# Tevatron Era - Status and Future Prospects

**Outline**

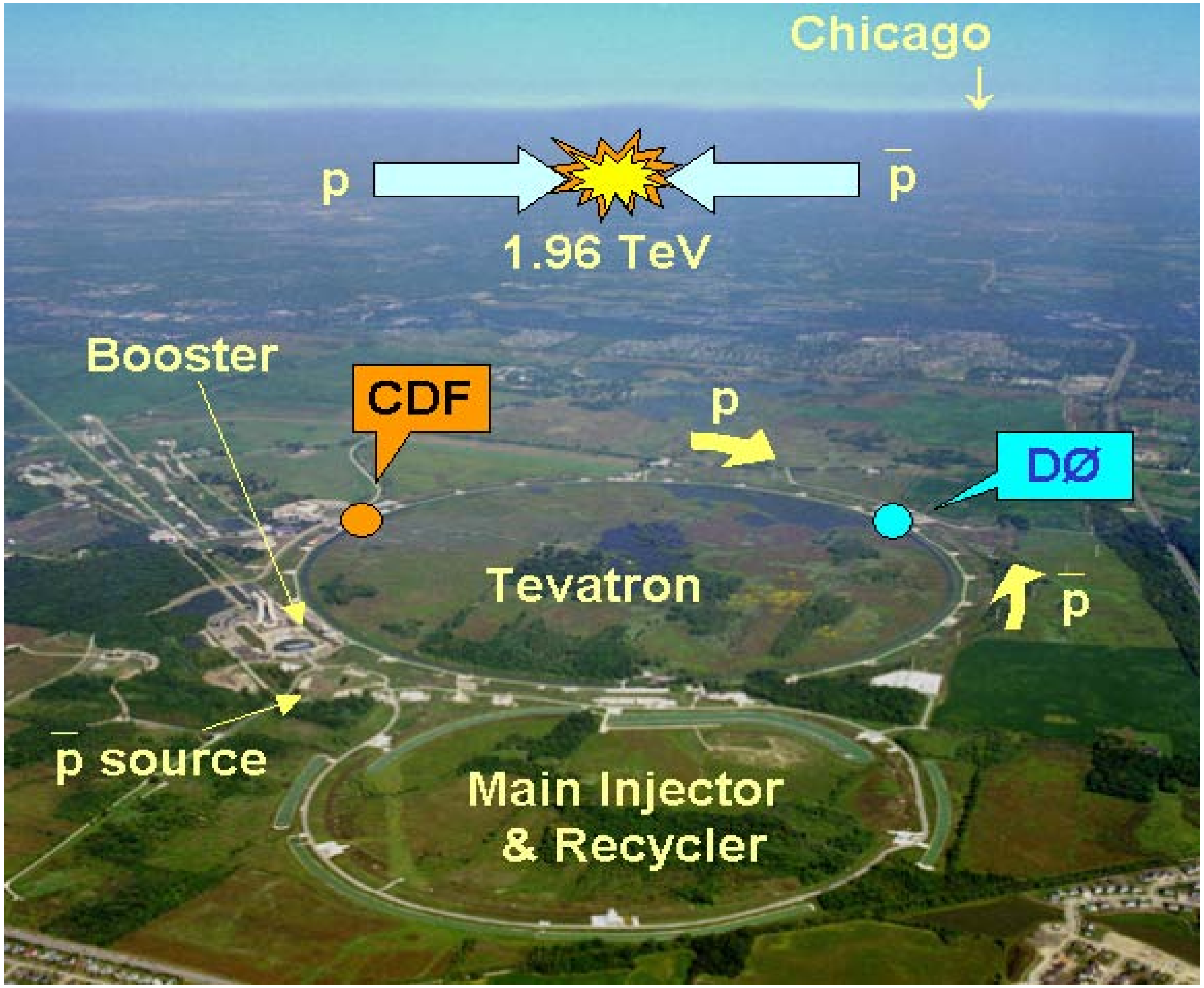
**Program goals**

**Detector and data**

**Highlights of the recent results**

**Future experimental program**

**Summary**




**La Thuile Round Table Discussion**

**March 3, 2010**


**Dmitri Denisov, Fermilab**

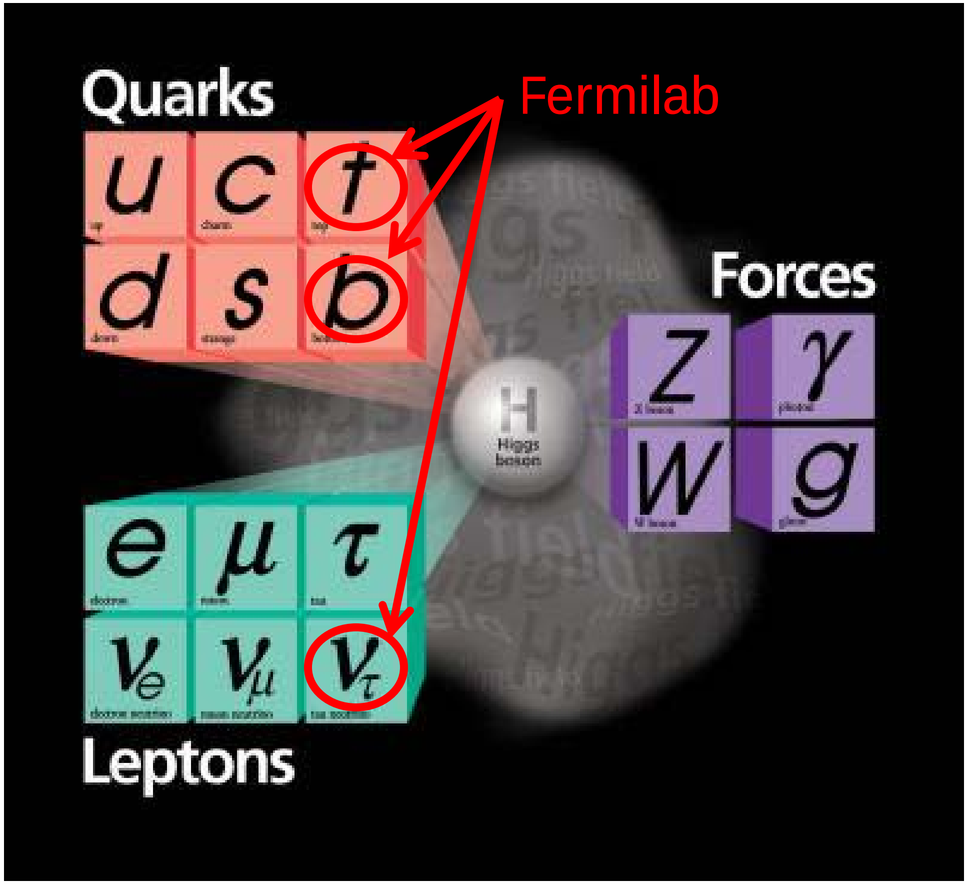
# Tevatron Physics Goals

**Precision tests of the Standard Model**

- **Weak bosons, top quark, QCD, B-physics...**

**Search for particles and forces beyond those known**

- **Higgs, supersymmetry, extra dimensions....**




**Addressing Fundamental Questions Facing Science**

**Origin of the mass?**

**Quark sub-structure?**

**Matter-antimatter asymmetry?**

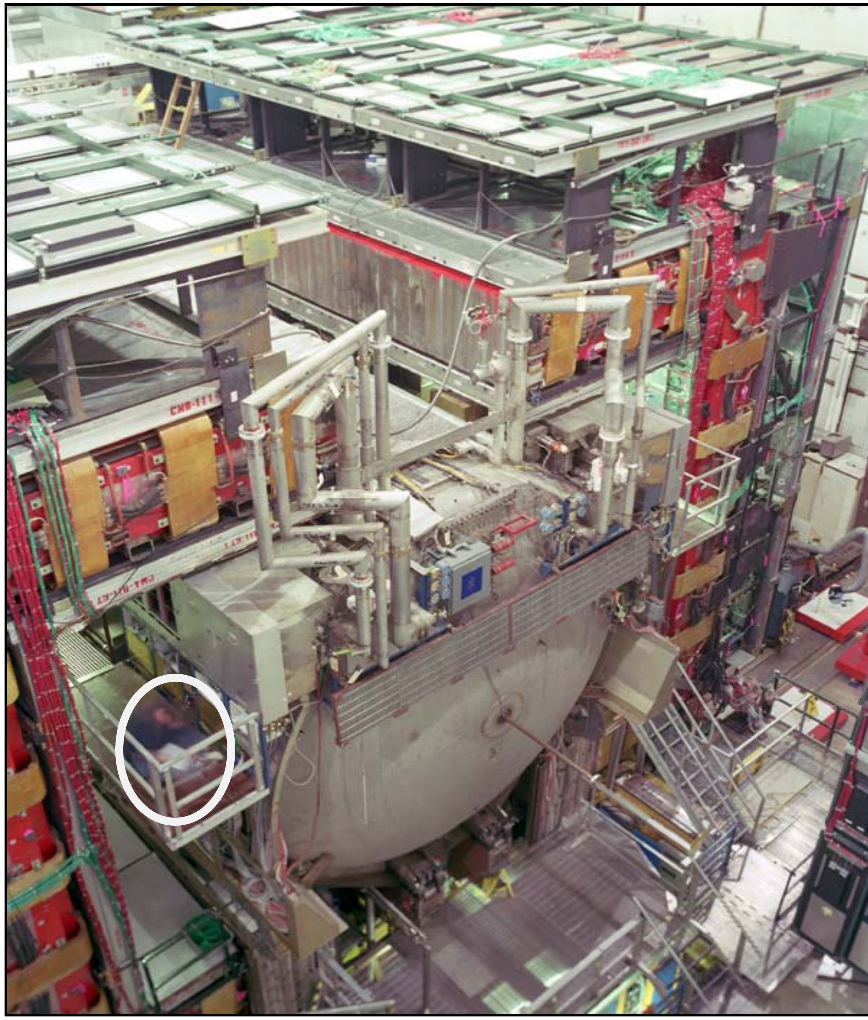
**What is cosmic dark matter?**

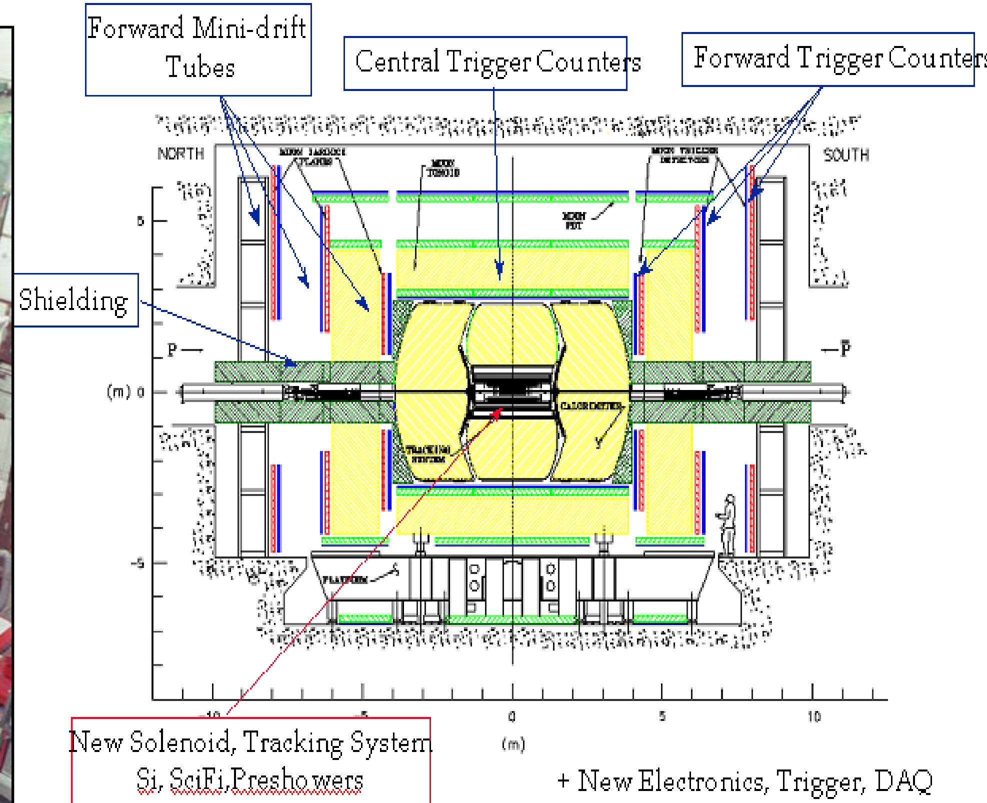
**SUSY?**

**What is space-time structure?**

**Extra dimensions?...**

# DØ Detector

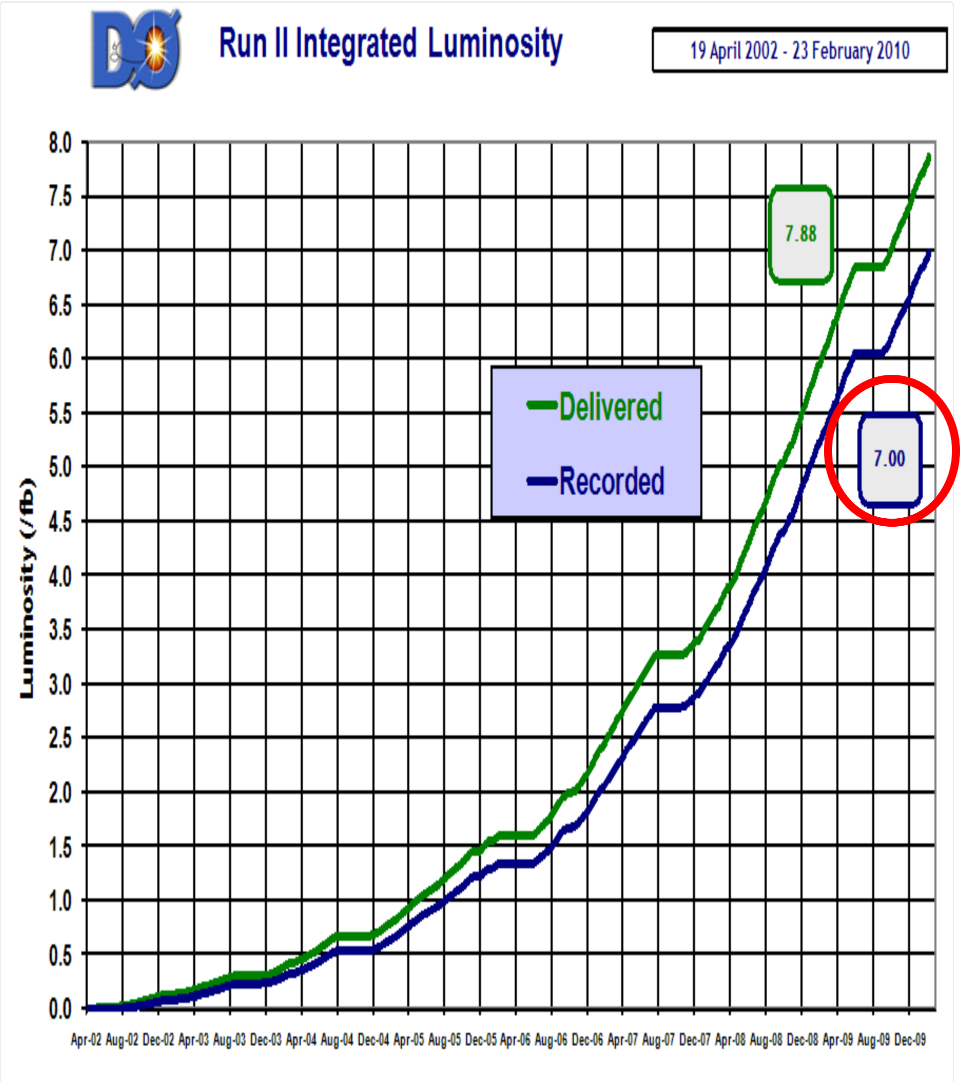





**Silicon Detector**
**2 T solenoid and central fiber tracker**
**Large coverage muon system**

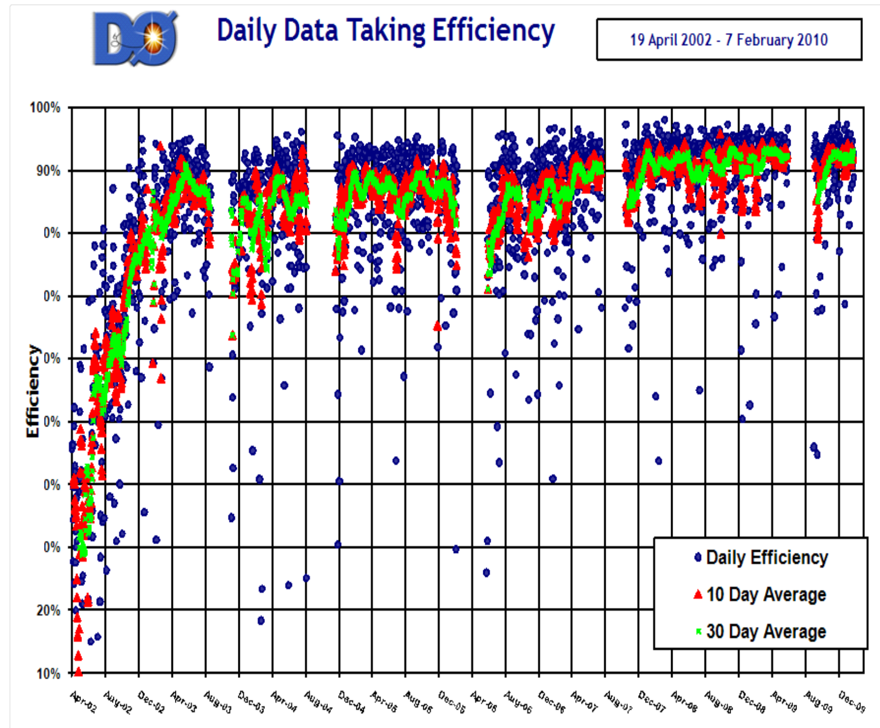
**Driven by physics goals detectors are becoming "similar":**
**silicon, central magnetic field, hermetic calorimetry and muon systems**

# Data Collection



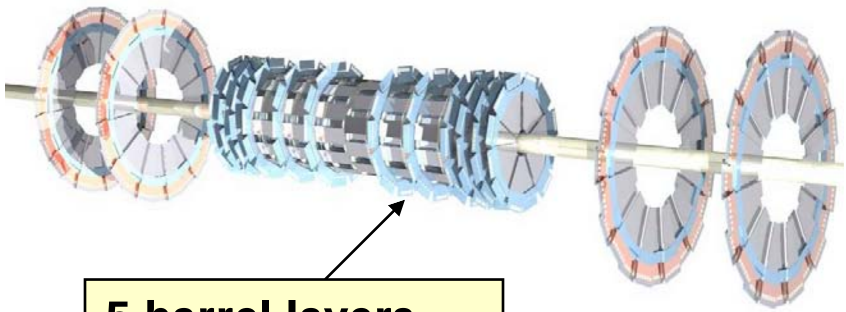

