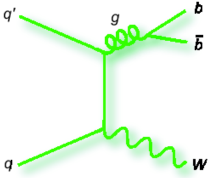
Preparing for Discovery

A Bard's-Eye View

Stephen Mrenna

Computing Division
Fermilab

LHC^{-1} Workshop



The New York Times

1315 Physicists Report Failure In Search for Supersymmetry

The negative result illustrates

EXPERIMENTAL EVIDENCE FOR MORE DIMENSIONS REPORTED

Gordon L. Kane
May 2011

The worldview of physicists working on unification theories has been changing rapidly recently. That change culminated in March, at the 46th annual Recontres de Moriond conference in Les Arcs, France, with the announcement of some startling data from CERN's Large Hadron Collider (LHC).

More than two hundred years ago, Charles Augustin Coulomb showed that the electrical force had the same form as the gravitational

ory. Because the work was well ahead of its time, and because of World War II, Klein's insight went largely unnoticed. See L. O'Raifeartaigh, *The Dawning of Gauge Theory*, Princeton University Press, 1977.)

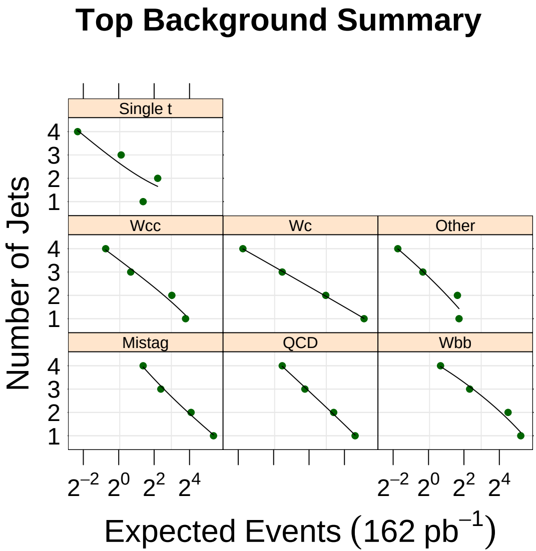
The fields of the higher-dimensional theory were the gravitational tensor field, the electromagnetic vector potential field and a scalar field. Of course, the theories of electricity and magnetism were unified without extra dimensions by Maxwell, and the

Shakespeare's Writing Method

- Develop a large vocabulary
- Play with words
- Invent new words and phrases
- Develop the common touch
- Read great literature
- Study the great orators, actors and the popular
- Live with passion
- Write, write, write!!!

First Steps

- LHC phenomenology begins with rediscovering the Standard Model
- The path starts at the Tevatron



Complicated

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

work on Mistags,Wbb,QCD

QCD,Mistags reducible

Method 2

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

- Common factors cancel

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

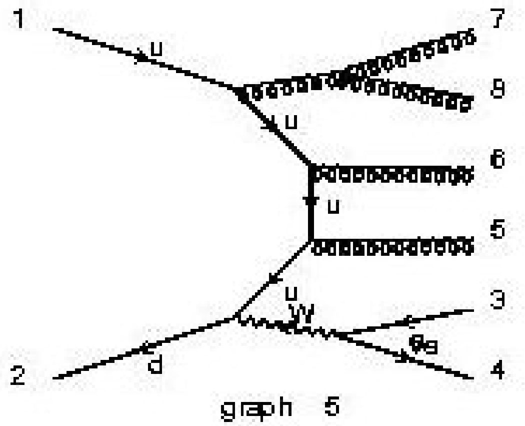
data$(W + b - jets) = R \times$data$(W + jets)$

