Top charge determination

J. Antoš

IEP SAS , Košice, Slovakia

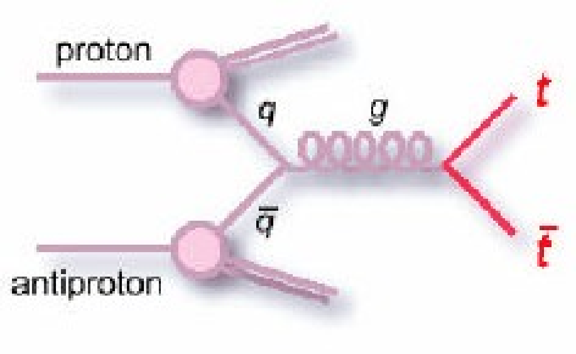
credit is given to my close collaborators on the topic:

Dr.Yen-Chu Chen, IPAS,Taiwan

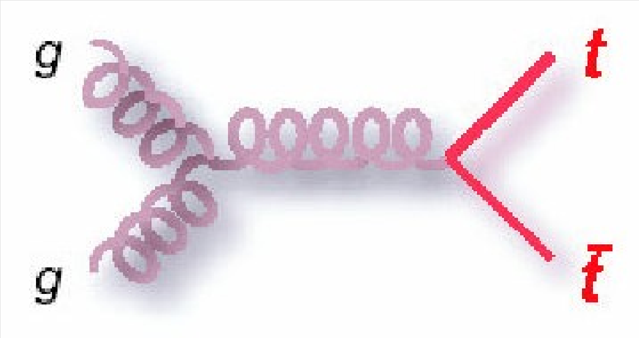
Dr. Andrew Beretvas, FNAL,USA

and all the Top Charge group at CDF

Top production according to SM at hadron colliders



85%

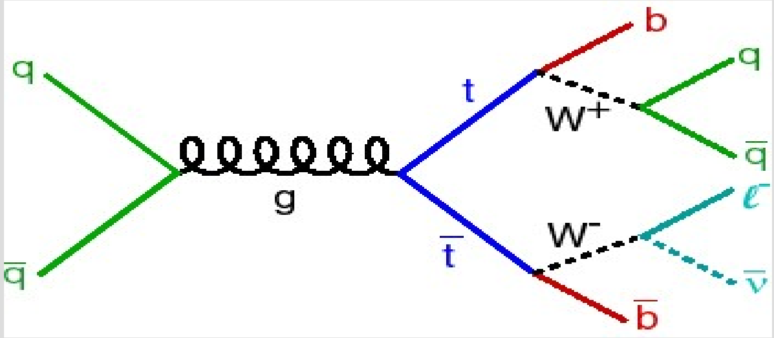


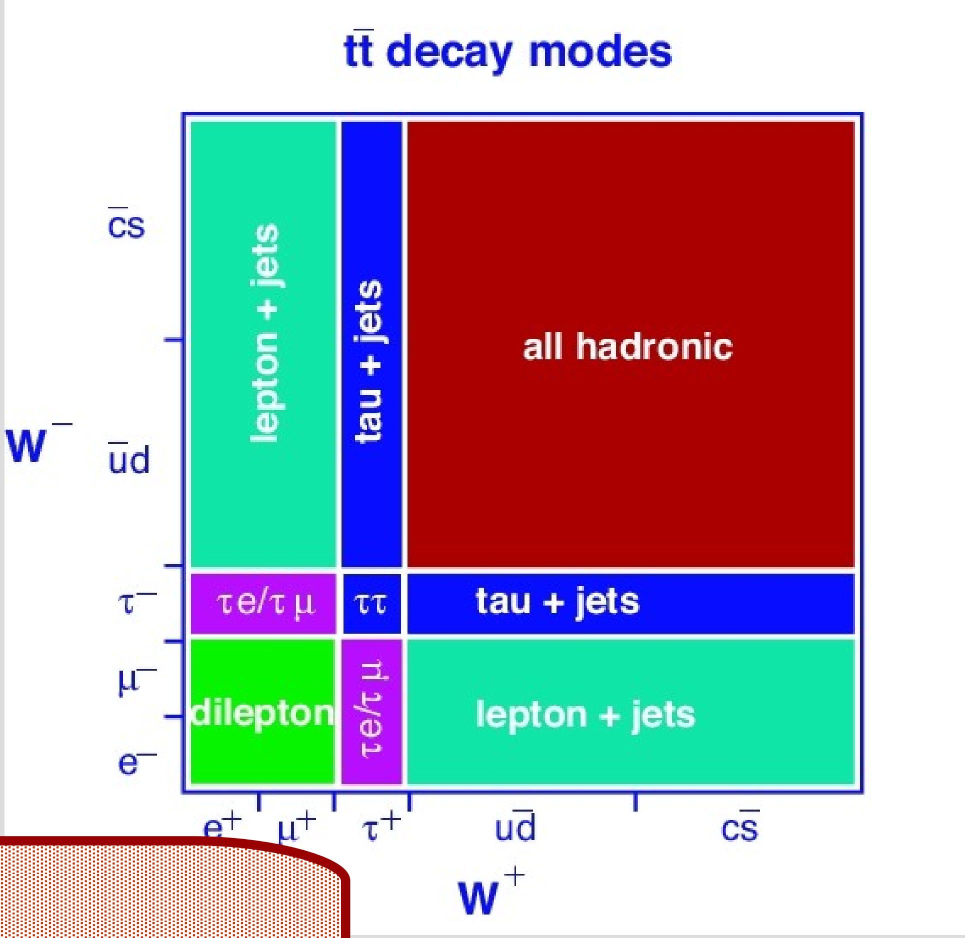
15%

- Production in pairs
- Reversed qq,gg fractions at LHC

	Run 1	Run 2	LHC
	ppbar	ppbar	***pp***
E_{CM}	1.8 TeV	1.96TeV	14 TeV
qq	90%	85%	5%
gg	10%	15%	95%
σ_{tt}	5.0 pb	6.7 pb	830 pb

Top properties according to SM





- $t \rightarrow Wb$ ~100%
- Charge +2/3
- Spin ½
- $\tau \sim 10^{-25}$ s

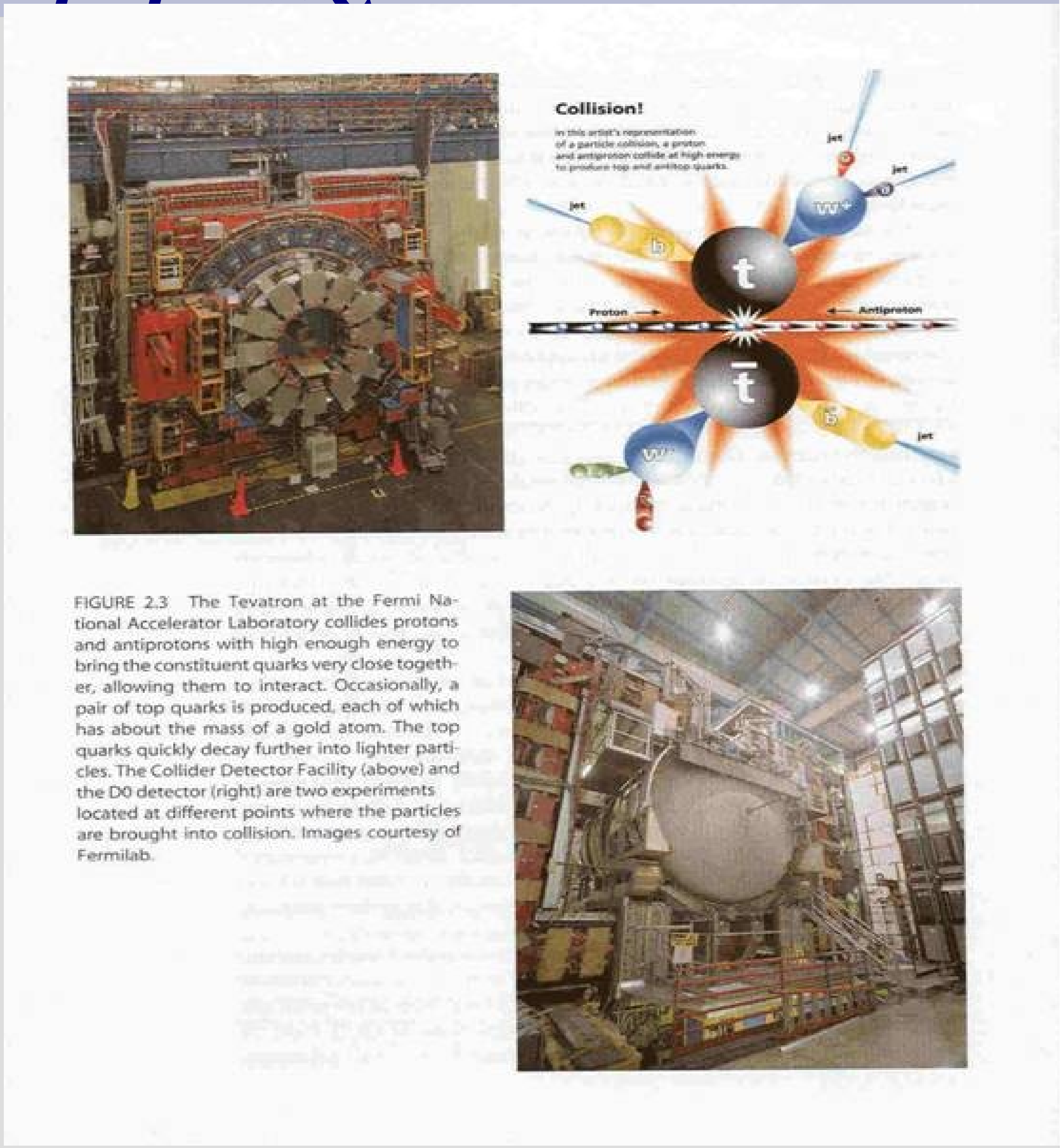
topologies

- $tt \rightarrow l\nu l\nu bb$ di-lepton 5% e+μ
- $tt \rightarrow l\nu qqbb$ lepton+jets 30% e+μ
- $tt \rightarrow qqqqbb$ all hadronic 45%

What we really experimentally know about top quark?

