Understanding Top and Its Backgrounds

Maximizing the Chances of Finding New Physics in Run2

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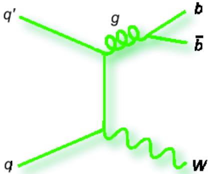
Top Quark Symposium 2005



Finding Physics In Run2

New Physics Algorithm (NPA)

1. Take data
2. Test, validate tools
3. Divide data into boxes based on observed objects

   "e","jet","γ","b-jet",$\cdots$
4. Make H_T, m_{ij} distributions
5. Rank according to level of discrepancy

   $$(\text{Observed-Expected})^2/\sigma^2(\text{Statistical,Tools})$$
6. Focus Person-Power until discrepancy drops

   Improve tools, analysis, etc.
7. Iterate

Quaero, Sleuth, etc. (Knuteson)

- In practice, analyses are done on specific channels
  - Specific question and answer, suitable for a student, etc.
  - Allows experimentalists to concentrate on what they want
- Top quark analyses are the closest thing we have to the NPA

ASSERTION

Understanding Top *backgrounds* and Top *production* is important to maximizing the New Physics potential of the Tevatron

PROOF

Listen to the talk!

Pick a box – any box

Compromise

- Signature $Wb\bar{b} + X$ is common to unconfirmed Standard Model processes and many new physics processes

$$X \Rightarrow \text{many boxes}$$

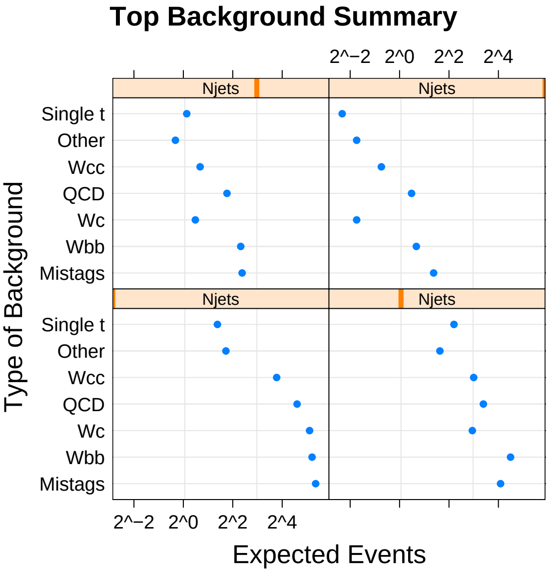
- we "know" that Standard Model top is there, thus we can study Not-Top

$$\text{Top} \equiv \text{Data} - \text{Not-Top}$$

- Claim: understanding Not-Top is more important than understanding Top itself
    - Not-Top challenges our tools
    - Better tools = more challenging questions

Not-Top Cocktail

CDF PRD, 162 ipb



Complicated Structure

$t\bar{t}$ contamination in Njets=3,4 (1.0,1,3)

work on Mistags,Wbb,QCD

QCD,Mistags reducible

trust basic properties of B,D hadron decays, e.g. K mesons

Mixing the Cocktail

Method 2

Monte Carlo ratio
$R = (W + b - jets)/(W + jets)$

Measure $W + jets$ (no b-tag)

data(W+b-jets) $=$ $R\times$data(W+jets)

Wcj/Wbb from Monte Carlo

Compare to predictions from MCFM

Campbell & Ellis
(see also Campbell & Huston)

MLM Method

Parton shower and hadronization are essential for studying b-jets

- Parton shower W+Npartons but reject emissions that are too hard
- Build up *inclusive* or *exclusive* samples
- R supplemented by phenomenological factor 1.5

$\delta R/R \sim$25-30%

Method 2 at Tree Level
Madevent (Stelzer and Maltoni)

Graph	Cross Sect(fb)
Sum (Wbb)	8.934
Sum (Wjj)	1061.627
ug$\rightarrow$e$^+$vedg	327.810
udx$\rightarrow$e$^+$vegg	257.060
gdx$\rightarrow$e$^+$veuxg	137.300
dxg$\rightarrow$e$^+$veuxg	48.591
uux$\rightarrow$e$^+$veuxd	47.425
udx$\rightarrow$e$^+$veddx	36.644
gu$\rightarrow$e$^+$vedg	34.445
udx$\rightarrow$e$^+$veuux	29.816
...	...

