Top and Electroweak Physics from the Tevatron

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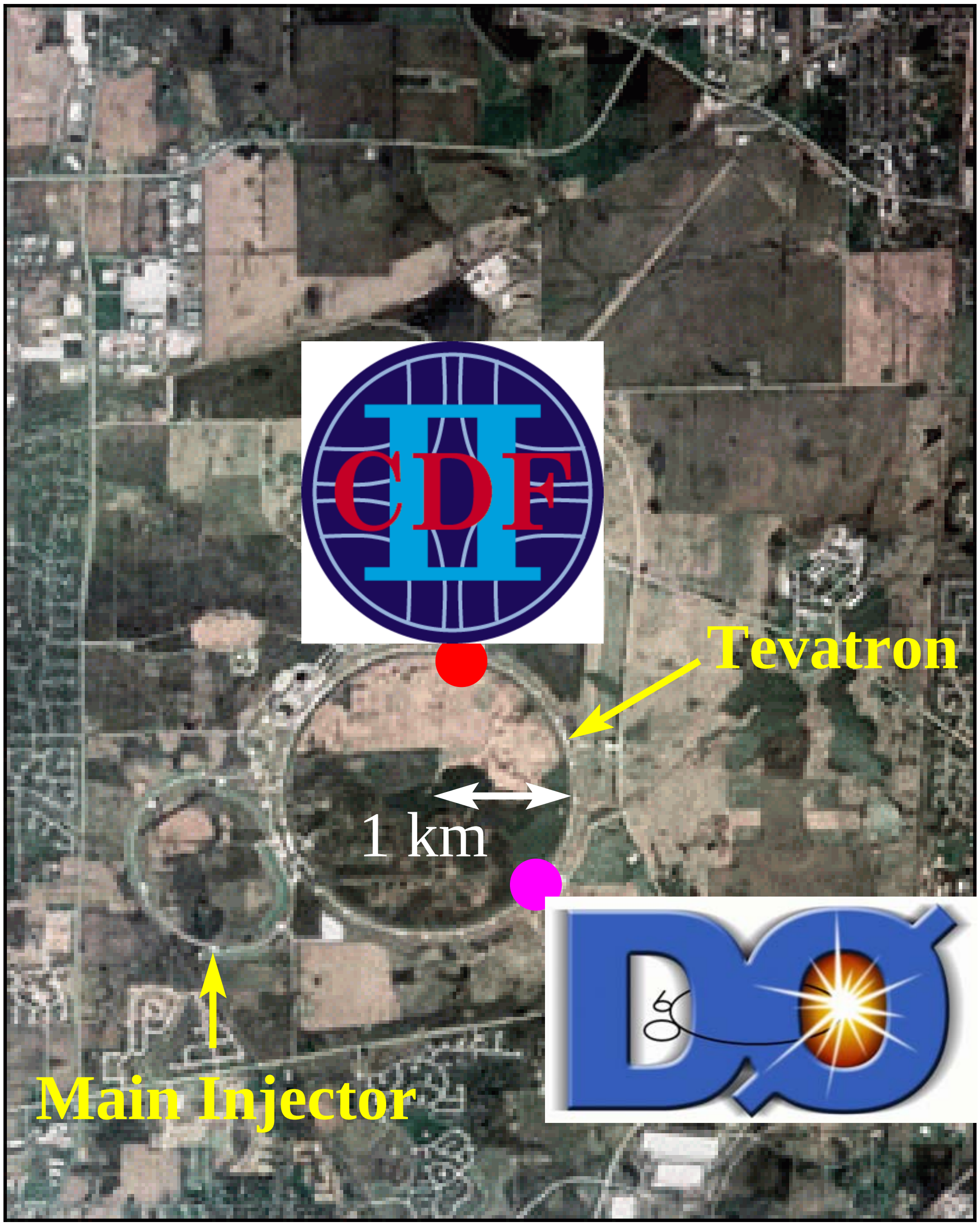


Tevatron currently operating with proton bunches on antiproton bunches at a centre-of-mass energy of 1.96 TeV.

Outline

- Brief status of the Tevatron and the CDF and DØ detectors
- W and Z, Diboson
- Top
- Higgs Physics
- Conclusions

- Emphasis on new Run 2 results and prospects

Tevatron "Runs" and Luminosity

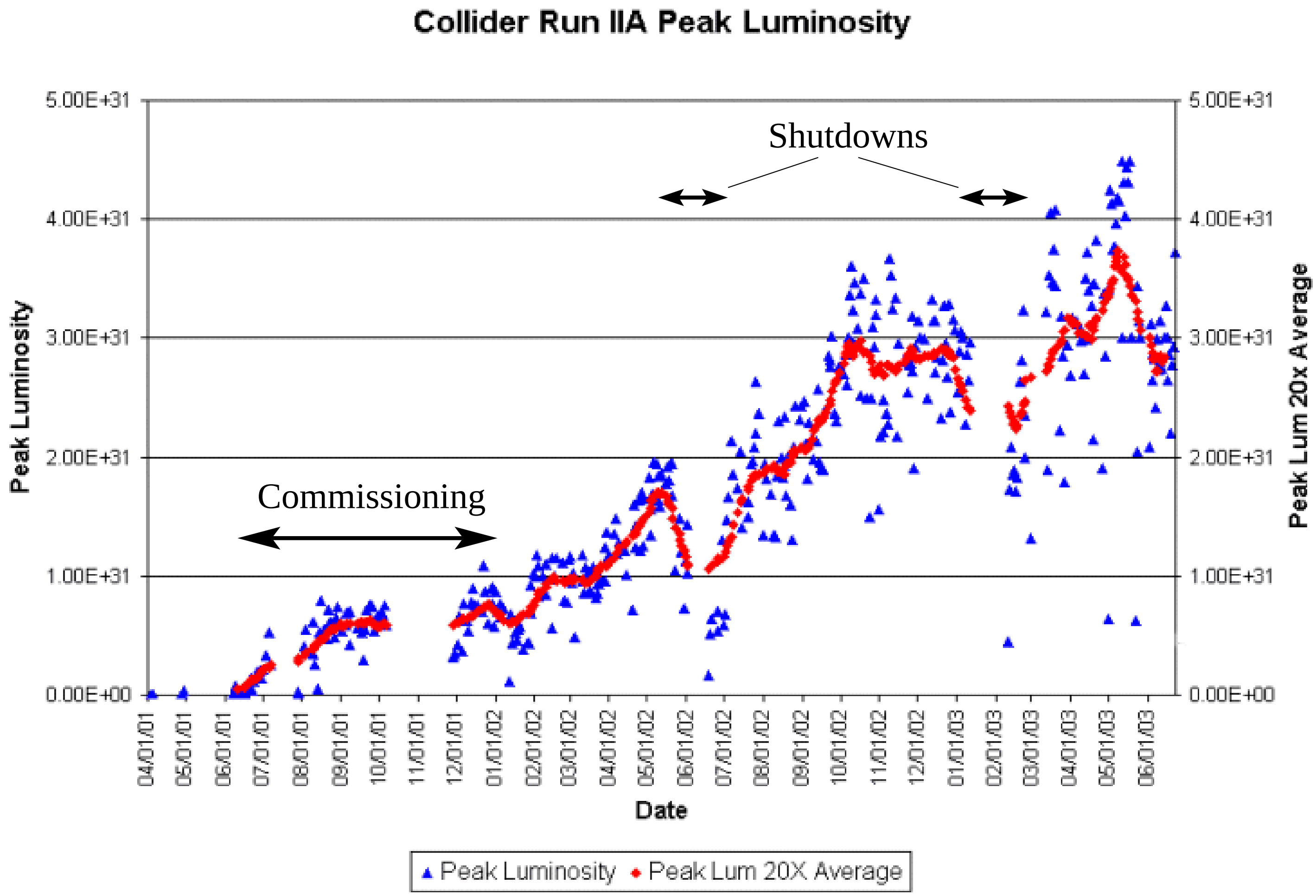
- Run 1: $\sqrt{s} = 1.8$ TeV, bunch spacing $= 3.6\,\mu s$
  Run 2: $\sqrt{s} = 1.96$ TeV, bunch spacing $= 396\,ns$
- Run 2 is underway ("good data" since January 2002).
- At the shutdown this August will see about $150\,\mathrm{pb}^{-1}$
  (Run 1 total integrated luminosity was about $100\,\mathrm{pb}^{-1}$)
- Results presented here use data recorded up to January 2003 shutdown. Relevant luminosities of analysis quality data:

	DØ	CDF
Total	$\sim 50 \pm 5$ pb^{-1}	72 ± 4 pb^{-1}
Total with SVX		57 ± 3 pb^{-1}

- Between January and April we have another ~ 50 pb^{-1} written to tape – the results from which will ready by the end of this summer.
- The Tevatron Goal is to deliver another ~ 250 pb^{-1} in FY2004 (of which we should write about 90% to tape).

Tevatron Status

- Initial Luminosity ($10^{31}\,cm^{-2}s^{-1}$)



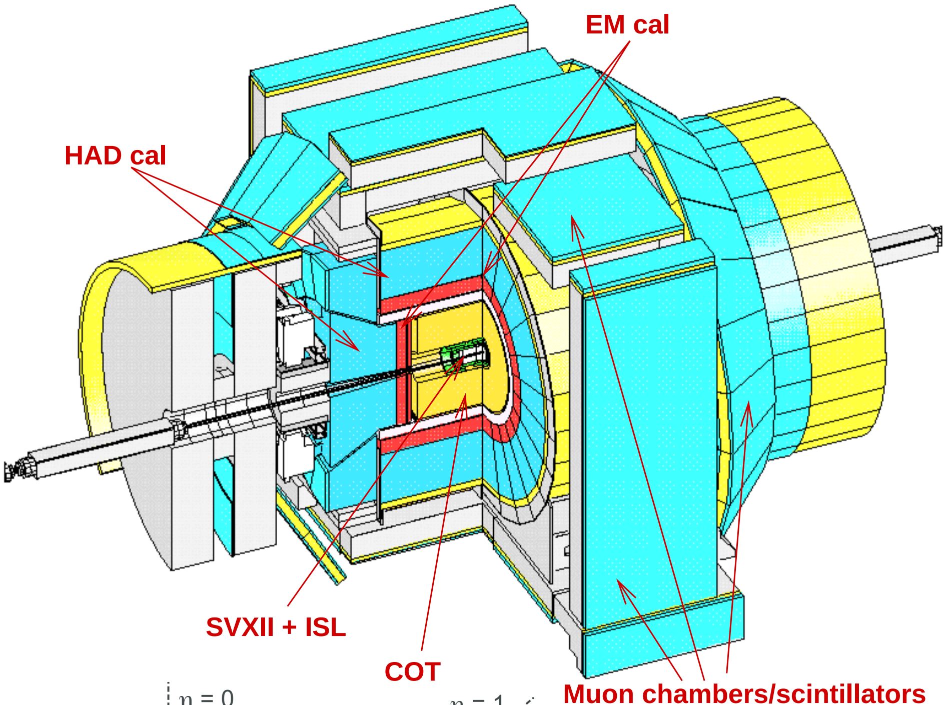
⇒ Initial luminosity has been steadily increasing

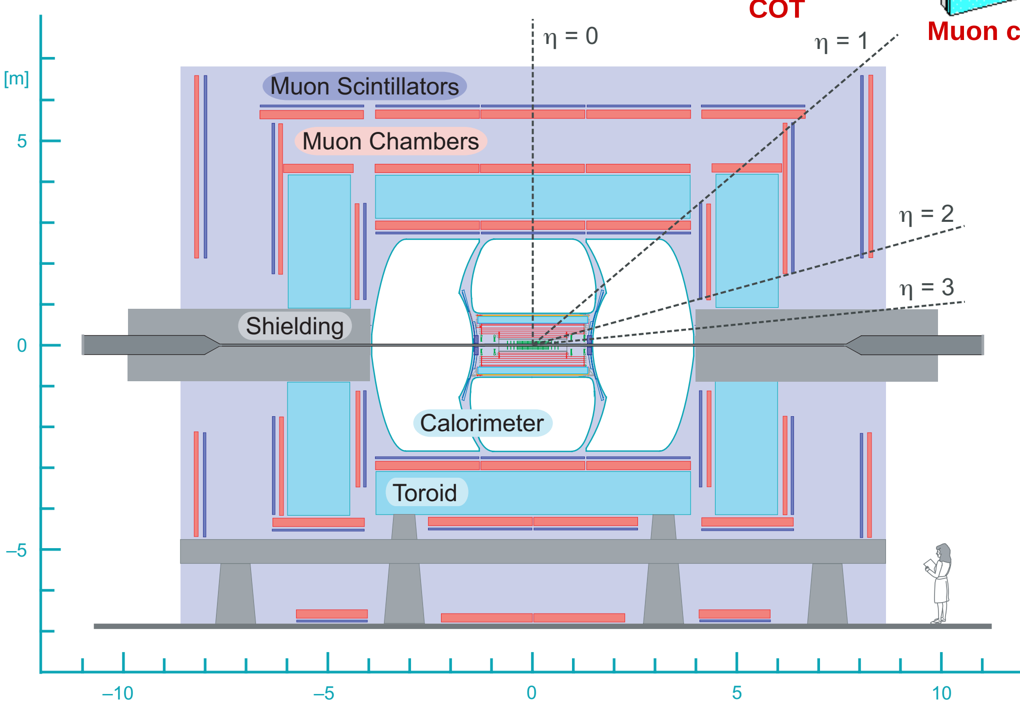
⇒ Run 2 goal is about 2×10^{32}

The CDF and DØ Run 2 Detectors

General purpose detectors: tracking systems, calorimetry, muon systems.

CDF





DØ

tracking	particle charge and momentum, secondary vertex finding
calorimetry	energy deposition by electrons, photons, jets
muon chambers	muon detection

Main Improvements from Run 1

- DØ

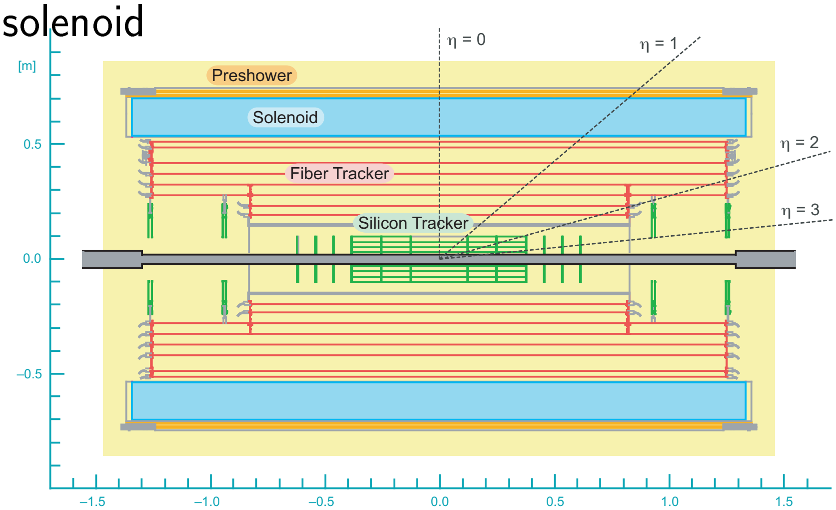
⇒ New inner tracking

Silicon detector, fiber tracker

2T superconducting solenoid

⇒ Upgraded μ system for better μ-ID

⇒ Track based triggers (esp. SVT)



