Top Mass in Dileptonic Channel using Kinematic Method at CDF

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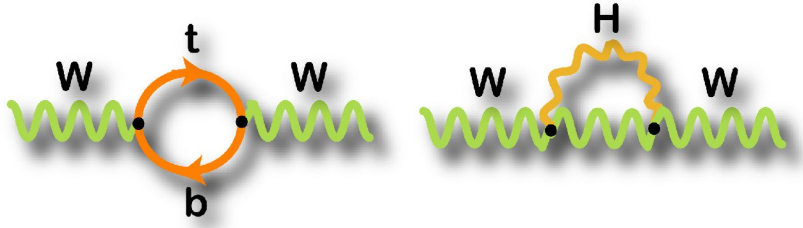
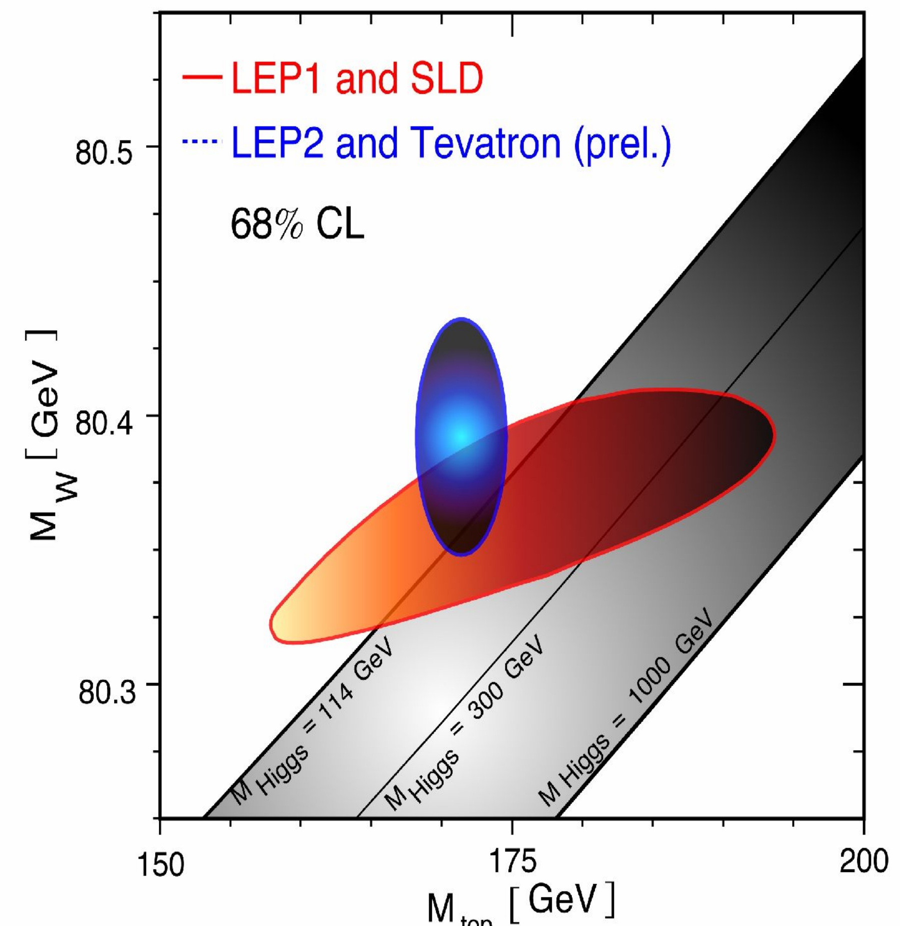
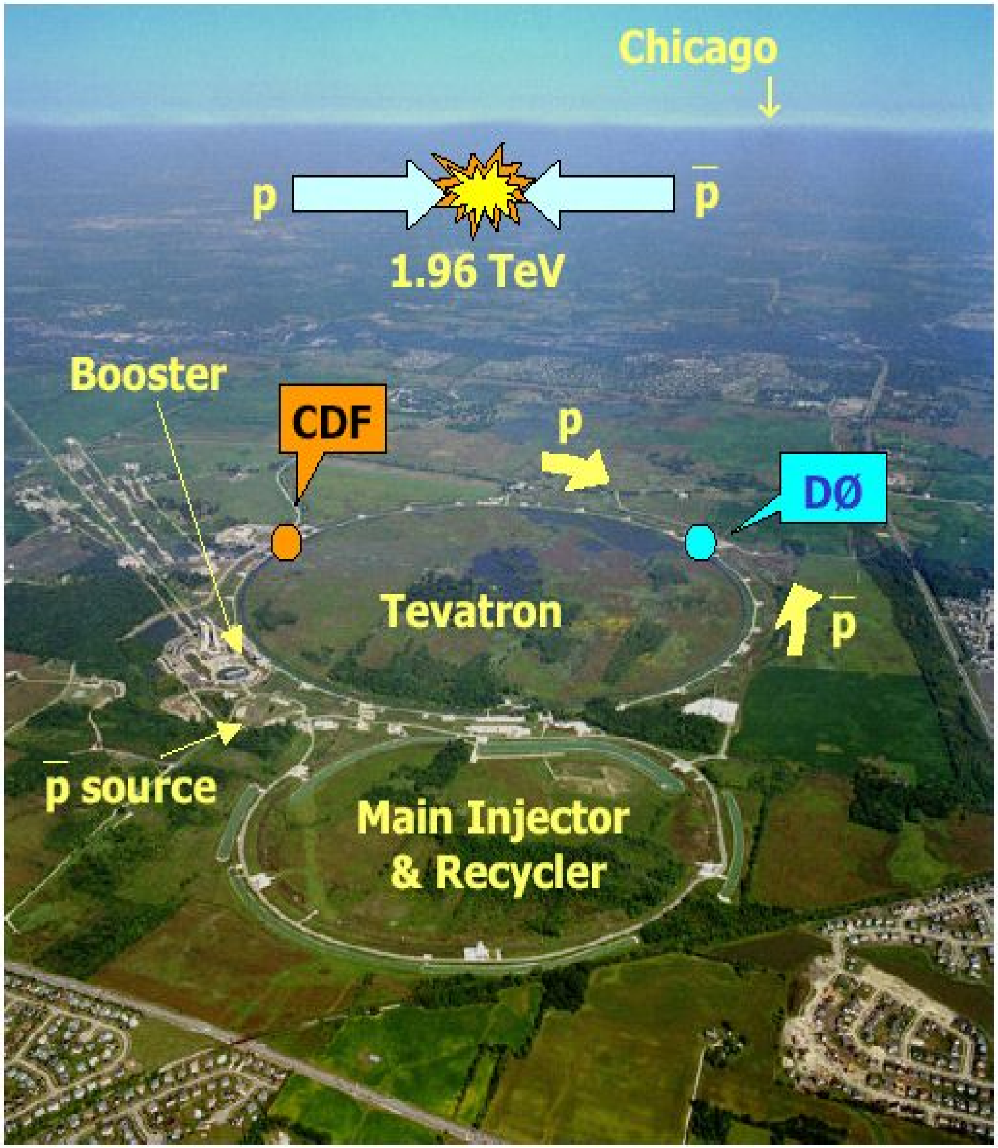
Introduction

