Di-leptons in 1 fb^{-1}

precision top mass measurement

Daniel Whiteson
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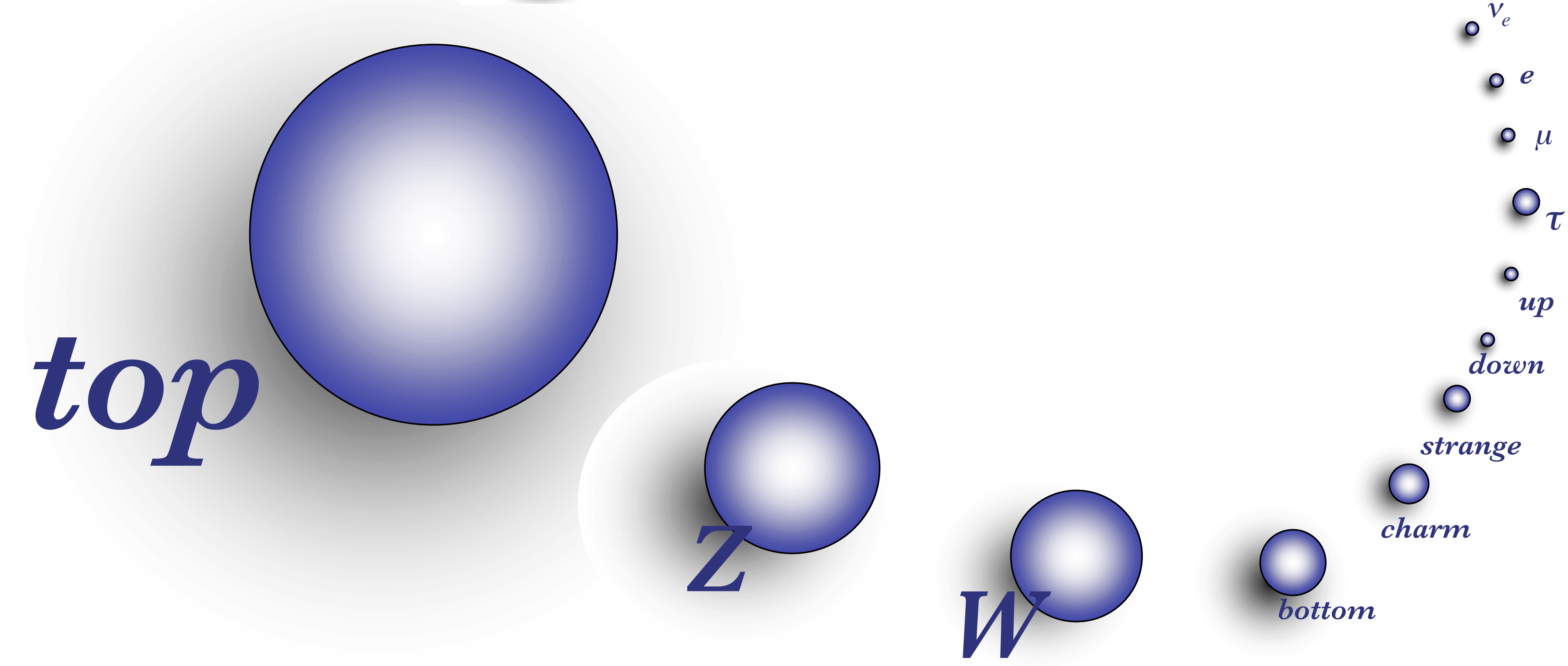
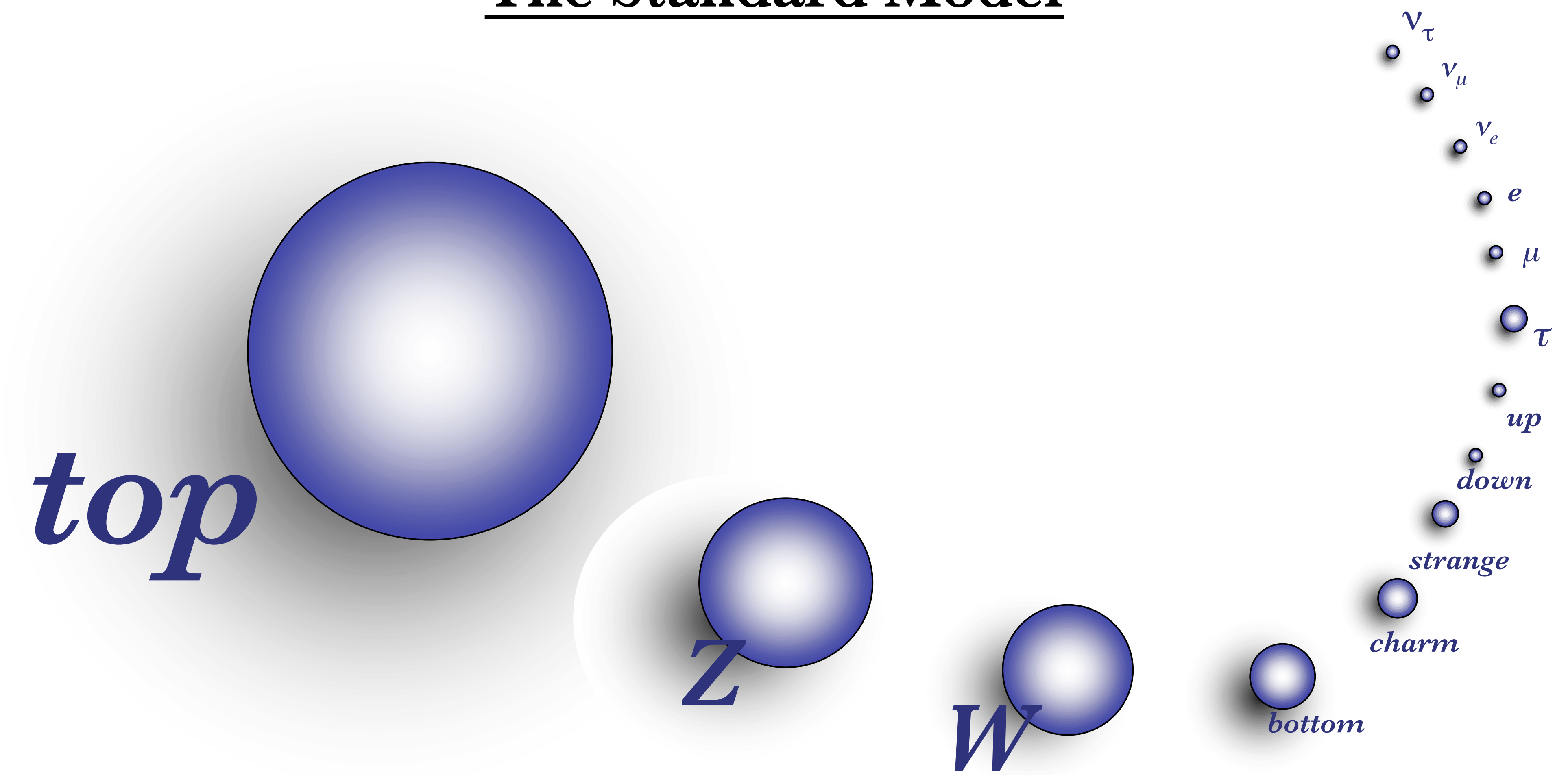


The Standard Model



State of the Art?

The Standard Model

$$-\frac{1}{2}\partial_\nu g^a_\mu \partial_\nu g^a_\mu - g_s f^{abc}\partial_\mu g^a_\nu g^b_\mu g^c_\nu - \frac{1}{4}g^2_s f^{abc}f^{ade}g^b_\mu g^c_\nu g^d_\mu g^e_\nu +$$
$$\frac{1}{2}ig^2_s(\bar{q}^\sigma_i\gamma^\mu q^\sigma_j)g^a_\mu + \bar{G}^a\partial^2G^a + g_s f^{abc}\partial_\mu\bar{G}^a G^b g^c_\mu - \partial_\nu W^+_\mu\partial_\nu W^-_\mu -$$
$$M^2 W^+_\mu W^-_\mu - \frac{1}{2}\partial_\nu Z^0_\mu\partial_\nu Z^0_\mu - \frac{1}{2c^2_w}M^2 Z^0_\mu Z^0_\mu - \frac{1}{2}\partial_\mu A_\nu\partial_\mu A_\nu - \frac{1}{2}\partial_\mu H\partial_\mu H -$$
$$\frac{1}{2}m^2_h H^2 - \partial_\mu\phi^+\partial_\mu\phi^- - M^2\phi^+\phi^- - \frac{1}{2}\partial_\mu\phi^0\partial_\mu\phi^0 - \frac{1}{2c^2_w}M\phi^0\phi^0 - \beta_h[\frac{2M^2}{g^2} +$$
$$\frac{2M}{g}H + \frac{1}{2}(H^2+\phi^0\phi^0+2\phi^+\phi^-)] + \frac{2M^4}{g^2}\alpha_h - igc_w[\partial_\nu Z^0_\mu(W^+_\mu W^-_\nu -$$
$$W^+_\nu W^-_\mu) - Z^0_\nu(W^+_\mu\partial_\nu W^-_\mu - W^-_\mu\partial_\nu W^+_\mu) + Z^0_\mu(W^+_\nu\partial_\nu W^-_\mu -$$
$$W^-_\nu\partial_\nu W^+_\mu)] - igs_w[\partial_\nu A_\mu(W^+_\mu W^-_\nu - W^+_\nu W^-_\mu) - A_\nu(W^+_\mu\partial_\nu W^-_\mu -$$
$$W^-_\mu\partial_\nu W^+_\mu) + A_\mu(W^+_\nu\partial_\nu W^-_\mu - W^-_\nu\partial_\nu W^+_\mu)] - \frac{1}{2}g^2 W^+_\mu W^-_\mu W^+_\nu W^-_\nu +$$
$$\frac{1}{2}g^2 W^+_\mu W^-_\nu W^+_\mu W^-_\nu + g^2c^2_w(Z^0_\mu W^+_\mu Z^0_\nu W^-_\nu - Z^0_\mu Z^0_\mu W^+_\nu W^-_\nu) +$$
$$g^2s^2_w(A_\mu W^+_\mu A_\nu W^-_\nu - A_\mu A_\mu W^+_\nu W^-_\nu) + g^2s_wc_w[A_\mu Z^0_\nu(W^+_\mu W^-_\nu -$$
$$W^+_\nu W^-_\mu) - 2A_\mu Z^0_\mu W^+_\nu W^-_\nu] - g\alpha[H^3 + H\phi^0\phi^0 + 2H\phi^+\phi^-] -$$
$$\frac{1}{8}g^2\alpha_h[H^4 + (\phi^0)^4 + 4(\phi^+\phi^-)^2 + 4(\phi^0)^2\phi^+\phi^- + 4H^2\phi^+\phi^- + 2(\phi^0)^2H^2] -$$
$$gMW^+_\mu W^-_\mu H - \frac{1}{2}g\frac{M}{c^2_w}Z^0_\mu Z^0_\mu H - \frac{1}{2}ig[W^+_\mu(\phi^0\partial_\mu\phi^- - \phi^-\partial_\mu\phi^0) -$$
$$W^-_\mu(\phi^0\partial_\mu\phi^+ - \phi^+\partial_\mu\phi^0)] + \frac{1}{2}g[W^+_\mu(H\partial_\mu\phi^- - \phi^-\partial_\mu H) - W^-_\mu(H\partial_\mu\phi^+ -$$
$$\phi^+\partial_\mu H)] + \frac{1}{2}g\frac{1}{c_w}(Z^0_\mu(H\partial_\mu\phi^0 - \phi^0\partial_\mu H) - ig\frac{s^2_w}{c_w}MZ^0_\mu(W^+_\mu\phi^- - W^-_\mu\phi^+) +$$
$$igs_wMA_\mu(W^+_\mu\phi^- - W^-_\mu\phi^+) - ig\frac{1-2c^2_w}{2c_w}Z^0_\mu(\phi^+\partial_\mu\phi^- - \phi^-\partial_\mu\phi^+) +$$
$$igs_wA_\mu(\phi^+\partial_\mu\phi^- - \phi^-\partial_\mu\phi^+) - \frac{1}{4}g^2W^+_\mu W^-_\mu[H^2 + (\phi^0)^2 + 2\phi^+\phi^-] -$$
$$\frac{1}{4}g^2\frac{1}{c^2_w}Z^0_\mu Z^0_\mu[H^2 + (\phi^0)^2 + 2(2s^2_w-1)^2\phi^+\phi^-] - \frac{1}{2}g^2\frac{s^2_w}{c_w}Z^0_\mu\phi^0(W^+_\mu\phi^- +$$
$$W^-_\mu\phi^+) - \frac{1}{2}ig^2\frac{s^2_w}{c_w}Z^0_\mu H(W^+_\mu\phi^- - W^-_\mu\phi^+) + \frac{1}{2}g^2s_wA_\mu\phi^0(W^+_\mu\phi^- +$$
$$W^-_\mu\phi^+) + \frac{1}{2}ig^2s_wA_\mu H(W^+_\mu\phi^- - W^-_\mu\phi^+) - g^2\frac{s_w}{c_w}(2c^2_w-1)Z^0_\mu A_\mu\phi^+\phi^- -$$
$$g^1 s^2_w A_\mu A_\mu\phi^+\phi^- - \bar{e}^\lambda(\gamma\partial + m^\lambda_e)e^\lambda - \bar{\nu}^\lambda\gamma\partial\nu^\lambda - \bar{u}^\lambda_j(\gamma\partial + m^\lambda_u)u^\lambda_j -$$
$$\bar{d}^\lambda_j(\gamma\partial + m^\lambda_d)d^\lambda_j + igs_wA_\mu[-(\bar{e}^\lambda\gamma^\mu e^\lambda) + \frac{2}{3}(\bar{u}^\lambda_j\gamma^\mu u^\lambda_j) - \frac{1}{3}(\bar{d}^\lambda_j\gamma^\mu d^\lambda_j)] +$$
$$\frac{ig}{4c_w}Z^0_\mu[(\bar{\nu}^\lambda\gamma^\mu(1+\gamma^5)\nu^\lambda) + (\bar{e}^\lambda\gamma^\mu(4s^2_w - 1 - \gamma^5)e^\lambda) + (\bar{u}^\lambda_j\gamma^\mu(\frac{4}{3}s^2_w -$$
$$1 - \gamma^5)u^\lambda_j) + (\bar{d}^\lambda_j\gamma^\mu(1 - \frac{8}{3}s^2_w - \gamma^5)d^\lambda_j)] + \frac{ig}{2\sqrt{2}}W^+_\mu[(\bar{\nu}^\lambda\gamma^\mu(1+\gamma^5)e^\lambda) +$$
$$(\bar{u}^\lambda_j\gamma^\mu(1+\gamma^5)C_{\lambda\kappa}d^\kappa_j)] + \frac{ig}{2\sqrt{2}}W^-_\mu[(\bar{e}^\lambda\gamma^\mu(1+\gamma^5)\nu^\lambda) + (\bar{d}^\kappa_j C^\dagger_{\lambda\kappa}\gamma^\mu(1+$$
$$\gamma^5)u^\lambda_j)] + \frac{ig}{2\sqrt{2}}\frac{m^\lambda_e}{M}[-\phi^+(\bar{\nu}^\lambda(1-\gamma^5)e^\lambda) + \phi^-(\bar{e}^\lambda(1+\gamma^5)\nu^\lambda)] -$$
$$\frac{g}{2}\frac{m^\lambda_e}{M}[H(\bar{e}^\lambda e^\lambda) + i\phi^0(\bar{e}^\lambda\gamma^5 e^\lambda)] + \frac{ig}{2M\sqrt{2}}\phi^+[-m^\kappa_d(\bar{u}^\lambda_j C_{\lambda\kappa}(1-\gamma^5)d^\kappa_j) +$$
$$m^\lambda_u(\bar{u}^\lambda_j C_{\lambda\kappa}(1+\gamma^5)d^\kappa_j] + \frac{ig}{2M\sqrt{2}}\phi^-[m^\lambda_d(\bar{d}^\lambda_j C^\dagger_{\lambda\kappa}(1+\gamma^5)u^\kappa_j) - m^\kappa_u(\bar{d}^\lambda_j C^\dagger_{\lambda\kappa}(1-$$
$$\gamma^5)u^\kappa_j] - \frac{g}{2}\frac{m^\lambda_u}{M}H(\bar{u}^\lambda_j u^\lambda_j) - \frac{g}{2}\frac{m^\lambda_d}{M}H(\bar{d}^\lambda_j d^\lambda_j) + \frac{ig}{2}\frac{m^\lambda_u}{M}\phi^0(\bar{u}^\lambda_j\gamma^5 u^\lambda_j) -$$
$$\frac{ig}{2}\frac{m^\lambda_d}{M}\phi^0(\bar{d}^\lambda_j\gamma^5 d^\lambda_j) + \bar{X}^+(\partial^2 - M^2)X^+ + \bar{X}^-(\partial^2 - M^2)X^- + \bar{X}^0(\partial^2 -$$
$$\frac{M^2}{c^2_w})X^0 + \bar{Y}\partial^2 Y + igc_wW^+_\mu(\partial_\mu\bar{X}^0X^- - \partial_\mu\bar{X}^+X^0) + igs_wW^+_\mu(\partial_\mu\bar{Y}X^- -$$
$$\partial_\mu\bar{X}^+Y) + igc_wW^-_\mu(\partial_\mu\bar{X}^-X^0 - \partial_\mu\bar{X}^0X^+) + igs_wW^-_\mu(\partial_\mu\bar{X}^-Y -$$
$$\partial_\mu\bar{Y}X^+) + igc_wZ^0_\mu(\partial_\mu\bar{X}^+X^+ - \partial_\mu\bar{X}^-X^-) + igs_wA_\mu(\partial_\mu\bar{X}^+X^+ -$$
$$\partial_\mu\bar{X}^-X^-) - \frac{1}{2}gM[\bar{X}^+X^+H + \bar{X}^-X^-H + \frac{1}{c^2_w}\bar{X}^0X^0H] +$$
$$\frac{1-2c^2_w}{2c_w}igM[\bar{X}^+X^0\phi^+ - \bar{X}^-X^0\phi^-] + \frac{1}{2c_w}igM[\bar{X}^0X^-\phi^+ - \bar{X}^0X^+\phi^-] +$$
$$igMs_w[\bar{X}^0X^-\phi^+ - \bar{X}^0X^+\phi^-] + \frac{1}{2}igM[\bar{X}^+X^+\phi^0 - \bar{X}^-X^-\phi^0]$$

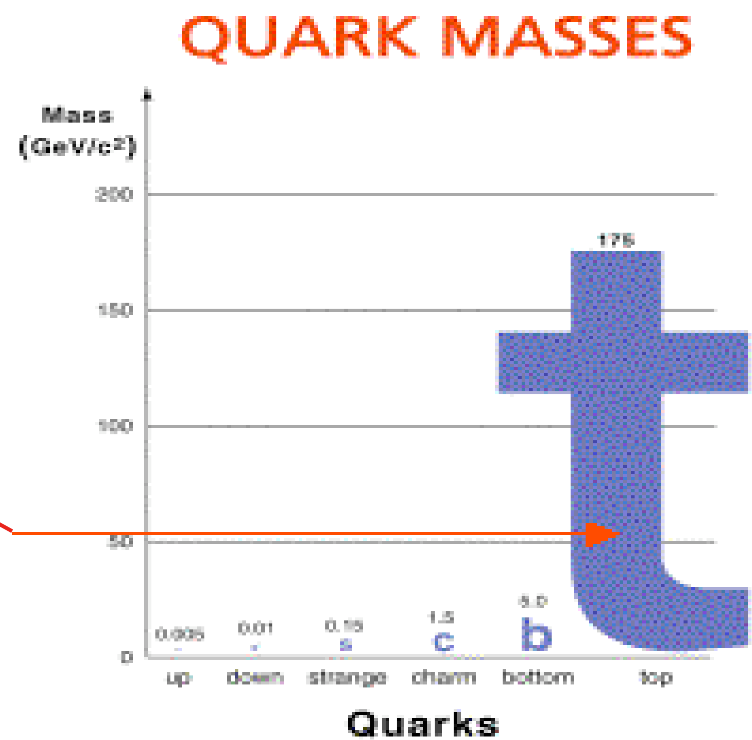
The Standard Model

The theoretical machinery is very effective and often beautiful…

…but its rather unlikely to be the simplest description.

Top Quark

What are the clues to an underlying simplicity?



Where does this mass structure come from?

What does it reveal?

Why is the top so heavy?

Why is its Yukawa coupling ~ 1 ?

Is it really the SM top we are seeing?

Are the observed top quark candidates due solely to SM top?

