SiD R&D Plan and Opportunities for New Collaborators

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SiD R&D Planning

- The LOI and SiD Critical R&D – 1st year

- Prioritization – 1st year LCRD

- What R&D is expected in 2nd and 3rd years for each SiD subsystem?

- Evolution of the SiD R&D plan towards a Detailed Baseline Design (DBD) in 2012 – selection of the KEY PRIORITIES in a limited resource scenario.

- Definition of the SiD Work Plan for the Research Director – due in October !

- For each area: where new collaborators can make important contributions.

Work plan after validation till 2012

Each validated detector group will produce a detailed baseline design by 2012. To this end the following steps are planned.

?? "Feasible" – something between a conceptual design and a full technical design?

1. Complete R&D on critical components.
   When there are options, at least one option for each subsystem will reach a level of maturity which verifies feasibility.

2. Define a feasible baseline design.
   While a baseline will be specified, options may also be considered.

3. Complete basic mechanical integration of the baseline design and identify all insensitive zones such as the beam holes, support structure, cables, gaps or inner detector material.

4. Develop a realistic simulation model of the baseline design, including the identified faults and limitations.

5. Develop a push-pull mechanism, working out the movement procedure, alignment and calibration scheme.

6. Develop a realistic concept of integration with the accelerator including the IR design.

7. Simulate and analyze benchmark reactions with the realistic detector model Include the impact of detector dead zones and updated background conditions.

8. Simulate and study some reactions at 1 TeV, including realistic higher energy backgrounds, demonstrating the detector performance.

R&D Priorities/Support

- Start from the LOI process – earlier this year.

- First we defined the areas of Critical R&D for SiD

  -> These items were used as input to LOI R&D chapter

- Applied priorities to first year funding request (LCRD)

- LCRD: Some projects were funded, but some areas we identified as critical to SiD were not funded.

- Guidance: Flat funding for years 2, 3 at year 1 rate.

Critical R&D for SiD

1) General
For the overall performance of the SiD detector, we need to demonstrate that the detector can adequately address the full spectrum of the physics at a 500GeV ILC, with extension to 1 TeV. This includes a full simulation of the detector, track reconstruction code, and development of a fully functional Particle Flow Algorithm (PFA). While we have working versions of the simulation, reconstruction, and the PFA, we anticipate significant further developments, which will provide the critical tools to optimize and finalize the detector design.

2) Vertex Detector.
No ILC-ready vertex detector sensor yet exists. The main needs are to develop one or more solutions for the sensors, a demonstrably stable and low mass mechanical support, and pulsed power/cooling solutions. Sensor technologies are being developed, as well as mechanical support materials, designs, pulsed power, and cooling.

3) Tracking Detector.
The priorities for tracking are testing a multi-sensor prototype in the absence of a magnetic field and at 5T, refining the track finding and fitting performance, understanding the optimal forward sensor configuration, and developing more detailed understanding of the mechanical stability and required alignment. Work is underway in all of these areas…

4) Electromagnetic Calorimetry.

For the baseline silicon-tungsten Ecal design, the operability of a fully integrated active layer inside the projected 1.25mm gap between absorber plates must be demonstrated. Sufficient S/N, successful signal extraction, pulse powering, and adequate cooling must be shown as well. Mechanical prototypes with steel rather than tungsten will first be built, followed by a full depth tower appropriate for beam tests. For the alternative MAPS technology being investigated in the U.K., a key need is production of large sensors with sufficient yield.

5) Hadronic Calorimetry.

The priority for hadronic calorimetry is to demonstrate the feasibility of assembling a fully integrated, full-size active layer within a ~8mm gap between absorber plates. Several technologies are being investigated: RPC's, GEM's, Micromegas, and scintillating tiles/SiPM's. All of this work is being carried in conjunction with the CALICE Collaboration, and the results will form a critical component of SiD's future technology selection. An alternative approach, using homogeneous crystal calorimetry with dual readout, is also being studied. This effort needs to demonstrate good hadronic energy linearity and resolution in a test beam, to develop suitable crystals, to produce a realistic conceptual design, and to simulate physics performance.

6) Electronics.

One critical item on electronics is a demonstration of the operation of 1024 channel version of the baseline KPiX chip. Another is to develop power distribution schemes for the vertex detector and tracker with DC-DC conversion or serial powering. Adapting and testing KPiX readout to the tracker, calorimeters, and muon systems must also be continued and perfected.

