Present Status of Physics at Tevatron/CDF
&
Prospect with Higher Luminosity

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for
CDF Collaboration

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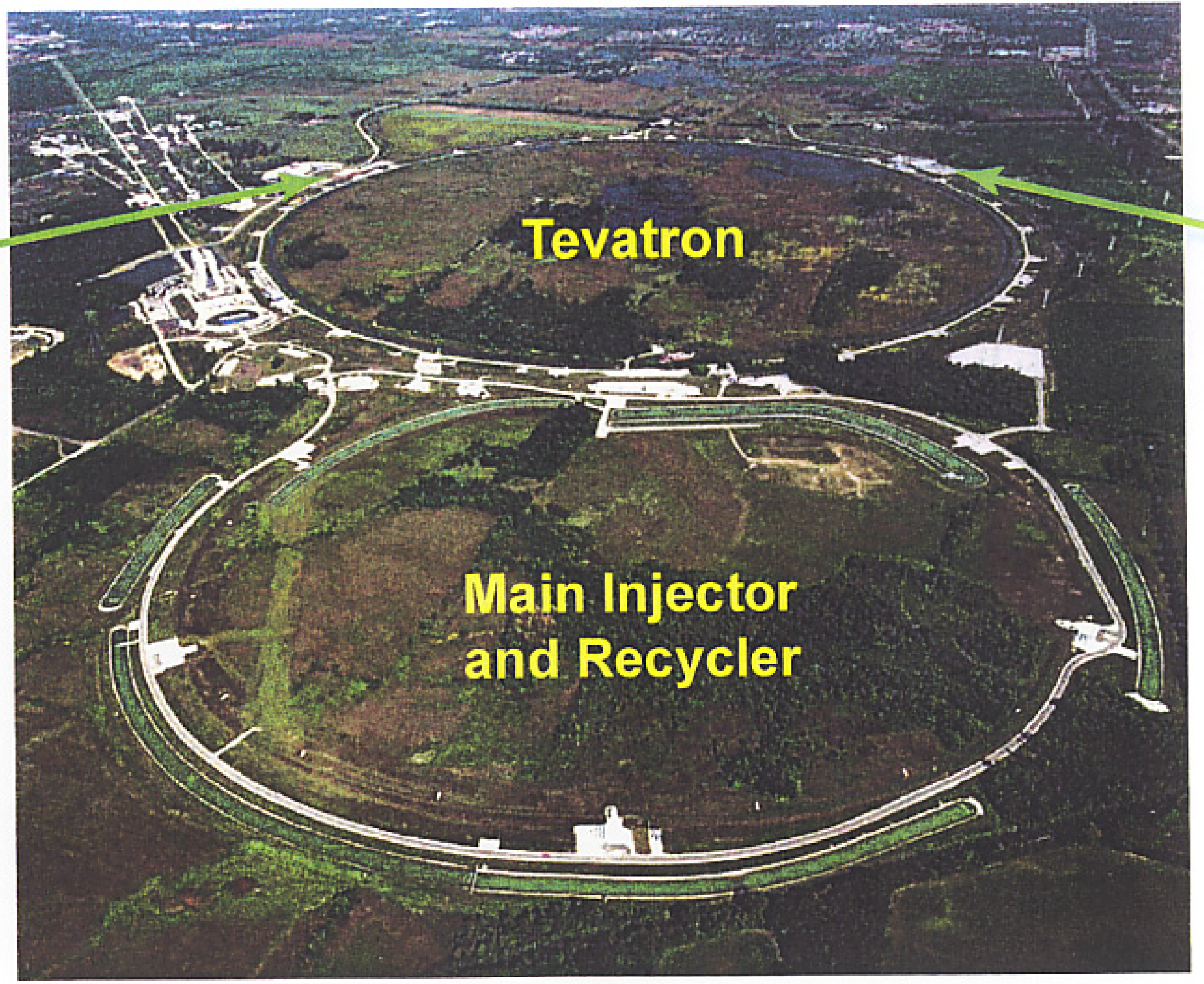
Tevatron/CDF Run 2 Upgrade
Present Status
Preliminary Physics Results
Future Prospects

Fermilab Accelerator Complex



Fermilab Accelerator Complex (2)

Tevatron Run 2 Upgrade

- Higher Energy Collisions $\sqrt{s}$ = 1.8 TeV $\rightarrow$ 1.96 TeV
- Increased number of p and $\bar{p}$ bunches 6 x 6 $\rightarrow$ 36 x 36
- Shorter bunch spacing 3.5 μs $\rightarrow$ 396 ns
- Newly built $\begin{cases} \text{150 GeV Main Injector} \\ \text{8 GeV Recycler} \end{cases}$

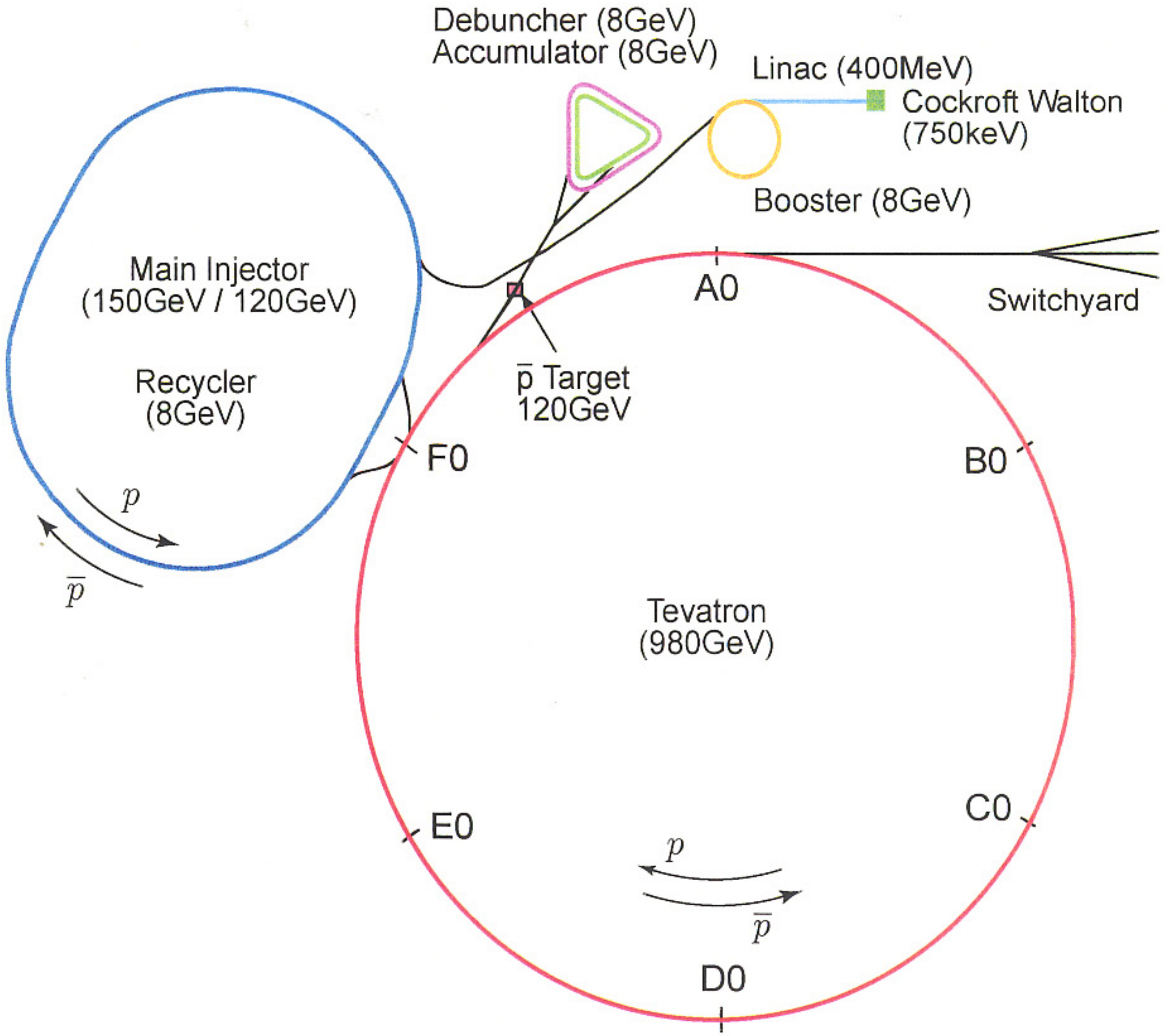
  for increasing luminosity at Tevatron

Fermilab Accelerator Complex (3)

- Cockroft-Walton (750keV)
- Linac (400MeV)
- Booster (8GeV)
- Main Injector
  (120GeV for p-bar production)
  (150GeV for injection to Tevatron)
- Debuncher (8GeV)
- Accumulator (8GeV)
- Recycler (8GeV)

} for p-bars

- Tevatron (980GeV)



Tevatron Status

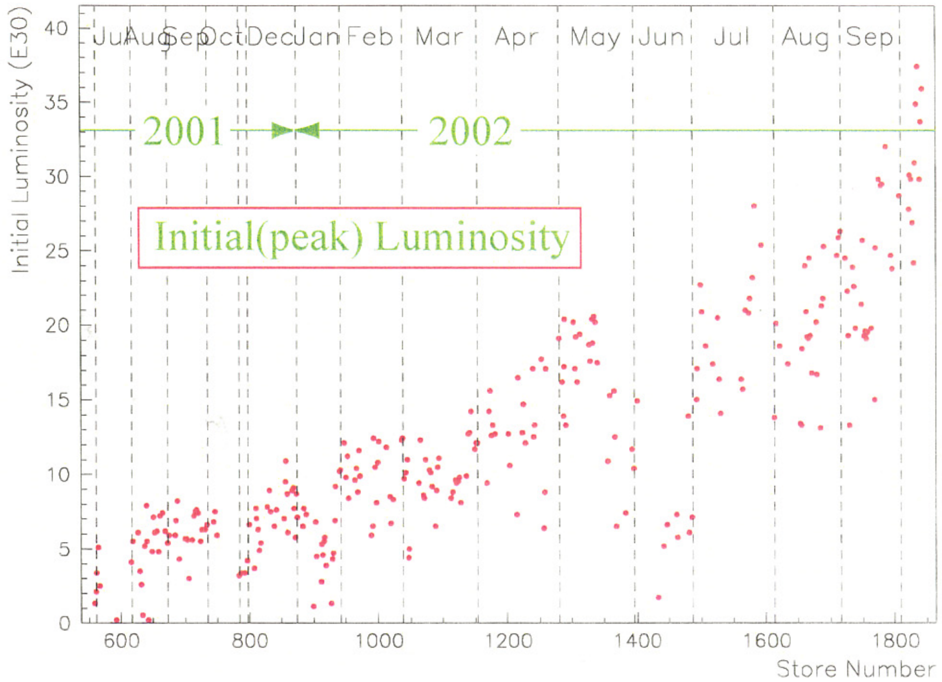
Tevatron Run 2 operation started in March 2001

