October 23, 2009

The SiD Work Plan: 2010-2012

The SiD collaboration

I. Introduction

The SiD Work Plan has been designed to provide milestones, schedule, and a list of resources needed to develop a detailed baseline design of the SiD detector, suitable for producing a Detector Technical Report by the end of 2012 to accompany the GDE's Technical Report. With the GDE's Technical Report, it is to serve as a proposal to the world high energy physics community to engage in the construction of the ILC and its detectors. Like the GDE report, the Detector Technical Report is to make a compelling case that detectors capable of fully exploiting the physics potential of the ILC are feasible, cost effective, and based on demonstrated detector technologies. Specifically, the Detector Technical Report addresses the Work Plan proposed by the ILC Research Director, which calls out the following goals for the Technical Reports:

- Demonstrate proof of principle for critical components
- Define a feasible baseline design
- Develop a realistic integrated mechanical design for the detector
- Develop a correspondingly realistic simulation model of the detector
- Develop the push-pull mechanism and procedures needed to interchange ILC detectors
- Simulate and analyze updated benchmark reactions with a realistic detector model, including the effects of backgrounds
- Simulate and analyze new benchmark reactions at 1 TeV
- Develop an improved cost estimate

This document is the natural outgrowth of the SiD R&D plan which was included in the SiD Letter of Intent. It elaborates the plans put forward there.

This document also extends the SiD R&D plan in an essential way, by including estimates of the resources needed to fulfill the goals of the Research Director's Work Plan. As will become clear, the resources required to produce a believable Detector Technical Report have not yet been secured. Perhaps the most important use for the present document is to quantify the differences between resources in hand and those needed to produce a credible proposal, in the hopes of thereby facilitating securing additional support.

SiD has attempted to adopt a minimalist approach in estimating the resources needed for this next phase of detector development. Our conception of the Technical Report differs from the common notion of a "technical design report", in that it doesn't attempt to produce full engineering designs of all the detector components, nor does it include production and testing of full detector prototypes. These are not imaginable with the present level of support. Rather it attempts to establish technical feasibility for key detector systems, conceptually engineered designs of detector subsystems, and proofs of principle of key engineering assumptions, in addition to an accurate rendition of detector and physics performance with a level of simulation detail previously unmatched in high energy physics proposals.

This approach has consequences. Several systems may not reach full technical maturity by 2012. The vertex detector, which depends on ongoing sensor development and advances in powering and materials, likely won't be ready for a construction start in 2013. The same is true of the beamcal, which also depends on future sensor development, which may or may not be demonstrated in time. These are both small systems, the design of the overall detector is essentially independent of their details, and the world detector community is making impressive progress on both fronts. Feasibility can be established in both cases without full prototype demonstrations and there will be time, before the ILC construction start, to complete this work. But other detector subsystems must be demonstrated, because they determine the global design of SiD. The tracking systems and calorimeter systems are in this category.

In what follows, we first briefly review milestones and timelines for the individual SiD systems. Secondly, we review the resources needed to proceed with the plan, and the level of resources already secured. Finally, we make some brief conclusions.

II. Milestones and Timelines for SiD Subsystems

Detailed schedules are given below in Appendix I, beginning with an overview of the schedule. SiD is already developing its computing infrastructure to accommodate a fully realistic detector description and further developing track finding and particle flow algorithms to improve their performance and adapt them to the realistic simulation. Global detector parameters will be re-optimized, and the key engineering questions associated with the Hcal gap thickness, overall Hcal depth, absorber material, and support, will be answered. With that input, global parameters will be frozen, in roughly a year's time. Engineering designs for individual subsystems will be developed sufficiently that realistic descriptions can be added to the Monte Carlo simulation, and the newly optimized baseline geometry established in Geant4. Engineering and detector R&D will proceed for each subsystem, and key detector and engineering assumptions checked with limited prototypes. With Geant4 complete, subsystem performance can be studied, and physics and background events simulated and reconstructed for subsequent benchmarking studies.

System by system, the critical milestones are as follows:

- **Vertex Detector.** Sensor development will proceed with both the Chronopix and VIP sensors, with the goal of demonstrating a working sensor around the 2012/2013 timeframe. Conceptual engineering, and test of concepts, will proceed with vertex mechanical issues, leading to a feasible design of the sensor support structure, integration of cooling, powering, and data transmission. Work on pulse powering the vertex detector will be coordinated with the SiD Electronics group.
- **Tracker.** In collaboration with SiD Sim/Recon, tracking software will be improved, a Kalman Fitter implemented, tracker design optimized, and performance studies begun. Emphasis will be given to testing the SiD tracking sensor, and developing bump bonding techniques and kapton cable designs to

test the sensor with KPiX readout, eventually with the full KPiX 1024 chip. As with the vertex detector, work on pulse-powering the tracker will be done with the SiD Electronics group. Mechanical stability of the lightweight carbon fiber support cylinders, especially under power pulsing, will be investigated and measured. And alignment systems using frequency scanned interferometry will be further developed, and feasibility demonstrated.

