Hadron Calorimeter

Andris Skuja

Doe/NSF Review

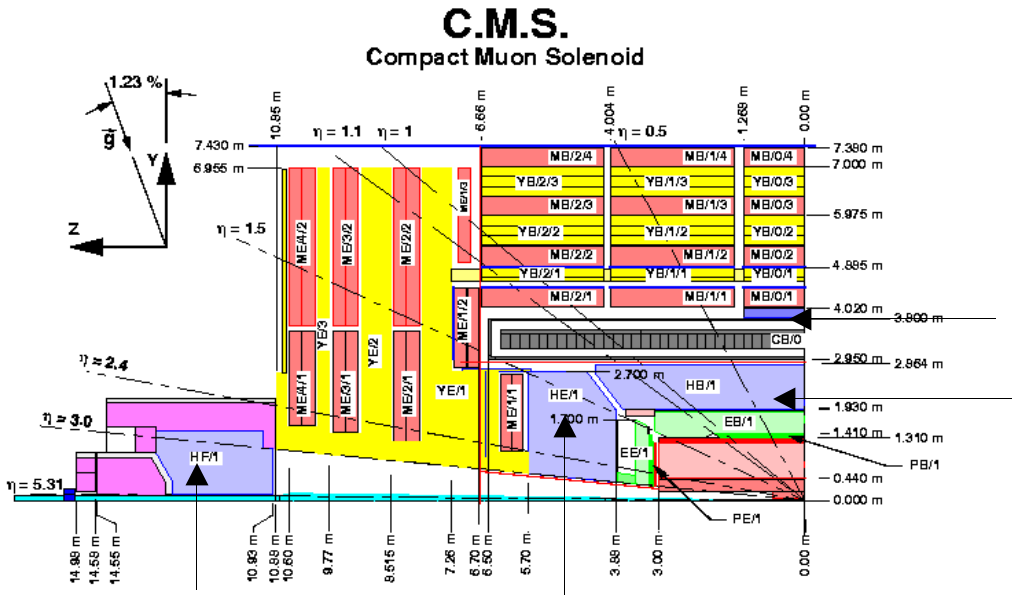
May 19, 1998

Outline

- System Overview
- US CMS Responsibilities
- Cost Estimate
- Organization, L2, L3
- Status and Progress
- Scope and Contingency Since Last Review
- WBS, Milestones, and Schedule
- Commitment and Resource Profiles
- Statements of Work
- Committee Concerns and Corrective Actions
- Summary and Conclusions

System Overview

HCAL: US does all of HB and optical cables, transducers, front end and readout electronics for HOB, HE and HF.



HOB 2.2

HB 2.1

HF 2.5

HE 2.3

Hadron Calorimeter Layout

The CMS Hadron Calorimeter consists of the 4 distinct subdetectors:

- **Hadron Barrel (HB) 0 < |eta| < 1.3 (WBS 2.1)**
- **Outer Hadron Barrel (HO-B) (WBS 2.2)**
- **Hadron Endcap (HE) 1.3 < |eta| < 3 (WBS 2.3)**
- **Outer Hadron Endcap (HO-E) (removed) (WBS 2.4)**
- **Hadron Forward (HF) 3 < |eta| < 5 (WBS 2.5)**

HCAL provides full hermetic coverage for the region 0 < |eta| < 5

US HCAL Responsibilities

The US construction responsibilities for all HCAL subdetectors are well defined:

- **HB: absorber, megatile production (optics), optical cables & connectors, readout boxes, photodetectors (HPD's), front end electronics, trigger/DAQ electronics, power supplies, controls: US CMS**
- **HE scintillator acquisition (only): US CMS**
- **HE optical connectors, readout boxes, photodetectors (HPD's), front end electronics, trigger/DAQ electronics, power supplies, controls: US CMS**
- **HO-B readout boxes, photodetectors, front end electronics, trigger/DAQ electronics, power supplies, controls: US CMS**
- **HF quartz fiber (Plastic cladding): US CMS**
- **HF readout boxes, photomultipliers, front end electronics, trigger/DAQ electronics, power supplies, controls: US CMS**

Non-US Responsibilities

Responsibilities of CMS collaborators

- HE: absorber, megatile production (optics) : R/DMS
- HO-B installation brackets & tooling, megatiles (including scintillator), optical cables: India
- HF absorber and installation tooling: Russia
- HF quartz fiber (quartz cladding): Hungary, Turkey
- HF quartz fiber installation: Hungary
- HB/HE/HF: HV Supply Engineering: Bulgaria

The division between US CMS HCAL PROJECT and the remaining CMS collaborators working on HCAL is well defined. US CMS has no responsibility for HCAL detector items being manufactured by non-US Institutes.