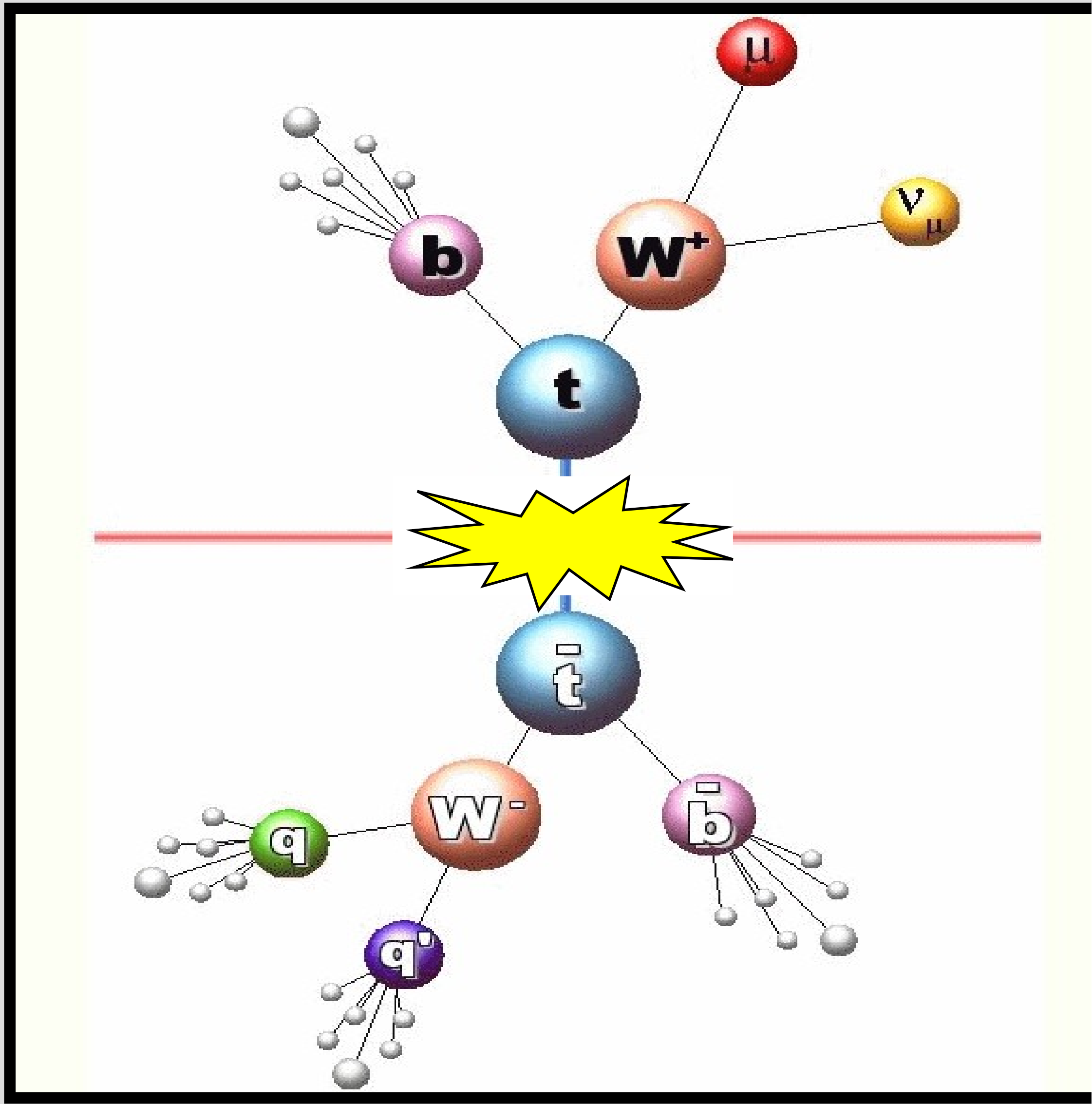
- Pair production at TEVATRON (xsection)
- Mass
- t->Wb BR consistent with ~1

All above consistent with SM!



Parameters of top quark measured recently or not measured yet !

- Charge
- Spin
- Lifetime
- Spin correlations
- Single top prod. xsection



Top charge determination

Assumptions involved:

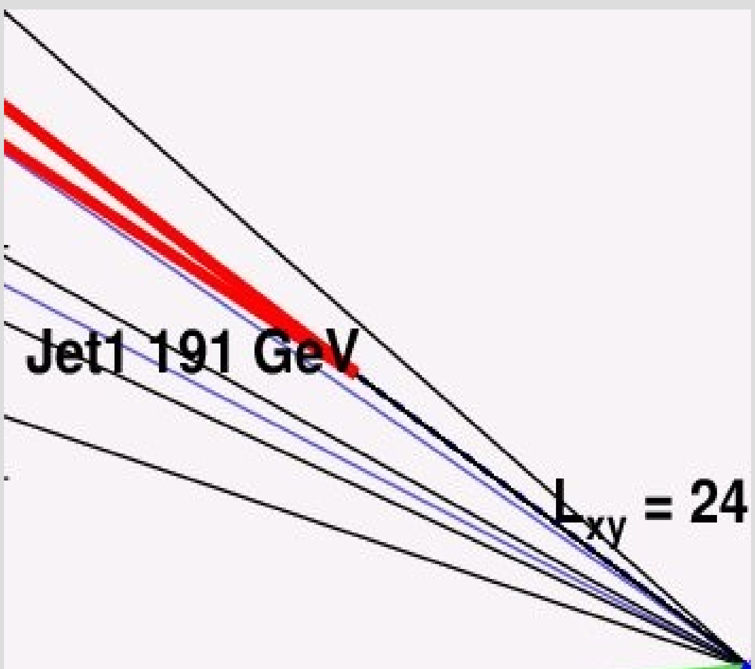
- We consider just two charge options: 2/3 or 4/3
- All properties (except charge) of particle decaying into Wb (top?) are the same as SM top

Determination of components

- Charge of b-jet

$$P_b^c = \int_{-1}^{0} P_b(x)\,dx.$$

$$Q_{jet} = \frac{\sum |\vec{p}_i . \vec{P_{jet}}|^{0.5} Q_i}{\sum |\vec{p}_i . \vec{P_{jet}}|^{0.5}}$$