Wcj/Wbb from Monte Carlo

- Several R's

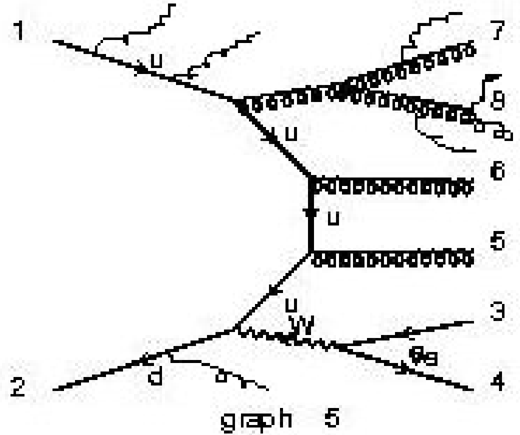
Toolkit

High Multiplicity Tree Graph

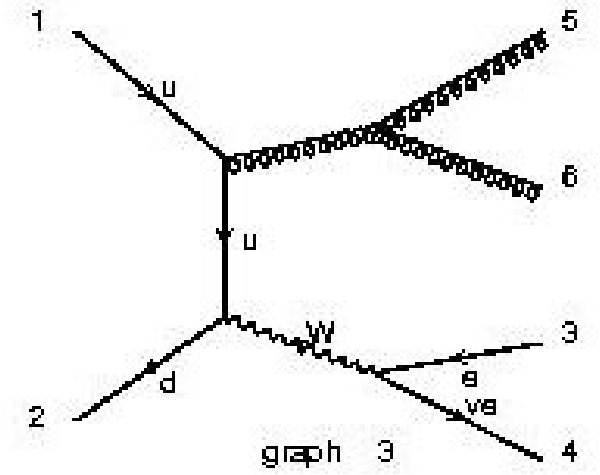


Toolkit

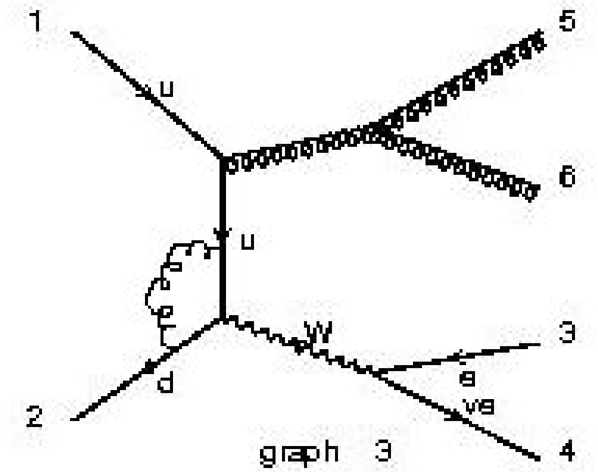
Tree Graph + Parton Shower



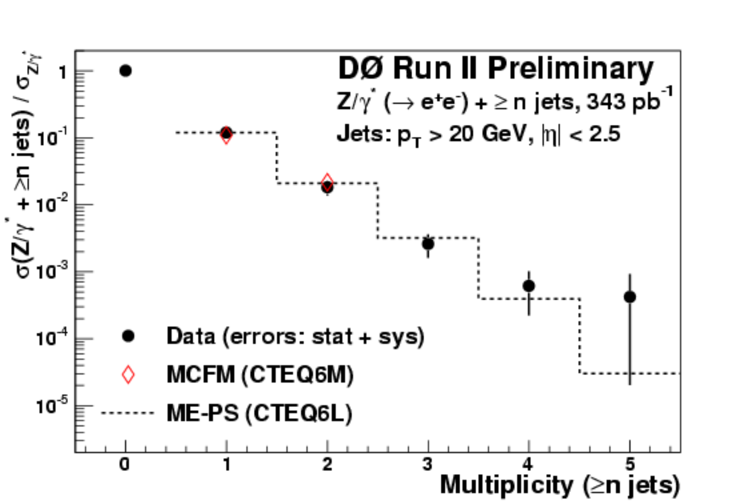
Lower Multiplicity Tree Graph



Lower Multiplicity NLO Graph



Cross check on Run2 data



Includes up to $Zjjj$, $j = q, g$

- To understand the data, look at the Vista of final states

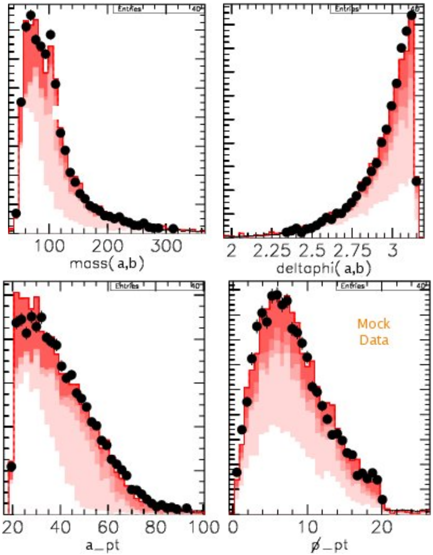
Final State	Chi2	data	bkg			
1b3j1pmiss_sumPt400+ [73]	9.0	451	374.5	+-	18	(pyth_jj_200 = 1
2b1e+2j [-]	8.0	15	6.5	+-	1.9	(ttop0z = 2.3 ,
2j_sumPt0-400 [161]	6.0	69704	67013.6	+-	1171.2	(pyth_jj_018 = 3
2j2mu+1pmiss [-]	-5.0	2	12.2	+-	3	(mad_mu+mu-jj =
1b2e+2j [-]	5.0	9	3.9	+-	1.5	(mrenna_e+e-jjj
1j1ph1pmiss [5]	4.0	2591	2470.1	+-	37.7	(pyth_pj_045 = 7
2j1mu+1ph [-]	4.0	11	11.2	+-	2.2	(mrenna_mu+mu-j
1e+1j1mu+ [-]	4.0	13	6.6	+-	2.1	(ztop5i = 3.4 ,
1e+2j1ph [-]	4.0	31	20.9	+-	2.7	(mad_aajj = 6.3
3j2mu+ [-]	4.0	34	23.2	+-	2.7	(mrenna_mu+mu-j
2b2j1pmiss_sumPt400+ [-]	-3.0	17	30.4	+-	4.2	(pyth_jj_200 = 1
1b2j_sumPt400+ [229]	3.0	4669	4518.6	+-	72.7	(pyth_jj_200 = 2
4j_sumPt0-400 [253]	-3.0	2611	2736.9	+-	42.3	(pyth_jj_040 = 1
2b1j1ph1pmiss [-]	3.0	6	2.7	+-	1.5	(pyth_jj_200 = 0
1b1j1mu+ [-]	3.0	67	53.8	+-	4.3	(pyth_jj_018 = 1
1j1ph [277]	3.0	31738	31149.8	+-	352.1	(pyth_pj_045 = 1
1e+1mu+ [-]	3.0	66	53.5	+-	3.2	(ztop5i = 38.8 ,
4j1mu+ [-]	3.0	73	61.3	+-	2.6	(pyth_jj_040 = 1
5j [269]	3.0	448	406	+-	14.5	(pyth_jj_040 = 1
1b5j [-]	3.0	8	8.9	+-	1.7	(pyth_jj_060 = 1
1b1j1pmiss_sumPt0-400 [-]	2.0	120	104	+-	7.2	(pyth_jj_040 = 3
2j1pmiss_sumPt0-400 [37]	2.0	2381	2281.2	+-	73.9	(pyth_jj_018 = 1

...

Final State	Chi2	data	bkg
1b2e+2j [-]	5.0	9	3.9 +- 1.5

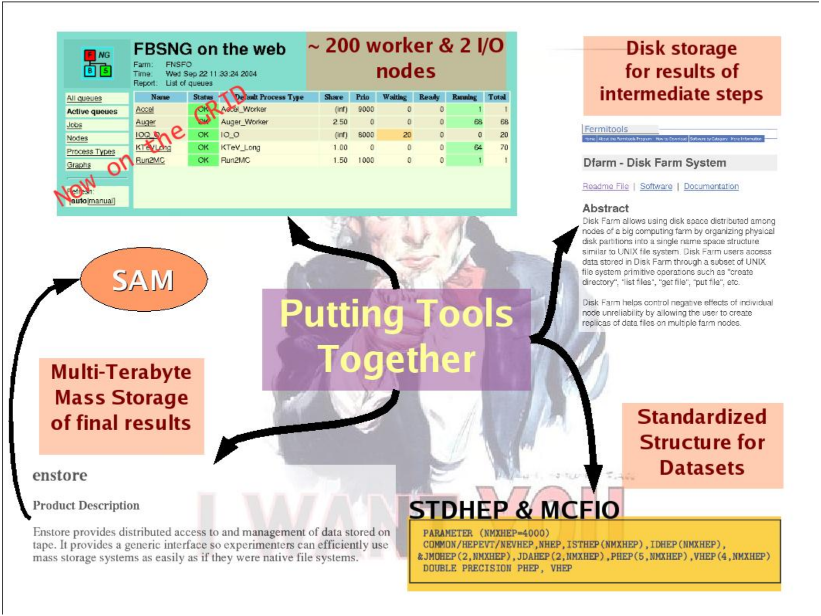
(mrenna_e+e-jjj = 1.9 , mad_e+e-jj = 0.5 , mrenna_e+e-jj = 0.4 , mad_e+e-b-b = 0.4 ,
ztopcz = 0.3 , pyth_jj_040 = 0.2 , mad_aajj = 0.1 , mrenna_e+vejjjj = 0.1 ,
hewk03 = 0.1 , wtop1z = 0.1)