Subdetector Organization

There are common systems shared between the subdetectors (e.g. front end electronics, trigger/DAQ electronics, etc.). US-CMS organization is across common systems and not by subdetector (often WBS Level 4):

HB Absorber & Installation tooling (WBS 2.1.1)

HB Megatiles & Optical cables (WBS 2.1.2)

HE Scintillator & Optical cables (WBS 2.3.2)

All (HB/HO-B/HE/HF) Readout Boxes (WBS 2.x.3)

All Photodetectors (WBS 2.x.4)

All Front End Electronics (WBS 2.x.5)

All Calibration (WBS 2.x.6)

All Trigger/DAQ electronics (WBS 2.x.7)

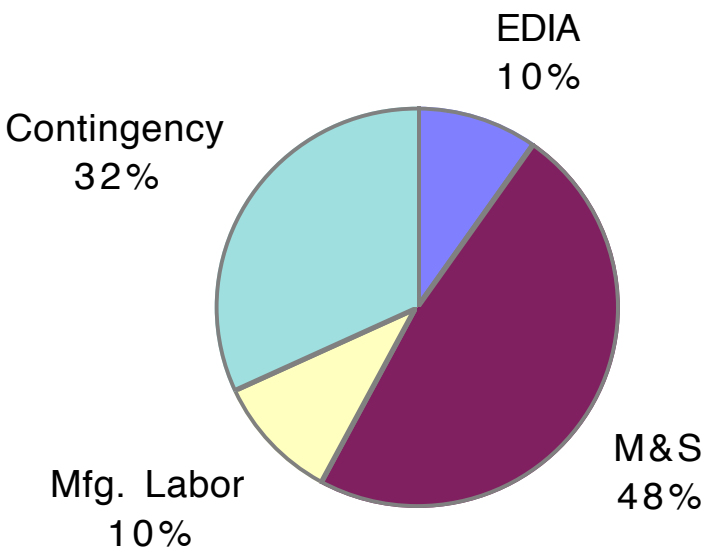
All power supplies and controls (WBS 2.x.8 & 2.x.9)

Prototypes (WBS 2.x.10)

HCAL Cost Estimate Summary

Base: $27.6M Contingency: $13.0 (47%)

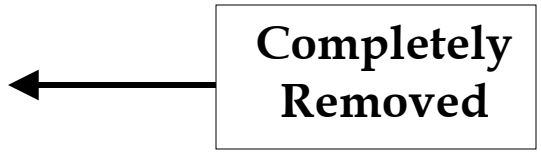
Total Estimated Cost (FY97 $): $40.6M



A new "bottoms-up" base line cost estimate has been completed for $27.6M. HCAL costs are driven by M&S purchases. The contingency is 47% of the Base Cost or 32% of the Total Cost.

HCAL Costs at L2/L3

WBS	BASE (M$)	Contingency(%)
2. HCAL	27.6	47
2.1 HB	20.3	44
2.2 HOB	1.5	57
2.3 HE	2.6	54
2.4 HOE	0.0	---
2.5 HF	3.2	56



HCAL Costs at L3/L4

Base: $27.6 Contingency: $13.0 (47%)

