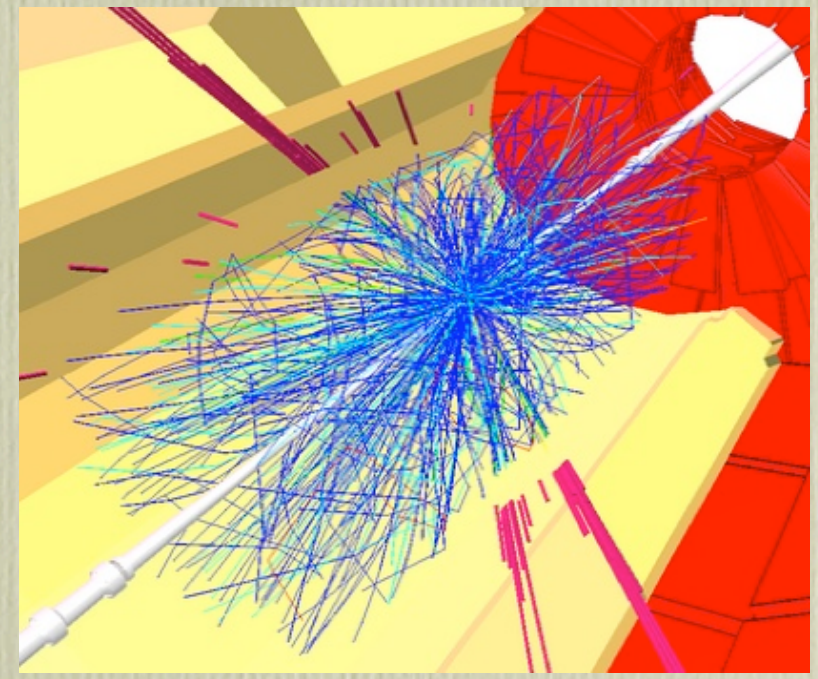
high energy physics in the LHC era



Joseph Lykken
Fermilab

PHENO 06, Madison, 15-17 May 2006

only 409 days until LHC

the Standard Model is not going away

- the SM still rules (almost) all
- below the energy frontier, new physics means (mostly) rare processes, small discrepancies, small inconsistencies
- at the energy frontier, SM backgrounds are about to get 100-500 times worse

case in point: B physics

- lots and lots and lots of data
- need precise SM predictions for dozens of observables
- the opportunities for big obvious signals of new physics are dwindling
- so now the game is looking for small discrepancies and small inconsistencies

status of theories beyond the standard model

(an analogy based on the SciFi Channel)

status of theories beyond the standard model

- The BSM models were created by man
- They evolved
- They rebelled
- There are many copies
- And they have a plan

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BSM circa 1983

- BSM theory was supersymmetry, grand unification, technicolor
- the models were primitive
- there was also a small strange community of “neutrino” people
- and a small strange community of “particle-astro” people

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BSM circa now

- string theory took the BSM high ground
- supersymmetry models are much more sophisticated, detailed, and ambitious
- supersymmetry has become a framework to describe everything from Higgs to B physics, from inflation to baryogenesis, from unification to LFV, from dark matter to branes
- technicolor mutated into AdS/CFT

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they rebelled

- after 30 years, SUSY is still not discovered , despite golden opportunities with LEP, Tevatron, B physics, EDMs, etc
- mysteries of flavor and of vacuum energy, which SUSY already had trouble with, have gotten worse
- theorists got worried (and bored) and decided to try radically new things...

extra dimensions

- extra dimensions are the other generic prediction of string theory and anyway are generic new degs of freedom
- they could be infinite but hidden, very large (.1 mm to 10 fm), large (Tev-1), or tiny but warped
- they could: break SUSY, explain dark matter or dark energy, explain flavor, solve the hierarchy problem

Higgs Schmiggs

- theorists are even questioning some of the holy assumptions:
  - models with no Higgs
  - landscape-inspired SUSY, including split-SUSY
- and combining ideas, e.g. Little Higgs and SUSY

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there are many copies

- despite different theoretical inputs, many BSM models end up looking the same phenomenologically
- this is because they are trying to do the same things
- while simultaneously getting around the bounds from existing data

there are many copies

- most BSM models have a WIMP dark matter, and thus missing energy signatures at colliders
-
- the EW precision data imply that the new heavy particles associated with EWSB are:
  - multi-TeV
  - conspiratorial
  - pair-produced and minimal flavor-violating

there are many copies

- so some new BSM models look like SUSY (Little Higgs with T-parity, UED,...)
- others resemble each other with new TeVish gauge bosons, top-partners, etc (Little Higgs, Randall-Sundrum, TeV extra dims, GUT-inspired,...)
- and it was already difficult to tell SUSY models apart

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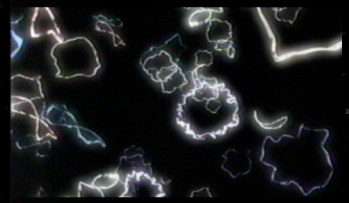
replace the standard paradigm by ~2015

the big picture 2006



string unification

supersymmetry

extra dimensions

neutrino origins?

broken

hidden

flavor origins?

new TeV scale physics
100 GeV? 1 TeV? 10 TeV?

new long distance physics?

LHC Olympics

http://www.phys.washington.edu/users/strasslr/LHCO.BBpage.html
CERN 25-26 July 2005 and 9-10 Feb 2006
next meeting: 24-25 August 2006 KITP

