The CDF Upgrade
(Muon Detection)

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CDF Upgrade DOE Review
2 December 1997

Outline

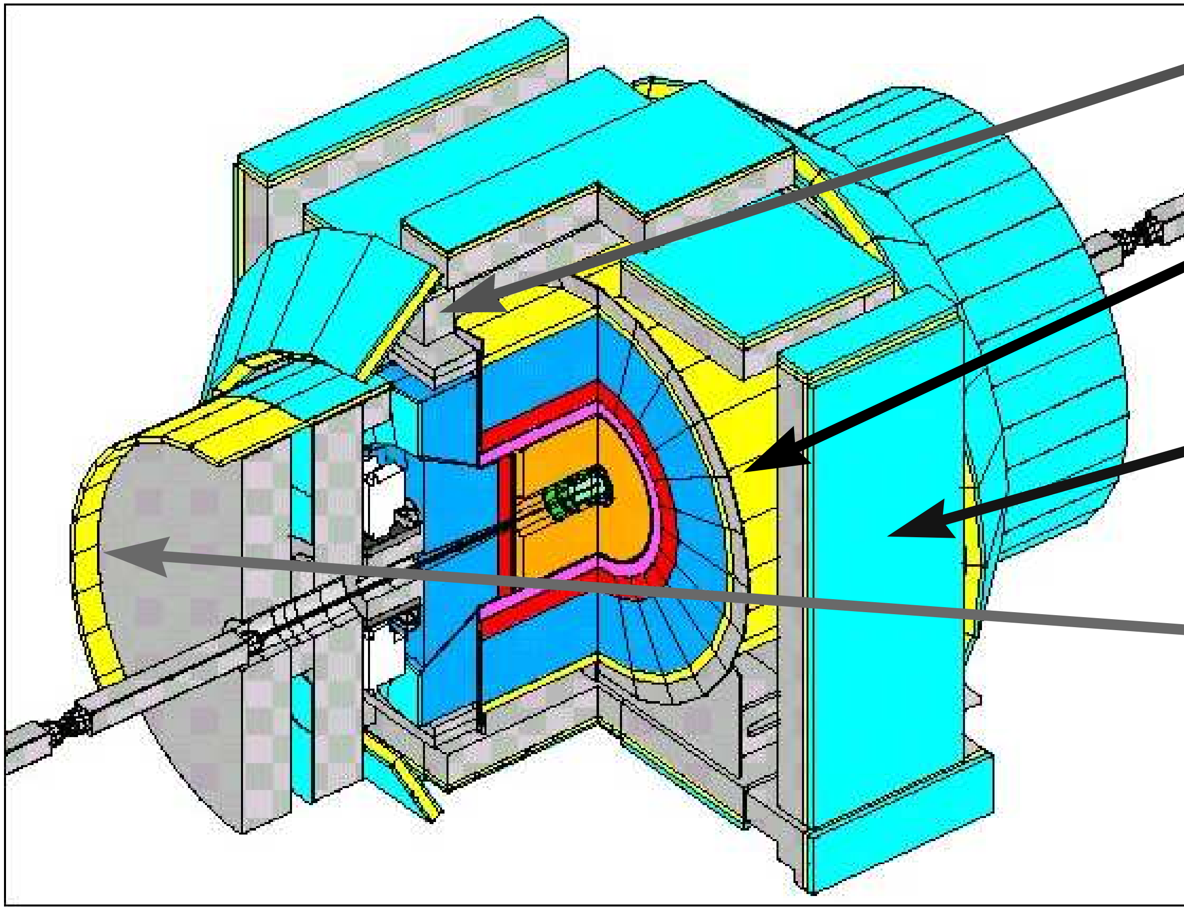
- Overview of Subproject.
  - Work Breakdown Structure
- Technical Progress and Status
  - Progress since last review.
  - Technical issues, concerns.
- Resources
  - Cost tracking - use of contingency
  - Labor
- Schedule
  - Milestones
  - Critical Path
  - Activities planned for FY 98.
- Summary

Muon Upgrade Overview

- Goal: To preserve CDF's ability to detect and trigger on muons at high luminosity and short bunch crossing times, while improving the solid angle coverage

- This project involves upgrading or constructing several different detectors, at different locations in CDF.
  - CMU:Central MUon
    (the original streamer chambers, behind 5λ of steel)
  - CMP: Central Muon uPgrade
    (drift chambers and counters behind 8λ of steel)
  - CMX: Central Muon eXtension
    ($0.6 < \eta < 1.0$ drift chambers and counters)
  - IMU: Intermediate MUon detectors ($1.0 < \eta < 1.5$ system)

Upgrade Components



- **C**entral **M**uon eXtension
- **C**entral **MU**on chambers
- **C**entral **M**uon u**P**grade
- **I**ntermediate **MU**on

Project Overview, WBS and Institutional Responsibilities

1.3 Muon Upgrade

1.3.1 CMU Modifications

1.3.1.2 ASD's, Preamps and End Electronics - Illinois

1.3.2 CMP Completion

1.3.2.1 Scintillators - Pisa, Trieste/Udine, Dubna

1.3.2.2 Chambers - Illinois

- CMU gain will drop to survive high luminosity. New electronics are required to do this
- 2/3 of the trigger rate comes from the 1/3 of the central muons without the CMP chambers and counters
- We will fill the gaps in the existing shielding with steel, and install chambers and counters behind this steel.
- Chambers are at FNAL now

WBS (Continued)

1.3 Muon Upgrade

1.3.3 CMX Completion

1.3.3.1 Scintillators - Pisa, Frascati

1.3.3.2 Chambers - Harvard

- The CMX covers $|\eta|$=0.6-1.0. Roughly 2/3 was installed for Run I.
- The CMX chambers for the lower 90 degrees (“miniskirt”) and upper 30 degrees are complete, and are at Harvard.
- The corresponding counters are also complete, and are at FNAL.
- The chambers and counters have to be attached, placed on the support stand, cabled up, and rolled into the hall.

WBS (Cont.)