**2002** **February 2010**

- **Smoothly recording physics data**
  - **Typical week is above 50 $pb^{-1}$**
  - **7 $fb^{-1}$ recorded!**
- **90% data taking efficiency**

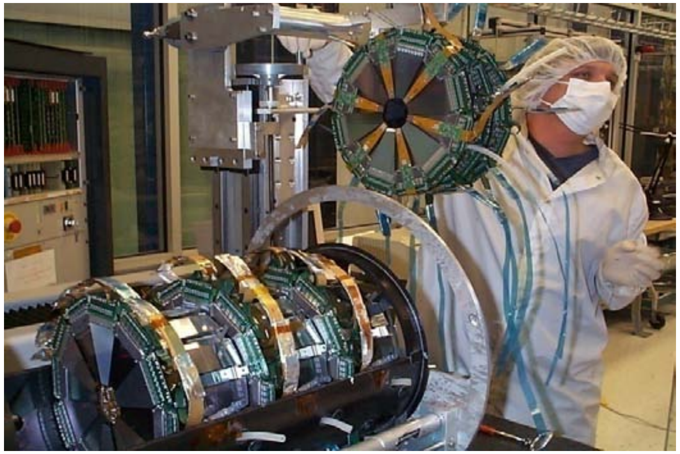


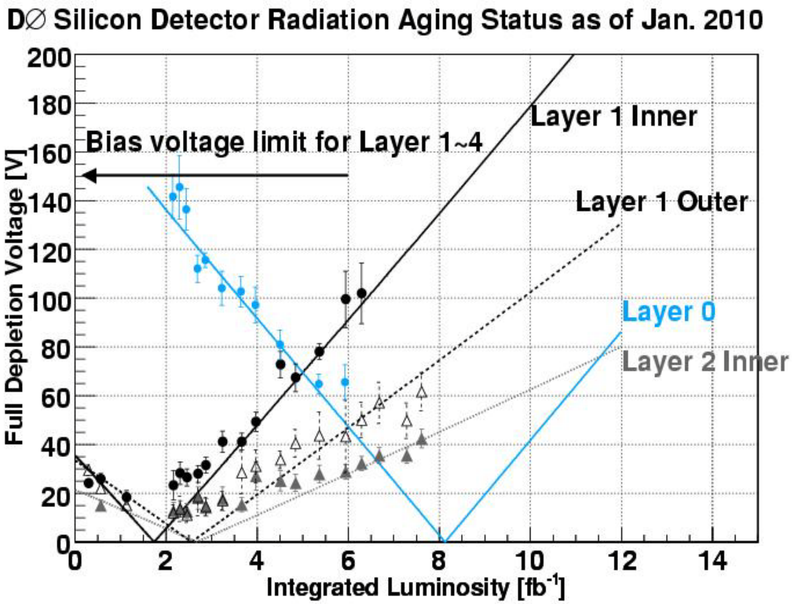

**2002** **February 2010**

# Silicon Vertex Tracker

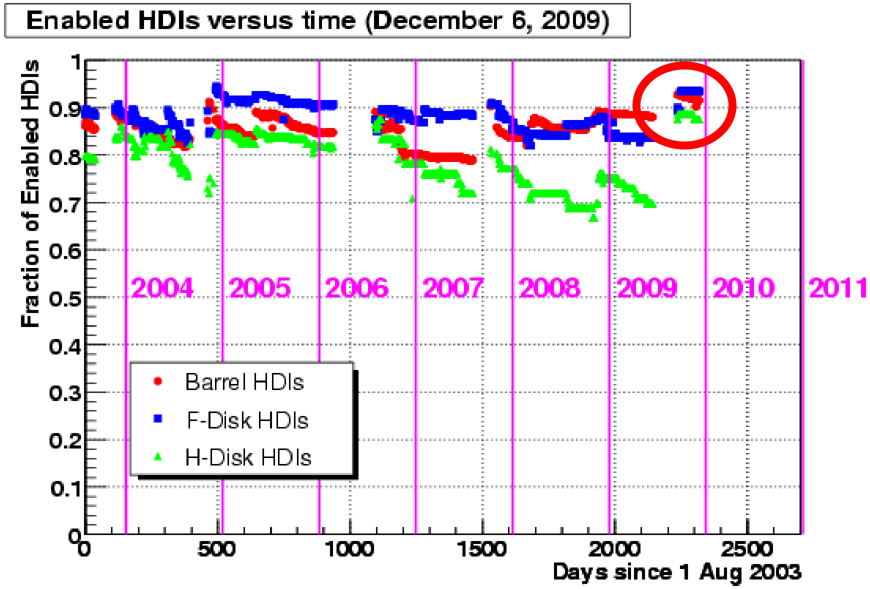


5 barrel layers
800k channels
~10 μm precision






**Detector is working well**
**Stable number of operating sensors**




**Radiation dose → no issues for running up to 12 $fb^{-1}$ of delivered luminosity**

# The DØ Collaboration

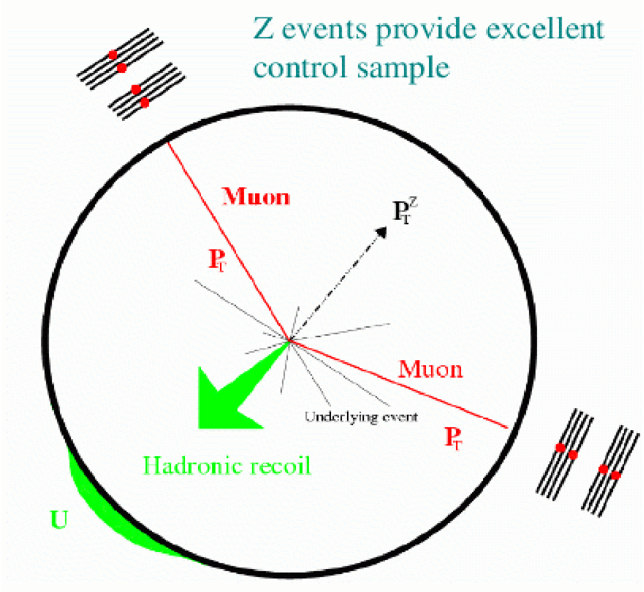
**DØ today is international Collaboration of 500 physicists from 19 nations**

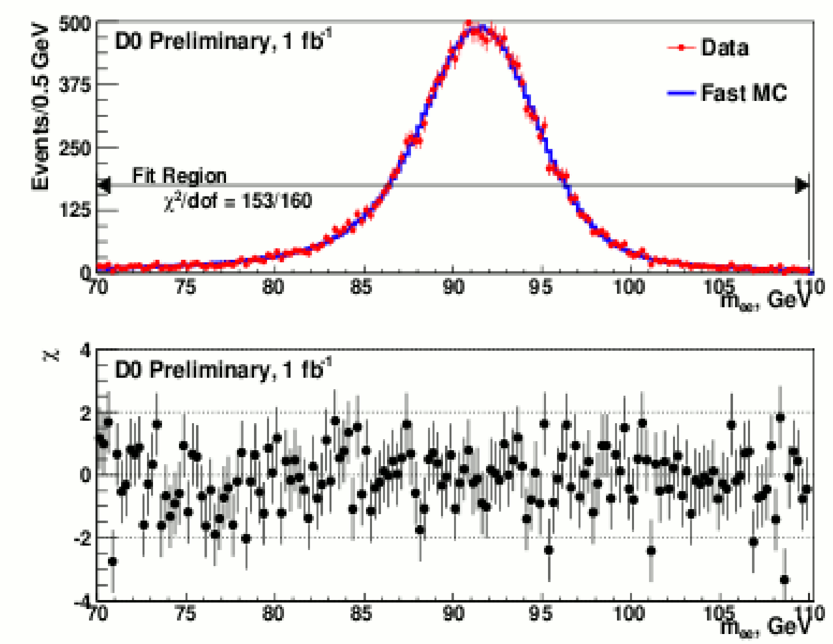


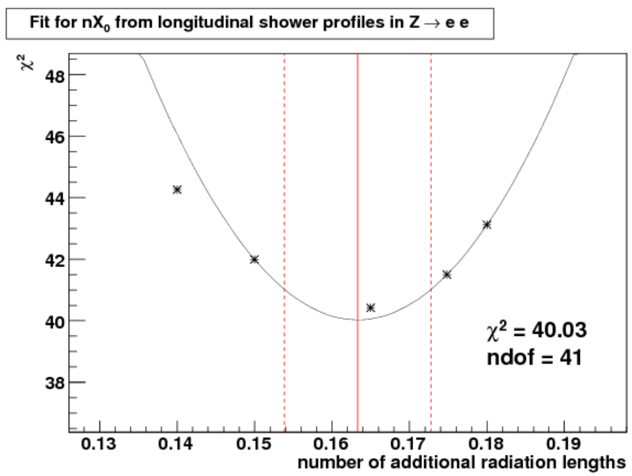
- **Excellent example of productive international cooperation**
    - **50/50 mix of US and non-US groups**
- **~50% of the collaboration are students and postdocs**

# Algorithms – "Test Beam at Collider"

- **Major efforts have been devoted at DØ to develop methods of particle identification**
  - **Electrons, muons, jets, charged particles, missing energy**
- **Large luminosity provides accurate "in situ" calibrations of the detector**
  - **"Standard candles"**