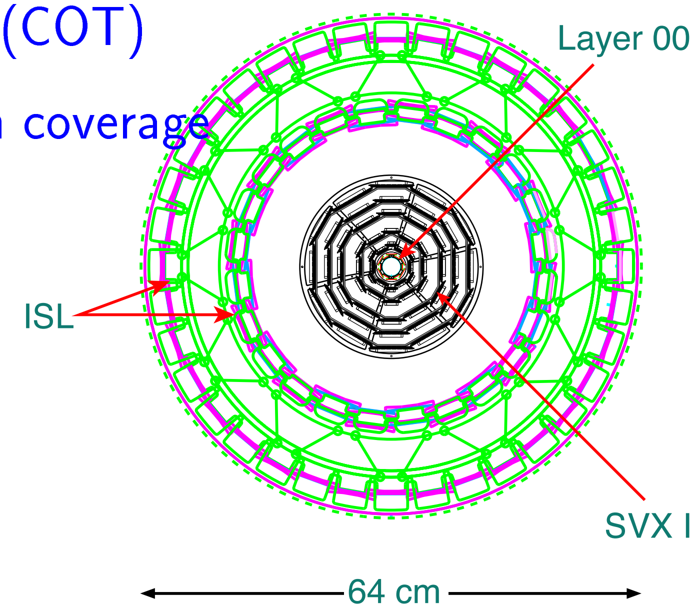
- CDF

⇒ Upgraded silicon system

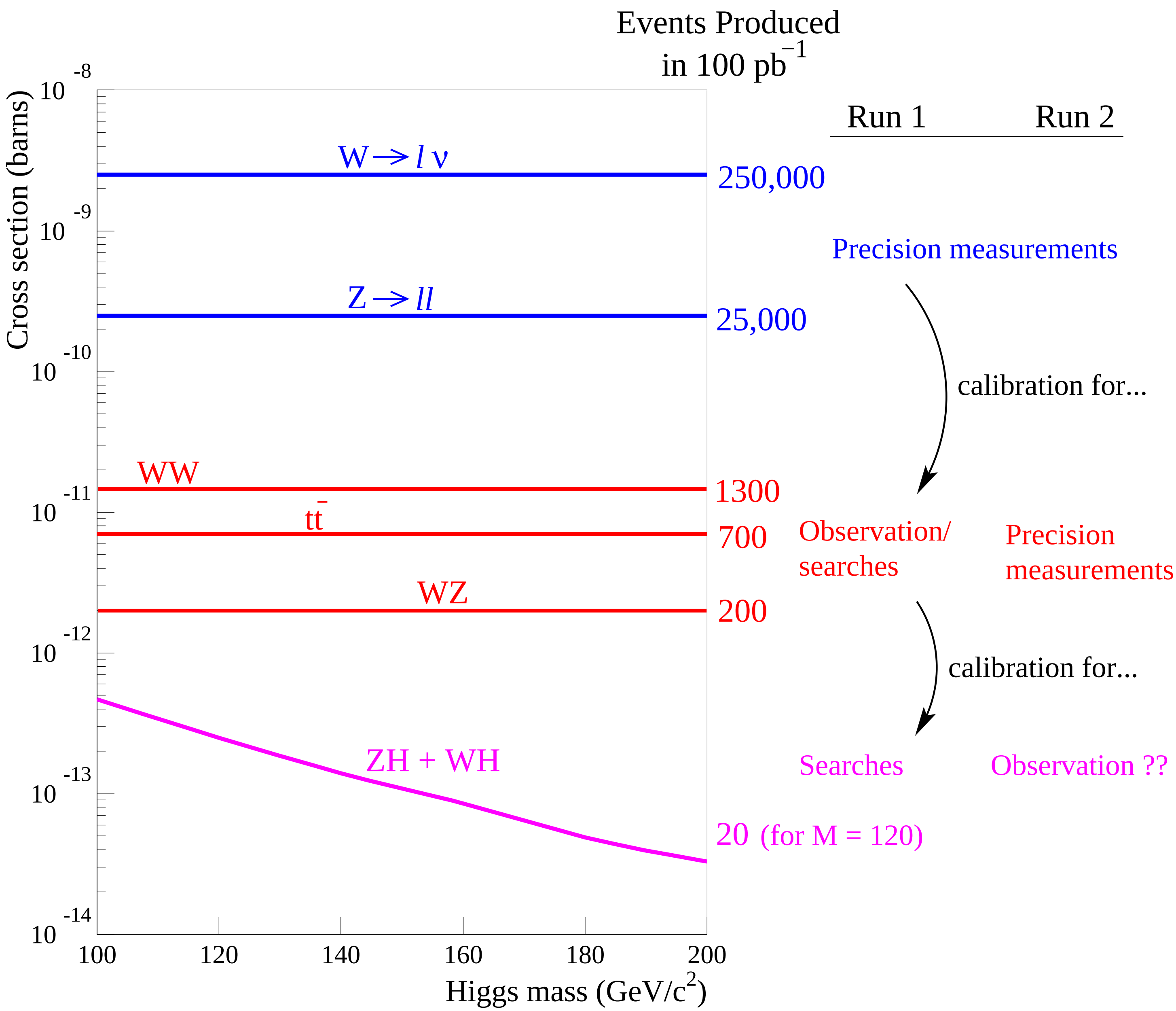
⇒ New tracking drift chamber (COT)

⇒ Extended electron and muon coverage

⇒ Track based triggers (esp. SVT)



Physics Processes @ Tevatron



The statistics from Run 2 will allow precision measurements of top quark and W boson properties, and detailed studies of diboson production which are important calibration samples for Higgs searches.

W and Z bosons

- Large cross-sections give large statistics for precision measurements
- $\sigma(p\bar{p} \to W + X) \times B(W \to \ell\nu) = 2.7\,\text{nb}$

  ⇒ $\sim 270,000\; W \to \ell\nu$ events produced every $100\,\text{pb}^{-1}$

  ⇒ $M_W = 80.456 \pm 0.059\,\text{GeV}$
  (Run 1 CDF + DØ – better than 0.1% precision)

- $\sigma(p\bar{p} \to Z + X) \times B(Z \to \ell^+\ell^-) = 0.26\,\text{nb}$

  ⇒ $\sim 26,000\; Z \to \ell\ell$ events produced every $100\,\text{pb}^{-1}$

- Measurements at the Tevatron:

  ⇒ W/Z cross-sections, and $\sigma(W)/\sigma(Z)$

  ⇒ Lepton Universality

  ⇒ Forward-Backward Asymmetry

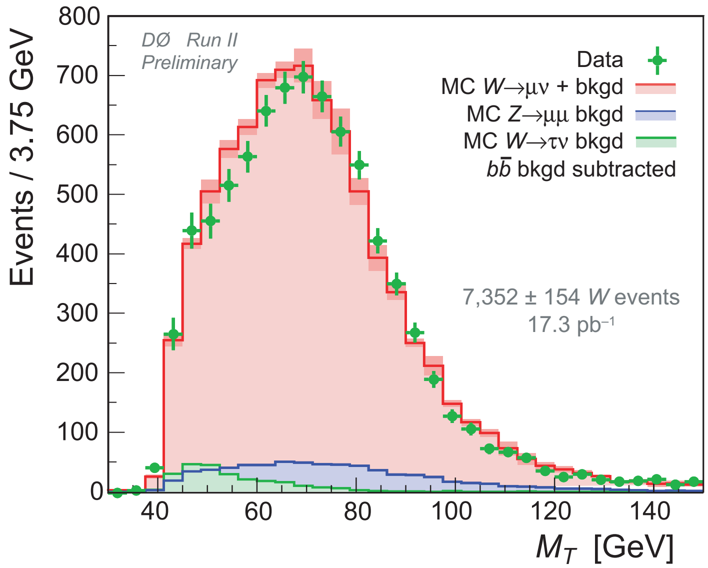
  ⇒ W charge Asymmetry

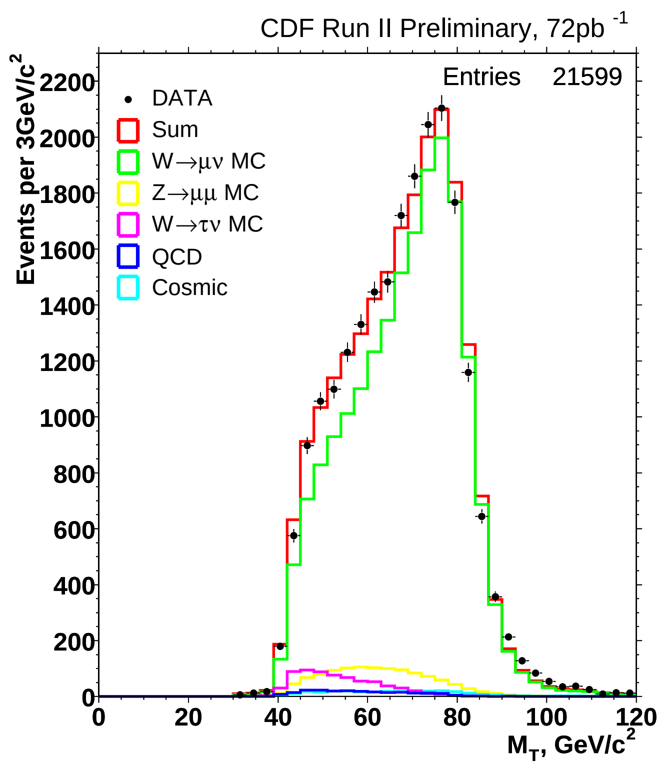
  ⇒ Diboson production

  ⇒ W mass and width

$\sigma(W) \times B(W \to \ell\nu)$ at 1.96 TeV

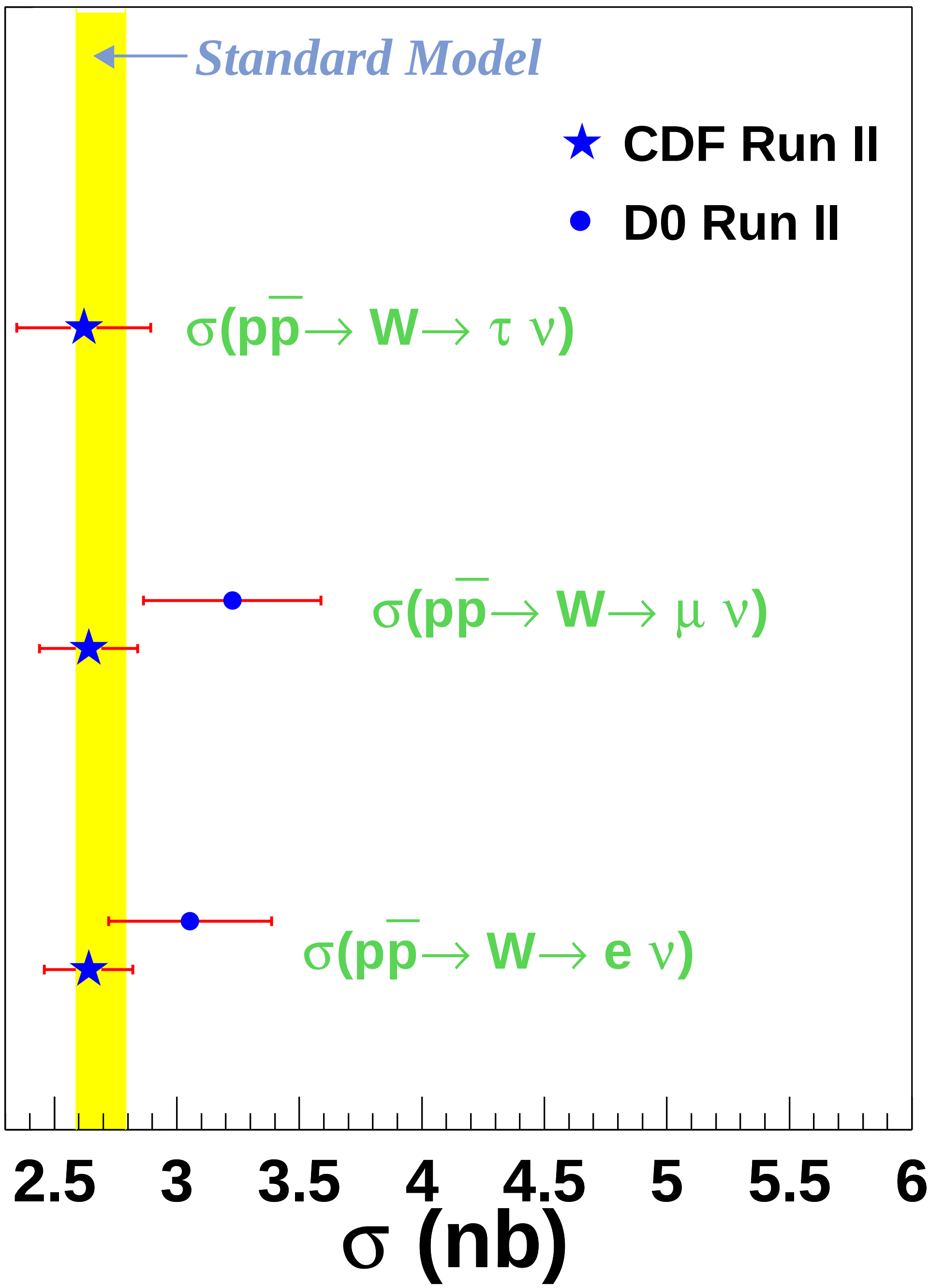
- Signature is one high-P_T lepton, and large missing tranverse energy $\to$ very clean signal.
- Backgrounds ($Z \to \ell\ell$, $W \to \tau\nu$, $b\bar{b}$) around 10% on average (26% for τ channel).
- Transverse mass spectra from $W \to \mu\nu$ events:





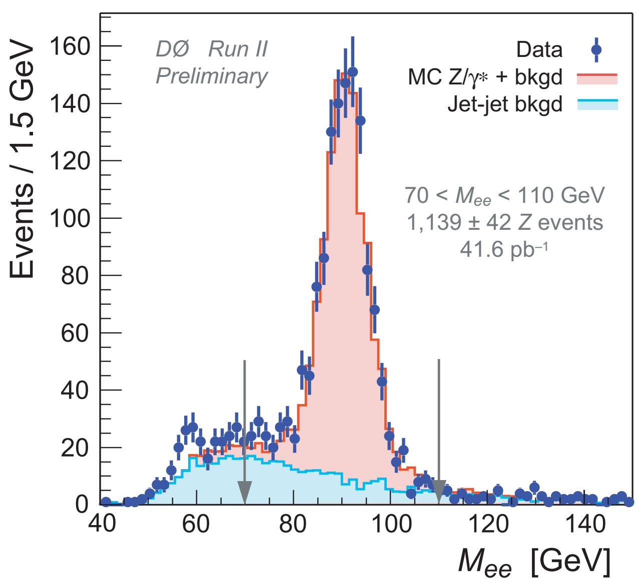
	DØ		CDF	
	sample	$\sigma \times B(W \to \ell\nu)$ (nb)	sample	$\sigma \times B(W \to \ell\nu)$ (nb)
e	27370	$3.05 \pm 0.10 \pm 0.09 \pm 0.31$	38625	$2.64 \pm 0.01 \pm 0.09 \pm 0.16$
μ	7352	$3.23 \pm 0.13 \pm 0.10 \pm 0.32$	21599	$2.64 \pm 0.02 \pm 0.12 \pm 0.16$
τ			2346	$2.62 \pm 0.07 \pm 0.21 \pm 0.16$

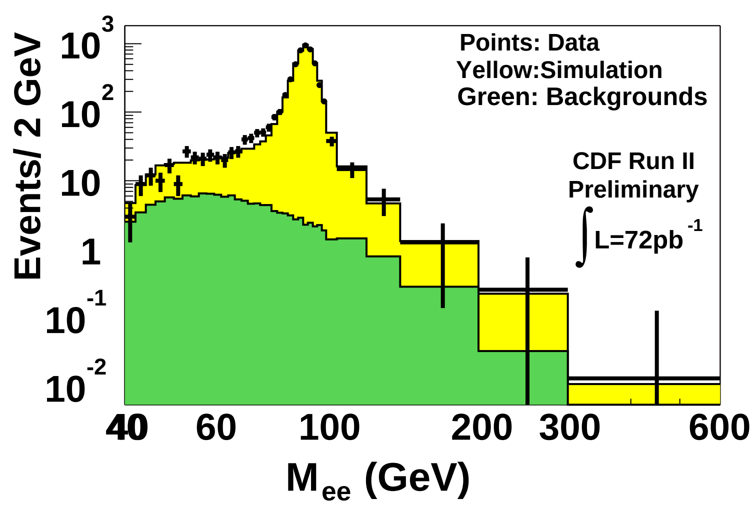
Summary of $\sigma(W) \times B(W \to \ell\nu)$ at 1.96 TeV



$\sigma(Z) \times B(Z \to \ell\ell)$ at 1.96 TeV

- Signature is two high-P_T leptons
- Backgrounds are very small (less than 1%)
- Sample is also used extensively in other analyses for energy scales, resolutions, and lepton ID efficiencies.
- Invariant mass spectra from $Z \to ee$ events:



