Silicon Main Tracker R&D:

Test beam present status and perspectives

Aurore Savoy-Navarro, LPNHE-UPMC/IN2P3-CNRS

on behalf of the SiLC R&D Collaboration

and of the SiD Detector Concept

ILC Detector Test Beam Workshop

FNAL, January 18, 2007

Main topics

- Why test beams are needed by R&D on the Silicon Main Tracker Sub detector for ILC?
- Present Status on Test beam activities
  - SiLC: Roadmap for test beams
  - SiLC: First test beam in DESY
  - SiLC: Preparation of test beam in 2007
- Perspectives for the coming years

Why test beams for Si trackers R&D?

Physics and Machine environment at the ILC are both imposing stringent conditions on the tracking system, namely:

- high performance in momentum resolution and spatial resolution
- Low material budget
- Reliability, simplicity and easy to build, monitor and calibrate.
- Full coverage (avoid dead regions and importance of End Caps)
- Easy to integrate in the detector and readout/DAQ architecture (part of particle flow)
- System able to handle very high magetic fields (3 to 5 Teslas)

This leads to develop an active R&D for ILC large Silicon trackers on:

- Sensors R&D
- Electronics R&D
- Mechanics R&D

Needed tools: Lab test benches and test beams plus simulations

Lab test benches of different types are a first approach towards experiencing in more realistic ways various real life conditions. The test beams are their indispensable continuation and extension to ensure that the device will satisfy the requirements and/or verify how much it satifies them.

Test beams allow identifying new problems, not yet anticipated even at Lab test bench.

Test beams allow combining several sub detectors.

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Present status of the test beams for large Si tracking

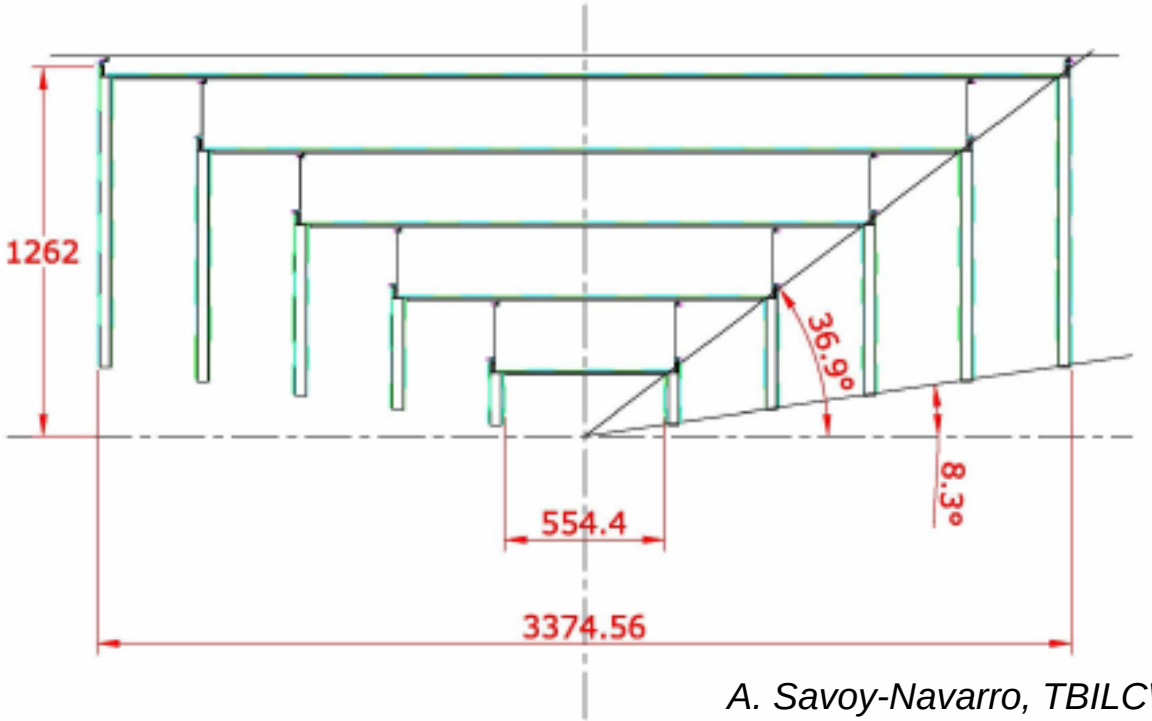
SiLC R&D* has undertaken in 2006 a test beam program for 4 years until (i.e. end 2009) including also in EUDET project.

- SiLC: First test beam in DESY
- SiLC: Roadmap for test beams
- SiLC: Preparation of test beam in 2007

* **SiLC (Si**licon tracking for the **L**inear **C**ollider) is a worldwide R&D Collaboration gathering about 20 Institutions from Asia, Europe and USA. The goal is to develop the next generation of large Silicon tracking system for the ILC. It is a generic R&D collaboration including teams working in GLD, LDC and SiD detector concepts for. Synergy with LHC & LHC future upgrades

The SiD Tracker

- Integrated silicon strip tracker with uniform technology and a fully integrated forward tracking system
- Minimal material in the tracking volume to reduce multiple scattering and secondary particle production
- High precision in a compact tracking volume with B = 5T



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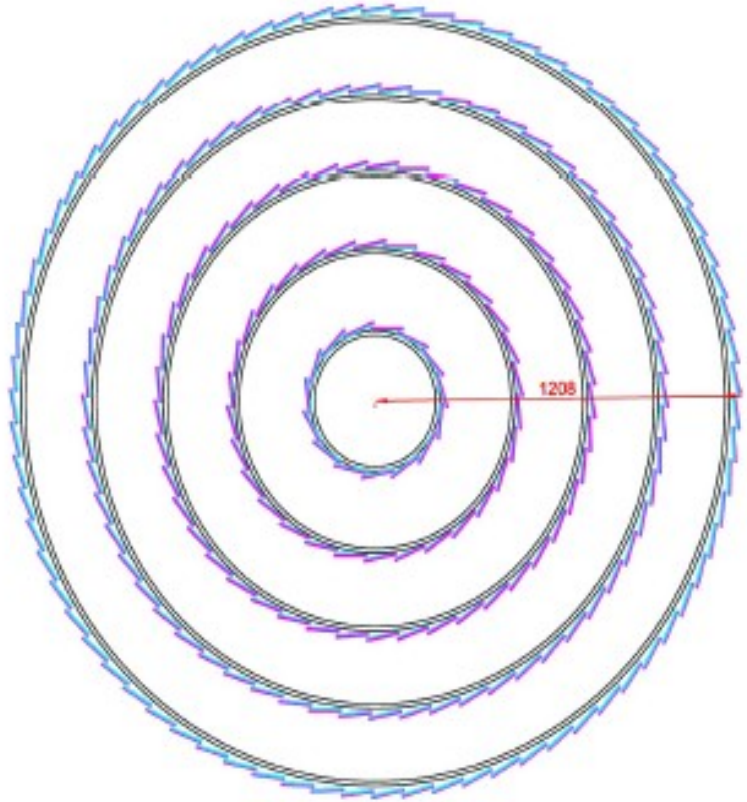
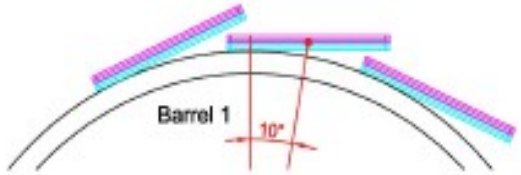
Slide prepared by Rich Partridge for the SiD

The SiD Tracker

- Baseline tracker design has 5 barrel layers, 4+4 disk layers
- Supports are carbon fiber / foam / carbon fiber sandwiches
- Modules are mounted on the supports in a pinwheel design



Sensors:
Cut dim's: 104.44 W x 84 L
Active dim's: 102.4 W x 81.96 L
Boxes:
Outer dim's: 107.44 W x 87 L x 4 H
Support cylinders:
OR: 213.5, 462.5, 700, 935, 1170
Number of phi: 15, 30, 45, 60, 75
Central tilt angle: 10 degrees
Sensor phi overlap (mm):
Barrel 1: 5.3
Barrel 2: 0.57
Barrel 3: 0.40
Barrel 4: 0.55
Barrel 5: 0.63
Cyan and magenta sensors and boxes are assumed to be at different Z's and to overlap in Z.
Within a given barrel, cyan sensors overlap in phi as do magneta sensors.