1.3 Muon Upgrade

1.3.4 IMU Construction

1.3.4.1 Barrel Detector

1.3.4.1.1 Chambers - Wisconsin

1.3.4.1.2 Counters - Florida, Pisa, Trieste/Udine, Dubna

1.3.4.2 Endwall Detector

1.3.4.3 Toroid Detector

1.3.4.4 Electronics and Slow Controls

- The barrel detector is a cylinder of chambers and counters mounted on the outside of the toroids. It's the principle muon detector over η=1.0-1.5
- Chambers are smaller version of the CMP - central outer muon - chambers.
- Counters are smaller versions of the corresponding counters

WBS (Cont.)

1.3 Muon Upgrade

1.3.4 IMU Construction

1.3.4.1 Barrel Detector

1.3.4.1.1 Chambers

1.3.4.1.2 Counters

1.3.4.2 Endwall Detector - Michigan State, Trieste/Udine, Dubna

1.3.4.3 Toroid Detector- Wisconsin, Trieste/Udine, Dubna

1.3.4.4 Electronics and Slow Controls

- The Endwall and Toroid detectors are scintillator hodoscopes used to improve purity, especially while triggering.
- Endwall counters cover η=1.0-1.3.
- Toroid counters cover η=1.3-1.5 and η=1.5-2.0 and are recycled from the existing Forward Muon counters.

WBS (Continued)

1.3 Muon Upgrade

1.3.4 IMU Construction

1.3.4.1 Barrel Detector

1.3.4.1.1 Chambers

1.3.4.1.2 Counters

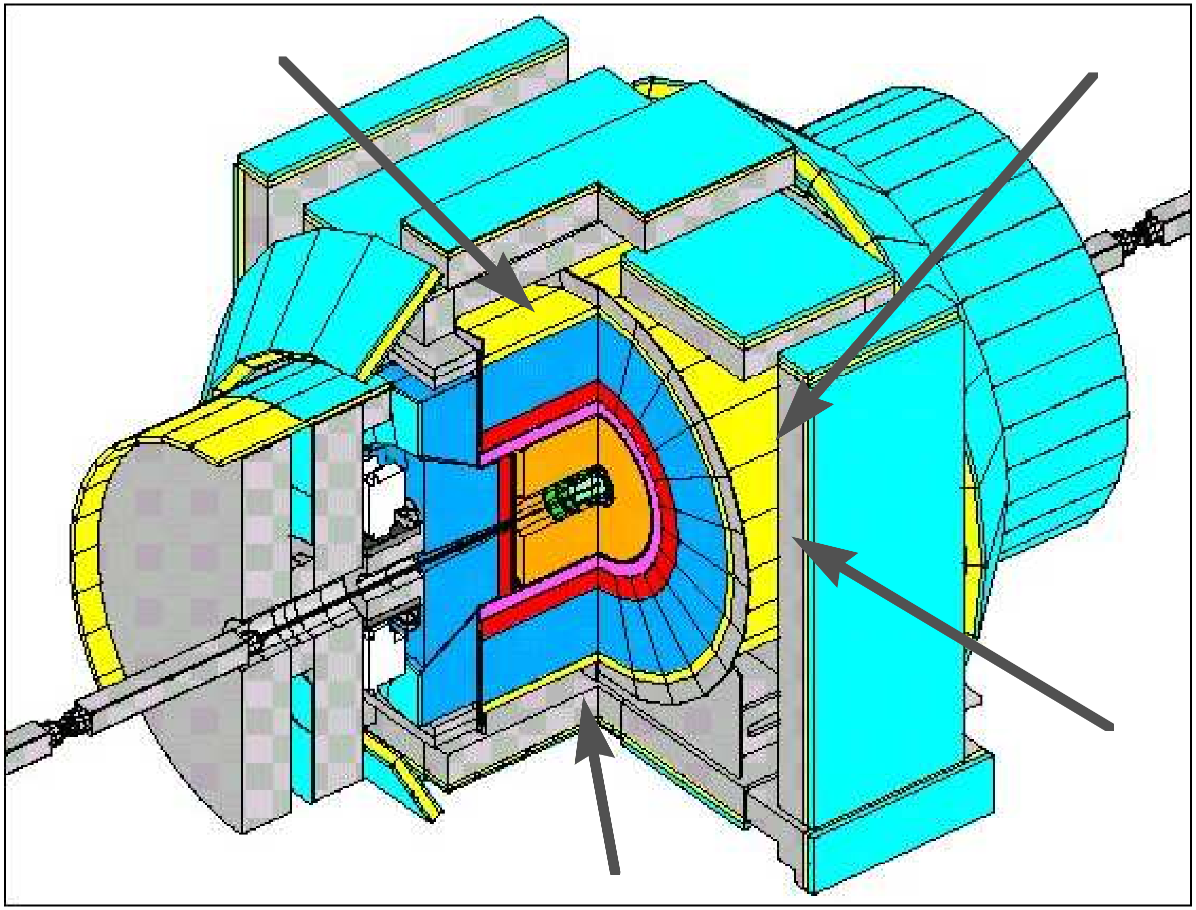
1.3.4.2 Endwall Detector

1.3.4.3 Toroid Detector

1.3.4.4 Electronics and Slow Controls - Argonne

- Electronics and Slow Controls covers adapter cards to the TDC's (TDCs are WBS 1.4.2) and the High Voltage control system.
- The TDC's and everything downstream of them is part of the Front End/Trigger upgrade. (WBS 1.4)

