# DØ: Running in 2010

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**for**


**Particle Physics Project Prioritization Panel (P5) Meeting,**
**1 February 2008, Fermilab**

# Executive Summary

- **DØ detector**
  - Smoothly collecting physics data – 3.0 $fb^{-1}$ recorded
  - No technical issues through 2010 expected
- **Triggering and data reconstruction**
  - Full high $P_t$ trigger menu up to highest anticipated luminosities
  - Reconstruction is keeping pace with data collection
- **Collaboration Resources**
  - Sufficient manpower to operate the experiment in 2009 and analyze data is available
  - There is strong collaboration interest in running in 2010
- **The DØ physics program**
  - Many exciting discoveries and measurements over the last three years
  - 2007 is the best year in history for number of publications
    - 2008 is expected to exceed this
  - Excellent physics prospects for 2010 running, including SM Higgs detection
  - Progress made in algorithm/analysis improvements which will augment Higgs sensitivity

**Recent DØ presentation to P5 (slides posted on P5 web page)**

- June 2007: Running in 2009, detector longevity, collaboration resources
- September 2007: Physics prospects for 2010 run

# The DØ Collaboration

DØ is an international collaboration of 580 physicists from 19 nations who have designed, built and operate the DØ detector at the Tevatron and perform data analysis

**Collaborators:**
**~ 50% from non-US institutions**
**~ 100 postdocs, ~140 graduate students**


**Institutions: 89 total, 38 US, 51 non-US**

**September 2007 DØ Collaboration Meeting**

# Physics Goals and Detector

Precision tests of the Standard Model

– Weak bosons, top quark, QCD, B-physics

Search for particles and forces beyond those known

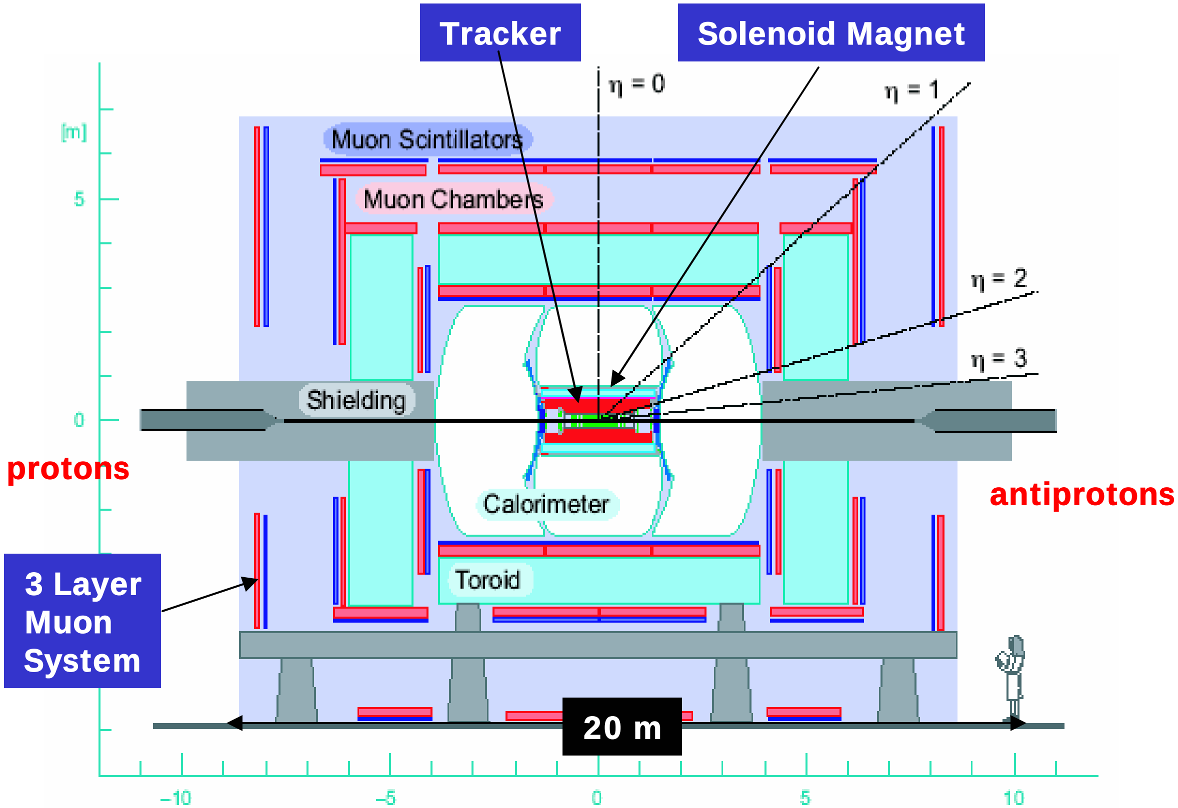
– Higgs, supersymmetry, extra dimensions….

**Driven by these goals, the detector emphasizes**

**Electron, muon** and **tau** identification

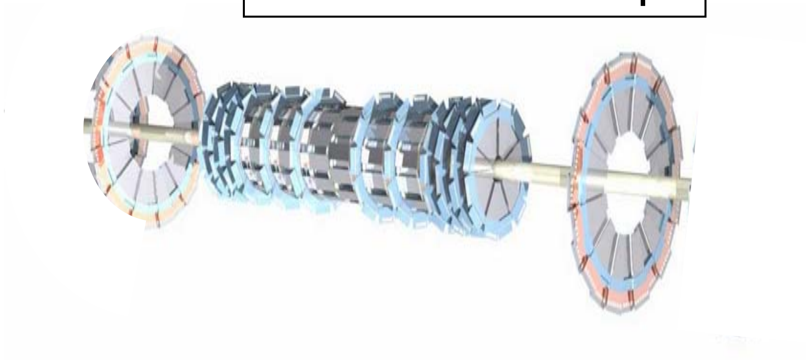
**Jets** and **missing transverse energy**

