A quick overview of DØ
Results in heavy flavour physics:
- $B_s$
- $D$
- top

All these results are new or updated for LP'05.
Another W&C in a couple of weeks with results for EPS'05.
The DØ Detector

Muon system:
- covers $|\eta|<2$,
- beam pipe shielding
- 1.8 T toroid

LAr-U calorimeter:
- hermetic
- fine segmentation

Pre-shower detectors

Central tracking system:
- 2 T solenoid
- silicon detector
- fibre tracker
Muon Trigger:
- trigger over full coverage ($|\eta|<2$)
- based on scintillator hits
- highly efficient
- low background
- write out almost all di-muons!

Muon Reconstruction:
- based on hits in 2/3 or 3/3 layers
- momentum measurement in toroid
- match to central track
  - improved $p_T$ resolution
  - excellent coverage
- requiring hits in the silicon tracker
- excellent vertex resolution
Rare Heavy Flavour Decays

The Tevatron has a complementary program to the B factories
- D∅ is competitive in di-muon modes!
- study Bs, as well as other heavier b hadrons (Bc, B**, Λb)

Tevatron is effectively a Bs factory, with wide program:
- Bs lifetime
- Bs lifetime difference between different mass / CP states
- CP violation
- Bs oscillations
- search for rare decays:
  - very sensitive to physics beyond the Standard Model

\[
B_s^0 \rightarrow \mu\mu \phi \text{ Search} \\
\text{Observation of } B_s^0 \rightarrow \psi(2S) \phi \\
\text{Updated } B_s^0 \rightarrow \mu\mu \text{ Search} \\
D^\pm \rightarrow \phi \pi^\pm \text{ Search}
\]
General Considerations:
- all analyses use di-muons
  - high efficiency, low backgrounds
- all use the vertexing capability of the DØ silicon detector

Basic analysis procedure:
- perform some pre-selection
- apply further cuts, optimised for the signal in question
- normalize result to a similar, but higher statistics channel
  - many systematics cancel.
Search for FCNC:
- small SM branching fraction
  \( \sim 1.6 \times 10^{-6} \) (C.Q. Geng, C.C. Liu)
- enhanced by various SUSY models
  - e.g. 2 higgs doublet model
    (G. Erkol & G. Turan)

Observation of excess would indicate new physics

Only current limit:
CDF, Run I: \( B(B_s^0 \rightarrow \mu \mu \phi) < 6.7 \times 10^{-5} \) (95% CL) PRD 65, 1111101

New DØ analysis, based on 300 pb\(^{-1}\)
- Search for \( B_s^0 \rightarrow \mu \mu \phi \rightarrow \mu \mu KK \)
- Normalize to \( B_s^0 \rightarrow J/\psi \phi \rightarrow \mu \mu KK \)
Pre-selection:
- select 2 good muons, $p_T > 2.5$ GeV, di-muon $p_T > 5$ GeV,
- muons form a vertex, with resolution $< 0.15$ mm

- di-muon mass window: 0.5 – 4.4 GeV
  - keep $J/\psi$ mass region
    - exclude from search, use for normalisation
    - exclude any events in $\psi(2S)$ mass region
- 2 additional tracks (K candidates) $p_T > 0.7$ GeV are added
- Require good match to the di-muon vertex
- K pair match $\phi$ mass: 1.008-1.032 GeV
Final selection then based on:
- decay length significance, \( L_{xy} \)
- angle between \( \mu \mu KK \) system and \( B_s \) direction, \( \alpha \)
- isolation of \( \mu \mu \phi \) system:

\[
I = \frac{|\vec{p}(\mu \mu \phi)|}{|\vec{p}(\mu \mu \phi)| + \sum_{\text{track } i \neq B} p_i(\Delta R < 1)}
\]

These cut values were optimised using a random grid search.
Maximize the variable:

\[
P = \frac{\epsilon_{\mu \mu \phi}}{\frac{a}{2} + \sqrt{N_{\text{Back}}}}
\]

\( \epsilon = \) efficiency (from MC)
\( N = \) expected background
\( a = \#\sigma \) (2=95% CL)

