Sleuth

Search Algorithm for New Physics at the Tevatron

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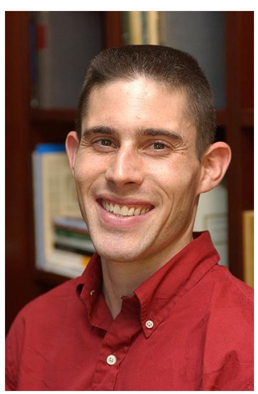

Bruce Knuteson


Conor Henderson


Markus Klute


Ray Culbertson


and myself

For the CDF collaboration

What is a discovery?

An observation:

- that is NOT a shortcoming of the SM simulation,
- that is NOT a detector effect,
- that is NOT a statistical fluctuation,

  – here comes *Sleuth*.
- of which we have a plausible interpretation.

  – Bruce Knuteson's talk.

quasi model independence

To be model-independent and yet sensitive,
Sleuth examines one simple
kinematic quantity of each event:

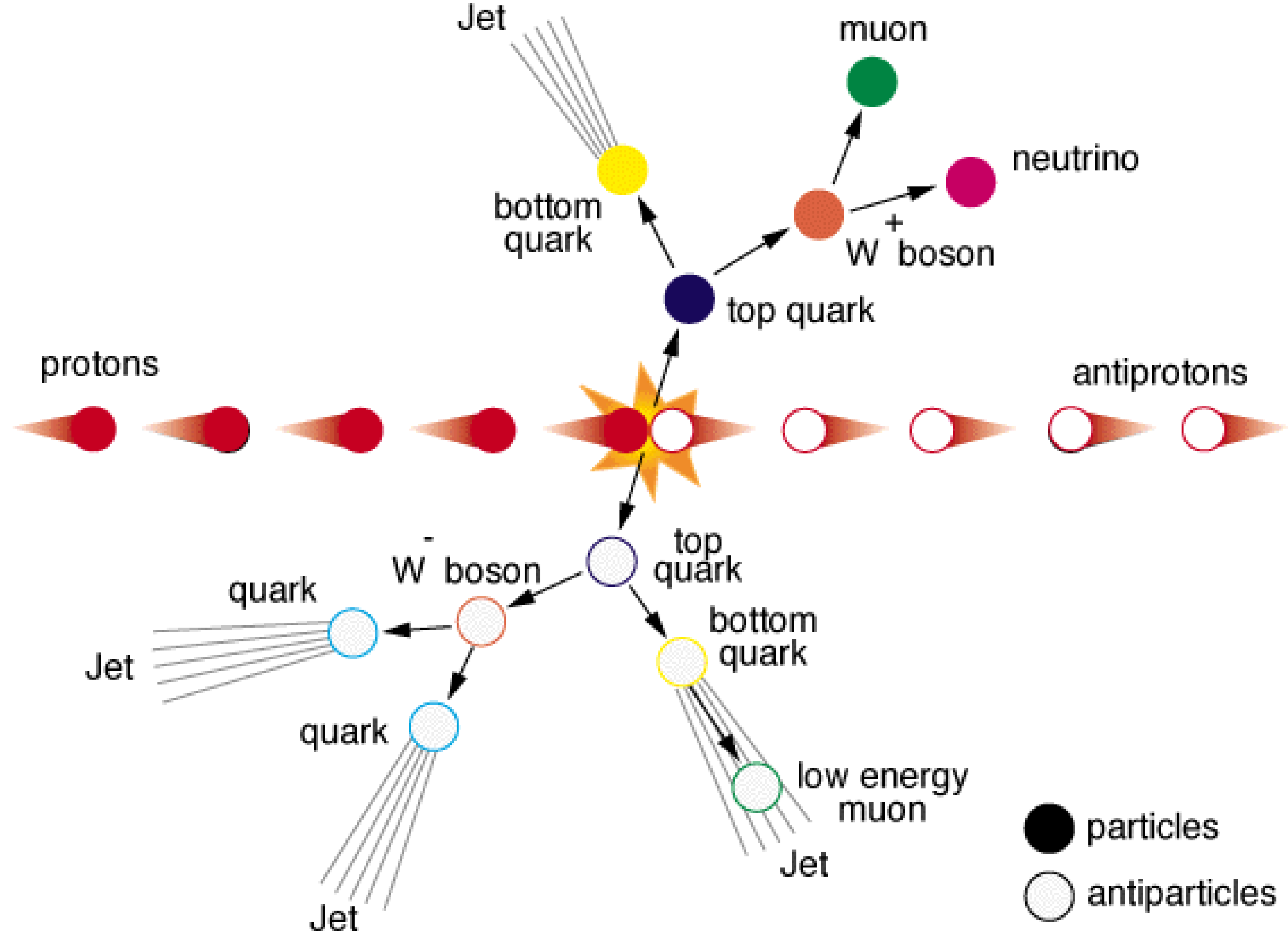
Σp_T = the scalar sum of the transverse momentum