Distributions



- Give a complete description of the Standard Model with the best tools

Patriot



FBSNG on the web
Farm: FNSFO
Time: Wed Sep 22 11:33:24 2004
Report: List of queues
~ 200 worker & 2 I/O nodes
All queues
Active queues
Jobs
Nodes
Process Types
Graphs
Refresh: auto|manual

Name	Status	Default Process Type	Share	Prio	Waiting	Ready	Running	Total
Accel	OK	Accel_Worker	(inf)	9000	0	0	1	1
Auger	OK	Auger_Worker	2.50	0	0	0	68	68
IOQ_O	OK	IO_O	(inf)	8000	20	0	0	20
KTeVLong	OK	KTeV_Long	1.00	0	0	0	64	70
Run2MC	OK	Run2MC	1.50	1000	0	0	1	1

Now on the GRID
Disk storage for results of intermediate steps
Fermitools
Dfarm - Disk Farm System
Readme File | Software | Documentation
Abstract
Disk Farm allows using disk space distributed among nodes of a big computing farm by organizing physical disk partitions into a single name space structure similar to UNIX file system. Disk Farm users access data stored in Disk Farm through a subset of UNIX file system primitive operations such as "create directory", "list files", "get file", "put file", etc.
Disk Farm helps control negative effects of individual node unreliability by allowing the user to create replicas of data files on multiple farm nodes.
SAM
Putting Tools Together
Multi-Terabyte Mass Storage of final results
enstore
Product Description
Enstore provides distributed access to and management of data stored on tape. It provides a generic interface so experimenters can efficiently use mass storage systems as easily as if they were native file systems.
I WANT YOU
Standardized Structure for Datasets
STDHEP & MCFIO
PARAMETER (NMXHEP=4000)
COMMON/HEPEVT/NEVHEP,NHEP,ISTHEP(NMXHEP),IDHEP(NMXHEP),
&JMOHEP(2,NMXHEP),JDAHEP(2,NMXHEP),PHEP(5,NMXHEP),VHEP(4,NMXHEP)
DOUBLE PRECISION PHEP, VHEP

Model-Independent and Quasi-Model-Independent Search for New Physics at CDF

Georgios Choudalakis,* Khaldoun Makhoul,† Markus Klute,‡ Conor Henderson,§ and Bruce Knuteson¶
MIT

Ray Culbertson**
FNAL

CDF Collaboration††

(Dated: February 1, 2006)

Data collected in Run II of the Fermilab Tevatron are searched for indications of new electroweak scale physics. Rather than focusing on particular new physics scenarios, CDF data are analyzed for discrepancies with the Standard Model prediction. A model-independent approach considers the gross features of the data, and is sensitive to new large cross section physics. A quasi-model-independent approach emphasizes the high-p_T tails, and is particularly sensitive to new electroweak scale physics. This global search for new physics in ≈ 600 pb^{-1} of $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV reveals

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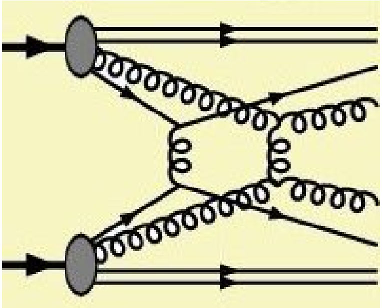
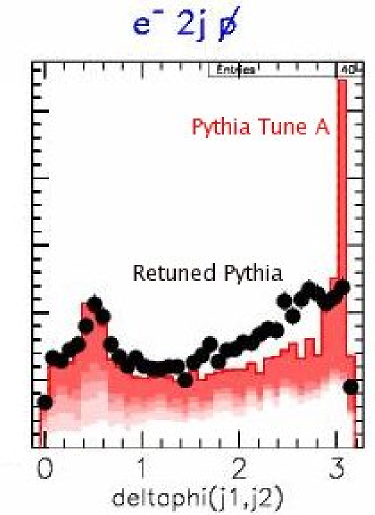
I. MOTIVATION

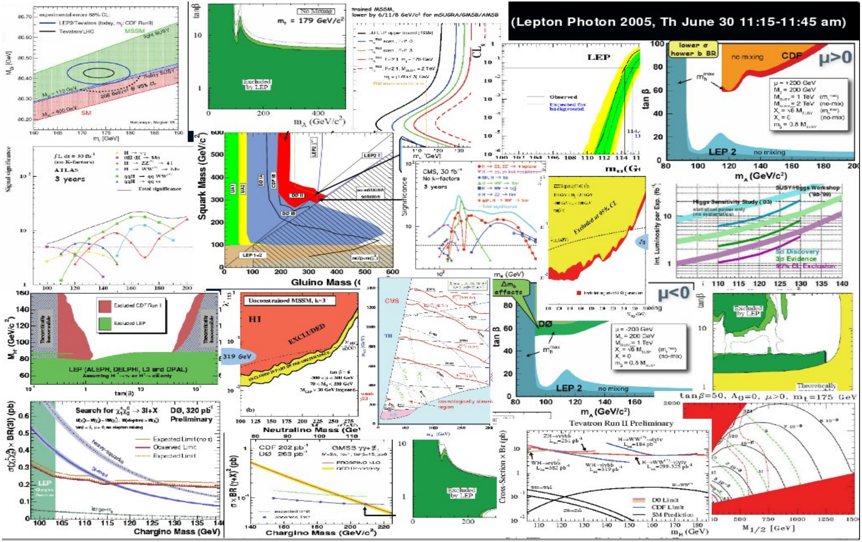
Checking Assumptions
Is description of Underlying Event universal?





