Top mass and properties

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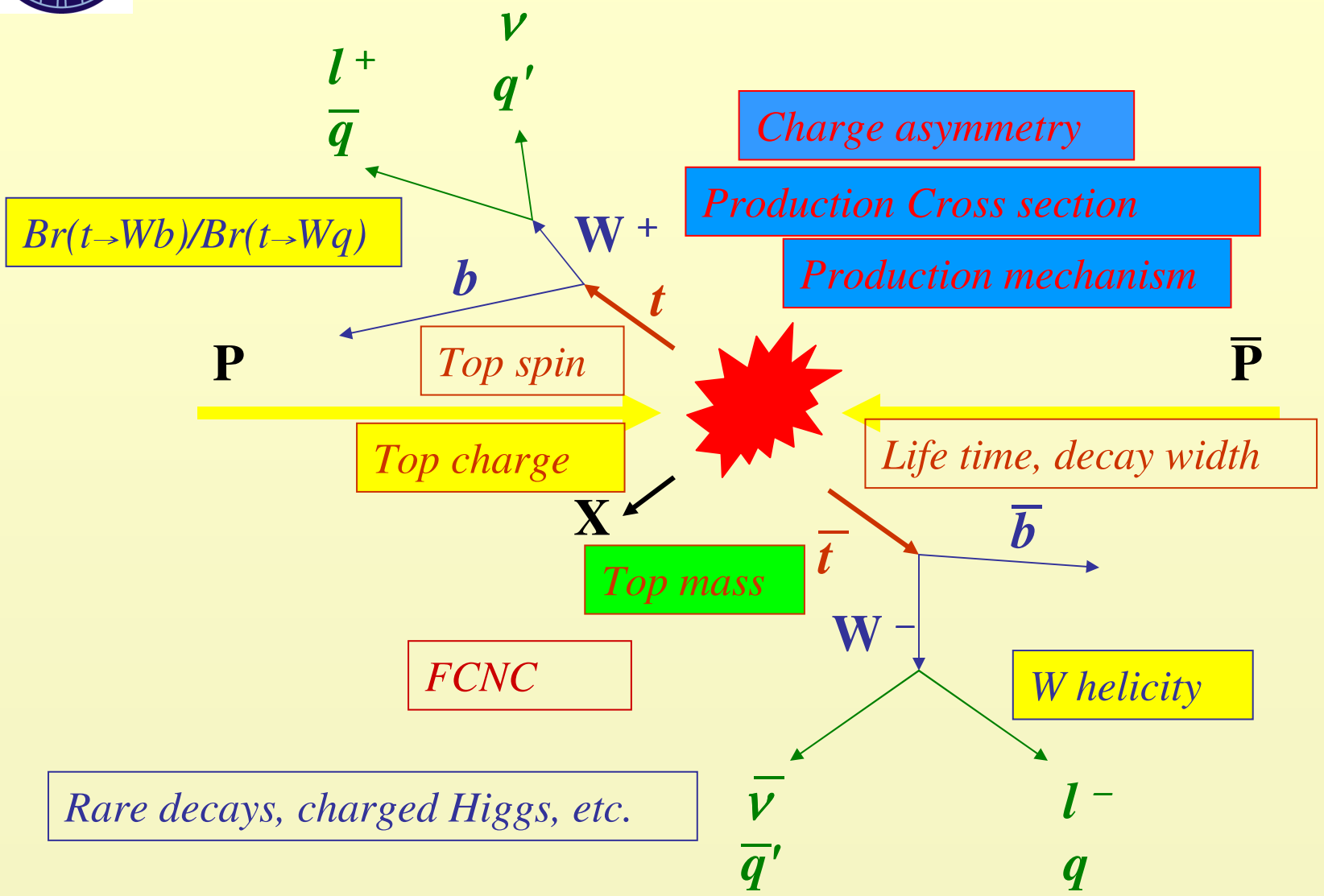
For the CDF and D0 collaboration

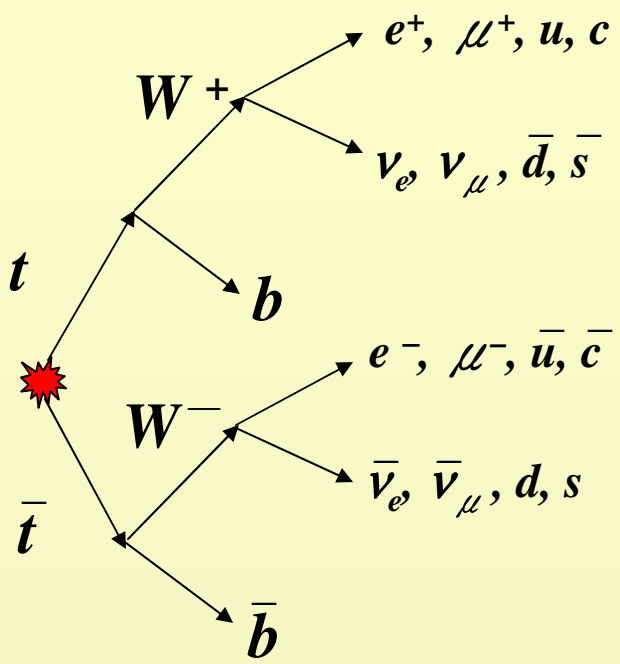
More than ten years after Top/Truth quark was found …

- *The mass is well measured.*
  - *Assuming that this is really the Top/Truth!*
- *Is it really Top/Truth of the Standard Model (SM)?*
  - *Studying the properties*