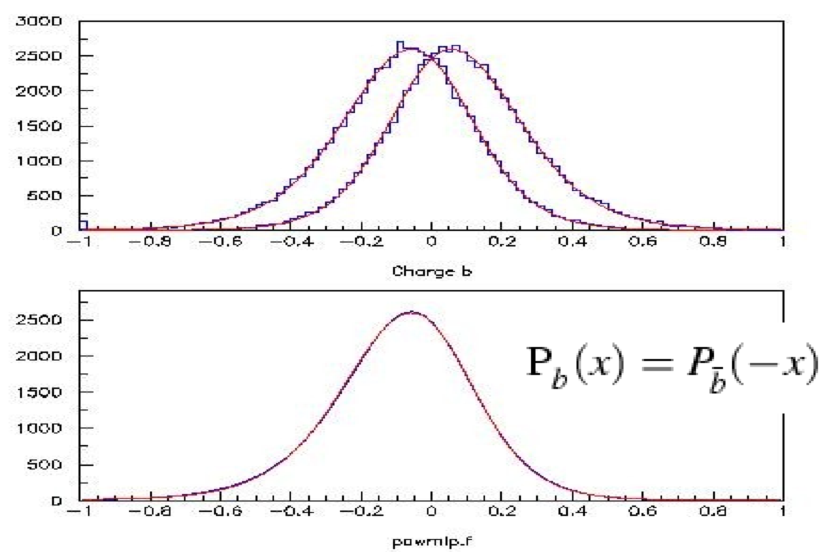
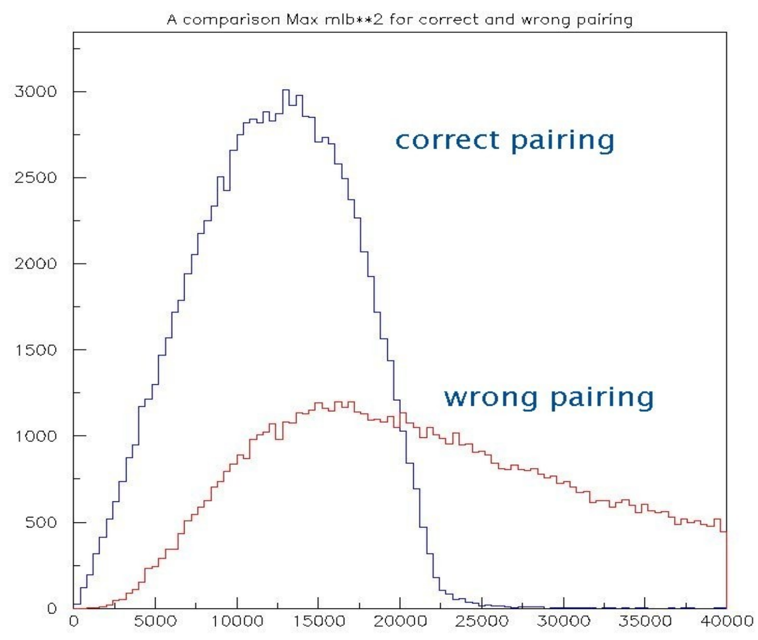
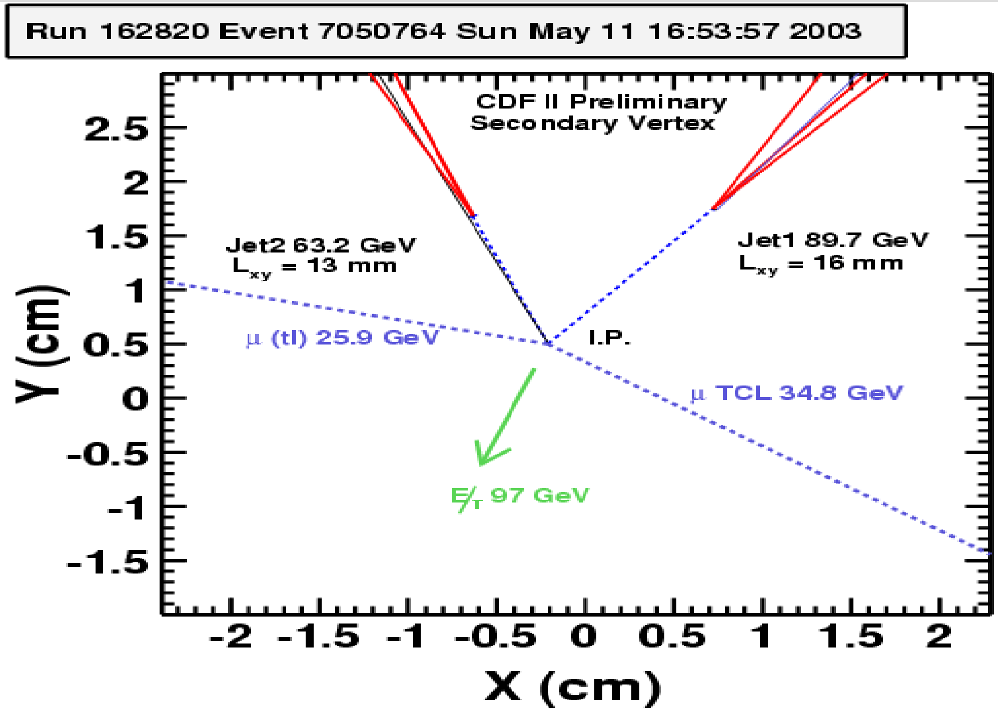


Figure 5: Reconstructed charge distribution for b and $\bar{b}$ and NN fit (upper plot), comparison of $f_b(x)$ and $f_{\bar{b}}(-x)$ from independent NN fit to MC

Determination of correct pairing of leptons and jets

Options – m^2_{lb} cut, kinematic reconstruction of an event





Expectation for standard and exotic model

A possible combination of lepton and b-jet charges:

Standard Model	+−	or −+
Exotic Model	++	or −−

Statistical analysis

- Binomial statistics (Purity, Number of measurements)

P^Q *can be directly estimated or*

$$P^Q = P_b^c P_{lb} + (1 - P_b^c)(1 - P_{lb})$$

to take into account background

$$P^Q_{comb} = P^Q P_F^{t\bar{t}} + 0.5 P_F^{Bkg}$$

Statistical variable for hypothesis testing

$$P_l(N^Q) = \sum_{i=0}^{N^Q} \binom{N}{i} (P^Q)^i (1 - P^Q)^{N-i}$$

$$P_l(N^Q) = \sum_{i=0}^{N^Q} \binom{N}{i} \int f(P^Q)(P^Q)^i (1 - P^Q)^{N-i} dP^Q$$

Statistical analysis

- Probability to reject wrong hypothesis at given CL

$$n(P_l,N)=\binom{N}{P_l^{-1}(N^Q)}(P^Q)^{P_l^{-1}(N^Q)}(1-P^Q)^{N-P_l^{-1}(N^Q)}$$

$$P_{\alpha,N}=\sum_{P_l\leq\alpha}n(P_l,N)$$

$$n^W(P_l,N)=\binom{N}{P_l^{-1}(N-N^Q)}(P^Q)^{P_l^{-1}(N-N^Q)}(1-P^Q)^{N-P_l^{-1}(N-N^Q)}$$

$$P^W_{\alpha,N}=\sum_{P_l\leq\alpha}n^W(P_l,N)$$

Statistical Analysis

Many thanks to Stat. Committee specially to Luc Demortier!

P_q - purity – probability to determine correctly top charge

N_q – number of pairs of leptons and b-jets with charge 2/3

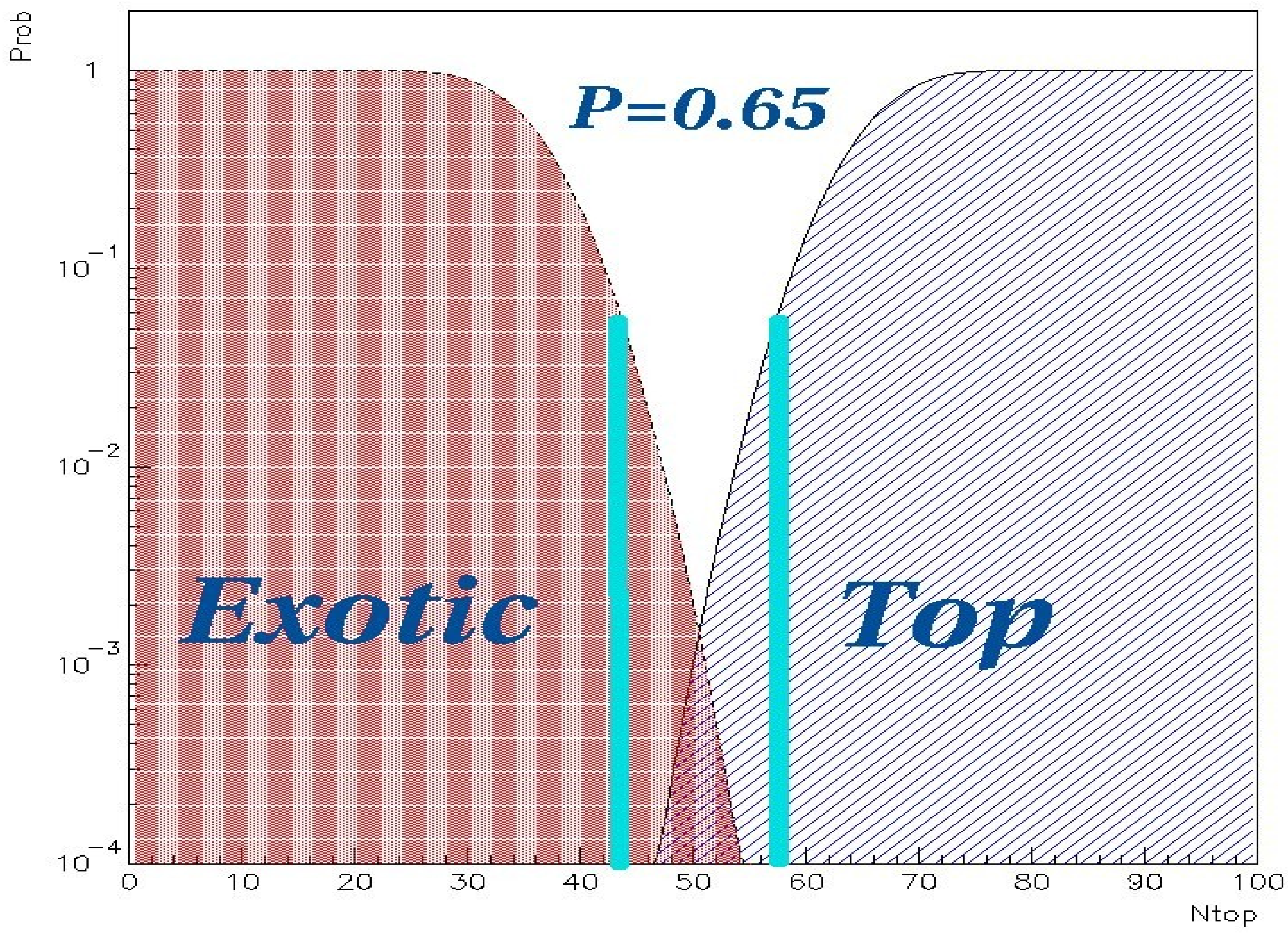
$P_{value} \equiv f(P_q, N_q, N) < \alpha$ top hypothesis is rejected

