the CDFII Collaboration

490 physicists from 41 institutions representing 8 countries

CDF physicists

US

Canada 3%

Taiwan 3%

Germany 2%

Japan 9%

Italy 20%

SUSY02, DESY Hamburg

Carmine Elvezio Pagliarone
Fermilab Tevatron Collider

Main Injector and Recycler

Booster

$p$ source

SUSY02, DESY Hamburg

Carmine Elvezio Pagliarone
The Fermilab Accelerator Complex

- Main Injector (150 GeV proton storage ring) replaces Main Ring (the original accelerator);
- Completely revamped stochastic cooling system for antiprotons;
- A new permanent magnet Recycler storage ring for antiprotons;
- Increased number of p and p-bar bunches: $6 \rightarrow 36$ (396 ns) $\rightarrow$ ~100 (132 ns)
- Higher center of mass energy 2 TeV achieved increasing the beam Energies $900 \rightarrow 980$ GeV
Tevatron Collider Improvements

\[ L = \frac{3 \gamma_r f_0}{\beta^*} N_B N_p \]

Total Antiprotons

\[ p \text{ per bunch} \]

Physics Opportunities

- Top
- Higgs
- QCD
- Electroweak
- B Physics
- New Phenomena

<table>
<thead>
<tr>
<th></th>
<th>Run 1b</th>
<th>Run 2a</th>
<th>Run 2b</th>
</tr>
</thead>
<tbody>
<tr>
<td>#bunches</td>
<td>6x6</td>
<td>36x36</td>
<td>140x103</td>
</tr>
<tr>
<td>( \sqrt{s} ) (TeV)</td>
<td>1.8</td>
<td>1.96</td>
<td>1.96</td>
</tr>
<tr>
<td>typ L (cm(^{-2})s(^{-1}))</td>
<td>1.6x10(^{30})</td>
<td>8.6x10(^{31})</td>
<td>5.2x10(^{32})</td>
</tr>
<tr>
<td>( \int L dt ) (pb(^{-1})/week)</td>
<td>3.2</td>
<td>17.3</td>
<td>105</td>
</tr>
<tr>
<td>bunch xing (ns)</td>
<td>3500</td>
<td>396</td>
<td>132</td>
</tr>
<tr>
<td>interactions/xing</td>
<td>2.5</td>
<td>2.3</td>
<td>4.8</td>
</tr>
</tbody>
</table>
Tevatron Run I History

Discovered: top, B_c, diffractive...
Measured: M_W, M_{top}, \sigma(t), \sin 2\beta, ...

L_{tot} = 110 \text{ pb}^{-1}
\sqrt{s} = 1.8 \text{ TeV}
Run II Luminosity Expectations

Run I (Oct 92 → Feb 96) ~ 120⁻¹ pb/Detector

Tevatron Run 1 Luminosity

\[ \sqrt{s} = 2 \text{TeV} \]

~ 1 yr to get x 10
Steady progress after that...

0.1 fb⁻¹

2 fb⁻¹ 15 fb⁻¹

5 \times 10^{32} \text{cm}^{-2} \text{s}^{-1}

2 \times 10^{32} \text{cm}^{-2} \text{s}^{-1}
Recent Machine Performance

- **Peak luminosity still low but improving**
  - X2 since January 2002
  - Best $2\times10^{31}$

- **Delivered/on tape**
  - 40/25 pb$^{-1}$

**Near Term**
- > 60 pb$^{-1}$ by July shutdown
- > 100 pb$^{-1}$ by end of 2002
Short term Luminosity Prospects

- Massive effort put into understanding and improving Luminosity
  - Fixed Accumulator → MI optics
  - Much work on stabilizing tunes in injection and low beta squeeze
  - Fight large antiproton emittances
  - Work on accumulator lattice to reduce beam heating
    - Access early June to add transverse cooling to accumulator is expected to improve L by factor 2-4
    - Max luminosity achievable without Recycler ~8x10^{31} (maybe by the end of 2002)

- Need recycler to get to 2x10^{32}
  - Major shutdown in October ’02 to finish Recycler work
  - Full benefits of Recycler ~Summer 2003
- Endplug Calorimeter
- Tracking
  - Layer 00
  - SVX II
  - ISL
  - COT
- Front End Electronics
- Trigger (pipelined)
- DAQ System
- Muon Systems
- Luminosity Monitor
- TOF
- Offline Software

CDF II

SUSY02, Hamburg

Carmine Elvezio Pagliarone
The CDFII Tracking System

• **Central Outer Tracker (COT):**
  - open cell drift chamber
  - maximum drift time 100ns
  - Small cell size, Fast gas
  - single hit resolution ~200 µm
  - excellent pattern recognition
  - improved stereo capabilities

