

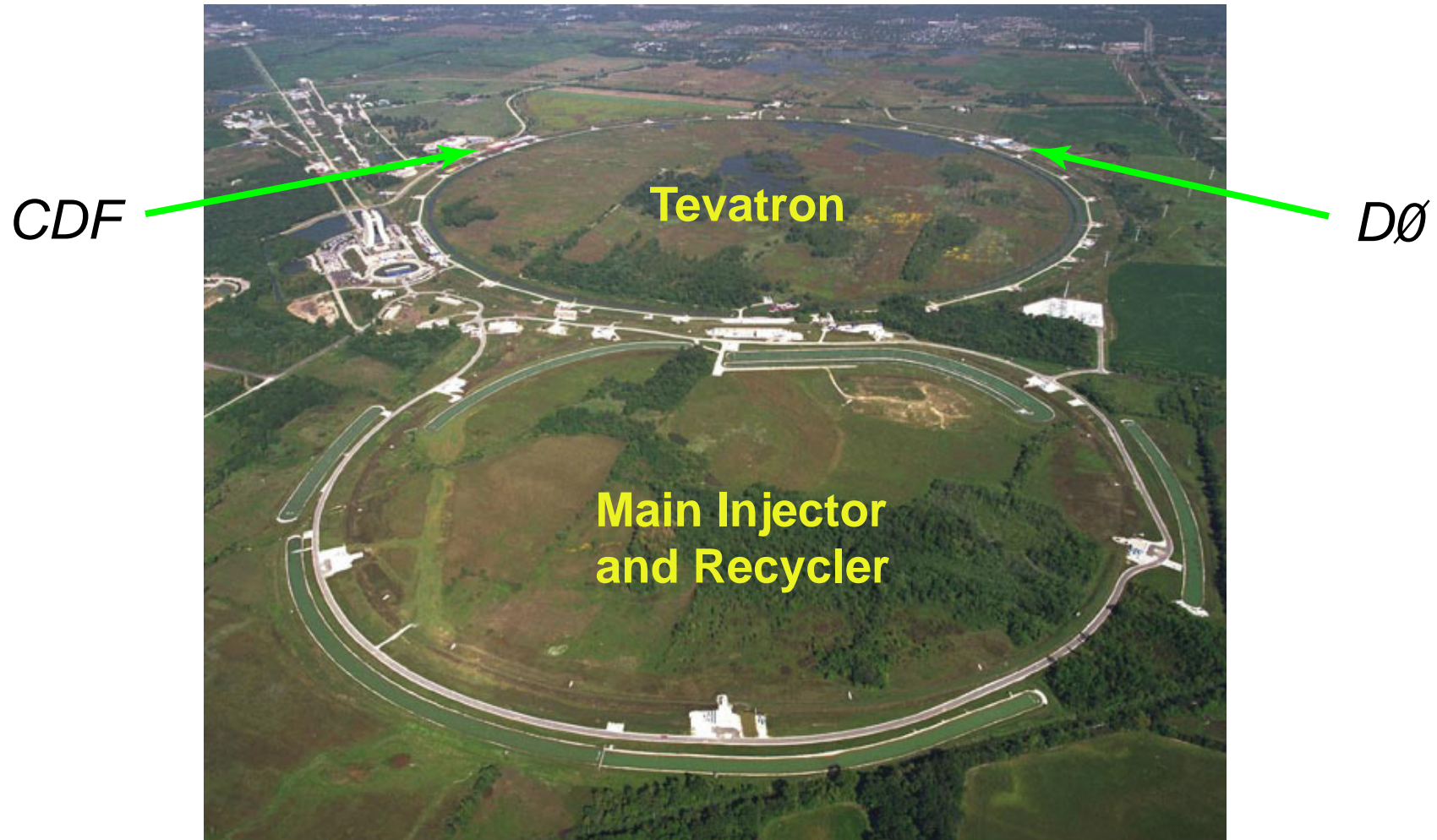
Present Status of Physics at Tevatron/CDF
&
Prospect with Higher Luminosity

Kazuhiro Yamamoto
(Osaka City University)
for
CDF Collaboration

RPIA2002, October 29th 2002

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

Fermilab Accelerator Complex



Fermilab Accelerator Complex (2)

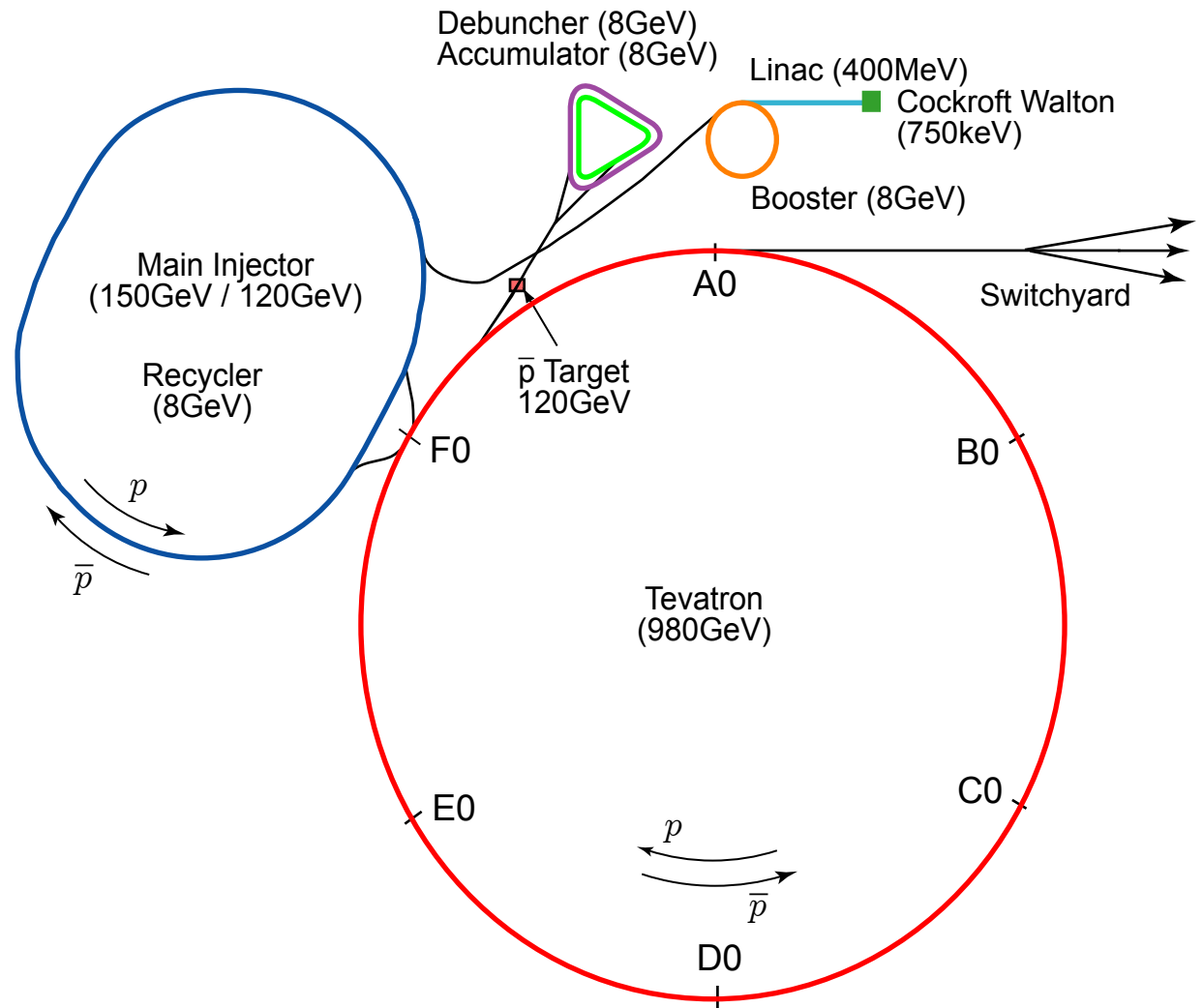
Tevatron Run 2 Upgrade

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

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)
 - Tevatron (980GeV)
- } for p-bars



