BTeV Tracking System

Pixel Vertex Detector (WBS 1.2)
Straw Tracker (WBS 1.6)
Silicon Tracker (WBS 1.7)

Simon Kwan (WBS 1.2)

Alan Hahn (WBS 1.6)

Luigi Moroni (WBS 1.7)

Overview

- **Brief description of the BTeV tracking system**
  - Pixel vertex detector
  - Forward tracker (Straw & Silicon strips)
- **Details of each sub-system**
  - Project requirements & Description
  - Project organization
  - Cost, Schedule, and Critical path
  - Milestones
  - Risk Assessment
  - Responses to DOE CD-1 recommendations
- **Presentations prepared for the breakout sessions**
- **Conclusion**
- **Glossary**

Introduction

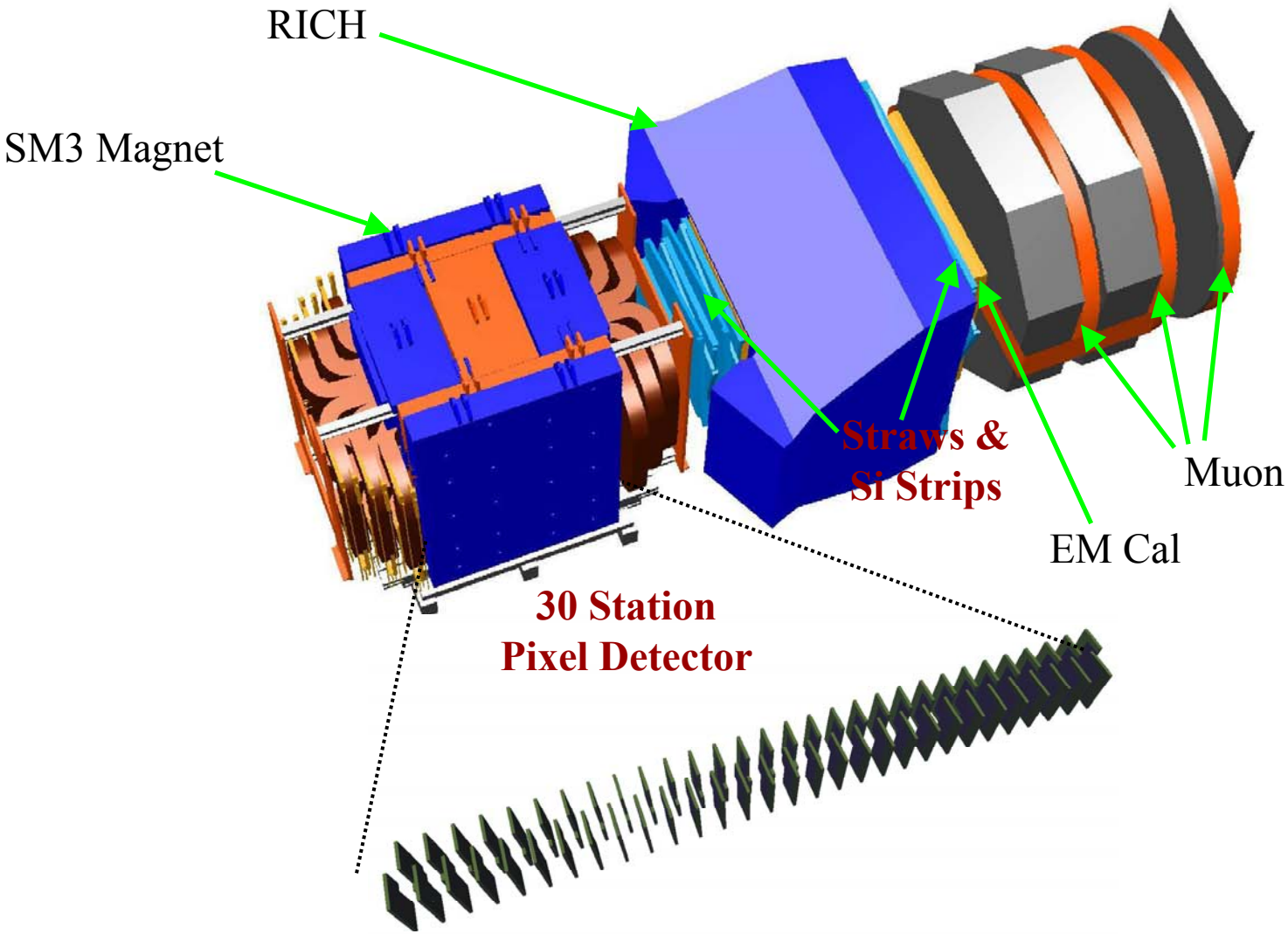
Requirements

- **Coverage**:
  - Aperture 300 mr
  - Momentum acceptance 3 - >100 GeV/c
- **Tracking efficiency > 98%**
- **Resolution for vertex detector:**
  - Spatial : < 9 μm
  - Time: < 50 fs
- **Vertex detector info available for use in L1 trigger**
- **Angular resolution**:
  - Better than 0.1 mr
- **Momentum resolution**:
  - 1% at 100 GeV/c
- **Can handle huge data rate and survive high radiation dosage**

Key features

- **Vertex Detector**
  - **Pixel Detector (WBS1.2)**
    - Precise vertex detection and reasonable momentum measurement capability
    - Fast info available for use in L1 vertex trigger
- **Forward Tracker**
  - **Straw (WBS1.6) and Silicon Strip (WBS1.7)**
    - Precise momentum measurement, Ks/Λ detection, project tracks into RICH, EMCAL, Muon chambers
    - Combination of **Silicon strips** near the beam and **Straw Chambers** at large radius

BTeV Detector



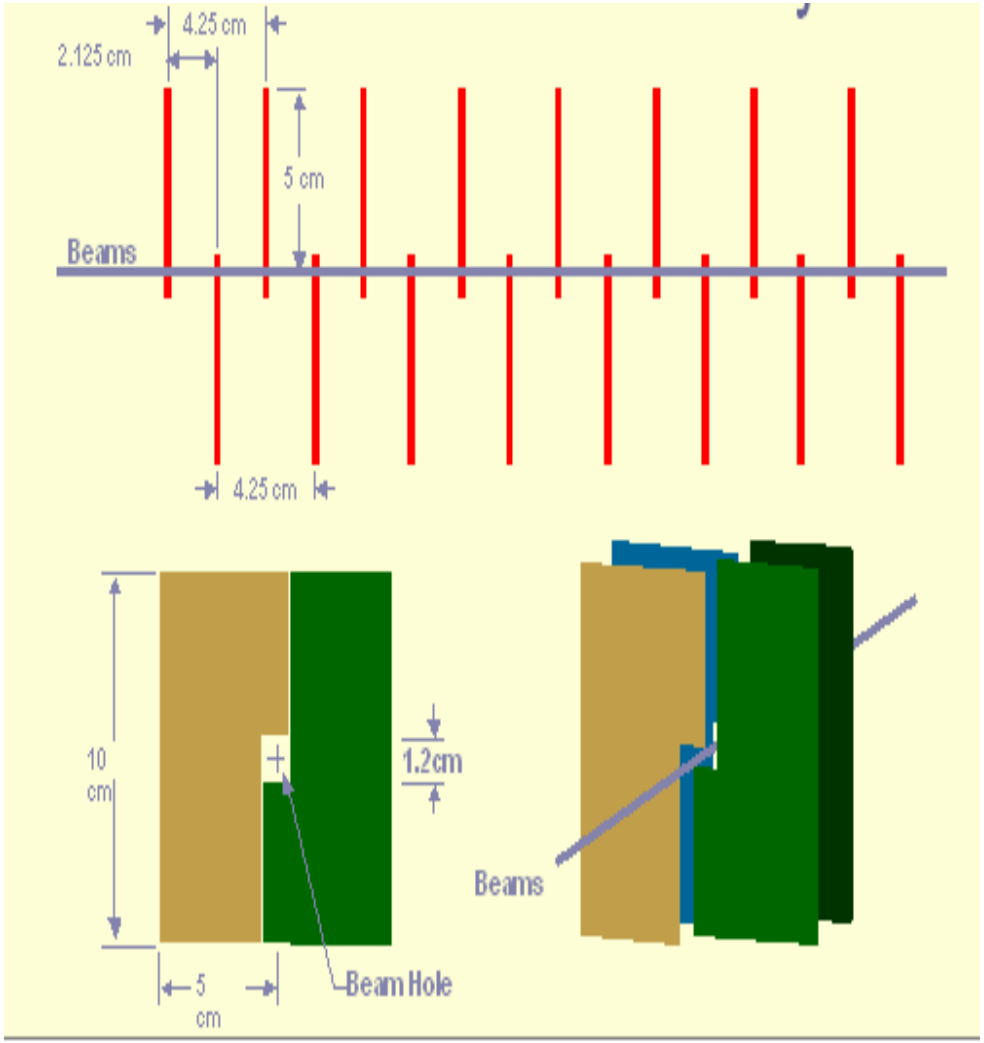
Technical Description of Pixel Detector WBS1.2

Reasons for Pixel Detector:

- Superior signal to noise
- Radiation Hard
- Excellent spatial resolution: <9 μm for all tracks
- Pattern recognition power
- Very low occupancy

Special features:

- Info used directly in the L1 trigger
- Placed inside a dipole and gives standalone momentum measurement
- Sitting close to beam and be retractable during beam refill -> needs vacuum system and rf shielding
- 30 stations with 23 million pixels in total
- Total length ~1.3m

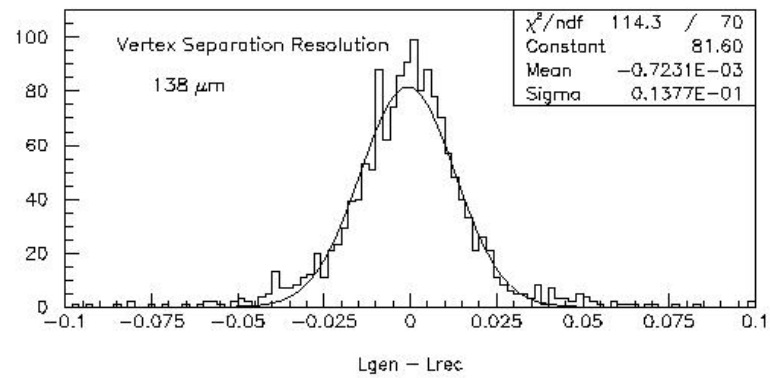


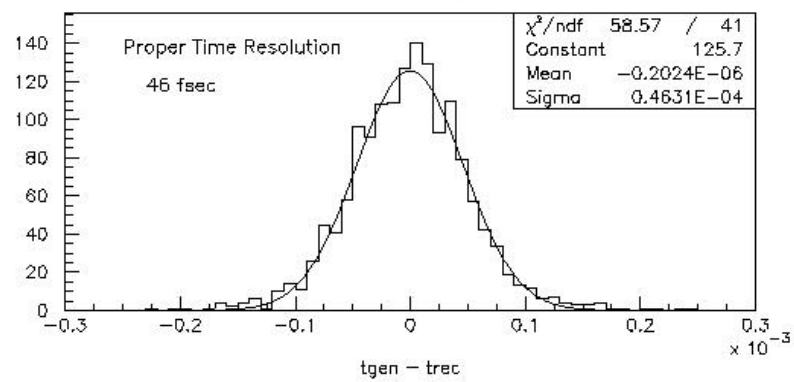
Pixel Detector Properties & Performance WBS1.2

Property	Value
Pixel Size	50 μm x 400 μm
Outer plane dimension	10 cm x 10 cm
Central square hole (adjustable)	Nominal setting: 12 mm x 12 mm
Number of planes	60
Number of stations	30
Number of pixels	23 million
Total Silicon active area	0.5 m^2
Separation of stations	4.25 cm

$B_s \rightarrow D_s \; K^+$

Primary-secondary vertex separation
Reconst - generated. $\sigma = 138\mu$





τ_{proper} (reconstructed) - τ_{proper} (generated)

$\sigma = 46$ fsec

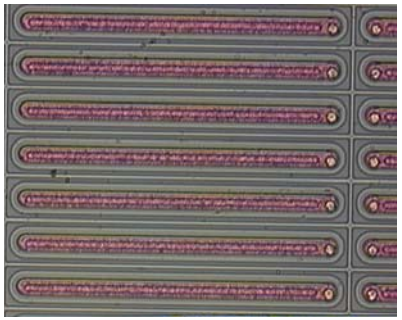
Pixel Components WBS 1.2

- WBS 1.2.1: Sensor & Detector Hybridization
  - Includes design, procurement and testing of sensor wafers, flip-chip mating of sensors to readout chips to get pixel modules
- WBS 1.2.2: Electronics
  - Includes pixel readout chips, data cables, PIFC, Feed-through Board (FTB), HV/LV power supplies and cables
- WBS 1.2.3: Mechanical & Vacuum system
  - Includes substrate, fixtures, vacuum vessel, position control system, cooling system, vacuum system, support structure, and rf shield
- WBS 1.2.4: System Integration
  - Includes production HDI, pixel module assembly and testing, test-stands, station assembly, detector assembly, beam test, control &monitoring, fast interlocks, system test, system software
- WBS 1.2.5: Project Management

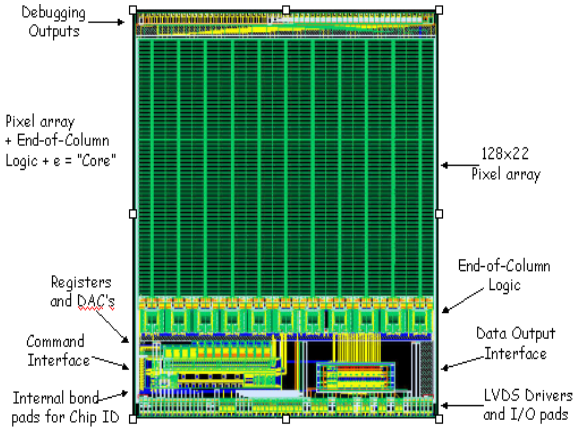
Pixel Detector WBS 1.2

- Pixel Sensor bump-bonded to Readout chip
- Fine segmentation
  - 50 μm x 400 μm
  - Large number of channels
  - Electronics in the active tracking volume
  - High power density (~ 3kW -> cooling system)
- Basic building block – Multichip Module (MCM)
  - 4 types (4, 5, 6, and 8 chip array)
  - Large number of HDI and flex cables
- Assemble modules on both sides of substrate to form pixel half plane; an x-measuring half-plane and a y-measuring half-plane form a half-station

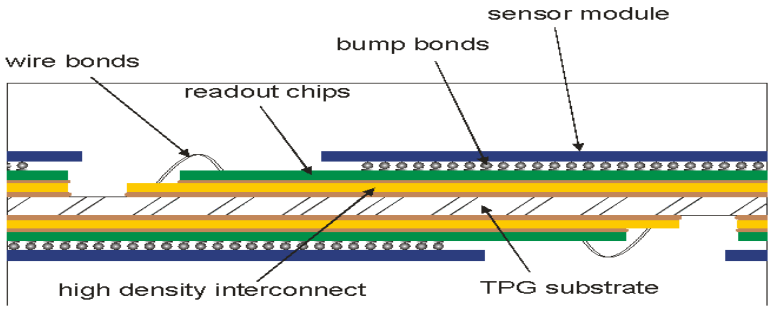
Si pixel sensors



Pixel Readout chip



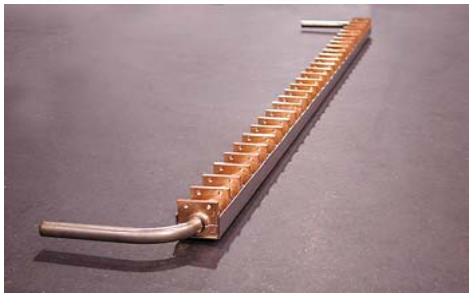
Multichip module



Pixel Half-Station WBS1.2

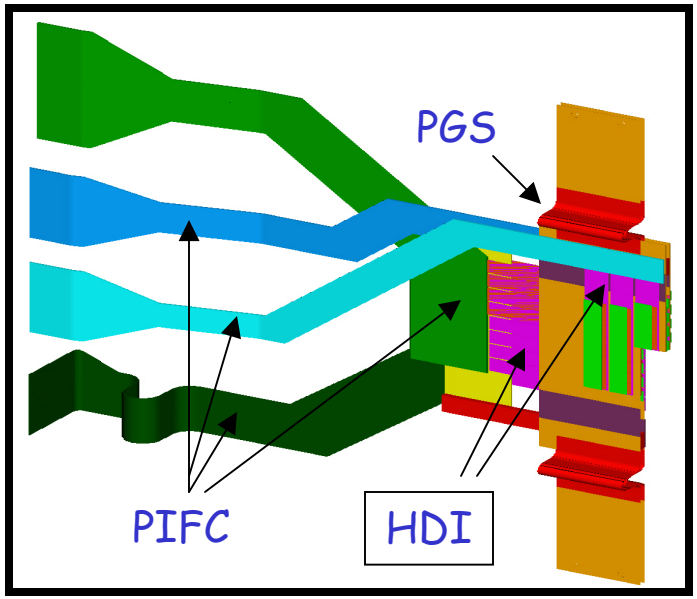
Temperature Control Heater
Y-view pixel modules
Carbon fiber spacer tube
PGS flexible thermal coupling
Carbon fiber mounting bracket
Precision mounting pin
X-view pixel modules
TPG substrate
Connection point to LN2 heat sink

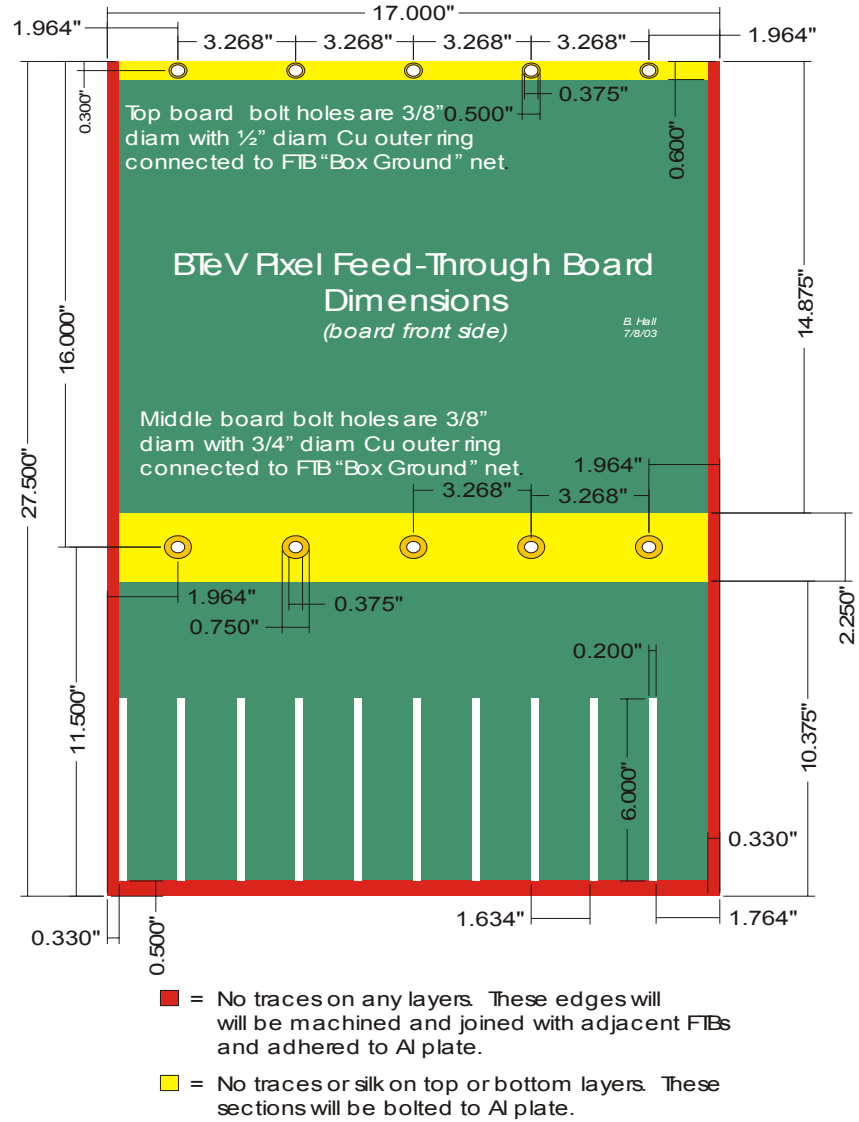
Cu tabs brazed to SS tube-LN_2 heat sink



