DØ Operations and Physics Reach through 2010

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for the
DØ Collaboration

DØ International Finance Committee Meeting

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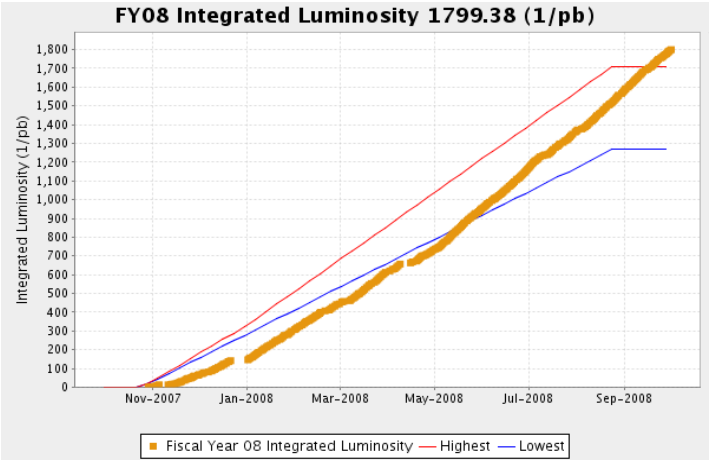
Executive Summary

- **DØ detector**
  - Smoothly collecting physics data – 4.5 fb^{-1} recorded
  - No technical issues through 2010 expected
  - Full high P_t trigger menu up to highest anticipated luminosities
- **Data reconstruction**
  - Please see Qizong Li's talk
- **Collaboration Resources**
  - Sufficient manpower to operate the experiment in 2009-2010 and analyze data is available
- **The DØ physics program**
  - Excellent physics prospects for running through 2010, including SM Higgs detection
  - Progress made in algorithm/analysis improvements which will augment Higgs sensitivity

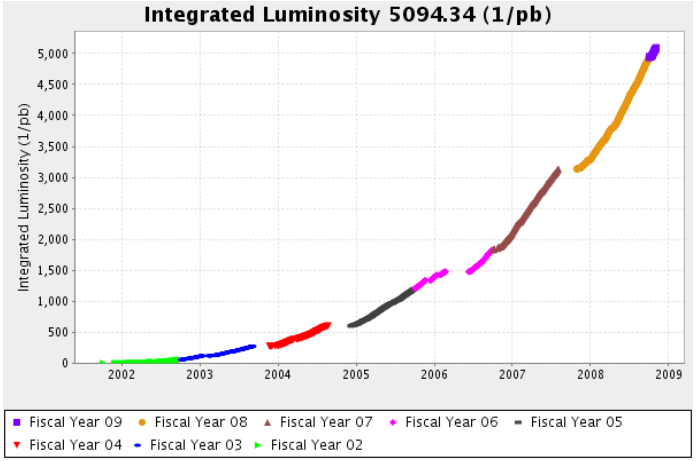
Tevatron Performance

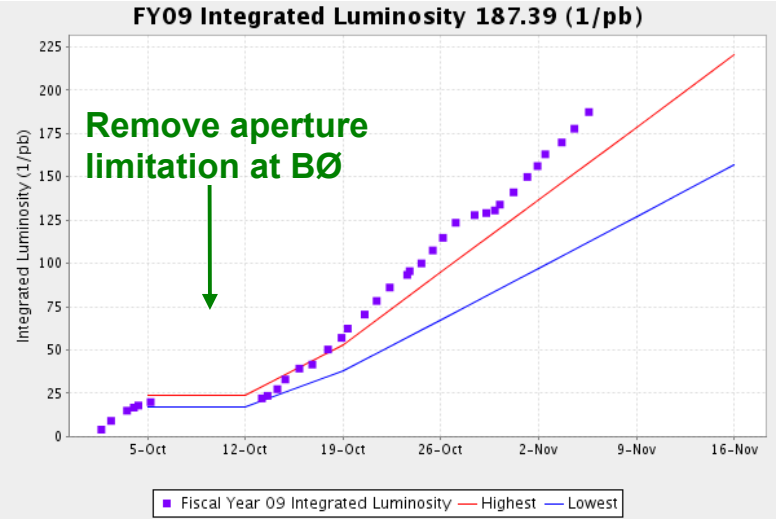


Surpassed target integrated luminosity for FY08:

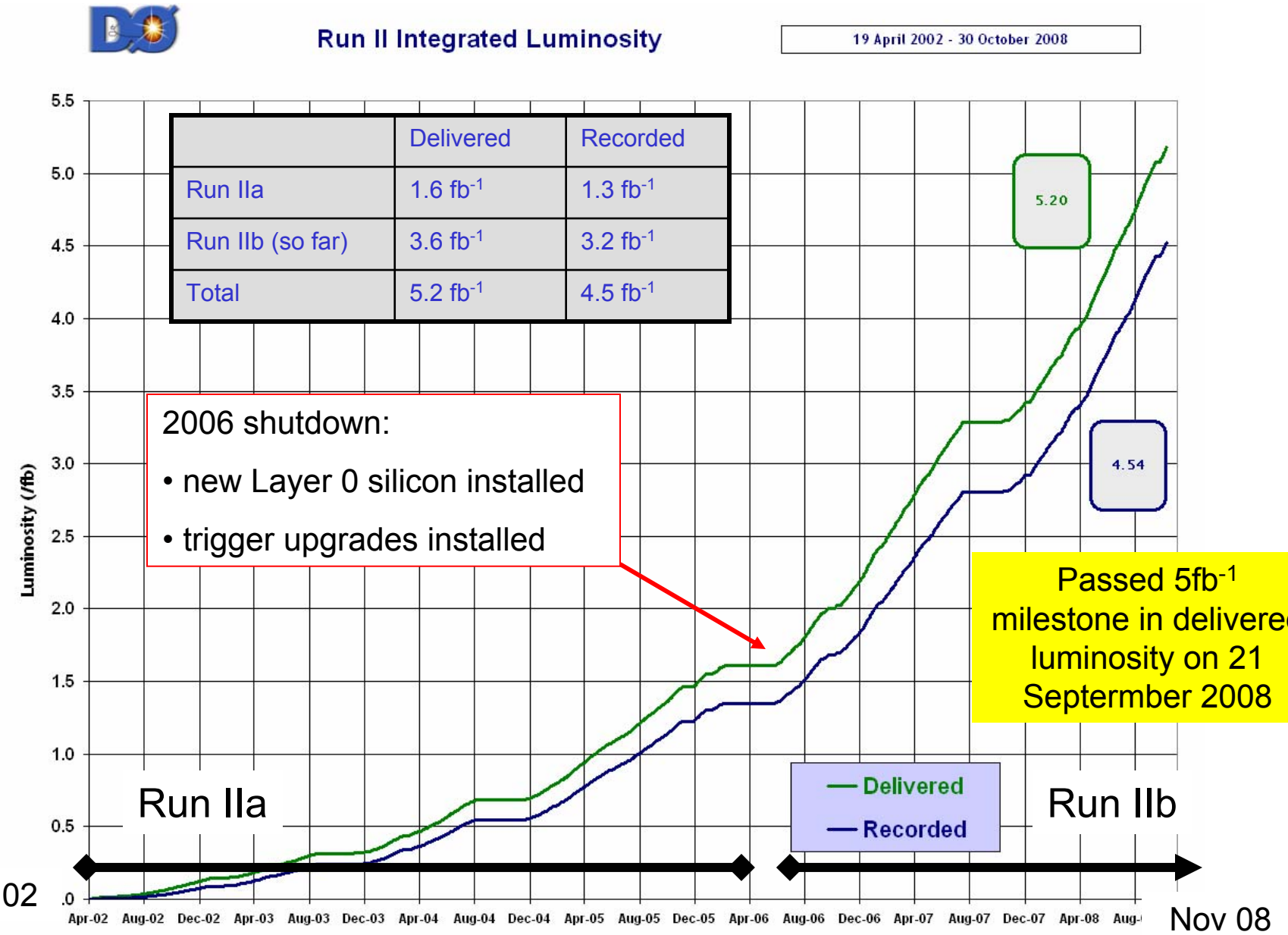
- increased stacking rate
- shorter turnaround time
- stability of machine (106 hours/week)
- improved luminosity lifetime