- **ECAL.** In collaboration with SiD Sim/Recon, design optimization will be pursued, the realistic description of the detector developed, and performance studies initiated. With SiD Engineering, the mechanical design will be finalized and feasibility demonstrated. A mechanical prototype, testing the design concepts, will be built. Sensor R&D will proceed like that for the tracker sensor, including bump bonding, cable design, and integration with the KPiX readout chip. This will culminate in a single tower prototype in late 2011. In addition to the development of the Si pixel baseline design, work will proceed on the MAPS alternate technology.
- **HCAL.** The baseline RPC choice will be tested extensively with the CALICE collaboration in a cubic meter calorimeter presently under construction. In parallel, a technical prototype will be engineered, and construction details tested, to establish hcal gap thickness, distribution of gas and HV, design of the ASIC readout, and chamber construction. In addition to the baseline, HCal alternate technologies using gas, namely GEMS and Micromegas, will be developed, and prepared for extensive beam testing. SiD will leave the development of the scintillator alternative to the CALICE collaboration, but will monitor progress, performance, and cost of this option.
- **FCAL.** With Sim/Recon, the measurement of the differential luminosity spectrum and the efficiency of the SUSY veto will be studied and quantified. With the SiD Engineering group, the beamcal and lumical designs will be finalized, and integrated with the beampipe and masking designs. Key mechanical assumptions will be tested empirically. In conjunction with the FCAL Collaboration, sensor technologies will be evaluated, and resources permitting, new options developed locally. Beamcal readout will be developed with the SiD Electronics group. Ideally, sensors will be prototyped and tested, radiation resistance evaluated, and final sensor designs suitable for the beamcal and lumical built and tested.
- **MUON.** Two candidate technologies, RPCs and scintillator strips, will be developed in parallel during 2010, leading to a baseline selection by mid-2011. Engineering of the flux return steel will be done so as to accommodate either design, and critical details of the designs developed in time for the detailed MC description. Critical R&D for the RPC's includes developing KPiX readout, performing lifetime tests, and developing and testing large technical prototype chambers. Scintillator R&D includes selection of a SiPM, development of the SiPM readout, and beam tests. With Sim/Recon, the baseline will be simulated and performance characterized.
- **ENGINEERING.** The SiD Engineering group coordinates and contributes to individual subsystem engineering design, and oversees detector integration issues, assembly, push-pull, MDI, and solenoid development in addition. Its

initial role will be to coordinate fixing the basic HCAL parameters, overall thickness, gap size, and absorber material, which will lead, along with input on optimization studies, to fixing the global dimensions of SiD's new baseline. There will be effort in parallel providing detailed designs for each of the subdetectors in time for the realistic Geant4 description to be developed. Critical features of these designs will be prototyped and tested. We plan to continue to work on the design of the solenoid, cryostat, and electrical and cryogenic supplies. This engineer doing this work is collaborating with the international group that is pursuing feasibility studies for large solenoids and developing new conductors. Engineering will also design the flux return iron, develop push-pull, support MDI work on vibration and support for the entire detector, and develop the beampipe design. Finally, the group provides project management for SiD, including developing a detailed project plan, document control and management, and cestimating and refining the cost estimate as the detector design advances.

- **ELECTRONICS.** SiD Electronics is developing readout and DAQ for SiD. Completing the development of the KPiX readout ASIC continues for the next two years, while ever larger versions of KPiX are submitted and tested, and designs refined. This will culminate in 2011 with production and test of the full 1024 channel KPiX. During the same time, the control, readout and timing boards that constitute the rest of the DAQ system will be developed and tested, following an architecture that has already been developed. The beamcal presents a unique readout challenge, and development work has already begun on a chip suitable for reading out rad hard detectors bunch crossing by bunch crossing. A final item, critical for the vertex detector and tracker, is the development of pulsed power delivery systems, which is already underway.
- **MDI.** The MDI group is closely coordinated with SiD engineering, and is working on two broad fronts. First, it is engaged in designing the beamline elements and alignment systems that will hold the inner quads, the beampipe and masks, and, in turn, the vertex detector/inner tracker support tubes. Understanding and controlling the vibrations of QD0, and providing the needed alignment systems, is a central task. Second, the group is developing and evaluating detector motion systems for push-pull, including the question of platform or no platform support for SiD and alignment after the push pull operation.
- **BENCHMARKING.** Key milestones include working with the SiD Sim/Recon group to improve the physics event generator and improve event generation and storage. Working with the Physics Common Task Group, SiD benchmarking will help in redefining benchmarks for both 500 and 1000 GeV running, and in developing new generators needed for physics studies. Also with the Sim/Recon group, benchmarking will help in generating the physics and background Monte Carlo data samples needed for the benchmarking exercise. Finally, starting about 2011, the group will reconstitute the SiD analysis team and begin analyzing fully simulated data for the Design Report benchmarking exercise.

- **SIM/RECON.** Work is already underway to adapt the simulation and reconstruction framework to accommodate a more realistic geometric description of SiD. So too are efforts coordinated with the tracking and calorimetry groups to improve the existing tracking and PFA reconstructions packages, and to adapt them to handle the new geometry. By mid-2011, the new SiD baseline must be encoded in the Geant4 description. This will proceed in close collaboration with the SiD subgroups. Once complete, the group's focus will change to physics event and background generation and reconstruction, and support of the phsyics benchmarking exercise.
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III. Resources for the SiD Work Plan