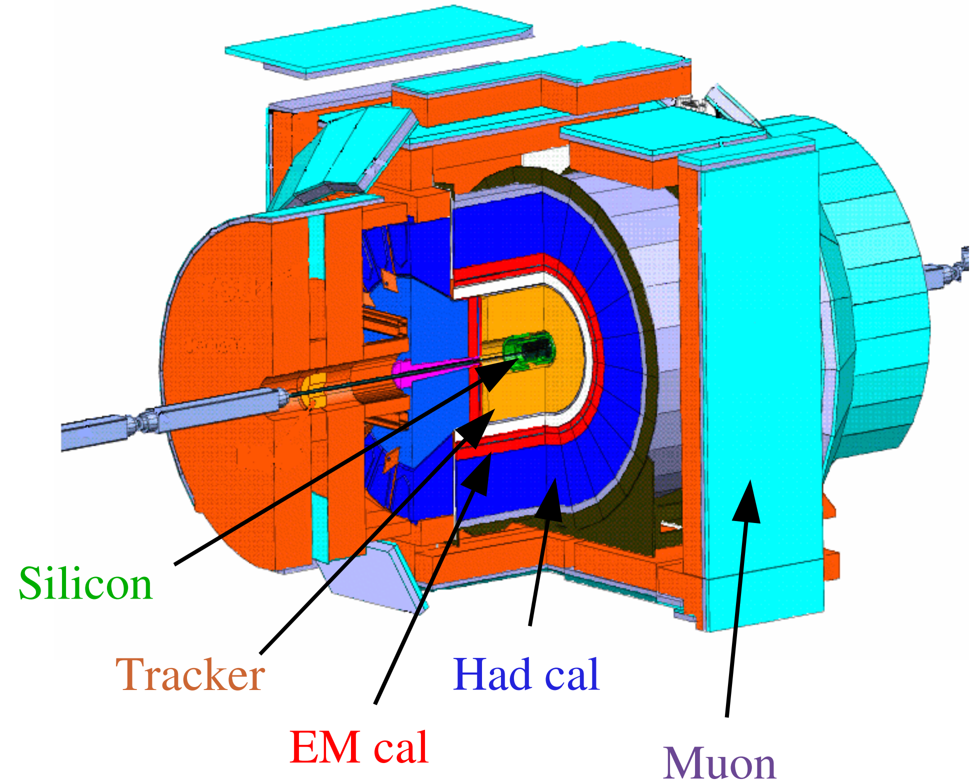
- Top mass fundamental SM parameter:
  - *tests SM predictions*
  - *important in radiative corrections*
  - *constrains SM Higgs mass*
- Top mass close to scale of electroweak symmetry breaking
- Constraints on SYSY models





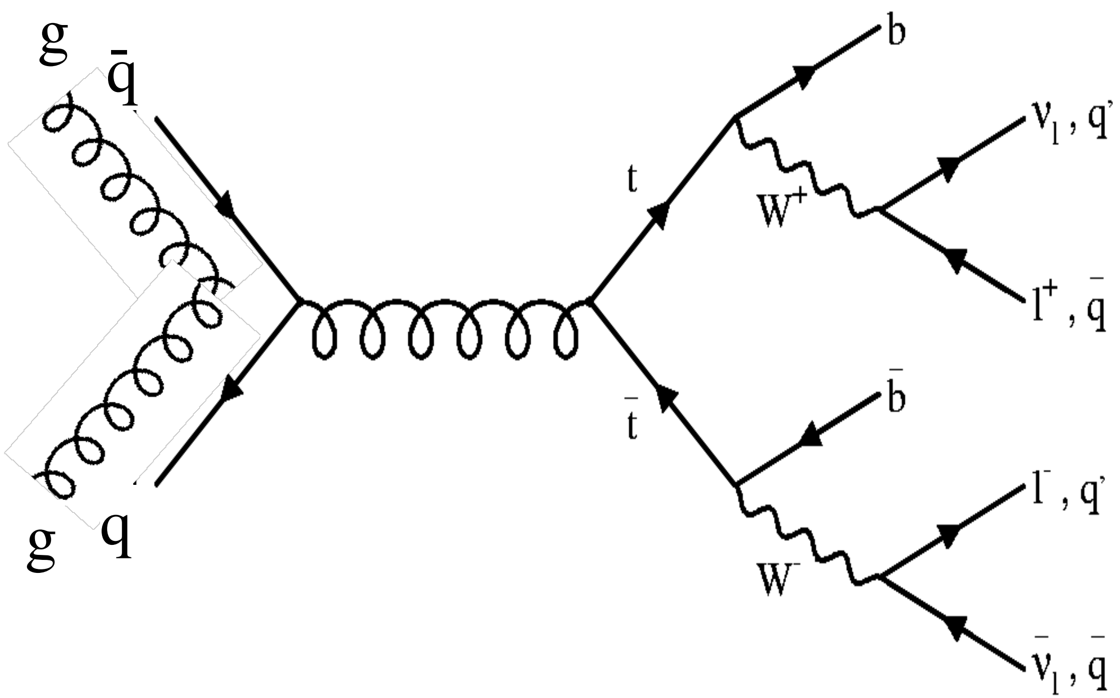
Tevatron and CDF





- Tevatron record instantanous luminosity: $2.3*10^{32}$ $cm^{-2}s^{-1}$
- CDF has collected 1.6 fb^{-1} data
- This analysis uses 1.0 fb^{-1}

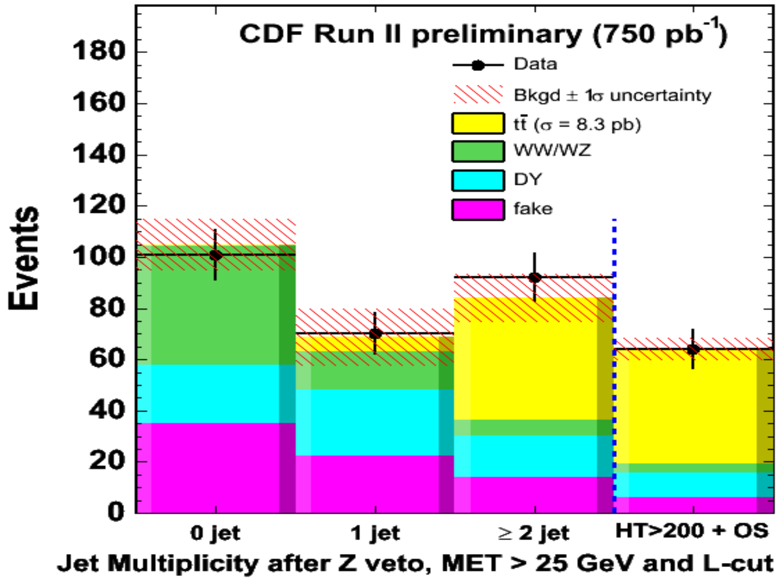
Top decay



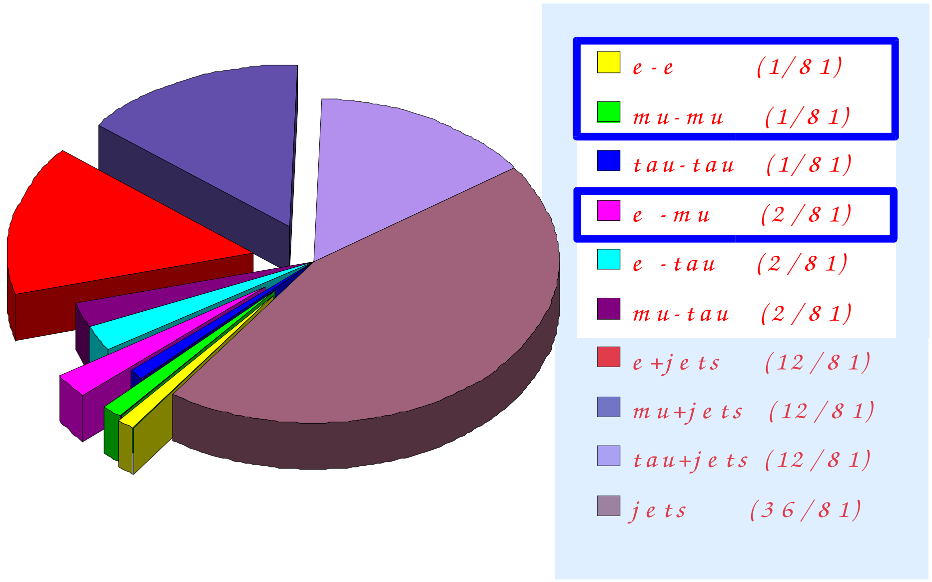
- Top mass measurements use pair produced top quarks
- Dilepton channel:
  - *both W-bosons decay leptonically*
- Experimental signature:
  - *two charged leptons*
  - *at least two jets*
  - *missing energy*