**Flavor tagging** through **displaced vertices** and **leptons**



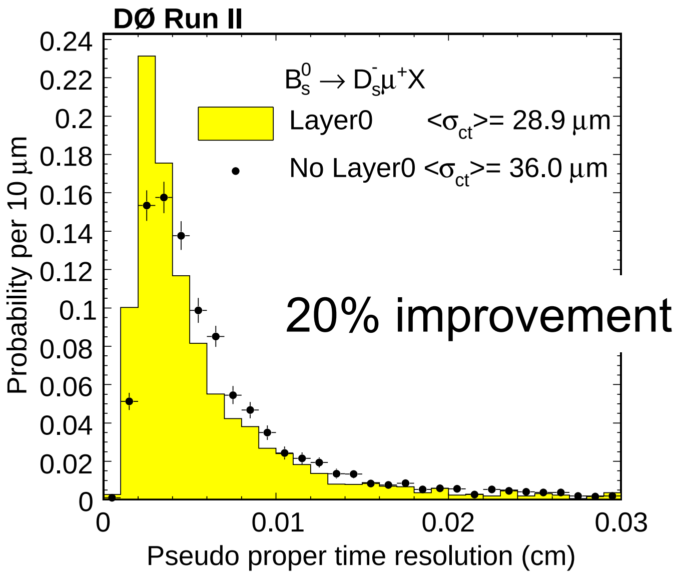
# Silicon Microstrip Tracker: Longevity

4 barrel layers
axial + stereo strips

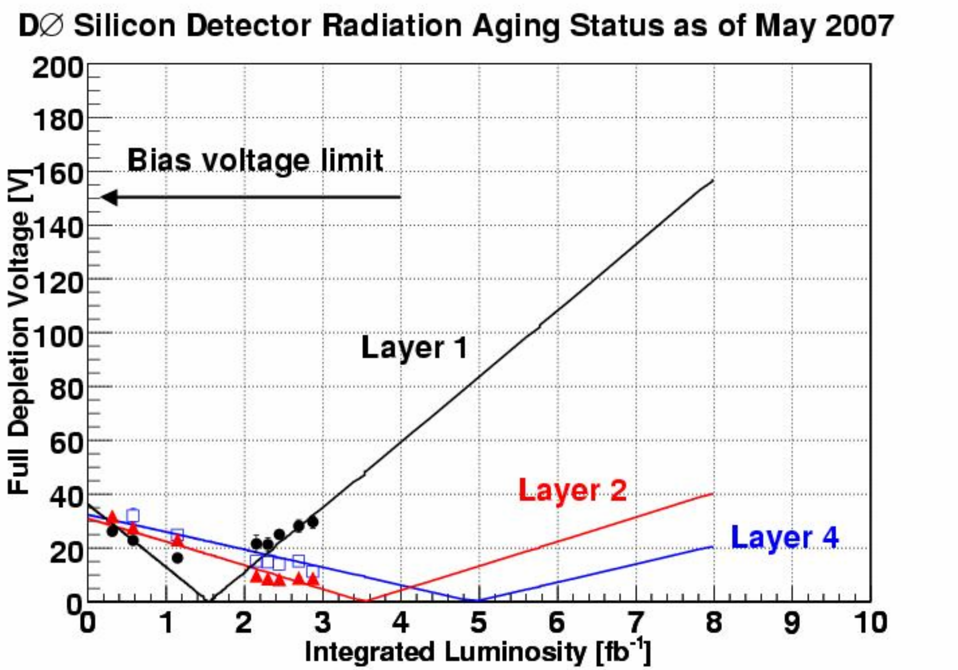


Radiation dose → no issues for running through 2010

Additional radiation-hard inner layer, “Layer 0” added in 2006

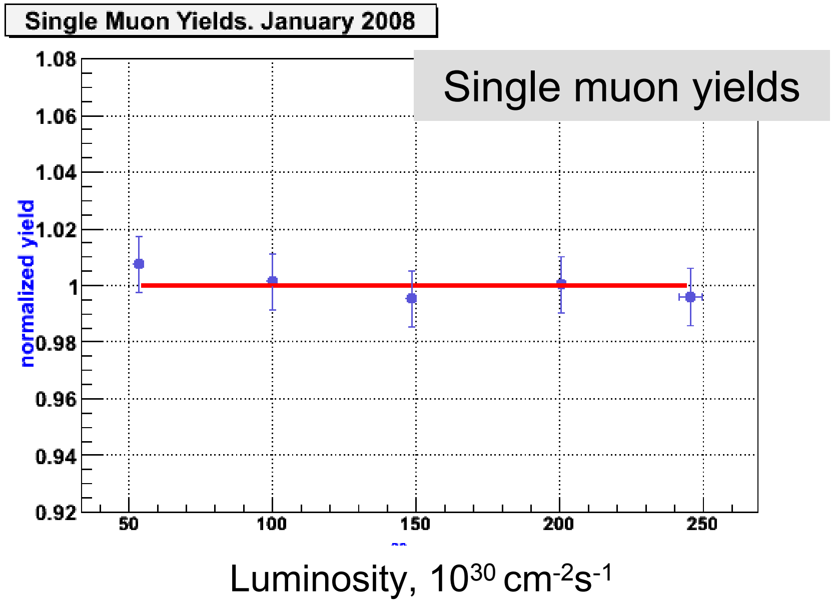


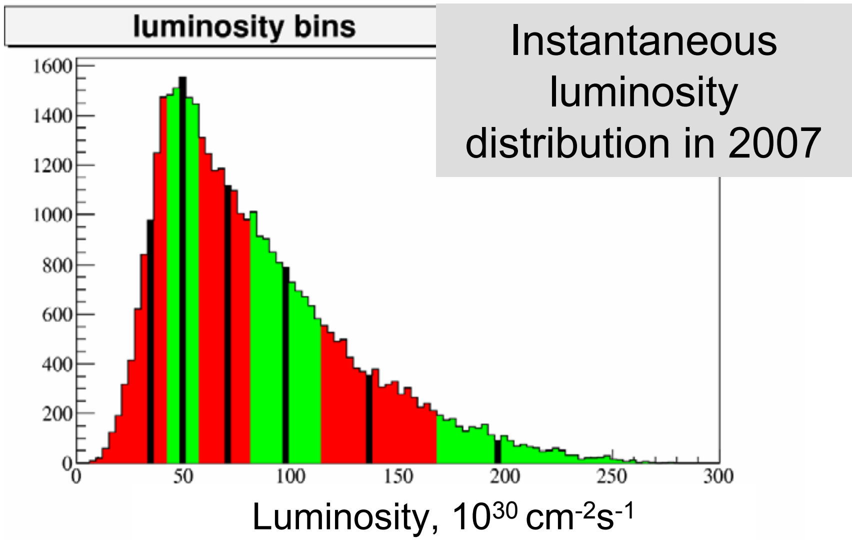

20% improvement



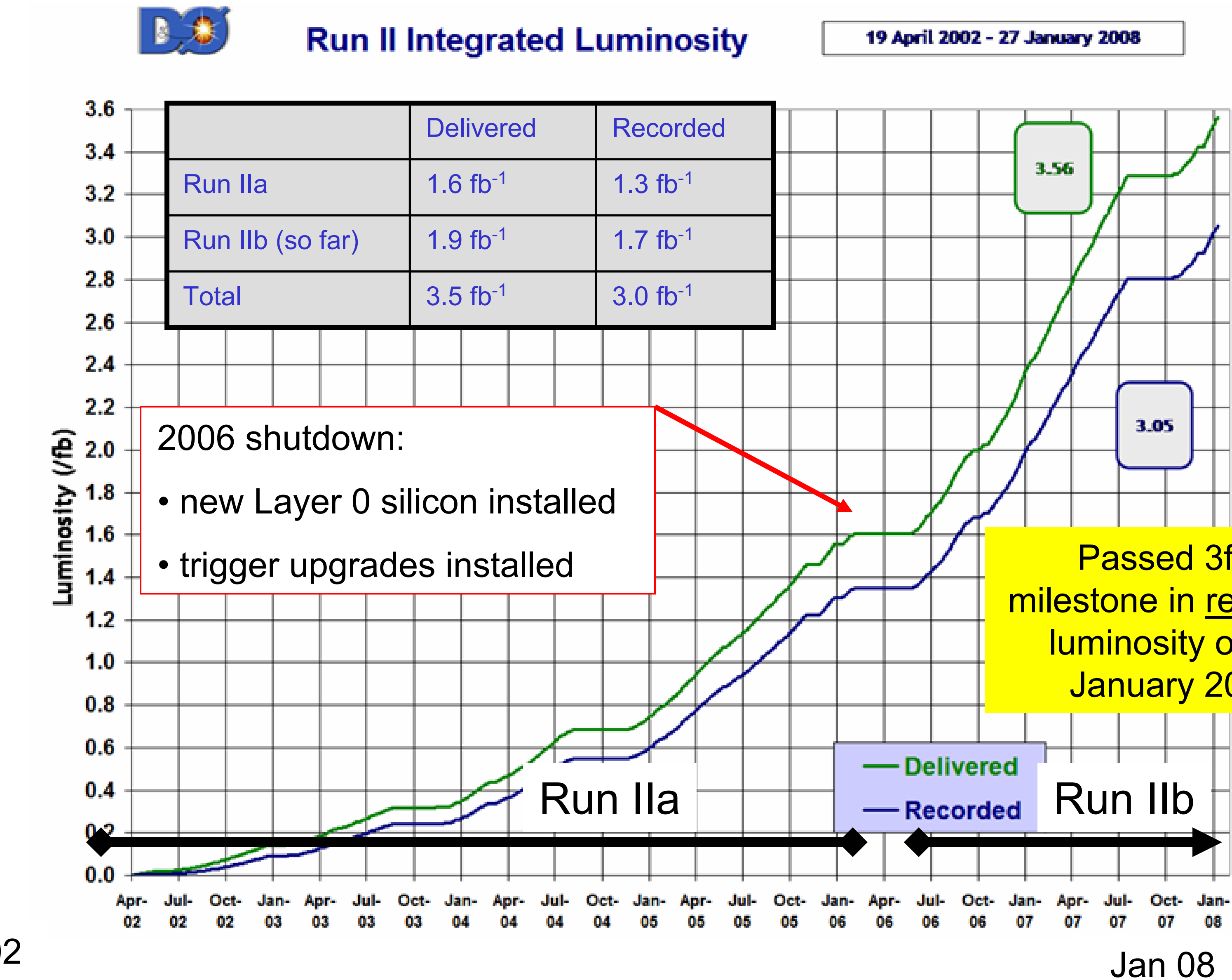
# DØ Subdetectors

- Scintillating Fiber Tracker
  - Number of operating channels >98%, operating stably
  - Upgraded readout electronics ("AFE II") installation completed in 2007
- Uranium Liquid Argon Calorimeter
  - Less than 0.1% non-operational channels
  - No radiation damage issues
- Muon system (scintillators and drift tubes)
  - Muon yield stable to ~1% over many years and in wide luminosity range
- Trigger
  - Upgrades installed in 2006
  - High $p_T$ physics menu runs un-prescaled at maximum luminosity of $3 \times 10^{32}$ $cm^{-2}s^{-1}$



# Integrated Luminosity




| | Delivered | Recorded |
|---|---|---|
| Run IIa | 1.6 $fb^{-1}$ | 1.3 $fb^{-1}$ |
| Run IIb (so far) | 1.9 $fb^{-1}$ | 1.7 $fb^{-1}$ |
| Total | 3.5 $fb^{-1}$ | 3.0 $fb^{-1}$ |

