Signature-Based Global Searches at CDF

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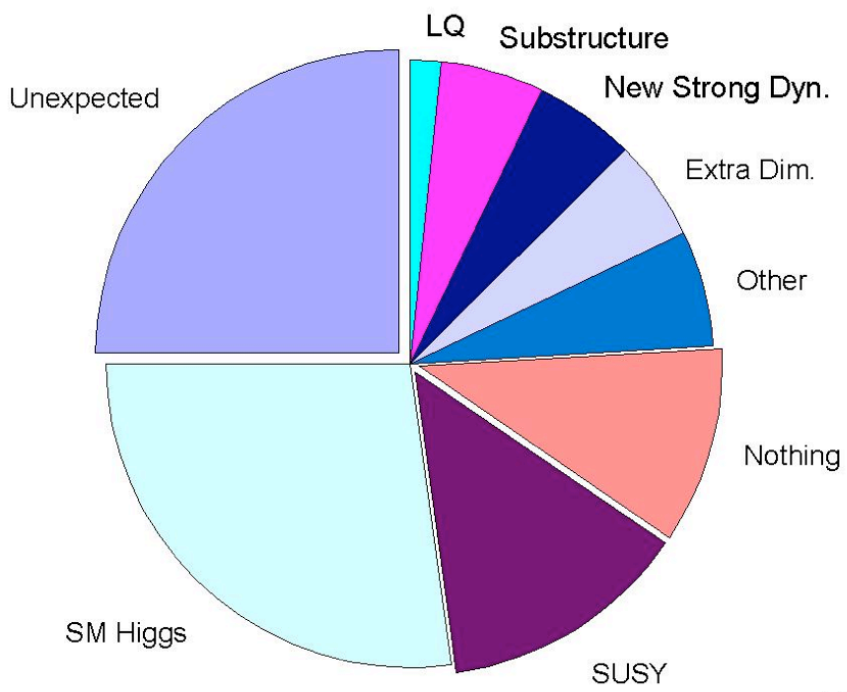
Motivation

- We all know today's SM is not the full story
  - At the very least, need EWSB mechanism
- What we don't know is how the SM will extend



Informal poll of ~300 physicists

- Lots of model classes
  - …with lots of submodels
  - …with lots of free params
- Wouldn't stake your life (= your experiment) to any one model
- Systematically search the entire high-p_T dataset for something we can't explain
  - Fight about what it is later

Model-Independent Search

The overall approach is two-tiered:

- "VISTA" --- model-independent
  - Obtain "panoramic view" of entire high-p_T dataset
  - Can SM (plus detector simulation, plus brains) describe gross features of the high-p_T data?
    - Number of events, basic kinematics, etc.

"BumpHunter" --- resonance search

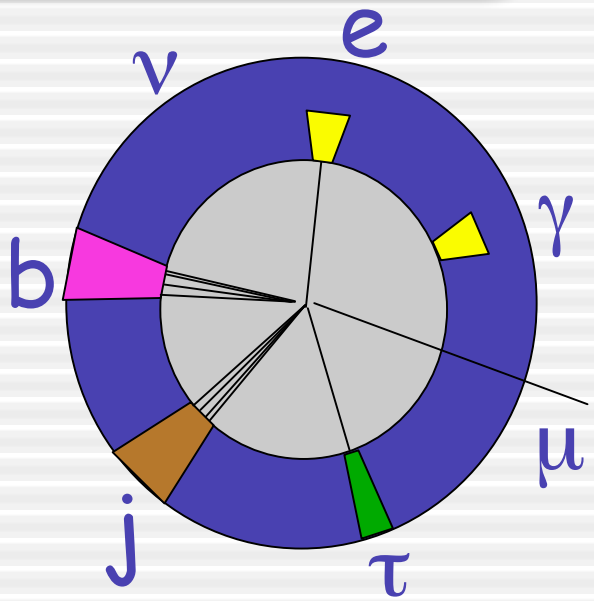
- Cluster objects and form invariant mass
- Look for excesses in varying mass windows

"SLEUTH" --- quasi-model-independent

- We're looking for new physics at the EWSB scale
- Search the high $\sum p_T$ tails of the data for excesses

VISTA algorithm

- Identify physics objects w/ p_T > 17 GeV
- Filter events of interest
  - μ > 25 GeV, γ > 60 GeV, b > 25 GeV + γ > 40 GeV, etc.
- Sort into exclusive final states
  - 3j, eej, μ2bγ, etc.



