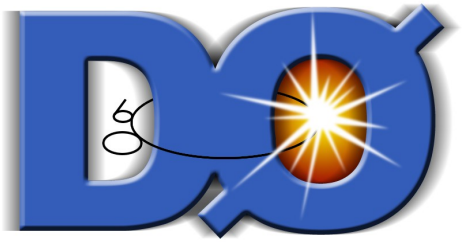
A Process-Factory for Top Physics with the DZERO Experiment

LHC-D Top Physics Workshop
Bad Honnef
Freitag, 26. 01. 2007



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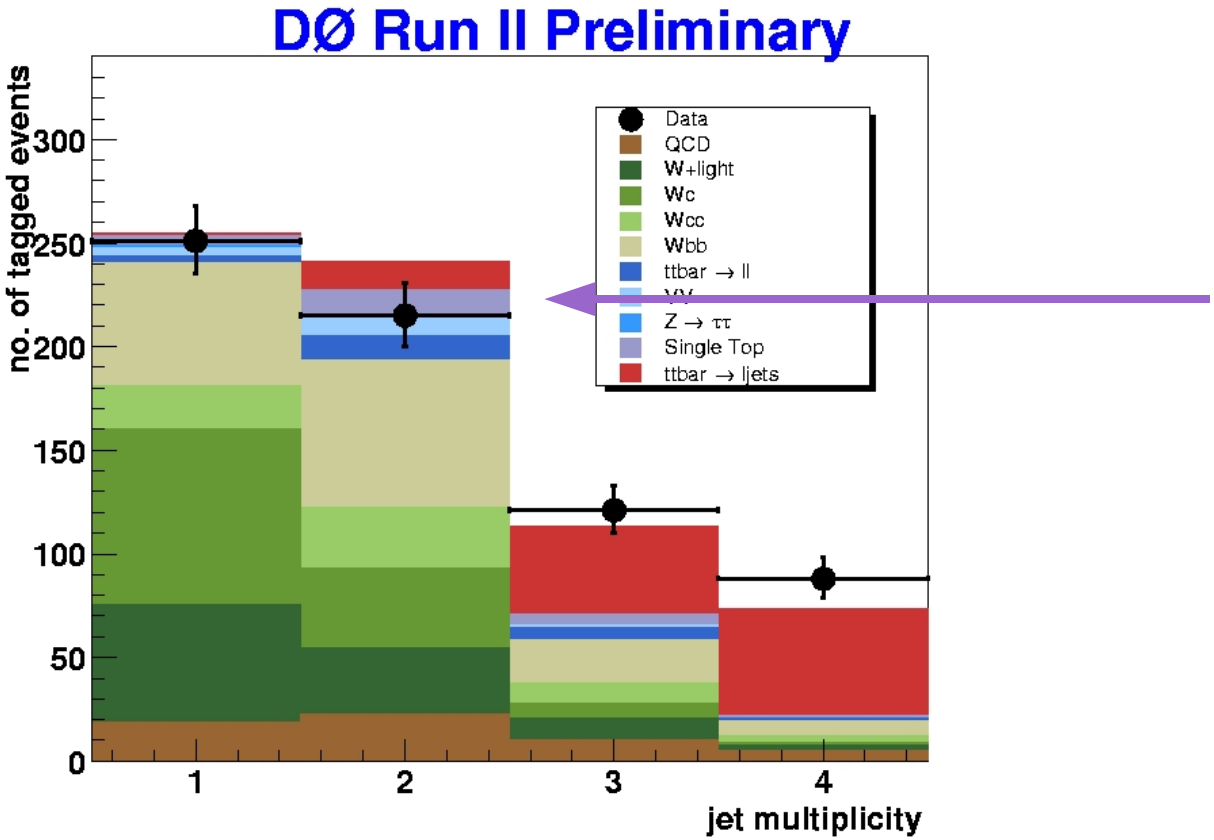
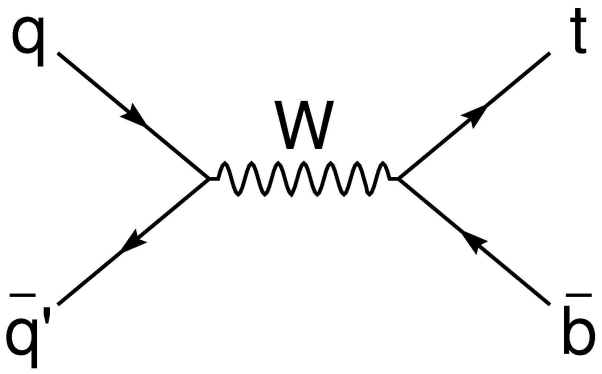
Multivariate Analyses

- **Multivariate Analyses are the key to signals that suffer from a hugh SM background:**
  - **Electroweak top production (single top)**
  - **Higgs**
  - **...**