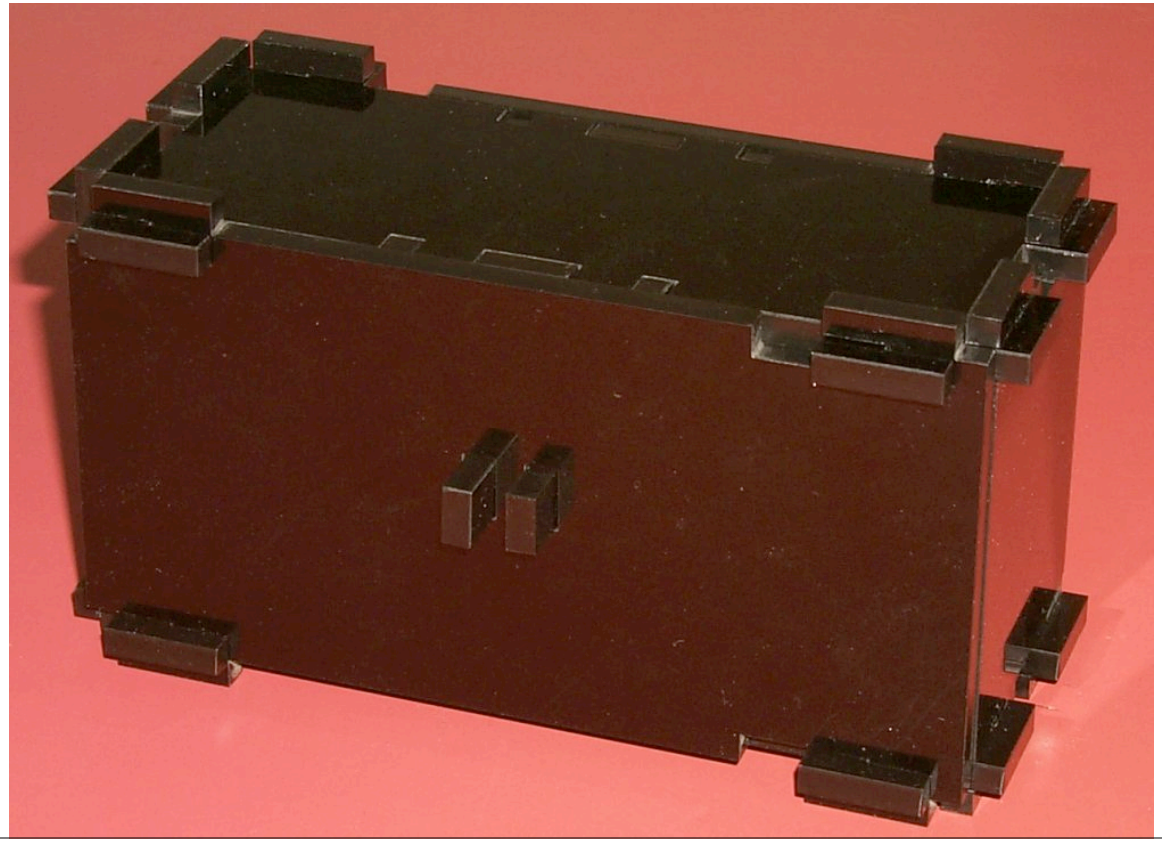
a “special” Olympics

originally designed to train
string theorists for basic life skills post-2007

LHC Olympics in 9.79 seconds

the steroid-enhanced Pheno all-stars don't need
6 months to figure out a black box signal
(do you?)

Black Box #1



- a black box sample of simulated LHC events was generated (somehow)
- jets, leptons, MET are all reconstructed objects from a detector simulation
- these objects are defined in an analysis note that you do not have access to
- the total integrated luminosity is less than one inverse femtobarn
- I will show you some selected histograms

basic cuts

$$\mathbf{PT_{min}(jet)} = \mathbf{30}\ \mathrm{GeV}$$

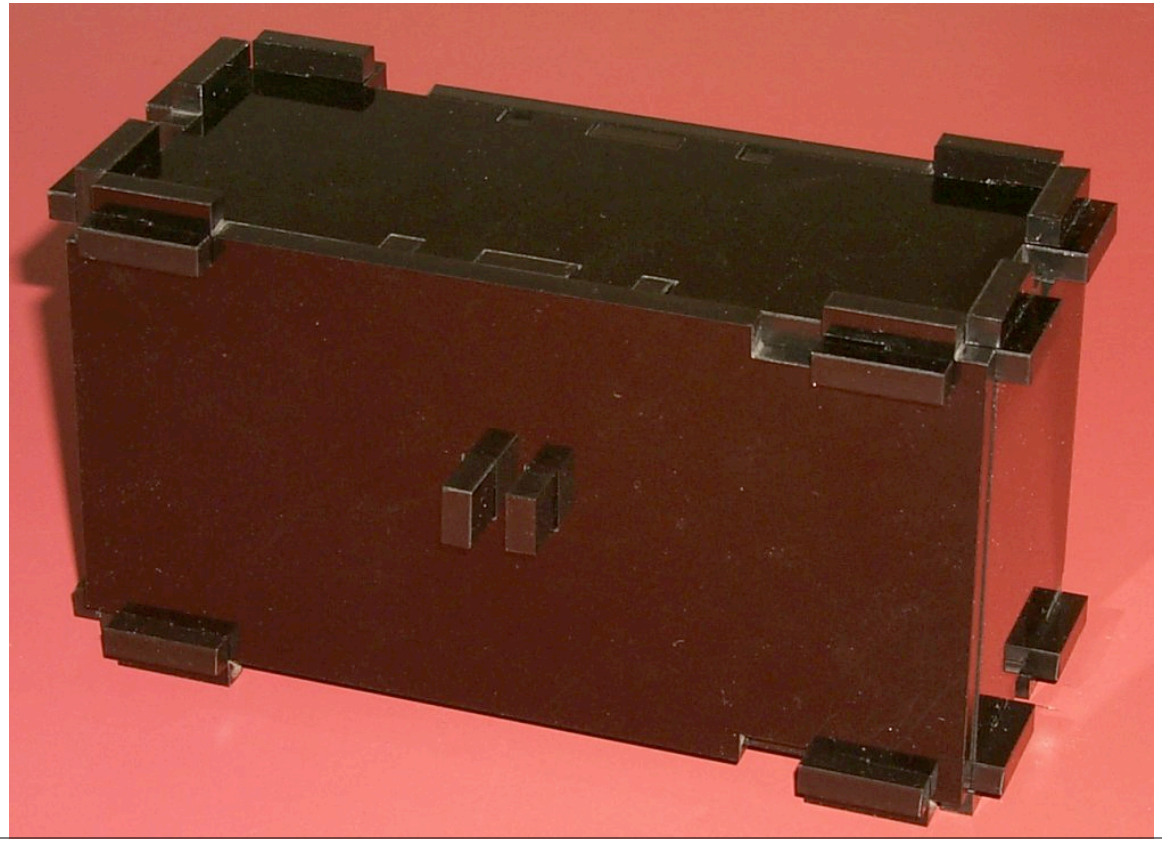
$$|\eta_{\mathbf{jet}}| \leq \mathbf{2.5}$$