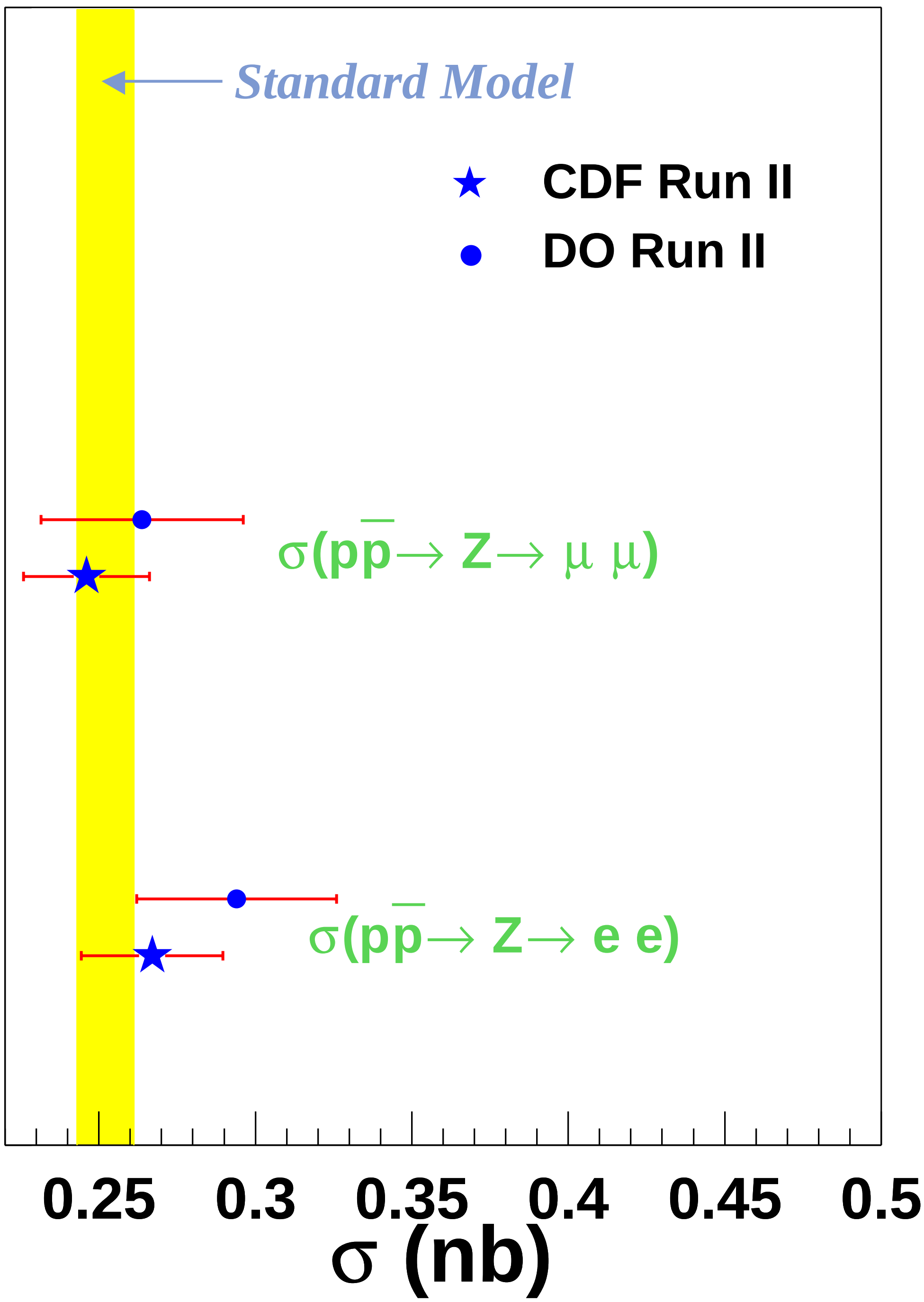


	DØ		CDF	
	sample	$\sigma \times B(Z \to \ell\ell)$ (pb)	sample	$\sigma \times B(Z \to \ell\ell)$ (pb)
e	1139	$294 \pm 11 \pm 8 \pm 29$	1830	$267 \pm 6 \pm 15 \pm 16$
μ	1585	$264 \pm 7 \pm 17 \pm 16$	1631	$246 \pm 6 \pm 12 \pm 15$

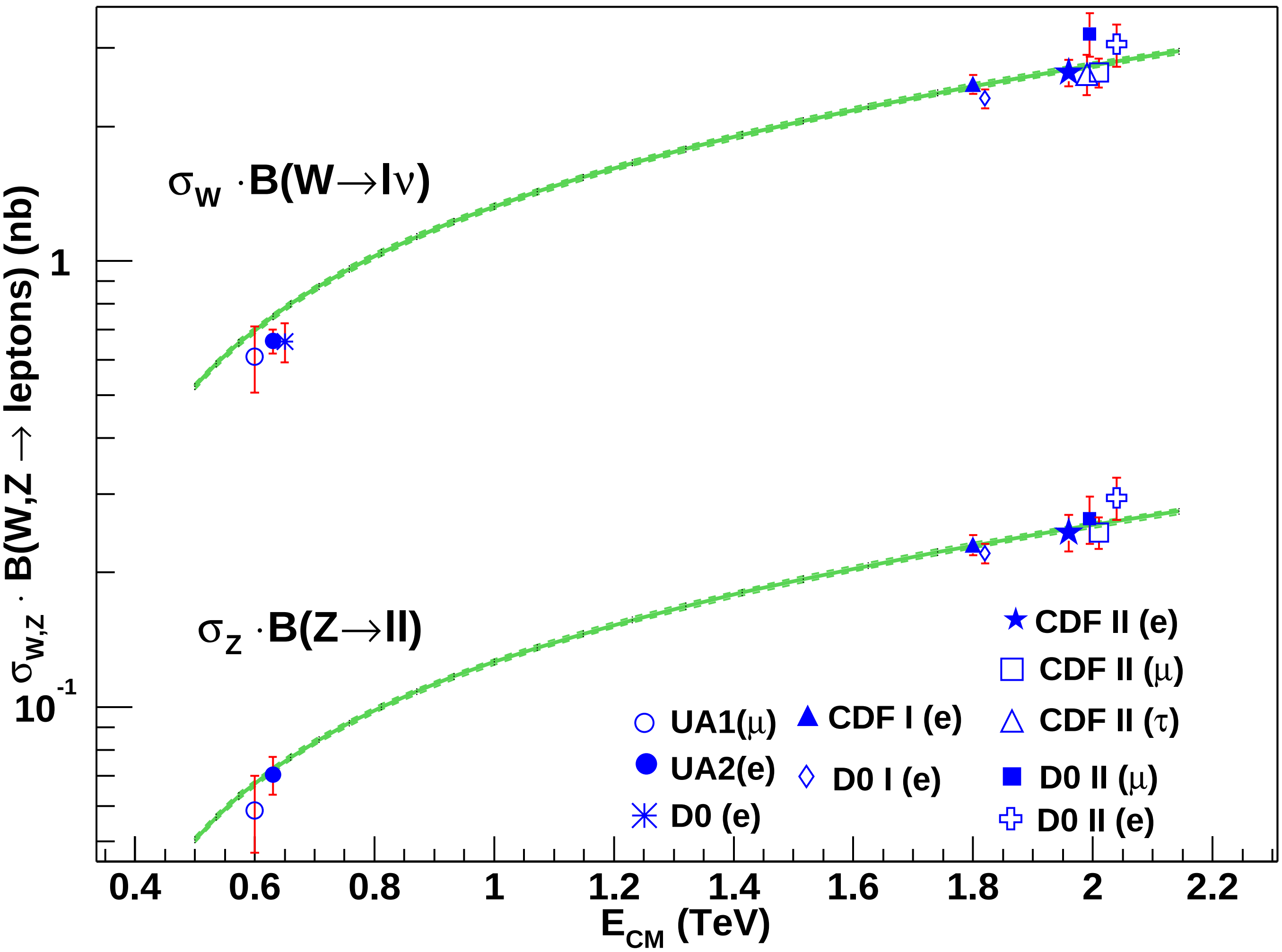
Summary of $\sigma(Z) \times B(Z \to \ell\ell)$ at 1.96 TeV

CDF Run

D0 Run II

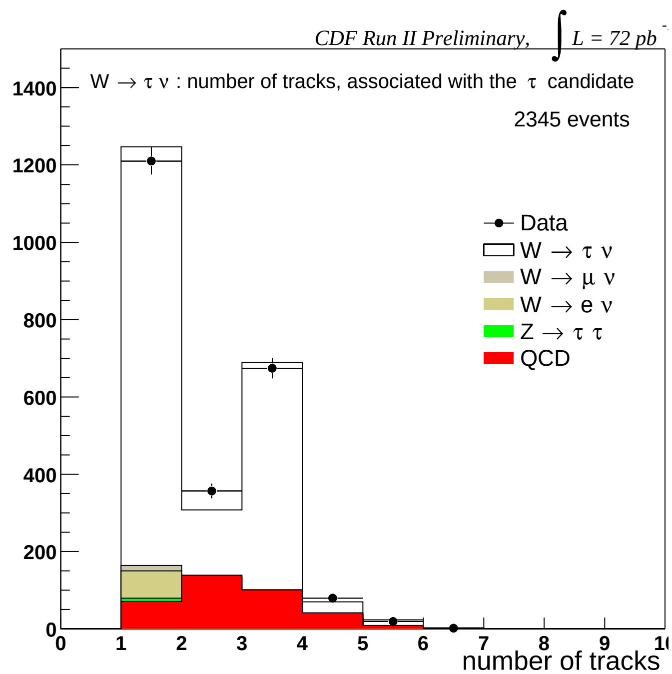


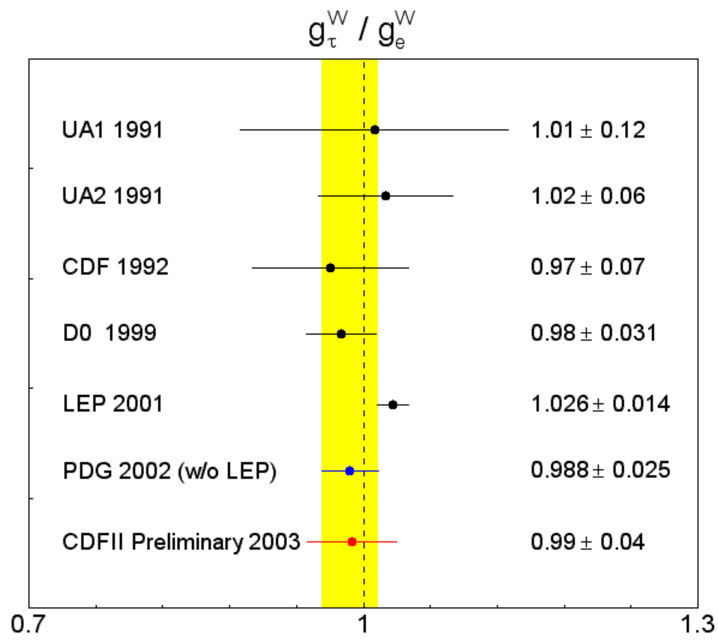
Tevatron W and Z Cross-Sections



More on $W \to \tau\nu$

- Test of Lepton Universality.
- Provides a baseline for all analyses using τ's – will be much more extensive in Run 2.



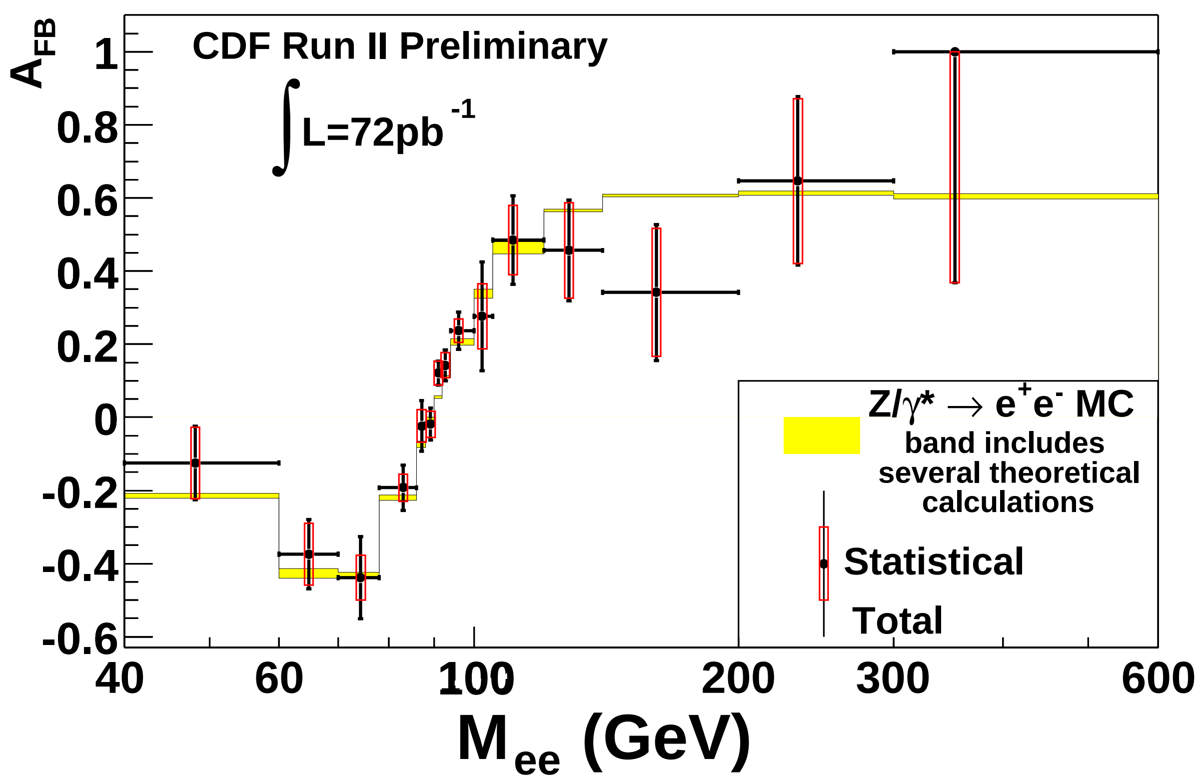


$$\frac{B(W \to \tau\nu)}{B(W \to e\nu)} = 0.99 \pm 0.04\,(\mathrm{stat}) \pm 0.07\,(\mathrm{syst})$$

Forward-Backward Asymmetry

$$A_{FB} = \frac{d\sigma(\cos\theta > 0) - d\sigma(\cos\theta < 0)}{d\sigma(\cos\theta > 0) + d\sigma(\cos\theta < 0)}$$

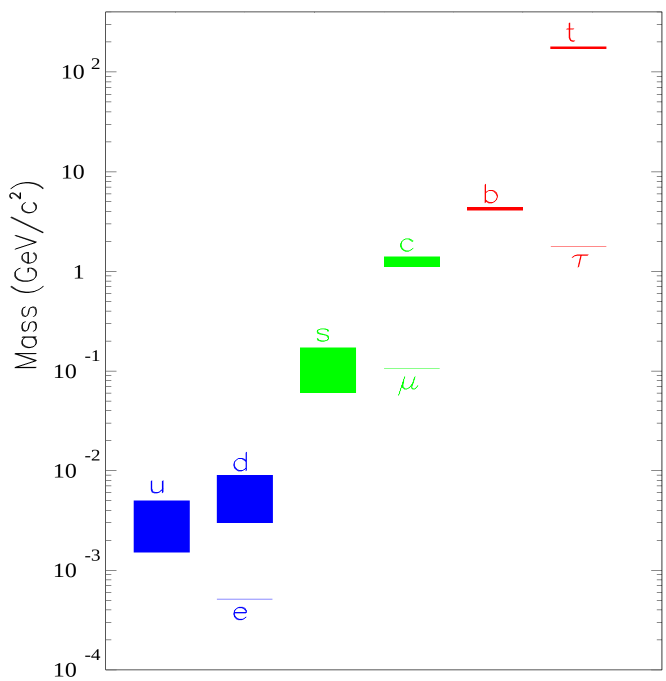
- Forward Calorimeters crucial for measurement.
- Direct probe of γ, Z couplings – deviation from expectation could be due to interference from new physics.
- High mass reach is unique to the Tevatron.
- With the current Run 2 statistics no deviation from the SM observed – new results out with double the data by end of summer.



