Developing medium size ladders and test bench results

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

ALCPG 2005, SNOWMASS, August 23nd 2005

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,

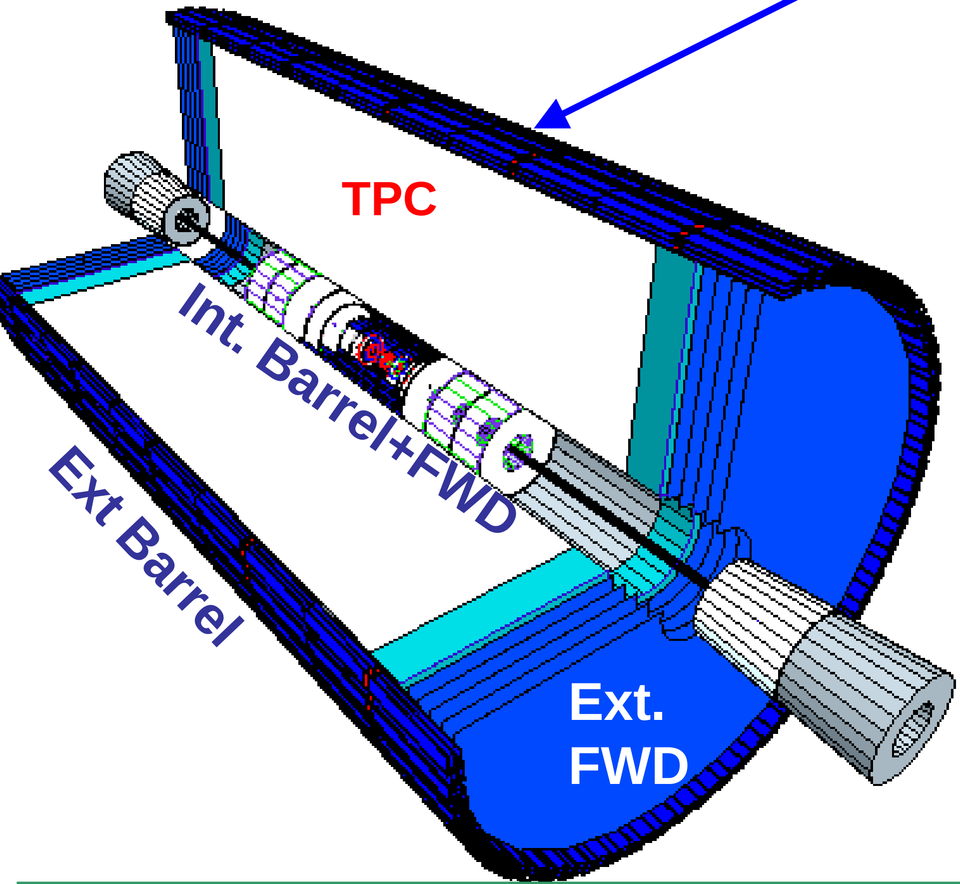
  possibly using one unique sensor type for most of the Si tracking components (*) = universal sensor.

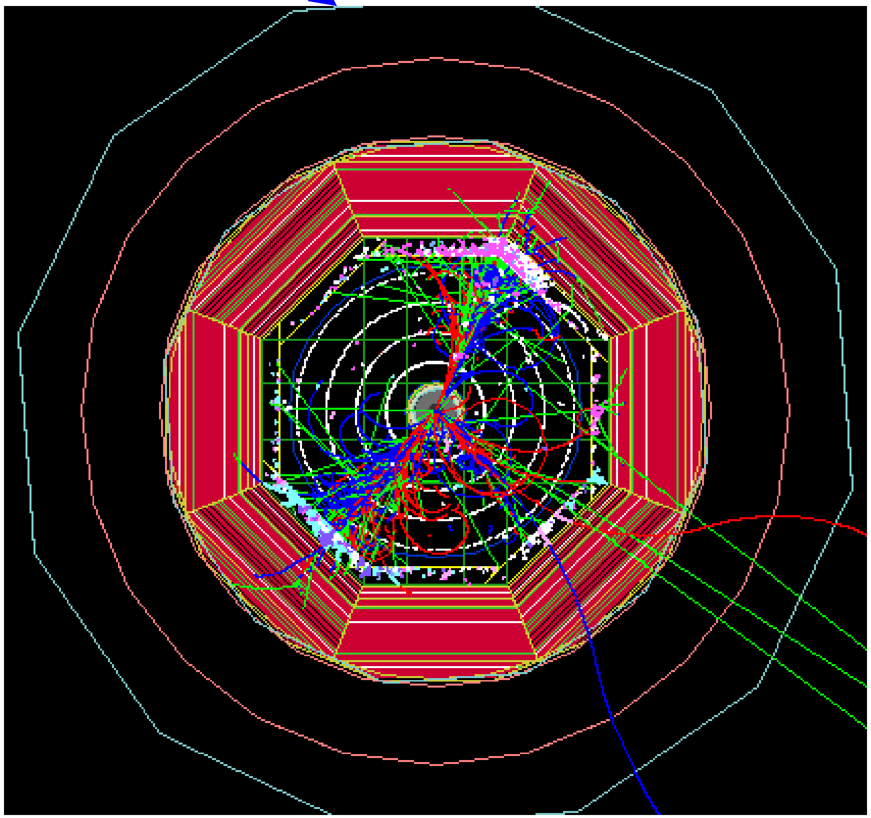
  Is it really needed?

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





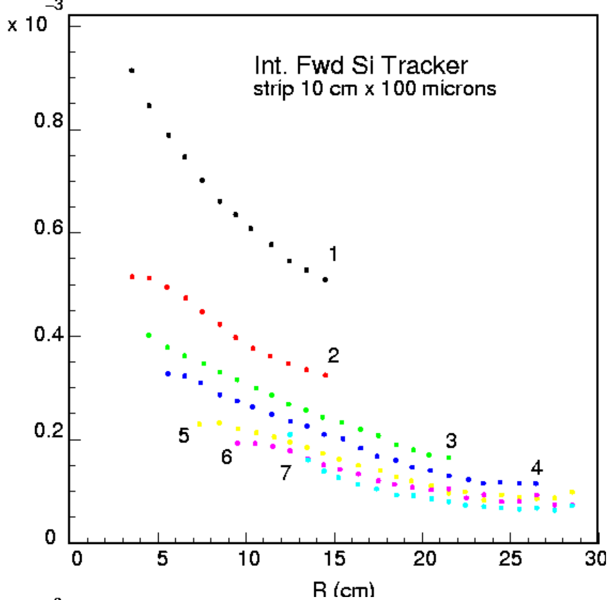
Si-envelope = internal & external components in barrel and end caps regions

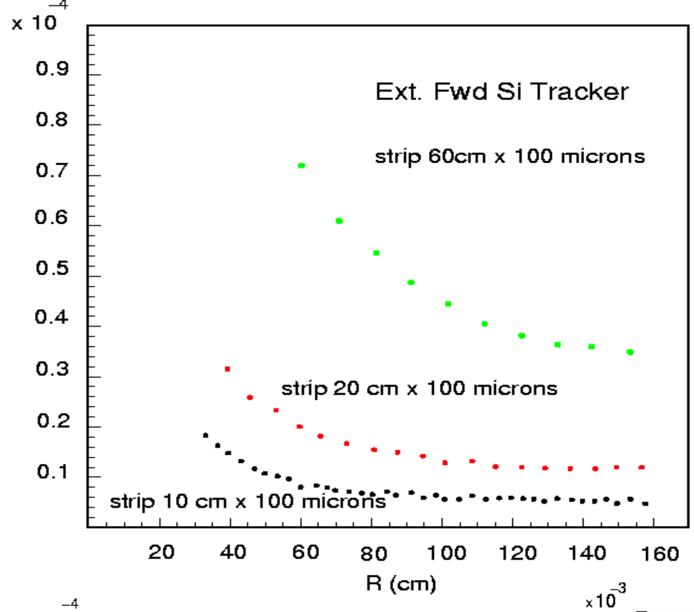
All-Si-tracking

The DB definition included in the official DB

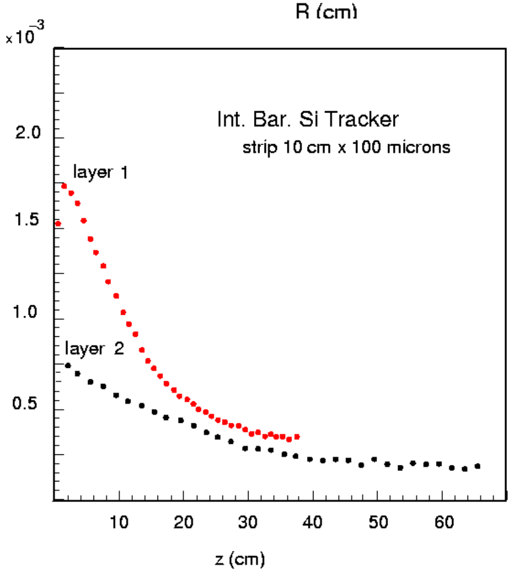
V. Saveleiev (Obninsk State U.)