To avoid bias, signal region hidden, \( > \pm 3\sigma \) sidebands used (1\( \sigma \sim 90 \) MeV) for background, MC used for signal.
After analysing 300 pb\(^{-1}\),
0 events in signal region
1.6 ± 0.4 expected background
$B_s^0 \rightarrow \mu \mu \phi$ Search

Normalisation channel: $B_s^0 \rightarrow J/\psi \phi \rightarrow \mu \mu KK$

Uncertainties:
- background extrapolation from sidebands (25%)
- number of $J/\psi \phi$ (14%)
- CP states in MC (8%)
- relative efficiencies (7.5%).

Feldman -Cousins limit

$$\frac{B(B_s^0 \rightarrow \mu^+ \mu^- \phi)}{B(B_s^0 \rightarrow J/\psi \phi)} = \mu(n_{obs}, n_{back}) \cdot \frac{\epsilon_{J/\psi \phi}}{\epsilon_{\mu \mu \phi}} \cdot B(J/\psi \rightarrow \mu \mu)$$

From MC (5.88 ± 0.1) %
Interpret results with frequentist confidence interval
- uncertainties parameterised by probability functions
- integrate using Feldman-Cousins scheme

Expected sensitivity: \( \mathcal{B}(B^0_s \to \mu^+ \mu^- \phi) < 1.0 \times 10^{-5} \) (95\%CL)

Limit (based on 300 pb\(^{-1}\), observing no events):

\[
\frac{\mathcal{B}(B^0_s \to \mu^+ \mu^- \phi)}{\mathcal{B}(B^0_s \to J/\psi \phi)} < 4.4 \ (3.5) \times 10^{-3} \text{ at } 95 \ (90) \ % \ C.L.
\]

Take world average for \( B(B^0_s \to J/\psi \phi) = (9.3 \pm 3.3) \times 10^{-4} \)

\[
\mathcal{B}(B^0_s \to \mu^+ \mu^- \phi) < 4.1 \ (3.2) \times 10^{-6} \text{ at } 95 \ (90) \ % \ C.L.
\]

A factor of 16 improvement on current limit (CDF Run I)!
Observation of $B_s^0 \rightarrow \psi(2S) \phi$

In $B$ system, decays to $J/\psi \phi$ and $\psi(2s)\phi$ observed
- rate for $\psi(2S)$ ~ 60% that of $J/\psi$.

For $B_s$ system, $J/\psi \phi$ observed at CDF and DØ
- only previous observation of $\psi(2S)\phi$ - ALEPH (1 candidate)

Look for both $B_s^0 \rightarrow \psi(2S) \phi$ and $B_s^0 \rightarrow J/\psi \phi$, extract ratio

As a cross check:
- measure ratio of $B^\pm \rightarrow \psi(2S)K^\pm$ to $B^\pm \rightarrow J/\psi K^\pm$
- has been measured elsewhere (e.g. BaBar)
Observation of $B_s^0 \rightarrow \psi(2S) \phi$

Same basic di-muon pre-selection as $B_s^0 \rightarrow \mu\mu\phi$ analysis
- but keep di-muons compatible with $J/\psi$ or $\psi(2S)$ mass

2 additional tracks (K candidates) $p_T > 0.9$ GeV are added

Require good match to the di-muon vertex
K pair match $\phi$ mass: 1.008-1.032 GeV
Decay length significance of $B > 4$
Colinearity of $B$ and decay products $> 0.9$

Observation of $B_s^0 \rightarrow \psi(2S) \phi$

$B_s^0 \rightarrow J/\psi \phi$

$B^\pm \rightarrow J/\psi K^\pm$

DØ Run II Preliminary

Mean = 5356.66 MeV
Width = 28.93 MeV
Signal = 200
Background = 68
$S/sqrt(B) = 24.227$

Mean = 5273.69 MeV
Width = 40.05 MeV
Signal = 1970
Background = 993
$S/sqrt(B) = 62.54$
Use same optimisation variables and procedure as $B_s^0 \rightarrow \mu \mu \phi$:
- angle between $B_s$ and decay products < 0.11
- decay length significance > 11.1
- isolation >0.74
Efficiency relative to pre-selection = 50.4 ± 2.5 %.