Top Physics

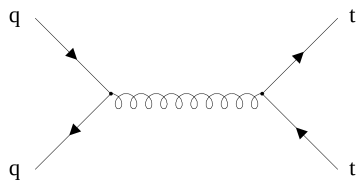
- The Fermilab Tevatron has been the only place to study the *top* quark, and will be until the LHC turns on.
- Everything we know directly about Top is based on about 100 $t\bar{t}$ events from the Tevatron "Run 1" by the DØ and CDF collaborations.
- With the significantly more $t\bar{t}$ events produced in Run 2, we will move beyond our discovery phase and make precision measurements of top quark properties to try and answer such questions as:
  - → Why is Top so heavy ?
  - → Is it, or the third generation, special ?
  - → Is Top involved in EWSB ?
  - → Is it connected to any new physics ?

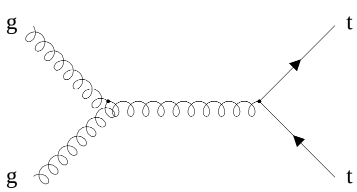
About 5 orders of magnitude range in quark masses !

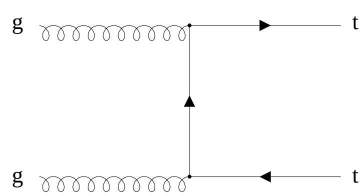


Top production at Hadronic Colliders

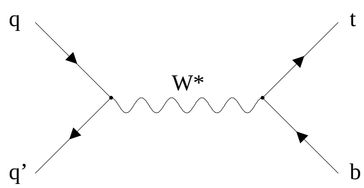
In pairs via the strong interaction

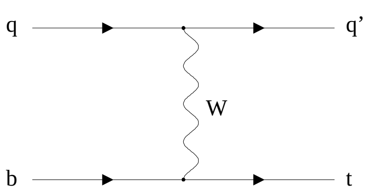


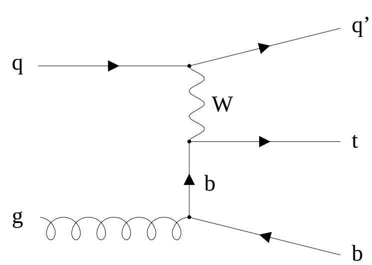


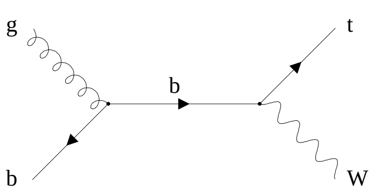


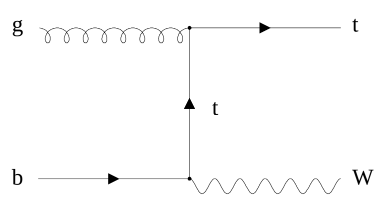
Singly via the electroweak interaction











Production Cross Section (pb)

Run 1	Run 2	LHC
$p\bar{p}$ 1.8 TeV	$p\bar{p}$ 2.0 TeV	pp 14 TeV
90%	85%	5%
10%	15%	95%
5.0	7.0	800
0.73	0.88	10.2
1.7	2.4	245
0.07	0.12	62

Expected top production numbers

	Run 1 ($100\,pb^{-1}$)	Run 2 (per fb^{-1})	LHC (per 10 fb^{-1})
CM Energy (TeV)	1.8	1.96	14.0
$\mathcal{L}(cm^{-2}s^{-1})$	2×10^{31}	2×10^{32}	10^{33}
$\sigma(t\bar{t})$ (pb)	5.0	7.0	800
σ(single top)	2.5	3.4	320
$N(t\bar{t})$ produced	500	7000	8,000,000
N(single top) produced	250	3500	3,200,000
$N(t\bar{t} \rightarrow dilepton)$	4	80	50,000
$N(t\bar{t} \rightarrow l+ \geq 3j)$ (≥ 1 b-tag)	25	700	400,000
$N(t\bar{t} \rightarrow l+ \geq 4j)$ (2 b-tags)	5	300	200,000
N(single top) ($W + 2j$, 1 b-tag)	3	70	60,000

- Run 1 uncertainties dominated by lack of statistics.
- Measurements in Run 2 (particularly of mass and cross section) will be dominated by systematics, which will require more work to reduce.

Top Decay

- In the SM, assuming V-A coupling with a CKM mixing parameter $|V_{tb}| = 1$ for the $t \to bW$ decay vertex, one gets (LO) :

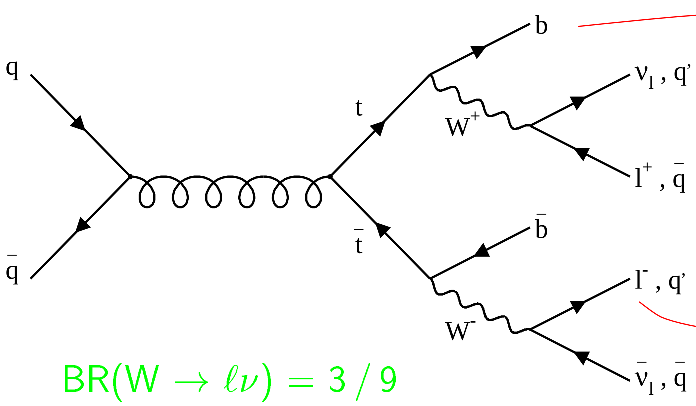
$$\Gamma(t \to bW) \approx 175\, MeV \left(\frac{M_t}{M_W}\right)^3 \qquad (M_t,\, M_W \gg M_b)$$

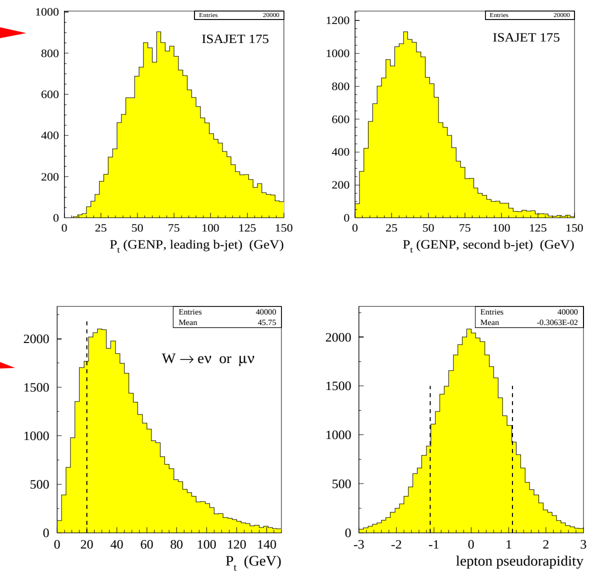
$$\Rightarrow \Gamma(t \to bW) \approx 1.5\, GeV \quad \Rightarrow \quad \tau(top) \approx 4 \times 10^{-25}\, s$$

- Non-perturbative QCD hadronization takes place in a time of order: $\Lambda_{QCD}^{-1} \sim (100\, MeV)^{-1} \sim 10^{-23}\, s$
  $\Rightarrow$ top decays as free quark (no top hadrons, no toponium spectroscopy)
  $\Rightarrow$ top decay will *remember* its original spin-$\frac{1}{2}$ state

- $t \to Ws$ and $t \to Wd$ allowed but suppressed by factors of $\sim 10^{-3}$ and $\sim 5 \times 10^{-5}$, respectively.

- Decay signatures and branching ratios :





BR(W $\to \ell\nu$) = 3 / 9
BR(W $\to q\bar{q}'$) = 6 / 9

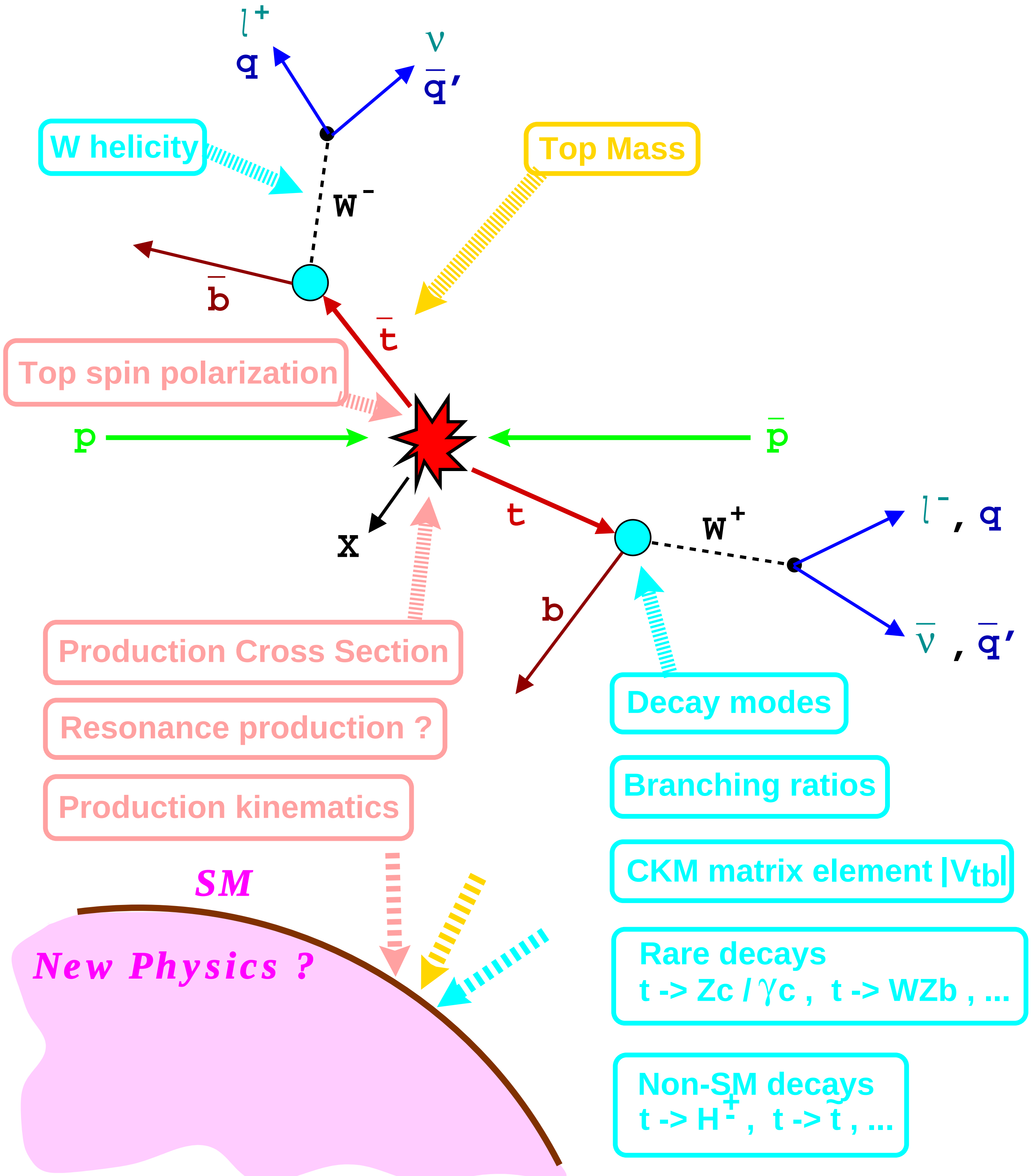
3 classes of signal :

Dilepton (2 high-P_T leptons, 2 b jets, large Missing E_T) : BR = 1 / 9
BR(ee,$\mu\mu$,$e\mu$) = 5%

Lepton + Jets (1 high-P_T lepton, 4 jets (2 b's), large Missing E_T) : BR = 4 / 9
BR(e, $\mu + jets$) = 30%

All-hadronic (6 jets) : BR = 4 / 9
BR = 44%

What we can measure from $t\bar{t}$



General event selection for top events

- Leptons : (from leptonic W decays)

  High P_T - $E_T(e), P_T(\mu) > 20\,GeV$

  Central ($|\eta| < 1.0$), isolated, good track and cal quality

- Jets : (from b quarks, hadronic W decays, ISR, FSR)

  $E_T > 15\,GeV$, $|\eta| < 2.0$

  b-tagging using SVX to measure secondary vertex (SVX)

  b-tagging using identification of lepton in jet (SLT)

  Jets corrected for detector response

- Missing transverse energy : (from neutrinos)

  $\not{E}_T > 25\,GeV$

- Kinematic variables : (exploits large M_{top})

  Sum of E_T of all objects (H_T)

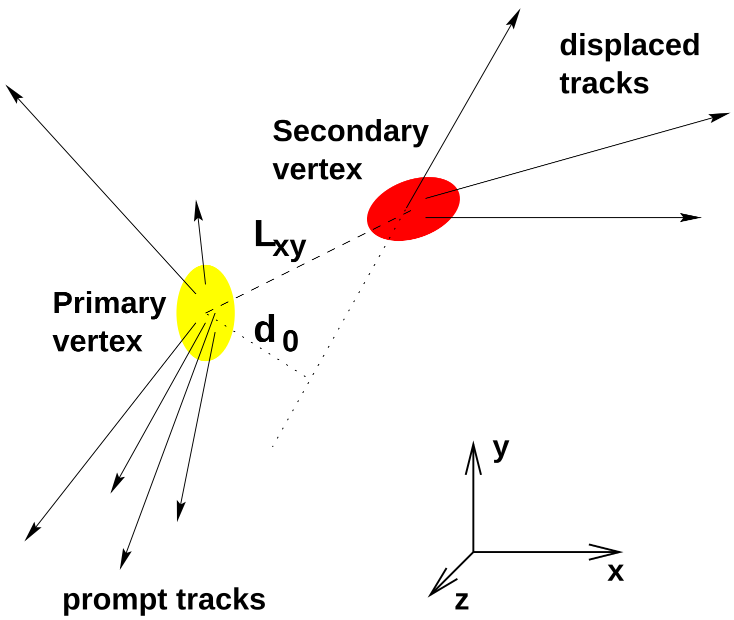
  Aplanarity, sphericity

  Neural nets

- Many of the Run 1 selection cuts were remnants of top search analyses.
- In Run 2 we are better optimising the selection for measurements – also many new tools being developed.

b tagging

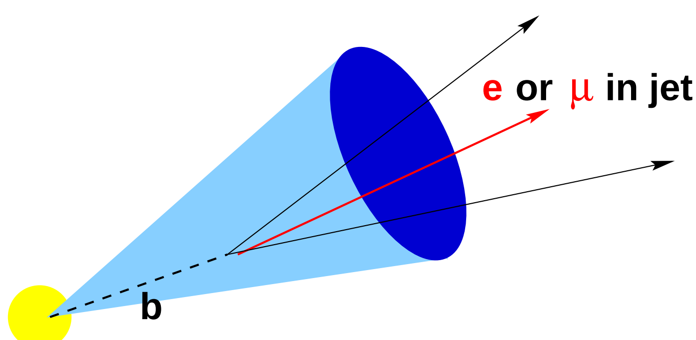
- b-quarks have a long lifetime : $\tau(\mathrm{b}) \sim 1.5\,\mathrm{ps}$ ($c\tau \sim 450\,\mu\mathrm{m}$)
  $\Longrightarrow$ B hadrons travel $\mathrm{L_{xy}} \sim 3\,\mathrm{mm}$ before decay.
- b-tagging using displaced vertices (SVX)



- Uses SVX tracking
- Secondary vertex $\geq$ 2 tracks
- Tagged if $\mathrm{L_{xy}}/\sigma_{\mathrm{L_{xy}}} > 3.0$ (typically $\sigma_{\mathrm{L_{xy}}} \sim 150\,\mu\mathrm{m}$)

$\epsilon_b \sim 25\%$
$\epsilon(\text{top event}) \sim 50\%$
$\epsilon_c \sim 4\%$
$\epsilon_{fake} \sim 0.2\%$ per jet

- Soft lepton tagging (SLT) of b quarks



- Identifies lepton in semi-leptonic b (or c) decays
- Lepton softer, less isolated than from W/Z decay

- $b \to \ell\nu c$ (BR $\sim 20\%$)
- $b \to c \to \ell\nu s$ (BR $\sim 20\%$)