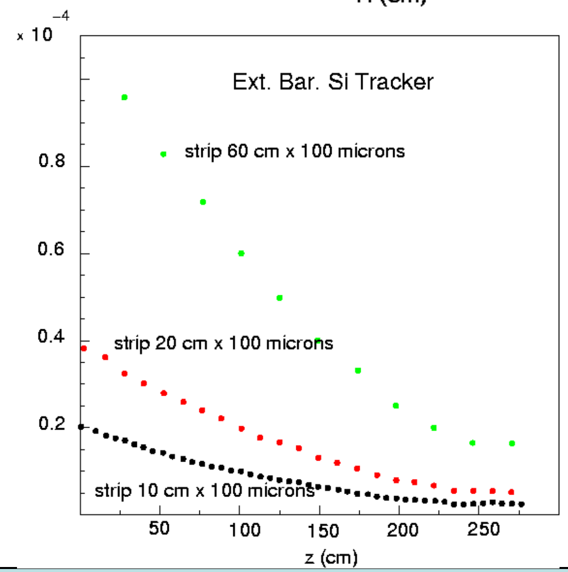
DETECTOR OCCUPANCIES

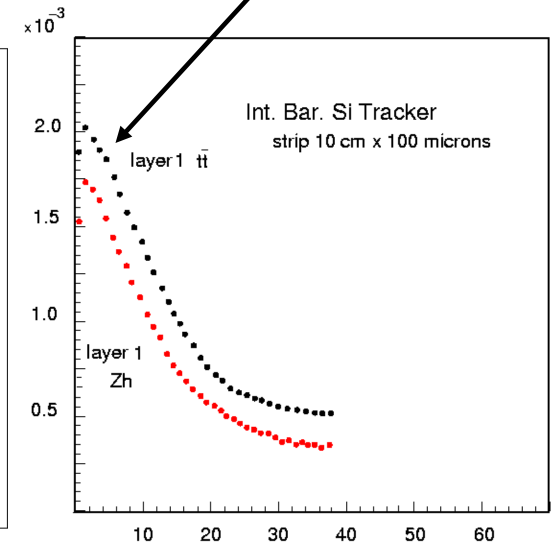




ttbar/ HZ gives ~20% higher occupancy





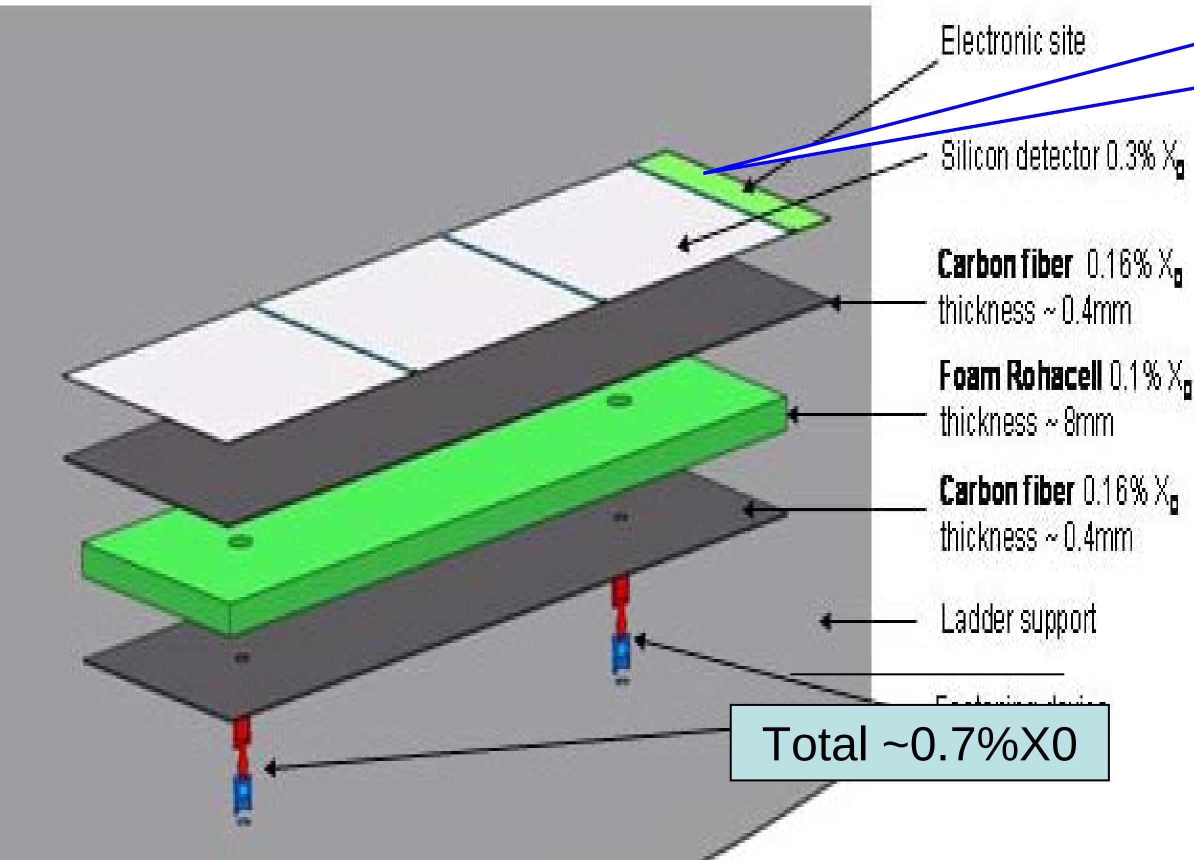


Occupancies calculated with BRAHMS full simulation (Si-Envelope+TPC), Higgstrahlung HZ with bbbar and q qbar at Ecm=500 GeV (no beam background included). Values at most of order 1% to 2% for the hotest places in the detector!

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

Elementary modules (revisiting existing techniques)

Including electronics F.E. Readout onto the ladder: under study



Longer strips but larger wafers.
So: easy to assemble

Key issues:

- ***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***

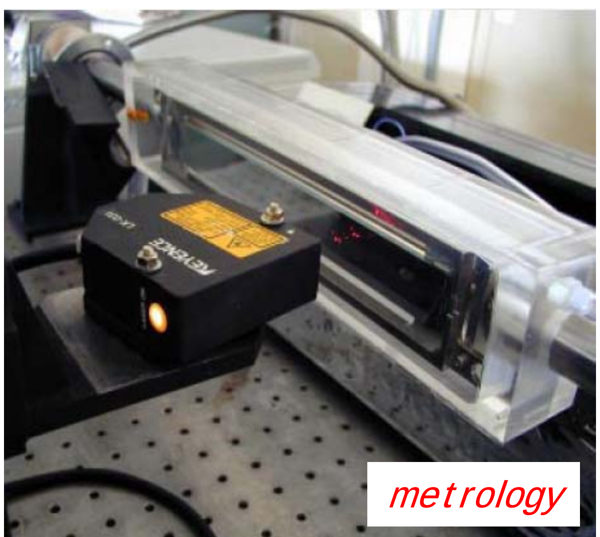
Be innovative!

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

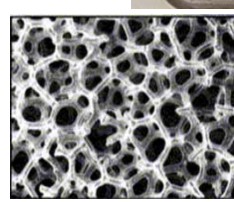
Vertex Detector Mechanical Studies

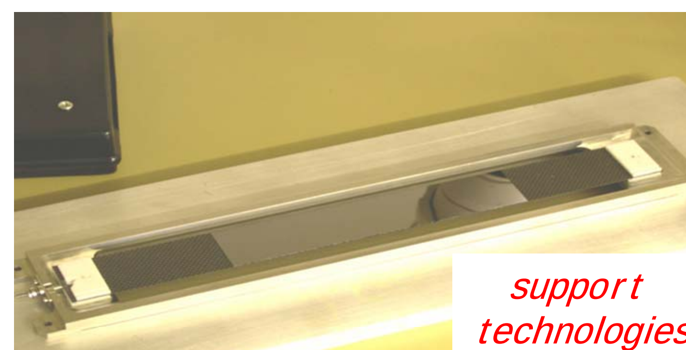
borrowed from LCFI status report at the 59th PRC DESY by Steve Worm.

- Thin Ladder (module) construction Goals are ambitious;
  - 0.1 % X/X_0 **(<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% X_0
  - **Several interesting new materials available**



materials studies





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) → one chip per ladder

  + Digitization included → 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 → 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

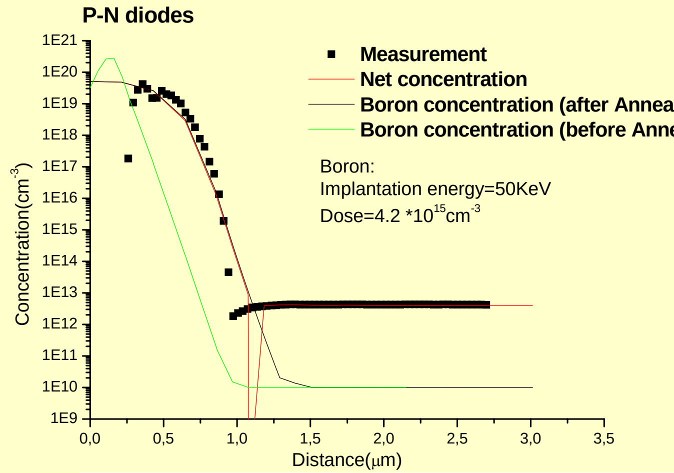
Strategy:

➢ 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.

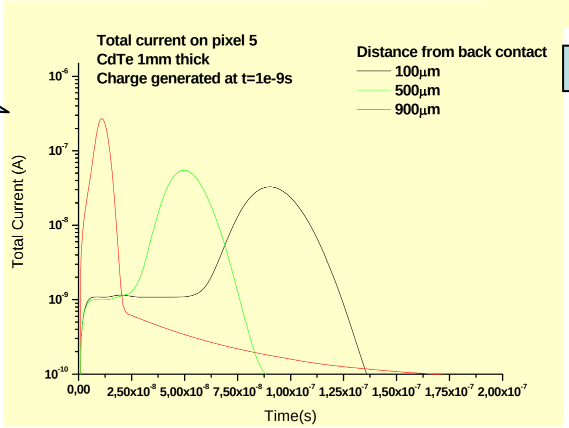
Si detector simulation:

important for the sensor & electronics studies and to include in G4 simu for detector studies

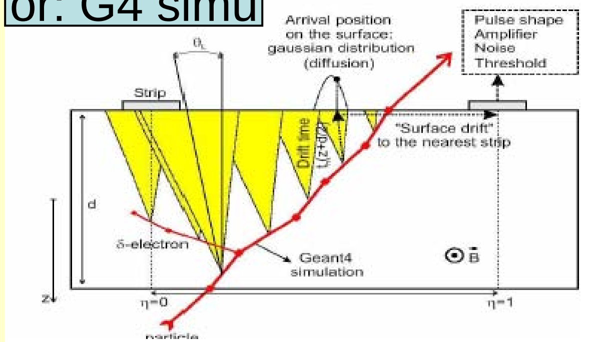
(ex: IMB-CNM, Helsinki, Karlsruhe, Prague, Paris)

