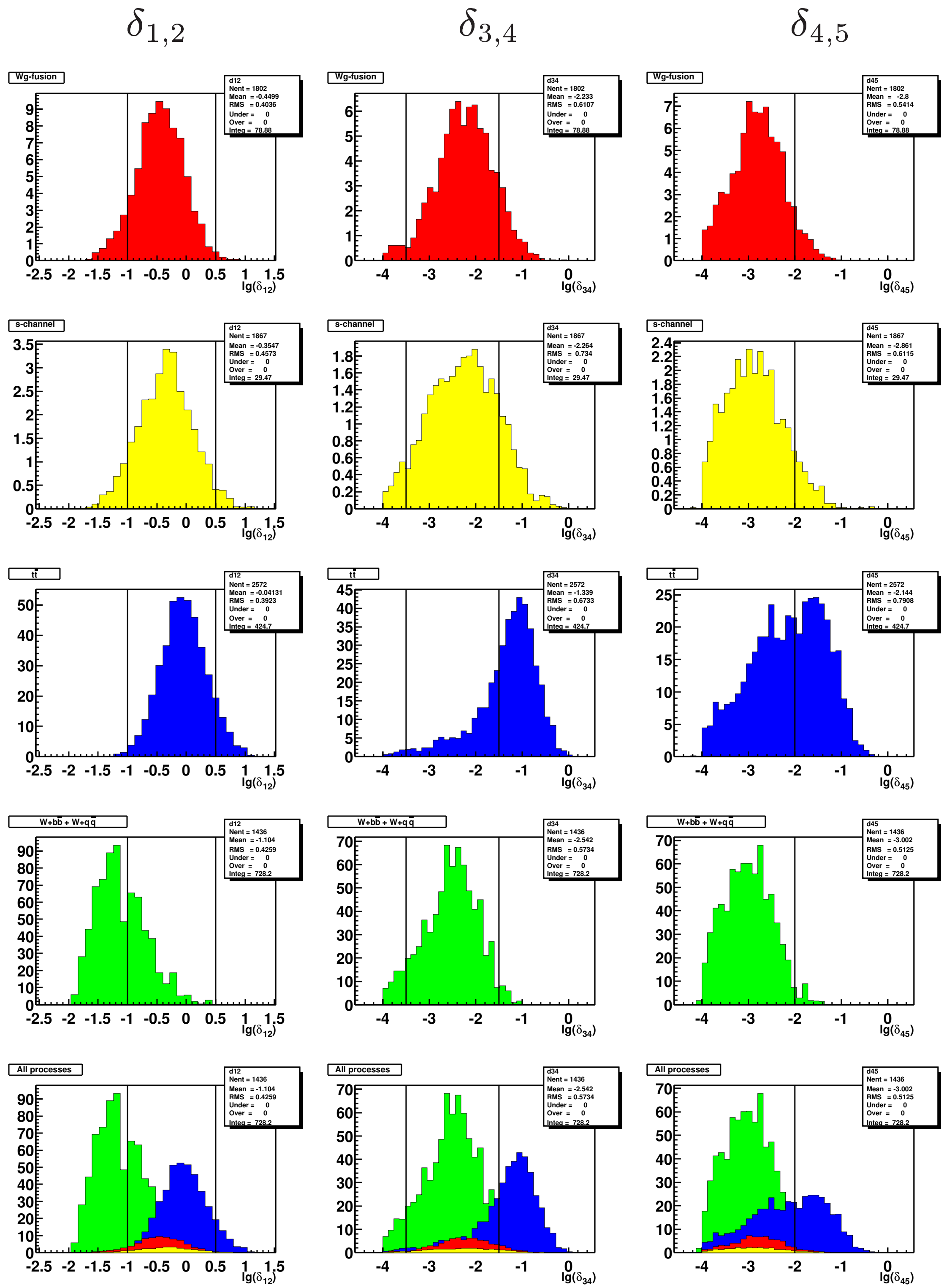
top W+gluon fusion



top W+gluon fusion



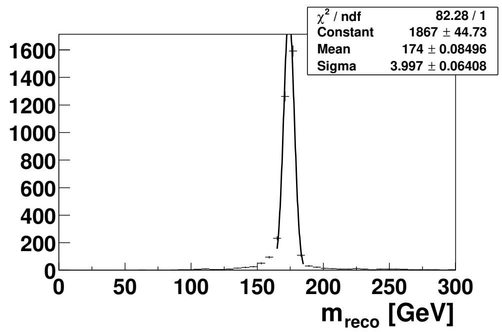
$t\bar{t}$ e.g.