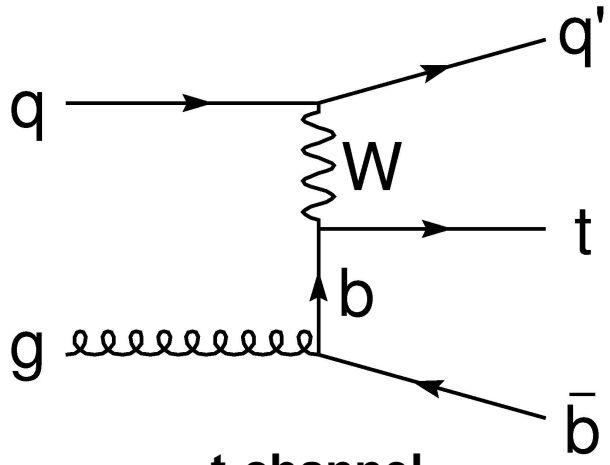


For Example: Electroweak Top Production



s-channel

+



t-channel

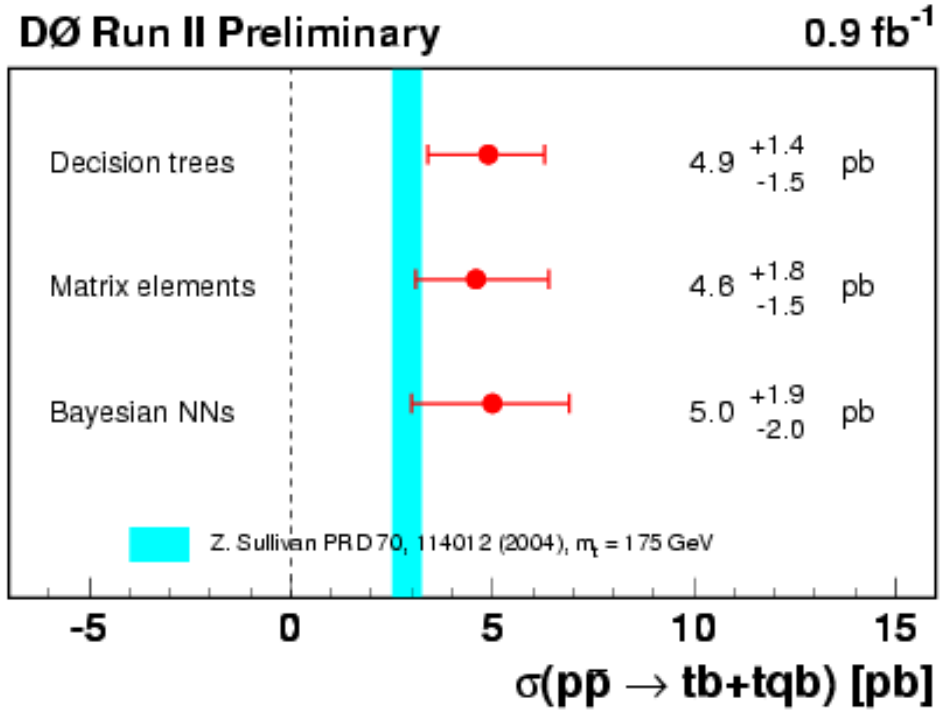
Process	$\sqrt{s}$	$\sigma(\mathrm{t}-\mathrm{channel})$	$\sigma(\mathrm{s}-\mathrm{channel})$	$\sigma(Wt)$
$p\bar{p} \to t/\bar{t}$	1.80 TeV	$1.45^{+0.20}_{-0.16}$ pb	(0.75 ± 0.10) pb	$0.14^{+0.05}_{-0.02}$ pb
$p\bar{p} \to t/\bar{t}$	1.96 TeV	$1.98^{+0.28}_{-0.22}$ pb	(0.88 ± 0.11) pb	$0.094^{+0.015}_{-0.012}$ pb
$pp \to t$	14.0 TeV	(156 ± 8) pb	(6.6 ± 0.6) pb	$14.0^{+3.8}_{-2.8}$ pb
$pp \to \bar{t}$	14.0 TeV	(91 ± 5) pb	(4.1 ± 0.4) pb	$14.0^{+3.8}_{-2.8}$ pb

Harris B W,et al. (2002), Phys. Rev. D 66 054024

First Evidence for Single Top Production at DZERO

- Three measurements of s+t-channel cross section in 0.9 fb^{-1} of RunII a data:
  - Boosted Decision Trees
  - Matrix Element Method
  - Bayesian NNs

all three results in very good agreement

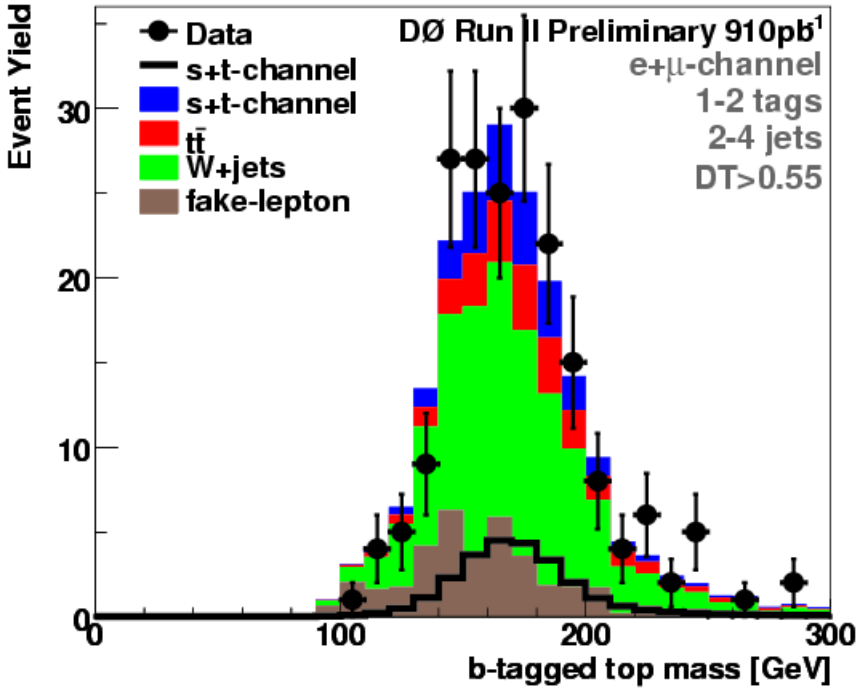


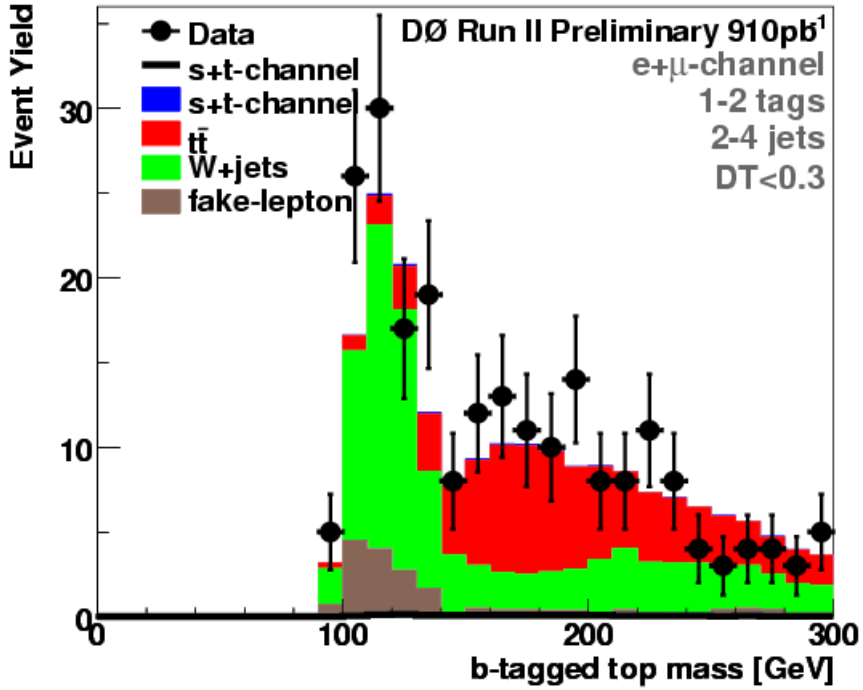
3.4 σ significance for the DT analysis!!!

hep-ex/0612052

Do we see Single Tops?