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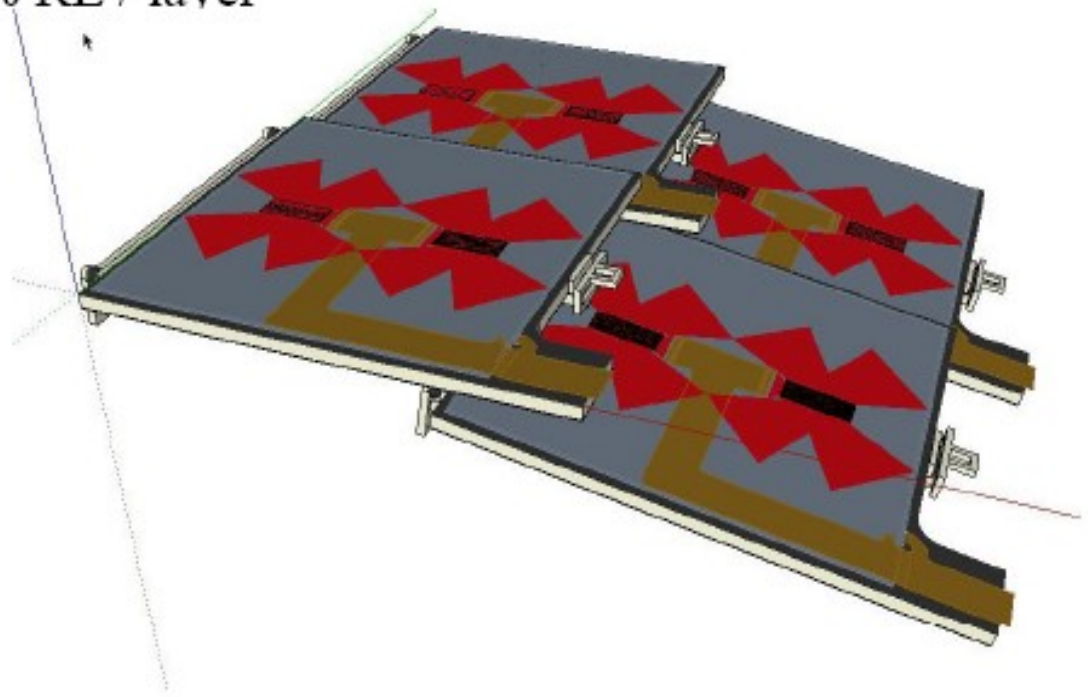
SiD Tracker Modules

- Key active element in the SiD tracker is the module
  - Barrel modules have one sensor with axial strips to measure bend coordinate
  - Forward disk modules have two sensors to make 3D hit measurements
  - Modules are ~10cm x 10cm
- Challenge: maintaining material budget (including supports) of ~0.8% RL / laver



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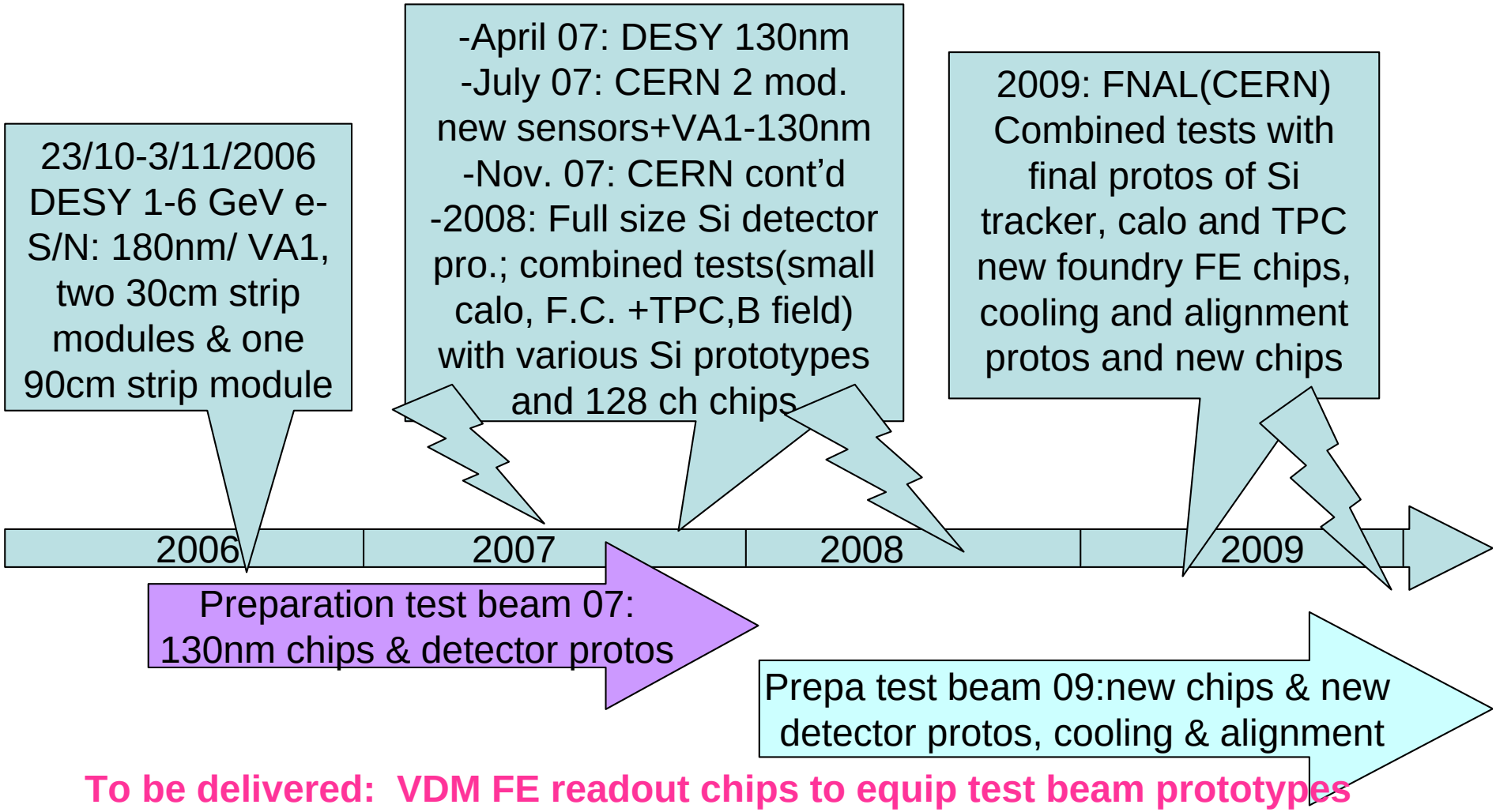
SiLC Roadmap & Scientific Objectives



To be delivered: VDM FE readout chips to equip test beam prototypes
Large area Sllicon tracking structure prototypes
Cooling & alignment systems
Series of testbeams Si alone or combined (see Roadmap)

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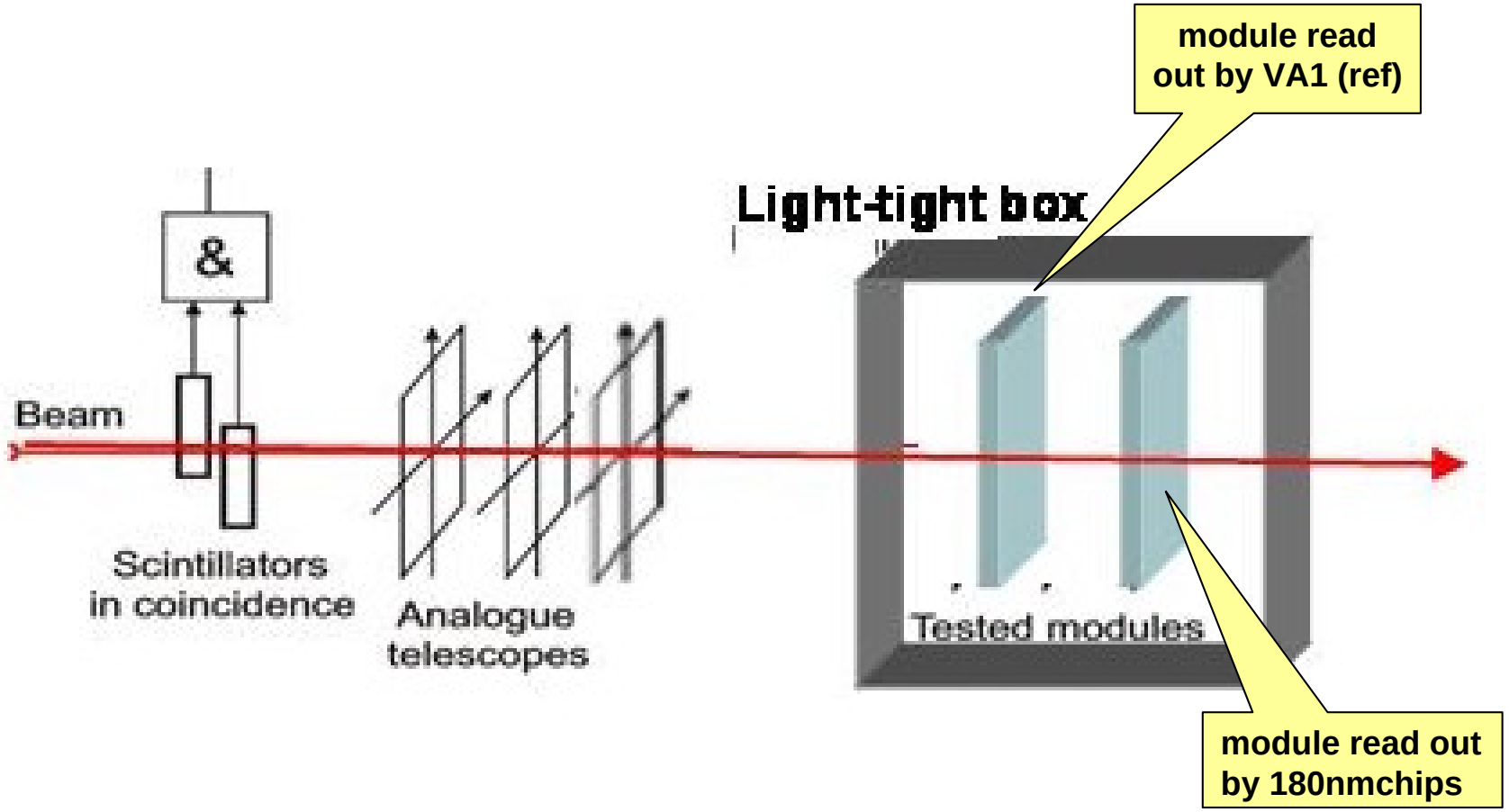
SiLC Test beams @DESY in 2006

First tests at the DESY e- test beam, no magnetic field, performed from October 23 to November 3; this will be pursued around April 07, goals:

- Test the complete new test set-up (modules, read out electronics, DAQ)
- Compare new first FEE prototypes (180nm UMC,wrt to reference: VA1 chips
- Measure S/N