$\epsilon_b \sim 7\%$
$\epsilon(\text{top event}) \sim 16\%$
$\epsilon_c \sim 4\%$
$\epsilon_{fake} \sim 1\%$ per jet

Dilepton decays

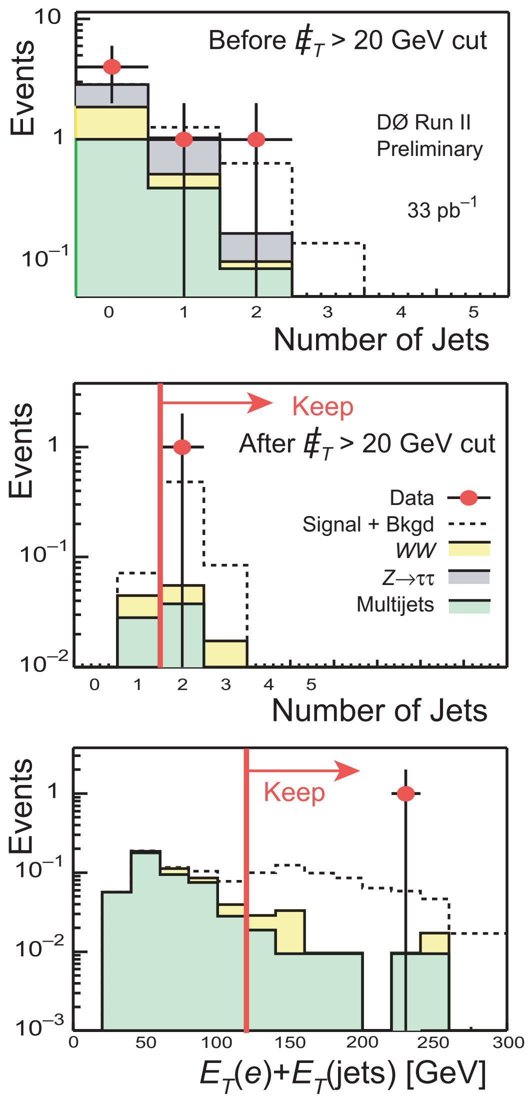
- $t\bar{t} \rightarrow W^+ b W^- \bar{b} \rightarrow \ell^+ \nu b \ell^- \bar{\nu} \bar{b}$ ($\ell = e$ or μ)
- Branching ratio small (5%), but signal to background ratio large $\rightarrow$ no b-tagging required.
- Event Selection :
  - $\Rightarrow$ 2 high-P_T leptons ($P_T > 20$ GeV)
  - $\Rightarrow$ Large Missing E_T
  - $\Rightarrow$ Veto ee and $\mu\mu$ events in Z mass window (DØ do not reject all events in this window but rather raise the Missing E_T cut)
  - $\Rightarrow$ At least 2 jets with large E_T
  - $\Rightarrow$ Large total transverse energy
  - $\Rightarrow$ Acceptance around 1%
- Main backgrounds :
  - $\Rightarrow$ WW + jets
  - $\Rightarrow$ $Z/\gamma^* \rightarrow ee, \mu\mu, \tau\tau$ + jets
  - $\Rightarrow$ W + jets (jet gives "fake" lepton)
- Cross Section:

$$\sigma_{t\bar{t}} = \frac{N - B}{A \times \mathcal{L}}$$

DØ Dilepton results: Run 2 preliminary

	ee	$\mu\mu$	$e\mu$
Background	1.00 ± 0.48	0.59 ± 0.30	0.07 ± 0.01
Expected $t\bar{t}$	0.25 ± 0.02	0.30 ± 0.02	0.50 ± 0.01
$B + t\bar{t}$	1.25 ± 0.48	0.89 ± 0.30	0.57 ± 0.02
Run 2 Data	4	2	1

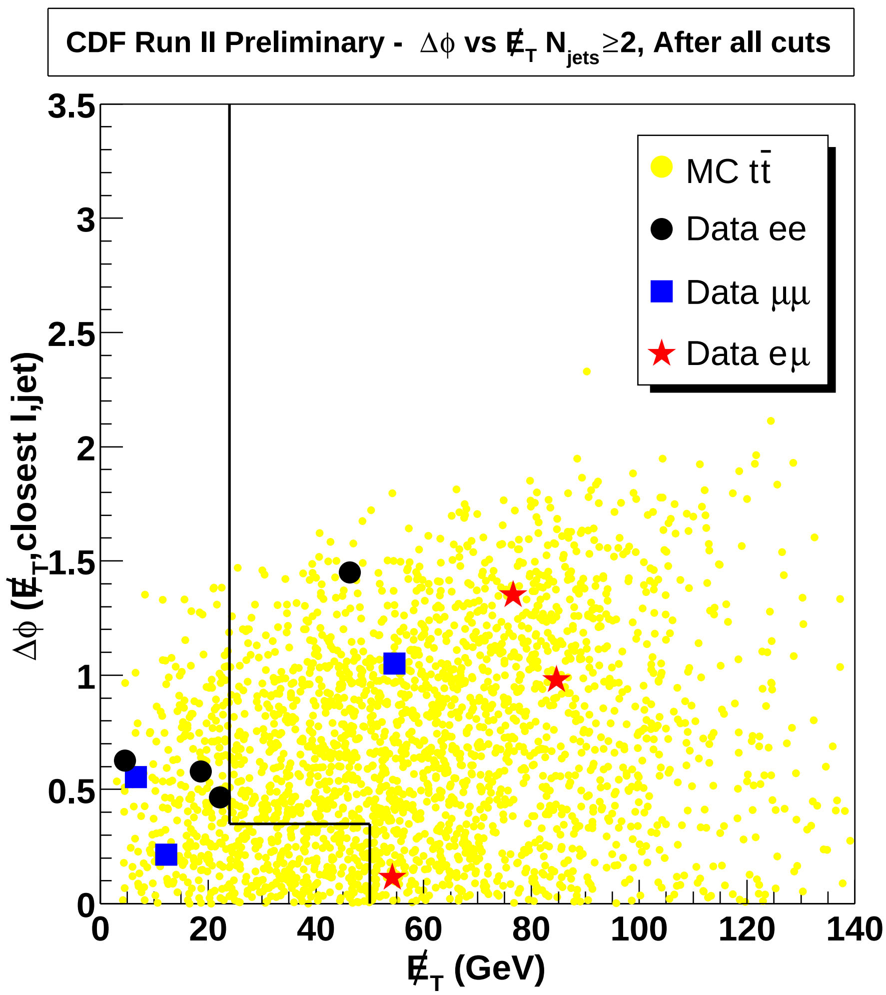
DØ $e\mu$ channel



$$\sigma_{t\bar{t}} = 29.9^{+21.0}_{-15.7}(\mathrm{stat})\ ^{+14.1}_{-6.1}(\mathrm{syst})\ ^{+3.0}_{-3.0}(\mathrm{lum})\ \mathrm{pb}$$

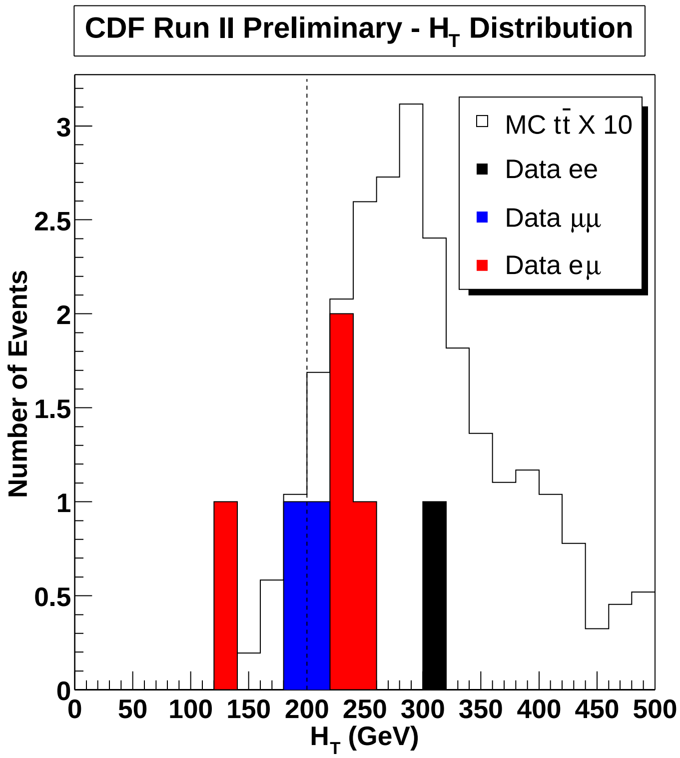
CDF Dilepton results: Run 2 preliminary

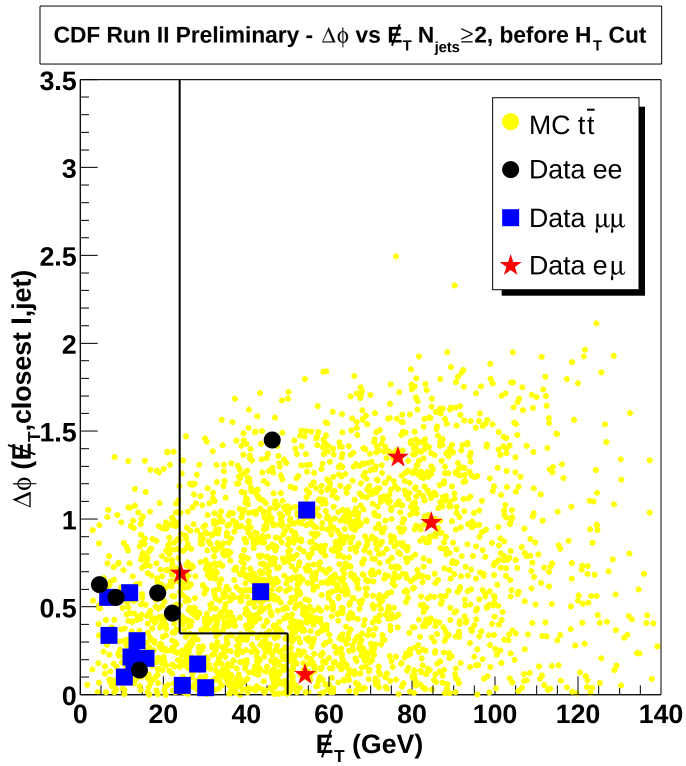
	ee	$\mu\mu$	$e\mu$
Background	0.10 ± 0.06	0.09 ± 0.05	0.10 ± 0.04
Expected $t\bar{t}$	0.47 ± 0.05	0.59 ± 0.07	1.44 ± 0.16
$B + t\bar{t}$	0.57 ± 0.08	0.68 ± 0.09	1.54 ± 0.16
Run 2 Data	1	1	3



$$\sigma_{t\bar{t}} = 13.2^{+7.3}_{-5.4}(\text{stat})\ ^{+2.0}_{-0.8}(\text{syst})\ ^{+0.8}_{-0.8}(\text{lum})\ \text{pb}$$

CDF Run 2 Dilepton kinematics
Before H_T cut



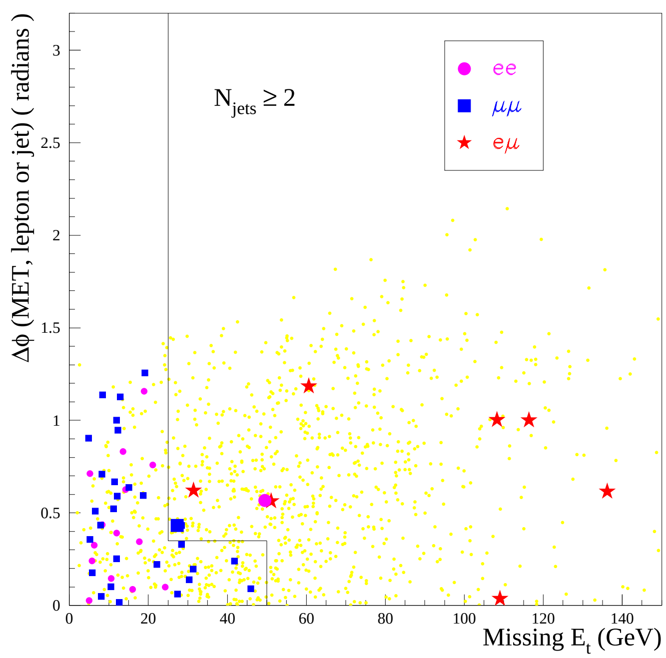


Compare with Run 1:

9 events observed

$B = 2.5 \pm 0.5$ $(B(e\mu) = 0.8 \pm 0.2)$

Expected $t\bar{t} = 4$ events $(2.2\ e\mu)$



Lepton + Jets decays

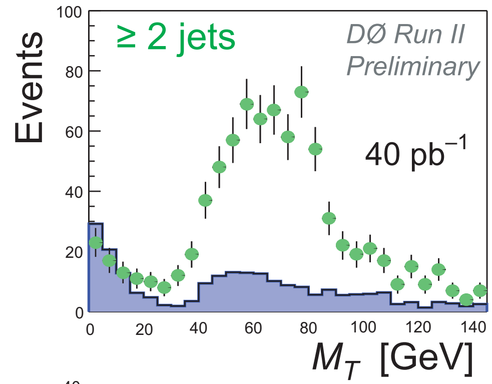
- $t\bar{t} \rightarrow W^+ b\, W^- \bar{b} \rightarrow q\bar{q}' b\, \ell \nu \bar{b}$
- Branching ratio larger (30%), but background much larger so b-tagging useful.
- Event Pre-Selection :
  - ⇒ 1 high-P_T e or μ ($P_T > 20$ GeV)
  - ⇒ Large Missing E_T
  - ⇒ At least 3 jets with large E_T
- Further selection to reduce background :
  - ⇒ topological: ≥ 4 jets + kinematic requirements (DØ)
  - ⇒ At least one jet with a Soft Lepton Tag (DØ)
  - ⇒ At least one jet with a displaced vertex (SVX tag) (CDF)
- Main backgrounds :
  - ⇒ W + jets
  - ⇒ multijets (jet gives "fake" lepton)
  - ⇒ dibosons

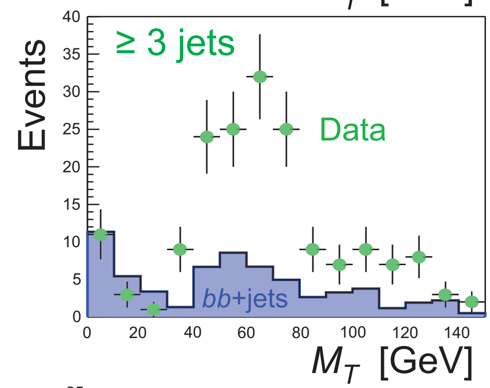
DØ Run 2 Lepton + Jets results

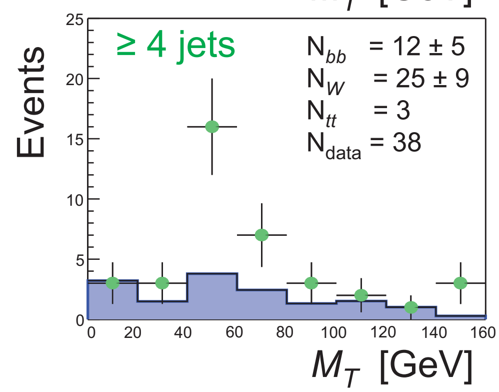
Topogical analysis: $\geq$ 4 jets, requirements on the total energy in the event.
SLT analysis: $\geq$ 3 jets, one with a soft μ, softer topological cuts

	e + jets	μ + jets	e + jets/μ	μ + jets/μ
Background	2.7 ± 0.6	2.7 ± 1.1	0.16 ± 0.10	0.74 ± 0.38
Expected $t\bar{t}$	1.8	2.4	0.54	0.82
$B + t\bar{t}$	4.5	5.1	0.70	1.6
Run 2 Data	4	4	2	0