Power β – for given α, probability to reject SM hypothesis if XM hyp. is true

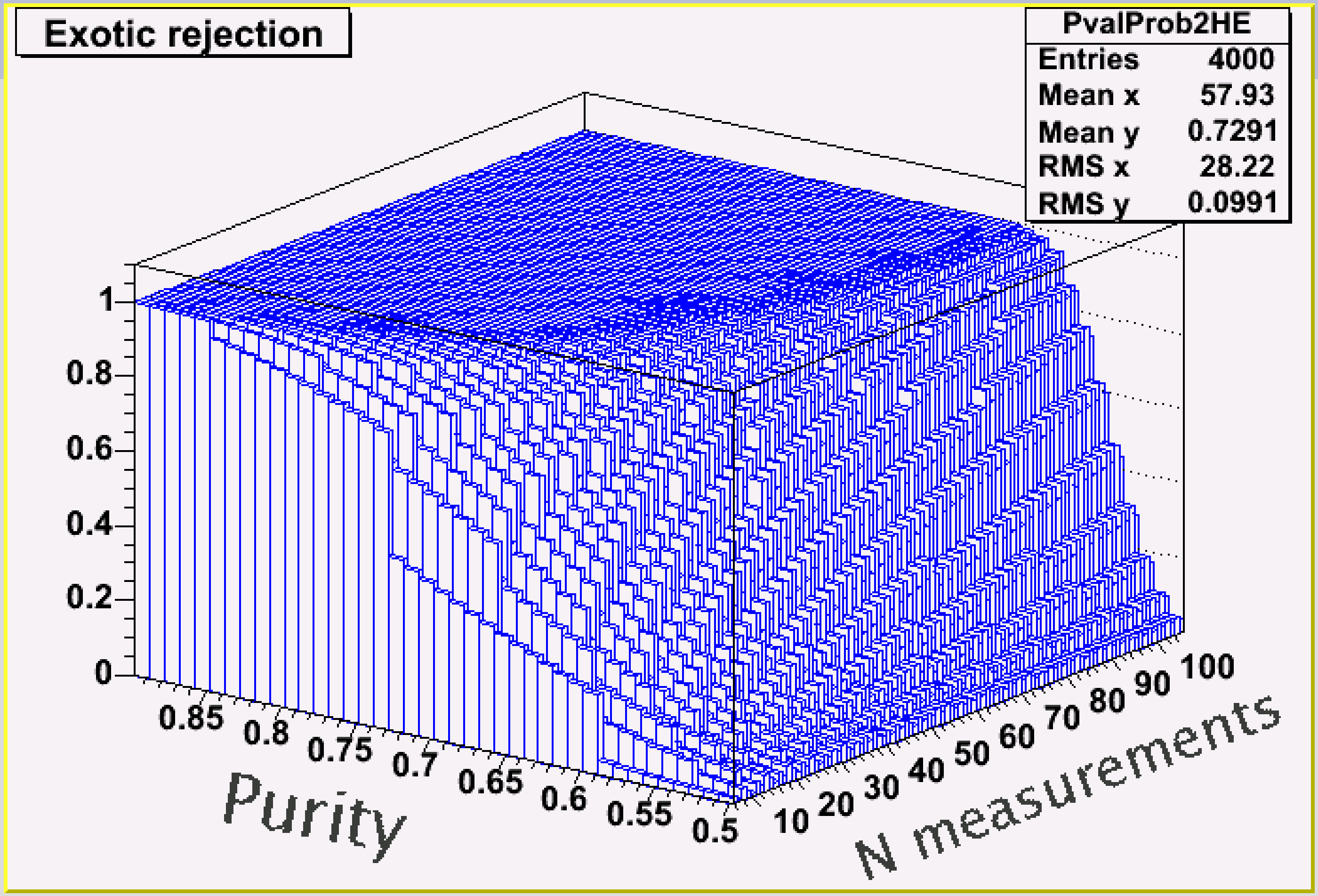
Bayes Factor – $P(N_q|SM)/P(N_q|XM)$ – odds of SM over XM

convention in statistics is:

2 ln(BF)	0-2	Not worth mentioning
	2-6	positive
	6-10	strong
	>10	very strong



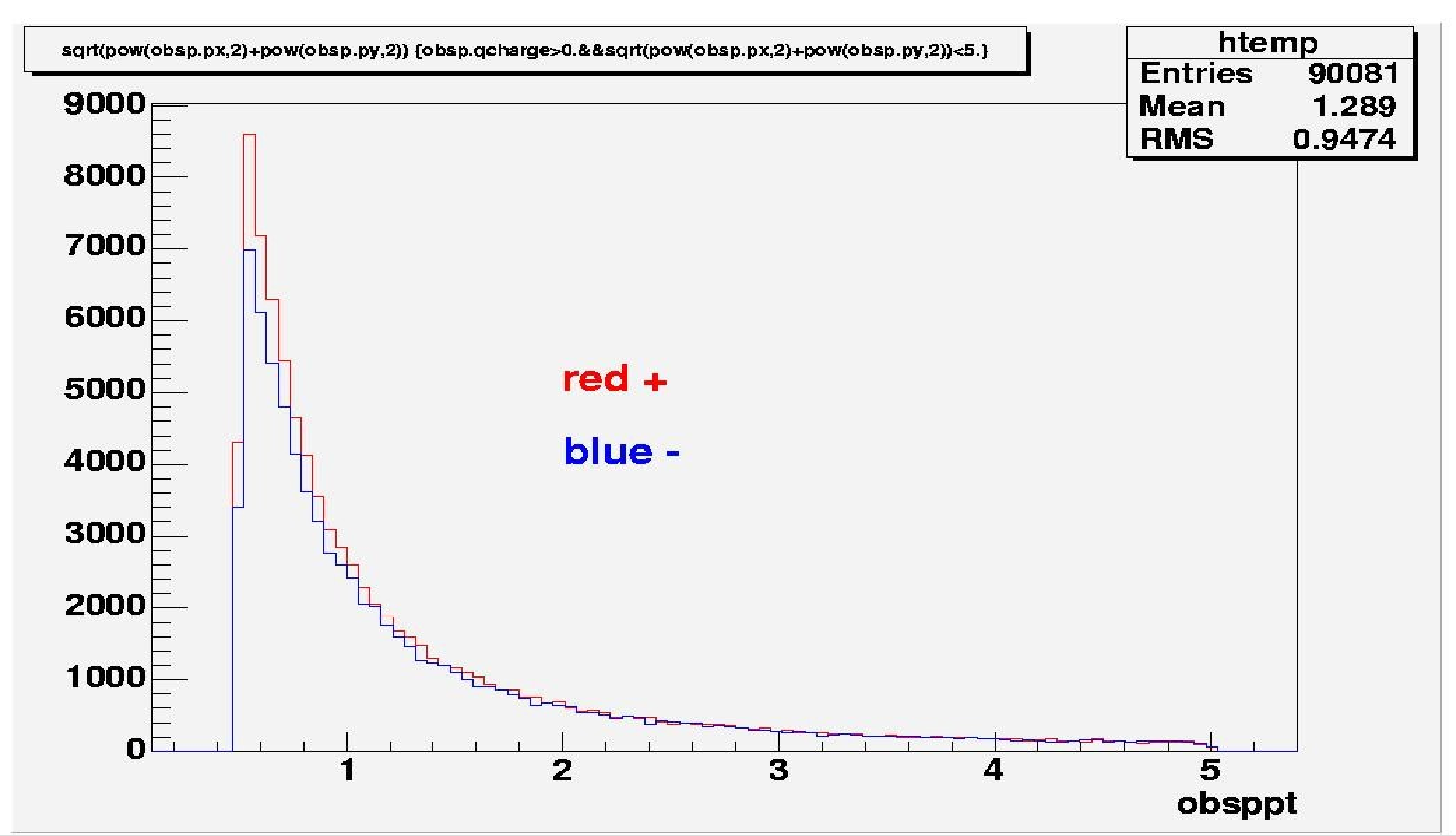
Prob
1
10^-1
10^-2
10^-3
10^-4
0
10
20
30
40
50
60
70
80
90
100
Ntop
P=0.65
Exotic
Top