Top quark physics



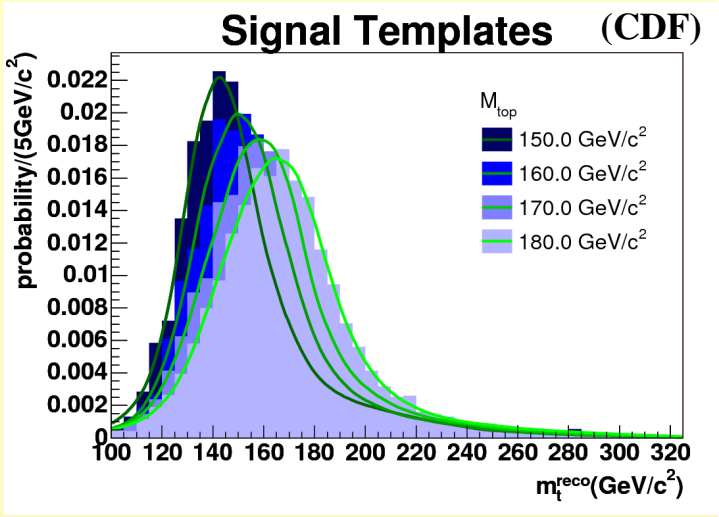
Top mass measurement

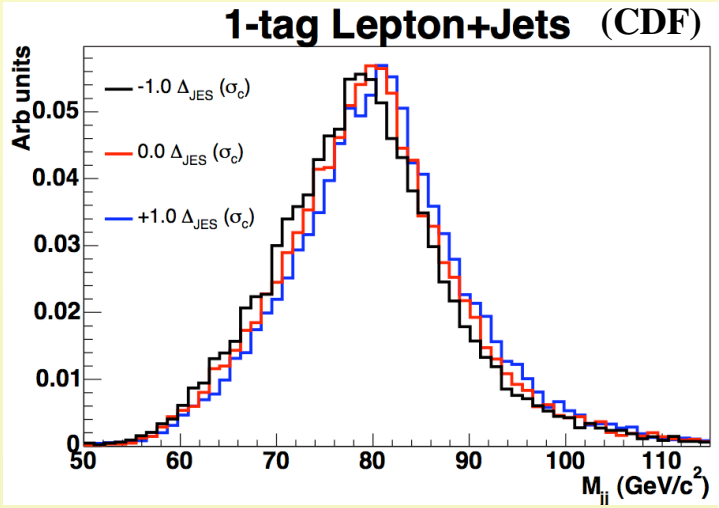


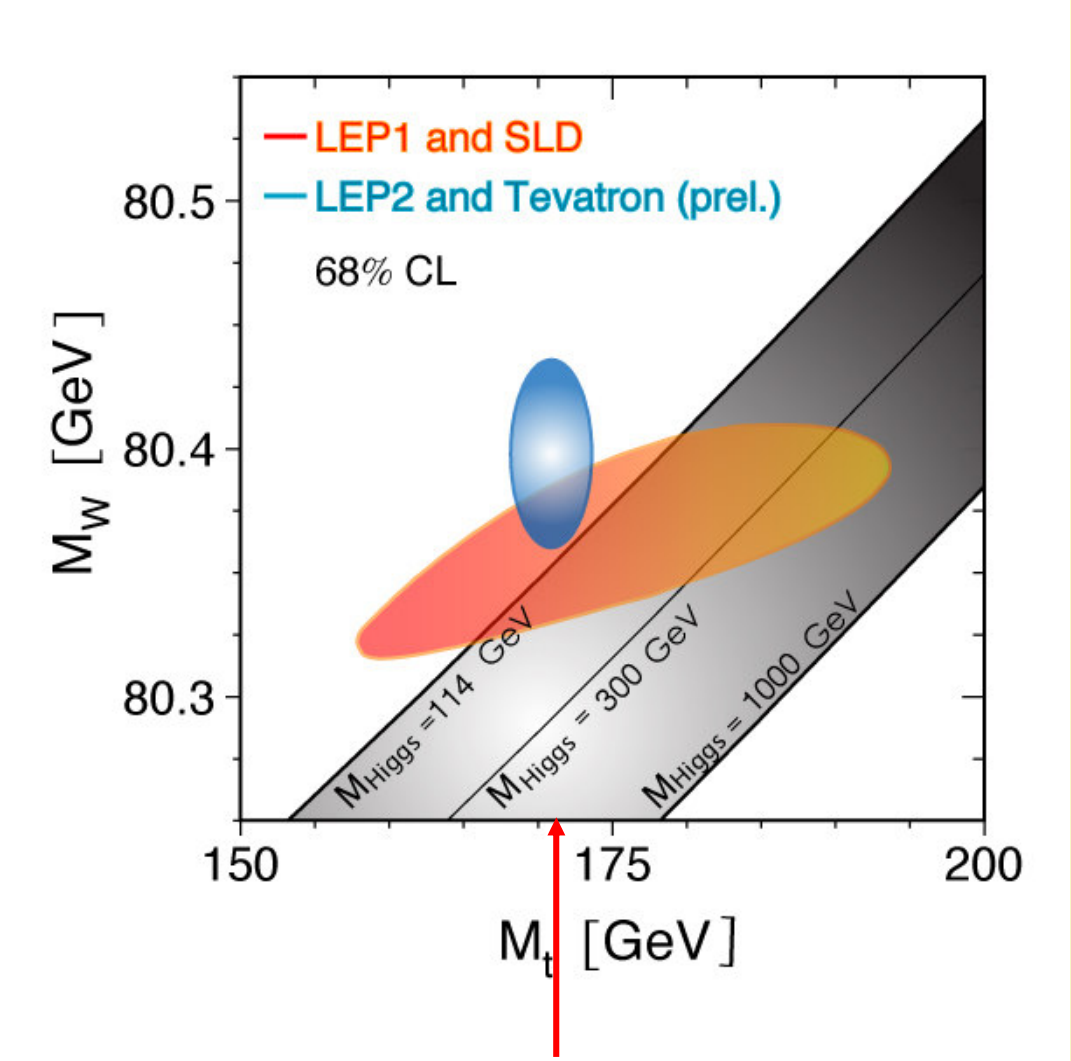
- *Di-lepton (DIL) channel:*
  - *both W decay to leptons,*
  - *in practice uses only e, μ.*
- *Lepton+Jets (LJ) channel:*
  - *one W decays to leptons,*
  - *the other decays to quarks.*
- *Hadronic channel:*
  - *both W decay to quarks.*

Top mass measurement the techniques

- Fit to reconstructed Top mass templates
- In-situ jet energy calibration
  - Based on W->jj
  - Constraint on W boson mass
- Using Matrix Element (ME):
  - Use leading order matrix element
  - Integrating over the phase space
  - Find the probability density as a function of Top mass
- Single sensitive variable, Lxy
- Matrix weighting
- Neutrino weighting
- Other methods not described here :
  - Kinematic method, constraint to Xsection...



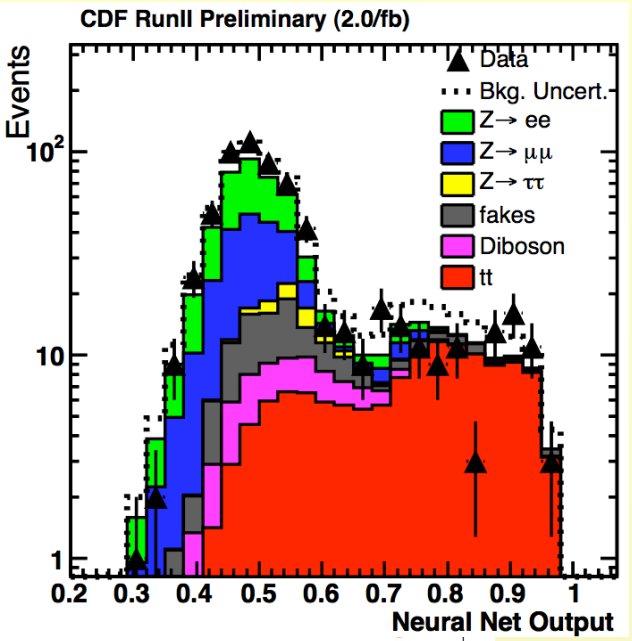


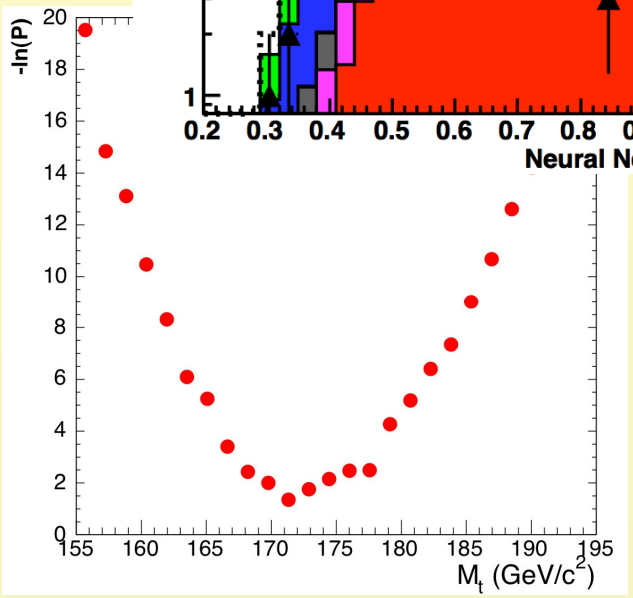


M_t = 170.9 ± 1.8 GeV/c^2,

from 1 fb^{-1} CDF+D0 combination

Top mass measurement, CDF

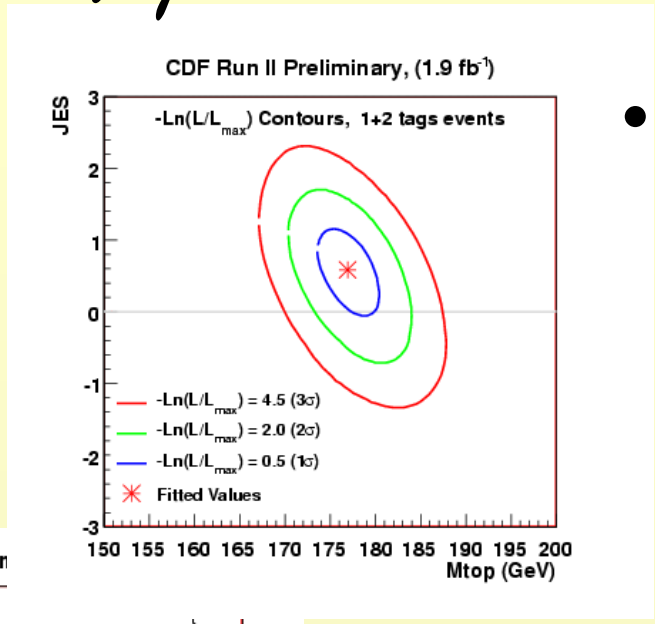


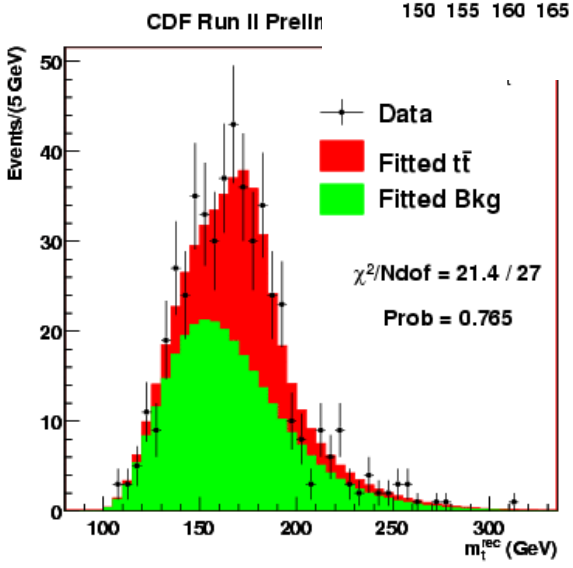


- *Use Neural Networks to select DIL Top candidates then perform ME, 2 fb^{-1}.*
  - *This neural networks is evolutional.*
  - *optimized on improving uncertainty.*