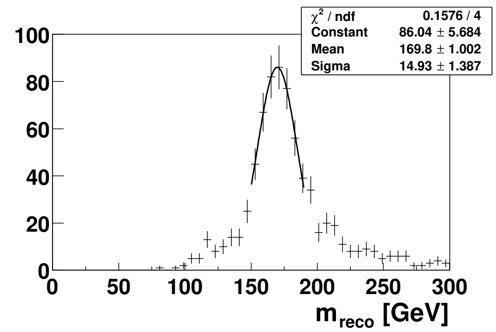
W+gluon fusion s-channel $t\bar{t}$ $W + 2$ jets

One word about mass reconstruction

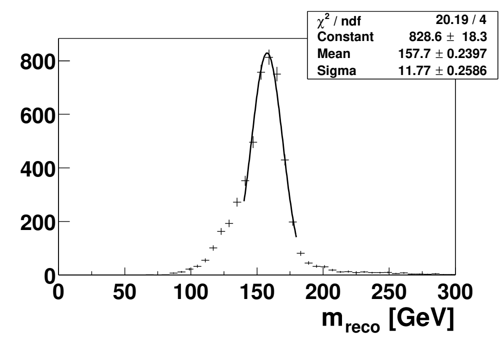
$P_{\text{top}} = P_e + P_\nu + P_{\text{b-jet}}$
P_ν from MET with constraint $m_W^2 = (P_e + P_\nu)^2$
$\rightarrow$ two solutions for p_z: use the smallest in $|p_z|$
Reconstructed top mass