Outline

- **Di-lepton sample**
  - **Laboratory for electroweak, top and new physics**

- **Top quark di-lepton decays**
  - **Fermilab Tevatron and CDF**
  - **Cross section measurement**

- **Precision mass measurements**
  - **Novel application of a powerful technique**

- **Result**
  - **Impact and Conclusions**

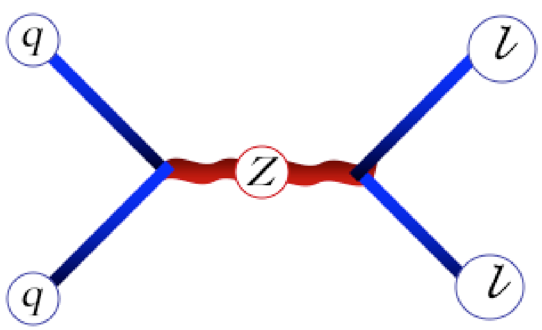
Leptons at Colliders

Critical handles
Reject QCD background

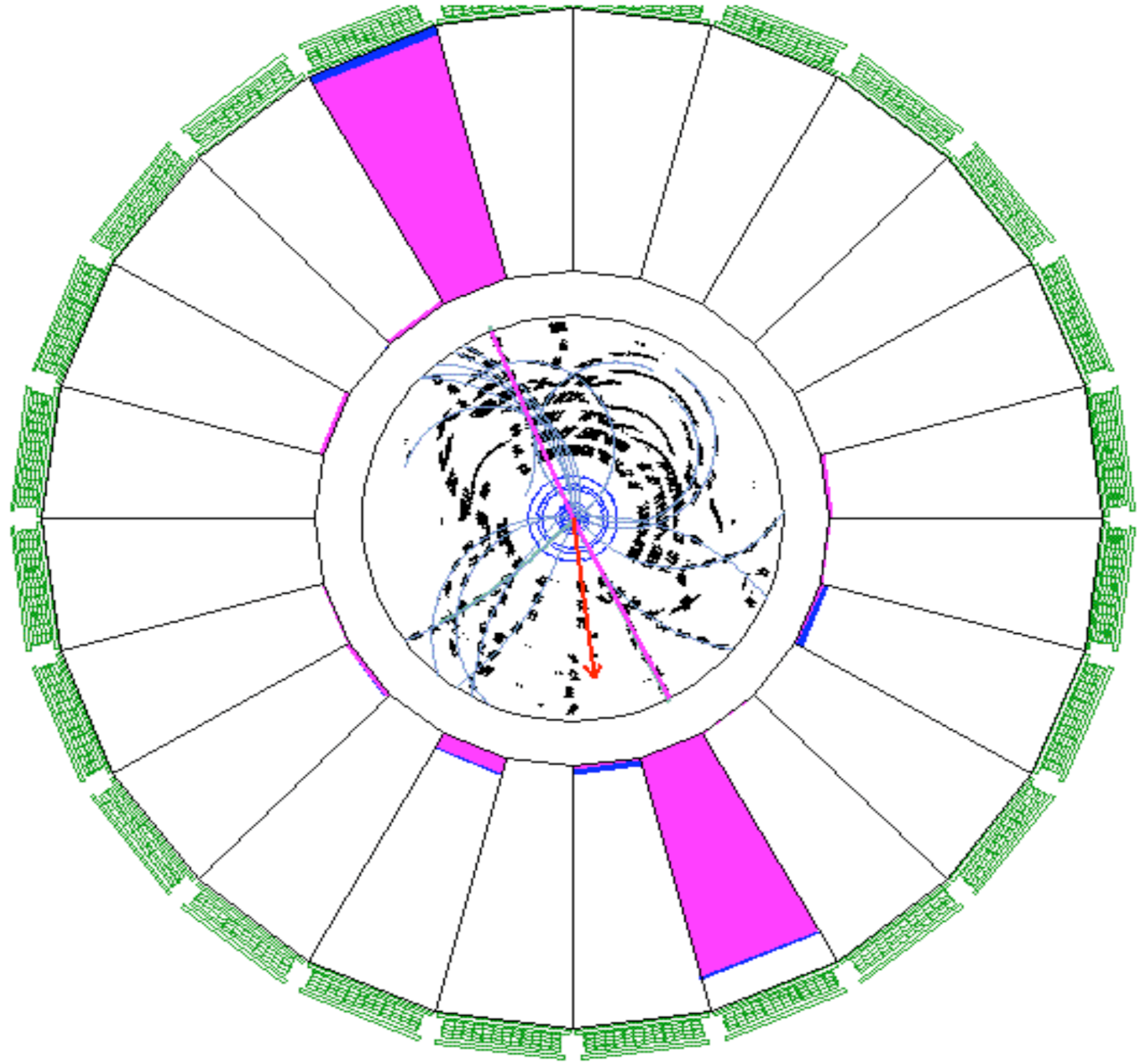
Well known standard candles
of leptonic production

Signature of important
physics

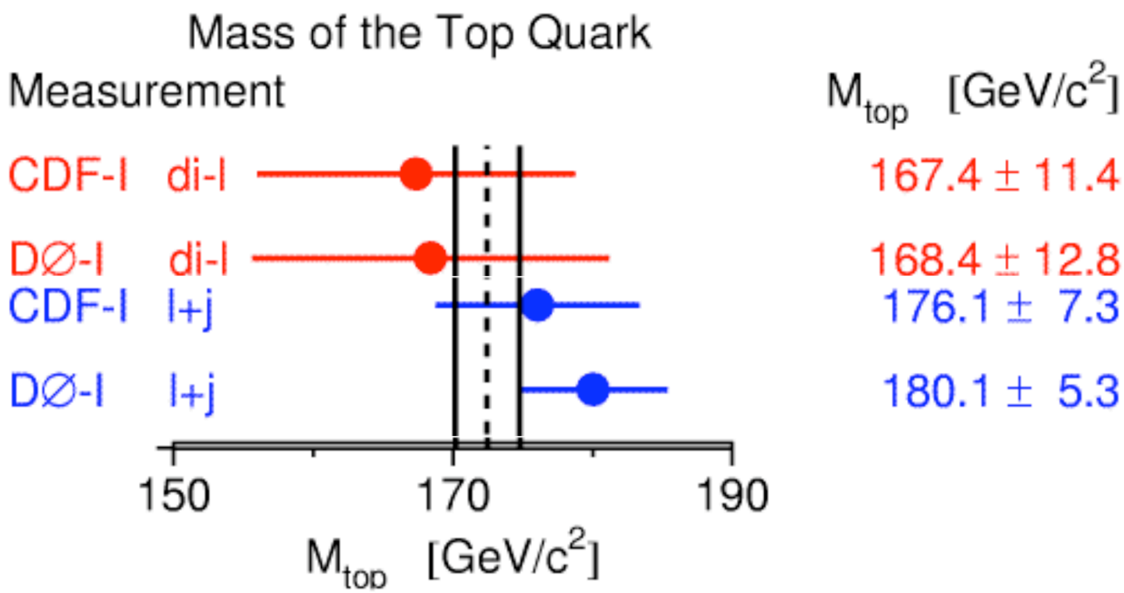
Leptons are excellent probes
Good coverage
Difficult to fake
Excellent resolution



$Z \rightarrow ee$ event at CDF



Top mass in Run 1



Mass in di-lepton channel appeared low, but statistical error was large.

Outline

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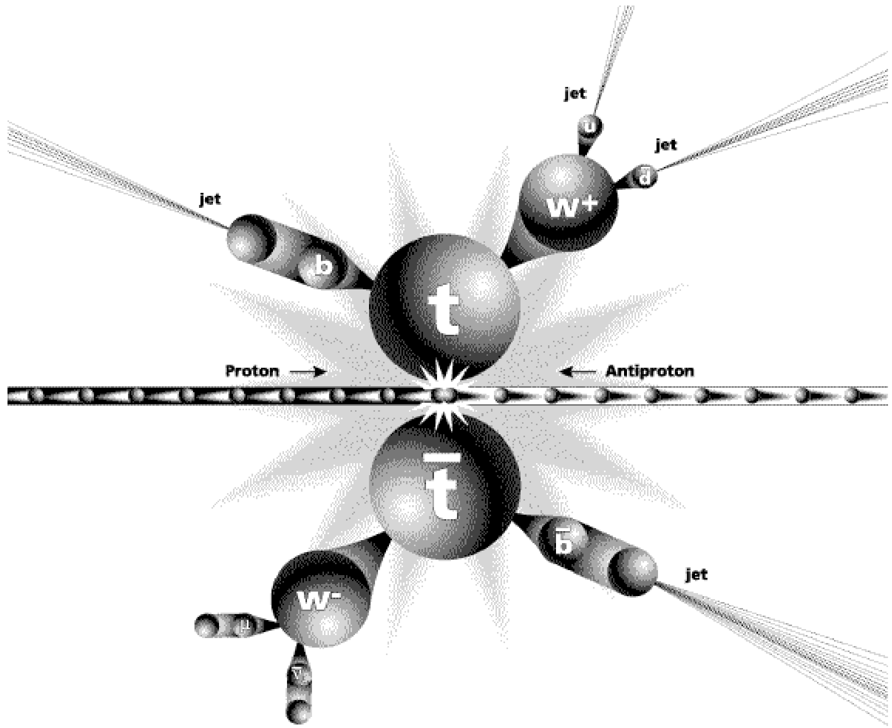
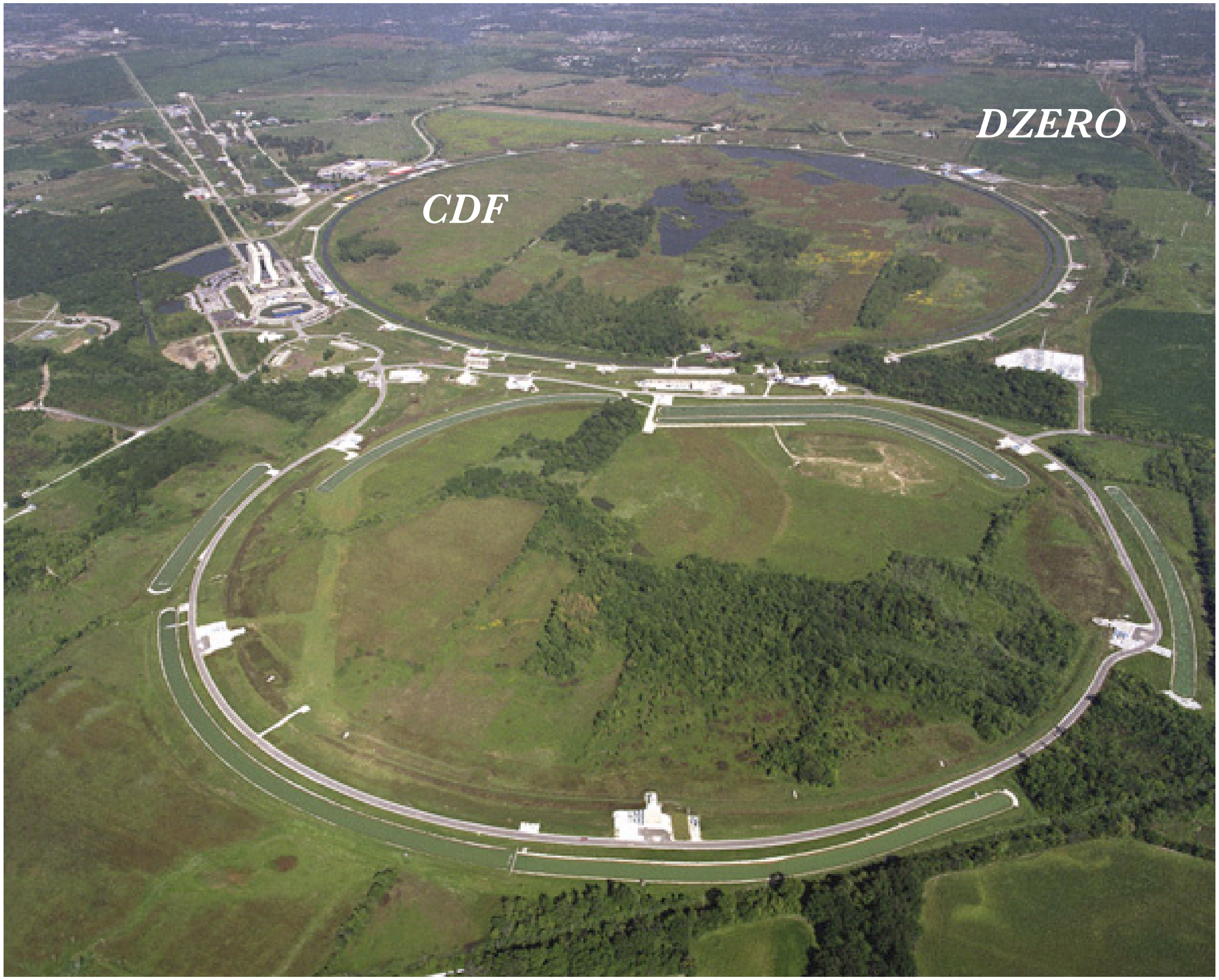
Top Quark Production

