Physics with 2 fb$^{-1}$

Part II

Outline:

- Doubling of data?
- Top
- Heavy Flavor
- QCD
- Needs?

Thanks to the true experts!

26 August 2006
Doubling the data?

Aren't we just doubling the data?

p17
1 fb$^{-1}$
p20
2 fb$^{-1}$
Doubling the data?

Aren't we just doubling the data?

Layer 0 SMT, AFEIIlt

Trigger upgrade capabilities

...but mitigated by high luminosity running

In many cases, no

Physics Improvement

1 fb⁻¹ → 2 fb⁻¹

2 fb⁻¹

2 fb⁻¹

p17 → p20

Time
• In many cases, "worth" more than a doubling of the data

- $b$-tagging with Layer 0 SMT
  Know level of improvement? Not yet, but has to improve

- Even more of a gain for secondary vertices, softer tracks, estimates later
Run 2b Goals

James Bond Rule of Thumb:

\[ m_W \text{ roughly equiv. to } 0.007 \cdot m_t \]
Top Quark Mass

D0 Lepton + jets: $170.6^{+4.1}_{-4.5}$ (stat. +JES) $^{+1.2}_{-1.8}$ (syst) GeV

$173.8 \pm 3.6$ (stat. +JES) $^{+2.2}_{-2.0}$ (syst) GeV

370 pb$^{-1}$

For illustrative purposes:

~Now (~no JES)
Top Quark Mass

D0 Lepton + jets: 170.6 $^{+4.1}_{-4.5}$ (stat. +JES) $^{+1.2}_{-1.8}$ (syst) GeV

173.8 ± 3.6 (stat. +JES) $^{+2.2}_{-2.0}$ (syst) GeV

Likelihood as function of $m_{\text{top}}$ and energy scale correction fix $M_W$

For illustrative purposes:

- If include prior JES knowledge

Total Top Mass Error [GeV]

Integrated Luminosity [fb$^{-1}$]

~1.5 stat

Worse you do

Thanks to Gaston Gutierrez
Top Quark Mass

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Likelihood as function of $m_{\text{top}}$ and energy scale correction fix $M_W$

For illustrative purposes:

~Now

Total Top Mass Error [GeV]

Integrated Luminosity [fb$^{-1}$]

~1.5 stat

Worse you do
Top Quark Mass

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Thanks to Gaston Gutierrez

For illustrative purposes:

Total Top Mass Error [GeV]

- 370 pb$^{-1}$
  - $\sim 4.0$
- 1 fb$^{-1}$
  - $\sim 2.5$
- 2 fb$^{-1}$
  - $\sim 2.0$
Top Quark Mass

- plus any future improvements will mean getting there sooner, e.g. optimization of "working point"

\[ \Delta m_{\text{top}}(\text{stat}) = \frac{\Delta(m_{\text{top}})}{\sqrt{N}} \]

- \( \sim 15\% \) reduction in error

- and this does not yet include Layer 0 improvement!
Summer 2006, indirect, take out top mass:

- High $Q^2$ except $m_t$
- 68% CL

Excluded

4.0, 2.5, 2.0 GeV error bands
Impact depends on central value!

$1 \text{ fb}^{-1}$
$2 \text{ fb}^{-1}$

definitely won't be a large gain, enter a long assault on systematics.
**All Jets mode:**

Two SVT $b$ jets $p_T > 45$ GeV

- 4 jets $p_T > 20$ GeV
- jet $p_T > 15$ GeV |$\eta|<2.4$
- all jets taggahia
- b JES v6.3 (extended)
- Candidates
- Random $+$ Jet Events
- bckg norm: $m_j < 50$ GeV
- $\sigma = 12.4 \pm 1.1$ pb

- $b$-jet-jet mass [GeV]

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- jet-jet mass [GeV]

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**Finish asap**

Moving on

- p17
- p20 (more automated input efficiencies, TRFS?)

Possibly consider it a transition point to focusing more on all-jets and dilepton modes to combine & check:

- any problems with the lepton + jets?
- new physics causing differences?

**Have started on p20**

- looked at $e +$ jets p17 vs. p20 data
- p20 single top selection...
Improvements?

- Luminosity from $W$'s (2-3%)  
- Measure ratio of $ttbar$ to $W$ cross section  
- Use large data sets to constrain model assumptions ($W$ fractions, gluon radiation, …)  
- Combine channels (here and for mass, plan ahead of time)

- Relatively slow improvement of precision of fundamental parameters after p17, increasing importance of other top properties

![Graph showing Luminosity and Statistical uncertainty](image)

- Luminosity
- Statistical
- Jet Energy Scale
- $W$ heavy flavor fractions
Single Top, $V_{tb}$

- Extrapolations did not consider systematic errors; but
- improvements in object reconstruction and analysis discrimination
- Conservative: evidence possible with 1 fb$^{-1}$ likely with 2 fb$^{-1}$ ("sweet spot")
Measuring a single parameter with error, fits to distributions, e.g., helicity fraction $f_+.