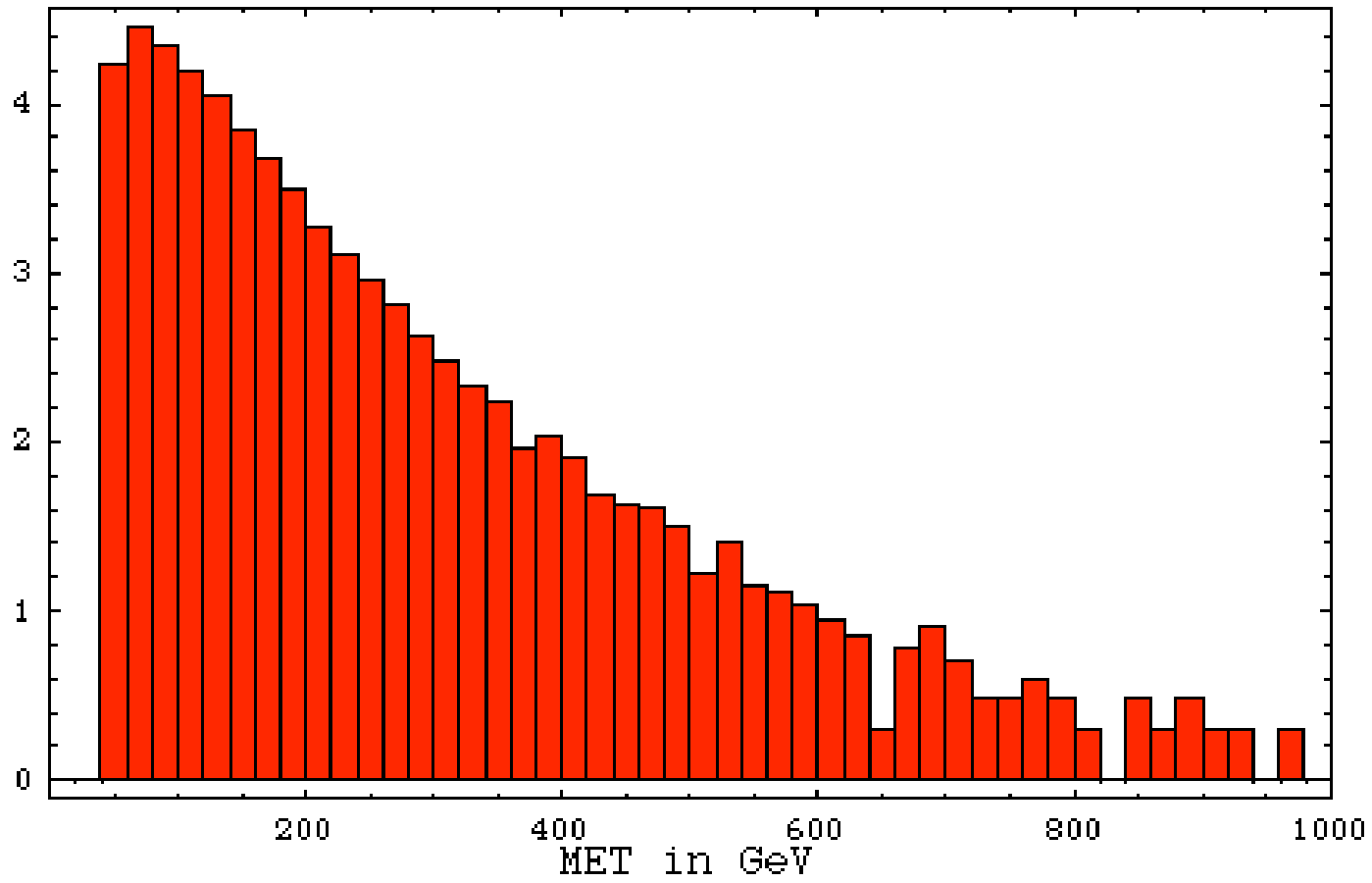
$$\mathbf{PT_{min}(lepton)} = \mathbf{20}\ \mathrm{GeV}$$

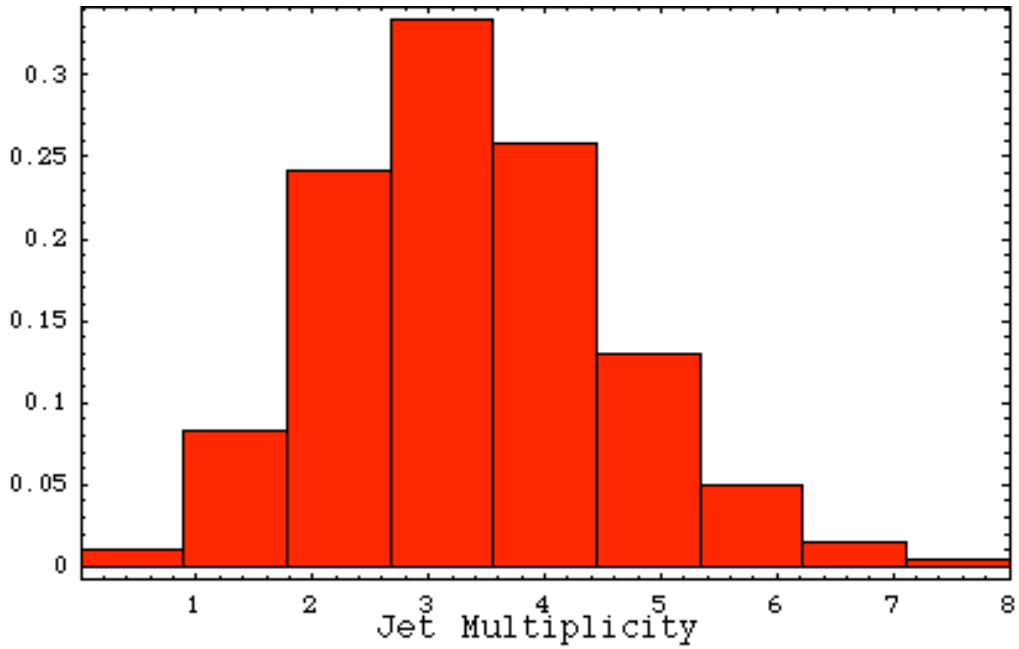
$$|\eta_{\mathbf{lepton}}| \leq \mathbf{2.5}$$