The FermiLab Tevatron has a monopoly on top quark observation



Tevatron

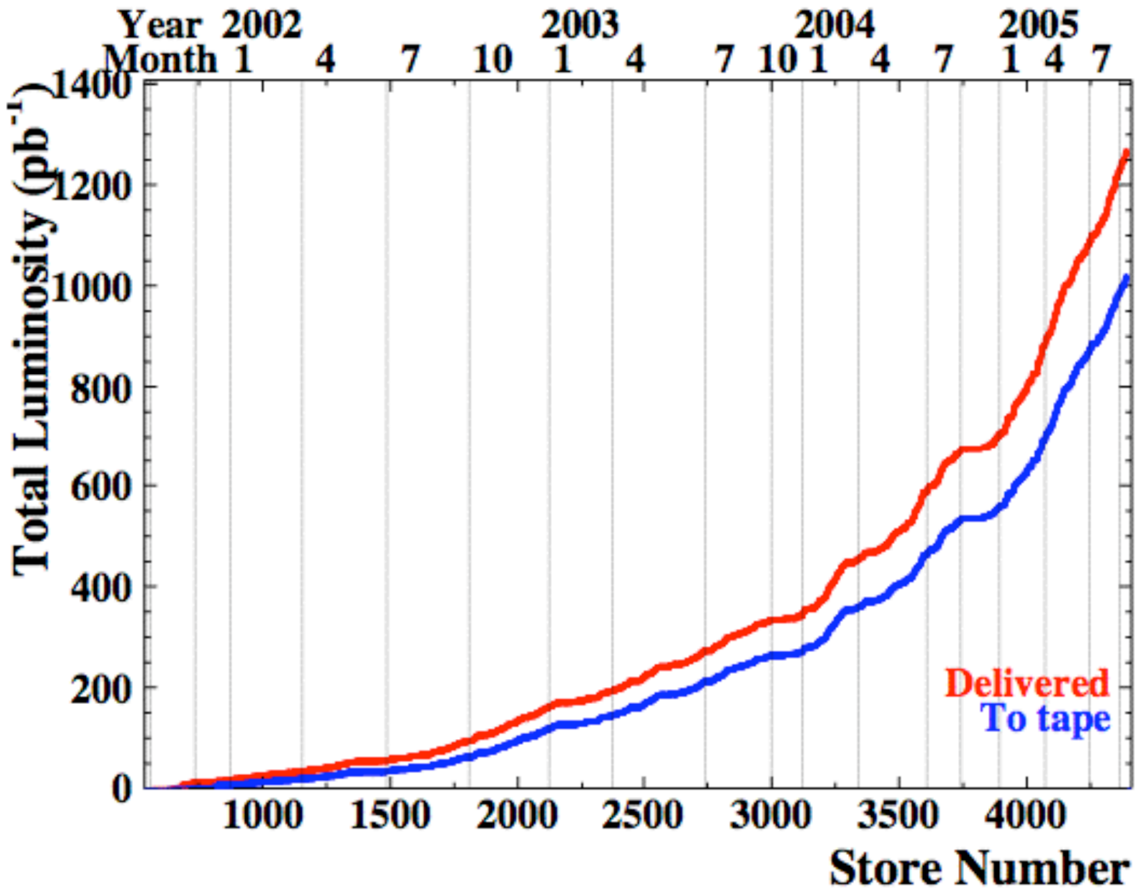


The frontier

Highest energy

Highest statistics

High Statistics



Dataset

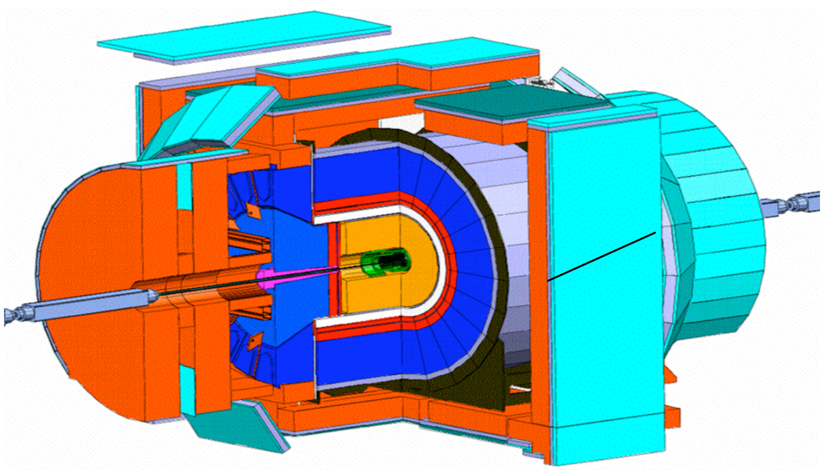
Run 1: 100 pb^{-1}

These results: 1000 pb^{-1}

Summer 2007: 2000 pb^{-1}

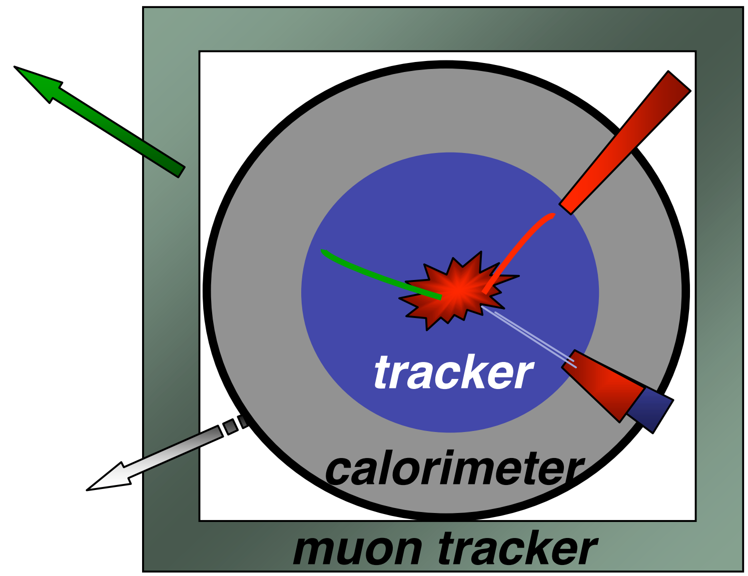
CDF for Run2

CDF II



muon
Muon track
Central track

electron
EM shower
Central track

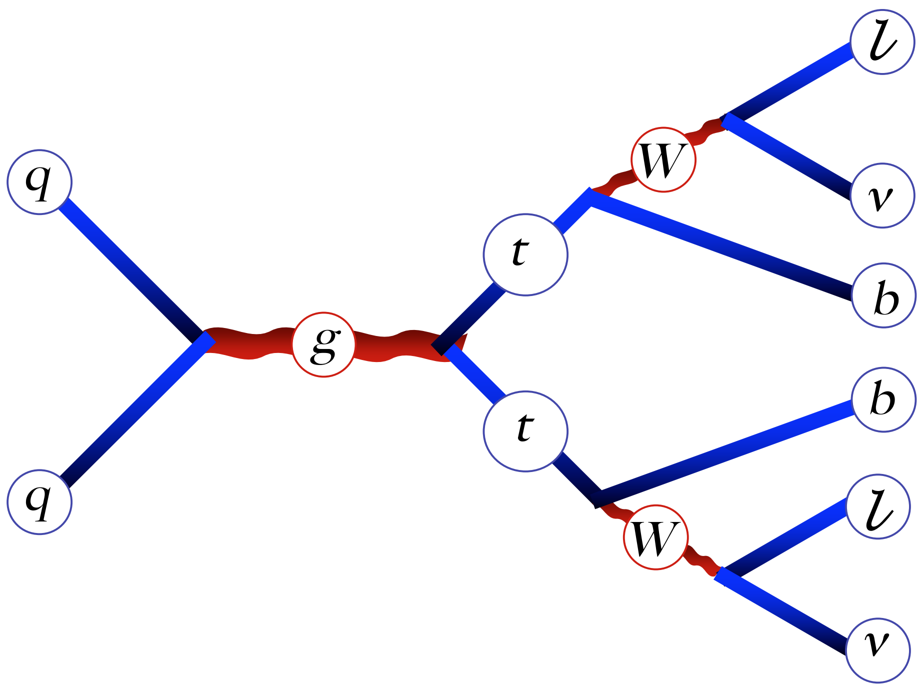


E_T
Missing Energy

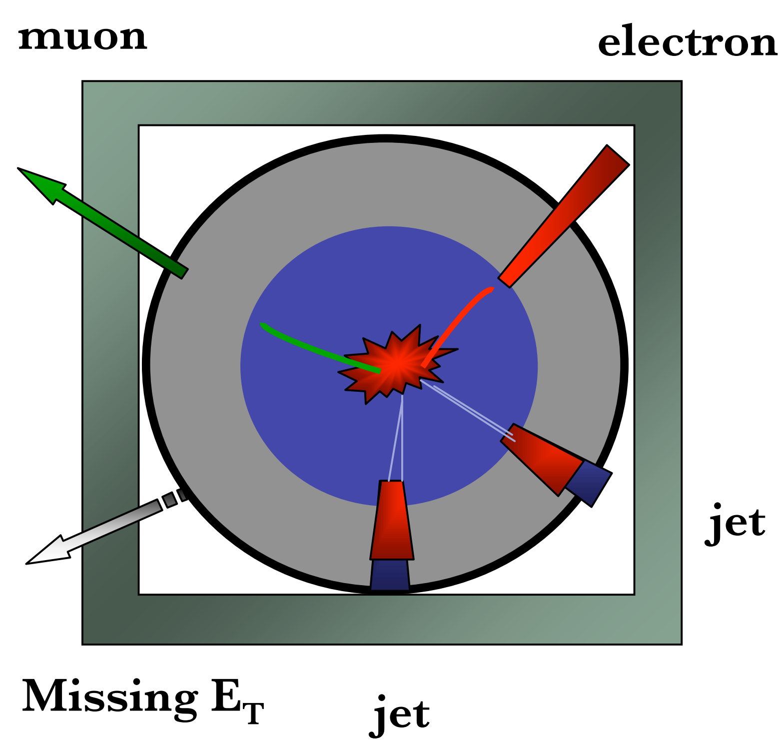
Jets
EM and hadronic showers

Top quark production

Production Process

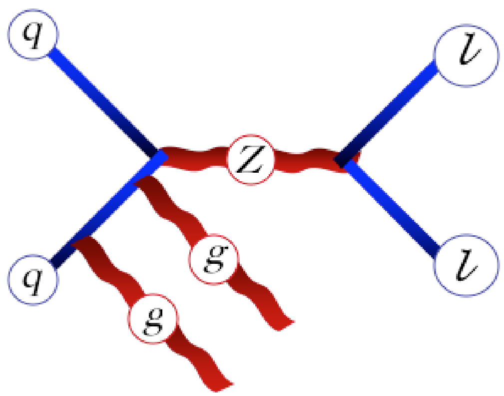


Detector Signature



Other standard model processes

Drell-Yan

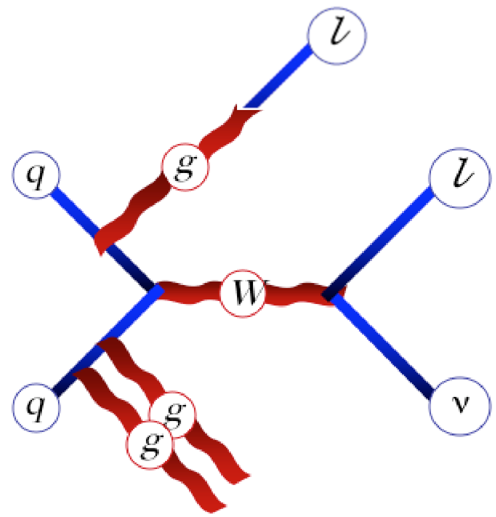


Reduce by requiring

Large missing E_T

Large $\sum E_T$

Misidentified Lepton

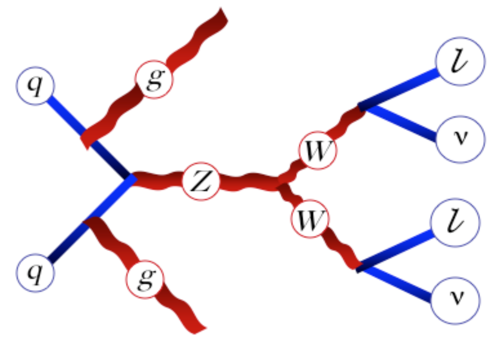


Reduce by requiring

Isolated lepton

Large $\sum E_T$

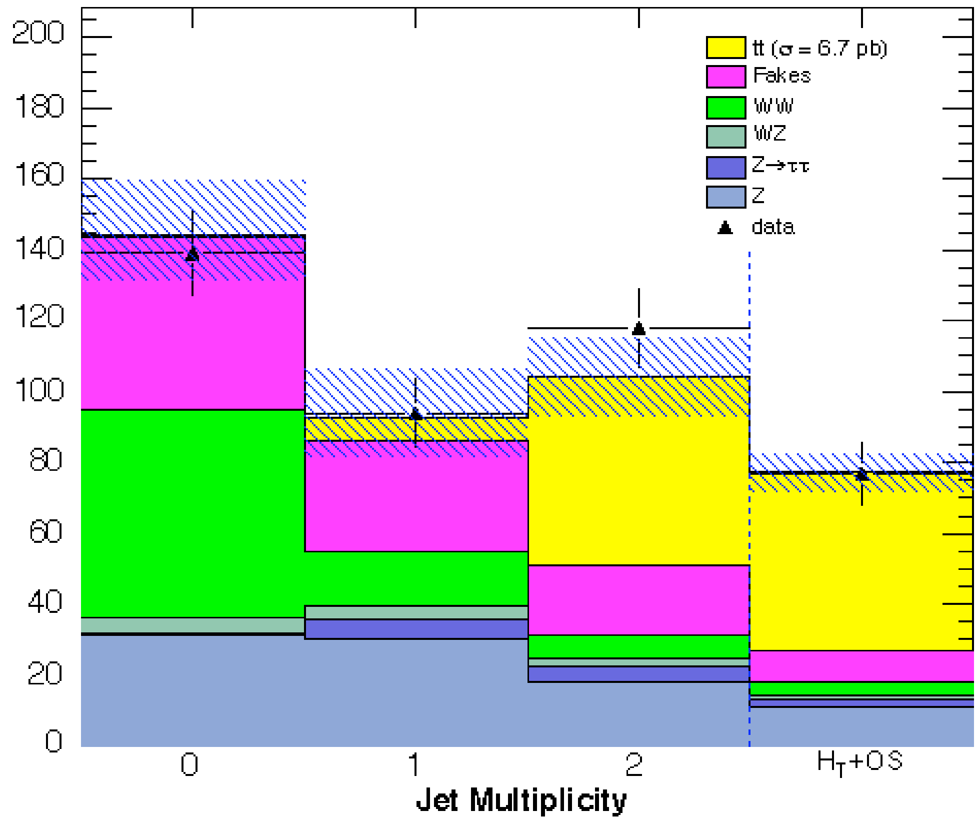
WW



Reduce by requiring

Large $\sum E_T$

Cross-section



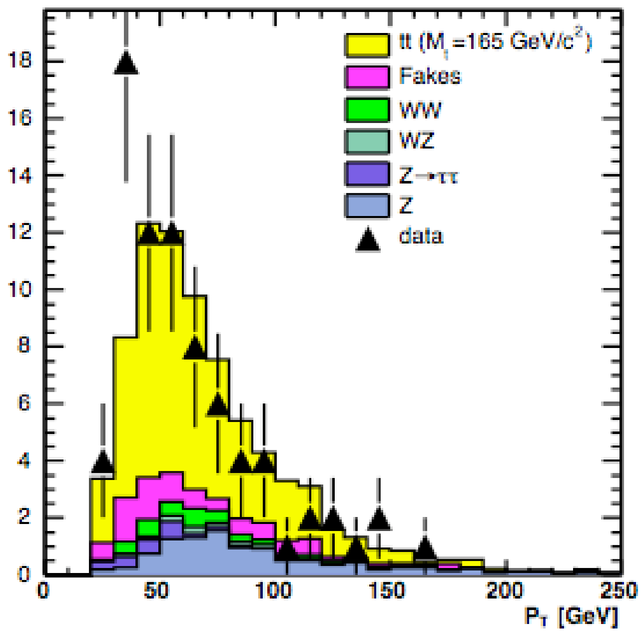
Sample	N_{events}
tt (M_t=175, σ = 6.7 pb)	50.2
Z →*ee/μμ*	10.9
MisID lepton	8.7
WW, WZ	5.0
Z → ττ	2.2
Total	77.1 ± 2.1
Observed	**78**

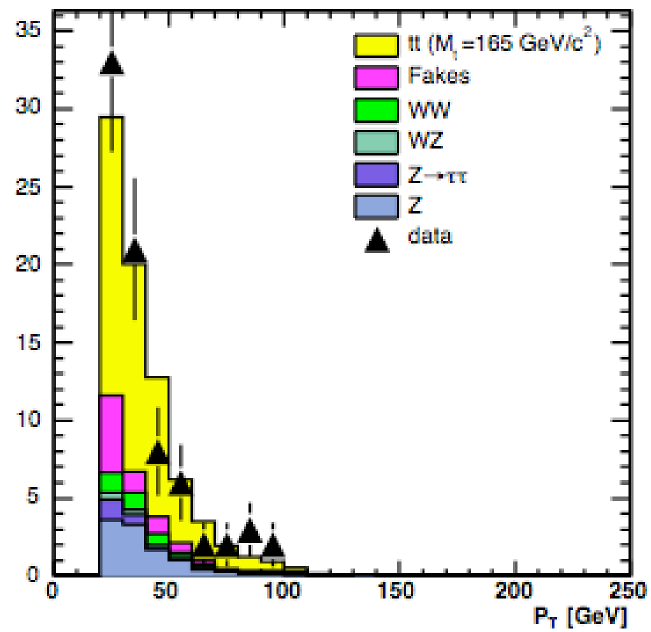
$$\sigma = 6.7 \pm 1.0_{(stat)} \pm 1.1_{(syst)}$$

**Speaker's unofficial calculation*

Kinematics

Cross-section is a counting experiment, sensitive only to thresholds.





Want to examine the kinematics, to see whether events are consistent with *tt*

Outline

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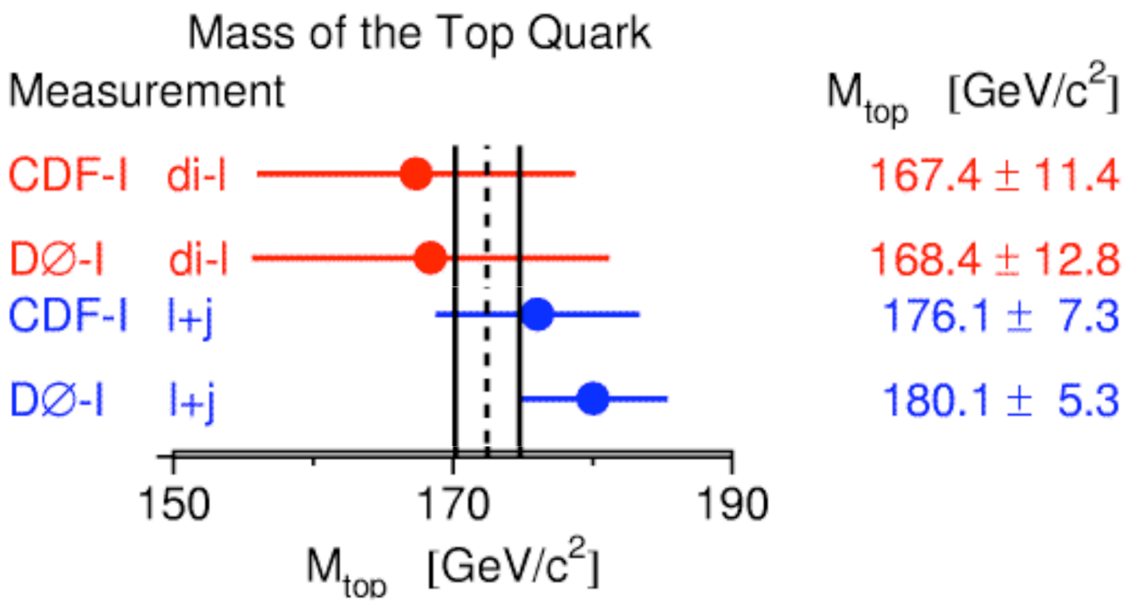
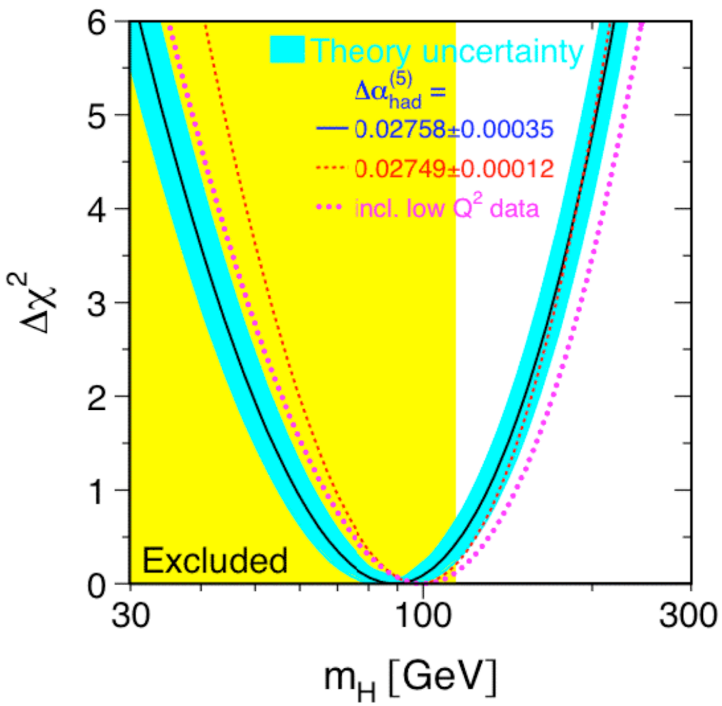
  - Fermilab Tevatron and CDF
  - Cross section measurement
- **Precision mass measurements**
  - Novel application of a powerful technique
- Result
  - Impact and Conclusions

Top mass in Run 1



Mass in dilepton channel appeared low, but statistical error was large.

Higgs

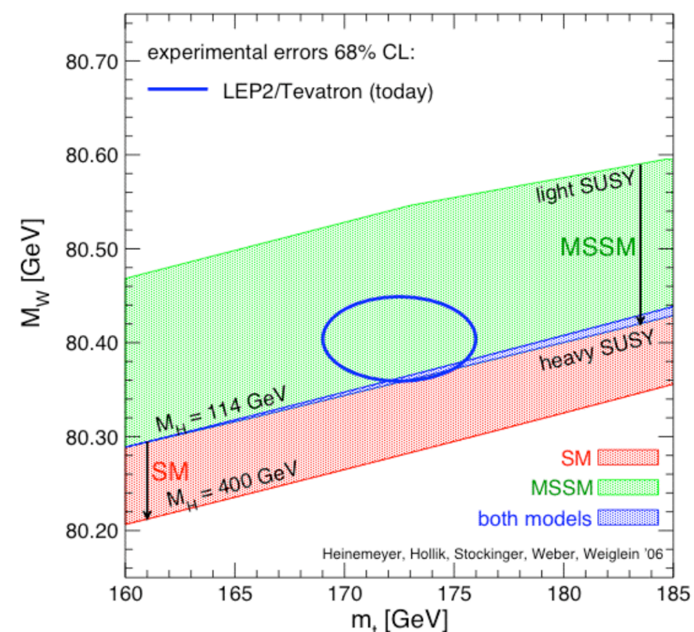


Higgs connection

Radiative correction to M_h via top loop

Heavy top means heavy Higgs

M_t provides constraints on M_h



Standard Model extensions

Top appears in many loops

Helps constrain SM extensions

How to measure mass

How do we measure the mass?

Can't just put the pieces back together again

Lost information

- Neutrinos have escaped undetected

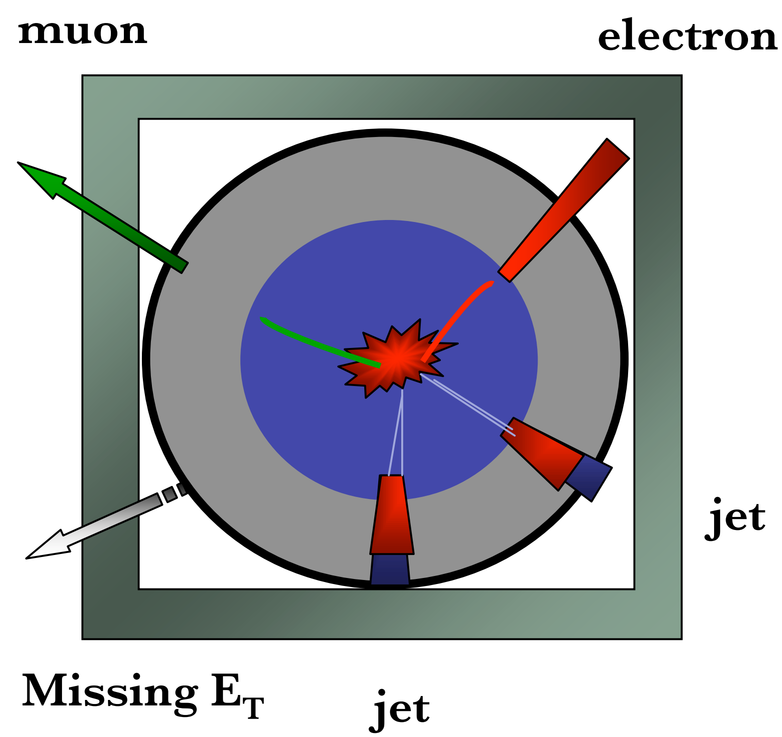
- Quarks have hadronized, showered, been clustered into *jets*

-Assignment of reconstructed objects to partons is not obvious

-Lepton resolution is good, but not perfect

Misinformation

-Background processes mimic top-ology



The Matrix-Element approach

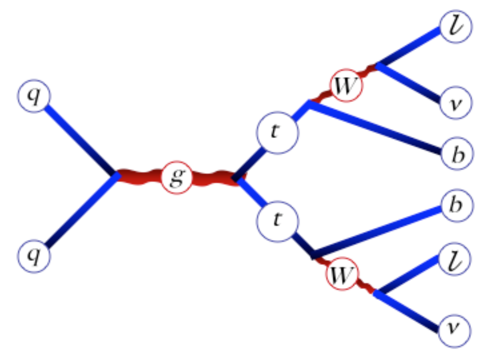
Context

Pioneered in Run1 by D0 for single lepton channel

Advantages

Direct test of *tt* hypothesis

Encode our knowledge
& assumptions transparently



Maximal statistical power

Use all information
Squeeze every correlation
Weigh well-measured events more heavily

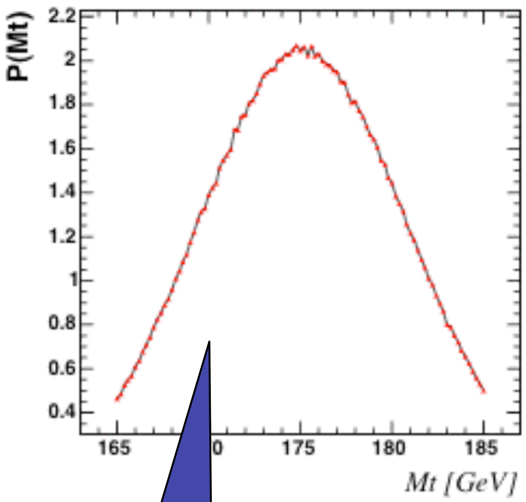
Difficulties

Complex numerical integration

Never applied to any other channel: *many new challenges*

Method

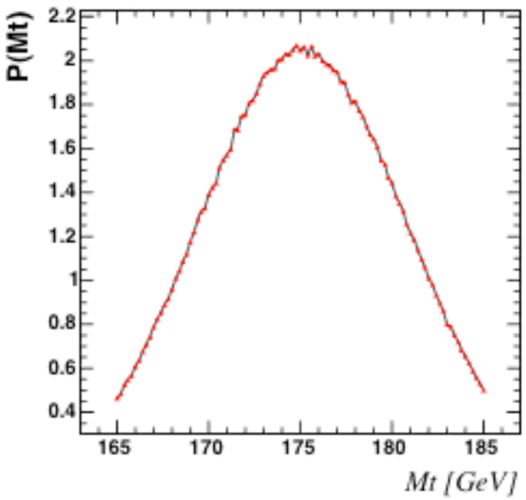
$$P\,(\,\textit{event } x \mid M_t)\quad :$$



*Each event has a **curve**, rather than a single **mass value***

Method

$$P\,(\,event\ x\mid M_t)\ :$$



$$= \frac{1}{\sigma(M_t)} \frac{d\sigma(M_t)}{d\mathbf{x}}$$

Direct Calculation

Differential cross-section calculation:

$$\frac{d\sigma(M_t)}{d\mathrm{x}} = \int d\Phi \; |\mathcal{M}_{t\bar{t}}(p; M_t)|^2 f_{PDF}(q_1) f_{PDF}(q_2)$$

Phase-space Integral

Matrix Element

But there is no reference to our measured quantities *x*!

Direct Calculation

Differential cross-section calculation:

$$\frac{d\sigma(M_t)}{d\mathbf{x}} = \int d\Phi \; |\mathcal{M}_{t\bar{t}}(p; M_t)|^2 \; P(\mathbf{x}|\, p) \; f_{PDF}(q_1) f_{PDF}(q_2)$$

Phase-space Integral

Matrix Element

Parton-to-Detector Transfer Function

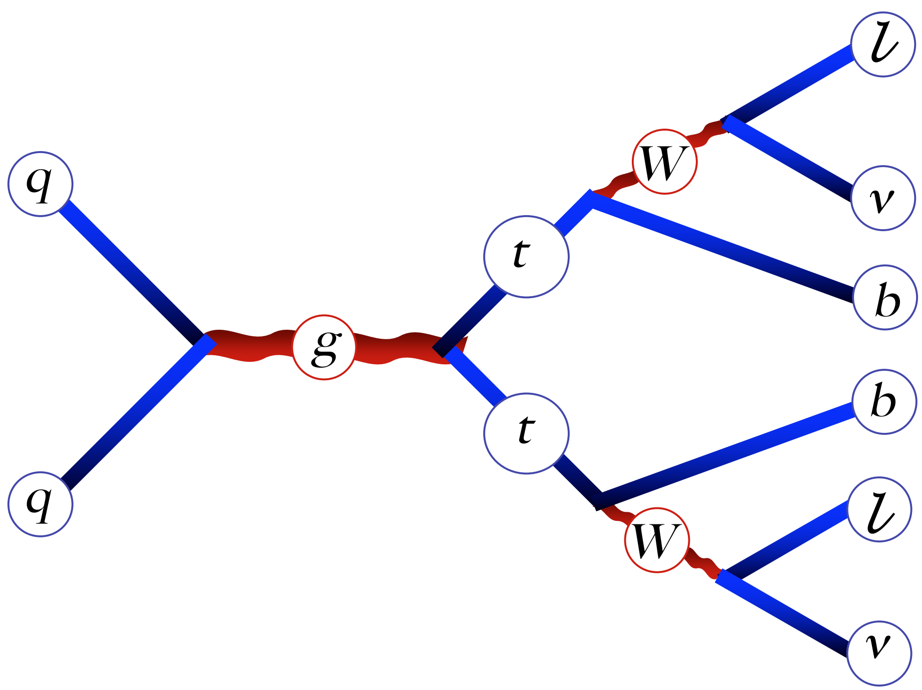
The problem

To compute this integral, we need a description of

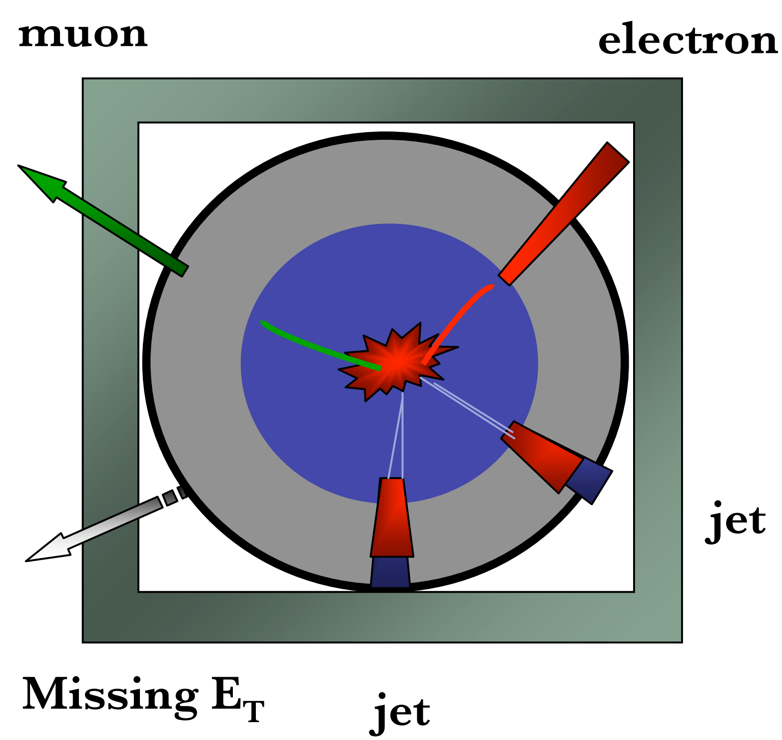
P(observe event x | parton configuration y)

