First CDF Run II Results
The CDF Collaboration

<table>
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581 physicists

ICHEP 2002, Amsterdam

F. Bedeschi, INFN-Pisa
First CDF Run II Results

Outline

- Status of the Tevatron
- Status of the CDF detector
- First results with Run II data
- Outlook and conclusions
Tevatron status

- Tevatron operations started in March 2001
  - Luminosity goals for run 2a:
    - $5 \times 10^{31}$ cm$^{-2}$sec$^{-1}$ w/o Recycler
    - $2 \times 10^{32}$ cm$^{-2}$sec$^{-1}$ with Recycler
  - Achieved:
    - $2.2 \times 10^{31}$ cm$^{-2}$sec$^{-1}$ in July '02
    - Now recovered from June shutdown to improve p-bar cooling
    - 54 pb$^{-1}$ delivered until early June
      - 35 pb$^{-1}$ are on tape
      - 10 – 20 pb$^{-1}$ used for analyses shown at this conference (details)

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The Upgraded CDF Detector
The Upgraded CDF Detector

- Major qualitative improvements over Run 1 detector:
  - Whole detector can run up to 132 nsec interbunch
  - New full coverage 7-8 layer 3-D Si-tracking up to $|\eta| \sim 2$
  - New faster drift chamber with 96 layers
  - New TOF system
  - New plug calorimeter
  - New forward muon system
  - New track trigger at Level 1 (XFT)
  - New impact parameter trigger at Level 2 (SVT)

- All systems working well
  - Silicon and L2 took longer to commission
Detector Performance

- Silicon detectors:
  - Typical S/N ~12
  - Alignment in R-\(\phi\) good
    - R-z ongoing

\[\text{Details} \]
Detector Performance

- TOF resolution within 10 –20% of design value
  - Improving calibrations and corrections
Detector Performance

Efficiency curve:
XFT cut at
$P_T = 1.5 \text{ GeV/c}$

- $\Delta p_T / p_T^2 = 1.8\% \text{ (GeV}^{-1})$
- $\Delta \phi = 8 \text{ mrad}$

- XFT: L1 trigger on tracks
- full design resolution

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Detector Performance

8 VME crates
Find tracks in Si in 20 $\mu$s with offline accuracy

- **Secondary VerTex L2 trigger**
  - Online fit of primary Vtx
  - Beam tilt aligned
  - D resolution as planned
    - 48 $\mu$m (33 $\mu$m beam spot transverse size)

Online track impact param.

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Physics with CDF-II

- Use data to understand the new detector:
  - energy scales in calorimeter and tracking systems
  - detector calibrations and resolutions
  - tune Monte Carlo to data

- Use data to do **physics analyses**
  - Real measurement beyond PR plots
  - Quality of standard signatures
  - Rates of basic physics signals
  - Surprisingly some results are already of relevance in spite of the limited statistics

Several CDF presentations made in the parallel sessions
In the following brief/incomplete summary of a lot of work
EM Calorimeter scale

- **638 Z → e⁺e⁻ in 10 pb⁻¹**
  - \( \sigma(M) \sim 4 \text{ GeV} \) FB asymmetry

- **Check Z mass in data and simulation after corrections**
  - **Central region:**
    - Mean: +1.2\% data, -0.6\% sim.
    - Resolution: +2\% simulation
  - **Forward region (Plug):**
    - Mean: +10/6.6\% data, +2.0\% simulation
    - Resolution: +4\% simulation

\[ N_Z = 247 \]
\[ N_Z (W+E) = 391 \]
Measurements with high $E_T^{e\pm}$

- Good modeling of observed $W \rightarrow e\nu$ distributions

**Transverse Energy**

- Data (5547 $W \rightarrow e\nu$ Candidates)
- Signal MC
- QCD Bkg (from Data)
- $W \rightarrow \tau \nu$ MC
- $Z \rightarrow e^+ e^-$ MC

$\int L \sim 10 \text{ pb}^{-1}$

March 2002 - June 2002

CDF Run II Preliminary

**Missing Transverse Energy**

- Data (5547 $W \rightarrow e\nu$ Candidates)
- Signal MC
- QCD Bkg (from Data)
- $W \rightarrow \tau \nu$ MC
- $Z \rightarrow e^+ e^-$ MC