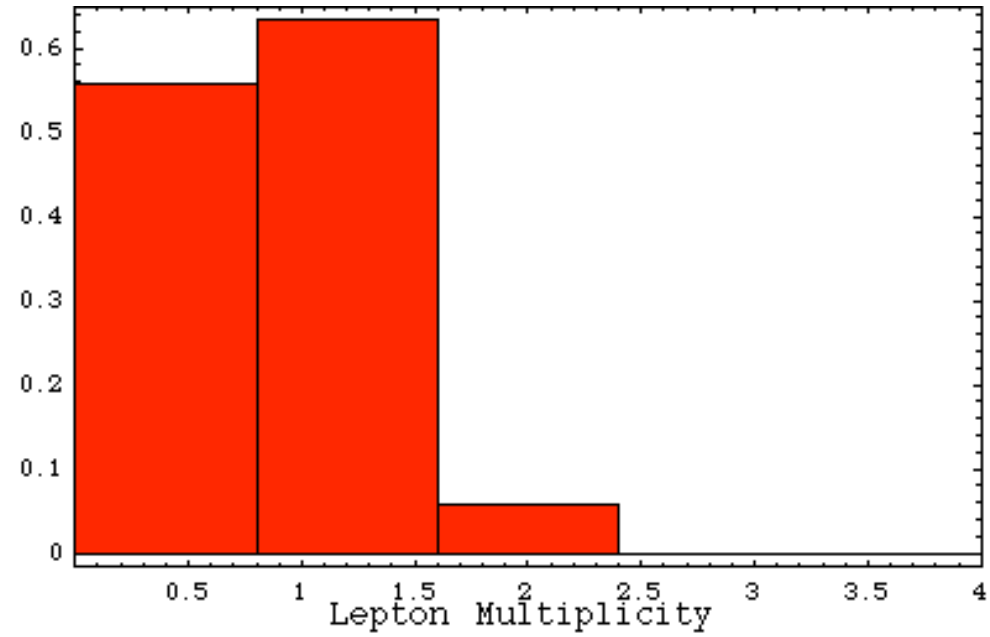
$$\mathbf{MET_{min}} = \mathbf{50}\ \mathrm{GeV}$$

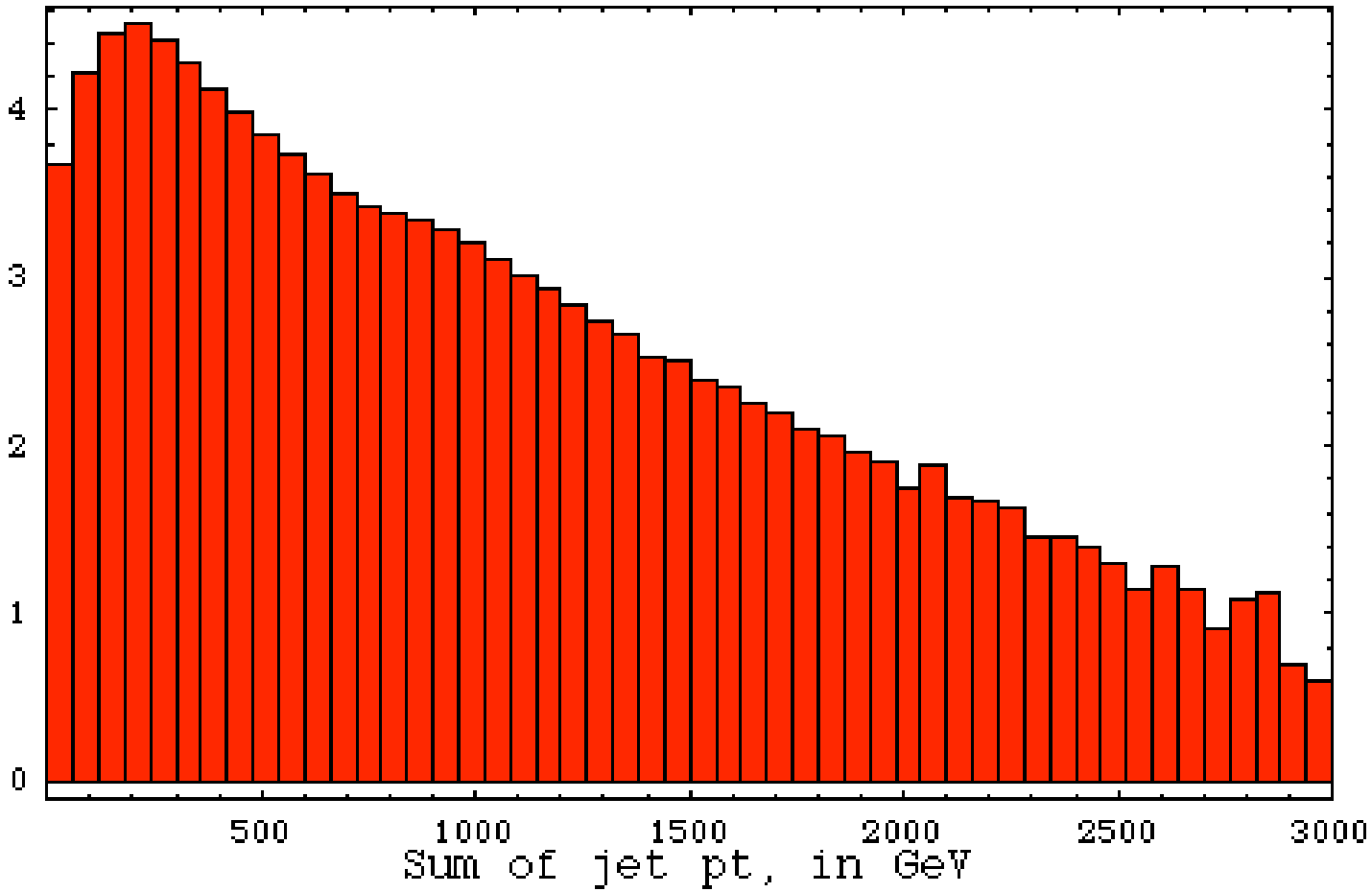
ready?



