The DØ Status Overview

Outline
- Run IIb Upgrade
- Data Taking
- Algorithms and Computing
- Manpower
- Review of Physics Results
- Summary

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The DØ Collaboration

DØ is an international collaboration of ~ 670 physicists from 20 nations who have designed, built and operate the DØ detector at the Tevatron.

Institutions: 91 total, 39 US, 52 non-US

Collaborators:
~ 50% from non-US institutions (note strong European involvement)
~ 100 postdocs, ~140 graduate students
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....

Driven by these goals, the detector emphasizes

Electron, muon and tau identification

Jets and missing transverse energy

Flavor tagging through displaced vertices and leptons

Fundamental questions

Quarks sub-structure?
What is cosmic dark matter? SUSY?
What is spacetime structure? 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
Run IIb Upgrade

- Major reasons for the D0 Run IIb upgrade
  - Silicon Layer 0 detector
    - Radiation damage to silicon, better b tagging closer to the vertex
  - AFEII boards - new electronics for the fiber tracker
    - Saturation of amplitude measurements at high luminosity
  - Trigger upgrades: Level 1 calorimeter, L1 fiber tracker and match between Level 1 tracks and calorimeter clusters
    - To keep trigger rates within available bandwidth as luminosity increases

Trigger system has to select ~50Hz of events to write to tape out of 1.7MHz interactions rate: ~ $10^5$ rejection needed

DØ capabilities:
Level 1 trigger ~2kHz
Level 2 trigger ~1kHz
Level 3 trigger ~100Hz
Silicon Layer 0 Upgrade

Original Run II Silicon Detector with 4 barrel layers

Added extra layer of barrel detectors very close to the beam pipe

Installation of Layer 0 – long and fragile detector – was performed safely during Spring 2006 shutdown

Cosmic without L0

Cosmic with L0

Layer 0 detector is working very well!

Same diameter as a golf ball
Run IIb Upgrade

- L1 calorimeter trigger upgrade provides considerable extra rejection and more flexibility
  - Replaces Run I trigger system!
- Installation progressed well on schedule
  - Started to use new trigger with first store of Run IIb

Fiber tracker electronics upgrade (AFE boards): detection of light using Visual Light Photon Counters. ~200 very complex boards with analog and digital processing, LHe cooled VLPS temperature control and monitoring, ~75k channels.

All major Run IIb upgrades are completed or in final stages of commissioning

Major enhancements to the DØ capabilities!
Data Taking

- Smooth operation of the experiment is critical for steady increase of the data set available for physics analysis
  - Started data taking in the first Run IIb store within an hour of first collisions!
  - Implemented new “Version 15” trigger list
    - Includes new Level 1 trigger tools
    - Includes Layer 0 silicon detector (in displaced vertex trigger)
- From time to time there are issues with quality of data we are collecting
  - Issues with silicon detector synchronization after addition of Layer 0
  - Calorimeter noise after change in muon clock frequency to accommodate L1 trigger upgrades
- The collaboration concentrates on resolving data taking issues with highest priority (days-weeks)
  - We have only one chance to select/write event to tape...

Writing to tapes ~90% of delivered luminosity!

Short and long term operational activities

Finish Run IIb upgrade commissioning (AFE boards, etc.)
Continue streamlining and improving data quality monitoring
Provide reliable experts and shifters coverage
Run II D0 Luminosity

- D0 Luminosity measurement is performed using “counting zero” method
- Issues with delays in Run II electronics arrival, selection of operational parameters and simulation caused underestimate in the D0 luminosity
- Corrected luminosity is reported starting September 29, 2006

D0 Luminosity Correction

As change is above quoted error of ~6%, errata will be issued to luminosity critical D0 results
Run IIb Data Reconstruction

- New reconstruction version “P20” is used to reconstruct Run IIb data
  - Incorporates new detector elements
  - Improves time needed to process an event
- Fermilab’s farms are keeping up with data taking
  - Processing most of the data within a week after they are collected

Full GEANT simulated MC production, critical for many D0 analyses, is progressing on remote farms providing ~10M events/week

Early Run IIb Calorimeter Calibration: $Z \rightarrow ee$

There are challenges, like calorimeter re-calibration for Run IIb (LAr is too slow...). Plan to re-reconstruct Run IIb data starting in a month, using remote farms: have Run IIa experience

All objects in P20 - electrons, muons, jets, missing $E_T$, taus, b-tagging, etc. have been studied and performing well
Algorithms - Challenges at High Luminosity