Which is usually computed numerically via Monte Carlo

Parton level



Detector level



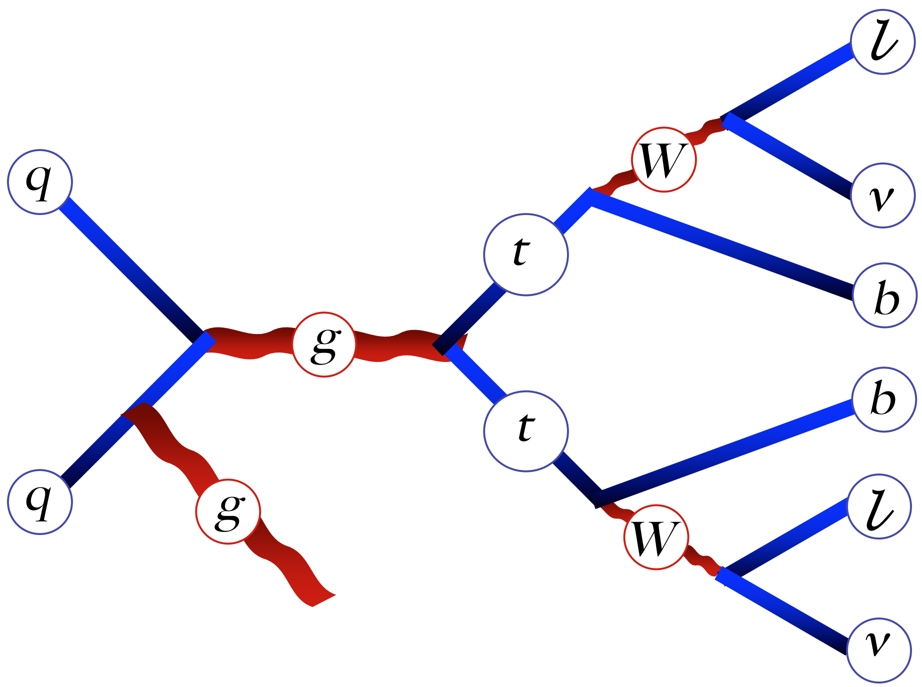
Model

Interpret events in *tt* hypothesis

Leptons

Energy and angle well measured

$P(x|p) = \delta(x-p)$



Initial state

Initial state gluon radiation

tt system may have p_T

Jets

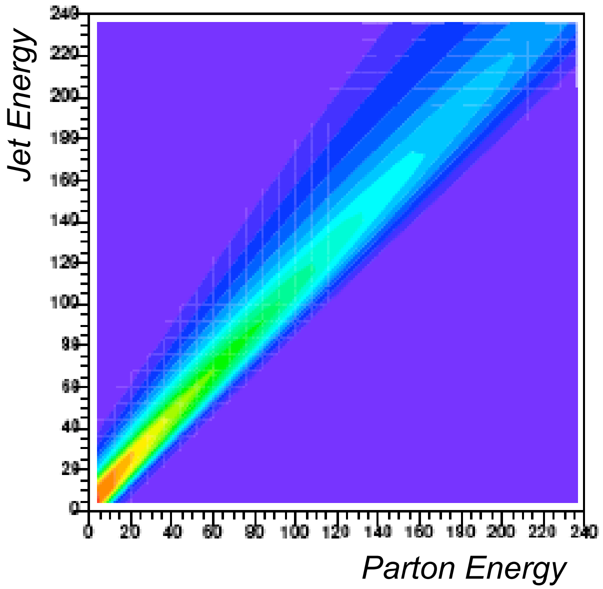
Leading jets are *b*'s

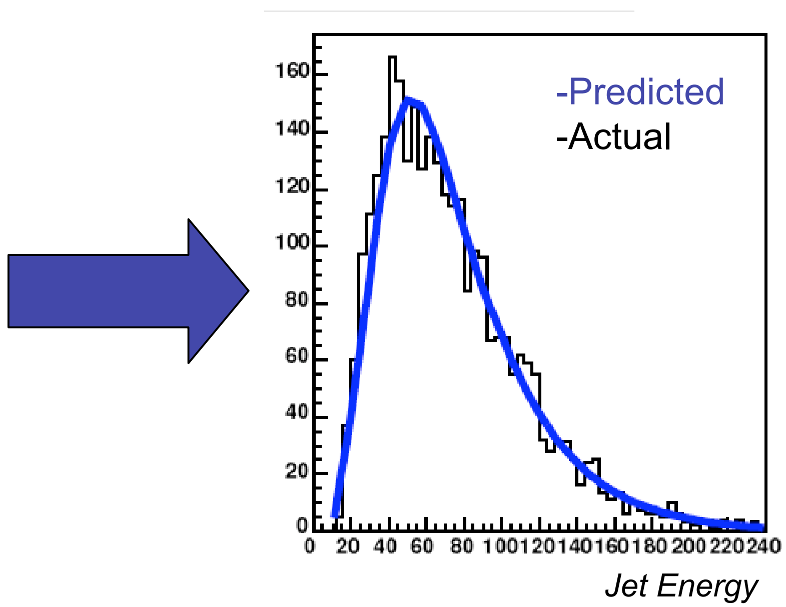
Jet angles well measured

Jet energies can be described by TFs

Jets

$$P(\ \text{event } x \mid \text{partons}\ ) = \delta(\phi-\phi)\ \delta(\theta-\theta)\ f_{jet}(E_{jet}-E_{parton})$$





Calculation

For each event*, *calculate differential cross-section:

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

Phase-space Integral

Matrix Element

Transfer Functions

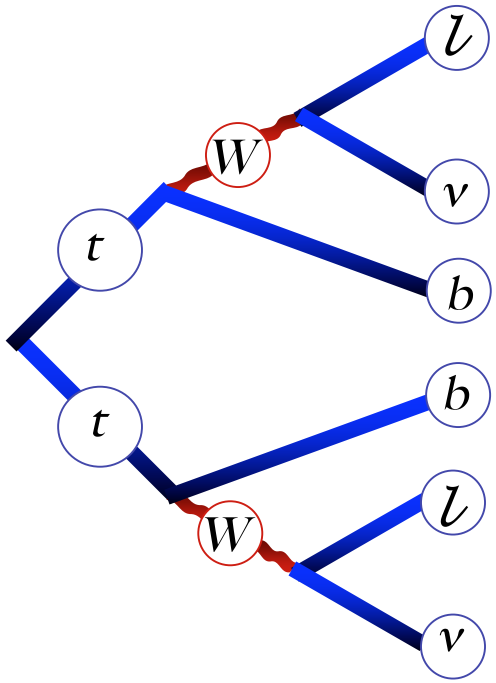
Only partial information available

Fix measured quantities

Integrate over unmeasured parton quantities

Neutrino solutions

8 unknowns



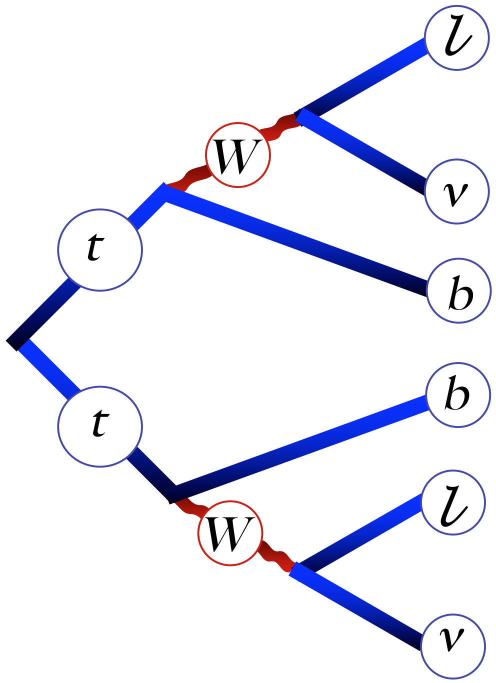
3 (neutrino)

1 (quark energy)

1 (quark energy)

3 (neutrino)

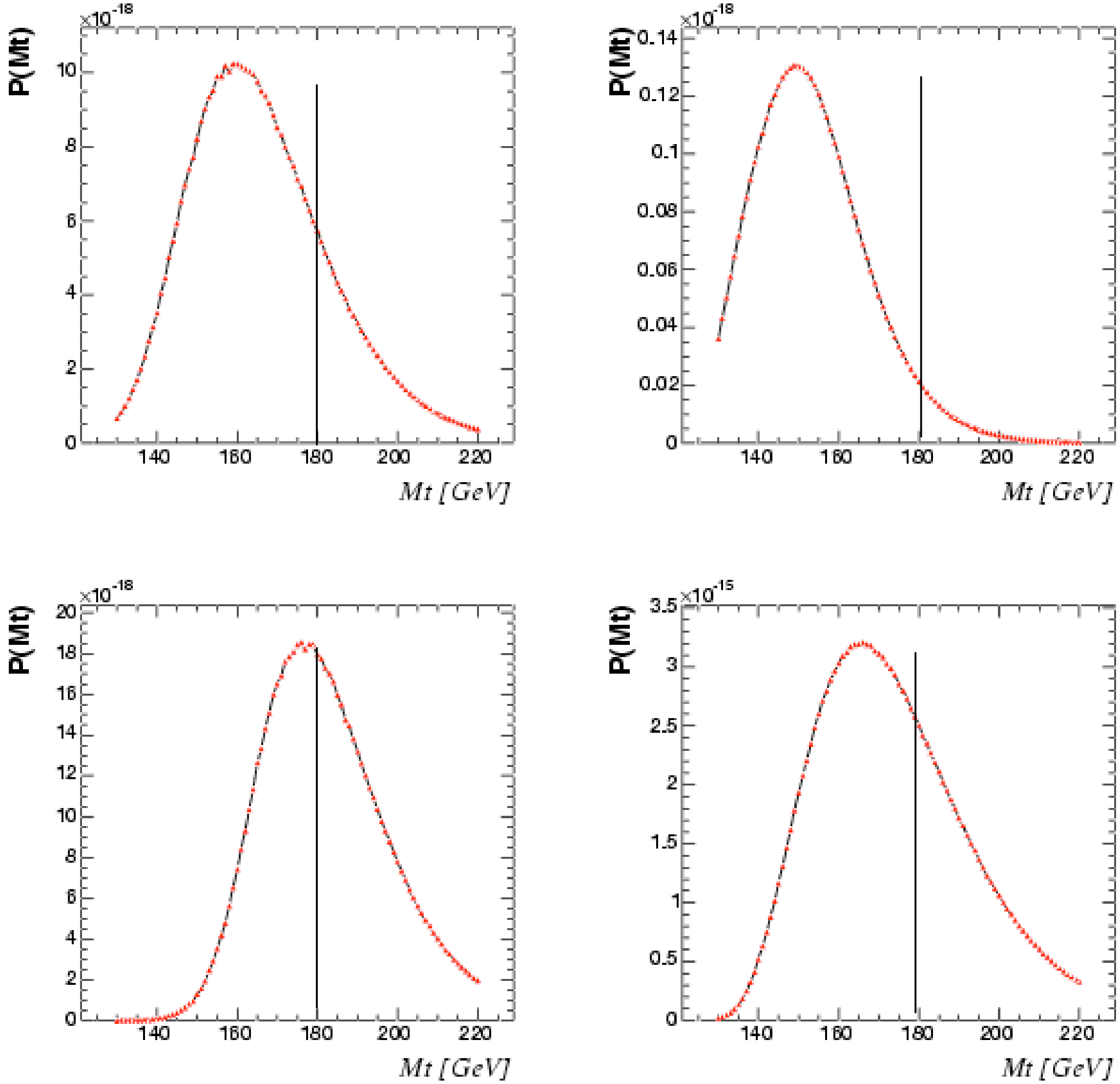
Neutrino solutions



8 unknowns	8 unknowns
3 (neutrino)	W, t invariant masses
1 (quark energy)	1 (quark energy)
1 (quark energy)	1 (quark energy)
3 (neutrino)	W, t invariant masses
	$p_{T,}$ ϕ of tt

Transformation accomplished numerically.
Integration done numerically [VEGAS]

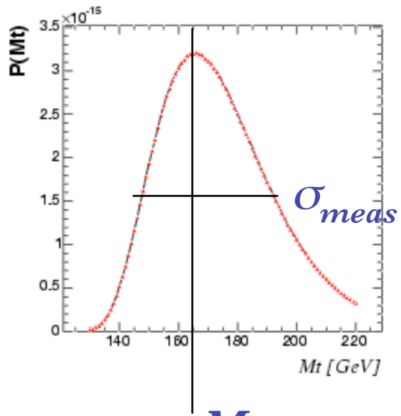
Examples



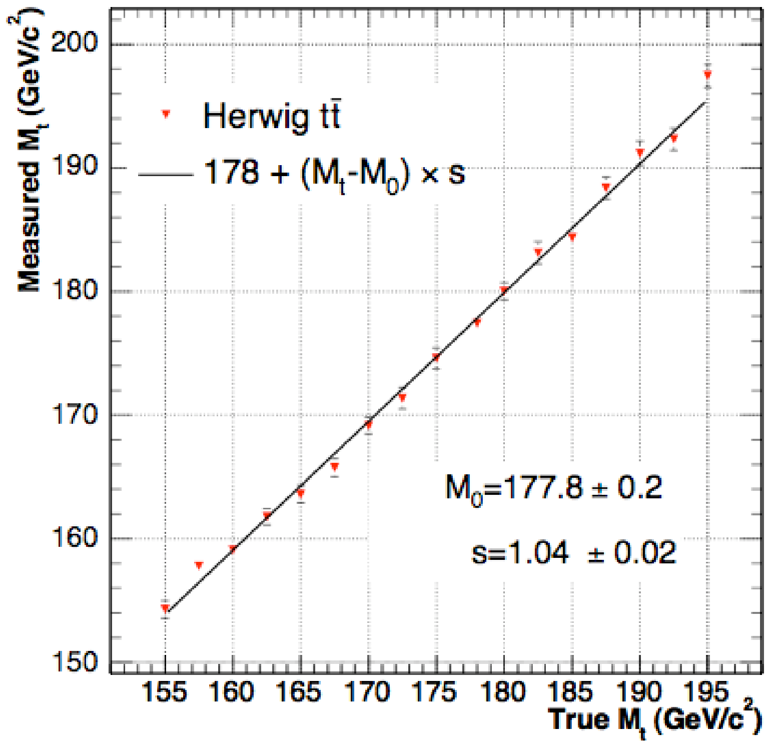
Four example events simulated by HERWIG (M_t=180 GeV)

Signal only results: full simulation

Joint probability in signal-only Monte Carlo experiments



Response = $\langle M_{meas} \rangle$



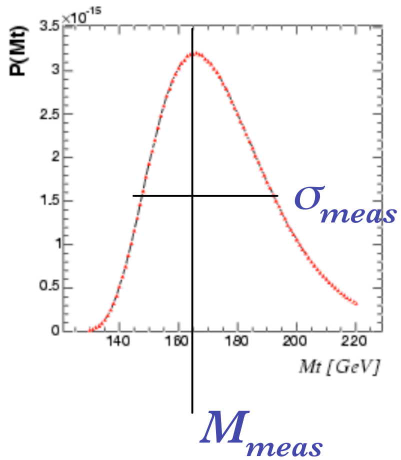
Response

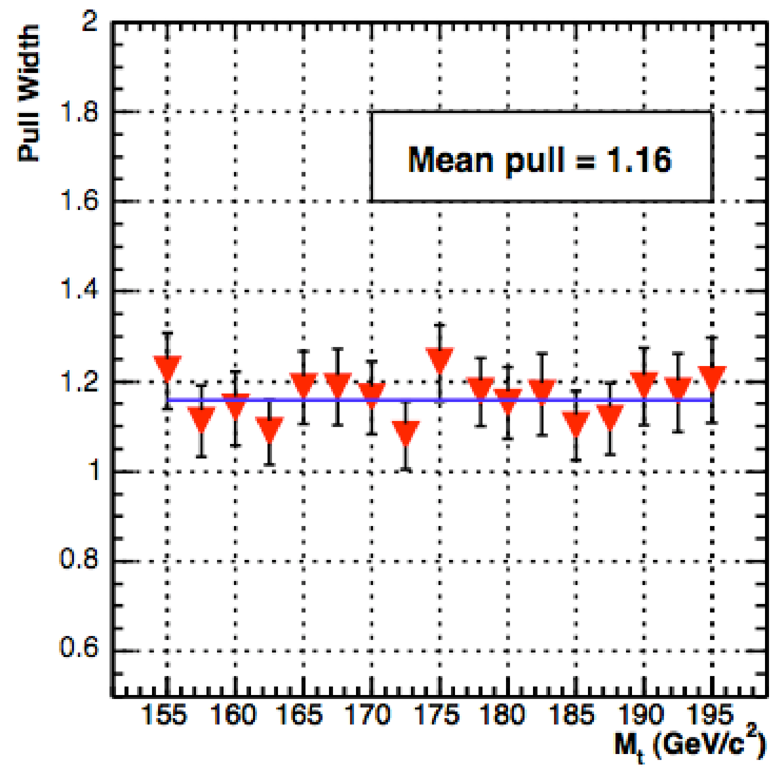
Linear.

Unbiased.

Signal only results: full simulation

Joint probability in signal-only Monte Carlo experiments





Response = $\langle M_{meas} \rangle$

Pull $= \dfrac{M_{meas} - M_{true}}{\sigma_{meas}}$

Pull width

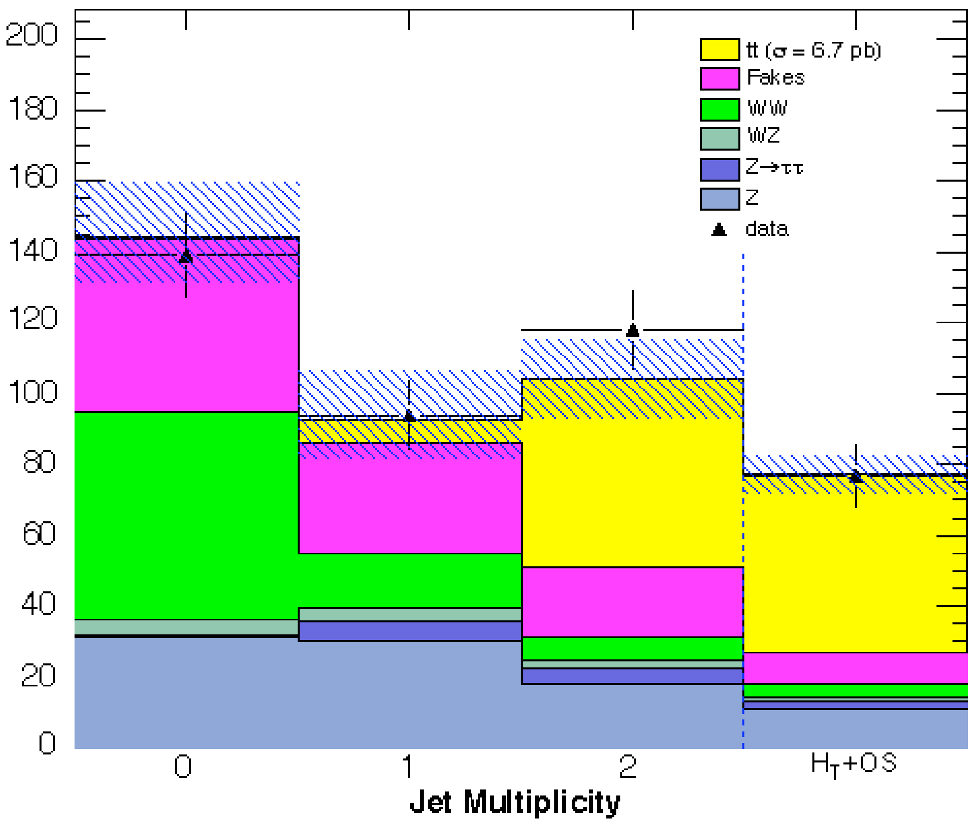
Flat.

Width is ~1.16 due to assumptions

Assumptions enforced: width is ~1.0.