Carbon support half cylinder (~1.26m long)

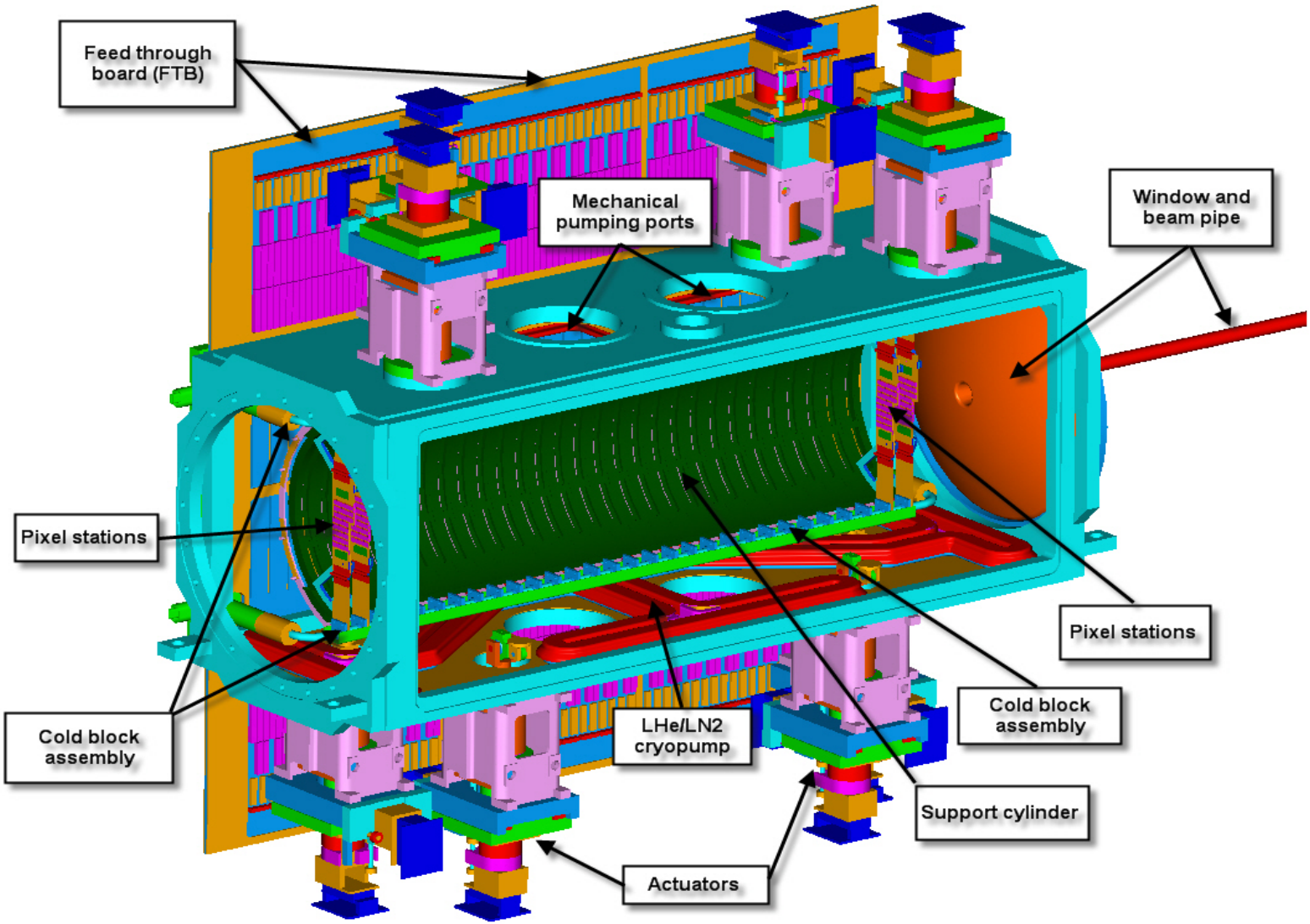
Feed-through Board (FTB) WBS1.2





- Signal path: ROC- HDI- PIFC- FTB- PDCB-trigger/DAQ system
- Board size: 17"x27.5"; more than 16 layers
- Full size FTB prototype will be delivered next month
- Key for mechanical and electrical tests
- FTB layout is very dense and can benefit from any possible simplification

Pixel Detector Assembly



Pixel Detector Participants WBS 1.2

Fermilab: J. A. Appel, D. C. Christian, S. Cihangir, J. Fast, R. Kutschke, S. Kwan, M. Marinelli, L. Uplegger, J. Andresen, M. Bowden, G. Cardoso, H. Cease, C. Gingu, J. Hoff, A. Mekkaoui, M. Turqueti, R. Yarema, J. Howell, C. Kendziora, M. Kozlovsky, M. Larwill, C.M. Lei, A. Shenai, M.L. Wong , S. Austin, S.Jakubowski, R. Jones, G. Sellberg, M. Ruschman, J. Rausch, R. Sanders, E. Skup

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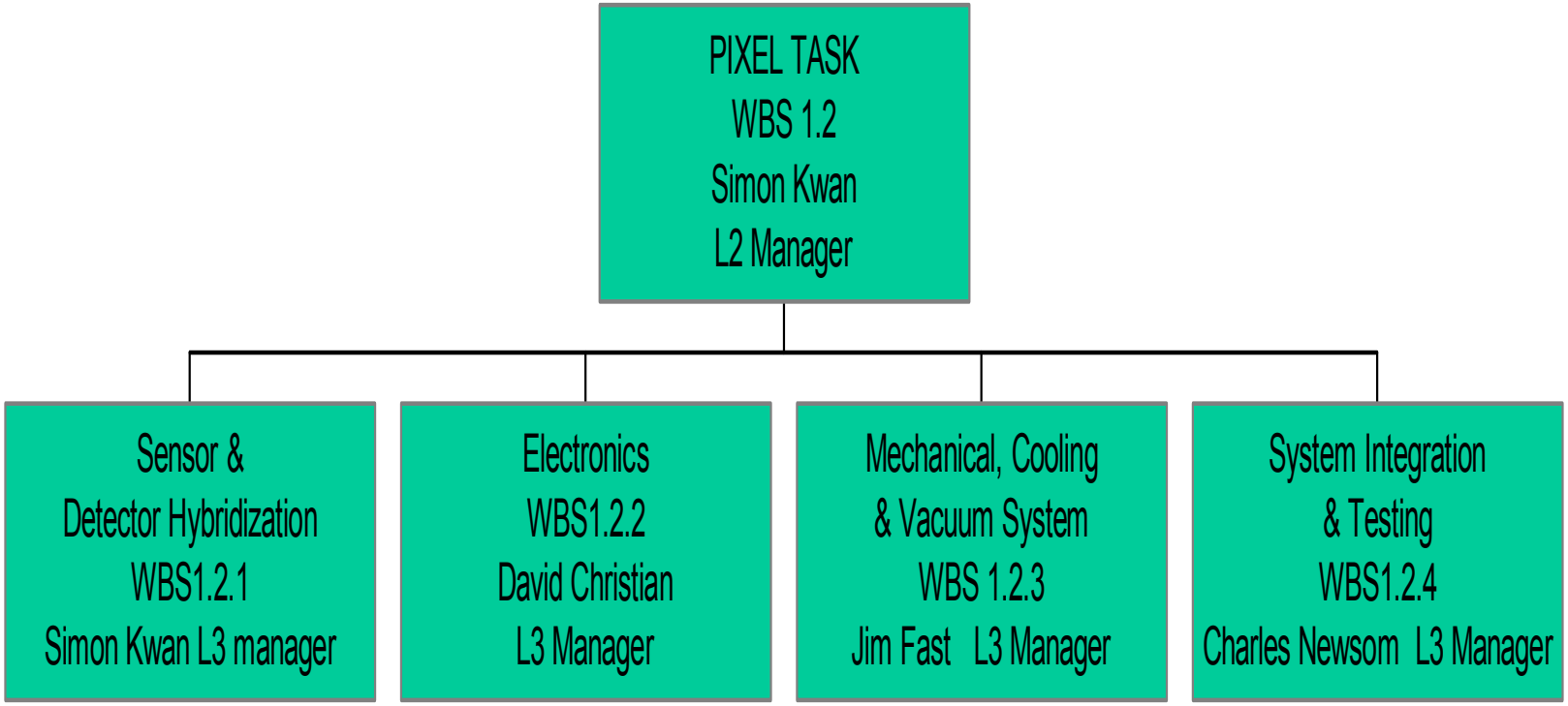
Tennessee T. Handler, R.Mitchell, S. Berridge

Wayne State: D. Cinabro, G. Bonvicini, A. Schreiner, A. Guiterrez, G. Gallay, S. LaPointe

-Physicist

- Technical staff

Pixel L2 & L3 Managers WBS1.2



Base cost: $14.57M (Material: $7.14M, Labor: $7.43M)

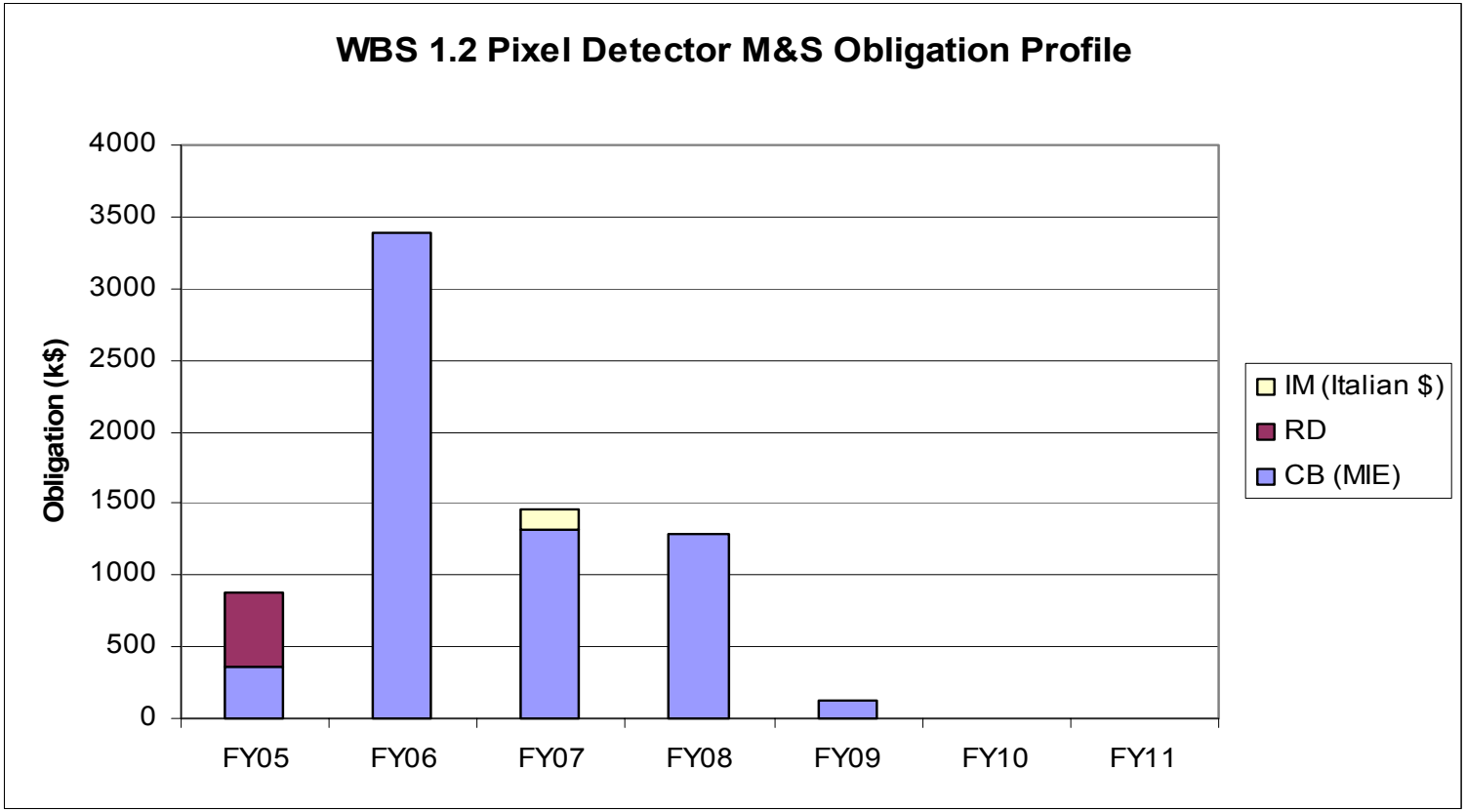
Pixel Construction Cost WBS 1.2

Activity ID	Activity Name	Base Cost ($)	Material Contingency (%)	Labor Contingency (%)	Total FY05	Total FY06	Total FY07	Total FY08	Total FY09	Total FY10	Total FY05-10
1.2.1	Sensors and Pixel Detector Hybridization	2,277,593	47	32	463,135	1,689,904	1,149,138	0	0	0	3,302,177
1.2.2	Pixel Detector Electronics	3,728,580	38	40	839,433	1,652,929	611,864	1,966,818	99,198	0	5,170,242
1.2.3	Mechanical Cooling and Vacuum System	4,163,408	48	38	617,761	2,413,926	1,578,080	1,304,943	0	0	5,914,710
1.2.4	System Integration & Testing	3,538,862	54	52	405,261	1,146,831	2,371,276	1,118,661	335,725	0	5,377,754
1.2.5	Pixel Detector Subproject Management	861,432	25	18	222,568	240,281	190,185	190,185	181,504	0	1,024,723
1.2	file_12_092004	14,569,875	44	41	2,548,158	7,143,872	5,900,544	4,580,606	616,427	0	20,789,607

CD1 Review: Base $15.5M Total $21.65M (contingency ~ 40%)

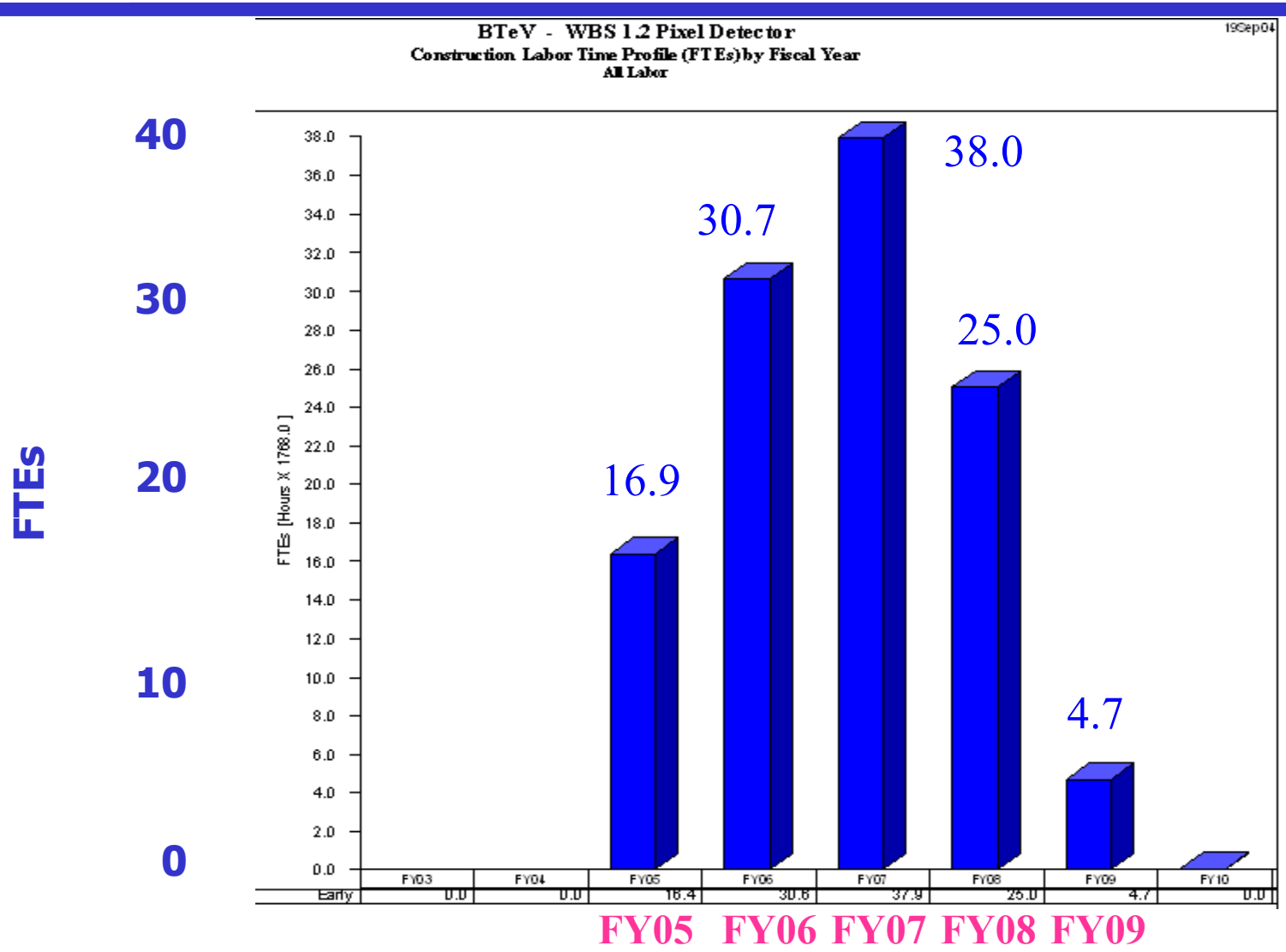
Reviewers estimate: 4.5% increase in labor but contingency goes up to 42%