CDF Run II Preliminary

MET resolution from MB data consistent with Run 1

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MET detail
Measurements with high Et e±

W cross section:

- \( \sigma_W \times \text{BR}(W \rightarrow e\nu) \, (\text{nb}) = 2.60 \pm 0.07_{\text{stat}} \pm 0.11_{\text{syst}} \pm 0.26_{\text{lum}} \)

- Consistent with Run 1 results rescaled for higher energy:
  \( 2.72 \pm 0.02_{\text{stat}} \pm 0.08_{\text{syst}} \pm 0.09_{\text{lum}} \)

  (use Sterling et al. NNLO predictions)

Nr. Candidates:
- 5547 in 10 pb⁻¹

Background:
- QCD: 260 ± 34 ± 78
- \( Z \rightarrow e^+ e^- \): 54 ± 2 ± 3
- \( W \rightarrow \tau \nu \): 95 ± 6 ± 1

0.16 soon!
Measurements with high $E_T\mu^\pm$

- Clear evidence of $Z\rightarrow \mu^+\mu^-$
  - Signal shown for OS muons detected in both inner and outer muon chambers

$$\begin{align*}
46.3 \text{ GeV} &amp; \rightarrow \mu_1 \\
2.17 \text{ GeV} &amp; \rightarrow E_T \rightarrow \mu_2 \\
44.8 \text{ GeV} &amp; \rightarrow \mu_2
\end{align*}$$

- 57 candidate events in $66<M_{inv}<116$ range
- $N_Z = 53.2\pm7.5 \pm2.7$

CDF run II preliminary
16 pb$^{-1}$

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Measurements with high \( \text{Et} \) \( \mu^\pm \)

- **W cross section:**
  
  \[
  \sigma_{\text{W}} \times \text{BR}(W \to \mu\nu) \ (\text{nb}) = 2.70 \pm 0.04_{\text{stat}} \pm 0.19_{\text{syst}} \pm 0.26_{\text{lum}}
  \]
  
  Consistent with Run 1 results rescaled for higher energy:
  
  \[
  2.41 \pm 0.08_{\text{stat}} \pm 0.15_{\text{syst}} \pm 0.16_{\text{lum}}
  \]
  (use Sterling et al. NNLO predictions)

- **Nr. Candidates:**
  
  - 4561 in 16 pb\(^{-1}\)

- **Background:**
  
  - QCD: 104 \( \pm \) 53
  - Cosmics: 73 \( \pm \) 30
  - \( Z \to \mu\mu \): 247 \( \pm \) 13
  - \( W \to \tau\nu \): 145 \( \pm \) 10

- **R**
  
  \[ R = \frac{\sigma(W \to \mu\nu)}{\sigma(Z \to \mu\mu)} = 13.66 \pm 1.94_{\text{stat}} \pm 1.12_{\text{syst}} \]
  
  Consistent with Run 1 results
Measurements with low Et \( \mu^\pm \)

- \( \psi \) trigger improved
  - \( p_T^{\mu} > 2.0 \rightarrow 1.5 \text{ GeV} \)
  - \( \Delta\phi > 5^\circ \rightarrow 2.5^\circ \)

- Observed \( \psi \) rates are consistent with expected increase due the lowering of the thresholds

CDF Run II Preliminary

Events: 108777 \( \pm \) 860
15 MeV with Silicon
\( \sigma = 21.6 \text{ MeV} \)

13 pb\(^{-1}\)
No Silicon
100k \( \psi \) only

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Measurements with low Et $\mu^{\pm}$

- Inclusive B lifetime with $\psi$’s
  - Fit pseudo-ctau = $L_{xy} \psi F_{MC} * M_{\psi}/p_{T,\psi}$ distribution
  - Output: b lifetime, fraction of $\psi$ from B
    - $\text{ctau} = 458\pm10$ stat. $\pm11$ syst. $\mu$m
      (PDG: $469\pm4$ $\mu$m)
    - $\psi$ from B = 17% ($p_{T,\psi} > 4$ GeV)