Description	Value	Cnstrnt?
Luminosity	1.990±0.05 fb^{-1}	Y
σ(4j,hi p_T) kfact	1.06±0.03	N
e ID eff. corr.	0.978±0.006	Y
b fk rate, lo p_T	0.0183±0.002	N
μ trigger eff.	0.916±0.004	Y

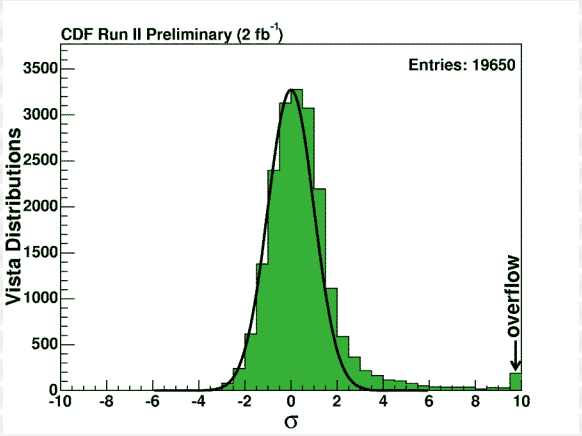
…plus 38 more…

- Get SM prediction for each final state
  - Detector simulation of object ID needs correcting
  - LO theory cross sections need correcting
  - Correction factors determined by global fit to all final states, subject to external constraints
- Compare data and SM predictions

VISTA output

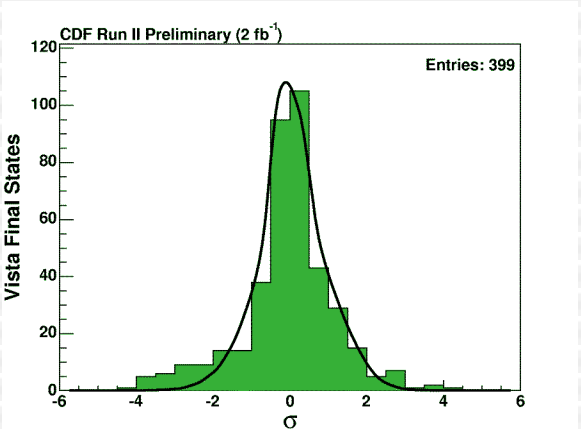
CDF Run 2 preliminary (2 fb^{-1})

Final state	Data	SM exp. ± stat.
be$^{\pm}$MET	690	817.7±9.2
$\gamma\tau^{\pm}$	1371	1217.6±13.3
$\mu^{\pm}\tau^{\pm}$	63	35.2±2.8
b2jMET(hi p_T)	255	327.2±8.9

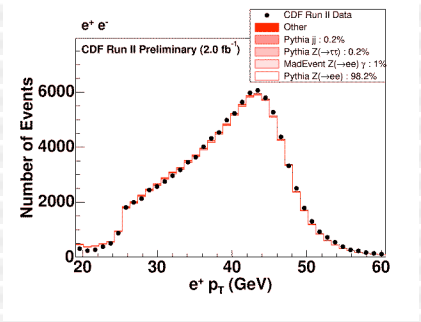


Kinematic distribution shape comparisons (data vs. expected)

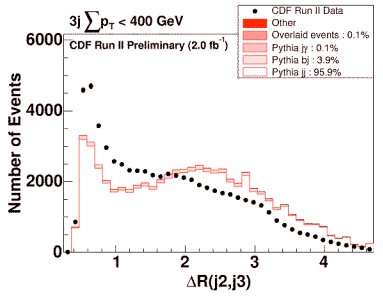
…plus 395 more (less and less discrepant) final states