M&S Obligation Profile by Fiscal Year WBS 1.2



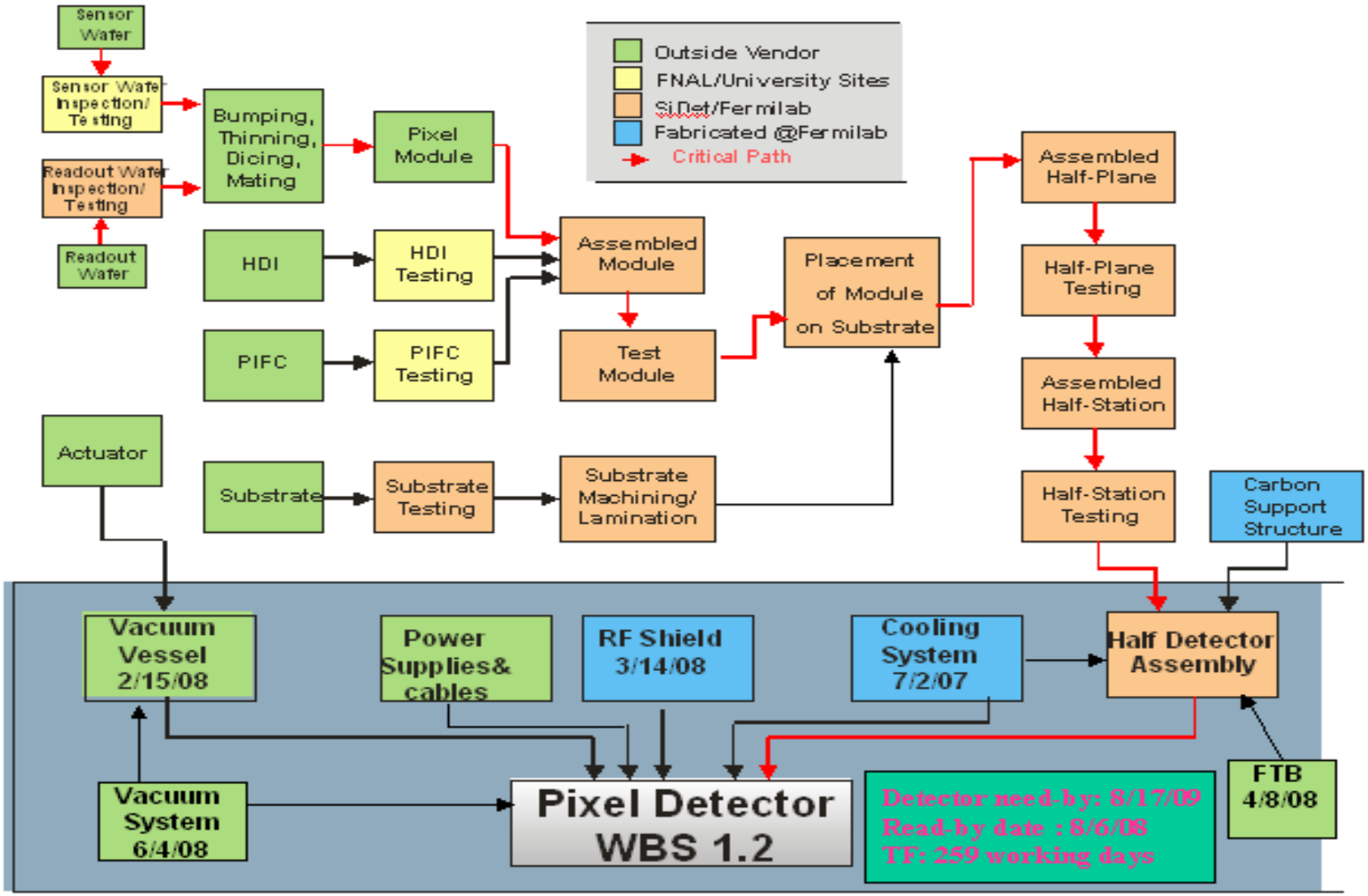
	FY05	FY06	FY07	FY08	FY09
CB (MIE)	355	3393	1322	1286	126
RD	517				
IM (Italian $)			143		

Labor Profile by Fiscal Year WBS 1.2



Pixel Flow Diagram

WBS1.2

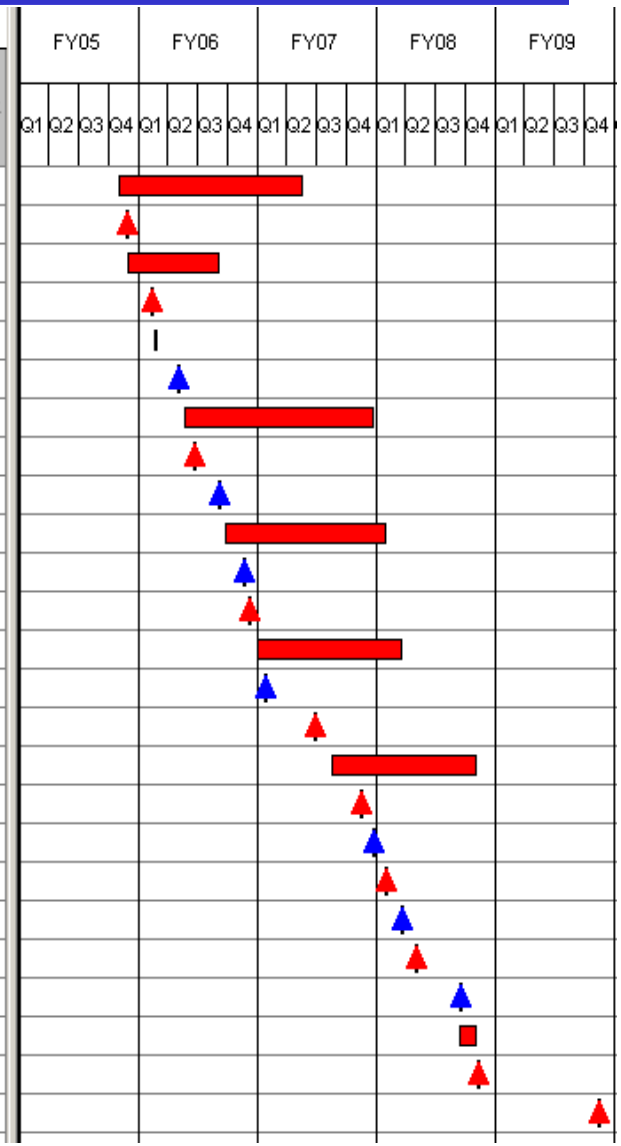


Critical Path Analysis WBS 1.2

- **Detector need-by date: August 17, 2009**
- Scheduled completion date: August 6, 2008 giving a total float of **259** working days
- Pixel Detector will be installed as one piece (vessel with stations inside)
- Pixel Detector has many components but the critical path is the making the pixel modules, placing them on a substrate (half-plane and half-station), and assemble the half-stations into the two half-detectors. This is a sequence of production, assembly and testing steps. Because we have 1380 modules in total, the duration of the each sequence is long (10 months or more). To keep this tight schedule,
  - A lot of staggering in the activities
  - Place the orders early (sensor, ROC, hybridization)
    - DOE CD1 Report: advance the critical component procurement in 2005
  - Multiple paths/vendors
  - Sustain the flow of parts and have more than one assembly/test line/shift
  - Engage qualified vendors early in QA and throughput discussion

Critical Path Gantt Chart WBS1.2

WBS	Activity Desc.	Early Start	Early Finish	Total Float
1.2.1.3.1	Production Sensors - FNAL	02Aug05	16Feb07	295d
1.2.1.3.1.3.6	T2M: Release funds for Production pixel sensors	24Aug05	24Aug05	306d
1.2.2.1.7	PRC Production - FNAL	29Aug05	07Jun06	264d
1.2.2.1.7.8.3	T2M: Release fund for production pixel ROC	10Nov05	10Nov05	319d
1.2.1.3.1.4.2.2	Receive first batch of Production Sensors	22Nov05	28Nov05	305d
1.2.2.1.7.9	T5M: Receive all FPIX wafers	31Jan06	31Jan06	279d
1.2.1.6	Hybridization & Testing of Production Detectors	24Feb06	20Sep07	262d
1.2.1.6.1.2.2	T2M:Release funds for production detector hybridization	21Mar06	21Mar06	262d
1.2.2.1.7.14	T5M: Production PRC completely tested	07Jun06	07Jun06	318d
1.2.4.1.4.8	Assembly and Test of PM	28Jun06	29Oct07	262d
1.2.1.6.1.2.7.2	T5M: first lot of pixel detectors delivered	21Aug06	21Aug06	337d
1.2.1.3.1.6	T4M: Production sensor wafers completely delivered & tested	05Sep06	05Sep06	438d
1.2.4.3.6	Production pixel station assembly	05Oct06	17Dec07	262d
1.2.3.2.3.23	T5M: all substrates ready for module placement	24Oct06	24Oct06	496d
1.2.4.3.6.2.8	T2M: Final pixel detector station assembly started	27Mar07	27Mar07	262d
1.2.4.4.8	Production pixel detector system assembly	22May07	06Aug08	258d
1.2.1.6.1.2.8	T4M: Receive all Production pixel detectors	13Aug07	13Aug07	268d
1.2.1.6.5.4	T5M: All Production pixel detectors delivered & tested	20Sep07	20Sep07	262d
1.2.4.1.4.10	T2M: Production Pixel Module Completed	31Oct07	31Oct07	263d
1.2.4.3.6.8	T5M: All pixel stations assembled	17Dec07	17Dec07	269d
1.2.4.3.7.6	T4M: All pixel stations assembled & tested	29Jan08	29Jan08	262d
1.2.4.4.8.11	T5M: Pixel detector fully assembled & ready for Test	17Jun08	17Jun08	258d
1.2.4.4.8.12	Testing of the assembled detector at SIDET	18Jun08	06Aug08	258d
1.2.7.2.2	T1M-6: Pixel System Tested/ Ready for Installation at C0	07Aug08	07Aug08	258d
1.2.6.4.2.19	Lk4M: Installation Need-by date for Pixel detector	17Aug09	17Aug09	0



Key Milestones With Distributed Float

WBS 1.2

Milestone	Date
T2M-3: Contract awarded for production pixel sensors	Nov 9, 2005
T2M-2: Contract awarded for production pixel readout chips	Jan 24, 2006
T1M-4: Contract awarded for production pixel detector hybridization	Jul 10, 2006
T3M-13: Vacuum System designed & approved for construction	Jul 24, 2007
T3M-14: Final pixel detector assembly started	Oct 12, 2007
T3M-15 Pixel modules completed (assembly & testing)	Apr 11, 2008
T1M-6: Pixel detector tested & ready to be shipped to C0	May 9, 2009

Need-by Date: August 17, 2009

Pixel Detector Risk Analysis WBS1.2

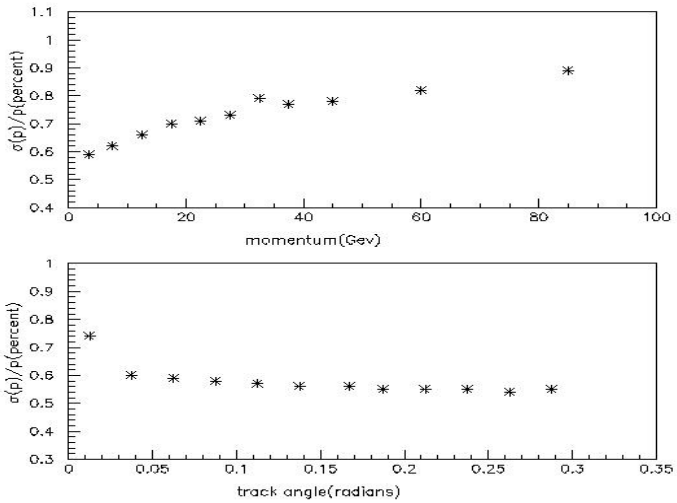
Risks	Mitigation strategy
Bump bonding vendors not available or have unacceptable yield or throughput	Identify more vendors. Keep close contact with LHC experiments and have information about their schedule and vendors
Cannot achieve the vacuum required due to gas load much bigger than expected and we don't have enough space for larger pumps or cryopanels	Repeat outgassing test with a model which includes close to final components and full size FTB. Prototype the cryopumps
Pixel temperature control, cooling, and vacuum system do not work as designed.	We have put in our plan a system demonstrator program that will happen early in the construction phase to study this and various failure modes.

Responses to CD1 recommendations WBS1.2

- Develop more conservative schedule with significant more float (> 6 months)
  - **We have followed their recommendation. By moving a few procurements forward and move back the detector need-by date, we have achieved a float of about 1 year.**
- Evaluating options for relaxing the funding profile constraints to achieve a more conservative approach
  - **DONE. We have increased the funding for FY05 to move up the production of sensors and speed up the module development.**
- Evaluate schedule and performance impact of staging options
  - **While we believe that the experiment will work with an efficiency of about 60% with say ½ of the pixel stations, to complete the installation of the other half of the pixel detector will lead to a long shutdown, estimated to be about 6 months or longer and with considerable risk to the forward tracking stations (which need to be removed first before the pixel vacuum vessel can be taken out). After careful consideration, we think that it's better to assign resources to guarantee the completion of the pixel detector on schedule and not pursue the staging option.**

Technical Description of Straw Tracker WBS1.6

- **Straws: chosen because of of small cell size (segmentation)**
- **Uses Atlas design as basis**
- **0.8% Xo per station**
- **Tracking resolution: 150μm/view**
- **Momentum resolution better than 1% over full momentum and angle range**



Momentum resolution

Straw size	4 mm, 8mm diameter
Central dead region	26 cm x 26 cm
Number of Stations	7
Z positions (cm)	96, 138, 196, 288, 332, 382, 725
Active Half size (cm)	27.2, 40.8, 61.2, 88.4, 102, 115.6, 197.2
Views per station	3
Layers per view	3
Total number of straws	26784
Total station thickness	0.8% X_0
Total channels	53568
Readout	ASDQ + TDC(8 bits), sparsified

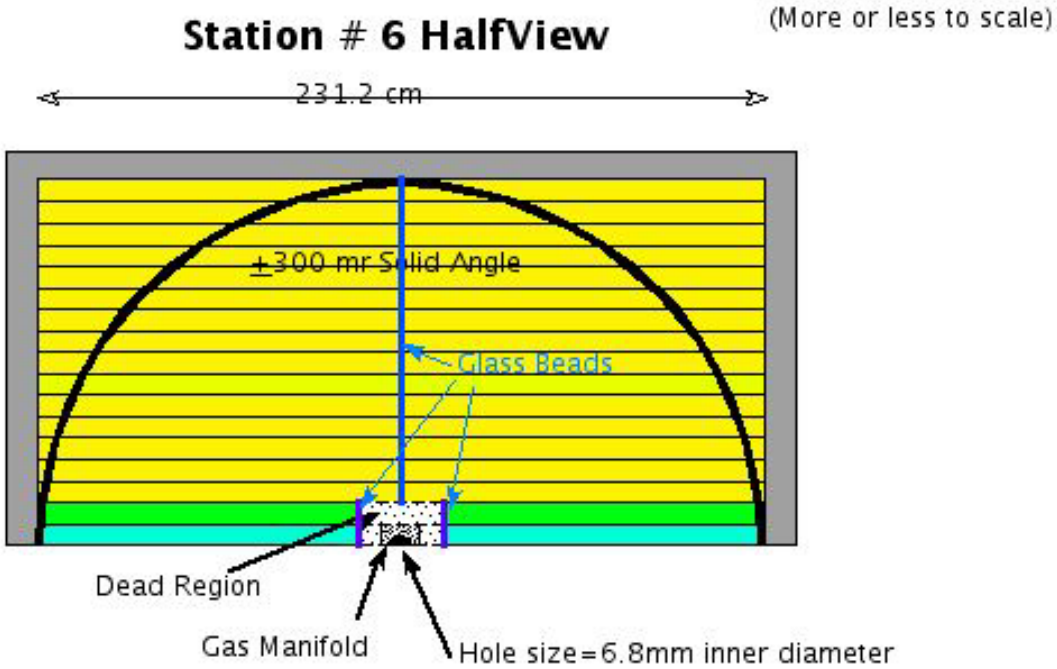
Straw Components WBS 1.6

- 1.6.1 - Straw Detectors (7 stations)
  - the physical Detector.
- 1.6.2 - Straw Electronics-
  - includes front-end electronics, High and Low Voltage power supplies and cables.
- 1.6.3 - "Other" Mechanical Subsystems
  - Gas system, temperature control…
- 1.6.4 - Hardware and Software specific to Straw Detector
  - Test Stations with database connections
  - Fast Interlocks and Slow Controls
- 1.6.5 - Management

Base cost: $10.0M (Material: $5.0M, Labor: $5.0M)

Straw Detector – "half-view"

Assembled in groups of 48 straws - Modules



17 modules/HalfView
Mod type 1=96 straws (short straw)
Mod type 2=48 straws
Mod type 3=720 straws

Mod type 1 (96 4mm diameter Straws, gas Manifold and 27 cm dead region)

Mod type 2 (48 4mm diameter Straws, 27 cm dead region)

Mod type 3 (48 4mm diameter Straws)