- Cut on the high and low discriminant output of the DT analysis
  - Single Top needed for good data/MC agreement!
  - Peak at top mass value

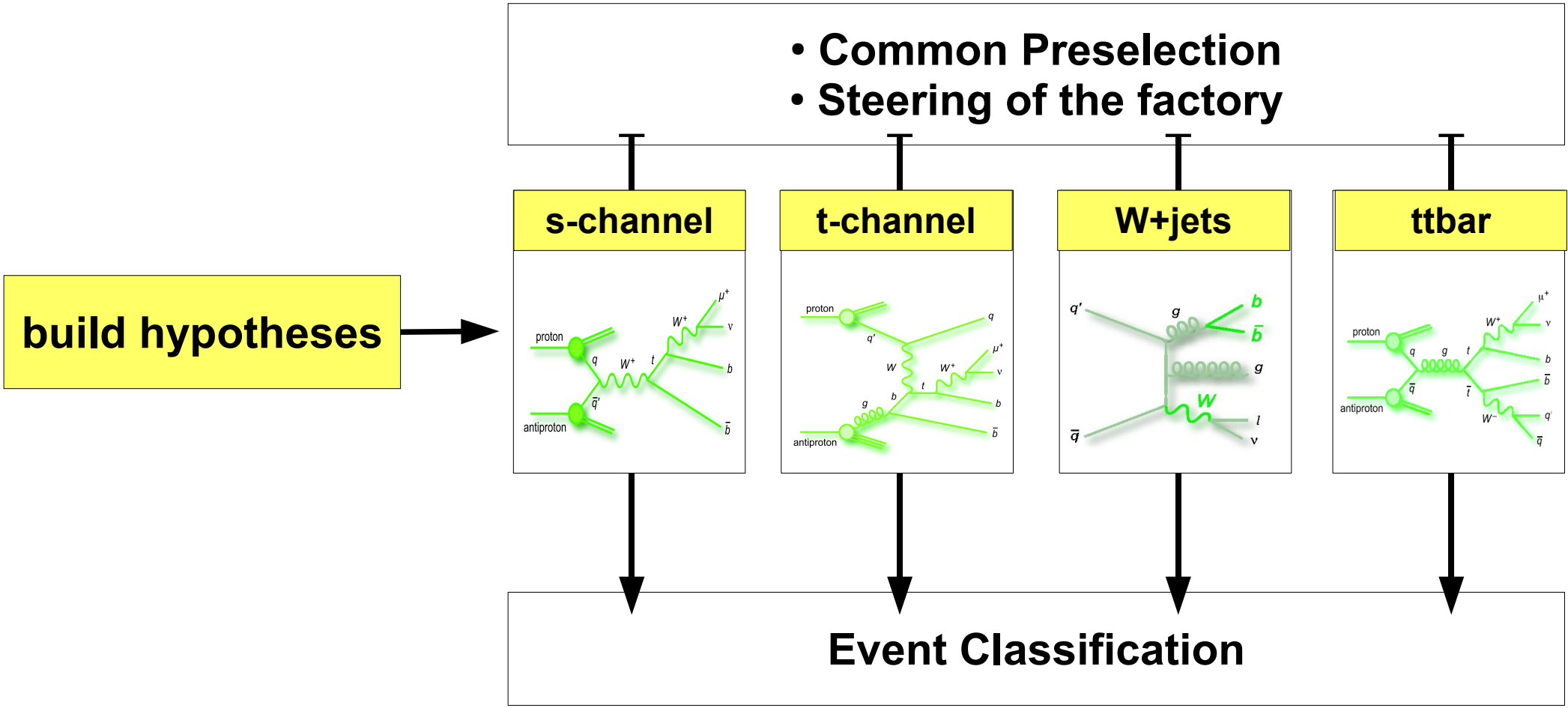




Our approach for the 2 fb^{-1} data: A Process-Factory

A Process-Factory

- Analyse an event under several hypotheses (signal and backgrounds) simultaneously
- Decide for the most probable hypothesis

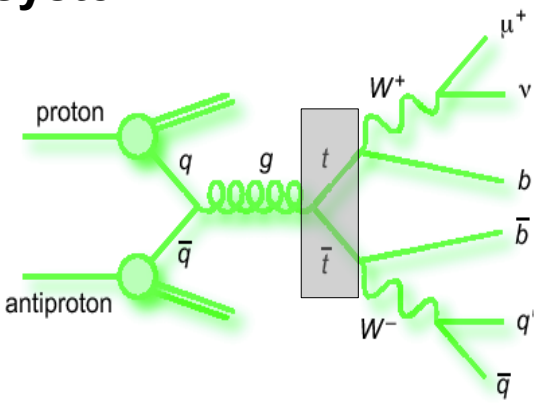


Same Event Under Different Hypotheses

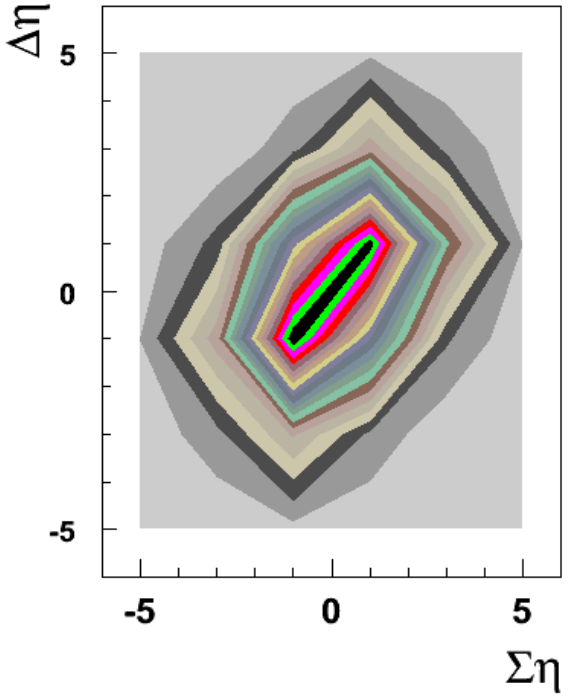
- Reconstructing the same event under the hypothesis of different physics processes leads to differences in distributions of observables
- Example for W and ttbar hypotheses using ttbar MC events:
- $\Delta\eta$: proportional to the scattering angle of the hard scattering system