$$m_t = 171.2 \pm 2.7(stat) \pm 2.9(sys)\,\mathrm{GeV/c^2}$$

Top mass measurement, CDF

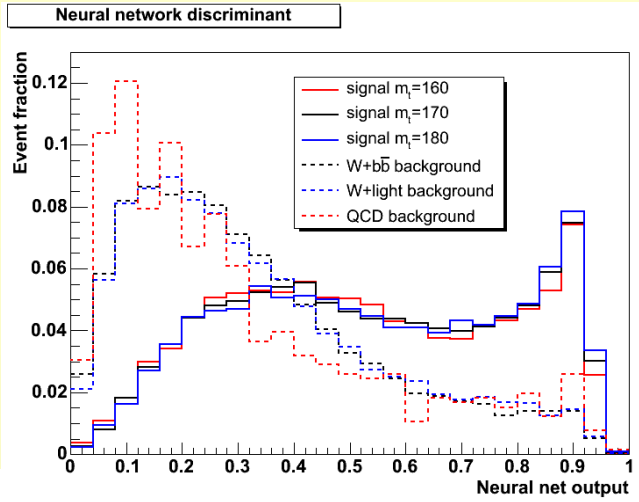


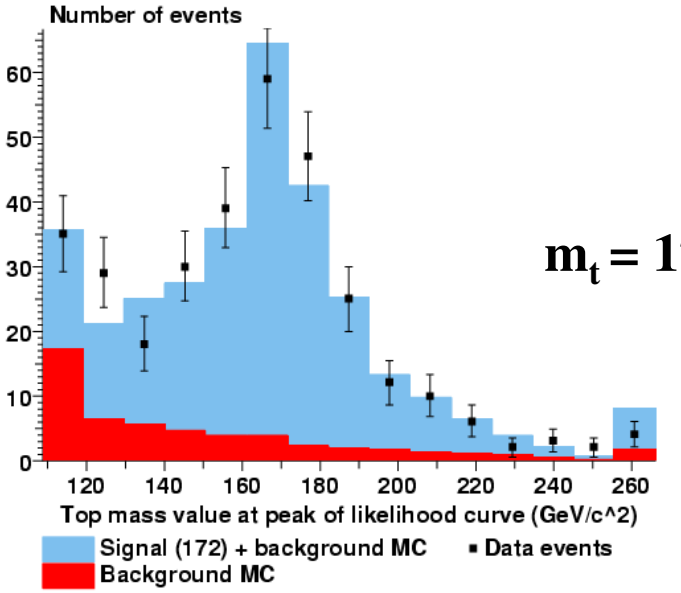


- *Top mass template, all hadronic, 1.9 fb^{-1}*
  - *Use Neural Networks for event selection.*
  - *Require b tagging.*
  - *Do In-situ jet energy calibration.*

m_t = 177.0 ± 3.7 (stat+JES) ± 1.6 (sys) GeV/c^2

Top mass measurement, CDF



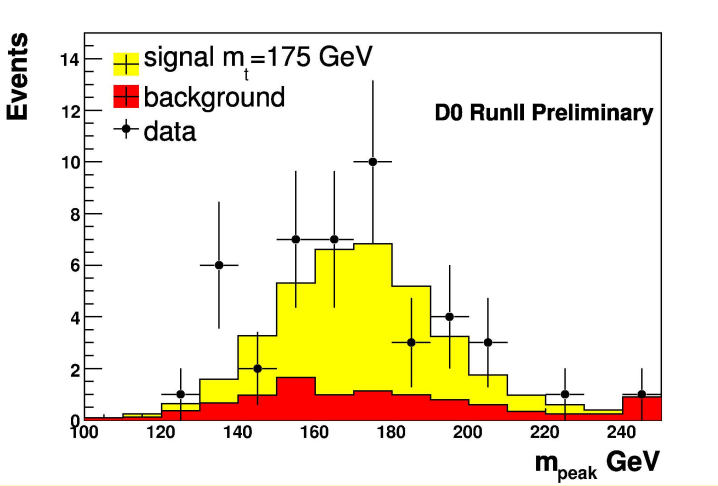


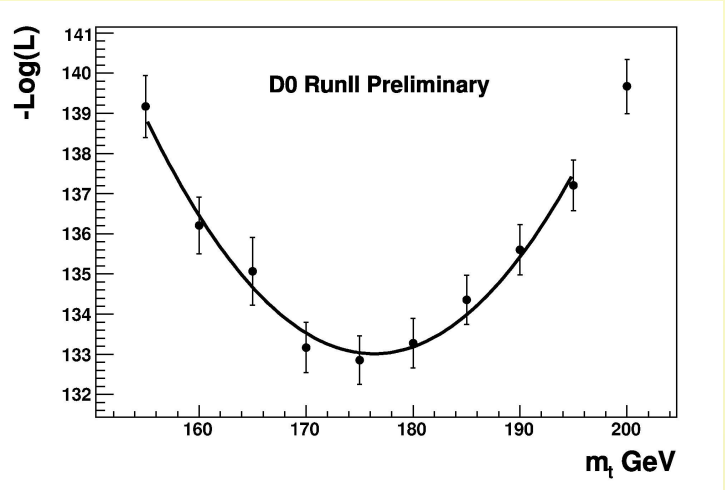
- *Matrix Element, LJ, 1.9 fb^{-1}*
  - *Use Neural Networks for background handling after event selection*
  - *Require b tagging*
  - *Do in-situ jet energy calibration*

m_t = 172.7 ± 1.2 (stat) ± 1.3 (JES) ± 1.2 (sys) GeV/c^2

Top mass measurement, D0

- *Matrix weighting, DIL, 1 fb^{-1}*
  - *For a given m_t try to resolve for Top, anti-Top momentum.*
  - *Define weight for each solution.*
  - *Account for detector resolution.*
  - *Take into account the background.*
  - *Scan through m_t to reach the max. weight and the min. of likelihood.*

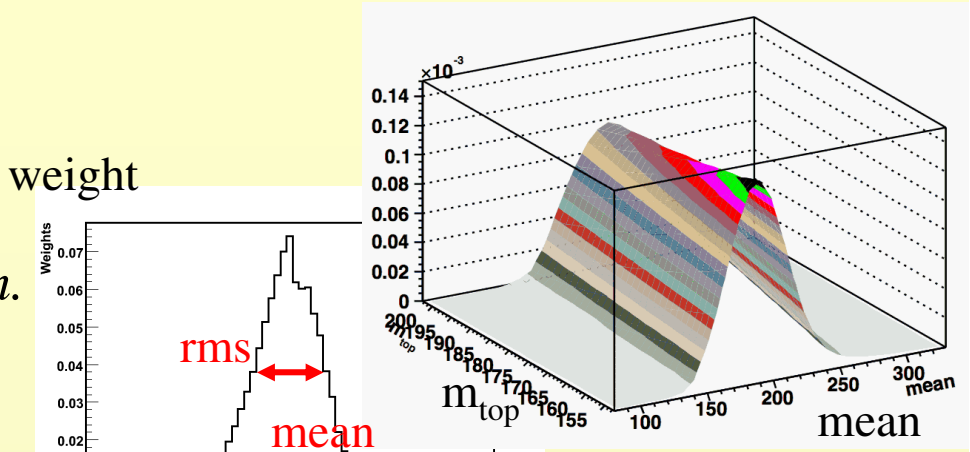


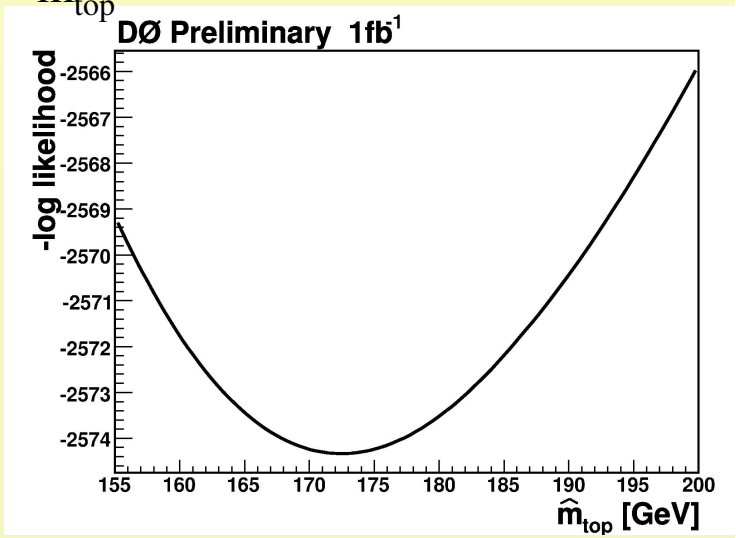


m_t = 175.2 ± 6.1 (stat) ± 3.4 (sys) GeV/c^2

Top mass measurement, D0

- *Neutrino weighting, DIL, 1 fb^{-1}*
  - *given m_t and η (from MC) for each ν; resolve for ν momentum.*
  - *For each event derive weight template based on $\not\!\!E_t$ expected (MC) and observed.*
  - *Take into account detector resolution and background.*
  - *Define maximum likelihood, $L(m_{top}, mean, rms)$.*