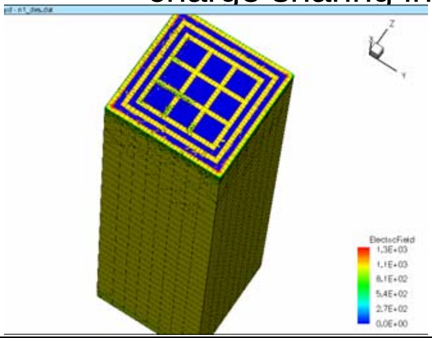


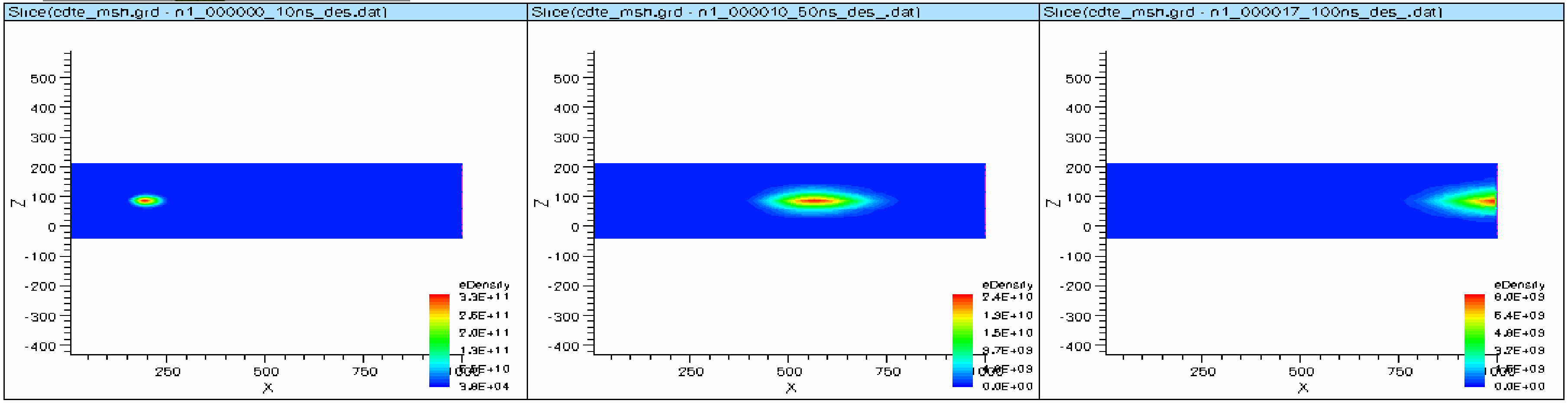
- ISE-TCAD, TMA, Silvaco
- Technology simulation
- Electrical simulation
  - Charge collection
  - charge sharing in 3D



or: G4 simu







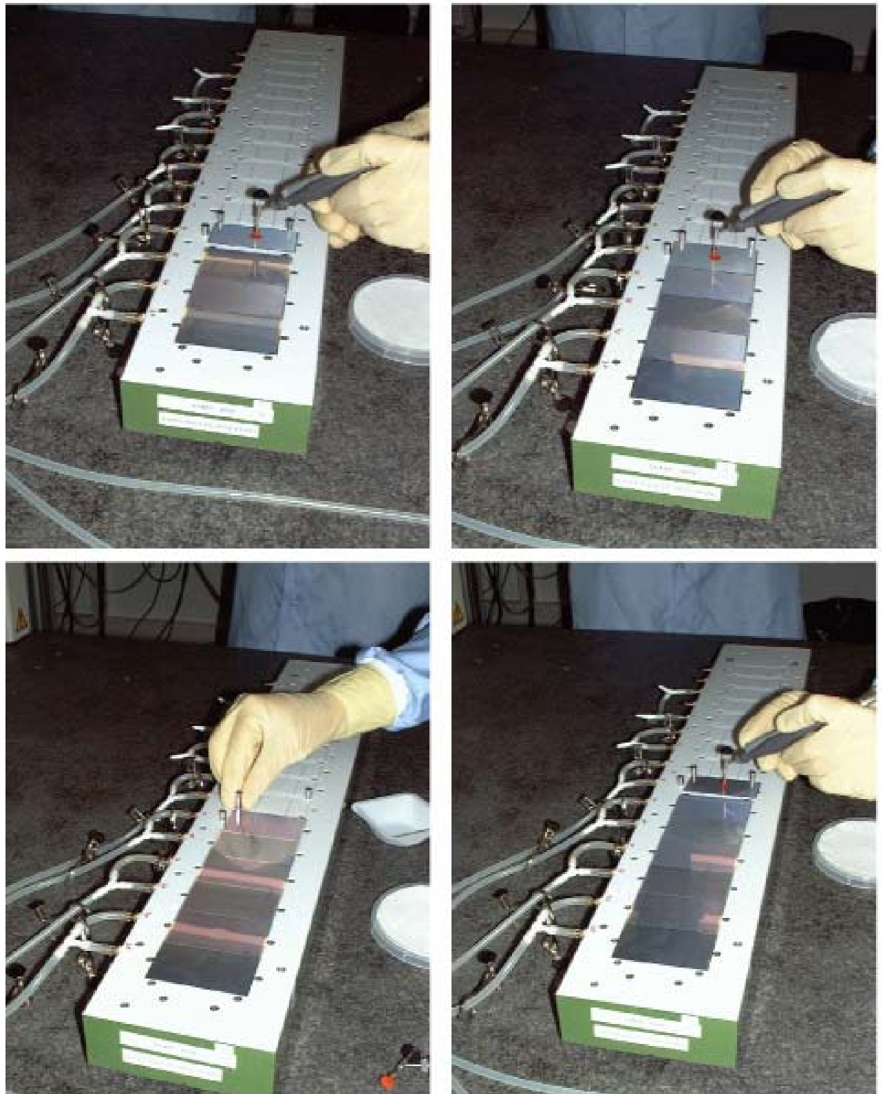
Easy to build device:
Learning from experience

- AMS long ladders (handmade)
- CMS robotic assembling

AMS: Assembly procedure

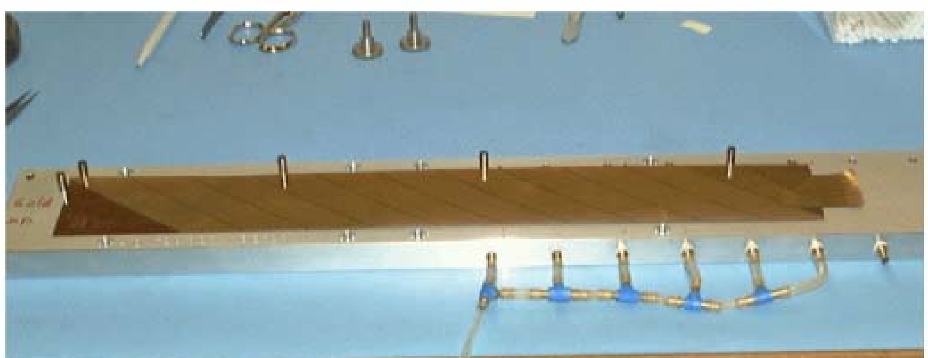
Geneva U., ETZ-Zurich, Perugia U.