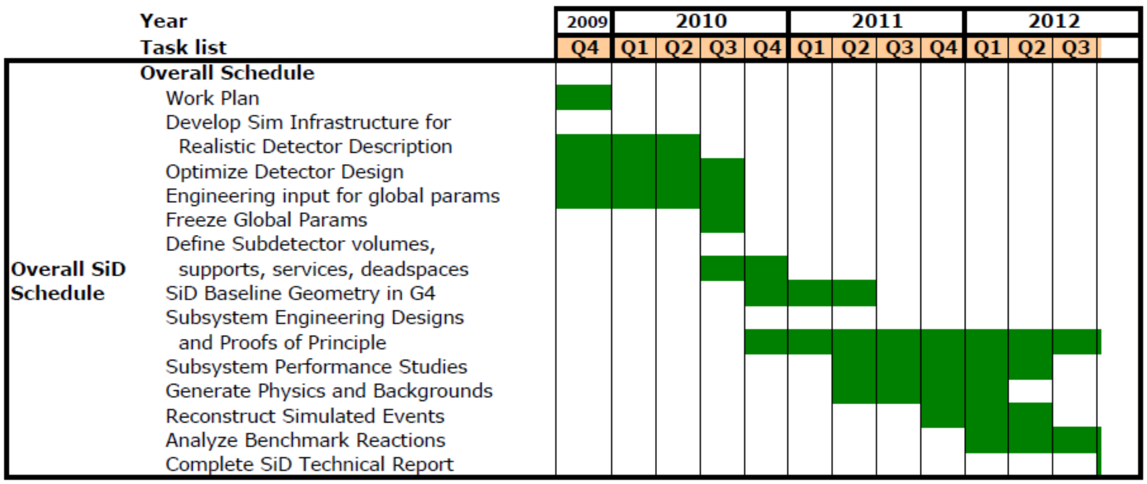
In Appendix II below is detailed information about the resources needed to accomplish the effort and workplan outlined above and in Appendix I. We have defined the following categories: Staff, Postdocs, Engineers, Students and M&S. All people resources are in FTEs. Staff is in general for senior scientists, postdocs and students are self explanatory and engineers are mechanical, electronic and software engineers. We also have a category for M&S which is in k$. We have listed the needs, as well as resources we feel are identified and funded. "Need" indicates what we feel is needed and "have" indicates what we feel is already identified as resources for SiD. The first Table shows a high level roll up of these resources simply summing them all for all of SiD. The second Table lists each subsystem/sub-effort and hwo it contributes to the overall resource need. For example in these tables there is a differentiation between mechanical, electronics and software engineers.

We arrived at these estimates by asking each subsystem to send us their estimate to be able to do the work outlined above and accomplish the milestones.

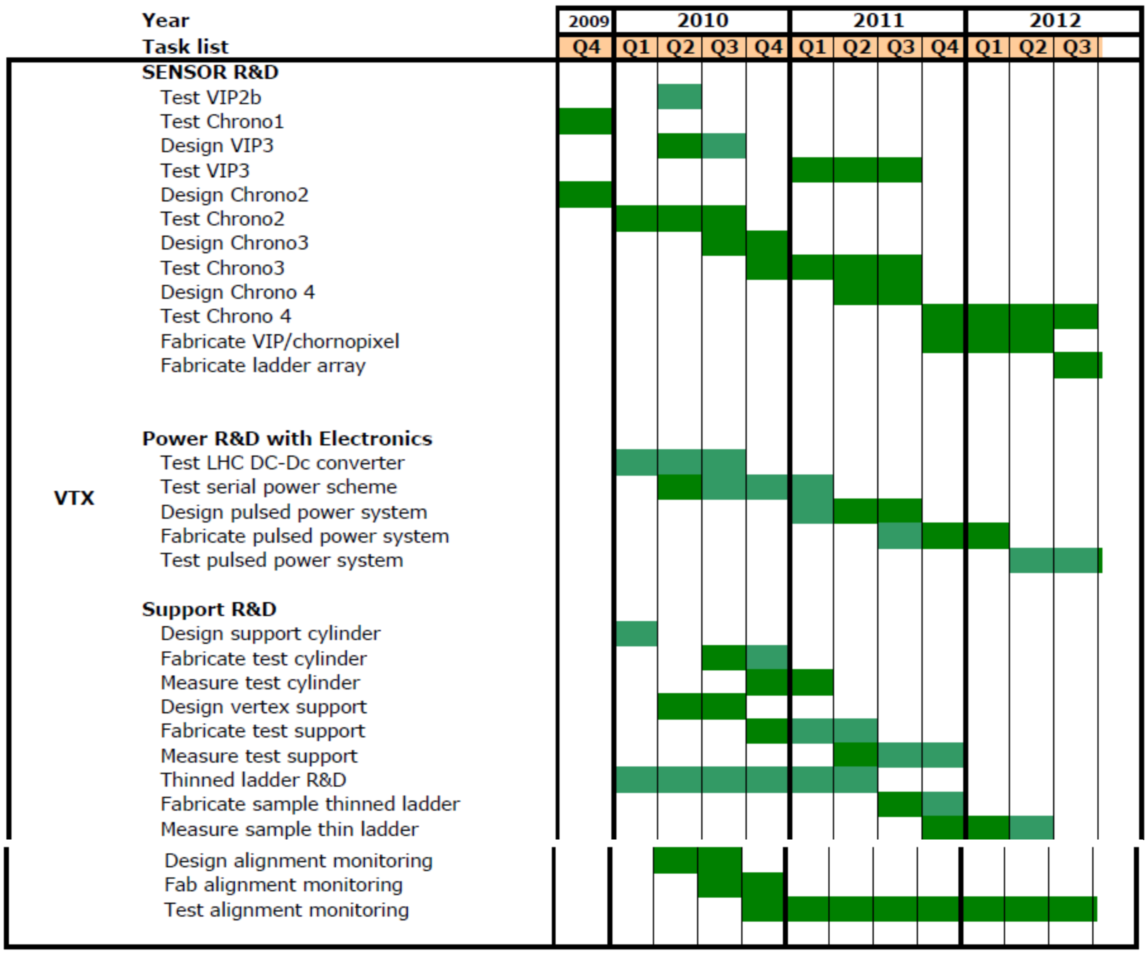
At first glance the resources required seem rather large, especially in the engineering category, with only about 50% identified. We feel that these estimates are somewhat on the high side. The estimates for postdocs are also high and only a quarter or less are identified. This also probably needs some refinement. In case of staff more then half of the needed resources are identified. Overall it is our feeling that these estimates will have to fine tuned and will result in smaller resources required.