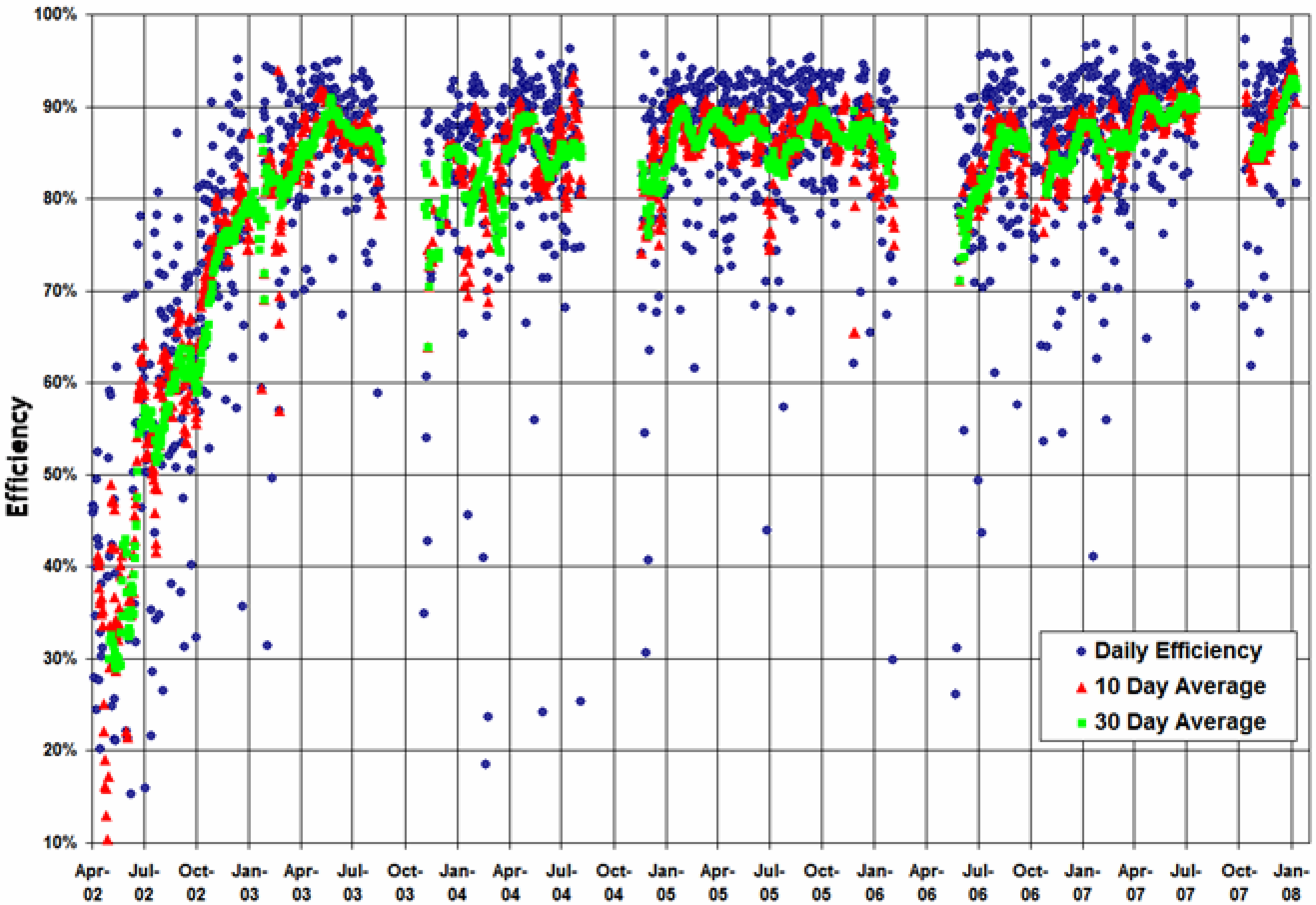
2006 shutdown:

- new Layer 0 silicon installed
- trigger upgrades installed

Passed 3$fb^{-1}$ milestone in <u>recorded</u> luminosity on 16 January 2008

# Data Taking Efficiency

Definition: recorded luminosity / delivered luminosity




30-day average efficiency = 93%

**High collection efficiency at high luminosity**

**Includes readout dead time**

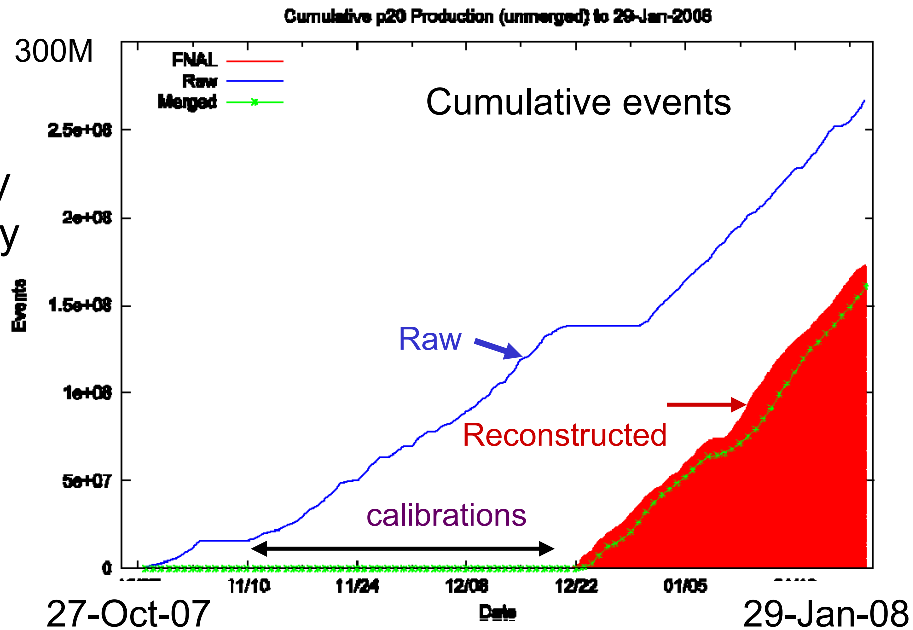
April 02

Jan 08

# Data Reconstruction and Processing

- D0 has collected 3.4x10$^9$ events so far in Run II
  - 255M events since 2007 shutdown
- Current reconstruction version in use since Summer 2006
  - Makes use of new RunIIb detectors and trigger upgrades
  - Faster and more robust
- Production Farm reconfiguration during 2007 shutdown
  - Stand alone farm → part of grid at Fermilab (Fermigrid)
  - Gives improved scalability and the ability to do opportunistic computing

- Reconstruction keeps up with incoming data plus has extra capacity for reprocessing, if needed
  - Writing to tape 4-6 M events per day
  - Reconstructing 5-8 M events per day
- Processed data are available for analyses within weeks of reconstruction



# Collaboration Manpower Analysis

Estimation is underway of experiment manpower for 2010 and beyond

- Needs: based on experience and future expectations from managers
- Availability: Estimates of available full-time-equivalent physicists (FTE's) are obtained from an analysis of the Memoranda of Understanding (MoU's) obtained from each institution in DØ
  - MoU's completed in 2005 covered 2005-2007
  - MoU's completed in February 2007 covered 2007-2009
  - We are currently collecting MoU's covering 2009-2011
    - As agreed by the DØ Institutional Board in September 2007
    - Assumptions: running through 2010, data analysis in 2011 and beyond
    - MoU's will be collected and analyzed by April 2008
- One-year overlap in each set of MoU's gives us a means to have continuous predictions

| Physicist FTE's | 2005 | 2006 | 2007 | 2008 | 2009 |
|---|---|---|---|---|---|
| 2005-2007 MoU data | 474 | 437 | 354 | | |
| 2007-2009 MoU data | | | 357 | 272 | 184 |
| Estimated service needs | 230 | 200 | 165 | 145 | 124 |

# Resource Management Goals

- Reduce FTE's needed in each area of the experiment
  - Control room shifts
    - Down to 4 shifters since June 1, 2007
  - Streamlining operations
    - Automation, experts cross training, minimizing changes
  - Stability of reconstruction algorithms
  - Continuing efforts with Computing Division on automation
- Attract collaborators and resources
  - Interest and excitement are keeping the collaboration together
    - Interesting physics
      - Large samples of high quality data
      - Precision measurements and hunts for new states/objects
    - Superb training opportunities for younger scientists

# International Support for 2010

- October 29th 2007: DØ International Finance Committee meeting
  - Representatives from DØ international funding agencies
  - Proposal to run in 2010 resonated well
  - Many DØ groups are planning to re-apply for funding in 2008 for 2009 and beyond
  - Funding agencies from Germany, France, Russia, UK and other countries are now ready to consider funding requests
    - Collaborators want to avoid a gap between Tevatron running and LHC physics
    - Students (and others) see an unique window of opportunity for exciting discoveries at DØ in the coming years
    - During last four months alone, 14 new students joined DØ from non-US institutions

# Selected physics highlights from DØ in Run II

**Top physics**

- Single top production evidence
- Tour de force of top quark property measurements
  - Mass = 172.1±2.4 GeV
  - Cross section, electric charge, W helicity, forward-backward asymmetry, B(t→Wb)/B(t→Wq)

**Electroweak**

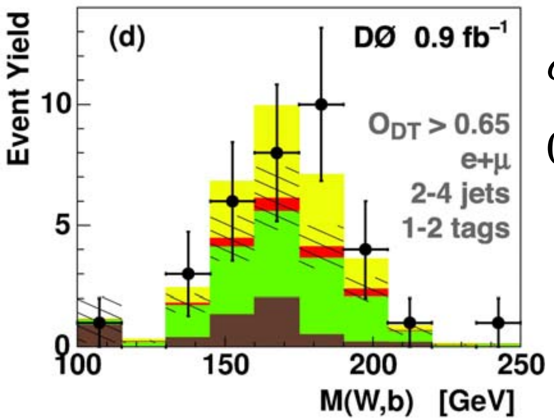
- First evidence for WZ production
- W-gamma radiation zero evidence
- Anomalous couplings search in W-gamma, Z-gamma, WZ, ZZ

**QCD**

- Precise inclusive jet cross section
  - with 1% calibration of jet energy scale
- W+charm production ratio measurement – probing strange content of proton

**Single Top**

December 2006: First evidence for single top and first direct measurement of $V_{tb}$



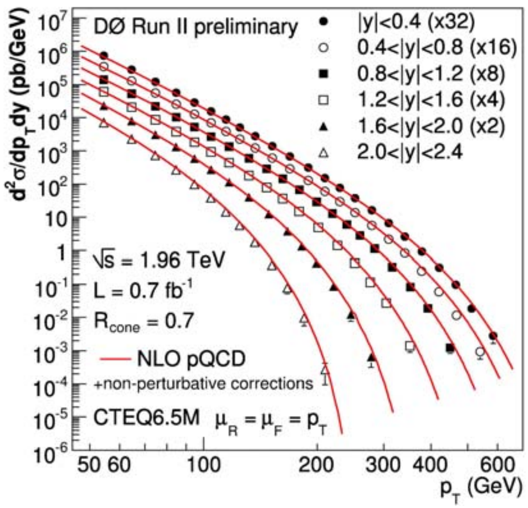

$$\sigma = 4.3 \pm 1.4 \text{ pb}$$

$$0.68 < |V_{tb}| < 1.0$$

(95% CL)