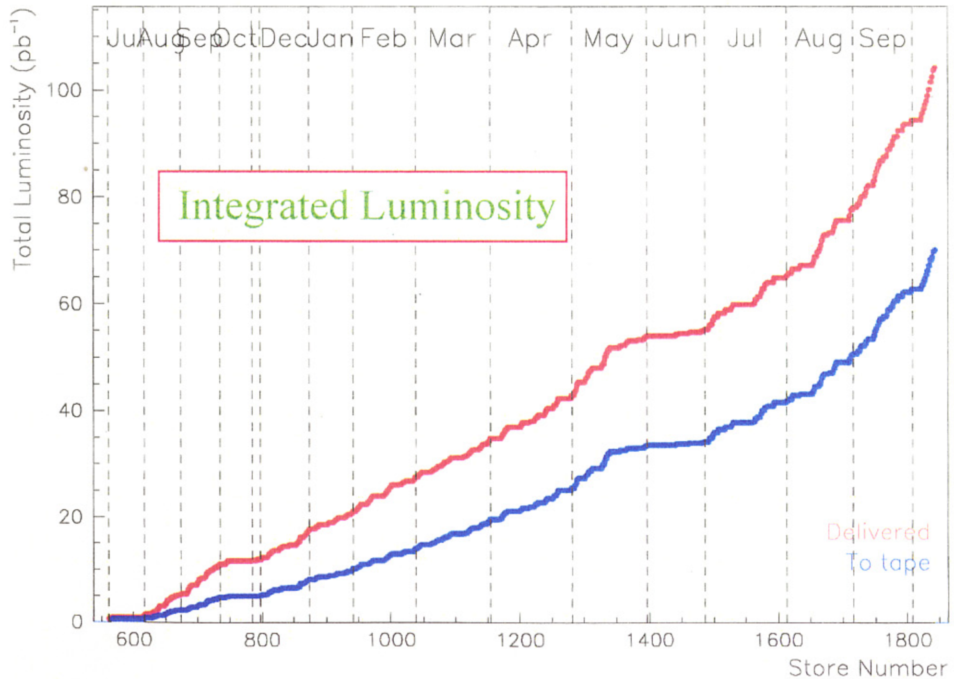
Present Status

- Now achieving typical peak luminosity of $2.5 \sim 3 \times 10^{31}\ cm^{-2}\ s^{-1}$
- $100\ pb^{-1}$ delivered, $70\ pb^{-1}$ recorded

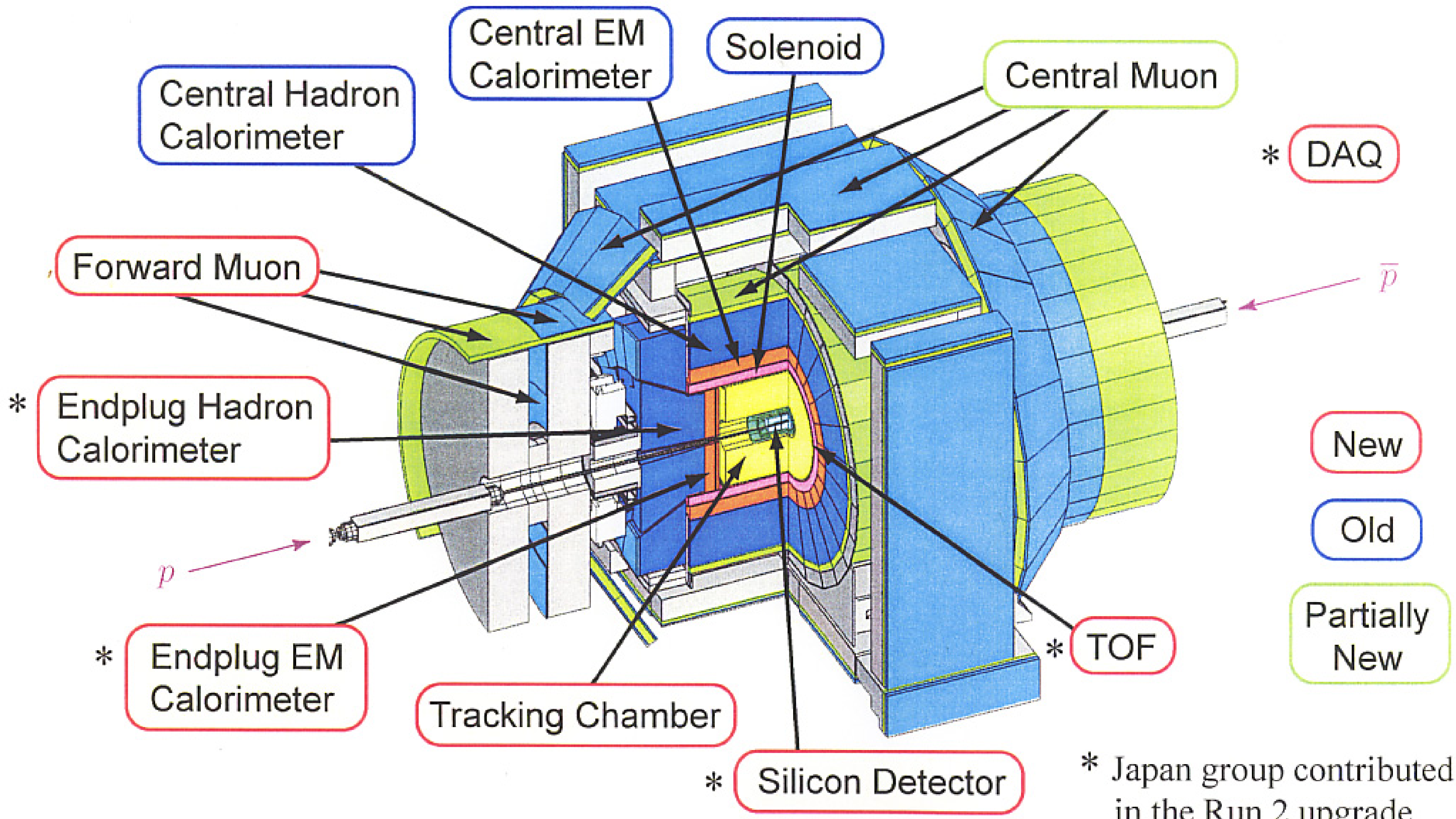
Luminosity goals for Run 2a

- $5 \sim 8 \times 10^{31}\ cm^{-2}s^{-1}$ w/o Recycler
  $2 \times 10^{32}\ cm^{-2}s^{-1}$ with Recycler
- Integrated luminosity of $2\ fb^{-1}$





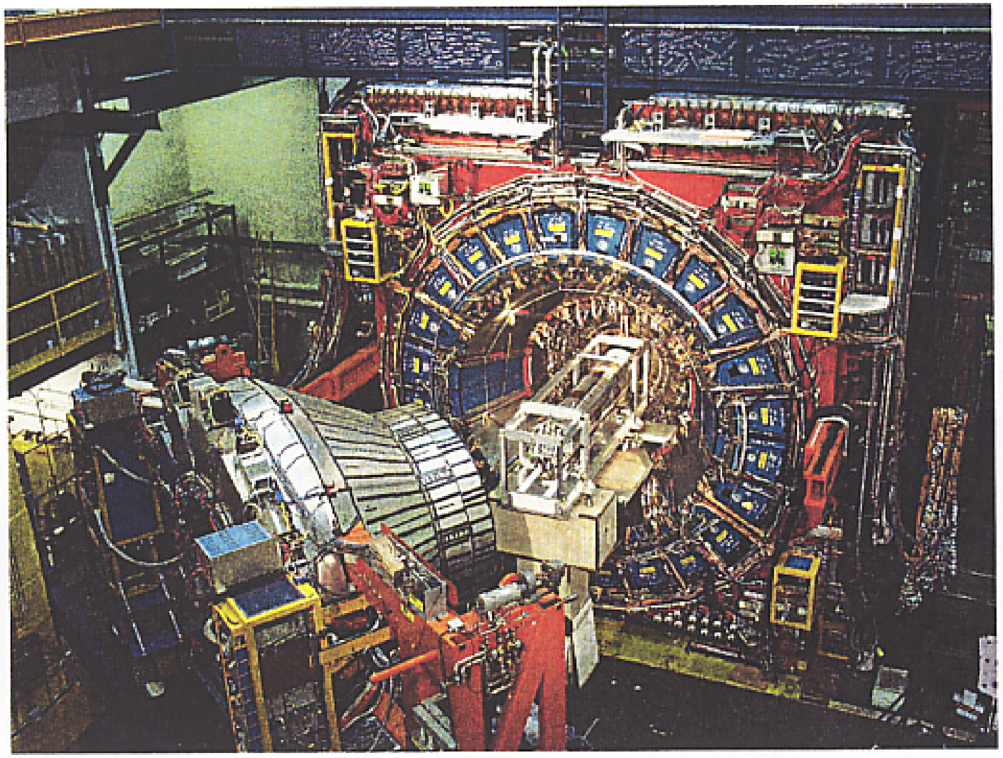
CDF II Detector



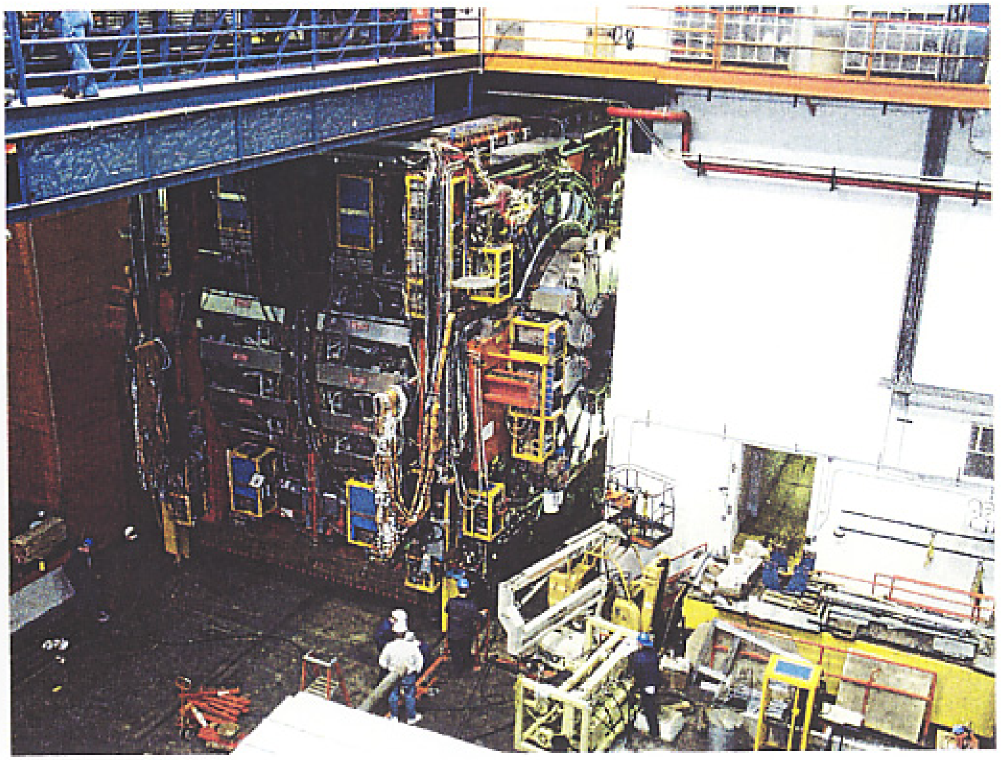
* Japan group contributed in the Run 2 upgrade