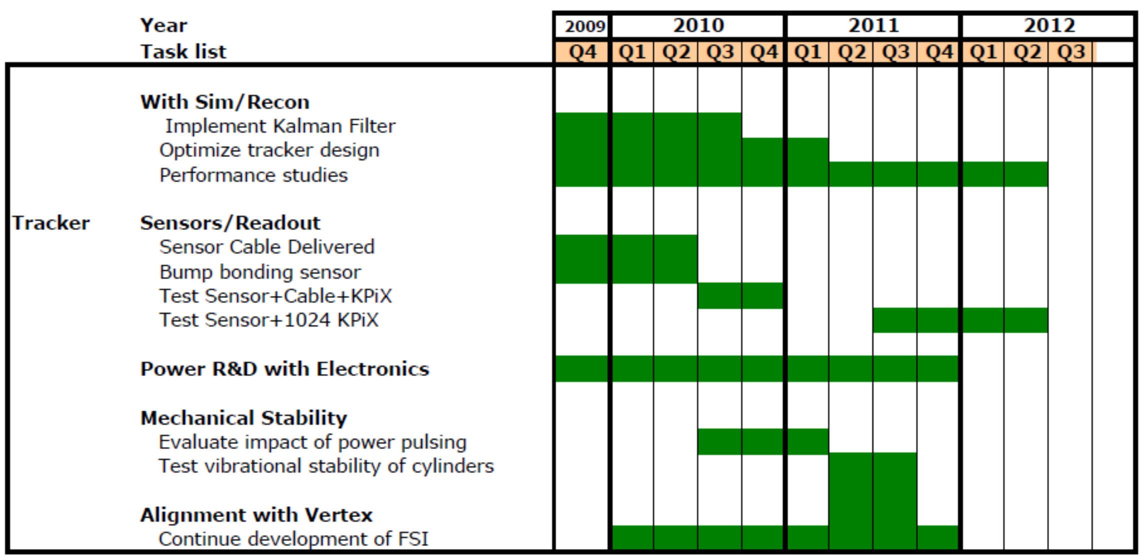
Appendix I: Overview of milestones and time lines.

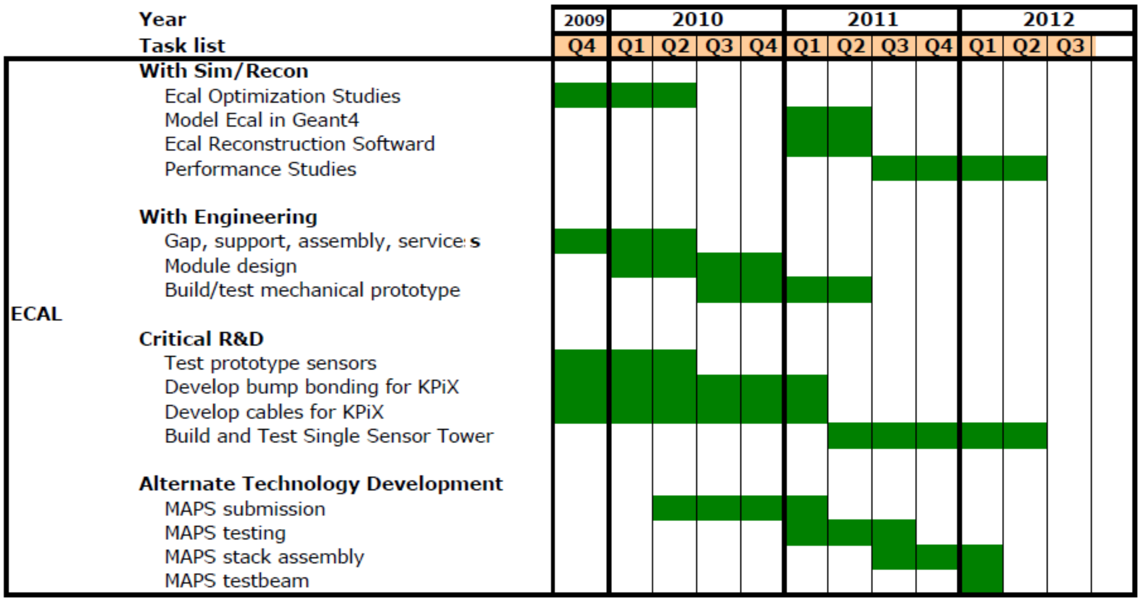
This information is available as a spreadsheet and this spreadsheet is included as part of the submission.
The first graph below shows the overall SiD milestones and schedule between now and the end of 2012. Typically the green bars indicate when work will be done and a milestone is at the end of the green bar.

