DESY PRC R&D 03-02
Project: SiLC
Addendum

SiLC: Silicon Tracking for the Linear Collider

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Abstract

This addendum reminds the goals and milestones of the SiLC R&D project. It describes in details the different tasks and the sharing of responsabilities between the different groups of this collaboration, especially for the first year of the project, i.e. until October 2004.

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1 Introduction

As stated in PRC-DESY-03-02, the SiLC collaboration, aims to pursue a generic R&D on Silicium tracking for the Linear Collider, with as ultimate goal the construction of the Si-tracking system needed for the LC experiment.

This R&D project gathers Institutions from Asia, Europe and USA, which all have expertise in Silicon tracking, some of them being even pioneer in the field. Due to this already existing experience, close contacts with most of the relevant high tech and industrial firms are established and will be further extended; All this constitutes a precious asset for this project. A brief summary of the available expertise in the collaboration is given in the Table 6, at the end of this addendum.

The project comprises: **R&D on sensors** pursuying two main lines of research, the long microstrips and the Si-drift sensors; **R&D on Electronics** with both the development of a FE including digitization, and of the readout electronics; **R&D on Mechanics** with the detailed CAD design of the structure supports for each detector component, addressing also the integration issues with the rest of the detector, the mechanical cooling and the alignment studies, the study of materials, and the issues related to the transfer to the Industry; Developing appropriate Lab **test set-ups**, and test beams; **Simulations studies**. The interest of each Institute in participating to these general main items is summarized in Table 1.

Institutions	Sensor techno	Electronics	Mechanics	Simus	Tests set-ups
University of Michigan	—	—	Yes	Yes	Yes
IMB-CNM (CSIC)	Yes	Yes	—	—	Yes
BNL	Yes	Yes	Yes	Yes	Yes
Wayne State Uni.	Yes	Yes	Yes	Yes	Yes
Geneva University	Yes	Yes	Yes	—	Yes
Helsinki University	—	—	Yes	—	Yes
IEKP-Karlsruhe	Yes	Yes	—	Yes	Yes
Korean Universities	Yes	Yes	Yes	Yes	Yes
Obninsk State University	Yes	—	—	Yes	—
LPNHE-Paris	Yes	Yes	Yes	Yes	Yes
Charles University	—	Yes	Yes	Yes	Yes
SCIPP/UCSC	Yes	Yes	—	Yes	Yes
Tokyo University	—	—	—	Yes	Yes
Torino University	Yes	Yes	Yes	Yes	Yes
HEPHY-Vienna	Yes	Yes	—	—	Yes

Table 1: *Main general focus of interest in each Institute*

The foreseen schedule for the three year duration of the SiLC R&D project is recalled in the three detailed chart-maps at the end of this addendum, one for the R&D on sensors (see fig 1), one for the electronics R&D (see fig 2), and the last one for the mechanics R&D

(see fig 3). In order to achieve these ambitious goals, and taking into account the fact that a certain number of Institutions are still strongly involved in on-going experiments or in the starting phase of the construction of the LHC detectors, we have subdivided our R&D program into two main phases, namely:

- *Phase 0*: from mid 2003 to mid 2004 is the *"warm-up"* period for the collaboration. It implies extending and organizing our collaborative work and accomplishing a first series of tests on prototyped Si-sensors and on the VFE electronics as well as a first step towards a final detailed CAD mechanical design of the various Si-trackers.

- *Phase A*: from mid 2004 to mid 2006, the collaboration will aim to achieve a series of measurements on Si-sensor prototypes and to design and produce prototypes of the associated FE readout. This generic R&D will result in the construction of a prototype ready for testbeam by fall 2006. On the mechanical side, the R&D will focuse on a full detailed design (including tools and related prototype studies).

The next two sections describe in more details these two phases in terms of tasks to be achieved and of sharing of responsabilities among the different teams.

2 First Year of this R&D Program: Phase 0

The main lines of research for this first phase are:

- *R&D on sensors*, following the 2 main technologies, namely: long Si-microstrips and Si-drift sensors[1]
- *R&D on F.E. electronics*, up to and including the digitization and data transmission.
- *R&D on Mechanics* including:
  - The detailed CAD design of each Si-detector components
  - Mechanical cooling studies
  - Alignment studies
  - Material studies for the support structure
  - Already addressing the industrialization issues
- *Simulation Studies*

2.1 R&D on Sensors

Two cases are currently studied: the long microstrips and the Si-drift sensors.