7) Magnet.

For the superconducting solenoid, it is required to demonstrate that a 5T field can be achieved with acceptable reliability and cost, and with acceptable forces. To address cost reduction, a new conductor is being studied. R&D for the Detector Integrated "anti" Dipole coils is also required. Field uniformity studies for the tracker.

8) Engineering Issues.

A credible scheme for push-pull operation is required that achieves acceptable repositioning of the detector, preserving internal alignment, in an acceptably short cycle time. Equally important is achieving the required mechanical stability of the quadrupole focusing lenses.

9) Forward Calorimetry.

A sensor that can survive the radiation environment in the forward region is required, along with suitable readout electronics. Some of this work is collaborative with the FCAL Collaboration.

10) Muon system.

Emphasis is placed on development of reliable, and robust RPCs. SiPMs for scintillator strips are a new technology of interest, also under development.

R&D Priorities for SiD

- Prioritization is complex – many factors/issues:

-> importance of the specific R&D for concept viability

-> expected return on investment

-> facilitating collaboration growth

-> relation to overall collaboration R&D activity

-> so far we mainly focused on the immediate future (one year), R&D is time dependent with different time scales for each project.

-> now we need to address the period through 2012 with respect to the Research Director's Work Plan.

R&D Priorities for SiD – Selection(1)

(in the order they were given in LCRD)

Calorimetry

Jet Energy Resolution -> PFA progress -> establish viability for large scale system -> Calorimetry is critical

Critical alternative technologies:

ECal – fine-grained Si-W (baseline), MAPS

HCal - RPC(baseline), GEM, micromegas, scintillator/SiPM and Homogeneous dual-readout as alternate approach.

☛ Ready the baseline technologies for large scale prototyping as soon as possible + further PFA development. Also strategically important to advance R&D on dual-readout.

R&D Priorities for SiD - Selection(2)

Tracking

Tracking uses silicon sensors with hybrid-less readout. Sensors are in hand -> high priority to development of an array of sensors, mounted on support structure -> test in beam.

Also priority to readout through baseline architecture using KPiX chip + reference architecture using LSTFE

Push-pull -> critical role for alignment -> preserve tracker alignment.

R&D Priorities for SiD - Selection(3)

Vertex

- Vertex detector -> Several technologies under development world-wide are followed and possible choice; SiD supporting development of 3-D vertically integrated Si and Chronopixel technologies.

Muon

- Muon detectors -> RPC (baseline) - priority, plus support for scintillator.

Note: Projects will be reviewed and re-assessed for progress and prioritization.

Beyond the first year

Vertex detector

Many technologies being pursued (DEPFET, CCDs, 3D Vertical Integrated Silicon, and MAPS) – current funding can only support development of limited choice.

Technology selection by time of start of ILC construction -> build/test small prototype.

∴ Extended R&D timescale for vertex detector – not strongly tied to DBD.

Beyond the first year

Tracking

- Emphasis is currently on the development of the double-metal sensor with the associated KPiX readout.

- Demonstrate mechanical robustness, power pulsing, stability/alignment.

- Small scale system consisting of a few sensors with full readout will be tested in a test beam -> test Lorentz forces and mechanical stability. 2010.

- Simulate LOI geometry with individual planar sensors, full digitization.

- Evolve towards technical design by 2012.

Beyond the first year

Calorimetry: ECal

- Si-W ECal: anticipate that the test-beam related data taking and analysis will continue well into 2010.

- First the module will be tested in an electron beam (possibly at SLAC), followed later by a beam test with hadrons.

- Completion of this R&D is expected by 2012.

- MAPS ECal: the goal is to make a second generation chip which is sufficiently large to make a ECAL stack to study digital electromagnetic calorimetry in detail.

Beyond the first year

Calorimetry: HCal

- RPC option -> continue with testing the 1m^3 stack. beyond the first year. Calorimeter will be exposed to muons and pions and positrons of various energies. The response and energy resolution will be measured together with characteristics of hadronic showers, for Particle Flow Algorithms. R&D for Technical Prototype – 2010-2012.

- GEM option will test its 1m^2 layers as part of the CALICE hadron calorimeter prototype (2010-2011), and will design and build a complete, integrated layer with minimal thickness and full services. Thick GEM prototypes will also be assembled and tested as large sections of thick GEMs become available. Gas studies for thick GEMs will also continue.