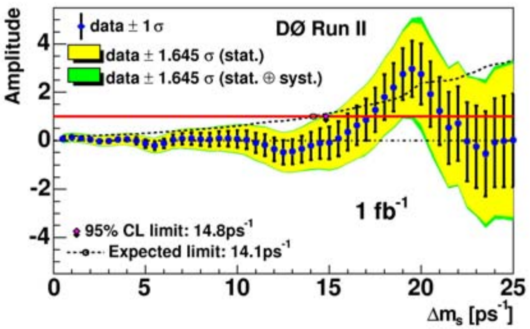
**Inclusive Jets**

January 2008: most precise measurement of the inclusive jet cross section over the widest kinematic range



# Selected physics highlights from DØ in Run II

## $B_s$ Mixing: March 2006

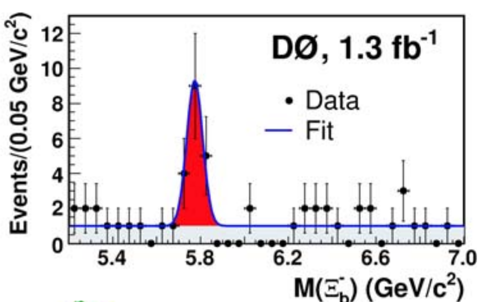


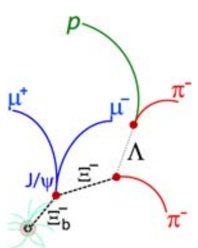

First two-sided limit on $B_s$ oscillations

$17 ps^{-1} < \Delta m_s < 21 ps^{-1}$

most cited HEP paper of 2006

## $\Xi_b$- Discovery: June 2007

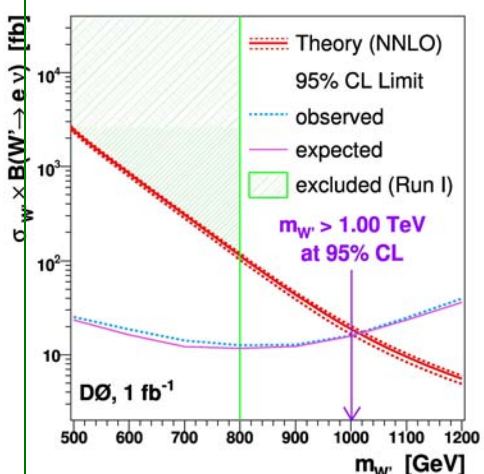



$M(\Xi_b^-) =$

5.774±0.019 $GeV/c^2$

## W' Limit> 1 TeV: October 2007




**B-physics**

- $B_s$ mixing – world's first two-sided limit
- $\Xi_b^-$ baryon discovery:
- CP violating parameter measurements: unique DØ capability from regular reversal of magnetic fields
- World's best limits on $B_s \to \mu\mu$ decay probability

**New Phenomena**

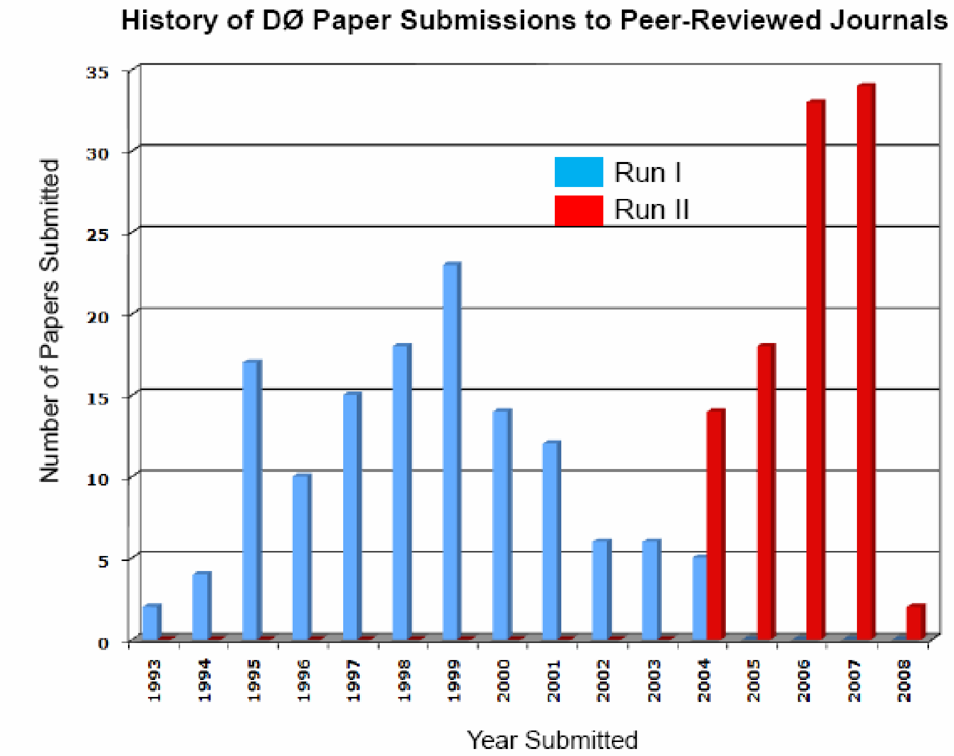
- W', Z' mass limits > 1 TeV
- Excited electron mass > 756 GeV: probing electron sub-structure
- Best limits on many SUSY processes (tripleptons, stop→l+b+MET, stop→c+MET, diphotons+MET,…)
- Searches for squark and gluinos: **first Tevatron publication with >2 $fb^{-1}$ of data**

**Higgs**

- SM Higgs cross section limits from nine different channels in 110-200 GeV mass range
- Best limits on MSSM higgs production

# DØ Physics Output

- 2007 was the best year ever with 34 papers submitted for publication
  – Expect more in 2008
- Reducing time from data taking to publication
  – Already published result with 2.1 $fb^{-1}$
  – Winter conference results with 2.3 $fb^{-1}$ expected
- DØ continues to be a great training ground for students and postdocs
  – 29 Ph.D. theses in 2007



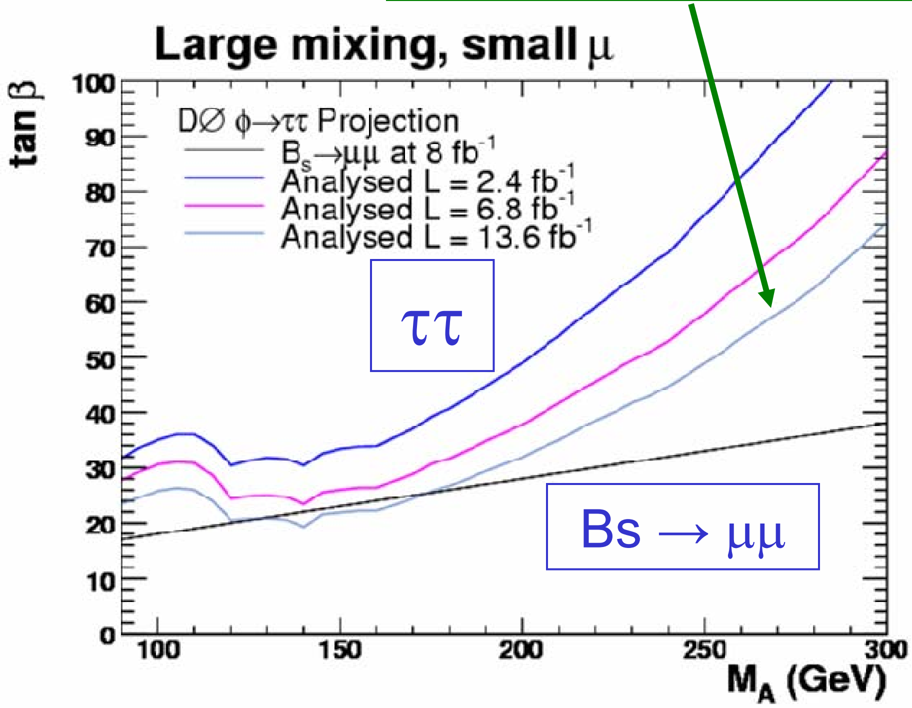
# 2010 Running: Parameters

- Based on estimates from Fermilab accelerator division, we anticipate
  - about 6.8 $fb^{-1}$ delivered by end of FY09
  - about 8.5 $fb^{-1}$ delivered by end of FY10 with a 2010 run
- We estimate about 80% of this delivered luminosity will finally be used in analyses
  - **5.5 $fb^{-1}$** by end of FY09
  - **6.8 $fb^{-1}$** by end of FY10 (=25% increase over FY09)
- **We will use "analyzed luminosity" for future projections so the projected results can be compared easily with existing results**
- Three specific physics analyses were projected to 6.8 $fb^{-1}$ for the September 2007 P5 meeting:
  - MSSM Higgs search in tau decays
  - $Bs \rightarrow \mu\mu$ rare decay search
  - SM Higgs search

# MSSM SUSY Higgs

- SUSY-enhanced Higgs cross sections increase in proportion to $\tan^2\beta$
- We can have significant reach in ($\tan\beta$, $M_A$) plane. Interesting region $= m_t/m_b \sim 35$
- Complementary channels with similar sensitivity:
  - $h \to \tau\tau$
  - $hb(b) \to \tau\tau b(b)$, $bbb(b)$
- Will benefit from optimized trigger strategy, so that new data will yield more sensitivity per $fb^{-1}$ than old data
- Synergies with SM Higgs search
  - b-tagging
  - Tau identification