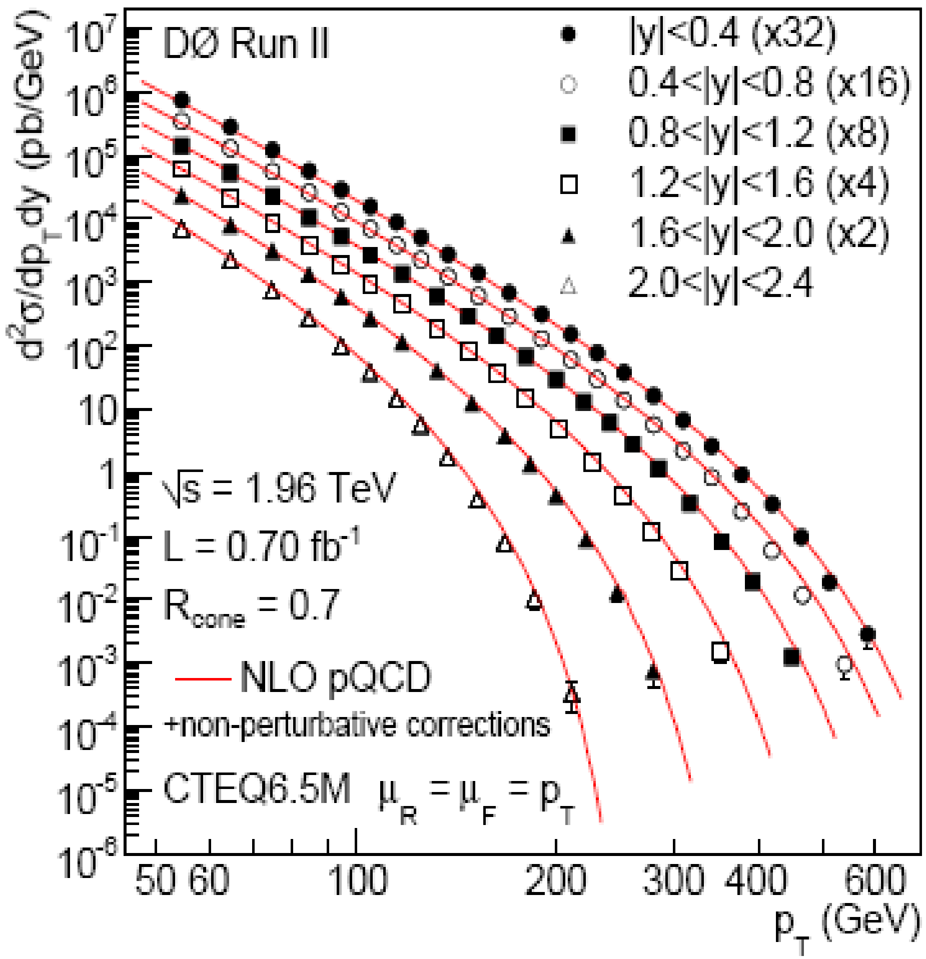



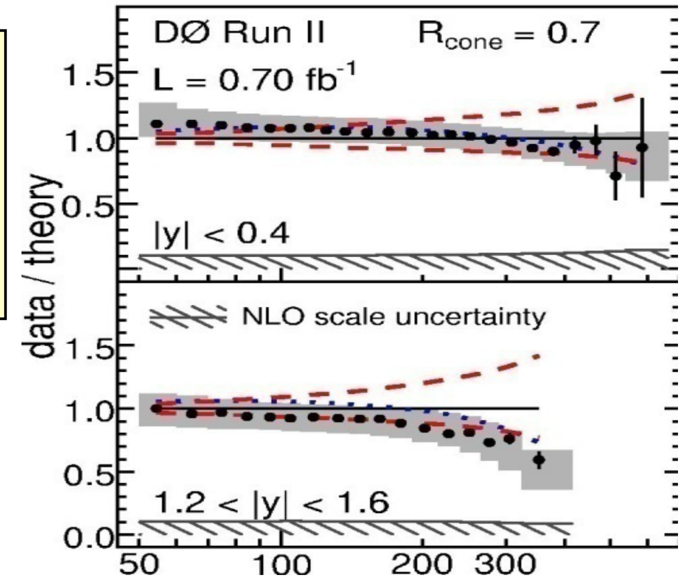




**Calorimeter calibration to ~0.05% accuracy and measurement of the material in the detector within $0.01X_0$**

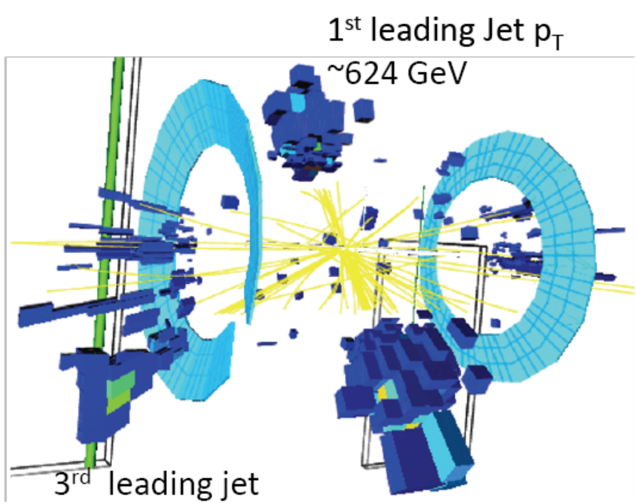
# QCD Studies

- Use parton scattering to study proton structure
  - Rutherford style experiments at $10^{-16}$ cm
- Jet cross sections, di-jet mass studies, angular distributions in $\eta$ and $\phi$



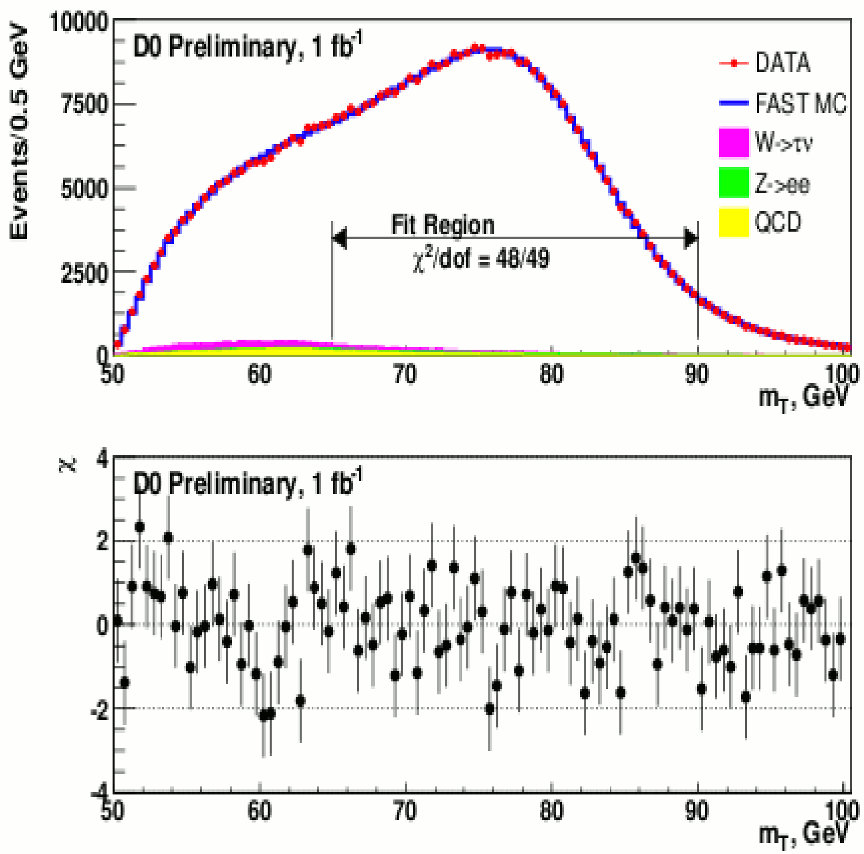

**1 TeV energy deposition!**

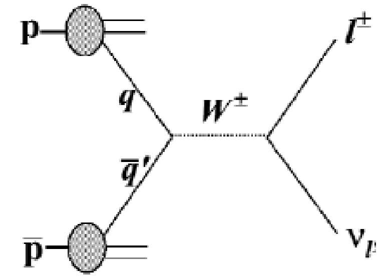


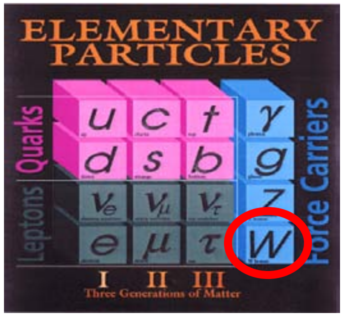
# Electroweak Physics

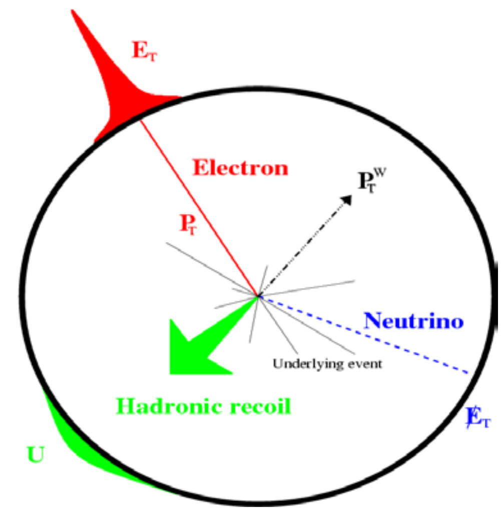
**Indirectly constrain new physics through precision measurements of parameters**
**Measure single and multi-boson production, W mass, W production asymmetry,...**

**World's most precise W mass measurement**



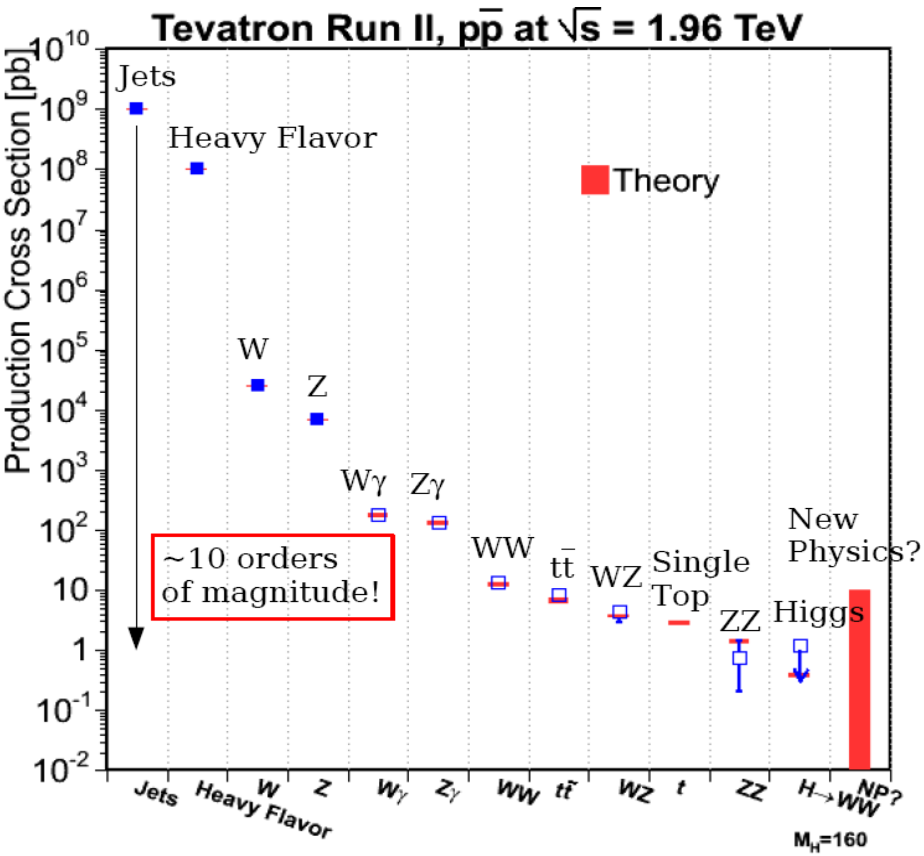




**$M_W$=80.401    0.021(stat)    0.038(syst)GeV**

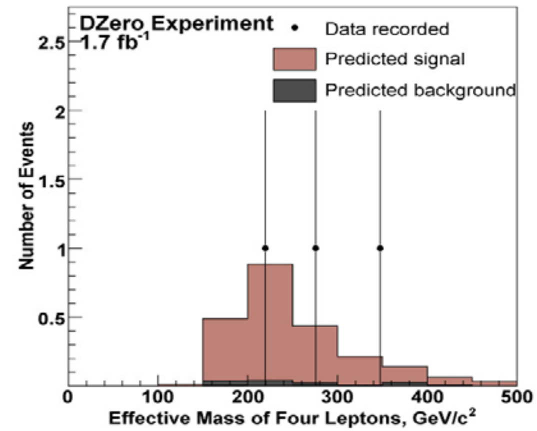
**World average is now**
**80.399    0.023 GeV (0.025%)**
**Provides strict Higgs mass constrains**

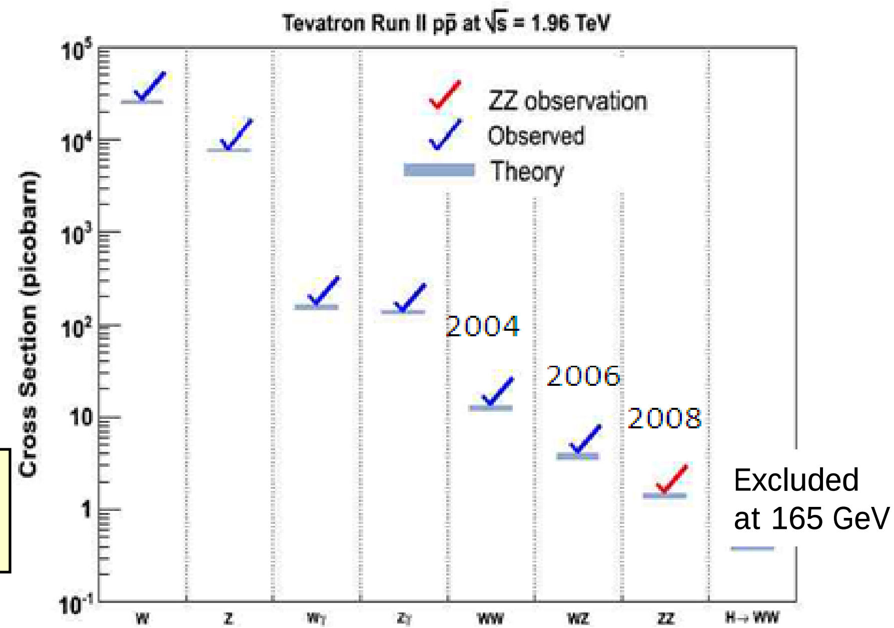
# Studies of di-boson Production

**Detect very rare processes, search for anomalous vector boson couplings and develop experimental methods for Higgs hunting**