$R \times 1.5$ =1.3% (MLM = 1.4%)

$\langle R \rangle$ roughly the same

Many different topologies

Dominant ones not $q\bar{q}$

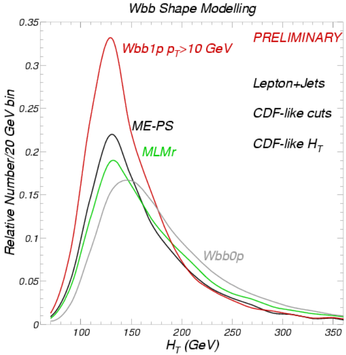
$$P_{qq}(z) = \frac{1}{2}(z^2 + (1-z)^2)$$

Different topologies parton shower and hadronize differently

Many effects have to be modelled well to have a reliable prediction

Matrix Element-Parton Shower Matching

SM, PR *JHEP 0405:040,2004*



Testing Different Predictions

- Matching scheme needed to make inclusive predictions with hard emissions
- Pseudoshower Method (ME-PS) reweights matrix elements to look like parton showers where they should. Motivated by Catani et al., but more flexible and tuned to Pythia, Herwig, etc.

Is getting δm_t to 1 GeV our highest priority?

- No. But the error matters.
- When do we understand Top?
- When we understand:
  - the Underlying Event
  - uncertainties from ISR/FSR
  - γ-jet balancing
    - jet energy scale
    - out-of-cone
- Inadequate tools mask NP

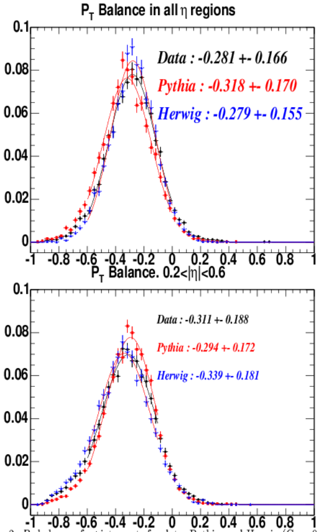
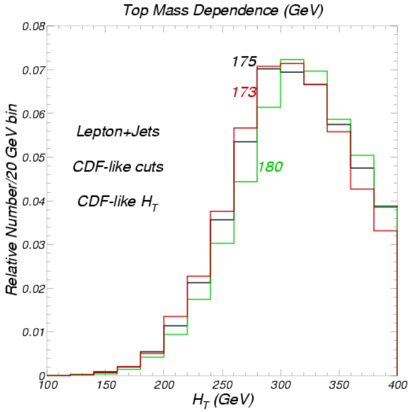


Figure 2: P_T balance of γ+jet events for data, Pythia, and Herwig (Cone 0.4)forallη regions (top) and for the central region (bottom).

Top^2 as a NP Background



Why we need to know m_t

- $t\bar{t}$ is the background to other things
- σ alone is not enough
- m_t induces a shift in kinematic distributions
  - We want to extrapolate out of the top region to find NP
  - Normalizing to X% in a big box does not extrapolate into a smaller one

More on m_t

Experimentalist's Testimonial

- What we hear all the time is that having a precise top mass measurement might be the *only* thing we will be able to do at the Tevatron in the search for the Higgs. That is, only constraining the Higgs mass.
- How precise do we need to measure it to help with the Higgs search at the Tevatron?
- If the mass is low $[\cdots]$ we might be able to find the Higgs at the Tevatron.
- If it is high, it would be out of reach for us.
- So the precision needed pretty much depends on the central value.

$m_t, m_W, \ln(m_H)$

The Formula

$$M_W^0 - M_W - .5\frac{\Delta\alpha_h}{.0280} + .5(\frac{m_t}{175})^2 - .0085\frac{\alpha_s}{.118} + c$$
$$= \ln(m_H/100)^{.06} + (\ln(m_H/100)^{.09})^2$$

The Fit

best m_H (GeV)	m_H^{95} (GeV)	m_t (GeV)
74^{+83}_{-47}	238	"new" (178)
45^{+69}_{-36}	184	"old" (174.5)

[Sirlin,Ferroglia,Ossola hep-ph/0406334]

[see, also: Awramik,Czakon,Freitas,Weiglein hep-ph/0311148]

Fighting for a logarithmic limit is hard work!

95% Confidence Level Expected/Measured Upper Limits
(after final selections, with systematics, using Bayesian statistics)

		s-channel	t-channel
Cut-Based	Electron	11.4/10.8	15.1/17.5
	Muon	13.0/15.2	18.1/13.0
	Combined	9.8/10.6	12.4/11.3
Decision Trees	Electron	6.9/7.9	9.3/13.8
	Muon	7.3/14.8	10.9/7.9
	Combined	4.5/8.3	6.4/8.1
Neural Networks	Electron	7.0/7.3	8.8/7.5
	Muon	7.0/8.7	9.5/7.4
	Combined	4.5/6.4	5.8/5.0

