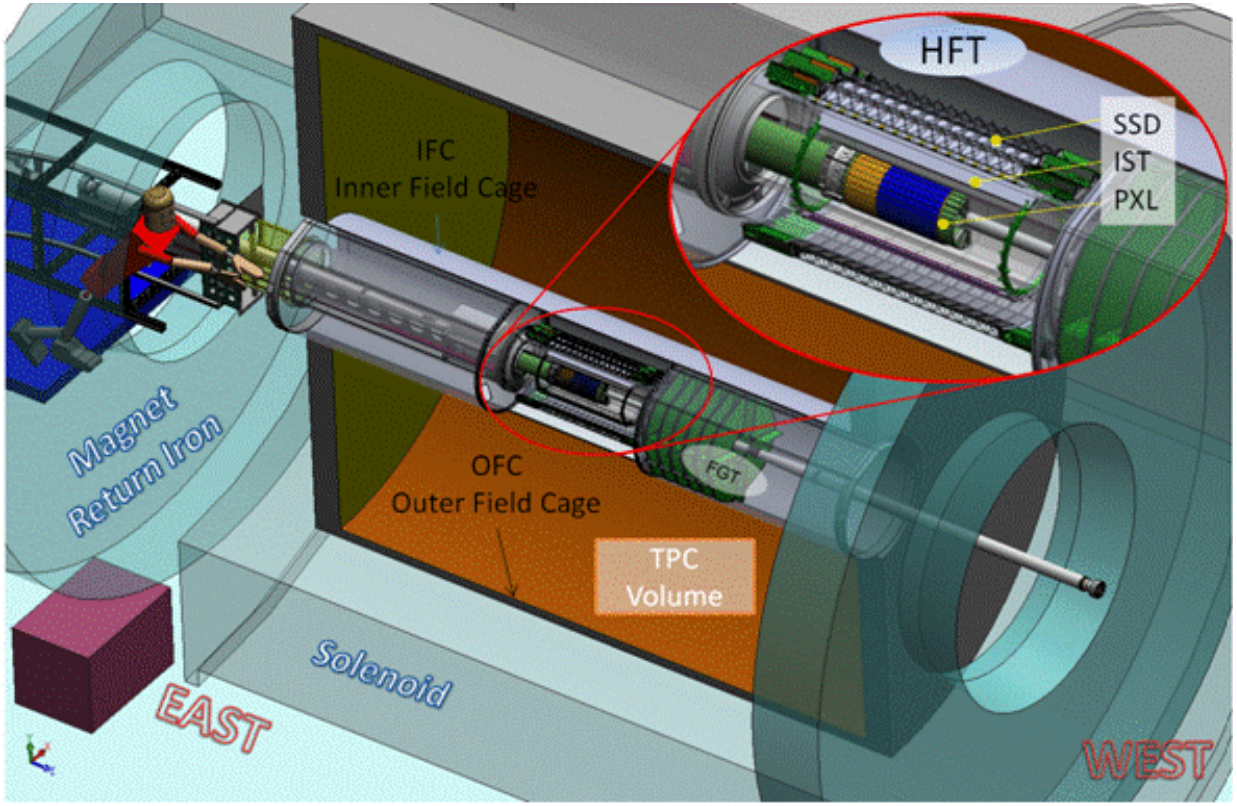
WBS 1.3 IST

Gerrit van Nieuwenhuizen
MIT

IST talk overview

- Requirements
- Detector overview
- Status and plans
  - Design status
  - Fabrication Plan
  - System testing
- Cost and Schedule
- Basis of estimates
- Resources
- Risk Assessment

IST in Inner Detector Upgrade



TPC – Time Projection Chamber (main tracking detector in STAR)

HFT – Heavy Flavor Tracker

- SSD – Silicon Strip Detector
  - r = 22 cm
- IST – Inner Silicon Tracker
  - r = 14 cm
- PXL – Pixel Detector
  - r = 2.5, 8 cm

We track inward from the TPC with graded resolution:

TPC → ~1mm → SSD → ~300μm → IST → ~250μm → PXL → <30μm → vertex

IST CD-4 requirements

3	Internal alignment IST and SSD	< 300 μm	Survey during construction and assembly
6	Detector hit efficiency IST	> 96% with 98% purity	Low noise electronics, source and cosmic tests
7	Live channels for PXL and IST	> 95%	<1% dead silicon pads, redundancy, spares, care...
8	PXL and IST Readout speed and dead time	<5% additional dead time @ 500 Hz average trigger rate and simulated occupancy	APV25-S1 readout time ~10-30us, fully parallel, appropriate buffering

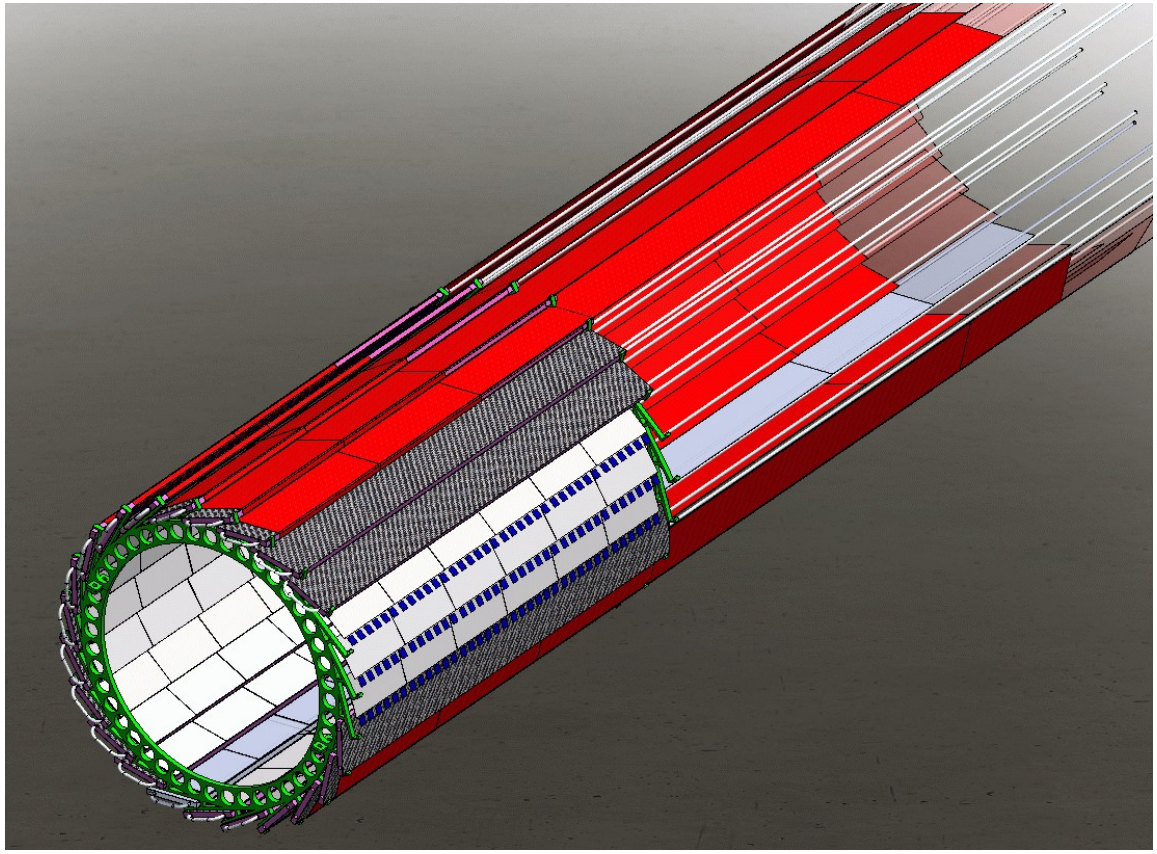
Current design will meet these requirements

IST additional requirements

- Resolution of ~200um in r-phi to provide required pointing resolution to PXL
- <1.5% Xo to limit multiple scattering ^ and to minimize the impact on mid-rapidity physics
- Radiation hard for 10 years of 30kRad/year
- Be able to resolve 107ns beam bunches