## Discovery of ZZ production



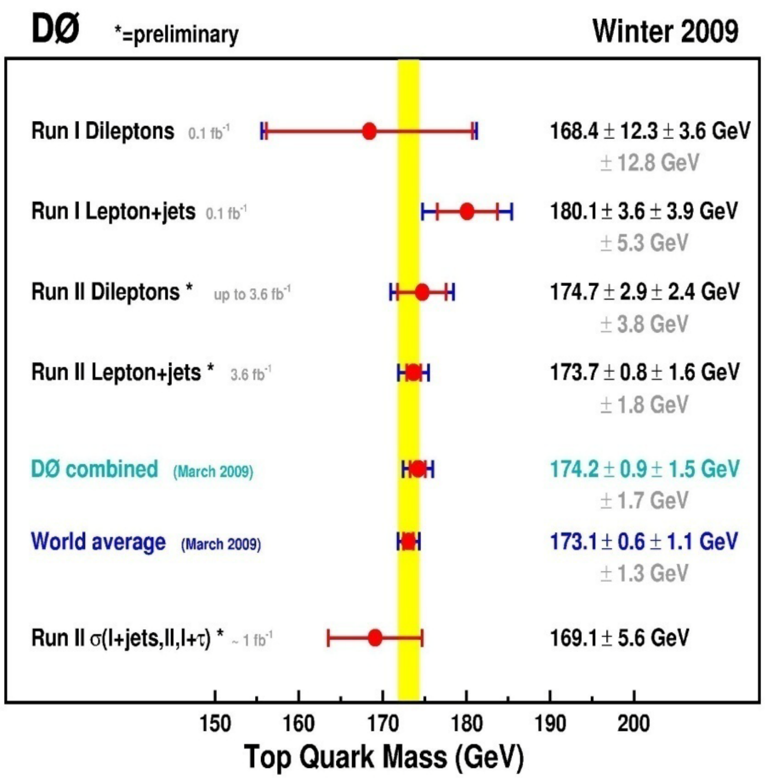



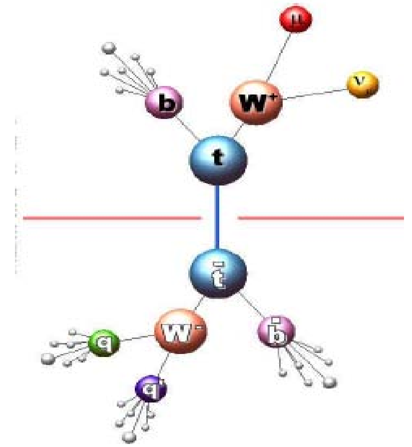

**ZZ cross section of 1.6 ± 0.1 pb is similar to anticipated Higgs cross section**

**H → WW**

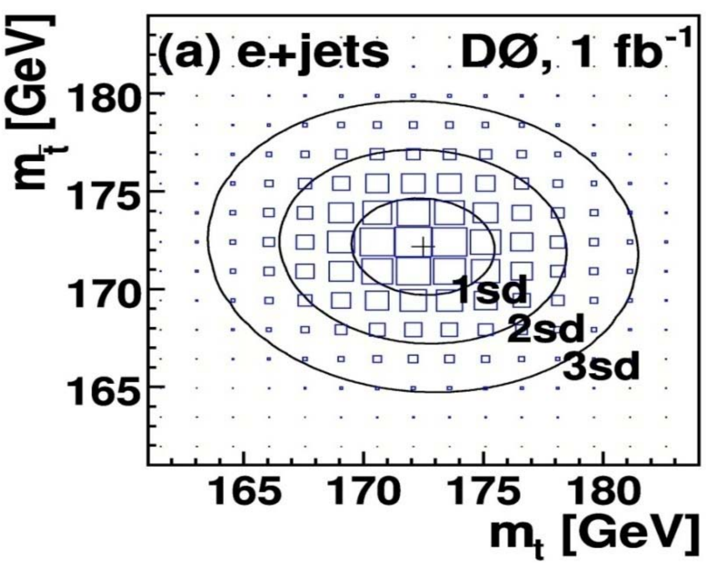
# Top Quark Mass Measurement

**Top mass is fundamental parameter of the Standard Model measured in many different decay channels**




**First measurement of quark-anti quark mass difference: CPT test in quark sector**




GeV

**DØ and CDF combined top mass**
**$m_t$ = 173.1±1.2 GeV**
**0.7 % accuracy**
**Best (of any) quark mass measurement!**

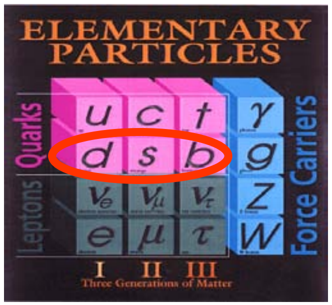
# b Quark Studies

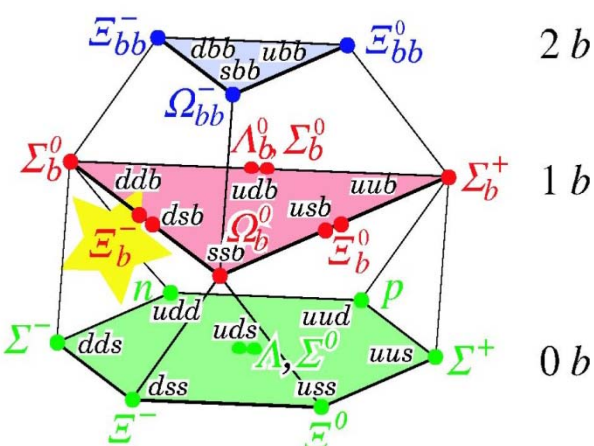
**High b quark cross section: ~$10^{-3}$ $\sigma_{tot}$**

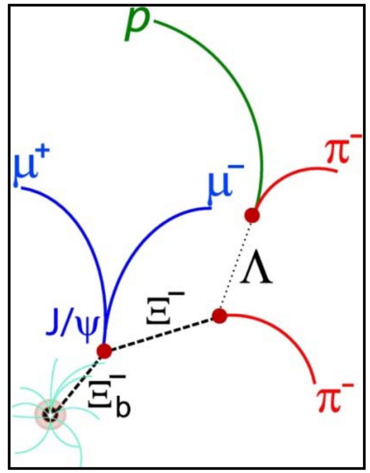
**~$10^4$ b's per second produced**

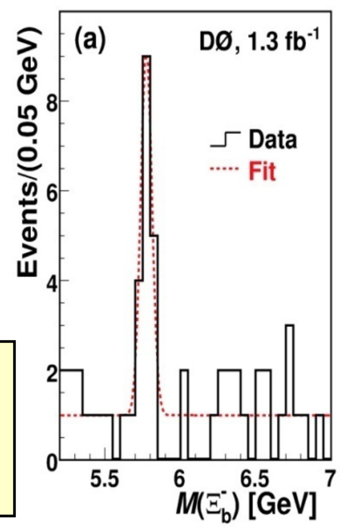
**All b containing species are produced**

**$B^{\pm}$, $B^0$, $B_s$, $B_c$, $\Lambda_b$…**



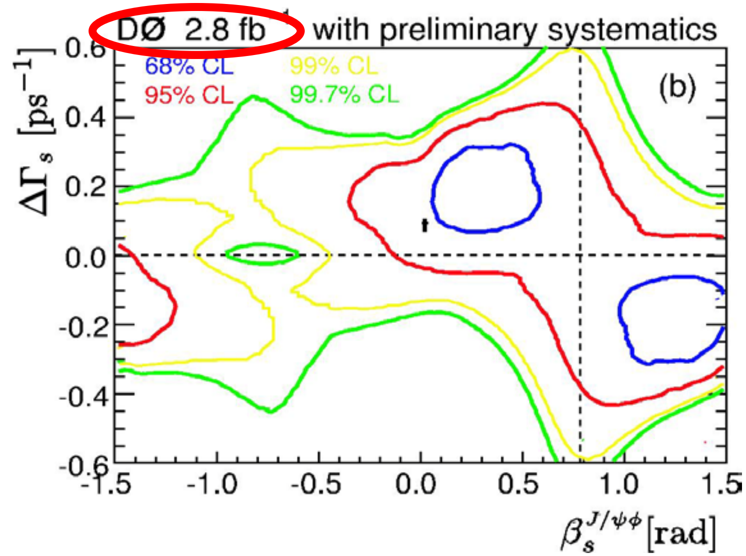



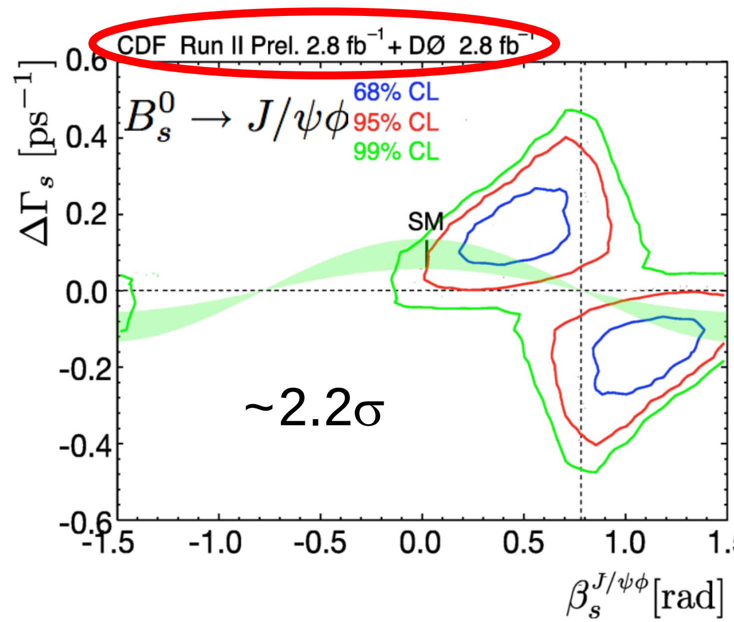




**First particle with quarks from all three generations observed!**

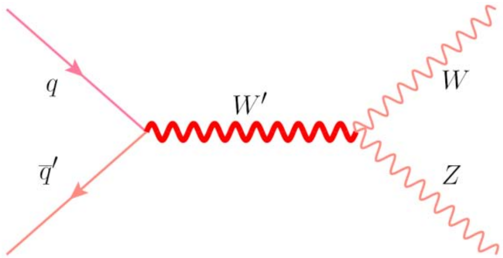
**Hint of physics beyond Standard Model in $B_s^0 \to J/\psi\phi$ decay?**

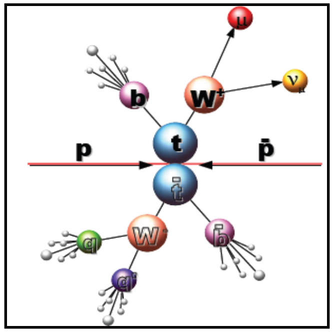


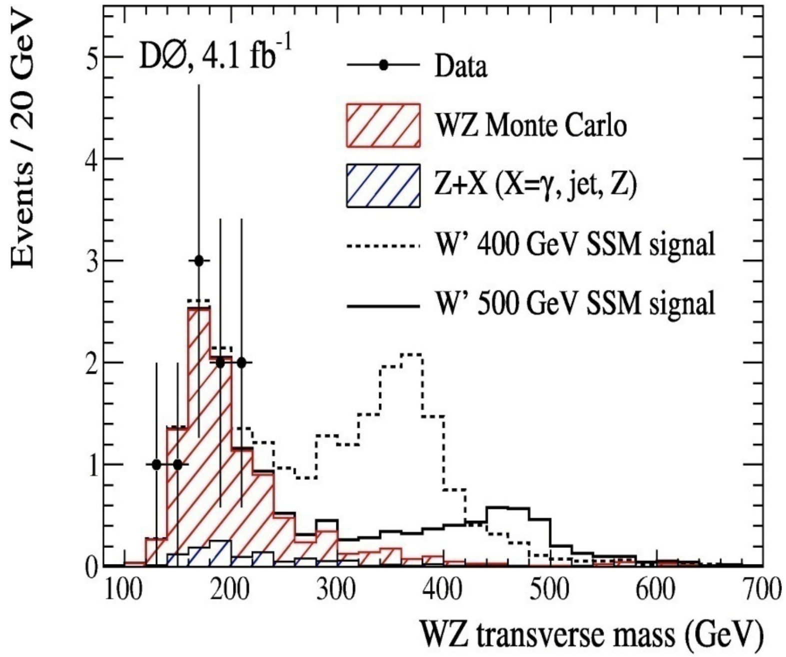



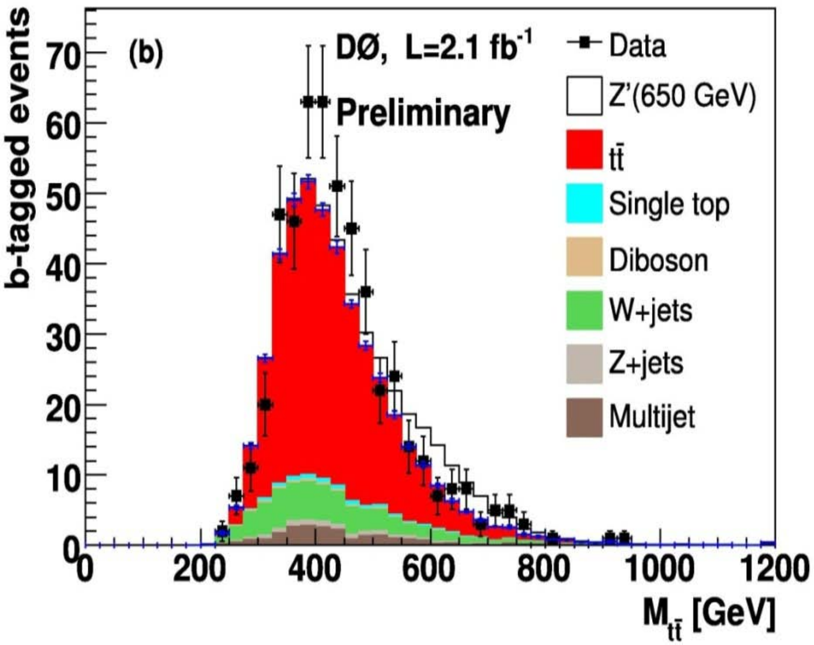
# Search for New Phenomena

**Recipe: search for irregularities in effective mass spectra or other kinematic parameters to find events not described by the Standard Model**