- Tevatron is already running with “LHC like” number of interactions per crossing
  - Trigger rates are non-linear vs luminosity
  - Efficiencies of reconstructed objects are going down
  - Number of “fake” reconstructed objects is going up
- Detector was not designed to handle well above one interaction per crossing
  - After reaching 80E30 luminosity, the plan was to switch to 132ns...
  - A lot of collaboration resources are directed toward handling triggering and algorithms at high luminosity

Number of interactions per crossing

Most challenging issues are with tracking:
small central tracking volume – high occupancy “per fiber”

Triggered event adds ~10% to the occupancy. Above is mean(!) occupancy – there are looong tails in this distribution.
Challenges at High Luminosity

- There are many areas which are affected by high luminosity
  - While some performance could be recovered, data are of intrinsically lower quality
- Working with the Lab and Accelerator Division to optimize physics output of the experiment
  - Collect more integrated luminosity, while keeping peak luminosity as low as possible

Tracking performance

![Efficiency and Purity](image)

- Compare eff/pur in p17 (red/blue) to p20 (green/yellow)

![Muon isolation efficiency](image)

- Number of muons matched for di-muon events generated
  - $1.5 \times 10^{32}$
  - $3.0 \times 10^{32}$
Manpower Issues

We expect(!) natural decline in manpower for the detector operations, computing and analysis. The challenge is how to fully utilize Tevatron and the experiment potential over next ~5 years.

Main issues are

- Total number of FTE vs experts in specific areas
- Continuing upgrades related activities
- Major efforts required to optimize running and reconstruction at high luminosity
- Unexpected, like calorimeter re-calibration

The experiment is working hard to monitor/improve situation

- Yearly reviews of everyone activities
- Signing MoUs
- Streamlining operations, analysis, reducing number of activities experiment is involved
- Working with DoE/NSF and foreign funding agencies to increase funding

Based on Collider Manpower Task Force report (early 2006), Fermilab provided considerable help: extra postdocs openings, two international fellowships, technical support for the experiment, etc. We are still waiting for detailed response from the Laboratory on Task Force Recommendations. It is critical to continue strong support of the experiment!

From Collider Manpower Task Force report

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<tr>
<td>Available</td>
<td>319</td>
<td>191</td>
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<tr>
<td>Required - Available</td>
<td>112 ~ 67</td>
<td>16 ~ -31</td>
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Summary of Results, Talks, Publications

- ~30 publications over last year
  - one publication every two weeks!
- 60 new results approved for Conferences
  - Most will be published
- 26 PhDs defended
- >250 invitations to Conferences per year
  - Invited talks at all major Conferences

For full list of DØ approved results and publications visit http://www-d0.fnal.gov/Run2Physics/WWW/results.htm including plain-English summaries

Due to the talk duration only very few “highlights” from 2006 results are going to be presented
QCD Studies

Use high energy jets production to measure proton structure → quarks sub-structure?
Resolve some outstanding puzzles → e.g. heavy flavor production
Understand the backgrounds to physics beyond SM
Study diffractive production, new objects like X(3872)

Jet energy scale (JES) uncertainty is starting to be comparable with PDF errors
No surprises... for now
Electroweak Physics

Indirectly constrain new physics through precision measurements of electroweak parameters

Measure single and multiboson production, W production asymmetry, forward-backward asymmetry in Z production, ...

**SM WZ pair production**

Select events with three high $P_T$ leptons and missing energy

<table>
<thead>
<tr>
<th>Decay Channel</th>
<th>Number of Candidates</th>
<th>Overall Efficiency</th>
<th>Expected Signal</th>
<th>Estimated Background</th>
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<tr>
<td>$eeee$</td>
<td>2</td>
<td>0.158±0.012</td>
<td>1.81±0.18</td>
<td>0.960±0.069</td>
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<tr>
<td>$ee\mu\mu$</td>
<td>1</td>
<td>0.167±0.029</td>
<td>1.88±0.52</td>
<td>0.485±0.053</td>
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<tr>
<td>$\mu\mu\mu$</td>
<td>7</td>
<td>0.175±0.043</td>
<td>1.77±0.66</td>
<td>0.963±0.080</td>
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<tr>
<td>$\mu\mu\mu$</td>
<td>2</td>
<td>0.205±0.033</td>
<td>2.04±0.54</td>
<td>1.203±0.143</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>12</strong></td>
<td>-</td>
<td><strong>7.5±1.36</strong></td>
<td><strong>3.61±0.20</strong></td>
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First evidence of WZ pair production at hadron colliders

3.3 σ statistical significance

In agreement with SM prediction of 3.7+-0.3pb

Lowest cross section measured at hadron colliders!

On the way to WH and ZH Higgs hunting
Search for New Phenomena

One of the most natural searches is to look for New Phenomena at energy frontier machine: SUSY, leptoquarks, Technicolor, new exotic particles, extra dimensions...