Tevatron Status

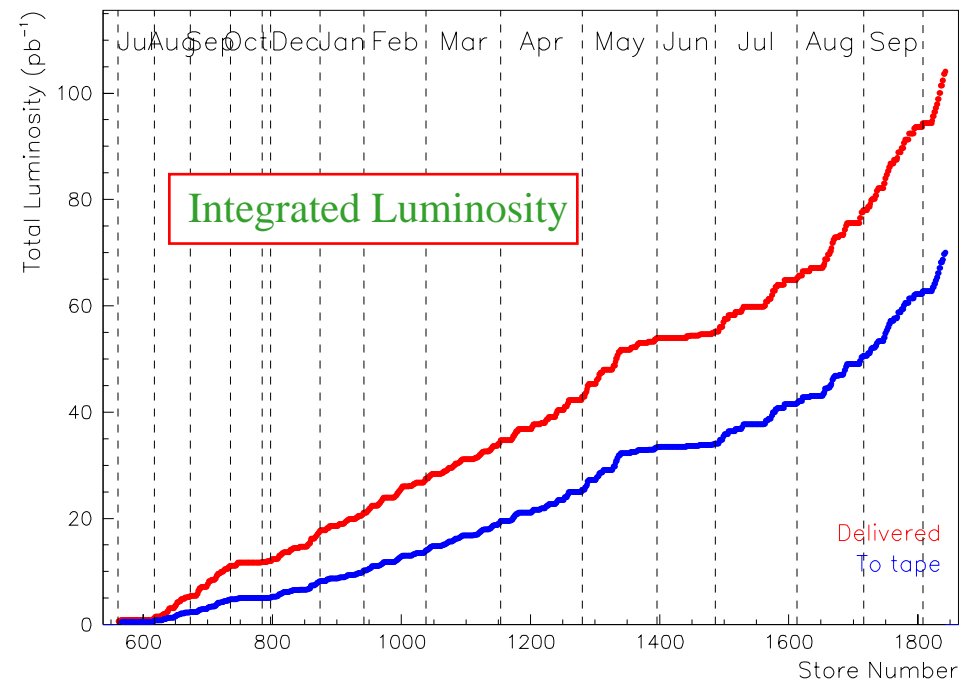
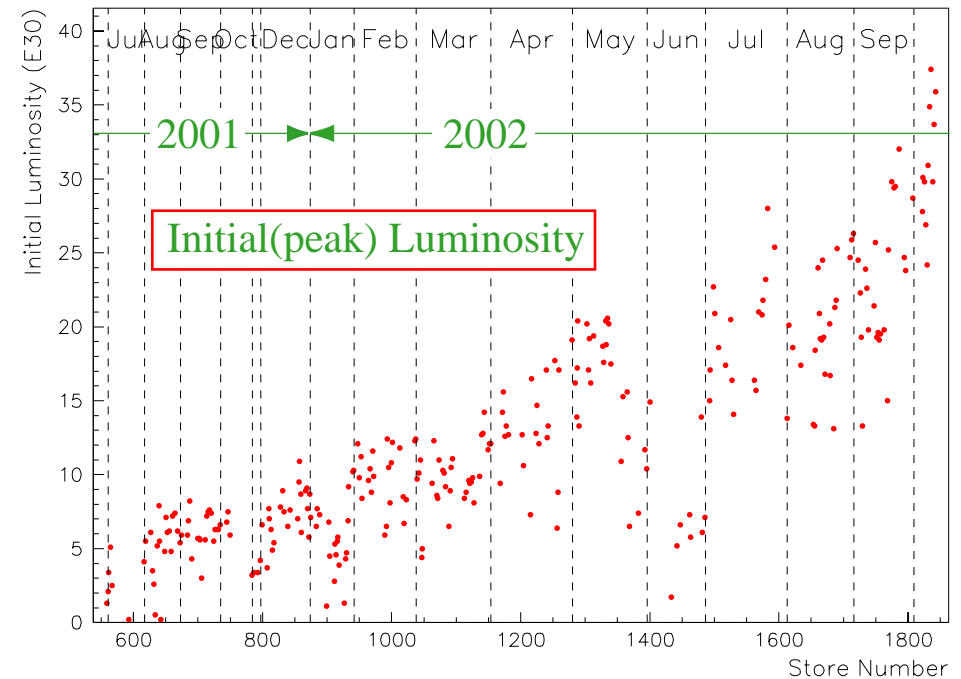
Tevatron Run 2 operation started in March 2001

Present Status

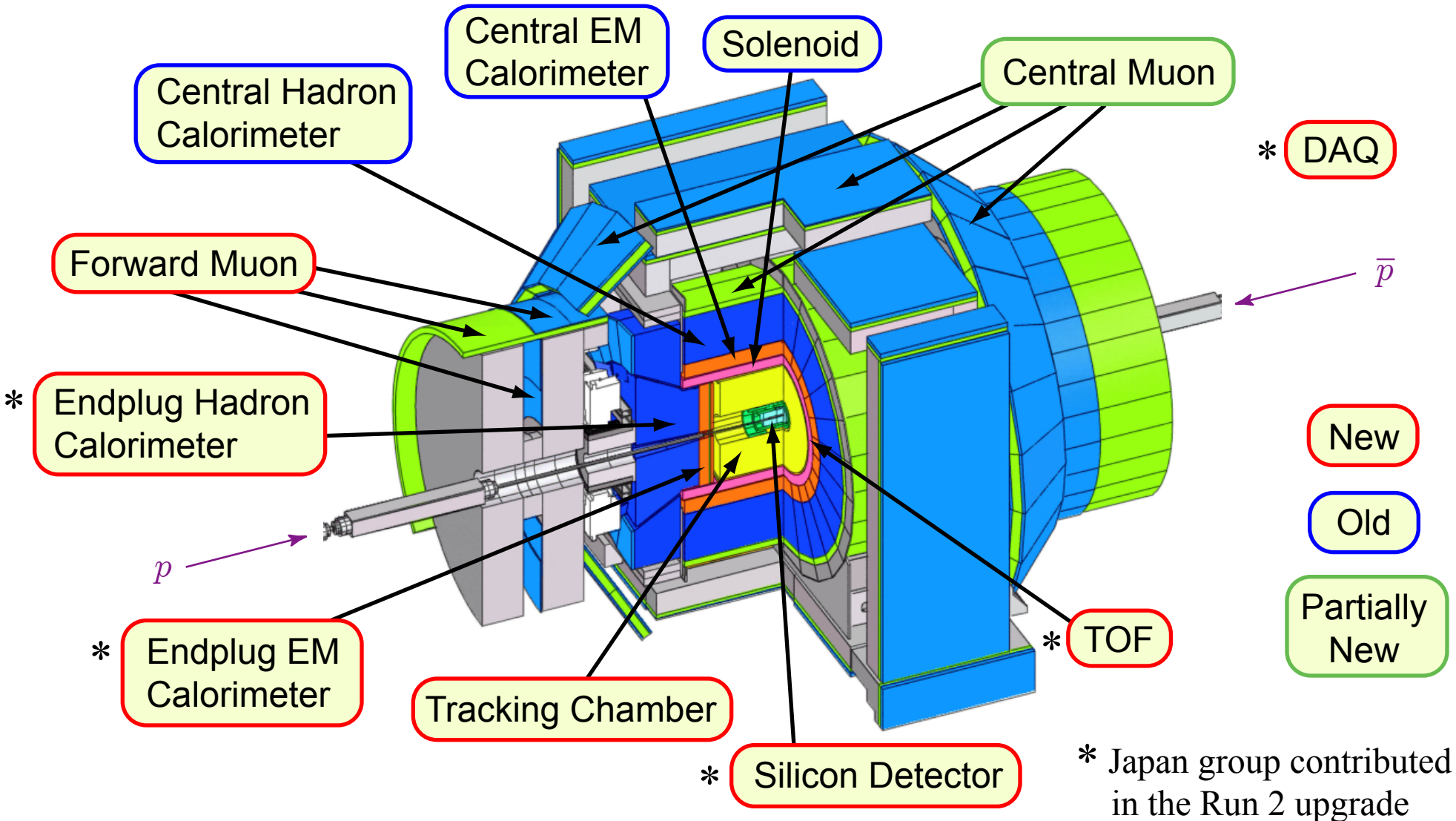
- Now achieving typical peak luminosity of $2.5 \sim 3 \times 10^{31} \text{ cm}^{-2} \text{ s}^{-1}$
- 100 pb^{-1} delivered, 70 pb^{-1} recorded