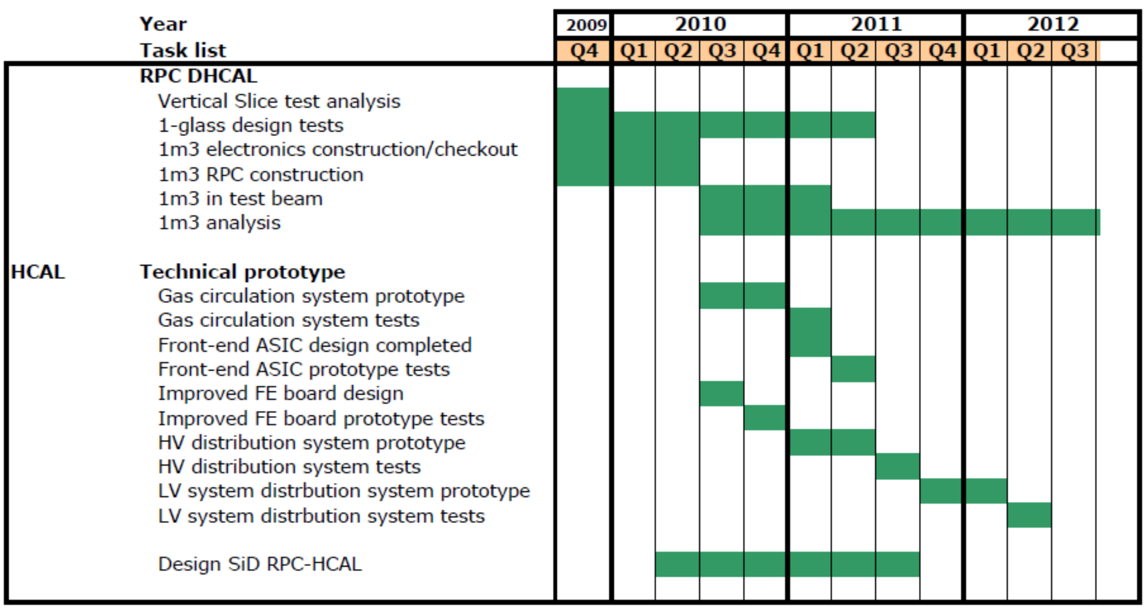


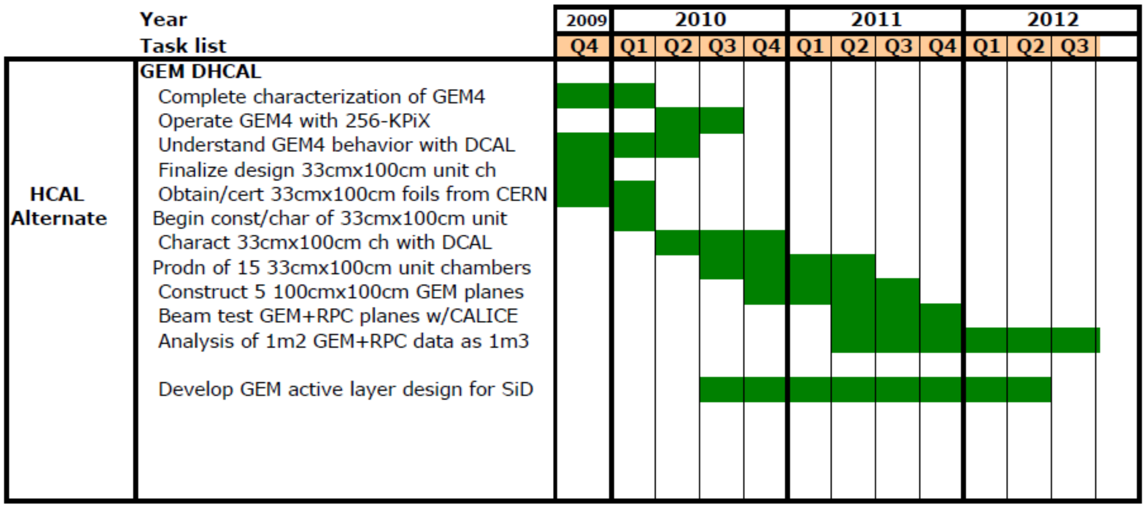
The very long graph below shows the SiD schedule for individual susbsystems.

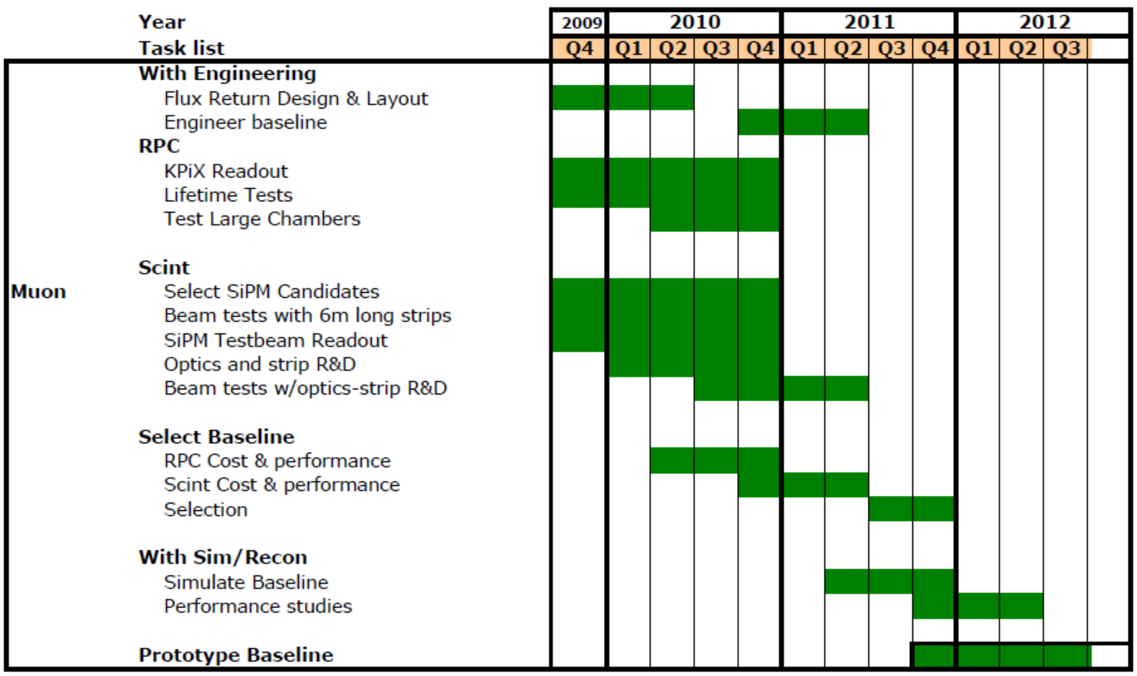

Year
Task list
2009
2010
2011
2012
Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3
VTX
SENSOR R&D
Test VIP2b
Test Chrono1
Design VIP3
Test VIP3
Design Chrono2
Test Chrono2
Design Chrono3
Test Chrono3
Design Chrono 4
Test Chrono 4
Fabricate VIP/chornopixel
Fabricate ladder array
Power R&D with Electronics
Test LHC DC-Dc converter
Test serial power scheme
Design pulsed power system
Fabricate pulsed power system
Test pulsed power system
Support R&D
Design support cylinder
Fabricate test cylinder
Measure test cylinder
Design vertex support
Fabricate test support
Measure test support
Thinned ladder R&D
Fabricate sample thinned ladder
Measure sample thin ladder
Design alignment monitoring
Fab alignment monitoring
Test alignment monitoring