FY09 started well





Integrated Luminosity



	Delivered	Recorded
Run IIa	1.6 fb^{-1}	1.3 fb^{-1}
Run IIb (so far)	3.6 fb^{-1}	3.2 fb^{-1}
Total	5.2 fb^{-1}	4.5 fb^{-1}

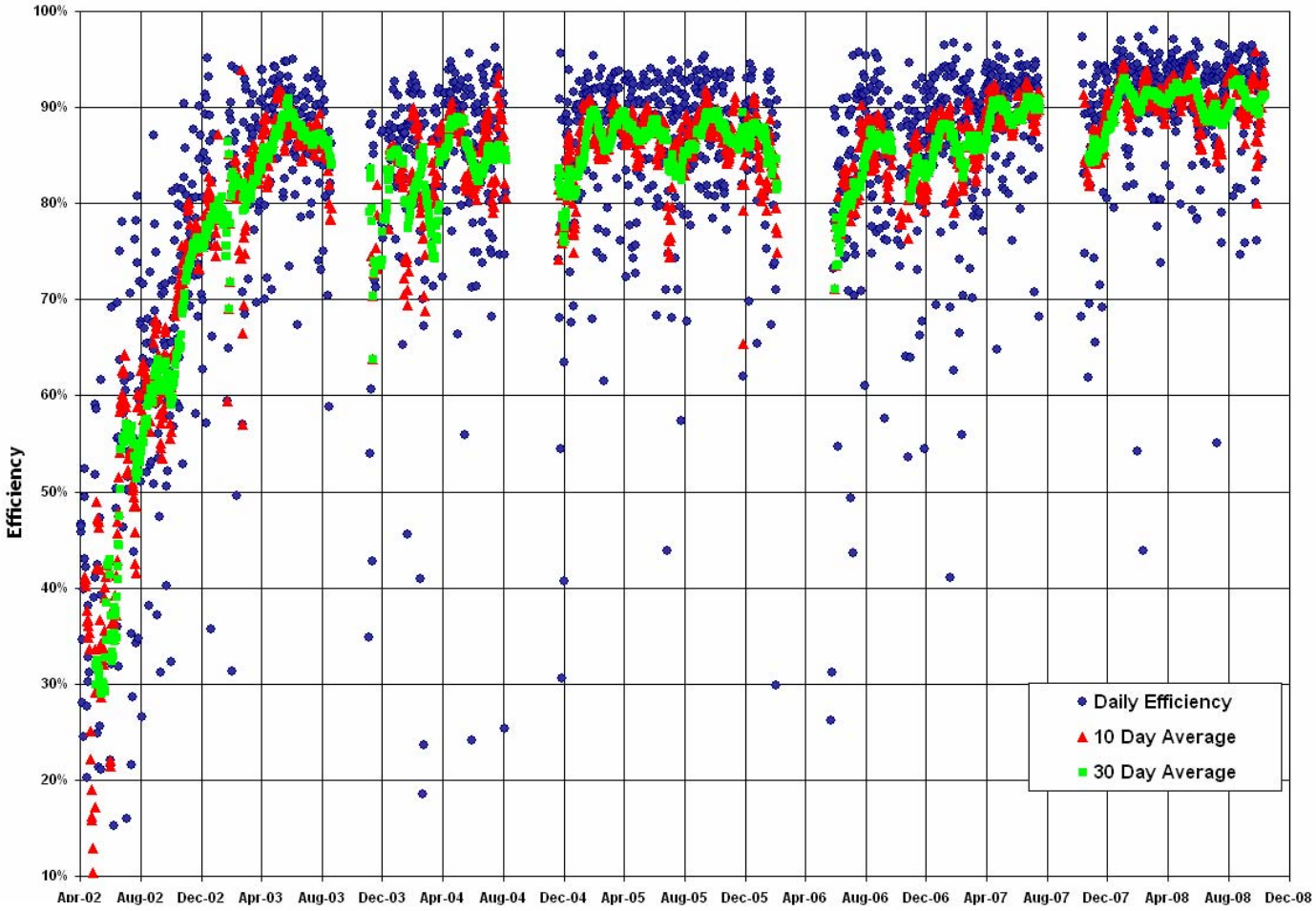
2006 shutdown:

- new Layer 0 silicon installed
- trigger upgrades installed

Passed 5fb^{-1} milestone in delivered luminosity on 21 Septermber 2008

Data Taking Efficiency

Definition: recorded luminosity / delivered luminosity



April 02

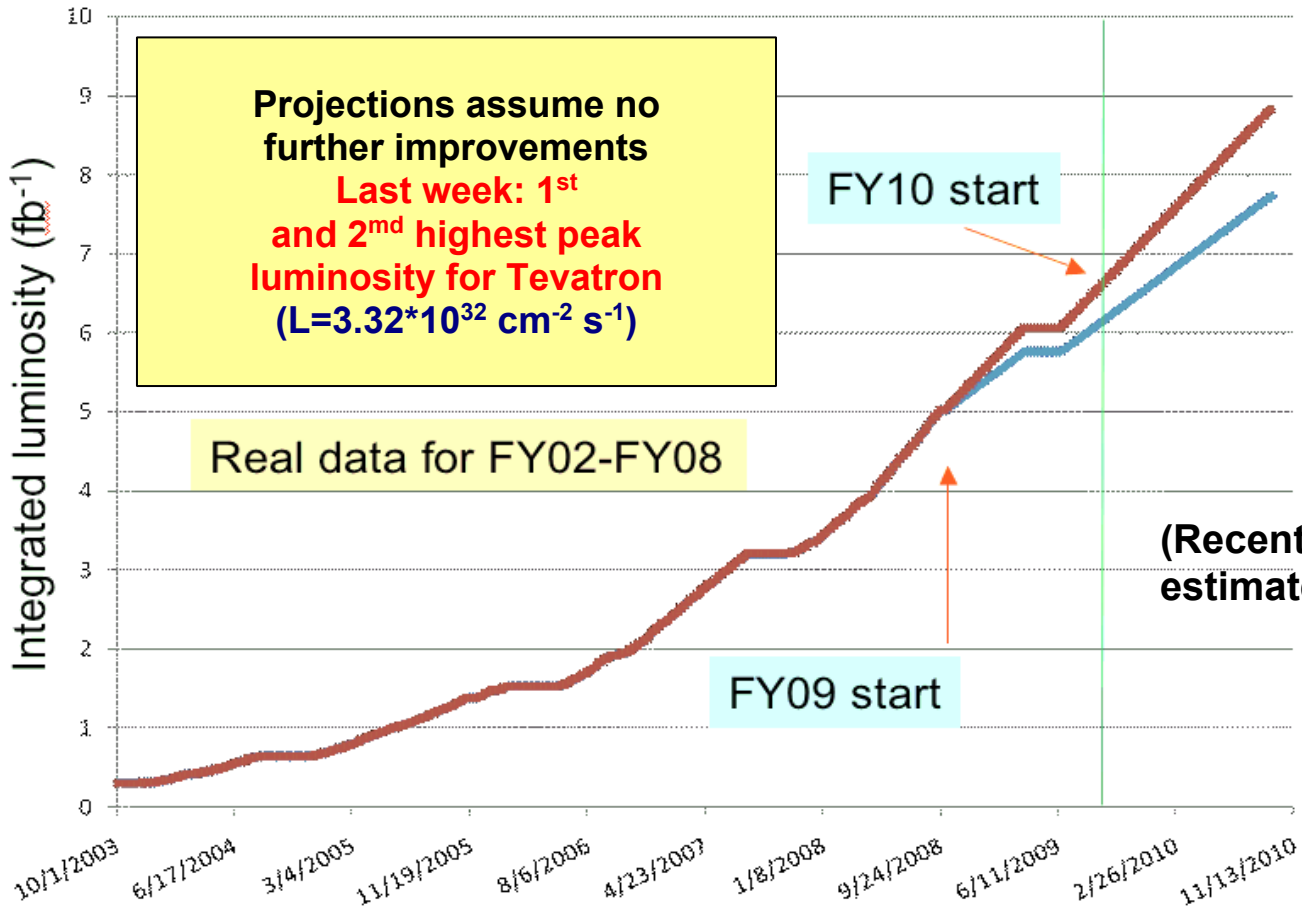
Nov 08

Fiscal Year 2008 average efficiency = 91%

High collection efficiency at high luminosity

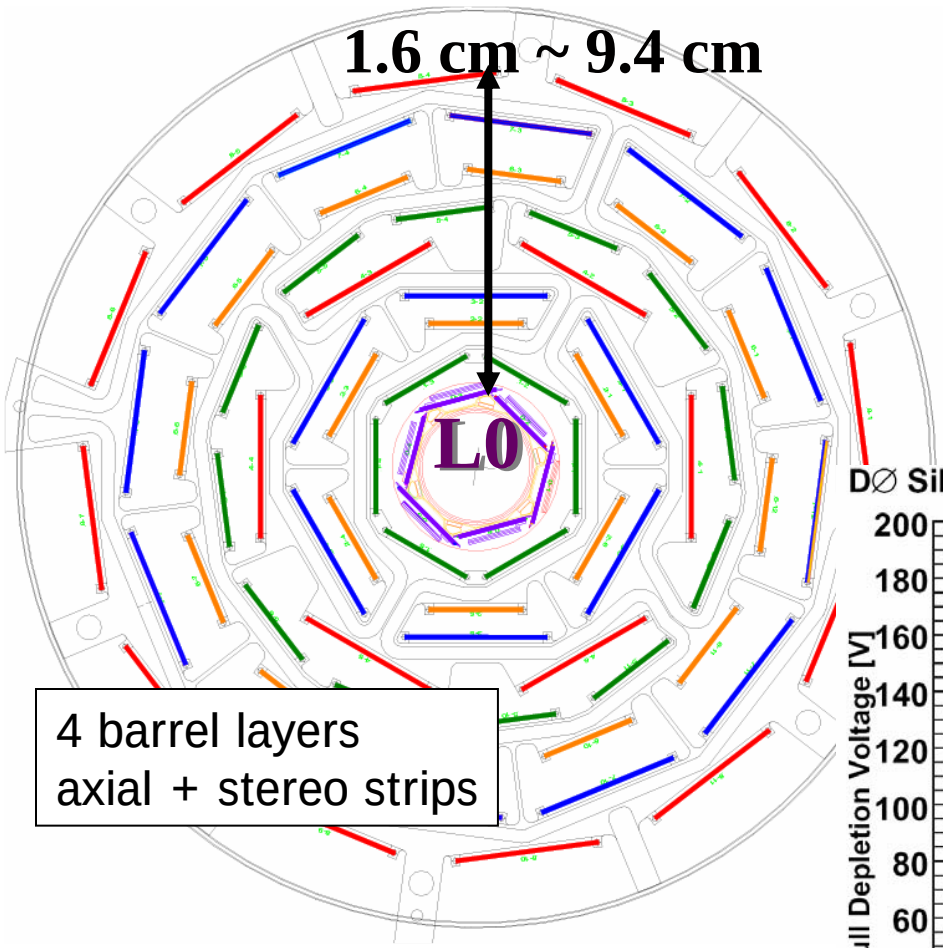
Includes readout dead time

Future Perspectives

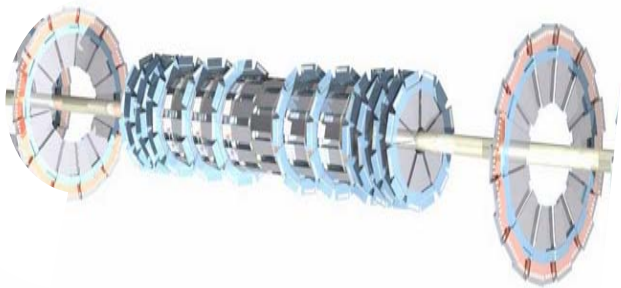


(Recently updated: previous estimate was 7.2-8.6 fb^{-1})

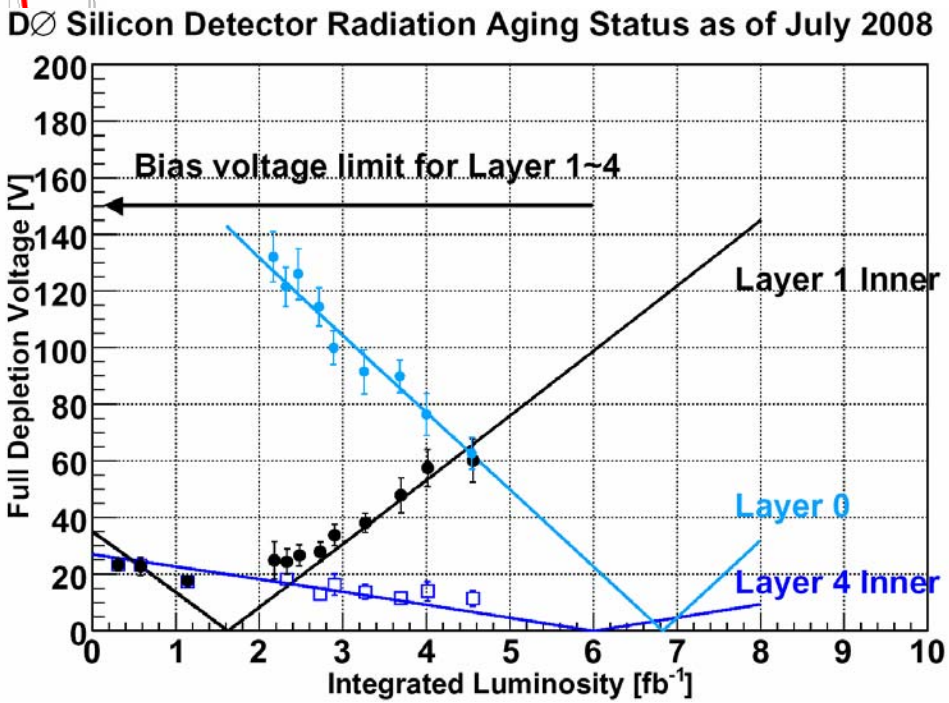
Silicon Microstrip Tracker: Longevity



4 barrel layers
axial + stereo strips



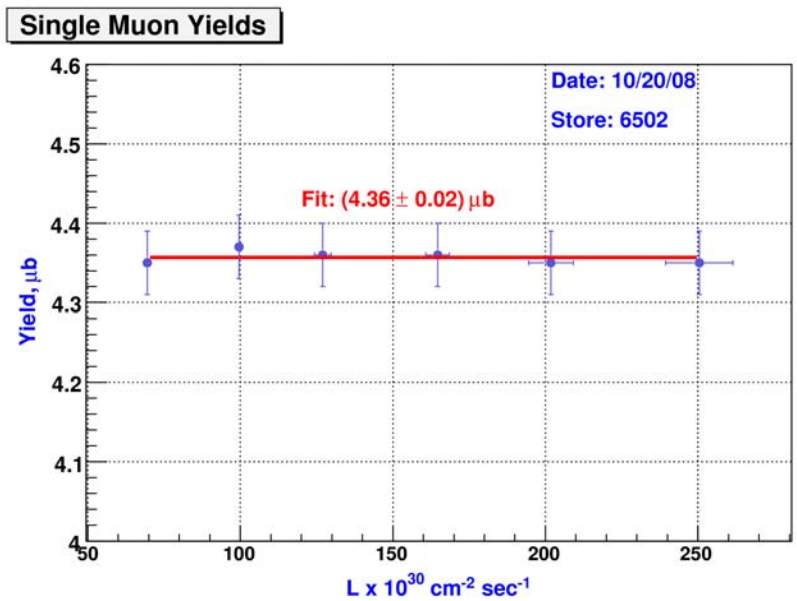
Additional radiation-hard inner layer, “Layer 0” added in 2006

