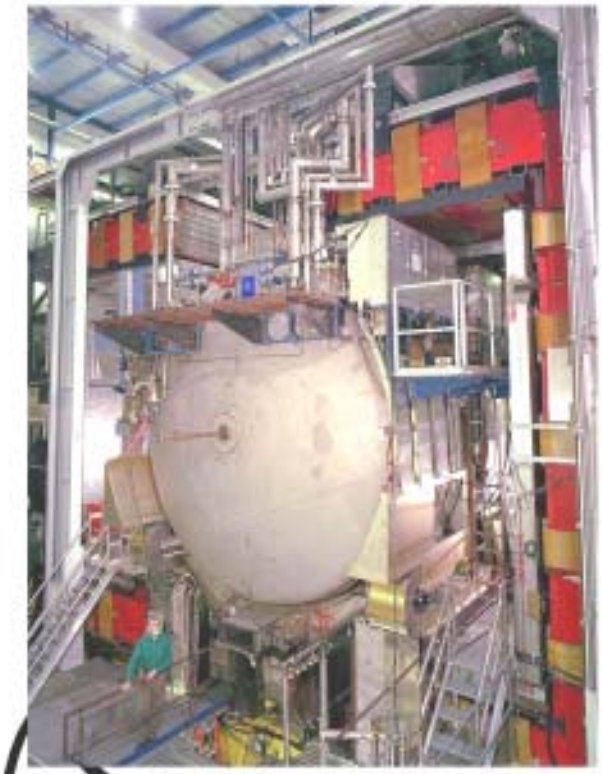
Quaero



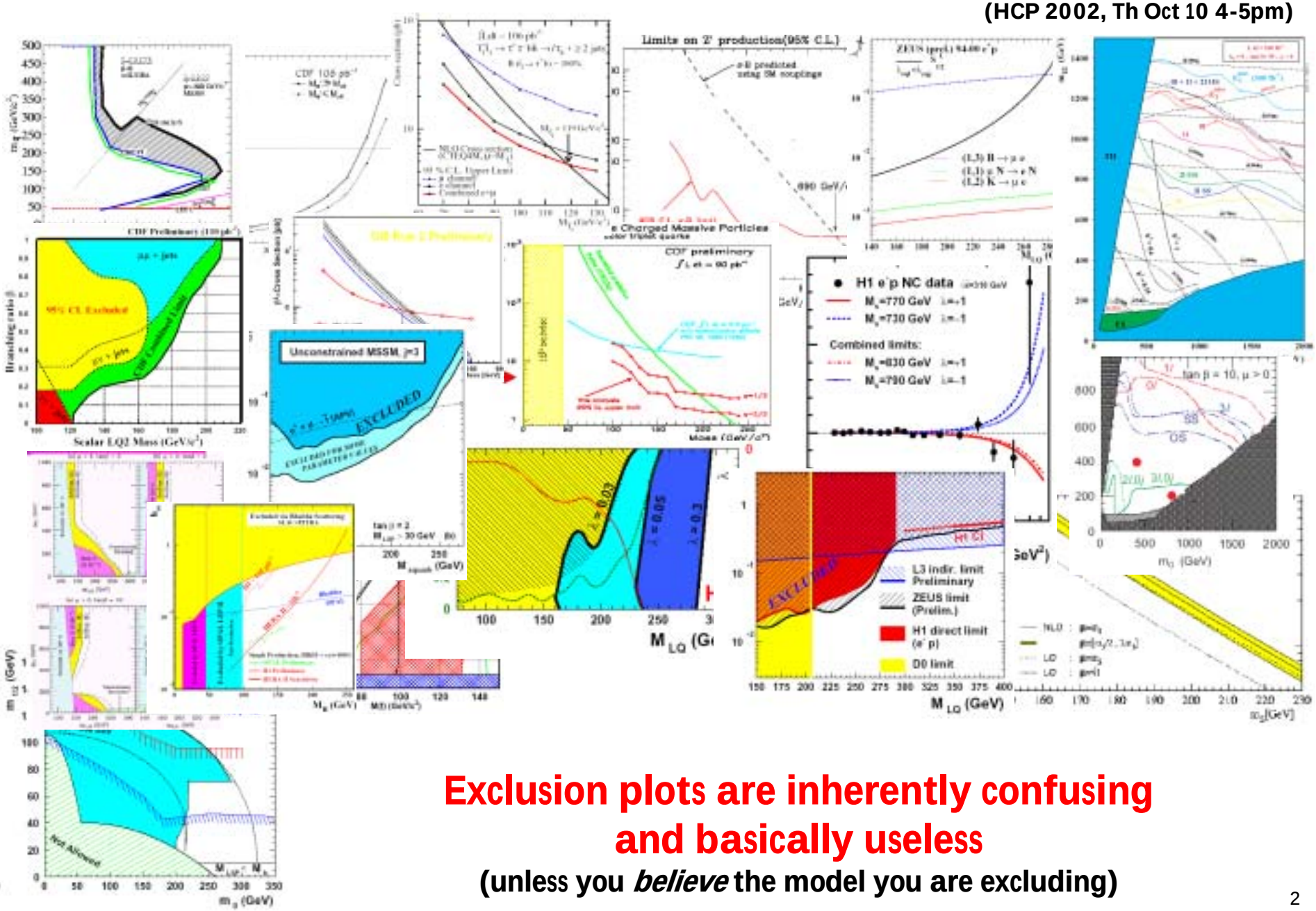
Motivation
Algorithm
DØ
LEP

Bruce Knuteson
University of Chicago

CHEP 2003

An hour's worth of a typical conference

(HCP 2002, Th Oct 10 4-5pm)