No 5σ outliers…



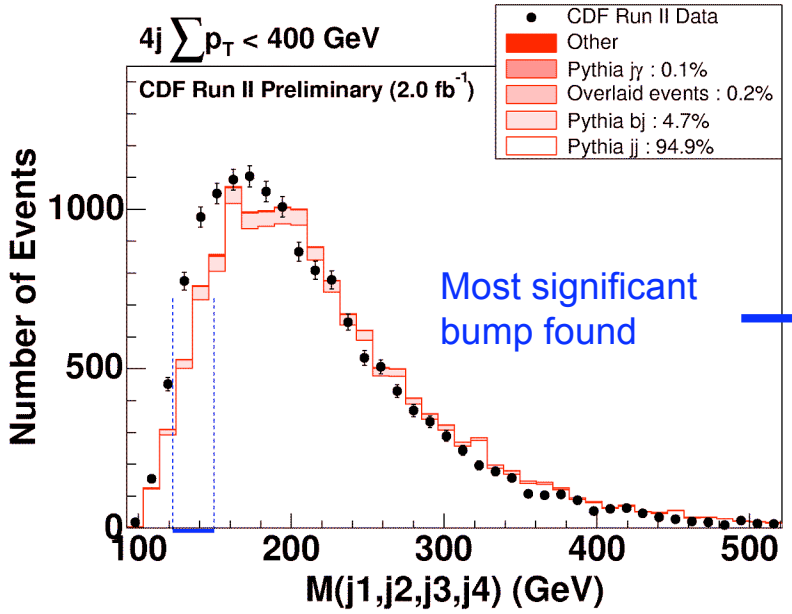
Some good…



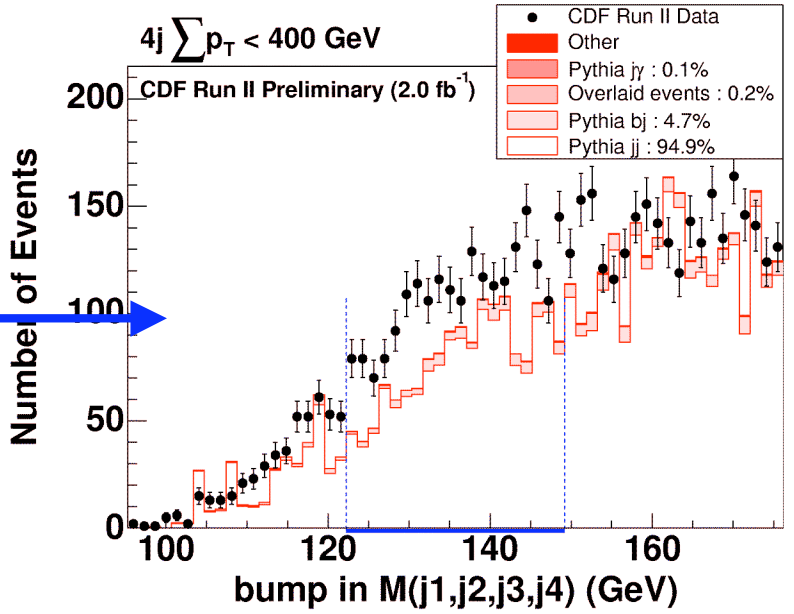
…and some bad (but not so interesting)

BumpHunter results

- All possible combinations of objects in a FS are considered
- Scan mass distributions with a window of width = $2\sqrt{\Delta m}$
- Quantify significance of any bumps found