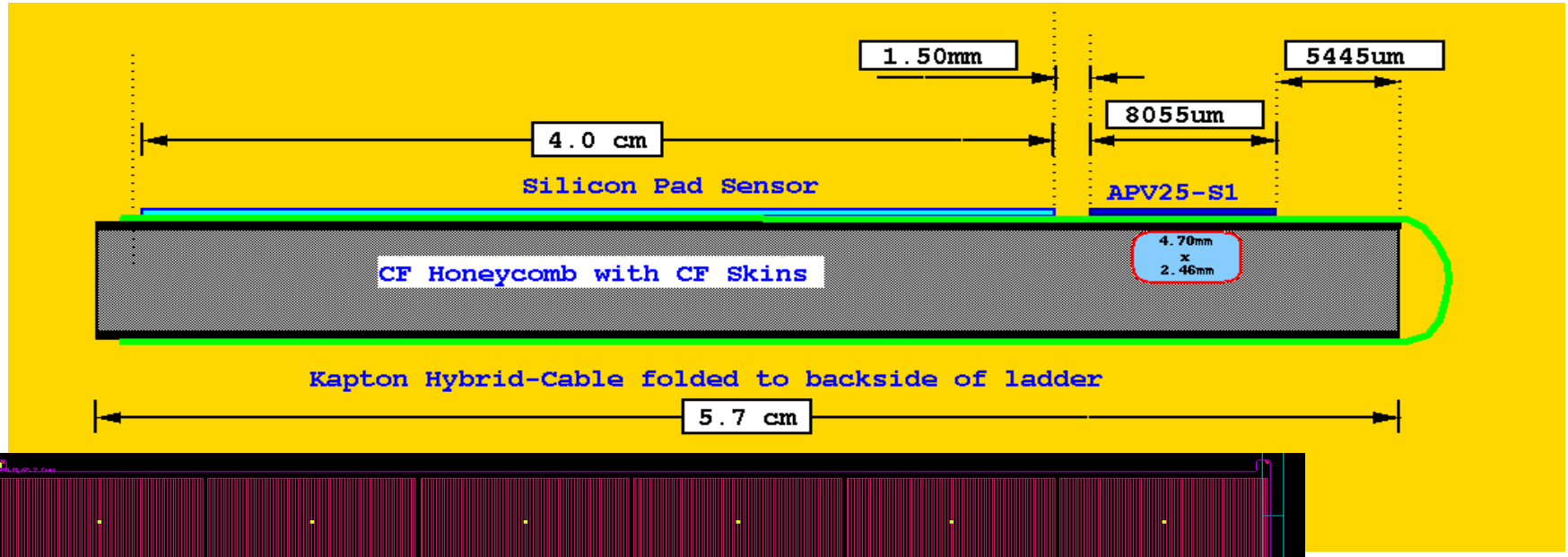
Careful choice of light weight materials, high-res. Sensors and fast readout system

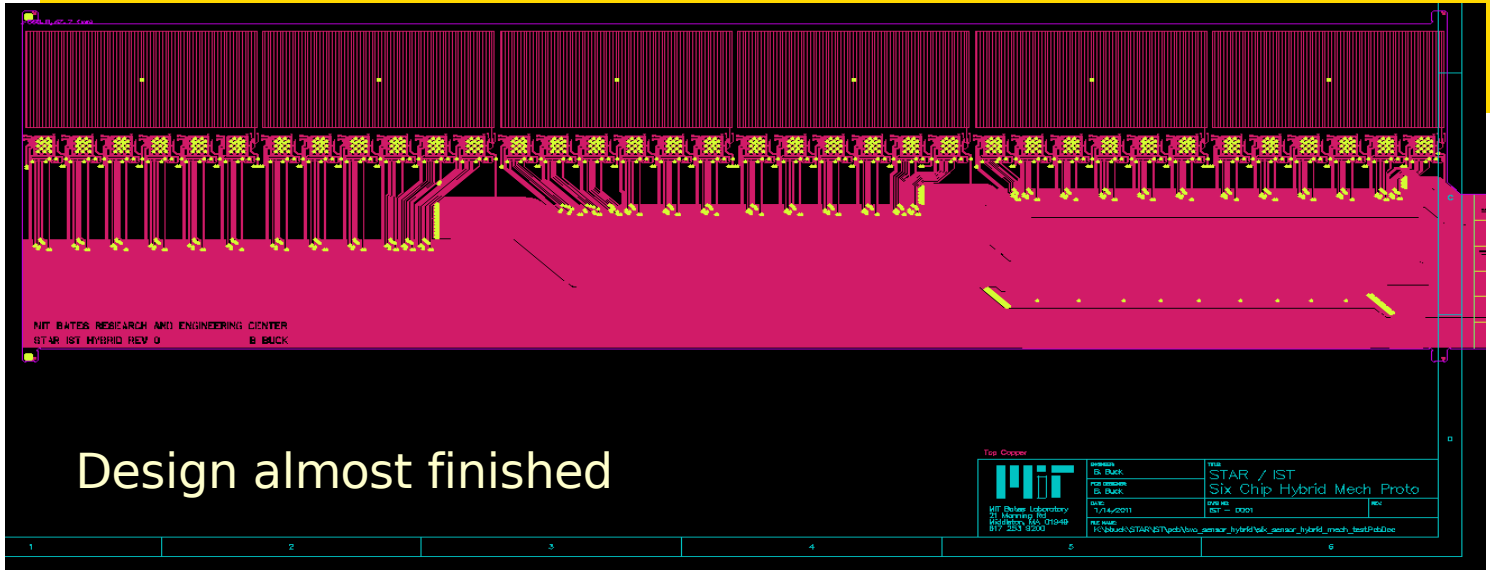
IST overview



Radius	14cm
Length	50cm
ϕ-Coverage	2π
$\lvert\eta\rvert$-Coverage	≤ 1.2
Number of ladders	24
Number of hybrids	24
Number of sensors	144
Number of readout chips	864
Number of channels	110592
R-ϕ resolution	172μm
Z resolution	1811μm
Z pad size	6000μm
R-ϕ pad size	600μm