$$\cos\theta^* \approx \tanh\left(\frac{\Delta\eta}{2}\right)$$

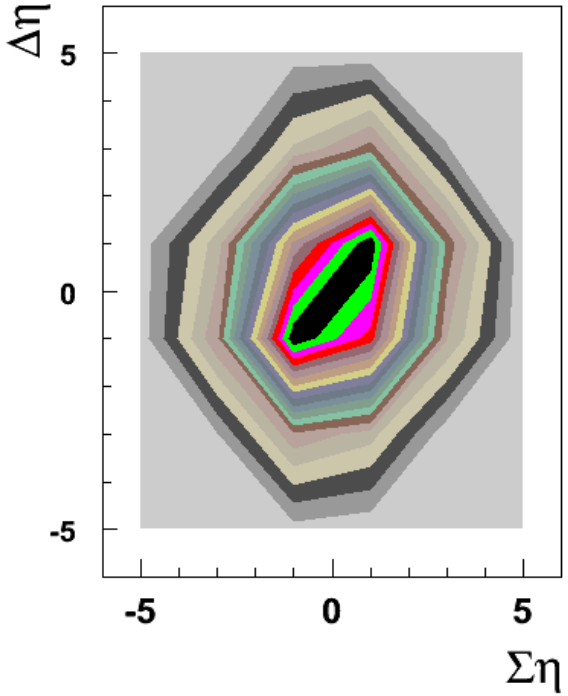
- $\Sigma\eta$: proportional to the boost of the system

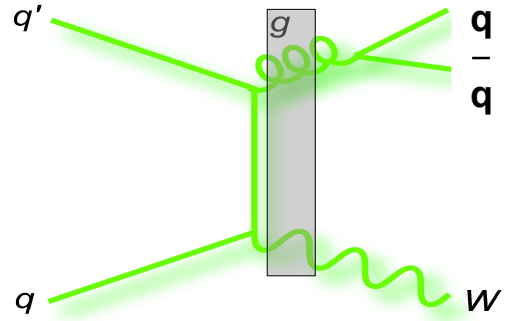


W+jets hypothesis



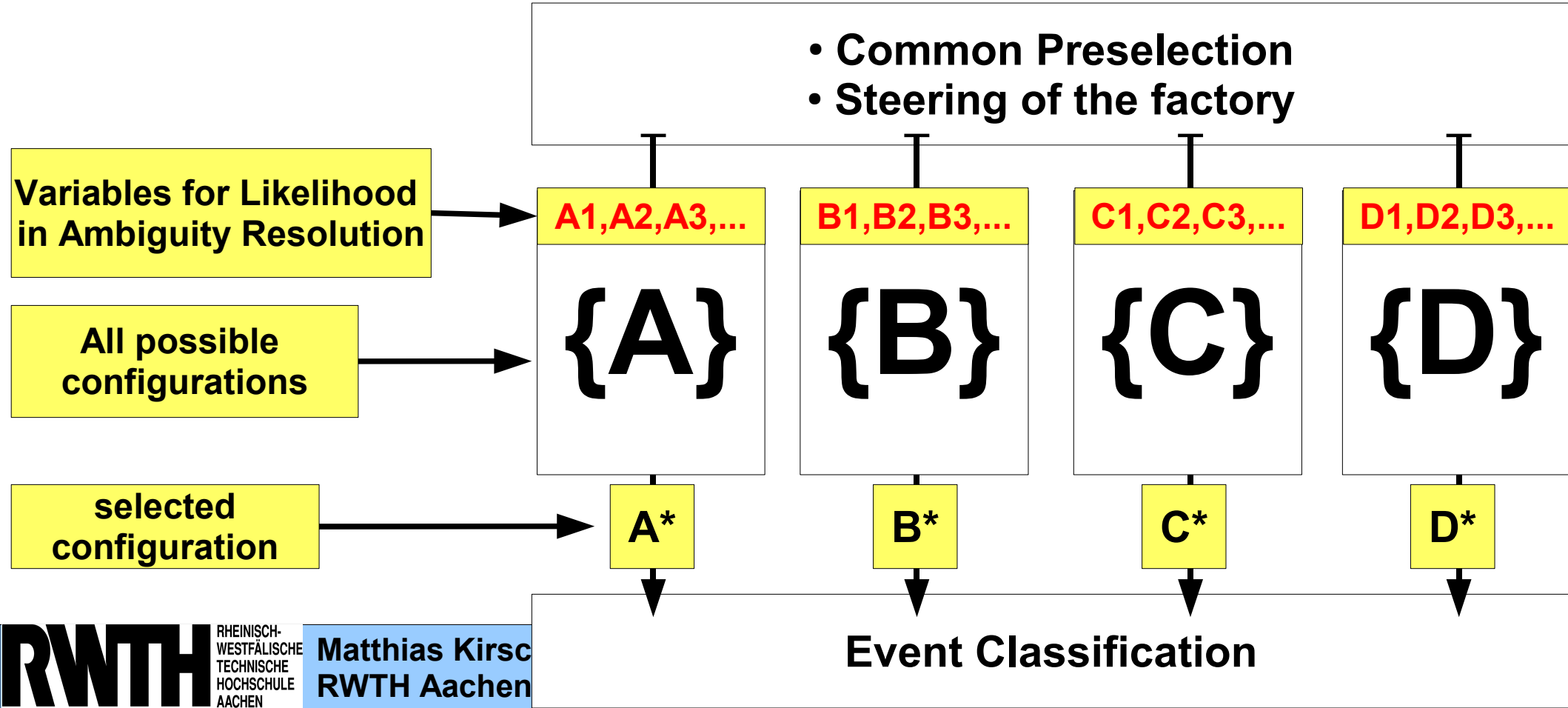
ttbar hypothesis





Resolve Ambiguities

- Reconstructing the parton picture of a hypothesis introduces ambiguities
- Resolve ambiguities using a standard likelihood method and distributions from matching generator with reconstruction information
- Choose best configuration for each hypothesis



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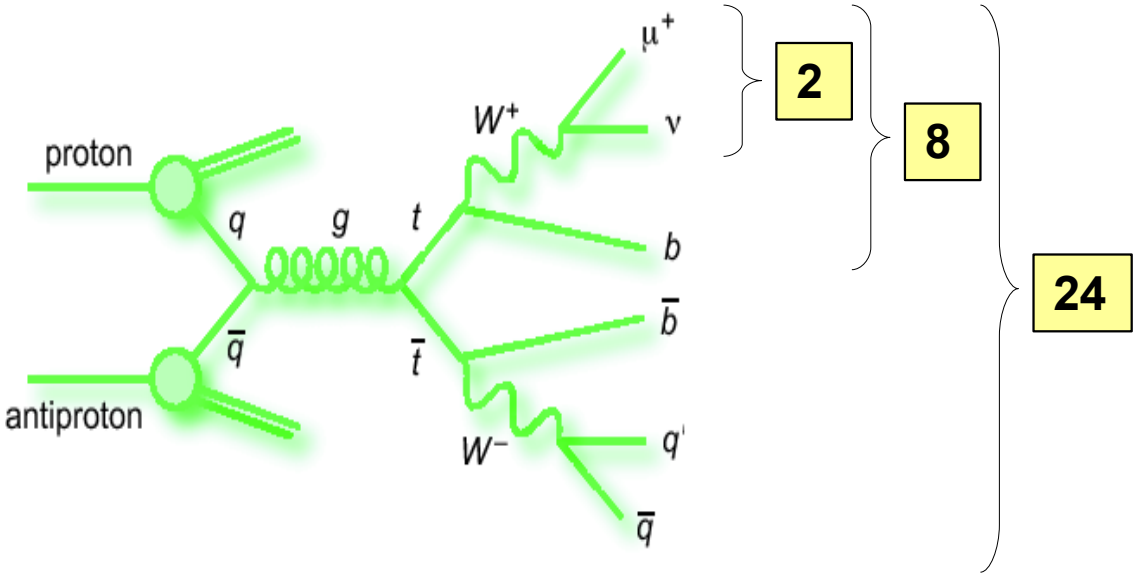
Ambiguities in Semileptonic Top Pair Decays