CMU Progress and Status

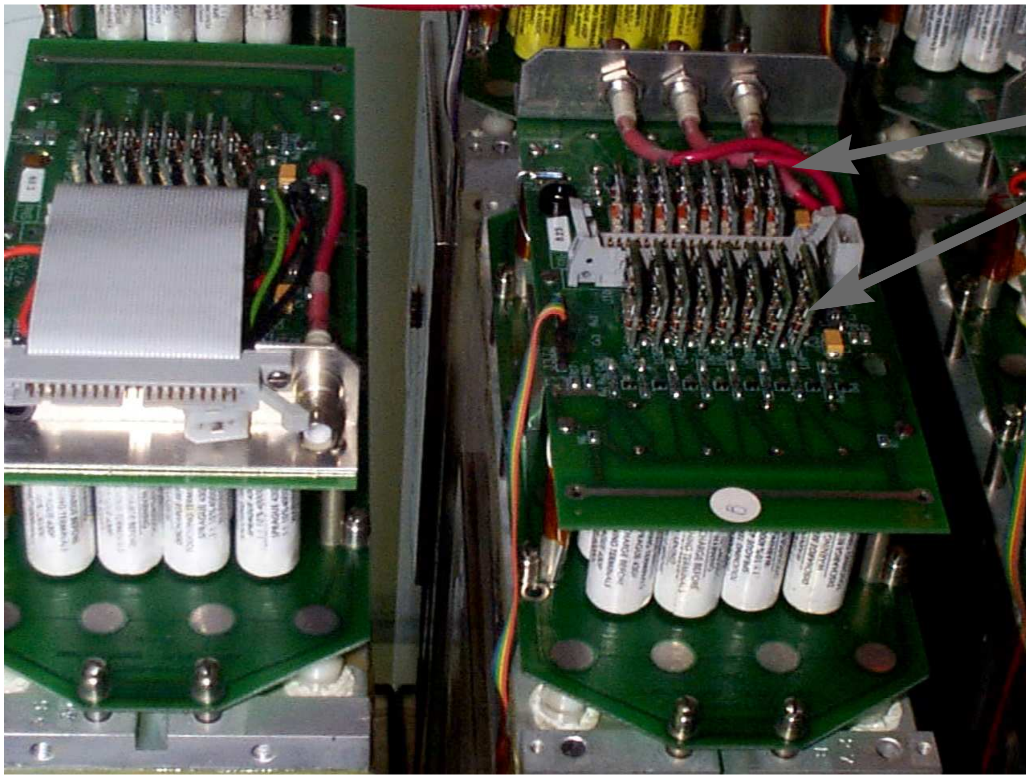


- **Tasks**
  - ➤Modify end electronics (add preamps)
  - ➤New ASD's
- Responsible Institution: Illinois

Technical Progress: CMU

- New pre-amps and motherboards
  - ➤All chambers have been removed, and new-preamps & motherboards have been installed and tested
  - ➤All but 4 chambers have been replaced
    - We're just waiting for a good time to do this
  - ➤We're well ahead of schedule
    - 20% of completion is a Level 3 milestone
      - **Milestone was 31 October 97**
      - **Actual date was 15 August 1997**
    - 100% completion is also a milestone
      - **Milestone is 31 July 1998**
      - **We will be finished any day now**

CMU Preamp Motherboards



- New Preamps
  - Designed at Harvard
  - Mount on clones of original motherboards (built by Illinois)

Installation of CMU

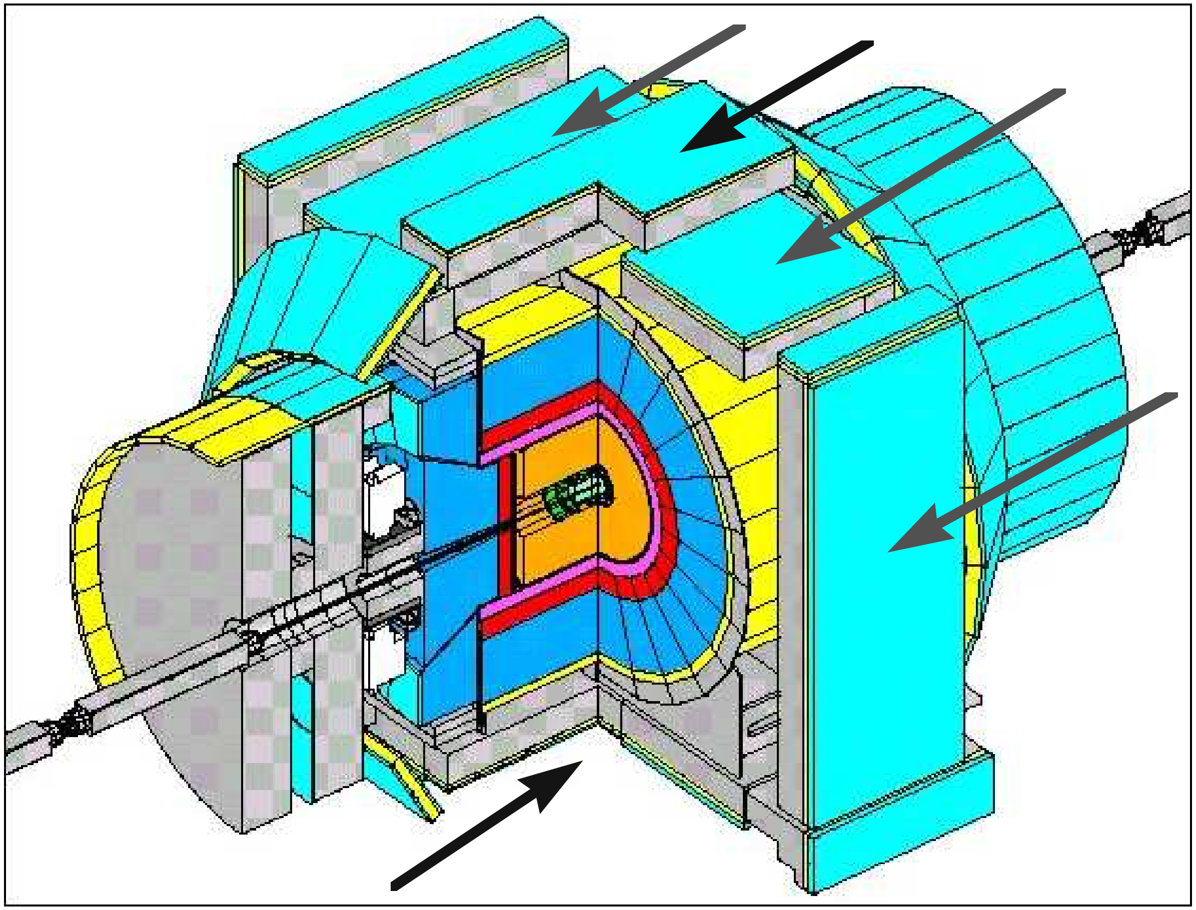
- 144 chamber stacks removed, refurbished & replaced.

