Installation and Commissioning of the D0 Detector

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1 Introduction

This document provides a brief overview of the installation and commissioning plan for the upgraded D0 detector. It contains a written description of the steps involved in putting the experiment together and preparing for physics; as such, it is complementary to the descriptive engineering sketches and other information that is provided in the talk given by J. Kotcher at the November 4, 1999 Lehman Review at Fermilab. The transparencies for this talk have been posted on the following web site:

http://www-d0.fnal.gov/inst_comm_review_dec99.html

This site provides the general documentation for the committee serving on the Director's Review of D0 Installation and Commissioning on December 7 and 8 at Fermilab, and contains additional support material – beyond installation and commissioning -- on the D0 Upgrade.

This document consists of four sections: a brief introduction, followed by two sections describing detector installation and commissioning, respectively. In order to enhance the clarity of the discussions for the reviewers, the final section contains a glossary of commonly-used acronyms in D0.

2 Detector Installation

We refer to the engineering sketches in the talk mentioned above, and go through them sequentially in some detail. We label them for reference by their title at the top of each slide.

2.1 D0 Detector Status (Jan, 1998)

This slide shows the status of the detector approximately two years after the completion of Run 1. The detector sits on a movable platform in the "pit" of the D0 Assembly Hall, which is bordered by the clean room on the east side, and the Shield Wall, consisting of rows of stacked concrete blocks, on the west side. The Collision Hall is just west of the shield wall. There is an elevated catwalk above the south sidewalk only, which is shown cross-hatched in the bottom right-hand region of the drawing.

During collider operation, the north and south end toroids, or EF irons, sit on the detector platform flush against the calorimeters (see slide labeled "Muon C-Layer and Shield Assembly/Installation" for inner detector configuration during running). In the configuration shown on the current slide, both end EF irons have been removed from the detector platform to the north and south sidewalks, in order to allow for both the removal of the Run 1 end A- and B-layer proportional drift tubes (PDTs), and the installation and servicing of the new planes of mini-drift-tubes (MDTs) and forward pixel scintillator detectors[1]. The irons will remain on the sidewalk until the detector is almost ready to roll in to the Collision Hall (see later discussion).

The Central Muon Iron (labeled CFE, for "East", and CFW) consists of two separable "C-" or clam-shell-shaped toroidal magnets, and is shown opened in this drawing. This allows access to the inner planes of PDTs and inner scintillation counters (called A-ϕ counters), as well as the calorimeter preamplifier boxes, which live atop the cryostats. At this time, the removal of the inner A-layer PDTs was in progress. The outline of the north end calorimeter (ECN) is shown in the most extended position that can be accommodated without uncabling the device. The south end calorimeter (ECS) is shown removed from the platform to the south sidewalk. The gap this creates between ECS and the central calorimeter (CC) is needed to install the inner central tracking detectors (Central Fiber Tracker (CFT), Silicon Detector (SMT), and Central Preshower (CPS)) and the solenoid. The inner tracking system from Run 1 has been uncabled and removed by this time.

During this period, the CPS was being installed on the solenoid in the clean room, as depicted here. The Movable Counting House (MCH) is attached to, and moves with, the detector via the cable umbilical (or cable bridge), and is shown in the northeast corner of the drawing. It houses much of the front-end electronics, trigger systems, and the data-acquisition (DAQ) apparatus. The primary staging and working area in the D0 Hall (called the Hi-Bay) is a large open space to the east of the clean room and MCH. It is here that the C-layer trusses and end muon detectors will be staged, assembled, and dressed.

2.2 Solenoid/CPS Installed (Jun 26, 1998)

The CPS was installed on the outer circumference of the solenoid, along with one radiation length of lead that is used as absorber. The coupled assembly was moved out as a unit to the Assembly Hall, and installed in the bore of the central calorimeter on the date given above. The magnet has since been serviced with liquid helium and powered up, with the field having been mapped in detail this past summer. The CPS awaits the arrival of the Visible Light Photon Counters (VLPCs), and attendant front-end and trigger

[1] The muon detector planes are labeled A, B, and C, in order of increasing distance from the interaction point, with the A (B) layers mounted on the inner (outer) face of the end toroids, and the C-layer mounted on the outlying end trusses.

readout electronics, when it will be fully commissioned. The configuration of the remaining portion of the detector is similar to those in the previous diagram.