[1] *Note that Si-drift is not a suitable technique for the forward disks though, because the drift direction will be wrongly aligned with the magnetic field in those detectors.*

2.1.1 *R&D on long Si-microstrips*

Contacts with vendors are already well established and will be further developed with: Hamamatsu (Korean Universities [2], Paris and Vienna), ST Microelectronics (Torino and Vienna). Vienna HEPHY will ensure the coordination of these efforts.
The characterization of the individual sensors as they are delivered by the vendors, and of the long ladders once they are built are another crucial aspect of this work; It includes:

- *i) the capabality to test single sensors*, with possibly the *serpentine* technique to mimic long ladders (i.e. to bond several microstrips on one single sensor to make a long strip); We refer to it as *serpentine*
- *ii) the capabality to build long ladders* (made of N sensors with $N \geq 3$), and
- *iii) the needed F.E. system* (presently used are the VA-type circuits as built by IDEAS) plus a test bench with a laser diode and/or radioactive source to test and characterize the sensors or long ladders

The Labs currently involved in these activities are: CNM-CSIC in Barcelona, the Korean Universities, SCIPP and UC Santa Cruz, Vienna and Karlsruhe, Paris plus Geneva and Torino, and the Charles University in Prague. Having various sites equipped with these facilities will permit to test several vendors and thus several types of sensors and to cross-check results. In the Table 2 are summarized the detailed sharing of responsabilities in this aspect of our R&D program.

Institutions				
Long microstrips:	Contact with Vendors	Construction Serpentine	Construction long ladders	Characterization sensors/longladders
IMB-CNM (CSIC)	—	Yes	—	Yes
Geneva University	—	—	Yes	Yes
IEKP-Karlsruhe	Yes	—	—	Yes
Korean Universities	Yes	Yes	Yes	Yes
LPNHE-Paris	Yes	Yes	Yes	Yes
Charles University	—	—	—	Yes
SCIPP/UCSC	—	Yes	Yes	Yes
Torino University	Yes	Yes	Yes	Yes
HEPHY-Vienna	Yes	Yes	Yes	Yes
Si-drift sensors:	Contact Vendors	Single sensors	long Si-drift long ladders	Characterization sensors/longSi-drift
BNL	Yes	Yes	Yes	Yes
Wayne State Uni.	Yes	Yes	Yes	Yes

Table 2: *Sharing of responsabilities for the R&D on Sensors*

[2] *The Korean Institutes use ETRI, a foundry in Korea that fabricates sensors for their R&D. Sensors and mask design are being done in Kyungpook National University.*

2.1.2 *R&D on Si-drift sensors*

Thanks to the work achieved on the Si-drift device for STAR, Wayne State University (WSU) has established contacts with various Si-drift vendors: SINTEF, CSEM, EUROSYS and CANBERRA. Hamamatsu seems also interested in this technology. Early R&D efforts will include the translation of the original four inch masks for the STAR drift detectors to six or eight inch processes. Thinning the detectors from the presently achievable 280 μm thickness to less than 150 μm is also envisioned. In addition the layout of the inactive guard area, the cathode spacing, and the internal resistor chain for voltage gradient support will be reevaluated. WSU and BNL are for the time being the main Labs pursuying this R&D. Both Labs are equipped with all the needed test facilities and will use them to test new Si-drift sensors. In one year from now, other teams in the collaboration or newcomers are expected to join this effort. Table 2 reflects the current situation.

2.2 R&D on Electronics

During the first phase of this project, it is to say during this first year, the main focuse is on developing the Front End electronics for each type of sensor.

2.2.1 *R&D on long microstrip FE electronics*

Presently two Labs have started this R&D effort: UC-Santa Cruz with SCIPP, and LPNHE-Paris. Their main goals are: a low noise preamplifier, a long shaping time (a few microseconds), digitization at the F.E. stage, a very low power dissipation and power cycling electronics.
UC Santa Cruz with SCIPP started early 2003 this development and foresee to submit for fundry a prototype in 0.25 μm TSMC technology, by the end of the year.
LPNHE-Paris is just starting the FE design using 0.18 μm AMS technology. The submission for fundry is expected by April 2004. So, at least one of the chip should be available by mid 2004 and thus the first test results on this prototype could be available by the next PRC in October 2004. Both Institutes already agreed to collaborate on the test of each FE chip once they are delivered.
Later on (by the second year of the project), HEPHY-Vienna, is interested in joining this R&D aspect of the project. The Korean Institutes are planning to do R&D on F.E. electronics as well.