Installation of CMU

Technical Progress: CMU

- New Amplifier-Shaper-Discriminators (ASD-2)
  - UIUC has built prototype cards
    - It’s being tested in a full system test
      - **CMU chamber with new end electronics & preamps**
      - **ASD-2 card**
      - **Michigan TDC**
  - Production is scheduled to begin later this year

CMP Status and Progress



- Tasks: Complete shielding (blue arrows), and add chambers and add counters to present gap region
- Responsible: Illinois (chambers), Italy (Counters)

Technical Progress: CMP

- Steel Shielding Status
  - ➢Safety review milestone was 30 June 1997
    - Last signature was obtained 30 July 1997
  - ➢Steel has been purchased for the top and bottom “notches”
  - ➢The top notch steel is being machined now
  - ➢Installation (see I&I talk) is on schedule

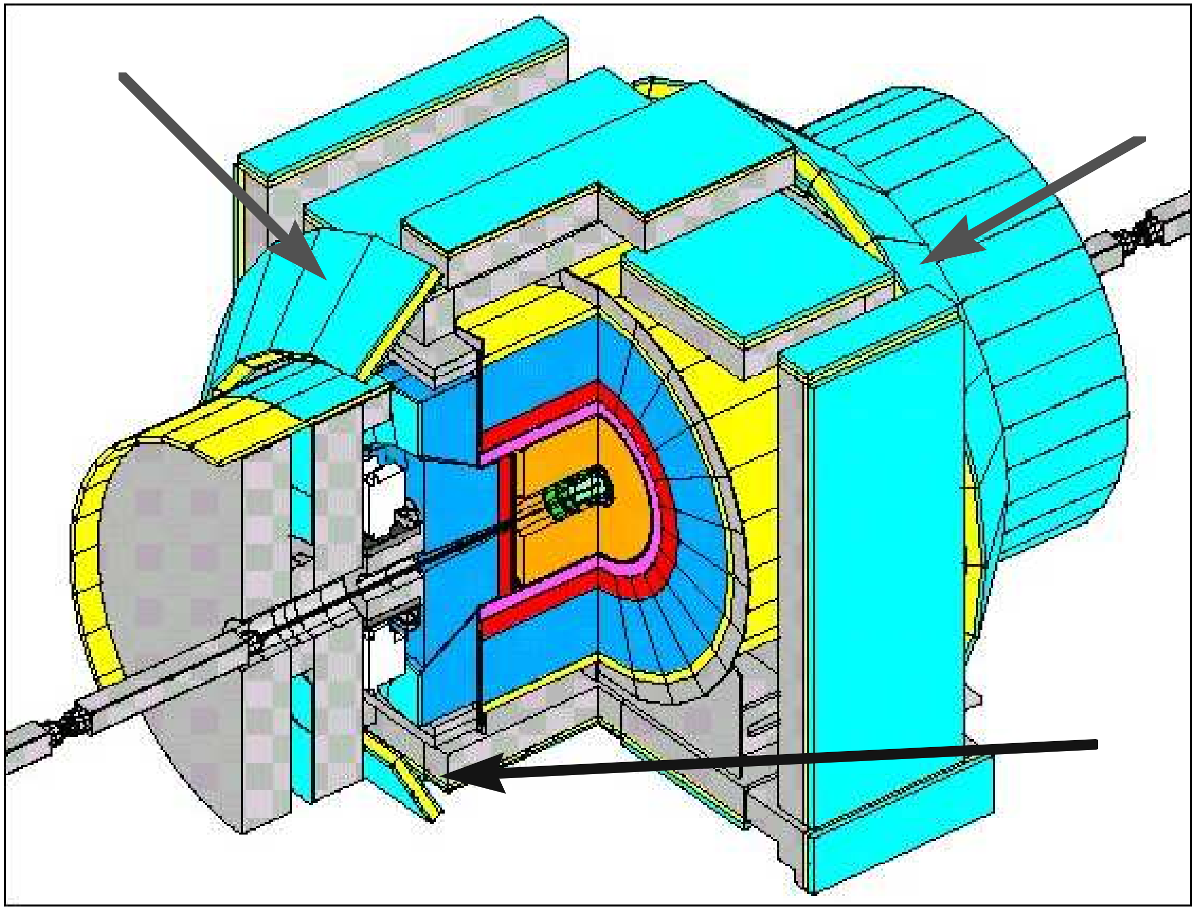
Effect on Magnetic Field

- Comment from the February Review: "*Nonetheless, it would be useful to do a full magnetic analysis which includes all the CDF magnetic materials to see if, in fact, the field has remained undisturbed*"
- Effect on central magnetic field has been calculated
  - ➤CDF Spec on maximum tolerable change is 500 ppm (this is conservative)
  - ➤Largest change is 65 ppm

Technical Progress: CMP

- Chamber Status
  - All chambers are assembled
  - All preamplifier motherboards have arrived
    - These boards have a lot of copper on them
    - The vendor looked at the artwork, and decided it was reversed
    - It wasn't
    - The vendor had to redo the order
    - Cost less than expected
  - A few motherboards have been installed
    - They test out fine

CMX Progress and Status



- Tasks: install chambers and counters in Run 1 gap region. The lower 90º is called the "miniskirt" (blue arrow)
- Responsible:
  - Harvard (chambers)
  - Italy (counters)

Technical Progress: CMX

- CMX parts have all been built
  - Some changes to the counters on the lower 90 degrees may be necessary to overcome a recently discovered mechanical interference (Est. cost $25,000)
- Installation occurs late in the schedule
- Assembly will begin July, 1998
- Can be ready for operation on 14 June 1999