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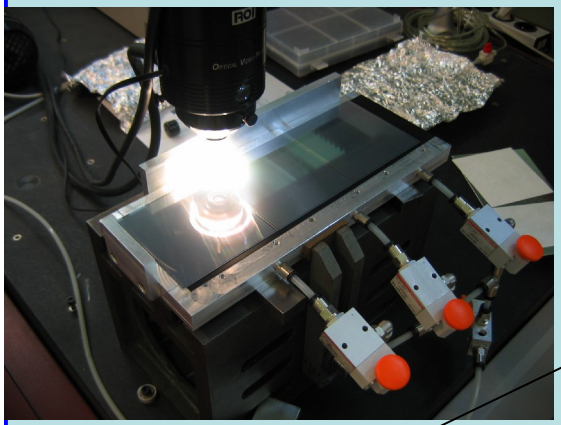
Detector prototypes

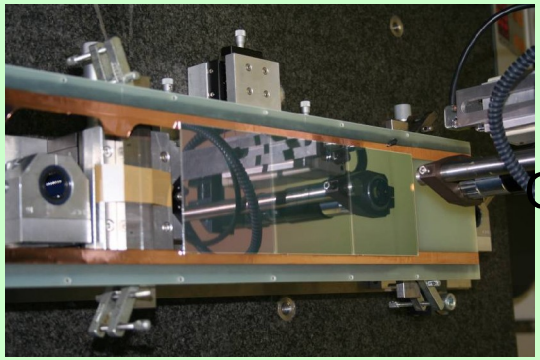
CERN(A.Honma), IEKP-Karlsruhe, LPNHE-Paris, IEHP-Vienna, Hamamatsu



Assembly

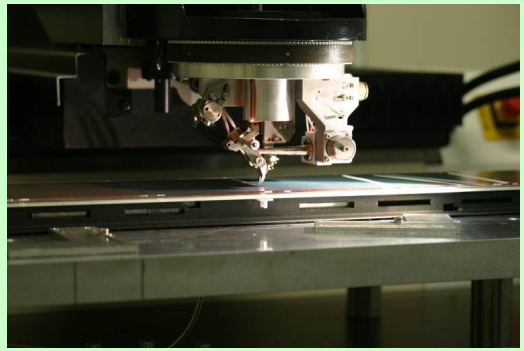
3 CMS sensors 28 cm strip long
Read out:
VA1+180UMC r.o
and all VA1 r.o.

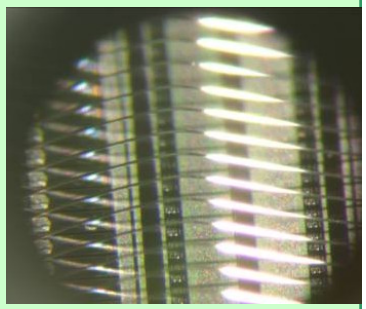
2 modules fabricated in Paris,
bonding CERN on automated CMS system
(Collab CERN-LPNHE)



Assembly:
Module = 10
GLAST sensors
90 cm strip long

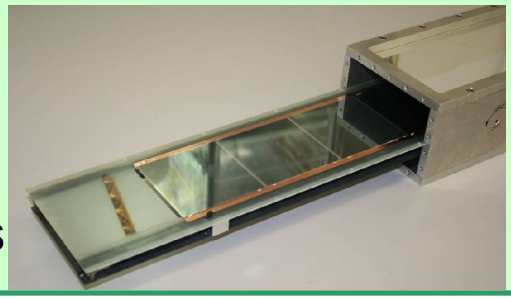
Bonding



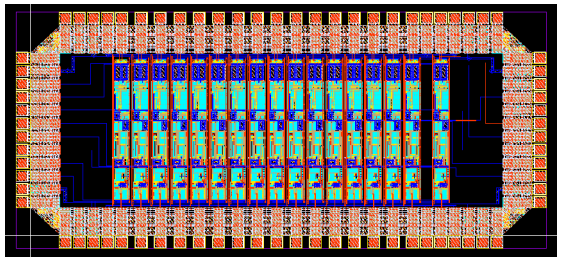


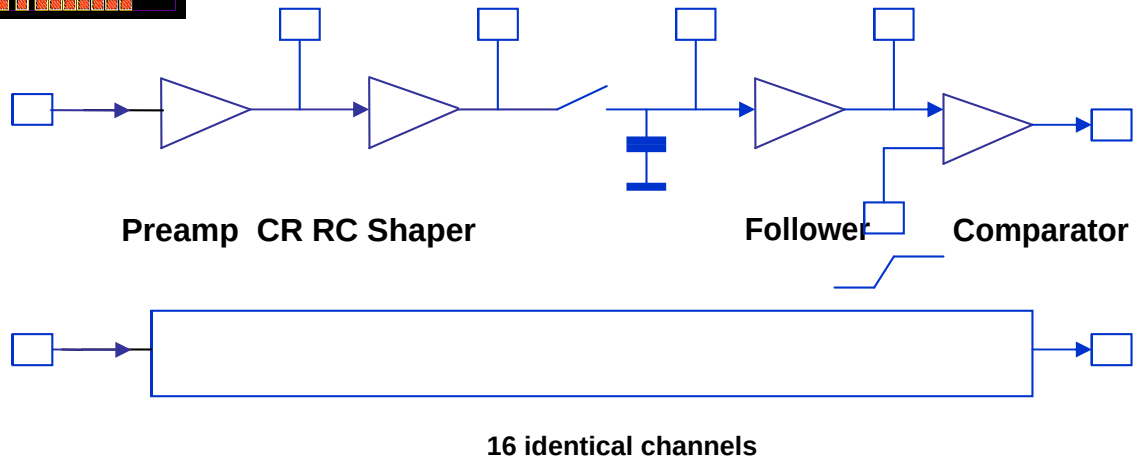
The full construction done at IEKP

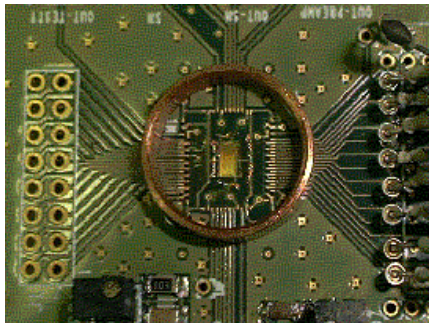
R.O.
Pitch adapter +
VA1 + 180UMC
provided by Paris



Front-end test chip in CMOS 180nm







- Low noise amplification + pulse shaping
- Sample & hold
- Comparator
- No power cycling yet

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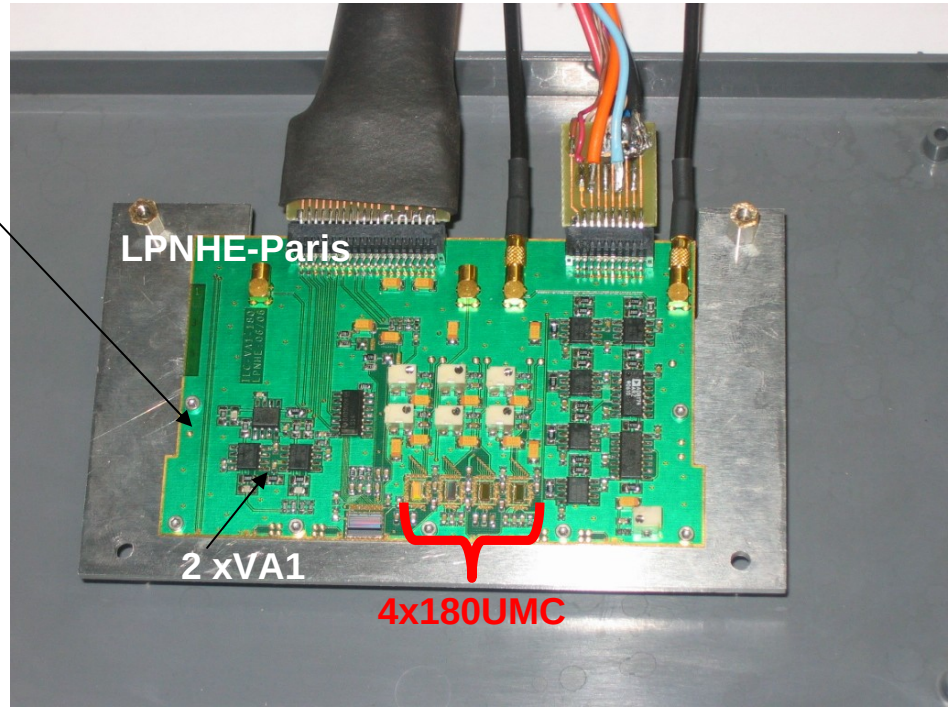
Readout Electronics: LPNHE Paris