Sensor Positioning under Metrology Control



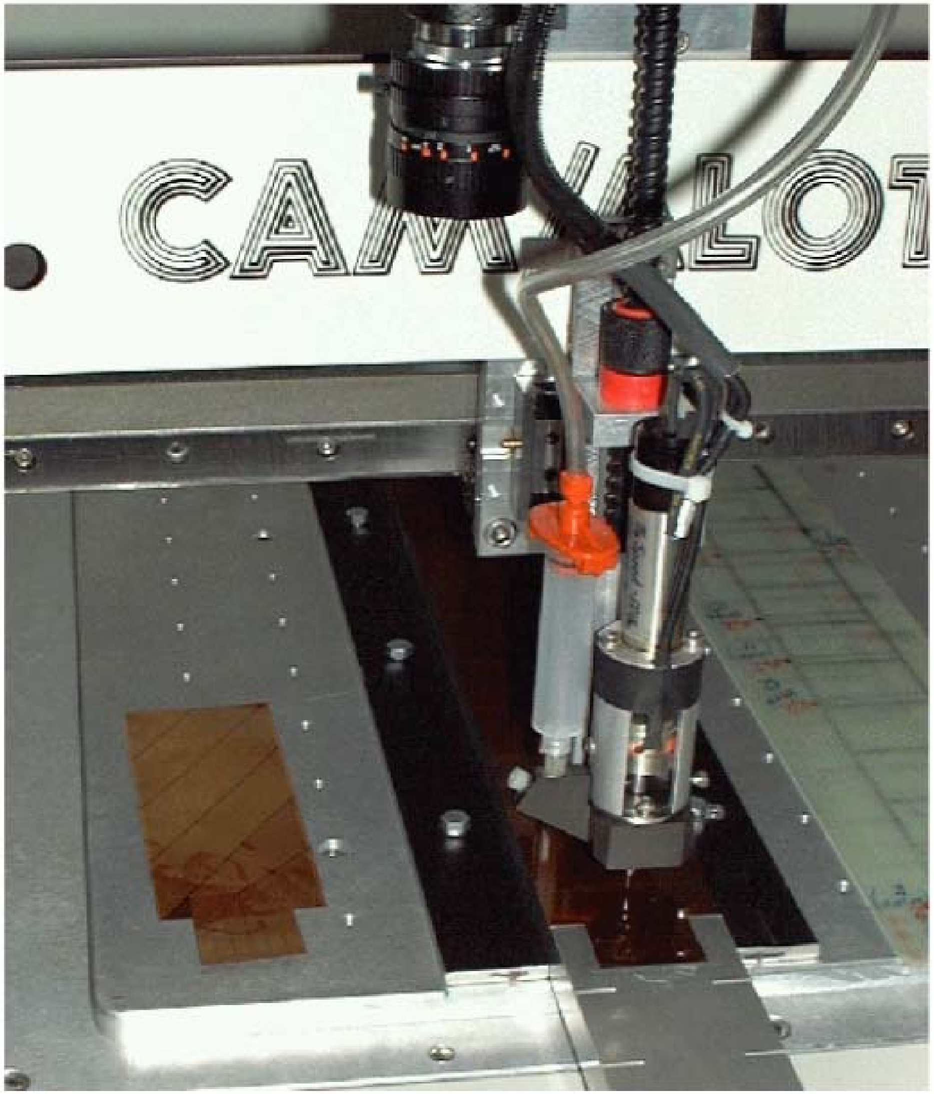
Assembly procedure

Upilex Positioning and Control



Assembly procedure

Glue Dispensing on Upilex



Assembly procedure

Joining Upilex and Sensors

Assembly procedure

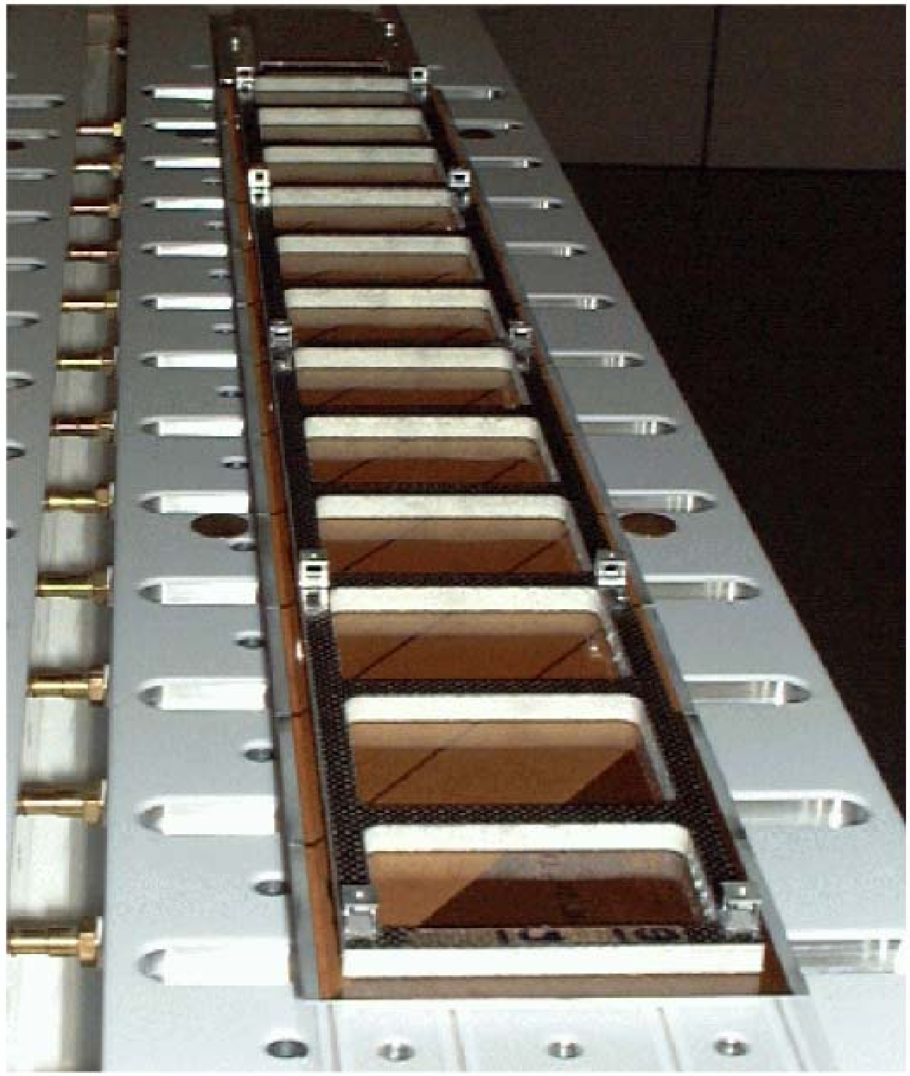
Hybride Gluing

Assembly procedure

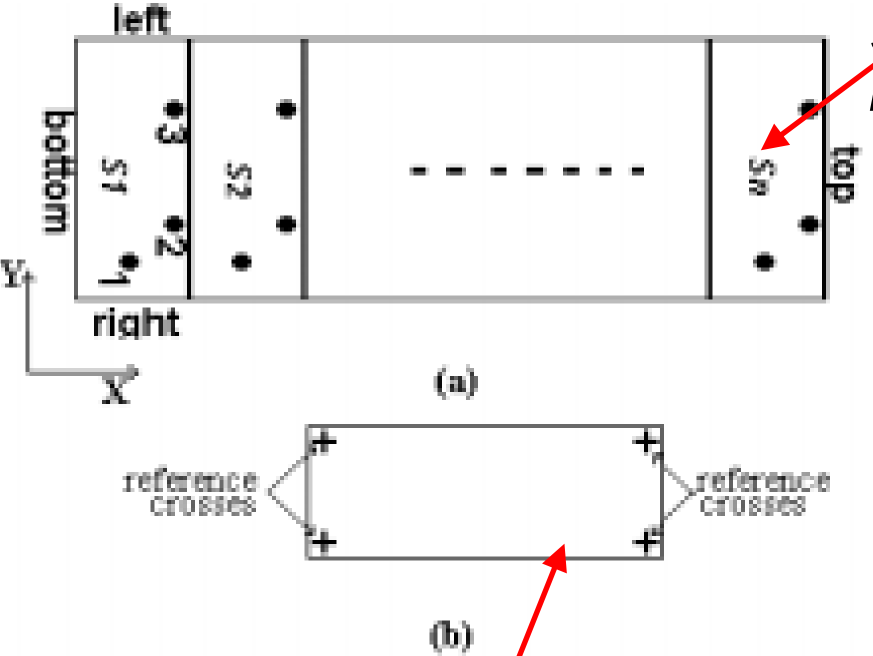
Wire Bonding

Assembly procedure

Gluing of Support Feet



Alignment method and achieved precision



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

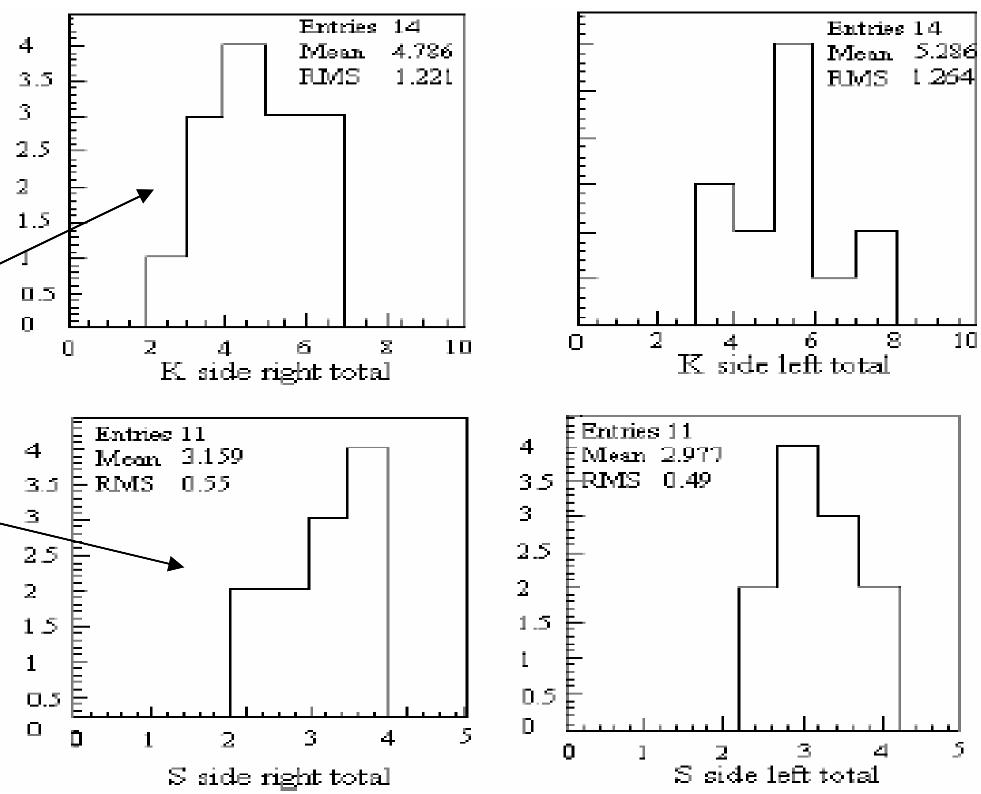
Alignment method:

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 sensor ….etc…

A silicon sensor with the reference crosses



Results:

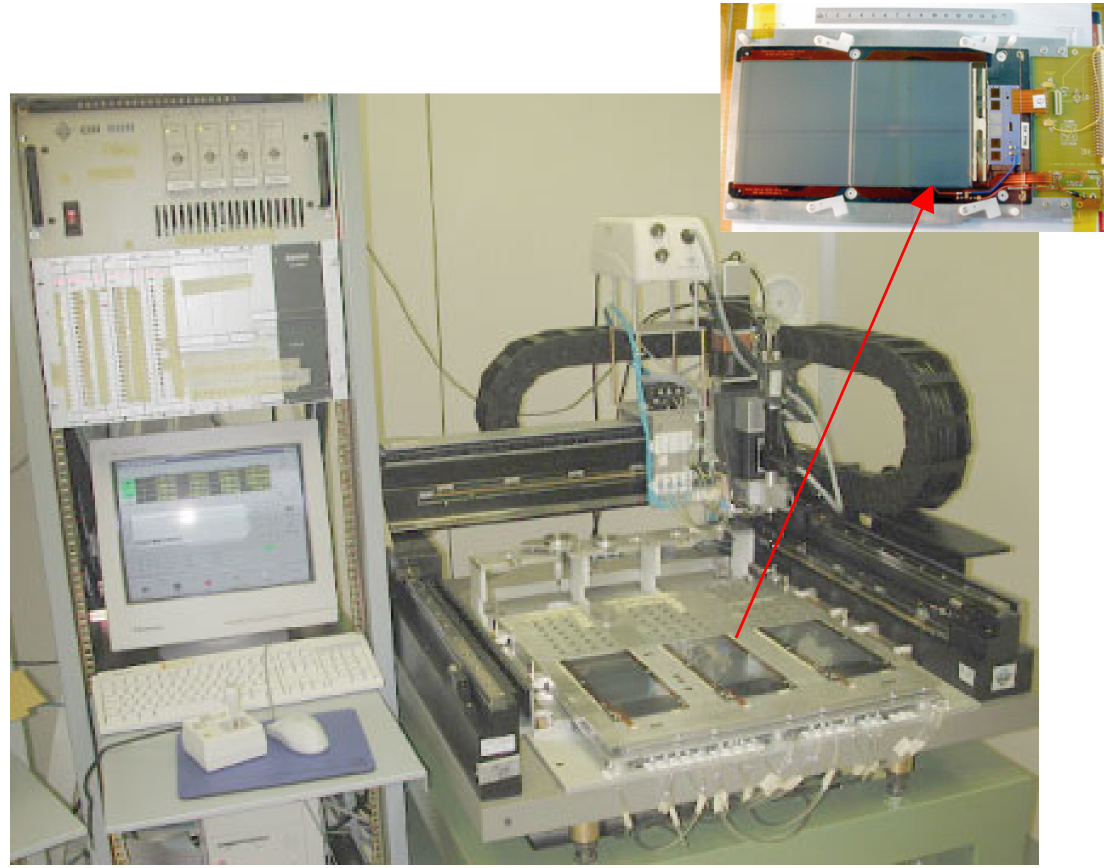
On the K side the r.m.s is at limit of 5μm.