• **Silicon Tracker System:**
  - increased z coverage (length ~ 1m)
  - η coverage up to | η | < 2
  - **3-D** track reconstruction
  - impact parameter resolution
    - \( \sigma_{\phi} < 30 \) µm
    - \( \sigma_{z} < 60 \) µm

• 3 different detectors: ≈750,000 channels
  - **L00:** inner most, \( R = 2.5 \) cm, rad-hard, SS
  - **SVXII:** 5 layers, 3<R<10 cm, DS (90 and sas)
  - **ISL:** 2 layers, 10<R<20 cm and large η, DS

**Trigger System:** two main improvements
- XFT: track reconstruction at L1
- SVT: displaced track triggering at L2
Run II detector improvements

- Improved z coverage of Silicon tracker ⇒
  +50% of Run I geometrical acceptance (top)

- 3D vertexing capabilities ⇒
  better fake rejection

- Track reconstruction can be extended to
  1<\eta<2 ⇒ several major effects:
  - b-tagging (recover ~30% of b’s in tt events)
  - lepton ID (electrons in Plug calorimeter)

- Increased muon system acceptance by 12% ⇒
  affects trigger, ID and SLT efficiency

<table>
<thead>
<tr>
<th>Efficiencies (%)</th>
<th>Run I</th>
<th>Run II</th>
</tr>
</thead>
<tbody>
<tr>
<td>SVX(b-jet)</td>
<td>44</td>
<td>65</td>
</tr>
<tr>
<td>SLT(b-jet)</td>
<td>13</td>
<td>13</td>
</tr>
</tbody>
</table>
**CDF-II Status**

- **Detector:**
  - All systems installed and commissioned;

- **DAQ and trigger:**
  - Running physics trigger table with > 100 trigger paths since Feb ’02
    - New SVT very successful
  - Typical running conditions:
    - \( L1: 3.5 \text{KHz} \), \( L2: 200 \text{Hz} \), \( L3: 20 \text{Hz} \)

- **Data processing:**
  - Reconstruction farm keeps up with data logging
  - Physics groups skim data:
    - Observe signals from low and high \( P_T \) triggers: \( \psi, D, B, W, Z \)
Run I Successes

CDF B Lifetimes

- $\tau(B^0) = 1.51 \pm 0.05$ ps
- $\tau(B^+) = 1.66 \pm 0.05$ ps
- $\tau(B_s^0) = 1.36 \pm 0.10$ ps
- $\tau(A^0) = 1.32 \pm 0.17$ ps
- $\tau(B_s^+) = 0.46 \pm 0.17$ ps
- $\tau(B^+)/\tau(B^0) = 1.09 \pm 0.05$

CDF $\Delta m_d$ Results

- $D^+_{lep} / SST$:
  - $0.471 \pm 0.070 \pm 0.086 \pm 0.034$ ps
- $D^+_{lep} / Q_{lep}$:
  - $0.500 \pm 0.052 \pm 0.043$ ps
- $e / \mu$:
  - $0.450 \pm 0.045 \pm 0.051$ ps
- $\mu / \mu$:
  - $0.503 \pm 0.064 \pm 0.071$ ps
- $D^+_{lep} / \Delta m_d$:
  - $0.516 \pm 0.099 \pm 0.023 \pm 0.035 \pm 0.035$ ps
- $D^+ / \Delta m_d$:
  - $0.562 \pm 0.068 \pm 0.041$ ps
- Average:
  - $0.495 \pm 0.026 \pm 0.025$ ps

W Mass Measurement

CDF(1B) Preliminary

$W \rightarrow ev$

$\chi^2/df = 82.6/70$ ($50 < M_T < 120$)

$\chi^2/df = 32.4/35$ ($65 < M_T < 100$)

$M_W = 80.473 \pm 0.065$ (stat) GeV

Backgrounds

KS(prob) = 16%

Top quark discovery (CDF&D0)

- 186.0 $\pm$ 12.8 GeV/c$^2$ Dilepton
- 176.1 $\pm$ 7.4 GeV/c$^2$ Lepton+jets
- 176.1 $\pm$ 7.4 GeV/c$^2$ Combined
- 186.4 $\pm$ 12.8 GeV/c$^2$ Dilepton
- 173.3 $\pm$ 7.8 GeV/c$^2$ Lepton+jets
- 172.3 $\pm$ 7.1 GeV/c$^2$ Combined

CDF preliminary

- HAD
- SVX
- SLT
- DIL
- Combined

Theory (4.7 - 5.9)