2 VA1 + 4x 180UMC channels: hybrid R.O. card under test

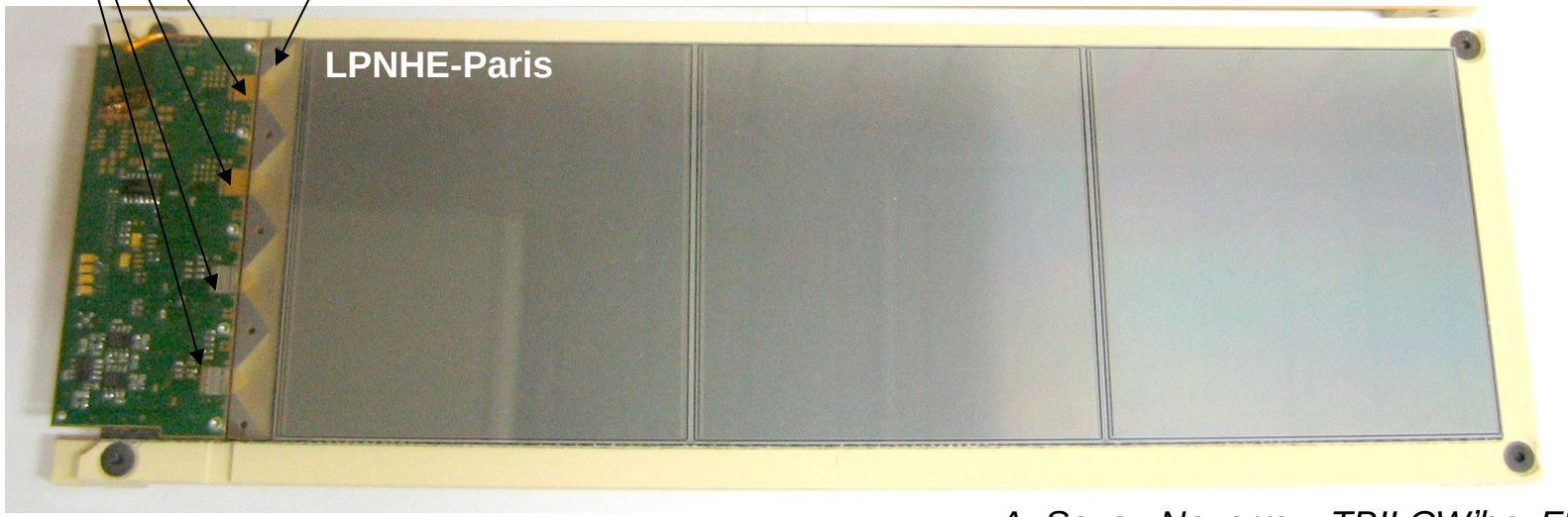


4 VA1 r.o card

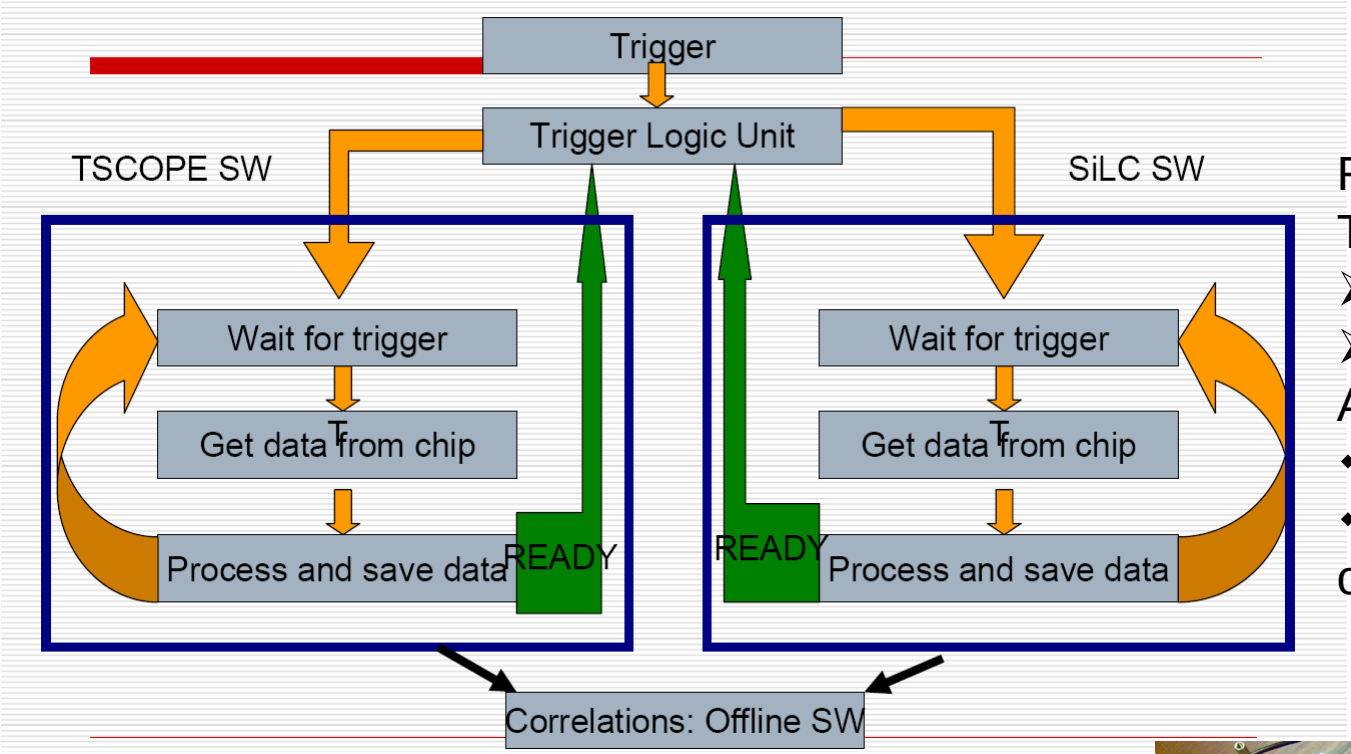
- VA1 r.o. card ready
- 2 hybrid r.o. cards: VA1+180UMC ready

Both being tested at Paris Lab test bench

Pitch adapter



DAQ: hardware & software

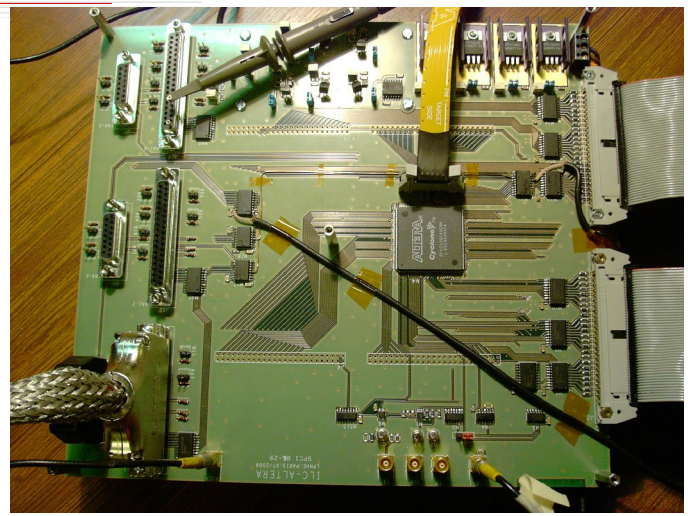


LPNHE-Paris:
Rebuilt its DAQ test bench
To be used both for
- Tests @ Lab t.b. before
- Tests @DESY t.b.

Adapted to
- new R.O. electronics
- and to be linked to DAQ

of the beam telescopes.

DESY and CU-Prague:
Use of the existing hardware and software developed by DESY for the beam telescopes implementing a very basic trigger logic for connecting the two DAQ systems.