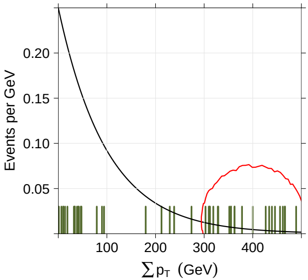
Midterm Summary

- The first New Physics to find is the Standard Model
- Need complete description of most important processes
- Understanding comes from looking at consistency of full dataset
- Then, how do we find New Physics?

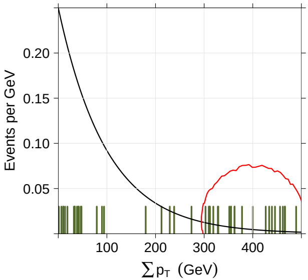

(Lepton Photon 2005, Th June 30 11:15-11:45 am)
MSSM
SM
No Mixing
Excluded by LEP
LEP
Observed
Expected for background
CDF
μ>0
no mixing
LEP 2
tan β
m_A (GeV/c²)
Squark Mass (GeV/c²)
Gluino Mass (
ATLAS
3 years
Total significance
CMS, 30 fb⁻¹
No k-factors
Significance
SUSY/Higgs Workshop
Higgs Sensitivity Study ('03)
5σ Discovery
3σ Evidence
95% CL Exclusion
Int. Luminosity per Exp. (fb⁻¹)
Excluded CDF Run I
Excluded LEP
LEP (ALEPH, DELPHI, L3 and OPAL)
Unconstrained MSSM, k=3
H1
EXCLUDED
319 GeV
Neutralino Mass (Ge
CMS
Δm_b effects
DØ
μ<0
Theoretically inaccessible
Search for $\tilde{\chi}_1^\pm \tilde{\chi}_2^0 \to 3l+X$
DØ, 320 pb⁻¹
Preliminary
Expected Limit
Observed Limit
Chargino Mass (GeV)
CDF 202 pb⁻¹
DØ 263 pb⁻¹
Chargino Mass (GeV/c²)
Tevatron Run II Preliminary
D0 Limit
CDF Limit
SM Prediction
Cross-Section × Br (pb)
m_H (GeV)
$M_{1/2}$ [GeV]

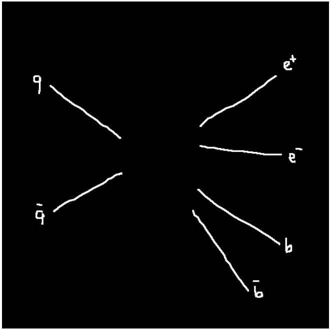
NOT YET THOUGHT OF
NOT YET THOUGHT OF
NOT THOUGHT
composite Higgs
hypercolor
supercolor
TC-TC
extended TC
5th gen
4th gen
vector-like fermions
fractionally charged
heavy Majorana ν
sterile ν
milli-charged
shadow matter
mirror symmetry
S, T, U
Type I
Type II
several 2HDM
spontaneous CP
superweak
milli-weak
Weinberg's 3HD
Majoron
axion
familon
NGB
quintessence
composite W, Z
NMSSM
MSSM
extra dim
string

$e^+e^- b\bar{b}$ Final State

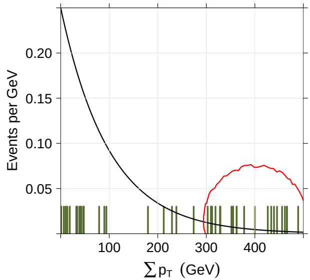


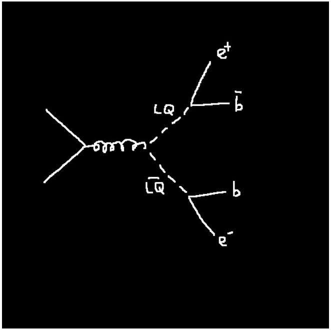
$e^+e^-b\bar{b}$ Final State



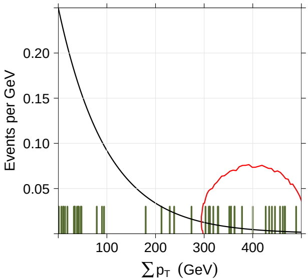


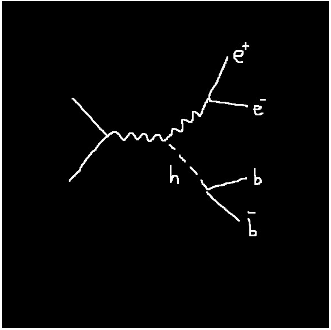
$e^+e^-b\bar{b}$ Final State



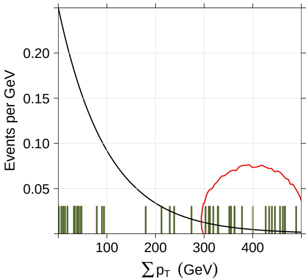


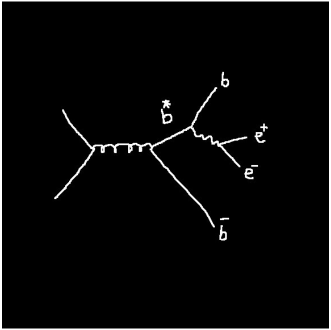
$e^+e^-b\bar{b}$ Final State





$e^+e^-b\bar{b}$ Final State





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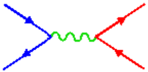
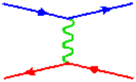
http://madgraph.hep.uiuc.edu/ Search

Home Bookmarks



MadGraph HomePage

by Fabio Maltoni and Tim Stelzer



Generate Process | Calculated Cross Sections | Source Codes | FAQ | Developments | Other approaches | Citations

Generate Process Code On-Line

Quarks: d u s c b t d~ u~ s~ c~ b~ t~

Leptons: e- mu- ta- ve vm vt e+ mu+ ta+ ve~ vm~ vt~

Bosons: A Z W+ W- h g

Special: P j (sums over d u s c d~ u~ s~ c~ g)

Process: PP > W+ > e+ ve jjjj Submit EXAMPLES

Max QCD Order: 4

Max QED Order: 2

To improve our web services we now request that you register. Registration is quick and free. You may register for a password by clicking here