Gaussian + linear background:
8.6 ± 3.3 signal events
1.8 ± 1.3 background events
$S/\sqrt{B} = 6.5$
Probability of b.g. fluctuation: 1.1 x 10^{-4}

$B_s^0 \rightarrow J/\psi \phi$:
110 ± 11 signal events over bg, after optimization cuts
Observation of $B_s^0 \rightarrow \psi(2S) \phi$

$$\frac{\mathcal{B}(B_s^0 \rightarrow \psi(2S) \phi)}{\mathcal{B}(B_s^0 \rightarrow J/\psi \phi)} = \frac{N_{B_s^0 \rightarrow \psi(2S) \phi}}{N_{B_s^0 \rightarrow J/\psi \phi}} \cdot \frac{\epsilon_{J/\psi \phi}}{\epsilon_{\psi(2S) \phi}} \cdot \frac{\mathcal{B}(J/\psi \rightarrow \mu^+ \mu^-)}{\mathcal{B}(\psi(2S) \rightarrow \mu^+ \mu^-)}$$

**MC:**
$$\epsilon_{J/\psi \phi} = (11.5 \pm 0.7) \times 10^{-5}$$
$$\epsilon_{\psi(2S) \phi} = (12.5 \pm 0.6) \times 10^{-5}$$

**Take measured values:**
$$\mathcal{B}(J/\psi \rightarrow \mu \mu) = (5.88 \pm 0.1) \%$$
$$\mathcal{B}(\psi(2S) \rightarrow \mu \mu) = (0.73 \pm 0.08) \%$$

**Cross check channel:**
$B^\pm \rightarrow \psi(2S)K^\pm / B^\pm \rightarrow J/\psi K^\pm$

ratio = $0.60 \pm 0.07 \text{ (stat)} \pm 0.04 \text{ (syst)} \pm 0.06 \text{ (B)}$

BaBar result: $0.64 \pm 0.06 \text{ (stat)} \pm 0.06 \text{ (syst)}$  PRD 65, 032001 (2002)

**DØ result, based on 300 pb$^{-1}$:**

$$\frac{\mathcal{B}(B_s^0 \rightarrow \psi(2S) \phi)}{\mathcal{B}(B_s^0 \rightarrow J/\psi \phi)} = 0.58 \pm 0.24 \text{ (stat)} \pm 0.06 \text{ (syst)} \pm 0.07 \text{ (B)}$$

CDF result (370pb$^{-1}$): $0.52 \pm 0.13\text{(stat)} \pm 0.04\text{(syst)} \pm 0.06 \text{ (B)}$
**B_{s}^{0} → μμ Search (Update)**

Same motivation as $B(B_{s}^{0} → μμφ)$: search for FCNC.

**SM prediction:** $B(B_{s}^{0} → μμ) = (3.42 ± 0.54) \times 10^{-9}$


Significantly smaller than $B(B_{s}^{0} → μμφ)$

Expect no events in Run II (DØ + CDF)

Observation would indicate new physics:

- SUSY: $B(B_{s}^{0} → μμ)$ rises with $\tan β$, (e.g. $\tan^6 β$ in MSSM)
  - high $\tan β$ favoured by some GUTs
- R-parity violating SUSY allows a tree level diagram
- adds to the information from the search for $b → sγ$
- This is an update, using $300pb^{-1}$ (previously $240pb^{-1}$)
Apply same basic di-muon pre-selection:
- di-muon mass between 4.5 and 6.2 GeV.