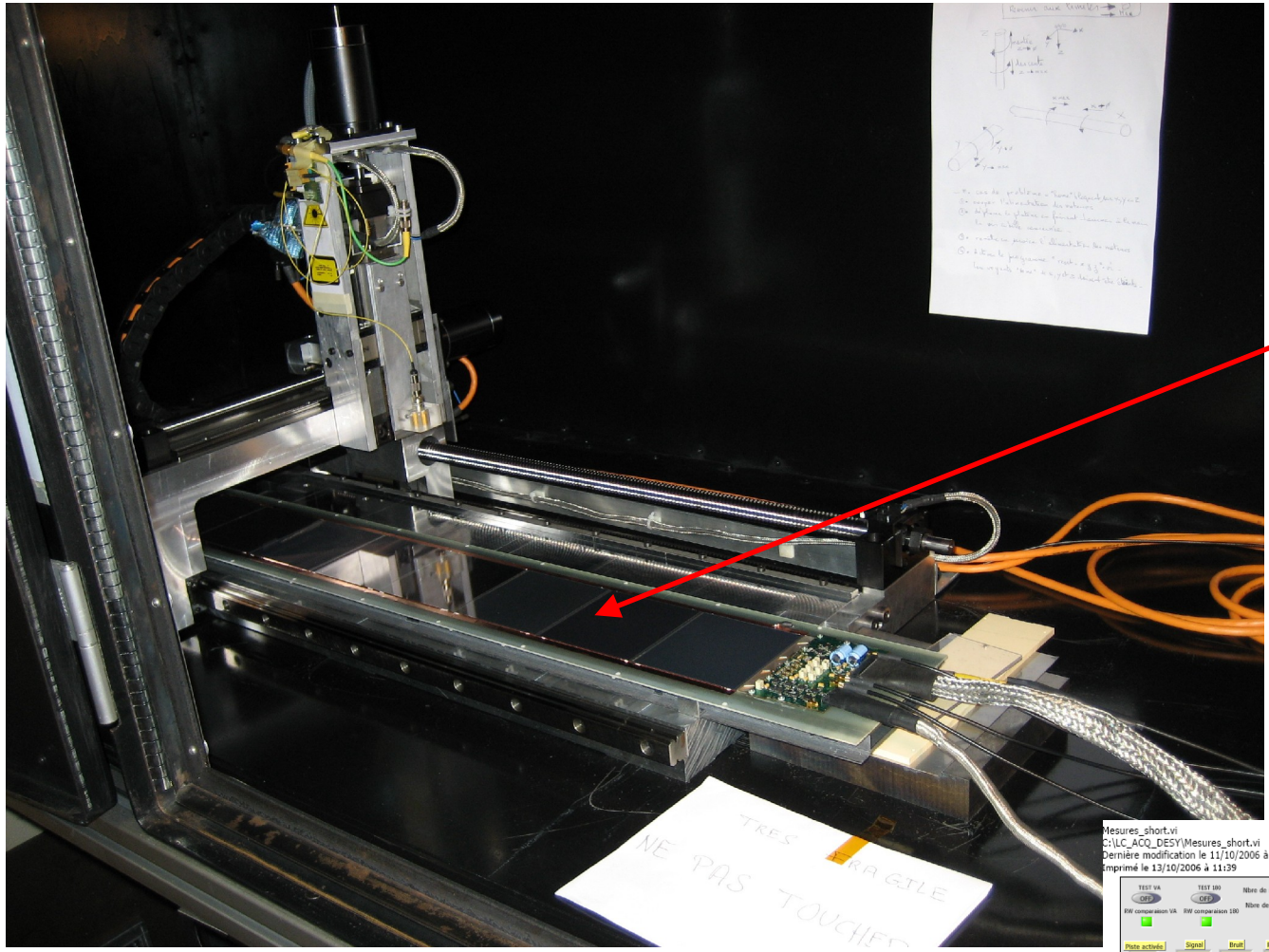


Tests at the Lab Test bench before DESY

- **Complete upgrade of the Paris Lab test bench**
- **Characterization of the new readout chips (VA1 and 180UMC)**
- **Characterization of the new Si modules:**
  - **→ 2 x 3CMSmodule**
  - **→ One long strip module**
- **Test of the functioning of the new DAQ hardware**
  - **→ New command card**
  - **→ New Altera card**
  - **→ Effect of 15 m long cable between Altera & detector R.O.**
- **Test 2 DAQ's running in parallel (beam telescope and Si detector R.O.)**
- **Test analysis packages with Lab test bench runs**

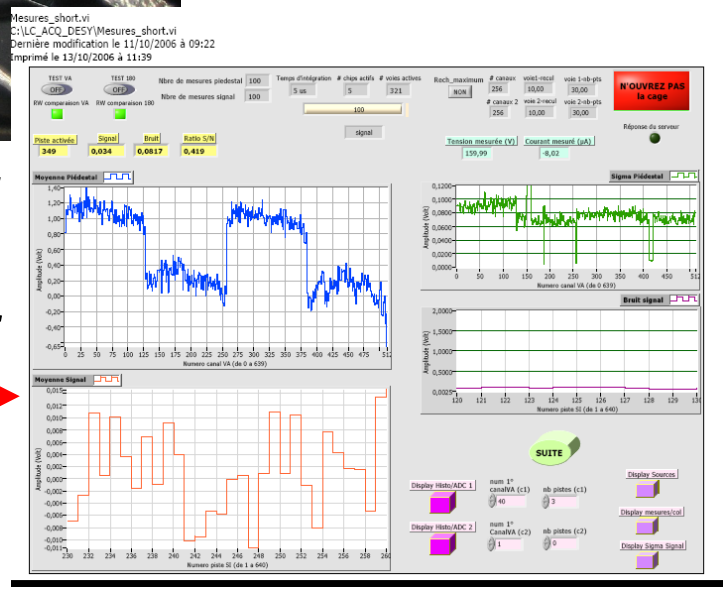
All these tests were performed at the Paris Lab test bench since end of September till October 20.

Tests were pursued at the Lab test bench after the first round at DESY for further investigations and completion of the measurements.



GLAST module sitting on the Lab test bench

Modules and readout electronics were tested on Lab test bench in Paris, before going to DESY., as for example, the GLAST module or the CMS-4VA1 module

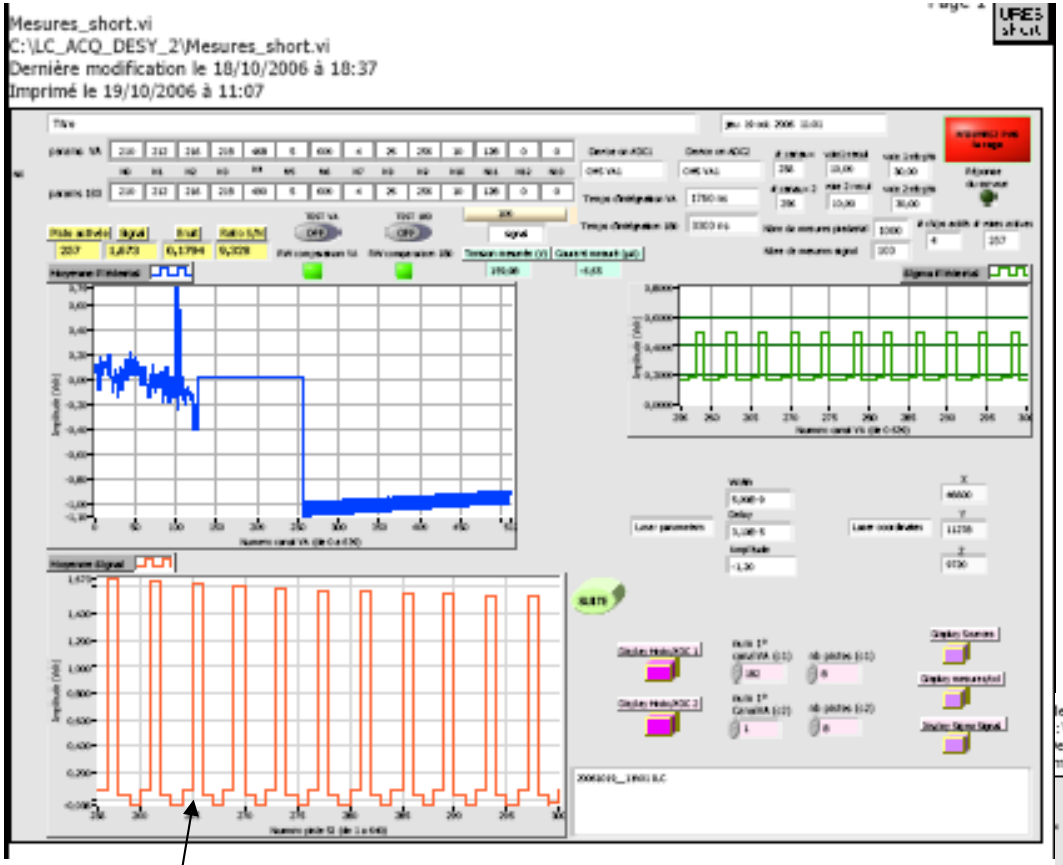


Preparation for the DESY test beam

October 23 to Nov 5, 2006

Sharing of tasks

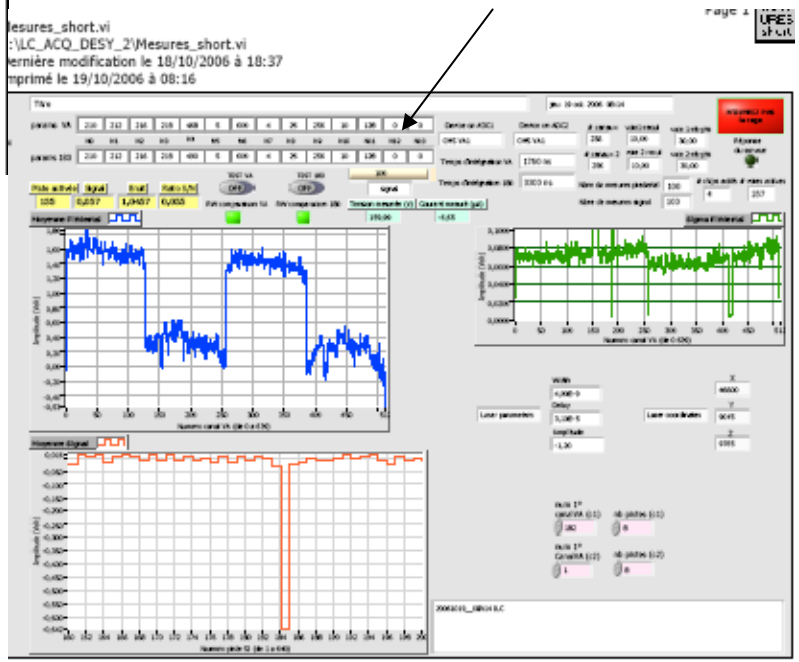
- Construction of the detector prototypes: **CERN, IEKP-Karlsruhe, LPNHE-Paris &** IHEP Vienna, Hamamatsu providing the sensors)
- Mechanics: DESY,LPNHE Paris, **IFIC Valencia**
- FE and readout electronics: **LPNHE-Paris**
- DAQ hardware: **DESY for beam telescopes, LPNHE-Paris for SiLC**
- DAQ software: **DESY, LPNHE-Paris, CU Prague**
- Test in test bench prior to go to test beam: **LPNHE-Paris,** IEKP Karlsruhe, CU Prague,
- Beam Telescopes and Beam infrastructures: DESY, OSU Obninsk, **CU Prague**, **IFCA**.
- Analysis tools: **CU Prague**, OSU Obninsk, LPNHE Paris
- Participation to the run: HIP Helsinki, IEKP Karlsruhe, OSU Obninsk, LPNHE Paris, CU Prague, IFIC Santander and contribution of DESY (beam & telescopes)