CDF II Detector (2)

Installing Silicon Detectors



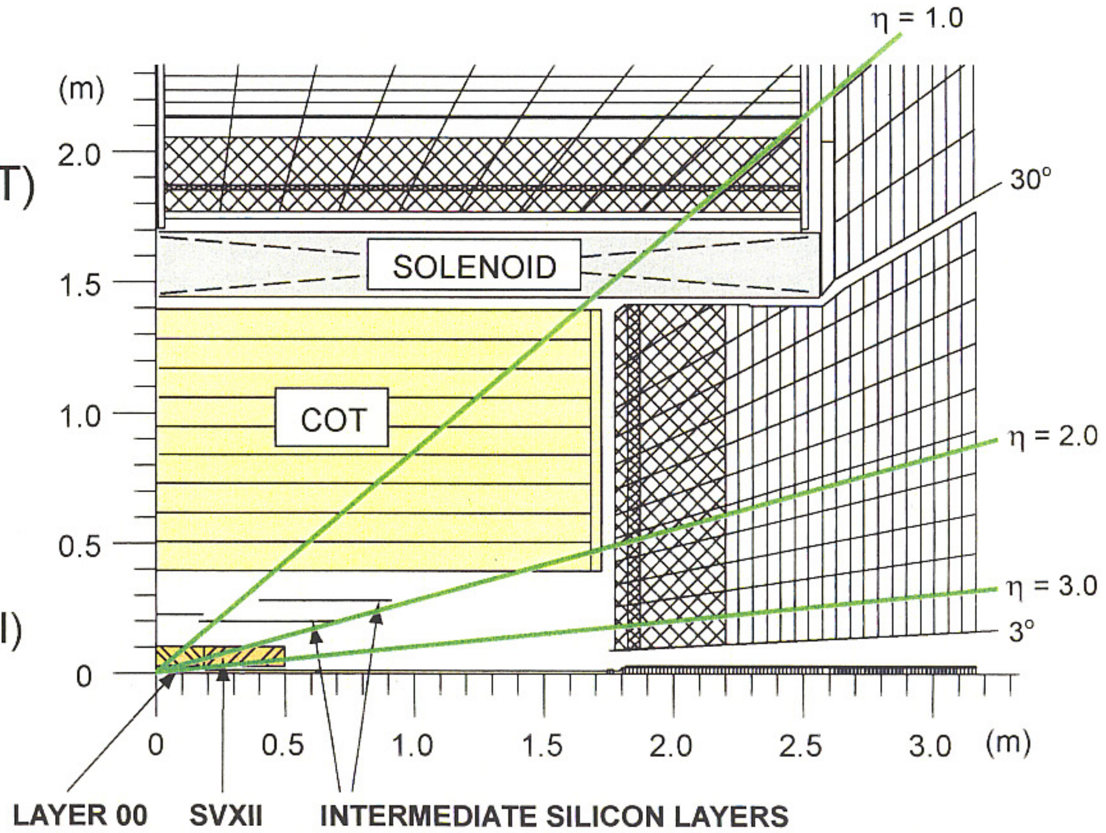
Rolling into the Collision Hall



CDF II Tracking

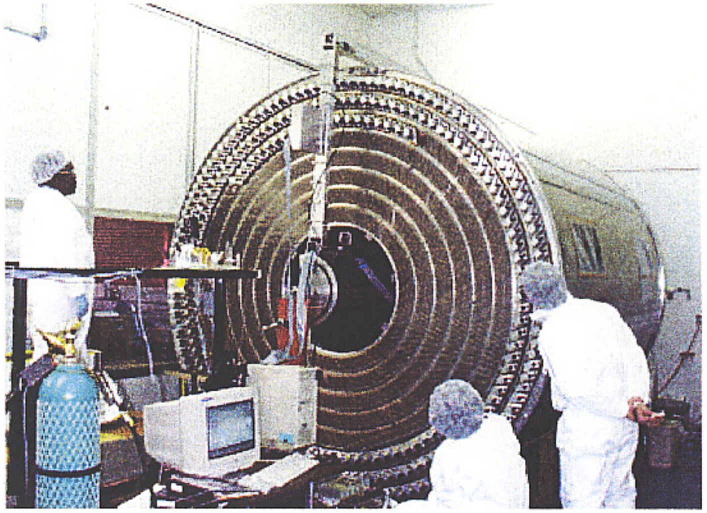
All tracking detectors inside the solenoid are new.

- Solenoid magnet (1.4T)
- Drift chamber (Central Outer Tracker, COT)
  30k sense wires
- Silicon detectors (SVXII, ISL, L00)
  8 tracking layers
  (SVXII : 5, ISL : 2, L00 : 1)
- $\delta p_T / p_T^2$ $\begin{cases} \sim 0.1\% \ (|\eta|<1.0, \text{COT+ISL+SVXII}) \\ \sim 0.4\% \ (1.0<|\eta|<2.0, \text{ISL+SVXII}) \end{cases}$

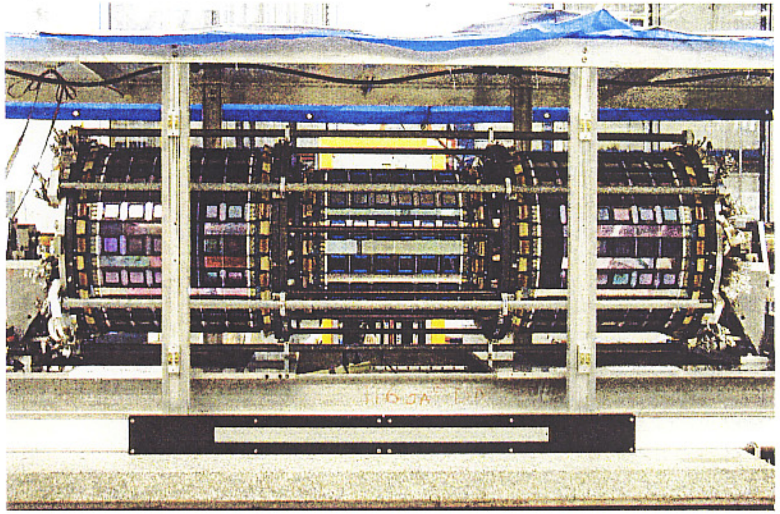


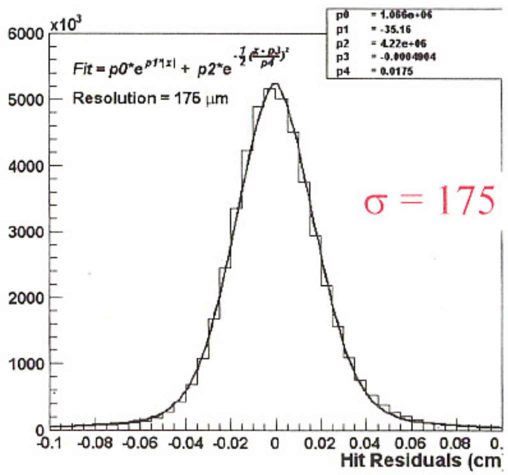
CDF II Tracking (2)

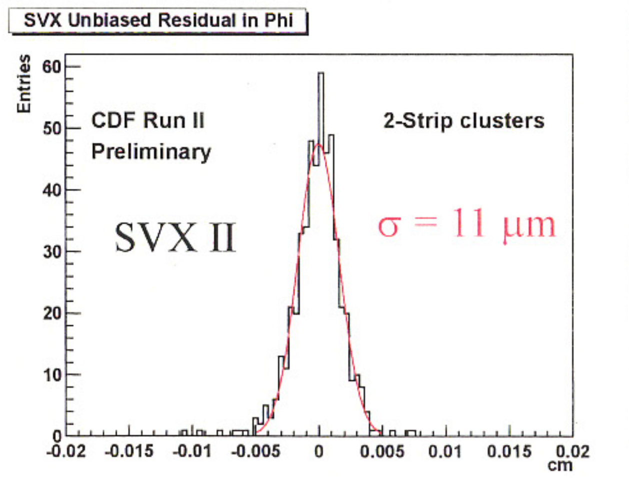
Central Outer Tracker



Silicon Detectors (ISL)