Luminosity goals for Run 2a

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

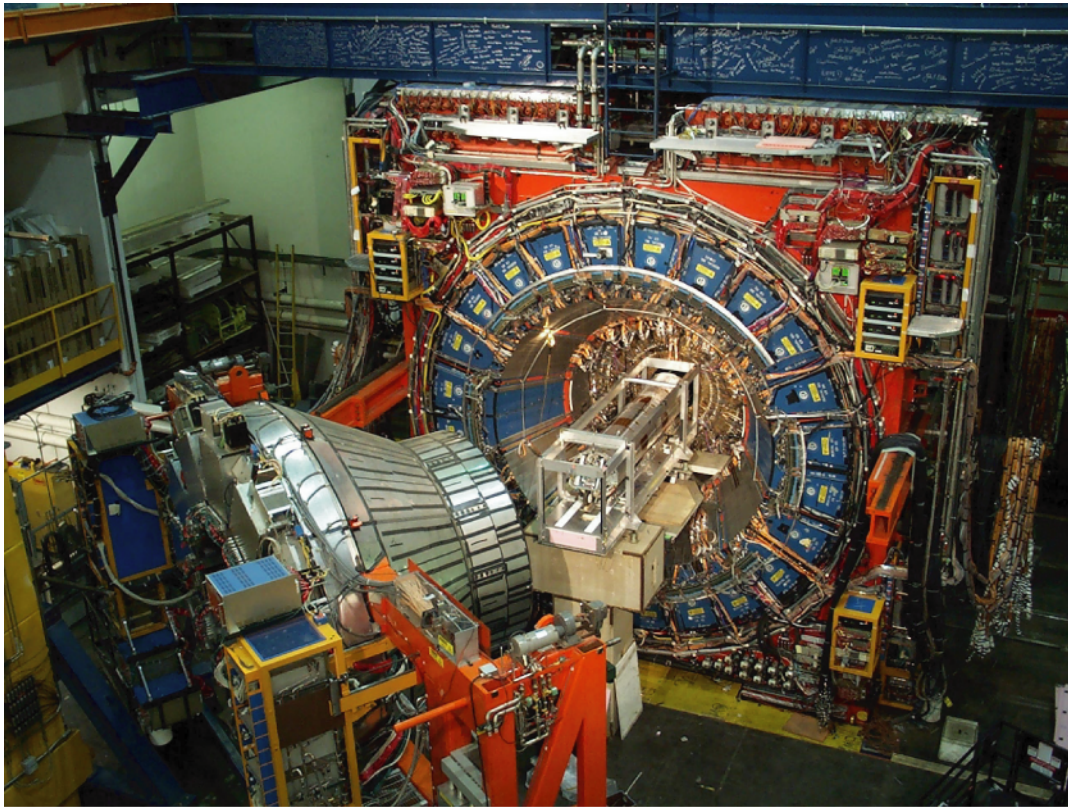


CDF II Detector

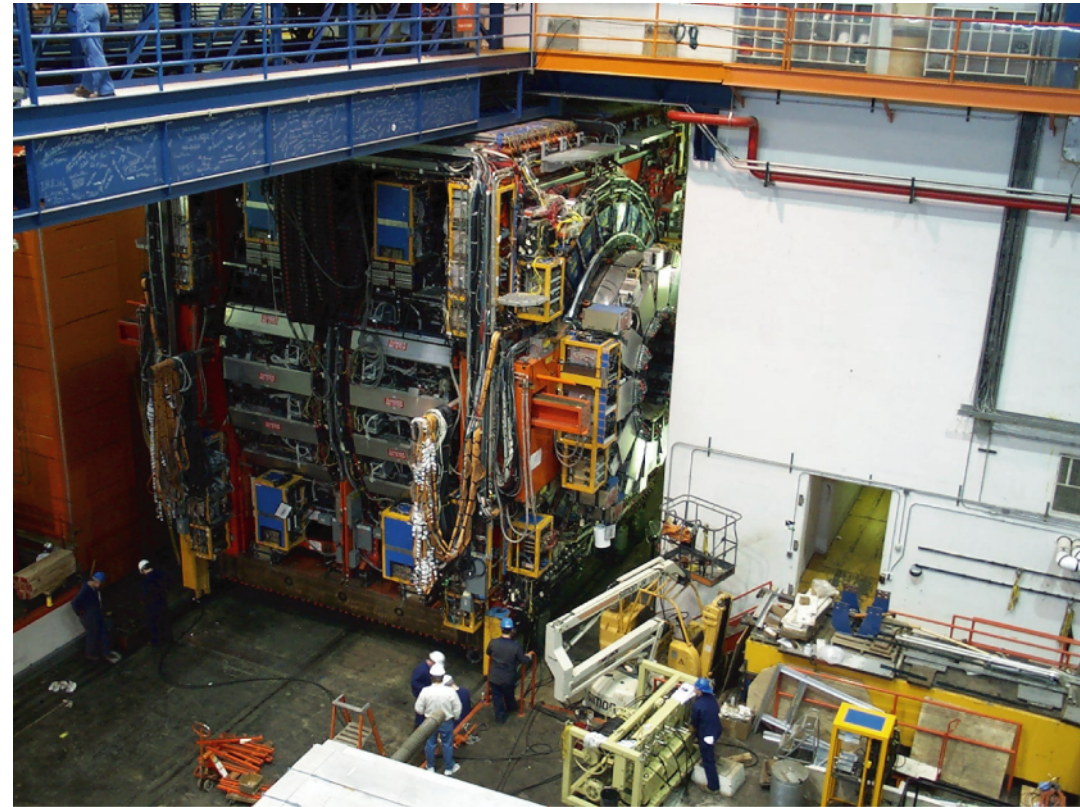


CDF II Detector (2)

Installing Silicon Detectors



Rolling into the Collision Hall

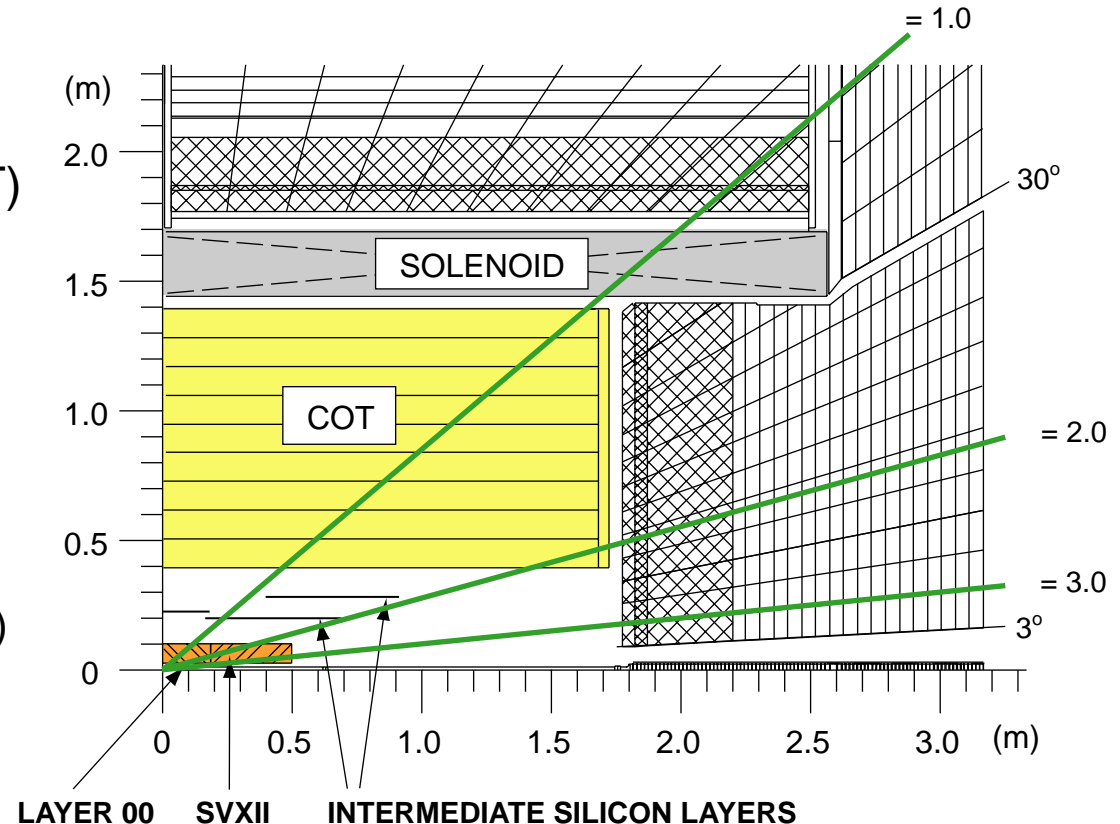


CDF II Tracking

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)

- p_T / p_T^2 f
 - ~ 0.1% ($|\eta| < 1.0$, COT+ISL+SVXII)
 - ~ 0.4% ($1.0 < |\eta| < 2.0$, ISL+SVXII)

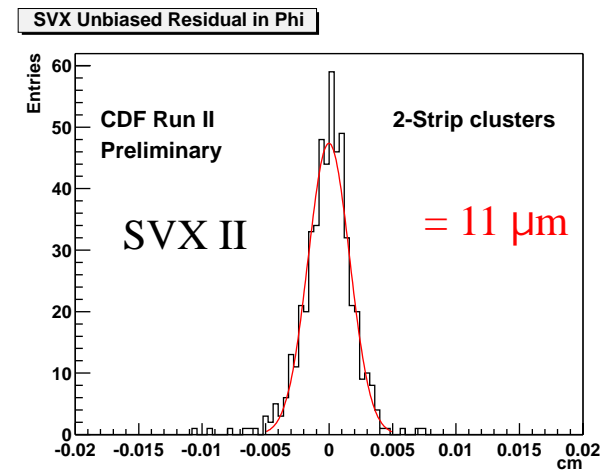
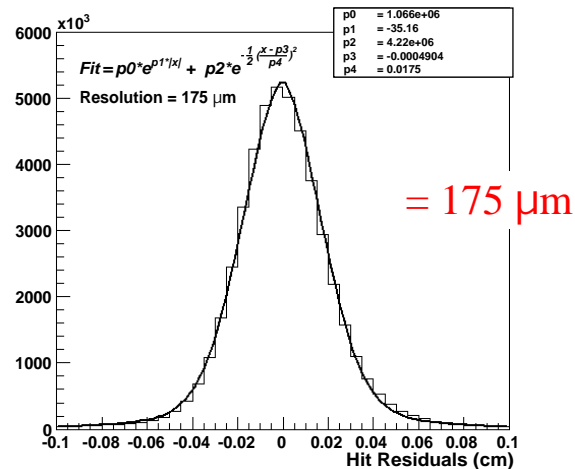
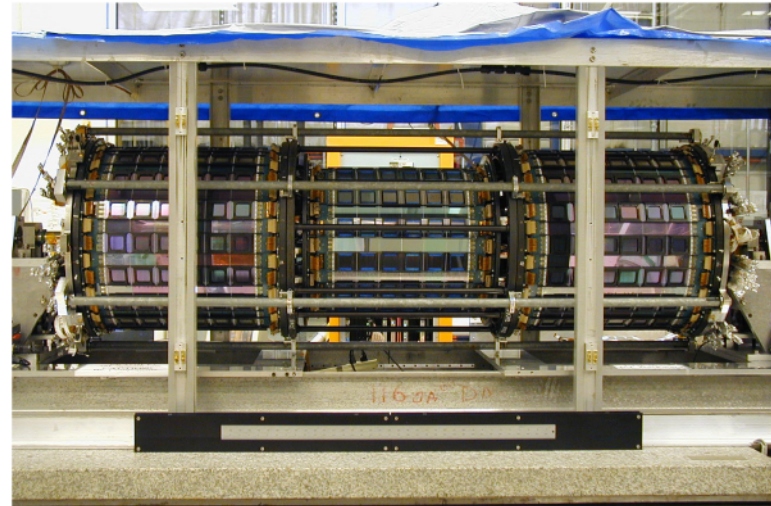


CDF II Tracking (2)

