ElectroWeak and Top Physics at the Tevatron

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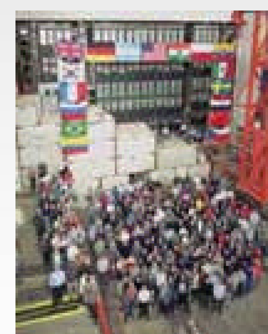
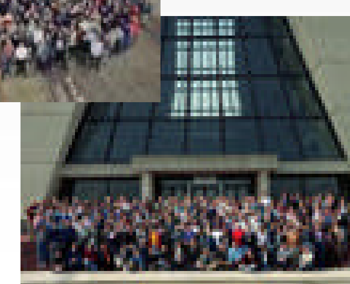


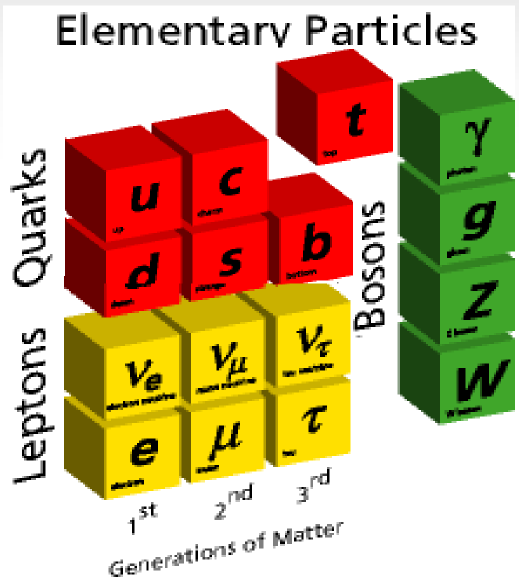
On behalf of the CDF and D0 Collaborations



SLAC Summer School
July 18th, 2006

Outline

Standard Model has been very successful at explaining matter as we know it.

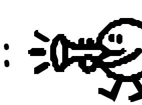


We still need to test the symmetry breaking mechanism:

- Higgs not yet observed
- which new physics to stabilize quantum corrections to Higgs mass?

In this talk, I present results from the Tevatron in EWK and top quark physics.

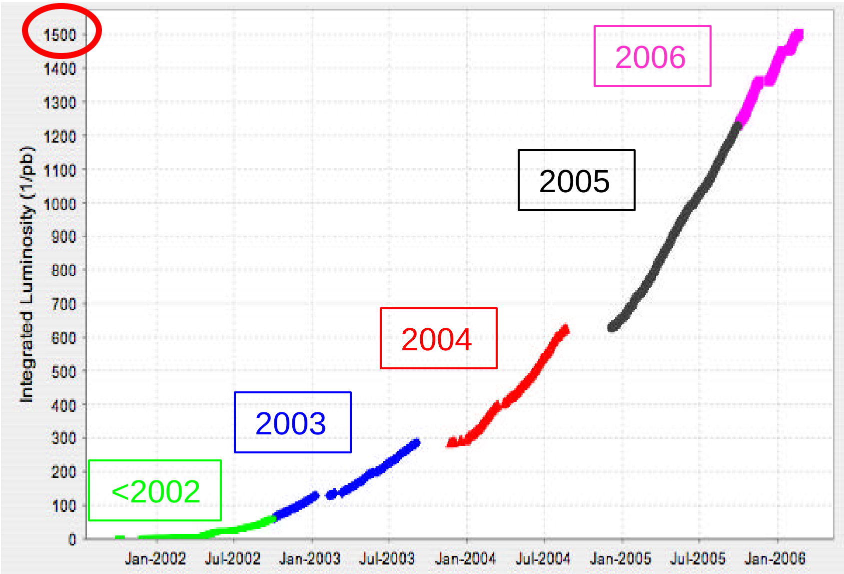
- Tevatron performance
- EWK/Top experimental signatures
- EWK Measurements:
  - Single boson
  - Diboson
- Top Measurements
  - Top cross section
  - Top decay properties
  - Top Searches

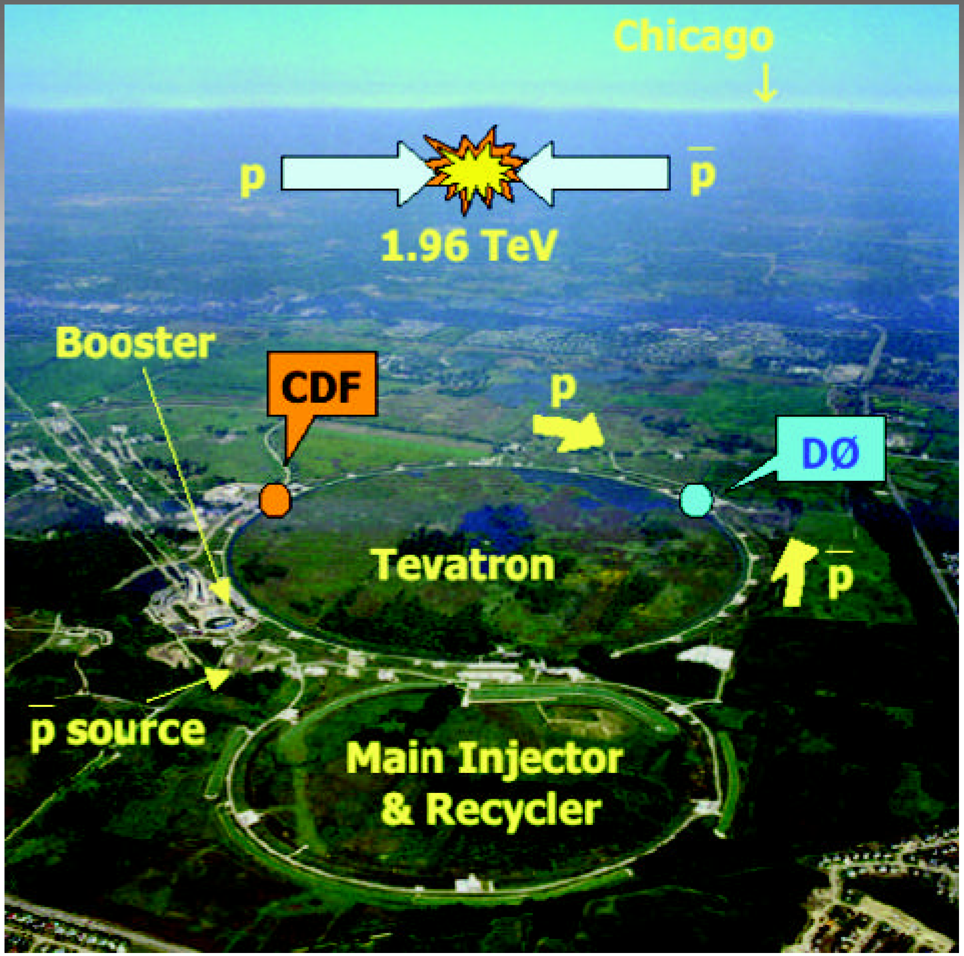
New (<1 yr old) results are marked: 

For details see CDF and D0 Public Results WEB pages.

Tevatron

- Run II with $\sqrt{s} = 1.96\,\text{TeV}$
- Record peak luminosity (Jan. '06): $1.7\times10^{32} cm^{-2}s^{-1}$
- Integrated delivered luminosity: 1.5 fb^{-1} /expt
- CDF/D0 recorded luminosity: 1.3 fb^{-1} /expt



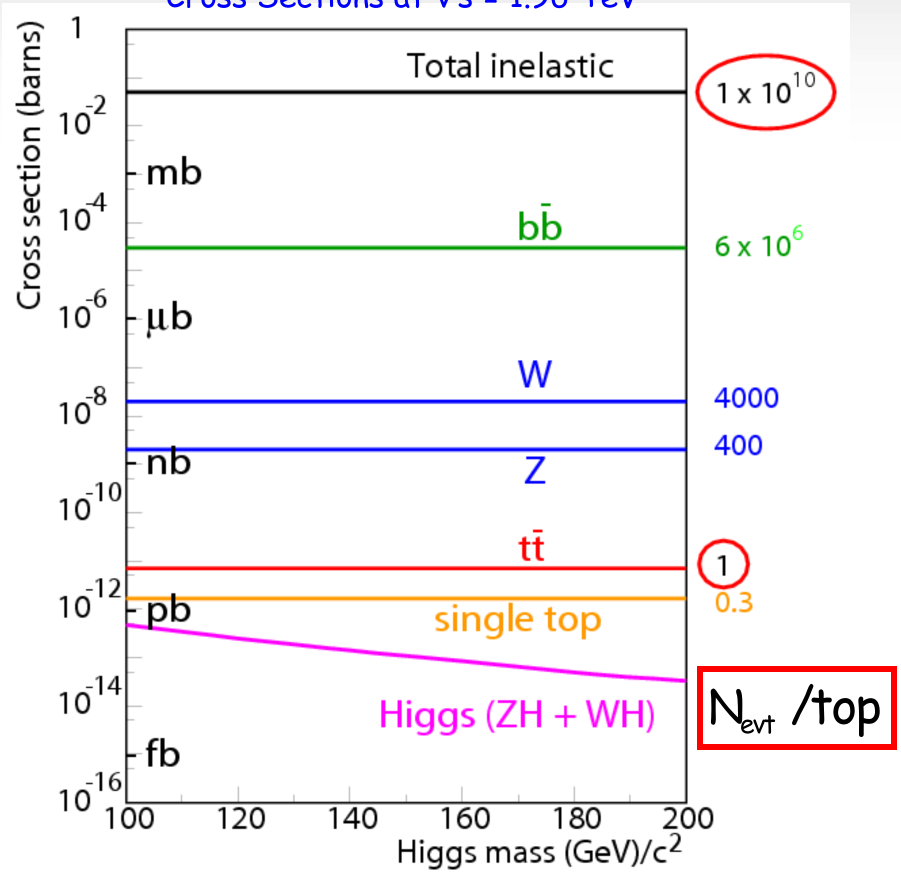


- Doubling time:~1 yr. Expect
  - ~2 fb^{-1} by 2006
  - ~4 fb^{-1} by 2007
  - ~8 fb^{-1} by 2009

Tevatron Physics

- Tevatron has huge physics breadth:

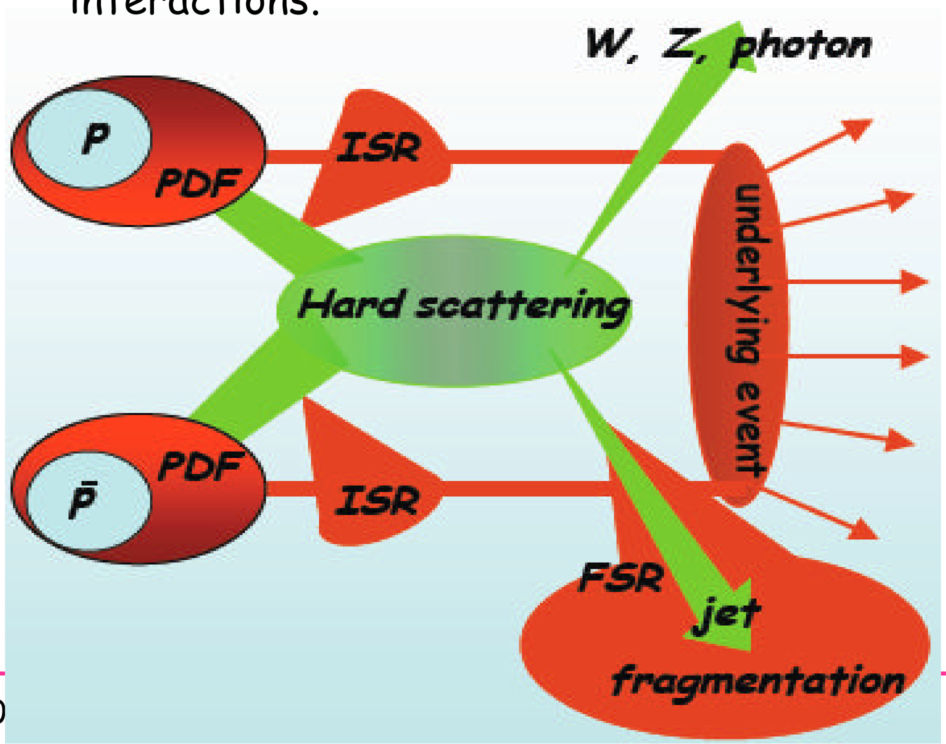
Cross Sections at √s = 1.96 TeV



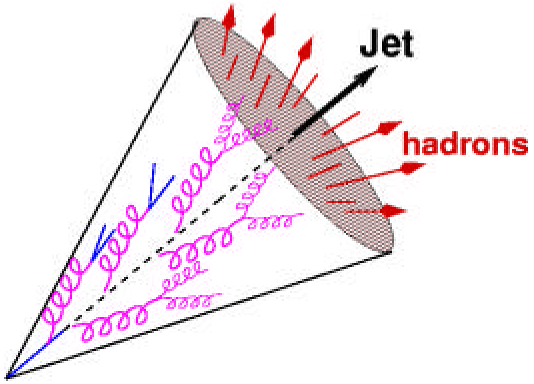
- Trigger is key in reducing the huge amount of interactions producing "something" in the final state (trigger efficiency for high pT leptons ~90% for both CDF and D0)

Tevatron Collisions

- The hard scattering is not all there is!
  - Parton Distribution Functions (PDF): fraction of (anti)proton carried by incoming partons.
  - Underlying Event (UE): extra stuff produce by spectator or multiple interactions.



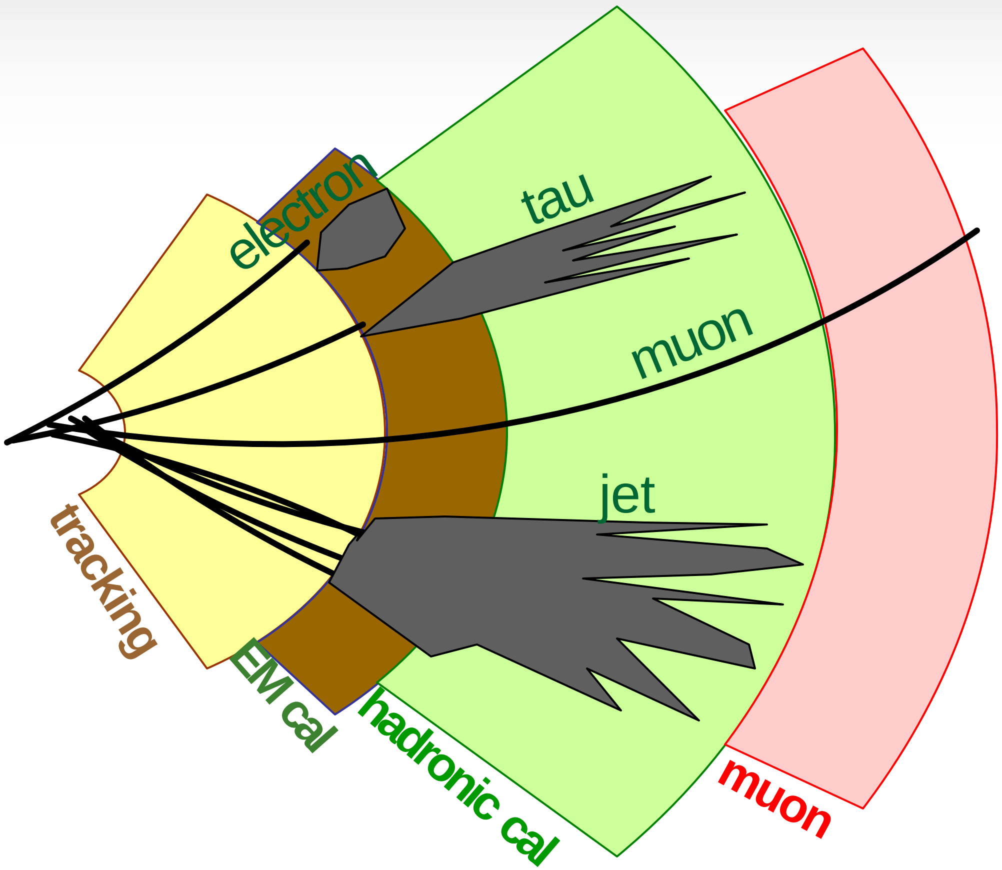
- Initial and Final State Radiation (ISR, FSR): extra gluons radiating off the original/final partons.
- Jets: fragmentation of quark/gluons and recombination into hadrons reconstructed inside a cone.

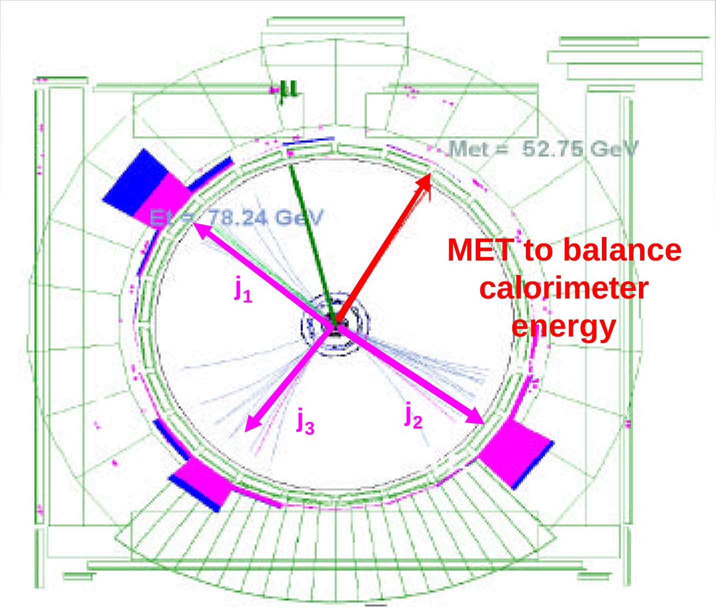


All of these processes, and more, have an impact on what we measure

Tevatron Experimental Signatures

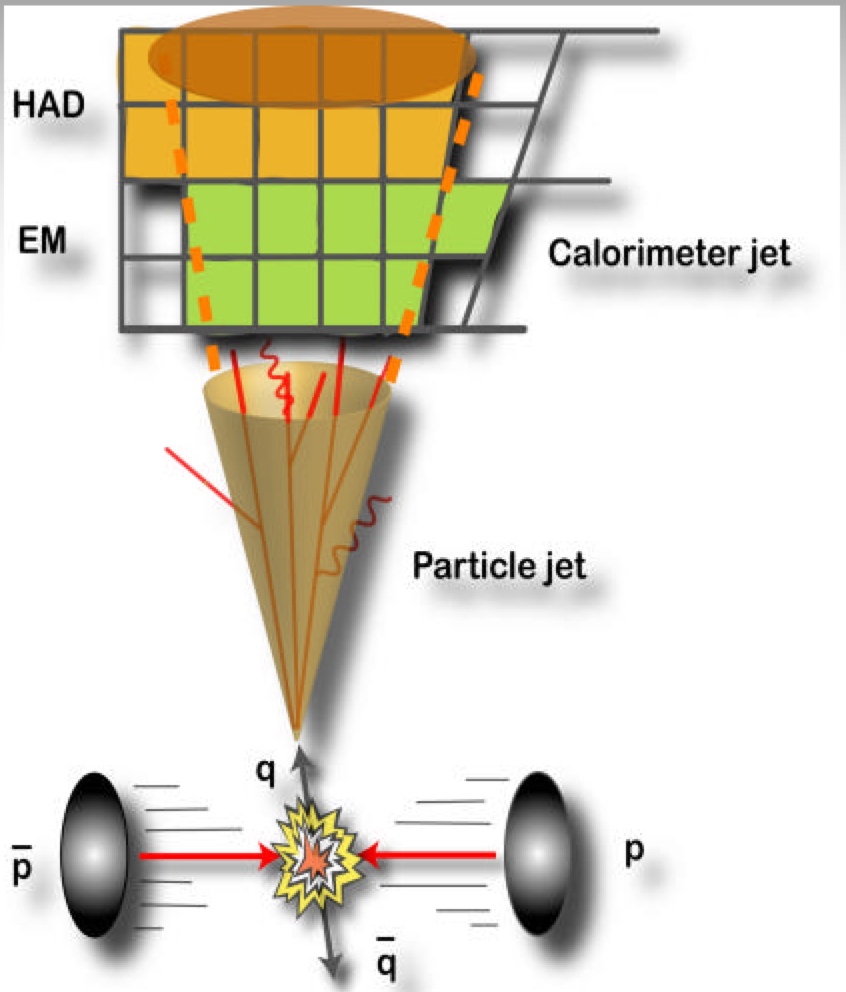
- EWK and Top Physics is mostly done with high p_T leptons (e, mu and tau) and jets.