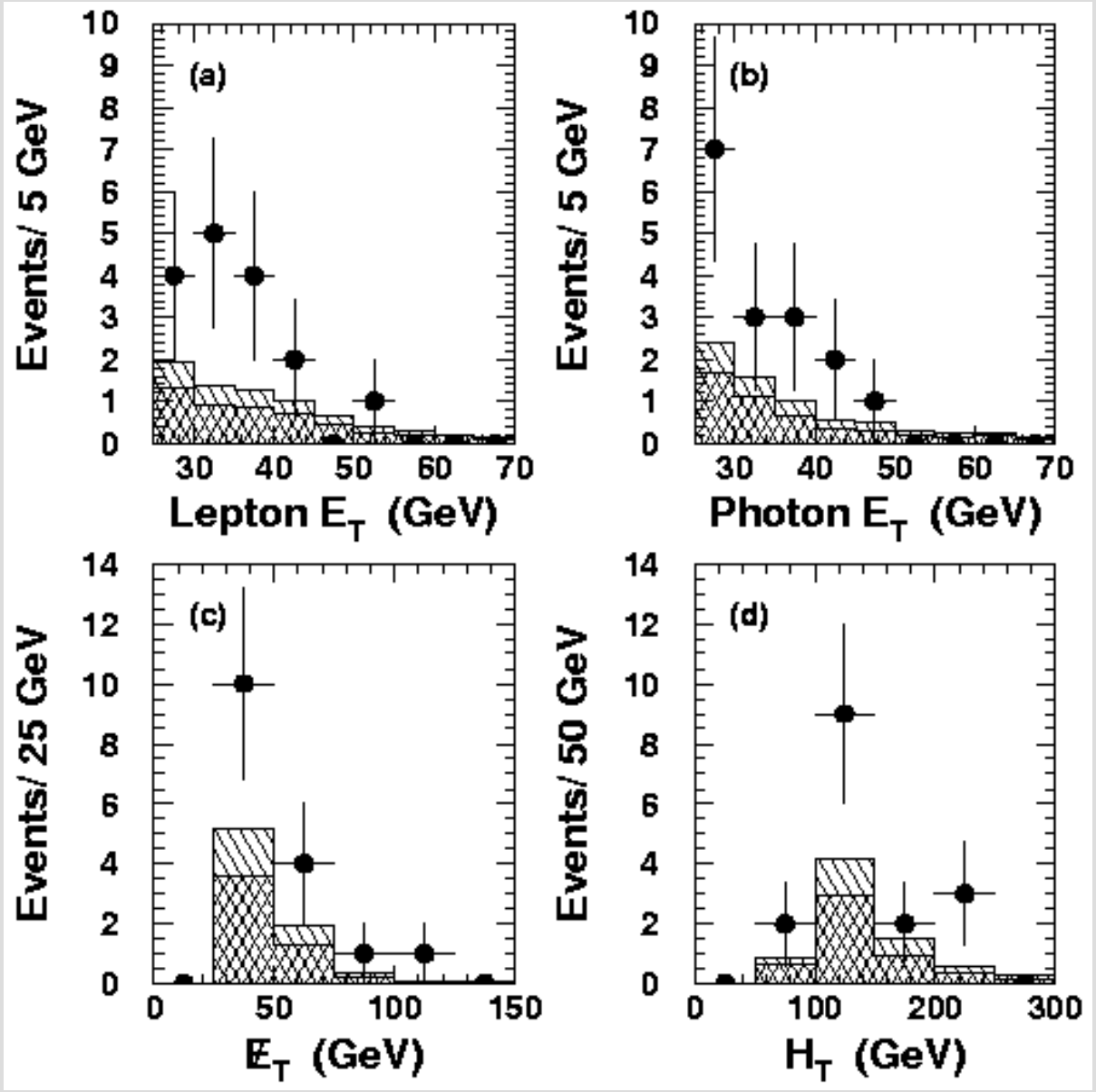
Exclusion plots are inherently confusing and basically useless

(unless you *believe* the model you are excluding)

How should we publish our results?

Histograms of data are clearly better

But the data are inherently *multidimensional*, and histograms are inherently one (perhaps two) dimensional



January 1999

Su	Mo	Tu	We	Th	Fr	Sa
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30
31						

February 1999

Su	Mo	Tu	We	Th	Fr	Sa
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28						

March 1999

Su	Mo	Tu	We	Th	Fr	Sa
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31			

April 1999

Su	Mo	Tu	We	Th	Fr	Sa
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
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May 1999

Su	Mo	Tu	We	Th	Fr	Sa
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16	17	18	19	20	21	22
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30	31					

June 1999

Su	Mo	Tu	We	Th	Fr	Sa
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6	7	8	9	10	11	12
13	14	15	16	17	18	19
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27	28	29	30			

July 1999

Su	Mo	Tu	We	Th	Fr	Sa
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
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August 1999

Su	Mo	Tu	We	Th	Fr	Sa
1	2	3	4	5	6	7
8	9	10	11	12	13	14
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September 1999

Su	Mo	Tu	We	Th	Fr	Sa
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
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26	27	28	29	30		

October 1999

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3	4	5	6	7	8	9
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24	25	26	27	28	29	30
31						