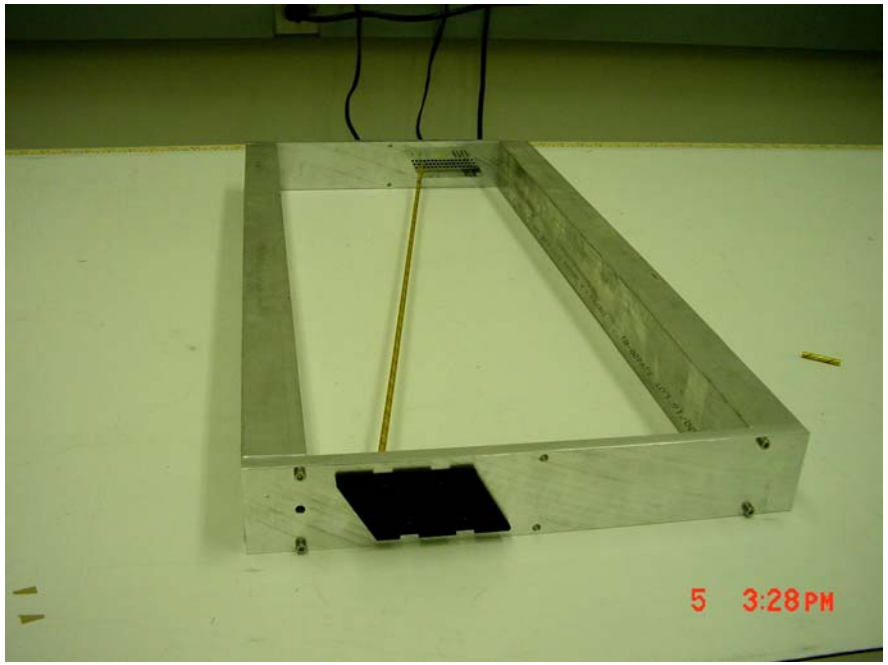
total=864 straws

4mm modules have 3 planes of 16 straws

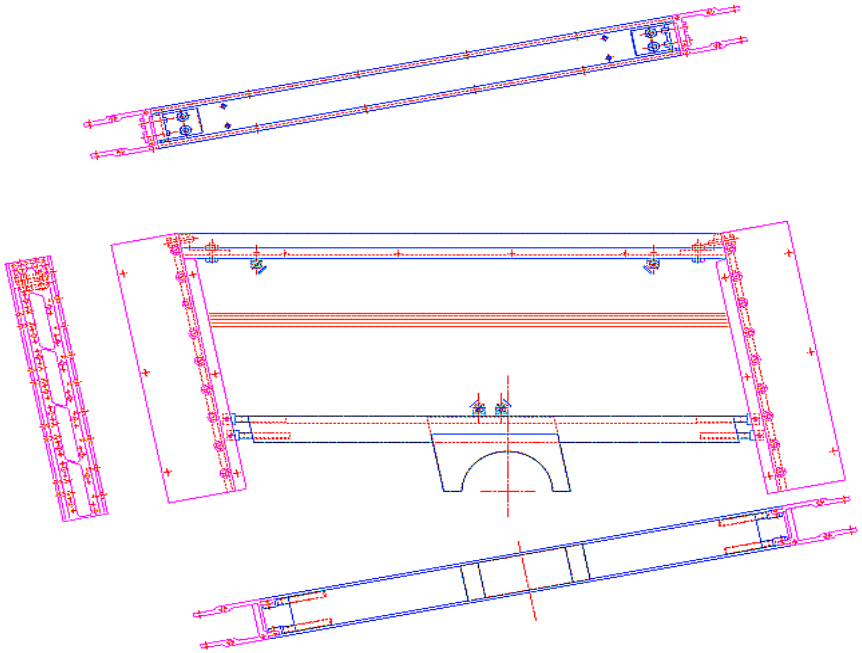
module is 6.8cm high (6.4 mm straws+2mm gap each side)

Straw Detector Stations 1 & 2

Straw Length =54 cm
384 Straws/View
1152 Straws/station

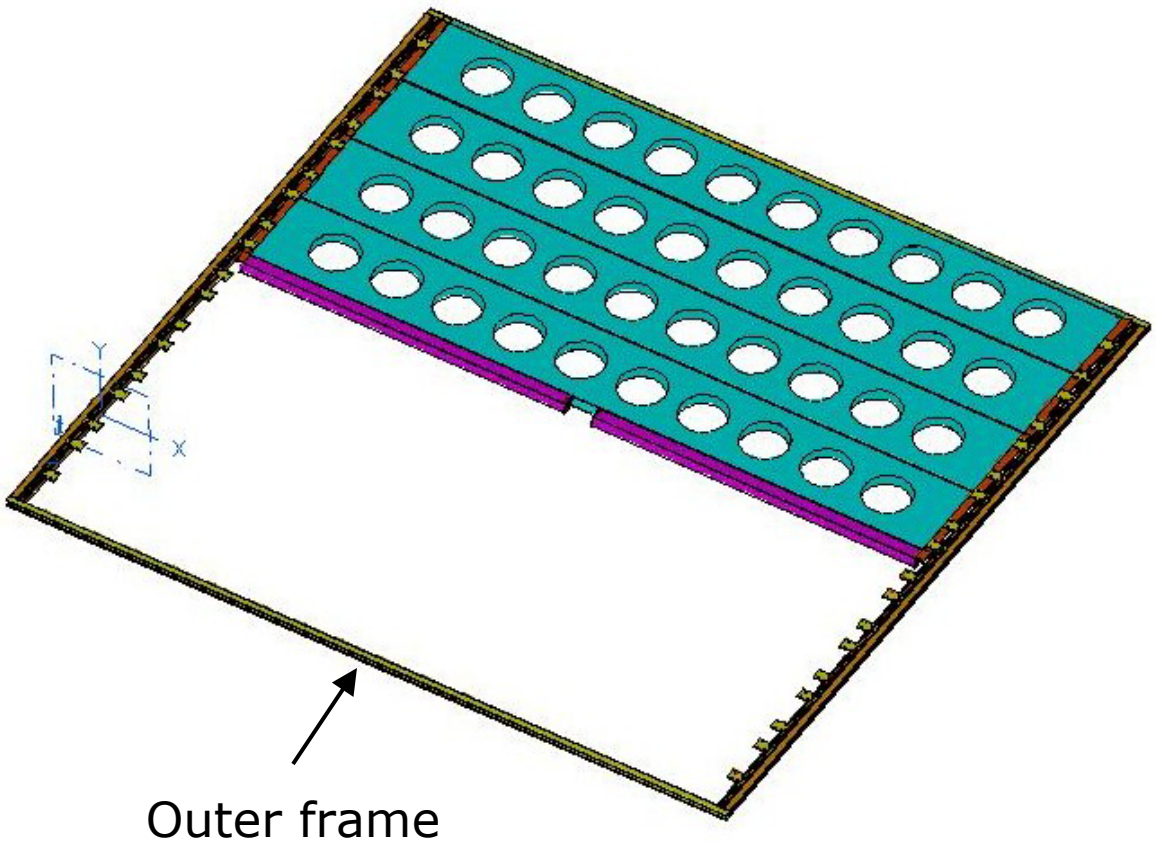


Station 1 "Prototype" Frame



Station #1 U,V HalfView Frame.
X View is simple rectangular shape

Station 7 – View Outer Frame (One VIEW)



Outer frame

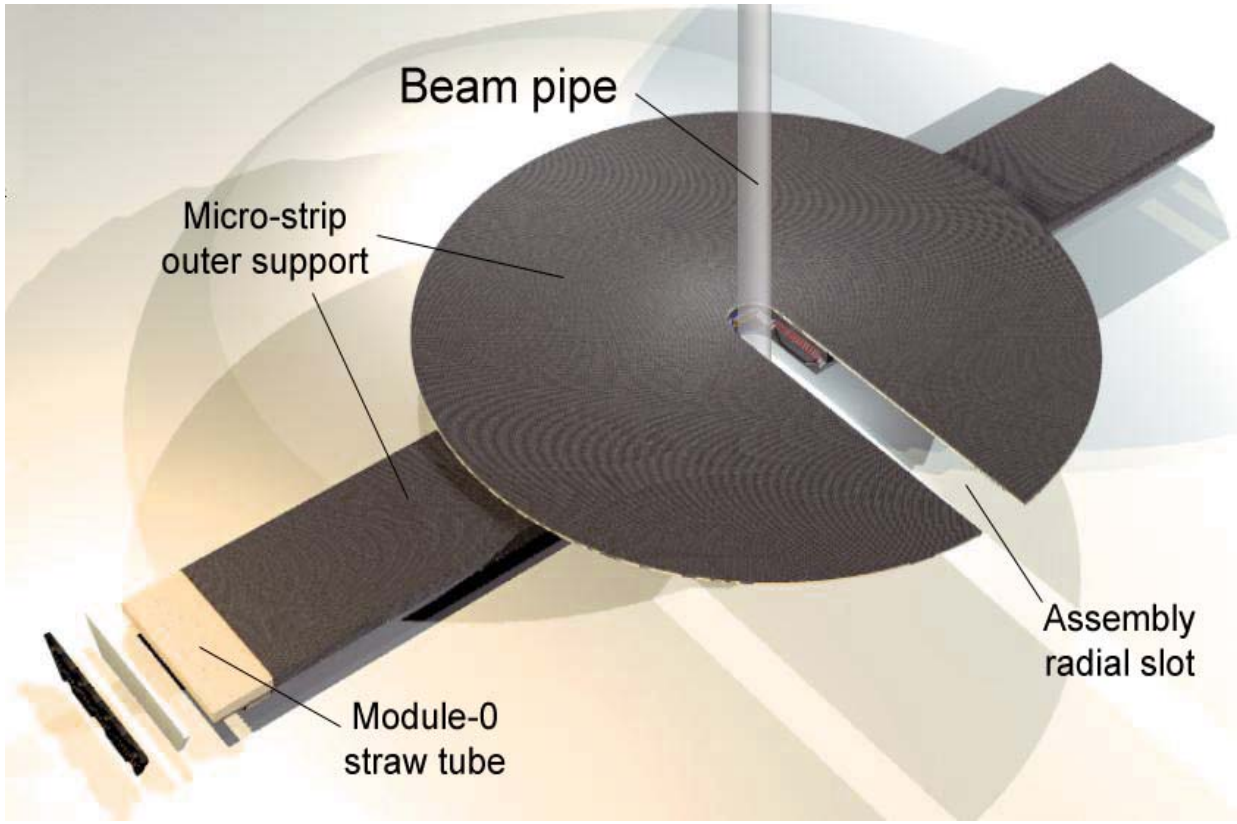
- Station 7 constructed of super-modules
- Super-module attached at ends to Outer Frame
- Outer Frame supports and aligns super-modules
- Each Outer frame supported individually from above by connecting rods

Straw MOX module – Silicon Support

New Straw module designed at Frascati to support the forward Silicon stations. Replaces the 2 modules in X-view that surround the beam-pipe. Supported independently of Straw station

Straws are embedded in rohacell so no tension needed to keep them straight. Module has carbon fiber shell.

Carbon fiber disk is attached for Silicon support



Straw Detector Participants WBS 1.6

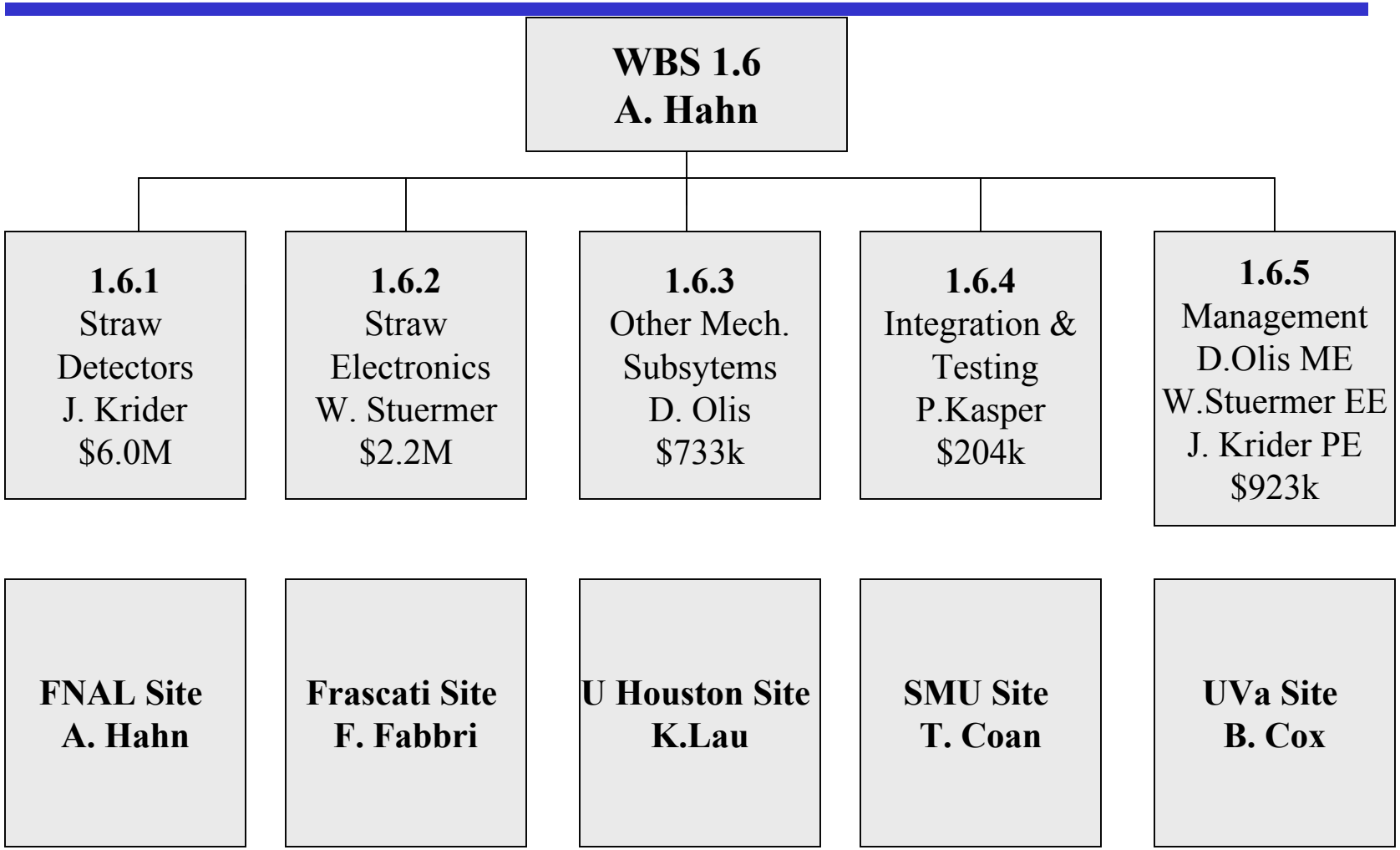
- **Fermilab: A.A. Hahn, P. Kasper, H. Cease, J. Howell, J. Krider, A. Lee, D. Olis, T. Tope, W. Stuermer, C. Serritella, Z.Shi, D. Butler, B. Pritchard, Y. Orlov**
- **Frascati: F. Bellucci, M. Bertani, L. Benussi, S. Bianco, M. A. Caponero, F. Fabbri, F. Felli, M. Giardoni, G. Mensitieri, A. La Monaca, E. Pace, M. Pallotta, A. Paolozzi, B. Ortenzi**
- **Southern Methodist University: T. Coan, M. Hosack**
- **University of Houston: K. Lau, B. Mayes, G. Xu, S.Subramania, A. Daniel, M.Ispiryan**
- **University of Virginia: M. Arenton, S. Conetti, B. Cox, A. Ledovskoy, M.Ronquest, D. Smith, D. Phillips, H. Powell, W. Stephens**

-Physicist

-Grad Students

- Technical staff

Straw Organization WBS 1.6

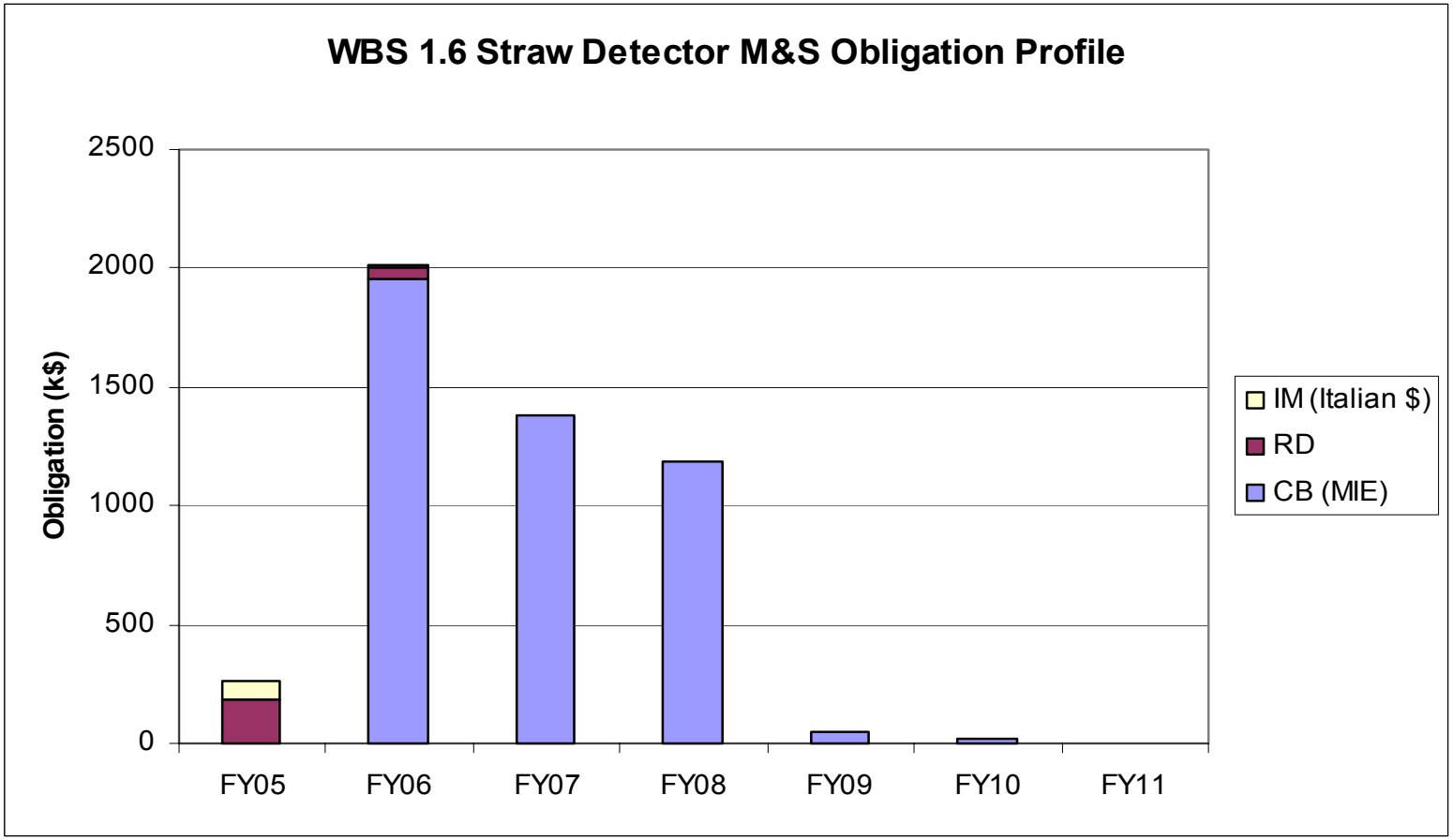


Base cost: $10.0M (Material:$5.0M, Labor:$5.0M)