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)

Quality control & Robotic assembly of CMS modules

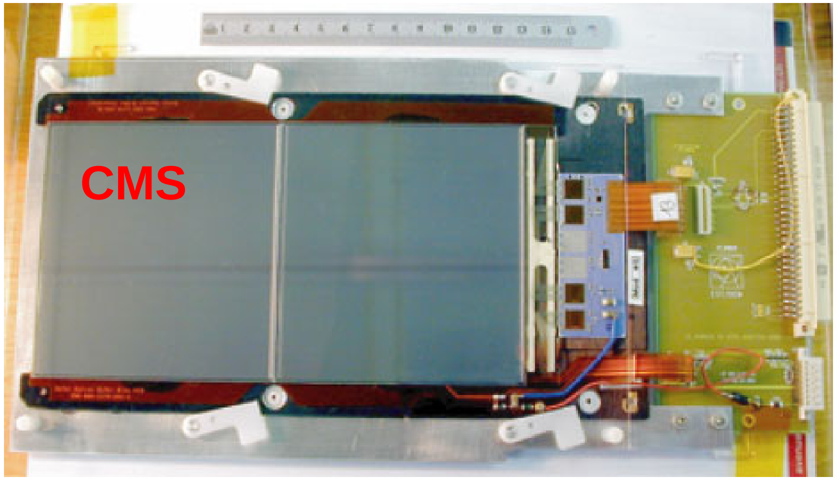
Probe station

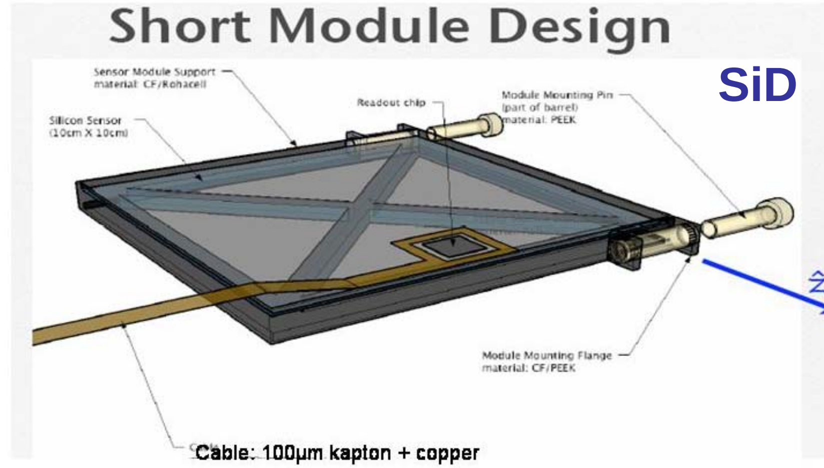


Robotic assembly system

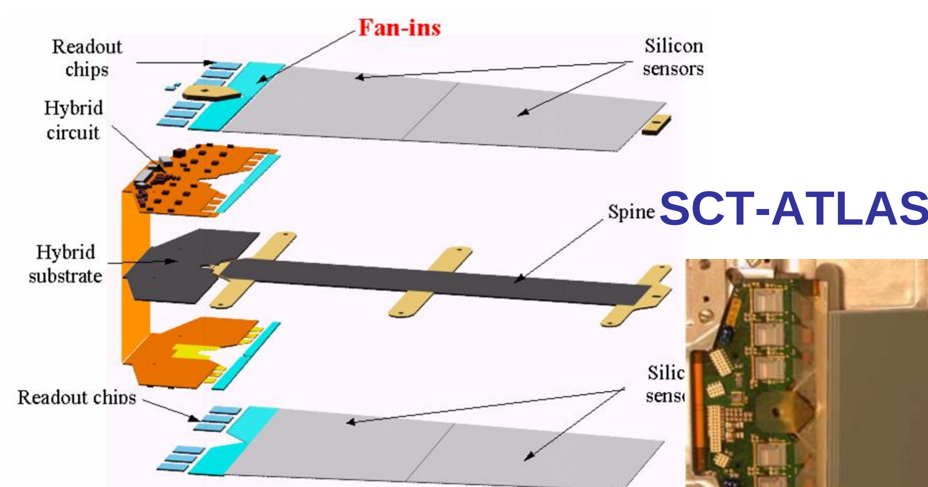
- Quality assurance, assembly and bonding realized under quasi-industrial conditions with high multiplicity: 4 centres are surveilling the overall sensor quality using fully automatic probe stations; 3 centres are monitoring the process quality; 2 centres are checking the radiation hardness.
- Assembly 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?

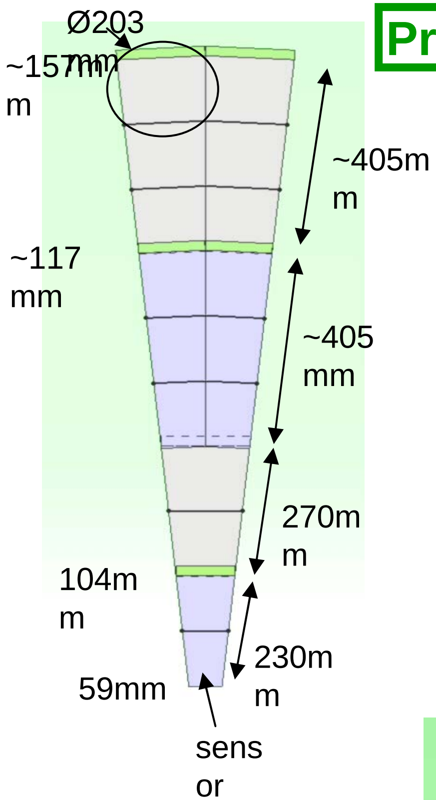




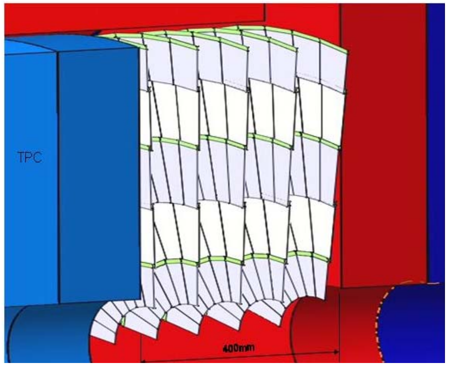
In the FWD region due to the local geometry (disks or trapezoid), various sensor shapes are under considerations. Mainly based on present experience from LHC experiments.



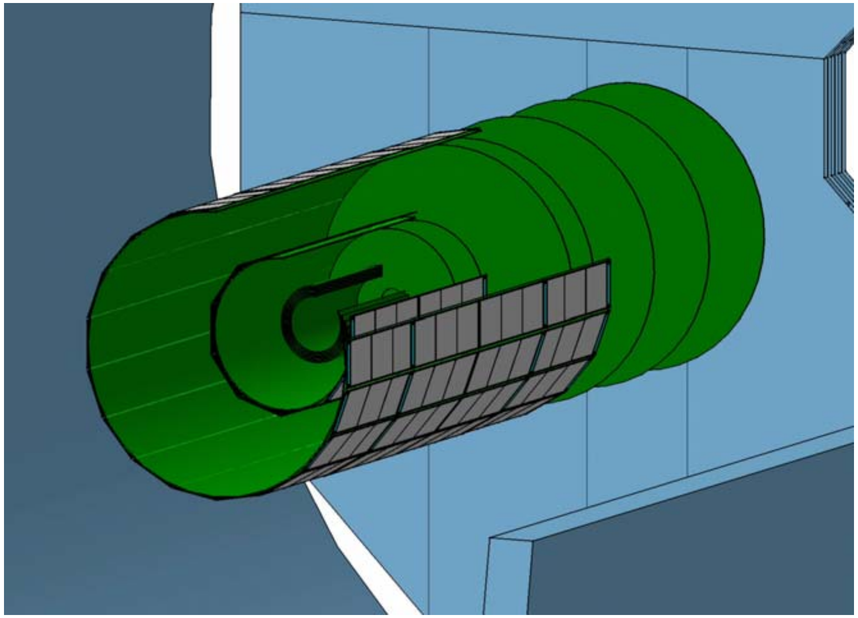
Elementary sub-units for various Si components