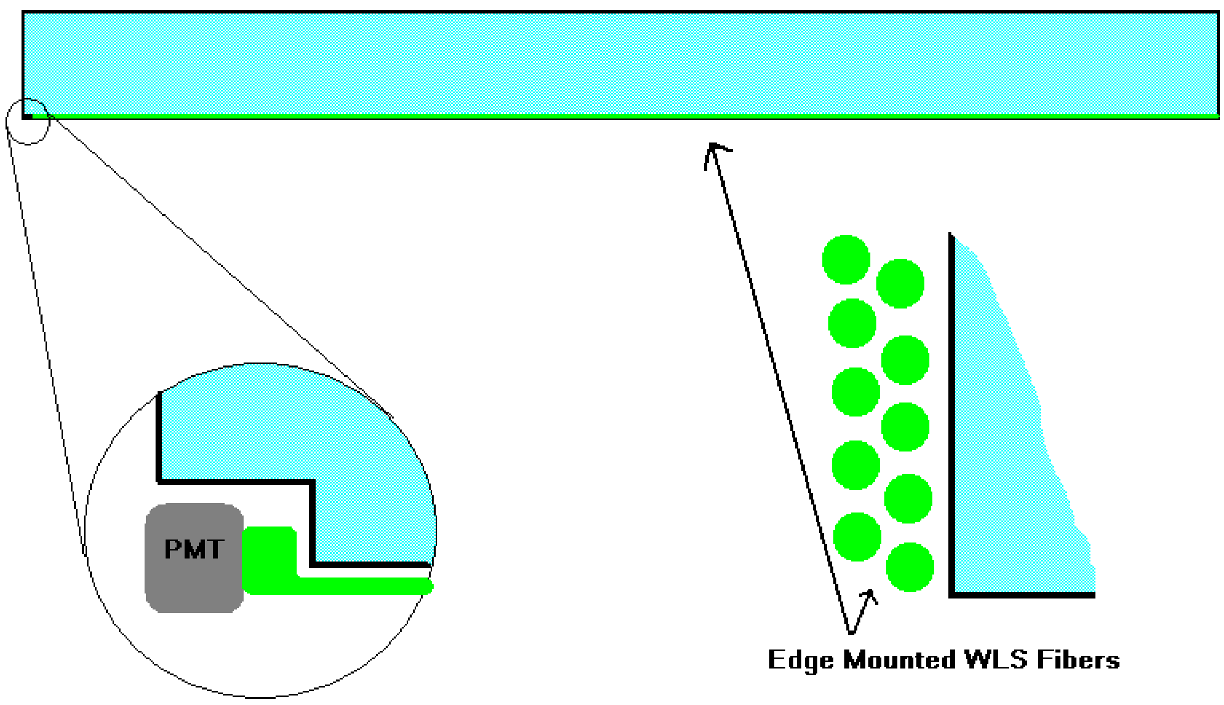
Technical Progress: Scintillators

- All new counters use the same basic design
  - ➢Edge attached WaveLength Shifter (WLS) fiber
  - ➢Hamamatsu R5600 phototube
  - ➢Light output more than adequate
- Scintillator Production has begun in Russia
  - ➢13 test counters have been built
  - ➢They work as expected
- PMT testing beginning in Trieste
  - ➢First production tubes arrive this month

Additional Plane of Scintillators

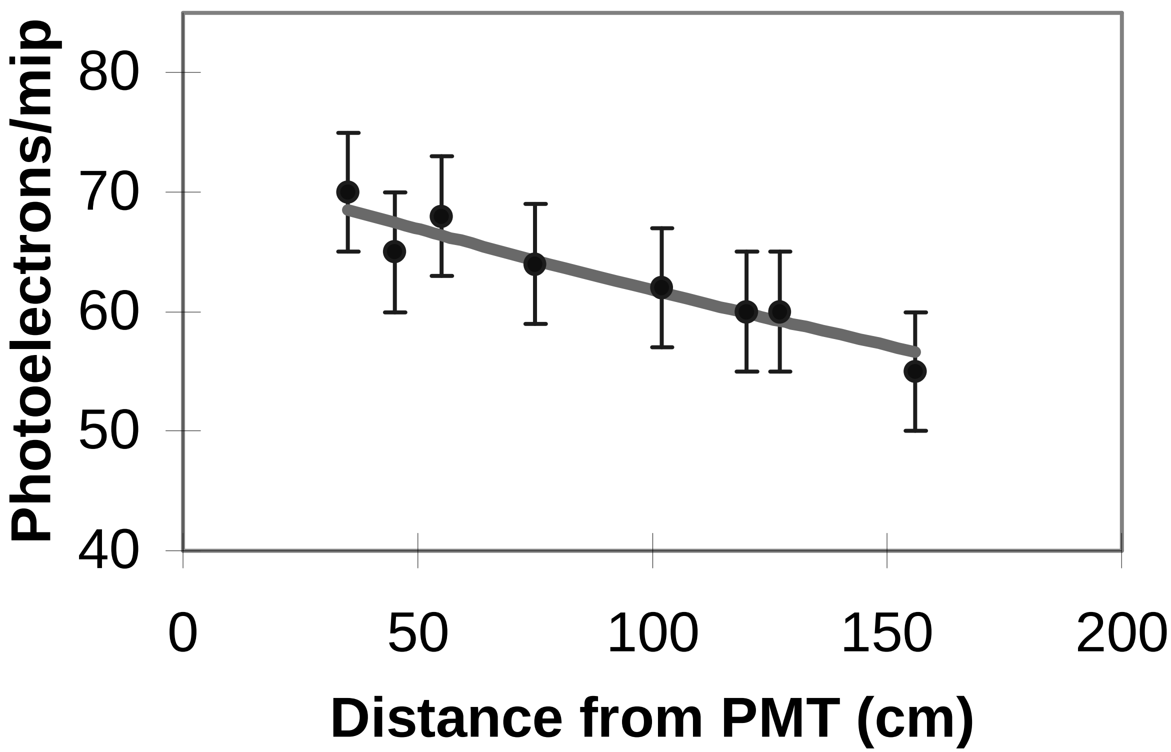
- The Committee recommended in February that CDF consider an additional plane of scintillator behind the outer toroid. We have evaluated several factors:
  - Cost: $500,000
    - $300,000 for counters
    - $200,000 for additional shielding
  - Schedule
    - Moves completion date from June 1999 to October 1999
    - Production cannot start until FY99
  - Physics
    - Improves off-line muon purity
    - Estimated rate too high to trigger inclusively
- CDF will defer a decision until FY99