Year
Task list
2009
2010
2011
2012
Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3
Tracker
With Sim/Recon
Implement Kalman Filter
Optimize tracker design
Performance studies
Sensors/Readout
Sensor Cable Delivered
Bump bonding sensor
Test Sensor+Cable+KPiX
Test Sensor+1024 KPiX
Power R&D with Electronics
Mechanical Stability
Evaluate impact of power pulsing
Test vibrational stability of cylinders
Alignment with Vertex
Continue development of FSI


Year
Task list
2009
2010
2011
2012
Q4
Q1
Q2
Q3
Q4
Q1
Q2
Q3
Q4
Q1
Q2
Q3
ECAL
With Sim/Recon
Ecal Optimization Studies
Model Ecal in Geant4
Ecal Reconstruction Softward
Performance Studies
With Engineering
Gap, support, assembly, services
Module design
Build/test mechanical prototype
Critical R&D
Test prototype sensors
Develop bump bonding for KPiX
Develop cables for KPiX
Build and Test Single Sensor Tower
Alternate Technology Development
MAPS submission
MAPS testing
MAPS stack assembly
MAPS testbeam


Year
Task list
2009
2010
2011
2012
Q4
Q1
Q2
Q3
Q4
Q1
Q2
Q3
Q4
Q1
Q2
Q3
HCAL
RPC DHCAL
Vertical Slice test analysis
1-glass design tests
1m3 electronics construction/checkout
1m3 RPC construction
1m3 in test beam
1m3 analysis
Technical prototype
Gas circulation system prototype
Gas circulation system tests
Front-end ASIC design completed
Front-end ASIC prototype tests
Improved FE board design
Improved FE board prototype tests
HV distribution system prototype
HV distribution system tests
LV system distrbution system prototype
LV system distrbution system tests
Design SiD RPC-HCAL


Year
Task list
2009
2010
2011
2012
Q4
Q1
Q2
Q3
Q4
Q1
Q2
Q3
Q4
Q1
Q2
Q3
HCAL Alternate
GEM DHCAL
Complete characterization of GEM4
Operate GEM4 with 256-KPiX
Understand GEM4 behavior with DCAL
Finalize design 33cmx100cm unit ch
Obtain/cert 33cmx100cm foils from CERN
Begin const/char of 33cmx100cm unit
Charact 33cmx100cm ch with DCAL
Prodn of 15 33cmx100cm unit chambers
Construct 5 100cmx100cm GEM planes
Beam test GEM+RPC planes w/CALICE
Analysis of 1m2 GEM+RPC data as 1m3
Develop GEM active layer design for SiD

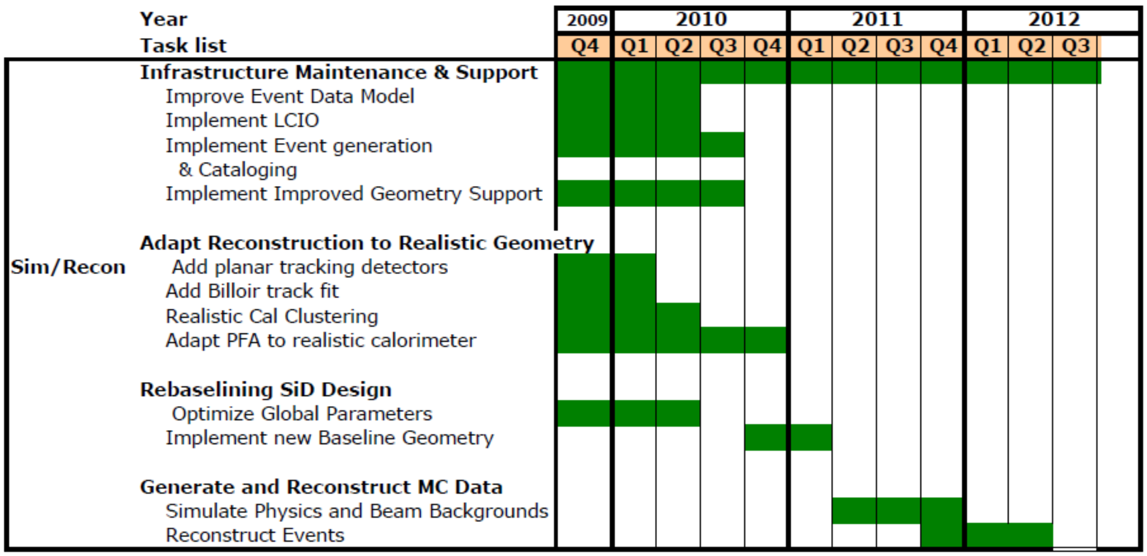

Year
Task list
2009
2010
2011
2012
Q4
Q1
Q2
Q3
Q4
Q1
Q2
Q3
Q4
Q1
Q2
Q3
Muon
With Engineering
Flux Return Design & Layout
Engineer baseline
RPC
KPiX Readout
Lifetime Tests
Test Large Chambers
Scint
Select SiPM Candidates
Beam tests with 6m long strips
SiPM Testbeam Readout
Optics and strip R&D
Beam tests w/optics-strip R&D
Select Baseline
RPC Cost & performance
Scint Cost & performance
Selection
With Sim/Recon
Simulate Baseline
Performance studies
Prototype Baseline