Top decay channels

- Dileptonic events: 5% BR in total
  - + *clean signature*
  - + *only two possible parton-jet assignments*
  - – *lowest statistics*
  - – *two neutrinos in final state ⇒ under-constraint system for fitting of top mass*



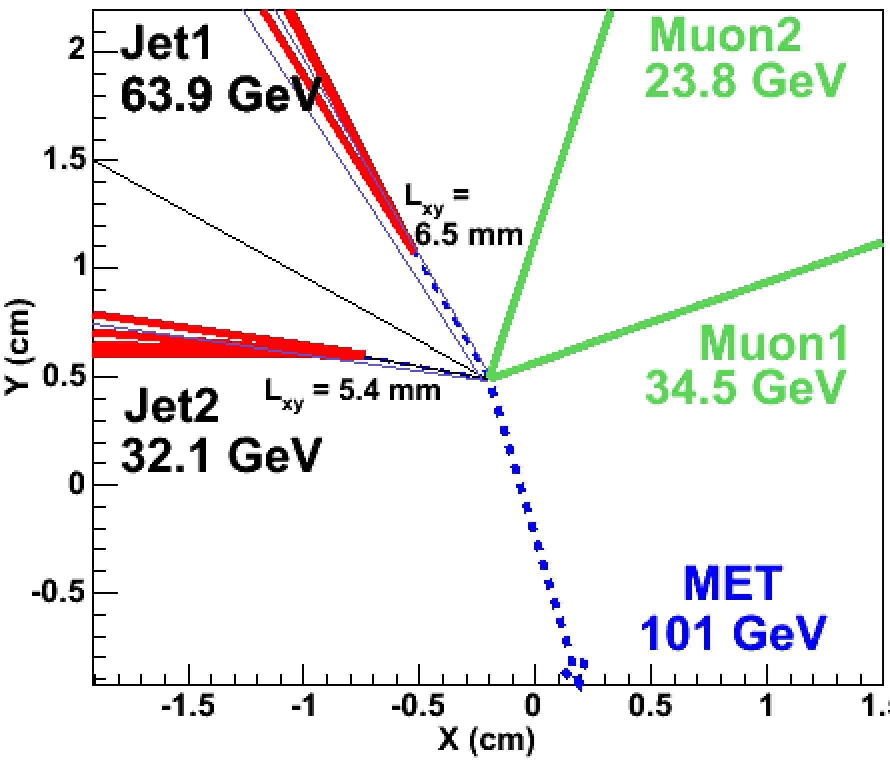
- Discrepancy between top mass measurements in different channels could indicate new physics



Event selection

- Events selected by requiring:
  - *2 isolated leptons (e,μ) with* $p_T > 2GeV$
  - *2 or more jets with* $E_T > 15$ *GeV*
  - *missing* $E_T > 25$ *GeV*
  - *two leptons must be oppositely charged and not from Z boson*
  - $H_T > 200$ *GeV*

Process	N events (1.0 fb^{-1})
WW	3.75±0.97
WZ	1.29±0.21
Drell-Yan	10.9±4.38
$Z\rightarrow\tau\tau$	2.22±0.53
Fakes	8.74±1.50
Total background	26.9±4.76
Signal (σ_{tt} =6.7 pb)	50.2±1.72
Total expected	77.1±5.45
Observed	78



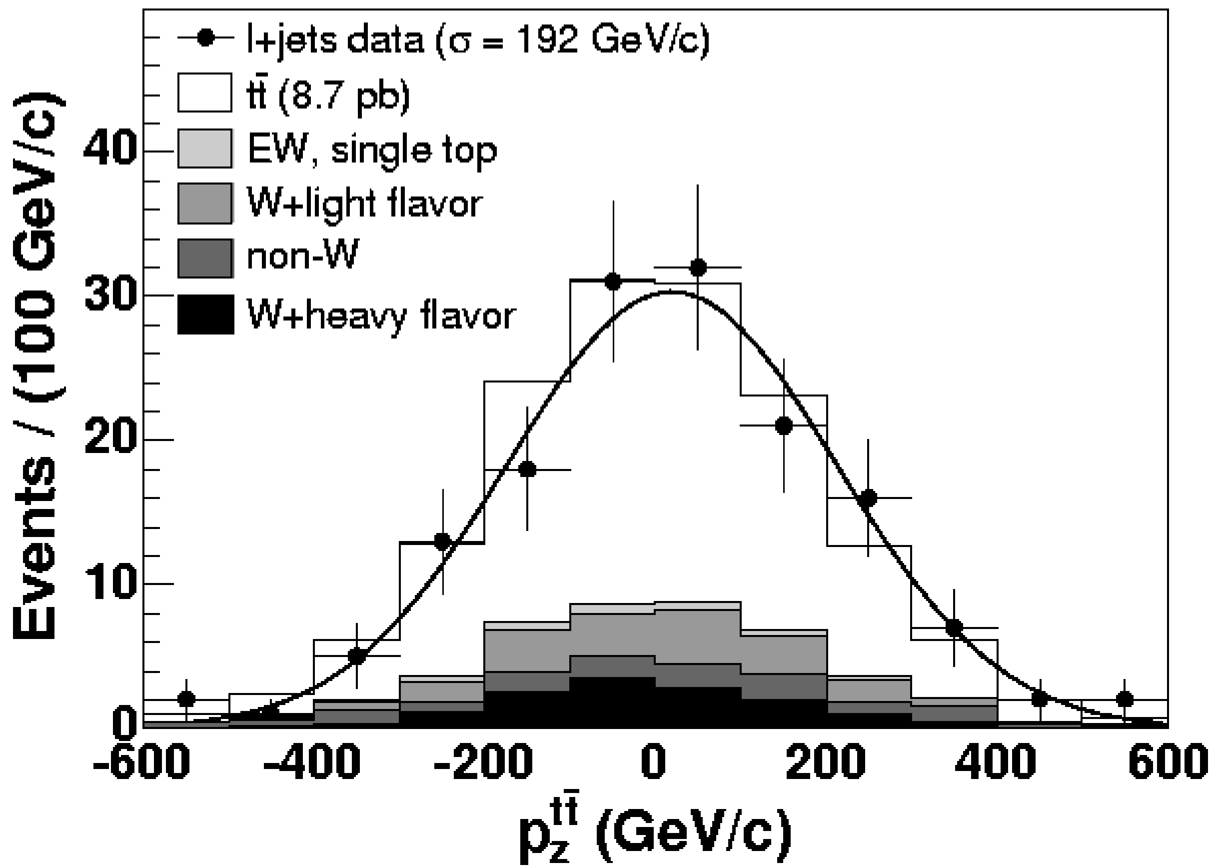
Mass reconstruction method

- 6 particles in final state ⇒ kinematics fully specified by 24 quantities
- Due to neutrinos in final state, we are only able to write 23 equations
- Under-constrained system for fitting of top mass ⇒ need an extra assumption

$$
\begin{aligned}
p_x^{\nu} + p_x^{\bar{\nu}} &= \not{E}_x \\
p_y^{\nu} + p_y^{\bar{\nu}} &= \not{E}_y \\
m_t &= m_{\bar{t}} \\
m_{W^\pm} &= 80.4\ \mathrm{GeV}/c^2 \\
m_\nu &= 0 \\
\vec{p}_b + \vec{p}_{W^+} &= \vec{p}_t \\
\vec{p}_{\bar{b}} + \vec{p}_{W^-} &= \vec{p}_{\bar{t}} \\
\vec{p}_{l^+} + \vec{p}_\nu &= \vec{p}_{W^+} \\
\vec{p}_{l^-} + \vec{p}_{\bar{\nu}} &= \vec{p}_{W^-}
\end{aligned}
$$