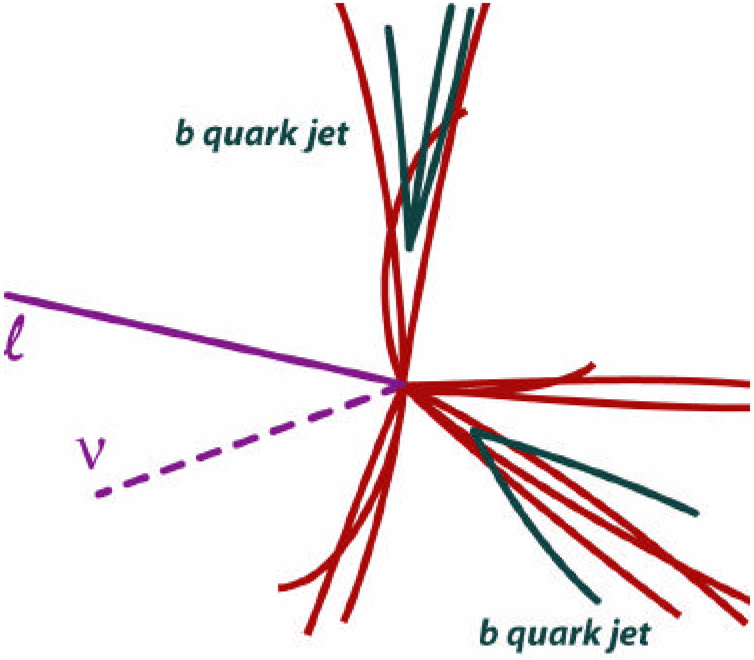


- Presence of neutrinos is revealed via Missing Transverse Energy (MET) in the calorimeter.

Tevatron Experimental Signatures



- Jet Energy Scale (JES) corrections are needed to go back to the energy of original parton
- b-jets are particularly prized: use (Silicon) vertex tracker to reconstructed displaced vertex

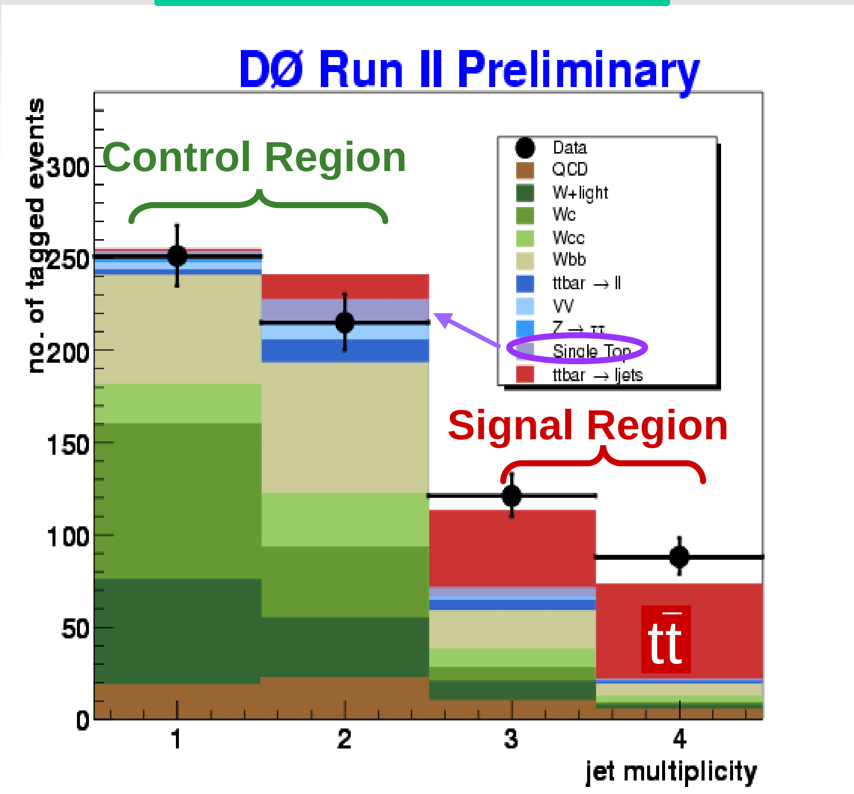


Backgrounds

Any process that can "emulate" the final state we are studying.

- Important distinction between:
  - Physics backgrounds
  - Instrumental backgrounds
- Backgrounds are measured using a combination of data driven and MC simulation methods.
- The backgrounds of today are the signal of tomorrow…

$t\bar{t}$ in l +MET+ b-jets



Systematics

Any uncertainty which has not to do with the sample statistics.

- Some systematics are common to all analysis
  - Luminosity uncertainty (6-7%).
- Some systematics are data-driven and scale with the luminosity
  - Lepton/jet identification.
  - Instrumental backgrounds.
  - Jet/lepton (E,p) scale and resolution.
- Some systematics come from theory and harder to beat down
  - PDF's, ISR, FSR.
  - MC modeling of recoil and fragmentation.
  - Physics backgrounds cross-section.

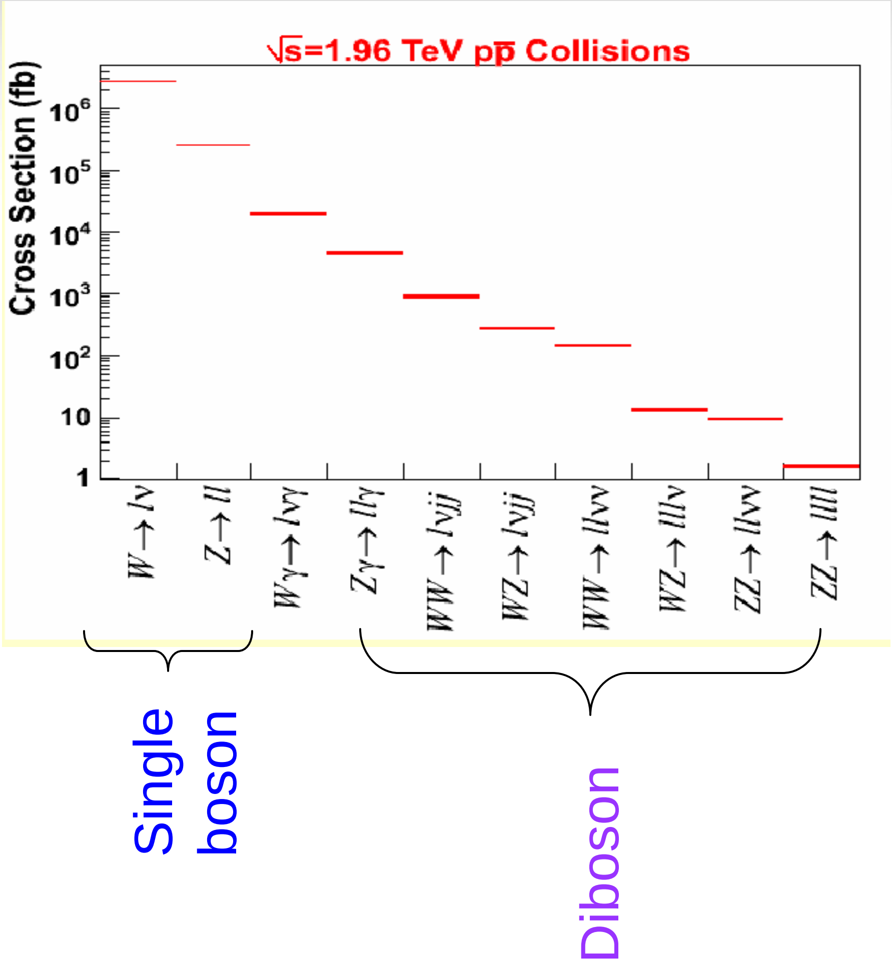
W Mass Systematics
(CDF Preliminary using 200 pb^{-1})

Systematic Uncertainty	Electrons	Muons	
Energy Scale & Resolution	70	30	*Constrain with data -- Roughly scale with $\mathcal{L}$*
Recoil Scale & Resolution	50	"	
W pT model	15	"	
PDFs	15	"	*Theoretical inputs -- do not directly scale with $\mathcal{L}$*
QED	15	20	
Backgrounds	20	20	

EWK Physics at the Tevatron

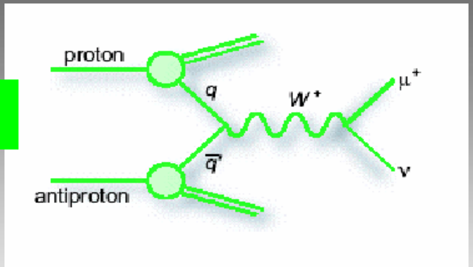
1. Single boson measurements
   - High statistics samples: "standard candles" of HEP!
   - Precision measurements of EWK parameters: W mass and width
   - Constraints on PDF's and test of NNLO predictions: asymmetries and differential cross-sections.

2. Diboson measurements
   - Low cross-section measurements.
   - Test of EWK theory gauge nature via boson self-interactions.
   - Test-bed for new/undiscovered particles searches.

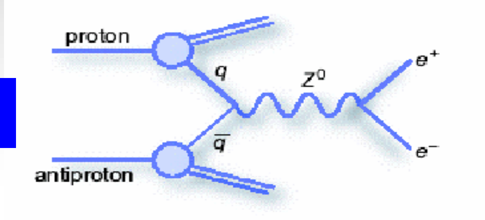


W and Z Cross-Sections

BR ~ 11%



BR ~ 3%

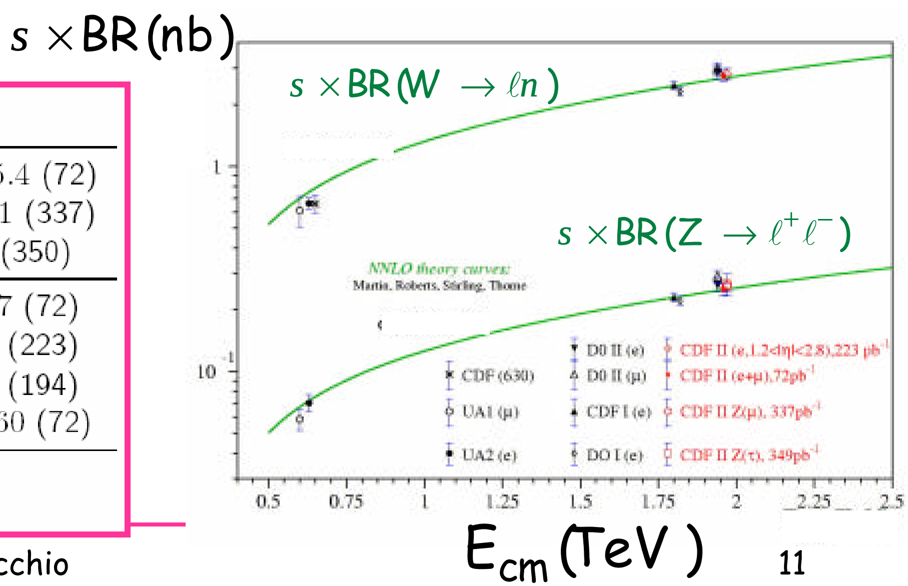


W and Z are identified via high p_T l+MET or l^+l^- events.

They provide samples used for:

- measuring trigger and lepton ID efficiencies
- calibrating energy and momentum scale
- understanding backgrounds
- checking luminosities
- identifying top!

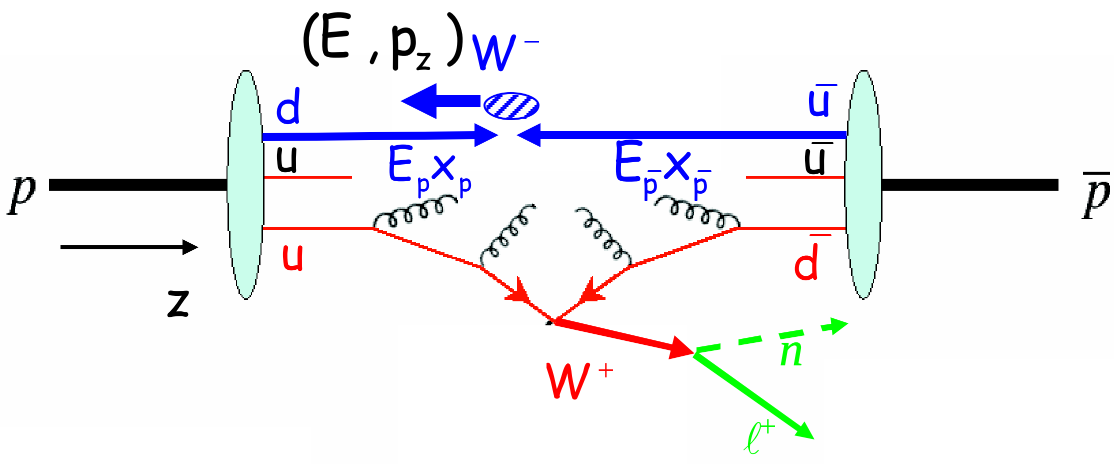
Cross-sections are consistent with NNLO predictions!



$\sigma \times$ BR	DØ	CDF
$Z \to ee$	$264.9 \pm 3.9 \pm 9.9 \pm 17.2$ (177)	$255.8 \pm 3.9 \pm 5.5 \pm 15.4$ (72)
$Z \to \mu\mu$	$291 \pm 3.0 \pm 6.9 \pm 18.9$ (148)	$261.2 \pm 2.7 ^{+5.8}_{-6.1} \pm 15.1$ (337)
$Z \to \tau\tau$	$237 \pm 15 \pm 18 \pm 15$ (226)	$265 \pm 20 \pm 21 \pm 15$ (350)
$W \to e\nu$	$2865 \pm 8.3 \pm 76 \pm 186$ (177)	$2780 \pm 14 \pm 60 \pm 167$ (72)
high η	—	$2815 \pm 13 ^{+94}_{-89} \pm 169$ (223)
$W \to \mu\nu$	$2989 \pm 15 \pm 81 \pm 194$ (96)	$2786 \pm 12 ^{+65}_{-55} \pm 166$ (194)
$W \to \tau\nu$	—	$2620 \pm 7.0 \pm 210 \pm 160$ (72)

Table: All values are in pb, $\pm$ stat $\pm$ syst $\pm$ lum then (Lum pb^{-1})

Boson Rapidity



W(Z) is produced in hard $q\bar{q}$ scattering inside $p\bar{p}$

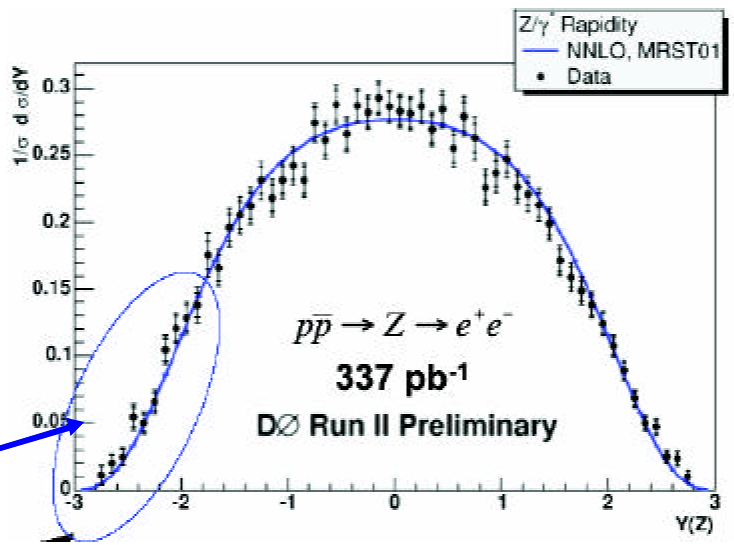
Relative size of x_p and $x_{\bar{p}}$ determines the longitudinal momentum of the boson

Define boson rapidity as:

$$y = \frac{1}{2} \ln[(E + p_z) / (E - p_z)]$$
$$= \frac{1}{2} \ln(x_p / x_{\bar{p}})$$

Precision measurements of boson rapidity measure PDF's at $Q^2 = M^2_W (M^2_Z)$.

High y region still statically limited but with more luminosity, it provides check/constraint NNLO calculation at high x.