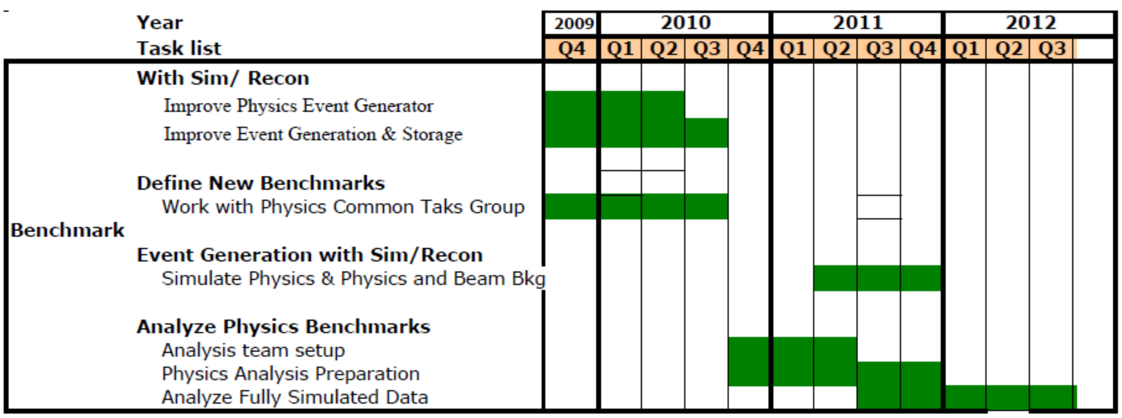
Forward Calorimetry

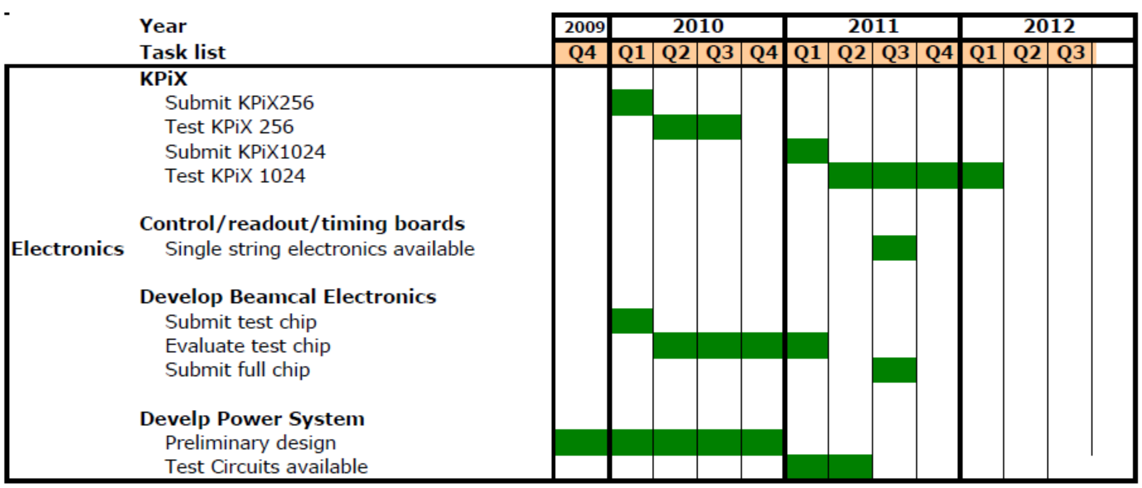
Year	2009	2010				2011				2012		
Task list	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3
With Engineering												
Beamcal & Lumical Design	■	■	■									
With Sim/Recon												
Simulate in Geant4				■	■	■						
Performance Studies							■	■	■	■		
Desirable Studies												
dL/dE measurement	■	■	■									
SUSY veto studeies	■	■	■									
Desirable R&D												
Evaluate Sensor Technology	■	■										
Design/Build Proto Sensor			■	■	■	■						
Test Sensor					■	■	■	■				
Rad test sensor							■	■	■			
Beamcal Readout	■	■	■	■	■	■						
Prototype beamcal/lumical petals									■	■	■	

Engineering

Year	2009	2010				2011				2012		
Task list	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3
Definition of Global Parameters (with other subgroups)												
Fix Hcal Thickness, Radiator, Gap	■	■	■									
Fix Global Dimensions		■	■									
Define all subdetector volumes			■	■								
Engineer Subsystem Designs (with subgroups)												
HCal	■	■	■	■	■	■	■					
Ecal	■	■	■	■	■	■	■					
Fcal			■	■	■	■	■					
Muon	■	■	■	■	■	■	■					
Vertex	■	■	■	■	■	■	■					
Tracker	■	■	■	■	■	■	■					
Design Iron/Motion Systems												
Design Flux Return					■	■	■					
Develop Motion System							■	■	■			
Solenoid Design												
Cable Development	■	■	■	■	■	■	■	■	■	■	■	■
Design He Facility									■	■	■	■
Solenoid concept drawings						■	■	■	■			
MDI (with MDI subgroup)												
Understand vibration/stability issues	■	■	■									
Decide on Platform	■	■	■	■	■							
Understand push-pull issues						■	■	■	■			
Design Beam Pipe and Inner Systems				■	■	■						
Layout Cryogenic and Gas Systems									■	■	■	■
Project Management												
Document and drawing management		■	■									
Detailed Project Plan	■	■										
Change control								■	■			
Cost Estimation										■	■	


