CDF Status

Rob Roser and Young-Kee Kim
on behalf of the CDF Collaboration

Physics: Highlights and Projections
(Young-Kee Kim)

The Challenge of High Luminosity and Shrinking Resources
(Rob Roser)
Detectors and Offline performing well. Collaboration is Strong and Committed!
CDF II Physics Results

http://www-cdf.fnal.gov/physics/pub_run2/

<table>
<thead>
<tr>
<th>Physics Papers</th>
<th>2001</th>
<th>First Collisions, Commissioning</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2002</td>
<td>First Physics Data</td>
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<tr>
<td></td>
<td>2003</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>2004</td>
<td>17</td>
</tr>
<tr>
<td>Dec 8, 2005</td>
<td></td>
<td>29</td>
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<tr>
<td>Dec 9-23, 2005</td>
<td></td>
<td>7</td>
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<tr>
<td>Total</td>
<td></td>
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<tr>
<td>NIM Papers</td>
<td>Total</td>
<td>31</td>
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35 physics papers currently under collaboration’s review

See the details in the backup slides.

Today’s presentation includes some (not all) of the new results. the others results - http://www-cdf.fnal.gov/physics/physics.html
Data delivered/recorded to date

CDF: 1.44 fb\(^{-1}\) delivered, 1.15 fb\(^{-1}\) on tape

FY05 - 84% data taking efficiency

16% ineff.: ~5% Trigger/DAQ dead time, ~5% Beam conditions

1.0 fb\(^{-1}\) good for physics without silicon, 0.9 fb\(^{-1}\) good for physics with silicon
Projected Data Sample Growth

- FY05: Double data up to FY04
- FY06: Double data up to FY05
- FY07: Double data up to FY06
- FY09: Double data up to FY07

Integrated Luminosity (fb^-1)
Momentum and Energy Scale Status

- Understand passive material well:
  - $E/p$ tail - data vs. simulation
  - Flatness of $J/\psi \rightarrow \mu^+\mu^-$ mass over a large $p_T$ range
  - $\Delta M_{J/\psi} = 0.05$ MeV, $\Delta M_B = 0.2$ MeV
  - $\Delta M_W$ due to P, E scale
    - Run II current (Run Ib)
    - $\mu$: 30 (87) MeV, $e$: 70 (80) MeV
    - better than Run Ib

$\frac{\Delta p}{p}$

$J/\psi \rightarrow \mu^+\mu^-$ mass vs $1/p_T^{\mu}$

$\Delta p / p = -0.0010 \pm 0.0001$

$\frac{\Delta p}{p} = -0.0013 \pm 0.0001$
Tagging and Jet Energy Calibration

- B Tagging (secondary vertex)
  - Better algorithms: Neural Network
  - Loose (1.8% mistag)
  - Tight (0.6% mistag)

- Hadronic Tau Tagging
  - $E_{\text{visible}} > 30$ GeV
    - ~50% efficient
    - 0.5 - 0.1% mis-identified

$\Delta E_{\text{jet}}/E_{\text{jet}}$ 3.5% at 50 GeV
2.6% at 100 GeV
2.8% at 200 GeV

About to submit to NIM: hep-ex/0510047
Top Mass Measurements

- lepton+jets (2 methods): 3 papers accepted/submitted
  - $173.5^{+3.9}_{-3.8}$ GeV (template), $173.2^{+4.1}_{-4.0}$ GeV (matrix element)
  - Single best measurement, better than Run I CDF+D0 measurements
- dilepton (4 methods): 2 papers will be submitted within a month
  \[ M_{\text{top}}^{\text{CDF II combined}} = 172.2 \pm 3.7 \text{ GeV} \ (\sim 2\% \text{ accuracy}) \]
Top Mass and Production Cross-section

\[ \sigma_{\text{top pair}}^{\text{CDF II}} \text{ vs. } M_{\text{top}} \text{ Tevatronn} \]

\[ \sigma(t\bar{t}) \text{ all channels combined} = 7.1 \pm 0.6(\text{stat.}) \pm 0.7(\text{syst.}) \pm 0.4(\text{lum.}) \]

Preliminary CDF combined $t\bar{t}$ production cross section for 350 pb$^{-1}$
@ Summer 2005 CDF+D0 combined top quark mass

CDF Status: Fermilab PAC Meeting, December 8-10, 2005
Electroweak Projections

\[
\Delta M_W [\text{MeV}] \quad \Delta M_{\text{Top}} [\text{GeV}] \quad \Delta M_{\text{Higgs}} / M_{\text{higgs}} [%]
\]