Use same optimisation variables and procedure as $B_s^0 \rightarrow \mu \mu \phi$:
- opening angle $< 0.11$
- decay length significance $> 11.1$
- isolation $> 0.74$

After analysing 300 pb$^{-1}$, 4 events in signal region
4.1 $\pm$ 1.2 expected b.g.
**B^0_s → μμ Search (Update)**

To set a limit, normalize to $B^± → J/ψ K^± → μμK^±$

- di-muon system in the J/psi window
- additional track (K), $p_T > 0.9$ GeV from same vertex
- apply same cuts on discriminating variables

**Uncertainties:**

- Signal / normalization eff. (MC)
- MC stats
- Branching fractions (theory)

**PDG: 0.270 ± 0.034**

**MC: 0.229 ± 0.016**
**B_s^0 \rightarrow \mu \mu Search (Update)**

Interpret results with frequentist confidence interval
- uncertainties parameterised by probability functions
- integrate using Feldman-Cousins scheme

**Published DØ limit (240 pb^{-1}):**
- Expected sensitivity: \( B(B_s^0 \rightarrow \mu \mu) < 4.2 \times 10^{-7} \) at 95 % CL
- \( B(B_s^0 \rightarrow \mu \mu) < 5.0 (4.1) \times 10^{-7} \) at 95 (90) % CL
  *(PRL 94, 071802)*

**Updated DØ result (300 pb^{-1}):**
- Expected sensitivity: \( B(B_s^0 \rightarrow \mu \mu) < 3.6 \times 10^{-7} \) at 95 % CL
- \( B(B_s^0 \rightarrow \mu \mu) < 3.7 (3) \times 10^{-7} \) at 95 (90) % CL
  *(preliminary)*

**Latest preliminary CDF result (364pb^{-1}):**
- Expected sensitivity: \( B(B_s^0 \rightarrow \mu \mu) < 2 \times 10^{-7} \) at 90% CL
- \( B(B_s^0 \rightarrow \mu \mu) < 2.1 (1.6) \times 10^{-7} \) at 95 (90) % CL
  - Official CDF + DØ combination well underway
An example of the impact of new limit:
e.g. Dermisek et al, hep-ph/0304101
dark matter and SO(10)
with soft SUSY breaking

Contours of $\text{B}(B_s^0 \rightarrow \mu \mu)$

Allowed by dark matter constraints

Excluded by DØ Run II
Complementary search for FCNC.
For example, R-parity violating SUSY could lead to FCNC for up type quarks, but not down type (or vice versa).

In this case, aim to normalise to $D_s^{±} → φ π^±$
- similar topology, larger branching fraction
- a signal only ever reported by the FOCUS experiment!
- analysis based on 508pb⁻¹
Event selection:
- 2 good muons, pT>2GeV
- mass consistent with phi mass

Add extra track to di-muon system:
- track pT >0.18 GeV
- 3-body mass in D range (1.3-2.5 GeV)
- form a good vertex

Yields an average of 3.3 candidate tracks per event.
Choose candidate which minimises:

$$\mathcal{M} = \chi^2_{vtx} + \left(1/p_T(\pi)\right)^2 + \Delta R^2_{\pi}$$

3-particle vertex $\chi^2$
pion $p_T$
$\Delta R$ between $\pi$ and $\mu\mu$ system

- selects correct candidate in 90% of MC events.
Suppress backgrounds using similar variables to B analyses:
- isolation of $\mu\mu\pi$ system
- $D^\pm$ decay length
- pointing angle
- ratio of $\pi$ impact parameter to $D^\pm$ impact parameter

Construct a likelihood ($d$) using signal MC and sideband data, Optimise for $\epsilon_s / \sqrt{\epsilon_{bg}}$

With tighter cut:
33 $D_s^\pm$ (7.8 $\sigma$ over bg)
13.2 $D^\pm$ - possible signal, but consistent with a 2.9$\sigma$ fluctuation

With more statistics, aim to definitively observe.
Extract a branching fraction using:
- number of events in $D^\pm$ and $D_s^\pm$ signals
- production fractions and efficiency ratio of $D^\pm$ and $D_s^\pm$

$$\frac{\mathcal{B}(D^+ \to \pi^+\mu^+\mu^-)}{\mathcal{B}(D_s^+ \to \pi^+\mu^+\mu^-)} = 0.17^{+0.08}_{-0.07}^{+0.06}_{-0.07}$$

$$\frac{\mathcal{B}(D^+ \to \pi^+\mu^+\mu^-)}{\mathcal{B}(D_s^+ \to \pi^+\mu^+\mu^-)} < 0.28 \text{ (90\% C.L.)}$$