In parallel to the design of a new FE electronics, both LPNHE-Paris and HEPHY-Vienna, have ongoing tests with VA- VFE electronics from IDEAS. We are in contact with IDEAS to investigate the possible development of a new VA-type VFE that would fit the requirements of a long microstrip device operating at the future LC. This is indeed important, because this firm has developed a unique expertise over the past 15 years in this domain. Karlsruhe, HEPHY-Vienna and LPNHE-Paris will pursue the close contacts with IDEAS.

2.2.2 *R&D on Si-drift FE electronics*

Testing the PASCAL chip, developed in 0.25 μm IBM technology for the Si-drift detector in the ALICE experiment is part of this activity. This is in view to possibly adapt this device to the LC-operation regime. BNL and WSU are presently in charge of this R&D aspect in our collaboration.
The experience with the STAR detector has shown that three F.E. stages are necessary to process the drift detector information: a preamplifier/shaper and switched capacitor array and an ADC. In the STAR design these parts were separated IC based on different process technologies. The European groups working on the ALICE Silicon drift detector have successfully re-designed the STAR frontend and combined all three chips in 0.25 μm IBM CMOS technology. This new chip will be the basis of our R&D effort. The main R&D area is the power consumption of the combined chip. We believe that by optimizing the amplification stage with a new design proposed by BNL the power consumption can be reduced by a factor five in which case simple air cooling would be sufficient to cool the detector and the on-detector electronics. We also investigate the use of tape-automated-bonding (TAB) instead of wirebonding between the sensor and the electronics. BNL and WSU are presently. This packaging technique will also be considered in the case of the FE for the long microstrips.

The ongoing R&D activities on Electronics and the corresponding sharing of responsabilities is summarized in the Table 3.

Institutions			
Long microstrips FE:	Tests on available FE	Design/fundry new FE	Characterization on test bench
IMB-CNM (CSIC)	—	—	Yes
Geneva University	—	—	Yes
IEKP-Karlsruhe	Yes	—	Yes
LPNHE-Paris	Yes	Yes	Yes
Charles University	—	—	Yes
SCIPP/UCSC	Yes	Yes	Yes
HEPHY-Vienna	Yes	Yes	Yes
Si-drift FE:	Tests on available FE	Design/fundry	Characterization on test bench
BNL	Yes	Yes	Yes
Wayne State Uni.	Yes	—	Yes

Table 3: *Sharing of responsabilities for the R&D on the Front End Electronics*

2.3 R&D on mechanics

This R&D activity is focused on being able to construct a large size Si-tracking system, with an extremely low material budget, very high stability and high spatial precision. This implies mechanical cooling studies, alignment and mechanical constraint studies, that are in progress. Besides, because of the strategic position of this system, an important aspect of the work on mechanics is to study the integration issues. Last but not least, the industrialization issues are part of the concerns in Mechanics already at this early stage of the project.

Two Institutes in the collaboration are currently very much involved in this activity: WSU for the Si-drift option and LPNHE-Paris for the long microstrip based detector.

2.3.1 *R&D on mechanics for the long microstrip based detector*

In the first phase of the project, SiLC is focusing in:

- *Developing the technique to build long ladders*
- *Detailed design of all the components of a Si-tracking system as well as,*
- *Detailed design of a complete Si-tracking system*, adressing all the related integration issues,
- *Mechanical stability, and material related issues*
- *Mechanical cooling studies*
- *Alignment*

Some of these issues such as studies of structure, cooling, alignment, imply constructing mechanical prototypes and/or developing tools.

2.3.2 *R&D on mechanics for the Si-drift detector*

Most or even all the issues mentioned here above apply also to the case of a Si-drift detector and are currently under study also in this case.The original support for the STAR Silicon Drift detectors is inappropriate to support the long ladders required in the LC tracker. Two major R&D developments are foreseen. First, the power consumption of the FE electronics will determine whether liquid or evaporative cooling is necessary. Should the R&D of the FE electronics lead to the desired results the presently available mechanical support could be significantly simplified. Second, a very stable triangular Carbon fiber structure was recently developed for a Silicon strip addition to the STAR SVT. This design will be enhanced to the required length for the LC ladders and a prototype will be manufactured and tested in the first year of R&D. Tests will include static deformation measurements and dynamic alignment parameters under stress such as enhanced air flow, beam conditions, and magnetic fields.

The Table 4, summarizes the present expertise among the teams in the SiLC collaboration in these various aspects of the R&D on Mechanics. In this Table, CAD design means both CAD design of each detector components and of the overall detector system, including the integration issues. "Structure" includes the study of the material for the structure support, developing tools and prototypes to further test the feasability of the proposed structure (mechanical constraint, stability etc...). Industry transfer involves the collaboration with firms that would be able to collaborate to the construction of the full detector system and/or produce in large quantity and with the appropriate quality control the basic elements of this detector, as for instance the long ladder supports.