November 1999

Su	Mo	Tu	We	Th	Fr	Sa
	1	2	3	4	5	6
7	8	9	10	11	12	13
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21	22	23	24	25	26	27
28	29	30				

December 1999

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			1	2	3	4
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12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

January 2000

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16	17	18	19	20	21	22
23	24	25	26	27	28	29
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February 2000

Su	Mo	Tu	We	Th	Fr	Sa
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20	21	22	23	24	25	26
27	28	29				

March 2000

Su	Mo	Tu	We	Th	Fr	Sa
			1	2	3	4
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April 2000

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21	22	23	24	25	26	27
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June 2000

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July 2000

Su	Mo	Tu	We	Th	Fr	Sa
						1
2	3	4	5	6	7	8
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16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31					

August 2000

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September 2000

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October 2000

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November 2000

Su	Mo	Tu	We	Th	Fr	Sa
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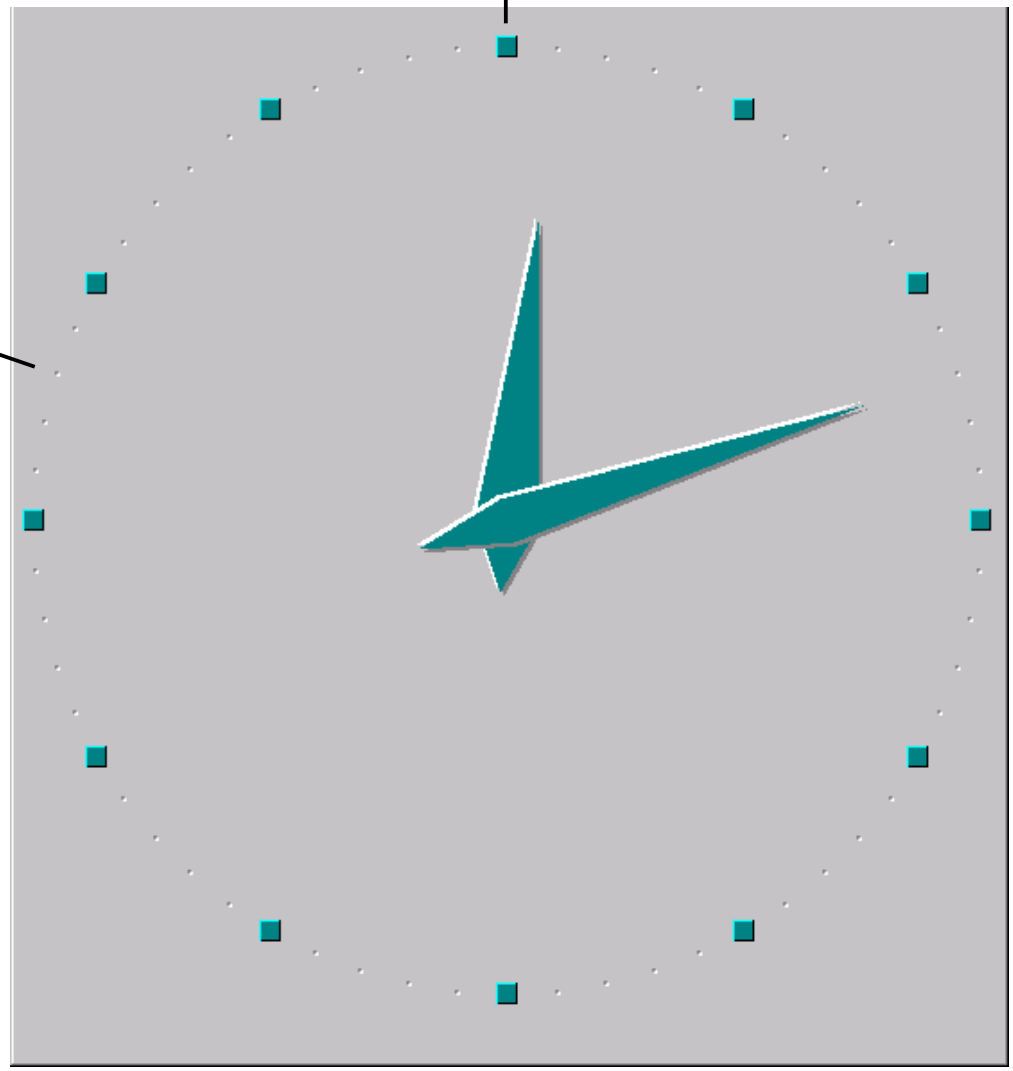
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30		