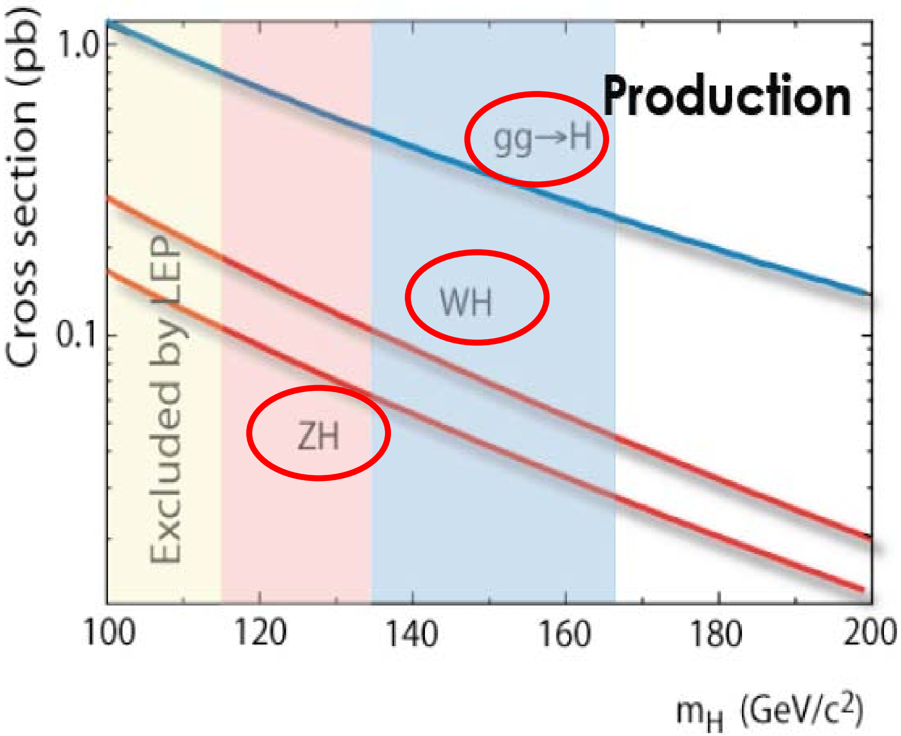



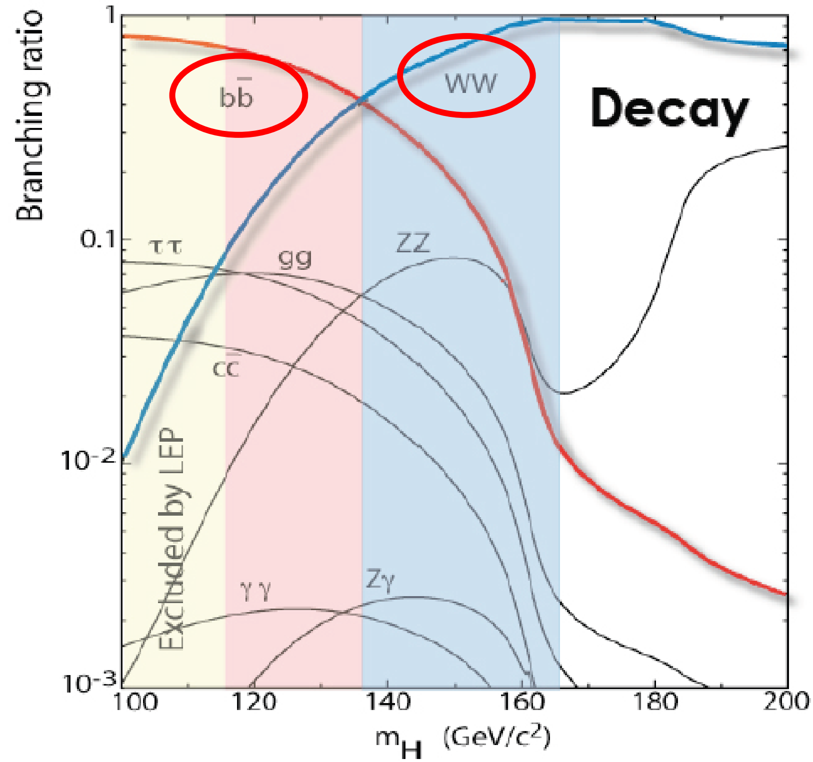




**In many searches reaching masses of ~1TeV – ½ of the Tevatron center of mass!**

# Higgs Production and Decays at the Tevatron



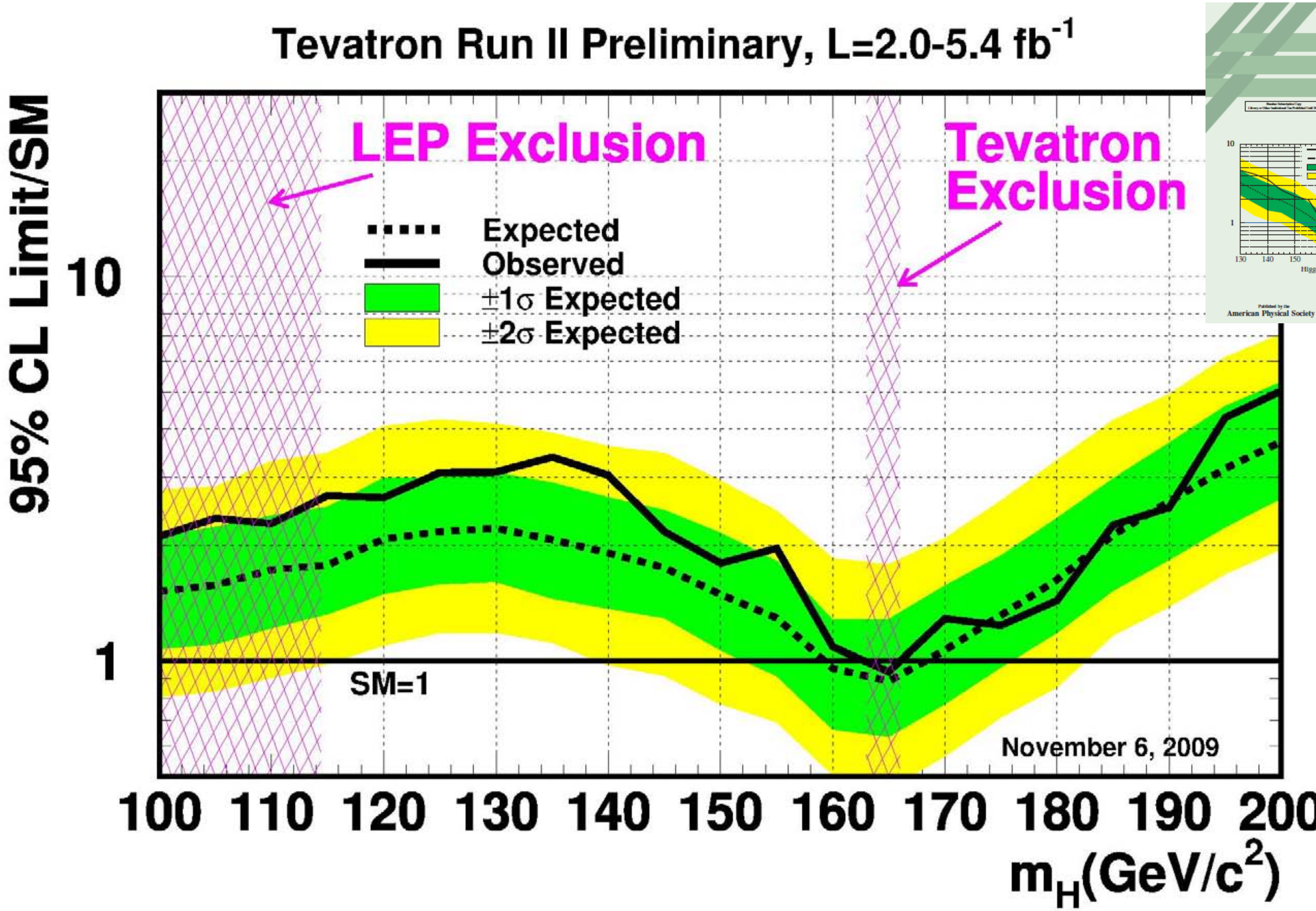

**Production cross sections**
→ in the 1 pb range for gg → H
→ in the 0.1 pb range for associated vector boson production

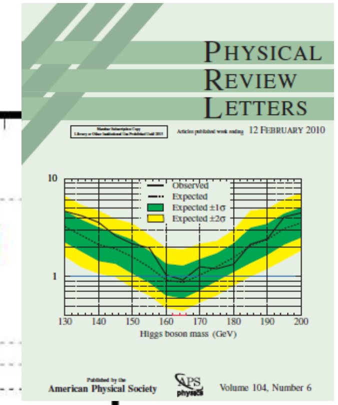
**Decays**
→ bb for $M_H$ < 130 GeV
→ WW for $M_H$ > 130 GeV

**Search strategy:**
$M_H$ <130 GeV associated production and Higgs to bb decay
$M_H$ >130 GeV gg → H production with decay to WW

**At 115 GeV ~5 inclusive Higgs bosons would be produced at Tevatron per day**
**Separation from large backgrounds is the major challenge**

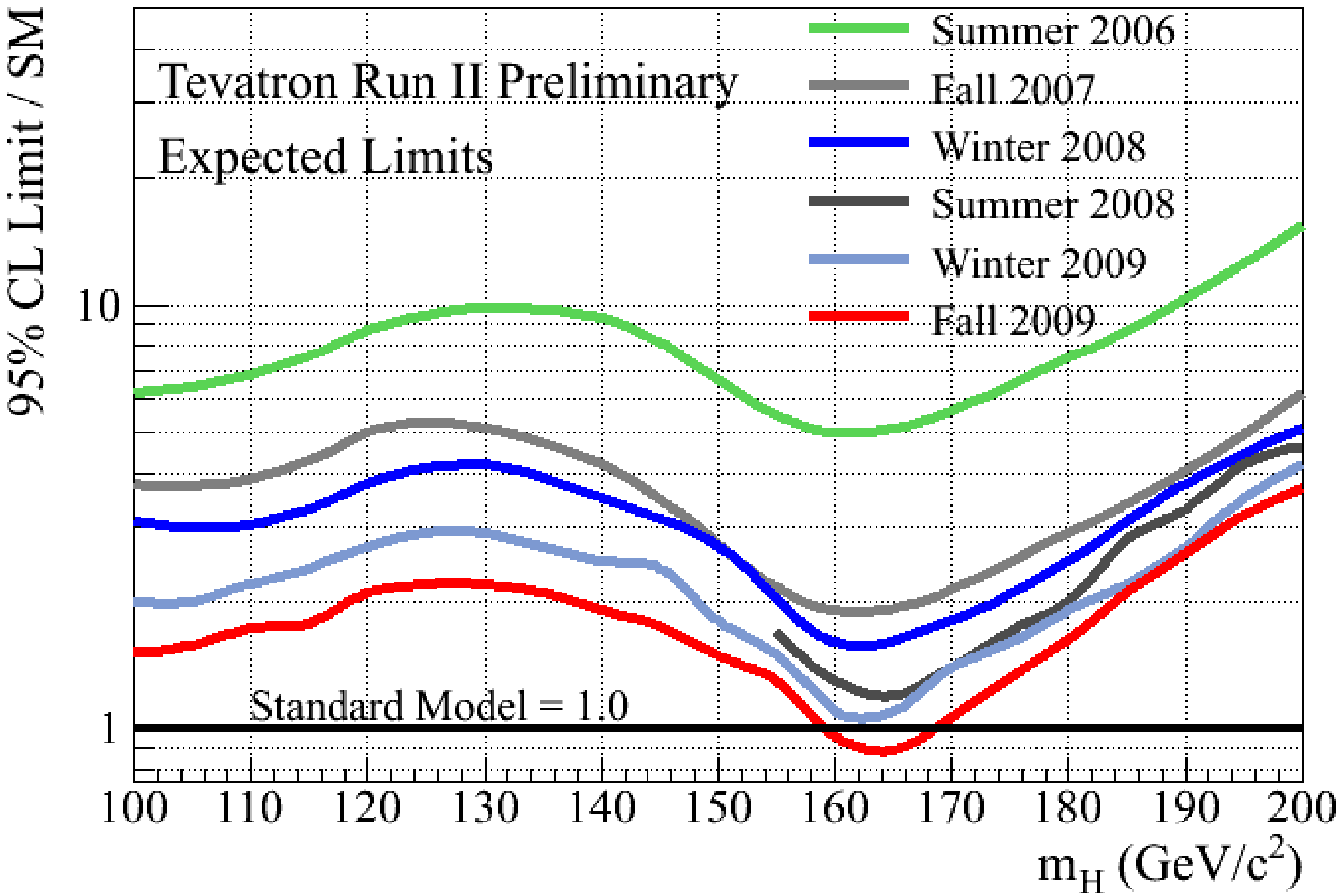
# Combining Two Experiments - exclusion!



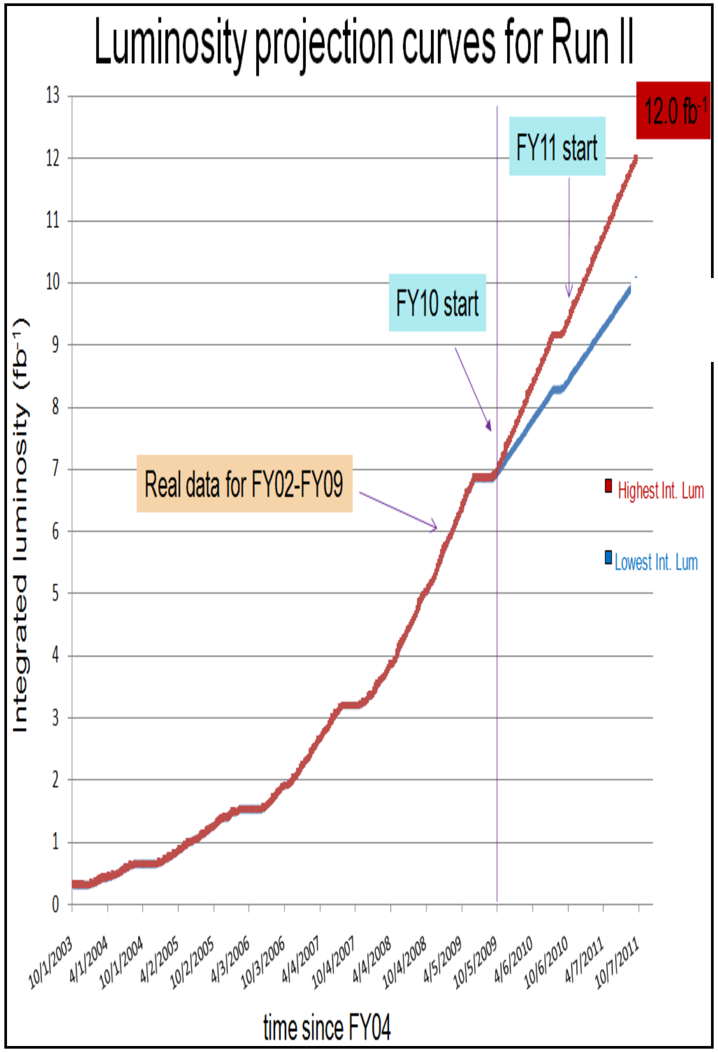

**Tevatron is sensitive to Higgs boson and already excluded masses around 165 GeV**

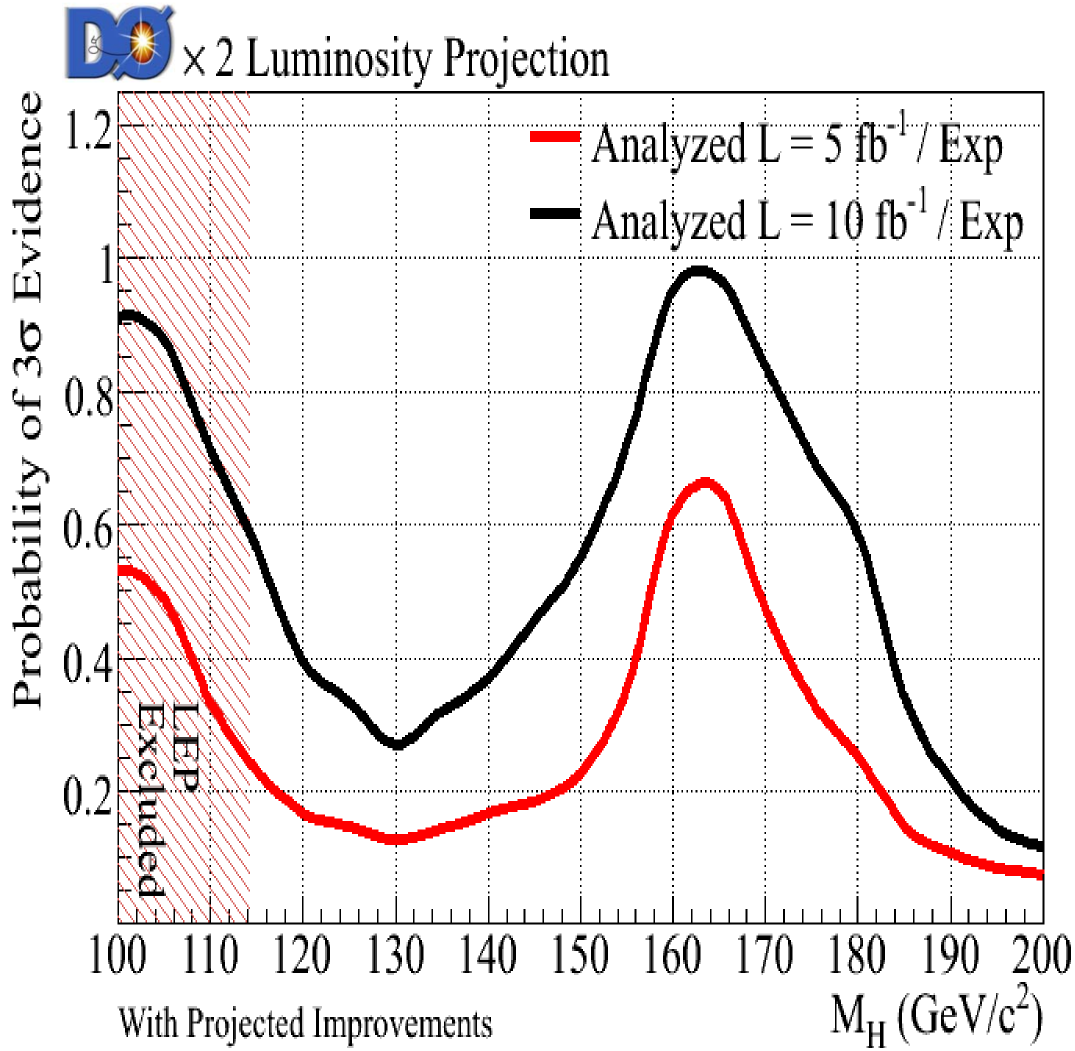
# Progress with Higgs limits at the Tevatron