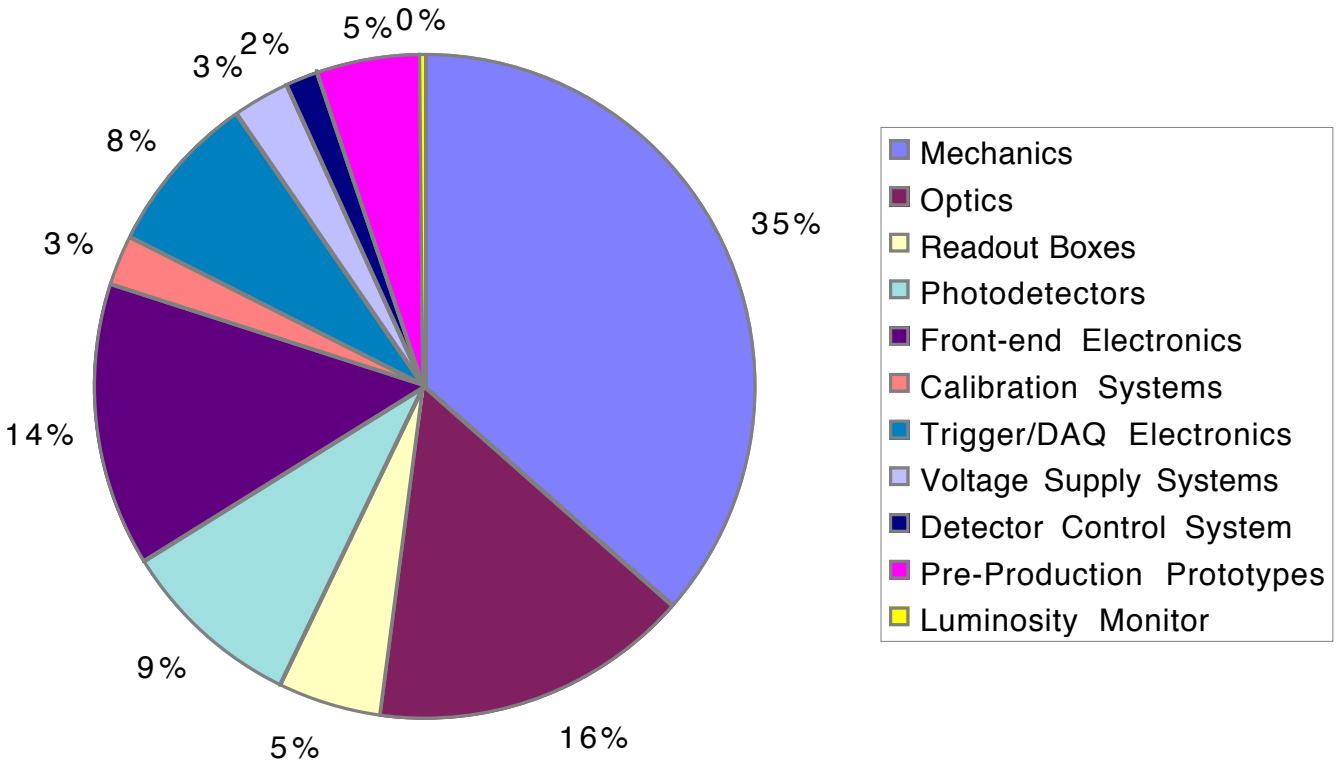
Total Estimated Cost (FY97 $): $40.6

Cost drivers: Absorber & Tooling (35%)

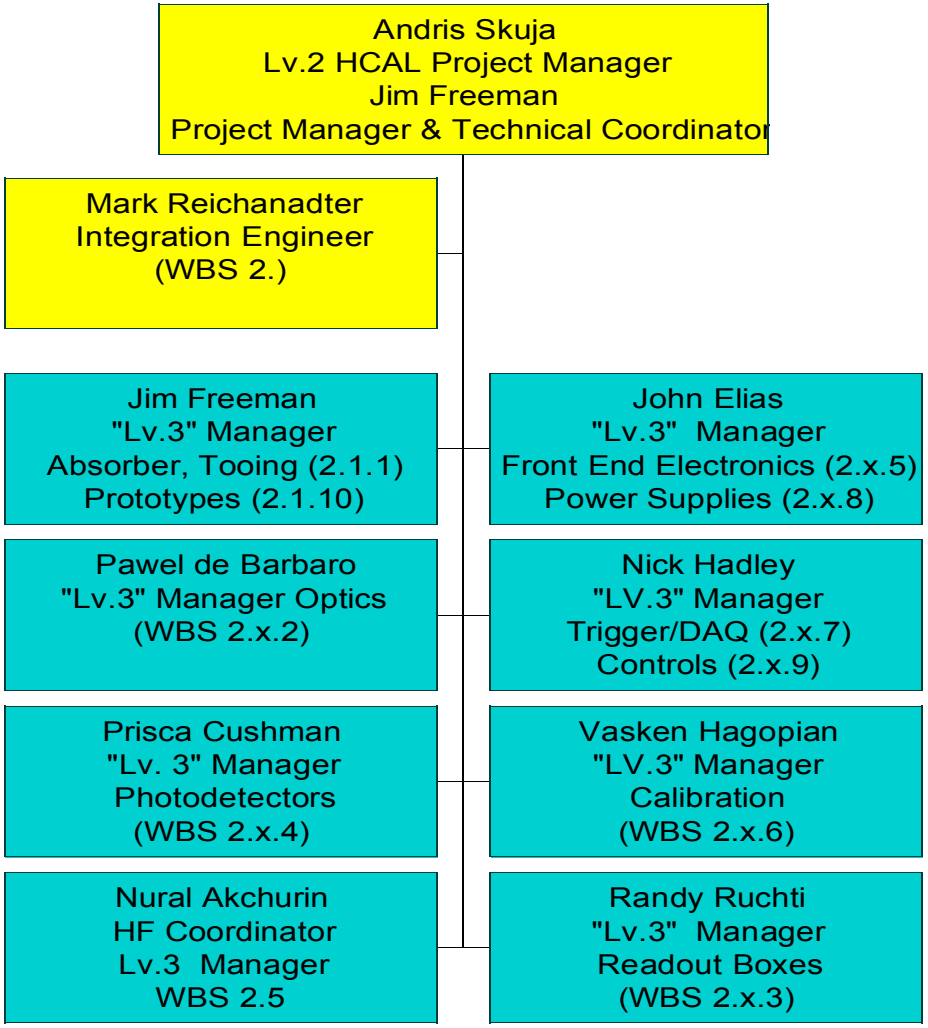
Optics (16%)

FEE (14%)

HPD's(9%)



Organization Links from Level 2 to "L3"



Organizational Meetings

US CMS HCAL meets once every 6 weeks, although more often recently. We also communicate by video and teleconferencing.