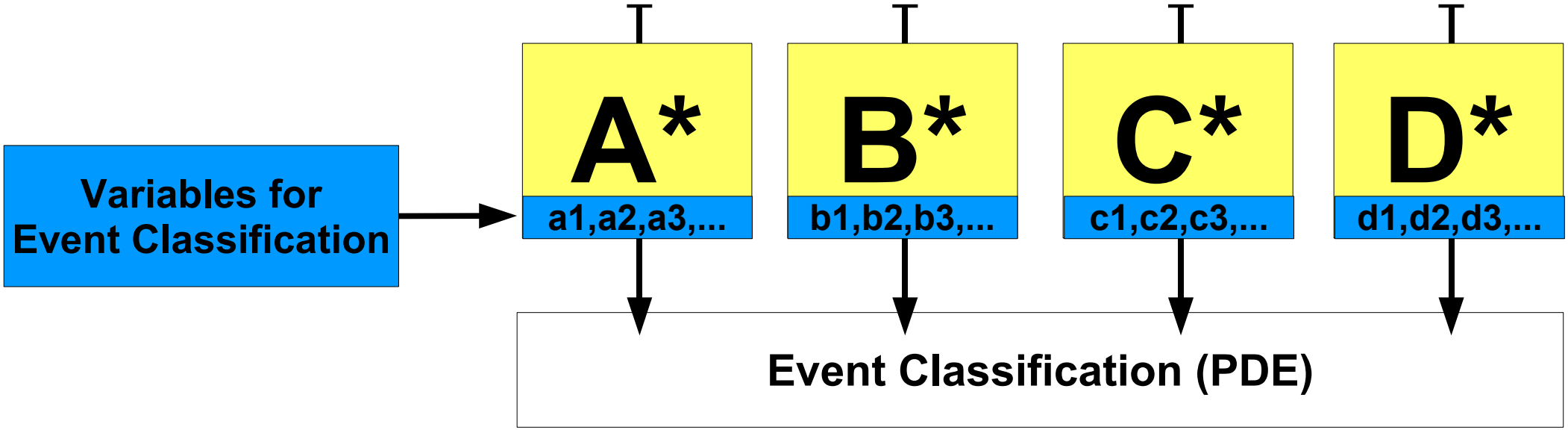


- Calculate a Likelihood measure for each possible ttbar configuration and chose the best one
- Use variables like: M(W[hadr]), ΔM(top), b-tag information,...

Efficiency to reconstruct both top quarks correctly: 49.7%

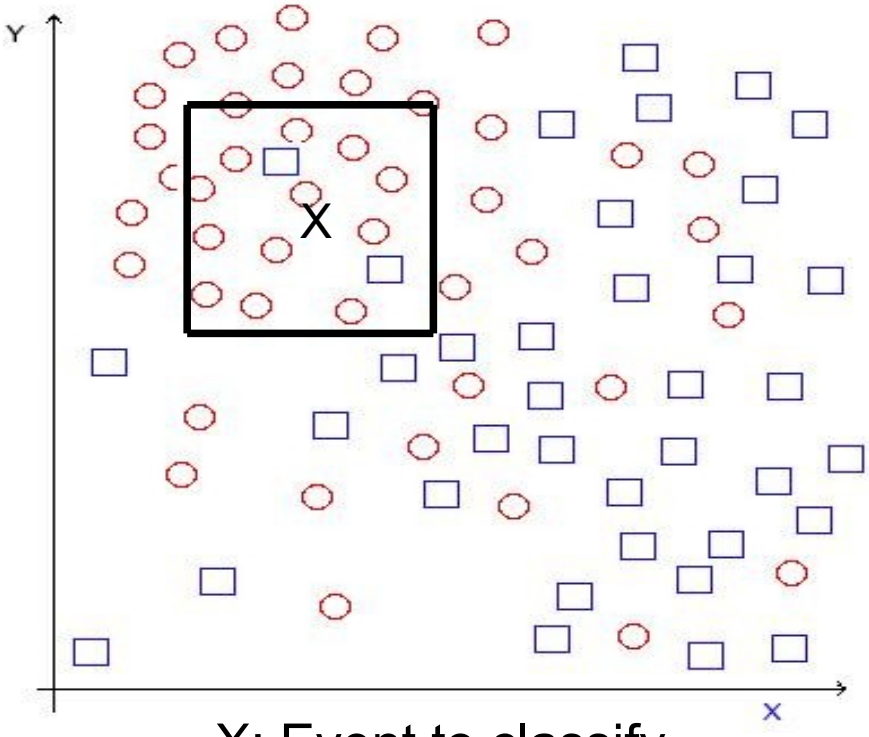
Event Classification

- Use the best configuration from each hypothesis to classify the event
- Calculate a new individual set of variables for each hypothesis
- Use these variables in a Probability Density Estimation (PDE) method for each hypothesis
- Classify the event by comparing the results of the different PDEs



The PDE Method

- **Analysis of data event X:**
  - **Count number MC signal and MC background events in phase space volume around X**
  - **Determine discriminant**
  - **Permute signal process and repeat calculation of discriminant**



X: Event to classify

: MC signal

: MC background

$$d = \frac{n_s}{n_s + c \cdot n_b}$$

where $c = \frac{N_s}{N_b}$

- **Performs close to NN, but no training necessary** **Koblitz et al.**
- **The uncertainty on the discriminant can be calculated**