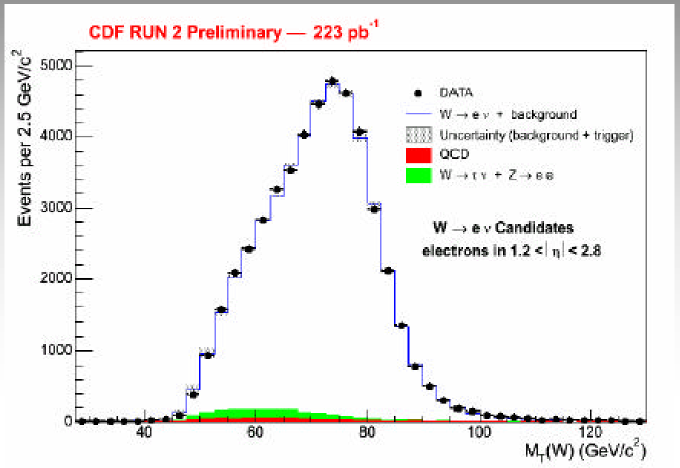


W Forward Cross-Section

CDF II (223 pb^{-1}) measure W->eν cross-section using forward electrons (1.2 <|η|<2.8).

$$\sigma(W \rightarrow e\nu) = 2796 \pm 13(stat) \pm 93(syst) \pm 162(lumi)\,pb$$

NLO prediction: $\sigma_W = 2684 \pm 54(syst)\,pb$



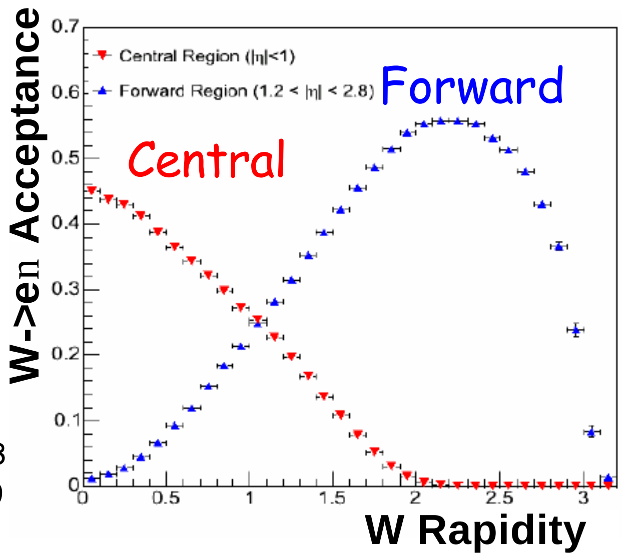
- Extension of W identification to large rapidity regions
- Allows test of W production theory
  - Ratio of W's reconstructed in central vs forward region is sensitive to W rapidity

$$\frac{N_W^{cen}}{N_W^{for}} = 0.925 \pm 0.033 = \frac{A^{cen}}{A^{for}} = R_{exp}^{cen/for}$$

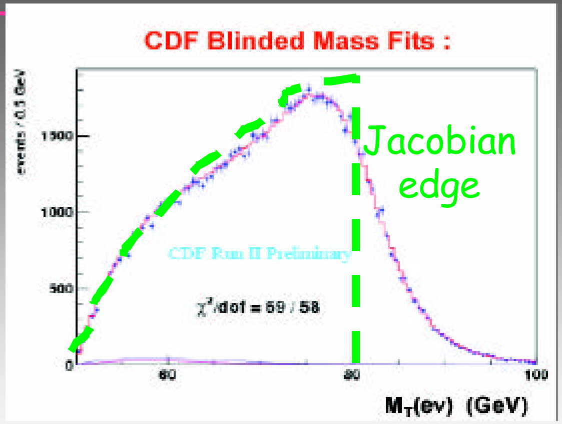
where $N_W = (N_{obs} - N_{bkg})/\varepsilon_{ID}$
and σ(R) accounts for:
- all but PDF uncertainties
- luminosity uncertainty ~1%

$$R_{CTEQ}^{cen/for} = 0.924^{+0.023}_{-0.030}$$

$$R_{MRST}^{cen/for} = 0.941^{+0.011}_{-0.015}$$



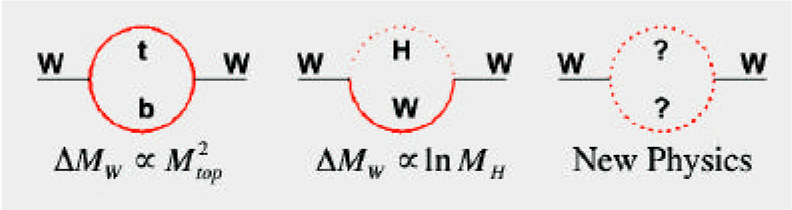
W Mass



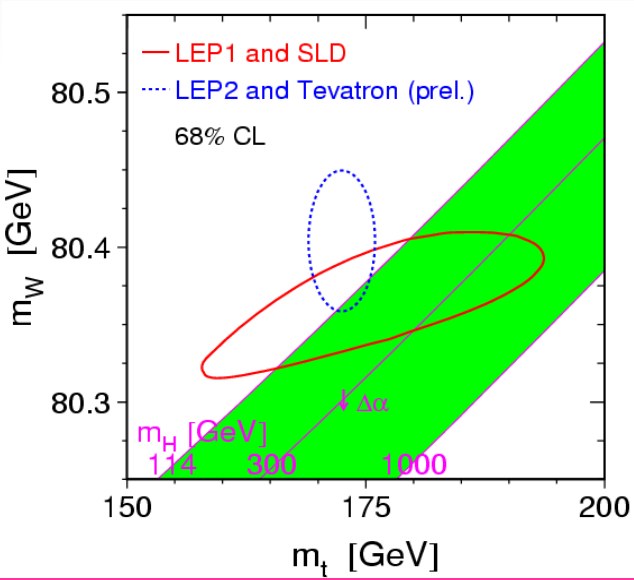
Fundamental EWK parameter

- Extracted from fit to Jacobian edge of $M_T(W)$ (or its decay products)

- Radiative corrections to W propagator induce dependence on (M_{top}, M_H, $M_?$)



➡ precisely measured M_W and M_{top} provide stringent constraints on Higgs mass.



- Equivalent constraint on M_H requires:
  - δM_{top}=+/-1.5 GeV ($\delta M/M_{top}$~1%)
  - δM_W=+/-10 MeV ($\delta M/M_W$<0.1%)

W Mass measurement is all about the systematic uncertainty

- CDF aims at controlling individual uncertainties to 10 MeV level to produce overall δM_W=25 MeV.
- D0 expects to achieve δM_W=40 MeV.

W Width

Try to find out whether Γ_W is consistent with $\Gamma(W \to l\nu)$.

1. Direct measurement of Γ_W using events in the $M_T(W)$ distribution away from Jacobian edge
2. Indirect measurement of Γ_W

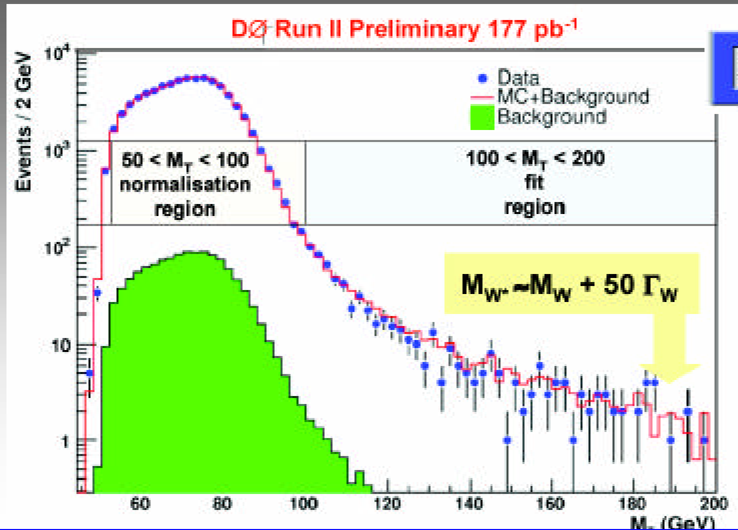
$$R = \frac{\sigma_W \cdot BR(W \to l\nu)}{\sigma_Z \cdot BR(Z \to l^+ l^-)} = \frac{\sigma_W}{\sigma_Z} \cdot \frac{\Gamma_Z}{\Gamma_{Z \to l^+ l^-}} \cdot \frac{\Gamma_{W \to l\nu}}{\Gamma_W}$$

SM : 3.370 ± 0.024

SM : 226.4 ± 0.3 MeV

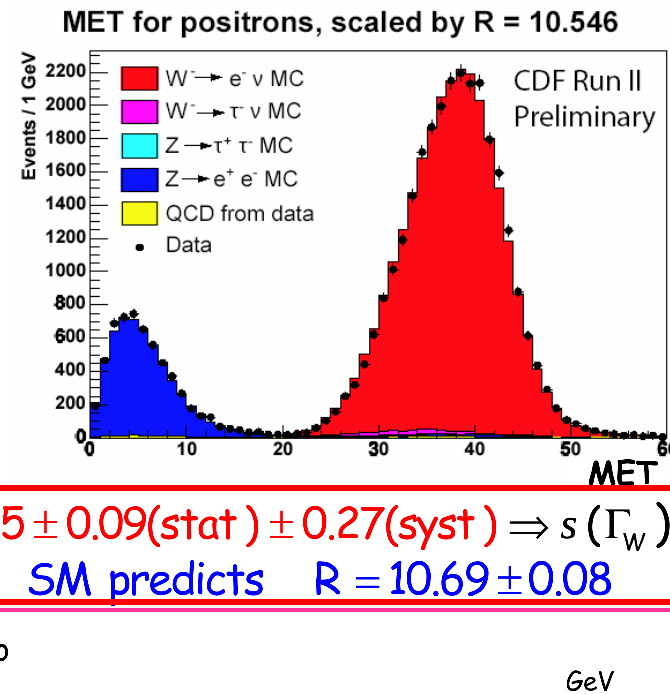
LEP : $BR(Z \to l^+ l^-) = 0.033658 \pm 0.000023$

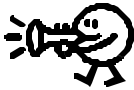
Identify W/Z events with a single set of cuts to maximally exploit uncertainty cancellation in the ratio



$$\Gamma_W = 2.011 \pm 0.093(stat) \pm 0.107(syst)\ GeV$$

SM predicts $\Gamma_W = 2.0921 \pm 0.025\ GeV$





$$R = 10.55 \pm 0.09(stat) \pm 0.27(syst) \Rightarrow s(\Gamma_W) = 47\,MeV$$

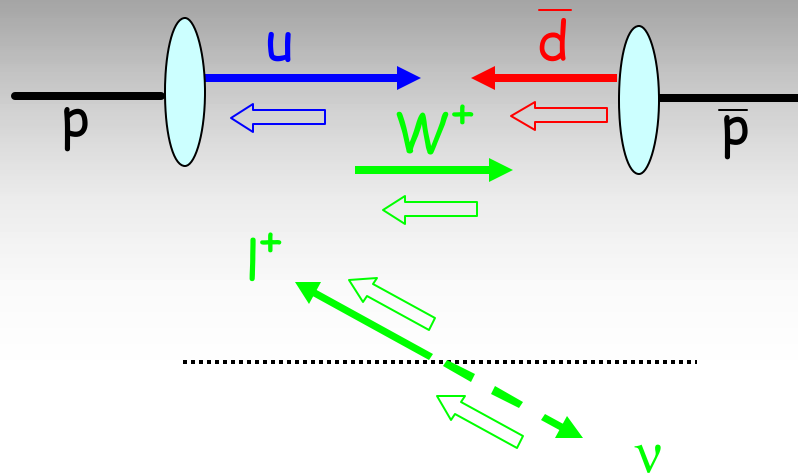
SM predicts $R = 10.69 \pm 0.08$

W Charge Asymmetry

Asymmetric PDF's u(x)>d(x)

⇕

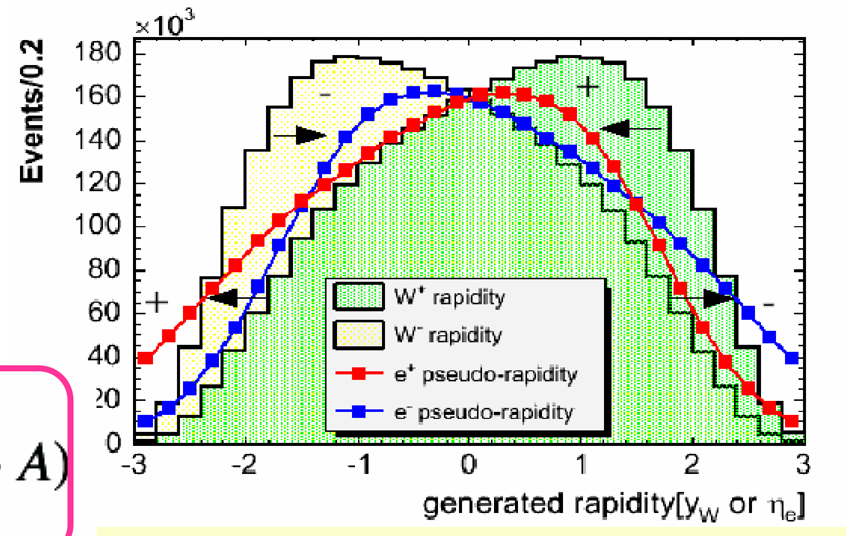
Asymmetric W+/W- rapidity distributions



Asymmetry in W production is measured with angular distribution of decay lepton and has to be convoluted with V-A nature of W decay.

⇒ W charge asymmetry

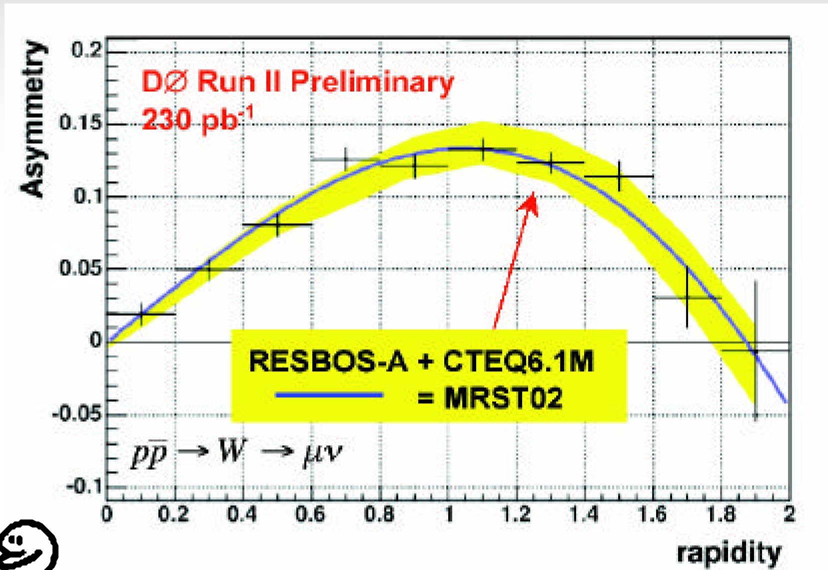
$$A(\eta_l) = \frac{d\sigma_+/d\eta - d\sigma_-/d\eta}{d\sigma_-/d\eta + d\sigma_+/d\eta} = A(y_W) \otimes (V-A)$$

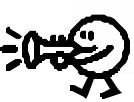


W Charge Asymmetry Measurement

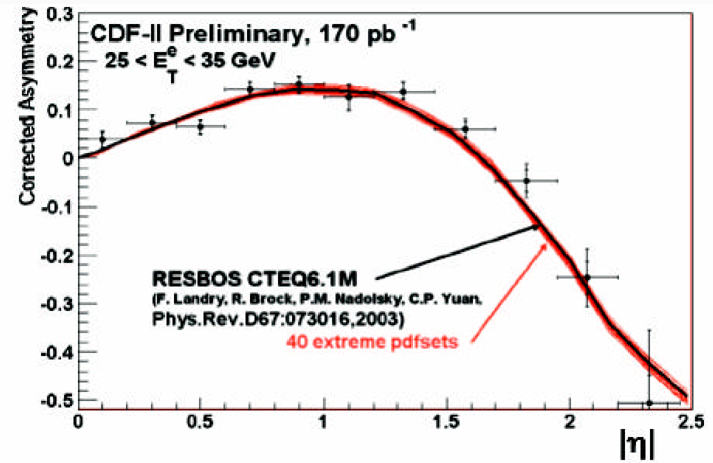
($230\ pb^{-1}$) use W->$\mu\nu$ decays

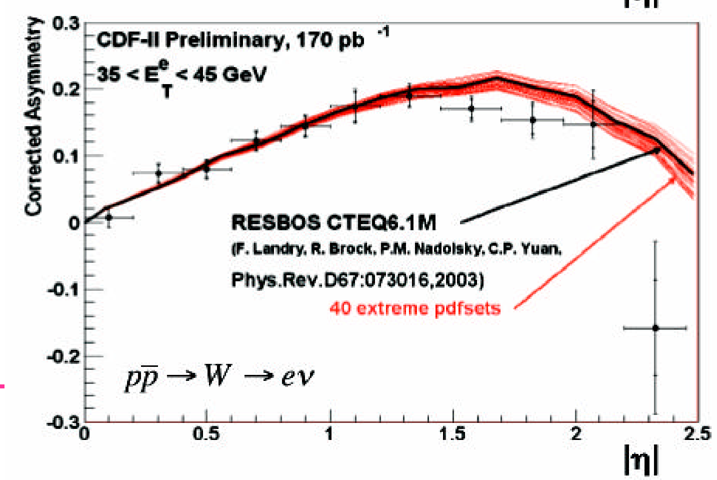
($170\ pb^{-1}$) use W->$e\nu$ decays





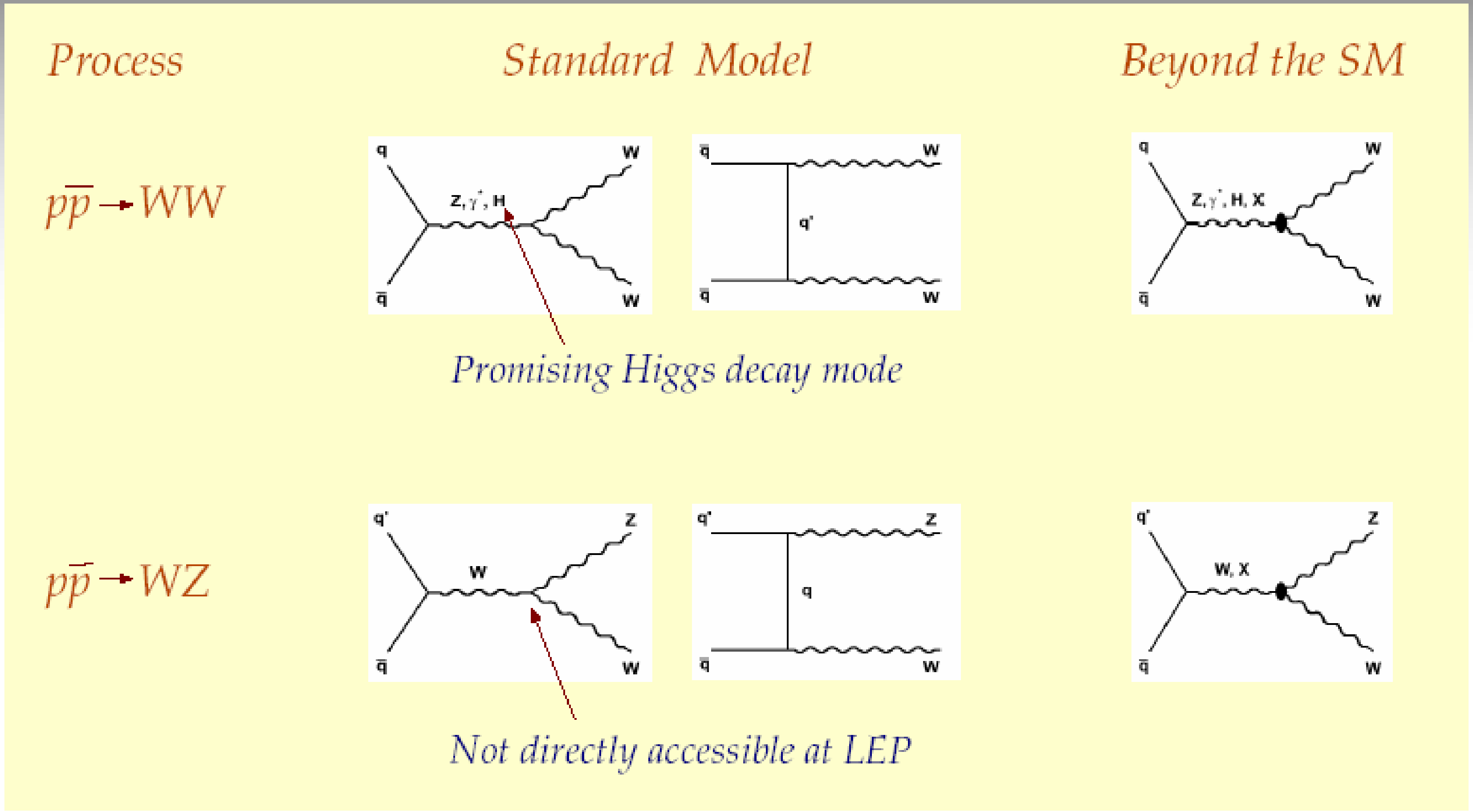
- Separate high p_T leptons, which are more sensitive to PDF's





- Error bars are sum of statistical (dominant) + systematic uncertainty and comparable to PDF's uncertainty

Diboson Production



- Probe boson self-interactions
- Background to $t\bar{t}$, H->WW, HW/HZ
- Sensitive to new physics

- Tevatron can study different combinations and explore higher vs than LEP.