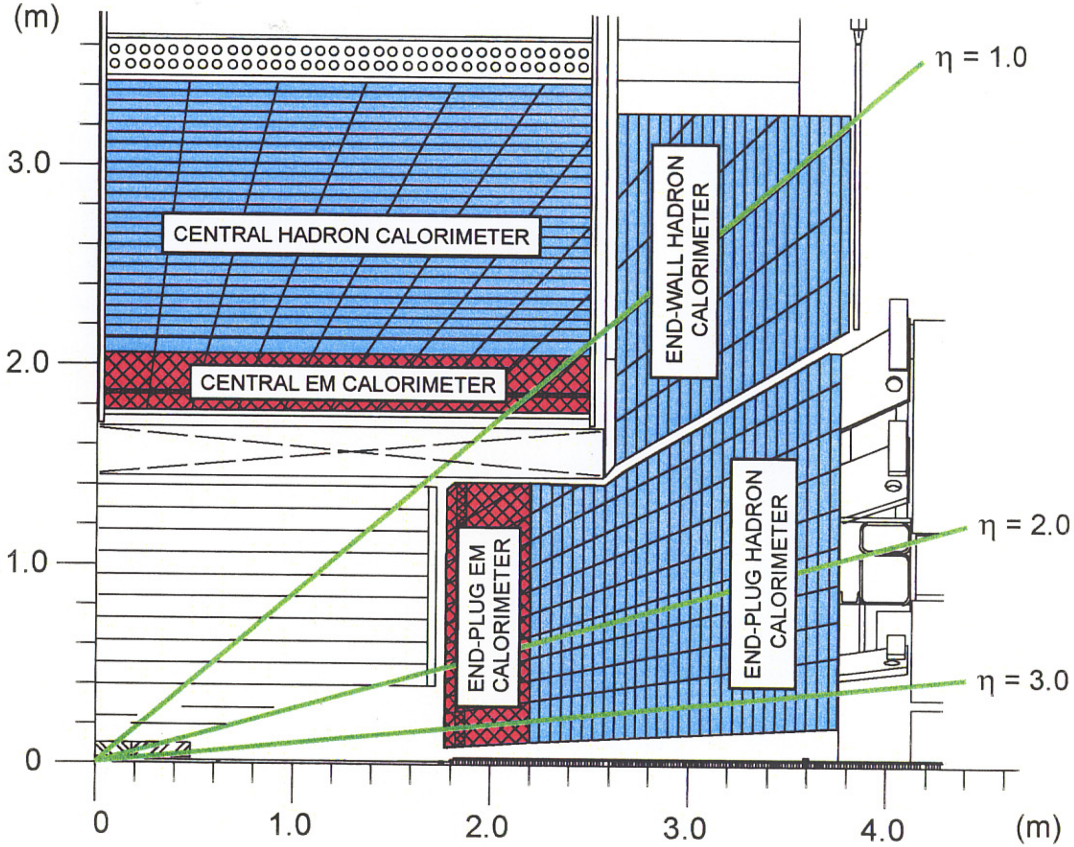


CDF II Calorimetry

- New End-Plug Calorimeters
  (EM & Hadron, $|\eta| < 3.6$)
- EM Calorimeters
  Scintillator / Lead sandwich

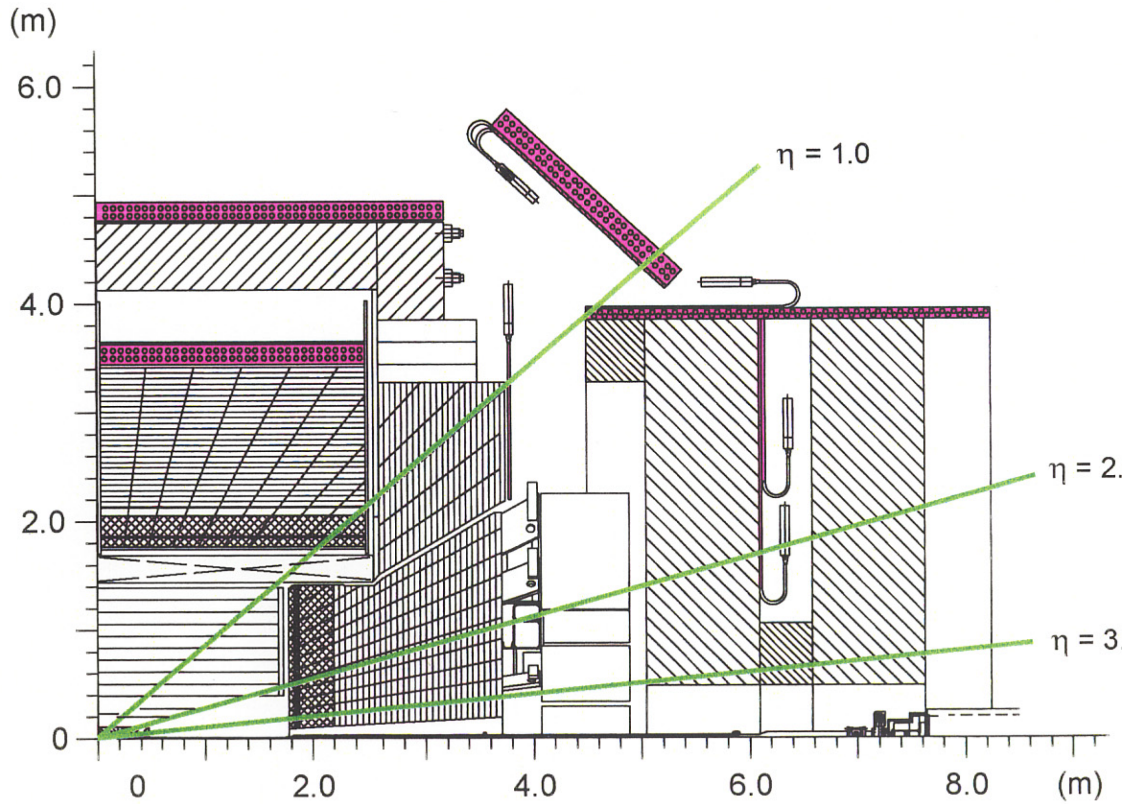
  $\sigma/E \sim 15\% / \sqrt{E}\,(\mathrm{GeV})$
- Hadron Calorimeters
  Scintillator / Fe sandwich

  $\sigma/E \sim 80\% / \sqrt{E}\,(\mathrm{GeV})$



CDF II Muon Detectors

- Increased ϕ and η coverage by about 50%
- New forward detectors ($1.0 < |\eta| < 1.5$)
- Drift tubes + Scintillation counters
- Detectable for $p_T > 1.4$ GeV/c



Brief History of CDF and Tevatron

Aug. 1981	CDF design report	
Oct. 1985	First $p\bar{p}$ collision (1.6 TeV)	
Dec. 1986	CDF construction completed	
Jan. 1987 - May 1987	First physics run (1.8 TeV)	$0.025pb^{-1}$
Jun. 1988 - May 1989	Run 0	$4.5pb^{-1}$

Detector upgrade

Apr. 1992 - May 1993	Run 1a	$19\ pb^{-1}$
Dec. 1993 - Feb. 1996	Run 1b	$87\ pb^{-1}$

Detector / Tevatron upgrade (1.96 TeV)

Oct. 2000 - Feb. 2001	Run 2 commissioning
Mar. 2001 -	Run 2a
2005 -	Run 2b

CDF Collaboration

North America

United States

3 Natl. Labs
28 Universities

Canada

1 University

Europe

Italy

1 Research Lab
6 Universities

Germany

1 University

United Kingdom

4 Universities

Russia

2 Research Labs

Spain

1 University

Switzerland

1 University

Asia

Korea

3 Universities

Taiwan

1 University

Japan

5 Universities
1 Research Lab

- Univ. of Tsukuba
- KEK
- Waseda Univ.
- Osaka City Univ.
- Hiroshima Univ.
- Okayama Univ.