$m_t = 172.5 \pm 5.8$ (stat) ± 3.5 (sys) GeV/c^2

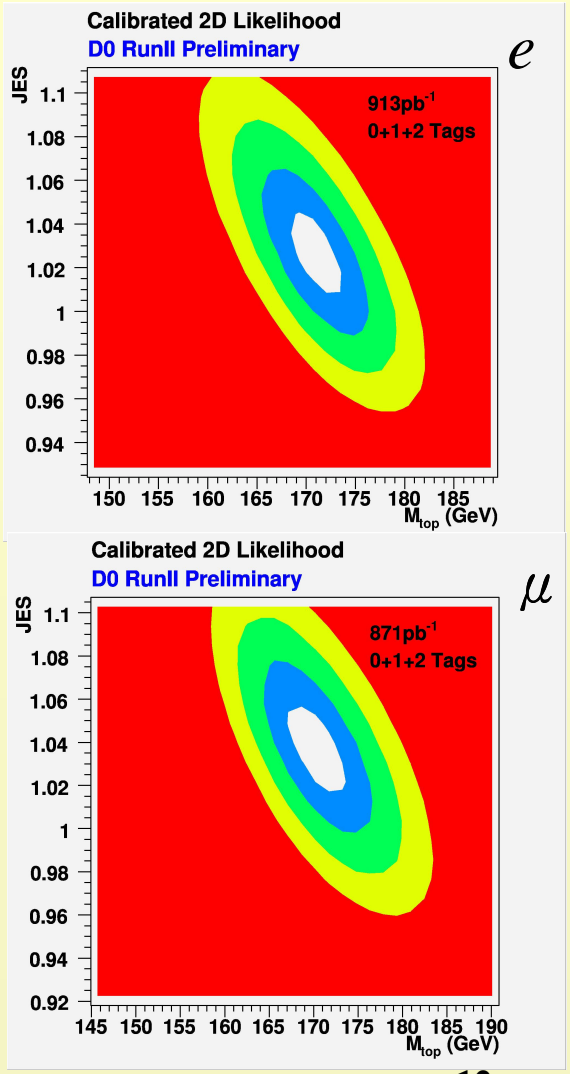
Top mass measurement, D0

- *Matrix Element, LJ, 1 fb^{-1} :*
  - *Use in-situ jet energy calibration.*
  - *Result without b tagging:*

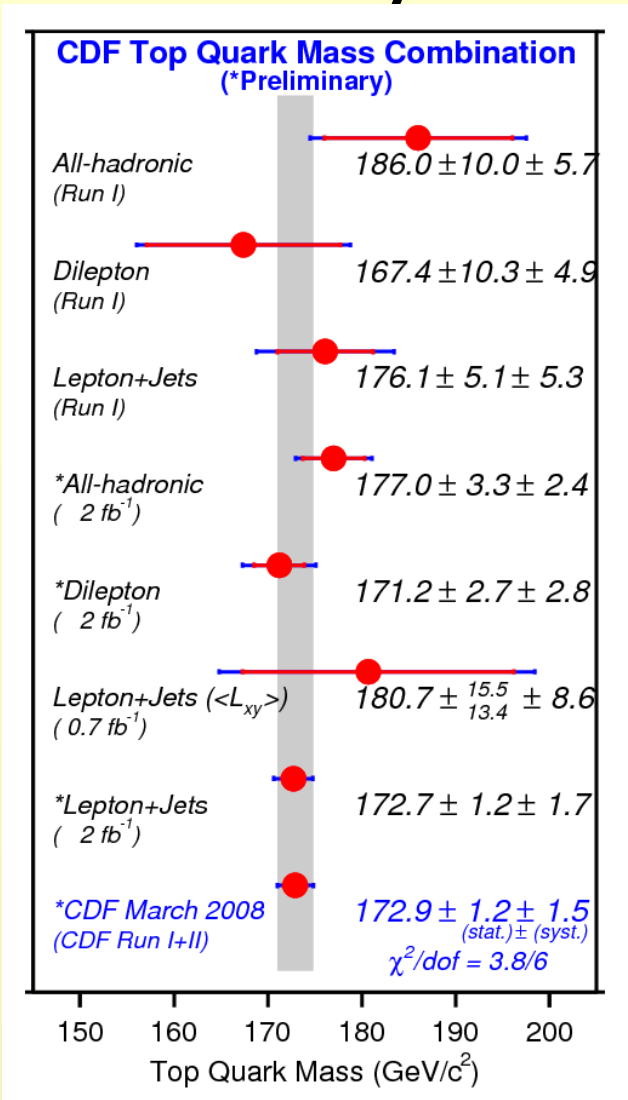
$m_t = 170.5 \pm 2.5\ (\text{stat+JES}) \pm 1.4\ (\text{sys})\ \text{GeV}/c^2$