- Shrink the stat. error in each bin
- Will then allow meaningful measurements (e.g., x10 stats)

Really need the statistics...
**B Physics**

Very few analyses of interest are systematics limited

- Already a 1 fb\(^{-1}\) publication, many 1 fb\(^{-1}\) prelim. and in pipeline
- Discussions of best way to access the p20 data and start using it asap, 2 fb\(^{-1}\) results soon after end of its collection
- Processing of some subsamples with extended AA?

**B\(_s\) System**

Probe all parts of the \(B\(_s\)\) system: \(m_s\), \(m_s\), \(\Gamma_s\) & other CP-violating tests

\[
\text{PRL 97 (2006) 021802}
\]

\(17 < m_s < 21 \text{ ps}^{-1}\) @ 90% C.L.

- First-ever two-sided limit, but only a limit!
- Need significance of 3\(\sigma\) and then 5\(\sigma\)
- How to get there?
**$B_s$ Oscillations**

Add statistics and...

- Add channels: $B_s^0 \rightarrow D_s \pi$, $eD_s \pi$, $\bar{D}_s \rightarrow KK^*$, $\bar{D}_s \rightarrow KK_S$
  
  Nasty reflections, solved

- Added bandwidth? Also pay attention to triggers

Significance of Signal

\[
\frac{1}{\mathcal{B}} = \sqrt{\frac{D^2}{2}} e^{\frac{(\langle K \rangle \bar{m}_s \bar{m}_s - 1)^2}{2}} \sqrt{S + B} \frac{1}{D_p}
\]

~20% improvement
**B_s Oscillations**

- Add channels: 
  - $B_s^0 \to D_s \ell \nu$
  - $eD_s \ell \nu$
  - $D_s \to KK^*$
  - $D_s \to KK_S$

  \[ \text{Nasty reflections, solved} \]

- Added bandwidth?

\[ \text{Significance of Signal} \]

\[ \frac{1}{\sqrt{2}} = \sqrt{\frac{D_p^2}{2}} e^{\frac{(<K>\overline{m}, \overline{m})^2}{2}} \frac{S}{\sqrt{S + B}} \frac{1}{D_p} \]

Scale factors to proper time error

Mass and vertex constraint
**$B_s$ Oscillations**

- Add channels
  
  \[ B_s^0 \quad D_s \quad K \]
  \[ D_s \quad K^* \quad K_K \]

- Added bandwidth? ~20% improvement

- "Tagging Power", \( \mathcal{D}^2 \sim 2.5\% \) for opposite-side flavor tagger

\[
\text{Significance of Signal} \quad \frac{1}{\sqrt{2}} = \sqrt{\frac{\mathcal{D}^2}{2} e^{(\text{<K>}_{m_s}^2/m_s^2)} \frac{(S - B/D_p)}{2}}
\]

- MC predictions, try to calibrate with data, \( \mathcal{D}^2 \sim 2.5\% \) surprisingly high, requires further study!

- If true, gain a factor \( \sqrt{2} \)

- Combine to single tag variable

- Same-side tag

\[ u, d, s \quad K^+, K^0, \bar{K}, \bar{K}^* \]
Projections

Integrated luminosity to reach 3\(\sigma\) significance?

- Only existing semileptonic modes, caveats of previous page

\[ 3\sigma \text{ signif. with } \sim 2.2 \text{ fb}^{-1} \]

- ...and it leaves out one of the most important factors, Layer 0!

For \( m_s = 17.4 \text{ ps}^{-1} \)
Significance of Signal
\[ \frac{1}{\sigma} = \sqrt{\frac{D^2}{2}} \]

\[ e^\left( \frac{(K - D) m_s}{2} \right) \]

\[ \frac{S}{\sqrt{S + B}} \frac{1}{D_p} \]

- Improvement due to better proper time resolution with Layer 0

- Old studies (D0 Note 4418) at least showed

Semileptonic
\[ t \sim 150 \text{ fs} \quad \sim 135 \text{ fs} \]

Hadronic
\[ t \sim 100 \text{ fs} \quad \sim 75 \text{ fs} \]

but just need to try w/ Layer 0 hits and see

\[ m_s = 17.33 \text{ ps}^{-1} \]

\[ R = \frac{t \text{ w/ 0 Layer 0 SMT}}{t \text{ w/ Layer 0 SMT}} \]
**$B_s$ Oscillations**

Hadronic decay modes

- **Control**
  - MC
  - $B^0_d$ + $D^*$

  - $B_s^0 ightarrow D^+ \pi^-$
  - $D_s^0 [K^+, K^-]$
  - $D_s^0 \Delta^+_s$
  - $D_s^0 \rho^-$
  - $D_s^0 \pi^+ \pi^-$