2.3 Forward Muon Detector Installation (Apr, 2000 – Aug, 2000)

The full view in this drawing is shifted east, with the Shield Wall/Collision Hall area no longer visible. Here, there are two installation efforts depicted that go on for a considerable period of time. First, the muon A- and B-layer pixel and MDT octants are being installed on the end irons. The north is shown with both the A- (toward overall detector center) and B- (away from detector center, on opposite side of iron) layer pixels and MDT planes installed. The south shows the installation in progress, with the A-layers in the process of being put in place. In the Hi-Bay, the forward muon trusses and shielding are being assembled and dressed, with services being installed and commissioned during this period. In the latter 3 months of this time period (early June through mid-August), the C-layer detectors are being installed and surveyed onto the trusses in the Hi-Bay.

Commissioning of all of these detectors occurs as they are installed, using jumper cables, as they are needed, to access the electronics in the MCH. For both the A- and B-layer detectors, which are on the sidewalk adjacent to the MCH, and the C-layer planes, assembled in various portions of the Hi-Bay, the capability will also exist for local PC-driven detector commissioning.

2.4 Install Silicon Tracker (Sep, 2000)

In this picture, the silicon tracker is shown being installed into the Fiber Tracker, which will have been installed into the bore of the solenoid in May. (A specific slide depicting the FT installation has been omitted for brevity.) At the present time, we expect the beryllium beam pipe will be installed in the silicon at SiDet, the silicon fabrication laboratory at Fermilab, with the coupled assembly brought over to the D0 Hall and installed in the detector as a unit. Our schedule allows for 5 weeks of hookup and checkout of the central silicon – after installation into the bore – before the south end calorimeter is put back on the platform and cabled up. This is expected to provide sufficient time to test for coherent noise, pickup, reliability of service connections, and so on – any problems that might require the silicon to be removed for additional servicing or shielding. It will require the uncabling and removal of ECS from the platform to get the central silicon out again – a process which we do not want to perform more than once.

Once the ECS is on the platform, the platform supporting the detector moves west to pick up both toroids, which have now been loaded with both their A- and B-layer MDT and pixel planes. The fully dressed platform then returns to the east position to allow the C-layer trusses, which are now loaded with detectors, to be dropped down via overhead crane and assembled on the north and south sidewalks. The detector must be in its east position during this series of operations to provide the space needed on the sidewalks

2.5 End Toroids on Platform (Nov, 2000)

Here, the detector is in its east-most position, in an open configuration: two of the three calorimeters are cabled up (ECS is in the process of being re-cabled during this month), with both end calorimeters in their extended positions to allow access to both the inner central tracking detectors and those mounted on the faces of the end calorimeters (Inter-Cryostat Detector (ICD), Forward Preshower Detector (FPS), and the Luminosity Monitor (LUM)). The end irons are pulled out to allow the calorimeter room for travel, and the CF clamshells are open to allow access. At this point, the detectors mounted on the south end calorimeter are in the process of being hooked up, and all detectors are being commissioned. The Shield Wall remains in place, and the sidewalks are empty.

2.6 Muon C-Layer and Shield Assembly/Installation (Nov, 2000 – Jan, 2001)

The north and south trusses, which are now loaded with installed and surveyed C-layer detector planes, are brought down to the sidewalks in two pieces each, and reassembled with their attendant shielding in preparation for being rolled into the Collision Hall. The trusses are each rolled in as a whole assembly, surveyed in place inside the Collision Hall, and are later met by the detector, which rolls into the Collision Hall independently. The shield wall is removed to allow for the truss and detector installation. The north C truss and shield are shown rolling into the Collision Hall; the south truss/shield is still in its position on the sidewalk. The detector is buttoned up, in preparation for rolling it in to meet the trusses after they are surveyed into place. This period offers the longest uninterrupted opportunity for commissioning the full detector.

2.7 D0 Detector Installed and Hooked Up (Feb 2, 2001)

The detector is shown fully installed and hooked up in the Collision Hall, with the shield wall having been re-assembled. The Movable Counting House has moved with the detector, with the cable bridge in its extended position. The detector is ready for beam on this date.