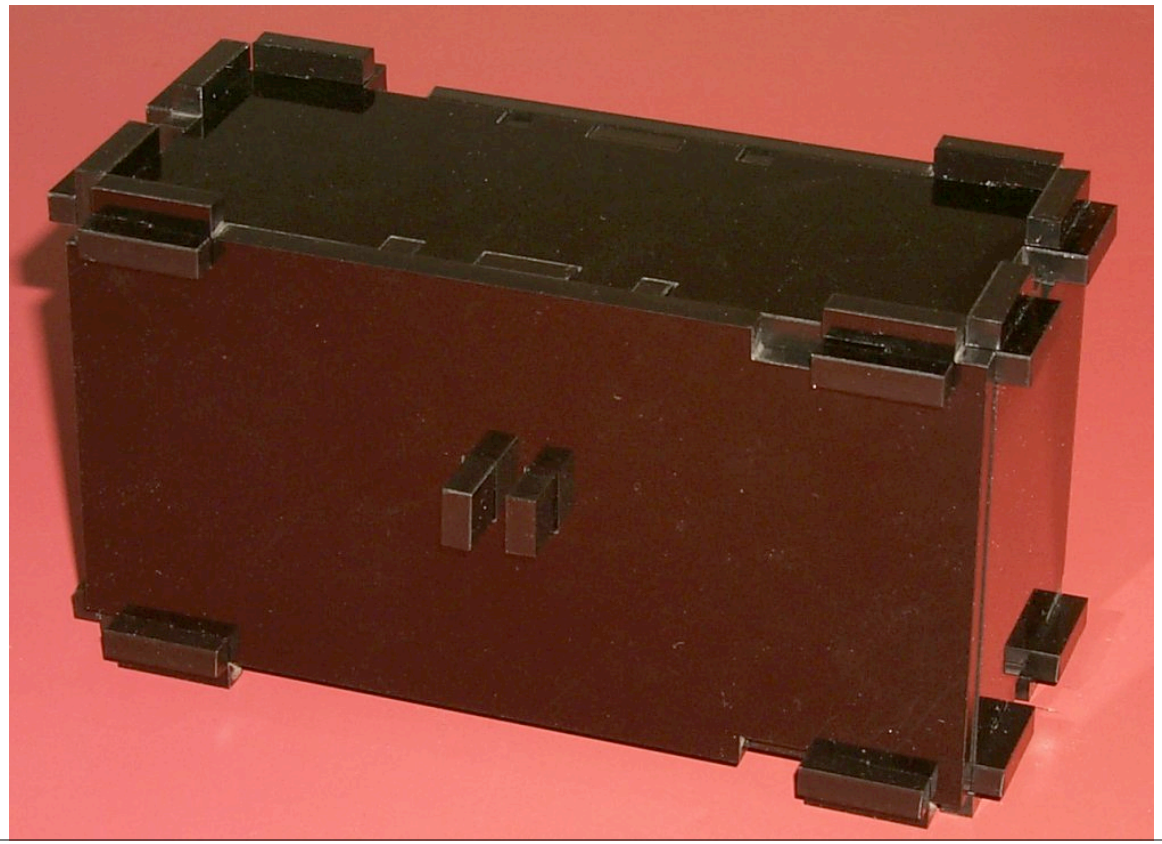

0
1
2
3
4
200
400
600
800
1000
MET in GeV


0.3
0.25
0.2
0.15
0.1
0.05
0
1
2
3
4
5
6
7
8
Jet Multiplicity


0.6
0.5
0.4
0.3
0.2
0.1
0
0.5
1
1.5
2
2.5
3
3.5
4
Lepton Multiplicity


4
3
2
1
0
500
1000
1500
2000
2500
3000
Sum of jet pt, in GeV

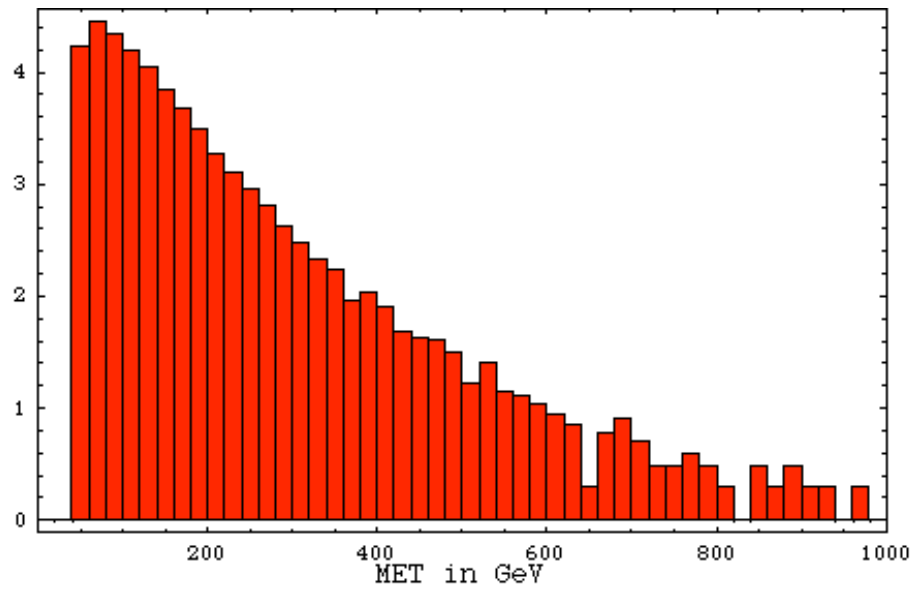
so what is it?