Sample composition

Sample is expected to be *3:2* signal to background

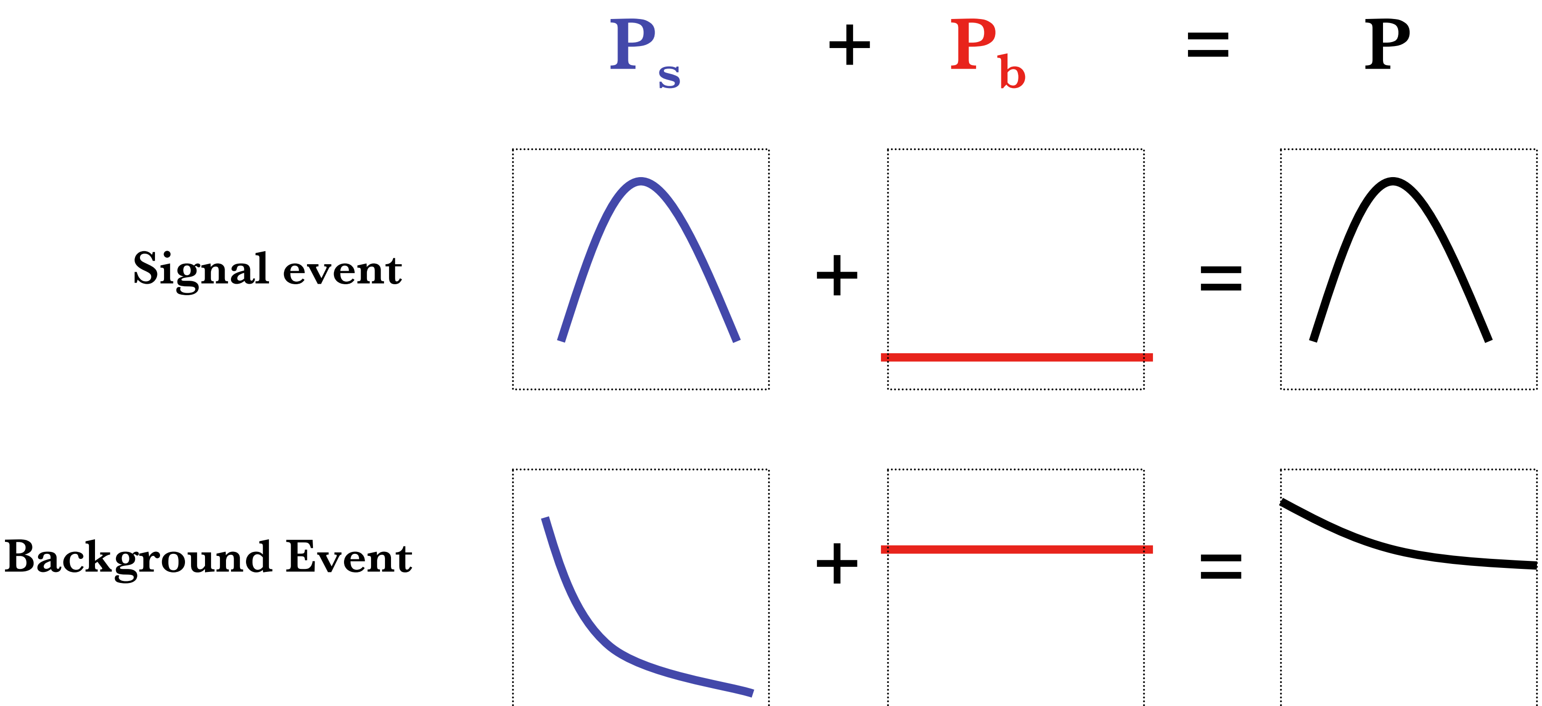


Sample	N_{events}
tt (M$_t$=175, σ = 6.7 pb)	50.2
Z →*ee*/*μμ*	10.9
Fake lepton	8.7
WW, WZ	5.0
Z → ττ	2.2
Total	**77.1 ± 2.1**
Observed	**78**

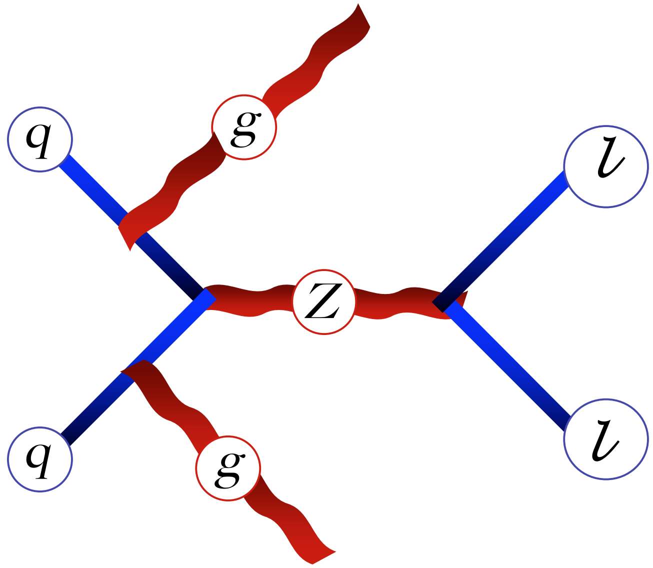
Background Likelihoods

We generalize the probability to be a weighted sum of signal & bg probabilities

$$P(\mathbf{x}|M_t) = P_s(\mathbf{x}|M_t)p_s + P_{bg1}(\mathbf{x})p_{bg1} + P_{bg2}(\mathbf{x})p_{bg2}\ldots$$



Z+jets



2 unknowns

1 parton energy

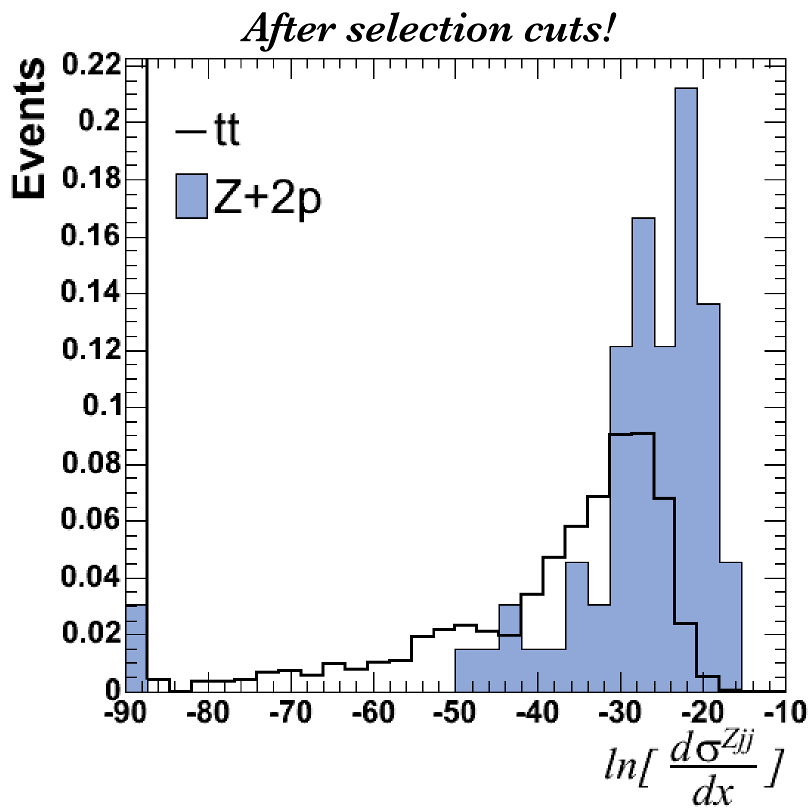
1 parton energy

Matrix Element & Integrals

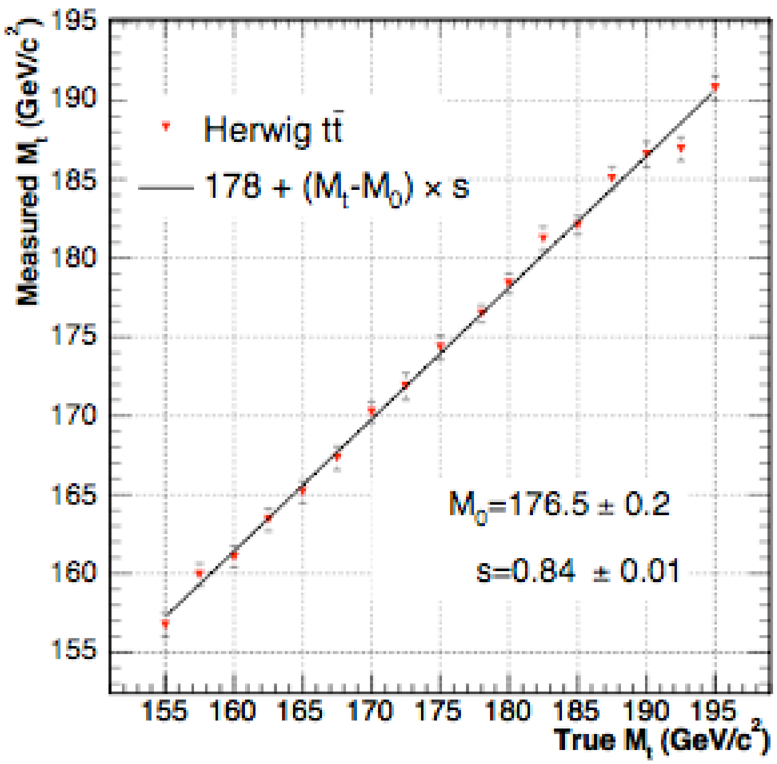
Alpgen subroutine for Z+2p

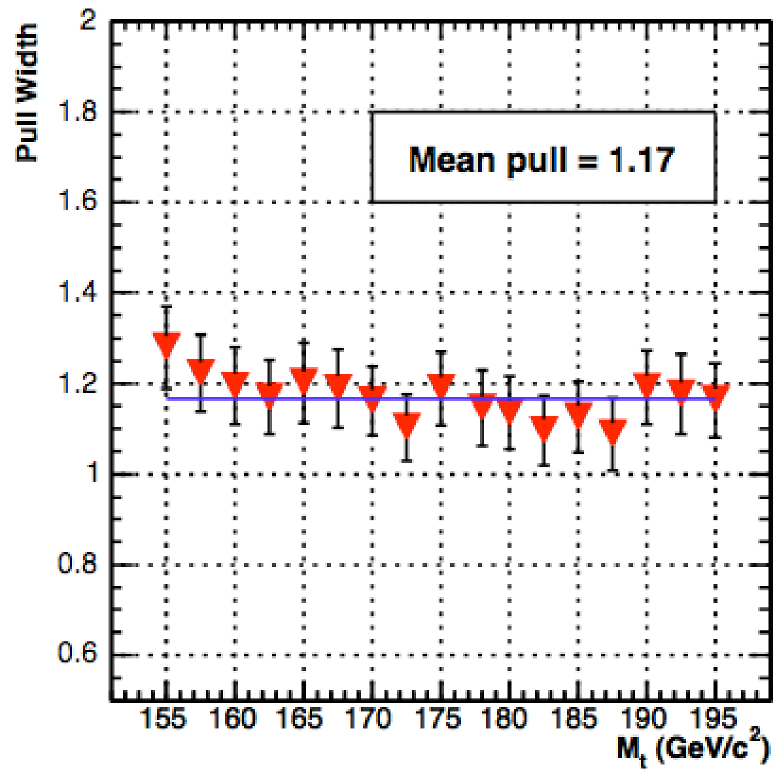
2 integrals for unclustered E_T

Integration with VEGAS



Response & Pulls





Response

Linear.

Slope < 1 due to backgrounds.

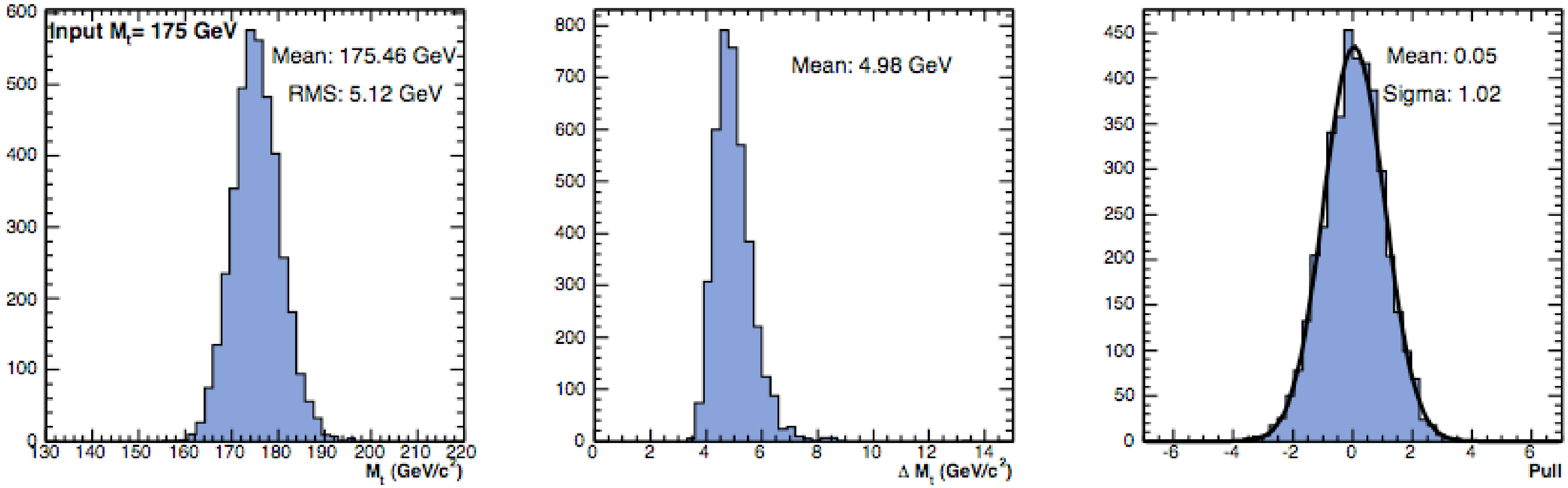
Error is reduced 15% by P_{bg}

Pull width

Flat

Response at mt=175

Residual, error, and pulls are well behaved.



Method	*Mean Error (L = 350 pb^{-1})*
Matrix Element	**9.4 GeV**
Neutrino Weighting	**12.8 GeV**
Kinematics	**14.6 GeV**
Neutrino Phi	**14.9 GeV**

Systematic Errors

Source	*$\Delta M_{top} (GeV/c^2)$*
Jet Energy Scale	**3.5**
Parton Distributions	**0.9**
Generator	**0.9**
Background Statistics	**0.7**
Background Shape	**0.7**
ISR/FSR	**0.7**
Sample Composition	**0.7**
Method	**0.6**
Total	**3.9**

Systematic Errors

Source	*$\Delta M_{top}(GeV/c^2)$*
Jet Energy Scale	3.5
Parton Distributions	0.9
Generator	0.9
Background Statistics	0.7
Background Shape	0.7
ISR/FSR	0.7
Sample Composition	0.7
Method	0.6
Total	**3.9**

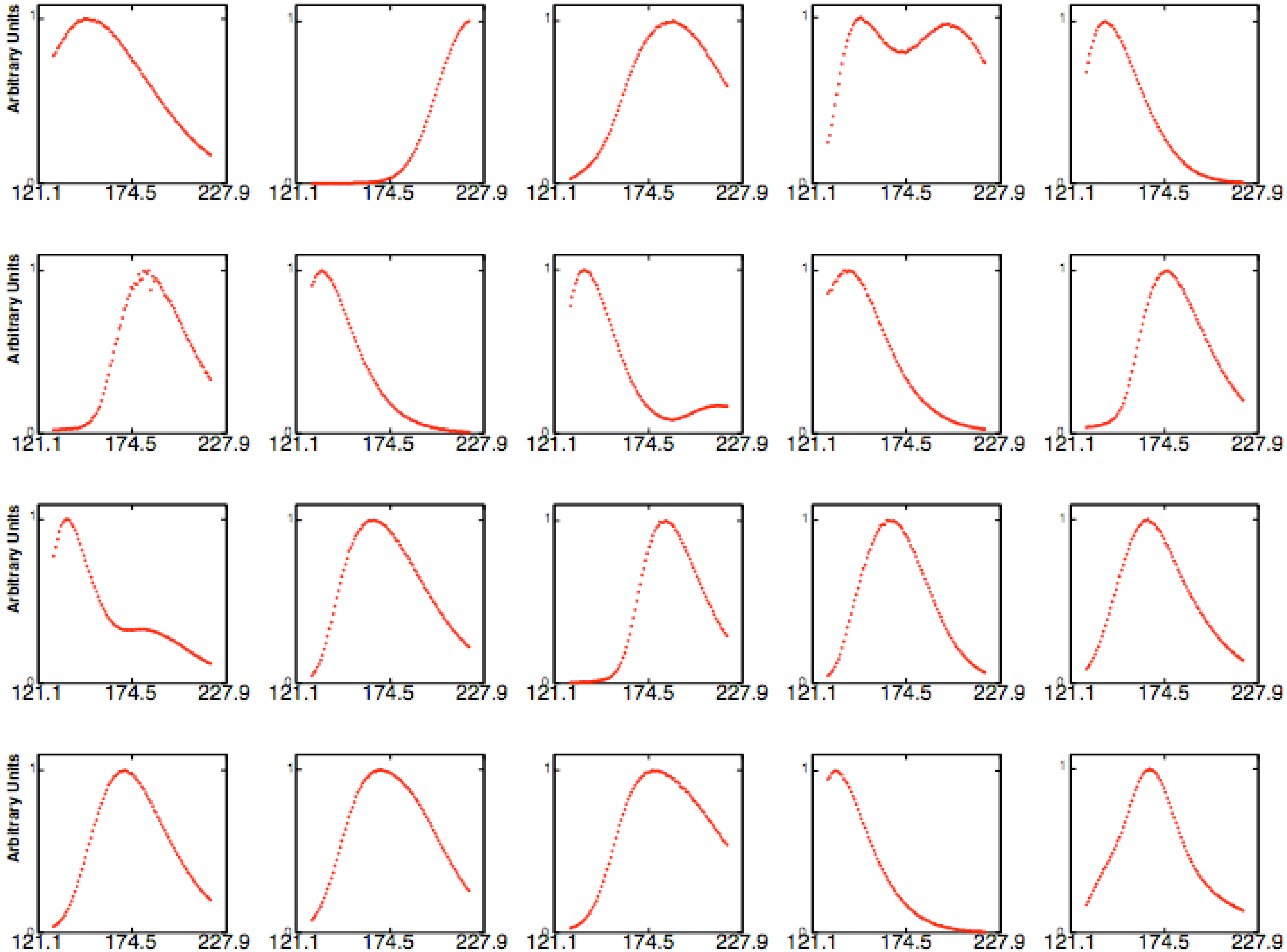
Can be reduced from using direct b-jet energy scale from Z to bb.

Outline

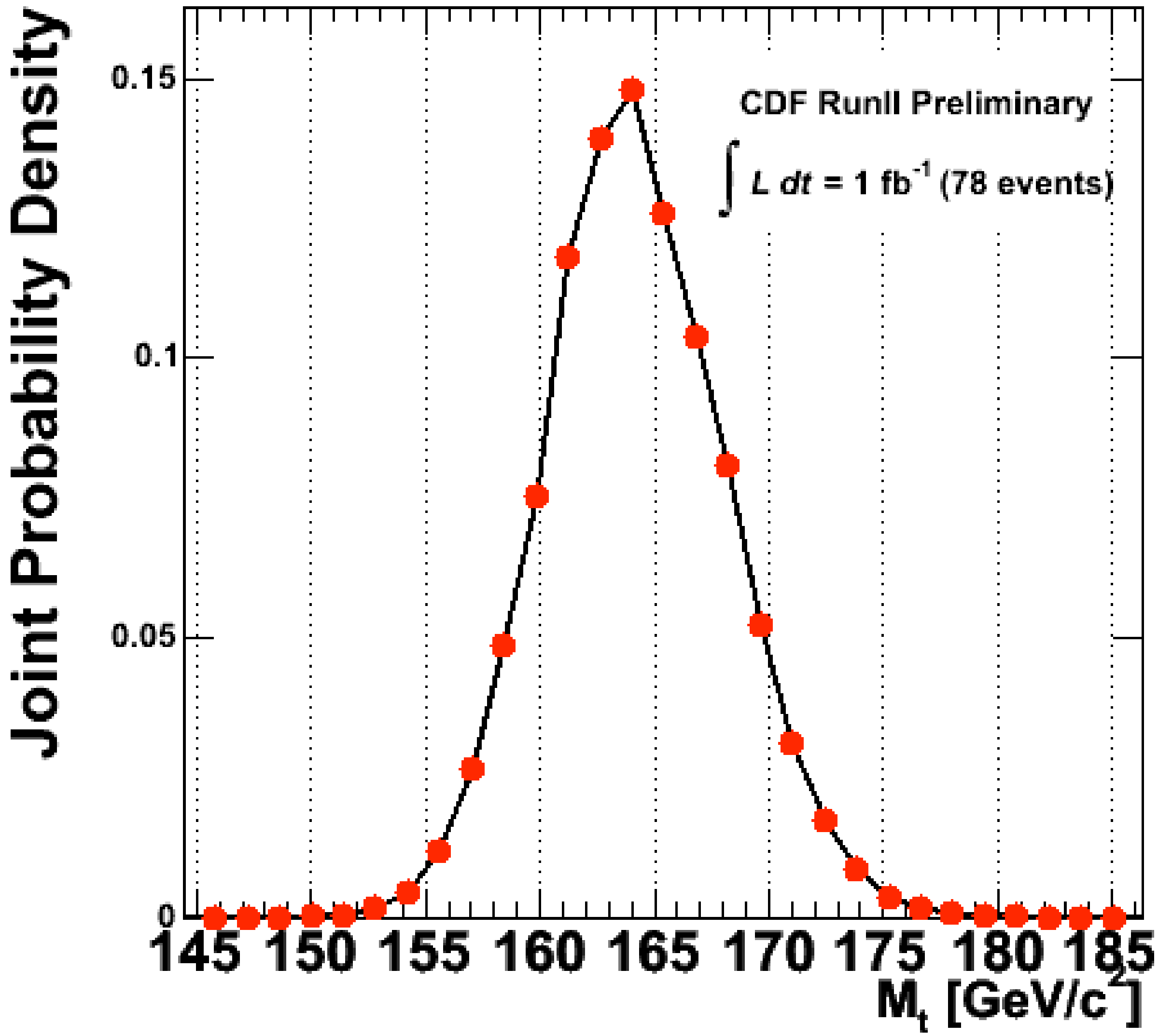
- Motivation for di-lepton top quark physics
  - Laboratory for electroweak, top and new physics
- Top quark di-lepton decays
  - Fermilab Tevatron and CDF
  - Cross section measurement
- Precision mass measurements
  - Novel application of a powerful technique
- **Result**
  - Impact and Conclusions

Data

20 example events…



Measurement!