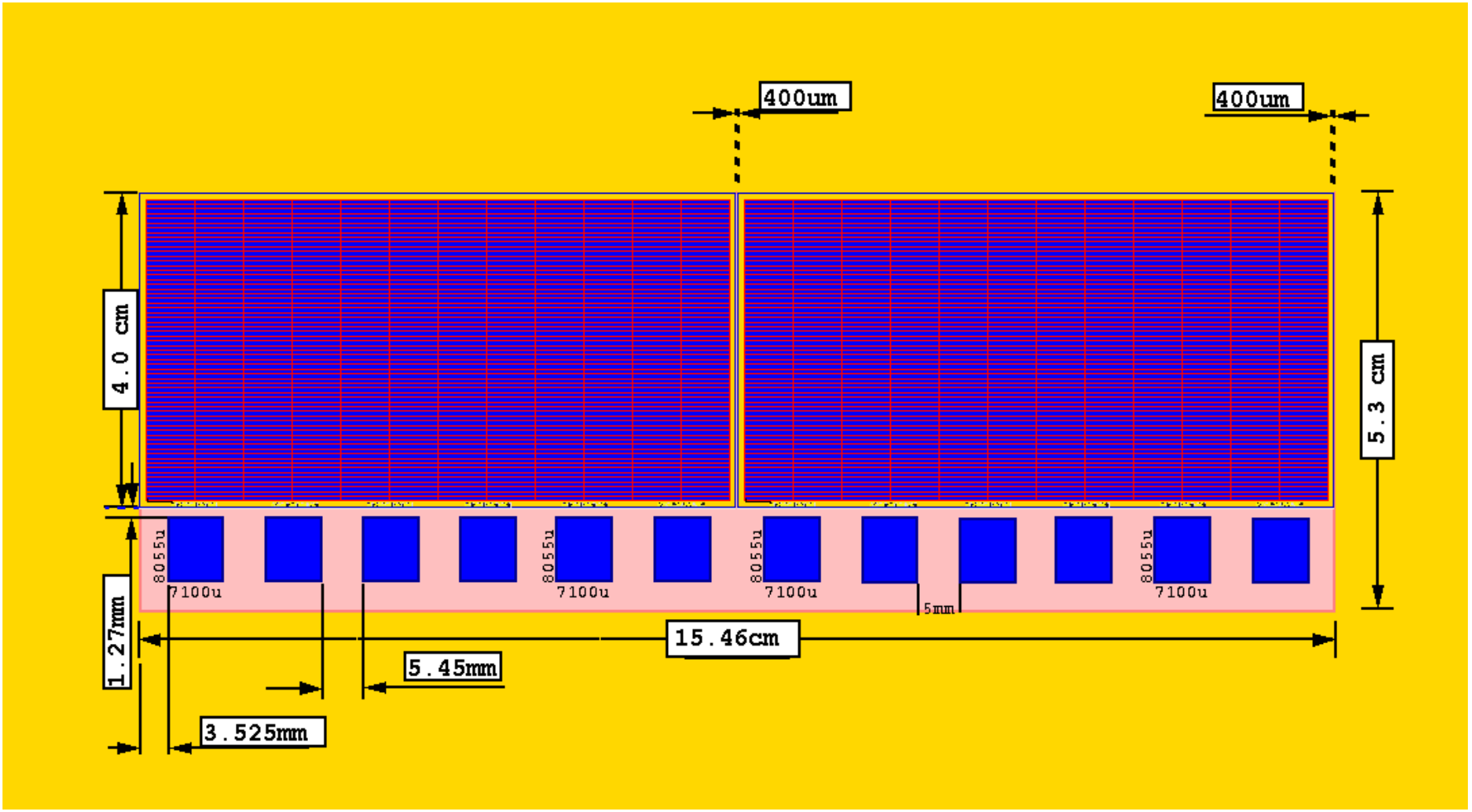
IST ladder and hybrid



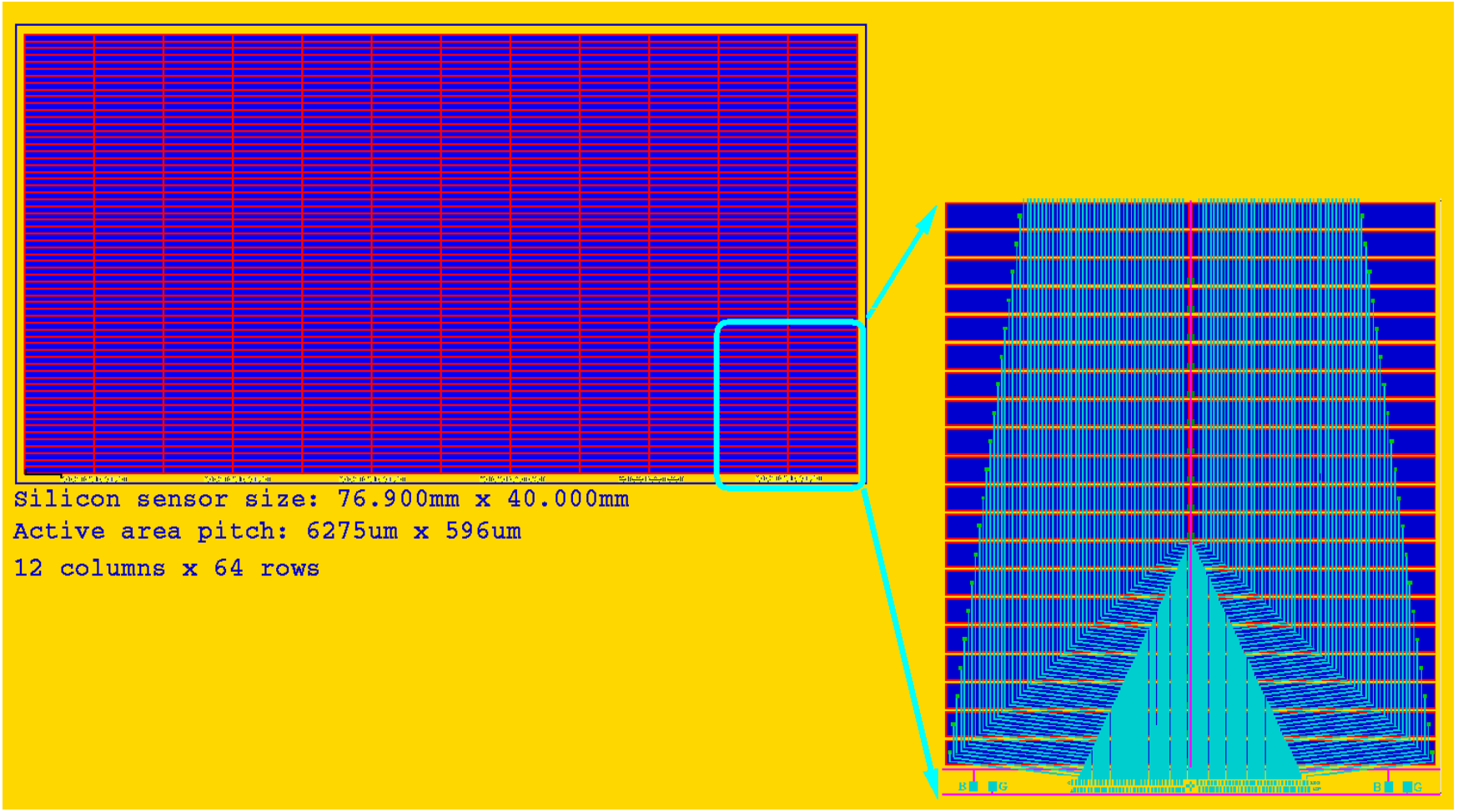


Design almost finished

IST unit

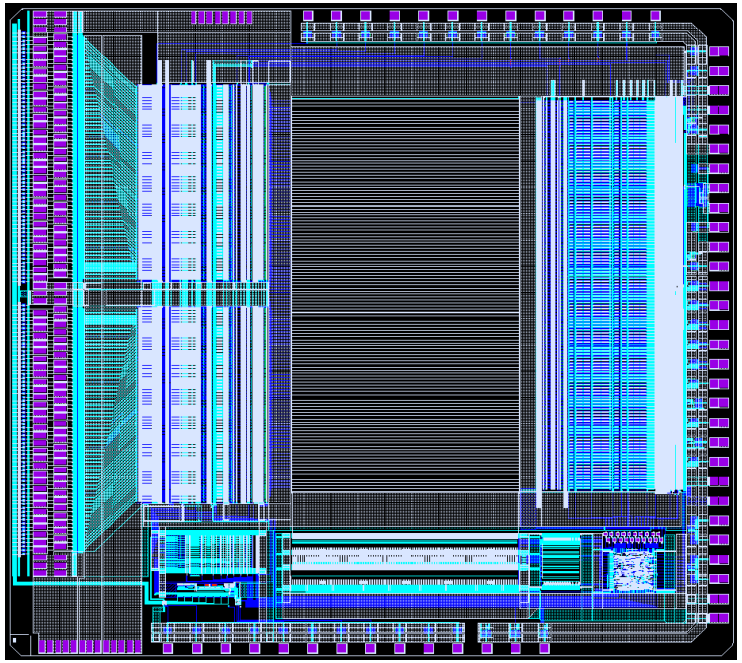

400um
400um
4.0 cm
5.3 cm
8055u
7100u
8055u
7100u
8055u
7100u
8055u
7100u
5mm
15.46cm
1.27mm
5.45mm
3.525mm

