Sleuth:

Results of a Quasi-Model-Independent Search for New Physics in 1 fb^{-1} at CDF

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on behalf of the CDF Collaboration

7 May 2007

PHENO 2007, Madison, WI.

Introduction: from Vista to Sleuth

- First understand bulk of data – Vista (see previous talk by Georgios Choudalakis)

- Then search for new physics in the high-p_T tails - Sleuth

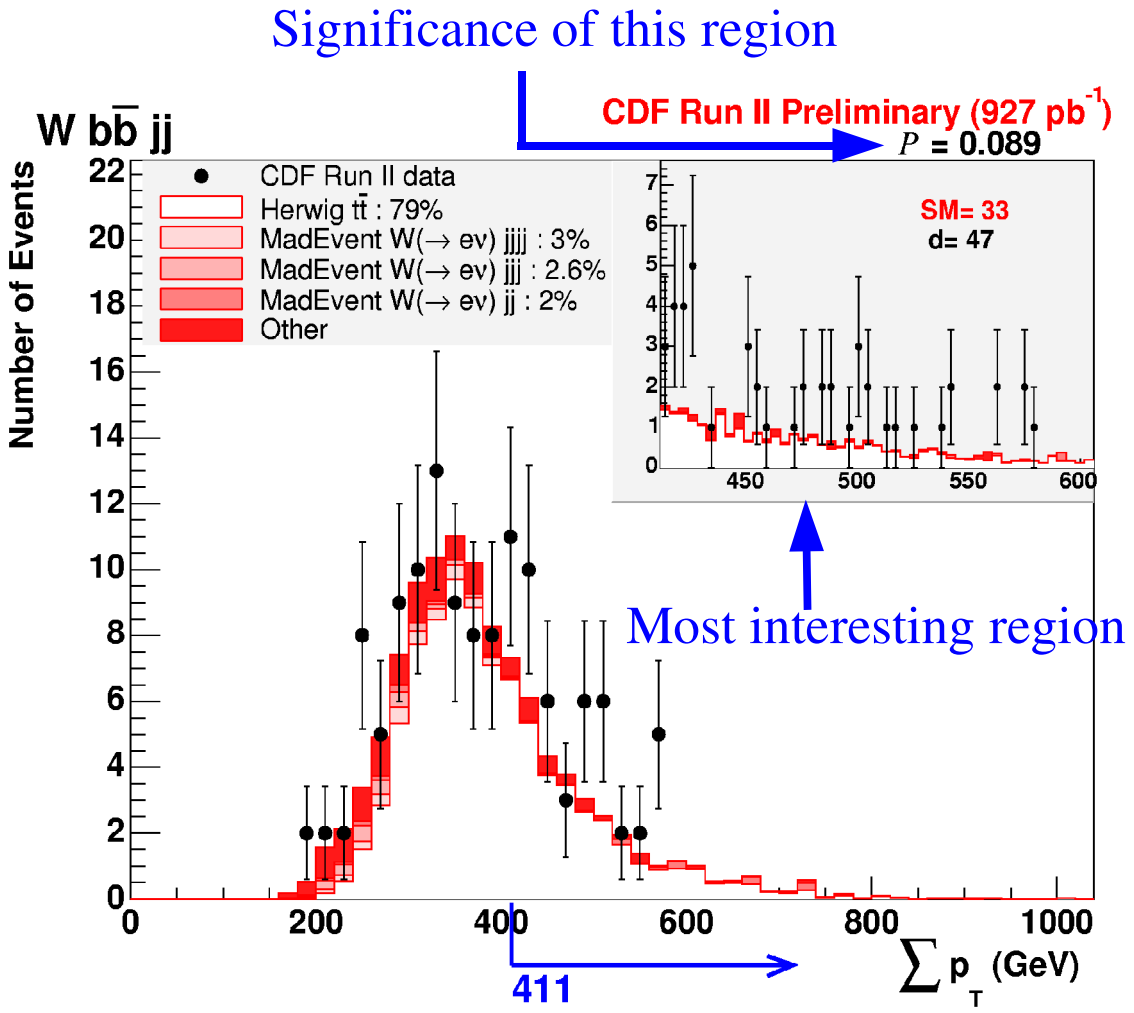
Introduction to Sleuth

- Sleuth relies on the following assumptions:
  - New physics will appear predominantly in one final state
  - New physics will appear as excess of data over SM
  - New physics will appear at high Σp_T
- Sleuth will be less sensitive to new physics which does not satisfy these assumptions
- The Standard Model prediction for each final state is obtained using Vista

What Sleuth Does

- Sleuth's variable: $$\sum p_T \equiv \sum_i |\vec{p}_i| + \left|\overrightarrow{\text{uncl}}\right| + \left|\vec{\not{p}}\right|,$$