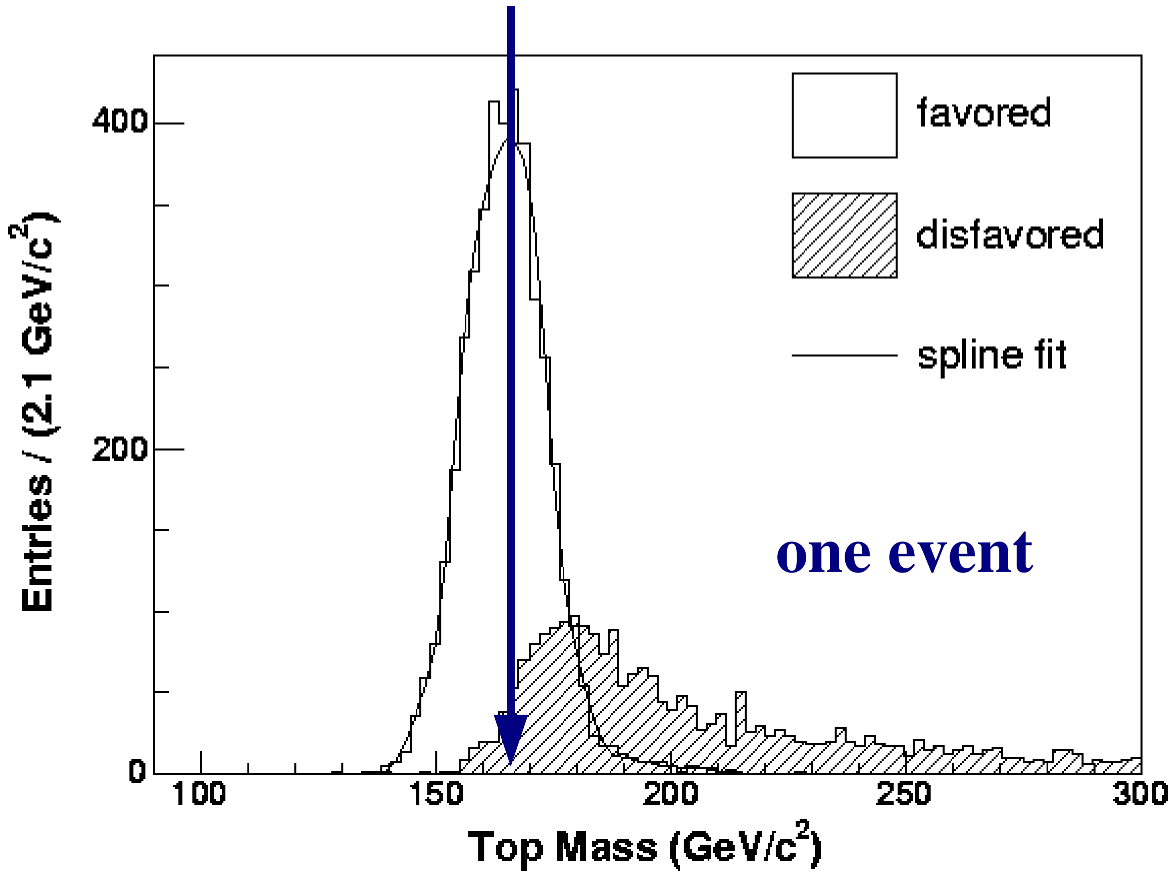
Mass reconstruction method

- Need distribution which is not top mass dependent
- We take longitudinal component of ttbar momentum.
  - *nearly independent on top mass*
  - *zero-centered Gaussian*
- Assumption tested with lepton+jet data



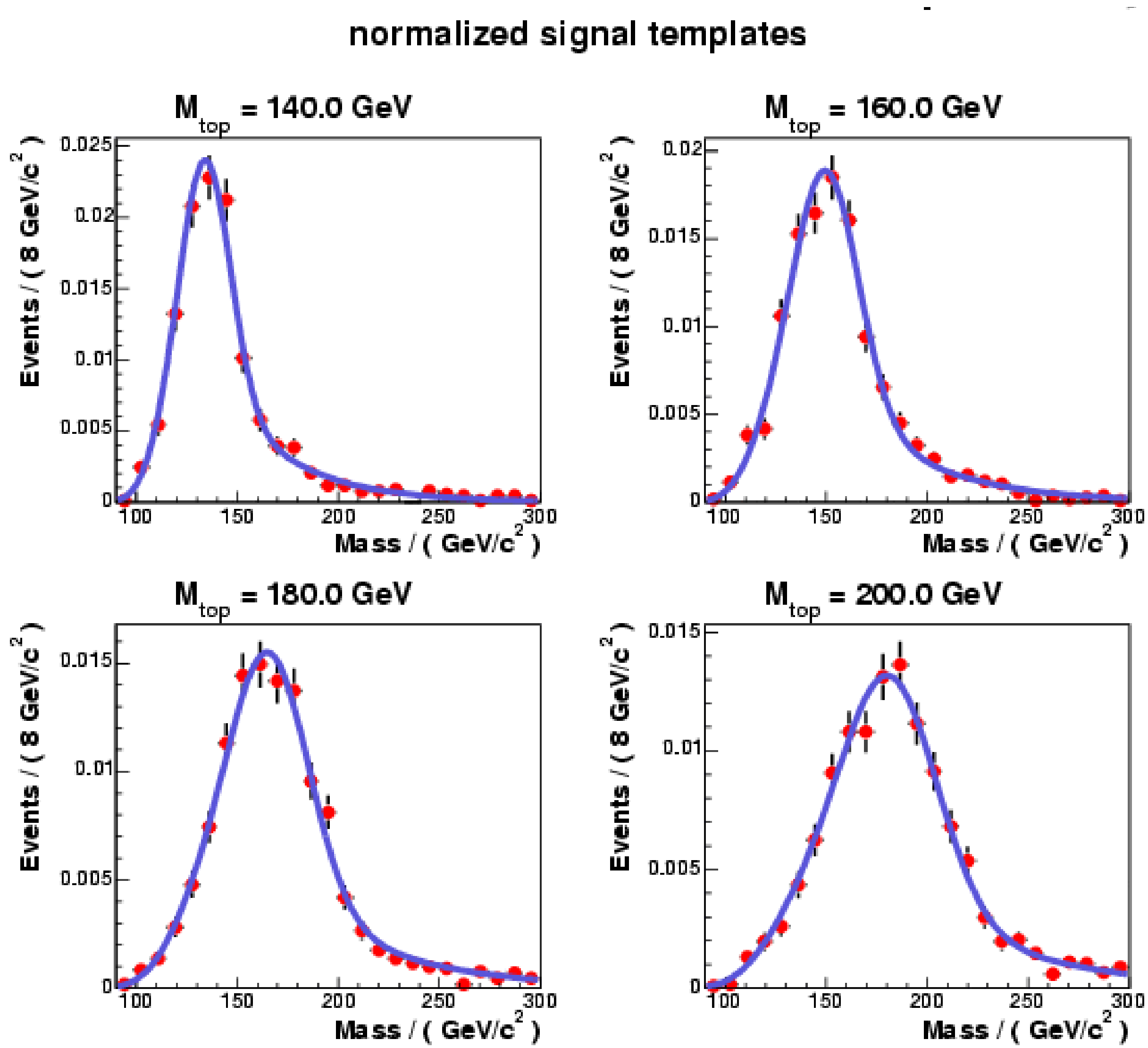
Mass reconstruction method

- Smear $P_z^{t\bar{t}}$, jet energies and missing E_T in the allowed phase space
- Perform kinematic reconstruction of m_t at each point using Newton's method
- For each event, we associate "raw top mass" as the MPV of spline fit



Signal templates

- Generate signal templates with different top masses
  - *"raw top masses" from several events*
- Parametrized with combination of Gaussian and Landau function
  - *function of reconstructed and true top mass*