Muon Counter Design



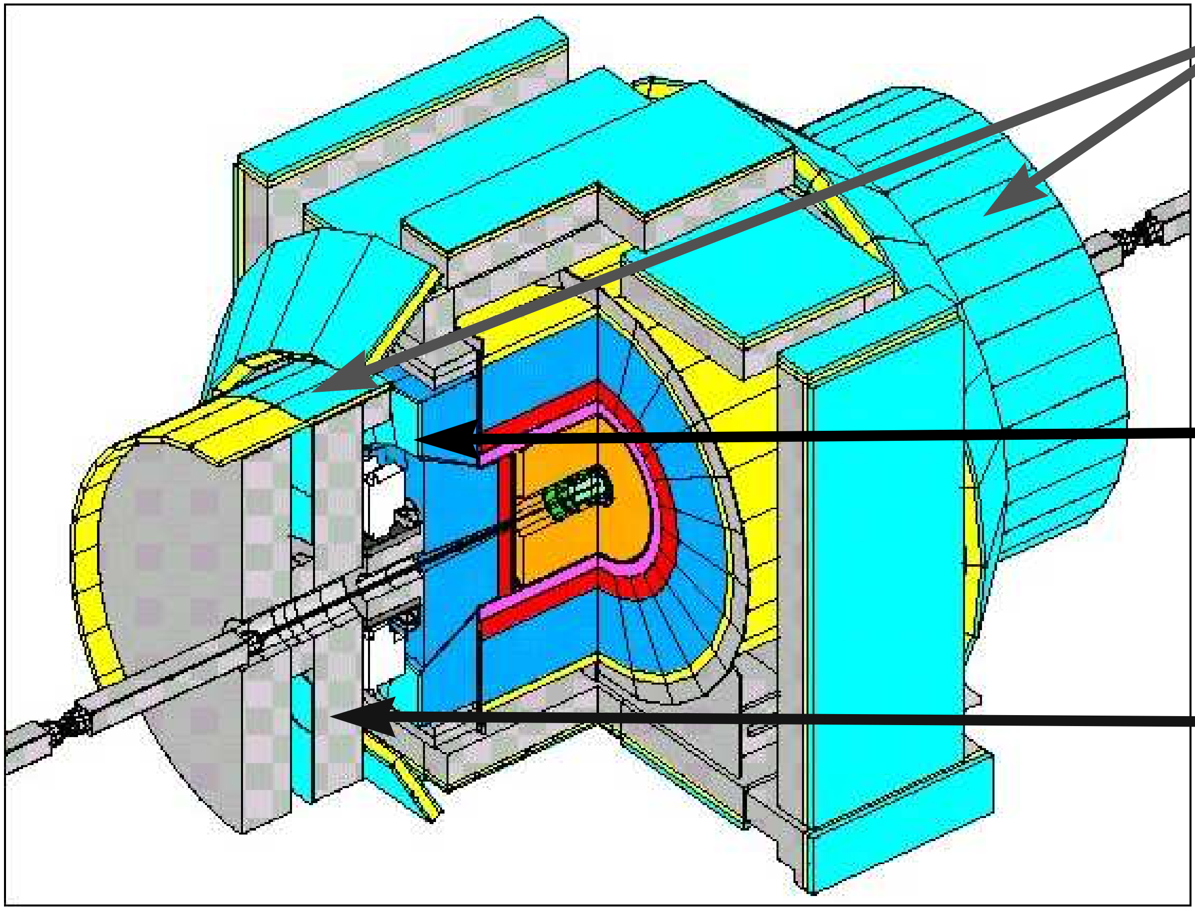
Test Counter Performance

Light Output vs. Position



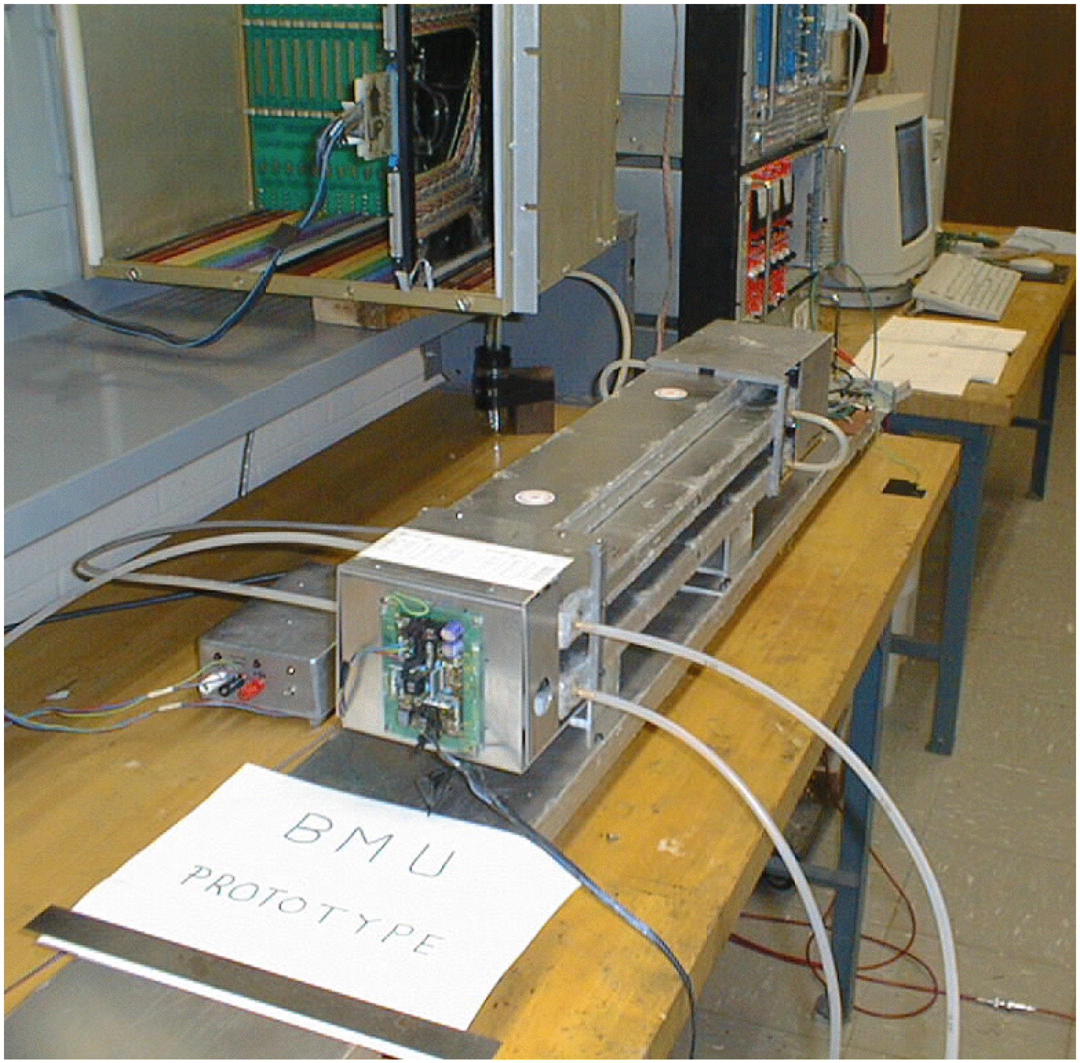
- Specification is 12 pe's/mip
- Test counters built at
  - Pisa
  - Trieste/Udine
  - MSU
- All counters exceed spec
- Fit to $Ae^{-x/\lambda}$ gives λ=632 cm.