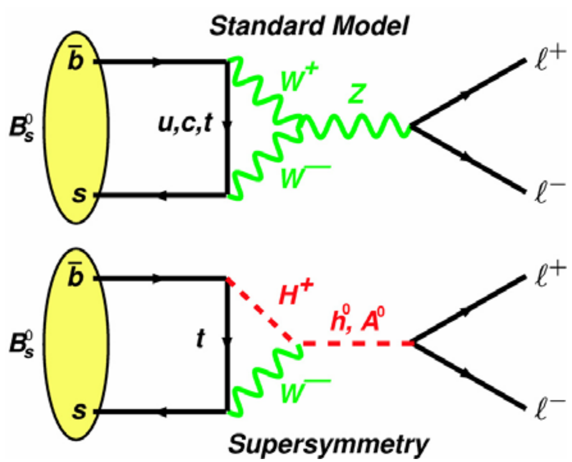
Projections for full 2010 data set (2 experiments)

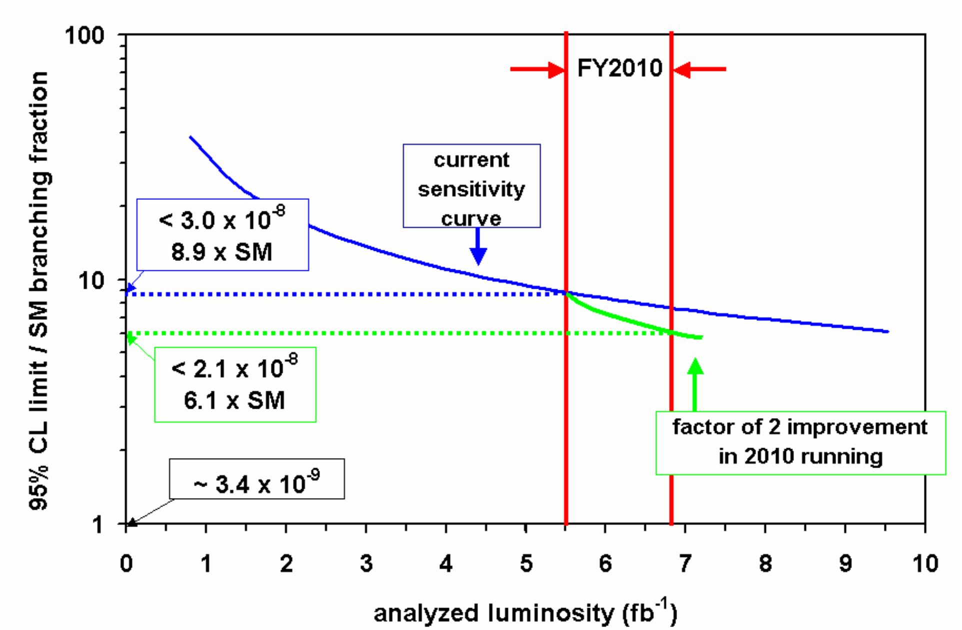



Substantial reduction in allowed parameter space

# $B_s \rightarrow \mu\mu$

- Clean rare decay channel
  - SM: $BR(B_s \rightarrow \mu\mu) = (3.4 \pm 0.5) \times 10^{-9}$
- BR can be enhanced significantly in new physics models
  - e.g. MSSM enhanced by $\tan^6\beta$
  - BR predictions as large as 10-10,000 times the SM prediction
- Trigger can be adjusted to give higher efficiency for low-mass muon pairs
  - Can have higher sensitivity in the new data



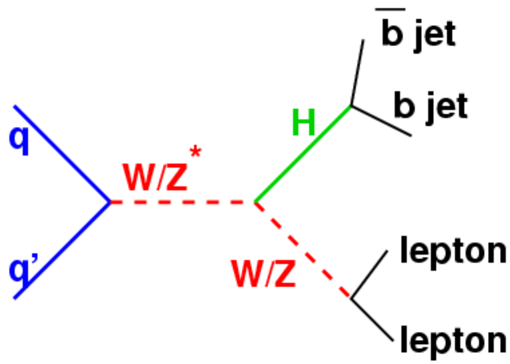



# SM Higgs search at the Tevatron

Low mass ($m_H$ <~135 GeV):
dominant decay:

$$H \to b\bar{b}$$

Use associated production modes to get better signal/background




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

$$q\bar{q} \to ZH \to \ell^+\ell^- b\bar{b}$$

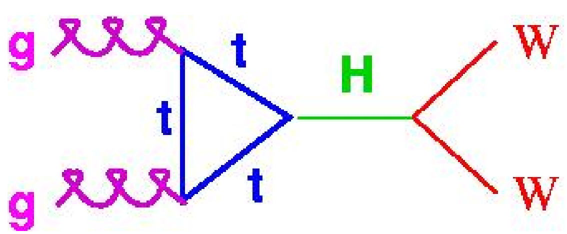
$$q\bar{q} \to ZH \to \nu\bar{\nu} b\bar{b}$$

Intermediate mass:

$$q\bar{q} \to WH \to WWW^{(*)}$$

High mass ($m_H$>~135 GeV):
dominant decay:

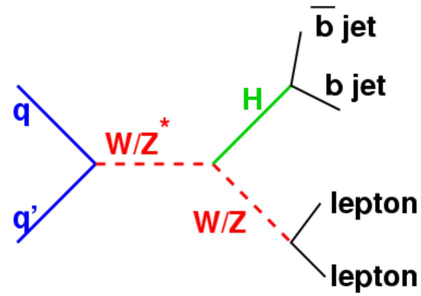
$$H \to WW^{(*)}$$



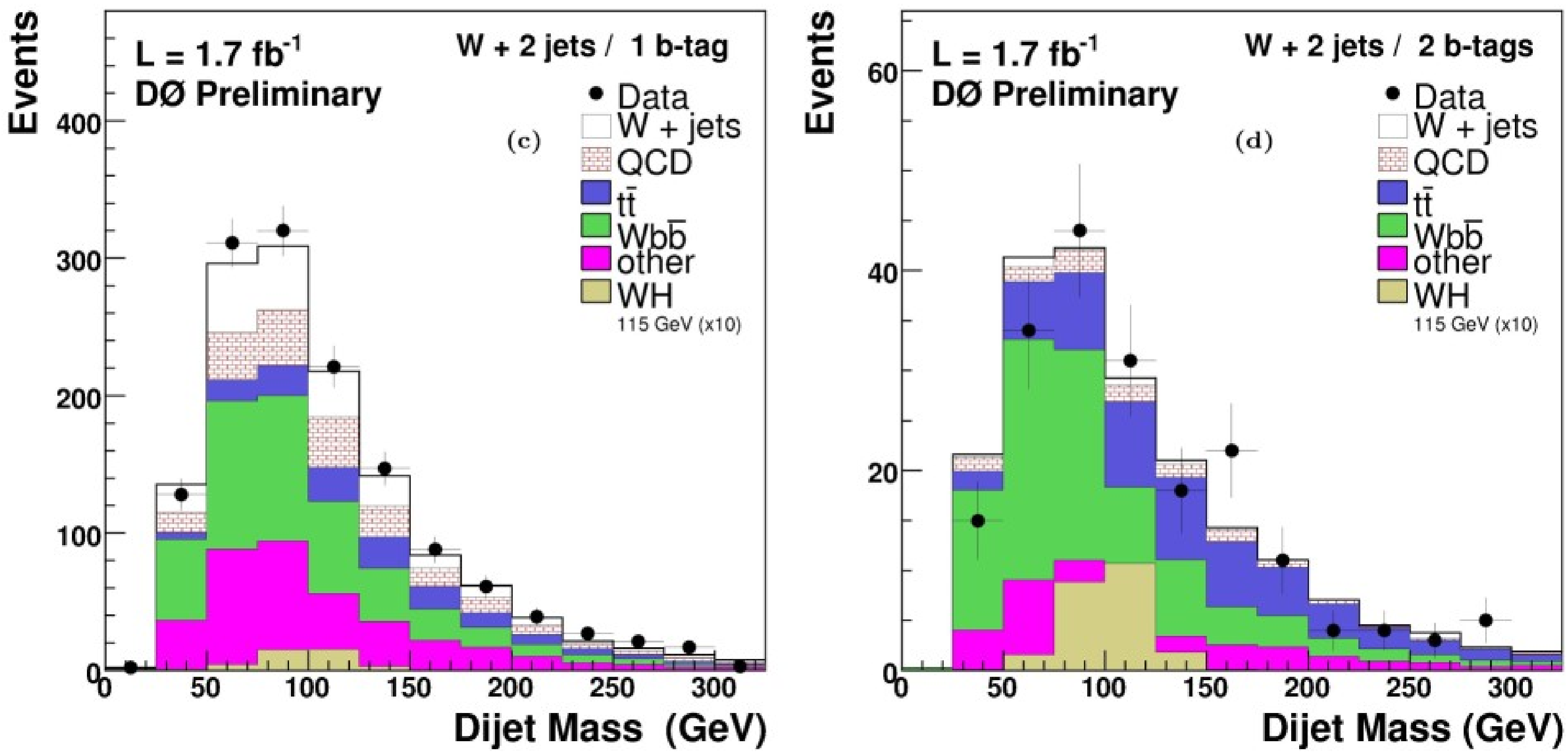

$$gg \to H \to WW \to \ell \nu \ell' \nu'$$

# Higgs Searches example: Low Mass

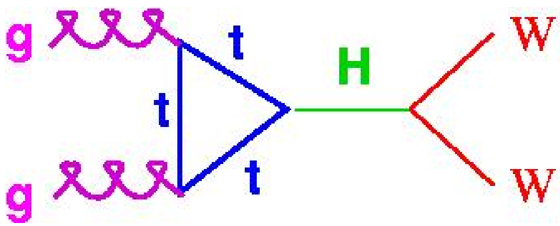
$WH \rightarrow \ell\nu bb$




1.7 $fb^{-1}$

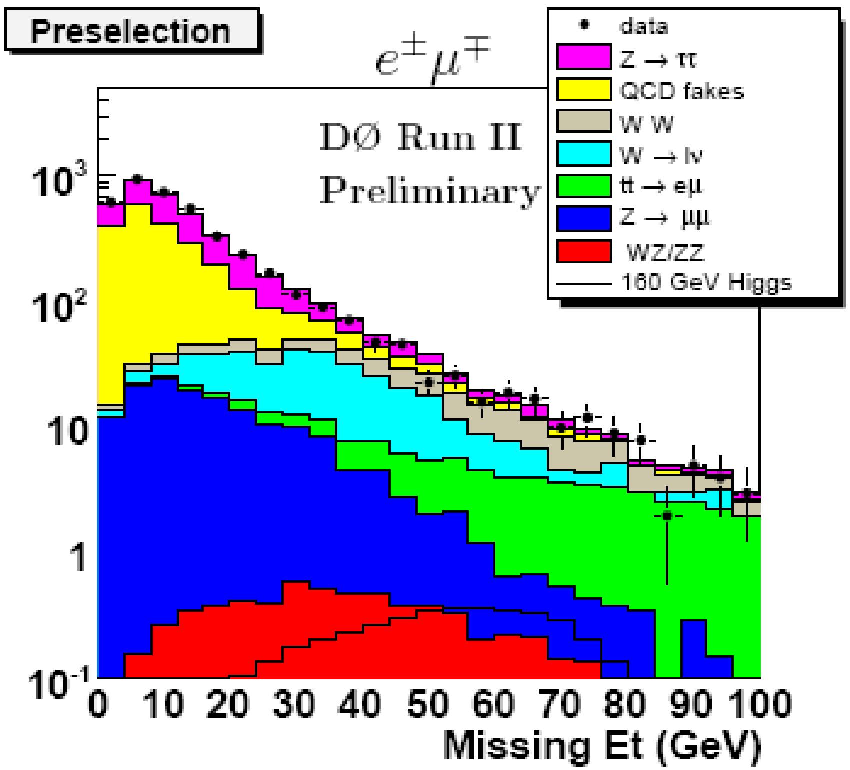


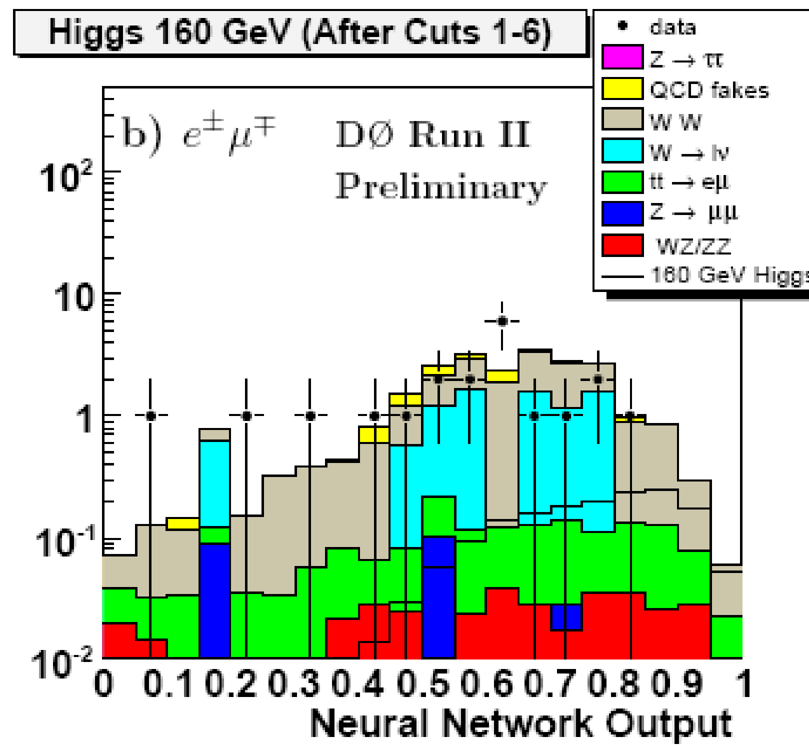
# High Mass: H->WW->eμνν




Basic pre-selection then multivariate for final stage

1.7 $fb^{-1}$



# Current State of DØ SM Higgs Analyses

## Low-mass channels

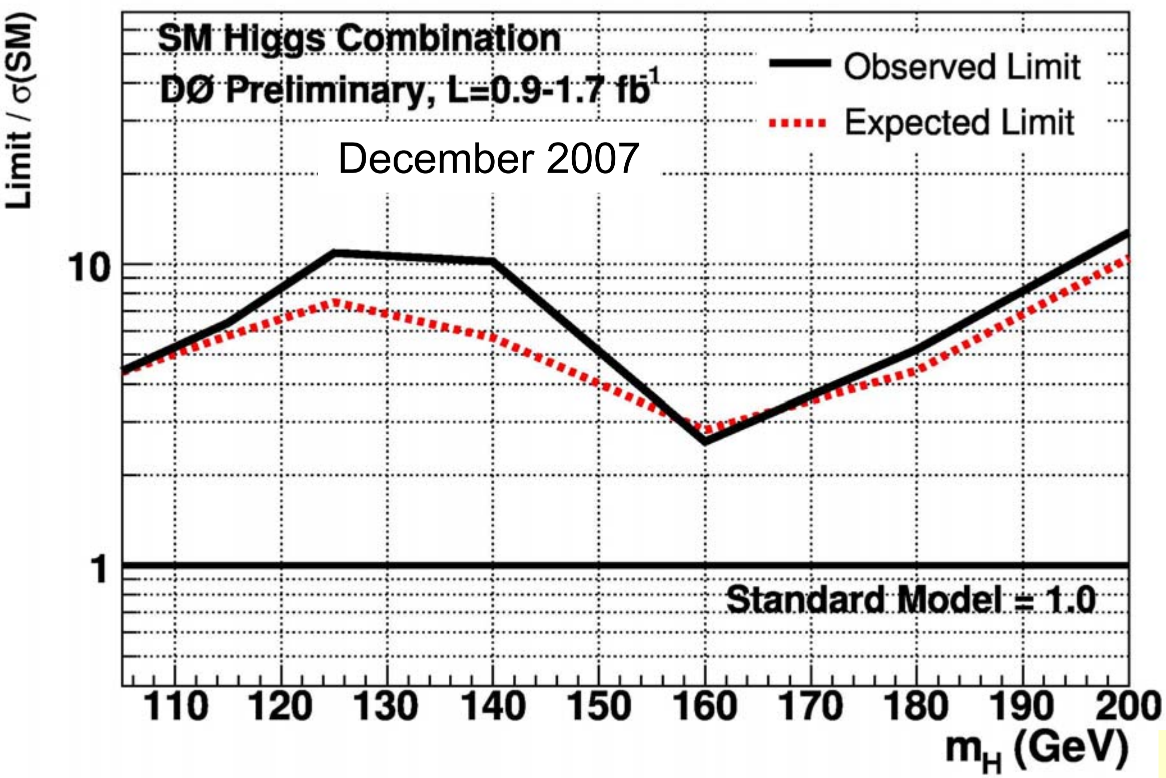
| Channel | Lum used in result |
|---|---|
| $WH \to e\nu b\bar{b}$ | 1.7 fb-1 |
| $WH \to \mu\nu b\bar{b}$ | 1.7 fb-1 |
| $ZH \to eeb\bar{b}$ | 1.1 fb-1 |
| $ZH \to \mu\mu b\bar{b}$ | 1.1 fb-1 |
| $ZH \to \nu\nu b\bar{b}$ | 0.9 fb-1 |

## Intermediate- and high-mass channels

| Channel | Lum used in result |
|---|---|
| $WH \to WWW^* \to \ell^\pm\ell^\pm + X$ | 1.0 fb-1 |
| $H \to WW \to e\nu e\nu$ | 1.7 fb-1 |
| $H \to WW \to \mu\nu\mu\nu$ | 1.7 fb-1 |
| $H \to WW \to e\nu\mu\nu$ | 1.7 fb-1 |
| $H \to WW \to \mu\nu\tau_h\nu$ | 1.0 fb-1 |

Most channels will be updated with 2.3 $fb^{-1}$ for the Winter 2008 conferences

# Current DØ SM Higgs Limits




Expected (observed) 95% CL relative to $\sigma_{SM}$

- For $m_H$=115 GeV: 5.8 (6.4)
- For $m_H$=160 GeV: 2.8 (2.6)

Note Improvement in expected limit at 160 GeV:

Aug 2007 → Dec 2007:

4.7→2.8

Limits on SM Higgs cross section have improved faster than simple 1/sqrt(L) scaling