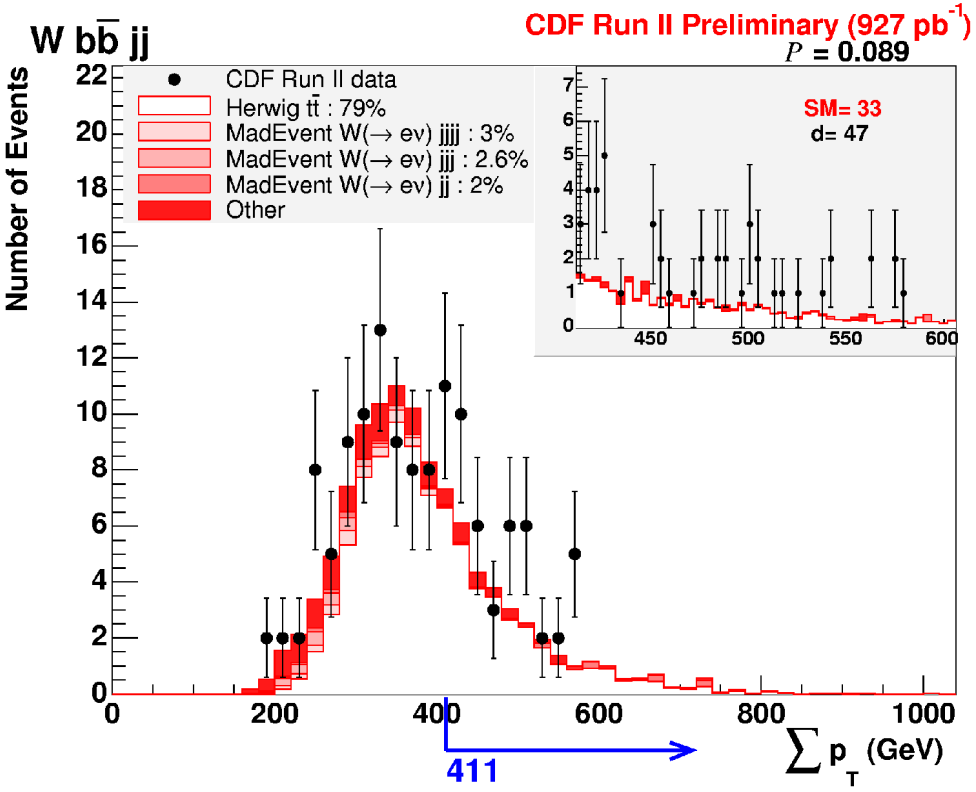
- Select the most interesting region in each final state
  - region requires >=3 data
- Perform pseudo-experiments to assess the significance $\rightarrow P$

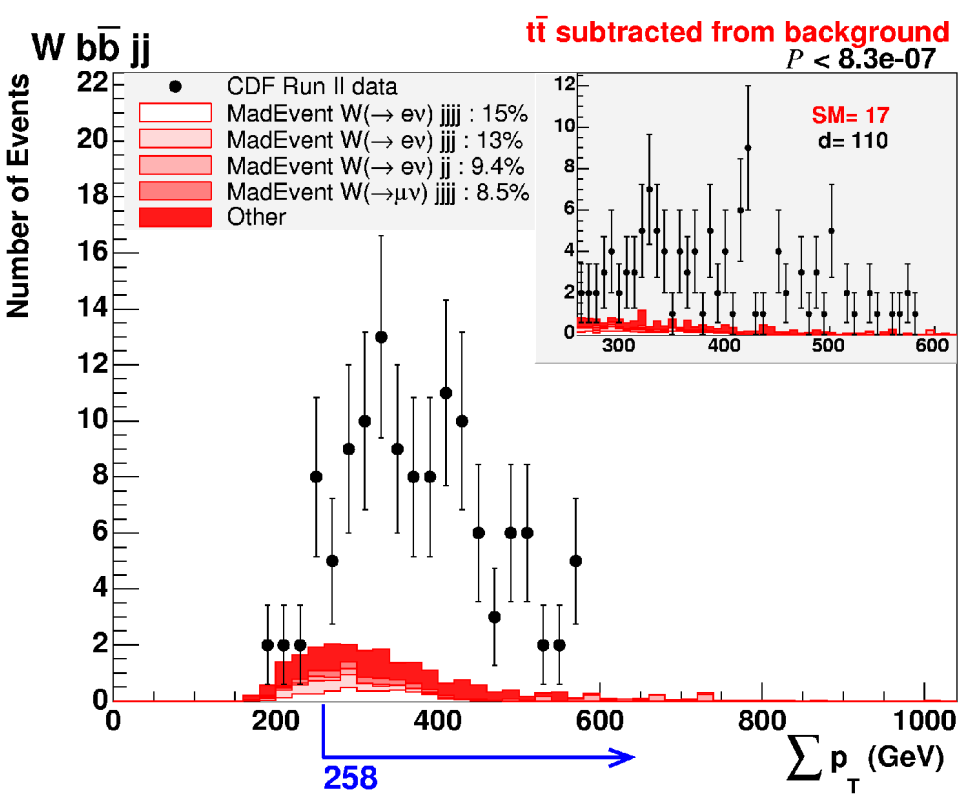


What Sleuth Does Next

- Now consider all Sleuth final states
  - if the data were just drawn from our SM implementation, what fraction of similar *complete CDF experiments* would have produced by chance a region in any final state as or more interesting than the most interesting one we found?
- We set the Sleuth discovery threshold: $\tilde{P} < 0.001$
- Sleuth rigorously accounts for the trials factor in the regions it searches
- Because of this trials factor, a Sleuth discovery $(\tilde{P} < 0.001)$ corresponds to a ~5σ effect in the selected region