Most significant bump found

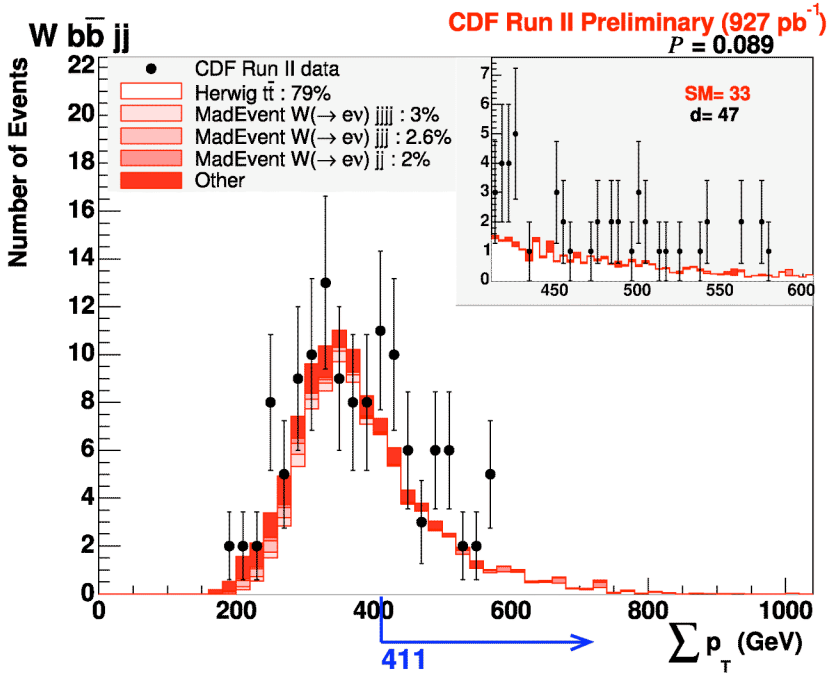


Noted discrepancy in $\Delta R(j2,j3)$ (prev. slide) underlies this bump

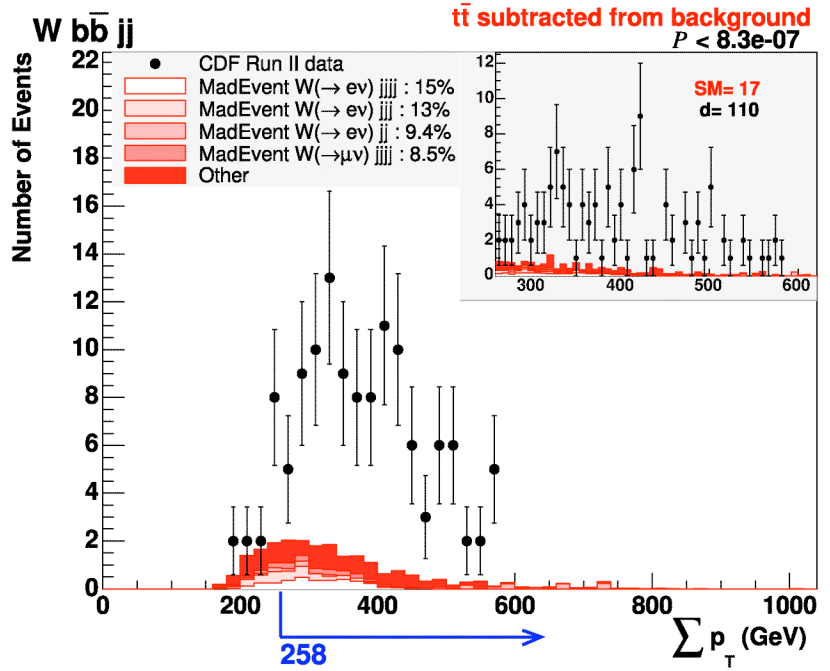
SLEUTH nutshelled

- SLEUTH sharpens the focus by making three (not very restrictive) assumptions on new physics:
  - It will appear as an excess…
  - …in the high $\sum p_T$ tails…
  - …in predominantly one final state (FS)
- Find the tail of a FS's $\sum p_T$ distribution with maximal data-SM discrepancy
- Pseudoexpts to determine probability of SM to produce that discrepancy (scriptP)
- For FS with smallest scriptP, quantify probability for SM to produce a FS (any FS) with that scriptP (or worse)
  - Takes into account the "trials factor"
  - If this probability (tildeScriptP) < 10^{-3}, get excited (roughly equivalent to a 5σ effect w/o trials factor)