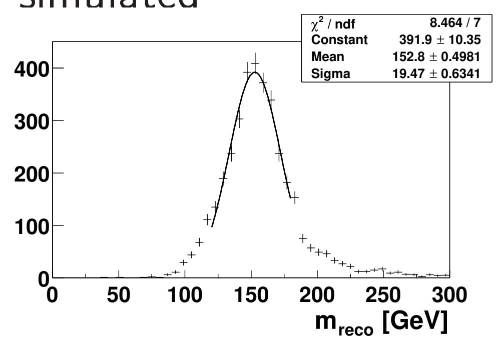
e simulated



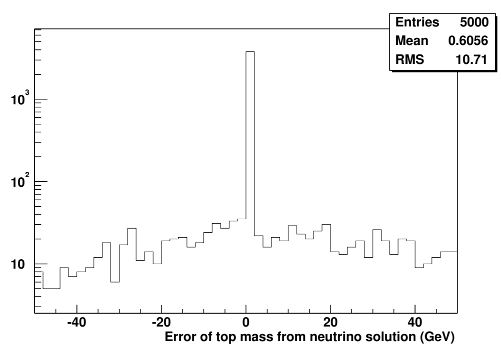
ν simulated



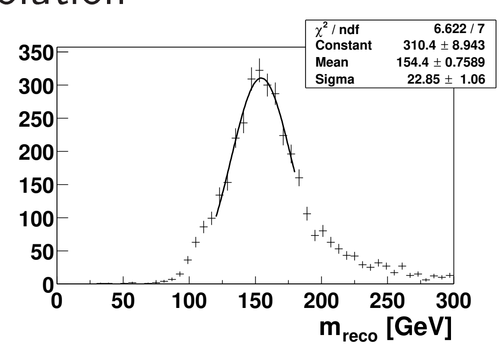
b-jet simulated



all simulated, correct ν solution



influence of ν solution



full simulation

Analysis potential

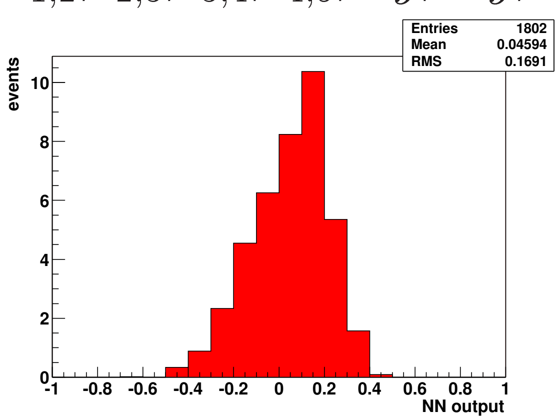
Preselection:

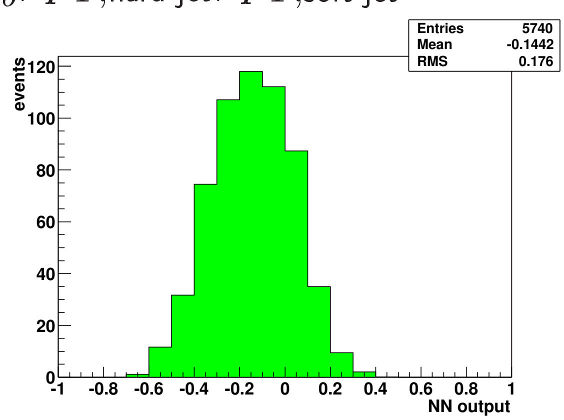
electron	$p_T > 15$ GeV
	$0.1 < \|\eta\| < 1.0$ or $1.2 < \|\eta\| < 2.8$
2 or more jets	$p_T > 10$ GeV
	$0 < \|\eta\| < 1.1$ or $1.5 < \|\eta\| < 2.8$
Missing E_T	> 15 GeV
b-tag	exactly one b-tag in $\|\eta\| < 2.0$ (parametrized)

Events for $1\text{fb}^{-1}(W \to e\nu)$:

	W+gluon fusion	s-channel	$t\bar{t}$	$Wb\bar{b}$	$Wq\bar{q}$
Produced	260	94	978	3560	2326545
After pre-selection	40	14	213	58	306

$\Rightarrow$ Put these events in an neural network (NeuroBayes, Michael Feindt) with the following variables:
$\delta_{1,2}$,$\delta_{2,3}$,$\delta_{3,4}$,$\delta_{4,5}$,Δy, Σy, $\cos\theta_{b\bar{b}}$, $p_{T,\text{hard jet}}$, $p_{T,\text{soft jet}}$