**Steady progress with increase in data set and analysis experience**
**Factor of 1.8 from prediction at Higgs mass of 115 GeV**

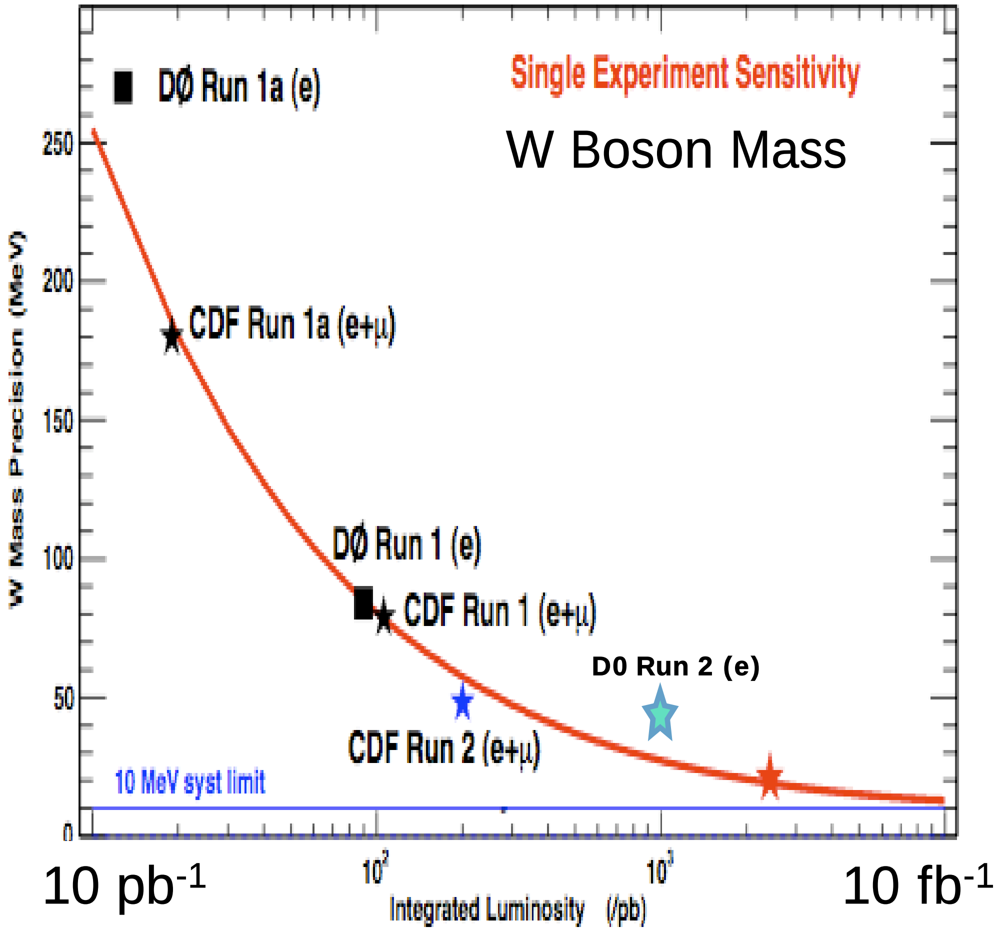
# Tevatron Standard Model Higgs Projections

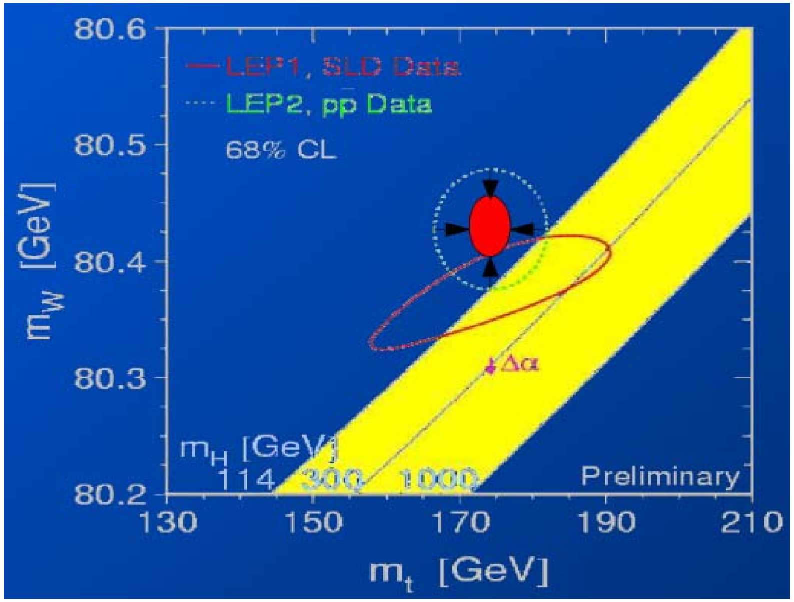


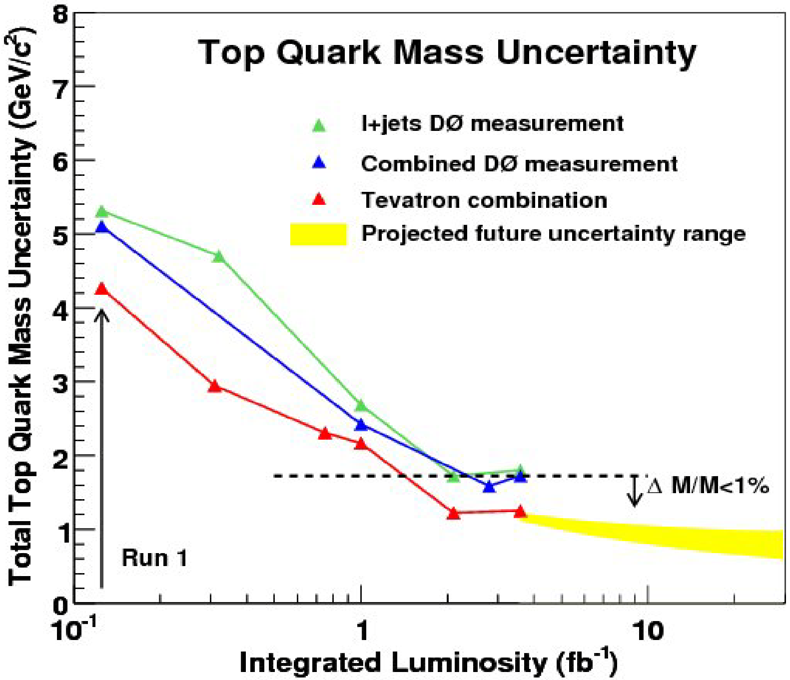




**With 10 $fb^{-1}$ available for analysis by the end of 2011 it will be possible to either exclude at 95% over entire allowed mass range or… see hints of the Higgs boson!**

# Tevatron Projections



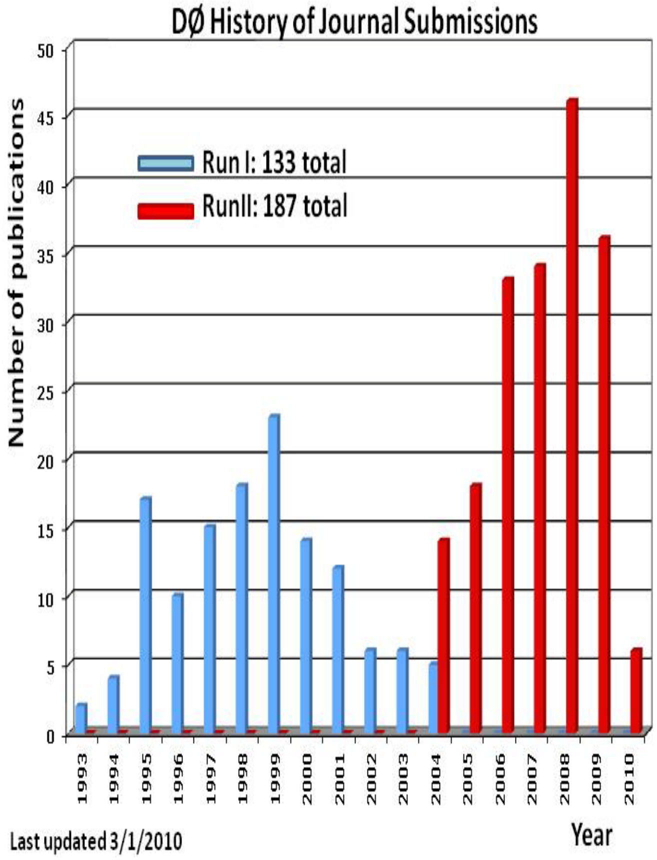

**15 MeV error on W boson mass and no changes in the mean value: Higgs exclusion with $M_H$ <117 GeV**

**Many other exciting studies progressing**

# Summary: 2010-2011

**Congratulations to our CERN colleagues with LHC startup and first impressive results!**

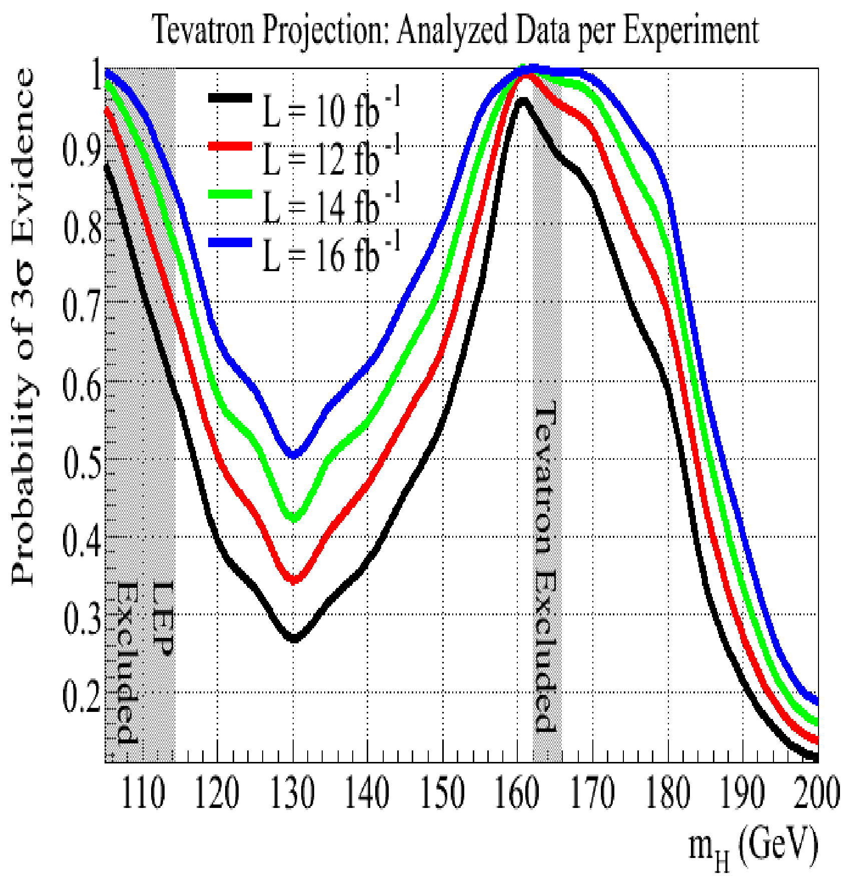
- **Tevatron run in 2011 is confirmed**
  - **Expect 10 $fb^{-1}$ on tapes for analysis, well understood detectors**
  - **100+ studies in progress**
- **Excellent chance to nail down "2 sigma" discrepancies**
- **Legacy measurements in progress**
  - **High precision, unique for ppbar**
- **Higgs search is in progress**
  - **~165 GeV excluded, getting sensitive at low mass**




**Natural opportunity for both Tevatron and LHC to produce excellent results over next two years!**

# Looking Beyond 2011

- Many topics have to be considered
  - Physics potential
    - Low mass Higgs sensitivity is steadily increasing
  - Detectors longevity
  - Collaborations strength
  - LHC progress
  - Fermilab's long term plans




- Discussing different options
  - Continue integrating luminosity?
  - Have Tevatron and detectors upgrades?
- Started efforts to study all of the above

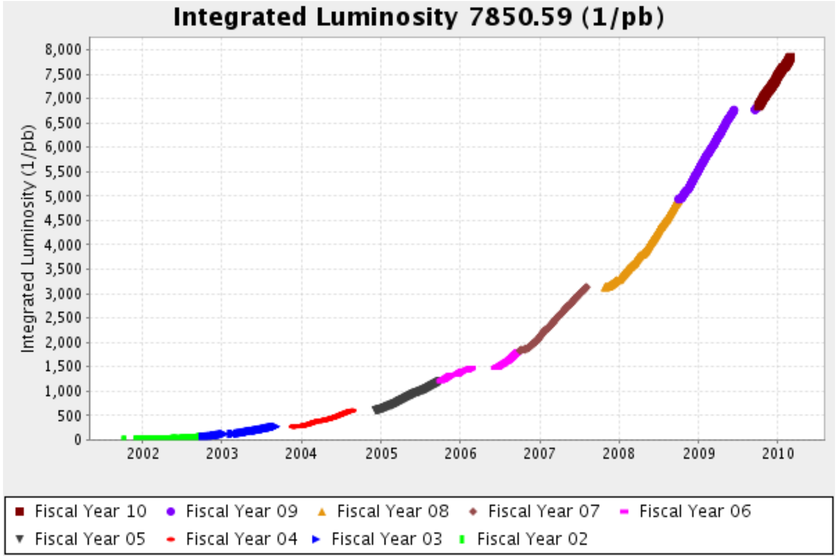
**It is a bad plan which admits of no modification**