SLEUTH example: top quark



default



A topless SM… tildeScriptP << 10^{-3}

SLEUTH easily discovers top in Run 2… and can do so with luminosities comparable to Run 1

SLEUTH results

CDF Run II Preliminary ($2.0\ \mathrm{fb}^{-1}$)

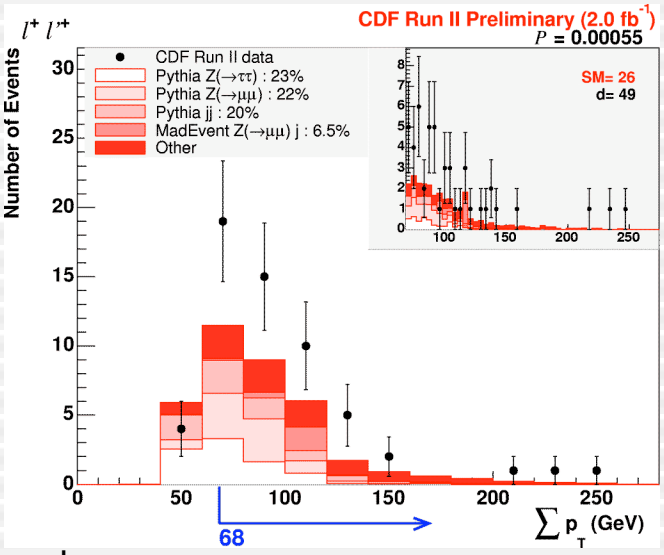
SLEUTH Final State	$\mathcal{P}$
$\ell^+\ell'^+$	0.00055
$\ell^+\ell'^+ \not{p} jj$	0.0021
$\ell^+\ell'^+ \not{p}$	0.0042
$\ell^+\ell^-\ell' \not{p}$	0.0047
$\ell^+\tau^+ \not{p}$	0.0065

…plus 82 more (less and less discrepant) final states

$$\tilde{\mathcal{P}} = 0.08$$

<< 10^{-3}… no indication of new physics

Most “discrepant” FS



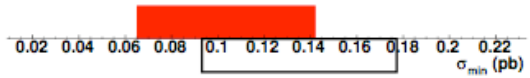
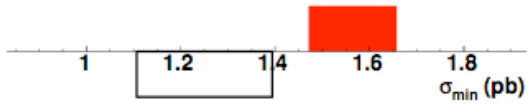
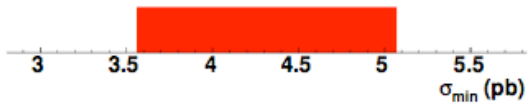
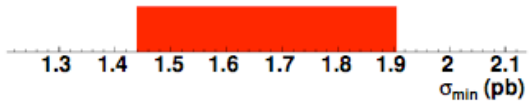
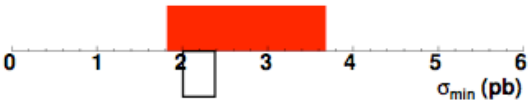
Conclusions

- CDF has developed a broad search for new physics that is not beholden to any particular new physics model
  - Complements direct searches targeted at specific models
- Data-driven nature of the approach lessens chance of new high-p_T physics slipping through the cracks
- The search has revealed no indication of new high-p_T physics in ~2 fb^{-1}
- Keep at it for Run 2, look forward to similar work from D0
- More details: hep-ex/0712.1311 (appearing in PRD)

Backuppery

Sensitivity

What xsec's could trigger a SLEUTH discovery in 1 fb^{-1}?