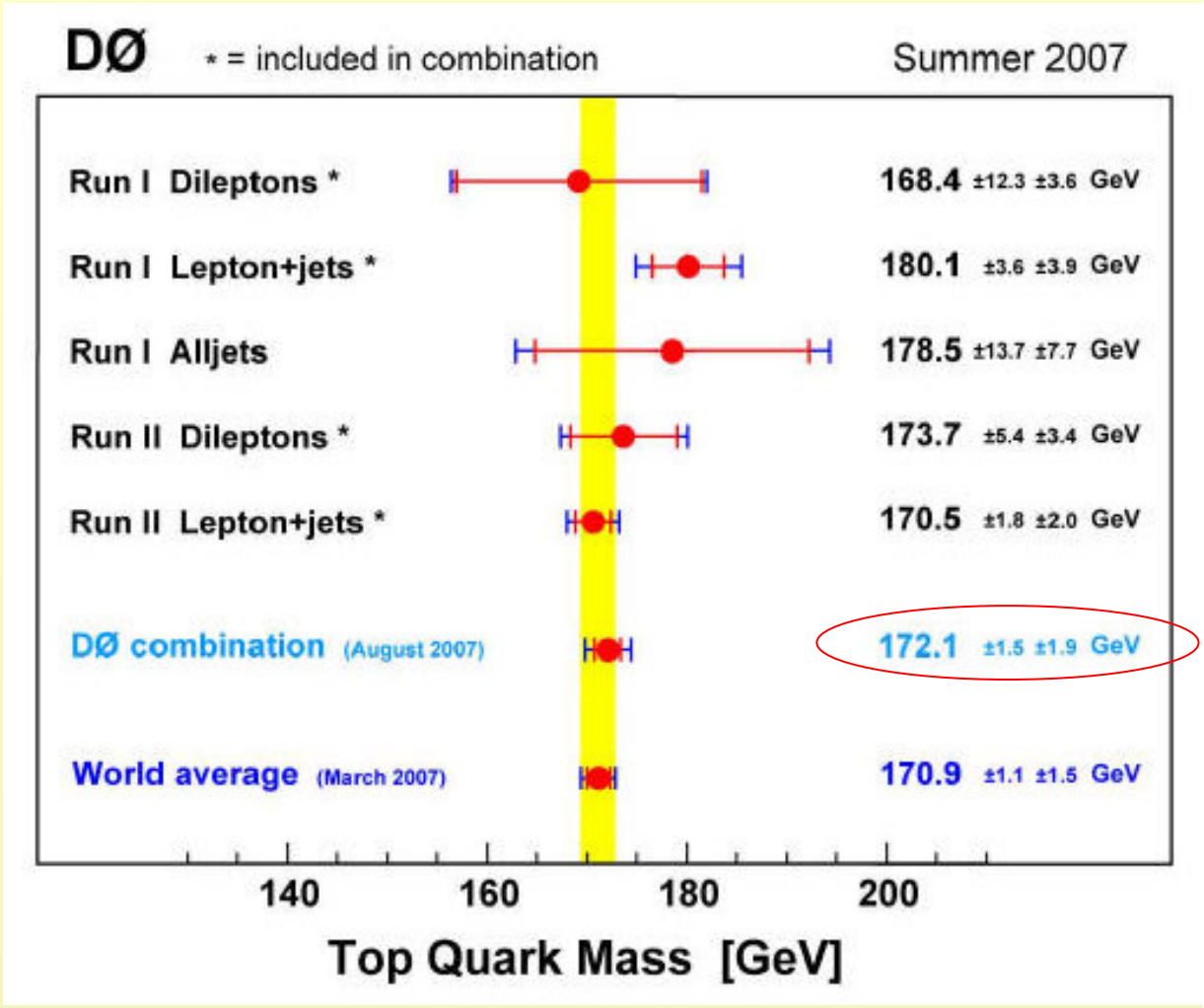
  - *Result with b tagging:*

$m_t = 170.5 \pm 2.4\ (\text{stat+JES}) \pm 1.2\ (\text{sys})\ \text{GeV}/c^2$

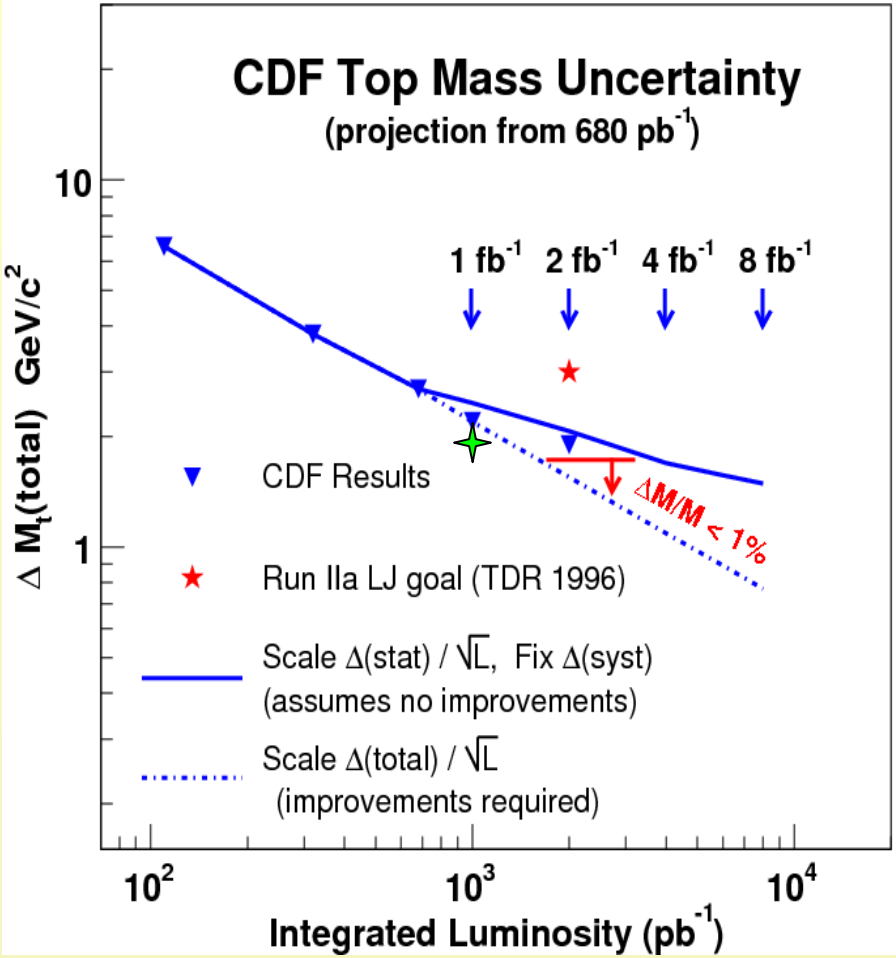


Top mass measurement, updated





Top mass measurement, the future



- *Tevatron Top mass, 2007 Mar.*

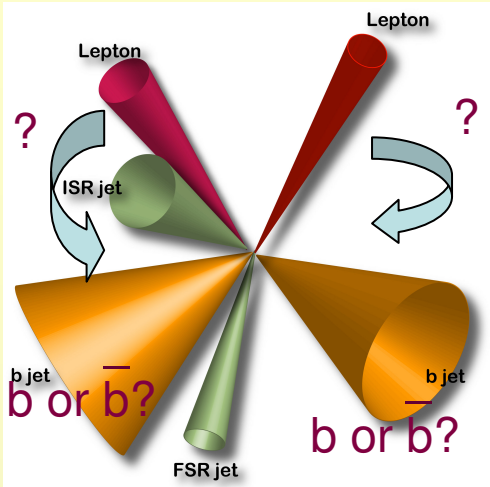
- *Reaching below 1% uncertainty!*
- *CDF and D0 are working together on the common systematic issues to reduce uncertainty.*

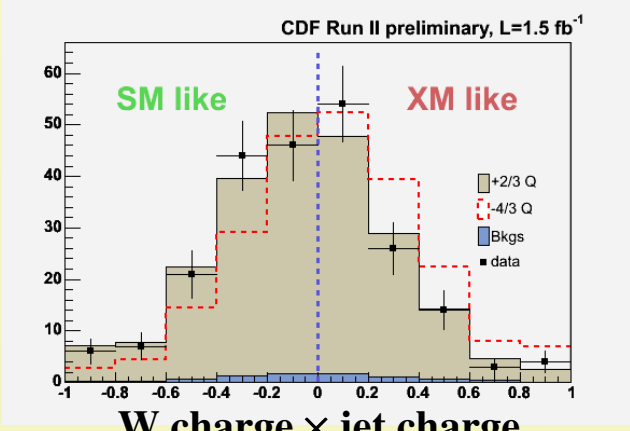
The charge of Top quark, CDF

SM : $t \rightarrow W^+ b$
XM: $t' \rightarrow W^- b$

- *SM: +2/3q XM: -4/3q*
- *Each event has lepton(s) and jets:*
  - *Pairing : Top mass as input, M_{lb}^2*
  - *Jet charge determination*

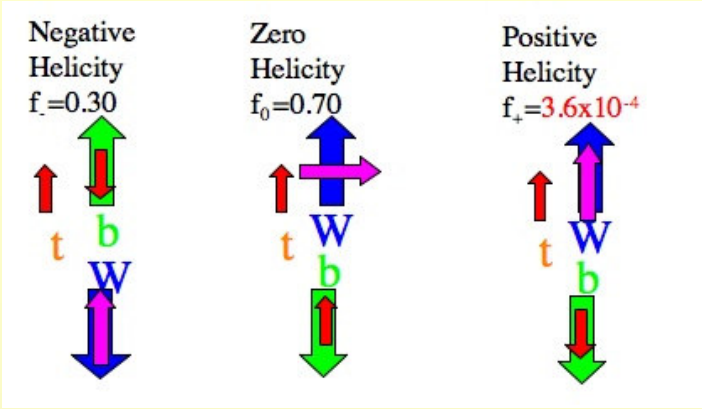
$$Q_{jet} = \frac{\sum |\vec{p}_i . \vec{P}_{jet}|^{\alpha} Q_i}{\sum |\vec{p}_i . \vec{P}_{jet}|^{\alpha}}$$

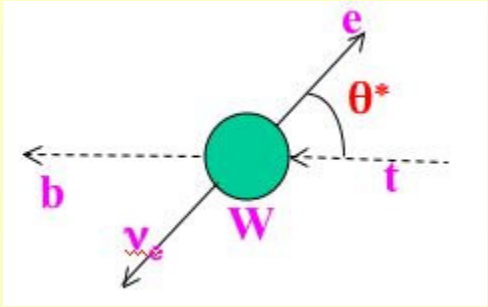


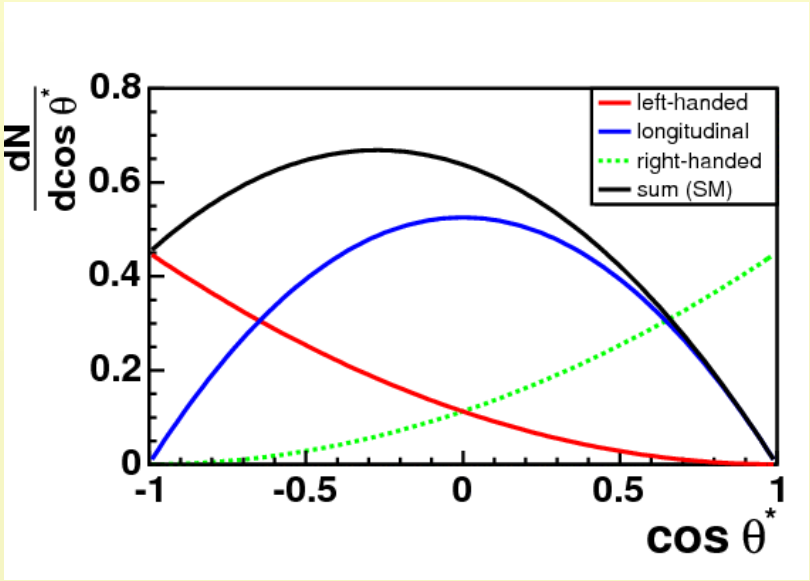


- ***The result (1.5 fb^{-1}) :***
  - ***Exclude XM at 87% CL.***

W helicity in Top decay







Theory:

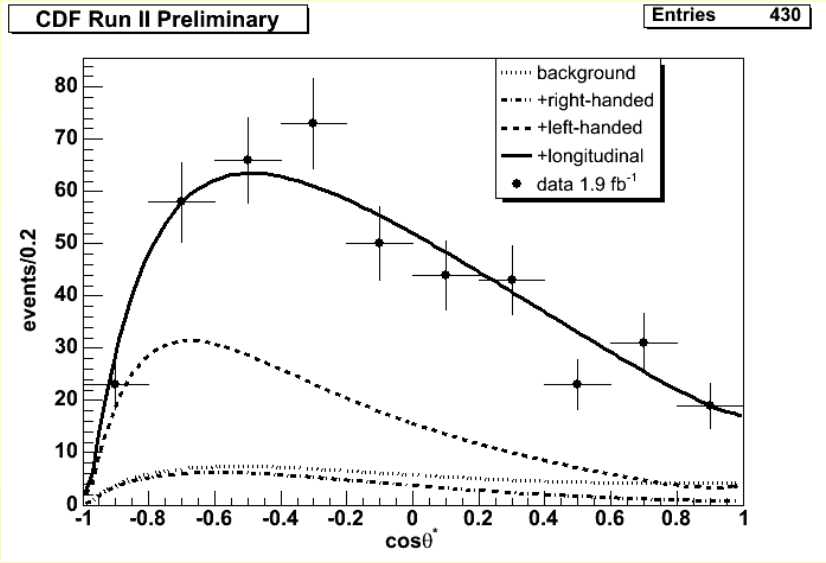
$f_0 = 0.7$, *longitudinal*

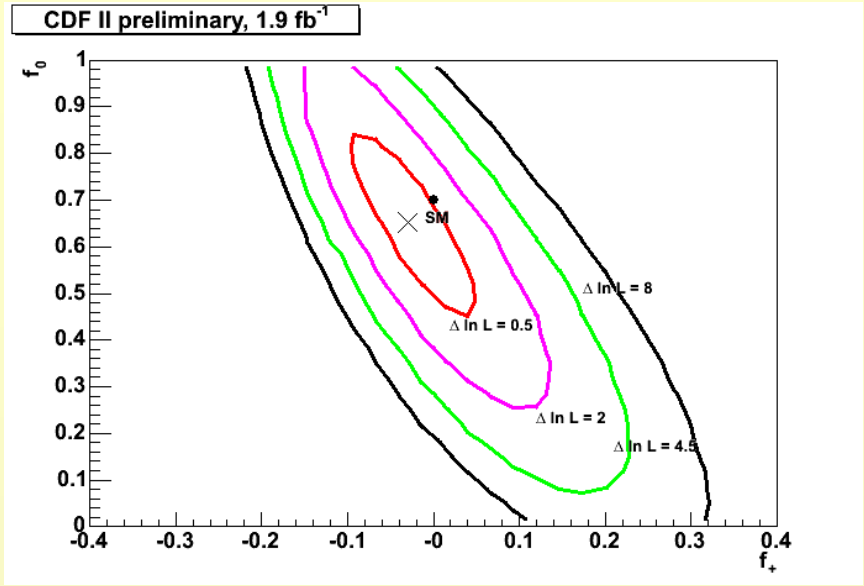
$f_- = 0.3$, *left handed*

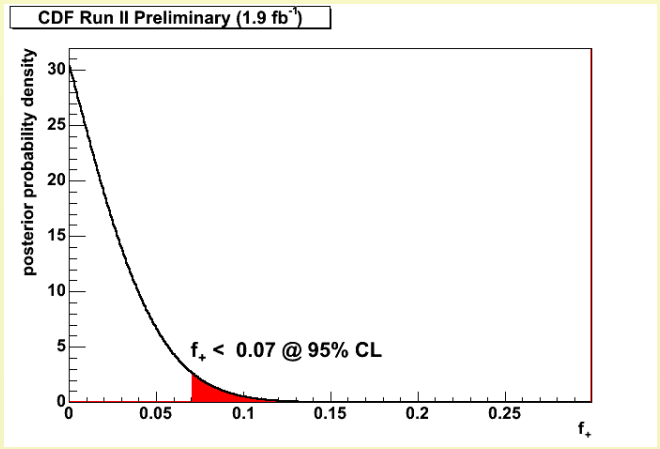
$f_+ = 0$, *right handed*

W helicity in Top decay

CDF







$f_0 = 0.65 \pm 0.19\ (stat) \pm 0.03\ (sys)$

$f_+ = -0.03 \pm 0.07\ (stat) \pm 0.03\ (sys)$

Fix f_0 to SM:

$f_+ = -0.04 \pm 0.04\ (stat) \pm 0.03\ (sys)$

$f_+ < 0.07$ @ 95% C.L.

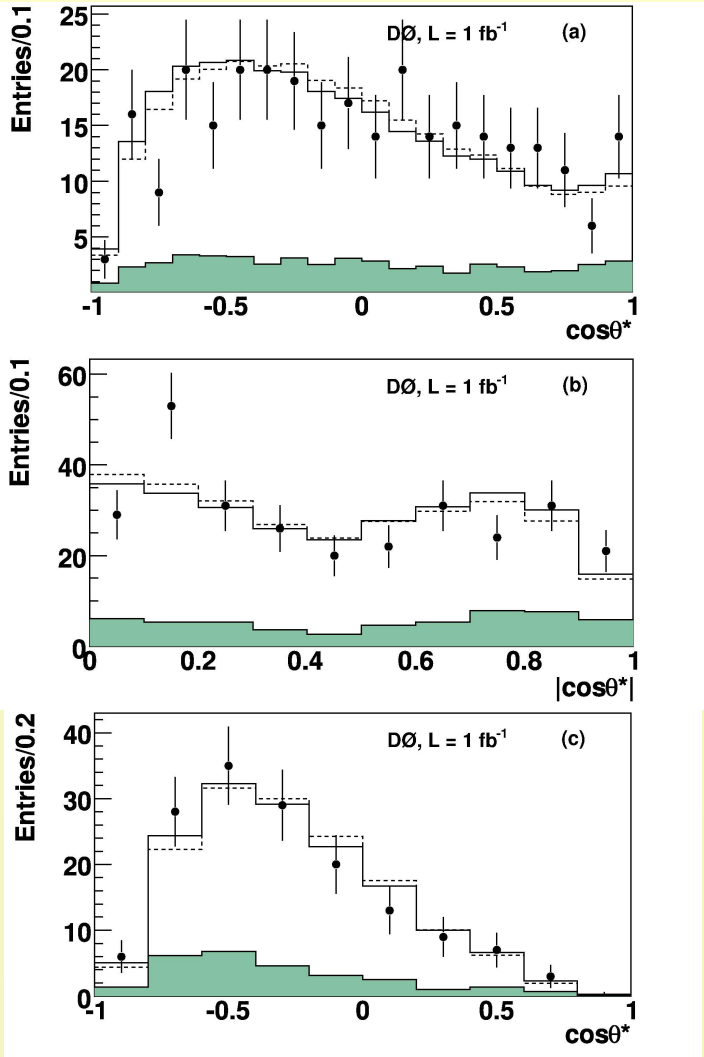
W helicity in Top decay

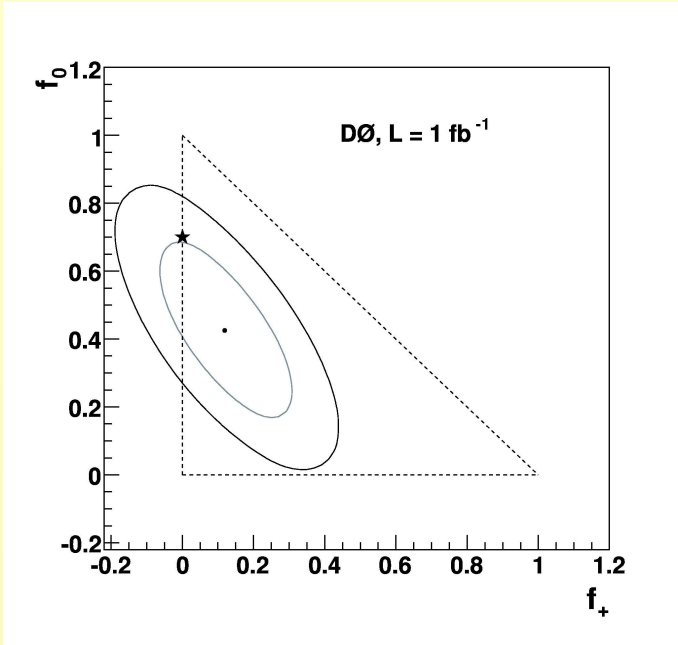
D0

LJ, Lep.