Beyond the first year

- **Calorimetry: HCal**

-Micromegas option -> continued testing of, and analysis of results from, the 1m^3 stack 2010-2011

- Scintillator/SiPM option -> insertion of the integrated readout layer planes fabricated with the CALICE/EUDET electronics into the CALICE absorber stack. This installation will be followed by the commissioning and exposure of this prototype to a test beam. 2010-2011?

- Homogeneous dual-readout calorimetry -> development of suitable crystals, photodetectors, and associated readout electronics, all in preparation for a demonstration of linearity and energy resolution for hadrons in a test beam, while developing a conceptual design for inclusion of this technology into SiD. 2010-2012?

Beyond the first year

Muon

-The 2nd and 3rd year of muon detector effort will work toward a technology choice (RPC/Scintillator) during 2011.

- RPC/KPIX proof of principle -2008-9, Optimize interface board & protection circuitry design 2009-10. CR/beam tests.

- Scintillator SiPMs -> development or acquisition of an SiPM compatible ASIC, possibly a modified KPiX.

- Planning for construction of a larger-scale prototype of the selected technology would begin, with simulation studies of overall detector performance for muons. The simulation model of the muon system would be derived from measurements with prototypes.

Beyond the first year

Forward Calorimetry

The first year outcomes of studies of the two photon backgrounds will be applied to the detector design choices for the forward calorimetry in years 2 and 3. The development of the radiation resistant detectors following year one will be designed to build on the successes and lessons from the first year of effort.

How will the R&D priorities evolve – as we approach a Detailed Baseline Design (DBD)?

Factors affecting R&D progress/priorities:

- availability of funds
- interest in/continuation of projects
- success or otherwise of specific initial R&D
- evolution of the overall SiD design
- R&D elsewhere (horizontal collaborations)
- overall ILC timescale – DBD in 2012

Evolution of R&D towards completion for DBD - contributions to LOI R&D Chapter.

Elements of complete SiD R&D plan:

Roles in validation etc:

1) We need a coherent plan to get us to the DBD

2) We need to have the R&D Work Plan validated for future funding support.

- List of **all** SiD R&D projects

  -> Project, who, when, funded,...

- Deliverables, milestones ?

The phases towards the TDR

Tech design Phase 1 -> 2010 (the current LCRD year 1)

Tech design Phase II -> 2010-2012

In 2011 -> completion of R&D

-> technology selection(s) for DBD

-> start DBD

2011 -> 2012…design/start to build/test sections (modules,..) of subsystems with selected technologies

DBD ready 2012, work on subsystem technical prototypes continues.

Developing the SiD Work Plan

Schedule and Milestones

2009

- **Simulation/Reconstruction:** PFA improvements; tracking simulation and reconstruction improvements and background studies; simulation of dual readout concept; optimization of SiD design.
- **Electronics:** Full KPiX chip; develop beamcal readout.
- **Tracker:** Sensor test; sensor with readout test; develop alignment concept.
- **ECAL:** Sensor test; sensor with readout test.
- **Beamcal:** Evaluation of beamcal sensor technologies.
- **HCAL:** RPC and GEM with readout tests; GEM slice test; Micromegas slice test; RPC construct 1 m^3; engineering design of HCAL module; dual readout crystal candidate selection and photon detection studies.
- **Vertex:** Develop sensors; continue mechanical and power distribution designs.
- **Muon:** Test RPCs, scintillating fiber, and RPC longevity.

Developing the SiD Work Plan

<u>2010</u>

- **Simulation/Reconstruction:** Update physics studies; dual readout full simulation and physics performance.
- **Electronics:** Test beamcal sensor readout; develop SiPM readout (if needed).
- **Tracker:** Test alignment concept; beam test sensors with readout and support system in B field; test Lorentz forces and mechanical stability with pulsed power.
- **ECAL:** Build and test ECAL tower; build mechanical prototype for ECAL module.
- **HCAL:** Produce engineering design of module with integrated readout; dual readout beam test of concept; continue beam tests and analysis; ready 1 m^2 modules of GEM and Micromegas; continue development of suitable crystals.
- **Vertex:** Develop sensors; continue mechanical and power distribution designs.
- **Muon:** Prototype muon chambers; longevity test; study costs.
- **MDI:** Develop push pull designs; vibration studies; study alignment issues.
- **Magnet:** Develop new conductor jointly with others.
- **Beamcal:** Design sensors.