3 Commissioning

The discussion contained here is facilitated by looking at the slide labeled "D0 Timeline". We define the commissioning of the experiment to consist of three phases, as shown, with all of these phases exploiting both cosmic ray muons and electronic or optical pulsers to verify connections and detector/readout integrity.

3.1 Phase I (present – end April, 2000)

One of the major goals of Phase I of the commissioning is to develop the central muon system as a prototype from which the readout of the remaining sub-detectors will be bootstrapped. Examples of commissioning activities that are now, or soon will be, in the process of being integrated during this period include the following: (a) single- and multi-crate readout of central muon PDTs, (b) online monitoring of data (using a set of programs and frameworks that we call EXAMINE), (c) online control and monitoring of the front-end crates and other hardware, (d) integration of final prototype Level 1 (hardware) muon trigger boards, (e) utilization of much of the final DAQ hardware, (f) first exercising of filtering in the Level 3 trigger, and (g) exercising the full data acquisition path to send data to the computer farm for running the current version of the reconstruction (RECO). The development of the functionality common to the remaining systems will be a direct extension of the primary steps made with the central muon readout. We are already well on our way in many of these processes.

In parallel during this period, the final front-end electronics for the tracker is being installed and commissioned in the MCH in the Assembly Building. This includes the final electronics for all 12 crates for the experiment (sequencers, VRBs, controllers, etc.). The online and DAQ system is being prepared to accommodate this installation, as it was our goal to exercise the standard data pathways and monitoring facilities to do this.

At the end of this period (end of April), the installation and commissioning of the A- and B-layer muon detectors on the end toroids will be taking place. The online and DAQ systems will be configured to allow this activity to occur in parallel.

Shifts will be organized during this period, as will the formal training of "DAQ experts": physicists and others well-versed in keeping the DAQ, online, and trigger systems up and running for people commissioning the hardware, and other users. These experts will be trained to diagnose problems in most aspects of the readout chain, fix whatever problems are accessible to them, and knowing which experts to call when problems arise that are outside their areas of expertise. In short, they will be responsible for keeping the experiment running in a steady-state mode.

Also in parallel with this are the two primary activities related to commissioning that are taking place in remote laboratories (*i.e.*, outside D0 Assembly Hall): a test of 10% of the silicon detector at SiDet, and a cosmic ray test at Lab 3, where VLPC readout is being exercised in conjunction with the CFT front-end. Much of the functionality being developed at these facilities will be carried over directly to the Assembly Hall. In fact, these efforts have helped to drive significant improvements and developments on a variety of fronts, including data formatting and unpacking, calibration issues, geometry databases, etc.

3.2 Phase II (early May, 2000 – mid September, 2000)

The second phase of commissioning is driven by the arrival of the readout for the inner scintillation-based tracking detectors: Central Fiber Tracker, and the Central and Forward Preshowers. These detectors consist of a total of 100k channels of readout, and use VLPCs, together with the requisite downstream analog and digital front-end boards, for triggering and readout. The VLPCs and CFT electronics will be in the process of being installed during the early portion of this phase, enabling readout of only portions of the detectors immediately after hookup of the clear waveguides. The full complement of electronics is scheduled to be installed during the final six weeks of this period, which will provide us with a reasonably extended opportunity to evaluate the performance of the full VLPC/CFT readout system prior to Phase III (see below).

In parallel during this period, all of the forward muon detectors are being installed and commissioned on the sidewalks and Hi-Bay. Production versions of the Level 1 muon trigger are being installed and commissioned. The final elements of the Level 2 muon, calorimeter, and CFT/PS (preshower) trigger are being installed and commissioned as well. This "pre-commissioning" will prepare us for sub-detector triggering during the full Cosmic Ray Run in Phase III.

3.3 Phase III (mid September, 2000 – end January, 2001)

This phase starts with the capability of reading out a full complement of calorimeter electronics (the central calorimeter will be first). Concurrently, the central silicon detector arrives and is installed, hooked up, and checked out. The additional calorimeters are added to the commissioning as the electronics becomes available, with ECS included only after the silicon is checked out, allowing the south calorimeter to be put back on the platform and recabled.