Taking the measured $D_s^\pm$ branching fraction:

$$\mathcal{B}(D^+ \to \pi^+\mu^+\mu^-) = (1.70^{+0.79}_{-0.73}^{+0.76}_{-0.82}) \times 10^{-6}$$

$$\mathcal{B}(D^+ \to \pi^+\mu^+\mu^-) < 3.14 \times 10^{-6} \text{ (90\% C.L.)}$$

factor of 3 better than previous best limit
(FOCUS, PLB572, 21)

With more statistics, should have sensitivity for definitive observation, and non-resonant $D^\pm \to \mu\mu\pi^\pm$ searches.
\[ \mathcal{B}_s^0 \rightarrow \mu \mu \phi \text{ Search:} \]
- new limit, factor of 16 better than best published!
- publish soon.

**Observation of \( \mathcal{B}_s^0 \rightarrow \psi(2s) \phi \):**
- new result using 300 pb\(^{-1}\)
- publish soon.

\[ \mathcal{B}_s^0 \rightarrow \mu \mu \text{ Search:} \]
- updated result using 300 pb\(^{-1}\)
- official combination with CDF well underway.

**D\(^{\pm}\)\rightarrow \phi \pi^{\pm} \rightarrow \mu \mu \pi^{\pm} \text{ Search:}**
- 7\(\sigma\) observation of \( \mathcal{D}_s^{\pm} \rightarrow \phi \pi^{\pm} \rightarrow \mu \mu \pi^{\pm} \)
- limit on \( D^{\pm} \) 3 times better than best published
- with more statistics, aim to observe
- carry out non-resonant \( D^{\pm} \rightarrow \mu \mu \pi^{\pm} \) searches.
Top Production and Properties

Tevatron is currently the only place to study the top quark
- discovery in Run I

In RunII we can study the top in detail:
- measure top properties:
  - production, decays, mass, charge
- is it the Standard Model particle we expect?
  - enhanced production, unusual decays,

- Branching fraction ratio (first DØ measurement).
- Updated top pair production cross section (di-leptons).
- New measurement of W helicity in top decays
Top Branching Ratio

$$R = \frac{\mathcal{B}(t \to Wb)}{\mathcal{B}(t \to Wq)}$$

Can express $R$ in terms of CKM matrix elements:

$$R = \frac{|V_{tb}|^2}{|V_{tb}|^2 + |V_{ts}|^2 + |V_{td}|^2} = |V_{tb}|^2$$

SM: $0.9980 < R < 0.9984$ (90% CL)

Measure $R \rightarrow$ the matrix element $V_{tb}$

Non-unitarity of CKM matrix would affect $R$
  - for example, a fourth quark generation.

This is the first measurement of $R$ at DØ
  - previously measured at CDF

Analysis is statistics limited:
Use lepton + jets channel (higher stats), analysing 230 pb$^{-1}$
Basic event selection:
20 GeV pT lepton
MET > 20 GeV
3-4 jets, $E_T > 15$ GeV

Main background is from W+jets:
- 2 (14) % of W+ 3(4) jets contain heavy flavours (b,c)
- 5 % contain a single c quark

Other backgrounds (1-7% of sample):
- multijets with fake lepton and mis-measured MET
  - estimate using lepton fake rates measured in data
- Z + jets, di-boson (significantly smaller)
  - determined with MC.
The key to this analysis is b-jet tagging of jets:
- measure the fraction of top events with 0, 1 and 2 b-jets
b-tagging based on secondary vertex identification.

Need to know:
- b-tagging efficiency
- c-tagging efficiency
- mis-tag rate

Average probability to tag:
- a top event ~ 60%
- a W + 4 light jets event ~ 4%
In order to use the zero-tag sample, need extra power.
- build a discriminant based on event topology:
  - event sphericity, based on jets
  - event centrality (ratio $E_T / E$ of jets)
  - jet $E_T$ distributions
Derive discriminant properties on $t\bar{t}$ and $W+$jets MC
For multijet background, use data with non-isolated leptons.
  - split zero-tag sample into 10 bins of the discriminant.
Number of events depends on:
- top cross section
- $t \rightarrow Wb$ branching fraction.