Institutions						
long microstrip case	Long Ladder	CAD design	Structure	Cooling	Alignment	Transfer
Univ. of Michigan	—	—	—	—	Yes	—
Geneva University	Yes	—	—	—	—	—
Helsinki University	Yes	—	Yes	Yes	—	Yes
IEKP-Karlsruhe	Yes	—	—	—	—	—
Korean Universities	Yes	Yes	—	—	—	—
LPNHE-Paris	Yes	Yes	Yes	Yes	Yes	Yes
Charles University	—	—	—	Yes	—	Yes
Roma1 University	—	—	—	—	Yes	—
SCIPP/UCSC	Yes	—	—	—	—	—
Torino University	Yes	Yes	Yes	Yes	Yes	Yes
HEPHY-Vienna	Yes	—	—	—	—	—
Si-drift case	Basic element	CAD design	Structure	Cooling	Alignment	Transfer
BNL	Yes	Yes	Yes	Yes	Yes	Yes
Wayne State Uni.	Yes	Yes	Yes	Yes	Yes	Yes

Table 4: *Sharing of responsabilities for the R&D on Mechanics*

The interferometer system studied by the University of Michigan for a very precise alignment monitoring, serves for both the long microstrip and the Si-drift options.

2.4 Simulation studies

There is in fact a lot of simulation studies and developments that are going on in the SiLC collaboration. The effort is now towards coordinating these efforts and trying to further develop common tools. The main topics on which the collaboration is concentrating are:

- Pulse development modelling
- Detector performance and design studies, using both fast and detailed simulations, i.e: GEANT-based simulations:
  - for each considered detectors and,
  - For comparing the various tracking detector designs between them, namely: the SD tracking versus the Silicon Envelope; the SD tracking versus L- or TESLA TPC; the SD tracking or the Silicon Envelope versus the TPC alone
- Track reconstruction
- Development of a GEANT-4 based simulation including BEAM inputs for both the NLC/GLC or TESLA machines

- Same as above with GEANT-3 based simulation: BRAHMS
- Physics simulations

Table 5 details the sharing of responsabilties for each of these items, among the various interested Institutes in the collaboration.

Institutions	Pulse Modelling	Performances & Det. design	Track rec.	GEANT4 developments	Physics simu
University of Michigan	—	—	—	—	Yes
Wayne State Uni.	—	Fast/GEANT4	Yes	Yes	Yes
Helsinki University	—	Fast/Brahms	—	—	—
IEKP-Karlsruhe	Yes	—	—	—	—
Korean Universities	—	Fast/GEANT4	Yes	—	—
Obninsk State University	—	Brahms/Geant4	Yes	Yes	Yes
LPNHE-Paris	—	Fast	—	—	Yes
Roma1 University	—	Yes	—	—	Yes
UCSC	Yes	Fast	—	—	Yes
/SLAC	—	GEANT	yes	Yes	Yes
Tokyo University	—	GEANT4	Yes	Yes	Yes

Table 5: *Sharing of responsabilities in the simulation tool development and studies*

Developing a set of common tools and in particular the full GEANT 4-based framework for the Si-tracking devices is one of the important goal of this R&D.

3 The Phase A of SiLC

The development of the R&D activities over the phase A, i.e; the year 2 and 3 will proceed as described in the 3 chart-maps at the end of this addendum. It can be detailed in the following way

3.1 Development of the R&D on Sensors in Phase A

This R&D activity will be pursued as already described in Phase 0. The main foreseen evolution is that some more teams will join the effort on the Si-drift sensors. A few teams that are presently only involved in the long microstrip R&D have already expressed their interest in also devoting some efforts on the other sensor technology later in the project. This will occur when some more forces will be available in their Lab. Furthermore, WSU has contacts with other teams that are presently involved in experiments using Si-drift and that are considering joining our collaboration.

If forces are available and if some bright ideas appear in the course of the R&D the collaboration could consider to dedicate some forces to new sensor technologies besides the two we are currently working on.

3.2 Development of the R&D on Electronics in Phase A

By the end of Phase 0, the results on the first two fundries will be available. A second pass will be undertaken by several Labs in the collaboration which will join this effort. Again already some of them have already expressed such an interest.
One aim is to have a new FE ready to be produced for the test beam scheduled for Fall 2006.