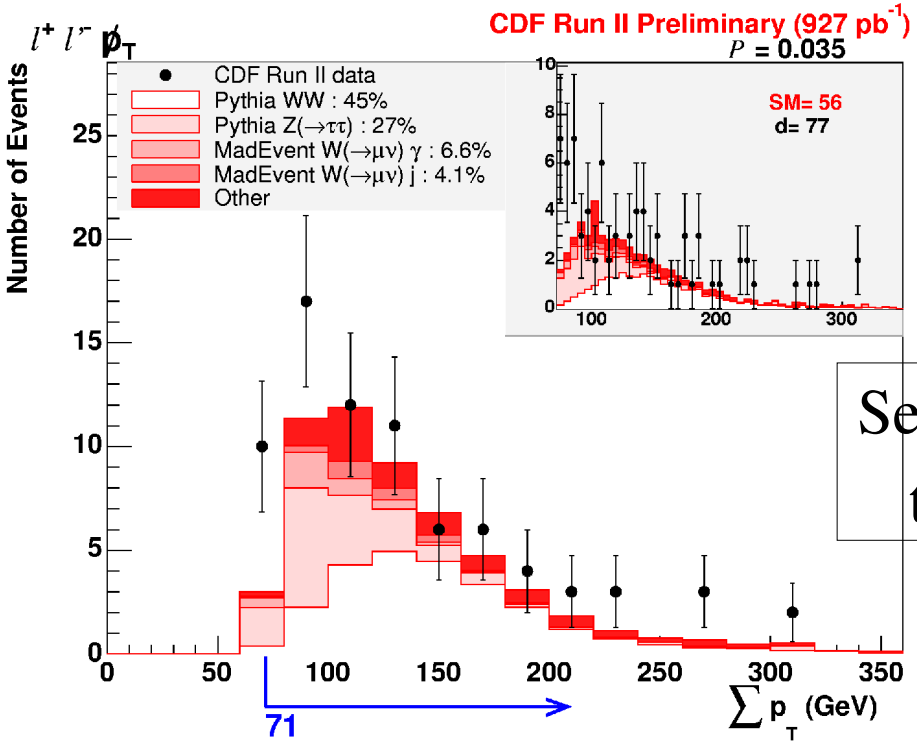
Would Sleuth Have Found the Top Quark?



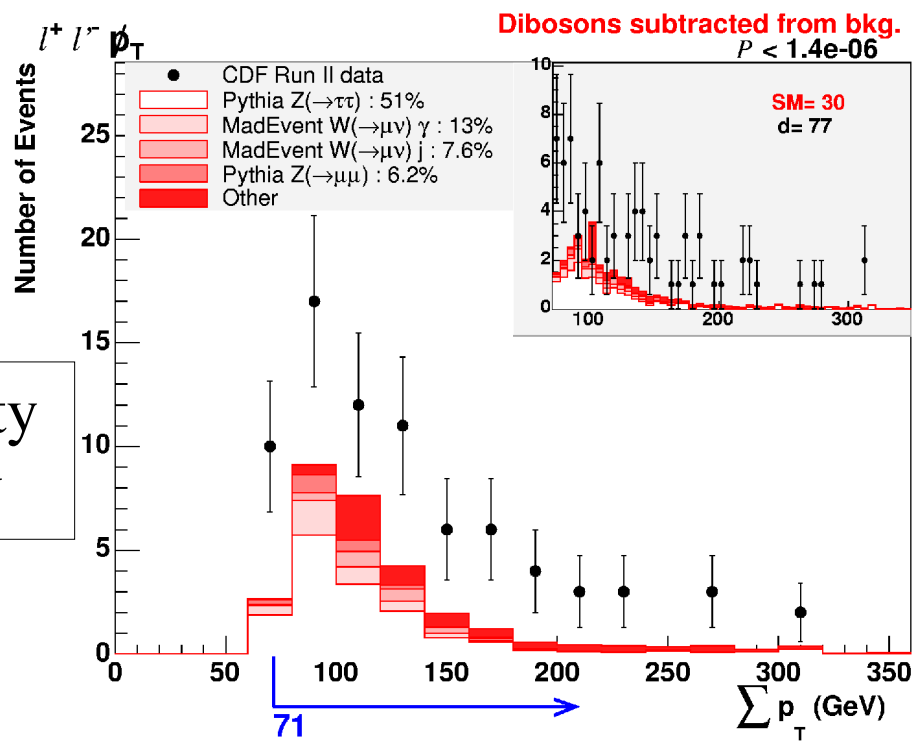


- Remove top quark from SM; refit correction factors
- Sleuth easily finds top in 1 fb^{-1}
- Estimated luminosity (with 2007 knowledge) for Sleuth discovery ~80 pb^{-1}
  (Run I discovery = 67 pb^{-1} at $\sqrt{s}$=1.8 TeV)

Sleuth Sensitivity to Other SM Processes



Sensitivity to WW

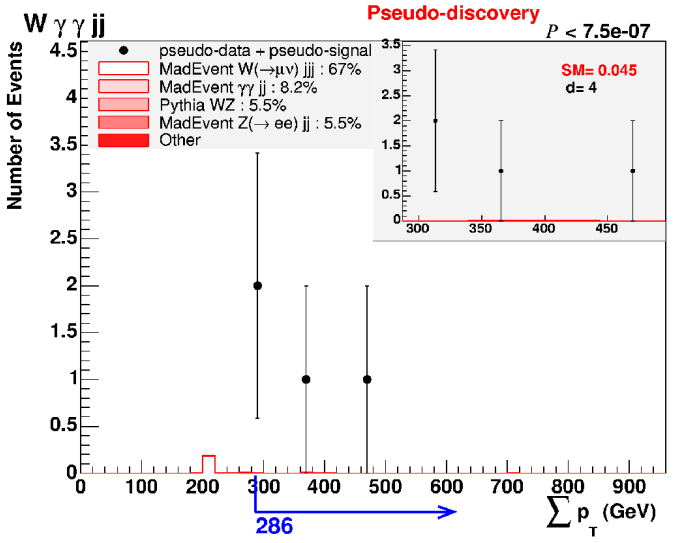


- WW: discovery if removed from SM background
- WZ: would require $\sigma \sim 21$ pb for discovery ($\sigma_{SM} = 5$ pb)
- Single top: would require $\sigma \sim 5.5$ pb for discovery ($\sigma_{SM} = 2.9$ pb)
- Light Higgs ($m_h \sim 120$ GeV): would require $\sigma \sim 6.5$ pb for discovery ($\sigma_{SM} = 0.2$ pb)
- Heavy Higgs ($m_h \sim 160$ GeV): would require $\sigma \sim 18$ pb for discovery ($\sigma_{SM} = 0.3$ pb)