IST silicon pad sensor



Prototype procurement in progress

IST readout chip

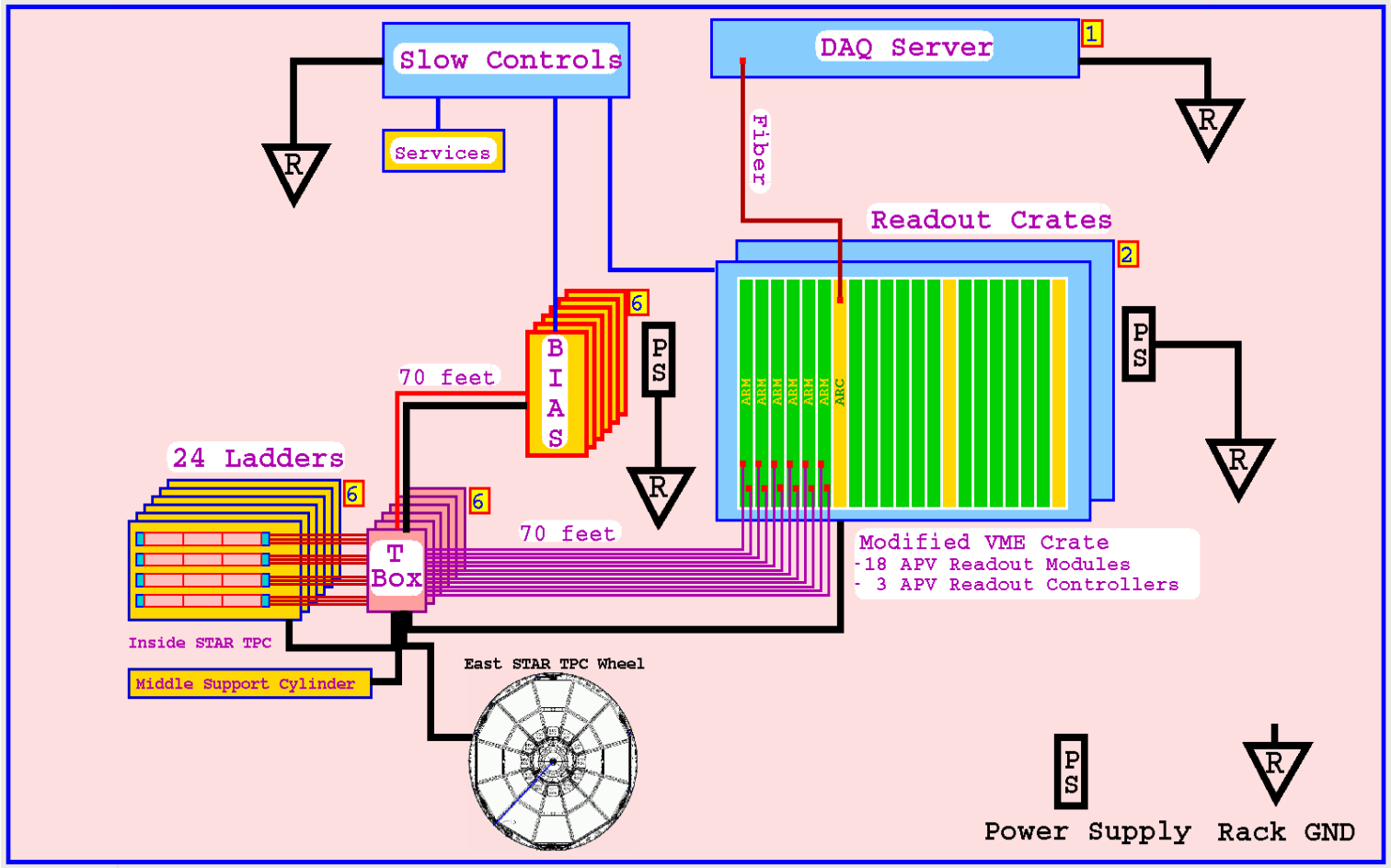


APV25-S1

Background, CMS, FGT, etc.

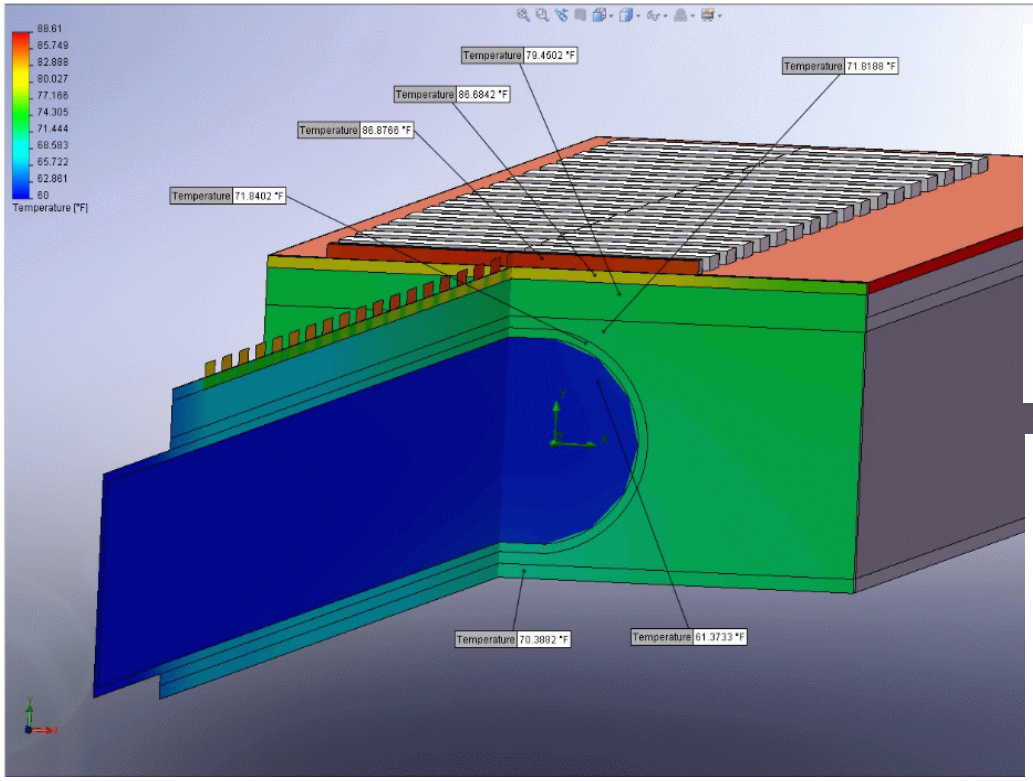
Specs and why it works for IST
....
...
..
.

IST readout system



Prototype ARM/ARC being tested, FGT as testbed

IST cooling



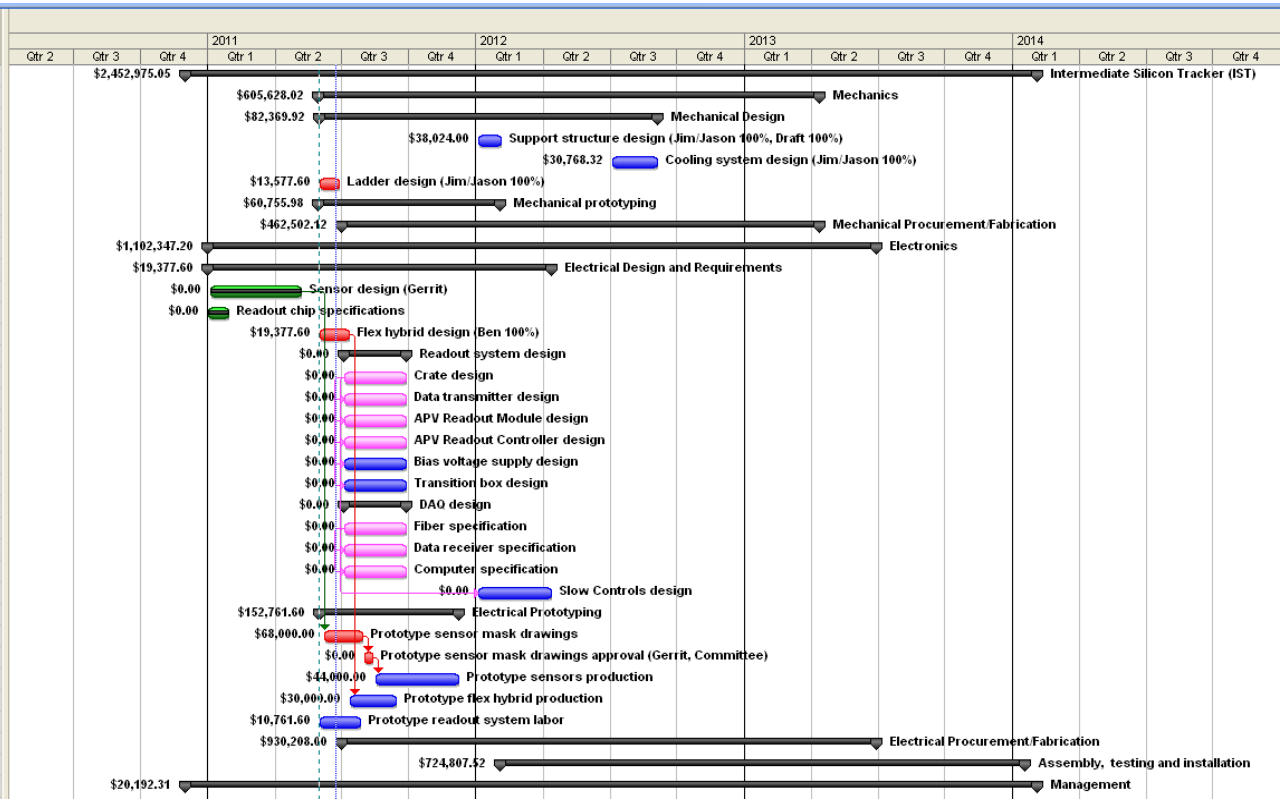
Maximum readout chip temperature	35°C
Cooling fluid velocity	0.3-3 m/s
Maximum pressure	0.2MPa
Cooling fluid inlet temperature	24°C