Luminosity / Experiment [fb⁻¹]

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CDF currently focusing on improving sensitivities (x10):
Jet energy resolution (~70%), b-tagging acceptance (~10%) and efficiency
(~50%), lepton acceptance (80~150%), analysis technique (~75%), …

We are in the half way. By summer 06, expect x5 sensitivity, x3 - x5 statistics.
Observing $B_s$ Mixing

CKM Fit Result: $\Delta m_s = 18.3^{+6.5}_{-1.5}$ ps$^{-1}$ (1σ), $18.3^{+11.4}_{-2.7}$ ps$^{-1}$ (2σ)
B_s Mixing Analysis: Winter 2005

CDF 95%CL Limit: 7.9 ps^{-1}

CDF Sensitivity: 8.4 ps^{-1}

\sim 900 signal events with B_s \rightarrow D_s \pi, D_s l\nu

where D_s \rightarrow K^*K, \phi \pi, \pi \pi \pi

With 355 pb^{-1}

CDFII Preliminary, 355 pb^{-1}, B_s \rightarrow D_s \pi, D_s \phi \pi

526 \pm 33 events

K^+K^-\pi^-\pi^+_B mass [GeV/c^2]

\chi^2/\text{NDF} = 132.7/125
prob: 30.18%
B_s Mixing Analysis: Fall 2005

- Hadronic modes
  - Improved taggers (better calibrations, NN for jet charge)
  - Improved vertex resolution (important for larger $\Delta m_s$)
  - Added a new decay mode $B_s \rightarrow D_s 3\pi$ (10% increase)

- Semileptonic modes
  - 2-track Silicon Vertex Trigger - x2 statistics

With new CDF results, the world limit moved from 14.4 ps$^{-1}$ to 16.6 ps$^{-1}$.
CDF $\Delta m_s$ Sensitivity Projections

Sensitivity in the semileptonic mode is limited to lower values of $\Delta m_s$. Higher values of $\Delta m_s$ are only accessible in the hadronic mode.
Lifetimes

- $\Lambda_b^0 \to J/\psi \Lambda^0$
  - $\tau = 1.45 \pm 0.13 \pm 0.02$ ps
  - Single best measurement in a fully reconstructed decay mode

- $B_c^0 \to J/\psi \nu$
  - $\tau = 0.474^{+0.073}_{-0.066} \pm 0.033$ ps
  - World’s best

CDF are making competitive and world leading measurements for all the heavier B hadrons.

*CDF Status: Fermilab PAC Meeting, December 8-10, 2005*
Observation of $B_c \rightarrow J/\psi \pi$

Evidence with 360 pb$^{-1}$
hep-ex/0505076

Observation with $\sim$800 pb$^{-1}$

\[ B_c \left( \begin{array}{c} b \\ \bar{c} \end{array} \right) \rightarrow \left( \begin{array}{c} c \\ \bar{c} \end{array} \right) J/\psi \pi \]

With 0.8 fb$^{-1}$, CDF $M(B_c) = 6275.2 \pm 4.3$ (stat.) $\pm 2.5$ (syst.) MeV
Lattice QCD Cal. $M(B_c) = 6304 \pm 12$ $^{+18}_{-0}$ MeV [hep-lat/0411027]

Used data up to Sept. 4, 2005 and approved as of Nov. 10, 2005. Demonstrates physics results with data through Feb. 06 by next summer.
QCD Measurements

Generic Jets: Data / NLO QCD

- Cone based
- 385 pb⁻¹
- CDF Prelim.

Kₜ Algorithm
- CDF Prelim.

Data / Theory

- Kₜ = 0.7
- 0.1 < |Y | < 0.7
- CDF Prelim.