Central Outer Tracker

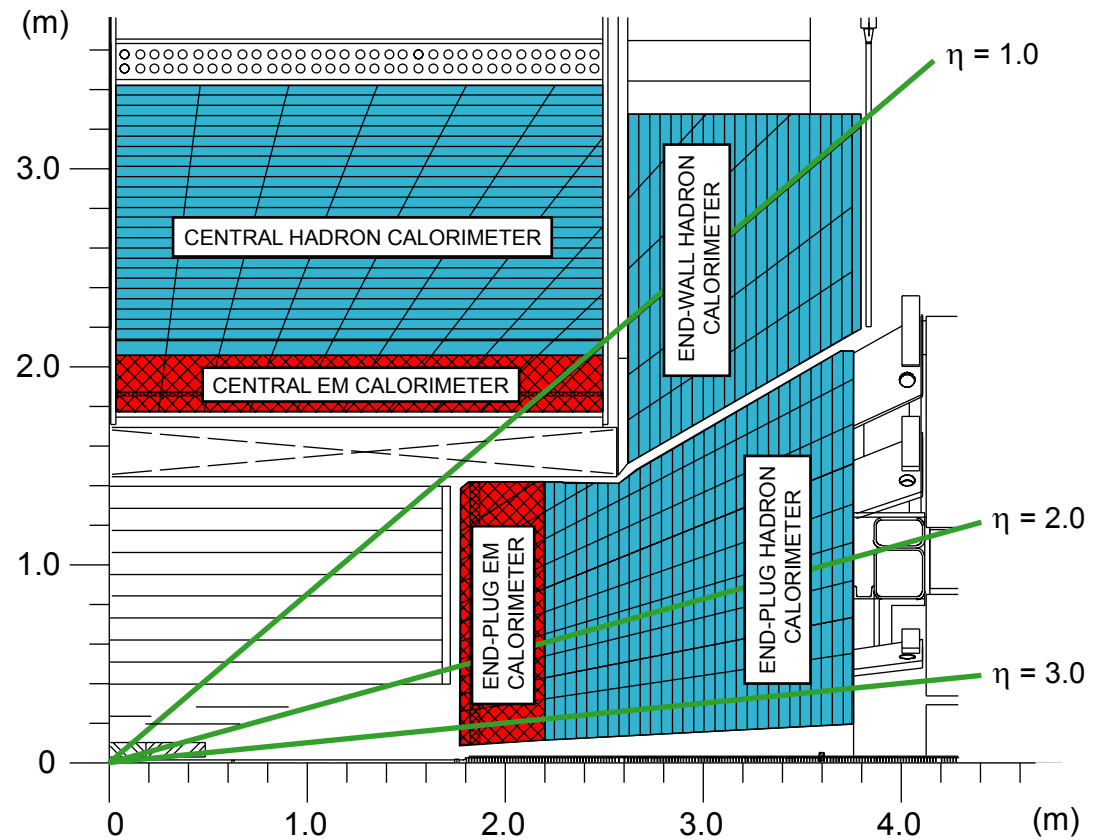


Silicon Detectors (ISL)



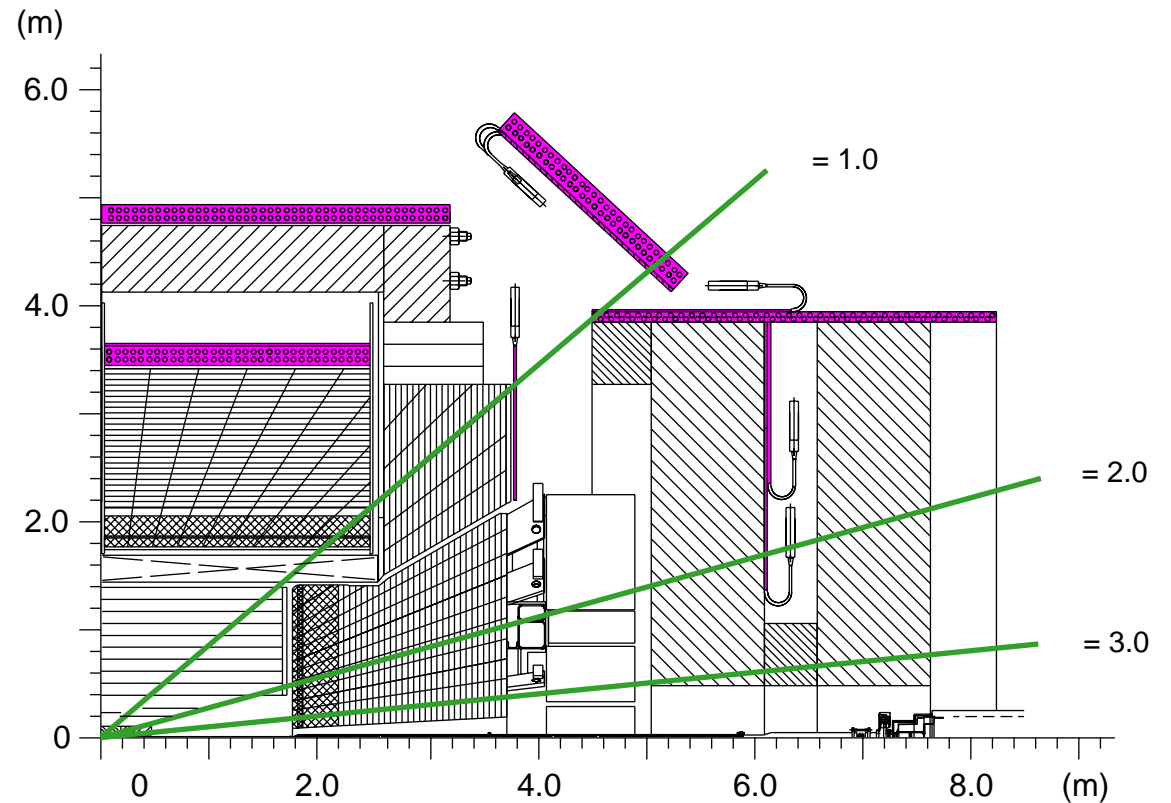
CDF II Calorimetry

- New End-Plug Calorimeters
(EM & Hadron, $|\eta| < 3.6$)
- EM Calorimeters
Scintillator / Lead sandwich
 $\sigma/E \sim 15\% / \sqrt{E} \text{ (GeV)}$
- Hadron Calorimeters
Scintillator / Fe sandwich
 $\sigma/E \sim 80\% / \sqrt{E} \text{ (GeV)}$



CDF II Muon Detectors

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



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

Totals

11 countries

58 institutes

581 physicists

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

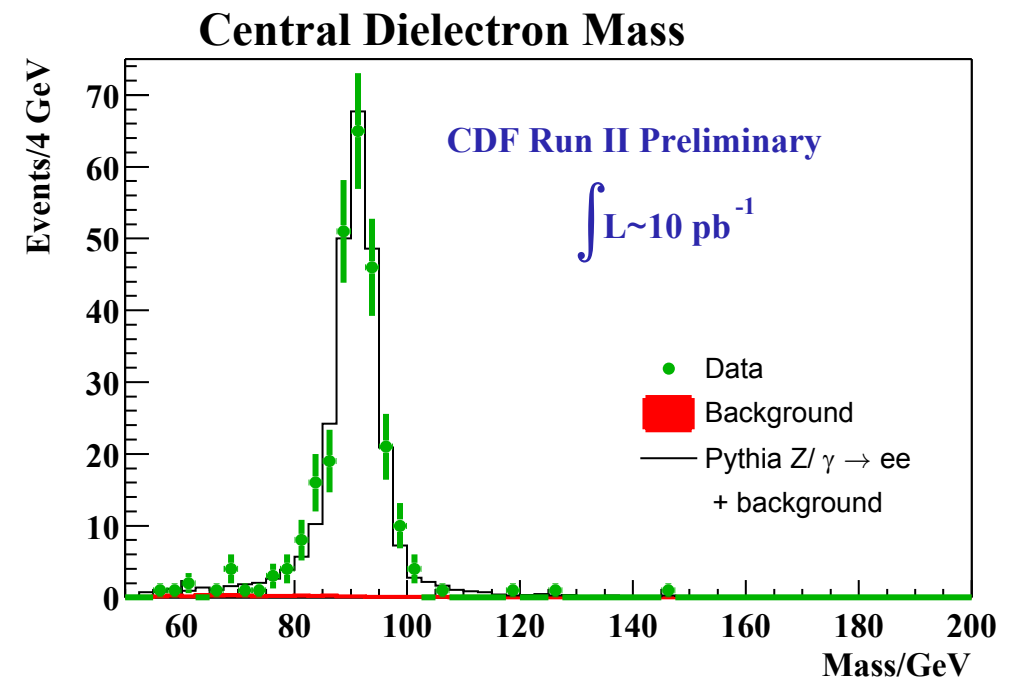
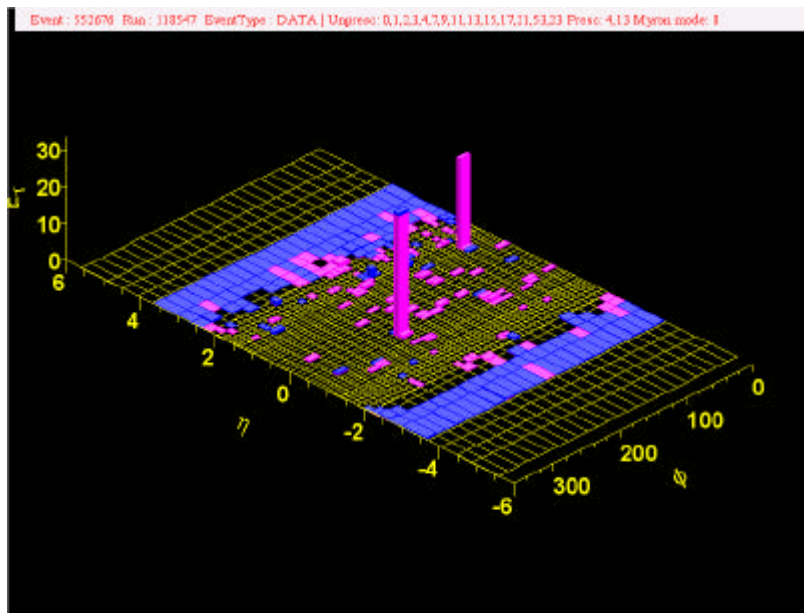
Japan