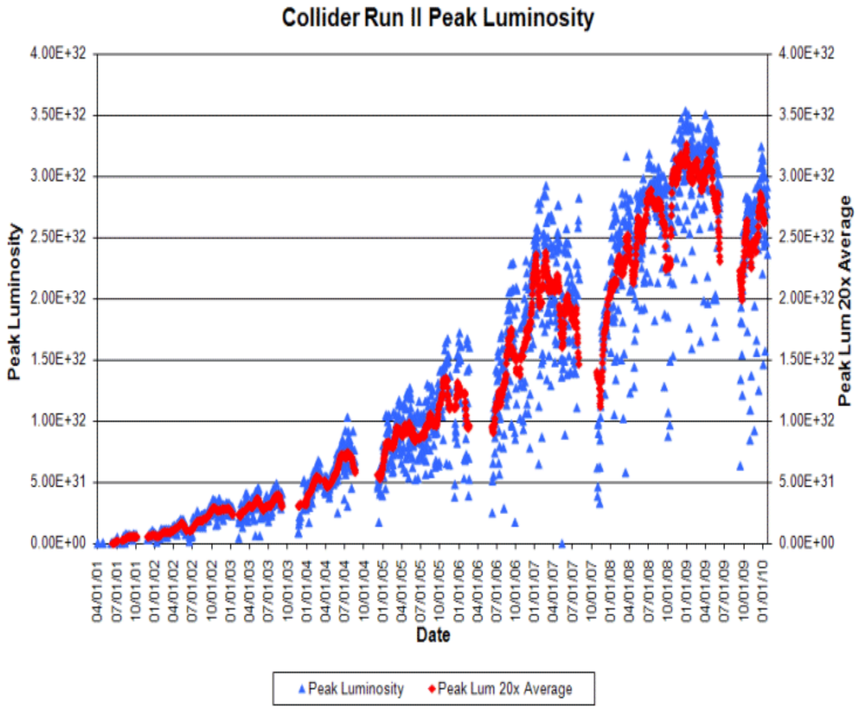
Publilius Syrus, 100 BC, Italy

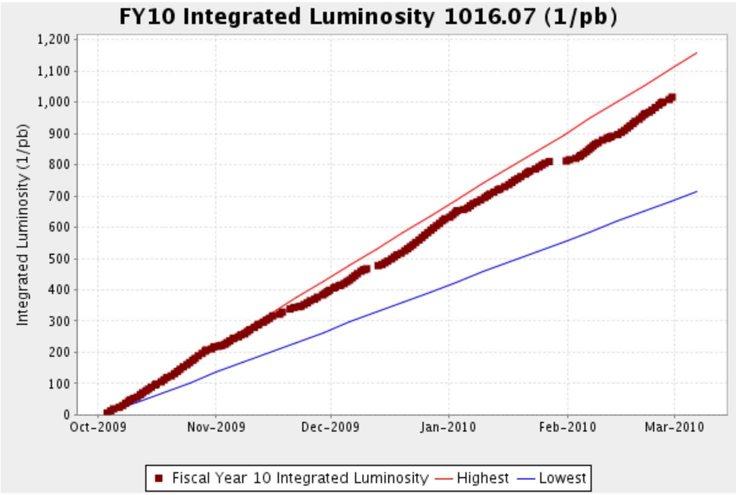
# Back up

# Fermilab Accelerator Complex Status

- **Tevatron complex**
  - **Smooth operation**
  - **Over 50 $pb^{-1}$ per week delivered**
- **7.8 $fb^{-1}$ delivered total and going**
- **Plan is to deliver 12 $fb^{-1}$ by the end of 2011**