Cooling fluid	3M Novec 7200
Cooling fluid	1m/s
Maximum pressure	0.14MPa
Calculated maximum temperature of readout chip	34.9°C

Fluorocarbon fluid based cooling
Simulations show proper cooling for one stave and possible daisy chaining of staves

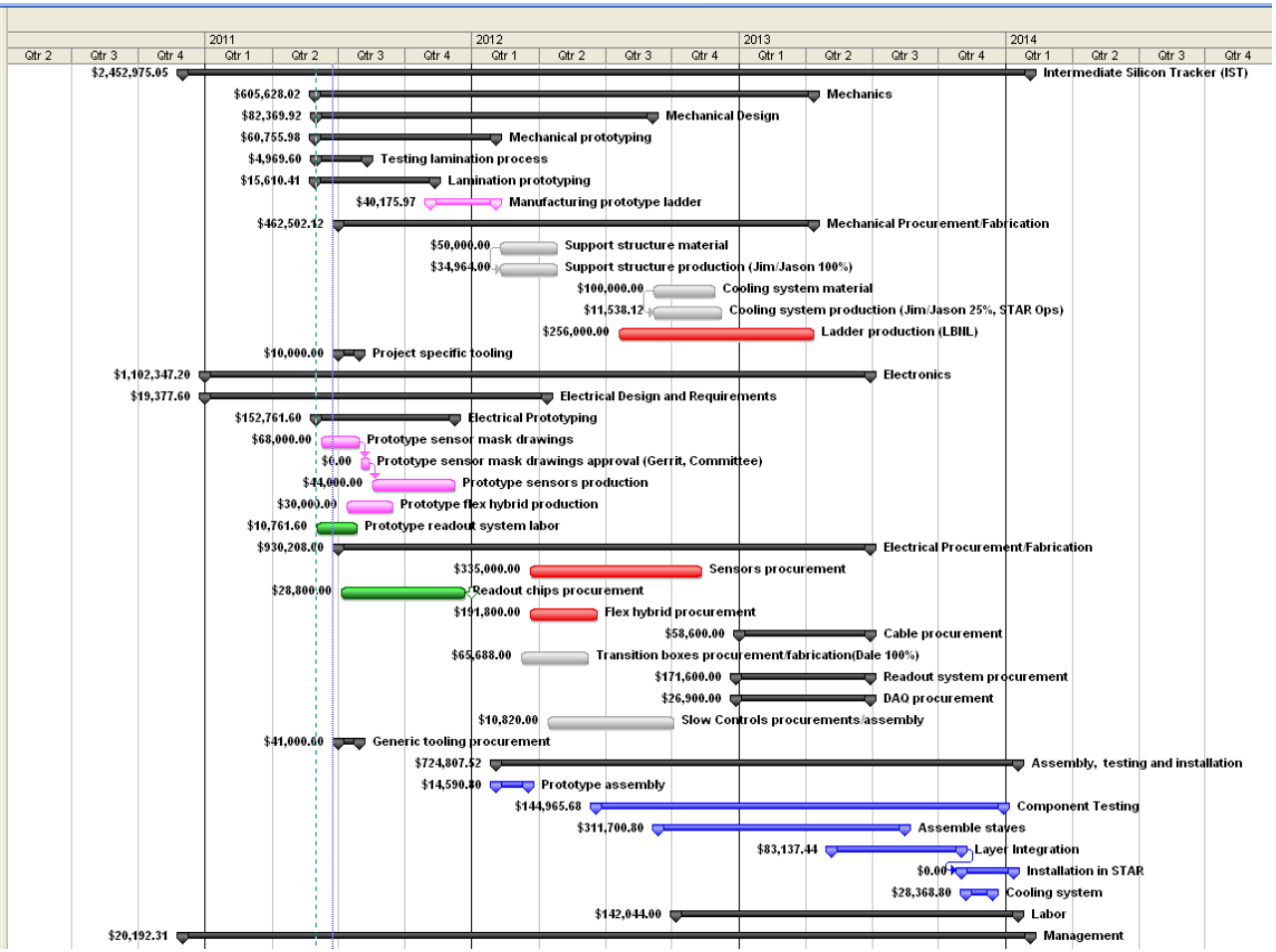
IST design status summary

WBS	Task Name
1.3	Intermediate Silicon Tracker (IST)
1.3.1	Mechanics
1.3.1.1	Mechanical Design
1.3.1.1.1	Support structure design (Jim/Jason 100%, Draft 100%)
1.3.1.1.2	Cooling system design (Jim/Jason 100%)
1.3.1.1.3	Ladder design (Jim/Jason 100%)
1.3.1.2	Mechanical prototyping
1.3.1.3	Mechanical Procurement/Fabrication
1.3.2	Electronics
1.3.2.1	Electrical Design and Requirements
1.3.2.1.1	Sensor design (Gerrit)
1.3.2.1.2	Readout chip specifications
1.3.2.1.3	Flex hybrid design (Ben 100%)
1.3.2.1.4	Readout system design
1.3.2.1.4.1	Crate design
1.3.2.1.4.2	Data transmitter design
1.3.2.1.4.3	APV Readout Module design
1.3.2.1.4.4	APV Readout Controller design
1.3.2.1.4.5	Bias voltage supply design
1.3.2.1.4.6	Transition box design
1.3.2.1.5	DAQ design
1.3.2.1.5.1	Fiber specification
1.3.2.1.5.2	Data receiver specification
1.3.2.1.5.3	Computer specification
1.3.2.1.6	Slow Controls design
1.3.2.2	Electrical Prototyping
1.3.2.2.1	Prototype sensor mask drawings
1.3.2.2.5	Prototype sensor mask drawings approval (Gerrit, Com
1.3.2.2.2	Prototype sensors production
1.3.2.2.3	Prototype flex hybrid production
1.3.2.2.4	Prototype readout system labor
1.3.2.3	Electrical Procurement/Fabrication
1.3.3	Assembly, testing and installation
1.3.4	Management