Year
Task list
2009
2010
2011
2012
Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3
Sim/Recon
Infrastructure Maintenance & Support
Improve Event Data Model
Implement LCIO
Implement Event generation
& Cataloging
Implement Improved Geometry Support
Adapt Reconstruction to Realistic Geometry
Add planar tracking detectors
Add Billoir track fit
Realistic Cal Clustering
Adapt PFA to realistic calorimeter
Rebaselining SiD Design
Optimize Global Parameters
Implement new Baseline Geometry
Generate and Reconstruct MC Data
Simulate Physics and Beam Backgrounds
Reconstruct Events


Year
Task list
2009
2010
2011
2012
Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3
Benchmark
With Sim/ Recon
Improve Physics Event Generator
Improve Event Generation & Storage
Define New Benchmarks
Work with Physics Common Taks Group
Event Generation with Sim/Recon
Simulate Physics & Physics and Beam Bkg
Analyze Physics Benchmarks
Analysis team setup
Physics Analysis Preparation
Analyze Fully Simulated Data


Year
Task list
2009
2010
2011
2012
Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3
Electronics
KPiX
Submit KPiX256
Test KPiX 256
Submit KPiX1024
Test KPiX 1024
Control/readout/timing boards
Single string electronics available
Develop Beamcal Electronics
Submit test chip
Evaluate test chip
Submit full chip
Develp Power System
Preliminary design
Test Circuits available

		2009	2010				2011				2012			
	Year	**2009**	**2010**				**2011**				**2012**			
	Task list	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	
MDI	**Design Beamline Elements and Alignment Systems**													
	Develop Motion/Support system for Push-Pull													

Appendix II: Resources required and available.

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		SiD all	2010 Need	2010 Have	2011 Need	2011 Have	2012 Need	2012 Have
Summary	SiD all	Staff	18.7	11.7	19.0	11.1	18.5	10.3
		Postdoc	16.0	4.5	19.0	3.5	19.5	3.5
		Engineering	16.0	7.9	16.0	7.8	13.5	6.8
		Student	2.0	2.0	1.5	1.5	1.0	1.0
		M&S(k$)	1450.0	778.0	1270.0	453.0	1075.0	453.0

			2010		2011		2012	
			Need	Have	Need	Have	Need	Have
SiD all	VTX	Staff	3	1.8	3	1.8	3	1.8
		Postdoc	2	0	2	0	2	0
		Engineering	0	0	0	0	0	0
		Student	0	0	0	0	0	0
		M&S(k$)	410	225	380	200	330	200
SiD all	Tracker	Staff	1.25	0.5	1.25	0.5	1.25	0.5
		Postdoc	0.5	0	0.5	0	0.5	0
		Engineering	0	0	0	0	0	0
		Student	0	0	0	0	0	0
		M&S(k$)	50	0	50	0	50	0
SiD all	ECAL base	Staff	2	1	2	1	2	1
		Postdoc	2	0	2	0	2	0
		Engineering	0	0	0	0	0	0
		Student	0	0	0	0	0	0
		M&S(k$)	0	0	0	0	0	0
SiD all	HCAL-base	Staff	2	2	2	2	1	1
		Postdoc	1	1	1	0	0.5	0
		Engineering	0	0	0	0	0	0
		Student	2	2	1.5	1.5	1	1
		M&S(k$)	400	400	100	100	100	100
SiD all	FCAL	Staff	0.70	0.5	0.70	0.5	0.7	0.5
		Postdoc	1	0.5	1	0.5	1.00	0.5
		Engineering	0	0	0	0	0	0
		Student	0	0	0	0	0	0
		M&S(k$)	50	25	50	25	50	25
SiD all	Muon	Staff	2	1.25	2.5	0.25	2.5	0.25
		Postdoc	2	0	2	0	2	0
		Engineering	0	0	0	0	0	0
		Student	0	0	0	0	0	0
		M&S(k$)	0	0	0	0	0	0
SiD all	MDI	Staff	0.5	0.5	0.5	0.5	0.5	0.5
		Postdoc	0	0	0	0	0	0
		Engineering	0	0	0	0	0	0
		Student	0	0	0	0	0	0
		M&S(k$)	0	0	0	0	0	0
SiD all	Electronincs	Staff	0	0	0	0	0	0
		Postdoc	0	0	0	0	0	0
		Engineering	3	1.25	3	1.25	2.5	1.25
		Student	0	0	0	0	0	0

		M&S(k$)	290	35	290	35	120	35
SiD all	Engineering	Staff	0	0	0	0	0	0
		Postdoc	0	0	0	0	0	0
		Engineering	10.95	5.65	10.95	5.55	9.95	4.55
		Student	0	0	0	0	0	0
		M&S(k$)	150	45	250	45	275	45
SiD all	Sim-Reco	Staff	3	2	2	2	2	2
		Postdoc	3	1	3	1	3	1
		Engineering	2	1	2	1	1	1
		Student	0	0	0	0	0	0
		M&S(k$)	0	0	0	0	0	0
SiD all	Benchmark	Staff	0.2	0.1	1	0.5	1.5	0.7
		Postdoc	1	0	3	0	4	0
		Engineering	0	0	0	0	0	0
		Student	0	0	0	0	0	0
		M&S(k$)	0	0	0	0	0	0
SiD all	ECAL-maps	Staff	2	1	2	1	2	1
		Postdoc	1.5	1	2	1.5	2	1.5
		Engineering	0	0	0	0	0	0
		Student	0	0	0	0	0	0
		M&S(k$)	0	0	0	0	0	0
SiD all	HCAL_gem	Staff	2	1	2	1	2	1
		Postdoc	2	1	2.5	0.5	2.5	0.5
		Engineering	0	0	0	0	0	0
		Student	0	0	0	0	0	0
		M&S(k$)	100	48	150	48	150	48