D0

- L+j (top)
- L+j (4.7)
- HAD
- Combined

SUSY02, DESY Hamburg

Carmine Elvezio Pagliarone
Run II Physics Highlights

- **Study Electroweak Symmetry Breaking**
  - Precision EW Measurements
    - Precise $M_W$ measurement ($10^7$ (IIa) - $10^8$ (IIb) events);
    - Better $M_{top}$ measurement ($10k$ (IIa) - $75k$ (IIb) events - $\Delta M_{top} \approx 2-3$ GeV/$c^2$);
    - Better top Cross Section Measurement ($\Delta \sigma(tt) \approx 8\%$);
    - Investigation of the Top properties;
  - Direct Searches for EWSB mechanisms
    - the Standard Model Higgs
    - SUSY

- **Searches for New Phenomena**
  - SUSY;
  - Large Extra Dimensions;
  - QCD tests: probe distance scales below 1 milli fermi;

- **Study CP Violation and the CKM Matrix**
  - $X_s$ Measurement (up to $\sim 60$);
  - $\sin 2\beta$ Measurement, $+\alpha, \gamma$
    - CP violation using $B \rightarrow J/\psi K_s^0$ ($B \rightarrow J/\psi K_S \rightarrow \mu\mu K_S$ 15k(IIa) - 100k (IIb))
    - CP violation using $B \rightarrow \pi^+ \pi^-$
  - Rare Decays: e.g. $B^+ \rightarrow \mu\mu K^+$
Beginning to look at Physics

• Electroweak:
  - $Z \rightarrow ee, \mu\mu$ Samples;
  - $W \rightarrow e\nu$ and $W \rightarrow \mu\nu$ Samples;
  - $W \rightarrow \tau\nu$ better samples from better $\tau$-ID;

• Top Physics
  - First top candidates;
  - top in dilepton will be done first
    - No $b$-tag is necessary;
    - Smaller backgrounds.

• Bottom/Charm Physics
  - Reconstruction of $B$ mesons;
  - Reconstruction of Charms
  - Beginning to develop analysis tools, look at rates
$Z \rightarrow e^+ e^-, \mu^+ \mu^-$ Candidates

CDF Run II Preliminary

Luminosity:
$\sim 8$ pb$^{-1}$

Date:
2001.12.7
$\sim$ 2002.3.2

231 Events

$M_{ee}$ (GeV/c$^2$)

CDF Preliminary

$Z \rightarrow \mu^+ \mu^-$

$\sim 6$ pb$^{-1}$

$M_{\mu\mu}$ (GeV)

Central - Central
$Z \rightarrow e^+ e^-$ candidates

Central - Plug
$Z \rightarrow e^+ e^-$ candidates

Plug - Plug
$Z \rightarrow e^+ e^-$ candidates

SUSY02, DESY Hamburg

Carmine Elvezio Pagliarone
$W \rightarrow e\nu$ and $W \rightarrow \mu\nu$ Candidates

- **Inclusive Electrons**
  - $W \rightarrow e\nu$ candidates
  - 1955 events
  - $(E_T > 20$ GeV, MET > 20 GeV)

  $\int L = 3.3$ pb$^{-1}$
  - December 2001-January 2002

- **$E_T$ vs. MET of $W \rightarrow e\nu$ candidates**
  - Nent = 1955

- **Isolation Fraction vs. MET**
  - $W \rightarrow e\nu$ signal region
    - Isolation Fraction < 0.1
    - MET > 20 GeV

- **$M_T$ of $W \rightarrow e\nu$ candidates**
  - Nent = 1955

  $\int L = 3.3$ pb$^{-1}$
  - December 2001-January 2002

- **$W \rightarrow \mu\nu$**
  - Stream A data
    - Nent = 349
    - Mean = 68.33
    - RMS = 14.46
  - MC data
    - Nent = 1678
    - Mean = 67.59
    - RMS = 13.19
$W \rightarrow \tau\nu$ Candidates

Very clean tau samples:

- Increased detector performances
- better tau ID algorithms:

*SUSY02, DESY Hamburg*

Carmine Elvezio Pagliarone
**Top dielectron candidate**

\[ t\bar{t} \rightarrow e^+ e^- j^1 j^2 + E_{T} \]

- **Run= 136286 - Event= 54713**

\[ E_{T}(e^+) = 73 \text{ GeV} \]
\[ E_{T}(e^-) = 56 \text{ GeV} \]
\[ \text{MET} = 43 \text{ GeV} \]
\[ E_{T}(\text{jet}^1) = 35 \text{ GeV} \]
\[ E_{T}(\text{jet}^2) = 34 \text{ GeV} \]