Straw Tracker Construction Cost WBS 1.6

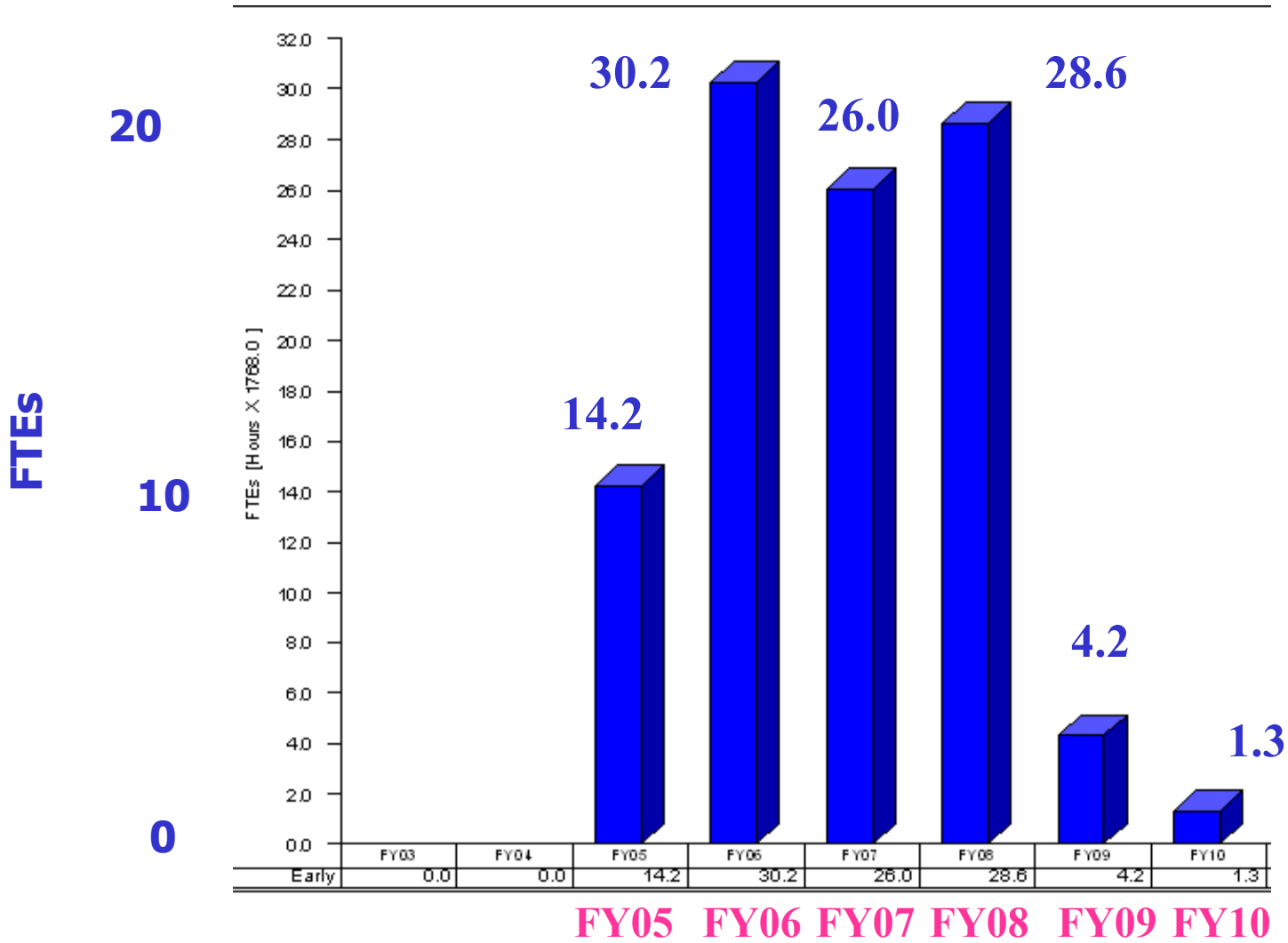
Activity ID	Activity Name	Base Cost ($)	Material Contingency (%)	Labor Contingency (%)	Total FY05	Total FY06	Total FY07	Total FY08	Total FY09	Total FY10	Total FY05-10
1.6.1	Straw Chambers	6,010,806	23	28	381,426	2,942,786	2,180,499	1,946,006	92,419	0	7,543,136
1.6.2	Straw Detector Electronics	2,168,546	27	36	456,470	894,403	985,464	486,232	8,652	0	2,831,221
1.6.3	Mechanical Gas Calibration & Other Support Systems (FNAL SMU)	733,011	30	37	40,769	199,303	170,646	553,044	18,213	0	981,975
1.6.4	Integration & Testing (all)	204,034	31	87	59,302	95,979	69,900	41,058	19,039	0	285,277
1.6.5	Forward Tracker Straw Detector Subproject Management	923,474	22	10	110,421	265,672	272,819	265,672	71,115	44,500	1,030,201
1.6	file_16S_13Sep04	10,039,870	25	28	1,048,389	4,398,143	3,679,327	3,292,013	209,438	44,500	12,671,810

M&S Obligation Profile by Fiscal Year WBS 1.6

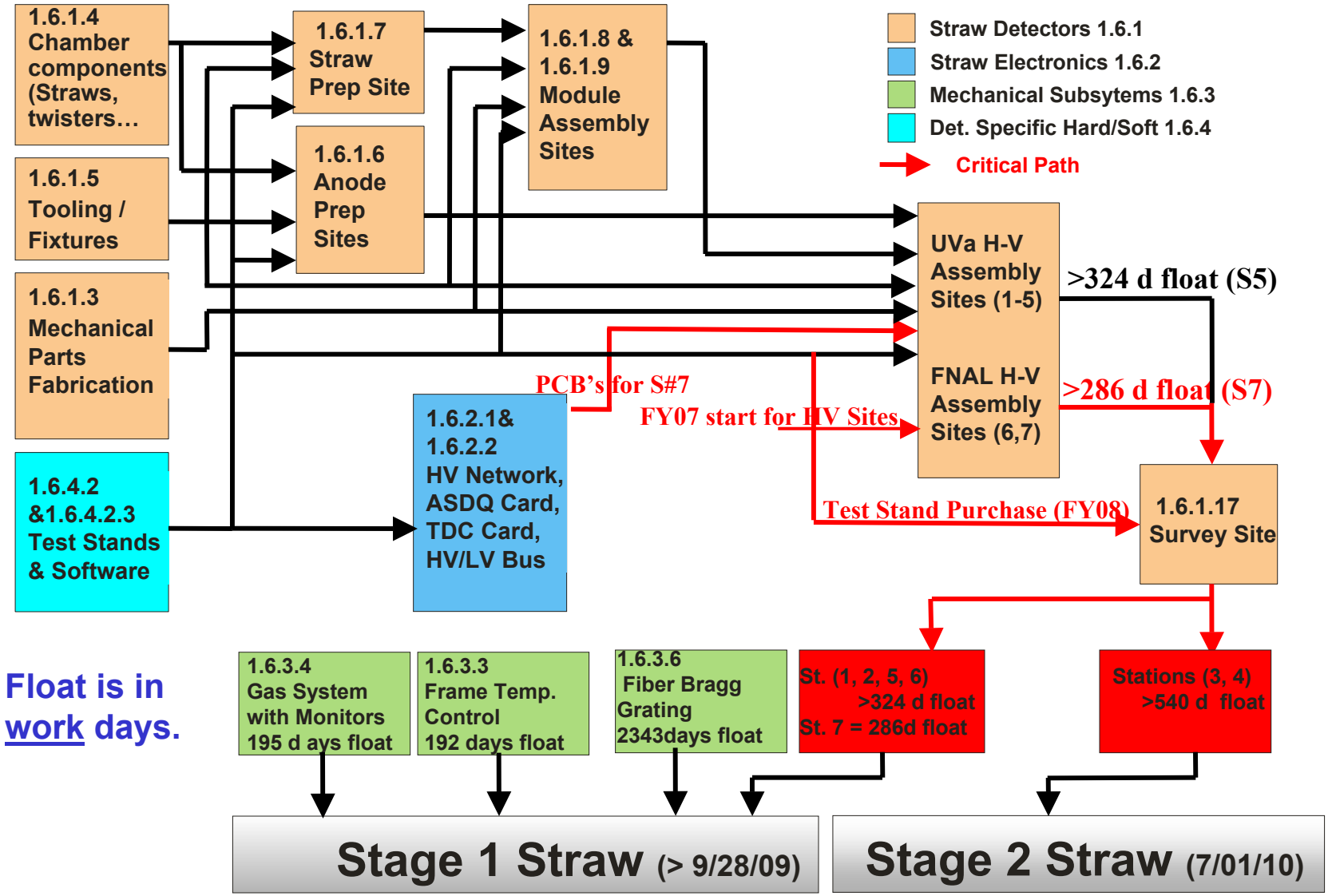


	FY05	FY06	FY07	FY08	FY09	FY10
CB (MIE)		1959	1382	1189	49	15
RD	184	42				
IM (Italian	77	10				

Labor Profile by Fiscal Year WBS 1.6



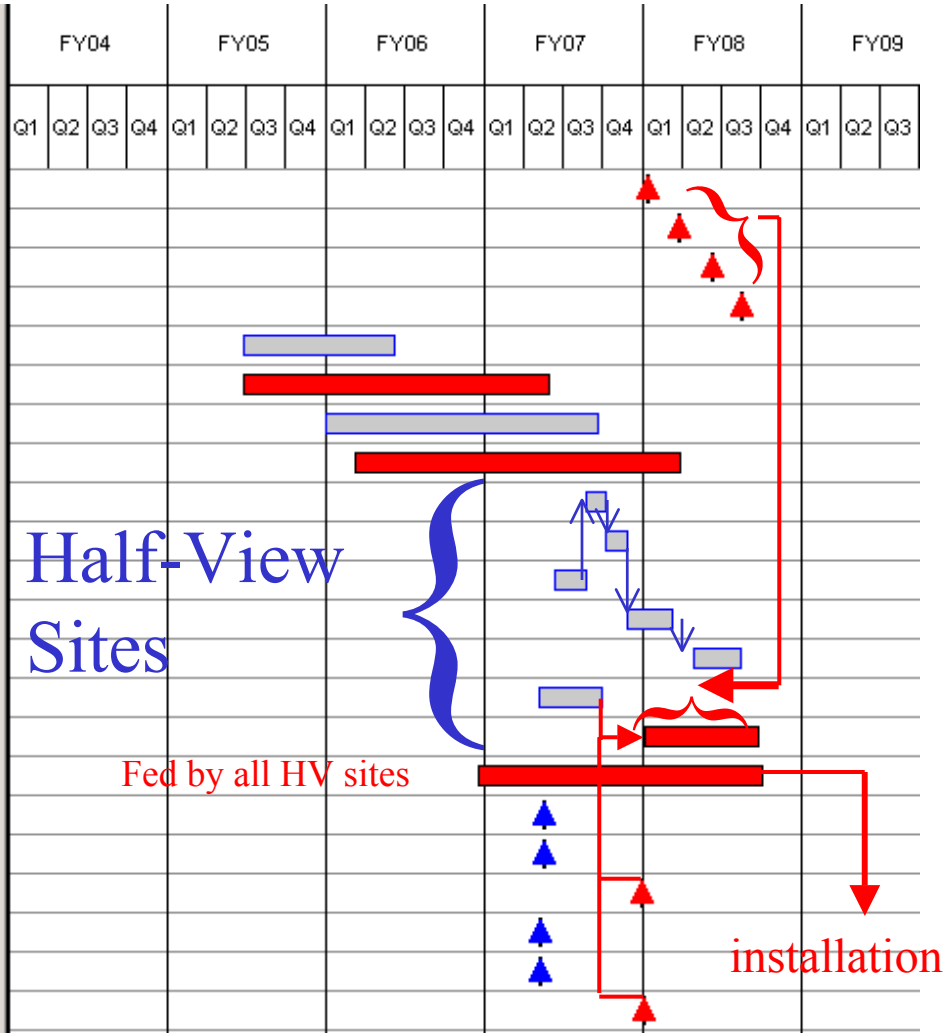
Description of Straw Project Flow WBS 1.6



Float is in work days.

WBS 1.6 Staged Gantt Chart

WBS	Activity Desc.	Total Float
1.6.1.3.3.3.2.16	T5M: S#7 Supermodules Shells Ready, H-V1,2,3	358d
1.6.1.3.3.3.2.17	T5M:S#7 Supermodules Shells Ready, H-V 4	334d
1.6.1.3.3.3.2.18	T5M: S#7Supermodules Shells Ready,H-V 5	310d
1.6.1.3.3.3.2.19	T5M:S#7 Supermodules Shells Ready,H-V 6	286d
1.6.1.4.1.2	Straw Production Ordering -HOUSTON	390.07d
1.6.1.4.3.2	Wire Centering Device Production Ordering - HOUSTON	324.01d
1.6.1.6	Anode Wire Sites (UVa, SMU)	239.80d
1.6.1.7	Straw Preparation Site (UH)	324.01d
1.6.1.10.1	Straw Station #1 Half-View Assembly Site (UVa)	353.62d
1.6.1.10.2	Straw Station #2 Half-View Assembly Site (UVa)	353.62d
1.6.1.10.3	Straw Station #3 Half-View Assembly Site (UVa)	353.62d
1.6.1.10.4	Straw Station #4 Half-View Assembly Site(UVa)	353.62d
1.6.1.10.5	Straw Station #5 Half-View Assembly Site(UVa)	324.01d
1.6.1.10.6	Straw Station #6 Half-View Assembly Site (FNAL)	378.17d
1.6.1.10.7.2	Straw Station #7 Production - FNAL	286d
1.6.1.11	Survey and Test Station Site (FNAL)	286d
1.6.2.2.1.3.18	T5M: HV Network Card for S#3	369.84d
1.6.2.2.1.3.21	T5M: HV Network Card for S#6	378.17d
1.6.2.2.1.3.22	T5M: HV Network Card for S#7	314.80d
1.6.2.2.2.4.18	T5M: Preamp Board for S#3	376.84d
1.6.2.2.2.4.21	T5M: Preamp Boardfor S#6	385.17d
1.6.2.2.2.4.22	T5M: PDB for S#7	309.80d



Critical Path Analysis WBS 1.6

- Straw Stations ready for Installation
  - Critical path is primarily set by funding profile
    - FY05
      - Continue Design Work
        - » Frames, Front End Electronics, TDC ASIC….
    - FY06
      - Start major procurements
        - Straws, Twisters, ASDQ's,…
      - Start Anode, Straw, and Module Production Sites.
    - FY07
      - Start Half View Assembly Sites
      - Production of Front End Electronics
  - The current production scheme builds (S3,S4,S1,S2,S5) and (S6, S7) at two parallel Half View production sites.
    - The production time scales are set by various assumptions on assembly lines (2/site) and a single shift. These assumptions (# sites, # assembly lines, # shifts, and order of station production) could be changed.

Straw Level 3 Milestones + WBS1.6

WBS1.6	Forward Straw Tracker	Date
1.6.7.4.1	T3M-38:PO Awarded: Production ASDQ Chips *	October 10, 2005
1.6.7.4.2	T3M-39:ASDQ Procurement completed	August 3, 2006
1.6.7.4.3	T3M-40:Straw Preparation Site Functional	March 7, 2006
1.6.7.4.4	T3M-41: Half-View Production/ Assembly Sites Functional	February 7, 2007
1.6.7.4.5	T3M-42: Station 1 ready for Installation *	April 3, 2008
1.6.7.4.6	T3M-43: Station 7 ready for Installation	August 26, 2008

* Also a Level 2 Milestone

+ With distributed Float

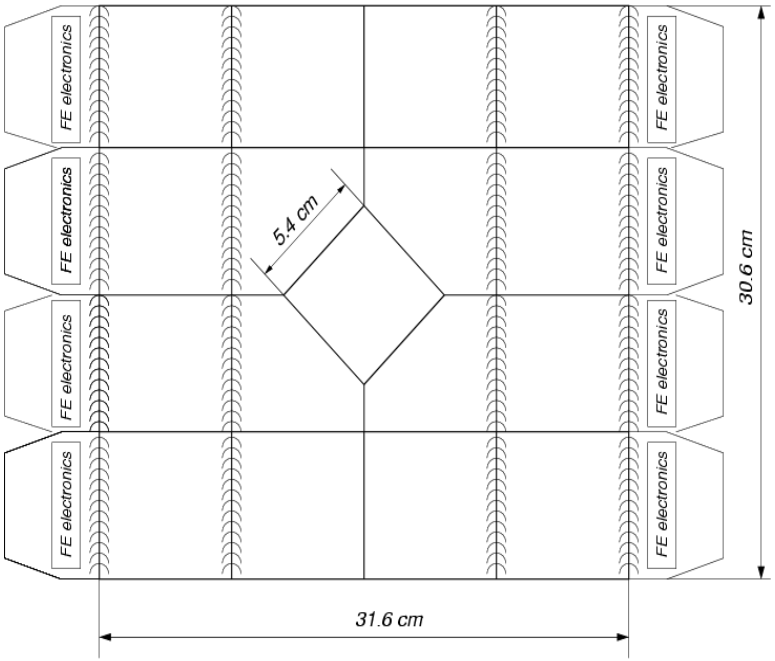
Responses to CD1 recommendations WBS1.6

- Select the straw material, straw diameter, and wire diameter within this year. Clear work plan should be provided.
  - **We will acquire new Copperized Kapton Straws and subject them to radiation tests. We will also test 30 μm Anode wire (currently use 25 μm wire). We will set up a work plan.**
- Put Additional Effort into aging test
  - **UH and UVa will test new straw materials (and anodes) and UH, UVa, and SMU have proposal to undertake Rad Damage test at IUCF.**
- Produce more prototypes (preferentially in all production sites) and test. They should be built with production components and tooling as much as possible
  - **This is consistent with our Station 3 prototype effort**
- Move up production schedule by ~6 months
  - **DONE**
- Strengthen management with a project engineer
  - **Production engineer and site managers now added to the org. chart.**

Technical Description of Silicon Tracker WBS1.7

- **Silicon Strips: simple single sided p^+/n design (CMS design)**
- **7 stations**
  - **3 in dipole fringe field**
  - **3 before RICH**
  - **1 after RICH**
- **Coverage from beam pipe to ±15.5cm from the beam**
- **Each station has 3 planes of 320 μm thick SMD with 100 μm pitch**
- **Each detector is 7.9 cm x 7.9 cm**
- **Four detectors form one ladder with readout at both ends**
- **New readout chip (FSSR) using 0.25μm CMOS; 1st prototype tested**
- **2nd prototype submission planned for early next year**

Property	Value
Silicon Sensors	$\sim 7.9 \times 7.9\ cm^2$, p-on-n type
Pitch	$100\ \mu m$
Thickness	$320\ \mu m$
Sensor configuration	4 ladders with 4 sensors each
Coverage	$30.6 \times 31.6\ cm^2$
Central Hole	$5.4 \times 5.4\ cm^2$ ($7 \times 7\ cm^2$ for last station)
Total Stations	7
Z Positions	85.5, 127.5, 185.5, 277.5, 321.5, 371.5, 714.5
Views per Station	3 (X,U,V)
Channels per view	6,144
Total Channels	129,024
Readout	Sparsified Binary