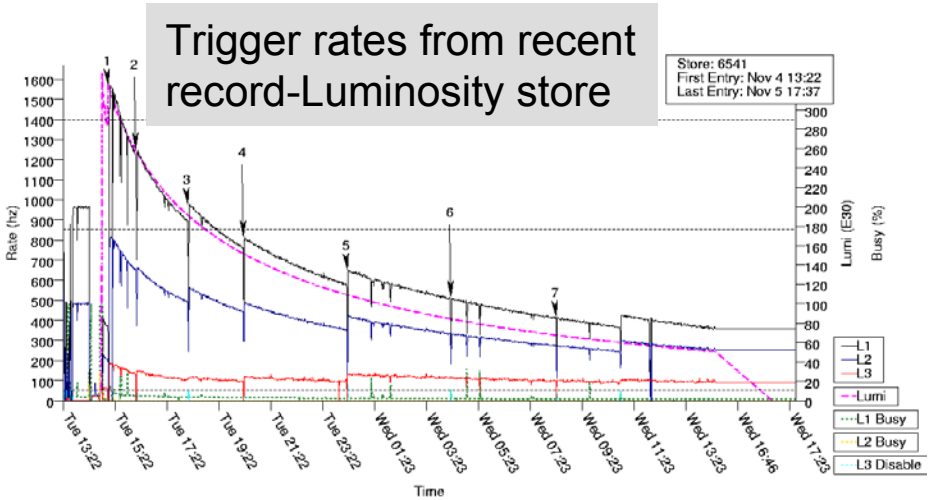


Radiation dose → no issues for running through 2010

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 3.5×10^{32} $cm^{-2}s^{-1}$





Collaboration Manpower Analysis

- Estimates of available full-time-equivalent physicists (FTE's) are obtained from an analysis of the Memoranda of Understanding (MoU's) submitted by each institution on DØ
  - MoU's completed in 2005 covered 2005-2007 period, completed early 2007 covered 2007-2009 period
- One-year overlap in each set of MoU's gives us a means to have continuous predictions and monitor changes in expectations

Physicist FTE's	2005	2006	2007	2008	2009
2005-2007 MoU data	474	437	354		
2007-2009 MoU data			357	272	184
Needs (excluding analysis)	230	200	165	145	124

P5 in June 2007 used above data to endorse 2009 run of the Tevatron

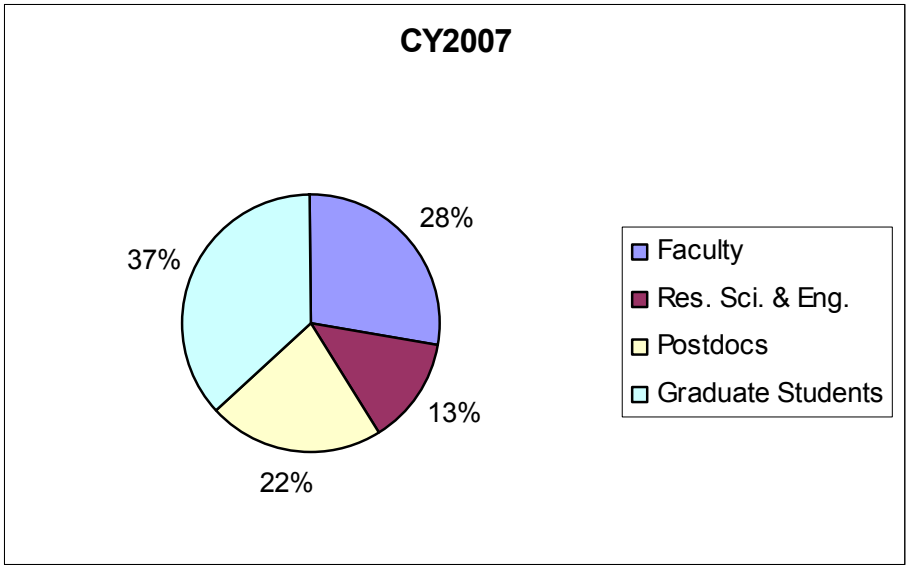
Collaboration MOUs

- In early 2008, we finished collection of MOU's covering 2009-2011 period.

Physicist FTE's	2007	2008	2009	2010	2011
2007-2009 MoU data	357	272	184		
2009-2011 MoU data			240	185	119

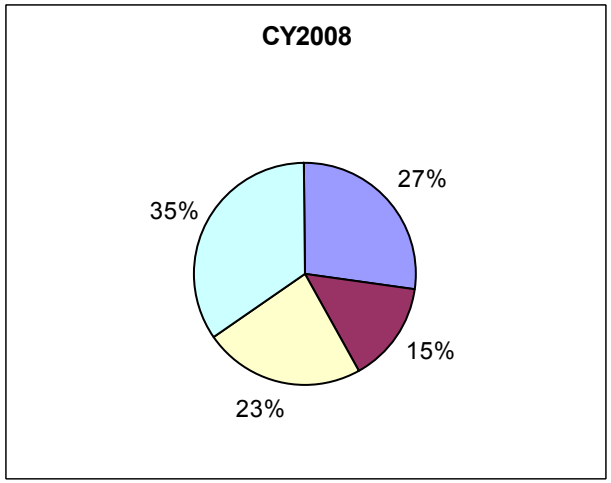
- 30% increase in 2009 FTE with respect to previous set of MoU's demonstrates the strengthened commitment of the Collaboration to continuing Tevatron program
- Preliminary estimate for 2010 manpower needs (excluding analysis) are ~100 FTE's
- Current FTE estimates for 2010 closely match previous estimates for 2009
  - Expect sufficient but lean manpower for 2010 run

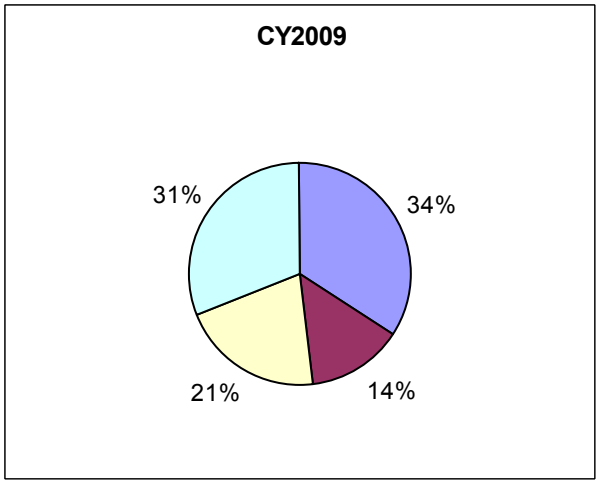
Collaboration Manpower Composition

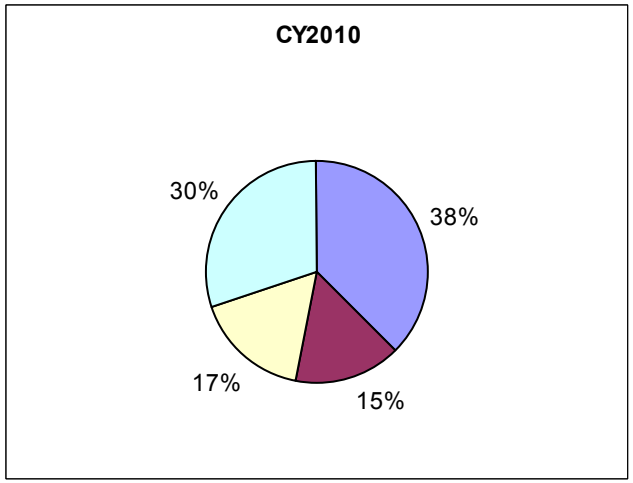


MoU's provide detailed information about composition of the DØ Collaboration manpower

- Faculty
- Research scientists
- Postdocs
- Graduate students







Composition is fairly stable and indicative of natural changes in the Collaboration at the current stage

Broad Physics Program for 2010

Selection of physics topics which are all currently statistics limited with substantial improvements expected with 2010 data

Heavy Flavor Physics

- B baryon searches
- **Rare decays, e.g. $B_s \rightarrow \mu\mu$**
- **CP violation in B_s decays, e.g. $B_s \rightarrow J/\psi\varphi$**
- Direct CP violation in $B^{\pm} \rightarrow J/\psi K^{\pm}$
  - Relies on unique DØ feature of regular magnetic fields reversal to control systematic uncertainties to <0.1% level.
- FCNC in D meson decays

New Phenomena searches

- SUSY in tri-leptons
- Stop searches
- Extra dimensions, e.g. in mono-photons
- **SUSY Higgs**

SM Higgs

QCD

- Cross sections for W/Z+heavy flavor
- Di-jet angular distributions at high di-jet mass
- Inclusive jets cross sections

Top quark physics

- Cross sections for low BR processes (e.g. lepton+tau)
- W boson helicity in top decays
- **Single top cross sections, V_{tb}**
- Non-standard top quark production
  - ttbar resonances, W', H+, top A_{fb}
- Non-standard/rare top decays