IST fabrication plan

WBS	Task Name
1.3	Intermediate Silicon Tracker (IST)
1.3.1	Mechanics
1.3.1.1	Mechanical Design
1.3.1.2	Mechanical prototyping
1.3.1.2.1	Testing lamination process
1.3.1.2.2	Lamination prototyping
1.3.1.2.3	Manufacturing prototype ladder
1.3.1.3	Mechanical Procurement/Fabrication
1.3.1.3.1	Support structure material
1.3.1.3.2	Support structure production (Jim/Jason 100%)
1.3.1.3.3	Cooling system material
1.3.1.3.4	Cooling system production (Jim/Jason 25%, STAR Ops)
1.3.1.3.5	Ladder production (LBNL)
1.3.1.3.6	Project specific tooling
1.3.2	Electronics
1.3.2.1	Electrical Design and Requirements
1.3.2.2	Electrical Prototyping
1.3.2.2.1	Prototype sensor mask drawings
1.3.2.2.5	Prototype sensor mask drawings approval (Gerrit, Committee)
1.3.2.2.2	Prototype sensors production
1.3.2.2.3	Prototype flex hybrid production
1.3.2.2.4	Prototype readout system labor
1.3.2.3	Electrical Procurement/Fabrication
1.3.2.3.1	Sensors procurement
1.3.2.3.2	Readout chips procurement
1.3.2.3.3	Flex hybrid procurement
1.3.2.3.4	Cable procurement
1.3.2.3.5	Transition boxes procurement/fabrication(Dale 100%)
1.3.2.3.6	Readout system procurement
1.3.2.3.7	DAQ procurement
1.3.2.3.8	Slow Controls procurements/assembly
1.3.2.3.9	Generic tooling procurement
1.3.3	Assembly, testing and installation
1.3.3.1	Prototype assembly
1.3.3.2	Component Testing
1.3.3.3	Assemble staves
1.3.3.4	Layer Integration
1.3.3.5	Installation in STAR
1.3.3.6	Cooling system
1.3.3.7	Labor
1.3.4	Management



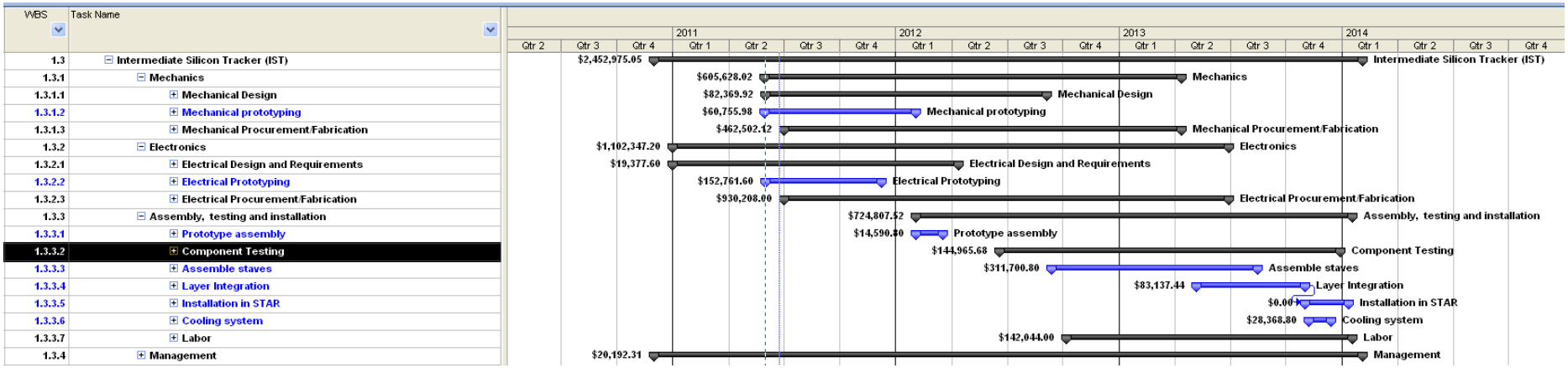
IST system test

Readout test
Source test
Cosmic ray test

IST cost by Level 3 WBS

WBS	Name	Cost	Duration	Start	Finish
1.3	**Intermediate Silicon Tracker (IST)**	**$2,452,132.70**	**783 days**	**8/31/10**	**10/17/13**
	MIT Scientist Contributed	$0.00		8/31/10	10/17/13
1.3.1	Mechanics	$605,628.02	464 days	3/1/11	1/10/13
1.3.2	Electronics	$1,102,347.20	619 days	10/1/10	3/29/13
1.3.3	Assembly, testing and installation	$724,823.52	485 days	11/3/11	10/17/13
1.3.4	Management	$19,333.96	780 days	8/31/10	10/14/13

IST schedule



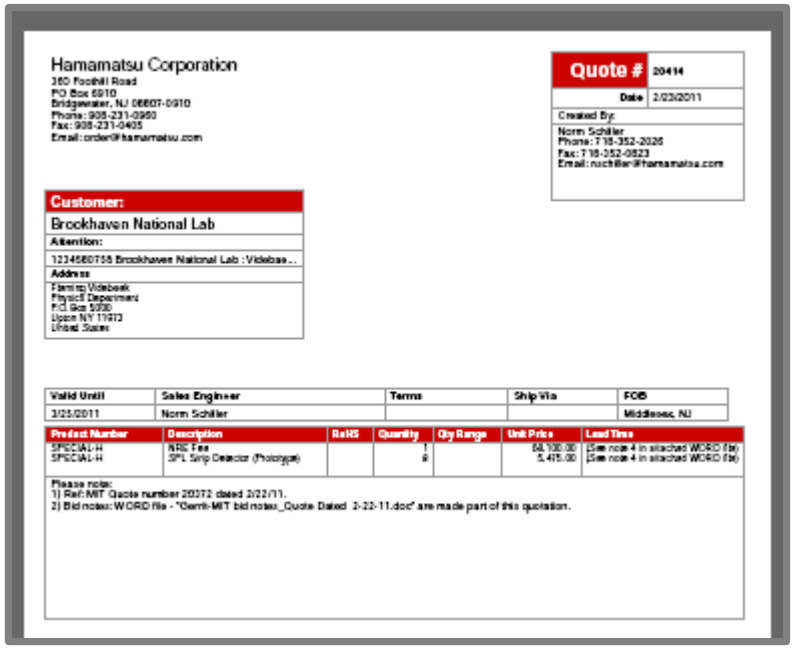
Looks just great, no problem!

IST basis of estimates

EMC² documentum eRoom

My eRooms > Heavy Flavor Tracker > DOE CD 2/3 Review > Project Documents > Reference Material

- Reference Material
  - 1.1_Management_supporting_documents
  - 1.2_Pixel_Detector_(PXL)_supporting_documents
  - 1.3_Intermediate_Silicon_Tracker_(IST)_supporting_documents
    - 1.3.1_Mechanics
      - 1.3.1.1_Mechanical_Design
      - 1.3.1.2_Mechanical_Procurement_Fabrication
        - 1.3.1.2.8_ProductionLadderPrice.txt
      - 1.3.1.3_Mechanical_Prototyping
        - 1.3.1.3_Ladder_Prototype.txt
    - 1.3.2_Electronics
      - 1.3.2.1_Electrical_Design_and_Requirements
      - 1.3.2.2_Electrical_Prototyping
        - 1.3.2.2.1_PrleiminaryQuote_30Jul2010.txt
        - 1.3.2.2.1_Sensor_Quote_Hamamatsu_23Feb2011.pdf
        - 1.3.2.2.1_Sensor_Quote_Hamamatsu_Notes_23Feb2011.doc
        - 1.3.2.2.2_PrleiminaryQuote_30Jul2010.txt
        - 1.3.2.2.3_IST_protohybrid_quote_FPC_08Feb2011.pdf
        - 1.3.2.2.3_IST_protohybrid_quote_Vulcan_09Feb2011.pdf
      - 1.3.2.3_Electrical_Procurement_Fabrication
    - 1.3.3_Assembly_Testing_Installation
    - 1.3.4_Management
  - 1.4_Silicon_Strip_Detector_(SSD)_supporting_documents
  - 1.5_Integration_and_Global_Supports_supporting_documentation
  - 1.6_Software_supporting_documentation



Hamamatsu Corporation
360 Foothill Road
PO Box 6910
Bridgewater, NJ 08807-0910
Phone: 908-231-0960
Fax: 908-231-0405
Email: order@hamamatsu.com

Quote # 20414

Date	2/23/2011
Created By:	
Norm Schiller Phone: 718-352-3026 Fax: 718-352-0823 Email: nschiller@hamamatsu.com	

