Developing medium size ladders and test bench results

Michel Baubillier, Guillaume Daubard, Christophe Evrard, Didier Imbault, Frederic Kapusta, Herve Lebbolo, Francois Rossel, Daniel Vincent, Aurore Savoy Navarro *LPNHE-Universites Paris 6&7/CNRS-IN2P3, France*

> Valeri Saveliev Obninsk State University, Russia

Zdenek Dolezal, Peter Kodys, Pavel Reznicek, Daniel Scheirich Charles University in Prague, Czech Republic

Celso Rivero, Alberto Ruiz, Ivan Vila *IFCA, Universidad de Cantabria, Spain*

This work is ongoing in the framework of the SiLC R&D Collaboration

ALCPG 2005, SNOWMASS, August 24th 2005 SiD detector session

Motivations

- To take advantage of the specifics of an ILC machine (relatively low occupancies and long cycling)
- To help minimizing the total number of channels to be read out, in order to spare not only on money but also on power dissipation and materiel budget
- To have basic structure, i.e. the ladder easy to fabricate (standardisation) and,

possibly using one unique sensor type for most of the Si tracking components (*) = universal sensor.

Is it really needed?

N.B. This sub-unit is the basic element of the overall Si tracking architecture !!

(*) Some components may need special types of sensors (not discussed here)

Geometry DB for Si tracking systems in G4 for both the LDC and SiD concepts





The DB definition included in the official DB

V. Saveleiev (Obninsk State U.)

All-Si-tracking



Occupancies calculated with BRAHMS full simulation (Si-Envelope+TPC), Higgstrahlung HZ with bbbar and q qbar at Ecm=500 GeV (no beam background included). Values at most of order 1% to 2% for the hotest places in the detector!

Strips of length from 30cm to 60cm are appropriate.



thickness ~ 0.4mm

thickness ~ 8mm

thickness ~ 0.4mm

Ladder support Total ~0.7%X0

Longer strips but larger wafers. So: easy to assemble

Foam Rohacell 0.1% X_a Key issues: Carbon fiber 0.16% X_a > Minimum material Budget > FE electronics connectics. packaging and cabling **Cooling** > New sensors > Strips alignment Module positioning on large size support structure Easy to build (robotisation ?) Transfer to Industry (large #) Universal sensor vs various types

Be innovative!

Minimum material budget: Issues are very similar despite the difference in scale.

Vertex Detector Mechanical Studies

borrowed from LCFI status report at the 59th PRC DESY by Steve Worm.

- Thin Ladder (module) construction Goals are ambitious;
 - 0.1 % X/X₀ (<1%) → Thinned silicon sensor, ultra-light support
 - Wire or Bump bondable, robust under thermal cycling
- Materials and mechanical support technology under study
 - Carbon fibre, carbon foam, Silicon carbide foam, diamond, beryllium, etc.
 - Reticulated vitreous carbon (RVC) foam; 3% relative density, 3.1 mm = 0.05% X₀
 - Several interesting new materials available





Sparing on material budget:

• Thining silicon sensor (2:1 achievable) (ex: firms in UK, Russia & France, under investigation)

Price to pay: Signal decrease, Noise increase (higher C), thinning limited by mechanical stability (150µ looks OK presently)

- New material for ladder support: Carbon fibre, carbon foam, Silicon carbide foam, Reticulated vitreous carbon (RVC) foam etc.: under investigation (idem LCFI)
- New look to the electronics on detector:

Reducing the number of FE readout chips: higher multiplexing factor (1024:1 thus 4 times more than LHC) \rightarrow one chip per ladder + Digitization included \rightarrow reduced signal cabling (digital fibers) More compact electronics: go to deeper DSM techno Closer integration of the chip into the silicon detector: new packaging (bump bonding TAB or ???), pitch adaptors Integration of services

Low power dissipation \rightarrow cooling is mainly wrt to environmental conditions: surrounding subdetectors & ILC >> LHC conditions!

Are the topics we are starting to work in details: The first FE chip prototype is instrumental to address those issues (several teams joining)

New strip sensors

- Double sided?
- Single sided?
- Thickness, pitch, wafer size?

Present goal:

- Develop double sided sensors:
 200 μ thickness, pitch 50 μ, 6 inches wafer
- Develop single sided sensors: thickness not an issue (thinning ?), pitch 100µ, 8 inches wafer

Strategy:

- Have Research Centers and Universities Lab working on developing the technology (Korean University consortium, IMB-CNM/Barcelona, Helsinki U.)
- Have associated 'small firms' to start industrialization process for relatively small sensor production.
- Find a firm for sensors mass production with the requested quality standard. The present winner is HAMAMATSU.



Easy to build device Learning from experience

AMS long ladders (handmade) Geneva U., ETHZ, Perugia U.