Sensitivity to Specific New Physics Models

- Inject signal into pseudo-data drawn from SM prediction
  - determine cross-section needed to trigger Sleuth's discovery threshold
  - systematic uncertainties not included
- Sensitivity broadly comparable to dedicated searches when signal satisfies Sleuth's basic assumptions
- Sleuth becomes less sensitive as the signal violates these assumptions

GMSB model



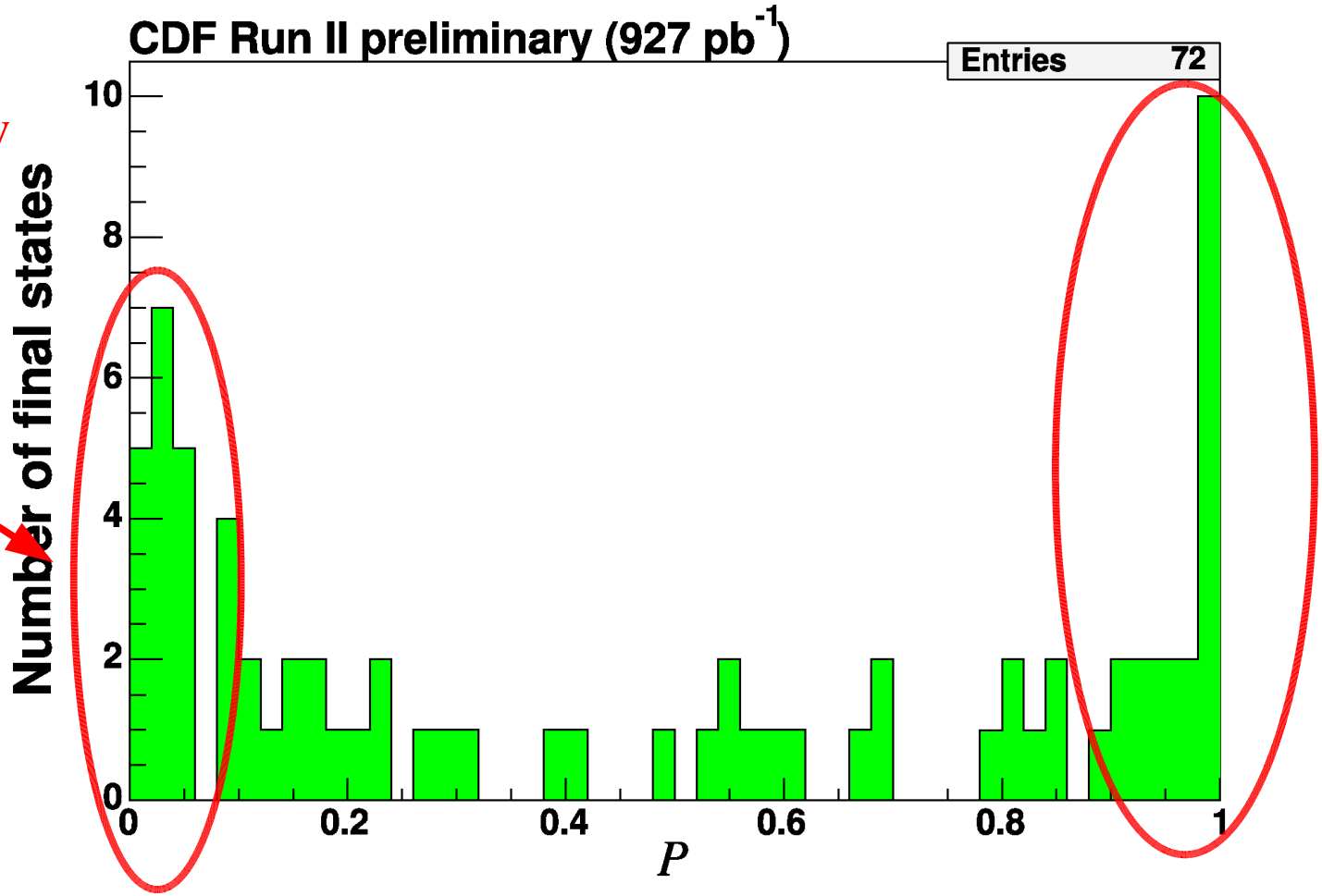
CDF Run II Preliminary

Name	Description	Sensitivity (pb)
Model 01	GMSB, $\Lambda = 82.6$ GeV, $\tan\beta = 15$, $\mu > 0$, 1 messenger of $M = 2\Lambda$	0.10 ± 0.04
Model 02	$Z'_{(250\,\mathrm{GeV/c^2})} \to \ell\bar{\ell}$, with $\ell \neq \nu$	1.56 ± 0.09
Model 03	$Z'_{(700\,\mathrm{GeV/c^2})} \to q\bar{q}$	4.3 ± 0.8
Model 04	$Z'_{(1\,\mathrm{TeV/c^2})} \to q\bar{q}$	1.67 ± 0.23
Model 05	mSUGRA, $M_0 = 100$ GeV, $M_{1/2} = 180$ GeV, $A_0 = 0$, $\tan\beta = 5$, $\mu > 0$	2.05 ± 0.18
Model 06	mSUGRA, $M_0 = 284$ GeV, $M_{1/2} = 100$ GeV, $A_0 = 0$, $\tan\beta = 5$, $\mu < 0$	1.55 ± 0.10
Model 07	mSUGRA, $M_0 = 300$ GeV, $M_{1/2} = 200$ GeV, $A_0 = 0$, $\tan\beta = 5$, $\mu < 0$	0.25 ± 0.09
Model 08	Standard Model $t\bar{t}$, with $t\bar{t}$ removed from background. Would need ~ 80 pb^{-1} to see.	0.30 ± 0.05
Model 09	Standard Model WW, with WW removed from background. Would need ~ 400 pb^{-1} to see.	5.7 ± 1.1
Model 10	MSSM $A \to \tau\tau$, $M_A = 160$ GeV, $\tan\beta = 5$	13.5 ± 1.9
Model 11	$Z'_{(500\,\mathrm{GeV/c^2})} \to t\bar{t}$	2.8 ± 0.9

Now for the data...