Totals

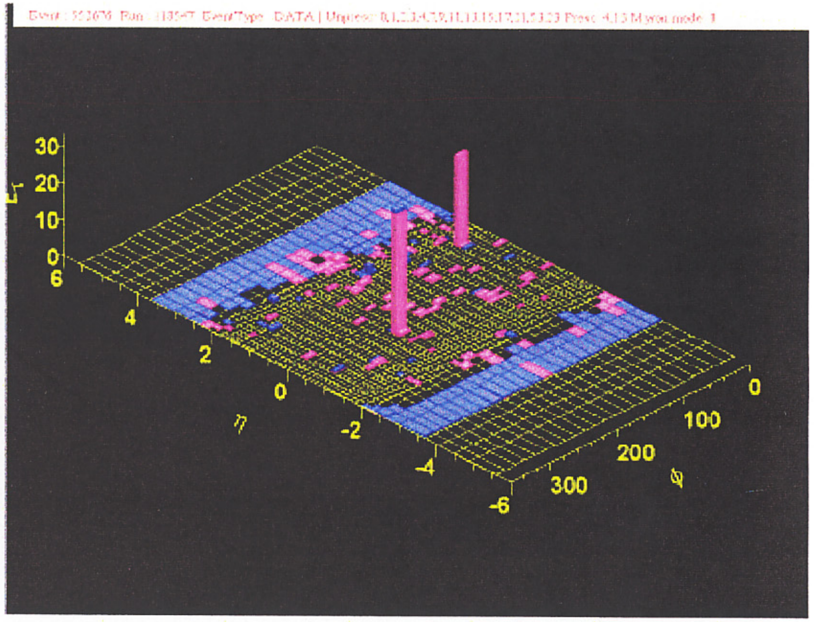
11 countries

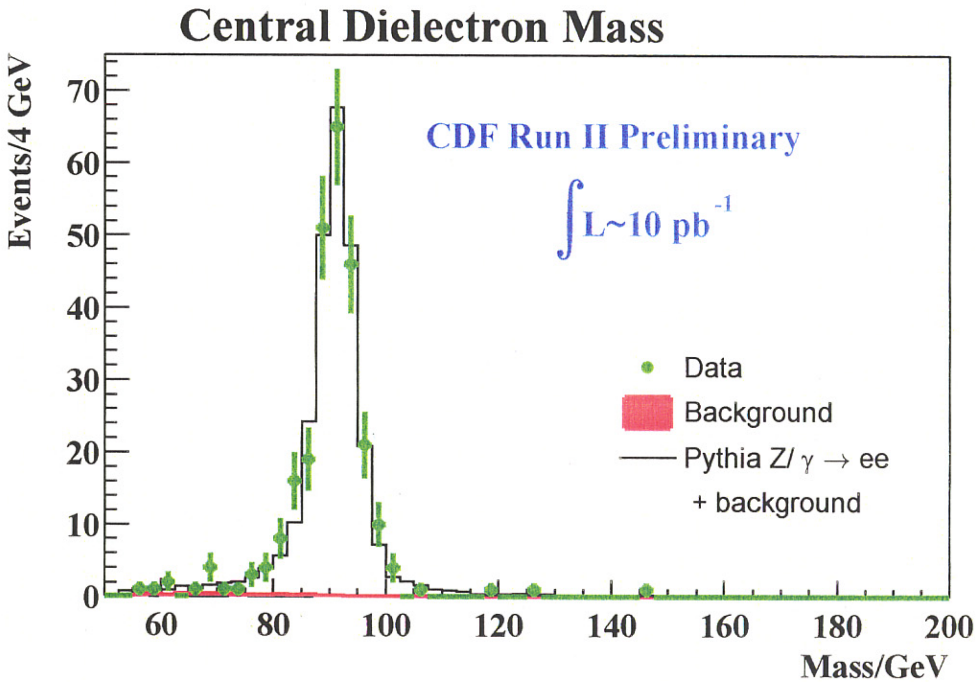
58 institutes

581 physicists

$Z \to e\,e$

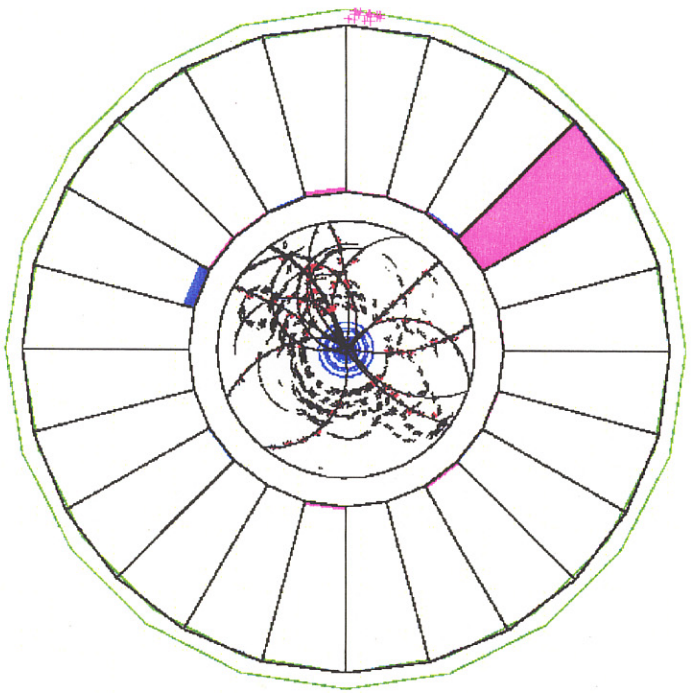
- Reconstruction of high P_T electron pairs
  (Inclusive high-P_T central electron trigger : $E_T > 18$ GeV, $P_T > 9$ GeV/c)



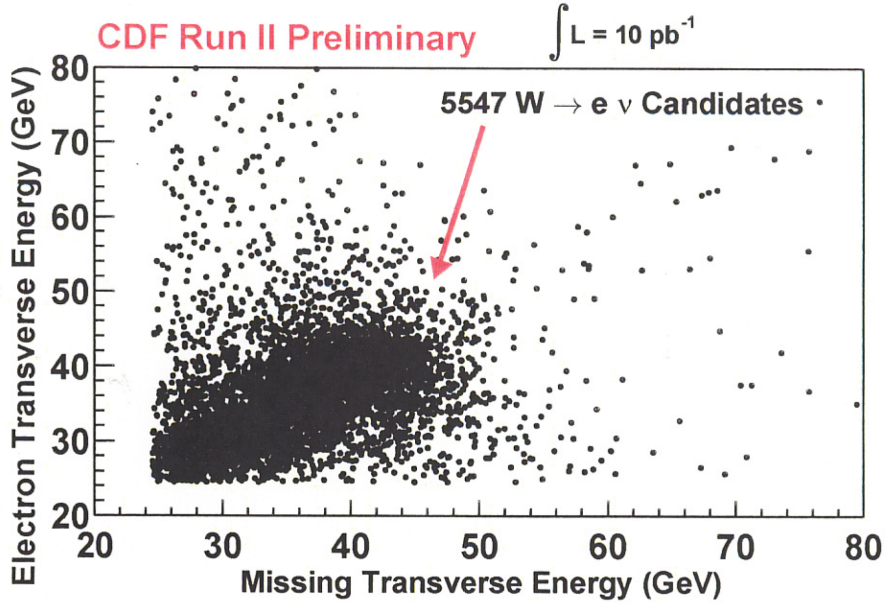


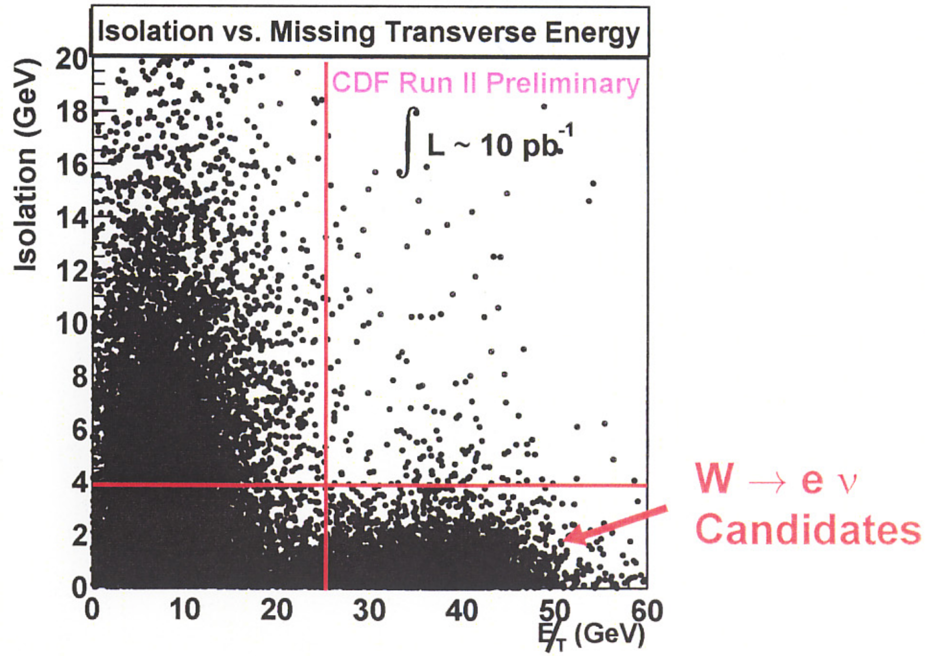
$W \to e\,\nu$

- Isolated electron
- Large E_T and $\not{E}_T$

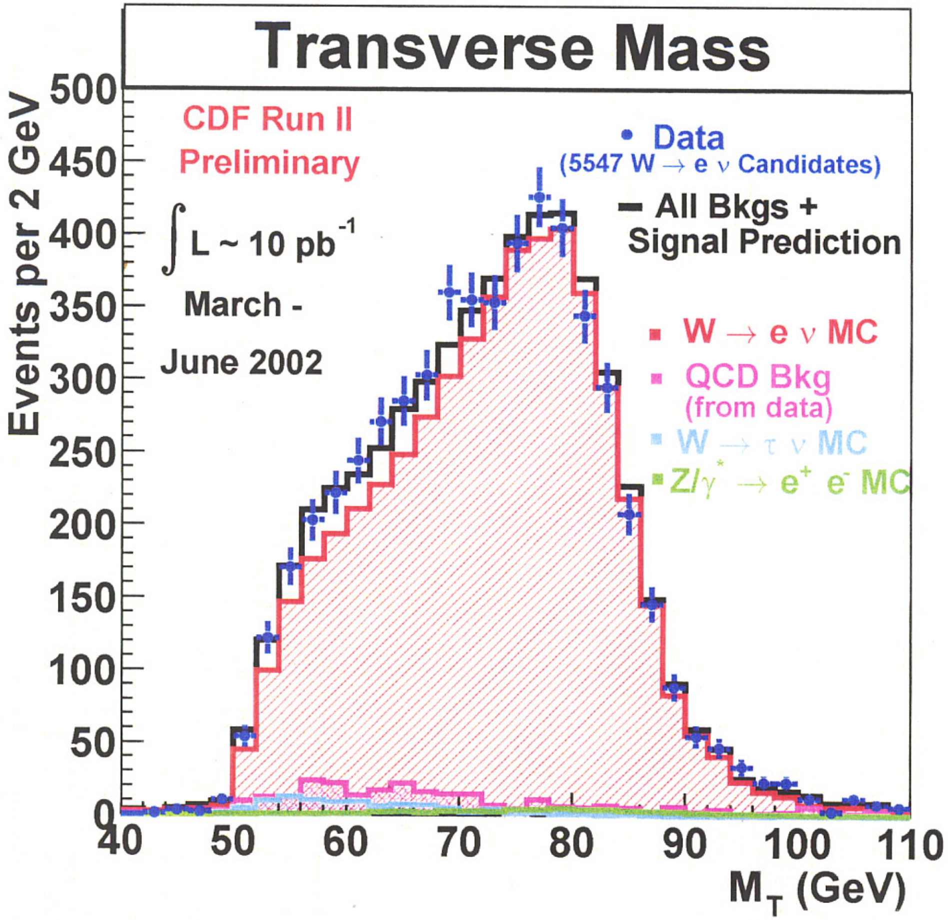


$E_T = 35$ GeV, $\not{E}_T = 38$ GeV





$W \to e\nu$ (2)



- Cross section measurement (preliminary)

  $\sigma(W)\cdot B(W \to e\nu)$
  $= 2.60 \pm 0.07(\text{stat}) \pm 0.11(\text{sys}) \pm 0.26(\text{lum})$ nb

  consistent with Run 1 result
  (after rescaling for higher CM energy)

  NNLO theory : 2.73 nb ($\sqrt{s} = 1.96$TeV)
  2.50 nb ($\sqrt{s} = 1.8$TeV)
  Run 1 : 2.49 ± 0.12 nb ($\sqrt{s} = 1.8$TeV)

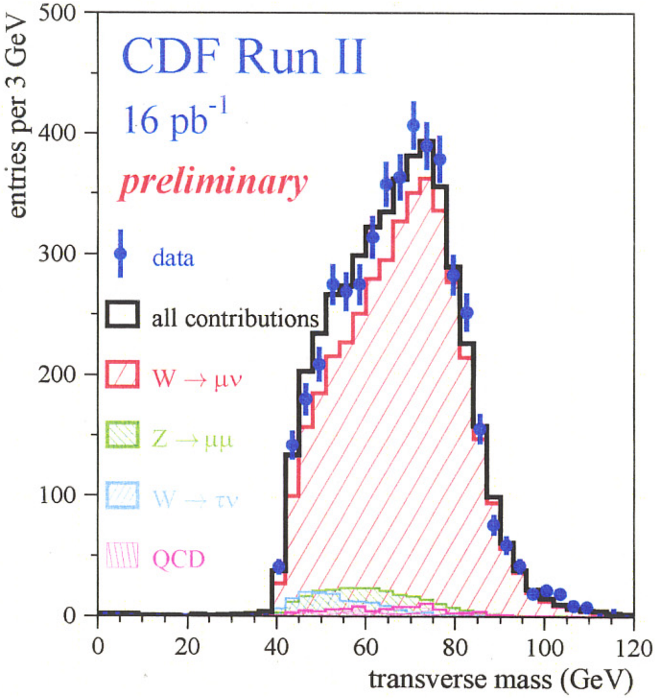
- W mass is extracted from a fit to transverse mass distribution (combined with $\mu\nu$ mode).