WW and WZ

WW and WZ have low cross-section (not observed in RunI!)

$p\bar{p} \to WW$ NLO cross section: 12.4 ± 0.8 pb

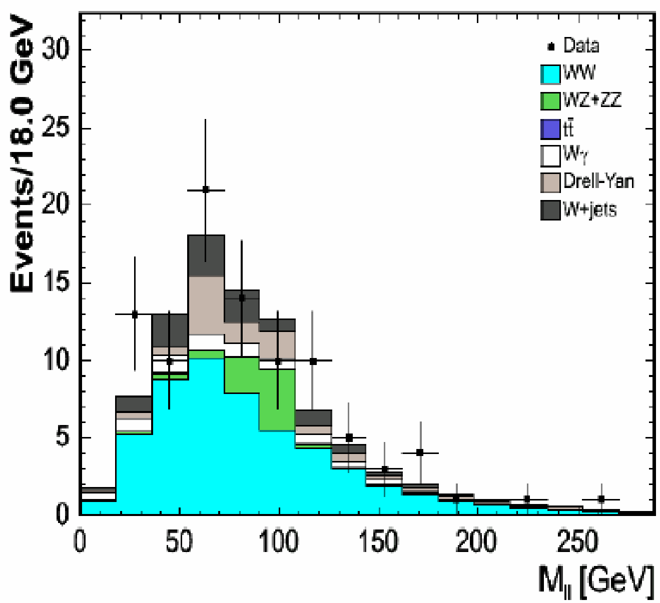
Campbell,Ellis, Phys.Rev. D60 (1999) 113006

$p\bar{p} \to WZ$ NLO cross section: 3.7 ± 0.1 pb

WW-> $l^+l^-\nu\nu$ are identified using a dilepton+MET selection which avoids the Z region and events with jets.

CDF (825 pb^{-1}) 95 events observed, expected background of 37.8 +/-4.8

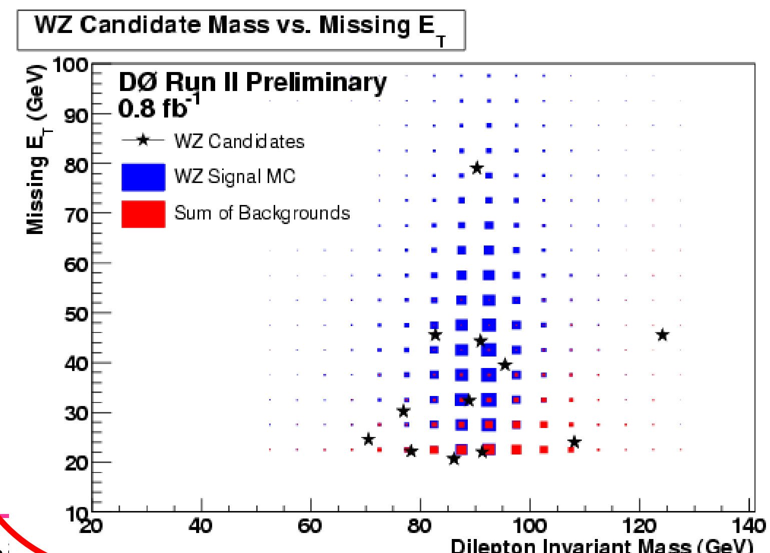
$$\sigma(p\bar{p} \to WW) = 13.6 \pm 2.3\,(\text{stat}) \pm 1.6\,(\text{syst}) \pm 1.2\,(\text{lum})\ \text{pb}$$



WZ-> $l^+l^-l\nu$ are identified using a trilepton+MET selection, with 2 leptons in the Z region.

DØ **(800 pb^{-1}) has first 3s observation!**: 12 evts observed, vs expected background of 3.6 +/-2.0

$$s\,(p\bar{p} \to WZ) = 3.98^{+1.91}_{-1.53}\ \text{pb}$$



EWK Summary

Many new results from the Tevatron: all in agreement with SM predictions!

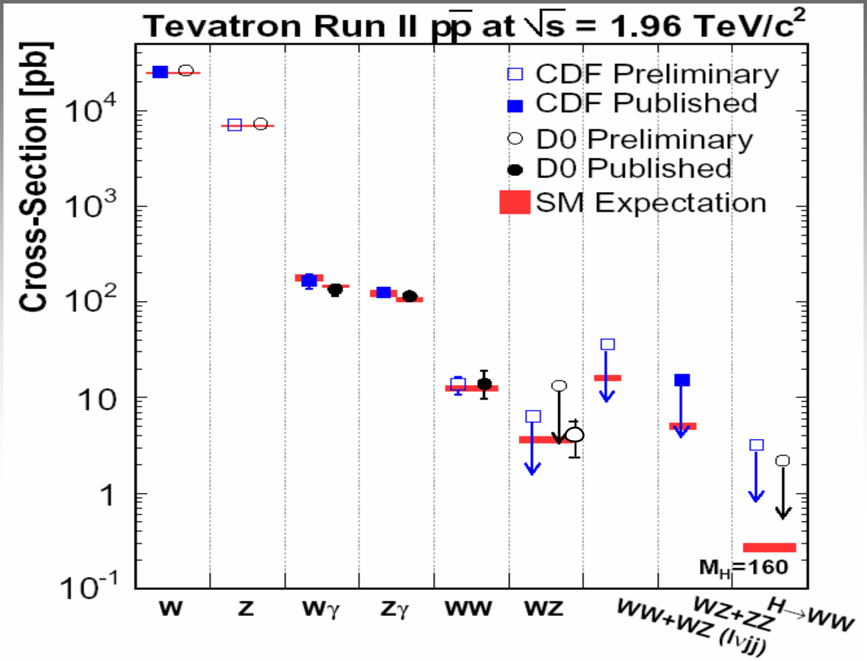
High precision in single boson channels is helping with the modeling of hadron collisions.

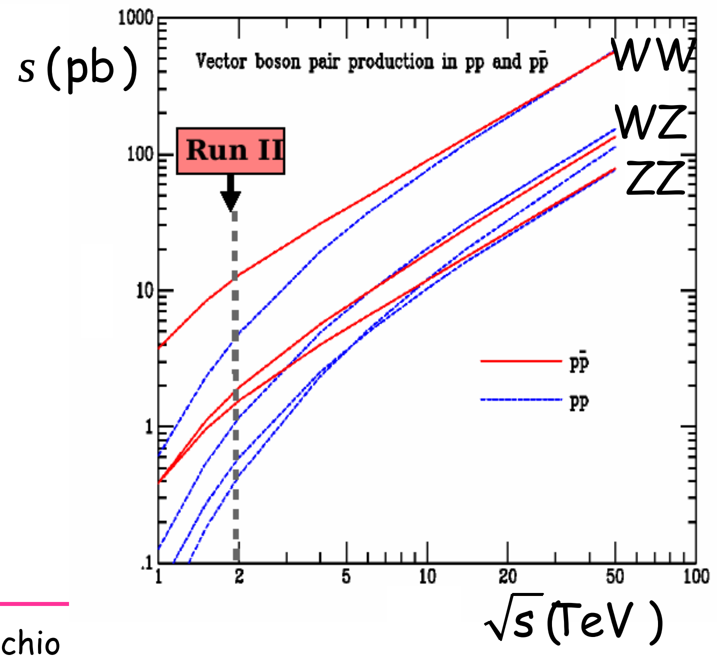
High statistics is allowing the study of previously inaccessible SM decays.

Detection techniques are improving and preparing the turf for Higgs and new physics searches.

LHC will benefit from big increase in production rate for EWK processes but life is not that easy…

LHC goal on W mass: δM_w=15 MeV
…but require knowledge of the lepton (E, p) scales to 0.02%!



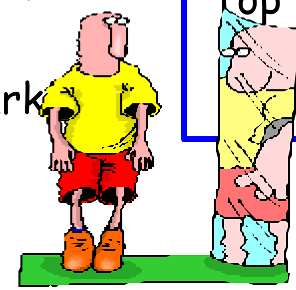


Top Physics

Can be studied only at Tevatron so far.

Still young!

Discovered in Run I with ~30 evts/experiment (L=110 pb^{-1})



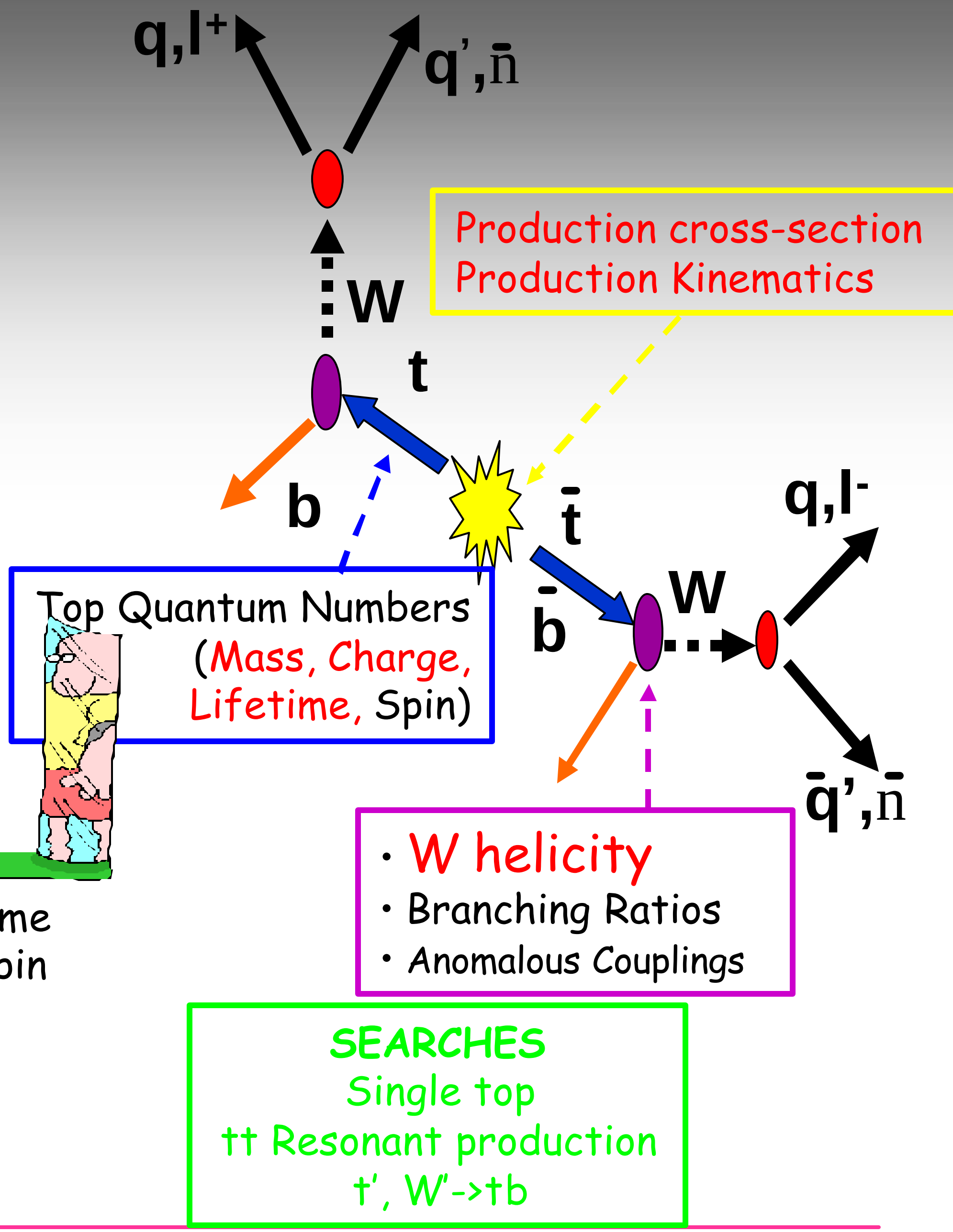
Large mass ~175 GeV ("golden quark")

- Special role in EWSB?
- Probe to physics beyond SM

Top lifetime ~10^{-25} sec (Γ=1.5 GeV) -> no time to hadronize -> can probe charge and spin of bare quark!

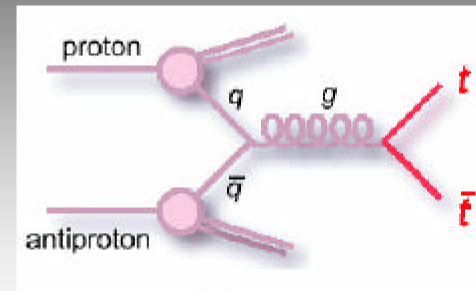
With 1 fb^{-1} we want to answer:

"Is it SM top?"



Top Production and Decay Event Topology

- At the Tevatron, top are produced in pairs via strong interactions.
- At LHC:
  - $\sigma(tt)_{LHC} \sim 100\mathrm{x}\ \sigma(tt)_{TEV}$
  - Fraction of qq vs gg is inverted



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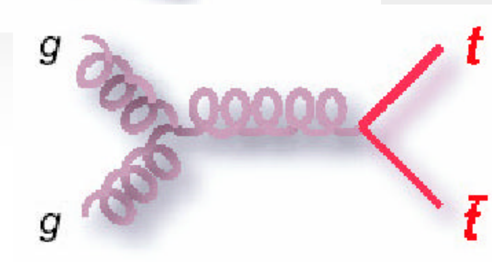

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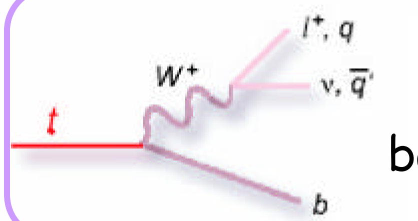
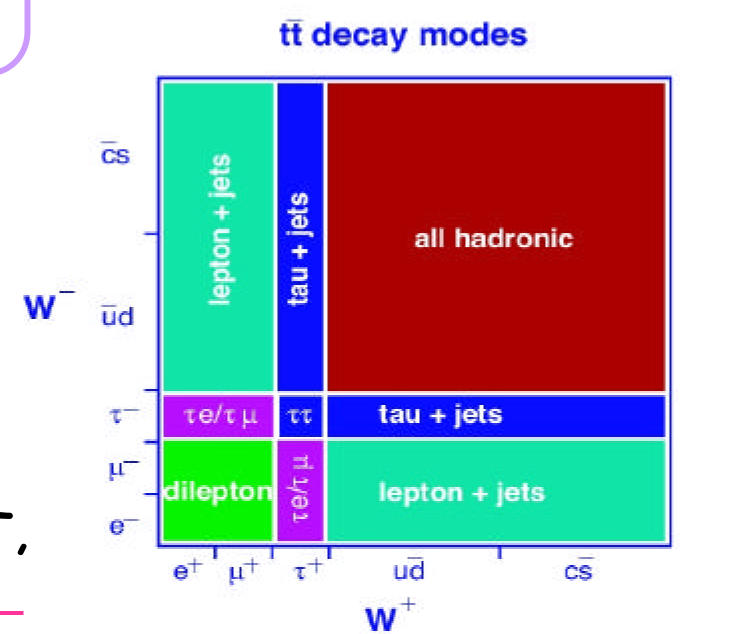


- $BR(t \to Wb) \approx 100\% \Rightarrow$

4 main decay topologies based on W decays ($l = e,\mu$)

		BR	S/B
1. Dilepton:	$t\bar{t} \to \ell^+\nu\ell^-\nu b\bar{b}$	5%	>1
2. Lepton+jets:	$t\bar{t} \to \ell\nu q\bar{q}b\bar{b}$	30%	~1(*)
3. All hadronic:	$t\bar{t} \to q\bar{q}q\bar{q}b\bar{b}$	45%	<1(*)
4. Tauonic:		20%	<1

(*) after b-tagging

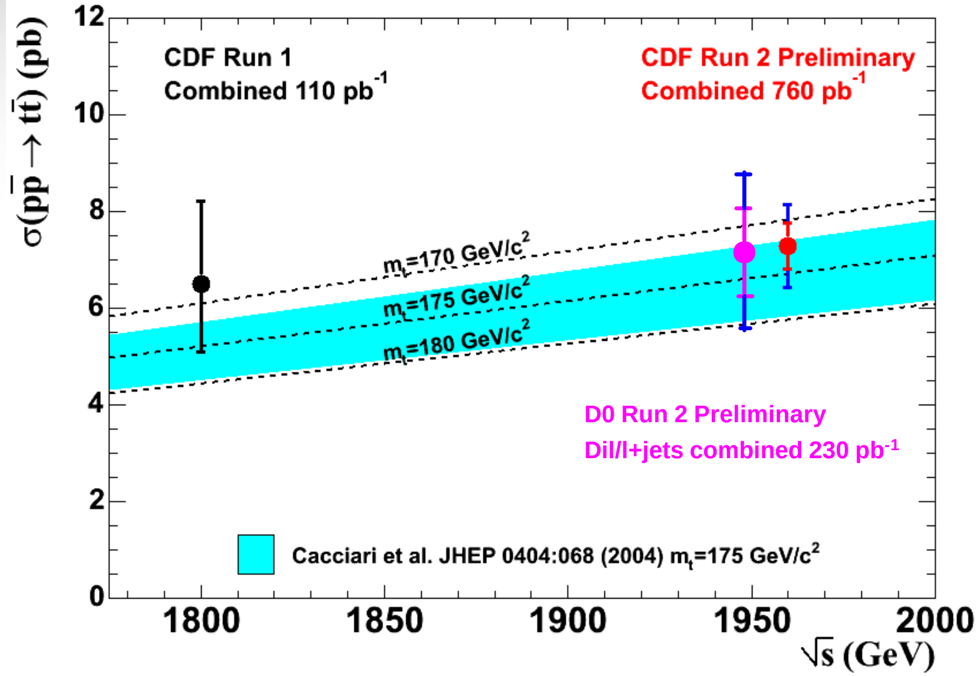


Some as EWK signatures! High p_T leptons, MET, jets (light and heavy-flavor).