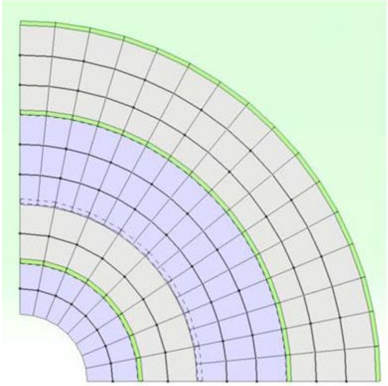


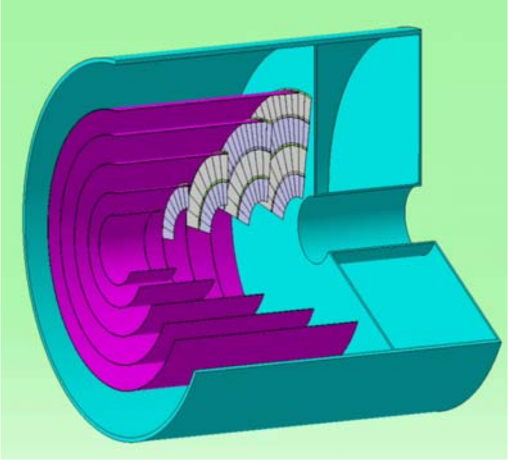
Projective

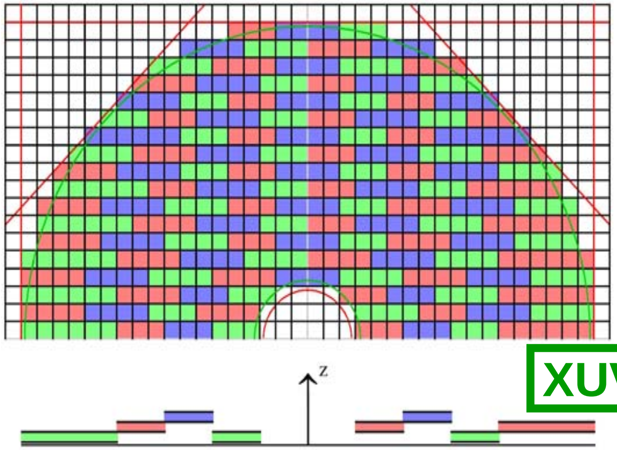


LDC design:
5 F.D.S stereo planes:
10240 sensors
3840 modules
2 to 4M channels









XUV

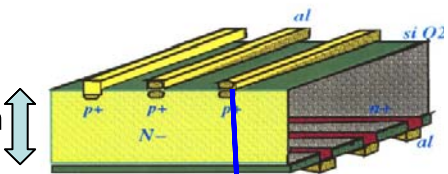
Tests & results on Si strips

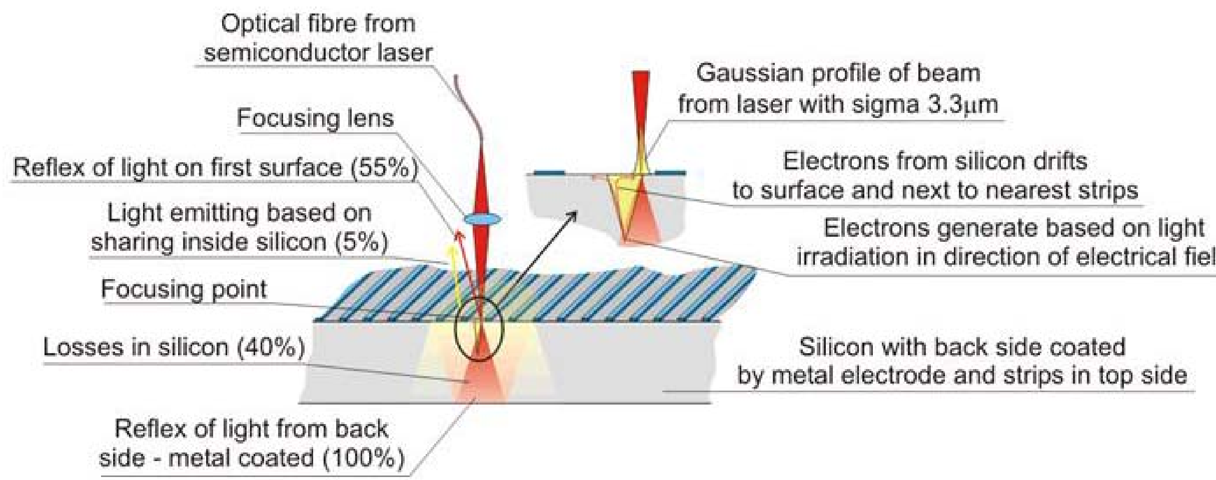
Laser energy of photon: 1.170 eV
Wavelength of light 1060nm

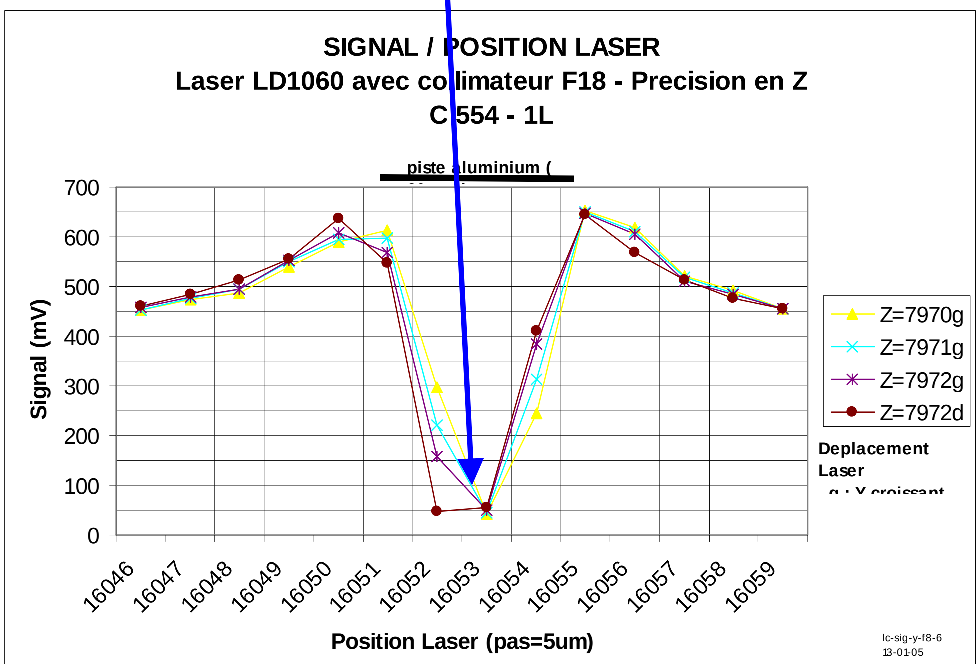
Paris test bench

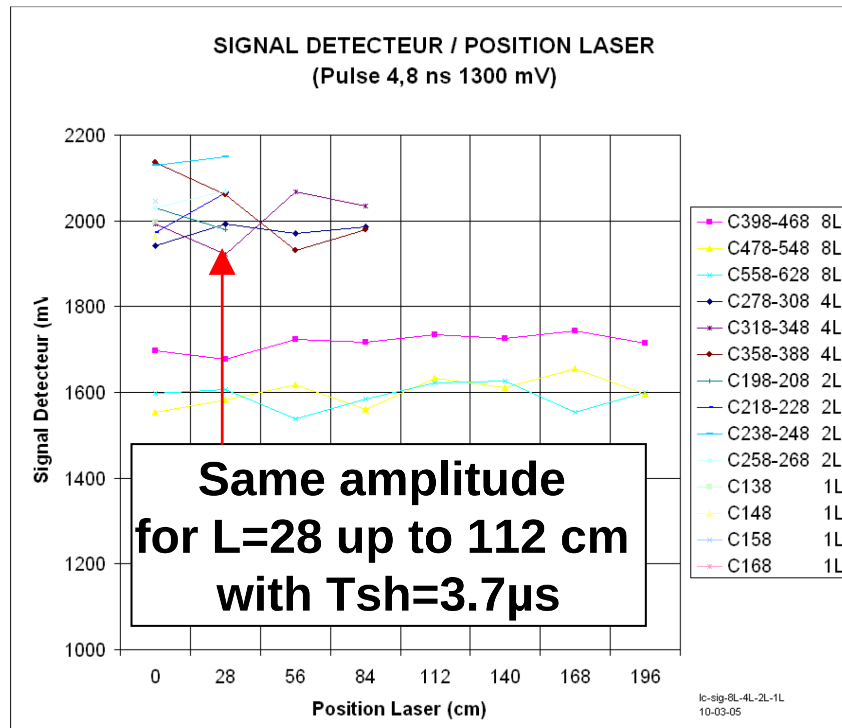
28cm x N=1,4

300µm









Same amplitude for L=28 up to 112 cm with Tsh=3.7µs

Signal over noise as a function of strip length

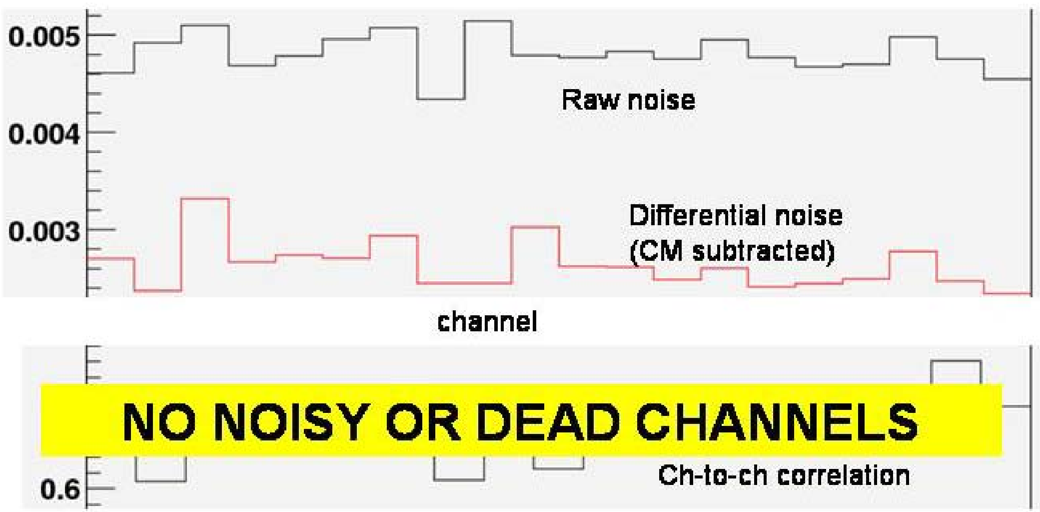
Noise determination (no signal)

Diff.noise $\sigma_i^d = \sqrt{\frac{\langle (v_i - v_{i+1})^2 \rangle - \langle (v_i - v_{i+1}) \rangle^2}{2}}$

Corrected signal $v_i^{CMS} = v_i - ped_i - CMN$

Correlation parameter $(\sigma_i^d)^2 = \sigma_i^2 (1-\rho)$

Final noise $\sigma_i^{CMS} = \sqrt{\langle v_i^{CMS^2} \rangle - \langle v_i^{CMS} \rangle^2}$



Signal spectrum is summed over a cluster after pedestal and common mode subtraction.
The radioactive source is a
Sr90-Y90 beta source.
The S/N measurements were achieved on variable length strips with the prototype at Paris test bench

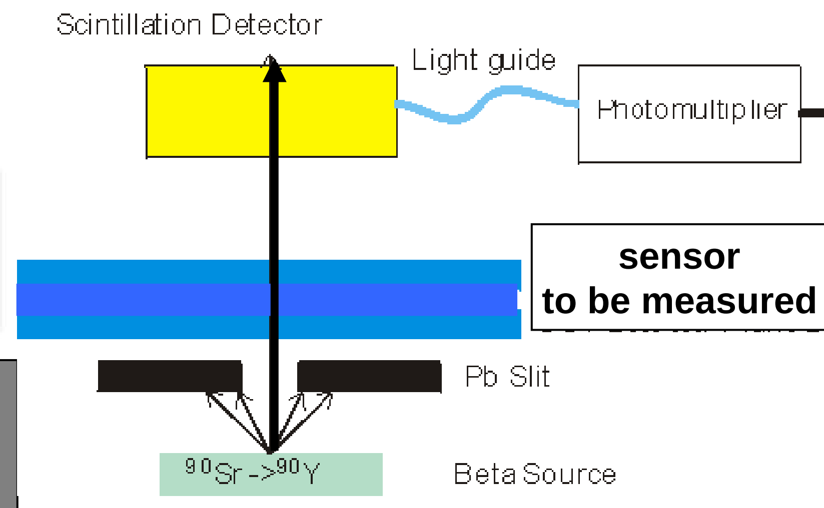
Common mode noise with signal

- mean of all channel values for one event

$|v_i| < 20$ mV~6σ (to exclude signal)