The second aspect of the R&D on Electronics in phase A will be to start developing the readout system for the Si-tracking detectors. This development will be pursued in close collaboration with the other sub-detectors. Indeed some of us are participating since the beginning to the LC-DAQ working group meetings. We presented t these occasions our preliminary ideas on the DAQ for the Si-tracking system. We will pursue this global collaborative effort. Several teams are already interested in this work.

The third aspect of the R&D on Electronics in phase A will be the development of the high-level processing system for the Si-tracking data.

The organization of these new activities and the sharing of the responsabilities will be organized in the course of Phase 0.

3.3 Development of the R&D on Mechanics in Phase A

The main goals here will be:

- To further extend the collaboration with the Industry and to build more and more realistic mechanical prototypes to better access the issues such as mechanical stability and precision, mechanical feasability, cooling etc...
- The construction of a fully operating alignment prototype
- the construction of a prototype for a test beam by fall 2006

3.4 Test beam(s)

A test beam is scheduled by Fall 2006. It will include a full tracking prototype, equipped with the FE electronics developed by the SiLC collaboration. The aim is to test both the ultimate working sensors and the FE electronics developed by this R&D. It will also be designed in such a way as to reproduce the current state-of the-art from the mechanics point of view. The overall collaboration is expected to contribute to this effort. We are interested in doing this test beam within a high magnetic field to mimic as well as possible the real running conditions at the future LC.
Some preliminary test beams on single ladder can be foreseen if this is demonstrated to be justified. This is under discussion and would be in any case a restricted effort in terms of means and of teams involved.

4 Towards an integrated Si-tracking system

The SiLC collaboration intends to very rapidly address the main aspects of an integrated Si-tracking system. Indeed some work has already started in this direction. The LPNHE-Paris has started to study in some details the CAD design of a Forward Si-tracker. This group has also studied the case of external Si tracking layers (SET) located between the TPC and the central e.m. calorimeter. The results of preliminary MC studies have been presented at various ECFA-DESY Extended Study Workshops. Some preliminaries studies are performed in the US based on the SD scenario; they address the integration of the Si-tracker with the Si-W calorimetry.Furthermore in the case of the JLC detector, the Tokyo team achieved a GEANT4-based simulation study, on the intermediate Si tracker. This device is similar to the SIT detector in the case of the TESLA detector design or to the intermediate silicon tracker in the North American design. This study aims to optimise the Si tracker design (number of layers and sensor technology) with respect to its role, as a link between the microvertex and the central tracking detector.

This R&D collaboration will organize a series of working meetings with the various following sub-detectors:

- *the microvertex collaboration*: this is to further study the internal Si-layers that will be in the immediate vicinity of the microvertex.
- *the TPC collaboration*: this is in order to better apprehend the environment and requirements in which will operate the Forward tracking (FCH), and eventually external Si central outer layers.
- *the Calorimetry*: this is in order to better comprehend the environment and requirements for the outer layers in both the central and the forward Si-tracking.

The common tool are the simulation packages, especially the full GEANT based simulation. The main first outcome of the Mechanics detailed CAD studies are to provide the inputs that serve to define the detailed Geometry DB of the detector. The simulation gives a *common language* for all the sub detectors and provides the means for a real exchange between sub-detectors. Developing both these tools and the contacts with the various concerned sub-detectors is high in our immediate priorities.