Generic Particles and Vertices

$$\mathcal{L}_{\mathtt{FFV}} = \bar{f}'\gamma^\mu \left(\mathtt{G}(1)\frac{1-\gamma_5}{2} + \mathtt{G}(2)\frac{1+\gamma_5}{2} \right) f V_\mu^*$$

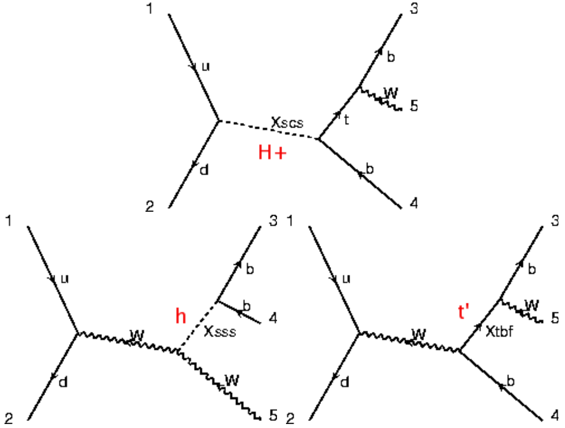
$$\mathcal{L}_{\mathtt{FFS}} = \bar{f}' \left(\mathtt{GC}(1)\frac{1-\gamma_5}{2} + \mathtt{GC}(2)\frac{1+\gamma_5}{2} \right) f S^*$$

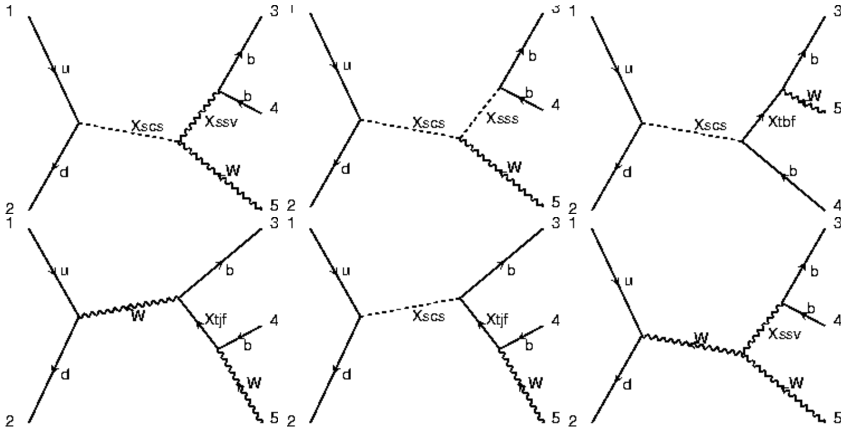
$$\begin{aligned} \mathcal{L}_{\mathtt{VVV}} = -i\mathtt{G} \; \{ & (\partial_\mu V_{1\nu}^*)(V_2^{\mu *} V_3^{\nu *} - V_2^{\nu *} V_3^{\mu *}) \\ & +(\partial_\mu V_{2\nu}^*)(V_3^{\mu *} V_1^{\nu *} - V_3^{\nu *} V_1^{\mu *}) \\ & +(\partial_\mu V_{3\nu}^*)(V_1^{\mu *} V_2^{\nu *} - V_1^{\nu *} V_2^{\mu *}) \} \end{aligned}$$

$$\mathcal{L}_{\mathtt{VVS}} = \mathtt{G} V_1^{\mu *} V_{2\mu}^* S^*$$

$$\mathcal{L}_{\mathtt{SSS}} = \mathtt{G}\, S_1^* S_2^* S_3^* \qquad \mathcal{L}_{\mathtt{VSS}} = i\mathtt{G} V_\mu^* S_2^* \overset{\leftrightarrow}{\partial}{}^\mu S_1^*$$

Simpler Problem
$Wb\bar{b}$ Anomaly

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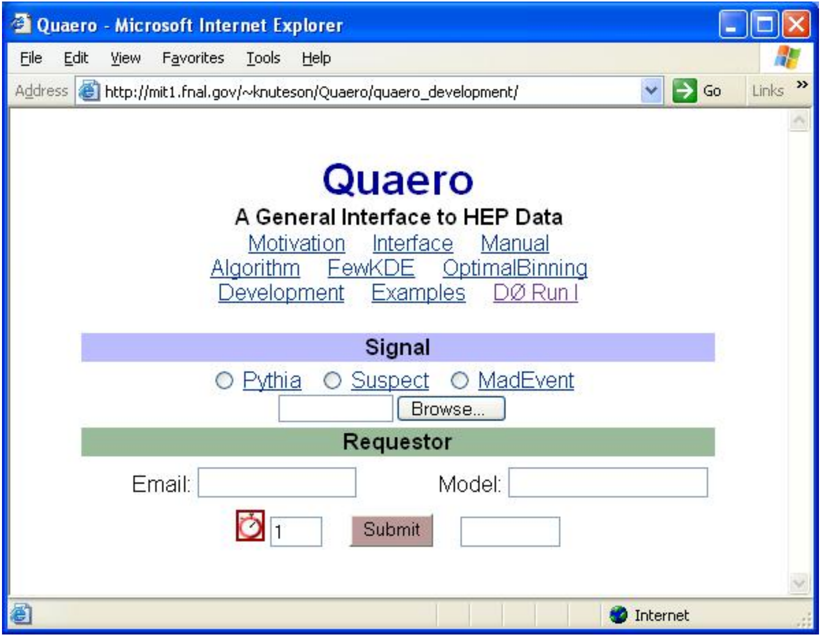
Quaero - Microsoft Internet Explorer
File Edit View Favorites Tools Help
Address http://mit1.fnal.gov/~knuteson/Quaero/quaero_development/
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Quaero
A General Interface to HEP Data
Motivation Interface Manual
Algorithm FewKDE OptimalBinning
Development Examples DØ Run I
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Pythia Suspect MadEvent
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Model:
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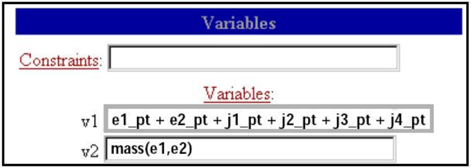
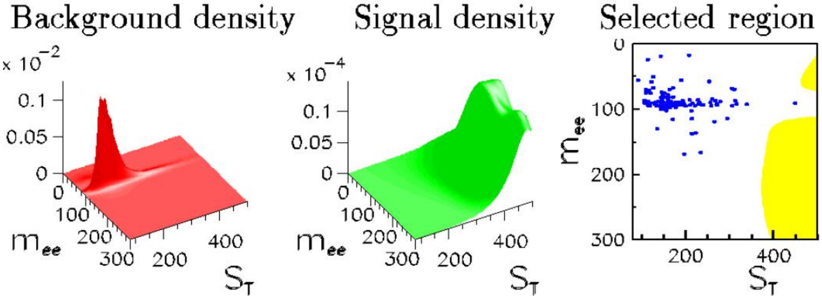
Internet