Single Top

New Physics Warm-Up

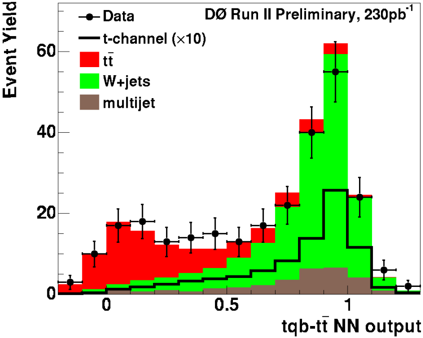
- current state of single-Top is where we will be at the LHC with a few quality fb^{-1}
- the size of other NP signals
- it is a playground for new analysis techniques
- it challenges our tools

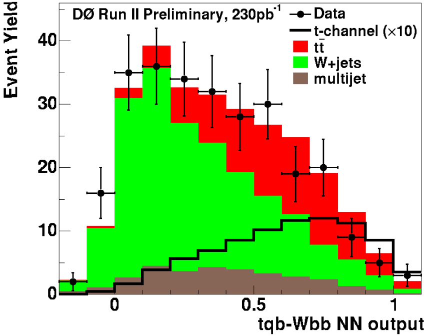
  Not specific to NN analyses: but they may be more sensitive to them

Many Kinematic Variables

	Signal-Background Pairs			
	tb		tqb	
	Wbb	$t\bar{t}$	Wbb	$t\bar{t}$
Individual object kinematics				
$p_T(\text{jet1}_{\text{tagged}})$	✓	✓	✓	—
$p_T(\text{jet1}_{\text{untagged}})$	—	—	✓	✓
$p_T(\text{jet2}_{\text{untagged}})$	—	—	—	✓
$p_T(\text{jet1}_{\text{nonbest}})$	✓	✓	—	—
$p_T(\text{jet2}_{\text{nonbest}})$	✓	✓	—	—
Global event kinematics				
$M_T(\text{jet1,jet2})$	✓	—	—	—
$p_T(\text{jet1,jet2})$	✓	—	✓	—
$M(\text{alljets})$	✓	✓	✓	✓
$H_T(\text{alljets})$	—	—	✓	—
$M(\text{alljets} - \text{jet1}_{\text{tagged}})$	—	—	—	✓
$H(\text{alljets} - \text{jet1}_{\text{tagged}})$	—	✓	—	✓
$H_T(\text{alljets} - \text{jet1}_{\text{tagged}})$	—	—	—	✓
$p_T(\text{alljets} - \text{jet1}_{\text{tagged}})$	—	✓	—	✓
$M(\text{alljets} - \text{jet}_{\text{best}})$	—	✓	—	—
$H(\text{alljets} - \text{jet}_{\text{best}})$	—	✓	—	—
$H_T(\text{alljets} - \text{jet}_{\text{best}})$	—	✓	—	—
$M(\text{top}_{\text{tagged}}) = M(W, \text{jet1}_{\text{tagged}})$	✓	✓	✓	✓
$M(\text{top}_{\text{best}}) = M(W, \text{jet}_{\text{best}})$	✓	—	—	—
$\sqrt{\hat{s}}$	✓	—	✓	✓
Angular variables				
$\Delta R(\text{jet1,jet2})$	✓	—	✓	—
$Q(\text{lepton}) \times \eta(\text{jet1}_{\text{untagged}})$	—	—	✓	✓
$\cos(\text{lepton}, Q(\text{lepton}) \times z)_{\text{top}_{\text{best}}}$	✓	—	—	—
$\cos(\text{lepton}, \text{jet1}_{\text{untagged}})_{\text{top}_{\text{tagged}}}$	—	—	✓	—
$\cos(\text{alljets}, \text{jet1}_{\text{tagged}})_{\text{alljets}}$	—	—	✓	✓
$\cos(\text{alljets}, \text{jet}_{\text{nonbest}})_{\text{all jets}}$	—	✓	—	—

Network Outputs





- How do we convince ourselves of a signal?
- How can we improve upon the search?

Known and Unknown Unknowns

Trusting/Improving the NN Result

- Now, R=Wbb/Wjj taken from MCFM (25% uncertainty)
    - Which distributions are the most important for testing this prediction?
    - Is there a kinematic difference between the different components?
    - Can we discriminate Wbb, Wjj and Wcj?
- Are we modelling $t\bar{t}$ adequately?
- How would `Quaero` do here (see RunI)?
- If the kinematics and composition of the Standard Model are understood, then a more generic $Wb\bar{b} + X$ search is possible

Final Words

What Experimentalists Should Do

- prepare for a long (and fruitful) Run2
- re-evaluate what the Tevatron can do well before the LHC

  make the case to the funding agencies!
- *don't listen to theorists!*

  i.e, don't *NOT* do an analysis because of a theoretical prediction
- Keep asking questions about Top and Not-Top
- Repeatedly ask:

  How can I maximize the New Physics Potential of Run2?