P for all Sleuth Final States

Maybe new physics here? Or just under-estimation of SM?

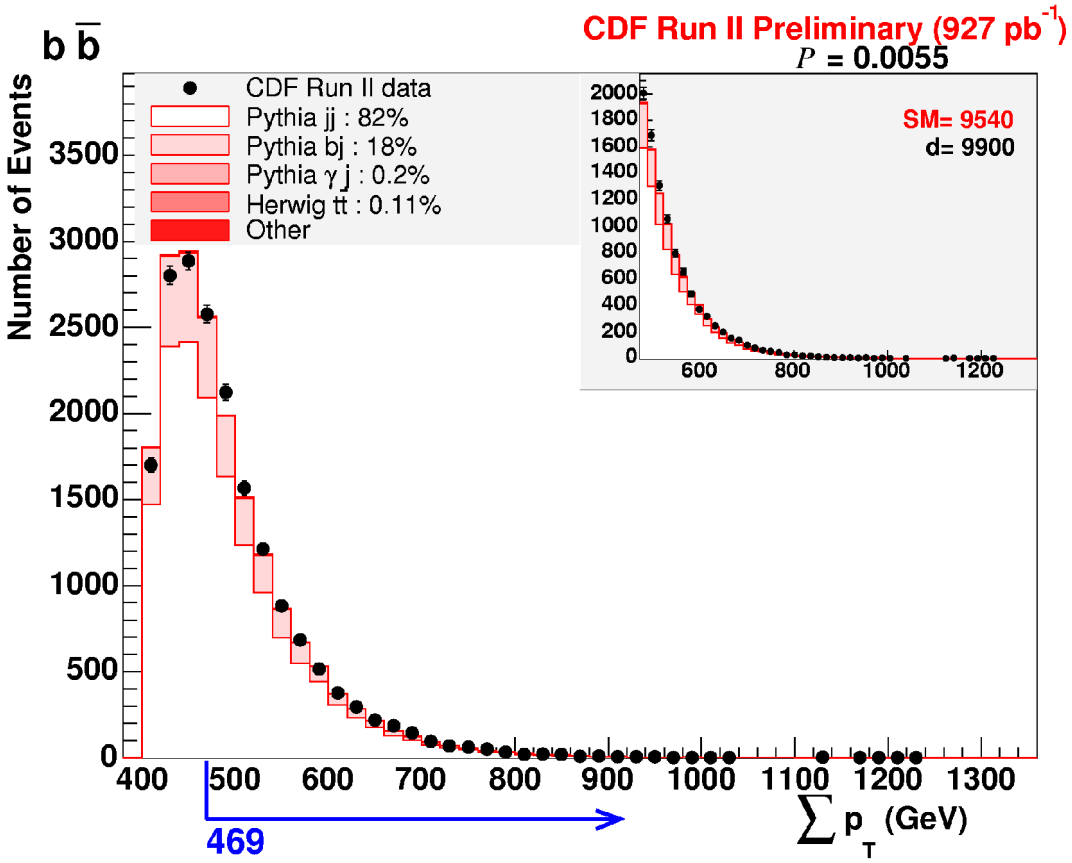


Probable over-estimation of SM background

If our simplified Standard Model prediction perfectly represented the data, we would expect this to be a uniform distribution

Sleuth's Most Discrepant Final States

#1



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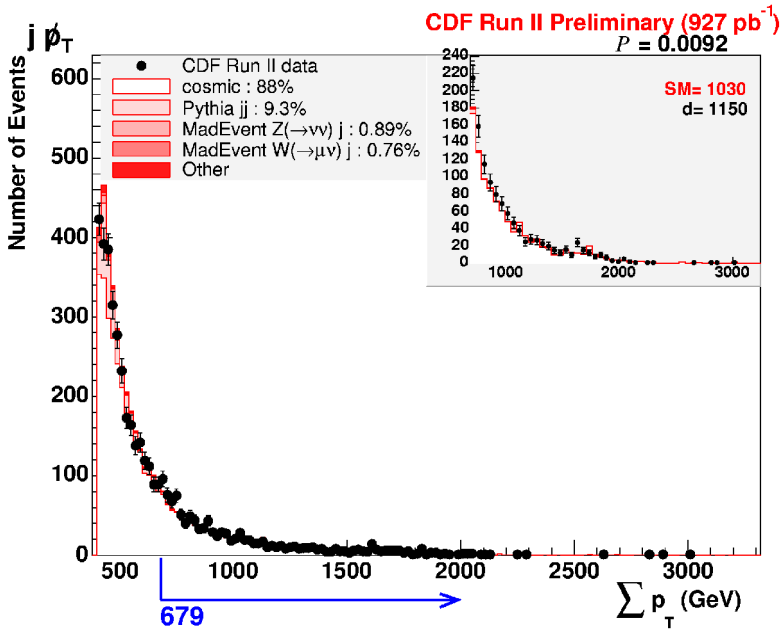