- Further analysis the same:

$$v_i^{CMS} = v_i - ped_i - CMN$$

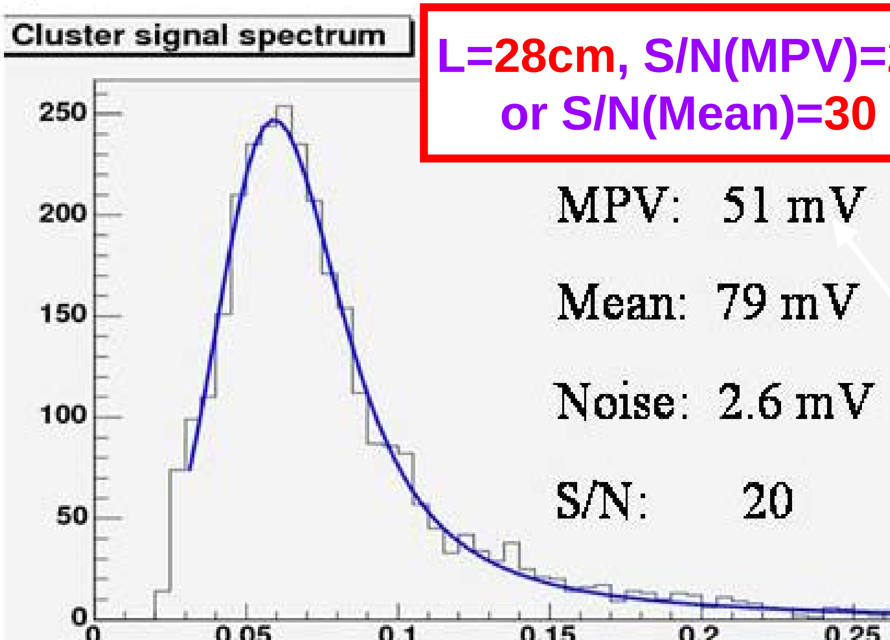


Results see next slide

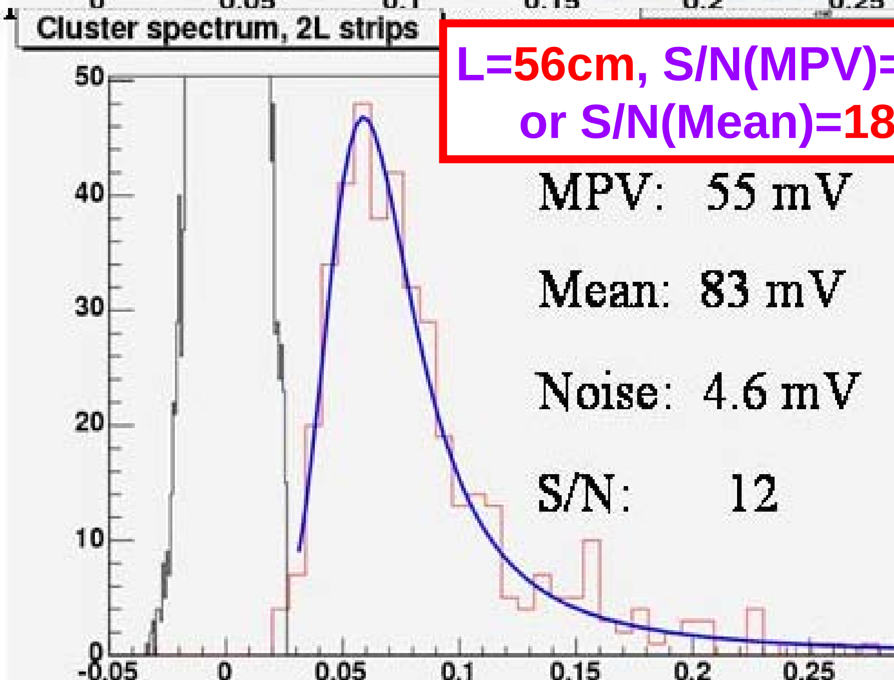
Collaboration Paris-Prague

New

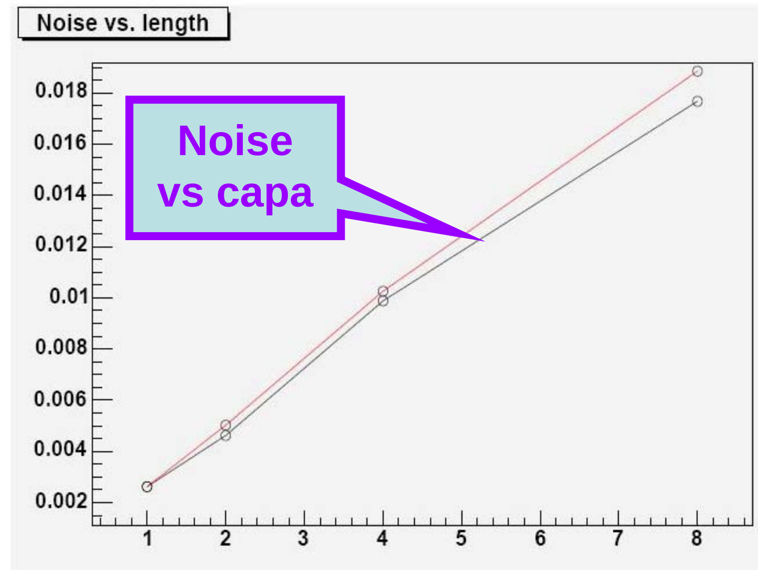
Results on S/N

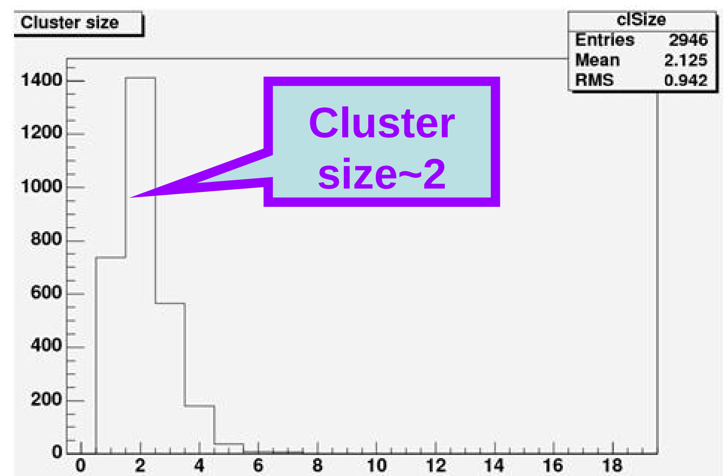


L=28cm, S/N(MPV)=20
or S/N(Mean)=30



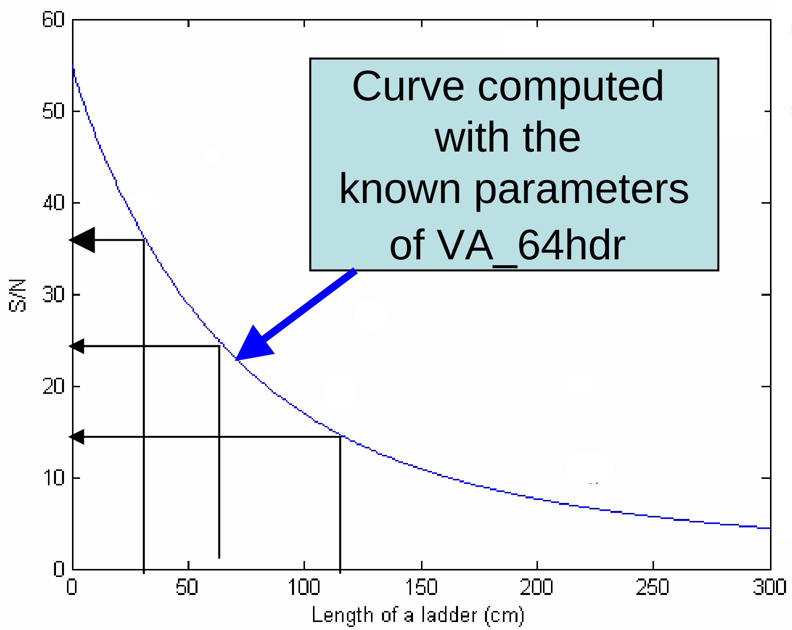
L=56cm, S/N(MPV)=12
or S/N(Mean)=18

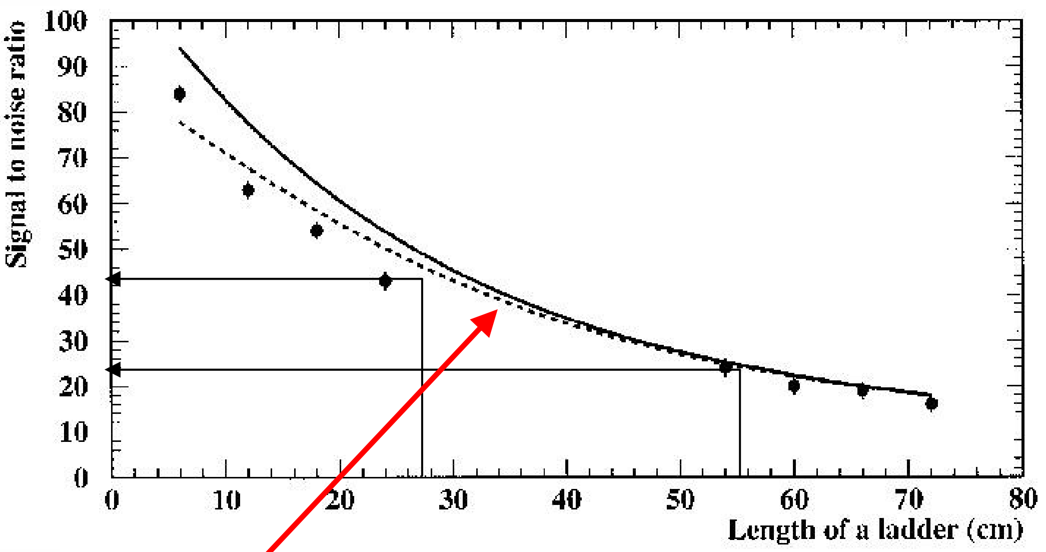




Next steps: Change detector & FE prototypes go to test beam

Some other S/N measurements and/or computations





Nomad experiment: results from beam tests on S/N with same sensors and VA1 FE chips

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.