180nm UMC channel attached to CMS sensor module: response to LD1060 signal

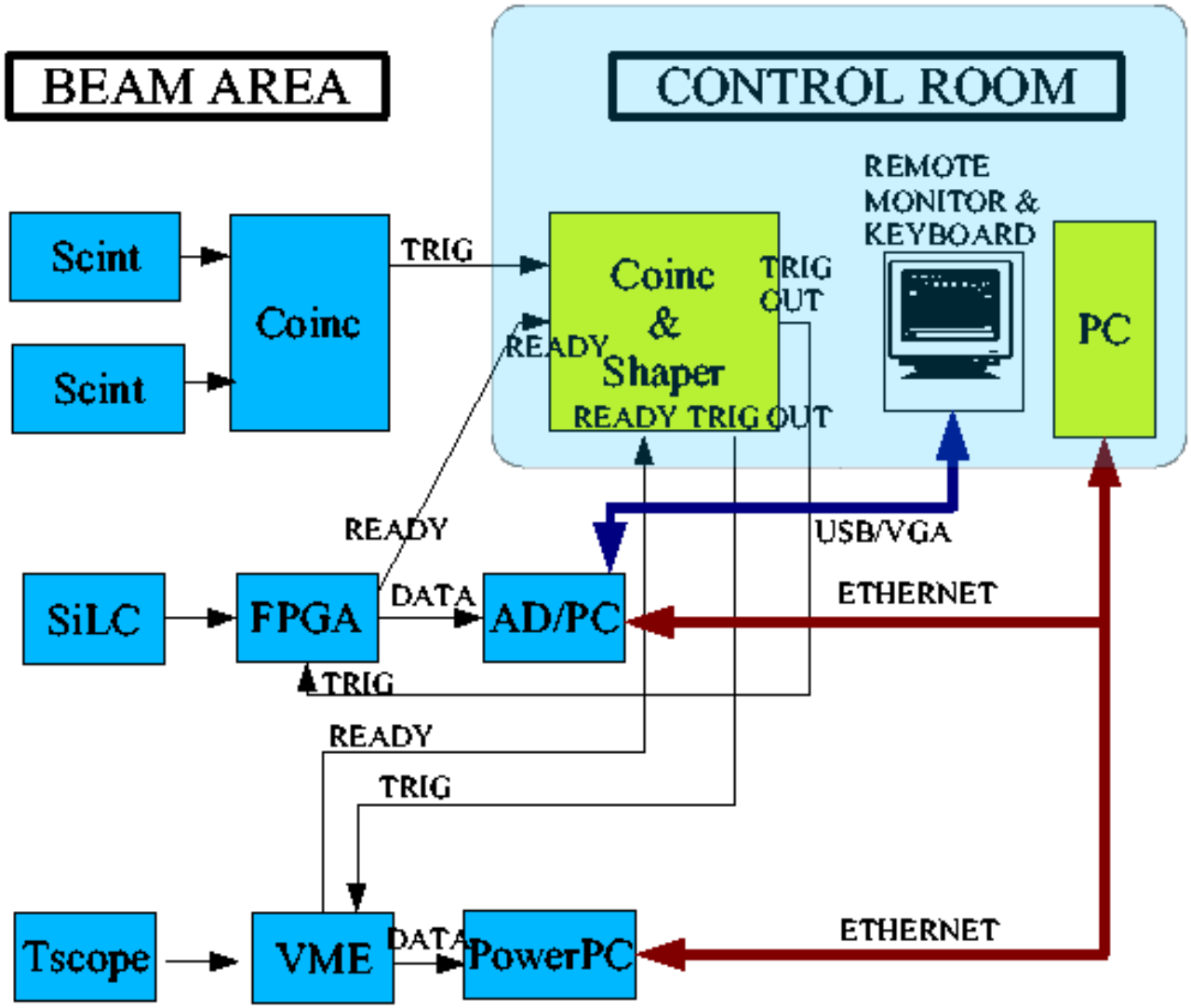
<u>Before leaving for DESY</u>: the 4VA1 readout card and the 180UMC+VA1 card are working fine when reading out LD1060 signal at the Lab test bench

CMS-4VA1 response to LD1060




October 23 to November 3 2006
SiLC test beam at DESY
On line

Test beam DAQ system in DESY for SiLC



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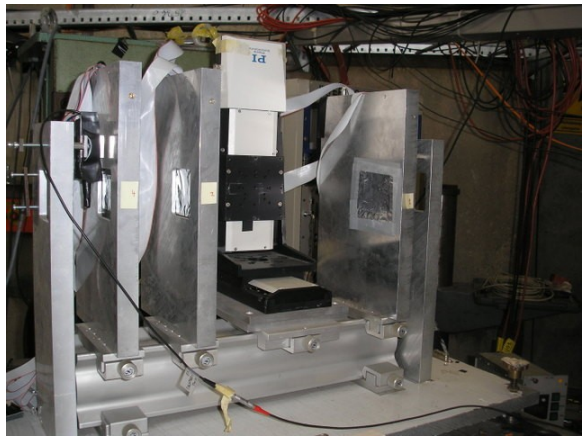
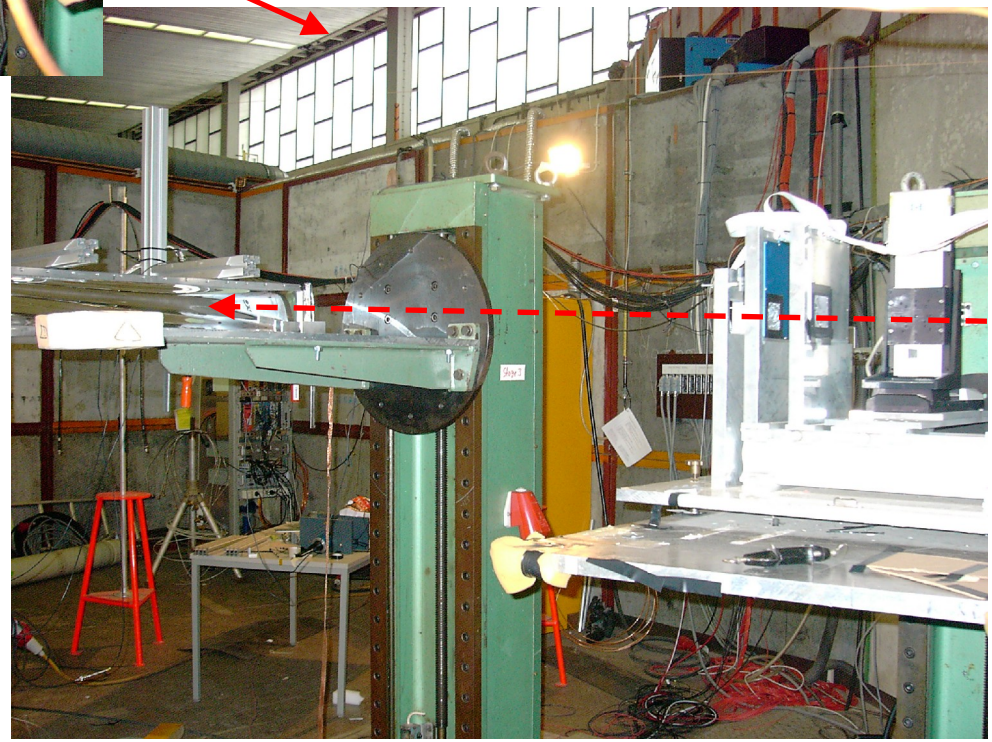
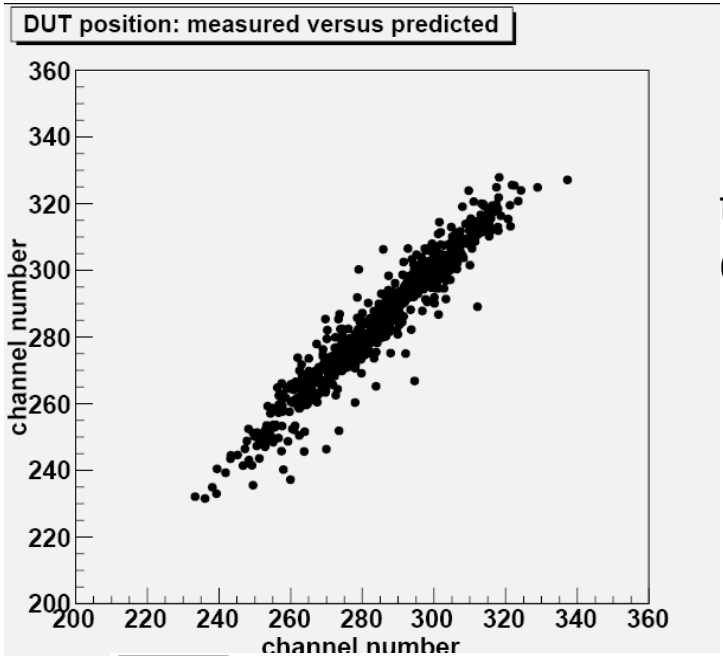
Test set-up 1: Two CMS modules
First one read out by 4VA1
Second one read out by
VA1&180nmUMC