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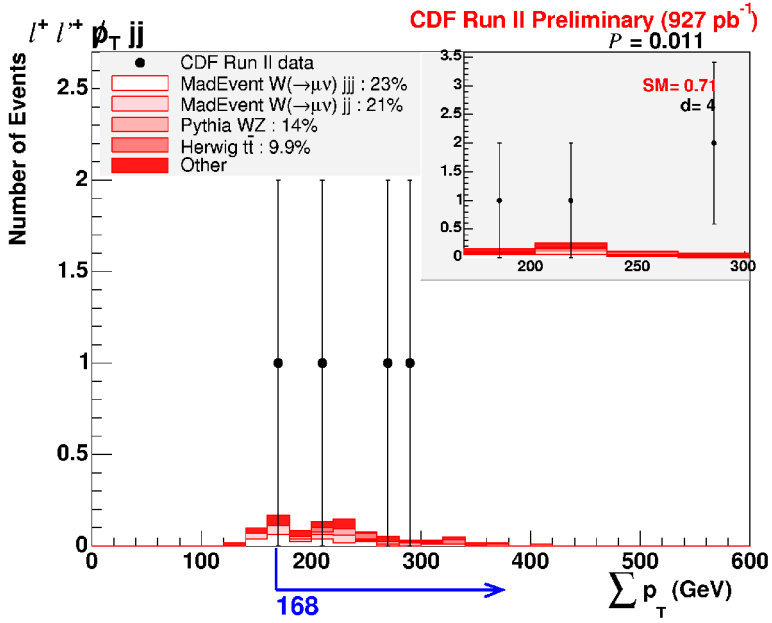


How significant is the largest Σp_T excess that we see in the data?
(after considering all the places in which we have looked)

Sleuth Results

- Sleuth's assessment of the significance of the largest discrepancy we observed in the data:
  - 46% of hypothetical similar experiments drawn from our simplified SM prediction would give a larger discrepancy

$$\tilde{\mathcal{P}} = 0.46$$

(>> 0.001)

- In 1 fb^{-1} of CDF data, we found no significant ~5σ excess of data over SM in the high Σp_T distributions
- This is not a proof that there is no new physics present in these data

Sleuth's Top 5 Most Discrepant Final States:

SLEUTH Final State	$\mathcal{P}$
$b\bar{b}$	0.0055
$j \not{p}$	0.0092
$\ell^+\ell'^+ \not{p} jj$	0.011
$\ell^+\ell'^+ \not{p}$	0.016
$\tau \not{p}$	0.016

CDF Run II Preliminary

Summary of Sleuth

- Sleuth searches for new physics appearing as an excess of data at high Σp_T relative to SM backgrounds
- Sensitivity tests of Sleuth show it to be broadly comparable to dedicated searches when the signal satisfies Sleuth's assumptions
- No significant ~5σ excess was found that might indicate new physics in 1 fb^{-1}

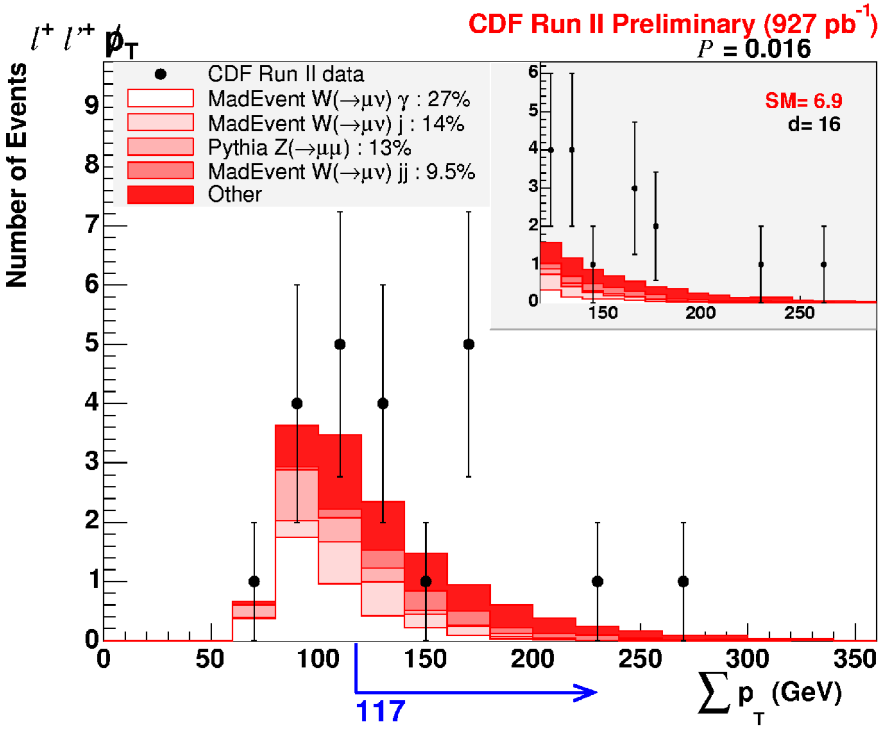
(But this is not a claim that there is no new physics present in our data)