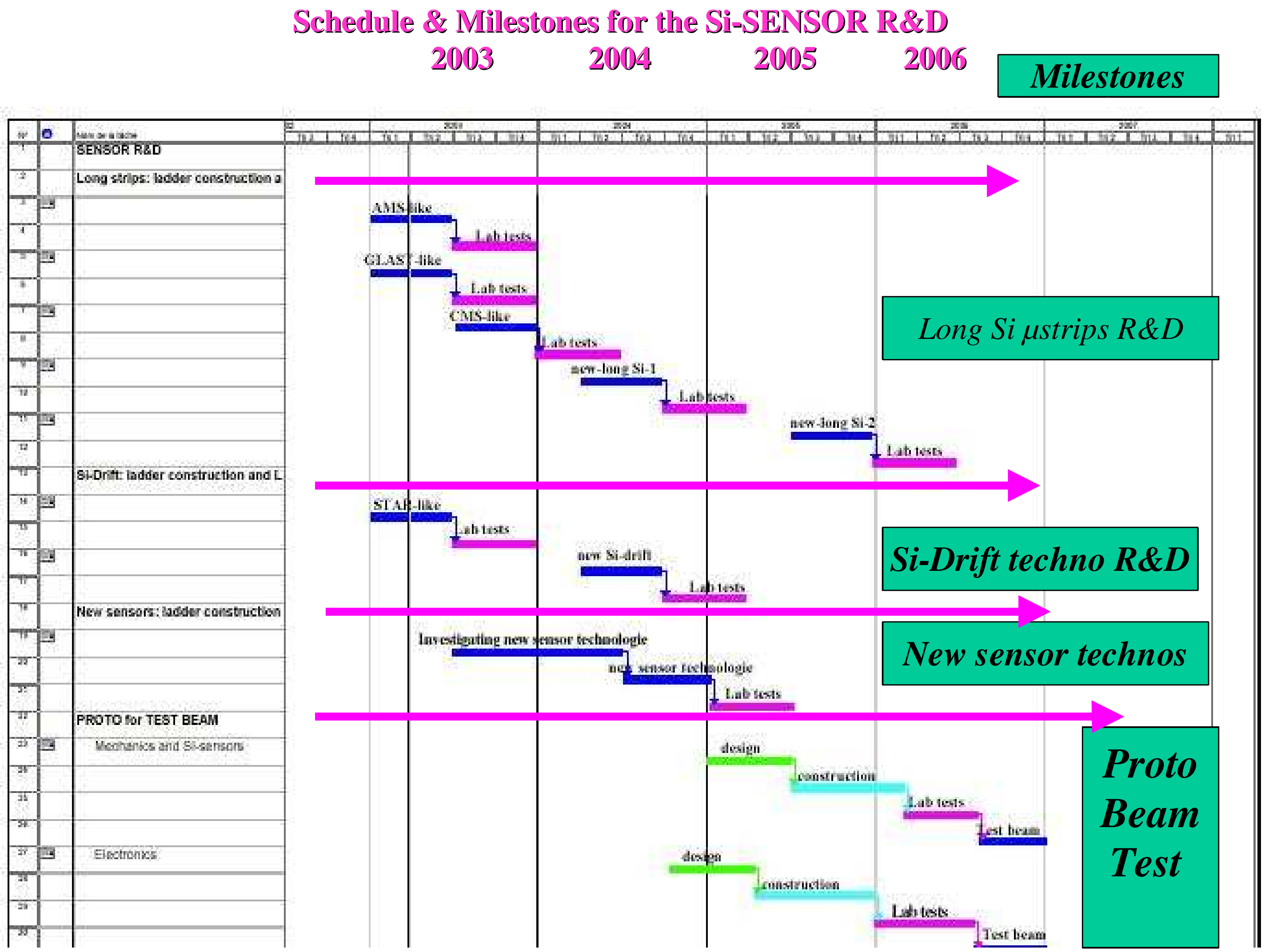

Figure 1: Schedule & Milestones of the R&D on sensors.