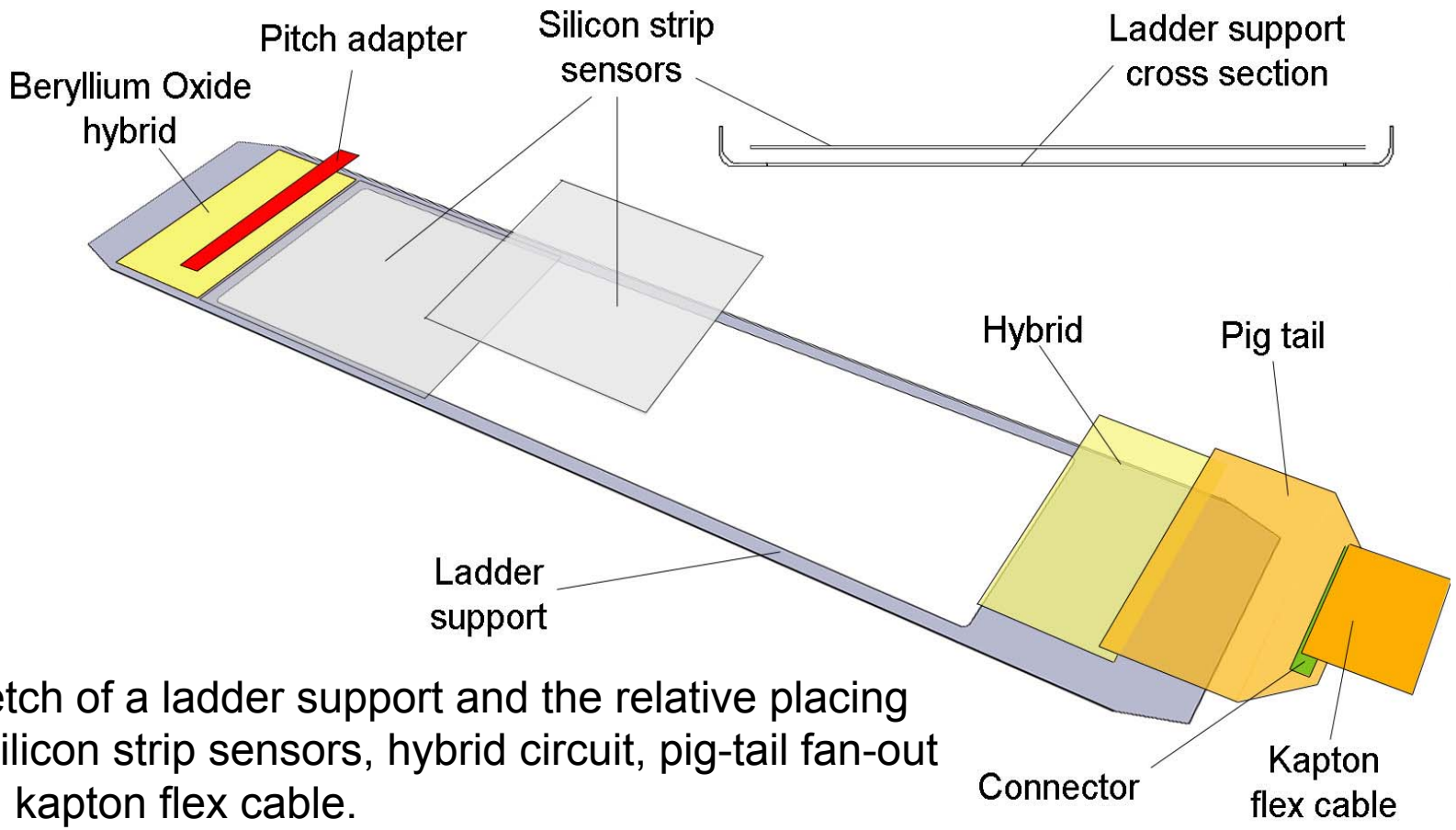


Silicon Strip Components WBS 1.7

Base cost: $7.5M (Material: $3.7M, Labor: $3.8M)

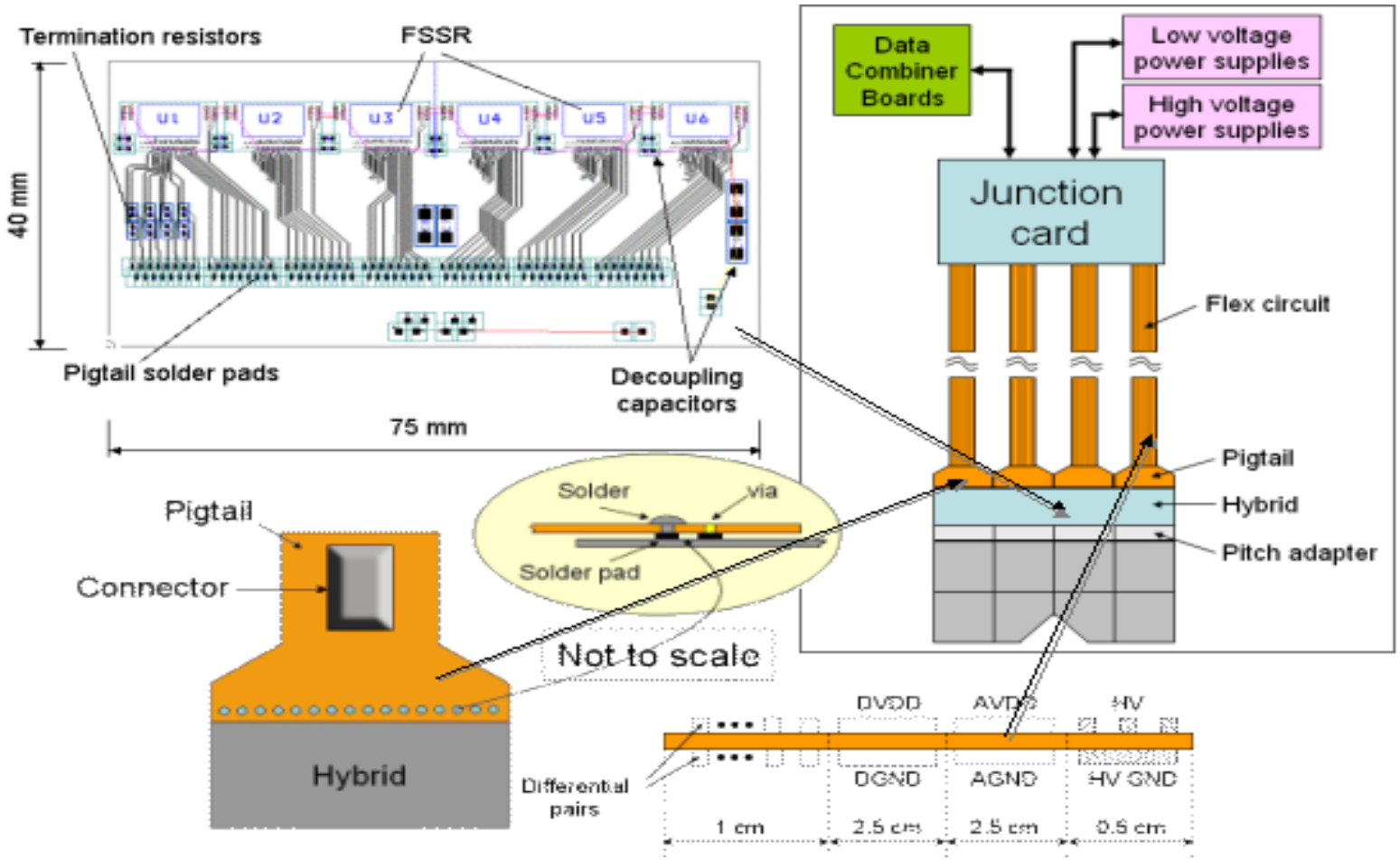
- Sensors
- Readout Chips
- Electronics Packaging & DA
  - Hybrids, Flex's, Junction Cards, Power Supplies, Cabling and DCB's
- Mechanics
  - Inner & Outer Supports
- Cooling
- Ladder Assembly
- System Integration & Testing
  - Detector Prototypes & Tests, Control & Monitor, Detector Specific Software

Silicon Strip Detector Ladder WBS1.7

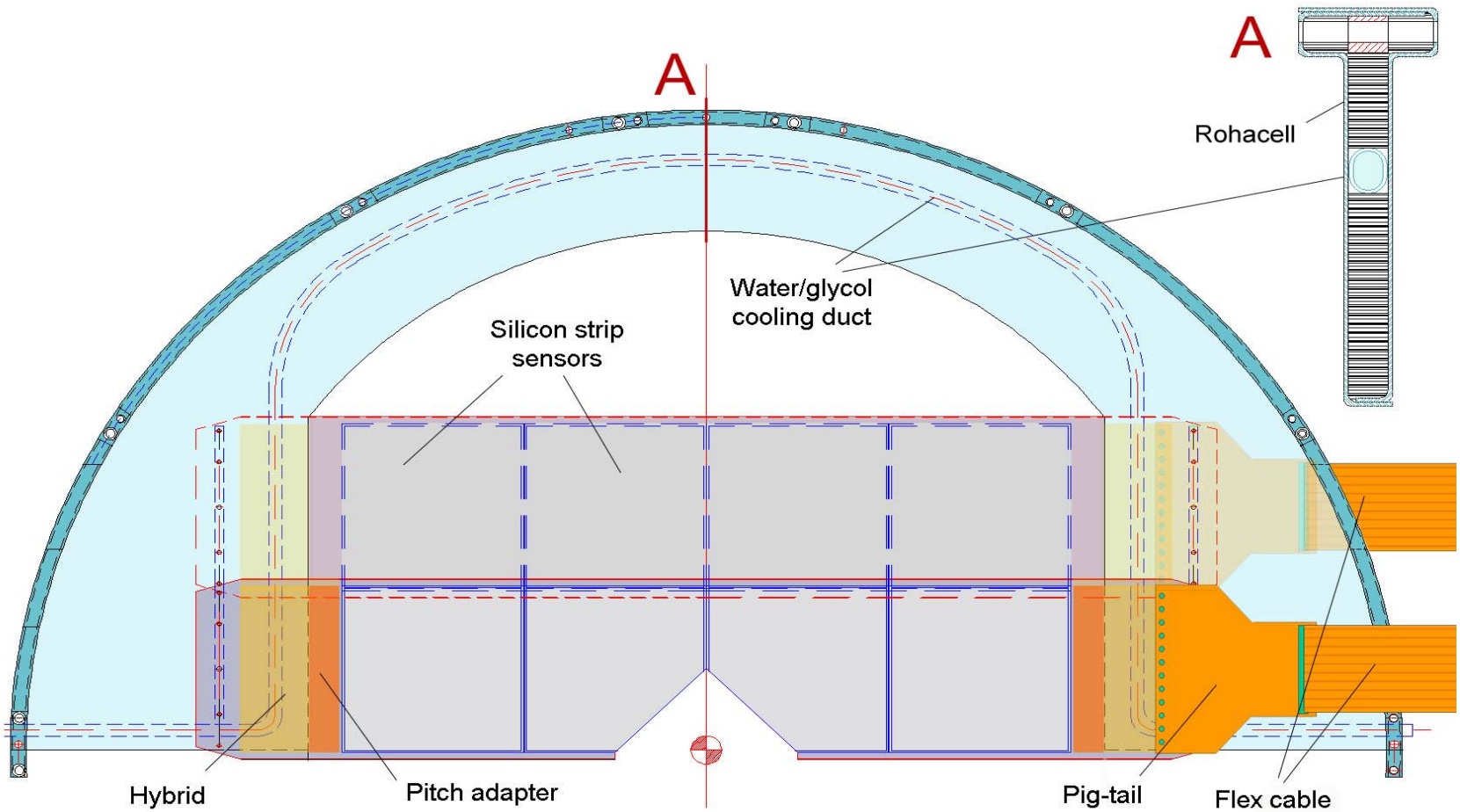


Sketch of a ladder support and the relative placing of silicon strip sensors, hybrid circuit, pig-tail fan-out and kapton flex cable.

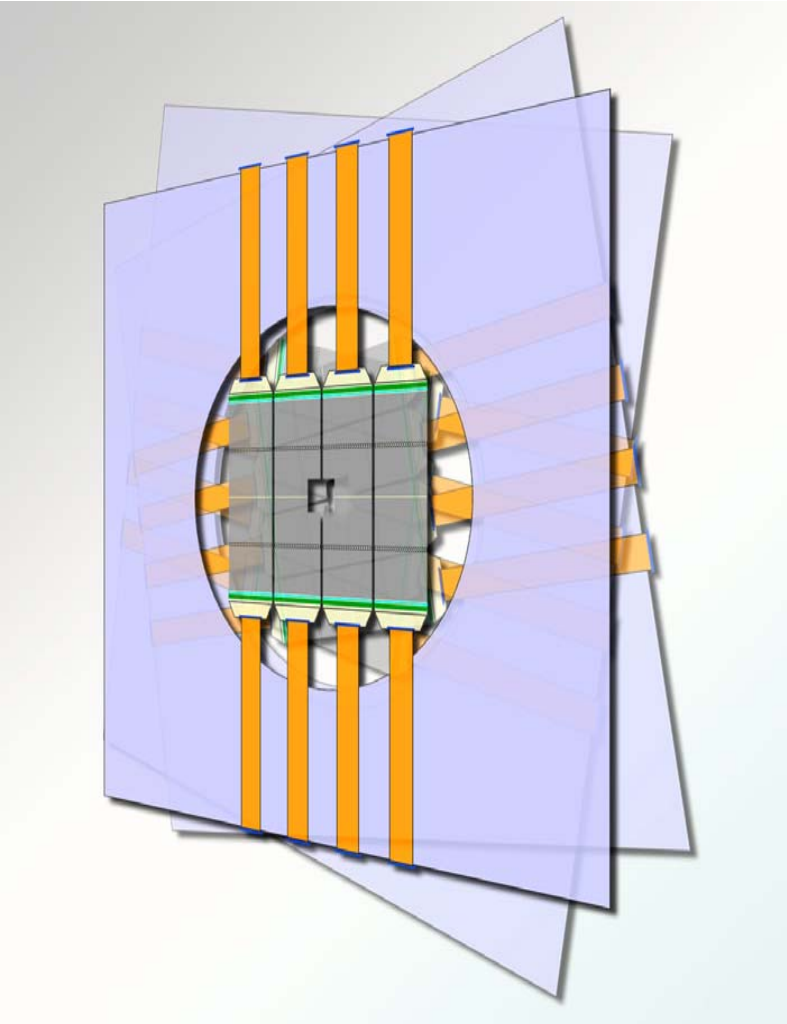
Benefit from CDF RUN IIB experience



Silicon Strip Detector Half Plane Support



Silicon Strip Stations WBS1.7



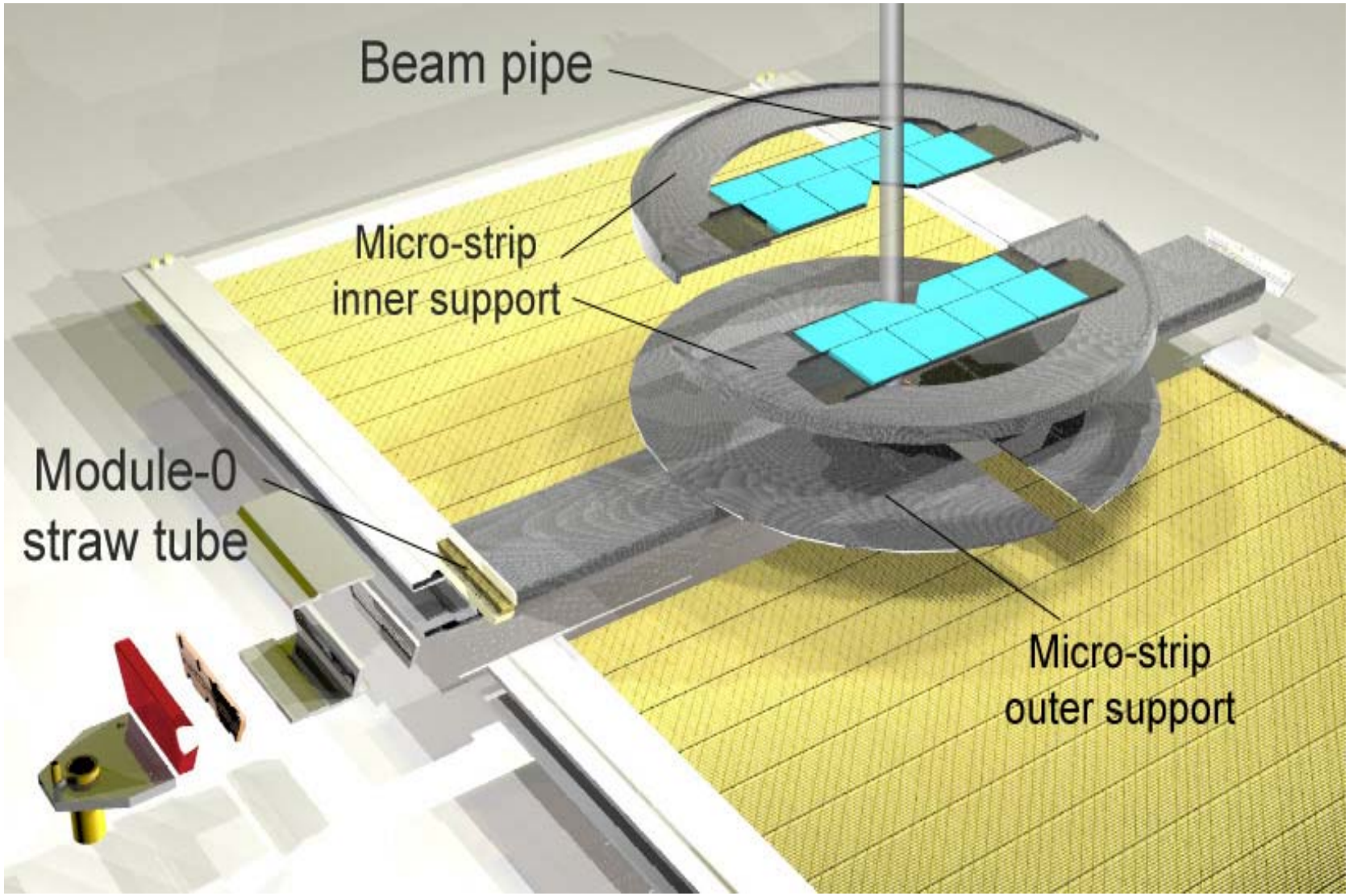
3 views:

X: 0° (horizontal)