December 2000

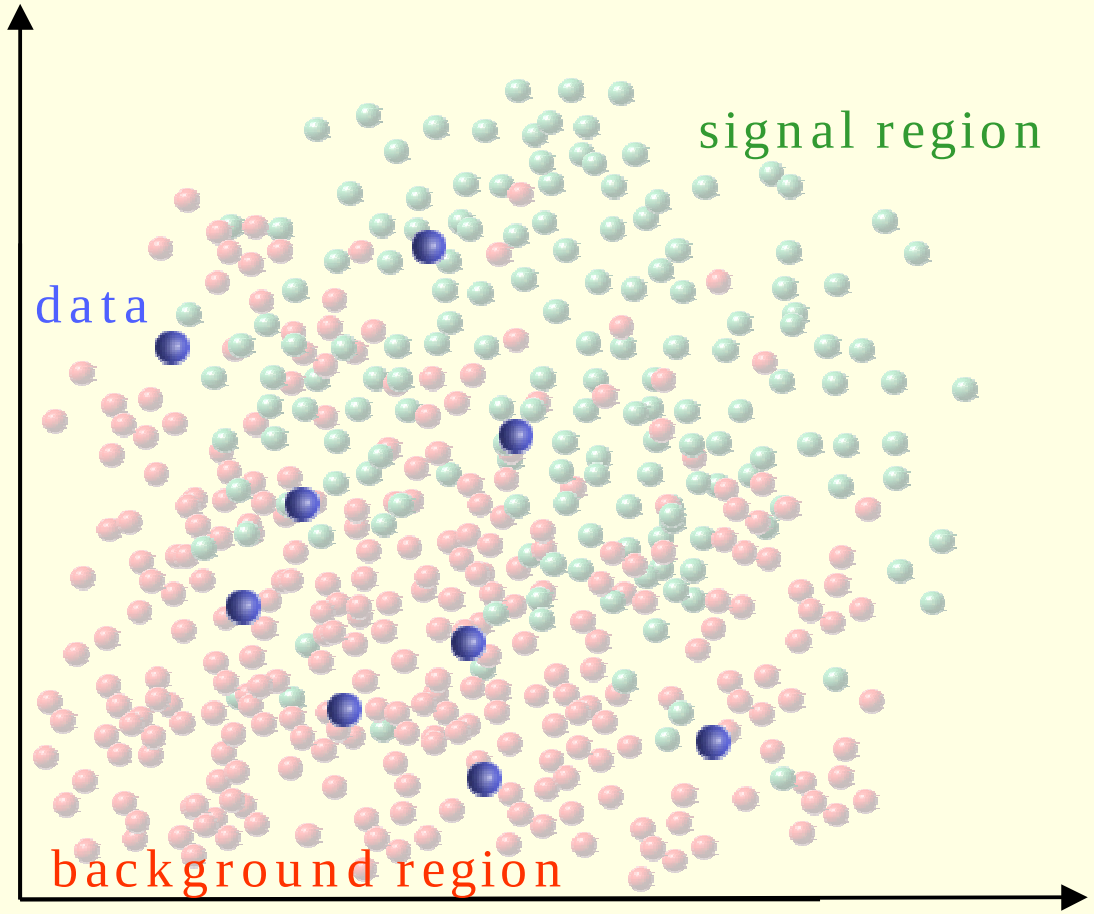
Su	Mo	Tu	We	Th	Fr	Sa
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30
31						