Electroweak

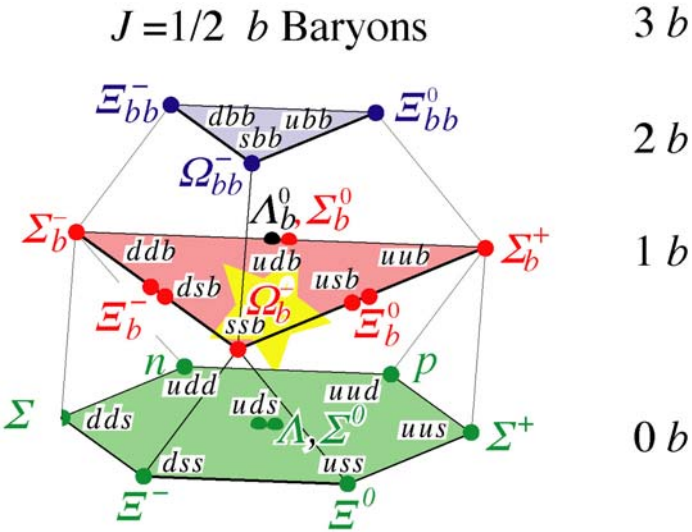
- Di-bosons and anomalous couplings
- $\sin^2\theta_W$ from A_{fb} in $Z \rightarrow ee$ decays

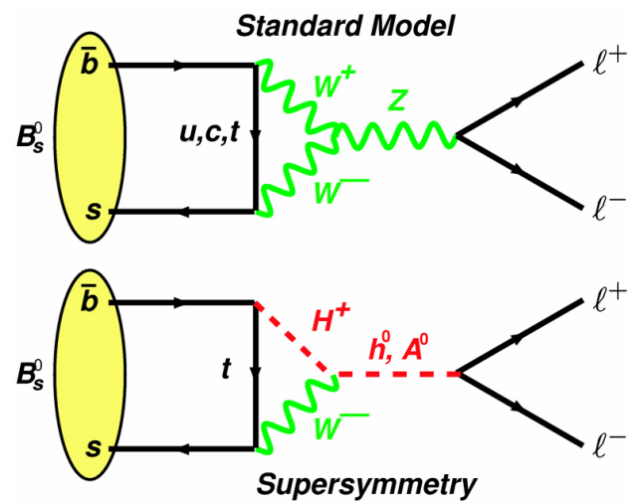
2010 Running: Parameters

- Based on estimates from Fermilab accelerator division, we assume
  - About 8.5 fb^{-1} delivered by the end of FY10
  - May in fact be higher, based on recent updates
- We estimate about 80% of this delivered luminosity will be used in analyses
  - 6.8 fb^{-1} by end of FY10
- We will use "analyzed luminosity" for all projections so the projected results can be compared easily with existing results
- Improvements and changes in detector and triggers which enhance 2010 run impact
  - Inner layer of silicon and trigger upgrade installed after first 1.3 fb^{-1} of Run II
  - New electronics for fiber tracker and pre-shower installed in 2006
  - Improved trigger list developed over last two years, went on line in March 2008
  - Keeping open the possibility of reallocating trigger bandwidth for latest part of the run to enhance data set for particular studies
    - while diminishing it for others

Rare B decays and B-baryons

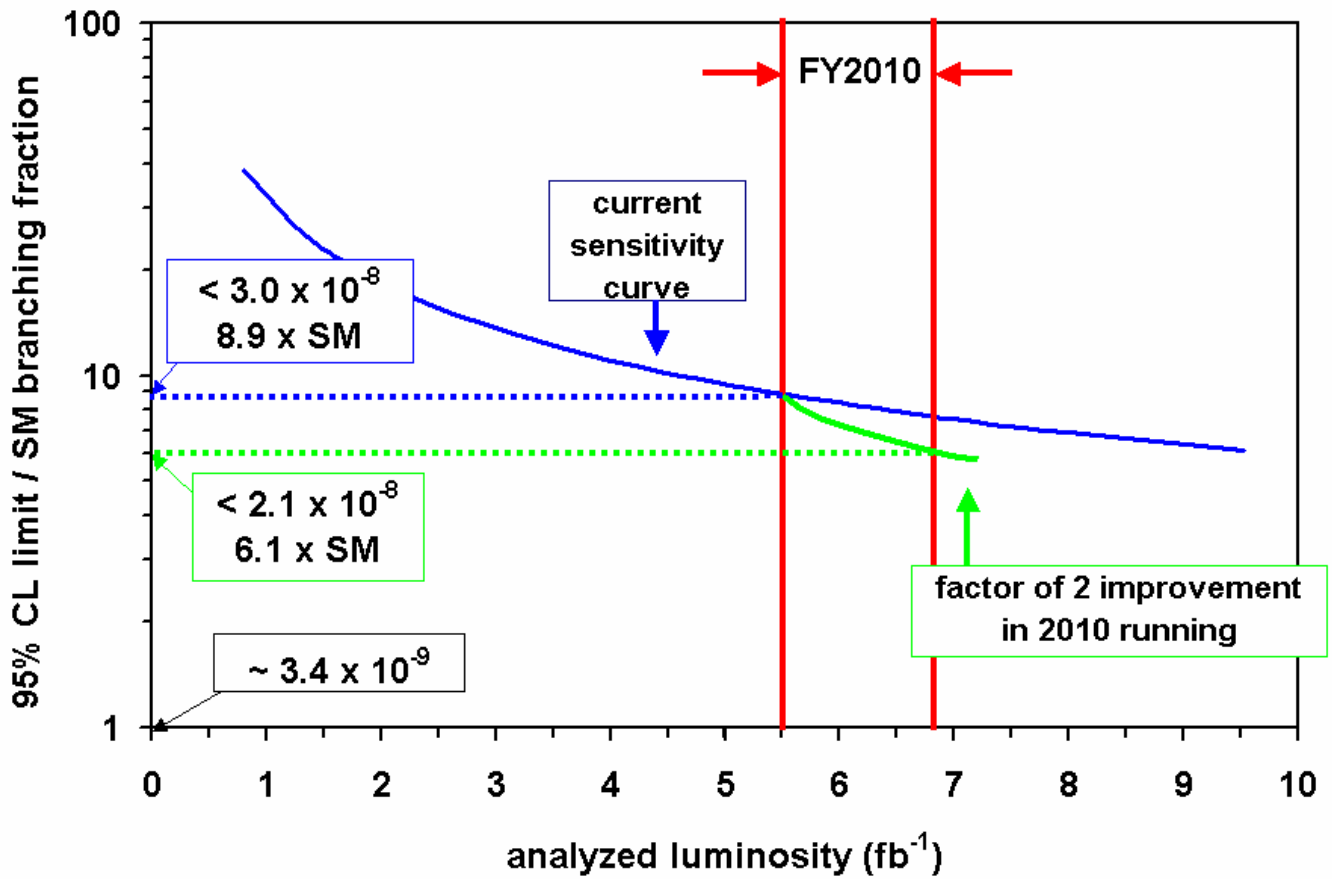
- B-baryons
  - Ξ_b^- and Ω_b^- discovered with 1.3 fb^{-1} of data
    - Measured mass, production rate
    - More properties require more statistics
  - Additional baryon discoveries possible with more data
- $B_s \rightarrow \mu\mu$ decay search
  - Clean rare decay channel
  - SM: $BR(B_s \rightarrow \mu\mu)=(3.5\pm0.5)\times10^{-9}$
  - 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
  - Low-mass di-muon trigger is used for all heavy flavor analyses listed earlier
  - Can have higher sensitivity in the new data