- **pass Run I dielectron Analysis cuts:**
- **Displaced vertex as expected from the b’s:**

\[ e^+: E_{T}=73 \text{ GeV} \]
\[ e^- : E_{T}=56 \text{ GeV} \]
\[ \text{Jet1: } E_{T}=35 \text{ GeV} \]
\[ \text{Jet2: } E_{T}=34 \text{ GeV} \]
\[ \text{Missing Et } = 43 \text{ GeV} \]
\[ \text{Mass (e-e+) } = 118 \text{ GeV} \]
A clear $J/\psi$ signal:

- Improved $J/\psi$ yield (factor 2-3 over Run I);
- **CMU or CMX Muons:**
  - Sample of 60,492 $J/\psi$;
  - cross section as expected (~9nb);
  - $\Gamma = 21.6 \pm 0.1$ MeV/c$^2$;
  - $\Gamma \approx 16$ with SVX II;

**First checks on physics:**

- Inclusive $B$ lifetime from $J/\psi$
  consistent with expectations:
  - $ct_B \sim 470$ mm (unbinned fit)
  - Systematics still out of control!
- **Prompt $\psi$ fraction $\sim 85\%$**
  - Consistent with lower $p_T$ cut relative to Run I;

CDF Run 2 Preliminary, 5 pb$^{-1}$, 27 Feb 2002

SUSY02, DESY Hamburg

Carmine Elvezio Pagliarone
First $B_u$, $B_d$, $B_s$ signals

$B^\pm$ Mesons ($L \approx 11 \text{ pb}^{-1}$)
- Selection cuts
  - $L_{xy} > 0$
  - $P_T(B) > 6.0 \text{ GeV/c}$
  - Vertex quality cuts

$B_s$ Mesons ($L \approx 11 \text{ pb}^{-1}$)
- Selection cuts
  - $L_{xy} > 0$
  - $P_T(B) > 5.0 \text{ GeV/c}$
  - Vertex quality cuts
  - Mass window on $\Phi$

SUSY02, DESY Hamburg

Carmine Elvezio Pagliarone
**Side Effects: Lots of Charms from SVT...**

**CDF Run II preliminary**

\[ D^+, D_s \rightarrow \phi \pi, \phi \rightarrow KK \]

**Num. events / 5 MeV**

<table>
<thead>
<tr>
<th>Pi</th>
<th>1.80</th>
<th>1.85</th>
<th>1.90</th>
<th>1.95</th>
<th>2.00</th>
<th>2.05</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>10</td>
<td>20</td>
<td>30</td>
<td>40</td>
<td>50</td>
<td>60</td>
</tr>
</tbody>
</table>

**Feb '02, Luminosity 1.05 pb\(^{-1}\)**

**CDF Run II preliminary (2/25/02)**

\[ D^+ \rightarrow KK \pi \pi \]

**750 nb\(^{-1}\)**

**Feb/26/2002**

\[ D^0 \rightarrow KK \]

**Events per 5 MeV/c\(^2\)**

<table>
<thead>
<tr>
<th>Mass (GeV/c(^2))</th>
<th>1.75</th>
<th>1.80</th>
<th>1.85</th>
<th>1.90</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>100</td>
<td>200</td>
<td>300</td>
</tr>
<tr>
<td>400</td>
<td>300</td>
<td>200</td>
<td>100</td>
<td>0</td>
</tr>
</tbody>
</table>

**CDF Run 2 Preliminary**

**E791 Focus**

- Large charm yield
- Poor particle ID
- Trigger bias
- Prompt and secondary charm

**Charm Studies in progress:**

- Understanding best use of the sample
- Cross section
- Ratio of direct versus B produced
- Rare decays
- CP Violation

**SUSY02, DESY Hamburg**

Carmine Elvezio Pagliarone
TOF System Performance

- **110 ps of average resolution**
  (from preliminary calibration)
- **Getting close to 100 ps goal:**

SUSY02, DESY Hamburg

---

TOF + track informations

- $p(K^+)<1.5$ GeV/c (no PID)
  - $N(q) = 2354 \pm 325$
  - $N(bkg) = 93113$

- $p(K^+)<1.5$ GeV/c + PID
  - $N(q) = 1942 \pm 93$
  - $N(bkg) = 4517$

Cut on TOF info


- $p$, $d$, $K$, $\pi$
Conclusions

- **CDF Detector is working well:**
  - **Trigger:** All of L1, much of L2;
  - **Detector:** All major systems are working;
  - **Offline:** All major parts are working;

- **(still) Some concern because:**
  - Tevatron Collider Luminosity is still too low;
  - L00 is still working on pedestal problems;
  - SVX coverage is still not complete (for trigger performance)

- **Started to look at Physics**
  - Reconstruction of bottom/charm, investigation of tools (TOF, vertexing, etc)
  - W's, Z's, and top candidates

- **Luminosity Expectations**
  - Possibly 100-200 pb⁻¹ by end 2002, 2fb⁻¹ by 2004