The Dawn of DØ

I apologize that much of this was shown at the 2007 DØ Workshop and a University of DØ talk … but the history is what it is.

P. Grannis – Last DØ Collaboration meeting June 10, 2014
Once upon a time at the dawn of the world, a Tevatron was conceived. A wise director said “We have an unused DØ interaction point. Let us populate it.” A large number of eager physicists roamed the land, inventing schemes for this DØ region. The PAC killed all proposals and selected one person to lead the new experiment. But the newly assembled collaboration could not decide on its name, so chose its address. Inspiration struck – let us use the uranium liquid argon calorimeter tool. No one has ever tried that before! The DØ band carefully prepared a design and showed it to the gods at DOE. The DOE gods said “It is good. Go forth and build this DØ.” Tools were invented and prototypes of tracking detectors, calorimeters, muon chambers were tested in beams. They worked and were pleasing to the gods! A special cave called DAB was prepared to house the growing collaboration and its subdetectors. Bold DØ hammered the pieces together, and intrepidly wrote code to analyze the data using the mantra of SASD. The work was complete. Armed with the new DØ tool, our intrepid heros went forth to slay the CDF dragons.

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Call for proposals for DØ IP in 1981

Lederman: “small, simple and clever”

19 Letters of intent

Partly amalgamated into DØ

- Pope et al.: 2 Pb glass fwd arrays; MWPC tracking
- Marx et al.: LAPDOG; Pb glass, 600 tons
- Green et al.: Muon scint hodoscopes above ground
- Ferbel et al.: move ISR R807 axial field spectrometer

Several more large (~4π) detectors

Special purpose: magnetic monopoles, forward physics, elastic scattering, particle multiplicities

e–p collisions: (2 proposals went to HERA)

Elements of these groups came together after all proposals were rejected.

Jockeying among the component proposals led to the plain vanilla name:
A flavor of an original proposals – LAPDOG

Large Angle Particle Detector Or Gammas

Focussed on W/Z and high $p_T$ hadron physics with extruded lead glass bar EM calorimeter. By 1983, it had merged with a proposal to build a muon spectrometer (in the berm) that morphed into a hadron calorimeter.

- Detector ~ 7m along beam (~1/3 of DØ)
- Central cal. rotated to accommodate MR.
- Note (ATLAS folks) the air toroids in the forward direction.
- Note advanced CAD system!

The “DØ dog” was born as the logo for LAPDOG, courtesy George Booth, my Stony Brook neighbor.
First DØ idea in August 1983 was built around scintillating glass bar calorimetry. Due to segmentation, radiation damage problems, we switched to liquid argon calorimetry with Uranium absorber (ensuring considerable delay while learning the LAr business). The December 1983 conceptual design was presented to the PAC and approved with a standing ovation (but no funds).

Unwieldy design: 5 LAr cryostats, 5 muon toroids, octagonal geometry

71 names on the 1983 proposal (9 still authors) from 12 institutions (all in the US).
Early 1984: HEPAP decided to give priority to SLD, nearly killing DØ. It was a gloomy time but we pressed on toward a buildable design, and planning the R&D and test beam prototypes. DOE agreed to review in fall ‘84.

First annual DØ workshop MSU July 1984. Focus was on fixing the design for the 1984 TDR and DOE Review
1984 Design Report

Tracking layout; central CDC, TRD, Vertex Det. The forward TRD later removed due to space constraints.

Four sectors of CDC in 1988 saw first collisions at DØ IP.
Calorimeter became realistic with engineered support design, projective geometry in $\phi$.

Barrel CC with EM, FH, CH structure

CC modules

2.3 mm Ar gap with resistive coat on signal boards

ECEM pad segmentation
1984 Design Report

Squared up the toroids. Eliminated intermediate toroid. Detector rolls on movable platform.

Ultimately the plug calorimeter was replaced by SAMUS toroid/muon detector

1984 design was close to what we ultimately built.

Muon PDT cells, with vernier pads for z-coordinate.

November 1984 DOE Review (Temple/Lehman) gave a positive recommendation. Some funding awarded for R&D.
First Tevatron collisions were recorded in the (partially complete) CDF detector.

How did DØ overcome the 4-5 year CDF head start?  The answer lies in the performance of the Tevatron. The luminosity steadily grew, making the head start irrelevant!
By 1986, the hall construction was well along. First job was welding the CF and EF toroids in place using steel from the Newport News cyclotron.
Muon PDTs

PDTs used Al extrusions with diamond shaped cathode pads. Factories at FNAL (CF/EF) and Protvino (SAMUS).