In 1998 we have had the following meetings:

- We met to prepare for the PMG presentations in early January
- February meeting in Florida
- March meeting at CERN
- April meetings to prepare for this review
- Meetings at the Lv.3 level for design and cost determination (e.g. Front End Electronics & Optics groups holds weekly meetings at FNAL, Test Beam at CERN)

Extensive interaction with International CMS to resolve common problems (e.g. Controls, Optical Links, Rad Tolerant LV power supplies)

Technical Tracking & Reviews

All Technical Designs & Proposals generated at Level 3 are reviewed at Level 2. Outside technical advice is solicited if required. We rely on the availability of FNAL and CERN expertise for such advice. All major HCAL systems designed or constructed at FNAL are subject to Fermilab Safety Committee Review (headed by Bob Trendler).

Major systems are reviewed at CERN by CERN designated engineers for engineering and safety requirements (e.g. absorber & electronics)

Major systems are reviewed by International CMS for performance and cost (e.g. absorber, front end & trigger/DAQ electronics)

Major systems are also reviewed by the LHCC on a yearly basis (performance, cost & schedule)

Major systems are reviewed by the CMS integration group for compatibility with other CMS detectors as well as the CERN CMS Installation plan

Schedule Tracking & Reporting

- Level 3 Managers report monthly to Level 2 the percentage completed of all WBS items in the previous month and an estimate of time - to - completion of specific items under construction at that time.
- Anticipated delays in start up and procurement are also reported and assessed.
- The MS Project is updated to represent schedule change (if necessary) and any impact on milestones is assessed. (The Base MS Project File remains untouched for comparison.)
- Progress is reported to US CMS Project Office according to CMS guidelines. Impact on milestones is reported and assessed.

Status and Progress

- A TDR was written in June, 1997 and accepted by the LHCC

Absorber & Prototypes

- The HB bolted absorber design was finished at the end of 1997 and an RFP (Request for Proposals) to construct two HB half barrels as well as two prototype wedges was distributed. A best and final offer was accepted in early March of 1998 from Felguera Construcciones Mecanicas, SA of Ovieda, Spain. The first of the prototype wedges (PPP1) is under construction.
- The megatiles for PPP1 are under construction
- A test beam table is under construction
- PPP1 will be tested in August in a beam at CERN

Status and Progress

Readout Boxes and HPD's

- The HB & HE readout boxes have been designed. An HB prototype is being assembled now and will be tested in Test Beam with HPD's in August.
- We have accepted delivery of newly engineered HPD's, matching our rise-time and amplification requirements. They are being evaluated
- Calibration
- The Calibration system has been redesigned to meet the scope requirements (but no more) of CMS HCAL
- The source system is the primary calibration
- Laser and LED systems provide stand alone and back up modes of operation

Status & Progress

Electronics

- The front end electronics (FEE) design now consists of a preamplifier, a channel control ASIC (the FNAL QIE) with an on-board ADC. It will be manufactured to be rad-tolerant (DMILL BiCMOS and Hewlett-Packard CMOS are a possibilities)
- The Trigger/DAQ system including the optical links connecting it to the FEE will be based on a CERN design. An HCAL requirements document is in preparation.
- The HV power supplies will be designed and manufactured by INRNE of Sofia. A '98 12KV prototype has been delivered to Fermilab and is undergoing tests. It will be used in the August Test Beam.
- The LV power supplies will be part of a CERN procurement of rad-tolerant LV supplies
- Controls are based on an EPICS/Arcnet model

Status & Progress

Forward Hadron Calorimeter (HF)

- The HF calorimeter has been redesigned to meet the cost envelopes of both International CMS and US-CMS
- This re-scoping has been accomplished by reducing the quartz fiber density imbedded in the calorimeter as well as reducing the granularity of the readout (now an eta-phi matrix)
- The luminometer function of HF has been restricted to measuring energy flow in certain HF towers as well as “counting zeros” in these towers.

Scope and Contingency Since Last Review

- **The HCAL subsystem was reviewed by the FNAL PMG in a full bottoms up cost estimate**
- **Contingency was assessed at the lowest WBS task level using the US CMS methodology (Maturity and Judgment factors).**
- **The REAL contingency was increased after the last review from 32 % to 47%.**
- **The base cost was reduced by 15% from the Lehman Review of '97 in order that US CMS maintain a fixed total project cost.**
- **This reduction was accomplished by reducing the scope of the US baseline, e.g.**
    - Reducing the HB interaction length (replace Cu by Cartridge Brass)
    - Remove HO-E entirely
    - Redesign Calibration, HF, Voltage and Controls Systems
    - International Collaborators (India, CERN, Russia) have assumed responsibility for some items (HOB optics, CERN transportation & rigging, HE optics)