- adding more channels
- improving detector and analysis techniques

Historical DØ σ(limit)/σ(SM) [expected]

| Integrated Luminosity analyzed | $m_H$=115 GeV | $m_H$=160 GeV |
|---|---|---|
| 0.2 $fb^{-1}$ | 69 | |
| 0.4 $fb^{-1}$ | 12 | 9 |
| 0.9-1.7 $fb^{-1}$ | 5.8 | 2.8 |

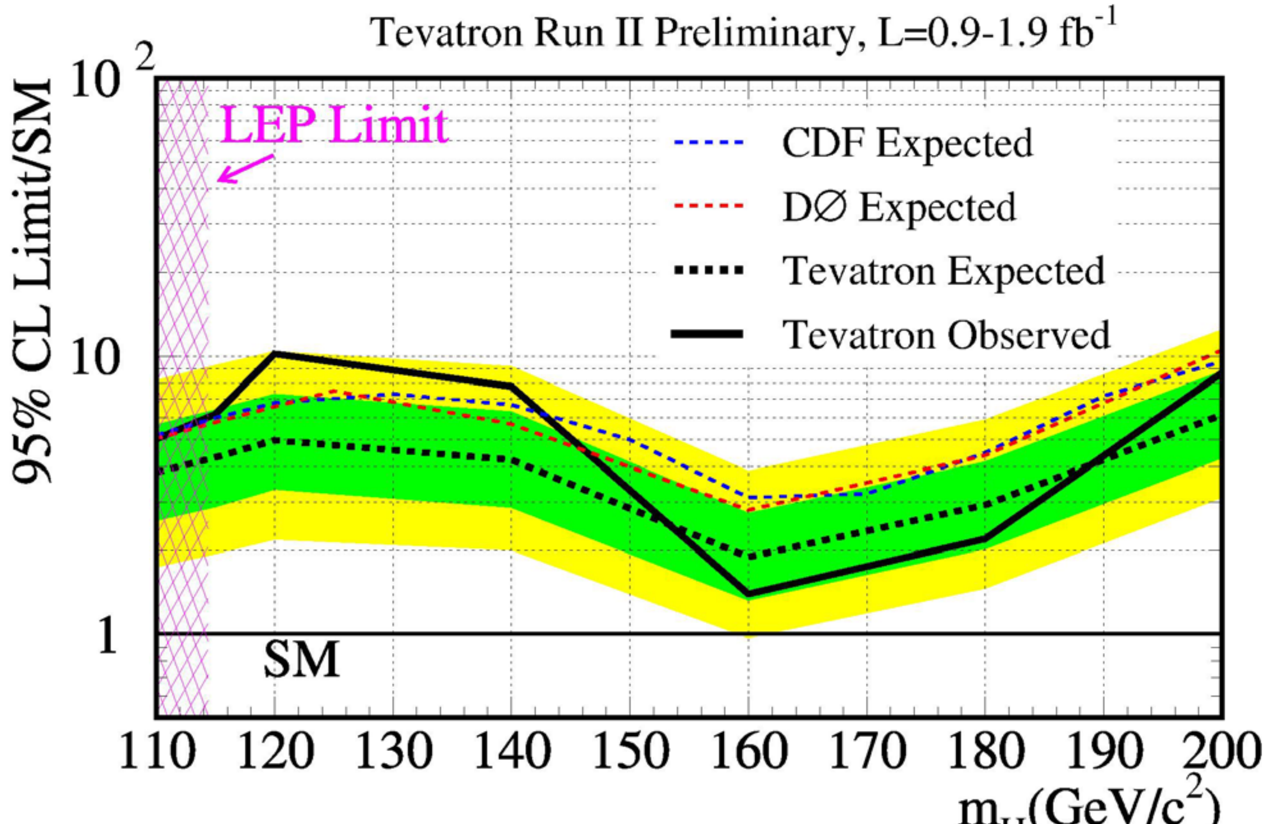
# Most Recent (December 2007) Tevatron Limits

- For $m_H$=115, expected (observed) 95% CL relative to $\sigma_{SM}$ = 4.3 (6.2)
- For $m_H$=160, expected (observed) 95% CL relative to $\sigma_{SM}$ = 1.9 (1.4)

Bands show expected background fluctuations

Green = 1σ

Yellow = 2σ



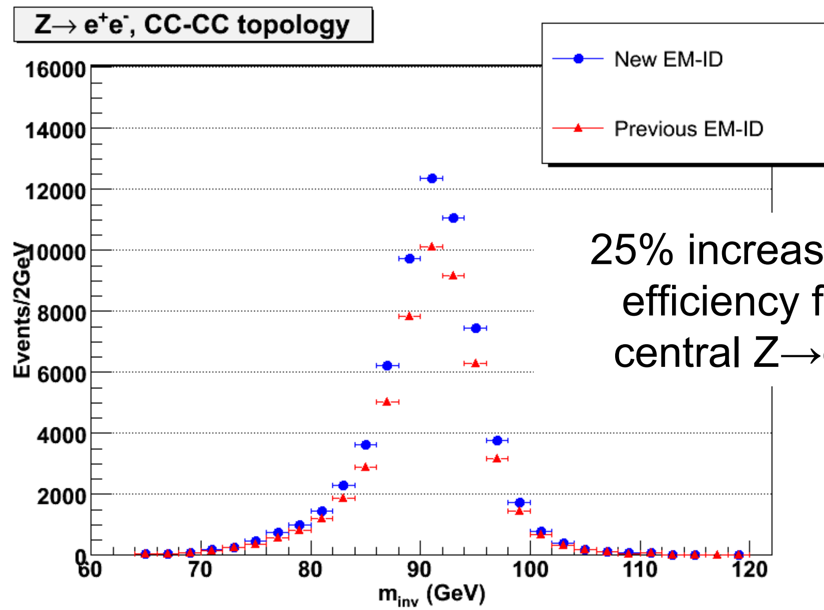

Tevatron New Phenomena/Higgs Working Group combination **December 2007 arXiv:0712.2383**

# Projecting Higgs Reach to 2010

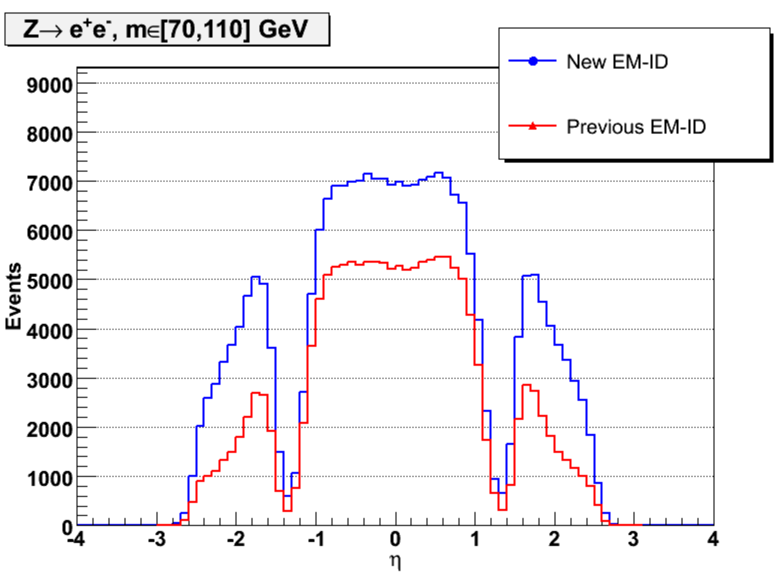
- Assumed improvements used in projections
  - Well-predicted improvements (not yet implemented) – expected gains known with good precision
    - update ZH→vvbb with Neural Net
    - add single-b-tag channel to ZH→vvbb
    - include forward electrons in WH
    - include 3-jet sample in WH
    - b-tagging with Layer 0 (~8% per tag efficiency increase)
    - add semileptonic b-tags (~5% per tag efficiency increase)
    - scaling of systematic uncertainties as a function of luminosity
  - Improvements in progress – gain factors estimated
    - di-jet mass resolution (from 18% to 15% in σ(m)/m)
    - increased lepton efficiency (10% per lepton)
    - multivariate analyses (~20% in sensitivity)
- Additional improvements not yet included in projection
  - inclusion of tau channels
  - charm rejection in single b-tag analyses
  - optimizing H→WW at low mass
  - …

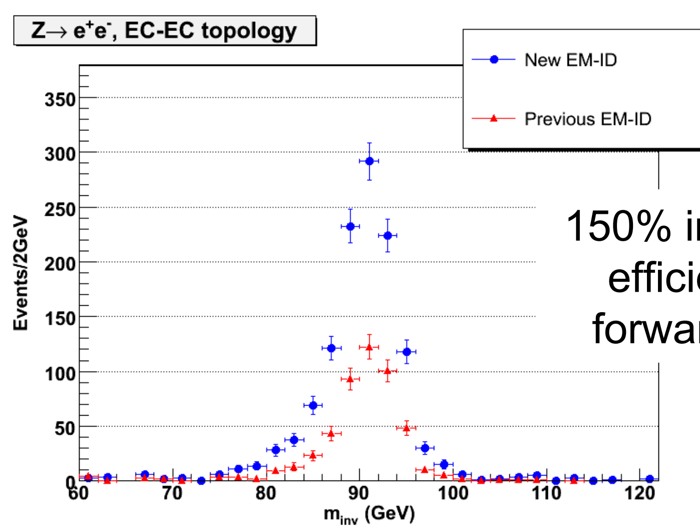
# Recent progress: Electron Identification

- Improved electron identification (ID) developed to increase efficiency
  - Particularly in forward regions
  - Substantial gain in central region as well
- Not yet incorporated in current results
  - Will improve future sensitivity
- Additional improvements under development