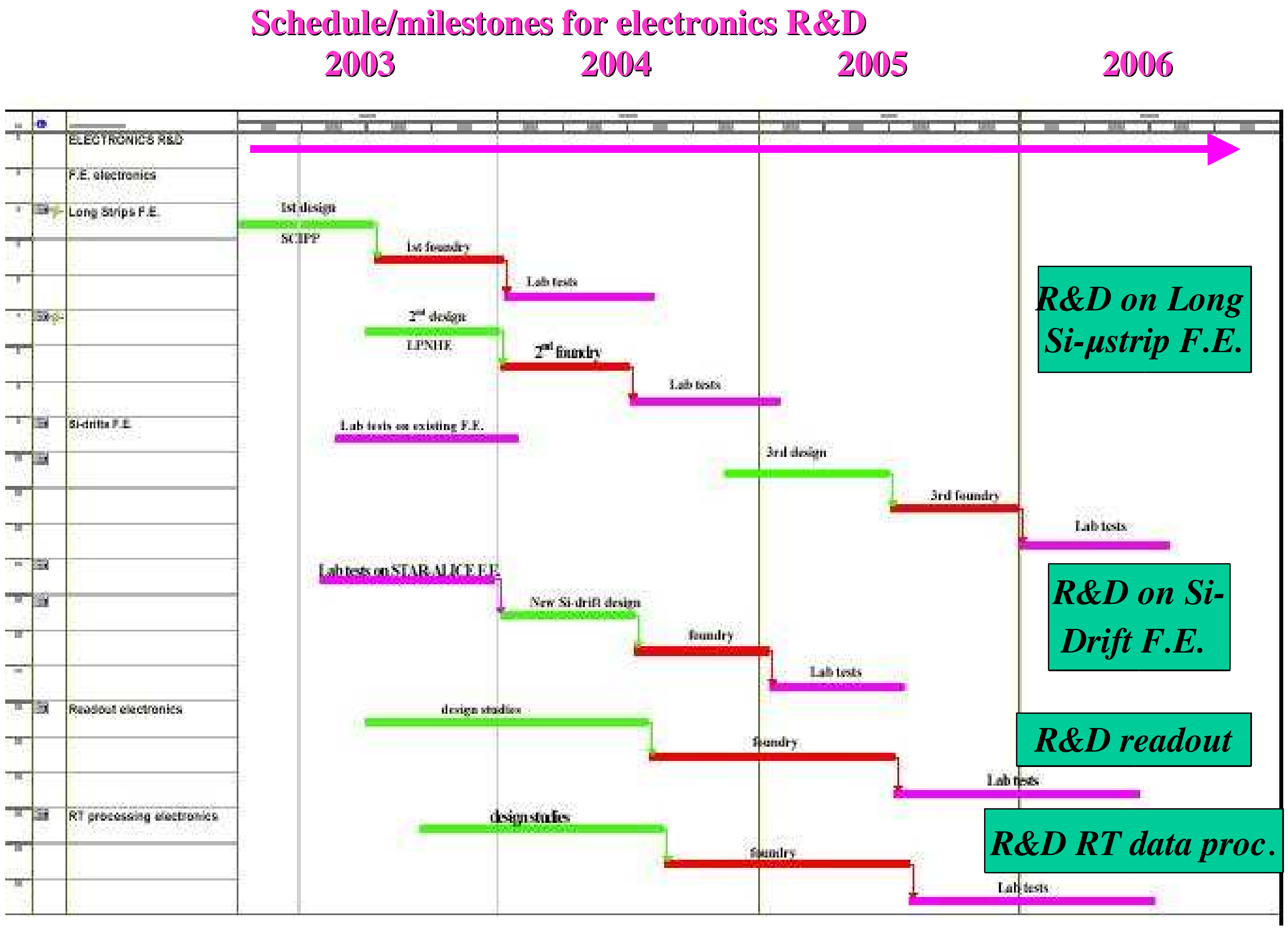

Figure 2: Schedule & Milestones of the R&D on electronics.