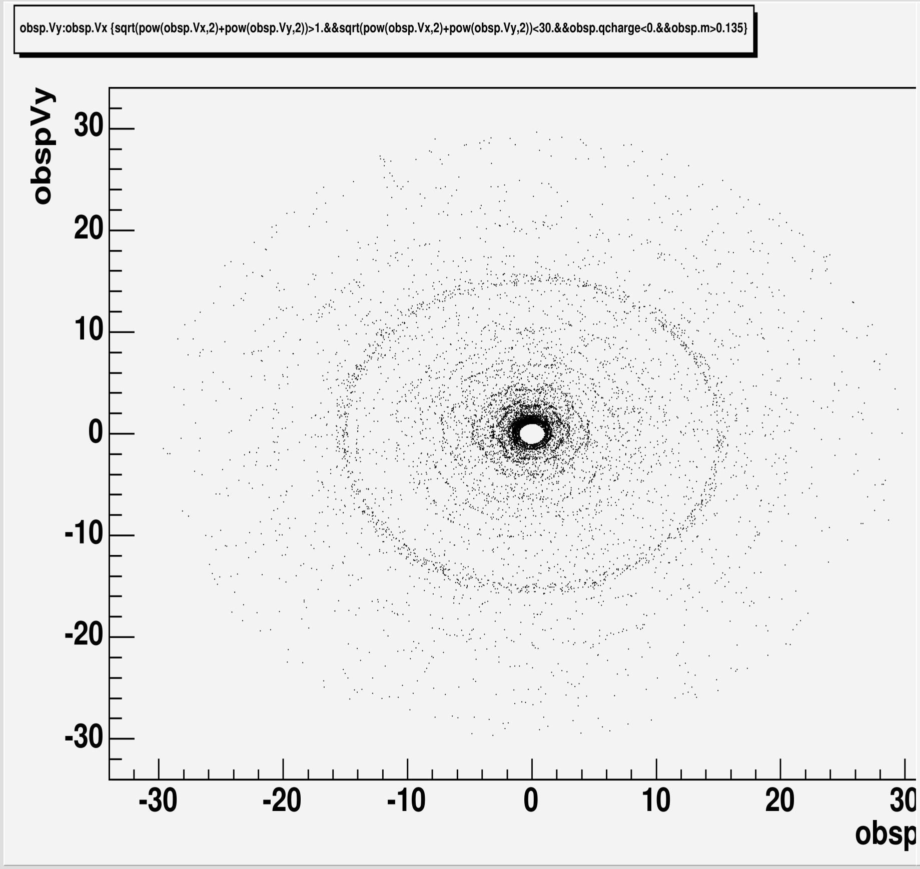
Exotic rejection
PvalProb2HE
Entries 4000
Mean x 57.93
Mean y 0.7291
RMS x 28.22
RMS y 0.0991
1
0.8
0.6
0.4
0.2
0
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
Purity
10
20
30
40
50
60
70
80
90
100
N measurements

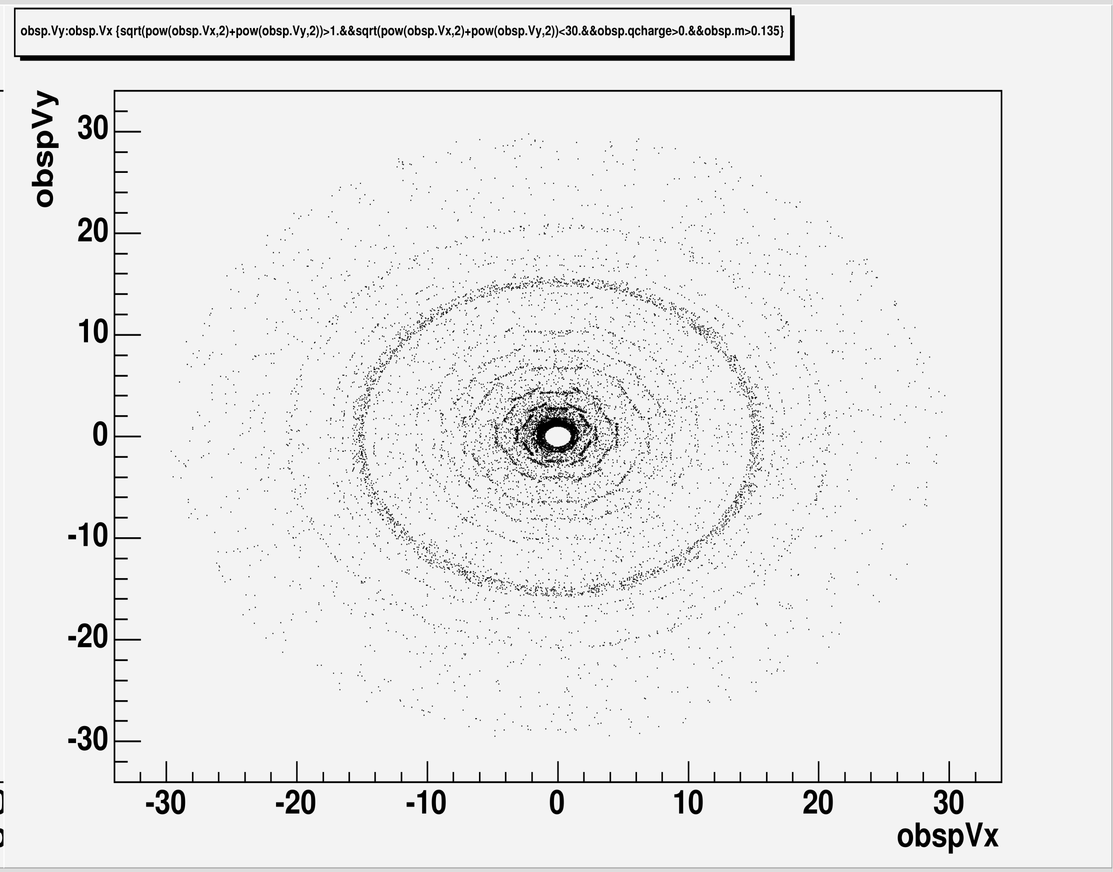
Realistic MC calculation

- Is charge symmetry there?