CDF Preliminary

$\sqrt{s} = 1.96$ TeV, $L \sim 335$ pb⁻¹

b Jets

- Data
- Pythia Tune A (CTEQ6.1)
- Systematics

Fit of Mass at Secondary Vertex

$\sqrt{s} = 1.96$ TeV, $L \sim 335$ pb⁻¹

- $E_T^{jet} = 20$ GeV
- $|y^{jet}| < 1.5$

- $N_{data} = 101$
- $N_{MC} = 99$
- $N_{light} = 30 \pm 12$
- $N_c = 23 \pm 19$
- $N_b = 46 \pm 15$

CDF Status: Fermilab PAC Meeting, December 8-10, 2005
MSSM Higgs Searches

\[ h/A/H \rightarrow \tau\tau \]

Accepted by PRL, hep-ex/0508051

- \( |\mu| = 200 \text{ GeV} \)
- \( M_2 = 200 \text{ GeV} \)
- \( M_{\text{gluino}} = 0.8 M_{\text{SUSY}} \)
- \( M_{\text{SUSY}} = 1 \text{ TeV}, X_t = \sqrt{6} M_{\text{SUSY}} (m_{h_{\text{max}}}) \)
- \( M_{\text{SUSY}} = 2 \text{ TeV}, X_t = 0 \) (no-mixing)

CDF Status: Fermilab PAC Meeting, December 8-10, 2005
New Physics Searches via Rare Decays

CDF Limits:
Br(B_s \rightarrow \mu \mu) < 2.0 \times 10^{-7} at 95\% CL - world’s best
Br(B_d \rightarrow \mu \mu) < 5.1 \times 10^{-8} at 95\% CL - world’s best

Could Find New Physics in Standard Model Samples?

$X \rightarrow e^+e^-, \mu^+\mu^-, \gamma\gamma$ mass spectrum
(paper in preparation)

Excited muon in $\mu\mu\gamma$
(paper in preparation)

$X \rightarrow$ top pair mass spectrum
(paper in preparation)
1 fb\(^{-1}\) Physics Challenge

<table>
<thead>
<tr>
<th>Data taking Period</th>
<th>Total Lum. (pb(^{-1}))</th>
<th>Data processed</th>
<th>Ntuples made</th>
<th>Physics results</th>
</tr>
</thead>
</table>
Concluding Remarks

• CDF experiment is operating well. Better than ever!
  – Typical data taking efficiencies in the mid 80%’s with increasing inst. Luminosity and Run IIb commissioning
  – All detectors are in excellent conditions
  – Stable offline software
  – Established fast calibrations, data processing scheme
  – Good detector simulation
  – MC production at remote sites

• Challenging ahead…
  – x2 higher instantaneous luminosity
  – x8 higher integrated luminosity
  – Resources going down

• CDF Strategies in preparation for the future
  – Planning ahead: we have been identifying those areas that need further development and are beginning to address them immediately. Goal is to complete the work by early 2006.
Concluding Remarks

• Looking forward to Summer 2006 conferences
  • Results with x3 increase in statistics over Summer 2005
  • Report on > 10 x Run I Luminosity !!

• The upcoming years will be an exciting time with increasing statistics
  • Discovery through searches
  • Discovery through precision experiments
  • CDF Experience:
    – With ~4 pb\(^{-1}\), Top limits set
    – With ~20 pb\(^{-1}\), Evidence paper out!
    – With ~65 pb\(^{-1}\), Discovery paper out!
  • Hoping for new evidence/discovery with ~1 fb\(^{-1}\)
  • New physics could appear with every factor of 3~4.

• CDF is committed to operating well and analyze the data through 2009.
Backup Slides
Tracking and High $p_T$ Lepton Status

• COT Tracking
  – Alignment: wire positions aligned better than 10 $\mu$m
  – Efficiency: 99.6% (isolated tracks), > 96% (non-isolated tracks)

• Silicon Tracking
  – Alignment: internal - 5 $\mu$m, w.r.t. COT < 10 $\mu$m
  – Efficiency: 94% with $r$-$\phi$, 83% with $r$-$\phi$ and $z$
  – Misidentified: 0.5% - 1.5%

• High $p_T$ Electron Identification
  – Efficiency: 82-93%, Misidentified jets: $\sim 10^{-4}$

• High $p_T$ Muon Identification
  – Efficiency: 93%, Misidentified jets: $\sim 10^{-4}$

• Numbers are stable with time, instantaneous luminosity up to $10^{32}$ cm$^{-1}$s$^{-1}$.
Publications: Top Physics

- Published / submitted
  - Top mass in l+jets (template)
  - Top mass in l+jets (temp + ME)
  - Top mass in l+jets (ME)
  - Top → H⁺ b
  - Top branching ratio
  - W helicity
  - tt-bar production in tau + lepton
  - tt-bar x-sec using kinematics
  - tt-bar x-sec using SLT b-tagging
  - Kinematics in tt-bar in dilepton
  - tt-bar x-sec using Kinematics and secondary vertex b-tagging
  - Single top
  - tt-bar x-sec in di-lepton