Developing the SiD Work Plan

<u>2011</u>

- **Technology Selections:** ECAL, HCAL, Muon.
- **Engineering:** Complete engineering designs for ECAL, HCAL and Muons for chosen technologies and forward systems; plan preproduction and detailed design phase.
- **Simulation/Reconstruction:** Complete detector optimization; realistic GEANT4 detector description based on technology choices; generate MC data.
- **Complete beam testing:** SiW ECAL, RPC, GEM, Micromegas, Scint & SiPM HCAL; proof of principle development of suitable crystals and photodetectors.
- **Tracker:** Test large scale system.
- **Vertex:** Test sensors; continue mechanical and power distribution designs.
- **Benchmarking:** Studies with final detector choices and optimized design.
- **Magnet:** Continue new conductor development.

<u>2012</u>

- Complete optimized SiD detector design.
- Begin tests of magnet material.
- Begin full scale prototyping.
- Write SiD proposal.

Beginnings of an overall SiD R&D plan

	2010	2011	2012
Vertex Detector	Continued development of SiD selected technologies + multiple non-SiD		
Tracking	Small scale/few sensor test	Large scale test? →	Technical design
ECal	Si-W 30 sensor stack tests -----------→ Design/build barrel module MAPS – dev of 2nd gen chip -→ stack test ---		
HCal	RPC 1m3 stack assembly and tests --------→ Tech sel. -→ Tech proto Options 1m2 -> 1m3 assembly/tests ----------		
FCal	Studies for detector design choices, dev of radiation resistant detectors		
Electronics/DAQ	Completion of KPiX design, creation/operational demo of 1024 ch.		
Muon	Completion of R&D --------→ Tech choice ------→ Large scale prototype		
Magnet	Solenoid/anti-DID studies --- dev of new conductor --- tests?		

Beginnings of an overall SiD R&D plan

- So…we have a good perspective on all the relevant R&D projects for SiD.
- We have lists of tasks…
- We have some idea of the timescale for each project…
- We have projections of resources (see Harry's talk)…
- We are beginning to understand the target (DBD/2012)
- BUT…we need to fully develop our Work Plan!!

Beginnings of an overall SiD R&D plan

- SiD Work Plan must be sent to Sakue in 3 weeks!
- Work Plan can be based on LOI tables.
- Work Plan can be updated later.
- "Feasible" = "if you had the $$, you could build it"!
- This implies considerable engineering between "feasible" and a real TDR/Engineering ("shop ready") design.

Beginnings of an overall SiD R&D plan

What we MUST do:

Major SiD R&D Priorities:

Tracker – array of sensors/support, beam test

ECal – Sensor + KPiX + cables…test + operability in 1.25mm space + plausible design in available space.

Electronics – demonstrate successful operation of 1024-channel KPiX chip.

HCal – Successful operation of large plane(s) of at least one technology with 8-12mm active gap + plausible design in available radial space/supports

FCal - Sensors

MDI – Push-pull, QD0 stability

There are many associated/parallel/alternative/desirable tasks – execution depends on available $$ + people

Beginnings of an overall SiD R&D plan

- Start with plan to achieve these basic goals and develop timeline + milestones + resources needed to get them done.
- Add associated tasks/options/exploration of alternative design ideas – see what can be achieved with anticipated resources, results from horizontal collaborations.
- Iterate with SiD subgroups on basic goals + other tasks.
- Write Work Plan, deliver in 3 weeks!

Opportunities for New SiD Collaborators

Vertex

– Mechanical design of thinned supports and ladders – recently organized “plume” collaboration (Bristol, Strasbourg, DESY and Oxford).
- Need physicists, engineers, techs to develop alignment
– Power Delivery, stability, and infrastructure – need physicists, engineers, techs.

Tracking

– software person to develop track fitting/Kalman filter
- software person to optimize tracking geometry
- study of physics reach of physics benchmarking studies with regard to tracking geometry
- characterization of double-metal sensors
- readout of double-metal sensor with cable and KPiX - test beam studies of above with and without B-field

Opportunities for New SiD Collaborators

ECal

- Optimization of Ecal layout for physics. 2009-10
- Engineering design: layout and services. 2010-12
- Electronics/KPiX: 1024 version, combine with sensor, cable; test beam work
- MAPS option: design/fabricate large scale sensor + PCB

- Opportunities for physicists, postdocs and students.