DØ μ + jets channel





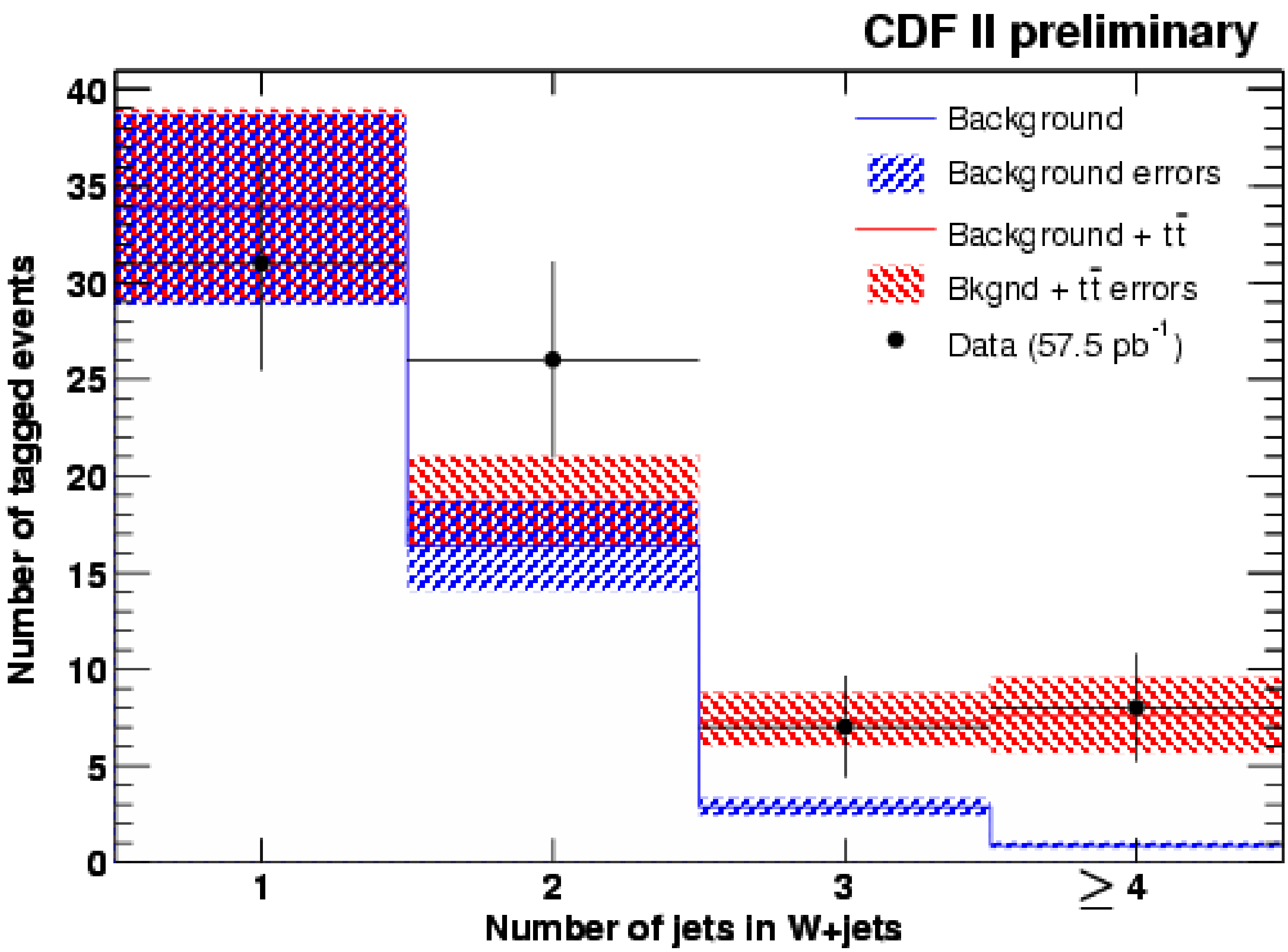


$$\sigma_{t\bar{t}} = 5.8^{+4.3}_{-3.4}(\text{stat})\ ^{+4.1}_{-2.6}(\text{syst})\ ^{+0.6}_{-0.6}(\text{lum})\ \text{pb}$$

CDF Run 2 Lepton + Jets results

SVX analysis: $\geq$ 3 jets, one jet with an SVX tag

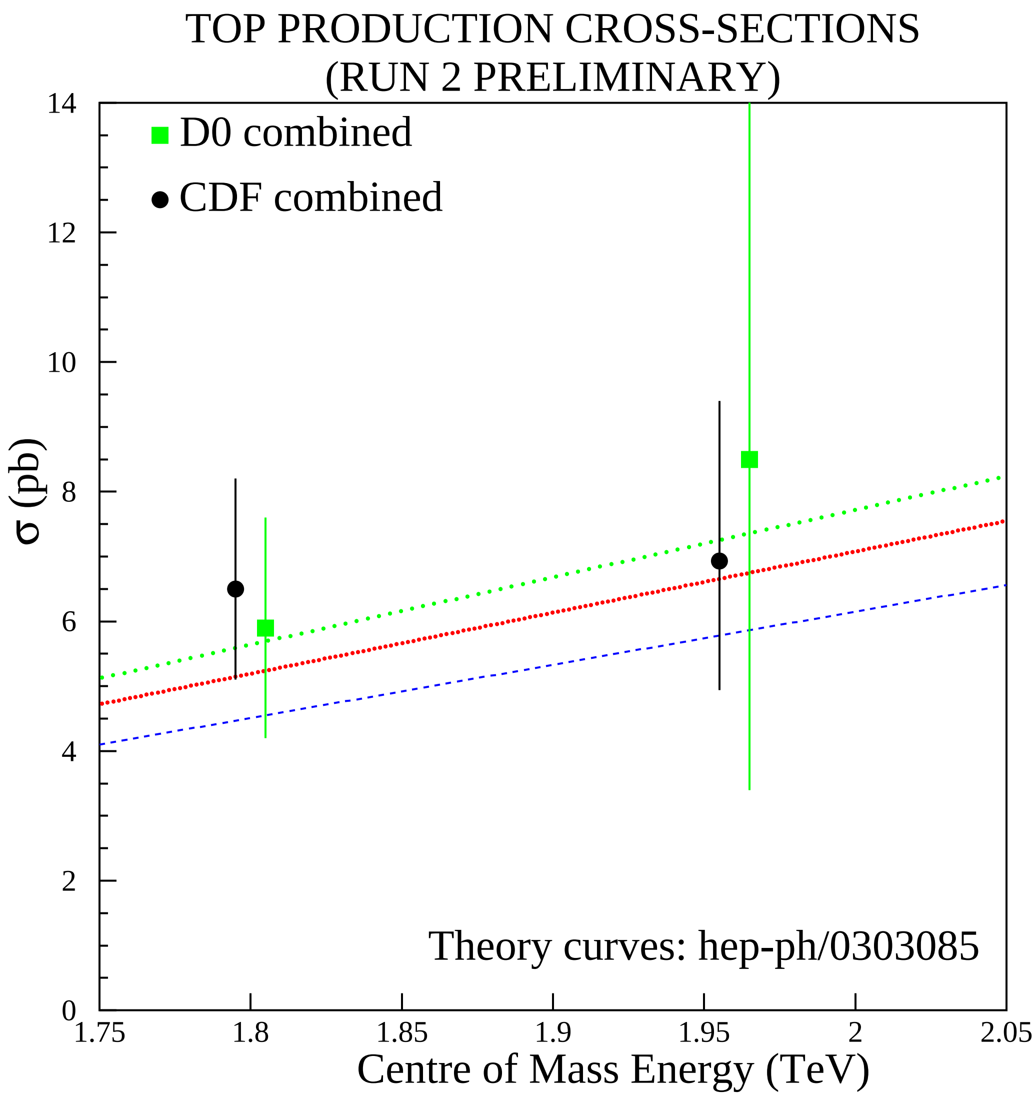
	W + 1 jet	W + 2 jets	W + 3 jets	W + $\geq$ 4 jets
Background	33.8 ± 5.0	16.4 ± 2.4	2.9 ± 0.5	0.9 ± 0.2
$B + t\bar{t}$	34.0 ± 5.0	18.7 ± 2.4	7.4 ± 1.4	7.6 ± 2.0
Run 2 Data	31	26	7	8



$$\sigma_{t\bar{t}} = 5.3^{+2.1}_{-1.8}(\text{stat})\ ^{+1.3}_{-0.6}(\text{syst})\ ^{+0.3}_{-0.3}(\text{lum})\ \text{pb}$$

Top quark cross-section summary

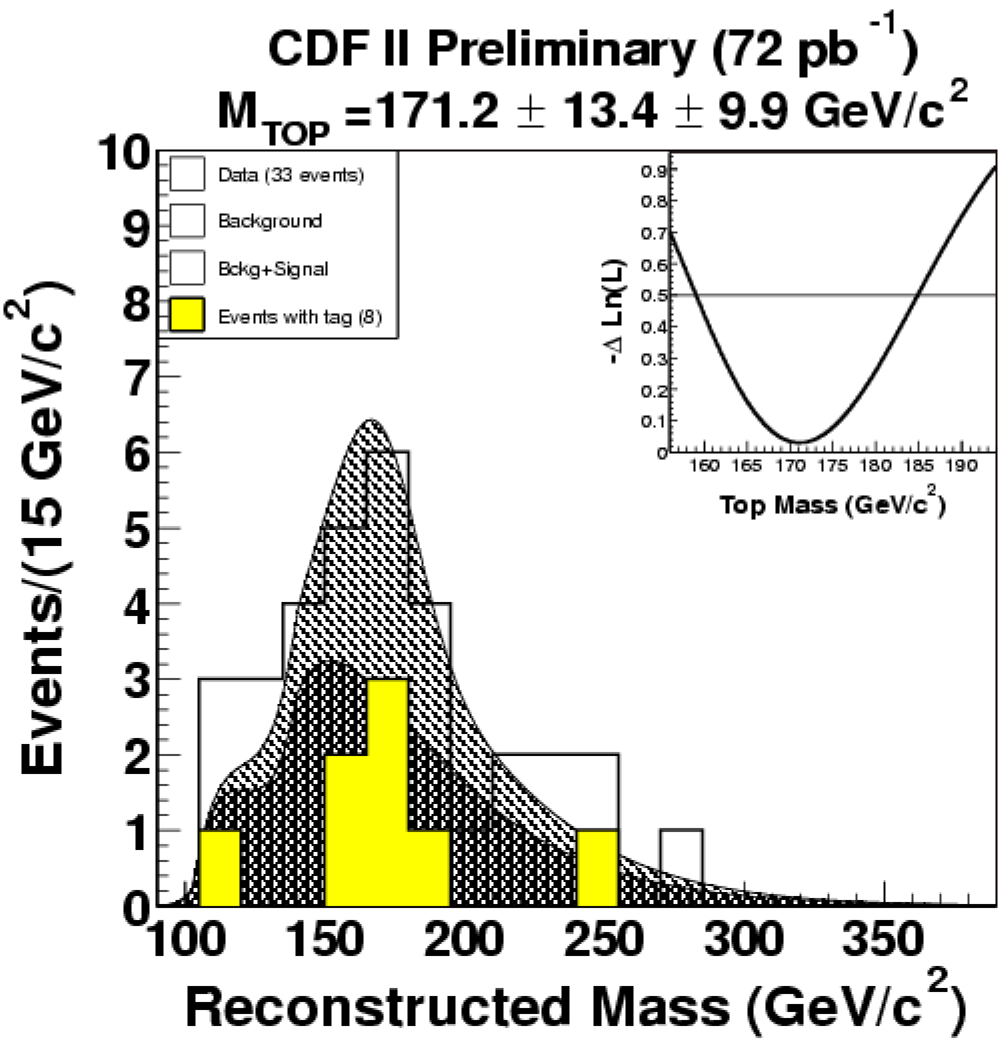
	Run 1 combined	Run 2 combined (preliminary)
DØ	5.9 ± 1.7 pb	$8.5^{+7.8}_{-5.1}$ pb
CDF	$6.5^{+1.7}_{-1.4}$ pb	$6.9^{+2.5}_{-2.0}$ pb



- Theory curves from hep-ph/0303085 (Cacciari, Frixione, Mangano, Nason, Ridolfi) where the upper and lower curves represent doubling and halving the central scale of m_{top} and incorporate the spread from different PDF's.

CDF Run 2 Top Mass measurement

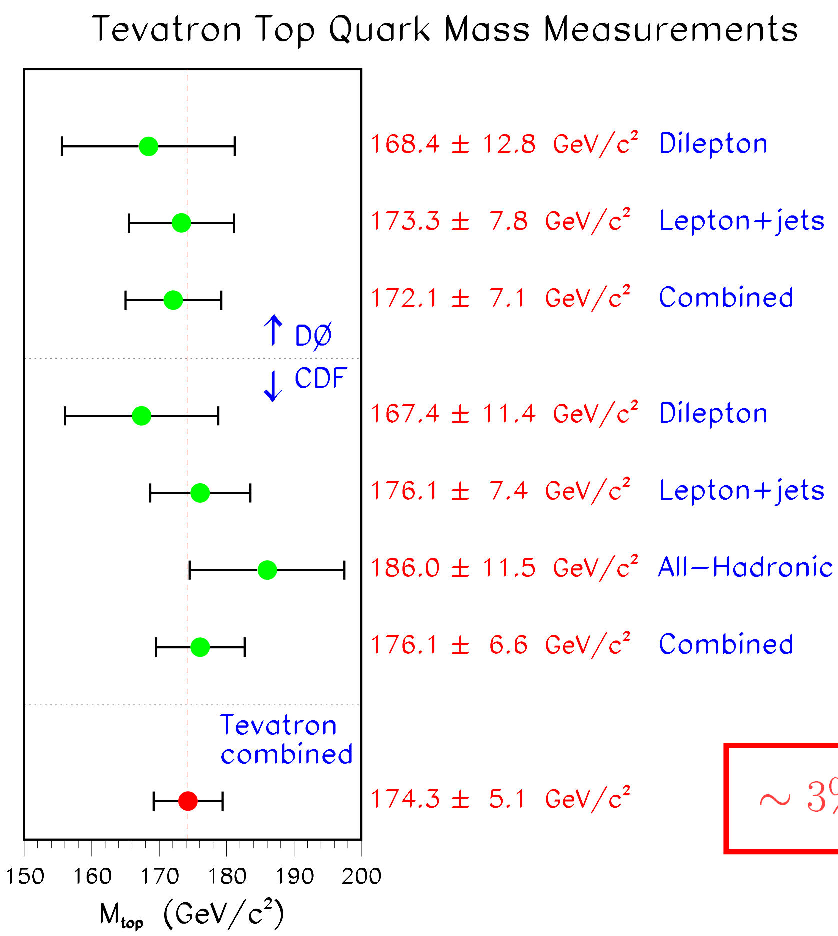
- With no tagging requirements 33 lepton + $\geq$ 4 jet events.
- 24 solutions for jet to parton assignments and $P_z(\nu)$ choice $\rightarrow$ choose one with lowest χ^2.
- Fit to signal and background shapes



- Largest systematic is jet energy resolution (9.3 GeV). Target for first fb^{-1} is 3 GeV.
- CDF and DØ working towards a mass from b-tagged events by the end of summer.

Tevatron Top Mass Summary

- From Run 1:



$\sim 3\%$ precision

- CDF Run 2 preliminary measurement in $72\,\mathrm{pb}^{-1}$ without a b-tag requirement:

$$M_{top} = 171.2 \pm 13.4\,(\mathrm{stat}) \pm 9.9\,(\mathrm{syst})\ \mathrm{GeV}/c^2$$

- DØ have a recent new analysis using a subset of the Run 1 events, in which all features of individual events are included, so well-measured events contribute more than poorly-measured ones.

$$M_{top} = 180.1 \pm 3.6\,(\mathrm{stat}) \pm 4.0\,(\mathrm{syst})\ \mathrm{GeV}/c^2$$

Improved sensitivity equivalent to 2.4 times more data !