25% increase in efficiency for central Z→ee

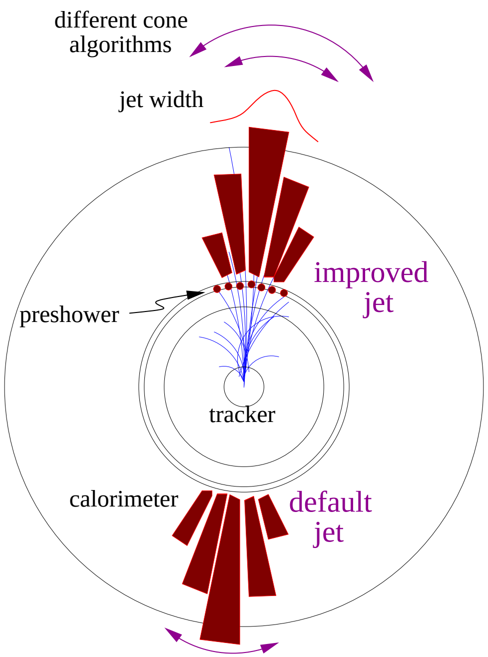


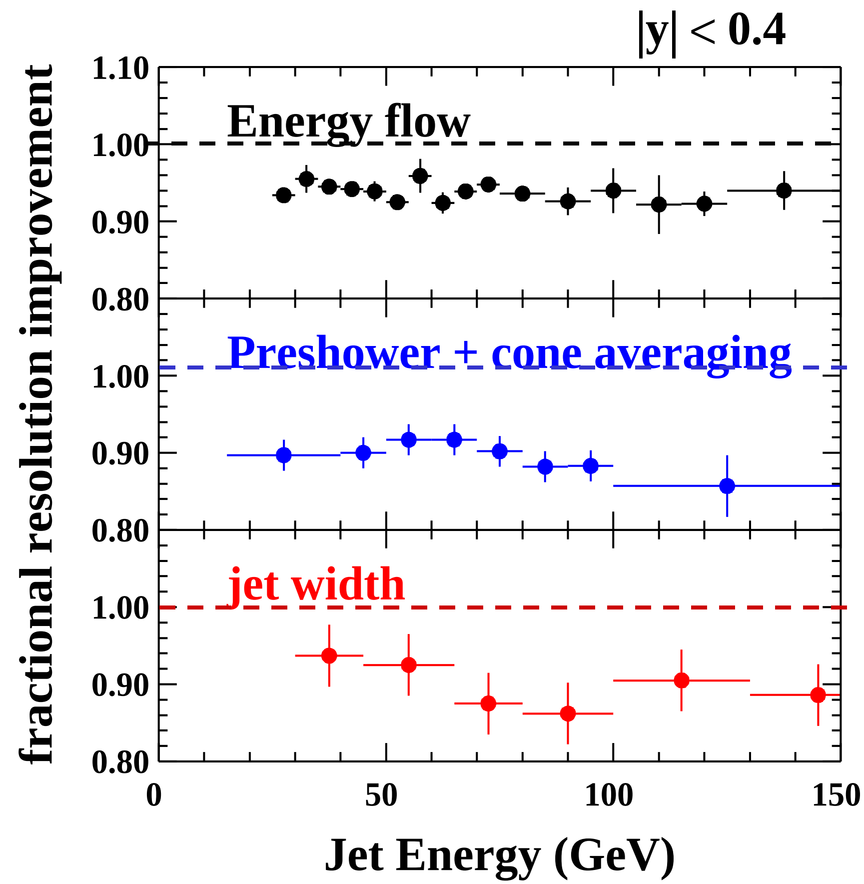

150% increase in efficiency for forward Z→ee

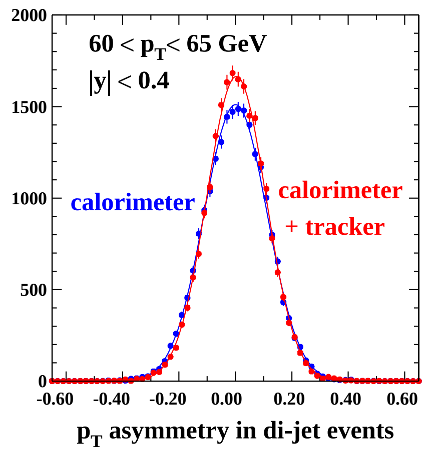
# Recent progress: Jet Resolution

- Di-jet mass resolution is critical for H→bb modes
- Dedicated group is working to optimize jet energy resolution

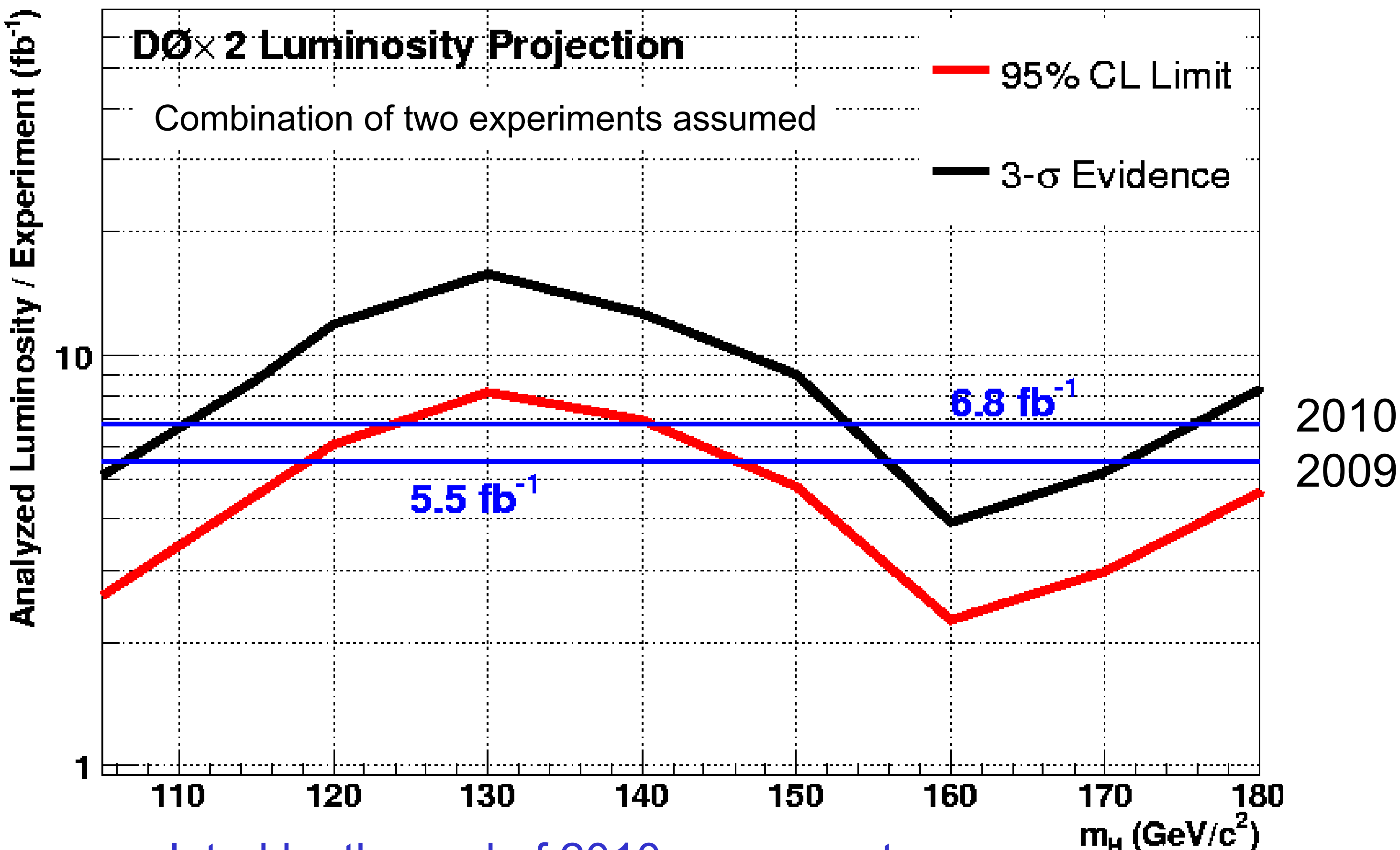



Several techniques show improvements of 5-15% in resolution each



# Median expected Higgs sensitivity




With data accumulated by the end of 2010, we expect

- 95% exclusion possible over almost entire allowed mass range
- 3σ evidence possible at low and high ends of range

# SM Higgs Prospects – Summary

- With data accumulated by the end of 2010, we will be able to explore much of the SM Higgs mass region allowed by the constraints from precision measurements and LEP direct exclusion
  - Expected 95% CL exclusion over whole allowed range, (except possibly around 130 GeV) - assuming the Higgs does not exist at these masses
  - Three-sigma evidence for a Higgs possible over almost entire range, and probable for the low end and high end
- Work is underway to achieve and exceed these levels of sensitivity. Examples shown:
  - Electron identification efficiency
  - Jet mass resolution

# Conclusion

- The DØ experiment is running better than ever
  - Data taking efficiency >85% (~93% recently)
  - Prompt reconstruction and analysis
  - Exciting measurements and discoveries
    - 2007 was best year ever in number of publications
- The future looks even more promising
  - Stable operations
  - Radiation aging should have no significant impact on detector performance
  - Great excitement for physics results with multi-fb$^{-1}$ data sample
  - New groups, students and postdocs joining
- We ask P5 to give its strong support to continuing the Tevatron run through 2010