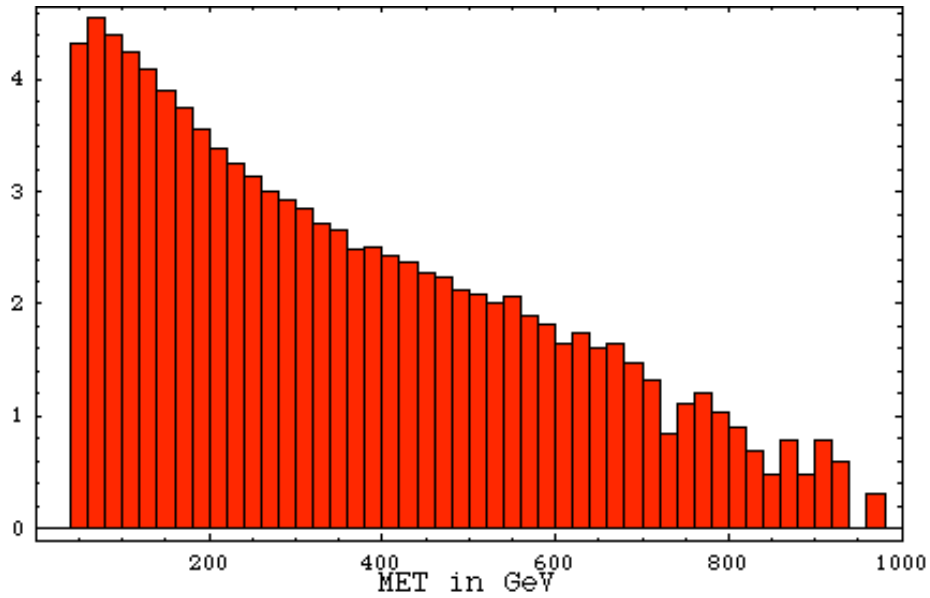



EQUIPMENT MUST BE BOOKED
AHEAD OF TIME...PLEASE CALL
X22764 FOR BOOKING AND
ACCESS ARRANGEMENTS
THANK YOU

Black Box #2

- a black box sample of simulated LHC events was generated (somehow)
- hint: it consists of the sample that I just showed you, plus something else added
- I will show you some selected histograms