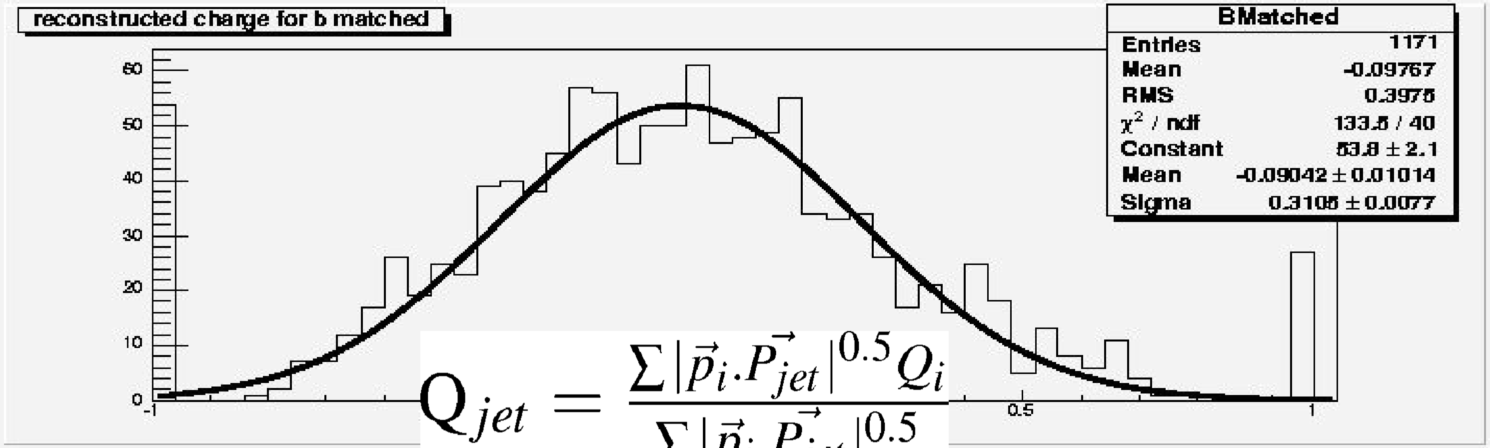
Origin of charge bias



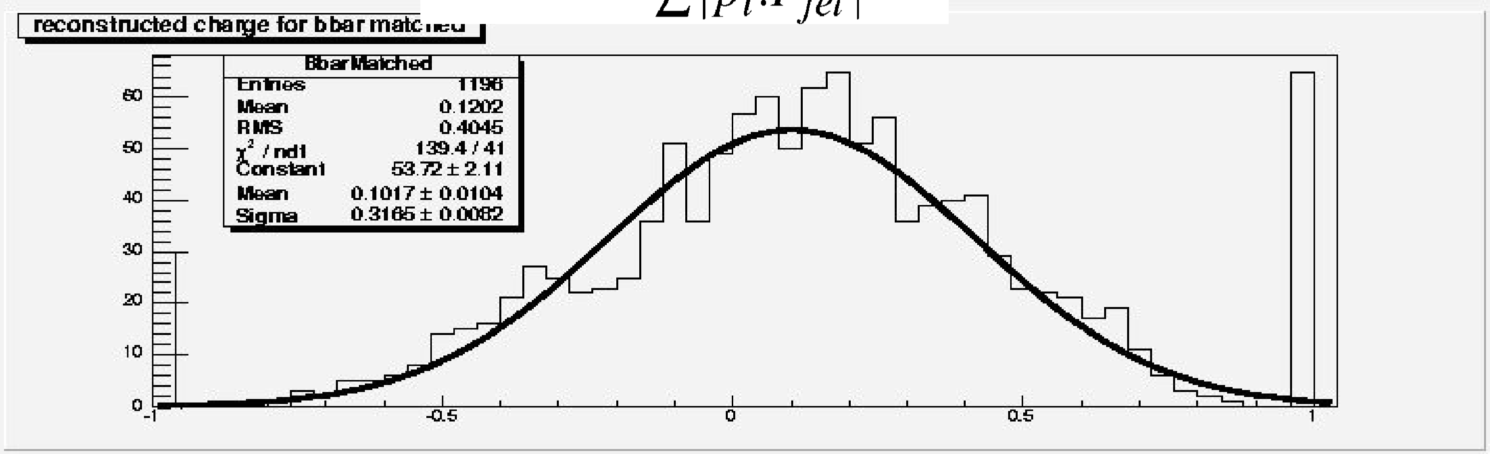


Realistic b-jet charge reconstruction

- Probability of correct b-jet charge calculation ~0.63



$$Q_{jet} = \frac{\sum |\vec{p}_i . \vec{P_{jet}}|^{0.5} Q_i}{\sum |\vec{p}_i . \vec{P_{jet}}|^{0.5}}$$



Determination of P_q for signal and background

Selection criteria:

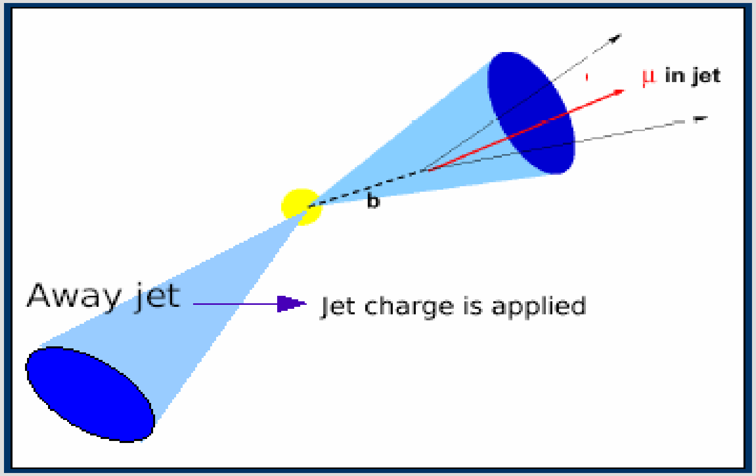
- standard selection for a given channel (dilept., lept+jets)
- b-jet charge - tight secvtx tracks, P_t >1.5 GeV/c^2,$|D_0|$<0.15 cm
- Pairing - m^2_{lbmax} >22k cut (dilept.), χ^2<9 cut (lept.+jets, top mass kin. fit)
- b-tagging (dilep – at least one jet), (2 jets in lept.+jets)

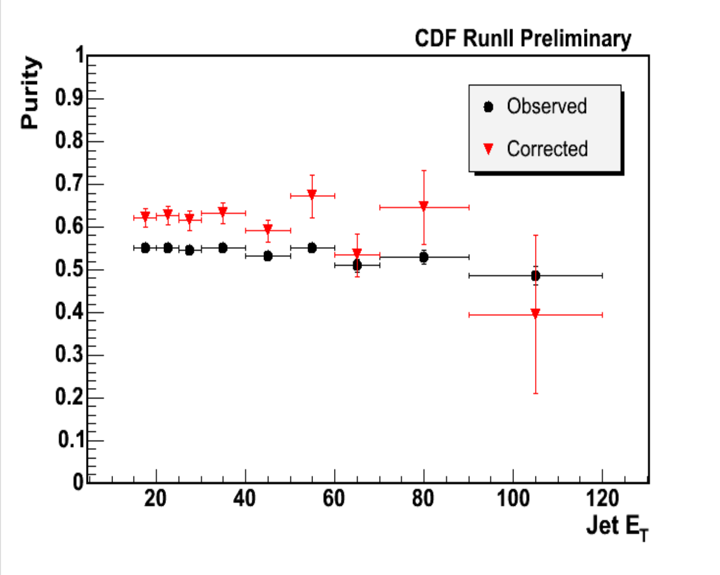
Background	N_b **or** N_s	**Purity**	N^+	N^-
L + J (695 pb^{-1})				
W+HF	0.77 ± 0.17	0.5 ± 0.0	0.38 ± 0.09	0.38 ± 0.09
QCD fakes	0.36 ± 0.27	$0.545^{+0.005}_{-0.04}$	0.20 ± 0.15	0.16 ± 0.12
Diboson	0.04 ± 0.02	0.5 ± 0.0	0.02 ± 0.01	0.02 ± 0.01
Mistag	0.11 ± 0.11	0.5 ± 0.0	0.05 ± 0.05	0.05 ± 0.05
Singletop	0.13 ± 0.01	0.58 ± 0.02	0.07 ± 0.01	0.05 ± 0.01
Total	1.40 ± 0.34	$0.518^{+0.006}_{-0.012}$	0.73 ± 0.18	0.67 ± 0.16
Signal	$35.35^{\pm 0.37(stat)}_{\pm 7.92(sys)}$	$0.582^{\pm 0.008(stat)}_{\pm 0.018(sys)}$	$20.57^{\pm 0.36(stat)}_{\pm 4.65(sys)}$	$14.78^{\pm 0.33(stat)}_{\pm 3.37(sys)}$
DIL (955 pb^{-1})				
Drell-Yan	$0 + 0.38$	0.5 ± 0.0	$0 + 0.38$	$0 + 0.38$
Fakes	$0 + 0.81$	0.5 ± 0.0	$0 + 0.81$	$0 + 0.81$
Diboson	$0 + 0.1$	0.5 ± 0.0	$0 + 0.1$	$0 + 0.1$
Total	$0 + 0.9$	-	$0 + 0.9$	$0 + 0.9$
Signal	$10.30^{\pm 0.43(stat)}_{\pm 1.66(sys)}$	$0.602^{\pm 0.011(stat)}_{\pm 0.023(sys)}$	$6.20^{\pm 0.28(stat)}_{\pm 1.03(sys)}$	$4.10^{\pm 0.21(stat)}_{\pm 0.70(sys)}$
Total Background	$1.40^{+0.96}_{-0.34}$	$0.518^{+0.006}_{-0.012}$	$0.73^{+0.92}_{-0.18}$	$0.67^{+0.91}_{-0.16}$
Total Signal	$45.65^{\pm 0.57(stat)}_{\pm 8.09(sys)}$	$0.586^{\pm 0.007(stat)}_{\pm 0.015(sys)}$	$26.77^{\pm 0.46(stat)}_{\pm 4.76(sys)}$	$18.87^{\pm 0.39(stat)}_{\pm 3.44(sys)}$

Table 2: Background and Signal purities and expected number of SM like (N^+) or Exotic Model like (N^-) events DILepton and Lepton+Jets.