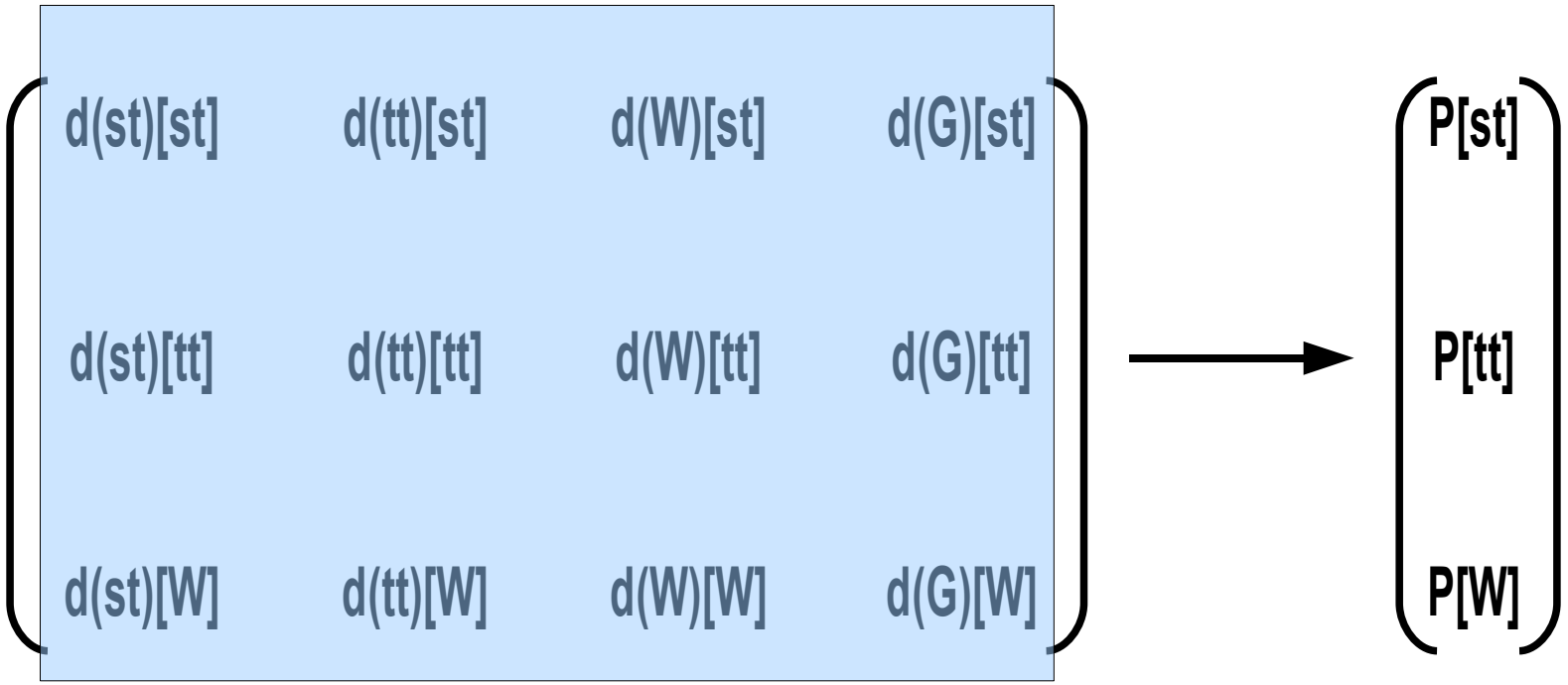
Event Classification (II)

- One PDE per hypothesis, plus additional PDE for global variables (e.g. event shape, energy,...)
- Gives us the 'Matrix' with dimension (n x (n+1))

	Interpretation(st)	Interpretation(tt)	Interpretation(W)	Interpretation(G)
st events	d(st)[st]	d(tt)[st]	d(W)[st]	d(G)[st]
tt events	d(st)[tt]	d(tt)[tt]	d(W)[tt]	d(G)[tt]
W events	d(st)[W]	d(tt)[W]	d(W)[W]	d(G)[W]

Evaluation of the Matrix

- Find a transformation to get a probabilty (not in the mathematical sense) for each hypothesis
- use d(G)[xx] as extra, decay tree independent input



Matrix vs. Other Analyses

- A topological ttbar analysis would use d(G)[tt] only

$$\begin{pmatrix} d(st)[st] & d(tt)[st] & d(W)[st] & d(G)[st] \\ d(st)[tt] & d(tt)[tt] & d(W)[tt] & d(G)[tt] \\ d(st)[W] & d(tt)[W] & d(W)[W] & d(G)[W] \end{pmatrix}$$

Matrix vs. Other Analyses

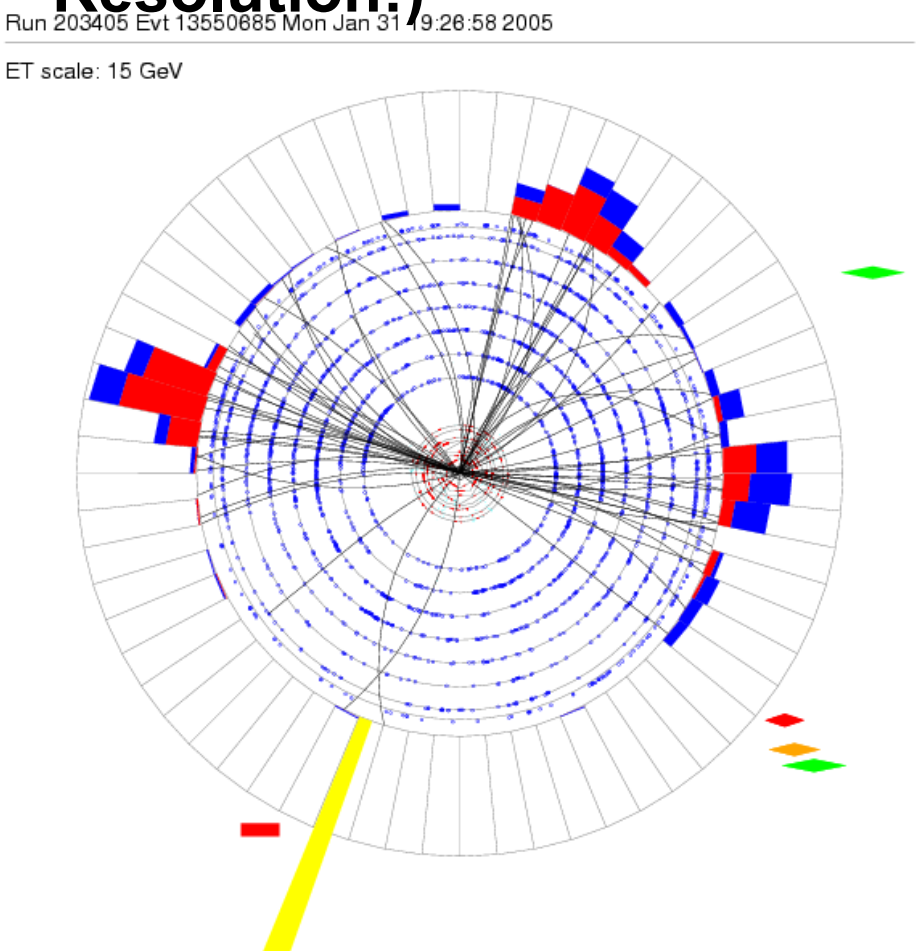
- A multivariate ttbar analysis would use d(tt)[tt]
  - Maybe it would use some information of d(G)[tt], too

$$\begin{pmatrix} d(st)[st] & d(tt)[st] & d(W)[st] & d(G)[st] \\ d(st)[tt] & d(tt)[tt] & d(W)[tt] & d(G)[tt] \\ d(st)[W] & d(tt)[W] & d(W)[W] & d(G)[W] \end{pmatrix}$$