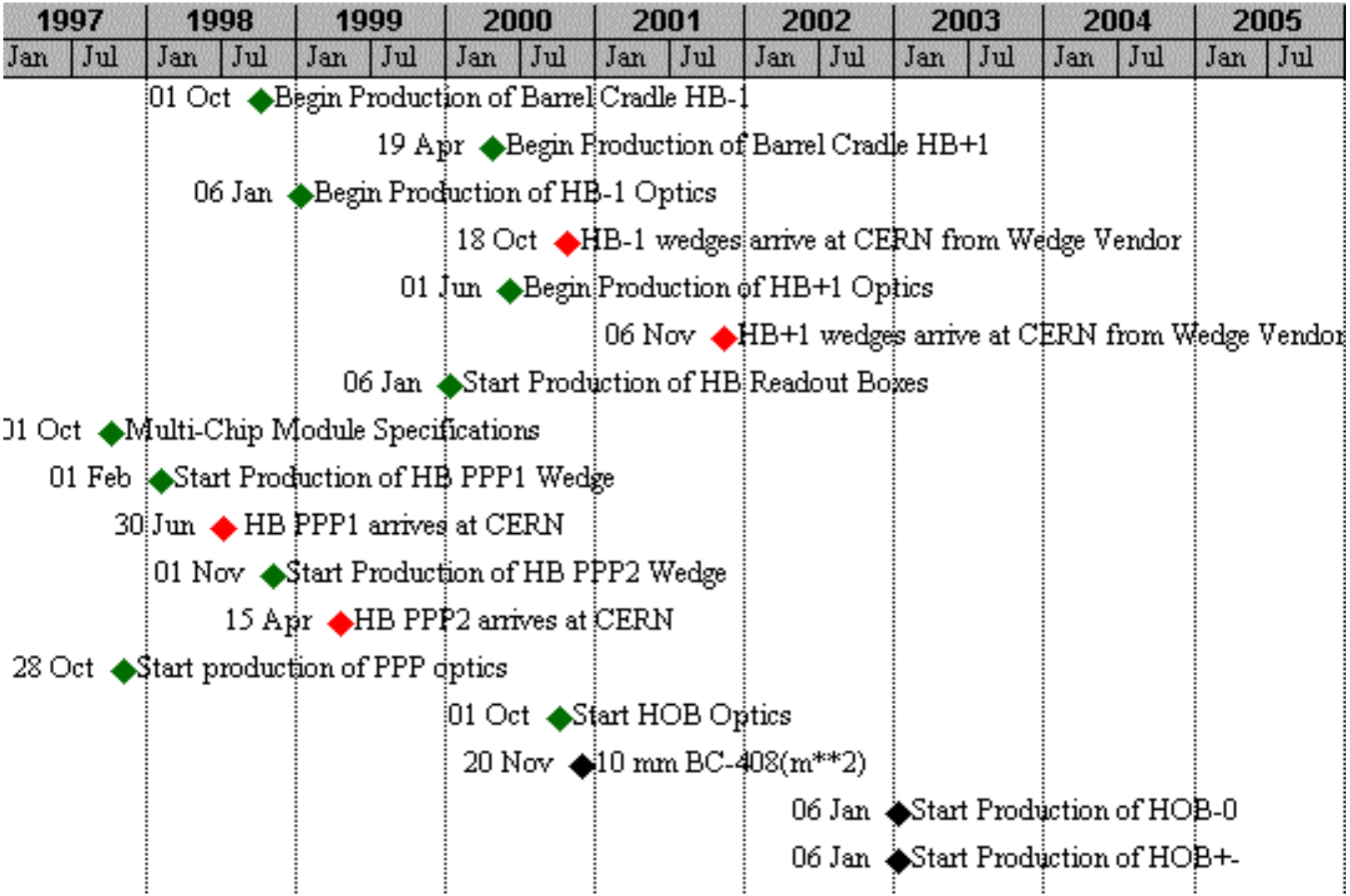
Scope Reduction and Physics

- HCAL scope reduction retained the full hermetic angular coverage but reduced redundancy and headroom. Reduced scope is recoverable.
- Redundancy was removed from the following systems:
  - Calibration
  - Power Supplies
  - Controls
  - Forward Calorimetry
- There is little impact in our fundamental goal of searching for new physics by these reductions