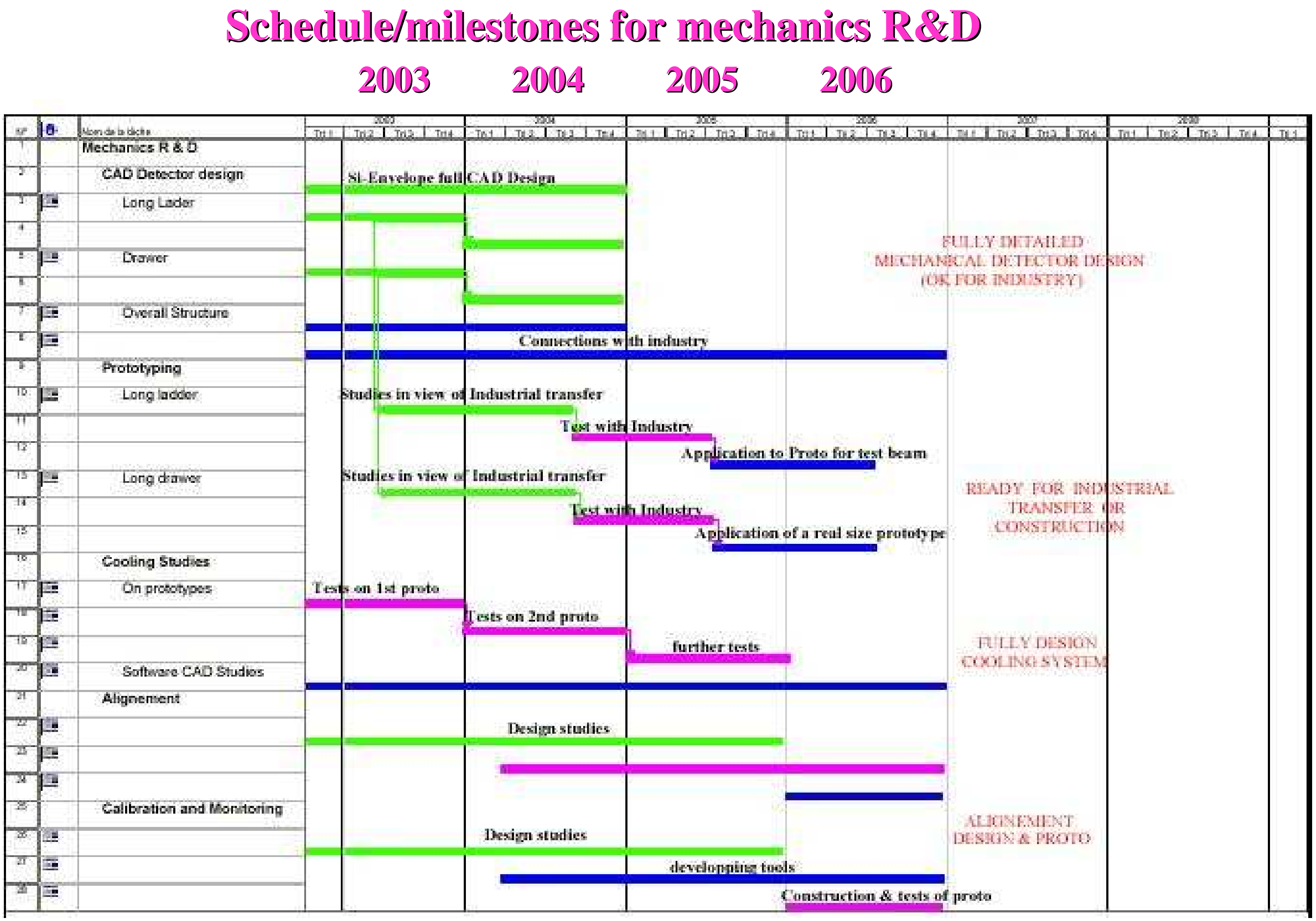

Figure 3: Schedule & Milestones of the R&D on Mechanics.

Institutions	Current relevant expertise in each Institution
U. of Michigan	Interferometry experience in the LIGO Experiment
IMB-CNM (CSIC)	Participation in the ATLAS experiment (fanins of EndCaps) Participation to RD50 (rad hard expertise) Expertise in silicon detector fabrication
BNL	Central role in STAR Si-drift tracker at RHIC Participation to the ATLAS experiment Pioneering expertise in very low noise F.E.electronics
Wayne State U.	Central role in STAR Si-drift tracker at RHIC
Geneva U.	Central role in the AMS Si-tracker Participation to the CDF II Si-detector (SVT-trigger) Participation to the Si-tracker in ATLAS
Helsinki U.	Participation in the construction of the DELPHI Microvertex Participation in the construction of the CDF RunIIb upgrade Expertise in low mass cables and mechanics
IEKP-Karlsruhe	Participation to the construction of the DELPHI Vertex (Barrel and pixels) Participation to the construction of ISL detector of CDF II Participation to the CMS Si-tracker Participation to.Rose R&D collaboration
Korean U.	Experience in design/simulation/fabrication of Si sensor including flexible PCB cables and mechanics
Obninsk State U.	Participation in the ATLAS TRT (simulations) Participation in HERA-B Outer Tracker and TRT Participation in TESLA hadronic Calorimeter, SiPM's, Simus
LPNHE-Paris	Participation to the construction of DELPHI Microvertex Expertise in Low noise preamplifier, DAQ electronics Expertise in large detector mechanical design and studies (ATLAS)
Pisa/INFN	Pioneering role in the CDF microvertex in run I and II, both for the detector and the related SVT trigger system Central role in the design and construction of the CMS Si-tracker R&D on Si-tracking trigger for LHC Contribution to SLC, Babar and GLAST Si-trackers
Charles U.	Central role in the ATLAS forward Silicon Tracker Long expertise in the development of Silicon Tracker
Roma1 U.	Contribution to the SVT trigger at CDF II Central role in the development of the Trigger system for ATLAS
SCIPP/UCSC	Exploration of CMOS and bipolar readout for particle detection Central role in GLAST tracking calorimeter
Tokyo U.	Central role in Belle Silicon vertex detector Expertise in Geant4-based detailed Simulations
Torino U.	Participation to the construction of the CMS Silicon Tracker Central role in ALICE Si-drift inner tracking system Expertise in large detector mechanical design & studies (Alice)
HEPHY-Vienna	Early experience with VA F.E. electronics in DELPHI Developt. & construction of DELPHI-VFT Tracker Construction of R.O system & fast trigger electronics of BELLE-SVD2 CMS: Si-sensor quality,Si-strips Opto-hybrids, Pixels R.O.

Table 6: *List of the most relevant expertises for this project in each Institution*