- Resolution function from large prompt component
  - $R = \text{narrow + wide Gaussian (19%)} + \text{exponential tails (1.2%)}$
  - Scale factor on error returned from vertex fit $1.069$

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Measurements with low Et \( \mu^\pm \)

- Use \( \psi \)'s to understand E-loss and B-field corrections
- Check with other known signals

**Graphical Content**

- **CDF Run 2 Preliminary**
  - Add B scale correction
  - Tune missing material \( \sim 20\% \)
  - Correct for material in GEANT
  - Raw tracks

- **Plot of D^0**
  - Before corrections
  - After corrections and fit bias removed
  - PDG \( \pm 1\sigma \)

- **Plot of J/\( \psi \)**
  - Events/30 MeV
  - 1S
  - 2S
  - 3S
Measurements with low Et $\mu^\pm$

- **B masses:**
  - $\psi(2S) \rightarrow J/\psi \pi^+\pi^-$ (control)
  - $B_u \rightarrow J/\psi K^+$ lifetime
  - $B_d \rightarrow J/\psi K_0^*$ ($K_0^* \rightarrow K^+\pi^-$)
  - $B_s \rightarrow J/\psi \phi$ ($\phi \rightarrow K^+K^-$)

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<th>$\sigma$(PDG)</th>
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<td>$\psi(2S)$</td>
<td>3686.43$\pm$0.54</td>
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<td>$B_u$</td>
<td>5280.60$\pm$1.70$\pm$1.1</td>
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<tr>
<td>$B_d$</td>
<td>5279.80$\pm$1.90$\pm$1.4</td>
<td>0.17</td>
<td>4.72</td>
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<td>$B_s$</td>
<td>5360.30$\pm$3.80$\pm$2.10$\pm$2.90</td>
<td>2.10 $\pm$1.81 $\pm$1.81</td>
<td>1.90</td>
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Measurements with jets

- Raw Et only:
  - Jet 1: $ET = 403$ GeV
  - Jet 2: $ET = 322$ GeV

Jet expectations
Raw jet distributions
Hadronic Energy Scale

- Use $J/\psi$ muons to measure MIP in hadron calorimeters
  - $\frac{(\text{Run II})}{(\text{Run 1})} = 0.96 \pm 0.005$

- Gamma-jet balancing
  - $f_b = \frac{(p_T^{\text{jet}} - p_T^{\gamma})}{p_T^{\gamma}}$
    - Run Ib (central): $f_b = -0.1980 \pm 0.0017$
    - Run II (central): $f_b = -0.2379 \pm 0.0028$
  - Plug region corrections in progress

$\Delta f_b = (4.0 \pm 0.4)\%$

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Measurements with jets

● Jet shapes:
  ➢ Narrower at higher $E_T$
  ➢ Calorimeter and tracking consistent
  ➢ Herwig modeling OK

CDF RUN II Preliminary (16 pb$^{-1}$)

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16 pb$^{-1}$ used for this study
Measurements with hadronic b triggers

- **L2 trigger on 2 tracks:**
  - $p_T > 2$ GeV
  - $|D| > 100$ μm (2 body)
  - $|D| > 120$ μm (multibody)

- Swamped by D mesons!
  - But see B’s as well….

CDF Run 2 preliminary

$D^0 \rightarrow K \pi$

$N_D = 56320$

10 pb$^{-1}$

$D_s^+ - D^+$ mass difference

- Both $D \rightarrow \phi \pi$ ($\phi \rightarrow KK$)
- $\Delta m = 99.28 \pm 0.43 \pm 0.27$ MeV
  - PDG: $99.2 \pm 0.5$ MeV
- Systematics dominated by background modeling

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Measure ratios of CKM suppressed decays

- $\Gamma(D \to KK)/\Gamma(D \to K\pi) = (11.17\pm0.48\pm0.98)\%$ (PDG: $10.84\pm0.45$)
  - Main systematics (8%): background modeling
- $\Gamma(D \to \pi\pi)/\Gamma(D \to K\pi) = (3.37\pm0.20\pm0.16)\%$ (PDG: $3.76\pm0.20$)
  - Main systematics (4%): relative acceptance

CDF Run 2 preliminary

Signal: 5670
$D^0 \to KK$

L = 10 pb$^{-1}$

Signal: 2020
$D^0 \to \pi\pi$

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Measurements with hadronic b triggers

D mesons:

What fraction from B?