Perform a binned likelihood fit
- background contributions estimated in data
- all systematics included

New $\text{DØ}$ Result, based on 230pb$^{-1}$:

$$\frac{B(t \rightarrow Wb)}{B(t \rightarrow Wq)} = 1.03^{+0.19}_{-0.17} \text{ (stat + syst)}$$

$$\sigma_{tt} = 7.9^{+1.7}_{-1.5} \text{ (stat + syst) } \pm 0.5 \text{(lumi)pb}$$

Best measurement to date!
Good agreement with Standard Model ($R \sim 1$)

CDF RunII, 162 pb$^{-1}$:  
$$R = 1.12^{+0.27}_{-0.23} \text{ (stat + syst)}$$  
(Submitted to PRL)
The top pair cross section tells us about top production.
- can be enhanced by some beyond Standard Model processes

Compare results in different modes
- test for non-SM top decays

Di-lepton mode has lowest background
- but is a small fraction of events....

This analysis:
updated result, using $370\text{pb}^{-1}$ (previously used $230\text{pb}^{-1}$)
- event selections re-optimised
- improved background estimates (e$\mu$ channel)
Common event selection:
- 2 isolated leptons
  - good quality
  - $p_T > 15$ GeV
  - opposite charge
- missing transverse energy (MET)
  - different cuts in each channel
- 2 high energy b-jets (note – no b-tagging used here)
  - jet $E_T > 20$ GeV.

Efficiencies measured in data and MC, a scale factor applied to MC.

Common physics backgrounds estimated using ALPGEN MC:
  - $Z \rightarrow \tau \tau +$ jets
  - $WW / WZ +$ jets

Muon ID efficiency vs $\eta$
Final Selection and backgrounds: ee channel
Cut to reject main background: Z->ee + jets.
- aim to maximise significance of signal yield
- cut on MET and di-electron mass.

Signal efficiency: 8.2 +- 0.2 %

Instrumental Background: Estimate with data.
Fake MET (in Z+jet events):
- use photon + jets to measure fake rate
Fake electrons (in W+jets events):
- look for 2 EM objects, low MET, outside Z mass window
- measure the fake rate.
**Final Selection and backgrounds:** $\mu\mu$ channel

Again, aim to maximise significance of signal yield.

**Cuts to reject main background:** $Z + \text{jets}$

1) Kinematic fit to the $Z$ mass – $t\bar{t}$ tends to have higher $\chi^2$
   - more effective than cutting on di-muon mass
2) contour cut in MET – $\Delta \phi(\text{MET, muon})$
   - $Z$ events tend to have MET aligned with a muon

**Signal efficiency:** $6.4 \pm 0.2 \%$

**Other background:** muons from heavy quark decays
- measure in data, using di-muon events
  - require non-isolated muon
  - measure probability other is isolated (fake rate).
Final Selection and backgrounds: $e\mu$ channel

Significantly lower backgrounds, can use much looser cuts. Optimum is just a cut on $H_T > 122$ GeV

where: $H_T = \sum \text{jet } E_T + \sum \text{lepton } p_T$

signal efficiency = 14.0 +- 0.2 %

Instrumental Backgrounds: estimate in data.