Recipe: search for irregularities in effective mass spectra or other kinematic parameters to select events not described by the SM

Example: Search for heavy $W'$ decaying to $e\nu$

First check prediction of SM processes in low mass region

Then look into high mass region

If no excess found, set limits

Reaching masses up to $\sim 1$ TeV - $\frac{1}{2}$ of Tevatron center of mass energy!
First Double Sided Limit on $B_s$ Mixing

In SM B-mixing is explained by box diagrams
→ Constrains $V_{td}$ and $V_{ts}$ elements of CKM matrix
→ New physics $\rightarrow$ new particles in the box
→ $\Delta m_s/\Delta m_d$ is free from many theoretical uncertainties

Use semileptonic data sample $\mu D_s$ (muon acceptance helps)
Decay mode $D_s \rightarrow \Phi \pi$, $\Phi \rightarrow K^+K^-$
Charge of the muon provides Final State Tag

March 2006!

Oscillation amplitude is $2.5\sigma$ above zero at $19\text{ ps}^{-1}$

Result announced 2 months after end of data taking!
Studies of $B_s$ System

- Tevatron is an excellent place to study $B_s$ system
  - Mass difference $\Delta m_s$
  - Lifetime $\Gamma$ and lifetime difference $\Delta \Gamma$
  - CP-violating phase $\delta \phi$

Using $B_s \rightarrow J/\psi \phi$ decay (CP- and CP+ final states) measure $\Gamma$, $\Delta \Gamma$ and $\delta \phi$

With sizable lifetime difference there is sensitivity to CP-violating phase: first measurement of this parameter!

<table>
<thead>
<tr>
<th>Observable</th>
<th>CP conserved</th>
<th>free $\delta \phi$</th>
<th>with $A_{st}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Delta \Gamma$ ($ps^{-1}$)</td>
<td>$0.12^{+0.08}_{-0.10}$</td>
<td>$0.17 \pm 0.09$</td>
<td>$0.15 \pm 0.08$</td>
</tr>
<tr>
<td>$\frac{1}{\Gamma} = \bar{\tau}$ ($ps$)</td>
<td>$1.52 \pm 0.08$</td>
<td>$1.49 \pm 0.08$</td>
<td>$1.50 \pm 0.07$</td>
</tr>
<tr>
<td>$\delta \phi$</td>
<td>$\equiv 1.53$</td>
<td>$\equiv 1.53$</td>
<td>$\equiv 1.53$</td>
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</table>

Dmitri Denisov

October 2006 PAC
Standard Model Higgs Search

Search strategy:

- $M_H < 130$ GeV associated production and $t\bar{t}$ decay $W(Z)H \rightarrow l\nu(l)\ b\ b$
  - Backgrounds: top, $Wbb$, $Zbb$...
- $M_H > 130$ GeV $gg \rightarrow H$ production with decay to $WW$
  - Backgrounds: electroweak $WW$ production...

ZH $\rightarrow llbb$

Getting close to SM expectations
- Have to analyze full available data set
- Add all channels
- Rip benefits of Run IIb upgrade – better b-tagging
Conclusions

- Run IIb upgrade is almost completed
- The DØ detector is working well with high data taking efficiency
  - Currently 1.7fb⁻¹ on tapes with full detector in readout
- Data processing is keeping pace with data collection, MC production is steady

Physics program is flourishing: Top Quark, QCD, Electroweak, B physics, Beyond SM searches, Higgs hunting

There are challenges which we are working on
- Technical: triggering, algorithms at high luminosity
- Manpower: support from Fermilab, DoE/NSF and foreign groups/agencies is critical

- Publishing with healthy rate of ~one paper every two weeks
- 26 PhDs defended over last year
- Large number of 1fb⁻¹ results is already available
- Looking forward for almost doubling data set over next year and for more new exciting results

We entered unexplored energy frontier territory - stay tuned!
Search strategy:

**M_H < 130 GeV** associated production and **bb decay W(Z)H → lν(l) bb**
- Backgrounds: top, Wbb, Zbb...

**M_H > 130 GeV** gg → H production with decay to WW
- Backgrounds: electroweak WW production...
Standard Model Higgs Search

Updated in 2003 in the low Higgs mass region \( W(Z)H \rightarrow l\nu(\nu\nu, ll)bb \) to include:
- using Run II data and full detector simulation
- optimization of analysis

Sensitivity in the mass region above LEP limit starts at \( \sim 2 \text{ fb}^{-1} \)

Meanwhile:
- optimizing analysis techniques
- understanding detectors better
- searching for non-SM Higgs with higher production cross sections or enhanced branching into modes with lower backgrounds