L = 350 pb^-1

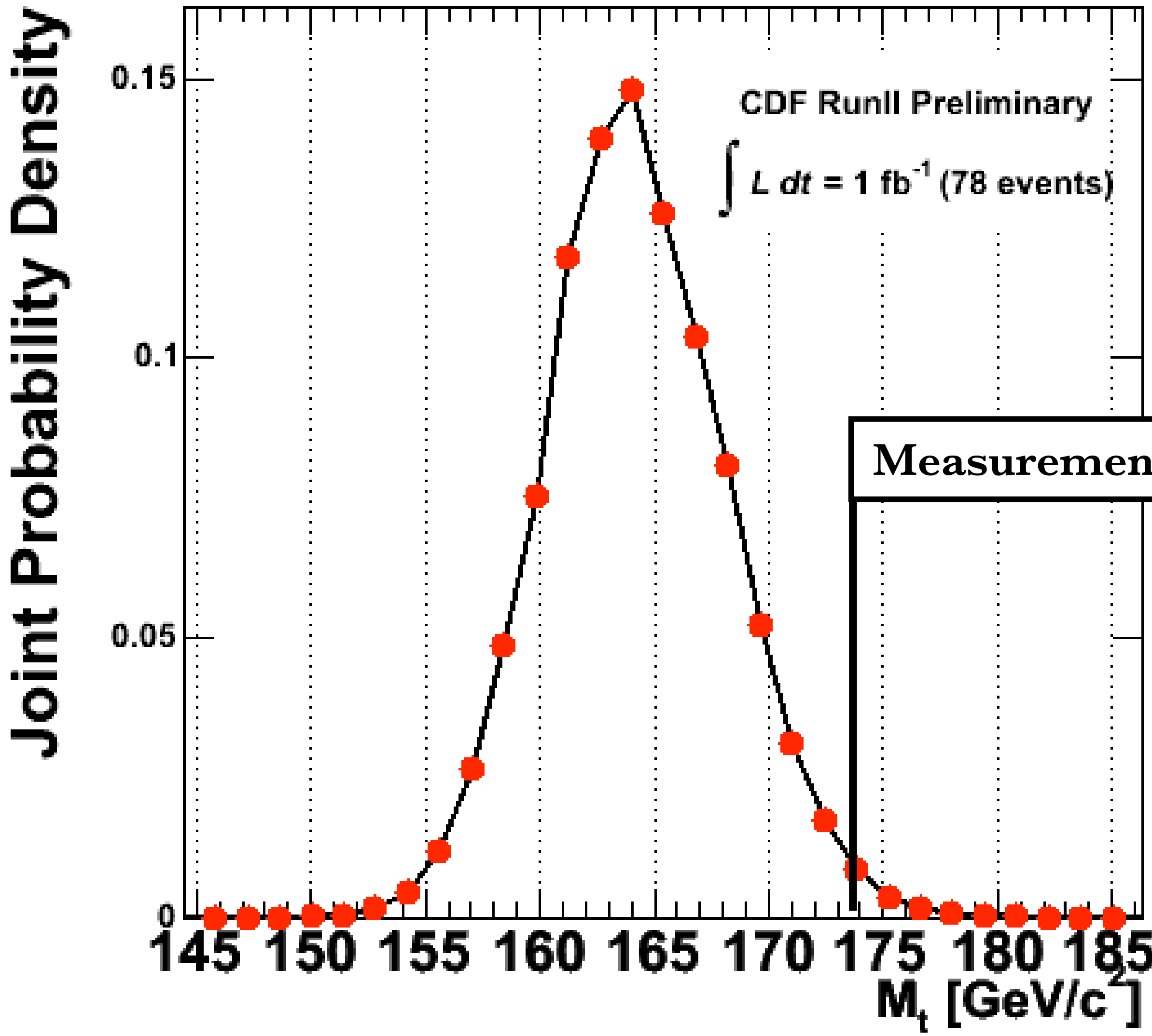
Phys. Rev. Lett	**96,** 152002 (2006)
Phys. Rev. D	Accepted (2006)
Thesis, A. Kovalev	Penn (2005)

L= 1000 pb^-1

Thesis, B. Jayatilaka	Michigan, 2006
Phys. Rev. Lett,	In preparation

$$M_t = 164.5 \pm 3.9_{stat} \pm 3.9_{syst}\ GeV/c^2$$

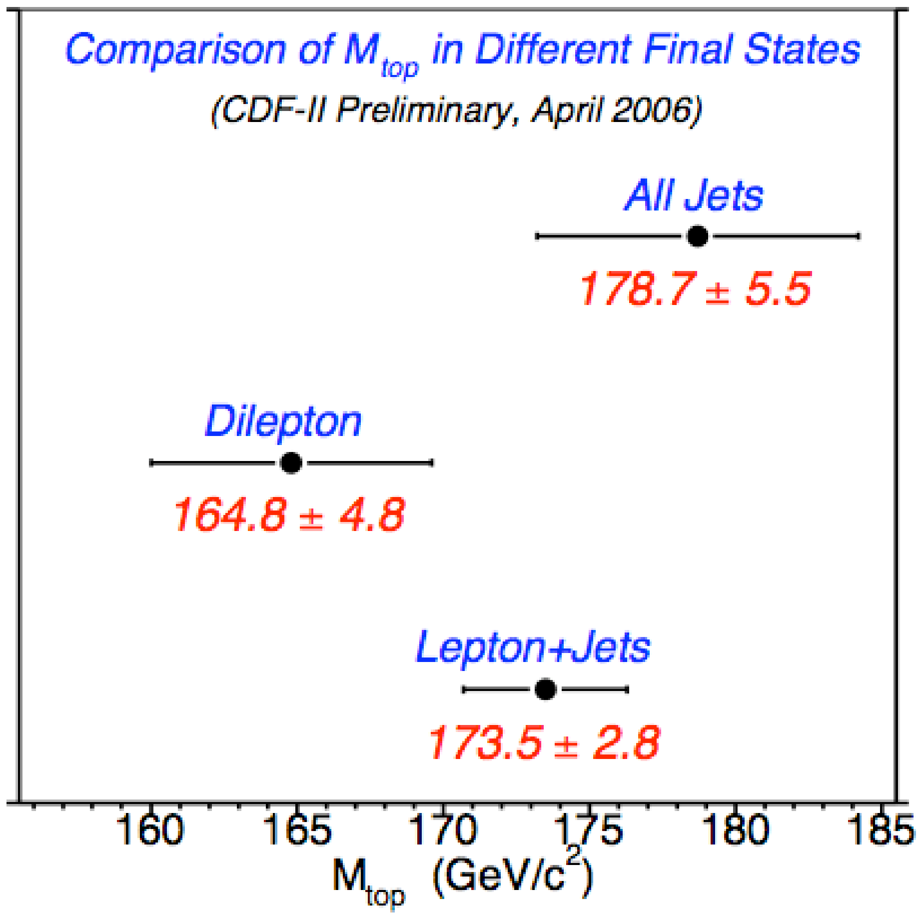
Measurement!



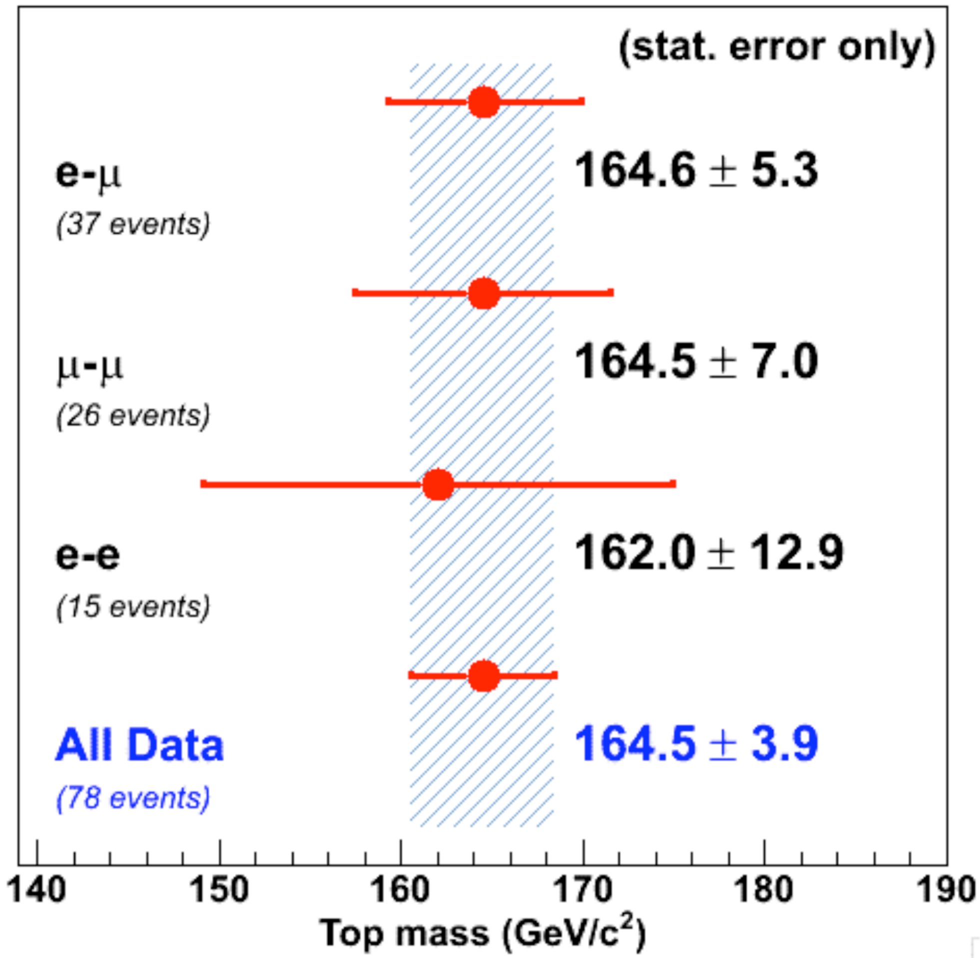
Measurement in single-lepton decays

$$M_t = 164.5 \pm 3.9_{stat} \pm 3.9_{syst}\ GeV/c^2$$

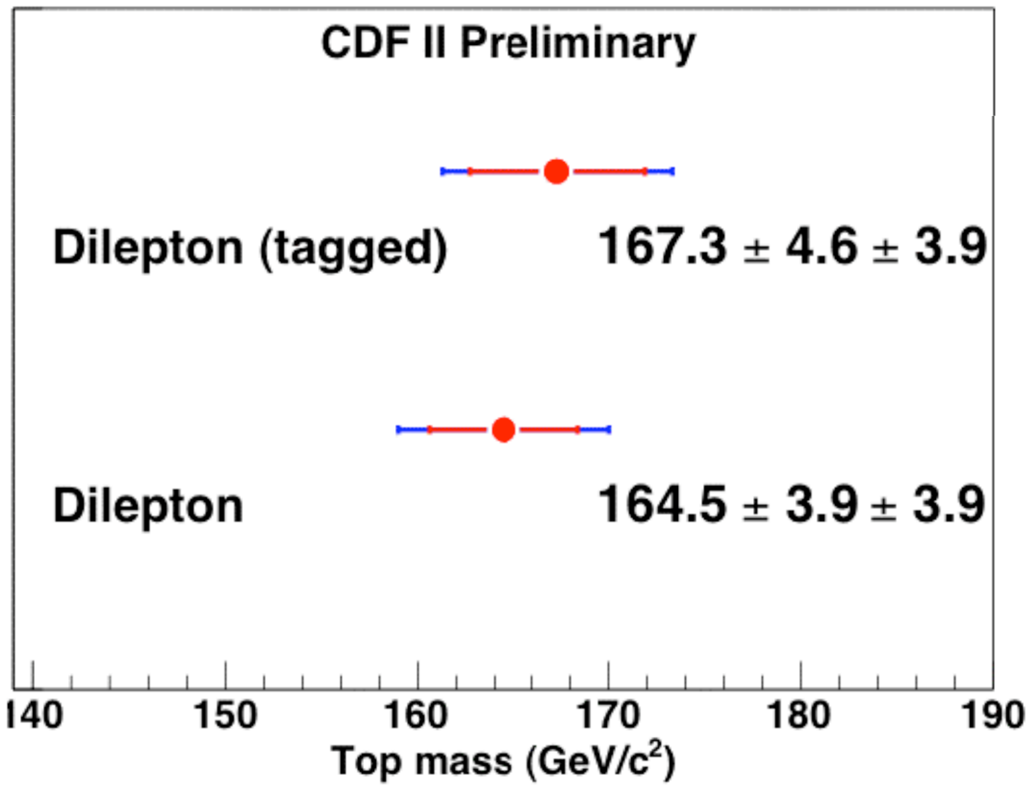
Different channels



Cross-Checks



B-tagged measurement

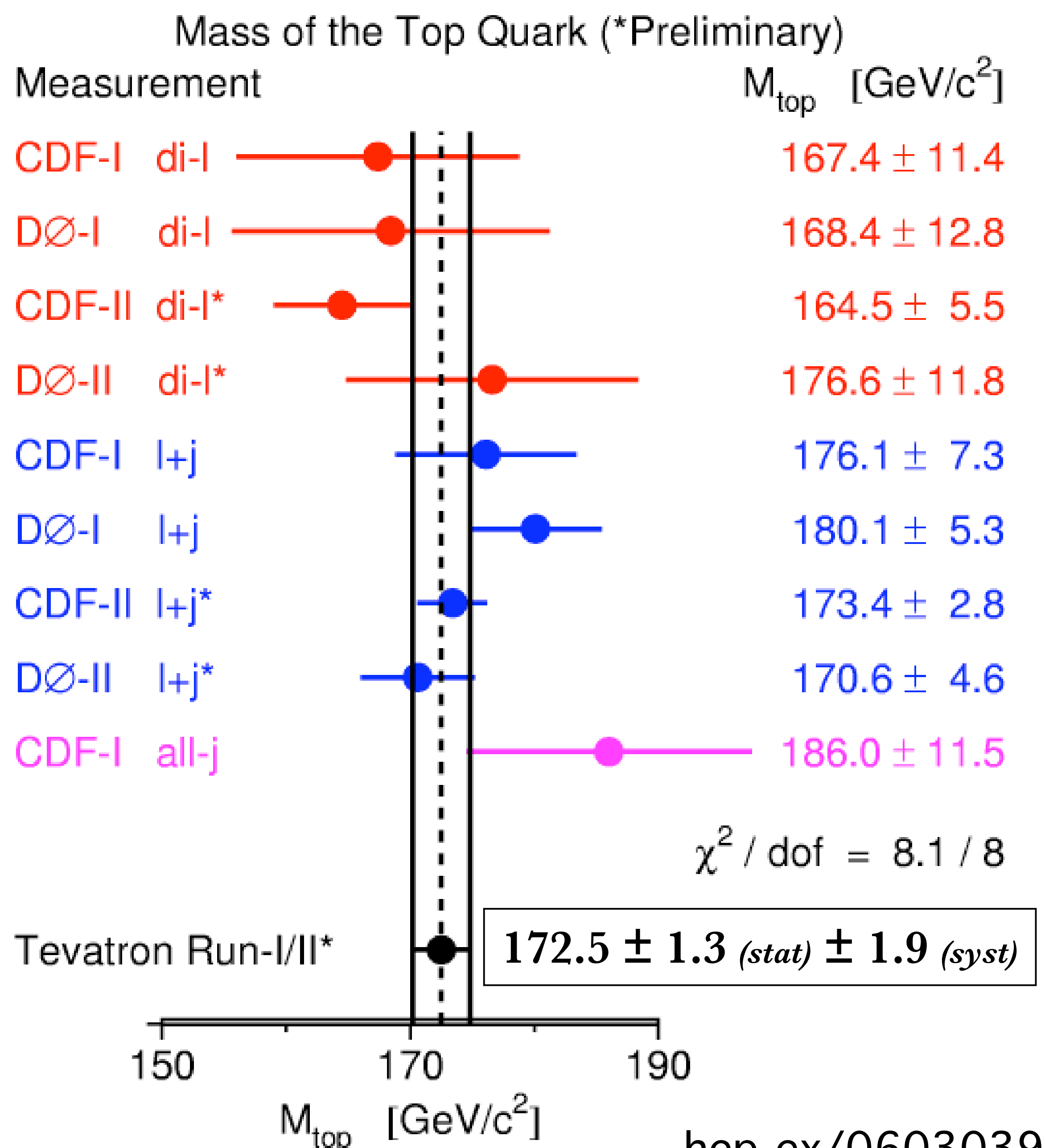


World Average

World Average

Pull of **-1.6**
Weight of **11%**

Error of **2.3 GeV,**
systematics limited.



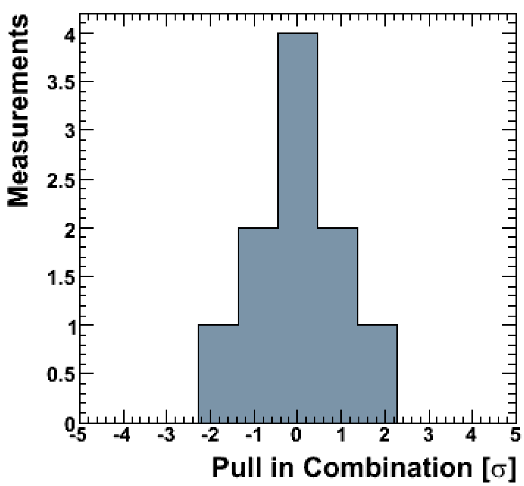
hep-ex/0603039

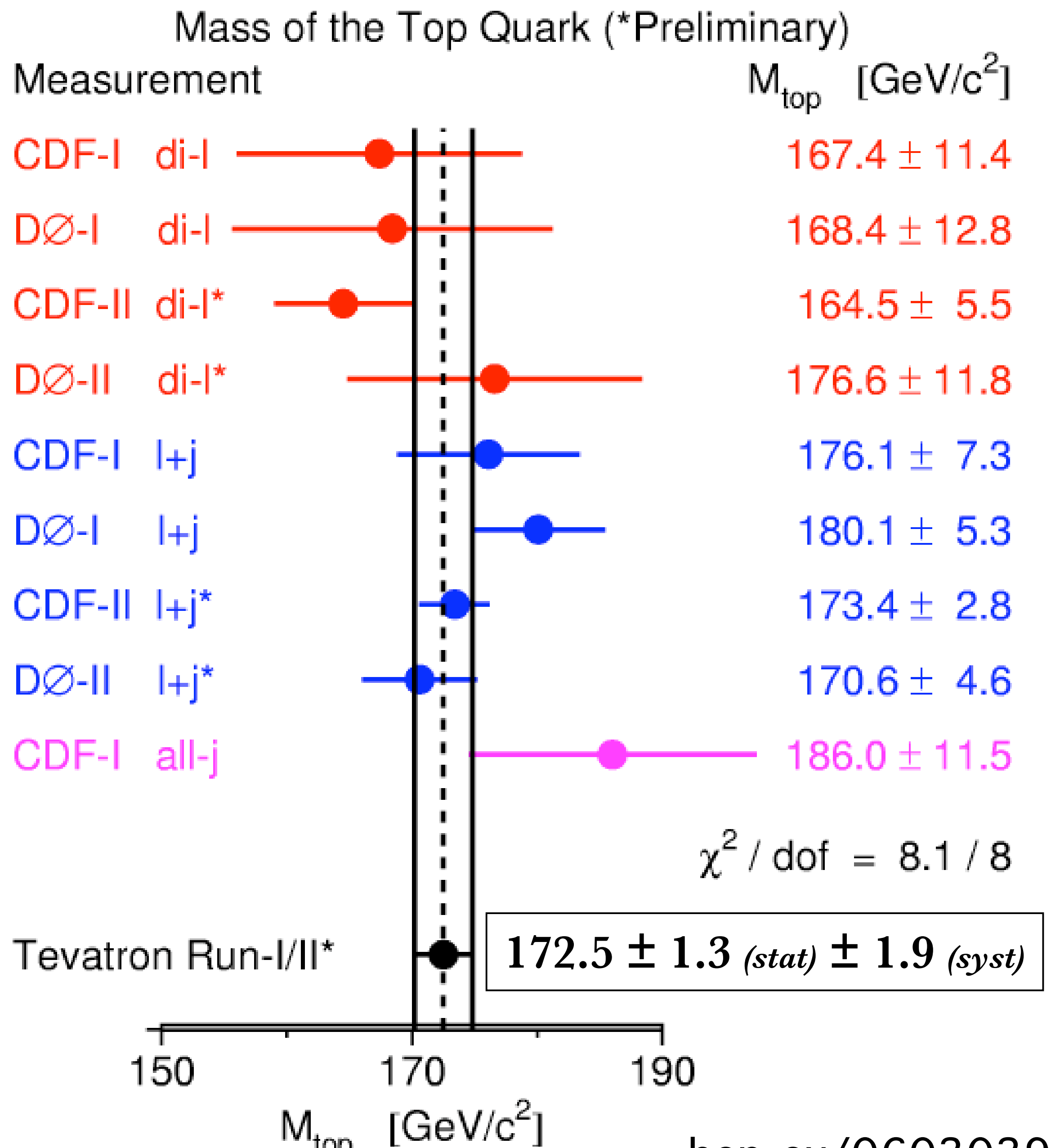
World Average

World Average

Pull of -1.6
Weight of 11%

Error of 2.3 GeV,
systematics limited.



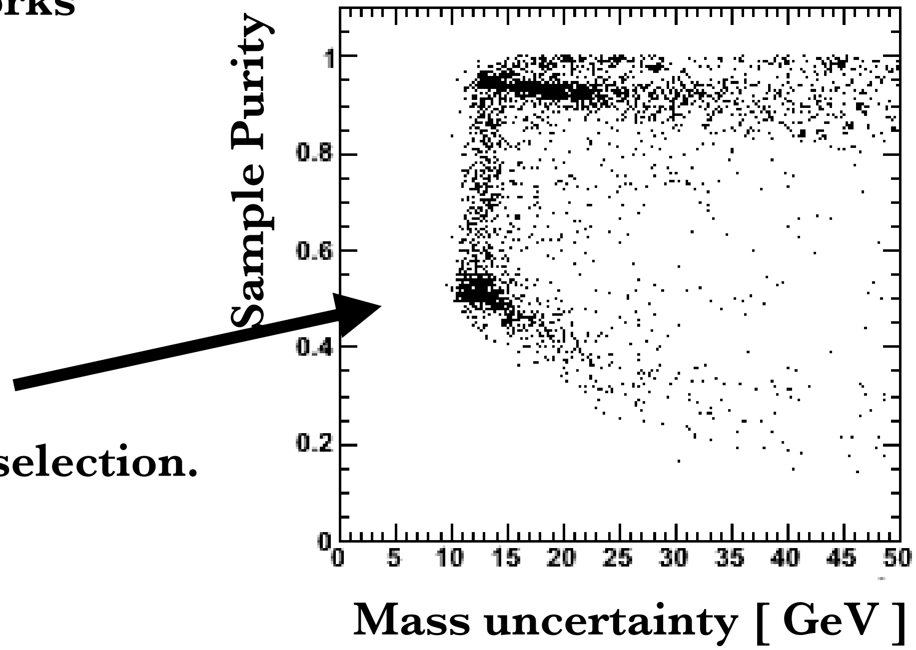


hep-ex/0603039

Next Steps: Statistical Error

Optimize with genetically-evolved neural networks

- Effect of backgrounds is non-trivial to predict
- Direct optimization of mass precision
- Power and flexibility of neural networks

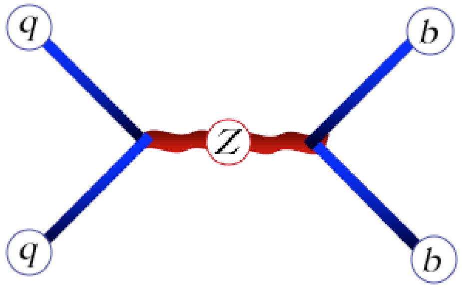


Most precise selection for mass is significantly looser than current selection.