Fake electrons:
- measure electron likelihood in Z-$\rightarrow$ee and QCD
- fit data distribution to measure fraction of signal and bg

Muons from heavy quark decays:
- measure isolation fake rate in background sample.
Top Cross Section (di-lepton)

<table>
<thead>
<tr>
<th>Category</th>
<th>ee</th>
<th>μμ</th>
<th>eμ</th>
<th>ll</th>
</tr>
</thead>
<tbody>
<tr>
<td>Z/γ*</td>
<td>0.30±0.10−0.15</td>
<td>1.01±0.22−0.34</td>
<td>1.22±0.33−0.39</td>
<td>2.53±0.41−0.54</td>
</tr>
<tr>
<td>WW/WZ</td>
<td>0.20±0.10−0.14</td>
<td>0.20±0.08−0.07</td>
<td>1.13±0.45−0.48</td>
<td>1.53±0.47−0.54</td>
</tr>
<tr>
<td>Instrumental leptons</td>
<td>0.54±0.15</td>
<td>0.13±0.04</td>
<td>2.13±2.50−1.66</td>
<td>2.97±2.50−1.67</td>
</tr>
<tr>
<td>Total background</td>
<td>1.0±0.2−0.3</td>
<td>1.3±0.3−0.4</td>
<td>4.5±2.6−1.8</td>
<td>6.8±2.6−1.8</td>
</tr>
<tr>
<td>Expected signal</td>
<td>3.5±0.4</td>
<td>2.5±0.3</td>
<td>11.3±1.2−1.4</td>
<td>17.3±1.3−1.5</td>
</tr>
<tr>
<td>SM expectation</td>
<td>4.5±0.4−0.5</td>
<td>3.8±0.4−0.5</td>
<td>15.8±2.8−2.3</td>
<td>24.1±2.9−2.4</td>
</tr>
</tbody>
</table>

Selected events

Statistical errors dominate!
Top Cross Section (di-lepton)

\[ \sigma_{\bar{t}t} = 7.9^{+5.2}_{-3.8} \text{ (stat)} ^{+1.3}_{-1.0} \text{ (syst)} \pm 0.5 \text{ (lumi) pb} \]

\[ \sigma_{e\mu} = 10.2^{+3.1}_{-2.6} \text{ (stat)} ^{+1.6}_{-1.3} \text{ (syst)} \pm 0.7 \text{ (lumi) pb} \]

\[ \sigma_{\mu\mu} = 1.8^{+4.8}_{-3.0} \text{ (stat)} ^{+1.0}_{-1.2} \text{ (syst)} \pm 0.1 \text{ (lumi) pb} \]

Combined cross section (370 pb\(^{-1}\)):

\[ \sigma_{\bar{t}t} = 8.6^{+2.3}_{-2.0} \text{ (stat)} ^{+1.2}_{-1.0} \text{ (syst)} \pm 0.6 \text{ (lumi) pb} \]

Previous DØ result (230 pb\(^{-1}\), submitted to PLB):

\[ \sigma_{\bar{t}t} = 8.6^{+3.2}_{-2.7} \text{ (stat)} \pm 1.1 \text{ (syst)} \pm 0.6 \text{ (lumi) pb} \]

Latest CDF result (200 pb\(^{-1}\)):

\[ 8.6 + 2.5 - 2.4 \text{ (stat)} \pm 1.1 \text{ (syst) pb} \]

New DØ preliminary is the best di-lepton result to date. Very good agreement with Standard Model Prediction!
W Helicity in Top Decays

A further probe of top decays:
- in the SM, top decays via V-A interaction:
  - expect only longitudinal and left-handed W bosons.
  - fraction of longitudinal W's given by:

\[
 f^0 \approx \frac{m_t^2}{m_t^2 + 2M_W^2 + m_b^2}
\]

expect ~70% longitudinal, 30% left handed.

Analysis strategy is to measure \( f^+ \) (right handed fraction)
- \( \sim 4 \times 10^{-4} \) in the Standard Model

Measured by CDF and DØ in Run I. CDF result:
\[
 f^+ = -0.02 \pm 0.11 \text{ (stat + syst)}
\]
which corresponds to \( f^+ < 0.18 \) at 95% CL.

DØ result from RunII, using lepton+jet \( t\bar{t} \) events:
\[
 f^+ = 0.00 \pm 0.13 \text{ (stat)} \pm 0.07 \text{ (syst)}
\]
which corresponds to \( f^+ < 0.25 \) at 95% CL.