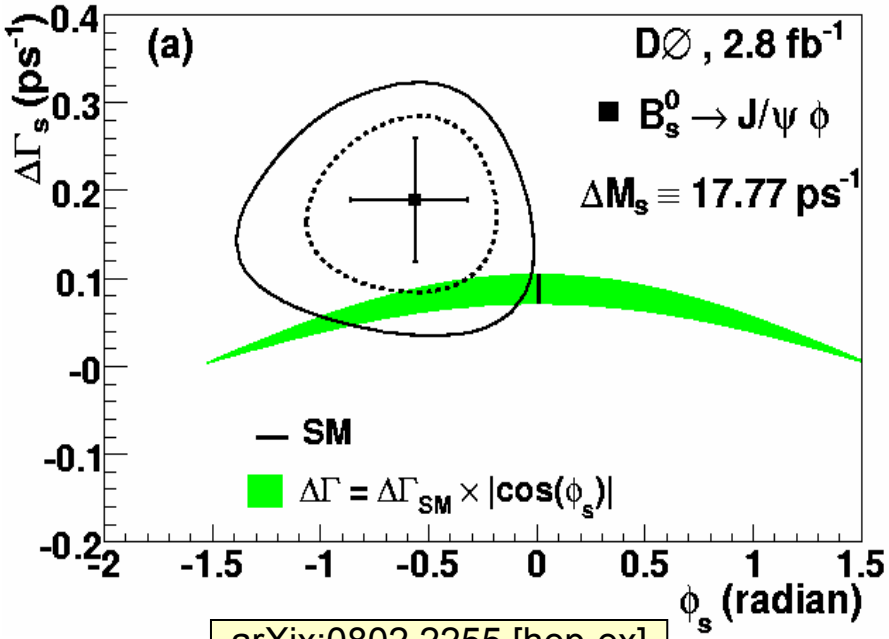
$B_s \rightarrow \mu\mu$ projections

- $B_s \rightarrow \mu\mu$ decay search complements the SUSY Higgs hunt with different channel in similar region of tanβ
- Assumptions for factor of two improvement in 2010
  - Single muon triggering pre-scales reduced
  - Looser di-muon trigger



CP violation in the B_s system

- $B_s \rightarrow J/\psi\varphi$ decay studies with 2.8 fb^{-1} of data so far
  - Measurements of $\Delta\Gamma_s$ (lifetime difference) and φ_s (CP violating phase)
  - Agreement with SM: ~6% (similar level of discrepancy observed by CDF)
  - Statistics limited
- We plan to actively continue this study
  - Will the discrepancy persists with higher statistics?
  - Potential to detect new physics effects with >3σ significance by the end of 2010



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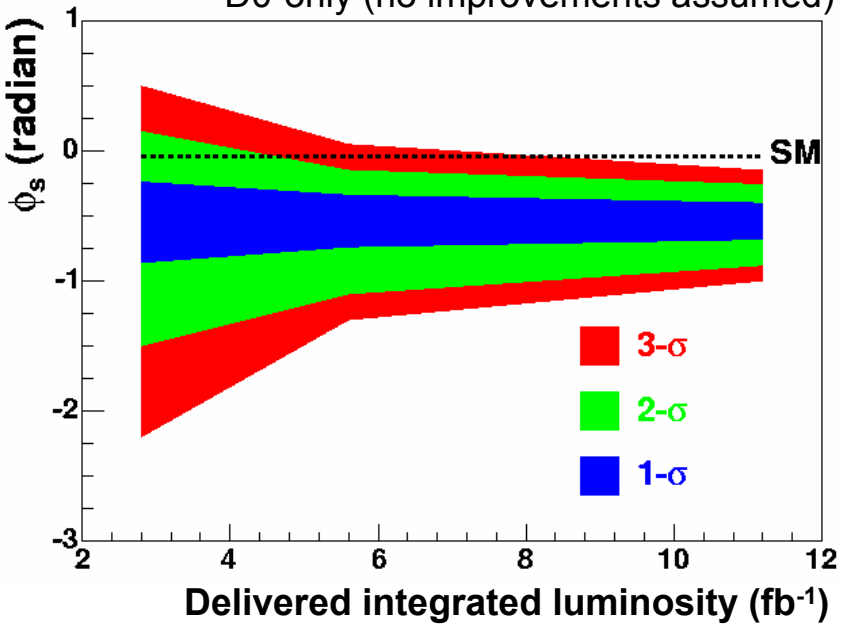
Accepted by PRL

D0-only (no improvements assumed)



Projected confidence level intervals on φ_s (compared to current D0 measurement)

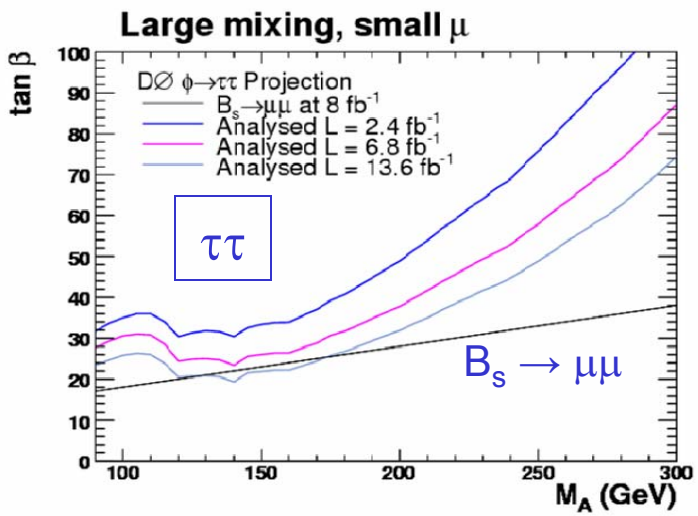
MSSM SUSY Higgs

- Tevatron has significant reach in ($\tan\beta$, M_A) plane. Interesting region $=m_t/m_b \sim 35$
- Three channels: $h \rightarrow \tau\tau$, $hbb \rightarrow \tau\tau b(b)$, $hbb \rightarrow bbb(b)$
- Will benefit from optimized trigger strategy, so that new data will yield more sensitivity per fb^{-1} than old data
  - Substantially improved tau triggering capabilities in Run IIb calorimeter trigger
- Considered two sets of model parameters (Carena, Menon, Wagner, arXiv:0704.1143v2)
  - small μ, large stop mixing
  - large μ, no stop mixing
- Doubled luminosity approximates reach of two Tevatron experiments

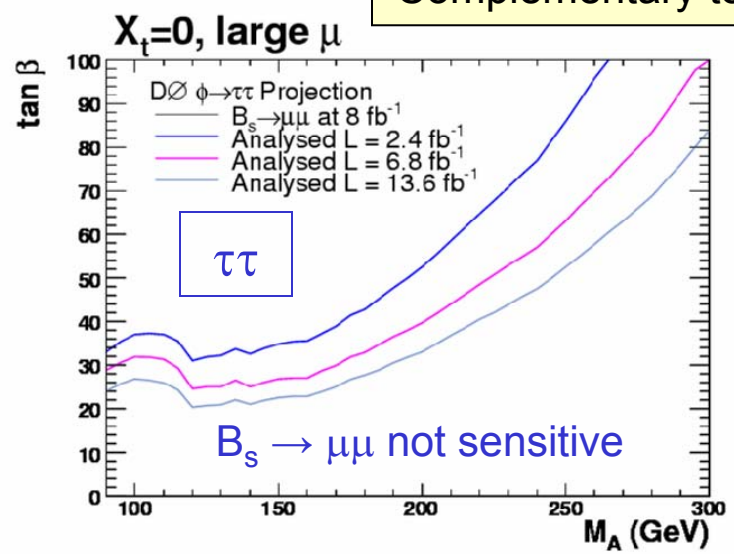
MSSM Higgs limit projections

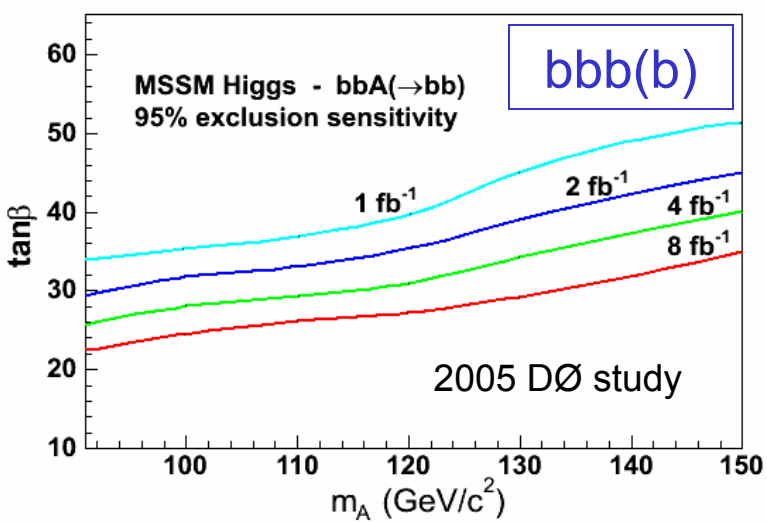
Full systematics included; assume 20% improvement from multivariate techniques