Physicist has an idea

Data returns a verdict

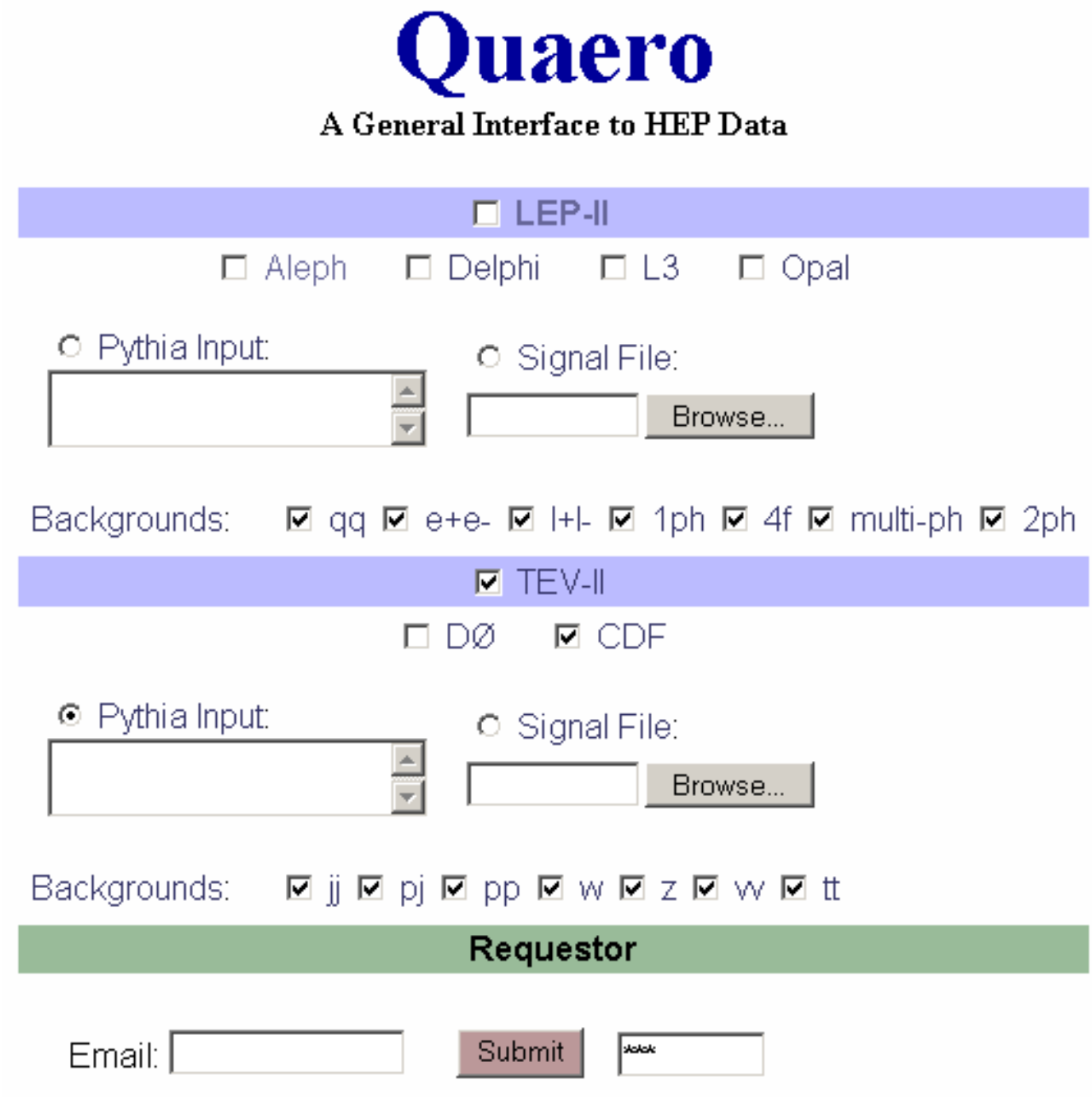


How can you choose a set of cuts without bias?



Wish list

- Reduce analysis time by factor of 10000
- Reduce human bias
- Publish data in full dimensionality
- Expunge exclusion contours from conference talks
- Automate optimization of analyses
- Rigorously propagate systematic errors
- Increase robustness of results
- Easily combine results among different experiments
- All of this on the web


Quaero
A General Interface to HEP Data
LEP-II
Aleph
Delphi
L3
Opal
Pythia Input:
Signal File:
Browse...
Backgrounds:
qq
e+e-
l+l-
1ph
4f
multi-ph
2ph
TEV-II
DØ
CDF
Pythia Input:
Signal File:
Browse...
Backgrounds:
jj
pj
pp
w
z
W
tt
Requestor
Email:
Submit

Any experiment wishing to use Quaero needs to provide 4 things:

- Data
  - Events, objects, 4-vectors
- Backgrounds
  - Events, objects, 4-vectors
- Systematic errors
  - Sources of error & effect on 4-vectors
- Detector simulation
  - Fast or full

Quaero is appropriate for high energy collider data

HERA I,II **LEP II** **Tevatron I,II** **LHC**

Each event can be usefully summarized by roughly a dozen numbers

object type ($e^{\pm}$ $\mu^{\pm}$ $\tau^{\pm}$ γ $\not{p}$ j b)
object 4-vectors

Data event:

data	1	189.2	
e^+	45.2	+0.11	0.21
e^-	47.3	-0.05	3.56
b	46.0	-0.16	1.71
b	48.2	-0.02	4.90
uncl	3.3	+0.07	3.97 ;

event_type weight sqrt(s)
object_type energy cos(θ) φ

Quaero algorithm overview

(you wish to test a hypothesis H)

- H events are run through the detector simulation
- H, SM, data are partitioned into final states
- Variables are chosen automatically
- Binning is chosen automatically
- A binned likelihood is calculated
- Results from different final states are combined
- Results from different experiments are combined
- Systematic errors are integrated numerically
- Result returned

$$\mathcal{L}(\mathcal{H}) = \frac{p(\mathcal{D}|\mathcal{H})}{p(\mathcal{D}|\mathrm{SM})}$$

Secrets of the Atom Revealed

By Jeffrey Benner

2:00 a.m. July 27, 2001 PDT

You can find a lot of information on the Web, but you just couldn't find a decent picture of the subatomic universe online.

Until now.

Scientists at the Fermilab in Illinois, home to the world's most powerful atom smasher, announced Wednesday that data collected during the last big round of experiments into the depths of the atom is now available online.