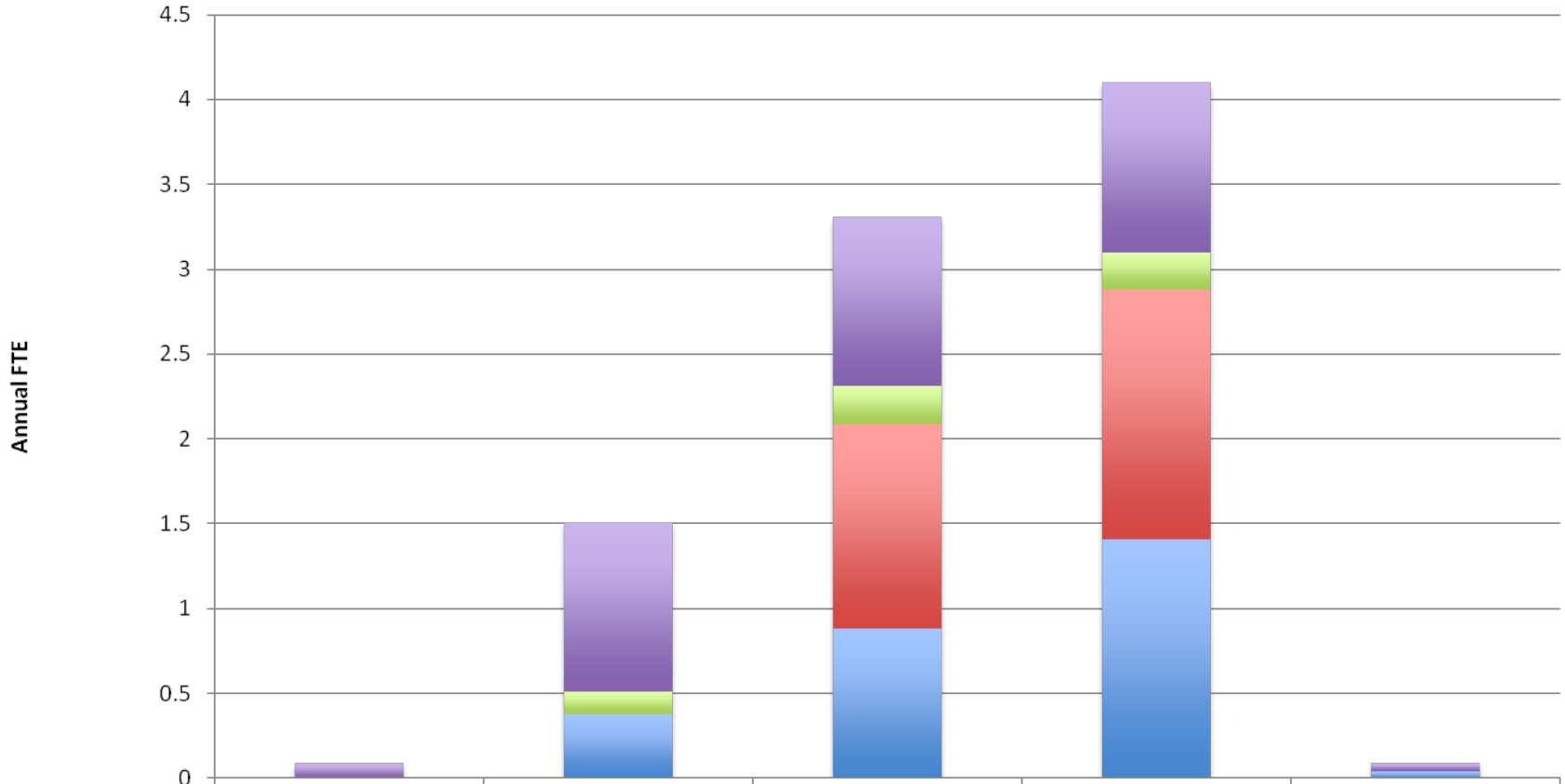
Customer:
Brookhaven National Lab
Attention:
1234560755 Brookhaven National Lab : Videbae...
Address
Fleming Videbaek
Physics Department
P.O. Box 5000
Upton NY 11973
United States

Valid Until	Sales Engineer	Terms	Ship Via	FOB
3/25/2011	Norm Schiller			Middlesex, NJ

Product Number	Description	RoHS	Quantity	Qty Range	Unit Price	Lead Time
SPECIAL-H	NRE Fee		1		$4,300.00	(See note 4 in attached WORD file)
SPECIAL-H	SPL Strip Detector (Prototype)		8		$ 475.00	(See note 4 in attached WORD file)

Please note:
1) Ref: MIT Quote number 20372 dated 2/22/11.
2) Bid notes: WORD file - "Gerrit-MIT bid notes_Quote Dated 2-22-11.doc" are made part of this quotation.

IST resources at MIT



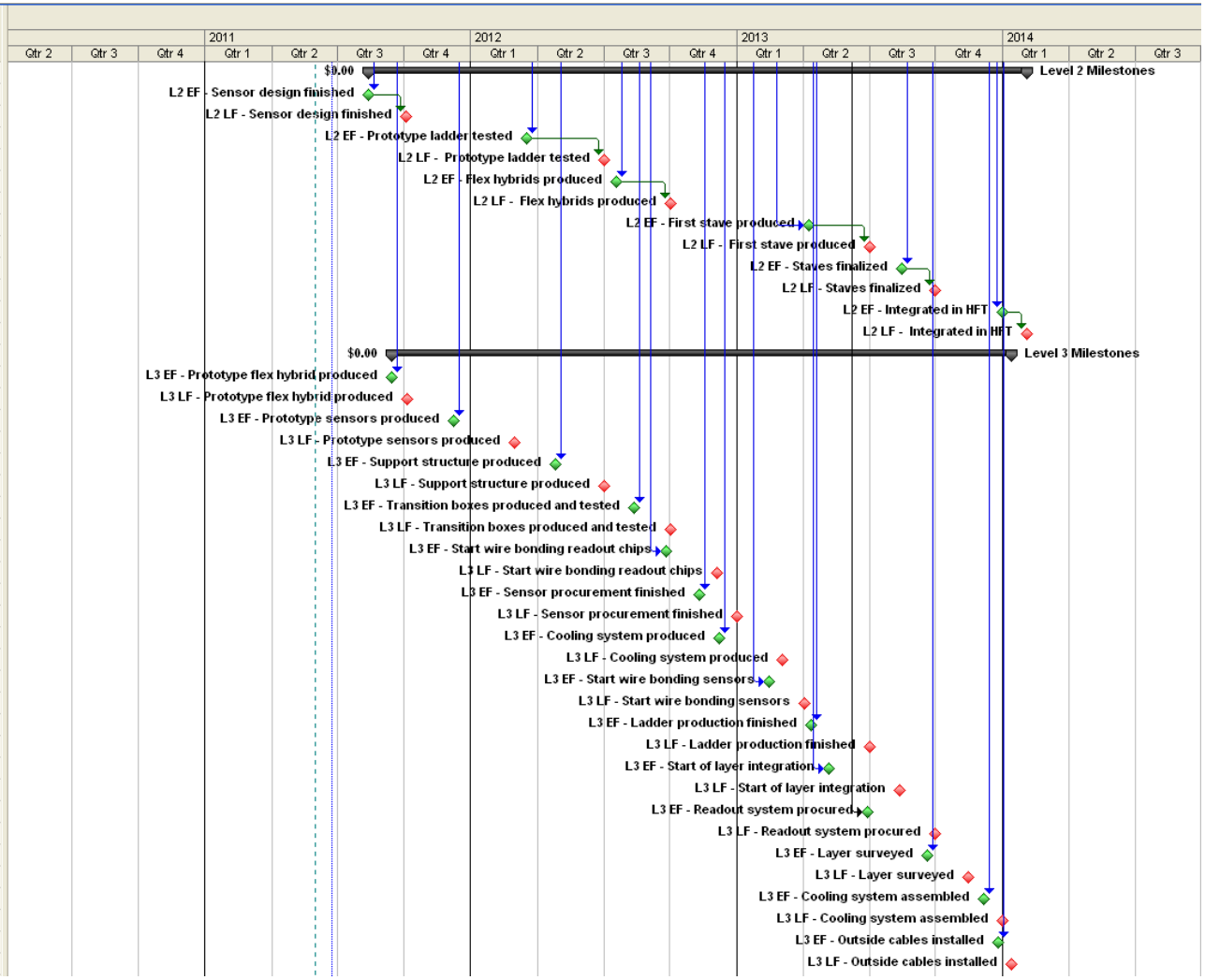
	2010	2011	2012	2013	2014
MIT Scientist	0.09	1.00	1.00	1.00	0.05
MIT PM Support	0	0.13	0.22	0.22	0
MIT Technical	0	0	1.21	1.47	0
MIT Engineer	0	0.38	0.88	1.41	0.04