U: 90° + 11.3°

V: 90° – 11.3°

Forward Tracker Station Assembly



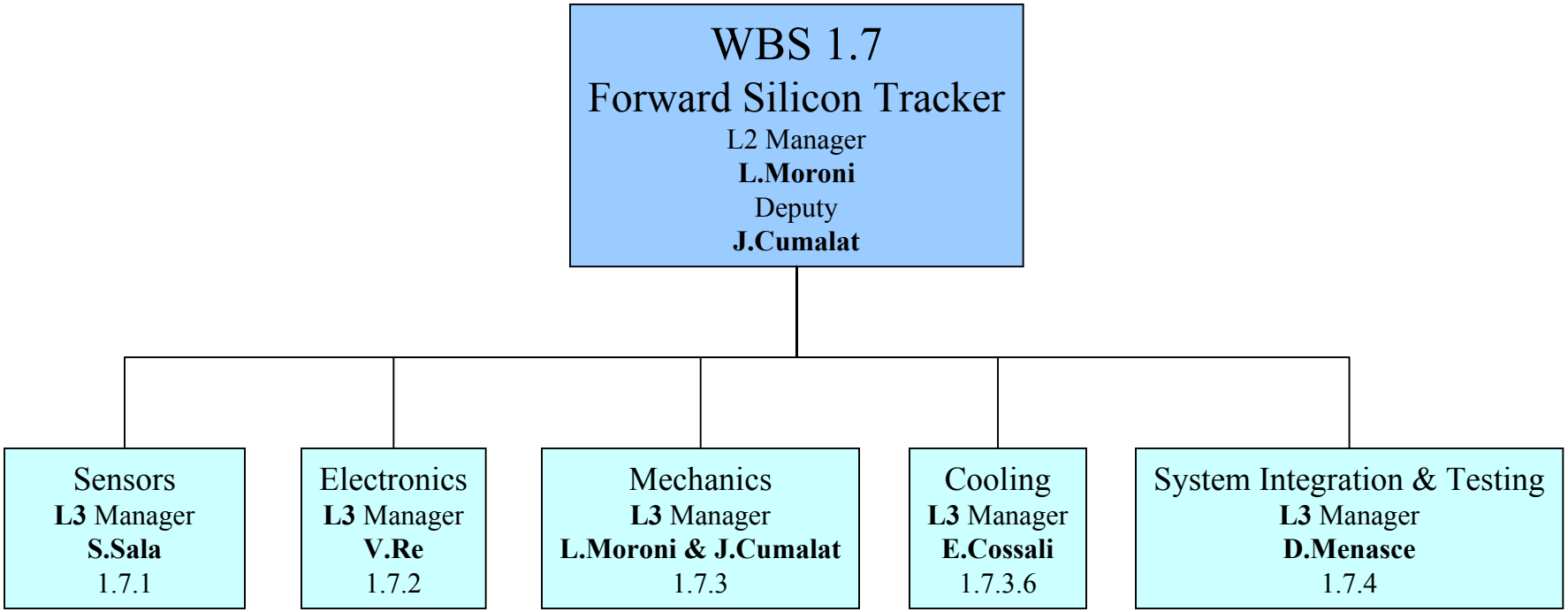
Silicon Tracker Participants WBS 1.7

- Colorado University: J.Cumalat, P.Rankin, Eric Erdos
- Fermilab: J. Andresen, G. Cardoso, C. Gingu, J. Hoff, M. Hrycyk, A. Mekkaoui, R. Yarema, J. Andresen, K. Knickerbocker, A. Dyer
- Frascati: M. Caponero, D. Colonna, A. Paolozzi, F. Fabbri, S. Bianco
- Insubria University: P. Ratcliffe, M. Rovere
- INFN Milano: G. Alimonti, M. Citterio, S. Magni, D. Menasce, L. Moroni, D. Pedrini, S. Sala, S. Erba, P. D'Angelo, S. Latorre, M.Malatesta
- INFN Pavia: G.E. Cossali, P.F. Manfredi, M. Manghisoni, M. Marengo, L. Ratti, V. Re, M. Santini, V. Speziali , D. Di Pietro, G. Traversi , K. Fisher, L. D'Angelo

-Physicist

- Technical staff

Silicon Tracker Organization WBS 1.7

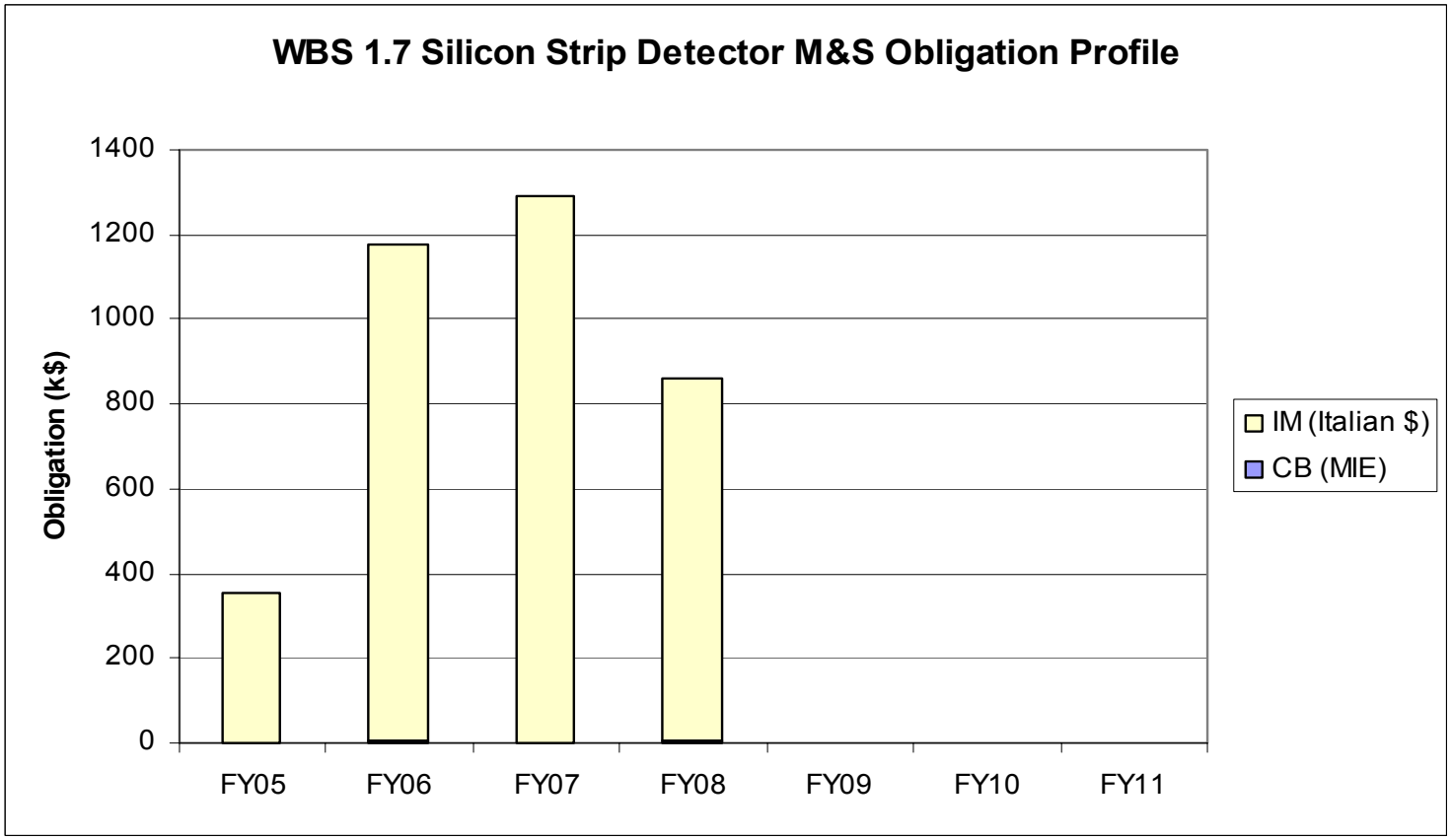


Base cost: $7.3M (Material: $3.7M, Labor: $3.6M)

Silicon Tracker Construction Cost WBS1.7

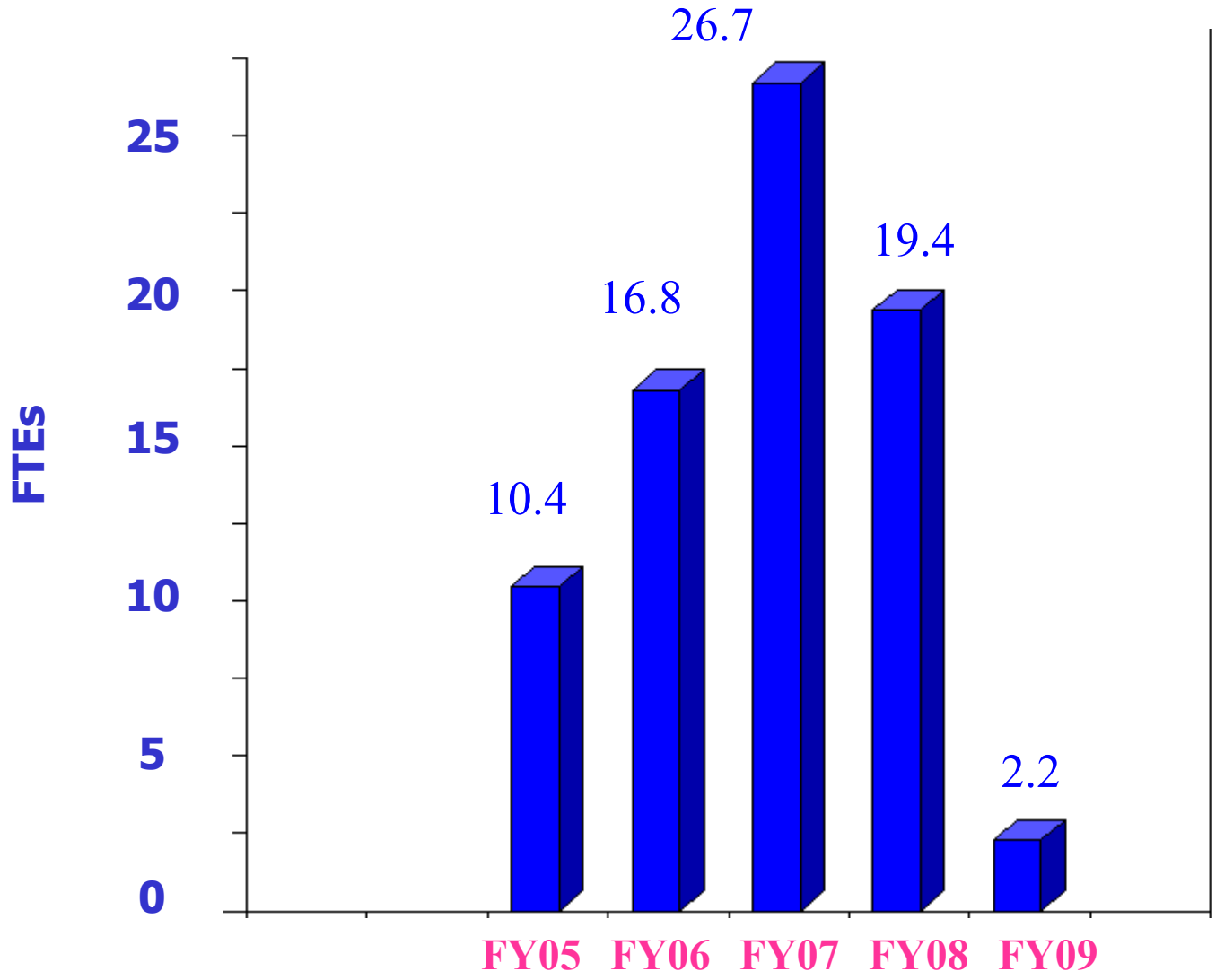
Activity ID	Activity Name	Base Cost ($)	Material Contingency(%)	Labor Contingency(%)	Total FY05	Total FY06	Total FY07	Total FY08	Total FY09	Total FY05-09
1.7.1	Sensors (SM)	1,077,577	25	28	0	183,406	178,085	986,953	0	1,348,444
1.7.2	Electronics	2,541,242	31	27	270,456	902,624	1,128,043	966,869	5,465	3,273,456
1.7.3	Mechanics & Cooling	1,150,348	53	39	104,380	492,320	410,540	626,359	47,843	1,681,442
1.7.4	Integration	2,094,197	45	36	499,604	536,546	506,700	1,239,501	121,300	2,903,651
1.7.5	Detector Subproj Mgmt	462,468	30	27	59,044	165,454	163,507	156,598	45,509	590,113
1.7.6	Milestones	0	0	0	0	0	0	0	0	0
1.7	file_17S_080604	7,325,832	35	32	933,484	2,280,350	2,386,874	3,976,280	220,117	9,797,106

M&S Obligation Profile by Fiscal Year WBS1.7

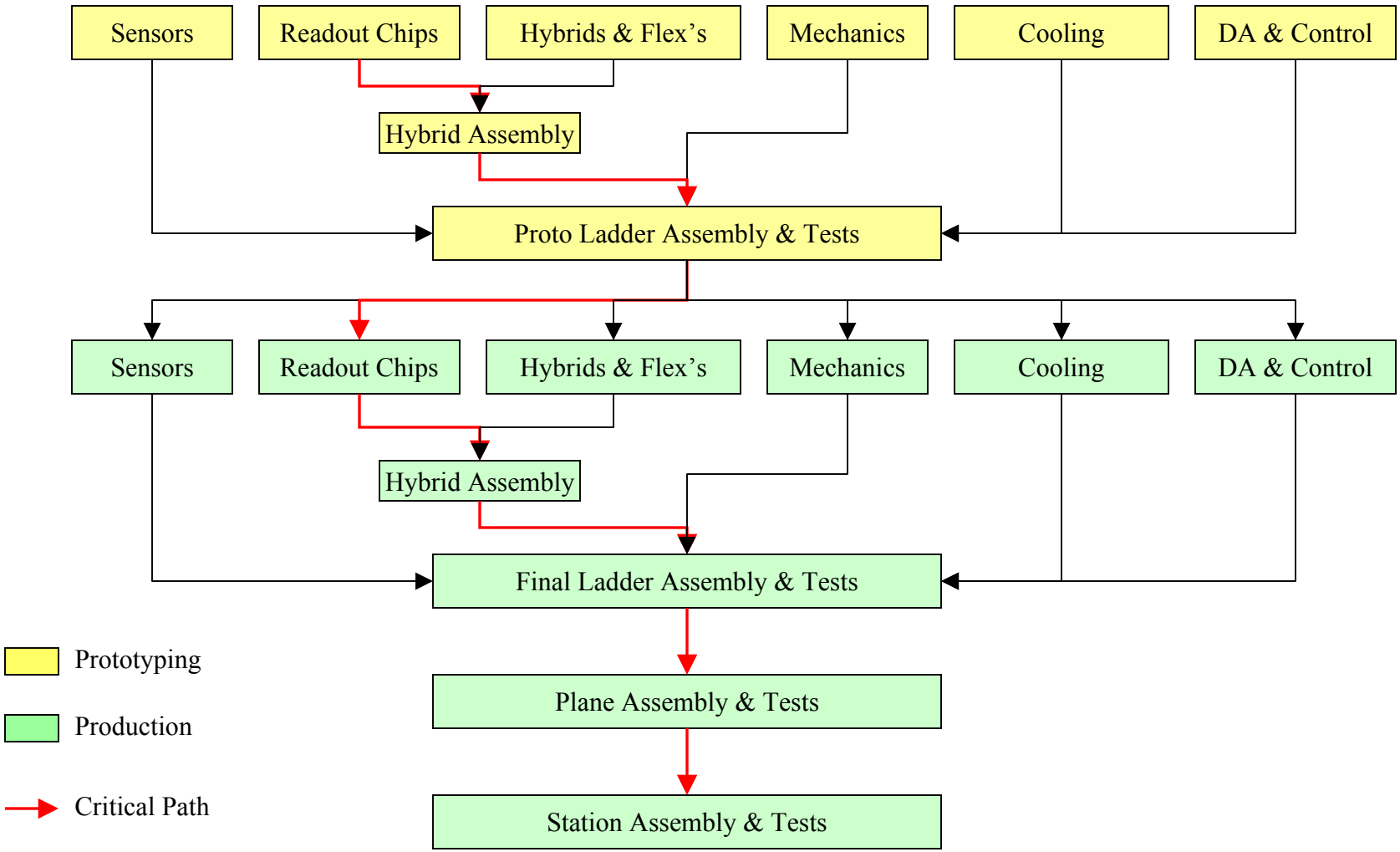


	FY05	FY06	FY07	FY08	FY09
CB (MIE)		4		4	
RD					
IM (Italian	354	1171	1290	855	

Labor Profile by Fiscal Year WBS 1.7



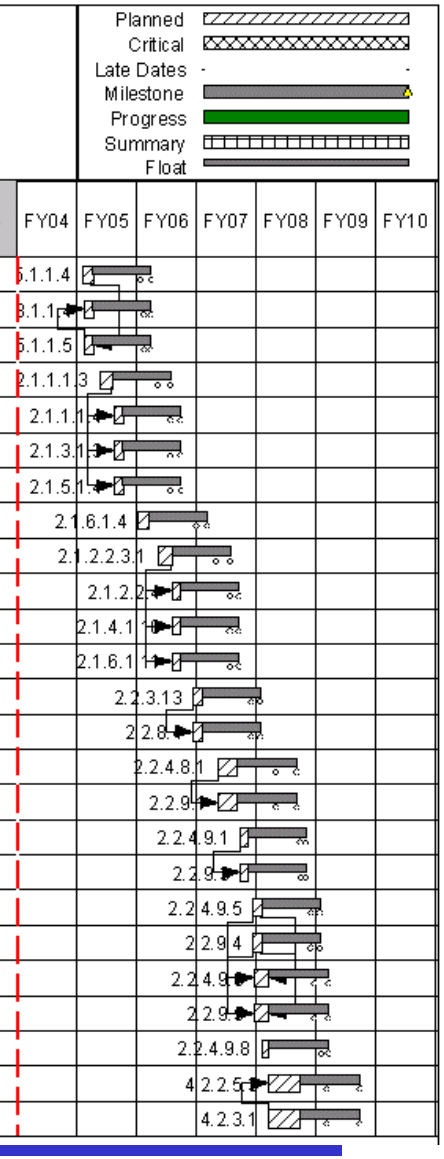
Description of Project Flow WBS 1.7



Gantt Chart for Strip Detector WBS1.7

BTeV - WBS 1.7 Forward Tracker Strip Detector
Barchart for Critical Path Analysis
Sorted by Float

Activity ID	Activity Description	Activity Type	Duration	Float	Early Start	Early Finish	Late Start
2.1.5.1.1.4	Layout Pass Two IC Des	ASAP	40d	247d	05Nov04	07Jan05	01Nov05
2.1.3.1.1.4	Sim Layout, Incorporate Des Changes & Revise Doc, as necessa	ASAP	30d	247d	19Nov04	07Jan05	15Nov05
2.1.5.1.1.5	Sim Layout, Incorporate Des Changes & Revise Doc, as necessa	ASAP	30d	247d	19Nov04	07Jan05	15Nov05
2.1.1.1.3	Vend Manfucture & Del Pass Two Protos	ASAP	60d	247d	21Feb05	13May05	08Feb06
2.1.1.1.4	Test Pass Two IC Protos	ASAP	40d	247d	16May05	12Jul05	03May06
2.1.3.1.3	Test Pass Two IC Protos	ASAP	40d	247d	16May05	12Jul05	03May06
2.1.5.1.4	Test Pass Two IC Protos	ASAP	40d	247d	16May05	12Jul05	03May06
2.1.6.1.4	Layout Final IC Design	ASAP	50d	247d	13Oct05	23Dec05	02Oct06
2.1.2.2.3.1	Vend Manfucture & Del Pre-Prod Run of Final ICs	ASAP	60d	247d	09Feb06	03May06	01Feb07
2.1.2.2.4	Test Pre-Prod Run of Final ICs	ASAP	40d	247d	04May06	29Jun06	26Apr07
2.1.4.1.10	Test Pre-Prod Run of Final ICs	ASAP	40d	247d	04May06	29Jun06	26Apr07
2.1.6.1.11	Test Pre-Prod Run of Final ICs	ASAP	40d	247d	04May06	29Jun06	26Apr07
2.2.3.13	Test Assembled Preproduction Hybrids for Station Tests	ASAP	40d	247d	12Sep06	06Nov06	04Sep07
2.2.8.4	Test Assembled Preproduction Hybrids for Station Tests	ASAP	40d	247d	12Sep06	06Nov06	04Sep07
2.2.4.8.1	Manufacture 1st Shipment of Hybrid	ASAP	90d	247d	08Feb07	14Jun07	04Feb08
2.2.9.1	Manufacture 1st Shipment of Hybrid	ASAP	90d	247d	08Feb07	14Jun07	04Feb08
2.2.4.9.1	Manufacture Final Shipment of Hybrid	ASAP	30d	247d	03Jul07	14Aug07	26Jun08
2.2.9.3	Manufacture Final Shipment of Hybrid	ASAP	30d	247d	03Jul07	14Aug07	26Jun08
2.2.4.9.5	Vend Assembles & Tests Hybrids for Ladder Production	ASAP	40d	247d	13Sep07	07Nov07	08Sep08
2.2.9.4	Vend Assembles & Tests Hybrids for Ladder Production	ASAP	40d	247d	13Sep07	07Nov07	08Sep08
2.2.4.9.6	Test Assembled Production Hybrids for Ladder Production	ASAP	60d	247d	27Sep07	21Dec07	22Sep08
2.2.9.5	Test Assembled Production Hybrids for Ladder Production	ASAP	60d	247d	27Sep07	21Dec07	22Sep08
2.2.4.9.8	Prod Hybrids ready for Ladder Assembly	ASAP	30d	247d	08Nov07	21Dec07	03Nov08
4.2.2.5.3	Test Ladder Prod at SiDet	ASAP	138d	247d	17Dec07	03Jul08	10Dec08
4.2.3.1	Assemble & Test Ladders at SiDet	ASAP	138d	247d	17Dec07	03Jul08	10Dec08



Critical Path Analysis Without Distributed Float

- Staged Installation
  - Stage 1: Stations 1, 2, 6, and 5 in FY09 shutdown
  - Stage 2: Rest of the stations in FY10 shutdown
- The shortest Total Float in the Forward Silicon Strip project is 247 days (for FY09 shutdown)
  - i.e. any delay up to 12 months can be absorbed by our schedule without impacting the deadline for installation.
  - Stations that will be installed in FY10 will have a minimum float of 449 days.