Alignment(s)

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 Michigan University
- **Embedded Straightness Monitor (just starting)**
  by the IFCA-Cantabria University

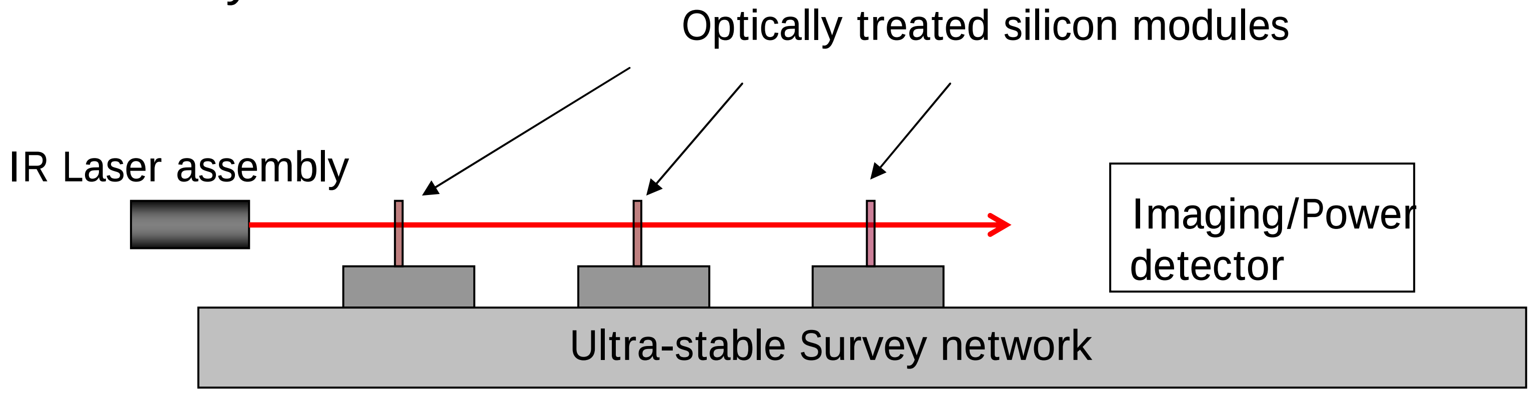
Embedded straightness monitor - Conceptual Design

- 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 improved its optical quality
- From and 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...

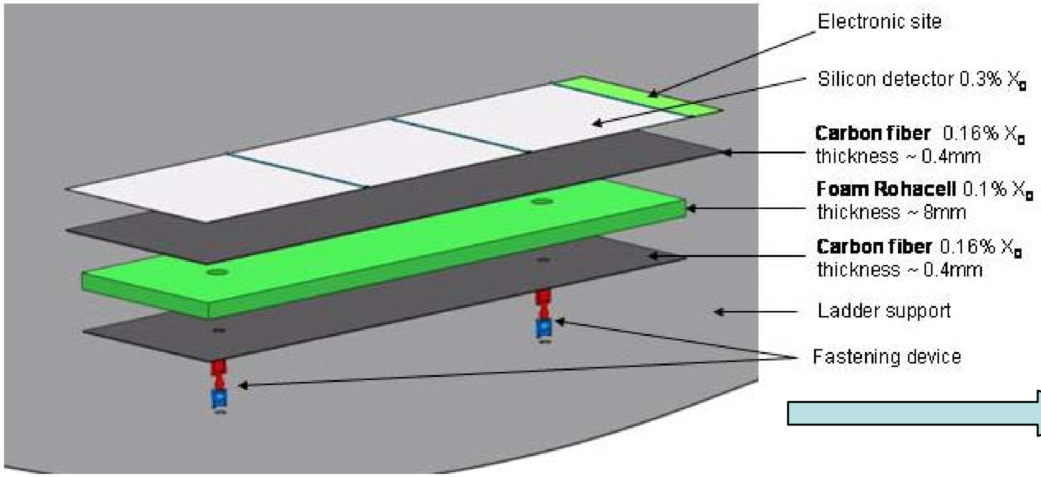


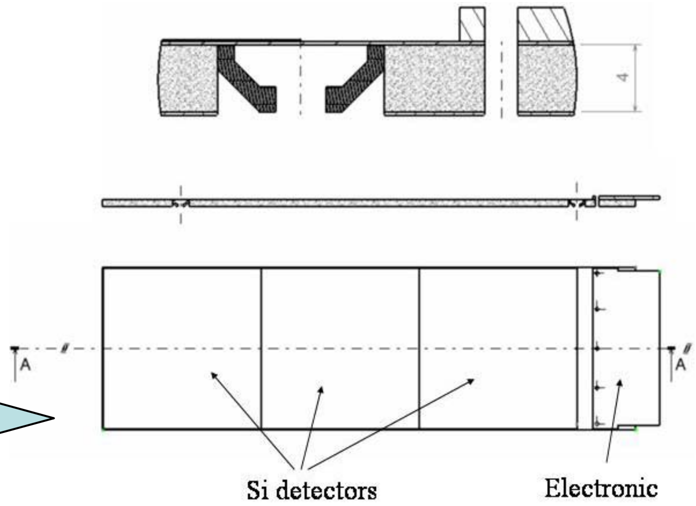
Embedded straightness monitor - Initial R&D

- 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.

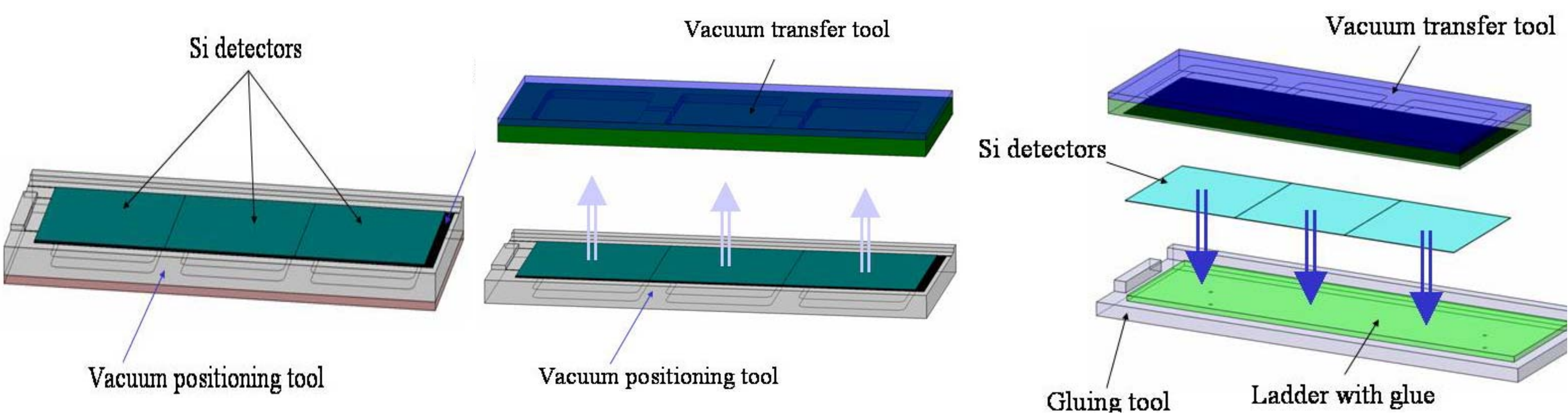
New medium size prototype: *under construction at LPNHE*





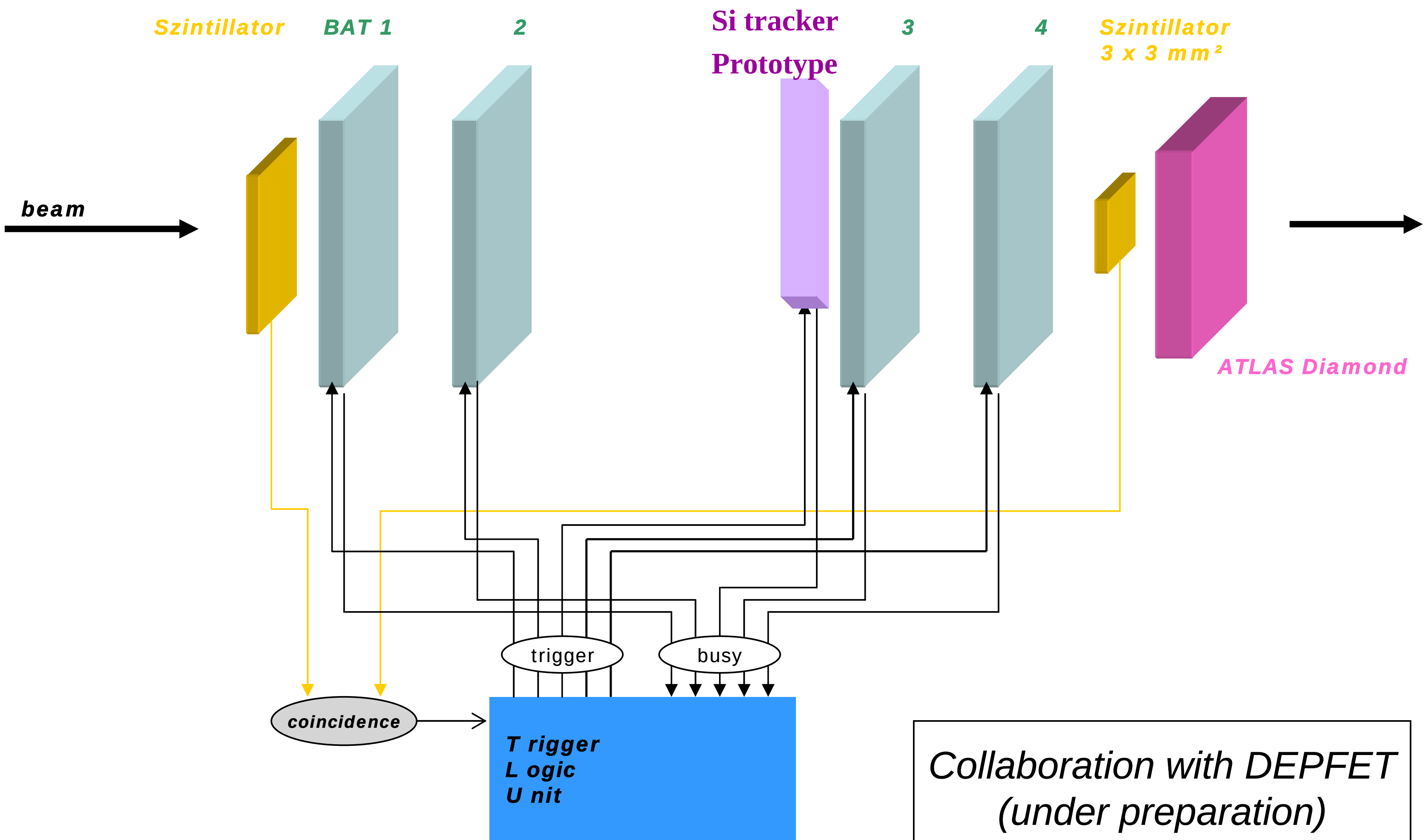
Ready by mid October

Positioning on assembling structure



Gluing proceadure of Si detectors onto the support structure

Using the test beam setup in Bonn



Collaboration with DEPFET
(under preparation)

Test beam schedule

Preparations tests Proto1

Beam tests: elementary modules construction endcap Prototype equipped with 128 ch. chips

Construction barrel prototype
Tests (cont'd) also combined with other sub detectors
New foundry (>=512 ch + techno)

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

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.