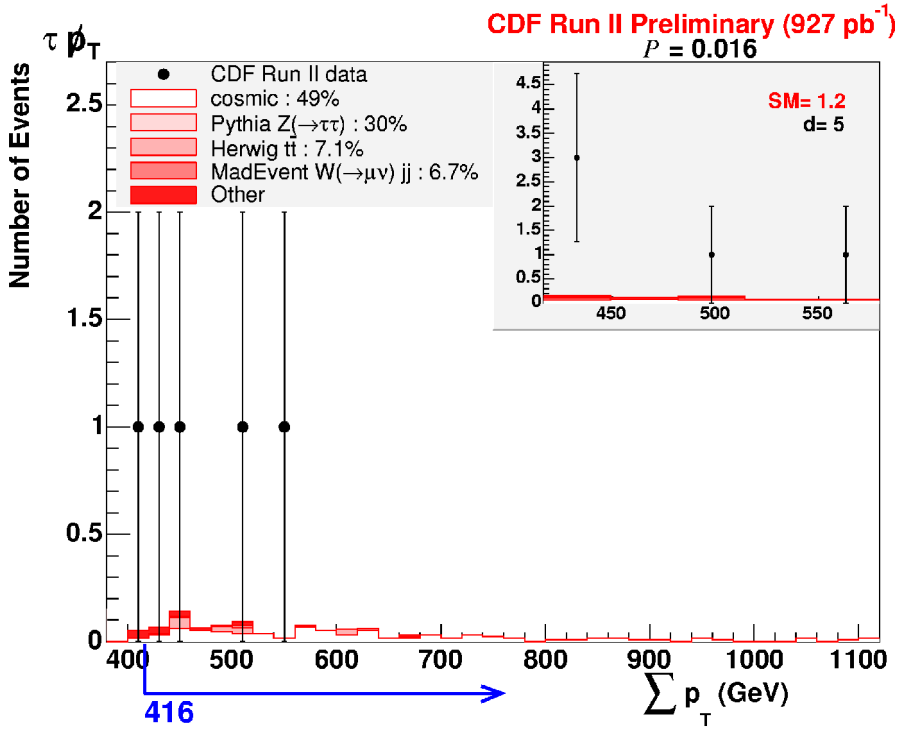
Future Plans

- The Tevatron expects to collect factor 5-8 more data
- Additional discrepancies that are seen will entail further improvements in our correction model
- The search for new physics at CDF - using this global search technique in parallel with dedicated searches - will continue with enthusiasm!

Backups

Sleuth's #4 and #5 Final States





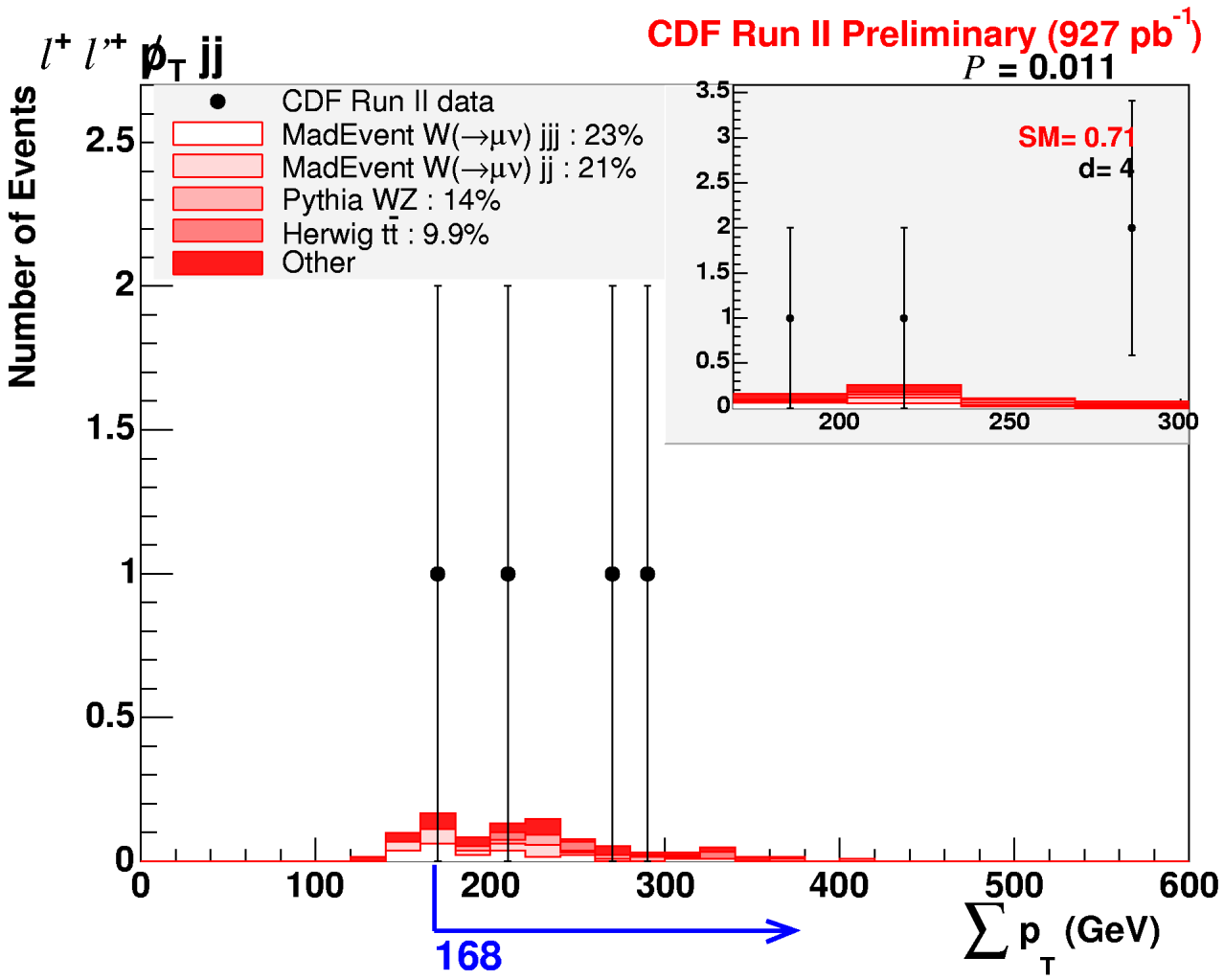
Sleuth Partition Rules

- Vista final states are merged in Sleuth to enhance signal/background
- Assumes that new physics will:
  - treat first 2 generations equivalently
  - be symmetric with respect to global charge conjugation
  - produce jets in pairs
  - conserve lepton flavour number