Σp_T is a well motivated choice

Something common in almost all theories beyond the SM is that:

New electro-weak scale physics gives new massive resonances, which decay into high-p_T particles.

Historical example: the top quark



A Top Antitop Quark Event

goal of Sleuth

- Search for any interesting* excess of data in the high-Σp_T tails.

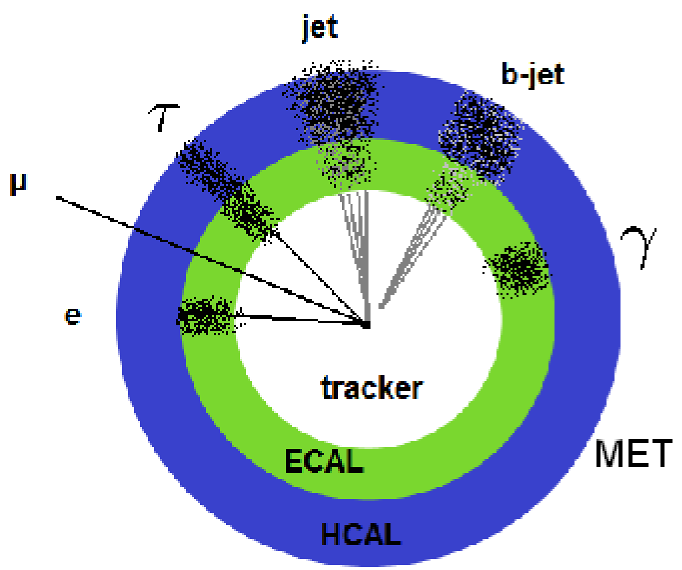
** "interesting" = "statistically significant"*
= "unlikely to be a fluctuation".