Top Cross Section

M_{top} (GeV) @ vs= 1.96 GeV	σ_{NLO}(pb) ± $\delta\sigma$ from PDF
170	7.8 ± 1.0
175	6.7 ± 0.8
180	5.7 ± 0.7

SM pred: Bonciani et al. hep-ph 0303085
Kidonakis et al. PRD 68 114014



- Measured in all topologies.
- Use complimentary techniques: topological (counting) vs shape fit.
- Provide sample composition needed for top property studies.

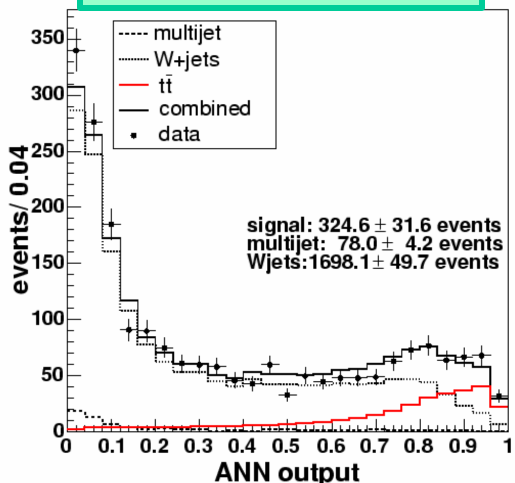
Deviation from SM expectations could indicate non-SM production mechanism or new physics in top sample.

Lepton+jet Cross Section

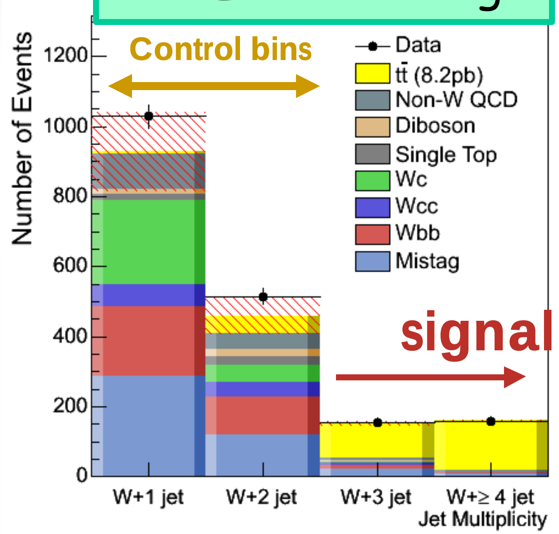
- This is the golden channel for its high yield and relative purity (after b-tag)!
- Used in top property measurements, single top and Higgs searches.

CDF has single best results in 750 pb^{-1}

l +MET+ >=3jets



l +MET+ >=1 b-tag



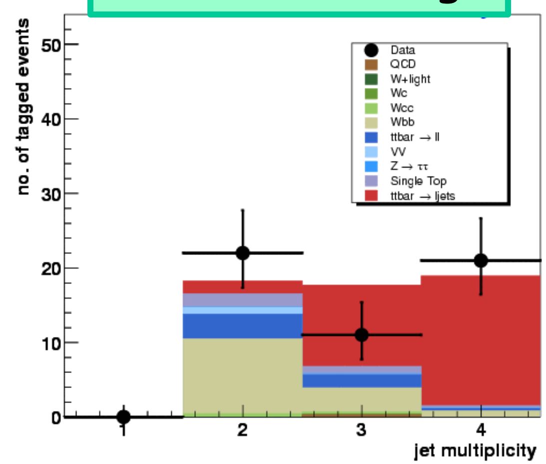
$\sigma_{t\bar{t}}(btag) = 8.2 \pm 0.6_{stat} \pm 1.0_{syst}$ pb

$\sigma_{t\bar{t}}(notag) = 6.0 \pm 0.6_{stat} \pm 1.1_{syst}$ pb

DØ has results up to 370 pb^{-1} with 1 and **2 btags**

$\sigma_{t\bar{t}}(btag) = 8.1 \pm 1.2_{stat+syst} \pm 0.5_{lumi}$ pb

l +MET+ 2 b-tag

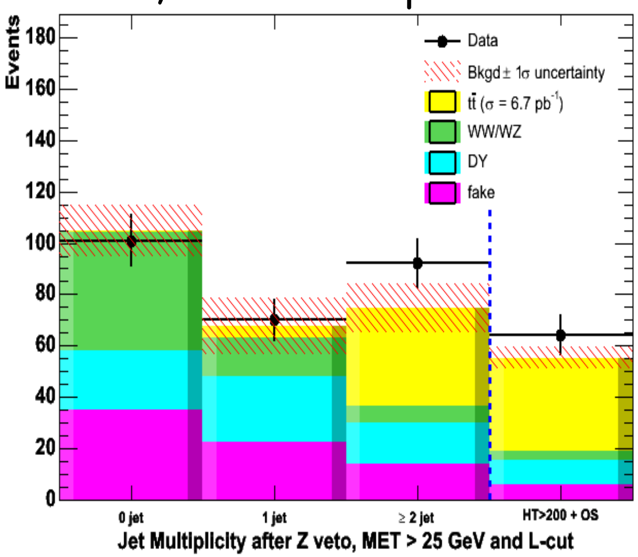


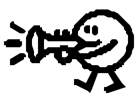
Dilepton Cross Section

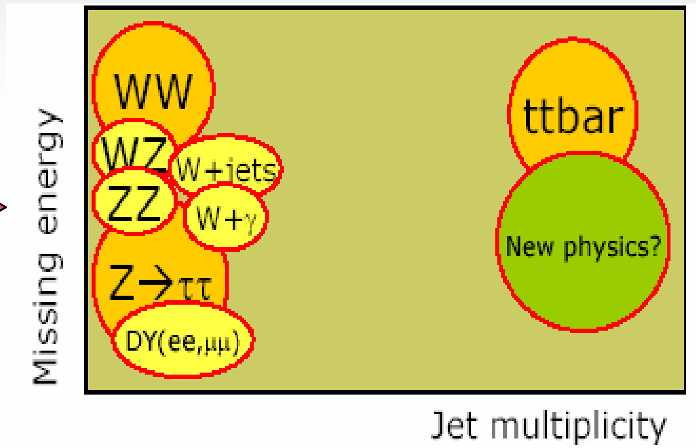
- S:B already good enough after 2 leptons + MET + >=2 jets
- b-tagging not needed
- Cross-section persistently higher that l+jets: add b-tag to improve S:B further.

CDF has single best result in 750 pb^{-1}.

New inclusive analysis in (N_{jet}, MET) plane to extract simultaneously $Z \to \tau\tau$, WW and top cross-sections.



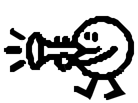




$$s_{t\bar{t}}(\text{incl}) = 8.5 \pm 2.3_{fit} \pm 0.5_{shape}\ \text{pb}$$

$$s_{t\bar{t}}(\text{notag}) = 8.3 \pm 1.5_{stat} \pm 1.0_{syst} \pm 0.5_{lumi}\ \text{pb}$$

DØ in 370 pb^{-1} uses looser ee/μμ/eμ selection +b-tagging

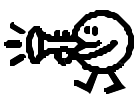


$$s_{t\bar{t}}(\text{btag}) = 8.6 \pm 1.8_{stat} \pm 1.1_{syst} \pm 0.6_{lumi}\ \text{pb}$$

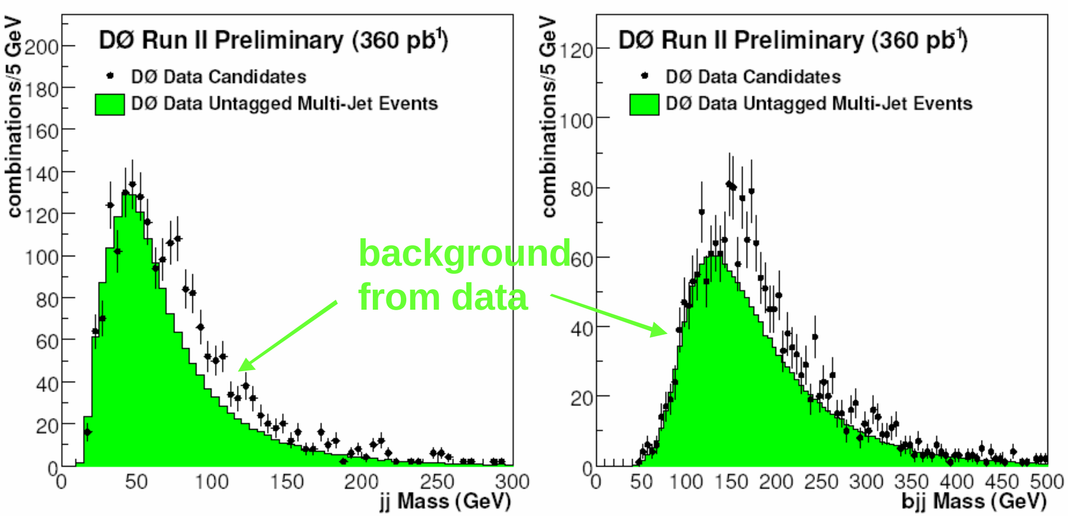
All Hadronic Cross Section

- Start from a sample >=6 jets (special trigger). Still overwhelmed by QCD multi-jets background.
- Combine topological selection and b-tag
- Lot's of data to model background (-: !

DØ (360 pb-1) requires 2 btags and fits the dijet (no btag) and trijet (1 btag) distribution

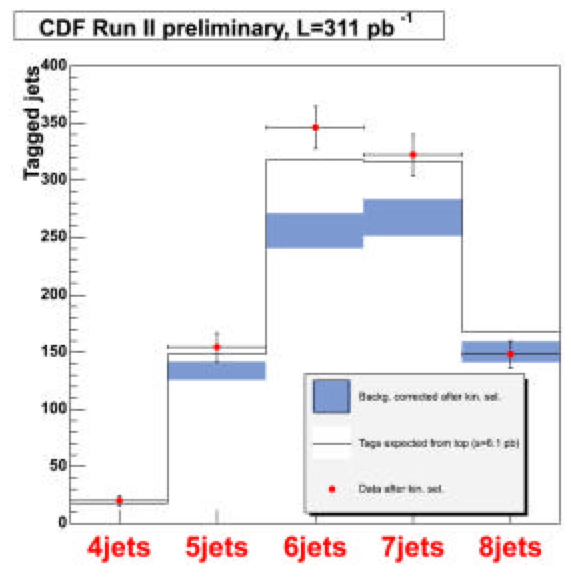


$s_{t\bar{t}}(\text{allhad}) = 12.1 \pm 4.9_{stat} \pm 4.6_{syst}$ pb



CDF (310 pb-1) requires at least 1 btag and anti-MET cut.

$s_{t\bar{t}}(\text{allhad}) = 8.0 \pm 1.8_{stat} \pm 3.0_{syst}$ pb



Tauonic Cross-Section

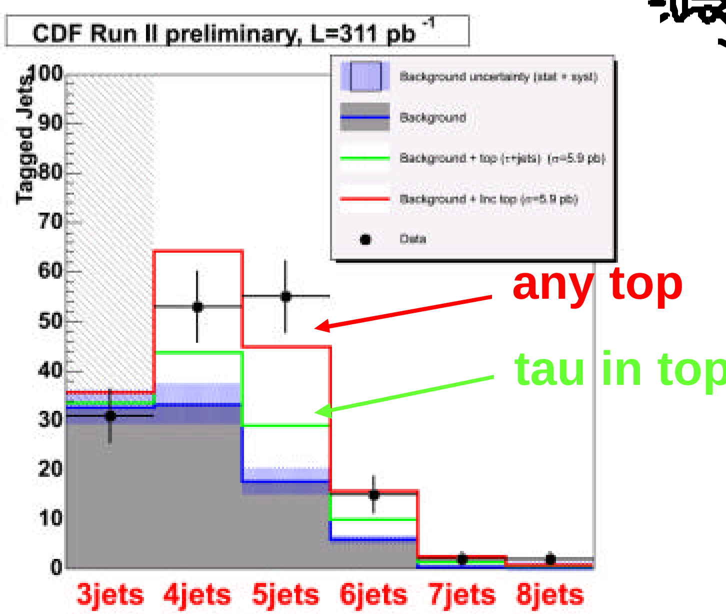
Search for $t\bar{t} \to t n \ell n b\bar{b}$
with τ decays to hadrons

	Electron + tau (359 pb-1)	Muon + tau (344 pb-1)
Jets fake taus	0.91 ± 0.29	0.92 ± 0.29
Elecs fake taus	0.10 ± 0.025	0.05 ± 0.012
Z? tt + 2 jets	0.38 ± 0.12	0.31 ± 0.09
WW + 2 jets	0.034 ± 0.011	0.027 ± 0.008
Total background	**1.42 ± 0.31**	**1.31 ± 0.30**
ttbar ? l+t	**1.32 ± 0.05**	**0.92 ± 0.05**

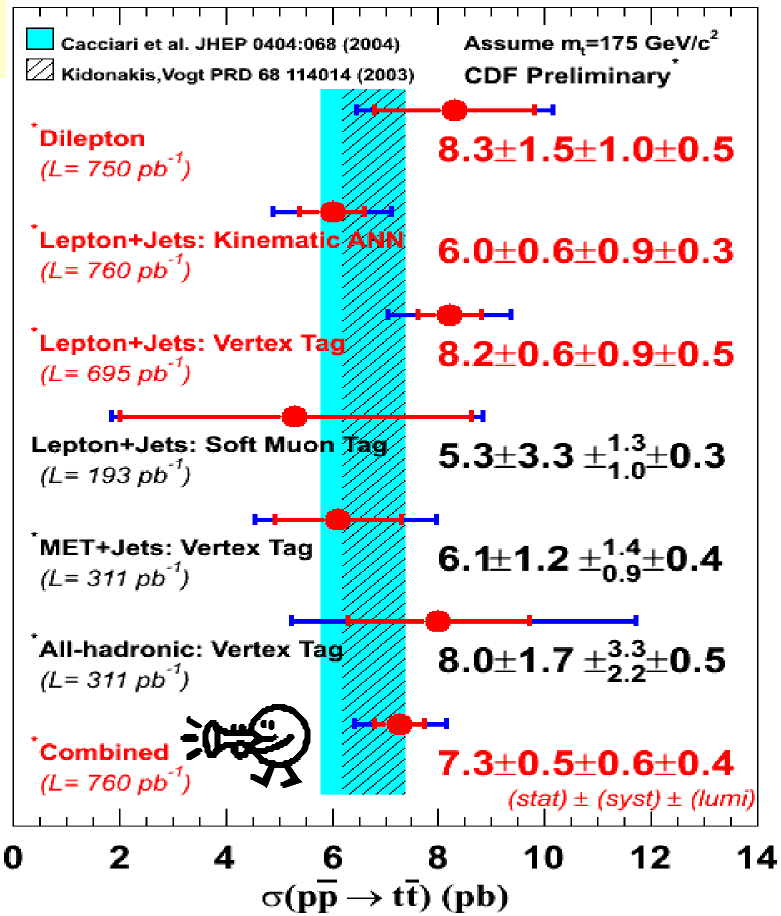
Probability for the expected background to have fluctuated to the 5 observed events or more (p-value) is 15%, equivalent to ~1 σ significance for signal observation.

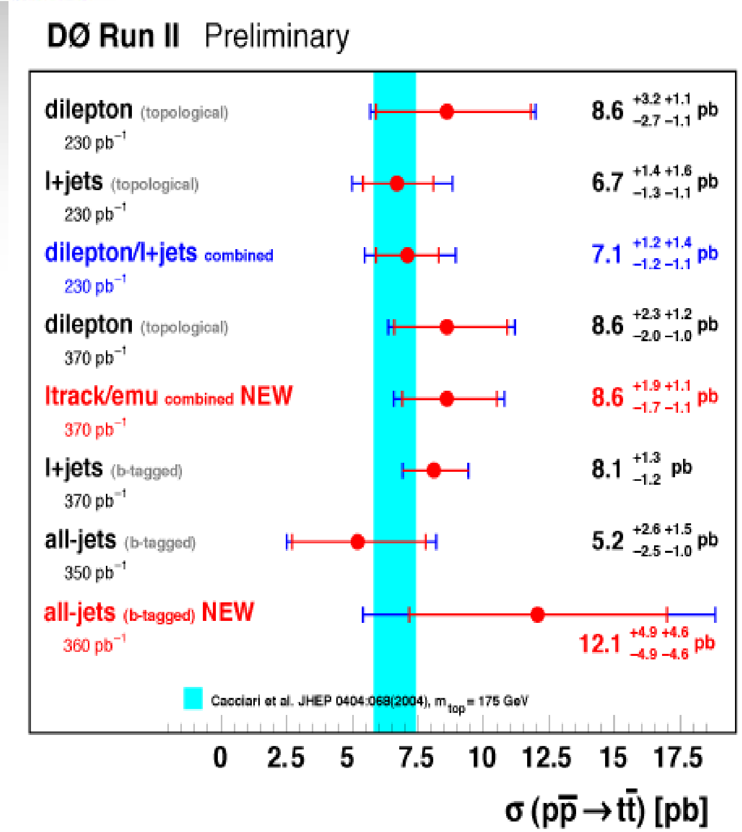
Using multi-jets trigger sample, require significant MET to identify tau hadronic decays (and recover l+jets acceptance).

$$s_{t\bar{t}}(\text{MET} + \text{jets}) = 5.8 \pm 1.2_{stat} \pm 0.8_{syst}\ \text{pb}$$



Top Cross-Section Summary



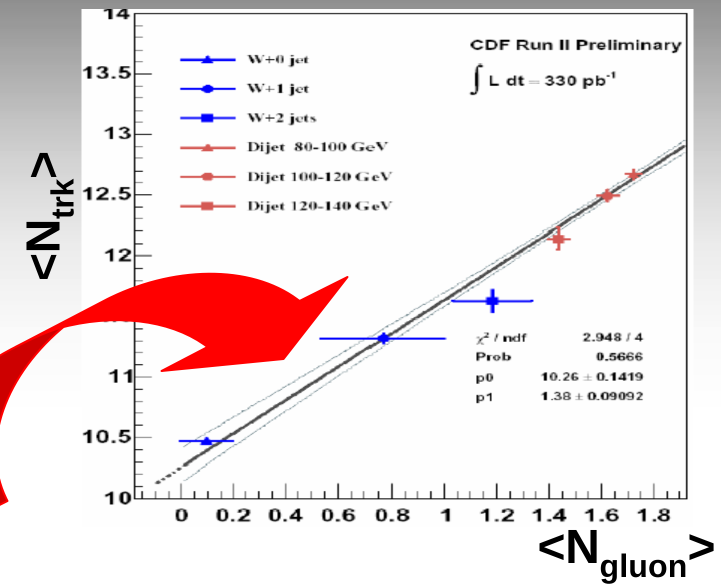


Tevatron goal: 10% uncertainty/experiment with 2 fb^{-1}
LHC goal: <10% uncertainty with 10 fb^{-1} and ultimately <5%.