Current Implementation

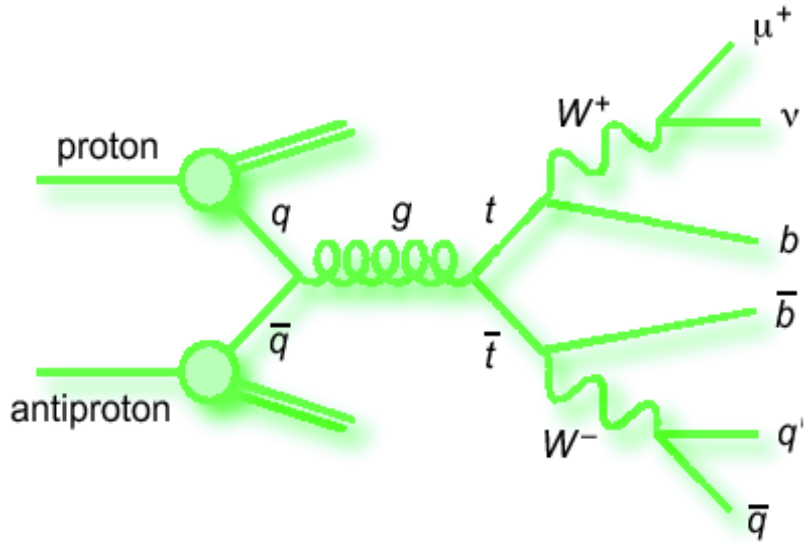
Global Process

- Calculates event shape variables
- Independant of underlying Feynman diagram (no Amiguity Resolution!)



Ttbar Process

- Reconstructs semileptonic ttbar decay
- resolves ambiguities
- Returns best ttbar hypothesis



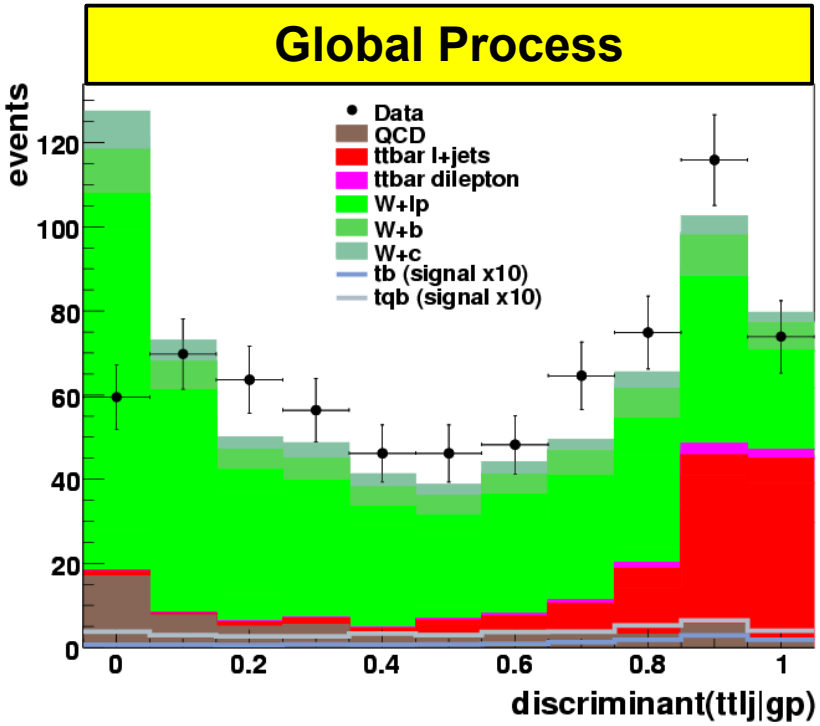
...in Terms of the Matrix

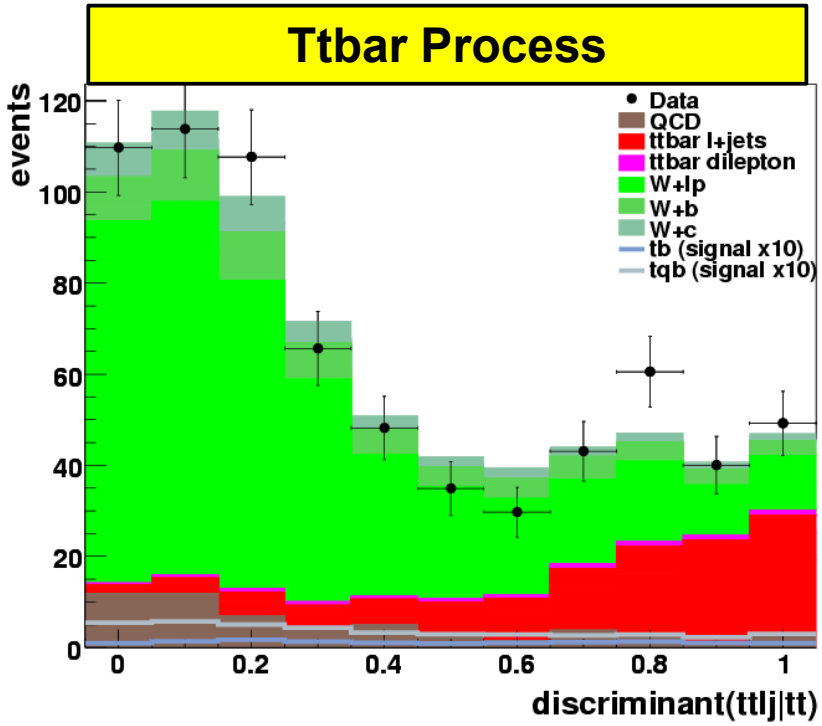
- Concentrating on:
  - the 4 jet bin (needed to reconstruct ttbar)
  - ttbar is an established signal to test the method
  - ttbar and W+jets MC samples