Response to CD-1 Review Recommendations WBS1.7

- From CD-1 Report:
  - The silicon strip tracking detector was **found to be in good shape** at the CD-1 review. The positive news about **INFN funding** makes the schedule for the silicon strip tracker **even more robust.**
- Indeed all the funding constraints were removed from the schedule and the float went from 112 days up to 247 days.
  - About 1 year delay can be safely absorbed!

Summary for WBS 1.2, WBS 1.6, and WBS 1.7

More information on the Pixel (WBS 1.2), Straw (WBS 1.6) and Silicon Strip Tracker (WBS 1.7) is available in the breakout sessions.

WBS 1.2

- **Overview – D. Christian**
- **Sensor & hybridization – S. Kwan**
- **Electronics – G. Cardoso**
- **Substrate & half-plane assembly – CM Lei**
- **Vacuum system – H. Cease**
- **Pixel Detector assembly – J. Fast**
- **Test beam – C. Newsom**
- **Cost and Schedule – S. Kwan**

WBS 1.7

- **Overview – L. Moroni**
- **Readout chip – V. Re**
- **Readout electronics – G. Cardoso**
- **FBG sensors for position monitoring – M. Caponero**
- **Cost and Schedule – L. Moroni**

WBS 1.6

- **Activities at University of Houston (K.Lau)**
- **Activities at Frascati (F.Fabbri)**
- **Activities at SMU (T.Coan)**
- **Activities at UVa (B.Cox)**
- **Latest results from Straw Test Beam Run (A.Ledovskoy)**
- **Recent Straw Aging Results (K. Lau)**
- **BTeV Straw Design and Prototyping Efforts (A.Hahn)**
- **BTeV Straw Detector Simulations (P.Kasper)**
- **Straw Response to Lehman CD1 (A.Hahn)**

Conclusion

- The BTeV tracking system has three elements: Pixel vertex detector, forward silicon tracker, and forward straw detector
- For all three detectors:
  - Baseline technical designs exist
  - Organization structure established
  - Detailed WBS leading to a base cost estimate and resource-loaded schedule for the construction of the baseline detector
  - We are ready to move on to the next phase of the project

Backup Slides

Pixel Glossary of Terms
WBS1.2

- HDI – High Density Interconnect
- PIFC – Pixel Interconnect Flex Cable
- FTB – Feed-through Board
- TPG – Thermal Pyrolytic Graphite
- PGS – Pyrolytic Graphite Sheet
- LN2 – Liquid Nitrogen
- LHe – Liquid Helium

Straw Glossary of Terms WBS 1.6

- Module : basic construction unit consisting of 48 straws
- Half-Views: Each Straw Station is made of 3 views (X, U, V). Each View is divided into two "Half-Views", in order to install detector around an existing beam pipe. Each Half-View is an independent working detector.
- ASDQ chip – Amplfier, Shaper, Discriminator and Charge chip; designed by the Upenn group and used in CDF COT
- MOX – Module O (closest to the beam pipe) X view

Silicon Strip Glossary of Terms WBS 1.7

- FSSR: Fermilab Silicon Strip Readout Chip
- DCB: Data Combiner Board (note: Pixel and silicon strip will use the same type of DCB)
- DA: Data Acquisition
- FBG: Fiber Bragg Grating

Key Milestones Without Distributed Float

Milestone	Date
T2M-3: Contract awarded for production pixel sensors	Aug 24, 2005
T2M-2: Contract awarded for production pixel readout chips	Nov 10, 2005
T1M-4: Contract awarded for production pixel detector hybridization	Mar 21, 2006
T3M-13: Vacuum System designed & approved for construction	May 14, 2007
T3M-14: Final pixel detector assembly started	Mar 27, 2007
T3M-15 Pixel modules completed (assembly & testing)	Nov 1, 2007
T1M-6: Pixel detector tested & ready to be shipped to C0	Aug 6, 2008

Need-by Date: August 17, 2009

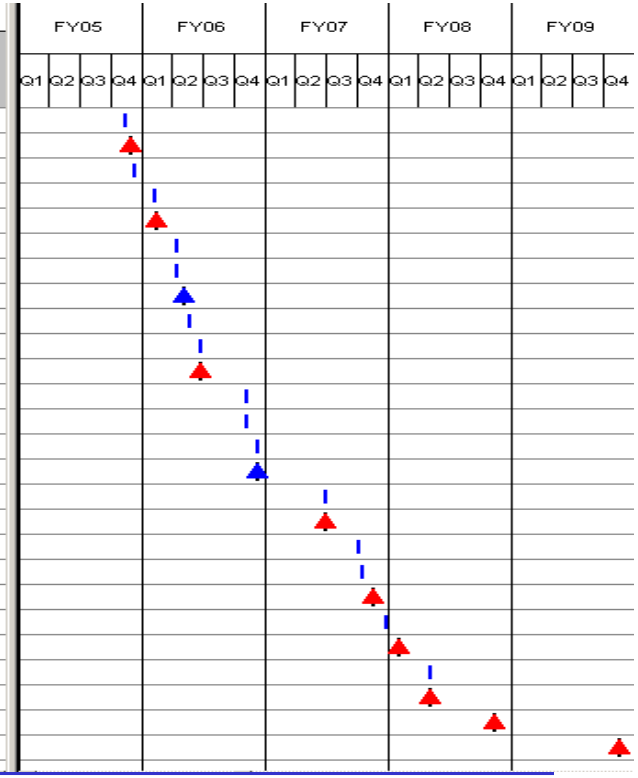
Total Float: 259 days

Schedule Contingtency WBS1.2

- Schedule contingency
  - Placed before key milestones or activities on critical or near critical path
  - Nominally zero duration
  - Distribute float throughout the duration of the project
  - Typically increase duration of activity by 20 to 30%.

11Aug05

WBS	Activity Desc.	Early Start	Early Finish	Sch. Cont.	Total Float
1.2.1.3.1.3.1	SC: Production sensor order schedule contingency task	11Aug05	11Aug05	30d	295d
1.2.1.3.1.3.6	T2M: Release funds for Production pixel sensors	24Aug05	24Aug05		306d
1.2.3.2.2.7.3	SC: Substrate design schedule contingency	06Sep05	06Sep05	50d	291d
1.2.2.1.7.8.1	SC: Production PRC schedule contingency	04Nov05	04Nov05	30d	264d
1.2.2.1.7.8.3	T2M: Release fund for production pixel ROC	10Nov05	10Nov05		319d
1.2.1.3.1.4.2.7	SC: Production sensor delivery schedule contingency task	10Jan06	10Jan06	30d	334d
1.2.1.3.1.5.2.7	SC: Production sensor delivery schedule contingency task	11Jan06	11Jan06	30d	438d
1.2.2.1.7.9	T5M: Receive all FPIX wafers	31Jan06	31Jan06		279d
1.2.1.5.2.1.1	SC: Pre-Production pixel detectors test schedule contingency	17Feb06	17Feb06	20d	182d
1.2.1.6.1.1.1.6	SC: Production detector hybridization procurement contingency task	21Mar06	21Mar06	20d	262d
1.2.1.6.1.2.2	T2M:Release funds for production detector hybridization	21Mar06	21Mar06		262d
1.2.4.1.4.7.4	SC: Production pixel module assembly/test schedule contingency	03Aug06	03Aug06	30d	363d
1.2.3.6.3.10.3	SC: Cooling system design schedule contingency	04Aug06	04Aug06	50d	369d
1.2.1.3.1.5.3.7	SC: Production sensor schedule contingency	05Sep06	05Sep06	30d	438d
1.2.1.3.1.6	T4M: Production sensor wafers completely delivered & tested	05Sep06	05Sep06		438d
1.2.4.3.6.2.7	SC: Pixel station assembly schedule contingency	27Mar07	27Mar07	30d	262d
1.2.4.3.6.2.8	T2M: Final pixel detector station assembly started	27Mar07	27Mar07		262d
1.2.4.4.8.2.4	SC: Pixel half-detector assembly/test schedule contingency	03Jul07	03Jul07	20d	268d
1.2.1.6.1.2.7.5.4	SC: Production detector hybridization delivery schedule contingency	16Jul07	16Jul07	60d	289d
1.2.1.6.1.2.8	T4M: Receive all Production pixel detectors	13Aug07	13Aug07		268d
1.2.1.6.5.3	SC: Production pixel detector testing schedule contingency task	20Sep07	20Sep07	20d	262d
1.2.4.1.4.10	T2M: Production Pixel Module Completed	31Oct07	31Oct07		263d
1.2.4.3.7.5	SC: Pixel station test schedule contingency	29Jan08	29Jan08	15d	262d
1.2.4.3.7.6	T4M: All pixel stations assembled & tested	29Jan08	29Jan08		262d
1.2.7.2.2	T1M-6: Pixel System Tested/ Ready for Installation at C0	07Aug08	07Aug08		258d
1.2.6.4.2.19	Lk4M: Installation Need-by date for Pixel detector	17Aug09	17Aug09		0

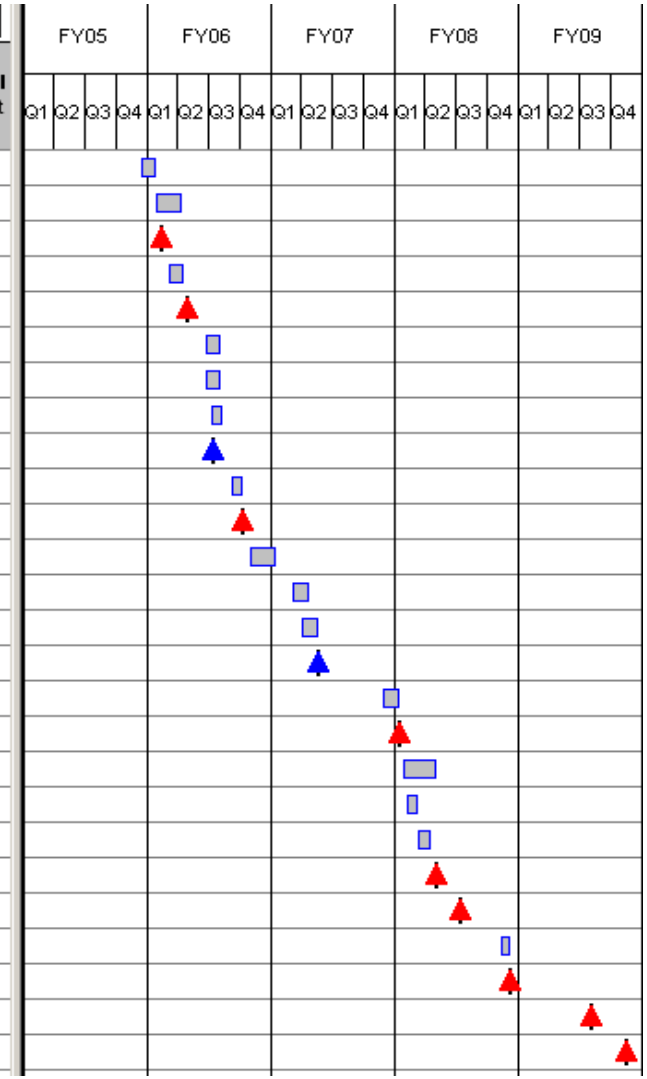


Critical Activities Gantt Chart With Distributed Float WBS1.2

25Oct05

WBS	Activity Desc.	Early Start	Early Finish	Sch. Cont.	Total Float
1.2.1.3.1.3.1	SC: Production sensor order schedule contingency task	14Sep05	25Oct05	30d	118d
1.2.3.2.2.7.3	SC: Substrate design schedule contingency	01Nov05	11Jan06	50d	166d
1.2.1.3.1.3.6	T2M: Release funds for Production pixel sensors	08Nov05	08Nov05		122d
1.2.2.1.7.8.1	SC: Production PRC schedule contingency	06Dec05	16Jan06	30d	82d
1.2.2.1.7.8.3	T2M: Release fund for production pixel ROC	23Jan06	23Jan06		137d
1.2.1.3.1.4.2.7	SC: Production sensor delivery schedule contingency task	24Mar06	04May06	30d	138d
1.2.1.3.1.5.2.7	SC: Production sensor delivery schedule contingency task	27Mar06	05May06	30d	212d
1.2.1.5.2.1.1	SC: Pre-Production pixel detectors test schedule contingency	11Apr06	08May06	20d	72d
1.2.2.1.7.9	T5M: Receive all FPIX wafers	11Apr06	11Apr06		116d
1.2.1.6.1.1.1.6	SC: Production detector hybridization procurement contingency task	09Jun06	07Jul06	20d	72d
1.2.1.6.1.2.2	T2M:Release funds for production detector hybridization	10Jul06	10Jul06		72d
1.2.3.6.3.10.3	SC: Cooling system design schedule contingency	04Aug06	13Oct06	50d	264d
1.2.4.1.4.7.4	SC: Production pixel module assembly/test schedule contingency	07Dec06	22Jan07	30d	166d
1.2.1.3.1.5.3.7	SC: Production sensor schedule contingency	04Jan07	15Feb07	30d	212d
1.2.1.3.1.6	T4M: Production sensor wafers completely delivered & tested	15Feb07	15Feb07		212d
1.2.4.3.6.2.7	SC: Pixel station assembly schedule contingency	30Aug07	11Oct07	30d	72d
1.2.4.3.6.2.8	T2M: Final pixel detector station assembly started	11Oct07	11Oct07		72d
1.2.1.6.1.2.7.5.4	SC: Production detector hybridiza				72d
1.2.4.4.8.2.4	SC: Pixel half-detector assembly/test schedule contingency	08Nov07	07Dec07	20d	123d
1.2.1.6.5.3	SC: Production pixel detector testing schedule contingency task	12Dec07	14Jan08	20d	105d
1.2.1.6.1.2.8	T4M: Receive all Production pixel detectors	01Feb08	01Feb08		72d
1.2.4.1.4.10	T2M: Production Pixel Module Completed	11Apr08	11Apr08		103d
1.2.4.3.7.5	SC: Pixel station test schedule contingency	14Aug08	04Sep08	15d	72d
1.2.4.3.7.6	T4M: All pixel stations assembled & tested	04Sep08	04Sep08		72d
1.2.7.2.2	T1M-6: Pixel System Tested/ Ready for Installation at C0	06May09	06May09		72d
1.2.6.4.2.19	Lk4M: Installation Need-by date for Pixel detector	17Aug09	17Aug09		0

T2M: Final pixel detector station assembly started



Straw Risk Analysis WBS1.6

Risk Event	Mitigation
Major Construction Problems with Half View Production	The best strategy is to have a robust production prototype construction so that we can identify production problems before we actually enter production. A standby strategy is to have backup sites which could contribute to Half-View production once their original function is accomplished. For example, once the Straw Preparation Facility has finished, it could convert to a Half-View Assembly site.
Process to produce ASDQ chips is shutdown, by the time our budget profile allows us to place order.	We need to identify a source of funds that allows us to commit to a wafer run as early in the project as possible-while the current wafer process still exists. We could delay the packaging to later in the project timeline, when more funds become available.

Straw Level 2&3 Milestones + WBS1.6

WBS1.6	Forward Straw Tracker	Date
1.6.7.4.1	T3M-38:PO Awarded: Production ASDQ Chips *	October 10, 2005
1.6.7.4.2	T3M-39:ASDQ Procurement completed	August 3, 2006
1.6.7.4.3	T3M-40:Straw Preparation Site Functional	March 7, 2006
1.6.7.4.4	T3M-41: Half-View Production/ Assembly Sites Functional	February 7, 2007
1.6.7.4.5	T3M-42: Station 1 ready for Installation *	April 3, 2008
1.6.7.4.6	T3M-43: Station 7 ready for Installation	June 12, 2008

* Also a Level 2 Milestone

+ without Distributed Float

Risk Analysis

- Risks

  1. 0.25μm CMOS process disappears before we go into production

- Mitigation

  1. Work with multiple vendors. Keep in close contact with vendors to understand their future plans.

Key Milestones WBS 1.7
Without Distributed Float

Milestone	Date
T3M-44 Sensor accepted for full production	Jan 10, 2007
T3M-45: Production sensors received and tested	Oct 18, 2007
T3M-46: Readout IC approved for production	Aug 3, 2006
T3M-48: Production ICs Received tested and thinned	Feb 8, 2007
T3M-49: Hybrids approved for production	Nov 13, 2006
T3M-50: Hybrids complete and tested	Jan 3, 2008
T3M-51: Station support procurement complete	Oct 3, 2008
T3M-52: Ladder production 100% Complete	Jul 8, 2008
T3M-53: First FSIL station ready to be installed in C0	Aug 27, 2008
T3M-54: Last FSIL station ready to be installed in C0	Sep 15, 2008