Top quark prospects in Run 2

Short-term (this year)

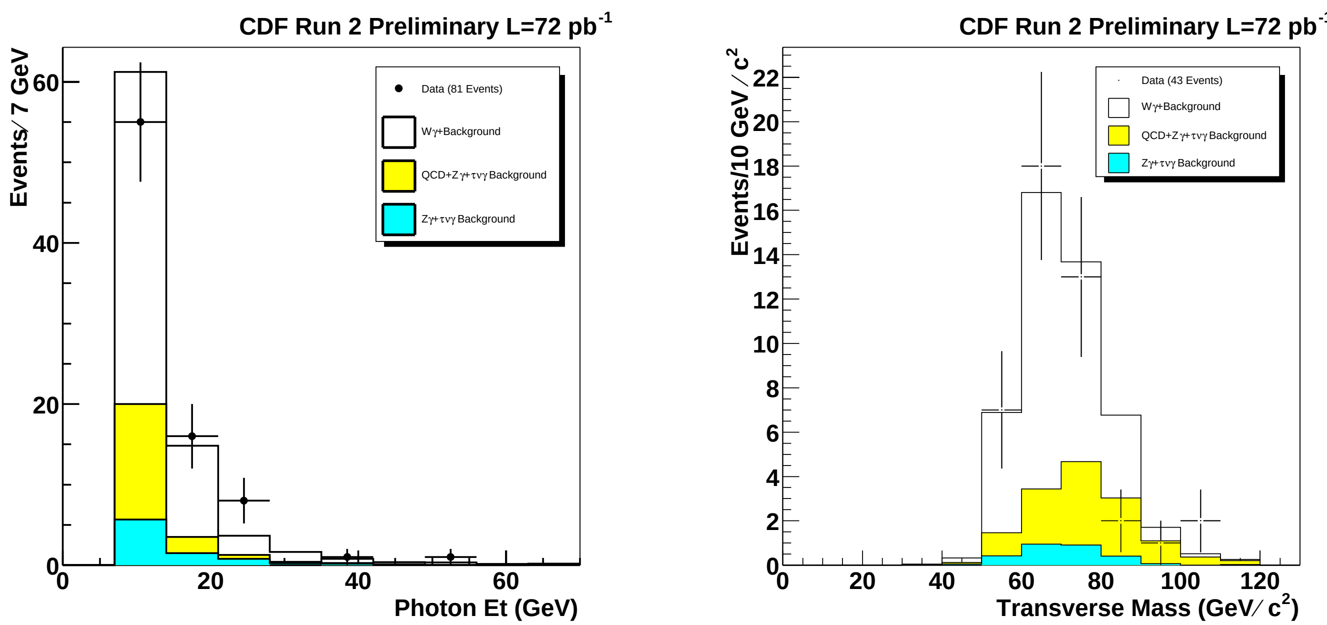
- DØ will soon include a $\sigma_{t\bar{t}}$ using SVX b-tagging.
- By the shutdown in August will have more than double the current Run 2 statistics (which will be about 50% more than Run 1) for improved measurements. Will also have improved systematics.
- Mass measurements, including those in the dilepton channel.
- Top in "all-hadronic" decay channel.
- Further elucidation on some Run 1 results: $e\mu$ channel, heavy flavour tagging in the lepton + jets channel.

Longer-term ($\sim$ 1 fb^{-1})

- Discover single top production.
- Measure cross-section to about 10%
- Measure top mass to about 3 GeV (CDF and DØ combined).
- Many other measurments to be made in order to maximize our understanding of the top quark: W helicity, top spin correlations, rare decays, $X \rightarrow t\bar{t}$, $|V_{tb}|$, ...

Diboson physics

- Measurement and understanding of WW and WZ production will not only provide useful measurements in their own right (as well as provide limits on anomalous couplings), but will serve as an important precursor and calibration for associated Higgs production searches ($q\bar{q} \to VH$ ($V = W, Z$)).
- WW and WZ Cross-sections of the same order as $t\bar{t}$ but harder to discriminate signal over background.
- Initial Run 2 studies of $W\gamma$, $Z\gamma$ and WW production are underway.
- $W\gamma$ analysis: 1 high-P_T lepton, missing energy, 1 photon.



	CDF					
	sample	B	$\sigma \times B(W\gamma \to \ell\nu\gamma)$ (pb)	sample	B	$\sigma \times B(Z\gamma \to \ell\ell\gamma)$ (pb)
e	43	33%	$17.2 \pm 3.8 \pm 2.8 \pm 1.0$	11	5%	$5.5 \pm 1.7 \pm 0.6 \pm 0.3$
μ	38	29%	$19.8 \pm 4.5 \pm 2.4 \pm 1.2$	14	5%	$6.0 \pm 1.6 \pm 0.7 \pm 0.4$

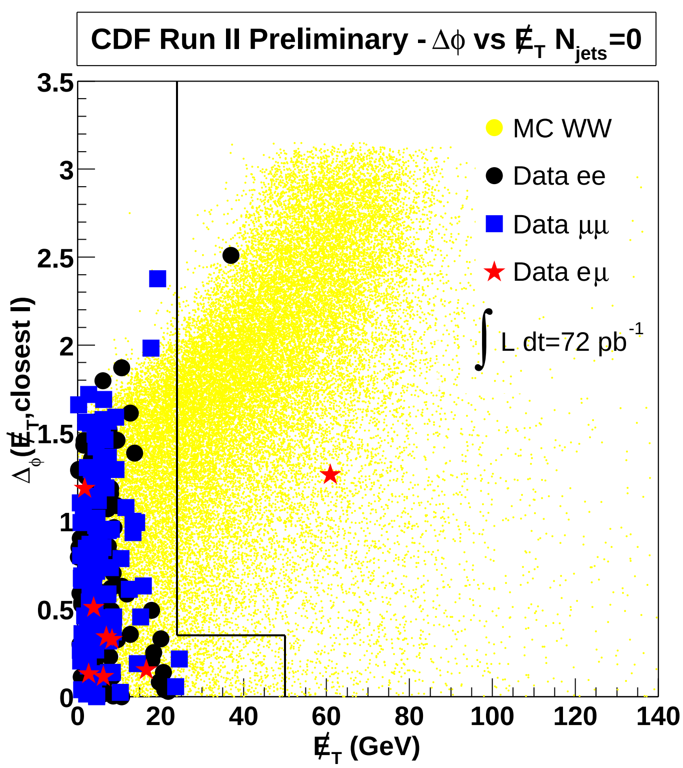
SM $\sigma \times B(W\gamma \to \ell\nu\gamma) = 18.7 \pm 1.3$ pb   ($E_T(\gamma) > 7$ GeV, $\Delta R(\ell, \gamma) > 0.7$).

WW production in the dilepton channel

- CDF results from a preliminary study of WW production in the dilepton channel.
- Signature is 2 high-P_T leptons, large missing energy. Require zero jets in the events.
- Largest backgrounds are WZ, $Z/\gamma^* \to \ell\ell$, Fakes.

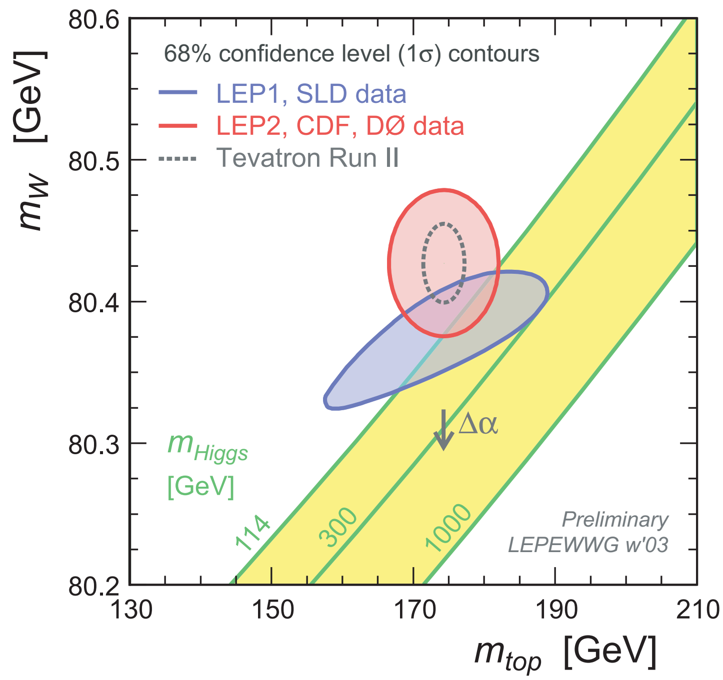
	CDF Run II Preliminary			
Source	ee	$\mu\mu$	$e\mu$	$\ell\ell$
Drell-Yan e^+e^-	0.16 ± 0.09	0	0	0.16 ± 0.09
Drell-Yan $\mu^+\mu^-$	0	0.34 ± 0.15	0.16 ± 0.09	0.50 ± 0.18
Drell-Yan $\tau^+\tau^-$	0.011 ± 0.004	0.012 ± 0.005	0.034 ± 0.013	0.056 ± 0.015
WZ	0.010 ± 0.001	0.017 ± 0.002	0.029 ± 0.003	0.057 ± 0.005
Fake	0.11 ± 0.10	0.095 ± 0.111	0.54 ± 0.59	0.74 ± 0.61
$t\bar{t}$	0.0039 ± 0.0025	0.0033 ± 0.0022	0.015 ± 0.006	0.022 ± 0.007
Total Background	0.29 ± 0.13	0.47 ± 0.19	0.77 ± 0.60	1.53 ± 0.64
$WW \to$ dileptons	0.55 ± 0.13	0.66 ± 0.15	1.58 ± 0.36	2.79 ± 0.62
Run 2 Data	1	0	1	2

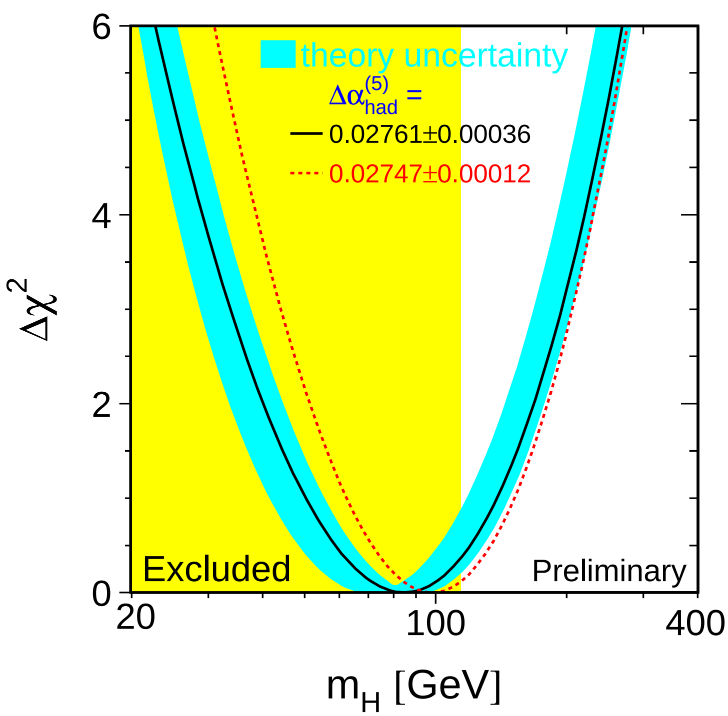
- Efforts now to get better fake estimate, optimize selection criteria - new results soon with more data.
- Analysis will naturally lead to high mass Higgs searches, $H \to WW$ 1– DØ already have preliminary Run 2 results from this search.



Searches for Higgs

- In the SM, Higgs integral to EWSB and mass generation
- Precision measurements of M_W and $M_{top} \Rightarrow M_H$
- Precision measurements of all EWK parameters predict a light SM Higgs:
  Preferred:
  $M_H = 91^{+58}_{-37} GeV/c^2$
  At 95% CL:
  $M_H < 211\, GeV/c^2$
- LEP2 have set a 95% CL lower limit of $\sim 114\, GeV/c^2$
- These results give guideline of where to look
- Possible to discover at the Tevatron in the next few years ??
- This is an important physics motivation for the Tevatron Run 2 programme

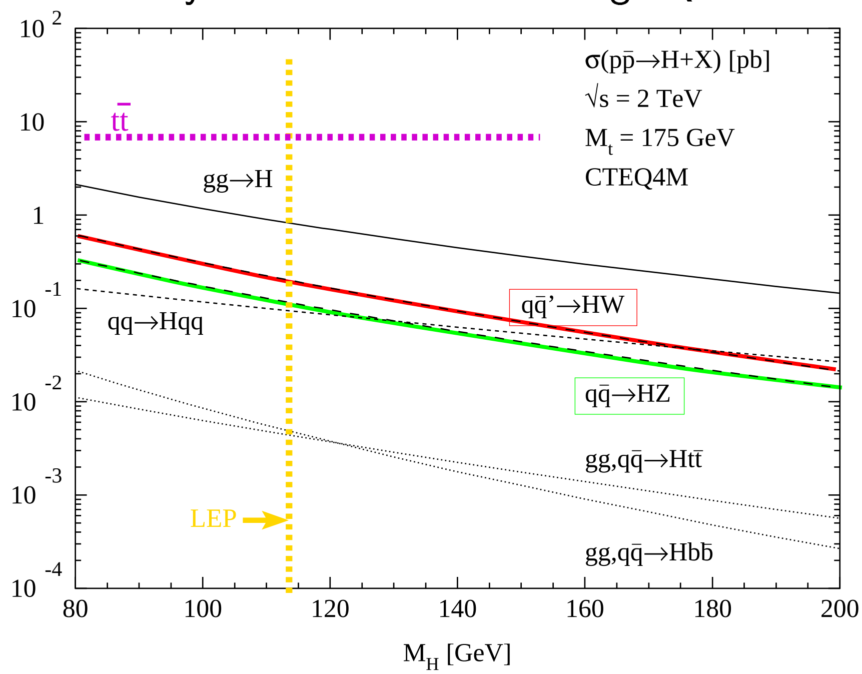




H^0 Production & Decay @ Tevatron

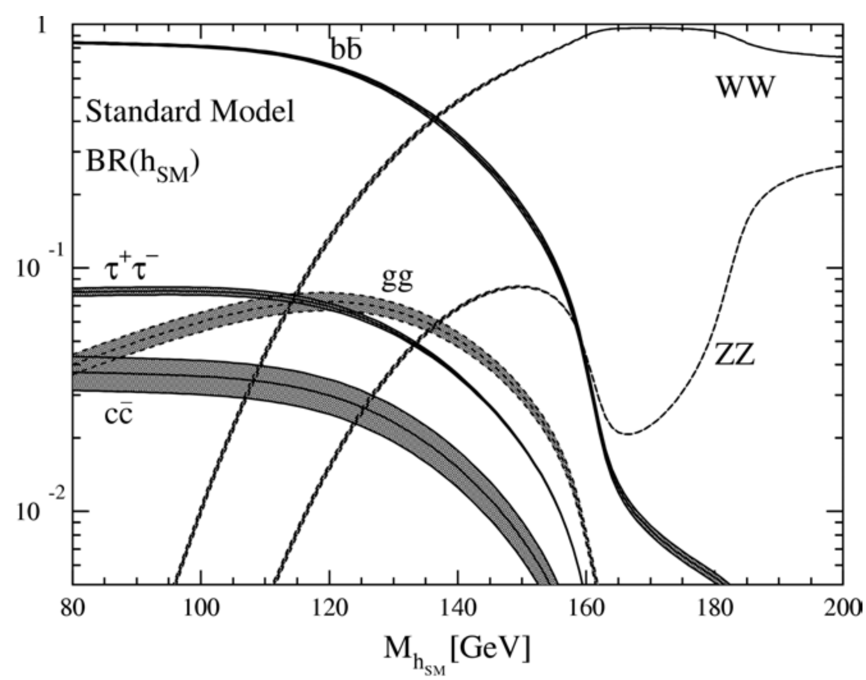
Production

- $gg \to H$ dominant, but no sensitivity to $H \to b\bar{b}$ due to large QCD background.
- WH/ZH provide most sensitive channels for light Higgs searches at the Tevatron.
- $\sigma(WH) \sim$ 0.15 - 0.05 pb (For $M_H \sim$ 120 - 160) $\sigma(WH)/\sigma(ZH) \approx 1.6$
- $\Rightarrow$ Need a LOT of luminosity !



Decay

- Light Higgs: $M_H < 130\,\text{GeV}/c^2$, $H \to b\bar{b}$ dominates.
- For $M_H > 130\,\text{GeV}/c^2$ $H \to W^+W^-$ significant, but $\sigma_{VH}^{130} \approx \frac{1}{4}\sigma_{VH}^{120}$



VH^0 Signatures, for $M_H < 130\,\mathbf{GeV}/c^2$

- For $M_H < 130\,\text{GeV}/c^2$ focus on VH production with $H \to b\bar{b}$. The decay channel then depends on the vector boson decay.