5 Universities
1 Research Lab

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

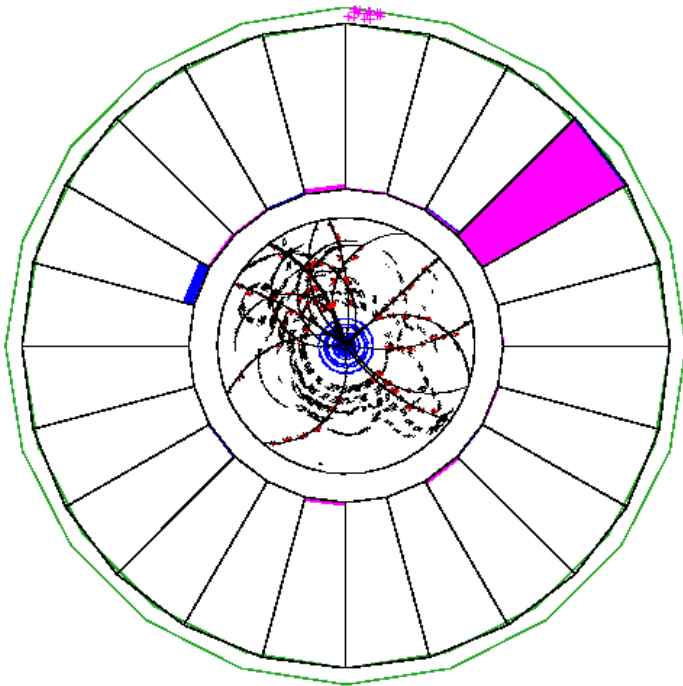
$$Z \rightarrow e e$$

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

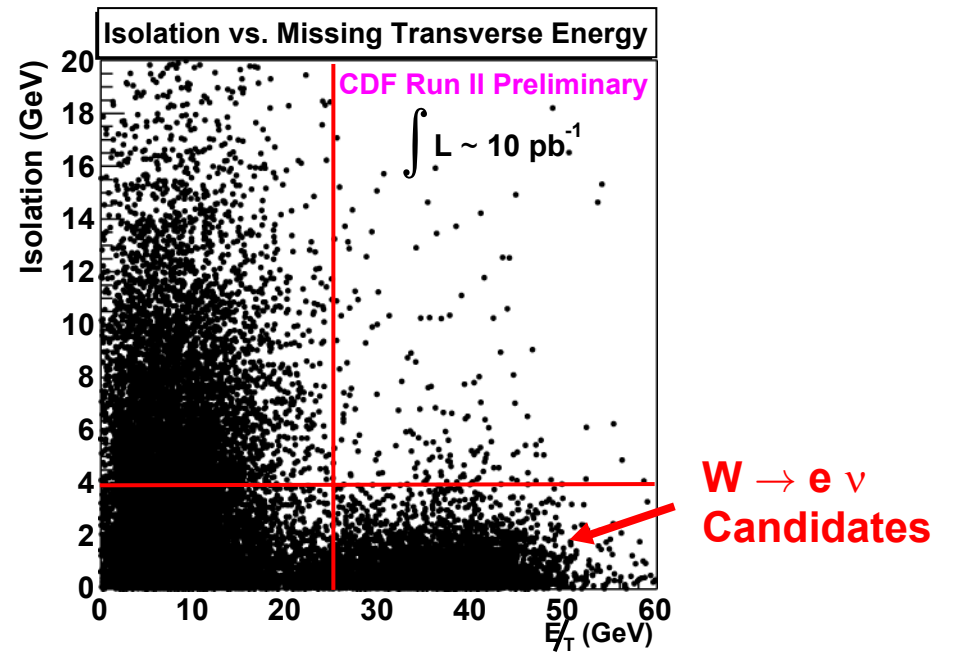
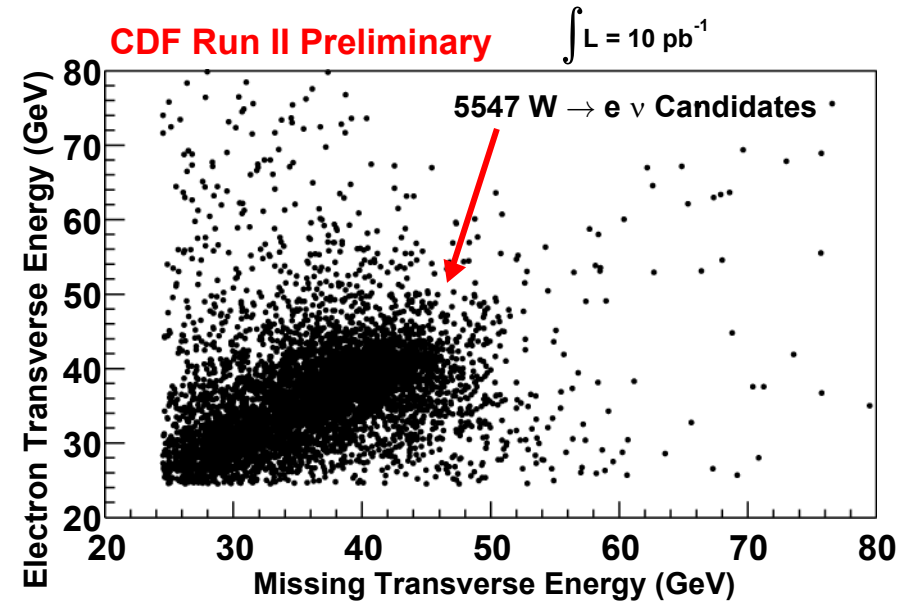


$W \rightarrow e \nu$

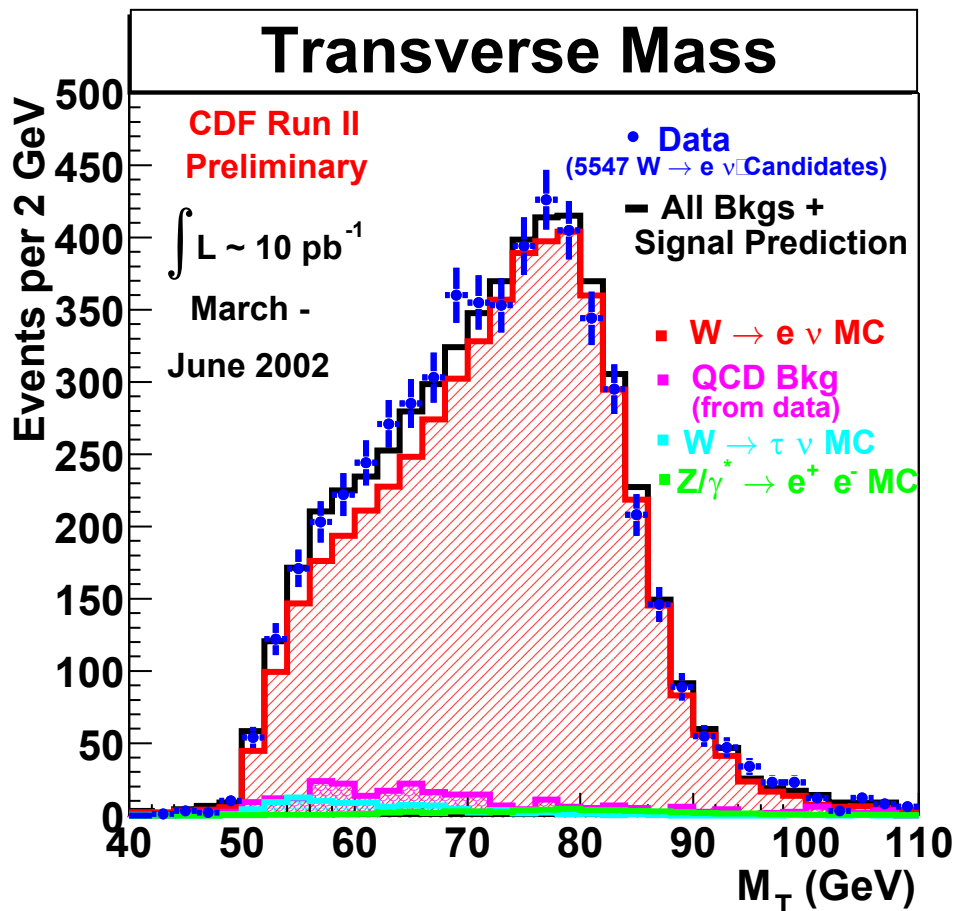
- Isolated electron
- Large E_T and \cancel{E}_T



$E_T = 35 \text{ GeV}$, $\cancel{E}_T = 38 \text{ GeV}$



$W \rightarrow e \nu (2)$

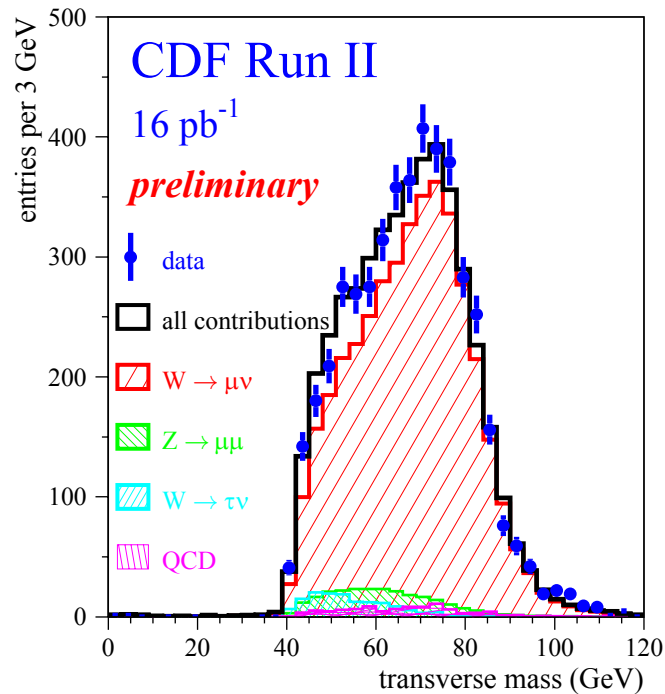


- Cross section measurement (preliminary)
 - $\sigma(W) \cdot B(W \rightarrow e \nu)$
 $= 2.60 \pm 0.07(\text{stat}) \pm 0.11(\text{sys}) \pm 0.26(\text{lum}) \text{ nb}$
 - consistent with Run 1 result
(after rescaling for higher CM energy)
 - NNLO theory : 2.73 nb ($\sqrt{s} = 1.96 \text{ TeV}$)
 2.50 nb ($\sqrt{s} = 1.8 \text{ TeV}$)
 - Run 1 : $2.49 \pm 0.12 \text{ nb}$ ($\sqrt{s} = 1.8 \text{ TeV}$)
- 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 2 fb^{-1}
(competitive to combined LEP2 result : $39 \text{ MeV}/c^2$)