Top Production Mechanism

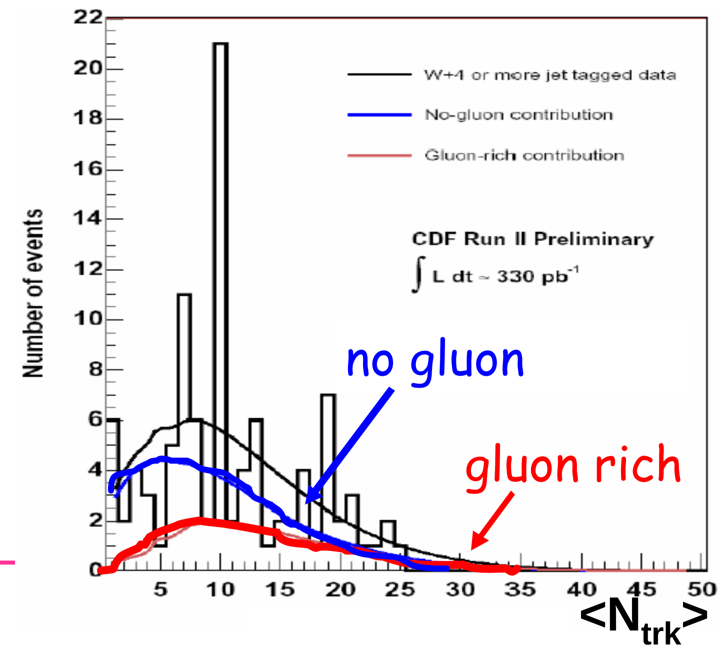
gg->tt vs qq->tt production mechanism results in different "underlying" activity.

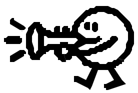
Use number of low p_T (0.3 to 2.9 GeV) tracks away from jets as a discriminator



- Calibrate $\langle N_g \rangle$ vs $\langle N_{trk} \rangle$ correlation using dijet and W+0/1/2 jet data.
- Fit l+jets tagged top sample (330 pb^{-1}) to gluon-rich and no-gluon templates

$$\frac{\sigma(gg \to t\bar{t})}{\sigma(p\bar{p} \to t\bar{t})} = 0.25 \pm 0.24(stat) \pm 0.10(syst)$$





Top Mass

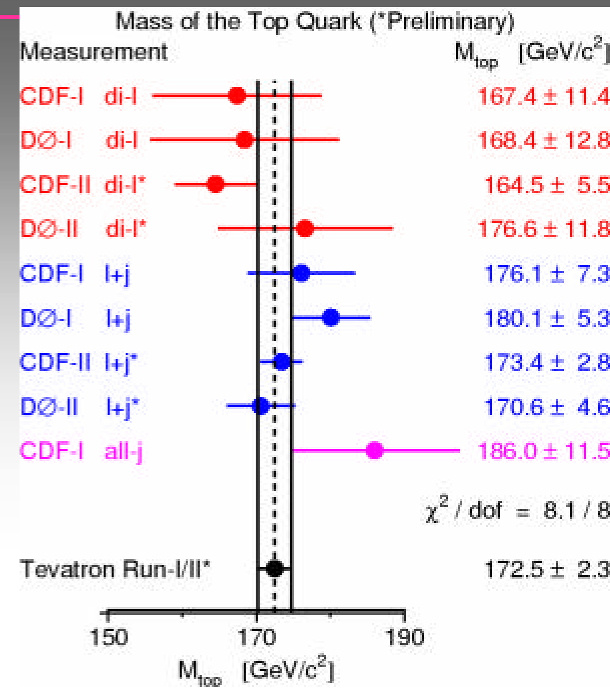
- Fundamental parameter of SM.
- Recent Tevatron combination:

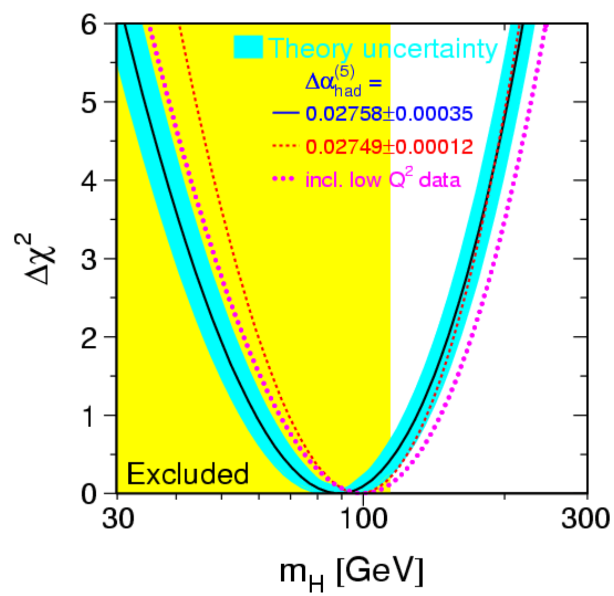
  $M_{top} = 172.5 \pm 2.3 GeV$ 

- EWK fit gives: $M_H = 89^{+42}_{-30} GeV$ (68% C.L.)

  $M_H < 175 GeV$ (95% C.L.)

- In Run II, expect $\delta M_W = \pm 25$ MeV and $\delta M_{top} = \pm 2$ GeV
  ⇨ 35% constraint on M_H.
- Sensitive to new physics through radiative corrections.

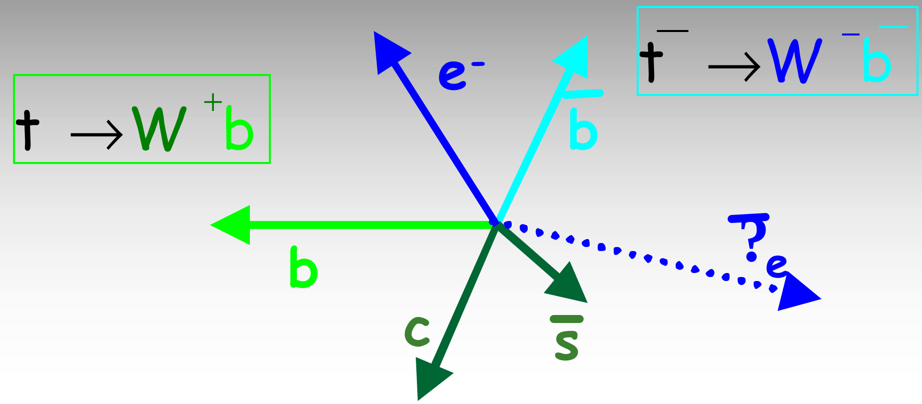


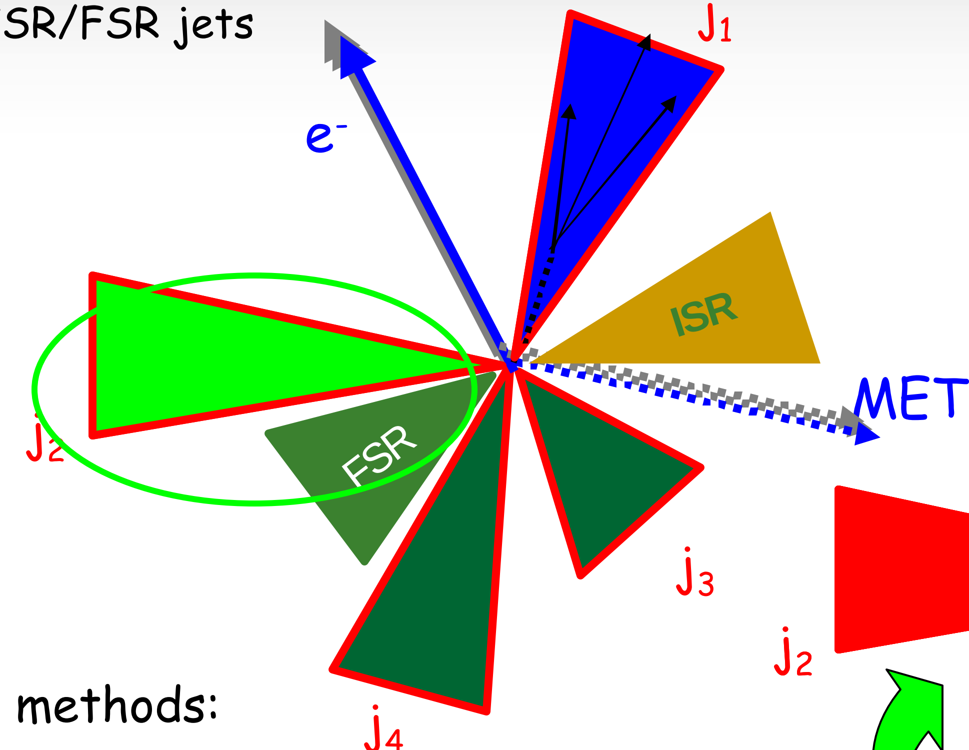


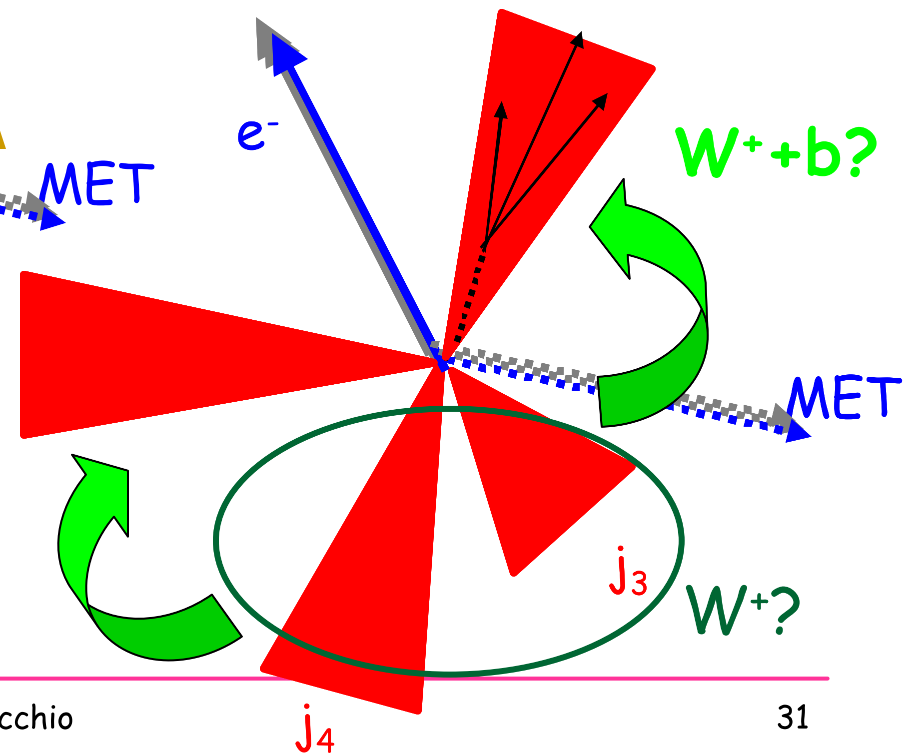
Top Mass Measurement

Why is it so hard??

- Life ain't pretty…
- Combinatorics of assigning jets to W/t
- ISR/FSR jets



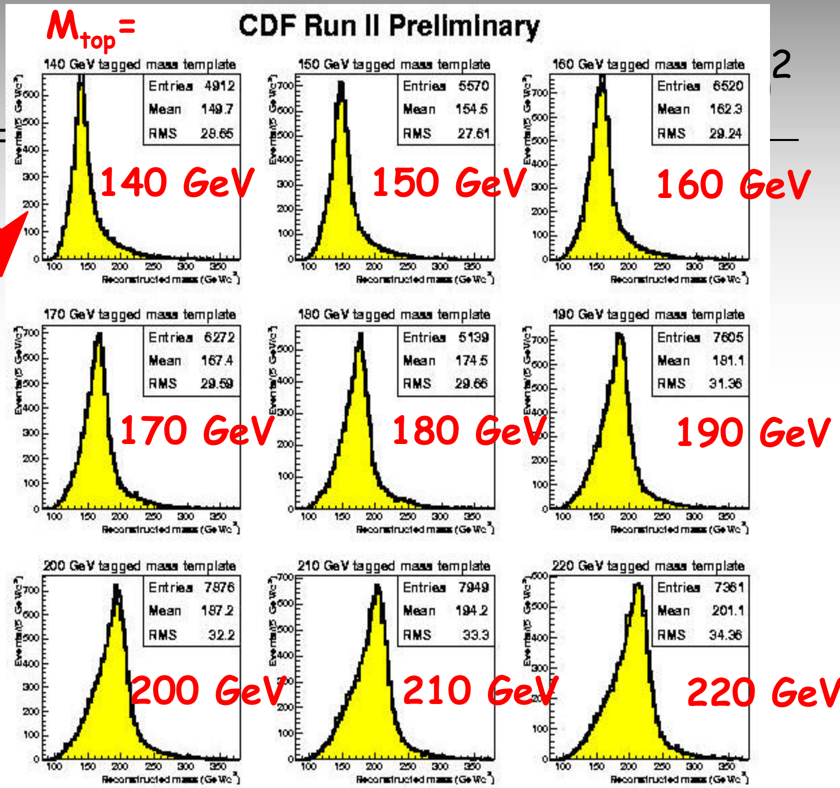


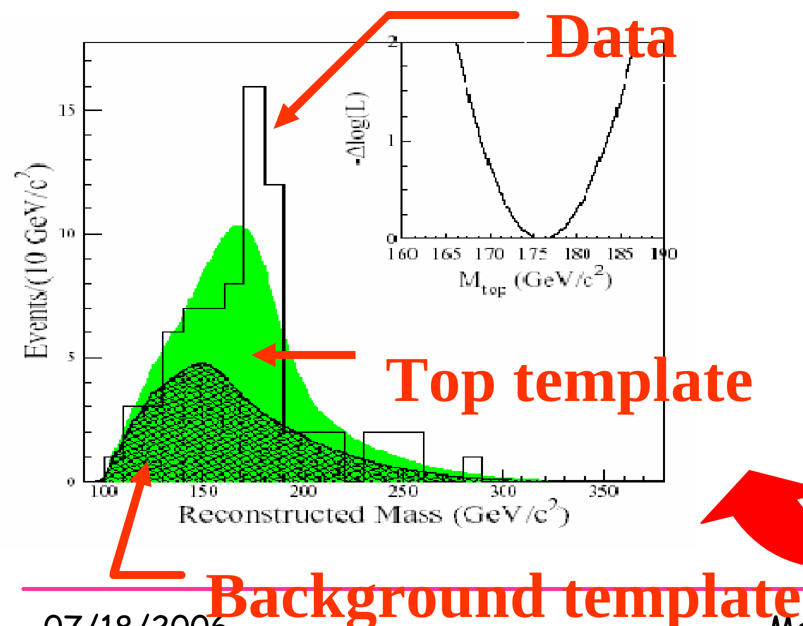


- Two methods:
  1. Template Methods
  2. Matrix Element Methods

Top Mass with Template Method

- Evaluate event-by-event best "reconstructed mass", M_{rec}, by using observed kinematics of ttbar event (e.g.: χ^2 fitter)
- Create "templates", i.e. MC predictions for M_{rec} using different true masses , M_{top}.



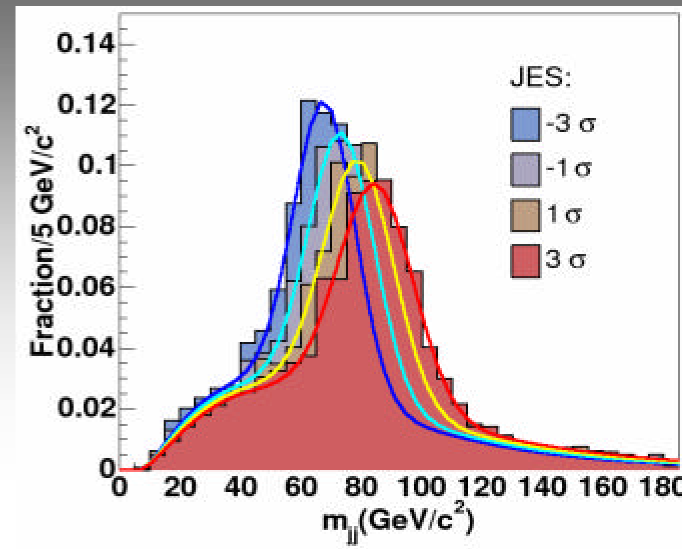


- Measure top mass with likelihood fit of data M_{rec} to signal + background template.

Top Mass in l+jets

JES uncertainties are the largest source of systematics:

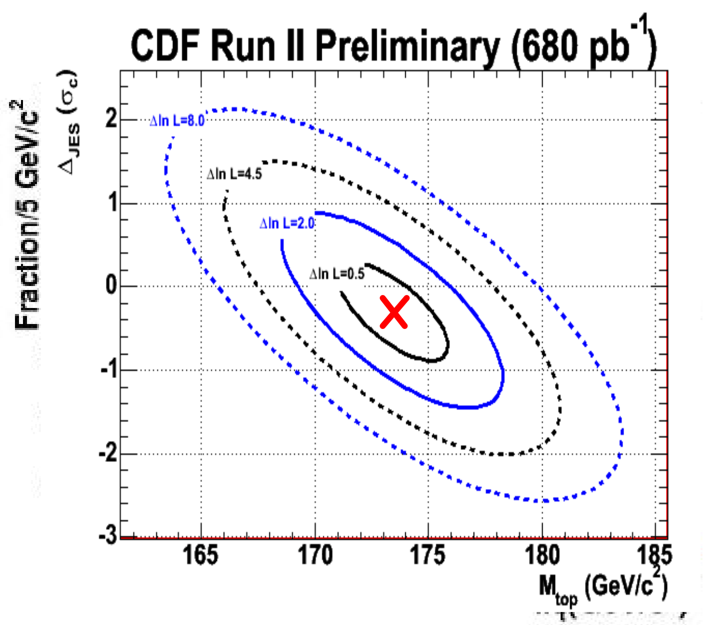
$$\pm 1 s_{JES} \Rightarrow s_{M_{top}} = \pm 3 GeV$$



Fit simultaneously for $M_{W\to jj}$ and M_{bjj} using 2D templates of true M_{top} and σ_{JES}

(680 pb^{-1}) achieves world single best measurement and improves JES systematics by 40% by using in-situ calibration

$$M_{top} = 173.4 \pm 2.5(\text{stat.} + \text{JES}) \pm 1.3\ (\text{syst.})\ GeV/c^2$$



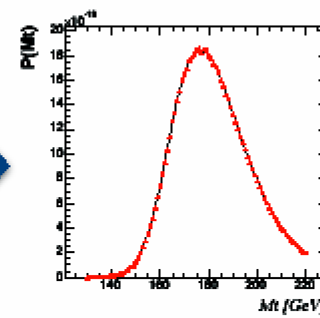
best measurement (370 pb^{-1}) uses a ME method with simultaneous JES fit

$$M_{top} = 170.6 \pm 4.4_{stat+JES} \pm 1.4_{syst}\ GeV$$

Top Mass Measurement with ME

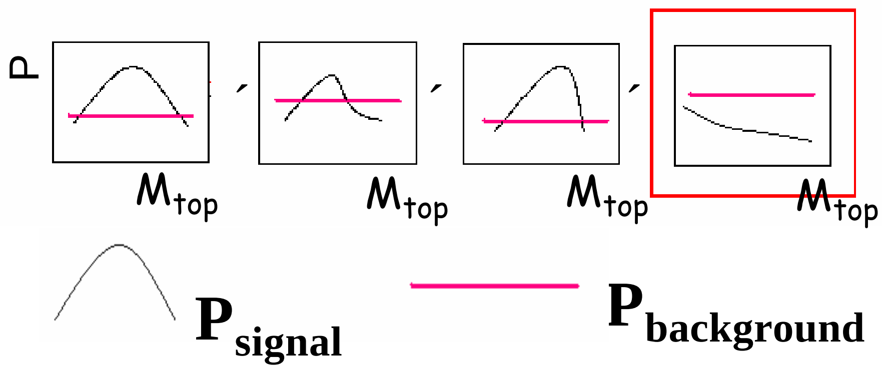
- Calculate event-by-event signal probability curve (rather than single M_{rec}) using decay matrix element and transfer functions.