  $\Delta M \sim 30\text{MeV}/c^2$ with 2fb^{-1}
  (competitive to combined LEP2 result : $39\text{MeV}/c^2$)

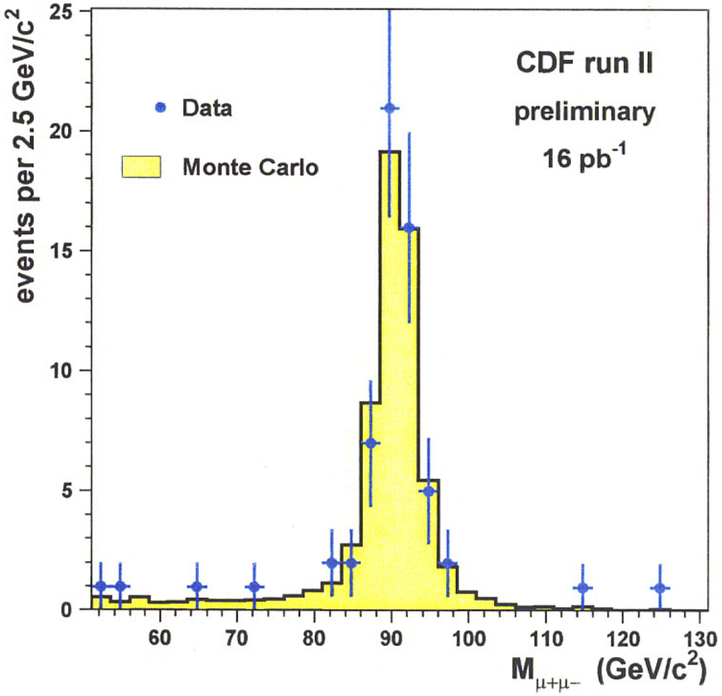
W and Z measurements with muons

- Inclusive high-P_T muon trigger sample ($P_T > 18$ GeV/c)

Transverse mass of $W \rightarrow \mu\nu$



Invariant mass of $Z \rightarrow \mu\mu$

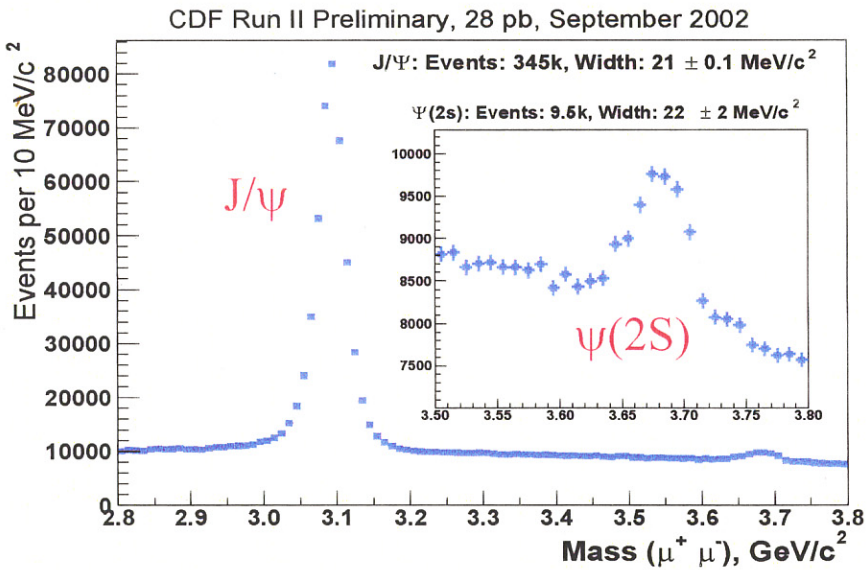


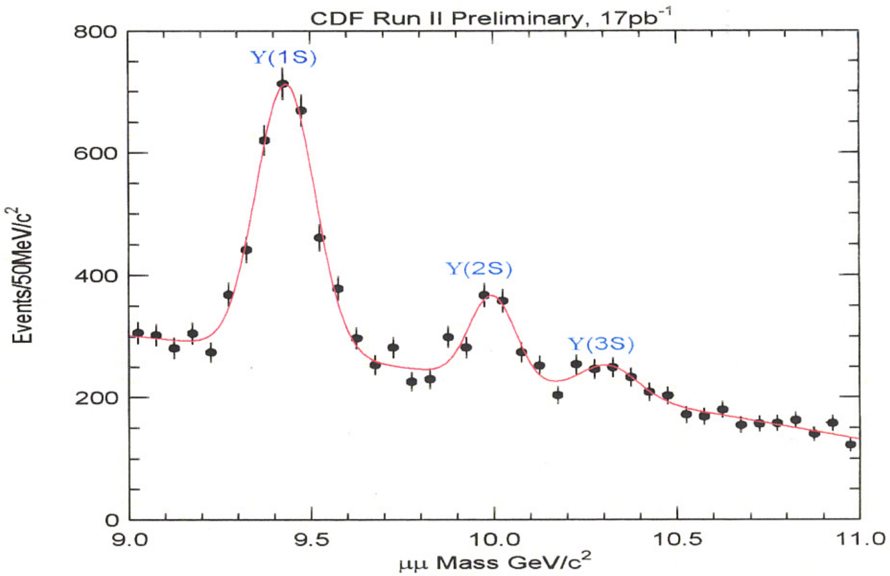
- $\sigma(W)\cdot B(W \rightarrow \mu\nu) = 2.70 \pm 0.04(\text{stat}) \pm 0.19(\text{sys}) \pm 0.27(\text{lum})$ nb (Run 2 preliminary)

Measurements with low p_T muons

- Di-muon trigger sample ($P_T > 1.5$ GeV/c)

$J/\psi \rightarrow \mu\mu$ $\Upsilon \rightarrow \mu\mu$





- Large sample of J/ψ is also utilized for tracking calibration.

Measurements of B Masses

- Cross check of tracking calibration using J/ψ decay channels

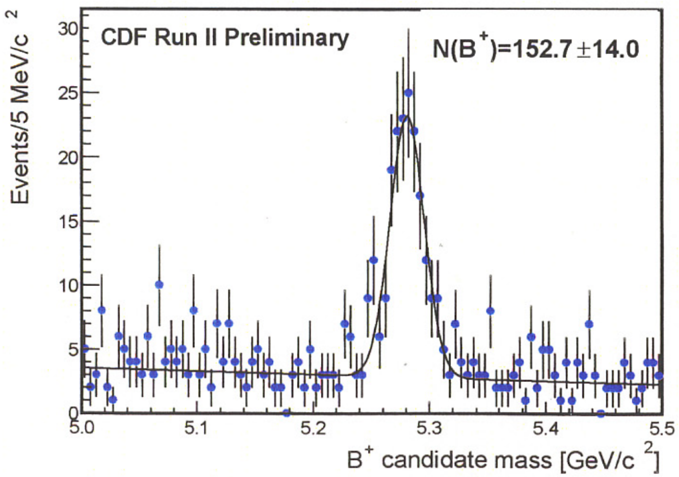
$$m(B^+) = 5280.6 \pm 1.7(\text{stat}) \pm 1.1(\text{sys})\ \text{MeV}/c^2 \quad (\text{PDG}: 5279.0 \pm 0.5\ \text{MeV}/c^2)$$

$$m(B^0) = 5279.8 \pm 1.9(\text{stat}) \pm 1.4(\text{sys})\ \text{MeV}/c^2 \quad (\text{PDG}: 5279.4 \pm 0.5\ \text{MeV}/c^2)$$

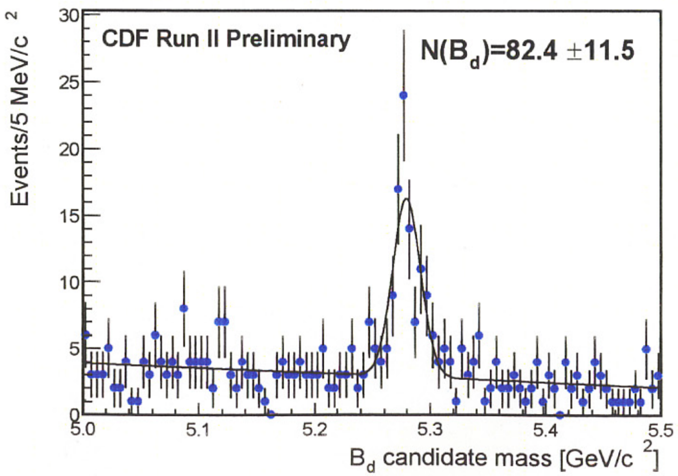
Starting to be competitive . . .

$$m(B_S^0) = 5360.3 \pm 3.8(\text{stat})\ ^{+2.1}_{-2.9}(\text{sys})\ \text{MeV}/c^2 \quad (\text{PDG}: 5369.6 \pm 2.4\ \text{MeV}/c^2)$$