Intermediate Muons



- Barrel Region
  - ➤η=1.0-1.5
  - ➤Chambers
  - ➤Counters
- Endwall Region
  - ➤η =1.0-1.3
  - ➤Counters
- Toroid Region
  - ➤η=1.3-1.5,1.5-2.0
  - ➤Counters

IMU prototype Chambers

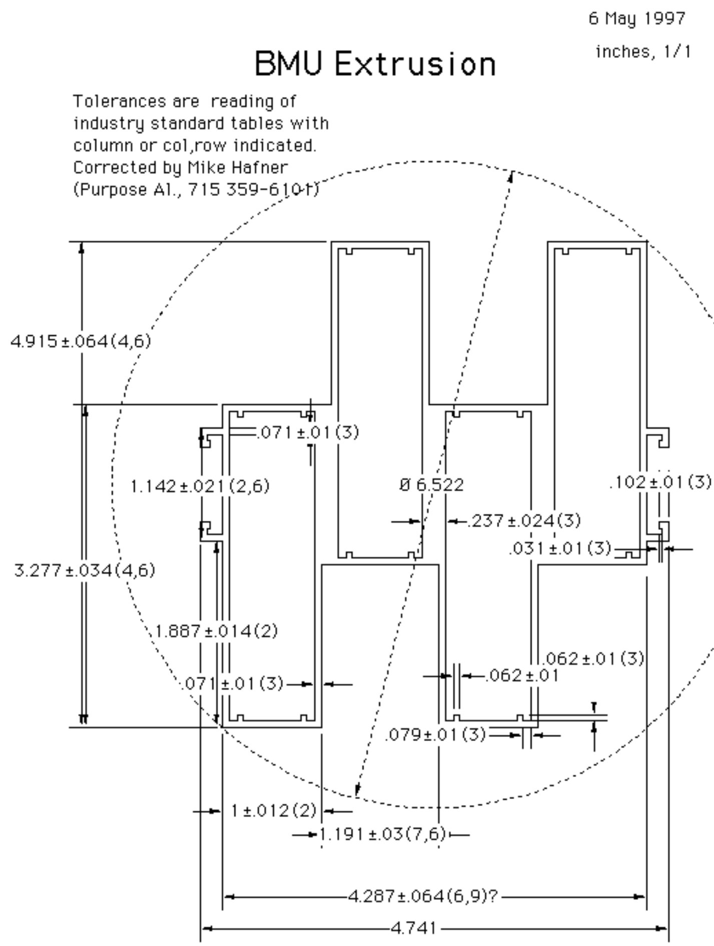


- 4-cell chamber shown
- Also a full-length 2-cell chamber

Technical Progress: IMU Chambers

- Short four-cell and two-cell full length prototypes built and tested (test beam and cosmic rays)
  - ➢Tested with CMP chamber electronics
    - Same as IMU chamber electronics except for packaging
  - ➢Everything is as expected
    - Resolution is ~200 μm. (Expectation was ~250 μm)
    - Single wire efficiency >99.4%
    - Stub reconstruction efficiency a little better than the central detector
- Virtually all the parts are ordered and are arriving in Madison

IMU Chamber Extrusions



- Four cells in one extrusion
  - ➤Large, complex die
  - ➤Chamber assembly greatly simplified
- One-half industry standard tolerance
  - ➤Low twist needed to assemble the cell stacks together

Quality Control

- IMU "Wedge Test" scheduled for January 1998
  - ➢Cosmic ray test of an IMU η-ϕ slice
    - Production chambers
    - Preproduction counters
    - CMP Readout electronics
  - ➢Allows an early start on system integration
  - ➢Test will evolve to include newer hardware as it arrives
- Scintillator standards defined
  - ➢Dimensional tolerance, polishing, light yield, etc.
  - ➢Prototype counters meet/exceed standards
  - ➢Italy bears the technical risk (backup is western scintillator)

Cost Performance

Recent Procurements (K$)		
Original Estimate	Actual Cost	Description
10	0	1.3.2.2.8.2. CMP Preamps
50	22	1.3.2.2.8.4 CMP Motherboards
51	118	1.3.4.1.1.2.1 IMU Aluminum Extrusions
50	39	1.3.4.1.1.3.1. IMU Electrode Material
13	13	1.3.4.1.1.3.3. IMU Electrode Machining (

These are all the completed tasks over $10000.

In spending ~$260k this year, we are ~$15k above expectations

Use of Contingency

CAPITAL EQUIPMENT M&S (FY 95 K$)		
Original Baseline EAC	Contingency Used	Current Baseline EAC
1232.9	67.7	1300.6

Contingency Use		
CR#	Change in Cost	Description
3.2	67.7	IMU Extrusion Cost Increase
TOTAL	**68**	

Use of Contingency

- This extrusion is large and complex
  - ➢We worked closely with one vendor before going out for bids
    - Estimate was based on information from that vendor
  - ➢That vendor (and dozens of others) did not bid
  - ➢We got one bid (for twice what we planned on)
  - ➢We spent several weeks trying to get a second bid, without success

Cost Estimate to Complete

U.S. Equipment M&S	FY 95 K$
Current Baseline EAC	1300.6
Most recent EAC	1283
FY 92-97 Costs and Obligations	504.2
Estimate to Complete	778.8

Total Estimate to Complete (including Non-U.S) = $1639

Labor Estimate

Labor Estimate to Complete			
	Present Level of Support	Average Require	Peak Require
Mech. Eng.	0.2	0.2	0.2
Mech. Tech.	4	4	6.4
Design/Draft	0.2	0.2	0.5
Elec. Eng.	0	0	0.2
Elec. Tech.	0	0.3	1
Comp. Prof	0	0	0

The peak of technician use is at installation time.