- **Data**
  - D0 Cuts
  - Signal-Monte-Carlo
  - partial rekonstruiertel $B$-Zerfall
  - Kombinatorik

- **Use K-factors**
  - $\# / 0.1 \text{GeV}$
  - $m_{D_s\pi} (\text{GeV})$

- **No K-factor**
  - $D_s e$

- **Data**
  - $B_s^0 \square$ all $190 \pm 15$
  - $B_s^0 \square$ $D_s \square$ $27$

- **Thorsten Kuhl, Catrin Bernius**

- **Measure consistent lifetime!**
- **Use composition from MC**
**Width Difference, $\Delta s$**

- Include estimated improvements on CP asymmetry $A_{SL}$

Could look like:

- $\bf D_{\Omega}$ - combined
- $B_s \rightarrow J/\psi\pi$ asymmetry band
  - $A_{sl}$ constraint

$$\tan(\phi) = -0.01 \pm 0.16 \text{ ps}^{-1}$$

- $\bf D_{\Omega}$ L=2/fb
- $B_s \rightarrow J/\psi$ asymmetry band
  - $A_{sl}$ constraint

$$\tan(\phi) = -0.01 \pm 0.08 \text{ ps}^{-1}$$

- $2 \text{ fb}^{-1}$

- Enough stats, start flavor tagging other side
Rare Decays

- Improvement with Likelihood ratio method

**Other**

- "Strangely beautiful baryon",
- $\mathbf{b} \rightarrow J/\psi \Xi$
- (Extended AA)
- Lifetimes, etc.
- Spectroscopy $B_{s}^{**}, D_{s}^{**}$
- all benefit from stats
"Primary D0 QCD WG Goals are only weakly related to 2fb-1 sample"

Getting results out the door, e.g., aspire to:

- Personpower shortfall, group members spend all their time on JES (necessity, i.e., 1–3% error in JES, 5–30% error in cross section)

JES uncertainties about same size as PDF uncertainties

- JES uncertainties about same size as PDF uncertainties
QCD

...but with JES subcorrections, \((p_T, y)\), ready to roll

Inclusive Jets

Dijets

Multijets

Isolated Photons (pub, nothing from CDF)

Diphotons (100 x more than CDF)

Jet properties, correlations, heavy flavor

2 fb\(^{-1}\) ?

Primary Effect:
- Reach higher \(p_T\) / Mass
- Study Rare Processes
  - w/ Small Cross Sections
  - Multi-Jet Production
  - Tail of Delta Phi Distribution
- Study Processes More Differential

Secondary Effects:
- Improved Understanding of Systematics
  - with more Data
  - Jet Energy Scale
  - Photon Purity

Keep checking for (unexplained) anomalies!

Diffractive Physics

- Pots can go in when lumi low enough
- Heavy flavor & Z diffractive production
What do we need to do to get at all this glorious physics?

Regular commissioning (Bob Hirosky's talk) - requires work!

- Lepton ID's not yet fully efficient (although many xxx certs "mature", take less time for p20 efficiencies, etc., in the end)
- tracking efficiency low
- problems like 3rd superbunch SMT loss
- calorimeter needs calibrating! Data quality documentation/stability

Taking advantage of what we already have - requires work!

- e.g., using CPS/FPS for their intended purpose...

Taking advantage of improvements, e.g., Layer 0, AFEIIIt - requires work!

- b-tagging, tuning of smearing of JLIP (part of NN)
- determination of resolution with Layer 0 hits ($B_s$ oscillations)
- using AFEIIIt in tracking, timing information?
Mitigating effects of high lumi running (Guennadi's talk) - requires work!

- ID development for high lumi
- effects on tracking and calorimetry
- using trigger upgrades effectively
- keeping reco time under control

Physics analysis strategy - requires work!

- keep internal combinations in mind in preparation for combinations with other experiments (separate analyses can be important for x-checks, but need to be thought out early on for consistency)
- data of higher quality will keep coming in! Don't take too long @ L/2 if not appropriate. Most results will be superceded.
- Is 2 fb^{-1} enough to justify an update? Sometimes yes, sometimes no. Shooting for stability if systematics limited.
- Keep the investment in common tools such as CAF/CAFE continuing, and it will continue to pay back for p20
By now, after this many years of running, many experiments would be considered "mature"
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...but Run 2b upgrades \(\longrightarrow\) Mid-Life Crisis \(\longrightarrow\) Buy a Ferrari!
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Commissioning, taking advantage of improvements \rightarrow Learn how to drive it (well!)
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High luminosity running $\rightarrow$ Take up street racing
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Now isn't that more interesting/exciting?
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