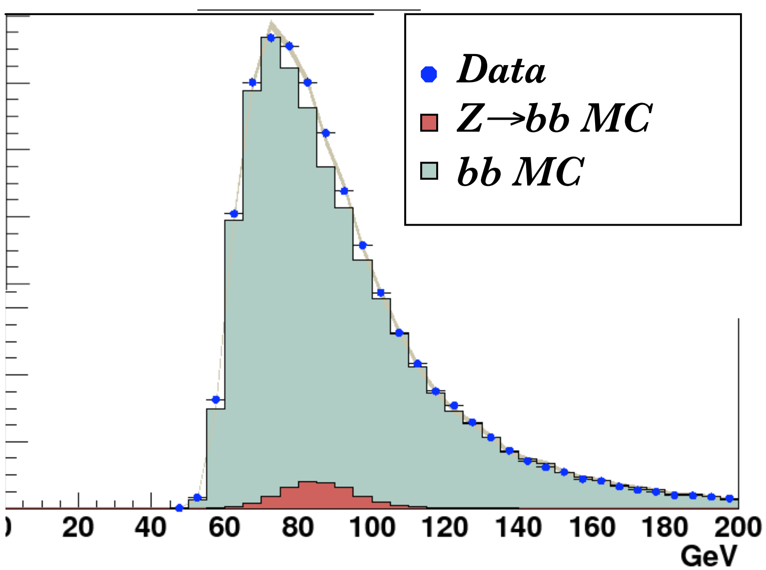
Same data, more precision!

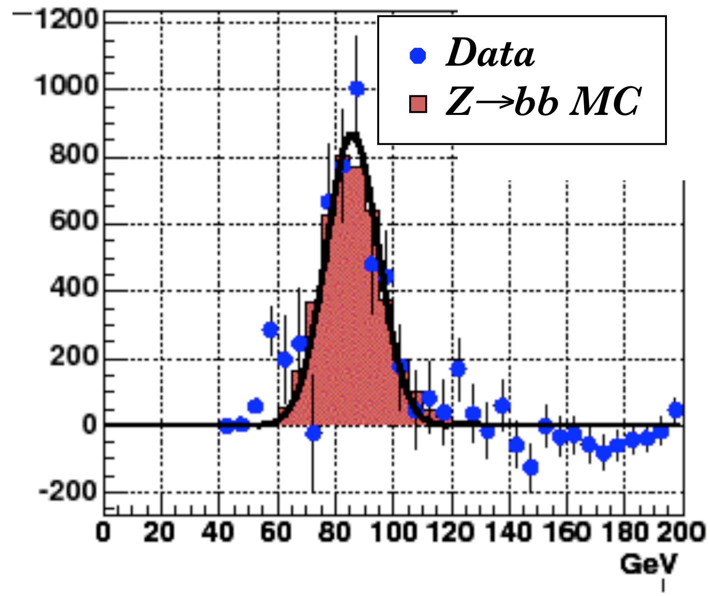
In submission [hep-ex/0607012]

Next Steps: Systematic Errors



To reduce the largest systematic, calibrate *b*-jets in data



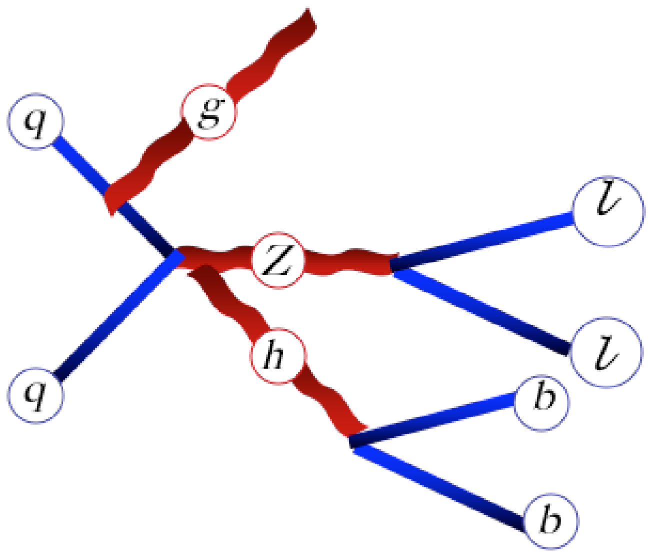


***Z→ bb* decays are difficult to see, due to enormous *bb* background.**

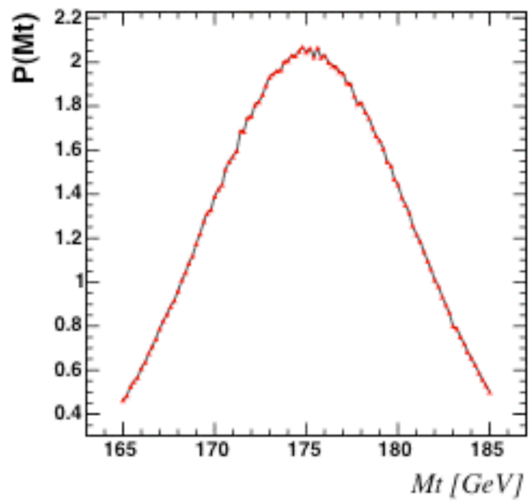
Measurement expected Winter 2007

Next Steps: Searches

$pp \rightarrow Zh \rightarrow ll\ bb$



$P(\text{event } x \mid M_h)$:



Summary & Outlook

Tevatron

Precision dilepton mass measurement gives first significant comparison between channels

With no improvements, expect statistical error of 2.0 GeV at $4fb^{-1}$

Dileptons are systematics limited!

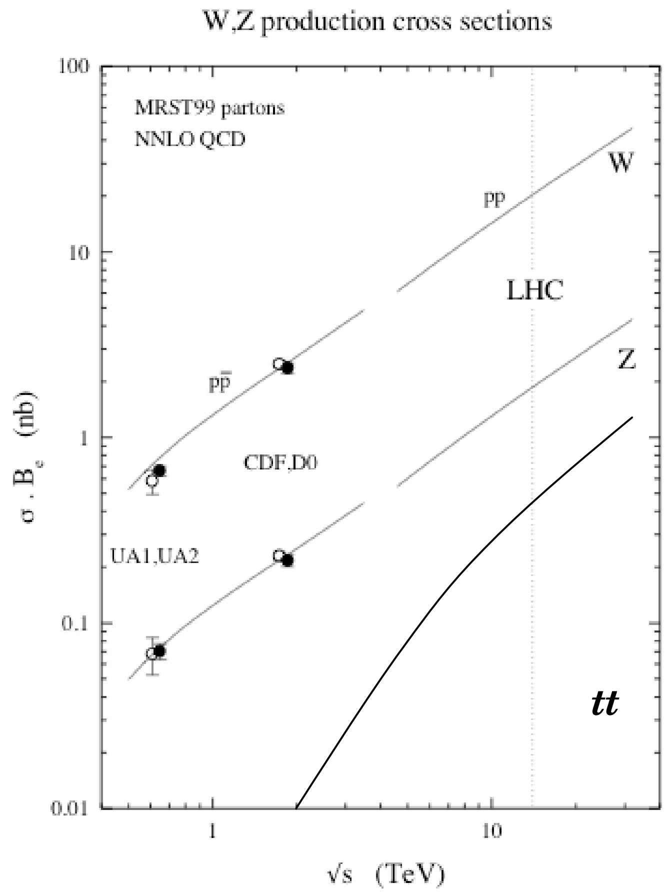
LHC

Order of magnitude greater statistics and energy

Lessons from Tevatron are critical.

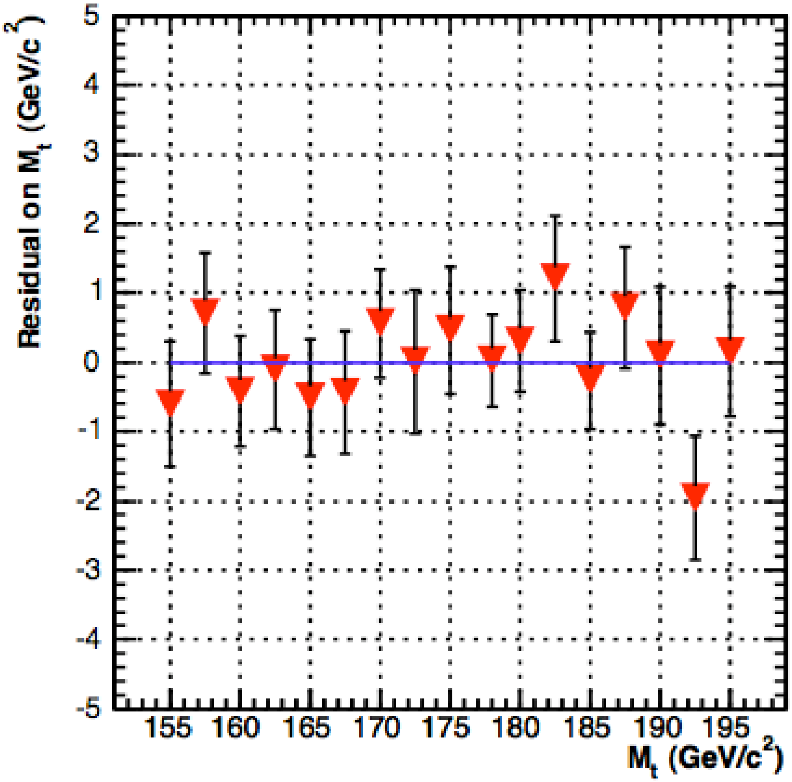
Use similar strategies:

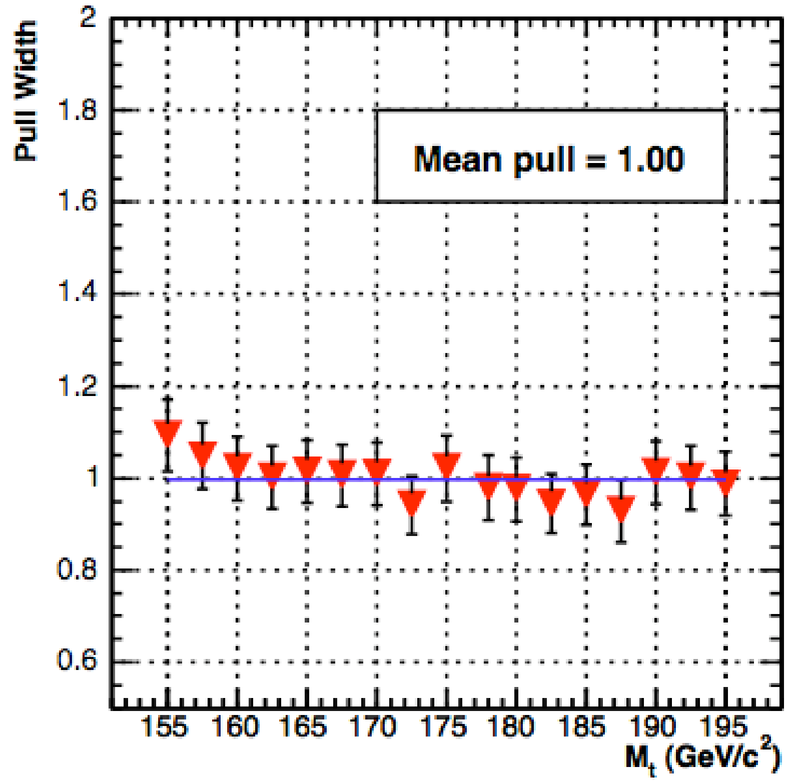
- ***Understand basic lepton ID in data***
- ***Observe familiar processes***
- ***Solid ground for discoveries***



Backup material

Response & Pulls





Response

After slope correction.

Pull width

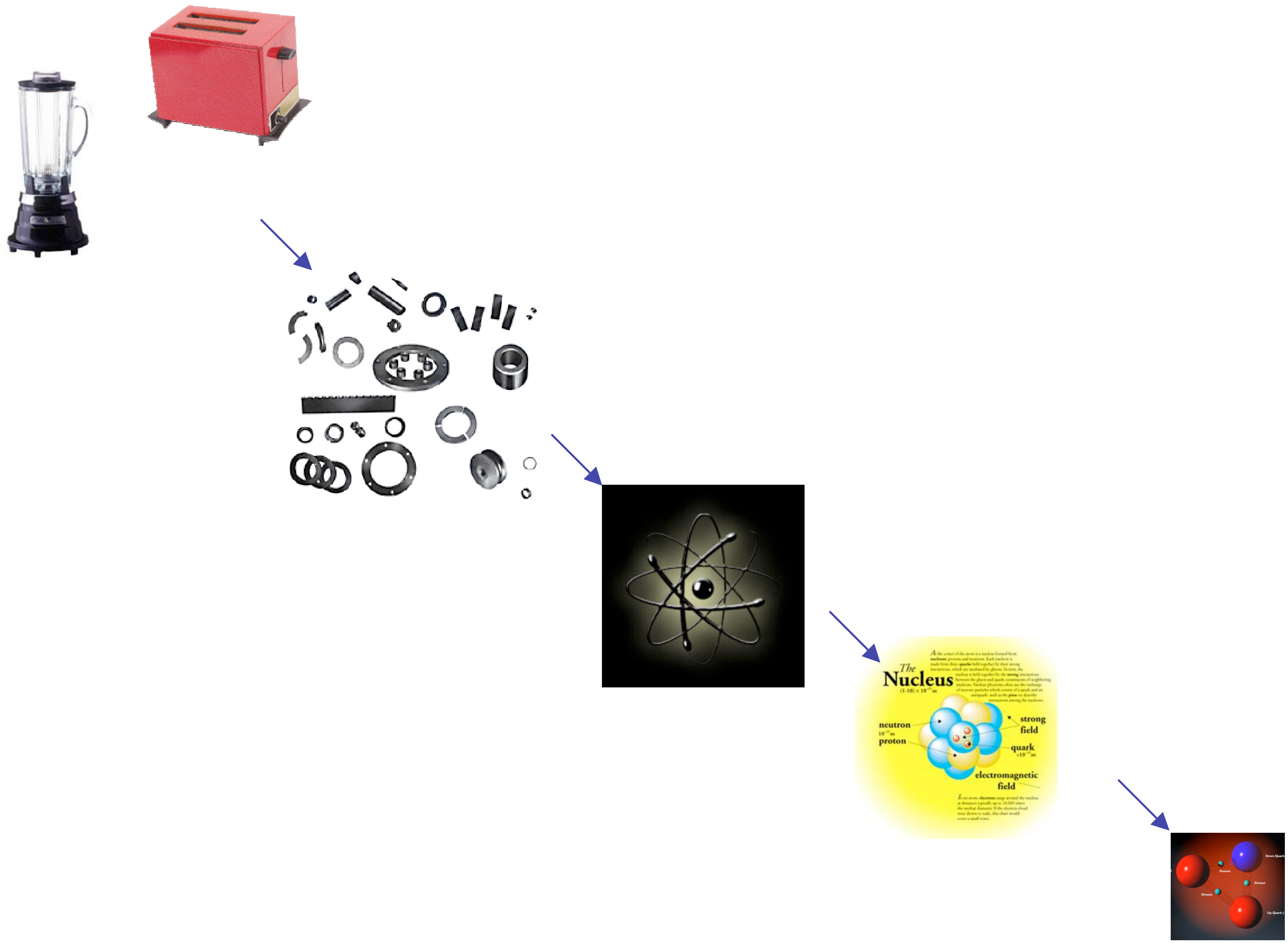
After error correction.

Leptons

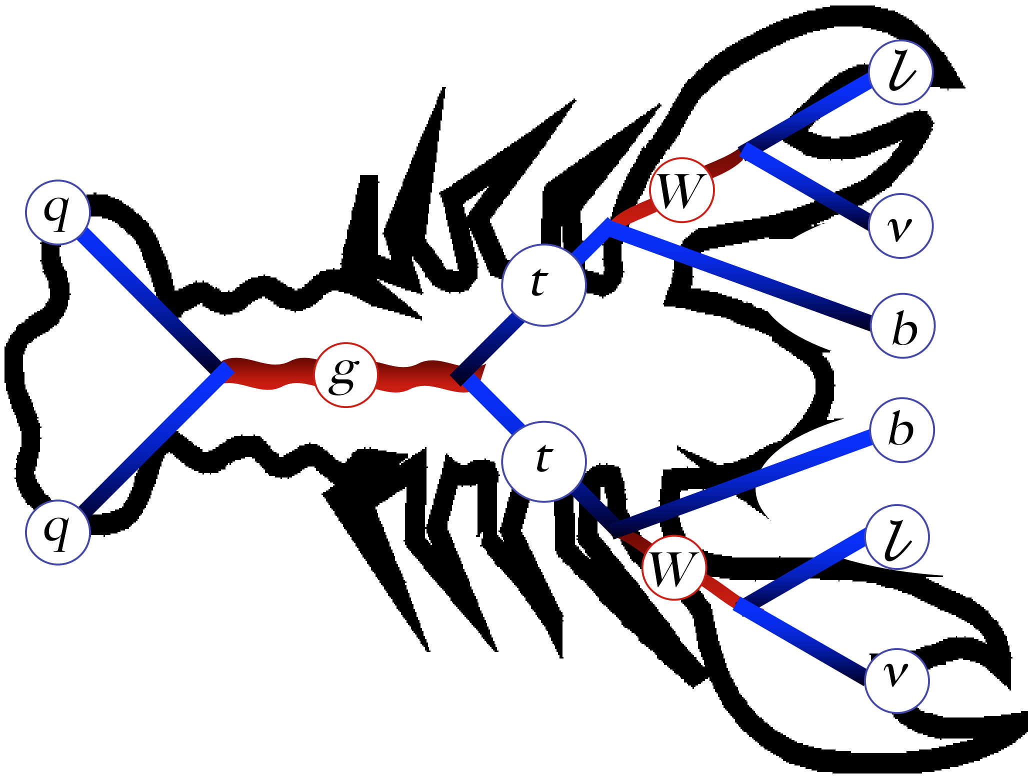
Sample	*ee*	*μμ*	*eμ*	*ll*
tt (M_t=175, σ = 6.7 pb)	11.1	11.7	27.0	50.2
Backgrounds	8.6	10.6	7.9	27.1
Total	19.7± 2.5	22.3± 2.6	34.9± 2.0	77.1± 2.1
Observed	15	26	37	78

We see additional *μμ* events, and a deficit of *ee*.

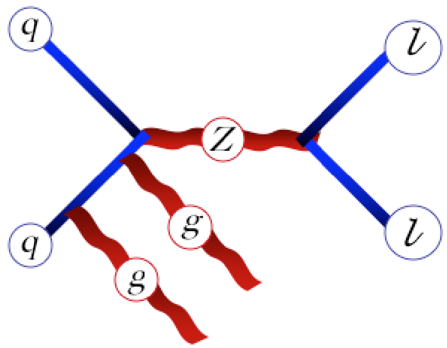
Probing the structure of our environment

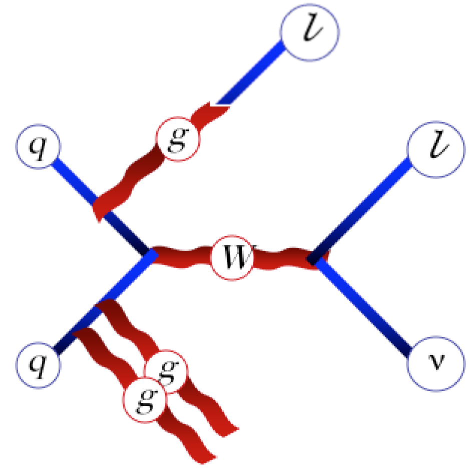


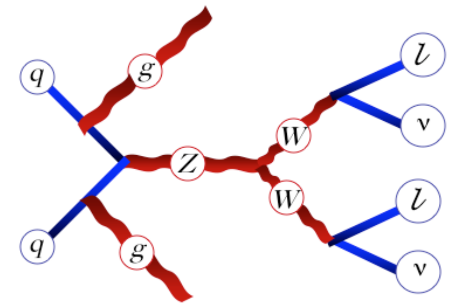
Lobster diagram



Backgrounds







	Drell-Yan	Misidentified Lepton	WW
Signature	*Two leptons* *Small missing* E_T *2 jets from ISR*	*Two leptons* *Significant* E_T *3 jets from ISR* *Misidentified lepton*	*Two leptons* *Significant* E_T *2 jets from ISR*
Removal	*Large missing* E_T *Large* $\sum E_T$	*Lepton isolation* *Large* $\sum E_T$	*Large* $\sum E_T$

Pull width

Assumptions held

Parton events: *width = 1.0*

Assemptions broken

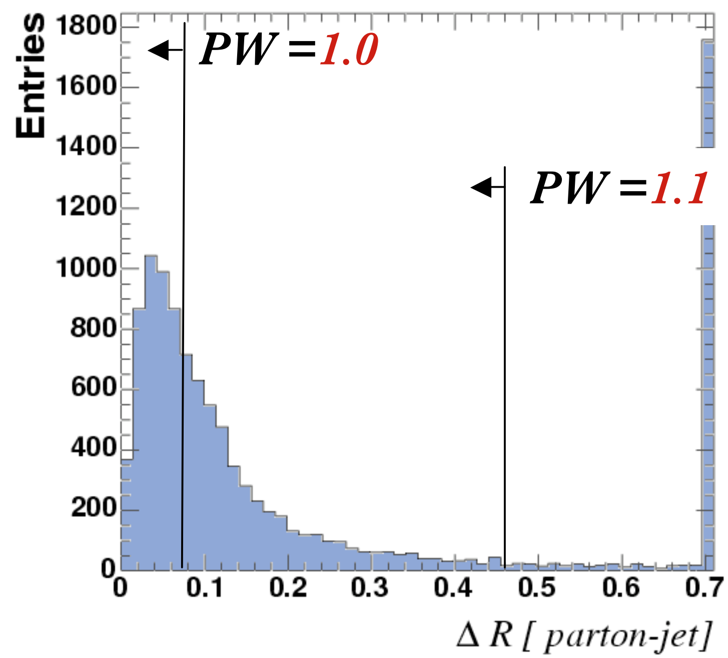
Full simulation : *width = 1.15*

- **Well measured leptons:** *width ➡ 1.1*
- **Small parton-jet angle:** *width ➡ 1.0*