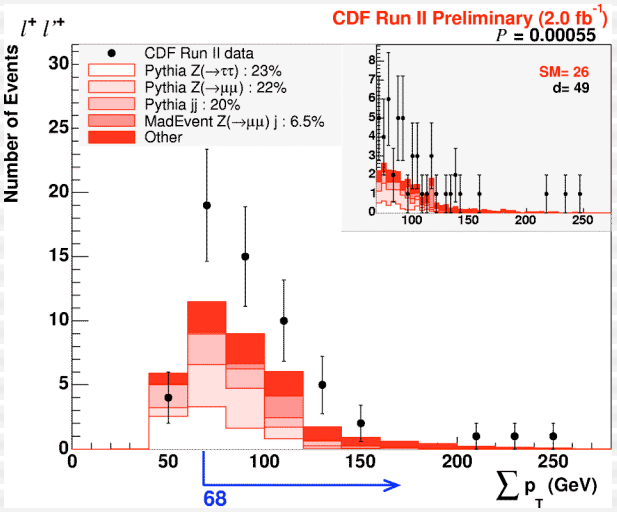
Model	Description	Sensitivity
1	GMSB, $\Lambda = 82.6$ GeV, $\tan\beta = 15$, $\mu > 0$, with one messenger of $M = 2\Lambda$.	
2	$Z' \to \ell^+\ell^-$, $m_{Z'} = 250$ GeV, with standard model couplings to leptons.	
3	$Z' \to q\bar{q}$, $m_{Z'} = 700$ GeV, with standard model couplings to quarks.	
4	$Z' \to q\bar{q}$, $m_{Z'} = 1$ TeV, with standard model couplings to quarks.	
5	$Z' \to t\bar{t}$, $m_{Z'} = 500$ GeV, with standard model couplings to $t\bar{t}$.	

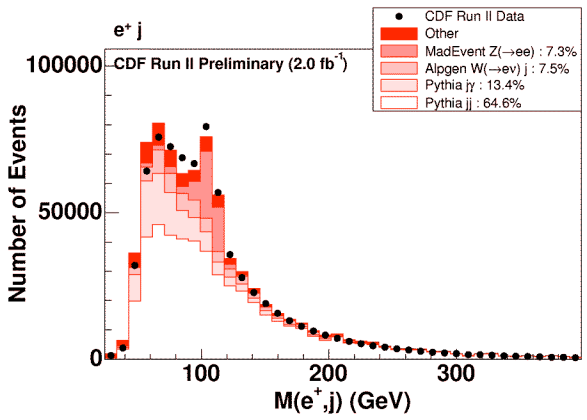
Red = SLEUTH

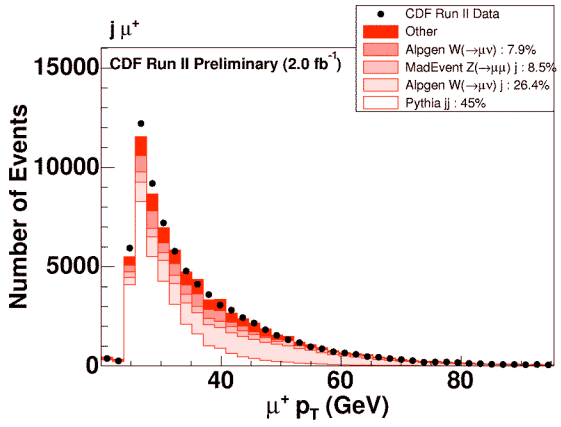
White = Other CDF

FOR ENTERTAINMENT PURPOSES ONLY (no systematics, etc.)

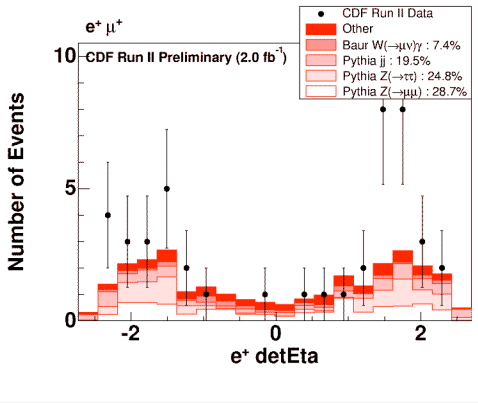
SLEUTH's favorite final state







Lepton fake rates well-constrained by dijet data



- Excess occurs in forward region
  - Poor tracking→charge misID
  - BUT… this is constrained by $e^{\pm}e^{\pm}$ final state ($Z \rightarrow ee$)