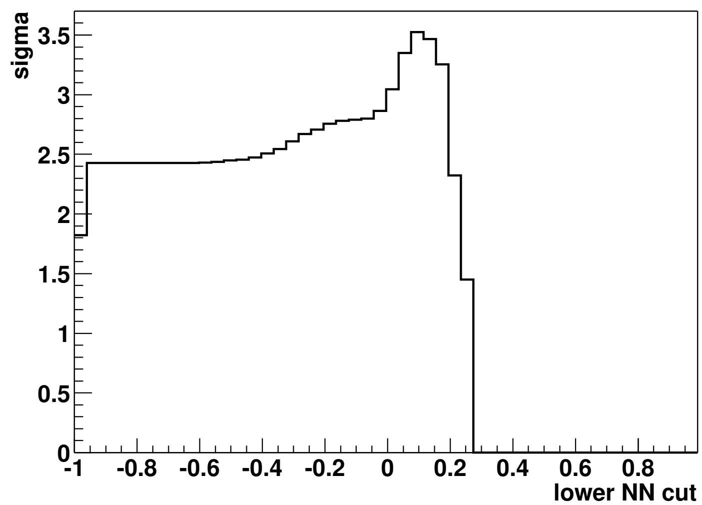


Output for signal

Output for background

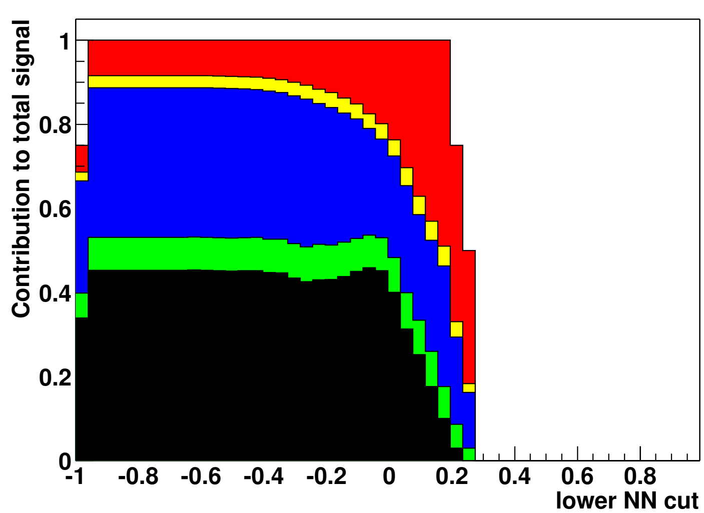
Significance

Combining electron and muon channel: 3σ at $\approx 500\text{pb}^{-1}$
At 500pb^{-1}: $\sigma(=$ Signal$/\sqrt{\text{Background}})$ depending on NN cut:



σ at different NN cuts (after additional mass cut)
best σ at NN cut of 0.12

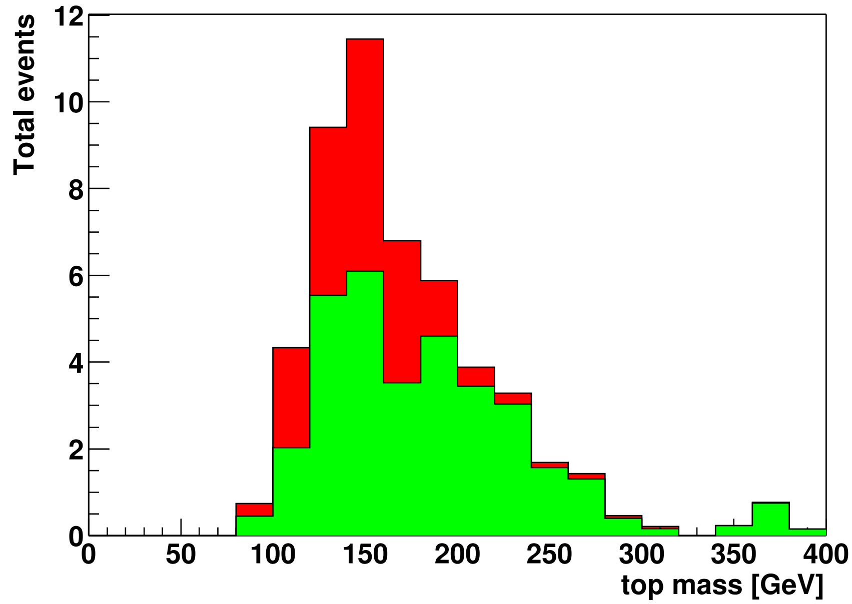
Contributions of the different channels changes with NN cut:



Contributions:
top-W+gluon fusion
top-s-channel
$t\bar{t}$
$Wb\bar{b}$
$Wq\bar{q}$

Contributions vs NN cut (after mass cut)

Reconstructed top mass



Reconstructed top mass for $500\mathrm{pb}^{-1}$ and best σ
(NN cut at 0.12)

Contributions: before mass cut / after mass cut	
top-W+gluon fusion	15 / 14
top-s-channel	2 / 1.5
$t\bar{t}$	15 / 8
$Wb\bar{b}$	4 / 3
$Wq\bar{q}$	15 / 7
$\rightarrow \sigma = \frac{S}{\sqrt{B}}$	2.91 / 3.77

Conclusions

observables related to parton scattering process:

$\Sigma y \quad \leftrightarrow \quad$ boost of parton–parton system

$\Delta y \quad \leftrightarrow \quad$ parton scattering angle

$\delta_{i,j} \quad \leftrightarrow \quad$ parton counting

have an excellent potential for top physics using Neural Network techniques.