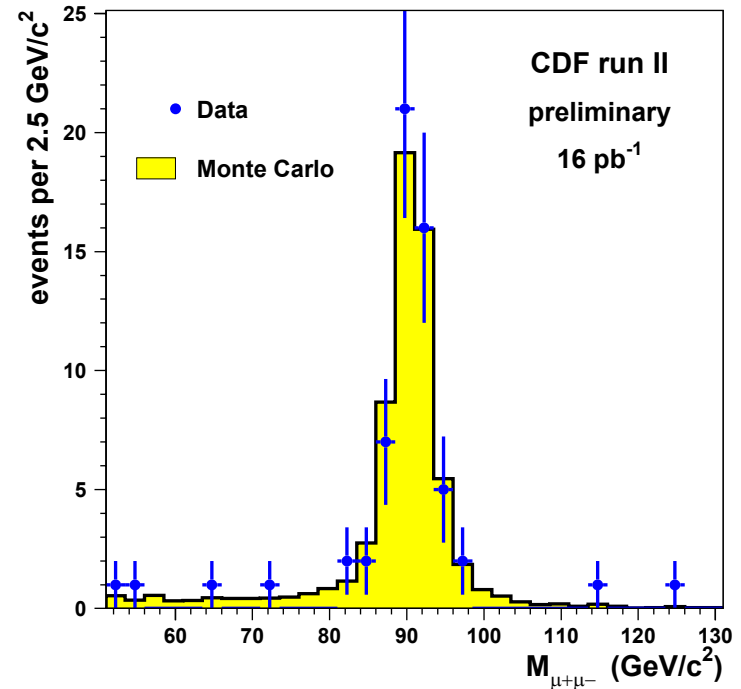
W and Z measurements with muons

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

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



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

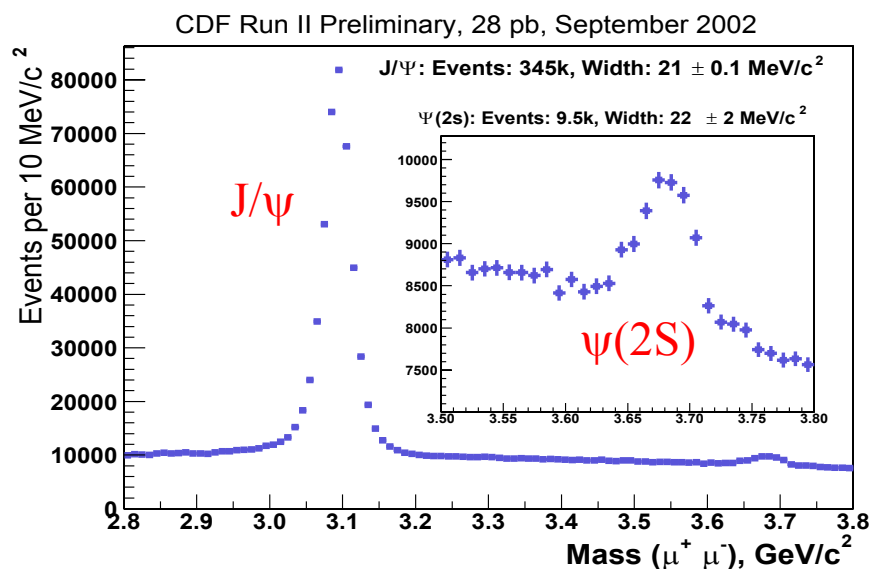


- $\sigma(W) \cdot B(W \rightarrow \mu\nu) = 2.70 \pm 0.04(\text{stat}) \pm 0.19(\text{sys}) \pm 0.27(\text{lum})$ nb
(Run 2 preliminary)

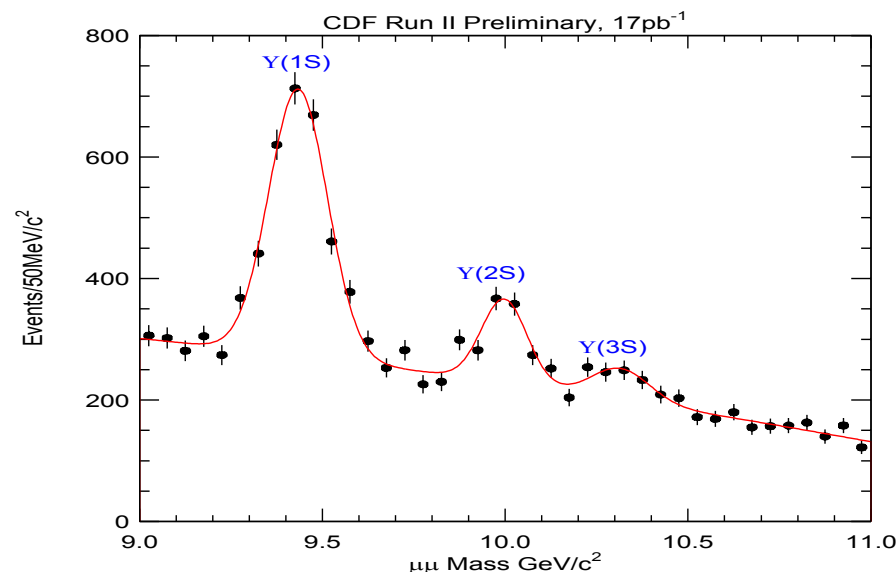
Measurements with low p_T muons

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

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



$Y \rightarrow \mu\mu$



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

Measurements of B Masses

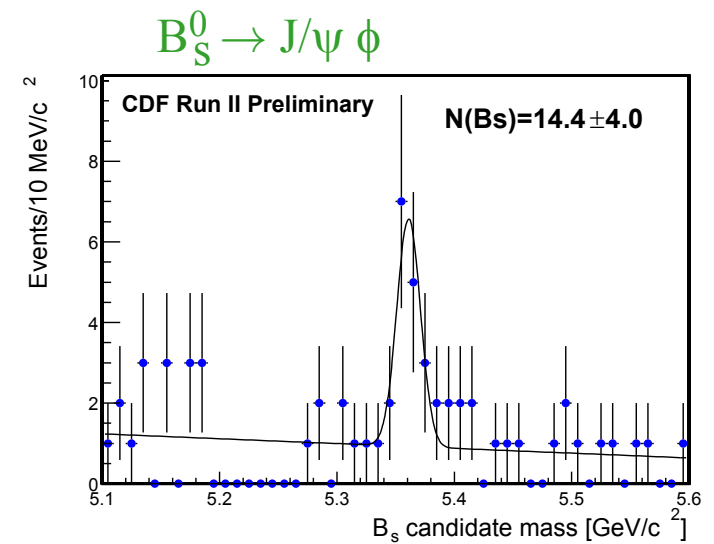
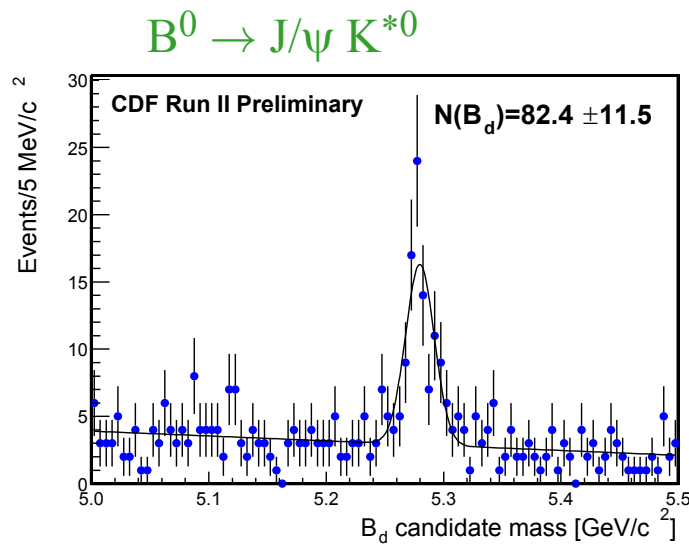
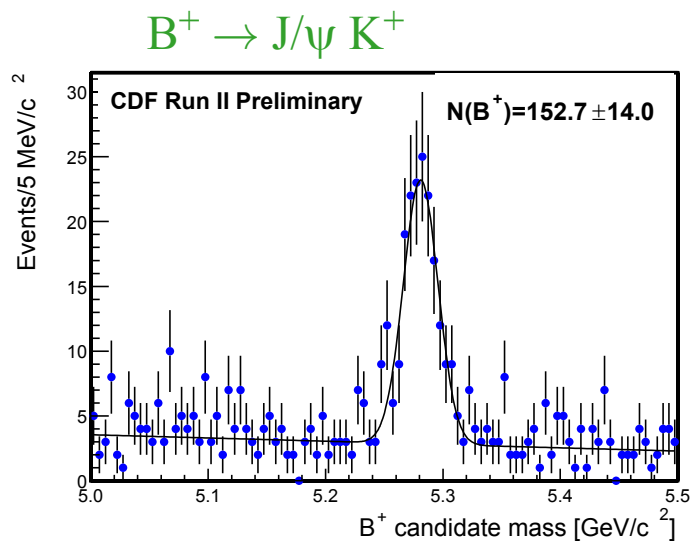
- Cross check of tracking calibration using J/ψ decay channels