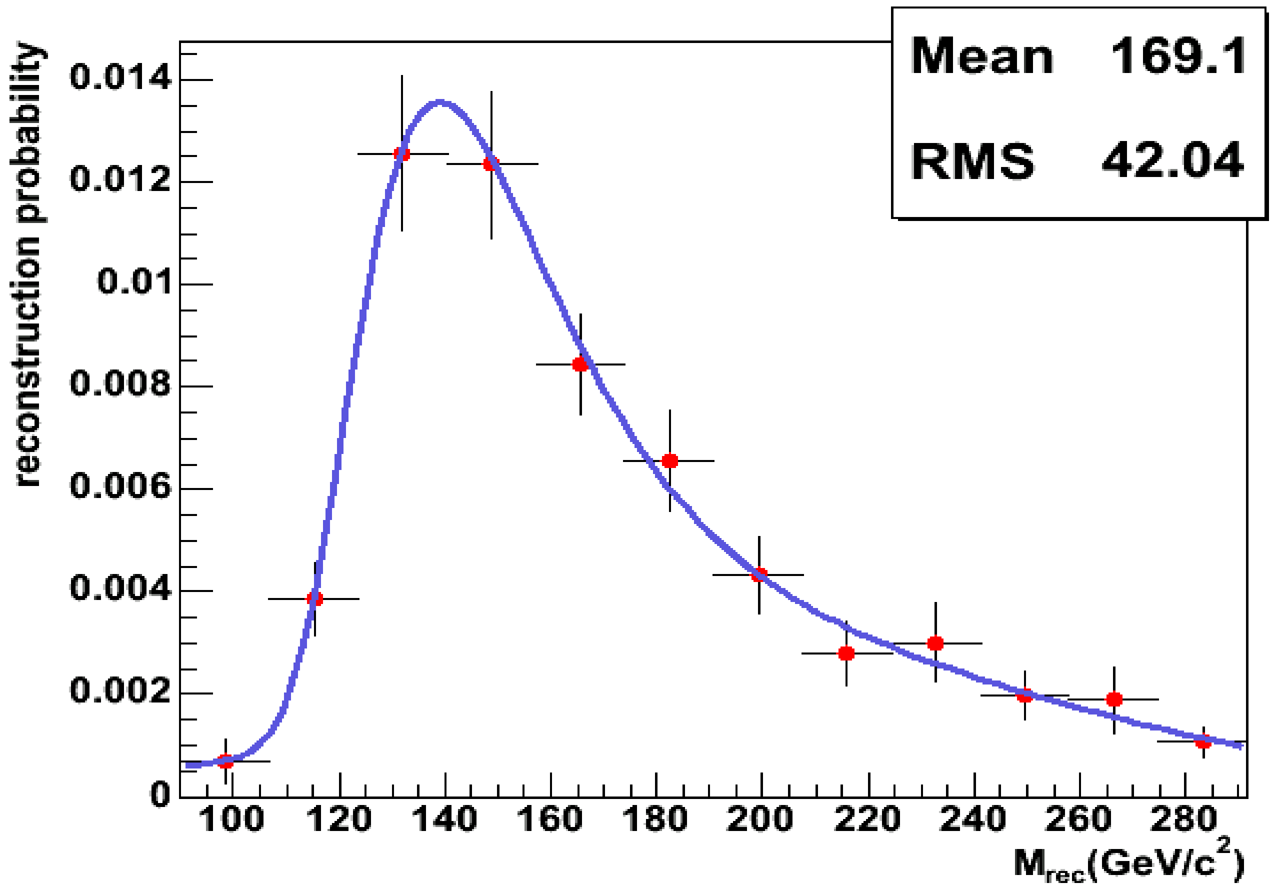


Background template

- Background template function of reconstructed top mass

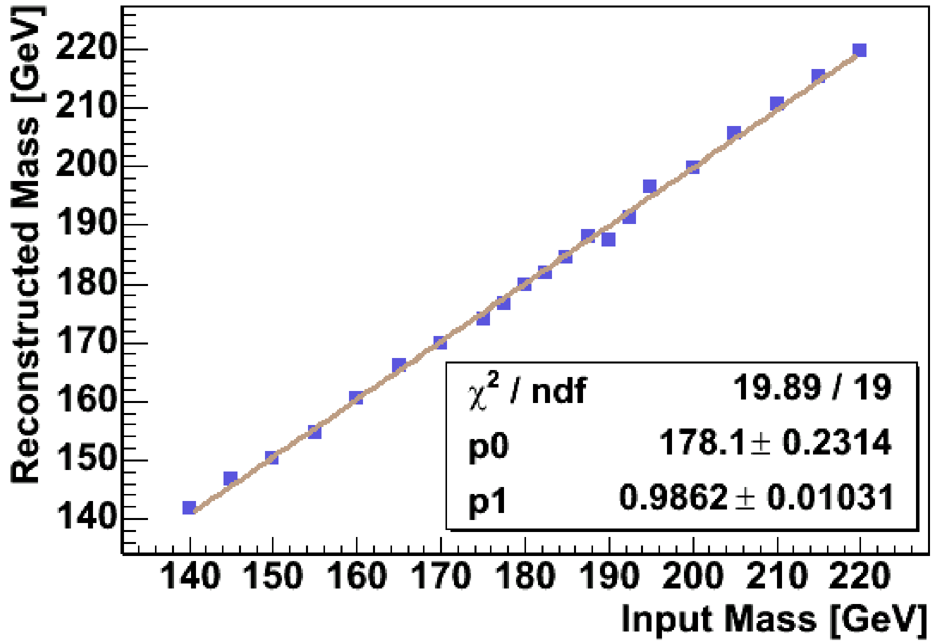
- Background processes:
  - WW 14%
  - WZ 4.8%
  - Drell-Yan 41%
  - Z→ττ 8.3%
  - Fakes 32%

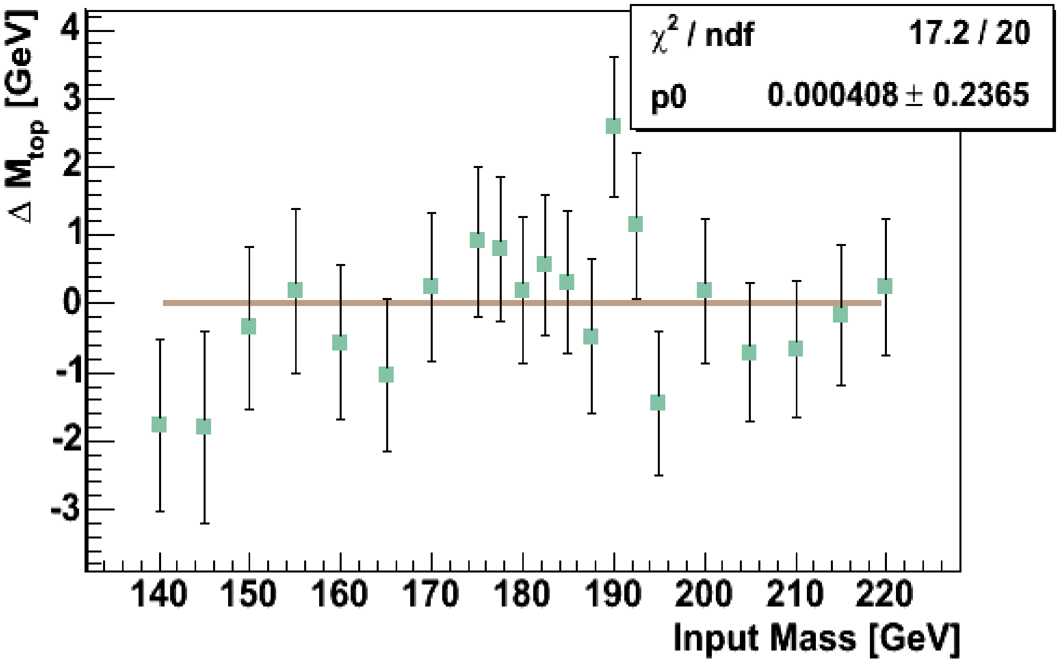
- Expected number of background events in 1.0 fb^{-1}: 16.4 events