- \( D^0 \): 16.4-23.1%
- \( D^{*+} \): 11.4-20.0%
- \( D^+ \): 11.3-17.3%
- \( D_s^+ \): 34.8-37.8%

Range of fract. from B using two extreme resolutions functions:
- single gaussian
- parametrization from \( K^0_S \) sample

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Measurements with hadronic b triggers

**B → h⁺ h⁻**

- Hadronic B decays observed
  - Yield lower than expected (*silicon coverage/SVT efficiency > x 3*)
  - S/N better than expected
    - Better S/N dilution compensates reduced statistics

---

**CDF Run II Preliminary**

- L = 11 pb⁻¹, 18 June 2002
- **B → h⁺ h⁻**
  - 33±9 signal events
  - Mean 5.215±0.013 GeV/c²
  - Width 0.053±0.011 GeV/c²

**CDF Run II Preliminary**

- L = 10 pb⁻¹
- **B⁺ → D⁰ π⁺**
  - #B⁺ = 56±12
Conclusion

- The CDF detector is fully functional and accumulating proton anti-proton data
- Tevatron is moving toward reaching performance goals
- Understanding of detector is advanced
- Many early physics results
  - sometimes competitive in spite of limited statistics
- Ready to exploit full Tevatron potential as luminosity increases

CDF is back!
Backup slides

- Tevatron plans
- Silicon detector performance
- Trigger and DAQ details
- Data sample
- Talks in parallel sessions
- \( Z \rightarrow e^+e^- \) FB asymmetry
- \( W \rightarrow e\nu \) selection details
- \( W \rightarrow \mu\nu \) details
- \( W \rightarrow \tau\nu \)
- MET resolution
- \( B \) mass plots
- \( B^+ \) lifetime
- Semileptonic B’s
- Jet expectations
- Jet raw Et distributions
Tevatron status

- **Short term plans:**
  - Run until October
    - Reach goal w/o Recycler: $5 \times 10^{31}$ cm$^{-2}$sec$^{-1}$
  - 1-2 months shutdown
    - Complete Recycler work
  - Commission and integrate Recycler during 2003
    - Mostly in parallel with Tevatron colliding beam operation
  - Expect 100 – 200 pb$^{-1}$ delivered in 2002 ~ Run 1 data set
Detector Performance

- **Commissioning:**
  - L00 > 95%
  - SVXII > 90%
  - ISL > 80%

Completing cooling work

- % of silicon ladders powered and read-out by silicon system vs. time

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**Detector Performance**

- **Trigger:**
  - Goal rates for $L = 2 \times 10^{32}$
    - $L1/L2/L3 = 50,000/300/50$ Hz
  - Typical now for $L \sim 10^{31}$
    - $L1/L2/L3 = 6,000/240/30$ Hz

- **DAQ**
  - Logging data at the planned rate of $\sim 20$ Mbyte/sec

- **Offline:**
  - Data is reconstructed in quasi real time on a dedicated production farm

---

**Dataflow of CDF “Deadtimeless” Trigger and DAQ**

- **Level 1:**
  - 7.6 MHz Synch. pipeline
  - 5544 ns latency
  - <50 kHz Accept rate

- **Level 2:**
  - Asynch. 2 stage pipeline
  - $\sim 20 \mu$s latency
  - 300 Hz Accept Rate

- **L1 + L2 rejection:** 20,000:1
Data Sample

- Stable physics trigger table established since January ’02

- Summary of data used for this conference:
  - Data period: January – June, 2002
  - Delivered luminosity: 33.0 pb\(^{-1}\)
  - Live (to-tape): 23.5 pb\(^{-1}\)
  - “Good runs”: 23.3 pb\(^{-1}\)
  - “Good runs” with all systems \(\sim 10.0\) pb\(^{-1}\) (cfr. 110 pb\(^{-1}\) Run 1)

- Radiation induced COT/SVX VME power supply failures (fixed!)
- Instabilities in Silicon readout (much improved)
CDF-II results in parallel sessions