IST milestones

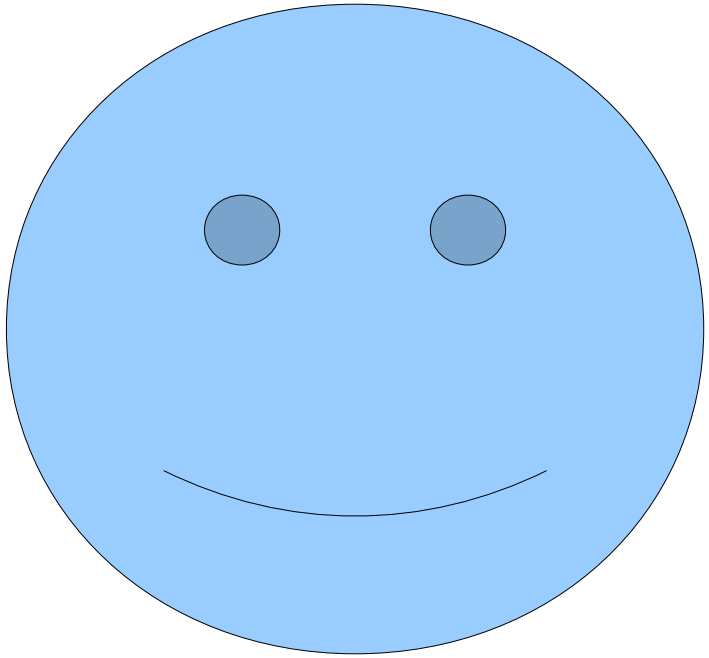
Lvl	Milestone	Early Finish	Late Finish	Actual	Float
1	CD-0 Approve Mission Need			Q2FY09 (A)	
1	CD-1 Approve Alternative Selection and Cost Range			Q4FY10 (A)	
1	CD-2 Approve Performance Baseline		Q3FY11		
1	CD-3 Approve Start of Fabrication		Q3FY11		
2	IST - Sensor design Finished	Q3FY11	Q4FY11		1 QTR
2	IST - Prototype ladder tested	Q1FY12	Q3FY12		2 QTR
2	IST - Flex hybrid produced	Q3FY12	Q4FY12		1 QTR
2	IST - First staves produced	Q2FY13	Q4FY13		2 QTRs
2	IST - Staves finalized	Q3FY13	Q4FY13		1 QTR
2	IST Integrated into HFT	Q1FY14	Q1FY14		
2	HFT Installed and Integrated into STAR	Q1FY14	Q1FY15		
1	CD-4 Approve Project Completion	Q1FY14	Q2FY15		5 QTRs

IST milestones control

WBS	Task Name
1.3.4.4	Level 2 Milestones
1.3.4.4.1	L2 EF - Sensor design finished
1.3.4.4.7	L2 LF - Sensor design finished
1.3.4.4.2	L2 EF - Prototype ladder tested
1.3.4.4.8	L2 LF - Prototype ladder tested
1.3.4.4.3	L2 EF - Flex hybrids produced
1.3.4.4.9	L2 LF - Flex hybrids produced
1.3.4.4.4	L2 EF - First stave produced
1.3.4.4.10	L2 LF - First stave produced
1.3.4.4.5	L2 EF - Staves finalized
1.3.4.4.11	L2 LF - Staves finalized
1.3.4.4.6	L2 EF - Integrated in HFT
1.3.4.4.12	L2 LF - Integrated in HFT
1.3.4.5	Level 3 Milestones
1.3.4.5.9	L3 EF - Prototype flex hybrid produced
1.3.4.5.15	L3 LF - Prototype flex hybrid produced
1.3.4.5.1	L3 EF - Prototype sensors produced
1.3.4.5.16	L3 LF - Prototype sensors produced
1.3.4.5.2	L3 EF - Support structure produced
1.3.4.5.17	L3 LF - Support structure produced
1.3.4.5.10	L3 EF - Transition boxes produced and tested
1.3.4.5.18	L3 LF - Transition boxes produced and tested
1.3.4.5.11	L3 EF - Start wire bonding readout chips
1.3.4.5.19	L3 LF - Start wire bonding readout chips
1.3.4.5.3	L3 EF - Sensor procurement finished
1.3.4.5.20	L3 LF - Sensor procurement finished
1.3.4.5.4	L3 EF - Cooling system produced
1.3.4.5.21	L3 LF - Cooling system produced
1.3.4.5.5	L3 EF - Start wire bonding sensors
1.3.4.5.22	L3 LF - Start wire bonding sensors
1.3.4.5.12	L3 EF - Ladder production finished
1.3.4.5.23	L3 LF - Ladder production finished
1.3.4.5.6	L3 EF - Start of layer integration
1.3.4.5.24	L3 LF - Start of layer integration
1.3.4.5.13	L3 EF - Readout system procured
1.3.4.5.25	L3 LF - Readout system procured
1.3.4.5.7	L3 EF - Layer surveyed
1.3.4.5.26	L3 LF - Layer surveyed
1.3.4.5.8	L3 EF - Cooling system assembled
1.3.4.5.27	L3 LF - Cooling system assembled
1.3.4.5.14	L3 EF - Outside cables installed
1.3.4.5.28	L3 LF - Outside cables installed



IST risk assessment

WBS	WBS description	Description	Technical Conseq.	Schedule Conseq.	Cost Impact ($K)	Type of Risk	Impact	Probability	Severity	Mitigation Strategy
	Intermediate Silicon Tracker									
1.2.3.1	Support structure	More than one iteration to meet requirements	none	possible delay	none	schedule	low	low	low	scheduling slack
1.2.3.3	Ladders	Failure to produce all ladders in time	none	delay in assembly pipeline	none	schedule	moderate	low	low	scheduling slack
1.3.2.1	Sensor drawings and masks	Design problems leading to multiple iterations	none	delay in prototype production	none	schedule	low	low	low	scheduling slack
1.3.2.2	Prototype sensors	Failure to function according to specifications	none	delay in start full production	$80k NRE + $32k prototypes	cost/schedule	moderate	low	low	scheduling slack,reliable vendor
1.3.2.3	Flex hybrid	Failure to function according to specifications	none	delay in full production	$5k	cost/schedule	low	low	low	scheduling slack, less prototypes
1.3.3.1	Sensors	Production problems	none	delay in assembly	none	schedule	moderate	low	low	reliable vendor, stage batch production
1.3.3.3	Flex hybrid	Production problems	none	delay in assembly	none	schedule	moderate	low	low	scheduling slack by producing early
1.3.3.4.1	Signal cables inside field cage	Production problems	none	delay in installation	none	schedule	low	low	low	conservative design, produce early
1.3.3.4.2	Signal cables outside field cage	Production problems	none	delay in installation	none	schedule	low	low	low	conservative design, produce early
1.3.3.4.3	Bias voltage cables outside field cage	Production problems	none	delay in installation	none	schedule	low	low	low	conservative design, produce early
1.3.3.5	Transition boxes	Fabrication problems	none	delay in installation	none	schedule	low	low	low	conservative design, produce early
1.3.3.6	Readout system									Problems straightened out by FGT
1.3.3.7	DAQ									Problems straightened out by FGT
1.4.3	Assemble modules	Assembly problems	none	delay in assembling staves	increase in labor cost, $20k/mo	cost/schedule	moderate	low	low	Establish conservative assembly pipeline
1.4.4	Assemble staves	Assembly problems	none	delay in layer integration	increase in labor cost, $20k/mo	cost/schedule	moderate	low	low	Establish conservative assembly pipeline
1.4.5	Layer Integration	Integration problems	none	delay in installation	none	schedule	moderate	low	low	delay installation
1.4.7	Cooling system	Assembly problems	none	delay in installation	parts and labor	cost/schedule	low	low	low	assemble early

Summary