Labor Discussion

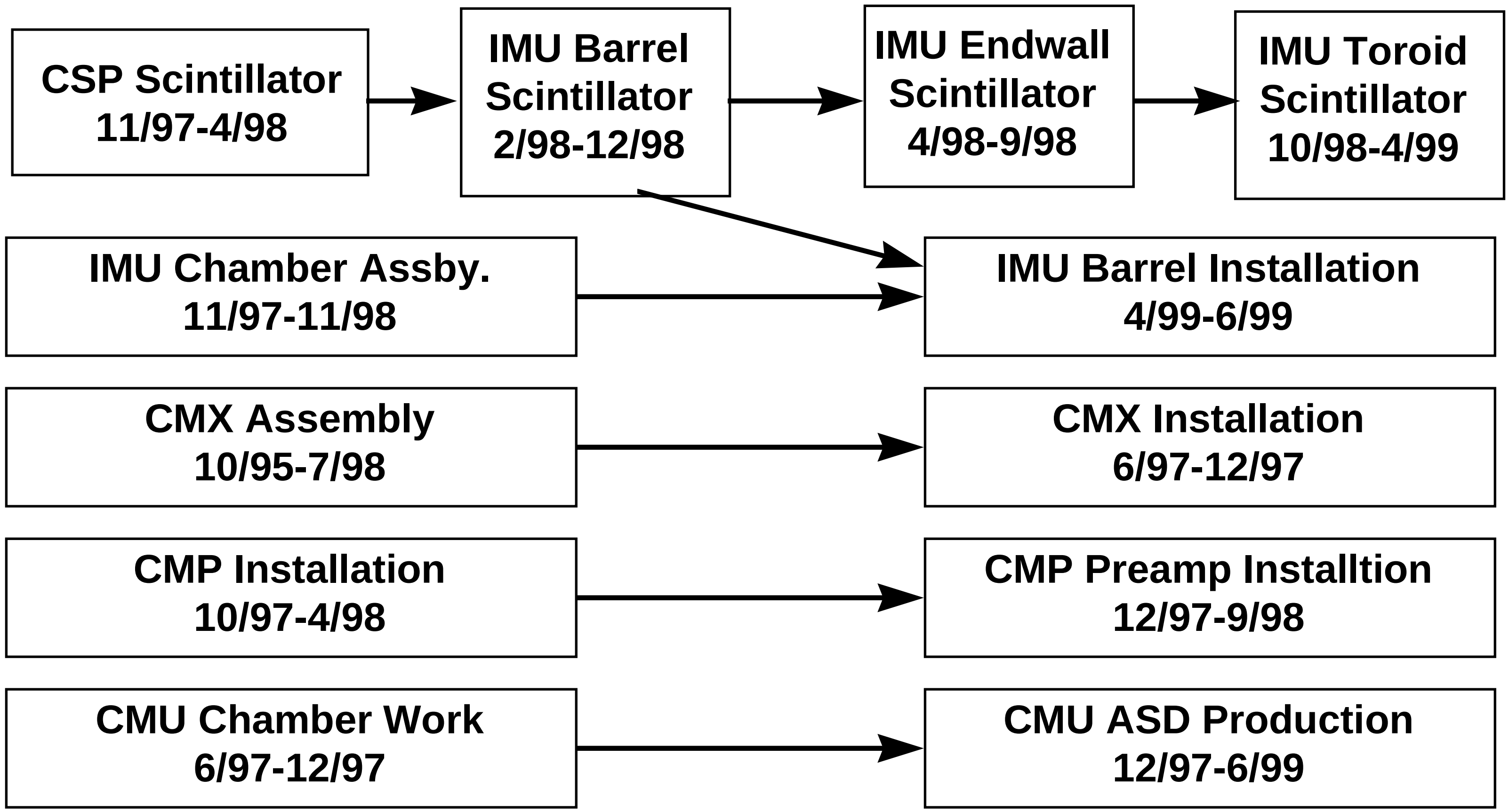
- Naming a lead technician (John Voirin) has been a big help
  - ➢Provides continuity
  - ➢Allows us to use FNAL techs on an “as needed basis”
  - ➢Provides valuable input in the design phase
- Installation Period is busy (for everyone)
  - ➢Plan to use University, ANL and INFN techs to fill the ranks
- Present level of effort seems well-matched to the Project
  - ➢We are not limited by technicians or engineers

Milestones

Level 1 and 2 Milestones		
Original Baseline	**Estimated Date**	**Description**
9/1/98	1/1/98	CMP Top Shielding Installed
1/31/98	4/18/98	20% of IMU Chambers Completed

Delay in IMU construction arises from time spent trying to get a second extrusion bid + vendor delay.

Schedule



We're ready for check-out with beam or cosmics (whatever is available) on 6/14/99. (Baseline is 10/13/99)

Subproject Critical Path

- We are not on the overall CDF critical path
- Our endgame schedule (and critical path) is closely coupled with the Installation schedule
  - ➢We're big, heavy, and in everybody's way
- Our critical item is CMX installation and hook-up
  - ➢Begins 4/2/99 (day after the door opens), ends 6/14/99
  - ➢We are ready 4 months after the door opens

Critical Path (II)

- Other items near the critical path
  - ➢CMU ASDs
    - scheduled to finish 6/99, but 3/99 is more realistic
  - ➢IMU chamber/counter attachment and hook-up
    - finishes 5/27/99 (eight weeks after the door opens)
    - chambers finish 6 months early, counters finish 2 months early
  - ➢IMU Toroid counter attachment and hookup
    - finishes at 5/27/99
    - counters ready in 4/99

Activities planned for FY 98

- Construct CMU ASD-2 boards
  - ➤20% are scheduled for FY98 (80% for FY99)
  - ➤We can go faster
- Install CMP notch steel and associated detectors
- Build CSP and 1/2 of the IMU counters
- Solve CMX installation interference problem
- Build IMU chambers

Summary

- We've stopped merely talking and started building
  - ➢1997 was the Year of Development
  - ➢1998 is the Year of Construction
  - ➢1999 is the Year of Installation
- Key roles filled
  - ➢Giovanni Pauletta (Udine): co-Project Leader
  - ➢John Voirin (FNAL): Lead Technician
- Progress in all major detector components

Summary (II)

- CMU
  - ➢Electronics replacement almost done (ahead of schedule)
- CMP
  - ➢Steel for shielding being fabricated
  - ➢Counters being constructed in Italy with scintillator provided by Russia
- IMU
  - ➢Learned a lot from prototypes
  - ➢starting construction on chambers
- **We're looking forward to beam!**