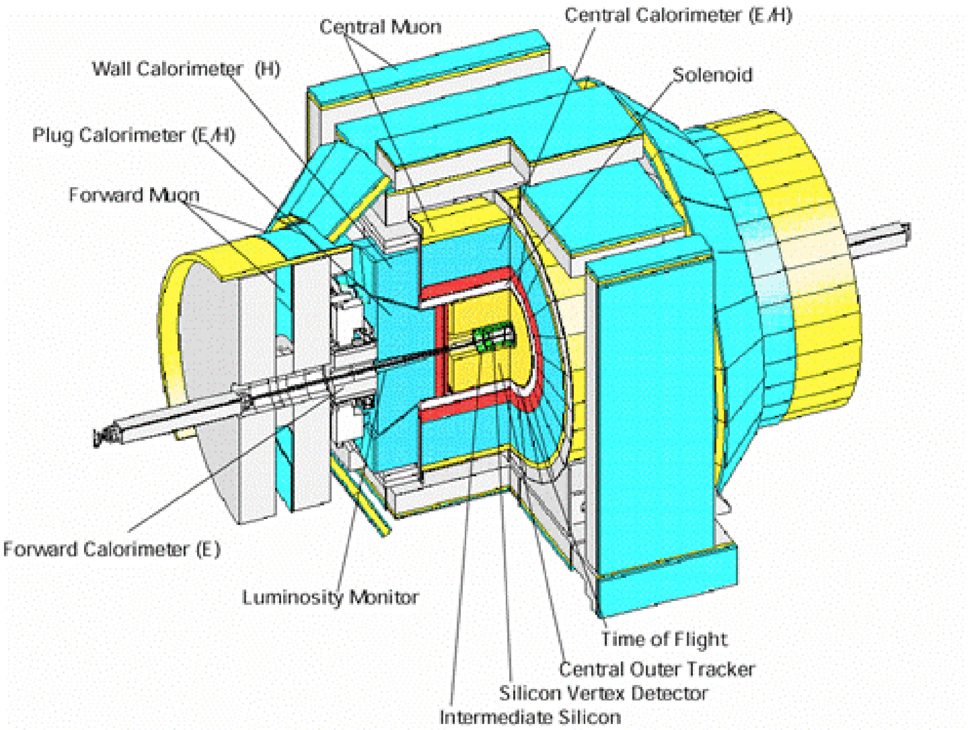
  - Reveal the most interesting Σp_T tail, and quantify its interestingness.
  - Return *one number* that expresses if there is a discovery or not in the data, from the statistical viewpoint.

notice: An excess is not a bump, though a bump is an excess.

preliminaries

- Collect data
- Generate SM MC
- Identify objects in each event





- Off-line selection:
  Keep any event with:
  - **e** or **μ** with p_T > 25 GeV or
  - **γ** with p_T > 60 GeV or
  - **jet** with p_T > 200 GeV
- Partition Data and SM MC into final states.

partitioning into final states

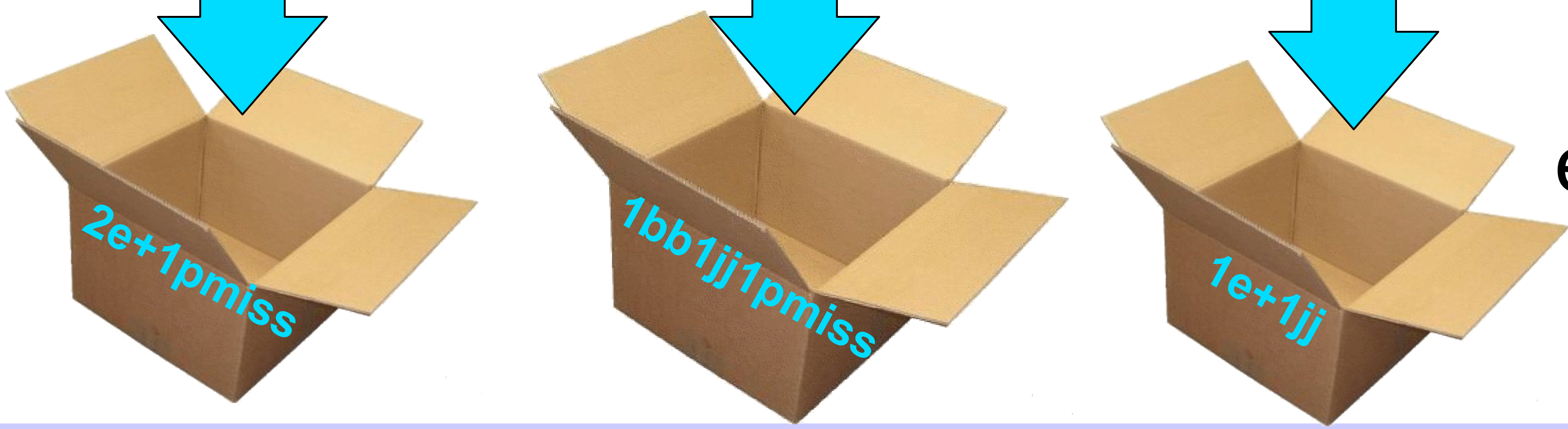
final objects:

$e^+ e^+$ pmiss
$\mu^+ \mu^+$ pmiss
$e^+ e^+$ j pmiss
$\mu^+ \mu^+$ j pmiss
$e^- e^-$ pmiss
$\mu^- \mu^-$ pmiss
$e^- e^-$ j pmiss
$\mu^- \mu^-$ j pmiss

b b j j pmiss
b j j pmiss
b b j j j pmiss
b j j j pmiss

e^+ j j
e^- j j
μ^+ j j
μ^- j j
e^+ j j j
e^- j j j
μ^+ j j j
μ^- j j j

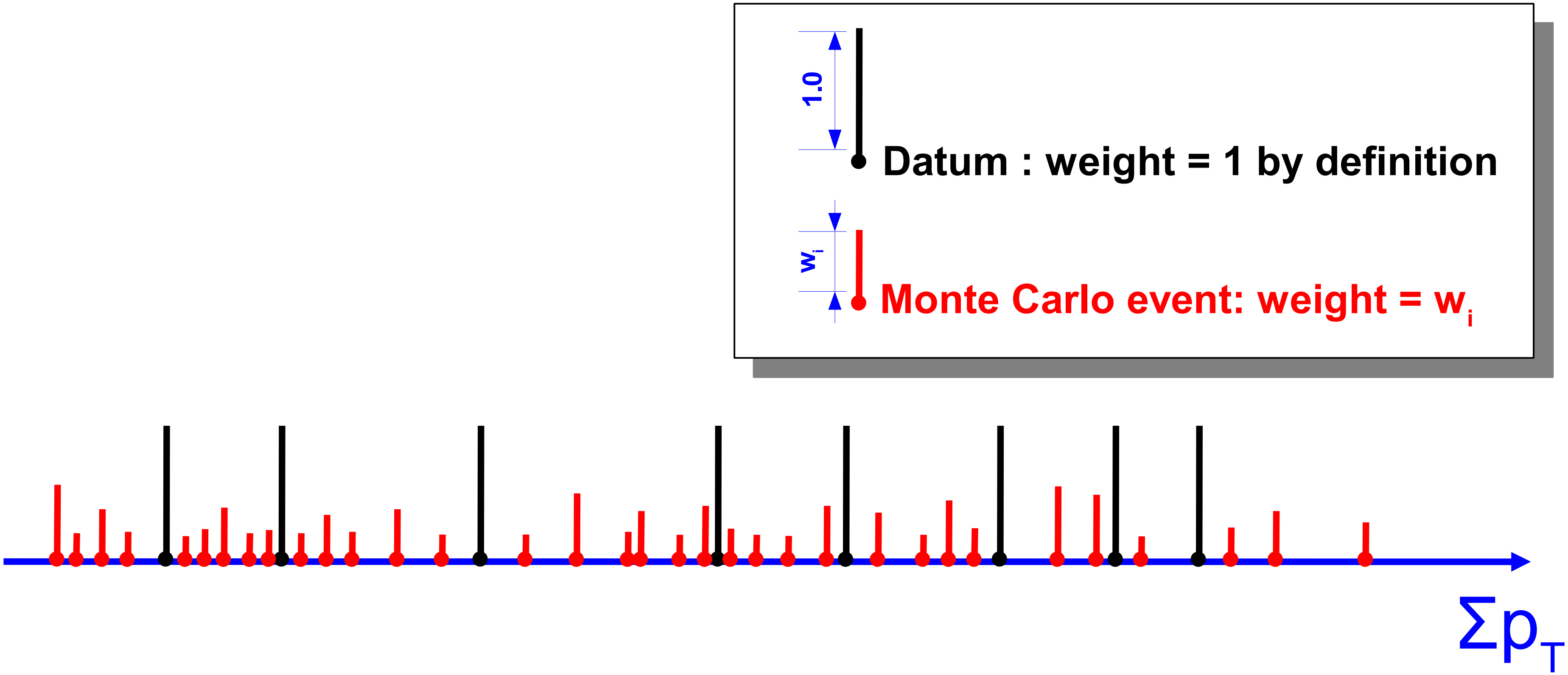
final state:



etc...