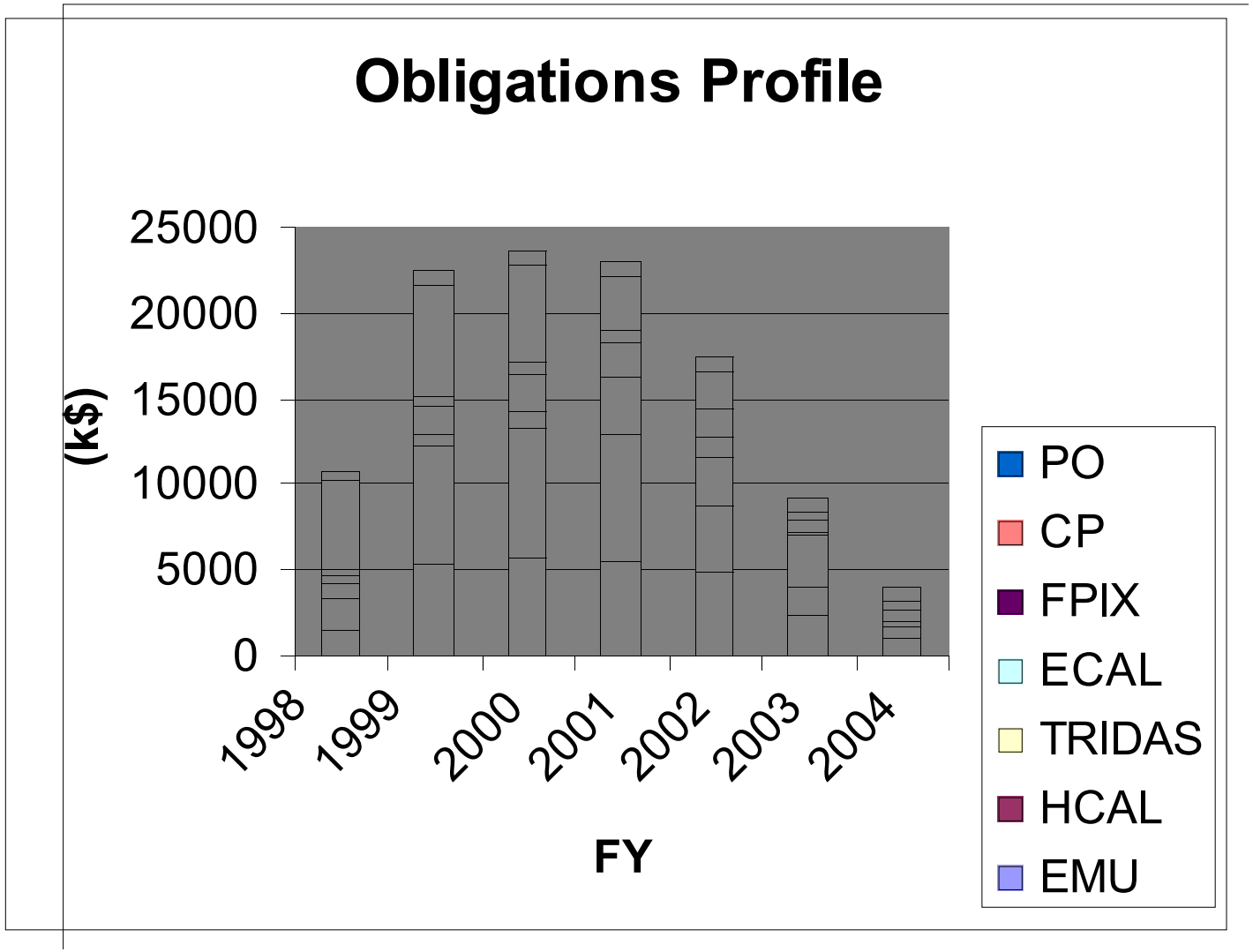
WBS, Milestones, and Schedule

- A fully resource loaded schedule has been provided for HCAL containing ~ 1500 US tasks.
- A WBS dictionary and basis of estimate has been produced, along with resource tables, all linked to MS Project.
- Lv.2 US Milestones (~ 250) have been specified for all subsystems and in many cases represent deliverables costing about $100K. In addition each subsystem has developed its own internal set of Milestones. All these Milestones will be tracked (& progress appropriately reported).
- The HCAL MS Project schedule will be updated monthly. The HCAL schedule is linked to the L1 US CMS schedule such that schedule slippage will be flagged at this level as well.