Leptoquarks $\rightarrow$ ee 2j



ε_{sig}	33%
$\hat{b}$	0.3 ± 0.1
N_{obs}	0
$\sigma^{95\%} \times \mathcal{B}$	0.07 pb



DESY 04–140 ISSN 0918–9833

A general search for new phenomena in ep scattering at HERA

H1 Collaboration

Abstract

A model-independent search for deviations from the Standard Model prediction is performed in e^+p and e^-p collisions at HERA using H1 data corresponding to an integrated luminosity of 117 pb^{-1}. For the first time all event topologies involving isolated electrons, photons, muons, neutrinos and jets with high transverse momenta are investigated in a single analysis. Events are assigned to exclusive classes according to their final state. A statistical algorithm is developed to search for deviations from the Standard Model in the distributions of the scalar sum of transverse momenta or invariant mass of final state particles and to quantify their significance. A good agreement with the Standard Model prediction is observed in most of the event classes. The most significant deviation is found for a topology containing an isolated muon, missing transverse momentum and a jet, consistent with a previously reported observation.

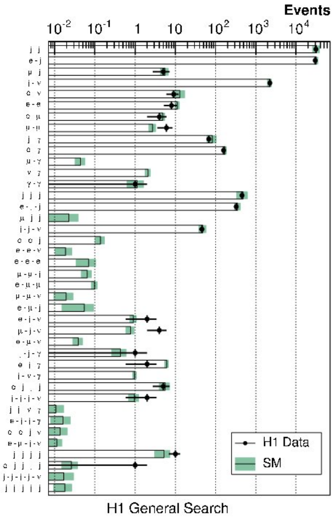
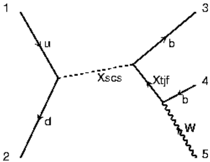
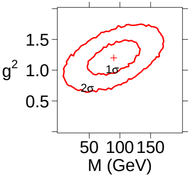
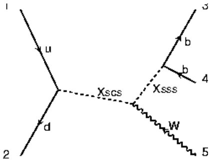
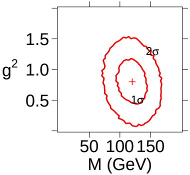
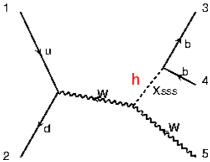
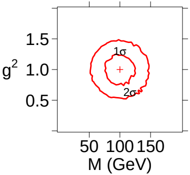


Figure 1: The data and the SM expectation for all event classes with a SM expectation greater than 0.01 events. The analysed data sample corresponds to an integrated luminosity of 117 pb^{-1}. The error bands on the predictions include model uncertainties and experimental systematic errors added in quadrature.

- ALEPH and L3 analyses underway

Quaero: DØ, hep-ex/0106039

Process	$\epsilon_{\rm sig}$	$\hat{b}$	$N_{\rm data}$	$\sigma^{95\%} \times \mathcal{B}$
$WW \to e\mu\not{E}_T$	0.14	19.0 ± 4.0	23	1.1 pb
$ZZ \to ee\,2j$	0.12	19.7 ± 4.1	19	0.8 pb
$t\bar{t} \to e\not{E}_T\,4j$	0.13	3.1 ± 0.9	8	0.8 pb
$t\bar{t} \to e\mu\not{E}_T\,2j$	0.14	0.6 ± 0.2	2	0.4 pb
$h_{175} \to WW \to e\not{E}_T\,2j$	0.02	29.6 ± 6.5	32	11.0 pb
$h_{200} \to WW \to e\not{E}_T\,2j$	0.07	66.0 ± 13.8	69	4.4 pb
$h_{225} \to WW \to e\not{E}_T\,2j$	0.06	43.1 ± 9.2	44	3.6 pb
$h_{200} \to ZZ \to ee\,2j$	0.15	17.9 ± 3.7	15	0.6 pb
$h_{225} \to ZZ \to ee\,2j$	0.15	18.8 ± 3.8	12	0.4 pb
$h_{250} \to ZZ \to ee\,2j$	0.17	18.1 ± 3.7	18	0.6 pb
$W'_{200} \to WZ \to e\not{E}_T\,2j$	0.05	27.7 ± 6.3	29	3.4 pb
$W'_{350} \to WZ \to e\not{E}_T\,2j$	0.23	22.7 ± 5.2	27	0.7 pb
$W'_{500} \to WZ \to e\not{E}_T\,2j$	0.26	2.1 ± 0.8	2	0.2 pb
$Z'_{350} \to t\bar{t} \to e\not{E}_T\,4j$	0.11	18.7 ± 4.0	20	1.1 pb
$Z'_{450} \to t\bar{t} \to e\not{E}_T\,4j$	0.14	18.7 ± 4.0	20	0.9 pb
$Z'_{550} \to t\bar{t} \to e\not{E}_T\,4j$	0.14	3.8 ± 1.0	2	0.3 pb
$Wh_{115} \to e\not{E}_T\,2j$	0.08	37.3 ± 8.2	32	2.0 pb
$Zh_{115} \to ee\,2j$	0.20	19.5 ± 4.1	25	0.8 pb
$LQ_{225}\overline{LQ}_{225} \to ee\,2j$	0.33	0.3 ± 0.1	0	0.07 pb

Story	Fit	$\log_{10} \frac{p(s+b)}{p(b)}$
		7
		5
		3

BARD: **Interpreting New Frontier Energy Collider Physics**

Bruce Knuteson*
MIT

Stephen Mrenna†
FNAL

No systematic procedure currently exists for inferring the underlying physics from discrepancies observed in high energy collider data. We present BARD, an algorithm designed to facilitate the process of model construction at the energy frontier. Top-down scans of model parameter space are discarded in favor of bottom-up diagrammatic explanations of particular discrepancies, an explanation space that can be exhaustively searched and conveniently tested with existing analysis tools.