LJ, Had.

DIL





$f_0 = 0.425 \pm 0.166\ (stat) \pm 0.102\ (sys)$

$f_+ = 0.119 \pm 0.090\ (stat) \pm 0.053\ (sys)$

Fix f_0 to SM:

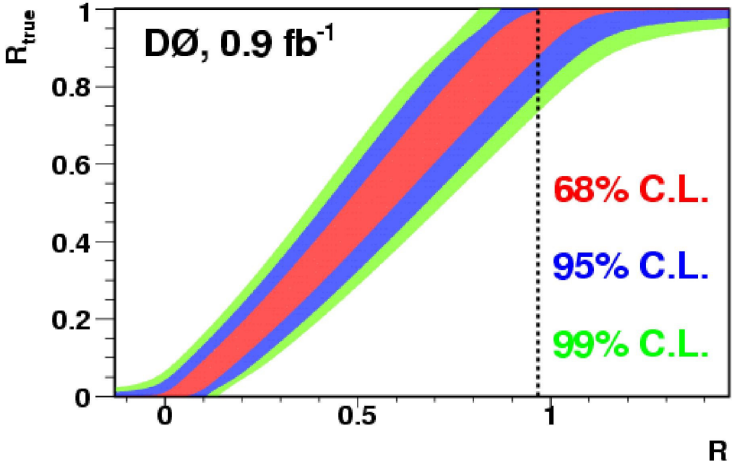
$f_+ = -0.002 \pm 0.047\ (stat) \pm 0.047\ (sys)$

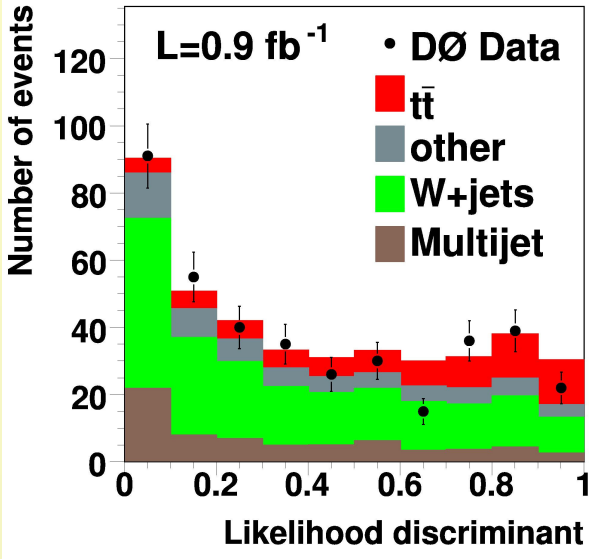
$f_+ < 0.13$ @ 95% C.L.

$\mathcal{R}_b = \mathcal{B}r(t\to Wb)/\mathcal{B}r(t\to Wq)$

D0

- *Simultaneous fit to the production cross section and $\mathcal{R}_b$.*
  - *LJ , 0.9 fb^{-1}*
  - $\mathcal{R}_b = 0.97\ ^{+0.09}_{-0.08}\ (stat + sys)$
    > 0.79 @ 95% CL
  - $|V_{tb}| > 0.89$ @ 95% CL
  - $\sigma_{tt} = 8.18\ ^{+0.90}_{-0.84}\ (stat+sys)$
    $\pm 0.50\ (lumi)$ pb



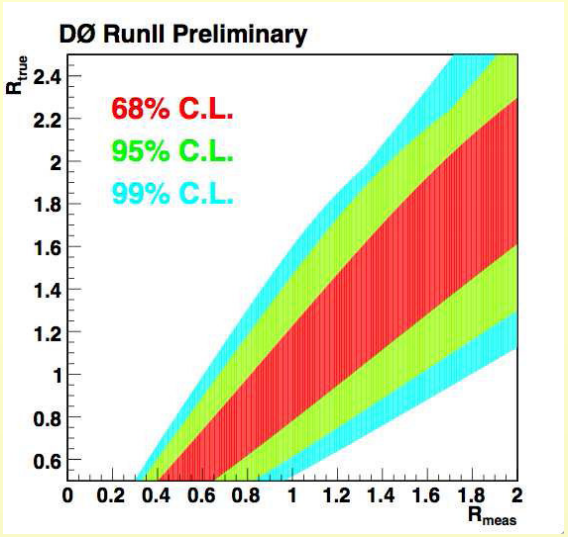


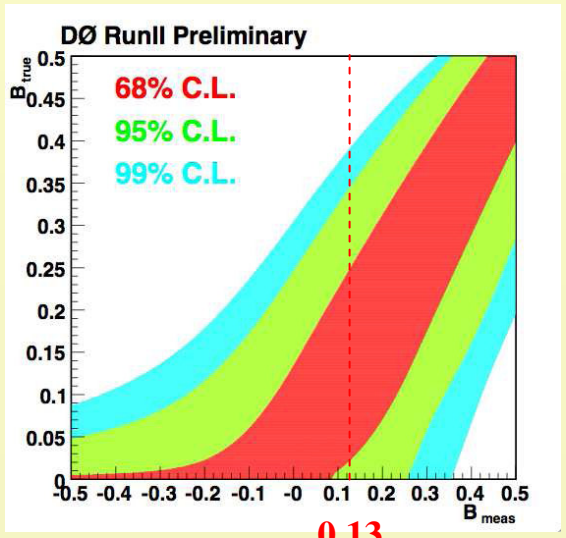
Search for charged Higgs in Top decay, D0

- What really considered:
  - $\mathcal{R} = \sigma(tt)_{\ell+jets} / \sigma(tt)_{\ell\ell}$
  - Assume the sys. issue of luminosity cancelled out
  - Assume $\mathcal{R}_b = 1$.

    $\mathcal{R} = 1.21\ ^{+0.27}_{-0.26}\ (stat + sys)$
- Extract info. for charge Higgs
  - $\mathcal{B} = \mathcal{B}(t \to Hb)$
  - $\mathcal{B} = 0.13\ ^{+0.12}_{-0.11}\ (stat+sys)$;

    $\mathcal{B} < 0.35$ @ 95% CL

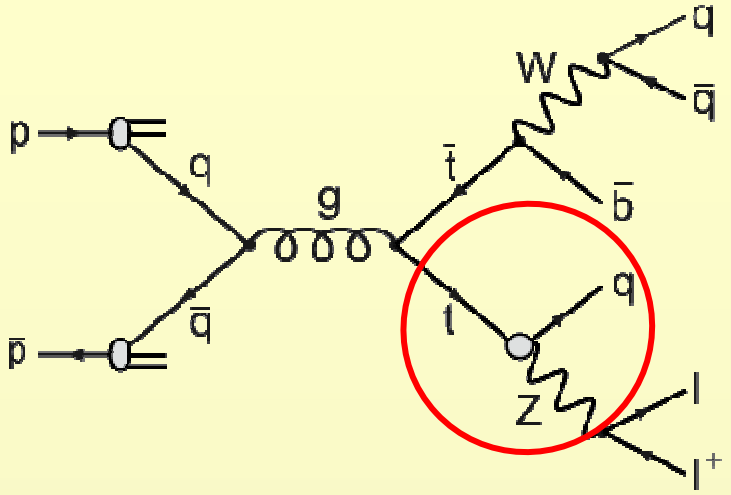




Search for FCNC in Top decay

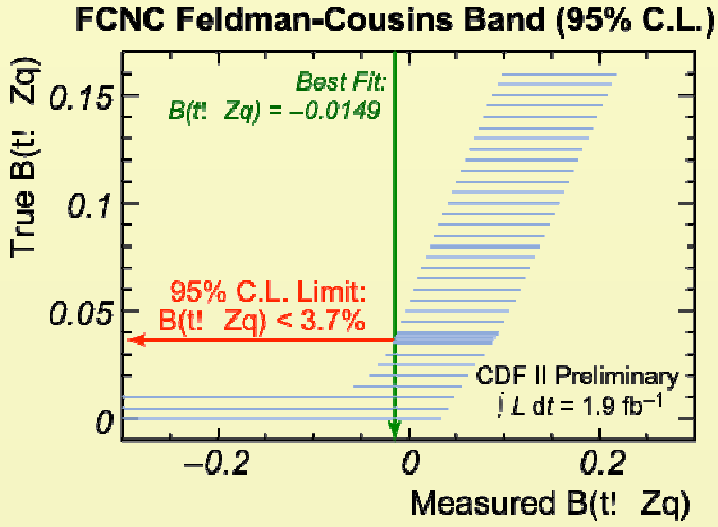
CDF

- SM : $\mathcal{B}(t \to Zq) = O(10^{-14})$
- Beyond SM : up to $O(10^{-4})$
- At LEP : < 13.7% @95% CL