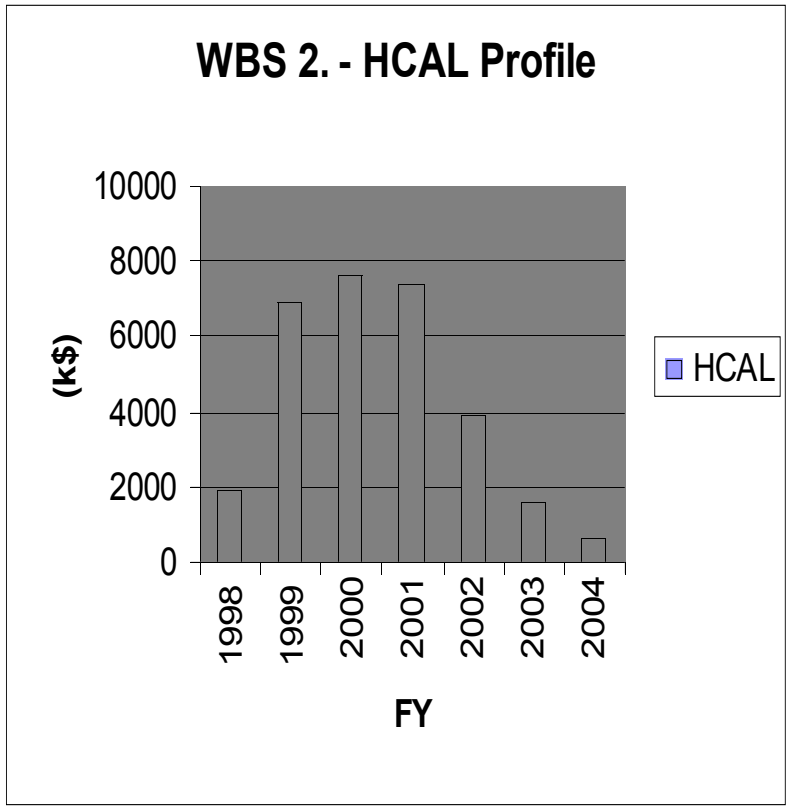
WBS, Milestones, and Schedule - HB



US CMS OBLIGATION PROFILE

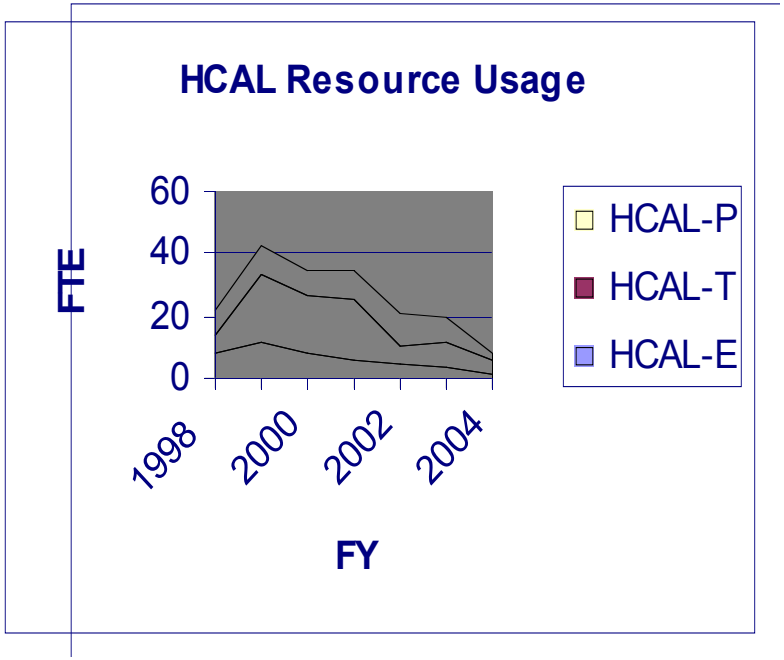


HCAL Obligation Profile



The Cost Profile has been extracted from MS Project. The Absorber payment schedule has been extended over several years to "soften" profile. Otherwise items are delivered for completion of wedge assembly in Building 186 of CERN.