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



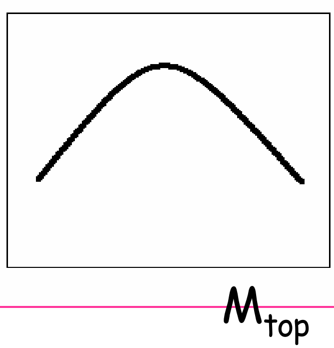
- Calculate event-by-event background probability (no dependence on M_{top}!).

$$\frac{d\sigma(M_t)}{d\mathbf{x}} = \frac{1}{N}\int d\Phi_6 |\mathcal{M}_{t\bar{t}}(p_i; M$$



- Combine signal and background probability in one likelihood vs M_{top} for entire sample.

=

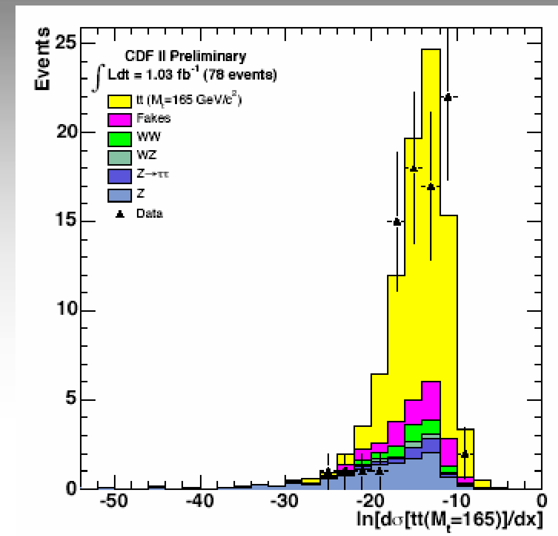


ME Method use maximal information per event at a price of simplified assumptions.

Final mass result and uncertainty is calibrated against simulated events.

Top Mass in dilepton

Under constrained system: two neutrinos but only one MET measurement.

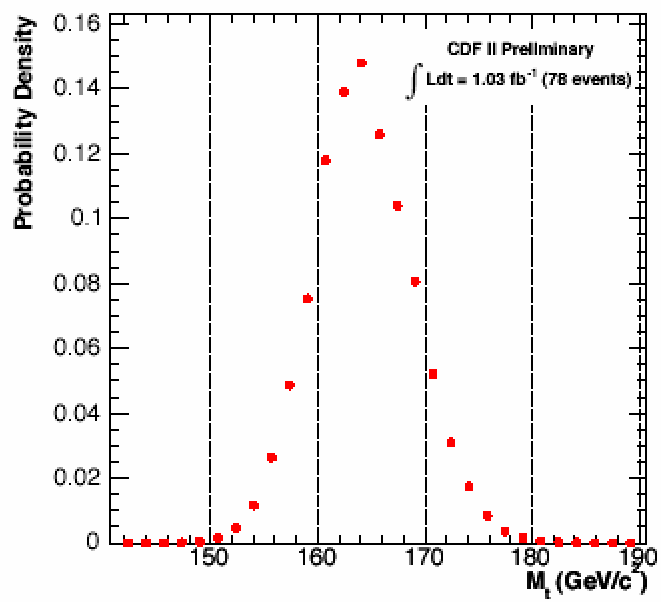


(1 fb^{-1}) assumes highest two E_T jets are the b-jets and integrate ME probability over 8 unknowns ($\vec{p}(\nu_1)$, $\vec{p}(\nu_2)$ and $p_T(tt)$)

Using 78 events (27.8 bkgr)

$$M_{top} = 164.5 \pm 3.9_{stat} \pm 3.9_{syst}\ GeV$$

- Confirmed in b-tag dilepton sample (S:B~1:30) .
- Consistent results in template measurements.



best measurement (370 pb^{-1}) uses Matrix Element Weighting method:

$$M_{top} = 178.1 \pm 6.7_{stat} \pm 4.8_{syst}\ GeV$$

Top Mass in All Hadronic

Low S/B (~1/8) and large combinatorial background (90 permutations for 6 jets)

Ideogram Method is a hybrid template and ME technique:

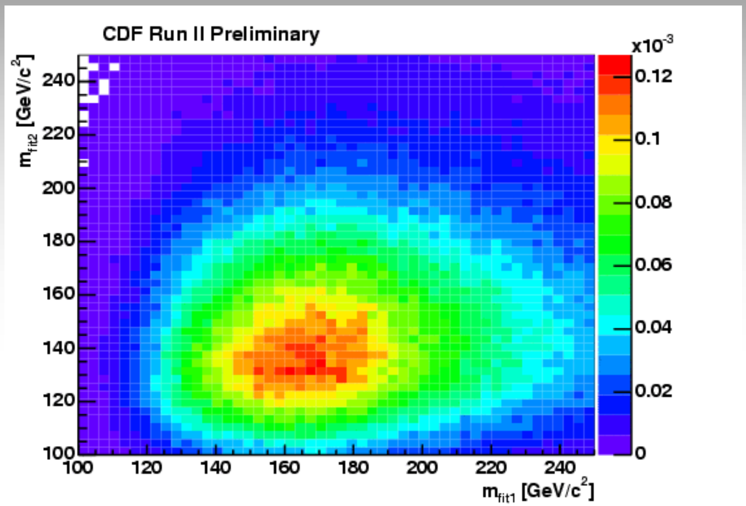
- Define event-by-event 2-D likelihood

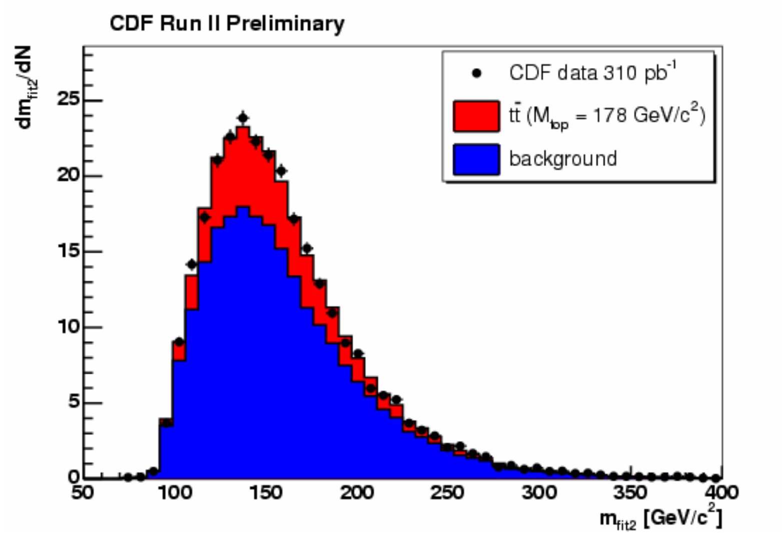
$$\mathbf{L}_{\mathbf{event}}(M_{top}, C_s) = \sum_{i=1}^{90} w_i \left[C_s \mathrm{Signal} + (1 - C_s)\mathrm{Bkgr} \right]$$

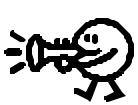
- Signal template is the combination of a 2D mass fitter and a combinatorics fitter

Using 370 pb^{-1},

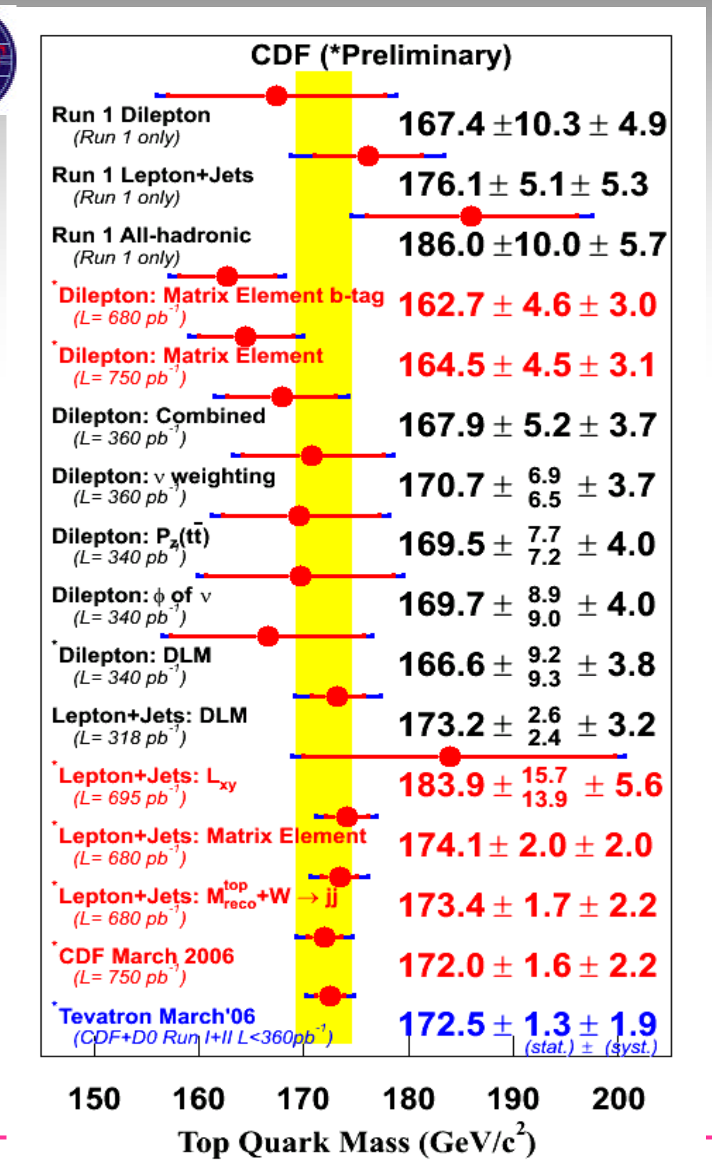
$$M_{top} = 177.1 \pm 4.9_{stat} \pm 4.7_{syst}\ \mathrm{GeV}$$

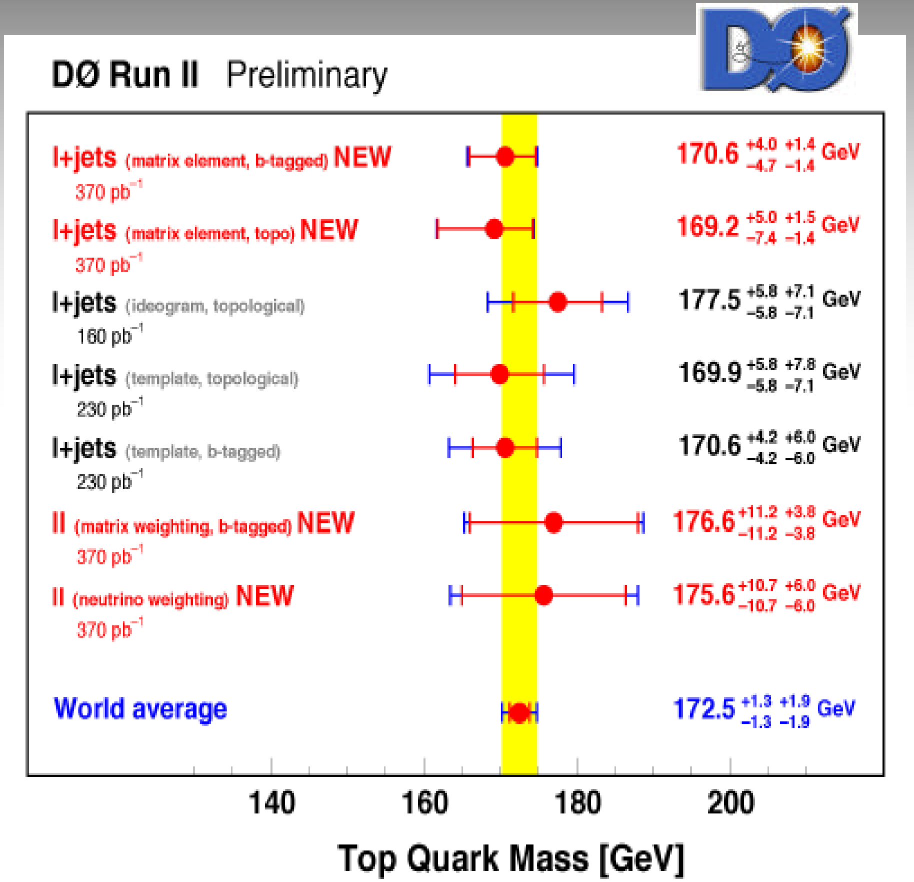






Top Mass Results



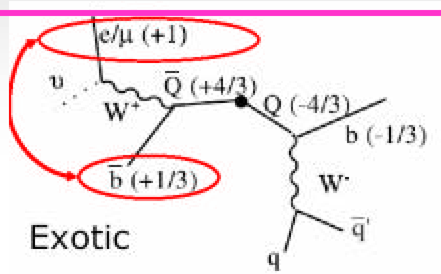


Tevatron Run II goal: d(M_{top})<3 GeV with 2 fb^{-1} already exceeded!

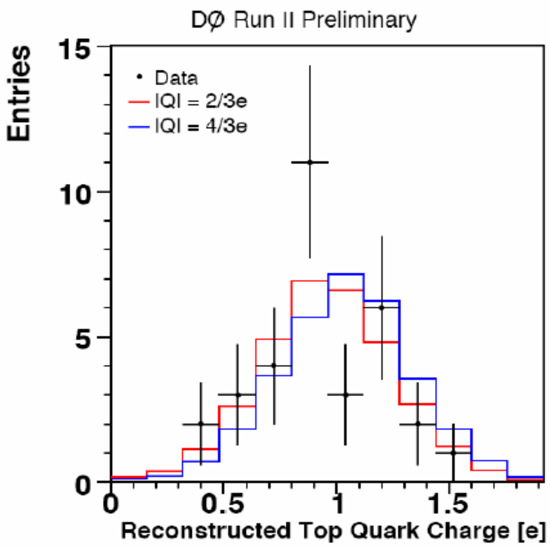
LHC Goal: d(M_{top})<1 GeV with 10 fb^{-1}

Top Charge and Lifetime

Top quark in SM has charge 2/3e. Some models propose an exotic 4th quark with Q=4/3e



DØ (365 pb^{-1}) in l +4jets (2 btag) use a jet charge algorithm to discriminate between b and $\bar{b}$.



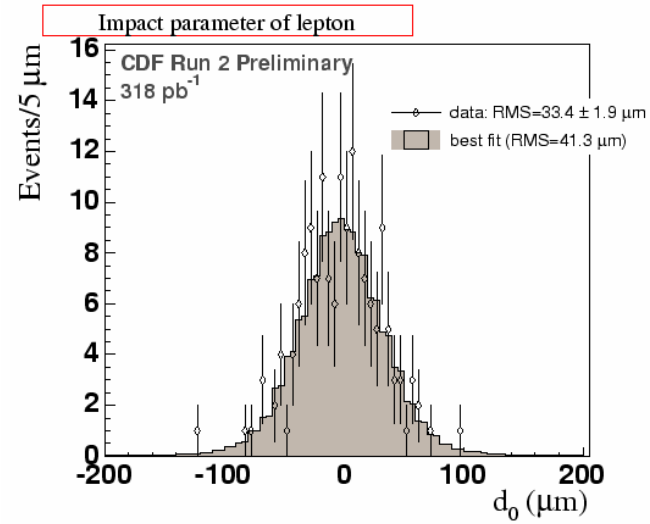
When paired to $\ell^{\pm}$, top charge is inferred.

Data excludes

Q = 4/3e @94% C.L.

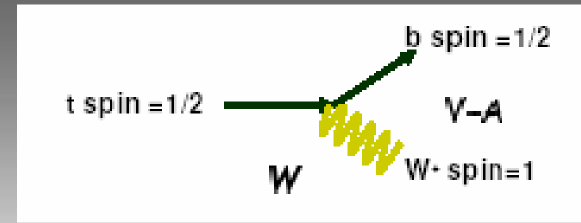
Top in SM has very short lifetime (SM $c\tau \sim 3\times10^{-10}\ \mu m$)

CDF (320 pb^{-1}) look for anomalous lifetime by fitting impact parameter of lepton in l+jets events



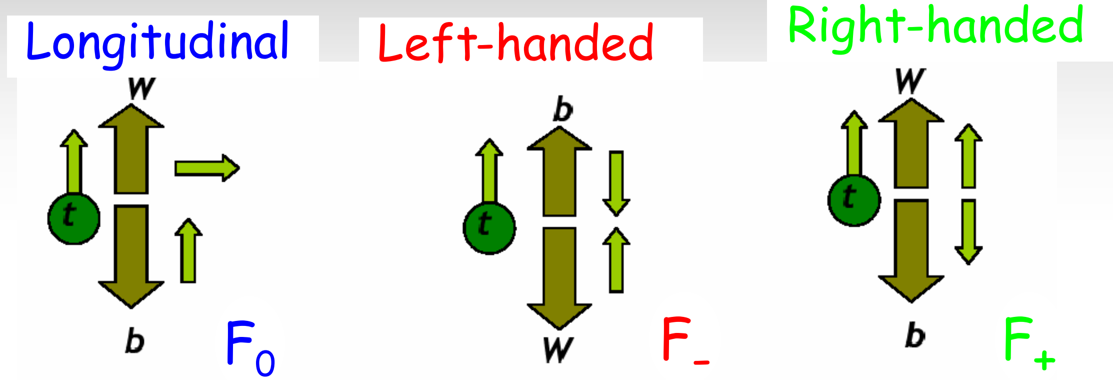
$c\tau < 52.5mm$ (@95% C.L.)

W Helicity in Top Decays



Top in SM has V-A decay.