$\mathrm{Z} \longrightarrow$	BR
$q\bar{q}$	70%
$\nu\bar{\nu}$	19%
$\ell^+\ell^-$ $(\ell = e, \mu)$	6.8%
$\tau^+\tau^-$	3.4%

$\mathrm{W} \longrightarrow$	BR
$q\bar{q}'$	67%
$\ell\nu_\ell$	22%
$\tau\nu_\tau$	11%

- 4 search channels:

$\Rightarrow$ $p\bar{p} \to W/Z + H^0 \to q\bar{q} + b\bar{b}$
require ≥ 2 b-tagged jets

$\Rightarrow$ $p\bar{p} \to W + H^0 \to \ell\nu + b\bar{b}$
require 1 b-tag only (st), or ≥ 2 b-tags (dt)

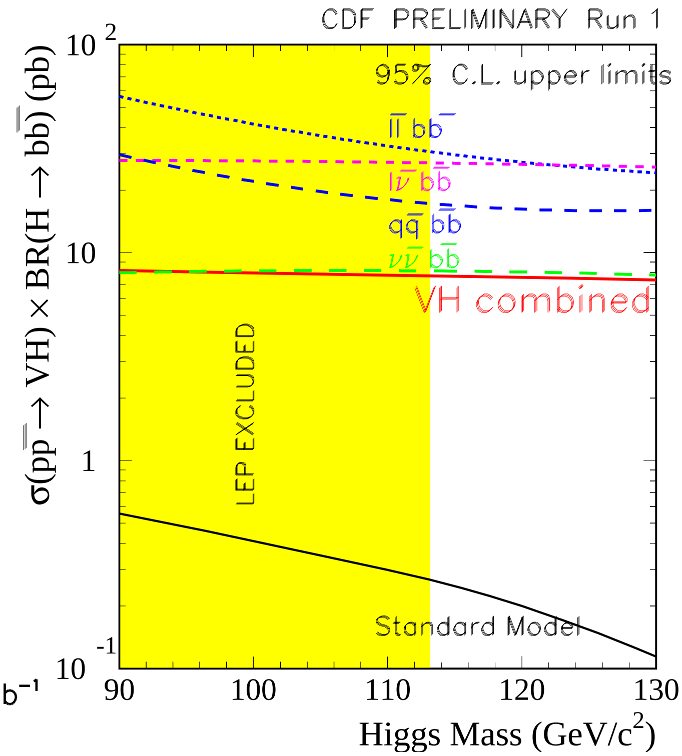
$\Rightarrow$ $p\bar{p} \to Z + H^0 \to \nu\bar{\nu} + b\bar{b}$
require 1 b-tag only (st), or ≥ 2 b-tags (dt)

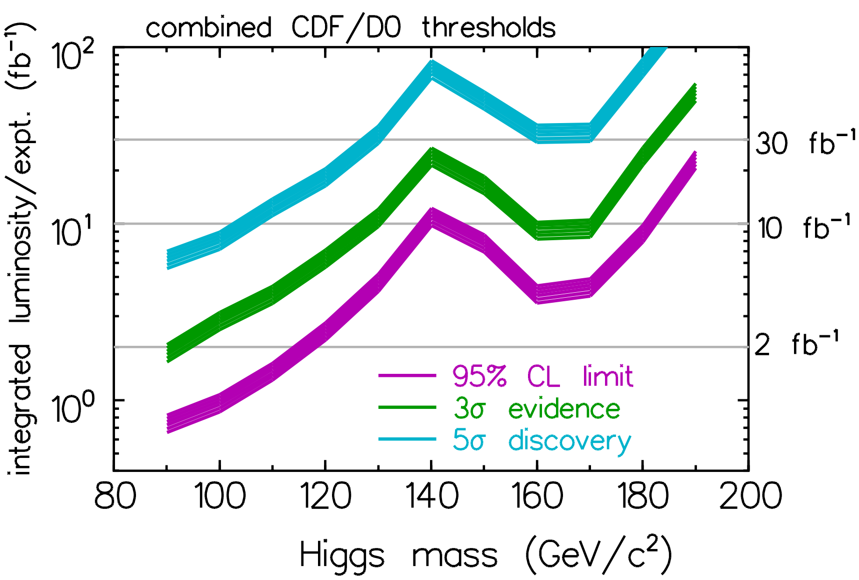
$\Rightarrow$ $p\bar{p} \to Z + H^0 \to \ell^+\ell^- + b\bar{b}$
require ≥ 1 b-tags

- b-tagging and $M_{b\bar{b}}$ resolution are critical for a light Higgs. Success of the CDF and DØ Silicon Vertex triggers is crucial $\Rightarrow$ large $Z \to b\bar{b}$ sample.

Prospects for Run 2

- In Run CDF set 95% CL limits about 30 times higher than SM prediction at $M_H \sim 115\,GeV$
  $\longrightarrow$ sets scale for required luminosity !





- For maximal sensitivity in Run 2, DØ and CDF will have to combine their results over all channels.

- More extensive use of NN's to optimize all kinematic information.
- With $\sim 10\,fb^{-1}$ could discover Higgs if $M_H < 130\,GeV/c^2$, or, exclude it up to $180\,GeV/c^2$.
- Run 2 sensitivity studies are in the process of being redone with the understanding of our new detectors.

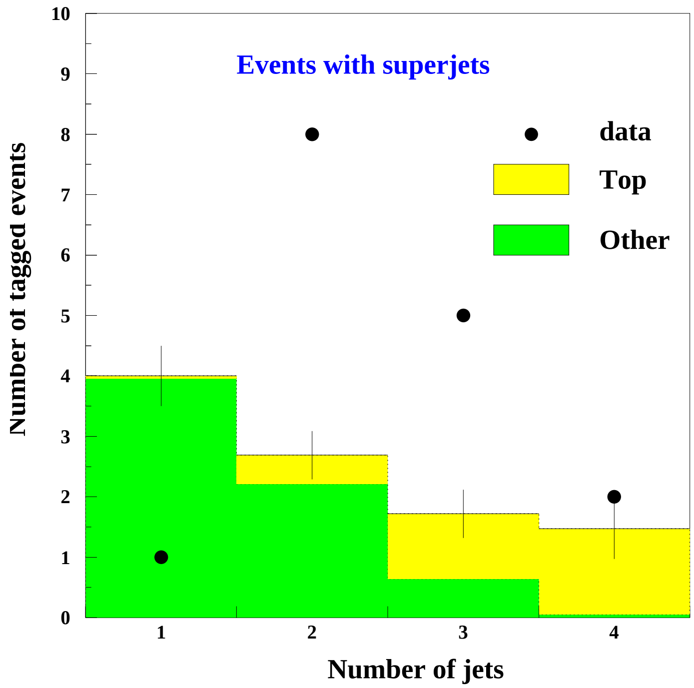
Conclusions

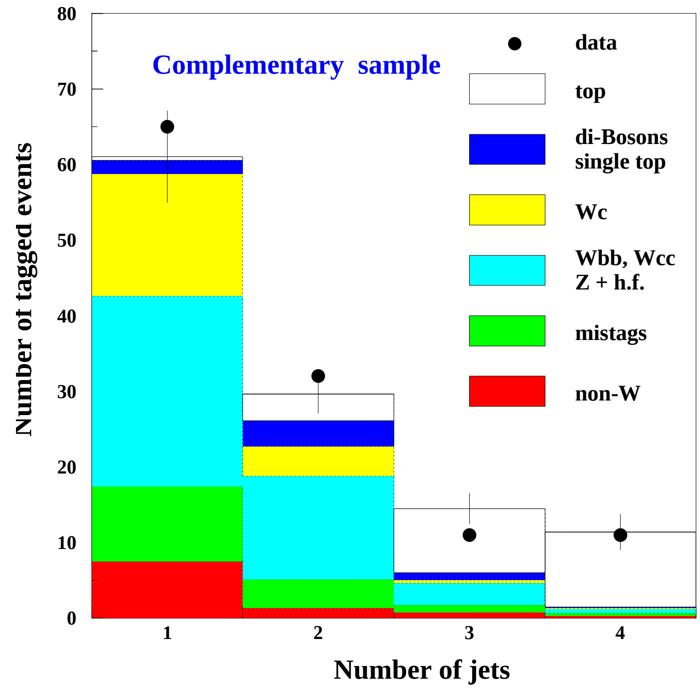
- Both the CDF and DØ detectors are now working well in Run 2, and the understanding of their performance is now leading to high quality physics results.
- The first Tevatron Run 2 W, Z and $t\bar{t}$ cross-sections have been measured, with the top quark observation re-established in Run 2.
- These measurements are only the beginning of a rich program in next few years in electroweak and top physics.
- The Higgs program is underway with background studies, and awaits the significantly more integrated luminosity expected for its observation.

backup slides

Heavy Flavour tags in lepton + $\not\!\!E_T$ + jets events

- Studies of the top cross section in the lepton(central) + jets channel with an SVX tag and an SLT tag prompted a detailed examination of the $W+$ heavy flavour sample.
- 13 lepton + $\not\!\!E_T$ + 2/3-jet events were found with one of the jets containing both a SVX and SLT tag.
- The SM expectation was 4.4 ± 0.6 events.

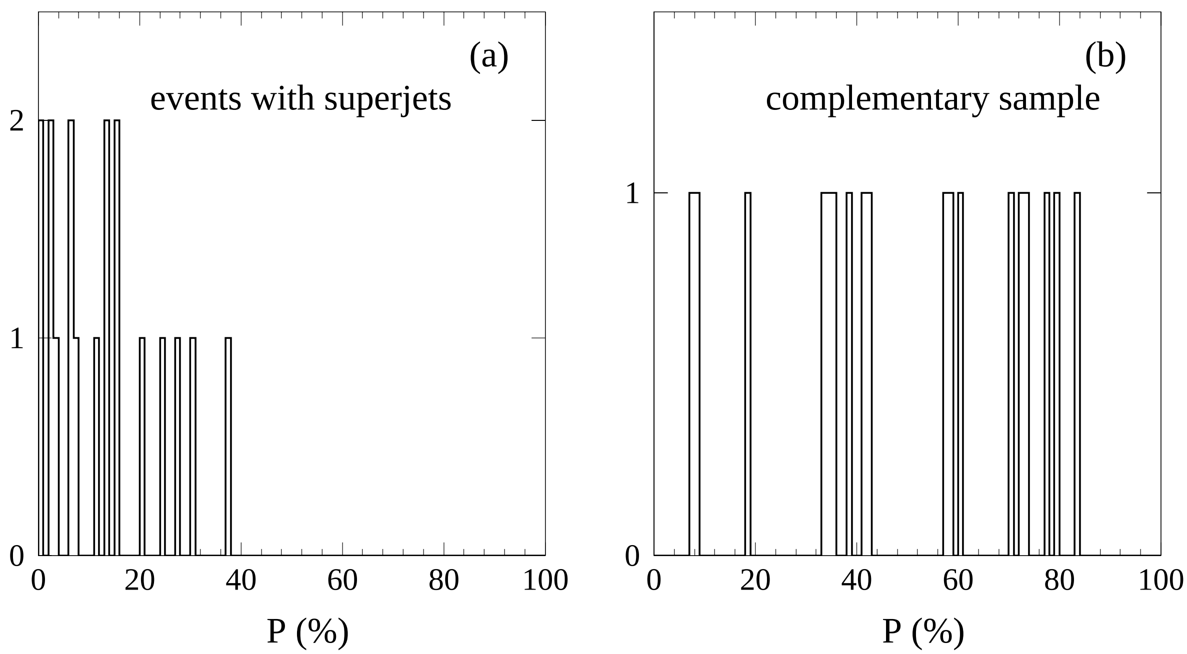




- A complimentary sample (SVX only tagged jets) consisted of 43 events with a SM expectation of 43.6 ± 3.3.
- Over all jet bins the probability of consistency with the SM is 0.65%.
- The "a posteriori" probability of observing 13 or more events in the 2 and 3 jet bins with a *superjet* is 0.1%.
- Look at kinematics.....

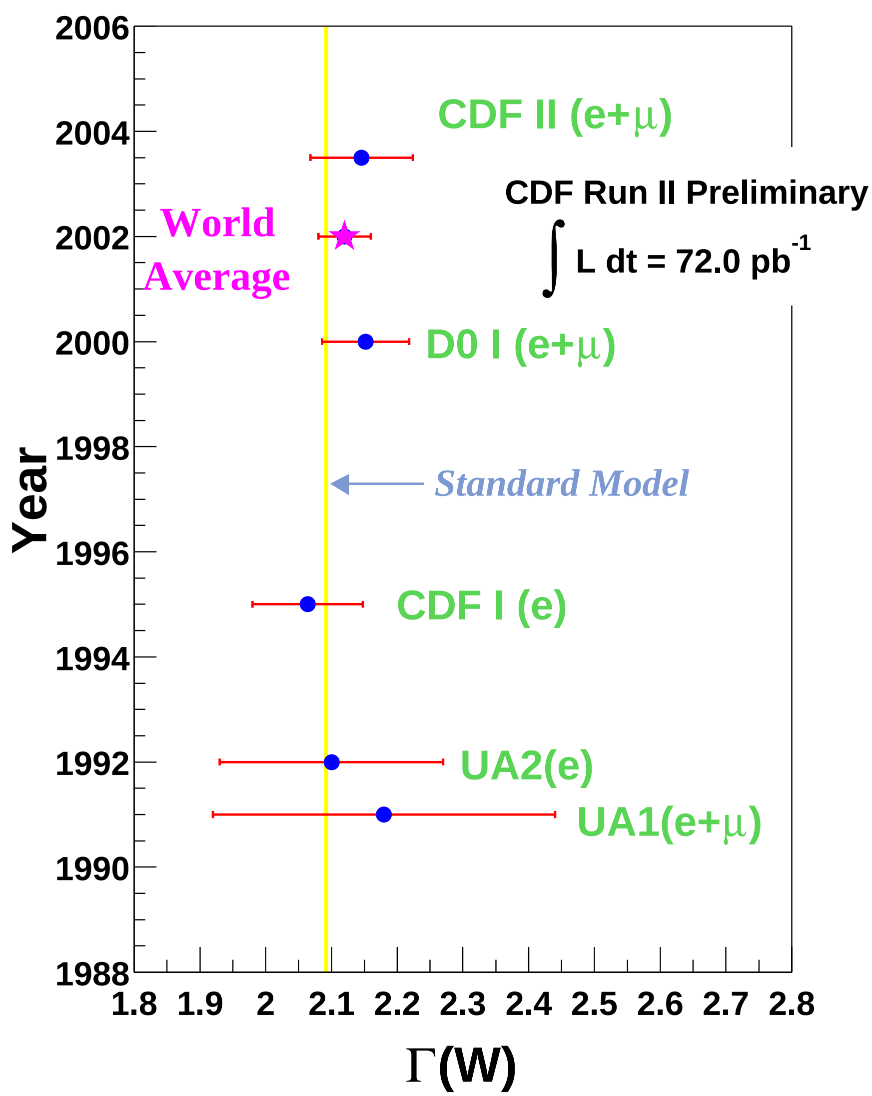
Heavy Flavour tags in lepton + $\not\!\!E_T$ + jets events

- If the 13 events are a statistical fluctuation, the kinematics of this sample should be consistent with the SM and the complimentary sample.
- 18 kinematic distributions of the 13 events, and of the complimentary sample, were compared with expected SM distributions, and their likelihoods determined.



- Comparisons by some authors with the complimentary sample showed the disagreement to be at the 10^{-6} level.
- Anomalies have no explanation within the SM. Also hard to reconcile in exotic models.
- Many cross-checks and further studies done.
- Detector effect ? Obscure feature of simulation ? New physics ? Run 2 will tell us.....

R and Γ_W



CDF II (e+μ)
CDF Run II Preliminary
∫ L dt = 72.0 pb^-1
World Average
D0 I (e+μ)
Standard Model
CDF I (e)
UA2(e)
UA1(e+μ)
Year
2006
2004
2002
2000
1998
1996
1994
1992
1990
1988
1.8
1.9
2
2.1
2.2
2.3
2.4
2.5
2.6
2.7
2.8
Γ(W)