- **Electroweak, session 4:**
  - Prospects for EW physics in Run 2 (D. Glenzinski)
  - W boson cross section and decay properties (K. Bloom)

- **QCD, session 5:**
  - Jet and gamma physics (J. Dittmann)
  - Heavy Flavor at CDF (C. Paus)

- **Heavy Quark, session 8:**
  - First results with a hadronic trigger (A. Cerri)

- **New Phenomena, session 10:**
  - MSSM Higgs at the Tevatron (A. Connoly)
  - CHAMP searches (B. Orejudos)

- **R&D, session 13:**
  - Calorimetry (R. Erbacher)
  - Tracking (S. Nahn)
Measurements with high Et e±

Uncorrected $Z \rightarrow e^+e^-$ angular distributions and asymmetries

Measurements compared with Pythia/CTEQ5L prediction

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Measurements with high Et e±

- Clear evidence for $W \rightarrow e\nu$ signal
  - Isolated central electron
  - $Et > 25$ GeV, $Et > 25$ GeV
Measurements with high Et $\mu^\pm$

- Good modeling of observed $W \rightarrow \mu \nu$ distributions
- Measure $\sigma(W \rightarrow \mu \nu)$ and $R = \sigma(W \rightarrow \mu \nu)/\sigma(Z \rightarrow \mu \mu)$

CDF Run II  
16 pb$^{-1}$  
*preliminary*

Longitudinal beam profile

entries per 2 GeV

met

transverse missing energy (GeV)

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**Evidence for typical \( \tau \) decay multiplicity in \( W \rightarrow \tau \nu \) selections**

\( W \rightarrow \tau \nu \) : number of tracks, associated with the \( \tau \) candidate

CDF Run II Preliminary, \( \int L \approx 15 \text{ pb}^{-1} \)
Minimum bias events

- Run 1: $0.53/\sqrt{\sum Et}$ with forward cal. Use $|\eta|<4.2$
- Run II: $0.60/\sqrt{\sum Et}$ with plug only $|\eta|<3.6$
  - With miniplug $|\eta|<5.5$

**Chi2 / ndf = 100.3 / 34**
Prob = 1.11e-09
p0 = -0.1109 ± 0.01549
p1 = 0.6095 ± 0.004244

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Measurements with low Et $\mu^\pm$

- More mass plots:
  - Bd, Bs

![Mass plots for Bd $\rightarrow \psi K^{*0}$ and Bs $\rightarrow \psi \phi$]
Measurements with low Et \( \mu^\pm \)

- **B^+ lifetime:**
  - \( B^+ \to J/\psi K^+ \)
  - **Fit results:**
    - \( c\tau = 446^{+43}_{-30} \pm 13 \) \( \mu \)m
    - \( (\Delta \text{PDG/}\sigma = 1.2) \)
    - Res. scale factor 1.16
    - Conservative systematic error

\( # B^+ \sim 154 \)
Measurements with inclusive leptons

- Find large samples of semileptonic B decays

CDF Run II Preliminary

\[ L = 11.5 \text{ pb}^{-1} \]

\[ B \rightarrow l \nu D^* X \ (l = e \text{ or } \mu) \]
\[ \rightarrow D^0 \pi \]
\[ \rightarrow K \pi \]

Right sign
Wrong sign

CDF Run II Preliminary

\[ L = 11.5 \text{ pb}^{-1} \]

\[ B \rightarrow l \nu D^0 X \]
\[ \rightarrow K \pi \]

Right sign
Wrong sign

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Measurements with jets

- Expectations:
  - Increase max. energy reach
  - Study both central and forward
    - New physics is mostly central
    - Pdf’s affect both regions

- Current work:
  - Accumulate large samples
  - Understand energy corrections
    - E-scale, jet shapes, MC tuning

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Measurements with jets

- Jet distr. from data
  - Raw $E_T$
  - Each trigger rescaled for pre-scale factor

**Leading Jet ET in CDF Jet Events**
CDF Run 2 Preliminary (12/14/2001 - 6/2/2002) 25.6 pb-1

Fixed cone algorithm: $R = 0.7$