Systematics in Vista and Sleuth

- The correction model explicitly does not include some sources of systematic uncertainty, eg parton distribution functions or shower parameters
- Other uncertainties relating to detector simulation and object reconstruction are determined within Vista, but not propagated to the calculation of $\tilde{P}$ in Sleuth
- Correction factors are mainly fit to bulk distributions in Vista; potential additional systematic uncertainty associated with the extrapolation of these values to high-p_T is not included
- Sleuth's search for interesting excesses only considers statistical uncertainties on the background; systematic uncertainties on the Σp_T distributions in Sleuth are estimated to be ~10-30%
- Sleuth already has a null result (no significant Σp_T excess found) – any additional uncertainty would only make this even more null

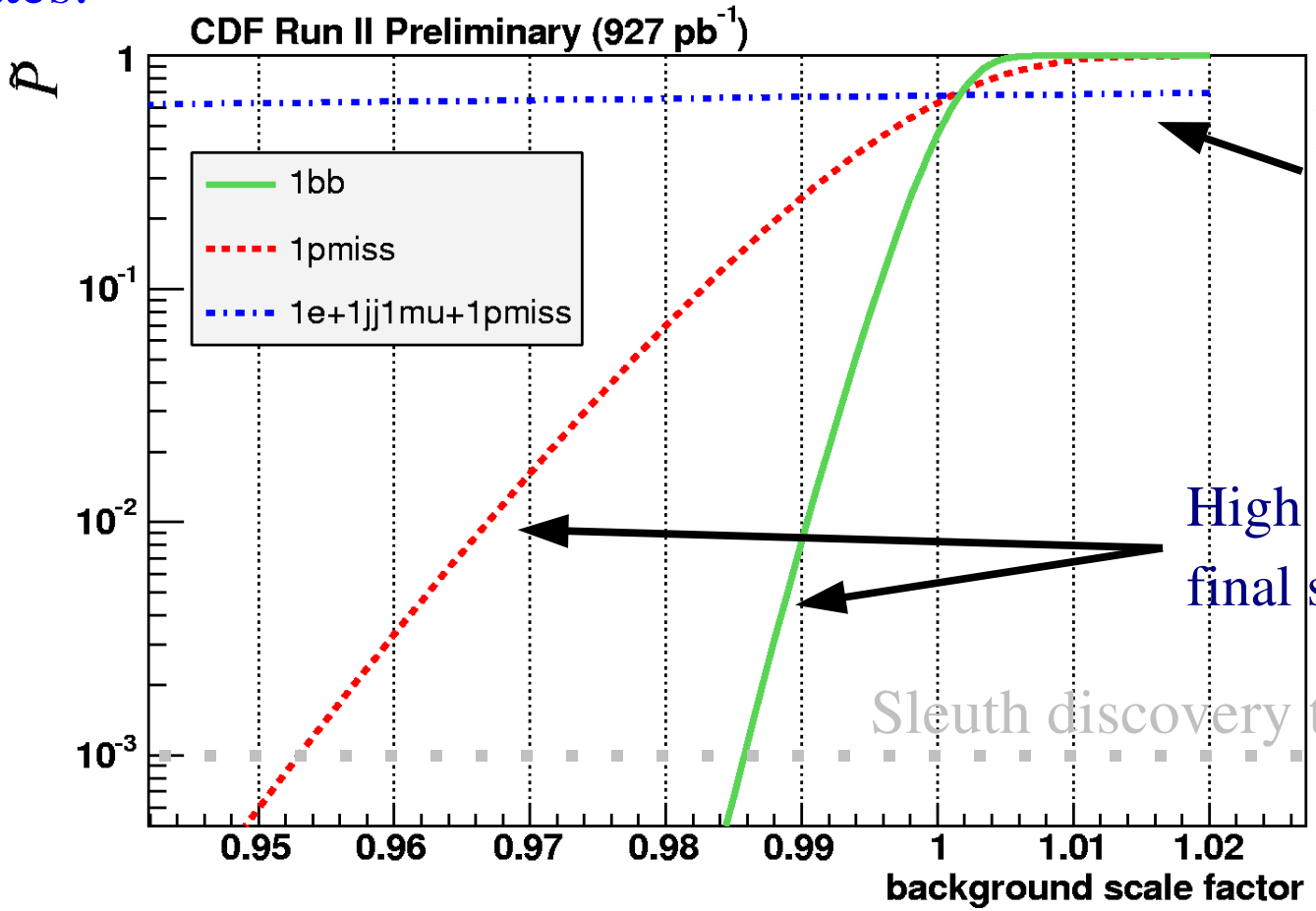
Estimation of Systematic Uncertainties



- Vista correction factors represent sources of systematic uncertainty
- Uncertainties in correction factor values obtained from Vista global fit
- For a particular final state, add in quadrature the appropriate contributions
- Estimate ~10% total systematic uncertainty on Sleuth backgrounds

Influence of Systematics on Result

- Variation of $\tilde{P}$ with background scale factor, for the top 3 Sleuth final states:



- For low population final states, statistics dominate over systematic uncertainty