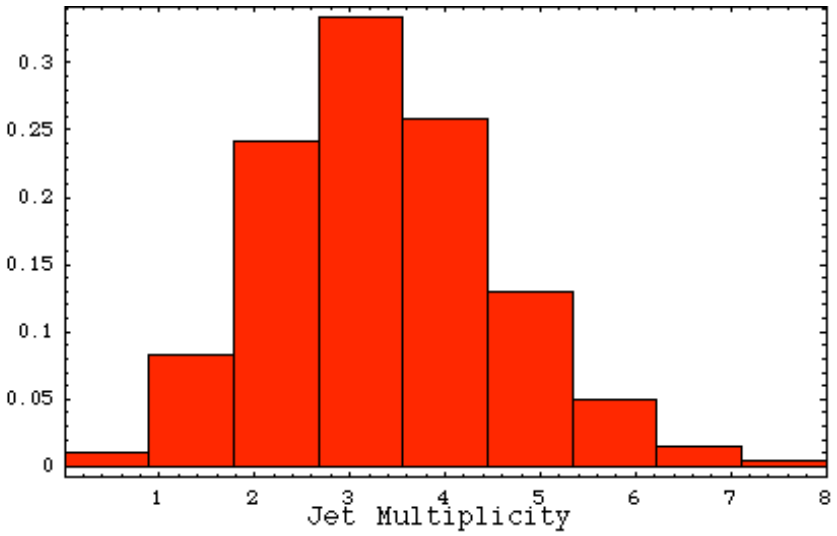


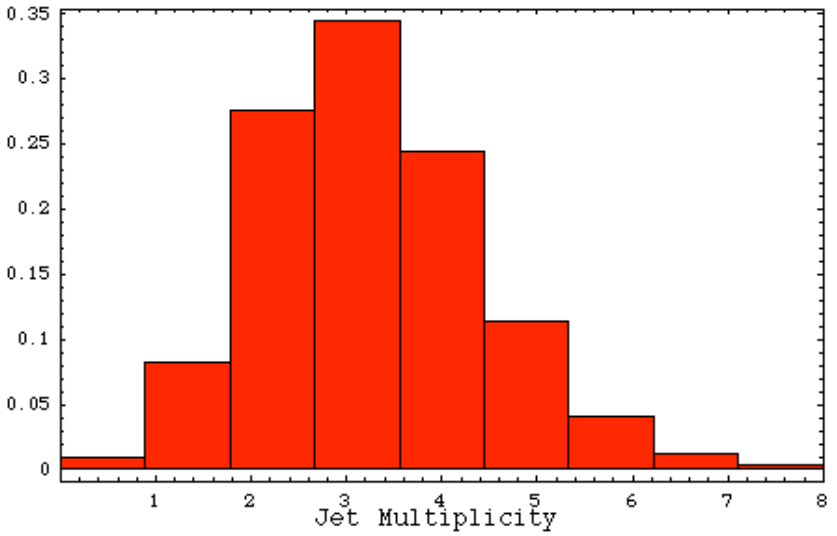


black box #1

black box #2

MET distribution

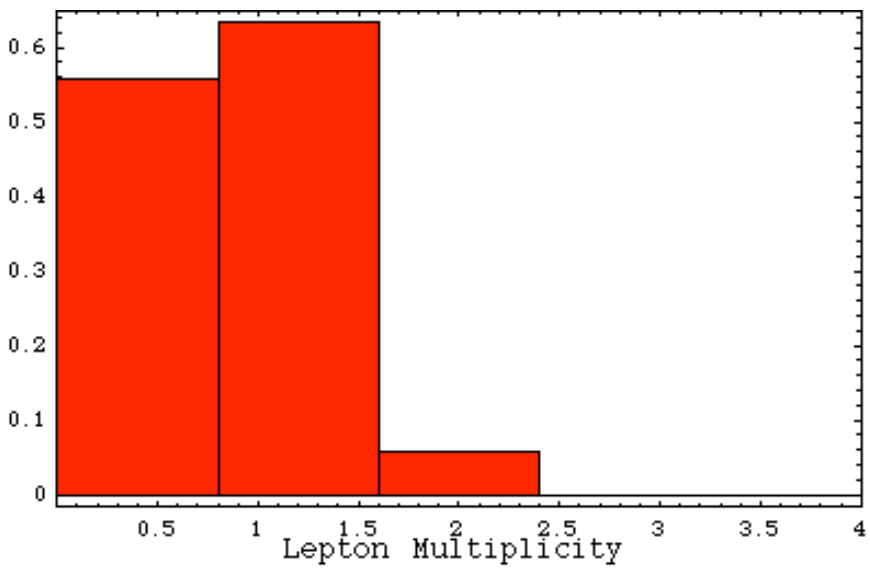


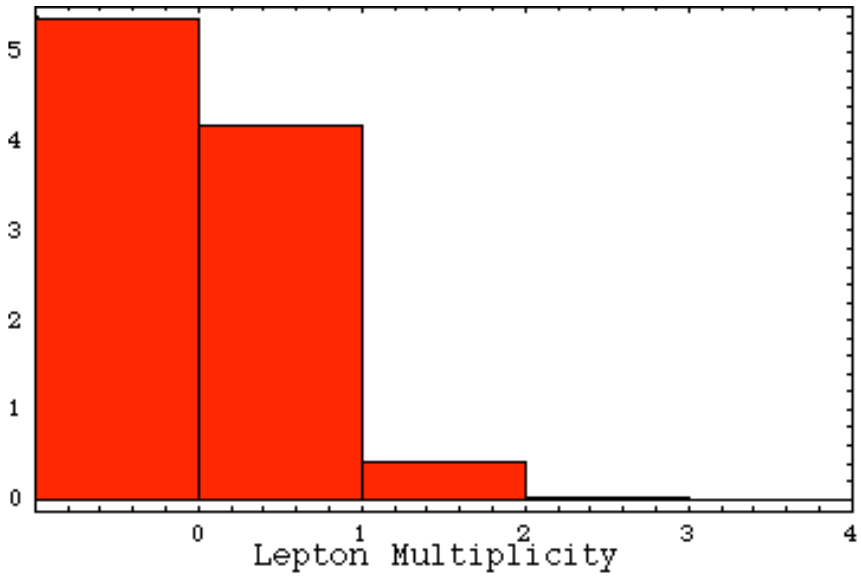


black box #1

black box #2

jet multiplicity

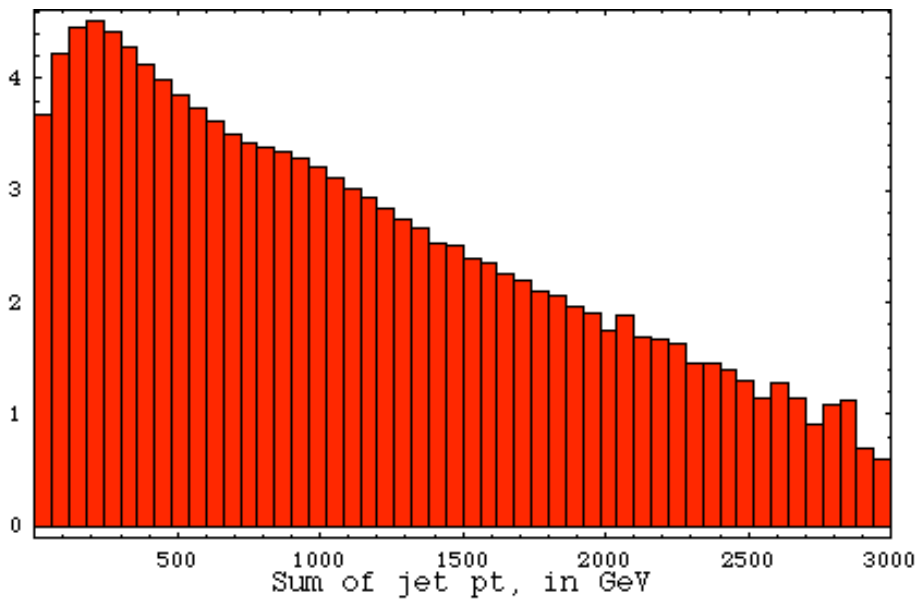




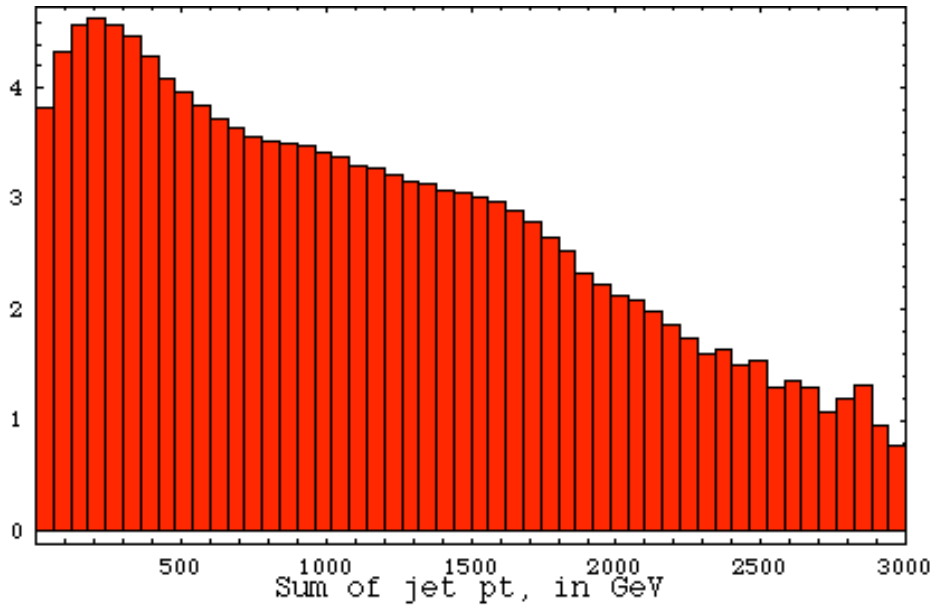
black box #1

black box #2

lepton multiplicity

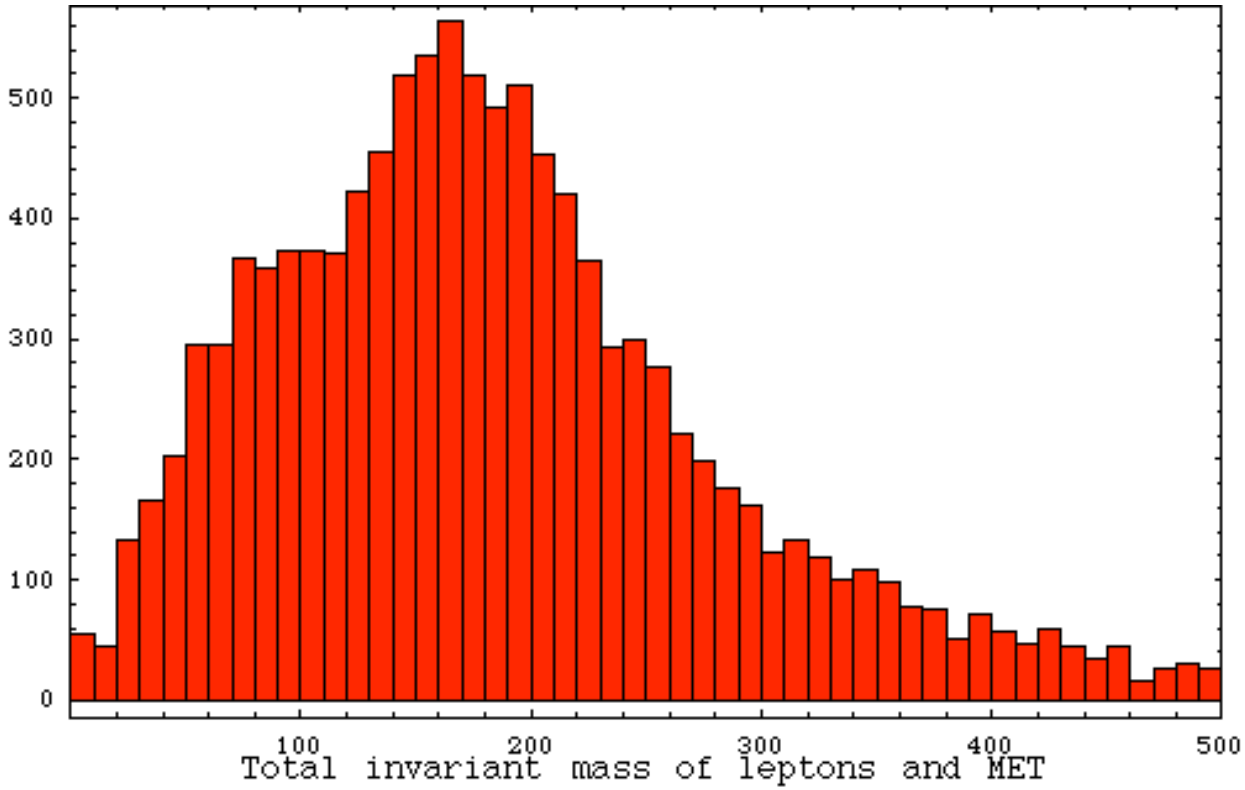


black box #1

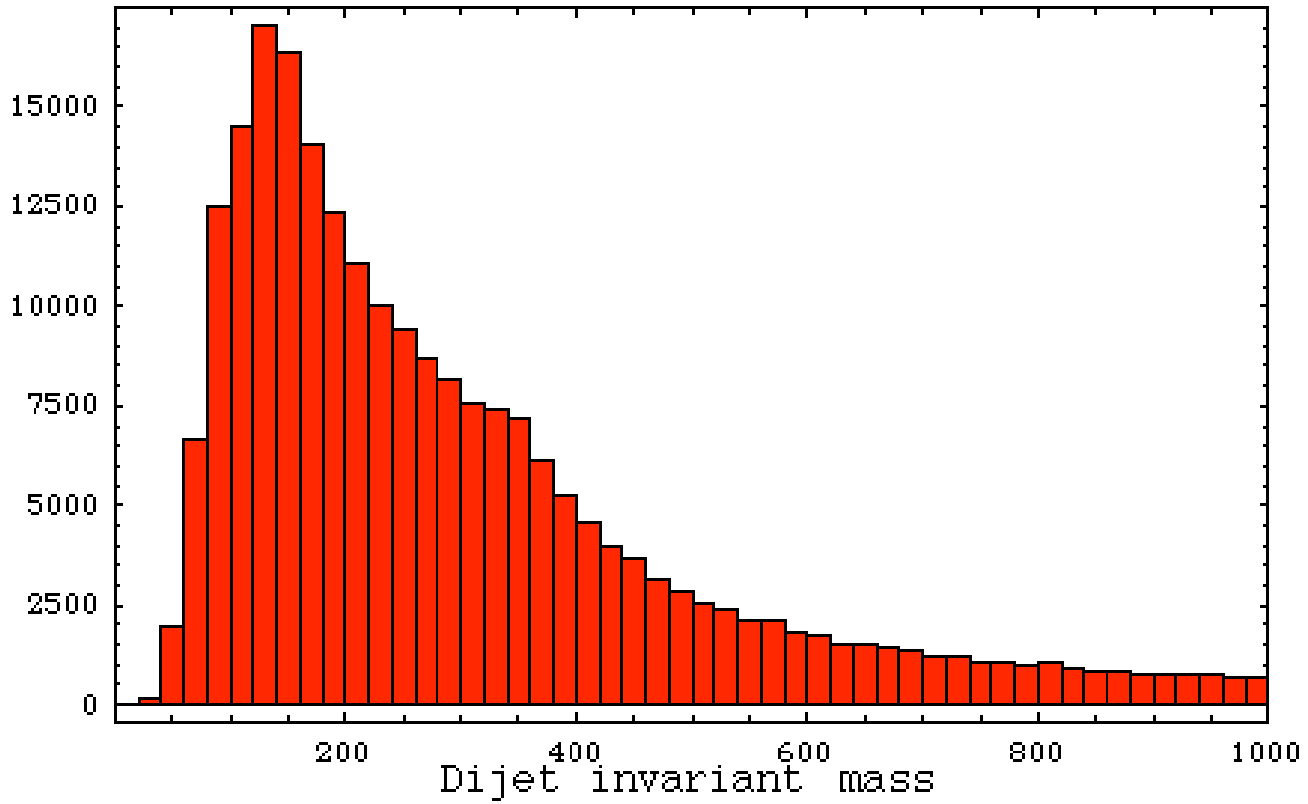


black box #2

sum of jet pt



for events with 2 or more leptons



invariant mass of the two leading jets
for events with 2 or more jets

so what is it?

Black Box #2

the future

“Never trust a theorist”

- S. Ting

Available on CMS information server

CMS NOTE 2008/018

The Compact Muon Solenoid Experiment

CMS Note

Mailing address: CMS CERN, CH-1211 GENEVA 23, Switzerland

6 December 2008

Evidence for squark and gluino production in pp collisions at $\sqrt{s}$ = 14 TeV

CMS collaboration

Abstract

Experimental evidence for squark and gluino production in pp collisions $\sqrt{s} = 14$ TeV with an integrated luminosity of 97 pb^{-1} at the Large Hadron Collider at CERN is reported. The CMS experiment has collected 320 events of events with several high $\mathrm{E_T}$ jets and large missing $\mathrm{E_T}$, and the measured effective mass, i.e. the scalar sum of the four highest $\mathrm{P_T}$ jets and the event $\not{E}_\mathrm{T}$, is consistent with squark and gluino masses of the order of 650 GeV/c^2. The probability that the measured yield is consistent with the background is 0.26%.

Submitted to *European Journal of Physics*

LHC theory initiative?