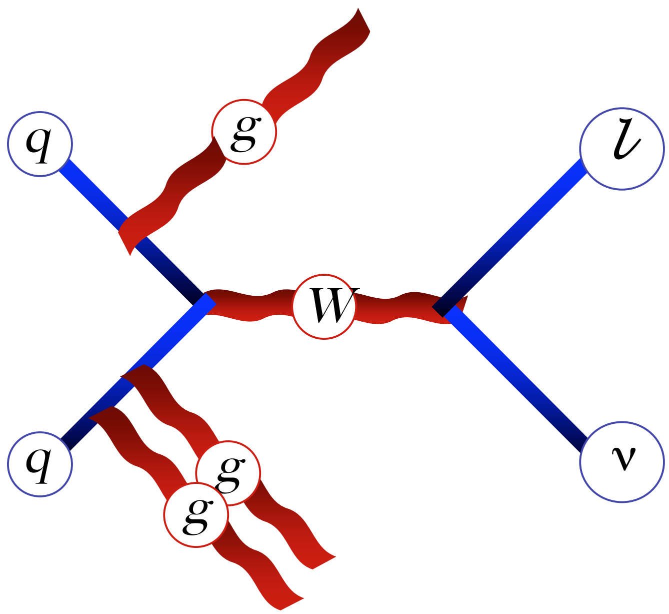
Scale factor for error

Flat in top mass

Flat in measured statistical error



Fakes



3 unknowns

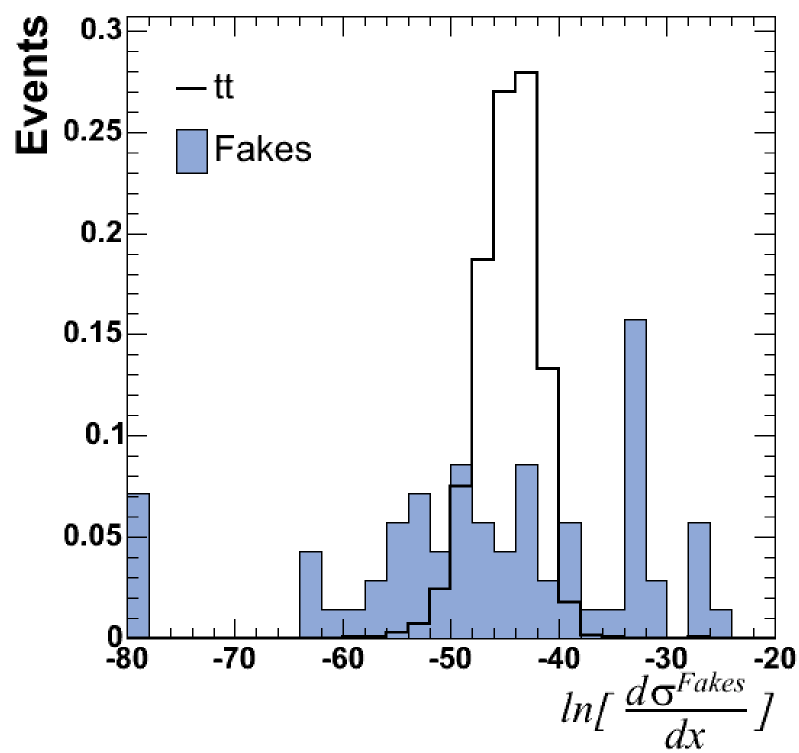
1 parton energy

1 parton energy

3 neutrino *(P components)*

-2 *(P_T conservation)*

After selection cuts

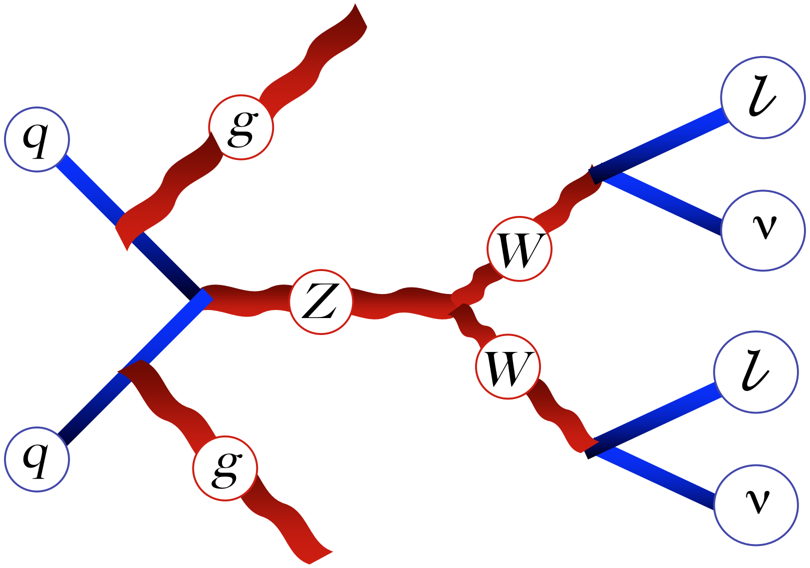


Matrix Element & Integrals

Alpgen subroutine for W+3p

Integration with VEGAS

WW+jets



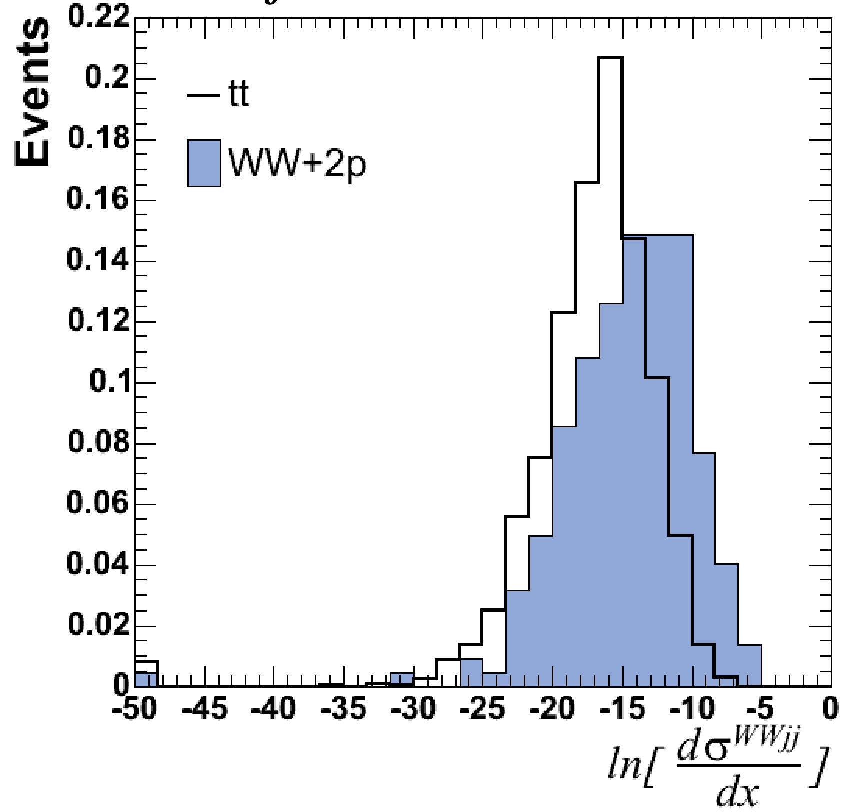
6 unknowns

Parton energy
Parton energy
3 neutrino *(P components)*
3 neutrino *(P components)*
-2 *(P_T conservation)*

Matrix Element & Integrals

Alpgen subroutine for WW+2p
Integration with VEGAS

After selection cuts

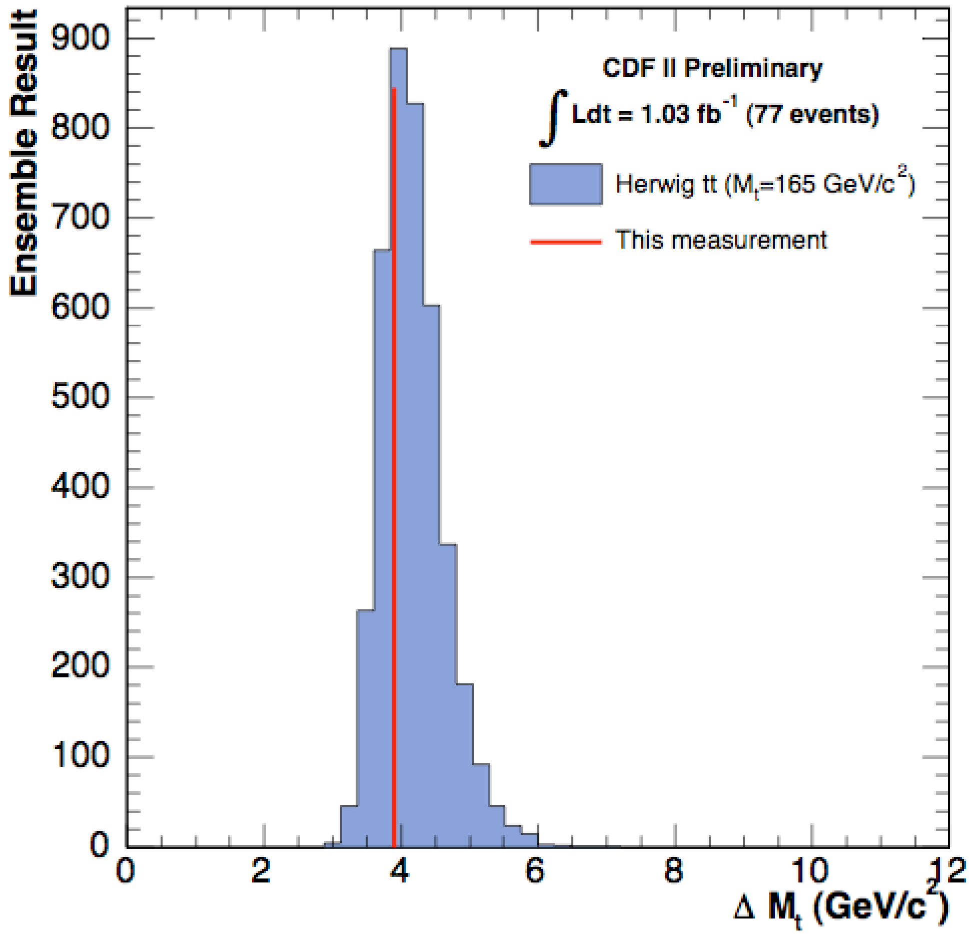


Expected Sensitivity

Sensitivity

If M_t = 165 GeV/c^2,
mean stat error is 4.1 GeV/c^2

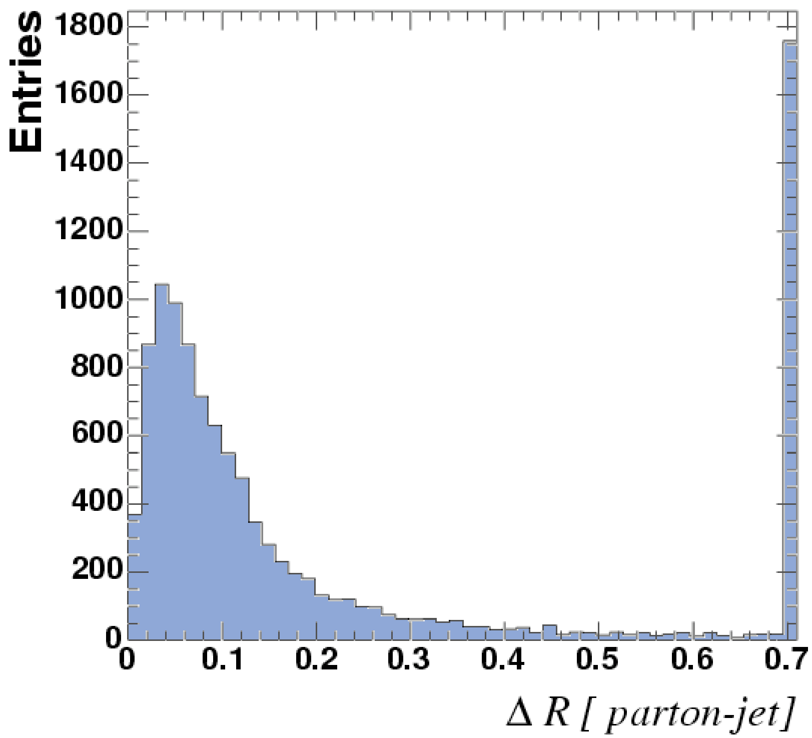
If M_t = 178 GeV/c^2
mean stat error is 5.1 GeV/c^2

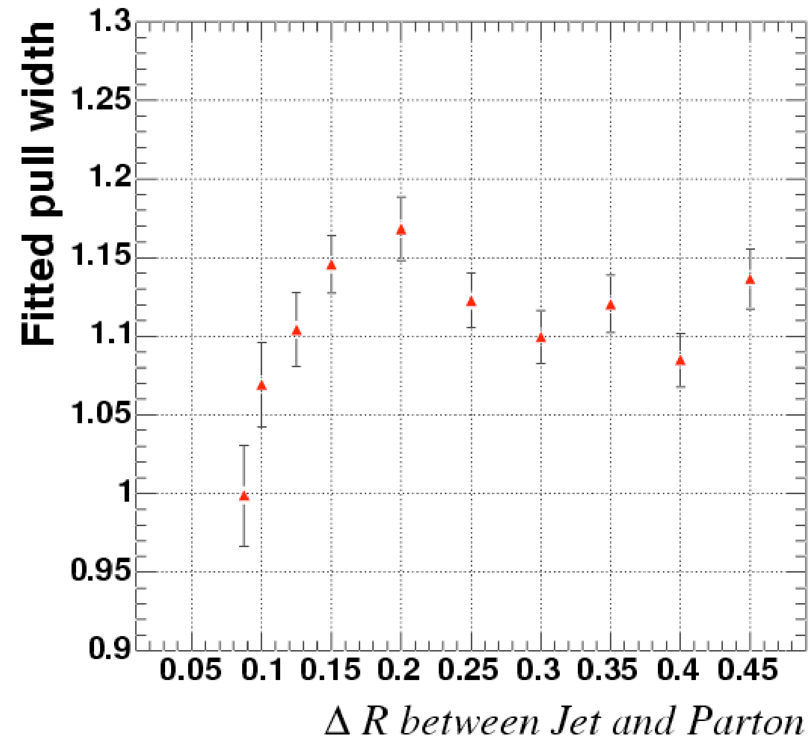


46% of pseudo-experiments
give smaller errors

Pull Width: jet angles

Requring two matched b-jets
Requiring well-measured leptons





Pull width decreases to ~1 as angle improves

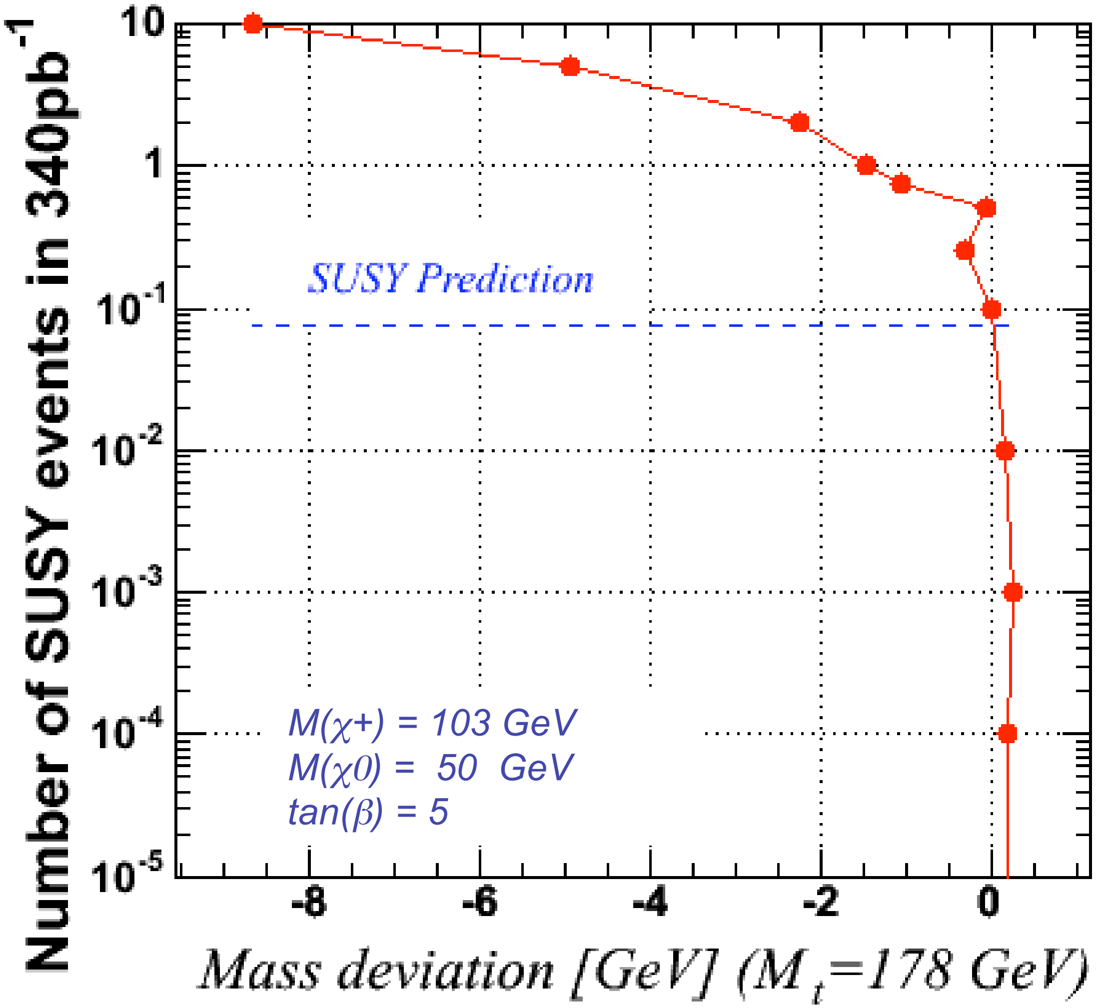
Effect of SUSY events on dilepton mass measurement

Chargino/Neutralino

Topology is lll+2j or llqq

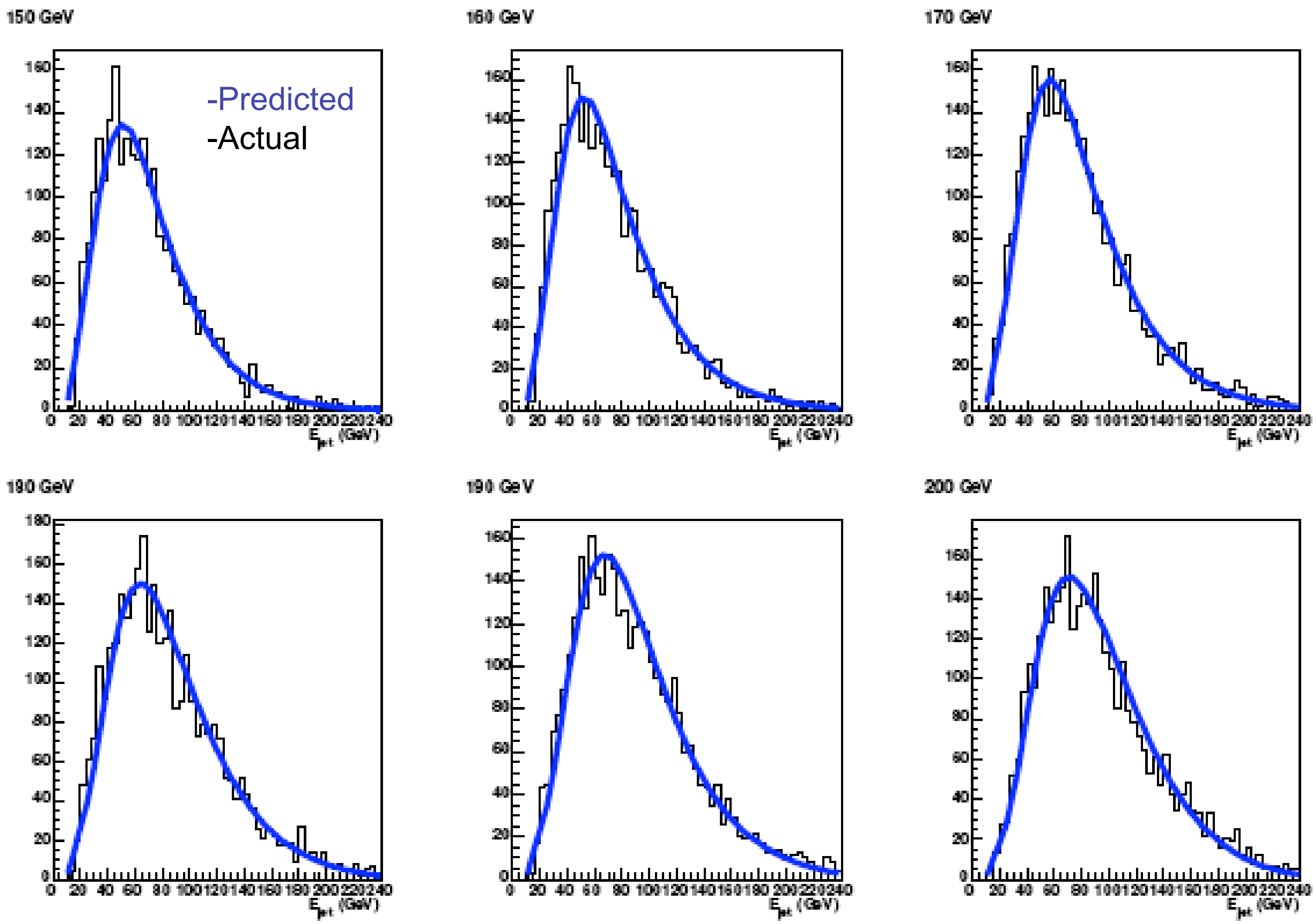
M(χ+) = 103 GeV
M(χ0) = 50 GeV
tan(β) = 5

*Sigma*br = 150 fb*
Acc = 0.15%



TFS

Transfer functions predict jet energy spectrum at varying top masses.



Standard Candles

Z decays are used to understand

Lepton acceptance & resolution
Calorimeter calibration & resolution
Missing energy resolution
Jet energy scale
Trigger efficiencies