Search for New Physics Using Quaero: A General Interface to DØ Event Data

Run I data

since June 2001

http://quaero.fnal.gov/

hep-ex/0106039

PRL 87 231801

Search for New Physics Using QUAERO: A General Interface to DØ Event Data

V.M. Abazov,[28] B. Abbott,[58] A. Abdesselam,[11] M. Abolins,[51] V. Abramov,[26] B.S. Acharya,[17] D.L. Adams,[60] M. Adams,[38] S.N. Ahmed,[21] G.D. Alexeev,[28] G.A. Alves,[2] N. Amos,[50] E.W. Anderson,[43] Y. Arnoud,[9] M.M. Baarmand,[55] V.V. Babintsev,[26] L. Babukhadia,[55] T.C. Bacon,[29] A. Baden,[47] B. Baldin,[37] P.W. Balm,[20] S. Banerjee,[17] E. Barberis,[30] P. Baringer,[44] J. Barreto,[2] J.F. Bartlett,[37] U. Bassler,[12] D. Bauer,[29] A. Bean,[44] M. Begel,[54] A. Belyaev,[58] S.B. Beri,[15] G. Bernardi,[12] I. Bertram,[27] A. Besson,[9] R. Beuselinck,[29] V.A. Bezzubov,[26] P.C. Bhat,[37] V. Bhatnagar,[11] M. Bhattacharjee,[55] G. Blazey,[39] S. Blessing,[58] A. Boehnlein,[37] N.I. Bojko,[26] F. Borcherding,[37] K. Bos,[20] A. Brandt,[60] R. Breedon,[31] G. Briskin,[59] R. Brock,[51] G. Brooijmans,[37] A. Bross,[37] D. Buchholz,[40] M. Buehler,[38] V. Buescher,[14] V.S. Burtovoi,[26] J.M. Butler,[43] F. Canelli,[54] W. Carvalho,[3] D. Casey,[51] Z. Casilum,[55] H. Castilla-Valdez,[19] D. Chakraborty,[39] K.M. Chan,[54] S.V. Chekulaev,[26] D.K. Cho,[54] S. Choi,[34] S. Chopra,[56] J.H. Christenson,[37] M. Chung,[38] D. Claes,[52] A.R. Clark,[30] J. Cochran,[34] L. Coney,[42] B. Connolly,[58] W.E. Cooper,[37] D. Coppage,[44] S. Crépé-Renaudin,[9] M.A.C. Cummings,[39] D. Cutts,[59] G.A. Davis,[54] K. Davis,[29] K. De,[60] S.J. de Jong,[21] K. Del Signore,[50] M. Demarteau,[37] R. Demina,[45] P. Demine,[9] D. Denisov,[37] S.P. Denisov,[26] S. Desai,[55] H.T. Diehl,[37] M. Diesburg,[37] G. Di Loreto,[51] S. Doulas,[49] P. Draper,[60] Y. Ducros,[13] L.V. Dudko,[25] S. Duensing,[21] L. Duflot,[11] S.R. Dugad,[17] A. Duperrin,[10] A. Dyshkant,[39] D. Edmunds,[51] J. Ellison,[34] V.D. Elvira,[37] R. Engelmann,[55] S. Eno,[47] G. Eppley,[62] P. Ermolov,[25] O.V. Eroshin,[26] J. Estrada,[54] H. Evans,[53] V.N. Evdokimov,[26] T. Fahland,[33] S. Feher,[37] D. Fein,[29] T. Ferbel,[54] F. Filthaut,[21] H.E. Fisk,[37] Y. Fisyak,[56] E. Flattum,[37] F. Fleuret,[30] M. Fortner,[39] H. Fox,[40] K.C. Frame,[51] S. Fu,[53] S. Fuess,[37] E. Gallas,[37] A.N. Galyaev,[26] M. Gao,[53] V. Gavrilov,[24] R.J. Genik II,[27] K. Genser,[37] C.E. Gerber,[38] Y. Gershtein,[59] R. Gilmartin,[35] G. Ginther,[54] B. Gómez,[5] G. Gómez,[47] P.I. Goncharov,[26] J.L. González Solís,[19] H. Gordon,[56] L.T. Goss,[61] K. Gounder,[37] A. Goussiou,[29] N. Graf,[56] G. Graham,[47] P.D. Grannis,[55] J.A. Green,[43] H. Greenlee,[37] S. Grinstein,[1] L. Groer,[53] S. Grünendahl,[37] A. Gupta,[17] S.N. Gurzhiev,[26] G. Gutierrez,[37] P. Gutierrez,[58] N.J. Hadley,[47] H. Haggerty,[37] S. Hagopian,[58] V. Hagopian,[58] R.E. Hall,[32] P. Hanlet,[49] S. Hansen,[37] J.M. Hauptman,[43] C. Hays,[53] C. Hebert,[44] D. Hedin,[39] J.M. Heinmiller,[38] A.P. Heinson,[34] U. Heintz,[48] T. Heuring,[58] M.D. Hildreth,[42] R. Hirosky,[63] J.D. Hobbs,[55] B. Hoeneisen,[8] Y. Huang,[50] R. Illingworth,[29] A.S. Ito,[37] M. Jaffré,[11] S. Jain,[17] R. Jesik,[29] K. Johns,[30] M. 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May,[40] A.A. Mayorov,[41] R. McCarthy,[55] T. McMahon,[57] H.L. Melanson,[37] M. Merkin,[25] K.W. Merritt,[37] C. Miao,[59] H. Miettinen,[62] D. Mihalcea,[39] C.S. Mishra,[37] N. Mokhov,[37] N.K. Mondal,[17] H.E. Montgomery,[37] R.W. Moore,[51] M. Mostafa,[1] H. da Motta,[2] E. Nagy,[10] F. Nang,[29] M. Narain,[48] V.S. Narasimham,[17] H.A. Neal,[50] J.P. Negret,[5] S. Negroni,[10] T. Nunnemann,[37] D. O'Neil,[51] V. Oguri,[3] B. Olivier,[12] N. Oshima,[37] P. Padley,[62] L.J. Pan,[40] K. Papageorgiou,[33] A. Para,[37] N. Parashar,[49] R. Partridge,[59] N. Parua,[55] M. Paterno,[54] A. Patwa,[55] B. Pawlik,[22] J. Perkins,[60] M. Peters,[31] O. Peters,[20] P. Pétroff,[11] R. Piegaia,[1] B.G. Pope,[51] E. Popkov,[48] H.B. Prosper,[35] S. Protopopescu,[58] J. Qian,[50] R. Raja,[37] S. Rajagopalan,[56] E. Ramberg,[37] P.A. Rapidis,[37] N.W. Reay,[45] S. Reucroft,[49] M. Ridel,[11] M. Rijssenbeek,[55] F. Rizatdinova,[45] T. Rockwell,[51] M. Roco,[37] P. Rubinov,[37] R. Ruchti,[42] J. 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Wang,[40] Z.-M. Wang,[55] J. Warchol,[42] G. Watts,[64] M. Wayne,[42] H. Weerts,[51] A. White,[60] J.T. White,[61] D. Whiteson,[30] J.A. Wightman,[43] D.A. Wijngaarden,[21] S. Willis,[39] S.J. Wimpenny,[34] J. Womersley,[37] D.R. Wood,[49] R. Yamada,[37] P. Yamin,[56] T. Yasuda,[37] Y.A. Yatsunenko,[28] K. Yip,[56] S. Youssef,[35] J. Yu,[37] Z. Yu,[40] M. Zanabria,[5] H. Zheng,[42] Z. Zhou,[43] M. Zielinski,[54] D. Zieminska,[41] A. Zieminski,[41] V. Zutshi,[56] E.G. Zverev,[25] and A. Zylberstejn[13]