Test set-up 2: one GLAST module
read out by VA1&180nmUMC

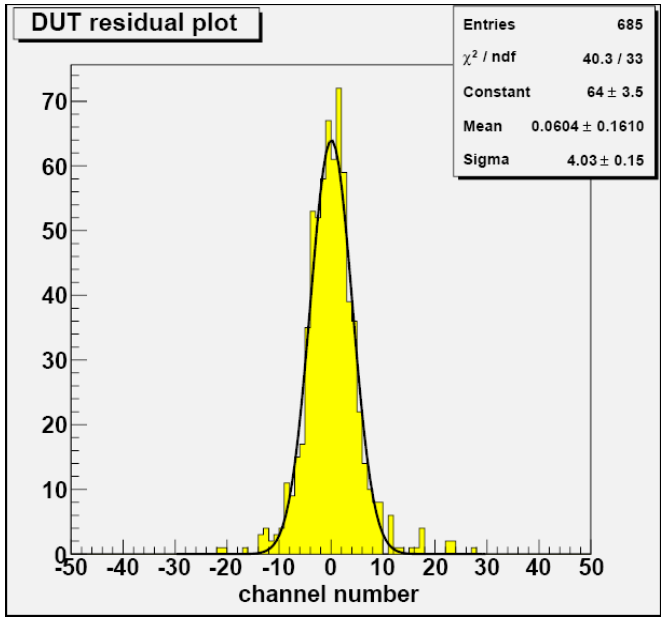


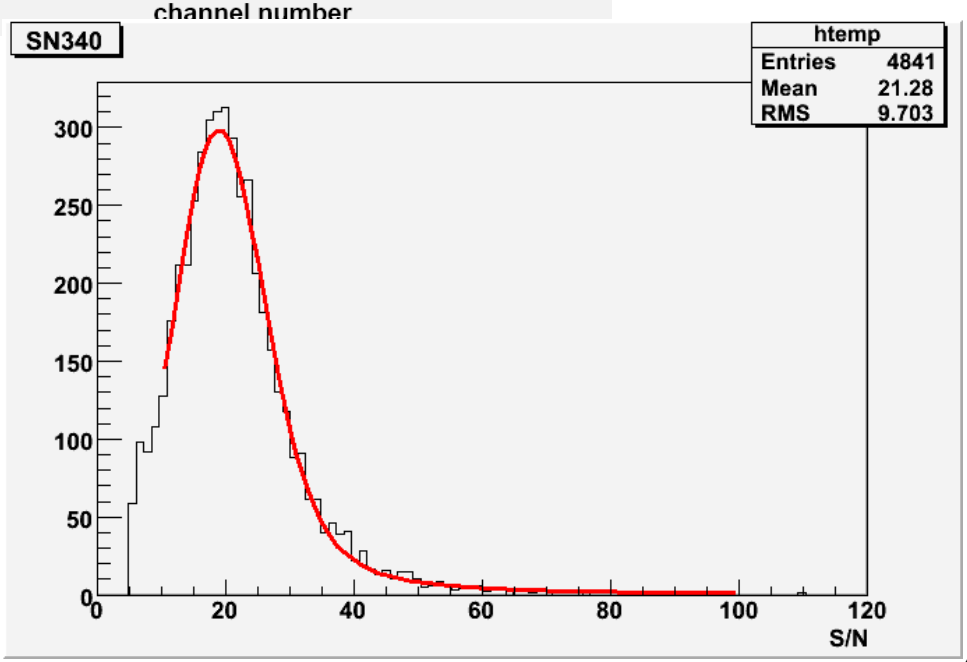


DESY Beam test analysis



Correlation beam telescopes & Silicon detector, based on the CMS-4VA1 module





Bias voltage	S/N (MPV)
200	13.62 +/- 0.33
260	15.79 +/- 0.29
299	15.70 +/- 0.25
350	**16.52 +/- 0.73**

Signal from the CMS-4VA1 module

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2007 Workpackages for SiLC/EUDET

WKP 0: Beam test in DESY (April 2007) with 130nm preprototypes.

WKP 1: Beam tests at CERN (July 2007)= « Rehearsal » for November run:

- 2 modules made of **new** single-sided sensors
  readout: VA1(ref)+ **130nm(preproto)**
- 3D-planar module test

WKP2: Beam test at CERN (Nov. 2007)

- Prototype 60x60cm2, new single-sided sensors, lecture VA1+130nm,
- First test beam of UCSC long ladder + TOT FE readout chip
- Expected to have first alignement systems (Michigan & IFCA)
- Expected to have first cooling system

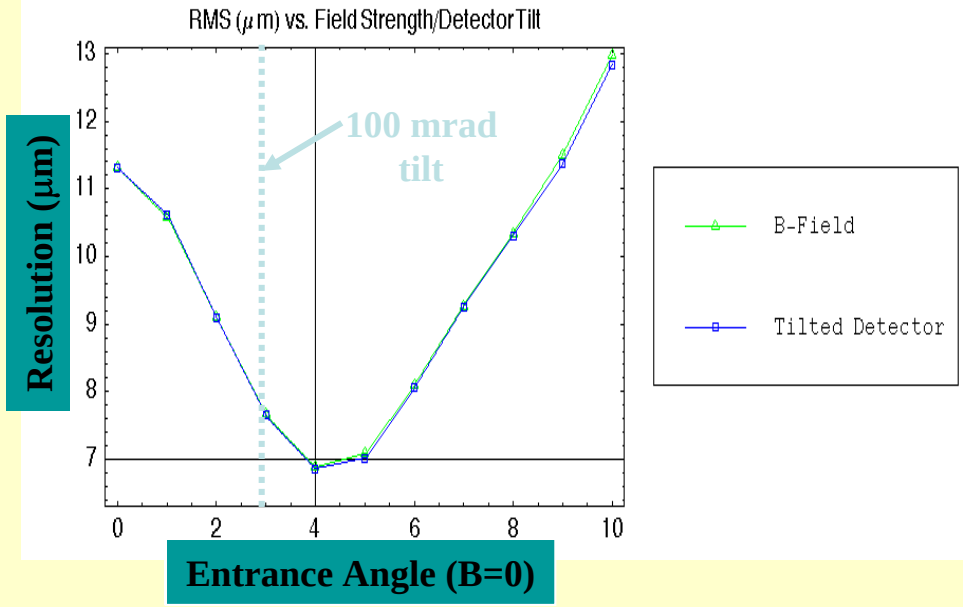
- *Other SiLC collaborators will join these beam tests and foresee to bring other detector prototypes.*

SCIPP ToT readout: Test beam Plans (Dreams?) for late 2007

by Bruce Schumm (SCIPP&UCSC)

CDF Layer00 Sensors

Dimensions:	type A : 1.48x7.84 cm^2 type B : 0.85x7.84 cm^2
Depletion Voltage:	60 V < Vdep < 100 V
Uniformity of V_{dep}:	< 20%
Biasing scheme:	Poly resistors on both sides
Poly resistor values:	4.5 ± 0.5 MΩ
passivation:	SiO_2 0.5 μm thick
implant strip width:	8 μm
implant depth:	>1.0 μm
doping of implant:	> $1 \cdot 10^{14}$ ions/cm^3
width of Al strips:	7-8 μm
thickness of Al strips:	>1 μm
resistivity of Al strips:	< 20 Ω·cm



2-3 μsec shaping time plus ~10 daisy-chained sensors ➔ stringent requirement on **leakage current**, **bias resistance**

Single CDF L00 sensor may be satisfactory, but "long" ladder may be single sensor plus equivalent capacitive load.

SCIPP simulation for ToT readout of long ladder:

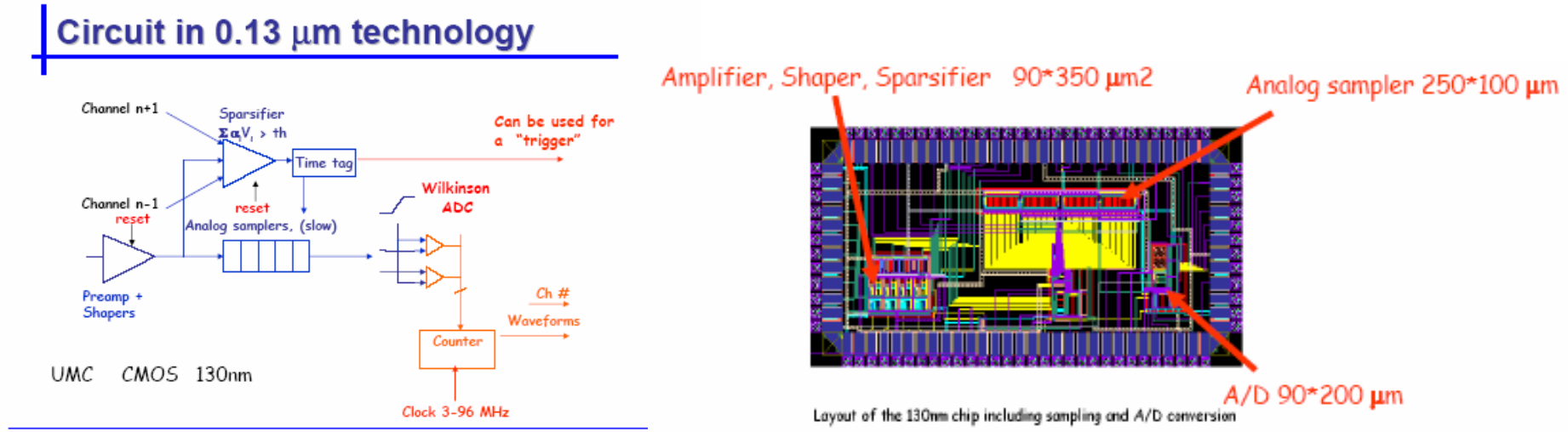
Expect 7 μm resolution, but with strong dependence on entrance angle (efficiency also).

Want to explore this in testbeam run.