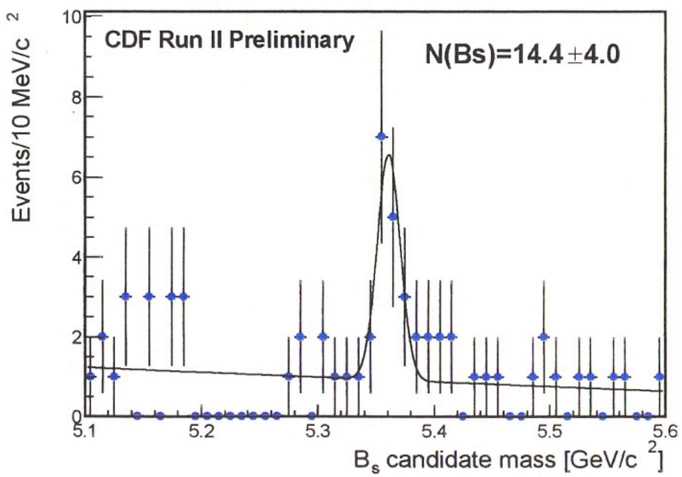
$B^+ \rightarrow J/\psi\, K^+$



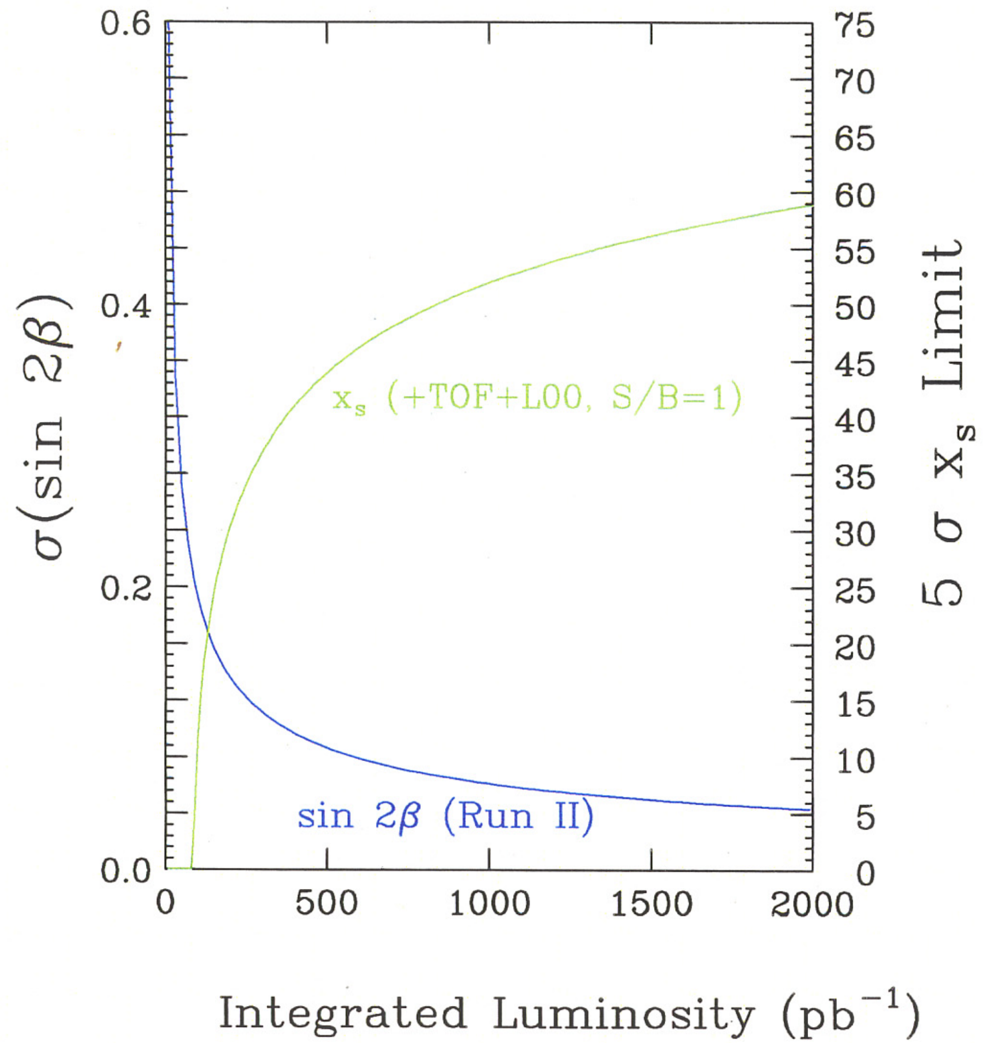
$B^0 \rightarrow J/\psi\, K^{*0}$



$B_S^0 \rightarrow J/\psi\, \phi$



B Physics Projections



- measurement of sin2β

  $B^0 \to J/\psi\ K_S$

  $\sigma(\sin 2\beta) \sim 0.05$ with 2 fb^{-1}

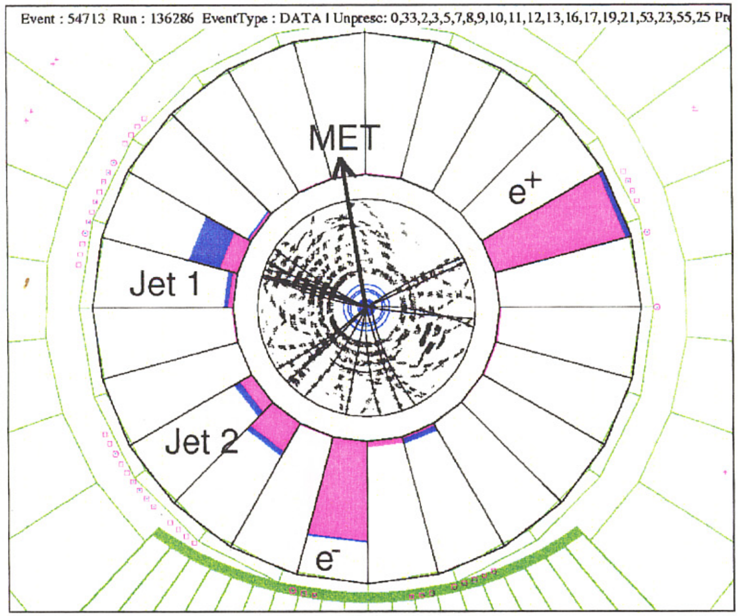
- B_s^0 - $\bar{B}_s^0$ mixing (⇐ unique at Tevatron)

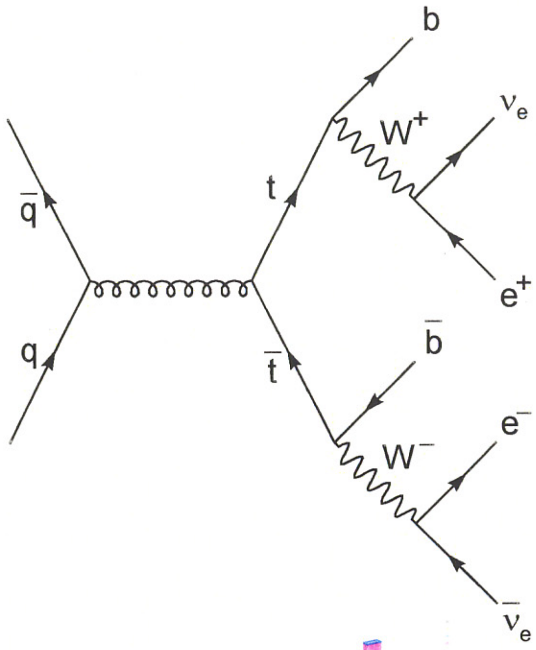
  $B_s^0 \to D_s\ \pi,\ \ D_s\ \pi\pi\pi$

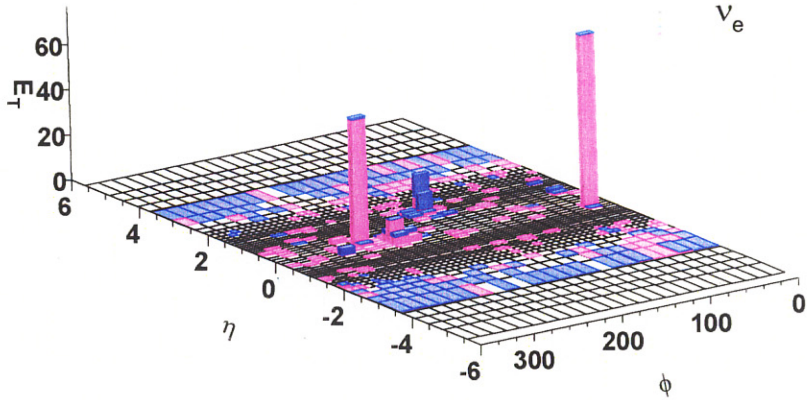
  CDF sensitivity at 5σ for $x_s < 60$

  ($x_s = \Delta m_s / \Gamma_s$)

Top Event Candidate



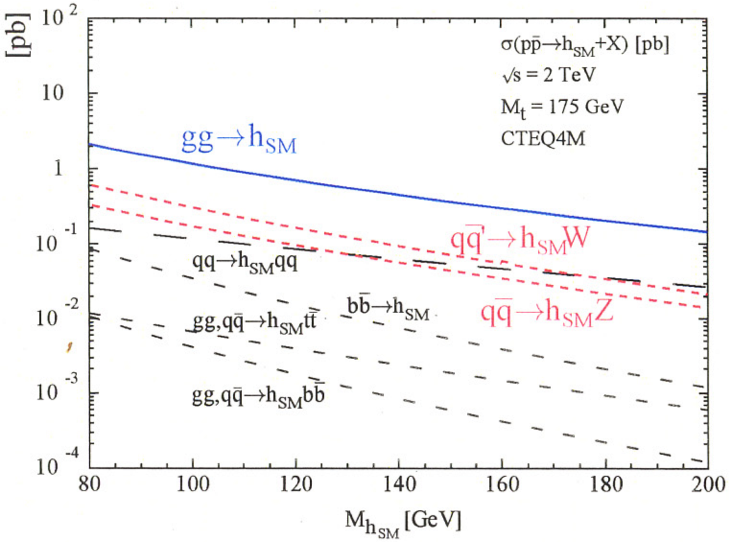


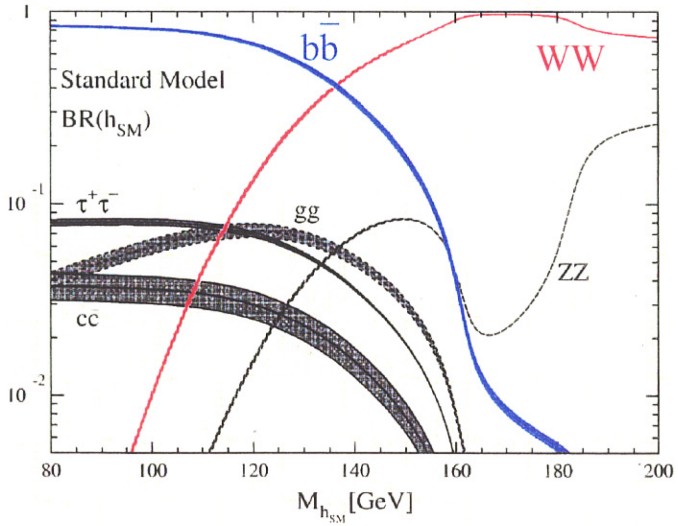


e^+ E_T = 73 GeV
e^- E_T = 56 GeV
Jet 1 E_T = 35 GeV
Jet 2 E_T = 34 GeV
MET E_T = 43 GeV
$M(e^+e^-)$ = 118 GeV

- 800 $t\bar{t}$ events with b-tagging are expected with 2 fb^{-1}

Higgs at the Tevatron





Low-mass SM Higgs (~ 130GeV/c²)