- Under collaboration’s review
  - Anomaly in W+b-jets
  - Top mass in l+jets (multivariate)
  - Top mass in dilepton (template)
  - Top mass in dilepton (ME)
  - tt-bar x-sec combined
  - tt-bar mass
  - tt-bar x-sec with secondary vertex and jet probability
  - tt-bar/WW/Z→ττ x-sec with dileptons
  - tt-bar x-sec in missing Et +jets
  - tt-bar x-sec in all hadronic channel
Publications: Bottom Physics

- **Published / submitted**
  - \( \Lambda_b \rightarrow \Lambda_c + \pi \)
  - \( B_s/B \) Branching fraction ratio
  - \( B \) mass
  - \( B_s \rightarrow J/\psi + \pi \)
  - \( B_d, B_s \rightarrow \mu\mu \)
  - \( \Lambda_b \rightarrow Kp, \pi p \)
  - Semileptonic moment
  - \( B_s \) lifetime difference
  - \( B_s \rightarrow \phi\phi \) etc
  - \( D^0 \) relative Br and CP asymmetry
  - \( J/\psi \) and B x-sec
  - \( B_s \rightarrow \mu\mu \) branching ratio
  - \( X(3872) \) observation
  - \( \text{Br}(D^0 \rightarrow \mu\mu) \)
  - Charm x-sec
  - \( D_s D^+ \) mass difference
  
- **Under collaboration’s review**
  - Cascade pentaquark
  - \( D_1 \) and \( D_2 \)
  - \( B \rightarrow hh \) and CP violation
  - \( X(3872) \) di-pion mass
  - \( B_s \rightarrow \psi(2s) + \phi \)
  - Ratio of \( \Lambda_b \) Br’s
  - Semileptonic B lifetime
  - \( B_c \) lifetime in \( J/\psi + e \)
  - \( \text{Br}(B_s \rightarrow D_s \pi, D_s 3\pi) \)
  - \( D^0 \rightarrow K \pi \) wrong sign anal
Publications: New Phenomena

• Published / Submitted
  – Monopole searches
  – Search for h/A/H → ττ
  – High mass dilepton
  – 1st generation lepto-quark
  – High mass di-τ
  – Lepto-quark in missing Et + dijet
  – Excited electron
  – Diphoton + missing Et
  – H^{++} search in dilepton
  – Stable H^{++} search

• Under collaboration’s review
  – 2nd generation lepto-quark
  – Gluino/Sbottom search
  – WH → lνbb search
  – Higgs to WW search
  – W′ → eν search
  – WH → WWW* search
  – Stop → charm + LSP
  – High mass di-photon
  – Lepton+photon+missingEt
  – Z′ using mass and angular distribution
  – Sneutrino to e/μ
  – Excited muon
  – Stop in RPV SUSY
Publications: Electroweak and QCD

- Published / submitted
  - W and Z x-sec (PRL)
  - ZZ+WZ x-sec
  - W Charge asymmetry
  - WW x-sec
  - W and Z x-sec (PRD)
  - Forward-backward asymmetry in dielectron
  - W / Z + photon x-sec
  - Diphoton x-sec
  - Jet shapes
  - Jet x-sec with cone algorithm

- Under collaboration’s review
  - W mass
  - Z → τ(e) τ(h)
  - Jet x-sec with $K_T$ algorithm
  - W/Z (2jets) + photon
  - B-jet x-sec
  - Forward jet x-sec with $K_T$ algorithm
  - Z + b-jet x-sec
  - 2-particle correlation in jets
Jet Algorithms

Raw Jet $P_T$ [GeV/c]
→ JetClu $R=0.7$
→ MidPoint $R=0.7$
→ $K_T$ $D=1.0$
→ $K_T$ $D=0.7$

Event 1860695  Run 185777

Only towers with $E_T > 0.5$ GeV are shown
High Lum. Impact on Reconstruction / Physics

- Understanding Tracking, B-tagging Performance at $3 \times 10^{32} \text{ cm}^{-2}\text{s}^{-1}$
  - $< \# \text{ of interactions }> \sim 10$
  - Data
    - vs primary vertices
    - vs bunch-by-bunch lum.
  - MC + multiple interactions

- Developing Analysis Techniques
  - $W$ Mass

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![Tracking performance vs. # vertices](image)

**Tracking performance vs. # vertices**

$Z \rightarrow \text{ee}$ events

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