- Look for 2 lep. + 4 jets.
- Constraint on masses of Top, Z and W.
- Best limit up to date ($1.9\ fb^{-1}$):

  < 3.7% @95% CL

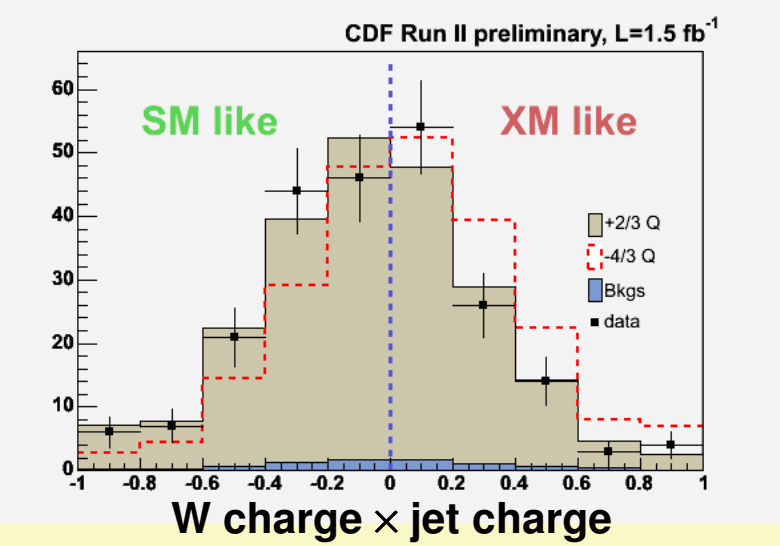


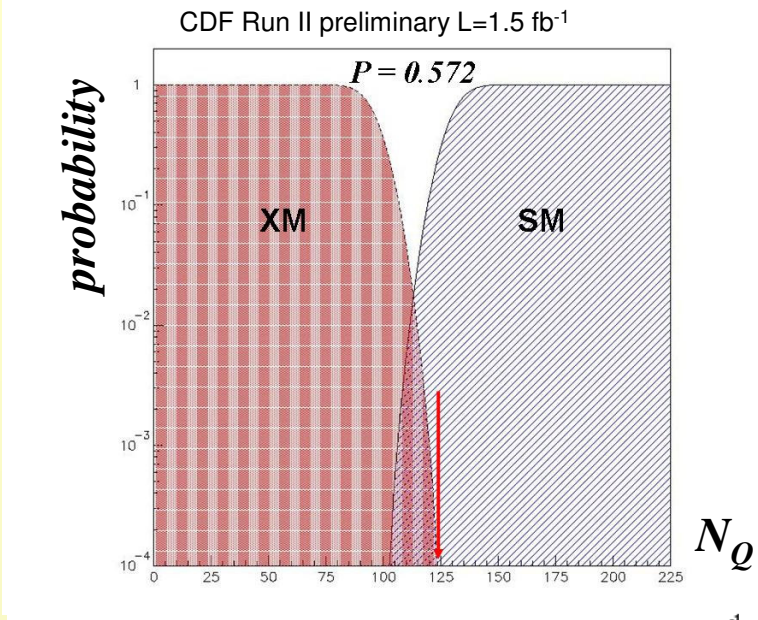
Conclusion

- More than ten years after the Top quark discovery:
  - Top quark mass is well measured to 1.1% level!
  - Up to date, within uncertainties, all measured quantities are consistent with the Standard Model expectations.
    - Top charge, W helicity , R_b, charged Higgs search, FCNC
  - Analysis in progress or not reported here,
    - Life time, decay width, top spin correlation, etc.
  - This is just the beginning of the sensitive studies of the Top quark properties! There are much room ahead for surprises!

The charge of Top quark

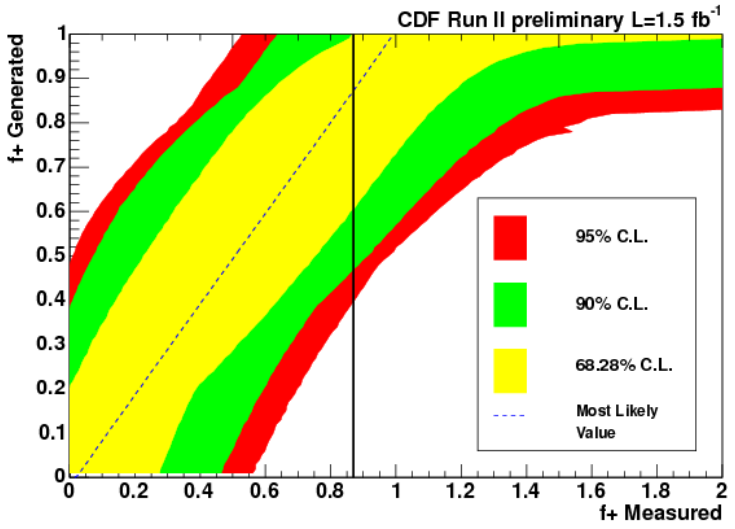
CDF



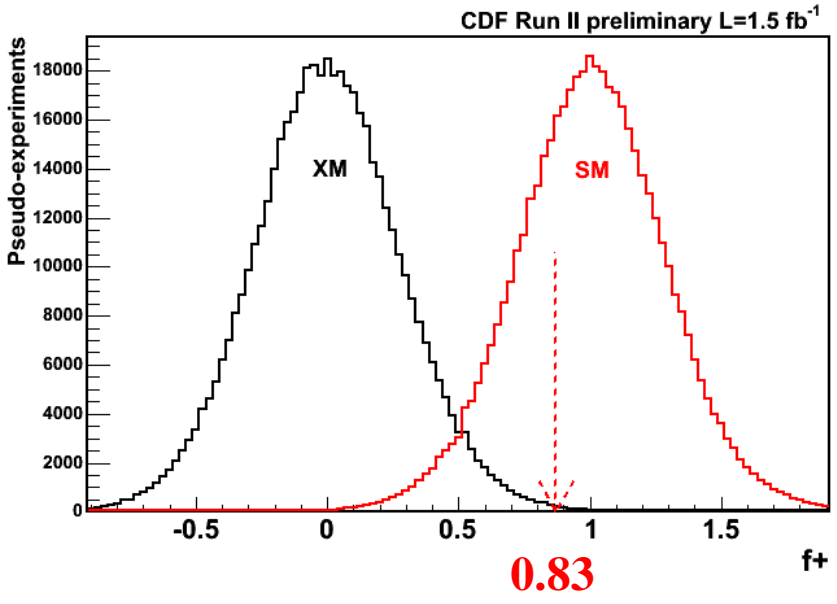


- *CDF result (1.5 fb^{-1}):*
  - *2Ln(Bayse factor) = 12.0*
  - *f+ = SM like / Total*

    > 0.4 @ 95% CL

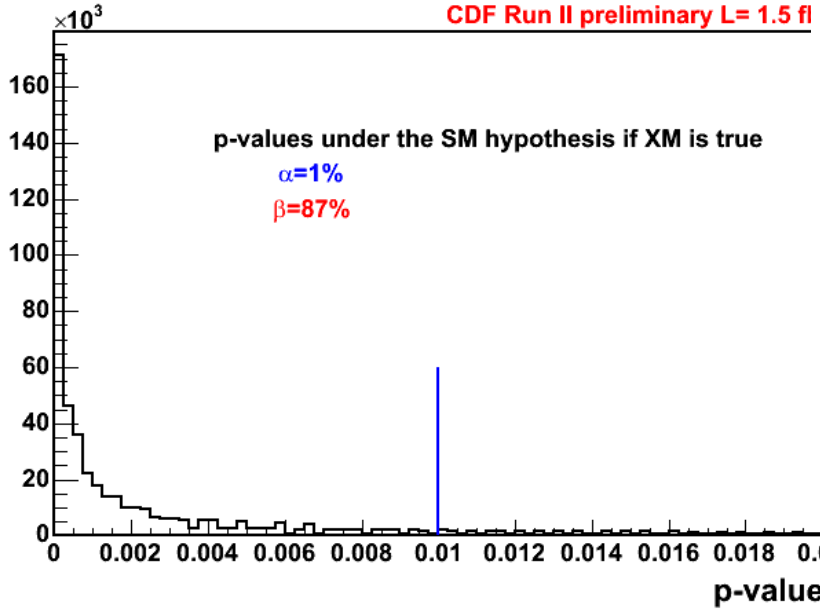


Top charge, CDF



0.83

f+ measured



p value observed : 0.31