	Interpretation(tt)	Interpretation(G)
tt events	d(tt)[tt]	d(G)[tt]
W events	d(tt)[W]	d(G)[W]

Discrimination Power of Single PDEs

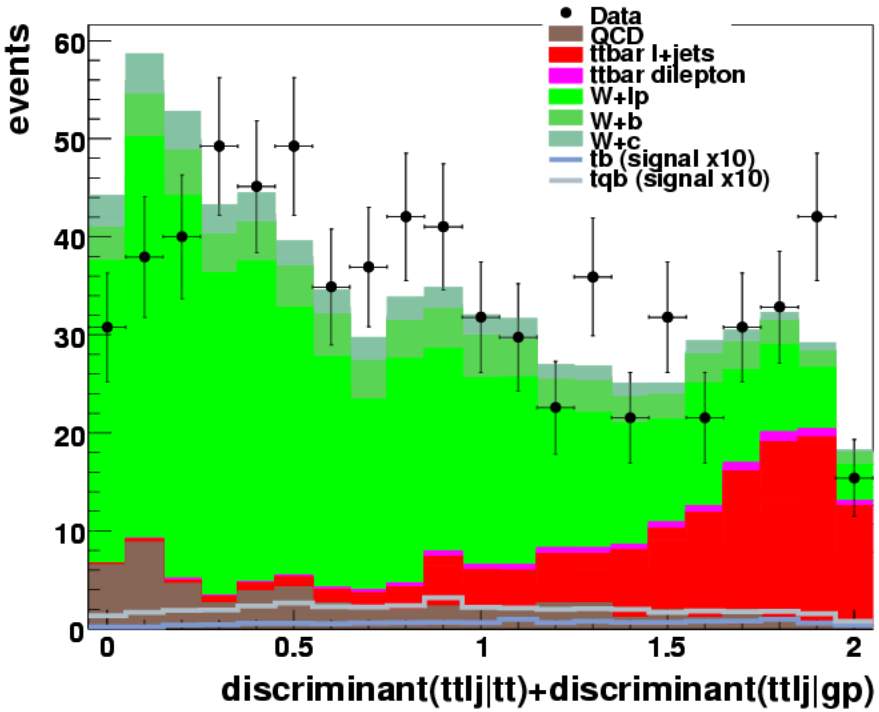
- Discriminant value for the ttbar signal hypothesis
- both discriminants are able to reject W+jets background





Matrix Evaluation

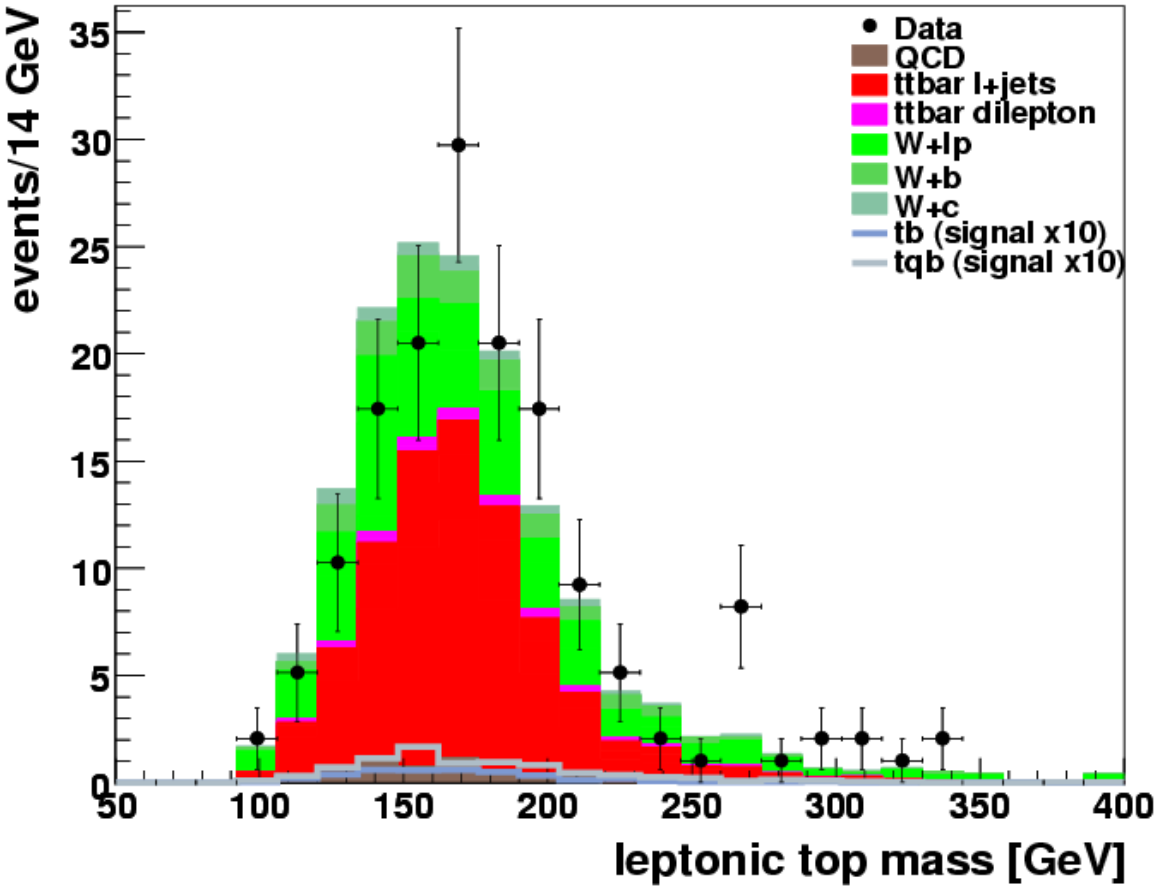
- First (simple) approach for matrix evaluation:
  - Add up discriminants for different hypotheses of the same event



	Interpretation(tt)	Interpretation(G)
tt events	d(tt)[tt]	d(G)[tt]
W events	d(tt)[W]	d(G)[W]

Out of Curiosity...

- Cut at 1.5 in the sum and plot leptonic top mass from semileptonic top decays



Summary

- Multivariate techniques are powerful tools for modern HEP analyses (e.g. latest success with 'Evidence for Single Top')
- We prepare a Process-Factory for the 2 fb^{-1} single top search with the DZERO experiment
- Use additional, decay tree dependent observables
- Method in brief:
  - → reconstruct decay trees
  - → resolve ambiguities
  - → classify event

Backup

Multi-Collision Separation

- several collisions during one bunch crossing
- Importance of separation of jets from different primary vertices
- ttbar candidate event display