Calculation

p 4-momentum of final partons
q 4-momentum of initial partons
x measured event variables

For each event, calculate differential cross-section:

$$P(\mathbf{x}|M_t) = \frac{1}{N}\int d\Phi_6 |\mathcal{M}_{t\bar{t}}(p; M_t)|^2 \prod_{jets} f(p_i,\mathbf{x})\, f_{PDF}(q_1) f_{PDF}(q_2)$$

Phase-space Integral

Matrix Element

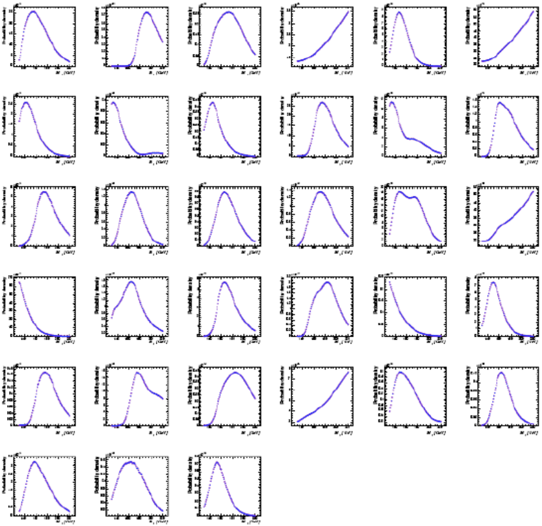
Transfer Functions

Only partial information available

Fix measured quantities

Integrate over unmeasured parton quantities
consistent with tt production and measured event.

Data



33 candidates

signal and bg probabilities

Slope and error corrections not applied

Range is 130-220 GeV/c^2

August 26, 2005

sss	sss	s	d	npm(1)	npW	s	Xsss	31
ssf	ssf~	f	s	npm(2)	npW	s	Xssf	32
szs	szs	s	d	npm(3)	npW	s	Xszs	33
szf	szf~	f	s	npm(4)	npW	s	Xszf	34
sas	sas~	s	d	npm(5)	npW	s	Xsas	35
saf	saf~	f	s	npm(6)	npW	s	Xsaf	36
sbs	sbs~	s	d	npm(7)	npW	s	Xsbs	37
sbf	sbf~	f	s	npm(8)	npW	s	Xsbf	38
scs	scs~	s	d	npm(9)	npW	s	Xscs	39
scf	scf~	f	s	npm(10)	npW	s	Xscf	40
...								
oss	oss	s	d	npm(51)	npW	o	Xoss	81
osf	osf~	f	s	npm(52)	npW	o	Xosf	82
ozs	ozs	s	d	npm(53)	npW	o	Xozs	83
ozf	ozf~	f	s	npm(54)	npW	o	Xozf	84
ssv	ssv	v	w	npm(55)	npW	s	Xssv	85
osv	osv	v	w	npm(56)	npW	s	Xosv	86
scv	scv~	v	w	npm(57)	npW	s	Xscv	87
...								

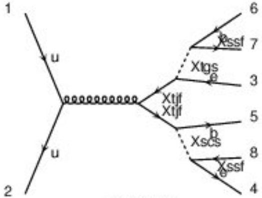
New Interactions

```
a    sas   sas~   np_coupl_c(453)   QNP
a    sbs   sbs~   np_coupl_c(455)   QNP
a    scs   scs~   np_coupl_c(457)   QNP
...
b    u     scs~   np_coupl_cLR(261)   QNP
b    u     scv~   np_coupl_rLR(41)   QNP
d    b     oss    np_coupl_cLR(408)   QNP
d    b     osv    np_coupl_rLR(27)   QNP
d    b     ozs    np_coupl_cLR(418)   QNP
d    b     sss    np_coupl_cLR(183)   QNP
...
z    tss   tzs~   np_coupl_c(466)   QNP
z    tzs   tzs~   np_coupl_c(474)   QNP
z    w+    scs~   np_coupl_c(438)   QNP
...
```

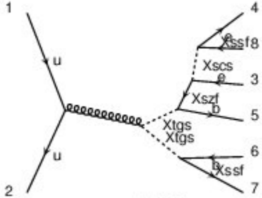
Pruning Rules

1. NP must couple to the initial state or an annihilation particle
2. SM particles must couple to either the initial or final state
3. No more than n NP particles can appear in a given diagram
4. NP particles can appear twice only in separate chains
5. ...

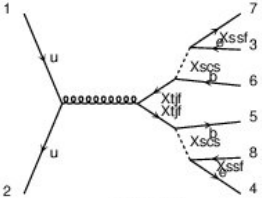
Pmiss Final States



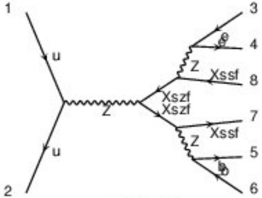
graph 13



graph 20



graph 37



graph 90

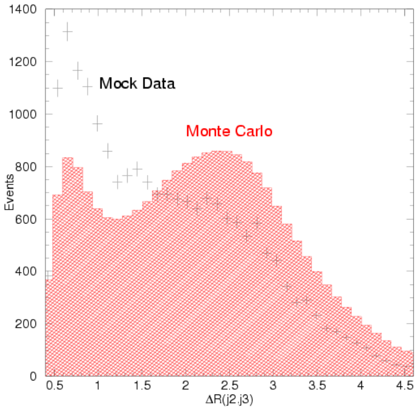
Table 1. Quantum numbers of scalar and vector leptoquarks with $SU(3) \times SU(2) \times U(1)$ invariant couplings to quark-lepton pairs ($Y = Q_{em} - T_3$).

	Spin	F = 3B + L	$SU(3)_C$	$SU(2)_W$	$U(1)_Y$
S_1	0	-2	3*	1	$\frac{1}{3}$
$\tilde{S}_1$	0	-2	3*	1	$\frac{4}{3}$
$\vec{S}_3$	0	-2	3*	3	$\frac{1}{3}$
V_2	1	-2	3*	2	$\frac{5}{6}$
$\tilde{V}_2$	1	-2	3*	2	$-\frac{1}{6}$
R_2	0	0	3	2	$\frac{7}{6}$
$\tilde{R}_2$	0	0	3	2	$\frac{1}{6}$
U_1	1	0	3	1	$\frac{2}{3}$
$\tilde{U}_1$	1	0	3	1	$\frac{5}{3}$
$\vec{U}_3$	1	0	3	3	$\frac{2}{3}$

Table 2. Couplings of scalar and vector leptoquarks to quark-lepton pairs. The subscripts L,R of the couplings refer to the lepton chirality.