- Each event falls in exactly one final state
- New physics is expected
  - to treat electrons and muons the same
  - to be symmetric under charge conjugation
  - to produce jets in pairs

the raw information *Sleuth* uses



- ***Nature*** provides the data.
- ***MadEvent*** & ***Pythia*** & ***CDF detector simulation*** give the SM MC events
- ***Vista*** adjusts their weights (w_i)

  (recall talk by Conor Henderson)

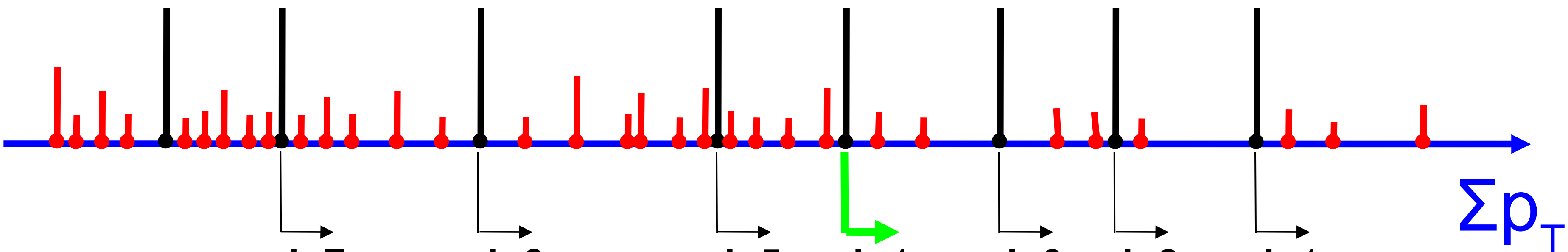
p-value and Pmin

For each final state:

- For each region:
  d = observed data
  b = expected background

- With **d** and b, calculate:
  p-value = The Poisson probability to observe **d** or more data in the tail, given that I expect b.

$$= \sum_{i=d}^{\infty} \frac{b^i}{i!} \exp(-b)$$



	d=7	**d**=6	**d**=5	**d**=4	**d**=3	**d**=2	**d**=1
	b=7.2	b=5.2	b=3.5	b=2.5	b=2.3	b=2.1	b=2.0
p-values:	**0.58**	**0.42**	**0.27**	**0.24**	**0.40**	**0.62**	**0.86**

- Most interesting region in this final state: the smallest p-value ≡ Pmin

from Pmin to scriptP

Remember: Now each final state has its own Pmin = min{p-values}.

For each final state, generate many sets of pseudo-data in order to estimate the:

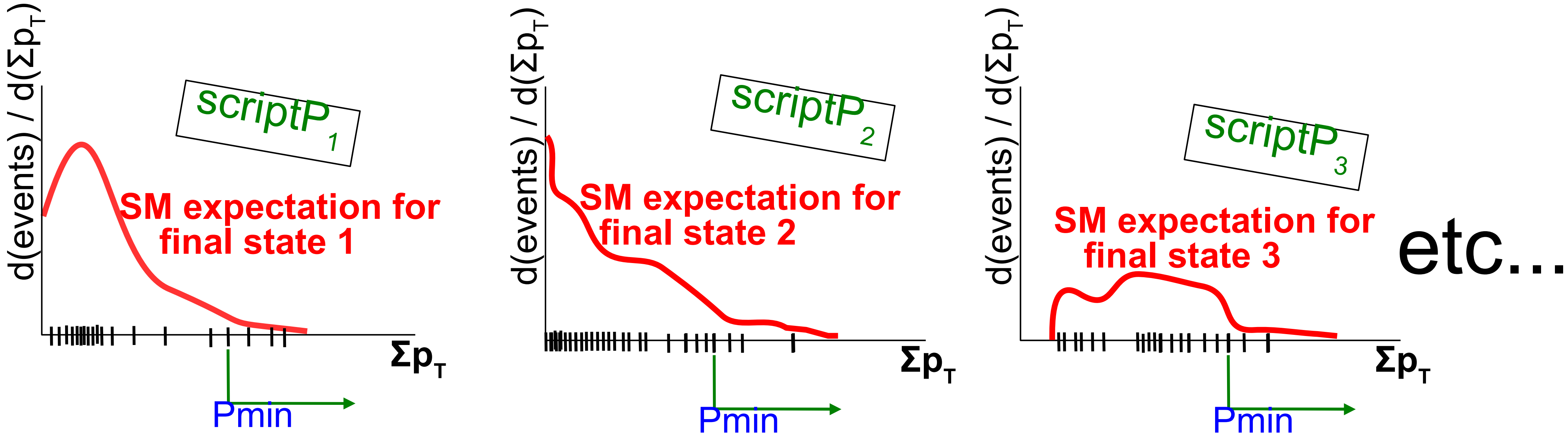
scriptP = fraction of SM-like pseudo-experiments which would have (in this final state) *any* tail with p-value ≤ the Pmin (of this final state).

in other words:

scriptP ~ the probability that the data of a SM-like pseudo-experiment would fluctuate in this final state to look as or more interesting than in the actual experiment.

The smaller the scriptP of a final state, the more interesting the final state and its prominent Σp_T region.

first goal achieved



At this point, *Sleuth*'s first goal is achieved:

- The most interesting final state is the one with the smallest scriptP, let's say final state 45, for which I know what events it contains.
- I know *how* interesting it is. That is $scriptP_{45}$.
- I know which one exactly the most interesting Σp_T tail is, *for example*, the tail starting at 130 GeV/c in the final state 45.

trials factor

But how interesting is the whole experiment with N~50 final states?
We didn't see what turned out to be most interesting at first trial, but rather after looking at N final states.

Analogy:

Joe tries the slot machine N=1 time and wins!
==> I suspect he has tampered the machine... his plays follow some non-standard model.

Joe tries N=1,000,000 times and wins at least once!
==> I wouldn't think he did anything interesting. His plays are consistent with the standard model.

This describes the infamous *trials factor* that has to be accounted for.

from scriptP to tildeScriptP

- To account for the trials factor, we define:

  tildeScriptP = 1 – (1 – min{scriptP})^N

  = The probability that the data of a SM-like experiment would fluctuate to make *any* Σp_T *tail in any final state* seem as or more interesting than the most interesting one that we actually observed.

- scriptP encapsulates all possible regions of a final state,

  tildeScriptP encapsulates all possible final states.

  ==> *Sleuth* rigorously accounts for the trials factor.

tildeScriptP

- Many of us think something has to be a “5σ” effect to be a discovery candidate.

  5σ means probability of 10^{-7}.

  But if you estimate the trials factor:
  10^{-7} x 100 students x 1 plot/week
  x 50 weeks/year x 2 years = 0.001

==> tildeScriptP < 1/1000 is even a conservative threshold for discovery.

- If tildeScriptP < 1/1000 then we prefer to question the SM than to attribute this data excess to “luck”.

What it means to be the 1/1000 guy

Summary

- *Sleuth* probes the high Σp_T tails
  - in minutes
  - globally and quasi model independently
  - without risk of human bias or error
- *Sleuth* rigorously accounts for the trials factor
- *Sleuth* returns an illustrative, clear answer about the statistical significance of the Σp_T tail of each final state and of the data as a whole.

==> We are currently using *Sleuth* to find new physics at the CDF.