Pseudo-experiments

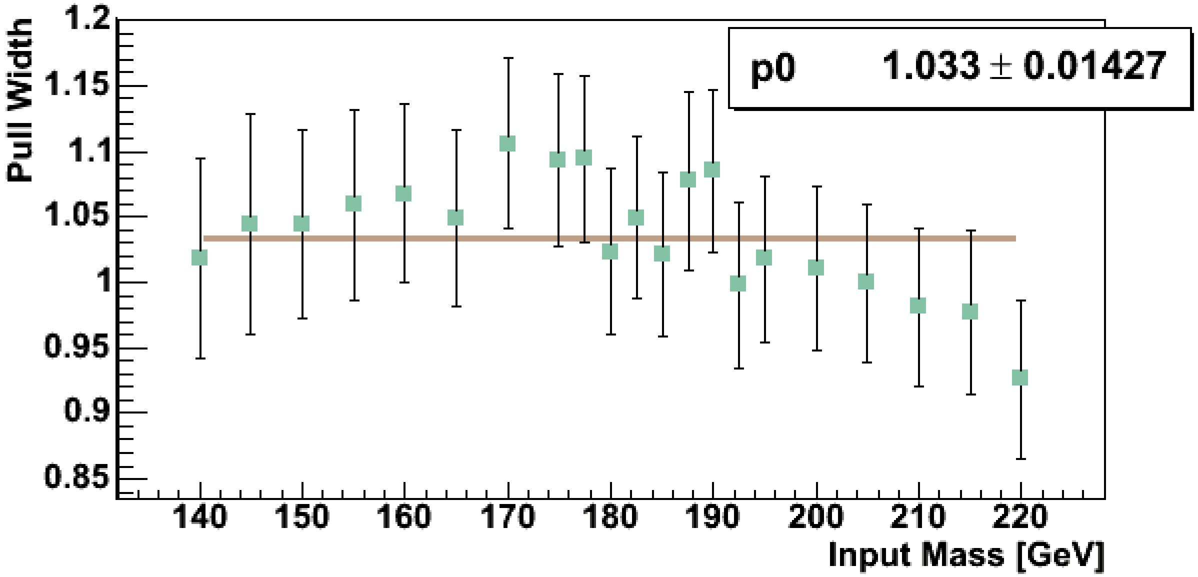
- Method tested with pseudo-experiments and blind samples
  - *method is unbiased*





Pseudo-experiments

- Method tested with pseudo-experiments and blind samples
  - *error returned by method is almost correct, correct it with 1.033 scale factor*



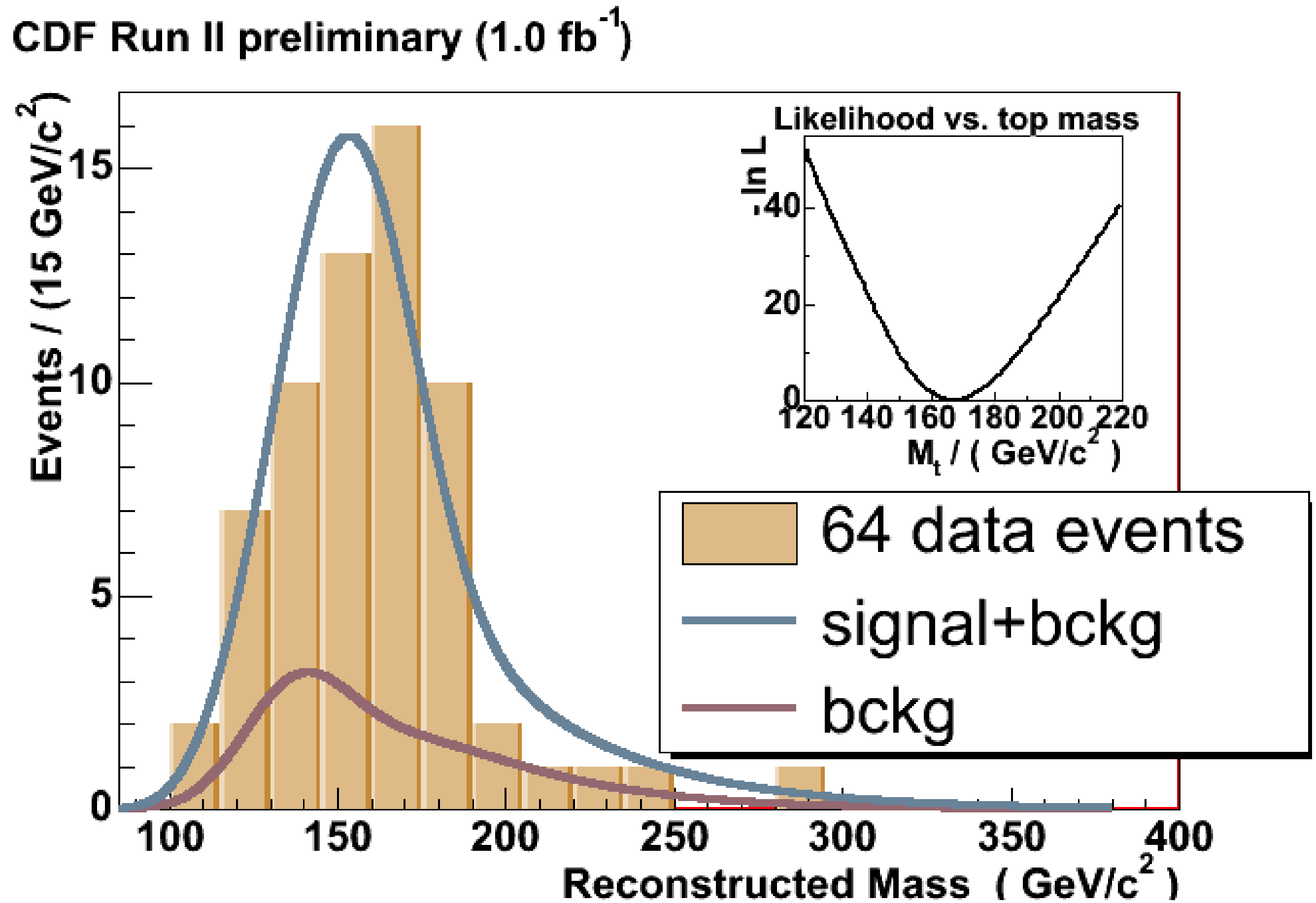
Systematic uncertainties

CDF Run II preliminary

Source	ΔM_{top} (GeV/c^2)
Jet Energy Scale	3.2
B-jet energy scale	0.6
Generators	0.6
ISR	0.6
FSR	0.3
PDFs	0.5
Signal statistics	0.4
Background shape	1.6
Background statistics	1.2
Multiple interactions	0.2
Lepton energy scale	0.4
Total	4.0

Extracted top mass

- 1.0 fb^{-1} of data collected by CDF:
  - *64 events pass event selection and mass reconstruction*