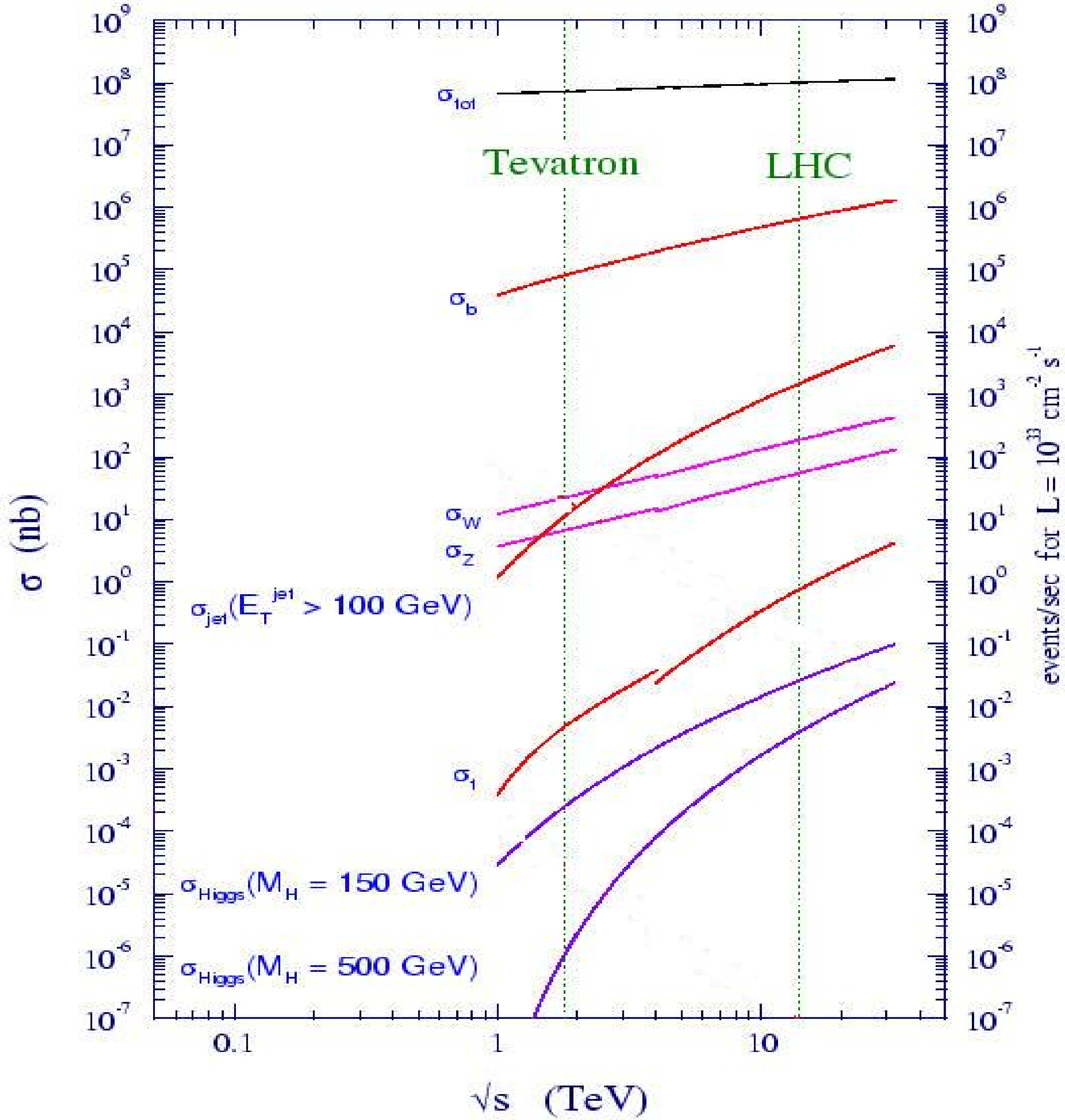


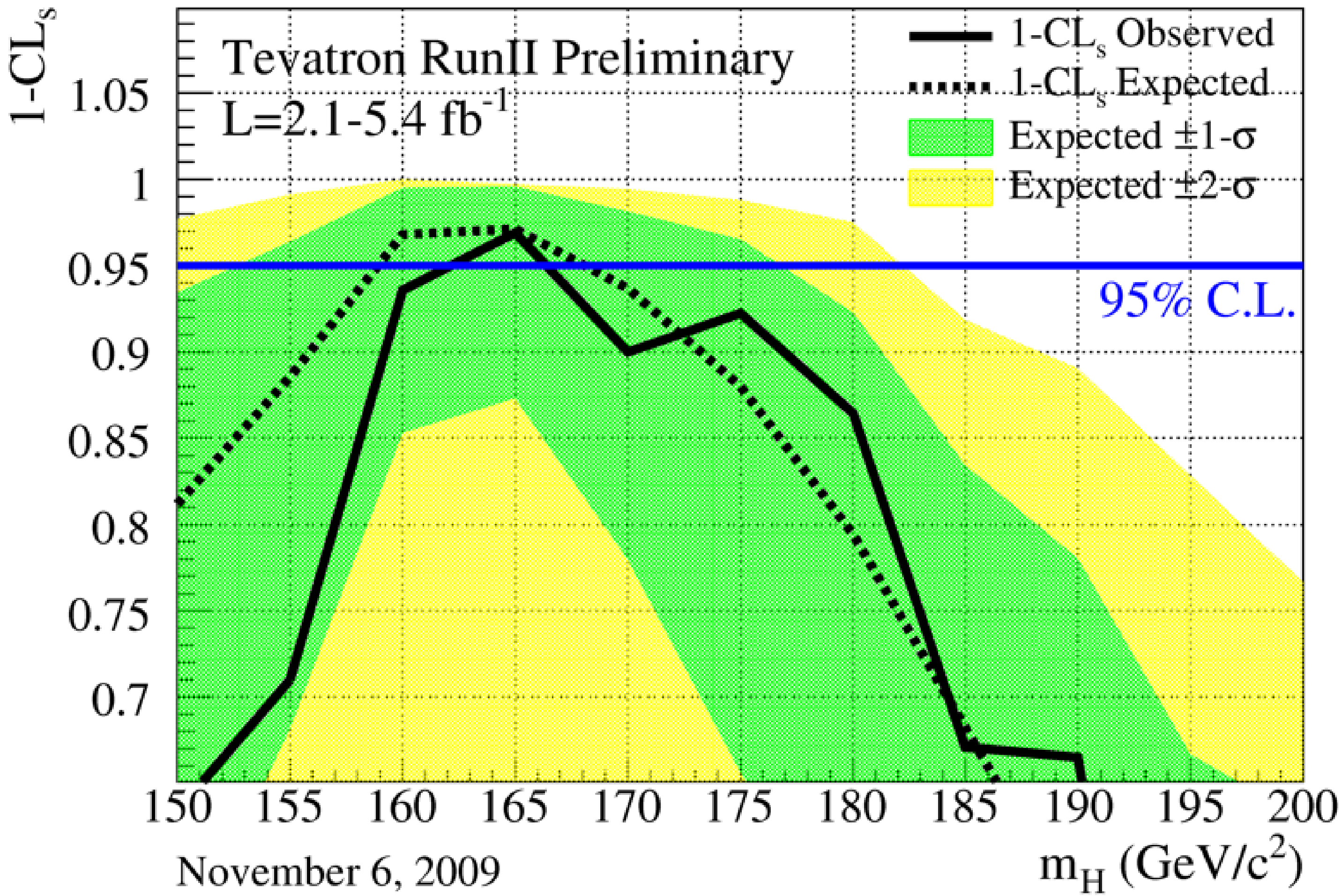




**Fermilab's accelerator team is devoted to continue accelerator improvements and reliable operation**

# proton - (anti)proton cross sections

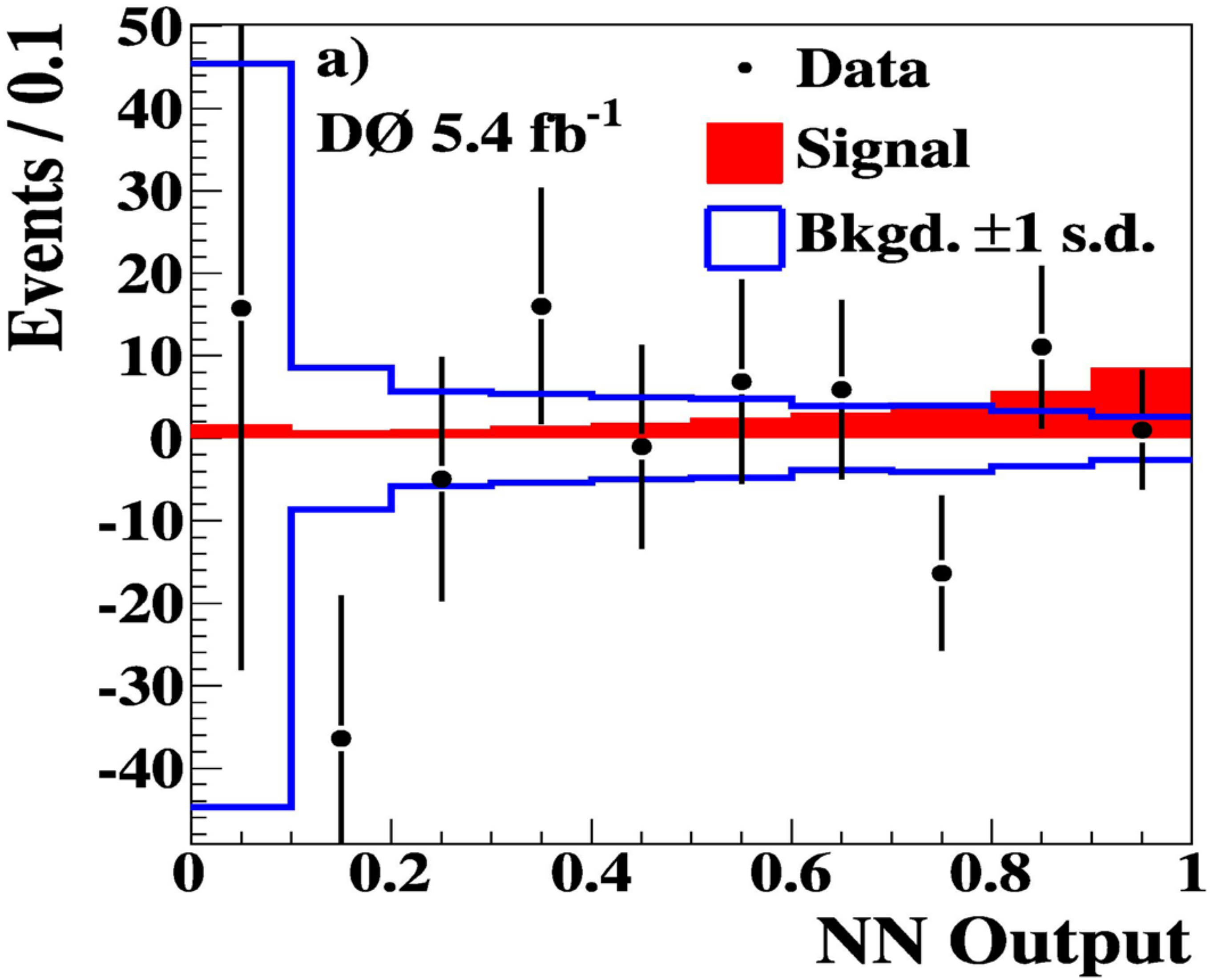


# Confidence Level Combined Plot




Higgs excluded in the range 163-166 GeV at 95% confidence level

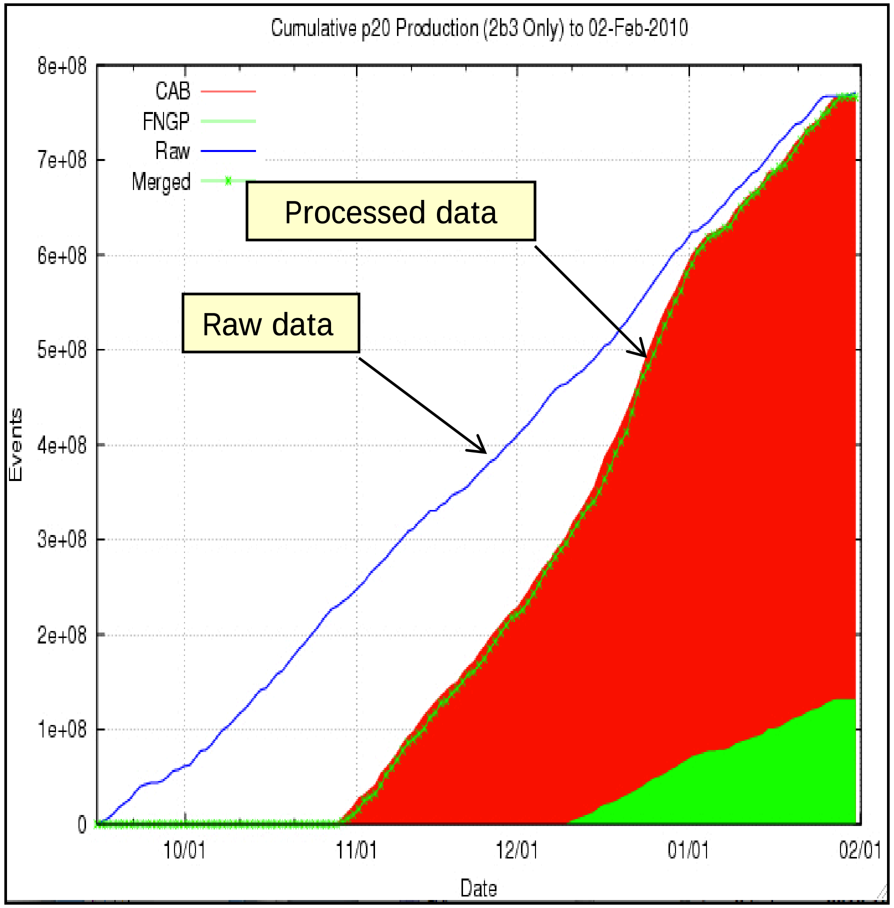
# H → WW

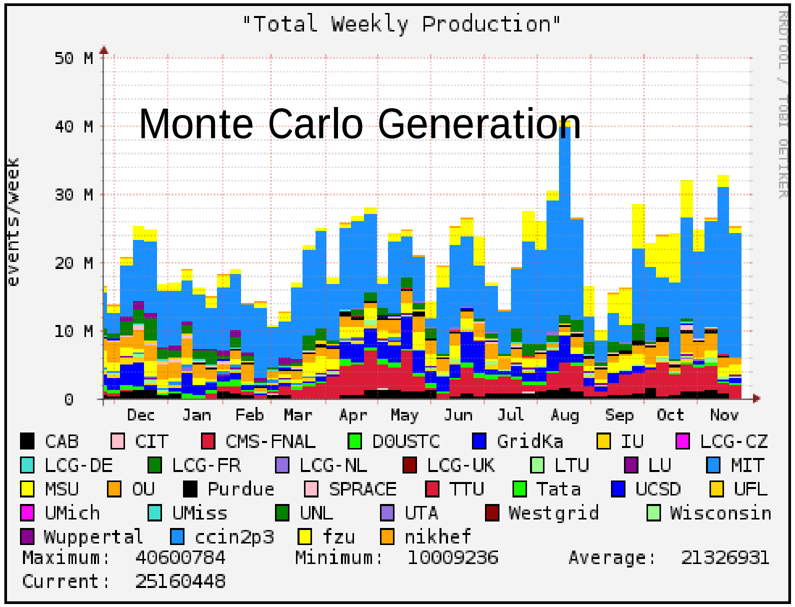


Events / 0.1
50
40
30
20
10
0
-10
-20
-30
-40
a)
DØ 5.4 fb$^{-1}$
Data
Signal
Bkgd. ±1 s.d.
0
0.2
0.4
0.6
0.8
1
NN Output

# Computing

- **Recording ~2 billion events per year**
  - **All processed within weeks after collection**
  - **Efforts are devoted to improvements in alignment, calibrations and reconstruction algorithms**
- **Extensive use of computing farms at Fermilab**

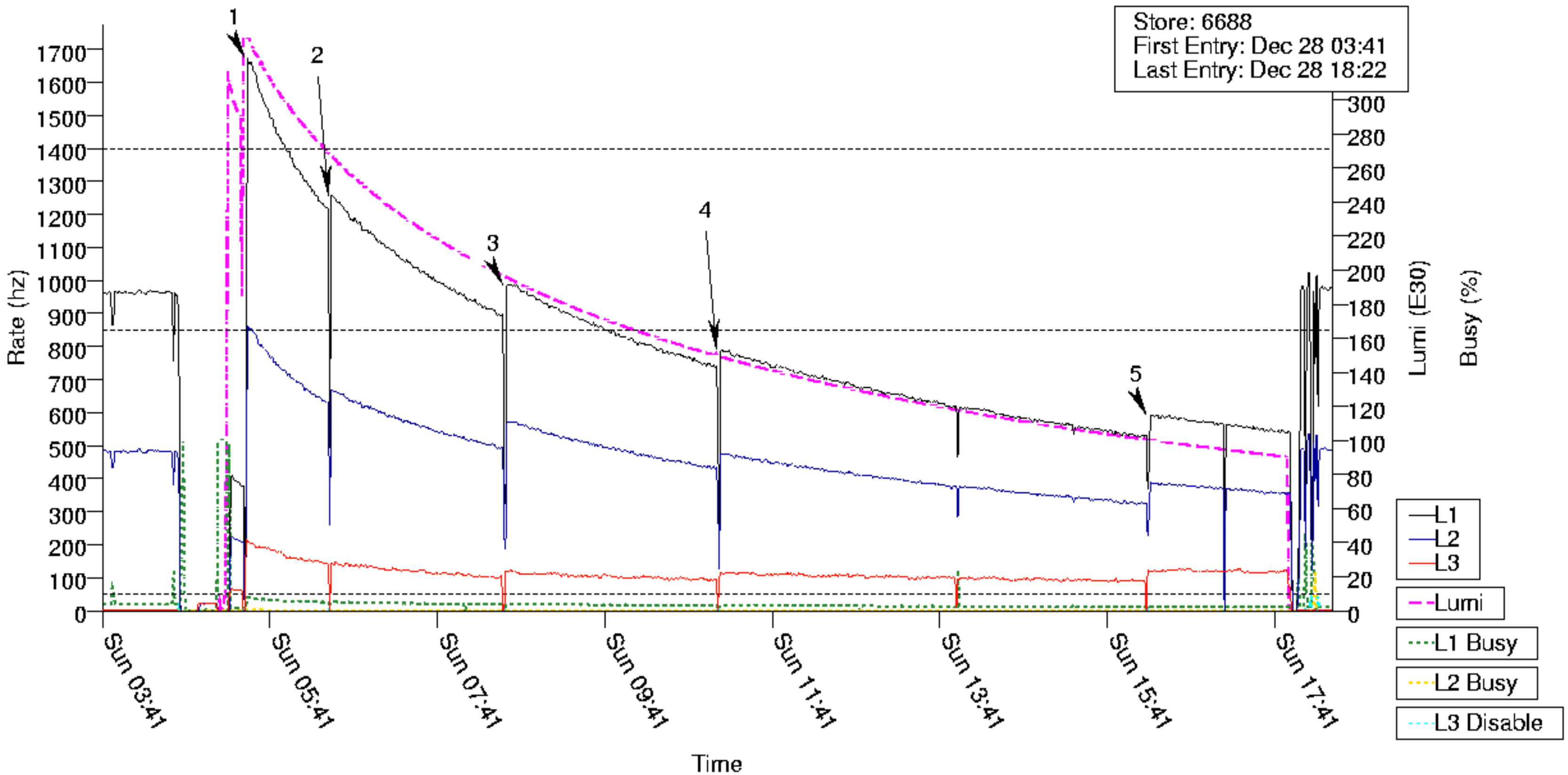



- **Monte Carlo generation, including Geant simulation of the detector, provides large samples of signal and background events**
  - **Dedicated computing centers**
  - **Extensive use of available Grid resources**

# Triggering at DØ

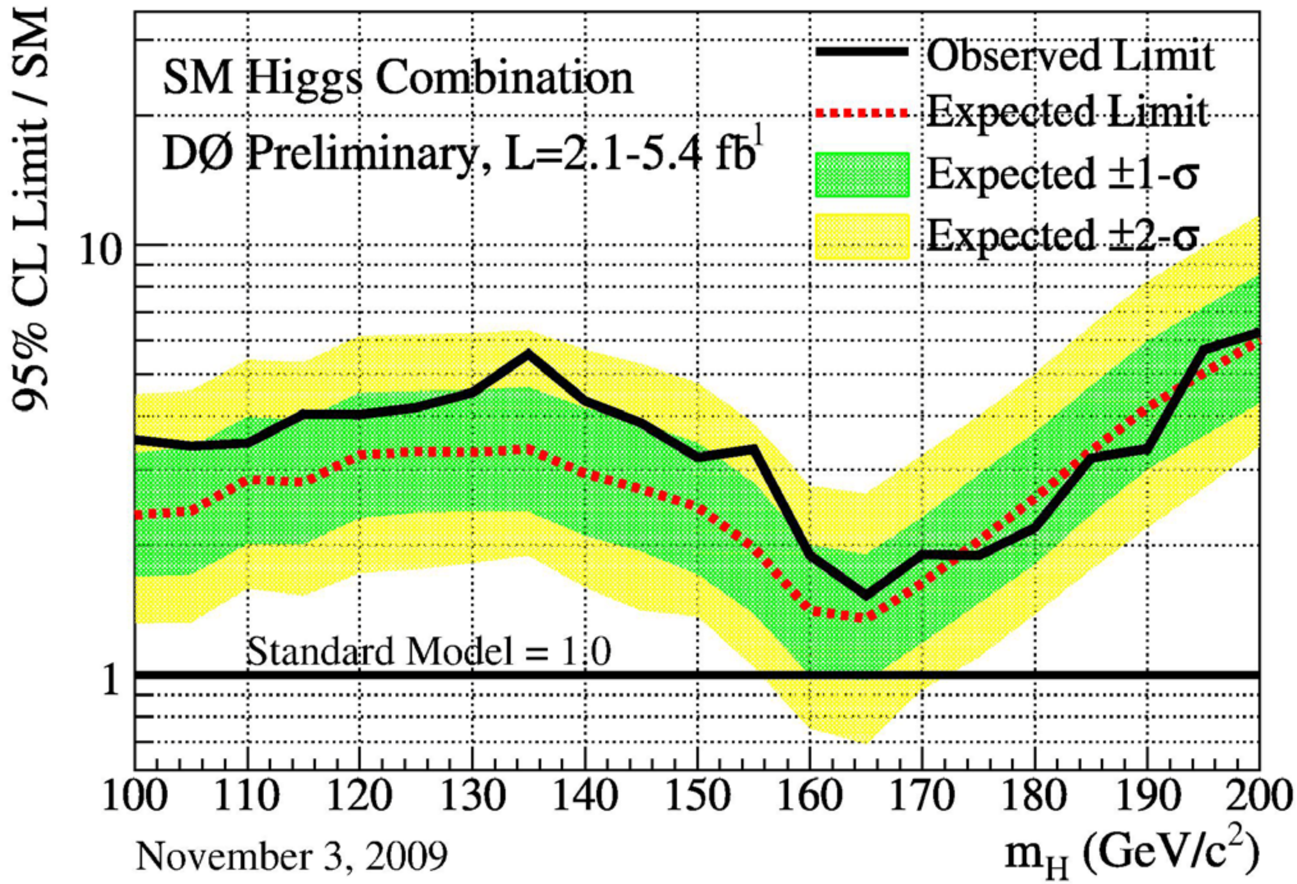
**With interaction rate of ~10 MHz the experiment is recording ~100 Hz to tape. Even at highest luminosities high $P_t$ physics program triggers remain unprescaled!**




**~12 hours store with starting luminosity of $3.5 \cdot 10^{32}$ $cm^{-2}sec^{-1}$, next store to follow within about an hour**

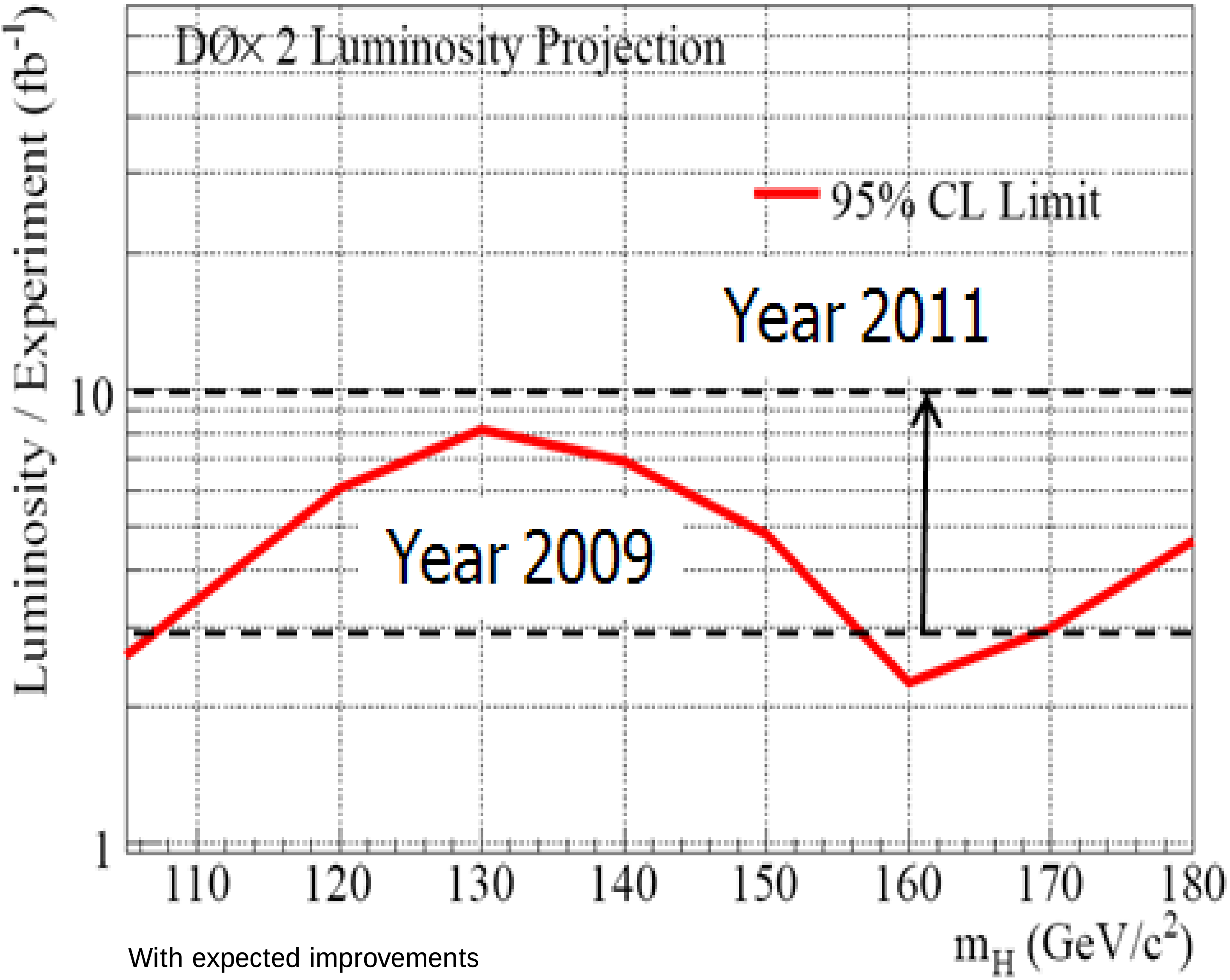
# Setting Limits on Standard Model Higgs

**Limits on Higgs cross section set in each individual search channel and normalized to Standard Model Higgs cross section at a given mass**




**When line equal to 1.0 is crossed – Higgs is excluded at that mass**

# Tevatron Higgs Exclusion Potential




With expected improvements