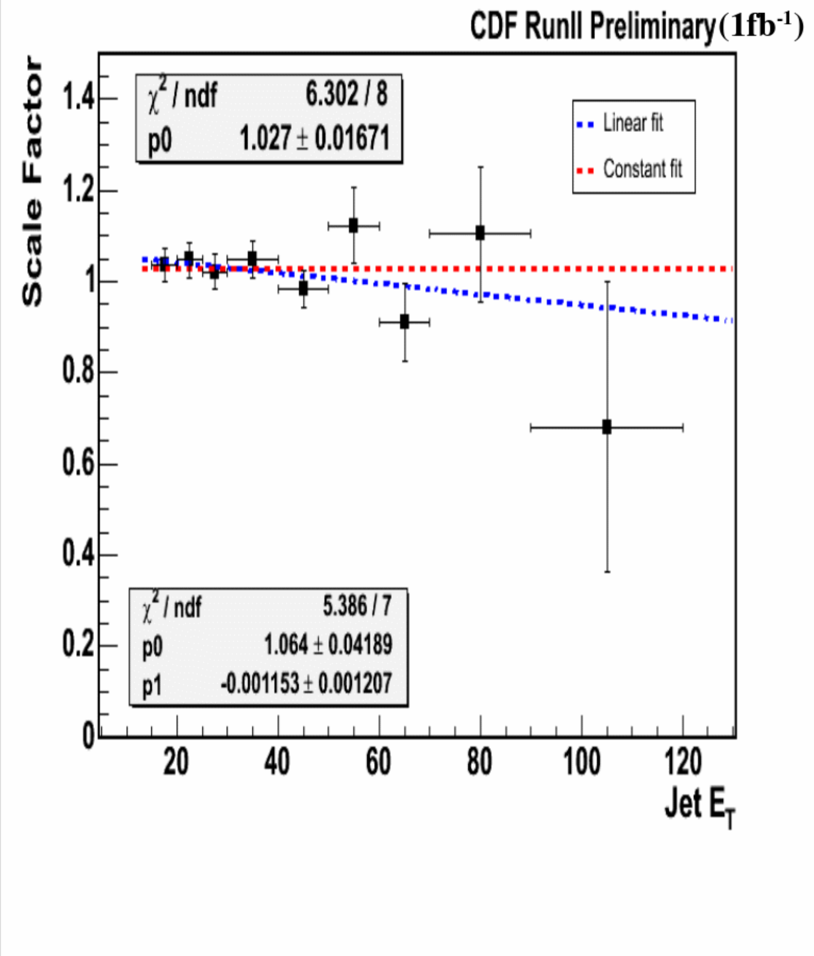
Comparison of b-jet charge determination from MC and Data

Dijet HF data and corresponding MC comparison





SF =1.03±0.02(stat.)±0.04(sys.)

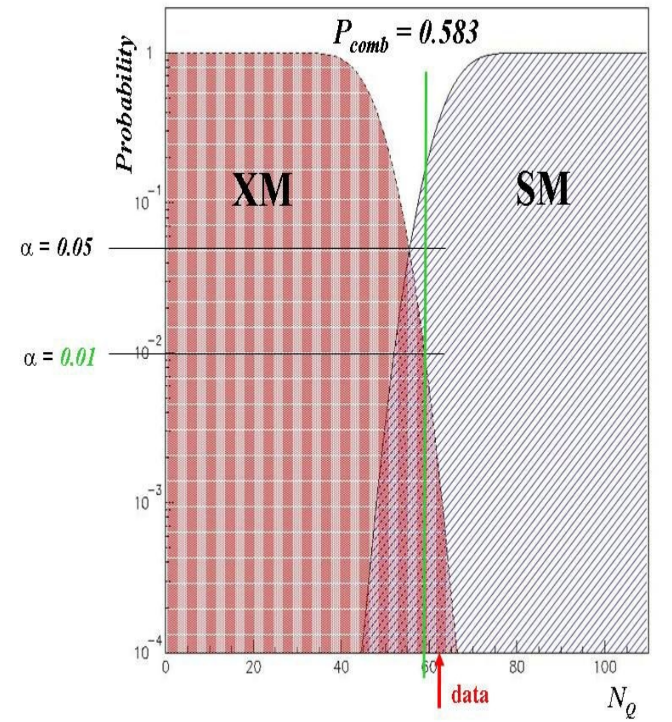


Final result (LJ 695 pb^{-1},Dil 955 pb^{-1})

Expected

N_s	$91.30 \pm 1.14(stat) \pm 16.18(sys)$
N_b	2.80 ± 1.92
p_s	$0.586 \pm 0.007(stat) \pm 0.015(sys)$
p_b	0.518 ± 0.012

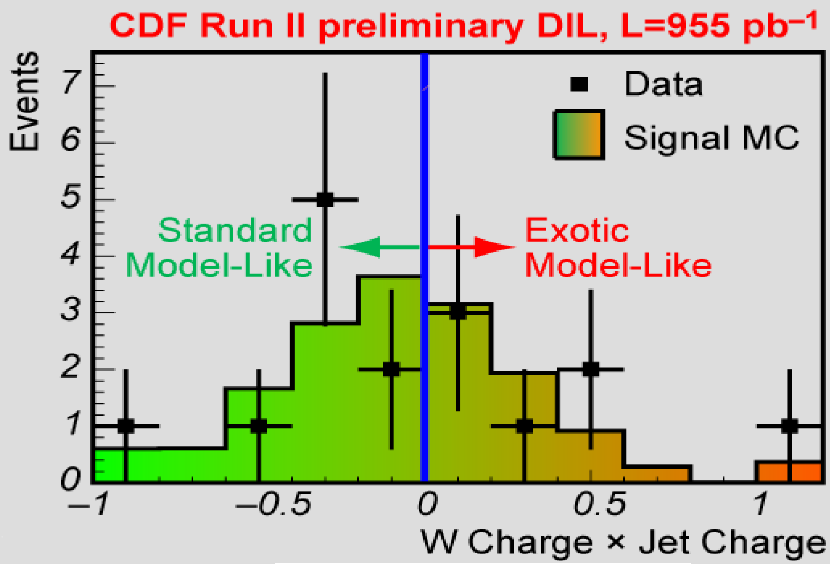
We decided to reject SM if $P_{value} < \alpha=0.01$!
(before looking at data)

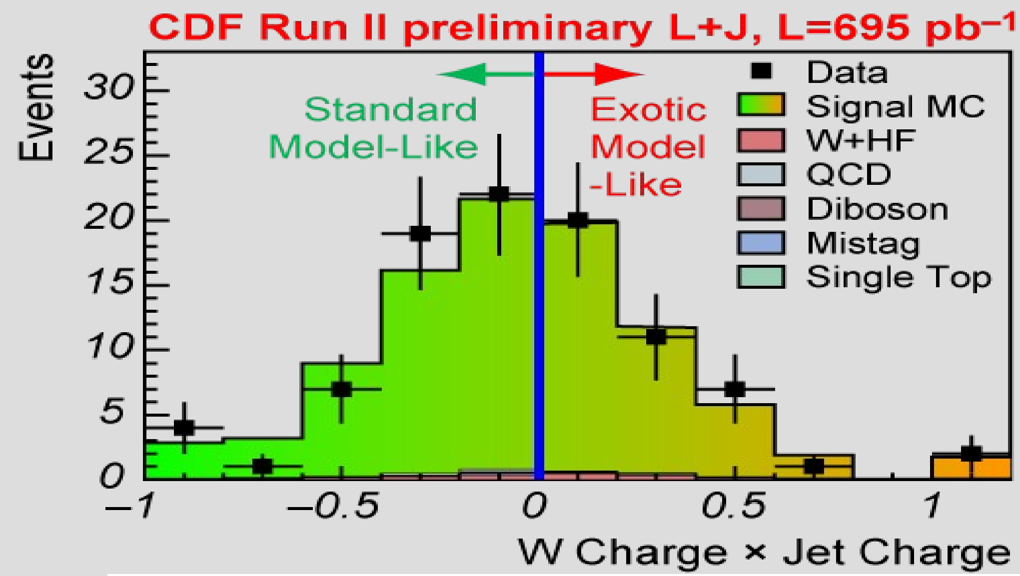


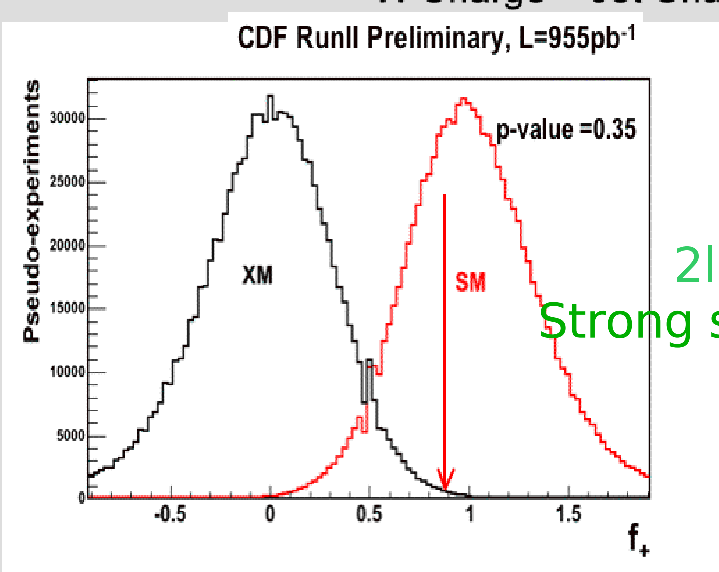
Observed

Yield	Observed	After Pairing	JQ defined	SM	XM
L + J	91	48	94 pairs	53	41
Dilepton	31	10	16 pairs	9	7
Total	122	58	110 pairs	62	48