CMS robotic assembling (quasi industrial fabline)

Sensor Positioning under Metrology Control



Glue Dispensing on Upilex

Sensor Positioning under Metrology Contro



AMS handmade long ladder production line

Upilex Positioning and Control





Hybride Gluing





Assembly proceadure results: achieved precision



A silicon sensor with the reference crosses

Results:

On the K side the r.m.s is at limit of 5µm. For the S side all ladders have values of r.m.s of 3µm with a dispersion of 0.5µm.

> System was developed by M. Pauluzzi et al. (Perugia)

Sketch of an AMS assembly jig with alignment pins located on the precise assembly jig. Alignment method:

1) the 3 pins are fixed in the first location (S1) on the jig and the first silicon sensor is aligned against them.

2) the aligned sensor is maintained in this position by vacuum and the pins are rotated and gently pulled off.

3) Restart with the second sensoretc...



Quality control & Robotic assembly of CMS modules



Probe station



Robotic assembly system

Quality assurance, assembly and bonding realized under quasi-industrial conditions with high multiplicity: 4 centres are surveilling the overall sensor quality using fully automatic probe stations;
 3 centres are monitoring the process quality; 2 centres are checking the radiation hardness.
 Assembly robots in 7 centres, plus industrial bonding machines in 12 places ensure high quality and reliability over the long construction period.

>All parameters and logistics are monitored using a special global database.

A universal sensor type or a few different types wrt to detector component/location?



In the FWD region due to the local geometry (disks or trapezoid), various sensor shapes are under considerations. Mainly based on present experience from LHC experiments.



Elementary sub-units for various Si components



Same sensor type





Our team is especially interested in building the endcap tracker

Tests & results on Si strips Laser energy of photon: 1.170 eV

Wavelength of light 1060nm



Signal over noise as a function of strip length





Some other S/N measurements and/or computations



These results and the ones we have obtained are confirming that 30 cm long strips have S/N greater than 20, and 60 cm long strips have S/N greater than 10. Nota bene: These results are of course dependent of the detector prototype and the associated F.E.E.



To ensure the challenging high precision performances of the Silicon tracking system in an ILC experiment, one crucial key issue is the alignment

Two techniques are so far developed in the collaboration:

 Frequency Scanned Interferometry (FSI) (quite advanced) by the University of Michigan (see Haijun 's presentation at this workshop)
 Embedded Straightness Monitor (just starting) by the IFCA-Cantabria University

Embedded straightness monitor -Conceptual Design

- Collimated laser beam (IR spectrum) going through silicon detector modules. The laser beam would be detected directly in the Si-modules.
- Based on previous AMS-1 experience we can project that few microns resolutions would be achieved.
- Main advantages:
 - Particle tracks and laser beam share the same sensors removing the need of any mechanical transfer.
 - No precise positioning of the aiming of the collimators. The number of measurements has to be redundant enough

Embedded straightness monitor - Initial R&D

- Silicon module surface requires special treatement to improve its optical quality
- From an optical point of view the silicon wafer will behave as a plane parallel plate.
- Dedicated ultra-stable test stand for "optical" caracterization of the modified silicon modules: reflectivity, transmitance, absorption, polarization sensitivity, wedge effect, response uniformity...



Embedded straightness monitor -Initial R&D

- Start up plan:
 - Study/selection of the precise laser wavelength(s)* adequated to the Si module sensibility.
 - Small laser test stand for Si-mod readout: determine spatial resolution achievable.
 - Study of feasibility of optical treatment of the Si wafer.
 - (*) Using more than one wavelengths may allow us to correct for "atmosferic" effects that will deflect the laser beams.

New medium size prototype: *under construction at LPNHE*



Ready by mid October

Positioning on assembling structure



Gluing proceadure of Si detectors onto the support structure

Test beam schedule





An R&D activity on a new scale is starting within SiLC when going to test beams.

Using the test beam setup in Bonn



Detector Prototypes: FNAL, CERN or ???



Support mobile

- Design (just started)
- Fabrication
- Assembling & Mounting
 Module with 3 sensors
 Module with 2 sensors

Second layer partly covering the first one.
Total of 60 trapezoidal sensors,
About 10 K readout channels
Ready by end 2006/beg. 2007
Other prototypes: Ladders of different sizes and sensors

Concluding remarks

A new development stage is starting in SiLC wrt the fundamental element of the overall architecture in any Si tracking system, e.g.: the elementary module or ladder.

It is the consequence of the very encouraging results on the first module prototype and of the first FE Readout chip prototype, as well as guidance from the ongoing simulation detailed studies. Medium size ladders (1 to 3 sensors) look like an interesting way to go.

The next elementary module prototypes are tackling in a rather realistic way the following issues:

- Minimizing material budget
- Close integration of the FE readout chip (one per module)
- Optimized FE electronics (see J.F. Genat's talk)
- Optimized handling of signal and services cabling
- New sensors
- Alignment, positioning and integration issues
- Optimized handling of mass production

A lot will be learnt by going to test beams with more and more sophisticated prototypes both for detectors and associated electronics.