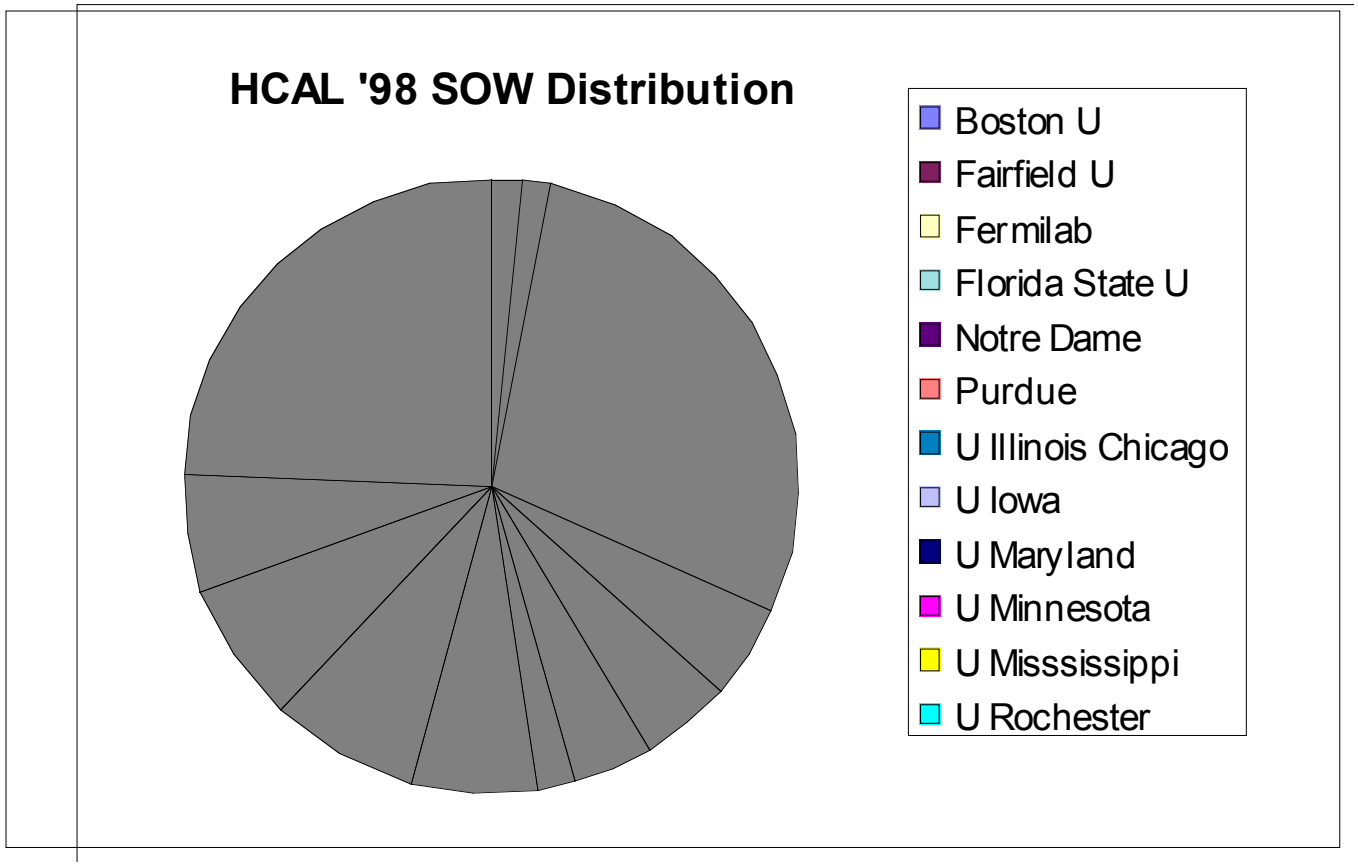
HCAL Resource Usage



The Personnel Usage Chart is derived from MS Project. The chart shows the build-up of technical personnel until 2000 for fabrication. The 2001 to 2004 period is dominated by CERN installation and HF construction.

Statements of Work

A SOW is in place for FY98 with all HCAL institutions which are active in detector construction. MOU's with all participating institutions for the full project will be drafted ASAP after US CMS is baselined



Committee Concerns and Corrective Actions (I)

A number of recommendations were presented by the Committee in 1997. Action has been taken on all recommendations. Namely:

- **Integration Engineer: Mark Reichanadter (of FNAL) has been hired**
- **Optical System Assembly Supervisor: Pawel de Barbaro of Rochester is the physicist in charge of megatile assembly. He is assisted by Howard Budd and George Ginther of Rochester. Todd Nebel is the supervisory senior tech for the operation.**
- **Rad Dam of electronics inside the detector: Electronics inside the Calorimeter Readout Boxes will be manufactured using rad hard process for BiCMOS (DMILL) and rad tolerant processes (HP and AT&T) for CMOS. The cost and schedule reflect these choices.**

Committee Concerns and Corrective Actions (II)

- Electronics Engineer:Sergey Los (Visiting Engineer from IHEP) has been assigned to coordinate the US HCAL electronics activities. He is in residence at Fermilab.
- Contingency Analysis: All contingency analysis was carried out using the UC CMS methodology at the lowest level (usually 7)
- Failure modes of the HPD's: The Failure modes have been identified and corrective action specified (see discussion in parallel session on Wednesday)
- Radiation tolerance of PMT's: Monte Carlo calculations indicate that we have a safety factor of 10 for a ten year exposure at the highest luminosities for our baseline PMT's. Studies are underway to determine the damage characteristics of less costly PMT's.
- Small Projects: Extensive time and attention has been devoted to HF (and similar size subdetectors).

Summary and Conclusions

- The concerns raised by the Committee have been addressed.
- A complete resource loaded schedule has been made.
- A new bottoms-up cost estimate has been completed.
- The contingency has been raised from 32% to 47% which is consistent with recent HEP experience.
- The base estimate for current scope is 15% less than the one presented to the Committee in 1997.
- The impact of scope reduction for HB/HE has been to reduce redundancy (calibration, HV/LV PS, controls) and headroom (HB interaction length depth, HOE), while preserving full hermetic coverage at unchanged energy resolution. The impact on PHYSICS PERFORMANCE remains minimal.
- HF scope reduction has reduced energy resolution, but has little effect on Higgs tagging.