$q\bar{q}' \to Wh \to \ell\nu b\bar{b}$

$q\bar{q} \to Zh \to \ell^+\ell^- b\bar{b},\ \nu\bar{\nu}b\bar{b}$

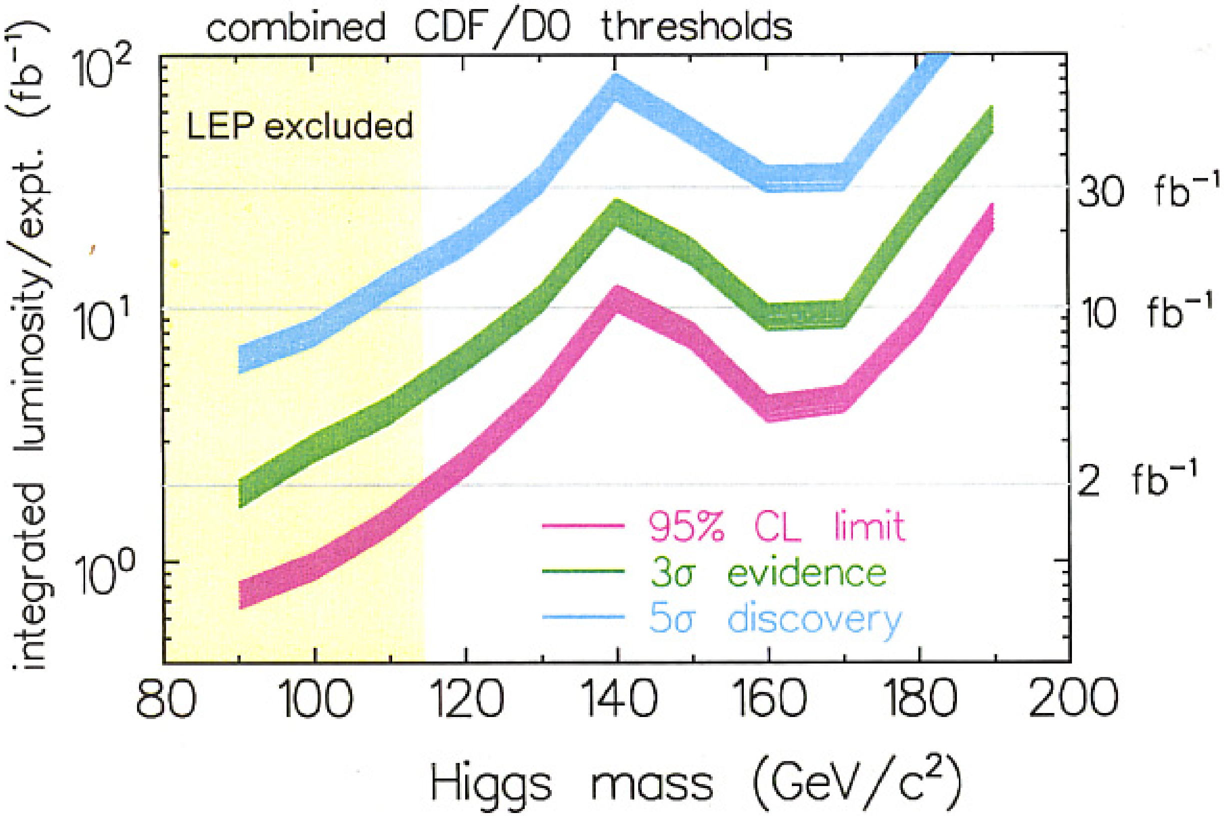
High-mass SM Higgs (130GeV/c² ~ 190GeV/c²)

$gg \to h \to W^*W^* \to \ell^+\ell^-\nu\bar{\nu}$

$q\bar{q}' \to Wh \to \ell^\pm\nu W^*W^* \to \ell^\pm\nu\ell^\pm\nu\, j\, j$

$q\bar{q} \to Zh \to \ell^\pm\ell^\mp W^*W^* \to \ell^\pm\ell^\mp\ell^\pm\nu\, j\, j$

Higgs at the Tevatron (2)



For m_h < 120 GeV/c^2,

- can be excluded with 2 fb^{-1}, if not there
- 3 σ evidence with 7 fb^{-1}
- 5 σ discovery with 15 fb^{-1}

Top / Electroweak Projections

- $\sqrt{s} = 1.96\text{TeV}$

  $\sigma(W)$, $\sigma(Z)$ ~ 10% higher

  $\sigma(t\bar{t})$ ~ 30% higher

- With 2 fb^{-1} (Run 2a)

  ΔM_W ~ 30 MeV/c^2

  $\Delta M_{top} \lesssim 3\ GeV/c^2$

  $\Rightarrow \Delta(\log M_H) \sim \log 2$

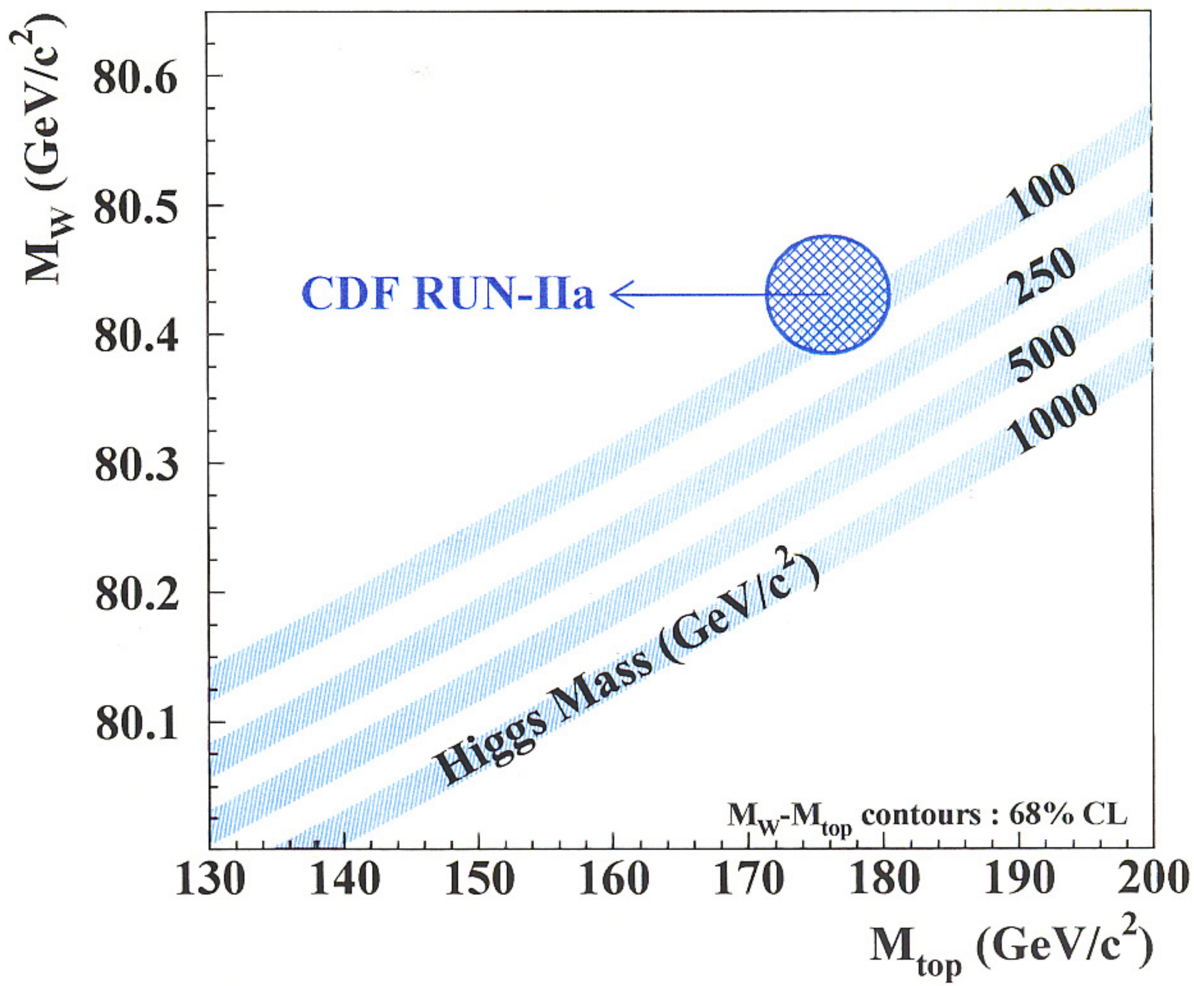
  $(1/2\, M_H < M_H < 2M_H)$

- With 15 fb^{-1} (Run 2b)

  $\Delta M_W \sim 20\ MeV/c^2$

  $\Delta M_{top} \lesssim 2\ GeV/c^2$

  $\Rightarrow \Delta(\log M_H) \sim \log 1.3$



Tevatron Plan and Luminosity Prospects

Run 2a

2002

- Expect to maintain peak luminosity in the range 2.5 ~ 4 x 10^{31} $cm^{-2}s^{-1}$
- Expect a delivered integrated luminosity of ~ 150 pb^{-1} in 2002

2003

- Six-week shutdown (in January ?)
  - Complete Recycler work
  - No major shutdown for rest of 2003
- Commission and integrate Recycler
  - Expect peak luminosity of 4 ~ 6 x 10^{31} $cm^{-2}s^{-1}$

Run 2a goal

- Typical peak luminosity of 2 x 10^{32} $cm^{-2}s^{-1}$
- Integrated luminosity of 2 fb^{-1} over 2 ~ 3 year period

Tevatron Plan and Luminosity Prospects (2)

Run 2b

- Increase anti-proton intensity by a factor of 3
- Peak luminosity up to 4×10^{32} $cm^{-1}s^{-1}$
- Silicon detector replacement at CDF and DØ (6-month shutdown in 2005)
  (Japan group is contributing to Run 2b silicon detector (SVXII-b) at CDF)
- Integrated luminosity of 15 fb^{-1} during ~4-year running (~ 2008)

Summary

- Fermilab accelerators and collider detectors were successfully upgraded. Run 2 started in March 2001.
- Collider detectors are working well.
- We are accumulating physics data of $p\bar{p}$ collisions. Data analyses are also in progress. Some preliminary results were presented.
- Luminosity of Tevatron is being improved. Hopefully, integrated luminosity of ~ 150 pb^{-1} in 2002, 2 fb^{-1} in 2 ~ 3 years, 15 fb^{-1} in ~2008.