95% CL exclusion



Complementary to $B_s \rightarrow \mu\mu$





Combination of all three channels

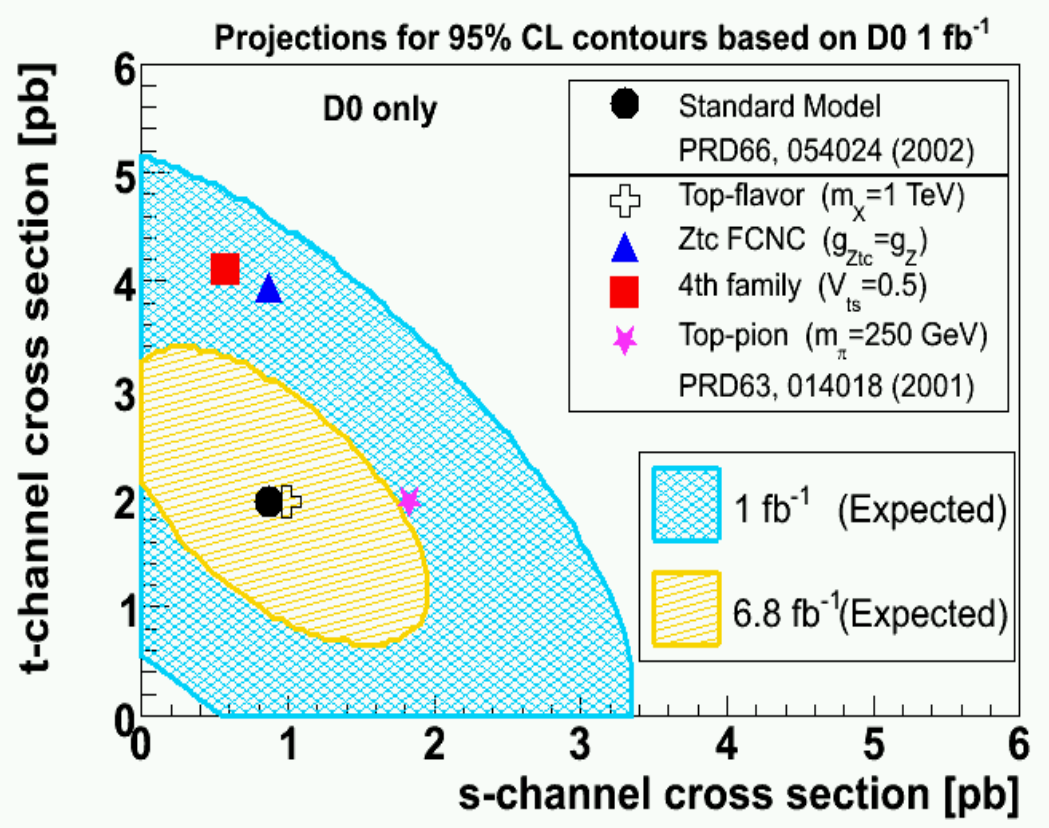
$h \rightarrow \tau\tau$, $hbb \rightarrow \tau\tau b(b)$, $hbb \rightarrow bbb(b)$

will further improve reach since the three channels have comparable sensitivity

Single Top Quark Studies

- Currently DØ results from 1fb^{-1} precision completely limited by statistics
  - 3.6-sigma signal significance
  - ~30% uncertainty on cross section
  - ~20% uncertainty on $|V_{tb}f_1^L|$

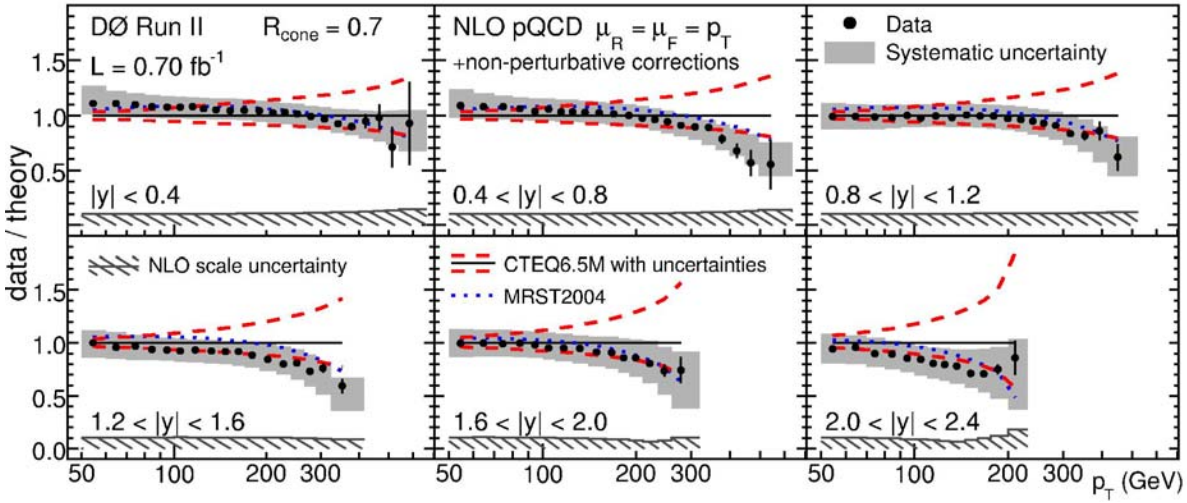
- Projections to dataset in 2010
  - Simultaneous measurement of s- and t-channel cross sections sensitive to New Physics affecting differently each channel
  - Projected precision on $|V_{tb}|$ (~5-10%) competitive with LHC



The Tevatron and the LHC

- At some point the energy frontier will move from the Tevatron to the LHC
  - There are topics are still better explored at a pbar-p machine
    - top quark asymmetry
    - t-tbar spin correlations
    - searches for color-singlet resonances (q-qbar initial state)
  - Legacy measurements from the Tevatron will be world's best for many years
    - top quark mass
    - W boson mass
    - Indirect constraints from such precision measurements are critical for interpretation of any new signals at LHC
  - Analyses from the Tevatron also provide crucial constraints on SM backgrounds at the LHC
    - W/Z+jets, W/Z+heavy flavor
    - PDF constraints from inclusive jets
      - *After years of work* 1% uncertainty on jet energy scale at DØ is starting to yield significant new information on PDFs
- All of the above will benefit greatly from data collected in 2010

Data from recent paper on inclusive jet production (at right) and W charge asymmetry provide PDF constraints in the highest available momentum transfers range

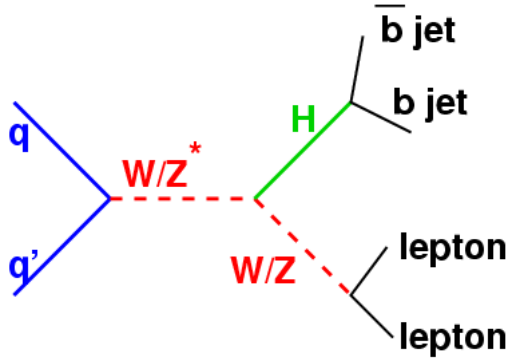


SM Higgs search at the Tevatron

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

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

Use associated production modes to get better signal/background



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

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

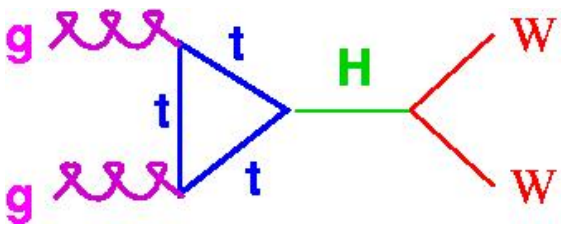
$$q\bar{q} \to ZH \to \nu\bar{\nu} b\bar{b}$$

Intermediate mass:

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

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

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

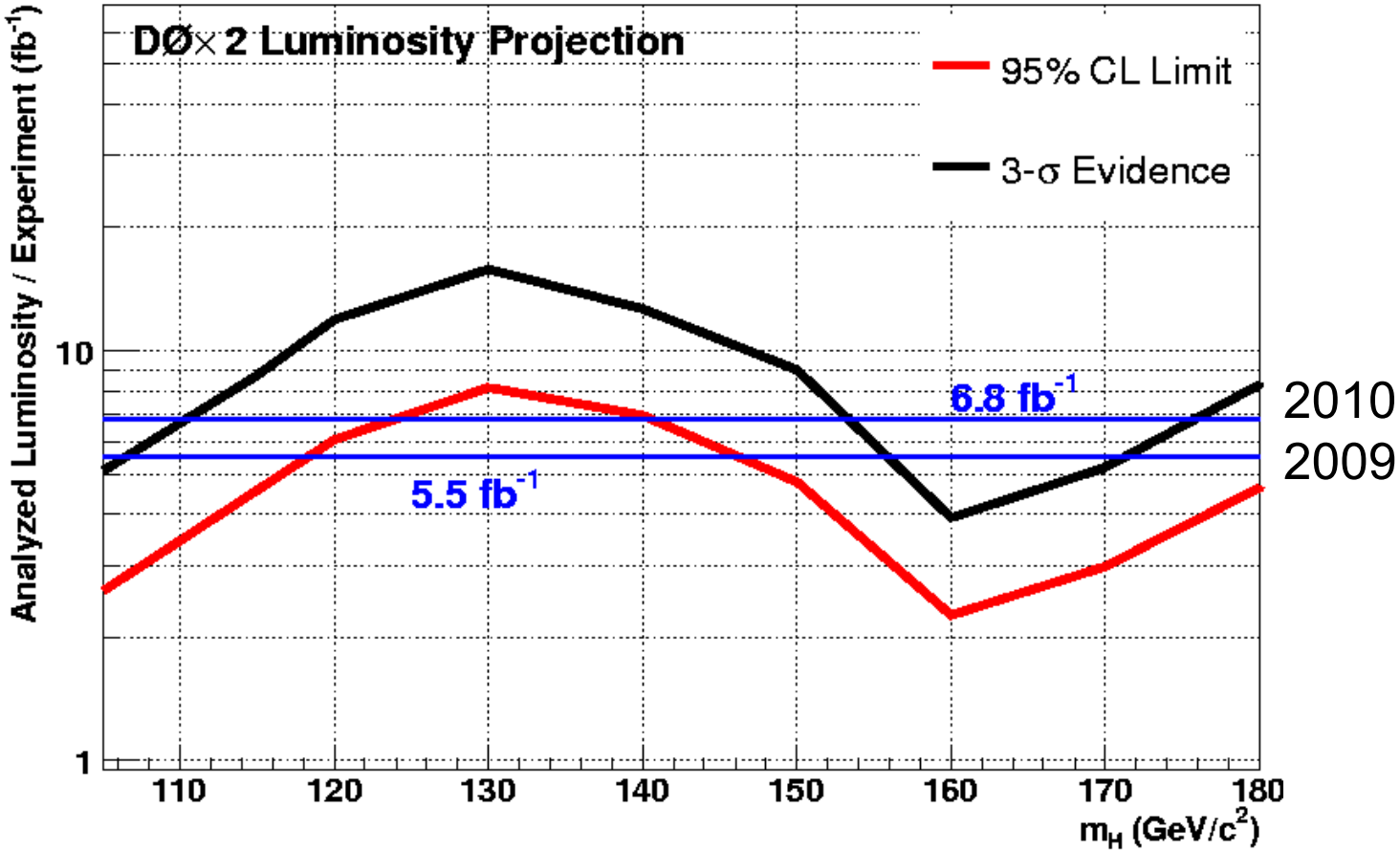


$$gg \to H \to WW \to \ell\nu\ell'\nu'$$

Projecting SM Higgs Reach to 2010

- Assumed improvements used in projections
  - Well-predicted improvements (not yet implemented) – expected gains known with good precision
    - update ZH→ννbb with Neural Net
    - add single-b-tag channel to ZH→ννbb
    - 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
  - …

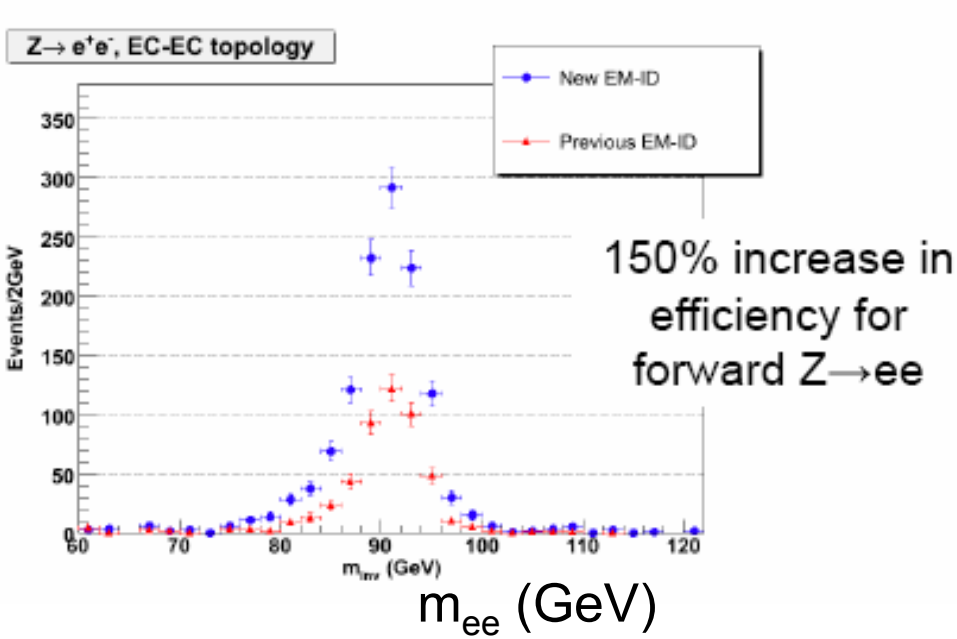
SM Higgs Limit Projections



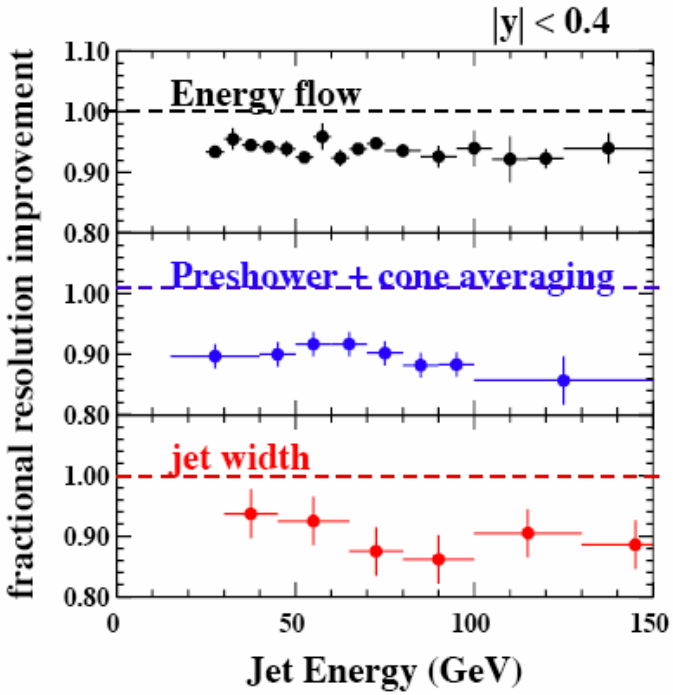
Future Improvements

The keys to future discoveries and high precision measurements are more luminosity <u>and</u> continuing improvements

Electron ID



Jet energy resolution



Summary

- **DØ detector**
  - Smoothly collecting physics data – 4.5 fb^{-1} recorded
  - Expect to record 7-8 fb^{-1} (6.5-7.5 fb^{-1} in analyses such as SM Higgs)
  - No technical issues expected through 2010
  - Full high P_t trigger menu up to highest anticipated luminosities
- **Collaboration Resources**
  - Sufficient manpower to operate the experiment in 2009-2010 and analyze data is available
- **The DØ physics program**
  - Excellent physics prospects for running through 2010, including SM Higgs detection
  - Many results are still limited by statistics
  - Progress made in algorithm/analysis improvements which will augment Higgs sensitivity
- **We look forward to continued strong participation from our international partners to exploit all of these opportunities**