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

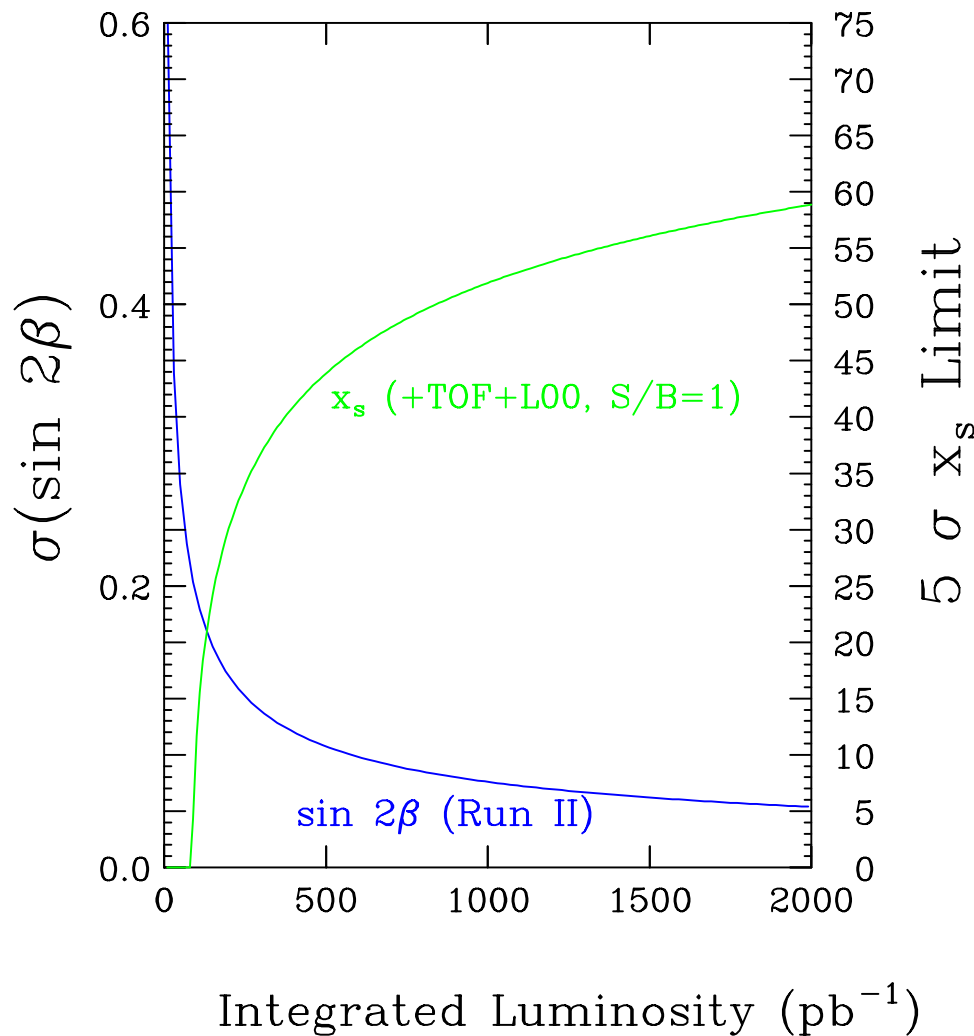
$$m(B^0) = 5279.8 \pm 1.9(\text{stat}) \pm 1.4(\text{sys}) \text{ MeV}/c^2 \quad (\text{PDG} : 5279.4 \pm 0.5 \text{ MeV}/c^2)$$

Starting to be competitive . . .

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



B Physics Projections

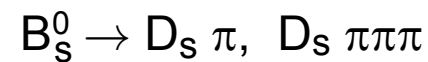


- measurement of $\sin 2\beta$



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

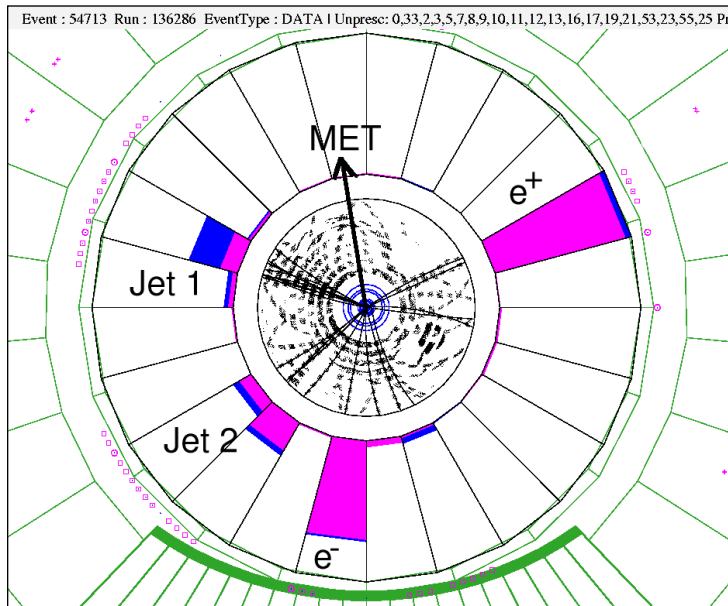
- $B_S^0 - \bar{B}_S^0$ mixing (\Leftarrow unique at Tevatron)



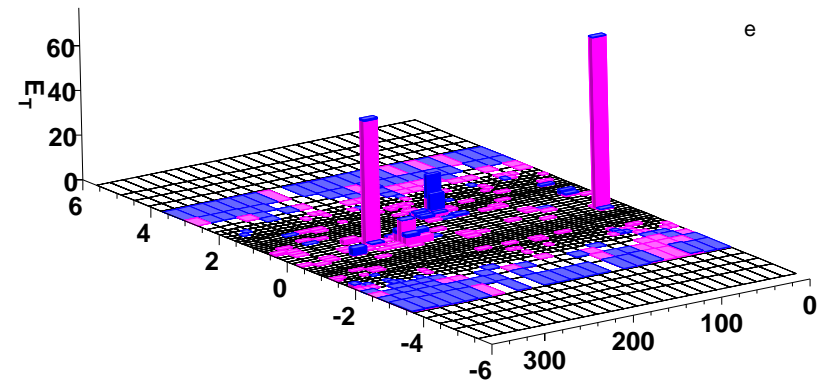
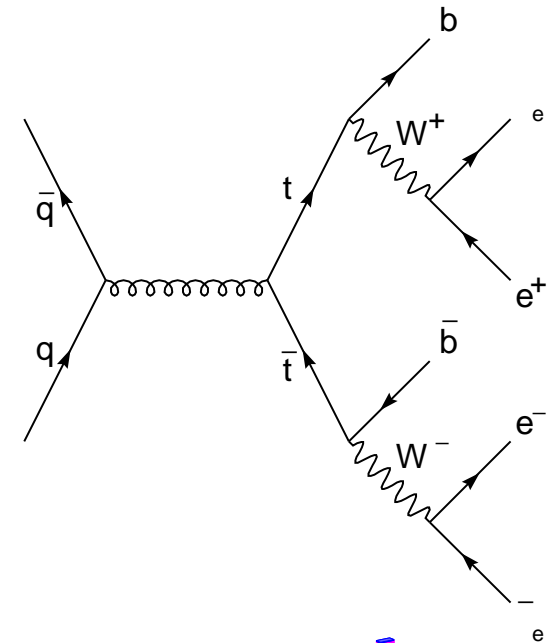
CDF sensitivity at 5σ for $x_s < 60$

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

Top Event Candidate

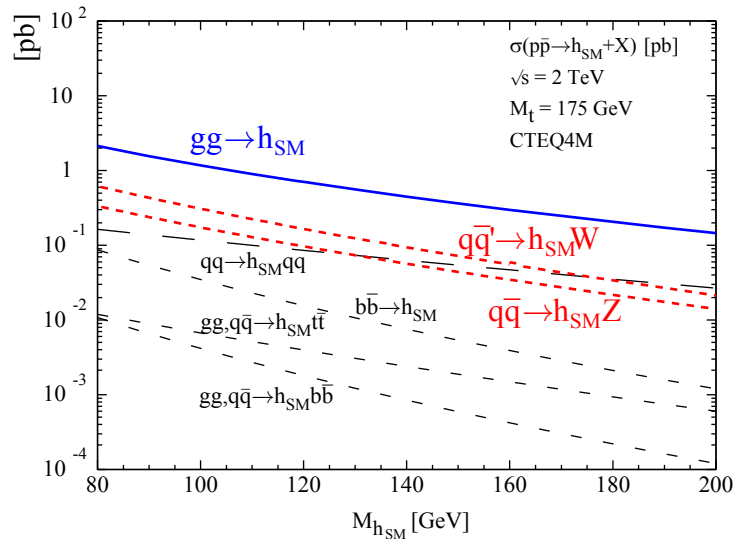


e⁺ E_T = 73 GeV
e⁻ E_T = 56 GeV
Jet 1 E_T = 35 GeV
Jet 2 E_T = 34 GeV
MET E_T = 43 GeV
M(e⁺e⁻) = 118 GeV



- 800 t t-bar events with b-tagging are expected with 2 fb⁻¹

Higgs at the Tevatron



Low-mass SM Higgs ($\sim 130 \text{ GeV}/c^2$)

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

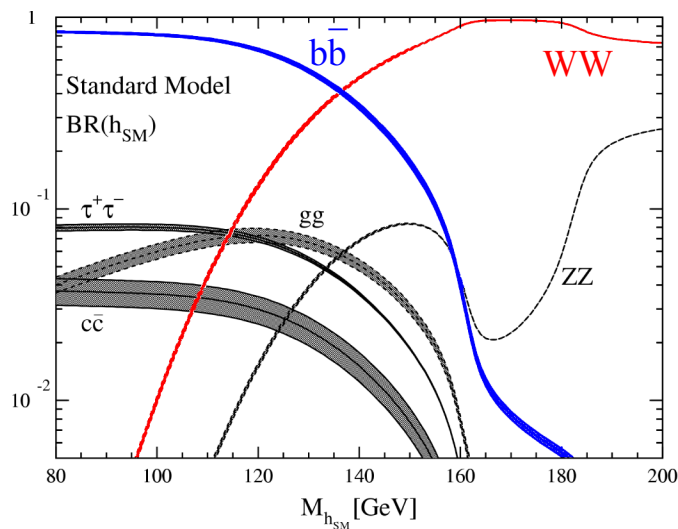
$$q\bar{q} \rightarrow Zh \rightarrow \ell^+\ell^- b\bar{b}, \nu\bar{\nu} b\bar{b}$$