- Helicity states of the W:



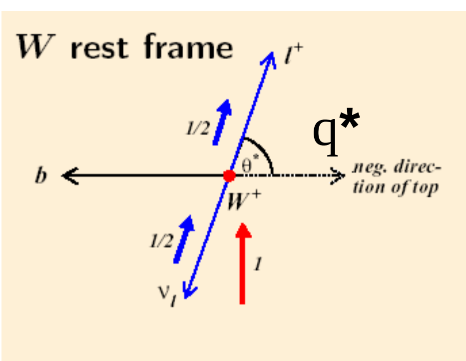
- Because top is heavy:

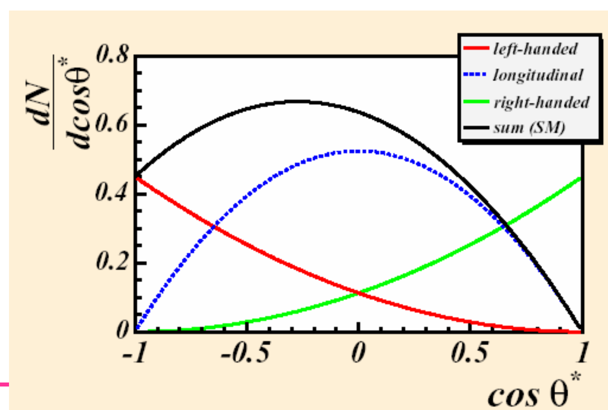
$$F_0 \approx \frac{m_t^2}{2M_W^2 + m_t^2 + m_b^2} = 0.703 \pm 0.012$$

$F_0 + F_- + F_+ = 1$

- SM test: if V-A interaction $F_- \sim 0.3$ $F_+ \sim 0$
  if V+A interaction $F_- \sim 0$ $F_+ \sim 0.3$

suppressed by factors of order m^2_b/m^2_t





Variables sensitive to W helicity are angular distributions of W products in W rest frame.

- $\cos(\theta^*)$ distribution
- M^2_{lb}
- Lepton p_T spectrum

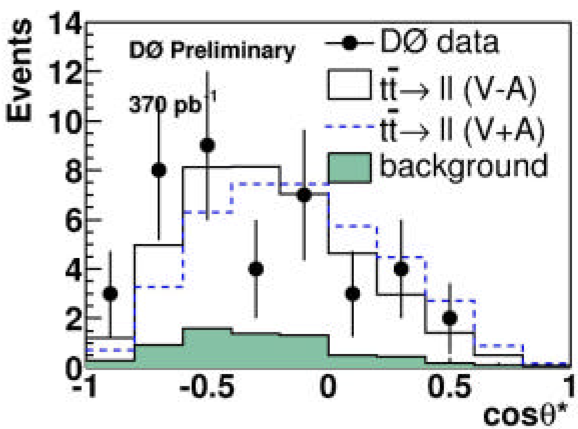
W Helicity Measurements

Assume V-A and measure F_0/F_- with other components fixed at SM value.

Measure F_+ and put limits on V+A/new physics.

DØ (370 pb^{-1}) reconstructs $\cos(\theta^*)$ in dilepton and lepton+jet events to extract F+

$$F_+ = 0.08 \pm 0.08_{stat} \pm 0.06_{syst}$$



CDF has 3 new measurements:

1. $\cos(\theta^*)$ (318 pb^{-1}) with full tt reconstruction in l+jets

$$F_0 = 0.85 \pm 0.19_{stat} \pm 0.06_{syst}$$
$$F_+ < 0.26 \ (@95\% \ C.L.)$$

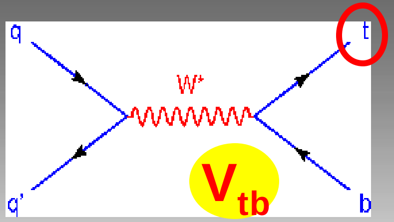
2. M^2_{lb} (750 pb^{-1}) in dil and l+jets

$$F_+ < 0.09 \ @95\% \ C.L.$$

3. $\cos(\theta^*)$ (955 fb^{-1}) in l+jet samples using the mass χ^2 fitter

$$F_0 = 0.61 \pm 0.12_{stat} \pm 0.04_{syst}$$
$$F_+ = -0.06 \pm 0.06_{stat} \pm 0.06_{syst}$$
$$F_+ < 0.11 \ (@95\% \ C.L.)$$

Search for Single Top

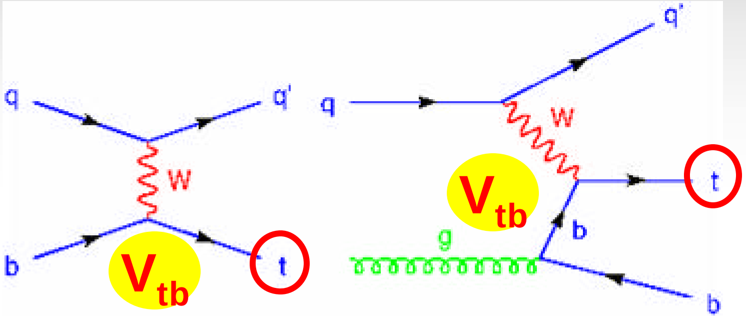


s-channel production (W)*

- Single top is produced via weak interaction at a rate ~1/3 that of top. Allows direct measurement of V_{tb}.

√s = 1.96TeV	NLO σ
t-channel	1.98±0.25 pb
s-channel	0.88±0.11 pb

B.W. Harris et al. Phys. Rev. D 66 054024 (2002)

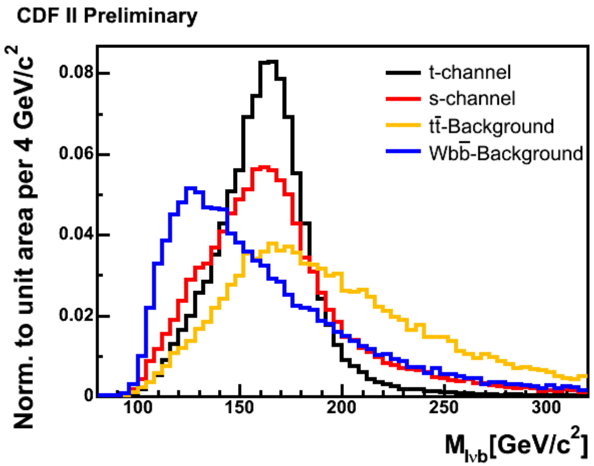


t-channel production (Wg fusion)

- Kinematically wedged between non-top and top signal, plus high backgrounds (S/B~1/20) require very sophisticated analysis techniques.

- Use l +MET+2jet (>=1 btag) events: same signature as $t\bar{t} \rightarrow WH(H \rightarrow b\bar{b})$

- s and t-channel searched jointly and separately (have different sensitivity to new physics).



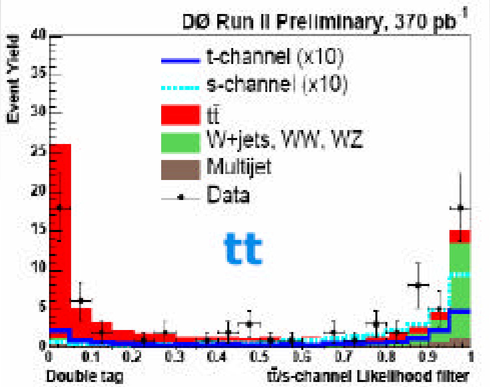
Single Top Limits

CDF (695 pb^{-1}) has 2 analysis:

1. Multivariate Likelihood Function
2. Neural Network

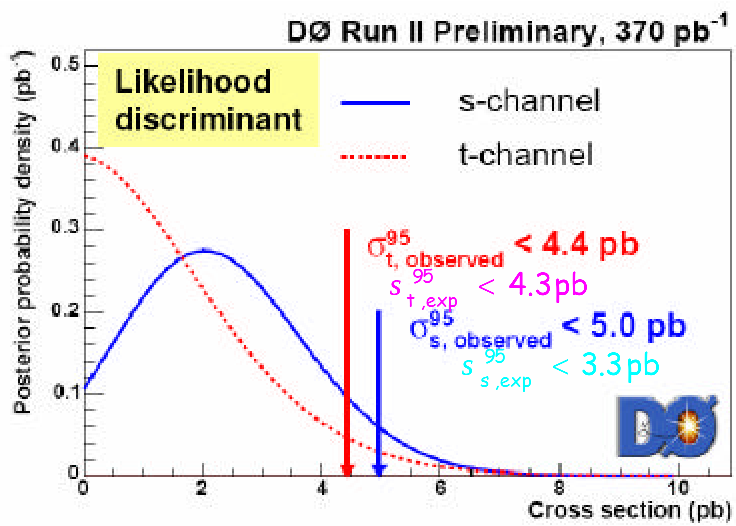
DØ (370 pb^{-1}) uses a likelihood discriminant.

The needle(x10!) in the haystack



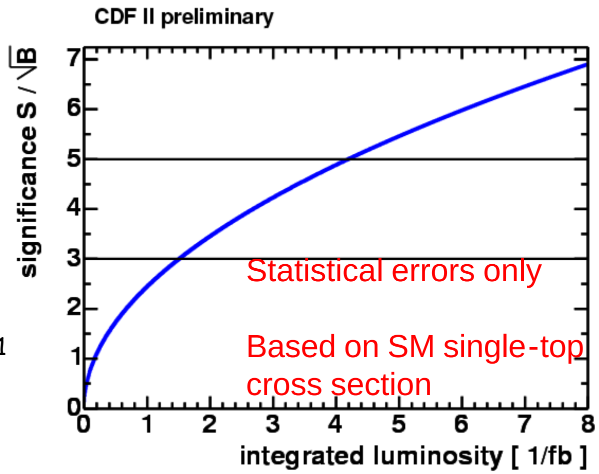
95% observed (expected) exclusion limit getting close to SM expectations!

Channel	s+t (pb)	t (pb)	s (pb)
SM σ_{NLO}	2.9 ± 0.4	2.0 ± 0.3	0.9 ± 0.1
Lhood $\sigma_{95\%}$	4.3 (3.4)	2.9 (2.6)	5.1 (5.7)
NN $\sigma_{95\%}$	3.4 (5.7)	3.1 (4.2)	3.2 (3.7)



Projections (ignoring syst):

- 2.4 σ excess with 1 fb^{-1}
- 3 σ excess around 1.5 fb^{-1}



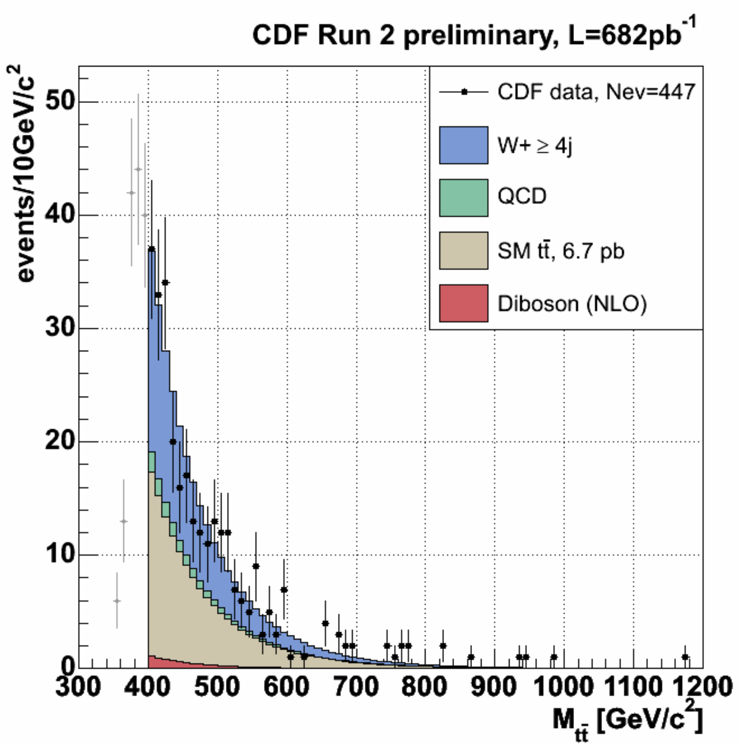
Search for Resonant Production

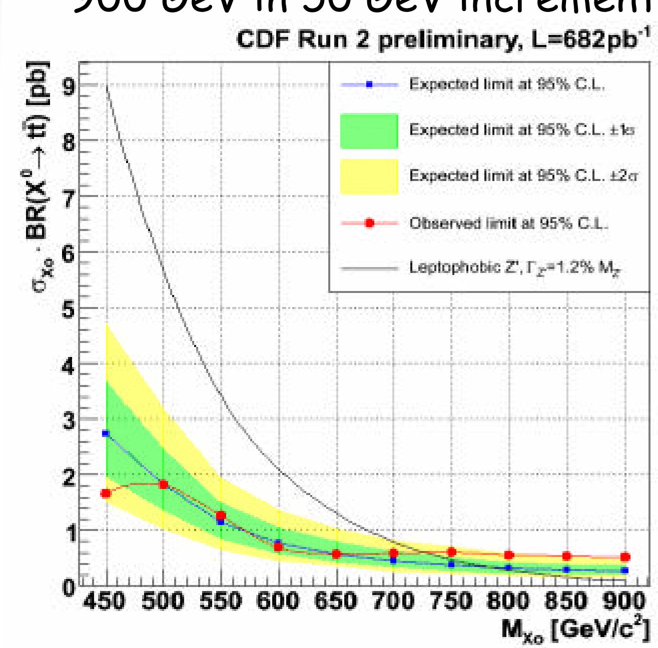
Look for bumps in the ttbar invariant mass spectrum

$$p\bar{p} \rightarrow X^0 \rightarrow t\bar{t}$$

(680 pb^{-1}) looks for generic spin 1 resonance (X^0)

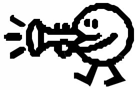
- Assume $\Gamma_{X0} = 1.2\% \times M_{X0}$
- Test masses between 450 GeV and 900 GeV in 50 GeV increments.





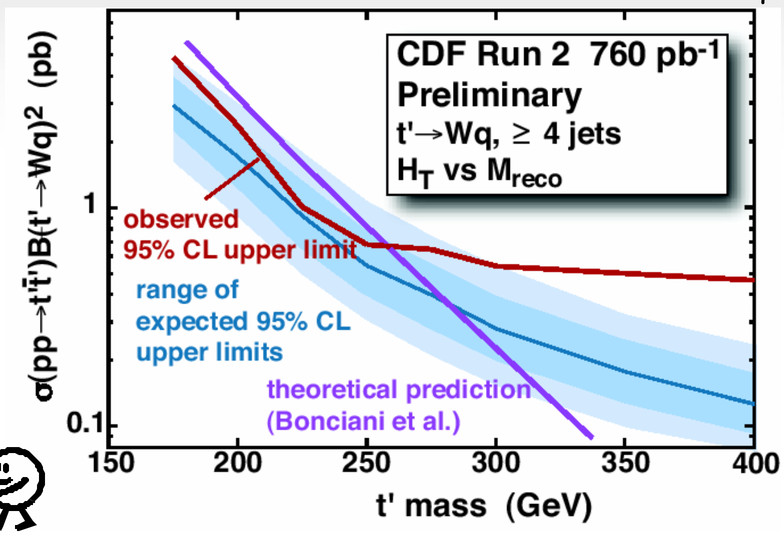
Set 95% confidence level limit for σ_{X0} at each mass.

Exclude leptophobic Z′ with $M_{Z'} < 725$ GeV.



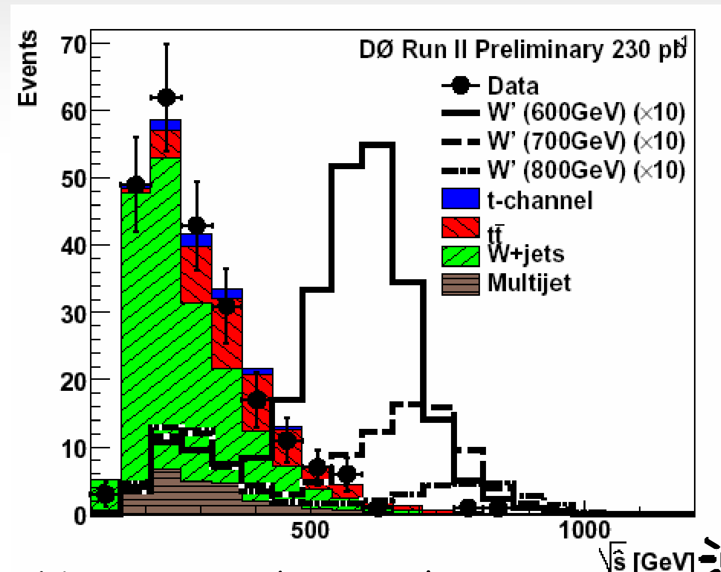
Other Searches in Top Sample

CDF (760 pb^{-1}) has search for something with "top-like" signature, t', by fitting H_T vs M_{Wq}



- No evidence for t' observed.
- Set 95% confidence level limits on $s(t')\times BR(t'\rightarrow Wq)^2$
- Exclude $m_{t'}$ < 258 GeV for $BR(t'\rightarrow Wq) = 100\%$

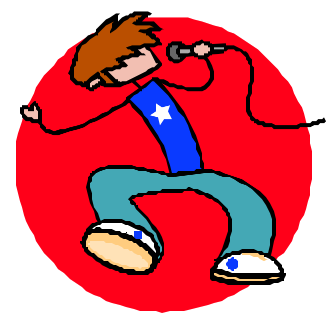
DØ (230 pb^{-1}) has search for $W'\rightarrow tb$ in the single top sample by fitting M_{tb}



- No excess observed
- 95% upper limit on W' production: 1.8/1.4/2.2 pb for Mw'=600/700/800 GeV.
- 200-650 GeV range excluded for W' with SM-like couplings.

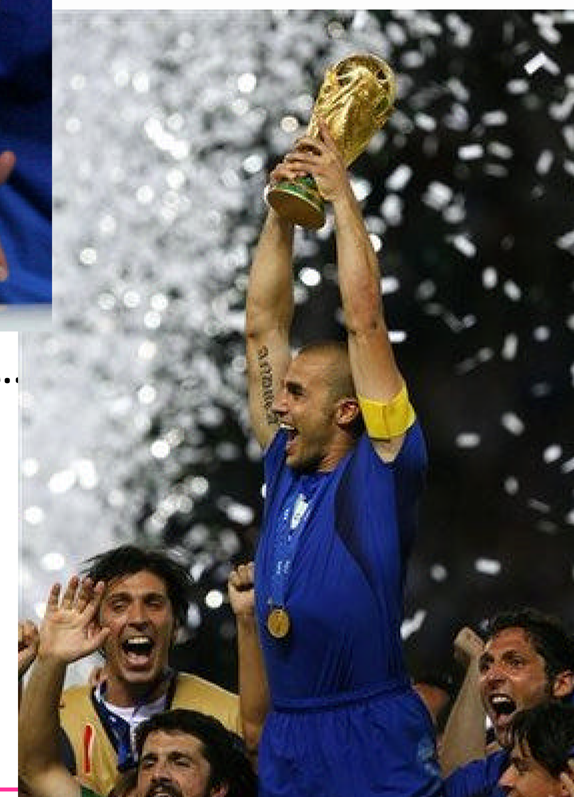
Are we on top of things?

- Top quark is a well behaved ~11 year old so far…..
- CDF and D0 have used samples 3-10 times the Run I statistics to:
  - re-established analysis tools for top physics
  - approached or even surpassed level of precision set for Run II
  - try new and daring ideas
- Top cross sections is measured at 15% level.
- Top mass precision is already known at 1.5% level.
- Single top is behind the corner….
- Still hoping it will act out as any teenager does!



Conclusions

- Tevatron is producin … results:
  - Making precision m … ortant Standard Model parameters
  - Discovering new SM … its on particles predicted in Beyon…
  - Unveiling SM top q…
- All results so far are…



…e what happen..