This period marks the time when all detectors are read out in concert, with trigger elements being brought up as well. A full Cosmic Ray Run will be in place. Tracks in all sub-detectors will be linked, and various trigger capabilities exercised. Full monitoring of multi-crate readout for all sub-detectors will be exercised. Shifts will be in full swing in preparation for running in collider mode, with captains identified and experts on call.

3.4 Commissioning Goals

Some collaboration commissioning goals, with descriptions, are listed below.

Feb 2, 2000: -- silicon front-end installed and commissioned (in MCH)

Mar 1, 2000: -- integrated DAQ/online system running in user mode

Mar 15, 2000:	-- install beam pipe scintillator to constrain tracks to beam line -- dual/multi-crate central muon PDT readout -- integrate prototype Level 1 (hardware) muon trigger -- begin muon filtering in Level 3 -- ship data through online/DAQ/farm chain, run reconstruction -- first exercise of online event display -- shifts being formed, DAQ expert training begun
Apr 15, 2000	-- begin multi-crate readout of full central muon system -- integrate Level 2 muon trigger at DAB test stand
Jul 15, 2000	-- half of CFT, CPS hooked up, checked out
Aug 15, 2000	-- forward muon A/B-layer MDTs/pixels installed, commissioned
Sep 1, 2000	-- initial triggering on Level 1 CFT, CPS, Central Muon (using final production boards) -- begin linking tracks in Central Muon, CFT, CPS (RECO) -- integrate event display for 3 sub-detectors -- integrate Level 2 trigger for Muon, CFT, PS, (CAL)
Sep 20, 2000	-- four quadrants available for CC readout -- begin commissioning Level 2 CAL trigger *in-situ* -- continue commissioning Central Muon, CFT, CPS, FPS -- integrate Central Calorimeter into trigger/data stream
Oct 1, 2000	-- forward muon C-layer MDTs and pixels installed/commissioned in Hi-Bay
Nov 1, 2000	-- Central Calorimeter added to trigger, reconstruction chain -- add SMT to readout chain -- full online event displays -- exercise full triggering with all major systems
Dec 15, 2000	-- full detector in steady state Cosmic Ray Commissioning

4 Glossary

Despite our attempts to avoid them, acronyms are difficult to eliminate completely during discussions of detector elements and construction. In an effort to reduce some of the confusion, a glossary is appended below that describes some of the most often used acronyms in D0.

DETECTOR ELEMENTS		
Acronym	Source Words	Location in Detector/Description
ICD	Inter-Cryostat Detector	Face of end calorimeters
LUM	Luminosity Monitor	Face of end calorimeters
FPS	Forward Preshower Detector	Face of end calorimeters
CPS	Central Preshower Detector	Inner bore, around shell of solenoid
PS	Preshower Detectors	Collective term for FPS, CPS
CFT	(Central) Scintillating Fiber Tracker	Inner bore of detector
SMT	Silicon Microstrip Tracker	Inner bore of detector
H-disks	Silicon disks	Outer end (in |z|) of silicon barrel
VLPCs	Visible Light Photon Counters	CFT/PS readout – below platform
CC	Central Calorimeter	Central cryostat
ECN, ECS	End Calorimeter N, S	Forward/backward cryostats
MDTs	Mini-drift tubes	Forward muon tracking detectors
Pixels	Scintillator pixel detectors	Forward muon trigger detectors
PDTs	Proportional drift tubes	Central muon tracking detectors
A-ϕ	Scintillator detectors	Central muon trigger detectors
EFN, S	End iron N, S	Muon end toroids (or “end irons”)
EMC	End Muon C-layer detectors	Mounted on end trusses
CFE,W	Central Muon East, West	Central muon toroids (or irons)
SVX	Silicon Readout Chip	Used for tracker readout, digitization
COMMON LOCATIONS OF LABORATORIES, STAGING AREAS, ETC.		
Acronym	Description	Location
MCH	Movable Counting House	Electronics counting house
DAB	D0 Assembly Building (or Hall)	Building housing assembly pit, Hi-Bay area, Collision Hall, and offices
SiDet	SiDet Facility	Silicon fabrication facility
Lab 3	Laboratory #3 in Fermilab Village	CFT fabrication, cosmic ray test
Lab F	Laboratory F in Fermilab Village	Forward muon production facility