Opportunities for New SiD Collaborators

Calorimeter (Hcal/RPC)

1) Areas: construction of RPCs, QA of RPCs, electronics check-out, test beam set-up and data taking, data analysis...

2) Qualifications: mechanical and electronics technicians, students, postdocs

3) Time frame: construction: now until spring 2010
electronics: now until spring 2010
testbeam: spring 2010 until fall 2011
analysis: now until 2012 (excellent thesis topics)

Opportunities for New SiD Collaborators

Calorimeter (Hcal/GEM)

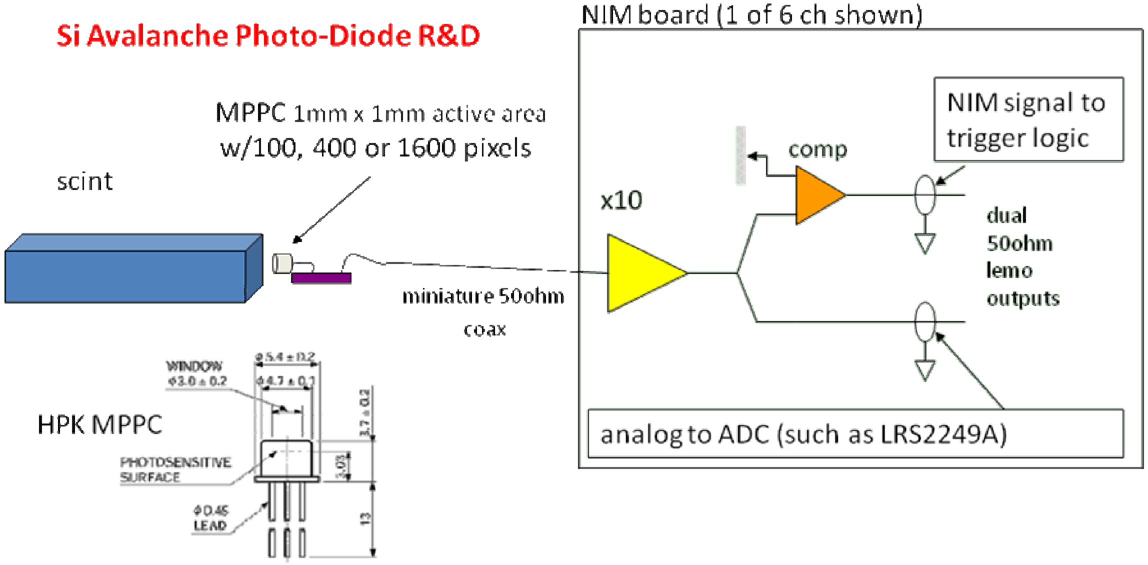
1) finishing 30cmx30cm chamber development and characterization with sources, cosmic ray and particle beams 2009-10
2) design and construct 1m x 33cm GEM chamber 2009-10
3) designing, and contructing 5 1m x 1m GEM DHCAL layers. 2010
4) testing the 5 layers in the CALICE stack. 2011
5) analyzing the data from the CALICE stack with GEMs included. 2011-12
6) developing a viable mechanical design for GEM DHCAL modules in SiD. 2011-12
7) including a detailed description of GEM DHCAL in the SiD simulation. 2010

This work presents opportunities for physicists, postdocs, students, and some engineering.

Opportunities for New SiD Collaborators

Muon tracking and identification

Two systems under study:
- Resistive plate chambers
- Strip scintillators with wavelength shifting fiber/MPPC readout



Opportunities:
- physicists and students (graduate and undergraduate) to work on prototype development and testing
- students, postdocs to work on simulation and analysis.

Opportunities for New SiD Collaborators

Forward Calorimetry

There are engineering opportunities for FCal (including MDI) mechanical design for Lumical and Beamcal.

There are also Postdoc level opportunities for FCal suimulation activities.

Summary

- A large amount of excellent R&D has been carried out

- Much still to do – many projects in process!

- Some critical areas not funded in present LCRD round

- The challenge to produce a Work Plan to achieve the DBD by 2012 has been issued.

- We have 3 weeks to firm up the elements of our initial plan!

- It is clear that we have much to do and there are MANY OPPORTUNITIES for NEW COLLABORATORS