New analysis using di-lepton mode, based on 370pb\(^{-1}\).
W Helicity in Top Decays

Event selection identical to published cross section:

<table>
<thead>
<tr>
<th>Source</th>
<th>e$\mu$</th>
<th>ee</th>
<th>$\mu\mu$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$Z/\gamma^* \rightarrow \ell^+\ell^-$</td>
<td>N/A</td>
<td>0.46 ± 0.15</td>
<td>0.95 ± 0.14</td>
</tr>
<tr>
<td>$Z/\gamma^* \rightarrow \tau\tau$</td>
<td>0.73 ± 0.16</td>
<td>0.30 ± 0.12</td>
<td>0.07 ± 0.02</td>
</tr>
<tr>
<td>$WW/WWZ$</td>
<td>0.74 ± 0.27</td>
<td>0.20 ± 0.07</td>
<td>0.20 ± 0.08</td>
</tr>
<tr>
<td>Fake lepton</td>
<td>0.32 ± 0.29</td>
<td>0.09 ± 0.03</td>
<td>0.13 ± 0.05</td>
</tr>
<tr>
<td>Total bkg</td>
<td>1.8 ± 0.4</td>
<td>1.0 ± 0.3</td>
<td>1.3 ± 0.4</td>
</tr>
<tr>
<td>Expected $tt$</td>
<td>9.8 ± 1.3</td>
<td>3.5 ± 0.4</td>
<td>2.5 ± 0.3</td>
</tr>
<tr>
<td>Observed</td>
<td>15</td>
<td>5</td>
<td>2</td>
</tr>
</tbody>
</table>

Assuming a 7pb cross section mass = 175GeV

Analysis is based on the lepton $p_T$ spectrum.

Left handed W

Longitudinal W

Right handed W

Lepton tends to be boosted in W direction $\rightarrow$ higher $p_T$
Generate MC samples with:
- $f^+ = 0$ (pure V-A)
- $f^+ = 30$ (pure V+A)

Extrapolate between these values.

For each value of $f^+$, calculate a likelihood based on:
- poisson probability for signal MC + background to match data in each bin
- use gaussian distribution of background
Result: \( f^+ = 0.13 \pm 0.20 \text{ (stat)} \pm 0.06 \text{ (syst)} \)

Statistics dominated!

Bayesian interpretation of result, with a flat prior between 0 and 0.3
DØ has two measurements in Run II:
\[ f^+ = 0.13 \pm 0.20 \text{ (stat)} \pm 0.06 \text{ (syst)} \text{ (this result, 370pb}^{-1}) \]
\[ f^+ = 0.00 \pm 0.13 \text{ (stat)} \pm 0.07 \text{ (syst)} \text{ (lepton+jet result)} \]

Combining gives:
\[ f^+ = 0.04 \pm 0.11 \text{ (stat)} \pm 0.06 \text{ (syst)} \]

with Bayesian limits of:
\[ 0.000 < f^+ < 0.216 \text{ (90 \% CL)} \]
\[ 0.000 < f^+ < 0.246 \text{ (95 \% CL)} \]

All results in agreement with the SM expectation \((f^+ = 0)\).
Other DØ results new for LP'05 I didn't have time for:

Search for $WH \rightarrow WWW^*$ in like sign di-leptons

Search for direct production of scalar bottom quarks

Search for second generation leptoquarks

Isolated photon cross section
Conclusions

The Tevatron is the only place to study:
- $B_s$ - new and updated limits rare decays:
  - best limit on $B_s^0 \rightarrow \mu \mu \phi$
  - observation of $B_s^0 \rightarrow \psi(2S) \phi$
  - updated limit on $B_s^0 \rightarrow \mu \mu$, combining with CDF
  - observation of $D_s^{\pm} \rightarrow \phi \pi^{\pm}$, best limit on $D^{\pm} \rightarrow \phi \pi^{\pm}$
- The top quark:
  - best measurement of the top branching fraction
  - best production cross section in di-lepton mode
  - new DØ measurement of $W$ helicity.

These analyses were new / updated for LP'05
- another wine and cheese on new results for EPS soon!
- also, more data, more results coming....

Gavin Hesketh, 8th July 2005