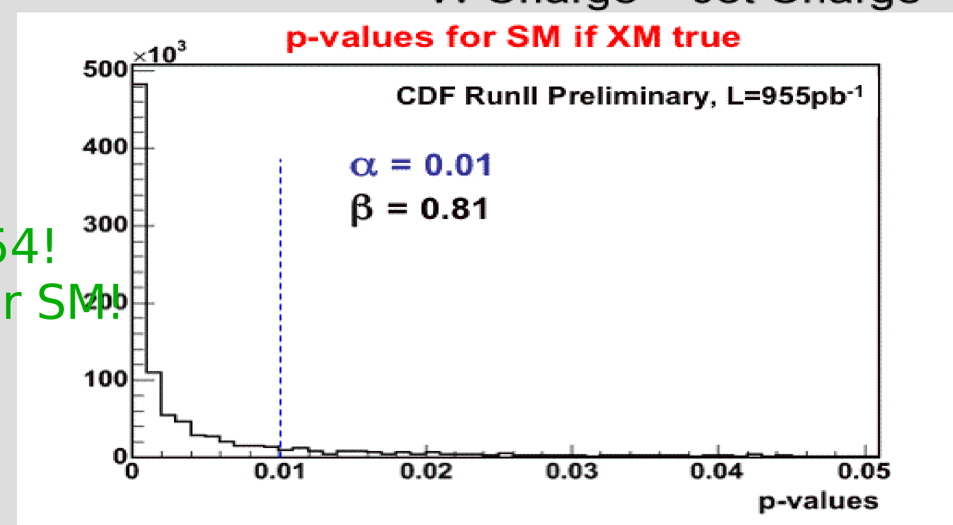
Final result





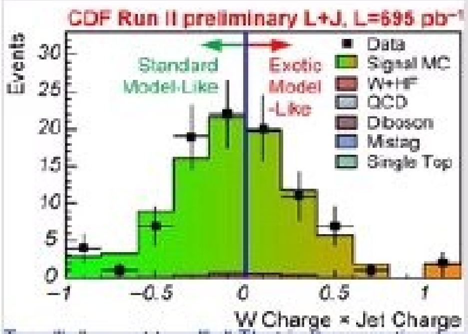


2ln(BF)=8.54!
Strong support for SM!



Fermilab Result of the Week

Charged on Top



To a "b," or not to a "b:" That is the question for the top quark. Shown is the product of the charge of the W and the associated b quark jet for candidate top quark decays. An excess of data in the exotic-like right-hand side could indicate that the top is not what we think it is. More details below(*).

Determining whether a jet of particles came from a b quark or an oppositely charged anti-b quark is at the heart of an existential question related to quarks: what is the true nature of the top quark? Since the top's discovery at the Tevatron more than 10 years ago, physicists have been asking themselves: Is this elusive particle really the top quark predicted by the Standard Model? Measuring its electric charge would help answer that question. According to the Standard Model, the top quark should have a charge of +2/3 and should decay to a W+ (charge +1) and a b quark (charge -1/3), while the anti-top should decay to a W- (charge -1) and an anti-b quark (charge +1/3).

The charge of the W can be obtained from the charge of the electron or muon it decays into, but what about distinguishing between a b quark and an anti-b quark? A team of CDF physicists answer this question by summing the charges of all the tracks inside a b jet. If the sum comes out positive, they assign the jet to an anti-b quark, and if it is negative, to a b quark. Using this algorithm, they estimate that they make the correct assignment about 60% of the time. This is a tough business!

The CDF physicists find that with about 1 inverse femtobarn of data, the Standard Model hypothesis for the top quark is strongly supported. This seems to indicate that this particle thought to be the top quark might indeed be the top quark...electrically speaking

(*)Continued from above: A perfectly reconstructed top or antitop quark would always have a negative value. Due to misreconstruction, about 60% of the time a correct assignment is expected to be made. In approximately 1fb-1 of data, CDF observed 62 negative and 48 positive events.

From left, top row: Stanislav Tokar (Comenius University, Bratislava), Kevin McFarland (University of Rochester), Jaroslav Antos (Slovak Academy of Science), and Kirsten Tollefson (Michigan State). Second and third rows, from left: Yen-Chu Chen (Academia Sinica), and Andy Beretvas (Fermilab); Zeynep Gunay Unalan (Michigan State University), and Peter Bednar (Comenius University, Bratislava). Bottom row, from left: Veronique Boisvert (University of Rochester), and Veronica Sorin (Michigan State University).

Update to 1.5 fb^{-1} !

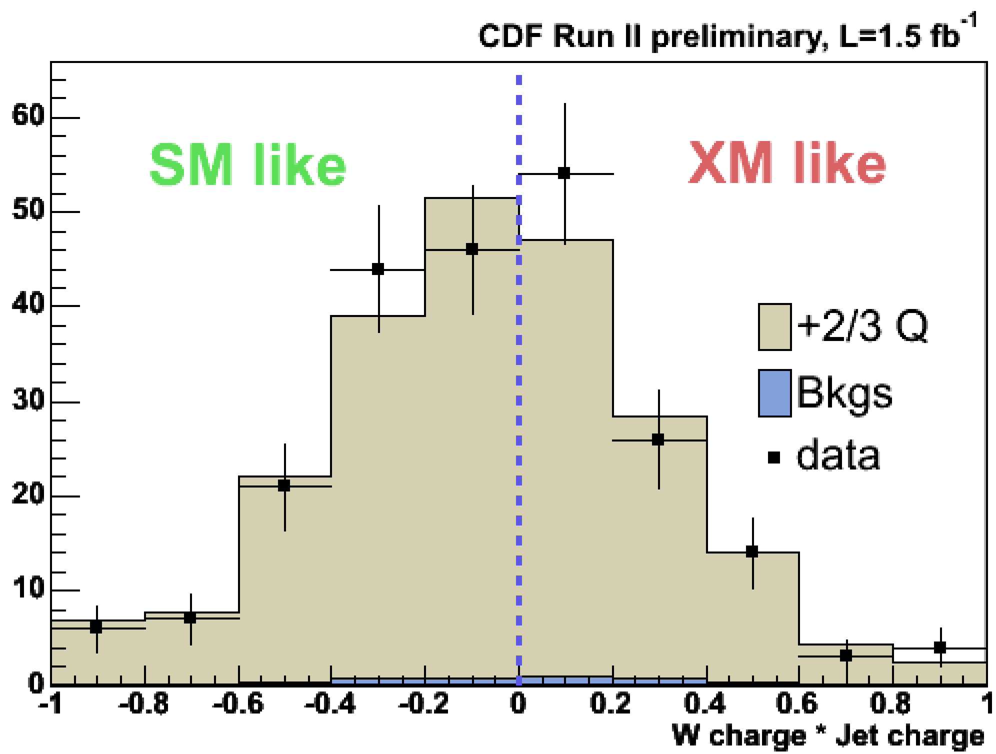
It would be may be a boring exercise if devil was sleeping …

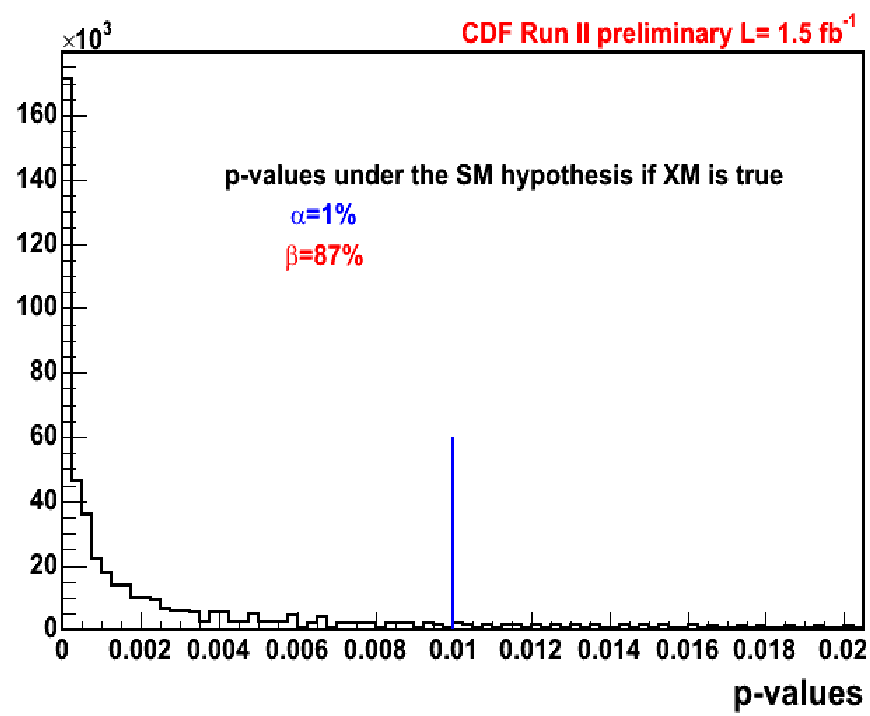
CDF Run II Preliminary L=1.5 fb^{-1}

Yield	Observed	After Pairing	JQ defined	SM	XM
L + J	193	102	199 pairs	111	88
Dilepton	44	14	26 pairs	13	13
Total	237	116	225 pairs	124	101

P-val=0.31

2ln(BF)=12.01 !





Conclussion

- *There is very strong support in 1.5 fb^{-1} of the CDF data for SM top!*
- *There is also seen something unusual and lets see what happens with at least factor 2 larger statistics!*