Install cathodes in extrusions

Routing PDT cathodes on Thermwood machine

Assemble into PDT panels

Gas/signal connections

Completed SAMUS chamber
Install PDTs in DAB, followed by CF/EF scintillator wall, and finally the SAMUS PDTs.
Learning to do U/LAr calorimetry

Rout signal board into $\eta \phi$ pads

Can’t weld to uranium. Supersonic Indium darts for HV connections

$\text{UO}_2$ is insidious. Oxide flakes cause shorts, Malter current and discharges. Repeated scrubs, washes etc.

Learn to make $100 \text{ M}\Omega/\square$ resistive epoxy coating

Traces to gang $\eta \phi$ signals from a fixed depth segment.

Feedthroughs to reorganize from depth segments to $\eta \phi$ towers
Making calorimeter modules

Probing CCFH module for defects after scrubbing

Last step: Power vacuuming; gate valve to evacuated tank made a huge sucking noise carrying out UO₂ dust

ECEM module

ECIH module
Assembly into cryostats in DAB

Main ring hole

CC finished

Move the three cryostats (gently) into the toroids.

ECS last to be installed
Around 1986 we realized that the energy degradation for jets traversing the cryostat walls would lead to large degradation of MET and jet energy resolution. The solution was the ICD between cryostats (and massless gaps inside them).
Central tracking

Vertex chamber

TRD in its support tube

Central drift chamber sector and full detector

Install and cable the central tracking detectors

Forward drift chamber
Feb. 14, 1992: DØ gathers to help push the detector into the collision hall.

Feb. 15, 1992: at rest in collision hall. 6 inches to spare under the lintel!
May 12, 1992: First $p\bar{p}$ collisions in DØ. Almost 9 years to form the collaboration, design, test, build, install and debug and ~$75M EQ funds (+R&D, operations)
Physics landscape in 1983

A decade of startling discoveries preceded.

1974: $J/\Psi$ discovery (BNL/SPEAR)
1975: SPEAR jets observed
1976: Open charm, tau discoveries (SPEAR)
1977: Upsilon discovery (FNAL E288)
1978: Open beauty meson discovery (CLEO)
1983: W/Z discoveries (UA1 and UA2)
1984: High $p_T$ jets seen at UA2

There was some suspension of disbelief when new indications emerged at SppS:
- UA1: Monojets (jets with large missing $E_T$) – Susy??
- UA1/UA2: anomalous $Z \rightarrow \ell^+ \ell^- \gamma$ – new resonance??
- UA1: top quark observation in $W \rightarrow t b$? … well maybe not !!

**DØ Proposal:** “Although the popular notions (for Beyond the SM) may be wrong, it is useful to note that almost all such models postulate observable new phenomena emerging in the mass region $100 < M < 500$ GeV, or in deviations from orthodoxy in $W$ and $Z$ parameters at the level of radiative corrections. Thus the role of Tevatron experiments will be to search for evidence of these new ingredients.”
What physics did we say we would do?

**Electroweak physics**

- $M_W$ to 0.5% and $\sin^2\theta_W$ to 0.0025. Measurement of $m_W/m_Z$ ($\rho$) would constrain $m_{\text{top}} < 130$ GeV

- $\Gamma_Z$ to 130 MeV, $\Gamma_W$ to 200 MeV

- Given anomalies in $Z \rightarrow l^+ l^- \gamma$, search for $X \rightarrow Z\gamma$ resonance

- Search for $t\bar{t}$ resonances up to 55 GeV (!)

- Leptonic asymmetry in $W$ production/decay

- Diboson production and $W\gamma$ radiation amplitude zero

- $W,Z$ production, and $W+\text{jets}$

- $W/Z$ decays to quarks, with flavor tagging via semileptonic decays
What physics did we say we would do?

**QCD and searches**

Inclusive jets to $p_T = 500$ GeV

3 jet/2 jet XS to get $\alpha_s$

Ratio $\alpha_{EM}/\alpha_s$ from comparison $\gamma$ to $g$ production

Direct photon production

Search for heavy charged and neutral leptons; lepton compositeness

Search for heavy W/Z to 150/230 GeV

SUSY searches (jets + MET)

Heavy quark searches

Technicolor/leptoquarks

Quark gluon plasma

What we did not advertise:

- Top quark discovery
- Single top
- Higgs
- ** B physics and CPV
There were a lot of itches to scratch. We did, and it felt good.

Many very dedicated and talented people made DØ a success.

It has been a wonderful experience!