(DØ Collaboration)

VOLUME 87, NUMBER 23 PHYSICAL REVIEW LETTERS 3 DECEMBER 2001

Search for New Physics Using QUAERO: A General Interface to D0 Event Data

(D0 Collaboration)

Perform the following 11 thesis-level analyses (and another dozen of your choice) in less than 24 hours:

Process	ϵ_{sig}	$\hat{b}$	N_{data}	$\sigma^{95\%} \times \mathcal{B}$
$WW \to e\mu\not{E}_T$	0.14	19.0 ± 4.0	23	1.1 pb
$ZZ \to ee2j$	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
$h_{200} \to ZZ \to ee2j$	0.15	17.9 ± 3.7	15	0.6 pb
$h_{225} \to ZZ \to ee2j$	0.15	18.8 ± 3.8	12	0.4 pb
$h_{250} \to ZZ \to ee2j$	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
$Zh_{115} \to ee2j$	0.20	19.5 ± 4.1	25	0.8 pb
$LQ_{225}\overline{LQ}_{225} \to ee2j$	0.33	0.3 ± 0.1	0	0.07 pb

Quaero is consistent with (and competitive with) previous results:

$W' \to WZ \to e\not{E}_T$ 2j

$m_{W'}$	$\sigma^{95\%} \times \mathcal{B}$ Quaero	$\sigma^{95\%} \times \mathcal{B}$ CDF
200	3.4 pb	6.6 pb
350	0.7 pb	2.0 pb
500	0.2 pb	0.5 pb

CDF, PRL 88 071806 (2002)

$t\bar{t} \to e\,\mu\,\not{E}_T$ 2j

Quaero

$\sigma \times \mathcal{B} = 0.14^{+0.15}_{-0.08}$ pb

2 data, 0.6 bkg

DØ PRL 79 1203 (1997)

ee, eμ, μμ 2.1σ

5 data, 1.4 bkg

$LQ\,\overline{LQ} \to ee$ 2j

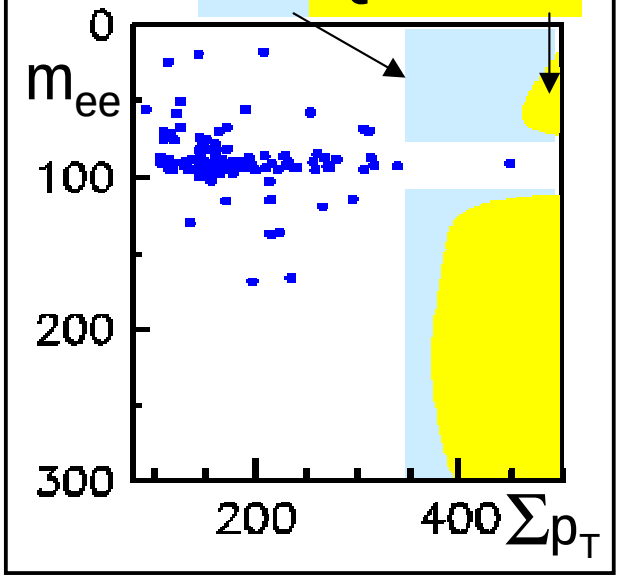
Quaero

$\sigma^{95\%} \times \mathcal{B}$ = 0.07 pb

DØ PRL 79 4321 (1997)

$\sigma^{95\%} \times \mathcal{B}$ = 0.07 pb

DØ Quaero



$Z' \to t\bar{t} \to e\not{E}_T$ 4j

$m_{Z'}$	$\sigma^{95\%} \times \mathcal{B}$ Quaero	$\sigma^{95\%} \times \mathcal{B}$ CDF
350	1.1 pb	-
450	0.9 pb	0.65 pb
550	0.3 pb	0.45 pb

CDF, PRL 85 2062 (2000)

$t\bar{t} \to e\,\not{E}_T$ 4j

Quaero

$\sigma \times \mathcal{B} = 0.39^{+0.21}_{-0.19}$ pb

8 data, 3.1 bkg

DØ PRL 79 1203 (1997)

e/μ 4j, no b-tag 2.6σ

19 data, 8.7 bkg

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

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

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. The region of variable space with maximal sensitivity contains 17.6 expected signal events and 32.7 ± 7.1 expected background events; 36 events are observed in the data.