Implementing new 130 nm chip

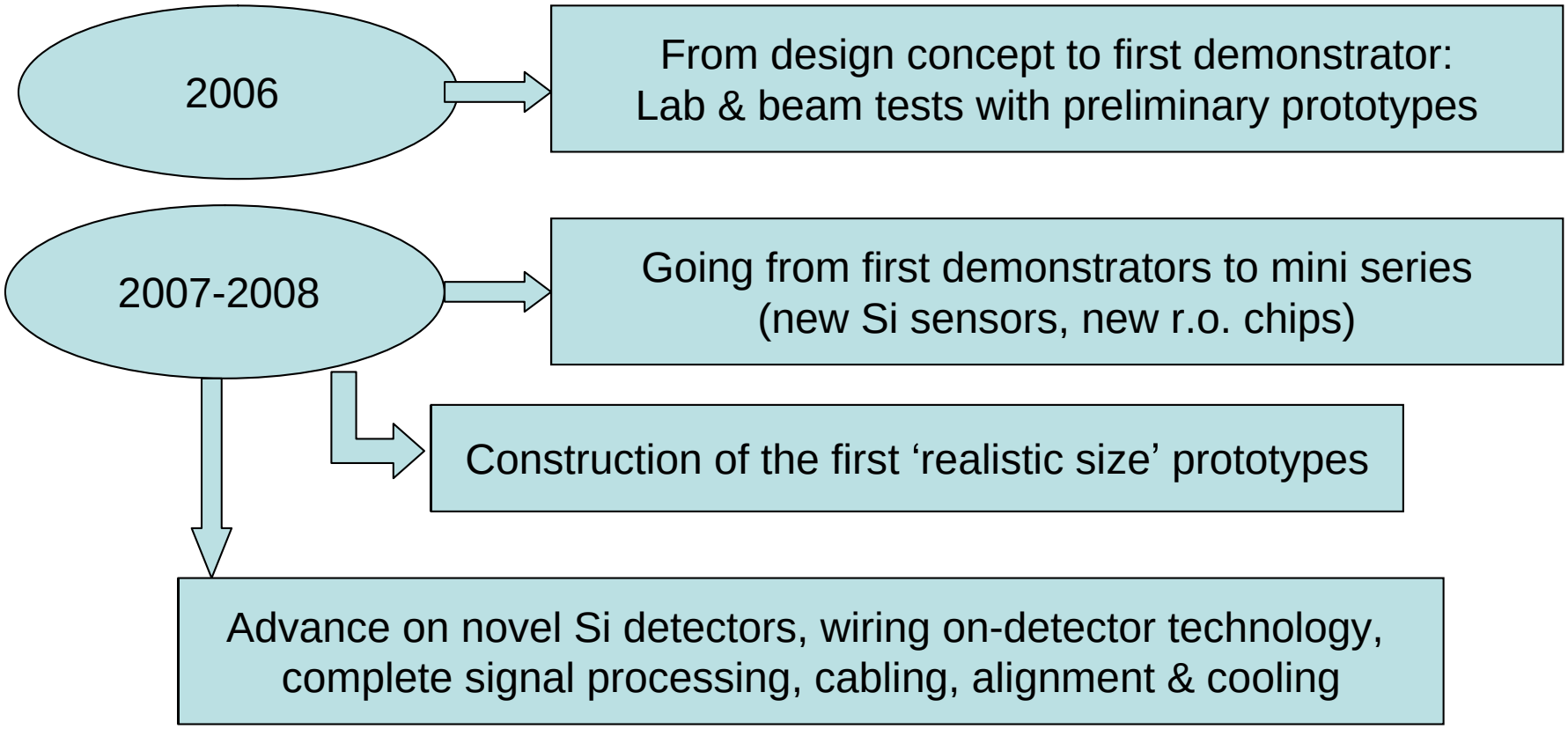
Implies lot of work: quite challenging!

- Testing the full functionality: analogue component, pipeline, digitization included in this chip



- Modify the DAQ hardware and software for this new processing of the detector information.
- Test it on the Lab test bench before going to test beam

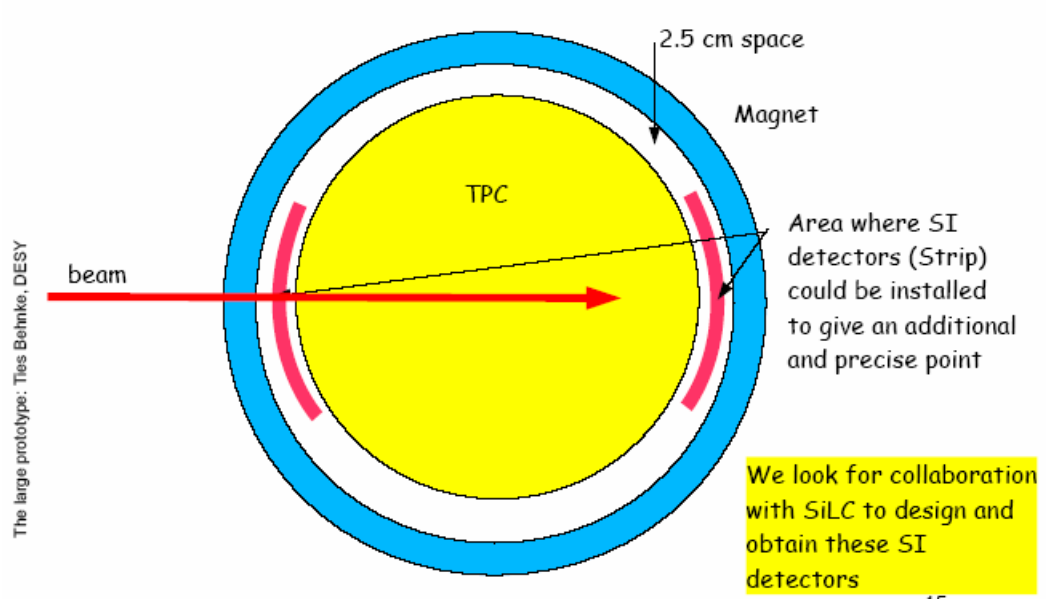
Transitions of phase:



In 2006, the first SiLC test beam has triggered the unification of the European collaborative efforts.
The 2007 SiLC beam tests will include the contributions of Asia and US

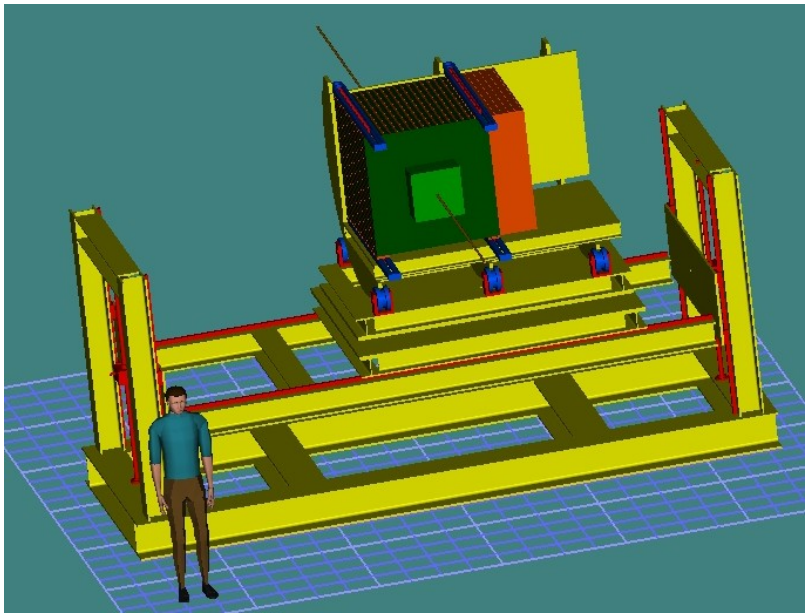
A. Savoy-Navarro, SiLC, Valencia, Nov’06

2008 & beyond: combined test beams

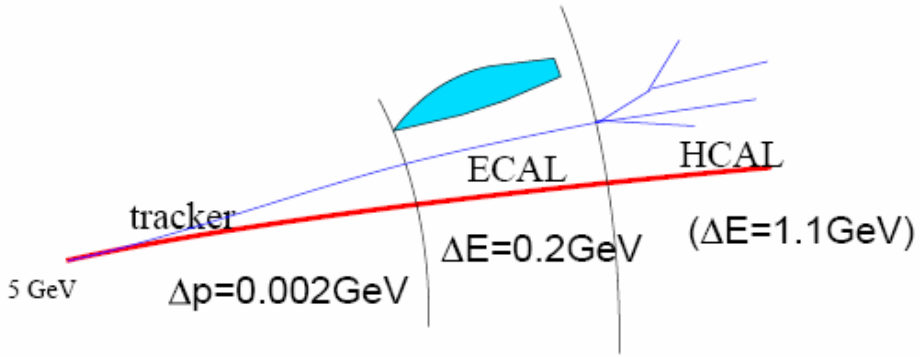


Testbeam with TPC Field Cage & strip layer surrounding it: SET(LDC)

Test beam with pixel detectors: tests on internal tracking region & Vertex + Silicon tracker



Testbeam with Si-W calorimeter & few Silicon strip layers in front: experience particle flow



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Test Beam Needs

- Recurring access to test beams beginning in early 2008
  - Study the performance of prototype sensors under controlled beam conditions
  - Compare performance among design alternatives that may emerge
  - Perform detailed studies of sensors that are developed
- System tests of tracker + calorimeter in 2009 – 2010 (?)
  - Particle flow "entangles" the tracking and calorimetric measurements
  - Plan to mount a slice of the tracker with in front of calorimeter modules
  - Study matching of charged tracks and calorimeter clusters
  - Measure calorimeter albedo and back-scatter into the tracker
  - Measure effect of tracker material (multiple scattering, production of secondaries) on tracker + calorimeter measurements
  - Estimate 2 m of space upstream of calorimeter is required for tracker slice
- Access to test beam with a high field magnet
  - Ideally, there would be at least one test beam with a 5T magnet
  - Need to validate charge collection models and verify sensor performance

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Slide prepared by Rich Partridge for the SiD

Wishlist: what we would like to see from test beam facilities

- Beam telescope and
- associated DAQ and trigger logic
- General DAQ framework
- High Field magnet > 3 Teslas
- Mechanics workshop access and support for last minute needs during installation
- 3D Table(s) to install and properly move the prototypes wrt beam.
- Easy access to computing facilities and LabNet
- Control room(s) with enough space (for several users) and needed infrastructure: racks, computing, storage places
- Lab staff responsible for the good running of the test beam.
- Crane to install and move heavy prototypes.
- A good coffee machine: NESPRESSO, what else???

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