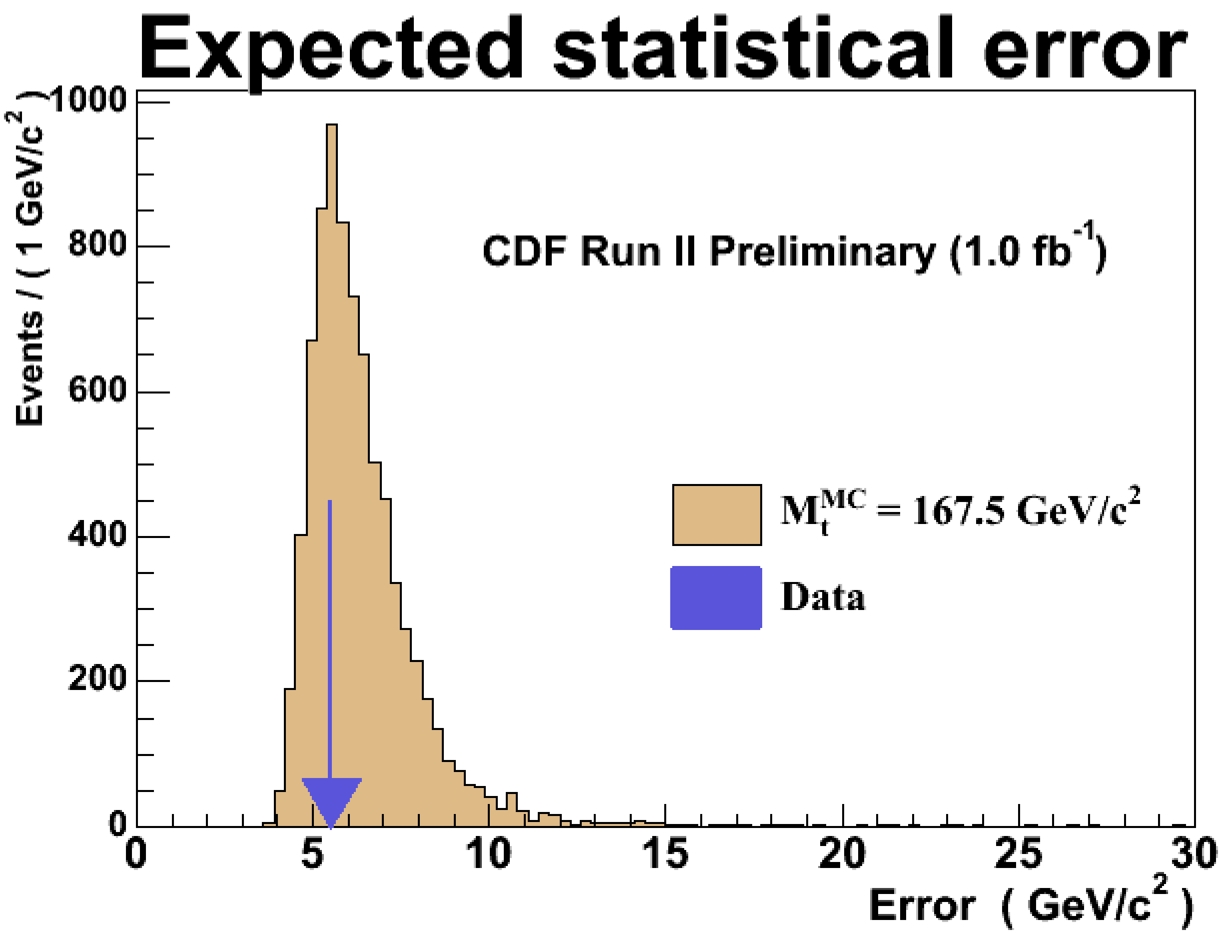


CDF Run II Preliminary

$$M_{top} = 168.1^{+5.6}_{-5.5}(\text{stat.}) \pm 4.0(\text{syst.}) \quad \text{GeV}/c^2$$

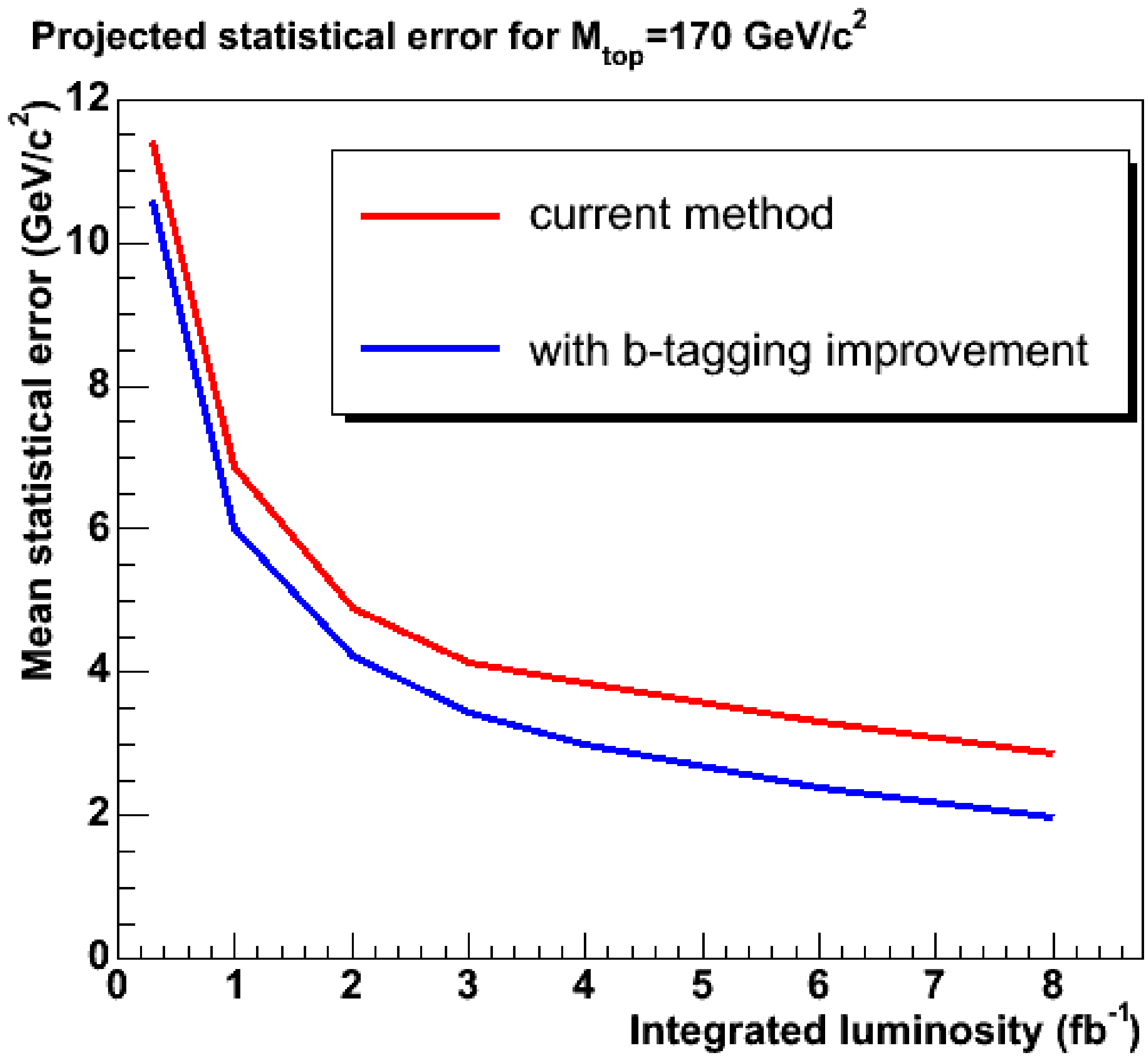
Expected statistical error

- Pseudo-experiments with observed number of events (64)
- 33% of pseudo-experiments return smaller statistical error than the measured statistical error



Future prospects

- Improvements on method:
  - *use b-tagging*
  - *optimized parameters*
  - *more under study*
- Most systematic uncertainties improve with more data and/or better method
- Measurement is becoming systematics limited



Conclusions

- It is important to measure top mass in all decay channels
  - *discrepancy between measurements could indicate new physics*
- Dileptonic events under-constrained for top mass measurement
  - *mass reconstruction possible using top mass dependent distribution*
  - *we use* $P_z^{t\bar{t}}$
- Extracted top mass from 1 fb^{-1} using kinematic method at CDF:

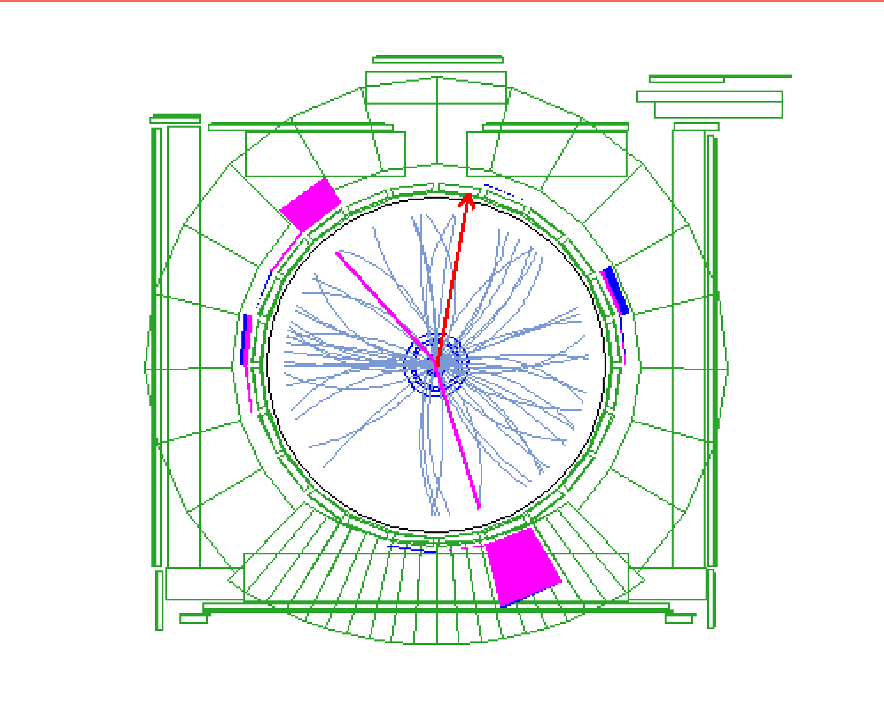
CDF Run II Preliminary

$$M_{top} = 168.1^{+5.6}_{-5.5}(\text{stat.}) \pm 4.0(\text{syst.}) \quad \text{GeV}/c^2$$

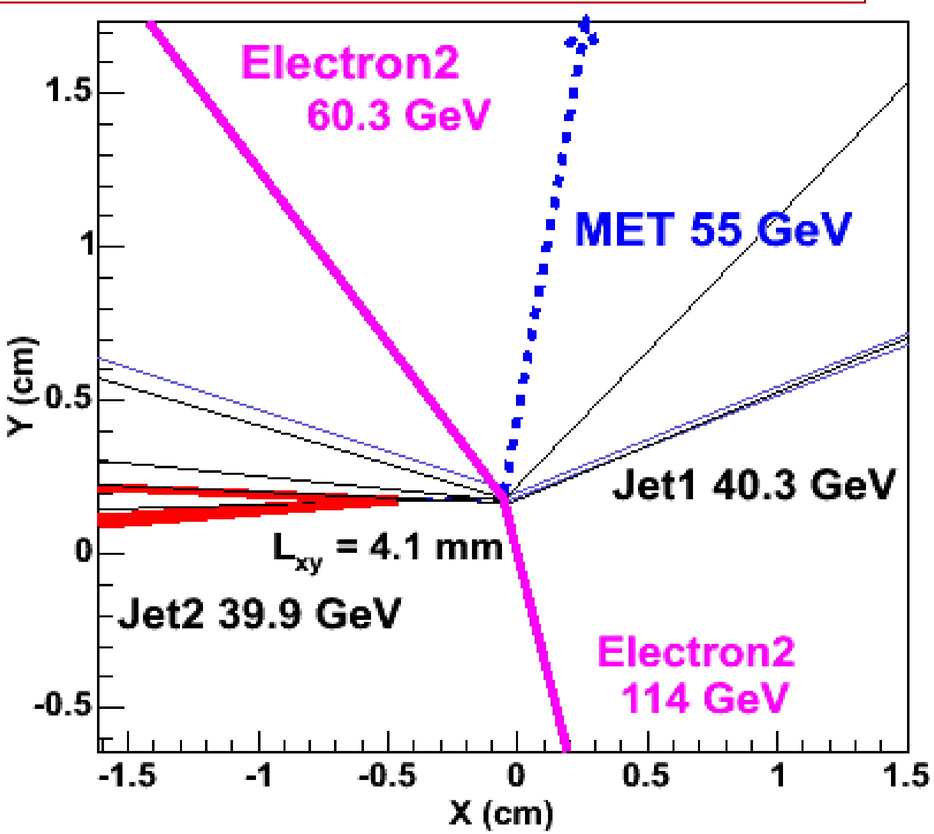
- Interesting times to come
  - *improved mass extraction technique and more data will make measurement more precise*

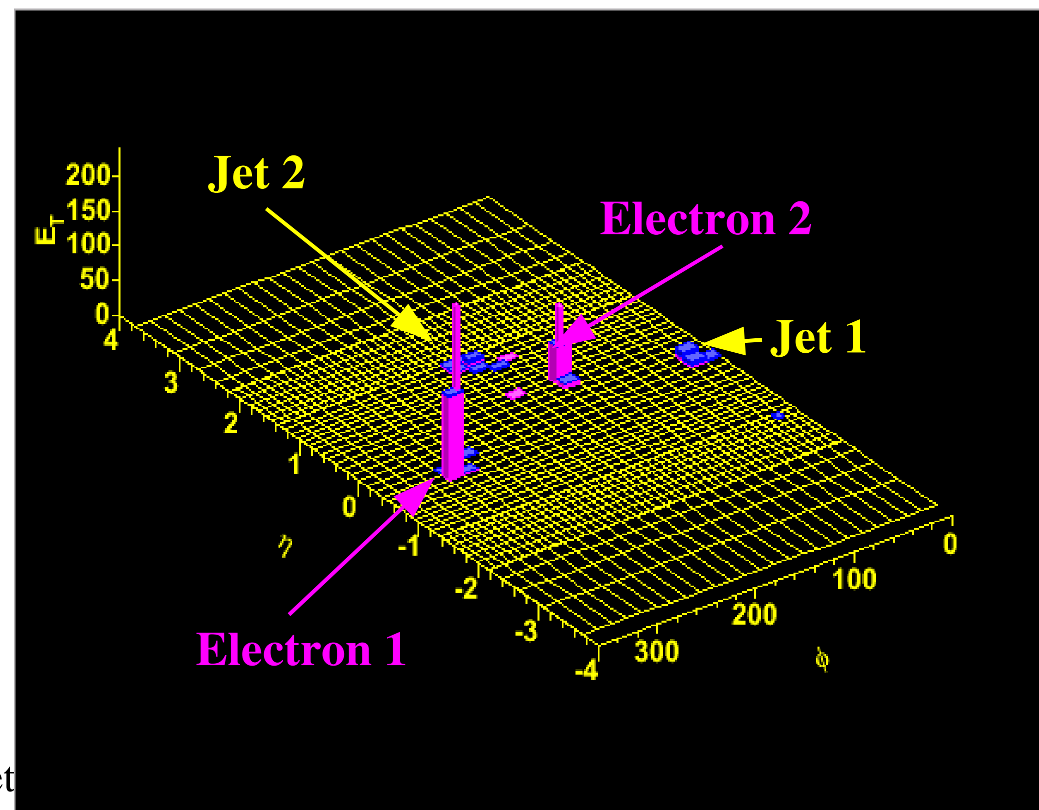
Backup

Event displays



electron-electron candidate event





Likelihood fit

- Final top mass estimate from likelihood fit of the data to the templates
- Fit parameters: number of signal events, number of background events and top mass

$$\mathcal{L}_{sample} \equiv \mathcal{L}_{shape} \times \mathcal{L}_{bg}$$

$$\mathcal{L}_{shape} \equiv \frac{e^{-(n_s+n_b)}(n_s+n_b)^N}{N!} \prod_{i=1}^{n} \frac{n_s \times f_s({m_{t_i}}^{rec}, m_t^{orig}) + n_b \times f_b({m_{t_i}}^{rec})}{n_s+n_b}$$

$$-\ln \mathcal{L}_{bg} \equiv \frac{(n_b - n_b^{exp})^2}{2\sigma_{n_b}^2}$$