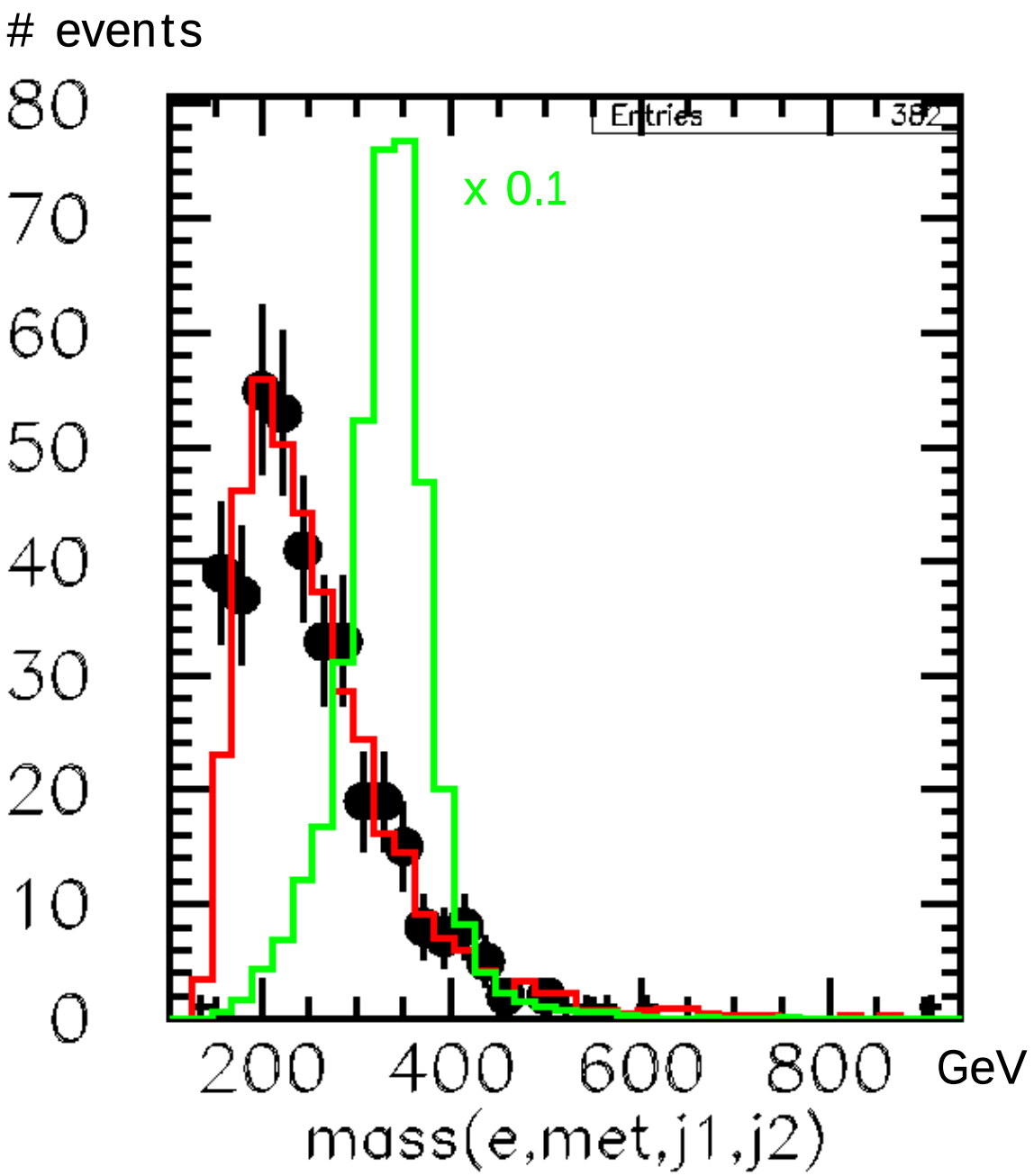
Plots

Plots of the variables you used are available for viewing at http://quaero.fnal.gov/quaero/requests/plots/29.ps.

— Background

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

● DØ Run I data



Quaero policy?

There are a number of ways Quaero can be implemented

Don't

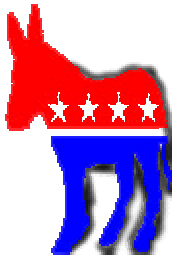
Keep Quaero as an internal tool

Make data available with limited scope and internal review

Restrict those who are allowed to use Quaero

Review all Quaero results before releasing them

Make data available with general scope and more limited internal review



"Put the data out there"

Make data available to all with no internal review

Many variations on these themes

CERN LEP data (e^+e^- at ≈100-200 GeV)

Collected: **1989-2000**

Cost to collect: **≈ 4 x 10^9 SFr.**

Next chance: **10+ years**

- **awaits a linear collider**

Natural shelf life: **≈ 2 years**

- **potential barrier to doing meaningful analysis increases with time as experts leave, retire**

We may want to re-analyze these data in light of Tevatron Run II results . . .

Current score card ★

CERN	Aleph	●
	L3	●
	Delphi	✗
	Opal	✗
DESY	H1	◆
	Zeus	◆
Fermilab	CDF	●
	Dÿ	✓

● Prototype under construction
Aleph: Marcello Maggi
L3: Andre Holzner

✗ Have decided not to pursue

◆ Potential future interest expressed

✓ Initial version achieved with Run I data

★ No collaboration commitments

Summary

Wish list

- Reduce analysis time by factor of 10000
- Reduce human bias
- Publish data in full dimensionality
- Expunge exclusion contours from conference talks
- Automate optimization of analyses
- Rigorously propagate systematic errors
- Increase robustness of results
- Easily combine results among different experiments
- Save LEP data

• Status

- Proof of principle achieved

  DØ Run I — http://quaero.fnal.gov/ — PRL 87 231801

- Efforts ongoing

Special thanks to:




and many others