High-mass SM Higgs ($130 \text{ GeV}/c^2 \sim 190 \text{ GeV}/c^2$)

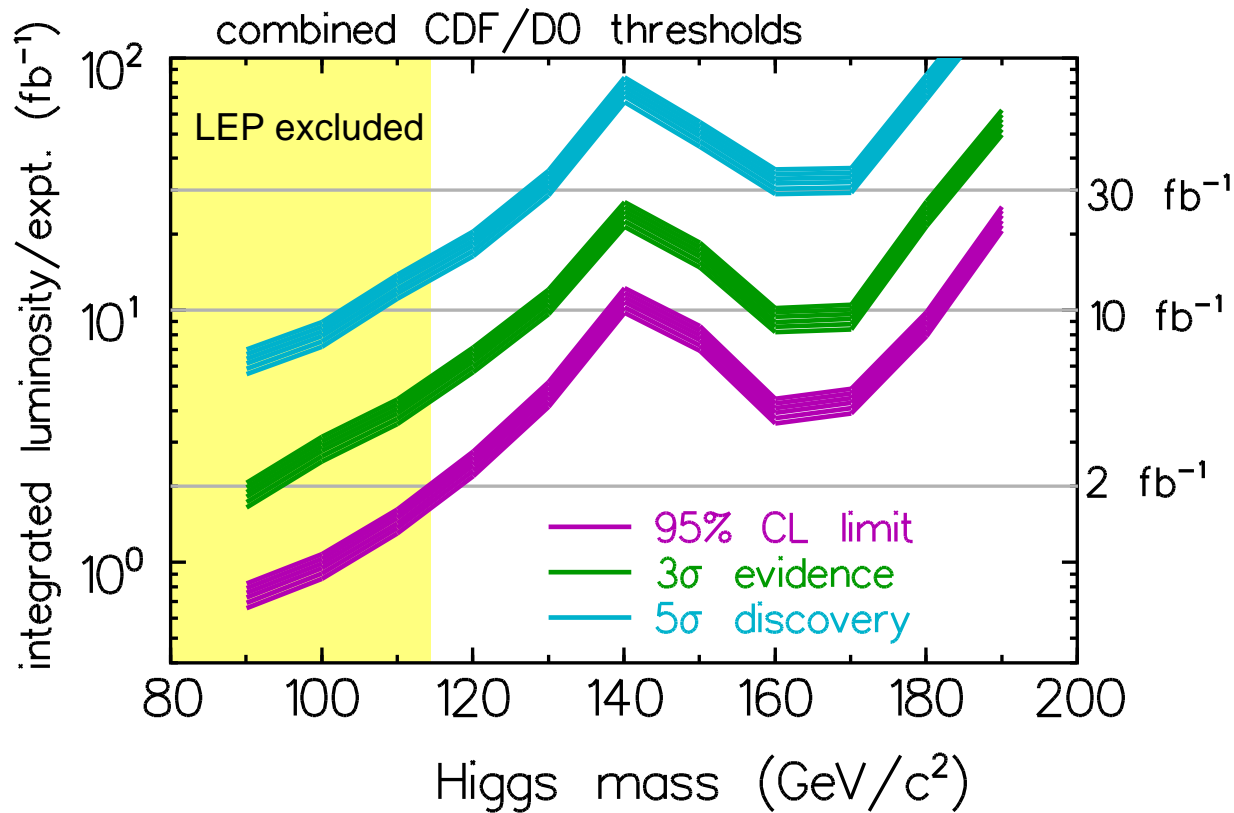
$$gg \rightarrow h \rightarrow W^*W^* \rightarrow \ell^+\ell^-\nu\bar{\nu}$$

$$q\bar{q}' \rightarrow Wh \rightarrow \ell^\pm\nu W^*W^* \rightarrow \ell^\pm\nu\ell^\pm\nu jj$$

$$q\bar{q} \rightarrow Zh \rightarrow \ell^\pm\ell^\mp W^*W^* \rightarrow \ell^\pm\ell^\mp\ell^\pm\nu jj$$



Higgs at the Tevatron (2)

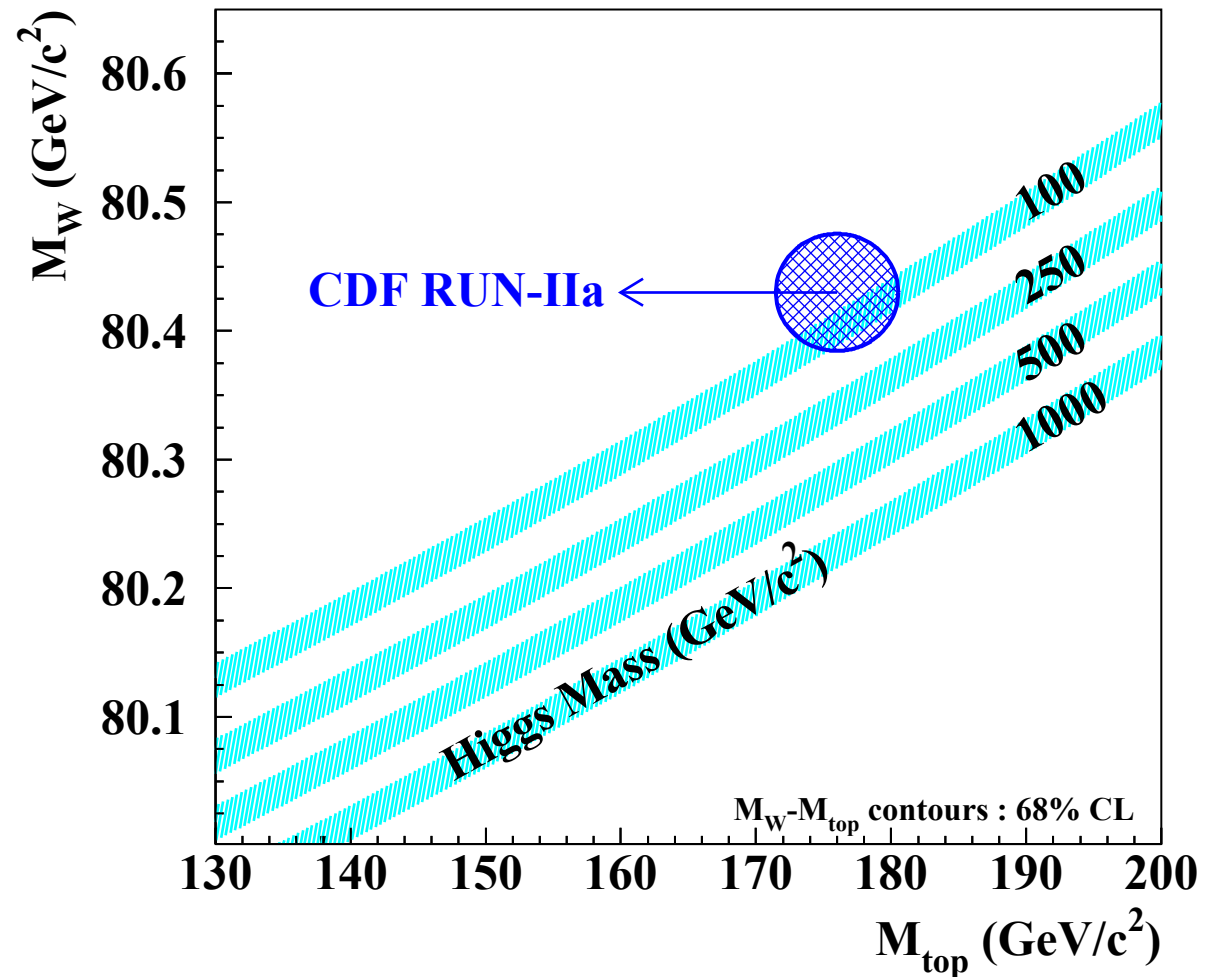


For $m_h < 120 \text{ GeV}/c^2$,

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

Top / Electroweak Projections

- $\sqrt{s} = 1.96\text{TeV}$
 $\sigma(W), \sigma(Z) \sim 10\%$ higher
 $\sigma(t\bar{t}) \sim 30\%$ higher
- With 2 fb^{-1} (Run 2a)
 $\Delta M_W \sim 30\text{ MeV}/c^2$
 $\Delta M_{\text{top}} \lesssim 3\text{ GeV}/c^2$
 $\Rightarrow \Delta(\log M_H) \sim \log 2$
($1/2 M_H < M_H < 2M_H$)
- With 15 fb^{-1} (Run 2b)
 $\Delta M_W \sim 20\text{ MeV}/c^2$
 $\Delta M_{\text{top}} \lesssim 2\text{ GeV}/c^2$
 $\Rightarrow \Delta(\log M_H) \sim \log 1.3$



Tevatron Plan and Luminosity Prospects

Run 2a

2002

- Expect to maintain peak luminosity in the range $2.5 \sim 4 \times 10^{31} \text{ cm}^{-2}\text{s}^{-1}$
- Expect a delivered integrated luminosity of $\sim 150 \text{ pb}^{-1}$ 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 $4 \sim 6 \times 10^{31} \text{ cm}^{-2}\text{s}^{-1}$

Run 2a goal

- Typical peak luminosity of $2 \times 10^{32} \text{ cm}^{-2}\text{s}^{-1}$
- 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 $4 \times 10^{32} \text{ cm}^{-1}\text{s}^{-1}$
- 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 $\sim 150 \text{ pb}^{-1}$ in 2002, 2 fb^{-1} in 2 \sim 3 years, 15 fb^{-1} in \sim 2008.