	F = -2, scalars			F = -2, vectors	
channel	S_1	$\tilde{S}_1$	$\vec{S}_3$	V_2	$\tilde{V}_2$
$e^-_{L,R}$ u	$g_{1L,R}$	-	$-g_{3L}$	g_{2R}	$\tilde{g}_{2L}$
ν_L d	$-g_{1L}$	-	$-g_{3L}$	g_{2L}	-
$e^-_{L,R}$ d	-	$\tilde{g}_{1R}$	$-\sqrt{2}\, g_{3L}$	$g_{2L,R}$	-
ν_L u	-	-	$\sqrt{2}\, g_{3L}$	-	$\tilde{g}_{2L}$
	F = 0, vectors			F = 0, scalars	
channel	U_1	$\tilde{U}_1$	$\vec{U}_3$	R_2	$\tilde{R}_2$
$e^-_{L,R}$ $\bar{d}$ $\bar{b}$	$h_{1L,R}$	-	$-h_{3L}$	$-h_{2R}$	$\tilde{h}_{2L}$
ν_L $\bar{u}$ $\bar{t}$	h_{1L}	-	h_{3L}	h_{2L}	-
$e^-_{L,R}$ $\bar{u}$ $\bar{t}$	-	$\tilde{h}_{1R}$	$\sqrt{2}\, h_{3L}$	$h_{2L,R}$	-
ν_L $\bar{d}$ $\bar{b}$	-	-	$\sqrt{2}\, h_{3L}$	-	$\tilde{h}_{2L}$

Büchmuller *et al.*


Mock Data
Monte Carlo
Events
ΔR(j2,j3)
1400
1200
1000
800
600
400
200
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5

The Bard at the LHC

- LHC phenomenology begins with understanding the Standard Model
- A look at the full Vista of final states at once is necessary to disentangle the components
- Discrepancies can and will arise in specific final states
- Bard can write a series of ranked stories to describe each
  - bottom-up
- Can test this on Run2 data

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- It works

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- Bard can write a series of ranked stories to describe each
  - bottom-up
- Can test this on Run2 data
- It works
- No, we haven't found anything $\cdots$ yet

Algorithm Signal events

1) The signal Monte Carlo is processed

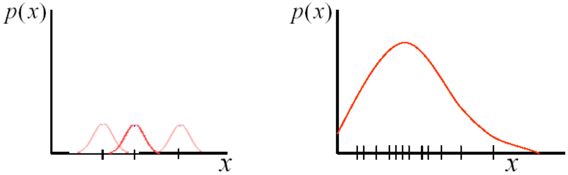
- (events are generated using Pythia, if requested)
- events are smeared with a fast detector simulation
- selection criteria are applied for desired final state
- particle identification efficiencies are considered

This gives

- total number of expected signal events in final state
- Monte Carlo signal events as they would look in the detector

2) An optimal region is chosen in the variables provided

a) Estimate signal and background densities using kernels



1) place "bumps of probability" around each Monte Carlo point

2) sum these bumps into a continuous distribution

$$p(x) = \sum_{i=1}^{N} \mathrm{gauss}(x - x_i)$$

The multivariate generalization is immediate

b) Define a *discriminant*

$$D(x) = \frac{p(x \mid s)}{p(x \mid s) + p(x \mid b)}$$

and choose a cut on D(x) that minimizes

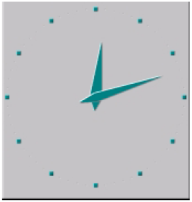
the 95% CL cross section limit you would expect to set assuming the data contains no signal.

We call 1/this quantity the "sensitivity"

Note that so far we have made no use of the data

3) Comparing number of observed events in the data to expected bkg, set 95% CL cross section limit on signal

4) Result is returned by email



Total elapsed time ≈ 1 hour

From: quaero@fnal.gov
Subject: Quaero Request #29

$W_R \to t\bar{b} \to e\not{E}_T\ 2j$

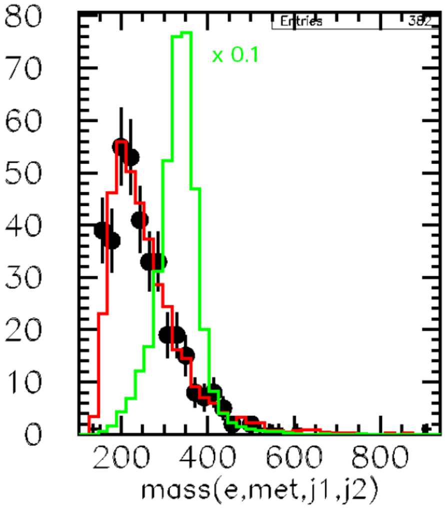
Result

Pythia cross section x branching ratio = 1.68 pb.

Upper limits on the cross section to this process at confidence levels of 50%, 90%, and 95% are found to be 0.8 pb, 1.8 pb, and 2.1 pb, respectively. Maximal sensitivity (0.73 pb^{-1}) is achieved in a region of variable space with 17.6 signal events expected, 32.7 +- 7.1 background events expected, and 36 events observed in the data.

Plots

Plots of the variables that you used are available for viewing at http://quaero.fnal.gov/quaero/requests/plots/29.ps. The red curve is the expected background; the green curve is your signal multiplied by a factor of 10; the black dots are D0 data.


Entries
382
x 0.1
80
70
60
50
40
30
20
10
0
200
400
600
800
mass(e,met,j1,j2)

Examples #11

Leptoquarks → ee 2j

Variables

Constraints:

Variables:

v1 e1_pt + e2_pt + j1_pt + j2_pt + j3_pt + j4_pt

v2 mass(e1,e2)

ε_{sig}	33%
$\hat{b}$	0.3 ± 0.1
N_{obs}	0
$\sigma^{95\%} \times \mathcal{B}$	0.07 pb

Background density Signal density Selected region